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Investigating the Use of a New Universal Breakaway Steel Post – Phase III

Dean L. Sicking
University of Nebraska - Lincoln, dsicking1@unl.edu

Ronald K. Faller
University of Nebraska - Lincoln, rfaller1@unl.edu

Robert W. Bielenberg
University of Nebraska - Lincoln, rbielenberg2@unl.edu

Karla A. Lechtenberg
University of Nebraska - Lincoln, kpolivka2@unl.edu

Jennifer D. Schmidt
University of Nebraska-Lincoln, jennifer.rasmussen@unl.edu

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INVESTIGATING THE USE OF A NEW UNIVERSAL BREAKAWAY STEEL POST – PHASE 3

Submitted by

Jennifer D. Schmidt, M.S.C.E., E.I.T.
Graduate Research Assistant

Dean L. Sicking, Ph.D., P.E.
Professor and MwRSF Director

Ronald K. Faller, Ph.D., P.E.
Research Assistant Professor

John D. Reid, Ph.D.
Professor

Robert W. Bielenberg, M.S.M.E., E.I.T.
Research Associate Engineer

Karla A. Lechtenberg, M.S.M.E., E.I.T.
Research Associate Engineer

MIDWEST ROADSIDE SAFETY FACILITY
University of Nebraska-Lincoln
130 Whittier Building
2200 Vine Street
Lincoln, Nebraska 68583-0853
(402) 472-0965

Submitted to

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16. Abstract (Limit: 200 words)

A new fracturing-bolt, Universal Breakaway Steel Post (UBSP) was developed and evaluated for use as a replacement for the wood controlled release terminal (CRT) post currently used in the thrie beam bullnose system. The breakaway steel post was implemented into the thrie beam bullnose barrier system and subjected to two full-scale vehicle crash test according to the Test Level 3(TL-3) guidelines provided in NCHRP Report No. 350. Test no. USPBN-3 (test designation no. 3-30) demonstrated that the breakaway steel post performed in a satisfactory manner in the bullnose system as the passenger car was captured and safely brought to a controlled stop. Test no. USPBN-4 (test designation no. 3-31) demonstrated that the breakaway steel post also performed in a satisfactory manner in the bullnose system as the pickup truck was captured and safely brought to a controlled stop. With the successful completion of these two full-scale crash tests along with other prior successful testing, it is recommended that the universal breakaway steel post be considered a safe alternative to the CRT posts in the original thrie beam bullnose median barrier system.

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UNCERTAINTY OF MEASUREMENT STATEMENT

The Midwest Roadside Safety Facility (MwRSF) has determined the uncertainty of measurements for several parameters involved in standard full-scale crash testing and non-standard testing of roadside safety features. Information regarding the uncertainty of measurements for critical parameters is available upon request by the sponsor and the Federal Highway Administration.

The Independent Approving Authority (IAA) for the data contained herein was Mr. Scott K. Rosenbaugh, Research Associate Engineer.

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J.C. Holloway, M.S.C.E., E.I.T., Test Site Manager
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C.L. Meyer, B.S.M.E., E.I.T., Research Associate Engineer
A.T. Russell, B.S.B.A., Shop Manager
K.L. Krenk, B.S.M.A, Maintenance Mechanic
A.T. McMaster, Laboratory Mechanic
Undergraduate and Graduate Research Assistants

Illinois Department of Transportation

David Piper, P.E., Highway Policy Engineer

Iowa Department of Transportation

David Little, P.E., Assistant District Engineer
Deanna Maifield, P.E., Methods Engineer
Chris Poole, P.E., Litigation/Roadside Safety Engineer

Kansas Department of Transportation

Ron Seitz, P.E., Bureau Chief
Rod Lacy, P.E., Metro Engineer
Scott King, P.E., Road Design Leader

Minnesota Department of Transportation

Michael Elle, P.E., Design Standard Engineer

Missouri Department of Transportation

Joseph G. Jones, P.E., Engineering Policy Administrator

Nebraska Department of Roads

Amy Starr, P.E., Research Engineer
Phil TenHulzen, P.E., Design Standards Engineer
Jodi Gibson, Research Coordinator

Ohio Department of Transportation

Dean Focke, P.E., Road Safety Engineer (Retired)
Michael Bline, P.E., Standards and Geometrics Engineer

South Dakota Department of Transportation

David Huft, Research Engineer
Bernie Clocksin, Lead Project Engineer

Wisconsin Department of Transportation

John Bridwell, P.E., Standards Development Engineer
Erik Emerson, P.E., Standards Development Engineer

Wyoming Department of Transportation

William Wilson, P.E., Standards Engineer

Federal Highway Administration

John Perry, P.E., Nebraska Division Office
Danny Briggs, Nebraska Division Office

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1 INTRODUCTION

1.1 Background

From 1997 through 2000, the Midwest Roadside Safety Facility (MwRSF) developed a thrie beam bullnose guardrail system for shielding median hazards found between divided highways [1-3]. The new, non-proprietary bullnose guardrail system was successfully full-scale crash tested and evaluated according to the Test Level 3 (TL-3) safety performance evaluation criteria provided in National Cooperative Highway Research Program (NCHRP) Report No. 350 [4].

Controlled release terminal (CRT) wood posts were used in the original bullnose guardrail system. Although the CRT posts adequately met the TL-3 safety requirements, these wood posts have several drawbacks. First, the properties and performance of wood posts are highly variable due to knots, checks, and splits, thus requiring grading and inspection of posts. Second, two holes are drilled into the CRT posts that allow them to break away upon impact. These holes expose the interior of the wood to the environment, which can accelerate deterioration. Wood posts can also swell under certain environmental conditions, making removal of broken posts from the steel foundation tubes difficult. Further, chemical preservatives used to treat the wood posts have been identified as harmful to the environment by some government agencies. Thus, the treated wood posts may require special consideration during disposal. Due to these concerns, a need existed for a breakaway steel post option for use in the thrie beam bullnose guardrail system.

Existing proprietary steel breakaway posts were investigated in the *Evaluation of an Existing Steel Post Alternative for the Thrie Beam Bullnose Guardrail System* [5]. After several proprietary steel post designs were reviewed and tested, a Road Systems, Inc. (RSI) Hinged Steel Post was chosen as the best option for the bullnose system. Two full-scale tests were performed on the bullnose system with the breakaway hinged steel posts, and both were unsuccessful due to the pickup truck overriding the system.

After the two failed full-scale tests, the focus shifted to the development of a new Universal Breakaway Steel Post (UBSP) to replace the CRT wood posts in the thrie beam bullnose system. While the previously-designed proprietary steel breakaway posts had been successfully used for guardrail end terminals, the bullnose system appeared to be more sensitive to subtle differences between wooden and steel breakaway posts. Thus, the design goal of the new, non-proprietary, UBSP was to mimic the strength and behavior of the wooden CRT post. The new post could also provide a replacement option for the CRT wood post in a wide variety of roadside hardware systems.

Following several rounds of bogie testing with CRT posts and a proposed UBSP, the bullnose system with the UBSP was full-scale crash tested according to test designation no. 3-38 of NCHRP Report No. 350 at the Midwest Roadside Safety Facility (MwRSF) [6]. In test no. USPBN-1, the performance of the UBSP bullnose median barrier was found to be unacceptable according to the NCHRP Report No. 350 criteria due to the pickup truck overriding the guardrail. Two factors were believed to have contributed to this behavior. First, the fracturing bolt posts did not absorb enough energy to safely capture and contain the vehicle. The posts rotated minimally in the soil and broke away quickly, which allowed the pickup to penetrate further into the system. Second, the second post remained intact longer than its wood counterpart, causing the pickup truck to redirect more than what was observed in previous tests on the wood-post bullnose barrier.

The UBSP bullnose median barrier system was modified and tested according to test designation no. 3-38 of NCHRP Report No. 350 [7]. Modifications to the UBSP bullnose median barrier previously tested at MwRSF included changing the second post on each side of the system from a UBSP to a BCT post, increasing the diameter of the fracturing bolts from ⅜ in. (9.5 mm) to 7/16 in. (11.1 mm), decreasing the bolt spacing from 10 13/16 in. x 2½ in. (275 mm x 64 mm) to 10 in. x 2½ in. (254 mm x 64 mm), and decreasing the embedment depth of the UBSP base from 45⅜ in. (1,153 mm) to 40 in. (1,016 mm). In test no. USPBN-2, the 2000P vehicle was adequately contained and no significant occupant compartment deformation occurred. Thus, test no. USPBN-2 conducted on a bullnose median barrier was determined to be acceptable according to the NCHRP Report No. 350 safety performance criteria for test designation no. 3-38. While test no. USPBN-2 demonstrated acceptable performance of the UBSP for test no. 3-38, two additional crash tests were required to fully evaluate the use of the new post design in the thrie beam bullnose barrier system.

1.2 Objective

The objective of the research project was to complete the full-scale test matrix required to evaluate the use of the UBSP design in the thrie beam bullnose system. Three full-scale crash tests were required to evaluate the use of the UBSP, test designation nos. 3-30, 3-31, and 3-38. Because the UBSP had previously been successfully tested under test designation no. 3-38, two additional TL-3 full-scale vehicle crash test (test designation nos. 3-30 and 3-31) were planned in order to demonstrate that the UBSP, used in combination with the thrie beam bullnose median barrier system, would meet the NCHRP Report No. 350 safety performance guidelines.

2 DESIGN DETAILS

The test installation was comprised of a bullnose median barrier system which utilized universal breakaway steel posts, as shown in Figures 1 through 23. Photographs of the test installation are shown in Figures 24 and 25. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix A.

A one-half barrier system was utilized for the testing program in order to reduce costs and construction time. The bullnose system was constructed with twenty-eight posts, with fourteen posts positioned on each side of the system. Each side of the system contained two BCT posts, six UBSP posts, four W6x8.5 (W152x12.6) standard guardrail posts, and two BCT anchorage posts, respectively from the nose of the system. The lower portion of the UBSP consists of a foundation tube with the lower base plate. The upper portion of the UBSP consists of a post with the upper base plate. Although the goal of this study was to develop an all-steel system, previous testing demonstrated that using BCT wood posts in the anchorage system allowed for improved performance and the effective capture of the pickup truck [5].

All of the posts were placed in a compacted coarse, crushed limestone material meeting Grading B of AASHTO M 147-65 as found in NCHRP Report No. 350. The soil was compacted in 2-ft (610-mm) diameter augured holes using 8-in. (203-mm) lifts. Also, the fracturing bolts in the breakaway posts were torqued to 60 to 75 ft-lbs (81.3 to 101.7 N-m) for the full-scale crash testing program.

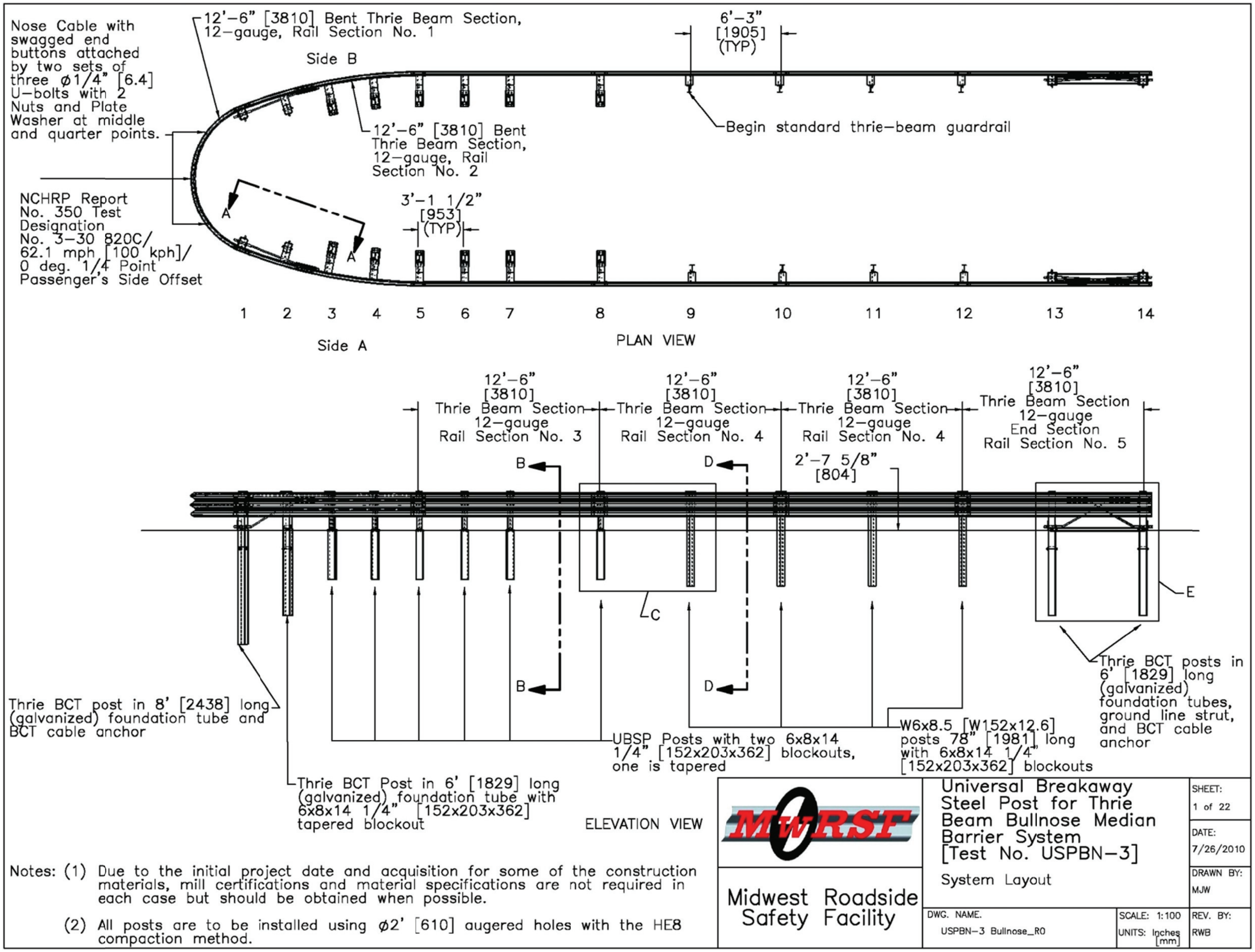


Figure 1. Test Installation Layout, Test No. USPBN-3

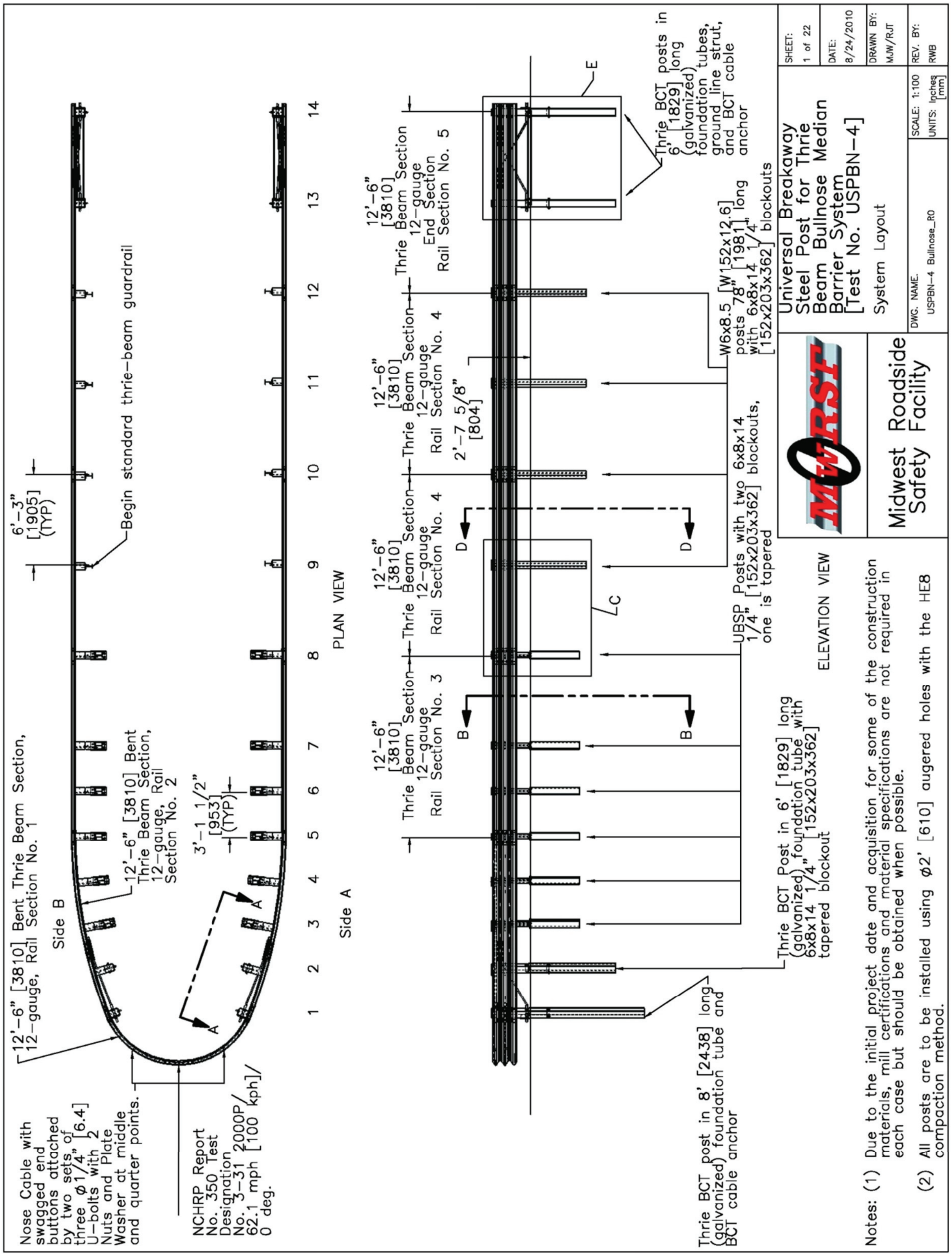


Figure 2. Test Installation Layout, Test No. USPBN-4

Post No.	Side A				Side B			
	Rear Face–D.S. Edge		Rear Face–U.S. Edge		Rear Face–D.S. Edge		Rear Face–U.S. Edge	
	X	Y	X	Y	X	Y	X	Y
1	61'–10 7/8"	2'–3 1/8"	62'–4"	2'–5"	61'–10 7/8"	2'–3 1/8"	62'–4"	2'–5"
2	58'–9 3/4"	1'–11 1/4"	59'–3"	2'–0 3/4"	58'–9 3/4"	1'–11 1/4"	59'–3 1/8"	2'–0 3/4"
3	55'–10 3/8"	1'–9 1/8"	56'–2 1/4"	1'–9 7/8"	55'–10 3/8"	1'–9 1/8"	56'–2 1/4"	1'–9 7/8"
4	52'–11 1/4"	1'–4 1/4"	53'–3 1/8"	1'–4 3/4"	52'–11 1/4"	1'–4 1/4"	53'–3 1/8"	1'–4 3/4"
5	49'–10 1/2"	1'–2 3/8"	50'–2 1/2"	1'–2 3/8"	49'–10 7/8"	1'–2 3/8"	50'–2 7/8"	1'–2 3/8"
6	46'–9"	1'–2 3/8"	47'–1"	1'–2 3/8"	46'–9 3/8"	1'–2 3/8"	47'–1 3/8"	1'–2 3/8"
7	43'–9"	1'–2 3/8"	44'–2 1/2"	1'–2 3/8"	43'–9"	1'–2 3/8"	44'–2 1/2"	1'–2 3/8"
8	37'–6"	1'–2 3/8"	37'–11 1/2"	1'–2 3/8"	37'–6"	1'–2 3/8"	37'–11 1/2"	1'–2 3/8"
9	31'–3"	6 3/8"	31'–8 1/2"	6 3/8"	31'–3"	6 3/8"	31'–8 1/2"	6 3/8"
10	25'–0"	6 3/8"	25'–5 1/2"	6 3/8"	25'–0"	6 3/8"	25'–5 1/2"	6 3/8"
11	18'–9"	6 3/8"	19'–2 1/2"	6 3/8"	18'–9"	6 3/8"	19'–2 1/2"	6 3/8"
12	12'–6"	6 3/8"	12'–11 1/2"	6 3/8"	12'–6"	6 3/8"	12'–11 1/2"	6 3/8"
13	6'–3"	0"	6'–8 1/2"	0"	6'–3"	0"	6'–8 1/2"	0"
14	0"	0"	5 1/2"	0"	0"	0"	5 1/2"	0"

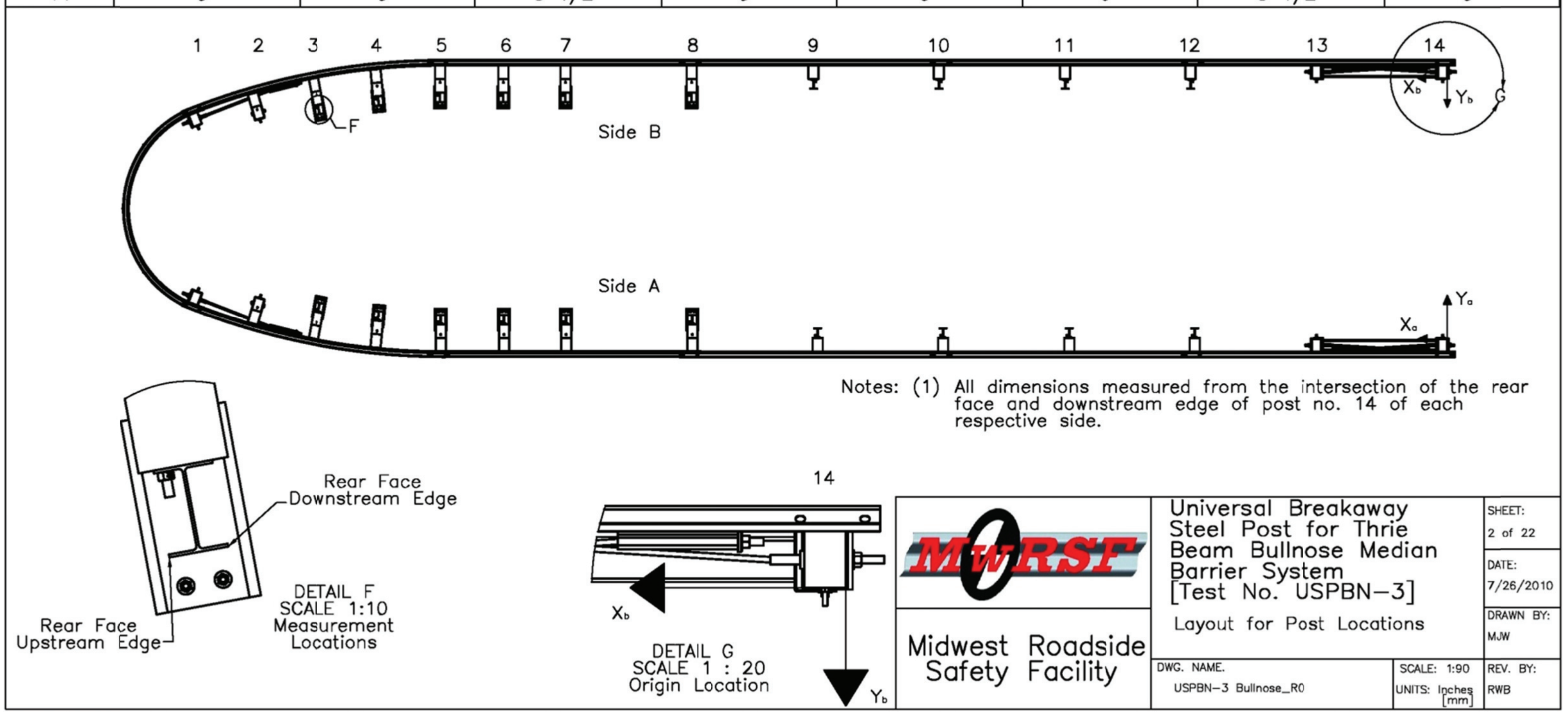
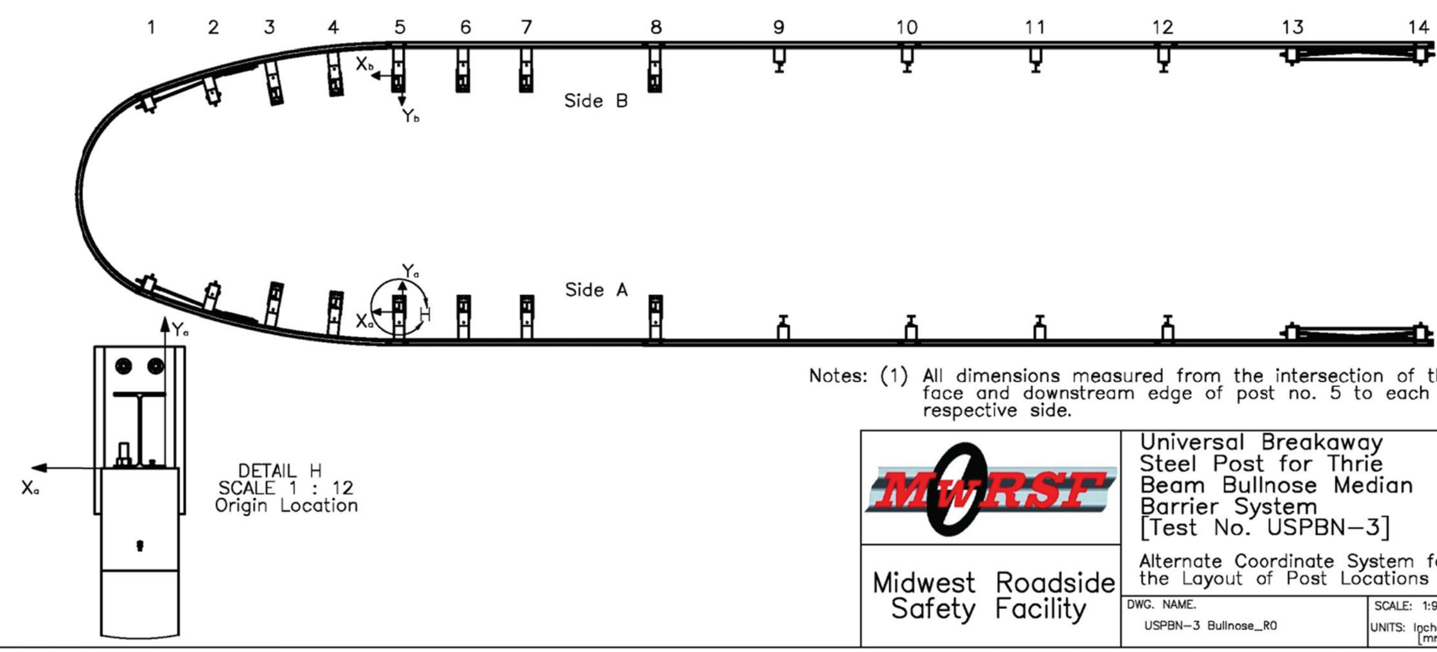


Figure 3. Post Locations, Test Nos. USPBN-3 and USPBN-4

Post No.	Rear Face–D.S. Edge		Rear Face–U.S. Edge	
	X_a and X_b	Y_a and Y_b	X_a and X_b	Y_a and Y_b
1	12'–0"	1'–6 5/8"	12'–5 1/8"	1'–8 1/2"
2	8'–10 7/8"	1'–2 3/4"	9'–4 1/8"	1'–4 1/4"
3	5'–11 3/8"	1'–0 5/8"	6'–3 1/4"	1'–1 3/8"
4	3'–0 1/4"	7 3/4"	3'–4 1/4"	8 1/8"
5	0"	5 7/8"	4"	5 7/8"



Notes: (1) All dimensions measured from the intersection of the front face and downstream edge of post no. 5 to each respective side.

Midwest Roadside Safety Facility	Universal Breakaway Steel Post for Thrie Beam Bullnose Median Barrier System [Test No. USPBN–3]		SHEET: 3 of 22
			DATE: 7/26/2010
	Alternate Coordinate System for the Layout of Post Locations		DRAWN BY: MJW
	DWG. NAME. USPBN–3 Bullnose_R0	SCALE: 1:90 UNITS: Inches [mm]	REV. BY: RWB

Figure 4. Post Locations, Alternate Coordinates, Test Nos. USPBN-3 and USPBN-4

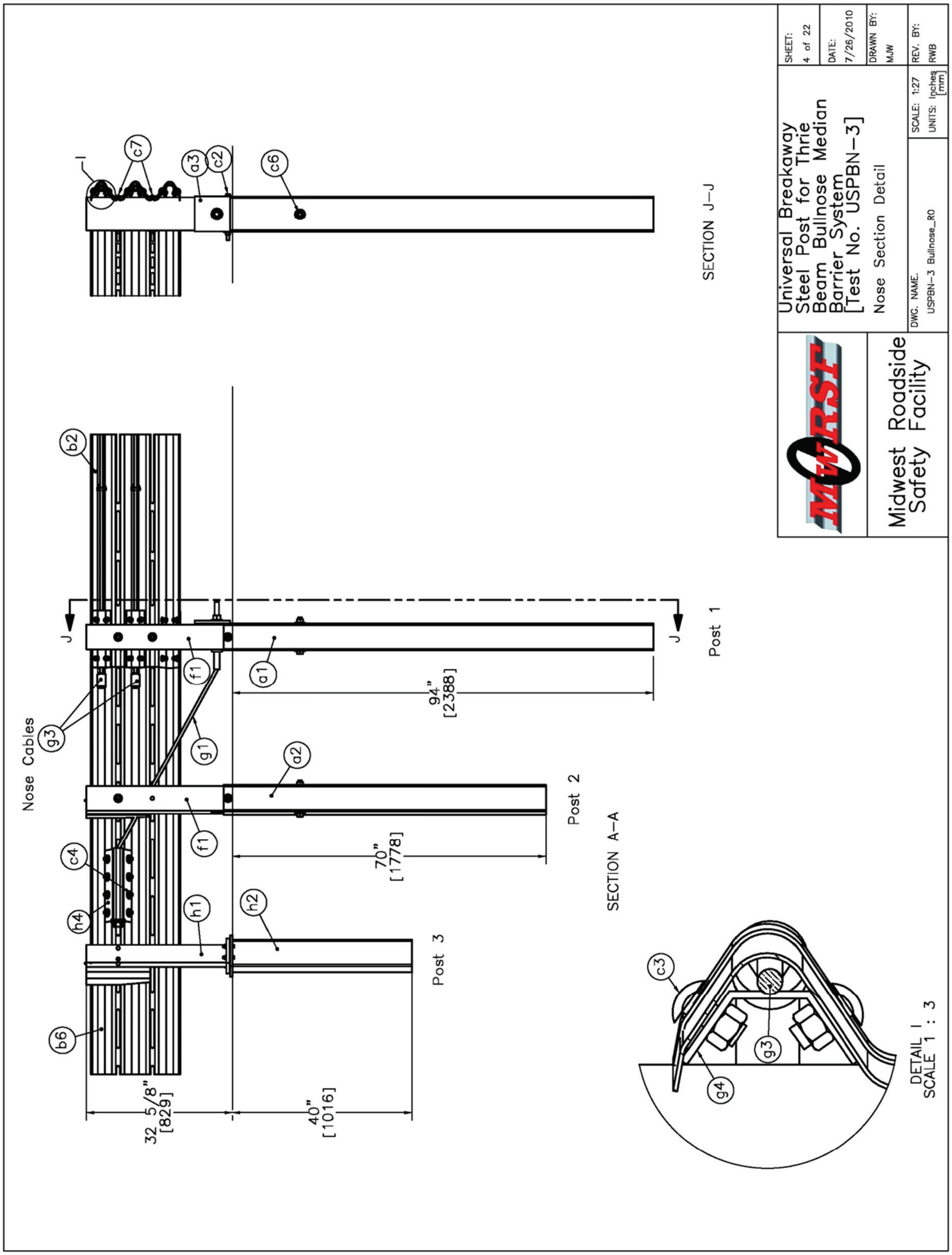


Figure 5. Nose Detail, Test Nos. USPBN-3 and USPBN-4

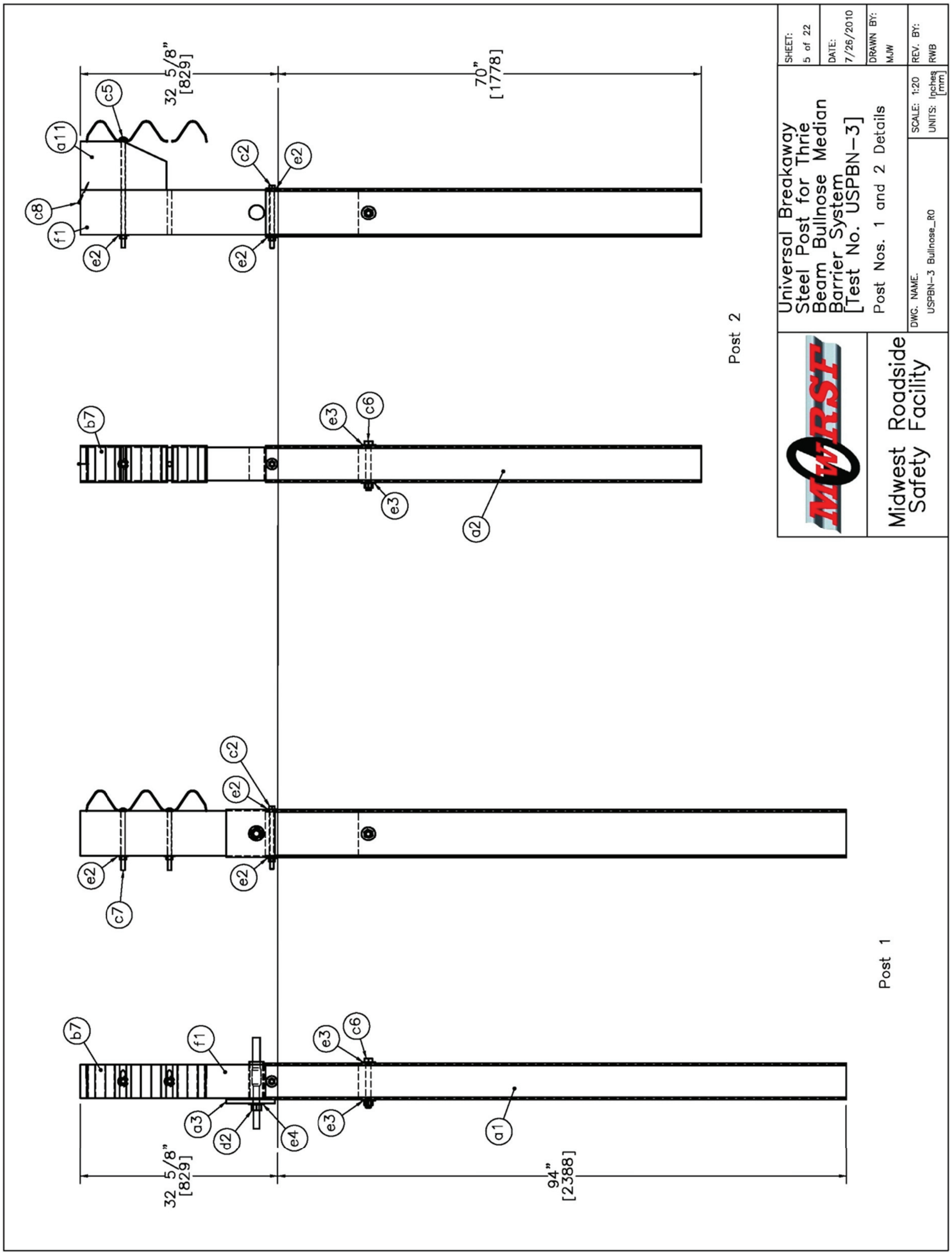


Figure 6. Post Nos. 1 and 2, Test Nos. USPBN-3 and USPBN-4

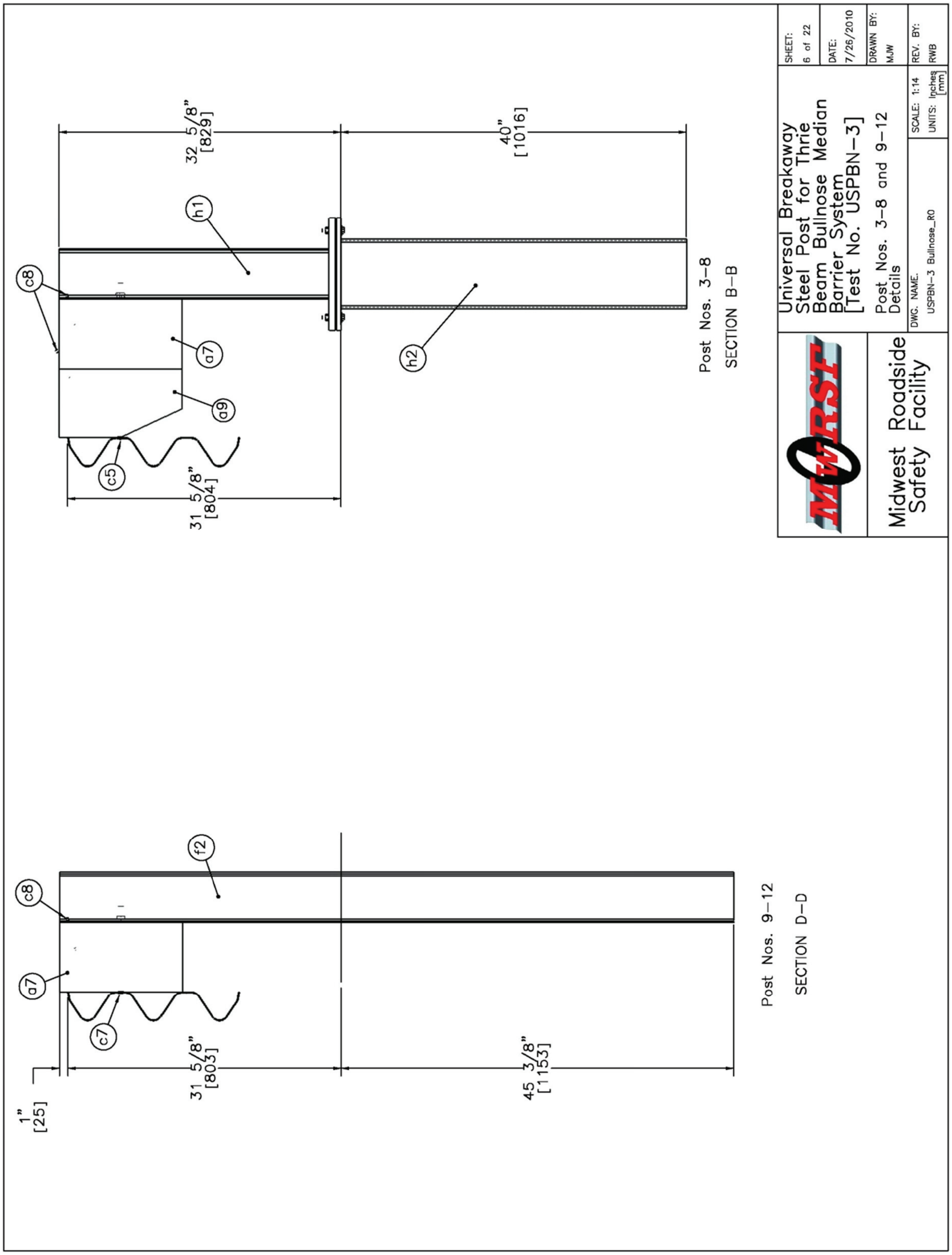


Figure 7. Post Nos. 3-12, Test Nos. USPBN-3 and USPBN-4

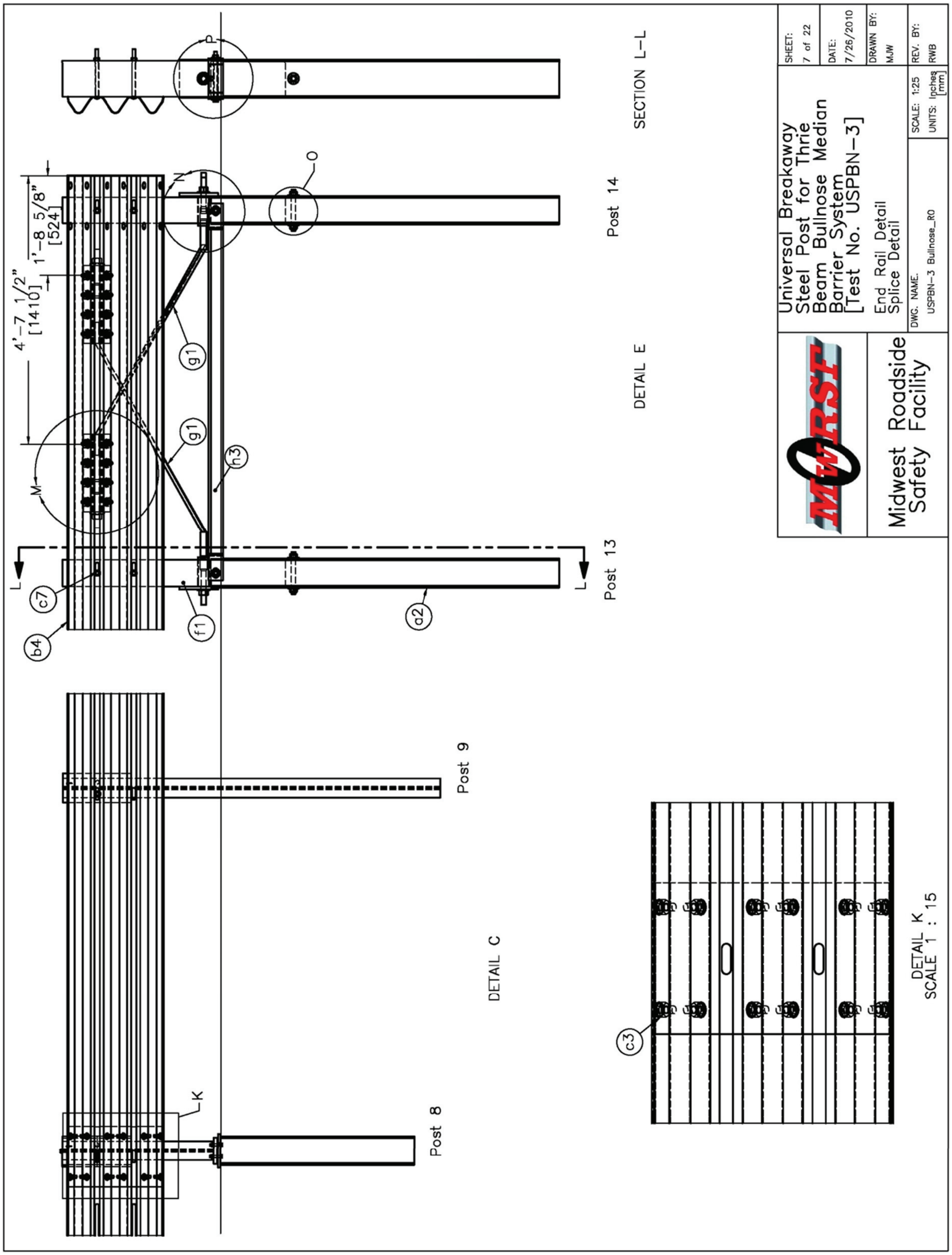


Figure 8. End Rail and Splice Details, Test Nos. USPBN-3 and USPBN-4

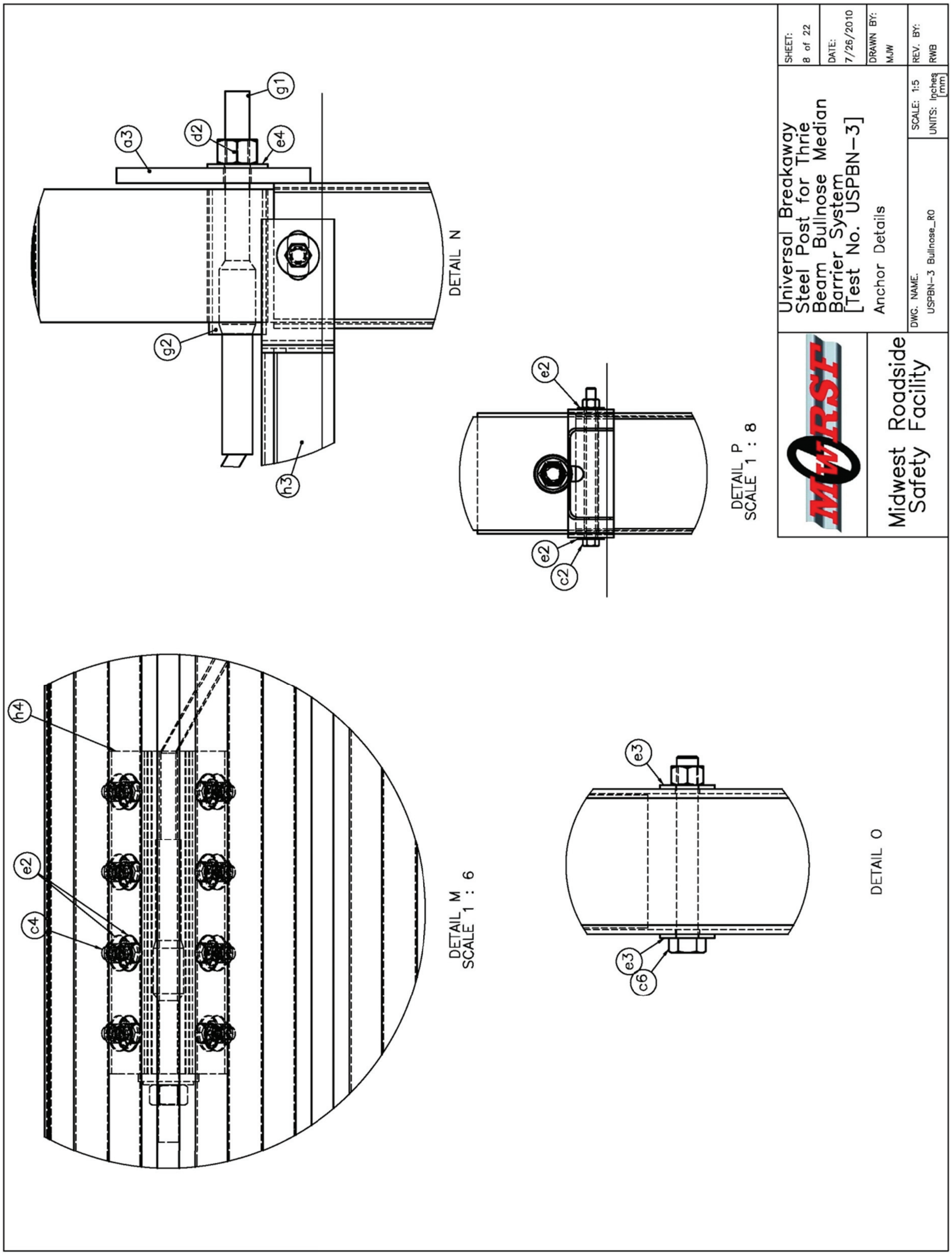


Figure 9. Anchor Details, Test Nos. USPBN-3 and USPBN-4

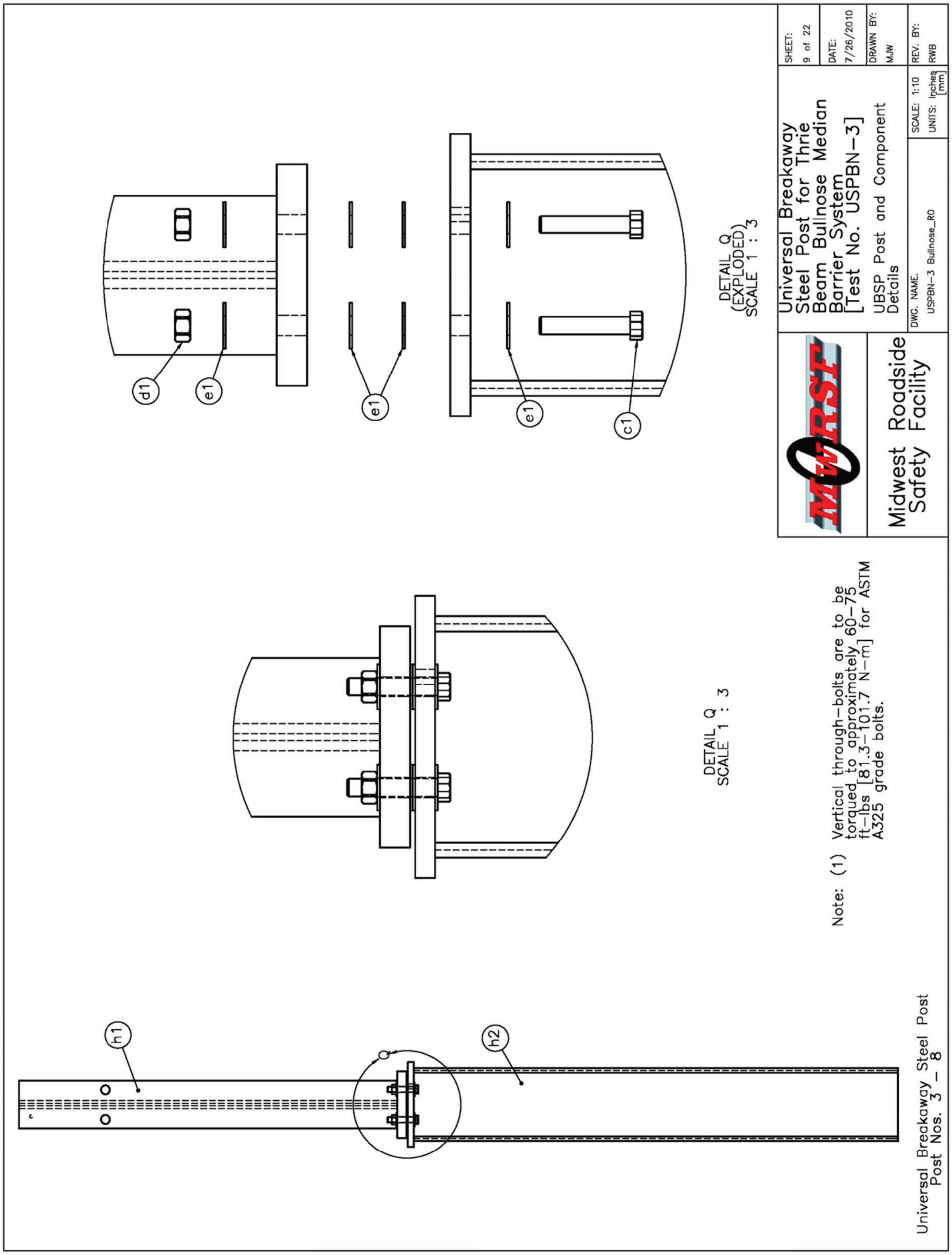


Figure 10. UBSP Post Details, Test Nos. USPBN-3 and USPBN-4

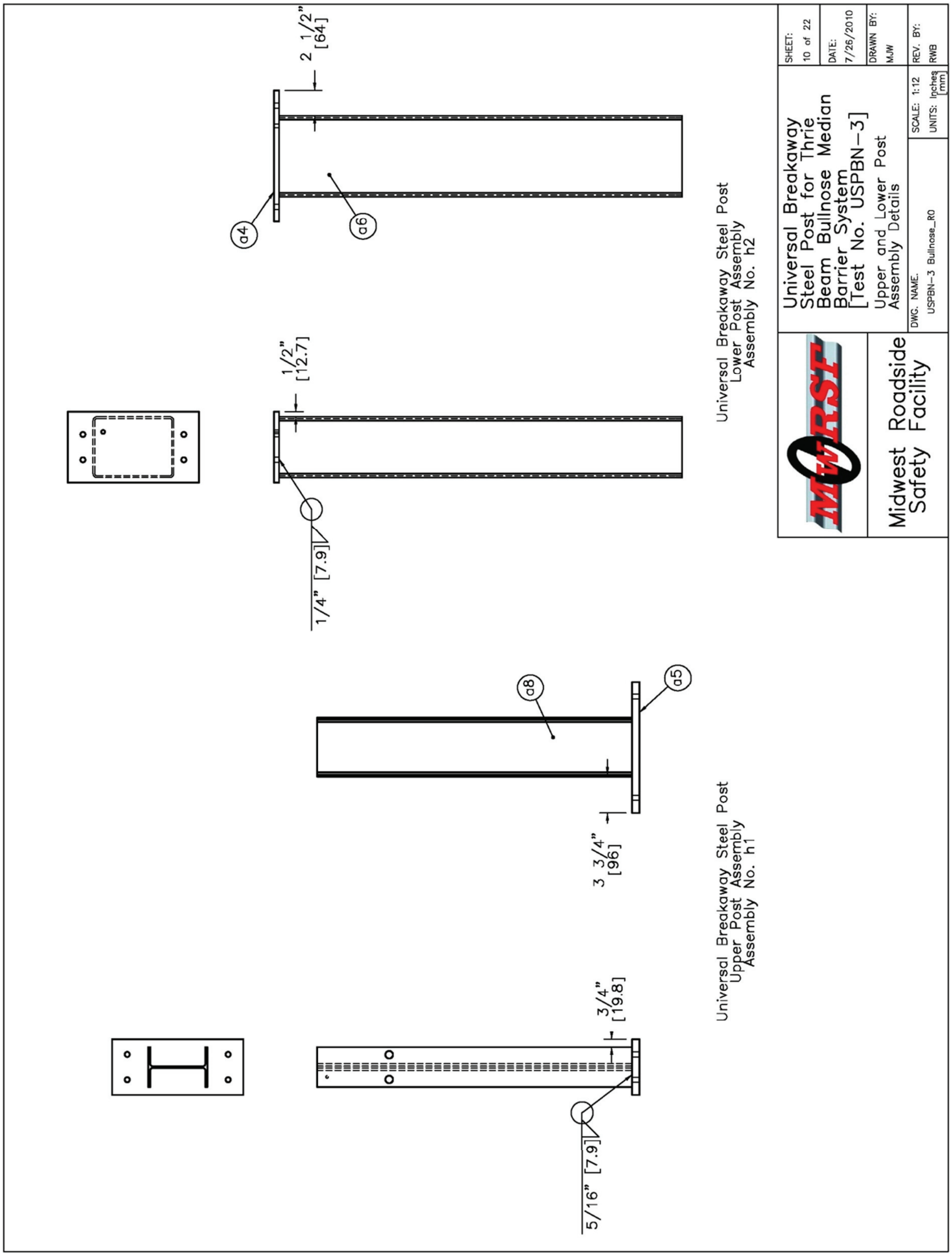


Figure 11. Upper and Lower Post Assembly, Test Nos. USPBN-3 and USPBN-4

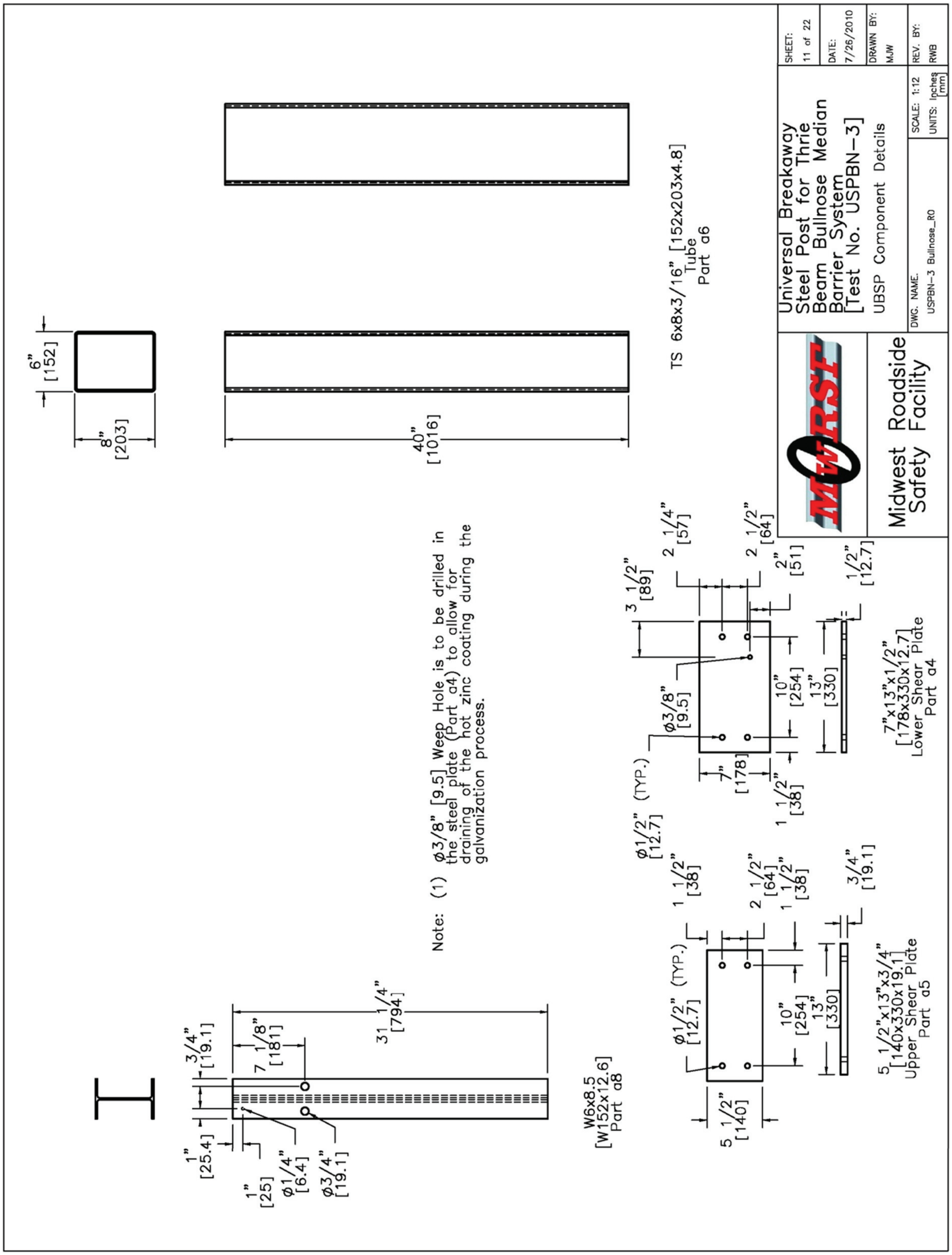


Figure 12. UBSP Component Details, Test Nos. USPBN-3 and USPBN-4

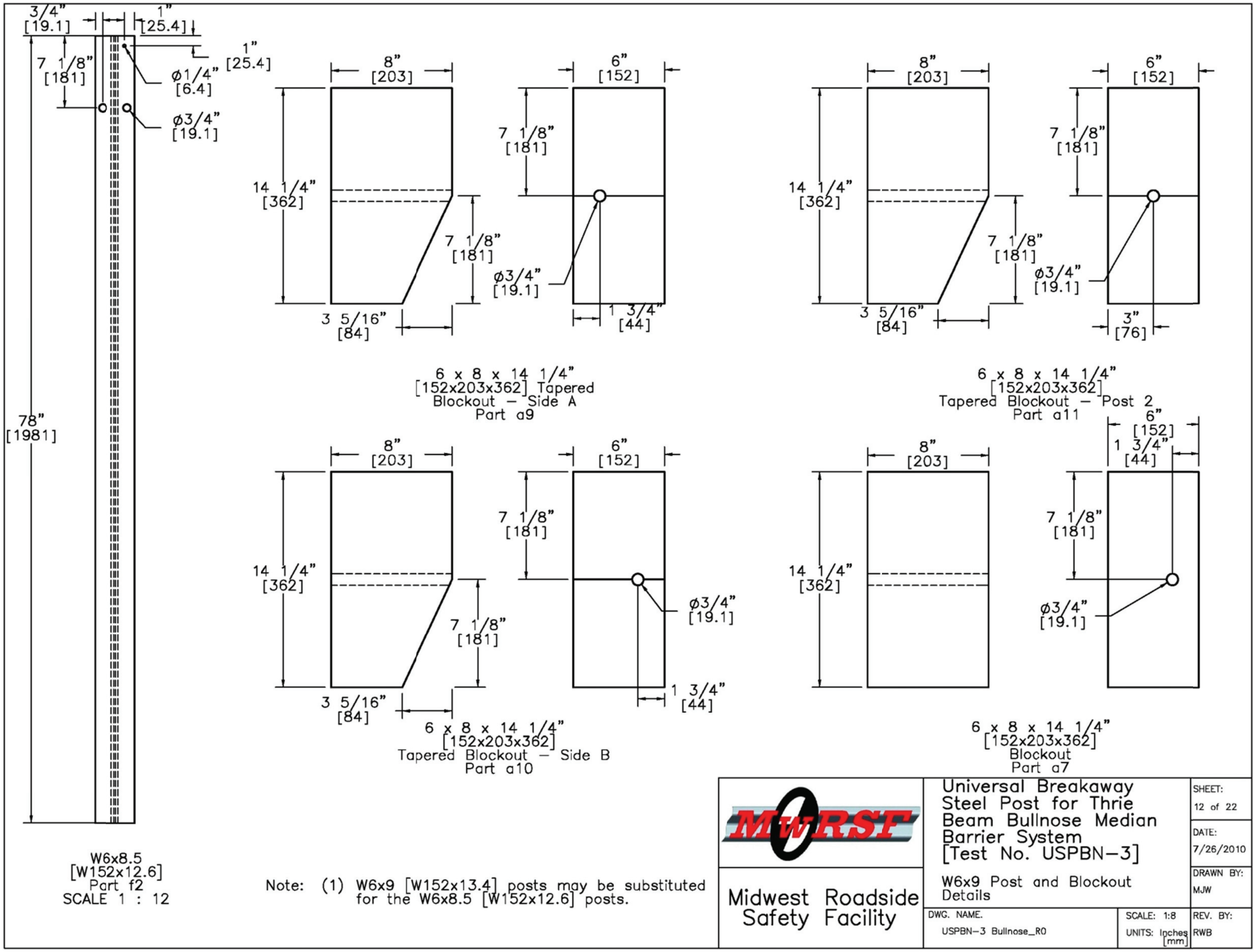


Figure 13. W6x9 Post and Blockout Details, Test Nos. USPBN-3 and USPBN-4

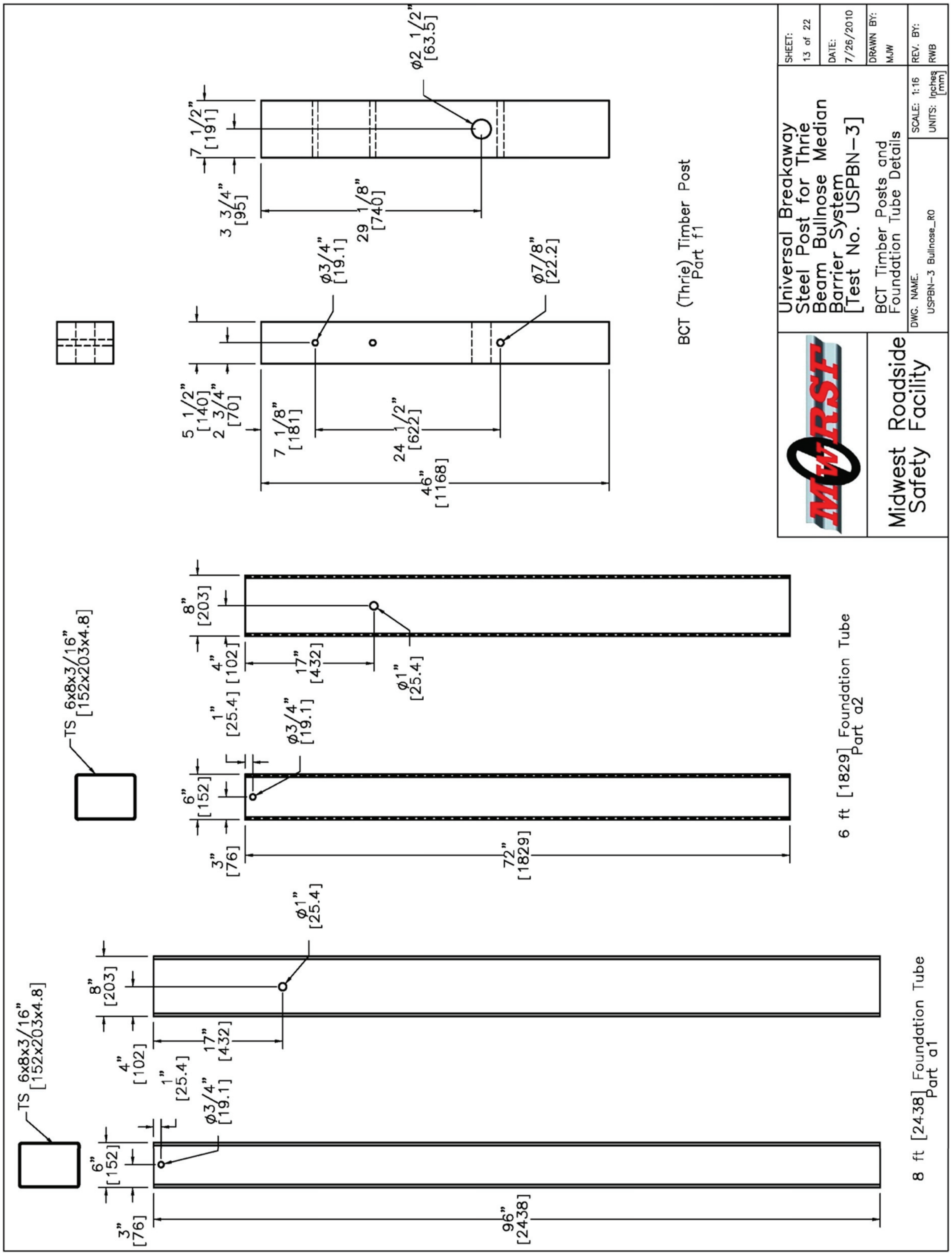


Figure 14. BCT Timber Posts and Foundation Tubes, Test Nos. USPBN-3 and USPBN-4

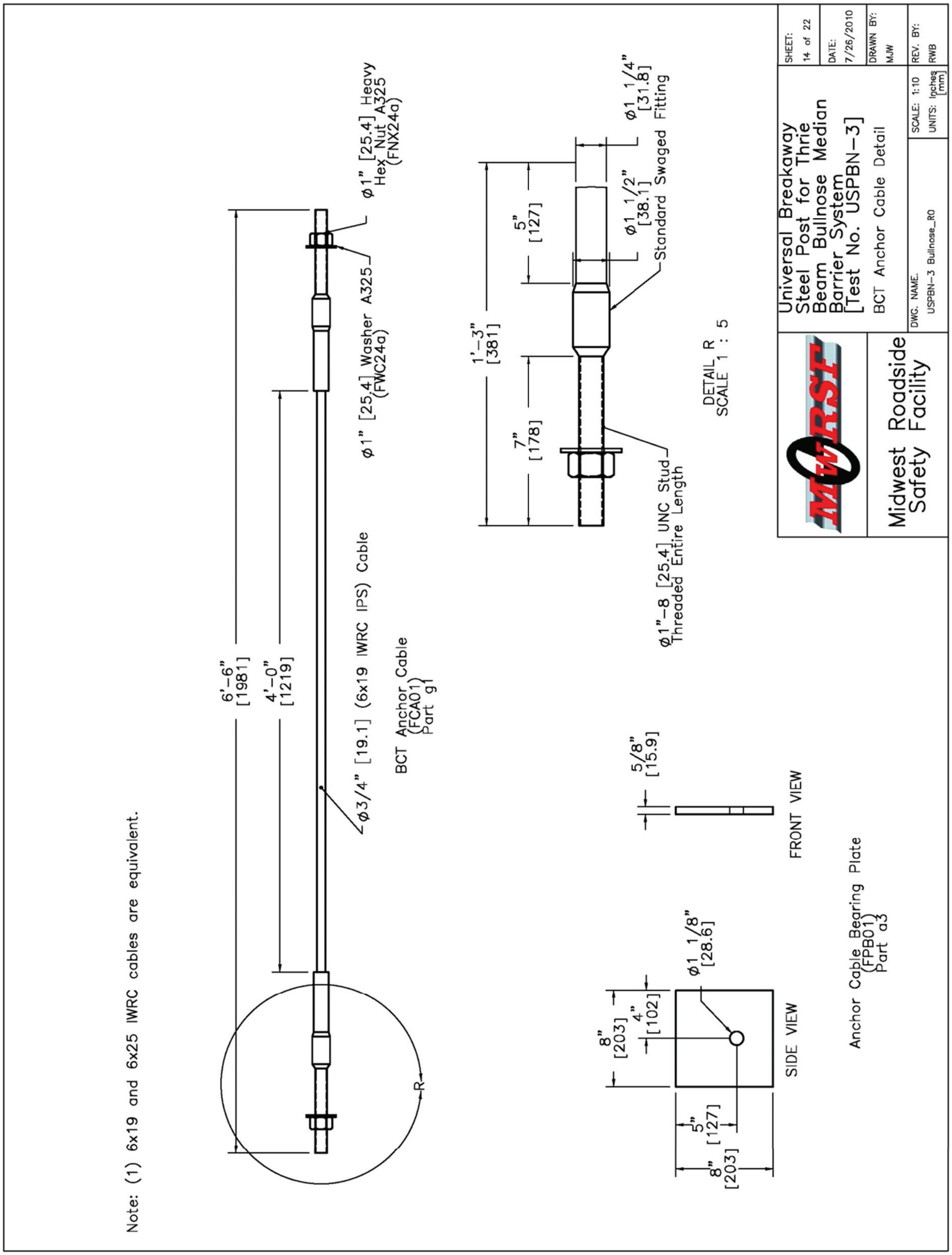


Figure 15. BCT Anchor Cable, Test Nos. USPBN-3 and USPBN-4

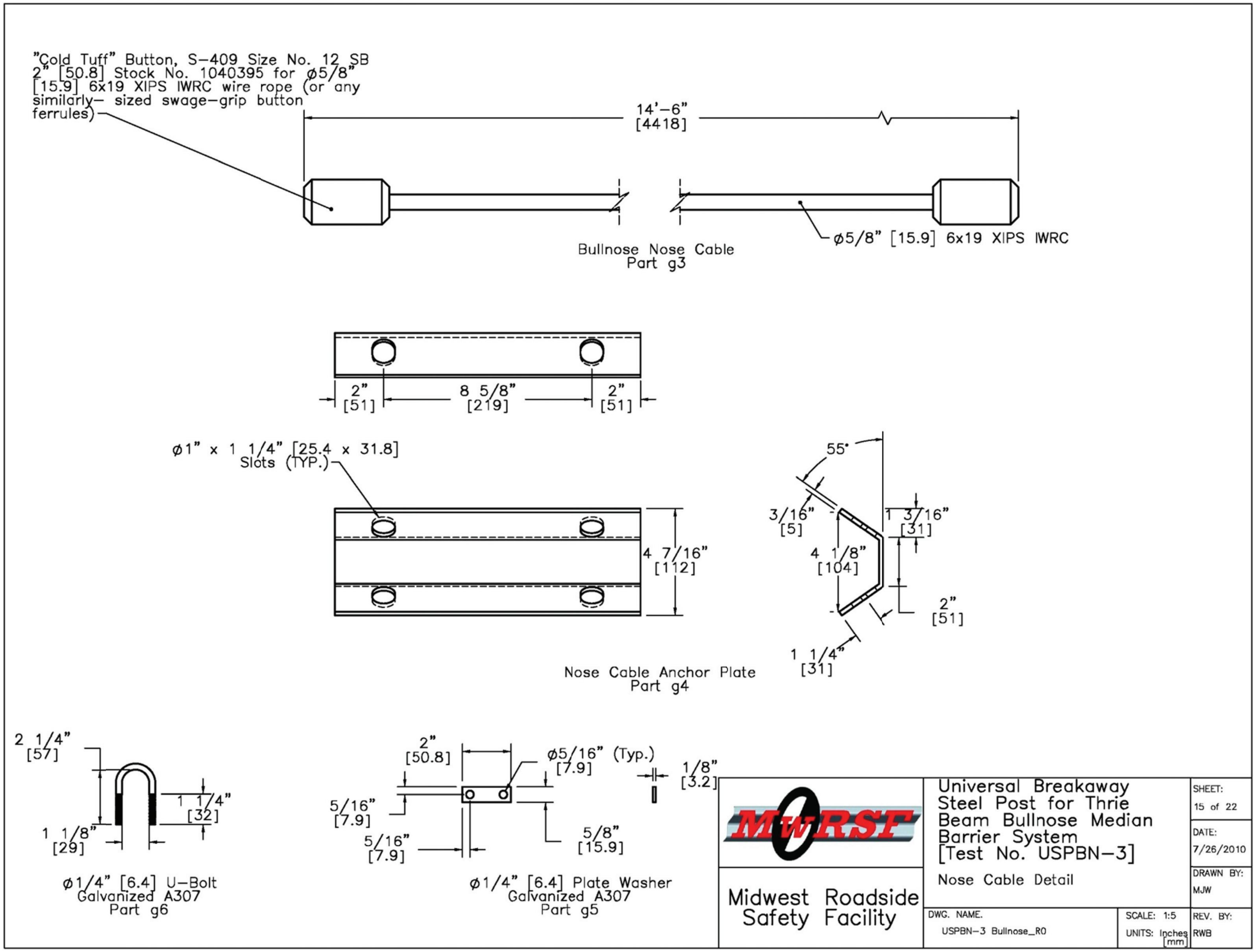


Figure 16. Nose Cable, Test Nos. USPBN-3 and USPBN-4

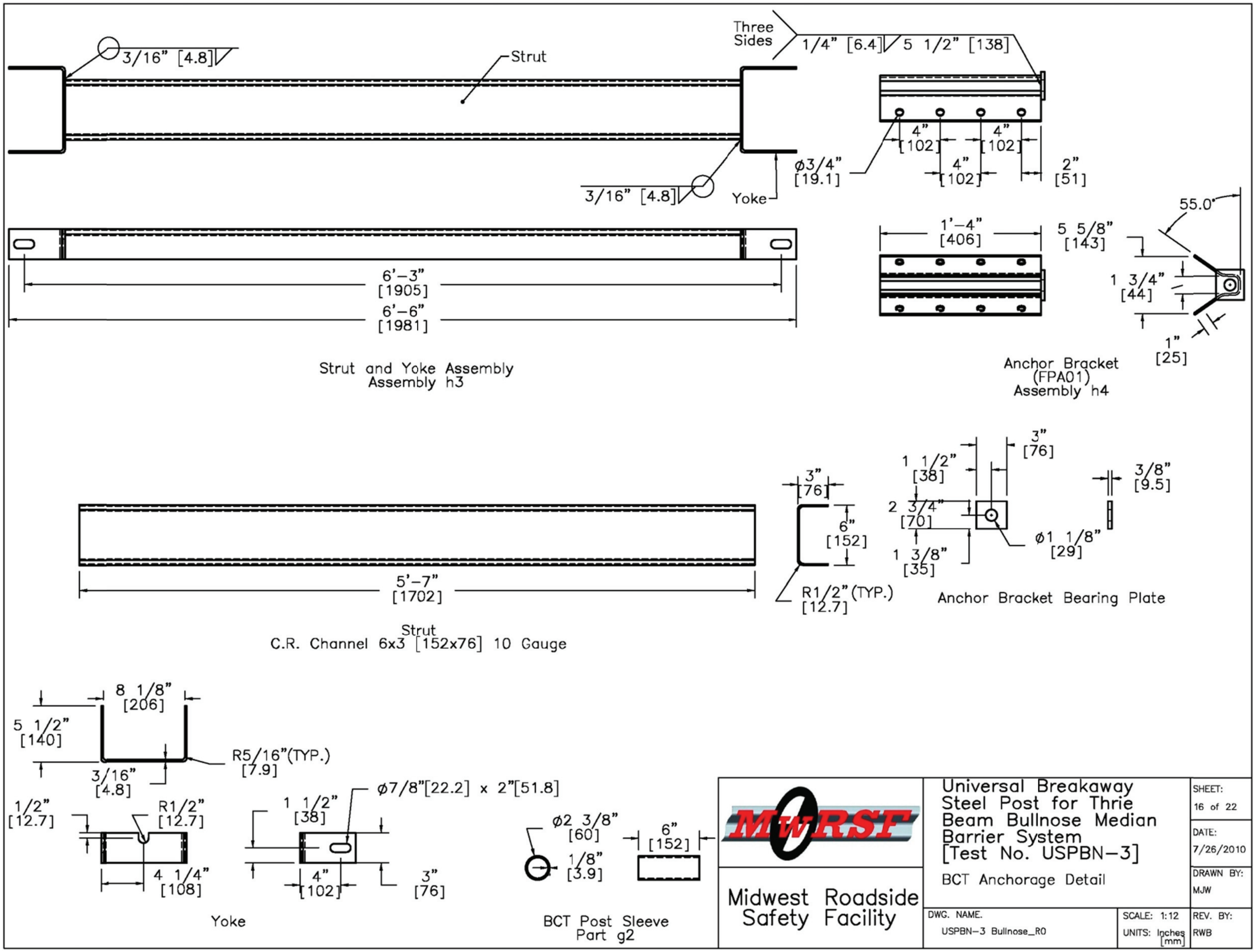


Figure 17. BCT Anchorage, Test Nos. USPBN-3 and USPBN-4

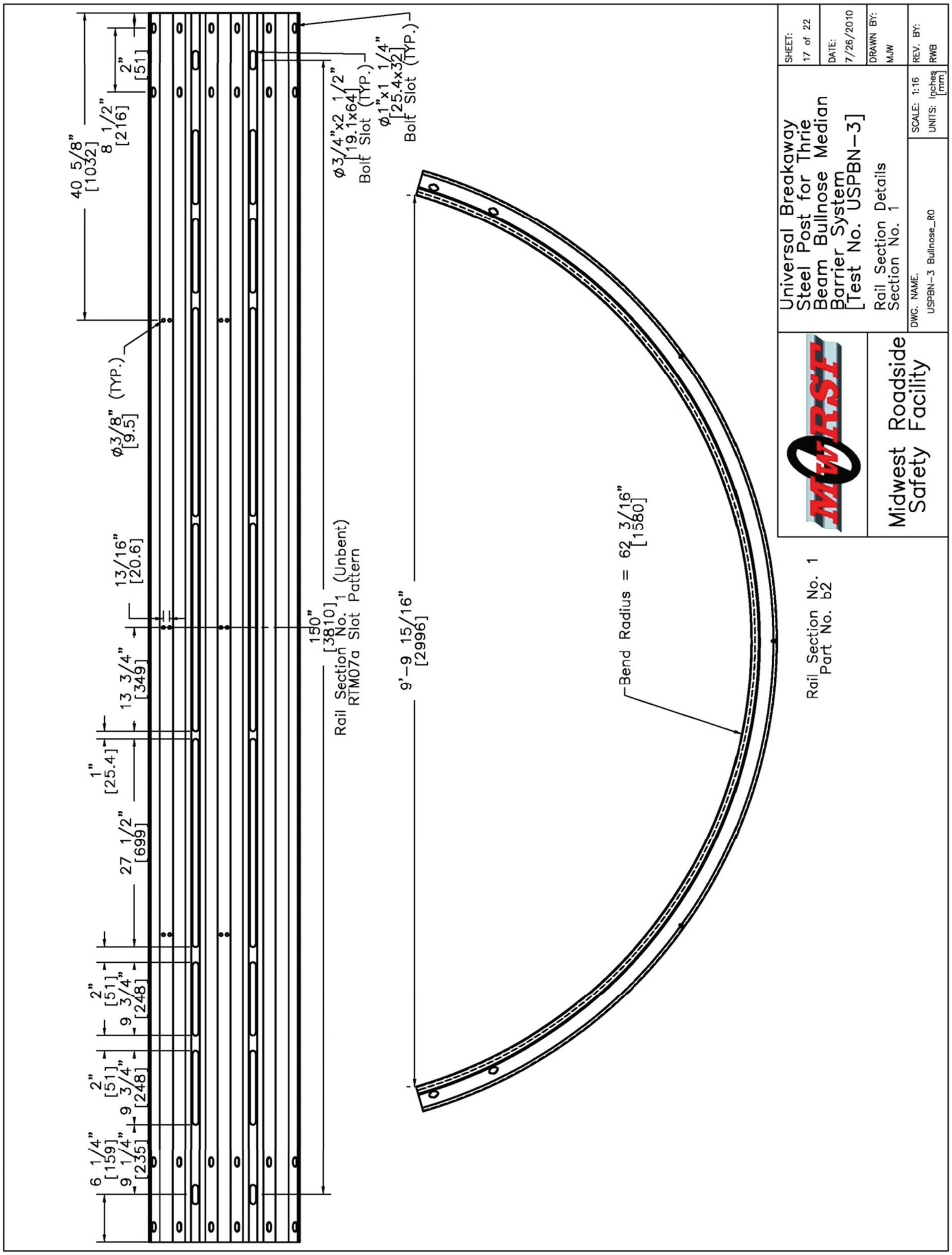


Figure 18. Rail Section No. 1, Test Nos. USPBN-3 and USPBN-4

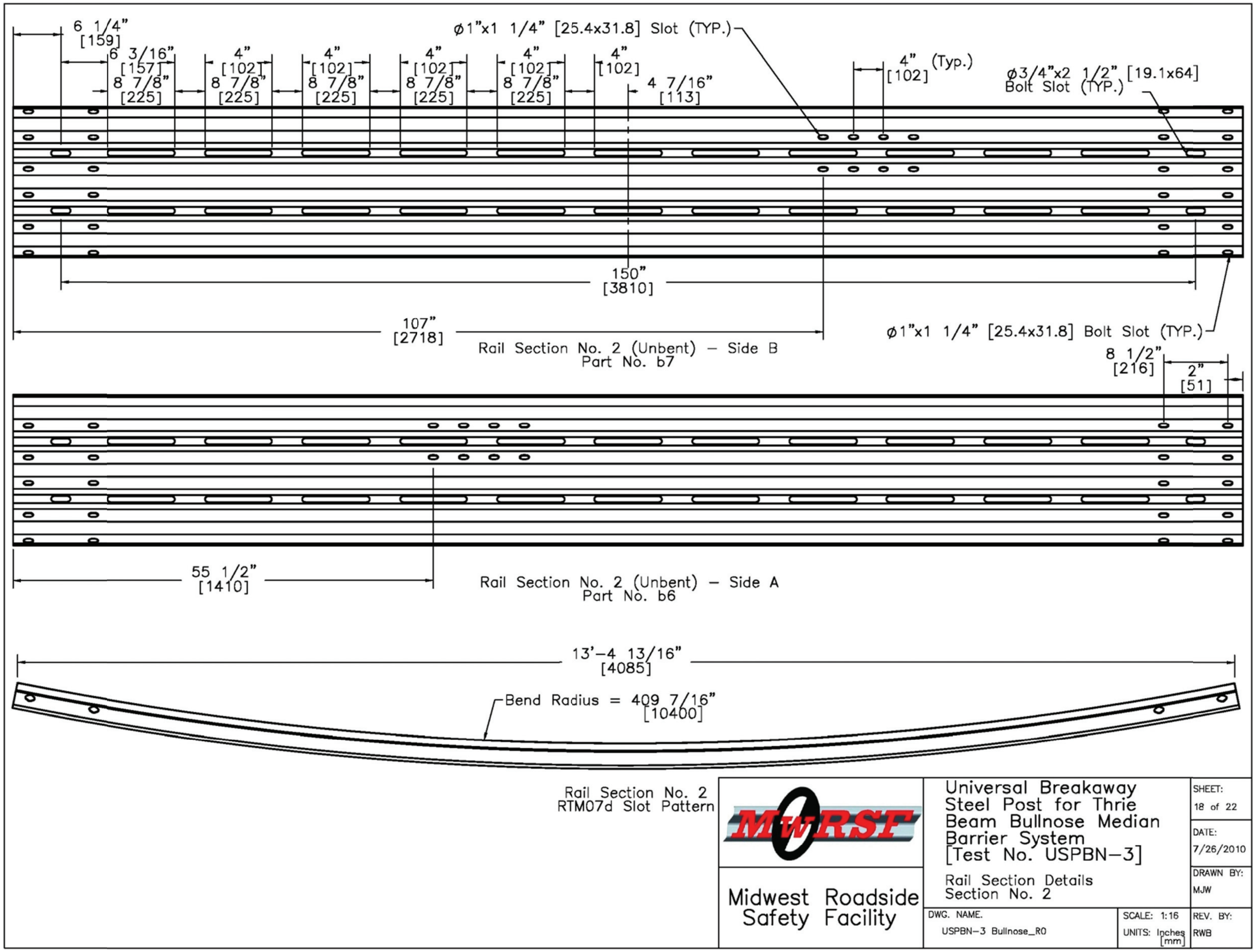


Figure 19. Rail Section No. 2, Test Nos. USPBN-3 and USPBN-4

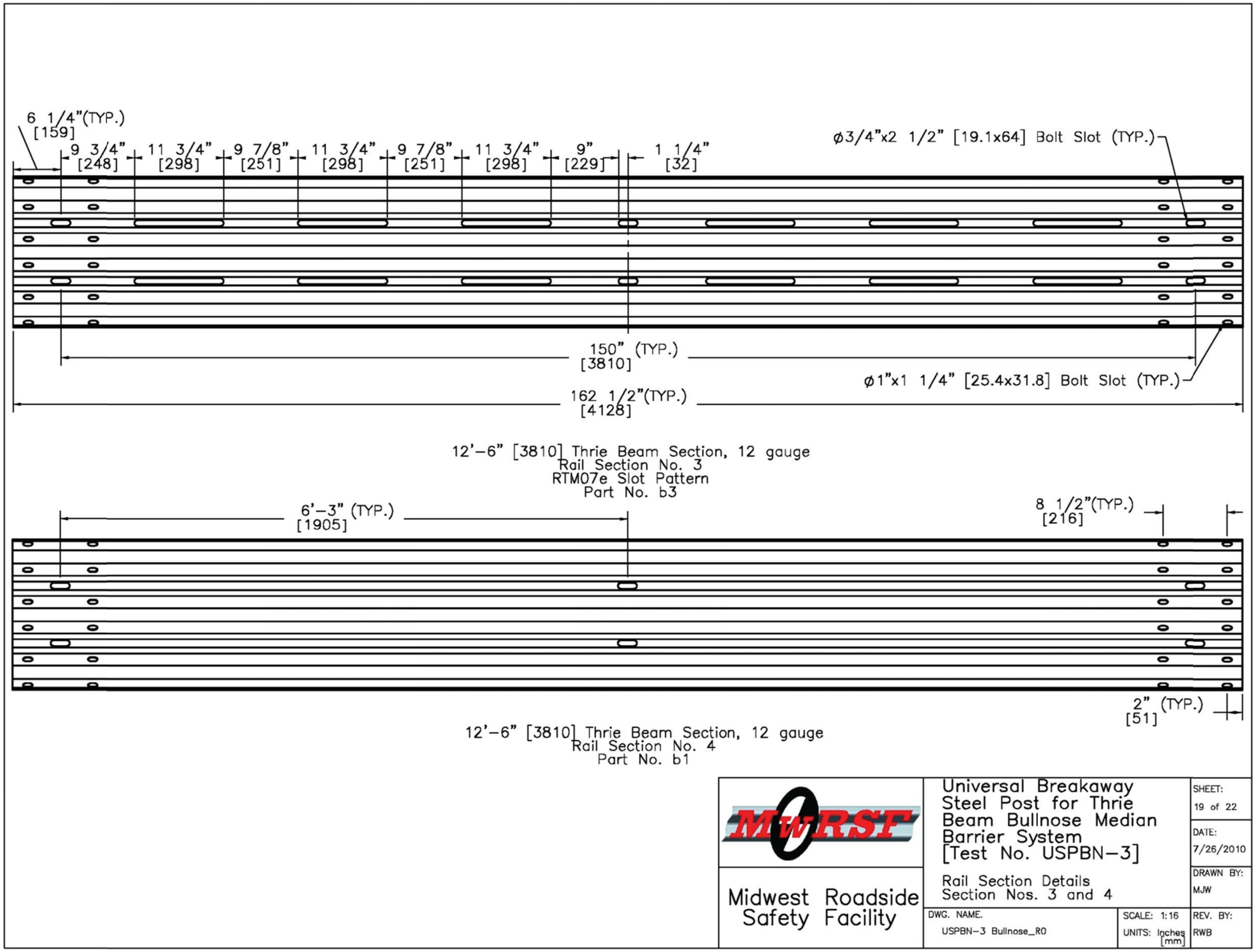


Figure 20. Rail Section Nos. 3 and 4, Test Nos. USPBN-3 and USPBN-4

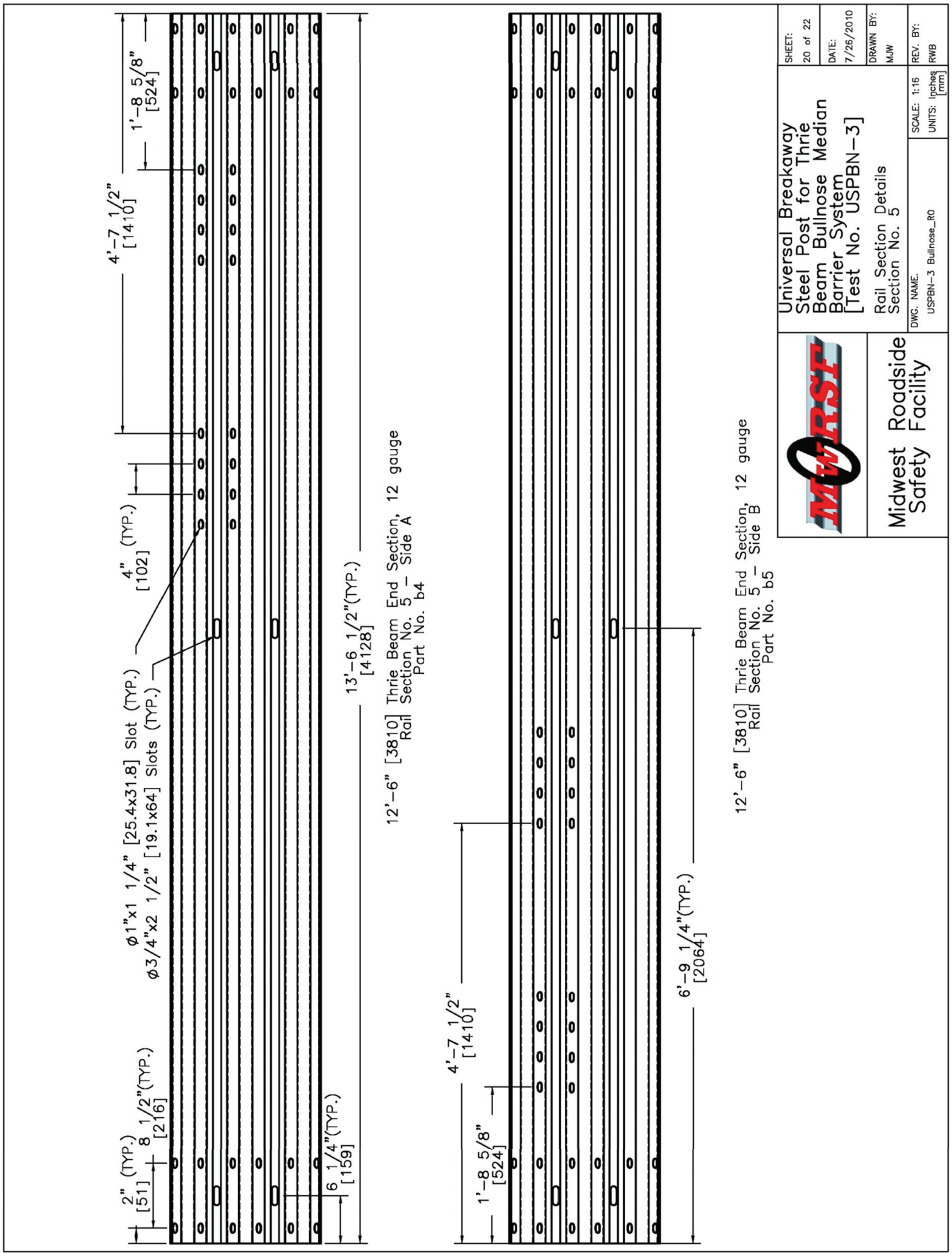


Figure 21. Rail Section No. 5, Test Nos. USPBN-3 and USPBN-4

UBSP-3 Bullnose				
Item No.	QTY.	Description	Material Specification	Hardware Guide
a1	2	96" [2438] Foundation Tube	ASTM A500 Grade B	PTE07
a2	6	72" [1829] Foundation Tube	ASTM A500 Grade B	PTE06
a3	6	8 x 8 x 5/8" [203 x 203 x 15.9] Anchor Bearing Plate	ASTM A36	FPB01
a4	12	13 x 7 x 1/2" [330 x 178 x 13] Lower Shear Plate	ASTM A36	–
a5	12	13 x 5 1/2 x 3/4" [330 x 140 x 19] Upper Shear Plate	ASTM A36	–
a6	12	6 x 8 x 3/16" [152 x 203 x 5] x 40" [1016] Foundation Tube	ASTM A500 Grade B	–
a7	20	6 x 8 x 14 1/4" [152 x 203 x362] Blockout	SYP Grade No.1 or better	PDB09
a8	12	W6x8.5 [W152 x 12.6] x 31 1/4" [794] (W6x9 [W152 x 13.4] can be substituted)	ASTM A36 (ASTM A992)	–
a9	6	6 x 8 x 14 1/4" [152 x 203 x 362] Tapered Blockout – Side A	SYP Grade No.1 or better	Blockout with Offset Holes
a10	6	6 x 8 x 14 1/4" [152 x 203 x 362] Tapered Blockout – Side B	SYP Grade No.1 or better	Blockout with Offset Holes
a11	2	6 x 8 x 14 1/4" [152 x 203 x 362] Tapered Blockout – Post 2	SYP Grade No.1 or better	PDB12
b1	4	12'–6" [3810] Thrie Beam Section No. 4	12 gauge AASHTO M180	RTM02a
b2	1	Bent 12'–6" [3810] Thrie Beam Section No. 1 – Radius 62 3/16" [1580]	12 gauge AASHTO M180	RTM07a
b3	2	12'–6" [3810] Thrie Beam Section No. 3 with Extra Slots	12 gauge AASHTO M180	RTM07e
b4	1	12'–6" [3810] Thrie Beam End Section No. 5 – Side A	12 gauge AASHTO M180	–
b5	1	12'–6" [3810] Thrie Beam End Section No. 5 – Side B	12 gauge AASHTO M180	–
b6	1	Bent 12'–6" [3810] Thrie Beam Section No. 2 – Radius 409 7/16" [10400] – Side A	12 gauge AASHTO M180	RTM07d
b7	1	Bent 12'–6" [3810] Thrie Beam Section No. 2 – Radius 409 7/16" [10400] – Side B	12 gauge AASHTO M180	RTM07d
c1	48	7/16" Dia. [11.1] UNC–14 x 2 1/2" [64] long Hex Tap Bolts (Fully Threaded)	SAE Grade 5/ASTM A325	–
c2	8	5/8" [15.9] Dia. x 10" [254] long Hex Head Bolt	Grade A307	FBX16a
c3	120	5/8" Dia. [15.9] x 1 1/2" [38] long Guardrail Bolt and Nut	ASTM A307	FBB01
c4	48	5/8" Dia. [15.9] x 1 1/2" [38]long Hex Head Bolt	ASTM A307	FBX16a
c5	14	5/8" Dia. [15.9] x 18" [457] long Guardrail Bolt and Nut	ASTM A307	FBB04
c6	8	7/8" [22.2] Dia. x 7 1/2" [191] long Hex Head Bolt and Nut	Grade A307	FBX22a
c7	20	5/8" Dia. [15.9] x 10" [254] long Guardrail Bolt and Nut	ASTM A307	FBB03
c8	34	16D Double Head Nail	–	–

Midwest Roadside Safety Facility

Universal Breakaway Steel Post for Thrie Beam Bullnose Median Barrier System [Test No. USPBN–3]

Bill of Materials

SHEET:	21 of 22
DATE:	7/26/2010
DRAWN BY:	MJW
DWG. NAME.	USPBN–3 Bullnose_R0
SCALE:	None
UNITS:	Inches [mm]
REV. BY:	RWB

Figure 22. Bill of Materials, Test Nos. USPBN-3 and USPBN-4

UBSP–3 Bullnose

Item No.	QTY.	Description	Material Specification	Hardware Guide
d1	48	7/16" Dia. [11.1] Hex Nut	ASTM A563DH Galvanized	–
d2	12	1" Dia. [25.4] Hex Nut	ASTM A563DH	–
e1	192	7/16" Dia. [11.1] Flat Washer	ASTM F436 Gr. 1 Galvanized	–
e2	118	5/8" [15.9] Dia. Flat Washer	Grade A307	FWC16a
e3	16	7/8" [22.2] Dia. Flat Washer	Grade A307	FWC22a
e4	12	1" Dia. [25.4] Flat Washer	ASTM F436 Gr. 1	FWC24a
f1	8	BCT Thrie Post	SYP Grade No. 1 or better (No knots, 18" [457] above or below ground line and on tension face)	PDF04
f2	8	W6x8.5 [W152x12.6] x 78" [1981] long (W6x9 [W152 x 13.4] can be substituted)	ASTM A36 (ASTM A992)	–
g1	6	BCT Cable 6'–6" [1981] Long	6x19 or 6x25 Cable IWRC IPS	FCA01
g2	6	2 3/8" [60] O.D. x 6" [152] long BCT Post Sleeve	ASTM A53 Grade B Schedule 40	FMM02
g3	2	Bullnose Nose Cable 5/8" Dia. [15.9] x 14.4' [4389] Long	"Cold Tuff" Button, S–409 Size No. 12 SB 2 7/8" [73] Stock No. 1040395 for 5/8" [16] Dia. (6x25) wire rope (or any similarly sized swage–grip button ferrules)	–
g4	4	Nose Cable Anchor Plates 12 5/8" [321] x 5 13/16" [148]	ASTM A36	–
g5	6	1/4" Dia. [6.4] U–Bolt Plate Washer	Zinc Coated or Galvanized ASTM A307	–
g6	6	1/4" Dia. [6.4] U–Bolt	Zinc Coated or Galvanized ASTM A307	–
g7	12	1/4" Dia. [6.4] Hex Nut	Zinc Coated or Galvanized ASTM A307	–
h1	12	UBSP Post – Top Assembly	–	–
h2	12	UBSP Post – Bottom Assembly	–	–
h3	2	Strut and Yoke Assembly	ASTM A36 Galvanized	–
h4	6	Anchor Bracket Assembly	ASTM A36	FPA01

Midwest Roadside Safety Facility

Universal Breakaway Steel Post for Thrie Beam Bullnose Median Barrier System [Test No. USPBN–3]

Bill Of Materials

SHEET:	22 of 22
DATE:	7/26/2010
DRAWN BY:	MJW
REV. BY:	RWB
DWG. NAME.	USPBN–3 Bullnose_R0
SCALE:	None
UNITS:	Inches [mm]

Figure 23. Bill of Materials, Test Nos. USPBN-3 and USPBN-4

Figure 24. Test Installation Photographs, Test Nos. USPBN-3 and USPBN-4

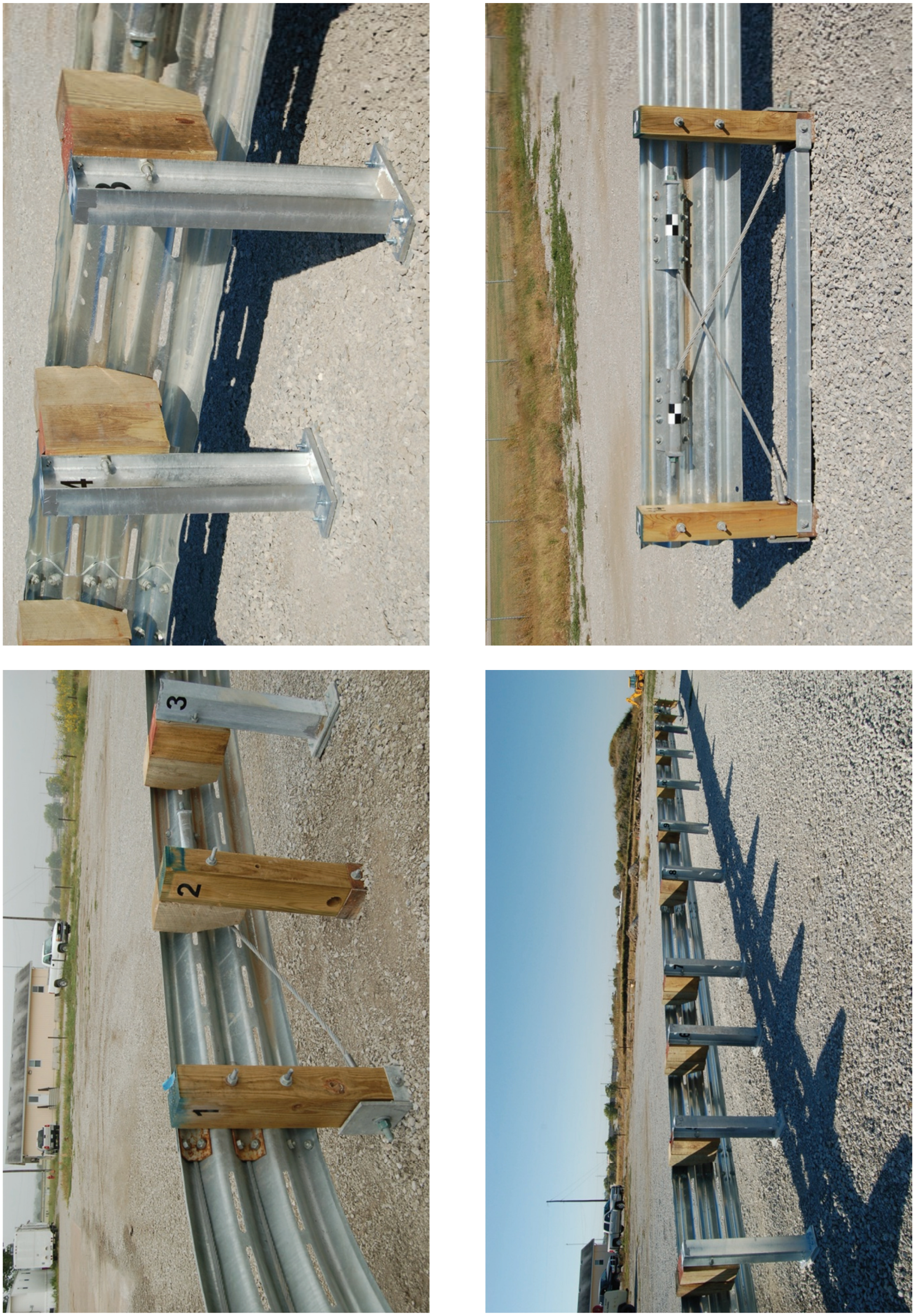


Figure 25. Test Installation Photographs, Test Nos. USPBN-3 and USPBN-4

3 TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 Test Requirements

Terminals and crash cushions, such as bullnose median barriers, must satisfy impact safety standards in order to be accepted by the Federal Highway Administration (FHWA) for use on National Highway System (NHS) new construction projects or as a replacement for existing designs not meeting current safety standards. In recent years, these safety standards have consisted of the guidelines and procedures published in NCHRP Report No. 350 [4]. From previous testing [3], the bullnose median barrier was defined as a non-gating barrier, and thus, must fulfill the requirements for a non-gating device. A non-gating device is designed to contain and either redirect or capture a vehicle when impacted downstream from the end of the device. According to Test Level 3 (TL-3) of NCHRP Report No. 350, non-gating terminals and crash cushions must be subjected to eight full-scale vehicle crash tests. The eight full-scale crash tests are as follows:

1. Test Designation 3-30 consisting of a 1,808-lb (820-kg) passenger car impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 0 degrees, respectively, on the tip of the barrier nose with a ¼-point offset.

2. Test Designation 3-31 consisting of a 4,409-lb (2,000-kg) pickup truck impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 0 degrees, respectively, on the tip of the barrier nose.

3. Test Designation 3-32 consisting of a 1,808-lb (820-kg) passenger car impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 15 degrees, respectively, on the tip of the barrier nose.

4. Test Designation 3-33 consisting of a 4,409-lb (2,000-kg) pickup truck impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 15 degrees, respectively, on the tip of the barrier nose.

5. Test Designation 3-36 consisting of a 1,808-lb (820-kg) passenger car impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 15 degrees, respectively, at the beginning of the LON (Length-of-Need).

6. Test Designation 3-37 consisting of a 4,409-lb (2,000-kg) pickup truck impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 20 degrees, respectively, at the beginning of the LON.

7. Test Designation 3-38 consisting of a 4,409-lb (2,000-kg) pickup truck impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 20 degrees at the Critical Impact Point (CIP), respectively.

8. Test Designation 3-39 consisting of a 4,409-lb (2,000-kg) pickup truck impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 20 degrees, respectively, in a reverse direction at one half the distance to the LON from the end of the terminal.

The test conditions of TL-3 longitudinal barriers are summarized in Table 1. The Critical Impact Point (CIP) mentioned above is defined for non-gating terminals as the point along the installation where it is unknown whether the guardrail will capture the impacting vehicle or redirect it.

Table 1. NCHRP Report No. 350 TL-3 Crash Test Conditions

Test Article	Test Designation	Test Vehicle	Impact Conditions			Evaluation Criteria [1]
			Speed		Angle (deg)	
			mph	km/h		
Non-gating Terminals and Crash Cushions	3-30	820C	62	100	0	C,D,F,H,I,K,N
	3-31	2000P	62	100	0	C,D,F,H,I,K,N
	3-32	820C	62	100	15	C,D,F,H,I,K,N
	3-33	2000P	62	100	15	C,D,F,H,I,K,N
	3-36	820C	62	100	15	A,D,F,H,I,K,M
	3-37	2000P	62	100	20	A,D,F,K,L,M
	3-38	2000P	62	100	20	A,D,F,K,L,M
	3-39	2000P	62	100	20	C,D,F,K,L,M,N

[1] Evaluation criteria explained in Table 2.

Previous testing of the bullnose guardrail system successfully passed all of the required tests on the wood-post, thrie beam bullnose system [1-3]. Based on the success of the previous testing, it was believed that the tests required for this project were those that would be affected by the change from the wood CRT posts to the steel fracturing bolt posts. Researchers determined that three full-scale crash tests would be required to verify that the UBSP provides acceptable safety performance when used in the bullnose median barrier system. The three tests are as follows:

Test Designation 3-38 (2000P at CIP);

Test Designation 3-30 (820C end-on, with ¼-point offset); and

Test Designation 3-31 (2000P end-on to evaluate penetration distance).

The bullnose median barrier system was successfully tested with UBSP posts according to test designation no. 3-38 as detailed in a previous research report [7].

3.2 Evaluation Criteria

Evaluation criteria for full-scale vehicle crash testing are based on three appraisal areas: (1) structural adequacy; (2) occupant risk; and (3) vehicle trajectory after collision. Criteria for structural adequacy are intended to evaluate the ability of the bullnose median barrier to contain and redirect impacting vehicles. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Vehicle trajectory after collision is a measure of the potential for the post-impact trajectory of the vehicle to result in secondary collisions with other vehicles or fixed objects, thereby increasing the risk of injury to the occupant of the impacting vehicle and to other vehicles. These evaluation criteria are summarized in Table 2 and defined in greater detail in NCHRP Report No. 350. The full-scale vehicle crash test was conducted and reported in accordance with the procedures provided in NCHRP Report No. 350.

In addition to the standard occupant risk measures, the Post-Impact Head Deceleration (PHD), the Theoretical Head Impact Velocity (THIV), and the Acceleration Severity Index (ASI) were determined and reported on the test summary sheet.

Table 2. NCHRP Report No. 350 Evaluation Criteria for Terminals and Crash Cushions

<table>
<tr><td rowspan="2">Structural Adequacy</td><td>A.</td><td colspan="3">Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td></tr>
<tr><td>C.</td><td colspan="3">Acceptable test article performance may be by redirection, controlled penetration, or controlled stopping of the vehicle.</td></tr>
<tr><td rowspan="10">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted. See discussion in Section 5.3 and Appendix E of NCHRP Report No. 350.</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocities (OIV) (see Appendix A, Section A5.3 of NCHRP Report No. 350 for calculation procedure) should satisfy the following:</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>29.5 ft/s
(9 m/s)</td><td>39.4 ft/s
(12 m/s)</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Accelerations (ORA) (see Appendix A, Section A5.3 of NCHRP Report No. 350 for calculation procedure) should satisfy the following:</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15 g’s</td><td>20 g’s</td></tr>
<tr><td rowspan="4">Vehicle Trajectory</td><td>K.</td><td colspan="3">After collision it is preferable that the vehicle’s trajectory not intrude into adjacent traffic lanes.</td></tr>
<tr><td>L.</td><td colspan="3">The occupant impact velocity in the longitudinal direction should not exceed 39.4 ft/s (12 m/s) and the occupant ridedown acceleration in longitudinal direction should not exceed 20 g’s.</td></tr>
<tr><td>M.</td><td colspan="3">The exit angle from the test article preferably should be less than 60 percent of the test impact angle, measured at time of vehicle loss of contact with test device.</td></tr>
<tr><td>N.</td><td colspan="3">Vehicle trajectory behind the test article is acceptable.</td></tr>
</table>

4 TEST CONDITIONS

4.1 Test Facility

The testing facility is located at the Lincoln Air Park on the northwest side of the Lincoln Municipal Airport and is approximately 5 miles (8.0 km) northwest of the University of Nebraska-Lincoln.

4.2 Vehicle Tow and Guidance System

A reverse cable tow system with a 1:2 mechanical advantage was used to propel the test vehicles. The distance traveled and the speed of the tow vehicle were one-half that of the test vehicle. The test vehicle was released from the tow cable before impact with the barrier system. A digital speedometer on the tow vehicle increased the accuracy of the test vehicle impact speed.

A vehicle guidance system developed by Hinch [8] was used to steer the test vehicles. A guide-flag, attached to the left-front wheel and the guide cable, was sheared off before impact with the barrier system. The ⅜-in. (9.5-mm) diameter guide cable was tensioned to approximately 3,500 lb (15.6 kN) and supported both laterally and vertically every 100 ft (30.48 m) by hinged stanchions. The hinged stanchions stood upright while holding up the guide cable, but as the vehicle was towed down the line, the guide-flag struck and knocked each stanchion to the ground.

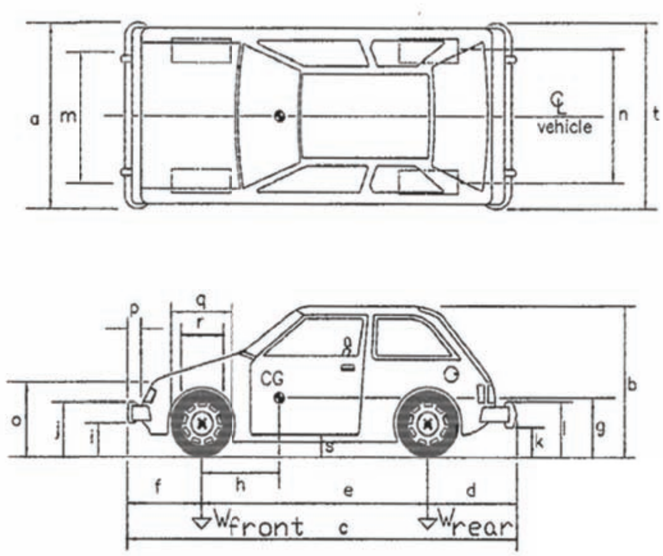
4.3 Test Vehicles

For test no. USPBN-3, a 2000 Suzuki Swift passenger car was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 1,857 lb (842 kg), 1,854 lb (841 kg), and 2,024 lb (918 kg), respectively. The test vehicle is shown in Figure 26, and vehicle dimensions are shown in Figure 27.

Figure 26. Test Vehicle, Test No. USPBN-3

Date:	9/13/2010	**Test Number:**	USPBN-3	**Model:**	820C/Swift
Make:	Suzuki	**Vehicle I.D.#:**	2S2AB21H5Y6600987		
Tire Size:	P155/80R13	**Year:**	2000	**Odometer:**	116825

***(All Measurements Refer to Impacting Side)**



Vehicle Geometry -- in. (mm)

a	61.25	(1556)	**b**	55.75	(1416)
c	149.5	(3797)	**d**	24.25	(616)
e	93	(2362)	**f**	32.25	(819)
g	21.5	(546)	**h**	33.67	(855)
i	8.25	(210)	**j**	21	(533)
k	12.25	(311)	**l**	26.5	(673)
m	54.5	(1384)	**n**	53.25	(1353)
o	22	(559)	**p**	4.5	(114)
q	22.5	(572)	**r**	14.25	(362)
s	12.75	(324)	**t**	61.5	(1562)

Wheel Center Height Front	10.25	(260)
Wheel Center Height Rear	10.625	(270)
Wheel Well Clearance (FR)	25	(635)
Wheel Well Clearance (RR)	25.75	(654)

Engine Type	4 cyl.
Engine Size	1.3

Transmission Type:

Automatic

FWD

Weights lb (kg)	**Curb**		**Test Inertial**		**Gross Static**	
W-front	1197	(543)	1184	(537)	1269	(576)
W-rear	660	(299)	671	(304)	755	(342)
W-total	1857	(842)	1854	(841)	2024	(918)

Note any damage prior to test: None

Figure 27. Vehicle Dimensions, Test No. USPBN-3

For test no. USPBN-4, a 2000 GMC C2500 pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 4,581 lb (2,078 kg), 4,429 lb (2,009 kg), and 4,429 lb (2,009 kg), respectively. The test vehicle is shown in Figure 28, and vehicle dimensions are shown in Figure 29.

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The location of the final c.g. is shown in Figures 27 and 30 for test no. USPBN-3. The location of the final c.g. is show in Figures 29 and 31 for test no. USPBN-4. Data used to calculate the location of the c.g. and ballast information are shown in Appendix B.

Square, black- and white-checkered targets were placed on the vehicles to aid in the analysis of the high-speed videos, as shown in Figure 30. Round, checkered targets were placed on the center of gravity on the left-side door, the right-side door, and the roof of the vehicles. The remaining targets were located for references so that they could be viewed from the high-speed cameras for video analysis.

The front wheels of the test vehicles were aligned for camber, caster, and toe-in values of zero so that the vehicles would track properly along the guide cable. A 5B flash bulb was mounted at the center of the vehicles' dashes and was fired by a pressure tape switch mounted at the impact corner of the bumper. The flash bulb was fired upon initial impact with the test article to create a visual indicator of the precise time of impact on the high-speed videos. A remote controlled brake system was installed in the test vehicles so the vehicles could be brought safely to a stop after the tests.

Figure 28. Test Vehicle, Test No. USPBN-4

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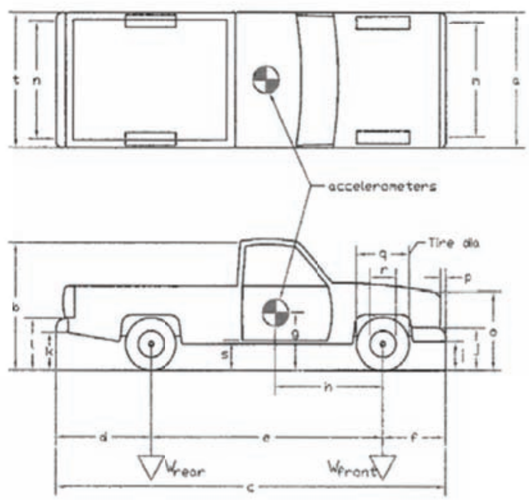
Date: 10/6/2010 **Test Number:** USPBN-4 **Model:** C2500/2000P

Make: GMC **Vehicle I.D.#:** 1GDGC24R9YF476679

Tire Size: 245/75 R16 **Year:** 2000 **Odometer:** 246417

***(All Measurements Refer to Impacting Side)**



Vehicle Geometry -- in. (mm)

a	73.75	(1873)	b	73.25	(1861)
c	218.25	(5544)	d	52	(1321)
e	131.5	(3340)	f	34.75	(883)
g	26.25	(667)	h	54.30	(1379)
i	18	(457)	j	27	(686)
k	22.5	(572)	l	30	(762)
m	62.75	(1594)	n	63.875	(1622)
o	40.5	(1029)	p	3	(76)
q	30.5	(775)	r	17.25	(438)
s	20	(508)	t	73	(1854)

Wheel Center Height Front	14.375	(365)
Wheel Center Height Rear	14.5	(368)
Wheel Well Clearance (FR)	36	(914)
Wheel Well Clearance (RR)	38	(965)
Frame Height (FR)	16.25	(413)
Frame Height (RR)	27	(686)
Engine Type	8cyl. Gas	
Engine Size	5.7L	

Transmission Type:

Automatic

RWD

GVWR F 4100, R 6000, Tot. 8600

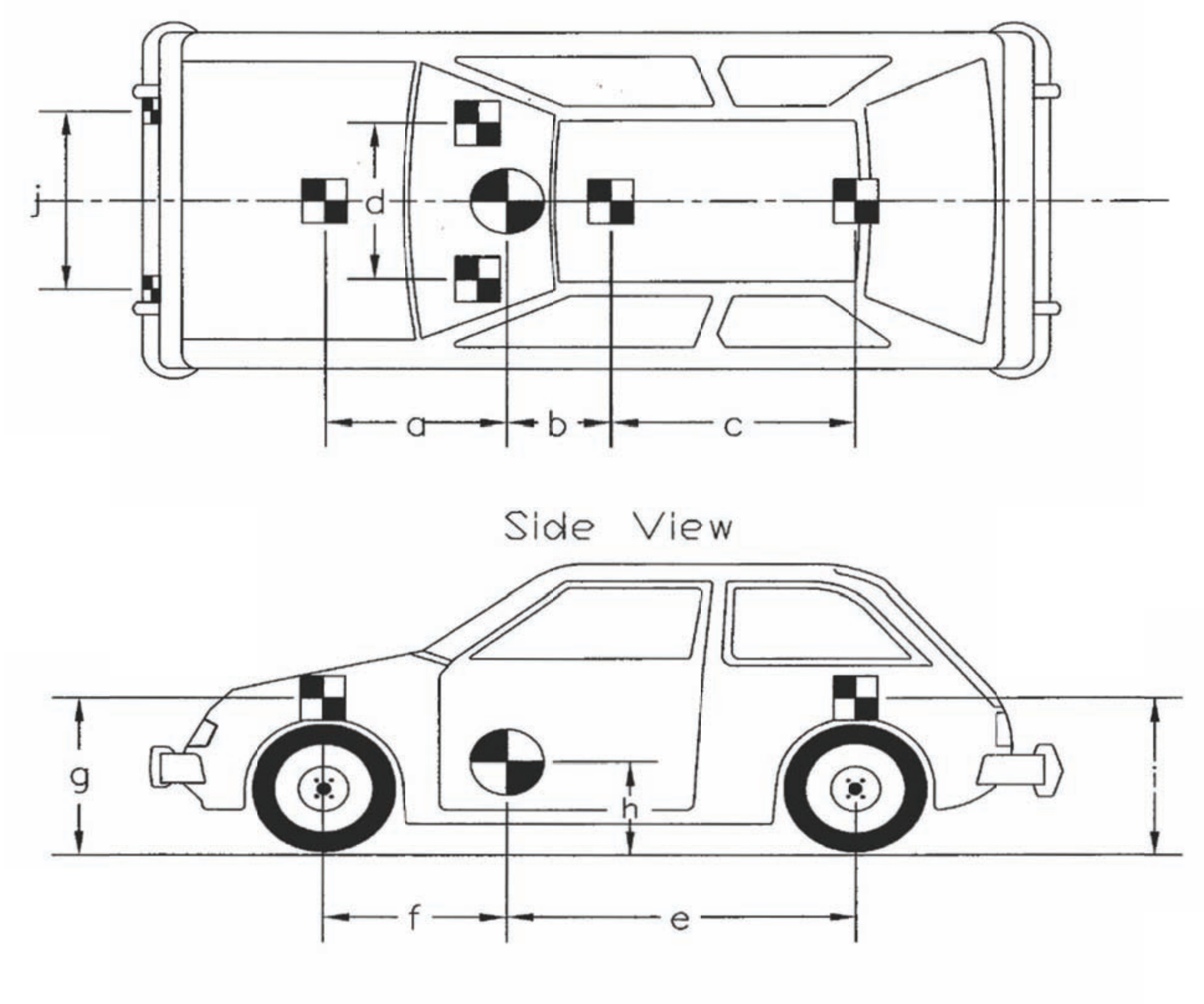
Mass Distribution Gross Static lb (kg)

LF	1359	(616)	RF	1241	(563)
LR	910	(413)	RR	919	(417)

Weights lb (kg)	Curb		Test Inertial		Gross Static	
W-front	2682	(1217)	2600	(1179)	2600	(1179)
W-rear	1899	(861)	1829	(830)	1829	(830)
W-total	4581	(2078)	4429	(2009)	4429	(2009)

Note any damage prior to test: Right side box dents/scrapes near cab

Figure 29. Vehicle Dimensions, Test No. USPBN-4

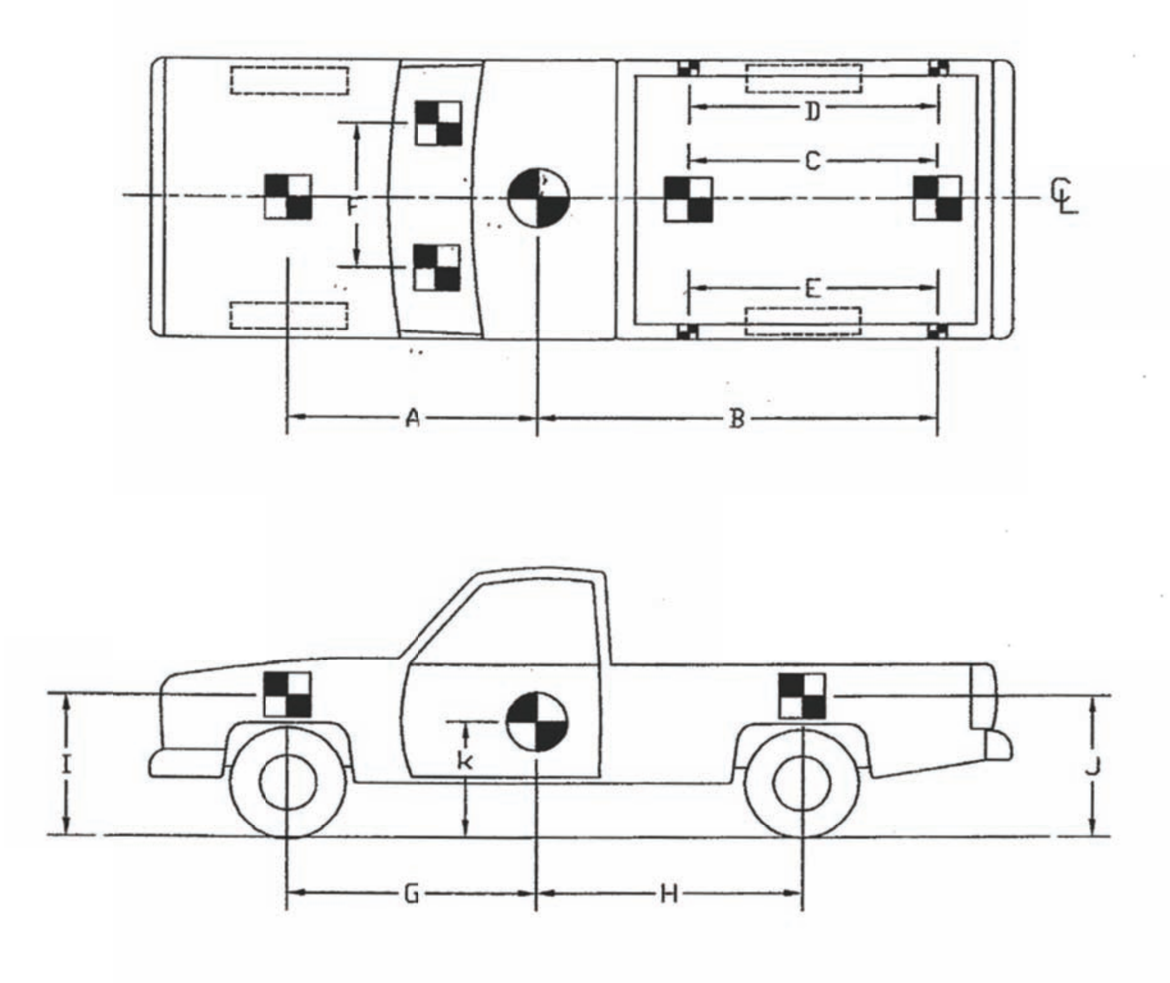


TEST #: USPBN-3

TARGET GEOMETRY-- in. (mm)

	in.	(mm)		in.	(mm)		in.	(mm)
A	42.625	(1083)	E	116.25	(2953)	I	30	(762)
B	16.5	(419)	F	33.25	(845)	J	30.625	(778)
C	30.625	(778)	G	28.625	(727)			
D	28.625	(727)	H	21.5	(546)			

Figure 30. Target Geometry, Test No. USPBN-3



TEST #: USPBN-4

TARGET GEOMETRY-- in. (mm)

A	52	**(1321)**	**E**	84.75	**(2153)**	**I**	39.875	**(1013)**
B	89.25	**(2267)**	**F**	38	**(965)**	**J**	42	**(1067)**
C	48	**(1219)**	**G**	54.25	**(1378)**	**K**	26.25	**(667)**
D	84.75	**(2153)**	**H**	77.25	**(1962)**			

Figure 31. Target Geometry, Test No. USPBN-4

4.4 Simulated Occupant

For test no USPBN-3, A Hybrid II 50th Percentile Adult Male Dummy, equipped with clothing and footwear, was placed in the left-front seat of the test vehicle with the seat belt fastened. The dummy, which had a final weight of 166 lb (75 kg), was represented by model no. 572, serial no. 451, and was manufactured by Android Systems of Carson, California. As recommended by MASH, the dummy was not included in calculating the c.g location.

4.5 Data Acquisition Systems

4.5.1 Accelerometers

Two environmental shock and vibration sensor/recorder systems were used to measure the accelerations in the longitudinal, lateral, and vertical directions. Both accelerometers were mounted near the center of gravity of the test vehicles.

One accelerometer system was a two-arm piezoresistive accelerometer system manufactured by Endevco of San Juan Capistrano, California. Three accelerometers were used to measure each of the longitudinal, lateral, and vertical accelerations independently at a sample rate of 10,000 Hz. Two additional accelerometers were used to measure longitudinal and lateral accelerations independently at the same sample rate. The accelerometers were configured and controlled using a system developed and manufactured by Diversified Technical Systems, Inc. (DTS) of Seal Beach, California. More specifically, data was collected using a DTS Sensor Input Module (SIM), Model TDAS3-SIM-16M. The SIM was configured with 16 MB SRAM memory and 8 sensor input channels with 250 kB SRAM/channel. The SIM was mounted on a TDAS3-R4 module rack. The module rack was configured with isolated power/event/communications, 10BaseT Ethernet and RS232 communication, and an internal backup battery. Both the SIM and module rack were crashworthy. The "DTS TDAS Control" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

The second system, Model EDR-3, was a triaxial piezoresistive accelerometer system manufactured by IST of Okemos, Michigan. The EDR-3 was configured with 256 kB of RAM memory, a range of ±200 g's, a sample rate of 3,200 Hz, and a 1,120 Hz low-pass filter. The "DynaMax 1 (DM-1)" computer software program and a customized Microsoft Excel worksheet were used to analyzed and plot the accelerometer data.

4.5.2 Rate Transducers

An angle rate sensor, the ARS-1500, with a range of 1,500 degrees/sec in each of the three directions (roll, pitch, and yaw) was used to measure the rates of rotation of the test vehicles. The angular rate sensor was mounted on an aluminum block inside the test vehicle near the center of gravity and recorded data at 10,000 Hz to the SIM. The raw data measurements were then downloaded, converted to the proper Euler angles for analysis, and plotted. The "DTS TDAS Control" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the angular rate sensor data.

An additional angle rate sensor, an Analog Systems 3-axis rate transducer with a range of 1,200 degrees/sec in each of the three directions (roll, pitch, and yaw), was used to measure the rates of motion of the test vehicles. The rate transducer was mounted inside the body of the EDR-4 6DOF-500/1200 and recorded data at 10,000 Hz to a second data acquisition board inside the EDR-4 6DOF-500/1200 housing. The raw data measurements were then downloaded, converted to the appropriate Euler angles for analysis, and plotted. The "EDR4COM" and "DynaMax Suite" computer software programs and a customized Microsoft Excel worksheet were used to analyze and plot the angular rate transducer data.

4.5.3 Pressure Tape Switches

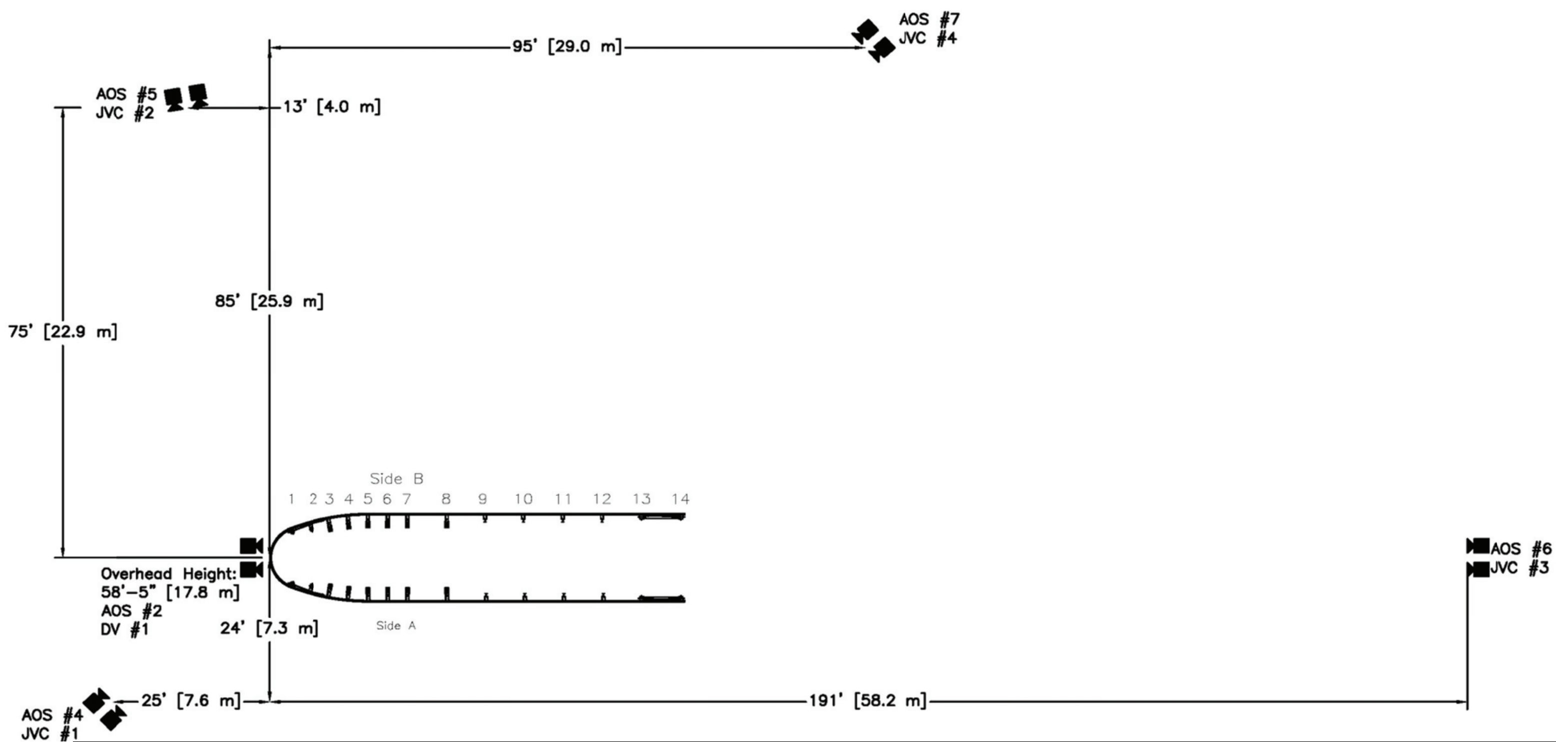
For test nos. USPBN-3 and USPBN-4, five pressure-activated tape switches, spaced at approximately 6.56 ft (2 m) intervals, were used to determine the speed of the vehicles before impact. Each tape switch fired a strobe light which sent an electronic timing signal to the data acquisition system as the right-front tire of the test vehicle passed over it. Test vehicle speeds were determined from electronic timing mark data recorded using TestPoint and LabVIEW computer software programs. Strobe lights and high-speed video analysis are used only as a backup in the event that vehicle speed cannot be determined from the electronic data.

4.5.4 Digital Cameras

Two AOS VITcam high-speed digital video cameras, three AOS X-PRI high-speed digital video cameras, four JVC digital video cameras, and two Canon digital video cameras were utilized to film test no. USPBN-3. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 32.

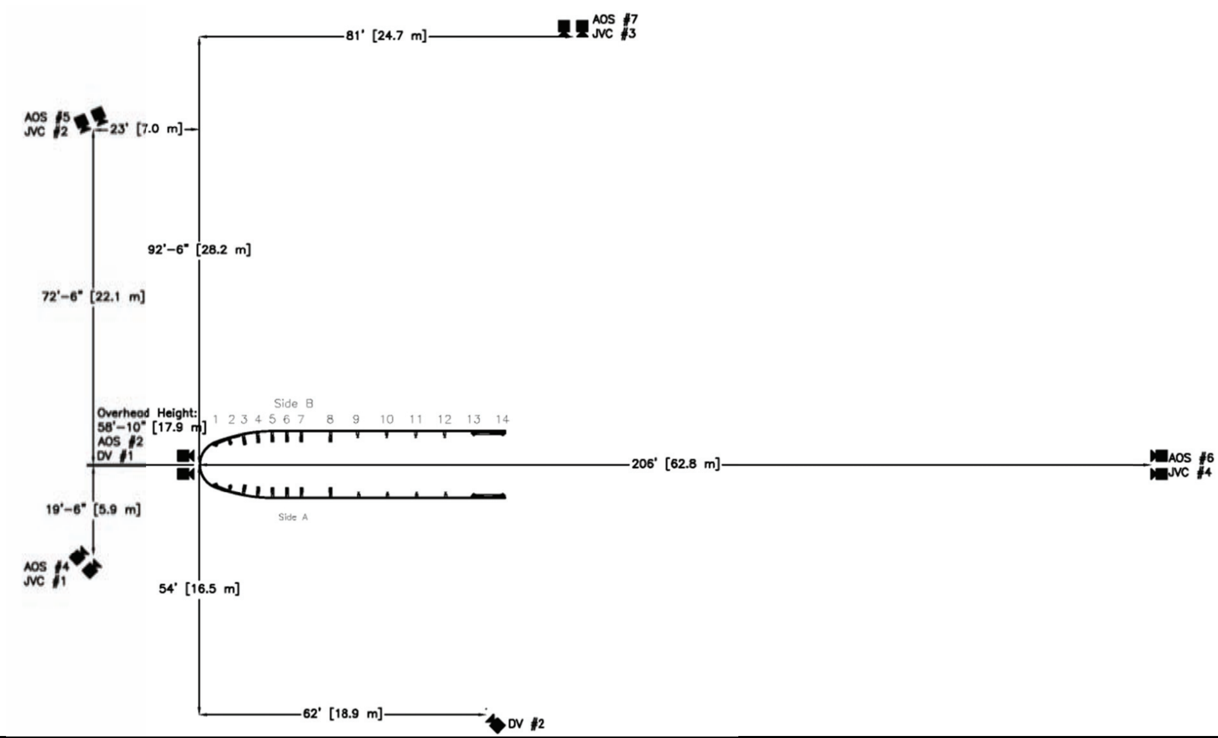
Two AOS VITcam high-speed digital video cameras, three AOS X-PRI high-speed digital video cameras, four JVC digital video cameras, and two Canon digital video cameras were utilized to film test no. USPBN-4. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 33.

The high-speed videos were analyzed using ImageExpress MotionPlus and RedLake MotionScope software programs. Actual camera speed and camera divergence factors were considered in the analysis of the high-speed videos. Also, a Nikon D50 digital still camera was used to document pre- and post-test conditions for the tests.



	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	2	AOS Vitcam CTM	500	Cosmicar 12.5 mm fixed	-
	4	AOS Vitcam CTM	500	Sigma Zoom 24-70	24
	5	AOS X-PRI Gigabit	500	Fujinon 50 mm fixed	-
	6	AOS X-PRI Gigabit	500	TV Zoom 17-102	67
	7	AOS X-PRI Gigabit	500	Sigma Zoom 24-135	50
Digital Video	1	JVC – GZ-MC500 (Everio)	29.97		
	2	JVC – GZ-MG27u (Everio)	29.97		
	3	JVC – GZ-MG27u (Everio)	29.97		
	4	JVC – GZ-MG27u (Everio)	29.97		
	1	Canon ZR90	29.97		
	2	Canon ZR10	29.97		

Figure 32. Camera Locations, Speeds, and Lens Settings, Test No. USPBN-3



	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	2	AOS Vitcam CTM	500	Cosmicar 12.5 mm fixed	-
	4	AOS Vitcam CTM	500	Sigma Zoom 24-70	24
	5	AOS X-PRI Gigabit	500	Fujinon 50 mm fixed	-
	6	AOS X-PRI Gigabit	500	TV Zoom 17-102	102
	7	AOS X-PRI Gigabit	500	Sigma Zoom 24-135	24
Digital Video	1	JVC – GZ-MC500 (Everio)	29.97		
	2	JVC – GZ-MG27u (Everio)	29.97		
	3	JVC – GZ-MG27u (Everio)	29.97		
	4	JVC – GZ-MG27u (Everio)	29.97		
	1	Canon ZR90	29.97		
	2	Canon ZR10	29.97		

Figure 33. Camera Locations, Speeds, and Lens Settings, Test No. USPBN-4

5 FULL-SCALE CRASH TEST NO. USPBN-3

5.1 Test No. USPBN-3

The 2,024-lb (918-kg) passenger car with a simulated occupant in the driver's seat impacted the bullnose median barrier at a speed of 63.3 mph (101.9 km/h) and at an angle of 0 degrees. A summary of the test results and sequential photographs are shown in Figure 34. Additional sequential photographs are shown in Figures 35 and 36. Documentary photographs of the crash test are shown in Figure 37.

5.2 Weather Conditions

Test no. USPBN-3 was conducted on September 13, 2010 at approximately 2:30 pm. The weather conditions, as per the National Oceanic and Atmospheric Administration (station 14939/LNK), were reported and are shown in Table 3.

Table 3. Weather Conditions, Test No. USPBN-3

Temperature	82°F
Humidity	65%
Wind Speed	10 mph
Wind Direction	140° from True North
Sky Conditions	Overcast
Visibility	9 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.03 in.
Previous 7-Day Precipitation	0.04 in.

5.3 Test Description

Initial vehicle impact was to occur with the passenger's side quarter point of the vehicle at the center of the bullnose, as shown in Figure 38. The actual point of impact was at the quarter point. A sequential description of the impact events is contained in Table 4. The vehicle came to rest 20 ft – 11 in. (6.4 m) downstream and 9 in. (0.2 m) to the left of the center of the bullnose. The vehicle trajectory and final position are shown in Figures 34 and 39.

Table 4. Sequential Description of Impact Events, Test No. USPBN-3

TIME (sec)	EVENT
0.000	The right-side bumper impacted the face of the thrie-beam nose.
0.016	Post nos. A1 and B1 deflected forward (away from the center of the system), and the left side of the bumper disengaged.
0.026	The rail kinked near the center of the nose.
0.036	Post nos. A1 and B1 deflected backward (toward the center of the system).
0.042	The rail buckled upstream of post no. B1.
0.046	The rail buckled upstream of post no A1.
0.072	The base of post no. B1 fractured.
0.078	The rail kinked at post no. B2.
0.080	The rail disengaged from post nos. B2 and B3.
0.094	The rail disengaged from post no. B4, and post no. B5 deflected forward (away from the center of the system).
0.118	The rail impacted post no. B2.
0.120	The base of post no. B2 fractured.
0.128	The base of post no. A1 fractured.
0.158	Post no. B2 impacted post no. B3.
0.176	The vehicle yawed towards the right.
0.176	The bottom corrugation ruptured at the impact point.
0.188	The rail kinked at post no. B3.
0.232	The base of post no. A2 fractured.
0.260	Post no. B3 broke away.
0.302	The rail buckled downstream of post no. A3.
0.316	The rail buckled at post no. B4.
0.414	Post no. B4 broke away.
0.426	Post no. A3 broke away.
0.530	The rail kinked downstream of post no. B5.
0.632	The vehicle reached maximum displacement.

5.4 Barrier Damage

Damage to the barrier was severe, as shown in Figures 40 through 42. Barrier damage consisted of guardrail buckling and flattening, deformation of the guardrail around the front of the car, and post fracture and disengagement on both sides of the bullnose. Deformation to the rail occurred from 11 in. (279 mm) downstream of post no. 3 on Side A to 7½ in. (191 mm) downstream of post no. 5 on Side B.

The first three posts on Side A were fractured and disengaged. BCT post nos. 1 and 2 fractured through the hole at ground level. The universal steel breakaway post no. 3 disengaged from the foundation tube and lower base plate when the bolts fractured. Post no. 3 was slightly twisted downstream in relation to the upper base plate, and there was some slight chipping on the blockout. Post no. 4 was slightly twisted upstream in relation to the upper base plate. Post nos. 1 and 3 had a ¼-in. (6-mm) soil gap and a ½-in. (13-mm) soil gap on the front side of the bases, respectively. There was no visible damage to post nos. 5 through 14 on Side A.

The first four posts on Side B were fractured and disengaged. BCT post nos. 1 and 2 fractured through the hole at ground level. Post no. 1 was split on the upstream face, and the cable bearing sleeve disengaged. UBSP nos. 3 and 4 were slightly twisted upstream in relation to their upper base plates and were disengaged from the foundation tube and lower base plate when the bolts fractured. The blockouts on post no. 5 were rotated downstream. A ½-in. (13-mm) soil gap was found on the downstream side of post no. 3 with an approximate 12-in. (30- mm) diameter by 2-in. (51-mm) high soil heave. The rail-to-post bolt was pulled out at post no. 6. There was no visible damage to post nos. 7 though 14 on Side B. There was no visible damage to the foundation tubes or lower base plates on either side of the system.

The damage to the thrie beam guardrail consisted of buckling, tearing, and flattening of the guardrail. Flattening occurred in the thrie beam from post no. 3 on Side A to post no. 4 on Side B. The Side B cable end anchorage threads fractured at the post no. 1 BCT anchorage. A buckle formed 11 in. (279 mm) downstream of post no. 3 on Side A with an 8-in. (203-mm) long horizontal tear in the upper slot. Another buckle formed at post no. 3 on Side A. A 2¼-in. (57-mm) long vertical tear was located 9 in. (229 mm) upstream of the Side A quarter point in rail section no. 1. The guardrail buckled 19 in. downstream of the center of the system towards Side A. Rail section no. 1 at the lower slot was torn completely through from 18½ in. (470 mm) downstream of the center of the system towards Side A through 10 in. (254 mm) downstream of the Side B quarter point on the nose. A 1¼-in. (32-mm) long vertical tear was located at the upper slot 14 in. (356 mm) downstream of the center of the system towards Side A. The guardrail buckled 10 in. (254 mm) downstream of the center of the system towards Side B. A 4½-in. (114-mm) long vertical tear in the upper slot and a buckle were located 10 in. (254 mm) downstream of the Side B quarter point on the nose. 10 in. (254 mm) downstream of the Side B quarter point. A 2¾-in. (70-mm) long horizontal tear was located at the lower slot at post no. 2 on Side B. Another 2½-in. (64-mm) long horizontal tear was located at the lower slot at post no. 3 on Side B. A buckle formed at post no. 4 on Side B, with a ⅞-in. (22-mm) long vertical tear in the upper slot and a 2¼-in. (57-mm) long vertical tear in the lower slot. The guardrail was kinked 7½ in. (191 mm) downstream of post no. 5 on Side B.

The working width envelope of the system was found to be 22 ft – 9 in. (6.9 m) longitudinally and 14 ft – 9¼ in. (4.5 m) laterally and is shown in Figure 44.

5.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figure 45. Deformations to the vehicle's floorboard were relatively minor, with maximum longitudinal and vertical deflections of ½ in. (13 mm) and ¼ in. (6 mm), respectively. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix C.

The left door was dented and crushed. A dent was found between the left door and quarter panel. The left-fender was crushed inward and backward. The left-front strut attachment was fractured and the steering rod was bent. The left-front CV joint was pulled out, and both ends of the half shaft were damaged or pulled out. A dent was found in the left-front rim. The left mirror was disengaged. The radiator was crushed inward and shifted to the right. Both headlights were fractured. The left bumper mount was fractured. The bumper fractured near its center. Minor cracking occurred in the lower left windshield in an area approximately 15 in. (381 mm) by 13 in. (330 mm). The hood was crushed backward and upward. The right side of the bumper cover was dented and torn. The right fender was crushed inward. The front of the right door was crushed and dented, and the door was ajar. The fuel tank was punctured, and small scrapes were found on the rear lower control arms. The roof and window glass remained undamaged.

5.6 Occupant Risk

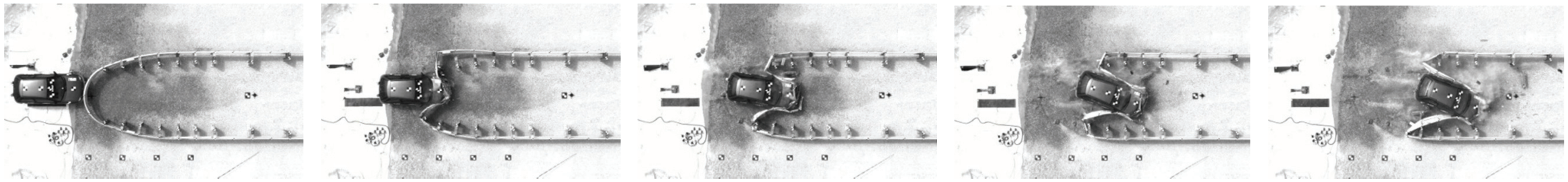
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 5. It is noted that the OIVs and ORAs were within the suggested limits provided in NCHRP Report No. 350. The calculated THIV, PHD, and ASI values are also shown in Table 5. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 34. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix D.

Table 5. Summary of OIV, ORA, THIV, and PHD Values, Test No. USPBN-3

Evaluation Criteria		**Transducer**		**NCHRP Report No. 350 Limits**
		EDR-3	**DTS**	
OIV ft/s (m/s)	Longitudinal	-33.63 (-10.25)	-32.18 (-9.81)	≤ 39.4 (12)
	Lateral	3.60 (1.10)	4.08 (1.24)	≤ 39.4 (12)
ORA g's	Longitudinal	-7.70	-7.70	≤ 20
	Lateral	5.01	-5.75	≤ 20
THIV ft/s (m/s)		-	32.58 (9.93)	not required
PHD g's		-	8.62	not required
ASI		0.93	0.88	not required

5.7 Discussion

The analysis of the test results for test no. USPBN-3 showed that the bullnose median barrier adequately contained and safely decelerated the 820C vehicle. There were no detached elements nor fragments which showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements were noted, as shown in Appendix D, and were deemed acceptable because they did not adversely influence occupant risk safety criteria nor cause rollover. After impact, the vehicle was contained by the bullnose median barrier. Therefore, test no. USPBN-3 conducted on a bullnose median barrier was determined to be acceptable according to the NCHRP Report No. 350 safety performance criteria for test designation no. 3-30.



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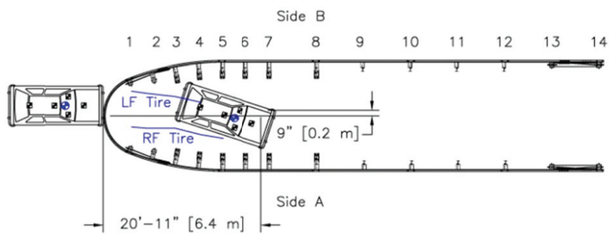
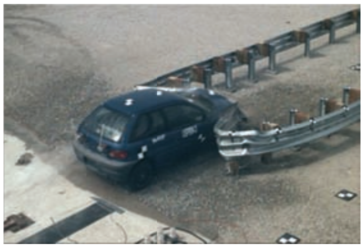


- Test Agency .... MwRSF
- Test Number USPBN-3
- Date 9/13/10
- NCHRP Report No. 350 Test Designation 3-30
- Test Article .... Bullnose Median Barrier
- Key Component – Rail
  - Type .... 12 ga. (2.66 mm) Thrie Beam
  - Top Mounting Height .... 31⅝ in. (803 mm)
  - Section Nos. 1-2 .... 12 ft – 6 in. (3.81 m) length, bent and slotted
  - Section No. 3 .... 12 ft – 6 in. (3.81 m) length, slotted
  - Section Nos. 4-5 .... 12 ft – 6 in. (3.81 m) length, standard
- Key Component – Post Nos. 1-2, 13-14
  - Type .... Thrie BCT Wood Posts
- Key Component – Post Nos. 3-8
  - Type .... Universal Steel Breakaway Posts
  - Shape W6x8.5 (W152x12.6)
  - Base Plates .... 2½ x 10 in. (64 x 254 mm) bolt spacing
  - Fracturing Bolts .... 7/16-in. (11.1-mm) diameter ASTMA325 hex tap
  - Base Tubes .... TS 6 x 8 x 3/16 x 40 in. (152 x 203 x 4.8 x 1016 mm)
- Key Component – Post Nos. 9-12
  - Type .... Standard Thrie Beam Posts
  - Shape W6x8.5 (W152x12.6)
- Soil Type .... Grading B AASHTO M147-65 (1990)
- Vehicle Make /Model .... Suzuki Swift passenger car
  - Curb .... 1,857 lb (842 kg)
  - Test Inertial .... 1,854 lb (841 kg)
  - Gross Static .... 2,024 lb (918 kg)
- Impact Conditions
  - Speed .... 63.3 mph (101.9 km/h)
  - Angle .... 0 deg
  - Impact Location .... passenger's side quarter point offset
- Exit Conditions
  - Speed .... NA
  - Angle .... NA
- Exit Box Criterion .... Pass
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 20 ft – 11 in. (6.4 m) downstream of impact
  9 in. (0.2 m) to the left of center
- Vehicle Damage .... Moderate
  - VDS[9] 12-FD-5
  - CDC[10] 12FDEW3
  - Maximum Interior Deformation .... ½ in. (13 mm)
- Test Article Damage .... Severe
- Working Width Envelope .... 22 ft – 9 in. (6.9 m) longitudinally
  14 ft – 9¼ in. (4.5 m) laterally
- Maximum Angular Displacements (DTS)
  - Roll .... -5.82 deg
  - Pitch .... -3.71 deg
  - Yaw .... 26.67 deg
- Transducer Data

Evaluation Criteria		Transducer EDR-3	Transducer DTS	NCHRP Report No. 350 Limits
OIV ft/s (m/s)	Longitudinal	-33.63 (-10.25)	-32.18 (-9.81)	≤ 39.4 (12)
	Lateral	3.60 (1.10)	4.08 (1.24)	≤ 39.4 (12)
ORA g's	Longitudinal	-7.70	-7.70	≤ 20
	Lateral	5.01	-5.75	≤ 20
THIV ft/s (m/s)		-	32.58 (9.93)	not required
PHD g's		-	8.62	not required
ASI		0.93	0.88	not required

Figure 34. Summary of Test Results and Sequential Photographs, Test No. USPBN-3


0.000 sec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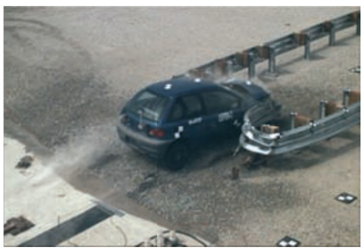
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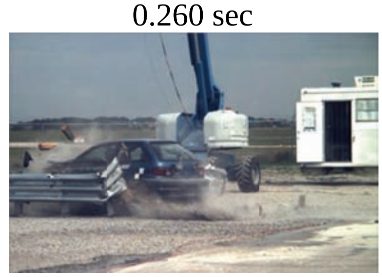
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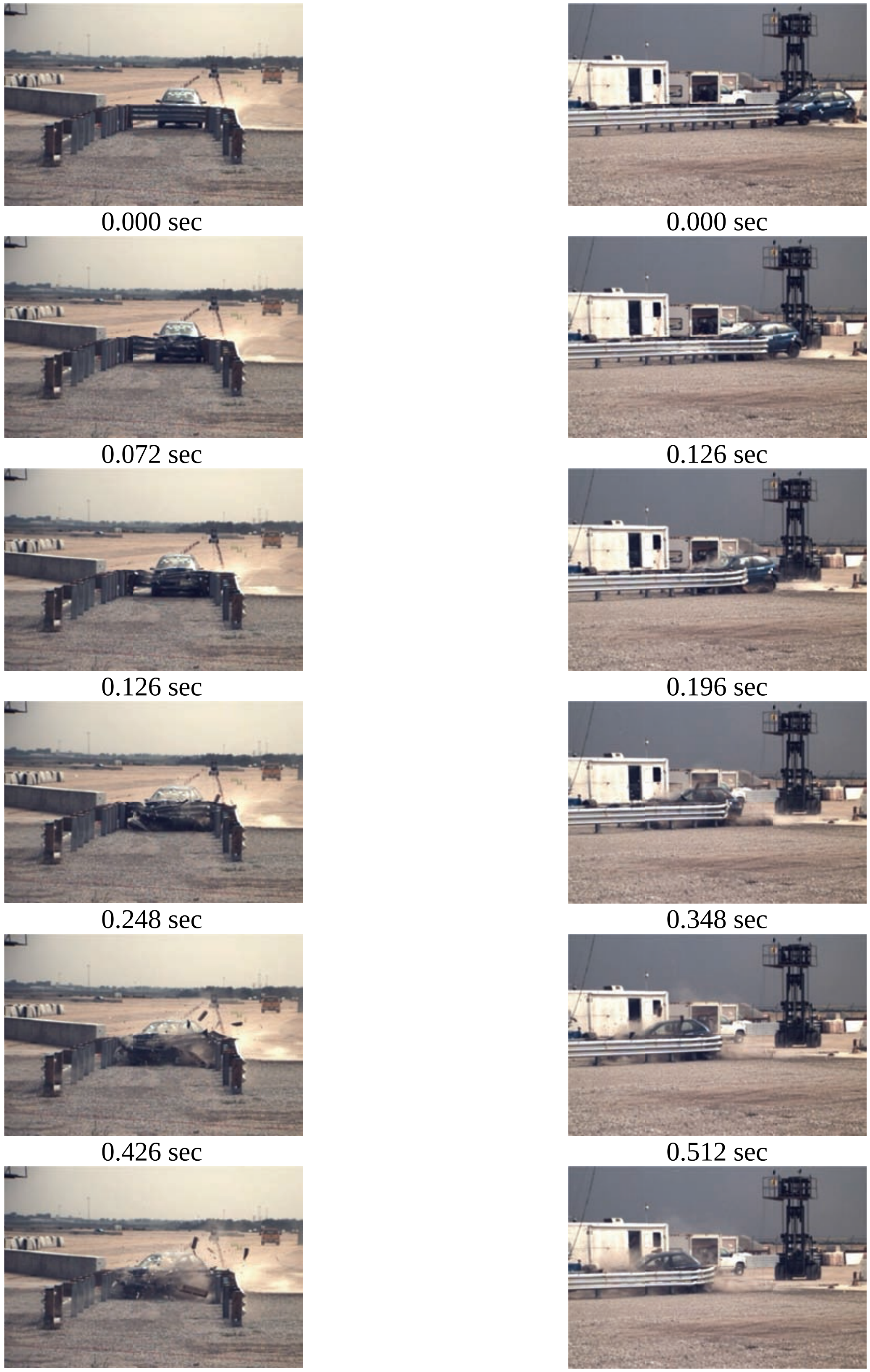
Figure 35. Additional Sequential Photographs, Test No. USPBN-3



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0.528 sec | 0.634 sec

Figure 36. Additional Sequential Photographs, Test No. USPBN-3

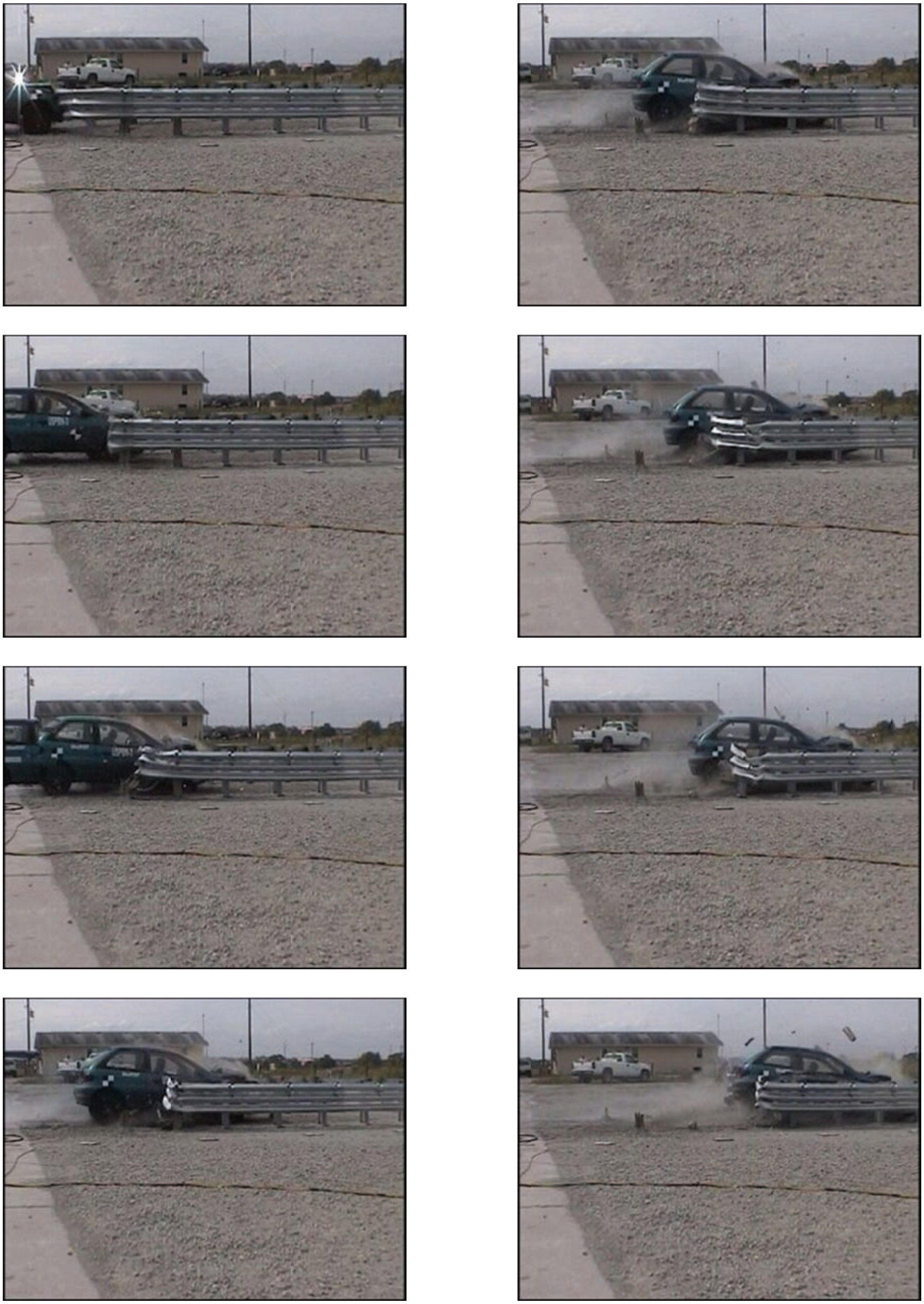


Figure 37. Documentary Photographs, Test No. USPBN-3

Figure 38. Impact Location, Test No. USPBN-3

Figure 39. Vehicle Final Position and Trajectory Marks, Test No. USPBN-3

Figure 40. System Damage, Test No. USPBN-3

Figure 41. System Damage, Test No. USPBN-3

Figure 42. System Damage, Test No. USPBN-3

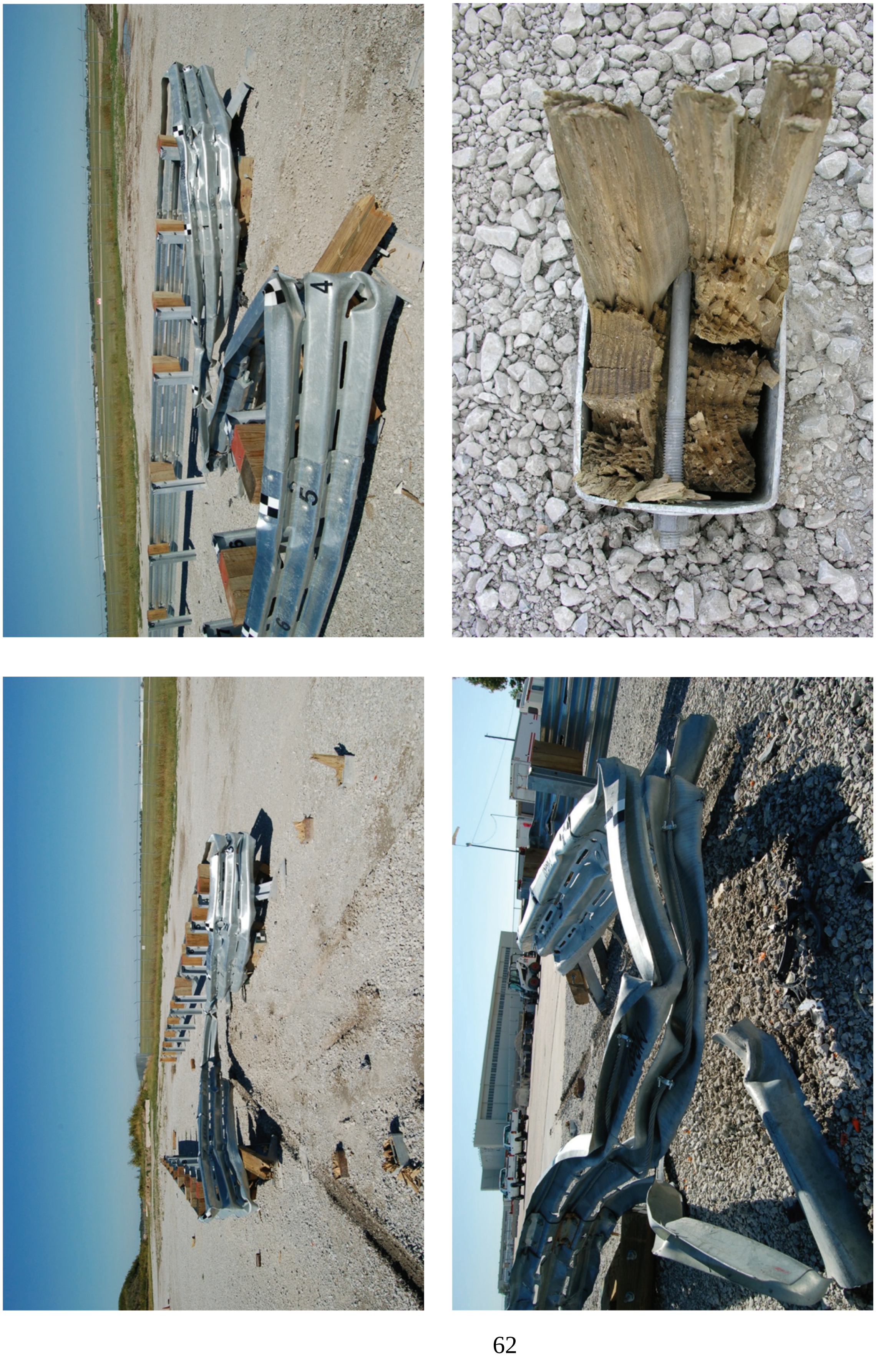


Figure 43. System Damage, Test No. USPBN-3

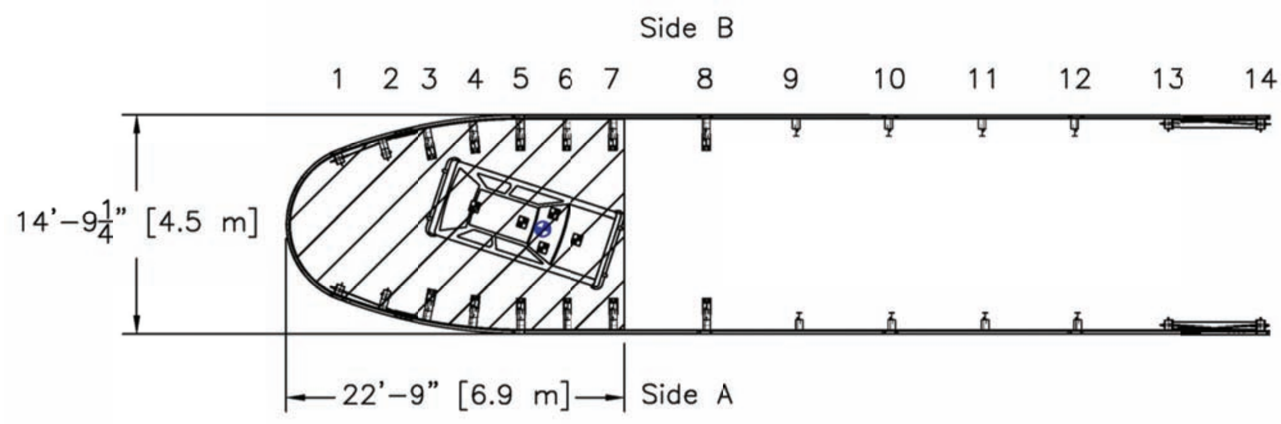


Figure 44. Working Width Envelope, Test No. USPBN-3

Figure 45. Vehicle Damage, Test No. USPBN-3

6 FULL-SCALE CRASH TEST NO. USPBN-4

6.1 Test No. USPBN-4

The 4,429-lb (2,009-kg) pickup truck impacted the bullnose median barrier at a speed of 64.5 mph (103.7 km/h) and at an angle of 0 degrees. A summary of the test results and sequential photographs are shown in Figure 46. Additional sequential photographs are shown in Figures 47 and 48.

6.2 Weather Conditions

Test no. USPBN-4 was conducted on October 6, 2010 at approximately 12:15 pm. The weather conditions, as per the National Oceanic and Atmospheric Administration (station 14939/LNK), were reported and are shown in Table 6.

Table 6. Weather Conditions, Test No. USPBN-4

Temperature	74°F
Humidity	50%
Wind Speed	8 mph
Wind Direction	330° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.0 in.
Previous 7-Day Precipitation	0.0 in.

6.3 Test Description

Initial vehicle impact was to occur at the centerline of the system, as shown in Figure 38. The actual point of impact was at the centerline of the system. A sequential description of the impact events is contained in Table 7. The vehicle came to rest 50 ft – 10 in. (15.5 m) downstream and 2 ft – 7 in. (0.8 m) to the left of the initial impact. The vehicle trajectory and final position are shown in Figures 46 and 50.

Table 7. Sequential Description of Impact Events, Test No. USPBN-4

TIME (sec)	EVENT
0	The bumper impacted the face of the thrie beam nose.
0.012	Kink formed in rail upstream of post no A1.
0.014	Kink formed in rail upstream of post no. B1
0.018	Hood, right-front quarter panel, and left-front quarter panel deflected.
0.060	The base of post no. A1 fractured, and the rail kinked at the midspan between post nos. A1 and A2 and at the midspan between post nos. B1 and B2.
0.070	The base of post no. B1 fractured.
0.098	Kink formed in rail at post no. B2.
0.104	Kink formed in rail at post no. A2.
0.136	The base of post no. B2 fractured.
0.152	Kink formed in rail at post no. B3.
0.154	Kink formed in rail at post no. A3.
0.190	Post no. A3 broke away.
0.202	Post no. B3 broke away.
0.240	Kink formed in rail at post no. B4.
0.248	Kink formed in rail upstream of post no. A4.
0.286	Post no. A4 broke away.
0.288	Post no. B4 broke away.
0.328	Kink formed in rail upstream of post no. A5.
0.336	The right-rear tire ruptured.
0.366	Kink formed in rail downstream of post no. B5.
0.382	Post no. A5 broke away.
0.384	Post no. B5 broke away.
0.390	Kink formed in rail at midspan between post nos. A5 and A6.
0.472	Kink formed in rail at post no. B6.
0.496	Kink formed in rail upstream of post no. A6.
0.522	Post no. B6 broke away.
0.568	Kink formed in rail downstream of post no. A7.
0.596	Kink formed in rail at midspan between post nos. B6 and B7.
0.616	Kink formed in rail at post no. B7.
0.656	Kink formed in rail downstream of post no. B7.
0.696	Post no. B7 broke away.
0.794	Kink formed in rail at midspan of post nos. B7 and B8.
0.860	Kink formed in rail upstream of midspan between post nos. A7 and A8.
0.982	Kink formed in rail upstream of post no. A8.
1.182	Vehicle reached maximum displacement into system.

6.4 Barrier Damage

Damage to the barrier was severe, as shown in Figures 51 through 53. Barrier damage consisted of guardrail buckling and flattening, deformation of the guardrail around the front of the pickup truck, and post fracture and disengagement on both sides of the bullnose. Deformation to the rail occurred from 13 in. (330 mm) upstream of post no. 8 on Side A to 15 in. (381 mm) upstream of post no. 8 on Side B.

Post nos. 1 through 6 and post no. 8 on Side A were fractured and disengaged. BCT post nos. 1 and 2 fractured through the hole at ground level. The majority of post no. 1 remained attached to the guardrail connected through the bottom bolt. The universal steel breakaway post nos. 3 through 6 and post no. 8 disengaged from the foundation tube and lower base plate when the bolts fractured. The top portion of post no. 3 was slightly twisted in relation to the upper base plate. The back blockout was disengaged from post no. 4 and the front flange was bent. The back blockout was disengaged from post no. 5, and the front blockout was partially disengaged. The weld at the base plate of post no. 7 fractured at the front flange on the upstream side. Post no. 7 was also bent and twisted downstream in relation to the upper base plate with the rear flange buckled 2 in. (51 mm) at the lower portion of the post. There was also a ⅜-in. (10-mm) soil gap on the upstream face of the foundation tube at post no. 7. Post no. 8 was twisted upstream in relation to the upper base plate, and the back flange and web were bent at the top of the post. Post nos. 9 and 10 had ½-in. (13-mm) soil gaps on the backside and frontside of the foundation tubes, respectively. There was no visible damage to post nos. 11 through 14 on Side A.

The first seven posts on Side B were fractured and disengaged. BCT post nos. 1 and 2 fractured through the hole at ground level. Post no. 1 was split on the upstream face. The universal steel breakaway post nos. 3 through 7 disengaged from the foundation tubes and lower base plates as the bolts fractured. Post no. 3 was slightly twisted downstream in relation to the upper base plate, and the back flange was bent and gouged. Post no. 4 was wedged underneath the left-rear tire. The front blockout on post no. 5 was fractured. The back flange was bent and the front blockout was split on post no. 7. A ½-in. (13-mm) soil gap was found on the upstream side of the foundation tube of post no. 8. The two upstream base plate bolts fractured on post no. 8, and the post was bent slightly downstream but still in its original location. There was no visible damage to post nos. 9 though 14 on Side B. There was no visible damage to the foundation tubes or lower base plates on either side of the system.

The damage to the Side A thrie beam guardrail consisted of buckling and tearing of the guardrail. A buckle formed 13 in. (330 mm) upstream of post no. 8. A 1½-in. (38-mm) long vertical tear was located in the upper slot 13 in. (330 mm) downstream of post no. 7 on the Side A. Another 2-in. (51-mm) long tear was located in the upper slot 21 in. (533 mm) downstream of post no. 6. The bottom corrugation had a 6-in. (152-mm) long vertical tear 17 in. (432 mm) upstream of post no. 5. The lower slot had a small vertical tear 43 in. (1,092 mm) upstream of post no. 5. Major folding and a buckle occurred in the thrie beam guardrail at the Side A quarter-point cable clip on rail section no. 1. The lower slots were torn completely through from post no. 1 through 13 in. (330 mm) downstream of the center of the nose on Side A. A 4-in. (102-mm) long vertical tear and an 8-in. (203-mm) long vertical tear were located 12 in. (305 mm) and 9 in. (229 mm) upstream from post no. 1, respectively. Another 4-in. (102-mm) long vertical tear was located in the bottom corrugation 13 in. (330 mm) downstream of the center of the nose on Side A.

The damage to the Side B thrie beam guardrail consisted of buckling, tearing and flattening of the guardrail. Folding and flattening occurred downstream of the center of the nose on Side B. A 2-in. (51-mm) long vertical tear was located 20 in. (508 mm) upstream of post no. 1. A 3-in. (76-mm) long vertical tear and a 4-in. (102-mm) long vertical tear were located at the lower slot 13 in. (330 mm) and 11 in. (279 mm) upstream of post no. 1, respectively. The guardrail was torn completely through at the lower slots 17 in. (432 mm) downstream of post no. 1. A 2-in. (51-mm) long vertical tear was found 7 in. (178 mm) upstream of post no. 2 at the upper slot. Another 1-in. (25-mm) long tear was found 4 in. (102 mm) downstream of post no. 3. A 3-in. (76-mm) long horizontal tear was located 43 in. (1,092 mm) downstream of post no. 7. The guardrail was buckled 15 in. (381 mm) upstream of post no. 8.

The working width envelope of the system was found to be 54 ft – ½ in. (16.5 m) longitudinally and 14 ft – 9¼ in. (4.5 m) laterally and is shown in Figure 54.

6.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figure 55. Deformations to the vehicle's floorboard were relatively minor, with maximum longitudinal, lateral, and vertical deflections of ½ in. (13 mm) located at the right side of the right-side floorboard near the dashboard, ½ in. (13 mm) located near the middle of the left-side floorboard, and ½ in. (13 mm) located at the right side of the right-side floorboard near the dashboard, respectively. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix C.

The left-rear quarter panel was crushed approximately 3 in. (76 mm). The left-front fender was crushed backward due to contact with the cable, and a 4-in. (102-mm) long tear occurred. The left headlight was disengaged. The left side of the hood was ajar. Scrape marks occurred along the bottom edge of the longitudinal frame members. Folding occurred in the left side of the front bumper, and the bumper was significantly crushed. The grill was crushed inward due to contact with the cable. The radiator was punctured and was leaking. The right headlight was crushed inward. The right-front fender was crushed inward approximately 5 in. (127 mm), and the fender was folded. The right side of the hood was ajar. The right-front tire had a 4-in.

(102-mm) long tear in the side wall, and the hub cap was fractured. The right-rear tire had a 13-in. (330-mm) long tear in the side wall. The roof and window glass remained undamaged.

6.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 5. It is noted that the OIVs and ORAs were within the suggested limits provided in NCHRP Report No. 350. The calculated THIV, PHD, and ASI values are also shown in Table 8. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 46. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix D.

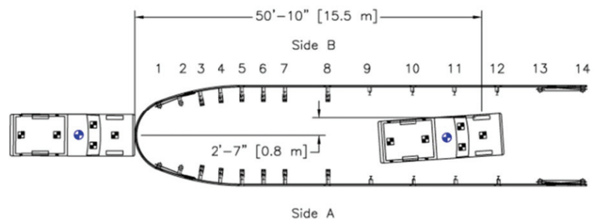
Table 8. Summary of OIV, ORA, THIV, and PHD Values, Test No. USPBN-4

Evaluation Criteria		Transducer		NCHRP Report No. 350 Limits
		EDR-3	DTS	
OIV ft/s (m/s)	Longitudinal	-21.82 (-6.65)	-21.75 (-6.63)	≤ 39.4 (12)
	Lateral	0.19 (0.06)	0.21 (0.06)	≤ 39.4 (12)
ORA g's	Longitudinal	-7.97	-7.84	≤ 20
	Lateral	7.46	7.34	≤ 20
THIV ft/s (m/s)		-	21.75 (6.63)	not required
PHD g's		-	8.99	not required
ASI		0.44	0.43	not required

6.7 Discussion

The analysis of the test results for test no. USPBN-4 showed that the bullnose median barrier adequately contained and safely decelerated the 2000P vehicle. There were no detached elements nor fragments which showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements were noted, as shown in Appendix D, and were deemed acceptable because they did not adversely influence occupant risk safety criteria nor cause rollover. After impact, the vehicle was contained by the bullnose median barrier. Therefore, test no. USPBN-4 conducted on a bullnose median barrier was determined to be acceptable according to the NCHRP Report No. 350 safety performance criteria for test designation no. 3-31.

0.000 sec | 0.200 sec | 0.324 sec | 0.472 sec | 0.692 sec



- Test Agency .... MwRSF
- Test Number USPBN-4
- Date 10/6/10
- NCHRP Report No. 350 Test Designation 3-31
- Test Article .... Bullnose Median Barrier
- Key Component – Rail
  - Type .... 12 ga. (2.66 mm) Thrie Beam
  - Top Mounting Height .... 31⅝ in. (803 mm)
  - Section Nos. 1-2 .... 12 ft – 6 in. (3.81 m) length, bent and slotted
  - Section No. 3 .... 12 ft – 6 in. (3.81 m) length, slotted
  - Section Nos. 4-5 .... 12 ft – 6 in. (3.81 m) length, standard
- Key Component – Post Nos. 1-2, 13-14
  - Type .... Thrie BCT Wood Posts
- Key Component – Post Nos. 3-8
  - Type .... Universal Steel Breakaway Posts
  - Shape W6x8.5 (W152x12.6)
  - Base Plates .... 2½ x 10 in. (64 x 254 mm) bolt spacing
  - Fracturing Bolts .... $^{7}/_{16}$-in. (11.1-mm) diameter ASTMA325 hex tap
  - Base Tubes .... TS 6 x 8 x $^{3}/_{16}$ x 40 in. (152 x 203 x 4.8 x 1016 mm)
- Key Component – Post Nos. 9-12
  - Type .... Standard Thrie Beam Posts
  - Shape W6x8.5 (W152x12.6)
- Soil Type .... Grading B AASHTO M147-65 (1990)
- Vehicle Make /Model .... GMC C2500 pickup truck
  - Curb .... 4,581 lb (2,078 kg)
  - Test Inertial .... 4,429 lb (2,009 kg)
  - Gross Static .... 4,429 lb (2,009 kg)
- Impact Conditions
  - Speed .... 64.5 mph (103.7 km/h)
  - Angle .... 0 deg
  - Impact Location .... centerline of the system
- Exit Conditions
  - Speed .... NA
  - Angle .... NA
- Exit Box Criterion .... Pass
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 50 ft – 10 in. (15.5 m) downstream of impact
  2 ft – 7 in. (0.8 m) to the left of impact
- Vehicle Damage .... Moderate
  - VDS[9] 12-FD-2
  - CDC[10] 12FDEW2
  - Maximum Interior Deformation .... ½ in. (13 mm)
- Test Article Damage .... Severe
- Working Width Envelope .... 54 ft – ½ in. (16.5 m) longitudinally
  14 ft – 9¼ in. (4.5 m) laterally
- Maximum Angular Displacements (DTS)
  - Roll .... 5.68 deg
  - Pitch .... -7.02 deg
  - Yaw .... -5.89 deg
- Transducer Data

Evaluation Criteria		Transducer		NCHRP Report No. 350 Limits
		EDR-3	DTS	
OIV ft/s (m/s)	Longitudinal	-21.82 (-6.65)	-21.75 (-6.63)	≤ 39.4 (12)
	Lateral	0.19 (0.06)	0.21 (0.06)	≤ 39.4 (12)
ORA g's	Longitudinal	-7.97	-7.84	≤ 20
	Lateral	7.46	7.34	≤ 20
THIV ft/s (m/s)		-	21.75 (6.63)	not required
PHD g's		-	8.99	not required
ASI		0.44	0.43	not required

Figure 46. Summary of Test Results and Sequential Photographs, Test No. USPBN-4

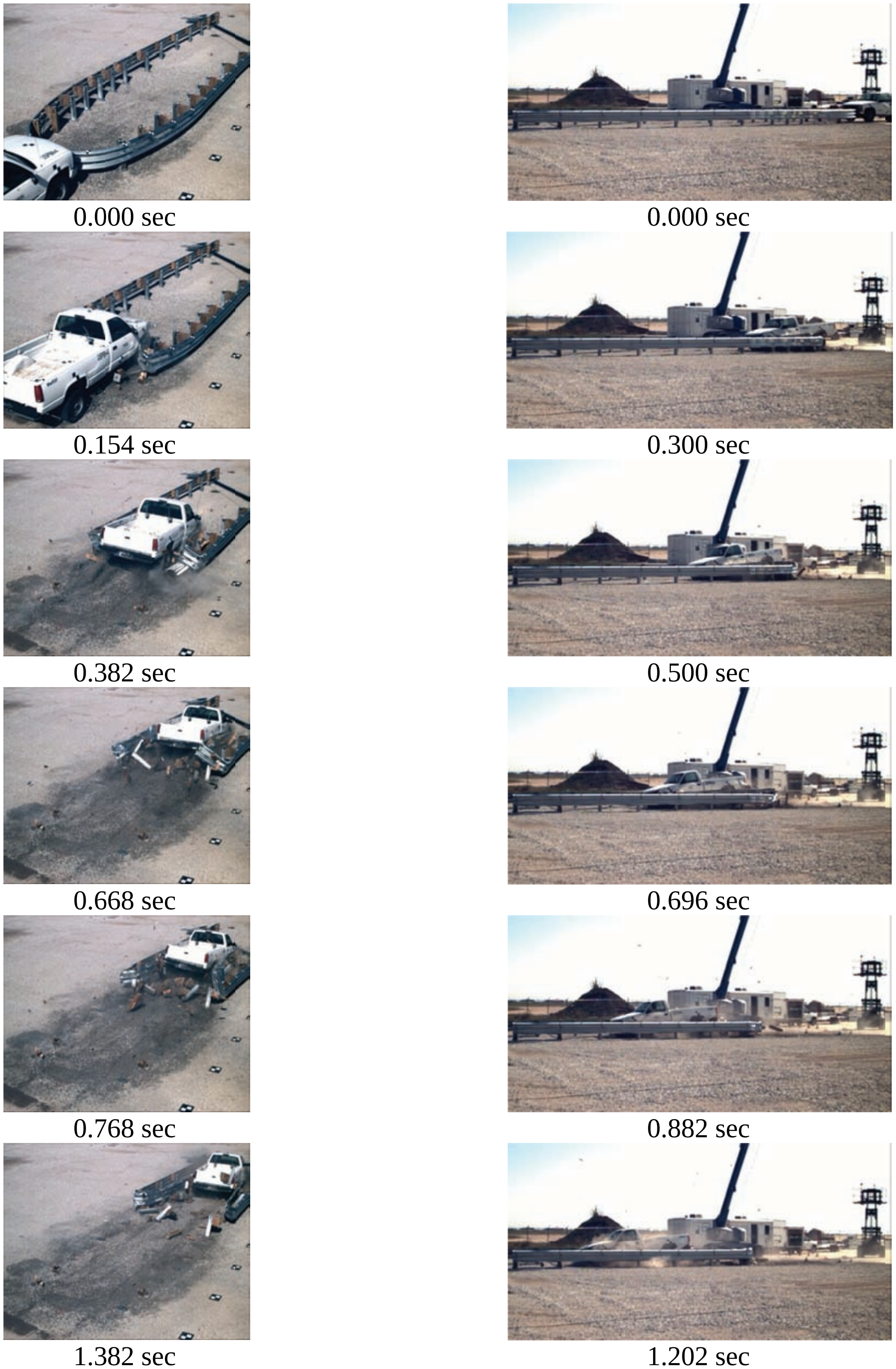


Figure 47. Additional Sequential Photographs, Test No. USPBN-4

0.000 sec
0.000 sec
0.084 sec
0.030 sec
0.152 sec
0.230 sec
0.202 sec
0.530 sec
0.288 sec
0.810 sec
0.384 sec
1.410 sec

Figure 48. Additional Sequential Photographs, Test No. USPBN-4

Figure 49. Impact Location, Test No. USPBN-4

Figure 50. Vehicle Final Position and Trajectory Marks, Test No. USPBN-4

Figure 51. System Damage, Test No. USPBN-4

Figure 52. System Damage, Test No. USPBN-4

Figure 53. Post Damage, Test No. USPBN-4

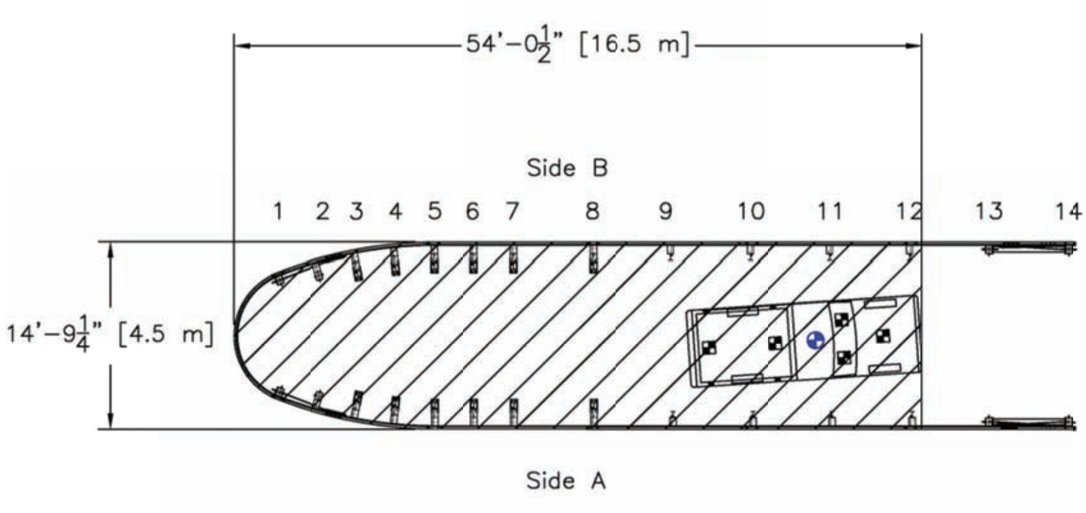


Figure 54. Working Width Envelope, Test No. USPBN-4

Figure 55. Vehicle Damage, Test No. USPBN-4

7 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A bullnose median barrier was developed with fracturing bolt, steel posts. The breakaway steel posts were designed to match the cantilevered bending capacities of the existing wood CRT posts about their strong and weak axis, as well as for a biaxial loading condition. The embedded portion of the UBSP was similar to the CRT post to assure comparable rotational resistance in the soil. The mass, general geometry, and the breakaway characteristics of the upper UBSP section were also similar to the CRT wood post. The lower portion of the UBSP consisted of a foundation tube with the lower base plate. The upper portion of the UBSP consisted of a post with the upper base plate. The bullnose system utilized BCT posts for the first two posts as well as for the last two anchorage posts on each side of the barrier. Post nos. 3 through 8 were UBSP, and the remaining posts were standard thrie beam guardrail steel posts. The system was subjected to test designation nos. 3-3- and 3-31 of NCHRP Report No. 350 to determine if it met the TL-3 safety performance criteria.

In full-scale crash test no. USPBN-3, a 2,024-lb (918-kg) passenger car impacted the barrier at the passenger's side quarter point offset of the bullnose at a speed of 63.3 mph (101.9 km/h) and at an angle of 0 degrees. A summary of the safety performance evaluation is provided in Table 9. The vehicle was safely contained and decelerated, and the barrier did not cause vehicle instability.

In full-scale crash test no. USPBN-4, a 4,429-lb (2,009-kg) pickup truck impacted the barrier at the centerline of the bullnose at a speed of 64.5 mph (103.7 km/h) and at an angle of 0 degrees. A summary of the safety performance evaluation is provided in Table 9. The vehicle was safely contained and decelerated, and the barrier did not cause vehicle instability. The bullnose median barrier with universal breakaway steel posts was determined to be acceptable according to the TL-3 safety performance criteria in NCHRP Report No. 350.

Based on this performance of the UBSP in the tests described herein and those conducted previously, the researchers believe that the UBSP is a suitable alternative for the wood, CRT post used in the original design. Because the performance of the system with the UBSP was nearly identical to the original system with CRT posts, no additional constraints or caveats need to be applied when using the alternative post design. In addition, recommendations made with respect to the design and implementation of the original bullnose median barrier system would still be applicable to the system when the UBSP is used.

It should be noted that the foundation tube and lower base plate of the UBSP was typically undamaged in the full-scale crash tests and could potentially be reused. MwRSF believes that the UBSP foundation tube and lower base plate can be reused if it displays no plastic deformation. In addition, if the UBSP foundation tube and lower base plate have not deflected more than ½ in. (13 mm) in the soil, it would be acceptable to re-compact the soil around the post base and mount a new top section (i.e., post and upper base plate) to the lower base plate to reset the post. Soil deflections greater than ½ in. (13 mm) would require pulling the post base, checking for damage, and resetting the post.

It should also be noted that the bullnose system constructed for use in this test program had dual cable anchorages employed on each side of the downstream end of the system. The function of these cable anchorages was to develop the appropriate rail tension required to simulate a typical field installation of the bullnose which would consist of a closed envelop or attachment of sides of the bullnose to a concrete bridge rail. Thus, for a closed envelope bullnose system or a bullnose that is attached to a bridge rail on both sides, these anchorages are not required. However, some states install the bullnose in a layout that attaches the oncoming traffic side to a bridge rail but leaves the reverse direction traffic side open and unattached. In this type of installation, the researchers would recommend that dual cable anchorages be employed similar to those used in the full-scale testing described herein.

Finally, the satisfactory performance of the UBSP in the bullnose median barrier system would suggest that there is potential for the UBSP as a surrogate in other CRT applications, such as in the long-span guardrail system and guardrail end terminals. However, further analysis and testing would be required to verify its performance in those other guardrail applications.

Table 9. Summary of Safety Performance Evaluation Results

<table>
<tr><th>Evaluation Factors</th><th colspan="2">Evaluation Criteria</th><th>Test No. USPBN-3</th><th>Test No. USPBN-4</th></tr>
<tr><td rowspan="2">Structural Adequacy</td><td>A.</td><td>Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td><td>S</td><td>S</td></tr>
<tr><td>C.</td><td>Acceptable test article performance may be by redirection, controlled penetration, or controlled stopping of the vehicle.</td><td>S</td><td>S</td></tr>
<tr><td rowspan="4">Occupant Risk</td><td>D.</td><td>Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted. See discussion in Section 5.3 and Appendix E of NCHRP Report No. 350.</td><td>S</td><td>S</td></tr>
<tr><td>F.</td><td>The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.</td><td>S</td><td>S</td></tr>
<tr><td>H.</td><td>Occupant Impact Velocities (OIV) (see Appendix A, Section A5.3 of NCHRP Report No. 350 for calculation procedure) should satisfy the following:<table><tr><th colspan="3">Occupant Impact Velocity Limits</th></tr><tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr><tr><td>Longitudinal and Lateral</td><td>29.5 ft/s
(9 m/s)</td><td>39.4 ft/s
(12 m/s)</td></tr></table></td><td>M</td><td>S</td></tr>
<tr><td>I.</td><td>The Occupant Ridedown Accelerations (ORA) (see Appendix A, Section A5.3 of NCHRP Report No. 350 for calculation procedure) should satisfy the following:<table><tr><th colspan="3">Occupant Ridedown Acceleration Limits</th></tr><tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr><tr><td>Longitudinal and Lateral</td><td>15 g’s</td><td>20 g’s</td></tr></table></td><td>S</td><td>S</td></tr>
<tr><td rowspan="4">Vehicle Trajectory</td><td>K.</td><td>After collision it is preferable that the vehicle’s trajectory not intrude into adjacent traffic lanes.</td><td>S</td><td>S</td></tr>
<tr><td>L.</td><td>The occupant impact velocity in the longitudinal direction should not exceed 39.4 ft/s (12 m/s) and the occupant ridedown acceleration in longitudinal direction should not exceed 20 g’s.</td><td>S</td><td>S</td></tr>
<tr><td>M.</td><td>The exit angle from the test article preferably should be less than 60 percent of the test impact angle, measured at time of vehicle loss of contact with test device.</td><td>NA</td><td>NA</td></tr>
<tr><td>N.</td><td>Vehicle trajectory behind the test article is acceptable.</td><td>S</td><td>S</td></tr>
</table>

S – Satisfactory M – Marginal U – Unsatisfactory NA - Not Applicable

8 REFERENCES

1. Bielenberg, B.W., Faller, R.K., Reid, J.D., Rohde, J.R., Sicking, D.L., and Keller, E.A., *Concept Development of a Bullnose Guardrail System for Median Applications*, Final Report to the Midwest States Regional Pooled Fund Program, MwRSF Research Report No. TRP-03-73-98, Project No. SPR-3(017)-Year 7, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, May 22, 1998.

2. Bielenberg, B.W., Reid, J.D., Faller, R.K., Rohde, J.R., Sicking, D.L., Keller, E.A., and Holloway, J.C., *Phase II Development of a Bullnose Guardrail System for Median Applications*, Final Report to the Midwest States Regional Pooled Fund Program, MwRSF Research Report No. TRP-03-78-98, Project No. SPR-3(017)-Years 7 and 8, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, December 18, 1998.

3. Bielenberg, B.W., Faller, R.K., Reid, J.D., Rohde, J.R., Sicking, D.L., Keller, E.A., Holloway, J.C., and Supencheck, L.L., *Phase III Development of a Bullnose Guardrail System for Median Applications*, Final Report to the Midwest States Regional Pooled Fund Program, MwRSF Research Report No. TRP-03-95-00, Project No. SPR-3(017)-Years 7 and 8, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, June 1, 2000.

4. Ross, H.E., Sicking, D.L., Zimmer, R.A., and Michie, J.D., *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, National Cooperative Highway Research Program (NCHRP) Report 350, Transportation Research Board, Washington, D.C., 1993.

5. Bielenberg, B.W., Faller, R.K., Rohde, J.R., and Reid, J.D., *Evaluation of an Existing Steel Post Alternative for the Thrie Beam Bullnose Guardrail System*, Letter Report to the Midwest States Regional Pooled Fund Program, MwRSF Research Report No. TRP-03-193-07, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, August 24, 2007.

6. Arens, S.W., Sicking, D.L., Faller, R.K., Reid, J.D., Bielenberg, R.W., Rohde, J.R., and Lechtenberg, K.A., *Investigating the Use of a New Universal Breakaway Steel Post*, Final Report to the Minnesota Department of Transportation (MnDOT), MwRSF Research Report No. TRP-03-218-09, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, August 3, 2009.

7. Schmidt, J.D., Sicking, D.L, Faller, R.K., Reid, J.D., Bielenberg, R.W., and Lechtenberg, K.A., *Investigating the Use of a New Universal Breakaway Steel Post – Phase 2*, Final Report to the Minnesota Department of Transportation (MnDOT), MwRSF Research Report No. TRP-03-230-10, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, August 9, 2010.

8. Hinch, J., Yang, T.L., and Owings, R., *Guidance Systems for Vehicle Testing*, ENSCO, Inc., Springfield, Virginia, 1986.

9. *Vehicle Damage Scale for Traffic Investigators*, Second Edition, Technical Bulletin No. 1, Traffic Accident Data (TAD) Project, National Safety Council, Chicago, Illinois, 1971.

10. *Collision Deformation Classification – Recommended Practice J224 March 1980*, Handbook Volume 4, Society of Automotive Engineers (SAE), Warrendale, Pennsylvania, 1985.

9 APPENDICES

Appendix A. Material Specifications

Certified Analysis

Trinity Highway Products , LLC
425 E. O'Connor
Lima, OH
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097
Project: RESALE

Order Number: 1114173
Customer PO: 2209
BOL Number: 51036
Document #: 1
Shipped To: NE
Use State: NE

As of: 9/11/09

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
4	209G	T12/12'6/6'3/S	M-180	A	2	125143	61,860	79,920	23.0	0.190	0.770	0.010	0.004	0.020	0.121	0.00	0.030	0.000	4
			M-180	A	2	0113812	60,600	82,200	24.8	0.210	0.910	0.010	0.010	0.020	0.010	0.000	0.020	0.000	4
			M-180	A	2	0113813	52,200	77,700	26.2	0.220	0.910	0.010	0.010	0.010	0.010	0.000	0.020	0.000	4
			M-180	A	2	125144	61,890	81,040	26.5	0.190	0.740	0.010	0.000	0.030	0.120	0.000	0.050	0.000	4
			M-180	A	2	125145	63,120	81,790	25.2	0.190	0.740	0.010	0.000	0.020	0.110	0.000	0.040	0.000	4
4	729G	TS 8X6X3/16X8'-0" SLEEVE	A-500			L2848	59,523	72,619	28.0	0.147	0.648	0.009	0.008	0.023	0.175	0.00	0.091	0.000	4
4	749G	TS 8X6X3/16X6'-0" SLEEVE	A-500			L2848	59,523	72,619	28.0	0.147	0.648	0.009	0.008	0.023	0.175	0.00	0.091	0.000	4
4	12379G	T12/12'6/SPEC/S 34'RCX	M-180	A	2	291920	68,500	73,700	28.0	0.066	0.720	0.010	0.010	0.011	0.067	0.04	0.026	0.001	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123, UNLESS OTHERWISE STATED.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 49100 LB

State of Ohio, County of Allen. Sworn and subscribed before me this 11st day of September, 2009
Notary Public:
Commission Expires 1/28/2012

Trinity Highway Products , LLC
Certified By:
Quality Assurance

1 of 8

Figure A-1. Nose Cables

Certified Analysis

Trinity Highway Products , LLC
425 E. O'Connor
Lima, OH
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097
Project: RESALE

Order Number: 1121475
Customer PO: 2270
BOL Number: 55149
Document #: 1
Shipped To: NE
Use State: KS

As of: 4/26/10

BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 49100 LB

State of Ohio, County of Allen. Sworn and subscribed before me this 26th day of April, 2010

Notary Public:
Commission Expires 1/28/2012

Trinity Highway Products , LLC
Certified By:
Quality Assurance

3 of 3

Figure A-2. Nose Cables

Certifi. Analysis

Trinity Highway Products , LLC
425 E. O'Connor
Lima, OH

Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097

Project: RESALE

Order Number: 1121496
Customer PO: 2269
BOL Number: 54132
Document #: 1
Shipped To: NE
Use State: KS

As of: 3/9/10

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
20	209G	T12/12'6/6'3/S	M-180	A	2	130217	64,020	83,600	21.8	0.190	0.760	0.013	0.005	0.020	0.150	0.00	0.060	0.000	4
			M-180	A	2	129151	63,860	81,300	26.8	0.190	0.740	0.010	0.004	0.020	0.090	0.000	0.050	0.000	4
			M-180	A	2	129154	61,190	79,690	24.8	0.180	0.730	0.012	0.006	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	129161	63,450	81,140	26.0	0.190	0.730	0.010	0.003	0.020	0.150	0.000	0.050	0.000	4
			M-180	A	2	129162	62,160	78,740	25.4	0.190	0.740	0.014	0.004	0.020	0.150	0.000	0.070	0.000	4
			M-180	A	2	130216	63,390	81,100	22.9	0.190	0.730	0.011	0.004	0.020	0.100	0.000	0.050	0.000	4
			M-180	A	2	130218	57,750	82,130	22.2	0.130	0.750	0.011	0.005	0.020	0.130	0.000	0.050	0.000	4
			M-180	A	2	130793	63,980	83,300	23.0	0.200	0.740	0.012	0.003	0.030	0.120	0.000	0.050	0.000	4
20	211G	T12/12'6/3'1.5/S	M-180	A	2	129155	61,190	81,210	23.8	0.190	0.730	0.011	0.003	0.020	0.150	0.00	0.060	0.000	4
			M-180	A	2	129152	62,700	80,900	25.2	0.190	0.720	0.012	0.004	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	129153	63,070	80,470	23.8	0.180	0.730	0.011	0.002	0.030	0.140	0.000	0.060	0.000	4
			M-180	A	2	129162	62,160	78,740	25.4	0.190	0.740	0.014	0.004	0.020	0.150	0.000	0.070	0.000	4
			M-180	A	2	129163	61,760	78,730	28.0	0.190	0.740	0.011	0.003	0.030	0.140	0.000	0.060	0.000	4
	211G		M-180	A	2	129163	61,760	78,730	28.0	0.190	0.740	0.011	0.003	0.030	0.140	0.00	0.060	0.000	4
			M-180	A	2	128756	62,920	81,360	24.4	0.190	0.740	0.012	0.004	0.020	0.110	0.000	0.060	0.000	4
			M-180	A	2	129151	63,860	81,300	26.8	0.190	0.740	0.010	0.004	0.020	0.090	0.000	0.050	0.000	4
			M-180	A	2	129152	62,700	80,900	25.2	0.190	0.720	0.012	0.004	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	129153	63,070	80,470	23.8	0.180	0.730	0.011	0.002	0.030	0.140	0.000	0.060	0.000	4
			M-180	A	2	129154	61,190	79,690	24.8	0.180	0.730	0.012	0.006	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	129155	61,190	81,210	23.8	0.190	0.730	0.011	0.003	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	129162	62,160	78,740	25.4	0.190	0.740	0.014	0.004	0.020	0.150	0.000	0.070	0.000	4
			M-180	A	2	129164	61,140	80,290	26.5	0.190	0.750	0.011	0.003	0.020	0.130	0.000	0.050	0.000	4
30	260G	T12/25/6'3/S	M-180	A	2	129163	61,760	78,730	28.0	0.190	0.740	0.011	0.003	0.030	0.140	0.00	0.060	0.000	4
			M-180	A	2	128756	62,920	81,360	24.4	0.190	0.740	0.012	0.004	0.020	0.110	0.000	0.060	0.000	4
			M-180	A	2	129151	63,860	81,300	26.8	0.190	0.740	0.010	0.004	0.020	0.090	0.000	0.050	0.000	4
			M-180	A	2	129152	62,700	80,900	25.2	0.190	0.720	0.012	0.004	0.020	0.150	0.000	0.060	0.000	4

1 of 6

Figure A-3. Rail Section No. 3

Certified Analysis

Trinity Highway Products , LLC
425 E. O'Connor
Lima, OH
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097
Project: RESALE

Order Number: 1121509
Customer PO: 2252
BOL Number: 55201
Document #: 1
Shipped To: NE
Use State: NE

As of: 4/28/10

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
4	209B	T12/12'6/6'3/S	M-180	A	2	132181	64,070	81,720	26.2	0.200	0.730	0.014	0.003	0.030	0.140	0.00	0.080	0.000	
			M-180	A	2	131905	63,690	81,990	24.1	0.190	0.730	0.013	0.004	0.030	0.120	0.000	0.060	0.000	
			M-180	A	2	132182	60,790	78,680	26.2	0.190	0.730	0.013	0.006	0.020	0.080	0.000	0.080	0.000	
			M-180	A	2	132182	60,790	78,680	26.2	0.190	0.730	0.013	0.006	0.020	0.140	0.000	0.080	0.000	
			M-180	A	2	132183	64,220	82,170	24.8	0.190	0.740	0.015	0.003	0.030	0.140	0.000	0.080	0.000	
			M-180	A	2	132189	62,000	79,120	26.5	0.190	0.720	0.012	0.004	0.030	0.110	0.000	0.060	0.000	
20	209G	T12/12'6/6'3/S	M-180	A	2	130794	63,340	81,340	26.6	0.190	0.750	0.011	0.003	0.030	0.110	0.00	0.060	0.000	4
			M-180	A	2	128756	62,920	81,360	24.4	0.190	0.740	0.012	0.004	0.020	0.110	0.000	0.060	0.000	4
			M-180	A	2	129161	63,450	81,140	26.0	0.190	0.730	0.010	0.003	0.020	0.150	0.000	0.050	0.000	4
			M-180	A	2	129162	62,160	78,740	25.4	0.190	0.740	0.014	0.004	0.020	0.150	0.000	0.070	0.000	4
			M-180	A	2	130216	63,390	81,100	22.9	0.190	0.730	0.011	0.004	0.020	0.100	0.000	0.050	0.000	4
			M-180	A	2	130217	64,020	83,600	21.8	0.190	0.760	0.013	0.005	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	130793	63,980	83,300	23.0	0.200	0.740	0.012	0.003	0.030	0.120	0.000	0.050	0.000	4
	209G		M-180	A	2	130216	63,390	81,100	22.9	0.190	0.730	0.011	0.004	0.020	0.100	0.00	0.050	0.000	4
			M-180	A	2	129152	62,700	80,900	25.2	0.190	0.720	0.012	0.004	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	129154	61,190	79,690	24.8	0.180	0.730	0.012	0.006	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	130217	64,020	83,600	21.8	0.190	0.760	0.013	0.005	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	130793	63,980	83,300	23.0	0.200	0.740	0.012	0.003	0.030	0.120	0.000	0.050	0.000	4
			M-180	A	2	130794	63,340	81,340	26.6	0.190	0.750	0.011	0.003	0.030	0.110	0.000	0.060	0.000	4
	209G		M-180	A	2	130217	64,020	83,600	21.8	0.190	0.760	0.013	0.005	0.020	0.150	0.00	0.060	0.000	4
			M-180	A	2	129151	63,860	81,300	26.8	0.190	0.740	0.010	0.004	0.020	0.090	0.000	0.050	0.000	4
			M-180	A	2	129154	61,190	79,690	24.8	0.180	0.730	0.012	0.006	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	129161	63,450	81,140	26.0	0.190	0.730	0.010	0.003	0.020	0.150	0.000	0.050	0.000	4
			M-180	A	2	129162	62,160	78,740	25.4	0.190	0.740	0.014	0.004	0.020	0.150	0.000	0.070	0.000	4
			M-180	A	2	130216	63,390	81,100	22.9	0.190	0.730	0.011	0.004	0.020	0.100	0.000	0.050	0.000	4
			M-180	A	2	130218	57,750	82,130	22.2	0.130	0.750	0.011	0.005	0.020	0.130	0.000	0.050	0.000	4

1 of 3

Figure A-4. Rail Section No. 3

Certified Analysis

Trinity Highway Products , LLC
425 E. O'Connor
Lima, OH
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097
Project: RESALE

Order Number: 1121509
Customer PO: 2252
BOL Number: 55201
Document #: 1
Shipped To: NE
Use State: NE

As of: 4/28/10

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
			M-180	A	2	130793	63,980	83,300	23.0	0.200	0.740	0.012	0.003	0.030	0.120	0.000	0.050	0.000	4
	209G		M-180	A	2	132181	64,070	81,720	26.2	0.200	0.730	0.014	0.003	0.030	0.140	0.00	0.080	0.000	4
			M-180	A	2	131905	63,690	81,990	24.1	0.190	0.730	0.013	0.004	0.030	0.120	0.000	0.060	0.000	4
			M-180	A	2	132182	60,790	78,680	26.2	0.190	0.730	0.013	0.006	0.020	0.080	0.000	0.080	0.000	4
			M-180	A	2	132182	60,790	78,680	26.2	0.190	0.730	0.013	0.006	0.020	0.140	0.000	0.080	0.000	4
			M-180	A	2	132183	64,220	82,170	24.8	0.190	0.740	0.015	0.003	0.030	0.140	0.000	0.080	0.000	4
			M-180	A	2	132189	62,000	79,120	26.5	0.190	0.720	0.012	0.004	0.030	0.110	0.000	0.060	0.000	4
40	260G	T12/25/6'3/S	M-180	A	2	130216	63,390	81,100	22.9	0.190	0.730	0.011	0.004	0.020	0.100	0.00	0.050	0.000	4
			M-180	A	2	129152	62,700	80,900	25.2	0.190	0.720	0.012	0.004	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	129154	61,190	79,690	24.8	0.180	0.730	0.012	0.006	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	130217	64,020	83,600	21.8	0.190	0.760	0.013	0.005	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	130793	63,980	83,300	23.0	0.200	0.740	0.012	0.003	0.030	0.120	0.000	0.050	0.000	4
			M-180	A	2	130794	63,340	81,340	26.6	0.190	0.750	0.011	0.003	0.030	0.110	0.000	0.060	0.000	4
6	1359B	T12/12'6/6'3/S 35'CX	M-180	A	2	130216	63,390	81,100	22.9	0.190	0.730	0.011	0.004	0.020	0.100	0.00	0.050	0.000	
			M-180	A	2	129152	62,700	80,900	25.2	0.190	0.720	0.012	0.004	0.020	0.150	0.000	0.060	0.000	
			M-180	A	2	129154	61,190	79,690	24.8	0.180	0.730	0.012	0.006	0.020	0.150	0.000	0.060	0.000	
			M-180	A	2	130217	64,020	83,600	21.8	0.190	0.760	0.013	0.005	0.020	0.150	0.000	0.060	0.000	
			M-180	A	2	130793	63,980	83,300	23.0	0.200	0.740	0.012	0.003	0.030	0.120	0.000	0.050	0.000	
			M-180	A	2	130794	63,340	81,340	26.6	0.190	0.750	0.011	0.003	0.030	0.110	0.000	0.060	0.000	
3	50694B	T12/12'6/6'3/S 5'-3" RCX	M-180	A	2	130216	63,390	81,100	22.9	0.190	0.730	0.011	0.004	0.020	0.100	0.00	0.050	0.000	
			M-180	A	2	129152	62,700	80,900	25.2	0.190	0.720	0.012	0.004	0.020	0.150	0.000	0.060	0.000	
			M-180	A	2	129154	61,190	79,690	24.8	0.180	0.730	0.012	0.006	0.020	0.150	0.000	0.060	0.000	
			M-180	A	2	130217	64,020	83,600	21.8	0.190	0.760	0.013	0.005	0.020	0.150	0.000	0.060	0.000	
			M-180	A	2	130793	63,980	83,300	23.0	0.200	0.740	0.012	0.003	0.030	0.120	0.000	0.050	0.000	
			M-180	A	2	130794	63,340	81,340	26.6	0.190	0.750	0.011	0.003	0.030	0.110	0.000	0.060	0.000	

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Figure A-5. Rail Section No. 3

Certified Analysis

Trinity Highway Products , LLC
425 E. O'Connor
Lima, OH
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097
Project: RESALE

Order Number: 1121509
Customer PO: 2252
BOL Number: 55201
Document #: 1
Shipped To: NE
Use State: NE

As of: 4/28/10

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36

ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123, UNLESS OTHERWISE STATED.

BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 49100 LB

State of Ohio, County of Allen. Sworn and subscribed before me this 28th day of April, 2010
Notary Public: Sherri L. Dondzella/Mann
Commission Expires 24 20 / 2014

Trinity Highway Products, LLC
Certified By: ______
Quality Assurance

3 of 3

Figure A-6. Rail Section No. 3

Certified Analysis

Trinity Highway Products , LLC
425 E. O'Connor
Lima, OH
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097
Project: RESALE

Order Number: 1121475
Customer PO: 2270
BOL Number: 55149
Document #: 1
Shipped To: NE
Use State: KS

As of: 4/26/10

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
20	209G	T12/12'6/6'3/S	M-180	A	2	130794	63,340	81,340	26.6	0.190	0.750	0.011	0.003	0.030	0.110	0.00	0.060	0.000	4
			M-180	A	2	128756	62,920	81,360	24.4	0.190	0.740	0.012	0.004	0.020	0.110	0.000	0.060	0.000	4
			M-180	A	2	129161	63,450	81,140	26.0	0.190	0.730	0.010	0.003	0.020	0.150	0.000	0.050	0.000	4
			M-180	A	2	129162	62,160	78,740	25.4	0.190	0.740	0.014	0.004	0.020	0.150	0.000	0.070	0.000	4
			M-180	A	2	130216	63,390	81,100	22.9	0.190	0.730	0.011	0.004	0.020	0.100	0.000	0.050	0.000	4
			M-180	A	2	130217	64,020	83,600	21.8	0.190	0.760	0.013	0.005	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	130793	63,980	83,300	23.0	0.200	0.740	0.012	0.003	0.030	0.120	0.000	0.050	0.000	4
	209G		M-180	A	2	130217	64,020	83,600	21.8	0.190	0.760	0.013	0.005	0.020	0.150	0.00	0.060	0.000	4
			M-180	A	2	129151	63,860	81,300	26.8	0.190	0.740	0.010	0.004	0.020	0.090	0.000	0.050	0.000	4
			M-180	A	2	129154	61,190	79,690	24.8	0.180	0.730	0.012	0.006	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	129161	63,450	81,140	26.0	0.190	0.730	0.010	0.003	0.020	0.150	0.000	0.050	0.000	4
			M-180	A	2	129162	62,160	78,740	25.4	0.190	0.740	0.014	0.004	0.020	0.150	0.000	0.070	0.000	4
			M-180	A	2	130216	63,390	81,100	22.9	0.190	0.730	0.011	0.004	0.020	0.100	0.000	0.050	0.000	4
			M-180	A	2	130218	57,750	82,130	22.2	0.130	0.750	0.011	0.005	0.020	0.130	0.000	0.050	0.000	4
			M-180	A	2	130793	63,980	83,300	23.0	0.200	0.740	0.012	0.003	0.030	0.120	0.000	0.050	0.000	4
	209G		M-180	A	2	130216	63,390	81,100	22.9	0.190	0.730	0.011	0.004	0.020	0.100	0.00	0.050	0.000	4
			M-180	A	2	129152	62,700	80,900	25.2	0.190	0.720	0.012	0.004	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	129154	61,190	79,690	24.8	0.180	0.730	0.012	0.006	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	130217	64,020	83,600	21.8	0.190	0.760	0.013	0.005	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	130793	63,980	83,300	23.0	0.200	0.740	0.012	0.003	0.030	0.120	0.000	0.050	0.000	4
			M-180	A	2	130794	63,340	81,340	26.6	0.190	0.750	0.011	0.003	0.030	0.110	0.000	0.060	0.000	4
20	729G	TS 8X6X3/16X8'-0" SLEEVE	A-500			N0266	54,007	72,010	29.0	0.057	0.645	0.008	0.008	0.014	0.000	0.00	0.000	0.000	4
20	749G	TS 8X6X3/16X6'-0" SLEEVE	A-500			N0266	54,007	72,010	29.0	0.057	0.645	0.008	0.008	0.014	0.000	0.00	0.000	0.000	4
20	12379G	T12/12'6/SPEC/S 34'RCX	M-180	A	2	129152	62,700	80,900	25.2	0.190	0.720	0.012	0.004	0.020	0.150	0.00	0.060	0.000	4

1 of 3

Figure A-7. Radius Guardrail

Certified Analysis

Trinity Highway Products , LLC
425 E. O'Connor
Lima, OH
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097
Project: RESALE

Order Number: 1121475
Customer PO: 2270
BOL Number: 55149
Document #: 1
Shipped To: NE
Use State: KS

As of: 4/26/10

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
			M-180	A	2	129155	61,190	81,210	23.8	0.190	0.730	0.011	0.003	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	129163	61,760	78,730	28.0	0.190	0.740	0.011	0.003	0.030	0.140	0.000	0.060	0.000	4
20	12383G	T12/12'6/6'3/SPEC SLOTS/S	M-180	A	2	130216	63,390	81,100	22.9	0.190	0.730	0.011	0.004	0.020	0.100	0.00	0.050	0.000	4
			M-180	A	2	129152	62,700	80,900	25.2	0.190	0.720	0.012	0.004	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	129154	61,190	79,690	24.8	0.180	0.730	0.012	0.006	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	130217	64,020	83,600	21.8	0.190	0.760	0.013	0.005	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	130793	63,980	83,300	23.0	0.200	0.740	0.012	0.003	0.030	0.120	0.000	0.050	0.000	4
			M-180	A	2	130794	63,340	81,340	26.6	0.190	0.750	0.011	0.003	0.030	0.110	0.000	0.060	0.000	4
10	12385G	T12/12'6/SPEC/S 5'RCX	M-180	A	2	130794	63,340	81,340	26.6	0.190	0.750	0.011	0.003	0.030	0.110	0.00	0.060	0.000	4
			M-180	A	2	128756	62,920	81,360	24.4	0.190	0.740	0.012	0.004	0.020	0.110	0.000	0.060	0.000	4
			M-180	A	2	129161	63,450	81,140	26.0	0.190	0.730	0.010	0.003	0.020	0.150	0.000	0.050	0.000	4
			M-180	A	2	129162	62,160	78,740	25.4	0.190	0.740	0.014	0.004	0.020	0.150	0.000	0.070	0.000	4
			M-180	A	2	130216	63,390	81,100	22.9	0.190	0.730	0.011	0.004	0.020	0.100	0.000	0.050	0.000	4
			M-180	A	2	130217	64,020	83,600	21.8	0.190	0.760	0.013	0.005	0.020	0.150	0.000	0.060	0.000	4
			M-180	A	2	130793	63,980	83,300	23.0	0.200	0.740	0.012	0.003	0.030	0.120	0.000	0.050	0.000	4
40	19361G	BNT PL 3/16X12-5/8X5-1/2	A-36			60747	66,820	75,200	29.0	0.078	1.220	0.012	0.006	0.021	0.010	0.05	0.025	0.003	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.
ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123, UNLESS OTHERWISE STATED.

2 of 3

Figure A-8. Radius Guardrail

Certified Analysis

Trinity Highway Products , LLC
425 E. O'Connor
Lima, OH
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097
Project: RESALE

Order Number: 1114173
Customer PO: 2209
BOL Number: 51036
Document #: 1
Shipped To: NE
Use State: NE

As of: 9/11/09

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
4	209G	T12/12'6/6'3/S	M-180	A	2	125143	61,860	79,920	23.0	0.190	0.770	0.010	0.004	0.020	0.121	0.00	0.030	0.000	4
			M-180	A	2	0113812	60,600	82,200	24.8	0.210	0.910	0.010	0.010	0.020	0.010	0.000	0.020	0.000	4
			M-180	A	2	0113813	52,200	77,700	26.2	0.220	0.910	0.010	0.010	0.010	0.010	0.000	0.020	0.000	4
			M-180	A	2	125144	61,890	81,040	26.5	0.190	0.740	0.010	0.000	0.030	0.120	0.000	0.050	0.000	4
			M-180	A	2	125145	63,120	81,790	25.2	0.190	0.740	0.010	0.000	0.020	0.110	0.000	0.040	0.000	4
4	729G	TS 8X6X3/16X8'-0" SLEEVE	A-500			L2848	59,523	72,619	28.0	0.147	0.648	0.009	0.008	0.023	0.175	0.00	0.091	0.000	4
4	749G	TS 8X6X3/16X6'-0" SLEEVE	A-500			L2848	59,523	72,619	28.0	0.147	0.648	0.009	0.008	0.023	0.175	0.00	0.091	0.000	4
4	12379G	T12/12'6/SPEC/S 34'RCX	M-180	A	2	291920	68,500	73,700	28.0	0.066	0.720	0.010	0.010	0.011	0.067	0.04	0.026	0.001	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123, UNLESS OTHERWISE STATED.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 49100 LB

State of Ohio, County of Allen, Sworn and subscribed before me this 11st day of September, 2009
Notary Public:
Commission Expires 1-28-2012

Trinity Highway Products , LLC
Certified By:
Quality Assurance

1 of 8

Figure A-9. Straight Slotted Guardrail

Certified Analysis

Trinity Highway Products , LLC
425 E. O'Connor
Lima, OH
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097
Project: RESALE

Order Number: 1114173
Customer PO: 2209
BOL Number: 51036
Document #: 1
Shipped To: NE
Use State: NE

As of: 9/11/09

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
4	12383G	T12/12'6/6'3/SPEC SLOTS/S	M-180	A	2	.0113811	61,700	84,700	22.4	0.220	0.940	0.015	0.007	0.010	0.010	0.00	0.020	0.000	4
			M-180	A	2	0113812	60,600	82,200	24.8	0.210	0.910	0.010	0.010	0.020	0.010	0.000	0.020	0.000	4
			M-180	A	2	0113813	52,200	77,700	26.2	0.220	0.910	0.010	0.010	0.010	0.010	0.000	0.020	0.000	4
			M-180	A	2	0153031	54,100	77,500	25.2	0.220	0.910	0.010	0.010	0.020	0.010	0.000	0.020	0.000	4
			M-180	A	2	0153046	56,800	78,800	27.2	0.210	0.900	0.010	0.010	0.010	0.010	0.000	0.020	0.000	4
			M-180	A	2	0153048	51,000	76,000	25.0	0.210	0.890	0.010	0.010	0.010	0.010	0.000	0.020	0.000	4
	12383G		M-180	A	2	191996	67,500	73,300	28.0	0.066	0.740	0.007	0.010	0.011	0.055	0.04	0.020	0.002	4
			M-180	A	2	191995	70,400	75,100	26.0	0.060	0.760	0.010	0.010	0.010	0.040	0.000	0.020	0.000	4
			M-180	A	2	191997	68,000	73,700	27.0	0.060	0.720	0.010	0.010	0.010	0.060	0.000	0.030	0.000	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123, UNLESS OTHERWISE STATED.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 49100 LB

State of Ohio, County of Allen. Sworn and subscribed before me this 11st day of September, 2009
Notary Public:
Commission Expires 11/28/2012

Trinity Highway Products , LLC
Certified By:
Quality Assurance

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Figure A-10. Straight Slotted Guardrail

Figure A-11. Breakaway Post Hardware

Appendix B. Vehicle Center of Gravity Determination

Test: USPBN-3 **Vehicle:** 820C/Swift

Vehicle CG Determination

	Equipment	Weight (lb)	Long CG (in.)	HOR M (lb-in.)
VEHICLE	+ Unbalasted Car	1857	33.05	61380
	+ Brake receivers/wires	6	115	690
	+ Brake Frame	5	28	140
	+ Brake Cylinder	28	62.5	1750
	+ Strobe Battery	5	55	275
	+ Hub	18	0	0
	+ CG Plate (EDRs)	5	39	195
	- Battery	-26	-12	312
	- Oil	-4	-6	24
	- Interior	-22	46	-1012
	- Spare Tire	-32	99	-3168
	- Coolant	-7	-17	119
	- Washer fluid	-5	-16.5	82.5
BALLAST	Water (fuel tank)			0
	Misc. DTS Unit	18	28	504
	Misc.			0
				61291.5
	TOTAL WEIGHT	1846 lb	CG Location (in.)	33.67

wheelbase 93

NCHRP 350 Targets		CURRENT	Difference
Test Inertial Weight	1808 (+/- 55)	1846	38.0
Long CG	31.5 (+/- 6)	33.67	2.17000

Note, Long. CG is measured from front axle of test vehicle

Curb Weight (lb)

	Left	Right
Front	581	616
Rear	369	291
FRONT	1197	
REAR	660	
TOTAL	1857	

Dummy = 166 lb

Gross Static wheel weight (lb)

	Left	Right
Front	661	608
Rear	397	358
FRONT	1269	
REAR	755	
TOTAL	2024	

Figure B-1. Vehicle Mass Distribution, Test No. USPBN-3

USPBN-4 **Vehicle:** C2500/2000P

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb)	Long CG (in.)	HOR M (lb-in.)
	+ Unbalasted Truck	4581	54.51	249718.5
	+ Brake receivers/wires	9	80	720
	+ Brake Frame	5	41	205
	+ Brake Cylinder	27	54	1458
	+ Strobe Battery	4	70	280
	+ Hub	29	0	0
	+ CG Plate (EDRs)	12	58	696
	- Battery	-30	-15	450
	- Oil	-6	10	-60
	- Interior	-110	54	-5940
	- Fuel	-52	97	-5044
	- Coolant	-13	-20.5	266.5
	- Washer fluid	-5	-18.5	92.5
	- Exhuast	-35	108	-3780
BALLAST	DTS Rack	18	70	1260
	EDR	7	58	406
	Misc.			0
				240728.5
	TOTAL WEIGHT	4441 lb	CG location (in.)	54.30

NCHRP 350 Targets		CURRENT	Difference
Test Inertial Weight (lb	4410 (+/-)100	4441	31.0
Long CG (in.)	55 (+/-)6	54.30	-0.70000

Note, Long. CG is measured from front axle of test vehicle

Curb Weight

	Left	Right
Front	1383	1299
Rear	949	950
FRONT	2682 lb	
REAR	1899 lb	
TOTAL	4581 lb	

Actual test inertial weight
(from scales)

	Left	Right
Front	1359	1241
Rear	910	919
FRONT	2600 lb	
REAR	1829 lb	
TOTAL	4429 lb	

Figure B-2. Vehicle Mass Distribution, Test No. USPBN-4

Appendix C. Vehicle Deformation Records

Occupant Compartment Deformation Index (OCDI)

Test No. USPBN-3
Vehicle Type: 820C/Swift

OCDI = XXABCDEFGHI

XX = location of occupant compartment deformation

A = distance between the dashboard and a reference point at the rear of the occupant compartment, such as the top of the rear seat or the rear of the cab on a pickup

B = distance between the roof and the floor panel

C = distance between a reference point at the rear of the occupant compartment and the motor panel

D = distance between the lower dashboard and the floor panel

E = interior width

F = distance between the lower edge of right window and the upper edge of left window

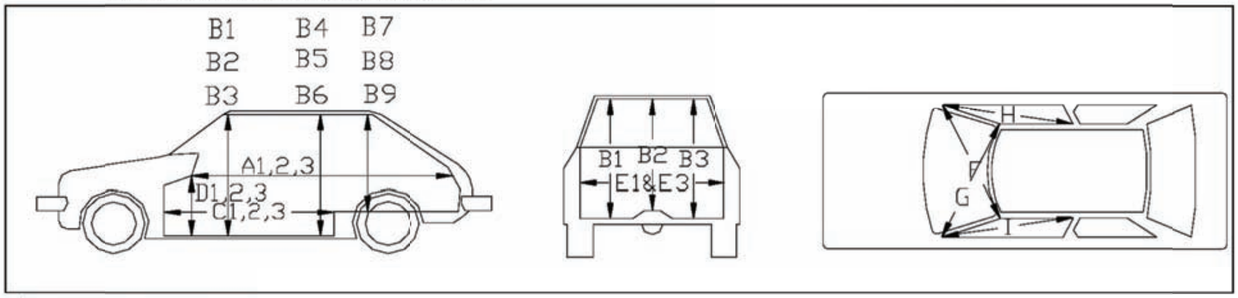
G = distance between the lower edge of left window and the upper edge of right window

H= distance between bottom front corner and top rear corner of the passenger side window

I= distance between bottom front corner and top rear corner of the driver side window

Severity Indices

0 - if the reduction is less than 3%
1 - if the reduction is greater than 3% and less than or equal to 10 %
2 - if the reduction is greater than 10% and less than or equal to 20 %
3 - if the reduction is greater than 20% and less than or equal to 30 %
4 - if the reduction is greater than 30% and less than or equal to 40 %



where,
1 = Passenger Side
2 = Middle
3 = Driver Side

Location:

Measurement	Pre-Test (in.)	Post-Test (in.)	Change (in.)	% Difference	Severity Index
A1	44.50	44.75	0.25	0.56	0
A2	45.50	45.50	0.00	0.00	0
A3	44.00	44.25	0.25	0.57	0
B1	38.75	39.00	0.25	0.65	0
B2	37.00	37.25	0.25	0.68	0
B3	39.00	39.00	0.00	0.00	0
C1	54.50	54.25	-0.25	-0.46	0
C2	59.25	58.75	-0.50	-0.84	0
C3	56.00	56.00	0.00	0.00	0
D1	18.25	18.50	0.25	1.37	0
D2	20.00	20.00	0.00	0.00	0
D3	19.25	19.25	0.00	0.00	0
E1	49.25	49.25	0.00	0.00	0
E3	49.50	49.50	0.00	0.00	0
F	44.25	44.25	0.00	0.00	0
G	44.00	43.75	-0.25	-0.57	0
H	38.50	38.50	0.00	0.00	0
I	43.50	43.50	0.00	0.00	0

Note: Maximum sevrity index for each variable (A-I) is used for determination of final OCDI value

	XX	A	B	C	D	E	F	G	H	I
Final OCDI:	LF	0	0	0	0	0	0	0	0	0

Figure C-1. Occupant Compartment Deformation Index, Test No. USPBN-3

VEHICLE PRE/POST CRUSH INFO
Set-1

TEST: USPBN-4
VEHICLE: C2500/2000P

Note: If impact is on driver side need to enter negative number for Y

POINT	X	Y	Z	X'	Y'	Z'	DEL X	DEL Y	DEL Z
1	31.25	-26.25	-3.5	31.25	-26.25	-3.5	0	0	0
2	31.25	-19.5	-4.25	31.25	-19.25	-4	0	0.25	0.25
3	30.5	-14.5	-4.5	30.5	-14.25	-4.25	0	0.25	0.25
4	25.75	-5.25	-0.75	25.75	-5	-0.5	0	0.25	0.25
5	28	-27	-6.25	28	-27.25	-6.25	0	-0.25	0
6	28	-21	-6.5	28	-21	-6.25	0	0	0.25
7	27.5	-14	-6.5	27.5	-13.75	-6.25	0	0.25	0.25
8	22.75	-4.75	-1.75	22.75	-4.75	-1.5	0	0	0.25
9	21.75	-29	-8.75	22	-29	-8.5	0.25	0	0.25
10	22.25	-21.75	-8.5	22.5	-22	-8.5	0.25	-0.25	0
11	22.25	-13	-8	22.25	-13	-7.75	0	0	0.25
12	18.5	-2.25	-2.25	18.5	-2.5	-1.75	0	-0.25	0.5
13	16.5	-27.75	-9.25	16.5	-27.75	-9	0	0	0.25
14	16.5	-21	-9	16.75	-21	-8.75	0.25	0	0.25
15	17	-13.25	-8.75	17	-13	-8.5	0	0.25	0.25
16	14.25	-4	-2.75	14	-4	-2.5	-0.25	0	0.25
17	11.25	-28.25	-9.75	11.5	-28.5	-9.5	0.25	-0.25	0.25
18	12.5	-19.75	-9.25	12.5	-19.5	-9	0	0.25	0.25
19	13	-12.75	-9	12.75	-12.5	-8.75	-0.25	0.25	0.25
20	11.5	-3.75	-3.25	11.5	-3.75	-3	0	0	0.25
21	25.25	7.25	-1	25.75	7.25	-0.75	0.5	0	0.25
22	30.75	19	-3.75	30.75	18.5	-3.25	0	-0.5	0.5
23	30.5	27.75	-4	30.5	27.25	-3.5	0	-0.5	0.5
24	18.75	6.25	-2.5	18.5	6.25	-2	-0.25	0	0.5
25	21.75	17.5	-8.25	21.75	17.5	-7.75	0	0	0.5
26	21.5	26	-8.25	21.5	25.75	-8	0	-0.25	0.25
27	12.5	10	-7.75	12.75	10	-7.5	0.25	0	0.25
28	12.5	20.5	-8.25	12.5	20.25	-8	0	-0.25	0.25
29							0	0	0
30									

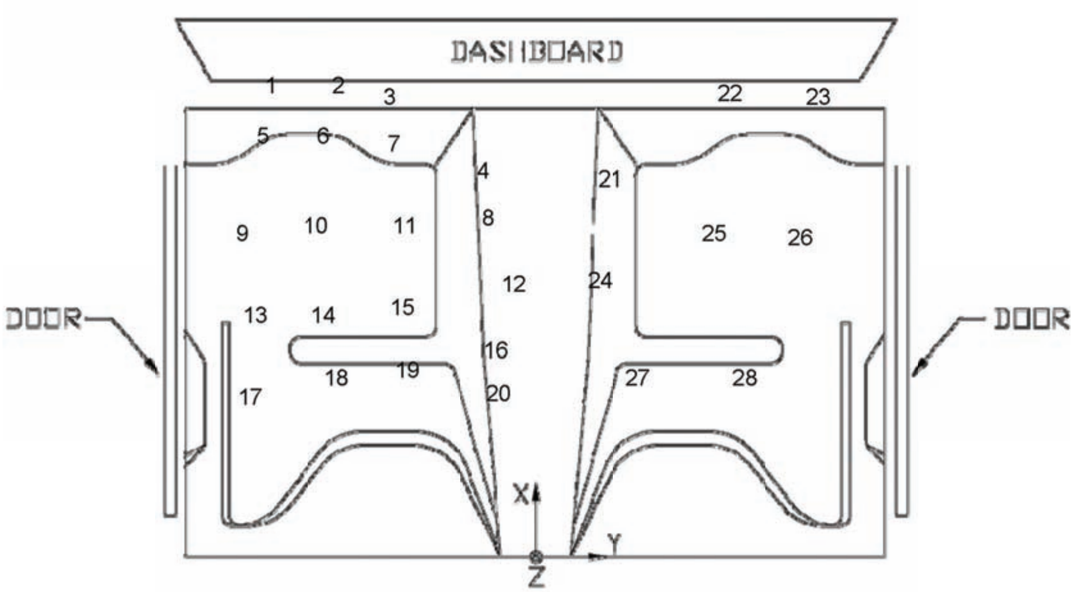


Figure C-2. Floor Pan Deformation Data – Set 1, Test No. USPBN-4

VEHICLE PRE/POST CRUSH INFO
Set-2

TEST: USPBN-4
VEHICLE: C2500/2000P

Note: If impact is on driver side need to enter negative number for Y

POINT	X	Y	Z	X'	Y'	Z'	DEL X	DEL Y	DEL Z
1	57	-17.75	-3.25	57.25	-18	-3.25	0.25	-0.25	0
2	57.75	-11	-4	57.75	-10.5	-4	0	0.5	0
3	57	-6.5	-4	57	-6	-4	0	0.5	0
4	52.25	3.5	-0.25	52.25	3.5	0	0	0	0.25
5	54.5	-18.75	-6.25	54	-18.75	-6.25	-0.5	0	0
6	54.5	-12.75	-6.25	54.75	-12.5	-6.25	0.25	0.25	0
7	54	-5.5	-6	54	-5.25	-6	0	0.25	0
8	49.25	3.75	-1.25	49.25	4	-1	0	0.25	0.25
9	48.75	-20.75	-8.75	48.25	-21	-8.75	-0.5	-0.25	0
10	49	-13.5	-8.5	49.25	-13.5	-8.25	0.25	0	0.25
11	49	-4.75	-7.5	49	-4.5	-7.5	0	0.25	0
12	45	6.25	-1.5	45	6.5	-1.5	0	0.25	0
13	43.25	-19.25	-9.25	43	-19.5	-9.25	-0.25	-0.25	0
14	43.5	-12.5	-8.5	43.5	-12.5	-8.5	0	0	0
15	43.75	-5	-8.5	44	-4.75	-8.25	0.25	0.25	0.25
16	40.75	4.5	-2.25	40.75	4.75	-2.25	0	0.25	0
17	38.25	-20	-9.5	38	-20	-9.5	-0.25	0	0
18	39.25	-11.25	-8.75	39.25	-11	-8.75	0	0.25	0
19	39.75	-4.25	-8.5	39.75	-4.25	-8.5	0	0	0
20	38	4.75	-2.5	38	5	-2.5	0	0.25	0
21	51.75	15.5	-0.25	51.75	15.5	0	0	0	0.25
22	57	27.25	-2.25	57	27.25	-2.25	0	0	0
23	56.25	36	-2.25	56.75	36.25	-2.25	0.5	0.25	0
24	45	14.5	-1.5	45	14.5	-1.25	0	0	0.25
25	48.5	25.5	-7	48.5	26	-6.75	0	0.5	0.25
26	48	34	-6.75	48.25	34.5	-6.75	0.25	0.5	0
27	39.5	18.25	-6.75	39.5	18.5	-6.75	0	0.25	0
28	39.25	28.5	-7	39.25	29	-7	0	0.5	0
29							0	0	0
30									

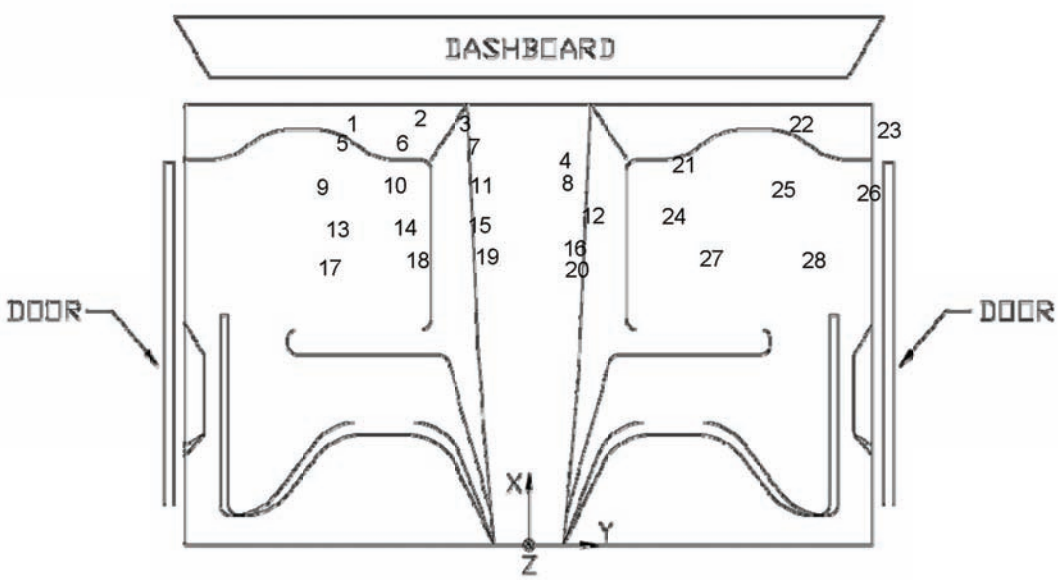


Figure C-3. Floor Pan Deformation Data – Set 2, Test No. USPBN-4

Occupant Compartment Deformation Index (OCDI)

Test No. USPBN-4
Vehicle Type: C2500/2000P

OCDI = XXABCDEFGHI

XX = location of occupant compartment deformation

A = distance between the dashboard and a reference point at the rear of the occupant compartment, such as the top of the rear seat or the rear of the cab on a pickup

B = distance between the roof and the floor panel

C = distance between a reference point at the rear of the occupant compartment and the motor panel

D = distance between the lower dashboard and the floor panel

E = interior width

F = distance between the lower edge of right window and the upper edge of left window

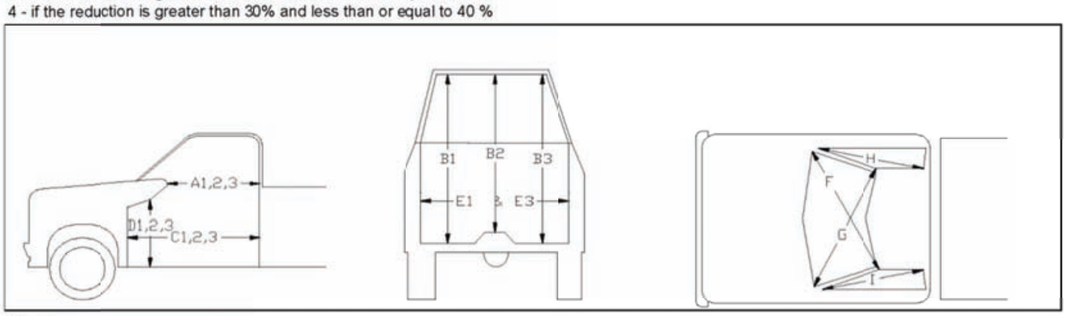
G = distance between the lower edge of left window and the upper edge of right window

H= distance between bottom front corner and top rear corner of the passenger side window

I= distance between bottom front corner and top rear corner of the driver side window

Severity Indices

0 - if the reduction is less than 3%
1 - if the reduction is greater than 3% and less than or equal to 10 %
2 - if the reduction is greater than 10% and less than or equal to 20 %
3 - if the reduction is greater than 20% and less than or equal to 30 %
4 - if the reduction is greater than 30% and less than or equal to 40 %



where,
1 = Passenger Side
2 = Middle
3 = Driver Side

Location:

Measurement	Pre-Test (in.)	Post-Test (in.)	Change (in.)	% Difference	Severity Index
A1	36.75	36.75	0.00	0.00	0
A2	39.25	39.00	-0.25	-0.64	0
A3	38.75	38.75	0.00	0.00	0
B1	44.00	44.00	0.00	0.00	0
B2	39.75	39.75	0.00	0.00	0
B3	44.25	44.25	0.00	0.00	0
C1	58.75	58.75	0.00	0.00	0
C2	51.50	51.50	0.00	0.00	0
C3	57.00	57.00	0.00	0.00	0
D1	21.50	21.50	0.00	0.00	0
D2	16.50	16.50	0.00	0.00	0
D3	22.75	22.50	-0.25	-1.10	0
E1	62.50	62.25	-0.25	-0.40	0
E3	63.50	63.50	0.00	0.00	0
F	56.00	56.00	0.00	0.00	0
G	56.00	55.75	-0.25	-0.45	0
H	40.75	40.75	0.00	0.00	0
I	40.75	40.75	0.00	0.00	0

Note: Maximum sevrity index for each variable (A-I) is used for determination of final OCDI value

Final OCDI:

XX	A	B	C	D	E	F	G	H	I
LF	0	0	0	0	0	0	0	0	0

Figure C-4. Occupant Compartment Deformation Index, Test No. USPBN-4

Appendix D. Accelerometer and Rate Transducer Data Plots, Test No. USPBN-3

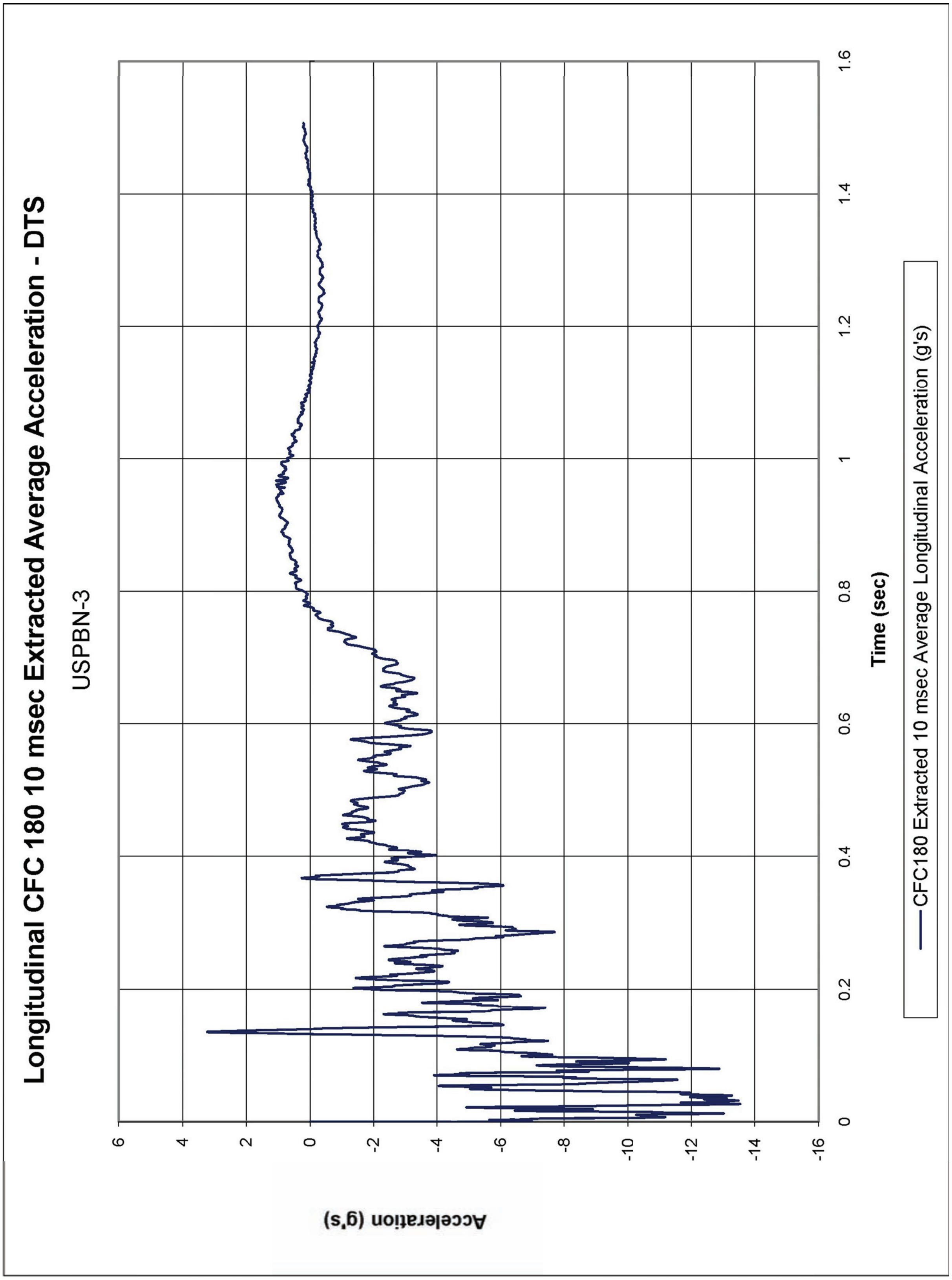


Figure D-1. 10-ms Average Longitudinal Deceleration (DTS), Test No. USPBN-3

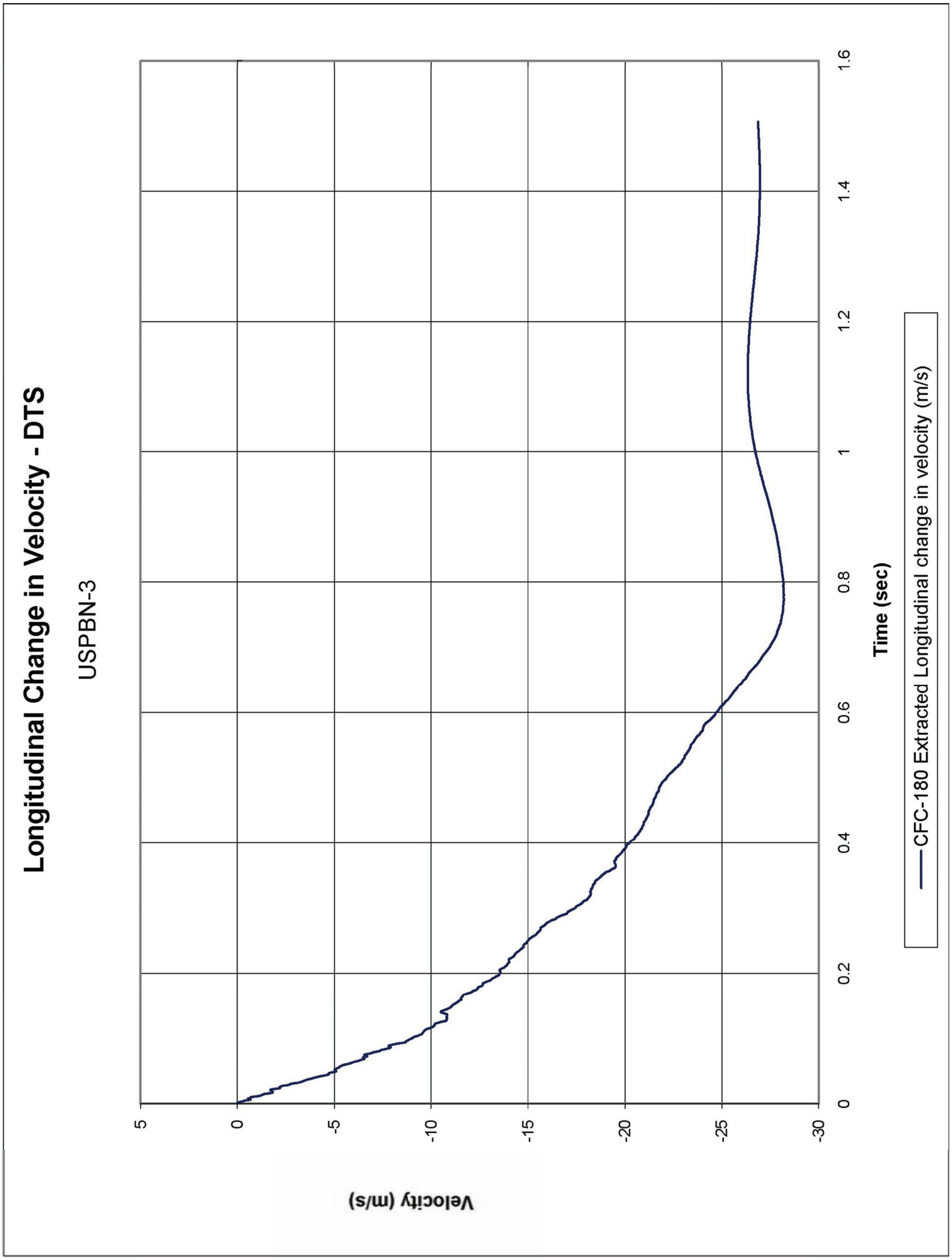


Figure D-2. Longitudinal Occupant Impact Velocity (DTS), Test No. USPBN-3

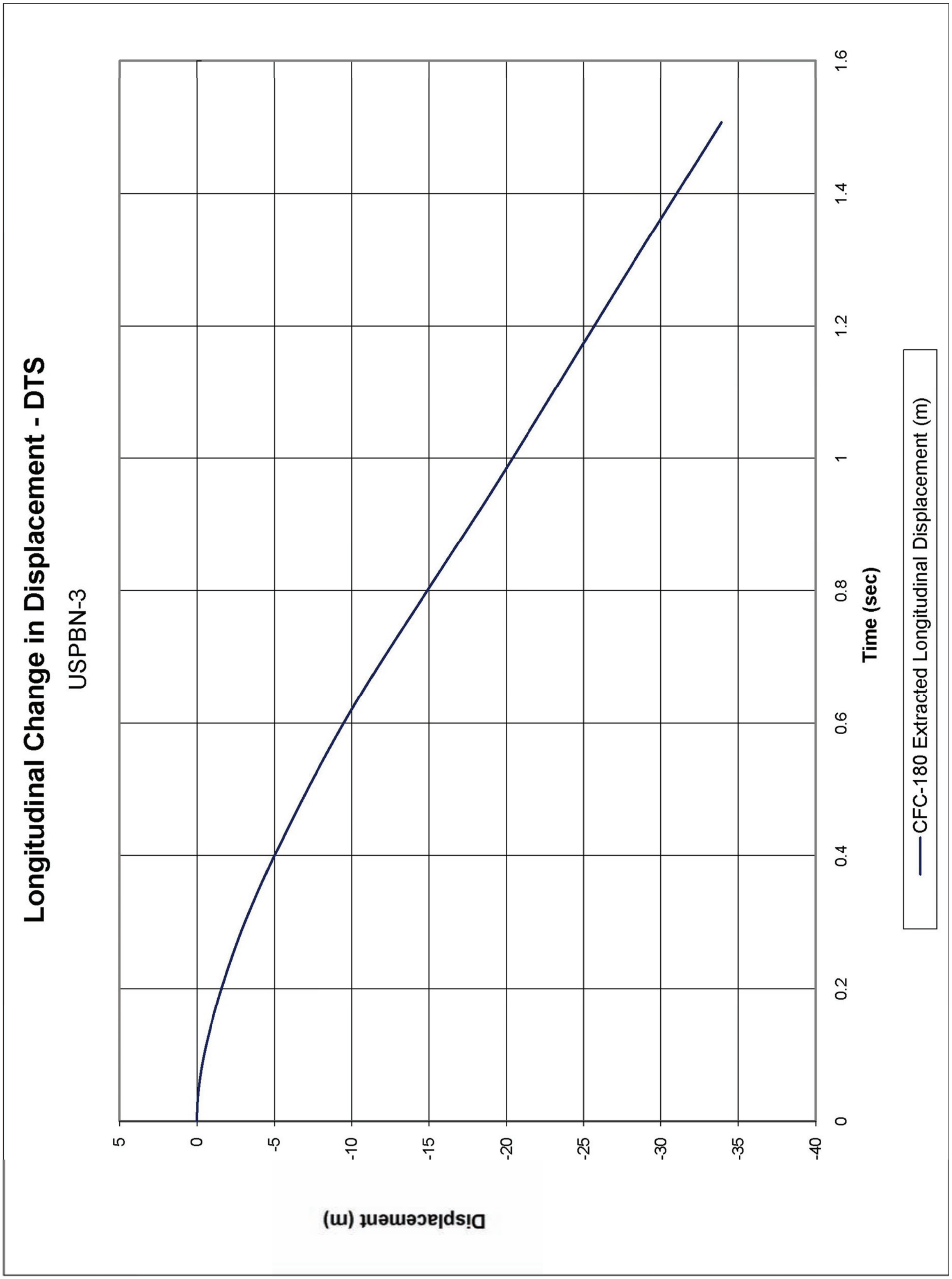


Figure D-3. Longitudinal Occupant Displacement (DTS), Test No. USPBN-3

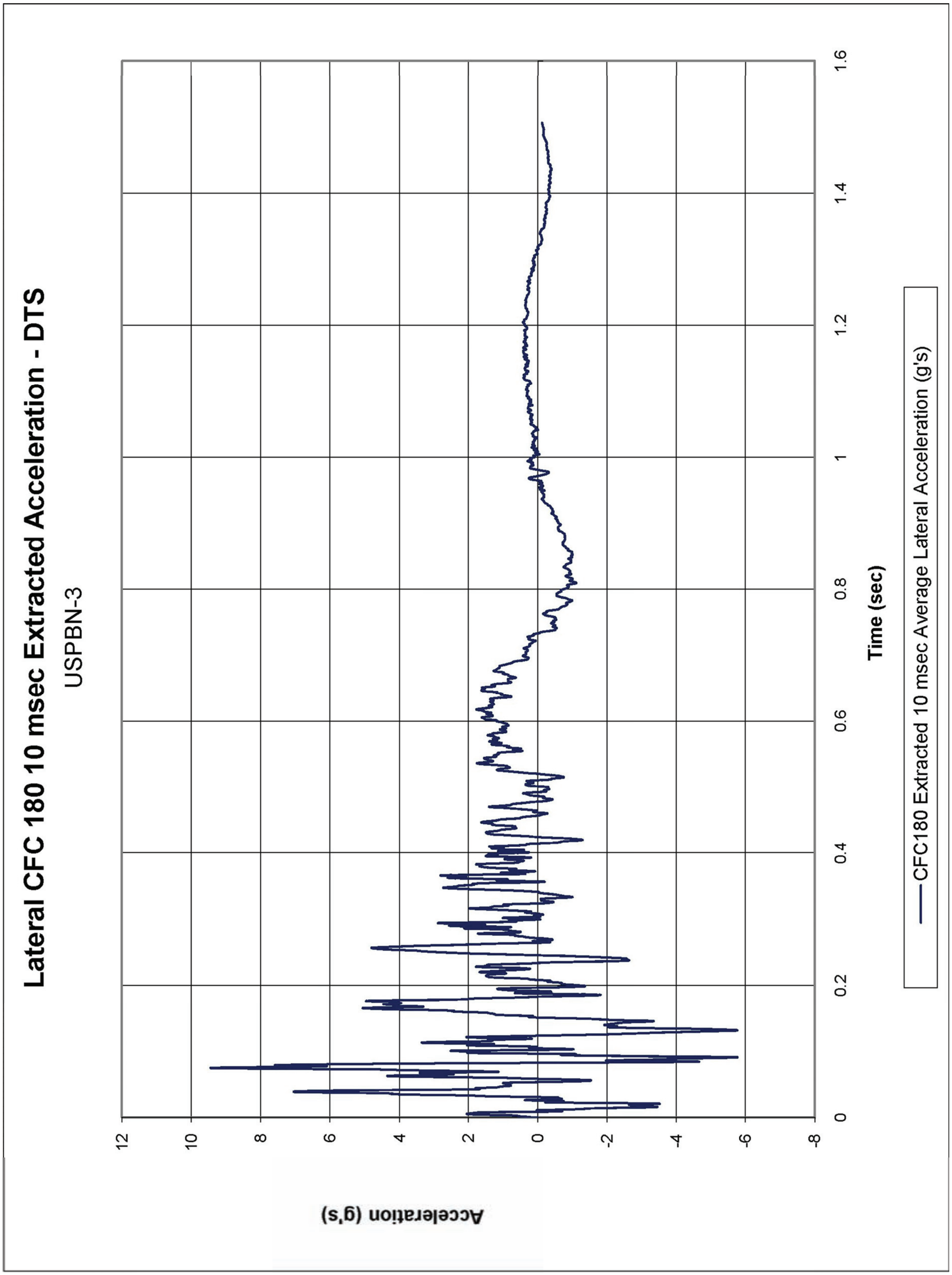


Figure D-4. 10-ms Average Lateral Deceleration (DTS), Test No. USPBN-3

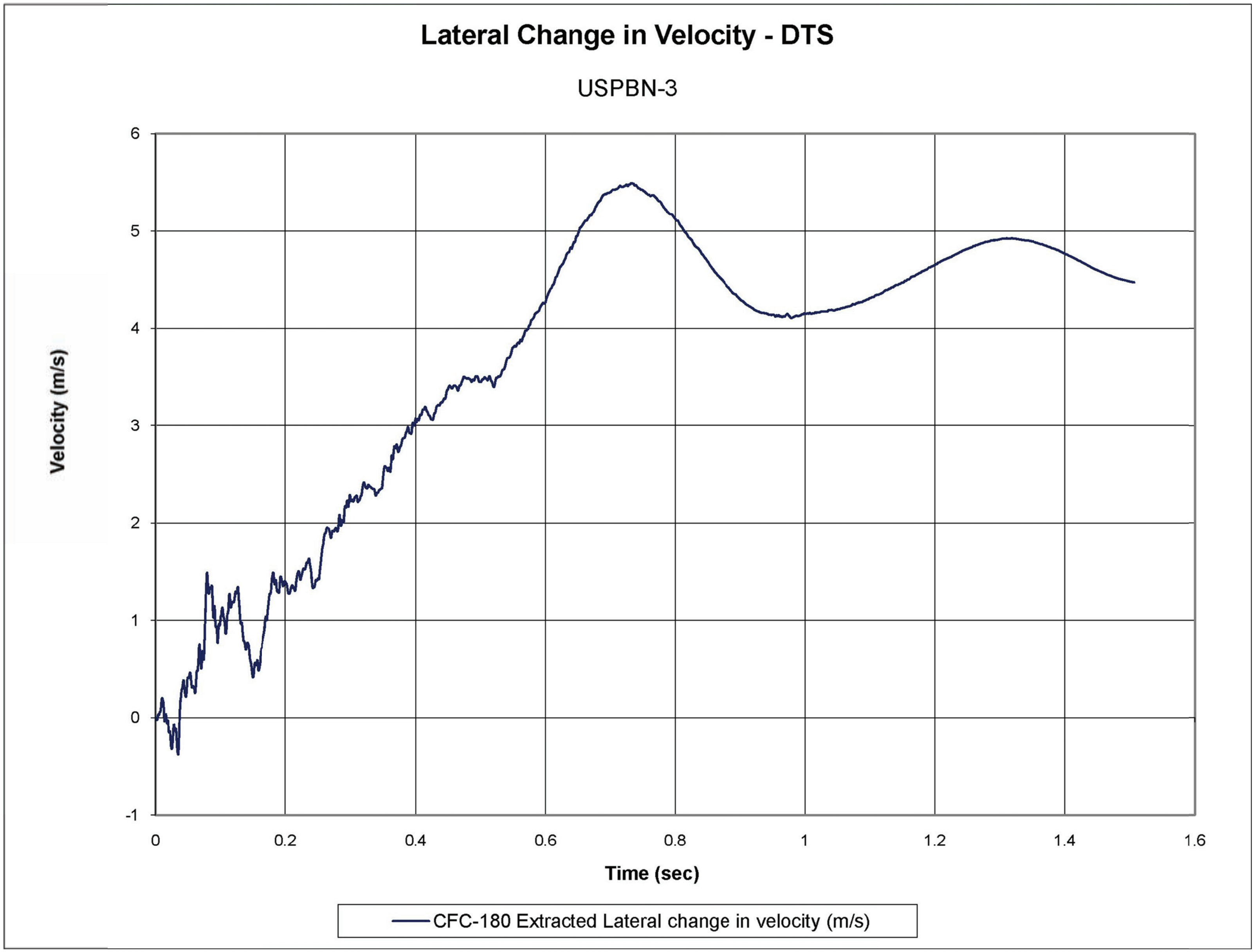


Figure D-5. Lateral Occupant Impact Velocity (DTS), Test No. USPBN-3

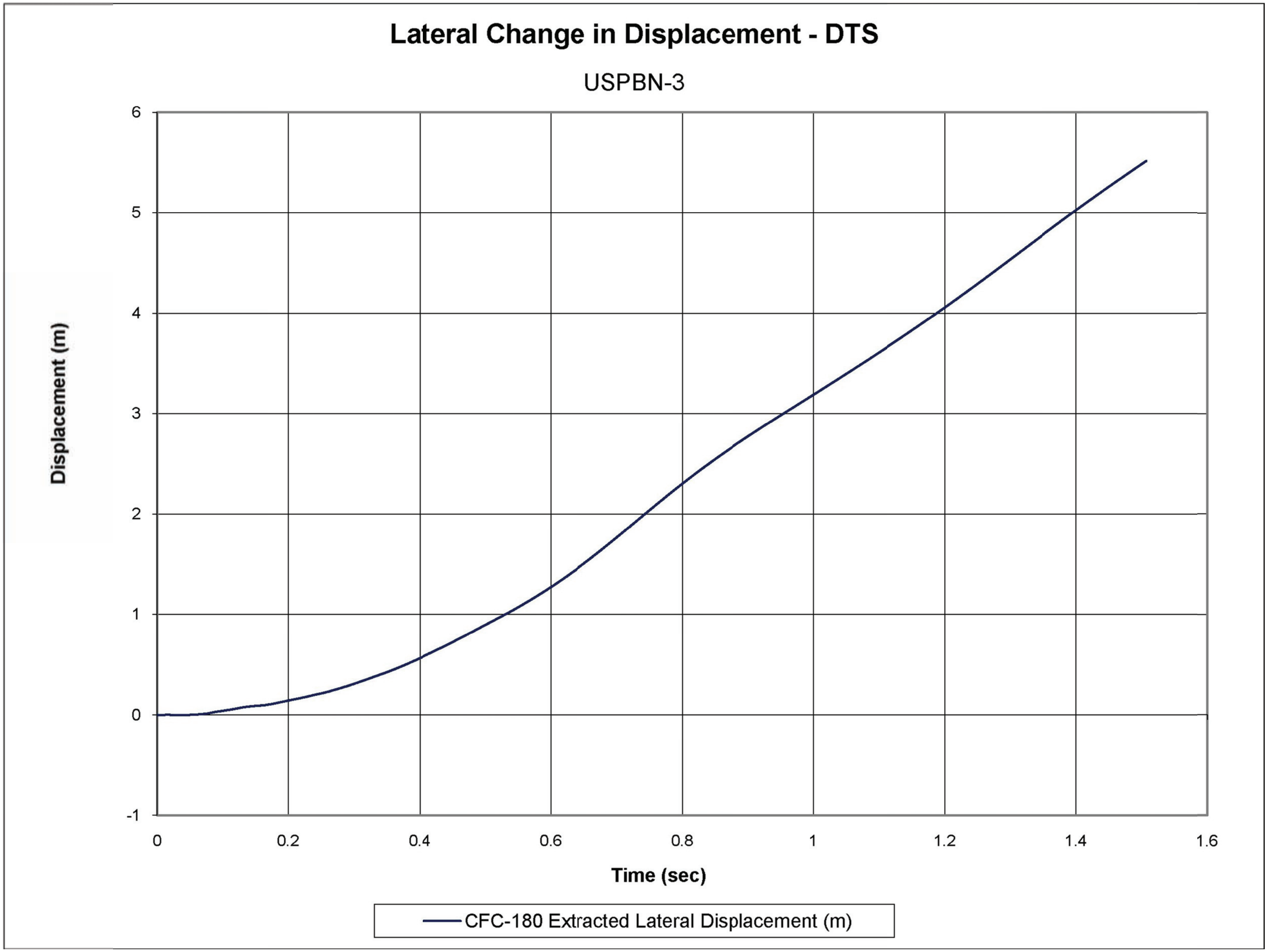


Figure D-6. Lateral Occupant Displacement (DTS), Test No. USPBN-3

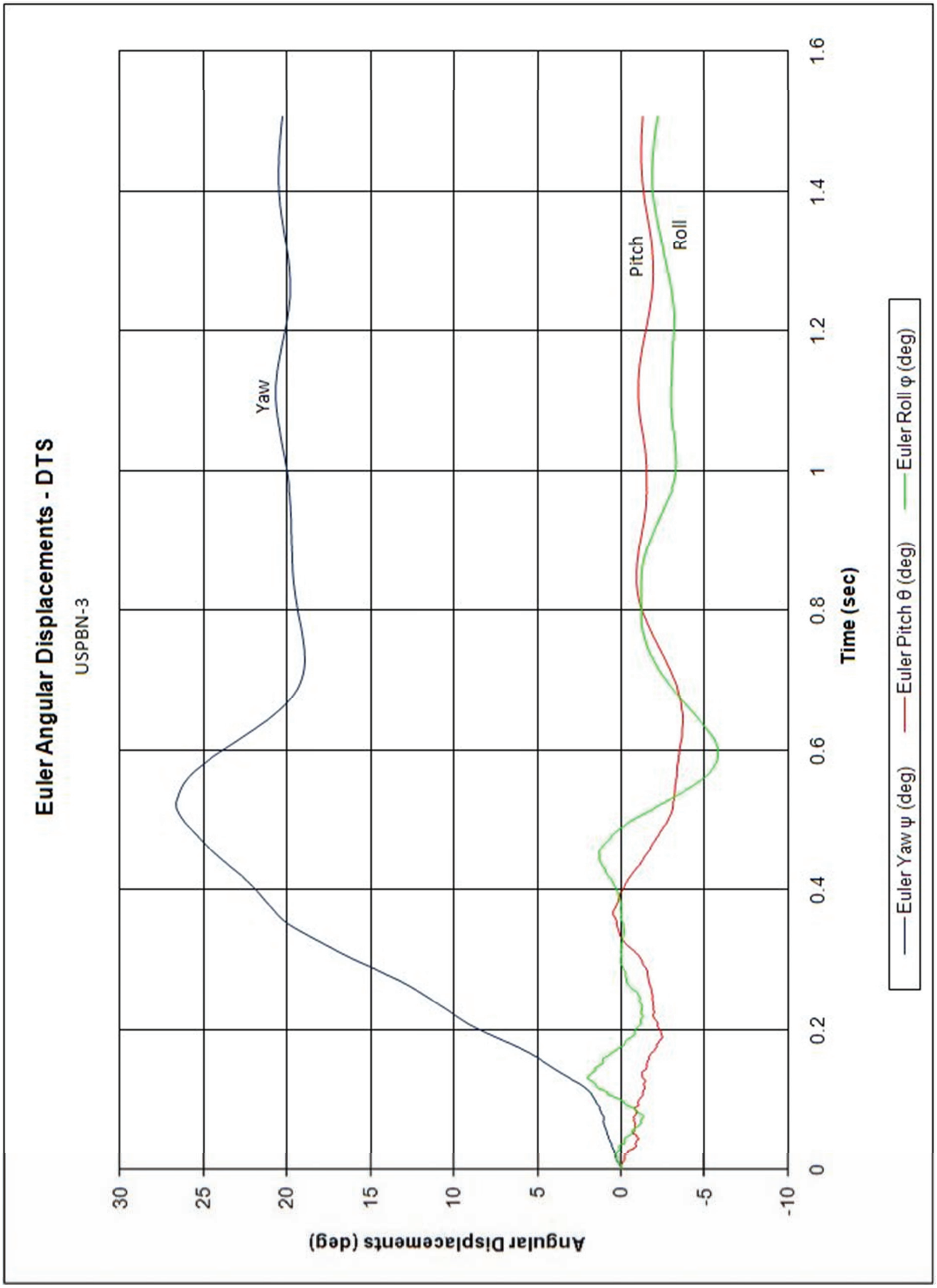


Figure D-7. Vehicle Angular Displacements (DTS), Test No. USPBN-3

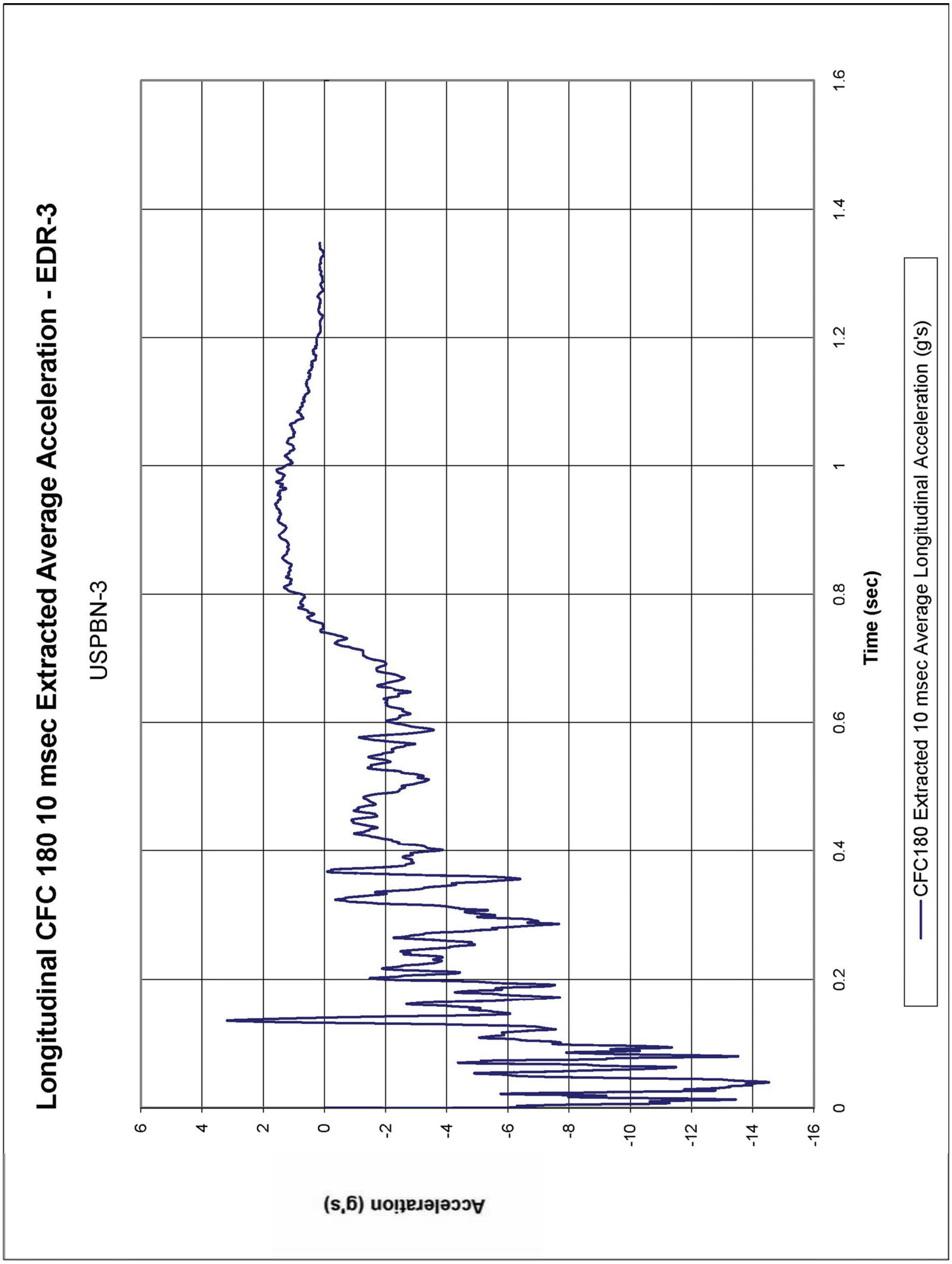


Figure D-8. 10-ms Average Longitudinal Deceleration (EDR-3), Test No. USPBN-3

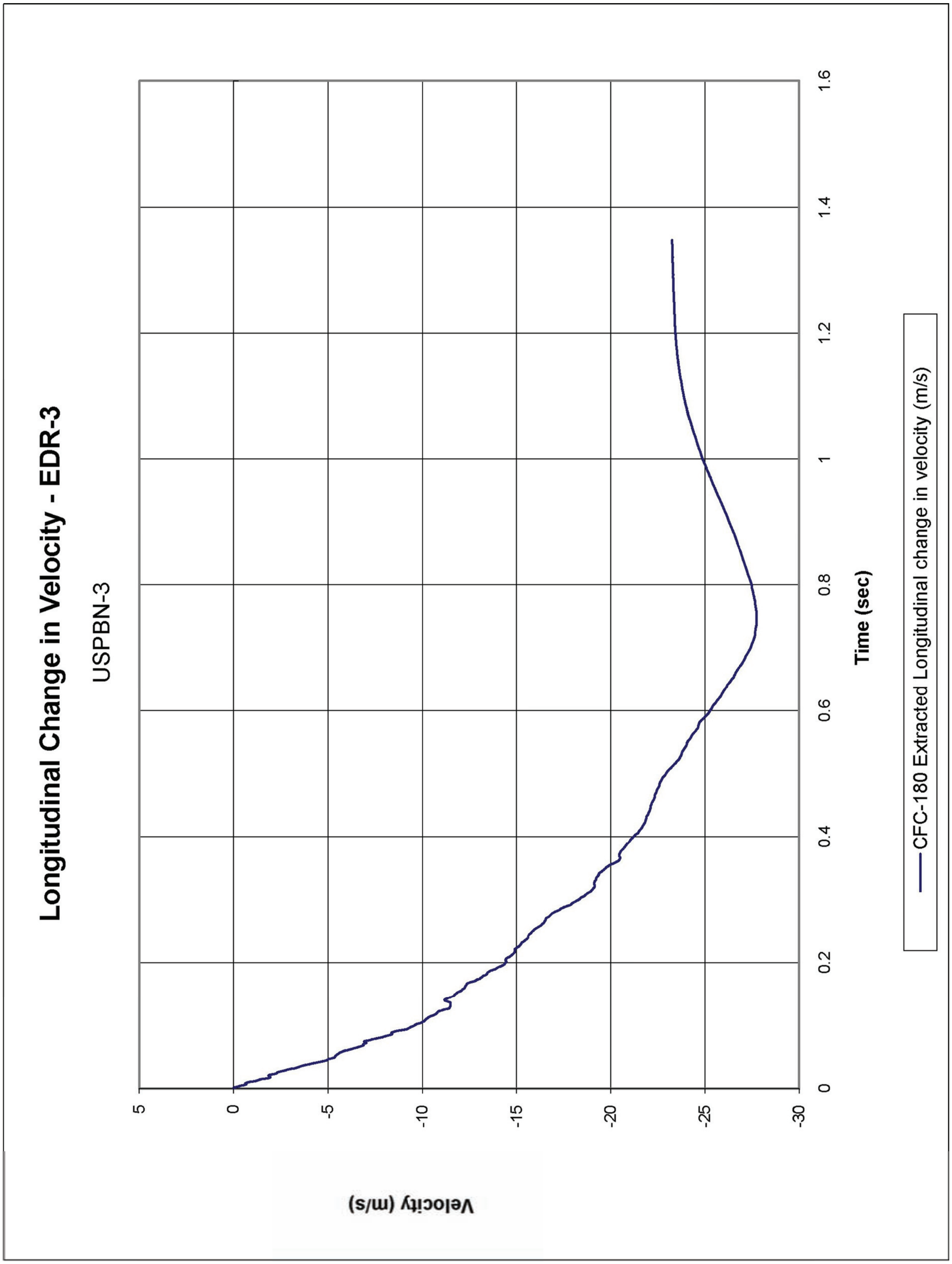


Figure D-9. Longitudinal Occupant Impact Velocity (EDR-3), Test No. USPBN-3

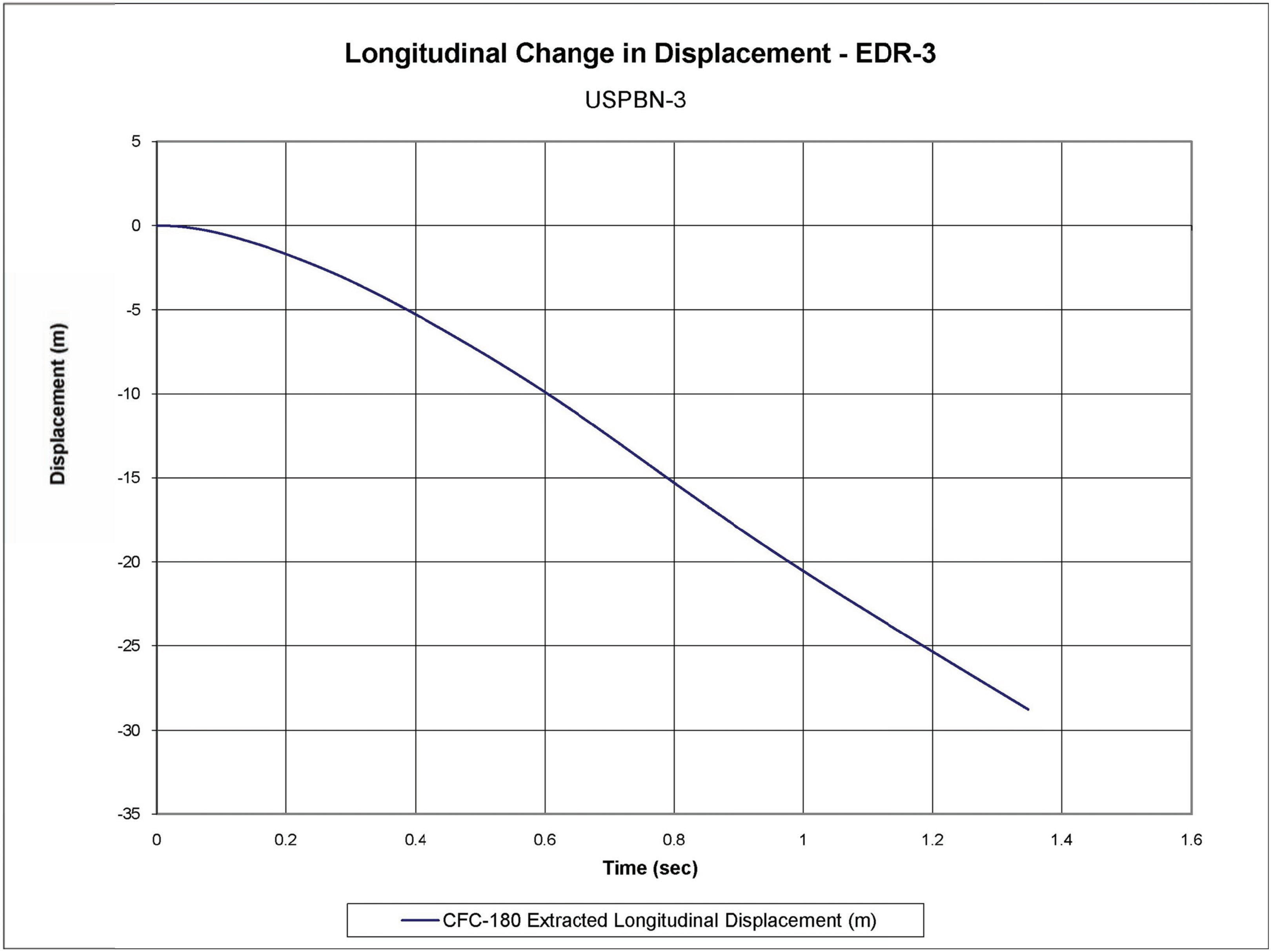


Figure D-10. Longitudinal Occupant Displacement (EDR-3), Test No. USPBN-3

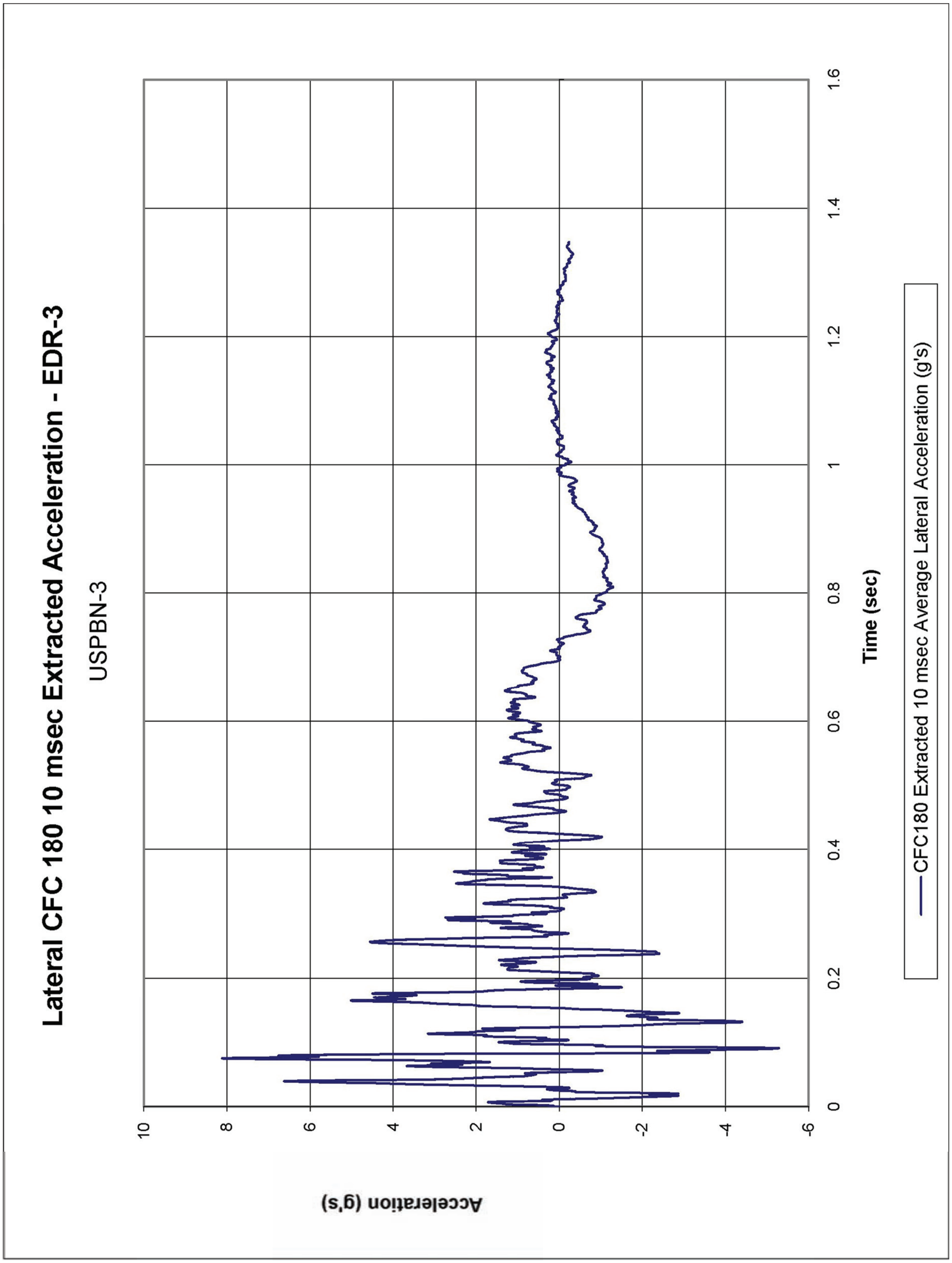


Figure D-11. 10-ms Average Lateral Deceleration (EDR-3), Test No. USPBN-3

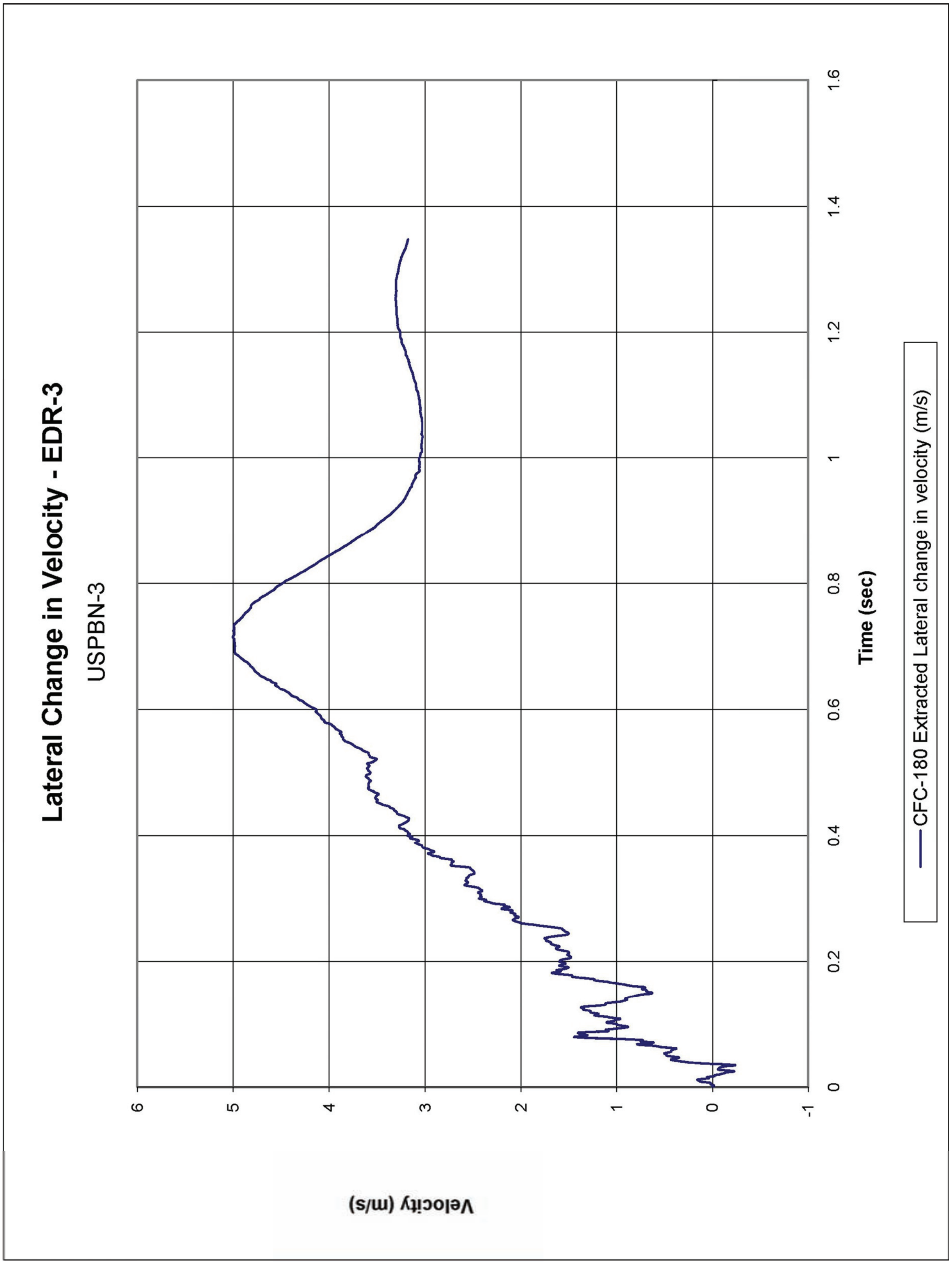


Figure D-12. Lateral Occupant Impact Velocity (EDR-3), Test No. USPBN-3

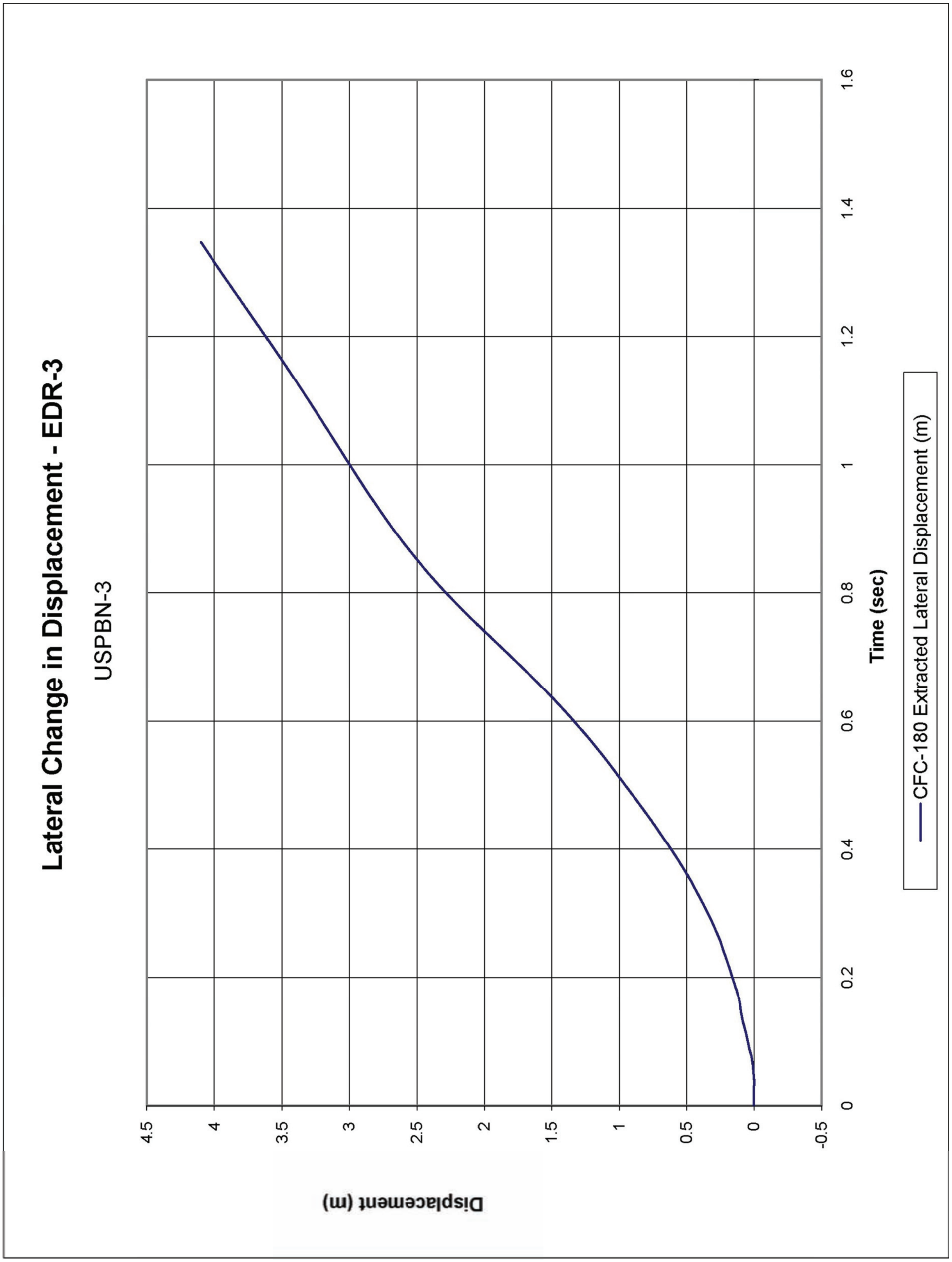


Figure D-13. Lateral Occupant Displacement (EDR-3), Test No. USPBN-3

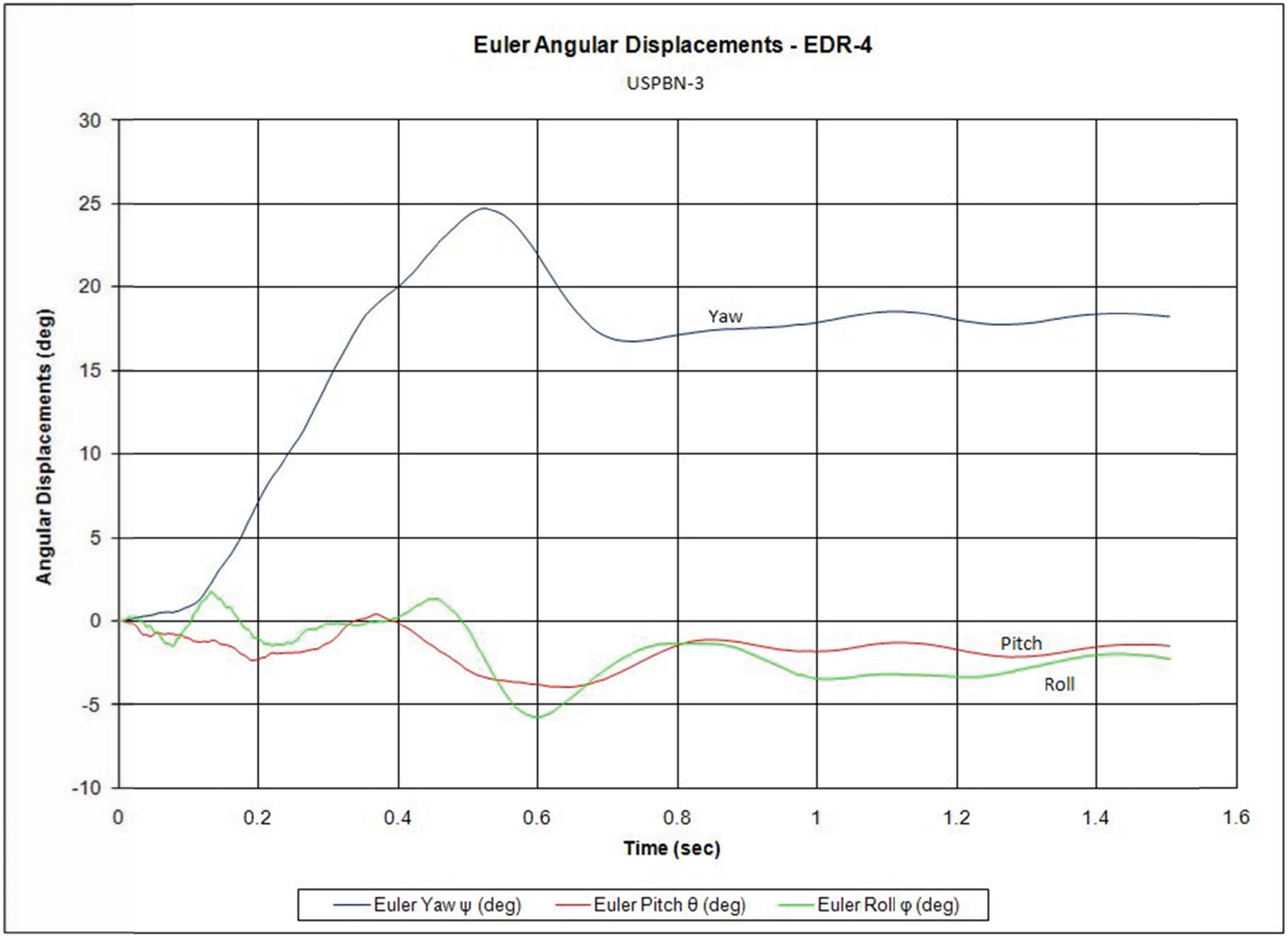


Figure D-14. Vehicle Angular Displacements (EDR-4), Test No. USPBN-3

Appendix E. Accelerometer and Rate Transducer Data Plots, Test No. USPBN-4

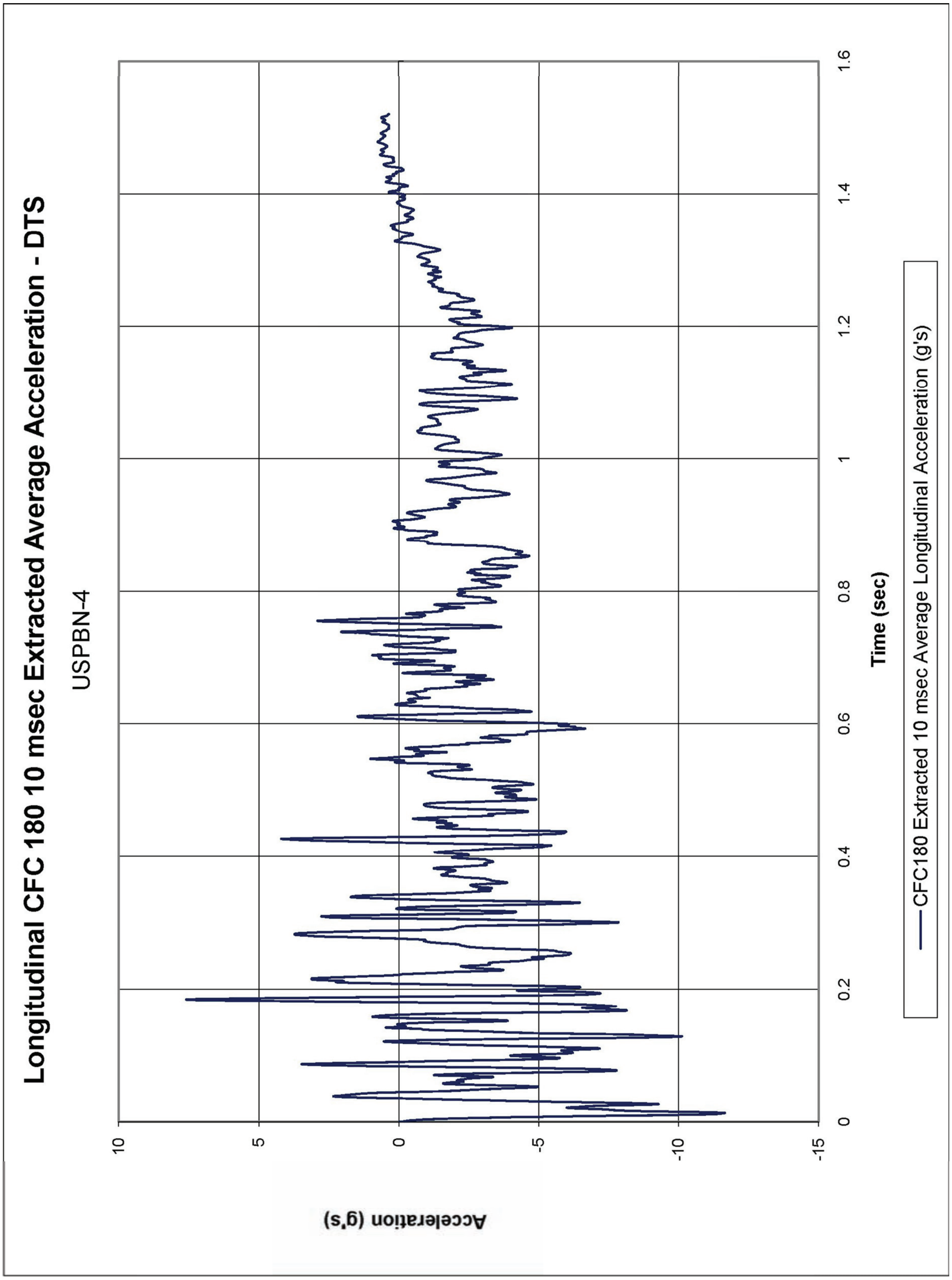


Figure E-1. 10-ms Average Longitudinal Deceleration (DTS), Test No. USPBN-4

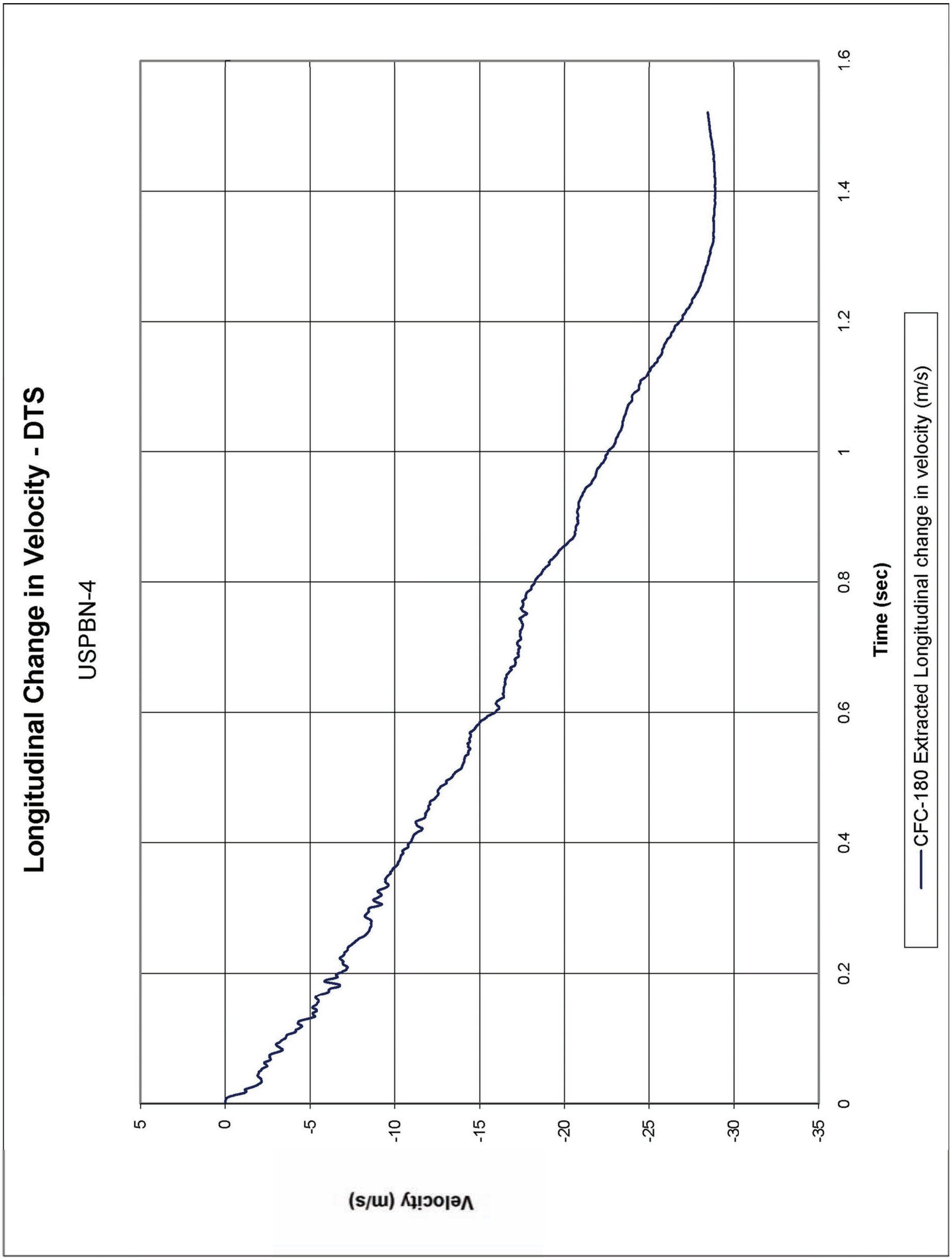


Figure E-2. Longitudinal Occupant Impact Velocity (DTS), Test No. USPBN-4

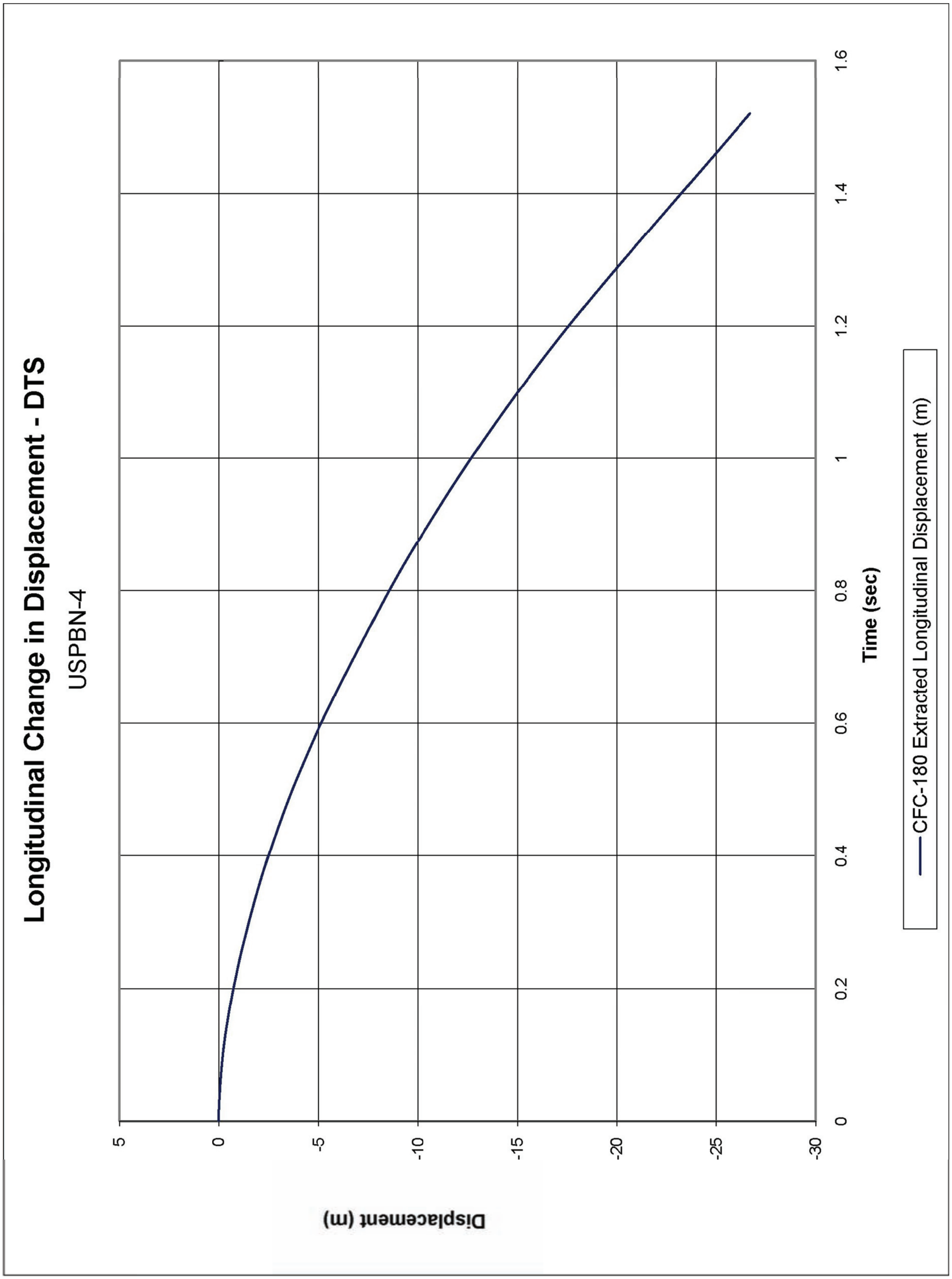


Figure E-3. Longitudinal Occupant Displacement (DTS), Test No. USPBN-4

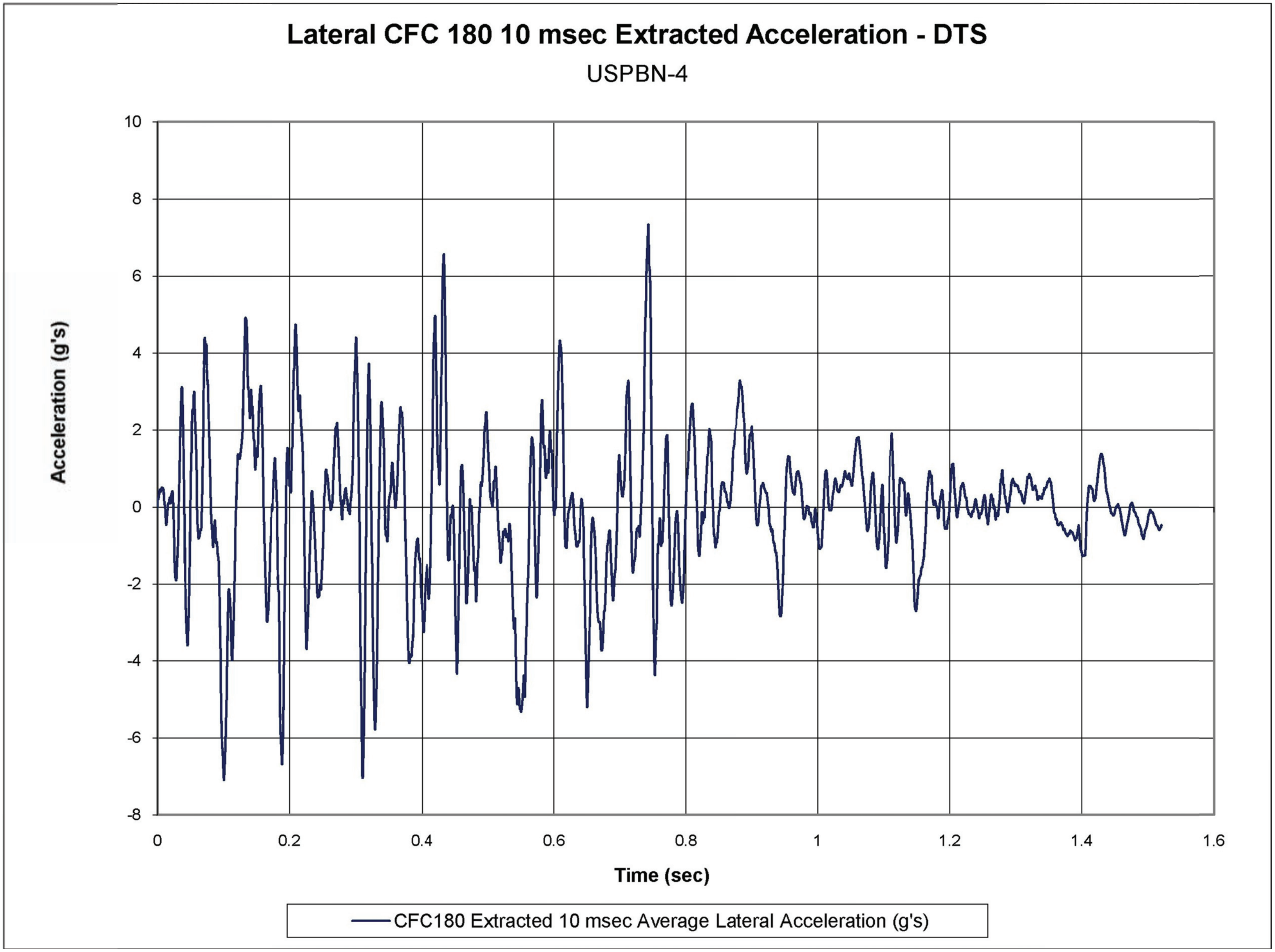


Figure E-4. 10-ms Average Lateral Deceleration (DTS), Test No. USPBN-4

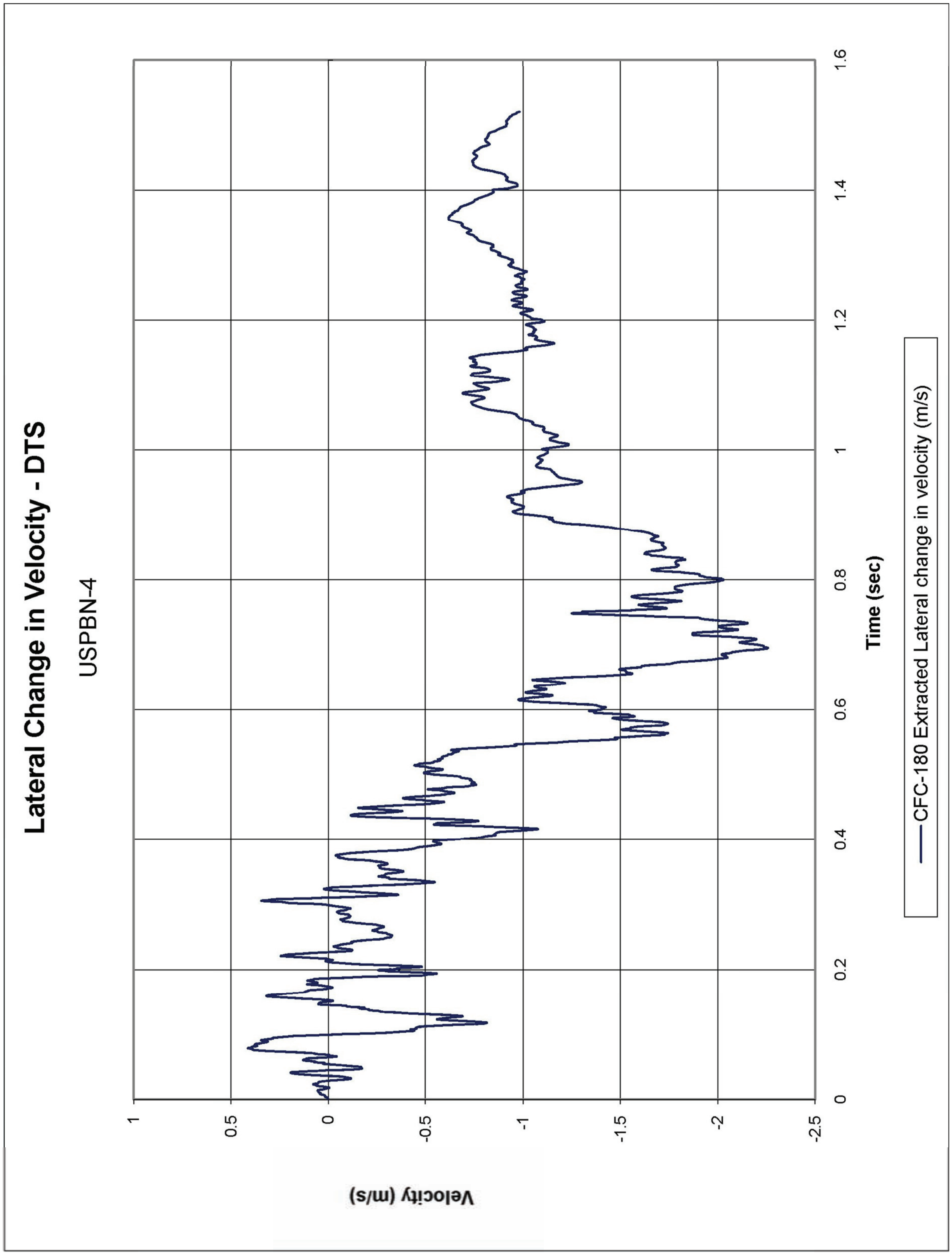


Figure E-5. Lateral Occupant Impact Velocity (DTS), Test No. USPBN-4

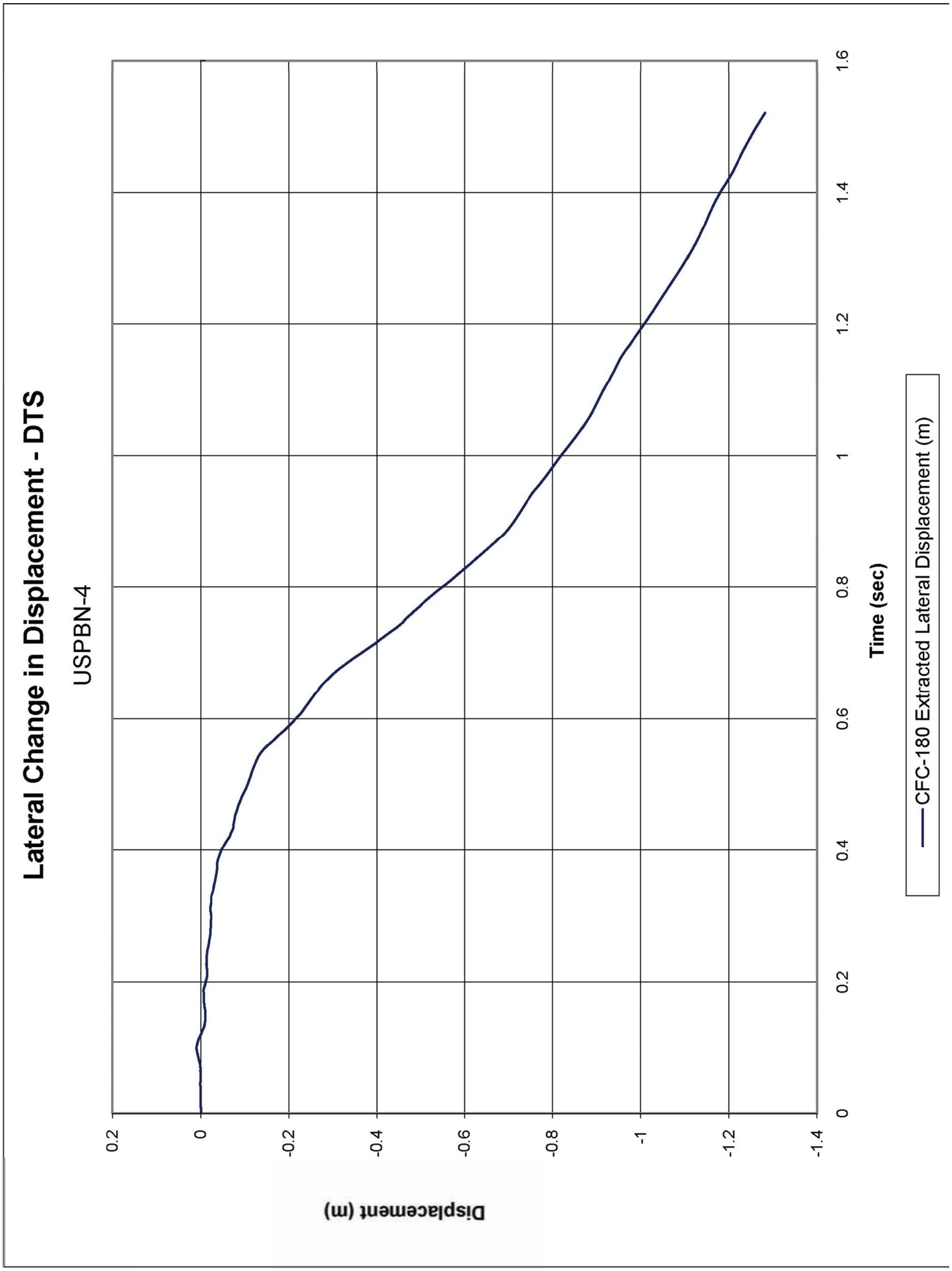


Figure E-6. Lateral Occupant Displacement (DTS), Test No. USPBN-4

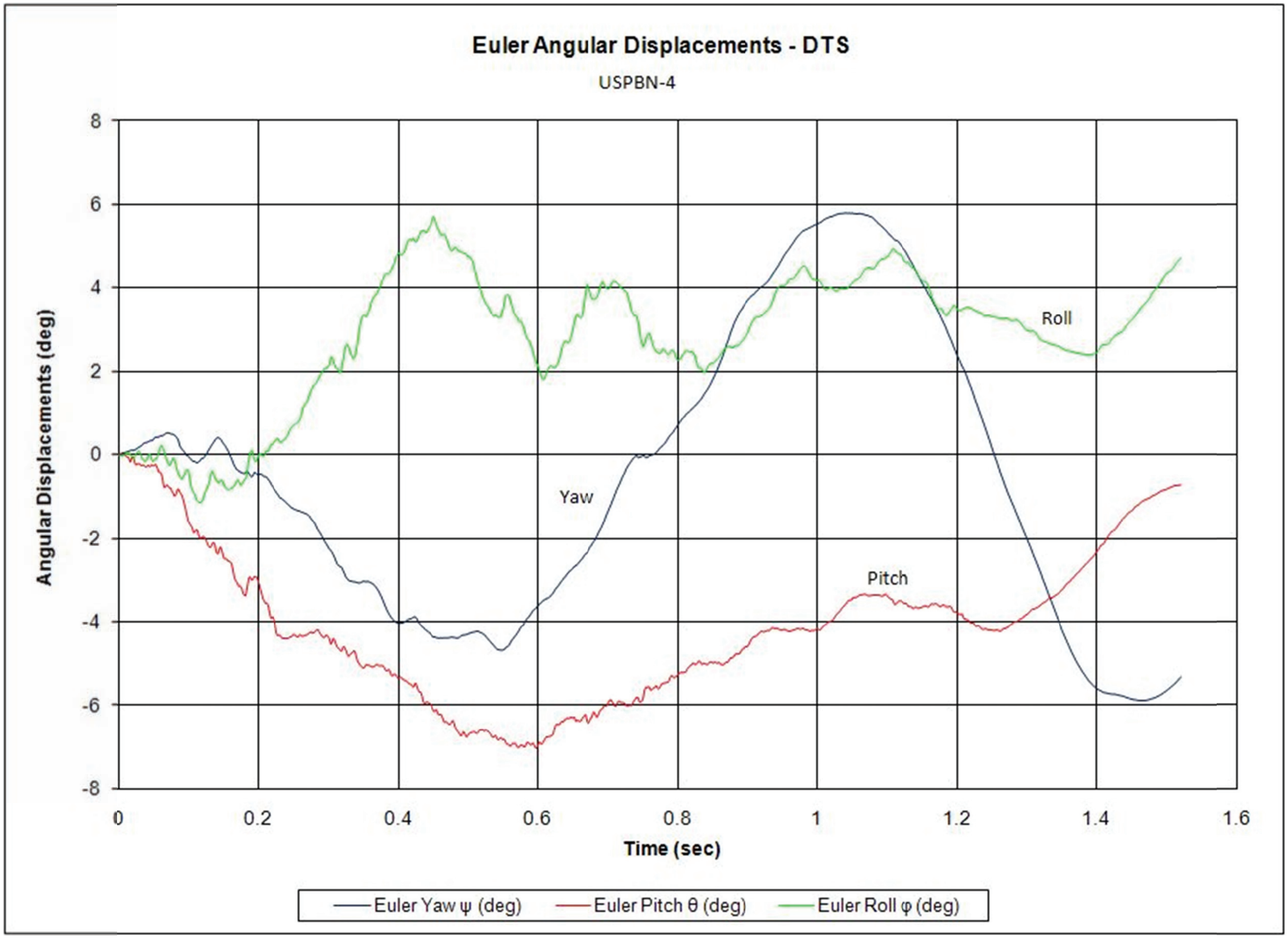


Figure E-7. Vehicle Angular Displacements (DTS), Test No. USPBN-4

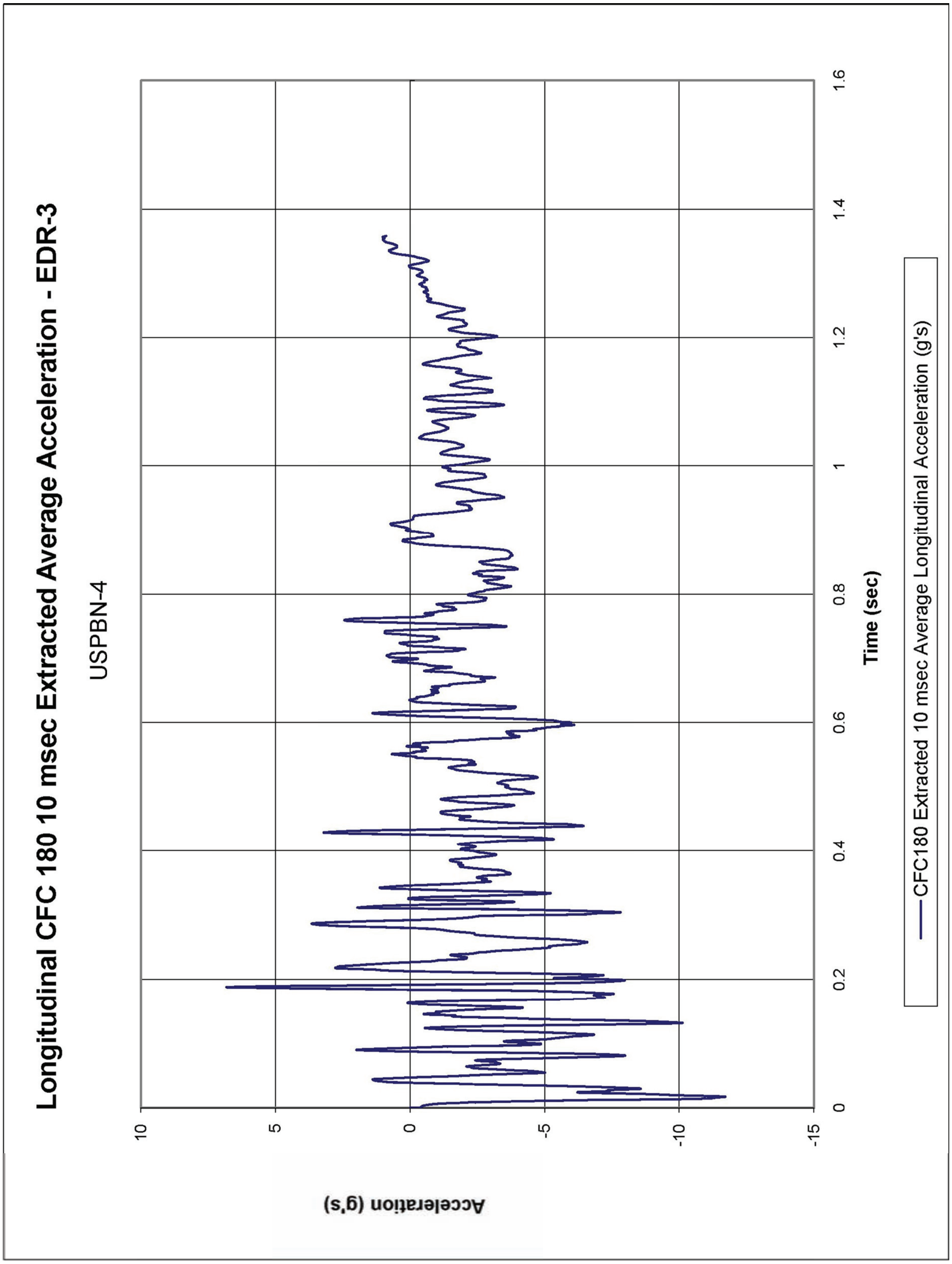


Figure E-8. 10-ms Average Longitudinal Deceleration (EDR-3), Test No. USPBN-4

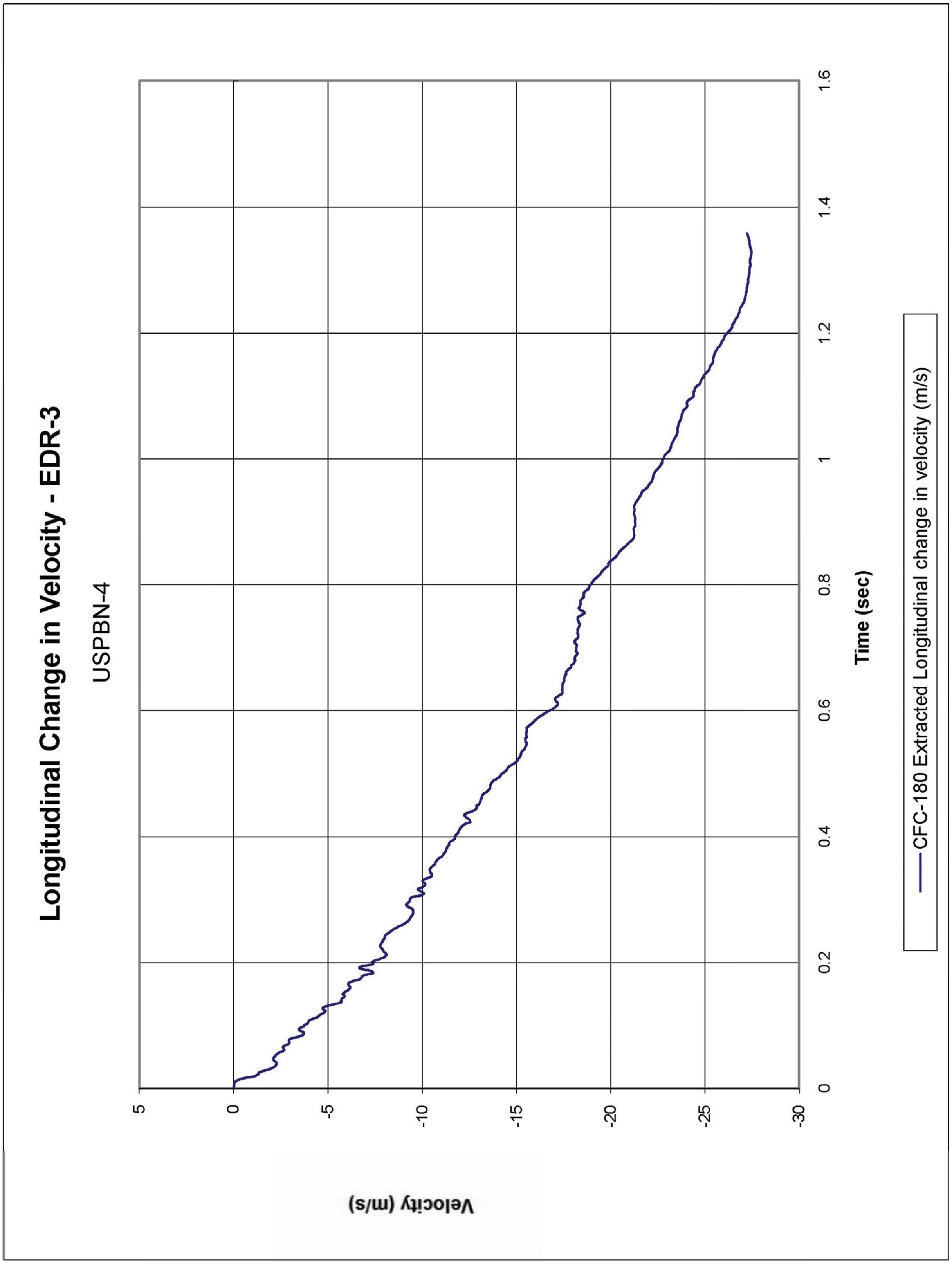


Figure E-9. Longitudinal Occupant Impact Velocity (EDR-3), Test No. USPBN-4

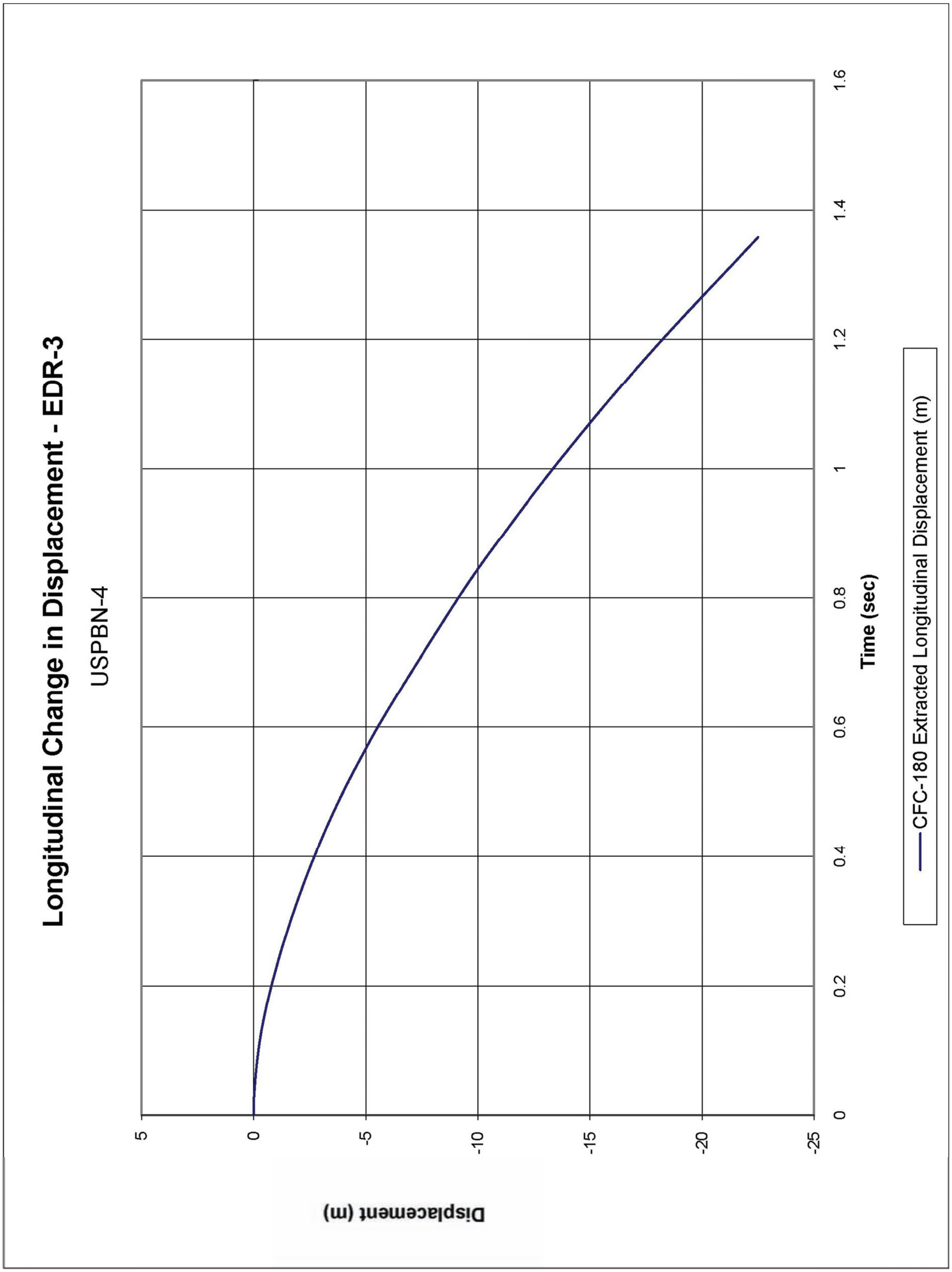


Figure E-10. Longitudinal Occupant Displacement (EDR-3), Test No. USPBN-4

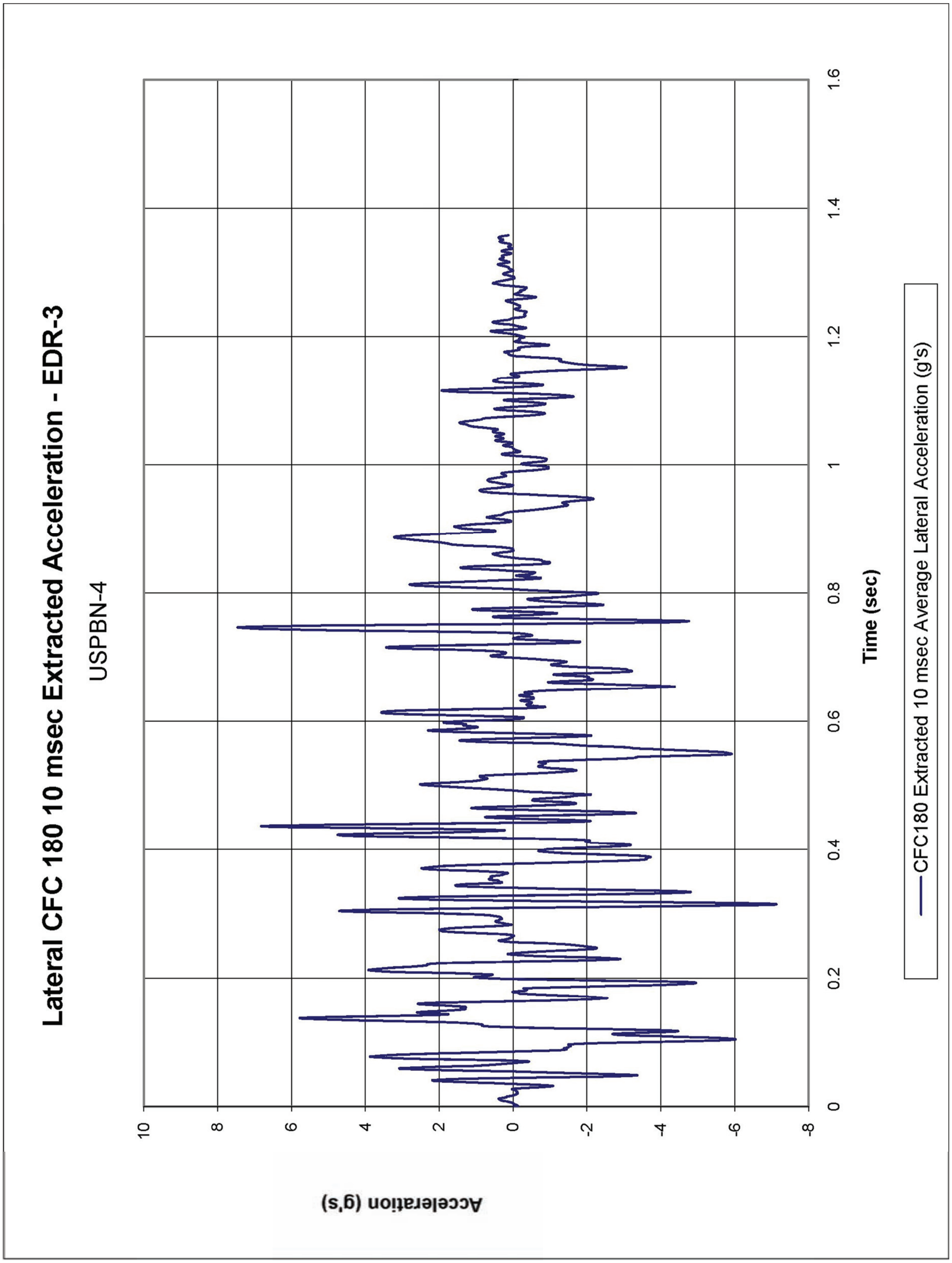


Figure E-11. 10-ms Average Lateral Deceleration (EDR-3), Test No. USPBN-4

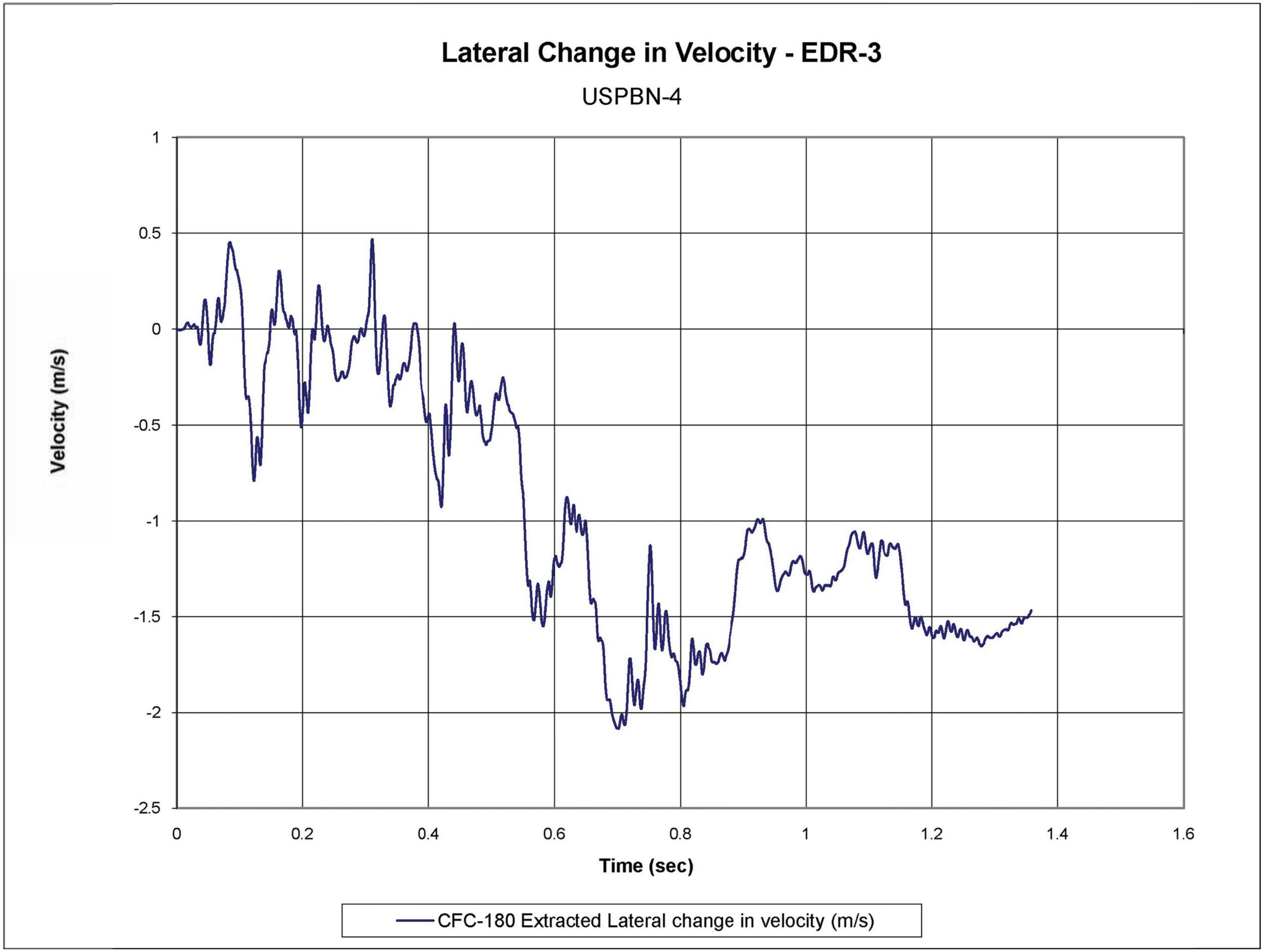


Figure E-12. Lateral Occupant Impact Velocity (EDR-3), Test No. USPBN-4

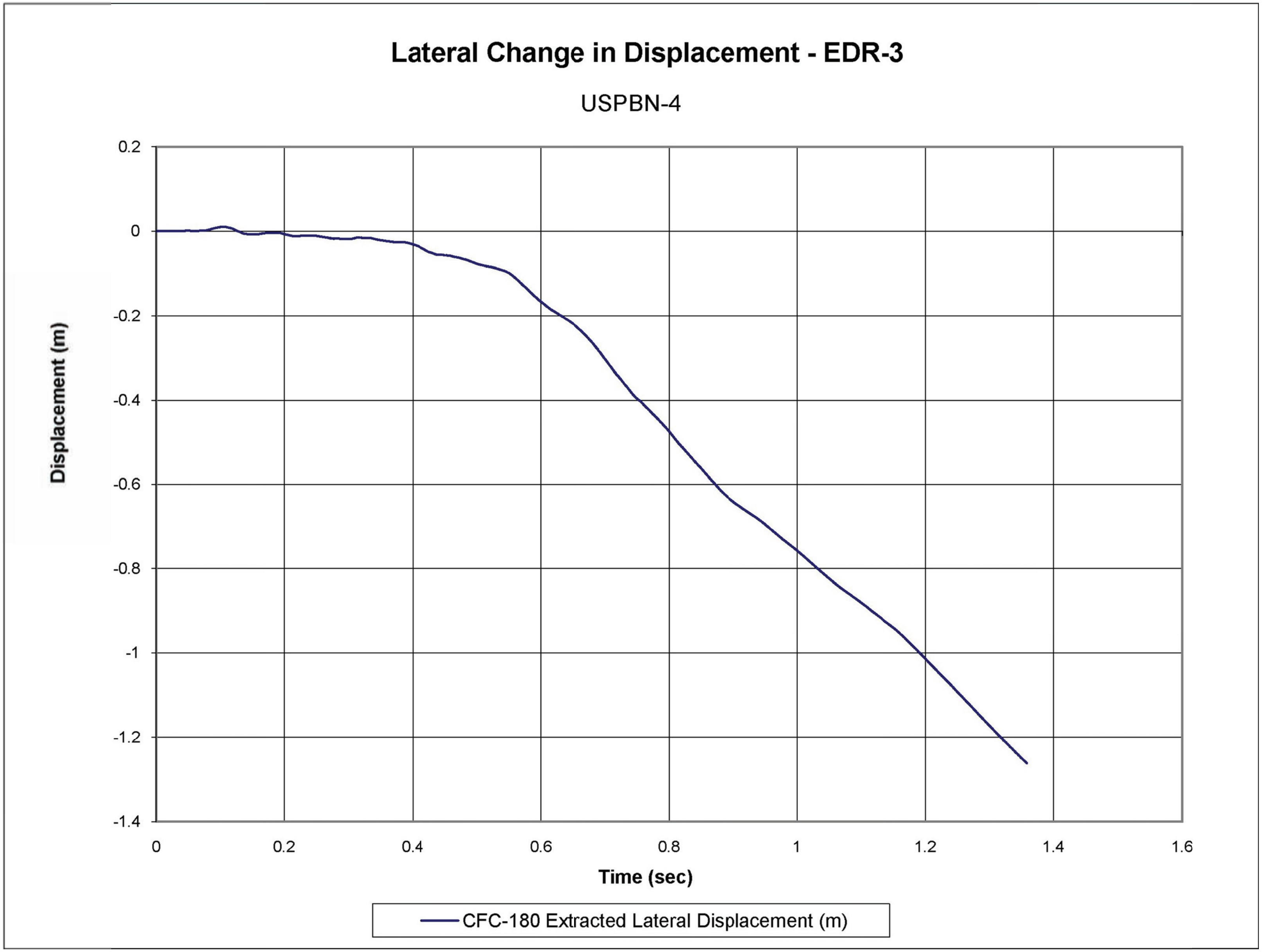


Figure E-13. Lateral Occupant Displacement (EDR-3), Test No. USPBN-4

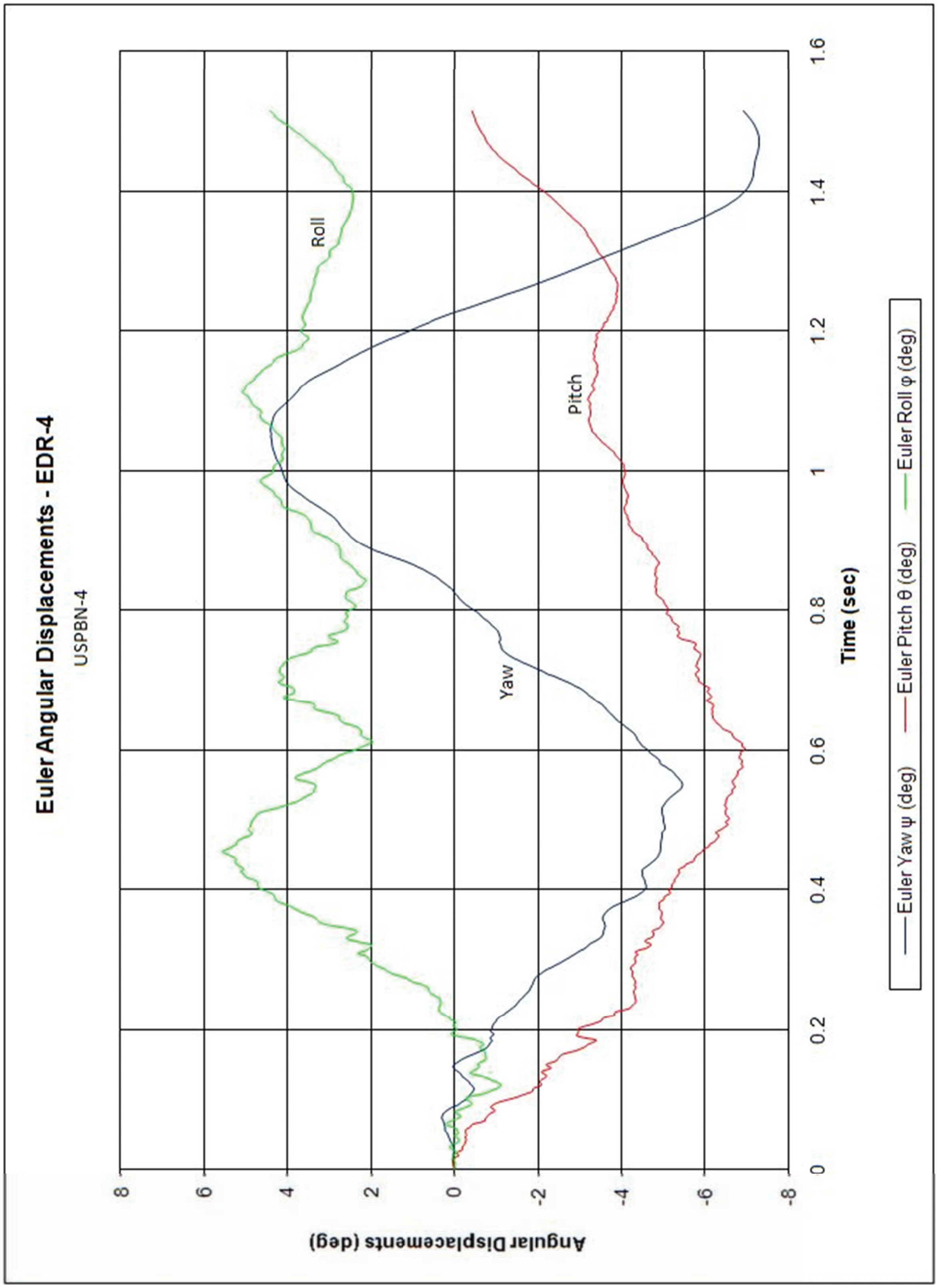


Figure E-14. Vehicle Angular Displacements (EDR-4), Test No. USPBN-4

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