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MASH TESTING OF BULLNOSE WITH BREAKAWAY STEEL POSTS (TEST NOS. MSPBN-4 THROUGH MSPBN-8)

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16. Abstract

This research study was Phase II of the evaluation a thrie-beam bullnose system using Universal Breakaway Steel Posts (UBSPs) to *Manual for Assessing Safety Hardware* (MASH) 2016 Test Level 3 (TL-3) criteria. Three full-scale crash tests were successfully conducted in Phase I to evaluate the bullnose system. In Phase II, test no. MSPBN-4 was conducted according to test designation no. 3-30 with an 1100C vehicle impacting the barrier at a speed of 62.1 mph (99.9 km/h) and an angle of 1.3 degrees. Test no. MSPBN-5 was conducted according to test designation no. 3-30 with an 1100C vehicle impacting the barrier at a speed of 62.7 mph (100.9 km/h) and an angle of 0.3 degrees. Test no. MSPBN-6 was conducted according to test designation no. 3-31 with a 2270P vehicle impacting the barrier at a speed of 63.4 mph (102.1 km/h) and an angle of 0.3 degrees. Test no. MSPBN-7 was conducted according to test designation no. 3-33 with a 2270P vehicle impacting the barrier at a speed of 63.1 mph (101.6 km/h) and an angle of 15.1 degrees Test no. MSPBN-8 was conducted according to test designation no. 3-37b with an 1100C vehicle impacting the barrier at a speed of 63.2 mph (101.8 km/h) and an angle of 25 degrees. Test no. MSPBN-4 was unacceptable according to MASH 2016 for test designation no. 3-30 due to the system inadequately containing or capturing the vehicle, and one MASH 2016 deformation limit was violated for the windshield. The bullnose system was modified by the use of an additional capture cable in the nose of the system for the remaining testing to address the failure observed in Test no. MSPBN-4. Test nos. MSPBN-5 through MSPBN-8 were deemed successful according to MASH 2016. The three successful full-scale crash tests from Phase I and the four successful crash tests from Phase II indicate that thrie-beam bullnose system meets the TL-3 test matrix for a MASH 2016-compliant crash cushion. Recommendations for system implementation were provided in the report.

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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.

INDEPENDENT APPROVING AUTHORITY

The Independent Approving Authority (IAA) for the data contained herein was Dr. Mojdeh Asadollahi Pajouh, Research Assistant Professor.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in.	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1,000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short ton (2,000 lb)	0.907	megagrams (or “metric ton”)	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela per square meter	cd/m^2
		FORCE & PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in.
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yard	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliter	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or “metric ton”)	1.103	short ton (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela per square meter	0.2919	foot-Lamberts	fl
		FORCE & PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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1 INTRODUCTION

1.1 Background

In 2009, the American Association of State Highway and Transportation Officials (AASHTO) implemented an updated standard for the evaluation of roadside hardware. The new standard, entitled the *Manual for Assessing Safety Hardware* (MASH) [1], improved the criteria for evaluating roadside hardware beyond the previous National Cooperative Highway Research Program (NCHRP) Report No. 350 standard [2] through updates to test vehicles, test matrices, and impact conditions. In an effort to encourage state departments of transportation and hardware developers to advance hardware designs, the Federal Highway Administration (FHWA) and AASHTO collaborated to develop a MASH implementation policy that includes sunset dates for various roadside hardware categories. Further, the 2009 MASH safety criteria were updated in 2016, thus resulting in the MASH 2016 document [3]. The new policy requires that safety devices installed on federal-aid roadways after the sunset dates to be evaluated according to MASH 2016.

The Midwest Pooled Fund Program members currently use several roadside hardware systems that were originally developed and evaluated under the NCHRP Report No. 350 criteria. One of those systems is a non-proprietary, thrie-beam bullnose system that was successfully developed and crash tested for use in shielding hazards within divided highways and roadways [4-9]. The thrie-beam bullnose system provides a safe, cost effective, non-proprietary option for shielding median piers and other median hazards. An evaluation of the barrier system to the MASH 2016 criteria would allow state departments of transportation (DOTs) to continue its use along their roadways and remain crashworthy with respect to the current vehicle fleet. Thus, a need existed to evaluate the thrie-beam bullnose system to the MASH 2016 criteria.

The Midwest Pooled Fund Program previously funded a research project to begin the evaluation of the thrie-beam bullnose system to the MASH 2016 Test Level 3 (TL-3) criteria using three critical full-scale crash tests selected from the ten potential required tests [10]. The results from these tests were used to determine if the remaining MASH 2016 TL-3 crash tests would be conducted, or if redesign/modification of the system was necessary. The three critical tests were test designation nos. 3-32, 3-34, and 3-35 in the MASH test matrix for crash cushions.

The Midwest Roadside Safety Facility (MwRSF) conducted test no. MSPBN-1 according to MASH 2016 test designation no. 3-35. For non-gating crash cushions, this test is designed to evaluate a critical impact point (CIP) where the crash cushion behavior transitions from capture to redirection with the 2270P vehicle. The CIP for test designation no. 3-35 was selected at post no. 3, which is halfway between the cable anchor at post no. 1 and the assumed beginning of the length of need (LON)/redirection point at post no. 5. In test no. MSPBN-1, a 5,001-lb (2268-kg) Dodge Ram Quad Cab pickup truck impacted the thrie-beam bullnose at a speed of 62.9 mph (101.3 km/h) and an angle of 25.1 degrees. After initial impact, the vehicle was captured and safely redirected by the bullnose system. As the vehicle redirected, the universal breakaway steel posts (UBSP's) at post nos. 5 through 8 were fractured and disengaged. This behavior created some pocketing and snag at post nos. 9 and 10, which were the first two W6x8.5 posts in the system. However, this behavior did not compromise vehicle capture or stability and did not negatively affect the occupant risk values. Occupant risk values for the test were well below the MASH limits, and occupant compartment deformations were minimal. Based on these values and the safe capture and redirection of the 2270P vehicle, this test was deemed acceptable under the MASH TL-3 criteria for test designation no. 3-35.

Test no. MSPBN-2 was conducted according to MASH 2016 test designation no. 3-34. This test is an impact of a 1100C small car at 15 degrees on the CIP where the crash cushion behavior transitions from capture to redirection. The CIP for test designation no. 3-34 was selected at post no. 2, which was upstream from the CIP for test designation no. 3-35 and was similar to previous MASH end terminal test CIPs, which used a similar anchorage system. In test no. MSPBN-2, a 2,448-lb (1,110-kg) Kia Rio small car impacted the thrie-beam bullnose system at a speed of 62.1 mph (100.0 km/h) and an angle of 14.7 degrees. After initial impact, the vehicle was captured and safely redirected by the bullnose system. As the vehicle redirected, Breakaway Cable Terminal (BCT) post no. 2 and UBSP post nos. 3 through 6 were deflected laterally, but none of the posts fractured and disengaged. The cable anchorage at post no. 1 remained engaged as well. Occupant risk values for the test were well below the MASH 2016 limits, and occupant compartment deformations were minimal. Based on these values and the safe capture and redirection of the 2270P vehicle, this test was deemed acceptable under the MASH 2016 TL-3 criteria for test designation no. 3-34.

Test no. MSPBN-3 was conducted according to MASH 2016 test designation no. 3-32. This test is an impact of an 1100C small car at an angle between 5 and 15 degrees on the center of the nose of the system and is meant to evaluate occupant risk and vehicle trajectory when a small car impacts the end of the system at an angle. Test designation no. 3-32 was conducted at an angle of 15 degrees as recommended in MASH 2016, as the width of the bullnose system made a lower-angle impact less critical. In test no. MSPBN-3, a 2,441-lb (1,107-kg) Kia Rio small car impacted the thrie-beam bullnose system at a speed of 62.7 mph (101.0 km/h) and an angle of 15.1 degrees. Following the initial impact, the nose of the bullnose system wrapped around the front of the small car. The lower hump of the thrie beam was pushed below the bumper and fractured, while the top two humps of the thrie beam engaged the vehicle above the bumper, capturing the vehicle. As the vehicle continued into the system, the thrie-beam rail was deformed and pulled downstream, and the breakaway posts in the system disengaged. These two actions dissipated the kinetic energy of the small car and decelerated it. The small car impacted the back side of post nos. 3 through 5 on the far side of the bullnose, which further decelerated the small car. The vehicle was brought to a controlled stop at approximately 800 ms after impact. Vehicle damage was moderate. Occupant risk values for the test were below the MASH 2016 limits, and occupant compartment deformations were minimal. Based on these values and the safe capture and deceleration of the 1100C vehicle, this test was deemed acceptable under the MASH 2016 TL-3 criteria for test designation no. 3-32.

Based on the successful completion of the first three critical MASH 2016 tests in the evaluation of the bullnose, it was believed that the remaining required MASH TL-3 test matrix should be completed to certify the MASH 2016 compliance of the thrie-beam bullnose system.

1.2 Objective

The research objective of the Phase II study contained herein was to conduct full scale crash testing on a thrie-beam bullnose median barrier system according to TL-3 of the MASH 2016 impact safety standards. Due to the extensive number of full-scale crash tests that are required to evaluate a thrie-beam bullnose system, the crash testing was phased in order to efficiently determine if the thrie-beam bullnose system could meet the TL-3 criteria. Phase II, which is described within this report, evaluated the bullnose system according to four remaining MASH 2016 TL-3 full-scale crash tests on the thrie-beam bullnose system.

1.3 Scope

Five full-scale crash tests were conducted to complete the MASH 2016 TL-3 evaluation of the thrie-beam bullnose system. Test nos. MSPBN-4 and MSPBN-5 were conducted according to MASH 2016 test designation no. 3-30. These tests utilized a small car weighing approximately 2,425 lb (1,100 kg) with target impact conditions of 62 mph (100 km/h) and an angle of 0 degrees. These tests were completed to evaluate the impact performance of the thrie-beam bullnose system when impacted with a ¼-vehicle offset from the center of the nose of the system. Test no. MSPBN-6 was conducted according to MASH 2016 test designation no. 3-31. This test utilized a pickup truck weighing approximately 5,000 lb (2,270 kg) with target impact conditions of 62 mph (100 km/h) and an angle of 0 degrees. This test was completed to evaluate the impact performance of the thrie-beam bullnose system when impacted at the center of the nose of the system. Test no. MPSBN-7 was conducted according to MASH 2016 test designation no. 3-33. This test utilized a pickup truck weighing approximately 5,000 lb (2,270 kg) with target impact conditions of 62 mph (100 km/h) and an angle of 15 degrees. This test was completed to evaluate the impact performance of the thrie-beam bullnose system when impacted at the center of the nose of the system at an angle. Finally, test no. MPSBN-8 was conducted according to MASH 2016 test designation no. 3-37b. This test utilized a small car weighing approximately 2,425 lb (1,100 kg) with target impact conditions of 62 mph (100 km/h) and an angle of 25 degrees. This test was completed to evaluate the impact performance of the thrie-beam bullnose system when impacted in the reverse direction.

2 TEST REQUIREMENTS AND EVALUATION CRITERIA

2.1 Background

Thrie-beam bullnose systems must satisfy impact safety standards. For new hardware, these safety standards consist of the guidelines and procedures published in MASH 2016 [3]. The thrie-beam bullnose system is classified as a non-gating, redirective, crash cushion for the purposes of evaluation. In MASH 2016, as many as ten full-scale crash tests are potentially required to evaluate this type of hardware, as shown in Table 1.

Table 1. MASH 2016 TL-3 Crash Test Conditions for Bullnose Guardrails

Test Article	Test Designation No.	Test Vehicle	Vehicle Weight, lb (kg)	Impact Conditions		Evaluation Criteria [1]
				Speed, mph (km/h)	Angle, degrees	
Terminals and Redirective Crash Cushions	3-30	1100C	2,425 (1,100)	62 (100)	0	A,D,F,H,I (non-gating)
	3-31	2270P	5,000 (2,270)	62 (100)	0	A,D,F,H,I (non-gating)
	3-32	1100C	2,425 (1,100)	62 (100)	5-15	A,D,F,H,I (non-gating)
	3-33	2270P	5,000 (2,270)	62 (100)	5-15	A,D,F,H,I (non-gating)
	3-34	1100C	2,425 (1,100)	62 (100)	15	A,D,F,H,I (non-gating)
	3-35	2270P	5,000 (2,270)	62 (100)	25	A,D,F,H,I
	3-36	2270P	5,000 (2,270)	62 (100)	25	A,D,F,H,I (non-gating)
	3-37a	2270P	5,000 (2,270)	62 (100)	25	A,D,F,H,I (non-gating)
	3-37b	1100C	2,425 (1,100)	62 (100)	25	A,D,F,H,I (non-gating)
	3-38	1500A	3,300 (1,500)	62 (100)	0	A,D,F,H,I (non-gating)

[1] Evaluation criteria explained in Table 2.

Table 2. MASH 2016 Evaluation Criteria for Bullnose Guardrails

<table>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td></tr>
<tr><td rowspan="9">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 should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</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>30 ft/s
(9.1 m/s)</td><td>40 ft/s
(12.2 m/s)</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</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>15.0 g’s</td><td>20.49 g’s</td></tr>
</table>

Out of the ten required crash tests, three tests have been completed (test designation nos. 3-32, 3-34, and 3-35) and three tests were deemed non-critical. Test designation no. 3-36, on the transition to a rigid structure, was not required as it was assumed that the bullnose system will use MASH 2016 TL-3 approved thrie-beam approach guardrail transitions for attachment to any rigid structures. Test designation no. 3-38 is intended to evaluate the performance of mid-sized sedan vehicles with terminals and crash cushions. However, MASH 2016 uses an analytical estimation of 1500A vehicle decelerations based on the results of test designation no. 3-31 to determine whether or not this test is required. Thus, test designation no. 3-38 was deemed non-critical until the results from analytical estimation of 1500A vehicle decelerations were known. The final non-critical test is test designation no. 3-37 for reverse-direction impacts, which includes test designation 3-37a with the 2270P vehicle and test designation 3-37b with the 1100C vehicle. For systems utilizing a breakaway cable system like end terminals and the thrie-beam bullnose system, MASH 2016 recommends test designation no. 3-37b as the critical test to evaluate snag of the 1100C vehicle on the cable anchorage system. Test designation no. 3-37a was deemed non-critical as the thrie-beam bullnose system should perform similarly to a longitudinal guardrail when impacted in the reverse direction upstream from the cable anchorage. Vehicle capture, stability, and occupant risk were anticipated to be more critical for the 1100C vehicle similar to previous MASH TL-3 end terminal evaluations. Previous research regarding small car impacts on trailing-end anchorages for the Midwest Guardrail System (MGS) determined a CIP using LS-DYNA computer simulations for wedging the 1100C vehicle underneath the rail and the cable anchor on the MGS [11-13]. This CIP was determined to be 112½ in. (2,876 mm) upstream from the end post in the system. Based on the similarity of the cable anchorage used in the MGS trailing-end anchorage system and the thrie-beam bullnose anchorage, the researchers elected to use the same CIP for test no. 3-37b to maximize the probability of vehicle and wheel snag on the cable anchor. This impact point corresponded to the center of third post upstream from the anchorage post on the bullnose system or the fourth post upstream of the end of the bullnose system.

Thus, four remaining required tests were conducted to complete the MASH 2016 TL-3 test matrix for evaluation of the thrie-beam bullnose system. It should be noted that any tests within the evaluation matrix deemed non-critical may eventually need to be evaluated based on additional knowledge gained over time or additional FHWA eligibility letter requirements.

2.2 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 guardrail to contain and redirect impacting vehicles. In addition, controlled lateral deflection of the test article is acceptable. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Post-impact vehicle trajectory is a measure of the potential of the vehicle to result in a secondary collision with other vehicles and/or fixed objects, thereby increasing the risk of injury to the occupants of the impacting vehicle and/or other vehicles. These evaluation criteria are summarized in Table 2 and defined in greater detail in MASH 2016. The full-scale vehicle crash tests were conducted and reported in accordance with the procedures provided in MASH 2016.

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. Additional discussion on PHD, THIV and ASI is provided in MASH 2016.

2.3 Soil Strength Requirements

In accordance with Chapter 3 and Appendix B of MASH 2016, foundation soil strength must be verified before any full-scale crash testing can occur. During the installation of a soil dependent system, W6x16 (W152x23.8) posts are installed near the impact region utilizing the same installation procedures as the system itself. Prior to full-scale testing, a dynamic impact test must be conducted to verify a minimum dynamic soil resistance of 7.5 kips (33.4 kN) at post deflections between 5 and 20 in. (127 and 508 mm) measured at a height of 25 in. (635 mm). If dynamic testing near the system is not desired, MASH 2016 permits a static test to be conducted instead and compared against the results of a previously established baseline test. In this situation, the soil must provide a resistance of at least 90% of the static baseline test at deflections of 5, 10, and 15 in. (127, 254, and 381 mm). Further details can be found in Appendix B of MASH 2016.

3 TEST CONDITIONS

3.1 Test Facility

The Outdoor Test Site 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.

3.2 Vehicle Tow and Guidance System

A reverse-cable, tow system with a 1:2 mechanical advantage was used to propel the test vehicle. 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 [15] was used to steer the test vehicles. A guide flag, attached to the right-front wheel for all five tests 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 (30.5 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.

3.3 Test Vehicles

For test no. MSPBN-4, a 2009 Kia Rio four door sedan was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,472 lb (1,121 kg), 2,429 lb (1,102 kg), and 2,593 lb (1,176 kg), respectively. The test vehicle is shown in Figures 1 and 2, and vehicle dimensions are shown in Figure 3.

For test no. MSPBN-5, a 2009 Hyundai Accent four door sedan was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,461 lb (1,116 kg), 2,409 lb (1,093 kg), and 2,573 lb (1,167 kg), respectively. The test vehicle is shown in Figures 4 and 5, and vehicle dimensions are shown in Figure 6.

For test no. MSPBN-6, a 2012 Dodge Ram 1500 crew cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,210 lb (2,363 kg), 5,061 lb (2,296 kg), and 5,236 lb (2,375 kg), respectively. The test vehicle is shown in Figures 7 and 8, and vehicle dimensions are shown in Figure 9.

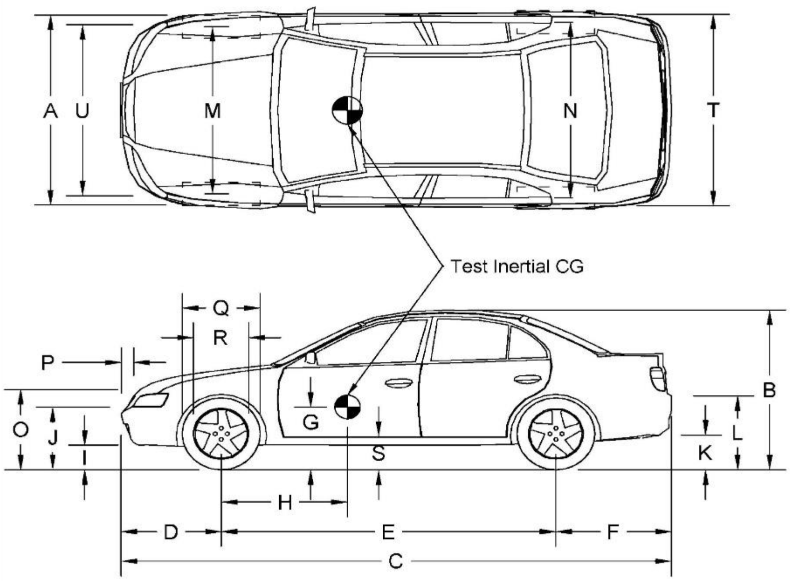
For test no. MSPBN-7, a 2012 Dodge Ram 1500 quad cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,271 lb (2,391 kg), 5,043 lb (2,287 kg), and 5,202 lb (2,360 kg), respectively. The test vehicle is shown in Figures 10 and 11, and vehicle dimensions are shown in Figure 12.

For test no. MSPBN-8, a 2011 Hyundai Accent sedan was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,476 lb (1,123 kg), 2,394 lb (1,086 kg), and 2,558 lb (1,160 kg), respectively. The test vehicle is shown in Figures 13 and 14, and vehicle dimensions are shown in Figure 15.

Figure 1. Test Vehicle, Test No. MSPBN-4

Figure 2. Test Vehicle Floor Pan and Undercarriage, Test No. MSPBN-4

Date:	4/18/2018	Test Name:	MSPBN-4	VIN No:	KNADE223496469475
Year:	2009	Make:	KIA	Model:	RIO
Tire Size:	185/65R14	Tire Inflation Pressure:	32 Psi	Odometer:	147278



Vehicle Geometry - in. (mm)
Target Ranges listed below

A:	64 7/8	(1648)	B:	57 1/2	(1461)
	65±3 (1650±75)				
C:	176 1/8	(4474)	D:	33	(838)
	169±8 (4300±200)			35±4 (900±100)	
E:	98 1/4	(2496)	F:	36	(914)
	98±5 (2500±125)				
G:	22 9/16	(573)	H:	36 1/4	(921)
				39±4 (990±100)	
I:	7 1/4	(184)	J:	22 3/4	(578)
K:	12 1/8	(308)	I:	25 1/4	(641)
M:	57 3/4	(1467)	N:	57 1/5	(1453)
	56±2 (1425±50)			56±2 (1425±50)	
O:	28	(711)	P:	3	(76)
	24±4 (600±100)				
Q:	22 1/2	(572)	R:	15 1/3	(389)
S:	11 1/4	(286)	T:	65 1/8	(1654)
			U (impact width):	56	(1422)

Top of radiator core support:	28 1/4	(718)
Wheel Center Height (Front):	11	(279)
Wheel Center Height (Rear):	11 1/4	(286)
Wheel Well Clearance (Front):	25	(635)
Wheel Well Clearance (Rear):	24 7/8	(632)
Bottom Frame Height (Front):	6	(152)
Bottom Frame Height (Rear):	9 1/2	(241)
Engine Type:	GAS	
Engine Size:	1.6L 4 CYL	
Transmission Type:	AUTOMATIC	
Drive Type:	FWD	

Mass Distribution lb (kg)

Gross Static	LF	845	(383)	RF	772	(350)
	LR	498	(226)	RR	478	(217)

Weights lb (kg)	Curb		Test Inertial		Gross Static	
W-front	1551	(704)	1533	(695)	1617	(733)
W-rear	921	(418)	896	(406)	976	(443)
W-total	2472	(1121)	2429	(1102)	2593	(1176)
			2420±55 (1100±25)		2585±55 (1175±50)	

GVWR Ratings lb		Surrogate Occupant Data	
Front	1918	Type:	Hybrid II
Rear	1874	Mass:	163 lb
Total	3638	Seat Position:	Left

Note any damage prior to test: None

Figure 3. Vehicle Dimensions, Test No. MSPBN-4

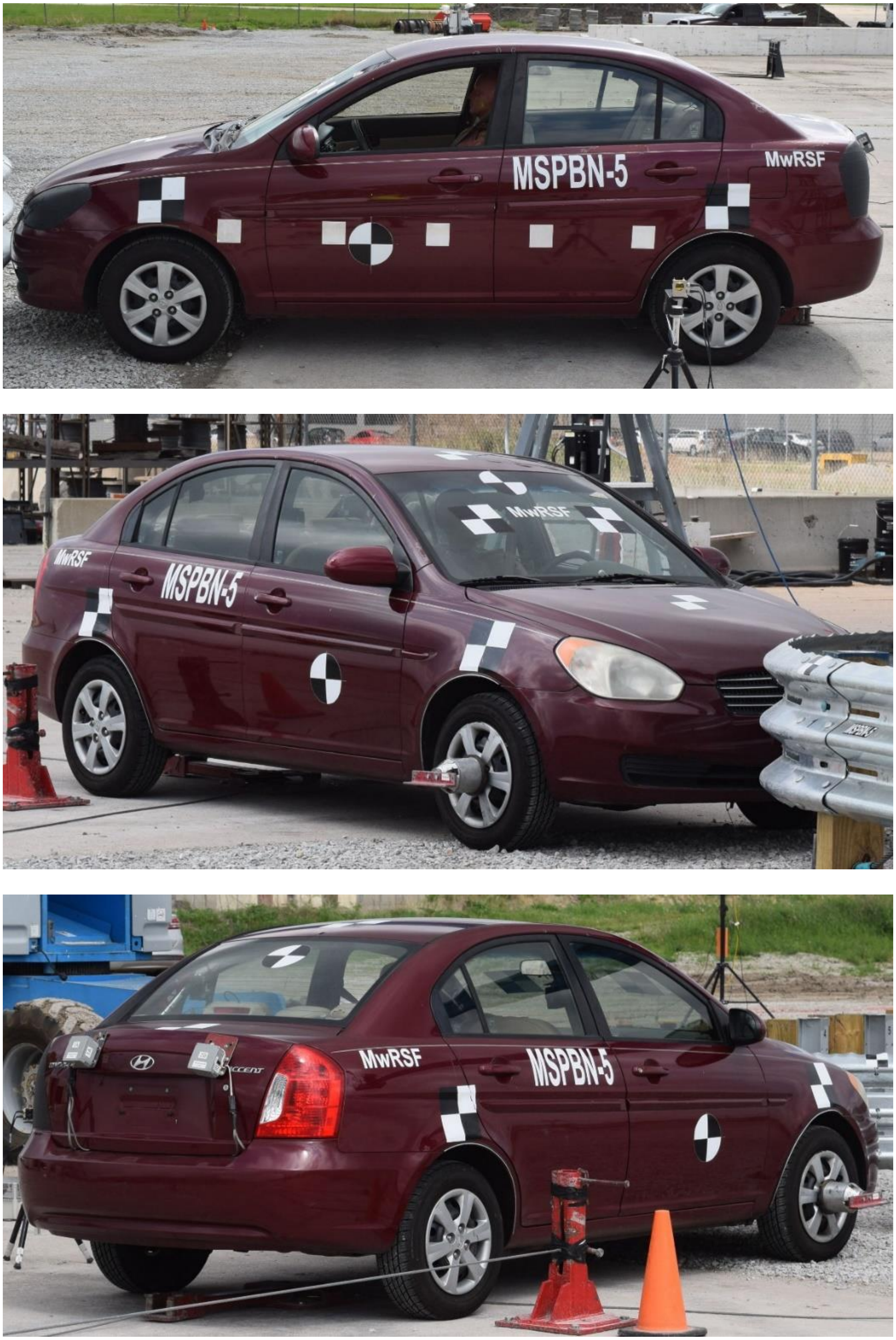
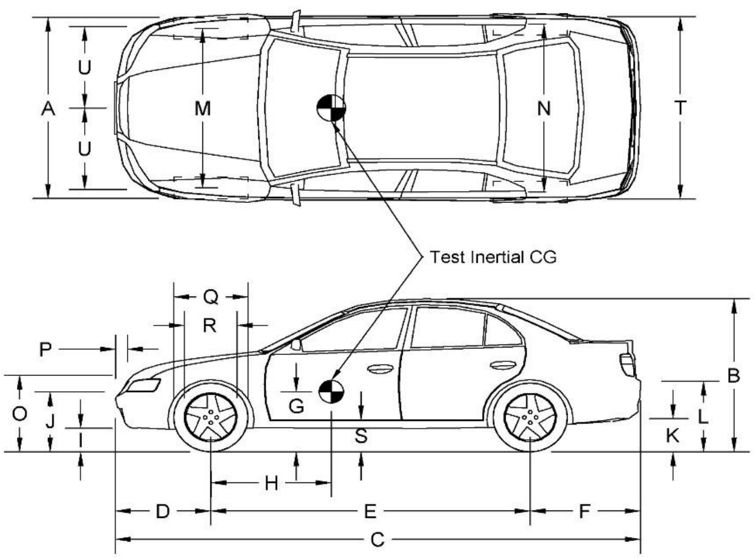


Figure 4. Test Vehicle, Test No. MSPBN-5

Figure 5. Test Vehicle Floor Pan and Undercarriage, Test No. MSPBN-5

Date:	5/15/2018	Test Name:	MSPBN-5	VIN No:	KMHCN46C39U386700
Year:	2009	Make:	ACCENT	Model:	HYUNDAI
Tire Size:	185/65R14	Tire Inflation Pressure:	32 Psi	Odometer:	128728



Vehicle Geometry - in. (mm)
Target Ranges listed below

A:	64 7/8	(1648)	B:	58 1/8	(1476)
	65±3 (1650±75)				
C:	164 7/8	(4186)	D:	30 11/16	(779)
	169±8 (4300±200)			35±4 (900±100)	
E:	98 5/8	(2505)	F:	35 1/2	(902)
	98±5 (2500±125)				
G:	22 7/8	(581)	H:	36 1/4	(921)
				39±4 (990±100)	
I:	8 3/4	(222)	J:	21 1/2	(546)
K:	11 7/8	(302)	I:	27 5/8	(702)
M:	57 13/16	(1468)	N:	57 3/16	(1453)
	56±2 (1425±50)			56±2 (1425±50)	
O:	28	(711)	P:	3	(76)
	24±4 (600±100)				
Q:	23 3/8	(594)	R:	15 3/8	(391)
S:	11 5/8	(295)	T:	65	(1649)

U (impact width):	32 1/2	(824)
Top of radiator core support:	28 7/8	(733)
Wheel Center Height (Front):	11 5/8	(297)
Wheel Center Height (Rear):	11 5/8	(296)
Wheel Well Clearance (Front):	4 7/8	(124)
Wheel Well Clearance (Rear):	9 1/2	(241)
Bottom Frame Height (Front):	8	(203)
Bottom Frame Height (Rear):	17	(432)
Engine Type:	Gasoline	
Engine Size:	1.6L 4cyl	
Transmission Type:	automatic	
Drive Type:	FWD	

Mass Distribution lb (kg)

Gross Static	LF	827	(375)	RF	781	(354)
	LR	497	(225)	RR	468	(212)

Weights lb (kg)	Curb		Test Inertial		Gross Static	
W-front	1582	(718)	1524	(691)	1608	(729)
W-rear	879	(399)	885	(401)	965	(438)
W-total	2461	(1116)	2409	(1093)	2573	(1167)
			2420±55 (1100±25)		2585±55 (1175±50)	

GVWR Ratings lb

Front	1918
Rear	1874
Total	3638

Surrogate Occupant Data

Type:	Hybrid II
Mass:	164 lb
Seat Position:	LEFT

Note any damage prior to test: None

Figure 6. Vehicle Dimensions, Test No. MSPBN-5

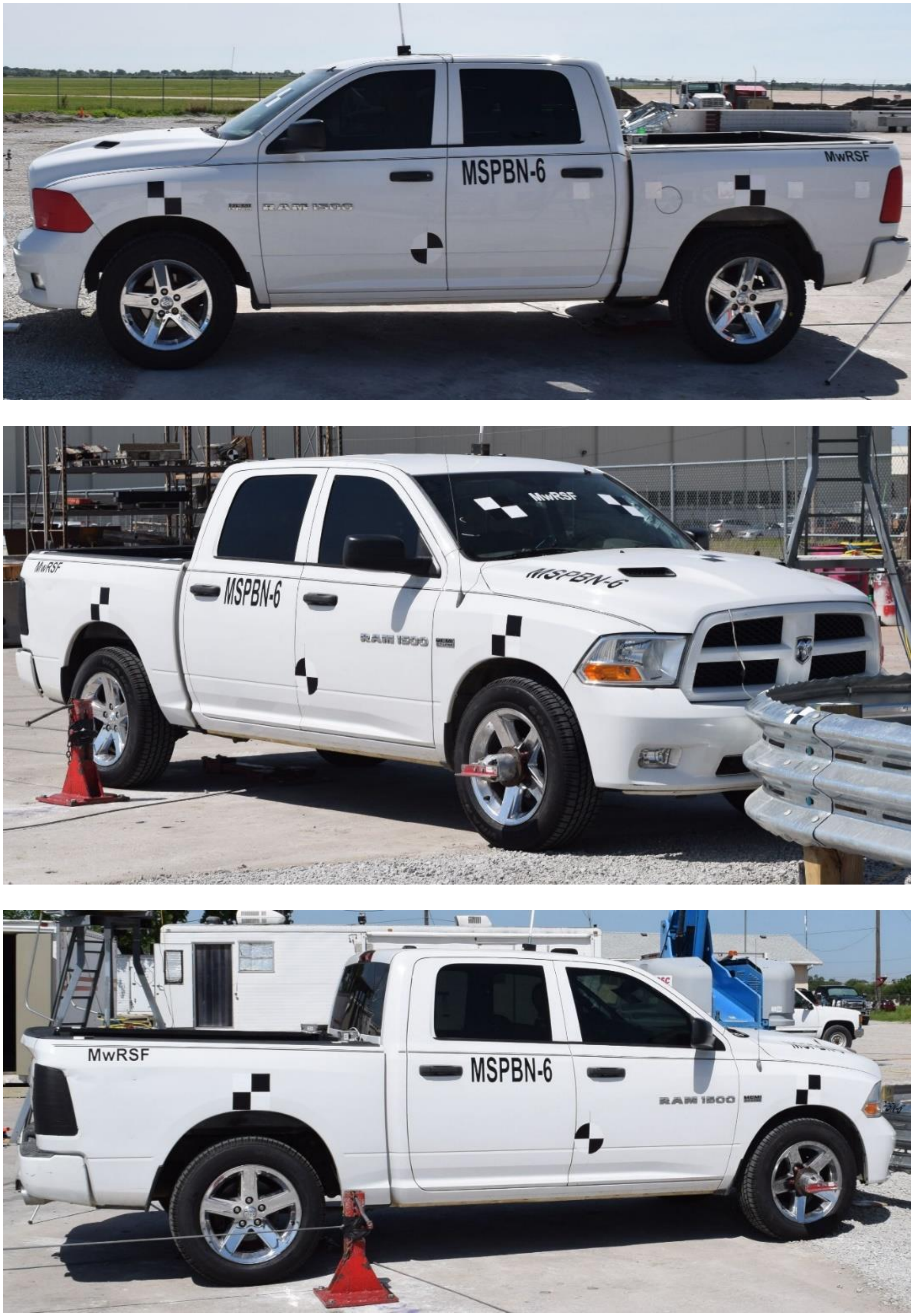


Figure 7. Test Vehicle, Test No. MSPBN-6

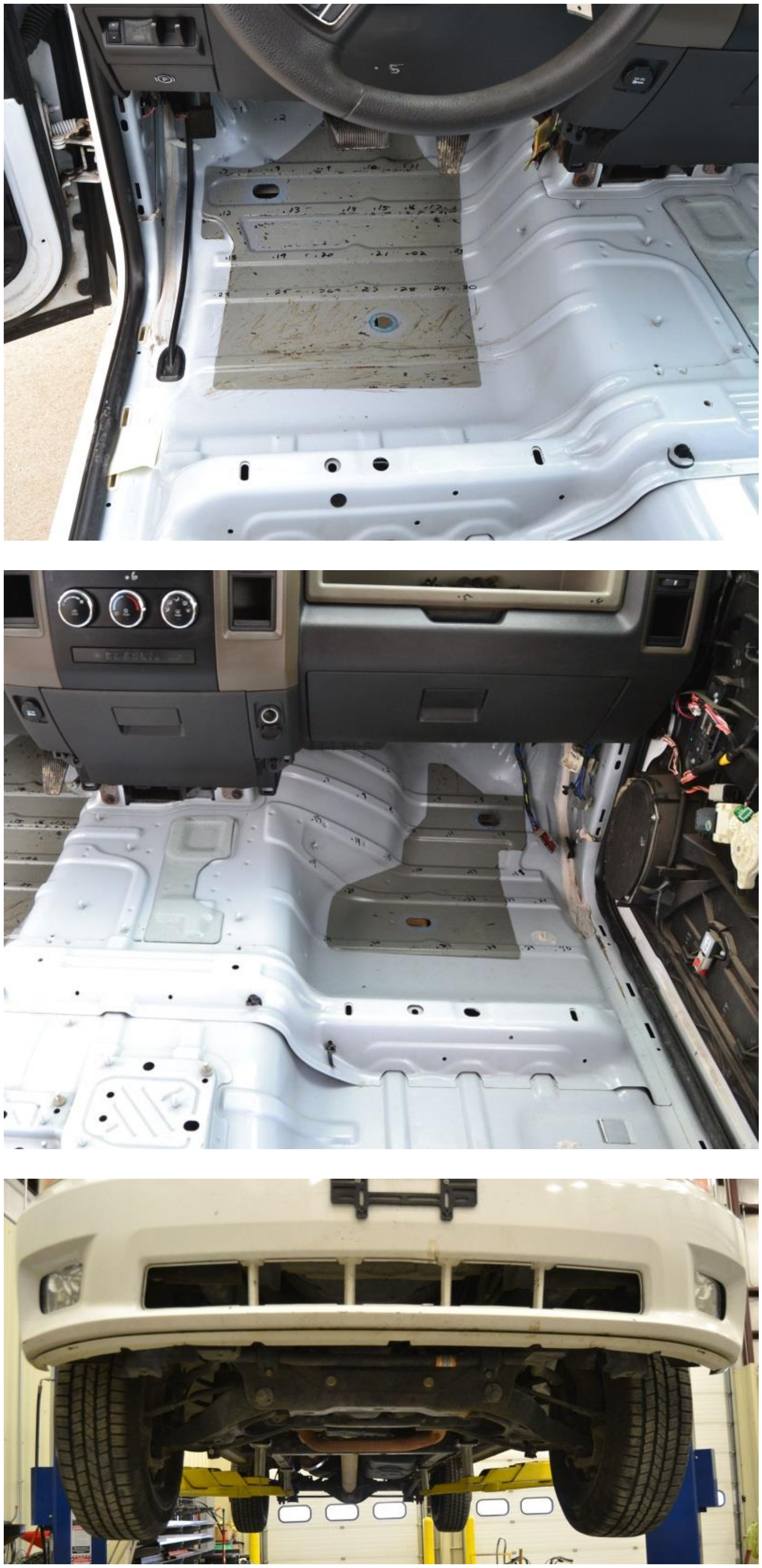
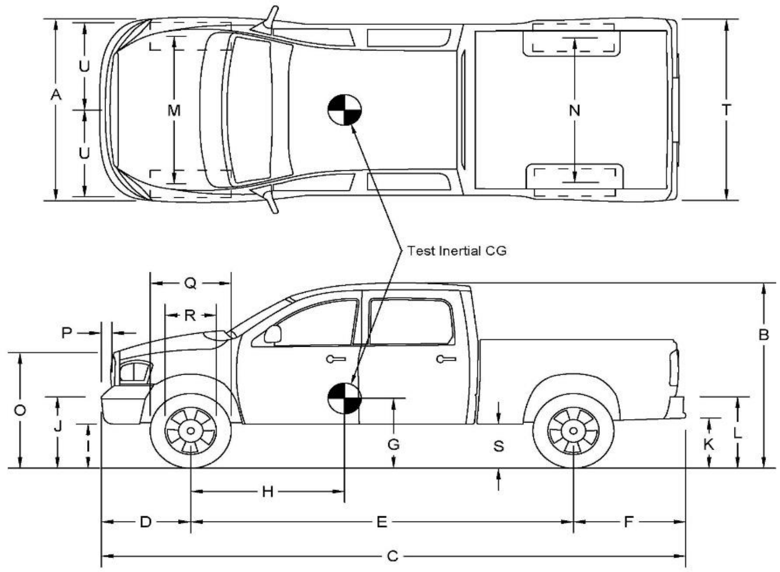


Figure 8. Test Vehicle Floor Pan and Undercarriage, Test No. MSPBN-6

Date:	6/5/2018	Test Name:	MSPBN-6	VIN No:	1C6RD6KT3CS268370
Year:	2012	Make:	Dodge	Model:	Ram 1500
Tire Size:	P275-60R20	Tire Inflation Pressure:	35 Psi	Odometer:	159054



Vehicle Geometry - in. (mm)
Target Ranges listed below

A:	77 1/2	(1969) 78±2 (1950±50)	B:	75 7/8	(1927)
C:	229 1/2	(5829) 237±13 (6020±325)	D:	40 3/8	(1026) 39±3 (1000±75)
E:	140 1/4	(3562) 148±12 (3760±300)	F:	48 7/8	(1241)
G:	29 7/16	(748) min: 28 (710)	H:	61 5/16	(1557) 63±4 (1575±100)
I:	12 7/8	(327)	J:	26 1/2	(673)
K:	20 1/2	(521)	L:	30 3/8	(772)
M:	67 3/4	(1721) 67±1.5 (1700±38)	N:	68 1/2	(1740) 67±1.5 (1700±38)
O:	48 1/8	(1222) 43±4 (1100±75)	P:	5 1/2	(140)
Q:	32	(813)	R:	21 1/2	(546)
S:	14 5/8	(371)	T:	78 3/8	(1991)

U (impact width): 77 1/2 (1969)

Mass Distribution lb (kg)

Gross Static LF	1394	(632)	RF	1549	(703)
LR	1144	(519)	RR	1149	(521)

Weights lb (kg)	Curb		Test Inertial		Gross Static	
W-front	2911	(1320)	2848	(1292)	2943	(1335)
W-rear	2299	(1043)	2213	(1004)	2293	(1040)
W-total	5210	(2363)	5061	(2296) 5000±110 (2270±50)	5236	(2375) 5165±110 (2343±50)

Wheel Center Height (Front):	16	(406)
Wheel Center Height (Rear):	16	(406)
Wheel Well Clearance (Front):	5 5/8	(143)
Wheel Well Clearance (Rear):	9 3/4	(248)
Bottom Frame Height (Front):	11 1/2	(292)
Bottom Frame Height (Rear):	24	(610)
Engine Type:	Gasoline	
Engine Size:	5.7 V8	
Transmission Type:	Auto	
Drive Type:	RWD	
Cab Style:	Crew Cab	
Bed Length:	67"	

GVWR Ratings lb

Front	3700
Rear	3900
Total	6800

Surrogate Occupant Data

Type:	Hybrid II
Mass:	160 lb
Seat Position:	RIGHT/PASSENGER

Note any damage prior to test: None

Figure 9. Vehicle Dimensions, Test No. MSPBN-6

Figure 10. Test Vehicle, Test No. MSPBN-7

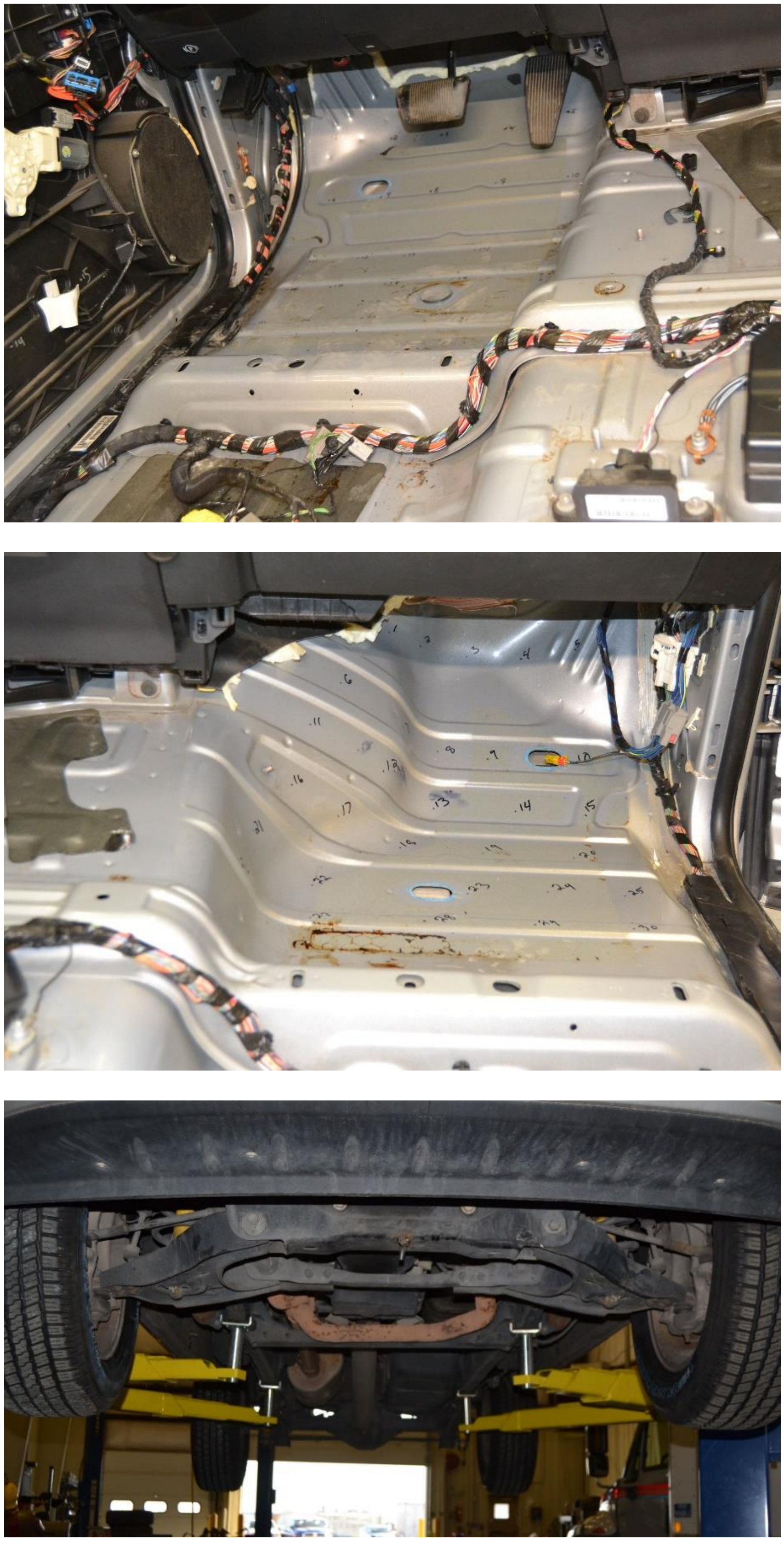
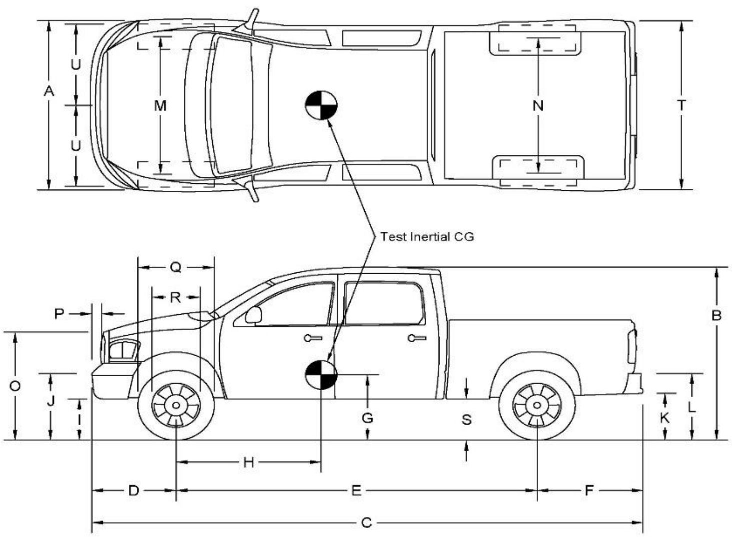


Figure 11. Vehicle Floor Pan and Undercarriage, Test No. MSPBN-7

Date:	6/5/2018	Test Name:	MSPBN7	VIN No:	1C6RD6KT4CS197048
Year:	2012	Make:	Dodge	Model:	Ram 1500
Tire Size:	P275/60R20	Tire Inflation Pressure:	35 Psi	Odometer:	227374



Vehicle Geometry - in. (mm)
Target Ranges listed below

A:	77	(1956)	B:	75 1/2	(1918)
	78±2 (1950±50)				
C:	229 3/4	(5836)	D:	36 1/4	(921)
	237±13 (6020±325)			39±3 (1000±75)	
E:	140 1/2	(3569)	F:	47	(1194)
	148±12 (3760±300)				
G:	29 1/8	(740)	H:	61 9/16	(1564)
	min: 28 (710)			63±4 (1575±100)	
I:	11	(279)	J:	31 5/8	(803)
K:	21	(533)	L:	29 7/8	(759)
M:	67 7/8	(1724)	N:	68	(1727)
	67±1.5 (1700±38)			67±1.5 (1700±38)	
O:	46 1/4	(1175)	P:	5	(127)
	43±4 (1100±75)				
Q:	31 7/8	(810)	R:	21 1/2	(546)
S:	15 3/4	(400)	T:	75	(1905)

U (impact width):	70 1/4	(1784)
Wheel Center Height (Front):	15 3/8	(391)
Wheel Center Height (Rear):	15 3/4	(400)
Wheel Well Clearance (Front):	36	(914)
Wheel Well Clearance (Rear):	38 1/4	(972)
Bottom Frame Height (Front):	10 3/4	(273)
Bottom Frame Height (Rear):	11	(279)
Engine Type:	Gasoline	
Engine Size:	5.7 l V8	
Transmission Type:	Automatic	
Drive Type:	RWD	
Cab Style:	Crew Cab	
Bed Length:	67"	

Mass Distribution lb (kg)

Gross Static	LF	1438	(652)	RF	1492	(677)
	LR	1110	(503)	RR	1162	(527)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2953 (1339)	2833 (1285)	2930 (1329)
W-rear	2318 (1051)	2210 (1002)	2272 (1031)
W-total	5271 (2391)	5043 (2287) 5000±110 (2270±50)	5202 (2360) 5165±110 (2343±50)

GVWR Ratings lb

Front	3700
Rear	3900
Total	6800

Surrogate Occupant Data

Type:	Hybrid II
Mass:	159 lb
Seat Position:	Front Right

Note any damage prior to test: Left rear tail light lens is cracked, small dent by RAM logo on left front door.

Figure 12. Vehicle Dimensions, Test No. MSPBN-7

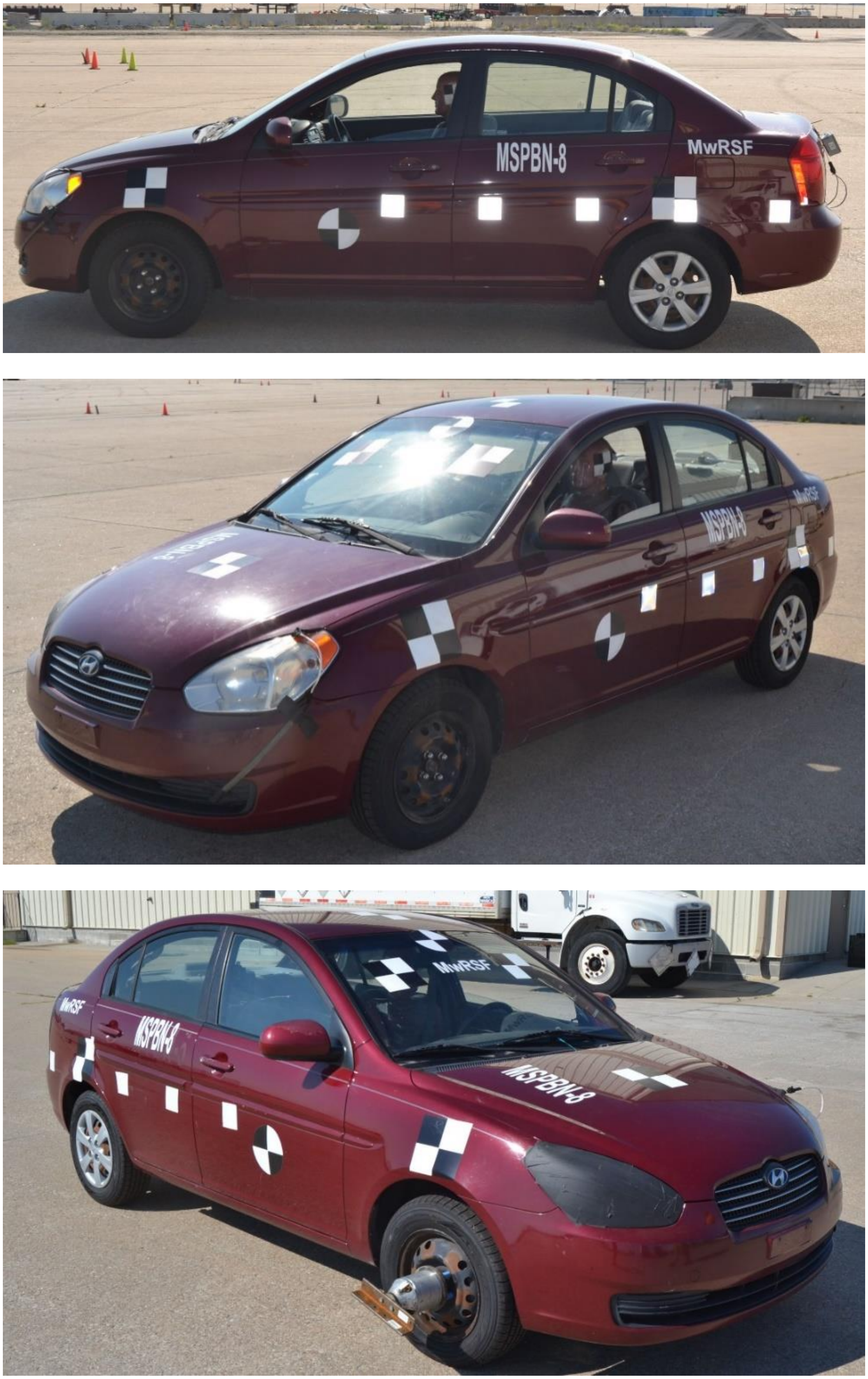
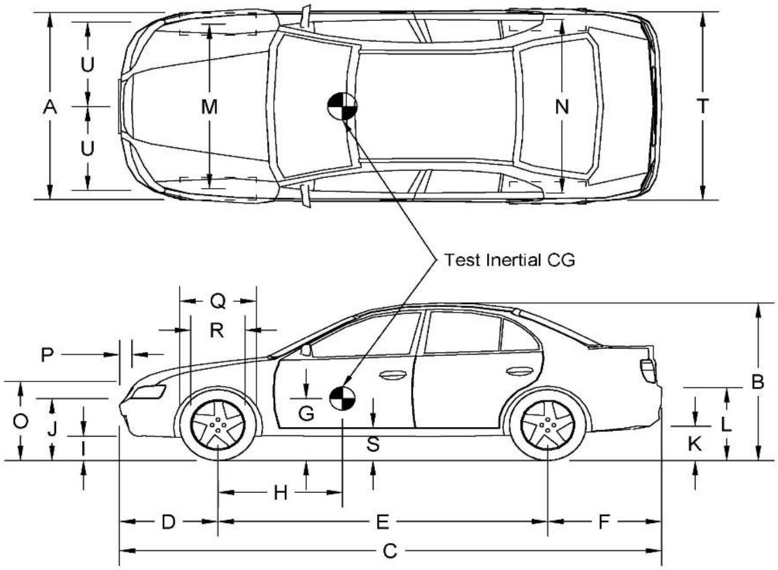


Figure 13. Test Vehicle, Test No. MSPBN-8

Figure 14. Vehicle Floor Pan and Undercarriage, Test No. MSPBN-8

Date:	8/29/2018	Test Name:	MSPBN-8	VIN No:	kmhcn4ac3bu533692
Year:	2011	Make:	Hyundai	Model:	Accent
Tire Size:	185/65r14	Tire Inflation Pressure:	32 Psi	Odometer:	153616



Vehicle Geometry - in. (mm)
Target Ranges listed below

A:	65 1/2	(1664)	B:	57 7/8	(1470)
	65±3 (1650±75)				
C:	168 1/4	(4274)	D:	33 1/2	(851)
	169±8 (4300±200)			35±4 (900±100)	
E:	98 1/2	(2502)	F:	36 1/4	(921)
	98±5 (2500±125)				
G:	22 5/16	(567)	H:	36 7/16	(926)
				39±4 (990±100)	
I:	8	(203)	J:	20 1/2	(521)
K:	12	(305)	l:	25 1/8	(638)
M:	57 1/2	(1461)	N:	57 1/4	(1454)
	56±2 (1425±50)			56±2 (1425±50)	
O:	27 5/8	(702)	P:	2 1/2	(64)
	24±4 (600±100)				
Q:	22 1/2	(572)	R:	15 3/8	(391)
S:	11 3/8	(289)	T:	65	(1651)

U (impact width):	29 1/8	(740)
Top of radiator core support:	27 1/2	(699)
Wheel Center Height (Front):	10 7/8	(276)
Wheel Center Height (Rear):	11 1/8	(283)
Wheel Well Clearance (Front):	26 1/2	(673)
Wheel Well Clearance (Rear):	25	(635)
Bottom Frame Height (Front):	7 1/4	(184)
Bottom Frame Height (Rear):	7 1/2	(191)
Engine Type:	gasoline	
Engine Size:	1.4L 4 cyl	
Transmission Type:	Manual	
Drive Type:	FWD	

Mass Distribution lb. (kg)

Gross Static	LF	781	(354)	RF	812	(368)
	LR	463	(210)	RR	502	(228)

Weights lb (kg)	Curb		Test Inertial		Gross Static	
W-front	1573	(714)	1509	(684)	1593	(723)
W-rear	903	(410)	885	(401)	965	(438)
W-total	2476	(1123)	2394	(1086)	2558	(1160)
			2420±55 (1100±25)		2585±55 (1175±50)	

GVWR Ratings lb

Front	1918
Rear	1874
Total	3638

Surrogate Occupant Data

Type:	Hybrid II
Mass:	163 lb
Seat Position:	right passenger

Note any damage prior to test: None

Figure 15. Vehicle Dimensions, Test No. MSPBN-8

It should be noted that the pickup truck test vehicles used were within 6 years of the research project contract date. MASH 2016 requires test vehicles used in crash testing to be no more than six model years old. For the small car tests, a 2009 model was used because the vehicle geometry of newer models did not comply with recommended vehicle dimension ranges specified in Table 4.1 of MASH 2016. The use of older test vehicles due to recent small car vehicle properties falling outside of MASH 2016 recommendations was allowed by FHWA and AASHTO in MASH implementation guidance dated May of 2018 [1414].

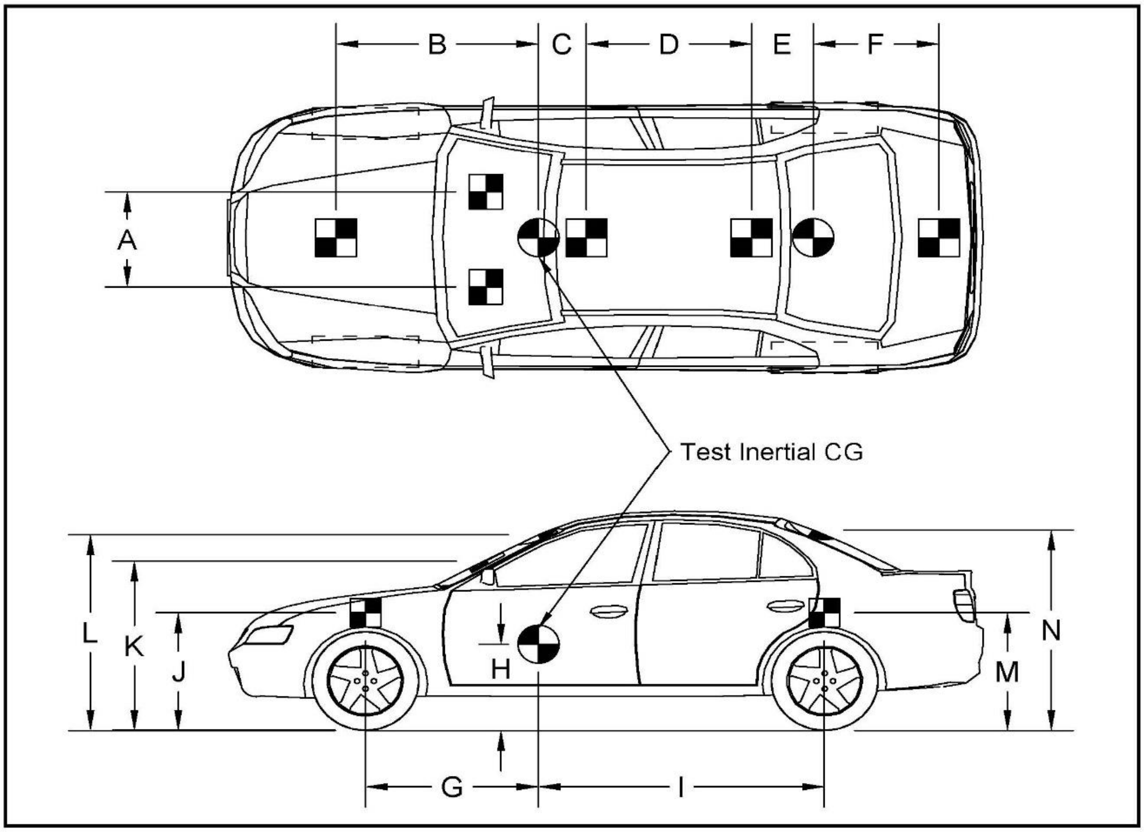
Additionally, it should be noted that the vehicle hood height denoted for the vehicle in test no. MSPBN-6 did not meet the hood height requirements in MASH. The hood height measurement has been an issue in recent years due to changes in the vehicle hood geometry that have altered the hood line but not the basic vehicle front end structure. As such, the hood height denoted herein was not considered an issue for full-scale testing. Recently, testing laboratories have agreed to measure hood height relative to the top of the radiator mount for consistency and improved compliance with MASH guidelines. However, that guidance was not available at the time of this testing.

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [16] was used to determine the vertical component of the c.g. for the 2270P vehicles. This method is based on the principle that the c.g. of any freely suspended body is in the vertical plane through the point of suspension. The vehicle was suspended successively in three positions, and the respective planes containing the c.g. were established. The intersection of these planes pinpointed the final c.g. location for the test inertial condition. The vertical component of the c.g. for the 1100C vehicles was determined utilizing a procedure published by SAE [17]. The location of the final c.g. is shown in Figures 3, 6, 9, 12, and 15. Data used to calculate the location of the c.g. and ballast information are shown in Appendix A.

Square, black- and white-checkered targets were placed on the vehicles for reference to be viewed from the high-speed digital video cameras and aid in the video analysis, as shown in Figures 16 through 20. Round, checkered targets were placed at the c.g. on the left-side door, the right-side door, and the roof of the vehicles.

The front wheels of the test vehicles were aligned to vehicle standards, except the toe-in value was adjusted to zero such that the vehicles would track properly along the guide cable. A 5B flash bulb was mounted under the vehicles' right-side windshield wiper for test nos. MSPBN-4, MSPBN-6, and MSPBN-7 and under the vehicle's left-side windshield wiper for test nos. MSPBN-5 and MSPBN-8. The bulb 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 digital videos. A remote-controlled brake system was installed in the test vehicles so the vehicles could be brought safely to a stop after the test.

Date:	4/18/2018	Test Name:	MSPBN-4	VIN:	KNADE223496469475
Year:	2009	Make:	KIA	Model:	RIO



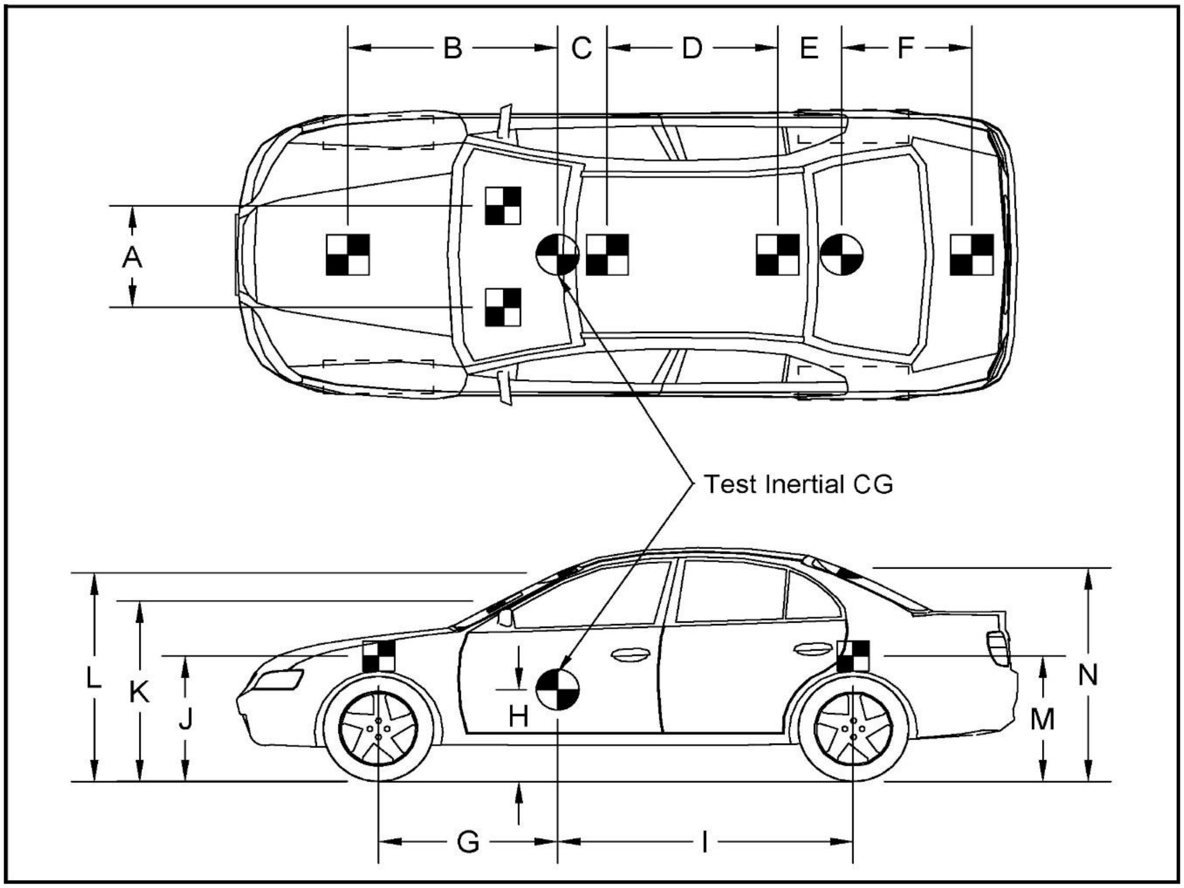
TARGET GEOMETRY-- in. (mm)

A:	24 1/8 (613)	F:	23 1/2 (597)	K:	48 (1219) Windshield Target
B:	42 (1067)	G:	36 1/16 (916)	L:	53 3/16 (1351) Front round CG target
C:	14 1/2 (368)	H:	10 7/8 (276)	M:	29 1/4 (743)
D:	31 (787)	I:	62 1/4 (1581)	N:	53 5/16 (1354) Rear Round target
E:	14 1/4 (362)	J:	29 3/4 (756)		

Figure 16. Target Geometry, Test No. MSPBN-4

Date: 5/14/2018 **Test Name:** MSPBN-5 **VIN:** KMHCN46C39U386700

Year: 2009 **Make:** ACCENT **Model:** HYUNDAI

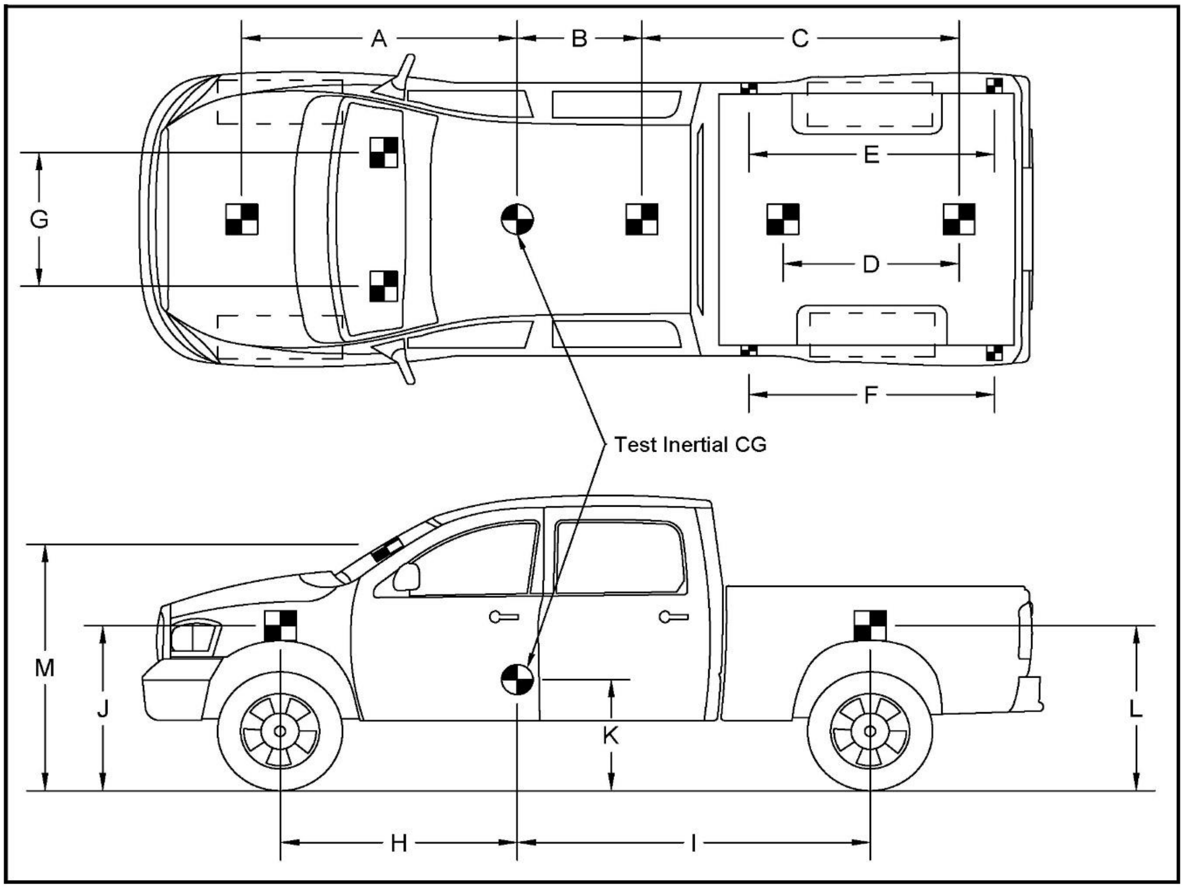


TARGET GEOMETRY-- in. (mm)

A:	24 3/4 (629)	F:	22 1/2 (572)	K:	47 1/4 (1200) Windshield Target
B:	43 1/4 (1099)	G:	36 1/4 (921)	L:	52 1/2 (1334) Front round CG target
C:	12 7/8 (327)	H:	22 7/8 (581)	M:	30 1/8 (765)
D:	35 1/8 (892)	I:	62 3/8 (1584)	N:	52 1/2 (1334) Rear Round target
E:	16 1/2 (419)	J:	30 1/8 (765)		

Figure 17. Target Geometry, Test No. MSPBN-5

Date:	5/24/2018	Test Name:	MSPBN-6	VIN:	1C6RD6KT3CS268370
Year:	2012	Make:	Dodge	Model:	Ram 1500

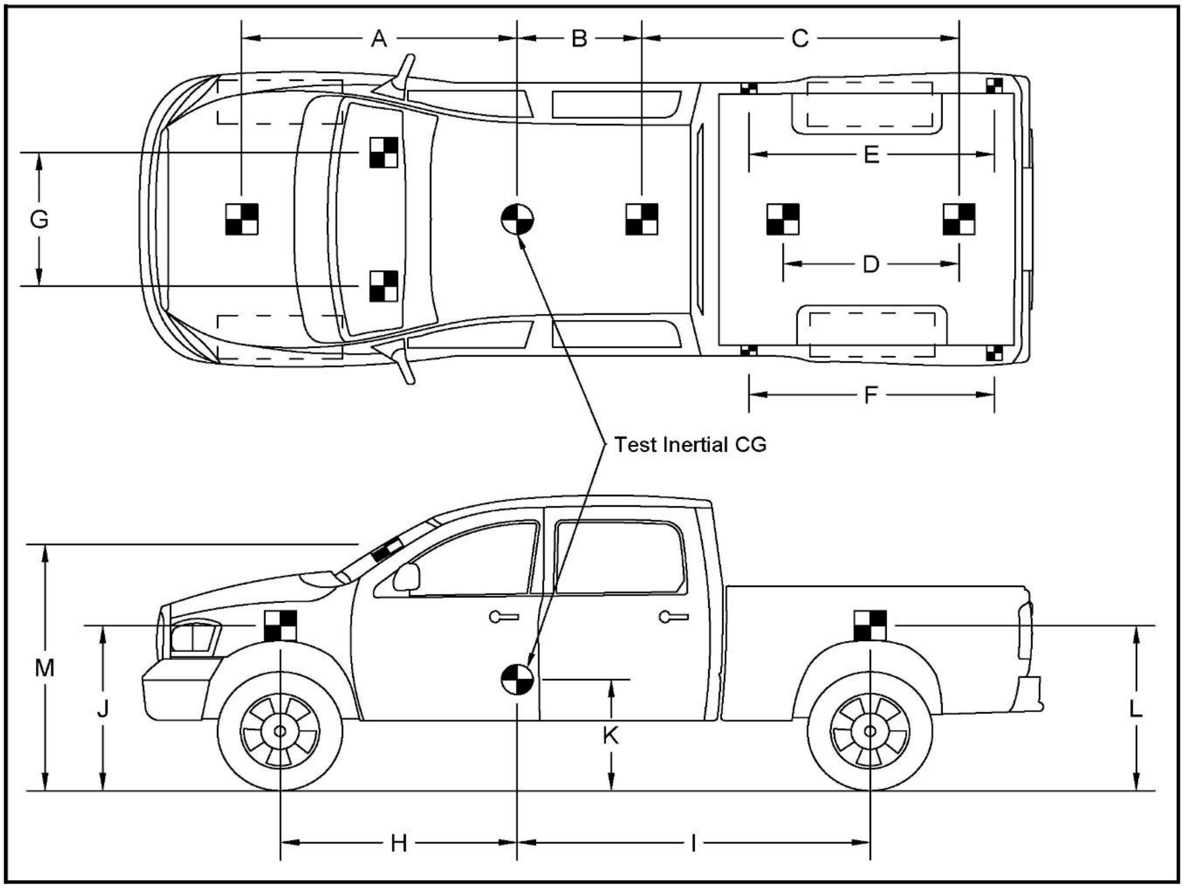


TARGET GEOMETRY-- in. (mm)

A:	75 1/2 (1918)	E:	53 5/8 (1362)	J:	41 (1041)
B:	32 1/2 (826)	F:	54 (1372)	K:	29 3/8 (746)
C:	64 1/4 (1632)	G:	33 1/4 (845)	L:	43 (1092)
D:	21 1/8 (537)	H:	61 1/4 (1556)	M:	64 1/4 (1632)
		I:	78 5/8 (1997)		

Figure 18. Target Geometry, Test No. MSPBN-6

Date:	6/5/2018	Test Name:	MSPBN7	VIN:	1C6RD6KT4CS197048
Year:	2012	Make:	Dodge	Model:	Ram 1500

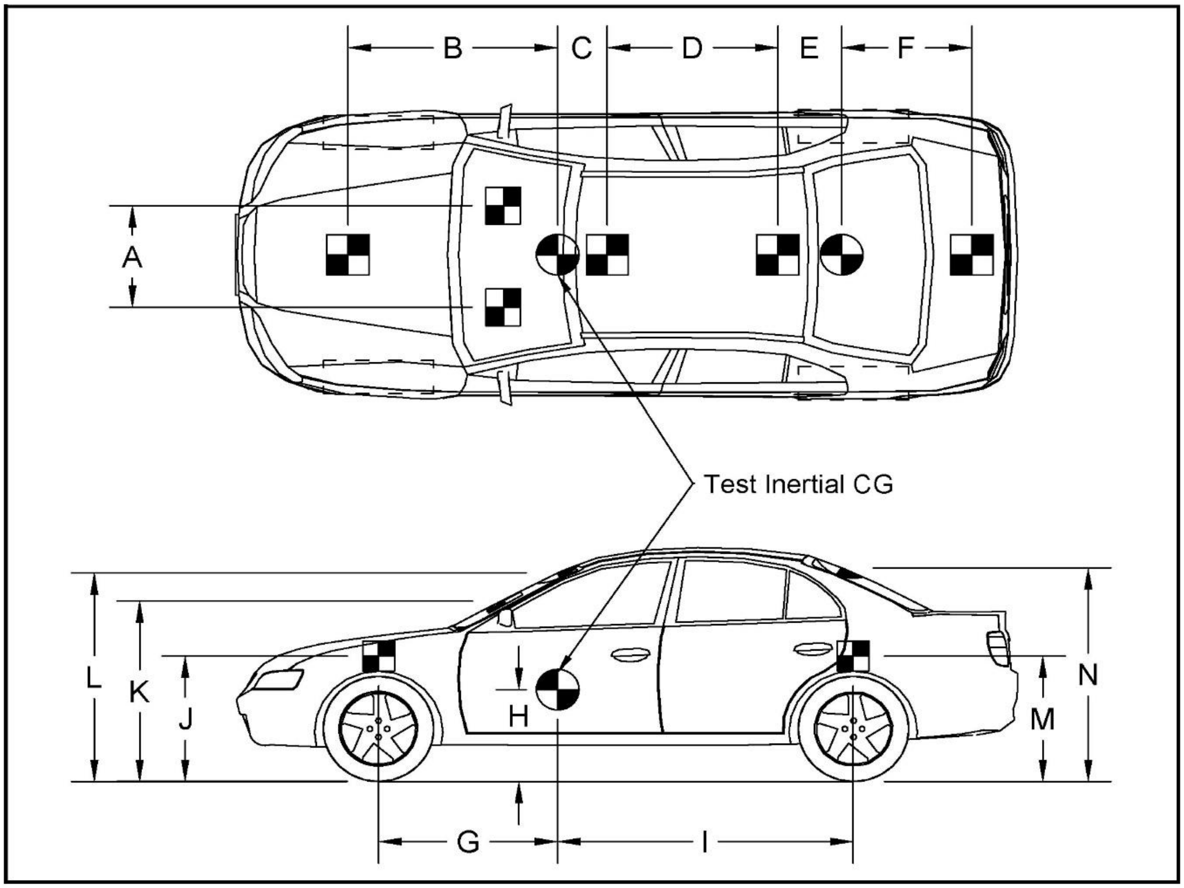


TARGET GEOMETRY-- in. (mm)

A:	75 1/2	(1918)	E:	54 1/2	(1384)	J:	40 1/4	(1022)
B:	31 1/2	(800)	F:	54 1/2	(1384)	K:	29 1/16	(738)
C:	70	(1778)	G:	34 1/2	(876)	L:	42 1/2	(1080)
D:	30 3/8	(772)	H:	61 9/16	(1564)	M:	66 1/4	(1683)
			I:	79	(2007)			

Figure 19. Target Geometry, Test No. MSPBN-7

Date:	8/29/2018	Test Name:	MSPBN-8	VIN:	kmhcn4ac3bu533692
Year:	2011	Make:	Hyundai	Model:	Accent



TARGET GEOMETRY-- in. (mm)

A:	27 5/8 (702)	F:	24 1/8 (613)	K:	48 3/8 (1229) Windshield Target
B:	44 7/8 (1140)	G:	36 1/2 (927)	L:	52 7/8 (1343) Front round CG target
C:	13 (330)	H:	22 1/2 (572)	M:	29 1/4 (743)
D:	32 1/4 (819)	I:	62 1/4 (1581)	N:	52 3/4 (1340) Rear Round target
E:	17 1/4 (438)	J:	29 1/2 (749)		

Figure 20. Target Geometry, Test No. MSPBN-8

3.4 Simulated Occupant

A Hybrid II 50th-Percentile, Adult Male Dummy, equipped with footwear, was placed in the left-front seat of the test vehicle for test nos. MSPBN-4 and MSPBN-5 and the right-front seat for test nos. MSPBN-6, MSPBN-7, and MSPBN-8, with the seatbelt fastened. The simulated occupant had a final weight of 163 lb (73.9 kg), 164 lb (74.4 kg), 160 lb (72.6 kg), 159 lb (72.1 kg), and 163 lb (73.9 kg) for test nos. MSPBN-4, MSPBN-5, MSPBN-6, MSPBN-7, and MSPBN-8, respectively. As recommended by MASH 2016, the simulated occupant was not included in calculating the c.g. location. simulated occupant weight was not included in calculating the c.g. location.

3.5 Data Acquisition Systems

3.5.1 Accelerometers

Two environmental shock and vibration sensor/recorder systems were used to measure the accelerations in the longitudinal, lateral, and vertical directions in each of the five tests. All accelerometers systems were mounted near the c.g. of the test vehicles. The electronic accelerometer data obtained in dynamic testing was filtered using the SAE Class 60 and the SAE Class 180 Butterworth filter conforming to the SAE J211/1 specifications [18]. Test no. MSPBN-4 used SLICE-1 and DTS units, while test nos. MSPBN-5 through MSPBN-8 used SLICE 1 and SLICE 2-units.

The first two systems, the SLICE-1 and SLICE-2 units, were modular data acquisition systems manufactured by Diversified Technical Systems, Inc. (DTS) of Seal Beach, California. The SLICE-1 unit was designated as the primary system for test nos. MSPBN-4, MSPBN-5, and MSPBN-8. SLICE-2 was the primary system for test nos. MSPBN-6 and MSPBN-7. The acceleration sensors were mounted inside the bodies of custom-built, SLICE 6DX event data recorders and recorded data at 10,000 Hz to the onboard microprocessor. Each SLICE 6DX was configured with 7 GB of non-volatile flash memory, a range of ±500 g's, a sample rate of 10,000 Hz, and a 1,650 Hz (CFC 1000) anti-aliasing filter. The "SLICEWare" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

The third accelerometer system, DTS, 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. The accelerometers were configured and controlled using a system developed and manufactured by 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 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.

3.5.2 Rate Transducers

Two identical angular rate sensor systems mounted inside the bodies of the SLICE-1 and SLICE-2 event data recorders were used to measure the rates of rotation of the test vehicle. Each SLICE MICRO Triax ARS had a range of 1,500 degrees/sec in each of the three directions (roll, pitch, and yaw) and recorded data at 10,000 Hz to the onboard microprocessors. The raw data measurements were then downloaded, converted to the proper Euler angles for analysis, and plotted. The “SLICEWare” computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the angular rate sensor data.

A third angular 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 in test no. MSPBN-4. The angular rate sensor was mounted on an aluminum block inside the test vehicle near the c.g. and recorded data at 10,000 Hz to the DTS 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.

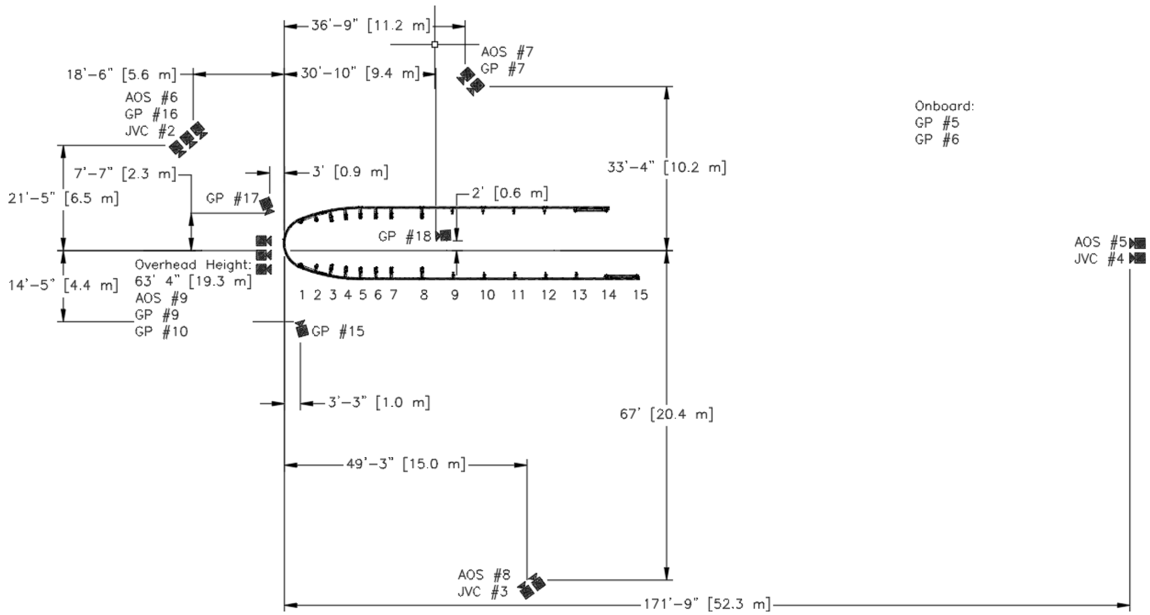
3.5.3 Retroreflective Optic Speed Trap

The retroreflective optic speed trap was used to determine the speed of the test vehicle before impact. Five retroreflective targets, spaced at approximately 18-in. (457-mm) intervals, were applied to the side of the vehicles. When the emitted beam of light was reflected by the targets and returned to the Emitter/Receiver, a signal was sent to the data acquisition computer, recording at 10,000 Hz, as well as the external LED box activating the LED flashes. The speed was then calculated using the spacing between the retroreflective targets and the time between the signals. LED lights and high-speed digital video analysis are only used as a backup in the event that vehicle speeds cannot be determined from the electronic data.

3.5.4 Digital Photography

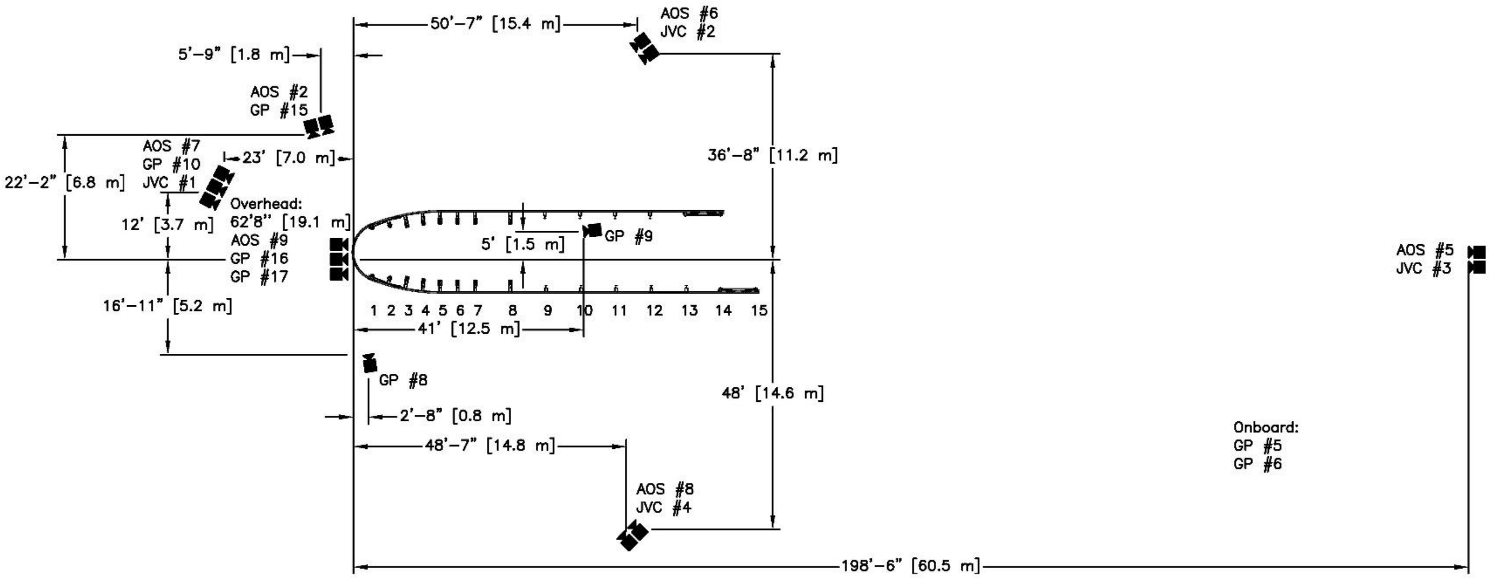
Five AOS high-speed digital video cameras, nine GoPro digital video cameras, and three JVC digital video cameras were utilized to film test no. MSPBN-4. Six AOS high-speed digital video cameras, eight GoPro digital video cameras, and four JVC digital video cameras were utilized to film test no. MSPBN-5. Six AOS high-speed digital video cameras, eleven GoPro digital video cameras, and one JVC digital video camera were utilized to film test no. MSPBN-6. Five AOS high-speed digital video cameras, twelve GoPro digital video cameras, and two JVC digital video cameras were utilized to film test no. MSPBN-7. Nine AOS high-speed digital video cameras, thirteen GoPro digital video cameras, two Panasonic digital video cameras, and one SoloShot digital video camera were utilized to film test no. MSPBN-8. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the systems are shown in Figures 21 through 25 and Tables 3 and 4.

The high-speed videos were analyzed using TEMA Motion and Redlake MotionScope software programs. Actual camera speed and camera divergence factors were considered in the analysis of the high-speed videos. A digital still camera was also used to document pre- and post-test conditions for all tests.



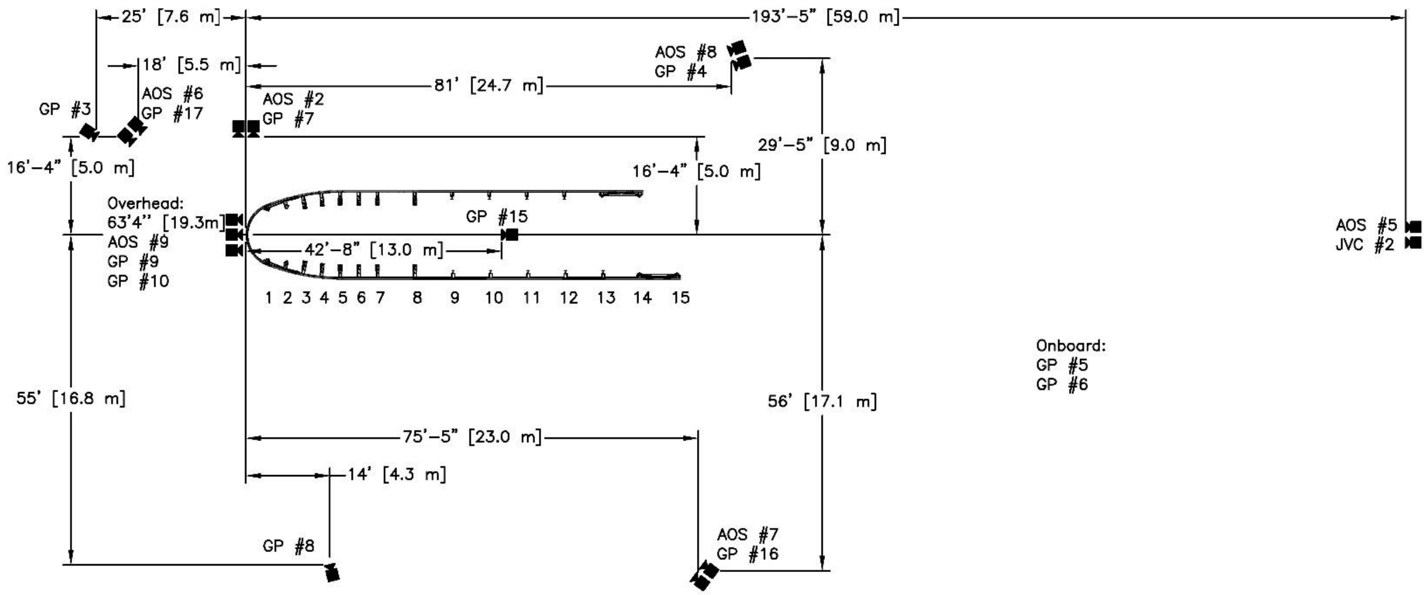
No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-5	AOS X-PRI	500	Cannon TV Zoom 17-102	102
AOS-6	AOS X-PRI	500	KOWA 25mm fixed	-
AOS-7	AOS X-PRI	500	SIGMA 28-70	28
AOS-8	AOS S-VIT 1531	500	SIGMA 28-70 DG	35
AOS-9	AOS TRI-VIT 2236	1000	KOWA 12mm fixed	-
GP-5	GoPro Hero 3+	120		
GP-6	GoPro Hero 3+	120		
GP-7	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-10	GoPro Hero 4	120		
GP-15	GoPro Hero 4	120		
GP-16	GoPro Hero 4	120		
GP-17	GoPro Hero 4	120		
GP-18	GoPro Hero 4	120		
JVC-2	JVC – GZ-MC500 (Everio)	29.97		
JVC-3	JVC – GZ-MG27u (Everio)	29.97		
JVC-4	JVC – GZ-MG27u (Everio)	29.97		

Figure 21. Camera Locations, Speeds, and Lens Settings, Test No. MSPBN-4



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-2	AOS Vitcam	500	KOWA 25 mm	-
AOS-5	AOS X-PRI Gigabit	500	Telesar 135 mm	-
AOS-6	AOS X-PRI Gigabit	500	Fujinon 50 mm	-
AOS-7	AOS X-PRI Gigabit	500	Sigma 28-70	35
AOS-8	AOS S-VIT 1531	500	Sigma 28-70	35
AOS-9	AOS TRI-VIT 2236	500	KOWA 12 mm	-
GP-5	GoPro Hero 3+	120		
GP-6	GoPro Hero 3+	120		
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-10	GoPro Hero 4	240		
GP-15	GoPro Hero 4	120		
GP-16	GoPro Hero 4	240		
GP-17	GoPro Hero 4	120		
JVC-1	JVC – GZ-MC500 (Everio)	29.97		
JVC-2	JVC – GZ-MG27u (Everio)	29.97		
JVC-3	JVC – GZ-MG27u (Everio)	29.97		
JVC-4	JVC – GZ-MG27u (Everio)	29.97		

Figure 22. Camera Locations, Speeds, and Lens Settings, Test No. MSPBN-5



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-2	AOS Vitcam	500	KOWA 16 mm	-
AOS-5	AOS X-PRI Gigabit	500	100 mm	-
AOS-6	AOS X-PRI Gigabit	500	KOWA 25 mm	-
AOS-7	AOS X-PRI Gigabit	500	Fujinon 35 mm	-
AOS-8	AOS S-VIT 1531	500	Fujinon 50 mm	-
AOS-9	AOS TRI-VIT 2236	500	KOWA 12 mm	-
GP-3	GoPro Hero 3+ w/ Computar 12.5 mm	120		
GP-4	GoPro Hero 3+ w/ Computar 12.5 mm	120		
GP-5	GoPro Hero 3+	120		
GP-6	GoPro Hero 3+	120		
GP-7	GoPro Hero 4	30		
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	240		
GP-10	GoPro Hero 4	120		
GP-15	GoPro Hero 4	120		
GP-16	GoPro Hero 4	120		
GP-17	GoPro Hero 4	120		
JVC-2	JVC – GZ-MG27u (Everio)	29.97		

Figure 23. Camera Locations, Speeds, and Lens Settings, Test No. MSPBN-6

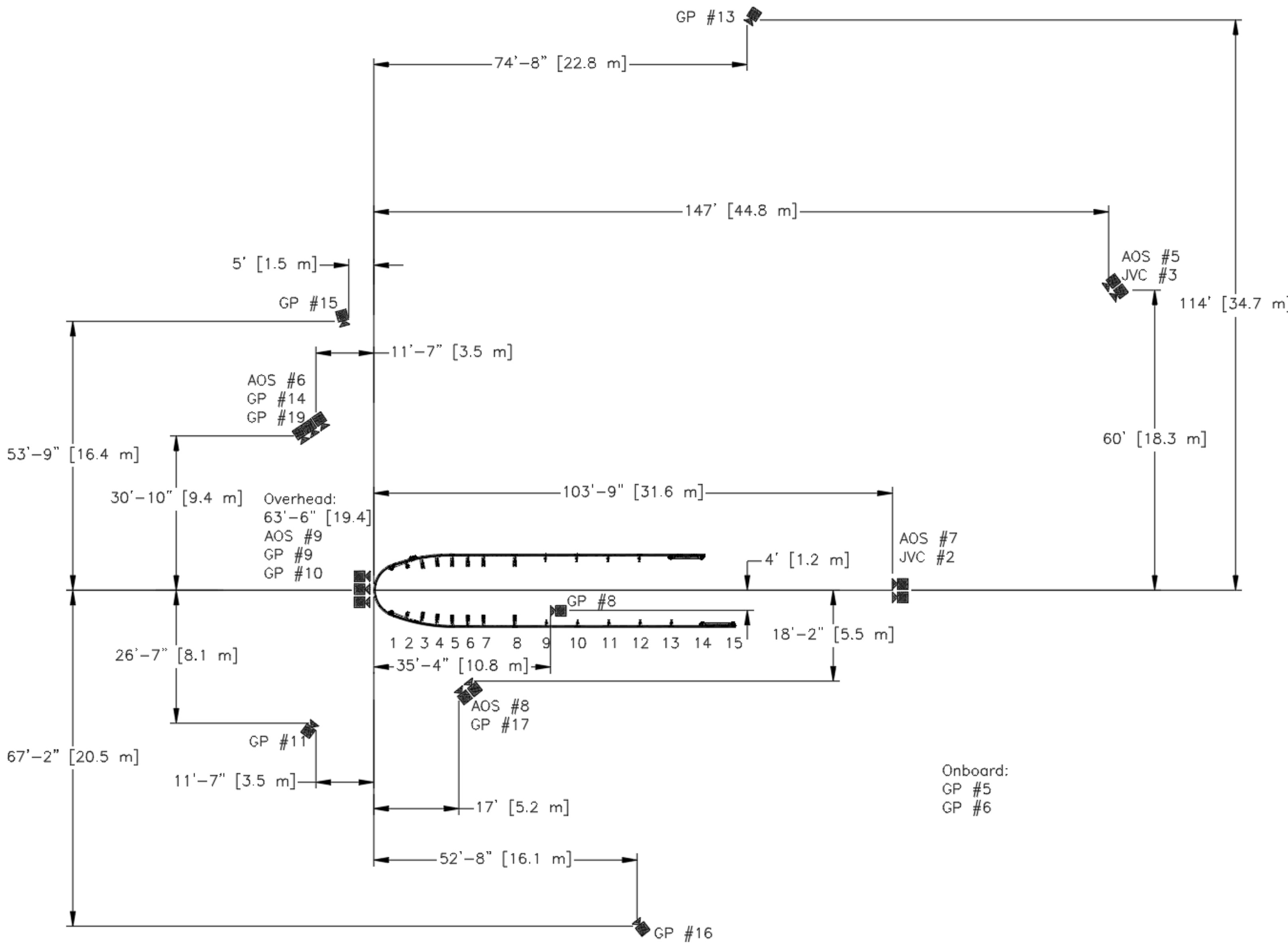


Figure 24. Camera Locations, Test No. MSPBN-7

Table 3. Camera Speeds and Lens Settings, Test No. MSPBN-7

No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-5	AOS X-PRI	500	100 mm fixed	-
AOS-6	AOS X-PRI	500	Fujinon 35 mm fixed	-
AOS-7	AOS X-PRI	500	Fujinon 50 mm fixed	-
AOS-8	AOS S-VIT 1531	500	KOWA 16 mm fixed	-
AOS-9	AOS TRI-VIT 2236	1000	KOWA 12mm fixed	-
GP-5	GoPro Hero 3+	120		
GP-6	GoPro Hero 3+	120		
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-10	GoPro Hero 4	120		
GP-11	GoPro Hero 4	240		
GP-13	GoPro Hero 4	240		
GP-14	GoPro Hero 4	240		
GP-15	GoPro Hero 4	240		
GP-16	GoPro Hero 4	120		
GP-17	GoPro Hero 4	120		
GP-19	GoPro Hero 6	120		
JVC-2	JVC – GZ-MC500 (Everio)	30		
JVC-3	JVC – GZ-MG27u (Everio)	30		

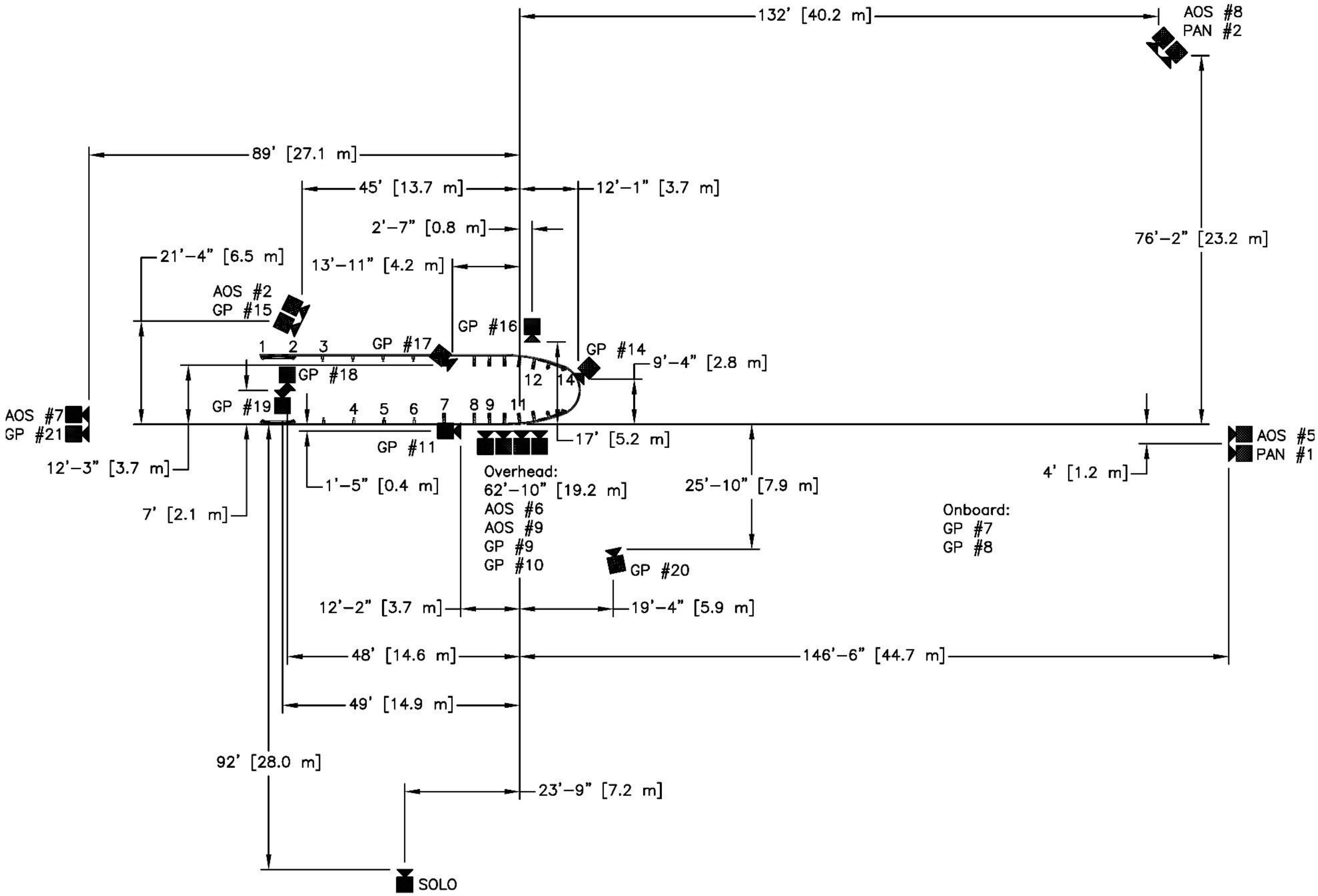


Figure 25. Camera Locations, Test No. MSPBN-8

Table 4. Camera Speeds and Lens Settings, Test No. MSPBN-8

No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-1	AOS Vitcam	500		-
AOS-2	AOS Vitcam	500	Sigma 28-70	50
AOS-3	AOS Vitcam	500		-
AOS-4	AOS Vitcam	500		-
AOS-5	AOS X-PRI	500	100 mm	-
AOS-6	AOS X-PRI	500	KOWA 16 mm	-
AOS-7	AOS X-PRI	500	Fujinon 50 mm	-
AOS-8	AOS S-VIT 1531	500	SIGMA 28-70	70
AOS-9	AOS TRI-VIT 2236	500	KOWA 12mm fixed	-
GP-7	GoPro Hero 4	120		
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-10	GoPro Hero 4	120		
GP-11	GoPro Hero 4	240		
GP-14	GoPro Hero 4	240		
GP-15	GoPro Hero 4	240		
GP-16	GoPro Hero 4	240		
GP-17	GoPro Hero 4	240		
GP-18	GoPro Hero 6	120		
GP-19	GoPro Hero 6	120		
GP-20	GoPro Hero 6	120		
GP-21	GoPro Hero 6	120		
PAN-1	Panisonic HC-V770	60		
PAN-2	Panisonic HC-V770	60		
SOLO	SoloShot	120		

4 DESIGN DETAILS, TEST NO. MSPBN-4

The barrier system for test no. MSPBN-4 consisted of a bullnose median barrier utilizing UBSPs, as shown in Figures 26 through 49. Photographs of the test installation are shown in Figure 50 through Figure 54. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

A one-half barrier system was utilized for the testing program in order to reduce costs and construction time. Note that a dual-cable end anchorage system was used on each free end of the bullnose system to provide tensile and compressive resistance at the end of the one-half barrier system, thus mimicking the behavior of a complete installation. The bullnose system was constructed with twenty-nine posts, which included fifteen posts on Side A and fourteen posts positioned on Side B. Side A of the system was slightly longer to span a below grade obstruction located at the test site that prevented installation of the BCT foundation tubes. Side A of the system contained two BCT posts, six UBSP posts, five W6x8.5 (W152x12.6) standard guardrail posts, and two BCT anchorage posts, respectively, from the nose of the system. Side B 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 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 upper and lower halves of the UBSP were connected with a series of four bolts that were designed to allow the upper portion of the post to disengage at specific force levels when loaded in the lateral and longitudinal directions.

The bullnose system was constructed with the rail lap splices oriented based on the traffic flow on each side of the system, such that the upstream rail segment overlapped the downstream rail segment. All of the full-scale crash testing for the thrie-beam bullnose system detailed herein was conducted on a splice configuration for median installations. Thus, for a median installation, the thrie-beam bullnose lap splicing proceeded in a continuous manner all the way around the system in the direction of oncoming traffic.

Two minor modifications were made to the UBSP as compared to iterations of the post design evaluated in previous research efforts [7-9, 19]. First, several weld sizes were altered for the welds connecting the W-section to the upper base plate and the tube to the lower base plate. These welds were reduced in size as the original welds were specified too large for the thickness of the welded parts and the additional weld was unnecessary. Thus, the weld connecting the top of the W6x8.5 post to the upper baseplate was changed to a ¼-in. (6-mm) fillet weld on the front and back of each post flange and to a $^{3}/_{16}$-in. (5-mm) fillet weld on each side of the web. The weld connecting the tube to the lower base plate was changed to a $^{3}/_{16}$-in. (5-mm) fillet weld that goes all the way around.

The second minor modification to the UBSP was a slight increase to the thickness of the base plate on the lower section of the post. Previous full-scale crash testing of systems with the UBSP demonstrated a tendency for deformations of the lower base plate during impacts. A slight increase in the thickness of the base plate was not expected to degrade the performance of the UBSP. However, it was anticipated that the thickness increase could prevent damage to the lower section of the UBSP and allow the lower section to be reused in an installation. Reuse of the base of the post would provide a significant reduction in the repair costs of the system by eliminating the need to dig up and replace the UBSP following an impact. Thus, the thickness of the base plate on the lower section of post was increased from ½ in. (13 mm) to ⅝ in. (16 mm).

All posts were embedded in coarse, crushed limestone, alternatively classified as well-graded gravel. The soil was compacted in 3-ft (914-mm) diameter augured holes using 8-in. (203-mm) lifts. 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.

Note that the downstream ends of the thrie-beam bullnose installation were configured with a bi-directional, trailing-end anchorage system. The guardrail anchorage system was utilized to simulate the anchorage tensile and compressive anchorage provided by continuous guardrail or attachment to an approach guardrail transition. The dual anchorage would not be required in a typical installation unless the bullnose system was configured with a free end similar to the test setup. The anchorage system consisted of timber posts, foundation tubes, anchor cables, bearing plates, rail brackets, and channel struts, which were components from the hardware used in a crashworthy, downstream ,trailing-end terminal [11-13].

It should also be noted that the cable anchor plate on bi-directional, trailing-end anchorage system for the thrie-beam bullnose system evaluated herein utilized two nails bent over the anchor plate to secure it from rotation. The original thrie-beam bullnose system was evaluated with only a single bent nail to limit rotation of the plate.

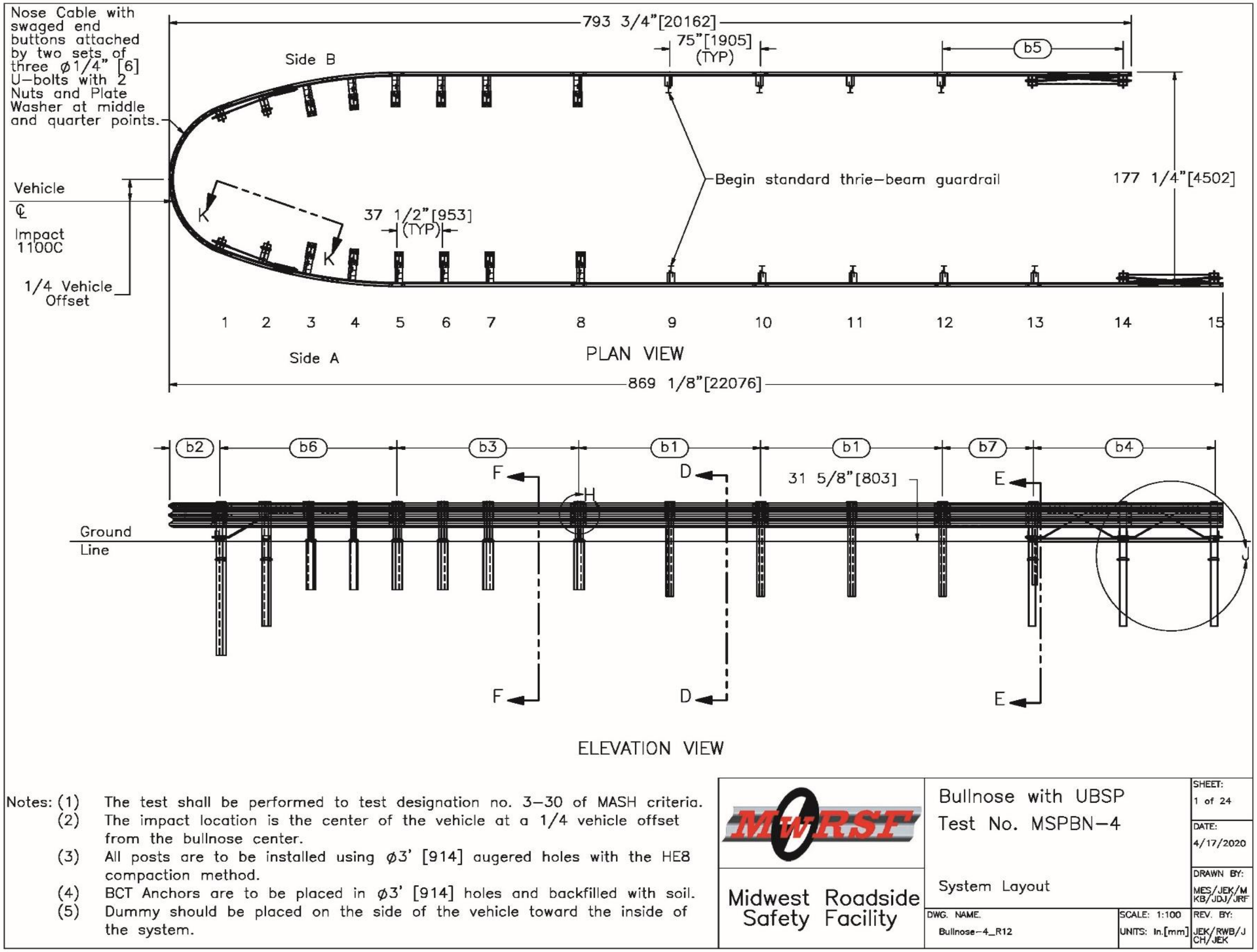


Figure 26. Test Installation Layout, Test No. MSPBN-4

Post No.	Side A				Side B			
	Rear Face–DS Edge		Rear Face–US Edge		Rear Face–DS Edge		Rear Face–US Edge	
	X	Y	X	Y	X	Y	X	Y
1	68'–1 7/8"	2'–3 1/8"	68'–7"	2'–5 1/8"	61'–10 7/8"	2'–3 1/8"	62'–4"	2'–5 1/8"
2	65'–0 3/4"	1'–11 1/4"	65'–6 1/8"	2'–0 3/4"	58'–9 3/4"	1'–11 1/4"	59'–3 1/8"	2'–0 3/4"
3	62'–1 1/4"	1'–9 3/8"	62'–5 1/8"	1'–10 1/8"	55'–10 1/4"	1'–9 3/8"	56'–2 1/8"	1'–10 1/8"
4	59'–2 1/4"	1'–4 3/8"	59'–6 1/8"	1'–4 3/4"	52'–11 1/4"	1'–4 3/4"	53'–3 1/8"	1'–4 3/4"
5	56'–3 3/4"	1'–2 3/8"	56'–7 3/4"	1'–2 3/8"	50'–0 3/4"	1'–2 3/8"	50'–4 3/4"	1'–2 3/8"
6	53'–2 1/4"	1'–2 3/8"	53'–6 1/4"	1'–2 3/8"	46'–11 1/4"	1'–2 3/8"	47'–3 1/4"	1'–2 3/8"
7	50'–0 3/4"	1'–2 3/8"	50'–4 3/4"	1'–2 3/8"	43'–9 3/4"	1'–2 3/8"	44'–1 3/4"	1'–2 3/8"
8	43'–9 3/4"	1'–2 3/8"	44'–1 3/4"	1'–2 3/8"	37'–6 3/4"	1'–2 3/8"	37'–10 3/4"	1'–2 3/8"
9	37'–6 3/4"	6 3/8"	37'–10 3/4"	6 3/8"	31'–3 3/4"	6 3/8"	31'–7 3/4"	6 3/8"
10	31'–3 3/4"	6 3/8"	31'–7 3/4"	6 3/8"	25'–0 3/4"	6 3/8"	25'–4 3/4"	6 3/8"
11	25'–0 3/4"	6 3/8"	25'–4 3/4"	6 3/8"	18'–9 3/4"	6 3/8"	19'–1 3/4"	6 3/8"
12	18'–9 3/4"	6 3/8"	19'–1 3/4"	6 3/8"	12'–6 3/4"	6 3/8"	12'–10 3/4"	6 3/8"
13	12'–6 3/4"	6 3/8"	12'–10 3/4"	6 3/8"	6'–3"	0"	6'–8 1/2"	0"
14	6'–3"	0"	6'–8 1/2"	0"	0"	0"	5 1/2"	0"
15	0"	0"	5 1/2"	0"	–	–	–	–

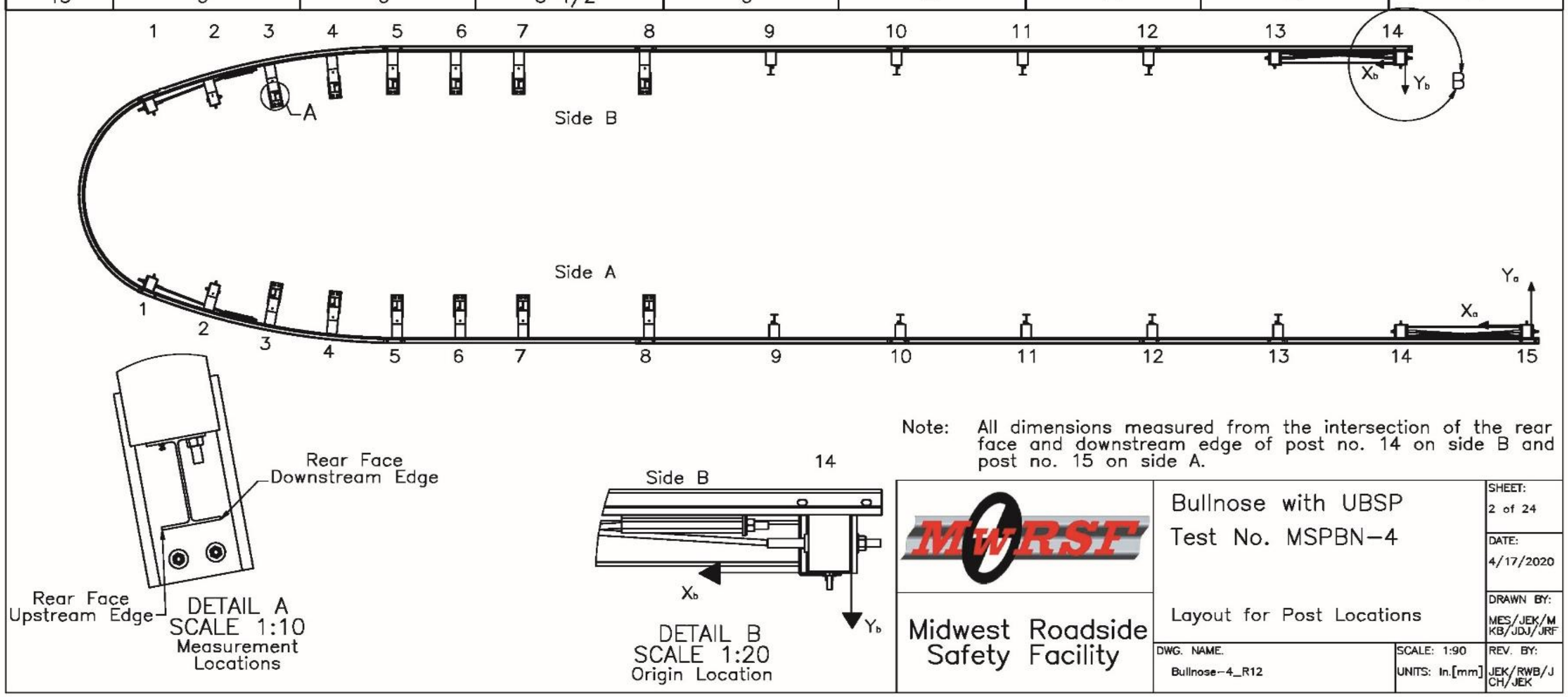


Figure 27. Layout for Post Locations, Test No. MSPBN-4

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

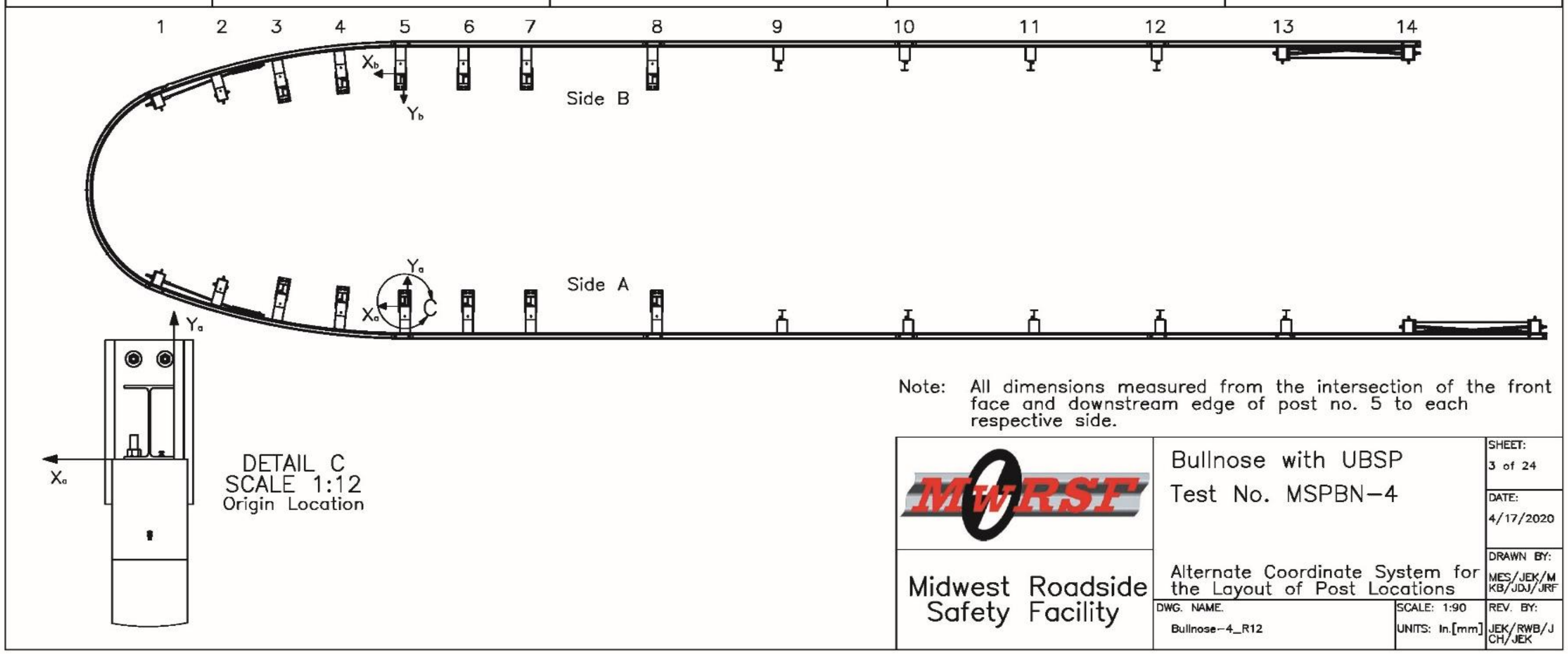


Figure 28. Alternate Coordinate System for the Layout of Post Locations, Test Nos. MSPBN-4

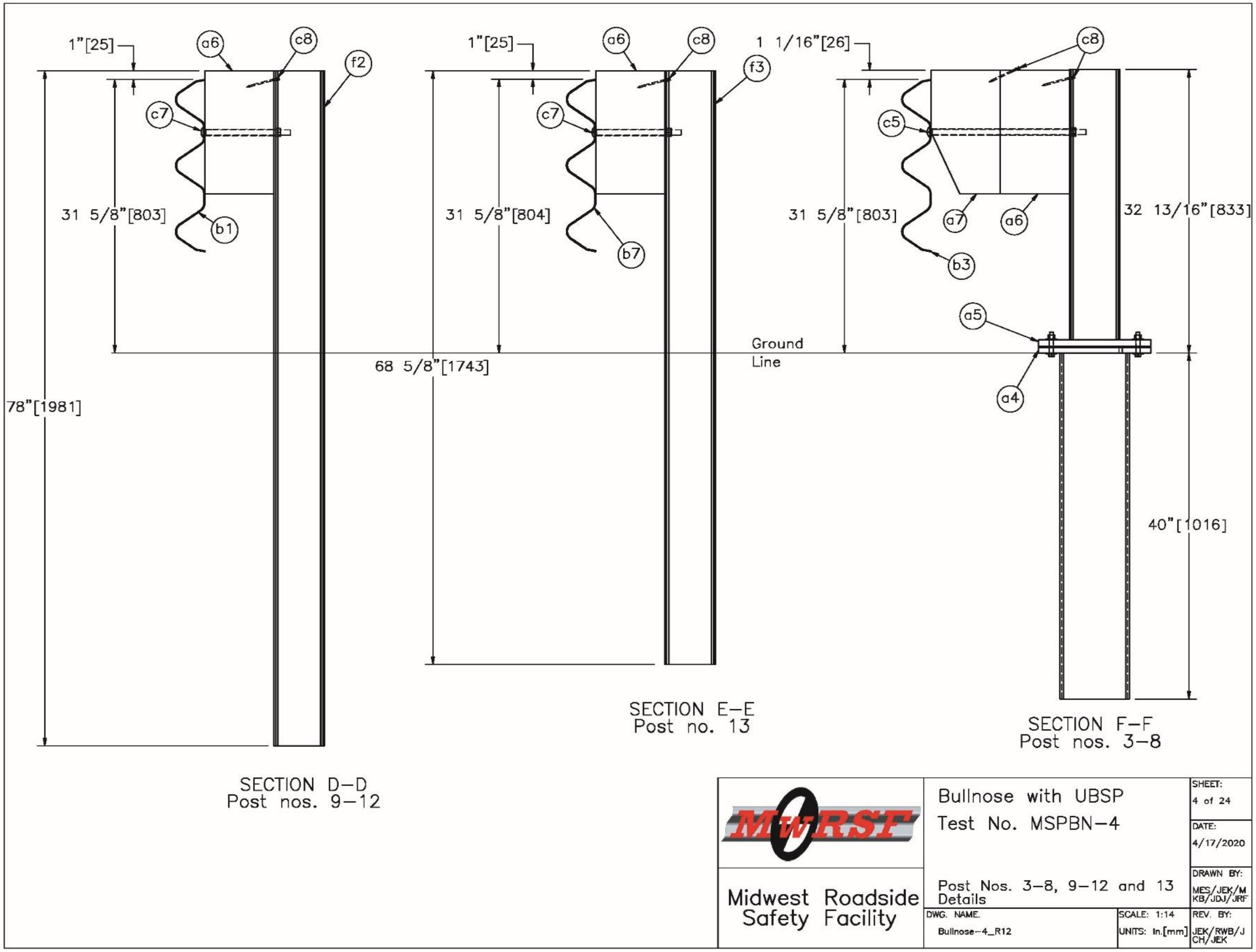


Figure 29. Post Nos. 3 through 8, 9 through 12, and 13 Details, Tests No. MSPBN-4

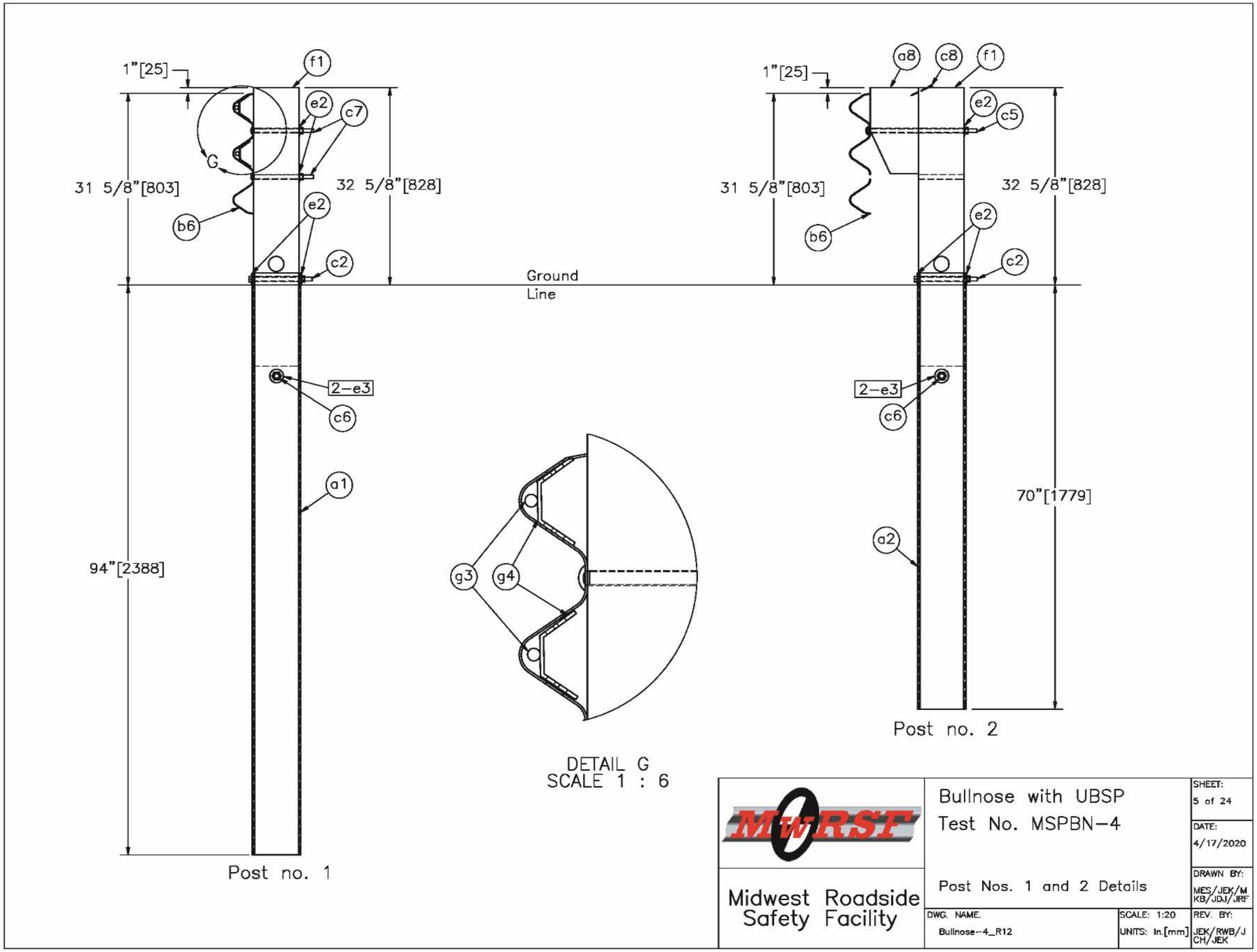


Figure 30. Post Nos. 1 and 2 Details, Tests No. MSPBN-4

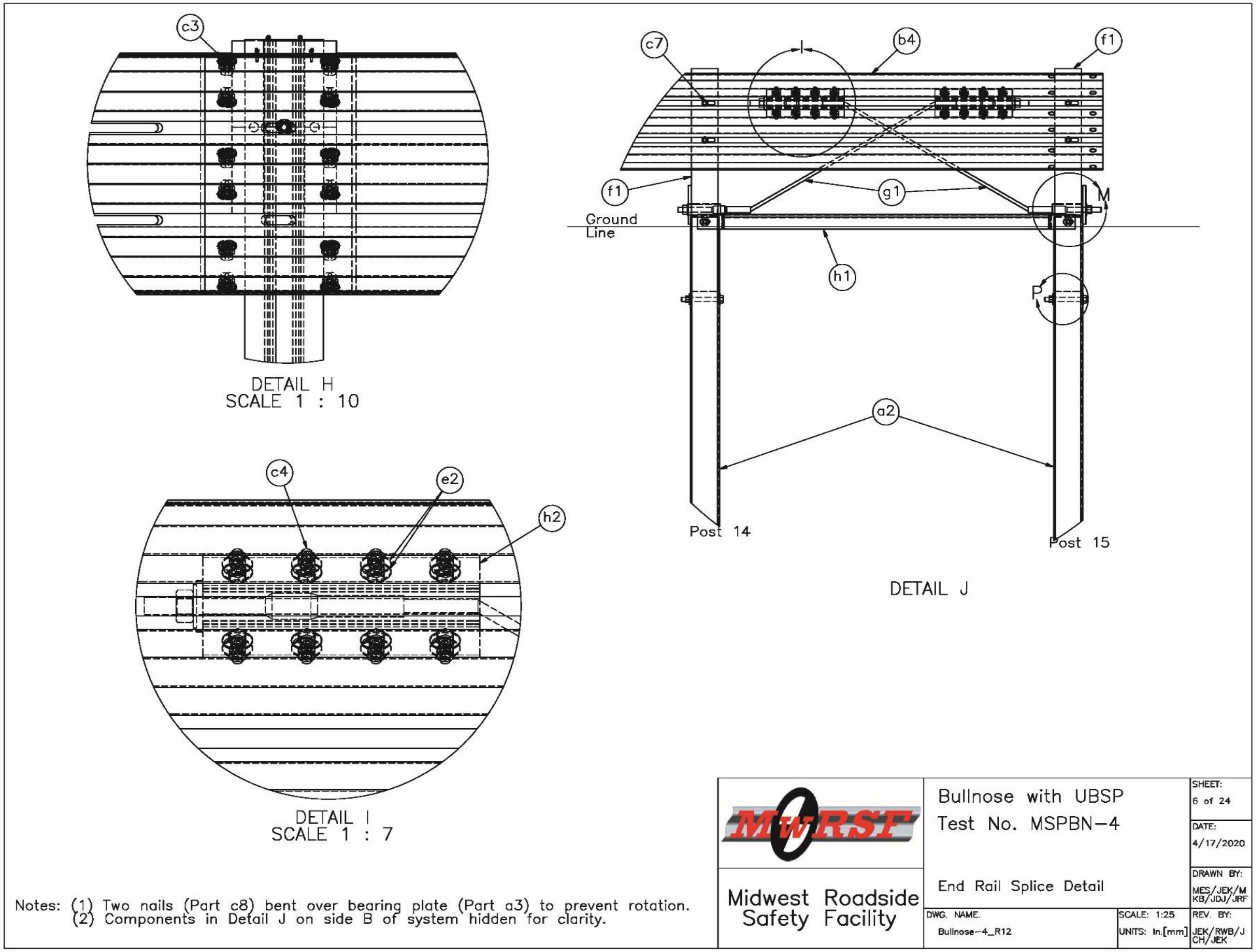


Figure 31. End Rail Splice Detail, Test No. MSPBN-4

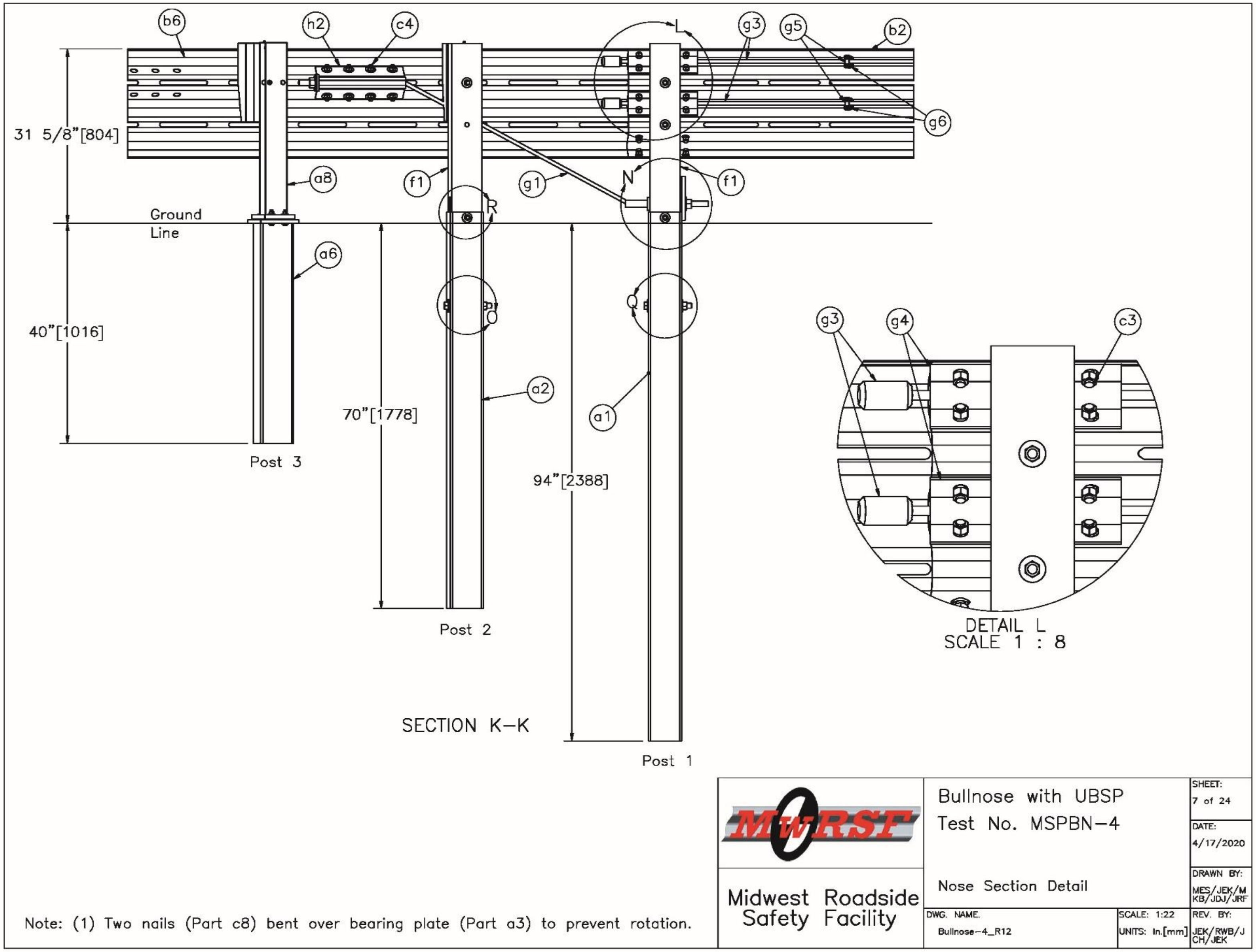


Figure 32. Nose Section Detail, Test No. MSPBN-4

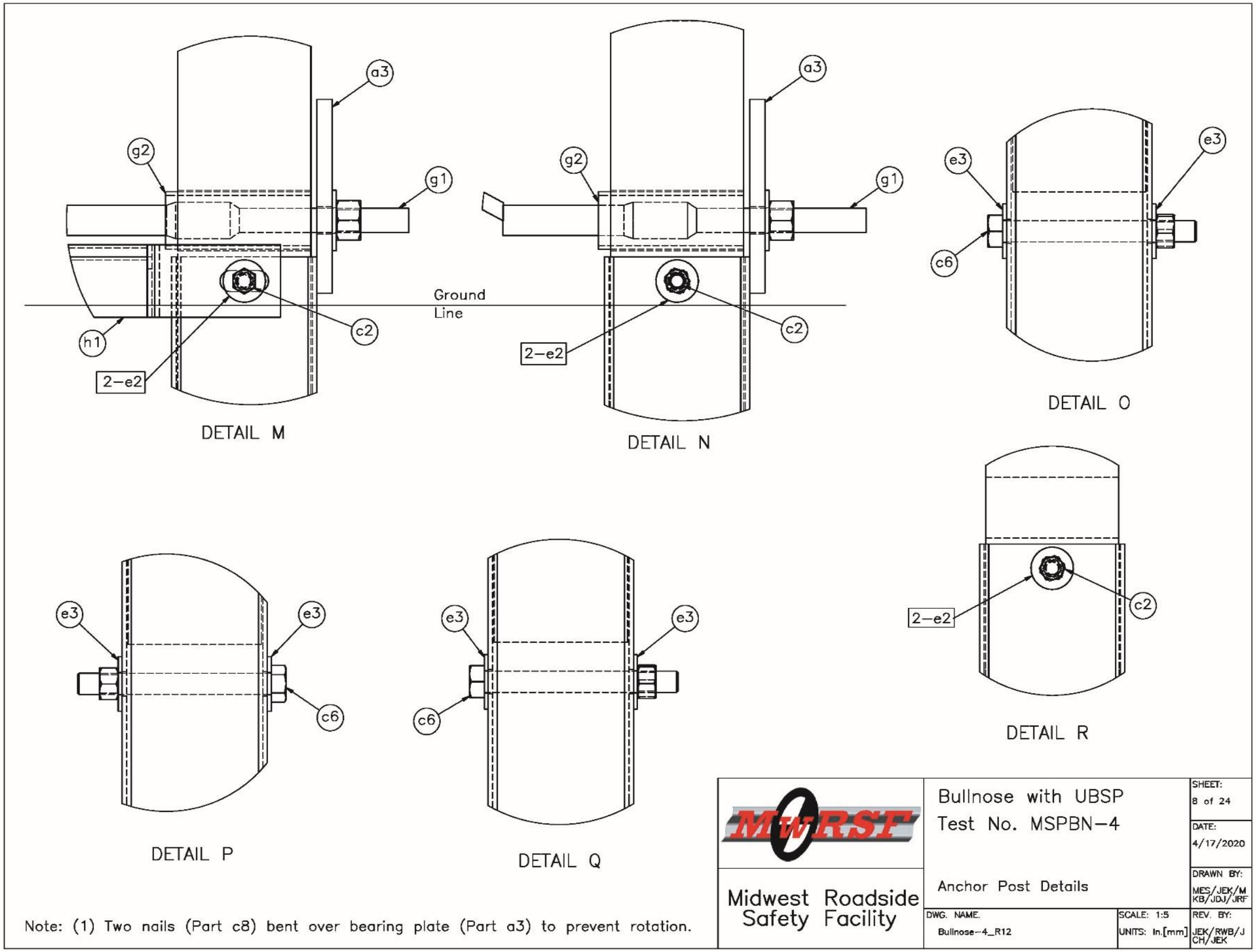


Figure 33. Anchor Post Details, Test No. MSPBN-4

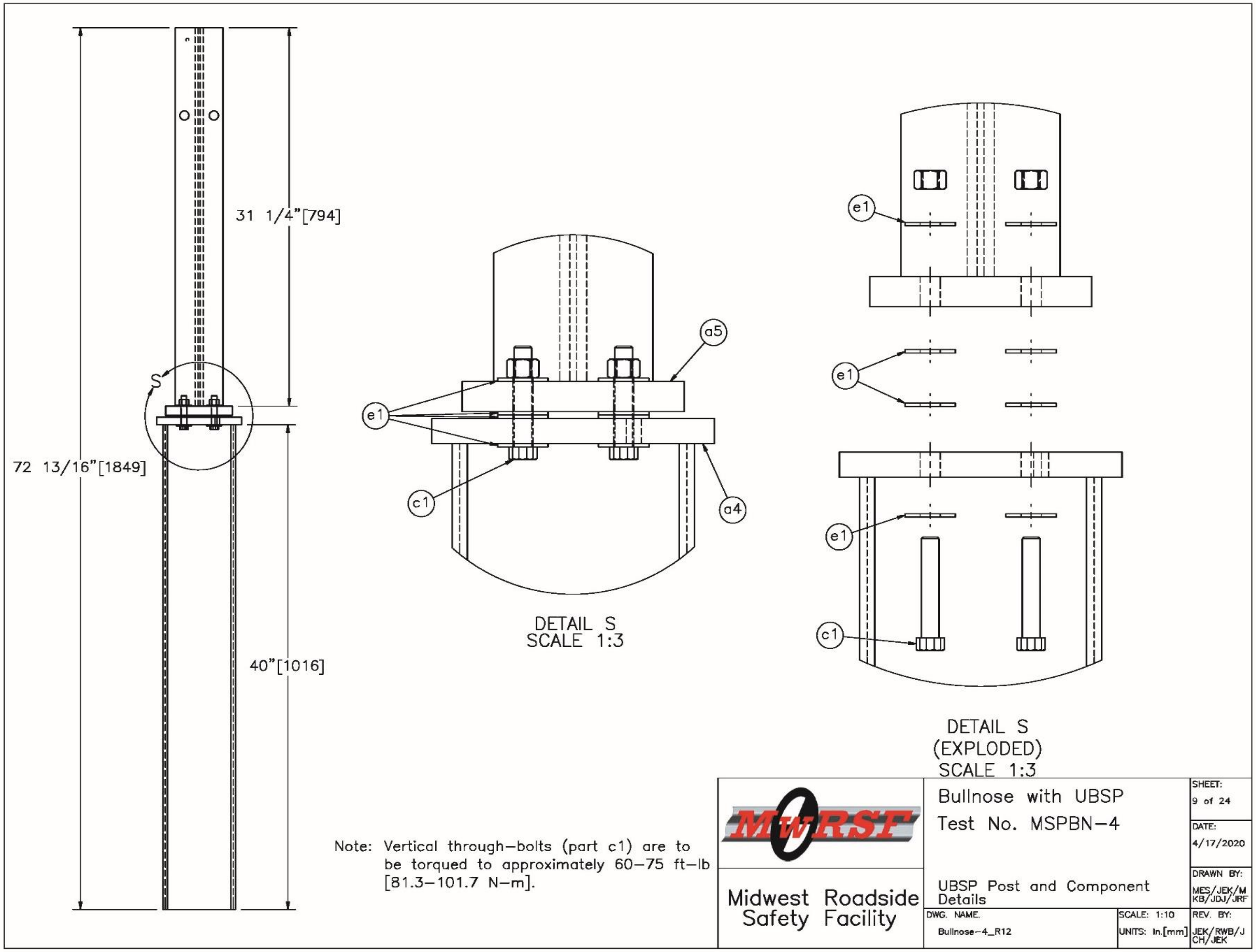


Figure 34. UBSP Post and Component Details, Test No. MSPBN-4

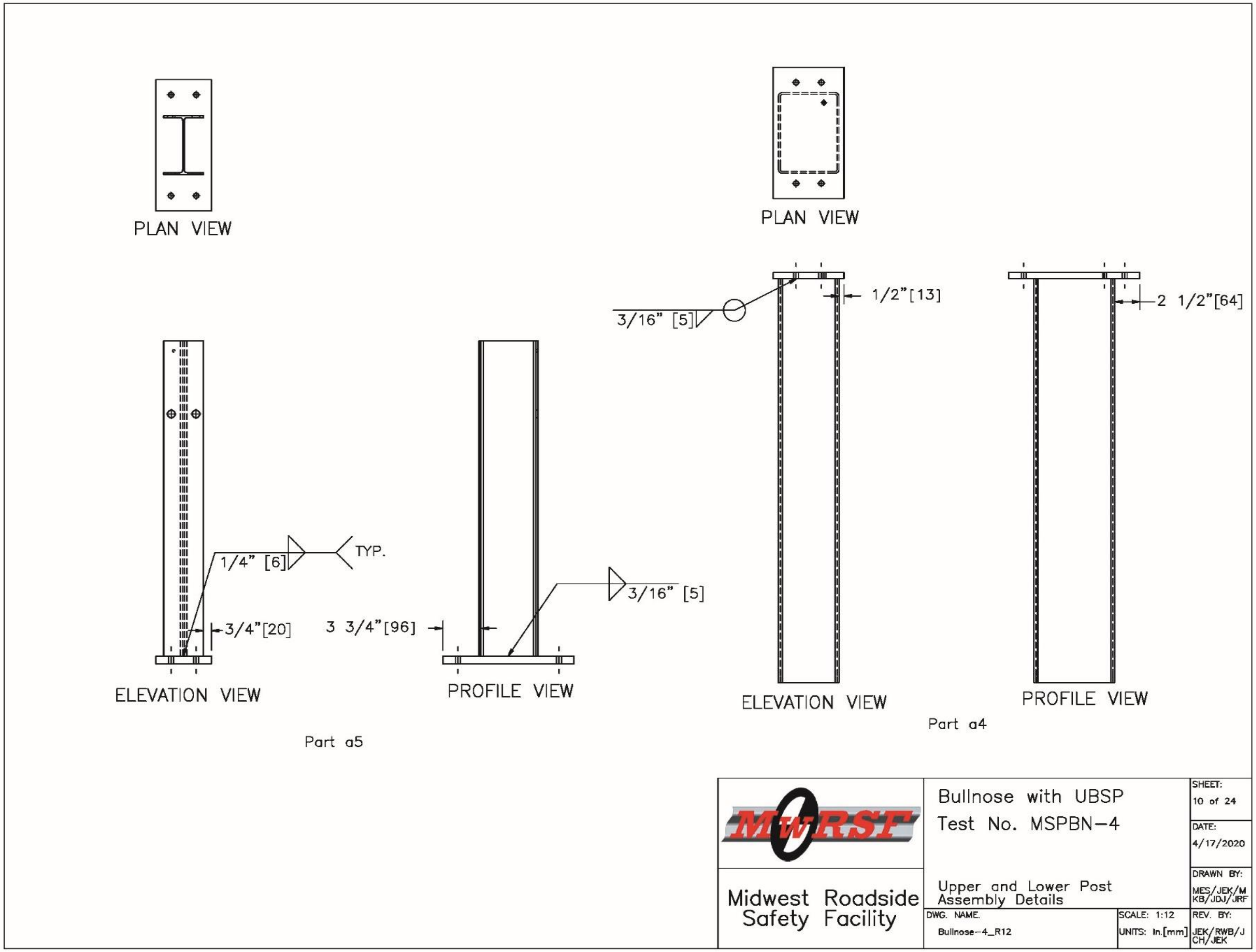


Figure 35. Upper and Lower Post Assembly Details, Test No. MSPBN-4

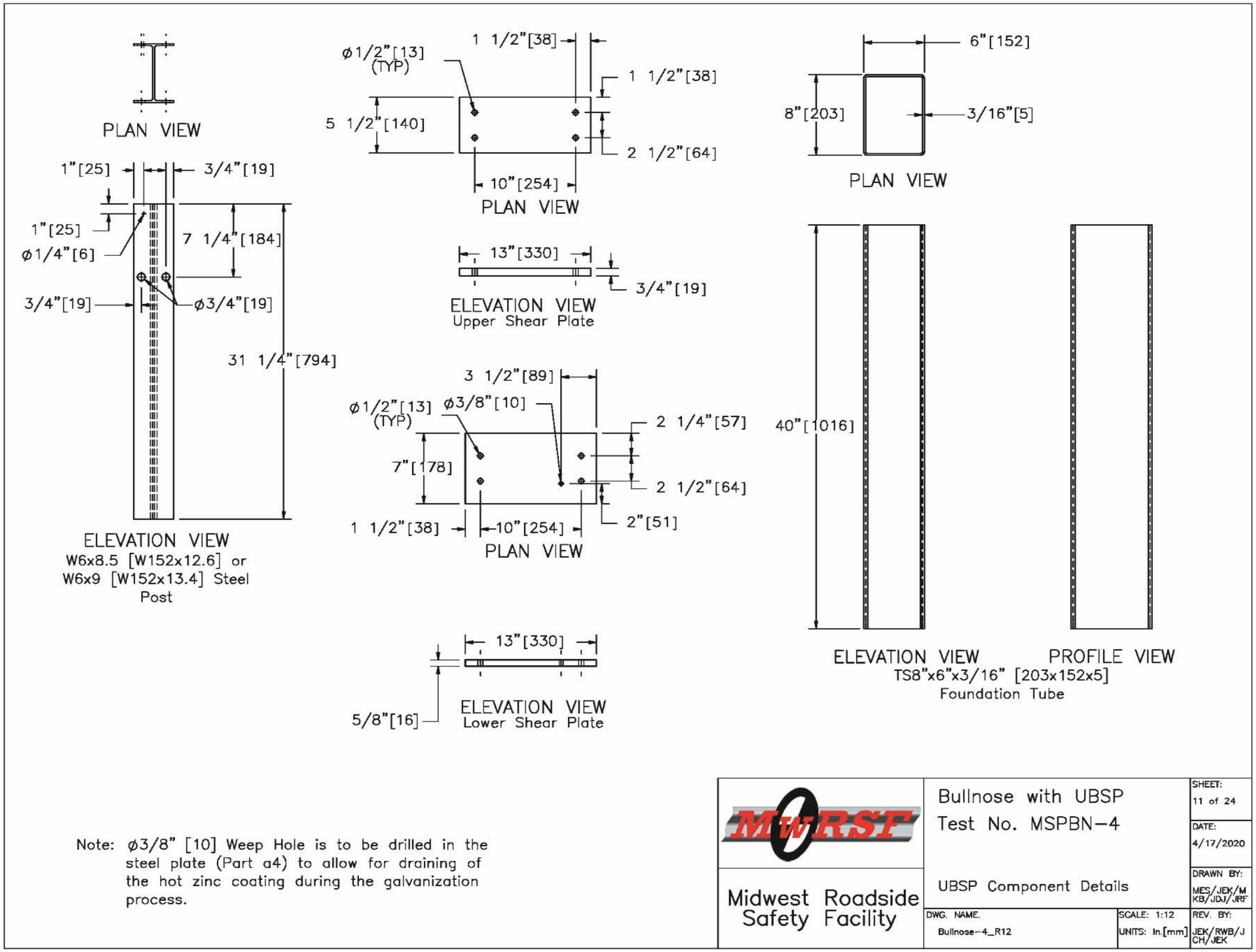


Figure 36. UBSP Component Details, Test No. MSPBN-4

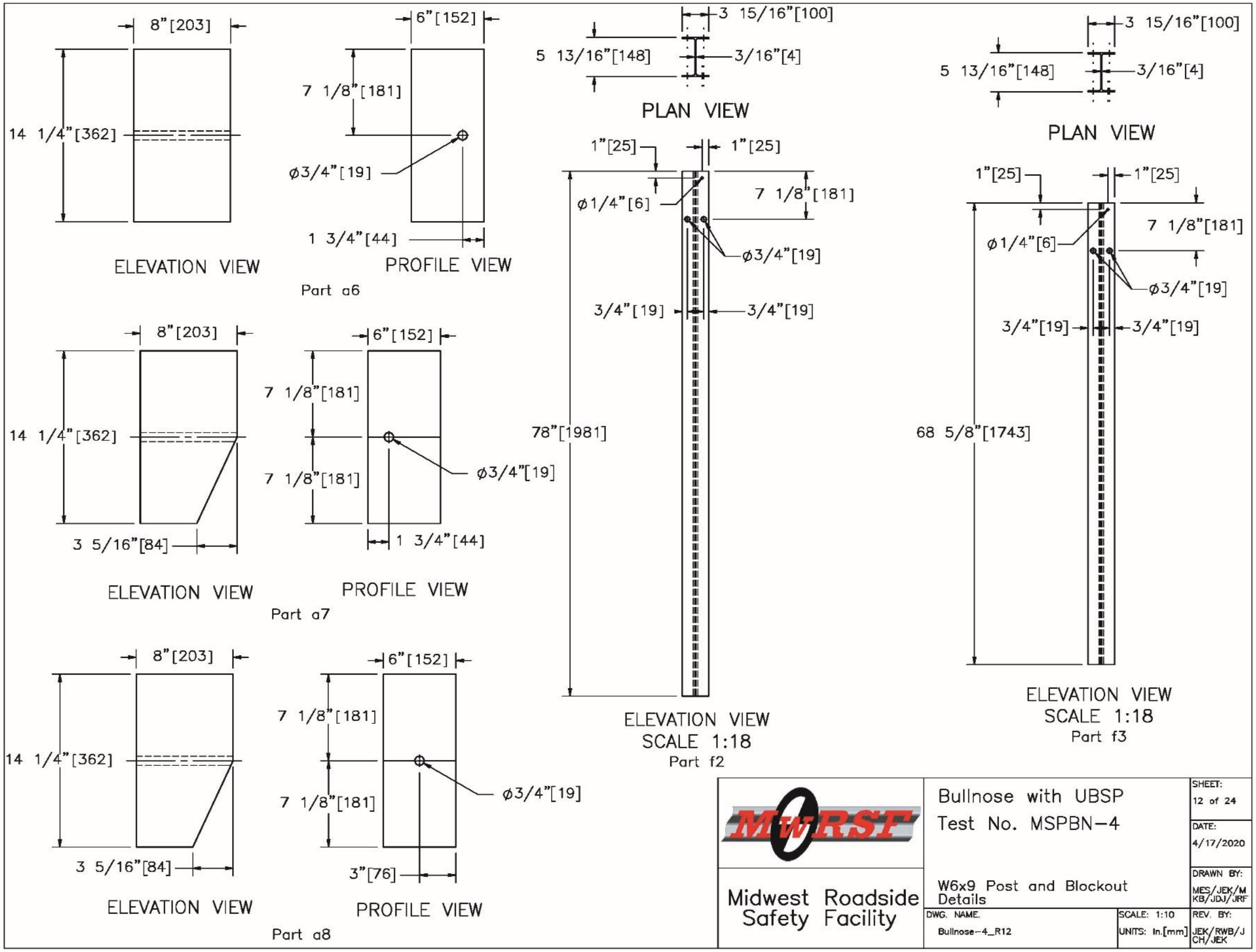


Figure 37. W6x9 Post and Blockout Details, Test No. MSPBN-4

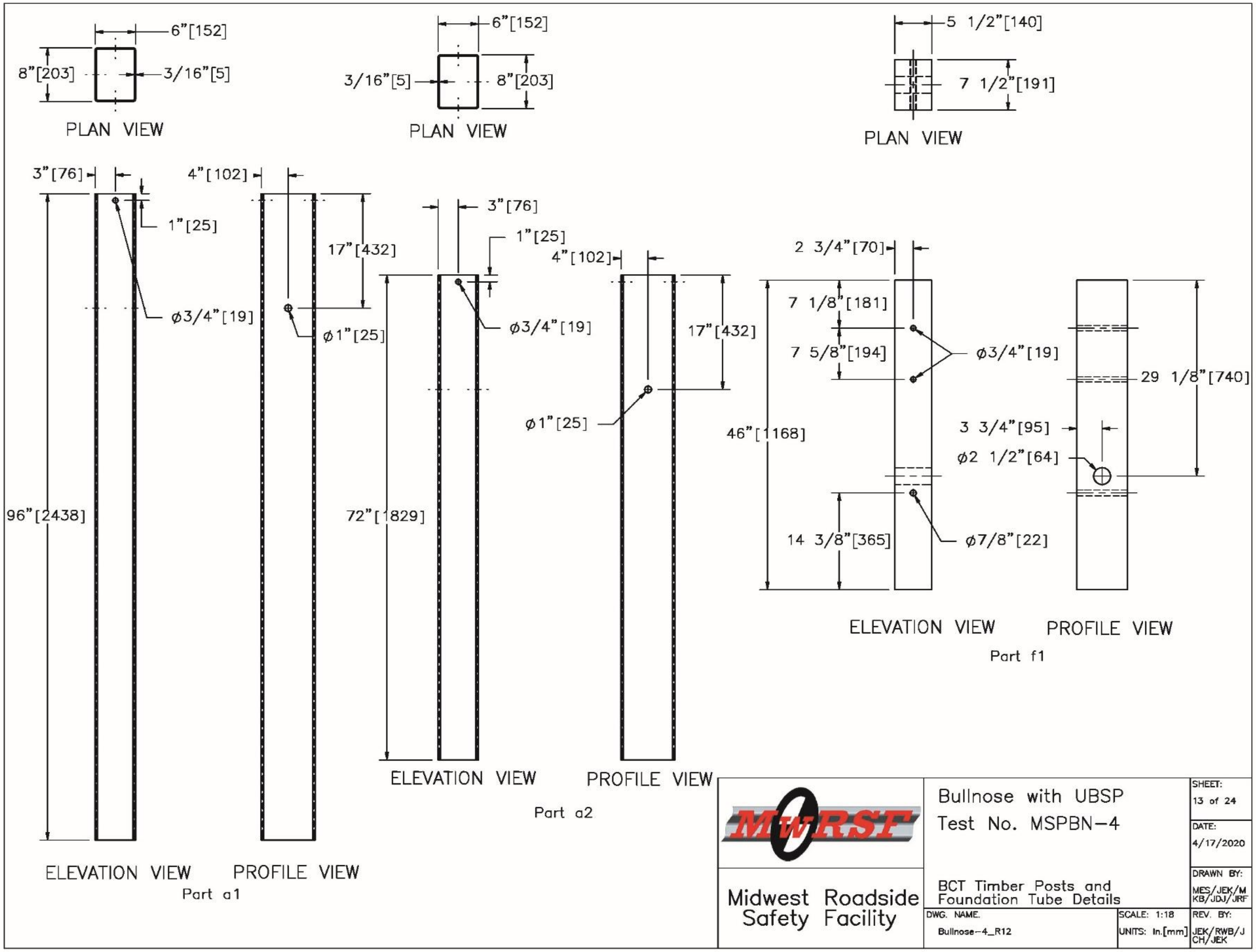


Figure 38. BCT Timber Posts and Foundation Tube Details, Test No. MSPBN-4

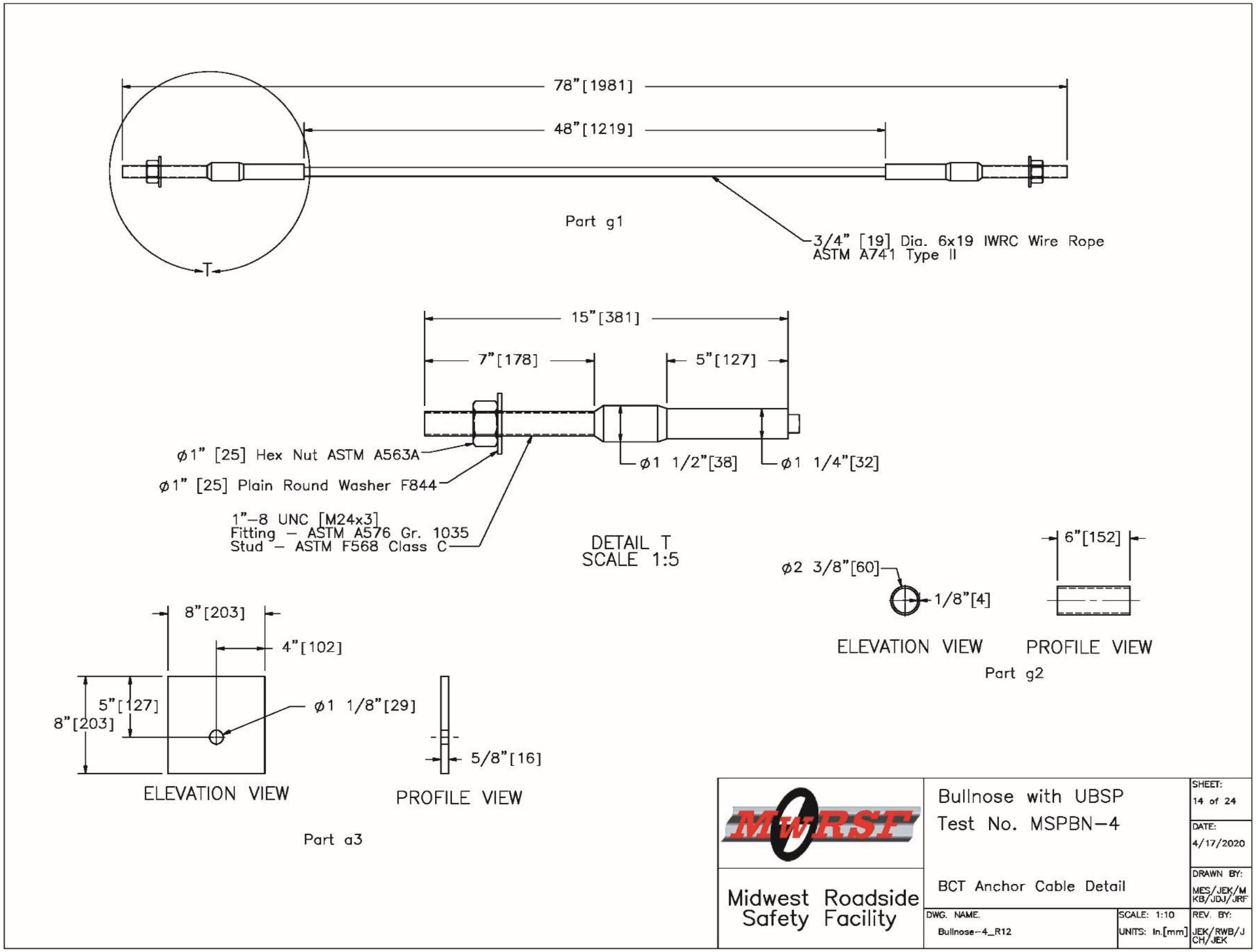


Figure 39. BCT Anchor Cable Detail, Test No. MSPBN-4

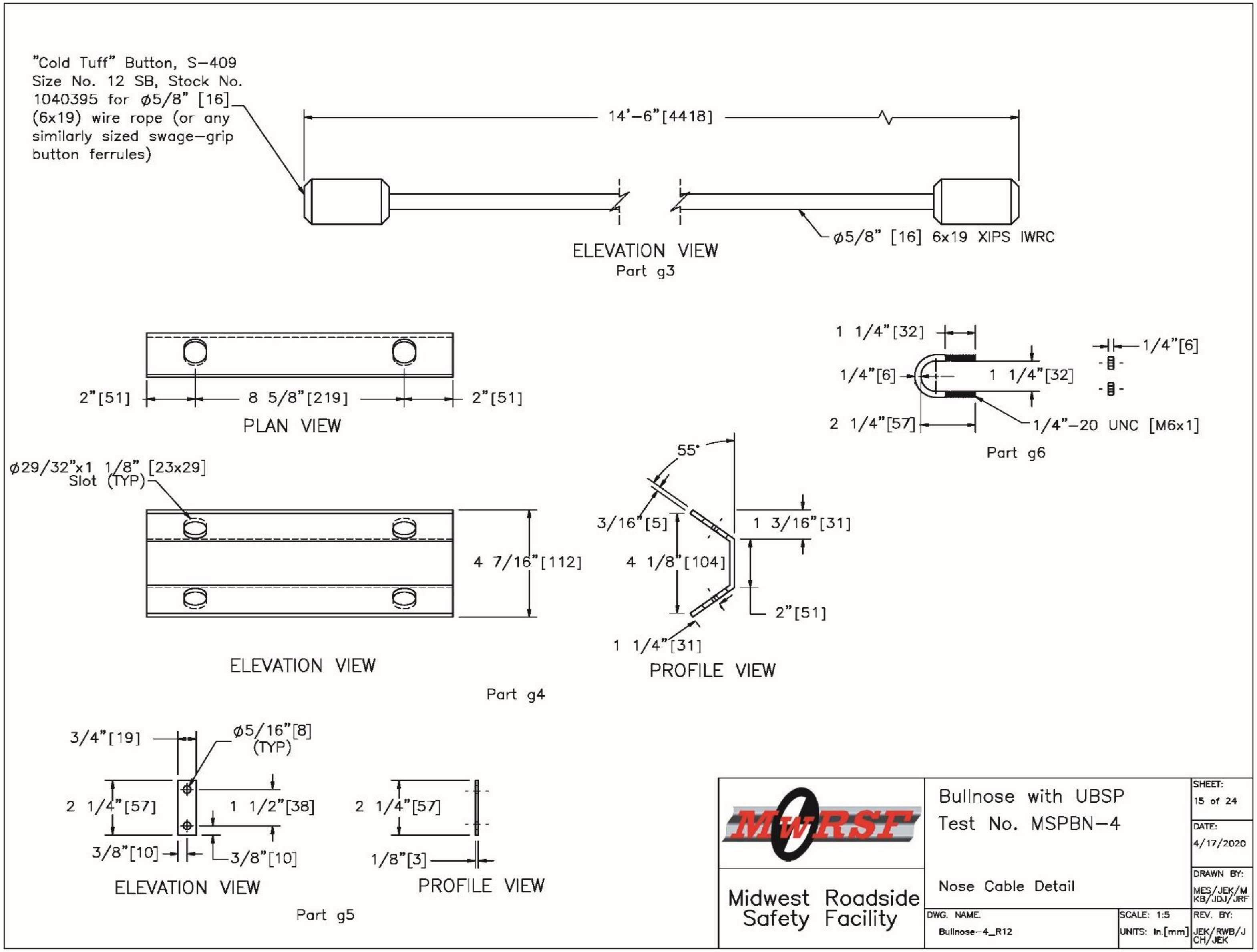


Figure 40. Nose Cable Detail, Test No. MSPBN-4

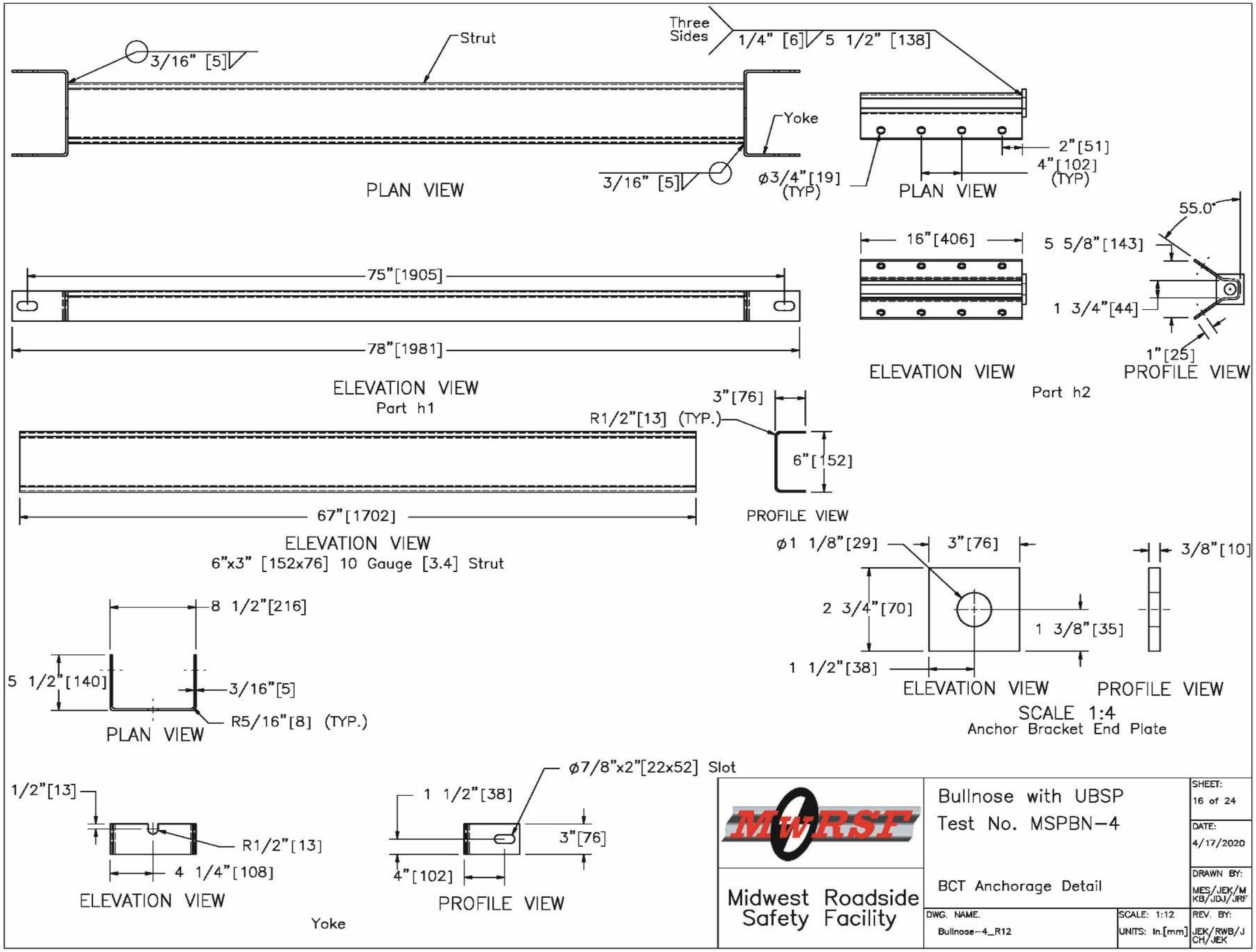


Figure 41. BCT Anchorage Detail, Test No. MSPBN-4

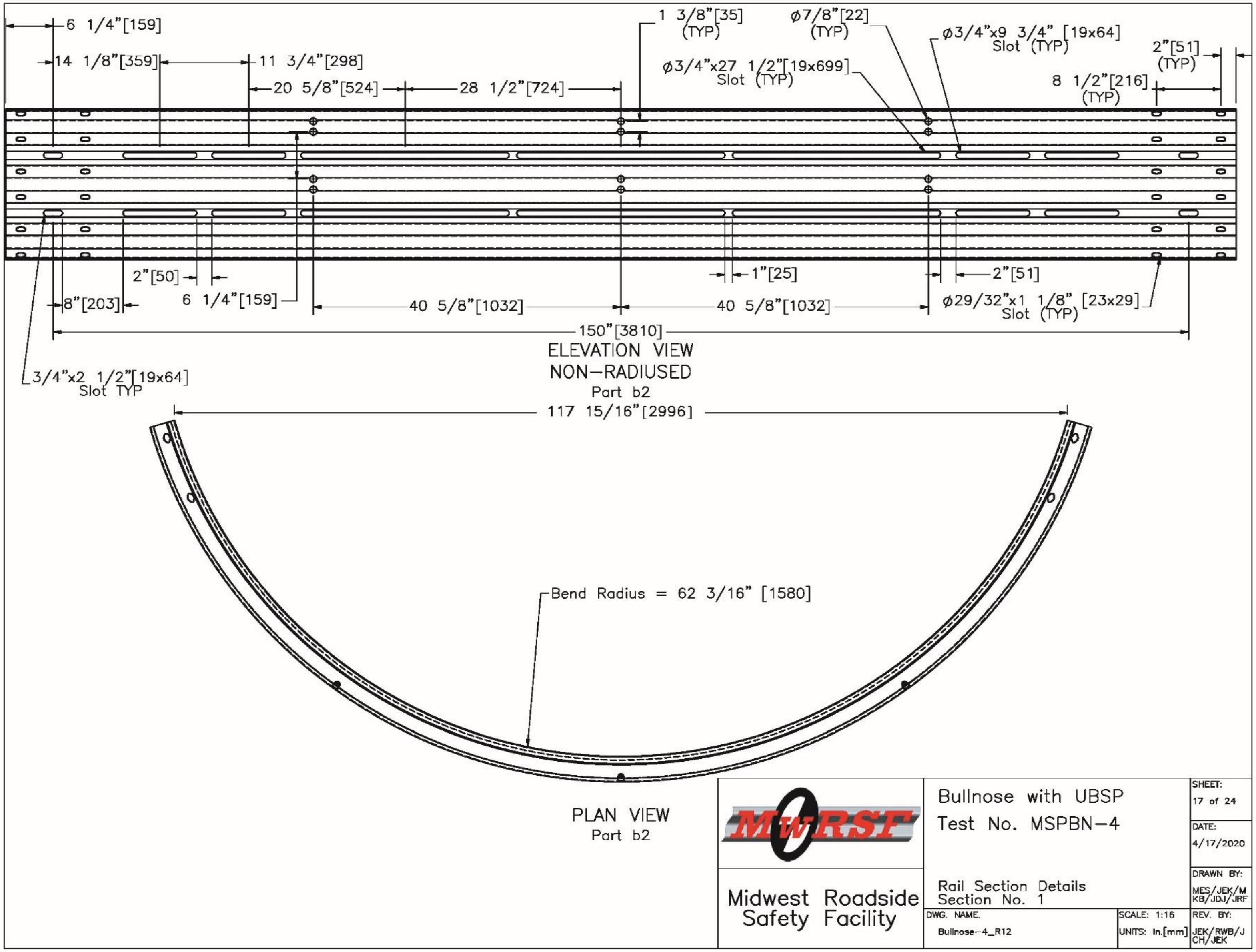


Figure 42. Rail Section Details Section No. 1, Test No. MSPBN-4

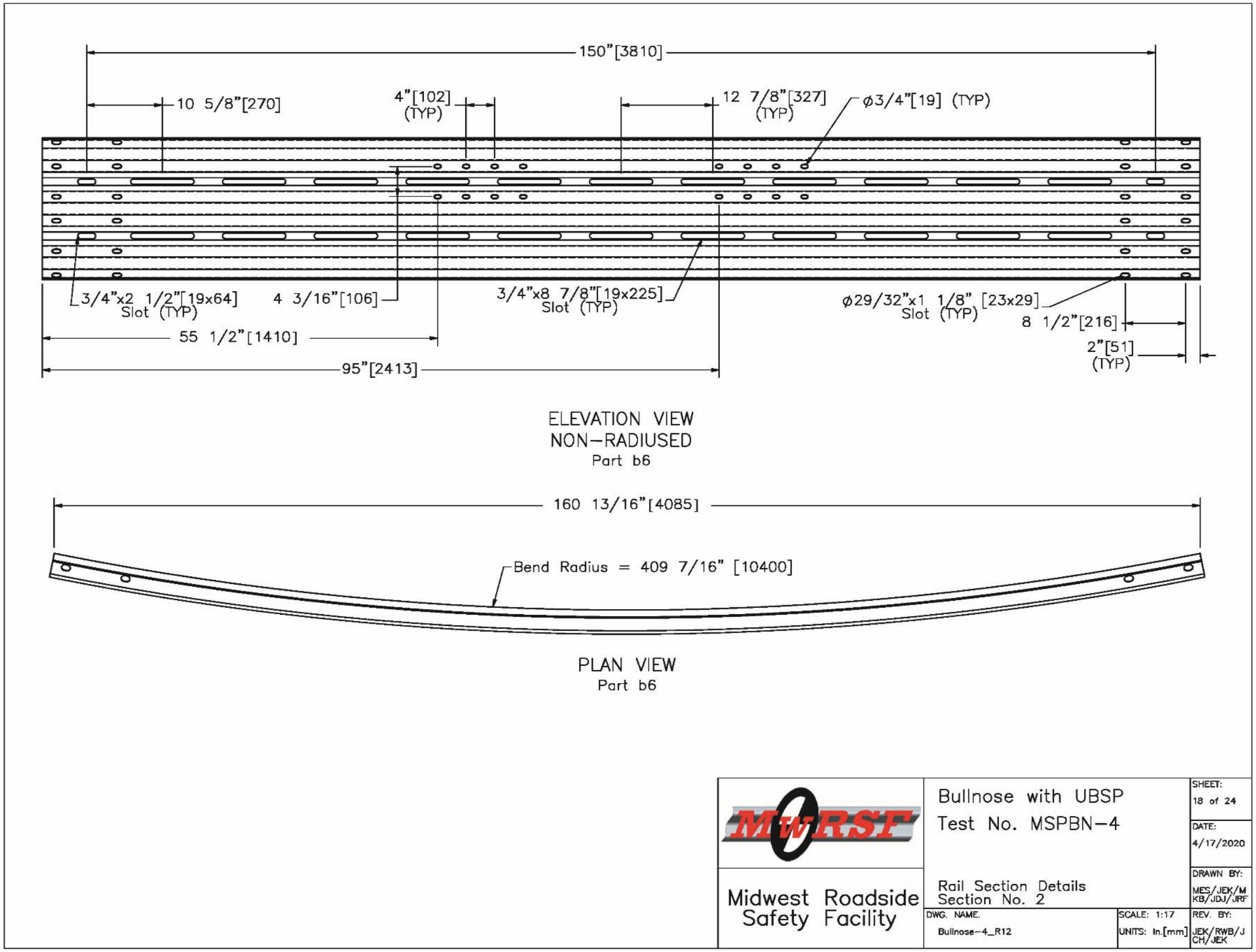


Figure 43. Rail Section Details Section No. 2, Test No. MSPBN-4

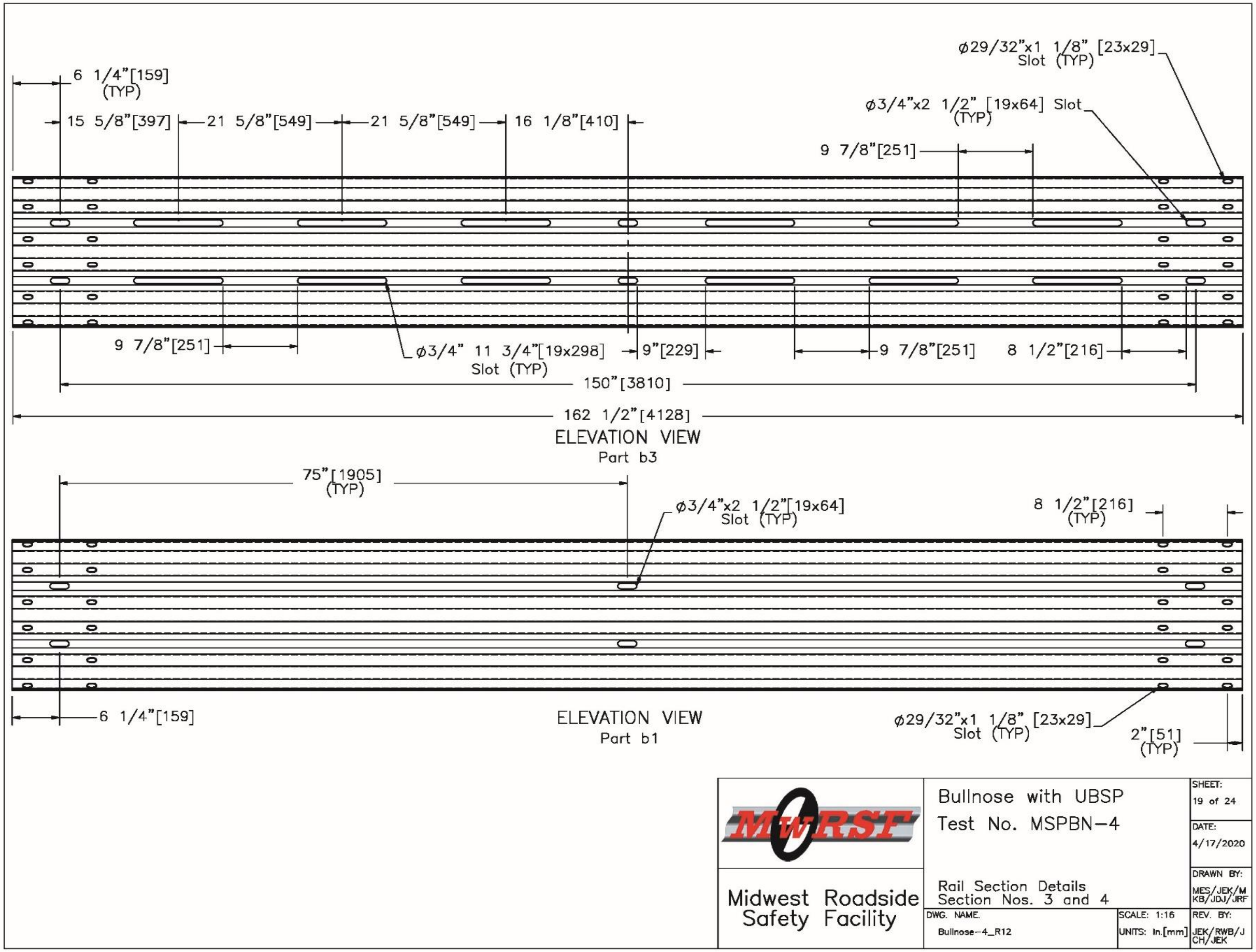


Figure 44. Rail Section Details Section Nos. 3 and 4, Test No. MSPBN-4

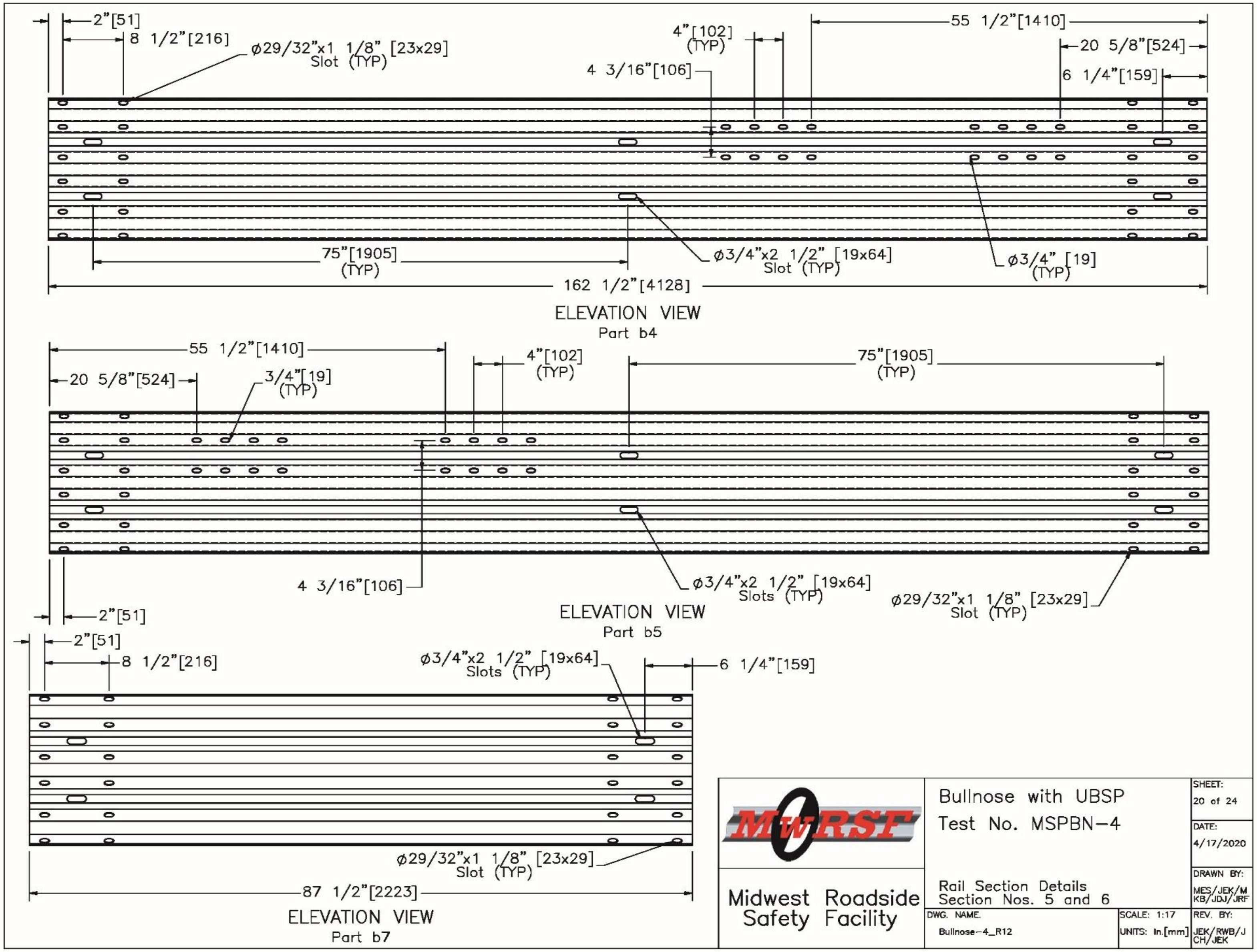


Figure 45. Rail Section Details Section Nos. 5 and 6, Test No. MSPBN-4

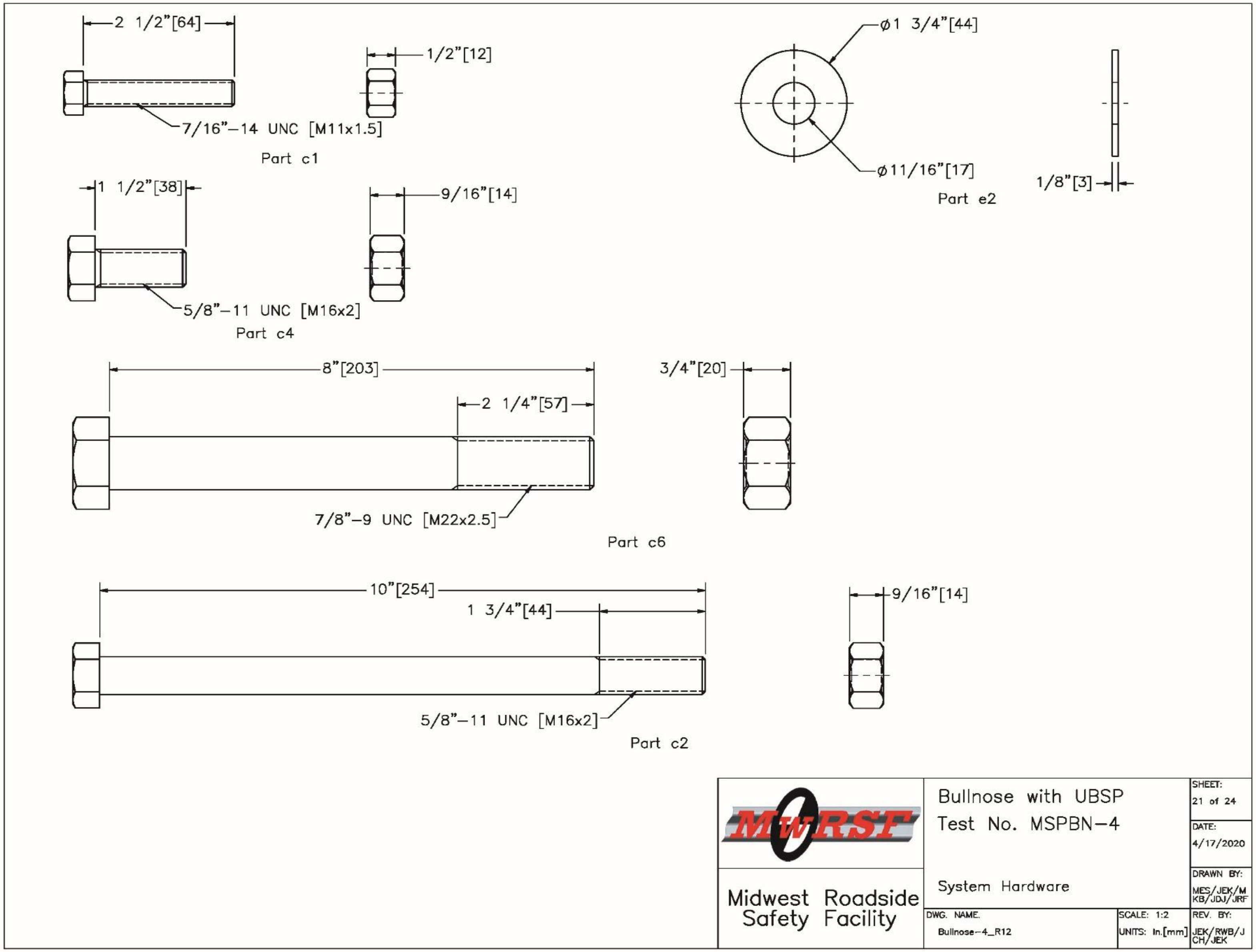


Figure 46. System Hardware, Test No. MSPBN-4

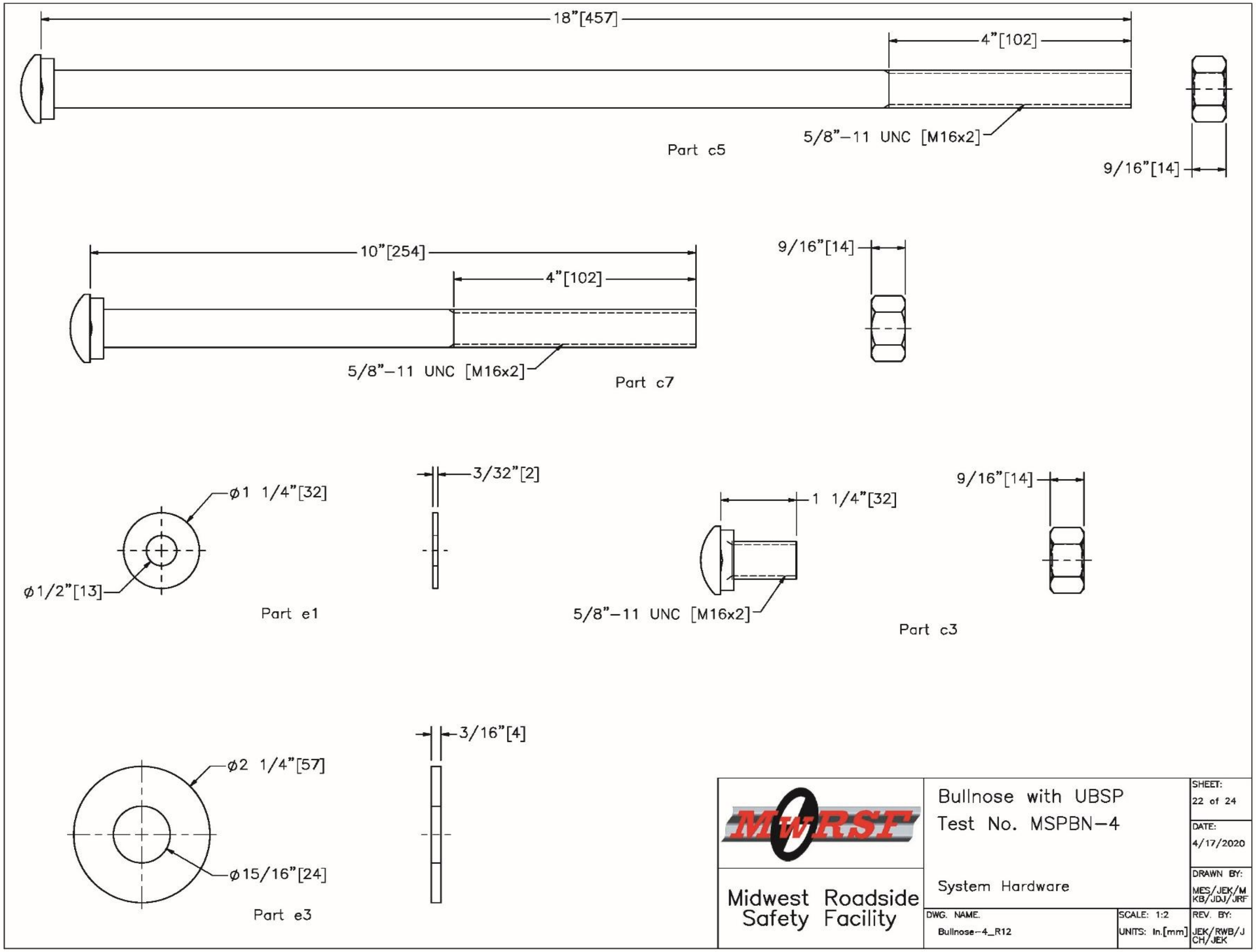


Figure 47. System Hardware, Test No. MSPBN-4

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	2	TS8"x6"x3/16" [203x152x5], 96" [2,438] Long Foundation Tube	ASTM A500 Gr. B	ASTM A123	PTE07
a2	6	TS8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	ASTM A123	PTE06
a3	6	8"x8"x5/8" [203x203x16] Anchor Bearing Plate	ASTM A36	ASTM A123	FPB01
a4	12	Lower Slip Post Assembly	Plate–ASTM A36 Foundation Tube–ASTM A500 Gr. B	ASTM A123	PTE08
a5	12	Upper Slip Post Assembly	Plate–ASTM A36 Post–ASTM A992	ASTM A123	PWE11
a6	21	6"x8"x14 1/4" [152x203x362] Timber Blockout	SYP Grade No. 1 or better	–	PDB09
a7	12	6"x8"x14 1/4" [152x203x362] Tapered Timber Blockout	SYP Grade No. 1 or better	–	PDB20
a8	2	6"x8"x14 1/4" [152x203x362] Tapered Timber Blockout – Post 2	SYP Grade No. 1 or better	–	PDB12
b1	4	12'–6" [3,810] 12 gauge [2.7] Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM02a
b2	1	12'–6" [3,810] 12 gauge [2.7] Bent Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM07a
b3	2	12'–6" [3,810] 12 gauge [2.7] Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM07e
b4	1	12'–6" [3,810] 12 gauge [2.7] Thrie Beam End Section – Side A	AASHTO M180	ASTM A123 or A653	–
b5	1	12'–6" [3,810] 12 gauge [2.7] Thrie Beam End Section – Side B	AASHTO M180	ASTM A123 or A653	–
b6	2	12'–6" [3,810] 12 gauge [2.7] Bent Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM07d
b7	1	6'–3" [1,905] 12–gauge [2.7] Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM18a
c1	48	7/16"–14 UNC [M11x1.5], 2 1/2" [64] Long Hex Tap Bolt (Fully Threaded) and Nut	Bolt – ASTM A449 or SAE J429 Gr. 5 Nut – ASTM A563DH or SAE J995 Gr. 5	ASTM A153 or B695 Class 55 or F2329	FBX12b
c2	8	5/8"–11 UNC [M16x2], 10" [254] Long Hex Head Bolt	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBX16a
c3	132	5/8"–11 UNC [M16x2], 1 1/4" [32] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB01
c4	48	5/8"–11 UNC [M16x2], 1 1/2" [38] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBX16a
c5	14	5/8"–11 UNC [M16x2], 18" [457] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB04
c6	8	7/8"–9 UNC [M22x2.5], 8" [203] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	–
c7	21	5/8"–11 UNC [M16x2], 10" [254] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB03
c8	46	16D Double Head Nail	–	–	–

MwRSF
Midwest Roadside Safety Facility

Bullnose with UBSP
Test No. MSPBN–4

Bill of Materials

SHEET: 23 of 24
DATE: 4/17/2020
DRAWN BY: MES/JEK/MKB/JDJ/JRF
REV. BY: JEK/RWB/JCH/JEK
DWG. NAME. Bullnose–4_R12
SCALE: None
UNITS: In.[mm]

Figure 48. Bill of Materials, Test No. MSPBN-4

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
e1	192	7/16" [11] Dia. Plain Round Washer	ASTM F844	ASTM A153 or B695 Class 55 or F2329	FWC12a
e2	118	5/8" [16] Dia. Plain Round Washer	ASTM F844	ASTM A153 or B695 Class 55 or F2329	FWC16a
e3	16	7/8" [22] Dia. Plain Round Washer	ASTM F844	ASTM A153 or B695 Class 55 or F2329	–
f1	8	BCT Timber Post – MGS Height	SYP Grade No. 1 or better (No knots +/– 18" [457] from ground on tension face)	–	PDF04
f2	8	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 78" [1,981] Long Steel Post	ASTM A992	ASTM A123	–
f3	1	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 68 5/8" [1,743] Long Steel Post	ASTM A992	ASTM A123	–
g1	6	BCT Anchor Cable Assembly	–		FCA01
g2	6	2 3/8" [60] O.D. x 6" [152] Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	ASTM A123	FMM02
g3	2	5/8" Dia. [15.9] x 14.4' [4,389] Long Cable and Swage Button	"Cold Tuff" Button, S–409 Size No. 12 SB, Stock No. 1040395 for 5/8" [16] Dia. (6x19) wire rope (or any similarly sized swage–grip button ferrules)	Wire Rope – Class A Coating	RCM02
g4	4	12 5/8"x5 13/16"x3/16" [321x148x5] Nose Cable Anchor Plate	ASTM A36	ASTM A123	FPA04
g5	6	2 1/4"x3/4" [57x19] 11 gauge [3] U–Bolt Plate Washer	ASTM A1011 CS Type B	ASTM A123	–
g6	6	1/4" [6] Dia. U–Bolt and Nut	U–Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	–
h1	2	Ground Strut Assembly	ASTM A36	ASTM A123	PFP01
h2	6	Anchor Bracket Assmbely	ASTM A36	ASTM A123	FPA01

Midwest Roadside Safety Facility

Bullnose with UBSP
Test No. MSPBN–4

Bill of Materials

SHEET: 24 of 24	DATE: 4/17/2020	DRAWN BY: MES/JEK/MKB/JDJ/JRF	DWG. NAME. Bullnose–4_R12	SCALE: None UNITS: In.[mm]	REV. BY: JEK/RWB/JCH/JEK

Figure 49. Bill of Materials, Test No. MSPBN-4

Figure 50. Test Installation Photographs, System Overview, Test No. MSPBN-4

Figure 51. Test Installation Photographs, End Anchorages and Nose Cables, Test No. MSPBN-4

Figure 52. Test Installation Photographs, Nose Details, Test No. MSPBN-4

Figure 53. Test Installation Photographs, Post Details, Test No. MSPBN-4

Figure 54. Test Installation Photographs, System Overview, Test No. MSPBN-4

5 FULL-SCALE CRASH TEST NO. MSPBN-4

5.1 Static Soil Test

Before full-scale crash test no. MSPBN-4 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. The static test results, as shown in Appendix C, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and full-scale crash testing could be conducted on the barrier system.

5.2 Weather Conditions

Test no. MSPBN-4 was conducted on April 18, 2018 at approximately 1:45 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 5.

Table 5. Weather Conditions, Test No. MSPBN-4

Temperature	45° F
Humidity	57%
Wind Speed	23 mph
Wind Direction	330° from True North
Sky Conditions	Cloudy/Windy
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.01 in.
Previous 7-Day Precipitation	0.44 in.

5.3 Test Description

Test no. MSPBN-4 was conducted under the MASH 2016 TL-3 guidelines for test designation no. 3-30. Test designation no. 3-30 is an impact of the 1100C vehicle at 62 mph (100 km/h) and 0 degrees into the nose of the system with a ¼-vehicle offset. Initial vehicle impact was to occur with the vehicle traveling parallel to the longitudinal centerline of the system and offset 16¼ in. (413 mm) laterally toward the A side, as shown in Figure 55. This distance represented one quarter of the vehicle's width.

In test no. MSPBN-4, the 2,429-lb (1,102-kg) small car impacted the thrie-beam bullnose system at a speed of 62.1 mph (99.9 km/h) and at an angle of 1.3 degrees. The actual impact occurred with the vehicle offset 14.9 in. (378 mm) from the centerline of the system. During the test, the vehicle was initially captured by the thrie-beam nose of the system. However, as the vehicle proceeded into the system, the slot between the upper two corrugations of thrie beam and the lowest corrugation opened. This behavior allowed the top two thrie-beam corrugations to move upward and the lower thrie-beam corrugation to move downward and rupture. This outcome compromised the capture of the vehicle's front end and allowed the vehicle to penetrate the system. The vehicle came to rest 95 ft – 8 in. (29.2 m) downstream from the impact point after brakes were applied.

A detailed description of the sequential impact events is contained in Table 6. Sequential photographs are shown in Figure 57. Documentary photographs of the crash test are shown in Figures 58 through 60. The vehicle trajectory and final position are shown in Figure 61.

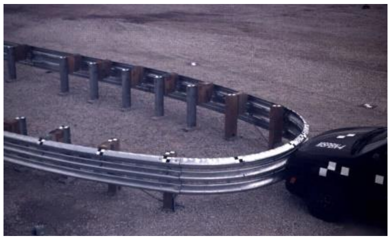
Figure 55. Impact Location, Test No. MSPBN-4

Table 6. Sequential Description of Impact Events, Test No. MSPBN-4

TIME (sec)	EVENT
0.000	Vehicle's front bumper impacted rail 14.9 in. (378 mm) from the centerline of the system on the Side A.
0.006	Vehicle's front bumper deformed, and vehicle's hood contacted rail.
0.008	Post nos. A1 and B1 deflected forward, and vehicle's hood and left-front fender deformed.
0.012	Post nos. A2 and B2 deflected forward.
0.020	Slot tab tore between middle and bottom rail corrugations.
0.022	Post no. B3 deflected forward.
0.028	Post no. B1 deflected backward.
0.034	Post no. A1 deflected backward.
0.042	Vehicle's right fender contacted rail.
0.044	Post no. A2 deflected backward, and vehicle's right fender deformed.
0.056	Rail’s bottom corrugation ruptured between post nos. A1 and B1.
0.064	Post no. A1 deflected downstream.
0.072	Rail disengaged from bolt at post no. A2.
0.076	Post no. B1 rotated backward.
0.082	Post no. A3 deflected downstream, vehicle's front bumper became disengaged, and post no. B1 fractured.
0.088	Rail disengaged from bolt at post no. A3.
0.102	Post no. B2 deflected backward.
0.109	Vehicle's right-front door contacted rail.
0.112	Rail’s middle corrugation ruptured between post nos. A1 and B1.
0.114	Post no. A1 fractured.
0.115	Rail disengaged from bolt at post no. A4.
0.140	Vehicle's left-front door contacted rail.
0.148	Vehicle's hood contacted windshield.
0.150	Post no. A1 contacted post no. A2.
0.178	Vehicle's left-front door deformed.
0.188	Vehicle's left A-pillar deformed.
0.194	Vehicle's right A-pillar contacted rail.
0.198	Vehicle's hood disengaged.
0.200	Vehicle's windshield cracked.
0.202	Vehicle's left A-pillar contacted rail, and post no. A2 fractured.
0.206	Post no. B2 deflected downstream.
0.224	Post no. B2 fractured.
0.232	Post no. A3 deflected backward.
0.238	Vehicle's hood contacted roof.

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

TIME (sec)	EVENT
0.262	Vehicle's windshield contacted rail.
0.264	Ruptured thrie-beam punctured windshield near left A-pillar/roof junction.
0.286	Vehicle's left quarter panel contacted rail, and vehicle underrode rail.
0.322	Vehicle's roof contacted rail.
1.134	Vehicle's right-front tire contacted post no. A13.
1.136	Post no. A13 deflected downstream and forward, vehicle yawed clockwise after impacting post no. A13.
1.142	Post no. A14 deflected forward and downstream.
1.148	Post no. A15 deflected backward.
1.226	Vehicle's front bumper contacted post no. A14, post no. A14 fractured.
1.236	Rail disengaged from bolt at post no. A14.
1.244	Post no. A15 deflected forward.
1.302	Vehicle's front bumper contacted rail between post nos. A14 and A15, vehicle pitched downward.
1.326	Rail disengaged from bolt at post no. A15.
1.402	Vehicle's front bumper contacted post no. A15.
1.408	Post no. A15 rotated forward.
1.410	Vehicle's left-rear tire became airborne.
1.414	Post no. A15 fractured.
1.468	Vehicle pitched upward.
1.474	Vehicle's right-rear tire became airborne.
1.678	Vehicle's left-rear tire regained contact with ground.
1.700	Vehicle's right-rear tire regained contact with ground.
2.236	Vehicle rotated through 180 degrees to face upstream and continued to yaw.
4.000	Vehicle came to rest 95 ft – 8 in. (29.2 m) downstream of impact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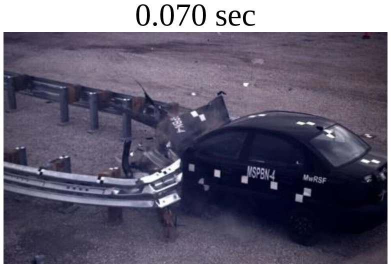
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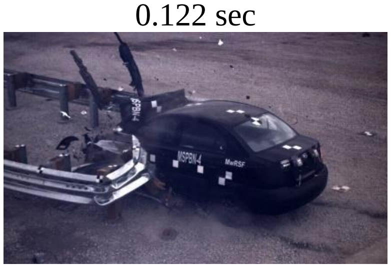
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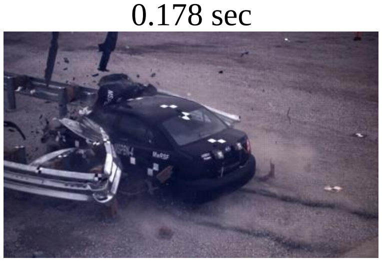
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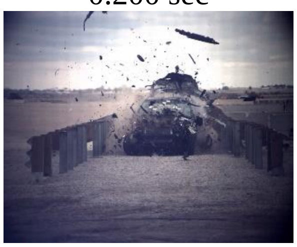
0.262 sec

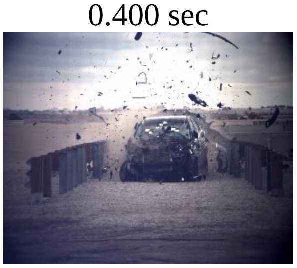
Figure 56. Sequential Photographs, Test No. MSPBN-4

0.000 sec

0.200 sec



0.400 sec



0.600 sec

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1.000 sec

0.000 sec

0.100 sec

0.200 sec

0.300 sec

0.400 sec

0.500 sec

Figure 57. Sequential Photographs, Test No. MSPBN-4

Figure 58. Documentary Photographs, Test No. MSPBN-4

Figure 59. Additional Documentary Photographs, Test No. MSPBN-4

Figure 60. Additional Documentary Photographs, Test No. MSPBN-4

Figure 61. Vehicle Final Position and Trajectory Marks, Test No. MSPBN-4

5.4 Barrier Damage

Damage to the barrier was extensive, as shown in Figures 62 through 68. Barrier damage primarily consisted of contact marks, deformation, bending, and tearing of the thrie-beam rail segments and disengagement of the breakaway posts. Additional damage was noted on the downstream end of the system after vehicle capture was compromised.

The thrie-beam nose section of the barrier and the adjacent rail sections on Side A and Side B were deformed backward and into the interior of the barrier as the vehicle entered the system. Rail tearing occurred at several locations in the nose of the system. The slot tabs connecting the top and middle rail corrugations located 75 in. (1,905 mm) upstream from post no. A1 were fractured. The slot tabs located 20 in. (508 mm) and 75 in. (1,905 mm) upstream from post no. A1 along the bottom corrugation were fractured, and a 65-in. (1,651-mm) long rupture of the bottom rail corrugation occurred 20 in. (508 mm) upstream from post no. A1. A tear was found 11½ in. (292 mm) upstream from post no. A1 along the bottom corrugation of the rail. Tearing also occurred 57 in. (1,448 mm) upstream from post no. A1 along the middle corrugation of the rail. A 58-in. (1,473-mm) long tear occurred 27½ in. (699 mm) upstream from post no. B1 along the bottom corrugation of the rail. The anchorage cables in the top two corrugations of the thrie-beam nose remained intact after impact.

Rail section no. 2 on Side A of the system was kinked, deformed, and bent inward toward the interior of the system at post no. A3. A second large kink and bend in the rail was observed at post no. A2. Additional deformations and kinks were observed on rail section no. 2 on Side A beginning at the upstream end of the rail section and extending to post no. A4. The bolt connecting post no. A6 to the rail pulled through the rail, leaving a tear 1¼ in. (32 mm) long by ¼ in. (6 mm) high.

Rail section no. 2 on Side B of the system was kinked, deformed, and bent inward toward the interior of the system a post no. B2. A second large kink and bend in the rail was observed at post no. B2. Additional deformations and kinks were observed on rail section no. 2 on Side B beginning at the upstream end of the rail section and extending slightly downstream of post no. B2.

Several of the breakaway posts in the bullnose were damaged and/or disengaged during the impact. On Side A of the system, post no. A1 was fractured through the BCT hole at the base of the post, and post no. A2 was fractured at its base and was also detached from the railing with the post bolt pulling away from the guardrail. The blockout of post no. A3 rotated downstream, and the bolt connecting post no. A4 pulled out of the rail. The UBSP posts on Side A of the system were undamaged. On Side B of the system, post no. B1 was fractured at its base, and post no. B2 was partially fractured at its base. The blockout attached to post no. B4 was rotated upstream. The UBSP posts on Side B of the system were undamaged. The BCT anchor cables were disengaged from post no. 1 on both sides of the system.

The downstream section of the A side of the system experienced significant damage. The test vehicle struck post nos. A13, A14, and A15. Post no. A13 had a 7-in. (178-mm) tall by 1-in. (25-mm) deep dent along the upstream back flange starting 17½ in. (445 mm) from the top of the post. Both post nos. A14 and A15 were fractured off at their bases. A 22¾-in. (578-mm) long by

1½-in. (38-mm) high contact mark was observed on the back side of the rail 11½ in. (292 mm) downstream from post no. A14.

The maximum longitudinal permanent set of the barrier system was 12 ft – 7 in. (3.8 m) at the midspan of the nose rail section, as measured in the field. The maximum lateral permanent set deflection was internal to the bullnose system and is not shown. A maximum longitudinal dynamic barrier deflection of 13 ft – 9.6 in. (4.2 m) was noted at the quarter point of the nose on Side A, as determined from high-speed digital video analysis. The maximum lateral dynamic barrier deflection was internal to the bullnose system and is not shown. Working widths for the system were not shown because the system did not capture the impacting vehicle. A schematic of the permanent set deflection is shown in Figure 69.

Figure 62. Overview of System Damage, Test No. MSPBN-4

Figure 63. Impact Location Damage, Test No. MSPBN-4

Figure 64. Close Up of Damage to Impact Area, Test No. MSPBN-4

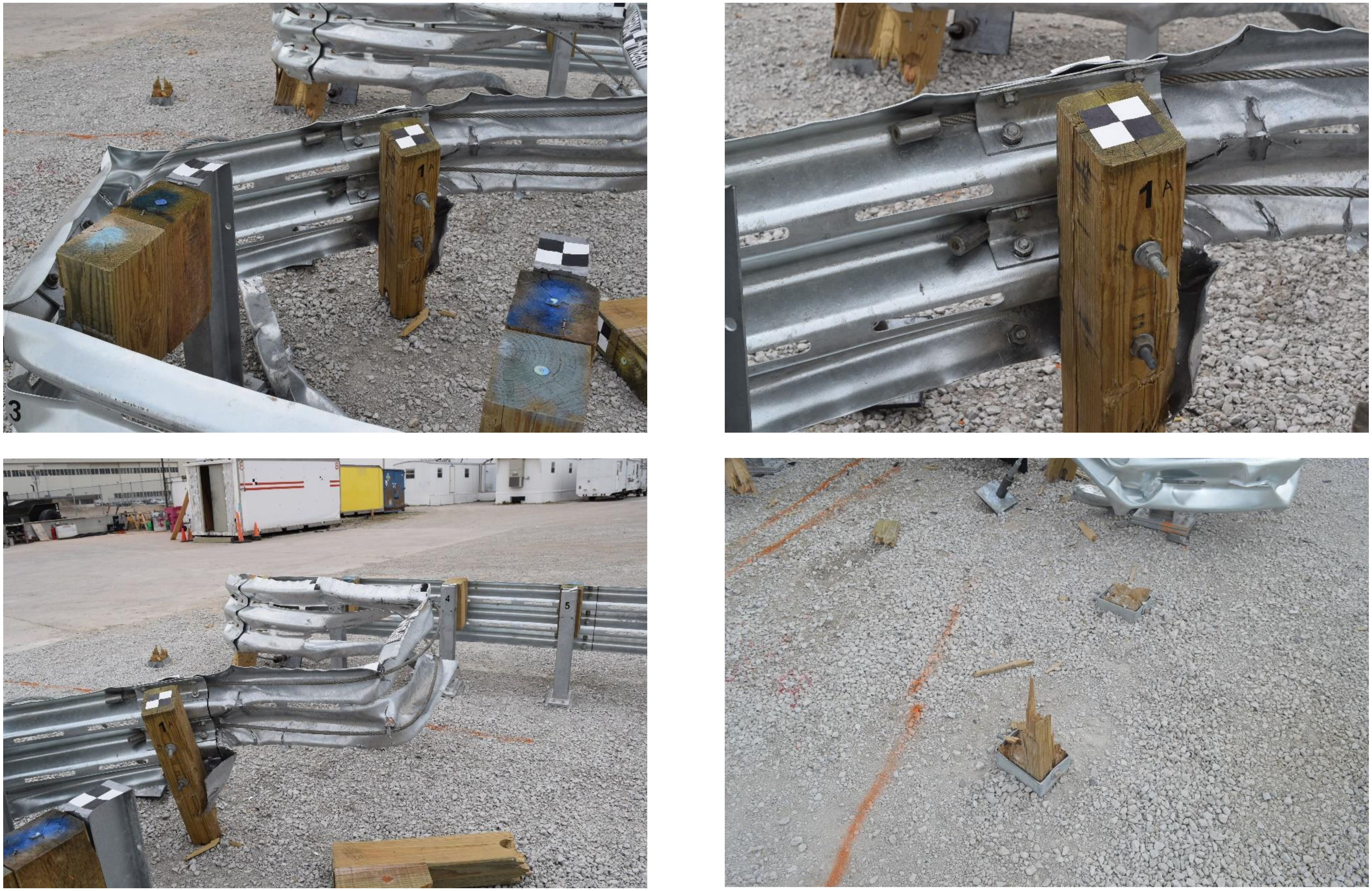


Figure 65. Damage to Post Nos. A1 and A2, Test No. MSPBN-4

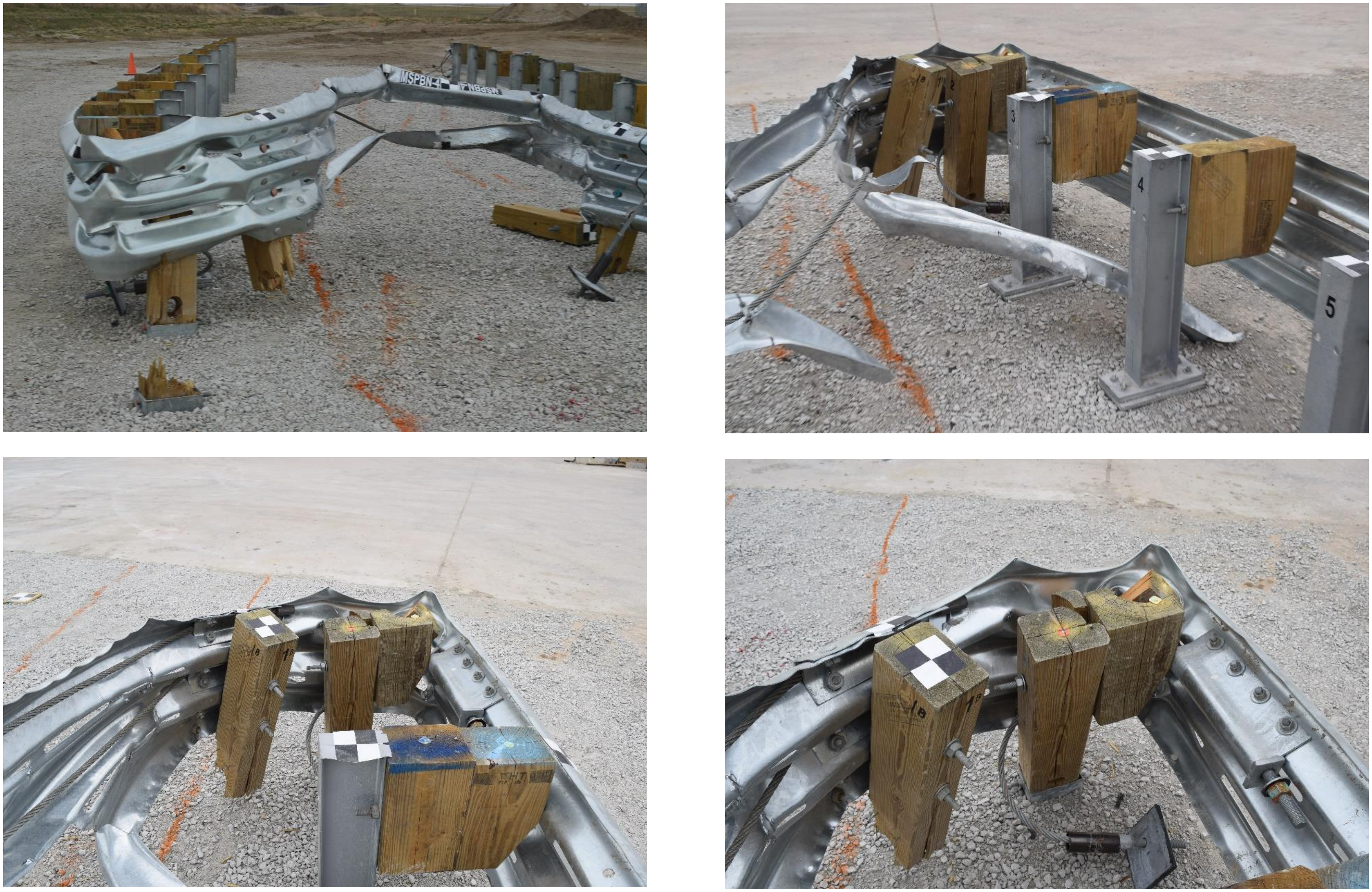


Figure 66. Damage to Post Nos. B1 and B2, Test No. MSPBN-4

Figure 67. Damage to Impact Location, Test No. MSPBN-4

Figure 68. Damage to Post Nos. A14 and A15, Test No. MSPBN-4

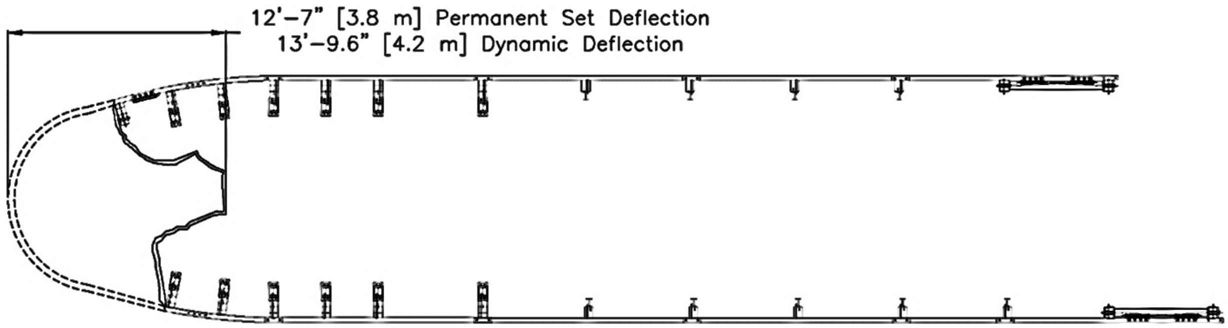


Figure 69. System Deformation, Test No. MSPBN-4

5.5 Vehicle Damage

The damage to the vehicle was extensive, as shown in Figures 70 through 73. The maximum occupant compartment deformations are listed in Table 8 along with the deformation limits established in MASH 2016 for various areas of the occupant compartment. Note that the windshield deformed 4¼ in. (108 mm), which violated the MASH 2016 deformation limits. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D.

The majority of the damage was concentrated on the front of the vehicle where the impact had occurred. The front grille and hood were disengaged from the vehicle. The right-front fender was peeled back, and the front portion of the left fender was crushed and pushed back. The center of the bumper was crushed inward toward the engine. The windshield was shattered and crushed inward due to contact with the thrie-beam and the vehicle hood as the vehicle underrode the rail. Additionally, a 6-in. (152-mm) long hole was torn in the upper left corner of the windshield. The right-front door was dented near the handle. The left-rear door and left-rear side panel had a large dent 56 in. (1,422 mm) long by 7 in. (178 mm) wide. The left-rear taillight was disengaged from its housing.

Figure 70. Vehicle Damage, Test No. MSPBN-4

Figure 71. Vehicle Damage, Test No. MSPBN-4

Figure 72. Vehicle Interior Damage, Test No. MSPBN-4

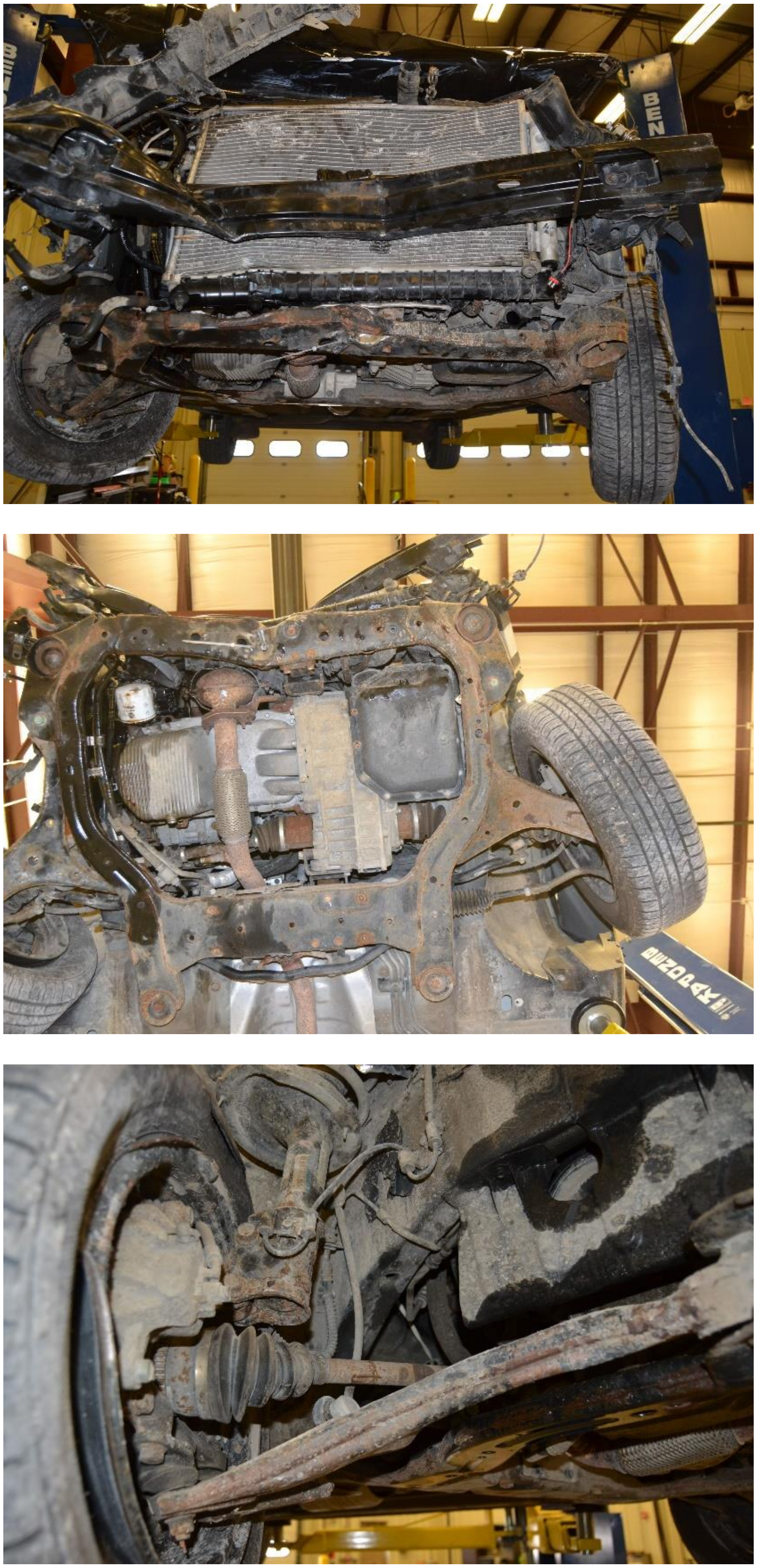


Figure 73. Undercarriage Damage, Test No. MSPBN-4

Table 8. Maximum Occupant Compartment Deformations by Location, Test No. MSPBN-4

LOCATION	MAXIMUM DEFORMATION in. (mm)	MASH 2016 ALLOWABLE DEFORMATION in. (mm)
Wheel Well & Toe Pan	½ (13)	≤ 9 (229)
Floor Pan & Transmission Tunnel	¼ (6)	≤ 12 (305)
A-Pillar	⅝ (16)	≤ 5 (127)
A-Pillar (Lateral)	0 (0)	≤ 3 (76)
B-Pillar	⅜ (10)	≤ 5 (127)
B-Pillar (Lateral)	⅛ (3)	≤ 3 (76)
Side Front Panel (in Front of A-Pillar)	⅛ (3)	≤ 12 (305)
Side Door (Above Seat)	⅛ (3)	≤ 9 (229)
Side Door (Below Seat)	⅛ (3)	≤ 12 (305)
Roof	¼ (6)	≤ 4 (102)
Windshield	4¼ (108)	≤ 3 (76)
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	⅜ (10)	N/A

N/A – Not applicable

5.6 Occupant Risk

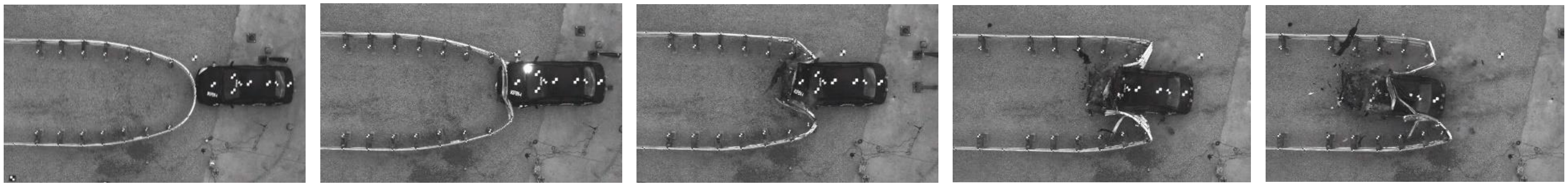
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 9. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 9. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix E.

Table 9. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. MSPBN-4

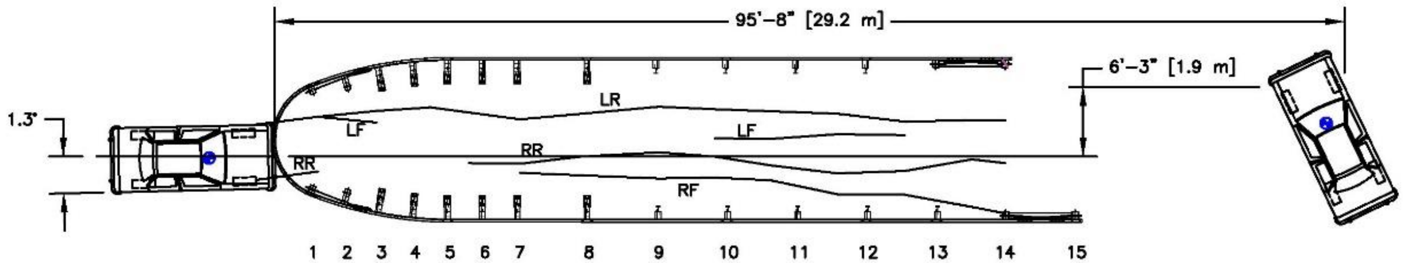
Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (primary)	DTS	
OIV ft/s (m/s)	Longitudinal	-26.35 (-8.03)	-27.00 (-8.23)	±40 (12.2)
	Lateral	-3.40 (-1.04)	-4.36 (-1.33)	±40 (12.2)
ORA g's	Longitudinal	-10.57	-12.32	±20.49
	Lateral	-5.66	-6.11	±20.49
MAX. ANGULAR DISPL. degrees	Roll	7.5	12.3	±75
	Pitch	5.9	9.2	±75
	Yaw	158.1	167.2	not required
THIV ft/s (m/s)		27.47 (8.37)	27.01 (8.23)	not required
PHD g's		5.76	4.73	not required
ASI		0.76	0.76	not required

5.7 Discussion

The analysis of the results for test no. MSPBN-4 showed that the system did not adequately capture and contain the 1100C vehicle with controlled longitudinal displacements of the barrier. The test vehicle penetrated the system by underriding the thrie-beam but remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix E, were deemed acceptable, because they did not adversely influence occupant risk nor cause rollover. Contact with the vehicle hood and thrie-beam rail elements caused excessive windshield deformation and created a tear in the upper left corner for the windshield. Therefore, test no. MSPBN-4 was determined to be unacceptable according to the MASH 2016 safety performance criteria for test designation no. 3-30. A summary of the results of test no. MSPBN-4 is shown in Figure 74.



0.000 sec | 0.023 sec | 0.104 | 0.208 sec | 0.316 sec



- Test Agency .... MwRSF
- Test Number MSPBN-4
- Date 4/18/18
- MASH 2016 Test Designation No. 3-30
- Test Article .... Steel Post Bullnose with Breakaway Posts
- Total Length .... 72 ft – 3 in. (22.0 m)
- Key Component – Thrie Beam
  - Thickness .... 12 gauge (2.7 mm)
  - Mounting Height .... 31⅝ in. (803 mm)
- Key Component – Breakaway Steel Post
  - Length .... $72\frac{7}{16}$ in. (1,849 mm)
  - Spacing .... 37½ in. (953 mm)
- Soil Type
- Vehicle Make /Model .... 2009 Kia Rio
  - Curb .... 2,472 lb (1,121 kg)
  - Test Inertial .... 2,429 lb (1,102 kg)
  - Gross Static .... 2,593 lb (1,176 kg)
- Impact Conditions
  - Speed .... 62.1 mph (99.9 km/h)
  - Angle .... 1.3 degrees
  - Impact Location .... 14.9 in (378 mm) from CL of the bullnose on the A side
- Impact Severity ...... 312.9 kip-ft (424.2 kJ) ≥ 288 kip-ft (390 kJ) limit from MASH 2016
- Exit Conditions
  - Speed .... N/A
  - Angle .... N/A
- Vehicle Stability .... Satisfactory
- Vehicle Capture and Containment .... Failed due to Underride
- Vehicle Stopping Distance .... 95 ft ─ 8 in. (29.2 m) downstream
- Vehicle Damage .... Severe
  - VDS [20] 12-FD-6
  - CDC [21] 12-FZMW-3
  - Maximum Interior Deformation .... 4¼ in. (108 mm)
- Test Article Damage .... Extensive
- Maximum Test Article Deflections
  - Permanent Set .... 12 ft – 7 in. (3.8 m) longitudinal
  - Dynamic .... 13 ft – 9.6 in. (4.2 m) longitudinal
  - Working Width .... NA
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limit
		SLICE-1 (primary)	TDAS-Pro	
OIV ft/s (m/s)	Longitudinal	-26.35 (-8.03)	-27.00 (-8.23)	±40 (12.2)
	Lateral	-3.40 (-1.04)	-4.36 (1.33)	±40 (12.2)
ORA g's	Longitudinal	-10.57	-12.32	±20.49
	Lateral	-5.66	-6.11	±20.49
MAX ANGULAR DISP. degrees	Roll	7.5	12.3	±75
	Pitch	5.9	9.2	±75
	Yaw	158.1	167.2	Not required
THIV – ft/s (m/s)		27.47 (8.37)	27.01 (8.23)	Not required
PHD – g's		5.76	4.73	Not required
ASI		0.78	0.76	Not required

Figure 74. Summary of Test Results and Sequential Photographs, Test No. MSPBN-4

6 DESIGN DETAILS, TEST NO. MSPBN-5 THROUGH MSPBN-7

6.1 Bullnose Design Modification Following Test No. MSPBN-4

Following test no. MSPBN-4, the researchers reviewed the results from the test to determine the factors that influenced the failure of the system as well as to suggest potential modifications to the thrie-beam bullnose system to improve its performance. The performance of the system was also compared with previous NCHRP Report No. 350 test designation no. 3-30 testing on the same thrie-beam bullnose system in test no. USPBN-3 [9]. Three observations were made related to the failure of test no. MSPBN-4.

1. Prior evaluation of the thrie-beam bullnose system under NCHRP Report No. 350 test designation no. 3-30 impact conditions did not display the same capture issue as observed in test no. MSPBN-4. However, the mass of the small car and corresponding kinetic energy of MASH test 3-30 increased 25 percent as compared to previous NCHRP Report 350 testing. The increased kinetic energy imparted into the system may have contributed to the fracture of the lowest corrugation of the thrie beam in test no. MSPBN-4 and increased the potential for vehicle underride of the guardrail.

2. The 1100C front-end geometry and structure appears to be significantly different than that for the 820C vehicle tested previously in test no. USPBN-3. These geometric differences may have altered the vehicle engagement and interlock with the nose rail and changed the nose rail slot tab tearing and corrugation separation. Differences in the front-end geometry of the 820C vehicle used in test designation no. USPBN-3 and the 1100C vehicle used in test designation no. MSPBN-4 are shown in Figure 75. The center of the bumper was in a similar location for both tests, but the 1100C vehicle has a more vertical profile, which may have contributed to the more rapid slot tab tearing and rail opening as well the vertical motion of the upper two corrugations of the thrie beam up and over the front of the vehicle. Additionally, it was noted that the behavior of the vehicle’s engine hood was different as the vehicle hood remained latched and in place in test no. USPBN-3, while the hood was opened, pushed back, and disengaged in test no. MSPBN-4.

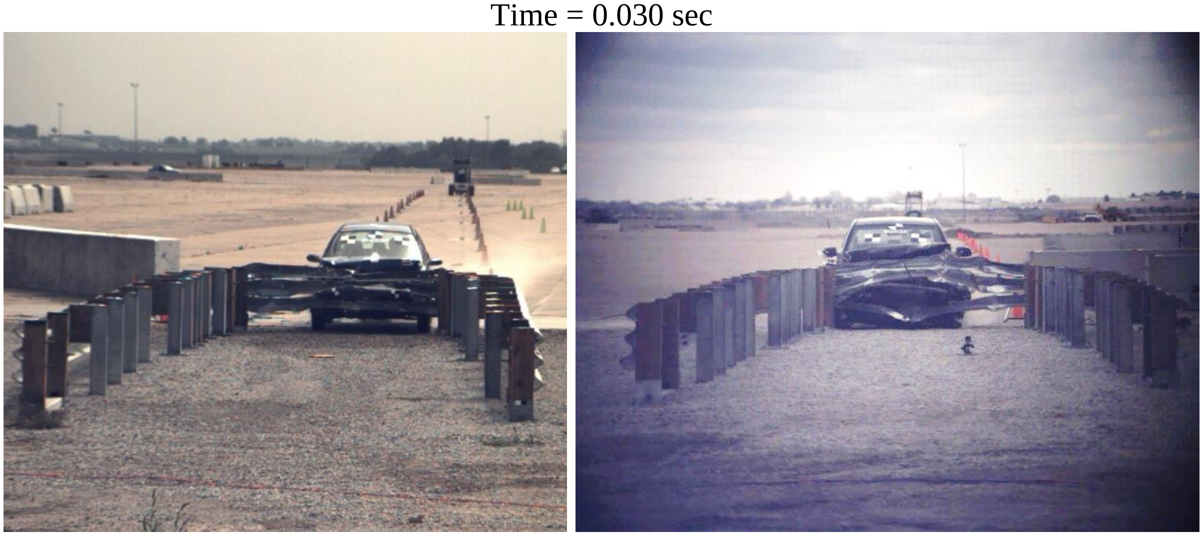
3. The previous two factors led to more rapid rupture of the thrie-beam slot tabs in the nose section, opening of the thrie beam between the middle and lower rail corrugations, upward movement of the upper two rail corrugations, and rupture of the lower rail corrugation, which allowed the vehicle to penetrate the system. Sequential views comparing the 820C vehicle from test no. USPBN-3 and the 1100C vehicle in test no. MSPBN-4 are shown in Figure 76 and Figure 77. The two tests displayed differences in the rail tearing, rail corrugation separation, and capture of the front of the small car. The bullnose systems in these tests were identical. Note that fracture of the lowest rail corrugation was noted in the previous 820C testing as well, but it occurred later in the impact event, and the upper two rail corrugations were more effective in capturing the vehicle.

Based on this analysis, it was determined that the best option for improving the system performance would be to add a third nose cable behind the lowest thrie-beam corrugation. Recall that the current bullnose system has reinforcing cable elements behind the top two rail corrugations that are used to retain the vehicle when the thrie-beam rail in the nose section ruptures during impacts on the end of the system. Adding a third cable to the lowest corrugation could provide similar capture benefits for the 1100C vehicle now that it had also been observed to fracture the rail in the nose section. Additional modification of the slot tabs in the nose section and/or the use of additional capture elements were considered, but these would significantly modify the system and require additional analysis.

Figure 75. Vehicle Geometry and Barrier Alignment Comparison, Test Nos. USPBN-3 (top) and MSPBN-4 (bottom)

Time = 0.000 sec

Time = 0.030 sec



Time = 0.050 sec

Figure 76. Time Sequential Comparison, Test Nos. USPBN-3 (left) and MSPBN-4 (right)

Time = 0.080 sec

Time = 0.120 sec

Figure 77. Time Sequential Comparison, Test Nos. USPBN-3 (left) MSPBN-4 (right)

It should be noted that the opening and separation of the lower corrugation from the upper two corrugations in test no. MSPBN-4 led to some concern that capture of the front end of the 1100C vehicle may not be optimal, even with the addition of a third nose cable. In test no. MSPBN-4, the lower corrugation was riding below the apex or middle of the vehicle's bumper prior to rupturing. The addition of the third nose cable would prevent loss of tension across the front of the vehicle, but the position of that capture element may not be as positive as observed in previous 820C testing. However, this was believed to be the best option moving forward. If the addition of the third nose cable was unsuccessful, additional research using LS-DYNA would likely be required to develop modifications necessary to improve the capture of the 1100C vehicle.

The addition of a third nose cable was not expected to affect the performance of the thrie-beam bullnose system relative to the three previous, successful MASH 2016 crash tests (test designation nos. 3-32, 3-34, and 3-35). Test designation nos. 3-34 and 3-35 were conducted on the side of the system outside of the region where the nose cables are located. Thus, the addition of a third nose cable would have no effect on the outcome of those tests. Test designation no. 3-32 was conducted with the 1100C vehicle impacting the nose of the system at an angle of 15 degrees. This test demonstrated no capture issues with respect to the 1100C vehicle with only the original two nose cables. Thus, the additional of the third nose cable was not expected to negatively affect the outcome of that test either. As such, it was determined that these tests would not need to be rerun on the thrie-beam bullnose system if the proposed modification was successful.

6.2 System Details

The barrier system for test nos. MSPBN-5 through MSPBN-7 consisted of a bullnose median barrier utilizing UBSPs, as shown in Figure 78 through Figure 103. Photographs of the test installations for all three tests are shown in Figure 104 through Figure 117. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

In order to improve the system performance from test no. MSPBN-5, a third nose cable was added to the system behind the lowest thrie-beam corrugation. All other details for the system were identical to those used in test no. MSPBN-4.

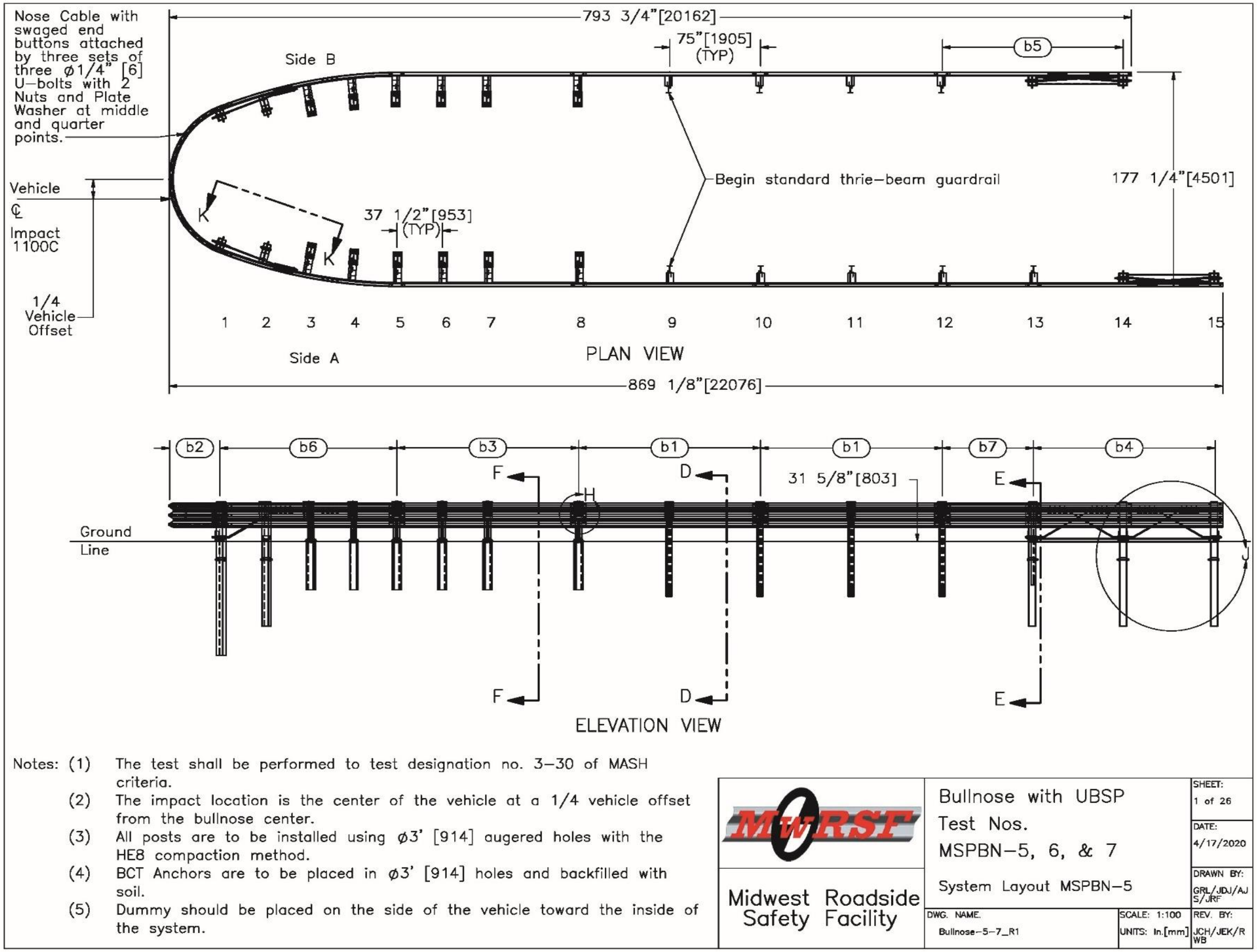


Figure 78. Test Installation Layout, Test No. MSPBN-5

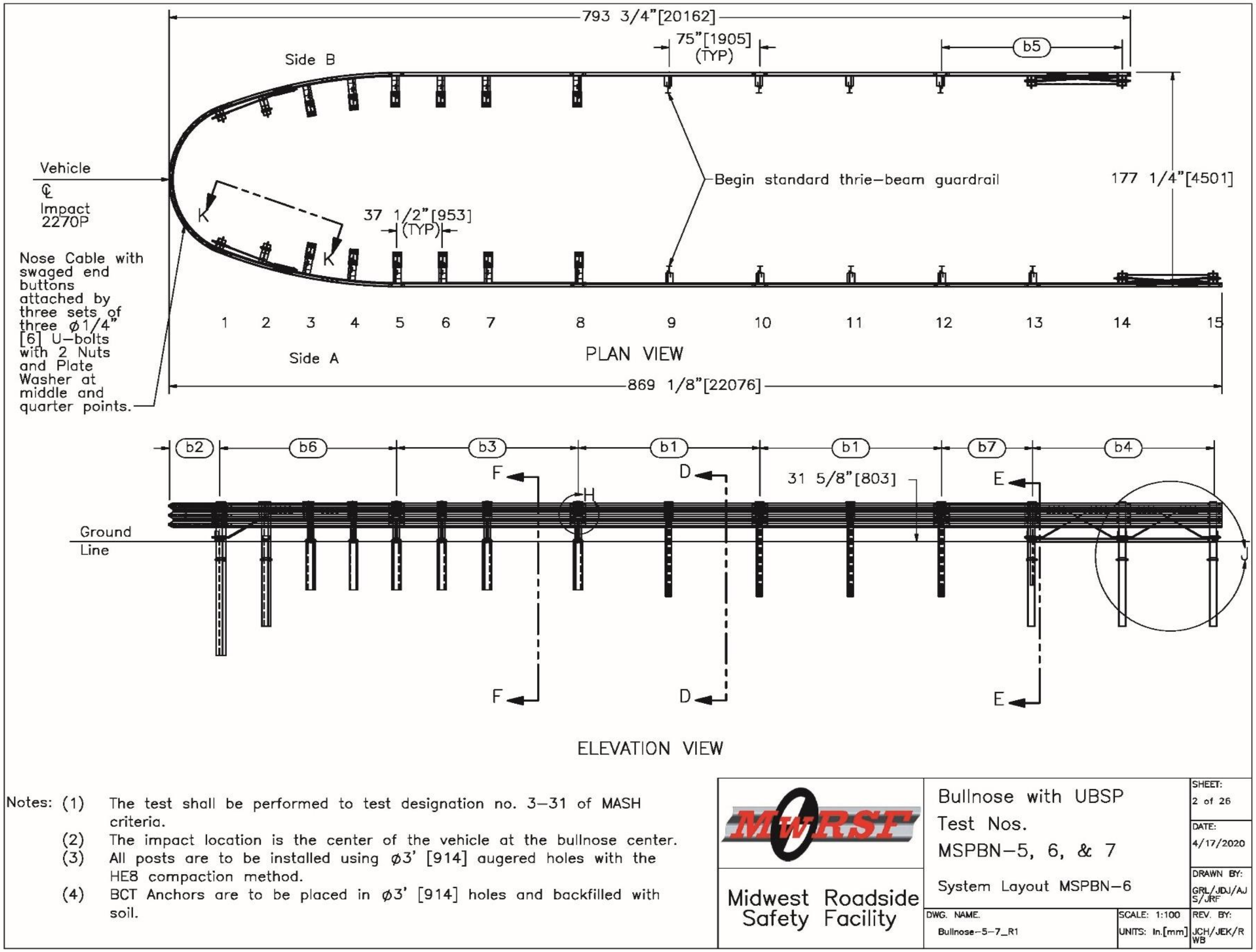


Figure 79. Test Installation Layout, Test No. MSPBN-6

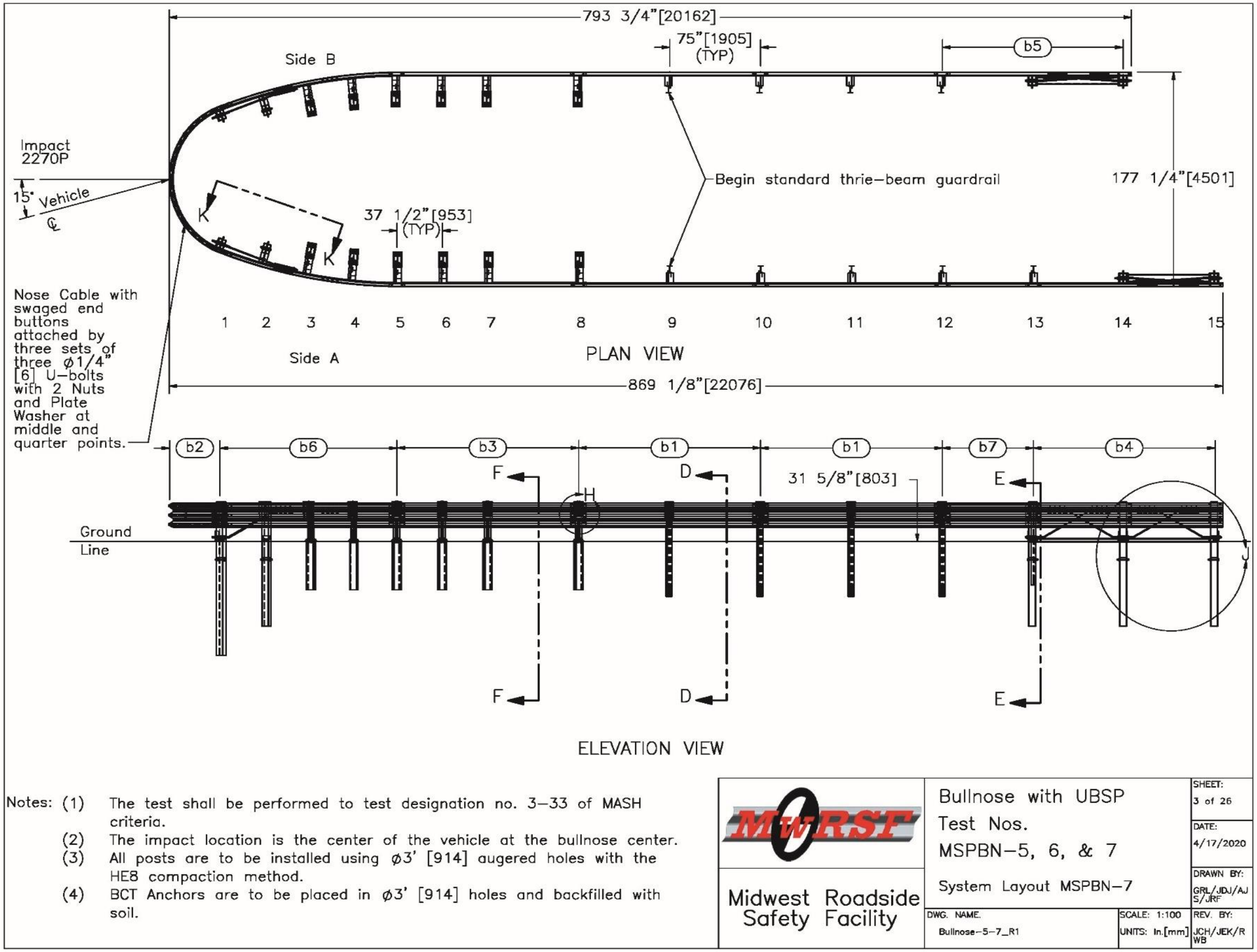


Figure 80. Test Installation Layout, Test No. MSPBN-7

Post No.	Side A				Side B			
	Rear Face–DS Edge		Rear Face–US Edge		Rear Face–DS Edge		Rear Face–US Edge	
	X	Y	X	Y	X	Y	X	Y
1	68'–1 7/8"	2'–3 1/8"	68'–7"	2'–5 1/8"	61'–10 7/8"	2'–3 1/8"	62'–4"	2'–5 1/8"
2	65'–0 3/4"	1'–11 1/4"	65'–6 1/8"	2'–0 3/4"	58'–9 3/4"	1'–11 1/4"	59'–3 1/8"	2'–0 3/4"
3	61'–1 3/8"	1'–9 3/8"	62'–5 1/8"	1'–10 1/8"	55'–10 1/4"	1'–9 3/8"	56'–2 1/8"	1'–10 1/8"
4	59'–2 1/4"	1'–4 3/8"	59'–6 1/8"	1'–4 3/4"	52'–11 1/4"	1'–4 3/8"	53'–3 1/8"	1'–4 3/4"
5	56'–3 3/4"	1'–2 3/8"	56'–7 3/4"	1'–2 3/8"	50'–0 3/4"	1'–2 3/8"	50'–4 3/4"	1'–2 3/8"
6	53'–2 1/4"	1'–2 3/8"	53'–6 1/4"	1'–2 3/8"	46'–11 1/4"	1'–2 3/8"	47'–3 1/4"	1'–2 3/8"
7	50'–0 3/4"	1'–2 3/8"	50'–4 3/4"	1'–2 3/8"	43'–9 3/4"	1'–2 3/8"	44'–1 3/4"	1'–2 3/8"
8	43'–9 3/4"	1'–2 3/8"	44'–1 3/4"	1'–2 3/8"	37'–6 3/4"	1'–2 3/8"	37'–10 3/4"	1'–2 3/8"
9	37'–6 3/4"	6 3/8"	37'–10 3/4"	6 3/8"	31'–3 3/4"	6 3/8"	31'–7 3/4"	6 3/8"
10	31'–3 3/4"	6 3/8"	31'–7 3/4"	6 3/8"	25'–0 3/4"	6 3/8"	25'–4 3/4"	6 3/8"
11	25'–0 3/4"	6 3/8"	25'–4 3/4"	6 3/8"	18'–9 3/4"	6 3/8"	19'–1 3/4"	6 3/8"
12	18'–9 3/4"	6 3/8"	19'–1 3/4"	6 3/8"	12'–6 3/4"	6 3/8"	12'–10 3/4"	6 3/8"
13	12'–6 3/4"	6 3/8"	12'–10 3/4"	6 3/8"	6'–3"	0"	6'–8 1/2"	0"
14	6'–3"	0"	6'–8 1/2"	0"	0"	0"	5 1/2"	0"
15	0"	0"	5 1/2"	0"	–	–	–	–

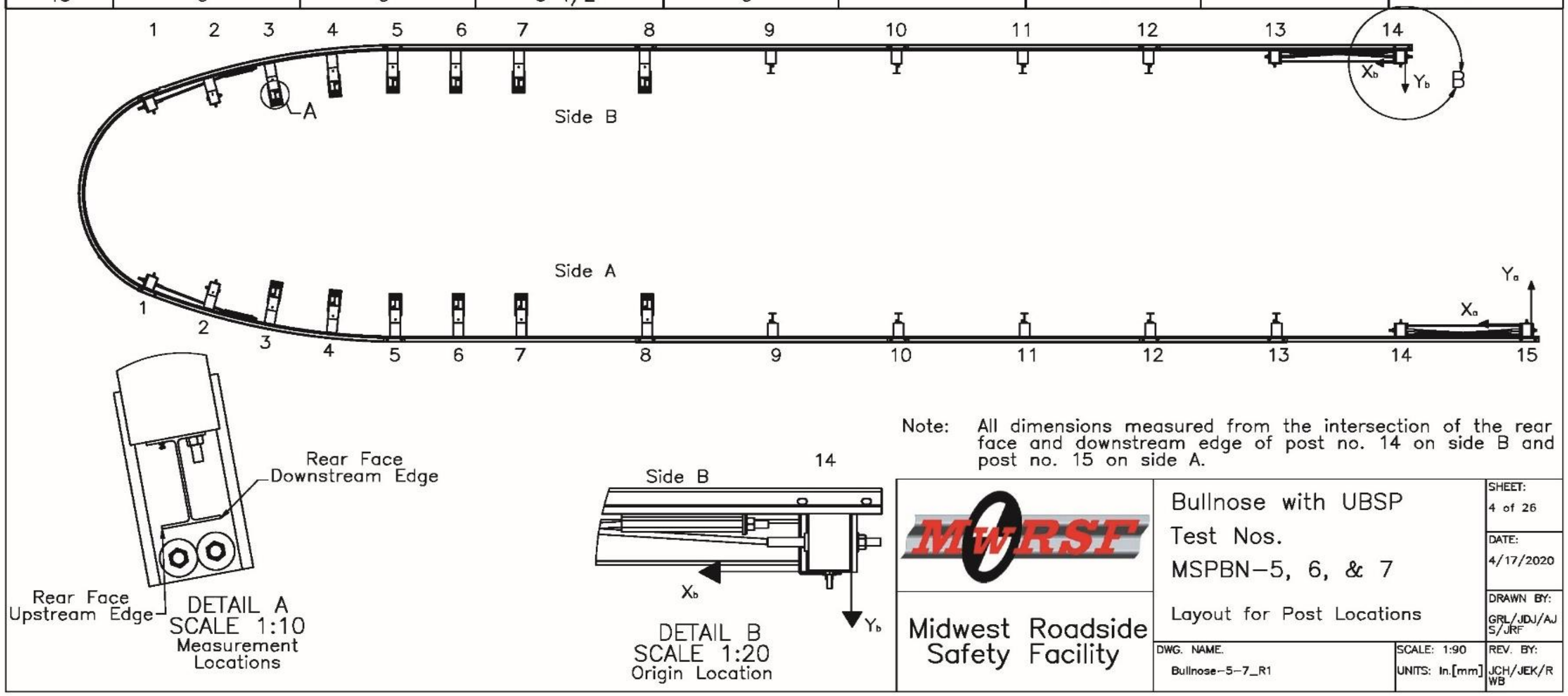


Figure 81. Layout for Post Locations, Test Nos. MSPBN-5 through MSPBN-7

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

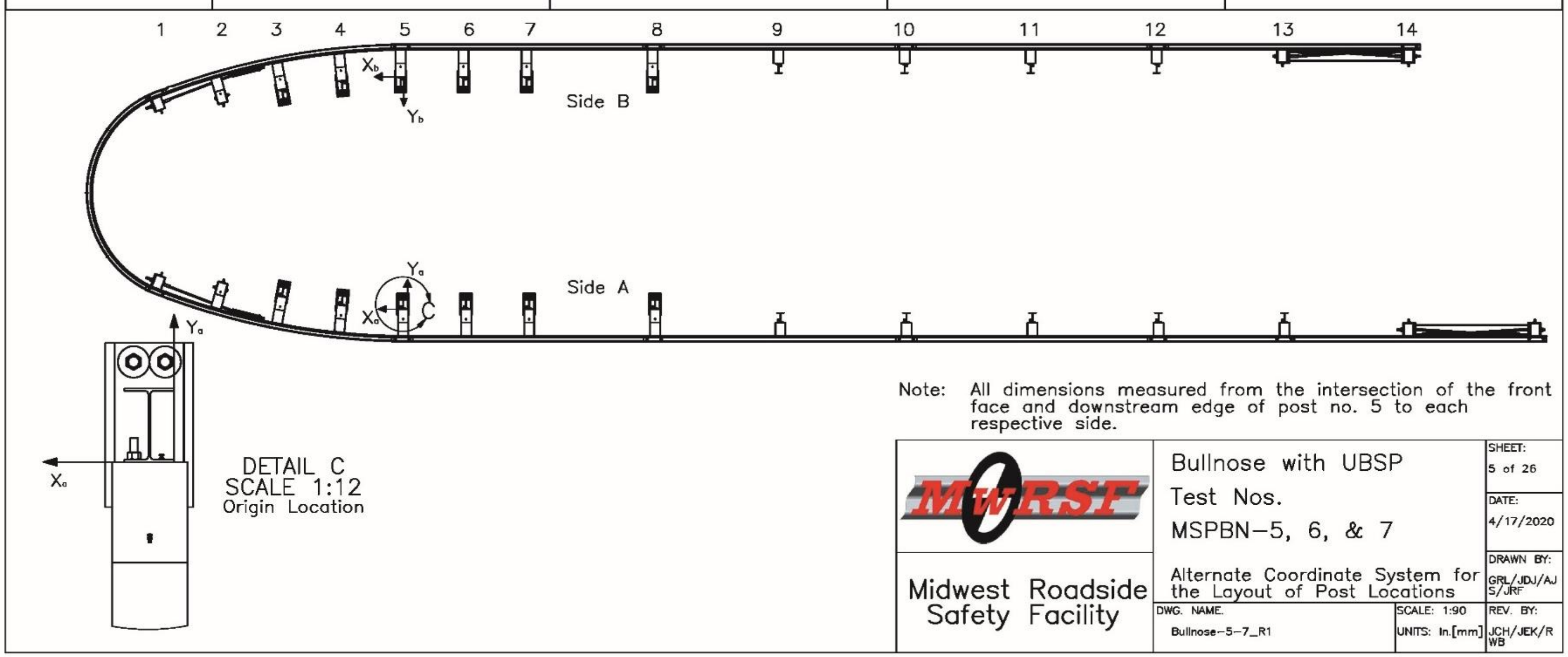


Figure 82. Alternate Coordinate System for the Layout of Post Locations, Test Nos. MSPBN-5 through MSPBN-7

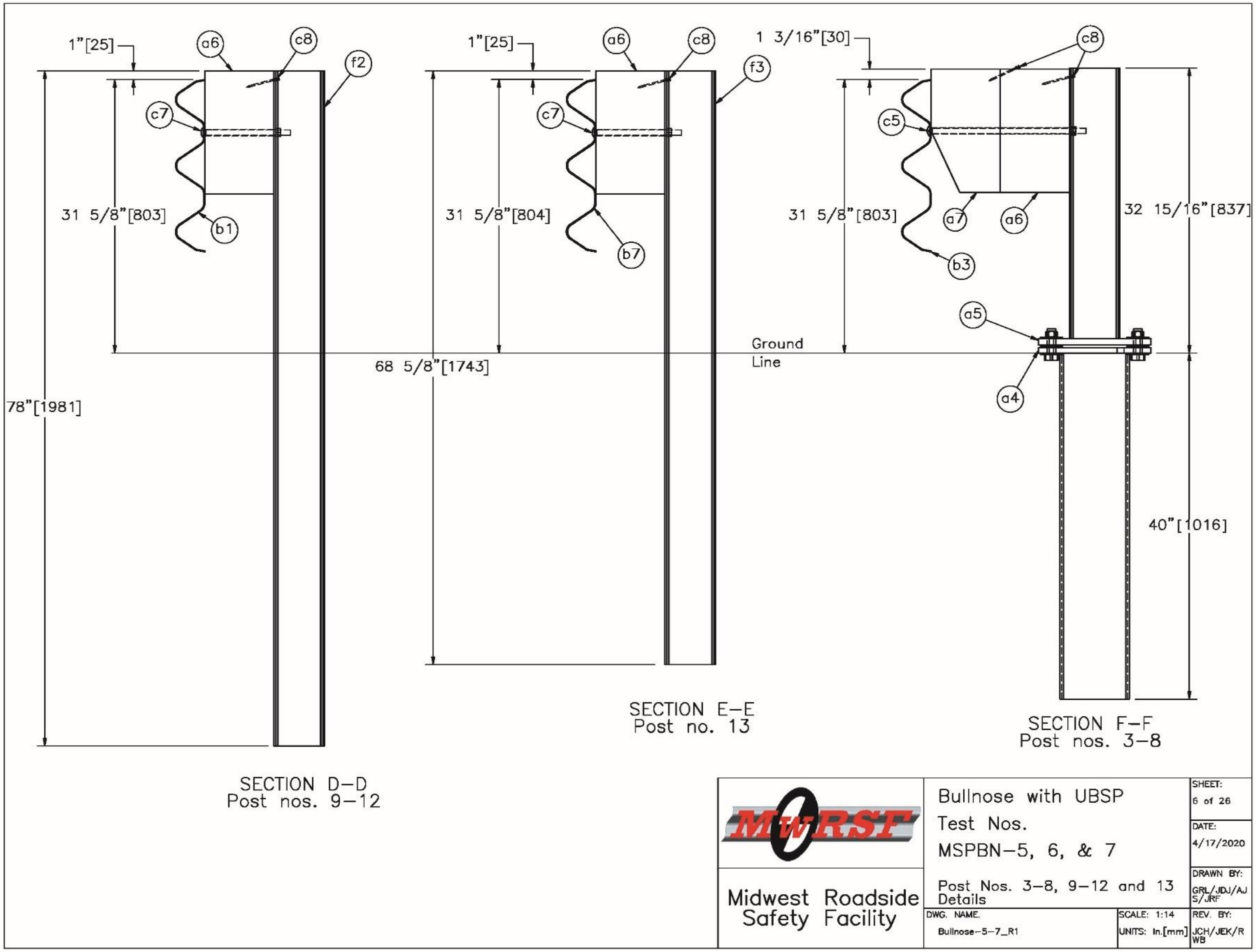


Figure 83. Post Nos. 3 through 8, 9 through 12, and 13 Details, Test Nos. MSPBN-5 through MSPBN-7

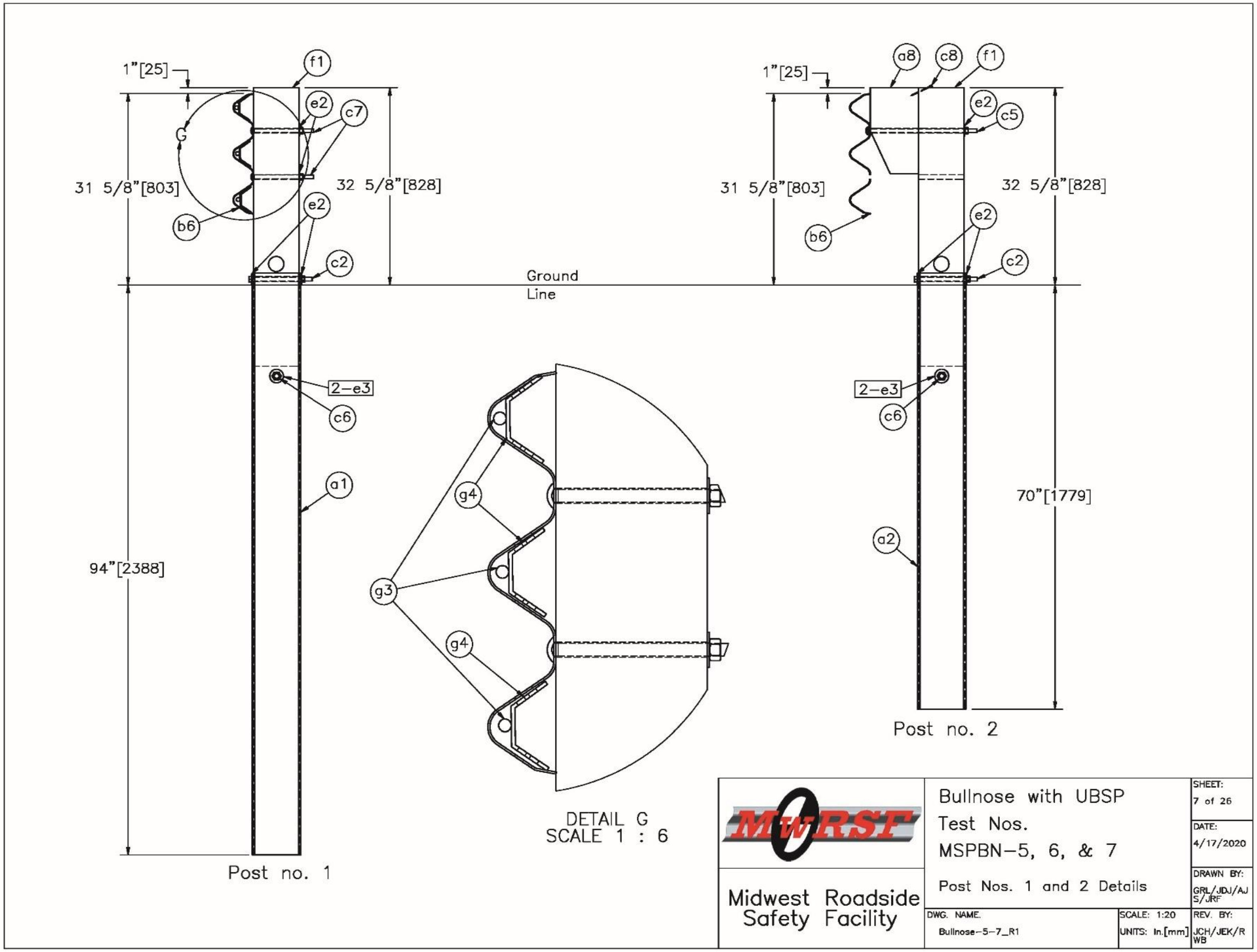


Figure 84. Post Nos. 1 and 2 Details, Test Nos. MSPBN-5 through MSPBN-7

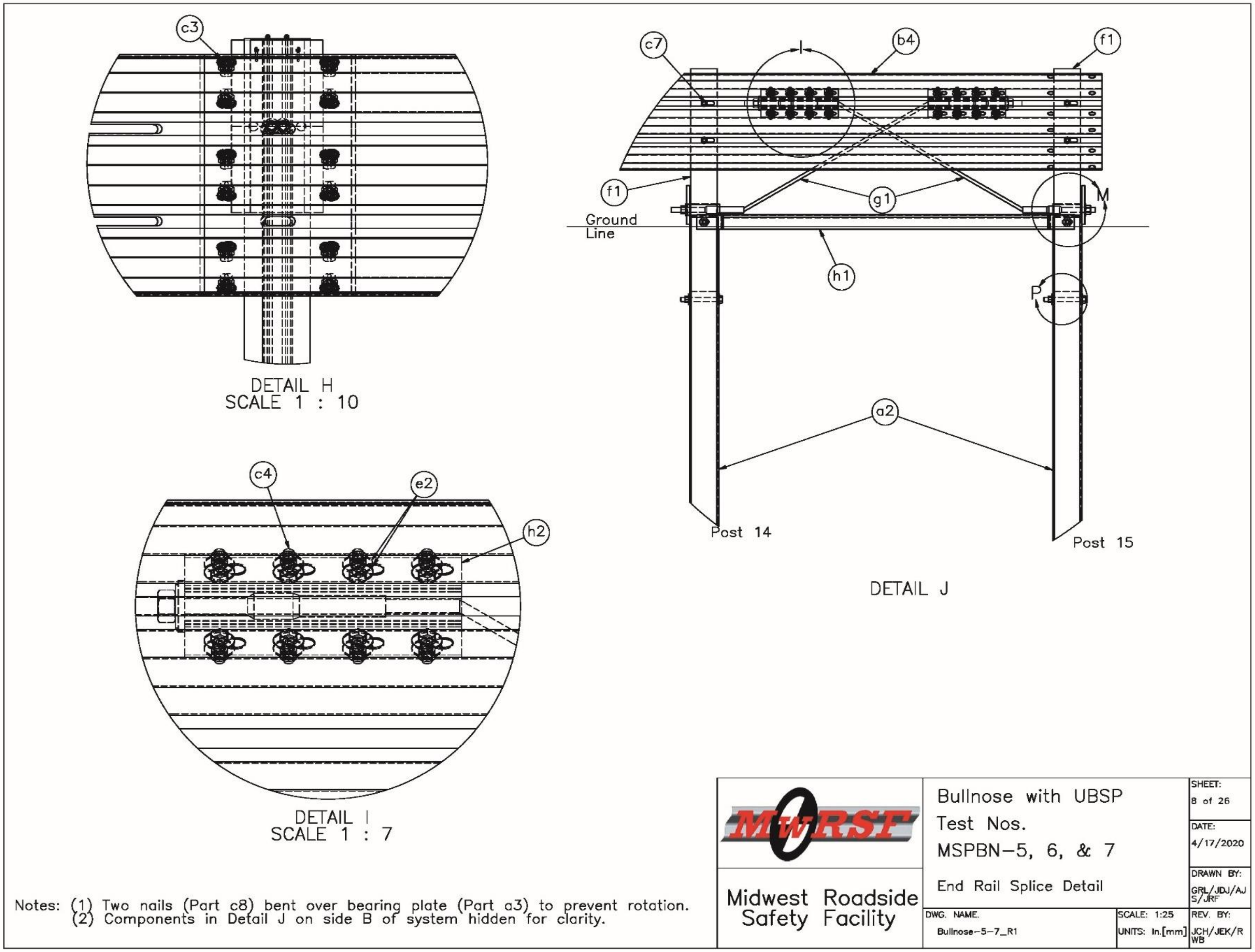


Figure 85. End Rail Splice Detail, Test Nos. MSPBN-5 through MSPBN-7

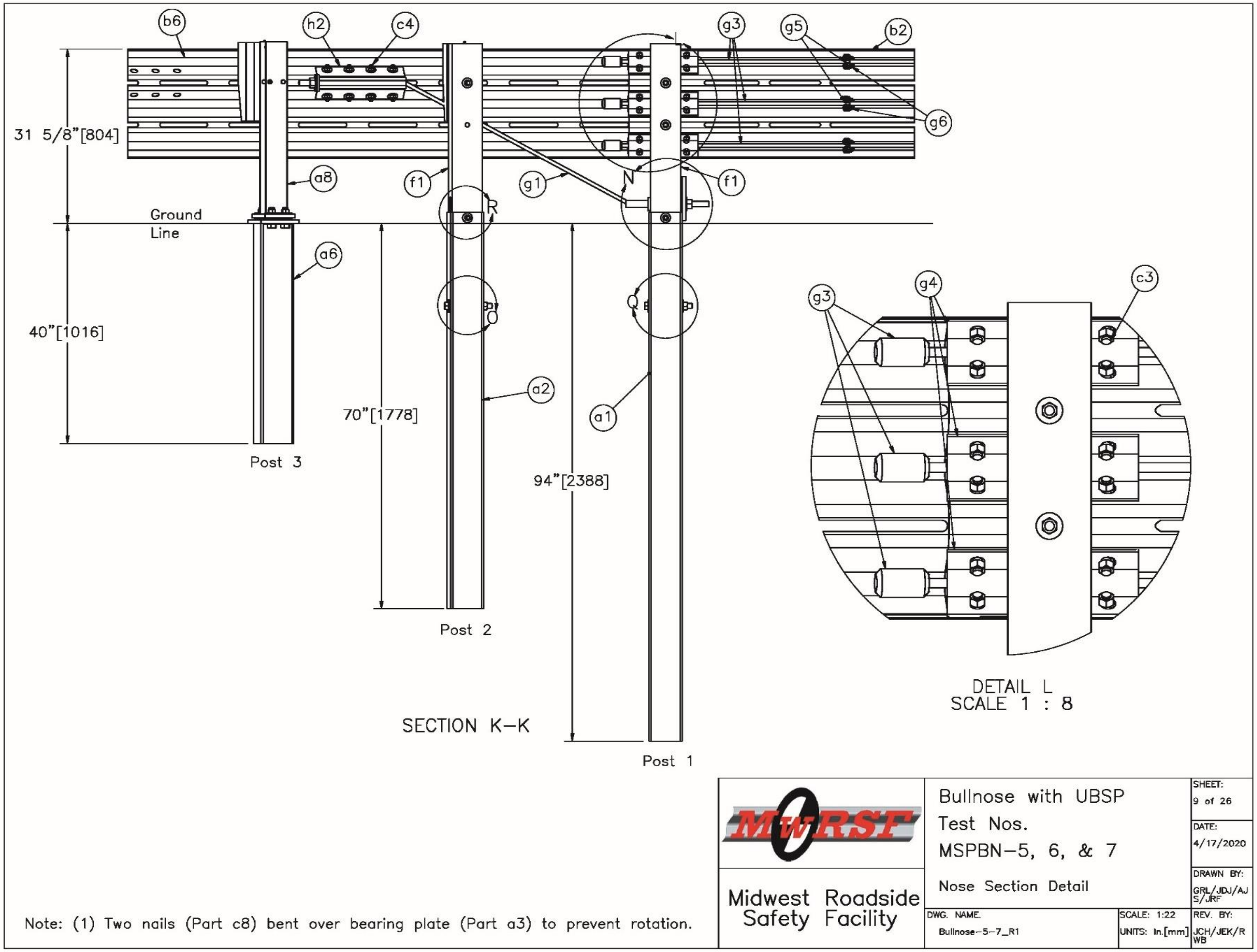


Figure 86. Nose Section Detail, Test Nos. MSPBN-5 through MSPBN-7

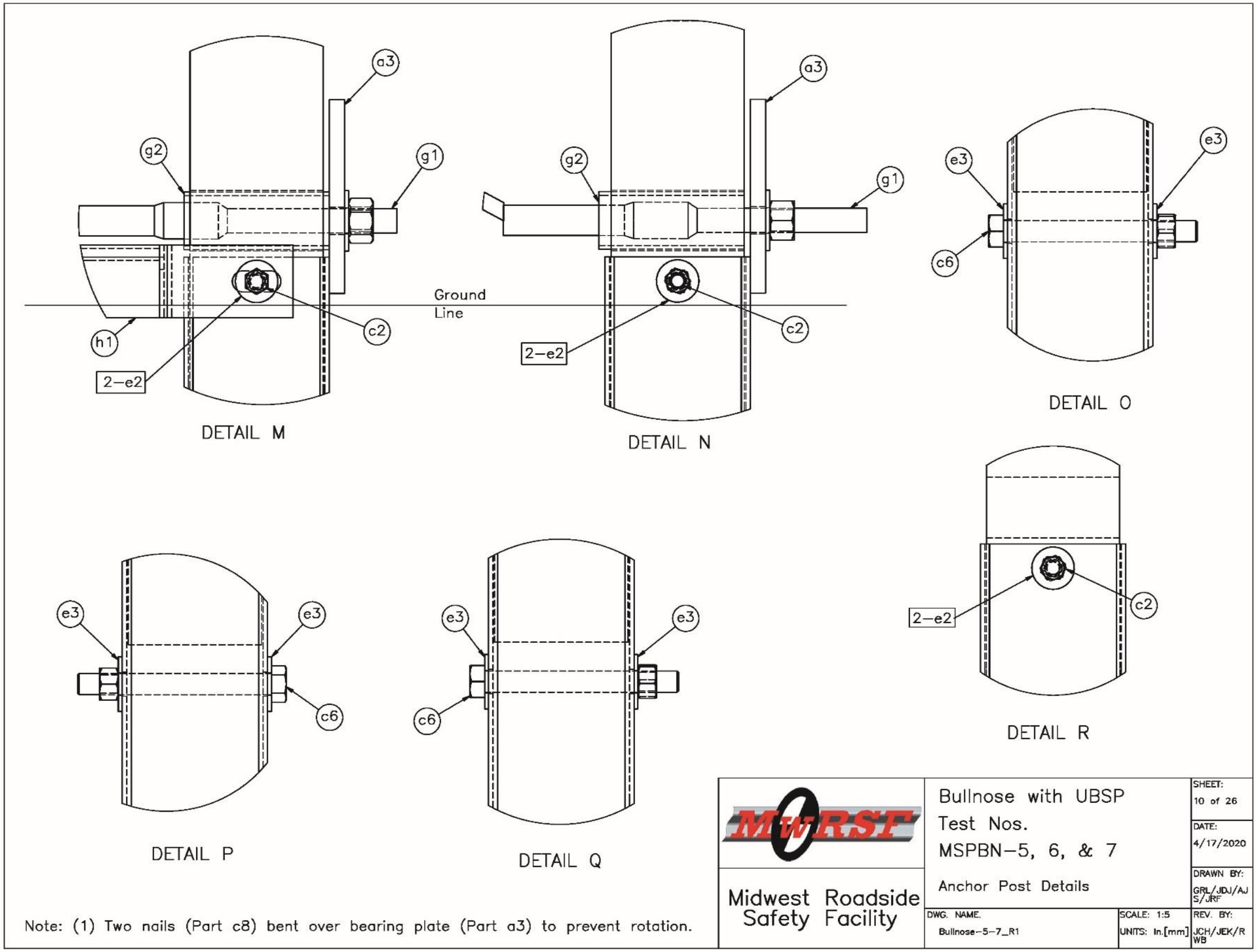


Figure 87. Anchor Post Details, Test Nos. MSPBN-5 through MSPBN-7

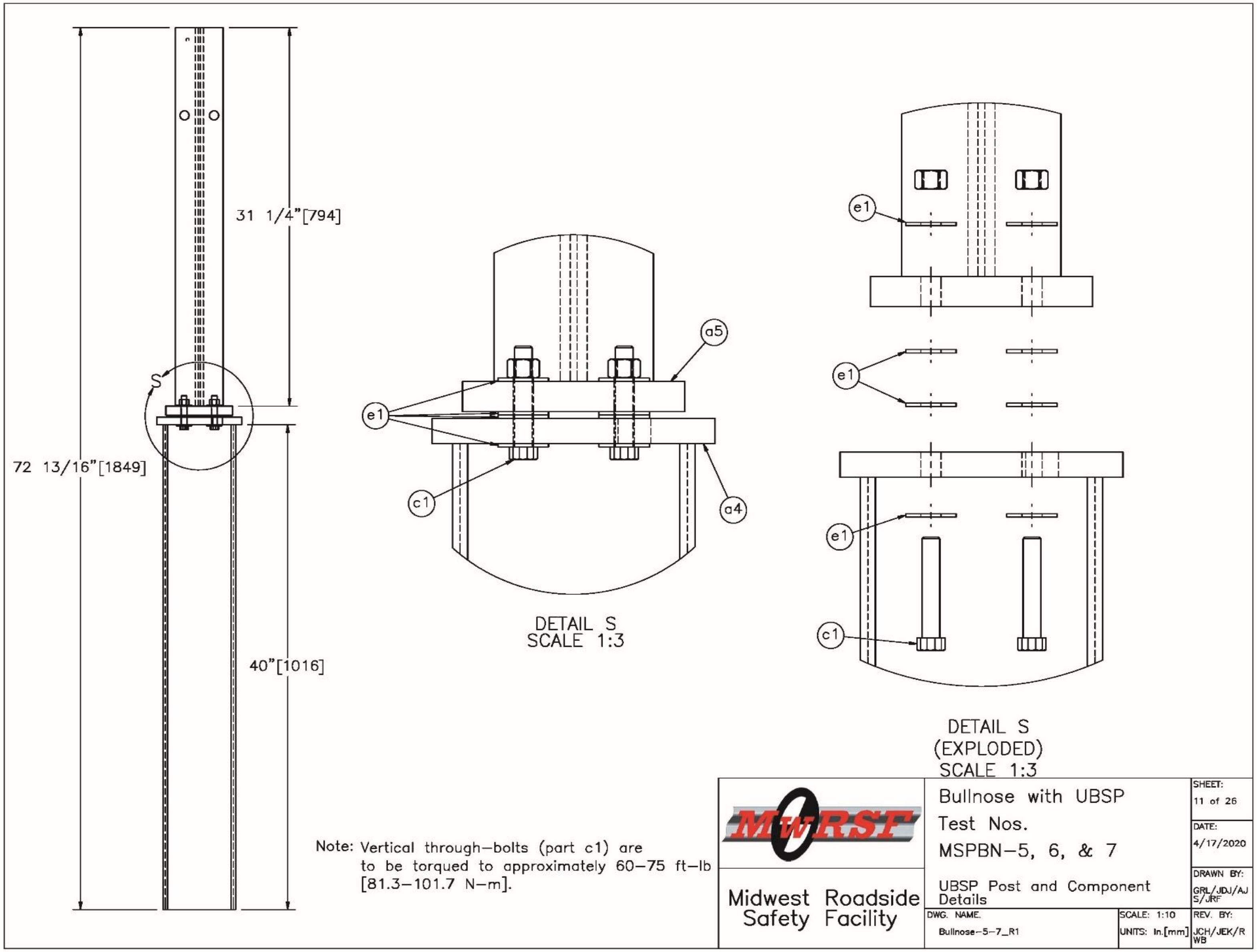


Figure 88. UBSP Post and Component Details, Test Nos. MSPBN-5 through MSPBN-7

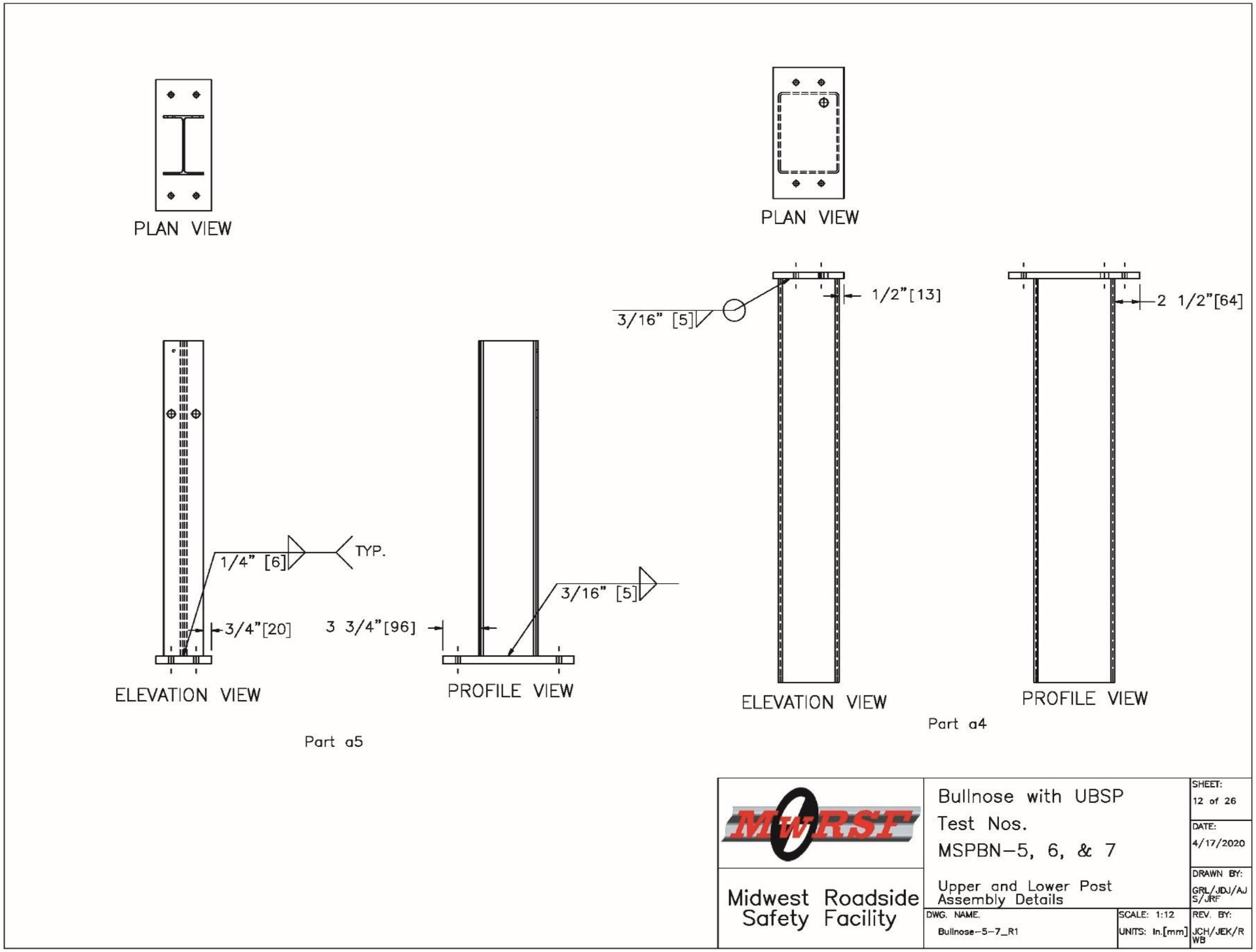


Figure 89. Upper and Lower Post Assembly Details, Test Nos. MSPBN-5 through MSPBN-7

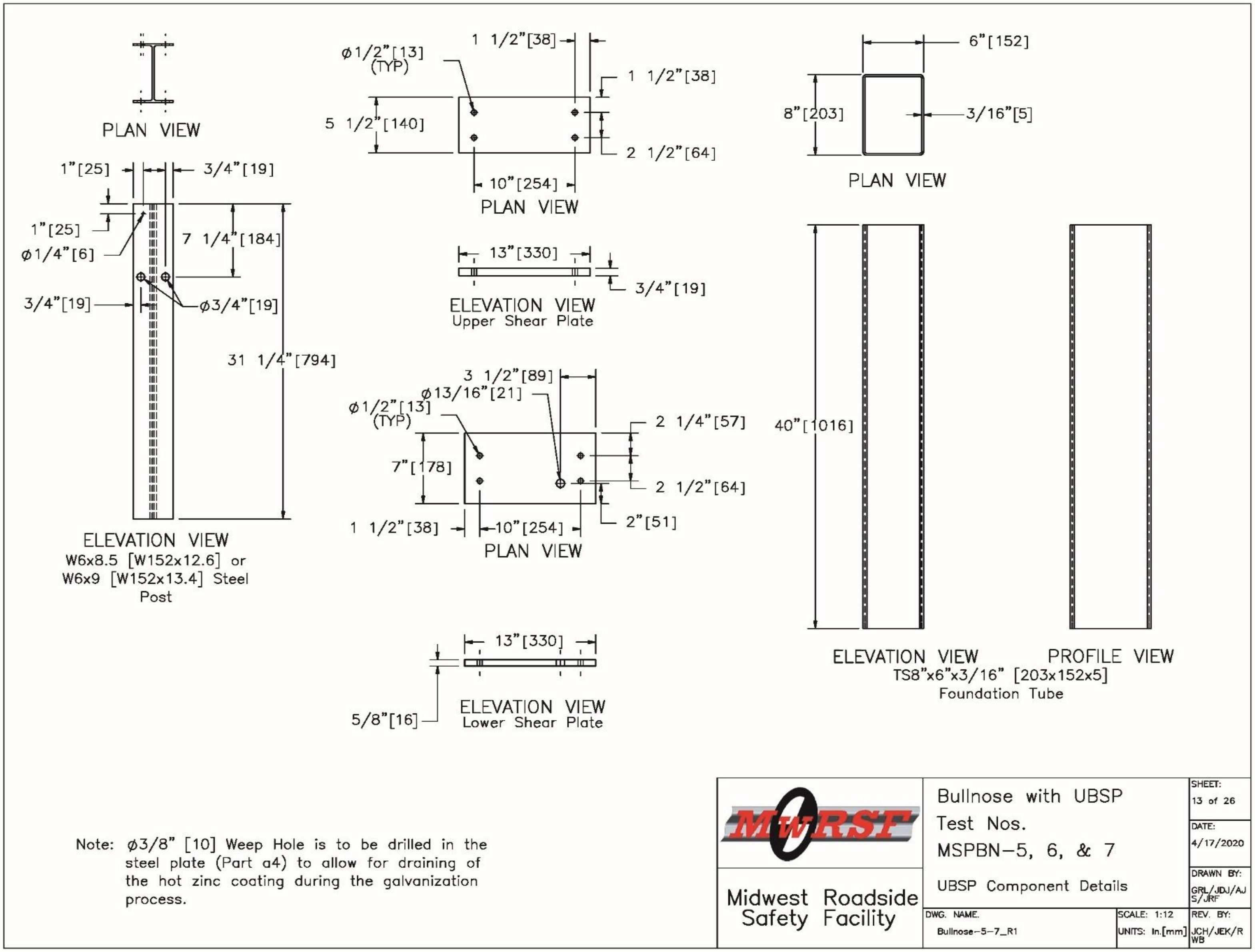


Figure 90. UBSP Component Details, Test Nos. MSPBN-5 through MSPBN-7

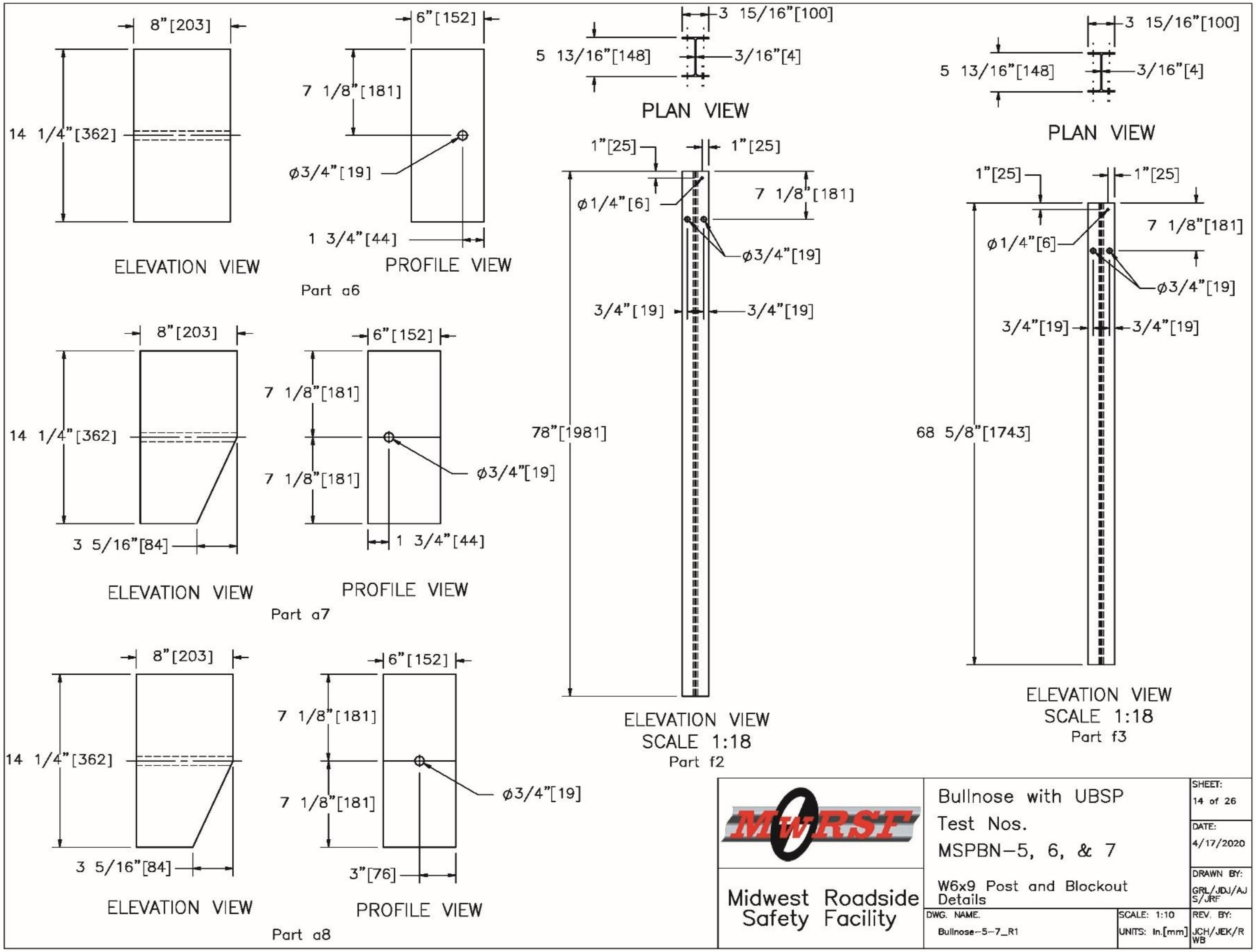


Figure 91. W6x9 Post and Blockout Details, Test Nos. MSPBN-5 through MSPBN-7

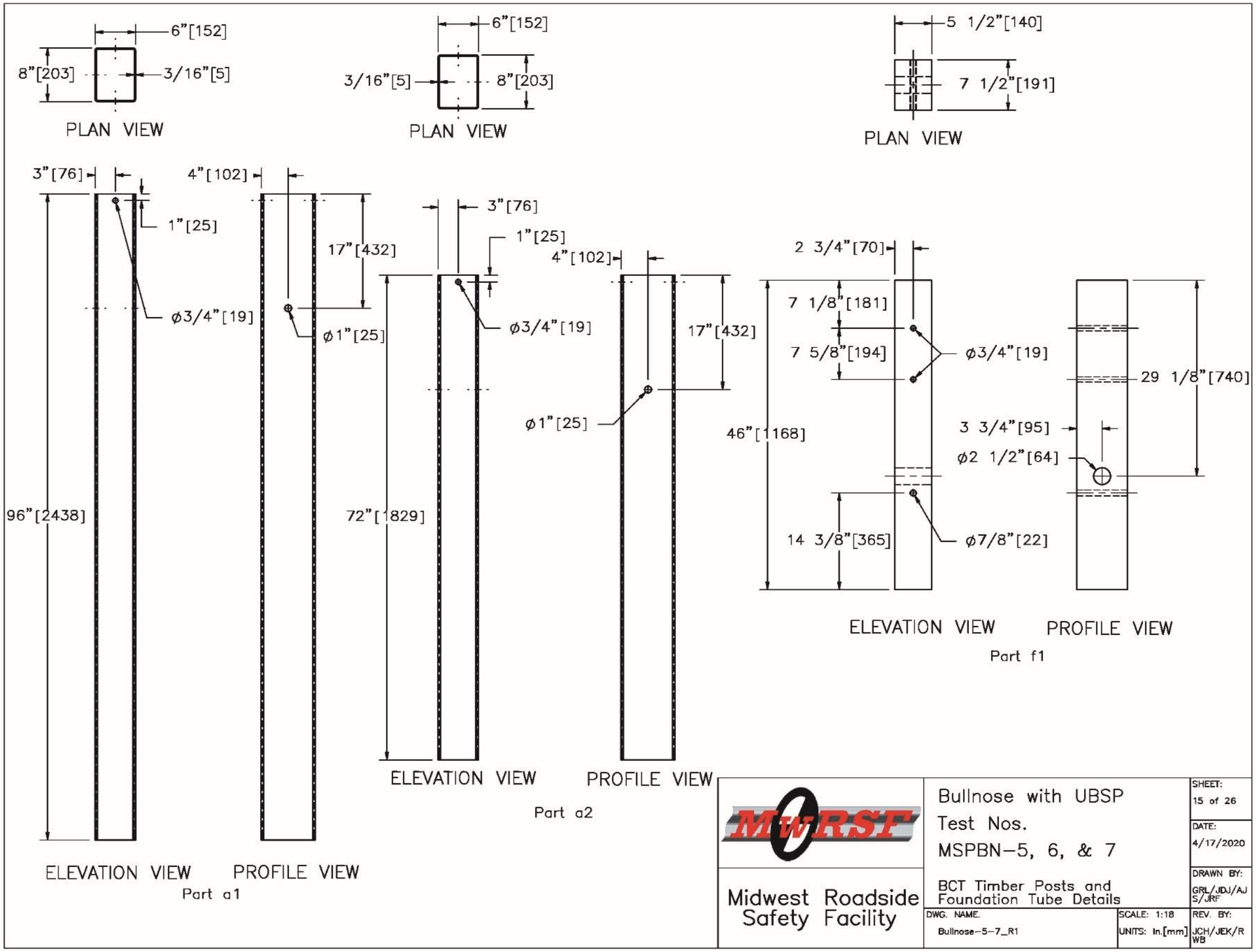


Figure 92. BCT Timber Posts and Foundation Tube Details, Test Nos. MSPBN-5 through MSPBN-7

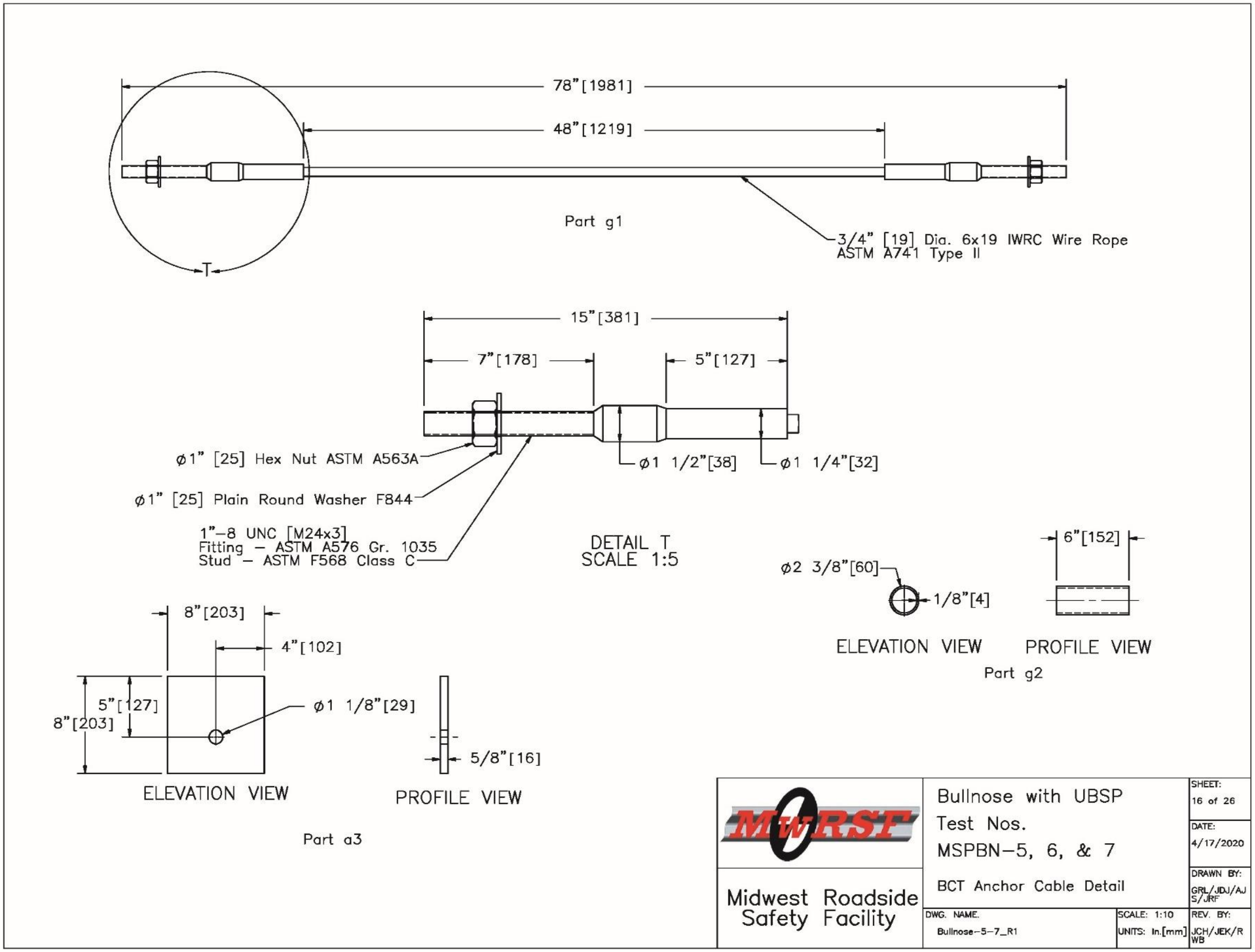


Figure 93. BCT Anchor Cable Detail, Test Nos. MSPBN-5 through MSPBN-7

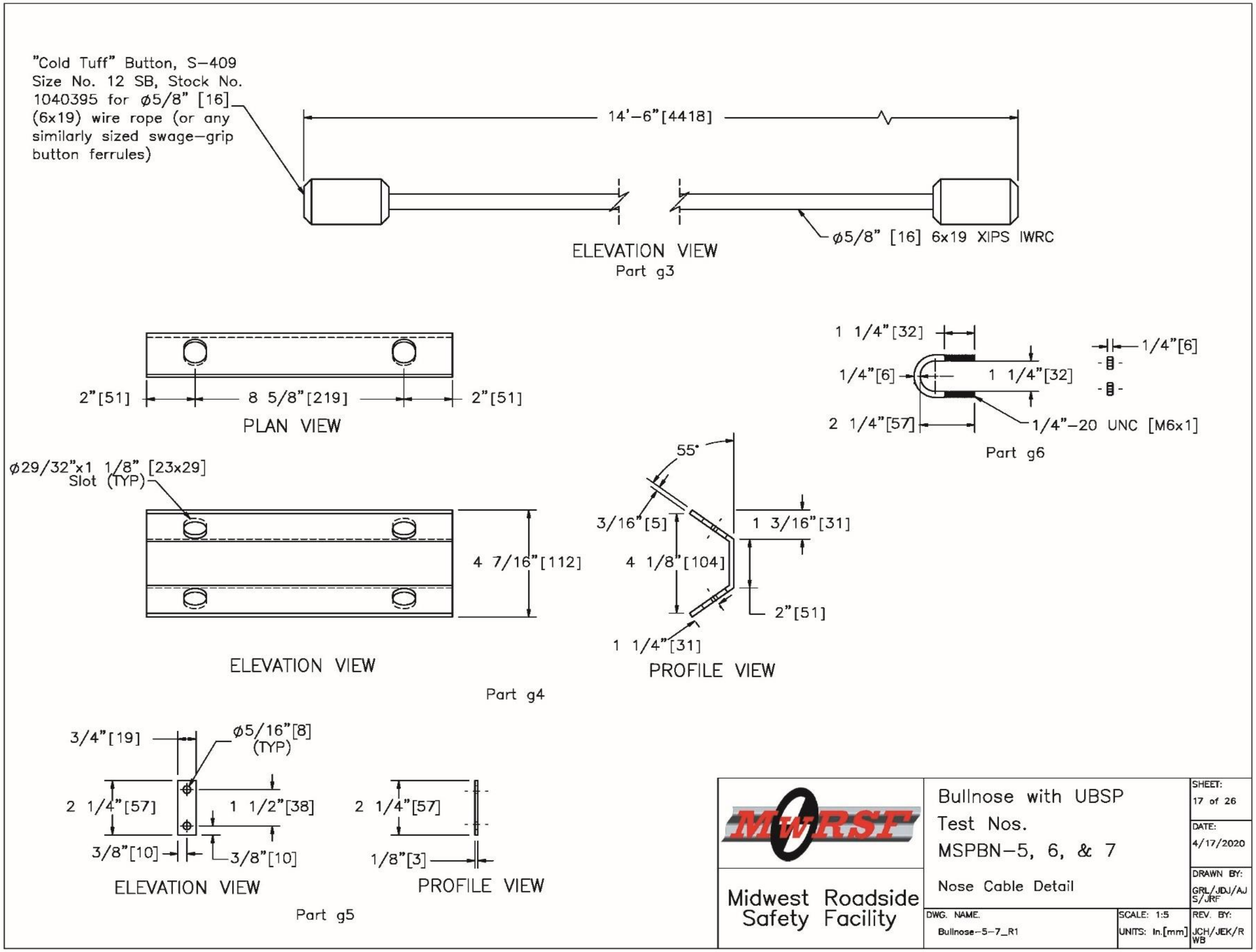


Figure 94. Nose Cable Detail, Test Nos. MSPBN-5 through MSPBN-7

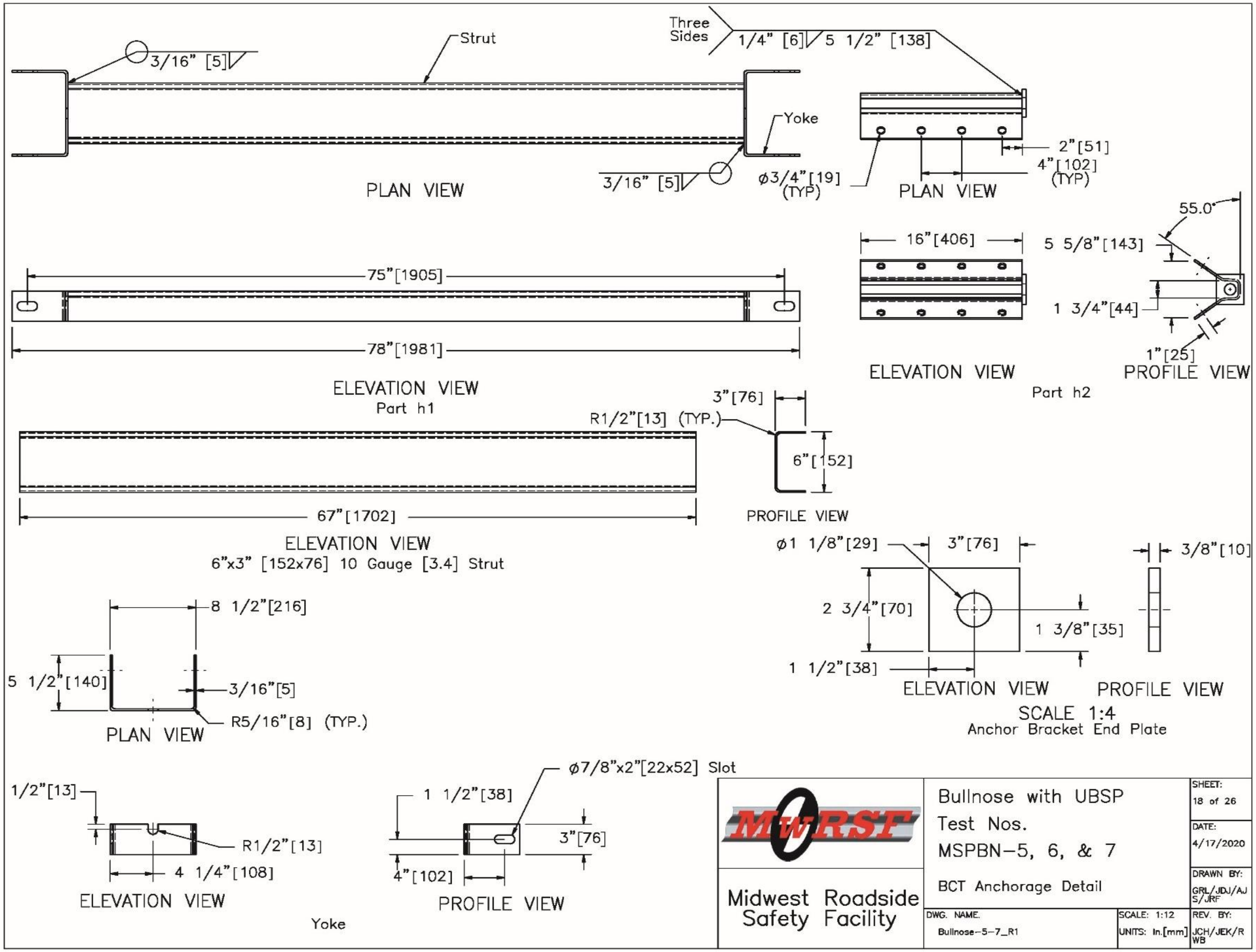


Figure 95. BCT Anchorage Details, Test Nos. MSPBN-5 through MSPBN-7

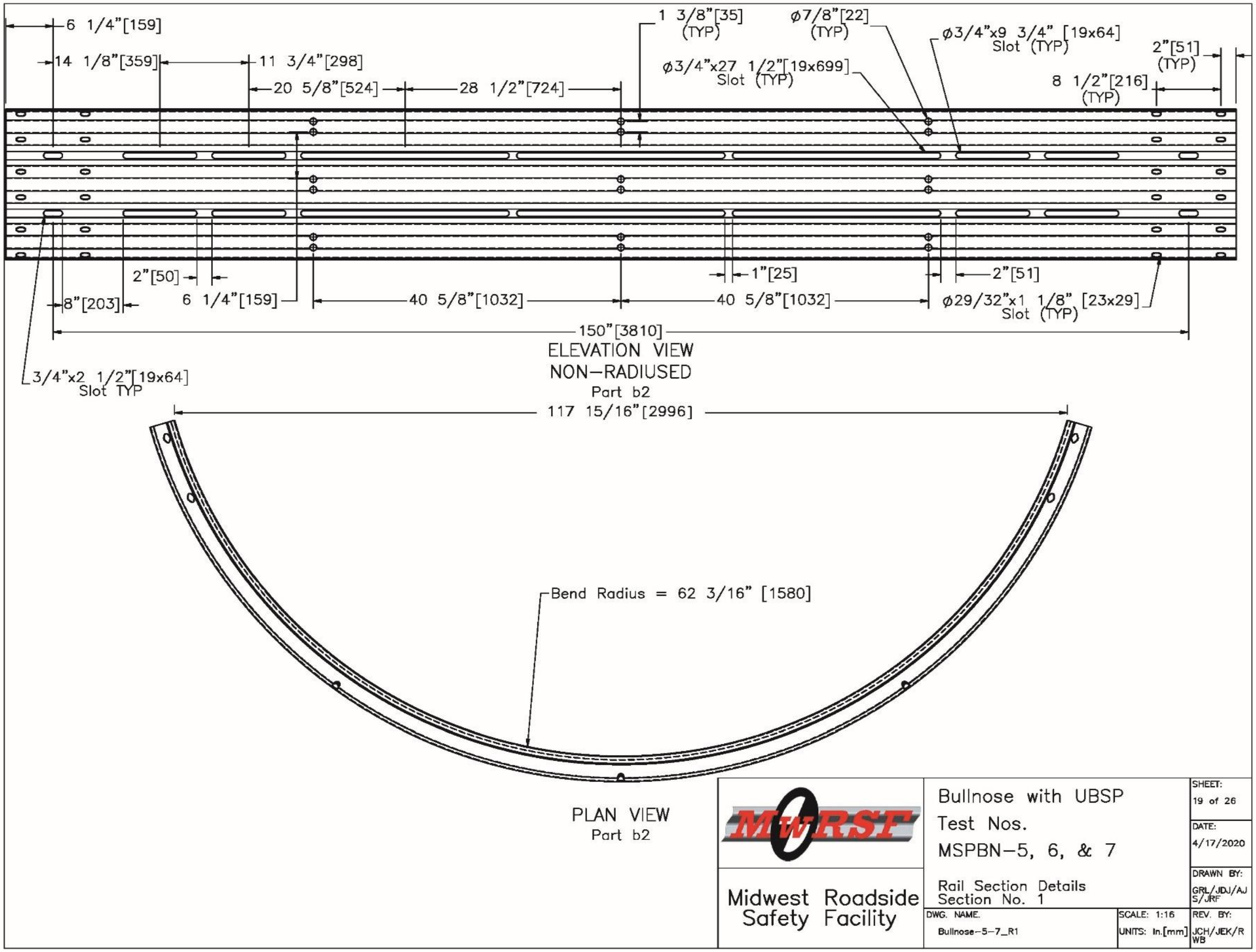


Figure 96. Rail Section Details Section No. 1, Test Nos. MSPBN-5 through MSPBN-7

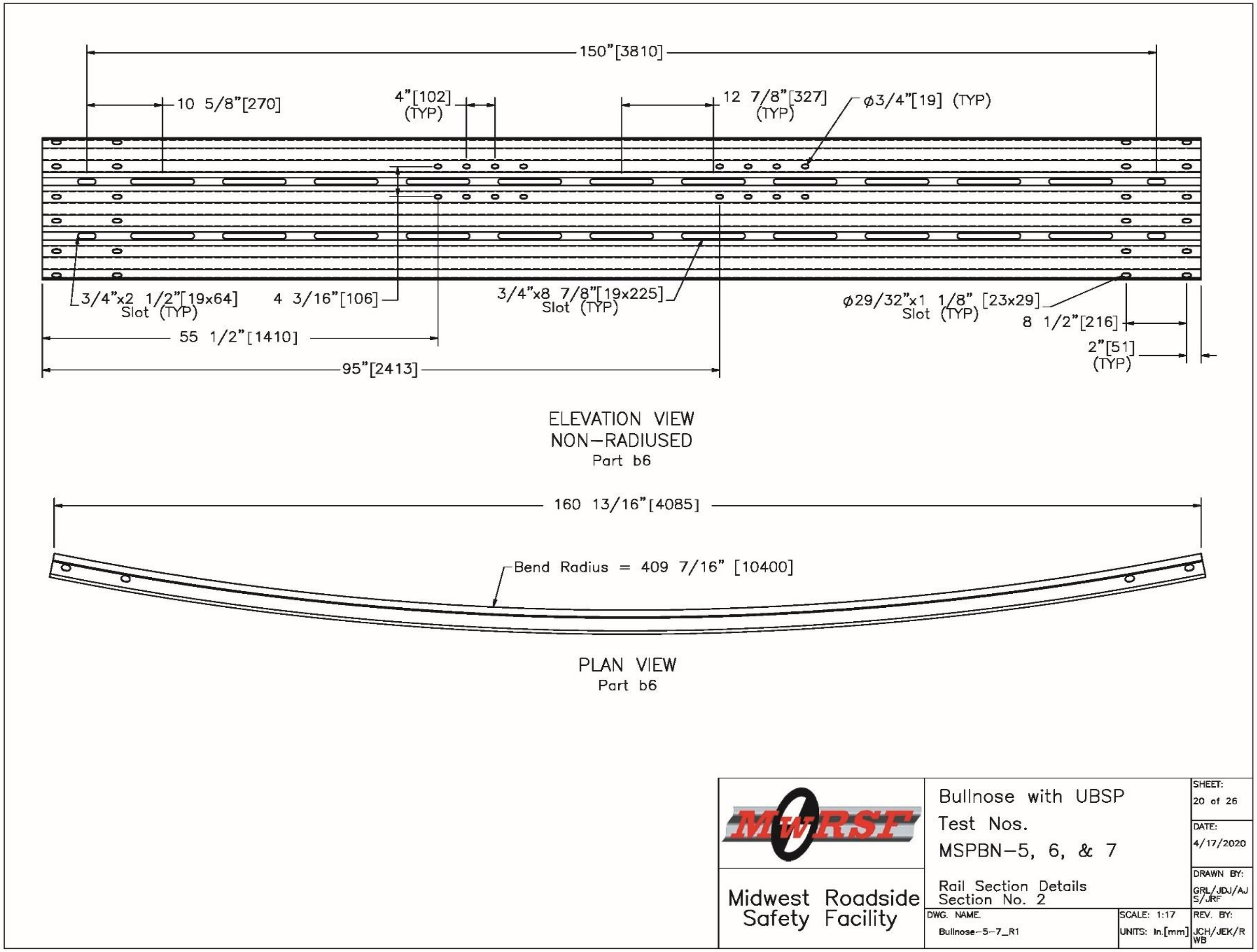


Figure 97. Rail Section Details Section No. 2, Test Nos. MSPBN-5 through MSPBN-7

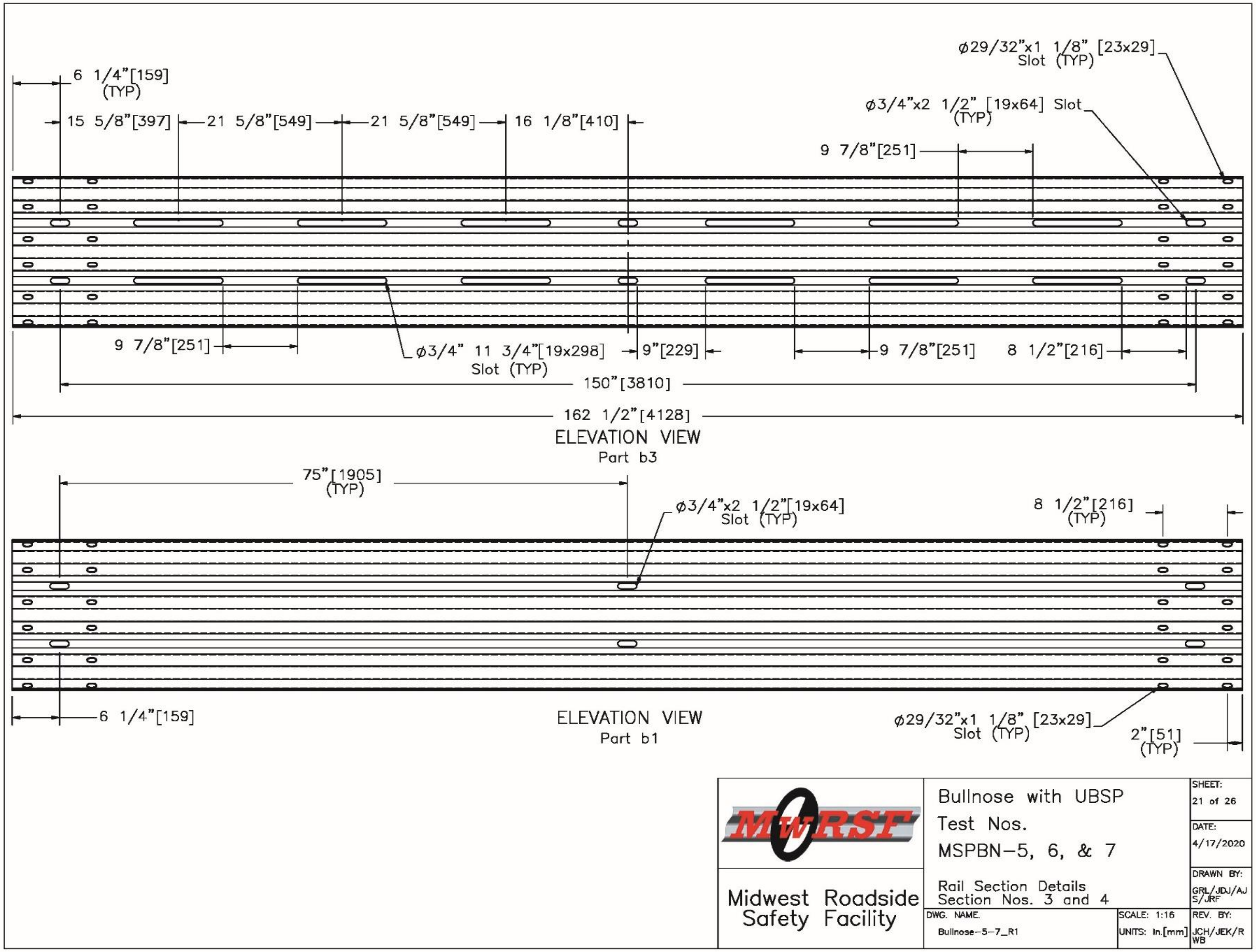


Figure 98. Rail Section Details Nos. 3 and 4, Test Nos. MSPBN-5 through MSPBN-7

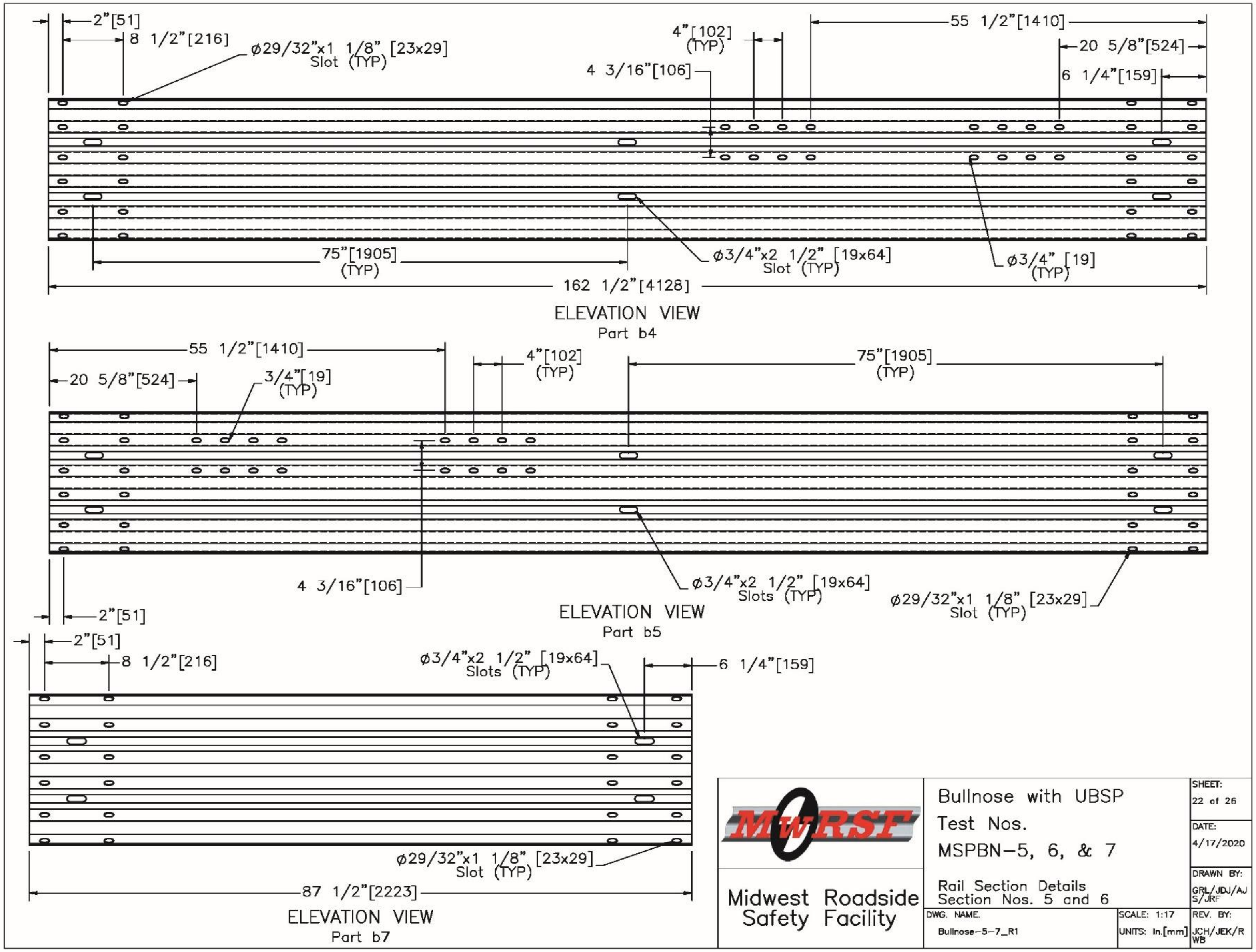


Figure 99. Rail Detail Section Nos. 5 and 6, Test Nos. MSPBN-5 through MSPBN-7

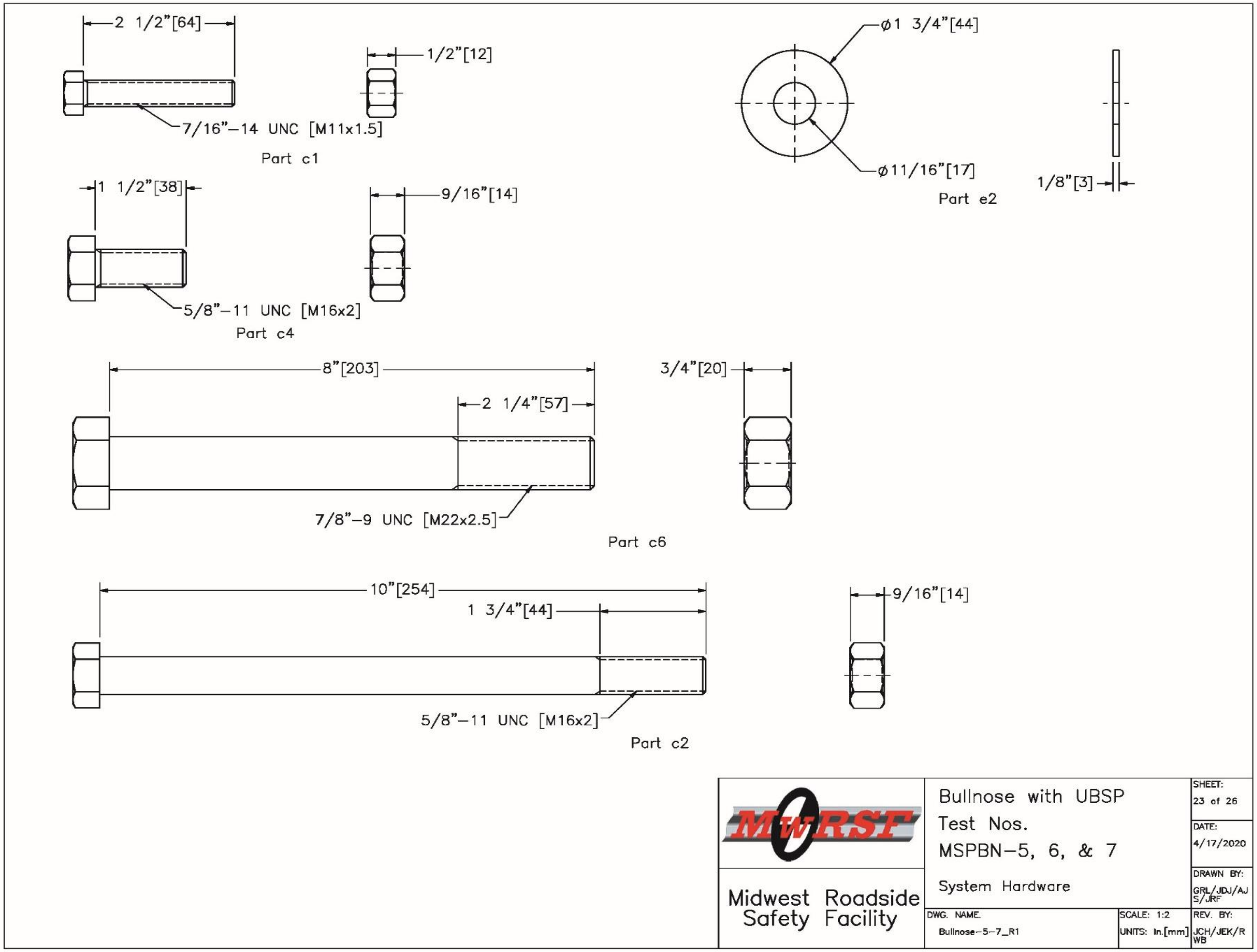


Figure 100. System Hardware, Test Nos. MSPBN-5 through MSPBN-7

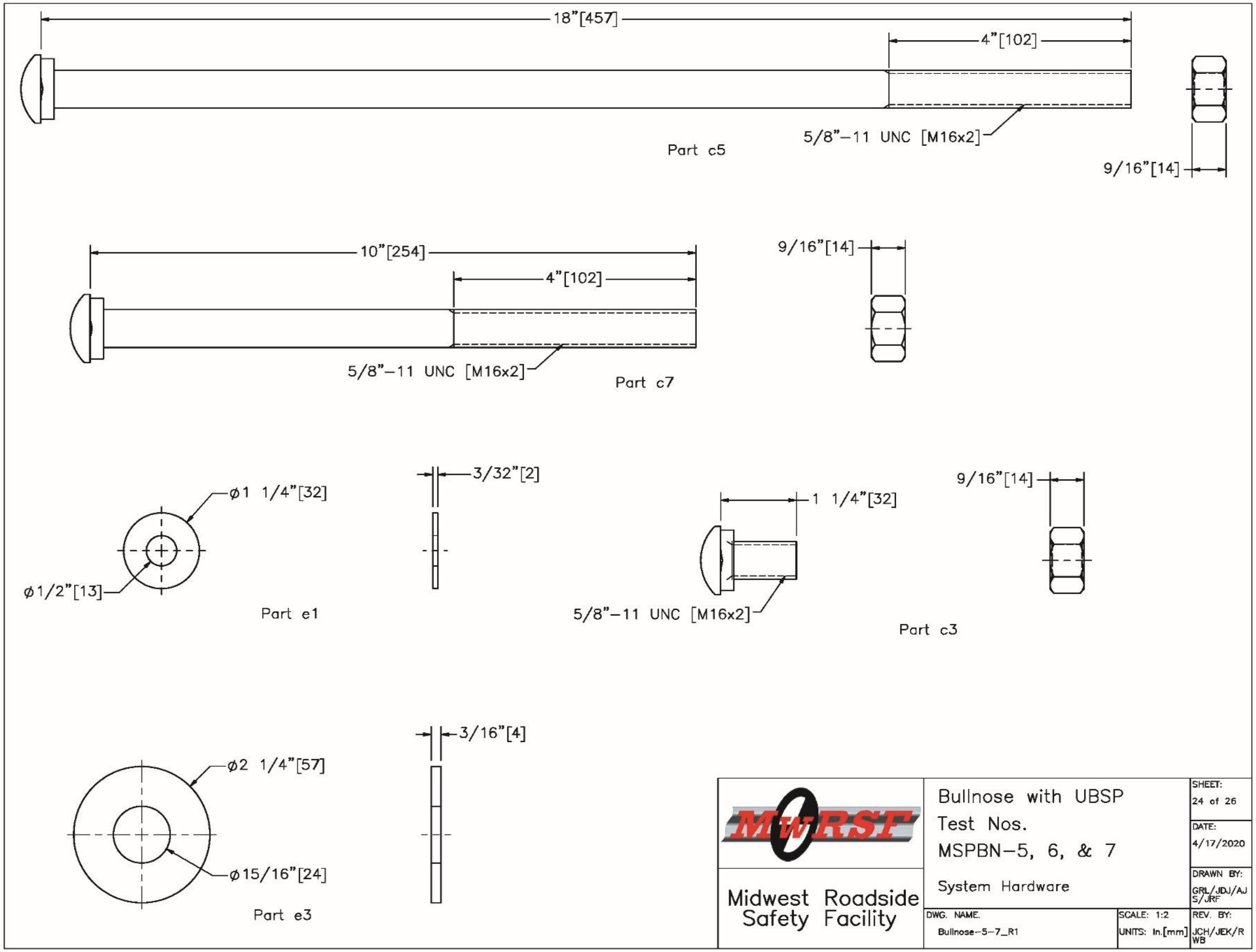


Figure 101. System Hardware, Test Nos. MSPBN-5 through MSPBN-7

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	2	TS8"x6"x3/16" [203x152x5], 96" [2,438] Long Foundation Tube	ASTM A500 Gr. B	ASTM A123	PTE07
a2	6	TS8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	ASTM A123	PTE06
a3	6	8"x8"x5/8" [203x203x16] Anchor Bearing Plate	ASTM A36	ASTM A123	FPB01
a4	12	Lower Slip Post Assembly	Plate–ASTM A36 Foundation Tube–ASTM A500 Gr. B	ASTM A123	PTE08
a5	12	Upper Slip Post Assembly	Plate–ASTM A36 Post–ASTM A992	ASTM A123	PWE11
a6	21	6"x8"x14 1/4" [152x203x362] Timber Blockout	SYP Grade No. 1 or better	–	PDB09
a7	12	6"x8"x14 1/4" [152x203x362] Tapered Timber Blockout	SYP Grade No. 1 or better	–	PDB20
a8	2	6"x8"x14 1/4" [152x203x362] Tapered Timber Blockout – Post 2	SYP Grade No. 1 or better	–	PDB12
b1	4	12'–6" [3,810] 12 gauge [2.7] Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM02a
b2	1	12'–6" [3,810] 12 gauge [2.7] Bent Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM07a
b3	2	12'–6" [3,810] 12 gauge [2.7] Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM07e
b4	1	12'–6" [3,810] 12 gauge [2.7] Thrie Beam End Section – Side A	AASHTO M180	ASTM A123 or A653	–
b5	1	12'–6" [3,810] 12 gauge [2.7] Thrie Beam End Section – Side B	AASHTO M180	ASTM A123 or A653	–
b6	2	12'–6" [3,810] 12 gauge [2.7] Bent Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM07d
b7	1	6'–3" [1,905] 12–gauge [2.7] Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM18a
c2	8	5/8"–11 UNC [M16x2], 10" [254] Long Hex Head Bolt	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBX16a
c3	132	5/8"–11 UNC [M16x2], 1 1/4" [32] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB01
c4	48	5/8"–11 UNC [M16x2], 1 1/2" [38] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBX16a
c5	14	5/8"–11 UNC [M16x2], 18" [457] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB04
c6	8	7/8"–9 UNC [M22x2.5], 8" [203] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	–
c7	21	5/8"–11 UNC [M16x2], 10" [254] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB03
c8	46	16D Double Head Nail	–	–	–

Midwest Roadside Safety Facility

Bullnose with UBSP
Test Nos.
MSPBN–5, 6, & 7

Bill of Materials

SHEET: 25 of 26
DATE: 4/17/2020
DRAWN BY: GRL/JDJ/AJS/JRF
DWG. NAME. Bullnose–5–7_R1
SCALE: None
UNITS: in.[mm]
REV. BY: JCH/JEK/RWB

Figure 102. Bill of Materials, Test Nos. MSPBN-5 through MSPBN-7

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
e1	192	7/16" [11] Dia. Plain Round Washer	ASTM F844	ASTM A153 or B695 Class 55 or F2329	FWC12a
e2	118	5/8" [16] Dia. Plain Round Washer	ASTM F844	ASTM A153 or B695 Class 55 or F2329	FWC16a
e3	16	7/8" [22] Dia. Plain Round Washer	ASTM F844	ASTM A153 or B695 Class 55 or F2329	–
f1	8	BCT Timber Post – MGS Height	SYP Grade No. 1 or better (No knots +/– 18" [457] from ground on tension face)	–	PDF04
f2	8	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 78" [1,981] Long Steel Post	ASTM A992	ASTM A123	–
f3	1	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 68 5/8" [1,743] Long Steel Post	ASTM A992	ASTM A123	–
g1	6	BCT Anchor Cable Assembly	–		FCA01
g2	6	2 3/8" [60] O.D. x 6" [152] Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	ASTM A123	FMM02
g3	3	5/8" Dia. [15.9] x 14.4' [4,389] Long Cable and Swage Button	"Cold Tuff" Button, S–409 Size No. 12 SB, Stock No. 1040395 for 5/8" [16] Dia. (6x19) wire rope (or any similarly sized swage–grip button ferrules)	Wire Rope – Class A Coating	RCM02
g4	6	12 5/8"x5 13/16"x3/16" [321x148x5] Nose Cable Anchor Plate	ASTM A36	ASTM A123	FPA04
g5	9	2 1/4"x3/4" [57x19] 11 gauge [3] U–Bolt Plate Washer	ASTM A1011 CS Type B	ASTM A123	–
g6	9	1/4" [6] Dia. U–Bolt and Nut	U–Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	–
h1	2	Ground Strut Assembly	ASTM A36	ASTM A123	PFP01
h2	6	Anchor Bracket Assmbely	ASTM A36	ASTM A123	FPA01

Midwest Roadside Safety Facility

Bullnose with UBSP
Test Nos.
MSPBN–5, 6, & 7

Bill of Materials

SHEET: 26 of 26
DATE: 4/17/2020
DRAWN BY: GRL/JDJ/AJS/JRF
REV. BY: JCH/JEK/RWB
DWG. NAME. Bullnose–5–7_R1
SCALE: None
UNITS: In.[mm]

Figure 103. Bill of Materials, Test Nos. MSPBN-5 through MSPBN-7

Figure 104. Test Installation Photos, System Overview, Test No. MSPBN-5

Figure 105. Test Installation Photographs, End Anchorages and Nose Cables, Test No. MSPBN-5

Figure 106. Test Installation Photographs, Post Details for Side A (top) and Side B (bottom), Test No. MSPBN-5

Figure 107. Test Installation Photographs, System Nose Details, Test No. MSBPN-5

Figure 108. Test Installation Photographs, Post Details for Side A (top) and Side B (bottom), Test No. MSPBN-5

Figure 109. Test Installation Photos, System Overview, Test No. MSPBN-6

Figure 110. Test Installation Photographs, End Anchorage and Nose Cables, Test No. MSPBN-6

Figure 111. Test Installation Photographs, Nose Details, Test No. MSPBN-6

Figure 112. Test Installation Photographs, Post Details, MSPBN-6

Figure 113. Test Installation Photograph, System Overview, Test No. MSPBN-7

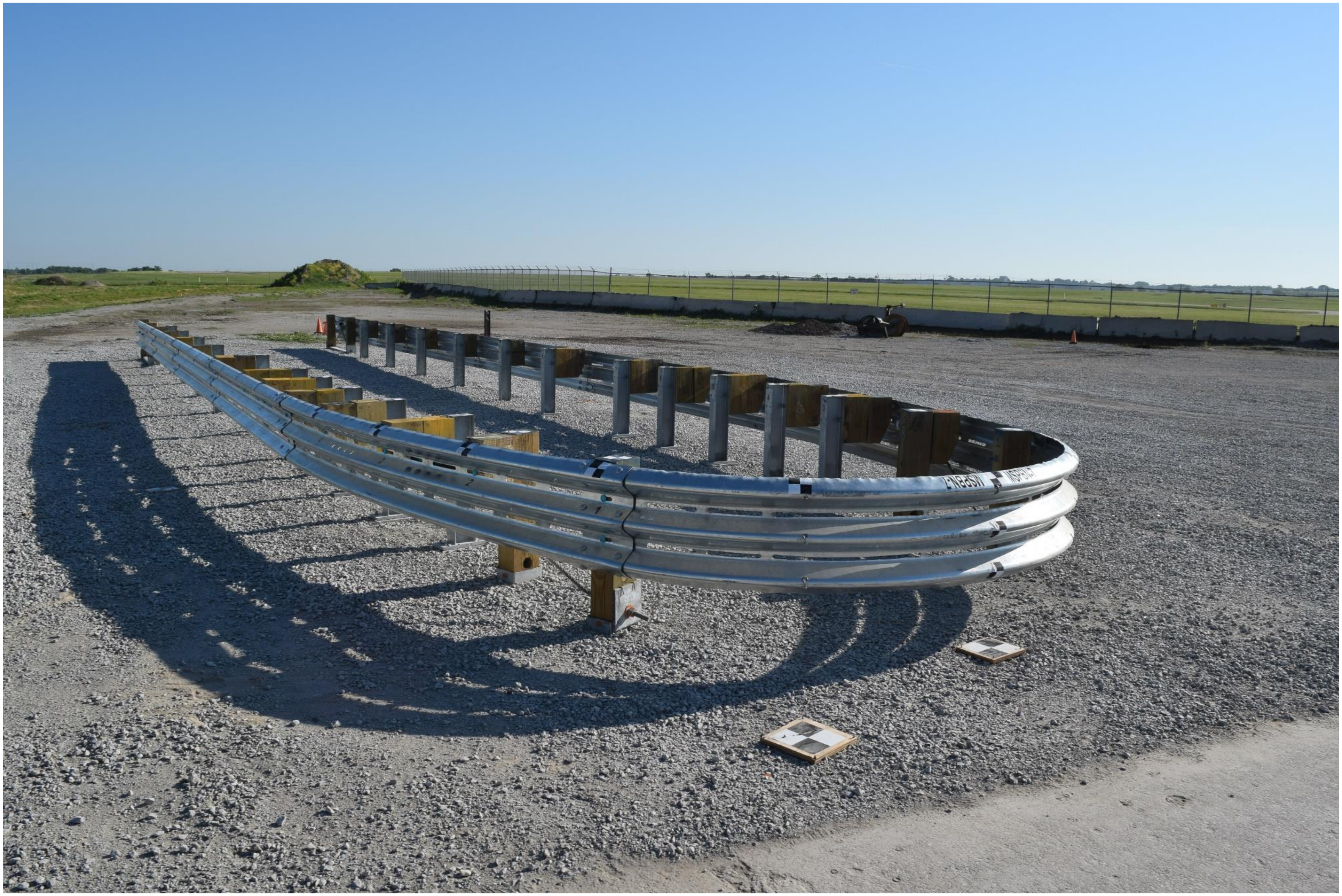


Figure 114. Test Installation Photograph, System Overview, Test No. MSPBN-7

Figure 115. Test Installation Photographs, Nose Cable and End Anchorage Details, Test No. MSPBN-7

Figure 116. Test Installation Photographs, Nose Details, Test No. MSPBN-7

Figure 117. Test Installation Photographs, Post Details, Test No. MSPBN-7

7 FULL-SCALE CRASH TEST NO. MSPBN-5

7.1 Static Soil Test

Before full-scale crash test no. MSPBN-5 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. The static test results, as shown in Appendix C, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and full-scale crash testing could be conducted on the barrier system.

7.2 Weather Conditions

Test no. MSPBN-5 was conducted on May 15, 2018 at approximately 11:45 a.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 10.

Table 10. Weather Conditions, Test No. MSPBN-5

Temperature	73° F
Humidity	59%
Wind Speed	6 mph
Wind Direction	50° from True North
Sky Conditions	Overcast
Visibility	10 Statute Miles
Pavement Surface	Dry / Wet / Icy
Previous 3-Day Precipitation	0.02 in.
Previous 7-Day Precipitation	0.49 in.

7.3 Test Description

Test no. MSPBN-5 was conducted under the MASH 2016 TL-3 guidelines for test designation no. 3-30. Test designation no. 3-30 is an impact of the 1100C vehicle at 62 mph (100 km/h) and 0 degrees on the nose of the system with a ¼-vehicle offset. Initial vehicle impact was with the vehicle traveling parallel to the longitudinal centerline of the system and offset by 16¼ in. [413 mm] laterally or ¼ of its width toward Side A of the system, as shown in Figure 118. The 2,409-lb (1,093-kg) small car impacted the modified bullnose barrier at a speed of 62.7 mph (100.9 km/h) and at an angle of 0.3 degrees. At impact, the vehicle was offset 16.3 in. (414 mm) from the centerline toward Side A of the system. During the test, the vehicle was captured by the thrie-beam nose of the system. As the vehicle proceeded into the system, the thrie-beam rail and nose cables remained wrapped around the front of the vehicle. The deformation of the thrie-beam panels and the disengagement of several breakaway posts on both sides of the system decelerated the vehicle to a safe and controlled stop. The vehicle came to rest in the interior of the system 30 ft – 2¼ in. (9.2 m) downstream from the initial impact.

A detailed description of the sequential impact events is contained in Table 11. Sequential photographs are shown in Figures 119 and 120. Documentary photographs of the crash test are shown in Figure 121. The vehicle's final position is shown in Figure 122.

Figure 118. Impact Location, Test No. MSPBN-5

Table 11. Sequential Description of Impact Events, Test No. MSPBN-5

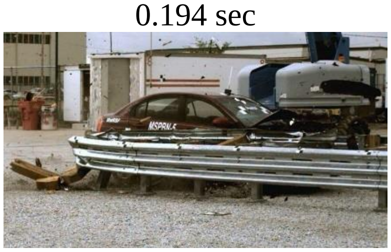
TIME (sec)	EVENT
0.000	Vehicle's front bumper contacted rail between post nos. A1 and B1 on centerline of bullnose.
0.020	Vehicle's left fender contacted rail.
0.030	Vehicle's right fender contacted rail.
0.032	Post no. B1 deflected backward.
0.040	Vehicle pitched downward.
0.044	Post no. A1 deflected backward, and vehicle's left-front tire contacted rail.
0.060	Vehicle's right-front tire contacted rail.
0.062	Vehicle's front bumper portion became disengaged, and vehicle yawed clockwise.
0.064	Post no. A1 fractured.
0.068	Rail disengaged from bolt at post no. A2.
0.076	Rail disengaged from bolt at post no. A3.
0.084	Post no. B1 fractured.
0.088	Rail disengaged from bolt at post no. A4.
0.092	Vehicle rolled slightly clockwise.
0.106	Post no. A1 contacted post no. A2.
0.114	Post no. A2 fractured.
0.150	Vehicle yawed clockwise within system.
0.152	Post no. A2 contacted post no. A3.
0.180	Vehicle's right-front door contacted rail.
0.182	Post no. B2 fractured.
0.210	Post no. A5 deflected forward.
0.216	Rail disengaged from bolt at post no. B2.
0.222	Post no. A3 bent downstream, and vehicle's left-front door contacted rail.
0.270	Post no. B3 twisted clockwise.
0.286	Post no. B3 bent downstream.
0.296	Post no. B3 detached.
0.316	Rail disengaged from bolt at post no. B3.
0.376	Post no. A4 detached, and post no. B3 contacted post no. B4.
0.430	Rail disengaged from bolt at post no. B4.
0.436	Post no. A4 contacted post no. A5.
0.444	Post no. B4 detached.
0.510	Post no. B4 contacted post no. B5.
0.554	Rail disengaged from bolt at post no. A5.
0.556	Post no. A5 detached.
0.572	Vehicle's left-rear door contacted rail.
1.202	Vehicle came to rest.


0.000 sec


0.064 sec


0.114 sec


0.194 sec


0.376 sec


0.654 sec


0.000 sec


0.062 sec


0.150


0.216 sec


0.422 sec


0.714 sec

Figure 119. Sequential Photographs, Test No. MSPBN-5

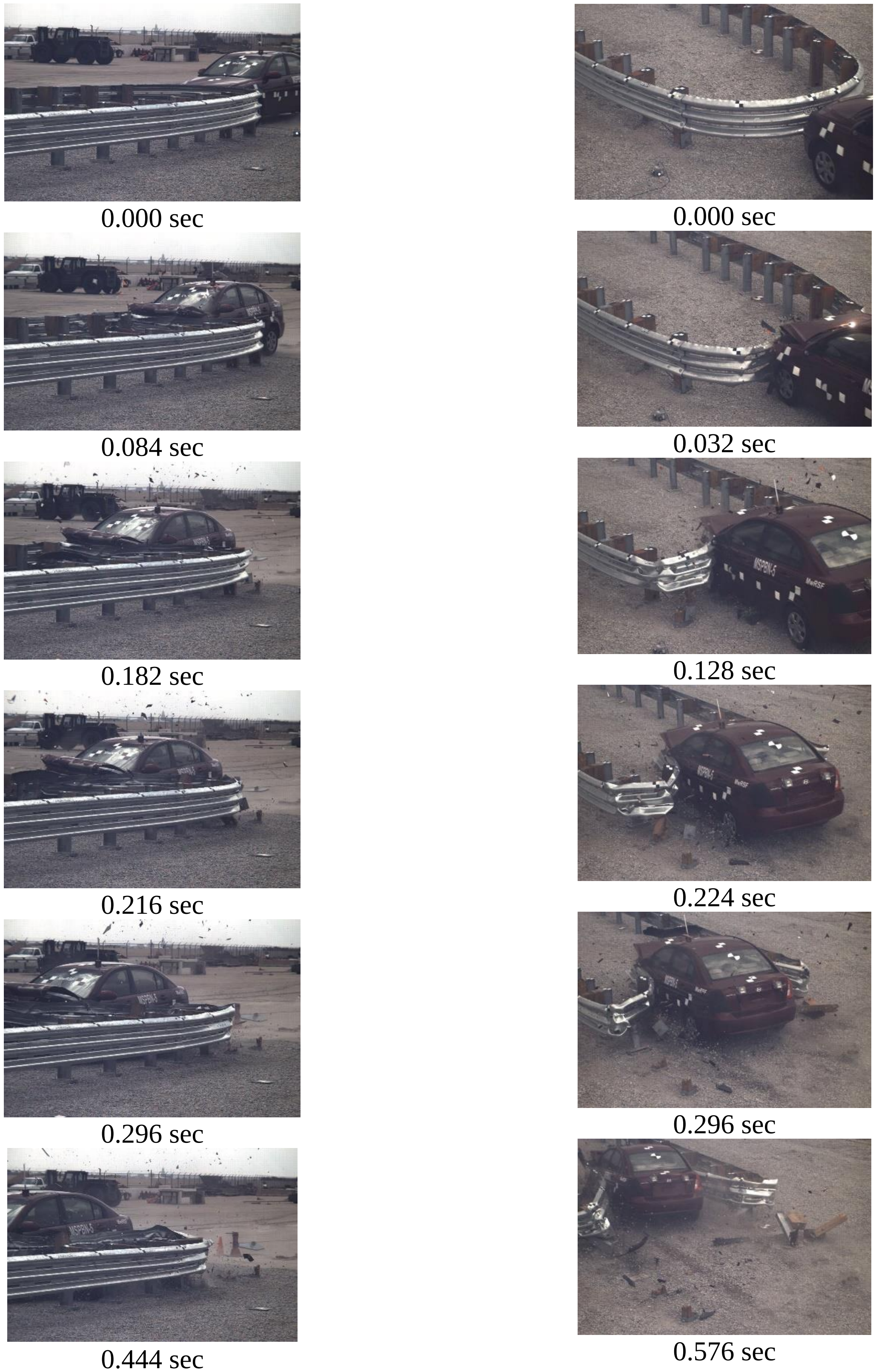


Figure 120. Additional Sequential Photographs, Test No. MSPBN-5

Figure 121. Documentary Photographs, Test No. MSPBN-5

Figure 122. Vehicle Final Position, Test No. MSPBN-5

7.4 Barrier Damage

Damage to the barrier was extensive, as shown in Figures 123 through 130. Barrier damage primarily consisted of contact marks, deformation, bending, and tearing of the thrie-beam rail segments and disengagement of the breakaway posts. Damage occurred to both sides A and B of the barrier and was contained from the nose section of bullnose downstream to posts nos. A6 and B5, respectively.

The thrie-beam nose section of the barrier and the adjacent rail sections on Side A and Side B were deformed backward and into the interior of the barrier as the vehicle entered the system. Rail tearing occurred at several locations in the nose of the system. In the nose section, the bottom thrie-beam corrugation was completely fractured, the middle thrie-beam corrugation was partially fractured, and the top thrie-beam corrugation remained intact. The nose cables were all intact following the impact event. A 7-in. (178-mm) long by 8-in. (203-mm) high tear was observed 21 in. (533 mm) downstream from the impact target. A 1-in. (25-mm) wide, 1-in. high (25-mm), ½-in. (13-mm) deep tear was found 57 in. (1,448 mm) upstream from the centerline of post no. B1 on the top edge of the top slot. A 5-in. (127-mm) wide, 6-in. (152-mm) high, 3-in. (76-mm) deep tear was found 57 in. (1,448 mm) upstream from the centerline of post no. B1 on the middle corrugation. Two tears were observed 57 in. (1,448 mm) upstream from post no. B1 in the middle of the corrugation and along the top edge of the top slot.

Rail section nos. 2 and 3 on Side A of the system were kinked, deformed, and bent inward toward the interior of the system just upstream of post no. A5. A 6-in. (152-mm) wide bend was observed 7 in. (178 mm) upstream from post no. A5 along the entire height of the rail. Minor kinking of the rail was also observed up to post no. A6.

Rail section nos. 2 and 3 on Side B of the system were kinked, deformed, and bent inward toward the interior of the system a post no. B5. Large kinks and bends occurred 5½ in. (140 mm) downstream from post no. B4 and 9 in. (229 mm) upstream from post no. B5 along the entire height of the rail.

All four of the BCT posts adjacent to the nose of the system were fractured and disengaged. Four UBSP posts were disengaged, while a fourth UBSP post yielded at the base as the thrie beam was pulled over the top of it. Post no. A1 was fractured and disconnected from its base, but it remained connected to the rail via the top bolt. Post no. A2 experienced bolt pullout, and the post was fractured at its base. Post no. A3 remained attached to its base with all four anchoring bolts also remaining intact. The post was bent downstream about its weak axis at an angle of approximately 60 degrees, and the blockout was still attached. Posts nos. A4 and A5 were disengaged at the base through complete fracture of the base plate bolts, and both posts were detached from the rail. Post no. A6 remained attached to the base, and its blockout remained attached to the post but was rotated clockwise. There was no damage found on post nos. 7A through 15A.

Post no. B1 was fractured at the base but remained attached to the rail. Post no. B2 was fractured off at its base and split into two pieces, with the blockout remaining attached to one of the pieces. Post nos. B3 and B4 were disconnected from its base through fracture of all four base plate bolts, and both posts were disconnected from the rail. Post no. B5 remained attached to its base but was bent 5 degrees downstream and twisted counterclockwise. No damage was found on post nos. 6B through 15B.

Review of the disengaged UBSP posts revealed some damage to the upper sections of the posts. No permanent deformation was noted to the base plates on either the upper or lower section of the UBSP post, and displacement of the base of the post was minimal for all of the disengaged UBSP posts.

The maximum longitudinal permanent set of the barrier system was 30 ft – 2¼ in. (9.2 m) in the rail at the centerline of the nose, as measured in the field. The maximum lateral permanent set deflection was internal to the bullnose system and is not shown. The maximum longitudinal dynamic barrier deflection was 30 ft – 4.3 in. (9.3 m) at the centerline target as determined from high-speed digital video analysis. The maximum lateral dynamic barrier deflection was internal to the bullnose system and is not shown. The longitudinal working width of the system was found to be 30 ft – 9.0 in. (9.4 m), and the lateral working width was found to be 15 ft – 4 in. (4.7 m), also determined from high-speed digital video analysis. A schematic of the working width is shown in Figure 131.

Figure 123. Overview of System Damage, Test No. MSPBN-5

Figure 124. Close-Up of Impacted Area, Test No. MSPBN-5

Figure 125. Damage to System at Post Nos. A1 and A2, Test No. MSPBN-5

Figure 126. Damage to System at Post Nos. A3 and A4, Test No. MSPBN-5

Figure 127. Damage to System at Post Nos. A5 and A6, Test No. MSPBN-5

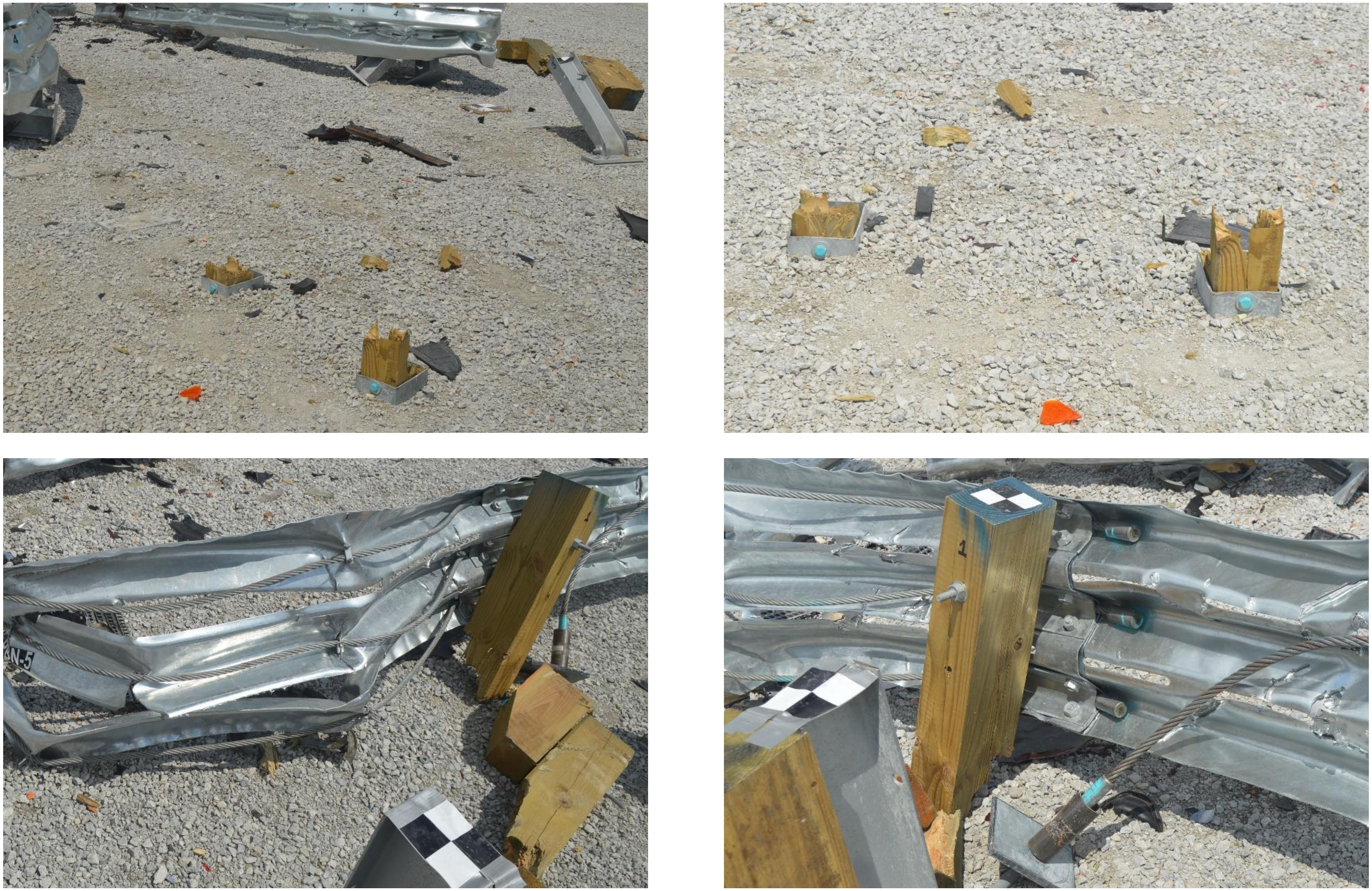


Figure 128. Damage to System at Post Nos. B1 and B2, Test No. MSPBN-5

Figure 129. Damage to Post Nos. B3 through B5, Test No. MSPBN-5

Figure 130. UBSP Bases, Test No. MSPBN-5

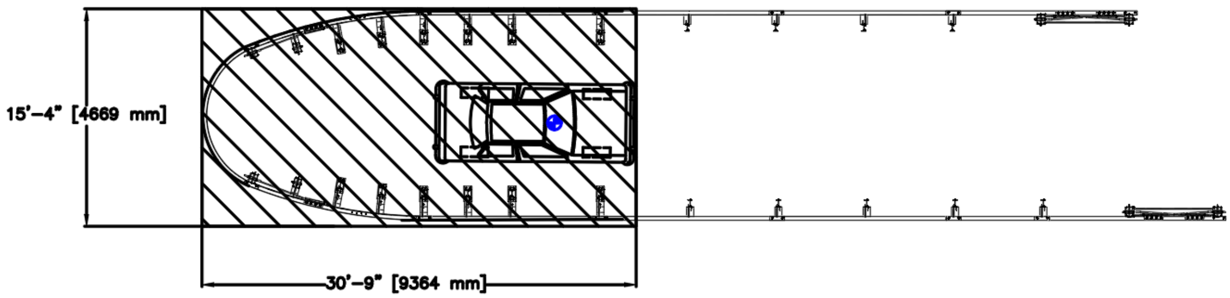


Figure 131. Working Width, Test No. MSPBN-5

7.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 132 through 136. The maximum occupant compartment deformations are listed in Table 12 along with the deformation limits established in MASH 2016 for various areas of the occupant compartment. Note that none of the established MASH 2016 deformation limits were violated. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D.

The majority of the damage was concentrated on the front of the vehicle where the impact had occurred. The front bumper cover was fully disengaged from the vehicle, and the front bumper support was crushed inward. The radiator was pushed into the engine by the front bumper support. The hood buckled in the middle and was pushed into the engine bay. The left-front quarter panel was bent into the engine bay in front of the tire and flared outward behind the tire. The right-front quarter panel was pushed into the engine bay in front of the tire and was flared outward behind the tire. The left-front door was dented inward. The right-front door was dented near the right-front quarter panel. The roof, windshield, and side windows remained undamaged. The lower control arm on the right side was bent backward at the ball joint.

Figure 132. Vehicle Damage, Test No. MSPBN-5

Figure 133. Vehicle Damage, Test No. MSPBN-5

Figure 134. Vehicle Damage, Test No. MSPBN-5

Figure 135. Interior Vehicle Damage, Test No. MSPBN-5

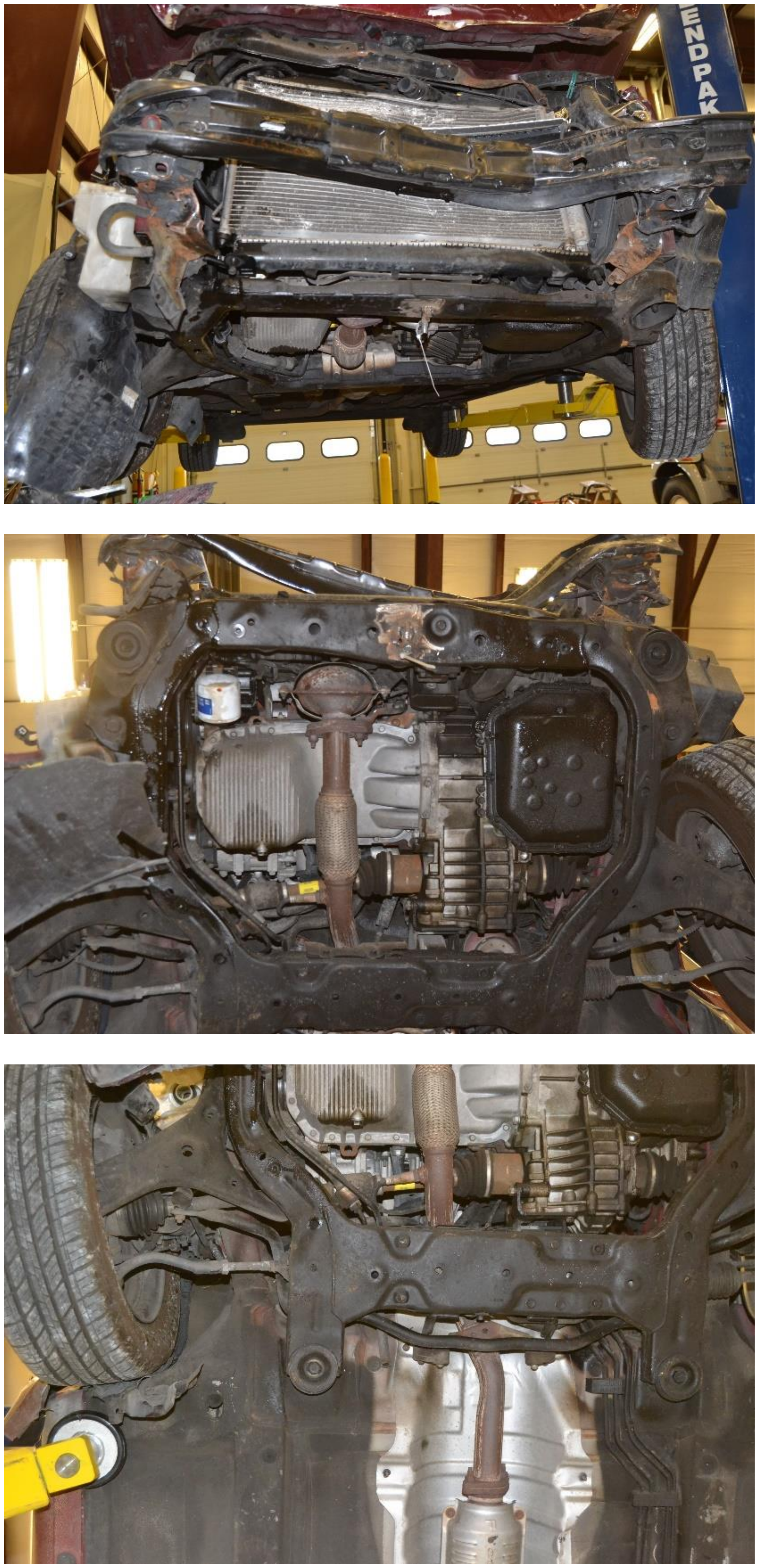


Figure 136. Undercarriage Damage, Test No. MSPBN-5

Table 12. Maximum Occupant Compartment Deformations by Location, Test No. MSPBN-5

LOCATION	MAXIMUM DEFORMATION in. (mm)	MASH 2016 ALLOWABLE DEFORMATION in. (mm)
Wheel Well & Toe Pan	0.2 (5)	≤ 9 (229)
Floor Pan & Transmission Tunnel	0.1 (3)	≤ 12 (305)
A-Pillar	0.3 (8)	≤ 5 (127)
A-Pillar (Lateral)	0.1 (3)	≤ 3 (76)
B-Pillar	0.1 (3)	≤ 5 (127)
B-Pillar (Lateral)	0.0 (0)	≤ 3 (76)
Side Front Panel (in Front of A-Pillar)	0.2 (5)	≤ 12 (305)
Side Door (Above Seat)	0.1 (3)	≤ 9 (229)
Side Door (Below Seat)	0.2 (5)	≤ 12 (305)
Roof	0.1 (3)	≤ 4 (102)
Windshield	0.0 (0)	≤ 3 (76)
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	0.3 (8)	N/A

N/A – Not applicable

7.6 Occupant Risk

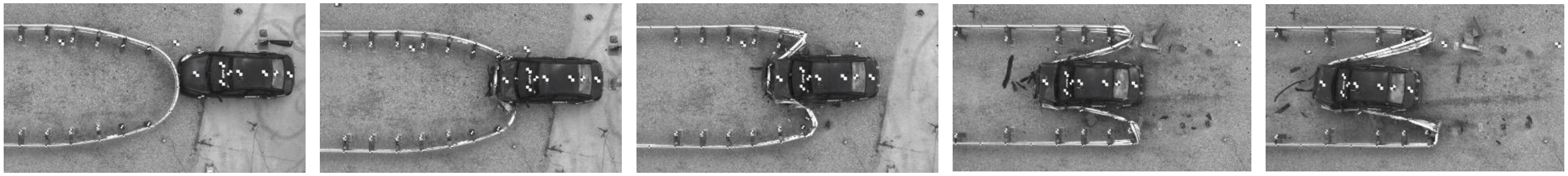
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 13. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 13. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix F.

Table 13. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. MSPBN-5

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (primary)	SLICE-2	
OIV ft/s (m/s)	Longitudinal	-25.60 (-7.80)	-25.47 (-7.76)	±40 (12.2)
	Lateral	-3.34 (-1.02)	-3.85 (-1.17)	±40 (12.2)
ORA g's	Longitudinal	-6.93	-6.65	±20.49
	Lateral	-4.24	-4.48	±20.49
MAX. ANGULAR DISPL. degrees	Roll	2.9	3.1	±75
	Pitch	-3.1	-2.9	±75
	Yaw	4.7	3.4	not required
THIV ft/s (m/s)		25.72 (7.84)	25.66 (7.82)	not required
PHD g's		8.12	7.96	not required
ASI		0.74	0.75	not required

7.7 Discussion

The analysis of the results for test no. MSPBN-5 showed that the system adequately contained and decelerated the 1100C vehicle to a controlled stop within the system. A summary of the test results is shown in Figure 137. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. 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, as shown in Appendix F, were deemed acceptable, because they did not adversely influence occupant risk nor cause rollover. Therefore, test no. MSPBN-5 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-30.



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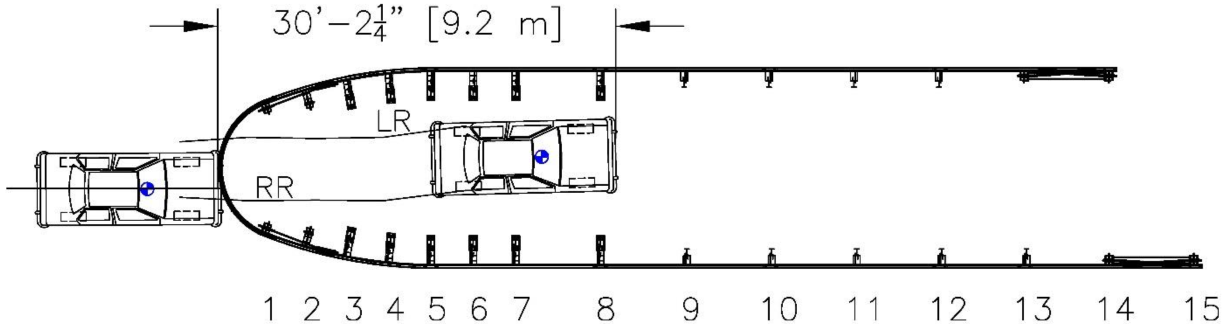

- Test Agency .... MwRSF
- Test Number MSPBN-5
- Date 5/15/18
- MASH 2016 Test Designation No. 3-30
- Test Article .... Steel Post Bullnose with Breakaway Posts
- Total Length .... 72 ft – 3 in (22.0 m)
- Key Component – Thrie Beam
  - Thickness .... 12 gauge (2.1 mm)
  - Mounting Height .... 31⅝ in. (803 mm)
- Key Component – Breakaway Steel Post
  - Length .... 72¹⁄₁₆ in. (1,849 mm)
  - Spacing .... 37½ in. (953 mm)
- Soil Type
- Vehicle Make /Model .... 2009 Hyundai Accent
  - Curb .... 2,461 lb (1,116 kg)
  - Test Inertial .... 2,409 lb (1,093 kg)
  - Gross Static .... 2,573 lb (1,167 kg)
- Impact Conditions
  - Speed .... 62.7 mph (100.9 km/h)
  - Angle .... 0.3 degrees
  - Impact Location .... 16.3 in. (414 mm) from CL of Bullnose
- Impact Severity ...... 316.6 kip-ft (429.3 kJ) ≥ 288 kip-ft (390 kJ) limit from MASH 2016
- Exit Conditions
  - Speed .... N/A
  - Angle .... N/A
- Vehicle Stability .... Pass
- Vehicle Capture and Containment .... Acceptable
- Vehicle Stopping Distance .... 30 ft - 2¼ in (9.2 m) downstream
- Vehicle Damage .... Moderate
  - VDS [20] 12-FD-6
  - CDC [21] 12FZMW2
  - Maximum Interior Deformation .... 0.3 in. (8 mm)
- Test Article Damage .... Extensive
- Maximum Test Article Deflections
  - Permanent Set .... 30 ft – 2¼ in. (9.2 m) longitudinal
  - Dynamic .... 30 ft – 4.3 in. (9.3 m) longitudinal
  - Working Width .... 30 ft – 9.0 in. (9.4 m) longitudinal, 15 ft – 4 in. (4.7 m) lateral
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limit
		SLICE-1 (primary)	SLICE-2	
OIV ft/s (m/s)	Longitudinal	-25.60 (-7.80)	-25.47 (-7.76)	±40 (12.2)
	Lateral	-3.34 (-1.02)	-3.85 (-1.17)	±40 (12.2)
ORA g's	Longitudinal	-6.93	-6.65	±20.49
	Lateral	-4.24	-4.48	±20.49
MAX ANGULAR DISP. degrees	Roll	2.9	3.1	±75
	Pitch	-3.1	-2.9	±75
	Yaw	4.7	3.4	Not required
THIV – ft/s (m/s)		25.72 (7.84)	25.66 (7.82)	Not required
PHD – g's		8.12	7.96	Not required
ASI		0.74	0.75	Not required

Figure 137. Summary of Test Results and Sequential Photographs, Test No. MSPBN-5

8 FULL-SCALE CRASH TEST NO. MSPBN-6

8.1 Static Soil Test

Before full-scale crash test no. MSPBN-6 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. The static test results, as shown in Appendix C, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and full-scale crash testing could be conducted on the barrier system.

8.2 Weather Conditions

Test no. MSPBN-6 was conducted on May 24, 2018 at approximately 12:00 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 14.

Table 14. Weather Conditions, Test No. MSPBN-6

Temperature	87° F
Humidity	42%
Wind Speed	13 mph
Wind Direction	150° from True North
Sky Conditions	Sunny
Visibility	9.9 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.63 in.

8.3 Test Description

Test no. MSPBN-6 was conducted under the MASH 2016 TL-3 guidelines for test designation no. 3-31. Test designation no. 3-31 is an impact of the 2270P vehicle at 62 mph (100 km/h) and 0 degrees on the centerline of the nose of the system. Initial vehicle impact was to occur on the vehicle’s centerline and the centerline of the bullnose system, as shown in Figure 138. During test no. MSPBN-6, the 5,061-lb (2,296-kg) pickup impacted the bullnose system at a speed of 63.4 mph (102.1 km/h) and at an angle of 0.3 degrees. The actual impact occurred with the centerline of the vehicle offset 0.1 in. (3 mm) left of the centerline of the bullnose. The vehicle was captured by the thrie-beam nose of the system as the thrie-beam rail and nose cables wrapped around the front of the vehicle. The deformation of the thrie-beam panels and the disengagement of several breakaway posts on both sides of the system decelerated the vehicle to a safe and controlled stop. The vehicle came to rest in the interior of the system 55 ft–7⅞ in. (17.0 m) downstream from initial impact. During the test two of the UBSPs were disengaged and propelled downstream from the test vehicle. Post no. A3 was disengaged from its base early in the impact and was caught by the folding thrie beam as the vehicle proceeded into the system. Eventually, this post rotated and disengaged from its interlock with the thrie-beam rail and was ejected downstream in front of the vehicle. Post no. B7 was also disengaged from its base and was propelled laterally into the interior of the system. The top section of the post impacted a portion of thrie-beam rail behind the vehicle at approximately 1.206 sec after impact and was propelled over the top of the vehicle and landed downstream in front of the vehicle. Both posts re-contacted the ground in the interior of the bullnose system, and neither post contacted the vehicle.

A detailed description of the sequential impact events is contained in Table 15. Sequential photographs are shown in Figures 139 and 140. Documentary photographs of the crash test are shown in Figure 141. The vehicle's final position is shown in Figure 142.

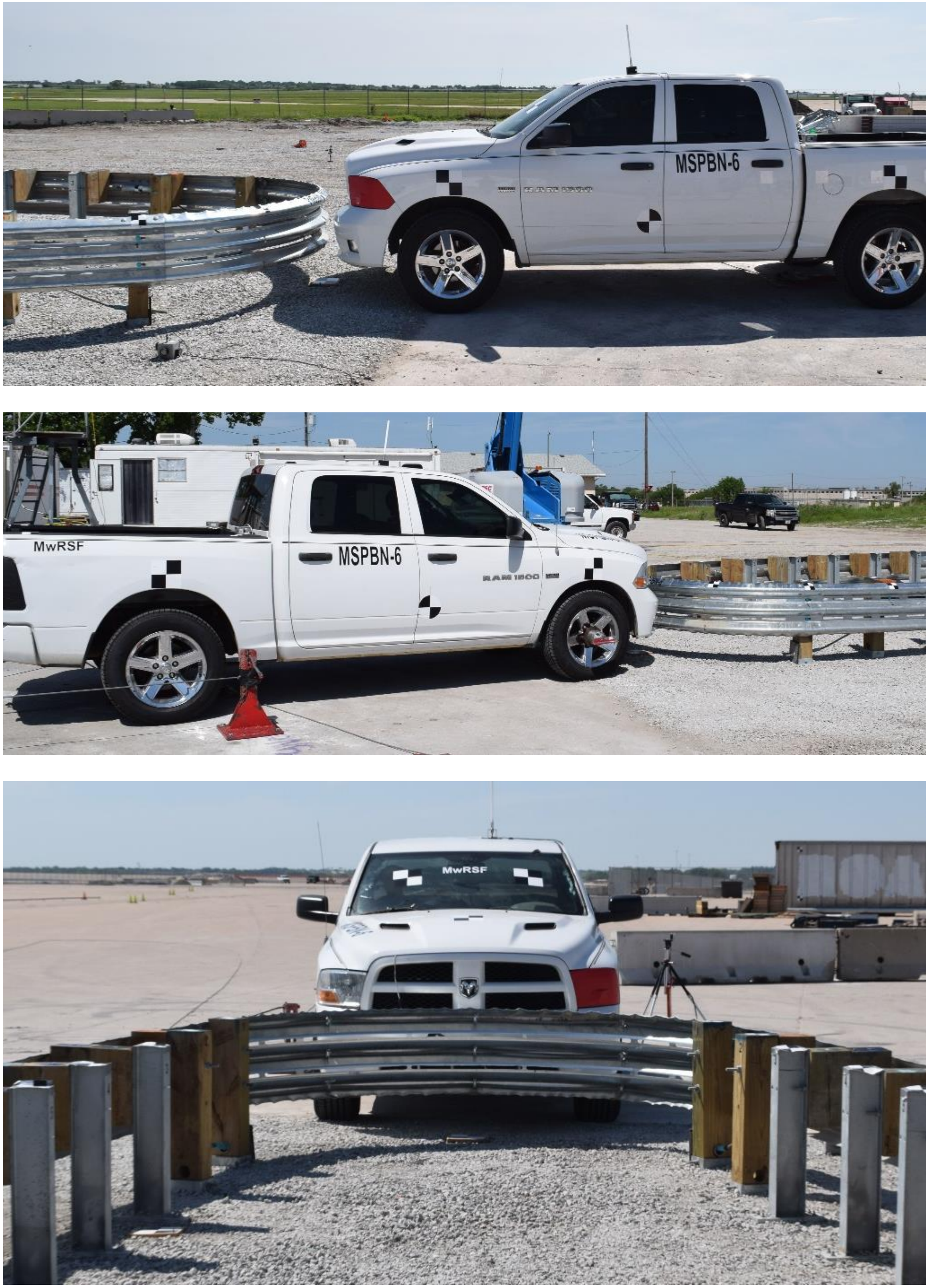

Figure 138. Impact Location, Test No. MSPBN-6

Table 15. Sequential Description of Impact Events, Test No. MSPBN-6

TIME (sec)	EVENT
0.000	Vehicle's front bumper contacted rail between post nos. A1 and B1.
0.006	Vehicle's grille contacted rail and deformed.
0.048	Vehicle's left fender contacted rail.
0.056	Vehicle's right fender contacted rail.
0.058	Vehicle's left fender deformed, and vehicle's right-front tire contacted rail.
0.060	Vehicle's right fender deformed, and post no. A1 fractured.
0.062	Post no. B1 fractured.
0.076	Rail contacted vehicle's left-front tire.
0.078	Rail disengaged from bolt at post no. A2, vehicle pitched downward.
0.088	Rail disengaged from bolt at post no. A3.
0.098	Post no. A1 contacted post no. A2.
0.106	Rail disengaged from bolt at post no. B2.
0.112	Post no. A2 fractured.
0.120	Post no. B1 contacted post no. B2.
0.130	Post no. B2 fractured.
0.136	Vehicle's right-front door contacted rail.
0.140	Post no. A2 contacted blockout no. A3.
0.156	Post no. B1 contacted post no. B3.
0.164	Rail disengaged from bolt at post no. B3.
0.166	Rail disengaged from bolt at post no. A4.
0.168	Post no. B3 detached.
0.172	Fragment of post no. B1 contacted vehicle's left-front door.
0.194	Vehicle's left-front door contacted rail.
0.208	Post no. A3 detached.
0.238	Post no. A3 contacted post no. A4.
0.256	Vehicle's right-rear door deformed, A-side upstream anchor cable contacted vehicle's right-rear door.
0.266	Rail disengaged from bolt at post no. B4.
0.276	Post no. A4 detached.
0.288	Post no. B4 detached.
0.326	Post no. B4 contacted post no. B5.
0.340	Post no. A4 contacted post no. A5.
0.342	Rail disengaged from bolt at post no. B5.
0.346	Rail disengaged from bolt at post no. A5.
0.356	Post no. B5 detached.
0.404	Post no. A5 detached.
0.410	Vehicle's right-rear door contacted rail.

Table 16. Sequential Description of Impact Events, Test No. MSPBN-6, Cont.

TIME (sec)	EVENT
0.424	Rail disengaged from bolt at post no. B6, post no. B5 contacted blockout no. B6.
0.432	Post no. A5 contacted post no. A6.
0.444	Vehicle's right quarter panel contacted rail.
0.460	Post no. B6 detached.
0.466	Post no. A6 detached.
0.508	A-side upstream anchor cable contacted vehicle's right-front door.
0.514	Vehicle's left-rear door contacted rail.
0.524	Post no. A6 contacted post no. A7.
0.564	Rail disengaged from bolt at post no. A7, post no. A7 detached.
0.600	Rail disengaged from bolt at post no. B7.
0.612	Post no. B7 detached.
0.670	Vehicle's left quarter panel contacted rail.
0.868	Vehicle's rear bumper contacted rail.
1.032	Post no. B8 detached.
1.050	Post no. A8 detached.
2.052	Vehicle came to rest.


0.000 sec


0.104 sec


0.248 sec


0.404 sec


0.534 sec


0.772 sec


0.000 sec


0.200 sec


0.400 sec


0.600 sec


0.800 sec


1.000 sec

Figure 139. Sequential Photographs, Test No. MSPBN-6


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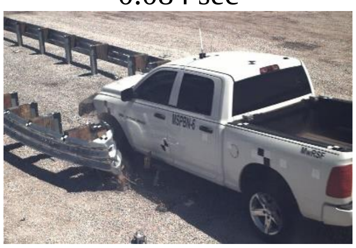
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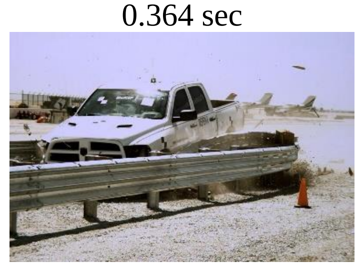
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Figure 140. Additional Sequential Photographs, Test No. MSPBN-6

Figure 141. Documentary Photographs, Test No. MSPBN-6

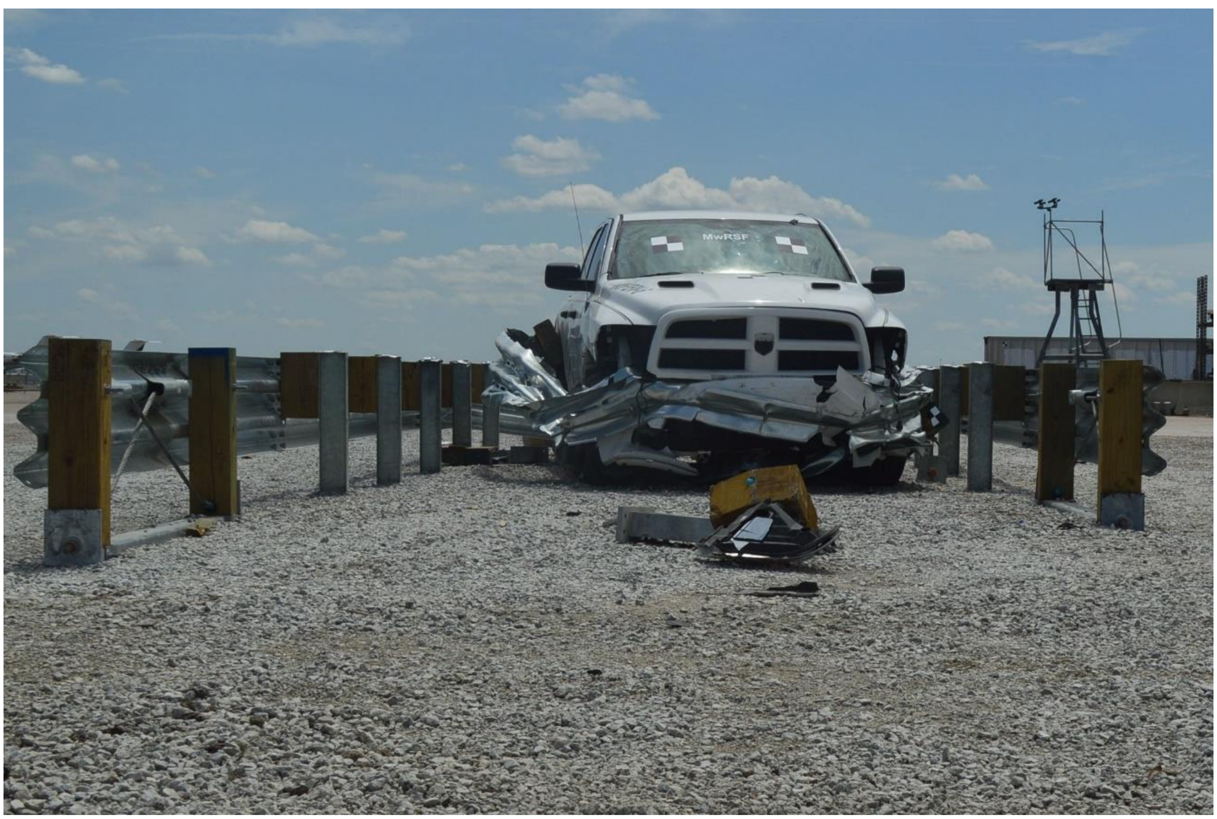


Figure 142. Vehicle Final Position, Test No. MSPBN-6

8.4 Barrier Damage

Damage to the barrier was extensive, as shown in Figures 143 through 154. Barrier damage primarily consisted of contact marks, deformation, bending, and tearing of the thrie-beam rail segments and disengagement of the breakaway posts. Damage occurred to both sides A and B of the barrier and was contained from the nose section of bullnose downstream to posts nos. A9 and B9 on each side of the system. Post nos. A1 through A8 and B1 through B8 were fractured or disengaged from their bases.

The thrie-beam nose section of the barrier and the adjacent rail sections on Side A and Side B were deformed backward and into the interior of the barrier as the vehicle entered the system. Rail tearing occurred at several locations in the nose of the system. The slot tabs on the bottom valley of the nose section were fractured, except for the two 2-in. (51-mm) wide slot tabs adjacent to post no. B1 and the first 2-in. (51-mm) wide slot tab adjacent to post no. A1. The 1-in. (25-mm) wide slot tab on the top valley of the nose section 60¼ in. (1,530 mm) upstream of post no. B1 was fractured as well. The middle corrugation of the nose-section thrie beam was completely fractured approximately 9 in. (229 mm) upstream from post no. A1. Several additional partial rail tears were noted on the nose section of the bullnose system. The nose cables were all intact following the impact event.

Rail section nos. 2 through 4 on Side A of the system were kinked, deformed, and bent inward toward the interior of the system just upstream from post no. A9. The railing was kinked and hinged at 14 in. (356 mm) upstream from splice no. A8. The thrie beam just upstream from post no. A9 was kinked and hinged along its entire height. The thrie-beam rail on Side A was twisted 180 degrees beginning just upstream from post no. A1 and ending at post no. A3.

Rail section nos. 2 through 4 on Side B of the system were kinked, deformed, and bent inward toward the interior of the system beginning at post no. B9. A large kink and hinge occurred just upstream from the rail splice at post no. B8. A second full-section hinge occurred at post no. B9.

All four of the BCT posts adjacent to the nose of the system were fractured and disengaged. All twelve UBSP posts were disengaged from their bases, six on each side of the system, due to fracture of the base plate connection bolts. Post nos. A1 and A2 were fractured at the ground and were disengaged from the rail. Post nos. A3 through A8 were all disconnected from their respective bases with all four base plate bolts being fractured, and each post was disconnected from the railing. Post no. A9 was disengaged from the rail, and a ⅛-in. (3-mm) soil gap was observed in front of the post. Post nos. A10 through A15 received no visible damage.

Post nos. B1 and B2 were fractured at the ground. Post no. B1 remained attached to the rail, while post no. B2 was disengaged from the rail. Post nos. B3 through B8 were all disconnected from their respective bases with all four base plate bolts being fractured. Only post no. B8 remaining attached to the thrie beam. Post no. B9 was twisted about its vertical axis, and a ⅛-in. (3-mm) soil gap was observed behind the post. Post nos. B10 through B14 received no visible damage.

Review of the disengaged UBSP posts revealed some damage to the upper sections of the posts. No permanent deformation was noted to the base plates on either the upper or lower section of the UBSP post, and displacement of the base of the post was minimal for all of the disengaged UBSP posts.

The maximum longitudinal permanent set of the barrier system was 55 ft – 7⅞ in. (17.0 m) at the centerline of the rail in the nose, as measured in the field. The maximum lateral permanent set of the barrier was interior to the system and was not reported. The maximum longitudinal dynamic barrier deflection was 55 ft – 11 in. (17.0 m) at the centerline of the barrier, as determined from high-speed digital video analysis. The maximum lateral dynamic barrier deflection was interior to the system and was not reported. The longitudinal working width of the system was found to be 56 ft – 5 in. (17.2 m), and the lateral working width was found to be 15 ft – 9 in. (4.8 m), as determined from high-speed digital video analysis. A schematic of the working width for test no, MSPBN-6 is shown in Figure 155.

Figure 143. Overview of System Damage with Vehicle Present, Test No. MSPBN-6

Figure 144. Overview of System Damage with Vehicle Removed, Test No. MSPBN-6.

Figure 145. Damage to Impact Location, Test No. MSPBN-6

Figure 146. Damage to Post Nos. A1 (middle) and A2 (bottom), Test No. MSPBN-6

Figure 147. Damage to Rail at Post Nos. A1 and A2, Test No. MSPBN-6

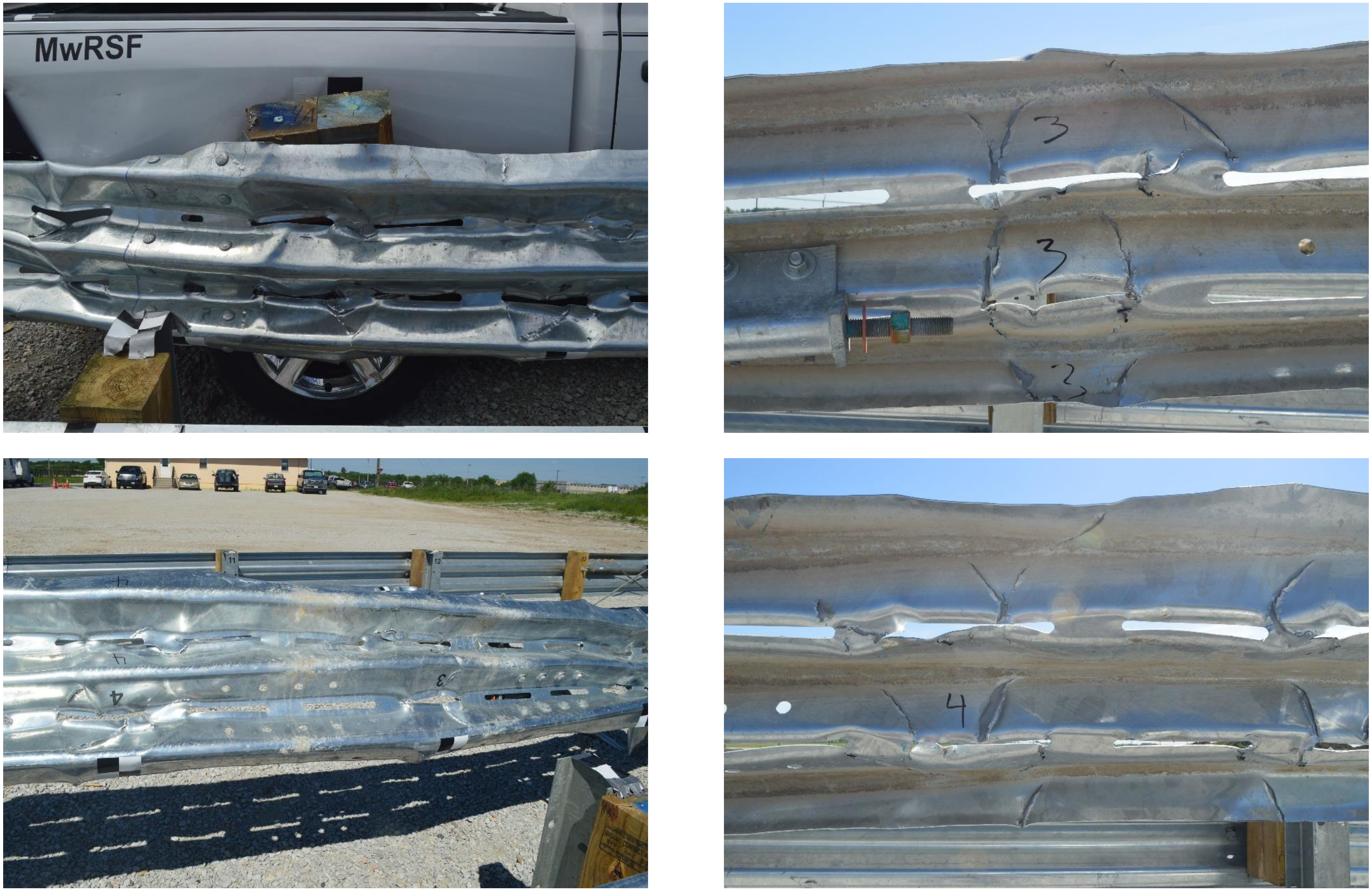


Figure 148. Damage to Rail at Post Nos. A3 and A4, Test No. MSPBN-6

Figure 149. Damage to Rail at Post Nos. A5 through A9, Test No. MSPBN-6

Figure 150. Damage to Post Nos. B1 and B2, Test No. MSPBN-6

Figure 151. Damage to Rail at Post Nos. B1 and B2, Test No. MSPBN-6

Figure 152. Damage to Rail at Post Nos. B3 through B5, Test No. MSPBN-6

Figure 153. Damage to Railing at Post Nos. B6 through B9, Test No. MSPBN-6

Figure 154. UBSP Post Bases, Test No. MSPBN-6

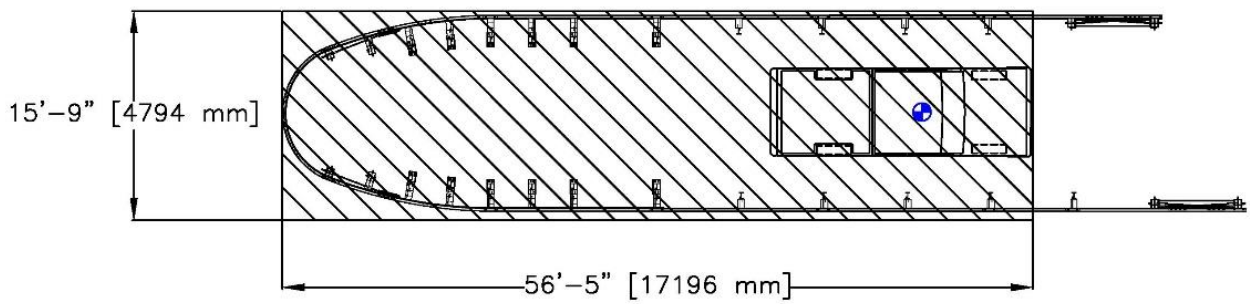


Figure 155. Working Width, Test No. MSPBN-6

8.5 Vehicle Damage

The damage to the vehicle was minimal, as shown in Figures 156 through 159. The maximum occupant compartment deformations are listed in Table 17 along with the deformation limits established in MASH 2016 for various areas of the occupant compartment. Note that none of the established MASH 2016 deformation limits were violated. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D.

The damage mainly occurred to the front and right side of the vehicle. The front bumper disengaged from the vehicle. An 8-in. (212-mm) long tear in the hood was observed. A 16-in. (406-mm) long by 5-in. (127-mm) deep dent was found in the right-front fender. The right-front door had a tear 6 in. (152 mm) long by 2¼ in. (57 mm) wide. A large dent 15 in. (381 mm) long by 11½ in. (292 mm) wide occurred on the right-front door. The right-rear door received a dent 38 in. (965 mm) long by 23 in. (584 mm) wide. Dents were also observed under the right-rear door and along the right side of the bed body. Damage to the suspension included a bent right-rear sway bar and damage due to rubbing of the front-right upper control arm. No damage was observed to the drivetrain or undercarriage. The windshield and side windows also remained undamaged.

Figure 156. Vehicle Damage, Test No. MSPBN-6

Figure 157. Vehicle Damage, Test No. MSPBN-6

Figure 158. Vehicle Interior Damage, Test No. MSPBN-6

Figure 159. Vehicle Undercarriage Damage, Test No. MSPBN-6

Table 17. Maximum Occupant Compartment Deformations by Location, Test No. MSPBN-6

LOCATION	MAXIMUM DEFORMATION in. (mm)	MASH 2016 ALLOWABLE DEFORMATION in. (mm)
Wheel Well & Toe Pan	0.5 (13)	≤ 9 (229)
Floor Pan & Transmission Tunnel	0.0 (0)	≤ 12 (305)
A-Pillar	0.3 (8)	≤ 5 (127)
A-Pillar (Lateral)	0.3 (8)	≤ 3 (76)
B-Pillar	0.5 (13)	≤ 5 (127)
B-Pillar (Lateral)	0.4 (10)	≤ 3 (76)
Side Front Panel (in Front of A-Pillar)	0.3 (8)	≤ 12 (305)
Side Door (Above Seat)	0.3 (8)	≤ 9 (229)
Side Door (Below Seat)	0.2 (5)	≤ 12 (305)
Roof	0.2 (5)	≤ 4 (102)
Windshield	0.0 (0)	≤ 3 (76)
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	0.3 (8)	N/A

N/A – Not applicable

8.6 Occupant Risk

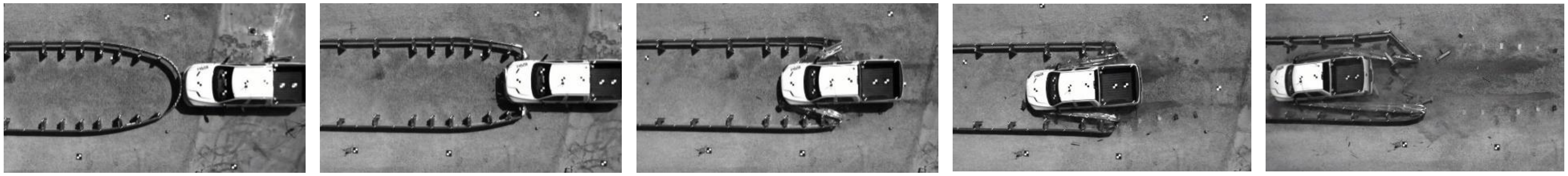
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 18. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 18. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix G.

Table 18. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. MSPBN-6

Evaluation Criteria		**Transducer**		**MASH 2016 Limits**
		SLICE-1	**SLICE-2 (primary)**	
OIV ft/s (m/s)	Longitudinal	-17.96 (-5.47)	-17.95 (-5.47)	±40 (12.2)
	Lateral	-1.22 (-0.37)	-1.63 (-0.50)	±40 (12.2)
ORA g's	Longitudinal	-8.18	-8.13	±20.49
	Lateral	-3.99	-3.90	±20.49
MAX. ANGULAR DISPL. degrees	Roll	11.5	8.8	±75
	Pitch	-4.4	-4.0	±75
	Yaw	-6.6	-7.8	not required
THIV ft/s (m/s)		18.0 (5.48)	18.0 (5.50)	not required
PHD g's		8.19	8.14	not required
ASI		0.36	0.36	not required

8.7 Discussion

The analysis of the results for test no. MSPBN-6 showed that the system adequately contained and decelerated the 2270P vehicle to a controlled stop within the system. A summary of the test results is shown in Figure 160. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. 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, as shown in Appendix G, were deemed acceptable, because they did not adversely influence occupant risk nor cause rollover. Therefore, test no. MSPBN-6 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-31.



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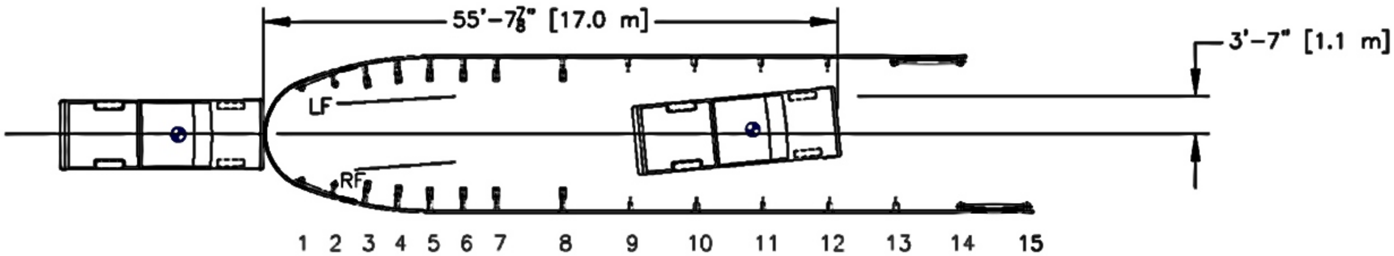


- Test Agency .... MwRSF
- Test Number MSPBN-6
- Date 5/24/18
- MASH 2016 Test Designation No. 3-31
- Test Article .... Steel Post Bullnose with Breakaway Posts
- Total Length .... 72 ft – 3 in. (22.0 m)
- Key Component – Thrie Beam
  - Thickness .... 12 gauge (2.7 mm)
  - Mounting Height .... 31⅝ in. (803 mm)
- Key Component – Breakaway Steel Post
  - Length .... $72\frac{1}{16}$ in. (1,849 mm)
  - Spacing .... 37½ in. (953 mm)
- Soil Type
- Vehicle Make /Model .... 2012 Dodge Ram 1500
  - Curb .... 5,210 lb (2,363 kg)
  - Test Inertial .... 5,061 lb (2,296 kg)
  - Gross Static .... 5,236 lb (2,375 kg)
- Impact Conditions
  - Speed .... 63.4 mph (102.1 km/h)
  - Angle .... 0.3 degrees
  - Impact Location .... 0.1 in. (3 mm) to the left of the CL of the bullnose
- Impact Severity ...... 680.7 kip-ft (922.9 kJ) ≥ 594 kip-ft (806 kJ) limit from MASH 2016
- Exit Conditions
  - Speed .... N/A
  - Angle .... N/A
- Vehicle Stability .... Satisfactory
- Vehicle Capture and Containment .... Acceptable
- Vehicle Stopping Distance .... 55 ft – 7⅞ in. (17.0 m) downstream
- Vehicle Damage .... Minimal
  - VDS [20] 12-FD-1
  - CDC [21] 12-FDMW-1
  - Maximum Interior Deformation .... 0.5 in. (13 mm)
- Test Article Damage .... Extensive
- Maximum Test Article Deflections
  - Permanent Set .... 55 ft – 7⅞ in. (17.0 m) longitudinal
  - Dynamic .... 55 ft – 11 in. (17.0 m) longitudinal
  - Working Width .... 56 ft – 5 in. (17.2 m) longitudinal, 15 ft – 9 in. (4.8 m) lateral
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limit
		SLICE-1	SLICE-2 (primary)	
OIV ft/s (m/s)	Longitudinal	-17.96 (-5.47)	-17.95 (-5.47)	±40 (12.2)
	Lateral	-1.22 (-0.37)	-1.63 (-0.50)	±40 (12.2)
ORA g's	Longitudinal	-8.18	-8.13	±20.49
	Lateral	-3.99	-3.90	±20.49
MAX ANGULAR DISP. degrees	Roll	11.5	8.8	±75
	Pitch	-4.4	-4.0	±75
	Yaw	-6.6	-7.8	Not required
THIV – ft/s (m/s)		18.0 (5.48)	18.0 (5.50)	Not required
PHD – g's		8.19	8.14	Not required
ASI		0.36	0.36	Not required

Figure 160. Summary of Test Results and Sequential Photographs, Test No. MSPBN-6

9 FULL-SCALE CRASH TEST NO. MSPBN-7

9.1 Static Soil Test

Before full-scale crash test no. MSPBN-7 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. The static test results, as shown in Appendix C, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and full-scale crash testing could be conducted on the barrier system.

9.2 Weather Conditions

Test no. MSPBN-7 was conducted on June 5, 2018 at approximately 11:30 a.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 19.

Table 19. Weather Conditions, Test No. MSPBN-7

Temperature	83° F
Humidity	59 %
Wind Speed	9 mph
Wind Direction	200° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.48 in.
Previous 7-Day Precipitation	2.09 in.

9.3 Test Description

Test no. MSPBN-7 was conducted under the MASH 2016 TL-3 guidelines for test designation no. 3-33. Test designation no. 3-33 involves the 2270P vehicle impacting the center of the nose of the system at 62 mph (100 km/h) and 15 degrees. Initial vehicle impact was to occur with the vehicle's centerline intersecting the centerline of the system's nose and at an angle of 15 degrees, as shown in Figure 161. During the test, the 5,043-lb (2,287-kg) crew cab pickup truck impacted the bullnose at a speed of 63.1 mph (101.6 km/h) and at an angle of 15.1 degrees. The actual point of impact was 0.9 in (22.6 mm) to the right of the impact target. During the test, the vehicle was captured by the system, and the thrie-beam rail and nose cables wrapped around the front of the vehicle. The deformation of the thrie-beam panels and the disengagement of breakaway posts on both sides of the system decelerated the vehicle to a safe and controlled stop. It was noted that late in the impact event, approximately 0.540 sec after impact, the vehicle engaged some of the buildup of breakaway post debris and the first non-breakaway post on the left side of the system, which caused the vehicle to climb up the posts and roll to the right slightly as it was brought to a stop. This behavior did not cause issues with vehicle capture or the overall stability of the vehicle, nor did the override of the post debris cause any contact or tearing of the floorboard. The vehicle came to rest 51 ft – 11¼ in. downstream of initial impact.

A detailed description of the sequential impact events is contained in Table 20. Sequential photographs are shown in Figures 162 and 163. Documentary photographs of the crash test are shown in Figures 164 and 165. The vehicle trajectory and final position are shown in Figure 166.

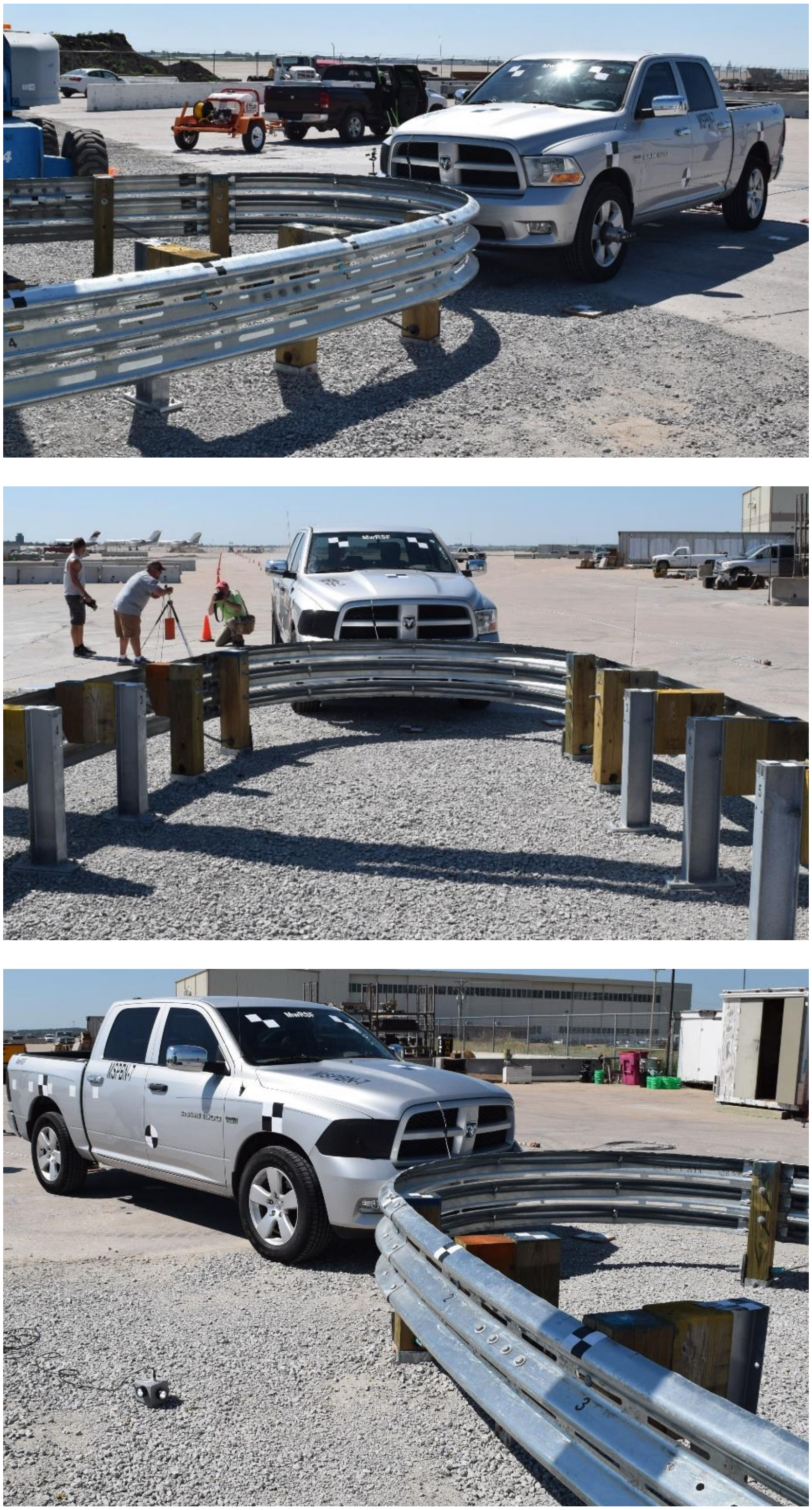


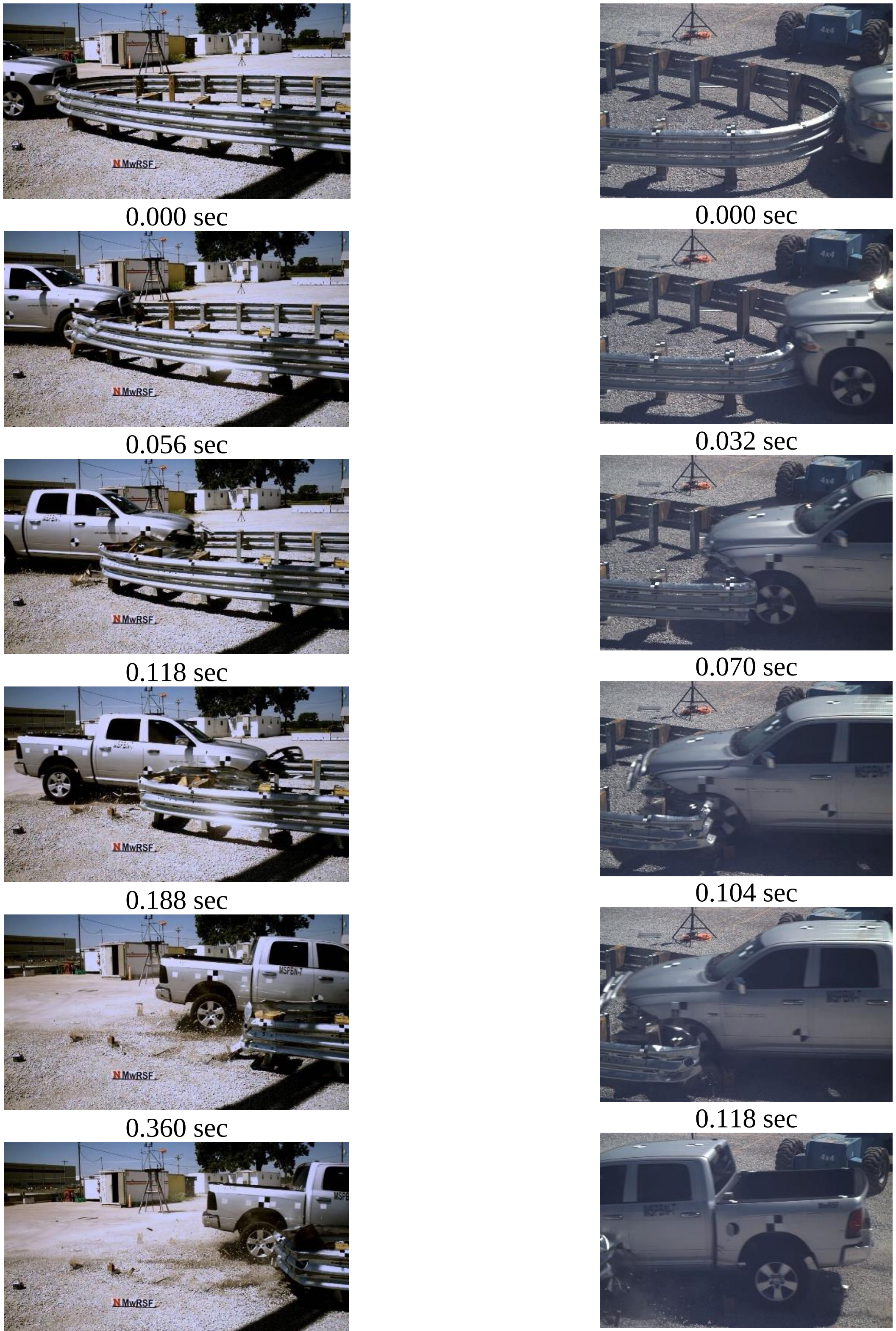
Figure 161. Impact Location, Test No. MSPBN-7

Table 20. Sequential Description of Impact Events, Test No. MSPBN-7

TIME (sec)	EVENT
0.000	Vehicle's front bumper contacted rail between post nos. A1 and B1.
0.004	Vehicle's grille contacted rail.
0.038	Rail disengaged from bolt at post no. B2.
0.046	Vehicle's right-front tire contacted rail, and post no. A1 fractured.
0.048	Vehicle's right fender contacted rail.
0.054	Vehicle's left-front tire contacted rail.
0.055	Post no. A1 rotated clockwise.
0.056	Vehicle yawed clockwise from system.
0.070	Vehicle’s left fender contacted rail.
0.080	Post no. B1 fractured.
0.082	Vehicle pitched downward.
0.084	Vehicle's grille became disengaged.
0.094	Rail disengaged from bolt at post no. B3.
0.100	Rail disengaged from bolt at post no. B4.
0.110	Post no. B2 fractured.
0.118	Post no. A2 fractured.
0.142	Post no. B3 detached.
0.188	Post no. B4 detached.
0.192	Post no. A3 detached.
0.220	Vehicle's left-front door deformed, post no. B5 detached.
0.227	Rail disengaged from bolt at post no. B6.
0.258	Post no. B6 detached.
0.264	Rail disengaged from bolt at post no. B7.
0.280	Post no. A4 detached.
0.308	Post no. B7 detached.
0.331	Post no. A4 contacted post no. A5.
0.360	Post no. A5 detached.
0.408	Vehicle pitched upward.
0.412	Post no. B8 detached.
0.413	Rail disengaged from bolt at post no. B8.
0.438	Rail disengaged from bolt at post no. B9.
0.455	Post no. A3 contacted vehicle's right-rear door.
0.457	Vehicle's right-rear door deformed.
0.526	Vehicle rolled away to right.
0.538	Post no. A6 detached.

Table 21. Sequential Description of Impact Events, Test No. MSPBN-7, Cont.

TIME (sec)	EVENT
0.570	Vehicle's left-front tire became airborne.
0.635	Rail disengaged from bolt at post no. B10.
0.772	Rail disengaged from bolt at post no. B11.
0.822	Blockout no. A3 contacted vehicle's right-rear door.
0.846	Post no. A4 contacted vehicle's right quarter panel.
0.850	Vehicle's right-front tire became airborne.
1.042	Vehicle's left-rear tire became airborne.
1.154	Vehicle's right-front tire regained contact with ground.
1.867	Vehicle came to rest.



0.000 sec | 0.000 sec
0.056 sec | 0.032 sec
0.118 sec | 0.070 sec
0.188 sec | 0.104 sec
0.360 sec | 0.118 sec
0.422 sec | 0.220 sec

Figure 162. Sequential Photographs, Test No. MSPBN-7

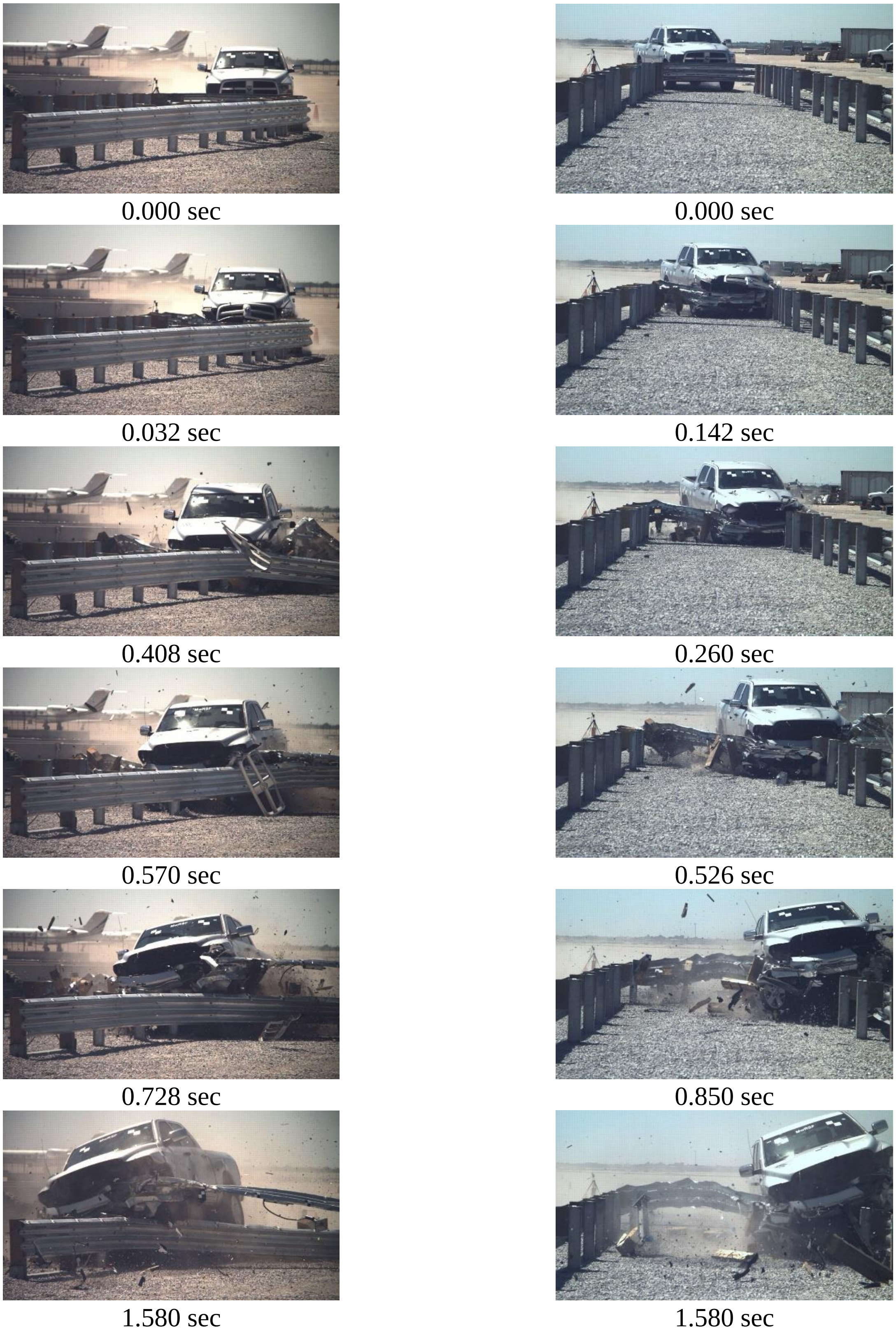


Figure 163. Additional Sequential Photographs, Test No. MSPBN-7

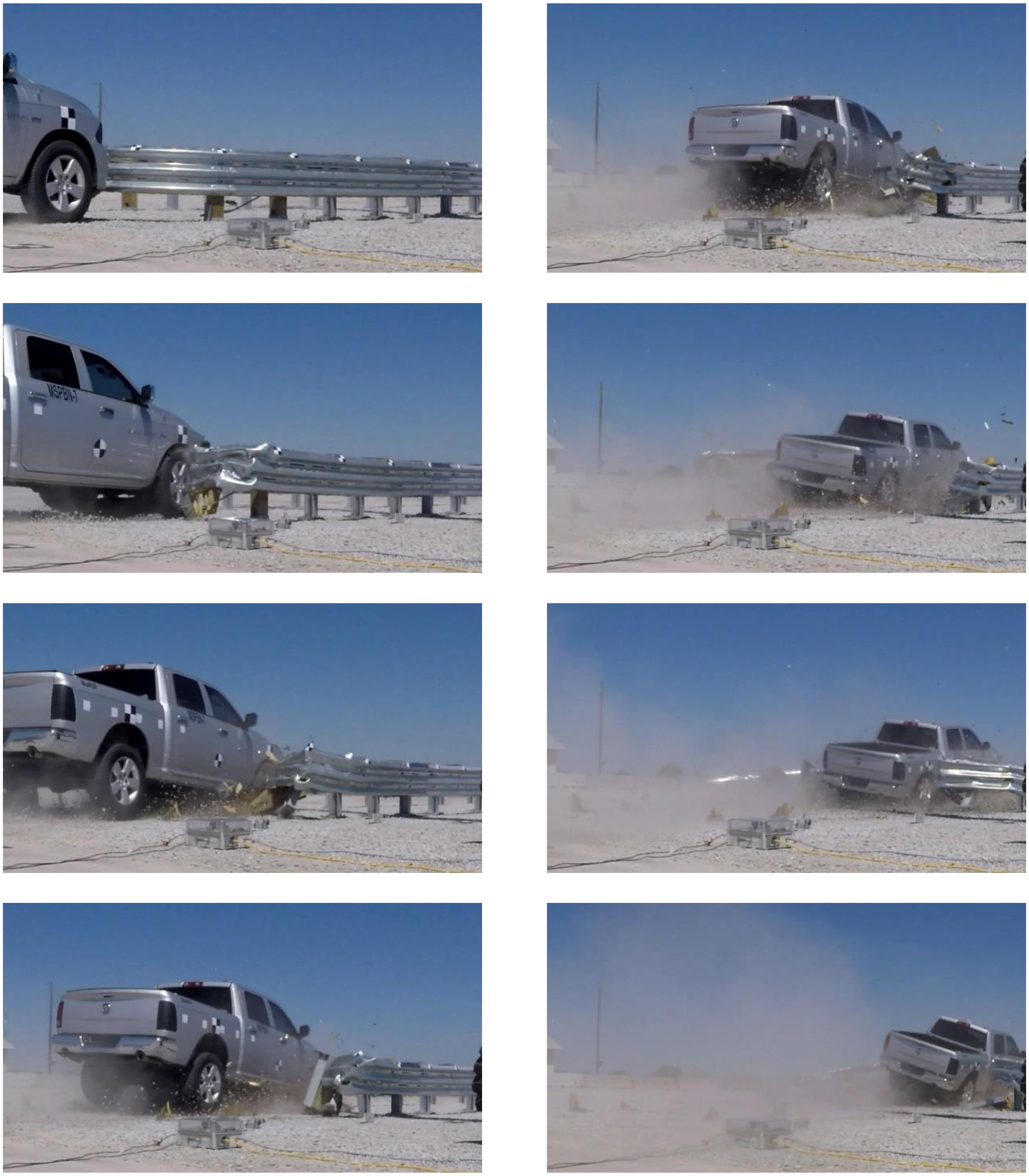


Figure 164. Documentary Photographs, Test No. MSPBN-7

Figure 165. Additional Documentary Photographs, Test No. MSPBN-7

Figure 166. Vehicle Final Position and Trajectory Marks, Test No. MSPBN-7

9.4 Barrier Damage

Damage to the barrier was extensive, as shown in Figures 167 through 178. Barrier damage primarily consisted of contact marks, deformation, bending, and tearing of the thrie-beam rail segments, disengagement of the breakaway posts, and deformation and displacement standard line posts. Damage occurred to both sides A and B of the barrier and was contained from the nose section of bullnose system downstream from posts nos. A8 and B12 on each side of the system. Post nos. A1 through A7 and B1 through B8 were fractured or disengaged from their bases.

The thrie-beam nose section of the barrier and the adjacent rail sections on Side A and Side B were deformed backward and into the interior of the barrier as the vehicle entered the system. Rail tearing occurred at several locations in the nose of the system. Rail tearing occurred at several locations in the nose of the system. The slot tabs on the bottom valley of the nose section were fractured, except for the first 2-in. (51-mm) wide slot tab adjacent to post no. A1. On the top valley of the nose section, all of the slot tabs in the rail were torn, except for the two, 2-in. (51-mm) wide slot tabs adjacent to post nos. A1 and B1. The top and middle corrugations of the nose section thrie beam was completely fractured approximately 55 in. (1,397 mm) upstream of post no. B1. The middle corrugation of the nose section thrie beam was completely fractured approximately 9 in. (229 mm) upstream of post no. A1. Several additional partial rail tears were noted on the all three corrugations of the nose section thrie beam. The nose cables were all intact following the impact.

Rail section nos. 2 through 3 on Side A of the system were kinked, deformed, and bent inward toward the interior of the system just upstream of post no A8. The railing was kinked and hinged at 34½ in. (876 mm) upstream from post no. A8. The rail was bent also kinked and hinged inward 2 in. (51 mm) downstream from post no. A6 and 9 in. (229 mm) upstream from post no. A7. A 3-in. (76-mm) long tear was observed on the bottom corrugation approximately 6 in. (406 mm) downstream from post no. A4.

Rail section nos. 2 through 4 on Side B of the system were kinked, deformed, and bent inward toward the interior of the system beginning at post no. B12. The thrie-beam rail on Side B was bent downward beginning a post B12 due to the truck climbing posts on Side B of the system. A full-section hinge in the rail occurred just upstream of the splice at post no. B8. A large hinge and 90-degree twist of the thrie beam occurred between post nos. B6 and B7.

All four of the BCT posts adjacent to the nose of the system were fractured and disengaged. Eleven UBSP posts were disengaged from their bases, five on Side A and six on Side B of the system, due to fracture of the base plate connection bolts. Post nos. A1 and A2 were fractured at the ground and were disengaged from the rail. Post nos. A3 through A7 were all disconnected from their respective bases with all four base plate bolts being fractured, and each post was disconnected from the railing. No visible damage was observed in post nos. A9 through A15.

Post nos. B1 and B2 were fractured at the ground. Post no. B1 remained attached to the rail, while post no. B2 was disengaged from the rail. Post nos. B3 through B8 were all disconnected from their respective bases with all four base plate bolts being fractured, and all of the posts were detached from the rail. Post nos. B9 through B11 were bent and rotated downstream and were detached from the rail as the vehicle overrode them. Post no. B12 was rotated forward and twisted counterclockwise, while the railing remained attached to the post. No visible damage was observed in post nos. B13 through A14.

Review of the disengaged UBSP posts revealed some damage to the upper sections of the posts. No permanent deformation was noted to the base plates on either the upper or lower section of the UBSP post, and displacement of the base of the post was minimal for all of the disengaged UBSP posts.

The maximum longitudinal permanent set of the barrier system was 52 ft – 1 in. (15.9 m) at the centerline of the bullnose, as measured in the field. The maximum lateral permanent set of the barrier was 12 ft – 1½ in (3.7 m) on the rail at post no. B6, as measured in the field. The maximum longitudinal dynamic deflection was 52 ft – 9 in. (16.1 m) on the rail near the center of the nose section, as determined from high-speed video analysis and post-test measurements. The maximum lateral dynamic barrier deflection was 14 ft – 6 in. (4.4 m) on the rail between post nos. B5 and B6, as determined from high-speed digital video analysis. The working width of the system was found to be 29 ft – 2 in. (8.9 m), also determined from high-speed digital video analysis. A schematic of the working width is shown in Figure 179.

Figure 167. Overview of System Damage with Vehicle Present, Test No. MSPBN-7

Figure 168. Overview of System Damage without Vehicle Present, Test No. MSPBN-7

Figure 169. Damage to Rail at Impact Location, Test No. MSPBN-7

Figure 170. Damage to Post Nos. A1 and A2, Test No. MSPBN-7

Figure 171. Damage to Rail at Post Nos. A1 through A3, Test No. MSPBN-7

Figure 172. Damage to Rail at Post Nos. A4 through A6, Test No. MSPBN-7

Figure 173. Damage to Rail at Post Nos. A6 through A8, Test No. MSPBN-7

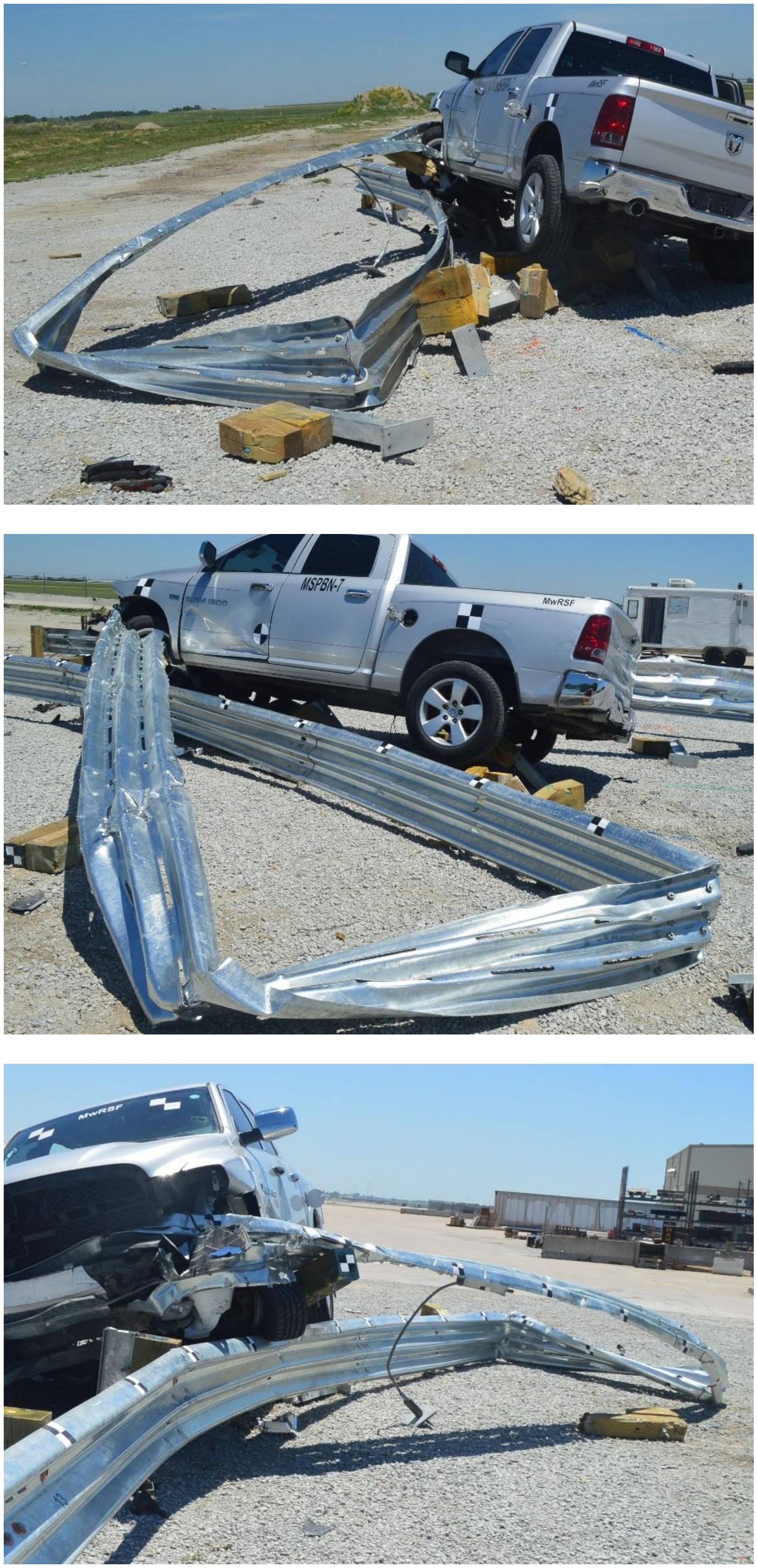


Figure 174. Overview of Damage to B Side of System, Test No. MSPBN-7

Figure 175. Damage to Rail at Post Nos. B1 through B4, Test No. MSPBN-7

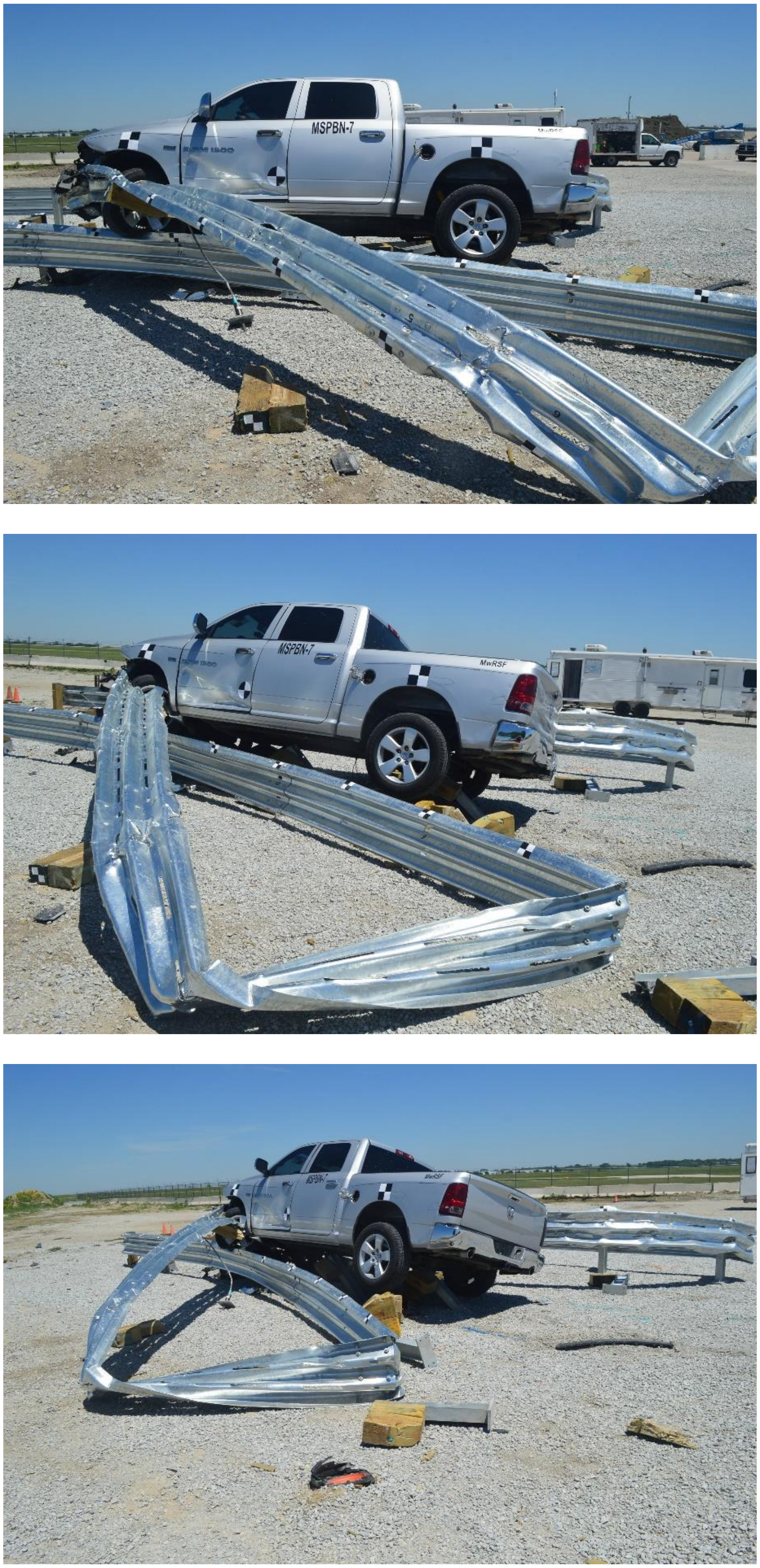


Figure 176. Damage to Rail at Post Nos. B5 through B8, Test No. MSPBN-7

Figure 177. Damage to Rail at Post Nos. B9 through B12, Test No. MSPBN-7

Figure 178. UBSP Post Bases, Test No. MSPBN-7

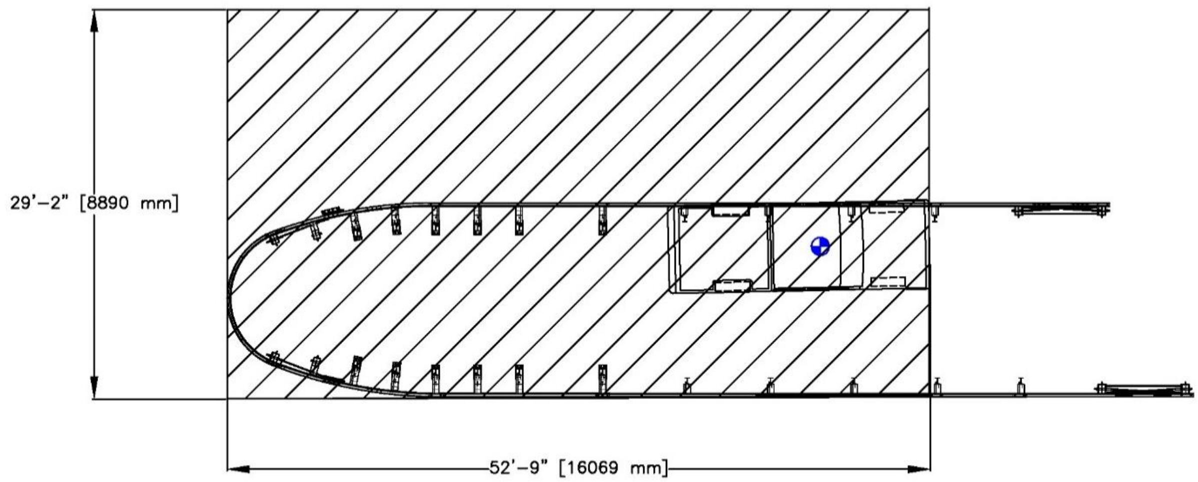


Figure 179. Working Width, Test No. MSPBN-7

9.5 Vehicle Damage

The damage to the vehicle was minimal, as shown in Figure 180 through Figure 183. The maximum occupant compartment deformations are listed in Table 22 along with the deformation limits established in MASH 2016 for various areas of the occupant compartment. Note that none of the established MASH 2016 deformation limits were violated. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D.

The majority of the damage was concentrated on the front of the vehicle. The front bumper, headlight, and grille were all disengaged. The left-front quarter panel in front of the tire was folded inward. The left-front door was crushed inward below the door handle over an area 43½ in. (1,105 mm) wide by 23½ in. (597 mm) high. The right-front quarter panel was folded inward in front of the tire and had a dent 9 in. (229 mm) long by 8¼ in. (210 mm) wide behind the tire. The right-rear door had a 7-in. (178-mm) long by 5-in. (127-mm) wide dent at the bottom and an 11-in. (279-mm) long gouge in the center. A 12-in. (305-mm) by 18-in. (457-mm) dent and a 6¼-in (159-mm) long gouge were observed in the right-rear quarter panel in front of the rear tire. The side windows and windshield remained undamaged.

Figure 180. Vehicle Damage, Test No. MSPBN-7

Figure 181. Additional Vehicle Damage, Test No. MSPBN-7

Figure 182. Vehicle Interior Damage, Test No. MSPBN-7

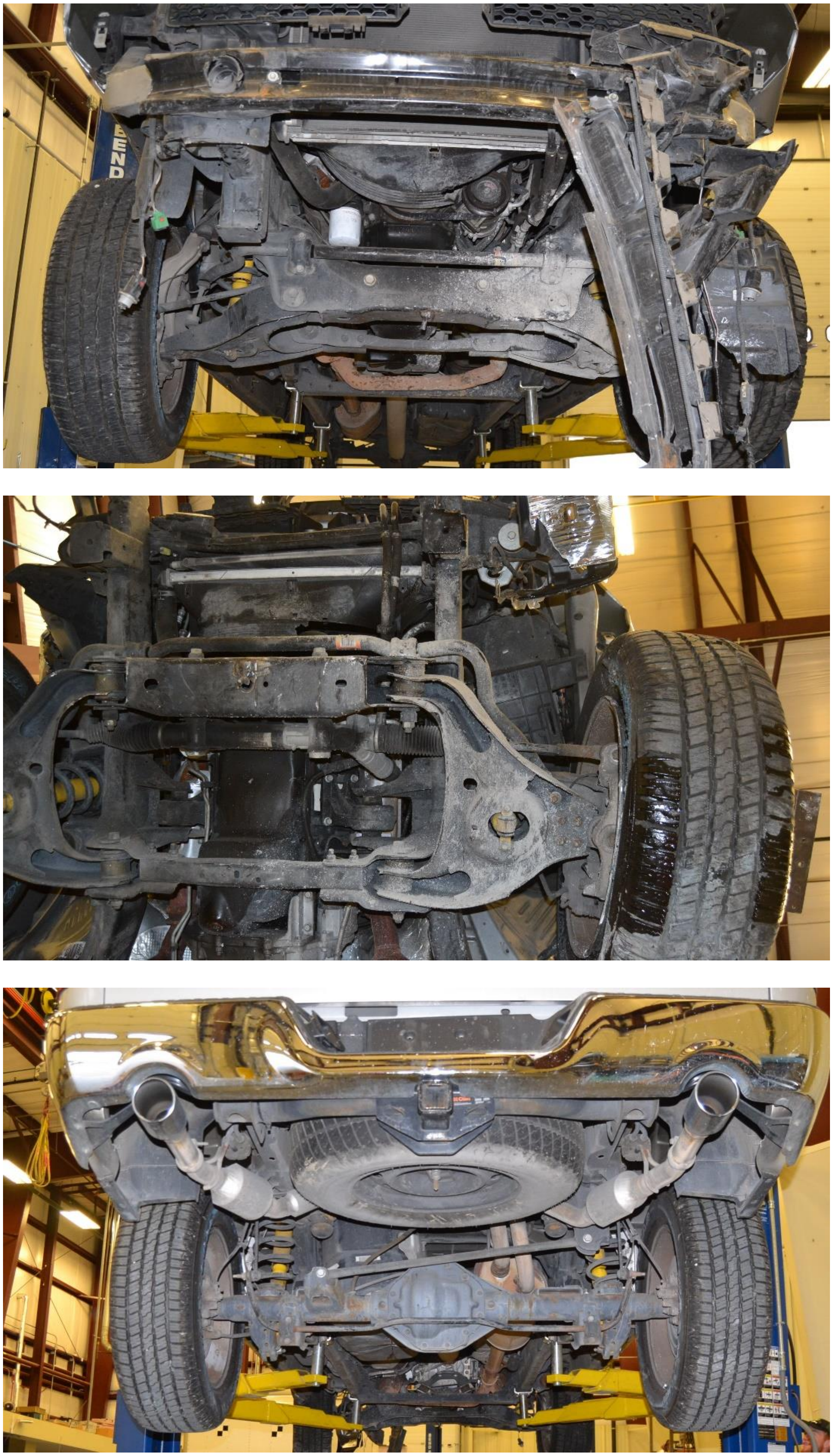


Figure 183. Vehicle Undercarriage Damage, Test No. MSPBN-7

Table 22. Maximum Occupant Compartment Deformations by Location, Test No. MSPBN-7

LOCATION	MAXIMUM DEFORMATION in. (mm)	MASH 2016 ALLOWABLE DEFORMATION in. (mm)
Wheel Well & Toe Pan	0.3 (8)	≤ 9 (229)
Floor Pan & Transmission Tunnel	-0.2 (-5)	≤ 12 (305)
A-Pillar	0.8 (20)	≤ 5 (127)
A-Pillar (Lateral)	0.7 (18)	≤ 3 (76)
B-Pillar	0.3 (8)	≤ 5 (127)
B-Pillar (Lateral)	-0.2 (-5)	≤ 3 (76)
Side Front Panel (in Front of A-Pillar)	-0.3 (-8)	≤ 12 (305)
Side Door (Above Seat)	-0.2 (-5)	≤ 9 (229)
Side Door (Below Seat)	-0.2 (-5)	≤ 12 (305)
Roof	0.1 (3)	≤ 4 (102)
Windshield	0.0 (0.0)	≤ 3 (76)
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	0.4 (10)	N/A

Note: Negative values denote outward deformation
N/A – Not applicable

9.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 23. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 23. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix H.

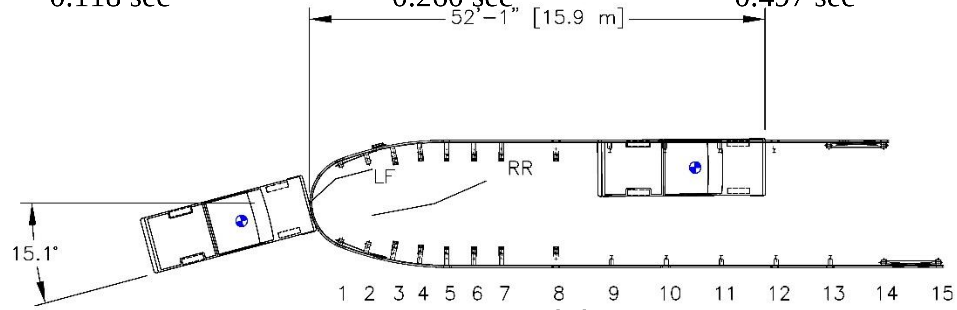
Table 23. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. MSPBN-7

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1	SLICE-2 (primary)	
OIV ft/s (m/s)	Longitudinal	-20.18 (-6.15)	-20.20 (-6.16)	±40 (12.2)
	Lateral	3.28 (1.00)	2.99 (0.91)	±40 (12.2)
ORA g's	Longitudinal	-6.92	-7.09	±20.49
	Lateral	6.37	7.03	±20.49
MAX. ANGULAR DISPL. degrees	Roll	22.7	22.4	±75
	Pitch	6.1	5.5	±75
	Yaw	16.3	13.8	not required
THIV ft/s (m/s)		20.51 (6.25)	20.44 (6.23)	not required
PHD g's		7.64	7.96	not required
ASI		0.41	0.41	not required

9.7 Discussion

The analysis of the results for test no. MSPBN-7 showed that the system adequately contained and decelerated the 2270P vehicle to a controlled stop within the system. A summary of the test results is shown in Figure 184. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. 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. It should be noted that the impacting vehicle did ride up some of the debris in the system and climbed onto Side B of the system late in the event. The vehicle remained securely captured by the thrie beam at the front of the vehicle and did not contact the ground outside of the bullnose system. Additionally, it was noted that the vehicle climb did not adversely affect vehicle stability, and there was no damage observed to the to the occupant compartment due to override of the posts. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix H, were deemed acceptable, because they did not adversely influence occupant risk nor cause rollover. Therefore, test no. MSPBN-7 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-33.

0.000 sec | 0.118 sec | 0.260 sec | 0.497 sec | 1.054 sec



- Test Agency .... MwRSF
- Test Number MSPBN-7
- Date 6/05/2018
- MASH 2016 Test Designation No. 3-33
- Test Article .... Steel Post Bullnose with Breakaway Posts
- Total Length .... 72 ft – 3 in. (22.0 m)
- Key Component - Thrie Beam
  - Thickness .... 12 gauge (2.7 mm)
  - Mounting Height .... 31⅝ in. (803 mm)
- Key Component - Post
  - Length .... 72 1/16 in. (1,849 mm)
  - Spacing .... 37½ in. (953 mm)
- Soil Type
- Vehicle Make /Model .... 2012 Dodge Ram 1500
  - Curb .... 5,271 lb (2,391 kg)
  - Test Inertial .... 5,043 lb (2,287 kg)
  - Gross Static .... 5,202 lb (2,360 kg)
- Impact Conditions
  - Speed .... 63.1 mph (101.6 km/h)
  - Angle .... 15.1 degrees
  - Impact Location .... 0.9 in. (23 mm) downstream of CL of system's nose
- Impact Severity……671.9 kip-ft (911.0 kJ) ≥ 594 kip-ft (806 kJ) limit from MASH 2016
- Exit Conditions
  - Speed .... N/A
  - Angle .... N/A
- Vehicle Stability .... Satisfactory
- Vehicle Capture and Containment .... Acceptable
- Vehicle Stopping Distance .... 52 ft – 1 in. (15.9 m)
- Vehicle Damage .... Minimal
  - VDS [20] 12-FD-2
  - CDC [21] 12-FDLW-1
  - Maximum Interior Deformation .... 0.8 in. (20 mm)
- Test Article Damage .... Extensive
- Maximum Test Article Deflections
  - Permanent Set .... 52 ft – 1 in. (15.9 m) longitudinal, 12 ft – 1½ in (3.7 m) lateral
  - Dynamic .... 52 ft – 9 in. (16.1 m) longitudinal, 14 ft – 6 in. (4.4 m) lateral
  - Working Width .... 52 ft – 9 in. (16.1 m) longitudinal, 29 ft – 2 in. (8.9 m) lateral
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limit
		SLICE-1	SLICE-2 (primary)	
OIV ft/s (m/s)	Longitudinal	-20.18 (-6.15)	-20.20 (-6.16)	±40 (12.2)
	Lateral	3.28 (1.00)	2.99 (0.91)	±40 (12.2)
ORA g's	Longitudinal	-6.92	-7.09	±20.49
	Lateral	6.37	7.03	±20.49
MAX ANGULAR DISP. degrees	Roll	22.7	22.4	±75
	Pitch	6.1	5.5	±75
	Yaw	16.3	13.8	Not Required
THIV – ft/s (m/s)		20.51 (6.25)	20.44 (6.23)	Not Required
PHD – g's		7.64	7.96	Not Required
ASI		0.41	0.41	Not Required

Figure 184. Summary of Test Results and Sequential Photographs, Test No. MSPBN-7

10 DESIGN DETAILS, TEST NO. MSPBN-8

The barrier system for test no. MSPBN-8 consisted of a bullnose median barrier utilizing UBSPs, as shown in Figures 185 through 208. Photographs of the test installation are shown in Figures 209 through 214. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

The system orientation for test no. MSPBN-8 was inverted for a reverse-direction impact event. Sides A and B were equivalent lengths due to the bullnose system being rebuilt with the new orientation. All other details for the system were identical to those used in test no. MSPBN-5 through MSPBN-7. Note that the post numbering for this test was reversed.

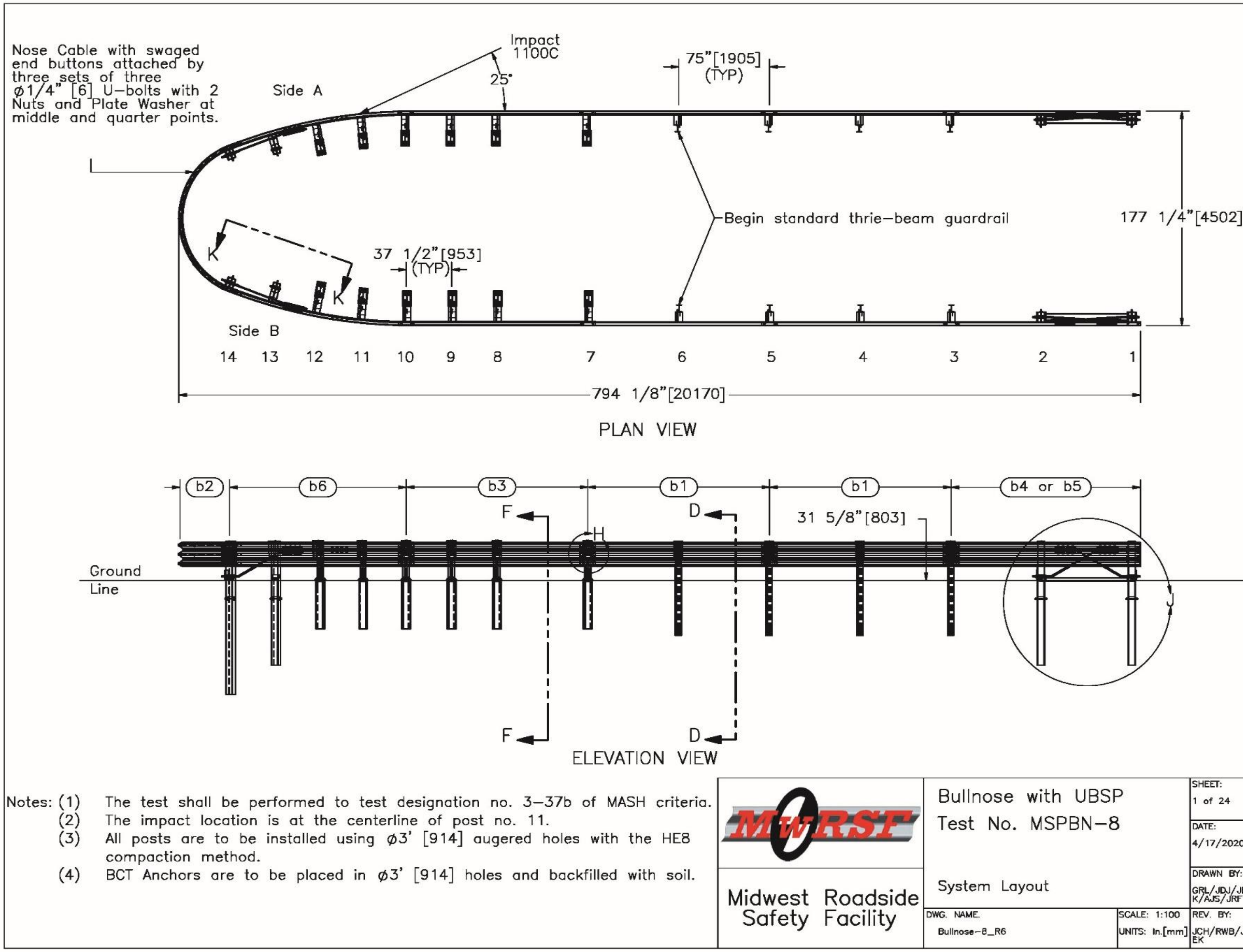


Figure 185. System Layout, Test No. MSPBN-8

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

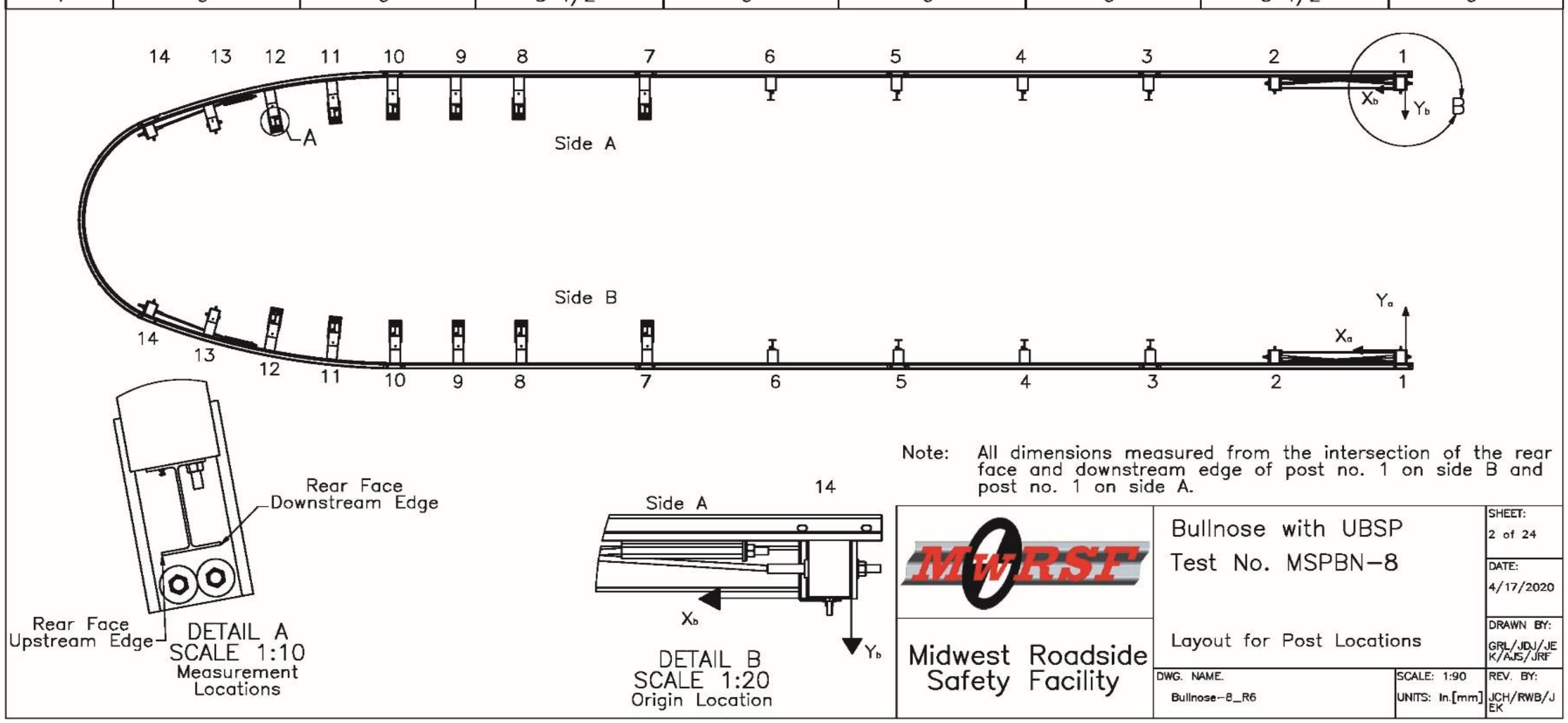


Figure 186. Layout for Post Locations, Test No. MSPBN-8

Post No.	Rear Face–DS Edge		Rear Face–US Edge	
	X_a and X_b	Y_a and Y_b	X_a and X_b	Y_a and Y_b
14	11'–10 1/8"	1'–6 5/8"	12'–3 1/4"	1'–8 5/8"
13	8'–9"	1'–2 3/4"	9'–2 3/8"	1'–4 1/4"
12	5'–9 1/2"	1'–0 7/8"	6'–3 3/8"	1'–1 5/8"
11	2'–10 1/2"	7 7/8"	3'–2 3/8"	8 1/4"
10	0"	5 7/8"	4"	5 7/8"

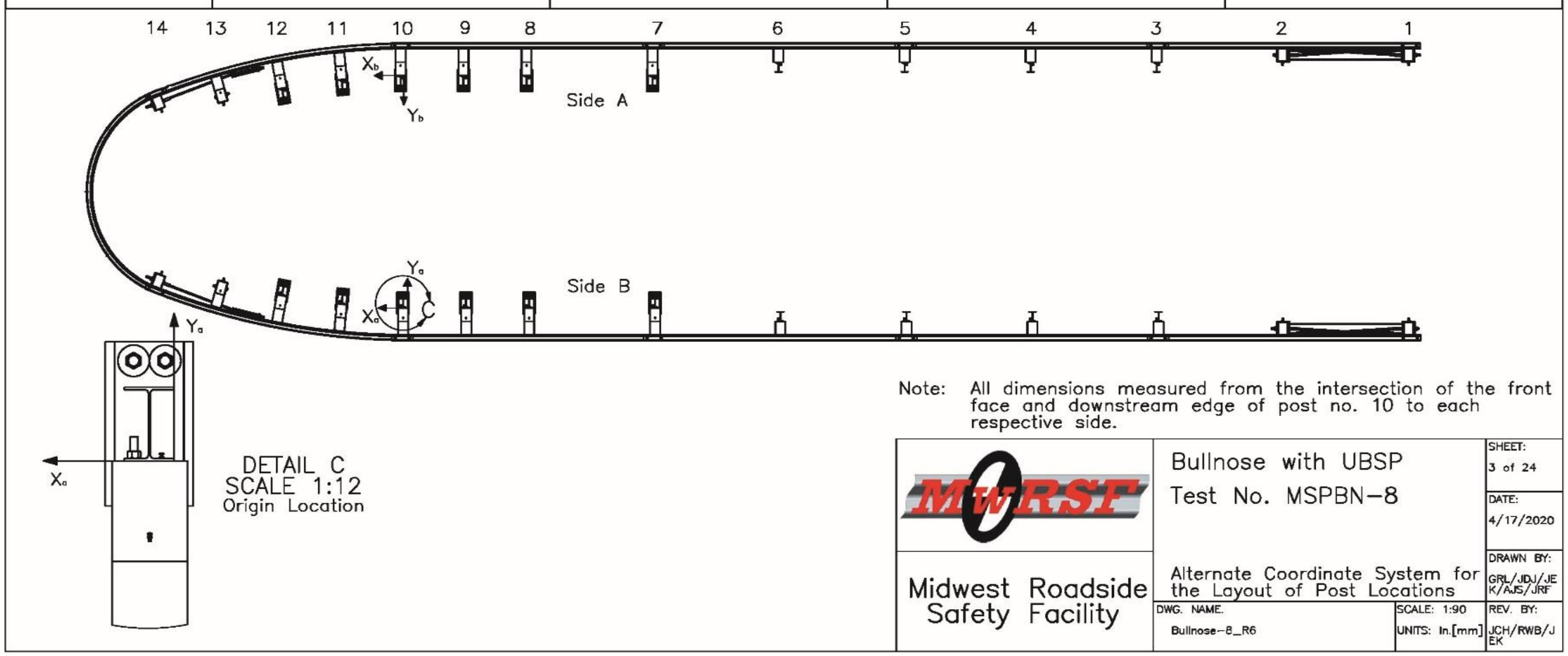


Figure 187. Alternative Coordinate System for the Layout of Post Locations, Test No. MSPBN-8

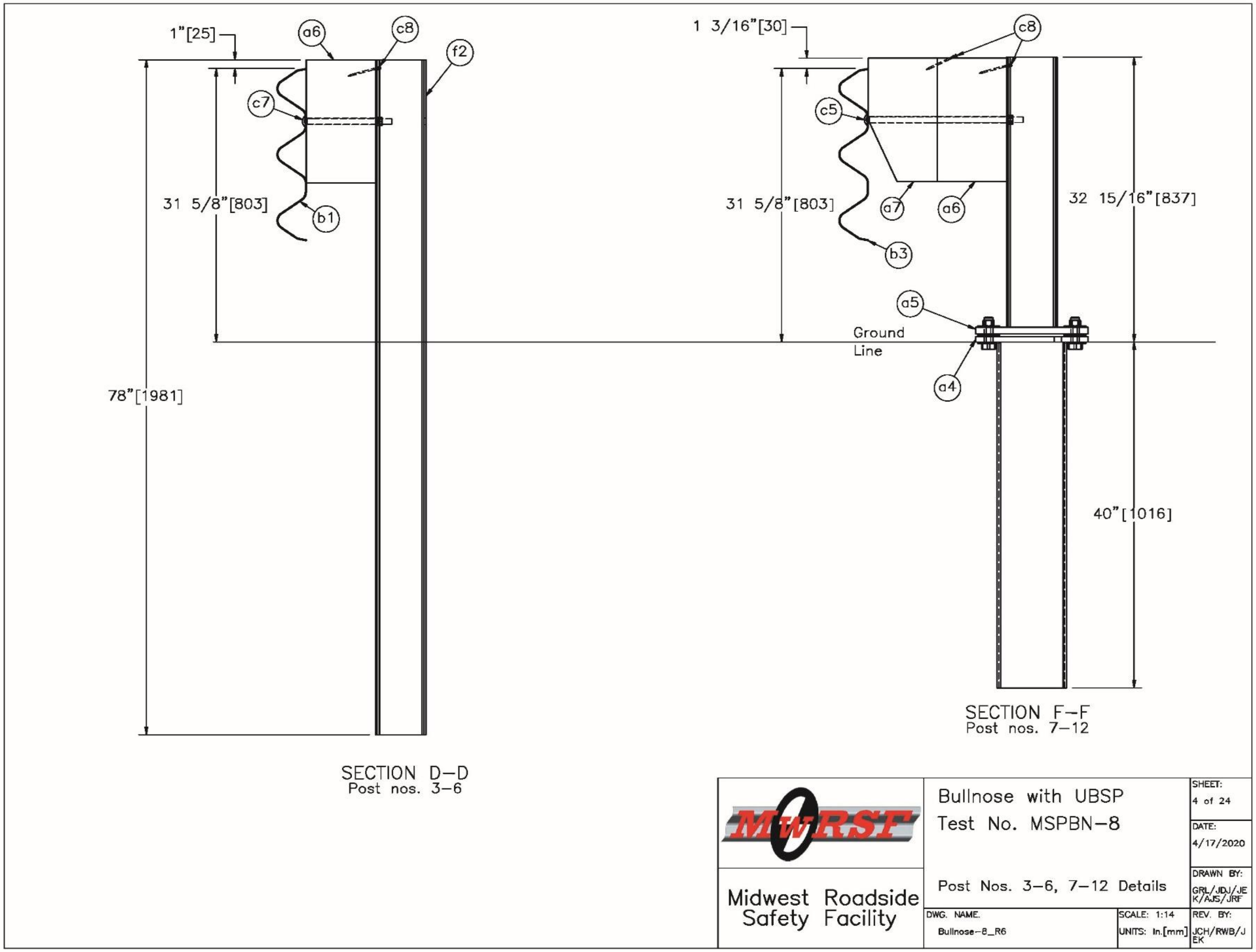


Figure 188. Post Nos. 3 through 6, 7 through 12, Test No. MSPBN-8

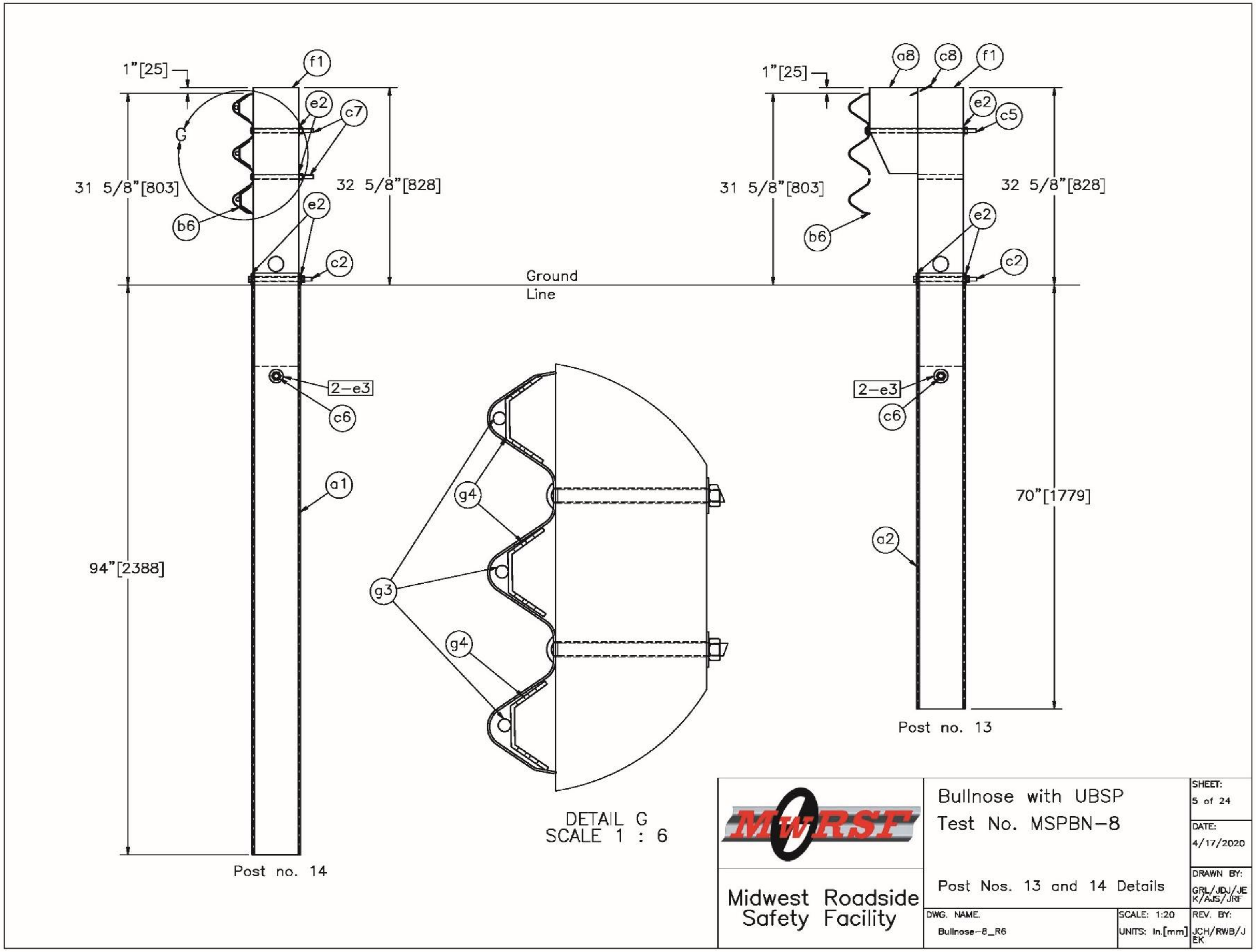


Figure 189. Post Nos. 13 and 14 Details, Test No. MSPBN-8

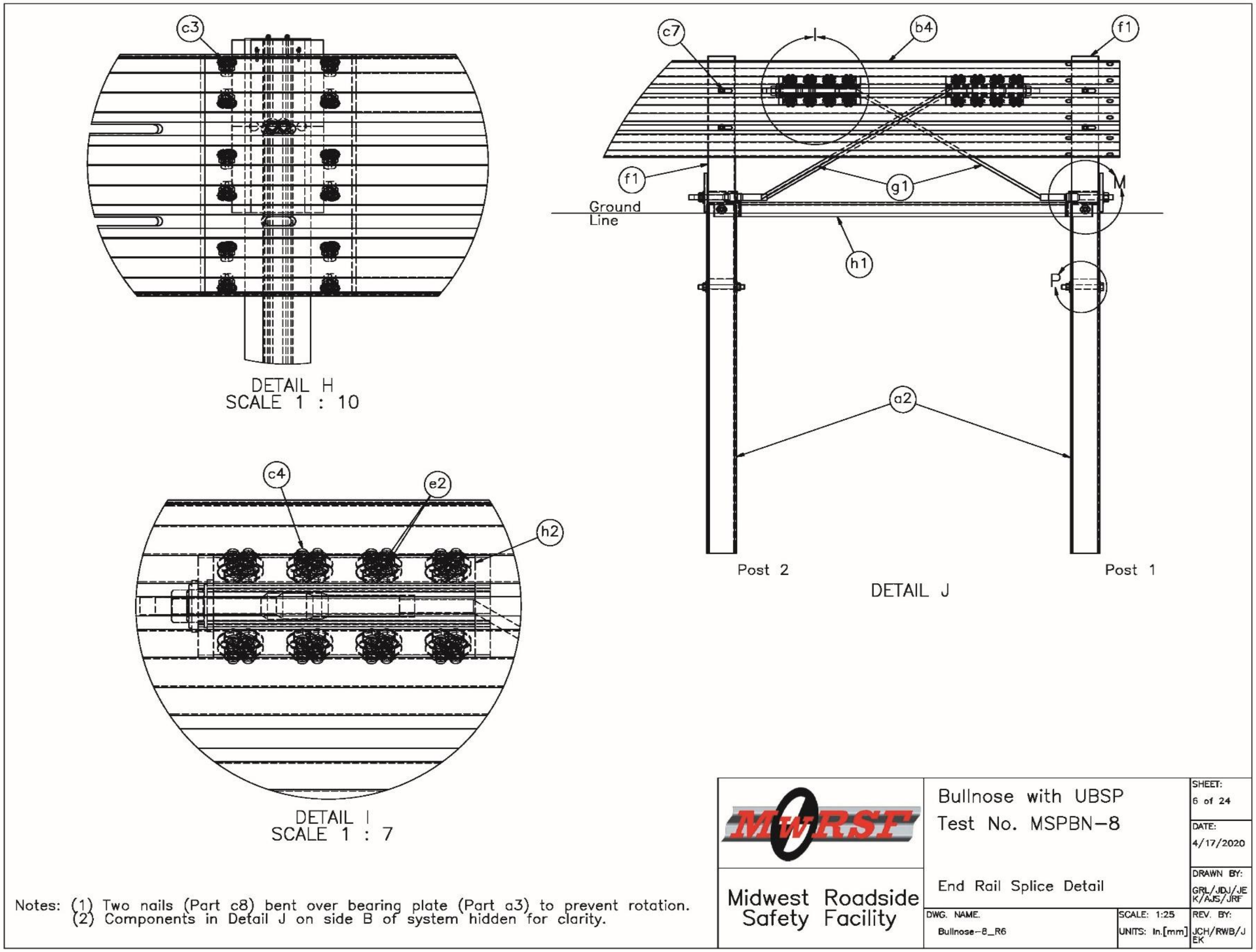


Figure 190. End Rail Splice Detail, Test No. MSPBN-8

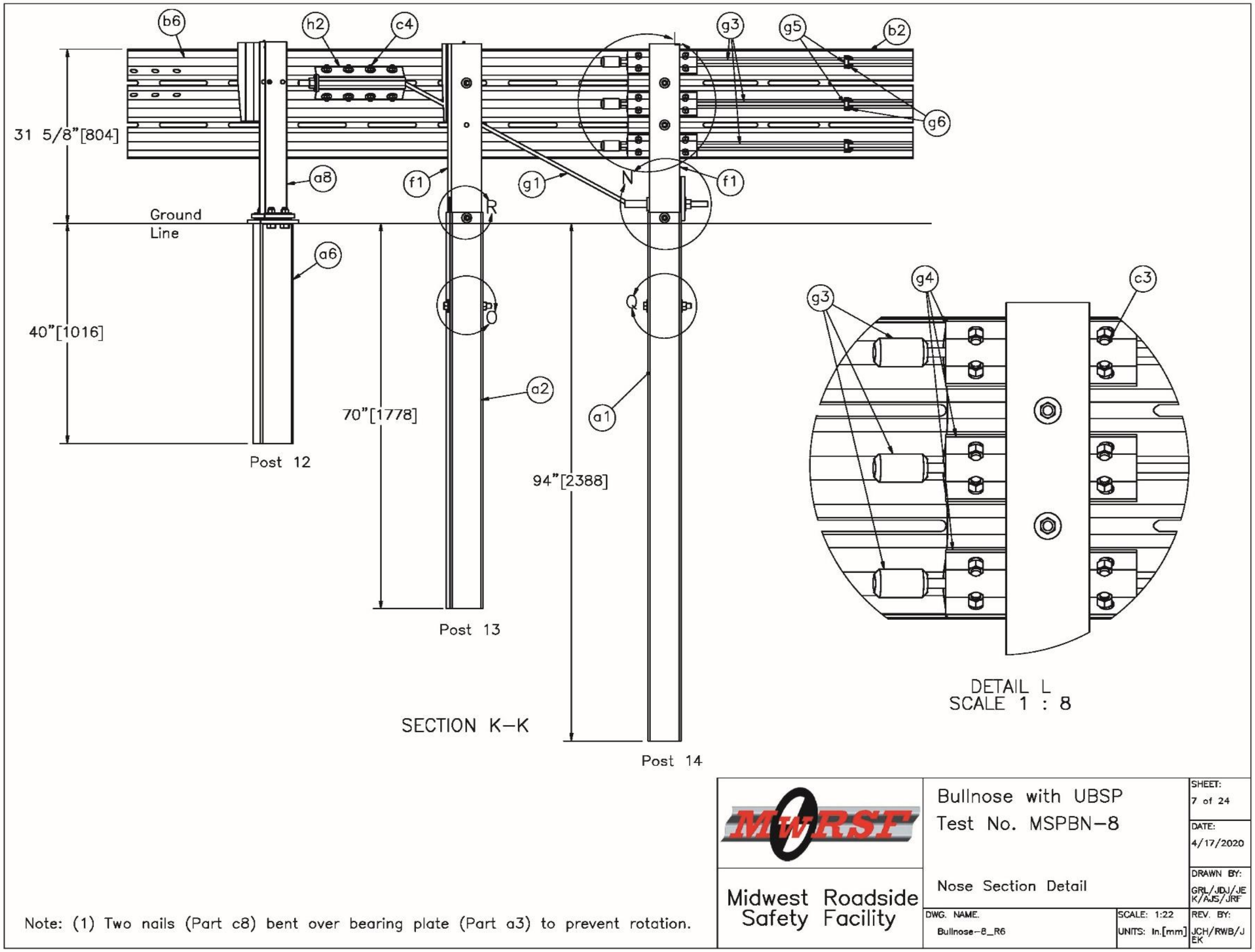


Figure 191. Nose Section Detail, Test No. MSPBN-8

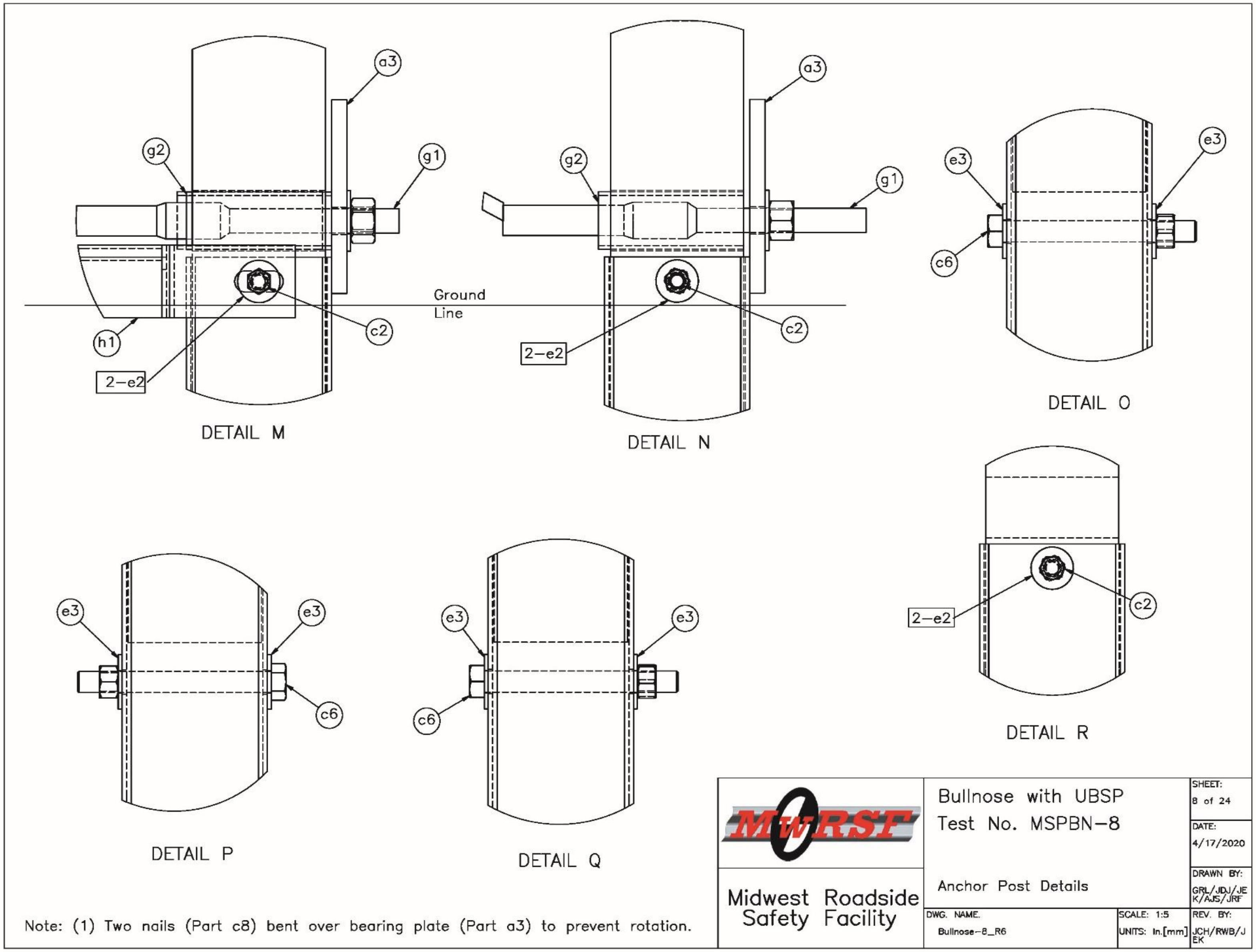


Figure 192. Anchor Post Details, Test No. MSPBN-8

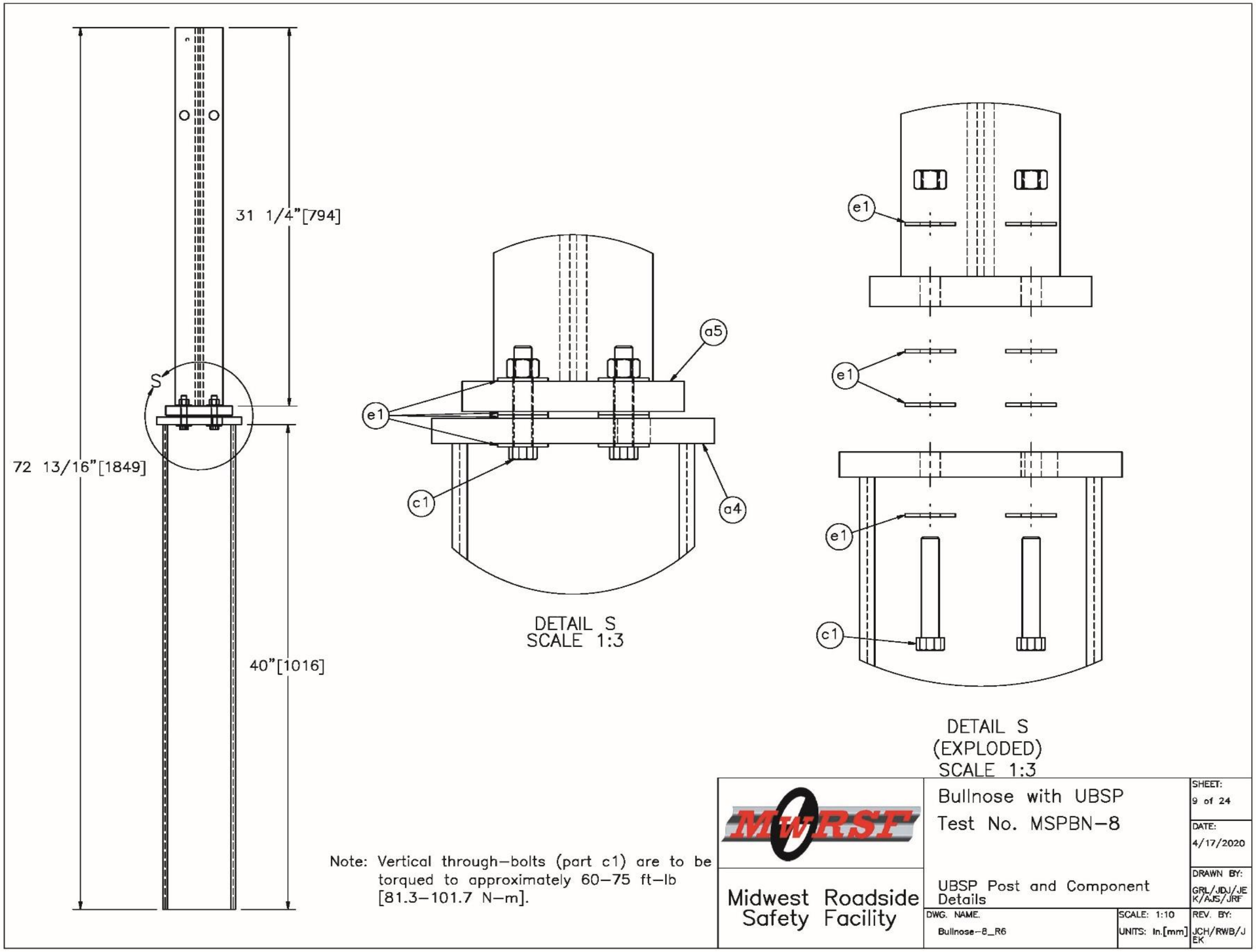


Figure 193. UBSP and Component Details, Test No. MSPBN-8

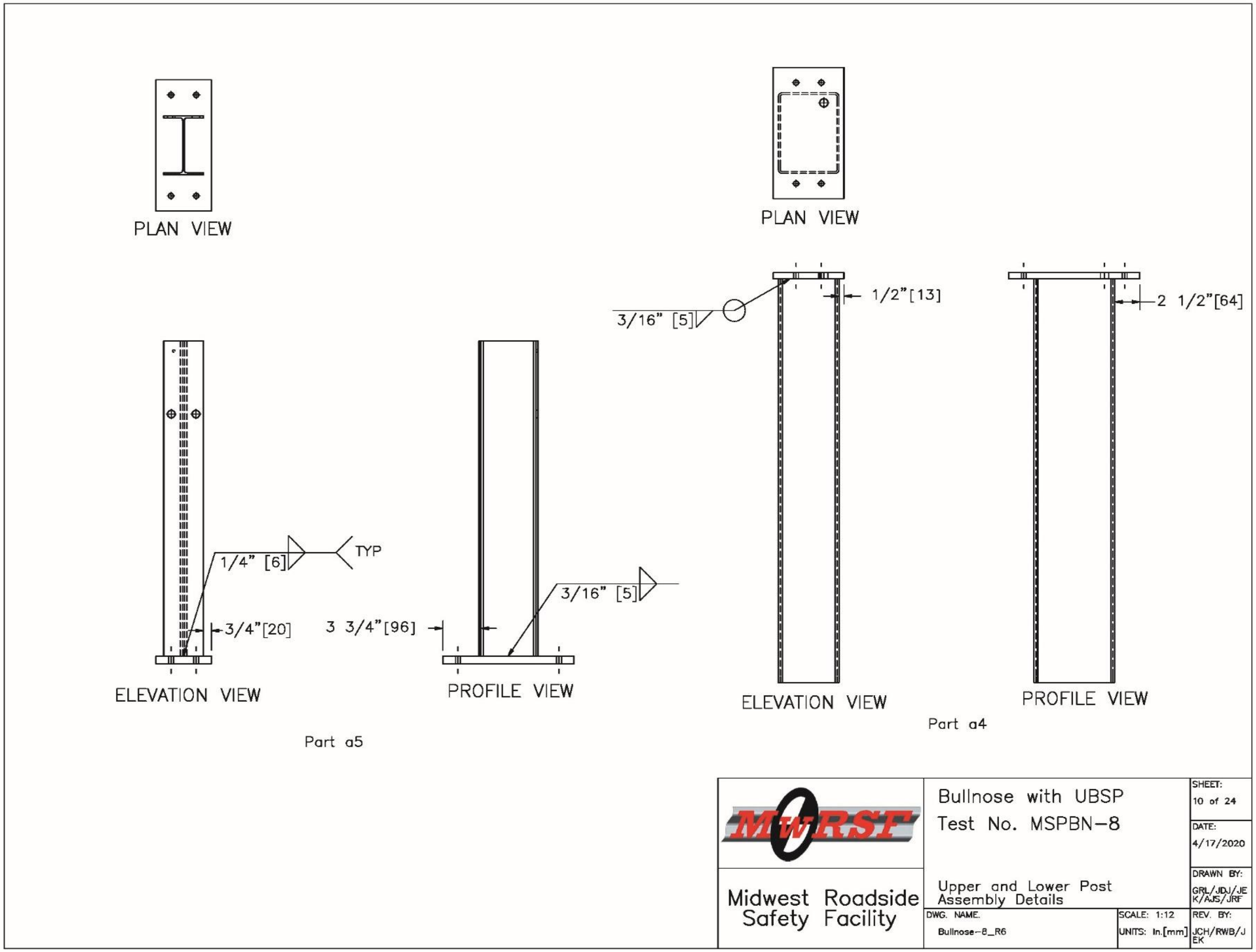


Figure 194. Upper and Lower Post Assembly Details, Test No. MSPBN-8

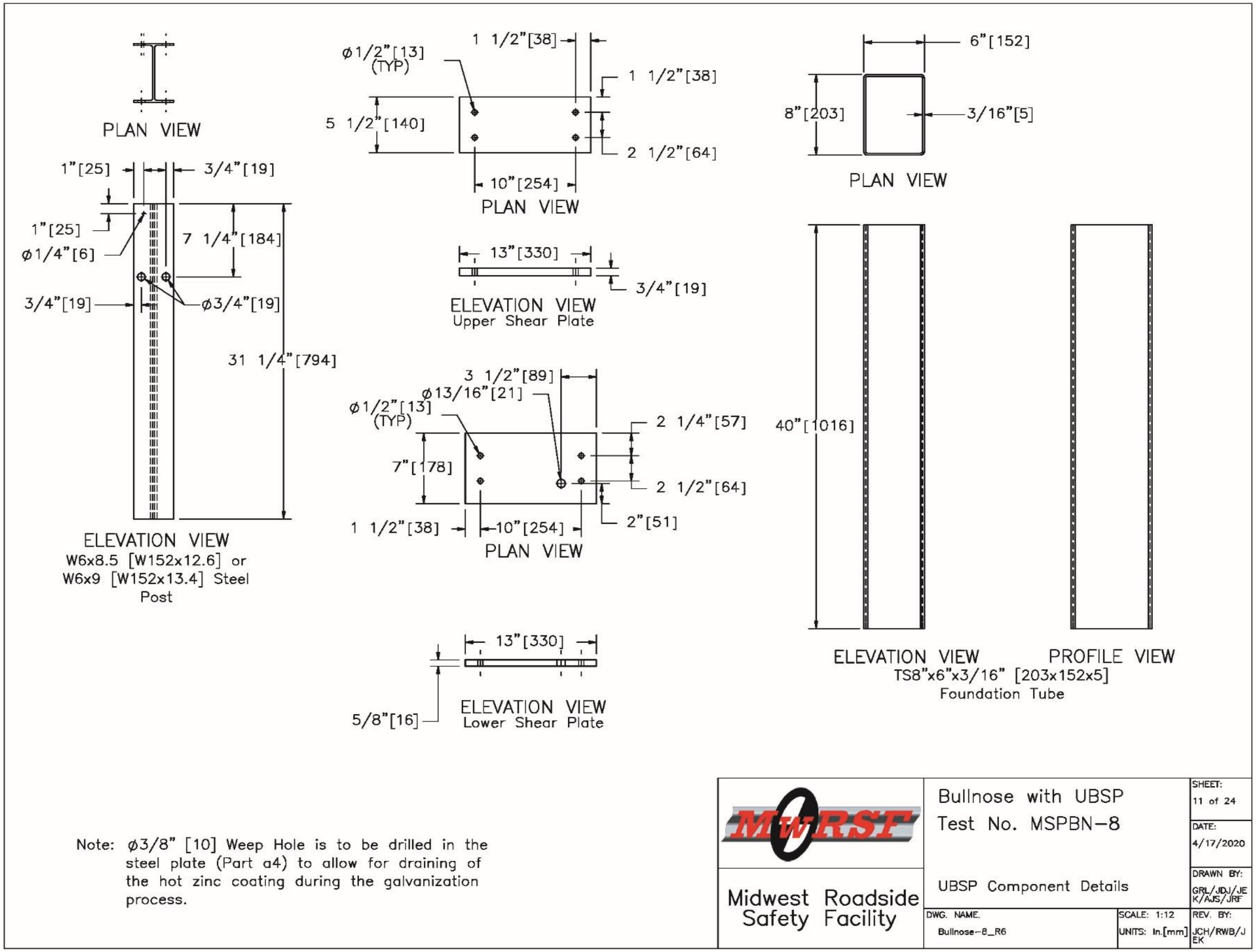


Figure 195. UBSP Component Details, Test No. MSPBN-8

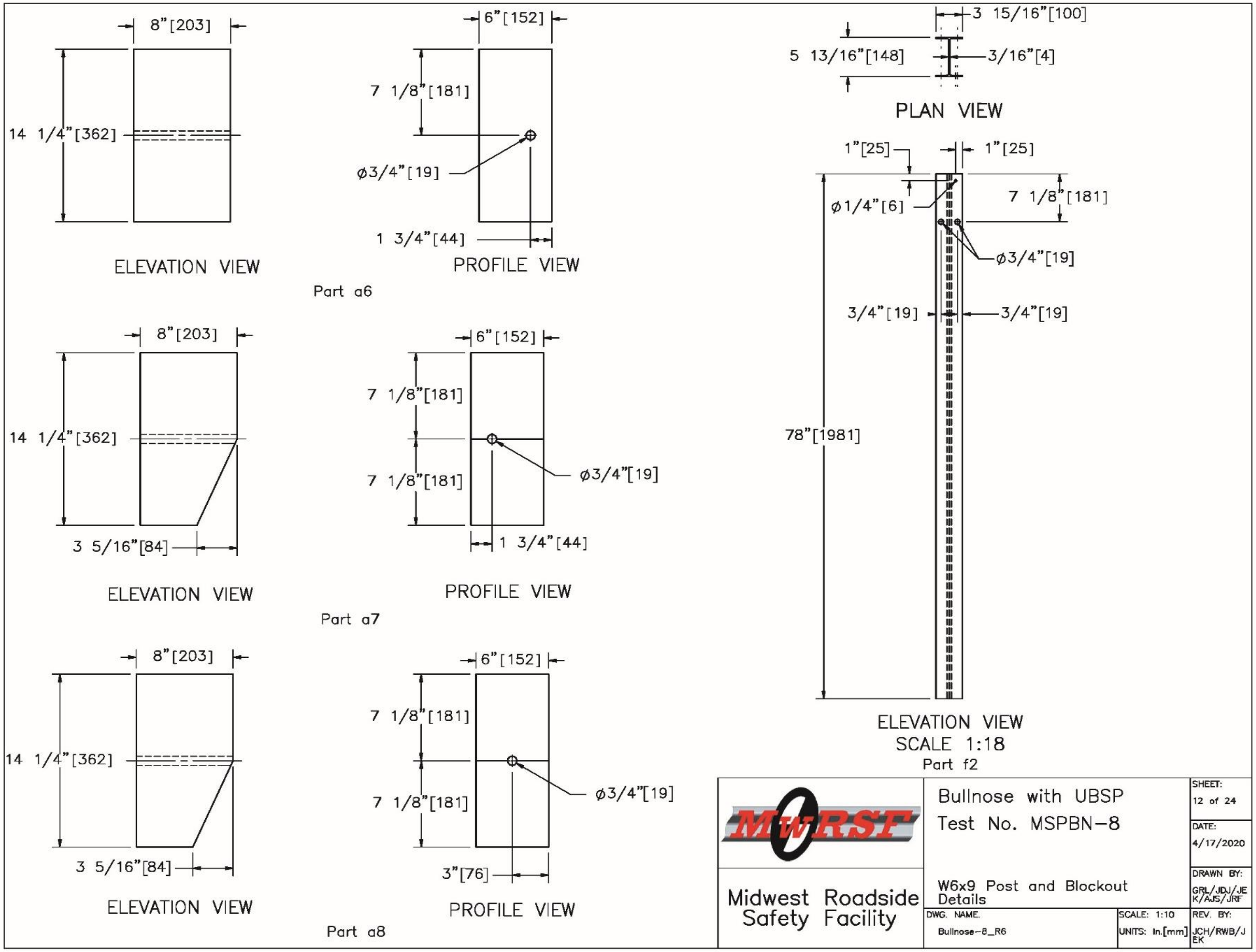


Figure 196. W6x9 Post and Blockout Details, Test No. MSPBN-8

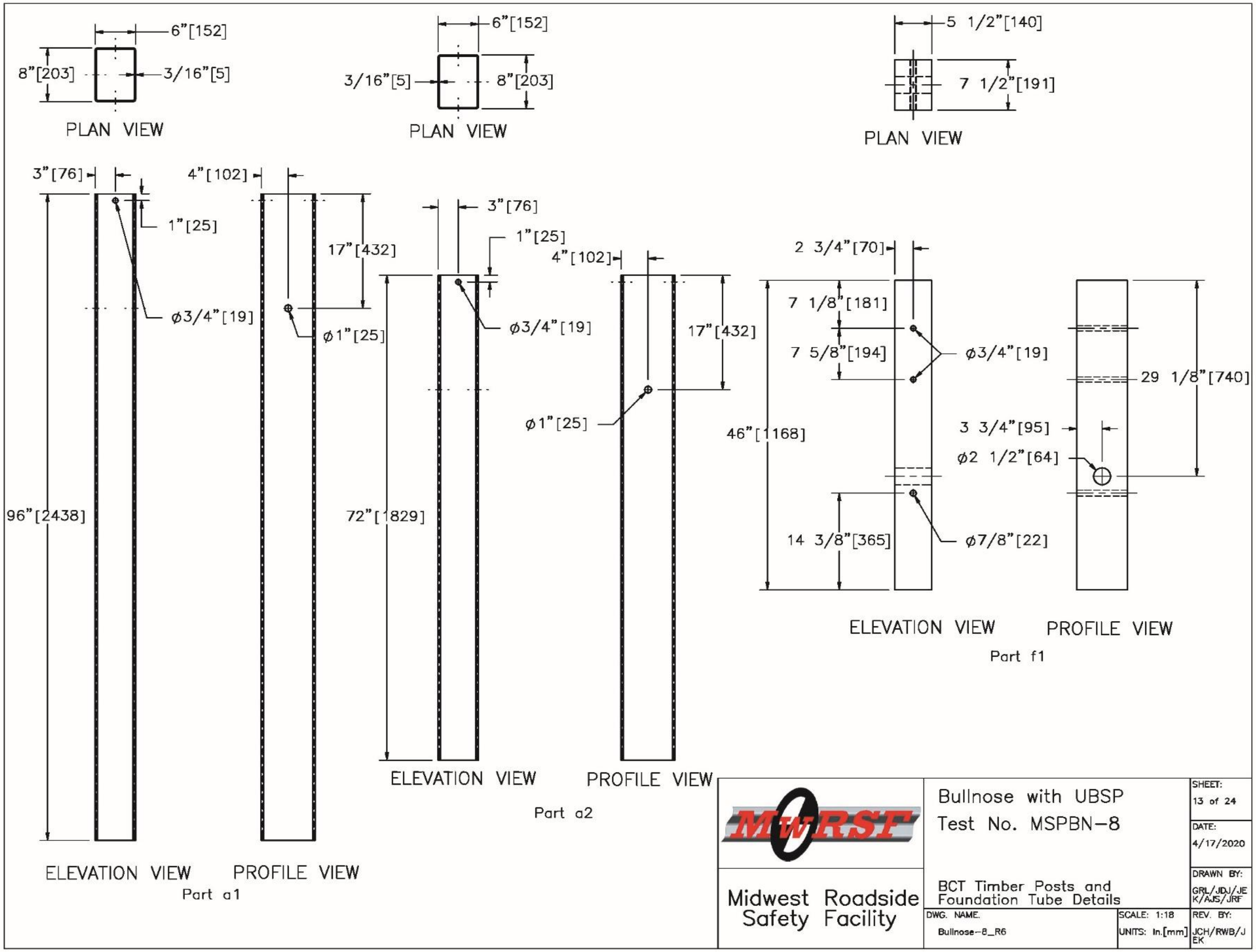


Figure 197. BCT Timber Posts and Foundation Tube Details, Test No. MSPBN-8

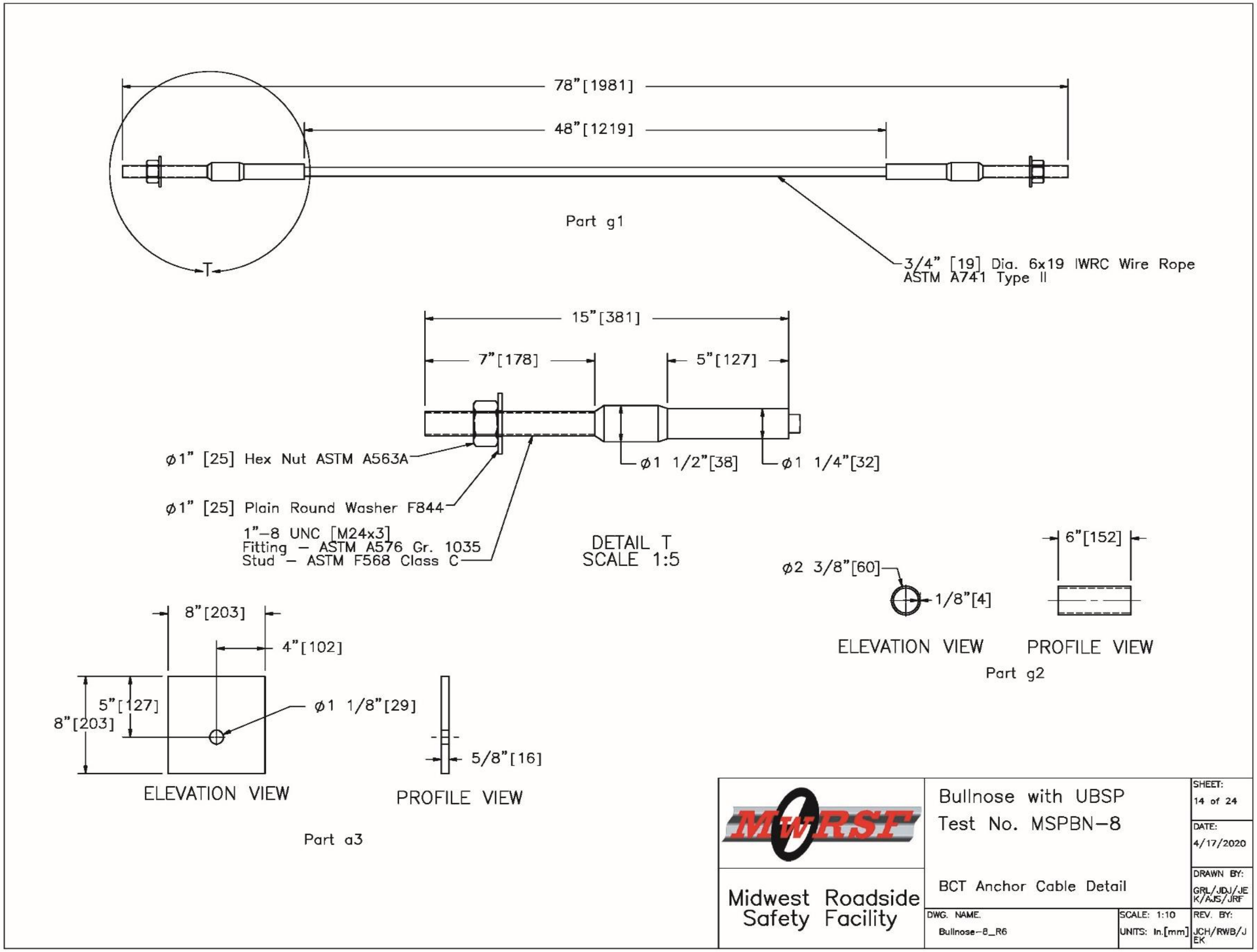


Figure 198. BCT Anchor Details, Test No. MSPBN-8

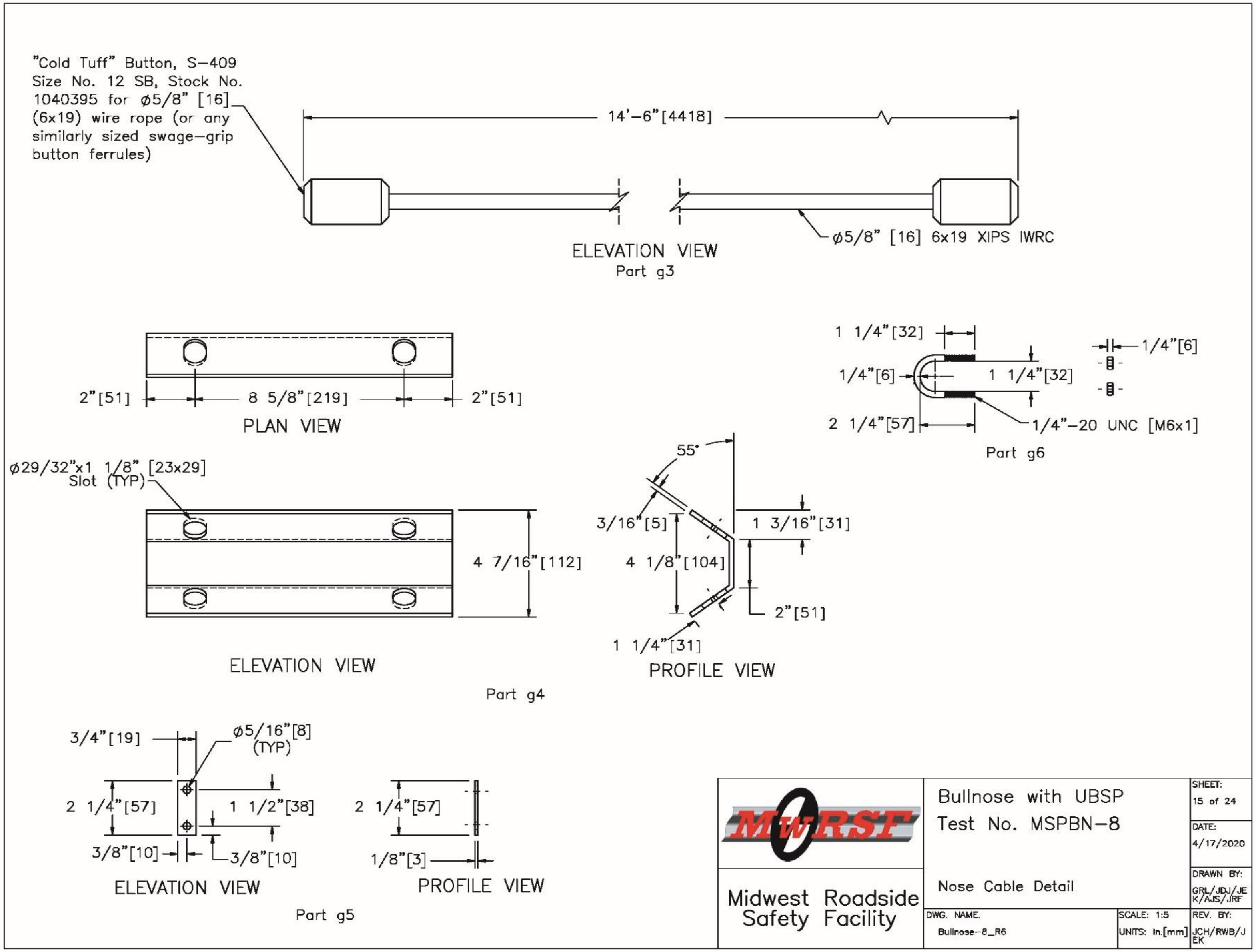


Figure 199. Nose Cable Detail, Test No. MSBPN-8

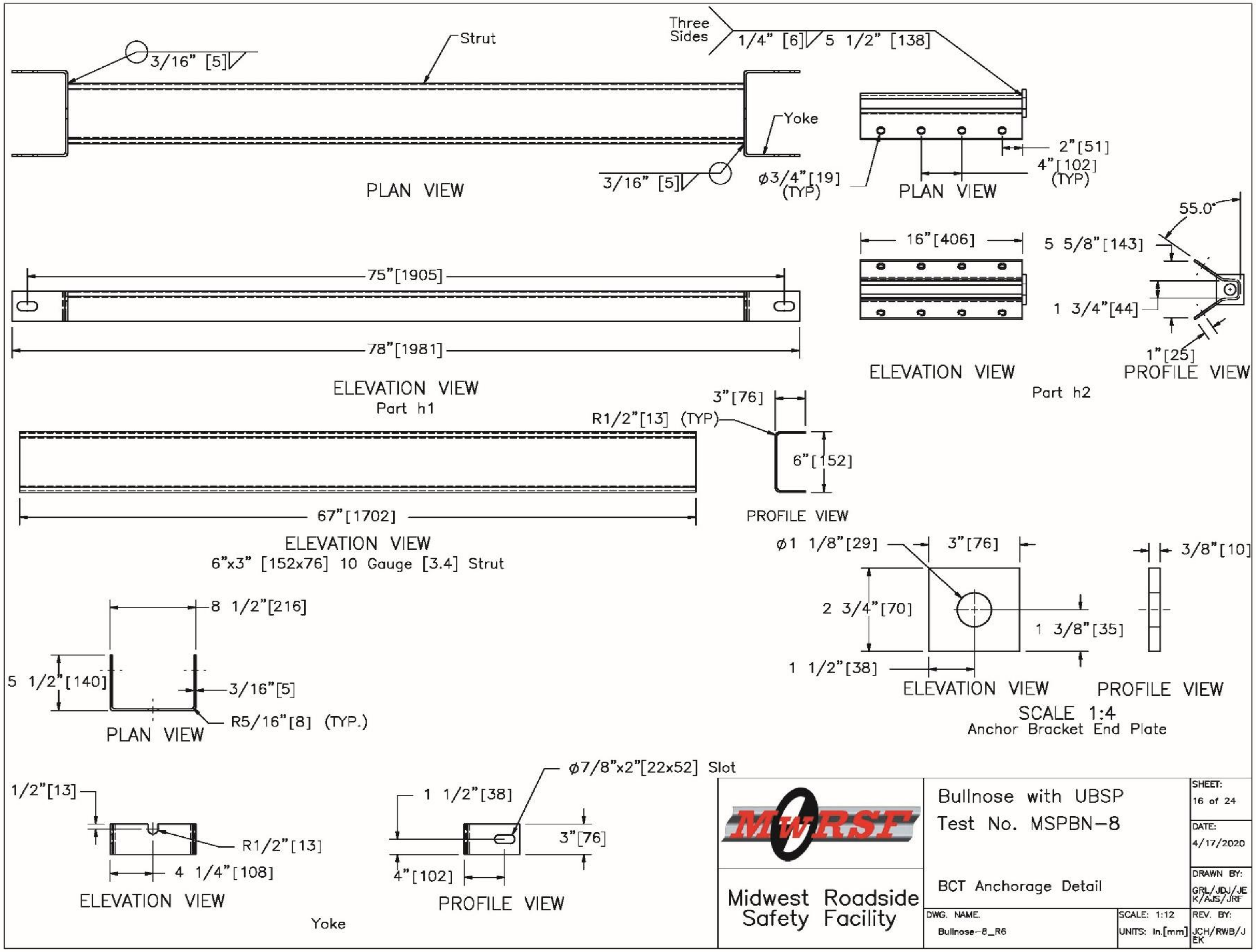


Figure 200. BCT Anchorage Detail, Test No. MSPBN-8

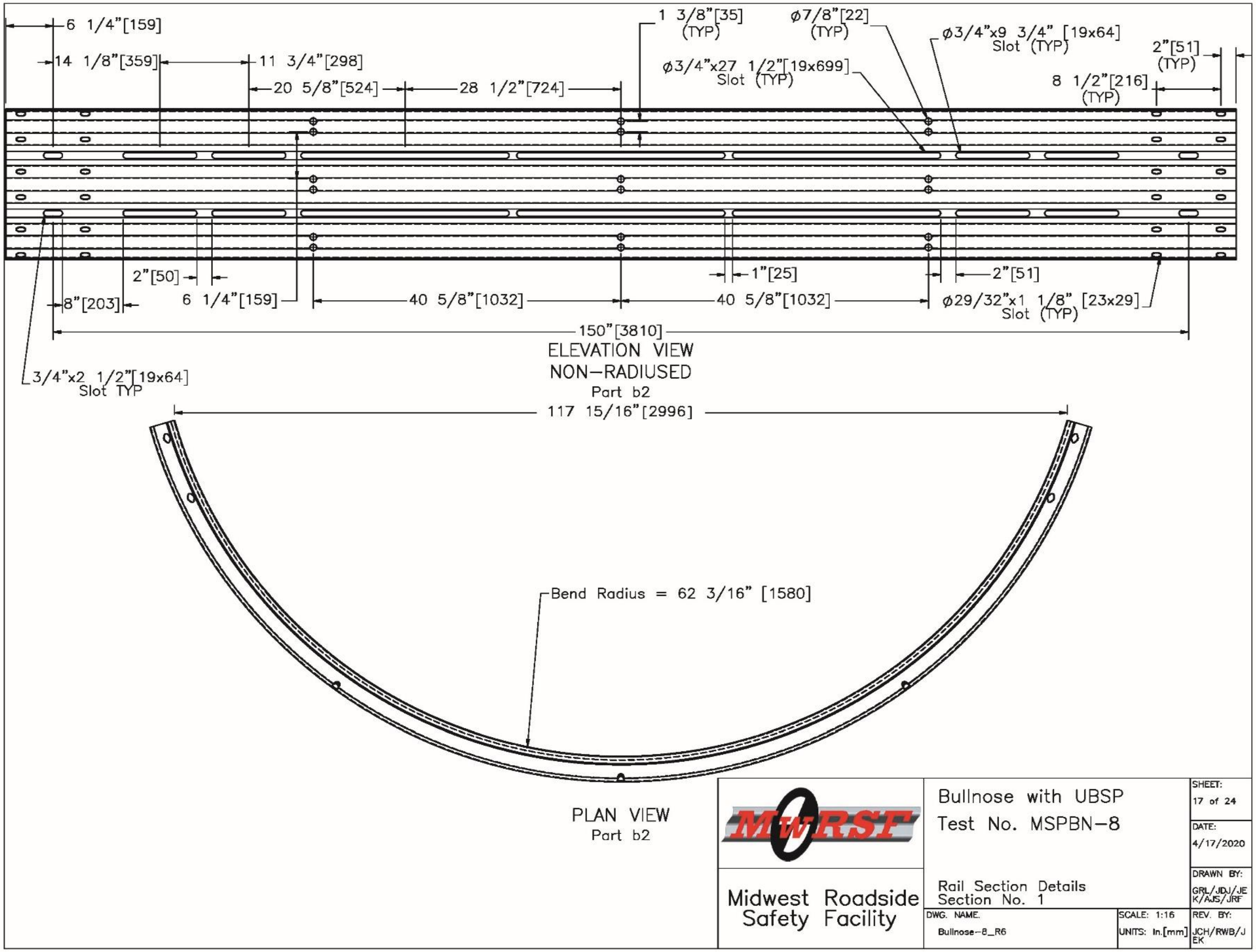


Figure 201. Rail Section Details, Section No. 1, Test No. MSPBN-8

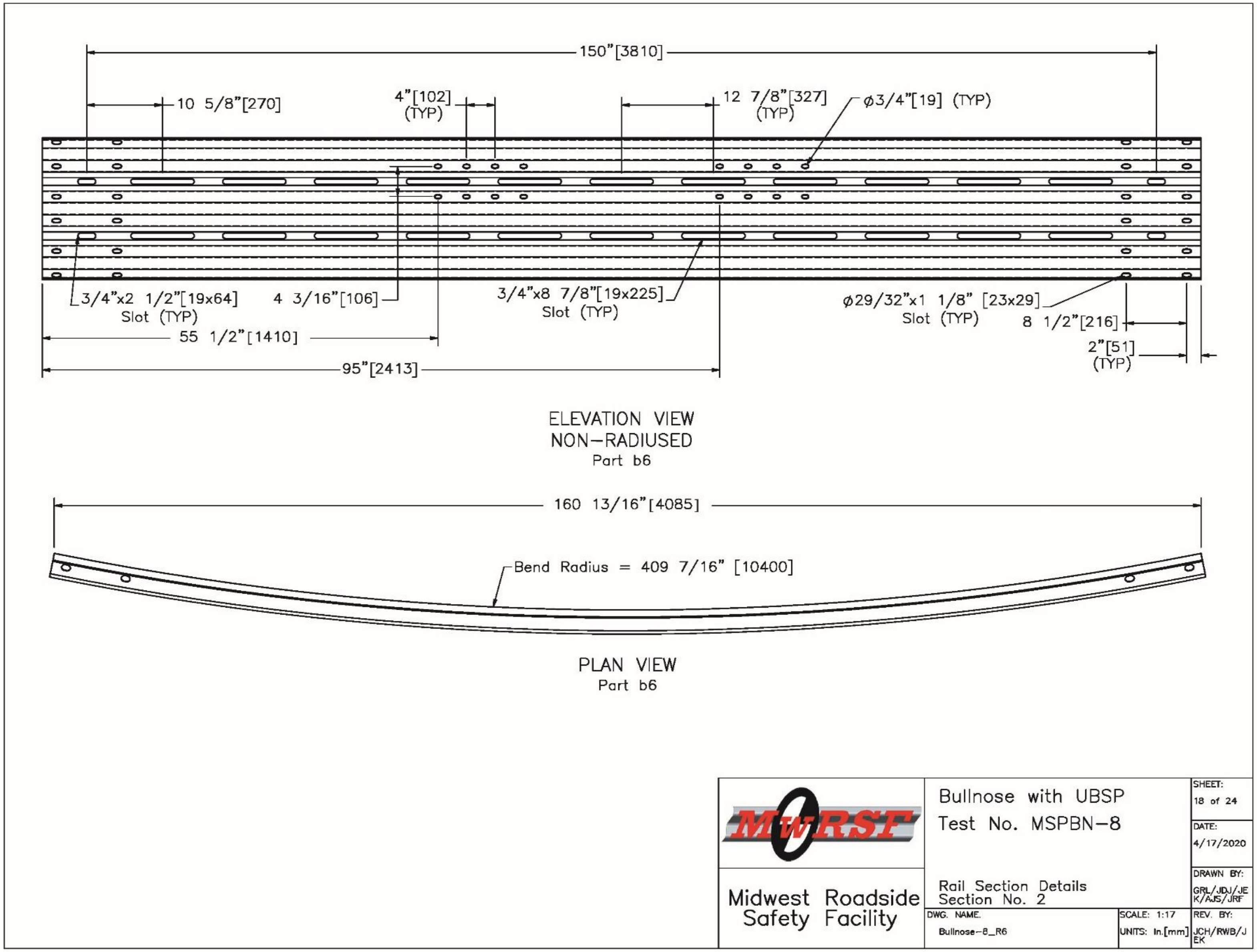


Figure 202. Rail Section Details, Section No. 2, Test No. MSPBN-8

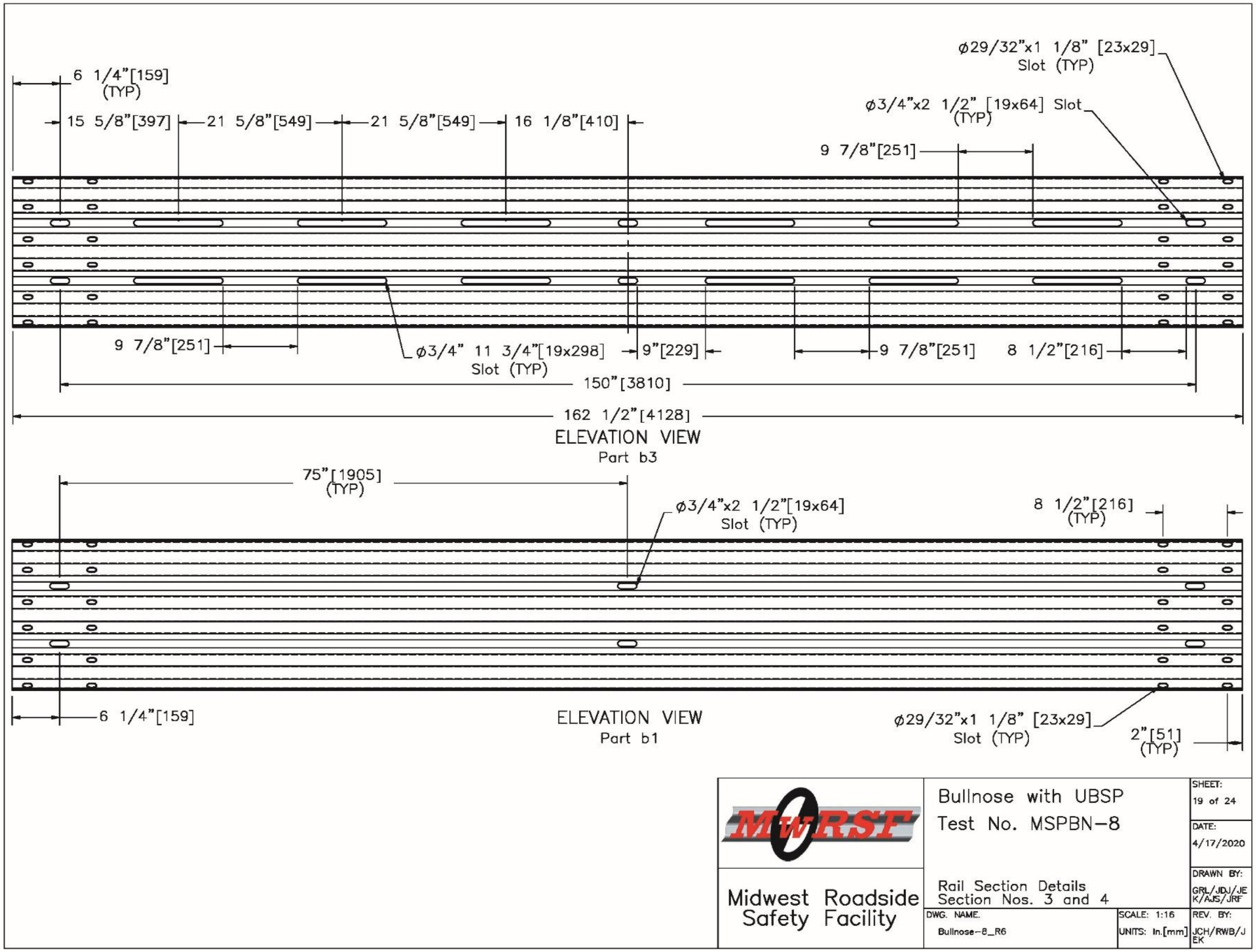


Figure 203. Rail Section Details, Section Nos. 3 and 4, Test No. MSPBN-8

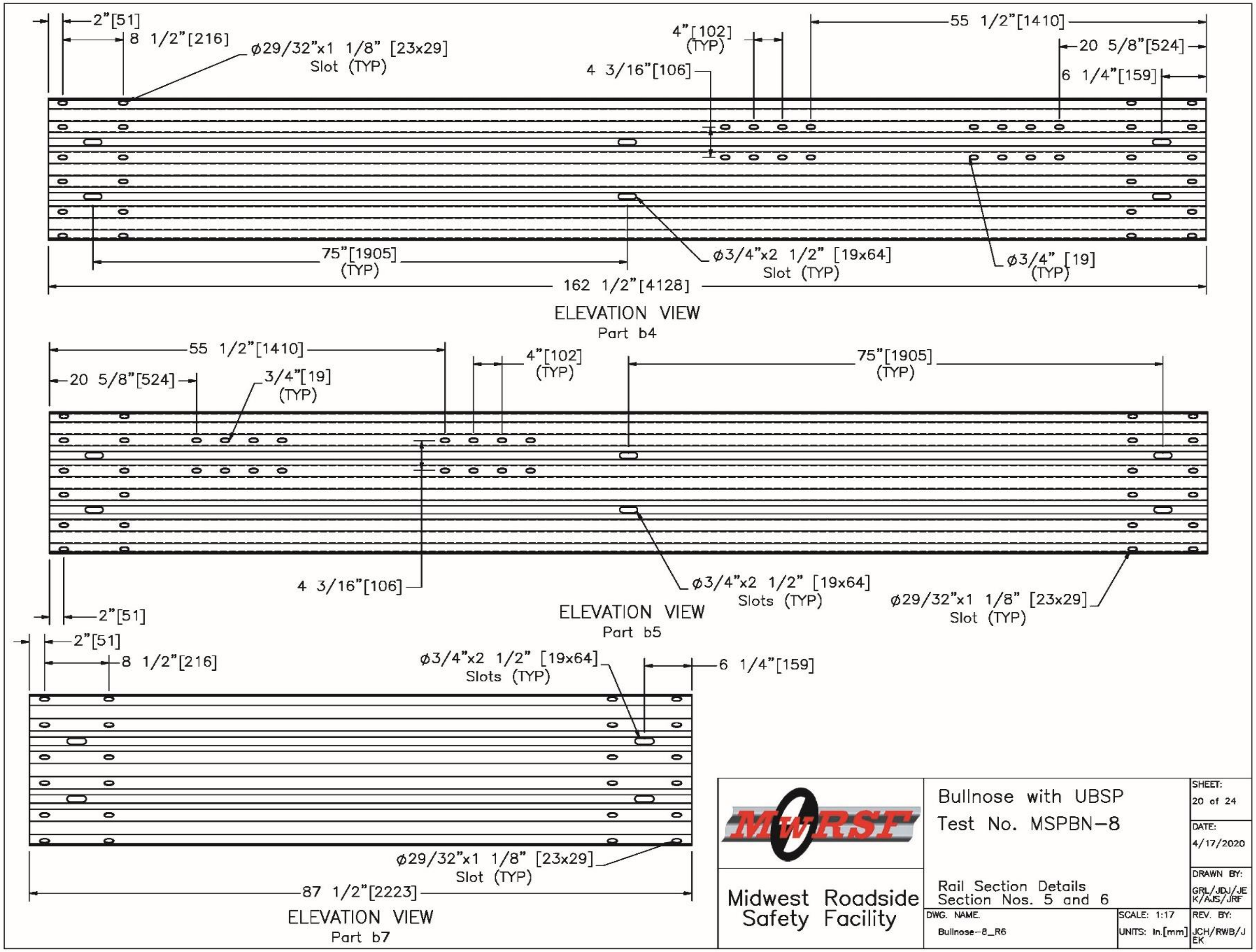


Figure 204. Rail Section Details, Section Nos. 5 and 6, Test No. MSPBN-8

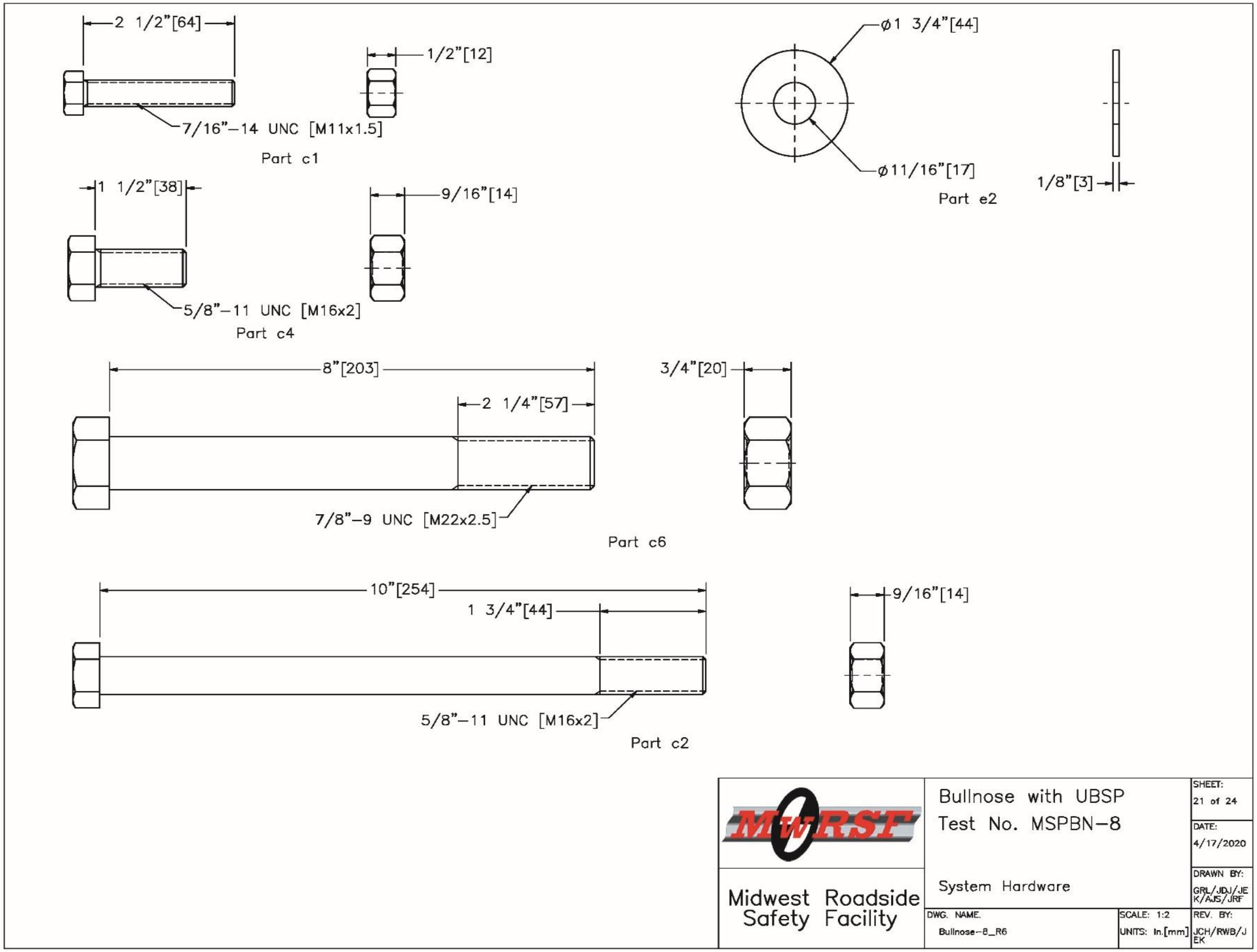


Figure 205. System Hardware, Test No. MSPBN-8

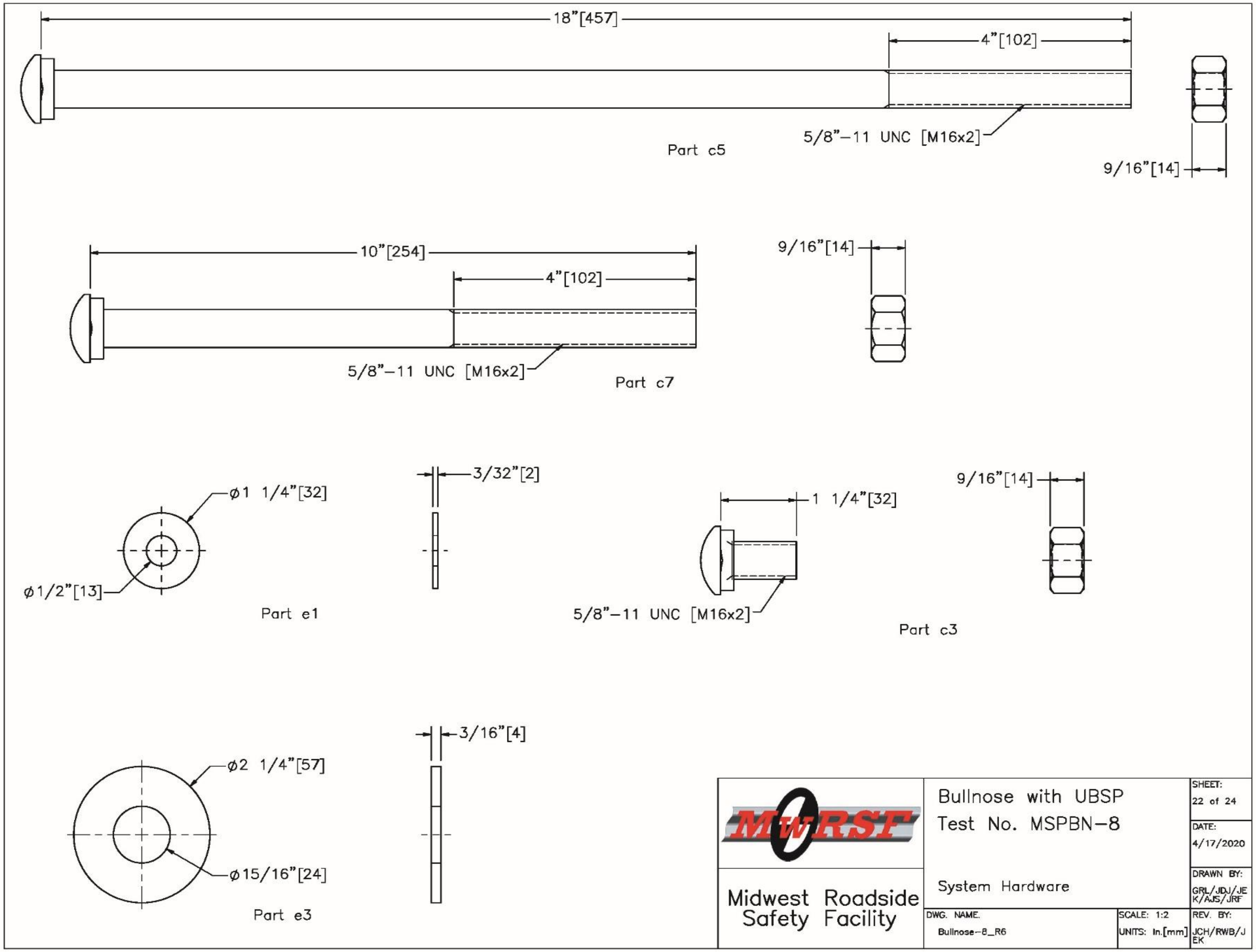


Figure 206. System Hardware, Test No. MSPBN-8

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	2	TS8"x6"x3/16" [203x152x5], 96" [2,438] Long Foundation Tube	ASTM A500 Gr. B	ASTM A123	PTE07
a2	6	TS8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	ASTM A123	PTE06
a3	6	8"x8"x5/8" [203x203x16] Anchor Bearing Plate	ASTM A36	ASTM A123	FPB01
a4	12	Lower Slip Post Assembly	Plate–ASTM A36 Foundation Tube–ASTM A500 Gr. B	ASTM A123	PTE08
a5	12	Upper Slip Post Assembly	Plate–ASTM A36 Post–ASTM A992	ASTM A123	PWE11
a6	20	6"x8"x14 1/4" [152x203x362] Timber Blockout	SYP Grade No. 1 or better	–	PDB09
a7	12	6"x8"x14 1/4" [152x203x362] Tapered Timber Blockout	SYP Grade No. 1 or better	–	PDB20
a8	2	6"x8"x14 1/4" [152x203x362] Tapered Timber Blockout – Post 2	SYP Grade No. 1 or better	–	PDB12
b1	4	12'–6" [3,810] 12 gauge [2.7] Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM02a
b2	1	12'–6" [3,810] 12 gauge [2.7] Bent Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM07a
b3	2	12'–6" [3,810] 12 gauge [2.7] Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM07e
b4	1	12'–6" [3,810] 12 gauge [2.7] Thrie Beam End Section – Side A	AASHTO M180	ASTM A123 or A653	–
b5	1	12'–6" [3,810] 12 gauge [2.7] Thrie Beam End Section – Side B	AASHTO M180	ASTM A123 or A653	–
b6	2	12'–6" [3,810] 12 gauge [2.7] Bent Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM07d
c1	48	7/16"–14 UNC [M11x1.5], 2 1/2" [64] Long Hex Tap Bolt (Fully Threaded) and Nut	Bolt – ASTM A449 or SAE J429 Gr. 5 Nut – ASTM A563DH or SAE J995 Gr. 5	ASTM A153 or B695 Class 55 or F2329	FBX12b
c2	8	5/8"–11 UNC [M16x2], 10" [254] Long Hex Head Bolt	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBX16a
c3	120	5/8"–11 UNC [M16x2], 1 1/4" [32] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB01
c4	48	5/8"–11 UNC [M16x2], 1 1/2" [38] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBX16a
c5	14	5/8"–11 UNC [M16x2], 18" [457] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB04
c6	8	7/8"–9 UNC [M22x2.5], 8" [203] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	–
c7	20	5/8"–11 UNC [M16x2], 10" [254] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB03
c8	46	16D Double Head Nail	–	–	–

Midwest Roadside Safety Facility

Bullnose with UBSP
Test No. MSPBN–8

Bill of Materials

SHEET: 23 of 24
DATE: 4/17/2020
DRAWN BY: GRL/JDJ/JEK/AJS/JRF
DWG. NAME. Bullnose–8_R6
SCALE: None
UNITS: in.[mm]
REV. BY: JCH/RWB/JEK

Figure 207. Bill of Materials, Test No. MSPBN-8

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
e1	192	7/16" [11] Dia. Plain Round Washer	ASTM F844	ASTM A153 or B695 Class 55 or F2329	FWC12a
e2	118	5/8" [16] Dia. Plain Round Washer	ASTM F844	ASTM A153 or B695 Class 55 or F2329	FWC16a
e3	16	7/8" [22] Dia. Plain Round Washer	ASTM F844	ASTM A153 or B695 Class 55 or F2329	–
f1	8	BCT Timber Post – MGS Height	SYP Grade No. 1 or better (No knots +/– 18" [457] from ground on tension face)	–	PDF04
f2	8	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 78" [1,981] Long Steel Post	ASTM A992	ASTM A123	–
g1	6	BCT Anchor Cable Assembly	–		FCA01
g2	6	2 3/8" [60] O.D. x 6" [152] Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	ASTM A123	FMM02
g3	3	5/8" Dia. [15.9] x 14.4' [4,389] Long Cable and Swage Button	"Cold Tuff" Button, S–409 Size No. 12 SB, Stock No. 1040395 for 5/8" [16] Dia. (6x19) wire rope (or any similarly sized swage–grip button ferrules)	Wire Rope – Class A Coating	RCM02
g4	6	12 5/8"x5 13/16"x3/16" [321x148x5] Nose Cable Anchor Plate	ASTM A36	ASTM A123	FPA04
g5	9	2 1/4"x3/4" [57x19] 11 gauge [3] U–Bolt Plate Washer	ASTM A1011 CS Type B	ASTM A123	–
g6	9	1/4" [6] Dia. U–Bolt and Nut	U–Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	–
h1	2	Ground Strut Assembly	ASTM A36	ASTM A123	PFP01
h2	6	Anchor Bracket Assmbely	ASTM A36	ASTM A123	FPA01

Midwest Roadside Safety Facility

Bullnose with UBSP
Test No. MSPBN–8

Bill of Materials

SHEET: 24 of 24
DATE: 4/17/2020
DRAWN BY: GRL/JDJ/JEK/AJS/JRF
DWG. NAME. Bullnose–8_R6
SCALE: None
UNITS: in.[mm]
REV. BY: JCH/RWB/JEK

Figure 208. Bill of Materials, Test No. MSPBN-8

Figure 209. Test Installation Photograph, System Overview, Test No. MSPBN-8

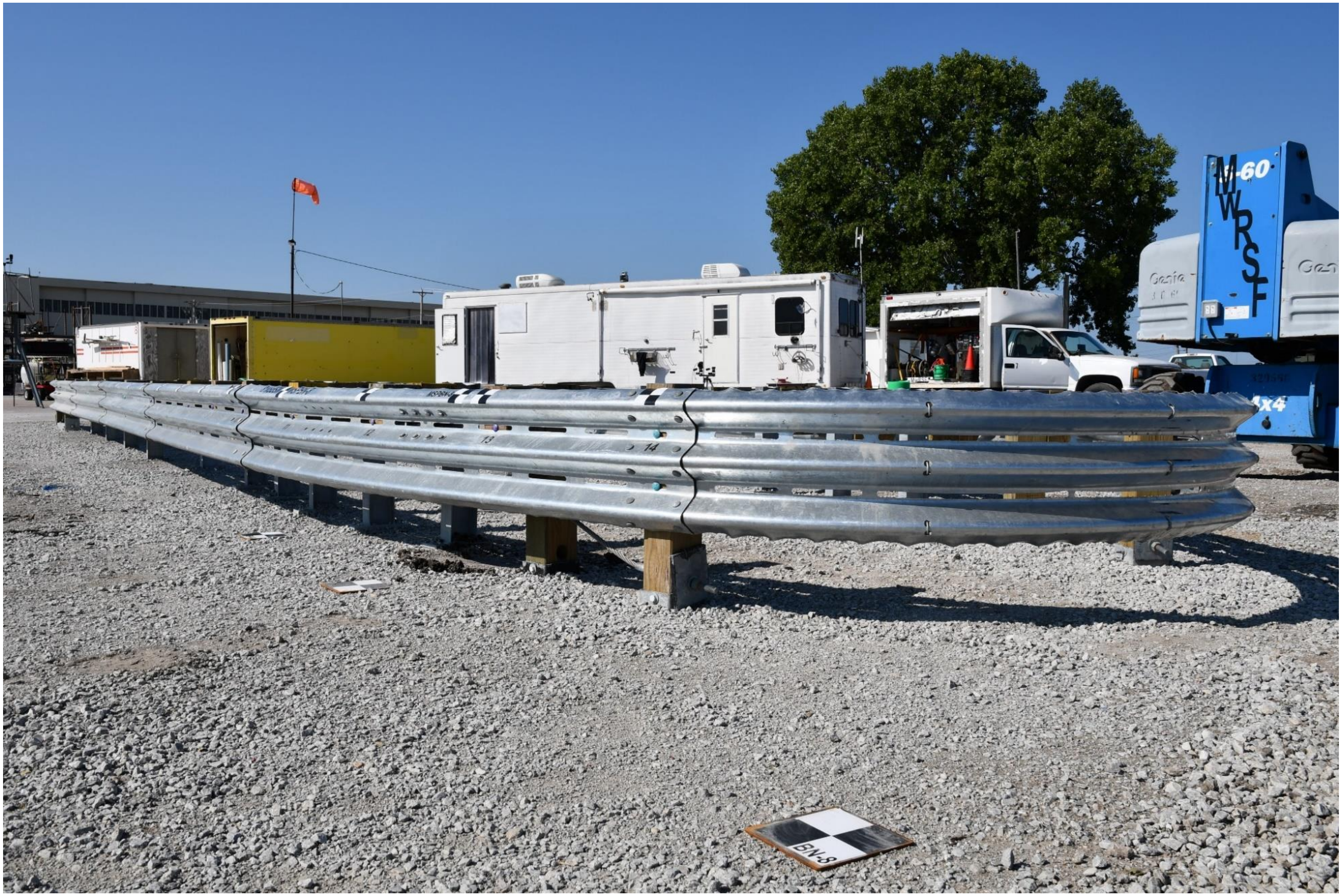


Figure 210. Test Installation Photograph, System Overview, Test No. MSPBN-8

Figure 211. Test Installation Photographs, End Anchorage and Nose Cable Details, Test No. MSPBN-8

Figure 212. Test Installation Photographs, Post Details, Test No. MSPBN-8

Figure 213. Test Installation Photographs, Nose Details, Test No. MSPBN-8

Figure 214. Test Installation Photographs, System Overview, Test No. MSPBN-8

11 FULL-SCALE CRASH TEST NO. MSPBN-8

11.1 Static Soil Test

Before full-scale crash test no. MSPBN-8 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. The static test results, as shown in Appendix C, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and full-scale crash testing could be conducted on the barrier system.

11.2 Weather Conditions

Test no. MSPBN-8 was conducted on August 29, 2018 at approximately 1:40 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 24.

Table 24. Weather Conditions, Test No. MSPBN-8

Temperature	76° F
Humidity	47 %
Wind Speed	6 mph
Wind Direction	60° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.65 in.
Previous 7-Day Precipitation	0.72 in.

11.3 Test Description

Test no. MSPBN-8 was conducted under the MASH 2016 TL-3 guidelines for test designation no. 3-37b. Test designation no. 3-37b is an impact of the 1100C vehicle at 62 mph (100 km/h) and 25 degrees on the system in the reverse direction. The critical impact point for this test was selected to maximize the potential for vehicle interaction and snag on the cable anchorage near the upstream end of the bullnose system. Initial vehicle impact was to occur at the centerline of post no. A11, as shown in Figure 215. The 2,394-lb (1,086-kg) small car impacted the bullnose with breakaway posts at a speed of 63.2 mph (101.8 km/h) and at an angle of 25.0 degrees. The actual point of impact was 0.8 in. (20 mm) downstream from the target location at the centerline of post no. A11. The vehicle was captured and redirected by the thrie beam on the side of the bullnose system. During the redirection of the vehicle, deflection of the UBSP and BCT posts was noted, but none of the posts fractured. Additionally, the vehicle's left-front wheel clipped the final BCT post and disengaged a small piece of the post near the base. However, vehicle interaction with the cable anchorage was not observed, and the anchorage remained intact. Vehicle capture and stability of the vehicle were acceptable during redirection and while exiting the barrier system. After exiting the bullnose system, the small car impacted protective portable concrete barriers at the MwRSF test site and rolled onto its side. The stability and trajectory of the vehicle prior to the secondary impact were acceptable, and the roll experienced during the secondary impact was not a concern with respect to the system's safety performance evaluation. The vehicle came to rest 156 ft – 6 in. (47.7 m) downstream from the impact location.

A detailed description of the sequential impact events is contained in Table 25. Sequential photographs are shown in Figures 216 and 217. Documentary photographs of the crash test are shown Figures 218 and 219. The vehicle trajectory and final position are shown in Figure 220.

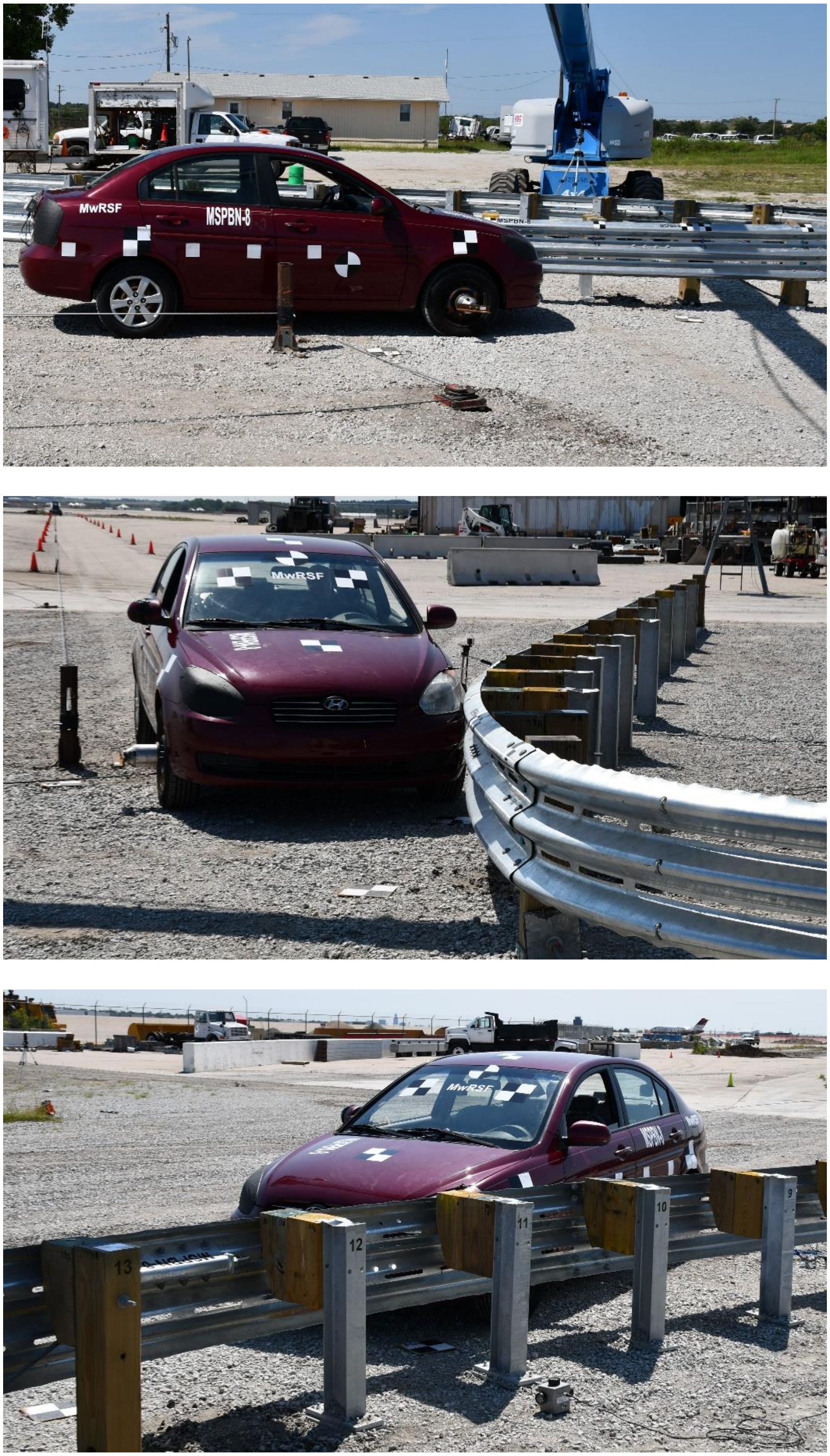


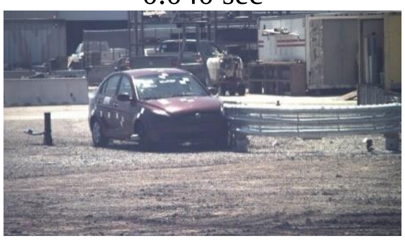
Figure 215. Impact Location, Test No. MSPBN-8

Table 25. Sequential Description of Impact Events, Test No. MSPBN-8

TIME (sec)	EVENT
0.000	Vehicle's front bumper contacted rail at post no. A11.
0.008	Vehicle's left-front tire contacted rail.
0.012	Post no. A11 deflected backward, vehicle's left-front fender deformed, vehicle's hood contacted rail, and vehicle's left-front fender contacted rail.
0.014	Vehicle yawed away from system.
0.016	Post no. A12 deflected backward, and post no. A10 deflected backward.
0.018	Post no. A13 deflected backward.
0.020	Post no. A14 deflected backward.
0.040	Vehicle's left-front door contacted rail, and vehicle's left-front door deformed.
0.042	Vehicle rolled away from system.
0.110	Vehicle's left-front tire contacted post no. A14.
0.116	Occupant's head contacted left-front window, and vehicle's left-front window shattered.
0.124	Vehicle's left-front tire ruptured.
0.148	Vehicle's left quarter panel contacted rail and deformed.
0.152	Vehicle rolled toward system.
0.236	Vehicle exited system.
0.334	Vehicle was parallel to system at a speed of 53.1 mph (85.4 km/h).
1.672	Vehicle pitched upward.
1.742	Vehicle's front bumper contacted secondary concrete barrier.
1.812	Vehicle's right-front tire became airborne.
1.832	Vehicle's right-rear tire became airborne.
2.390	Vehicle came to a rest on its side.

0.000 sec

0.040 sec



0.080 sec

0.120 sec

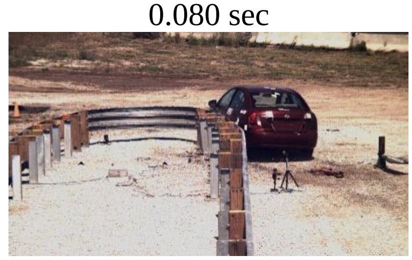
0.160 sec

0.200 sec

0.000 sec

0.040 sec

0.080 sec



0.120 sec

0.200 sec

0.280 sec

Figure 216. Sequential Photographs, Test No. MSPBN-8

0.000 sec

0.040 sec

0.080 sec

0.120 sec

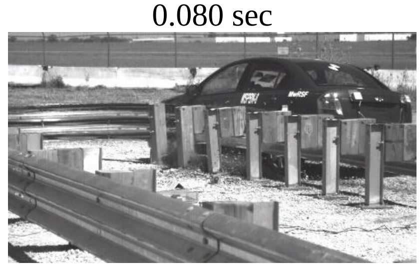
0.160 sec

0.240 sec

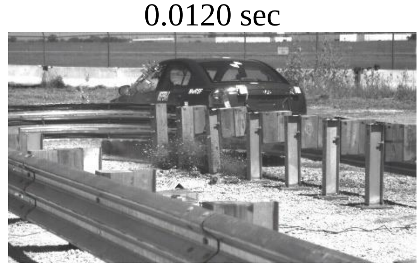
0.000 sec

0.040 sec

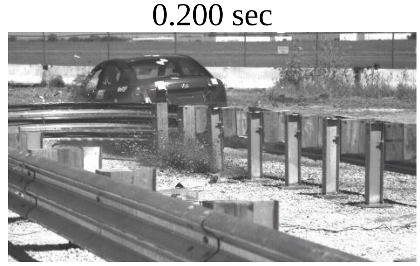
0.080 sec



0.0120 sec



0.200 sec



0.280 sec

Figure 217. Additional Sequential Photographs, Test No. MSPBN-8

Figure 218. Documentary Photographs, Test No. MSPBN-8

Figure 219. Additional Documentary Photographs, Test No. MSPBN-8

Figure 220. Vehicle Final Position and Trajectory Marks, Test No. MSPBN-8

11.4 Barrier Damage

Damage to the barrier was minimal, as shown in Figures 221 through 224. Barrier damage occurred primarily to Side A of the system where the impact had occurred. Damage consisted of rotation of posts in soil, contact marks on the rail, and deformation of the rail.

Rail damage was limited to rail section no. 2 on Side A where the impact had occurred. Contact marks were observed along all three of the rail corrugations. The overall length of these marks was 9 ft – 3¾ in. (2.8 m) and they were observed starting 32¾ in. (832 mm) downstream from post no. A10 and continued downstream. Two small kinks in the thrie-beam rail were observed 40 in. (1,016 mm) and 71½ in. (1,816 mm) downstream from post no. A10 along the top and bottom edges, respectively. A 2½-in. (64-mm) long by ¾-in. (19-mm) wide kink occurred 35 in. (889 mm) downstream from post no. A11 along the bottom corrugation. A 3½-in. (89-mm) long by ½-in. (13 mm) wide dent occurred in the thrie-beam rail 13 in. (330 mm) downstream from post no. A12 on the middle corrugation. A 7½-in. (191-mm) long kink occurred along the bottom edge of the thrie-beam rail 6 in. (152 mm) upstream from post no. A14. Deformation of the lower portion of the bottom corrugation of the thrie beam was observed from approximately midway between post nos. 11 and 12 to post no. 14.

None of the UBSP posts or the BCT posts in the impact region were disengaged. Post nos. A11 through A13 were deflected in the soil, but they did not display damage or deformation. Post no. A14 was rotated both backward and downstream. The upstream front corner of post no. A14, just above the post sleeve had a 2½-in. (64-mm) tall by 2-in. (51-mm) long by ½-in. (13-mm) deep gouge caused by wheel contact with the post. The cable anchorage did not show any signs of vehicle contact, and the anchorage remained intact following the impact.

The maximum lateral permanent set of the barrier system was 2¾ in. (70 mm), which occurred at post no. A12, as measured in the field. The maximum lateral dynamic barrier deflection was 5.2 in. (132 mm) on the rail at post no. A12 as determined from high-speed digital video analysis. The working width of the system was found to be 177¼ in. (4,502 mm). A schematic of the initial and final positions is shown in Figure 225.

Figure 221. Overview of Damage to System, Test No. MSPBN-8

Figure 222. Damage to Impacted Area, Test No. MSPBN-8

Figure 223. Damage to System at Post Nos. A11 and A12, Test No. MSPBN-8

Figure 224. Damage to System at Post Nos. A13 and A14, Test No. MSPBN-8

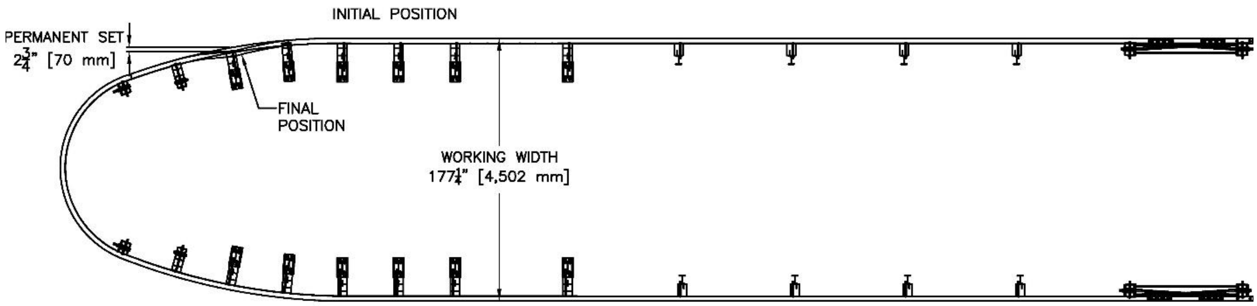


Figure 225. Initial and Final Positions, Test No. MSPBN-8

11.5 Vehicle Damage

Vehicle damage was minimal due to the primary impact and consisted mainly of crushing of the left-front vehicle structure and deformed sheet metal. Secondary impact damage was more extensive due to the impact with the concrete barrier and the subsequent roll onto the vehicle side. The damage to the vehicle is shown in Figure 226 through Figure 228. The maximum occupant compartment deformations are listed in Table 26 along with the deformation limits established in MASH 2016 for various areas of the occupant compartment. Note that none of the established MASH 2016 deformation limits were violated. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D.

Figure 226. Vehicle Damage, Test No. MSPBN-8

Figure 227. Vehicle Damage, Test No. MSPBN-8

Figure 228. Occupant Compartment and Undercarriage Damage, Test No. MSPBN-8

Table 26. Maximum Occupant Compartment Deformations by Location, Test No. MSPBN-8

LOCATION	MAXIMUM DEFORMATION in. (mm)	MASH 2016 ALLOWABLE DEFORMATION in. (mm)
Wheel Well & Toe Pan	0.2 (5)	≤ 9 (229)
Floor Pan & Transmission Tunnel	0.2 (5)	≤ 12 (305)
A-Pillar	0.0 (0)	≤ 5 (127)
A-Pillar (Lateral)	0.0 (0)	≤ 3 (76)
B-Pillar	0.1 (3)	≤ 5 (127)
B-Pillar (Lateral)	0.1 (3)	≤ 3 (76)
Side Front Panel (in Front of A-Pillar)	0.1 (3)	≤ 12 (305)
Side Door (Above Seat)	0.6 (15)	≤ 9 (229)
Side Door (Below Seat)	-0.1 (-3)	≤ 12 (305)
Roof	0.0 (0)	≤ 4 (102)
Windshield	0.0 (0)	≤ 3 (76)
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	0.5 (13)	N/A

Note: Negative values denote outward deformation
N/A – Not applicable

The majority of the vehicle damage was caused by impact with the test article, which was concentrated on the left-front corner of the vehicle where impact had occurred. The front bumper was crushed inward toward the engine bay. The left-front quarter panel was crushed inward, dented, and was scraped along its length. The left-front door was crushed inward along its length. Scrapes and dents were also observed along the length of the door. The left-side mirror was partially disengaged but remained attached with wires. The left-rear door was also scraped and dented along its middle length. A dent was observed along the top frame above the left-rear door. The left-rear quarter panel was dented along its length and scraped in several places. The rear bumper was scraped along its left side where it contacted the system.

The left-front window fractured due to contact with the simulated occupant's head during the initial impact and shattered when the vehicle was brought to a stop downstream from the test article. Damage that occurred to the right side of the vehicle was due to secondary impact with portable concrete barriers located downstream from the test article. The vehicle's engine hood was opened during the secondary impact event.

11.6 Occupant Risk

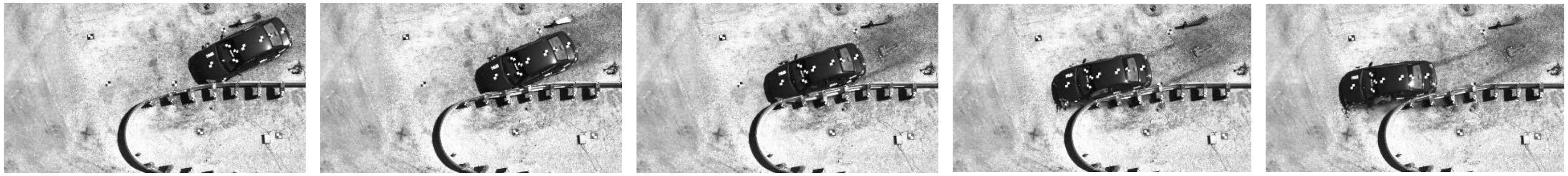
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 27. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 27. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix I.

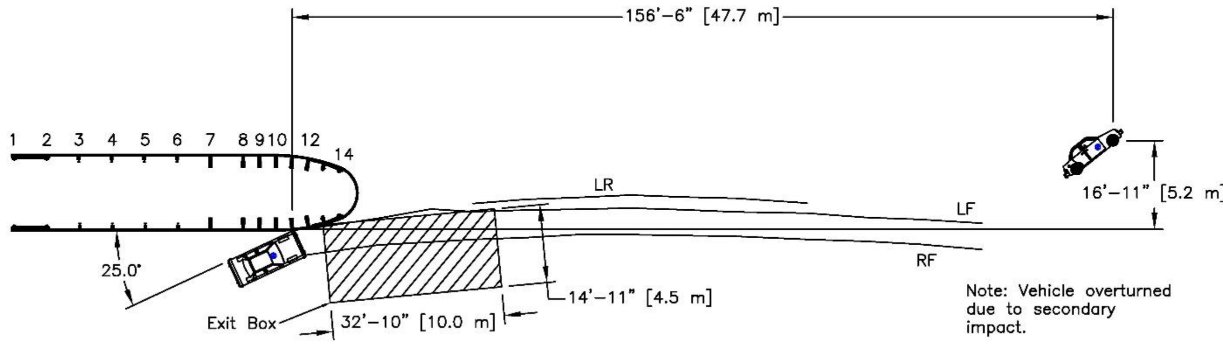
Table 27. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. MSPBN-8

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (primary)	**SLICE-2**	
OIV ft/s (m/s)	Longitudinal	-11.98 (-3.65)	-11.11 (-3.39)	±40 (12.2)
	Lateral	20.45 (6.23)	19.43 (5.92)	±40 (12.2)
ORA g's	Longitudinal	-0.92	0.68	±20.49
	Lateral	8.80	8.07	±20.49
MAX. ANGULAR DISPL. degrees	Roll	4.9	5.8	±75
	Pitch	-3.3	-4.8	±75
	Yaw	40.9	40.5	not required
THIV ft/s (m/s)		21.19 (6.46)	21.72 (6.62)	not required
PHD g's		5.08	5.46	not required
ASI		0.99	0.93	not required

11.7 Discussion

The analysis of the results for test no. MSPBN-8 showed that the system adequately contained and redirected the 1100C vehicle with controlled lateral displacements of the barrier. A summary of the test results is shown in Figure 229. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. 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, as shown in Appendix I, were deemed acceptable, because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the barrier at an angle of 8.4 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. MSPBN-8 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-37b.





- Test Agency .... MwRSF
- Test Number MSPBN-8
- Date 8/29/2018
- MASH 2016 Test Designation No. 3-37b
  - Test Article .... Steel Bullnose with Breakaway Posts
  - Total Length .... 66 ft (20.1 m)
  - Key Component – Thrie Beam
    - Thickness .... 12 gauge (2.7 mm)
    - Mounting Height .... 31⅝ in. (803 mm)
  - Key Component – Breakaway Steel Post
    - Length .... 72¹⁄₁₆ in. (1,849 mm)
    - Spacing .... 37½ in. (953 mm)
- Soil Type
- Vehicle Make /Model .... Hyundai Accent
  - Curb .... 2,476 lb (1,123 kg)
  - Test Inertial .... 2,394 lb (1,086 kg)
  - Gross Static .... 2,558 lb (1,160 kg)
- Impact Conditions
  - Speed .... 63.2 mph (101.8 km/h)
  - Angle .... 25.0 degrees
  - Impact Location .... 0.8 in. (20 mm) downstream from CL of post no. A11
- Impact Severity .... 57.3 kip-ft (77.7 kJ) ≥ 51 kip-ft (69.7 kJ) limit from MASH 2016
- Exit Conditions
  - Speed .... 54.9 mph (88.4 km/h)
  - Angle .... 8.4 degrees
- Exit Box Criterion .... Pass
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 156 ft – 6 in. (47.7 m) downstream
- Vehicle Damage .... Minimal
  - VDS [20] 11-LFQ-3
  - CDC [21] 11-FLES-2
  - Maximum Interior Deformation .... 0.6 in. (15 mm)
- Test Article Damage .... Minimal
- Maximum Test Article Deflections
  - Permanent Set .... 2¾ in. (70 mm) laterally
  - Dynamic .... 5.2 in. (132 mm) laterally
  - Working Width .... 177¼ in. (4,502 mm)
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limit
		SLICE-1 (primary)	SLICE-2	
OIV ft/s (m/s)	Longitudinal	-11.98 (-3.65)	-11.11 (-3.39)	±40 (12.2)
	Lateral	20.45 (6.23)	19.43 (5.92)	±40 (12.2)
ORA g's	Longitudinal	-0.92	0.68	±20.49
	Lateral	8.80	8.07	±20.49
MAX ANGULAR DISP. degrees	Roll	4.9	5.8	±75
	Pitch	-3.3	-4.8	±75
	Yaw	40.9	40.5	Not required
THIV – ft/s (m/s)		21.19 (6.46)	21.72 (6.62)	Not required
PHD – g's		5.08	5.46	Not required
ASI		0.99	0.93	Not required

Figure 229. Summary of Test Results and Sequential Photographs, Test No. MSPBN-8

12 MASH TEST DESIGNATION NO. 3-38 - 1500A ESTIMATION PROCEDURE

As noted previously in the discussion of required full-scale crash tests for the evaluation of the thrie-beam bullnose system, MASH 2016 test designation no. 3-38 is intended to evaluate the performance of mid-sized, sedan vehicles with terminals and crash cushions. MASH allows the use of an analytical estimation procedure of 1500A vehicle decelerations based on the results of test designation no. 3-31 to determine whether or not this test is required. The procedure consists of estimating the occupant risk values for the 1500A test based on the acceleration trace obtained from test designation no. 3-31. Test designation no. 3-31 consists of a 2270P vehicle impact with the vehicle's centerline aligned with the centerline of the test article. This test involves a heavier vehicle impacting under the same impact conditions as test designation no. 3-38. Thus, the acceleration traces from this test can be used to identify the need for the 1500A test. The acceleration traces can be integrated to obtain the force-deflection characteristics of the test article. The force-deflection data can then be applied to the smaller vehicle in order to obtain reasonable estimates of the Occupant Impact Velocity (OIV) and Occupant Ridedown Deceleration (ORD). Note that this analysis will be conservative, because the heavier mass of the 2270P vehicle and its higher crush stiffness will produce higher impact forces than will be experienced during a mid-sized vehicle impact. Therefore, if the force versus deflection analysis predicts that a terminal or crash cushion will meet OIV and ORD evaluation guidelines for a passenger vehicle with a mass of 3,307 lb (1,500 kg), then conducting test designation no. 3-38 is not recommended.

An analysis was performed using the acceleration versus time data from the primary accelerometer in test no. MSPBN-6 to estimate the occupant risk values for the 1500A sedan vehicle, as described in MASH 2016 Appendix G. The results are shown in Table 28. The estimated OIV and ORA values for the 1500A vehicle impact with the thrie-beam bullnose system were well below the MASH limits. As such, test designation no. 3-38 was deemed non-critical on the thrie-beam bullnose system and was not conducted as part of the system's crashworthiness evaluation.

Table 28. Longitudinal OIV and ORA Estimates for MASH 1500A Estimation Procedure for Thrie-Beam Bullnose Based on Test No. MSPBN-6

Evaluation Criteria		**1500A Estimation Procedure**	**MASH 2016 Limits**
OIV ft/s (m/s)	Longitudinal	-24.37 (-7.43)	±40 (12.2)
ORA g's	Longitudinal	-13.75	±20.49

13 SUMMARY AND CONCLUSIONS

The research detailed in this report describes the continued full-scale crash testing and evaluation program for the thrie-beam bullnose system to the MASH 2016 TL-3 criteria. Ten full-scale crash tests are potentially required to evaluate a non-gating, redirective crash cushion such as the thrie-beam bullnose system. Review of the system design and test requirements led the researchers to determine that test designation nos. 3-36 and 3-37a were not critical for evaluating the system. Test designation no. 3-38 was deemed non-critical based on an analysis of a midsized sedan impact using the results from test designation no. 3-31. Thus, seven full-scale crash tests were selected for evaluation of the thrie-beam bullnose system. The Phase I research effort included three full-scale crash tests on the thrie-beam bullnose system: test designation nos. 3-32, 3-34, and 3-35 in the MASH 2016 test matrix for crash cushions [10]. All three of these crash tests were successful and met the MASH 2016 TL-3 safety requirements.

In this research effort, four remaining crash tests were used to evaluate the thrie-beam bullnose system to the MASH 2016 TL-3 criteria. These tests consisted of test designation nos. 3-30, 3-31, 3-33, and 3-37b in the MASH 2016 test matrix for crash cushions. The first test, test no. MSPBN-4, was conducted according to MASH 2016 test designation no. 3-30 with a 1100C vehicle. In test no. MSPBN-4, a 2,429-lb (1,102-kg) small car impacted the barrier at a speed of 62.1 mph (99.9 km/h) and at an angle of 1.3 degrees. During the test, the vehicle was initially captured by the thrie-beam nose of the system. However, as the vehicle proceeded into the system, the slot tabs between the upper two rail corrugations of thrie beam and the lowest rail corrugation opened. This behavior allowed the top two thrie-beam rail corrugations to push upward and the lower thrie-beam rail corrugation to move downward and rupture. This outcome compromised the capture of the vehicle’s front end and allowed the vehicle to penetrate the system. Thus, the system performance was unacceptable under the MASH 2016 TL-3 criteria.

Following test no. MSPBN-4, the researchers reviewed the results from the test to determine factors that influenced the failure of the system as well as to suggest potential modifications to the thrie-beam bullnose system to improve its performance. Based on this analysis, it was determined that the best option for improving system performance would be to add a third nose cable behind the lowest thrie-beam corrugation. The addition of a third nose cable was not expected to affect the performance of the thrie-beam bullnose system relative to the three previously successful MASH 2016 crash tests (test designation nos. 3-32, 3-34, and 3-35). It was determined that these three tests would not need to be rerun if the proposed modification was successful.

The second test, test no. MSPBN-5, was conducted as a repeat of MASH 2016 test designation no. 3-30 with a 1100C vehicle on the modified thrie-beam bullnose system. In test no. MSPBN-5, the 2,409-lb (1,093-kg) small car impacted the modified bullnose at a speed of 62.7 mph (100.9 km/h) and at an angle of 0.3 degrees. During the test, the vehicle was captured by the thrie-beam nose section with cables and the system decelerated the vehicle to a safe and controlled stop. Thus, the system was deemed acceptable under the MASH 2016 TL-3 criteria. Based on the successful testing of the modified thrie-beam bullnose system with three nose cables, the remaining testing on the system was conducted on the modified system.

The third test, test no. MSPBN-6, was conducted as MASH 2016 test designation no. 3-31 with a 2270P vehicle at a speed of 63.4 mph (102.1 km/h) and at an angle of 0.3 degrees. During the test, the vehicle was captured by the thrie-beam bullnose system, and the system decelerated the vehicle to a safe and controlled stop. The fourth test, test no. MSPBN-7, was conducted as MASH 2016 test designation no. 3-33 with a 2270P vehicle at a speed of 63.1 mph (101.6 km/h) and at an angle of 15.1 degrees. During the test, the vehicle was captured by the thrie-beam bullnose system, and the system decelerated the vehicle to a safe and controlled stop. The final test, test no. MSPBN-8, was conducted as MASH 2016 test designation no. 3-37b with a 1100C vehicle at a speed of 63.2 mph (101.8 km/h) and at an angle of 25.0 degrees at a CIP determined to maximize the potential for vehicle snag on the cable anchorage when impacted in the reverse direction. During the test, the vehicle was captured and redirected by the thrie beam on the side of the bullnose system, vehicle interaction with the cable anchorage was not observed, and the anchorage remained intact. All three full-scale crash tests met the MASH 2016 TL-3 safety requirements. The results from the five crash tests performed in this Phase II study are summarized in Table 29.

Following the full-scale crash testing, an analysis procedure was performed using the accelerometer data from test no. MSPBN-6 to determine if test designation no. 3-38 was required for evaluating the thrie-beam bullnose system. The results of the analysis found that the estimated OIV and ORA values for the 1500A vehicle impact with the thrie-beam bullnose system were well below the MASH 2016 limits. As such, test designation no. 3-38 was deemed non-critical on the thrie-beam bullnose system.

As noted previously, the thrie-beam bullnose was modified to include a third retention cable behind the thrie beam in the nose of the barrier following the unsuccessful result observed in test no. MSPBN-4. Because the crash testing results observed prior to that modification were unaffected by the selected modification, it was believed that the modified thrie-beam bullnose system would perform acceptably in all of the full-scale crash tests. Based on the three successful full-scale crash tests conducted in the Phase I study, the four successful full-scale crash tests conducted in the Phase II study, and the results from the estimation procedure for test designation no. 3-38, the modified thrie-beam bullnose system with a third nose cable meets all of the safety requirements for MASH 2016 TL-3. Final design details for the MASH 2016 TL-3 thrie-beam bullnose are shown in Figure 230 through Figure 252.

Table 29. Summary of Safety Performance Evaluation

<table>
<tr><th>Evaluation Factors</th><th colspan="4">Evaluation Criteria</th><th>Test No. MSPBN-4</th><th>Test No. MSPBN-5</th><th>Test No. MSPBN-6</th><th>Test No. MSPBN-7</th><th>Test No. MSPBN-8</th></tr>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td><td>U</td><td>S</td><td>S</td><td>S</td><td>S</td></tr>
<tr><td rowspan="12">Occupant Risk</td><td rowspan="2">D.</td><td colspan="3">1. 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.</td><td>U</td><td>S</td><td>S</td><td>S</td><td>S</td></tr>
<tr><td colspan="3">2. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.</td><td>U</td><td>S</td><td>S</td><td>S</td><td>S</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td><td>S</td><td>S</td><td>S</td><td>S</td><td>S</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td><td rowspan="4">S</td><td rowspan="4">S</td><td rowspan="4">S</td><td rowspan="4">S</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>30 ft/s (9.1 m/s)</td><td>40 ft/s (12.2 m/s)</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td><td rowspan="4">S</td><td rowspan="4">S</td><td rowspan="4">S</td><td rowspan="4">S</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>15.0 g’s</td><td>20.49 g’s</td></tr>
<tr><td colspan="5">MASH 2016 Test Designation No.</td><td>3-30</td><td>3-30</td><td>3-31</td><td>3-33</td><td>3-37b</td></tr>
<tr><td colspan="5">Final Evaluation (Pass or Fail)</td><td>Fail</td><td>Pass</td><td>Pass</td><td>Pass</td><td>Pass</td></tr>
</table>

S – Satisfactory U – Unsatisfactory NA - Not Applicable

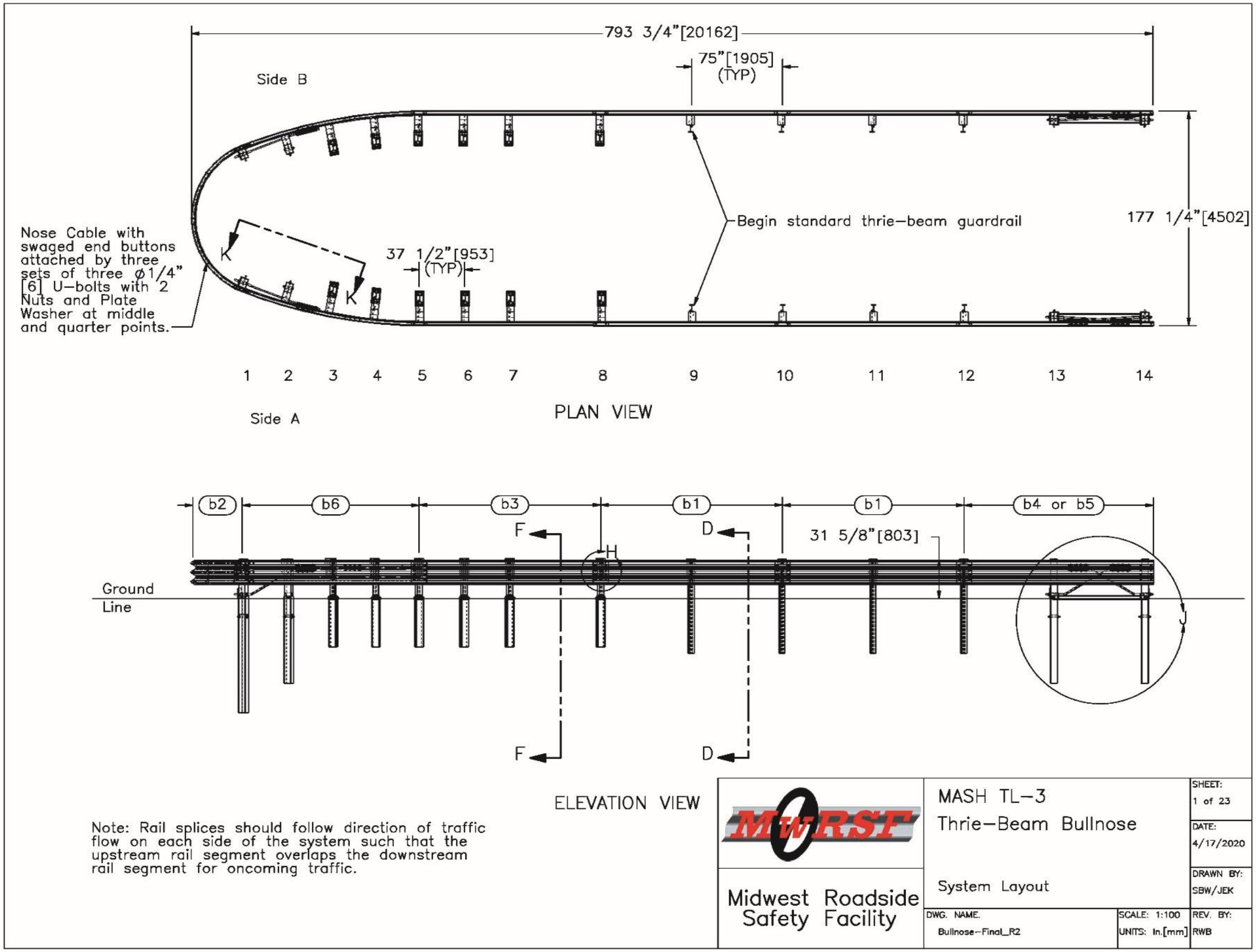


Figure 230. Test Installation Layout, Bullnose Final

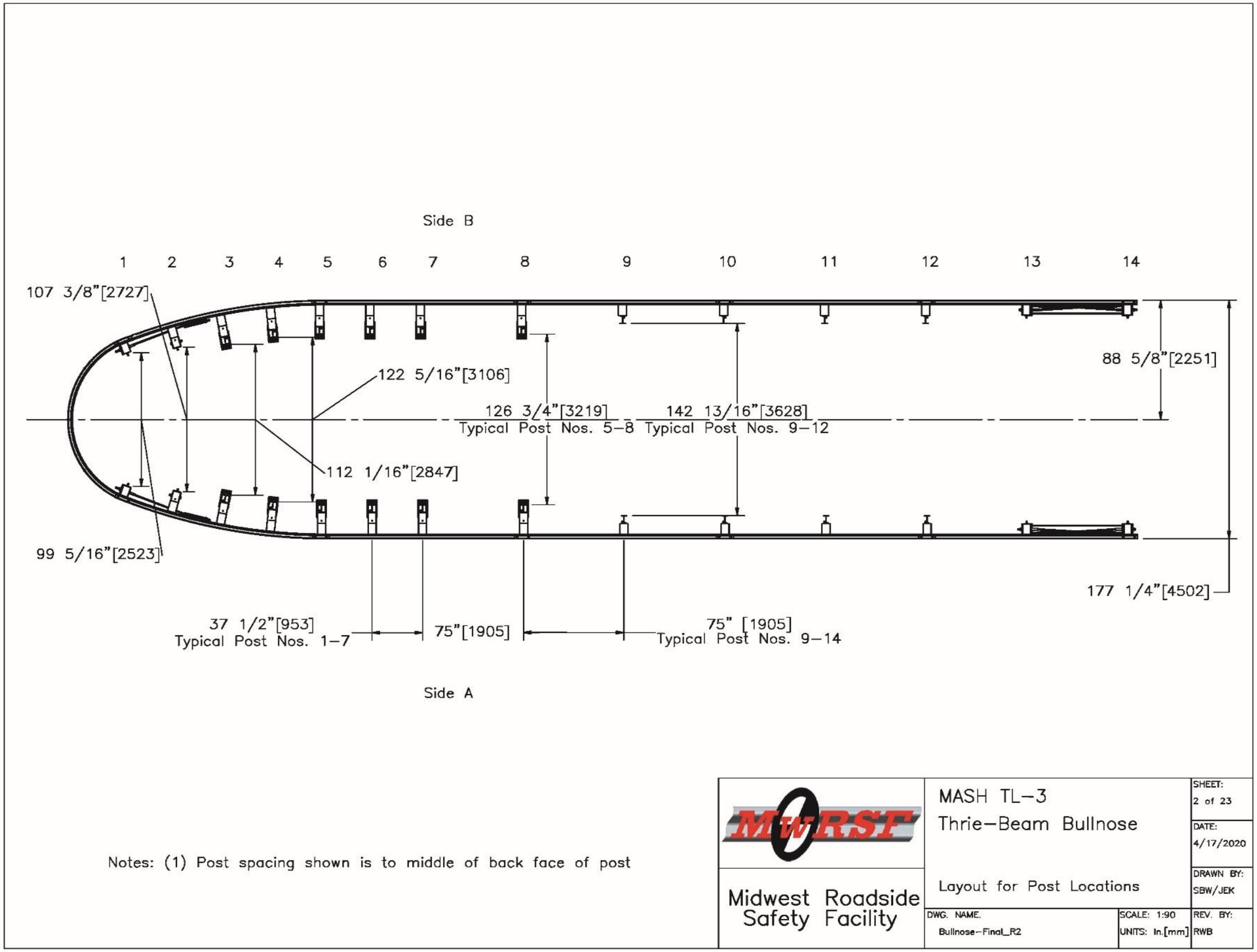


Figure 231. Layout for Post Locations, Bullnose Final

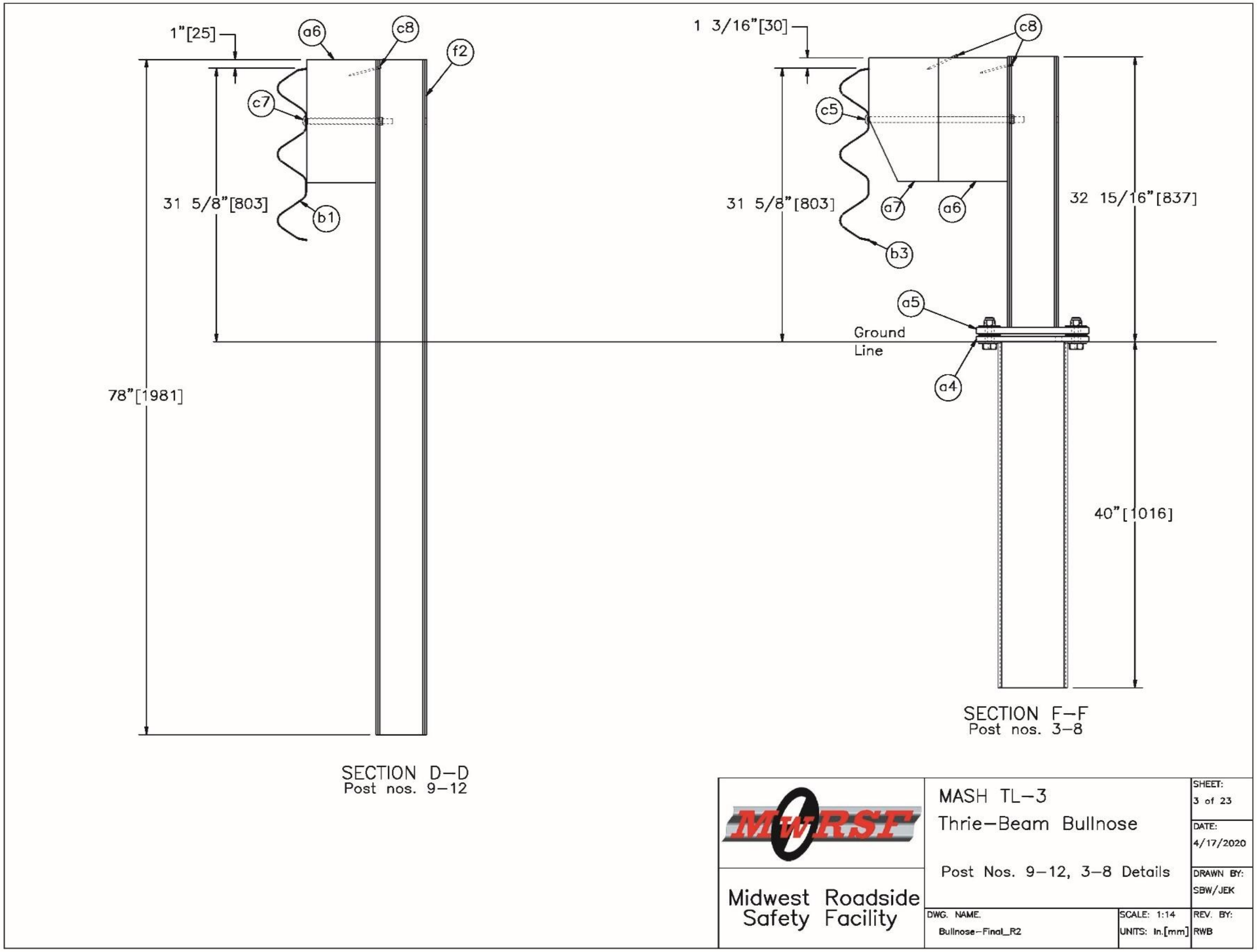


Figure 232. Post Nos. 3 through 8 and 9 through 12 Details, Bullnose Final

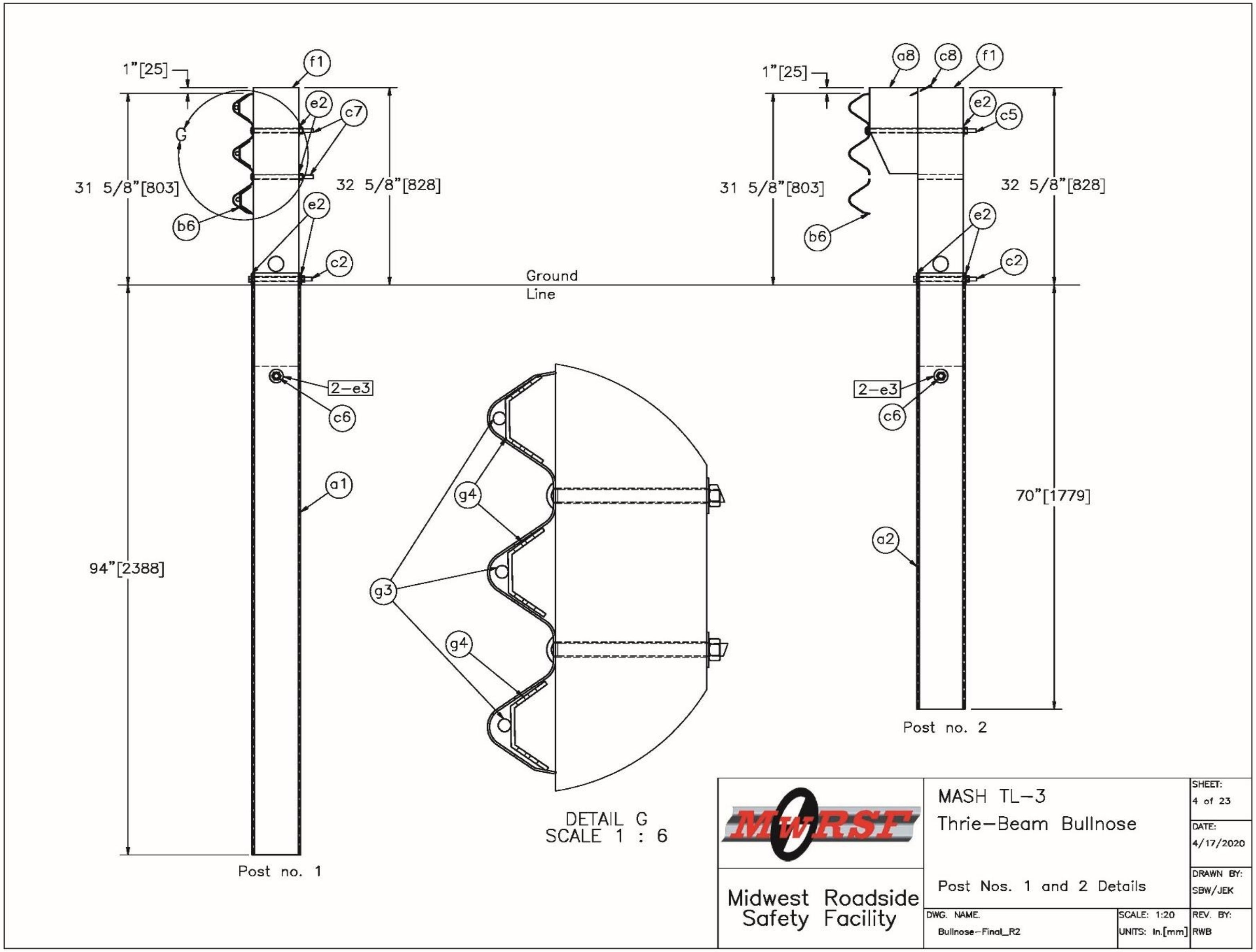


Figure 233. Post Nos. 1 and 2 Details, Bullnose Final

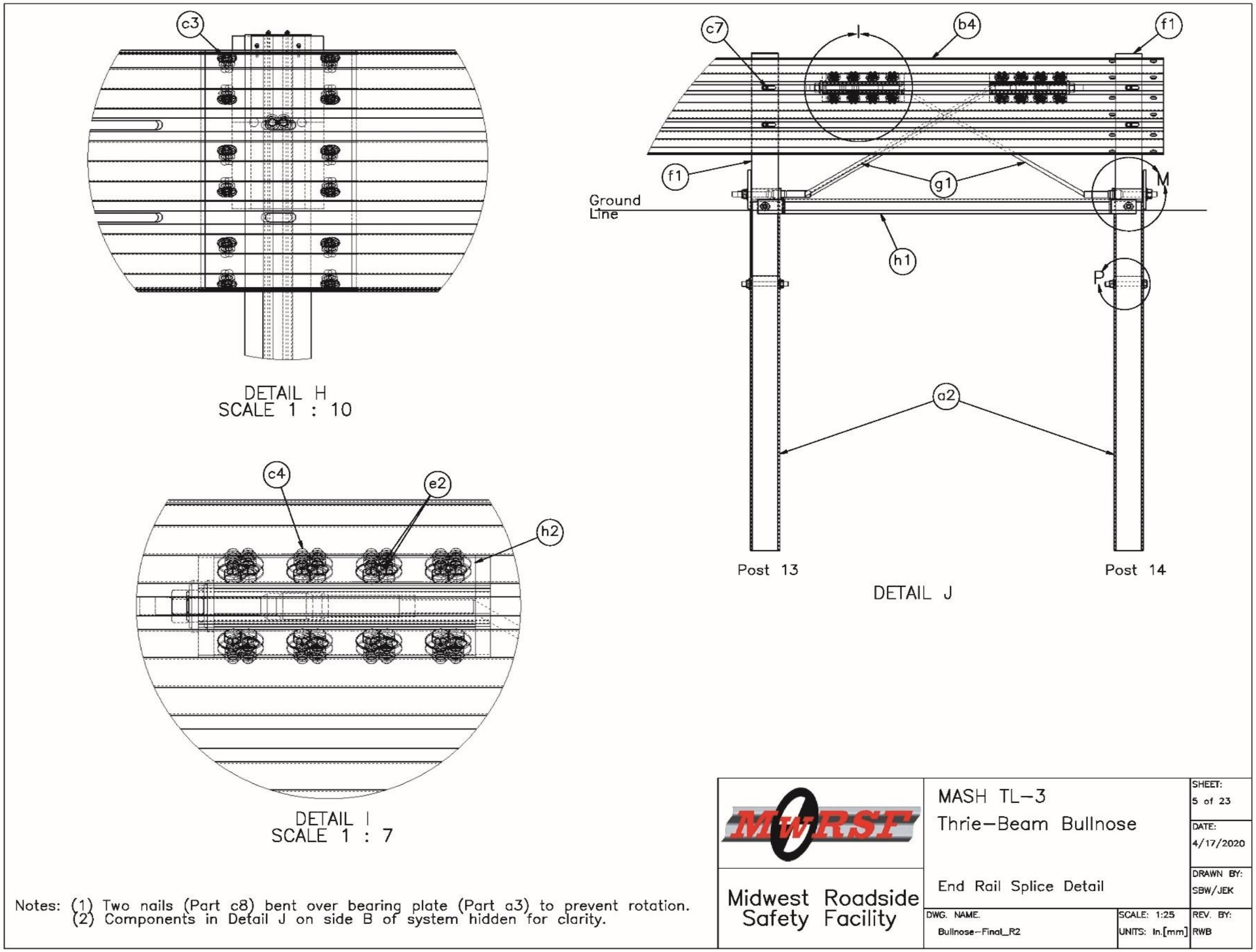


Figure 234. End Rail Splice Detail, Bullnose Final

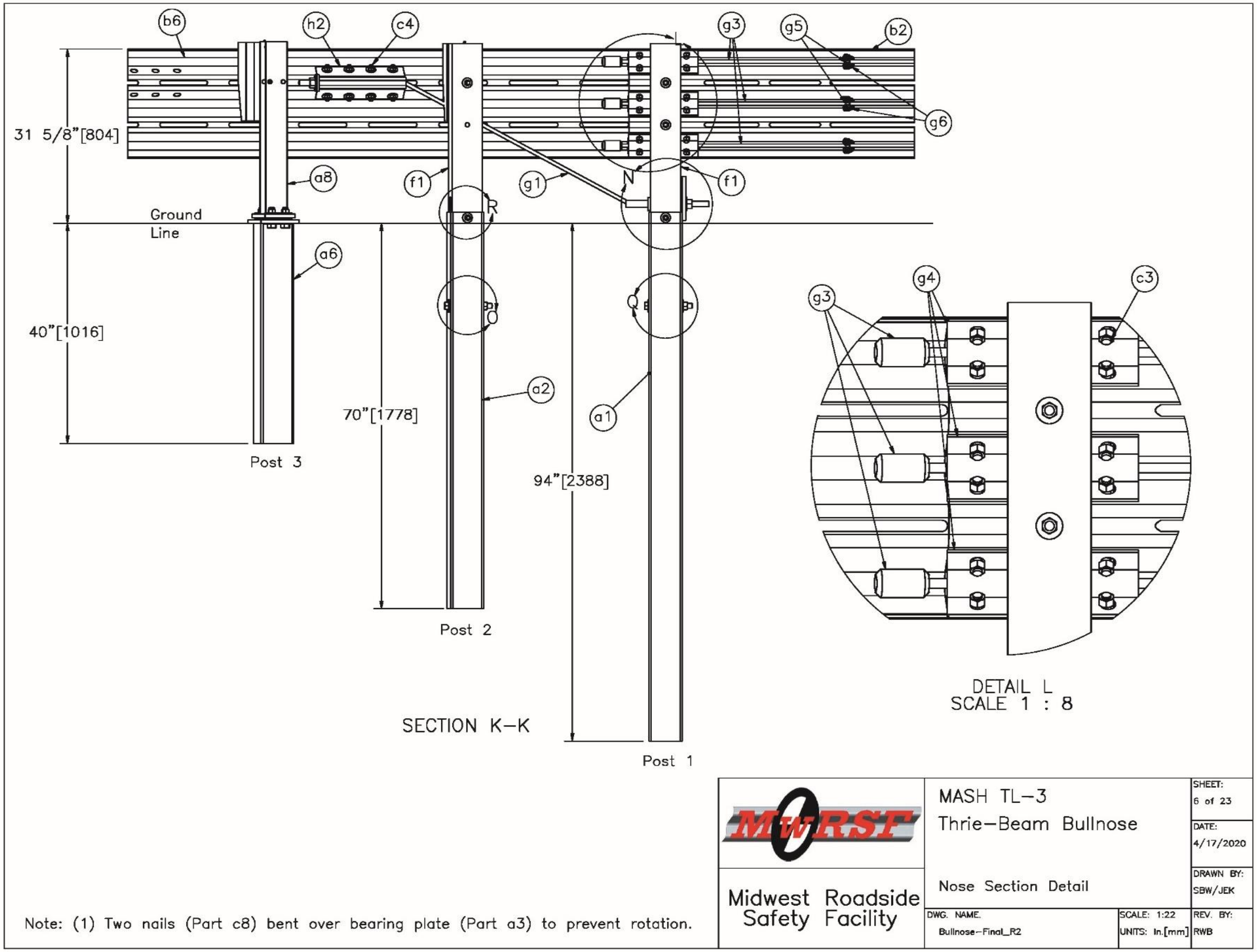


Figure 235. Nose Section Detail, Bullnose Final

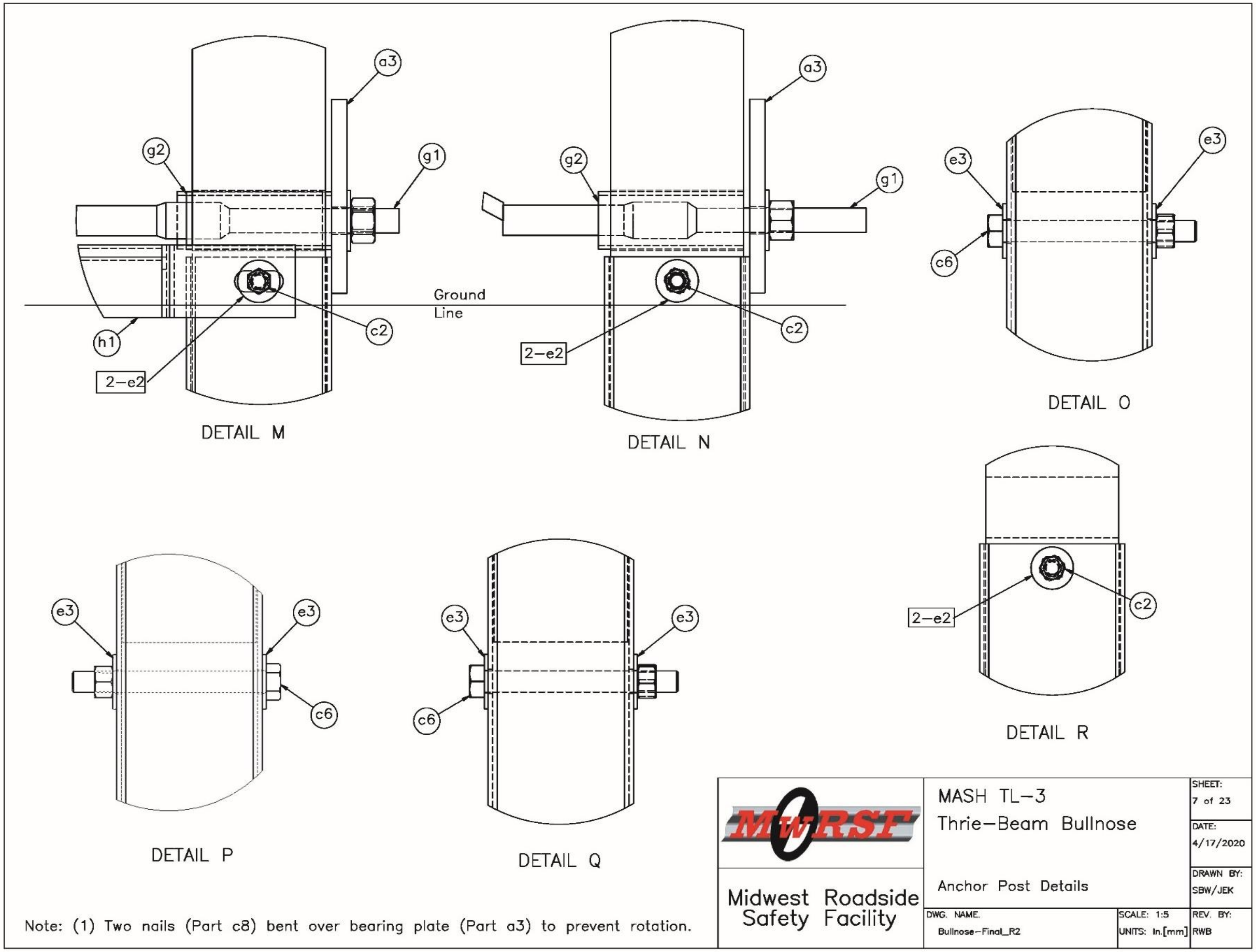


Figure 236. Anchor Post Details, Bullnose Final

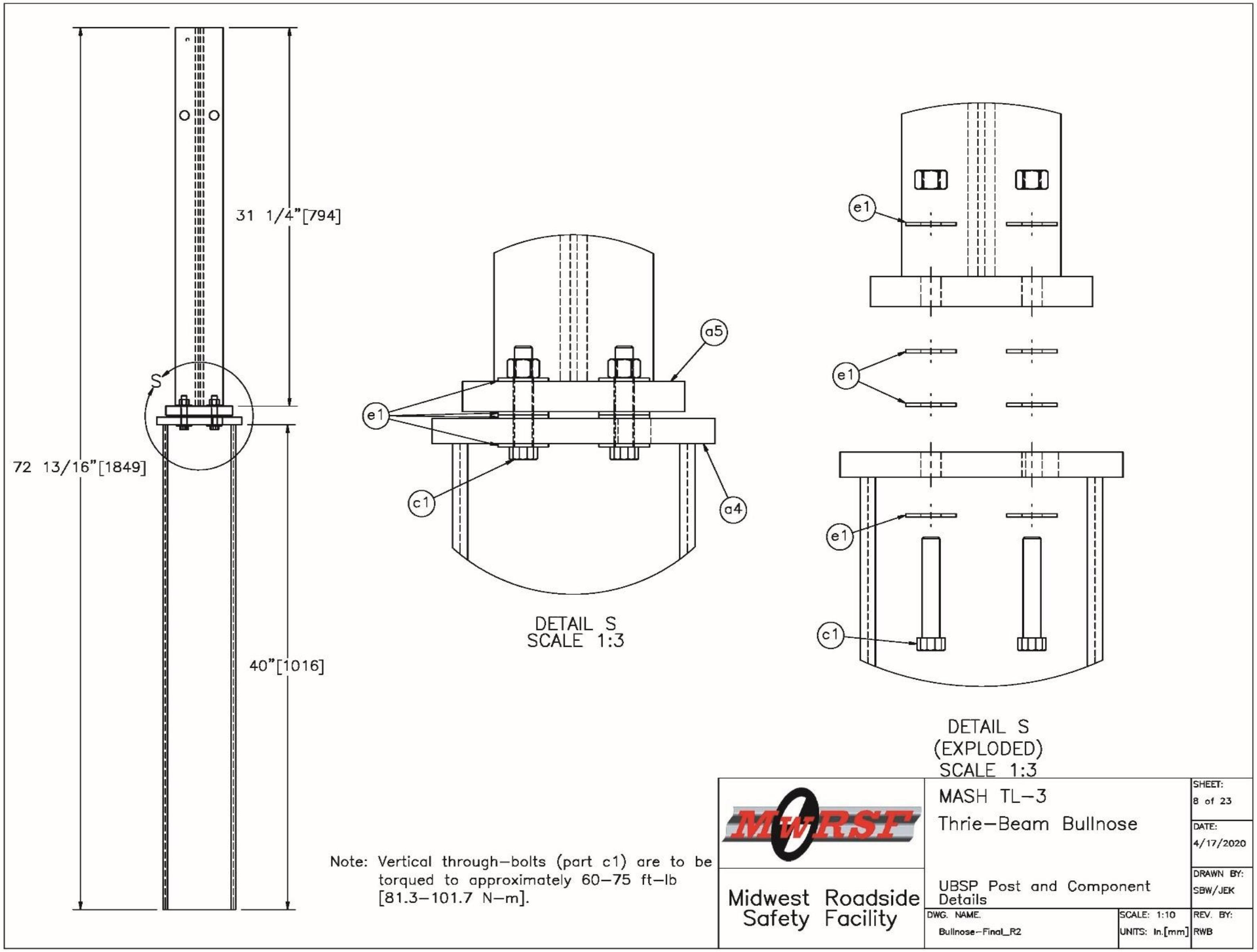


Figure 237. UBSP and Component Details, Bullnose Final

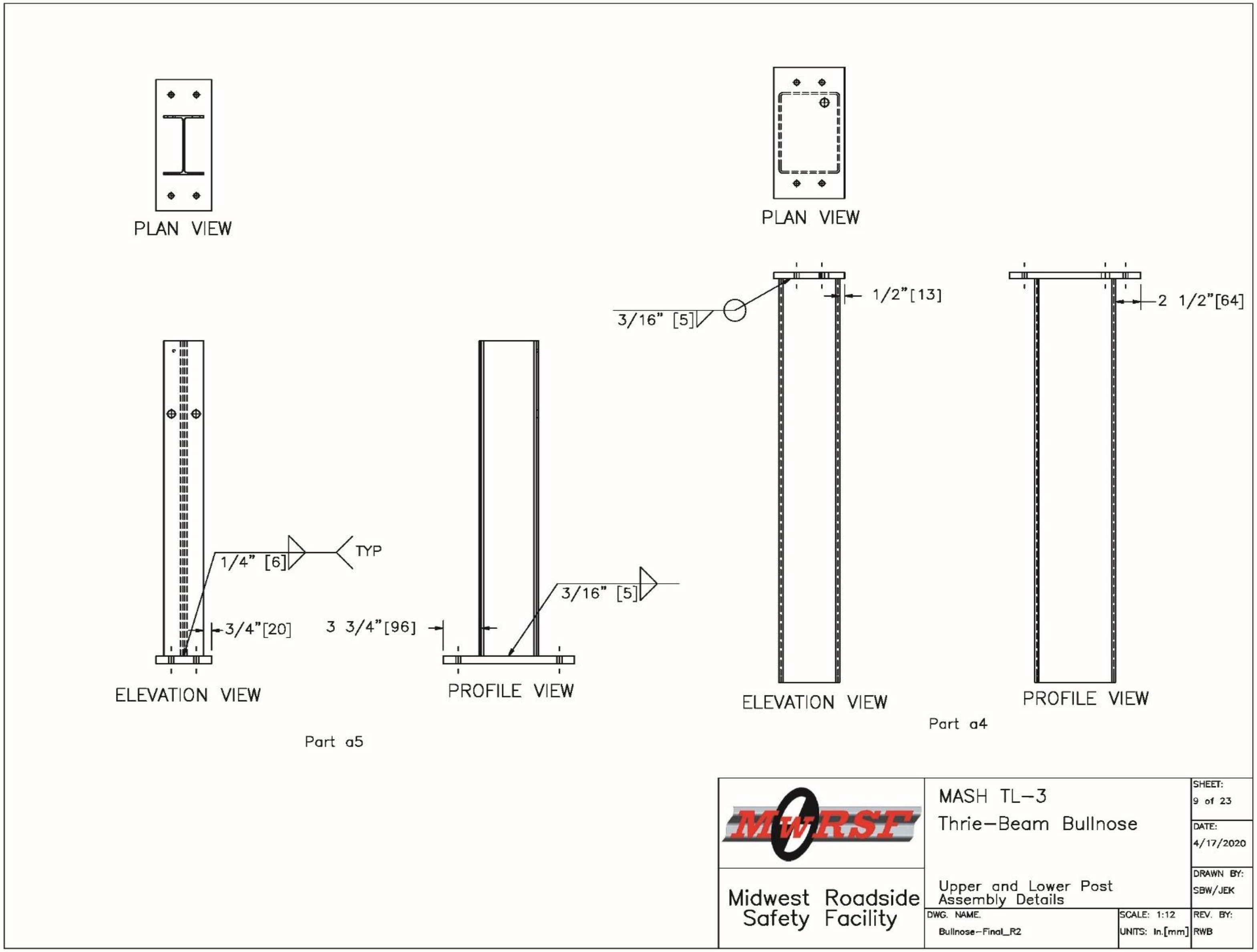


Figure 238. Upper and Lower Post Assembly Details, Bullnose Final

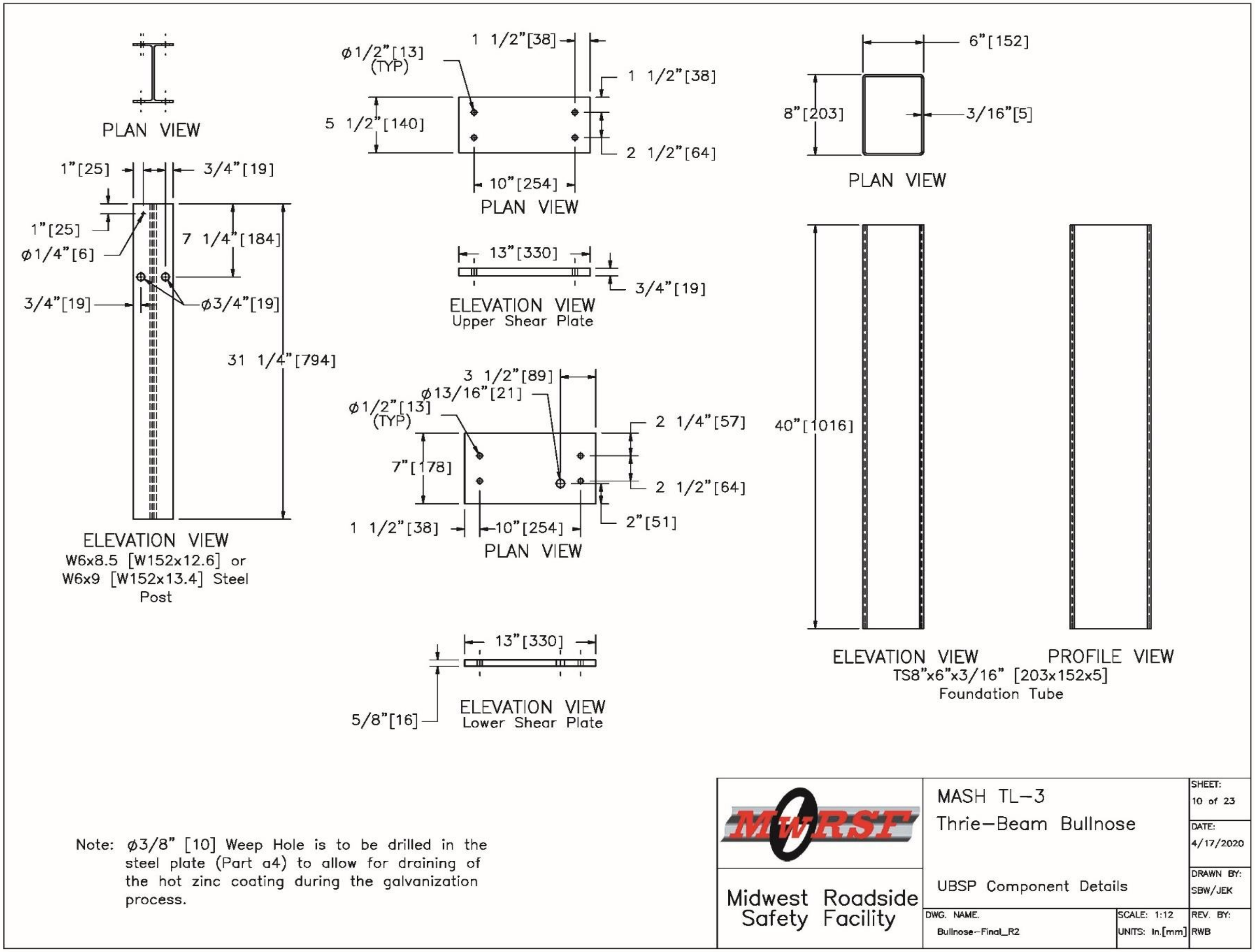


Figure 239. UBSP Component Detail, Bullnose Final

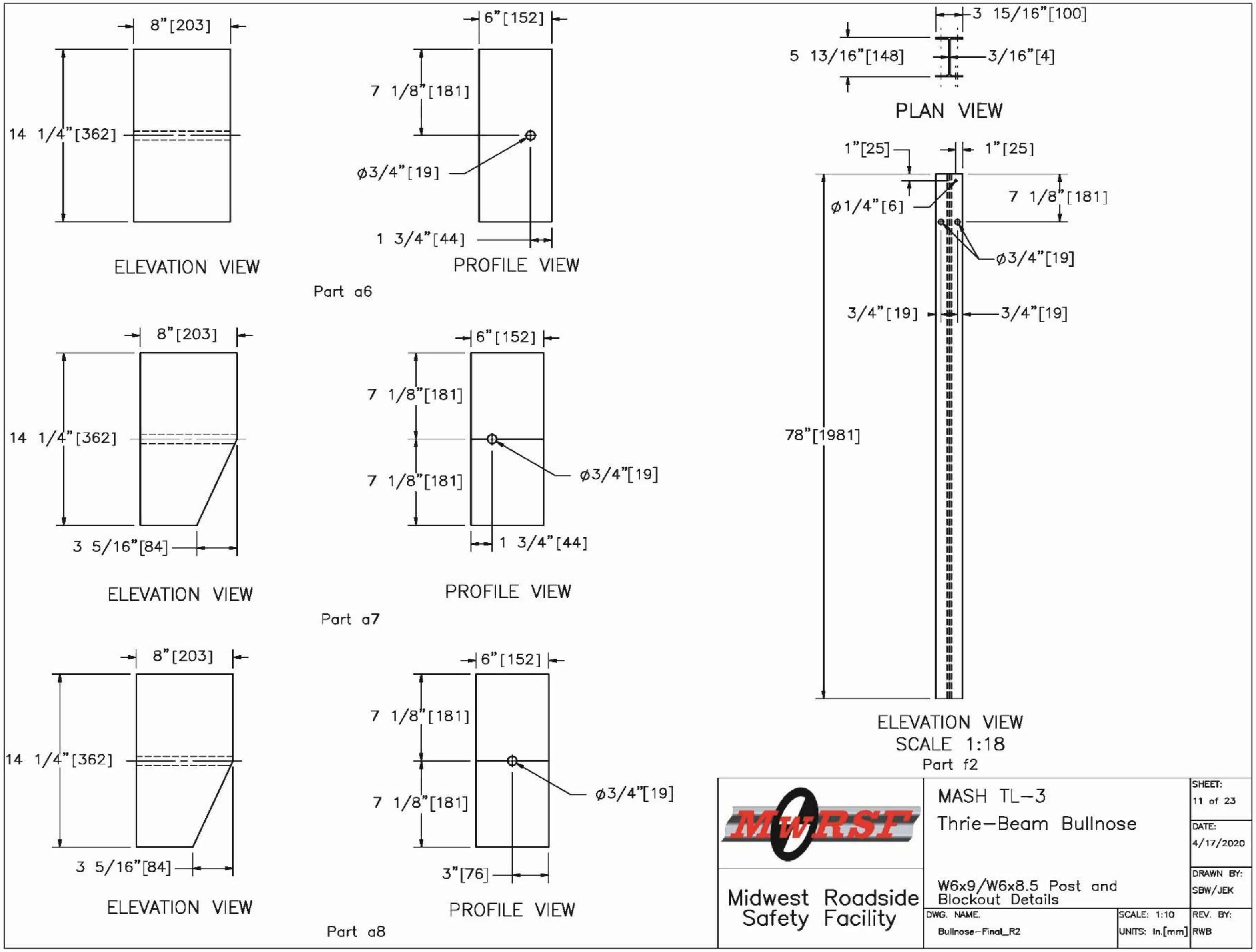


Figure 240. W6x9 Post and Blockout Details, Bullnose Final

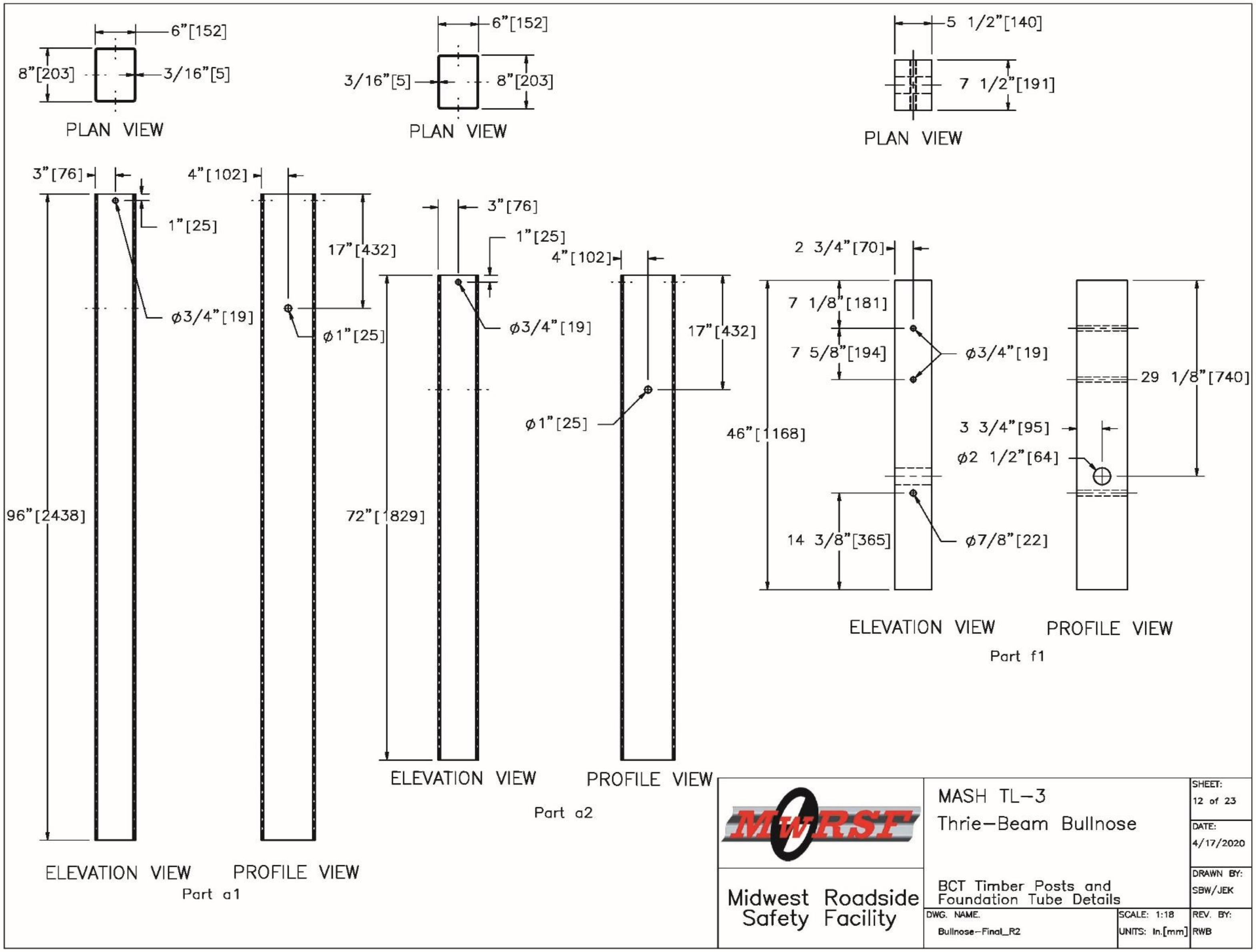


Figure 241. BCT Timber Post and Foundation Tube Details, Bullnose Final

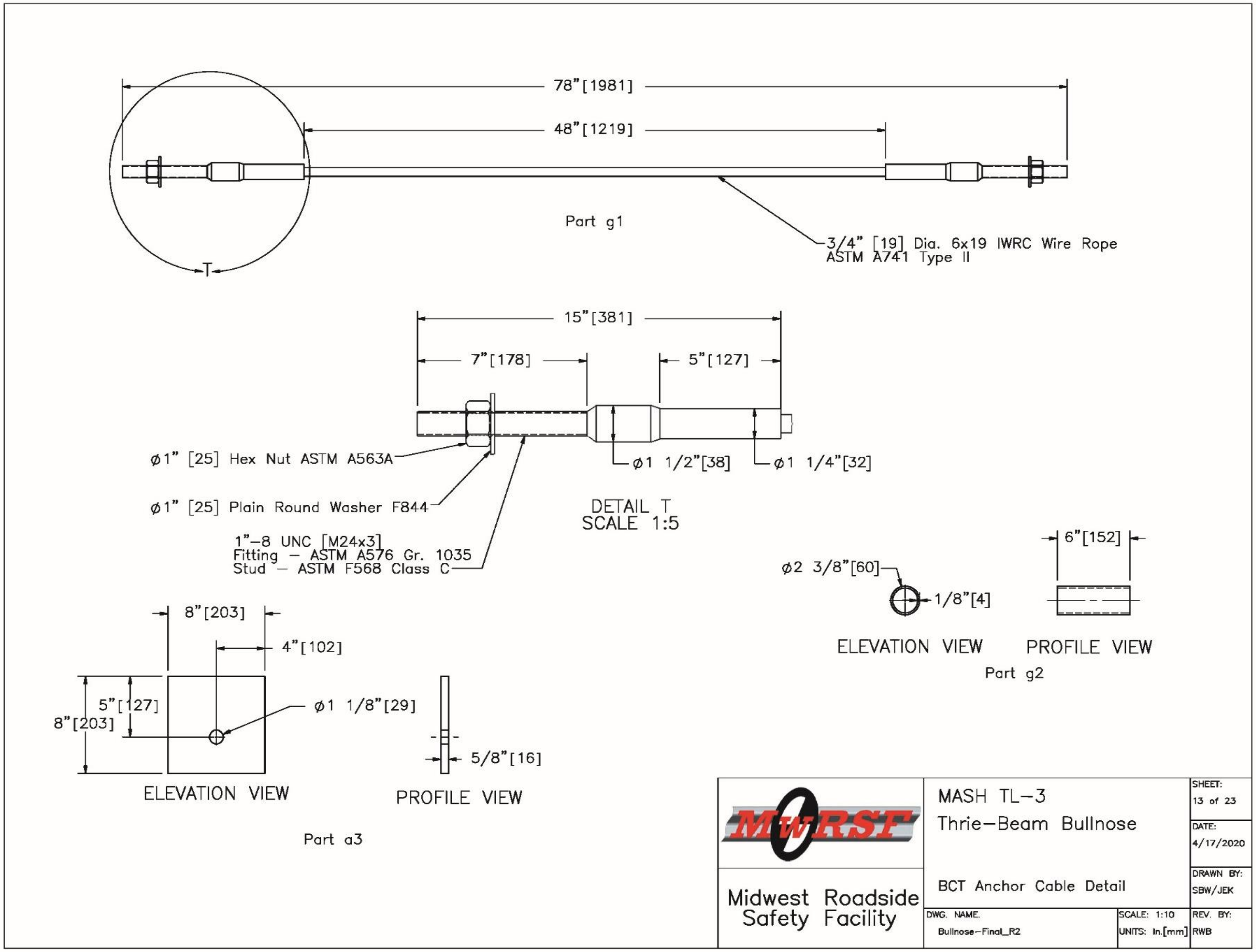


Figure 242. BCT Anchor Cable Detail, Bullnose Final

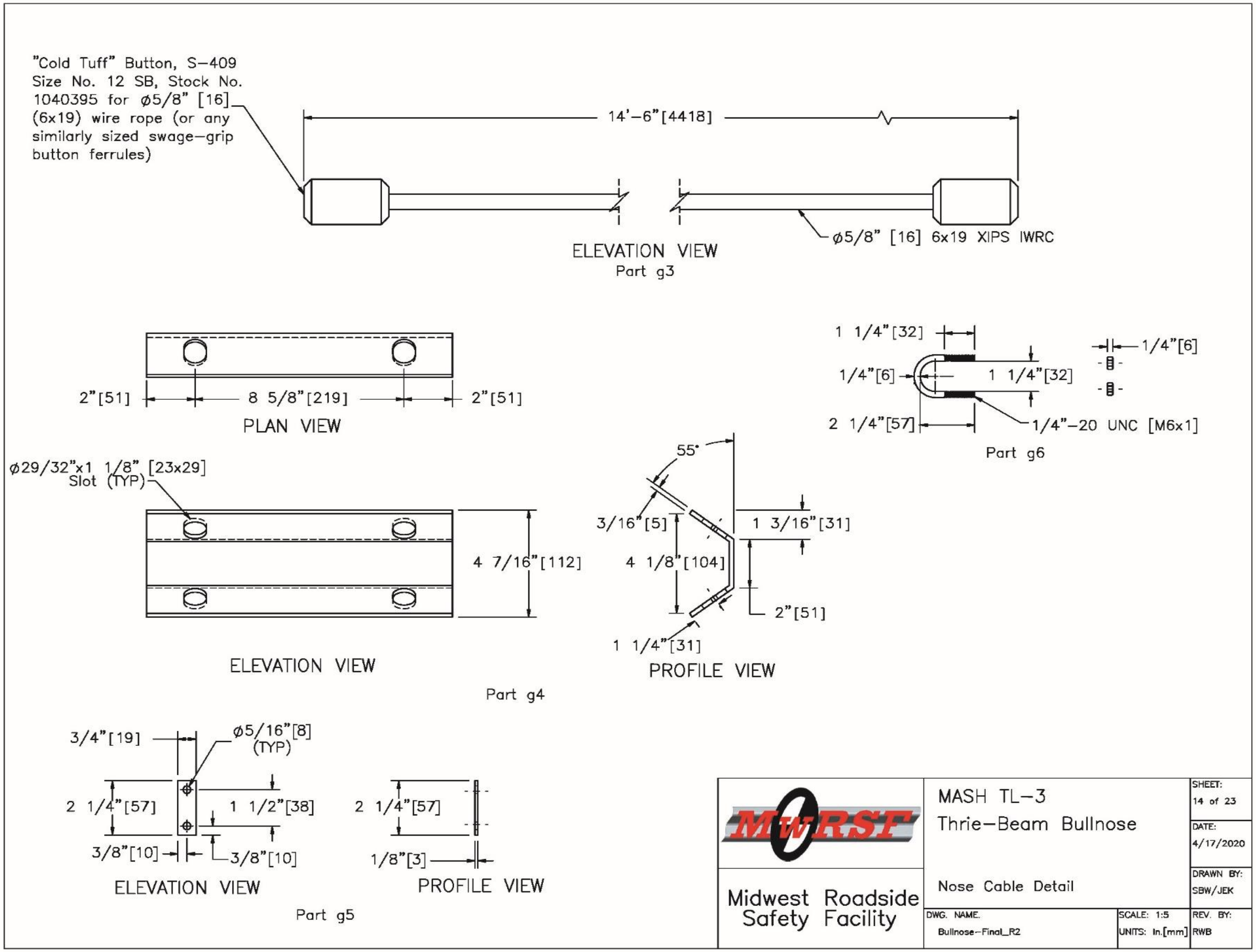


Figure 243. Nose Cable Detail, Bullnose Final

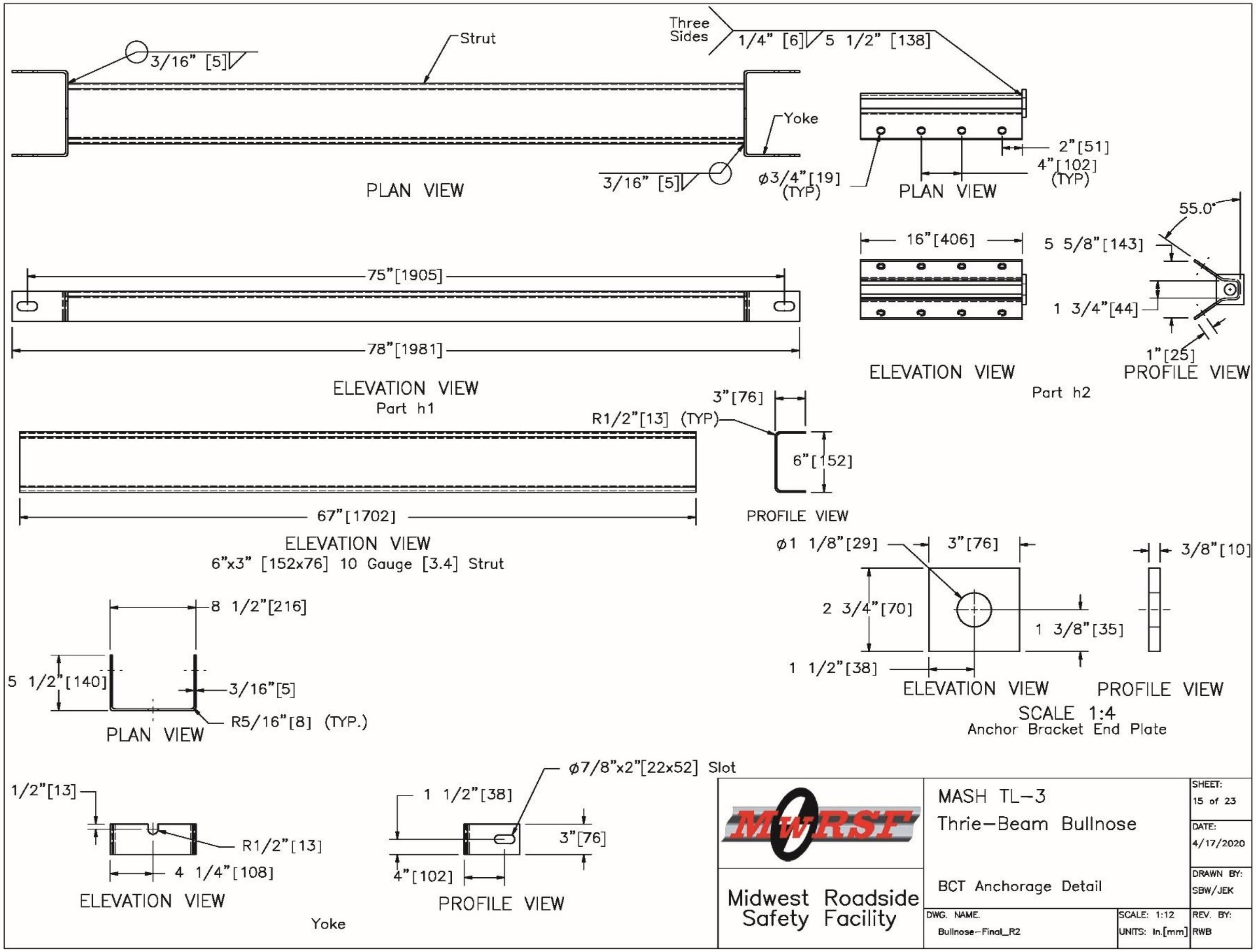


Figure 244. BCT Anchorage Detail, Bullnose Final

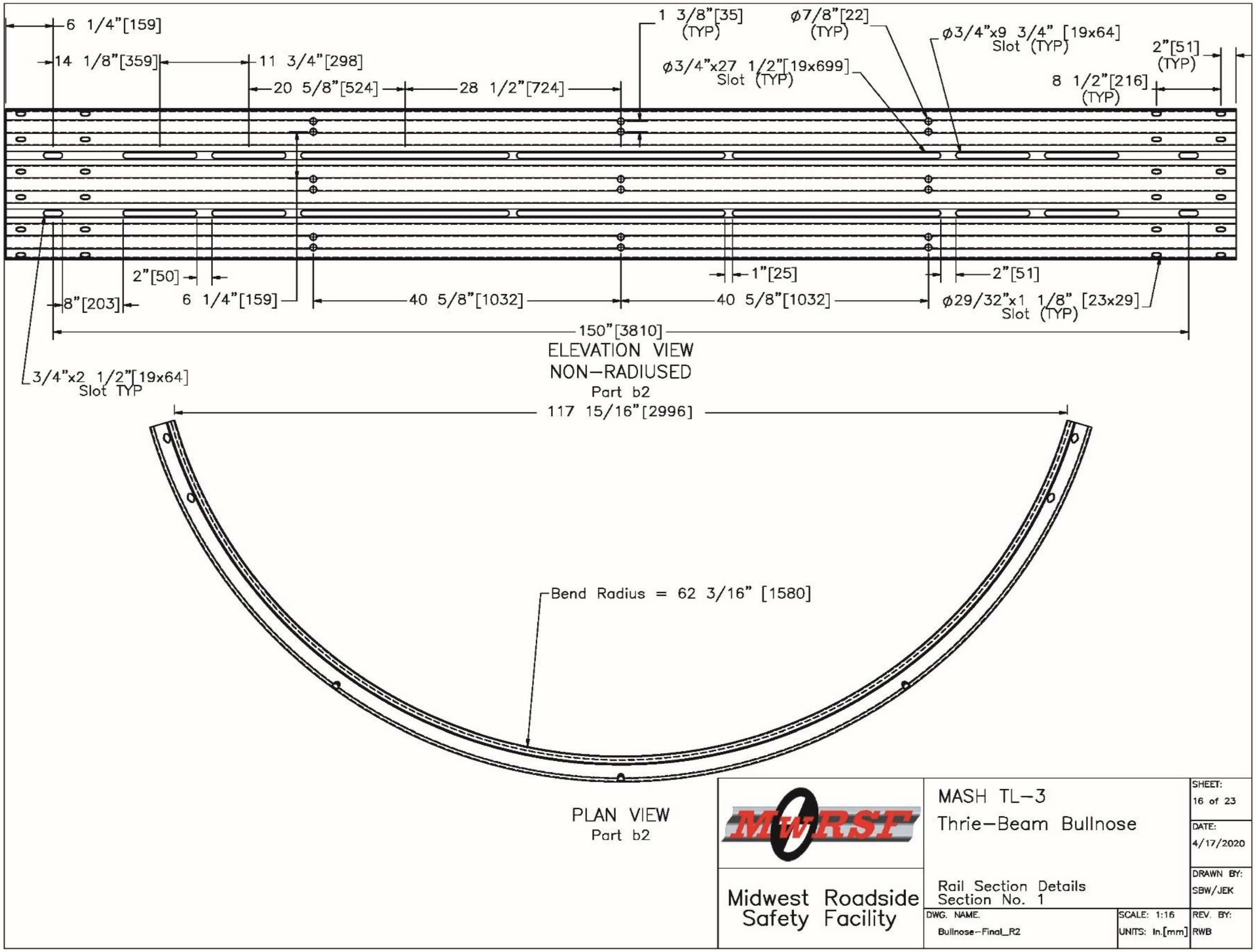


Figure 245. Rail Section Details, Section No. 1, Bullnose Final

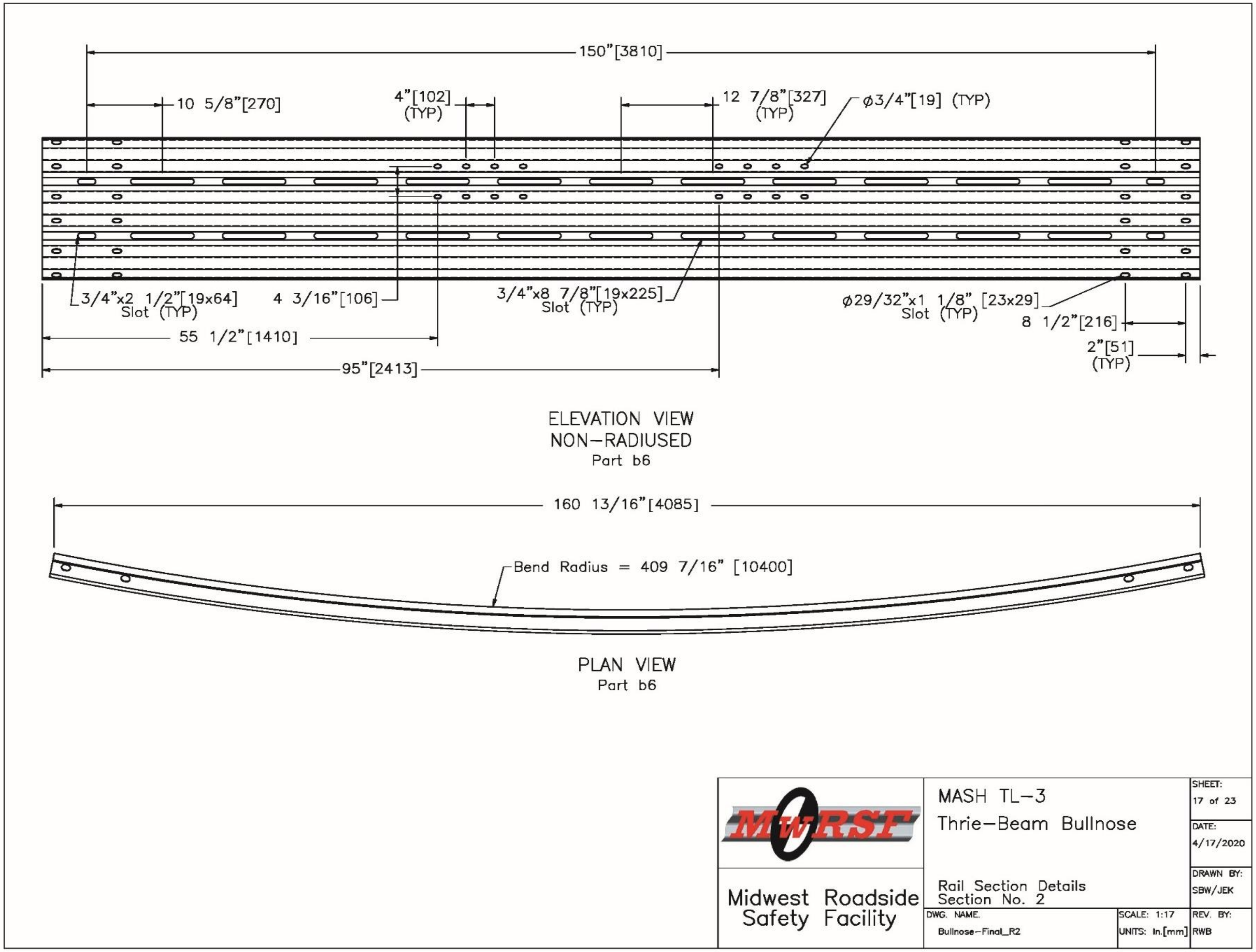


Figure 246. Rail Section Details, Section No. 2, Bullnose Final

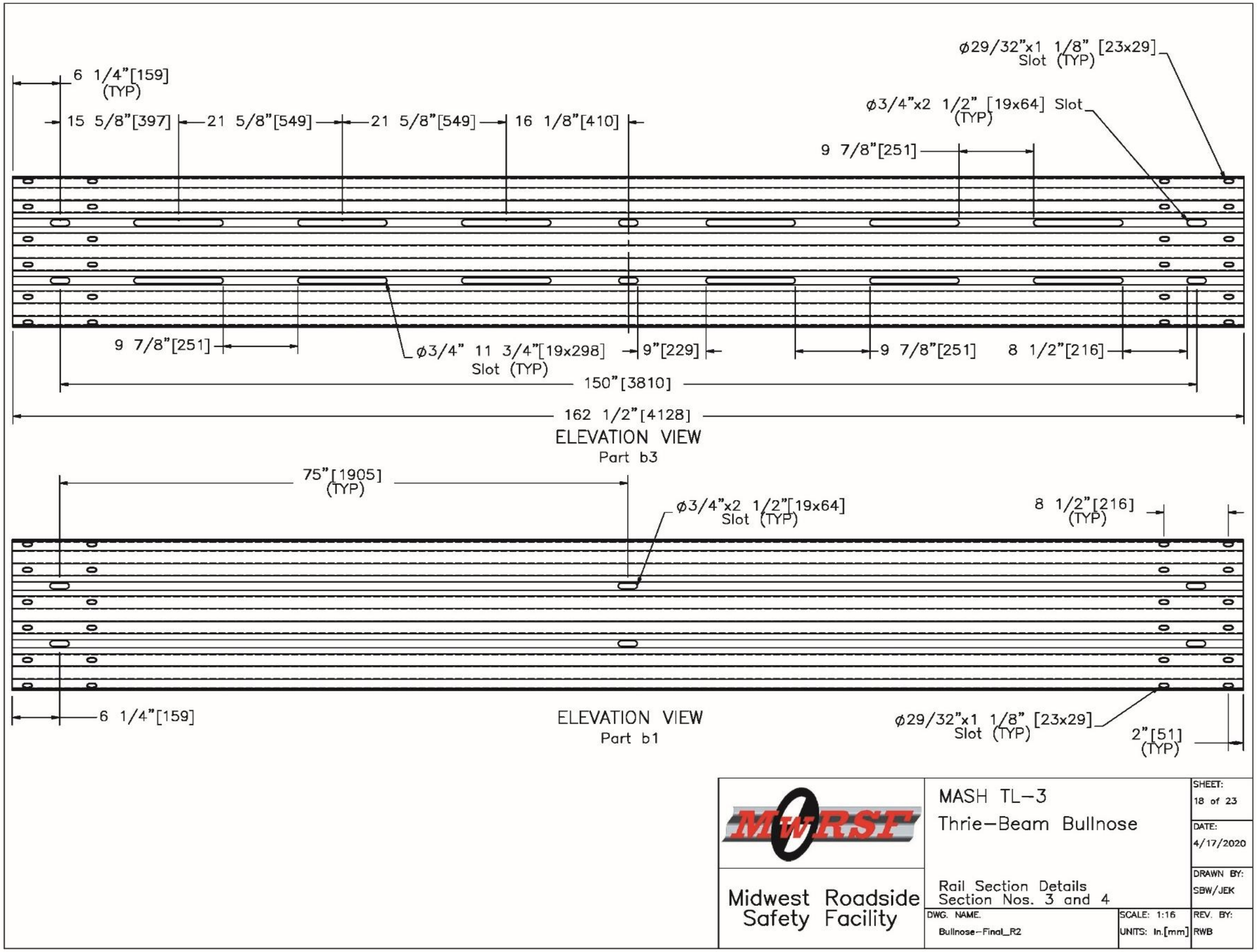


Figure 247. Rail Section Details, Section Nos. 3 and 4, Bullnose Final

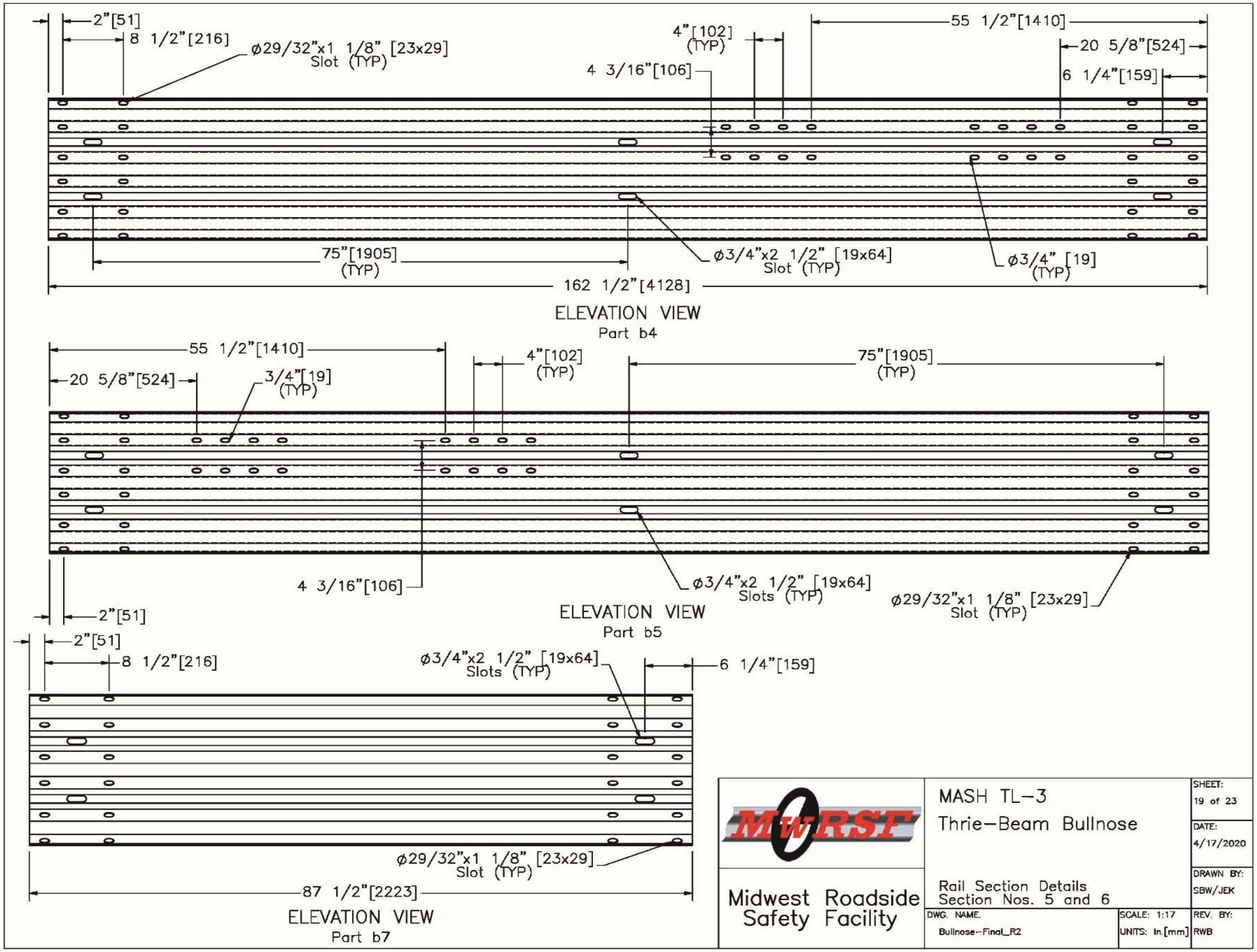


Figure 248. Rail Section Details, Section Nos. 5 and 6, Bullnose Final

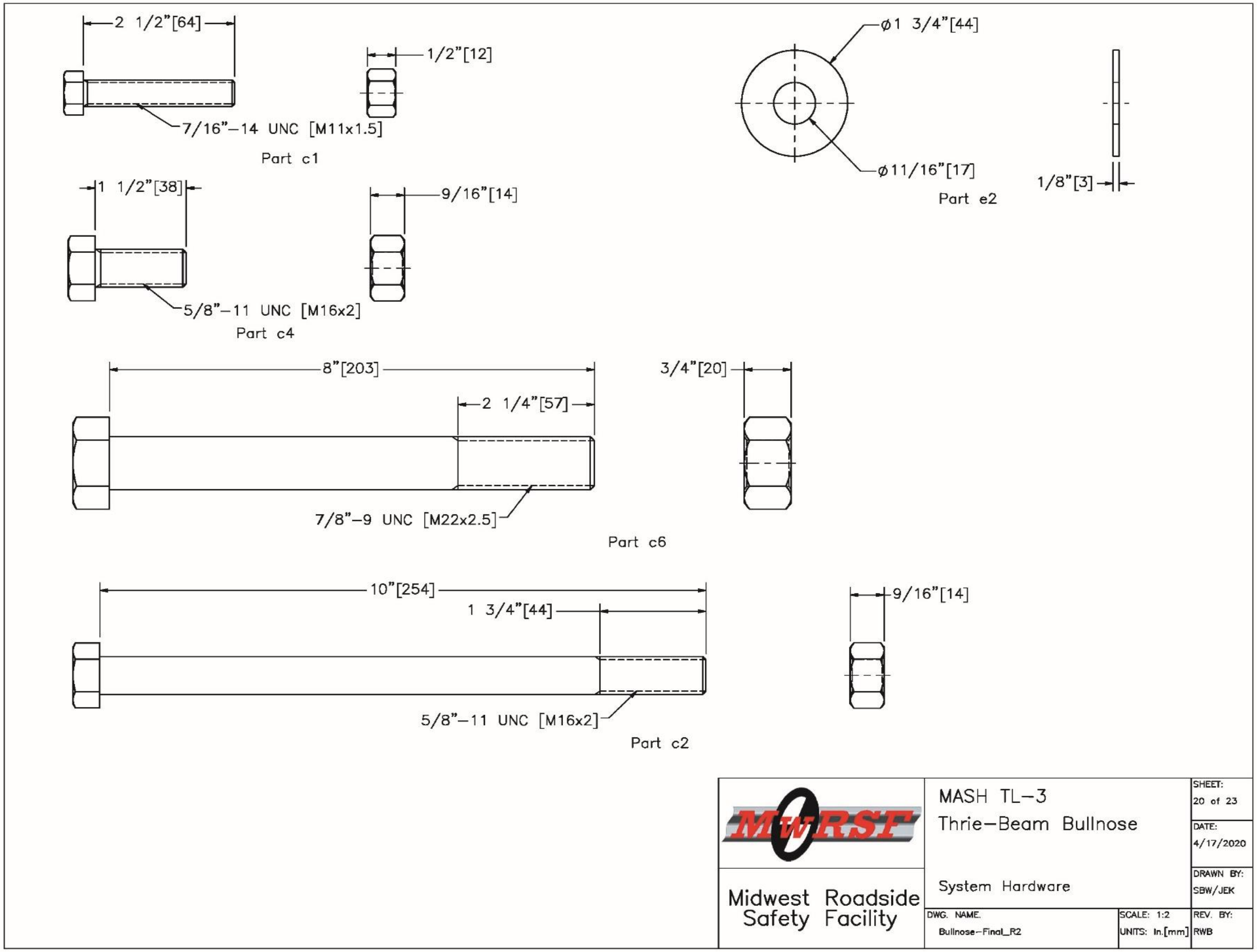


Figure 249. System Hardware, Bullnose Final

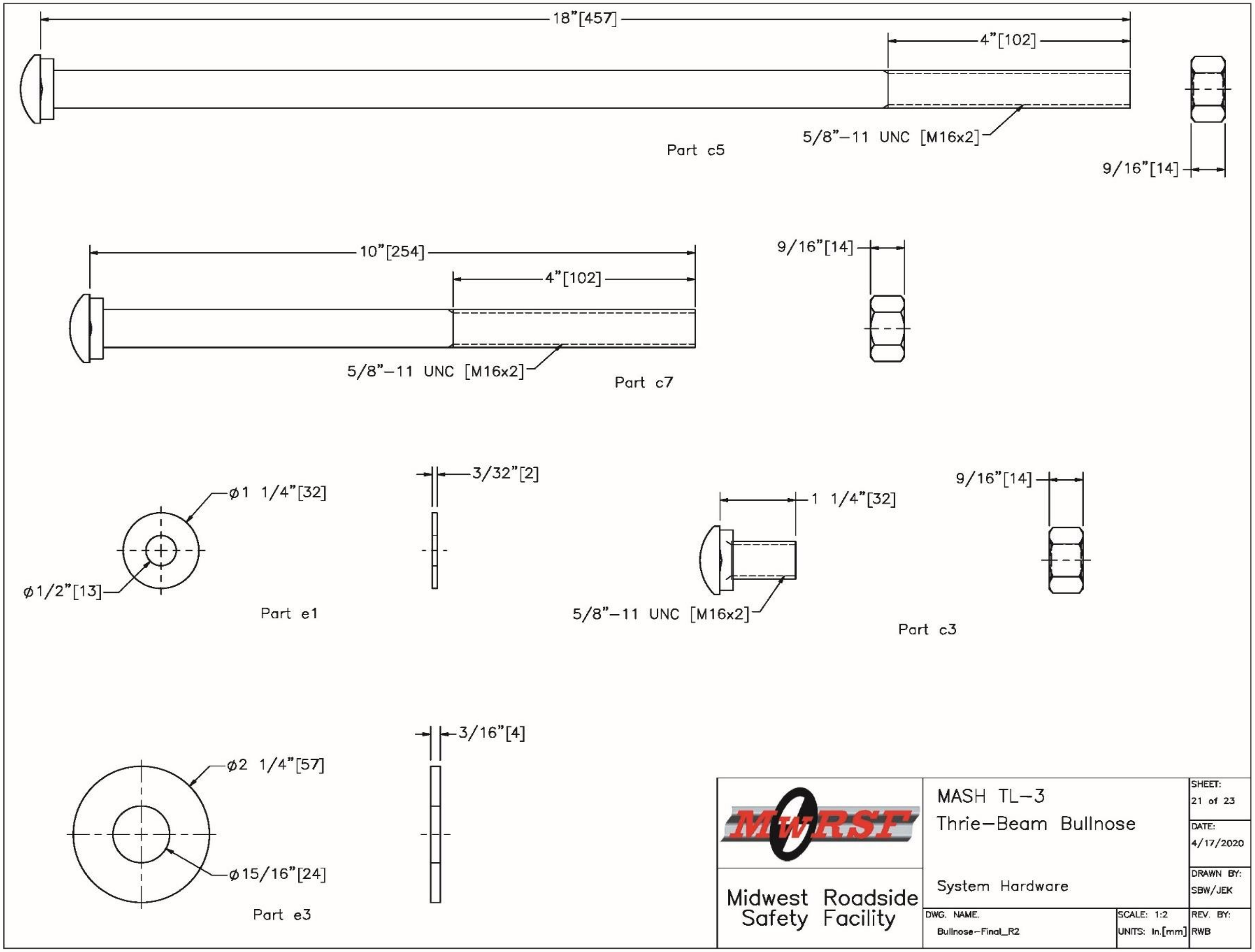


Figure 250. System Hardware, Bullnose Final

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	2	TS8"x6"x3/16" [203x152x5], 96" [2,438] Long Foundation Tube	ASTM A500 Gr. B	ASTM A123	PTE07
a2	6	TS8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	ASTM A123	PTE06
a3	6	8"x8"x5/8" [203x203x16] Anchor Bearing Plate	ASTM A36	ASTM A123	FPB01
a4	12	Lower Slip Post Assembly	Plate–ASTM A36 Foundation Tube–ASTM A500 Gr. B	ASTM A123	PTE08
a5	12	Upper Slip Post Assembly	Plate–ASTM A36 Post–ASTM A992	ASTM A123	PWE11
a6	20	6"x8"x14 1/4" [152x203x362] Timber Blockout	SYP Grade No. 1 or better	–	PDB09
a7	12	6"x8"x14 1/4" [152x203x362] Tapered Timber Blockout	SYP Grade No. 1 or better	–	PDB20
a8	2	6"x8"x14 1/4" [152x203x362] Tapered Timber Blockout – Post 2	SYP Grade No. 1 or better	–	PDB12
b1	4	12'–6" [3,810] 12 gauge [2.7] Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM02a
b2	1	12'–6" [3,810] 12 gauge [2.7] Bent Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM07a
b3	2	12'–6" [3,810] 12 gauge [2.7] Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM07e
b4	1	12'–6" [3,810] 12 gauge [2.7] Thrie Beam End Section – Side A	AASHTO M180	ASTM A123 or A653	–
b5	1	12'–6" [3,810] 12 gauge [2.7] Thrie Beam End Section – Side B	AASHTO M180	ASTM A123 or A653	–
b6	2	12'–6" [3,810] 12 gauge [2.7] Bent Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM07d
c1	48	7/16"–14 UNC [M11x1.5], 2 1/2" [64] Long Hex Tap Bolt (Fully Threaded) and Nut	Bolt – ASTM A449 or SAE J429 Gr. 5 Nut – ASTM A563DH or SAE J995 Gr. 5	ASTM A153 or B695 Class 55 or F2329	FBX12b
c2	8	5/8"–11 UNC [M16x2], 10" [254] Long Hex Head Bolt	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBX16a
c3	120	5/8"–11 UNC [M16x2], 1 1/4" [32] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB01
c4	48	5/8"–11 UNC [M16x2], 1 1/2" [38] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBX16a
c5	14	5/8"–11 UNC [M16x2], 18" [457] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB04
c6	8	7/8"–9 UNC [M22x2.5], 8" [203] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	–
c7	20	5/8"–11 UNC [M16x2], 10" [254] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB03
c8	46	16D Double Head Nail	–	–	–

Midwest Roadside Safety Facility

MASH TL–3
Thrie–Beam Bullnose

Bill of Materials

SHEET: 22 of 23
DATE: 4/17/2020
DRAWN BY: SBW/JEK
DWG. NAME. Bullnose–Final_R2
SCALE: None
UNITS: In.[mm]
REV. BY: RWB

Figure 251. Bill of Materials, Bullnose Final

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
e1	192	7/16" [11] Dia. Plain Round Washer	ASTM F844	ASTM A153 or B695 Class 55 or F2329	FWC12a
e2	118	5/8" [16] Dia. Plain Round Washer	ASTM F844	ASTM A153 or B695 Class 55 or F2329	FWC16a
e3	16	7/8" [22] Dia. Plain Round Washer	ASTM F844	ASTM A153 or B695 Class 55 or F2329	–
f1	8	BCT Timber Post – MGS Height	SYP Grade No. 1 or better (No knots +/– 18" [457] from ground on tension face)	–	PDF04
f2	8	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 78" [1,981] Long Steel Post	ASTM A992	ASTM A123	–
g1	6	BCT Anchor Cable Assembly	–		FCA01
g2	6	2 3/8" [60] O.D. x 6" [152] Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	ASTM A123	FMM02
g3	3	5/8" Dia. [15.9] x 14.4' [4,389] Long Cable and Swage Button	"Cold Tuff" Button, S–409 Size No. 12 SB, Stock No. 1040395 for 5/8" [16] Dia. (6x19) wire rope (or any similarly sized swage–grip button ferrules)	Wire Rope – Class A Coating	RCM02
g4	6	12 5/8"x5 13/16"x3/16" [321x148x5] Nose Cable Anchor Plate	ASTM A36	ASTM A123	FPA04
g5	9	2 1/4"x3/4" [57x19] 11 gauge [3] U–Bolt Plate Washer	ASTM A1011 CS Type B	ASTM A123	–
g6	9	1/4" [6] Dia. U–Bolt and Nut	U–Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	–
h1	2	Ground Strut Assembly	ASTM A36	ASTM A123	PFP01
h2	6	Anchor Bracket Assmbely	ASTM A36	ASTM A123	FPA01

Midwest Roadside Safety Facility

MASH TL–3
Thrie–Beam Bullnose

Bill of Materials

SHEET: 23 of 23
DATE: 4/17/2020
DRAWN BY: SBW/JEK
DWG. NAME. Bullnose–Final_R2
SCALE: None
UNITS: in.[mm]
REV. BY: RWB

Figure 252. Bill of Materials, Bullnose Final

14 RECOMMENDATIONS

The MASH 2016 TL-3 thrie-beam bullnose system detailed herein was evaluated using a basic test configuration on level terrain. Real-world installations will likely involve other design considerations. The following sections provide recommendations for use in the implementation of the thrie-beam bullnose system. Additionally, there are three foreseeable field applications for the bullnose barrier system: (1) the protection of the gap between twin bridges; (2) gore area protection; and (3) protection of narrow median hazards, such as bridge piers and overhead sign support structures. For each of the three bullnose applications, there are installation and design factors that should be addressed before the system can properly be used in these situations. These additional considerations will be addressed for each application.

14.1 Breakaway Posts

The thrie-beam bullnose system evaluated herein utilized UBSPs for the majority of the breakaway posts. The original NCHRP Report No. 350 TL-3 thrie-beam bullnose system was evaluated with both timber CRT posts and UBSPs. While it is believed that timber CRT posts would likely provide similar performance to the UBSPs used in this system, further evaluation of the thrie-beam bullnose system with the timber CRT posts would be required to confirm their performance under MASH 2016 TL-3 conditions. There may be potential to evaluate the CRT post variation using a smaller subset of critical tests similar to the method that was used to evaluate the UBSP under the NCHRP Report No. 350 criteria [7-9].

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.

A final note with respect to the UBSPs relates to the bolts used to hold the upper and lower sections of the post together. These bolts can potentially be difficult to install due to the lower base plate being flush with the ground. A potential solution to this issue had been proposed using welded nuts on the lower base plate that would eliminate the need for excavation. While this solution would make installation easier, removal of fractured bolts would tend to be quite difficult. Thus, it would be up to end users to determine whether or not to use the welded nut option.

14.2 Downstream End Anchorage

It should also be noted that the thrie-beam bullnose system constructed for use in this testing 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 envelope or attachment of the 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 system where only one of the two sides is connected to other barrier systems. In this type of installation, the researchers would recommend that dual cable anchorages be employed on the unattached end similar to those observed in the full-scale testing program described herein.

14.3 Increased Impact Speeds

The thrie-beam bullnose system absorbs the kinetic energy of impacting vehicles through a combination of rail deformation and disengagement of breakaway posts. Due to these behaviors, there has been interest in potentially increasing the longitudinal length of the system as well as the number of slotted rail sections and breakaway posts to increase the capability to accommodate higher vehicle impact velocities. In terms of the impacts on the end or nose of the system, there may exist the potential to accommodate increased impact velocity with system modifications and further system evaluation. However, one must also account for impacts along the sides of the system where redirection of the impacting vehicle is required. The effect of higher impact velocities away from the nose of the system are not known with respect to vehicle redirection and capture, barrier capacity, and anchorage. Additionally, higher impact velocities may affect system performance with respect to test designation nos. 3-34 and 3-35. Thus, while the potential exists for the bullnose system to accommodate higher impact velocities, further research and evaluation would be required.

14.4 Transitioning to MGS

For many applications, end users may wish to transition the thrie-beam bullnose to the MGS system. It is recommended that the asymmetrical W-to-thrie transition segment be used to connect the bullnose to MGS. It is recommended that the asymmetrical W-to-thrie transition section not be added until the end of rail section no. 5 or post no. 12. This guidance is based on previous analysis of the length of the deformation of the thrie-beam rail and posts in the full-scale crash tests and a desire to maintain the post section and spacing and the rail section similar to the as-tested configuration.

If transitioning to the MGS, there is a need to transition the splices to the mid-span as well. It is recommended that this transition be accomplished by placing the first post downstream from the asymmetrical W-to-thrie transition piece at ½-post spacing and then using standard spacing from that point on. This layout would correspond to putting in a post at ½-post spacing after post no. 14 in the thrie-beam bullnose system and using standard post spacing afterwards. A schematic of the recommended transition is shown in Figure 253. As the top rail height of the thrie-beam bullnose is currently 31⅝ in. (803 mm), the height of the barrier system would need to be transitioned to match the 31-in. (787-mm) height of the MGS following the adjustment of the post spacing and splice location. Thus, the height transition should occur beginning at post no. 16.

It should be noted that the proposed transition design is based on the best currently available transition research and engineering judgment. Further analysis and full-scale crash testing would be required to actually verify the safety performance of the proposed transition.

It should be noted that there may be a desire to attach the thrie-beam bullnose system to the G9 thrie-beam guardrail system rather than the MGS. However, standard G9 thrie-beam guardrail has not met the MASH 2016 TL-3 safety requirements at this time and is currently not recommended for attachment to the thrie-beam bullnose system. A thrie-beam guardrail system was crash tested to MASH 2009 TL-3 that consisted of a 12-gauge thrie-beam rail mounted on 6 ft – 6 in. (1,981-mm) long W6x8.5 steel posts spaced 6 ft – 3 in. (1,905 mm) apart with 6-in. x 8-in. x 22-in. (152-mm x 203-mm x 559-mm) long routed wood blockouts. The mounting height of the thrie-beam rail element was 31⅝ in. (803 mm) to the top of the thrie-beam element. The thrie-beam guardrail did not perform acceptably when impacted by the 2270P vehicle. The thrie-beam guardrail contained and redirected the 2270P vehicle. However, the 2270P vehicle rolled after losing contact with the guardrail [22].

Previous testing of modified thrie-beam guardrail, the thrie-beam bullnose system, and various approach guardrail transitions have employed the use of shorter and/or tapered blockouts with thrie beam to improve the barriers' performance with respect to the 2270P vehicle. Previous tests of approach guardrail transitions have shown that full height blockouts can prevent the lower rail corrugation from folding back and allowing the wheel below the rail. In some tests, this behavior has induced roll in the vehicle toward the barrier that eventually led to vehicle rollover. It is believed that this behavior may have been a factor in the failed MASH 2009 TL-3 test of thrie-beam guardrail. As such, it is recommended that further MASH evaluation of thrie-beam guardrail consider the use of shortened blockouts to improve its safety performance.

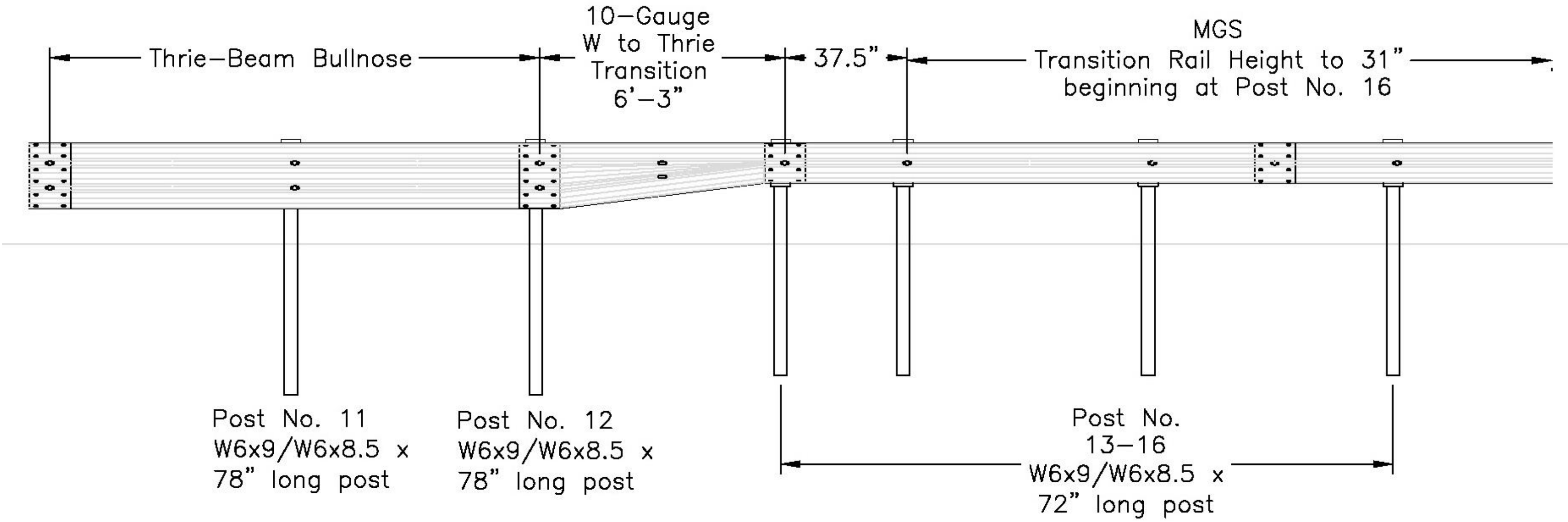


Figure 253. Thrie-Beam Bullnose Transition to MGS

14.5 Transitioning to Thrie-Beam AGTs

Another application for the thrie-beam bullnose system involves its attachment directly to a thrie-beam approach guardrail transition (AGT) when used to shield twin-bridge median hazards. Attachment of the bullnose to an AGT should consider both the length of the bullnose system required upstream of the AGT as well as the configuration of the connection between the thrie-beam bullnose system and the AGT. The results from test no. MSPBN-6 showed deformation of the thrie-beam guardrail as far as the end of rail section no. 5 or post no. 12. This deformation pattern was the farthest distance downstream from the nose of the barrier that guardrail deformation was observed in bullnose testing. Due to the importance of guardrail deformation in the proper performance of the bullnose system, it is believed that placement of any transition within the region where the thrie-beam guardrail deformed could degrade system behavior. Therefore, it is recommended that any transitions used in conjunction with the bullnose median barrier should be placed no closer than the end of rail section no. 5 or post no. 12. This guidance should allow for the necessary deformation of the thrie-beam guardrail in advance of any transition.

In addition to the location of the AGT connection, the thrie-beam bullnose system should be attached to a MASH-compliant, thrie-beam AGT that is crashworthy at both the upstream stiffness transition and the connection to the bridge rail, concrete buttress, or concrete parapet. MwRSF has previously developed an upstream stiffness transition for use in connecting the MGS to thrie-beam AGTs [23-24]. This upstream stiffness transition should be applicable to the thrie-beam bullnose system, because the sides of the bullnose system would have similar to greater lateral stiffness and strength when compared to the MGS.

A schematic of the proposed transition from the thrie-beam bullnose system to a thrie-beam AGT alongside and the original MGS upstream stiffness transition is shown in Figure 254. In order to adopt the MGS upstream stiffness transition to the bullnose system, the 10-gauge W-thrie transition piece and adjacent 75-in. (1,905-mm) long, 12-gauge thrie-beam section were removed and replaced with a single 150-in. (3,810-mm) long, 12-gauge thrie-beam section. In addition, the first post at ½-post spacing on the upstream end of the stiffness transition was removed. The remainder of the MGS upstream stiffness transition was retained, including the ½-post spacing and the use of 12-in. (305-mm) deep blockouts. The proposed transition design currently shows the use of 6-ft (1.8-m) long posts in the MGS upstream stiffness transition in order to minimize changes to the basic AGT configuration. However, there would be no safety performance concerns with switching to 6.5-ft (2.0-m) long posts in that region of the MGS upstream stiffness transition if end users desired to limit the number of post types. For the downstream connection to the bridge rail, any MASH TL-3, crashworthy, thrie-beam AGT could be applied as long as it is compatible with the bridge rail, parapet, or end buttress.

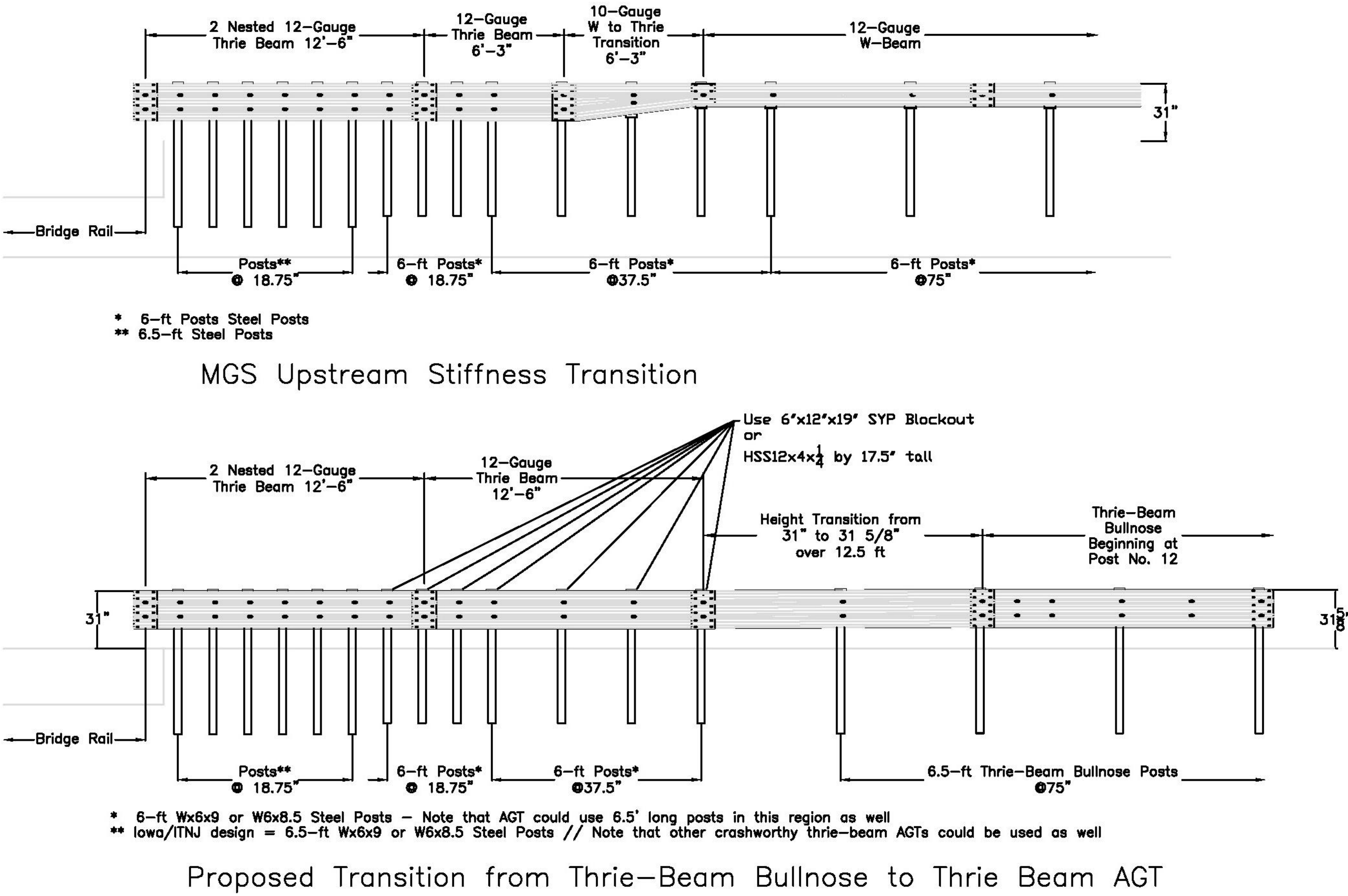


Figure 254. Thrie-Beam Bullnose Transition to Thrie-Beam AGTs

It should be noted that the proposed transition is based on the best, currently available, transition research and engineering judgment. Further analysis and full-scale crash testing would be required to verify the performance of the transition.

14.6 Working Width – Lateral and Longitudinal Offsets

During the crash testing program, the maximum longitudinal vehicle penetration and barrier deflection was approximately 56 ft – 5 in. (17.2 m) downstream from the nose of the system or 53 ft (16.1 m) downstream from post no. 1, as observed in test no. MSPBN-6. In the test, the front of the pickup truck came to rest about one quarter of the way down rail section no. 6 of the bullnose system. Based on this test deformation, a minimum of 66 ft – 1¾ in. (18.942 m) of guardrail, as measured longitudinally from the end of the nose, or five sections of guardrail downstream from post no. 1 of the system, is recommended in front of any hazard. The recommended distance is slightly higher than the maximum observed deflection in order to provide a factor of safety for the bullnose system, and it also allows for a whole number of guardrail sections in front of the hazard.

In test no. MSPBN-7, Side B of the bullnose system extended outward from the system for a distance of 14 ft – 6 in. (4.4 m) laterally, which resulted in a working width of 29 ft – 2 in. (8.9 m) relative to Side A of the system. This distance should serve as the lateral working width on one or both sides of the system depending on the direction of traffic flow. For example, if the bullnose system is installed in a median with opposing traffic, then the lateral working width would only be applied relative to the oncoming traffic side of the system. For a gore installation, the lateral working width would need to be considered relative to both sides of the system.

An additional consideration for the application of the bullnose barrier to a narrow median hazard situation is the lateral clearance between the tangent segments of the bullnose barrier system and the face of a hazard. For thrie-beam bullnose systems transitioning to the MGS or an approved thrie-beam transition, the working widths for those systems should be used to establish the lateral barrier offset to the hazard. As noted previously, the G9 thrie-beam guardrail system is not MASH TL-3 compliant. Thus, lateral offsets from thrie-beam guardrail to the hazard are not currently available.

14.7 Grading Requirements

As with any barrier system, grading of the terrain adjacent to the thrie-beam bullnose system is an important aspect of installation to ensure proper function of the system. The thrie-beam bullnose system should be installed on a maximum grade of 10H:1V. This grade applies to cross slopes and V- and flat-bottomed ditches. It is also recommended that the 10H:1V slope area be applied for at least 60 ft (18.3 m) in front of the nose of the bullnose system to provide sufficient space to improve stable tracking of errant vehicles prior to impact. For the longitudinal slopes prior to the 10H:1V grading directly adjacent to the nose of the system, MwRSF previously developed several grading configurations in conjunction with the Minnesota DOT during the implementation of the NCHRP Report No. 350 bullnose system for 4H:1V ditch configurations. Those schematic details are shown in Figure 255 through Figure 258. These recommendations limited the transition from the ditch to the 10H:1V slope to an 8H:1V. However, a 10H:1V transition slope was preferred. Similar grading is recommended for the MASH 2016 TL-3 thrie-beam bullnose system. These grading recommendations would also be extended to sloped ditches shallower than 4H:1V.

14.8 Splice Lapping

The thrie-beam bullnose system detailed herein consists of an envelope of guardrail that shields a hazard. The system may be employed in median applications where traffic moves in opposing directions on each side of the system or in a gore application where traffic would move in the same direction on both sides of the system. In order to reduce the potential for vehicle snag on the lap splices between the rail segments, it is recommended that the laps splices always be oriented based on the traffic flow on each side of the system, such that the upstream rail segment overlaps the downstream rail segment. Thus, for a median installation, the thrie-beam bullnose lap splicing would proceed in a continuous manner all the way around the system in the direction of oncoming traffic. All of the full-scale crash tests detailed herein were conducted on a splice configuration for median installations. For a gore installation, the lap splicing would be reversed on one side to match the traffic direction.

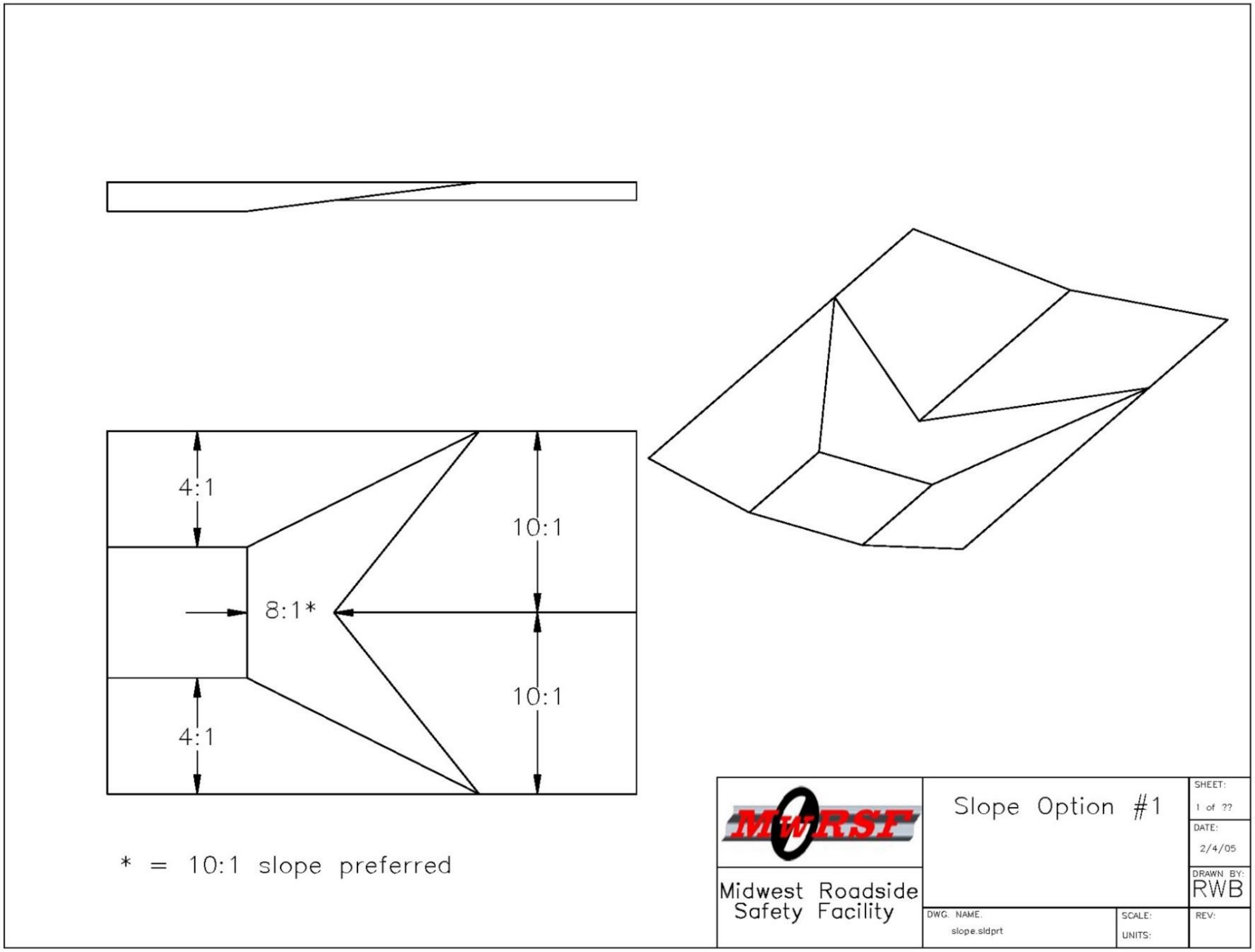


Figure 255. Thrie-Beam Bullnose Ditch Grading Schematic, Option 1

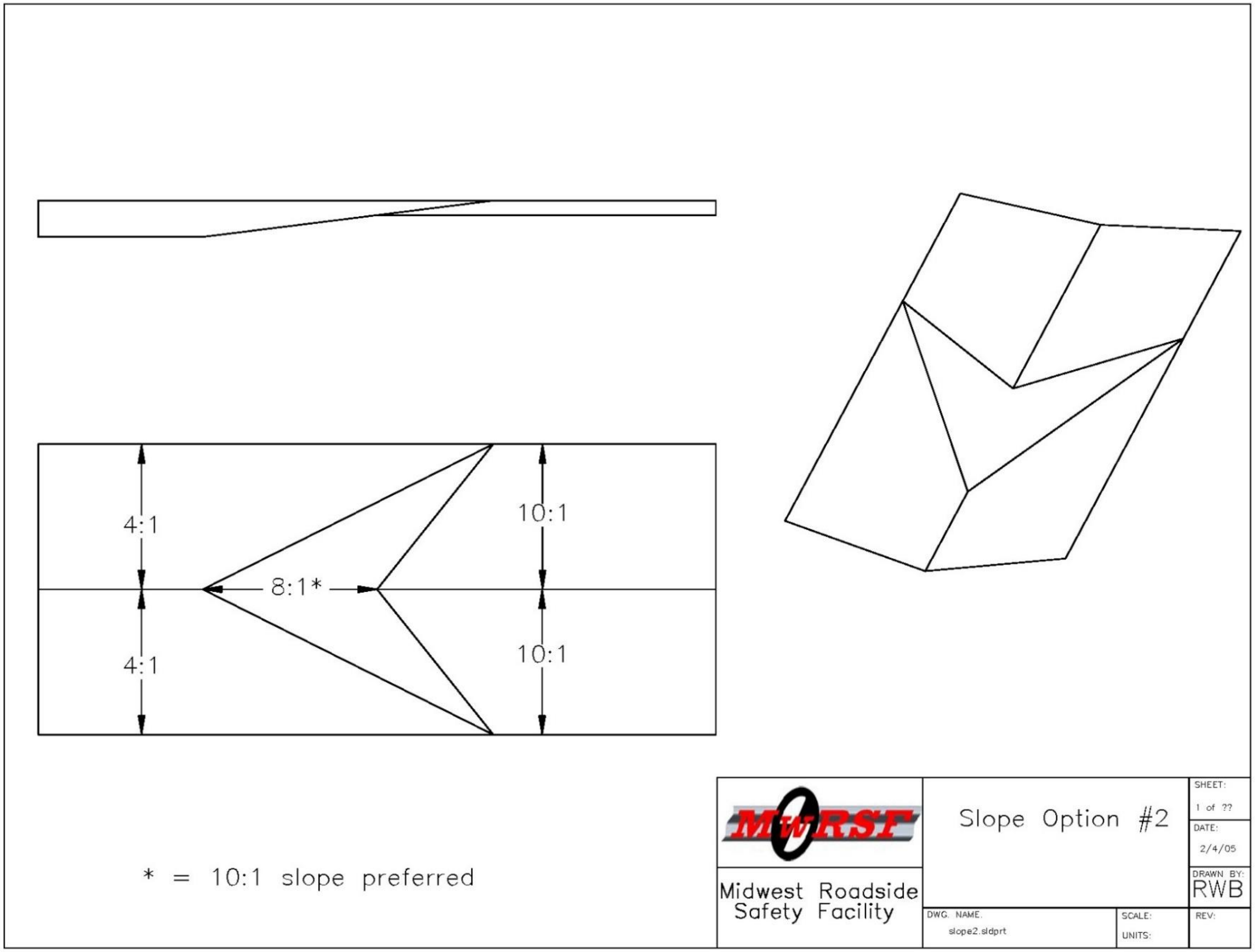


Figure 256. Thrie-Beam Bullnose Ditch Grading Schematic, Option 2

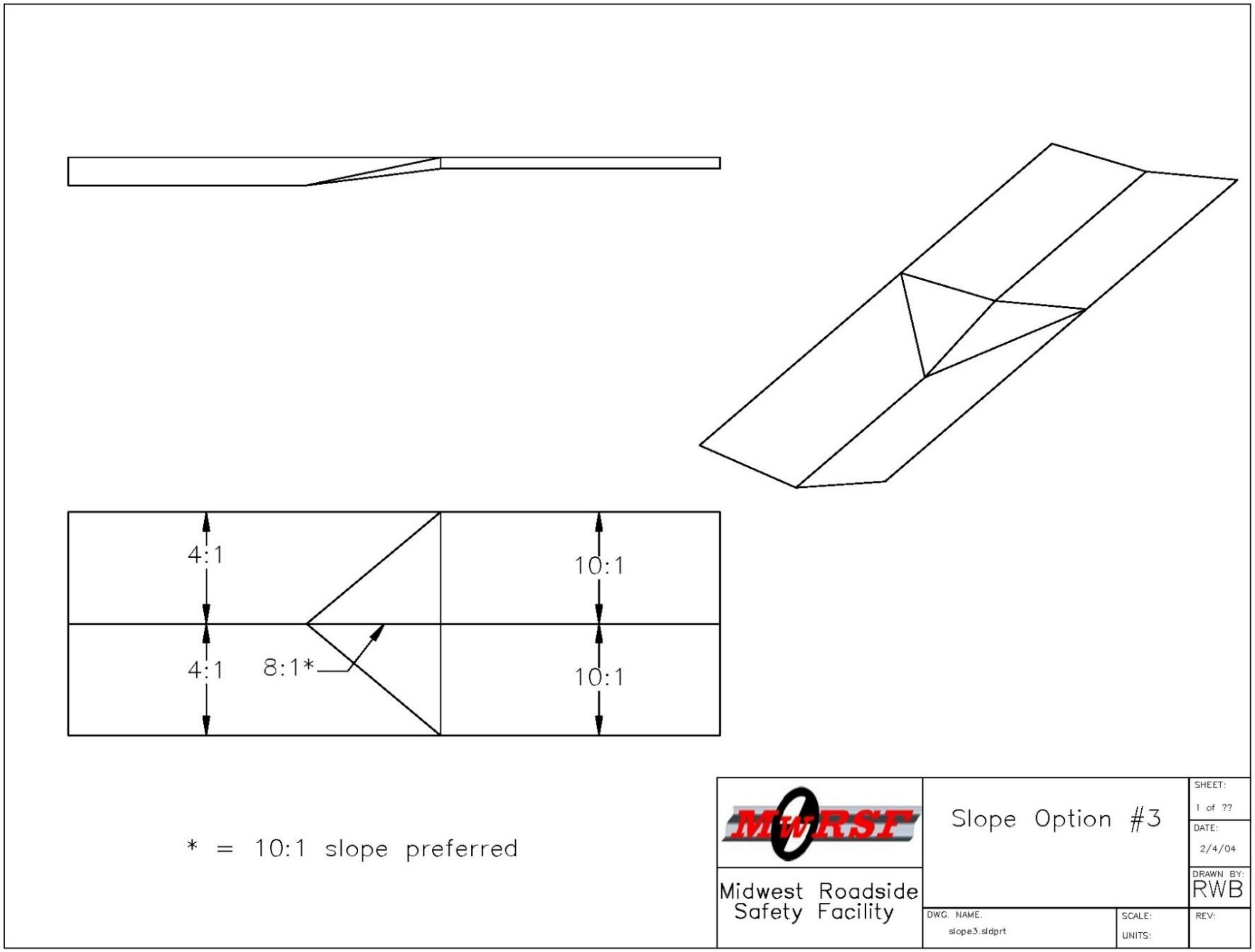


Figure 257. Thrie-Beam Bullnose Ditch Grading Schematic, Option 3

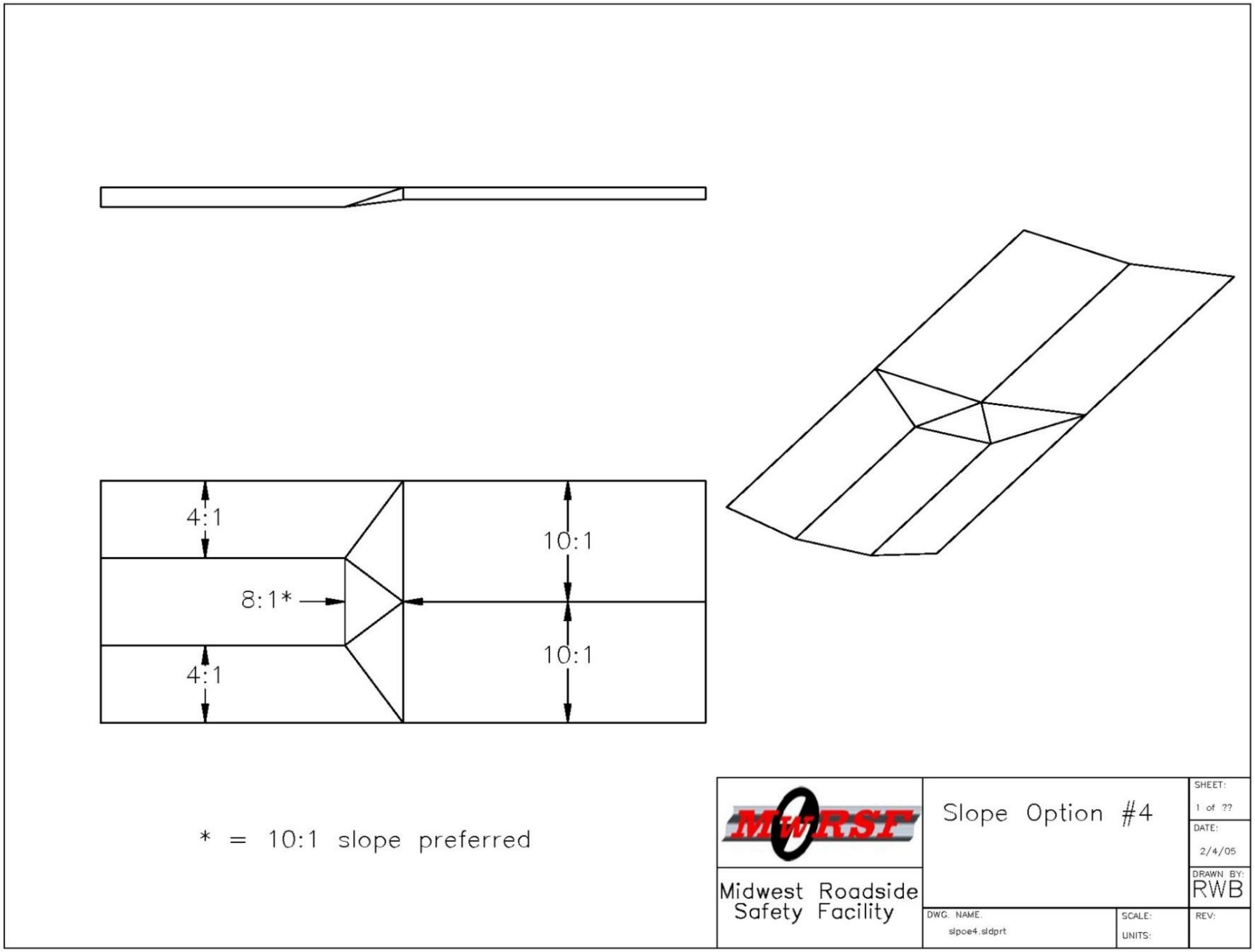


Figure 258. Thrie-Beam Bullnose Ditch Grading Schematic, Option 4

14.9 Curbs

There may be a desire to install the thrie-beam bullnose barrier adjacent to curbs and gutters to address water flow and drainage issues. No full-scale crash testing of the thrie-beam bullnose system, or any other crash cushion or end terminal, has been conducted in combination with curbs. Limited research regarding the simulation of end terminal impacts with curbs was conducted previously [25]. This research suggested that shorter curbs and wedge-shaped curbs would reduce the effect of the curb on the vehicle's trajectory. However, definitive guidance for the use of curbs and end terminals could not be developed without further research and testing.

It is known that vehicle traversal of curbs can affect vehicle trajectory, including vehicle pitch and the height of the vehicle's bumper and front-end structure. Thus, impacts near the nose of the system that include a curb traversal prior to impact with the nose may affect the vehicle's trajectory and capture. Along the parallel sides of the installation, the curbs may be less likely to create issues based on previous testing of the MGS with curbs if the curb offset is less than or equal to 6 in. (152 mm) in front of the face of rail [26-31]. However, no full-scale testing has been conducted on thrie-beam guardrail systems adjacent to a curb.

As such, further research would be required to determine the effect of curbs adjacent to the thrie-beam bullnose system. If the thrie-beam bullnose system were transitioned to a thrie-beam AGT or the MGS, curbs could be used within those regions in accordance with previous crash testing and guidance.

14.10 Wide Designs

The thrie-beam bullnose barrier system was tested with a 177¼-in. (4,502-mm) width, which represented the minimum system width. A narrow bullnose installation requires tighter guardrail radii and induces greater stresses and strains in the guardrail when an impacting vehicle deforms the nose of the system. The tighter guardrail radii and higher stresses and strains would likely increase the propensity for rail rupture and impart higher decelerations on impacting vehicles. Therefore, the narrow design was selected for evaluation as it provided a worst-case test installation.

The median area used to separate divided highways is often 30 ft (9 m) or more wide. Therefore, this median width may not be easily protected by the 177¼-in. (4,502-mm) wide, as-tested version of the thrie-beam bullnose median barrier. In order to better accommodate larger widths, two wider bullnose barrier configurations were previously developed during the original NCHRP Report No. 350 bullnose research and development, as shown in Figure 259 through Figure 264. Note that the designs shown in these figures are drawn with the original timber CRT post in the detail, which would not apply to the MASH 2016 TL-3 system tested herein. However, the overall layouts of the wide designs are still valid.

The two wider bullnose configurations were created by laterally pushing out the sides of the system and then modifying the size of the nose section. It is noted that the geometry and slot patterns of rail section nos. 2 and 3 remained unchanged. For the two new configurations, an 18.75-ft (5.7-m) long and 25-ft (7.6-m) long section of thrie-beam guardrail was bent to form the 93$^{5}/_{16}$-in. (2,370-mm) and 124⅜-in. (3,159-mm) radii, respectively. A 12.5-ft (3.8-m) long section of guardrail was used for the nose section of the system that was crash tested. While the size of the nose section was increased, it was simply scaled upward to account for the longer section length and did not change in shape. The new widths for the widened bullnose configurations are 235$^{5}/_{16}$ in. (5,977 mm) and 293$^{7}/_{16}$ in. (7,453 mm). These widened systems may be used for shielding twin bridges on divided highways. The wider bullnose systems offer economy over the narrower, crash-tested configuration as the potential exists for reduced lengths of flared guardrail between the bullnose barrier and the bridge rail and transition systems. It should be noted that the proposed wide designs are based on the best, currently available, engineering judgment. Further analysis and full-scale crash testing would be required to verify the performance of the wide designs.

The current configurations are as wide as the bullnose can be made without modifying any rail sections other than the nose or using a nose section of guardrail that is longer than 300 in. (7,620 mm). It is currently unknown how further system widening would affect the safety performance of the system. Modification of rail section no. 2 is not advisable due to the unforeseen effects this would have on the system. This curved section aids in the buckling of the guardrail and may require further testing if modified. Using an even longer section of guardrail in the nose potentially presents other problems, with the most obvious being the issue of the added cantilever weight from the additional guardrail. It is also believed that as the bullnose system is widened, the energy absorption of the system changes. The wider systems do not bend the guardrail through as severe an angle as a narrow system, and the rail loading imparted to the posts as the guardrail system deforms changes as well. These differences could be significant if the bullnose is widened further than the alternatives described above.

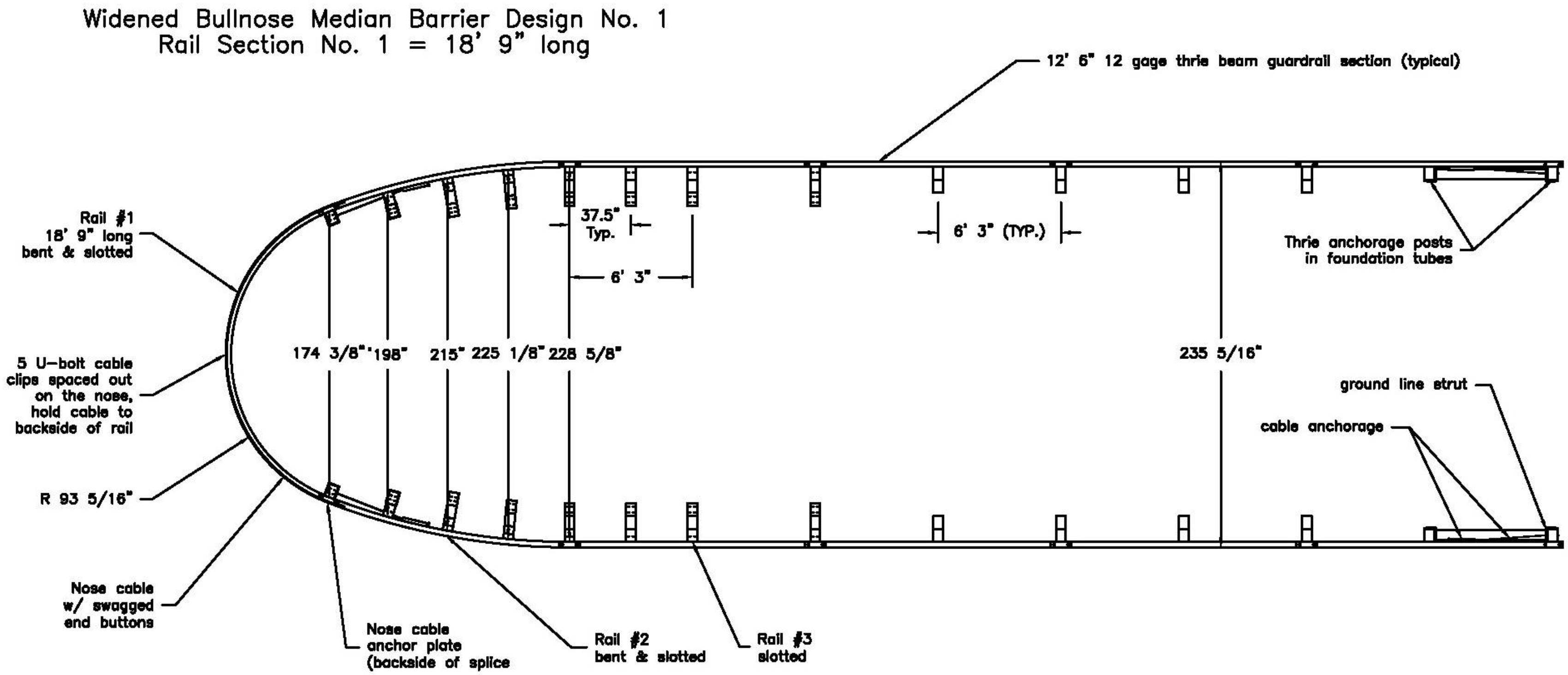


Figure 259. Wide Thrie-Beam Bullnose, Option 1

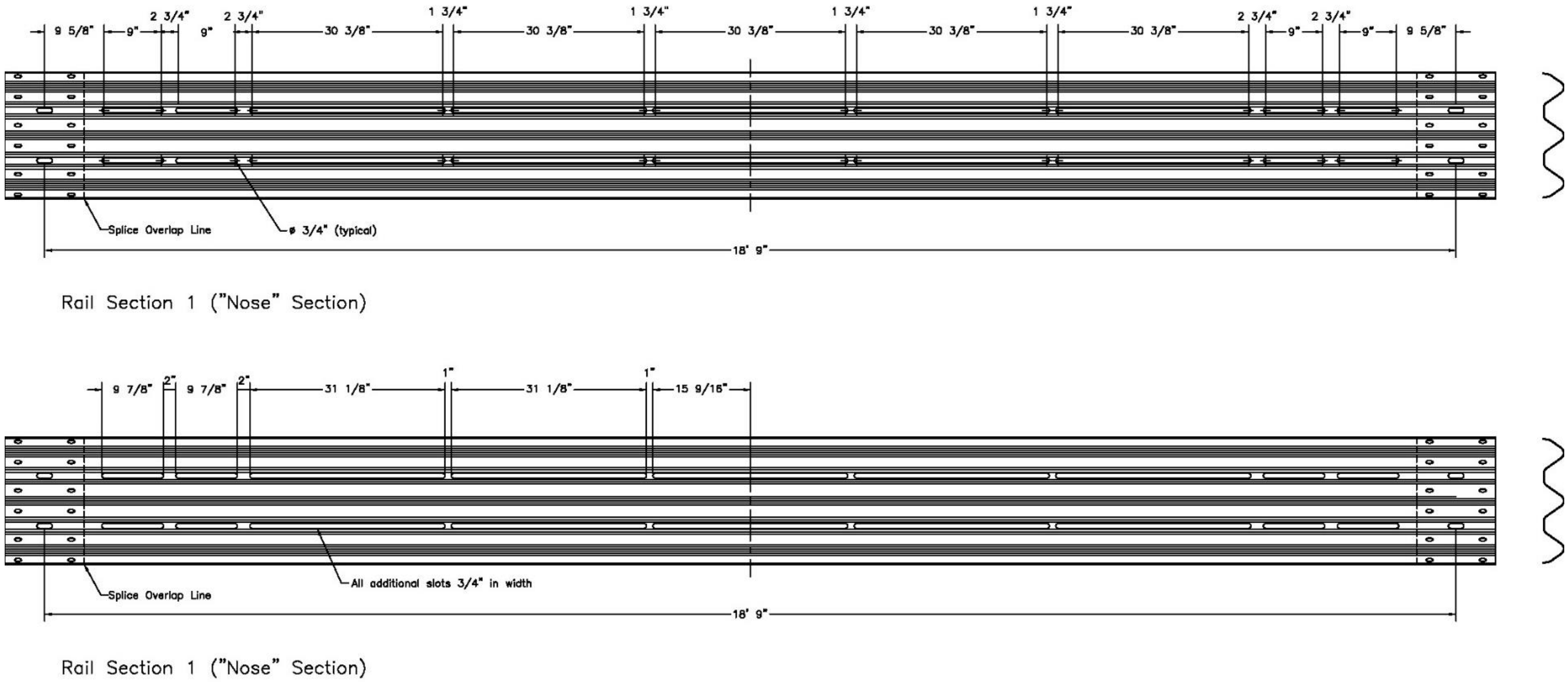


Figure 260. Wide Thrie-Beam Bullnose, Option 1

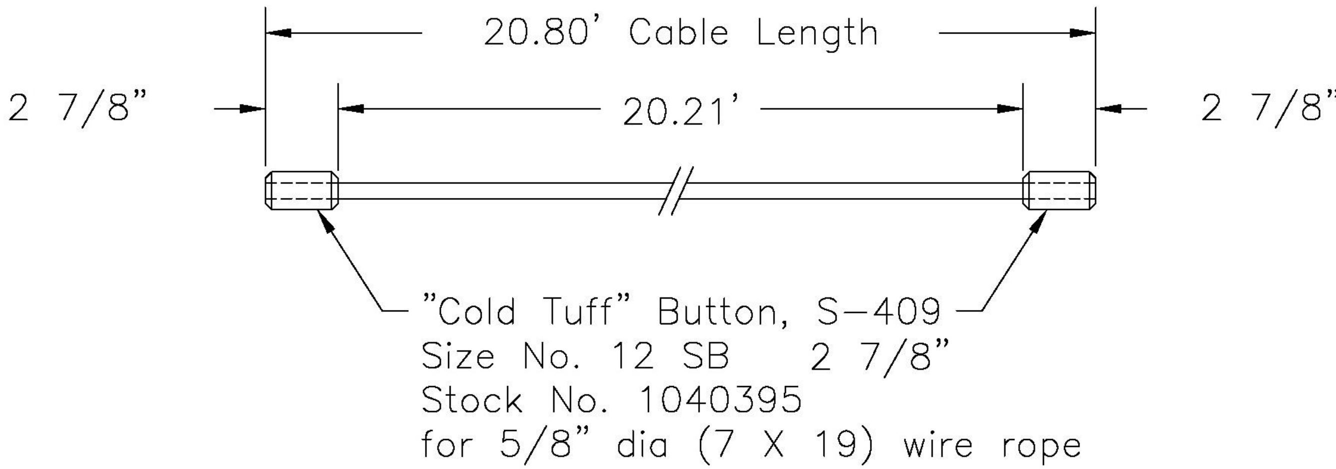


Figure 261. Wide Thrie-Beam Bullnose, Option 1

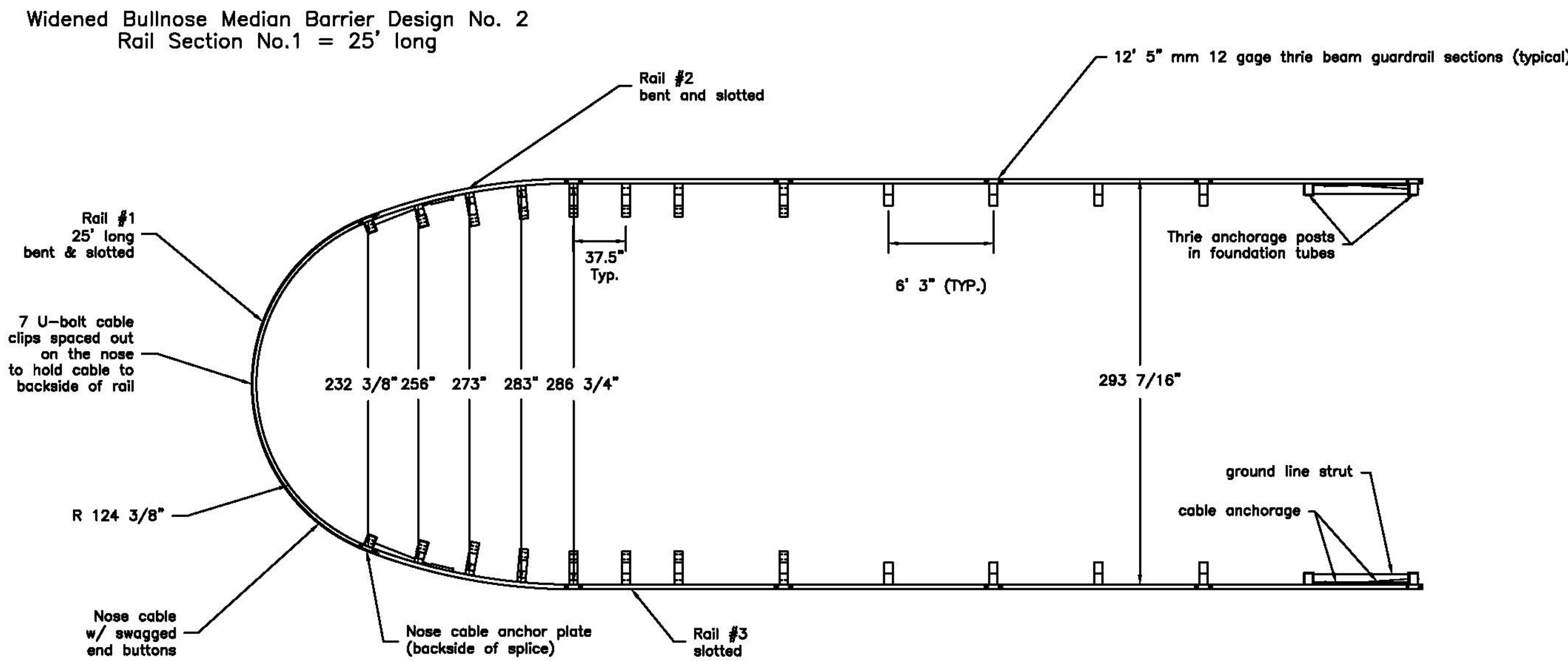
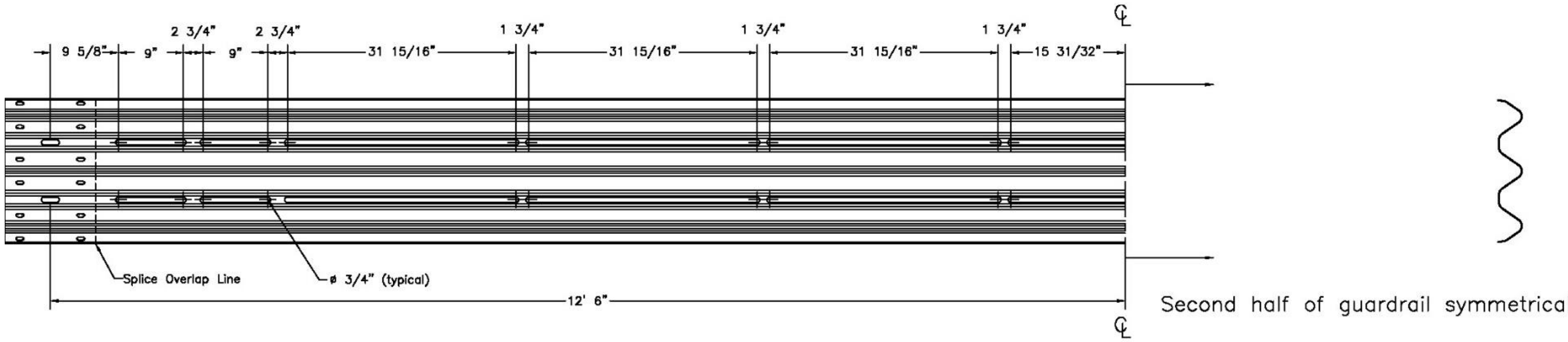
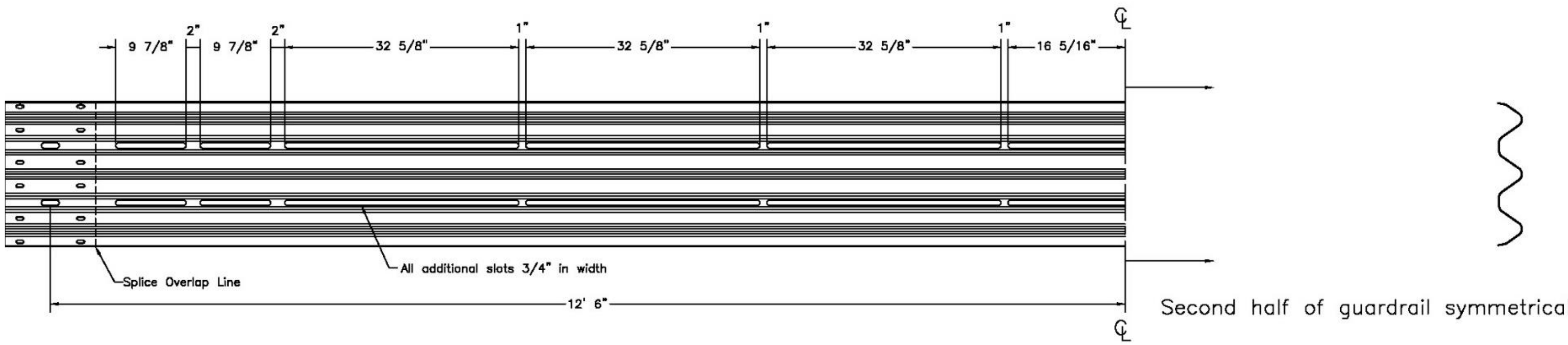


Figure 262. Wide Thrie-Beam Bullnose, Option 2



Rail Section 1 ("Nose" Section) (only half shown, total length 25')



Rail Section 1 ("Nose" Section) (only half shown, total length 25')

Figure 263. Wide Thrie-Beam Bullnose, Option 2

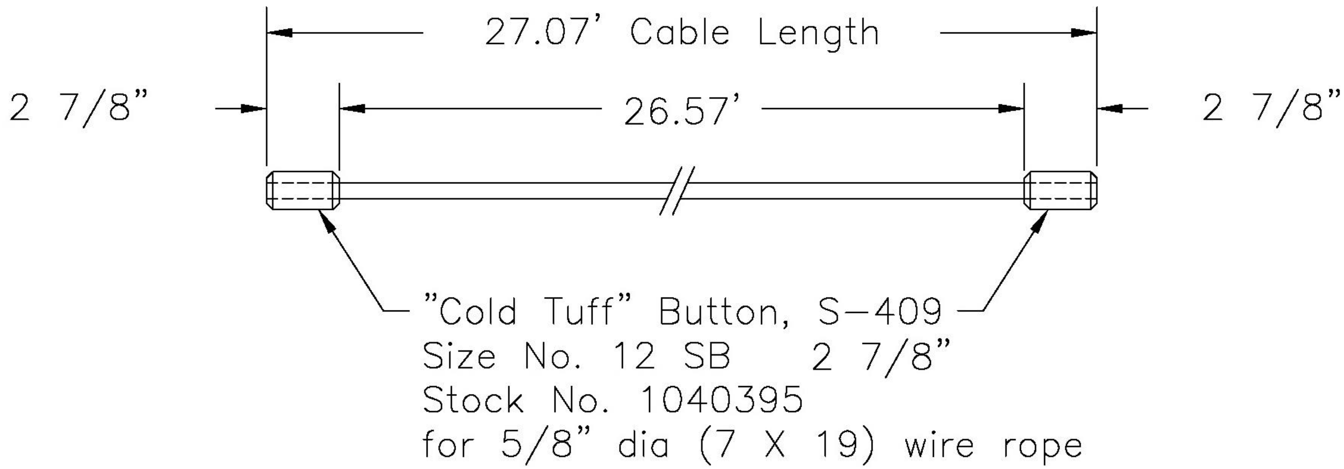


Figure 264. Wide Thrie-Beam Bullnose, Option 2

14.11 Flaring

Flaring the sides of the thrie-beam bullnose system may also be desired in certain applications. For example, while the widened bullnose median barrier may improve the adaptability of the system to applications across wide medians, an appropriate flare will likely be required in most installations in order to meet existing bridge rails. The flare rates used for the bullnose should be obtained based on guidelines set forth in the AASHTO *Roadside Design Guide* [34], or other applicable research. The use of slightly higher flare rates can greatly reduce the length of the bullnose system without creating a significantly higher impact angle on the flared sections. It is recommended that the flare begin no sooner than the start of rail section no. 3 or post no. 5. It is believed that flaring the bullnose system prior to this first straight section could adversely affect the performance of the barrier. While the shape of rail section no. 2 should not be changed, it should be allowable to straighten the end of the section to meet the specified flare rate. Such a configuration would facilitate a smooth transition from the curved guardrail to the flare. A schematic of the three bullnose designs applied to a 30-ft (9.1-m) wide median with twin bridges is shown in Figure 265.

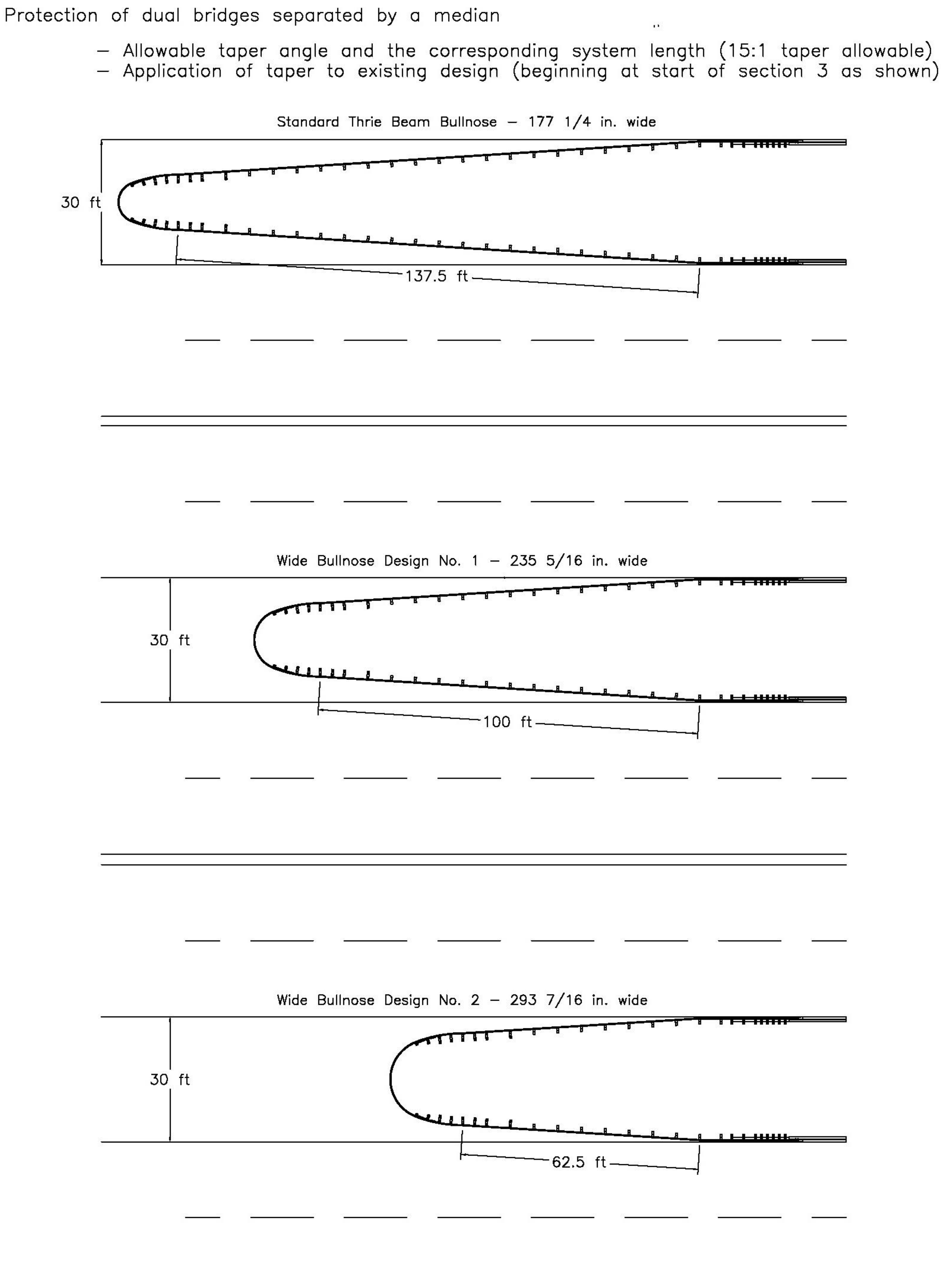


Figure 265. Example of Flared Thrie-Beam Bullnose at Twin Bridge Installations

15 MASH EVALUATION

The thrie-beam bullnose system was evaluated to determine its compliance with MASH 2016 TL-3 evaluation criteria. The thrie-beam bullnose system consists of a guardrail envelope comprising of thrie-beam panels mounted at a height of 31⅝ in. (803 mm) and supported by UBSPs. The nose rail section and the first two adjacent rail sections are radiused and slotted, and the fourth and fifth rail sections are slotted. The combination of the radiused and slotted rail segments and the breakaway posts allows the system to safely capture and decelerate vehicles impacting near the end or nose of the system, while redirecting vehicles impacting along the side. The barrier system was originally developed and evaluated under NCHRP Report No. 350 [4-9].

15.1 Test Matrix

The thrie-beam bullnose system is classified as a non-gating, redirective crash cushion for the purposes of evaluation. In MASH 2016, as many as ten full-scale crash tests are potentially required to evaluate this type of hardware, as shown in Table 30.

As noted previously, Phase I of the research effort consisted of the evaluation of the thrie-beam bullnose system with three critical tests from the recommended MASH test matrix. Based on the previous development and testing of the thrie-beam bullnose system, it was believed that test designation nos. 3-32, 3-34, and 3-35 would be the most critical for evaluation of the system. Test designation nos. 3-34 and 3-35 are conducted on the CIP of the non-gating, redirective crash cushions where it is unknown if the bullnose will capture or redirect the vehicle. It was also recommended that test designation no. 3-32 be conducted early in the research effort to evaluate the capture and safe deceleration of the 1100C small car vehicle when impacting the nose of the system.

Test designation nos. 3-34 and 3-35 are required to be conducted at a CIP where the behavior of the crash cushion transitions between capture and redirection of the impacting vehicle. In order to identify CIPs for these impacts, MwRSF reviewed previous testing of the thrie-beam bullnose system and end terminals and compared this data with the MASH impact conditions for test designation nos. 3-34 and 3-35. In NCHRP No. 350 testing of the steel and wood post bullnose, MwRSF conducted a test similar to MASH test designation no. 3-35 with the 2000P vehicle at post no. 2 in the system at an angle of 20 degrees, and it proved to be a very difficult test to pass. For MASH test designation no. 3-35, the impact angle increased to 25 degrees and the mass of the pickup truck increased. Thus, there was reason to expect that the behavior of the bullnose when impacted at post no. 2 would continue to be capture rather than redirection. One would also expect that the potential to redirect the vehicle becomes high while approaching post no. 5 in the system when the rail becomes parallel to the road and the impact is 12.5 ft (3.8 m) from the anchor. This finding would correlate with post no. 3 for a standard guardrail end terminal, which is typically used for the beginning of the length of need (LON) in terminal impacts. Thus, it was determined that the CIP for MASH test designation no. 3-35 be located at post no. 3, which is halfway between the cable anchor at post no. 1 and the assumed beginning of LON/redirection point at post no. 5.

Table 30. MASH 2016 TL-3 Crash Test Conditions for Bullnose Guardrails

Test Article	Test Designation No.	Test Vehicle	Vehicle Weight, lb (kg)	Impact Conditions		Evaluation Criteria[1]
				Speed, mph (km/h)	Angle, degrees	
Terminals and Redirective Crash Cushions	3-30	1100C	2,420 (1,100)	62 (100)	0	A,D,F,H,I (non-gating)
	3-31	2270P	5,000 (2,270)	62 (100)	0	A,D,F,H,I (non-gating)
	3-32	1100C	2,425 (1,100)	62 (100)	5-15	A,D,F,H,I (non-gating)
	3-33	2270P	5,000 (2,270)	62 (100)	5-15	A,D,F,H,I (non-gating)
	3-34	1100C	2,425 (1,100)	62 (100)	15	A,D,F,H,I (non-gating)
	3-35	2270P	5,000 (2,270)	62 (100)	25	A,D,F,H,I
	3-36	2270P	5,000 (2,270)	62 (100)	25	A,D,F,H,I (non-gating)
	3-37a	2270P	5,000 (2,270)	62 (100)	25	A,D,F,H,I (non-gating)
	3-37b	1100C	2,425 (1,100)	62 (100)	25	A,D,F,H,I (non-gating)
	3-38	1500A	3,300 (1,500)	62 (100)	0	A,D,F,H,I (non-gating)

[1] Evaluation criteria explained in MASH 2016 Table 5-1A through 5-1C

A small car test of the CIP of the transition from capture to redirection was not conducted on the thrie-beam bullnose under NCHRP Report No. 350 as it was not required. Due to the lack of previous thrie-beam bullnose data related to this test, the researchers reviewed MASH terminal testing for the SoftStop and the MASH-Compliant Sequential Kinking Terminal (MSKT) [32-33]. Test designation no. 3-34 on the SoftStop impacted at post no. 1 in the system (at the impact head). Test designation no. 3-35 on the Softstop was conducted at the beginning of LON, and the impact point was at post no. 3. For the MSKT, test designation no. 3-34 was conducted with the impact point at post no. 2, and test designation no. 3-35 was conducted with the impact point at post no. 3. Thus, it appeared that test designation no. 3-34 has been typically conducted upstream from the system LON based on the test having a reduced impact angle of 15 degrees and a lighter vehicle mass than provided by test designation no. 3-35. Because the thrie-beam bullnose system uses as similar cable anchorage to existing end terminal designs near the nose, it was believed that test designation no. 3-34 should be conducted upstream from the LON for end terminals, which would correspond to the third post on a typical end terminal and the fifth post on the thrie-beam bullnose system. Additionally, it was noted previously that test designation no. 3-35 should be conducted on the thrie-beam bullnose system with the CIP located at post no. 3. Thus, the 1100C impact in test designation no. 3-34 should be located upstream from post no. 3 due to the lighter vehicle mass and reduced impact angle. Placement of the CIP at post no. 1 would eliminate the potential for vehicle redirection as the cable anchorage is connected to that post. Thus, post no. 2 on the thrie-beam bullnose system was selected as the CIP for evaluation of the transition of the system's behavior from capture to redirection as this point was upstream from the CIP for test designation no. 3-35 and downstream from a predicted capture behavior at post no. 1 where the cable anchor is located.

MASH 2016 test designation no. 3-32 consists of an 1100C vehicle impacting the center of the nose of the system at an angle ranging from 5 to 15 degrees. The lower end of the angle range is typically recommended for evaluating gating end terminal systems. MASH 2016 recommends that non-gating redirective systems be impacted at a 15-degree angle for this test. Thus, the thrie-beam bullnose system was evaluated with at 15-degree impact angle in test designation no. 3-32.

Phase II of the MASH 2016 TL-3 evaluation of the thrie-beam bullnose system consisted of conducting the remaining full-scale crash tests. Out of the remaining crash tests, three tests were deemed non-critical. Test designation no. 3-36 on the transition to the rigid structure was not be required as it was assumed that the bullnose will use MASH 2016 TL-3 approved, thrie-beam, approach guardrail transitions when connecting to rigid structures. Test designation no. 3-38 is intended to evaluate the performance of mid-sized sedan vehicles with terminals and crash cushions. However, MASH 2016 uses an analytical estimation procedure for 1500A vehicle decelerations based on the results of test designation no. 3-31 to determine whether or not this test is required. Thus, test designation no. 3-38 was deemed non-critical after the analytical results for the 1500A vehicle decelerations were determined. The final non-critical test is test designation no. 3-37 for reverse-direction impacts, which includes test designation 3-37a with the 2270P vehicle and test designation 3-37b with the 1100C vehicle. For systems utilizing a breakaway cable system, such as in end terminals and the thrie-beam bullnose system, MASH 2016 recommends designation no. 3-37b as the critical test to evaluate snag of the 1100C vehicle on the cable anchorage system. Test designation no. 3-37a was deemed non-critical as the thrie-beam bullnose system should perform similar to a longitudinal guardrail when impacted in the reverse direction upstream from the cable anchorage. Further, vehicle capture, stability, and occupant risk were anticipated to be more critical for the 1100C vehicle, similar to previous MASH 2016 TL-3 end terminal evaluations. Previous research regarding small car impacts on trailing-end anchorages for the MGS determined a CIP using LS-DYNA for wedging the 1100C vehicle underneath the rail and the cable anchor on the MGS [11-13]. This CIP was determined to be 112½ in. (2,876 mm) upstream from the end post in the system. Based on the similarity of the cable anchorage used in the MGS trailing-end anchorage and the thrie-beam bullnose anchorage, the researchers elected to use the same CIP for test designation no. 3-37b to maximize the probability of vehicle and wheel snag on the cable anchor. This impact point corresponded to the center of the fourth post upstream from the anchorage post on the bullnose system.

Thus, a total of seven tests were conducted to complete the MASH 2016 TL-3 test matrix for evaluation of the thrie-beam bullnose system. These tests were test designation nos. 3-30, 3-31, 3-32, 3-33, 3-34, 3-35, and 3-37b.

15.2 Full-Scale Crash Test Results

The results of the MASH TL-3 full-scale crash testing of the thrie-beam bullnose system are summarized below. A summary of the full-scale crash testing is provided in Table 31. A plan and elevation view of the final system configuration and a system photo are provide in Figure 266.

1. Test no. MSPBN-1 – Test no. MSPBN-1 was conducted on the thrie-beam bullnose system according to MASH 2016 test designation no. 3-35 with a 2270P vehicle at an impact speed of 62.9 mph (101.2 km/h) and an angle of 25.1 degrees. Test no. MSPBN-1 was conducted to examine the CIP of the bullnose system where its behavior transitioned from capture to redirection. During the test, the vehicle was captured and safely redirected by the bullnose system, and test no. MSPBN-1 met all the safety requirements for MASH 2016 TL-3.

2. Test no. MSPBN-2 - Test no. MSPBN-2 was conducted on the thrie-beam bullnose system according to MASH 2016 test designation no. 3-34 with an 1100C vehicle at an impact speed of 62.1 mph (99.9 km/h) and an angle of 14.7 degrees. Test no. MSPBN-2 was conducted to evaluate the impact performance of the bullnose at the point where the device transitions from capture to redirection. During the test, the vehicle was captured and safely redirected by the bullnose system, and test no. MSPBN-2 met all the safety requirements for MASH 2016 TL-3.

3. Test no. MSPBN-3 - Test no. MSPBN-3 was conducted on the thrie-beam bullnose system according to MASH 2016 test designation no. 3-32 with an 1100C vehicle at an impact speed of 62.7 mph (100.9 km/h) and an angle of 15.1 degrees. Test no. MPSNB-3 was conducted to evaluate the bullnose behavior during oblique impacts on the end or nose of the system. During the test, the vehicle was captured and safely decelerated to a controlled stop by the bullnose system, and test no. MSPBN-3 met all the safety requirements for MASH 2016 TL-3.

4. Test no. MSPBN-4 - Test no. MSPBN-4 was conducted on the thrie-beam bullnose system according to MASH 2016 test designation no. 3-30 with an 1100C vehicle at an impact speed of 62.1 mph (99.9 km/h) and an angle of 1.3 degrees. During the test, the vehicle was initially captured by the thrie-beam nose of the system. However, as the vehicle proceeded into the system, the slot between the upper two corrugations of thrie beam and the lowest corrugation opened. This behavior allowed the top two thrie-beam corrugations to push upward and the lower thrie-beam corrugation to move downward and rupture. This separation compromised the capture of the vehicle front end and allowed the vehicle to penetrate the system. Thus, the system was not acceptable under the MASH 2016 TL-3 criteria. Following test no. MSPBN-4, the researchers reviewed the results from the test to determine factors that influenced the failure of the system as well as to suggest potential modifications to the thrie-beam bullnose system to improve its performance. Based on this analysis, it was determined that the best option for improving the system performance would be to add a third nose cable behind the lowest thrie-beam corrugation. All subsequent tests were conducted on a modified version of the bullnose system with a third nose cable.

5. Test no. MSPBN-5 - Test no. MSPBN-5 was conducted on the modified thrie-beam bullnose system according to MASH 2016 test designation no. 3-30 with an 1100C vehicle

at an impact speed of 62.7 mph (100.9 km/h) and at an angle of 0.3 degrees. During the test, the vehicle was captured by the thrie-beam nose of the system, and the system decelerated the vehicle to a safe and controlled stop. Test no. MSPBN-5 met all the safety requirements for MASH 2016 TL-3.

6. Test no. MSPBN-6 - Test no. MSPBN-6 was conducted on the modified thrie-beam bullnose system according to MASH 2016 test designation no. 3-31 with an 2270P vehicle at an impact speed of 63.4 mph (102.1 km/h) and at an angle of 0.3 degrees. During the test, the vehicle was captured by the thrie-beam bullnose system, and the system decelerated the vehicle to a safe and controlled stop. Test no. MSPBN-6 met all the safety requirements for MASH 2016 TL-3.

7. Test no. MSPBN-7 - Test no. MSPBN-7 was conducted on the modified thrie-beam bullnose system according to MASH 2016 test designation no. 3-33 with an 2270P vehicle at an impact speed of 63.1 mph (101.6 km/h) and at an angle of 15.1 degrees. During the test, the vehicle was captured by the thrie-beam bullnose system, and the system decelerated the vehicle to a safe and controlled stop. Test no. MSPBN-7 met all the safety requirements for MASH 2016 TL-3.

8. Test no. MSPBN-8 - Test no. MSPBN-8 was conducted on the modified thrie-beam bullnose system according to MASH 2016 test designation no. 3-37b with an 1100C vehicle at an impact speed of 63.2 mph (101.8 km/h) and at an angle of 25.0 degrees at a CIP determined to maximize the potential for vehicle snag on the cable anchorage when impacted in the reverse direction. During the test, the vehicle was captured and redirected by the thrie beam on the side of the bullnose system, vehicle interaction with the cable anchorage was not observed, and the anchorage remained intact. Test no. MSPBN-8 met all the safety requirements for MASH 2016 TL-3.

Table 31. MASH 2016 TL-3 Crash Test Summary for Thrie-Beam Bullnose

MwRSF Test No.	MASH Test Designation No.	MwRSF Report No.	Date of Test	Pass/Fail	System Version
MSPBN-1	3-35	TRP-03-389-20	03/03/17	Pass	1
MSPBN-2	3-34	TRP-03-389-20	03/22/17	Pass	1
MSPBN-3	3-32	TRP-03-389-20	04/11/17	Pass	1
MSPBN-4	3-30	TRP-03-418-20	04/18/185	Fail	1
MSPBN-5	3-30	TRP-03-418-20	05/15/18	Pass	2
MSPBN-6	3-31	TRP-03-418-20	05/24/18	Pass	2
MSPBN-7	3-33	TRP-03-418-20	06/05/18	Pass	2
MSPBN-8	3-37b	TRP-03-418-20	08/29/18	Pass	2

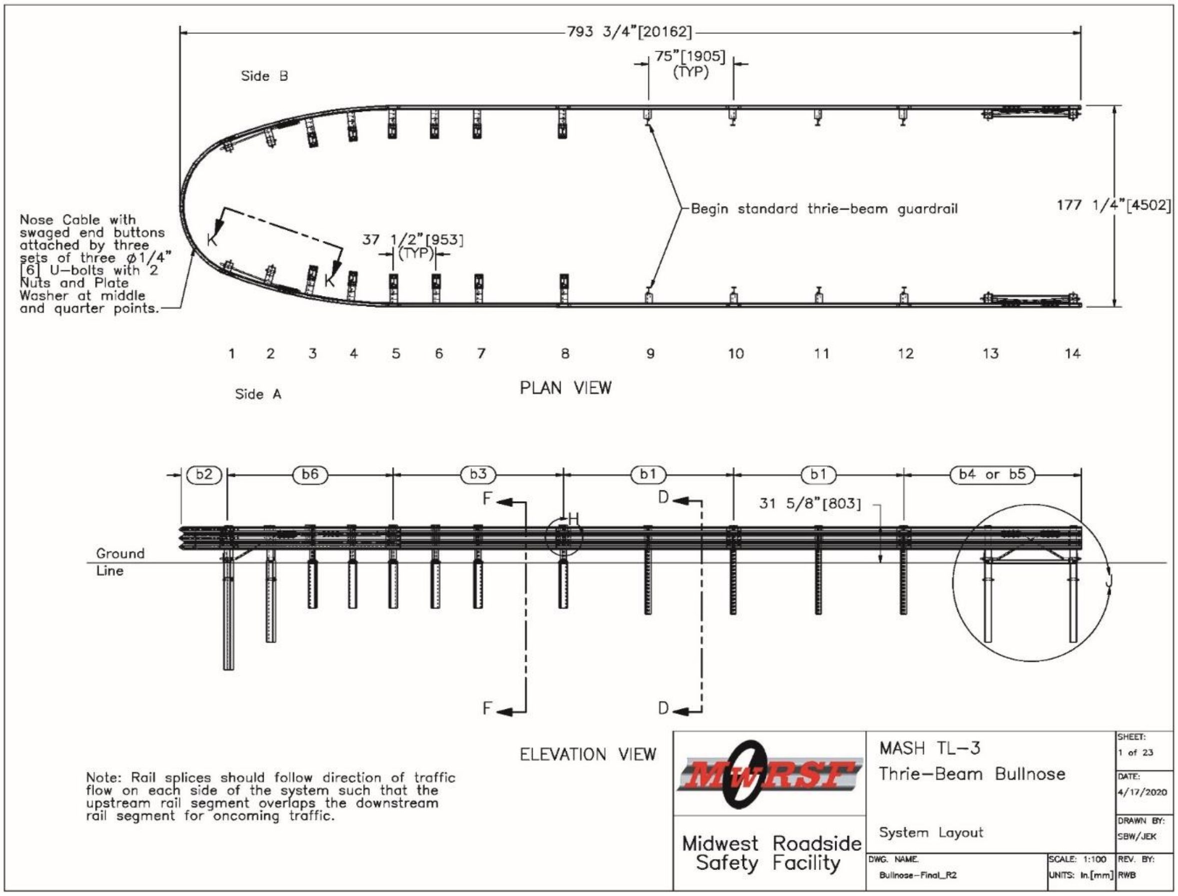


Figure 266. MASH TL-3 Thrie-Beam Bullnose

15.3 Bullnose Modification

Following the unsuccessful results from test no. MSPBN-4, the researchers reviewed the test to determine factors that influenced the failure of the system as well as to suggest potential modifications to the thrie-beam bullnose system to improve its performance. Based on this analysis, it was determined that the best option for improving system performance would be to add a third nose cable behind the lowest thrie-beam corrugation.

The addition of a third nose cable was not expected to affect the safety performance of the thrie-beam bullnose system relative to the three previous, successful MASH 2016 crash tests (test designation nos. 3-32, 3-34, and 3-35). Test designation nos. 3-34 and 3-35 were conducted on the side of the system outside of the region where the nose cables are located. Thus, the addition of a third nose cable would have no effect on the outcome of those tests. Test designation no. 3-32 was conducted with the 1100C vehicle impacting the nose of the system at an angle of 15 degrees. This test demonstrated no capture issues with respect to the 1100C vehicle with only the original two nose cables. Thus, the additional of the third nose cable was not expected to negatively affect the outcome of that test either. As such, it was determined that these tests would not need to be rerun on the thrie-beam bullnose system if the proposed modification was successful.

15.4 1500A Estimation Procedure

Following the full-scale crash testing, an analysis procedure was performed using the accelerometer data from test no. MSPBN-6 to determine if test designation no. 3-38 was required for evaluating of the thrie-beam bullnose system. MASH 2016 allows the use of an analytical estimation procedure for the 1500A vehicle based on the results from test designation no. 3-31 to determine whether or not this test is required. The procedure consists of estimating the occupant risk values for the 1500A test based on the acceleration trace obtained from test designation no. 3-31.

An analysis was performed using the acceleration versus time data from the primary accelerometer in test no. MSPBN-6 to estimate the occupant risk values for the 1500A sedan vehicle, as described in MASH 2016 Appendix G. The results are shown in Table 32. The estimated OIV and ORA values for the 1500A vehicle impact with the thrie-beam bullnose system were well below the MASH 2016 limits. As such, test designation no. 3-38 was deemed non-critical for the thrie-beam bullnose system and was not conducted.

Table 32. Longitudinal OIV and ORA Estimates for MASH 2016 1500A Estimation Procedure for Thrie-Beam Bullnose System Based on Test No. MSPBN-6

Evaluation Criteria		**1500A Estimation Procedure**	**MASH 2016 Limits**
OIV ft/s (m/s)	Longitudinal	-24.37 (-7.43)	±40 (12.2)
ORA g's	Longitudinal	-13.75	±20.49

15.5 MASH 2016 Evaluation

Based on the results of the three successful full-scale crash tests conducted in the previous study, the four successful full-scale crash tests conducted in this study, and the results of the estimation procedure for test designation no. 3-38, the modified thrie-beam bullnose system with a third nose cable meets all of the safety requirements for MASH 2016 TL-3.

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17 APPENDICES

Appendix A. Vehicle Center of Gravity Determination

Date:	4/18/2018	Test Name:	MSPBN-4	VIN:	KNADE223496469475
Year:	2009	Make:	KIA	Model:	RIO

Vehicle CG Determination

	Vehicle Equipment	Weight (lb.)
+	Unballasted Car (Curb)	2472
+	Hub	19
+	Brake activation cylinder & frame	7
+	Pneumatic tank (Nitrogen)	27
+	Strobe/Brake Battery	5
+	Brake Receiver/Wires	6
+	CG Plate including DAS	10
-	Battery	-25
-	Oil	-10
-	Interior	-48
-	Fuel	-23
-	Coolant	-7
-	Washer fluid	
+	Water Ballast (In Fuel Tank)	
+	Onboard Supplemental Battery	0
-	Junk in the Trunk	10
+	DTS	17

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb.) 2460

Vehicle Dimensions for C.G. Calculations

Wheel Base:	98 1/4	in.	Front Track Width:	57 3/4	in.
Roof Height:	57 1/2	in.	Rear Track Width:	57 1/5	in.

Center of Gravity	1100C MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb.)	2420 ± 55	2429	9.0
Longitudinal CG (in.)	39 ± 4	36.242075	-2.75793
Lateral CG (in.)	NA	-0.626975	NA
Vertical CG (in.)	NA	22.58	NA

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

Note: Lateral CG measured from centerline - positive to vehicle right (passenger) side

CURB WEIGHT (lb.)

	Left	Right
Front	800	751
Rear	454	467

FRONT	1551	lb.
REAR	921	lb.
TOTAL	2472	lb.

TEST INERTIAL WEIGHT (lb.)

	Left	Right
Front	797	736
Rear	444	452

FRONT	1533	lb.
REAR	896	lb.
TOTAL	2429	lb.

Figure A-1. Vehicle Mass Distribution, Test No. MSPBN-4

Date:	5/15/2018	Test Name:	MSPBN-5	VIN:	KMHCN46C39U386700
Year:	2009	Make:	ACCENT	Model:	HYUNDAI

Vehicle CG Determination

	Vehicle Equipment	Weight (lb.)
+	Unballasted Car (Curb)	2461
+	Hub	19
+	Brake activation cylinder & frame	8
+	Pneumatic tank (Nitrogen)	22
+	Strobe/Brake Battery	5
+	Brake Receiver/Wires	5
+	CG Plate including DAS	13
-	Battery	-31
-	Oil	-13
-	Interior	-55
-	Fuel	-16
-	Coolant	-6
-	Washer fluid	-7
+	Water Ballast (In Fuel Tank)	0
+	Onboard Supplemental Battery	0

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb.) 2405

Vehicle Dimensions for C.G. Calculations

Wheel Base:	98.625 in.		Front Track Width:	57.813 in.	
Roof Height:	58.125 in.		Rear Track Width:	57.188 in.	

Center of Gravity	1100C MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb.)	2420 ± 55	2409	-11.0
Longitudinal CG (in.)	39 ± 4	36.232	-2.768
Lateral CG (in.)	NA	0.06	NA
Vertical CG (in.)	NA	22.882	NA

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

Note: Lateral CG measured from centerline - positive to vehicle right (passenger) side

CURB WEIGHT (lb.)

	Left	Right
Front	808	774
Rear	434	445

FRONT	1582	lb.
REAR	879	lb.
TOTAL	2461	lb.

TEST INERTIAL WEIGHT (lb.)

	Left	Right
Front	759	765
Rear	443	442

FRONT	1524	lb.
REAR	885	lb.
TOTAL	2409	lb.

Figure A-2. Vehicle Mass Distribution, Test No. MSPBN-5

Date:	6/5/2018	Test Name:	MSPBN-6	VIN:	1C6RD6KT3CS268370
Year:	2012	Make:	Dodge	Model:	Ram 1500

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb.)	Vertical CG (in.)	Vertical M (lb.-in.)
+	Unballasted Truck (Curb)	5210	29.41824	153269.03
+	Hub	19	16	304
+	Brake activation cylinder & frame	7	30 1/2	213.5
+	Pneumatic tank (Nitrogen)	30	26 3/4	802.5
+	Strobe/Brake Battery	5	29 3/4	148.75
+	Brake Receiver/Wires	6	55 1/4	331.5
+	CG Plate including DAS	50	33 11/16	1684.375
-	Battery	-37	44	-1628
-	Oil	-14	19	-266
-	Interior	-77	37 3/8	-2877.875
-	Fuel	-164	22 1/2	-3690
-	Coolant	-6	36 1/4	-217.5
-	Washer fluid	-2	40 3/4	-81.5
+	Water Ballast (In Fuel Tank)	0	0	0
+	Onboard Supplemental Battery	14	27	378
				0
				0
				148370.78

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb.)	5041
Vertical CG Location (in.)	29.4328

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.25 in.

Front Track Width: 67.75 in.

Rear Track Width: 68.5 in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb.)	5000 ± 110	5061	61.0
Longitudinal CG (in.)	63 ± 4	61.326467	-1.67353
Lateral CG (in.)	NA	0.275946	NA
Vertical CG (in.)	28 or greater	29.43	1.43281

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

Note: Lateral CG measured from centerline - positive to vehicle right (passenger) side

CURB WEIGHT (lb.)

	Left	Right
Front	1463	1448
Rear	1146	1153

FRONT	2911	lb.
REAR	2299	lb.
TOTAL	5210	lb.

TEST INERTIAL WEIGHT (lb.)

	Left	Right
Front	1384	1464
Rear	1126	1087

FRONT	2848	lb.
REAR	2213	lb.
TOTAL	5061	lb.

Figure A-3. Vehicle Mass Distribution, Test No. MSPBN-6

Date:	6/5/2018	Test Name:	MSPBN7	VIN:	1C6RD6KT4CS197048
Year:	2012	Make:	Dodge	Model:	Ram 1500

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb.)	Vertical CG (in.)	Vertical M (lb.-in.)
+	Unballasted Truck (Curb)	5271	29.563757	155830.56
+	Hub	19	15.375	292.125
+	Brake activation cylinder & frame	8	28 1/2	228
+	Pneumatic tank (Nitrogen)	27	26 1/4	708.75
+	Strobe/Brake Battery	5	27	135
+	Brake Receiver/Wires	6	54 3/8	326.25
+	CG Plate including DAS	50	32 1/8	1606.25
-	Battery	-48	45	-2160
-	Oil	-12	16	-192
-	Interior	-106	55 1/2	-5883
-	Fuel	-159	20 3/4	-3299.25
-	Coolant	-16	36	-576
-	Washer fluid	0	0	0
+	Water Ballast (In Fuel Tank)	0	0	0
+	Onboard Supplemental Battery	14	25 1/2	357
+	Supplemental Test Equipment	9	24 1/2	220.5
				0
				147594.19

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb.)	5068
Vertical CG Location (in.)	29.1228

Vehicle Dimensions for C.G. Calculations

Wheel Base:	140.5	in.	Front Track Width:	67.875	in.
			Rear Track Width:	68	in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb.)	5000 ± 110	5043	43.0
Longitudinal CG (in.)	63 ± 4	61.571485	-1.42851
Lateral CG (in.)	NA	0.0875657	NA
Vertical CG (in.)	28 or greater	29.12	1.12277

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

Note: Lateral CG measured from centerline - positive to vehicle right (passenger) side

CURB WEIGHT (lb.)

	Left	Right
Front	1489	1464
Rear	1148	1170

FRONT	2953	lb.
REAR	2318	lb.
TOTAL	5271	lb.

TEST INERTIAL WEIGHT (lb.)

	Left	Right
Front	1424	1409
Rear	1091	1119

FRONT	2833	lb.
REAR	2210	lb.
TOTAL	5043	lb.

Figure A-4. Vehicle Mass Distribution, Test No. MSPBN-7

Date:	8/28/2018	Test Name:	MSPBN-8	VIN:	kmhcn4ac3bu533692
Year:	2011	Make:	Hyundai	Model:	Accent

Vehicle CG Determination

	Vehicle Equipment	Weight (lb.)
+	Unballasted Car (Curb)	2476
+	Hub	19
+	Brake activation cylinder & frame	7
+	Pneumatic tank (Nitrogen)	22
+	Strobe/Brake Battery	5
+	Brake Receiver/Wires	5
+	CG Plate including DAS	13
-	Battery	-31
-	Oil	-9
-	Interior	-72
-	Fuel	-20
-	Coolant	-6
-	Washer fluid	-8
+	Water Ballast (In Fuel Tank)	0
+	Onboard Supplemental Battery	0
+	Smart	9

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb.) 2410

Vehicle Dimensions for C.G. Calculations

Wheel Base:	98.5	in.	Front Track Width:	57.5	in.
Roof Height:	57.875	in.	Rear Track Width:	57.25	in.

Center of Gravity	1100C MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb.)	2420 ± 55	2394	-26.0
Longitudinal CG (in.)	39 ± 4	36.413	-2.587
Lateral CG (in.)	NA	-0.072	NA
Vertical CG (in.)	NA	22.332	NA

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

Note: Lateral CG measured from centerline - positive to vehicle right (passenger) side

CURB WEIGHT (lb.)

	Left	Right
Front	798	775
Rear	447	456

FRONT	1573	lb.
REAR	903	lb.
TOTAL	2476	lb.

TEST INERTIAL WEIGHT (lb.)

	Left	Right
Front	761	748
Rear	439	446

FRONT	1509	lb.
REAR	885	lb.
TOTAL	2394	lb.

Figure A-5. Vehicle Mass Distribution, Test No. MSPBN-8

Appendix B. Material Specifications

Table B-1. Bill of Materials, Test No. MSPBN-4

Item No.	Description	Material Spec	Material Cert Reference
a1	TS8"x6"x$^{3}/_{16}$" [203x152x5], 96" [2,438] Long Foundation Tube	ASTM A500 Gr. B	H#A49248
a2	TS8"x6"x$^{3}/_{16}$" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	H#A49248
a3	8"x8"x⅝" [203x203x16] Anchor Bearing Plate	ASTM A36	H#DL15103543 H#4181496
a4	Lower Slip Post Assembly	Plate-ASTM A36 Foundation Tube-ASTM A500 Gr. B	Tube: H#17043541 Plate: H#7503198
a5	Upper Slip Post Assembly	Plate: ASTM A36 Post: ASTM A992	H#B7TS144-02 Post: H#58031555
a6	6"x8"x14¼" [152x203x362] Timber Blockout	SYP Grade No. 1 or better	Charge#24195
a7	6"x8"x14¼" [152x203x362] Tapered Timber Blockout -Side A	SYP Grade No. 1 or better	Charge#22927
a8	6"x8"x14¼" [152x203x362] Tapered Timber Blockout -Side B	SYP Grade No. 1 or better	Charge#4844
b1	12'-6" [3,810] 12 gauge [2.7] Thrie Beam Section	AASHTO M180	H#219447 H#220022 H#220023
b2	12'-6" [3,810] 12 gauge [2.7] Bent Thrie Beam Section	AASHTO M180	H#203662 H#206981
b3	12'-6" [3,810] 12 gauge [2.7] Thrie Beam Section	AASHTO M180	H#L32817 H#206981 H#206982 H#A86939
b4	12'-6" [3,810] 12 gauge [2.7] Thrie Beam End Section -Side A	AASHTO M180	H#130217
b5	12'-6" [3,810] 12 gauge [2.7] Thrie Beam End Section -Side B	AASHTO M180	H#208318 H#208674
b6	12'-6" [3,810] 12 gauge [2.7] Bent Thrie Beam Section -Side A	AASHTO M180	H#L31917
c1	$^{7}/_{16}$" [11] Dia. UNC, 2½" [64] Long Hex Tap Bolt (Fully Threaded) and Nut	Bolt - ASTM A449 or SAE J429 Gr. 5 Nut - ASTM A563DH or J995 Gr. 5	Bolts: H#4209984BB Nuts: H#360796
c2	⅝" [16] Dia. UNC, 10" [254] Long Hex Head Bolt	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolts: H#DL15107048 Nuts: H#331608011
c3	⅝" [16] Dia. UNC, 1¼" [32] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolt: H#20460760 Nut: H#10470360
c4	⅝" [16] Dia. UNC, 1½" [38] Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolt: H#816070039 Nut: H#331608011
c5	⅝" [16] Dia. UNC, 18" [457] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolt: H#29145-B Nut: H#10470360

Table B-2. Bill of Materials, Test No. MSPBN-4, Cont.

Item No.	Description	Material Spec	Material Cert Reference
c6	⅞" [22] Dia. UNC, 8" [203] Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	6" Bolt: H#2038622 Nut: H#NF12101054 8" Bolt: H#X51512089002 Nut: H#1XS51
c7	⅝" [16] Dia. UNC, 10" [254] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolt: H#20351510 Nut: H#10470360
c8	16D Double Head Nail	-	L# 97812A109
e1	$^{7}/_{16}$" [11] Dia. Plain Round Washer	ASTM F844	L#33183
e2	⅝" [16] Dia. Plain Round Washer	ASTM F844	n/a
e3	⅞" [22] Dia. Plain Round Washer	ASTM F844	n/a
f1	BCT Timber Post - MGS Height	SYP Grade No. 1 or better (No knots +/- 18" [457] from ground on tension face)	Charge#24096
f2	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 78" [1,981] Long Steel Post	ASTM A992	H#55044245
g1	BCT Anchor Cable Assembly	-	North End: R#18-642 South End: R#17-282
g2	2⅜" [60] O.D. x 6" [152] Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	H#A79999
g3	⅝" Dia. [15.9] x 14.4' [4,389] Long Cable and Swage Button	"Cold Tuff" Button, S-409 Size No. 12 SB, Stock No. 1040395 for ⅝" [16] Dia. (6x19) wire rope (or any similarly sized swage-grip button ferrules)	Order#248853
g4	12⅝"x5$^{13}/_{16}$"x$^{3}/_{16}$" [321x148x5] Nose Cable Anchor Plate	ASTM A36	H#B4M5475
g5	2¼"x¾" [57x19] 11 gauge [3] U-Bolt Plate Washer	ASTM A1011 CS Type B	H#B609769
g6	¼" [6] Dia. U-Bolt and Nut	U-Bolt-ASTM A307 Gr.A Nut-ASTM A563A	Bolt: H#71067E Nut: H#184259
h1	Ground Strut Assembly	ASTM A36	PO#2030
h2	Anchor Bracket Assembly	ASTM A36	H#JK16101488

Table B-3. Bill of Materials, Test No. MSPBN-5

Item No.	Description	Material Spec	Material Cert Reference
a1	TS8"x6"x$^3/_{16}$" [203x152x5], 96" [2,438] Long Foundation Tube	ASTM A500 Gr. B	H#A49248
a2	TS8"x6"x$^3/_{16}$" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	H#A49248
a3	8"x8"x⅝" [203x203x16] Anchor Bearing Plate	ASTM A36	H#DL15103543 H#4181496
a4	Lower Slip Post Assembly	Plate-ASTM A36 Foundation Tube-ASTM A500 Gr. B	Tube: H#17043541 Plate: H#7503198
a5	Upper Slip Post Assembly	Plate: ASTM A36 Post: ASTM A992	H#B7TS144-02 Post: H#58031555
a6	6"x8"x14¼" [152x203x362] Timber Blockout	SYP Grade No. 1 or better	Charge#24195 Charge#4844
a7	6"x8"x14¼" [152x203x362] Tapered Timber Blockout -Side A	SYP Grade No. 1 or better	Charge#22927
a8	6"x8"x14¼" [152x203x362] Tapered Timber Blockout -Side B	SYP Grade No. 1 or better	Charge#22927
b1	12'-6" [3,810] 12 gauge [2.7] Thrie Beam Section	AASHTO M180	H#219447 H#220022 H#220023
b2	12'-6" [3,810] 12 gauge [2.7] Bent Thrie Beam Section	AASHTO M180	H#203662 H#206981
b3	12'-6" [3,810] 12 gauge [2.7] Thrie Beam Section	AASHTO M180	H#L32817 H#206981 H#206982 H#A86939
b4	12'-6" [3,810] 12 gauge [2.7] Thrie Beam End Section -Side A	AASHTO M180	H#130217
b5	12'-6" [3,810] 12 gauge [2.7] Thrie Beam End Section -Side B	AASHTO M180	H#208318 H#208674
b6	12'-6" [3,810] 12 gauge [2.7] Bent Thrie Beam Section -Side A	AASHTO M180	H#L31917
c1	$^7/_{16}$" [11] Dia. UNC, 2½" [64] Long Hex Tap Bolt (Fully Threaded) and Nut	Bolt - ASTM A449 or SAE J429 Gr. 5 Nut - ASTM A563DH or J995 Gr. 5	Bolts: H#4209984BB Nuts: H#360796
c2	⅝" [16] Dia. UNC, 10" [254] Long Hex Head Bolt	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolts: H#DL15107048 H#JK17100352 Nuts: H#331608011
c3	⅝" [16] Dia. UNC, 1¼" [32] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolt: H#20460760 Nut: H#10470360
c4	⅝" [16] Dia. UNC, 1½" [38] Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolt: H#816070039 Nut: H#331608011
c5	⅝" [16] Dia. UNC, 18" [457] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolt: H#NF16102734 H#100885399 Nut: H#10470360

Table B-4. Bill of Materials, Test No. MSPBN-5, Cont.

Item No.	Description	Material Spec	Material Cert Reference
c6	⅞" [22] Dia. UNC, 8" [203] Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	6” Bolt: H#2038622 Nut: H#NF12101054 8” Bolt: H#X51512089002 Nut: H#1XS51
c7	⅝" [16] Dia. UNC, 10" [254] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolt: H#20351510 H#DL16102715 Nut: H#10470360
c8	16D Double Head Nail	-	L# 97812A109
e1	7/16" [11] Dia. Plain Round Washer	ASTM F844	L#33183
e2	⅝" [16] Dia. Plain Round Washer	ASTM F844	n/a
e3	⅞" [22] Dia. Plain Round Washer	ASTM F844	n/a
f1	BCT Timber Post - MGS Height	SYP Grade No. 1 or better (No knots +/- 18" [457] from ground on tension face)	Charge#24096
f2	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 78" [1,981] Long Steel Post	ASTM A992	H#55044245
g1	BCT Anchor Cable Assembly	-	R#18-642
g2	2⅜" [60] O.D. x 6" [152] Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	H#A79999
g3	⅝" Dia. [15.9] x 14.4' [4,389] Long Cable and Swage Button	"Cold Tuff" Button, S-409 Size No. 12 SB, Stock No. 1040395 for ⅝" [16] Dia. (6x19) wire rope (or any similarly sized swage-grip button ferrules)	H#590070
g4	12⅝"x5 13/16"x3/16" [321x148x5] Nose Cable Anchor Plate	ASTM A36	H#B4M5475
g5	2¼"x¾" [57x19] 11 gauge [3] U-Bolt Plate Washer	ASTM A1011 CS Type B	H#B609769
g6	¼" [6] Dia. U-Bolt and Nut	U-Bolt-ASTM A307 Gr.A Nut-ASTM A563A	Bolt: H#71067E Nut: H#184259
h1	Ground Strut Assembly	ASTM A36	PO#2030
h2	Anchor Bracket Assembly	ASTM A36	H#JK16101488

Table B-5. Bill of Materials, Test Nos. MSPBN-6 and MSPBN-7

Item No.	Description	Material Spec	Material Cert Reference
a1	TS8"x6"x$^{3}/_{16}$" [203x152x5], 96" [2,438] Long Foundation Tube	ASTM A500 Gr. B	H#A49248
a2	TS8"x6"x$^{3}/_{16}$" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	H#A49248
a3	8"x8"x⅝" [203x203x16] Anchor Bearing Plate	ASTM A36	H#DL15103543 H#4181496
a4	Lower Slip Post Assembly	Plate-ASTM A36 Foundation Tube-ASTM A500 Gr. B	Tube: H#17043541 Plate: H#7503198
a5	Upper Slip Post Assembly	Plate: ASTM A36 Post: ASTM A992	H#B7TS144-02 Post: H#58031555
a6	6"x8"x14¼" [152x203x362] Timber Blockout	SYP Grade No. 1 or better	Ch#24195 Ch#22927 Ch#24096
a7	6"x8"x14¼" [152x203x362] Tapered Timber Blockout -Side A	SYP Grade No. 1 or better	Ch#24195 Ch#22927
a8	6"x8"x14¼" [152x203x362] Tapered Timber Blockout -Side B	SYP Grade No. 1 or better	Ch#24195 Ch#22927
b1	12'-6" [3,810] 12 gauge [2.7] Thrie Beam Section	AASHTO M180	H#219447 H#220022 H#220023
b2	12'-6" [3,810] 12 gauge [2.7] Bent Thrie Beam Section	AASHTO M180	H#203663 H#216682 H#216683
b3	12'-6" [3,810] 12 gauge [2.7] Thrie Beam Section	AASHTO M180	H#208318 H#206981 H#206982
b4	12'-6" [3,810] 12 gauge [2.7] Thrie Beam End Section -Side A	AASHTO M180	H#219447 H#220022 H#130217
b5	12'-6" [3,810] 12 gauge [2.7] Thrie Beam End Section -Side B	AASHTO M180	H#208318 H#208674
b6	12'-6" [3,810] 12 gauge [2.7] Bent Thrie Beam Section -Side A	AASHTO M180	H#220023
b7	6'-3" [1,905] 12-gauge [2.7] Thrie Beam Section	AASHTO M180	H#A86939
c1	$^{7}/_{16}$" [11] Dia. UNC, 2½" [64] Long Hex Tap Bolt (Fully Threaded) and Nut	Bolt - ASTM A449 or SAE J429 Gr. 5 Nut - ASTM A563DH or J995 Gr. 5	Bolts: H#4209984BB Nuts: H#360796
c2	⅝" [16] Dia. UNC, 10" [254] Long Hex Head Bolt	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	H#DL15107048 H#JK17100352
c3	⅝" [16] Dia. UNC, 1¼" [32] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolt: H#20460760 Nut: H#10470360
c4	⅝" [16] Dia. UNC, 1½" [38] Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolt: H#816070039 Nut: H#331608011

Table B-6. Bill of Materials, Test Nos. MSPBN-6 and MSPBN-7, Cont.

Item No.	Description	Material Spec	Material Cert Reference
c5	⅝" [16] Dia. UNC, 18" [457] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	H#100885399
c6	⅞" [22] Dia. UNC, 8" [203] Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	6" Bolt: H#2038622 Nut: H#NF12101054 8" Bolt: H#X51512089002 Nut: H#1XS51
c7	⅝" [16] Dia. UNC, 10" [254] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolt: H#20351510 H#DL16102715 Nut: H#10470360
c8	16D Double Head Nail	-	L# 97812A109
e1	7/16" [11] Dia. Plain Round Washer	ASTM F844	L#33183
e2	⅝" [16] Dia. Plain Round Washer	ASTM F844	n/a
e3	⅞" [22] Dia. Plain Round Washer	ASTM F844	n/a
f1	BCT Timber Post - MGS Height	SYP Grade No. 1 or better (No knots +/- 18" [457] from ground on tension face)	Charge#24096
f2	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 78" [1,981] Long Steel Post	ASTM A992	H#55044245
f3	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 68⅝" [1,743]	ASTM A992	H#55044245
g1	BCT Anchor Cable Assembly	-	R#18-642
g2	2⅜" [60] O.D. x 6" [152] Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	H#B712810
g3	⅝" Dia. [15.9] x 14.4' [4,389] Long Cable and Swage Button	"Cold Tuff" Button, S-409 Size No. 12 SB, Stock No. 1040395 for ⅝" [16] Dia. (6x19) wire rope (or any similarly sized swage-grip button ferrules)	R#18-642 R#17-282
g4	12⅝"x5 13/16"x3/16" [321x148x5] Nose Cable Anchor Plate	ASTM A36	H#B4M5475
g5	2¼"x¾" [57x19] 11 gauge [3] U-Bolt Plate Washer	ASTM A1011 CS Type B	H#B609769
g6	¼" [6] Dia. U-Bolt and Nut	U-Bolt-ASTM A307 Gr.A Nut-ASTM A563A	Bolt: H#71067E Nut: H#184259
h1	Ground Strut Assembly	ASTM A36	PO#2030
h2	Anchor Bracket Assembly	ASTM A36	H#JK16101488

Table B-7. Bill of Materials, Test No. MSPBN-8

Item No.	Description	Material Spec	Material Cert Reference
a1	TS8"x6"x3/16" [203x152x5], 96" [2,438] Long Foundation Tube	ASTM A500 Gr. B	H#A49248
a2	TS8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	H#A49248 Post 13A H#811T08220
a3	8"x8"x⅝" [203x203x16] Anchor Bearing Plate	ASTM A36	H#DL15103543 H#4181496
a4	Lower Slip Post Assembly	Plate-ASTM A36 Foundation Tube-ASTM A500 Gr. B	Tube: H#17043541 Plate: H#7503198
a5	Upper Slip Post Assembly	Plate: ASTM A36 Post: ASTM A992	Post: H#59072444/02 Plate: H#B6U5630
a6	6"x8"x14¼" [152x203x362] Timber Blockout	SYP Grade No. 1 or better	Ch#24195 Ch#24883
a7	6"x8"x14¼" [152x203x362] Tapered Timber Blockout -Side A	SYP Grade No. 1 or better	Ch#22416 Ch#24195 Ch#24883
a8	6"x8"x14¼" [152x203x362] Tapered Timber Blockout -Side B	SYP Grade No. 1 or better	Ch#24683
b1	12'-6" [3,810] 12 gauge [2.7] Thrie Beam Section	AASHTO M180	H#219447 H#220022 H#220023
b2	12'-6" [3,810] 12 gauge [2.7] Bent Thrie Beam Section	AASHTO M180	H#L32118
b3	12'-6" [3,810] 12 gauge [2.7] Thrie Beam Section	AASHTO M180	H#L32817
b4	12'-6" [3,810] 12 gauge [2.7] Thrie Beam End Section -Side A	AASHTO M180	H#206981 H#206982
b5	12'-6" [3,810] 12 gauge [2.7] Thrie Beam End Section -Side B	AASHTO M180	H#219447 H#220022 H#220023
b6	12'-6" [3,810] 12 gauge [2.7] Bent Thrie Beam Section -Side A	AASHTO M180	HC#L31418
c1	7/16" [11] Dia. UNC, 2½" [64] Long Hex Tap Bolt (Fully Threaded) and Nut	Bolt - ASTM A449 or SAE J429 Gr. 5 Nut - ASTM A563DH or J995 Gr. 5	Bolt: H#H1708007009 Nut: H#351607718 Nut: H#331509977
c2	⅝" [16] Dia. UNC, 10" [254] Long Hex Head Bolt	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	H#DL15107048 H#JK17100352 H#20297970
c3	⅝" [16] Dia. UNC, 1¼" [32] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolts: H#20455760 Nuts: H#20479830
c4	⅝" [16] Dia. UNC, 1½" [38] Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolt: H#816070039 Nut: H#331608011
c5	⅝" [16] Dia. UNC, 18" [457] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	H#DL17100591

Table B-8. Bill of Materials, Test No. MSPBN-8, Cont.

Item No.	Description	Material Spec	Material Cert Reference
c6	⅞" [22] Dia. UNC, 8" [203] Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	6” Bolt: H#2038622 Nut: H#NF12101054 H#331704677
c7	⅝" [16] Dia. UNC, 10" [254] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	H#DL16102715
c8	16D Double Head Nail	-	L# 97812A109
e1	7/16" [11] Dia. Plain Round Washer	ASTM F844	L#33183
e2	⅝" [16] Dia. Plain Round Washer	ASTM F844	n/a
e3	⅞" [22] Dia. Plain Round Washer	ASTM F844	n/a
f1	BCT Timber Post - MGS Height	SYP Grade No. 1 or better (No knots +/- 18" [457] from ground on tension face)	Charge#24096 Ch#24233 Ch#25033
f2	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 78" [1,981] Long Steel Post	ASTM A992	Side A: H#55044245 Side B: H#2714032
g1	BCT Anchor Cable Assembly	-	R#18-642
g2	2⅜" [60] O.D. x 6" [152] Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	H#A79999
g3	⅝" Dia. [15.9] x 14.4' [4,389] Long Cable and Swage Button	"Cold Tuff" Button, S-409 Size No. 12 SB, Stock No. 1040395 for ⅝" [16] Dia. (6x19) wire rope (or any similarly sized swage-grip button ferrules)	H#284559
g4	12⅝"x5 13/16"x3/16" [321x148x5] Nose Cable Anchor Plate	ASTM A36	H#B4M5475
g5	2¼"x¾" [57x19] 11 gauge [3] U-Bolt Plate Washer	ASTM A1011 CS Type B	H#B609769
g6	¼" [6] Dia. U-Bolt and Nut	U-Bolt-ASTM A307 Gr.A Nut-ASTM A563A	Bolt: H#71067E Nut: H#184259
h1	Ground Strut Assembly	ASTM A36	PO#2030 H#163375
h2	Anchor Bracket Assembly	ASTM A36	H#JK16101488

8/5/2016

ACCREDITED
TESTING CERT # 2914.01

CERTIFIED REPORT OF CHEMICAL ANALYSIS AND MECHANICAL TESTS

ArcelorMittal

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SOLD TO	VENDOR
MARUICHI LEAVITT PIPE & T 1717 W 115TH ST CHICAGO IL	ArcelorMittal Riverdale LLC. 13500 South Perry Avenue Riverdale, IL 60827

SHIP TO	ORDER INFORMATION
MARUICHI LEAVITT PIPE & TUBE SOUTH PLANT DIVISION 1900 W 119TH ST CHICAGO IL	PO#: 00490/10 LoadID # 02583356 SO#: 859202 Carrier: Steel Transport, Inc. Date Of Issuance/ Shipped: 8/4/2016

ORDERED DIMENSIONAL INFORMATION

Heat	Coil	Thickness (in)	Width (in)	Weight (tons)	Reduction Ratio
A49248	119239	0.170	56.257	4.7	92.15% (13:1)

HEAT NUMBER IS BEING USED AS CERTIFICATE NUMBER. COUNTRY OF ORIGIN/EXPORT COUNTRY IS USA. FOR QUESTIONS CONCERNING IMPORTATION OF THIS MATERIAL PLEASE CONTACT JOSE CISNEROS, 1 SOUTH DEARBORN ST , CHICAGO, IL, 60603, TEL +1 (312) 899 3796 EML Jose.Cisneros@arcelormittal.com

PRODUCT INFORMATION

Grade	Part Number	Product Description	Comments
LEAVITT B15-106	HB1705625-	Hot Band Prime	

This material was melted and manufactured in the USA. All products are strand cast and free of mercury or radioactive elements. Elongation based on 2" gage length

MECHANICAL / PHYSICAL TEST RESULTS

Heat	Coil	Yield (ksi)	Tensile (ksi)	El (%)	Dir	N-Value	N-Range	Hardness	Ft-lbs	°F	Size	Dir
A49248	119239	58.0KSI	75.8 KSI	29.0 %	L							
A49248		58.9KSI	76.0 KSI	29.0 %	L							

* Material tested in accordance with ISO 17025 by an accredited lab.

CHEMICAL TEST RESULTS

Heat	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Cb	V	Al
A49248	.20	.81	.014	.002	.04	.02	.02	.04	.00	.000	.001	.020
	N	Sn	B	Ti	Ca	Sb						
	.0033	.001	.0001	.0020	.0011	.0010						

Chemical analysis was performed by ArcelorMittal Riverdale, Inc. in accordance with the Current Version of ASTM E415 and E1019.

We hereby certify the above is correct as contained in the records of the corporation. All tests peformed to the current standard to date unless otherwise noted. Uncertainties of measurements estimated and are available upon request. These results relate only to the items tested. Test results marked with an asterisk (*) were reported by an external accredited lab and with double asterisk(**) were reported by an internal laboratory.

Ryan N Fritz
Manager - Quality
13500 South Perry Ave., Riverdale IL 60827
T+708 392 1077 | Ryan.Fritz@ArcelorMittal.com

Figure B-1. Foundation Tube Material Specification, Test Nos. MSPBN-4 through MSPBN-8

NUCOR
NUCOR CORPORATION
NUCOR STEEL SOUTH CAROLINA

Mill Certification
7/30/2015

MTR #: 0000087896
300 Steel Mill Road
DARLINGTON, SC 29540
(843) 393-5841
Fax: (843) 395-8701

Sold To: TRINITY INDUSTRIES INC
ROLLFORM ACCOUNTING-4TH FLOOR
PO BOX 568887
DALLAS, TX 75356-8887
(214) 689-0847
Fax: (214) 589-8535

Ship To: TRINITY INDUSTRIES LIMA
550 E. ROBB AVENUE
PLANT 55
LIMA, OH 45801-0000
(214) 589-8407
Fax: (214) 589-8420

Customer P.O.	171075	Sales Order	229472.1
Product Group	Merchant Bar Quality	Part Number	5362580024010W0
Grade	NUCOR MULTIGRADE	Lot #	DL1510354303
Size	5/8x8" Flat	Heat #	DL15103543
Product	5/8x8" Flat 20' NUCOR MULTIGRADE	B.L. Number	C1-668702
Description	NUCOR MULTIGRADE	Load Number	C1-347435
Customer Spec		Customer Part #	100395B

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Roll Date: 6/22/2015 Melt Date: 6/18/2015 Qty Shipped LBS: 45,929 Qty Shipped Pcs: 135

Melt Date: 6/18/2015

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Cb	Sn
0.15%	0.75%	0.013%	0.025%	0.20%	0.36%	0.09%	0.09%	0.021%	0.0500%	0.003%	0.016%
Ti	CE4020										
0.001%	0.34%										

CE4020: C. E. CSA G4020, AASHTO M270

Roll Date: 6/22/2015

Yield 1: 58,000psi	Tensile 1: 74,000psi	Elongation: 25% in 8"(% in 203.3mm)
Yield 2: 58,000psi	Tensile 2: 74,000psi	Elongation 25% in 8"(% in 203.3mm)

Specification Comments: NUCOR MULTIGRADE MEETS THE REQUIREMENTS OF: ASTM A36/A36M-12, A529/529M-05(2009) GR50(345), A572/572M-13A GR50(345), A709/709M-13A GR36(250) & GR50(345), CSA G40.21-04 GR44W(300W) & GR50W(350W) AASHTO M270/M270M-10 GR36(270) & GR50(345), ASME SA36/SA36M-07, QQ-S-741D, KILLED FG PRACTICE

1. WELDING OR WELD REPAIR WAS NOT PERFORMED ON THIS MATERIAL
2. MELTED AND MANUFACTURED IN THE USA
3. MERCURY, RADIUM, OR ALPHA SOURCE MATERIALS IN ANY FORM HAVE NOT BEEN USED IN THE PRODUCTION OF THIS MATERIAL

James H. Blew
Division Metallurgist

NBMG-10 January 1, 2012

Page 1 of 1

Figure B-2. Anchor Bearing Plate Material Specification, Test Nos. MSPBN-4 through MSPBN-8

GREGORY HIGHWAY PRODUCTS, INC.
4100 13th St. SW
Canton, Ohio 44710

MIDWEST MACHINERY & SUPPLY CO.
P. O. BOX 703

MILFORD,NE,68405

Test Report
Ship Date: 11/17/2017
Customer P.O.: 3515
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project:
GHP Order No: 128AA

HT # code	LOT#	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
A74070		0.21	0.46	0.012	0.002	0.03	76100	58800	25.2	4	A	2	12GA TB TRANS.
4181496		0.24	0.84	0.014	0.01	0.01	72400	44800	34	4		2	5/8IN X 8IN X 8IN BRG. PL.
4181489		0.09	0.45	0.012	0.004	0.01	58000	43100	27	4		2	350 STRUT & YOKE
196828BM		0.04	0.84	0.014	0.003		76000	74000	25			2	350 STRUT & YOKE
E22985		0.17	0.51	0.013	0.008	0.008	72510	64310	29.5	4		2	2IN X 5 1/2IN PIPE SLEEVE
811T08220		0.22	0.81	0.013	0.006	0.005	71412	56323	35	8		2	3/16IN X 6IN X 8IN X 6FT0IN TUBE SLEEVE

James P. Dehnke
Notary Public, State of Ohio
My Commission Expires 10-19-2019

All Galvanizing has occurred in the United States
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Steel used meets Title 23CFR 635.410 - Buy America
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All controlled oxidized/corrosion resistant Guardrail and terminal sections meet ASTM A606, Type 4.

By:

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by Andrew Artar this 21 day of November, 2017

Notary Public, State of Ohio

Figure B-3. Anchor Bearing Plate Material Specification, Test Nos. MSPBN-4 through MSPBN-8

Atlas Tube (Chicago)
1855 East 1[illegible]
Chicago, Illinois, USA
60633
Tel: 773-646-4500
Fax: 773-646-6128

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

Ref.B/L: 80775333
Date: 08.02.2017
Customer: 179

MATERIAL TEST REPORT

Sold to

Steel & Pipe Supply Company
PO Box 1688
MANHATTAN KS 66505
USA

Shipped to

Steel & Pipe Supply Company
310 Smith Road
JONESBURG MO 63351
USA

Material: 6.0x6.0x250x20'0"0(3x3). **Material No:** 600602502000 **Made in:** USA **Melted in:** USA

Sales order: 1197957 **Purchase Order:** 4500291163 **Cust Material #:** 6560025020

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
V2543	0.180	0.680	0.013	0.008	0.020	0.029	0.150	0.009	0.020	0.060	0.100	0.002	0.001	0.000	0.007

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800713984	9	069204 Psi	084064 Psi	28 %	ASTM A500-13 GRADE B&C	0.34

Material Note:
Sales Or.Note:

Material: 8.0x4.0x313x40'0"0(3x2). **Material No:** 800403134000 **Made in:** USA **Melted in:** USA

Sales order: 1202413 **Purchase Order:** 4500292047 **Cust Material #:** 6680040031340

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
17049081	0.210	0.720	0.006	0.003	0.020	0.029	0.100	0.001	0.010	0.040	0.040	0.002	0.000	0.000	0.008

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800719620	6	066696 Psi	082026 Psi	30 %	ASTM A500-13 GRADE B&C	0.35

Material Note:
Sales Or.Note:

Material: 8.0x6.0x188x40'0"0(3x2). **Material No:** 800601884000 **Made in:** USA **Melted in:** USA

Sales order: 1201377 **Purchase Order:** 4500291779 **Cust Material #:** 6680060018840

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
17043541	0.190	0.360	0.006	0.002	0.030	0.023	0.100	0.000	0.010	0.040	0.060	0.002	0.000	0.000	0.008

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800715933	6	058484 Psi	072393 Psi	30 %	ASTM A500-13 GRADE B&C	0.28

Material Note:
Sales Or.Note:

Authorized by Quality Assurance:
The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
Calculated using the AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Page : 2 Of 3

Metals Service Center Institute

Figure B-4. Lower Slip Post Tube Assembly Material Specification, Test Nos. MSPBN-4 through MSPBN-8

Certificate of Mill Test Results

CHI-000000-000

PO/Rel

Pg 1/1

PART NO.

Attn:

NUCOR PLATE MILL

P.O.Box 279
Winton, NC 27986
(252) 356-3700

Mill Test Report

Page 4

1505 River Rd
Cofield, NC 27922
(252) 356-3700

NUCOR It's Our Nature

Issuing Date :	05/17/2017	B/L No. : 472281	Load No. : 481495	Our Order No. : 145962/5	Cust. Order No. : CHI-10604
Vehicle No:	LW 62153		Sold To:	CHAPEL STEEL CORP 590 N BETHLEHEM PIKE PO BOX 1000 SPRINGHOUSE,PA 19477	Ship To: CHAPEL STEEL - CHICAGO (RAIL) CHAPEL STEEL RAIL TRACK #708 YARD 11 INDIAN OAKS,IL 60914
Specification:	0.6250" x 96.000" x 240.000" ASTM A572 Grade 50-15/ASTM A709 Grade 50-16a/AASHTO M270-50 Type 2 Al killed				

Marking :

Heat No	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al(tot)	V	Nb	Ti	N	Ca	B	Sn	Ceq	Pcm
7503198	0.18	0.92	0.010	0.003	0.18	0.30	0.10	0.10	0.02	0.028	0.025	0.000	0.002		0.0028	0.0002	0.012	0.39	0.26

Tensile Test								Charpy Impacts											
Plate Serial No	Pieces	Tons	Dir.	(psi) Yield	(psi) Tensile	Elongation % in 2"	Elongation % in 8"	Dir.	1	(%) shear	2	(%) shear	3	(%) shear	Ave.	(%) shear	Size	Temp	Min Ave.
7503198-09	5	10.20	T	51,900	75,300		21.3												
			T	61,600	76,900		24.0												

Manufactured to fully killed fine grain practice by Electric Arc Furnace. Welding or weld repair was not performed on this material. Mercury has not been used in the direct manufacturing of this material. Produced as continuous cast discrete plate as-rolled, unless otherwise noted in Specification. For Mexico shipments: nho-SalesMX@Nucor.com
Yield by 0.5EUL method unless otherwise specified. Ceq = C+(Mn/6)+((Cr+Mo+V)/5)+((Cu+Ni)/15)
Pcm = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B
Melted and Manufactured in the USA. ISO 9001:2008 certified (#010940) by SRI Quality System Registrar (#0065-09). PED 97/23/EC 7/2 Annex 1, Para. 4.3 Compliant.
DIN 50049 3.1.B/EN 10204 3.1B(2004), DIN EN 10204 3.1(2005) compliant. For ABS grades only, Quality Assurance certificate 14-MMPQA-723

We hereby certify that the contents of this report are accurate and correct. All test results and operations performed by the material manufacturer are in compliance with the applicable specifications, including customer specifications.

T. A. Depratis, Metallurgist

5/18/2017 2:57:21 PM

Doc No. 338408 Indexed 19May17 by 144lnowe

Figure B-5. Lower Slip Post Plate Assembly Material Specification, Test Nos. MSPBN-4 through MSPBN-8

9/19/2017 - 3:56 AM

Steel & Pipe Supply Co.
Midwest Steel Works, Inc.
Customer PO: 49764

Heat: 7G0887M
Shipment: 0017028822

NUCOR
NUCOR STEEL TUSCALOOSA, INC.

MILL TEST CERTIFICATE

1700 HOLT RD N.E.
Tuscaloosa, AL 35404-1000
800 800-8204
customerservice@nucortusk.com

Load Number	Tally	Mill Order Number	PO NO | Line NO	Part Number	Certificate Number	Prepared
T158924	00000000738119	N-157551-001	4500290442 1		S73811901-1	07/28/2017 12:52

Grade

Order Description:
Hot Roll Plate From Coil
A36, 0.7500 IN x 72.000 IN x 120.000 IN
Quality Plan Description:
A36/SA36/A70936: ASTM A36-14/A709-36-15/ASME SA36-13/M270-36

Customer:
Sold TO:
STEEL AND PIPE SUPPLY CO INC GARDNER KS
Ship TO:
Kansas City Warehouse New Century KS
Sent TO:

Shipped Item	Certified By	Heat/Slab Number	Yield ksi	Tensile ksi	Y/T %	ELONGATION % 2"	ELONGATION % 8"	Bend OK?	Hard HB	Charpy Impacts (ft-lbs) Size mm	Charpy 1	Charpy 2	Charpy 3	Charpy Avg	Shear % 1	Shear % 2	Shear % 3	Shear % Avg	Test Temp
7G0887M	S7G0887FTT	B7T5144-01 ***	50.4	69.2	72.8	39.8													
7G0887M	S7G0887MTT	B7T5144-01 ***	49.8	65.7	75.8	37.9													
7G0888E	S7G0887FTT	B7T5144-02 ***	50.4	69.2	72.8	39.8													
7G0888E	S7G0889FTT	B7T5144-02 ***	47.5	69.9	68.0		26.2												
7G0888E	S7G0887MTT	B7T5144-02 ***	49.8	65.7	75.8	37.9													
7G0888E	S7G0889MTT	B7T5144-02 ***	45.0	64.0	70.3		26.5												
7G0888F	S7G0887FTT	B7T5144-02 ***	50.4	69.2	72.8	39.8													
7G0888F	S7G0889FTT	B7T5144-02 ***	47.5	69.9	68.0		26.2												
7G0888F	S7G0887MTT	B7T5144-02 ***	49.8	65.7	75.8	37.9													
7G0888F	S7G0889MTT	B7T5144-02 ***	45.0	64.0	70.3		26.5												
7G0888G	S7G0887FTT	B7T5144-02 ***	50.4	69.2	72.8	39.8													
7G0888G	S7G0889FTT	B7T5144-02 ***	47.5	69.9	68.0		26.2												
7G0888G	S7G0887MTT	B7T5144-02 ***	49.8	65.7	75.8	37.9													
7G0888G	S7G0889MTT	B7T5144-02 ***	45.0	64.0	70.3		26.5												
7G0888H	S7G0887FTT	B7T5144-02 ***	50.4	69.2	72.8	39.8													
7G0888H	S7G0889FTT	B7T5144-02 ***	47.5	69.9	68.0		26.2												
7G0888H	S7G0887MTT	B7T5144-02 ***	49.8	65.7	75.8	37.9													
7G0888H	S7G0889MTT	B7T5144-02 ***	45.0	64.0	70.3		26.5												

Items: 5 **PCS:** 22 **Weight:** 40429 LBS

Mercury has not come in contact with this product during the manufacturing process nor has any mercury been used by the manufacturing process. Certified in accordance with EN 10204 3.1. No weld repair has been performed on this material. Manufactured to a fully killed fine grain practice. NUTEMPER TEMPER PASSED plate from coil
ISO 9001:2015 Registered, PED Certified

"***" indicates Heats melted and Manufactured in the U.S.A.

We hereby certify that the product described above passed all of the tests required by the specifications.

Dr. Quilin Yu - Metallurgist

Figure B-6. Upper Slip Plate Assembly Material Specification, Test Nos. MSPBN-4 through MSPBN-7

GERDAU

US-ML-MIDLOTHIAN
300 WARD ROAD
MIDLOTHIAN, TX 76065
USA

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
STEEL & PIPE SUPPLY CO INC 401 NEW CENTURY PKWY NEW CENTURY,KS 66031-1127 USA	STEEL & PIPE SUPPLY CO INC MANHATTAN,KS 66505-1688 USA	A992/A572-50	Wide Flange Beam / 6 X 9# / 150 X 13.5	0000166450

LENGTH	WEIGHT	HEAT / BATCH
40'00"	17,280 LB	58031555/02

SALES ORDER	CUSTOMER MATERIAL N°
5782497/000030	000000000037690040

SPECIFICATION / DATE or REVISION
ASTM A6-14
ASTM A709-15
ASTM A992-11 (2015), A572-15
CSA G40.21-13 345WM

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
4500297205	1327-0000256919	11/08/2017

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.07	0.86	0.010	0.017	0.18	0.27	0.13	0.23	0.041	0.007	0.001	0.013	0.003

CHEMICAL COMPOSITION

CEqyA6 %
0.30

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	Y/T rati %	G/L Inch
57563	75927	397	524	0.760	8.000
57547	77066	397	531	0.750	8.000

MECHANICAL PROPERTIES

G/L mm	Elong. %
200.0	24.80
200.0	24.70

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 769-1014 Email: Bhaskar.Yalamanchili@gerdau.com

WADE LUMPKINS
QUALITY ASSURANCE MGR.
Phone: 972-779-3118 Email: Wade.Lumpkins@gerdau.com

Figure B-7. Upper Slip Post Assembly Material Specification, Test Nos. MSPBN-4 through MSPBN-7

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

1098 East Maple St
Sutton, NE 68979
Phone: 402.773.4319
Email: nick@nebraskawood.com

CERTIFICATE OF COMPLIANCE

Shipped To: Midwest Machinery and Supply
BOL# 10057594
Customer PO# 3475
Preservative: CCA – C 0.60D pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
GR6806PST	6x8-6′ Thrie Beam Post	70	24232	.636
GS6846PST	5.5x7.5-46′ BCT	42	24233	.627
GR61219BLK	6x12-19″ Thrie OCD Block	168	24230	.638
GR61222BLK	6x12-22″ Thrie OCD Block	56	24089	.673
GR6814BLK	6x8-14″ OCD Block	126	24195	.648

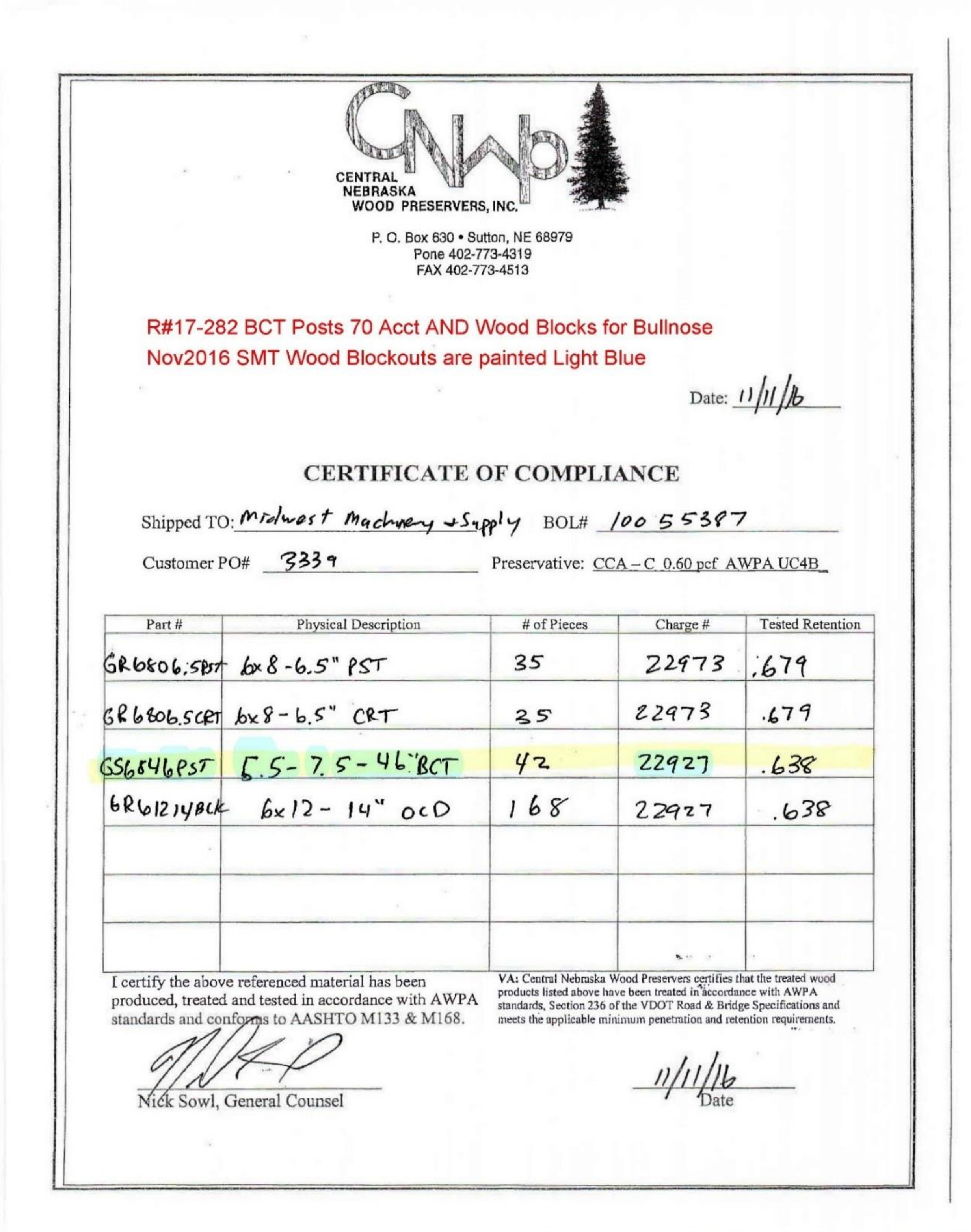
I certify the above referenced material has been produced, treated and tested in accordance with and conforms to AASHTO M133 & M168 standards.

VA: Iowa Wood Preservers certifies that the treated wood products listed above have been treated in accordance with AWPA standards, Section 236 of the VDOT Road & Bridge Specifications and meets the applicable minimum penetration and retention requirements.

Nicholas Sowl, General Counsel

8/25/2017
Date

Figure B-8. Timber Blockout and BCT Timber Post Certificate of Compliance, Test Nos. MSPBN-4 through MSPBN-8



CENTRAL NEBRASKA WOOD PRESERVERS, INC.

P. O. Box 630 • Sutton, NE 68979
Pone 402-773-4319
FAX 402-773-4513

R#17-282 BCT Posts 70 Acct AND Wood Blocks for Bullnose
Nov2016 SMT Wood Blockouts are painted Light Blue

Date: 11/11/16

CERTIFICATE OF COMPLIANCE

Shipped TO: Midwest Machinery + Supply BOL# 10055387

Customer PO# 3339 Preservative: CCA – C 0.60 pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
GR6806.5PST	6x8-6.5" PST	35	22973	.679
GR6806.5CRT	6x8-6.5" CRT	35	22973	.679
GS6846PST	5.5-7.5-46" BCT	42	22927	.638
GR61214BLK	6x12-14" OCD	168	22927	.638

I certify the above referenced material has been produced, treated and tested in accordance with AWPA standards and conforms to AASHTO M133 & M168.

VA: Central Nebraska Wood Preservers certifies that the treated wood products listed above have been treated in accordance with AWPA standards, Section 236 of the VDOT Road & Bridge Specifications and meets the applicable minimum penetration and retention requirements.

Nick Sowl, General Counsel

11/11/16
Date

Figure B-9. Tapered Timber Blockout and BCT Timber Post Certificate of Compliance, Test Nos. MSPBN-4 through MSPBN-7

PERMA-TREAT OF ILLINOIS, INC.

1800 PERMA-TREAT DRIVE, PO BOX 99
MARION, IL 62959
PH# 800.572.7384 FAX# 618.993.8680

This is to certify that the guardrail material has been treated and inspected according to the Iowa Department of Transportation Specification requirements and IM 462. Also, conforms to State of Illinois specification.

This material has been processed from Rough Sawn #1 Southern Yellow Pine.

Company:

Bill of Lading:

Quantity	Description	Charge #	Date of Treatment	Treatment	MC prior to Treatment
30	6X8X7' 2H	4835	4-4-11	.60 CCA-C	20%
30	6X8X7' 2H	4800	12-6-10	.60 CCA-C	20%
30	6X8X7' 2H	4843	4-8-11	.60 CCA-C	20%
60	6X8X6' CRT	4850	4-19-11	.60 CCA-C	20%
90	6X8X6' CRT	4845	4-15-11	.60 CCA-C	20%
252	6X12X14" 1H	4844	4-12-11	.60 CCA-C	20%
288	6X8X18" 2H TRANS	4851	4-19-11	.60 CCA-C	20%
144	6X8X18" 2H TRANS	4844	4-12-11	.60 CCA-C	20%
				.60 CCA-C	20%
				.60 CCA-C	20%
				.60 CCA-C	20%
				.60 CCA-C	20%

Perma-Treat of Illinois, Inc

By: [signature]

Title: President

Date: 5/10/11

NOTARIZED

Sworn to and described
Before me this 10th day of
May 2011

By: Sara Bond

Official Seal

OFFICIAL SEAL
SARA BOND
Notary Public, State of Illinois
My Commission Expires 01-31-2015

Figure B-10. Tapered Timber Blockout and BCT Timber Post Certificate of Compliance, Test Nos. MSPBN-4 through MSPBN-7

Certified Test Report

NORTH STAR BLUESCOPE STEEL LLC
6767 County Road 9
Delta Ohio 43515
Telephone: (888) 822-2112

Customer:	Trinity Highway Products, LLC			**Ordered Width (mm/in)**	1447.8 / 57	**Weight(kg/lb)**	
2525 Stemmons Freeway		**Order #**	387817	**Ordered Gauge (mm/in)**	2.438 / 0.096	21155 / 46639	
Dallas, TX 75207		**Line Item #**	1	**Produced Date/Time**	9/21/17 13:16		
Customer P.O:	185910-3	**Heat #**	219447	**Coil #**	1754757		
Cust. Ref/Part #	100012B Pickle/Slit	**Material Desc:**	1018 CQ Modified, Guardrail Type 2				

Chemical Analysis (wt%)

Type	C	Mn	P	S	Si	Al	Cu	Cr	Ni	Mo	Sn	N	B	V	Nb	Ti	Ca	Pb
Heat	0.20	0.73	0.011	0.005	0.02	0.03	0.13	0.08	0.07	0.02	0.00	0.007	0.0001	0.001	0.000	0.000	0.001	0.001

Mechanical Test Report

	Yield Strength	Tensile Strength	% Elongation in 2 inches
Tail	61900 psi	80080 psi	25.4%

This hot rolled steel has been produced to conform to DIN EN 10204:2005 3.1 and has been manufactured to a fully killed fine grain practice. This hot rolled steel has been produced and tested in accordance with each of the following applicable standards:ASTM E1806-09, ASTM E415-14, ASTM A751-14, ASTM 1370-14, JIS Z2201:1998, JIS Z2241:2011. Pressure Equipment Directive (PED) 2014/68/EU, Annex I, Paragraph 4.3 Compliant. This report certifies that the above test results are representative of those contained in the records of North Star BlueScope Steel LLC for the material identified in this test report and is intended to comply with the requirements of the material description. North Star BlueScope Steel LLC is not responsible for the inability of this material to meet specific applications. Any modifications to this certification as provided negates the validity of this test report. All reproductions must have the written approval of North Star BlueScope Steel.This product was manufactured, melted, cast, and hot-rolled (min. 3:1 reduction ratio), entirely within the U.S.A at North Star BlueScope Steel LLC, Delta, Ohio. This material was not exposed to Mercury or any alloy which is liquid at ambient temperature during processing or while in North Star BlueScope Steel LLC possession. Test. equipment calibration certificates are available upon request. NIST traceability is established through test equipment calibration certificates which are available upon request. Uncertainty calculations are calculated in accordance with NIST standards and are maintained at a 4:1 ratio in accordance with NIST standards. Uncertainty data is available upon request.

Tim Mitchell **Manager Quality Assurance and Technology**

Date Issued: Oct 11, 2017 3:18 PM
Revision#: 01

Figure B-11. 12-ft 6-in. (3.8-m) 12-ga (2.7-mm) Thrie Beam Material Certification, Test Nos. MSPBN-4 through MSPBN-8

Certified Test Report

NORTH STAR BLUESCOPE STEEL LLC
6767 County Road 9
Delta, Ohio 43515
Telephone: (888) 822-2112

Customer: Trinity Highway Products, LLC
2525 Stemmons Freeway
Dallas, TX 75207
Customer P.O.: 186321-3
Cust. Ref/Part # 100212B

Order # 389604
Line Item # 1
Heat # 220022
Coil # 1759633

Ord Width (mm/in) 1504.950 / 59.250
Ord Gauge (mm/in) 2.438 / 0.096
Material Description 1018 CQ Modified, Guardrail Type 2
Production Date/Time Oct 7 2017 11:41AM

Weight (kg/lb) 21019 / 46339

Heat Chemical Analysis (wt%)

Type	C	Mn	P	S	Si	Al	Cu	Cr	Ni	Mo	Sn	N	B	V	Nb	Ti	Ca	Pb
Heat	0.18	0.72	0.012	0.002	0.02	0.02	0.09	0.06	0.04	0.02	0.00	0.005	0.0000	0.001	0.000	0.001	0.002	0.001

Mechanical Test Report

	Yield Strength	Tensile Strength	% Elongation in 2 inches
Tail	63,060 psi	80,170 psi	26.6%

This hot rolled steel has been produced to conform to DIN/EN 10204:2005 3.1 and has been manufactured to a fully killed fine grain practice. This hot rolled steel has been produced and tested in accordance with each of the following applicable standards: ASTM E1806-09, ASTM E415-14, ASTM A751-14, ASTM 1370-14, JIS Z2201:1998, JIS Z 2241:2011. Pressure Equipment Directive (PED) 97/23/EC 7/2, Annex I, Paragraph 4.3 Compliant. This report certifies that the above test results are representative of those contained in the records of North Star BlueScope Steel LLC for the material identified in this test report and is intended to comply with the requirements of the material description. North Star BlueScope Steel LLC is not responsible for the inability of this material to meet specific applications. Any modifications to this certification as provided negates the validity of this test report. All reproductions must have the written approval of North Star BlueScope Steel. This product was manufactured, melted, cast, and hot-rolled (min. 3:1 reduction ratio), entirely within the U.S.A at North Star BlueScope Steel LLC, Delta, Ohio. This material was not exposed to Mercury or any alloy which is liquid at ambient temperature during processing or while in North Star BlueScope Steel LLC possession. Test equipment calibration certificates are available upon request. NIST traceability is established through test equipment calibration certificates which are available upon request. Uncertainty calculations are calculated in accordance with NIST standards and are maintained at a 4:1 ratio in accordance with NIST standards. Uncertainty data is available upon request.

Tim Mitchell Manager Quality Assurance and Technology

Date Issued: Nov 06, 2017 10:41:39
Revision#: 01

Figure B-12. 12-ft 6-in. (3.8-m) 12-ga (2.7-mm) Thrie Beam Material Certification, Test Nos. MSPBN-4 through MSPBN-8

Certified Test Report

NORTH STAR BLUESCOPE STEEL LLC
6767 County Road 9
Delta, Ohio 43515
Telephone: (888) 822-2112

Customer: Trinity Highway Products, LLC
2525 Stemmons Freeway
Dallas, TX 75207
Customer P.O.: 186321-3
Cust. Ref/Part # 100212B

Order # 389604
Line Item # 1
Heat # 220023
Coil # 1759637

Ord Width (mm/in) 1504.950 / 59.250
Ord Gauge (mm/in) 2.438 / 0.096
Material Description 1018 CQ Modified, Guardrail Type 2
Production Date/Time Oct 7 2017 11:59AM

Weight (kg/lb) 22412 / 49410

Heat Chemical Analysis (wt%)

Type	C	Mn	P	S	Si	Al	Cu	Cr	Ni	Mo	Sn	N	B	V	Nb	Ti	Ca	Pb
Heat	0.19	0.73	0.011	0.005	0.01	0.02	0.12	0.07	0.04	0.01	0.00	0.008	0.0000	0.001	0.000	0.000	0.001	0.000

Mechanical Test Report

	Yield Strength	Tensile Strength	% Elongation in 2 inches
Tail	61,250 psi	79,890 psi	23.1%

This hot rolled steel has been produced to conform to DIN/EN 10204:2005 3.1 and has been manufactured to a fully killed fine grain practice. This hot rolled steel has been produced and tested in accordance with each of the following applicable standards: ASTM E1806-09, ASTM E415-14, ASTM A751-14, ASTM 1370-14, JIS Z2201:1998, JIS Z 2241:2011. Pressure Equipment Directive (PED) 97/23/EC 7/2, Annex I, Paragraph 4.3 Compliant. This report certifies that the above test results are representative of those contained in the records of North Star BlueScope Steel LLC for the material identified in this test report and is intended to comply with the requirements of the material description. North Star BlueScope Steel LLC is not responsible for the inability of this material to meet specific applications. Any modifications to this certification as provided negates the validity of this test report. All reproductions must have the written approval of North Star BlueScope Steel. This product was manufactured, melted, cast, and hot-rolled (min. 3:1 reduction ratio), entirely within the U.S.A at North Star BlueScope Steel LLC, Delta, Ohio. This material was not exposed to Mercury or any alloy which is liquid at ambient temperature during processing or while in North Star BlueScope Steel LLC possession. Test equipment calibration certificates are available upon request. NIST traceability is established through test equipment calibration certificates which are available upon request. Uncertainty calculations are calculated in accordance with NIST standards and are maintained at a 4:1 ratio in accordance with NIST standards. Uncertainty data is available upon request.

Tim Mitchell — Manager Quality Assurance and Technology

Date Issued: Oct 23, 2017 08:32:08
Revision#: 01

Figure B-13. 12-ft 6-in. (3.8-m) 12-ga (2.7-mm) Thrie Beam Material Certification, Test Nos. MSPBN-4 through MSPBN-8

Certified Test Report

NORTH STAR BLUESCOPE STEEL LLC
6767 County Road 9
Delta, Ohio 43515
Telephone: (888) 822-2112

Customer: Trinity Industries
2525 Stemmons Freeway
Dallas, TX 75207
Customer P.O.: 176195M-3
Cust. Ref/Part # 200212B

Order # 356803
Line Item # 1
Heat # 203662
Coil # 1620558

Ord Width (mm/in) 1504.950 / 59.250
Ord Gauge (mm/in) 2.438 / 0.096
Material Description 1018 CQ Modified, Guardrail Type 2
Production Date/Time Jun 4 2016 4:26PM

Weight (kg/lb) 26526 / 58480

Heat Chemical Analysis (wt%)

Type	C	Mn	P	S	Si	Al	Cu	Cr	Ni	Mo	Sn	N	B	V	Nb	Ti	Ca	Pb
Heat	0.19	0.72	0.011	0.005	0.02	0.03	0.13	0.06	0.08	0.01	0.01	0.005	0.0001	0.000	0.000	0.000	0.002	0.000

Mechanical Test Report

	Yield Strength	Tensile Strength	% Elongation in 2 inches
Tail	61,220 psi	78,610 psi	25.1%

This hot rolled steel has been produced to conform to DIN/EN 10204:2005 3.1 and has been manufactured to a fully killed fine grain practice. This hot rolled steel has been produced and tested in accordance with each of the following applicable standards: ASTM E1806-09, ASTM E415-14, ASTM A751-14, ASTM 1370-14, JIS Z2201:1998, JIS Z 2241:2011. Pressure Equipment Directive (PED) 97/23/EC 7/2, Annex I, Paragraph 4.3 Compliant. This report certifies that the above test results are representative of those contained in the records of North Star BlueScope Steel LLC for the material identified in this test report and is intended to comply with the requirements of the material description. North Star BlueScope Steel LLC is not responsible for the inability of this material to meet specific applications. Any modifications to this certification as provided negates the validity of this test report. All reproductions must have the written approval of North Star BlueScope Steel. This product was manufactured, melted, cast, and hot-rolled (min. 3:1 reduction ratio), entirely within the U.S.A at North Star BlueScope Steel LLC, Delta, Ohio. This material was not exposed to Mercury or any alloy which is liquid at ambient temperature during processing or while in North Star BlueScope Steel LLC possession. Test equipment calibration certificates are available upon request. NIST traceability is established through test equipment calibration certificates which are available upon request. Uncertainty calculations are calculated in accordance with NIST standards and are maintained at a 4:1 ratio in accordance with NIST standards. Uncertainty data is available upon request.

Tim Mitchell [signature] **Manager Quality Assurance and Technology**

Date Issued: Jun 07, 2016 08:31:43
Revision#: 01

Figure B-14. 12-ft 6-in. (3.8-m) 12-ga (2.7-mm) Thrie Beam Material Certification, Test Nos. MSPBN-4 and MSPBN-5

Certified Test Report

NORTH STAR BLUESCOPE STEEL LLC
6767 County Road 9
Delta, Ohio 43515
Telephone: (888) 822-2112

Customer: Trinity Industries
2525 Stemmons Freeway
Dallas, TX 75207
Customer P.O.: 179261M-3
Cust. Ref/Part # 200212B

Order # 363307
Line Item # 1
Heat # 206981
Coil # 1648979

Ord Width (mm/in) 1504.950 / 59.250
Ord Gauge (mm/in) 2.438 / 0.096
Material Description 1018 CQ Modified, Guardrail Type 2
Production Date/Time Sep 16 2016 6:19PM

Weight (kg/lb) 26462 / 58339

Heat Chemical Analysis (wt%)

Type	C	Mn	P	S	Si	Al	Cu	Cr	Ni	Mo	Sn	N	B	V	Nb	Ti	Ca	Pb
Heat	0.19	0.74	0.014	0.003	0.02	0.03	0.15	0.07	0.09	0.01	0.01	0.007	0.0002	0.000	0.000	0.001	0.002	0.001

Mechanical Test Report

	Yield Strength	Tensile Strength	% Elongation in 2 inches
Tail	63,430 psi	80,850 psi	25.7%

This hot rolled steel has been produced to conform to DIN/EN 10204:2005 3.1 and has been manufactured to a fully killed fine grain practice. This hot rolled steel has been produced and tested in accordance with each of the following applicable standards: ASTM E1806-09, ASTM E415-14, ASTM A751-14, ASTM 1370-14, JIS Z2201:1998, JIS Z 2241:2011. Pressure Equipment Directive (PED) 97/23/EC 7/2, Annex I. Paragraph 4.3 Compliant. This report certifies that the above test results are representative of those contained in the records of North Star BlueScope Steel LLC for the material identified in this test report and is intended to comply with the requirements of the material description. North Star BlueScope Steel LLC is not responsible for the inability of this material to meet specific applications. Any modifications to this certification as provided negates the validity of this test report. All reproductions must have the written approval of North Star BlueScope Steel. This product was manufactured, melted, cast, and hot-rolled (min. 3:1 reduction ratio), entirely within the U.S.A at North Star BlueScope Steel LLC, Delta, Ohio. This material was not exposed to Mercury or any alloy which is liquid at ambient temperature during processing or while in North Star BlueScope Steel LLC possession. Test equipment calibration certificates are available upon request. NIST traceability is established through test equipment calibration certificates which are available upon request. Uncertainty calculations are calculated in accordance with NIST standards and are maintained at a 4:1 ratio in accordance with NIST standards. Uncertainty data is available upon request.

Tim Mitchell **Manager Quality Assurance and Technology**

Date Issued: Sep 19, 2016 23:30:27
Revision#: 01

Figure B-15. 12-ft 6-in. (3.8-m) 12-ga (2.7-mm) Thrie Beam Material Certification, Test Nos. MSPBN-4 through MSPBN-8

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296

Customer: UNIVERSITY OF NEBRASKA BOARD
OF REGENTS
3835 HOLDREGE STREET
LINCOLN, NE 68583-0745

Project: NDOR SPECS

Order Number: 1287937 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: SIGNED QUOTE
BOL Number: 102892 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 12/13/17

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
8	209G	T12/12'6/6'3/S			2	L34617													
			M-180	A	2	220389	57,310	76,740	23.1	0.190	0.710	0.009	0.003	0.020	0.100	0.000	0.060	0.002	4
			M-180	A	2	220390	59,530	79,920	23.0	0.190	0.730	0.009	0.003	0.020	0.110	0.000	0.050	0.002	4
			M-180	B	2	218080	57,310	74,880	28.1	0.190	0.720	0.010	0.004	0.010	0.120	0.000	0.070	0.002	4
			M-180	A	2	220389	57,310	76,740	23.1	0.190	0.710	0.009	0.003	0.020	0.100	0.000	0.060	0.002	4
			M-180	A	2	220390	59,530	79,920	23.0	0.190	0.730	0.009	0.003	0.020	0.110	0.000	0.050	0.002	4
			M-180	B	2	218080	57,310	74,880	28.1	0.190	0.720	0.010	0.004	0.010	0.120	0.000	0.070	0.002	4
6	12379G	T12/12'6/SPEC/S 34'RCX			2	L31917													
			M-180	A	2	208674	63,250	82,410	22.7	0.190	0.730	0.011	0.003	0.020	0.100	0.000	0.060	0.002	4
6	12383G	T12/12'6/6'3/SPEC SLOTS/S			2	L32817													
			M-180	A	2	216682	60,950	80,100	24.8	0.190	0.710	0.011	0.003	0.020	0.130	0.000	0.070	0.002	4
			M-180	A	2	216683	65,000	82,920	22.8	0.190	0.730	0.013	0.002	0.020	0.130	0.000	0.060	0.001	4
2	12385G	T12/12'6/SPEC/S 5'RCX			2	L32917													
			M-180	A	2	216682	60,950	80,100	24.8	0.190	0.710	0.011	0.003	0.020	0.130	0.000	0.070	0.002	4
			M-180	A	2	216683	65,000	82,920	22.8	0.190	0.730	0.013	0.002	0.020	0.130	0.000	0.060	0.001	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT , 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.

ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED

1 of 2

Figure B-16. 12-ft 6-in. (3.8-m) 12-ga (2.7-mm) Thrie Beam Material Certification, Test Nos. MSPBN 4, MSPBN-5, and MSPBN-8

Certified Test Report

NORTH STAR BLUESCOPE STEEL LLC
6767 County Road 9
Delta, Ohio 43515
Telephone: (888) 822-2112

Customer: Trinity Industries
2525 Stemmons Freeway
Dallas, TX 75207
Customer P.O.: 179261M-3
Cust. Ref/Part # 200212B

Order # 363307
Line Item # 1
Heat # 206982
Coil # 1648983

Ord Width (mm/in) 1504.950 / 59.250
Ord Gauge (mm/in) 2.438 / 0.096
Material Description 1018 CQ Modified, Guardrail Type 2
Production Date/Time Sep 16 2016 6:40PM

Weight (kg/lb) 26453 / 58319

Heat Chemical Analysis (wt%)

Type	C	Mn	P	S	Si	Al	Cu	Cr	Ni	Mo	Sn	N	B	V	Nb	Ti	Ca	Pb
Heat	0.19	0.73	0.010	0.003	0.01	0.03	0.14	0.05	0.08	0.01	0.01	0.006	0.0000	0.000	0.000	0.000	0.001	0.000

Mechanical Test Report

	Yield Strength	Tensile Strength	% Elongation in 2 inches
Tail	58,150 psi	79,150 psi	26.2%

This hot rolled steel has been produced to conform to DIN/EN 10204:2005 3.1 and has been manufactured to a fully killed fine grain practice. This hot rolled steel has been produced and tested in accordance with each of the following applicable standards: ASTM E1806-09, ASTM E415-14, ASTM A751-14, ASTM 1370-14, JIS Z2201:1998, JIS Z 2241:2011. Pressure Equipment Directive (PED) 97/23/EC 7/2, Annex I, Paragraph 4.3 Compliant. This report certifies that the above test results are representative of those contained in the records of North Star BlueScope Steel LLC for the material identified in this test report and is intended to comply with the requirements of the material description. North Star BlueScope Steel LLC is not responsible for the inability of this material to meet specific applications. Any modifications to this certification as provided negates the validity of this test report. All reproductions must have the written approval of North Star BlueScope Steel. This product was manufactured, melted, cast, and hot-rolled (min. 3:1 reduction ratio), entirely within the U.S.A at North Star BlueScope Steel LLC, Delta, Ohio. This material was not exposed to Mercury or any alloy which is liquid at ambient temperature during processing or while in North Star BlueScope Steel LLC possession. Test equipment calibration certificates are available upon request. NIST traceability is established through test equipment calibration certificates which are available upon request. Uncertainty calculations are calculated in accordance with NIST standards and are maintained at a 4:1 ratio in accordance with NIST standards. Uncertainty data is available upon request.

Tim Mitchell Manager Quality Assurance and Technology

Date Issued: Sep 20, 2016 03:33:43
Revision#: 01

Figure B-17. 12-ft 6-in. (3.8-m) 12-ga (2.7-mm) Thrie Beam Material Certification, Test Nos. MSPBN-4 through MSPBN-8

GREGORY HIGHWAY PRODUCTS, INC.
4100 13th St. SW
Canton, Ohio 44710

Customer: MIDWEST MACHINERY & SUPPLY CO.
P. O. BOX 703

MILFORD,NE,68405

Test Report
Ship Date: 11/27/2017
Customer P O: 3523
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project: INVENTORY
GHP Order No.: 217460

HT # code	Heat #	C.	MN.	P.	S.	SI.	Tensile	Yield	Elong.	Quanity	Class	Type	Description
0903	9416522	0.2	0.74	0.011	0.005	0.02	79773	57921	25.4	60	A	2	12GA 25FT0IN 3FT1 1/2IN WB T2
0971	B6446	0.2	0.72	0.007	0.002	0.04	74504	54650	17-1	140	A	2	12GA 25FT0IN 3FT1 1/2IN WB T2
0684	A86939	0.19	0.46	0.006	0.002	0.02	73747	53839	27.58	20	A	2	12GA 6FT3IN/3FT1 1/2IN TB T2
0488	A85303	0.2	0.48	0.009	0.002	0.03	72478	56954	23.42	40	A	2	12GA 25FT TB T2

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.
All other galvanized material conforms with ASTM-123 & ASTM-653
All Galvanizing has occurred in the United States
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Steel used meets Title 23CFR 635.410 - Buy America
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All controlled oxidized/corrosion resistant Guardrail and terminal sections meet ASTM A606, Type 4.

By: ____________________
Andrew Artar, VP of Sales & Marketing
Gregory Highway Products, Inc.

James P. Dehnke
Notary Public, State of Ohio
My Commission Expires 10-19-2019

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by
Andrew Artar this 28 day of November, 2017

Notary Public, State of Ohio

Figure B-18. 12-ft 6-in. (3.8-m) 12-ga (2.7-mm) Thrie Beam Material Certification, Test Nos. MSPBN-4 through MSPBN-7

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 B-19. 12-ft 6-in. (3.8-m) 12-ga (2.7-mm) Thrie Beam Material Certification, Test Nos. MSPBN-4 through MSPBN-7

Certified Test Report

NORTH STAR BLUESCOPE STEEL LLC
6767 County Road 9
Delta, Ohio 43515
Telephone: (888) 822-2112

Customer: Trinity Highway Products, LLC
2525 Stemmons Freeway
Dallas, TX 75207
Customer P.O.: 179844M-2
Cust. Ref/Part # 200212B

Order # 366172
Line Item # 1
Heat # 208318
Coil # 1660481

Ord Width (mm/in) 1504.950 / 59.250
Ord Gauge (mm/in) 2.438 / 0.096
Material Description 1018 CQ Modified, Guardrail Type 2
Production Date/Time Oct 25 2016 11:08PM

Weight (kg/lb) 26448 / 58308

Heat Chemical Analysis (wt%)

Type	C	Mn	P	S	Si	Al	Cu	Cr	Ni	Mo	Sn	N	B	V	Nb	Ti	Ca	Pb
Heat	0.19	0.72	0.011	0.003	0.02	0.02	0.11	0.06	0.04	0.01	0.00	0.008	0.0000	0.002	0.000	0.001	0.002	0.000

Mechanical Test Report

	Yield Strength	Tensile Strength	% Elongation in 2 inches
Tail	64,140 psi	81,540 psi	24.5%

This hot rolled steel has been produced to conform to DIN/EN 10204:2005 3.1 and has been manufactured to a fully killed fine grain practice. This hot rolled steel has been produced and tested in accordance with each of the following applicable standards: ASTM E1806-09, ASTM E415-14, ASTM A751-14, ASTM 1370-14, JIS Z2201:1998, JIS Z 2241:2011. Pressure Equipment Directive (PED) 97/23/EC 7/2, Annex I, Paragraph 4.3 Compliant. This report certifies that the above test results are representative of those contained in the records of North Star BlueScope Steel LLC for the material identified in this test report and is intended to comply with the requirements of the material description. North Star BlueScope Steel LLC is not responsible for the inability of this material to meet specific applications. Any modifications to this certification as provided negates the validity of this test report. All reproductions must have the written approval of North Star BlueScope Steel. This product was manufactured, melted, cast, and hot-rolled (min. 3:1 reduction ratio), entirely within the U.S.A at North Star BlueScope Steel LLC, Delta, Ohio. This material was not exposed to Mercury or any alloy which is liquid at ambient temperature during processing or while in North Star BlueScope Steel LLC possession. Test equipment calibration certificates are available upon request. NIST traceability is established through test equipment calibration certificates which are available upon request. Uncertainty calculations are calculated in accordance with NIST standards and are maintained at a 4:1 ratio in accordance with NIST standards. Uncertainty data is available upon request.

Tim Mitchell **Manager Quality Assurance and Technology**

Date Issued: Nov 02, 2016 08:30:59
Revision#: 01

PASSED & CERTIFIED
NOV - 2 2016
Trinity Highway Products, LLC
Dallas, Texas Plant 99

Figure B-20. 12-ft 6-in. (3.8-m) 12-ga (2.7-mm) Thrie Beam Material Certification, Test Nos. MSPBN-4 through MSPBN-7

Certified Test Report

NORTH STAR BLUESCOPE STEEL LLC
6767 County Road 9
Delta, Ohio 43515
Telephone: (888) 822-2112

Customer: Trinity Highway Products, LLC
2525 Stemmons Freeway
Dallas, TX 75207
Customer P.O.: 179844M-4
Cust. Ref/Part # 200212B

Order # 367396
Line Item # 1
Heat # 208674
Coil # 1663489

Ord Width (mm/in) 1504.950 / 59.250
Ord Gauge (mm/in) 2.438 / 0.096
Material Description 1018 CQ Modified, Guardrail Type 2
Production Date/Time Nov 5 2016 12:38PM

Weight (kg/lb) 26712 / 58890

Heat Chemical Analysis (wt%)

Type	C	Mn	P	S	Si	Al	Cu	Cr	Ni	Mo	Sn	N	B	V	Nb	Ti	Ca	Pb
Heat	0.19	0.73	0.011	0.003	0.02	0.02	0.10	0.06	0.04	0.01	0.01	0.007	0.0000	0.002	0.000	0.000	0.001	0.000
Coil Tail	0.19	0.73	0.011	0.003	0.02	0.02	0.10	0.06	0.04	0.01	0.01	0.007	0.0000	0.002	0.000	0.000	0.001	0.000
Coil Head	0.19	0.73	0.013	0.003	0.02	0.03	0.10	0.06	0.03	0.01	0.00	0.007	0.0000	0.000	0.001	0.001	0.001	0.000

Mechanical Test Report

	Yield Strength	Tensile Strength	% Elongation in 2 inches
Tail	63,250 psi	82,410 psi	22.7%

This hot rolled steel has been produced to conform to DIN/EN 10204:2005 3.1 and has been manufactured to a fully killed fine grain practice. This hot rolled steel has been produced and tested in accordance with each of the following applicable standards: ASTM E1806-09, ASTM E415-14, ASTM A751-14, ASTM 1370-14; JIS Z2201:1998, JIS Z 2241:2011. Pressure Equipment Directive (PED) 97/23/EC 7/2, Annex I, Paragraph 4.3 Compliant. This report certifies that the above test results are representative of those contained in the records of North Star BlueScope Steel LLC for the material identified in this test report and is intended to comply with the requirements of the material description. North Star BlueScope Steel LLC is not responsible for the inability of this material to meet specific applications. Any modifications to this certification as provided negates the validity of this test report. All reproductions must have the written approval of North Star BlueScope Steel. This product was manufactured, melted, cast, and hot-rolled (min. 3:1 reduction ratio), entirely within the U.S.A at North Star BlueScope Steel LLC, Delta, Ohio. This material was not exposed to Mercury or any alloy which is liquid at ambient temperature during processing or while in North Star BlueScope Steel LLC possession. Test equipment calibration certificates are available upon request. NIST traceability is established through test equipment calibration certificates which are available upon request. Uncertainty calculations are calculated in accordance with NIST standards and are maintained at a 4:1 ratio in accordance with NIST standards. Uncertainty data is available upon request.

Tim Mitchell — Manager Quality Assurance and Technology

Date Issued: Nov 11, 2016 14:30:17
Revision#: 01

PASSED & CERTIFIED
NOV 11 2016
Trinity Highway Products, LLC
Dallas, Texas Plant 99

Figure B-21. 12-ft 6-in. (3.8-m) 12-ga (2.7-mm) Thrie Beam Material Certification, Test Nos. MSPBN-4 through MSPBN-7

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296

Order Number: 1287937 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: SIGNED QUOTE
BOL Number: 102892 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 12/13/17

Customer: UNIVERSITY OF NEBRASKA BOARD
OF REGENTS
3835 HOLDREGE STREET

LINCOLN, NE 68583-0745

Project: NDOR SPECS

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
8	209G	T12/12'6/6'3/S			2	L34617													
			M-180	A	2	220389	57,310	76,740	23.1	0.190	0.710	0.009	0.003	0.020	0.100	0.000	0.060	0.002	4
			M-180	A	2	220390	59,530	79,920	23.0	0.190	0.730	0.009	0.003	0.020	0.110	0.000	0.050	0.002	4
			M-180	B	2	218080	57,310	74,880	28.1	0.190	0.720	0.010	0.004	0.010	0.120	0.000	0.070	0.002	4
			M-180	A	2	220389	57,310	76,740	23.1	0.190	0.710	0.009	0.003	0.020	0.100	0.000	0.060	0.002	4
			M-180	A	2	220390	59,530	79,920	23.0	0.190	0.730	0.009	0.003	0.020	0.110	0.000	0.050	0.002	4
			M-180	B	2	218080	57,310	74,880	28.1	0.190	0.720	0.010	0.004	0.010	0.120	0.000	0.070	0.002	4
6	12379G	T12/12'6/SPEC/S 34'RCX			2	L31917													
			M-180	A	2	208674	63,250	82,410	22.7	0.190	0.730	0.011	0.003	0.020	0.100	0.000	0.060	0.002	4
6	12383G	T12/12'6/6'3/SPEC SLOTS/S			2	L32817													
			M-180	A	2	216682	60,950	80,100	24.8	0.190	0.710	0.011	0.003	0.020	0.130	0.000	0.070	0.002	4
			M-180	A	2	216683	65,000	82,920	22.8	0.190	0.730	0.013	0.002	0.020	0.130	0.000	0.060	0.001	4
2	12385G	T12/12'6/SPEC/S 5'RCX			2	L32917													
			M-180	A	2	216682	60,950	80,100	24.8	0.190	0.710	0.011	0.003	0.020	0.130	0.000	0.070	0.002	4
			M-180	A	2	216683	65,000	82,920	22.8	0.190	0.730	0.013	0.002	0.020	0.130	0.000	0.060	0.001	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT , 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.
ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED

1 of 2

Figure B-22. 12-ft 6-in. (3.8-m) 12-ga (2.7-mm) Thrie Beam Material Certification, Test Nos. MSPBN-4 and MSPBN-5

QUALITY CERTIFICATE

NINGBO JINDING FASTENING PIECE CO., LTD

XIJINGTANG JIULONGHU NINGBO CHINA TEL:+86-574-86530122 FAX: +86-574-86530858

Customer:	FASTENAL COMPANY PURCHASING - IMPORT	Date :	2015 09 21
Product:	HEX TAP BOLT	Contract No:	14JDF907T
Class:	5	Invoice No:	15-00997648
Size:	7/16-14X2-1/2	Lot No:	3339950007
Marking:	JDF three radius	Order No.	120219926
Quantity:	3.600 mpcs	Part No.	0167260
		Production Date	2015-01-26
Dimensions Of SPEC:		Certificate No.:	201502130052

Inspection Items		Standard	Result	Sample	Pass
Visual Appearance		-------------	OK	22	22
Body Diameter		/	/	4	4
Thread	Go	2A	OK	15	15
	No Go	2A	OK	15	15
Width Across Flats		0.625-0.612	0.616-0.617	4	4
Width Across Corners		0.722-0.698	0.703-0.705	4	4
Major Diameter		0.426-0.436	0.429-0.430	15	15
Head Height		0.291-0.272	0.283-0.285	4	4
Total Length		2.500-2.440	2.469-2.474	15	15
Thread Length		min 2.321	2.377-2.416	15	15
Mechanical Properties					
CharacTeristics		Standard	Result		
Surface Hardness	[30N]	MAX 54	43-46	15	15
Core Hardness	[HRC]	25-34	27-29	15	15
Wedge Strength	[psi]	min 119880	131345-136134	4	4
Yield Strength	[psi]	min 91869	102028-115816	4	4
Elongation	[%]	min 14	15.8-18.9	4	4
Reduction Of area	[%]	min 35	41.5-56.2	4	4
Proof Load	[Ib]	9050	9050	4	4
Decarburization		N≥1/2H1 HV0.3	306.00 306.00 302.00	4	4
HV2>=HV1-30, HV3<=HV1+30		G 0.0006max			

CHEMICAL COMPOSITION(%)

Heat No		C	Si	Mn	P	S	Cr	Ni	Cu	Mo	B
35#	4209984BB	0.35	0.16	0.65	0.020	0.007					

Surface Coating: PLAIN

Thread Specification: ASME B1.1 2008, UNIFIED INCH SCREW THREADS(UN AND UNR THREAD FORM)

Sampling Dimension Specification: ASME B18.18.2 2011 inspection and quality assurance for high-volume machine assembly fasteners

Dimension Specification: ASME B18.2.1 2012, HEX CAP SCREWS

Sampling mechanical properties specification: ASTM F1470 2012 Standard Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

Mechanical Properties: SAE J429 2014, MECHANICAL AND MATERIAL REQUIREMENTS FOR EXTERNALLY THREADED FASTENERS

Surface Defect: ASTM F788/F788M, SURFACE DISCONTINUITIES OF BOLTS, SCREWS, AND STUDS

Quality Control Supervisor | Quality Control Manager

NINGBO JINDING FASTENING PIECE CO., LTD INSPECTION DEP
宁波金鼎紧固件
有限公司质检科

Figure B-23. $^{7}/_{16}$-in. (11-mm) Dia. 2½-in. (64-mm) Long Hex Tap Bolt Material Specification, Test Nos. MSPBN-4 through MSPBN-7

SUPER CHENG INDUSTRIAL CO.,LTD.

NO. 18 BEN-GONG 2nd ROAD., BEN CHOU INDUSTRIAL PARK, KAOHSIUNG COUNTY 820, TAIWAN R.O.C.
TEL：886-7-6225326-30(5 LINES) FAX：886-7-6215377/6212335/6235829

CERTIFICATE OF INSPECTION

CERT. #： S32170505 ISSUED DATE： 2017/6/22 PAGE 1 OF 1

CLIENT：SUPER CHENG INDUSTRIAL CO., LTD.
ADDRESS：NO. 18 BEN-GONG 2nd ROAD., BEN CHOU INDUSTRIAL PARK, KAOHSIUNG COUNTY 820, TAIWAN R.O.C.

PURCHASER：FASTENAL COMPANY PURCHASING PO #：220025396
PART# 36307 QTY SHIPPED：20,400 PCS

COMMODITY：GRADE 5 FIN HEX NUT FINISH： PLN
SIZE： 7/16-14 LOT#： S32170505 SAMPLING PLAN：ASME B18.18-11 / ASTM F1470-12
QTY： 20400 PCS MATERIAL： SWRCH10A HEAT NO.： 360796
MANUFACTURER：SUPER CHENG IND. CO., LTD. MANU. DATE： 2017/6/15

DIMENSIONAL INSPECTION SPEC.：ANSI/ASME B18.2.2-15 SAMPLED BY： SU YUN CHUANG

ITEM	SAMPLE SIZE	SPECIFIED	ACTUAL RESULT	JUDGMENT
APPEARANCE	29	ASTM F812-12	GOOD	OK
THREAD	15	ASME B1.1-03	PASS	OK
W.A.F.	4	0.688 ~ 0.675 in	0.677 ~ 0.676 in.	OK
W.A.C.	4	0.794 ~ 0.768 in	0.776 ~ 0.774 in.	OK
THICKNESS	4	0.385 ~ 0.365 in	0.380 ~ 0.378 in.	OK

MECHANICAL PROPERTIES SPEC.：SAE J995-12 SAMPLED BY： SU YUN CHUANG

ITEM	SAMPLE SIZE	TEST METHOD	SPECIFIED	ACTUAL RESULT	JUDGMENT
HARDNESS	4	ASTM F606/F606M-16	MAX HRC32	97 ~ 96 HRBW	PASS
PROOF LOAD	3	ASTM F606/F606M-16	MIN 12800 LB	12915 ~ 12915 LB	PASS

REMARK：1、THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL WITHOUT WRITTEN APPROVAL OF THE LAB.
2、THIS INSPECTION CERTIFICATE IS FOR RESPONSIBILITY UNDER SAMPLE ONLY
3、ABOVE SAMPLES TESTED CONFORM TO THE FASTENER SPECIFICATION OR STANDARDS

世鋮工廠產業股份有限公司 測試實驗室專用章 SUPER CHENG INDUSTRIAL CO., LTD.

LAB. DIRECTOR(SIGNATORY)：

表單編號：LQC 10E Rev.0

Figure B-24. 7/16-in. (11-mm) Dia. Heavy Hex Nut Material Specification, Test Nos. MSPBN-4 through MSPBN-7

Certificate of Compliance

Birmingham Fastener Manufacturing
PO Box 10323
Birmingham, AL 35202
(205) 595-3512

Customer	Midwest Machinery	**Date Shipped**	06/16/2016
Customer Order Number	3275	**BFM Order Number**	1338859

Item Description

Description 5/8"-11 x 10" Hex Bolt **Qty** 157

Lot # 208977 **Specification** ASTM A307-14 Gr A **Finish** ASTM F2329

Raw Material Analysis

Heat# DL15107048

Chemical Composition (wt% Heat Analysis) By Material Supplier

C	Mn	P	S	Si	Cu	Ni	Cr	Mo
0.22	0.82	0.007	0.010	0.27	0.20	0.06	0.10	0.015

Mechanical Properties

Sample #	Hardness	Tensile Strength (lbs)	Tensile Strength (psi)
1	91 HRBW	21,700	97,660
2			
3			
4			
5			

This information represents the most recent analysis of the product supplied on the stated customer order. The samples tested conform to the ASTM standard listed above.
All steel melted and manufactured in the U.S.A.

Authorized Signature: [signature] **Date:** 6/16/2016

Brian Hughes
Quality Assurance

Figure B-25. ⅝-in. (16-mm) Dia., 10-in. (254-mm) Long Hex Bolt Material Specification, Test Nos. MSPBN-4 through MSPBN-8

ISO/TS 16949
BUREAU VERITAS
Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER : GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2017/03/23

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 110216407
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 5/8-11 NC O/T 0.51MM
LOT NO : 1N1680027
SHIP QUANTITY : 23, 400 PCS
LOT QUANTITY 170, 278 PCS
HEADMARKS :

PACKING NO : GEM160919007
INVOICE NO : GEM/FNL-160929WI
PART NO : 36713
SAMPLING PLAN : ASME B18. 18-2011(Category. 2)/ASTM F1470-2012
HEAT NO : 331608011
MATERIAL : ML08
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

MANUFACTURE DATE : 2016/08/26
COUNTRY OF ORIGIN : CHINA

R#17-507 H#331608011
BCT Cable Bracket Nuts

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2007

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0.5800		0.1300	0.2300	
Test Value	0.0350	0.0700	0.4100	0.0160	0.0060	0.0500

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18. 2. 2-2010

SAMPLED BY : DWTING

INSPECTIONS ITEM	SAMPLE	SPECIFIED		ACTUAL RESULT	ACC.	REJ.
WIDTH ACROSS CORNERS	6PCS	ASME B18. 2. 2-2010	1.0510-1.0830 inch	1.0560-1.0690 inch	6	0
FIM	15PCS		Max. 0.0210 inch	0.0020-0.0040 inch	15	0
THICKNESS	6PCS		0.5350-0.5590 inch	0.5390-0.5570 inch	6	0
WIDTH ACROSS FLATS	6PCS		0.9220-0.9380 inch	0.9240-0.9340 inch	6	0
SURFACE DISCONTINUITIES	29PCS		ASTM F812-2012	PASSED	29	0
THREAD	15PCS		GAGING SYSTEM 21	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2007

SAMPLED BY : GDAN LIAN

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15 PCS	ASTM F606-2014		68-107 HRB	79-81 HRB	15	0
PROOF LOAD	4 PCS	ASTM F606-2014		Min. 90 KSI	OK	4	0
PLATING THICKNESS(μm)	5 PCS	ASTM B568-1998		>=53	70.02-75.81	5	0

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER

Quality Supervisor: Erin

page 1 of 1

Figure B-26. ⅝-in. (16-mm) Dia. Hex Nut Material Specification, Test Nos. MSPBN-4 through MSPBN-8

CERTIFICATE OF COMPLIANCE

ROCKFORD BOLT & STEEL CO.
126 MILL STREET
ROCKFORD, IL 61101
815-968-0514 FAX# 815-968-3111

CUSTOMER NAME: GREGORY INDUSTRIES

CUSTOMER PO: 37464

SHIPPER#: 060204
DATE SHIPPED: 04/10/2017

LOT#: 29256-G

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE:	SPEC:	60,000 psi*min	RESULTS:	66,593 67,960
HARDNESS:		100 max		70.40 70.30

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
ROGERS GALVANIZE: 29256-G

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
CHARTER	1010	20460760	.09	.33	.006	.003	.06

QUANTITY AND DESCRIPTION:

105,000 PCS 5/8" X 1.25" GUARD RAIL BOLT
P/N 1001G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS

10th DAY OF April, 2017 — Linda McLomas — APPROVED SIGNATORY — 4/10/17 DATE

Merry F. Shane

OFFICIAL SEAL
MERRY F. SHANE
NOTARY PUBLIC – STATE OF ILLINOIS
MY COMMISSION EXPIRES OCTOBER 3, 2018

Figure B-27. ⅝-in. (16-mm) Dia., 1¼-in. (32-mm) Long Guardrail Bolt Certificate of Compliance, Test Nos. MSPBN-4 through MSPBN-7

CHARTER STEEL
A Division of Charter Manufacturing Company, Inc.

EMAIL

1658 Cold Springs Road
Saukville, Wisconsin 53080
(262) 268-2400
1-800-437-8789
Fax (262) 268-2570

CHARTER STEEL TEST REPORT

Melted in USA Manufactured in USA

Decker Manufacturing Corp.
703 N. Clark St.
Albion,MI-49224

Cust P.O.	50366-1704
Customer Part #	1.125 1010
Charter Sales Order	30127572
Heat #	10470360
Ship Lot #	3257182
Grade	1010 A AK FG RHQ 1-1/8
Process	HRCC
Finish Size	1-1/8
Ship date	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed below and that it satisfies these requirements. The recording of false, fictitious and fraudulent statements or entries on this document may be punishable as a felony under federal statute.

Test results of Heat Lot # 10470360

Lab Code: 7388

CHEM	C	MN	P	S	SI	NI	CR	MO	CU	SN	V
%Wt	.09	.44	.008	.009	.090	.04	.07	.02	.06	.004	.001
	AL	N	B	TI	NB						
	.025	.0070	.0001	.001	.001						

Test results of Rolling Lot # 1201860

	# of Tests	Min Value	Max Value	Mean Value	
ROCKWELL B (HRBW)	3	62	62	62	RB LAB = 0356-02
ROD SIZE (Inch)	10	1.122	1.133	1.128	
ROD OUT OF ROUND (Inch)	5	.004	.006	.005	

REDUCTION RATIO=30:1

Specifications: Manufactured per Charter Steel Quality Manual Rev Date 12/12/13
Charter Steel certifies this product is indistinguishable from background radiation levels by having process radiation detectors in place to measure for the presence of radiation within our process & products.
Meets customer specifications with any applicable Charter Steel exceptions for the following customer documents:
Customer Document = ASTM A29/A29M Revision = 15 Dated = 01-NOV-15

Additional Comments:

Melt Source:
Charter Steel
Saukville, WI, USA

Rem: Load1,Fax0,Mail0

ACCREDITED Testing Laboratory

This MTR supersedes all previously dated MTRs for this order

Janice Barnard Division Mgr. of Quality Assurance
barnardJ@chartersteel.com
Printed Date : 04/12/2017

Page 1 of 2

Figure B-28. ⅝-in. (16-mm) Dia. Hex Nut Material Specification, Test Nos. MSPBN-4 through MSPBN-7

CERTIFIED MATERIAL TEST REPORT
FOR ASTM A307, GRADE A - MACHINE BOLTS

FACTORY: NINGBO ECONOMIC & TECHNICAL DEVELOPMENT ZONE YONGGANG FASTENERS CO., LTD.
REPORT DATE:2016/12/29
R#17-507 H#816070039
ADDRESS: FuShan South Road No.17,BeiLun NingBo China
BCT Cable Bracket Bolts
MANUFACTURE DATE:2016/12/2
TEL#(852)25423366
CUSTOMER: FASTENAL MFG LOT NUMBER:M-2016HT927-9
SAMPE SIZE: ACC.TO Dimension:ASME B18.18-11;Mechanical Properties:ASTM F1470-12
MANU QTY: 4800PCS SHIPPED QTY: 4800PCS
SIZE: 5/8-11X1 1/2 HDG
HEADMARKS: 307A PLUS NY PO NUMBER:220023115
PART NO:1191919

STEEL PROPERTIES:
MATERIAL TYPE:Q195 HEAT NUMBER: 816070039

CHEMISTRY SPEC:	C %*100	Mn%*100	P %*1000	S %*1000
Grade A ASTM A307-12	0.29max	1.20 max	0.04max	0.15max
TEST:	0.07	0.28	0.016	0.003

DIMENSIONAL INSPECTIONS Unit:inch SPECIFICATION: ASME B18.2.1 - 2012

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
*********************	***********************************	******************	********	********
VISUAL	ASTM F788-2013	PASSED	22	0
THREAD	ASME B1.1-2003,3A GO,2A NOGO	PASSED	15	0
WIDTH FLATS	0.906-0.938	0.915-0.928	4	0
WIDTH A/C	1.033-1.083	1.048-1.057	4	0
HEAD HEIGHT	0.378-0.444	0.394-0.424	4	0
THREAD LENGTH	1.420-1.560	1.435-1.541	15	0
LENGTH	1.420-1.560	1.435-1.541	15	0

MECHANICAL PROPERTIES: SPECIFICATION: ASTM A307-2012 GR-A

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
********************	******************	*****************	*****************	********	********
CORE HARDNESS :	ASTM F606-2014	69-100 HRB	76-79 HRB	4	0
WEDGE TENSILE:	ASTM F606-2014	Min 60 KSI	65-69 KSI	4	0

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
COATINGS OF ZINC:		SPECIFIATION:ASTM F2329-2013			
HOT DIP GALVANIZED	ASTM B568-98(2104)	Min 0.0017"	0.0017" -0.0018"	4	0

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.

Maker's ISO# 00109Q16722R3M/3302

NINGBO ECONOMIC & TECHNICAL DEVELOPMENT ZONE YONGGANG FASTENERS CO., LTD

(SIGNATURE Q.A. LAB MGR.)
(NAME OF MANUFACTURER)

Figure B-29. ⅝-in. (16-mm) Dia., 1½-in. (38-mm) Long Guardrail Bolt Material Specifications, Test Nos. MSPBN-4 through MSPBN-8

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: RESALE

Order Number: 1269489 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3346
BOL Number: 97457 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 11/7/16

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
175	3580G	5/8"X18" GR BOLT A307	HW			29145-B													
6	6696G	CBL 5/8"X14'4.75/DBL BTN	HW			248853													
400	6740B	PLYMR BLK 6X12X14 MT	HW			27950													
4	9852A	STRUT & YOKE ASSY	A-36			195070	52,940	69,970	31.1	0.190	0.520	0.014	0.004	0.020	0.110	0.000	0.050	0.000	4
7	12379G	T12/12'6/SPEC/S 34'RCX	RHC		2	L34713													4
			M-180	A	2	172876	55,930	72,020	31.4	0.190	0.720	0.014	0.002	0.020	0.130	0.000	0.080	0.000	4
			M-180	A	2	172876	55,930	72,020	31.4	0.190	0.720	0.014	0.002	0.020	0.130	0.000	0.080	0.000	4
6	12383G	T12/12'6/6'3/SPEC SLOTS/S	RHC			L33814													4
			M-180	A		182997	58,340	76,890	26.9	0.180	0.730	0.014	0.004	0.010	0.130	0.000	0.060	0.001	4
			M-180	A		182998	60,310	78,910	25.4	0.200	0.730	0.012	0.006	0.010	0.140	0.000	0.050	0.001	4
			M-180	A		182997	58,340	76,890	26.9	0.180	0.730	0.014	0.004	0.010	0.130	0.000	0.060	0.001	4
			M-180	A		182998	60,310	78,910	25.4	0.200	0.730	0.012	0.006	0.010	0.140	0.000	0.050	0.001	4
3	12385G	T12/12'6/SPEC/S 5'RCX			2	L34416													
			M-180	A	2	208318	64,140	81,540	24.5	0.190	0.720	0.011	0.003	0.020	0.110	0.000	0.060	0.000	4
24	19361G	BNT PL 3/16X12-5/8X5-1/2	A-36			B4M5475	46,800	70,400	29.1	0.180	0.840	0.007	0.008	0.060	0.170	0.000	0.070	0.001	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT , 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.

Figure B-30. ⅝-in. (16-mm) Dia., 18-in. (457-mm) Long Guardrail Bolt, Test No. MSPBN-4

From: FAXmaker To: 1-815-877-0734 Page: 1/1 Date: 5/14/2015 4:00:16 PM

Heat Number	Shipper No	Invoice No	Customer PO#	Customer Name
2038622	680907	701917	5-7-2015 MIKE	GAFFNEY BOLT CO.

CMC

1SERIES-BPS®

CMC STEEL SOUTH CAROLINA
310 New State Road
Cayce SC 29033-3704

CERTIFIED MILL TEST REPORT
For additional copies call
800-637-3227

We hereby certify that the test results presented here
are accurate and conform to the reported grade specification

Richard S. Ray

Richard S. Ray - CMC Steel SC
Quality Assurance Manager

HEAT NO.:2038622 SECTION: ROUND 7/8 x 40'0" A36/52950 GRADE: ASTM A36-12/A529-05 Gr 50 ROLL DATE: 09/09/2014 MELT DATE: 09/08/2014	SOLD TO	Infra-Metals - Mars 1601 Broadway St Marseilles IL US 61341-9326 8009875283	SHIP TO	Infra-Metals - Mars 1601 Broadway St Marseilles IL US 61341-9326 8009875283	Delivery#: 81471569 BOL#: 70533247 CUST PO#: CE-485729 CUST P/N: DLVRY LBS / HEAT: 9075.000 LB DLVRY PCS / HEAT: 111 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.16%	Elongation Gage Lgth test 1	8IN		
Mn	0.73%	Reduction of Area test 1	58%		
P	0.013%	Yield to tensile ratio test1	0.75		
S	0.021%	Yield Strength test 2	56.9ksi		
Si	0.22%	Tensile Strength test 2	76.5ksi		
Cu	0.32%	Elongation test 2	25%		
Cr	0.13%	Elongation Gage Lgth test 2	8IN		
Ni	0.10%	Reduction of Area test 2	57%		
Mo	0.027%	Yield to tensile ratio test2	0.74		
V	0.000%	C+(Mn/6)	0.28%		
Cb	0.026%				
Sn	0.010%				
Al	0.000%				
Ti	0.001%				
N	0.0084%				
Carbon Eq A529	0.38%				
Yield Strength test 1	57.1ksi				
Tensile Strength test 1	76.3ksi				
Elongation test 1	23%				

THIS MATERIAL IS FULLY KILLED, 100% MELTED AND MANUFACTURED IN THE USA, WITH NO WELD REPAIR OR MERCURY CONTAMINATION IN THE PROCESS.

REMARKS :

ALSO MEETS ASTM GRADE A36 REV-03A, A529 GR.50, A572-2013A GR.50, A709 GR.36, A709 GR.50, A992, AASHTO GRADE M270 GR.36, M270 GR.50, CSA G40.21-04 GRADE 44W, 50WASME SA-36 2008A ADDEND A.

03/18/2015 14:05:35
Page 1 OF 1

Figure B-31. ⅞-in. (22-mm) Dia., 8-in. (203-mm) Long Hex Bolt Material Specification, Test Nos. MSPBN-4 through MSPBN-8

INSPECTION CERTIFICATE

Customer	Specification	Size	Lot No.	Date
	ASTM A-563 GRADE DH HEAVY HEX NUT	7/8- 9 UNC	WA651	Jun. 29,'12

UNYTITE, INC.
One Unytite Drive
Peru, Illinois 61354
815-224-2221 — FAX# 815-224-3434

Mechanical properties tested in accordance to ASTM F606/F606M, ASTM A370, ASTM E18

Chemical Composition (%)

Mill Maker	Material Size	Heat No.	Spec.	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	
NUCOR	CARBON			0.20 0.55	-	MIN. 0.60	MAX. 0.040	MAX. 0.050	-	-	-	-	-
STEEL	STEEL	12101054		0.43	0.24	0.87	0.015	0.020	0.09	0.04	0.08	-	-

Mechanical Property Inspection

Item	Proof Load	Cone stripping	Hardness	After Heat Treatment Hardness	Absorbed Energy	Heat Treatment
Spec.	80,850 lbf	- kN·kgf·lbf	24-38 HrC	HrB·HB	j·kgfm·ftlbf	T:MIN.800 F
Results	n: 5	n: -	29.4 28.9 29.7 29.7 29.5 29.4	5 Piece Average After Heat Treament		Q:FORGING Q (W.Q.) T:1058 F/45M. (W.C.
	Results: GOOD	Results: -		Hardness Treatment After 24 Hr.X °F(°C)	at °F(°C)	Q: Quenching T: Tempering ST: Solution Treatment

Shape & Dimension Inspection	ANSI B18.2.2 GOOD
Thread Precision Inspection	ANSI B1.1 CLASS 2B GOOD
Appearance Inspection	GOOD

Remarks:

"DH U"

Production Quantity 22,391 pcs.

BCT Foundation Tube
Keeper Bolt Nuts
R#15-0600 June 2015 SMT

OFFICIAL SEAL
JEAN MARGHERIO
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES:10/18/13
07-10-12

Material used for the nut was melted and manufactured in the USA. The nut was manufactured in the USA to the above specification.

We hereby certify that the material described has been manufactured and inspected satisfactorily with the requirement of the above specification.

Chief of Quality Assurance Section

Figure B-32. ⅞-in. (22-mm) Dia. Hex Nut Material Specification, Test Nos. MSPBN-4 through MSPBN-8 songhyun KPF VINA

INSPECTION CERTIFICATE(According to EN10204 Type 3.1)

Certificate No. : KPF VINA QC-20160504 - 586
P/O No. : 160119236
Part No. : 13429
Date Issued : 2016/05/04
Date Shipped : 2016/05/18
Date Tested : 2016/05/04
Date Manufactured : 2016/05/03
Specifications : SAE J429 - 2014

Customer : FASTENAL
Description : H C/SCW GR.5 ZN
Grade : GR.5
Size : 7/8 - 9UNC 8
Marking : LOGO, 3LINES(120°)
Surface Condition : ZN.Cr 3+
Lot No. : V2G04769 - 00
Q'ty Shipped : 450 PCS

KPF VINA
Marketing : 601 Yongtan-dong, Chungju-city,
Chunghcheongbuk-do, 380-250, South Korea
TEL : +82) (0) 43 - 849 - 1217
FAX : +82) (0) 43 - 849 - 1230
FACTORY : Plot XN2, Dai An Expansion IZ,Lai Cach Town, Cam Giang Dist,
Hai Duong Province,Vietnam
TEL : +84) (0) 320 - 3555 - 127
FAX : +84) (0) 320 - 3555 - 125 ~ 126

PAGE 1/2

1. Chemical Composition (%)

Heat No.		C x100	Si x100	Mn x100	P x1000	S x1000	Cr x100	Mo x100	Ni x100	B x10000	Cu x100	Ti x1000	V x100	Al x1000	
Spec.	Min.	15													
	Max.	40			25	25				30					
X51512089002		35	16	77	13	9	12	0.4	0.6	20	1	65	0.6	38	

2. Macroetch Meet

Division	Surface Condition	Random Condition	Center Segregation	Spec. of Test Method
Spec.				
Results				
Tested By				

3. Mechanical Properties

Division		Hardness Surface	Hardness core	Specimen Tensile Yield Strength	Specimen Tensile Tensile Strength	Specimen Tensile Elongation	Specimen Tensile Reduction of Area	Proof Load Load	Proof Load Elongation	Wedge Tensile Load	Plate Thickness	Salt Spray	Baking Treatment Temperature	Baking Treatment Time	Thread go Ring Gauge 2A & 3A	Impact Test	Complete Decarburization the thread	Decarburized thread zone
Sample Size		3	3					2		2	9	3			9			2
Unit		HR 30N	HRC	psi	psi	%	%	lbf	inch	lbf	inch	Hour						HV
Spec.	Min.	-	25					39,300		55,400	0.0001	6 (No White rust) 12 (No Red rust)						1/2 H
	Max.	54	34						0.0005									-
Result	Min.	46	30					39,465	0.0000394	65,307	0.0003625	Pass			Pass			Pass
	Avg.	47	30					39,471	0.0000788	65,756	0.0003743							Pass
	Max.	47	31					39,450	0.0000788	66,116	0.0003861							Pass
Tested By		Vu Van Quyen	Nguyen Van Manh					Nguyen Huu Minh		Nguyen Van Dung	Vu Chi Pha	Vu Chi Pha			Vu Chi Pha			Vu Van Quyen
Spec. of Test Method		ASTM E18 - 14	ASTM F606 - 14					ASTM F606 - 14		ASTM F606 - 14	ASTM F1941 - 10	ASTM F1941/F1941M - 15			ASME B1.3M - 2007			ASTM F2328 - 14

Reference :
+ Complete Decaburization the thread of Test Method: Hardness vickers Method.
+ Non - Decarburized thread zone of Test Method: Microscope Method.
+Tempering Temperature: 427°C
+ Sampling Size follow by ASTM F1470-12

This is to certify that the above results are true and correct in every details.

PRODUCTION DIRECTOR
Lee Chaegyu
Chief of Quality Control Dept.

Mã hiệu (Code)	F.23 - QC.PR.01	Ngày ban hành (Date Issued)	1-May-12	Ngày sửa đổi (Date Modify)	-
Lần ban hành (Times Issued)	1	Số trang (Page No)	00	Số lần sửa đổi (Rev)	00

A4(210x297)mm

Figure B-33. ⅞-in. (22-mm) Dia., 8-in. (203-mm) Long Hex Bolt Material Specification, Test Nos. MSPBN-4 through MSPBN-7

SUPER CHENG INDUSTRIAL CO.,LTD.

NO. 18 BEN-GONG 2nd ROAD., BEN CHOU INDUSTRIAL PARK, KAOHSIUNG COUNTY 820, TAIWAN R.O.C.
TEL：886-7-6225326-30(5 LINES) FAX：886-7-6215377/6212335/6235829

CERTIFICATE OF INSPECTION

CERT. #： S01-1212-02FT ISSUED DATE： 2013/1/14 PAGE 1 OF 1

CLIENT：SUPER CHENG INDUSTRIAL CO., LTD.
ADDRESS：NO. 18 BEN-GONG 2nd ROAD., BEN CHOU INDUSTRIAL PARK, KAOHSIUNG COUNTY 820, TAIWAN R.O.C.

PURCHASER： RAPIDFIX INDUSTRIAL(ASIA)LIMITED PO #：41200014
PART #36318 QTY SHIPPED：12,000 PCS

COMMODITY：GRADE 5 FIN HEX NUT FINISH： TRIVALENT ZINC
SIZE： 7/8-9 LOT#： S01-1212-02F SAMPLING PLAN：ANSI/ASME B18.18.2M-93
QTY： 50477 PCS MATERIAL： 10B21 HEAT NO.： 1XS51
MANUFACTURER：SUPER CHENG IND. CO., LTD. MANU. DATE： 2012/12/10

DIMENSIONAL INSPECTION SPEC.：ANSI/ASME B18.2.2-10 SAMPLED BY： HSUAN HUI WENG

ITEM	SAMPLE SIZE	SPECIFIED	ACTUAL RESULT	JUDGMENT
APPEARANCE	100	ASTM F812-07	GOOD	OK
W.A.F.	32	1.312 ~ 1.269 in.	1.276 ~ 1.272 in.	OK
W.A.C.	8	1.516 ~ 1.447 in.	1.467 ~ 1.456 in.	OK
THICKNESS	8	0.776 ~ 0.724 in.	0.746 ~ 0.740 in.	OK
THREAD	32	ANSI/ASME B1.1	PASS	OK

MECHANICAL PROPERTIES SPEC.：SAE J995-12 SAMPLED BY： HSUAN HUI WENG

ITEM	SAMPLE SIZE	TEST METHOD	SPECIFIED	ACTUAL RESULT	JUDGMENT
HARDNESS	8	ASTM F606-11	MAX HRC32	18.0 ~ 16.0 HRC	PASS
PROOF LOAD	4	ASTM F606-11	MIN 55400LB	55991 ~ 55704 LB	PASS
PLATING THICKNESS	4	ASTM B568-98	MIN 0.0001 in	0.00027 ~ 0.00020 in	PASS

REMARK：1、THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL WITHOUT WRITTEN APPROVAL OF THE LAB.
2、THIS INSPECTION CERTIFICATE IS FOR RESPONSIBILITY UNDER SAMPLE ONLY
3、ABOVE SAMPLES TESTED CONFORM TO THE FASTENER SPECIFICATION OR STANDARDS

LAB. DIRECTOR(SIGNATORY)：

表單編號：LQC 10E Rev.0

Figure B-34. ⅞-in. (22-mm) Dia. Hex Nut Material Specification, Test Nos. MSPBN-4 through MSPBN-7

350ab

EMAIL

CHARTER STEEL
A Division of Charter Manufacturing Company, Inc

1650 Cold Springs Road
Saukville, Wisconsin 53080
(262) 268-2400
1-800-437-8789
Fax (262) 268-2570

CHARTER STEEL TEST REPORT

Melted in USA Manufactured in USA

Cust P.O.	160532M-11
Customer Part #	100941B
Charter Sales Order	70057033
Heat #	20351510
Ship Lot #	2073852
Grade	1010 R AK FG RHQ 41/64
Process	HR
Finish Size	41/64
Ship date	27-OCT-14

Trinity Industries Inc.
2525 Stemmons Frwy, 4th Floor
Dallas,TX-75207
Kind Attn : Material Certifications Dept.

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed below and that it satisfies these requirements. The recording of false, fictitious and fraudulent statements or entries on this document may be punishable as a felony under federal statute.

Test results of Heat Lot # 20351510

Lab Code: 125544

CHEM %Wt	C	MN	P	S	SI	NI	CR	MO	CU	SN	V
	.09	.33	.007	.002	.060	.04	.05	.01	.05	.004	.001
	AL	N	B	TI	NB						
	.028	.0070	.0001	.001	.001						

Test results of Rolling Lot # 2073852

REDUCTION RATIO=152:1

Specifications: Manufactured per Charter Steel Quality Manual Rev Date 9/12/12
Meets customer specifications with any applicable Charter Steel exceptions for the following customer documents:
Customer Document = ASTM A29/A29M-12 Revision = Dated = 01-MAY-12

Additional Comments:

Charter Steel
Cuyahoga Heights, OH, USA

Rem: Load1,Fax0,Mail0

ACCREDITED
Testing Laboratory

Page 1 of 2

This MTR supersedes all previously dated MTRs for this order

Janice Barnard
Manager of Quality Assurance
Printed Date : 10/27/2014

Figure B-35. ⅝-in. (16-mm) Dia., 10-in. (254-mm) Long Guardrail Bolt Material Specification, Test Nos. MSPBN-4 through MSPBN-7

McMASTER-CARR. Certificate of Compliance

600 N County Line Rd
Elmhurst IL 60126-2081
630-600-3600
chi.sales@mcmaster.com

University of Nebraska
Midwest Roadside Safety Facility
M W R S F
4630 Nw 36TH St
Lincoln NE 68524-1802
Attention: Shaun M Tighe
Midwest Roadside Safety Facility

Purchase Order
E000357170

Order Placed By
Shaun M Tighe

McMaster-Carr Number
2098331-01

Page 1 of 1

Line		Product	Ordered	Shipped
1	**97812A109**	Steel Double-Headed Nail Size 16D, 3" Length, .16" Shank Diameter, 200 Pieces/Pack, Packs of 5	**5 Packs**	**5**

Certificate of compliance

This is to certify that the above items were supplied in accordance with the description and as illustrated in the catalog. Your order is subject only to our terms and conditions, available at www.mcmaster.com or from our Sales Department.

Sarah Weinberg
Compliance Manager

Figure B-36. 16D Double Head Nail Certificate of Compliance, Test Nos. MSPBN-4 through MSPBN-8

TEST REPORT

USS FLAT WASHER, HDG

CUSTOMER:	DATE: **2017-04-05**
PO NUMBER: **220024002**	MFG LOT NUMBER: **33183**
SIZE: **7/16**	PART NO: **M-SWE0411885-18**
HEADMARKS:	QNTY: **24,600 PCS**

DIMENSIONAL INSPECTIONS — SPECIFICATION: **ASME B18.21.1(2009)**

CHARACTERISTICS		SPECIFIED	ACTUAL RESULT	ACC.	REJ.
**********************		************************************	*******************	********	********
APPEARANCE		**ASTM F788-07**	**PASSED**	**100**	**0**
OUTSIDE DIA		**1.243-1.280**	**1.249-1.252**	**8**	**0**
INSIDE DIA		**0.495-0.515**	**0.506-0.508**	**8**	**0**
THICKNESS		**0.064-0.104**	**0.068-0.072**	**8**	**0**
HOT DIP GALVANIZED	**ASTM A153 class C. RoHS Compliant**	**Min 0.0017"**	**Min 0.0019 In**	**8**	**0**

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION.
WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.
MFG ISO 9001:2015 SGS Certificate # HK04/0105

IFI & MORGAN LTD.
检验专用章
QUANLITY CONTROL

(SIGNATURE OF Q.A LAB MGR.)
(NAME OF MANUFACTURER)

IFI & MORGAN LTD. ***ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan, Zhejiang, China***

Figure B-37. $^{7}/_{16}$-in. (11-mm) Dia. Plain Round Washer Material Specification, Test Nos. MSPBN-4 through MSPBN-8

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

1098 East Maple St
Sutton, NE 68979
Phone: 402.773.4319
Email: nick@nebraskawood.com

CERTIFICATE OF COMPLIANCE

Shipped To: Midwest Machinery and Supply
BOL# 10057336
Customer PO# 3460
Preservative: CCA – C 0.60D pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
GR6806.5CRT	6x8-6.5′ CRT	105	24080	.603
GR61222BLK	6x12-22″ Block	56	24003	.700
GR6822CH	6x8-22″ Block	84	24108	.666
GS6846PST	5.5x7.5-46″ BCT	42	24096	.661
GS6806.5PST	5.5x7.5-6.5′ Rub Post	126	24080	.603
GS6823BLK	5.5x7.5-23″ Rub Block	84	24075	.654
GR61219BLK	6x12-19″ Routered Blk	168	24074	.676

Marked Yellow Tab

I certify the above referenced material has been produced, treated and tested in accordance with and conforms to AASHTO M133 & M168 standards.

VA: Iowa Wood Preservers certifies that the treated wood products listed above have been treated in accordance with AWPA standards, Section 236 of the VDOT Road & Bridge Specifications and meets the applicable minimum penetration and retention requirements.

Nicholas Sowl, General Counsel

7/24/2017
Date

Figure B-38. 5½-in. (140-mm) x 7½-in. (191-mm) x 46-in. (1,168-mm) BCT Timber Post Certificate of Compliance, Test Nos. MSPBN-4 through MSPBN-8

GERDAU

CERTIFIED MATERIAL TEST REPORT

Page 1/1

US-ML-CARTERSVILLE
384 OLD GRASSDALE ROAD NE
CARTERSVILLE, GA 30121
USA

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
HIGHWAY SAFETY CORP 473 W FAIRGROUND ST MARION,OH 43302-1701 USA	HIGHWAY SAFETY CORP GLASTONBURY,CT 06033-0358 USA	A992/A709-36	Wide Flange Beam / 6 X 8.5# / 150 X 13.0	0000000000

LENGTH	WEIGHT	HEAT / BATCH
39'00"	41,766 LB	55044245/05

SALES ORDER	CUSTOMER MATERIAL Nº
3399484/000020	

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
0001677110 IB-B0600800	1323-0000067912	04/13/2016

SPECIFICATION / DATE or REVISION
ASTM A6-14
ASTM A709-13A
ASTM A992-11
CSA G40.21-13 345WM

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %
0.14	0.92	0.015	0.027	0.20	0.30	0.09	0.12	0.027	0.015	0.017	0.001

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	G/L Inch	Elong. %
52500	71600	362	494	8.000	21.90
53200	72400	367	499	8.000	22.60

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

YAN WANG
QUALITY ASSURANCE MGR.

Figure B-39. W6-in. x 8.5-in. (W152-mm x 216-mm), 78-in. (1,981-mm) Long Steel Post Material Specification, Test Nos. MSPBN-4 through MSPBN-8

EXLTUBE

1000 BURLINGTON STREET, NORTH KANSAS CITY, MO 64116 1-816-474-6210 TOLL FREE 1-800-892-TUBE

STEEL VENTURES, LLC dba EXLTUBE

Certified Test Report

Customer:	Size:	Customer Order No:	Date:
SPS - New Century 401 New Century Parkway NEW CENTURY KS 66031-1127	02.375	4500269918	07/25/2016
	Gauge: .154	Delivery No:82798116 Load No.3774661	
	Specification: ASTM A500-13 Gr.B/C, ASTM A53-12 Gr.B BNT*, ASME SA53 Gr.B BNT*		

Heat No	Yield KSI	Tensile KSI	Elongation % 2 inch
A79999	63.2	67.3	31.00

R#17-175 H#A79999
BCT Post Sleeves QTY 8
Oct 2016 SMT

Heat No	C	MN	P	S	SI	CU	NI	CR	MO	V
A79999	0.0700	0.8400	0.0110	0.0040	0.0200	0.1500	0.0500	0.0600	0.0200	0.0010

This material was melted & manufactured in the U.S.A.
We hereby certify that all test results shown in this report are correct as contained in the records of our company. All testing and manufacturing is in accordance to A.S.T.M. parameters encompassed within the scope of the specifications denoted in the specification and grade tiles above. This product was manufactured in accordance with your purchase order requirements.
BNT=Grade B not pressure tested - meets tensile & chemical properties ONLY.

This material has not come into direct contact with mercury, any of its compounds, or any mercury bearing devices during our manufacturing process, testing, or inspections.

This material is in compliance with EN 10204 Section 4.1 Inspection Certificate Type 3.1

This material has passed NDE (eddy current, A309) testing. This material has passed flattening tests.

Tensile test completed using test specimen with 3/4" reduced area.

STEEL VENTURES, LLC dba EXLTUBE

Jonathan Wolfe
Quality Assurance Manager

Figure B-40. 2⅜-in. (60-mm), 6-in. (152-mm) Long BCT Post Sleeve Material Specification, Test Nos. MSPBN-4, MSPBN-5, and MSPBN-8

COMMERCIAL GROUP LIFTING PRODUCTS 66966

AUGUST 19th, 2016

SOLD TO:
TRINITY HIGHWAY PRODUCTS, LLC
PO BOX 566028, MAILSTOP 7115
DALLAS, TX 75356-6028

SHIP TO:
TRINITY HIGHWAY PRODUCTS, LLC PLT-
550 EAST ROBB AVE
ATTN: KEITH HAMBURG
LIMA, OH 45801-3037

CERTIFICATON

CGLP ORDER# 248853
TRINITY PO# 178817

THIS LETTER AND THE ENCLOSED ATTACHMENTS ARE TO CERTIFY THAT THE FOLLOWING ITEMS WERE 100% MANUFACTURED IN THE UNITED STATES OF AMERICA.

50 PCS, PART#6696G, 5/8IN X 14FT 4.75IN, DOUBLE SWAGE GUARD RAIL ASSEMBLYS.

THEY SHOW THE DOMESTICITY OF ALL MATERIAL USED, 100% MELTED & MANUFACTURED IN THE USA. THESE ITEMS ARE HOT DIPPED GALVANIZED TO ASTM-153 SPECIFICATIONS AND STANDARDS, GALV PROCESS ALSO TOOK PLACE IN THE U.S.A.

ATTACHMENTS:

NUMBERS USED IN PRODUCTION OF THESE ASSEMBLYS ARE AS FOLLOWS:

(WIRE ROPE) WIRECO WORLD GROUP REEL# 428-660971-1 / HEAT #S 585464, 567595, 581839, 582607, 578851, 578342, 576237, 552215.
(EVRAZ / ROCKY MOUNTAIN STEEL) ***** BUTTONS #12, MUNCY: HEAT# 5171023
(REPUBLIC STEEL)

** KORNS GALVANIZING CO JOHNSTOWN, PA. (GALVANIZING

VERY TRULY YOURS
Matt Glynn
MAT GLYNN
GENERAL MGR FLINT OFFICE

HEADQUARTERS	FLINT BRANCH	CLEVELAND BRANCH
12801 UNIVERSAL DRIVE	G2427 E. JUDD ROAD	5213 GRANT AVE
TAYLOR, MI 48180	BURTON, MI 48529	CLEVELAND, OH 44105
NEW PH# (734) 947-4000	PH# (810) 744-4540	PH# (216) 641-4100
NEW FAX# (734) 947-4004	FAX# (810) 744-1588	FAX# (216) 641-1814

Figure B-41. ⅝-in. (16-mm) Dia., 14.4-ft (4.3-m) Long Nose Cable, Test No. MSPBN-4

66966

WireCo® WorldGroup

MILL TEST CERTIFICATE

This form meets the requirements of the
U.S. Department of Labor, Occupational Safety and Health Administration
Form No. 4

Product Description: 26213 5/8" 6X25F-IWRC DGXIP B SZ (RR) US 100% Melted & Manufactured in the United States

Certificate No: 660971

Distributor: Commercial Group Lifting Products- Burton PO#: 068618

Reel No: 428-660971-1

Order No: 181279

Total Length: 1 X 3500 ft

Manufacturer or Supplier of the rope: UNION, WIRECO WORLD GROUP SEDALIA, MO

Nominal diameter: 5/8"

Measured diameter (in): .650
(measured under no load)

Number of strands: 25

Number of wires per strand: 25

Lay: RIGHT REGULAR

Grade of rope: DGXIP

Date of qualifying rope test: 7/25/16

Load at which sample broke (lb): 45,000 lbs.

Minimum breaking force (lb): 41,200 lbs.

If the design factor is 5, the safe working load is 8,240 lbs.

Organization carrying out the examination and test: SAME AS ABOVE

Organization issuing this certificate: WireCo WorldGroup, Sedalia, Missouri 65301.

This rope was manufactured to conform to the current ASTM A 1023 unless otherwise indicated in the product description.

I certify that the above particulars are correct and that the examination and test were carried out by a competent person in compliance with the applicable specification.

Signature: Michele Johnson

(Date) 7/25/16

Position of Signatory: Quality Process Administrative Assistant

SHEILA DOWDY
Notary Public - Notary Seal
State of Missouri, Pettis County
Commission Number 00454267
My Commission Expires Jun 6, 2020

Domestic Wire Rope and Cable
Stranded and Closed in the USA

Sheila Dowdy
07-25-2016

Figure B-42. ⅝-in. (16-mm) Dia., 14.4-ft (4.3-m) Long Nose Cable, Test No. MSPBN-5 through MSPBN-8

66966

MUNCY MACHINE™ AND TOOL CO., INC.

P.O. Box 205
Muncy, PA 17756
Phone: 570-649-5188
Fax: 570-649-5850
www.muncy-upson.com

Certificate of Conformance

January 8, 2016

Customer Name: Matt Glynn
Commerical Group Lifting Products
2427 East Judd Street
Burton, Mich. 48529

CGLP Purchase Order # 065570
Muncy Industries Order # 29342

This letter is to certify that the following items were 100% manufactured in the United States of America.

Quantity: 500 Pieces #12 Cold Tuff (SB/NB-20) Hot Dipped Galvanized Buttons.

Steel Heat Number: 5171023 (Republic Steel)

Country of Melt: 5171023 (Republic Steel)

Steel Heat Number: 590070 (Niagara Lasalle)

Country of Melt: 590070 (Niagara Lasalle)

Hot Dipped Galvanizing: (Korns Galvanizing)

This is to certify that the above mentioned order was manufactured per the specifications as per the above mentioned purchase order and the referenced drawing (s).

Sincerely,
Donald Murray
Donald Murray
Q.A.Manager

Serving the Wire Rope Industry Since 1949

Figure B-43. Nose Cable Swage Button Certificate of Compliance, Test No. MSPBN-4 through MSPBN-8

30006

Wirerope Works, Inc 100 Maynard St Williamsport, PA 17701
Manufacturer of Bethlehem Wire Rope ®
" Our Quality Management Systems are registered to ISO 9001: 2008 and API-Q1"

CERTIFICATE OF COMPLIANCE

Assembly Specialty Products, Inc.
PO#: 37094
REF#: W-24-DG
INSP: Quade
DATE: 8/1/2016
ASPI REEL(S): 10503, 10504

CUSTOMER: ASSEMBLY SPECIALTY

CUST. PO #37094

WW FILE NAME 209013

REEL# 6209013

DESCRIPTION: 3/4" 0619 W GA IPS RR SAC GALVANIZED WIRE ROPE IN ACCORDANCE WITH AASHTO DESIGNATION M30-02

ACTUAL TEST RESULTS
ACTUAL BREAKING STRENGTH: 61,300 LBS
REQUIRED BREAKING STRENGTH: 42,800 LBS

MINIMUM MASS OF COATING:
WIRE DIAMETER MAINWIRES
.054" MINIMUM CLASS A COATING .40- ACTUAL RANGE .60/.71 oz/fl2
.040" MINIMUM CLASS A COATING .40- ACTUAL RANGE .59/.69 oz/fl2

STEEL CERTIFICATES FOR ROD MANUFACTURER ARE ATTACHED
The following are heat numbers and wire diameters as shown on the Steel Certificates

.054" HEAT # 20424780
.040" HEAT # 20407870
.061" HEAT # 20405020
.046" HEAT # 20407870

ALL MATERIALS " MELTED AND MANUFACTURED IN THE USA"

Patti Watkins DATE: 04/22/16 CERTIFICATE# AA30316
PATTI WATKINS, Inv.Control/QA Customer Coordinator
Per the authority of, ROGER GILLILAND, DIRECTOR OF ENGINEERING

Figure B-44. BCT Cable Assembly Cable, Test No. MSPBN-4 through MSPBN-8

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: RESALE

Order Number: 1269489 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3346
BOL Number: 97457 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 11/7/16

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
175	3580G	5/8"X18" GR BOLT A307	HW			29145-B													
6	6696G	CBL 5/8"X14'4.75/DBL BTN	HW			248853													
400	6740B	PLYMR BLK 6X12X14 MT	HW			27950													
4	9852A	STRUT & YOKE ASSY	A-36			195070	52,940	69,970	31.1	0.190	0.520	0.014	0.004	0.020	0.110	0.000	0.050	0.000	4
7	12379G	T12/12'6/SPEC/S 34'RCX	RHC		2	L34713													4
			M-180	A	2	172876	55,930	72,020	31.4	0.190	0.720	0.014	0.002	0.020	0.130	0.000	0.080	0.000	4
			M-180	A	2	172876	55,930	72,020	31.4	0.190	0.720	0.014	0.002	0.020	0.130	0.000	0.080	0.000	4
6	12383G	T12/12'6/6'3/SPEC SLOTS/S	RHC			L33814													4
			M-180	A		182997	58,340	76,890	26.9	0.180	0.730	0.014	0.004	0.010	0.130	0.000	0.060	0.001	4
			M-180	A		182998	60,310	78,910	25.4	0.200	0.730	0.012	0.006	0.010	0.140	0.000	0.050	0.001	4
			M-180	A		182997	58,340	76,890	26.9	0.180	0.730	0.014	0.004	0.010	0.130	0.000	0.060	0.001	4
			M-180	A		182998	60,310	78,910	25.4	0.200	0.730	0.012	0.006	0.010	0.140	0.000	0.050	0.001	4
3	12385G	T12/12'6/SPEC/S 5'RCX			2	L34416													
			M-180	A	2	208318	64,140	81,540	24.5	0.190	0.720	0.011	0.003	0.020	0.110	0.000	0.060	0.000	4
24	19361G	BNT PL 3/16X12-5/8X5-1/2	A-36			B4M5475	46,800	70,400	29.1	0.180	0.840	0.007	0.008	0.060	0.170	0.000	0.070	0.001	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT , 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.

Figure B-45. 12⅝-in. x 5 13/16-in. x 3/16-in. (321-mm x 148-mm x 5-mm) Nose Cable Anchor Plate Material Specification, Test Nos. MSPBN-4 through MSPBN-8

STEEL AND PIPE SUPPLY
SPS Coil Processing Tulsa
5275 Bird Creek Ave.
Port of Catoosa, OK 74015

METALLURGICAL TEST REPORT

PAGE 1 of 1
DATE 08/02/2016
TIME 10:25:48
USER WILLIAMR

SOLD TO
66031-1127

SHIP TO
13716
Kansas City Warehouse
401 New Century Parkway
NEW CENTURY KS

R#17-393 U-Bolt Galvanized Plate Washers for Bullnose SMT

Order	Material No.	Description	Quantity	Weight	Customer Part	Customer PO	Ship Date
40267215-0010	801148120TM	11GA 48 X 120 A1011-CS-TYB TEMP HS	25	5,000			08/02/2016

Chemical Analysis

Heat No. B609769 Vendor STEEL DYNAMICS COLUMBUS DOMESTIC Mill STEEL DYNAMICS COLUMBUS Melted and Manufactured in the USA
Batch 0004412124 25 EA 5,000 LB

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.0700	0.3500	0.0110	0.0030	0.0200	0.0300	0.0600	0.0100	0.0001	0.0900	0.0260	0.0000	0.0020	0.0010	0.0036	0.0050

Mechanical/ Physical Properties

Mill Coil No. 16B647053

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen

Chemical Analysis

Heat No. B609769 Vendor STEEL DYNAMICS COLUMBUS DOMESTIC Mill STEEL DYNAMICS COLUMBUS Melted and Manufactured in the USA
Batch 0004412121 50 EA 10,000 LB

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.0700	0.3500	0.0110	0.0030	0.0200	0.0300	0.0600	0.0100	0.0001	0.0900	0.0260	0.0000	0.0020	0.0010	0.0036	0.0050

Mechanical/ Physical Properties

Mill Coil No. 16B647053

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen

THE CHEMICAL, PHYSICAL, OR MECHANICAL TESTS REPORTED ABOVE ACCURATELY REFLECT INFORMATION AS CONTAINED IN THE RECORDS OF THE CORPORATION.
The material is in compliance with EN 10204 Section 4.1 Inspection Certificate Type 3.1

Figure B-46. 2¼-in. x ¾-in. (57-mm x 19-mm), 11-gauge, U-Bolt Plate Washer Material Specification, Test Nos. MSPBN-4 through MSPBN-8

Chicago Hardware & Fixture Company

9100 Parklane Avenue
Franklin Park, Illinois 60131
(847) 455-6609
Fax (847) 455-0012
www.chicagohardware.com

American Owned
American Made
American Quality

DROP FORGED PRODUCTS
Turnbuckles
Shackles
Wire Rope Clips (also malleable)
Machinery Eye Bolts
Eye Bolts regular & shoulder
Eye Nuts
Rod Ends blank & machined
Ring Bolts
Hooks
Swivels
Pad Eyes
Yoke Ends

WIRE PRODUCTS
"S" Hooks
U-Bolts (galv. & zinc) rd., sq. & long tangent
Turned Eye Bolts (threaded) lag, mach. or welded
Threaded Rod

OTHER PRODUCTS
Alloy Steel Hoist Rings
Wire Rope Thimbles
Bevel Washers
Clevis Pins
Coupling Nuts
Plated Steel Shapes
Brass rounds, flats & angles

STAINLESS & METRIC (check availability)
Eye Bolts & Eye Nuts
U-Bolts
"S" Hooks
Wire Rope Clips
Blank Rod Ends
Threaded Rods

SPECIAL PRODUCTS
Manufactured to Specifications

WAREHOUSE LOCATIONS:
Chino, CA (909) 591-1099
Monroe, GA (770) 266-5600
Houston, TX (713) 664-7722

JANUARY 4, 2017

THE STRUCTURAL BOLT CO.
2140 CORNHUSKER HWY.
LINCOLN, NE 68521

R#17-250 H#71067E Bullnose U-Bolts (Different Nuts Used)

C E R T I F I C A T I O N

THIS IS TO CERTIFY THAT OUR PART NO. 536264, STOCK #6HG, THE ¼ X 1-1/4 X 2-1/4" GALVANIZED U-BOLTS AND PLATES FURNISHED AGAINST YOUR PURCHASE ORDER NO. 19624 HAVE BEEN MADE IN THE U.S.A. FROM DOMESTIC ASTM-307, C-1010 STEEL AND ARE HOT DIP GALVANIZED TO ASTM-153 SPECIFI-CATIONS.

U-BOLT: HEAT # 71067E C .11 Mn .42 P .004 S .013

PLATE: HEAT#2507326 C .08 Mn .34 P .009 S .003

CHICAGO HARDWARE & FIXTURE CO.

MICHAEL ZERBE

Figure B-47. ¼-in. (6-mm) U-Bolt Certificate of Compliance, Test Nos. MSPBN-4 through MSPBN-8

R#17-297 Bullnose U-Bolt NUts
December 2016 SMT

Certified Material Test Report to BS EN 10204-2004 3.1
FOR ASTM A563, GRADE A HEX FIN NUTS

FACTORY: IFI & Morgan Ltd. Haiyan Office
ADDRESS: Haiyan, Zhejiang, China

REPORT DATE:05 JULY,2016

CUSTOMER:

MFG LOT NUMBER: GL16187-1

SAMPLE SIZE: ACC. TO ASME B18.18-11;ASTM F1470-12
SIZE: 1/4-20 HDG QTY: 75000 PCS

PO NUMBER:220022071

PART NO: 1136701

STEEL PROPERTIES
STEEL GRADE: Q195

HEAT NUMBER: 184259

CHEMISTRY SPEC:	C %*100	Mn%*100	P %*1000	S %*1000
ASTM A563 GRADE A	0.55max	min	0.12max	0.15max
TEST:	0.08	0.34	0.022	0.022

DIMENSIONAL INSPECTIONS SPECIFICATION: ASME-B18.2.2-2010

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
**********************	*****************	*******************	*******************	********	********
APPEARANCE	ASTM F812-2013		PASSED	29	0
THREAD	ASME B1.3-2003 2B		PASSED	15	0
WIDTH A/F	0.438-0.428		0.432-0.430	5	0
WIDTH A/C	0.505-0.488		0.499-0.495	3	0
HEIGHT	0.226-0.212		0.219-0.217	4	0

MECHANICAL PROPERTIES: 1/4" to 1 1/2" SPECIFICATION: ASTM A563-07a GR-A

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
*********************	******************	******************	******************	********	********
HARDNESS :	ASTM F606-2014	B68-C32 Max(107HRB)	C25-27	15	0
PROOF LOAD :	ASTM F606-2014	Min 68 Ksi	72 Ksi	5	0

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
*********************	****************	******************	*****************	********	********
HOT DIP GALVANIZED	ASTM F2329-05	MIN 2.10miu	2.50miu	4	0

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM OR SAE SPECIFICATION. WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.

(SIGNATURE OF Q.A. LAB MGR.)
(NAME OF MANUFACTURER)

Figure B-48. ¼-in. (6-mm) Hex Nut Material Specification, Test Nos. MSPBN-4 through MSPBN-8

425 E. O'Connor
Lima, OH

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

LINCOLN, NE 68501-1097

Sales Order: 1093497
Customer PO: 2030
BOL # 43073
Document # 1

Print Date: 6/30/08
Project: RESALE
Shipped To: NE
Use State: KS

Trinity Highway Products, LLC

Certificate Of Compliance For Trinity Industries, Inc. ** SLOTTED RAIL TERMINAL **

NCHRP Report 350 Compliant

Pieces	Description
64	5/8"X10" GR BOLT A307
192	5/8"X18" GR BOLT A307
32	1" ROUND WASHER F844
64	1" HEX NUT A563
192	WD 6'0 POST 6X8 CRT
192	WD BLK 6X8X14 DR
64	NAIL 16d SRT
64	WD 3'9 POST 5.5X7.5 BAND
32	STRUT & YOKE ASSY
128	SLOT GUARD '98
32	3/8 X 3 X 4 PL WASHER

MGSBR

Ground Strut

090453-8

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

06/04/2009 16:36 402-761-3288

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 OTHER GALVANIZED MATERIAL CONFORMS WITH ASTM-123.
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 30th day of June, 2008

Notary Public:
Commission Expires

Trinity Highway Products, LLC
Certified By:

2 of 4

Figure B-49. Ground Strut Certificate of Compliance, Test Nos. MSPBN-4 through MSPBN-8

NUCOR
NUCOR STEEL JACKSON, INC.

Mill Certification
7/27/2016

MTR #: M1-150903
NUCOR STEEL JACKSON, INC.
3630 Fourth Street
Flowood, MS 39232
(601) 939-1623
Fax: (601) 936-6202

Sold To: O'NEAL STEEL INC
ATTN ACCOUNTS PAYABLE
PO BOX 98
BIRMINGHAM, AL 35202-0098
(205) 599-8000
Fax: (205) 599-8052

Ship To: O'NEAL STEEL INC
4530 MESSER-AIRPORT HWY
BIRMINGHAM, AL 35222
(205) 599-8000
Fax: (205) 599-8052

Customer P.O.	00771356	Sales Order	343125.5
Product Group	Merchant Bar Quality	Part Number	5350030024010W0
Grade	NUCOR MULTIGRADE	Lot #	JK1610148801
Size	1/2x3" Flat	Heat #	JK16101488
Product	1/2x3" Flat 20' NUCOR MULTIGRADE	B.L. Number	M1-429898
Description	NUCOR MULTIGRADE	Load Number	M1-150903
Customer Spec		Customer Part #	00777557

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Roll Date: 4/5/2016 Melt Date: 3/30/2016 Qty Shipped LBS: 4,900 Qty Shipped Pcs: 48

Melt Date: 3/30/2016

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Cb	Sn
0.16%	0.78%	0.017%	0.028%	0.20%	0.28%	0.09%	0.14%	0.020%	0.0280%	0.001%	0.010%
CE4020	CEA529										
0.35%	0.39%										

CE4020: C. E. CSA G4020, AASHTO M270
CEA529: A529 CARBON EQUIVALENT

Roll Date: 4/5/2016

Yield 1: 56,172psi	Tensile 1: 75,460psi	Elongation: 25% in 8"(% in 203.3mm)
Yield 2: 56,126psi	Tensile 2: 76,500psi	Elongation 25% in 8"(% in 203.3mm)

Specification Comments: NUCOR MULTIGRADE MEETS THE REQUIREMENTS OF: ASTM A36/36M, ASTM A529/529M GR50 ASTM A572/572M GR50 ASTM709/709M GR36/GR50 CSA G40.21 GR44W(300W)/GR50W(350W) AASHTO M270/M270M GR36/GR50 ASME SA36/SA36M MEETS EN10204 SEC 3.1 REPORTING REQUIREMENTS

ALL MANUFACTURING PROCESSES OF THE STEEL MATERIALS IN THIS PRODUCT, INCLUDING MELTING, HAVE OCCURRED WITHIN THE UNITED STATES. ALL PRODUCTS PRODUCED ARE WELD FREE. MERCURY, IN ANY FORM, HAS NOT BEEN USED IN THE PRODUCTION OR TESTING OF THIS MATERIAL.

QA Approved
SI# 777557

Christopher Smith
Christopher Smith
Division Metallurgist

NBMG-10 January 1, 2012

Page 1 of 1

Figure B-50. Anchor Bracket Assembly Material Specification, Test Nos. MSPBN-4 through MSPBN-8

Birmingham Fastener Manufacturing

P.O. Box 10323
Birmingham, Alabama 35202
(205) 595-3512

Pg 1 of 1

Certificate of Compliance

Customer : Midwest Machinery & Supply
P.O. # : 3443

BFM # : 1425884
Date Shipped : 6/26/2017

	Quantity	Description	Lot#	Heat #	Specification	Finish
1	201	5/8"-11 x 19" Hex Bolt	213830	JK17100352	ASTM 307A	HDG
2	523	7/8"-9 x 16" Hex Bolt	213831	58024495	ASTM 307A	HDG
3	180	5/8"-11 x 8" Hex Bolt	213832	JK17100352	ASTM 307A	HDG
4	157	5/8"-11 x 10" Hex BOLT	213833	JK17100352	ASTM 307A	HDG

Birmingham Fastener Manufacturing. hereby certifies that the material furnished in reference to the above purchase order number will meet or exceed the above assigned specifications.

Signed: [signature] **Date:** 07/07/2017
Brian Hughes

Figure B-51. ⅝-in. (16-mm) Dia., 10-in. (254-mm) Long Hex Bolt Material Specification, Test Nos. MSPBN-5 through MSPBN-8

35806

CERTIFICATE OF COMPLIANCE

ROCKFORD BOLT & STEEL CO.
126 MILL STREET
ROCKFORD, IL 61101
815-968-0514 FAX# 815-968-3111

CUSTOMER NAME: TRINITY INDUSTRIES

CUSTOMER PO: 180129

SHIPPER #: 058945
DATE SHIPPED: 10/20/2016

LOT#: 29145-B

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE: SPEC: 60,000 psi*min RESULTS: 78,212
77,960

HARDNESS: 100 max 85.30
84.60

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
ROGERS GALVANIZE: 29145-B

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
NUCOR	1010	NF16102734	.10	.54	.012	.017	.15

QUANTITY AND DESCRIPTION:

4,500 PCS 5/8" X 18" GUARD RAIL BOLT
P/N 3580G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS

20th DAY OF October 2016

Merry F Shane

Linda McComas
APPROVED SIGNATORY

10/20/16
DATE

OFFICIAL SEAL
MERRY F. SHANE
NOTARY PUBLIC – STATE OF ILLINOIS
MY COMMISSION EXPIRES OCTOBER 3, 2018

Figure B-52. ⅝-in. (16-mm) Dia., 18-in. (457-mm) Long Guardrail Bolt Certificate of Compliance, Test Nos. MSPBN-5

CERTIFICATE OF COMPLIANCE

ROCKFORD BOLT & STEEL CO.
126 MILL STREET
ROCKFORD, IL 61101
815-968-0514 FAX# 815-968-3111

CUSTOMER NAME: TRINITY INDUSTRIES

CUSTOMER PO: 184469

SHIPPER #: 060902
DATE SHIPPED: 06/30/2017

LOT#: 29882

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE: SPEC: 60,000 psi*min RESULTS: 77,389
77,362

HARDNESS: 100 max 88.30
88.10

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
ROGERS GALVANIZE: 29882

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
NUCOR	1010	100885399	.12	.51	.018	.029	.16

QUANTITY AND DESCRIPTION:

7,200 PCS 5/8" X 18" GUARD RAIL BOLT
P/N 3580G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS

30th DAY OF June 2017 Linda McComas 6/30/17
Merry F. Shane APPROVED SIGNATORY DATE

OFFICIAL SEAL
MERRY F. SHANE
NOTARY PUBLIC – STATE OF ILLINOIS
MY COMMISSION EXPIRES OCTOBER 3, 2018

Figure B-53. ⅝-in. (16-mm) Dia., 18-in. (457-mm) Long Guardrail Bolt Certificate of Compliance, Test Nos. MSPBN-5 through MSPBN-7

CERTIFICATE OF COMPLIANCE

ROCKFORD BOLT & STEEL CO.
126 MILL STREET
ROCKFORD, IL 61101
815-968-0514 FAX# 815-968-3111

CUSTOMER NAME: TRINITY INDUSTRIES

CUSTOMER PO: 183621

SHIPPER #: 060458
DATE SHIPPED: 05/11/2017

LOT#: 29783-B

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE: SPEC: 60,000 psi*min RESULTS: 72,977
72,530
HARDNESS: 100 max 84.70
85.00

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
ROGERS GALVANIZE: 29783-B

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
NUCOR	1010	DL16102715	.11	.45	.004	.018	.13

7,875 PCS 5/8" X 10" GUARD RAIL BOLT
P/N 3500G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS
11th DAY OF May, 20 17 Linda McLomas 5/11/17
APPROVED SIGNATORY DATE

Merry F. Shane

OFFICIAL SEAL
MERRY F. SHANE
NOTARY PUBLIC – STATE OF ILLINOIS
MY COMMISSION EXPIRES OCTOBER 3, 2018

Figure A-19. ⅝-in. (16-mm) Dia., 10-in. (254-mm) Long Guardrail Bolt Certificate of Compliance, Test Nos. MSPBN-5 through MSPBN-8

T-4

1412 150th Street
Hammond IN 46327-1799

CERTIFICATION

CERTIFICATE	Rev
H161467	2
DATE 05/05/15	
PAGE 2	

SHIP TO
MUNCY MACHINE & TOOL INC.
5820 SUSQUEHANNA TRAIL
TURBOTVILLE PA 17772
USA

PURCHASE ORDER	4812		
ORDER	856770-2		
CUSTOMER ITEM		ITEM	111562204184
GRADE	1018	SHAPE	Round
SIZE	1.5620	SIZE MM	39.6748 MM
LENGTH	17' 0" / 24' 0"	LENGTH MM	5181.6 / 7315.2

1018 AI /FG COLD DRAWN STRESS RELIEVED HBN 153 (RB 83) MAX SURFACE MELTED & MFG IN USA ONLY Spec/Rev Spec/Rev
ASTM A29/A29M-12e1

HEAT	GRAIN PRACTICE	SOURCE / MELTED	CAST	REDUCTION RATIO	DI
590070	FINE(5-8)	ARCELORMITTAL - EC-IND. (USA)	STRAND	23.6:1	

CHEMISTRY

C	MN	P	S	SI	NI	CR	MO	CU	AL	V
0.160	0.650	.009	.017	0.210	0.090	0.110	.030	.250	.031	.002

N	TE	AS	PB	SE	BI	B	NB
N/A	N/A	N/A	N/A	N/A	N/A	N/A	.0080

MECHANICAL

JOB	TENSILE	.2% YIELD	ELONG	R OF A	HARDNESS	.02% YIELD	SR TEMP
h752160	PSI	PSI	0.00	0.00			

LOT

LOT	JOB	WEIGHT (LBS)	PIECES	LOT	JOB	WEIGHT (LBS)	PIECES
4917599	h752160	4,436	40	4917639	h752160	4,680	42
4917688	h752160	4,625	44	4917765	h752160	4,540	41
4917836	h752160	4,550	41	4917850	h752160	4,815	43
4917943	h752160	4,685	42				

HEAT 590070 - MELTED & MFG IN USA SURFACE HBN = 149

WE hereby certify that these goods were produced in compliance with all applicable requirements of sections 6, 7, and 12 of the Fair Labor Standards Act, as amended and all regulations and orders of the United States Department of Labor issued under section 14 thereof. Material was not exposed to mercury or any metal alloy that is liquid at ambient temerature during processing or while in our possession. No weld repairs performed on the above material

CERTIFICATE OF TEST By: Walter P. Kretzler - Director of Q.A./Chief Metallurgist

Figure B-54. ⅝-in. (16-mm) Dia., 14.4-ft (4.3-m) Long Cable and Swage Button Certificate of Compliance, Test Nos. MSPBN-5 through MSPBN-7

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

1098 East Maple St
Sutton, NE 68979
Phone: 402.773.4319
Email: nick@nebraskawood.com

CERTIFICATE OF COMPLIANCE

Shipped To: Midwest Machinery and Supply
BOL# 10057336
Customer PO# 3460
Preservative: CCA – C 0.60D pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
GR6806.5CRT	6x8-6.5′ CRT	105	24080	.603
GR61222BLK	6x12-22″ Block	56	24003	.700
GR6822CH	6x8-22″ Block	84	24108	.666
GS6846PST	5.5x7.5-46″ BCT	42	24096	.661
GS6806.5PST	5.5x7.5-6.5′ Rub Post	126	24080	.603
GS6823BLK	5.5x7.5-23″ Rub Block	84	24075	.654
GR61219BLK	6x12-19″ Routered Blk	168	24074	.676

I certify the above referenced material has been produced, treated and tested in accordance with and conforms to AASHTO M133 & M168 standards.

VA: Iowa Wood Preservers certifies that the treated wood products listed above have been treated in accordance with AWPA standards, Section 236 of the VDOT Road & Bridge Specifications and meets the applicable minimum penetration and retention requirements.

Nicholas Sowl, General Counsel

7/24/2017
Date

Figure B-55. 6-in. x 8-in. x 14-in. (152-mm x 203-mm x 362-mm) Timber Blockout Material Certification, Test Nos. MSPBN-6 and MSPBN-7

Certified Test Report

NORTH STAR BLUESCOPE STEEL LLC
6767 County Road 9
Delta, Ohio 43515
Telephone: (888) 822-2112

Customer: Trinity Industries
2525 Stemmons Freeway
Dallas, TX 75207
Customer P.O.: 176195M-1
Cust. Ref/Part # 200012B

Order # 356470
Line Item # 1
Heat # 203663
Coil # 1620567

Ord Width (mm/in) 1447.800 / 57.000
Ord Gauge (mm/in) 2.438 / 0.096
Material Description 1018 CQ Modified, Guardrail Type 2
Production Date/Time Jun 4 2016 5:23PM

Weight (kg/lb) 21119 / 46559

Heat Chemical Analysis (wt%)

Type	C	Mn	P	S	Si	Al	Cu	Cr	Ni	Mo	Sn	N	B	V	Nb	Ti	Ca	Pb
Heat	0.19	0.72	0.012	0.004	0.02	0.02	0.12	0.08	0.04	0.01	0.01	0.007	0.0000	0.000	0.000	0.001	0.001	0.000

Mechanical Test Report

	Yield Strength	Tensile Strength	% Elongation in 2 inches
Tail	63,290 psi	81,680 psi	25.6%

This hot rolled steel has been produced to conform to DIN/EN 10204:2005 3.1 and has been manufactured to a fully killed fine grain practice. This hot rolled steel has been produced and tested in accordance with each of the following applicable standards: ASTM E1806-09, ASTM E415-14, ASTM A751-14, ASTM 1370-14, JIS Z2201:1998, JIS Z 2241:2011. Pressure Equipment Directive (PED) 97/23/EC 7/2, Annex I, Paragraph 4.3 Compliant. This report certifies that the above test results are representative of those contained in the records of North Star BlueScope Steel LLC for the material identified in this test report and is intended to comply with the requirements of the material description. North Star BlueScope Steel LLC is not responsible for the inability of this material to meet specific applications. Any modifications to this certification as provided negates the validity of this test report. All reproductions must have the written approval of North Star BlueScope Steel. This product was manufactured, melted, cast, and hot-rolled (min. 3:1 reduction ratio), entirely within the U.S.A at North Star BlueScope Steel LLC, Delta, Ohio. This material was not exposed to Mercury or any alloy which is liquid at ambient temperature during processing or while in North Star BlueScope Steel LLC possession. Test equipment calibration certificates are available upon request. NIST traceability is established through test equipment calibration certificates which are available upon request. Uncertainty calculations are calculated in accordance with NIST standards and are maintained at a 4:1 ratio in accordance with NIST standards. Uncertainty data is available upon request.

Tim Mitchell [signature] **Manager Quality Assurance and Technology**

Date Issued: Jun 15, 2016 09:31:16
Revision#: 01

Figure B-56. 12-ft 6-in. (3.8-m) 12-ga (2.7-mm) Thrie Beam Material Certification, Test Nos. MSPBN-6 and MSPBN-7

Certified Test Report

NORTH STAR BLUESCOPE STEEL LLC
6767 County Road 9
Delta, Ohio 43515
Telephone: (888) 822-2112

Customer: Trinity Highway Products, LLC
2525 Stemmons Freeway
Dallas, TX 75207
Customer P.O.: 184242-3
Cust. Ref/Part # 100212B

Order # 383308
Line Item # 1
Heat # 216682
Coil # 1731308

Ord Width (mm/in) 1504.950 / 59.250
Ord Gauge (mm/in) 2.438 / 0.096
Material Description 1018 CQ Modified, Guardrail Type 2
Production Date/Time Jul 3 2017 5:21AM

Weight (kg/lb) 22470 / 49538

Heat Chemical Analysis (wt%)

Type	C	Mn	P	S	Si	Al	Cu	Cr	Ni	Mo	Sn	N	B	V	Nb	Ti	Ca	Pb
Heat	0.19	0.71	0.011	0.003	0.02	0.02	0.13	0.07	0.04	0.01	0.01	0.008	0.0000	0.002	0.000	0.001	0.001	0.000

Mechanical Test Report

	Yield Strength	Tensile Strength	% Elongation in 2 inches
Tail	60,950 psi	80,100 psi	24.8%

This hot rolled steel has been produced to conform to DIN/EN 10204:2005 3.1 and has been manufactured to a fully killed fine grain practice. This hot rolled steel has been produced and tested in accordance with each of the following applicable standards: ASTM E1806-09, ASTM E415-14, ASTM A751-14, ASTM 1370-14, JIS Z2201:1998, JIS Z 2241:2011. Pressure Equipment Directive (PED) 97/23/EC 7/2, Annex I, Paragraph 4.3 Compliant. This report certifies that the above test results are representative of those contained in the records of North Star BlueScope Steel LLC for the material identified in this test report and is intended to comply with the requirements of the material description. North Star BlueScope Steel LLC is not responsible for the inability of this material to meet specific applications. Any modifications to this certification as provided negates the validity of this test report. All reproductions must have the written approval of North Star BlueScope Steel. This product was manufactured, melted, cast, and hot-rolled (min. 3:1 reduction ratio), entirely within the U.S.A at North Star BlueScope Steel LLC, Delta, Ohio. This material was not exposed to Mercury or any alloy which is liquid at ambient temperature during processing or while in North Star BlueScope Steel LLC possession. Test equipment calibration certificates are available upon request. NIST traceability is established through test equipment calibration certificates which are available upon request. Uncertainty calculations are calculated in accordance with NIST standards and are maintained at a 4:1 ratio in accordance with NIST standards. Uncertainty data is available upon request.

Tim Mitchell [signature] **Manager Quality Assurance and Technology**

Date Issued: Jul 27, 2017 08:37:47
Revision#: 01

Figure B-57. 12-ft 6-in. (3.8-m) 12-ga (2.7-mm) Thrie Beam Material Certification, Test Nos. MSPBN-6 and MSPBN-7

Certified Test Report

NORTH STAR BLUESCOPE STEEL LLC
6767 County Road 9
Delta, Ohio 43515
Telephone: (888) 822-2112

Customer: Trinity Highway Products, LLC
2525 Stemmons Freeway
Dallas, TX 75207
Customer P.O.: 184242-3
Cust. Ref/Part # 100212B

Order # 383308
Line Item # 1
Heat # 216683
Coil # 1731312

Ord Width (mm/in) 1504.950 / 59.250
Ord Gauge (mm/in) 2.438 / 0.096
Material Description 1018 CQ Modified, Guardrail Type 2
Production Date/Time Jul 3 2017 5:39AM

Weight (kg/lb) 22398 / 49379

Heat Chemical Analysis (wt%)

Type	C	Mn	P	S	Si	Al	Cu	Cr	Ni	Mo	Sn	N	B	V	Nb	Ti	Ca	Pb
Heat	0.19	0.73	0.013	0.002	0.02	0.03	0.13	0.06	0.08	0.01	0.00	0.007	0.0001	0.001	0.000	0.001	0.001	0.000

Mechanical Test Report

	Yield Strength	Tensile Strength	% Elongation in 2 inches
Tail	65,000 psi	82,920 psi	22.8%

This hot rolled steel has been produced to conform to DIN/EN 10204:2005 3.1 and has been manufactured to a fully killed fine grain practice. This hot rolled steel has been produced and tested in accordance with each of the following applicable standards: ASTM E1806-09, ASTM E415-14, ASTM A751-14, ASTM 1370-14, JIS Z2201:1998, JIS Z 2241:2011. Pressure Equipment Directive (PED) 97/23/EC 7/2, Annex I, Paragraph 4.3 Compliant. This report certifies that the above test results are representative of those contained in the records of North Star BlueScope Steel LLC for the material identified in this test report and is intended to comply with the requirements of the material description. North Star BlueScope Steel LLC is not responsible for the inability of this material to meet specific applications. Any modifications to this certification as provided negates the validity of this test report. All reproductions must have the written approval of North Star BlueScope Steel. This product was manufactured, melted, cast, and hot-rolled (min. 3:1 reduction ratio), entirely within the U.S.A at North Star BlueScope Steel LLC, Delta, Ohio. This material was not exposed to Mercury or any alloy which is liquid at ambient temperature during processing or while in North Star BlueScope Steel LLC possession. Test equipment calibration certificates are available upon request. NIST traceability is established through test equipment calibration certificates which are available upon request. Uncertainty calculations are calculated in accordance with NIST standards and are maintained at a 4:1 ratio in accordance with NIST standards. Uncertainty data is available upon request.

Tim Mitchell **Manager Quality Assurance and Technology**

Date Issued: Jul 12, 2017 16:33:15
Revision#: 01

Figure B-58. 12-ft 6-in. (3.8-m) 12-ga (2.7 -mm) Thrie Beam Material Certification, Test Nos. MSPBN-6 and MSPBN-7

Atlas Tube (Alabama), Inc.
171 Cleage Dr
Birmingham, Alabama, USA
35217
Tel:
Fax:

Atlas *Tube*
A DIVISION OF ZEKELMAN INDUSTRIES

Ref.B/L: 80791452
Date: 11.10.2017
Customer: 179

MATERIAL TEST REPORT

Sold to

Steel & Pipe Supply Compan
PO Box 1688
MANHATTAN KS 66505
USA

Shipped to

Steel & Pipe Supply Compan
401 New Century Parkway
NEW CENTURY KS 66031
USA

Material: 3.0x2.0x188x40'0"0(5x4). **Material No:** 0300201884000-B **Made in:** USA **Melted in:** USA

Sales order: 1226976 **Purchase Order:** 4500296656 **Cust Material #:** 6630020018840

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
B704212	0.200	0.450	0.010	0.004	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.28
40867002	20	064649 Psi	087652 Psi	24 %	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

Material: 2.375x154x42'0"0(34x1). **Material No:** R023751544200 **Made in:** USA **Melted in:** USA

Sales order: 1226976 **Purchase Order:** 4500296656 **Cust Material #:** 642004042

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
B712810	0.210	0.460	0.012	0.002	0.020	0.024	0.100	0.002	0.020	0.030	0.060	0.004	0.002	0.000	0.008

Bundle No	PCs	Yield	Tensile	Eln.2in	Rb	Certification	CE: 0.32
MC00006947	34	063688 Psi	083220 Psi	25 %	91	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

Material: 2.375x154x42'0"0(34x1). **Material No:** R023751544200 **Made in:** USA **Melted in:** USA

Sales order: 1226976 **Purchase Order:** 4500296656 **Cust Material #:** 642004042

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
17037261	0.210	0.810	0.005	0.004	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.35
41532001	34	066144 Psi	082159 Psi	27 %	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

Authorized by Quality Assurance:
The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
Calculated using the AWS D1.1 method.

Steel Tube Institute

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Metals Service Center Institute

Figure B-59. 2⅜-in. (60-mm), 6-in. (152-mm) Long BCT Post Sleeve Material Specification, Test Nos. MSPBN-6 and MSPBN-7

GREGORY HIGHWAY PRODUCTS, INC.
4100 13th St. SW
Canton, Ohio 44710

MIDWEST MACHINERY & SUPPLY CO.
P. O. BOX 703

MILFORD,NE,68405

Test Report
Ship Date: 10/26/2017
Customer P.O.: 3501
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project: STOCK
GHP Order No: 7044AA

HT # code	LOT#	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
616137		0.21	0.93	0.011	0.003	0.02	73148	58210	32	15		2	3/16IN X 6IN X 8IN X 5FT0IN TUBE SLEEVE
811T08220		0.22	0.81	0.013	0.006	0.005	71412	56323	35	10		2	3/16IN X 6IN X 8IN X 6FT0IN TUBE SLEEVE
214482		0.04	0.83	0.014	0.005	0.02	75275	68023	28.6	25			10GA MGS TB TRAN APPROACH END-RIGHT
214143		0.04	0.81	0.015	0.006	0.02	75565	69618	29.7	18			10GA MGS TB TRAN DEPARTURE END-LEFT

James P. Dehnke
Notary Public, State of Ohio
My Commission Expires 10-19-2019

All Galvanizing has occurred in the United States
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Steel used meets Title 23CFR 635.410 - Buy America
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All controlled oxidized/corrosion resistant Guardrail and terminal sections meet ASTM A606, Type 4.

By:____________________

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by Andrew Artar this 31 day of October, 2017

Notary Public, State of Ohio

Figure B-60. 8-in. x 6-in. x $^{3}/_{16}$-in. (203-mm x 152-mm x 5-mm), 72-in. (1,829-mm) Long Foundation Tube, Test No. MSPBN-8

GERDAU

US-ML-MIDLOTHIAN
300 WARD ROAD
MIDLOTHIAN, TX 76065
USA

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
STEEL & PIPE SUPPLY CO INC JONESBURG INDUSTRIAL PARK JONESBURG,MO 63351 USA	STEEL & PIPE SUPPLY CO INC MANHATTAN,KS 66505-1688 USA	A992/A572-50	Wide Flange Beam / 6 X 9# / 150 X 13.5	0000068771

LENGTH	WEIGHT	HEAT / BATCH
40'00"	8,640 LB	59072444/02

SALES ORDER	CUSTOMER MATERIAL Nº
4481119/000020	000000000037690040

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
4500277171	1327-0000217277	11/28/2016

SPECIFICATION / DATE or REVISION
ASTM A6-14
ASTM A709-15
ASTM A992-11 (2015), A572-15
CSA G40.21-13 345WM

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.07	0.92	0.013	0.035	0.21	0.24	0.09	0.13	0.018	0.005	0.002	0.011	0.003

CHEMICAL COMPOSITION

CEqvA6 %
0.28

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	Y/T rati %	G/L Inch
55973	69803	386	481	0.802	8.000
56818	70847	392	489	0.802	8.000

MECHANICAL PROPERTIES

G/L mm	Elong. %
200.0	23.90
200.0	24.00

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 769-1014 Email: Bhaskar.Yalamanchili@gerdau.com

TOM HARRINGTON
QUALITY ASSURANCE MGR.
Phone: 972-779-1872 Email: Tommy.Harrington@gerdau.com

Figure B-61. 6x9 Wide Flange Beam for Upper Slip Post Assembly Material Certification, Test No. MSPBN-8

NUCOR
Nucor Steel Tuscaloosa, Inc.

MILL TEST CERTIFICATE

1700 HOLT RD N.E.
Tuscaloosa, AL 35404-1000
800 800-8204
customerservice@nucortusk.com

Page:1 of 1

Load Number	Tally	Mill Order Number	PO NO | Line NO	Part Number	Certificate Number	Prepared
T132130	00000000685654	N-149191-001	4500271472 1		S68565401-1	08/25/2016 09:58

Grade

Customer:

Order Description:
Hot Roll Plate From Coil
A36, 0.7500 IN x 72.000 IN x 120.000 IN

Quality Plan Description:
A36/SA36/A70936: ASTM A36-14/A709-36-15/ASME SA36-13/M270-36

Sold TO:
STEEL AND PIPE SUPPLY CO INC LONGVIEW TX

Ship TO:
Longview Warehouse Longview TX

Sent TO:

Shipped Item	Heat/Slab Number	Certified By	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Cb	V	Al	Ti	N2	B	Ca	Sn	CEV	ACI
6H1808B	B6U5630-04 ***	B6U5630	0.18	0.86	0.008	0.005	0.03	0.11	0.04	0.05	0.016	0.001	0.003	0.025	0.001	0.007	0.0001	0.0021			
6H1808C	B6U5630-04 ***	B6U5630	0.18	0.86	0.008	0.005	0.03	0.11	0.04	0.05	0.016	0.001	0.003	0.025	0.001	0.007	0.0001	0.0021			
6H1808D	B6U5630-04 ***	B6U5630	0.18	0.86	0.008	0.005	0.03	0.11	0.04	0.05	0.016	0.001	0.003	0.025	0.001	0.007	0.0001	0.0021			

Shipped Item	Certified By	Heat Number	Yield ksi	Tensile ksi	Y/T %	ELONGATION %		Bend OK?	Hard HB	Charpy Impacts (ft-lbs)					Shear %				Test Temp
						2"	8"			Size mm	1	2	3	Avg	1	2	3	Avg	
6H1808B	S6H1808FTT	B6U5630 ***	51.9	68.2	76.1	39.6													
6H1808B	S6H1808MTT	B6U5630 ***	51.8	65.1	79.6	40.3													
6H1808C	S6H1808FTT	B6U5630 ***	51.9	68.2	76.1	39.6													
6H1808C	S6H1808MTT	B6U5630 ***	51.8	65.1	79.6	40.3													
6H1808D	S6H1808FTT	B6U5630 ***	51.9	68.2	76.1	39.6													
6H1808D	S6H1808MTT	B6U5630 ***	51.8	65.1	79.6	40.3													

Items: 3 **PCS:** 25 **Weight:** 45943 LBS

Mercury has not come in contact with this product during the manufacturing process nor has any mercury been used by the manufacturing process. Certified in accordance with EN 10204 3.1. No weld repair has been performed on this material. Manufactured to a fully killed fine grain practice. NUTEMPER TEMPER PASSED plate from coil
ISO 9001:2008 Registered, PED Certified

"***" indicates Heats melted and Manufactured in the U.S.A.

We hereby certify that the product described above passed all of the tests required by the specifications.

Dr. Quilin Yu - Metallurgist

Figure B-62. ¾-in. (19-mm) Plate for Upper Slip Post Assembly Test Certificate, Test No. MSPBN-8

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

1098 East Maple St
Sutton, NE 68979
Phone: 402.773.4319
Email: nick@nebraskawood.com

CERTIFICATE OF COMPLIANCE

Shipped To: Midwest Machinery and Supply
BOL# N01210
Customer PO# 3560
Preservative: CCA – C 0.60D pcf AWPA UC4B

R#18-763 Painted Yellow
Purchased for Bullnose

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
4075b	6x8-14″ Block	126	24833	.604
GR6814 BLK	6x8-14″ OCD Block	252	24883	.669
6120b	6x12-14″ Block	84	24861	.661

I certify the above referenced material has been produced, treated and tested in accordance with and conforms to AASHTO M133 & M168 standards.

VA: Iowa Wood Preservers certifies that the treated wood products listed above have been treated in accordance with AWPA standards, Section 236 of the VDOT Road & Bridge Specifications and meets the applicable minimum penetration and retention requirements.

Nick Sowl, General Counsel

3/26/18
Date

Figure B-63. Timber Blockout and BCT Timber Post Certificate of Compliance, Test No. MSPBN-8

CENTRAL
NEBRASKA
WOOD PRESERVERS, INC.

P. O. Box 630 • Sutton, NE 68979
Pone 402-773-4319
FAX 402-773-4513

Date: 7/18/16

CERTIFICATE OF COMPLIANCE

Shipped TO: Midwest Machinery + Supply BOL# 10054525

Customer PO# : 3289 Preservative: CCA – C 0.60 pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
GR6814BLK	6x8 - 14" BLK	126	22416	.623
GR6819BLK	6x8 - 19" BLK	84	22402	.676
GR61219BLK	6x12 - 19" BLK	168	22402	.676
GR61219BLK	6x12 - 19" BLK	168	22416	.623
GR61219BLK	6x12 - 19" BLK	56	22397	.607
GR61219BLK	6x12 - 19" BLK Trap	56	22402	.676

I certify the above referenced material has been produced, treated and tested in accordance with AWPA standards and conforms to AASHTO M133 & M168.

VA: Central Nebraska Wood Preservers certifies that the treated wood products listed above have been treated in accordance with AWPA standards, Section 236 of the VDOT Road & Bridge Specifications and meets the applicable minimum penetration and retention requirements.

Nick Sowl, General Counsel

7/18/16
Date

Figure B-64. Tapered Timber Blockout and BCT Timber Post – Side A Certificate of Compliance, Test No. MSPBN-8

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

1098 East Maple St
Sutton, NE 68979
Phone: 402.773.4319
Email: nick@nebraskawood.com

CERTIFICATE OF COMPLIANCE

Shipped To: Midwest Machinery and Supply
BOL# 100588715
Customer PO# 3528
Preservative: CCA - C 0.60D pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
4075b	6x8-14" Block	126	24683	.665
6120b	6x12-14" Block	84	23888	.678
GS6806.5 PST	5.5x7.5-6.5' Rub Post	84	24604	.652
GS6806.5 PST	5.5x7.5-6.5' Rub Post	42	24603	.643
GS6814 BLK	5.5x7.5-14' Block	126	24194	.633

I certify the above referenced material has been produced, treated and tested in accordance with and conforms to AASHTO M133 & M168 standards.

VA: Iowa Wood Preservers certifies that the treated wood products listed above have been treated in accordance with AWPA standards, Section 236 of the VDOT Road & Bridge Specifications and meets the applicable minimum penetration and retention requirements.

Nick Sowl, General Counsel

1/11/2018
Date

Figure B-65. Timber Blockout and BCT Timber Post Certificate of Compliance, Test No. MSPBN-8

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296

Customer: MIDWEST MACH & SUPPLY CO
P. O. BOX 703

MILFORD, NE 68405

Project: STOCK

Order Number: 1295719   Prod Ln Grp: 0-OE2.0
Customer PO: 3597
BOL Number: 104805   Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 6/11/18

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	224112	63,490	81,930	25.0	0.190	0.730	0.014	0.005	0.020	0.130	0.000	0.060	0.010	4
4	12385G	T12/12'6/SPEC/S 5'RCX			2	L32917													
			M-180	A	2	216682	60,950	80,100	24.8	0.190	0.710	0.011	0.003	0.020	0.130	0.000	0.070	0.002	4
			M-180	A	2	216683	65,000	82,920	22.8	0.190	0.730	0.013	0.002	0.020	0.130	0.000	0.060	0.001	4
			M-180	A	2	216682	60,950	80,100	24.8	0.190	0.710	0.011	0.003	0.020	0.130	0.000	0.070	0.002	4
			M-180	A	2	216683	65,000	82,920	22.8	0.190	0.730	0.013	0.002	0.020	0.130	0.000	0.060	0.001	4
	12385G				2	L32118													
			M-180	A	2	226511	61,110	79,440	27.4	0.180	0.720	0.009	0.004	0.010	0.110	0.000	0.070	0.002	4
			M-180	A	2	226512	61,440	81,340	20.7	0.180	0.720	0.011	0.004	0.010	0.110	0.000	0.080	0.001	4
12	19361G	BNT PL 3/16X12-5/8X5-1/2	A-36			B4M5475	46,800	70,400	29.1	0.180	0.840	0.007	0.008	0.060	0.170	0.000	0.070	0.001	4
20	32218G	T10/TRAN/TB:WB/ASYM/R	M-180	B		C85478	59,700	82,500	21.7	0.200	0.480	0.010	0.002	0.040	0.140	0.001	0.100	0.001	4
12	32219G	T10/TRAN/TB:WB/ASYM/LT	M-180	B		A86840	62,700	83,800	23.0	0.200	0.680	0.010	0.003	0.030	0.130	0.002	0.060	0.001	4
100	54043G	7'0 PST/6X15/DB:3HI	A-572			1803344	56,100	66,600	27.1	0.070	0.800	0.008	0.030	0.220	0.140	0.025	0.040	0.003	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT, 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.
ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED

3 of 4

Figure B-66. 12-ft 6-in. (3.8-m) 12-ga (2.7-mm) Thrie Beam Material Certification, Test No. MSPBN-8

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH & SUPPLY CO
P. O. BOX 703

MILFORD, NE 68405
Project: STOCK

Order Number: 1295719 Prod Ln Grp: 0-OE2.0
Customer PO: 3597
BOL Number: 104805 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 6/11/18

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
6	974G	T12/TRANS RAIL/6'3"/3'1.5	M-180	A	2	208675	62,100	81,170	22.7	0.190	0.730	0.012	0.004	0.020	0.090	0.000	0.050	0.001	4
600	3320G	3/16"X1:75"X3" WASHER	HW			P37836													
13,000	3340G	5/8" GR HEX NUT	HW			17-35-042													
7,000	3360G	5/8"X1.25" GR BOLT	HW			20180212811													
150	3448G	1/4"X4"X4" SNOW LOAD	HW			61423													
200	3480G	5/8"X8" GR BOLT A307	HW			30459-B													
450	3500G	5/8"X10" GR BOLT A307	HW			30928-B													
875	3540G	5/8"X14" GR BOLT A307	HW			30869-P													
600	3560G	5/8"X16" GR BOLT A307	HW			30861-B													
50	3660G	5/8"X26" GR BOLT A307	HW			30994													
10	6696G	CBL 5/8"X14'4.75/DBL BTN	HW			284559													
10	9852A	STRUT & YOKE ASSY	A-36			195070	52,940	69,970	31.1	0.190	0.520	0.014	0.004	0.020	0.110	0.000	0.050	0.000	4
9	12379G	T12/12'6/SPEC/S 34'RCX			2	L31418													
			M-180	A	2	222038	63,780	82,280	22.9	0.190	0.750	0.012	0.002	0.030	0.100	0.000	0.070	0.001	4
			M-180	A	2	222878	64,680	81,820	25.2	0.180	0.740	0.012	0.003	0.020	0.130	0.000	0.070	0.002	4
			M-180	A	2	224111	61,010	81,710	26.1	0.190	0.730	0.011	0.003	0.020	0.120	0.000	0.060	0.002	4

Figure B-67. 12-ft 6-in. (3.8-m) 12-ga (2.7-mm) Thrie Beam Material Certification, Test No. MSPBN-8

CERTIFIED MATERIAL TEST REPORT
FOR SAE J429 GRADE 5 HEX TAP BOLTS

SUPPLIER'S NAME:ZHEJIANG HEITER MFG & TRADE CO.LTD REPORT DATE: 2018-1-18
ADDRESS: XITANGQIAO HAIYAN ZHEJIANG CHINA MANUFACTURE COMPLETE DATE: 2017-12-25
CONTACT INFORMATION: JACK /(86)-0573-86862565
CUSTOMER: FASTENAL COMPANY PURCHASING--IMPORT TRAFFIC
MFG LOT NUMBER: 171223SM01
SAMPLING PLAN PER ASME B18.18-2011 Categories 2;ASTM F1470- PO NUMBER: 220026125
DESCRIPTION: HEX TAP BOLTS GRADE 5 ZINC PLATED
SIZE: 7/16-14X2-1/2" QTY: 16450 PCS PART NO: 0144506
HEADMARKS: NDF+THREE RADIAL LINE

STEEL PROPERTIES:
STEEL GRADE:1035 HEAT NUMBER: I11708007009

CHEMISTRY SPEC:	C %	Mn%	P %	S %
	0.25~0.55	min	0.025max	0.025max
TEST:	0.33	0. 78	0.025	0.01

DIMENSIONAL INSPECTIONS SPECIFICATION: ASME B18.2.1-2012

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
**********************	***********************************	******************	********	********
APPEARANCE	ASTM F788/F788M-13	PASSED	100	0
THREAD	ASME B1.1-08 2A	PASSED	32	0
WIDTH FLATS	0.625 " - 0.603 "	0.615 " - 0.621 "	8	0
WIDTH A/C	0.722 " - 0.687 "	0.699 " - 0.715 "	8	0
HEAD HEIGHT	0.316 " - 0.272 "	0.279 " - 0.303 "	8	0
MAJOR DIA	0.436 " - 0.426 "	0.433 " - 0.435 "	8	0
LENGTH	2.54 " - 2.44 "	2.48 " - 2.51 "	8	0

MECHANICAL PROPERTIES: 1/4"thru1" SPECIFICATION: SAE J429-2014 GR-5

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
********************	*****************	*****************	******************	********	********
CORE HARDNESS:	ASTM F606-14	25-34 HRC	28 - 31 HRC	8	0
SURFACE HARDNESS :	ASTM F606-14	30N54 MAX	48 - 50	8	0
WEDGE TENSILE:	ASTM F606-14	MIN 120000 PSI	132563 - 133441 PSI	4	0
PROOF LOAD	ASTM F606-14	MIN 85000 PSI	PASS	1	0
DECARBURIZATION	ASTM F2328-14		PASSED	1	0

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
*****************	******************	*****************	******************	********	********
ZINC PLATED	ASTM F1941-15	Clear Zinc FE/Zn 3AN			
Thickness	ASTM B568-98	Min3 μ m	4.8-5.5 μ m	8	0
Salt Spray Corrosion	ASTM B117-11	6 hours NO White Corrosion 12 hours NO Red Rust	PASS	8	0

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE SAE SPECIFICATION. WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.
All parts meet the requirements of FQA and records of compliance are on file.
Maker's ISO#CN11/20818

(SIGNATURE OF Q.A. MGR.)
(ZHEJIANG GOLDEN AUTOMOTIVE FASTENER CO.LTD)

Figure B-68. 7/16-in.-14 UNC (11-mm x 1.5-mm), 2½-in. (64-mm) Long Hex Tap Bolt Material, Test No. MSPBN-8

ISO/TS 16949 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER :GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2016/06/27

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 210110355
COMMODITY : FINISHED HEX NUT GR-5
SIZE : 7/16-14 NC
LOT NO : 1N1640142
SHIP QUANTITY : 3,000 PCS
LOT QUANTITY 115,012 PCS
HEADMARKS : GENIUS SYMBOL & 2 ARC LINES(120 DEGREE)
MANUFACTURE DATE : 2016/04/11
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM160606004
INVOICE NO : GEM/FNL-160628ED-1
PART NO : 1136308
SAMPLING PLAN : ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : 331509977
MATERIAL : 1015A
FINISH : Fe/Zn 3AN ASTM F1941/F1941M-2015

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO SAE J995-2012

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.			0.3000			
MAX.		0.5500		0.0500	0.1500	
Test Value	0.0480	0.1500	0.4100	0.0160	0.0110	0.0300

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2010

SAMPLED BY : FCHUN

INSPECTIONS ITEM	SAMPLE	SPECIFIED		ACTUAL RESULT	ACC.	REJ.
WIDTH ACROSS CORNERS	5PCS	ASME B18.2.2-2010	0.7680-0.7940 inch	0.7710-0.7770 inch	5	0
FIM	15PCS		Max. 0.0180 inch	0.0150-0.0170 inch	15	0
THICKNESS	5PCS		0.3650-0.3850 inch	0.3680-0.3720 inch	5	0
WIDTH ACROSS FLATS	5PCS		0.6750-0.6880 inch	0.6770-0.6860 inch	5	0
SURFACE DISCONTINUITIES	29PCS		ASTM F812-2012	PASSED	29	0
THREAD	15PCS		GAGING SYSTEM 21	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO SAE J 995-2012

SAMPLED BY : REN PING

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15 PCS	ASTM F606-2014		Max. 32 HRC	8-10 HRC	15	0
PROOF LOAD	5 PCS	ASTM F606-2014		Min. 120,000 PSI	OK	5	0
PLATING THICKNESS(μm)	29 PCS	ASTM B568-1998		>=3	3.57-4.92	29	0
SALT SPRAY TEST	15 PCS	ASTM B117-11		6 HOURS NO WHITE RUST, 12 HOURS NO RED RUST	OK	15	0

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER

Quality Supervisor: [signature]

page 1 of 1

Figure B-69. $^{7}/_{16}$-in. (11-mm) Hex Nut Material Certificate, Test No. MSPBN-8

ISO/TS 16949 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER :GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2017/05/15

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 210131208
COMMODITY : FINISHED HEX NUT GR-5
SIZE : 7/16-14 NC
LOT NO : 1N1730528
SHIP QUANTITY : 22,500 PCS
LOT QUANTITY 171,526 PCS
HEADMARKS : GENIUS SYMBOL & 2 ARC LINES(120 DEGREE)
MANUFACTURE DATE : 2017/04/06
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM170505002
INVOICE NO : GEM/FNL-170517ED
PART NO : 1136308
SAMPLING PLAN : ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : 351607718
MATERIAL : 1015A
FINISH : Fe/Zn 3AN ASTM F1941/F1941M-2016

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO SAE J995-2012

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.			0.3000			
MAX.		0.5500		0.0500	0.1500	
Test Value	0.0470	0.1600	0.5300	0.0150	0.0050	0.0400

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2015

SAMPLED BY : LXHUA

INSPECTIONS ITEM	SAMPLE	SPECIFIED		ACTUAL RESULT	ACC.	REJ.
WIDTH ACROSS CORNERS	6PCS	ASME B18.2.2-2015	0.7680-0.7940 inch	0.7800-0.7800 inch	6	0
FIM	15PCS		Max. 0.0180 inch	0.0150-0.0170 inch	15	0
THICKNESS	6PCS		0.3650-0.3850 inch	0.3710-0.3720 inch	6	0
WIDTH ACROSS FLATS	6PCS		0.6750-0.6880 inch	0.6810-0.6830 inch	6	0
SURFACE DISCONTINUITIES	29PCS		ASTM F812-2012	PASSED	29	0
THREAD	15PCS		GAGING SYSTEM 21	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO SAE J 995-2012

SAMPLED BY : TANGHAO

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15 PCS	ASTM F606-2014		Max. 32 HRC	28-29 HRC	15	0
PROOF LOAD	6 PCS	ASTM F606-2014		Min. 120,000 PSI	OK	6	0
PLATING THICKNESS(μm)	29 PCS	ASTM B568-1998		>=3	3.21-4.89	29	0
SALT SPRAY TEST	15 PCS	ASTM B117-16		6 HOURS NO WHITE RUST, 12 HOURS NO RED RUST	OK	15	0

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER

Quality Supervisor: Erin

page 1 of 1

Figure B-70. $^{7}/_{16}$-in. (11-mm) Hex Nut Material Certificate, Test No. MSPBN-8

R#15-0627 H#20297970 L#140530L
5/8x10" Guardrail Bolt
June 2015 SMT White Paint 3500G

TRINITY HIGHWAY PRODUCTS, LLC
425 East O'Connor Ave.
Lima, Ohio 45801
419-227-1296

7/31/14

MATERIAL CERTIFICATION

Customer: Stock
Date: June 25,2014
Invoice Number:
Lot Number: 140530L
Part Number: 3500G
Quantity: 17,173 Pcs.
Description: 5/8" x 10" G.R. Bolt
Heat Numbers: 20297970 17,173

Specification: ASTM A307-A / A153 / F2329

MATERIAL CHEMISTRY

Heat	C	MN	P	S	SI	NI	CR	MO	CU	SN	V	AL	N	B	TI	NB
20297970	.09	.33	.006	.001	.06	.03	.04	.01	.08	.002	.001	.026	.008	.0001	.001	.002

PLATING OR PROTECTIVE COATING

HOT DIP GALVANIZED (Lot Ave.Thickness / Mils) 2.54 (2.0 Mils Minimum)

****THIS PRODUCT WAS MANUFACTURED IN THE UNITED STATES OF AMERICA****

THE MATERIAL USED IN THIS PRODUCT WAS MELTED AND MANUFACTURED IN THE U.S.A
WE HEREBY CERTIFY THAT TO THE BEST OF OUR KNOWLEDGE ALL INFORMATION CONTAINED HEREIN IS CORRECT.

TRINITY HIGHWAY PRODUCTS LLC

STATE OF OHIO, COUNTY OF ALLEN
SWORN AND SUBSCRIBED BEFORE ME THIS 11th day of July 2014

NOTARY PUBLIC

425 E. O'CONNOR AVENUE LIMA, OHIO 45801 419-227-1296.

SHERRI BRAUN
Notary Public, State of Ohio
My Commission Expires
April 20, 2019

NOTARIAL SEAL STATE OF OHIO

JUL 11 2014
Trinity Highway Products, LLC
Dallas, Texas Plant 99

Figure B-71. ⅝-in. x 10-in. (16-mm x 254-mm) Bolt, Test No. MSPBN-8

GREGORY HIGHWAY PRODUCTS, INC.
4100 13th St. SW
Canton, Ohio 44710

MIDWEST MACHINERY & SUPPLY CO.
P. O. BOX 703

MILFORD,NE,68405

Test Report
Ship Date: 1/30/2018
Customer P.O.: 3532-REPL
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project: INVENTORY
GHP Order No: 220607

HT # code	LOT#	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
20455760		0.14	0.34	0.005	0.003	0.09				4000			5/8IN X 1 1/4IN SPL. BOLT

All Galvanizing has occurred in the United States
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Steel used meets Title 23CFR 635.410 - Buy America
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All controlled oxidized/corrosion resistant Guardrail and terminal sections meet ASTM A606, Type 4.

By: *Jeffery L Grover*
Jeffery L Grover, VP of Highway Products Sales & Marketing
Gregory Highway Products, Inc.

NOTARIAL SEAL
STATE OF OHIO

James P Dehnke
Notary Public - State of Ohio
My Commission Expires
October 19, 2019

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by Jeffery Grover this 5 day of February, 2018

Notary Public, State of Ohio

Figure B-72. ⅝-in. (16-mm), 1¼-in. (32-mm) Long Guardrail Bolt Material Report, Test No. MSPBN-8

CHARTER STEEL
A Division of Charter Manufacturing Company, Inc.

EMAIL

1658 Cold Springs Road
Saukville, Wisconsin 53080
(262) 268-2400
1-800-437-8789
Fax (262) 268-2570

CHARTER STEEL TEST REPORT

Melted in USA Manufactured in USA

Johnstown Wire Technologies
124 Laurel Ave.
Johnstown,PA-15906

Cust P.O.	91693
Customer Part #	AXA18CB-5/16
Charter Sales Order	30124802
Heat #	20479830
Ship Lot #	2117839
Grade	1018 X AK FG RHQ 5/16
Process	HR
Finish Size	5/16
Ship date	13-JAN-17

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed below and that it satisfies these requirements. The recording of false, fictitious and fraudulent statements or entries on this document may be punishable as a felony under federal statute.

Test results of Heat Lot # 20479830

Lab Code: 125544

CHEM	C	MN	P	S	SI	NI	CR	MO	CU	SN	V
%Wt	.16	.64	.006	.004	.060	.03	.05	.01	.04	.003	.001
	AL	N	B	TI	NB						
	.051	.0050	.0001	.001	.001						

CAT DI=.35

Test results of Rolling Lot # 2117839

	# of Tests	Min Value	Max Value	Mean Value	
TENSILE (KSI)	1	68.6	68.6	68.6	TENSILE LAB = 0358-04
REDUCTION OF AREA (%)	1	72	72	72	RA LAB = 0358-04

NUM DECARB=1
REDUCTION RATIO=637:1

AVE DECARB (inch)=.000

Specifications: Manufactured per Charter Steel Quality Manual Rev Date 12/12/13
Charter Steel certifies this product is indistinguishable from background radiation levels by having process radiation detectors in place to measure for the presence of radiation within our process & products.
Meets customer specifications with any applicable Charter Steel exceptions for the following customer documents:
Customer Document = RW007-RW100 Revision = Dated = 08-NOV-13

Additional Comments:

Melt Source:
Charter Steel
Cuyahoga Heights, OH, USA

Rem: Load1,Fax0,Mail0

Testing Laboratory
Page 1 of 2

This MTR supersedes all previously dated MTRs for this order
Janice Barnard Division Mgr. of Quality Assurance
barnardJ@chartersteel.com
Printed Date : 01/13/2017

Figure B-73. ⅝-in. (16-mm) Dia. 1¼-in. (32-mm) Long Guardrail Bolt Test Report, Test No. MSPBN-8

CERTIFICATE OF COMPLIANCE

ROCKFORD BOLT & STEEL CO.
126 MILL STREET
ROCKFORD, IL 61101
815-968-0514 FAX# 815-968-3111

CUSTOMER NAME: TRINITY INDUSTRIES

CUSTOMER PO: 185896

SHIPPER #: 061432
DATE SHIPPED: 09/06/2017

LOT#: 30213-B

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE: SPEC: 60,000 psi*min RESULTS: 67,070
67,354

HARDNESS: 100 max 80.10
80.30

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
ROGERS GALVANIZE: 30213-B

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
NUCOR	1010	DL17100591	.09	.41	.004	.002	.05

QUANTITY AND DESCRIPTION:

1,500 PCS 5/8" X 18" GUARD RAIL BOLT
P/N 3580G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS

7TH DAY OF SEPTEMBER, 2017
Lisa A. Berg

Linda McLomas
APPROVED SIGNATORY

9/7/17
DATE

Official Seal
Lisa A Berg
Notary Public State of Illinois
My Commission Expires 06/06/2020

Figure B-74. ⅝-in. (16-mm) Dia., 18-in. (457-mm) Long Guardrail Bolt Test Report, Test No. MSPBN-8

ISO/TS 16949 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER : GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2018/03/28

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 110254885
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 7/8-9 NC O/T 0.56MM
LOT NO : 1N1810005
SHIP QUANTITY : 9,000 PCS
LOT QUANTITY 55,748 PCS
HEADMARKS :

MANUFACTURE DATE : 2018/01/05
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM180115010
INVOICE NO : GEM/FNL-180201WI-1
PART NO : 36717
SAMPLING PLAN : ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : 331704677
MATERIAL : XGML08
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2015

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0.5800		0.1300	0.2300	
Test Value	0.0360	0.0600	0.4500	0.0140	0.0030	0.0300

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2015

SAMPLED BY : WDANDAN

INSPECTIONS ITEM	SAMPLE	SPECIFIED		ACTUAL RESULT	ACC.	REJ.
WIDTH ACROSS CORNERS	5PCS		1.4470-1.5160 inch	1.4850-1.4930 inch	5	0
FIM	15PCS	ASME B18.2.2-2015	Max. 0.0250 inch	0.0110-0.0200 inch	15	0
THICKNESS	5PCS		0.7240-0.7760 inch	0.7460-0.7570 inch	5	0
WIDTH ACROSS FLATS	5PCS		1.2690-1.3120 inch	1.2930-1.2980 inch	5	0
SURFACE DISCONTINUITIES	29PCS		ASTM F812-2012	PASSED	29	0
THREAD	15PCS		GAGING SYSTEM 21	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2015

SAMPLED BY : TANGHAO

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15 PCS	ASTM F606-2014		68-107 HRB	86-90 HRB	15	0
PROOF LOAD	5 PCS	ASTM F606-2014		Min. 31,416 LBF	OK	5	0
PLATING THICKNESS(μm)	29 PCS	ASTM B568-1998		>=53	62.38-62.57	29	0

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER

Quality Supervisor: [signature]

page 1 of 1

Figure B-75. ⅞-in. (22-mm) Dia. Hex Nut Material Specification, Test No. MSPBN-8

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

1098 East Maple St
Sutton, NE 68979
Phone: 402.773.4319
Email: nick@nebraskawood.com

CERTIFICATE OF COMPLIANCE

Shipped To: Midwest Machinery and Supply
BOL# 10057594
Customer PO# 3475
Preservative: CCA – C 0.60D pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
GR6806PST	6x8-6′ Thrie Beam Post	70	24232	.636
GS6846PST	5.5x7.5-46′ BCT	42	24233	.627
GR61219BLK	6x12-19″ Thrie OCD Block	168	24230	.638
GR61222BLK	6x12-22″ Thrie OCD Block	56	24089	.673
GR6814BLK	6x8-14″ OCD Block	126	24195	.648

marked orange Tab

I certify the above referenced material has been produced, treated and tested in accordance with and conforms to AASHTO M133 & M168 standards.

VA: Iowa Wood Preservers certifies that the treated wood products listed above have been treated in accordance with AWPA standards, Section 236 of the VDOT Road & Bridge Specifications and meets the applicable minimum penetration and retention requirements.

Nicholas Sowl, General Counsel

8/25/2017
Date

Figure B-76. 5½-in. (140-mm) x 7½-in. (191-mm) x 46-in. (1,168-mm) BCT Timber Post Certificate of Compliance, Test No. MSPBN-8

CNWP

1098 East Maple St
Sutton, NE 68979
Phone: 402.773.4319
Email: nick@nebraskawood.com

CERTIFICATE OF COMPLIANCE

Shipped To: Midwest Machinery and Supply
BOL# N02529
Customer PO# 3560
Preservative: CCA – C 0.60D pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
GR6806.5 CRT	6x8-6.5 CRT	70	25008	.740
GS6846 PST	5.5x7.5-46" BCT	84	25033	.864
GR6814 BLKTAP	6x8-14" Tapered Block	90	25041	.892
GR668 3HB	6x6-8" 3 Hole Block	56	25033	.864
GR6819 BLK	6x8-19" OCD Block	168	25024	.941
GR61219 BLK	6x12-19" Thrie Block	168	25033	.864
GR61219 BLK	6x12-19" Trans Block	56	25042	.733
GR61222 BLK	6x12-22" Block	112	25042	.733

I certify the above referenced material has been produced, treated and tested in accordance with and conforms to AASHTO M133 & M168 standards.

VA: Iowa Wood Preservers certifies that the treated wood products listed above have been treated in accordance with AWPA standards, Section 236 of the VDOT Road & Bridge Specifications and meets the applicable minimum penetration and retention requirements.

Nick Sowl, General Counsel

4/18/18
Date

Figure B-77. 5½-in. (140-mm) x 7½-in. (191-mm) x 46-in. (1,168-mm) BCT Timber Post Certificate of Compliance, Test No. MSPBN-8

HIGHWAY SAFETY CORP

P.O. BOX 358
GLASTONBURY, CT 06033

CERTIFICATE OF COMPLIANCE/ANALYSIS REPORT

SOLD TO:
MIDWEST MACHINERY & SUPPLY
974-238th Road

Milford, NE, USA

SHIP TO:
MIDWEST MACHINERY & SUPPLY
974 238TH ROAD
MILFORD,

INVOICE / S.O.: 0201953 / 0148588
CUSTOMER P.O.: 3514

REFERENCE: STOCK
DATE SHIPPED: 10/31/2017

QTY:	HEAT/LOT NO:	ITEM NUMBER: YIELD:	CC: TENSILE: %ELONG:	DESCRIPTION: C: Mn: P: S: Si: Cl: Type ACW
50	2714032	T-POG060080606B	IB-B0600800	THRIE POST W06 x 008.5# x 06'06 F/ RTD WOOD THRIE BLOC
800		T-POG060080600	IB-B0600800	THRIE POST W06 x 008.5# x 06'00 GALV
(600)	1713906			
(150)	2713903			
(50)	55048942			

ALL STEEL USED IN MANUFACTURING IS MADE AND MELTED IN THE USA, INCLUDING HARDWARE FASTENERS, AND COMPLIES WITH THE BUY AMERICA ACT. ALL COATINGS PROCESSES ARE PERFORMED IN THE USA AND COMPLY WITH THE BUY AMERICA ACT. BOLTS COMPLY WITH ASTMA-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTMA-153, UNLESS OTHERWISE STATED. NUTS COMPLY WITH ASTMA-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTMA-153, UNLESS OTHERWISE STATED. WASHERS COMPLY WITH ASTM F-436 AND/OR F-844 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTMA-153, UNLESS OTHERWISE STATED. ALL GUARDRAIL MEETS AASHTO M-180 AND ALL STRUCTURAL STEEL MEETS AASHTO M-270. ALL OTHER GALVANIZED MATERIAL CONFORMS WITH ASTMA-123. ALL OTHER ITEMS COMPLY WITH AASHTO M-111, M-165, M-133, M-265, ASTM A36, ASTMA-709, ASTMA-123, ASTM A505, AND ASTMA588 SPECIFICATIONS IF APPLICABLE. COMPLIANCE WITH ALL SPECIFICATIONS OF DEPARTMENT OF PUBLIC WORKS, DEPARTMENT OF HIGHWAYS AND TRANSPORTATION, DIVISION OF ROADS AND BRIDGES AND STATE HIGHWAY ADMINISTRATION IS MET IN ALL RESPECTS.

HIGHWAY SAFETY CORPORATION

QUALITY ASSURANCE MANAGER

NOTARIZED UPON REQUEST:
STATE OF CONNECTICUT COUNTY OF HARTFORD
SWORN AND SUBSCRIBED BEFORE ME THIS 9th DAY OF Nov, 20 17

Notary Public

DEBRA M. THOMPSON
NOTARY PUBLIC
MY COMMISSION EXPIRES NOV. 30, 2018

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Figure B-78. W6-in. x 8.5-in. (W152-mm x 126-mm), 78-in. (1,981-mm) Long Steel Post Material Specification, Test No. MSPBN-8

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH & SUPPLY CO
P. O. BOX 703

MILFORD, NE 68405
Project: STOCK

Order Number: 1295719 Prod Ln Grp: 0-OE2.0
Customer PO: 3597
BOL Number: 104805 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 6/11/18

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
6	974G	T12/TRANS RAIL/6'3"/3'1.5	M-180	A	2	208675	62,100	81,170	22.7	0.190	0.730	0.012	0.004	0.020	0.090	0.000	0.050	0.001	4
600	3320G	3/16"X1:75"X3" WASHER	HW			P37836													
13,000	3340G	5/8" GR HEX NUT	HW			17-35-042													
7,000	3360G	5/8"X1.25" GR BOLT	HW			20180212811													
150	3448G	1/4"X4"X4" SNOW LOAD	HW			61423													
200	3480G	5/8"X8" GR BOLT A307	HW			30459-B													
450	3500G	5/8"X10" GR BOLT A307	HW			30928-B													
875	3540G	5/8"X14" GR BOLT A307	HW			30869-P													
600	3560G	5/8"X16" GR BOLT A307	HW			30861-B													
50	3660G	5/8"X26" GR BOLT A307	HW			30994													
10	6696G	CBL 5/8"X14'4.75/DBL BTN	HW			284559													
10	9852A	STRUT & YOKE ASSY	A-36			195070	52,940	69,970	31.1	0.190	0.520	0.014	0.004	0.020	0.110	0.000	0.050	0.000	4
9	12379G	T12/12'6/SPEC/S 34'RCX			2	L31418													
			M-180	A	2	222038	63,780	82,280	22.9	0.190	0.750	0.012	0.002	0.030	0.100	0.000	0.070	0.001	4
			M-180	A	2	222878	64,680	81,820	25.2	0.180	0.740	0.012	0.003	0.020	0.130	0.000	0.070	0.002	4
			M-180	A	2	224111	61,010	81,710	26.1	0.190	0.730	0.011	0.003	0.020	0.120	0.000	0.060	0.002	4

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Figure B-79. ⅝-in. (16-mm) Dia., 14.4-ft (4.3-m) Long Cable and Swage Button Certificate of Compliance, Test No. MSPBN-8

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: STOCK

Order Number: 1214903 Prod Ln Grp: 9-End Terminals (Dom)
Customer PO: 2878
BOL Number: 80278 Ship Date:
Document #: 1
Shipped To: NE
Use State: KS

As of: 3/7/14

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
36	749G	TS 8X6X3/16X6'-0" SLEEVE	A-500			0173175	55,871	74,495	31.0	0.160	0.610	0.012	0.009	0.010	0.030	0.000	0.030	0.000	4
20	3000G	CBL 3/4X6'6/DBL	HW			98790													
22	9852A	STRUT & YOKE ASSY	A-1011-SS			163375	48,380	64,020	32.9	0.190	0.520	0.011	0.003	0.030	0.110	0.000	0.050	0.000	4
	9852A		A-36			11237730	45,500	70,000	30.0	0.170	0.500	0.010	0.008	0.020	0.080	0.000	0.070	0.001	4

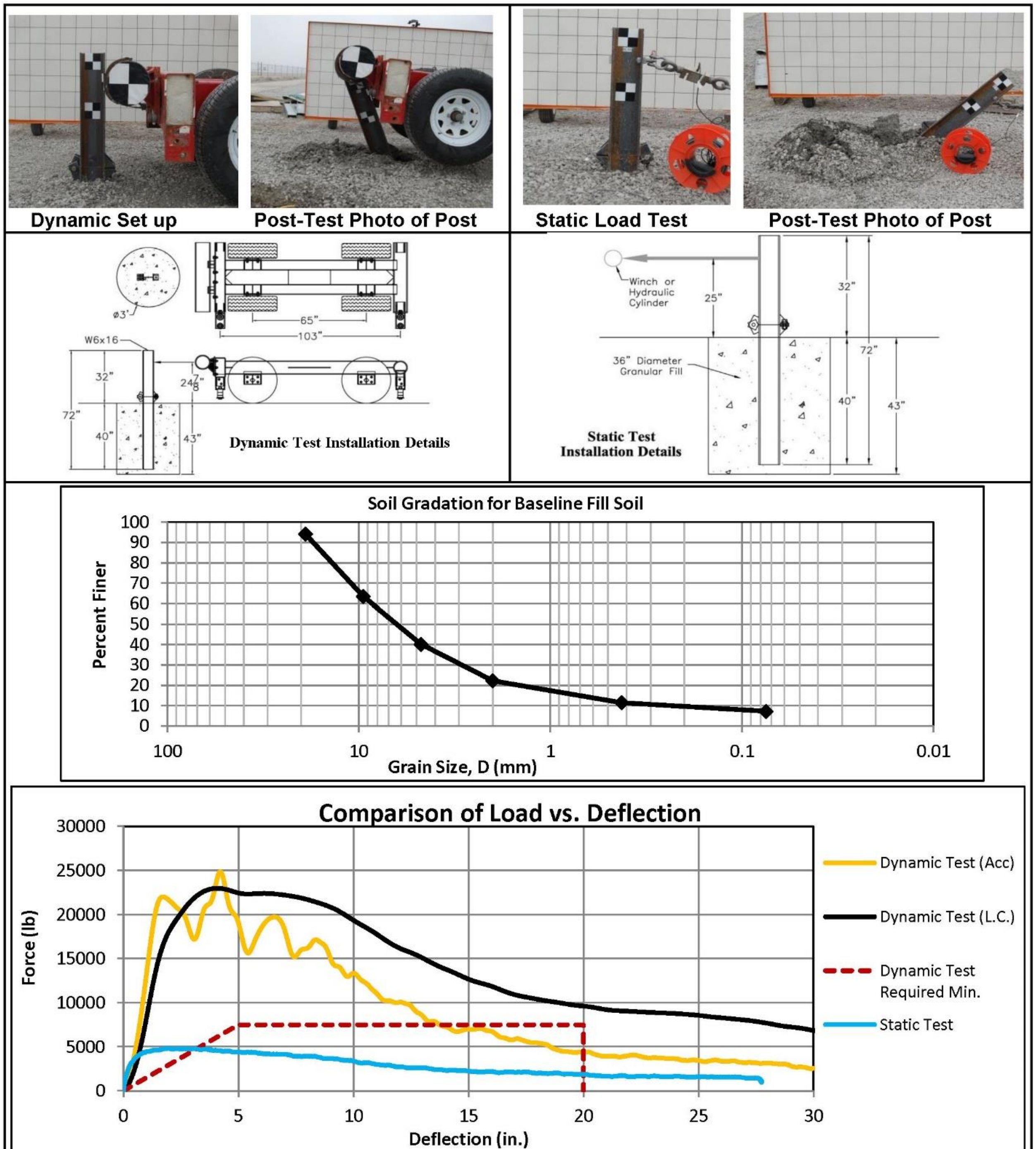
Ground Strut Green Paint
R#15-0157 September 2014 SMT

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 COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT"
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A123 & ISO 1461 (INTERNATIONAL SHIPMENTS)
FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED
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.
WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329.
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 – 46000 LB

1 of 2

Figure B-80. Ground Strut and Yolk Assembly Material Certification, Test No. MSPBN-8

Appendix C. Static Soil Tests

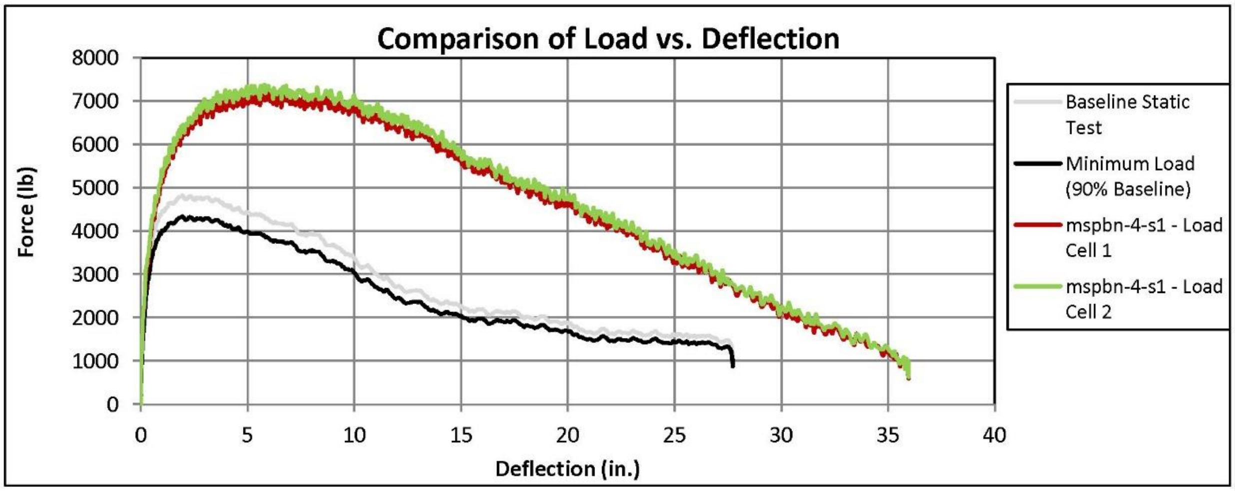


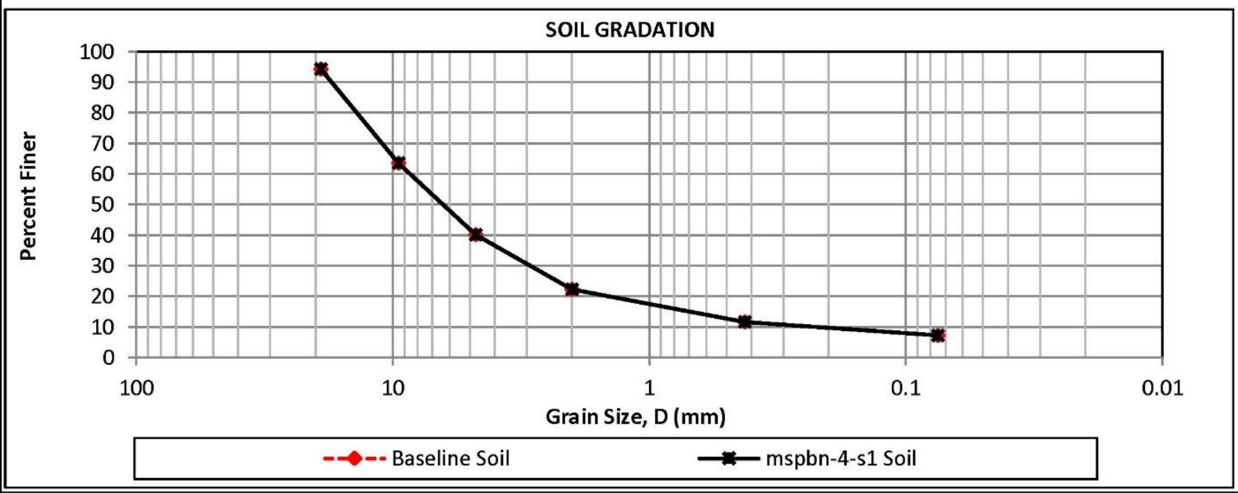
Date...	2/16/2018			
Test Facility & Site Location........................	Midwest Roadside Safety Facility			
In situ soil description (ASTM D2487)..........	Well-Graded Gravel (GW)			
Fill material description (ASTM D2487)........	Well-Graded Gravel (GW) (see sieve analyses above)			
Description of fill placement procedure.......	H.E.-8			
Bogie Weight..	1786	lb	810	kg
Impact Velocity...	20.9	mph	33.7	km/h

Figure C-1. Soil Strength, Initial Calibration, Test No. MSPBN-4 through MSPBN-8

Static Load Test Setup

Post-Test Photo of Post



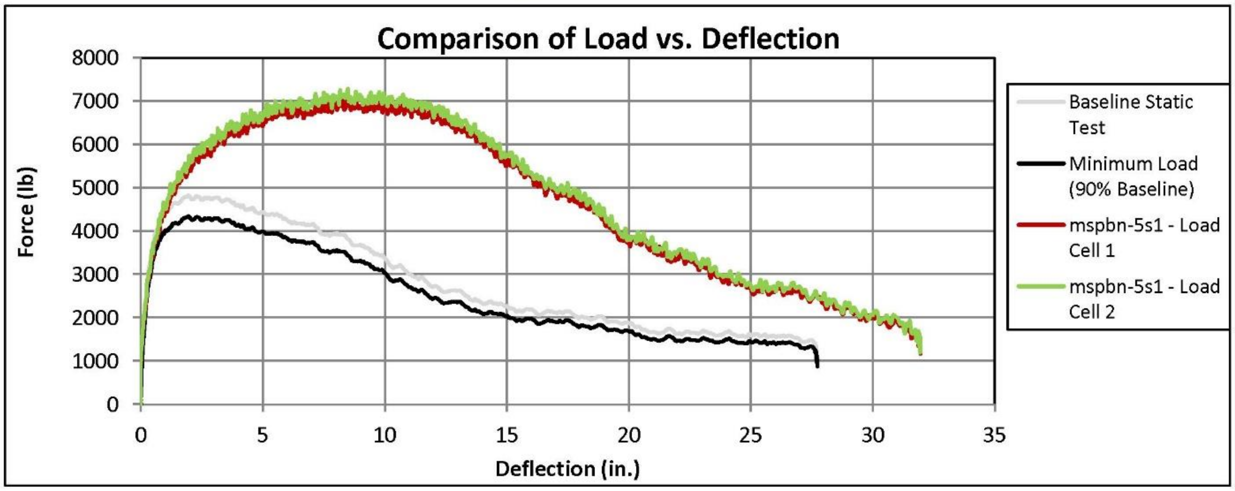


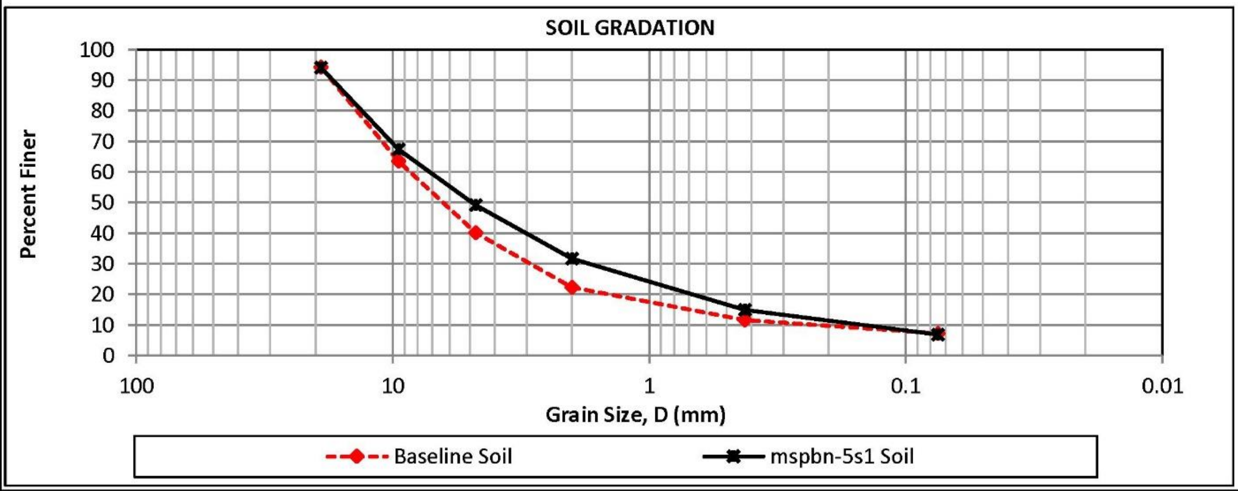
Date..	4/18/2018
Test Facility & Site Location.......................	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)..........	Low Plasticity Silt (ML)
Fill material description (ASTM D2487)........	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure.......	8-inch lifts tamped with a pneumatic compactor

Figure C-2. Static Soil Test, Test No. MSPBN-4

Static Load Test Setup

Post-Test Photo of Post



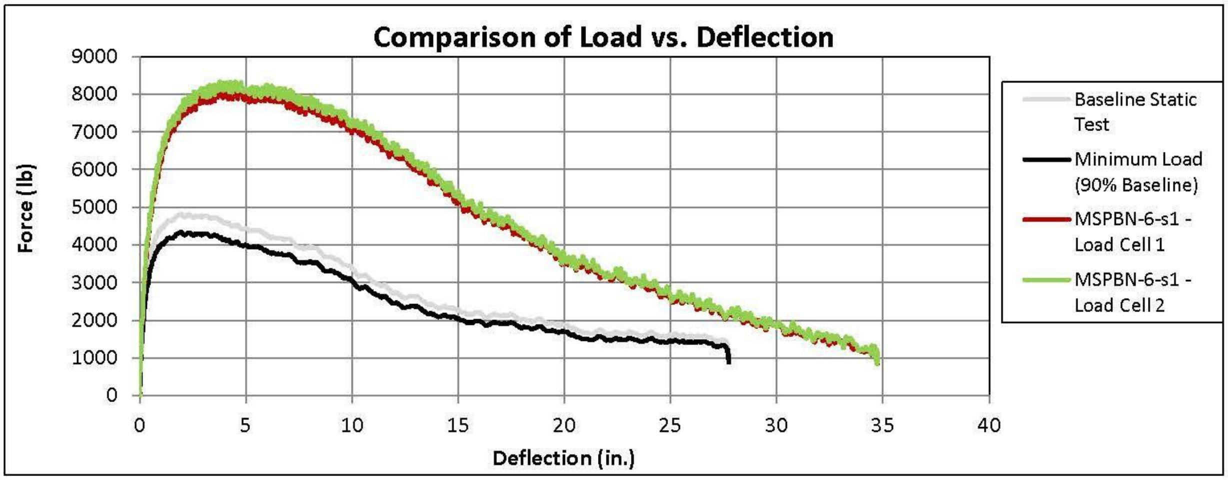


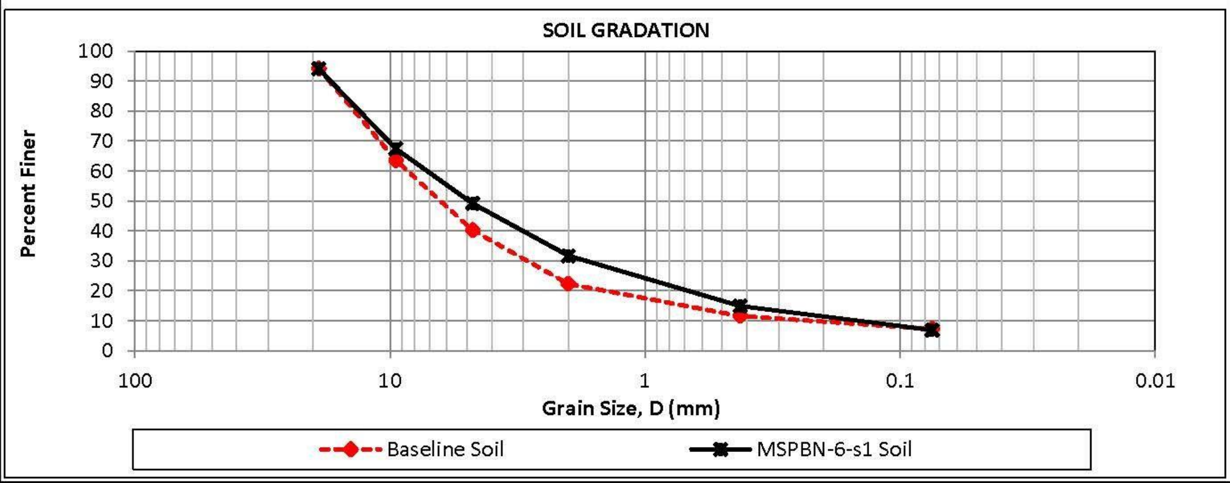
Date..	5/15/2018
Test Facility & Site Location......................	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)..........	Low Plasticity Silt (ML)
Fill material description (ASTM D2487)........	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure.......	8-inch lifts tamped with a pneumatic compactor

Figure C-3. Static Soil Test, Test No. MSPBN-5

Static Load Test Setup

Post-Test Photo of Post



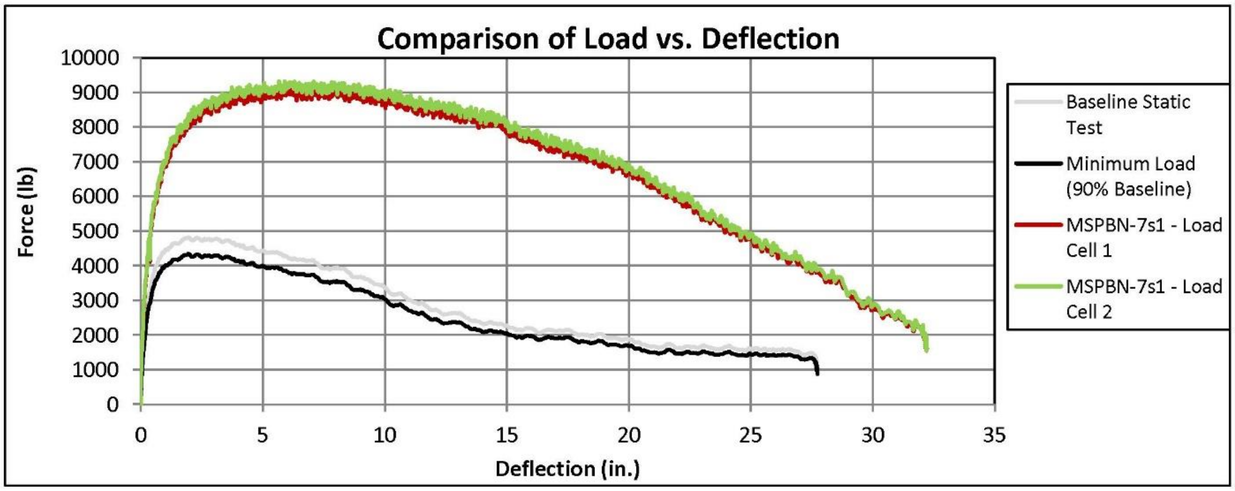


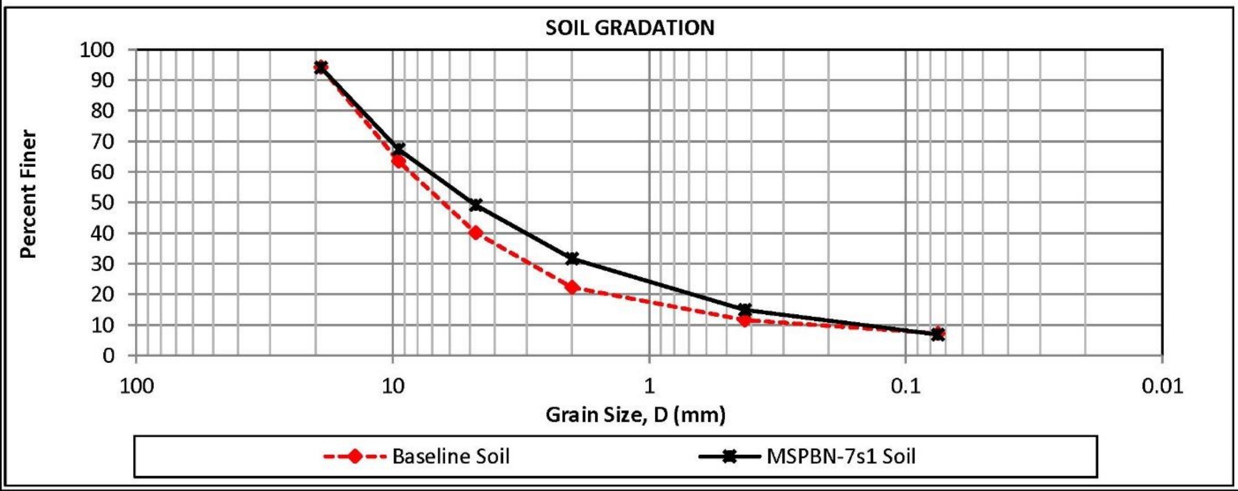
Date	5/24/2018
Test Facility & Site Location	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)	Low Plasticity Silt (ML)
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure	8-inch lifts tamped with a pneumatic compactor

Figure C-4. Static Soil Test, Test No. MSPBN-6

Static Load Test Setup

Post-Test Photo of Post



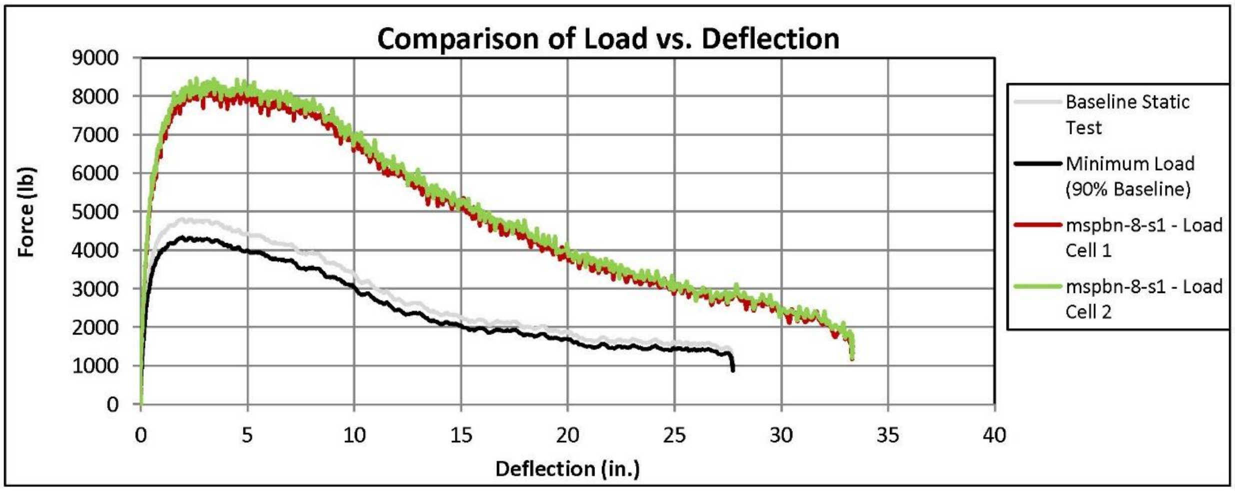


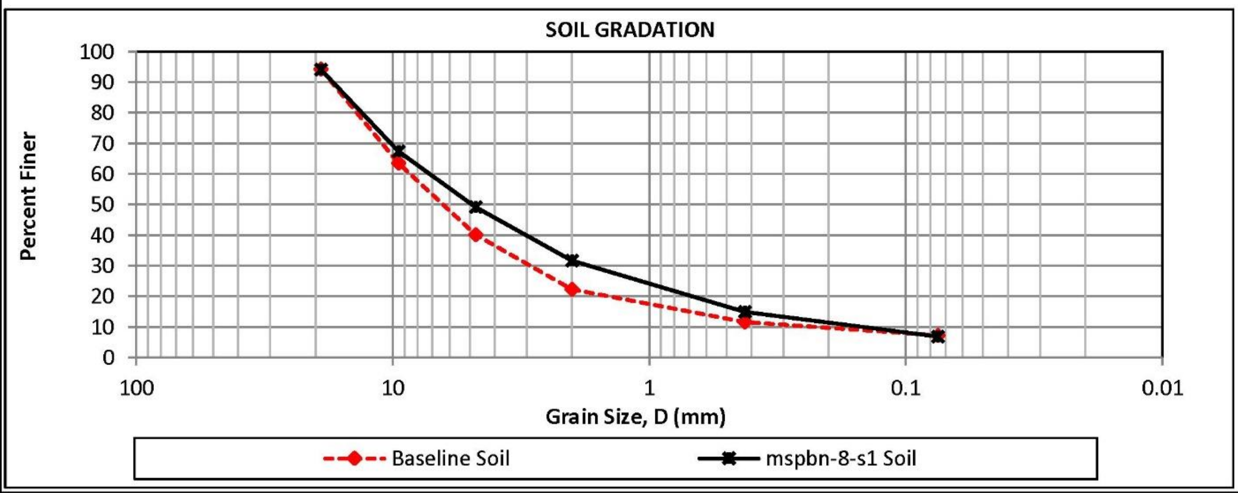
Date..	6/5/2018
Test Facility & Site Location.......................	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)..........	Low Plasticity Silt (ML)
Fill material description (ASTM D2487)........	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure.......	8-inch lifts tamped with a pneumatic compactor

Figure C-5. Static Soil Test, Test No. MSPBN-7

Static Load Test Setup

Post-Test Photo of Post





Date……………………………………………	8/29/2018
Test Facility & Site Location…………………	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)……….	Low Plasticity Silt (ML)
Fill material description (ASTM D2487)……..	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure…….	8-inch lifts tamped with a pneumatic compactor

Figure C-6. Static Soil Test, Test No. MSPBN-8

Appendix D. Vehicle Deformation Records

Date: 4/18/2018 Test Name: MSPBN-4 VIN: KNADE223496469475
Year: 2009 Make: KIA Model: RIO

VEHICLE PRE/POST CRUSH
FLOOR PAN - SET 1 left

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX [A] (in.)	ΔY [A] (in.)	ΔZ [A] (in.)	Total Δ (in.)	Crush [B] (in.)	Directions for Crush [C]
TOE PAN - WHEEL WELL (X, Z)	1	54.490	-13.888	1.312	54.438	-13.857	1.324	0.052	0.030	0.011	0.061	0.053	X, Z
	2	54.453	-10.624	1.284	54.410	-10.613	1.367	0.043	0.011	0.083	0.094	0.094	X, Z
	3	54.338	-7.642	1.010	54.309	-7.629	1.055	0.029	0.013	0.045	0.055	0.054	X, Z
	4	54.319	-4.341	1.403	54.308	-4.355	1.442	0.012	-0.013	0.039	0.042	0.040	X, Z
	5	54.010	-1.115	0.909	53.948	-1.172	0.906	0.063	-0.057	-0.003	0.085	0.063	X
	6	51.866	-14.044	-0.697	51.848	-14.027	-0.636	0.018	0.017	0.061	0.066	0.064	X, Z
	7	51.626	-10.878	-0.425	51.613	-10.922	-0.391	0.013	-0.044	0.035	0.058	0.037	X, Z
	8	51.673	-7.438	-0.618	51.650	-7.453	-0.601	0.023	-0.015	0.017	0.032	0.028	X, Z
	9	51.246	-4.428	-0.500	51.215	-4.422	-0.491	0.032	0.007	0.009	0.034	0.033	X, Z
	10	51.026	-1.371	-0.919	50.986	-1.403	-0.926	0.040	-0.031	-0.006	0.051	0.040	X
FLOOR PAN (Z)	11	46.008	-15.414	-2.066	45.959	-15.399	-2.003	0.049	0.015	0.063	0.081	0.063	Z
	12	45.364	-11.077	-2.023	45.420	-11.089	-1.997	-0.056	-0.012	0.025	0.062	0.025	Z
	13	45.454	-8.363	-2.045	45.432	-8.329	-2.036	0.022	0.034	0.009	0.042	0.009	Z
	14	45.426	-5.735	-2.108	45.452	-5.671	-2.054	-0.026	0.064	0.054	0.088	0.054	Z
	15	45.083	-2.421	-1.896	45.027	-2.467	-1.873	0.056	-0.046	0.023	0.076	0.023	Z
	16	41.618	-16.974	-2.658	41.624	-16.968	-2.585	-0.006	0.006	0.073	0.073	0.073	Z
	17	41.236	-13.063	-2.044	41.221	-13.009	-1.993	0.015	0.054	0.050	0.075	0.050	Z
	18	40.904	-9.230	-2.091	40.863	-9.255	-2.072	0.041	-0.026	0.019	0.052	0.019	Z
	19	40.413	-6.218	-2.382	40.409	-6.270	-2.308	0.004	-0.052	0.073	0.090	0.073	Z
	20	40.384	-3.194	-2.811	40.383	-3.146	-2.792	0.001	0.048	0.020	0.052	0.020	Z
	21	36.746	-17.904	-2.730	36.748	-17.854	-2.663	-0.002	0.050	0.067	0.083	0.067	Z
	22	36.224	-13.906	-2.082	36.209	-13.877	-2.045	0.016	0.028	0.037	0.049	0.037	Z
	23	35.934	-9.835	-2.139	35.905	-9.808	-2.127	0.029	0.027	0.012	0.042	0.012	Z
	24	35.746	-6.393	-2.506	35.713	-6.339	-2.543	0.034	0.054	-0.036	0.073	-0.036	Z
	25	35.650	-3.413	-2.863	35.655	-3.318	-2.853	-0.006	0.095	0.010	0.096	0.010	Z
	26	32.679	-18.217	-2.351	32.645	-18.175	-2.289	0.034	0.041	0.062	0.082	0.062	Z
	27	32.859	-14.076	-2.110	32.883	-14.101	-2.071	-0.024	-0.025	0.039	0.053	0.039	Z
	28	32.495	-10.134	-2.163	32.463	-10.093	-2.131	0.033	0.041	0.032	0.062	0.032	Z
	29	32.541	-7.576	-2.192	32.572	-7.544	-2.200	-0.031	0.032	-0.008	0.045	-0.008	Z
	30	32.104	-5.086	-2.527	32.089	-5.093	-2.527	0.015	-0.007	0.001	0.017	0.001	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations.

Pretest Floor Pan

Posttest Floor Pan

Figure D-1. Floor Pan Deformation Data – Set 1 Left, Test No. MSPBN-4

Date: 4/18/2018 Test Name: MSPBN-4 VIN: KNADE223496469475
Year: 2009 Make: KIA Model: RIO

VEHICLE PRE/POST CRUSH
FLOOR PAN - SET 1 right

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX [A] (in.)	ΔY [A] (in.)	ΔZ [A] (in.)	Total Δ (in.)	Crush [B] (in.)	Directions for Crush [C]
TOE PAN - WHEEL WELL (X, Z)	1	54.309	12.399	1.515	54.246	12.146	1.532	0.063	0.252	0.017	0.261	0.066	X, Z
	2	54.479	15.388	1.711	54.355	15.071	1.668	0.124	0.317	-0.043	0.343	0.124	X
	3	54.538	18.462	1.707	54.422	18.189	1.716	0.116	0.273	0.009	0.297	0.116	X, Z
	4	54.422	21.826	2.023	54.315	21.583	2.104	0.107	0.243	0.081	0.278	0.134	X, Z
	5	53.579	24.901	2.939	53.430	24.687	3.099	0.149	0.214	0.160	0.306	0.218	X, Z
	6	50.391	12.419	-0.881	50.354	12.222	-0.921	0.037	0.198	-0.040	0.205	0.037	X
	7	50.310	15.785	-0.794	50.227	15.564	-0.767	0.083	0.221	0.026	0.237	0.087	X, Z
	8	50.477	18.772	-0.686	50.437	18.561	-0.685	0.040	0.211	0.001	0.215	0.040	X, Z
	9	50.446	22.564	-0.592	50.385	22.381	-0.580	0.062	0.183	0.011	0.193	0.063	X, Z
	10	50.370	27.136	0.037	50.240	26.866	0.048	0.130	0.270	0.011	0.300	0.131	X, Z
FLOOR PAN (Z)	11	44.953	11.646	-2.051	44.978	11.429	-2.095	-0.025	0.217	-0.044	0.223	-0.044	Z
	12	44.746	15.269	-2.254	44.754	15.092	-2.233	-0.008	0.177	0.022	0.178	0.022	Z
	13	45.079	19.516	-2.038	45.084	19.300	-2.129	-0.006	0.216	-0.091	0.235	-0.091	Z
	14	44.728	22.861	-2.299	44.764	22.707	-2.367	-0.035	0.154	-0.068	0.172	-0.068	Z
	15	44.618	26.973	-2.280	44.656	26.865	-2.322	-0.038	0.109	-0.042	0.123	-0.042	Z
	16	41.169	11.222	-2.664	41.129	11.008	-2.732	0.040	0.214	-0.068	0.228	-0.068	Z
	17	40.897	14.666	-2.758	40.911	14.411	-2.746	-0.014	0.256	0.012	0.257	0.012	Z
	18	40.968	19.010	-2.339	40.945	18.759	-2.439	0.023	0.251	-0.100	0.271	-0.100	Z
	19	40.777	22.932	-2.395	40.815	22.764	-2.483	-0.038	0.168	-0.088	0.193	-0.088	Z
	20	40.864	27.386	-2.872	40.831	27.132	-2.943	0.033	0.254	-0.071	0.266	-0.071	Z
	21	37.312	11.095	-2.890	37.271	10.842	-2.945	0.041	0.253	-0.055	0.262	-0.055	Z
	22	37.058	14.654	-2.933	37.031	14.402	-2.954	0.028	0.252	-0.021	0.255	-0.021	Z
	23	36.869	18.594	-2.393	36.866	18.377	-2.522	0.003	0.217	-0.129	0.253	-0.129	Z
	24	36.557	22.928	-2.430	36.562	22.670	-2.524	-0.005	0.258	-0.094	0.274	-0.094	Z
	25	36.049	28.040	-2.981	36.057	27.778	-3.023	-0.008	0.261	-0.042	0.265	-0.042	Z
	26	32.355	10.836	-2.702	32.441	10.585	-2.794	-0.087	0.251	-0.092	0.281	-0.092	Z
	27	32.324	14.448	-2.760	32.356	14.254	-2.868	-0.032	0.194	-0.108	0.224	-0.108	Z
	28	31.997	18.381	-2.435	31.991	18.096	-2.538	0.005	0.285	-0.103	0.303	-0.103	Z
	29	31.917	22.546	-2.447	31.792	22.299	-2.553	0.125	0.247	-0.106	0.297	-0.106	Z
	30	31.036	28.195	-2.682	30.907	27.934	-2.724	0.129	0.261	-0.042	0.295	-0.042	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations.

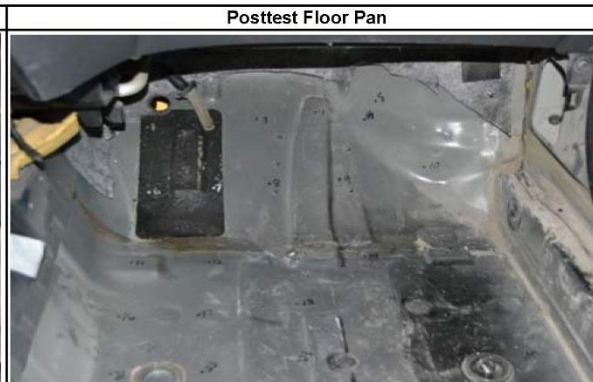
Pretest Floor Pan	Posttest Floor Pan
	

Figure D-2. Floor Pan Deformation Data – Set 1 Right, Test No. MSPBN-4

Date: 4/18/2018 Test Name: MSPBN-4 VIN: KNADE223496469475
Year: 2009 Make: KIA Model: RIO

VEHICLE PRE/POST CRUSH
FLOOR PAN - SET 2 left

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX [A] (in.)	ΔY [A] (in.)	ΔZ [A] (in.)	Total Δ (in.)	Crush [B] (in.)	Directions for Crush [C]
TOE PAN - WHEEL WELL (X, Z)	1	64.088	-22.925	-4.200	64.236	-22.680	-4.336	-0.148	0.245	-0.136	0.317	0.000	
	2	64.060	-19.661	-4.218	64.164	-19.427	-4.293	-0.104	0.234	-0.076	0.267	0.000	
	3	63.957	-16.678	-4.482	64.133	-16.387	-4.581	-0.176	0.291	-0.100	0.354	0.000	
	4	63.945	-13.379	-4.077	64.152	-13.147	-4.155	-0.207	0.231	-0.078	0.320	0.000	
	5	63.650	-10.150	-4.563	63.859	-9.993	-4.678	-0.209	0.157	-0.115	0.285	0.000	
	6	61.479	-23.066	-6.231	61.624	-22.828	-6.326	-0.144	0.238	-0.095	0.294	0.000	
	7	61.247	-19.900	-5.950	61.373	-19.668	-6.090	-0.127	0.232	-0.140	0.299	0.000	
	8	61.306	-16.460	-6.130	61.479	-16.296	-6.259	-0.173	0.164	-0.128	0.271	0.000	
	9	60.887	-13.449	-6.005	61.045	-13.250	-6.146	-0.157	0.199	-0.141	0.290	0.000	
	10	60.680	-10.390	-6.415	60.880	-10.195	-6.550	-0.200	0.195	-0.135	0.311	0.000	
FLOOR PAN (Z)	11	55.629	-24.413	-7.652	55.864	-24.198	-7.706	-0.235	0.215	-0.054	0.323	-0.054	Z
	12	54.997	-20.074	-7.598	55.170	-19.895	-7.707	-0.173	0.179	-0.109	0.271	-0.109	Z
	13	55.096	-17.361	-7.610	55.242	-17.126	-7.738	-0.147	0.235	-0.128	0.305	-0.128	Z
	14	55.077	-14.732	-7.664	55.271	-14.484	-7.753	-0.195	0.248	-0.089	0.328	-0.089	Z
	15	54.742	-11.418	-7.443	54.931	-11.197	-7.553	-0.189	0.221	-0.110	0.312	-0.110	Z
	16	51.239	-25.958	-8.284	51.467	-25.777	-8.338	-0.228	0.181	-0.054	0.296	-0.054	Z
	17	50.863	-22.048	-7.659	51.060	-21.836	-7.743	-0.197	0.212	-0.084	0.301	-0.084	Z
	18	50.544	-18.213	-7.696	50.701	-18.012	-7.817	-0.157	0.201	-0.122	0.282	-0.122	Z
	19	50.064	-15.199	-7.979	50.265	-14.989	-8.110	-0.201	0.210	-0.131	0.319	-0.131	Z
	20	50.048	-12.173	-8.399	50.260	-11.976	-8.520	-0.213	0.197	-0.121	0.315	-0.121	Z
	21	46.365	-26.872	-8.398	46.574	-26.599	-8.455	-0.209	0.273	-0.057	0.349	-0.057	Z
	22	45.850	-22.875	-7.740	46.036	-22.694	-7.815	-0.187	0.181	-0.075	0.270	-0.075	Z
	23	45.573	-18.803	-7.786	45.728	-18.610	-7.891	-0.156	0.194	-0.106	0.270	-0.106	Z
	24	45.398	-15.359	-8.142	45.623	-15.132	-8.287	-0.225	0.227	-0.145	0.351	-0.145	Z
	25	45.313	-12.378	-8.489	45.588	-12.127	-8.605	-0.274	0.251	-0.116	0.389	-0.116	Z
	26	42.293	-27.174	-8.053	42.479	-27.004	-8.063	-0.186	0.170	-0.010	0.252	-0.010	Z
	27	42.484	-23.034	-7.796	42.771	-22.863	-7.834	-0.287	0.171	-0.038	0.336	-0.038	Z
	28	42.133	-19.091	-7.838	42.241	-18.873	-7.917	-0.108	0.219	-0.078	0.256	-0.078	Z
	29	42.186	-16.533	-7.858	42.386	-16.323	-7.952	-0.200	0.210	-0.095	0.305	-0.095	Z
	30	41.760	-14.040	-8.187	41.998	-13.841	-8.283	-0.238	0.200	-0.096	0.325	-0.096	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations.

Pretest Floor Pan

Posttest Floor Pan

Figure D-3. Floor Pan Deformation Data – Set 2 Left, Test No. MSPBN-4

Date:	4/18/2018	Test Name:	MSPBN-4	VIN:	KNADE223496469475
Year:	2009	Make:	KIA	Model:	RIO

VEHICLE PRE/POST CRUSH
FLOOR PAN - SET 2 right

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX [A] (in.)	ΔY [A] (in.)	ΔZ [A] (in.)	Total Δ (in.)	Crush [B] (in.)	Directions for Crush [C]
TOE PAN - WHEEL WELL (X, Z)	1	64.170	3.519	-4.368	64.148	3.528	-4.028	0.022	-0.009	0.340	0.341	0.341	X, Z
	2	64.352	6.507	-4.172	64.267	6.451	-3.882	0.085	0.056	0.291	0.308	0.303	X, Z
	3	64.425	9.581	-4.177	64.347	9.569	-3.824	0.078	0.012	0.353	0.362	0.362	X, Z
	4	64.322	12.946	-3.861	64.251	12.962	-3.425	0.072	-0.017	0.436	0.442	0.442	X, Z
	5	63.491	16.024	-2.946	63.372	16.066	-2.426	0.120	-0.042	0.520	0.535	0.534	X, Z
	6	60.253	3.555	-6.765	60.271	3.626	-6.503	-0.018	-0.071	0.262	0.272	0.262	Z
	7	60.186	6.921	-6.678	60.156	6.968	-6.340	0.030	-0.048	0.339	0.343	0.340	X, Z
	8	60.366	9.907	-6.572	60.377	9.964	-6.247	-0.011	-0.056	0.325	0.330	0.325	Z
	9	60.351	13.700	-6.478	60.339	13.784	-6.130	0.012	-0.085	0.348	0.358	0.348	X, Z
	10	60.293	18.271	-5.850	60.208	18.267	-5.488	0.085	0.004	0.362	0.372	0.372	X, Z
FLOOR PAN (Z)	11	54.813	2.804	-7.937	54.899	2.858	-7.711	-0.087	-0.054	0.226	0.248	0.226	Z
	12	54.620	6.428	-8.141	54.690	6.522	-7.838	-0.069	-0.094	0.303	0.325	0.303	Z
	13	54.971	10.674	-7.925	55.036	10.728	-7.719	-0.065	-0.054	0.206	0.223	0.206	Z
	14	54.635	14.020	-8.188	54.730	14.137	-7.949	-0.095	-0.117	0.239	0.283	0.239	Z
	15	54.541	18.133	-8.169	54.638	18.295	-7.891	-0.097	-0.163	0.279	0.337	0.279	Z
	16	51.026	2.396	-8.551	51.052	2.454	-8.371	-0.025	-0.058	0.180	0.191	0.180	Z
	17	50.770	5.841	-8.646	50.847	5.857	-8.376	-0.078	-0.016	0.270	0.282	0.270	Z
	18	50.858	10.184	-8.228	50.896	10.204	-8.055	-0.038	-0.020	0.173	0.179	0.173	Z
	19	50.684	14.107	-8.285	50.782	14.210	-8.087	-0.098	-0.103	0.198	0.244	0.198	Z
	20	50.789	18.561	-8.763	50.817	18.580	-8.534	-0.028	-0.018	0.229	0.232	0.229	Z
	21	47.169	2.285	-8.779	47.194	2.304	-8.607	-0.025	-0.018	0.172	0.175	0.172	Z
	22	46.931	5.845	-8.823	46.968	5.864	-8.607	-0.038	-0.019	0.216	0.220	0.216	Z
	23	46.758	9.786	-8.284	46.816	9.839	-8.163	-0.059	-0.053	0.121	0.144	0.121	Z
	24	46.464	14.121	-8.322	46.529	14.133	-8.153	-0.066	-0.012	0.168	0.181	0.168	Z
	25	45.977	19.235	-8.874	46.047	19.245	-8.639	-0.070	-0.010	0.235	0.246	0.235	Z
	26	42.211	2.047	-8.593	42.363	2.065	-8.486	-0.152	-0.018	0.108	0.187	0.108	Z
	27	42.195	5.659	-8.652	42.292	5.735	-8.548	-0.097	-0.076	0.104	0.161	0.104	Z
	28	41.885	9.593	-8.328	41.941	9.577	-8.208	-0.056	0.016	0.120	0.133	0.120	Z
	29	41.823	13.759	-8.341	41.758	13.781	-8.211	0.064	-0.022	0.130	0.146	0.130	Z
	30	40.965	19.411	-8.577	40.896	19.420	-8.370	0.069	-0.008	0.208	0.219	0.208	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations.

Pretest Floor Pan

Posttest Floor Pan

Figure D-4. Floor Pan Deformation Data – Set 2 Right, Test No. MSPBN-4

Date: 4/18/2018 Test Name: MSPBN-4 VIN: KNADE223496469475

Year: 2009 Make: KIA Model: RIO

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1 left

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX [A] (in.)	ΔY [A] (in.)	ΔZ [A] (in.)	Total Δ (in.)	Crush [B] (in.)	Directions for Crush [C]
DASH (X, Y, Z)	1	39.970	5.749	26.476	39.758	-1.178	27.840	0.212	6.927	1.364	7.063	7.063	X, Y, Z
	2	40.146	-8.465	29.121	40.092	-8.780	29.208	0.053	-0.316	0.087	0.332	0.332	X, Y, Z
	3	41.889	-19.543	25.820	41.961	-19.714	25.919	-0.072	-0.171	0.099	0.210	0.210	X, Y, Z
	4	34.785	4.828	18.896	34.767	4.604	18.916	0.019	0.224	0.020	0.226	0.226	X, Y, Z
	5	37.737	-1.740	18.407	37.852	-2.254	18.592	-0.115	-0.514	0.185	0.558	0.558	X, Y, Z
	6	38.845	-19.791	18.472	38.867	-20.031	18.542	-0.022	-0.240	0.070	0.251	0.251	X, Y, Z
SIDE PANEL (Y)	7	45.182	-21.649	4.509	45.177	-21.860	4.590	0.006	-0.211	0.081	0.226	-0.211	Y
	8	46.083	-21.583	6.518	46.158	-21.785	6.564	-0.075	-0.202	0.047	0.220	-0.202	Y
	9	50.660	-21.251	9.185	50.567	-21.456	9.137	0.092	-0.205	-0.048	0.230	-0.205	Y
IMPACT SIDE DOOR (Y)	10	41.422	-22.700	24.155	41.426	-22.885	24.284	-0.004	-0.186	0.129	0.226	-0.186	Y
	11	27.655	-23.348	25.170	27.681	-23.540	25.240	-0.026	-0.192	0.070	0.206	-0.192	Y
	12	12.921	-24.424	25.493	12.879	-24.634	25.582	0.042	-0.210	0.088	0.232	-0.210	Y
	13	42.917	-23.049	15.961	42.934	-23.241	16.049	-0.017	-0.192	0.087	0.211	-0.192	Y
	14	27.255	-24.062	14.558	27.349	-24.248	14.617	-0.094	-0.185	0.059	0.216	-0.185	Y
	15	14.933	-24.441	15.161	14.883	-24.661	15.285	0.050	-0.220	0.124	0.257	-0.220	Y
ROOF - (Z)	16	25.356	2.882	41.479	25.056	2.632	40.754	0.300	0.250	-0.724	0.823	-0.724	Z
	17	25.402	-5.878	41.586	25.117	-6.085	40.919	0.285	-0.207	-0.667	0.754	-0.667	Z
	18	24.907	-12.216	41.396	24.771	-12.558	40.900	0.137	-0.341	-0.496	0.617	-0.496	Z
	19	20.670	2.537	44.170	20.546	2.234	44.028	0.124	0.303	-0.142	0.357	-0.142	Z
	20	21.022	-6.169	43.984	20.974	-6.342	43.985	0.048	-0.173	0.001	0.180	0.001	Z
	21	20.688	-12.990	43.644	20.769	-13.163	43.670	-0.081	-0.173	0.026	0.193	0.026	Z
	22	18.381	2.244	44.590	18.385	2.042	44.649	-0.004	0.203	0.058	0.211	0.058	Z
	23	19.060	-2.715	44.451	19.066	-2.982	44.459	-0.007	-0.267	0.008	0.267	0.008	Z
	24	19.116	-7.212	44.301	19.022	-7.378	44.347	0.094	-0.166	0.046	0.196	0.046	Z
	25	19.103	-12.399	43.991	19.143	-12.532	44.031	-0.040	-0.133	0.040	0.144	0.040	Z
	26	15.944	1.690	44.944	15.793	1.540	44.942	0.151	0.150	-0.002	0.213	-0.002	Z
	27	17.003	-3.143	44.763	16.931	-3.306	44.815	0.072	-0.164	0.052	0.186	0.052	Z
	28	17.279	-7.182	44.593	17.289	-7.451	44.620	-0.009	-0.269	0.027	0.271	0.027	Z
	29	17.621	-12.612	44.216	17.506	-12.736	44.285	0.115	-0.125	0.069	0.183	0.069	Z
	30	15.566	-5.836	44.869	15.584	-6.113	44.901	-0.018	-0.277	0.032	0.279	0.032	Z
A-PILLAR Lateral (Y)	31	45.126	-20.219	28.840	45.168	-20.380	28.933	-0.042	-0.161	0.093	0.191	-0.161	Y
	32	40.653	-19.585	31.858	40.673	-19.784	31.919	-0.019	-0.199	0.061	0.209	-0.199	Y
	33	35.863	-18.808	34.735	36.764	-19.020	34.684	-0.900	-0.212	-0.051	0.926	-0.212	Y
	34	31.527	-18.163	36.898	31.530	-18.414	36.921	-0.003	-0.251	0.023	0.252	-0.251	Y
B-PILLAR Lateral (Y)	35	4.220	-18.288	40.280	4.353	-18.508	40.420	-0.133	-0.220	0.140	0.293	-0.220	Y
	36	7.442	-20.367	36.330	7.488	-20.609	36.428	-0.047	-0.242	0.098	0.265	-0.242	Y
	37	4.955	-21.867	32.909	4.990	-22.136	32.959	-0.035	-0.269	0.050	0.275	-0.269	Y
	38	8.860	-22.951	29.338	8.904	-23.201	29.445	-0.043	-0.250	0.107	0.275	-0.250	Y
	39	5.707	-23.389	26.562	5.756	-23.654	26.618	-0.049	-0.265	0.057	0.276	-0.265	Y
	40	10.080	-23.392	23.230	10.156	-23.653	23.323	-0.075	-0.261	0.093	0.287	-0.261	Y
A-PILLAR Maximum (X, Y, Z)	31	45.126	-20.219	28.840	45.168	-20.380	28.933	-0.042	-0.161	0.093	0.191	0.305	Z
	32	40.653	-19.585	31.858	40.673	-19.784	31.919	-0.019	-0.199	0.061	0.209	0.247	Z
	33	35.863	-18.808	34.735	36.764	-19.020	34.684	-0.900	-0.212	-0.051	0.926	0.000	
	34	31.527	-18.163	36.898	31.530	-18.414	36.921	-0.003	-0.251	0.023	0.252	0.152	Z
B-PILLAR Maximum (X, Y, Z)	35	4.220	-18.288	40.280	4.353	-18.508	40.420	-0.133	-0.220	0.140	0.293	0.374	Z
	36	7.442	-20.367	36.330	7.488	-20.609	36.428	-0.047	-0.242	0.098	0.265	0.313	Z
	37	4.955	-21.867	32.909	4.990	-22.136	32.959	-0.035	-0.269	0.050	0.275	0.224	Z
	38	8.860	-22.951	29.338	8.904	-23.201	29.445	-0.043	-0.250	0.107	0.275	0.327	Z
	39	5.707	-23.389	26.562	5.756	-23.654	26.618	-0.049	-0.265	0.057	0.276	0.238	Z
	40	10.080	-23.392	23.230	10.156	-23.653	23.323	-0.075	-0.261	0.093	0.287	0.305	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations.

Figure D-5. Occupant Compartment Deformation Data – Set 1 Left, Test No. MSPBN-4

Date: 4/18/2018 Test Name: MSPBN-4 VIN: KNADE223496469475
Year: 2009 Make: KIA Model: RIO

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1 right

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX [A] (in.)	ΔY [A] (in.)	ΔZ [A] (in.)	Total Δ (in.)	Crush [B] (in.)	Directions for Crush [C]
DASH (X, Y, Z)	1	39.784	6.621	26.438	39.831	6.610	26.518	-0.047	0.012	0.080	0.093	0.093	X, Y, Z
	2	39.438	14.261	26.250	39.473	14.296	26.317	-0.036	-0.035	0.066	0.083	0.083	X, Y, Z
	3	39.800	25.550	25.575	39.819	25.547	25.617	-0.019	0.003	0.041	0.046	0.046	X, Y, Z
	4	34.610	5.715	18.797	34.611	5.790	18.967	0.000	-0.075	0.169	0.185	0.185	X, Y, Z
	5	36.415	13.605	19.005	36.421	13.654	19.116	-0.006	-0.049	0.111	0.121	0.121	X, Y, Z
	6	36.740	24.890	19.565	36.695	24.882	19.567	0.045	0.008	0.002	0.046	0.046	X, Y, Z
SIDE PANEL (Y)	7	43.539	31.558	3.960	43.501	31.412	3.988	0.038	0.147	0.029	0.154	0.147	Y
	8	47.738	31.678	3.859	47.692	31.495	3.802	0.046	0.183	-0.057	0.197	0.183	Y
	9	44.723	31.490	7.885	44.639	31.336	7.990	0.084	0.154	0.106	0.205	0.154	Y
IMPACT SIDE DOOR (Y)	10	39.546	32.841	22.280	39.411	32.750	22.276	0.135	0.090	-0.004	0.162	0.090	Y
	11	27.119	31.897	23.748	26.989	31.882	23.777	0.130	0.015	0.029	0.134	0.015	Y
	12	14.278	31.128	24.767	14.030	31.183	24.793	0.249	-0.055	0.027	0.256	-0.055	Y
	13	40.519	32.465	11.986	40.330	32.352	11.985	0.189	0.113	-0.001	0.220	0.113	Y
	14	25.494	32.149	14.041	25.346	32.112	14.084	0.148	0.037	0.043	0.159	0.037	Y
	15	14.194	31.512	13.845	14.011	31.526	13.893	0.184	-0.014	0.048	0.190	-0.014	Y
ROOF - (Z)	16	25.236	5.302	41.444	24.986	5.290	40.682	0.250	0.012	-0.763	0.803	-0.763	Z
	17	24.440	14.006	41.331	24.189	13.981	40.896	0.251	0.025	-0.435	0.503	-0.435	Z
	18	22.636	22.670	40.747	22.617	22.784	40.668	0.019	-0.113	-0.079	0.140	-0.079	Z
	19	20.350	5.198	44.174	20.140	5.199	43.995	0.210	-0.001	-0.180	0.276	-0.180	Z
	20	19.749	12.773	43.929	19.644	12.840	43.888	0.105	-0.068	-0.042	0.131	-0.042	Z
	21	18.291	21.060	43.400	18.234	21.108	43.418	0.058	-0.047	0.018	0.077	0.018	Z
	22	17.955	4.878	44.610	17.846	4.883	44.721	0.109	-0.005	0.111	0.156	0.111	Z
	23	17.970	9.845	44.425	17.917	9.791	44.451	0.054	0.054	0.026	0.080	0.026	Z
	24	17.744	14.609	44.152	17.697	14.674	44.154	0.048	-0.065	0.002	0.080	0.002	Z
	25	17.072	20.183	43.714	17.049	20.200	43.732	0.023	-0.017	0.018	0.033	0.018	Z
	26	15.061	4.612	45.006	14.923	4.559	45.044	0.138	0.054	0.037	0.153	0.037	Z
	27	15.096	9.044	44.863	14.965	9.084	44.887	0.131	-0.040	0.025	0.140	0.025	Z
	28	15.505	13.889	44.531	15.390	13.909	44.557	0.114	-0.020	0.026	0.119	0.026	Z
	29	15.065	19.526	44.079	14.991	19.564	44.108	0.073	-0.038	0.029	0.088	0.029	Z
	30	13.013	11.559	44.958	12.965	11.522	45.001	0.048	0.037	0.043	0.075	0.043	Z
A-PILLAR Lateral (Y)	31	42.815	30.673	27.641	42.855	30.668	27.765	-0.040	0.005	0.124	0.131	0.005	Y
	32	38.063	29.400	31.513	38.085	29.443	31.568	-0.022	-0.043	0.056	0.074	-0.043	Y
	33	33.657	28.258	34.047	33.571	28.275	34.211	0.086	-0.017	0.164	0.186	-0.017	Y
	34	29.195	27.066	36.493	29.212	27.128	36.557	-0.017	-0.062	0.064	0.091	-0.062	Y
B-PILLAR Lateral (Y)	35	4.526	24.968	39.473	4.484	24.988	39.481	0.042	-0.020	0.008	0.048	-0.020	Y
	36	2.065	25.871	37.368	1.978	25.889	37.339	0.087	-0.018	-0.029	0.094	-0.018	Y
	37	5.494	27.237	34.558	5.429	27.238	34.590	0.065	0.000	0.032	0.073	0.000	Y
	38	2.509	27.998	31.751	2.462	27.987	31.794	0.047	0.011	0.043	0.065	0.011	Y
	39	6.376	28.737	29.874	6.336	28.736	29.900	0.041	0.001	0.025	0.048	0.001	Y
	40	3.471	29.526	24.134	3.434	29.513	24.152	0.037	0.012	0.018	0.043	0.012	Y
A-PILLAR Maximum (X, Y, Z)	31	42.815	30.673	27.641	42.855	30.668	27.765	-0.040	0.005	0.124	0.131	0.353	Y, Z
	32	38.063	29.400	31.513	38.085	29.443	31.568	-0.022	-0.043	0.056	0.074	0.236	Z
	33	33.657	28.258	34.047	33.571	28.275	34.211	0.086	-0.017	0.164	0.186	0.414	XZ
	34	29.195	27.066	36.493	29.212	27.128	36.557	-0.017	-0.062	0.064	0.091	0.253	Z
B-PILLAR Maximum (X, Y, Z)	35	4.526	24.968	39.473	4.484	24.988	39.481	0.042	-0.020	0.008	0.048	0.100	XZ
	36	2.065	25.871	37.368	1.978	25.889	37.339	0.087	-0.018	-0.029	0.094	0.087	X
	37	5.494	27.237	34.558	5.429	27.238	34.590	0.065	0.000	0.032	0.073	0.190	XZ
	38	2.509	27.998	31.751	2.462	27.987	31.794	0.047	0.011	0.043	0.065	0.214	X, Y, Z
	39	6.376	28.737	29.874	6.336	28.736	29.900	0.041	0.001	0.025	0.048	0.165	X, Y, Z
	40	3.471	29.526	24.134	3.434	29.513	24.152	0.037	0.012	0.018	0.043	0.141	X, Y, Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations.

Figure D-6. Occupant Compartment Deformation Data – Set 1 Right, Test No. MSPBN-4

Date: 4/18/2018 Test Name: MSPBN-4 VIN: KNADE223496469475
Year: 2009 Make: KIA Model: RIO

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2 left

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX [A] (in.)	ΔY [A] (in.)	ΔZ [A] (in.)	Total Δ (in.)	Crush [B] (in.)	Directions for Crush [C]
DASH (X, Y, Z)	1	49.426	-3.324	20.917	49.476	-10.056	22.142	-0.050	-6.732	1.225	6.843	6.843	X, Y, Z
	2	49.540	-17.547	23.513	49.772	-17.663	23.490	-0.231	-0.117	-0.023	0.260	0.260	X, Y, Z
	3	51.278	-28.618	20.186	51.614	-28.595	20.179	-0.336	0.023	-0.007	0.337	0.337	X, Y, Z
	4	44.300	-4.203	13.292	44.559	-4.228	13.207	-0.259	-0.025	-0.085	0.274	0.274	X, Y, Z
	5	47.237	-10.777	12.803	47.618	-11.097	12.880	-0.382	-0.320	0.077	0.504	0.504	X, Y, Z
	6	48.293	-28.832	12.813	48.560	-28.878	12.784	-0.268	-0.046	-0.029	0.273	0.273	X, Y, Z
SIDE PANEL (Y)	7	54.736	-30.659	-1.105	54.940	-30.693	-1.138	-0.204	-0.034	-0.033	0.210	-0.034	Y
	8	55.620	-30.603	0.911	55.911	-30.628	0.843	-0.290	-0.025	-0.068	0.299	-0.025	Y
	9	60.177	-30.293	3.616	60.307	-30.324	3.440	-0.130	-0.031	-0.175	0.221	-0.031	Y
IMPACT SIDE DOOR (Y)	10	50.816	-31.768	18.506	51.075	-31.759	18.532	-0.259	0.008	0.026	0.260	0.008	Y
	11	37.039	-32.380	19.409	37.322	-32.360	19.409	-0.283	0.020	0.000	0.284	0.020	Y
	12	22.300	-33.415	19.611	22.514	-33.393	19.665	-0.214	0.021	0.054	0.221	0.021	Y
	13	52.375	-32.093	10.324	52.628	-32.098	10.304	-0.252	-0.005	-0.020	0.253	-0.005	Y
	14	36.722	-33.056	8.792	37.047	-33.035	8.782	-0.325	0.021	-0.009	0.326	0.021	Y
	15	24.395	-33.401	9.295	24.575	-33.399	9.379	-0.181	0.002	0.084	0.199	0.002	Y
ROOF - (Z)	16	34.685	-6.201	35.792	34.718	-6.222	34.985	-0.034	-0.021	-0.807	0.808	-0.807	Z
	17	34.705	-14.961	35.868	34.743	-14.940	35.124	-0.038	0.021	-0.744	0.745	-0.744	Z
	18	34.194	-21.298	35.652	34.369	-21.411	35.084	-0.176	-0.113	-0.567	0.605	-0.567	Z
	19	29.976	-6.542	38.444	30.188	-6.611	38.232	-0.212	-0.069	-0.212	0.308	-0.212	Z
	20	30.305	-15.248	38.230	30.581	-15.189	38.167	-0.276	0.059	-0.063	0.289	-0.063	Z
	21	29.954	-22.067	37.864	30.350	-22.008	37.830	-0.396	0.059	-0.033	0.402	-0.033	Z
	22	27.683	-6.829	38.845	28.022	-6.796	38.840	-0.339	0.033	-0.005	0.341	-0.005	Z
	23	28.349	-11.790	38.694	28.685	-11.822	38.640	-0.336	-0.032	-0.054	0.341	-0.054	Z
	24	28.394	-16.287	38.529	28.622	-16.217	38.515	-0.229	0.070	-0.014	0.240	-0.014	Z
	25	28.368	-21.472	38.200	28.724	-21.371	38.184	-0.356	0.102	-0.016	0.371	-0.016	Z
	26	25.242	-7.378	39.177	25.427	-7.288	39.117	-0.185	0.090	-0.060	0.215	-0.060	Z
	27	26.288	-12.213	38.987	26.545	-12.138	38.982	-0.257	0.075	-0.005	0.268	-0.005	Z
	28	26.554	-16.252	38.805	26.887	-16.284	38.778	-0.333	-0.032	-0.028	0.336	-0.028	Z
	29	26.883	-21.682	38.412	27.085	-21.569	38.428	-0.201	0.113	0.016	0.231	0.016	Z
	30	24.843	-14.902	39.072	25.187	-14.939	39.052	-0.344	-0.037	-0.020	0.346	-0.020	Z
A-PILLAR Lateral (Y)	31	54.489	-29.314	23.230	54.801	-29.284	23.210	-0.312	0.031	-0.020	0.314	0.031	Y
	32	49.994	-28.678	26.214	50.291	-28.677	26.172	-0.297	0.001	-0.042	0.300	0.001	Y
	33	45.184	-27.897	29.055	46.370	-27.905	28.917	-1.186	-0.008	-0.139	1.195	-0.008	Y
	34	40.832	-27.247	31.186	41.127	-27.284	31.127	-0.295	-0.036	-0.059	0.303	-0.036	Y
B-PILLAR Lateral (Y)	35	13.498	-27.306	34.349	13.930	-27.276	34.473	-0.432	0.030	0.124	0.450	0.030	Y
	36	16.746	-29.379	30.418	17.079	-29.377	30.492	-0.333	0.002	0.074	0.342	0.002	Y
	37	14.282	-30.861	26.972	14.594	-30.884	27.005	-0.312	-0.023	0.034	0.314	-0.023	Y
	38	18.213	-31.944	23.428	18.523	-31.955	23.510	-0.310	-0.012	0.082	0.321	-0.012	Y
	39	15.080	-32.362	20.625	15.389	-32.387	20.664	-0.309	-0.025	0.039	0.312	-0.025	Y
	40	19.480	-32.366	17.329	19.808	-32.395	17.394	-0.327	-0.029	0.065	0.335	-0.029	Y
A-PILLAR Maximum (X, Y, Z)	31	54.489	-29.314	23.230	54.801	-29.284	23.210	-0.312	0.031	-0.020	0.314	0.031	Y
	32	49.994	-28.678	26.214	50.291	-28.677	26.172	-0.297	0.001	-0.042	0.300	0.001	Y
	33	45.184	-27.897	29.055	46.370	-27.905	28.917	-1.186	-0.008	-0.139	1.195	0.000	
	34	40.832	-27.247	31.186	41.127	-27.284	31.127	-0.295	-0.036	-0.059	0.303	0.000	
B-PILLAR Maximum (X, Y, Z)	35	13.498	-27.306	34.349	13.930	-27.276	34.473	-0.432	0.030	0.124	0.450	0.353	Y, Z
	36	16.746	-29.379	30.418	17.079	-29.377	30.492	-0.333	0.002	0.074	0.342	0.272	Y, Z
	37	14.282	-30.861	26.972	14.594	-30.884	27.005	-0.312	-0.023	0.034	0.314	0.183	Z
	38	18.213	-31.944	23.428	18.523	-31.955	23.510	-0.310	-0.012	0.082	0.321	0.286	Z
	39	15.080	-32.362	20.625	15.389	-32.387	20.664	-0.309	-0.025	0.039	0.312	0.197	Z
	40	19.480	-32.366	17.329	19.808	-32.395	17.394	-0.327	-0.029	0.065	0.335	0.255	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations.

Figure D-7. Occupant Compartment Deformation Data – Set 2 Left, Test No. MSPBN-4

Date: 4/18/2018 Test Name: MSPBN-4 VIN: KNADE223496469475
Year: 2009 Make: KIA Model: RIO

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2 right

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX [A] (in.)	ΔY [A] (in.)	ΔZ [A] (in.)	Total Δ (in.)	Crush [B] (in.)	Directions for Crush [C]
DASH (X, Y, Z)	1	49.595	-2.200	20.577	49.557	-2.254	20.865	0.038	-0.054	0.287	0.295	0.295	X, Y, Z
	2	49.279	5.441	20.390	49.226	5.434	20.689	0.053	0.007	0.299	0.304	0.304	X, Y, Z
	3	49.688	16.729	19.718	49.614	16.687	20.032	0.074	0.043	0.314	0.326	0.326	X, Y, Z
	4	44.425	-3.083	12.931	44.379	-3.028	13.279	0.045	0.055	0.348	0.355	0.355	X, Y, Z
	5	46.260	4.799	13.142	46.215	4.829	13.468	0.045	-0.029	0.326	0.330	0.330	X, Y, Z
	6	46.631	16.083	13.704	46.525	16.054	13.962	0.106	0.029	0.258	0.280	0.280	X, Y, Z
SIDE PANEL (Y)	7	53.472	22.727	-1.893	53.447	22.618	-1.552	0.025	0.109	0.342	0.359	0.109	Y
	8	57.671	22.829	-1.989	57.639	22.688	-1.712	0.032	0.142	0.277	0.313	0.142	Y
	9	54.652	22.653	2.033	54.560	22.524	2.457	0.091	0.129	0.424	0.452	0.129	Y
IMPACT SIDE DOOR (Y)	10	49.466	24.021	16.424	49.251	23.903	16.716	0.216	0.118	0.292	0.382	0.118	Y
	11	37.035	23.128	17.880	36.817	23.072	18.138	0.218	0.056	0.258	0.342	0.056	Y
	12	24.190	22.410	18.886	23.849	22.413	19.073	0.341	-0.003	0.188	0.389	-0.003	Y
	13	50.447	23.644	6.130	50.230	23.539	6.429	0.217	0.105	0.298	0.383	0.105	Y
	14	35.419	23.389	8.171	35.233	23.343	8.436	0.186	0.046	0.265	0.328	0.046	Y
	15	24.118	22.797	7.964	23.898	22.796	8.175	0.220	0.001	0.211	0.305	0.001	Y
ROOF - (Z)	16	35.027	-3.463	35.569	34.621	-3.575	34.933	0.406	-0.111	-0.636	0.762	-0.636	Z
	17	34.267	5.244	35.457	33.852	5.118	35.174	0.414	0.126	-0.282	0.517	-0.282	Z
	18	32.498	13.916	34.873	32.311	13.927	34.969	0.186	-0.011	0.097	0.210	0.097	Z
	19	30.137	-3.548	38.294	29.755	-3.661	38.216	0.382	-0.113	-0.078	0.406	-0.078	Z
	20	29.568	4.029	38.050	29.286	3.982	38.134	0.282	0.047	0.084	0.298	0.084	Z
	21	28.144	12.323	37.521	27.906	12.256	37.686	0.238	0.067	0.166	0.297	0.166	Z
	22	27.741	-3.859	38.727	27.456	-3.972	38.928	0.285	-0.114	0.201	0.367	0.201	Z
	23	27.777	1.109	38.544	27.544	0.937	38.676	0.232	0.172	0.133	0.318	0.133	Z
	24	27.570	5.874	38.271	27.343	5.822	38.396	0.228	0.053	0.124	0.265	0.124	Z
	25	26.921	11.451	37.834	26.717	11.351	37.990	0.204	0.100	0.156	0.275	0.156	Z
	26	24.846	-4.113	39.121	24.530	-4.288	39.231	0.316	-0.175	0.111	0.378	0.111	Z
	27	24.899	0.319	38.978	24.588	0.238	39.092	0.311	0.081	0.114	0.341	0.114	Z
	28	25.327	5.163	38.648	25.032	5.063	38.782	0.296	0.100	0.134	0.340	0.134	Z
	29	24.911	10.802	38.196	24.654	10.721	38.351	0.256	0.081	0.155	0.310	0.155	Z
	30	22.826	2.843	39.072	22.595	2.682	39.202	0.231	0.161	0.130	0.310	0.130	Z
A-PILLAR Lateral (Y)	31	52.721	21.839	21.788	52.654	21.790	22.218	0.067	0.050	0.431	0.439	0.050	Y
	32	47.960	20.585	25.654	47.857	20.567	25.987	0.103	0.018	0.333	0.349	0.018	Y
	33	43.548	19.460	28.184	43.323	19.405	28.599	0.225	0.055	0.415	0.475	0.055	Y
	34	39.079	18.286	30.626	38.946	18.264	30.914	0.133	0.022	0.288	0.318	0.022	Y
B-PILLAR Lateral (Y)	35	14.399	16.287	33.582	14.193	16.197	33.681	0.205	0.090	0.099	0.245	0.090	Y
	36	11.943	17.201	31.474	11.704	17.115	31.526	0.240	0.086	0.052	0.260	0.086	Y
	37	15.380	18.554	28.668	15.176	18.462	28.804	0.205	0.092	0.135	0.262	0.092	Y
	38	12.401	19.327	25.858	12.228	19.231	25.992	0.173	0.096	0.134	0.239	0.096	Y
	39	16.273	20.051	23.986	16.116	19.974	24.124	0.157	0.077	0.139	0.223	0.077	Y
	40	13.377	20.852	18.242	13.252	20.782	18.362	0.125	0.070	0.120	0.187	0.070	Y
A-PILLAR Maximum (X, Y, Z)	31	52.721	21.839	21.788	52.654	21.790	22.218	0.067	0.050	0.431	0.439	0.661	X, Y, Z
	32	47.960	20.585	25.654	47.857	20.567	25.987	0.103	0.018	0.333	0.349	0.587	X, Y, Z
	33	43.548	19.460	28.184	43.323	19.405	28.599	0.225	0.055	0.415	0.475	0.684	X, Y, Z
	34	39.079	18.286	30.626	38.946	18.264	30.914	0.133	0.022	0.288	0.318	0.554	X, Y, Z
B-PILLAR Maximum (X, Y, Z)	35	14.399	16.287	33.582	14.193	16.197	33.681	0.205	0.090	0.099	0.245	0.386	X, Y, Z
	36	11.943	17.201	31.474	11.704	17.115	31.526	0.240	0.086	0.052	0.260	0.342	X, Y, Z
	37	15.380	18.554	28.668	15.176	18.462	28.804	0.205	0.092	0.135	0.262	0.431	X, Y, Z
	38	12.401	19.327	25.858	12.228	19.231	25.992	0.173	0.096	0.134	0.239	0.416	X, Y, Z
	39	16.273	20.051	23.986	16.116	19.974	24.124	0.157	0.077	0.139	0.223	0.411	X, Y, Z
	40	13.377	20.852	18.242	13.252	20.782	18.362	0.125	0.070	0.120	0.187	0.374	X, Y, Z

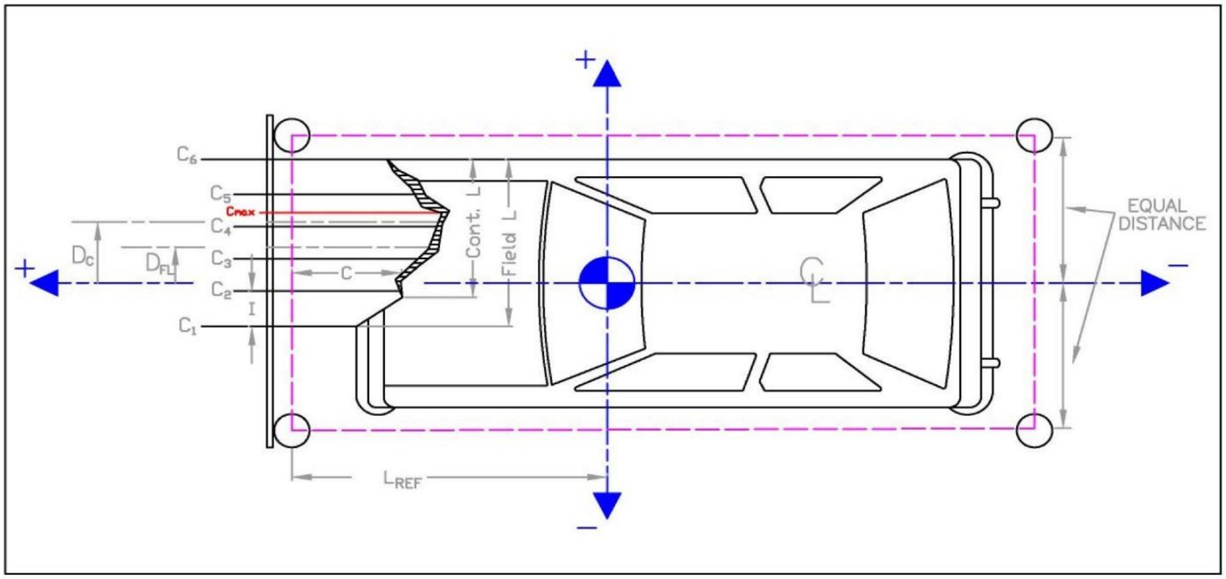
[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations.

Figure D-8. Occupant Compartment Deformation Data – Set 2 Right, Test No. MSPBN-4

Date:	4/23/2018	**Test Name:**	MSPBN-4	**VIN:**	KNADE223496469475
Year:	2009	**Make:**	KIA	**Model:**	RIO



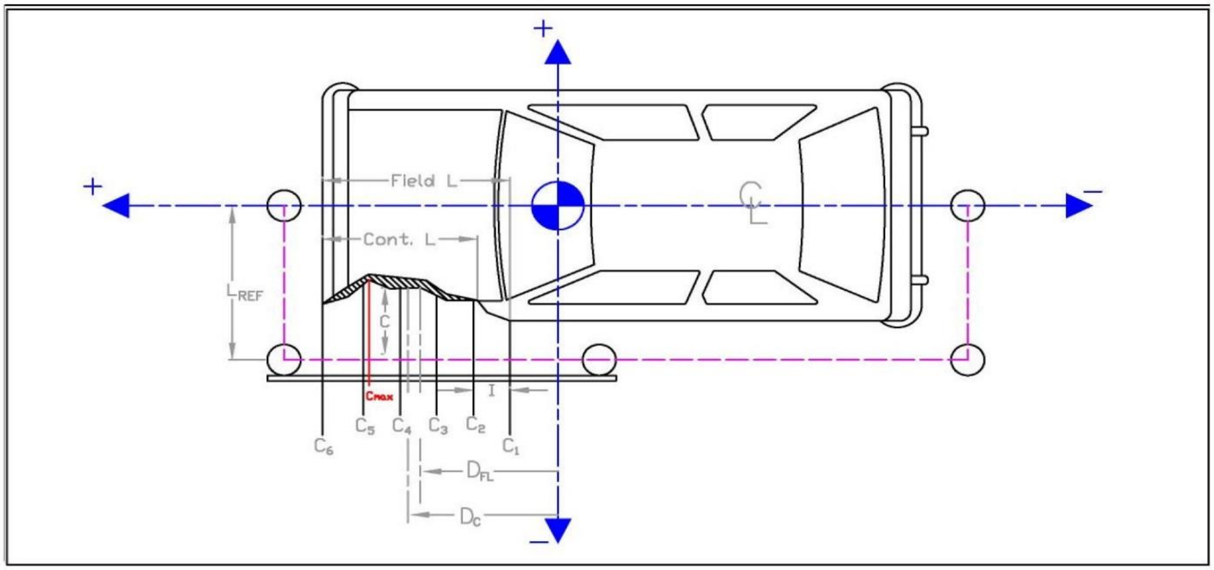
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	72 3/8	(1838)
Total Width of Vehicle:	64 7/8	(1648)
Width of contact and induced crush - Field L:	64 7/8	(1648)
Crush measurement spacing interval (L/5) - I:	13	(330)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	64 7/8	(1648)
Distance from center of vehicle to center of contact damage - D_C:	0	()

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	n/a	######	-32 1/2	-(826)	24	(610)	-3 1/8	-(79)	#VALUE!	#VALUE!
C_2	14 1/2	(368)	-19 1/2	-(495)	8 3/8	(213)			9 1/4	(235)
C_3	15 3/4	(400)	-6 1/2	-(165)	6 1/8	(156)			12 3/4	(324)
C_4	14 3/4	(375)	6 1/2	(165)	6 1/8	(156)			11 3/4	(298)
C_5	14 1/2	(368)	19 1/2	(495)	8 3/8	(213)			9 1/4	(235)
C_6	N/A	######	32 1/2	(826)	24	(610)			#VALUE!	#VALUE!
C_{MAX}	15 3/4	(400)	-6 1/2	-(165)	6 1/8	(156)			12 3/4	(324)

Figure D-9. Exterior Vehicle Crush (NASS) - Front, Test No. MSPBN-4

Date:	4/23/2018	Test Name:	MSPBN-4	VIN:	KNADE223496469475
Year:	2009	Make:	KIA	Model:	RIO



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	44	(1118)
Total Vehicle Length:	176 1/8	(4474)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-15 4/5	-(402)
Width of contact and induced crush - Field L:	176 1/8	(4474)
Crush measurement spacing interval (L/5) - I:	35 1/4	(895)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-31 4/5	-(808)
Width of Contact Damage:	176 1/8	(4474)
Distance from vehicle c.g. to center of contact damage - D_C:	-31 4/5	-(808)

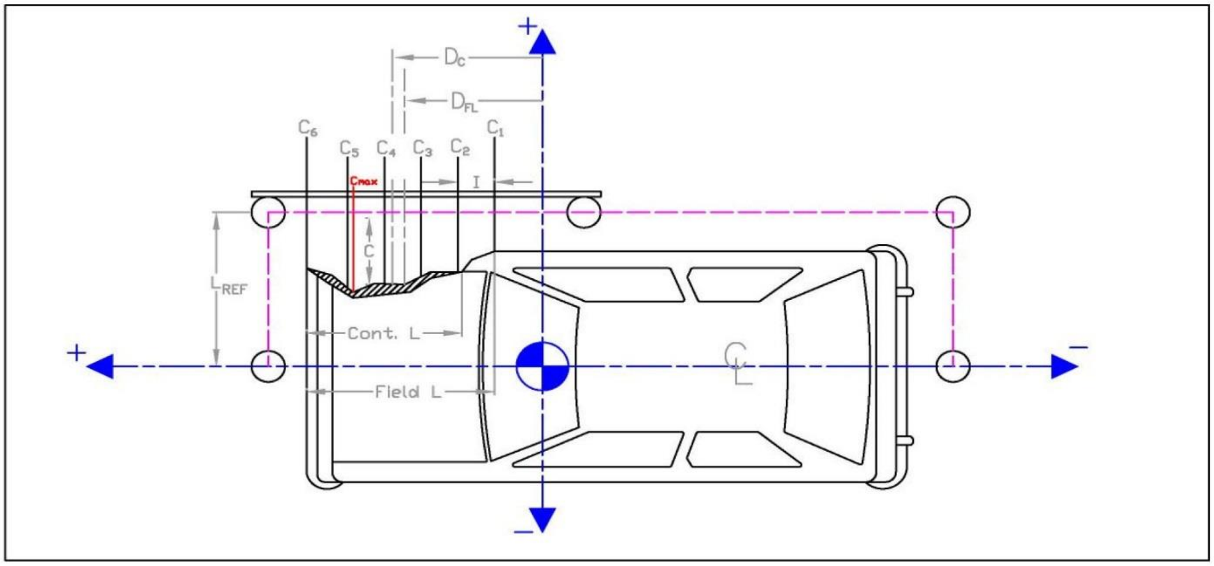
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/A	#VALUE!	-119 7/8	-(3045)	26	(660)	8	(203)	#VALUE!	#VALUE!
C_2	12 3/4	(324)	-84 5/8	-(2149)	5 1/2	(140)			- 3/4	-(19)
C_3	11	(279)	-49 3/8	-(1254)	4	(102)			-1	-(25)
C_4	10 3/4	(273)	-14 1/8	-(359)	3 5/8	(92)			- 7/8	-(22)
C_5	10 1/2	(267)	21 1/8	(537)	3 5/8	(92)			-1 1/8	-(29)
C_6	24	(610)	56 3/8	(1432)	5 3/8	(137)			10 5/8	(270)
C_{MAX}	24	(610)	56 3/8	(1432)	5 3/8	(137)			10 5/8	(270)

Figure D-10. Exterior Vehicle Crush (NASS) – Left Side, Test No. MSPBN-4

Date: 4/23/2018 Test Name: MSPBN-4 VIN: KNADE223496469475

Year: 2009 Make: KIA Model: RIO



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	50 1/2	(1283)
Total Vehicle Length:	176 1/8	(4474)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-15 4/5	-(402)
Width of contact and induced crush - Field L:	90	(2286)
Crush measurement spacing interval (L/5) - I:	18	(457)
Distance from vehicle c.g. to center of Field L - D_{FL}:	25 1/2	(648)
Width of Contact Damage:	53 1/2	(1359)
Distance from vehicle c.g. to center of contact damage - D_C:	42	(1067)

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	17 1/2	(445)	-19 1/2	-(495)	3 5/8	(92)	14 1/2	(368)	- 5/8	-(16)
C_2	17 3/4	(451)	-1 1/2	-(38)	3 3/4	(95)			- 1/2	-(13)
C_3	17 5/8	(448)	16 1/2	(419)	3 3/4	(95)			- 5/8	-(16)
C_4	23 3/8	(594)	34 1/2	(876)	3 1/4	(83)			5 5/8	(143)
C_5	23 1/2	(597)	52 1/2	(1334)	4 3/8	(111)			4 5/8	(117)
C_6	N/A	#VALUE!	70 1/2	(1791)	21 3/4	(552)			#VALUE!	#VALUE!
C_{MAX}	23 3/8	(594)	34 1/2	(876)	3 1/4	(83)			5 5/8	(143)

Figure D-11. Exterior Vehicle Crush (NASS) – Right Side, Test No. MSPBN-4

Date: 5/15/2018 Test Name: MSPBN-5 VIN: KMHCN46C39U386700
Year: 2009 Make: ACCENT Model: HYUNDAI

VEHICLE DEFORMATION
FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	63.3636	-1.4316	3.3773	63.2485	-1.3780	3.8805	0.1151	0.0536	0.5032	0.5190	0.5162	X, Z
	2	62.9156	-3.9758	3.2822	62.7905	-3.9849	3.7589	0.1251	-0.0091	0.4767	0.4929	0.4928	X, Z
	3	62.6106	-6.6326	3.4960	62.6073	-6.6124	3.8767	0.0033	0.0202	0.3807	0.3812	0.3807	X, Z
	4	62.4469	-9.3478	3.4216	62.3334	-9.3460	3.8480	0.1135	0.0018	0.4264	0.4413	0.4412	X, Z
	5	62.2193	-12.8374	3.3759	62.0906	-12.9103	3.7683	0.1287	-0.0729	0.3924	0.4194	0.4130	X, Z
	6	60.3870	-0.8993	5.2765	60.3633	-0.8664	5.7068	0.0237	0.0329	0.4303	0.4322	0.4310	X, Z
	7	59.8319	-3.6231	5.2174	59.7730	-3.6357	5.6584	0.0589	-0.0126	0.4410	0.4451	0.4449	X, Z
	8	59.3761	-6.2554	5.5378	59.2770	-6.2277	5.9686	0.0991	0.0277	0.4308	0.4429	0.4421	X, Z
	9	59.1345	-8.9663	5.4639	59.0524	-8.9755	5.8623	0.0821	-0.0092	0.3984	0.4069	0.4068	X, Z
	10	58.9030	-12.4804	5.4633	58.8154	-12.4384	5.8228	0.0876	0.0420	0.3595	0.3724	0.3700	X, Z
FLOOR PAN (Z)	11	56.5484	0.6292	6.3291	56.4122	0.6898	6.6580	0.1362	-0.0606	0.3289	0.3611	0.3289	Z
	12	55.6656	-3.6199	7.0385	55.6779	-3.7387	7.3864	-0.0123	-0.1188	0.3479	0.3678	0.3479	Z
	13	55.0864	-6.4663	7.1308	55.1029	-6.5374	7.4898	-0.0165	-0.0711	0.3590	0.3663	0.3590	Z
	14	54.7669	-9.8595	6.9772	54.7524	-9.9129	7.3424	0.0145	-0.0534	0.3652	0.3694	0.3652	Z
	15	54.6700	-13.4616	7.1791	54.5748	-13.5268	7.5182	0.0952	-0.0652	0.3391	0.3582	0.3391	Z
	16	51.3071	1.2902	6.3906	51.2895	1.2475	6.8383	0.0176	0.0427	0.4477	0.4501	0.4477	Z
	17	50.7121	-2.9968	7.8520	50.6248	-3.0084	7.4841	0.0873	-0.0116	-0.3679	0.3783	-0.3679	Z
	18	49.2547	-7.5246	7.4148	49.2030	-7.4924	7.7499	0.0517	0.0322	0.3351	0.3406	0.3351	Z
	19	49.1077	-10.5930	7.4063	49.0014	-10.5671	7.7297	0.1063	0.0259	0.3234	0.3414	0.3234	Z
	20	48.5413	-15.2206	7.9801	48.5611	-15.2874	8.2487	-0.0198	-0.0668	0.2686	0.2775	0.2686	Z
	21	43.8947	1.9579	6.5809	43.8267	1.9149	6.9865	0.0680	0.0430	0.4056	0.4135	0.4056	Z
	22	43.6526	-2.0817	8.2951	43.5817	-2.1155	8.1943	0.0709	-0.0338	-0.1008	0.1278	-0.1008	Z
	23	43.0635	-7.0700	7.6248	43.0470	-6.9824	7.9013	0.0165	0.0876	0.2765	0.2905	0.2765	Z
	24	43.0261	-10.2907	7.5878	42.9309	-10.2957	7.8663	0.0952	-0.0050	0.2785	0.2944	0.2785	Z
	25	42.8909	-14.6330	8.2417	42.8402	-14.6465	8.4887	0.0507	-0.0135	0.2470	0.2525	0.2470	Z
	26	39.3714	-1.8441	7.9707	39.2237	-1.8862	8.1402	0.1477	-0.0421	0.1695	0.2287	0.1695	Z
	27	39.0570	-6.8652	7.7352	39.0034	-6.8870	8.0055	0.0536	-0.0218	0.2703	0.2764	0.2703	Z
	28	38.6643	-11.0502	7.6838	38.5972	-11.1181	7.9200	0.0671	-0.0679	0.2362	0.2548	0.2362	Z
	29	35.0052	0.0835	4.3728	34.9609	0.1107	4.6548	0.0443	-0.0272	0.2820	0.2868	0.2820	Z
	30	34.0311	-11.0081	4.3007	34.0607	-10.9236	4.4978	-0.0296	0.0845	0.1971	0.2165	0.1971	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.
[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.
[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

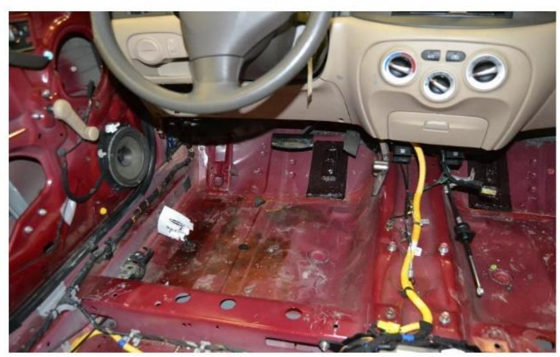
Pretest Floor Pan	Posttest Floor Pan
	

Figure D-12. Floor Pan Deformation Data – Set 1 Left, Test No. MSPBN-5

Date: 5/15/2018 Test Name: MSPBN-5 VIN: KMHCN46C39U386700
Year: 2009 Make: ACCENT Model: HYUNDAI

VEHICLE DEFORMATION
FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	62.1243	10.7857	4.7168	62.1230	10.5583	4.9238	0.0013	0.2274	0.2070	0.3075	0.2070	X, Z
	2	62.2558	14.5961	4.4961	62.2345	14.4405	4.6452	0.0213	0.1556	0.1491	0.2166	0.1506	X, Z
	3	62.8798	18.7988	4.5376	62.8433	18.6308	4.7135	0.0365	0.1680	0.1759	0.2460	0.1796	X, Z
	4	63.3257	22.3854	4.4091	63.2925	22.2334	4.6027	0.0332	0.1520	0.1936	0.2484	0.1964	X, Z
	5	63.0840	26.8467	3.0125	62.9368	26.7068	3.2514	0.1472	0.1399	0.2389	0.3135	0.2806	X, Z
	6	58.9163	10.6601	6.0149	58.9423	10.5251	6.2349	-0.0260	0.1350	0.2200	0.2594	0.2200	Z
	7	59.4618	14.6323	6.4888	59.4757	14.5531	6.6882	-0.0139	0.0792	0.1994	0.2150	0.1994	Z
	8	59.9013	18.8598	6.4054	59.8545	18.6728	6.6586	0.0468	0.1870	0.2532	0.3182	0.2575	X, Z
	9	60.7107	23.2277	6.1203	60.7181	23.1090	6.3547	-0.0074	0.1187	0.2344	0.2628	0.2344	Z
	10	61.7738	28.3283	5.5979	61.8070	28.2231	5.8266	-0.0332	0.1052	0.2287	0.2539	0.2287	Z
FLOOR PAN (Z)	11	55.6466	10.7602	5.9302	55.6774	10.6251	6.1462	-0.0308	0.1351	0.2160	0.2566	0.2160	Z
	12	56.3482	15.4330	7.1835	56.3276	15.3093	7.3914	0.0206	0.1237	0.2079	0.2428	0.2079	Z
	13	56.2901	18.6048	7.1837	56.3120	18.4073	7.4088	-0.0219	0.1975	0.2251	0.3003	0.2251	Z
	14	56.3397	22.8864	7.1749	56.3396	22.7688	7.3904	0.0001	0.1176	0.2155	0.2455	0.2155	Z
	15	56.8726	27.7616	7.1204	56.9275	27.6611	7.3149	-0.0549	0.1005	0.1945	0.2257	0.1945	Z
	16	53.0858	12.9033	7.5186	53.0923	12.8462	7.6605	-0.0065	0.0571	0.1419	0.1531	0.1419	Z
	17	53.1958	15.4499	7.5162	53.1454	15.2967	7.4523	0.0504	0.1532	-0.0639	0.1735	-0.0639	Z
	18	53.2696	18.6428	7.3168	53.2979	18.5465	7.5434	-0.0283	0.0963	0.2266	0.2478	0.2266	Z
	19	53.1922	22.8819	7.3195	53.2494	22.7968	7.5393	-0.0572	0.0851	0.2198	0.2425	0.2198	Z
	20	53.5438	28.7275	7.8042	53.5472	28.6651	8.0084	-0.0034	0.0624	0.2042	0.2135	0.2042	Z
	21	46.8695	13.3394	8.1148	46.9028	13.2661	8.2862	-0.0333	0.0733	0.1714	0.1894	0.1714	Z
	22	47.0390	16.8461	8.0642	47.0423	16.7140	8.1693	-0.0033	0.1321	0.1051	0.1688	0.1051	Z
	23	47.3934	20.7666	7.5931	47.4528	20.6221	7.8281	-0.0594	0.1445	0.2350	0.2822	0.2350	Z
	24	48.1245	24.7626	7.5159	48.2262	24.6779	7.7380	-0.1017	0.0847	0.2221	0.2585	0.2221	Z
	25	48.2789	29.8019	8.1661	48.4118	29.7653	8.3377	-0.1329	0.0366	0.1716	0.2201	0.1716	Z
	26	41.0036	13.8639	7.7944	41.0440	13.7900	8.0040	-0.0404	0.0739	0.2096	0.2259	0.2096	Z
	27	40.7227	16.9638	7.9343	40.7159	16.8901	8.1558	0.0068	0.0737	0.2215	0.2335	0.2215	Z
	28	40.9199	21.1181	7.7683	40.9858	21.0020	7.9910	-0.0659	0.1161	0.2227	0.2596	0.2227	Z
	29	41.0923	24.5704	7.7253	41.0935	24.4918	7.9452	-0.0012	0.0786	0.2199	0.2335	0.2199	Z
	30	41.1283	29.4703	7.9042	41.1273	29.4062	8.0942	0.0010	0.0641	0.1900	0.2005	0.1900	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Pretest Floor Pan

Posttest Floor Pan

Figure D-13. Floor Pan Deformation Data – Set 1 Right, Test No. MSPBN-5

Date: 5/15/2018 Test Name: MSPBN-5 VIN: KMHCN46C39U386700
Year: 2009 Make: ACCENT Model: HYUNDAI

VEHICLE DEFORMATION
FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	63.6832	-10.6615	2.5752	63.5700	-10.6143	2.8788	0.1132	0.0472	0.3036	0.3274	0.3240	X, Z
	2	63.5701	-13.2426	2.4847	63.4545	-13.2592	2.7698	0.1156	-0.0166	0.2851	0.3081	0.3076	X, Z
	3	63.6174	-15.9162	2.7013	63.6179	-15.8876	2.8958	-0.0005	0.0286	0.1945	0.1966	0.1945	Z
	4	63.8087	-18.6296	2.6278	63.7030	-18.6337	2.8770	0.1057	-0.0041	0.2492	0.2707	0.2707	X, Z
	5	64.0381	-22.1191	2.5836	63.9265	-22.1994	2.8083	0.1116	-0.0803	0.2247	0.2634	0.2509	X, Z
	6	60.6874	-10.5201	4.5130	60.6718	-10.4763	4.7505	0.0156	0.0438	0.2375	0.2420	0.2380	X, Z
	7	60.4920	-13.2931	4.4600	60.4475	-13.2992	4.7171	0.0445	-0.0061	0.2571	0.2610	0.2609	X, Z
	8	60.3879	-15.9619	4.7850	60.2993	-15.9325	5.0405	0.0886	0.0294	0.2555	0.2720	0.2704	X, Z
	9	60.5014	-18.6813	4.7131	60.4338	-18.6865	4.9432	0.0676	-0.0052	0.2301	0.2399	0.2398	X, Z
	10	60.7308	-22.1956	4.7140	60.6505	-22.1508	4.9145	0.0803	0.0448	0.2005	0.2206	0.2160	X, Z
FLOOR PAN (Z)	11	56.6960	-9.5044	5.6159	56.5668	-9.4454	5.7622	0.1292	0.0590	0.1463	0.2039	0.1463	Z
	12	56.3848	-13.8315	6.3349	56.4287	-13.9289	6.5112	-0.0439	-0.0974	0.1763	0.2061	0.1763	Z
	13	56.1835	-16.7291	6.4335	56.2258	-16.7783	6.6295	-0.0423	-0.0492	0.1960	0.2065	0.1960	Z
	14	56.3078	-20.1351	6.2826	56.3169	-20.1712	6.4945	-0.0091	-0.0361	0.2119	0.2151	0.2119	Z
	15	56.6846	-23.7188	6.4841	56.6156	-23.7766	6.6803	0.0690	-0.0578	0.1962	0.2159	0.1962	Z
	16	51.4145	-9.5334	5.7457	51.4186	-9.5605	6.0242	-0.0041	-0.0271	0.2785	0.2798	0.2785	Z
	17	51.4033	-13.8595	7.2129	51.3257	-13.8641	6.6890	0.0776	-0.0046	-0.5239	0.5296	-0.5239	Z
	18	50.5440	-18.5394	6.7926	50.5061	-18.4943	6.9867	0.0379	0.0451	0.1941	0.2028	0.1941	Z
	19	50.7989	-21.6007	6.7847	50.7075	-21.5690	6.9759	0.0914	0.0317	0.1912	0.2143	0.1912	Z
	20	50.8489	-26.2619	7.3639	50.8956	-26.3043	7.5113	-0.0467	-0.0424	0.1474	0.1603	0.1474	Z
	21	43.9815	-9.8389	6.0324	43.9357	-9.8727	6.2914	0.0458	-0.0338	0.2590	0.2652	0.2590	Z
	22	44.2911	-13.8733	7.7479	44.2383	-13.8956	7.5111	0.0528	-0.0223	-0.2368	0.2436	-0.2368	Z
	23	44.3497	-18.8967	7.0832	44.3393	-18.7918	7.2364	0.0104	0.1049	0.1532	0.1860	0.1532	Z
	24	44.7327	-22.0948	7.0452	44.6564	-22.0919	7.2099	0.0763	0.0029	0.1647	0.1815	0.1647	Z
	25	45.1740	-26.4167	7.6990	45.1445	-26.4148	7.8423	0.0295	0.0019	0.1433	0.1463	0.1433	Z
	26	40.0116	-14.1972	7.4791	39.8874	-14.2374	7.5269	0.1242	-0.0402	0.0478	0.1390	0.0478	Z
	27	40.3525	-19.2166	7.2456	40.3201	-19.2247	7.4057	0.0324	-0.0081	0.1601	0.1635	0.1601	Z
	28	40.5090	-23.4172	7.1974	40.4686	-23.4730	7.3352	0.0404	-0.0558	0.1378	0.1541	0.1378	Z
	29	35.3850	-12.8606	3.9390	35.3459	-12.8284	4.1067	0.0391	0.0322	0.1677	0.1752	0.1677	Z
	30	35.8666	-23.9846	3.8747	35.8923	-23.8863	3.9863	-0.0257	0.0983	0.1116	0.1509	0.1116	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Pretest Floor Pan	Posttest Floor Pan
	

Figure D-14. Floor Pan Deformation Data – Set 2 Left, Test No. MSPBN-5

Date: 5/15/2018 Test Name: MSPBN-5 VIN: KMHCN46C39U386700
Year: 2009 Make: ACCENT Model: HYUNDAI

VEHICLE DEFORMATION
FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	60.8980	1.2877	3.9175	60.8765	1.1209	4.1847	0.0215	0.1668	0.2672	0.3157	0.2681	X, Z
	2	60.5286	5.0822	3.6916	60.4747	4.9826	3.8887	0.0539	0.0996	0.1971	0.2273	0.2043	X, Z
	3	60.5997	9.3305	3.7211	60.5290	9.2169	3.9329	0.0707	0.1136	0.2118	0.2505	0.2233	X, Z
	4	60.5724	12.9442	3.5835	60.5004	12.8465	3.8021	0.0720	0.0977	0.2186	0.2500	0.2302	X, Z
	5	59.7333	17.3323	2.1861	59.5469	17.2271	2.4361	0.1864	0.1052	0.2500	0.3291	0.3118	X, Z
	6	57.7507	0.7484	5.2574	57.7413	0.6781	5.5306	0.0094	0.0703	0.2732	0.2823	0.2734	X, Z
	7	57.7794	4.7590	5.7205	57.7461	4.7437	5.9612	0.0333	0.0153	0.2407	0.2435	0.2430	X, Z
	8	57.6629	9.0075	5.6274	57.5807	8.8772	5.9103	0.0822	0.1303	0.2829	0.3221	0.2946	X, Z
	9	57.8921	13.4429	5.3279	57.8516	13.3867	5.5785	0.0405	0.0562	0.2506	0.2600	0.2539	X, Z
	10	58.2741	18.6372	4.7869	58.2545	18.5963	5.0172	0.0196	0.0409	0.2303	0.2347	0.2311	X, Z
FLOOR PAN (Z)	11	54.4950	0.4211	5.2150	54.4907	0.3485	5.4772	0.0043	0.0726	0.2622	0.2721	0.2622	Z
	12	54.5972	5.1487	6.4548	54.5335	5.0843	6.6956	0.0637	0.0644	0.2408	0.2573	0.2408	Z
	13	54.1259	8.2858	6.4529	54.1116	8.1535	6.7002	0.0143	0.1323	0.2473	0.2808	0.2473	Z
	14	53.6167	12.5374	6.4395	53.5665	12.4809	6.6634	0.0502	0.0565	0.2239	0.2363	0.2239	Z
	15	53.5086	17.4402	6.3736	53.5065	17.4074	6.5611	0.0021	0.0328	0.1875	0.1904	0.1875	Z
	16	51.6971	2.2161	6.8347	51.6523	2.2197	7.0104	0.0448	-0.0036	0.1757	0.1814	0.1757	Z
	17	51.4740	4.7553	6.8285	51.3812	4.6547	6.7914	0.0928	0.1006	-0.0371	0.1418	-0.0371	Z
	18	51.1282	7.9301	6.6252	51.1068	7.8969	6.8673	0.0214	0.0332	0.2421	0.2453	0.2421	Z
	19	50.4988	12.1228	6.6250	50.5011	12.1040	6.8459	-0.0023	0.0188	0.2209	0.2217	0.2209	Z
	20	50.0912	17.9656	7.0998	50.0309	17.9632	7.2873	0.0603	0.0024	0.1875	0.1970	0.1875	Z
	21	45.4852	1.8396	7.5113	45.4679	1.8275	7.7019	0.0173	0.0121	0.1906	0.1918	0.1906	Z
	22	45.1953	5.3383	7.4553	45.1526	5.2632	7.5692	0.0427	0.0751	0.1139	0.1430	0.1139	Z
	23	45.0293	9.2703	6.9760	45.0432	9.1895	7.2072	-0.0139	0.0808	0.2312	0.2453	0.2312	Z
	24	45.2320	13.3272	6.8857	45.2767	13.3111	7.0917	-0.0447	0.0161	0.2060	0.2114	0.2060	Z
	25	44.7363	18.3453	7.5291	44.7993	18.3821	7.6681	-0.0630	-0.0368	0.1390	0.1570	0.1390	Z
	26	39.5973	1.5940	7.2667	39.5885	1.5769	7.4816	0.0088	0.0171	0.2149	0.2158	0.2149	Z
	27	38.9163	4.6311	7.4074	38.8580	4.6079	7.6241	0.0583	0.0232	0.2167	0.2256	0.2167	Z
	28	38.5680	8.7752	7.2350	38.5843	8.7187	7.4392	-0.0163	0.0565	0.2042	0.2125	0.2042	Z
	29	38.2882	12.2204	7.1866	38.2326	12.1921	7.3777	0.0556	0.0283	0.1911	0.2010	0.1911	Z
	30	37.6871	17.0836	7.3606	37.6228	17.0693	7.5058	0.0643	0.0143	0.1452	0.1594	0.1452	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Pretest Floor Pan	Posttest Floor Pan
	

Figure D-15. Floor Pan Deformation Data – Set 2 Right, Test No. MSPBN-5

Date: 5/15/2018 Test Name: MSPBN-5 VIN: KMHCN46C39U386700
Year: 2009 Make: ACCENT Model: HYUNDAI

VEHICLE DEFORMATION
INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	46.6809	-16.4088	-20.2169	46.9536	-16.2635	-20.0020	-0.2727	0.1453	0.2149	0.3764	0.3764	X, Y, Z
	2	43.7276	-6.5327	-23.4971	44.1534	-6.3791	-23.3461	-0.4258	0.1536	0.1510	0.4772	0.4772	X, Y, Z
	3	46.9351	6.7684	-21.0460	47.3457	6.8483	-20.8334	-0.4106	-0.0799	0.2126	0.4692	0.4692	X, Y, Z
	4	46.0712	-15.0659	-9.8356	46.3205	-14.9556	-9.6547	-0.2493	0.1103	0.1809	0.3272	0.3272	X, Y, Z
	5	45.7634	-5.8947	-9.5143	46.0418	-5.8389	-9.3178	-0.2784	0.0558	0.1965	0.3453	0.3453	X, Y, Z
	6	44.0471	2.6396	-11.3530	44.3782	2.7060	-11.1919	-0.3311	-0.0664	0.1611	0.3742	0.3742	X, Y, Z
SIDE PANEL (Y)	7	50.7721	-21.4519	2.5288	50.9279	-21.3976	2.7922	-0.1558	0.0543	0.2634	0.3108	0.0543	Y
	8	55.3206	-21.5276	2.3953	55.4229	-21.5177	2.6255	-0.1023	0.0099	0.2302	0.2521	0.0099	Y
	9	51.0907	-20.6030	-1.1694	51.2057	-20.5409	-0.9858	-0.1150	0.0621	0.1836	0.2254	0.0621	Y
IMPACT SIDE DOOR (Y)	10	18.8110	-19.5184	-17.1996	19.1641	-19.1891	-17.1852	-0.3531	0.3293	0.0144	0.4830	0.3293	Y
	11	30.2899	-20.2639	-17.7167	30.6312	-19.9208	-17.6166	-0.3413	0.3431	0.1001	0.4942	0.3431	Y
	12	42.8463	-21.4470	-16.9201	43.1166	-21.1851	-16.6310	-0.2703	0.2619	0.2891	0.4746	0.2619	Y
	13	24.5066	-20.0665	0.0927	24.7194	-19.9431	0.2459	-0.2128	0.1234	0.1532	0.2898	0.1234	Y
	14	34.8662	-20.9489	0.8314	35.1204	-20.8181	1.0291	-0.2542	0.1308	0.1977	0.3476	0.1308	Y
	15	42.0574	-20.9691	0.4171	42.2718	-20.8602	0.6371	-0.2144	0.1089	0.2200	0.3259	0.1089	Y
ROOF - (Z)	16	28.7921	-10.6763	-35.8320	29.2537	-10.4281	-35.7408	-0.4616	0.2482	0.0912	0.5320	0.0912	Z
	17	29.3485	-7.7016	-36.0898	29.8183	-7.4776	-35.9862	-0.4698	0.2240	0.1036	0.5307	0.1036	Z
	18	29.8442	-4.7097	-36.3173	30.2898	-4.4773	-36.2196	-0.4456	0.2324	0.0977	0.5120	0.0977	Z
	19	30.3990	-1.5727	-36.4594	30.9496	-1.3999	-36.3104	-0.5506	0.1728	0.1490	0.5960	0.1490	Z
	20	30.8991	1.4655	-36.5260	31.3565	1.6629	-36.4110	-0.4574	-0.1974	0.1150	0.5113	0.1150	Z
	21	25.7003	-9.9967	-37.8372	26.1905	-9.7327	-37.7564	-0.4902	0.2640	0.0808	0.5626	0.0808	Z
	22	25.8455	-6.4160	-38.2147	26.2576	-6.2214	-38.1332	-0.4121	0.1946	0.0815	0.4630	0.0815	Z
	23	25.8483	-2.0401	-38.5853	26.3700	-1.7983	-38.4811	-0.5217	0.2418	0.1042	0.5844	0.1042	Z
	24	26.0472	0.7493	-38.7264	26.5343	1.0671	-38.6263	-0.4871	-0.3178	0.1001	0.5902	0.1001	Z
	25	26.3531	3.8002	-38.8166	26.8191	4.1114	-38.7127	-0.4660	-0.3112	0.1039	0.5699	0.1039	Z
	26	20.9483	-8.1065	-38.5722	21.4182	-7.7946	-38.5202	-0.4699	0.3119	0.0520	0.5664	0.0520	Z
	27	21.3952	-6.1147	-38.7339	21.8103	-5.8351	-38.6773	-0.4151	0.2796	0.0566	0.5037	0.0566	Z
	28	21.8082	-3.5602	-38.9185	22.2265	-3.3854	-38.8426	-0.4183	0.1748	0.0759	0.4597	0.0759	Z
	29	22.1943	-0.8909	-39.0711	22.5883	-0.6123	-38.9965	-0.3940	0.2786	0.0746	0.4883	0.0746	Z
	30	22.5194	2.1337	-39.1955	22.9616	2.4050	-39.1153	-0.4422	-0.2713	0.0802	0.5250	0.0802	Z
A-PILLAR Maximum (X, Y, Z)	31	34.9525	-14.9941	-32.7000	35.3147	-14.7899	-32.5289	-0.3622	0.2042	0.1711	0.4496	0.2664	Y, Z
	32	37.4672	-15.7477	-31.4818	37.9156	-15.5602	-31.3470	-0.4484	0.1875	0.1348	0.5044	0.2309	Y, Z
	33	40.6064	-16.7133	-29.8769	41.0534	-16.5450	-29.6950	-0.4470	0.1683	0.1819	0.5111	0.2478	Y, Z
	34	44.4412	-17.8832	-27.5583	44.8309	-17.7256	-27.3432	-0.3897	0.1576	0.2151	0.4722	0.2667	Y, Z
	35	47.6775	-18.8121	-25.5767	48.0193	-18.6599	-25.4122	-0.3418	0.1522	0.1645	0.4087	0.2241	Y, Z
	36	49.6240	-19.3547	-24.1425	49.9735	-19.2116	-24.0342	-0.3495	0.1431	0.1083	0.3929	0.1795	Y, Z
A-PILLAR Lateral (Y)	31	34.9525	-14.9941	-32.7000	35.3147	-14.7899	-32.5289	-0.3622	0.2042	0.1711	0.4496	0.2042	Y
	32	37.4672	-15.7477	-31.4818	37.9156	-15.5602	-31.3470	-0.4484	0.1875	0.1348	0.5044	0.1875	Y
	33	40.6064	-16.7133	-29.8769	41.0534	-16.5450	-29.6950	-0.4470	0.1683	0.1819	0.5111	0.1683	Y
	34	44.4412	-17.8832	-27.5583	44.8309	-17.7256	-27.3432	-0.3897	0.1576	0.2151	0.4722	0.1576	Y
	35	47.6775	-18.8121	-25.5767	48.0193	-18.6599	-25.4122	-0.3418	0.1522	0.1645	0.4087	0.1522	Y
	36	49.6240	-19.3547	-24.1425	49.9735	-19.2116	-24.0342	-0.3495	0.1431	0.1083	0.3929	0.1431	Y
B-PILLAR Maximum (X, Y, Z)	37	10.3413	-12.0019	-34.0940	10.7924	-11.6505	-34.1652	-0.4511	0.3514	-0.0712	0.5762	0.3514	Y
	38	10.7783	-16.5676	-24.3110	11.1305	-16.2352	-24.3456	-0.3522	0.3324	-0.0346	0.4855	0.3324	Y
	39	14.1844	-16.3478	-24.0521	14.4954	-16.0233	-24.0856	-0.3110	0.3245	-0.0335	0.4507	0.3245	Y
	40	13.2573	-17.7356	-17.8892	13.5966	-17.4344	-17.8606	-0.3393	0.3012	0.0286	0.4546	0.3026	Y, Z
B-PILLAR Lateral (Y)	37	10.3413	-12.0019	-34.0940	10.7924	-11.6505	-34.1652	-0.4511	0.3514	-0.0712	0.5762	0.3514	Y
	38	10.7783	-16.5676	-24.3110	11.1305	-16.2352	-24.3456	-0.3522	0.3324	-0.0346	0.4855	0.3324	Y
	39	14.1844	-16.3478	-24.0521	14.4954	-16.0233	-24.0856	-0.3110	0.3245	-0.0335	0.4507	0.3245	Y
	40	13.2573	-17.7356	-17.8892	13.5966	-17.4344	-17.8606	-0.3393	0.3012	0.0286	0.4546	0.3012	Y

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-16. Occupant Compartment Deformation Data – Set 1 Left, Test No. MSPBN-5

Date: 5/15/2018 Test Name: MSPBN-5 VIN: KMHCN46C39U386700
Year: 2009 Make: ACCENT Model: HYUNDAI

VEHICLE DEFORMATION
INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	50.5454	26.4606	-20.0208	50.7579	26.4000	-19.7827	-0.2125	0.0606	0.2381	0.3248	0.3248	X, Y, Z
	2	50.1575	21.3777	-20.0646	50.3695	21.3002	-19.8494	-0.2120	0.0775	0.2152	0.3119	0.3119	X, Y, Z
	3	49.2298	16.9589	-20.3628	49.4257	16.9178	-20.1470	-0.1959	0.0411	0.2158	0.2943	0.2943	X, Y, Z
	4	47.2207	17.4588	-14.3372	47.3309	17.4190	-14.1662	-0.1102	0.0398	0.1710	0.2073	0.2073	X, Y, Z
	5	48.1914	21.6922	-14.5650	48.3102	21.6487	-14.3507	-0.1188	0.0435	0.2143	0.2489	0.2489	X, Y, Z
	6	48.3498	27.1296	-14.4527	48.4764	27.0242	-14.2189	-0.1266	0.1054	0.2338	0.2860	0.2860	X, Y, Z
SIDE PANEL (Y)	7	59.9027	32.7462	2.9443	59.9557	32.5619	3.2496	-0.0530	0.1843	0.3053	0.3605	0.1843	Y
	8	55.8245	32.5715	-0.8112	55.8746	32.3426	-0.4569	-0.0501	0.2289	0.3543	0.4248	0.2289	Y
	9	55.5590	33.3389	3.0641	55.6067	33.1581	3.2893	-0.0477	0.1808	0.2252	0.2927	0.1808	Y
IMPACT SIDE DOOR (Y)	10	47.8250	34.8135	-16.3805	47.8741	34.6820	-16.1709	-0.0491	0.1315	0.2096	0.2523	0.1315	Y
	11	35.0671	36.0648	-16.4635	35.1555	36.0288	-16.2704	-0.0884	0.0360	0.1931	0.2154	0.0360	Y
	12	22.6626	36.9156	-16.3702	22.7721	36.9728	-16.2983	-0.1095	-0.0572	0.0719	0.1429	-0.0572	Y
	13	45.4022	35.0861	-2.1582	45.3931	34.8475	-1.9408	0.0091	0.2386	0.2174	0.3229	0.2386	Y
	14	36.5791	36.1277	-0.8878	36.6025	35.9458	-0.7204	-0.0234	0.1819	0.1674	0.2483	0.1819	Y
	15	27.5953	36.5448	-1.0099	27.6345	36.4410	-0.8501	-0.0392	0.1038	0.1598	0.1945	0.1038	Y
ROOF - (Z)	16	32.3481	26.7020	-35.6145	32.5910	26.6773	-35.5020	-0.2429	0.0247	0.1125	0.2688	0.1125	Z
	17	32.1700	22.2638	-36.1544	32.3925	22.2874	-36.0536	-0.2225	-0.0236	0.1008	0.2454	0.1008	Z
	18	32.1165	19.3473	-36.3181	32.3369	19.3702	-36.2170	-0.2204	-0.0229	0.1011	0.2436	0.1011	Z
	19	32.0939	16.0280	-36.4710	32.3813	16.0914	-36.3476	-0.2874	-0.0634	0.1234	0.3191	0.1234	Z
	20	32.0073	13.3309	-36.5564	32.2393	13.3784	-36.4592	-0.2320	-0.0475	0.0972	0.2560	0.0972	Z
	21	26.1086	24.9875	-38.2327	26.4819	25.0066	-38.1189	-0.3733	-0.0191	0.1138	0.3907	0.1138	Z
	22	26.4589	22.5795	-38.4001	26.6463	22.7098	-38.3011	-0.1874	-0.1303	0.0990	0.2488	0.0990	Z
	23	26.7863	19.8900	-38.5423	27.0285	19.9719	-38.4439	-0.2422	-0.0819	0.0984	0.2740	0.0984	Z
	24	27.2889	16.3487	-38.6490	27.6045	16.4189	-38.5422	-0.3156	-0.0702	0.1068	0.3405	0.1068	Z
	25	27.3592	13.8992	-38.7152	27.6122	13.9992	-38.6227	-0.2530	-0.1000	0.0925	0.2873	0.0925	Z
	26	22.4198	25.1003	-38.5942	22.6978	25.0974	-38.5101	-0.2780	0.0029	0.0841	0.2905	0.0841	Z
	27	22.4410	22.6872	-38.8079	22.6439	22.7784	-38.7240	-0.2029	-0.0912	0.0839	0.2377	0.0839	Z
	28	22.5067	19.8501	-39.0041	22.7615	19.8605	-38.9288	-0.2548	-0.0104	0.0753	0.2659	0.0753	Z
	29	22.4788	16.4401	-39.1856	22.7356	16.4390	-39.1162	-0.2568	0.0011	0.0694	0.2660	0.0694	Z
	30	22.5657	14.0904	-39.2590	22.7962	14.1657	-39.1856	-0.2305	-0.0753	0.0734	0.2534	0.0734	Z
A-PILLAR Maximum (X, Y, Z)	31	39.5441	29.8165	-32.4431	39.8696	29.8039	-32.2704	-0.3255	0.0126	0.1727	0.3687	0.1732	Y, Z
	32	42.5592	30.1834	-31.2372	42.7969	30.1595	-31.0887	-0.2377	0.0239	0.1485	0.2813	0.1504	Y, Z
	33	45.3951	30.5766	-29.5294	45.5797	30.5333	-29.3964	-0.1846	0.0433	0.1330	0.2316	0.1399	Y, Z
	34	49.0973	31.0691	-27.2607	49.3348	31.0208	-27.0091	-0.2375	0.0483	0.2516	0.3493	0.2562	Y, Z
	35	52.2534	31.4489	-25.3650	52.4350	31.3801	-25.1420	-0.1816	0.0688	0.2230	0.2957	0.2334	Y, Z
	36	54.1514	31.6760	-23.9872	54.3343	31.5919	-23.7719	-0.1829	0.0841	0.2153	0.2948	0.2311	Y, Z
A-PILLAR Lateral (Y)	31	39.5441	29.8165	-32.4431	39.8696	29.8039	-32.2704	-0.3255	0.0126	0.1727	0.3687	0.0126	Y
	32	42.5592	30.1834	-31.2372	42.7969	30.1595	-31.0887	-0.2377	0.0239	0.1485	0.2813	0.0239	Y
	33	45.3951	30.5766	-29.5294	45.5797	30.5333	-29.3964	-0.1846	0.0433	0.1330	0.2316	0.0433	Y
	34	49.0973	31.0691	-27.2607	49.3348	31.0208	-27.0091	-0.2375	0.0483	0.2516	0.3493	0.0483	Y
	35	52.2534	31.4489	-25.3650	52.4350	31.3801	-25.1420	-0.1816	0.0688	0.2230	0.2957	0.0688	Y
	36	54.1514	31.6760	-23.9872	54.3343	31.5919	-23.7719	-0.1829	0.0841	0.2153	0.2948	0.0841	Y
B-PILLAR Maximum (X, Y, Z)	37	16.3125	31.6733	-31.7541	16.5775	31.6963	-31.7002	-0.2650	-0.0230	0.0539	0.2714	0.0539	Z
	38	17.1137	32.7785	-29.2195	17.3169	32.8120	-29.1124	-0.2032	-0.0335	0.1071	0.2321	0.1071	Z
	39	17.9150	33.7770	-26.3301	18.2049	33.7966	-26.2405	-0.2899	-0.0196	0.0896	0.3041	0.0896	Z
	40	18.8613	34.5748	-23.1572	19.0387	34.6105	-23.0142	-0.1774	-0.0357	0.1430	0.2306	0.1430	Z
B-PILLAR Lateral (Y)	37	16.3125	31.6733	-31.7541	16.5775	31.6963	-31.7002	-0.2650	-0.0230	0.0539	0.2714	-0.0230	Y
	38	17.1137	32.7785	-29.2195	17.3169	32.8120	-29.1124	-0.2032	-0.0335	0.1071	0.2321	-0.0335	Y
	39	17.9150	33.7770	-26.3301	18.2049	33.7966	-26.2405	-0.2899	-0.0196	0.0896	0.3041	-0.0196	Y
	40	18.8613	34.5748	-23.1572	19.0387	34.6105	-23.0142	-0.1774	-0.0357	0.1430	0.2306	-0.0357	Y

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-17. Occupant Compartment Deformation Data – Set 1 Right, Test No. MSPBN-5

Date: 5/15/2018 Test Name: MSPBN-5 VIN: KMHCN46C39U386700
Year: 2009 Make: ACCENT Model: HYUNDAI

VEHICLE DEFORMATION
INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	49.0790	-27.5423	-20.6159	48.8717	-27.6729	-20.8480	0.2073	-0.1306	-0.2321	0.3375	0.3375	X, Y, Z
	2	44.8509	-18.1333	-23.8739	44.7229	-18.2755	-24.1951	0.1280	-0.1422	-0.3212	0.3739	0.3739	X, Y, Z
	3	46.3370	-4.5266	-21.4520	46.1997	-4.7193	-21.8464	0.1373	-0.1927	-0.3944	0.4599	0.4599	X, Y, Z
	4	48.3854	-26.2759	-10.2302	48.2959	-26.3584	-10.4982	0.0895	-0.0825	-0.2680	0.2943	0.2943	X, Y, Z
	5	46.9007	-17.2205	-9.9084	46.8268	-17.3546	-10.2174	0.0739	-0.1341	-0.3090	0.3449	0.3449	X, Y, Z
	6	44.0839	-8.9809	-11.7348	44.0125	-9.1213	-12.1118	0.0714	-0.1404	-0.3770	0.4086	0.4086	X, Y, Z
SIDE PANEL (Y)	7	53.9702	-31.9870	2.0966	53.9795	-32.0167	1.8846	-0.0093	-0.0297	-0.2120	0.2143	-0.0297	Y
	8	58.4892	-31.4761	1.9259	58.4465	-31.5464	1.6166	0.0427	-0.0703	-0.3093	0.3200	-0.0703	Y
	9	54.1467	-31.1088	-1.6043	54.0603	-31.1678	-1.9045	0.0864	-0.0590	-0.3002	0.3179	-0.0590	Y
IMPACT SIDE DOOR (Y)	10	21.8677	-34.2140	-17.3695	21.7768	-34.1987	-17.3802	0.0909	0.0153	-0.0107	0.0928	0.0153	Y
	11	33.3424	-33.4745	-17.9805	33.2284	-33.4207	-18.0672	0.1140	0.0538	-0.0867	0.1530	0.0538	Y
	12	45.9525	-33.0285	-17.2866	45.7899	-33.0230	-17.3570	0.1626	0.0055	-0.0704	0.1773	0.0055	Y
	13	27.7263	-34.0014	-0.1244	27.7587	-34.0453	-0.0752	-0.0324	-0.0439	0.0492	0.0735	-0.0439	Y
	14	38.1189	-33.5404	0.5296	38.1988	-33.5375	0.4774	-0.0799	0.0029	-0.0522	0.0955	0.0029	Y
	15	45.2491	-32.6341	0.0564	45.2833	-32.6430	-0.0768	-0.0342	-0.0089	-0.1332	0.1378	-0.0089	Y
ROOF - (Z)	16	30.4746	-24.1830	-36.0850	30.2214	-24.3692	-36.2199	0.2532	-0.1862	-0.1349	0.3420	-0.1349	Z
	17	30.6409	-21.1617	-36.3480	30.3872	-21.3727	-36.4984	0.2537	-0.2110	-0.1504	0.3626	-0.1504	Z
	18	30.7450	-18.1311	-36.5803	30.4544	-18.3389	-36.7630	0.2906	-0.2078	-0.1827	0.4013	-0.1827	Z
	19	30.8897	-14.9490	-36.7276	30.7012	-15.2025	-36.8898	0.1885	-0.2535	-0.1622	0.3551	-0.1622	Z
	20	30.9934	-11.8718	-36.7989	30.6991	-12.1139	-37.0206	0.2943	-0.2421	-0.2217	0.4409	-0.2217	Z
	21	27.3049	-23.9101	-38.0649	27.0504	-24.1023	-38.1702	0.2545	-0.1922	-0.1053	0.3359	-0.1053	Z
	22	26.9843	-20.3410	-38.4445	26.6465	-20.6165	-38.5724	0.3378	-0.2755	-0.1279	0.4543	-0.1279	Z
	23	26.4200	-16.0017	-38.8160	26.1680	-16.2207	-38.9531	0.2520	-0.2190	-0.1371	0.3609	-0.1371	Z
	24	26.2566	-13.2101	-38.9594	25.9505	-13.3601	-39.1216	0.3061	-0.1500	-0.1622	0.3775	-0.1622	Z
	25	26.1660	-10.1454	-39.0527	25.8301	-10.3058	-39.2353	0.3359	-0.1604	-0.1826	0.4146	-0.1826	Z
	26	22.3431	-22.6490	-38.7615	22.0492	-22.8160	-38.8385	0.2939	-0.1670	-0.0770	0.3467	-0.0770	Z
	27	22.5282	-20.6164	-38.9272	22.1764	-20.8236	-39.0179	0.3518	-0.2072	-0.0907	0.4182	-0.0907	Z
	28	22.6070	-18.0302	-39.1158	22.2627	-18.3422	-39.2094	0.3443	-0.3120	-0.0936	0.4740	-0.0936	Z
	29	22.6446	-15.3337	-39.2720	22.2529	-15.5472	-39.3906	0.3917	-0.2135	-0.1186	0.4616	-0.1186	Z
	30	22.5762	-12.2925	-39.3998	22.2231	-12.5083	-39.5384	0.3531	-0.2158	-0.1386	0.4364	-0.1386	Z
A-PILLAR Maximum (X, Y, Z)	31	37.1653	-27.6668	-33.0027	36.8719	-27.8648	-33.1169	0.2934	-0.1980	-0.1142	0.3719	0.2934	X
	32	39.7660	-28.0885	-31.8050	39.5765	-28.2749	-31.9892	0.1895	-0.1864	-0.1842	0.3234	0.1895	X
	33	43.0163	-28.6393	-30.2256	42.8516	-28.8224	-30.4021	0.1647	-0.1831	-0.1765	0.3030	0.1647	X
	34	46.9886	-29.3023	-27.9383	46.8017	-29.4731	-28.1288	0.1869	-0.1708	-0.1905	0.3169	0.1869	X
	35	50.3335	-29.8038	-25.9832	50.1263	-29.9612	-26.2644	0.2072	-0.1574	-0.2812	0.3831	0.2072	X
	36	52.3453	-30.0893	-24.5648	52.1655	-30.2377	-24.9275	0.1798	-0.1484	-0.3627	0.4312	0.1798	X
A-PILLAR Lateral (Y)	31	37.1653	-27.6668	-33.0027	36.8719	-27.8648	-33.1169	0.2934	-0.1980	-0.1142	0.3719	-0.1980	Y
	32	39.7660	-28.0885	-31.8050	39.5765	-28.2749	-31.9892	0.1895	-0.1864	-0.1842	0.3234	-0.1864	Y
	33	43.0163	-28.6393	-30.2256	42.8516	-28.8224	-30.4021	0.1647	-0.1831	-0.1765	0.3030	-0.1831	Y
	34	46.9886	-29.3023	-27.9383	46.8017	-29.4731	-28.1288	0.1869	-0.1708	-0.1905	0.3169	-0.1708	Y
	35	50.3335	-29.8038	-25.9832	50.1263	-29.9612	-26.2644	0.2072	-0.1574	-0.2812	0.3831	-0.1574	Y
	36	52.3453	-30.0893	-24.5648	52.1655	-30.2377	-24.9275	0.1798	-0.1484	-0.3627	0.4312	-0.1484	Y
B-PILLAR Maximum (X, Y, Z)	37	12.3632	-27.8733	-34.1955	12.1201	-27.9925	-34.2168	0.2431	-0.1192	-0.0213	0.2716	0.2431	X
	38	13.4643	-32.3321	-24.4154	13.2712	-32.3968	-24.3763	0.1931	-0.0647	0.0391	0.2074	0.1970	X, Z
	39	16.8157	-31.6749	-24.1846	16.5837	-31.7418	-24.1942	0.2320	-0.0669	-0.0096	0.2416	0.2320	X
	40	16.1251	-33.1627	-18.0139	15.9512	-33.1972	-17.9874	0.1739	-0.0345	0.0265	0.1793	0.1759	X, Z
B-PILLAR Lateral (Y)	37	12.3632	-27.8733	-34.1955	12.1201	-27.9925	-34.2168	0.2431	-0.1192	-0.0213	0.2716	-0.1192	Y
	38	13.4643	-32.3321	-24.4154	13.2712	-32.3968	-24.3763	0.1931	-0.0647	0.0391	0.2074	-0.0647	Y
	39	16.8157	-31.6749	-24.1846	16.5837	-31.7418	-24.1942	0.2320	-0.0669	-0.0096	0.2416	-0.0669	Y
	40	16.1251	-33.1627	-18.0139	15.9512	-33.1972	-17.9874	0.1739	-0.0345	0.0265	0.1793	-0.0345	Y

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-18. Occupant Compartment Deformation Data – Set 2 Left, Test No. MSPBN-5

Date: 5/15/2018 Test Name: MSPBN-5 VIN: KMHCN46C39U386700

Year: 2009 Make: ACCENT Model: HYUNDAI

VEHICLE DEFORMATION
INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	47.1023	15.2712	-20.5394	47.1968	15.2498	-20.5668	-0.0945	0.0214	-0.0274	0.1007	0.1007	X, Y, Z
	2	47.3795	10.1810	-20.5788	47.4827	10.1430	-20.6171	-0.1032	0.0380	-0.0383	0.1165	0.1165	X, Y, Z
	3	47.0325	5.6786	-20.8673	47.1204	5.6733	-20.8919	-0.0879	0.0053	-0.0246	0.0914	0.0914	X, Y, Z
	4	45.0364	5.9208	-14.8216	45.0601	5.9182	-14.8832	-0.0237	0.0026	-0.0616	0.0661	0.0661	X, Y, Z
	5	45.4449	10.2443	-15.0595	45.4711	10.2393	-15.0907	-0.0262	0.0050	-0.0312	0.0410	0.0410	X, Y, Z
	6	44.8946	15.6562	-14.9492	44.9295	15.5903	-14.9727	-0.0349	0.0659	-0.0235	0.0782	0.0782	X, Y, Z
SIDE PANEL (Y)	7	55.7923	22.7544	2.3287	55.8179	22.6611	2.3200	-0.0256	0.0933	-0.0087	0.0971	0.0933	Y
	8	51.7339	22.0446	-1.3850	51.7508	21.8915	-1.3281	-0.0169	0.1531	0.0569	0.1642	0.1531	Y
	9	51.4099	22.7763	2.4927	51.4292	22.6796	2.4198	-0.0193	0.0967	-0.0729	0.1226	0.0967	Y
IMPACT SIDE DOOR (Y)	10	43.3536	23.2035	-16.8721	43.2970	23.0943	-16.9325	0.0566	0.1092	-0.0604	0.1370	0.1092	Y
	11	30.5413	22.7818	-16.8251	30.5117	22.7541	-16.8552	0.0296	0.0277	-0.0301	0.0505	0.0277	Y
	12	18.1332	22.0094	-16.6054	18.1127	22.0591	-16.7103	0.0205	-0.0497	-0.1049	0.1179	-0.0497	Y
	13	41.0598	23.1780	-2.6259	41.0113	22.9884	-2.6691	0.0485	0.1896	-0.0432	0.2004	0.1896	Y
	14	32.1894	23.0630	-1.2657	32.1702	22.9244	-1.3271	0.0192	0.1386	-0.0614	0.1528	0.1386	Y
	15	23.2272	22.3058	-1.2961	23.2141	22.2339	-1.3312	0.0131	0.0719	-0.0351	0.0811	0.0719	Y
ROOF - (Z)	16	28.8721	13.1178	-35.9468	28.9378	13.0696	-36.0285	-0.0657	0.0482	-0.0817	0.1154	-0.0817	Z
	17	29.2684	8.6936	-36.4845	29.3117	8.6896	-36.5678	-0.0433	0.0040	-0.0833	0.0940	-0.0833	Z
	18	29.5936	5.7947	-36.6474	29.6386	5.7899	-36.7242	-0.0450	0.0048	-0.0768	0.0891	-0.0768	Z
	19	30.0022	2.5005	-36.7999	30.1127	2.5450	-36.8483	-0.1105	-0.0445	-0.0484	0.1286	-0.0484	Z
	20	30.2668	-0.1850	-36.8843	30.3278	-0.1635	-36.9520	-0.0610	0.0215	-0.0677	0.0936	-0.0677	Z
	21	22.8831	10.6014	-38.5011	23.0667	10.5986	-38.5553	-0.1836	0.0028	-0.0542	0.1915	-0.0542	Z
	22	23.5424	8.2593	-38.6718	23.5297	8.3427	-38.7349	0.0127	-0.0834	-0.0631	0.1053	-0.0631	Z
	23	24.2160	5.6353	-38.8172	24.2672	5.6785	-38.8771	-0.0512	-0.0432	-0.0599	0.0899	-0.0599	Z
	24	25.1746	2.1894	-38.9288	25.3047	2.2318	-38.9759	-0.1301	-0.0424	-0.0471	0.1447	-0.0471	Z
	25	25.5628	-0.2301	-38.9955	25.6300	-0.1660	-39.0513	-0.0672	0.0641	-0.0558	0.1083	-0.0558	Z
	26	19.2076	10.2321	-38.8249	19.2985	10.1887	-38.8932	-0.0909	0.0434	-0.0683	0.1217	-0.0683	Z
	27	19.5408	7.8420	-39.0387	19.5477	7.8820	-39.1013	-0.0069	-0.0400	-0.0626	0.0746	-0.0626	Z
	28	19.9737	5.0374	-39.2354	20.0458	5.0042	-39.3014	-0.0721	0.0332	-0.0660	0.1032	-0.0660	Z
	29	20.3885	1.6526	-39.4164	20.4682	1.6084	-39.4811	-0.0797	0.0442	-0.0647	0.1118	-0.0647	Z
	30	20.7801	-0.6658	-39.4904	20.8268	-0.6374	-39.5465	-0.0467	0.0284	-0.0561	0.0783	-0.0561	Z
A-PILLAR Maximum (X, Y, Z)	31	35.6326	17.1478	-32.8491	35.7847	17.1403	-32.9068	-0.1521	0.0075	-0.0577	0.1628	0.0075	Y
	32	38.5863	17.9061	-31.6741	38.6556	17.8830	-31.7673	-0.0693	0.0231	-0.0932	0.1184	0.0231	Y
	33	41.3639	18.6678	-29.9953	41.3878	18.6267	-30.1153	-0.0239	0.0411	-0.1200	0.1291	0.0411	Y
	34	44.9931	19.6416	-27.7645	45.0785	19.6141	-27.7824	-0.0854	0.0275	-0.0179	0.0915	0.0275	Y
	35	48.0917	20.4320	-25.9011	48.1296	20.3859	-25.9600	-0.0379	0.0461	-0.0589	0.0839	0.0461	Y
	36	49.9578	20.9064	-24.5427	50.0031	20.8514	-24.6173	-0.0453	0.0550	-0.0746	0.1032	0.0550	Y
A-PILLAR Lateral (Y)	31	35.6326	17.1478	-32.8491	35.7847	17.1403	-32.9068	-0.1521	0.0075	-0.0577	0.1628	0.0075	Y
	32	38.5863	17.9061	-31.6741	38.6556	17.8830	-31.7673	-0.0693	0.0231	-0.0932	0.1184	0.0231	Y
	33	41.3639	18.6678	-29.9953	41.3878	18.6267	-30.1153	-0.0239	0.0411	-0.1200	0.1291	0.0411	Y
	34	44.9931	19.6416	-27.7645	45.0785	19.6141	-27.7824	-0.0854	0.0275	-0.0179	0.0915	0.0275	Y
	35	48.0917	20.4320	-25.9011	48.1296	20.3859	-25.9600	-0.0379	0.0461	-0.0589	0.0839	0.0461	Y
	36	49.9578	20.9064	-24.5427	50.0031	20.8514	-24.6173	-0.0453	0.0550	-0.0746	0.1032	0.0550	Y
B-PILLAR Maximum (X, Y, Z)	37	12.3653	15.9629	-31.9234	12.4564	15.9513	-32.0117	-0.0911	0.0116	-0.0883	0.1274	0.0116	Y
	38	13.0412	17.1666	-29.3972	13.0777	17.1650	-29.4370	-0.0365	0.0016	-0.0398	0.0540	0.0016	Y
	39	13.7347	18.2651	-26.5161	13.8676	18.2694	-26.5800	-0.1329	-0.0043	-0.0639	0.1475	0.0000	NA
	40	14.6011	19.1838	-23.3531	14.6167	19.1767	-23.3469	-0.0156	0.0071	0.0062	0.0182	0.0094	Y, Z
B-PILLAR Lateral (Y)	37	12.3653	15.9629	-31.9234	12.4564	15.9513	-32.0117	-0.0911	0.0116	-0.0883	0.1274	0.0116	Y
	38	13.0412	17.1666	-29.3972	13.0777	17.1650	-29.4370	-0.0365	0.0016	-0.0398	0.0540	0.0016	Y
	39	13.7347	18.2651	-26.5161	13.8676	18.2694	-26.5800	-0.1329	-0.0043	-0.0639	0.1475	-0.0043	Y
	40	14.6011	19.1838	-23.3531	14.6167	19.1767	-23.3469	-0.0156	0.0071	0.0062	0.0182	0.0071	Y

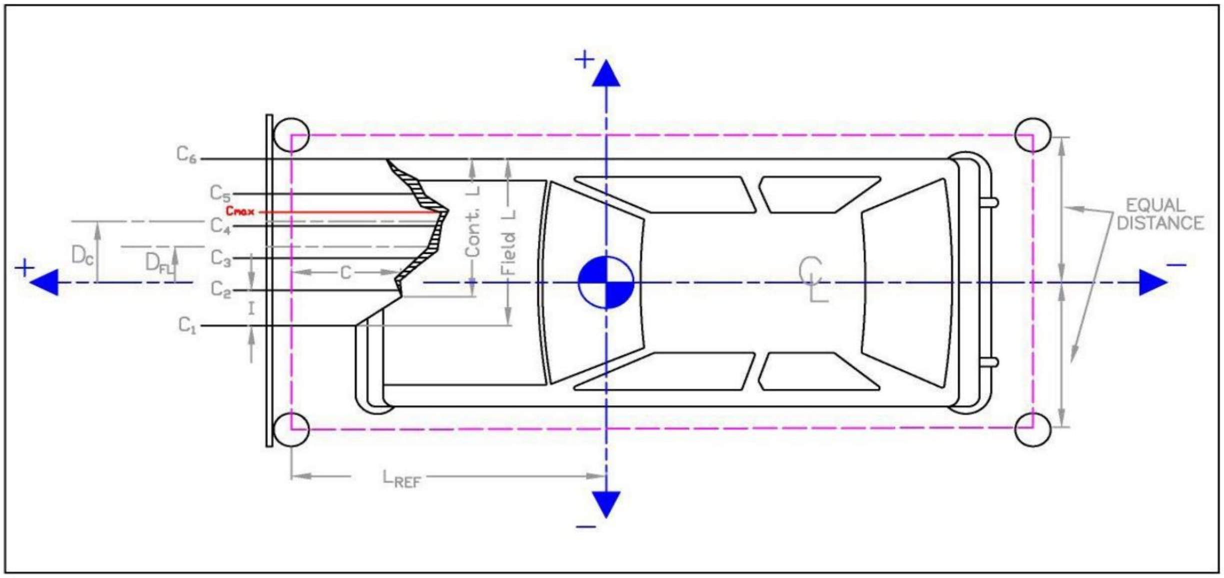
[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-19. Occupant Compartment Deformation Data – Set 2 Right, Test No. MSPBN-5

Date:	5/16/2018	Test Name:	MSPBN-5	VIN:	KMHCN46C39U386700
Year:	2009	Make:	ACCENT	Model:	HYUNDAI



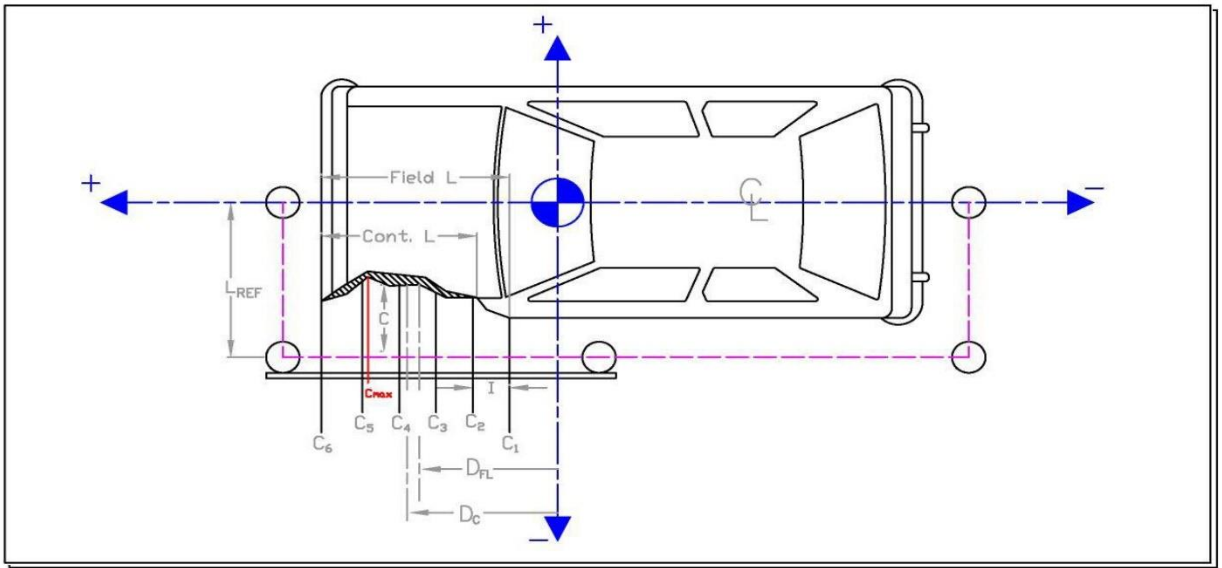
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	79 3/4	(2026)
Total Width of Vehicle:	64 7/8	(1648)
Width of contact and induced crush - Field L:	64 7/8	(1648)
Crush measurement spacing interval (L/5) - I:	13	(330)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	64 7/8	(1648)
Distance from center of vehicle to center of contact damage - D_C:	0	()

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/A	######	-32 1/2	-(826)	24	(610)	4 5/8	(117)	#VALUE!	#VALUE!
C_2	14	(356)	-19 1/2	-(495)	8 3/8	(213)			1	(25)
C_3	21 7/8	(556)	-6 1/2	-(165)	6 1/8	(156)			11 1/8	(283)
C_4	19	(483)	6 1/2	(165)	6 1/8	(156)			8 1/4	(210)
C_5	16 7/8	(429)	19 1/2	(495)	8 3/8	(213)			3 7/8	(98)
C_6	N/A	######	32 1/2	(826)	24	(610)			#VALUE!	#VALUE!
C_{MAX}	21 7/8	(556)	19 1/2	(495)	8 3/8	(213)			8 7/8	(225)

Figure D-20. Exterior Vehicle Crush (NASS) - Front, Test No. MSPBN-5

Date:	5/16/2018	**Test Name:**	MSPBN-5	**VIN:**	KMHCN46C39U386700
Year:	2009	**Make:**	ACCENT	**Model:**	HYUNDAI



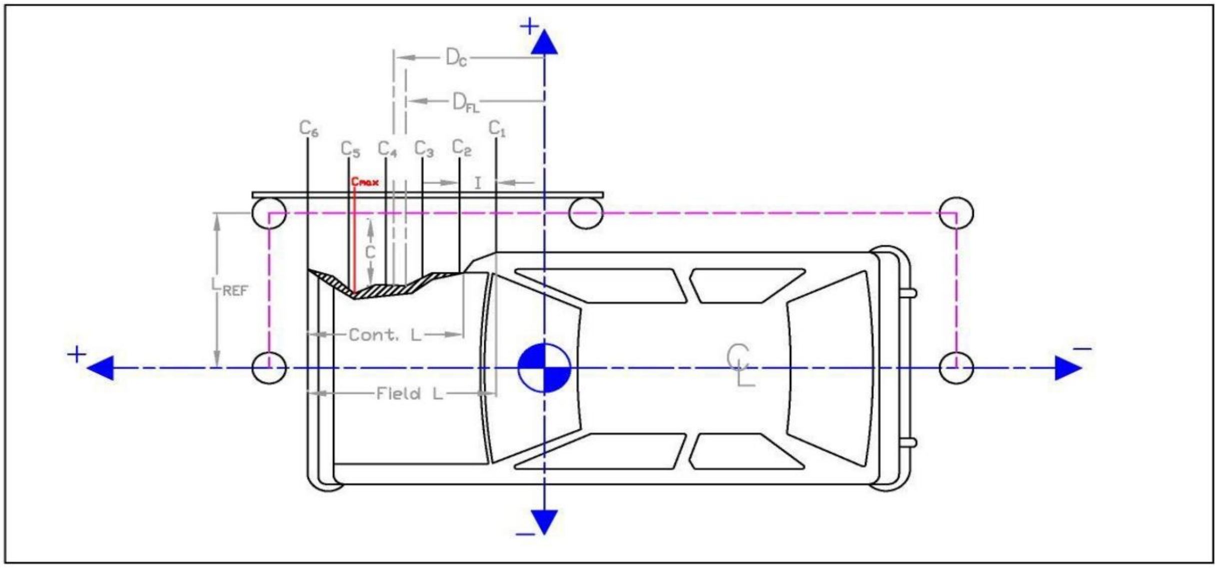
	in.	(mm)
Distance from centerline to reference line - L_{REF}:	47 3/4	(1213)
Total Vehicle Length:	164 4/5	(4186)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-10 2/3	-(271)
Width of contact and induced crush - Field L:	107	(2718)
Crush measurement spacing interval (L/5) - I:	21 3/8	(543)
Distance from vehicle c.g. to center of Field L - D_{FL}:	13 1/8	(333)
Width of Contact Damage:	107	(2718)
Distance from vehicle c.g. to center of contact damage - D_C:	13 1/8	(333)

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	15 7/8	(403)	-40 3/8	-(1026)	3 5/8	(92)	11 3/4	(298)	1/2	(13)
C_2	14 7/8	(378)	-19	-(483)	3 5/8	(92)			- 1/2	-(13)
C_3	15	(379)	2 3/8	(60)	3 3/4	(95)			- 4/7	-(14)
C_4	12 3/4	(324)	23 3/4	(603)	3 1/4	(83)			-2 1/4	-(57)
C_5	16	(406)	45 1/8	(1146)	3 1/4	(83)			1	(25)
C_6	n/a	#VALUE!	66 1/2	(1689)	20 1/4	(514)			#VALUE!	#VALUE!
C_{MAX}	26 3/4	(679)	59	(1499)	7 1/8	(181)			7 7/8	(200)

Figure D-21. Exterior Vehicle Crush (NASS) – Left Side, Test No. MSPBN-5

Date:	5/16/2018	Test Name:	MSPBN-5	VIN:	KMHCN46C39U386700
Year:	2009	Make:	ACCENT	Model:	HYUNDAI



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	43 1/5	(1097)
Total Vehicle Length:	164 4/5	(4186)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-10 2/3	-(271)
Width of contact and induced crush - Field L:	64	(1626)
Crush measurement spacing interval (L/5) - I:	12 3/4	(324)
Distance from vehicle c.g. to center of Field L - D_{FL}:	36	(914)
Width of Contact Damage:	64	(1626)
Distance from vehicle c.g. to center of contact damage - D_C:	36	(914)

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)

NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	10 1/4	(260)	4	(102)	3 3/4	(95)	7 1/5	(183)	- 2/3	-(17)
C_2	11 1/8	(283)	16 3/4	(425)	3 3/4	(95)			1/5	(5)
C_3	n/a	#VALUE!	29 1/2	(749)	3 1/4	(83)			#VALUE!	#VALUE!
C_4	16 1/2	(419)	42 1/4	(1073)	3 1/4	(83)			6	(154)
C_5	22 1/2	(572)	55	(1397)	5 1/2	(140)			9 4/5	(249)
C_6	n/a	#VALUE!	67 3/4	(1721)	21 3/4	(552)			#VALUE!	#VALUE!
C_{MAX}	22 1/2	(572)	55	(1397)	5 1/2	(140)			9 4/5	(249)

Figure D-22. Exterior Vehicle Crush (NASS) – Right Side, Test No. MSPBN-5

Date:	6/5/2018	Test Name:	MSPBN-6	VIN:	1C6RD6KT3CS268370
Year:	2012	Make:	Dodge	Model:	Ram 1500

VEHICLE DEFORMATION
FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	62.8023	-23.4119	-1.9933	62.8655	-23.1384	-1.9779	-0.0632	0.2735	-0.0154	0.2811	0.0000	NA
	2	63.7393	-20.5724	-0.6174	63.7763	-20.3287	-0.6065	-0.0370	0.2437	-0.0109	0.2467	0.0000	NA
	3	63.9464	-17.9997	0.0051	64.0283	-17.6811	0.0368	-0.0819	0.3186	-0.0317	0.3305	0.0000	NA
	4	63.7434	-13.7516	0.1440	63.7380	-13.4439	0.2163	0.0054	0.3077	-0.0723	0.3161	0.0054	X
	5	63.3149	-11.1714	0.1738	63.3747	-11.0230	0.2749	-0.0598	0.1484	-0.1011	0.1893	0.0000	NA
	6	62.0472	-8.2613	-0.4376	62.0478	-7.9498	-0.3350	-0.0006	0.3115	-0.1026	0.3280	0.0000	NA
	7	60.0160	-24.6843	1.7317	60.1251	-24.3627	1.7405	-0.1091	0.3216	-0.0088	0.3397	0.0000	NA
	8	60.2405	-20.9468	1.6884	60.2996	-20.6655	1.7321	-0.0591	0.2813	-0.0437	0.2907	0.0000	NA
	9	60.2598	-17.2400	1.7072	60.2974	-16.8272	1.7540	-0.0376	0.4128	-0.0468	0.4171	0.0000	NA
	10	60.3181	-14.0548	1.7087	60.3100	-13.6331	1.7801	0.0081	0.4217	-0.0714	0.4278	0.0081	X
FLOOR PAN (Z)	11	60.3491	-11.0356	1.7342	60.5688	-10.6294	1.6773	-0.2197	0.4062	0.0569	0.4653	0.0569	Z
	12	57.0316	-24.6008	3.3662	57.0913	-24.3712	3.4011	-0.0597	0.2296	-0.0349	0.2398	-0.0349	Z
	13	57.1241	-20.0946	3.3458	57.1972	-19.8090	3.3672	-0.0731	0.2856	-0.0214	0.2956	-0.0214	Z
	14	57.1651	-15.7897	3.3624	57.2320	-15.4949	3.3886	-0.0669	0.2948	-0.0262	0.3034	-0.0262	Z
	15	57.2484	-13.4997	3.3501	57.3015	-13.2282	3.3823	-0.0531	0.2715	-0.0322	0.2785	-0.0322	Z
	16	57.2445	-11.2750	3.3751	57.2822	-10.9456	3.4107	-0.0377	0.3294	-0.0356	0.3335	-0.0356	Z
	17	57.2861	-9.6959	3.3671	57.2682	-9.5261	3.4264	0.0179	0.1698	-0.0593	0.1807	-0.0593	Z
	18	53.9081	-24.1312	4.8677	53.9101	-23.8266	4.9111	-0.0020	0.3046	-0.0434	0.3077	-0.0434	Z
	19	53.9043	-20.9168	4.8885	53.9568	-20.5758	4.9177	-0.0525	0.3410	-0.0292	0.3463	-0.0292	Z
	20	53.9208	-17.9132	4.8938	53.8885	-17.6477	4.9428	0.0323	0.2655	-0.0490	0.2719	-0.0490	Z
	21	53.9546	-14.0183	4.9144	53.9570	-13.6912	4.9576	-0.0024	0.3271	-0.0432	0.3299	-0.0432	Z
	22	53.9038	-11.4175	4.9449	53.9313	-11.2130	4.9766	-0.0275	0.2045	-0.0317	0.2088	-0.0317	Z
	23	54.0258	-8.3642	4.9567	54.0534	-8.0139	4.9929	-0.0276	0.3503	-0.0362	0.3532	-0.0362	Z
	24	50.1930	-24.6794	4.9814	50.2473	-24.3633	5.0065	-0.0543	0.3161	-0.0251	0.3217	-0.0251	Z
	25	50.1833	-21.2473	4.9942	50.2716	-20.9507	5.0199	-0.0883	0.2966	-0.0257	0.3105	-0.0257	Z
	26	50.1857	-18.2968	5.0017	50.2534	-17.9392	5.0290	-0.0677	0.3576	-0.0273	0.3650	-0.0273	Z
	27	50.3182	-15.3182	5.0183	50.3582	-15.0367	5.0486	-0.0400	0.2815	-0.0303	0.2859	-0.0303	Z
	28	50.3264	-12.7803	5.0301	50.3388	-12.4468	5.0623	-0.0124	0.3335	-0.0322	0.3353	-0.0322	Z
	29	50.2399	-10.4885	5.0457	50.2428	-10.1361	5.0806	-0.0029	0.3524	-0.0349	0.3541	-0.0349	Z
	30	50.2138	-8.5165	5.0633	50.2513	-8.1787	5.0983	-0.0375	0.3378	-0.0350	0.3417	-0.0350	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Pretest Floor Pan

Posttest Floor Pan

Figure D-23. Floor Pan Deformation Data – Set 1 Left, Test No. MSPBN-6

Date: 6/5/2018 | Test Name: MSPBN-6 | VIN: 1C6RD6KT3CS268370
Year: 2012 | Make: Dodge | Model: Ram 1500

VEHICLE DEFORMATION
FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	58.8335	17.4465	-3.0817	58.5775	17.7615	-3.0298	0.2560	-0.3150	-0.0519	0.4092	0.2560	X
	2	59.2032	19.3088	-1.8476	58.9208	19.5867	-1.8027	0.2824	-0.2779	-0.0449	0.3987	0.2824	X
	3	59.9929	21.2740	0.4727	59.6959	21.5831	0.5836	0.2970	-0.3091	-0.1109	0.4428	0.2970	X
	4	60.4397	24.1166	1.5775	60.1172	24.3898	1.6732	0.3225	-0.2732	-0.0957	0.4334	0.3225	X
	5	60.4530	27.8037	1.5785	60.1478	28.1430	1.6463	0.3052	-0.3393	-0.0678	0.4614	0.3052	X
	6	60.5757	30.0116	1.5219	60.2173	30.2645	1.6176	0.3584	-0.2529	-0.0957	0.4490	0.3584	X
	7	55.1317	14.3588	-2.6484	54.8289	14.6539	-2.5662	0.3028	-0.2951	-0.0822	0.4307	0.3028	X
	8	55.6237	17.1129	-1.1334	55.3375	17.3989	-1.0633	0.2862	-0.2860	-0.0701	0.4106	0.2862	X
	9	56.2758	19.5419	0.4146	56.0216	19.8728	0.5064	0.2542	-0.3309	-0.0918	0.4272	0.2542	X
	10	57.1609	21.7464	2.9592	56.6782	22.1096	3.3975	0.4827	-0.3632	-0.4383	0.7463	0.4827	X
FLOOR PAN (Z)	11	57.2777	25.0694	3.3649	56.9907	25.3571	3.4231	0.2870	-0.2877	-0.0582	0.4105	-0.0582	Z
	12	57.3914	29.2253	3.3250	57.1031	29.5238	3.3589	0.2883	-0.2985	-0.0339	0.4164	-0.0339	Z
	13	51.8183	13.5611	-0.9589	51.5483	13.8523	-0.9147	0.2700	-0.2912	-0.0442	0.3996	-0.0442	Z
	14	52.5909	16.7468	1.1346	52.3168	17.0519	1.2148	0.2741	-0.3051	-0.0802	0.4179	-0.0802	Z
	15	53.4336	19.5081	3.2753	53.1958	19.8161	3.3673	0.2378	-0.3080	-0.0920	0.3998	-0.0920	Z
	16	54.0737	22.0689	4.9591	53.8456	22.4156	5.0012	0.2281	-0.3467	-0.0421	0.4171	-0.0421	Z
	17	54.1855	26.7285	4.9617	53.9257	26.9797	4.9849	0.2598	-0.2512	-0.0232	0.3621	-0.0232	Z
	18	54.1404	30.5691	4.9711	53.8971	30.8653	5.0169	0.2433	-0.2962	-0.0458	0.3860	-0.0458	Z
	19	48.7982	13.5632	0.8640	48.5062	13.8574	0.9365	0.2920	-0.2942	-0.0725	0.4208	-0.0725	Z
	20	49.9577	16.3333	4.2977	49.6910	16.6026	4.3535	0.2667	-0.2693	-0.0558	0.3831	-0.0558	Z
	21	50.3130	20.8760	5.0507	50.0548	21.1104	5.1105	0.2582	-0.2344	-0.0598	0.3538	-0.0598	Z
	22	50.4016	25.8604	5.0469	50.1209	26.1351	5.0963	0.2807	-0.2747	-0.0494	0.3958	-0.0494	Z
	23	50.4650	29.2698	5.0541	50.1905	29.6089	5.1021	0.2745	-0.3391	-0.0480	0.4389	-0.0480	Z
	24	50.4743	31.6192	5.0647	50.1337	31.9077	5.1121	0.3406	-0.2885	-0.0474	0.4489	-0.0474	Z
	25	44.3937	14.8415	4.6619	44.1448	15.1645	4.7386	0.2489	-0.3230	-0.0767	0.4149	-0.0767	Z
	26	44.5100	18.2010	5.0659	44.2716	18.5343	5.1134	0.2384	-0.3333	-0.0475	0.4125	-0.0475	Z
	27	44.4914	23.0109	5.0635	44.1833	23.3699	5.1039	0.3081	-0.3590	-0.0404	0.4748	-0.0404	Z
	28	44.4933	26.6596	5.0661	44.1812	26.9001	5.1079	0.3121	-0.2405	-0.0418	0.3962	-0.0418	Z
	29	44.6393	29.4410	5.0687	44.3759	29.6994	5.1100	0.2634	-0.2584	-0.0413	0.3713	-0.0413	Z
	30	44.6260	31.8439	5.0802	44.2983	32.1844	5.1250	0.3277	-0.3405	-0.0448	0.4747	-0.0448	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Pretest Floor Pan

Posttest Floor Pan

Figure D-24. Floor Pan Deformation Data – Set 1 Right, Test No. MSPBN-6

Date: 6/5/2018 Test Name: MSPBN-6 VIN: 1C6RD6KT3CS268370
Year: 2012 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	65.9615	8.4294	6.2097	66.0161	8.2647	5.7204	-0.0546	0.1647	0.4893	0.5192	0.4893	Z
	2	66.9119	5.6027	4.8168	66.9303	5.4671	4.3269	-0.0184	0.1356	0.4899	0.5087	0.4899	Z
	3	67.1331	3.0344	4.1807	67.1897	2.8244	3.6666	-0.0566	0.2100	0.5141	0.5582	0.5141	Z
	4	66.9560	-1.2141	4.0212	66.9168	-1.4130	3.4643	0.0392	-0.1989	0.5569	0.5927	0.5583	X, Z
	5	66.5436	-3.7967	3.9798	66.5637	-3.8351	3.3940	-0.0201	-0.0384	0.5858	0.5874	0.5858	Z
	6	65.2959	-6.7178	4.5805	65.2544	-6.9176	3.9947	0.0415	-0.1998	0.5858	0.6203	0.5873	X, Z
	7	63.1557	9.7029	2.4998	63.2461	9.4983	2.0272	-0.0904	0.2046	0.4726	0.5229	0.4726	Z
	8	63.4036	5.9668	2.5237	63.4368	5.8020	2.0129	-0.0332	0.1648	0.5108	0.5378	0.5108	Z
	9	63.4459	2.2603	2.4863	63.4514	1.9639	1.9688	-0.0055	0.2964	0.5175	0.5964	0.5175	Z
	10	63.5240	-0.9245	2.4687	63.4778	-1.2299	1.9241	0.0462	-0.3054	0.5446	0.6261	0.5466	X, Z
FLOOR PAN (Z)	11	63.5738	-3.9433	2.4280	63.7505	-4.2330	2.0078	-0.1767	-0.2897	0.4202	0.5401	0.4202	Z
	12	60.1668	9.6089	0.8741	60.2015	9.5030	0.3864	-0.0347	0.1059	0.4877	0.5003	0.4877	Z
	13	60.2875	5.1034	0.8717	60.3276	4.9412	0.3932	-0.0401	0.1622	0.4785	0.5068	0.4785	Z
	14	60.3551	0.7989	0.8334	60.3812	0.6275	0.3465	-0.0261	0.1714	0.4869	0.5168	0.4869	Z
	15	60.4528	-1.4905	0.8340	60.4607	-1.6389	0.3392	-0.0079	-0.1484	0.4948	0.5166	0.4948	Z
	16	60.4626	-3.7151	0.7979	60.4512	-3.9214	0.2977	0.0114	-0.2063	0.5002	0.5412	0.5002	Z
	17	60.5141	-5.2939	0.7978	60.4434	-5.3408	0.2738	0.0707	-0.0469	0.5240	0.5308	0.5240	Z
	18	57.0416	9.1274	-0.6200	57.0129	8.9531	-1.1059	0.0287	0.1743	0.4859	0.5170	0.4859	Z
	19	57.0578	5.9131	-0.6569	57.0739	5.7026	-1.1317	-0.0161	0.2105	0.4748	0.5196	0.4748	Z
	20	57.0929	2.9097	-0.6773	57.0182	2.7744	-1.1733	0.0747	0.1353	0.4960	0.5195	0.4960	Z
	21	57.1509	-0.9847	-0.7175	57.1040	-1.1816	-1.2115	0.0469	-0.1969	0.4940	0.5339	0.4940	Z
	22	57.1162	-3.5856	-0.7608	57.0890	-3.6597	-1.2448	0.0272	-0.0741	0.4840	0.4904	0.4840	Z
	23	57.2571	-6.6379	-0.7883	57.2250	-6.8580	-1.2805	0.0321	-0.2201	0.4922	0.5401	0.4922	Z
	24	53.3229	9.6529	-0.7195	53.3472	9.4741	-1.1743	-0.0243	0.1788	0.4548	0.4893	0.4548	Z
	25	53.3345	6.2210	-0.7495	53.3864	6.0618	-1.2076	-0.0519	0.1592	0.4581	0.4877	0.4581	Z
	26	53.3552	3.2705	-0.7717	53.3814	3.0503	-1.2341	-0.0262	0.2202	0.4624	0.5128	0.4624	Z
	27	53.5062	0.2929	-0.8036	53.4988	0.1485	-1.2713	0.0074	0.1444	0.4677	0.4895	0.4677	Z
	28	53.5302	-2.2447	-0.8282	53.4907	-2.4414	-1.2999	0.0395	-0.1967	0.4717	0.5126	0.4717	Z
	29	53.4579	-4.5369	-0.8550	53.4047	-4.7523	-1.3310	0.0532	-0.2154	0.4760	0.5252	0.4760	Z
	30	53.4440	-6.5089	-0.8824	53.4216	-6.7095	-1.3601	0.0224	-0.2006	0.4777	0.5186	0.4777	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Pretest Floor Pan

Posttest Floor Pan

Figure D-25. Floor Pan Deformation Data – Set 2 Left, Test No. MSPBN-6

Date: 6/5/2018 Test Name: MSPBN-6 VIN: 1C6RD6KT3CS268370
Year: 2012 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	50.1664	-26.2128	-26.7216	49.9500	-26.1410	-26.6381	0.2164	0.0718	0.0835	0.2428	0.2428	X, Y, Z
	2	46.4709	-15.3566	-29.3155	46.3333	-15.3288	-29.2715	0.1376	0.0278	0.0440	0.1471	0.1471	X, Y, Z
	3	45.4130	4.3890	-26.5907	45.3740	4.4772	-26.5304	0.0390	-0.0882	0.0603	0.1137	0.1137	X, Y, Z
	4	45.5779	-25.9677	-15.6520	45.3643	-25.9228	-15.5291	0.2136	0.0449	0.1229	0.2505	0.2505	X, Y, Z
	5	46.8633	-15.2048	-11.6440	46.7589	-15.0897	-11.4992	0.1044	0.1151	0.1448	0.2124	0.2124	X, Y, Z
	6	43.1109	3.9407	-20.2394	43.0890	4.1011	-20.2512	0.0219	-0.1604	-0.0118	0.1623	0.1623	X, Y, Z
SIDE PANEL (Y)	7	54.4217	-28.4020	-5.0978	54.2223	-28.3466	-4.9799	0.1994	0.0554	0.1179	0.2382	0.0554	Y
	8	59.2997	-28.4243	-5.8973	59.0380	-28.3925	-5.8537	0.2617	0.0318	0.0436	0.2672	0.0318	Y
	9	55.7609	-28.3249	0.3950	55.5685	-28.2711	0.4105	0.1924	0.0538	0.0155	0.2004	0.0538	Y
IMPACT SIDE DOOR (Y)	10	23.1904	-30.9889	-17.5839	22.9223	-30.7459	-17.5584	0.2681	0.2430	0.0255	0.3627	0.2430	Y
	11	30.5158	-30.8765	-17.6368	30.2166	-30.6703	-17.4736	0.2992	0.2062	0.1632	0.3983	0.2062	Y
	12	38.6651	-31.2875	-15.3936	38.4252	-31.1085	-15.4289	0.2399	0.1790	-0.0353	0.3014	0.1790	Y
	13	24.0554	-30.6468	1.7934	23.7692	-30.4433	1.8306	0.2862	0.2035	0.0372	0.3531	0.2035	Y
	14	33.9616	-31.0190	0.9409	33.6427	-30.8488	1.1411	0.3189	0.1702	0.2002	0.4132	0.1702	Y
	15	40.4788	-31.3468	-0.6618	40.3377	-31.2001	-0.5787	0.1411	0.1467	0.0831	0.2199	0.1467	Y
ROOF - (Z)	16	37.6094	-18.7148	-42.4166	37.4113	-18.5657	-42.3522	0.1981	0.1491	0.0644	0.2562	0.0644	Z
	17	39.1592	-14.4613	-42.4575	38.9570	-14.2515	-42.4081	0.2022	0.2098	0.0494	0.2955	0.0494	Z
	18	40.1256	-10.2957	-42.5500	40.0253	-10.1680	-42.4438	0.1003	0.1277	0.1062	0.1940	0.1062	Z
	19	40.9403	-6.0369	-42.5790	40.8292	-5.8153	-42.4905	0.1111	0.2216	0.0885	0.2632	0.0885	Z
	20	41.3563	-1.4449	-42.6706	41.2847	-1.3214	-42.5583	0.0716	0.1235	0.1123	0.1816	0.1123	Z
	21	31.9812	-17.6314	-44.9925	31.8130	-17.5227	-44.9183	0.1682	0.1087	0.0742	0.2136	0.0742	Z
	22	32.6122	-14.2128	-45.2222	32.4269	-13.9155	-45.1720	0.1853	0.2973	0.0502	0.3539	0.0502	Z
	23	33.2660	-8.9951	-45.4953	33.1744	-8.7026	-45.4222	0.0916	0.2925	0.0731	0.3151	0.0731	Z
	24	33.7338	-5.6676	-45.5834	33.5799	-5.4522	-45.5176	0.1539	0.2154	0.0658	0.2728	0.0658	Z
	25	34.1249	-1.4440	-45.6545	34.0593	-1.2687	-45.5728	0.0656	0.1753	0.0817	0.2042	0.0817	Z
	26	28.8504	-16.8761	-45.5752	28.7161	-16.6545	-45.5206	0.1343	0.2216	0.0546	0.2648	0.0546	Z
	27	29.3269	-12.8795	-45.8534	29.1984	-12.6461	-45.7937	0.1285	0.2334	0.0597	0.2730	0.0597	Z
	28	30.1116	-8.9482	-46.0067	29.9735	-8.7619	-45.9439	0.1381	0.1863	0.0628	0.2403	0.0628	Z
	29	30.6957	-5.6453	-46.0841	30.5040	-5.3683	-46.0300	0.1917	0.2770	0.0541	0.3412	0.0541	Z
	30	30.9552	-1.6000	-46.1703	30.8675	-1.3672	-46.0994	0.0877	0.2328	0.0709	0.2587	0.0709	Z
A-PILLAR Maximum (X, Y, Z)	31	53.4911	-26.8699	-28.3841	53.2473	-26.8811	-28.3219	0.2438	-0.0112	0.0622	0.2519	0.2516	X, Z
	32	49.9771	-26.3621	-30.7002	49.7786	-26.3062	-30.6592	0.1985	0.0559	0.0410	0.2103	0.2103	X, Y, Z
	33	45.0000	-24.8457	-34.0422	44.7066	-24.7656	-34.0483	0.2934	0.0801	-0.0061	0.3042	0.3041	X, Y
	34	42.2335	-23.9652	-36.0796	41.9559	-23.8728	-36.0980	0.2776	0.0924	-0.0184	0.2932	0.2926	X, Y
	35	39.6479	-23.0264	-37.1361	39.4279	-22.9656	-37.0746	0.2200	0.0608	0.0615	0.2364	0.2364	X, Y, Z
	36	35.6589	-22.8706	-40.2562	35.3969	-22.7425	-40.2570	0.2620	0.1281	-0.0008	0.2916	0.2916	X, Y
A-PILLAR Lateral (Y)	31	53.4911	-26.8699	-28.3841	53.2473	-26.8811	-28.3219	0.2438	-0.0112	0.0622	0.2519	-0.0112	Y
	32	49.9771	-26.3621	-30.7002	49.7786	-26.3062	-30.6592	0.1985	0.0559	0.0410	0.2103	0.0559	Y
	33	45.0000	-24.8457	-34.0422	44.7066	-24.7656	-34.0483	0.2934	0.0801	-0.0061	0.3042	0.0801	Y
	34	42.2335	-23.9652	-36.0796	41.9559	-23.8728	-36.0980	0.2776	0.0924	-0.0184	0.2932	0.0924	Y
	35	39.6479	-23.0264	-37.1361	39.4279	-22.9656	-37.0746	0.2200	0.0608	0.0615	0.2364	0.0608	Y
	36	35.6589	-22.8706	-40.2562	35.3969	-22.7425	-40.2570	0.2620	0.1281	-0.0008	0.2916	0.1281	Y
B-PILLAR Maximum (X, Y, Z)	37	10.2333	-24.4327	-37.1787	10.0068	-24.2375	-37.1173	0.2265	0.1952	0.0614	0.3052	0.3052	X, Y, Z
	38	10.4289	-27.5983	-25.3760	10.2025	-27.3723	-25.2472	0.2264	0.2260	0.1288	0.3449	0.3449	X, Y, Z
	39	12.8509	-24.3611	-37.3897	12.6219	-24.1688	-37.3195	0.2290	0.1923	0.0702	0.3072	0.3072	X, Y, Z
	40	13.8151	-27.5000	-26.1686	13.5212	-27.2891	-26.1304	0.2939	0.2109	0.0382	0.3638	0.3638	X, Y, Z
B-PILLAR Lateral (Y)	37	10.2333	-24.4327	-37.1787	10.0068	-24.2375	-37.1173	0.2265	0.1952	0.0614	0.3052	0.1952	Y
	38	10.4289	-27.5983	-25.3760	10.2025	-27.3723	-25.2472	0.2264	0.2260	0.1288	0.3449	0.2260	Y
	39	12.8509	-24.3611	-37.3897	12.6219	-24.1688	-37.3195	0.2290	0.1923	0.0702	0.3072	0.1923	Y
	40	13.8151	-27.5000	-26.1686	13.5212	-27.2891	-26.1304	0.2939	0.2109	0.0382	0.3638	0.2109	Y

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-26. Occupant Compartment Deformation Data – Set 1 Left, Test No. MSPBN-6

Date: 6/5/2018 Test Name: MSPBN-6 VIN: 1C6RD6KT3CS268370
Year: 2012 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	49.1927	27.6338	-25.7351	49.1183	27.3825	-25.7298	0.0744	0.2513	0.0053	0.2621	0.2621	X, Y, Z
	2	48.5383	18.1351	-26.1445	48.4384	17.9215	-26.0700	0.0999	0.2136	0.0745	0.2473	0.2473	X, Y, Z
	3	45.4530	4.3748	-26.6157	45.2979	4.2389	-26.5779	0.1551	0.1359	0.0378	0.2097	0.2097	X, Y, Z
	4	46.9688	29.5953	-18.9897	46.9141	29.3769	-19.0789	0.0547	0.2184	-0.0892	0.2422	0.2422	X, Y, Z
	5	46.4723	21.7852	-18.9781	46.4134	21.6461	-18.9745	0.0589	0.1391	0.0036	0.1511	0.1511	X, Y, Z
	6	43.1363	3.9153	-20.2593	42.9933	3.7524	-20.2605	0.1430	0.1629	-0.0012	0.2168	0.2168	X, Y, Z
SIDE PANEL (Y)	7	59.4946	36.2103	-5.2707	59.5385	35.9060	-5.2820	-0.0439	0.3043	-0.0113	0.3077	0.3043	Y
	8	54.8068	36.0074	-4.7586	54.8567	35.7216	-4.7518	-0.0499	0.2858	0.0068	0.2902	0.2858	Y
	9	54.8576	35.8812	2.3901	54.8789	35.6098	2.3122	-0.0213	0.2714	-0.0779	0.2832	0.2714	Y
IMPACT SIDE DOOR (Y)	10	46.0779	38.4557	-15.9908	46.0147	38.1167	-16.1900	0.0632	0.3390	-0.1992	0.3982	0.3390	Y
	11	36.8540	39.2905	-15.3136	36.7585	39.3427	-15.2546	0.0955	-0.0522	0.0590	0.1238	-0.0522	Y
	12	26.1090	39.0373	-15.8382	25.9394	39.0808	-15.7116	0.1696	-0.0435	0.1266	0.2161	-0.0435	Y
	13	40.9237	38.8993	0.9640	40.7930	38.7276	0.9594	0.1307	0.1717	-0.0046	0.2158	0.1717	Y
	14	34.8274	38.9072	1.4802	34.7094	38.7730	1.5131	0.1180	0.1342	0.0329	0.1817	0.1342	Y
	15	24.9229	38.4762	0.0689	24.8124	38.3779	0.1198	0.1105	0.0983	0.0509	0.1564	0.0983	Y
ROOF - (Z)	16	38.1609	26.3289	-42.2514	38.3609	26.1034	-42.1001	-0.2000	0.2255	0.1513	0.3373	0.1513	Z
	17	39.1794	23.5018	-42.3336	39.3962	23.2672	-42.1545	-0.2168	0.2346	0.1791	0.3662	0.1791	Z
	18	39.9483	20.6201	-42.4376	40.0753	20.3756	-42.2850	-0.1270	0.2445	0.1526	0.3150	0.1526	Z
	19	40.6466	16.8587	-42.5568	40.8131	16.5630	-42.3582	-0.1665	0.2957	0.1986	0.3932	0.1986	Z
	20	41.3237	13.0847	-42.5567	41.3597	12.9105	-42.4327	-0.0360	0.1742	0.1240	0.2168	0.1240	Z
	21	32.5443	25.1635	-44.9133	32.6054	25.2351	-44.8304	-0.0611	-0.0716	0.0829	0.1254	0.0829	Z
	22	33.3684	22.3439	-45.0321	33.4274	22.3943	-44.9519	-0.0590	-0.0504	0.0802	0.1116	0.0802	Z
	23	33.8542	20.0801	-45.1299	33.8482	20.0623	-45.0738	0.0060	0.0178	0.0561	0.0592	0.0561	Z
	24	34.6841	16.0916	-45.2320	34.7211	16.0917	-45.1549	-0.0370	-0.0001	0.0771	0.0855	0.0771	Z
	25	35.1133	13.3956	-45.2781	35.1183	13.3360	-45.2059	-0.0050	0.0596	0.0722	0.0938	0.0722	Z
	26	30.4295	24.5802	-45.3704	30.4463	24.6764	-45.2930	-0.0168	-0.0962	0.0774	0.1246	0.0774	Z
	27	31.3486	21.9564	-45.4621	31.2634	22.0042	-45.4100	0.0852	-0.0478	0.0521	0.1107	0.0521	Z
	28	32.0437	19.7762	-45.5144	31.9706	19.8164	-45.4639	0.0731	-0.0402	0.0505	0.0975	0.0505	Z
	29	32.9879	15.9642	-45.5828	32.9160	15.9856	-45.5232	0.0719	-0.0214	0.0596	0.0958	0.0596	Z
	30	33.4384	13.4612	-45.6117	33.3751	13.4809	-45.5469	0.0633	-0.0197	0.0648	0.0927	0.0648	Z
A-PILLAR Maximum (X, Y, Z)	31	53.6210	34.6295	-28.1990	53.6502	34.3316	-28.1644	-0.0292	0.2979	0.0346	0.3013	0.2999	Y, Z
	32	51.0199	34.1032	-30.2716	51.0492	33.7702	-30.3416	-0.0293	0.3330	-0.0700	0.3415	0.3330	Y
	33	46.0899	32.5127	-33.6999	46.1497	32.2881	-33.6563	-0.0598	0.2246	0.0436	0.2365	0.2288	Y, Z
	34	42.9961	31.7825	-35.7633	43.0288	31.5388	-35.7725	-0.0327	0.2437	-0.0092	0.2461	0.2437	Y
	35	39.9591	30.6312	-37.3421	39.9648	30.4483	-37.3045	-0.0057	0.1829	0.0376	0.1868	0.1867	Y, Z
	36	36.3188	30.7156	-40.1278	36.2801	30.6325	-40.0342	0.0387	0.0831	0.0936	0.1310	0.1310	X, Y, Z
A-PILLAR Lateral (Y)	31	53.6210	34.6295	-28.1990	53.6502	34.3316	-28.1644	-0.0292	0.2979	0.0346	0.3013	0.2979	Y
	32	51.0199	34.1032	-30.2716	51.0492	33.7702	-30.3416	-0.0293	0.3330	-0.0700	0.3415	0.3330	Y
	33	46.0899	32.5127	-33.6999	46.1497	32.2881	-33.6563	-0.0598	0.2246	0.0436	0.2365	0.2246	Y
	34	42.9961	31.7825	-35.7633	43.0288	31.5388	-35.7725	-0.0327	0.2437	-0.0092	0.2461	0.2437	Y
	35	39.9591	30.6312	-37.3421	39.9648	30.4483	-37.3045	-0.0057	0.1829	0.0376	0.1868	0.1829	Y
	36	36.3188	30.7156	-40.1278	36.2801	30.6325	-40.0342	0.0387	0.0831	0.0936	0.1310	0.0831	Y
B-PILLAR Maximum (X, Y, Z)	37	13.4583	32.0432	-38.7020	13.5554	32.0611	-38.6196	-0.0971	-0.0179	0.0824	0.1286	0.0824	Z
	38	10.5472	32.1019	-38.6767	10.7376	32.1192	-38.5586	-0.1904	-0.0173	0.1181	0.2247	0.1181	Z
	39	15.7025	36.0850	-20.6329	15.8685	36.0404	-20.5826	-0.1660	0.0446	0.0503	0.1791	0.0672	Y, Z
	40	11.8508	36.1564	-20.1789	11.8133	35.9564	-20.4556	0.0375	0.2000	-0.2767	0.3435	0.2035	X, Y
B-PILLAR Lateral (Y)	37	13.4583	32.0432	-38.7020	13.5554	32.0611	-38.6196	-0.0971	-0.0179	0.0824	0.1286	-0.0179	Y
	38	10.5472	32.1019	-38.6767	10.7376	32.1192	-38.5586	-0.1904	-0.0173	0.1181	0.2247	-0.0173	Y
	39	15.7025	36.0850	-20.6329	15.8685	36.0404	-20.5826	-0.1660	0.0446	0.0503	0.1791	0.0446	Y
	40	11.8508	36.1564	-20.1789	11.8133	35.9564	-20.4556	0.0375	0.2000	-0.2767	0.3435	0.2000	Y

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-27. Occupant Compartment Deformation Data – Set 1 Right, Test No. MSPBN-6

Date: 6/5/2018　　Test Name: MSPBN-6　　VIN: 1C6RD6KT3CS268370
Year: 2012　　Make: Dodge　　Model: Ram 1500

VEHICLE DEFORMATION
INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	53.4150	-10.8837	-30.7655	53.2009	-10.9725	-30.6890	0.2141	-0.0888	0.0765	0.2441	0.2441	X, Y, Z
	2	49.7594	-0.0042	-33.3180	49.5655	-0.0989	-33.2671	0.1939	-0.0947	0.0509	0.2217	0.2217	X, Y, Z
	3	48.7545	19.7315	-30.5033	48.5145	19.4877	-30.5080	0.2400	0.2438	-0.0047	0.3421	0.3421	X, Y, Z
	4	48.7985	-10.6764	-19.7068	48.7217	-10.6734	-19.5365	0.0768	0.0030	0.1703	0.1868	0.1868	X, Y, Z
	5	50.1062	0.0637	-15.6450	50.0632	0.0747	-15.4958	0.0430	-0.0110	0.1492	0.1557	0.1557	X, Y, Z
	6	46.4345	19.2606	-24.1602	46.3071	19.2296	-24.0947	0.1274	0.0310	0.0655	0.1466	0.1466	X, Y, Z
SIDE PANEL (Y)	7	57.6073	-13.1871	-9.1412	57.5232	-13.1341	-8.9936	0.0841	0.0530	0.1476	0.1780	0.0530	Y
	8	62.4873	-13.2206	-9.9283	62.3671	-13.1691	-9.8670	0.1202	0.0515	0.0613	0.1444	0.0515	Y
	9	58.9324	-13.1399	-3.6447	58.9047	-13.0571	-3.5018	0.0277	0.0828	0.1429	0.1675	0.0828	Y
IMPACT SIDE DOOR (Y)	10	26.4009	-15.6200	-21.7202	26.4089	-15.6077	-21.6549	-0.0080	0.0123	0.0653	0.0669	0.0123	Y
	11	33.7267	-15.5298	-21.7536	33.6136	-15.4946	-21.5802	0.1131	0.0352	0.1734	0.2100	0.0352	Y
	12	41.8688	-15.9762	-19.4913	41.7400	-15.9119	-19.4080	0.1288	0.0643	0.0833	0.1663	0.0643	Y
	13	27.2165	-15.3713	-2.3393	27.1666	-15.3564	-2.2603	0.0499	0.0149	0.0790	0.0946	0.0149	Y
	14	37.1237	-15.7698	-3.1679	36.9684	-15.7040	-2.9834	0.1553	0.0658	0.1845	0.2500	0.0658	Y
	15	43.6440	-16.1100	-4.7552	43.6592	-16.0292	-4.6533	-0.0152	0.0808	0.1019	0.1309	0.0808	Y
ROOF - (Z)	16	40.9218	-3.2739	-46.4576	40.8582	-3.2103	-46.4059	0.0636	0.0636	0.0517	0.1037	0.0517	Z
	17	42.4846	0.9750	-46.4745	42.4480	1.0086	-46.3949	0.0366	-0.0336	0.0796	0.0938	0.0796	Z
	18	43.4639	5.1379	-46.5450	43.4343	5.1494	-46.4551	0.0296	-0.0115	0.0899	0.0953	0.0899	Z
	19	44.2917	9.3944	-46.5519	44.1802	9.4361	-46.4950	0.1115	-0.0417	0.0569	0.1319	0.0569	Z
	20	44.7219	13.9854	-46.6209	44.2577	13.5762	-46.5289	0.4642	0.4092	0.0920	0.6256	0.0920	Z
	21	35.3037	-2.1613	-49.0429	34.9979	-2.5395	-48.8326	0.3058	-0.3782	0.2103	0.5299	0.2103	Z
	22	35.9457	1.2564	-49.2550	35.5979	1.0298	-49.0879	0.3478	0.2266	0.1671	0.4475	0.1671	Z
	23	36.6161	6.4733	-49.5019	36.2698	6.2382	-49.3635	0.3463	0.2351	0.1384	0.4409	0.1384	Z
	24	37.0942	9.7998	-49.5732	36.6917	9.5823	-49.4624	0.4025	0.2175	0.1108	0.4707	0.1108	Z
	25	37.4983	14.0224	-49.6235	37.1947	13.6749	-49.5024	0.3036	0.3475	0.1211	0.4771	0.1211	Z
	26	32.1767	-1.3936	-49.6302	31.8095	-1.6483	-49.4397	0.3672	-0.2547	0.1905	0.4858	0.1905	Z
	27	32.6661	2.6027	-49.8884	32.2709	2.3488	-49.7202	0.3952	0.2539	0.1682	0.4989	0.1682	Z
	28	33.4632	6.5322	-50.0212	33.3664	6.4943	-49.9596	0.0968	0.0379	0.0616	0.1208	0.0616	Z
	29	34.0575	9.8337	-50.0816	33.9906	9.8248	-50.0223	0.0669	0.0089	0.0593	0.0898	0.0593	Z
	30	34.3295	13.8785	-50.1482	34.3013	13.8277	-50.0821	0.0282	0.0508	0.0661	0.0880	0.0661	Z
A-PILLAR Maximum (X, Y, Z)	31	56.7419	-11.5432	-32.4225	56.4199	-11.8224	-32.2735	0.3220	-0.2792	0.1490	0.4515	0.3548	X, Z
	32	53.2356	-11.0137	-34.7453	52.8628	-11.2870	-34.6137	0.3728	-0.2733	0.1316	0.4806	0.3953	X, Z
	33	48.2719	-9.4665	-38.0930	47.9350	-9.6734	-37.9922	0.3369	-0.2069	0.1008	0.4080	0.3517	X, Z
	34	45.5134	-8.5680	-40.1334	45.1790	-8.7911	-40.0303	0.3344	-0.2231	0.1031	0.4150	0.3499	X, Z
	35	42.9333	-7.6164	-41.1921	42.6142	-7.8962	-41.0384	0.3191	-0.2798	0.1537	0.4514	0.3542	X, Z
	36	38.9530	-7.4338	-44.3218	38.6078	-7.6206	-44.2663	0.3452	-0.1868	0.0555	0.3964	0.3496	X, Z
A-PILLAR Lateral (Y)	31	56.7419	-11.5432	-32.4225	56.4199	-11.8224	-32.2735	0.3220	-0.2792	0.1490	0.4515	-0.2792	Y
	32	53.2356	-11.0137	-34.7453	52.8628	-11.2870	-34.6137	0.3728	-0.2733	0.1316	0.4806	-0.2733	Y
	33	48.2719	-9.4665	-38.0930	47.9350	-9.6734	-37.9922	0.3369	-0.2069	0.1008	0.4080	-0.2069	Y
	34	45.5134	-8.5680	-40.1334	45.1790	-8.7911	-40.0303	0.3344	-0.2231	0.1031	0.4150	-0.2231	Y
	35	42.9333	-7.6164	-41.1921	42.6142	-7.8962	-41.0384	0.3191	-0.2798	0.1537	0.4514	-0.2798	Y
	36	38.9530	-7.4338	-44.3218	38.6078	-7.6206	-44.2663	0.3452	-0.1868	0.0555	0.3964	-0.1868	Y
B-PILLAR Maximum (X, Y, Z)	37	13.5148	-8.9326	-41.3174	13.2057	-9.1013	-41.2239	0.3091	-0.1687	0.0935	0.3643	0.3229	X, Z
	38	13.6700	-12.1539	-29.5293	13.3703	-12.2560	-29.4106	0.2997	-0.1021	0.1187	0.3381	0.3224	X, Z
	39	16.1331	-8.8680	-41.5214	15.8095	-9.0509	-41.3874	0.3236	-0.1829	0.1340	0.3951	0.3502	X, Z
	40	17.0586	-12.0623	-30.3127	16.7123	-12.1777	-30.2563	0.3463	-0.1154	0.0564	0.3694	0.3509	X, Z
B-PILLAR Lateral (Y)	37	13.5148	-8.9326	-41.3174	13.2057	-9.1013	-41.2239	0.3091	-0.1687	0.0935	0.3643	-0.1687	Y
	38	13.6700	-12.1539	-29.5293	13.3703	-12.2560	-29.4106	0.2997	-0.1021	0.1187	0.3381	-0.1021	Y
	39	16.1331	-8.8680	-41.5214	15.8095	-9.0509	-41.3874	0.3236	-0.1829	0.1340	0.3951	-0.1829	Y
	40	17.0586	-12.0623	-30.3127	16.7123	-12.1777	-30.2563	0.3463	-0.1154	0.0564	0.3694	-0.1154	Y

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-28. Occupant Compartment Deformation Data – Set 2 Left, Test No. MSPBN-6

Date: 6/5/2018 Test Name: MSPBN-6 VIN: 1C6RD6KT3CS268370
Year: 2012 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	52.5860	43.0028	-29.4979	52.3247	42.9684	-29.5932	0.2613	0.0344	-0.0953	0.2803	0.2803	X, Y, Z
	2	51.9065	33.5082	-29.9607	51.7218	33.5027	-29.9477	0.1847	0.0055	0.0130	0.1852	0.1852	X, Y, Z
	3	48.7845	19.7594	-30.5152	48.6928	19.7961	-30.4853	0.0917	-0.0367	0.0299	0.1032	0.1032	X, Y, Z
	4	50.3494	44.9337	-22.7479	50.0770	44.9369	-22.9491	0.2724	-0.0032	-0.2012	0.3387	0.3387	X, Y, Z
	5	49.8312	37.1251	-22.7802	49.6376	37.2022	-22.8562	0.1936	-0.0771	-0.0760	0.2218	0.2218	X, Y, Z
	6	46.4493	19.2718	-24.1676	46.3659	19.2834	-24.1782	0.0834	-0.0116	-0.0106	0.0849	0.0849	X, Y, Z
SIDE PANEL (Y)	7	62.8561	51.4393	-8.9594	62.5911	51.5493	-9.0916	0.2650	-0.1100	-0.1322	0.3159	-0.1100	Y
	8	58.1664	51.2466	-8.4610	57.9087	51.3269	-8.5812	0.2577	-0.0803	-0.1202	0.2955	-0.0803	Y
	9	58.1975	51.0814	-1.3130	57.9023	51.2064	-1.5173	0.2952	-0.1250	-0.2043	0.3801	-0.1250	Y
IMPACT SIDE DOOR (Y)	10	49.4748	53.7802	-19.7032	49.0957	53.6656	-20.0534	0.3791	0.1146	-0.3502	0.5287	0.1146	Y
	11	40.2514	54.6368	-19.0463	39.8262	54.8165	-19.1553	0.4252	-0.1797	-0.1090	0.4743	-0.1797	Y
	12	29.5072	54.4164	-19.6013	29.0116	54.4688	-19.6579	0.4956	-0.0524	-0.0566	0.5016	-0.0524	Y
	13	44.2760	54.1459	-2.7602	43.7977	54.2134	-2.9253	0.4783	-0.0675	-0.1651	0.5105	-0.0675	Y
	14	38.1782	54.1679	-2.2604	37.7117	54.2096	-2.3970	0.4665	-0.0417	-0.1366	0.4879	-0.0417	Y
	15	28.2765	53.7721	-3.7007	27.8241	53.7373	-3.8322	0.4524	0.0348	-0.1315	0.4724	0.0348	Y
ROOF - (Z)	16	41.5955	41.8183	-46.0507	41.6463	41.6239	-46.0099	-0.0508	0.1944	0.0408	0.2050	0.0408	Z
	17	42.6064	38.9889	-46.1456	42.7045	38.7961	-46.0633	-0.0981	0.1928	0.0823	0.2314	0.0823	Z
	18	43.3676	36.1057	-46.2631	43.4072	35.9102	-46.1946	-0.0396	0.1955	0.0685	0.2109	0.0685	Z
	19	44.0558	32.3430	-46.4010	44.1757	32.1037	-46.2693	-0.1199	0.2393	0.1317	0.2983	0.1317	Z
	20	44.7225	28.5673	-46.4196	44.7518	28.4558	-46.3459	-0.0293	0.1115	0.0737	0.1368	0.0737	Z
	21	35.9829	40.6830	-48.7340	35.9094	40.7131	-48.7653	0.0735	-0.0301	-0.0313	0.0854	-0.0313	Z
	22	36.7995	37.8619	-48.8659	36.7546	37.8792	-48.8868	0.0449	-0.0173	-0.0209	0.0525	-0.0209	Z
	23	37.2793	35.5972	-48.9747	37.1945	35.5507	-49.0098	0.0848	0.0465	-0.0351	0.1029	-0.0351	Z
	24	38.0984	31.6071	-49.0963	38.0994	31.5873	-49.0920	-0.0010	0.0198	0.0043	0.0203	0.0043	Z
	25	38.5204	28.9102	-49.1559	38.5188	28.8350	-49.1447	0.0016	0.0752	0.0112	0.0760	0.0112	Z
	26	33.8678	40.1081	-49.2000	33.7568	40.1378	-49.2376	0.1110	-0.0297	-0.0376	0.1209	-0.0376	Z
	27	34.7798	37.4822	-49.3035	34.5957	37.4723	-49.3544	0.1841	0.0099	-0.0509	0.1913	-0.0509	Z
	28	35.4690	35.3005	-49.3658	35.3206	35.2903	-49.4081	0.1484	0.0102	-0.0423	0.1546	-0.0423	Z
	29	36.4029	31.4863	-49.4524	36.2968	31.4672	-49.4680	0.1061	0.0191	-0.0156	0.1089	-0.0156	Z
	30	36.8465	28.9822	-49.4937	36.7759	28.9663	-49.4928	0.0706	0.0159	0.0009	0.0724	0.0009	Z
A-PILLAR Maximum (X, Y, Z)	31	57.0404	49.9994	-31.9118	56.8111	49.9565	-32.0003	0.2293	0.0429	-0.0885	0.2495	0.2333	X, Y
	32	54.4434	49.4917	-33.9941	54.2238	49.3771	-34.1891	0.2196	0.1146	-0.1950	0.3152	0.2477	X, Y
	33	49.5183	47.9335	-37.4444	49.3502	47.8600	-37.5261	0.1681	0.0735	-0.0817	0.2008	0.1835	X, Y
	34	46.4281	47.2231	-39.5200	46.2442	47.0885	-39.6562	0.1839	0.1346	-0.1362	0.2655	0.2279	X, Y
	35	43.3922	46.0889	-41.1132	43.1954	45.9755	-41.2023	0.1968	0.1134	-0.0891	0.2440	0.2271	X, Y
	36	39.7598	46.1985	-43.9082	39.5209	46.1337	-43.9472	0.2389	0.0648	-0.0390	0.2506	0.2475	X, Y
A-PILLAR Lateral (Y)	31	57.0404	49.9994	-31.9118	56.8111	49.9565	-32.0003	0.2293	0.0429	-0.0885	0.2495	0.0429	Y
	32	54.4434	49.4917	-33.9941	54.2238	49.3771	-34.1891	0.2196	0.1146	-0.1950	0.3152	0.1146	Y
	33	49.5183	47.9335	-37.4444	49.3502	47.8600	-37.5261	0.1681	0.0735	-0.0817	0.2008	0.0735	Y
	34	46.4281	47.2231	-39.5200	46.2442	47.0885	-39.6562	0.1839	0.1346	-0.1362	0.2655	0.1346	Y
	35	43.3922	46.0889	-41.1132	43.1954	45.9755	-41.2023	0.1968	0.1134	-0.0891	0.2440	0.1134	Y
	36	39.7598	46.1985	-43.9082	39.5209	46.1337	-43.9472	0.2389	0.0648	-0.0390	0.2506	0.0648	Y
B-PILLAR Maximum (X, Y, Z)	37	16.8992	47.5818	-42.5367	16.7798	47.3791	-42.6260	0.1194	0.2027	-0.0893	0.2516	0.2353	X, Y
	38	13.9882	47.6484	-42.5190	13.9614	47.4147	-42.5767	0.0268	0.2337	-0.0577	0.2422	0.2352	X, Y
	39	19.1057	51.5191	-24.4399	18.9857	51.3543	-24.5747	0.1200	0.1648	-0.1348	0.2444	0.2039	X, Y
	40	15.2529	51.5987	-23.9960	14.9308	51.2377	-24.4647	0.3221	0.3610	-0.4687	0.6736	0.4838	X, Y
B-PILLAR Lateral (Y)	37	16.8992	47.5818	-42.5367	16.7798	47.3791	-42.6260	0.1194	0.2027	-0.0893	0.2516	0.2027	Y
	38	13.9882	47.6484	-42.5190	13.9614	47.4147	-42.5767	0.0268	0.2337	-0.0577	0.2422	0.2337	Y
	39	19.1057	51.5191	-24.4399	18.9857	51.3543	-24.5747	0.1200	0.1648	-0.1348	0.2444	0.1648	Y
	40	15.2529	51.5987	-23.9960	14.9308	51.2377	-24.4647	0.3221	0.3610	-0.4687	0.6736	0.3610	Y

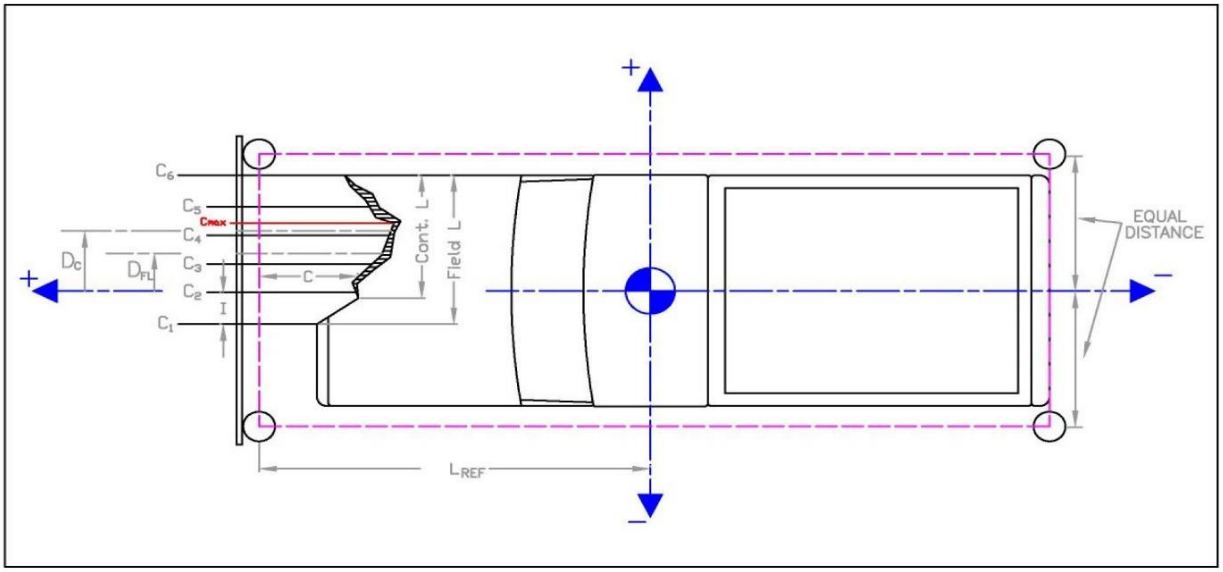
[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-29. Occupant Compartment Deformation Data – Set 2 Right, Test No. MSPBN-6

Date:	6/4/2018	Test Name:	MSPBN-6	VIN:	1C6RD6KT3CS268370
Year:	2012	Make:	Dodge	Model:	Ram 1500



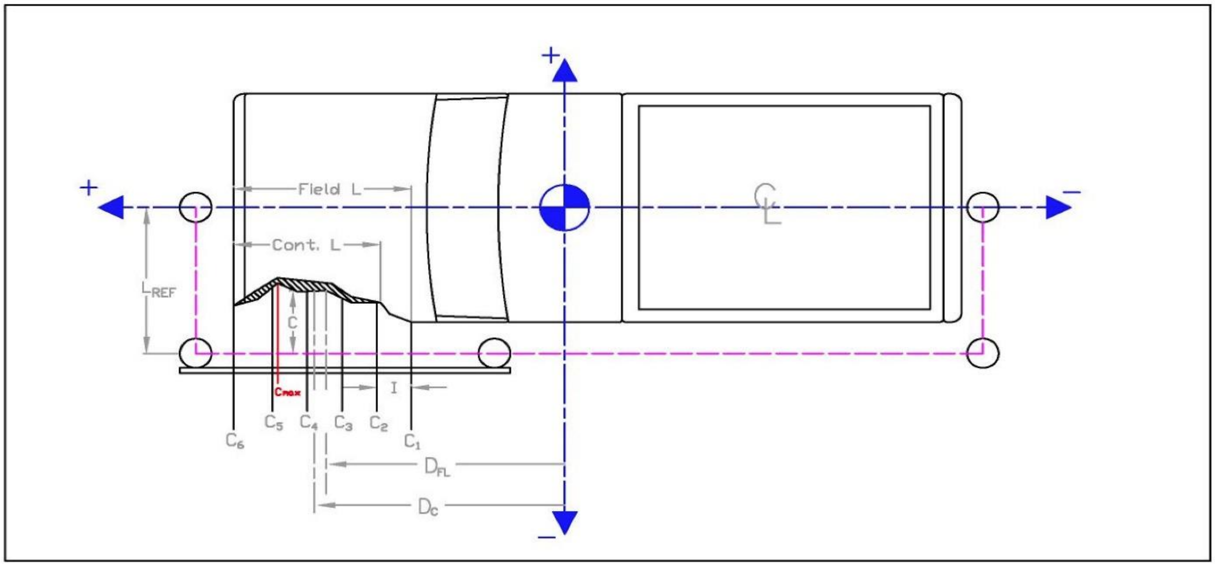
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	114 1/4	(2902)
Total Vehicle Width:	77 1/2	(1969)
Width of contact and induced crush - Field L:	77 1/2	(1969)
Crush measurement spacing interval (L/5) - I:	15 1/2	(394)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	77 1/2	(1969)
Distance from center of vehicle to center of contact damage - D_C:	0	()

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/A	#VALUE!	-38 3/4	-(984)	22 1/2	(572)	8 2/3	(221)	#VALUE!	#VALUE!
C_2	15 3/8	(391)	-23 1/4	-(591)	6 1/2	(165)			1/5	(5)
C_3	12 3/4	(324)	-7 3/4	-(197)	4 1/4	(108)			- 1/5	-(5)
C_4	12 3/8	(314)	7 3/4	(197)	4 1/4	(108)			- 4/7	-(14)
C_5	15 3/4	(400)	23 1/4	(591)	6 1/4	(159)			4/5	(21)
C_6	N/A	#VALUE!	38 3/4	(984)	20 1/2	(521)			#VALUE!	#VALUE!
C_{MAX}	22 1/2	(572)	31 1/2	(800)	10 1/2	(267)			3 1/3	(84)

Figure D-30. Exterior Vehicle Crush (NASS) - Front, Test No. MSPBN-6

Date:	6/4/2018	**Test Name:**	MSPBN-6	**VIN:**	1C6RD6KT3CS268370
Year:	2012	**Make:**	Dodge	**Model:**	Ram 1500



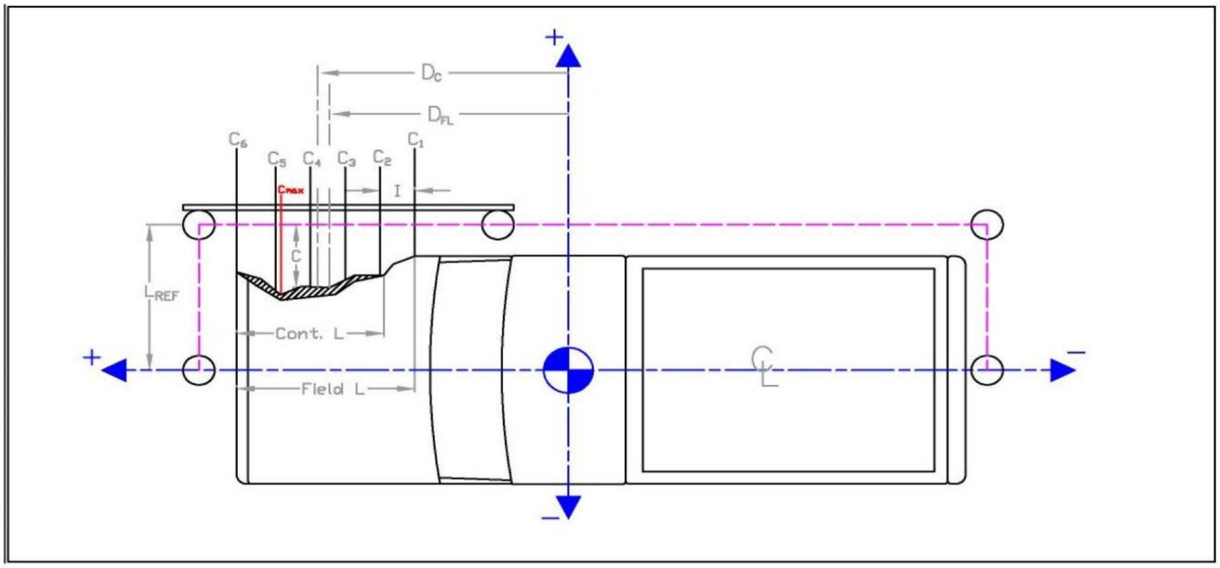
	in.	(mm)
Distance from centerline to reference line - L_{REF}:	48	(1219)
Total Vehicle Length:	229 1/2	(5829)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-4 4/7	-(116)
Width of contact and induced crush - Field L:	27	(686)
Crush measurement spacing interval (L/5) - I:	5 3/8	(137)
Distance from vehicle c.g. to center of Field L - D_{FL}:	88 1/2	(2248)
Width of Contact Damage:	27	(686)
Distance from vehicle c.g. to center of contact damage - D_C:	88 1/2	(2248)

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual	Crush
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	9 3/8	(238)	75	(1905)	5 3/4	(146)	4	(102)	- 3/8	-(10)
C_2	15	(381)	80 3/8	(2042)	5	(127)			6	(152)
C_3	17	(432)	85 3/4	(2178)	5 3/4	(146)			7 1/4	(184)
C_4	22 3/4	(578)	91 1/8	(2315)	6	(152)			12 3/4	(324)
C_5	23	(584)	96 1/2	(2451)	6 3/4	(171)			12 1/4	(311)
C_6	n/a	#VALUE!	101 7/8	(2588)	9 3/4	(248)			#VALUE!	#VALUE!
C_{MAX}	22 3/4	(578)	91 1/8	(2315)	6	(152)			12 3/4	(324)

Figure D-31. Exterior Vehicle Crush (NASS) – Left Side, Test No. MSPBN-6

Date:	6/4/2018	Test Name:	MSPBN-6	VIN:	1C6RD6KT3CS268370
Year:	2012	Make:	Dodge	Model:	Ram 1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	48	(1219)
Total Vehicle Length:	229 1/2	(5829)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-4 4/7	-(116)
Width of contact and induced crush - Field L:	229 1/2	(5829)
Crush measurement spacing interval (L/5) - I:	45 7/8	(1165)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-13 3/8	-(340)
Width of Contact Damage:	229 1/2	(5829)
Distance from vehicle c.g. to center of contact damage - D_C:	-13 3/8	-(340)

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual	Crush
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	n/a	#VALUE!	-128 1/8	-(3254)	33 1/2	(851)	4	(102)	#VALUE!	#VALUE!
C_2	9	(229)	-82 1/4	-(2089)	5 1/2	(140)			- 1/2	-(13)
C_3	9 1/4	(235)	-36 3/8	-(924)	5 3/4	(146)			- 1/2	-(13)
C_4	8 3/4	(222)	9 1/2	(241)	5	(127)			- 1/4	-(6)
C_5	n/a	#VALUE!	55 3/8	(1407)	5 5/8	(143)			#VALUE!	#VALUE!
C_6	n/a	#VALUE!	101 1/4	(2572)	9 1/4	(235)			#VALUE!	#VALUE!
C_{MAX}	12 3/4	(324)	23 1/2	(597)	5 1/8	(130)			3 5/8	(92)

Figure D-32. Exterior Vehicle Crush (NASS) – Right Side, Test No. MSPBN-6

Date: 6/5/2018 Test Name: MSPBN-7 VIN: 1C6RD6KT4CS197048
Year: 2012 Make: Dodge Ram Model: Ram 1500

VEHICLE DEFORMATION
FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	61.1514	-24.1341	-0.4119	61.1477	-23.9087	-0.4677	0.0037	0.2254	0.0558	0.2322	0.0559	X, Z
	2	62.3793	-20.2369	0.6057	62.3808	-20.0260	0.5534	-0.0015	0.2109	0.0523	0.2173	0.0523	Z
	3	62.3346	-16.4992	0.7675	62.3662	-16.2338	0.7259	-0.0316	0.2654	0.0416	0.2705	0.0416	Z
	4	62.1911	-11.9349	0.8477	62.2120	-11.7648	0.8086	-0.0209	0.1701	0.0391	0.1758	0.0391	Z
	5	61.4312	-7.4431	-0.0247	61.4316	-7.2037	-0.0535	-0.0004	0.2394	0.0288	0.2411	0.0288	Z
	6	58.0183	-24.1339	3.0556	57.9916	-23.8668	3.0109	0.0267	0.2671	0.0447	0.2721	0.0521	X, Z
	7	57.8702	-20.1740	3.1059	57.8451	-19.8511	3.1069	0.0251	0.3229	-0.0010	0.3239	0.0251	X
	8	57.9804	-16.5164	3.0770	57.9006	-16.3302	3.0923	0.0798	0.1862	-0.0153	0.2032	0.0798	X
	9	58.0844	-12.0844	3.0398	58.0854	-11.8948	3.0135	-0.0010	0.1896	0.0263	0.1914	0.0263	Z
	10	58.0778	-7.3657	3.0673	58.0846	-7.1439	3.0396	-0.0068	0.2218	0.0277	0.2236	0.0277	Z
FLOOR PAN (Z)	11	53.0306	-24.1075	5.2257	53.0498	-23.8757	5.2057	-0.0192	0.2318	0.0200	0.2335	0.0200	Z
	12	52.9676	-20.5753	5.2371	52.9634	-20.3722	5.2108	0.0042	0.2031	0.0263	0.2048	0.0263	Z
	13	52.8463	-17.3266	5.2490	52.8593	-17.0998	5.2201	-0.0130	0.2268	0.0289	0.2290	0.0289	Z
	14	52.9201	-12.6956	5.2679	52.8701	-12.3894	5.2376	0.0500	0.3062	0.0303	0.3117	0.0303	Z
	15	53.0423	-7.6201	5.3030	53.0358	-7.4042	5.2699	0.0065	0.2159	0.0331	0.2185	0.0331	Z
	16	49.1753	-23.9744	5.2625	49.1852	-23.8205	5.2427	-0.0099	0.1539	0.0198	0.1555	0.0198	Z
	17	49.1906	-21.0772	5.2713	49.1949	-20.8311	5.2482	-0.0043	0.2461	0.0231	0.2472	0.0231	Z
	18	49.1063	-17.3353	5.2720	49.1463	-17.0752	5.2474	-0.0400	0.2601	0.0246	0.2643	0.0246	Z
	19	49.2076	-13.0781	5.2874	49.2397	-12.7857	5.2619	-0.0321	0.2924	0.0255	0.2953	0.0255	Z
	20	49.1472	-7.6850	5.3200	49.1365	-7.4319	5.2984	0.0107	0.2531	0.0216	0.2542	0.0216	Z
	21	44.9364	-24.3654	5.2703	44.9264	-24.1533	5.2216	0.0100	0.2121	0.0487	0.2178	0.0487	Z
	22	44.9358	-21.5493	5.2590	44.9618	-21.3436	5.2474	-0.0260	0.2057	0.0116	0.2077	0.0116	Z
	23	44.9756	-17.3717	5.2686	44.9556	-17.1001	5.2528	0.0200	0.2716	0.0158	0.2728	0.0158	Z
	24	44.9955	-12.8678	5.2969	45.0761	-12.6373	5.2821	-0.0806	0.2305	0.0148	0.2446	0.0148	Z
	25	45.1927	-7.5153	5.3039	45.2366	-7.3139	5.2901	-0.0439	0.2014	0.0138	0.2066	0.0138	Z
	26	40.5602	-24.4533	5.2681	40.6562	-24.2433	5.2526	-0.0960	0.2100	0.0155	0.2314	0.0155	Z
	27	40.6470	-21.2828	5.2744	40.6242	-21.0541	5.2659	0.0228	0.2287	0.0085	0.2300	0.0085	Z
	28	40.6348	-17.4157	5.2606	40.6561	-17.1898	5.2532	-0.0213	0.2259	0.0074	0.2270	0.0074	Z
	29	40.6831	-12.8694	5.2875	40.6794	-12.6421	5.2754	0.0037	0.2273	0.0121	0.2277	0.0121	Z
	30	40.8836	-7.3101	5.2354	40.9128	-7.0518	5.2216	-0.0292	0.2583	0.0138	0.2603	0.0138	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.
[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.
[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Pretest Floor Pan	Posttest Floor Pan
	

Figure D-33. Floor Pan Deformation Data – Set 1 Left, Test No. MSPBN-7

Date: 6/5/2018 Test Name: MSPBN-7 VIN: 1C6RD6KT4CS197048
Year: 2012 Make: Dodge Ram Model: Ram 1500

VEHICLE DEFORMATION
FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	62.2858	20.5795	-3.3578	62.2965	20.6160	-3.3728	-0.0107	-0.0365	0.0150	0.0409	0.0150	Z
	2	63.5073	22.5526	-2.2597	63.5059	22.5703	-2.2968	0.0014	-0.0177	0.0371	0.0411	0.0371	X, Z
	3	64.6631	25.5298	-1.3812	64.6503	25.5481	-1.3786	0.0128	-0.0183	-0.0026	0.0225	0.0128	X
	4	64.1280	28.7562	-1.5187	64.0797	28.8029	-1.4968	0.0483	-0.0467	-0.0219	0.0707	0.0483	X
	5	62.8407	31.7697	-2.5620	62.8608	31.7982	-2.6074	-0.0201	-0.0285	0.0454	0.0572	0.0454	Z
	6	56.6094	17.9298	-1.9242	56.5555	17.9175	-1.9246	0.0539	0.0123	0.0004	0.0553	0.0539	X, Z
	7	57.6386	21.5077	0.7921	57.5985	21.5228	0.8189	0.0401	-0.0151	-0.0268	0.0505	0.0401	X
	8	58.4166	23.5694	2.5542	58.4490	23.5773	2.5352	-0.0324	-0.0079	0.0190	0.0384	0.0190	Z
	9	58.1063	26.4476	2.7685	58.1267	26.4543	2.7577	-0.0204	-0.0067	0.0108	0.0240	0.0108	Z
	10	58.0606	31.6476	2.7937	58.0372	31.6728	2.8111	0.0234	-0.0252	-0.0174	0.0385	0.0234	X
FLOOR PAN (Z)	11	53.3481	16.4107	-0.6646	53.3547	16.4304	-0.6793	-0.0066	-0.0197	0.0147	0.0255	0.0147	Z
	12	54.1036	20.3754	2.1334	54.0824	20.3560	2.1126	0.0212	0.0194	0.0208	0.0355	0.0208	Z
	13	54.9177	23.2082	4.5683	54.9112	23.2619	4.5759	0.0065	-0.0537	-0.0076	0.0546	-0.0076	Z
	14	54.8707	27.8453	4.5990	54.8840	27.7974	4.5926	-0.0133	0.0479	0.0064	0.0501	0.0064	Z
	15	54.6090	31.6974	4.4866	54.5611	31.7368	4.5147	0.0479	-0.0394	-0.0281	0.0681	-0.0281	Z
	16	50.2408	15.6792	1.4280	50.2138	15.6665	1.4172	0.0270	0.0127	0.0108	0.0317	0.0108	Z
	17	51.0317	18.0137	3.4462	51.0155	18.0375	3.4981	0.0162	-0.0238	-0.0519	0.0594	-0.0519	Z
	18	51.3442	21.2862	5.2573	51.3513	21.3386	5.2659	-0.0071	-0.0524	-0.0086	0.0536	-0.0086	Z
	19	51.2078	25.6364	5.3174	51.1961	25.6021	5.3249	0.0117	0.0343	-0.0075	0.0370	-0.0075	Z
	20	51.0600	30.4290	5.3252	50.9991	30.4200	5.3342	0.0609	0.0090	-0.0090	0.0622	-0.0090	Z
	21	46.5212	14.1858	2.2075	46.4882	14.1876	2.2111	0.0330	-0.0018	-0.0036	0.0332	-0.0036	Z
	22	47.1496	16.8449	5.2597	47.1214	16.8694	5.2688	0.0282	-0.0245	-0.0091	0.0384	-0.0091	Z
	23	46.9223	24.4241	5.3489	46.8644	24.4398	5.3628	0.0579	-0.0157	-0.0139	0.0616	-0.0139	Z
	24	47.3202	28.4278	5.3339	47.2794	28.4533	5.3440	0.0408	-0.0255	-0.0101	0.0492	-0.0101	Z
	25	47.1715	32.2016	5.3449	47.1471	32.2313	5.3539	0.0244	-0.0297	-0.0090	0.0395	-0.0090	Z
	26	42.4702	13.9918	1.5756	42.5083	14.2892	2.5284	-0.0381	-0.2974	-0.9528	0.9989	-0.9528	Z
	27	43.8181	16.8874	5.1100	43.8103	16.9704	5.1107	0.0078	-0.0830	-0.0007	0.0834	-0.0007	Z
	28	43.8224	22.1266	5.1021	43.8371	22.1630	5.1050	-0.0147	-0.0364	-0.0029	0.0394	-0.0029	Z
	29	43.8375	27.1694	5.1070	43.7657	27.1902	5.1139	0.0718	-0.0208	-0.0069	0.0751	-0.0069	Z
	30	43.8050	31.8099	5.1232	43.7725	31.8124	5.1286	0.0325	-0.0025	-0.0054	0.0330	-0.0054	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Pretest Floor Pan	Posttest Floor Pan
	

Figure D-34. Floor Pan Deformation Data – Set 1 Right, Test No. MSPBN-7

Date: 6/5/2018 Test Name: MSPBN-7 VIN: 1C6RD6KT4CS197048
Year: 2012 Make: Dodge Ram Model: Ram 1500

VEHICLE DEFORMATION
FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	63.0297	-8.1096	-4.5702	63.0761	-8.1264	-4.5531	-0.0464	-0.0168	-0.0171	0.0522	0.0000	NA
	2	64.2948	-4.2299	-3.5318	64.3446	-4.2615	-3.5080	-0.0498	-0.0316	-0.0238	0.0636	0.0000	NA
	3	64.2887	-0.4927	-3.3541	64.3692	-0.4701	-3.3186	-0.0805	0.0226	-0.0355	0.0908	0.0000	NA
	4	64.1926	4.0725	-3.2548	64.2618	3.9999	-3.2165	-0.0692	0.0726	-0.0383	0.1074	0.0000	NA
	5	63.4826	8.5757	-4.1104	63.5341	8.5728	-4.0621	-0.0515	0.0029	-0.0483	0.0707	0.0000	NA
	6	59.8850	-8.0914	-1.1133	59.9022	-8.0665	-1.0909	-0.0172	0.0249	-0.0224	0.0377	0.0000	NA
	7	59.7782	-4.1304	-1.0464	59.7977	-4.0499	-0.9775	-0.0195	0.0805	-0.0689	0.1077	0.0000	NA
	8	59.9267	-0.4741	-1.0592	59.8904	-0.5298	-0.9760	0.0363	-0.0557	-0.0832	0.1065	0.0363	X
	9	60.0772	3.9567	-1.0771	60.1224	3.9037	-1.0338	-0.0452	0.0530	-0.0433	0.0820	0.0000	NA
	10	60.1197	8.6750	-1.0294	60.1717	8.6541	-0.9864	-0.0520	0.0209	-0.0430	0.0706	0.0000	NA
FLOOR PAN (Z)	11	54.8905	-8.0221	1.0402	54.9491	-8.0330	1.0779	-0.0586	-0.0109	-0.0377	0.0705	-0.0377	Z
	12	54.8644	-4.4895	1.0666	54.8997	-4.5287	1.0984	-0.0353	-0.0392	-0.0318	0.0616	-0.0318	Z
	13	54.7771	-1.2398	1.0920	54.8301	-1.2555	1.1219	-0.0530	-0.0157	-0.0299	0.0628	-0.0299	Z
	14	54.8992	3.3901	1.1311	54.8905	3.4544	1.1607	0.0087	-0.0643	-0.0296	0.0713	-0.0296	Z
	15	55.0744	8.4638	1.1883	55.1087	8.4373	1.2163	-0.0343	0.0265	-0.0280	0.0516	-0.0280	Z
	16	51.0367	-7.8488	1.0646	51.0851	-7.9370	1.0950	-0.0484	-0.0882	-0.0304	0.1051	-0.0304	Z
	17	51.0822	-4.9520	1.0859	51.1264	-4.9479	1.1140	-0.0442	0.0041	-0.0281	0.0525	-0.0281	Z
	18	51.0371	-1.2094	1.1024	51.1174	-1.1917	1.1299	-0.0803	0.0177	-0.0275	0.0867	-0.0275	Z
	19	51.1828	3.0464	1.1365	51.2561	3.0964	1.1642	-0.0733	-0.0500	-0.0277	0.0930	-0.0277	Z
	20	51.1787	8.4397	1.1921	51.2092	8.4508	1.2243	-0.0305	-0.0111	-0.0322	0.0457	-0.0322	Z
	21	46.7940	-8.1955	1.0566	46.8232	-8.2246	1.0501	-0.0292	-0.0291	0.0065	0.0417	0.0065	Z
	22	46.8228	-5.3794	1.0574	46.8882	-5.4156	1.0888	-0.0654	-0.0362	-0.0314	0.0811	-0.0314	Z
	23	46.9063	-1.2026	1.0851	46.9268	-1.1723	1.1133	-0.0205	0.0303	-0.0282	0.0462	-0.0282	Z
	24	46.9731	3.3008	1.1328	47.0942	3.2888	1.1633	-0.1211	0.0120	-0.0305	0.1255	-0.0305	Z
	25	47.2263	8.6507	1.1634	47.3109	8.6101	1.1962	-0.0846	0.0406	-0.0328	0.0994	-0.0328	Z
	26	42.4172	-8.2374	1.0394	42.5522	-8.2695	1.0583	-0.1350	-0.0321	-0.0189	0.1400	-0.0189	Z
	27	42.5371	-5.0682	1.0596	42.5538	-5.0803	1.0858	-0.0167	-0.0121	-0.0262	0.0333	-0.0262	Z
	28	42.5654	-1.2011	1.0623	42.6266	-1.2165	1.0907	-0.0612	-0.0154	-0.0284	0.0692	-0.0284	Z
	29	42.6611	3.3443	1.1089	42.6978	3.3306	1.1335	-0.0367	0.0137	-0.0246	0.0463	-0.0246	Z
	30	42.9198	8.9014	1.0814	42.9905	8.9183	1.1062	-0.0707	-0.0169	-0.0248	0.0768	-0.0248	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

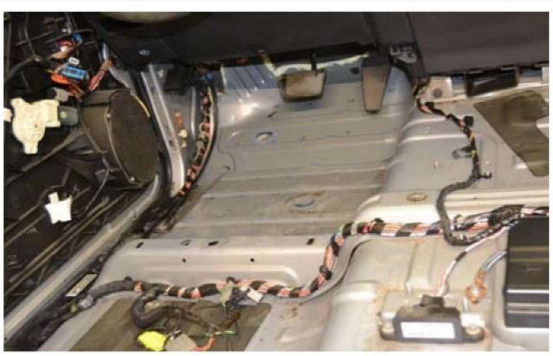
Pretest Floor Pan	Posttest Floor Pan
	

Figure D-35. Floor Pan Deformation Data – Set 2 Left, Test No. MSPBN-7

Date: 6/5/2018 Test Name: MSPBN-7 VIN: 1C6RD6KT4CS197048
Year: 2012 Make: Dodge Ram Model: Ram 1500

VEHICLE DEFORMATION
FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	64.6460	36.3491	-7.5100	64.4399	36.3970	-7.2481	0.2061	-0.0479	-0.2619	0.3367	0.2061	X
	2	65.8841	38.3037	-6.3974	65.6641	38.3333	-6.1565	0.2200	-0.0296	-0.2409	0.3276	0.2200	X
	3	67.0683	41.2639	-5.4999	66.8350	41.2945	-5.2182	0.2333	-0.0306	-0.2817	0.3670	0.2333	X
	4	66.5687	44.4966	-5.6240	66.2993	44.5556	-5.3237	0.2694	-0.0590	-0.3003	0.4077	0.2694	X
	5	65.3183	47.5288	-6.6579	65.1177	47.5688	-6.4262	0.2006	-0.0400	-0.2317	0.3091	0.2006	X
	6	58.9354	33.7542	-6.1124	58.6633	33.7522	-5.8422	0.2721	0.0020	-0.2702	0.3835	0.2721	X
	7	59.9917	37.3077	-3.3747	59.7300	37.3333	-3.0762	0.2617	-0.0256	-0.2985	0.3978	0.2617	X
	8	60.7846	39.3524	-1.5995	60.5931	39.3707	-1.3457	0.1915	-0.0183	-0.2538	0.3185	0.1915	X
	9	60.5044	42.2328	-1.3726	60.2999	42.2498	-1.1111	0.2045	-0.0170	-0.2615	0.3324	0.2045	X
	10	60.5148	47.4328	-1.3224	60.2650	47.4687	-1.0333	0.2498	-0.0359	-0.2891	0.3838	0.2498	X
FLOOR PAN (Z)	11	55.6526	32.2645	-4.8734	55.4406	32.2931	-4.6204	0.2120	-0.0286	-0.2530	0.3313	-0.2530	Z
	12	56.4391	36.2073	-2.0532	56.1951	36.1976	-1.8061	0.2440	0.0097	-0.2471	0.3474	-0.2471	Z
	13	57.2735	39.0194	0.3986	57.0416	39.0829	0.6752	0.2319	-0.0635	-0.2766	0.3665	-0.2766	Z
	14	57.2765	43.6566	0.4515	57.0621	43.6183	0.7135	0.2144	0.0383	-0.2620	0.3407	-0.2620	Z
	15	57.0569	47.5117	0.3567	56.7810	47.5612	0.6528	0.2759	-0.0495	-0.2961	0.4077	-0.2961	Z
	16	52.5288	31.5567	-2.7971	52.2811	31.5524	-2.5438	0.2477	0.0043	-0.2533	0.3543	-0.2533	Z
	17	53.3364	33.8727	-0.7644	53.0968	33.9050	-0.4475	0.2396	-0.0323	-0.3169	0.3986	-0.3169	Z
	18	53.6766	37.1330	1.0637	53.4582	37.1940	1.3378	0.2184	-0.0610	-0.2741	0.3557	-0.2741	Z
	19	53.5870	41.4840	1.1443	53.3475	41.4585	1.4164	0.2395	0.0255	-0.2721	0.3634	-0.2721	Z
	20	53.4909	46.2778	1.1746	53.2012	46.2782	1.4477	0.2897	-0.0004	-0.2731	0.3981	-0.2731	Z
	21	48.7901	30.0998	-2.0400	48.5360	30.1091	-1.7761	0.2541	-0.0093	-0.2639	0.3665	-0.2639	Z
	22	49.4343	32.7374	1.0276	49.1816	32.7697	1.2976	0.2527	-0.0323	-0.2700	0.3712	-0.2700	Z
	23	49.2885	40.3181	1.1525	49.0037	40.3418	1.4265	0.2848	-0.0237	-0.2740	0.3959	-0.2740	Z
	24	49.7297	44.3172	1.1584	49.4610	44.3507	1.4290	0.2687	-0.0335	-0.2706	0.3828	-0.2706	Z
	25	49.6217	48.0923	1.1870	49.3683	48.1298	1.4563	0.2534	-0.0375	-0.2693	0.3717	-0.2693	Z
	26	44.7399	29.9526	-2.6893	44.5558	30.2512	-1.4787	0.1841	-0.2986	-1.2106	1.2604	-1.2106	Z
	27	46.1042	32.8166	0.8645	45.8726	32.9063	1.1230	0.2316	-0.0897	-0.2585	0.3585	-0.2585	Z
	28	46.1651	38.0554	0.8820	45.9540	38.0982	1.1423	0.2111	-0.0428	-0.2603	0.3379	-0.2603	Z
	29	46.2346	43.0977	0.9113	45.9354	43.1258	1.1748	0.2992	-0.0281	-0.2635	0.3997	-0.2635	Z
	30	46.2521	47.7381	0.9497	45.9907	47.7475	1.2117	0.2614	-0.0094	-0.2620	0.3702	-0.2620	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Pretest Floor Pan	Posttest Floor Pan
	

Figure D-36. Floor Pan Deformation Data – Set 2 Right, Test No. MSPBN-7

Date: 6/5/2018 Test Name: MSPBN-7 VIN: 1C6RD6KT4CS197048
Year: 2012 Make: Dodge Ram Model: Ram 1500

VEHICLE DEFORMATION
INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	44.9831	5.5266	-26.5238	45.0258	5.7871	-26.5660	-0.0427	-0.2605	-0.0422	0.2673	0.2673	X, Y, Z
	2	46.6154	-9.3183	-28.7516	46.6123	-9.0450	-28.7283	0.0031	0.2733	0.0233	0.2743	0.2743	X, Y, Z
	3	46.9769	-19.4522	-28.5658	46.9987	-19.2020	-28.6026	-0.0218	0.2502	-0.0368	0.2538	0.2538	X, Y, Z
	4	44.6216	-7.8615	-14.3818	44.6581	-7.6467	-14.3299	-0.0365	0.2148	0.0519	0.2240	0.2240	X, Y, Z
	5	44.0494	-14.1556	-14.0511	44.0079	-13.9249	-14.1141	0.0415	0.2307	-0.0630	0.2427	0.2427	X, Y, Z
	6	46.0060	-20.7610	-13.5103	46.0450	-20.5706	-13.4308	-0.0390	0.1904	0.0795	0.2100	0.2100	X, Y, Z
SIDE PANEL (Y)	7	54.2184	-27.8335	-5.9384	54.2972	-27.5717	-5.8686	-0.0788	0.2618	0.0698	0.2822	0.2618	Y
	8	58.7627	-27.7161	-3.1266	58.7556	-27.4587	-3.0956	0.0071	0.2574	0.0310	0.2594	0.2574	Y
	9	54.2708	-27.8329	-1.5579	54.2554	-27.5677	-1.5689	0.0154	0.2652	-0.0110	0.2659	0.2652	Y
IMPACT SIDE DOOR (Y)	10	23.4286	-29.9422	-19.5828	23.4207	-29.8577	-19.5903	0.0079	0.0845	-0.0075	0.0852	0.0845	Y
	11	33.5914	-29.7795	-19.6028	33.6375	-29.6311	-19.6156	-0.0461	0.1484	-0.0128	0.1559	0.1484	Y
	12	43.5261	-29.8027	-19.7519	43.5276	-29.5693	-19.8434	-0.0015	0.2334	-0.0915	0.2507	0.2334	Y
	13	23.5246	-30.2343	-0.9106	23.5349	-29.8611	-0.8476	-0.0103	0.3732	0.0630	0.3786	0.3732	Y
	14	33.2524	-30.6321	-0.4932	33.2924	-30.2284	-0.4121	-0.0400	0.4037	0.0811	0.4137	0.4037	Y
	15	39.9405	-30.9244	-0.7490	39.9501	-30.5197	-0.7336	-0.0096	0.4047	0.0154	0.4051	0.4047	Y
ROOF - (Z)	16	38.0400	-17.2324	-42.2507	38.1502	-17.0286	-42.1767	-0.1102	0.2038	0.0740	0.2432	0.0740	Z
	17	39.2694	-12.8553	-42.3911	39.3564	-12.6946	-42.3222	-0.0870	0.1607	0.0689	0.1953	0.0689	Z
	18	40.2936	-7.1262	-42.5303	40.3600	-6.9588	-42.4720	-0.0664	0.1674	0.0583	0.1893	0.0583	Z
	19	40.8298	-2.1702	-42.5759	40.8333	-1.9003	-42.5541	-0.0035	0.2699	0.0218	0.2708	0.0218	Z
	20	41.0165	2.7674	-42.6146	41.0052	3.0354	-42.6028	0.0113	-0.2680	0.0118	0.2685	0.0118	Z
	21	34.0904	-16.5230	-42.9703	34.1371	-16.2761	-42.9390	-0.0467	0.2469	0.0313	0.2532	0.0313	Z
	22	34.9987	-12.5682	-43.2236	35.0704	-12.4152	-43.1716	-0.0717	0.1530	0.0520	0.1768	0.0520	Z
	23	36.1832	-7.1838	-43.3469	36.1952	-6.9078	-43.3233	-0.0120	0.2760	0.0236	0.2773	0.0236	Z
	24	36.7250	-2.0878	-43.4207	36.7632	-1.8861	-43.3886	-0.0382	0.2017	0.0321	0.2078	0.0321	Z
	25	36.8509	2.5116	-43.4850	36.8512	2.7570	-43.4703	-0.0003	-0.2454	0.0147	0.2458	0.0147	Z
	26	31.5900	-16.0166	-45.1181	31.6416	-15.8152	-45.0862	-0.0516	0.2014	0.0319	0.2103	0.0319	Z
	27	31.9692	-11.8469	-45.4042	32.0562	-11.6066	-45.3703	-0.0870	0.2403	0.0339	0.2578	0.0339	Z
	28	32.7881	-6.9448	-45.5496	32.8383	-6.6654	-45.5246	-0.0502	0.2794	0.0250	0.2850	0.0250	Z
	29	33.1773	-1.9541	-45.6587	33.2213	-1.6543	-45.6340	-0.0440	0.2998	0.0247	0.3040	0.0247	Z
	30	33.4977	2.5682	-45.6611	33.5484	2.8746	-45.6367	-0.0507	-0.3064	0.0244	0.3115	0.0244	Z
A-PILLAR Maximum (X, Y, Z)	31	51.3103	-26.1356	-29.5199	51.2953	-25.8871	-29.5691	0.0150	0.2485	-0.0492	0.2538	0.2490	X, Y
	32	49.6893	-25.7440	-30.8540	49.6854	-25.5201	-30.8642	0.0039	0.2239	-0.0102	0.2242	0.2239	X, Y
	33	46.5848	-24.0664	-32.4533	46.5935	-23.8251	-32.4813	-0.0087	0.2413	-0.0280	0.2431	0.2413	Y
	34	42.8569	-23.4668	-35.6711	42.9290	-23.1839	-35.7199	-0.0721	0.2829	-0.0488	0.2960	0.2829	Y
	35	39.7680	-22.5235	-37.0366	39.8191	-22.2207	-37.1039	-0.0511	0.3028	-0.0673	0.3144	0.3028	Y
	36	35.5165	-22.5125	-40.1937	35.5570	-22.2640	-40.2054	-0.0405	0.2485	-0.0117	0.2521	0.2485	Y
A-PILLAR Lateral (Y)	31	51.3103	-26.1356	-29.5199	51.2953	-25.8871	-29.5691	0.0150	0.2485	-0.0492	0.2538	0.2485	Y
	32	49.6893	-25.7440	-30.8540	49.6854	-25.5201	-30.8642	0.0039	0.2239	-0.0102	0.2242	0.2239	Y
	33	46.5848	-24.0664	-32.4533	46.5935	-23.8251	-32.4813	-0.0087	0.2413	-0.0280	0.2431	0.2413	Y
	34	42.8569	-23.4668	-35.6711	42.9290	-23.1839	-35.7199	-0.0721	0.2829	-0.0488	0.2960	0.2829	Y
	35	39.7680	-22.5235	-37.0366	39.8191	-22.2207	-37.1039	-0.0511	0.3028	-0.0673	0.3144	0.3028	Y
	36	35.5165	-22.5125	-40.1937	35.5570	-22.2640	-40.2054	-0.0405	0.2485	-0.0117	0.2521	0.2485	Y
B-PILLAR Maximum (X, Y, Z)	37	9.8420	-23.4450	-39.7915	9.9195	-23.2081	-39.7694	-0.0775	0.2369	0.0221	0.2502	0.2379	Y, Z
	38	12.6827	-23.3341	-40.0089	12.6858	-23.0897	-40.0173	-0.0031	0.2444	-0.0084	0.2446	0.2444	Y
	39	10.4134	-27.0269	-29.2968	10.5387	-26.7727	-29.3489	-0.1253	0.2542	-0.0521	0.2882	0.2542	Y
	40	13.5797	-26.8974	-29.6897	13.5962	-26.6514	-29.7133	-0.0165	0.2460	-0.0236	0.2477	0.2460	Y
B-PILLAR Lateral (Y)	37	9.8420	-23.4450	-39.7915	9.9195	-23.2081	-39.7694	-0.0775	0.2369	0.0221	0.2502	0.2369	Y
	38	12.6827	-23.3341	-40.0089	12.6858	-23.0897	-40.0173	-0.0031	0.2444	-0.0084	0.2446	0.2444	Y
	39	10.4134	-27.0269	-29.2968	10.5387	-26.7727	-29.3489	-0.1253	0.2542	-0.0521	0.2882	0.2542	Y
	40	13.5797	-26.8974	-29.6897	13.5962	-26.6514	-29.7133	-0.0165	0.2460	-0.0236	0.2477	0.2460	Y

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-37. Occupant Compartment Deformation Data – Set 1 Left, Test No. MSPBN-7

Date: 6/5/2018 Test Name: MSPBN-7 VIN: 1C6RD6KT4CS197048
Year: 2012 Make: Dodge Ram Model: Ram 1500

VEHICLE DEFORMATION
INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	44.9375	5.5485	-26.4978	45.0291	5.7733	-26.5435	-0.0916	-0.2248	-0.0457	0.2470	0.2470	X, Y, Z
	2	47.5943	14.4140	-25.9241	47.6403	14.7643	-25.9380	-0.0460	-0.3503	-0.0139	0.3536	0.3536	X, Y, Z
	3	48.3278	25.8330	-25.8906	48.3199	26.1207	-25.8672	0.0079	-0.2877	0.0234	0.2888	0.2888	X, Y, Z
	4	42.2441	4.7982	-16.9774	42.2777	5.0041	-16.9673	-0.0336	-0.2059	0.0101	0.2089	0.2089	X, Y, Z
	5	44.0565	14.6686	-15.9760	44.0727	14.8596	-15.9146	-0.0162	-0.1910	0.0614	0.2013	0.2013	X, Y, Z
	6	44.5504	25.6461	-16.0622	44.5488	25.9112	-15.9883	0.0016	-0.2651	0.0739	0.2752	0.2752	X, Y, Z
SIDE PANEL (Y)	7	58.6838	36.8466	-6.0891	58.7104	37.1151	-6.0840	-0.0266	-0.2685	0.0051	0.2699	-0.2685	Y
	8	54.1841	36.6212	-6.0202	54.1628	36.8938	-5.9580	0.0213	-0.2726	0.0622	0.2804	-0.2726	Y
	9	55.2543	36.5037	1.4510	55.2002	36.7658	1.5155	0.0541	-0.2621	0.0645	0.2753	-0.2621	Y
IMPACT SIDE DOOR (Y)	10	45.0572	38.6192	-19.7583	45.0268	38.8375	-19.7022	0.0304	-0.2183	0.0561	0.2274	-0.2183	Y
	11	34.1834	38.4837	-18.7495	34.2021	38.7075	-18.7524	-0.0187	-0.2238	-0.0029	0.2246	-0.2238	Y
	12	24.1068	38.4802	-19.5554	24.1397	38.6838	-19.4948	-0.0329	-0.2036	0.0606	0.2150	-0.2036	Y
	13	38.3443	39.7429	-3.1773	38.3565	39.9757	-3.0960	-0.0122	-0.2328	0.0813	0.2469	-0.2328	Y
	14	33.7403	39.2512	0.7313	33.6992	39.4934	0.8543	0.0411	-0.2422	0.1230	0.2747	-0.2422	Y
	15	25.8772	38.6866	-0.6293	25.9917	38.9251	-0.5046	-0.1145	-0.2385	0.1247	0.2925	-0.2385	Y
ROOF - (Z)	16	41.0383	6.1361	-42.6750	41.1121	6.3079	-42.5472	-0.0738	-0.1718	0.1278	0.2265	0.1278	Z
	17	40.7537	12.6244	-42.5969	40.7367	12.7856	-42.5234	0.0170	-0.1612	0.0735	0.1780	0.0735	Z
	18	40.1163	17.0071	-42.5106	40.1816	17.1857	-42.4071	-0.0653	-0.1786	0.1035	0.2165	0.1035	Z
	19	39.2385	21.3792	-42.3598	39.2192	21.5594	-42.3055	0.0193	-0.1802	0.0543	0.1892	0.0543	Z
	20	38.3668	24.8673	-42.1449	38.3640	25.0457	-42.0919	0.0028	-0.1784	0.0530	0.1861	0.0530	Z
	21	36.7417	7.3150	-43.5399	36.7928	7.4428	-43.4296	-0.0511	-0.1278	0.1103	0.1764	0.1103	Z
	22	36.5466	12.5417	-43.3768	36.5665	12.7547	-43.2897	-0.0199	-0.2130	0.0871	0.2310	0.0871	Z
	23	35.7312	16.7993	-43.3293	35.7461	17.0370	-43.2471	-0.0149	-0.2377	0.0822	0.2520	0.0822	Z
	24	34.9309	21.0342	-43.1365	34.9615	21.2365	-43.0641	-0.0306	-0.2023	0.0724	0.2170	0.0724	Z
	25	34.0046	24.6578	-42.9066	34.0113	24.8750	-42.8437	-0.0067	-0.2172	0.0629	0.2262	0.0629	Z
	26	34.5102	6.7670	-45.4805	34.5721	6.8911	-45.3756	-0.0619	-0.1241	0.1049	0.1739	0.1049	Z
	27	33.8205	11.9247	-45.4833	33.8272	12.1016	-45.4019	-0.0067	-0.1769	0.0814	0.1948	0.0814	Z
	28	33.5282	16.2493	-45.3337	33.5712	16.4955	-45.2471	-0.0430	-0.2462	0.0866	0.2645	0.0866	Z
	29	32.6139	20.7093	-45.1914	32.6420	20.8552	-45.1243	-0.0281	-0.1459	0.0671	0.1630	0.0671	Z
	30	31.8984	24.5077	-44.9599	31.9253	24.7202	-44.8935	-0.0269	-0.2125	0.0664	0.2243	0.0664	Z
A-PILLAR Maximum (X, Y, Z)	31	52.2090	35.1726	-28.5567	52.3087	35.3542	-28.4719	-0.0997	-0.1816	0.0848	0.2239	0.0848	Z
	32	50.1895	34.7098	-30.2017	50.2751	34.9111	-30.0807	-0.0856	-0.2013	0.1210	0.2500	0.1210	Z
	33	46.8016	33.1225	-31.9023	46.8490	33.2933	-31.8246	-0.0474	-0.1708	0.0777	0.1935	0.0777	Z
	34	44.0363	32.8412	-34.3499	44.0672	33.0277	-34.2714	-0.0309	-0.1865	0.0785	0.2047	0.0785	Z
	35	40.0802	31.5647	-36.4148	40.1417	31.7451	-36.3293	-0.0615	-0.1804	0.0855	0.2089	0.0855	Z
	36	12.7163	31.8196	-39.6627	35.8895	31.6035	-39.5966	-23.1732	0.2161	0.0661	23.1743	0.2260	Y, Z
A-PILLAR Lateral (Y)	31	52.2090	35.1726	-28.5567	52.3087	35.3542	-28.4719	-0.0997	-0.1816	0.0848	0.2239	-0.1816	Y
	32	50.1895	34.7098	-30.2017	50.2751	34.9111	-30.0807	-0.0856	-0.2013	0.1210	0.2500	-0.2013	Y
	33	46.8016	33.1225	-31.9023	46.8490	33.2933	-31.8246	-0.0474	-0.1708	0.0777	0.1935	-0.1708	Y
	34	44.0363	32.8412	-34.3499	44.0672	33.0277	-34.2714	-0.0309	-0.1865	0.0785	0.2047	-0.1865	Y
	35	40.0802	31.5647	-36.4148	40.1417	31.7451	-36.3293	-0.0615	-0.1804	0.0855	0.2089	-0.1804	Y
	36	12.7163	31.8196	-39.6627	35.8895	31.6035	-39.5966	-23.1732	0.2161	0.0661	23.1743	0.2161	Y
B-PILLAR Maximum (X, Y, Z)	37	12.7049	31.8159	-39.6734	12.7289	32.0516	-39.6393	-0.0240	-0.2357	0.0341	0.2394	0.0341	Z
	38	10.3654	32.1261	-39.5726	10.3638	32.3650	-39.5061	0.0016	-0.2389	0.0665	0.2480	0.0665	X, Z
	39	13.7533	34.8662	-31.2791	13.7506	35.1084	-31.1920	0.0027	-0.2422	0.0871	0.2574	0.0871	X, Z
	40	10.6999	35.3309	-29.5463	10.6490	35.5510	-29.4971	0.0509	-0.2201	0.0492	0.2312	0.0708	X, Z
B-PILLAR Lateral (Y)	37	12.7049	31.8159	-39.6734	12.7289	32.0516	-39.6393	-0.0240	-0.2357	0.0341	0.2394	-0.2357	Y
	38	10.3654	32.1261	-39.5726	10.3638	32.3650	-39.5061	0.0016	-0.2389	0.0665	0.2480	-0.2389	Y
	39	13.7533	34.8662	-31.2791	13.7506	35.1084	-31.1920	0.0027	-0.2422	0.0871	0.2574	-0.2422	Y
	40	10.6999	35.3309	-29.5463	10.6490	35.5510	-29.4971	0.0509	-0.2201	0.0492	0.2312	-0.2201	Y

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-38. Occupant Compartment Deformation Data – Set 1 Right, Test No. MSPBN-7

Date: 6/5/2018 Test Name: MSPBN-7 VIN: 1C6RD6KT4CS197048
Year: 2012 Make: Dodge Ram Model: Ram 1500

VEHICLE DEFORMATION
INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	47.2746	21.8226	-30.6149	47.3465	22.0676	-30.6437	-0.0719	-0.2450	-0.0288	0.2570	0.2570	X, Y, Z
	2	48.7564	6.9710	-32.9023	48.7821	7.2282	-32.8605	-0.0257	-0.2572	0.0418	0.2618	0.2618	X, Y, Z
	3	49.0092	-3.1669	-32.7598	49.0583	-2.9329	-32.7751	-0.0491	0.2340	-0.0153	0.2396	0.2396	X, Y, Z
	4	46.7278	8.3862	-18.5332	46.7822	8.5888	-18.4647	-0.0544	-0.2026	0.0685	0.2207	0.2207	X, Y, Z
	5	46.0874	2.0972	-18.2322	46.0634	2.3171	-18.2775	0.0240	-0.2199	-0.0453	0.2258	0.2258	X, Y, Z
	6	47.9716	-4.5310	-17.7137	48.0258	-4.3530	-17.6132	-0.0542	0.1780	0.1005	0.2115	0.2115	X, Y, Z
SIDE PANEL (Y)	7	56.0814	-11.7237	-10.1446	56.1699	-11.4736	-10.0454	-0.0885	0.2501	0.0992	0.2832	0.2501	Y
	8	60.6169	-11.6671	-7.3166	60.6175	-11.4201	-7.2533	-0.0006	0.2470	0.0633	0.2550	0.2470	Y
	9	56.1184	-11.7428	-5.7639	56.1100	-11.4866	-5.7460	0.0084	0.2562	0.0179	0.2570	0.2562	Y
IMPACT SIDE DOOR (Y)	10	25.3191	-13.4441	-23.9048	25.3289	-13.3698	-23.9054	-0.0098	0.0743	-0.0006	0.0749	0.0743	Y
	11	35.4830	-13.3897	-23.8888	35.5475	-13.2535	-23.8871	-0.0645	0.1362	0.0017	0.1507	0.1362	Y
	12	45.4174	-13.5184	-24.0036	45.4386	-13.2977	-24.0733	-0.0212	0.2207	-0.0697	0.2324	0.2207	Y
	13	25.3463	-13.8187	-5.2339	25.3638	-13.4508	-5.1626	-0.0175	0.3679	0.0713	0.3752	0.3679	Y
	14	35.0678	-14.3221	-4.7844	35.1147	-13.9254	-4.6878	-0.0469	0.3967	0.0966	0.4110	0.3967	Y
	15	41.7533	-14.6847	-5.0184	41.7702	-14.2872	-4.9827	-0.0169	0.3975	0.0357	0.3995	0.3975	Y
ROOF - (Z)	16	40.1447	-0.7922	-46.4658	40.2912	-0.6087	-46.3769	-0.1465	0.1835	0.0889	0.2511	0.0889	Z
	17	41.4211	3.5721	-46.5826	41.5447	3.7126	-46.4996	-0.1236	-0.1405	0.0830	0.2047	0.0830	Z
	18	42.5068	9.2905	-46.6931	42.6108	9.4378	-46.6215	-0.1040	-0.1473	0.0716	0.1940	0.0716	Z
	19	43.0959	14.2407	-46.7150	43.1389	14.4912	-46.6808	-0.0430	-0.2505	0.0342	0.2565	0.0342	Z
	20	43.3354	19.1761	-46.7313	43.3643	19.4249	-46.7084	-0.0289	-0.2488	0.0229	0.2515	0.0229	Z
	21	36.2054	-0.0375	-47.1959	36.2898	0.1903	-47.1530	-0.0844	0.2278	0.0429	0.2467	0.0429	Z
	22	37.1567	3.9084	-47.4286	37.2656	4.0418	-47.3657	-0.1089	-0.1334	0.0629	0.1833	0.0629	Z
	23	38.3989	9.2803	-47.5242	38.4504	9.5373	-47.4900	-0.0515	-0.2570	0.0342	0.2643	0.0342	Z
	24	38.9953	14.3705	-47.5737	39.0728	14.5528	-47.5322	-0.0775	-0.1823	0.0415	0.2024	0.0415	Z
	25	39.1703	18.9686	-47.6173	39.2112	19.1950	-47.5944	-0.0409	-0.2264	0.0229	0.2312	0.0229	Z
	26	33.7181	0.5048	-49.3501	33.8084	0.6869	-49.3086	-0.0903	-0.1821	0.0415	0.2075	0.0415	Z
	27	34.1427	4.6715	-49.6166	34.2696	4.8919	-49.5737	-0.1269	-0.2204	0.0429	0.2579	0.0429	Z
	28	35.0143	9.5651	-49.7375	35.1057	9.8249	-49.7043	-0.0914	-0.2598	0.0332	0.2774	0.0332	Z
	29	35.4571	14.5519	-49.8233	35.5432	14.8320	-49.7915	-0.0861	-0.2801	0.0318	0.2948	0.0318	Z
	30	35.8256	19.0705	-49.8047	35.9191	19.3571	-49.7741	-0.0935	-0.2866	0.0306	0.3030	0.0306	Z
A-PILLAR Maximum (X, Y, Z)	31	53.2745	-9.8919	-33.7283	53.2866	-9.6601	-33.7511	-0.0121	0.2318	-0.0228	0.2332	0.2318	Y
	32	51.6625	-9.4773	-35.0663	51.6862	-9.2704	-35.0514	-0.0237	0.2069	0.0149	0.2088	0.2074	Y, Z
	33	48.5816	-7.7597	-36.6689	48.6197	-7.5355	-36.6744	-0.0381	0.2242	-0.0055	0.2275	0.2242	Y
	34	44.8717	-7.1063	-39.8970	44.9760	-6.8415	-39.9257	-0.1043	0.2648	-0.0287	0.2860	0.2648	Y
	35	41.7978	-6.1241	-41.2690	41.8825	-5.8392	-41.3187	-0.0847	0.2849	-0.0497	0.3014	0.2849	Y
	36	37.5577	-6.0540	-44.4408	37.6334	-5.8237	-44.4382	-0.0757	0.2303	0.0026	0.2424	0.2303	Y, Z
A-PILLAR Lateral (Y)	31	53.2745	-9.8919	-33.7283	53.2866	-9.6601	-33.7511	-0.0121	0.2318	-0.0228	0.2332	0.2318	Y
	32	51.6625	-9.4773	-35.0663	51.6862	-9.2704	-35.0514	-0.0237	0.2069	0.0149	0.2088	0.2069	Y
	33	48.5816	-7.7597	-36.6689	48.6197	-7.5355	-36.6744	-0.0381	0.2242	-0.0055	0.2275	0.2242	Y
	34	44.8717	-7.1063	-39.8970	44.9760	-6.8415	-39.9257	-0.1043	0.2648	-0.0287	0.2860	0.2648	Y
	35	41.7978	-6.1241	-41.2690	41.8825	-5.8392	-41.3187	-0.0847	0.2849	-0.0497	0.3014	0.2849	Y
	36	37.5577	-6.0540	-44.4408	37.6334	-5.8237	-44.4382	-0.0757	0.2303	0.0026	0.2424	0.2303	Y
B-PILLAR Maximum (X, Y, Z)	37	11.8735	-6.7141	-44.1317	11.9855	-6.4925	-44.1133	-0.1120	0.2216	0.0184	0.2490	0.2224	Y, Z
	38	14.7160	-6.6326	-44.3388	14.7540	-6.4030	-44.3491	-0.0380	0.2296	-0.0103	0.2330	0.2296	Y
	39	12.3699	-10.3477	-33.6510	12.5223	-10.1061	-33.7051	-0.1524	0.2416	-0.0541	0.2907	0.2416	Y
	40	15.5387	-10.2503	-34.0323	15.5823	-10.0163	-34.0561	-0.0436	0.2340	-0.0238	0.2392	0.2340	Y
B-PILLAR Lateral (Y)	37	11.8735	-6.7141	-44.1317	11.9855	-6.4925	-44.1133	-0.1120	0.2216	0.0184	0.2490	0.2216	Y
	38	14.7160	-6.6326	-44.3388	14.7540	-6.4030	-44.3491	-0.0380	0.2296	-0.0103	0.2330	0.2296	Y
	39	12.3699	-10.3477	-33.6510	12.5223	-10.1061	-33.7051	-0.1524	0.2416	-0.0541	0.2907	0.2416	Y
	40	15.5387	-10.2503	-34.0323	15.5823	-10.0163	-34.0561	-0.0436	0.2340	-0.0238	0.2392	0.2340	Y

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-39. Occupant Compartment Deformation Data – Set 2 Left, Test No. MSPBN-7

Date: 6/5/2018 Test Name: MSPBN-7 VIN: 1C6RD6KT4CS197048
Year: 2012 Make: Dodge Ram Model: Ram 1500

VEHICLE DEFORMATION
INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	47.2388	21.8758	-30.5602	47.0826	21.8210	-30.6103	0.1562	0.0548	-0.0501	0.1729	0.1729	X, Y, Z
	2	49.9888	30.7085	-29.9246	49.7962	30.7776	-29.9492	0.1926	-0.0691	-0.0246	0.2061	0.2061	X, Y, Z
	3	50.8453	42.1185	-29.8219	50.6084	42.1248	-29.8189	0.2369	-0.0063	0.0030	0.2370	0.2370	X, Y, Z
	4	44.4998	21.0998	-21.0548	44.2820	21.0369	-21.0496	0.2178	0.0629	0.0052	0.2268	0.2268	X, Y, Z
	5	46.4146	30.9440	-19.9891	46.1879	30.8653	-19.9403	0.2267	0.0787	0.0488	0.2449	0.2449	X, Y, Z
	6	47.0273	41.9159	-20.0096	46.7936	41.9108	-19.9569	0.2337	0.0051	0.0527	0.2396	0.2396	X, Y, Z
SIDE PANEL (Y)	7	61.2411	52.9052	-9.9166	61.0436	52.8989	-9.9382	0.1975	0.0063	-0.0216	0.1988	0.0063	Y
	8	56.7390	52.7281	-9.8666	56.4932	52.7303	-9.8322	0.2458	-0.0022	0.0344	0.2482	-0.0022	Y
	9	57.7782	52.5559	-2.3920	57.4976	52.5532	-2.3552	0.2806	0.0027	0.0368	0.2830	0.0027	Y
IMPACT SIDE DOOR (Y)	10	47.6886	54.9038	-23.6283	47.4384	54.8488	-23.6042	0.2502	0.0550	0.0241	0.2573	0.0550	Y
	11	36.8101	54.8801	-22.6627	36.6091	54.8409	-22.7000	0.2010	0.0392	-0.0373	0.2082	0.0392	Y
	12	26.7373	54.9902	-23.5079	26.5502	54.9389	-23.4842	0.1871	0.0513	0.0237	0.1954	0.0513	Y
	13	40.9226	56.0045	-7.0674	40.7121	55.9831	-7.0204	0.2105	0.0214	0.0470	0.2167	0.0214	Y
	14	36.2982	55.5400	-3.1797	36.0330	55.5359	-3.0919	0.2652	0.0041	0.0878	0.2794	0.0041	Y
	15	28.4349	55.0683	-4.5742	28.3251	55.0647	-4.4856	0.1098	0.0036	0.0886	0.1411	0.0036	Y
ROOF - (Z)	16	43.4103	22.5987	-46.7488	43.2394	22.4805	-46.6272	0.1709	0.1182	0.1216	0.2408	0.1216	Z
	17	43.1954	29.0892	-46.6341	42.9397	28.9620	-46.5727	0.2557	0.1272	0.0614	0.2921	0.0614	Z
	18	42.6050	33.4779	-46.5249	42.4357	33.3677	-46.4368	0.1693	0.1102	0.0881	0.2204	0.0881	Z
	19	41.7739	37.8584	-46.3521	41.5241	37.7517	-46.3174	0.2498	0.1067	0.0347	0.2738	0.0347	Z
	20	40.9391	41.3543	-46.1203	40.7088	41.2468	-46.0899	0.2303	0.1075	0.0304	0.2560	0.0304	Z
	21	39.1301	23.8289	-47.6235	38.9374	23.6703	-47.5219	0.1927	0.1586	0.1016	0.2695	0.1016	Z
	22	38.9908	29.0565	-47.4309	38.7727	28.9838	-47.3564	0.2181	0.0727	0.0745	0.2417	0.0745	Z
	23	38.2212	33.3223	-47.3618	38.0023	33.2751	-47.2959	0.2189	0.0472	0.0659	0.2334	0.0659	Z
	24	37.4659	37.5644	-47.1475	37.2661	37.4825	-47.0951	0.1998	0.0819	0.0524	0.2222	0.0524	Z
	25	36.5778	41.1964	-46.9003	36.3576	41.1308	-46.8606	0.2202	0.0656	0.0397	0.2332	0.0397	Z
	26	36.9006	23.3163	-49.5760	36.7186	23.1543	-49.4798	0.1820	0.1620	0.0962	0.2620	0.0962	Z
	27	36.2666	28.4811	-49.5516	36.0348	28.3732	-49.4832	0.2318	0.1079	0.0684	0.2647	0.0684	Z
	28	36.0204	32.8077	-49.3779	35.8296	32.7690	-49.3076	0.1908	0.0387	0.0703	0.2070	0.0703	Z
	29	35.1537	37.2765	-49.2133	34.9510	37.1387	-49.1669	0.2027	0.1378	0.0464	0.2495	0.0464	Z
	30	34.4784	41.0809	-48.9626	34.2786	41.0105	-48.9197	0.1998	0.0704	0.0429	0.2161	0.0429	Z
A-PILLAR Maximum (X, Y, Z)	31	54.8377	51.4308	-32.4186	54.7159	51.3237	-32.3610	0.1218	0.1071	0.0576	0.1721	0.1721	X, Y, Z
	32	52.8198	50.9994	-34.0741	52.6840	50.9124	-33.9804	0.1358	0.0870	0.0937	0.1865	0.1865	X, Y, Z
	33	49.4218	49.4587	-35.7971	49.2466	49.3435	-35.7465	0.1752	0.1152	0.0506	0.2157	0.2157	X, Y, Z
	34	46.6633	49.2214	-38.2571	46.4722	49.1226	-38.2061	0.1911	0.0988	0.0510	0.2211	0.2211	X, Y, Z
	35	42.7019	47.9997	-40.3448	42.5406	47.8963	-40.2867	0.1613	0.1034	0.0581	0.2002	0.2002	X, Y, Z
	36	15.3554	48.5692	-43.6978	38.3007	47.8207	-43.5723	-22.9453	0.7485	0.1255	22.9578	0.7589	Y, Z
A-PILLAR Lateral (Y)	31	54.8377	51.4308	-32.4186	54.7159	51.3237	-32.3610	0.1218	0.1071	0.0576	0.1721	0.1071	Y
	32	52.8198	50.9994	-34.0741	52.6840	50.9124	-33.9804	0.1358	0.0870	0.0937	0.1865	0.0870	Y
	33	49.4218	49.4587	-35.7971	49.2466	49.3435	-35.7465	0.1752	0.1152	0.0506	0.2157	0.1152	Y
	34	46.6633	49.2214	-38.2571	46.4722	49.1226	-38.2061	0.1911	0.0988	0.0510	0.2211	0.0988	Y
	35	42.7019	47.9997	-40.3448	42.5406	47.8963	-40.2867	0.1613	0.1034	0.0581	0.2002	0.1034	Y
	36	15.3554	48.5692	-43.6978	38.3007	47.8207	-43.5723	-22.9453	0.7485	0.1255	22.9578	0.7485	Y
B-PILLAR Maximum (X, Y, Z)	37	15.3440	48.5657	-43.7086	15.1474	48.5405	-43.7087	0.1966	0.0252	-0.0001	0.1982	0.1982	X, Y
	38	13.0076	48.9006	-43.6152	12.7856	48.8810	-43.5837	0.2220	0.0196	0.0315	0.2251	0.2251	X, Y, Z
	39	16.3920	51.5560	-35.2927	16.1693	51.5434	-35.2421	0.2227	0.0126	0.0506	0.2287	0.2287	X, Y, Z
	40	13.3370	52.0438	-33.5692	13.0660	52.0139	-33.5579	0.2710	0.0299	0.0113	0.2729	0.2729	X, Y, Z
B-PILLAR Lateral (Y)	37	15.3440	48.5657	-43.7086	15.1474	48.5405	-43.7087	0.1966	0.0252	-0.0001	0.1982	0.0252	Y
	38	13.0076	48.9006	-43.6152	12.7856	48.8810	-43.5837	0.2220	0.0196	0.0315	0.2251	0.0196	Y
	39	16.3920	51.5560	-35.2927	16.1693	51.5434	-35.2421	0.2227	0.0126	0.0506	0.2287	0.0126	Y
	40	13.3370	52.0438	-33.5692	13.0660	52.0139	-33.5579	0.2710	0.0299	0.0113	0.2729	0.0299	Y

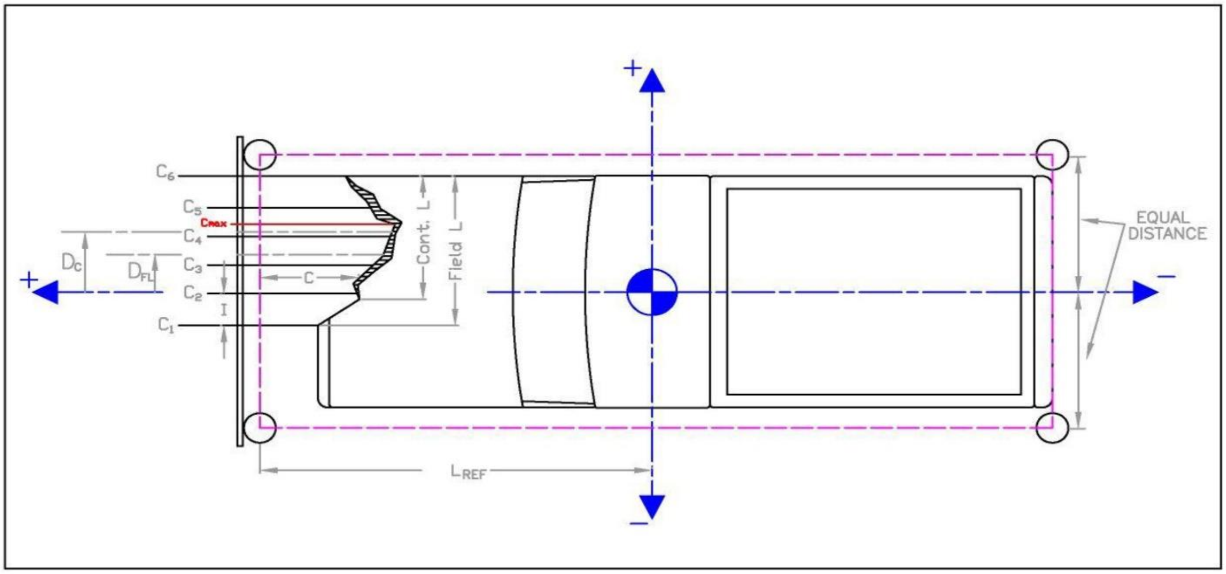
[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-40. Occupant Compartment Deformation Data – Set 2 Right, Test No. MSPBN-7

Date:	6/7/2018	Test Name:	MSPBN7	VIN:	1C6RD6KT4CS197048
Year:	2012	Make:	Dodge	Model:	Ram 1500



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	125 1/2	(3188)
Total Vehicle Width:	72	(1829)
Width of contact and induced crush - Field L:	72	(1829)
Crush measurement spacing interval (L/5) - I:	14 3/8	(365)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	72	(1829)
Distance from center of vehicle to center of contact damage - D_C:	36	(914)

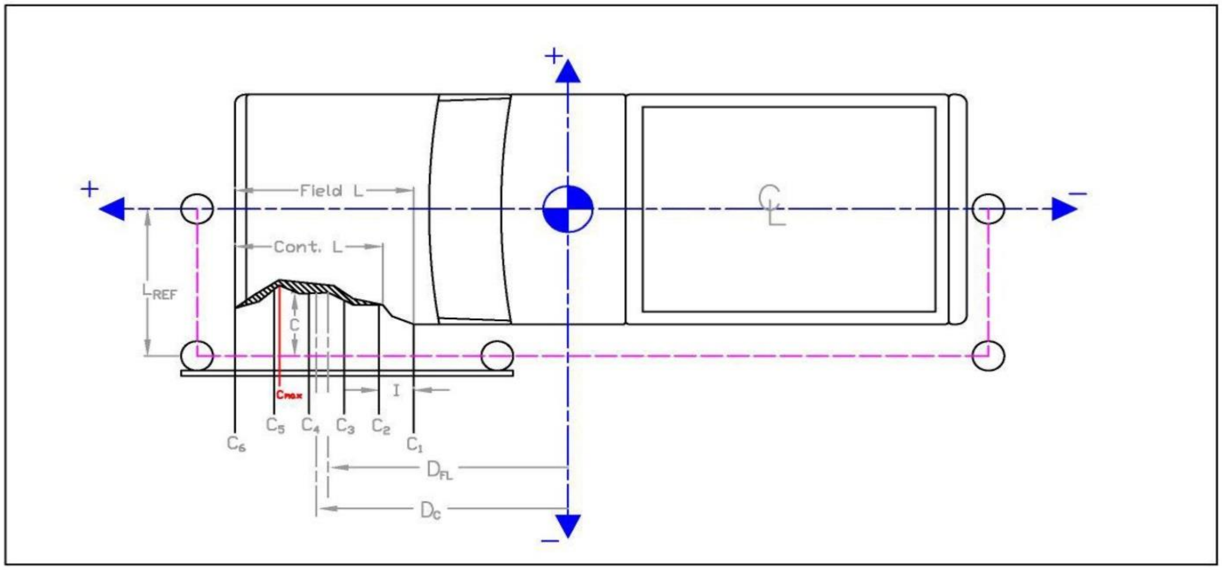
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)

NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/a	#VALUE!	-36	-(914)	15 1/8	(384)	20	(506)	#VALUE!	#VALUE!
C_2	27 1/2	(699)	-21 5/8	-(549)	6	(152)			1 4/7	(40)
C_3	26 7/8	(683)	-7 1/4	-(184)	4 1/4	(108)			2 2/3	(68)
C_4	26 3/8	(670)	7 1/8	(181)	4 1/4	(108)			2 1/5	(56)
C_5	27 1/2	(699)	21 1/2	(546)	5 7/8	(149)			1 2/3	(43)
C_6	41	(1041)	35 7/8	(911)	15	(381)			6	(154)
C_{MAX}	41	(1041)	35 7/8	(911)	15	(381)			6	(154)

Figure D-41. Exterior Vehicle Crush (NASS) - Front, Test No. MSPBN-7

Date:	6/7/2018	**Test Name:**	MSPBN7	**VIN:**	1C6RD6KT4CS197048
Year:	2012	**Make:**	Dodge	**Model:**	Ram 1500



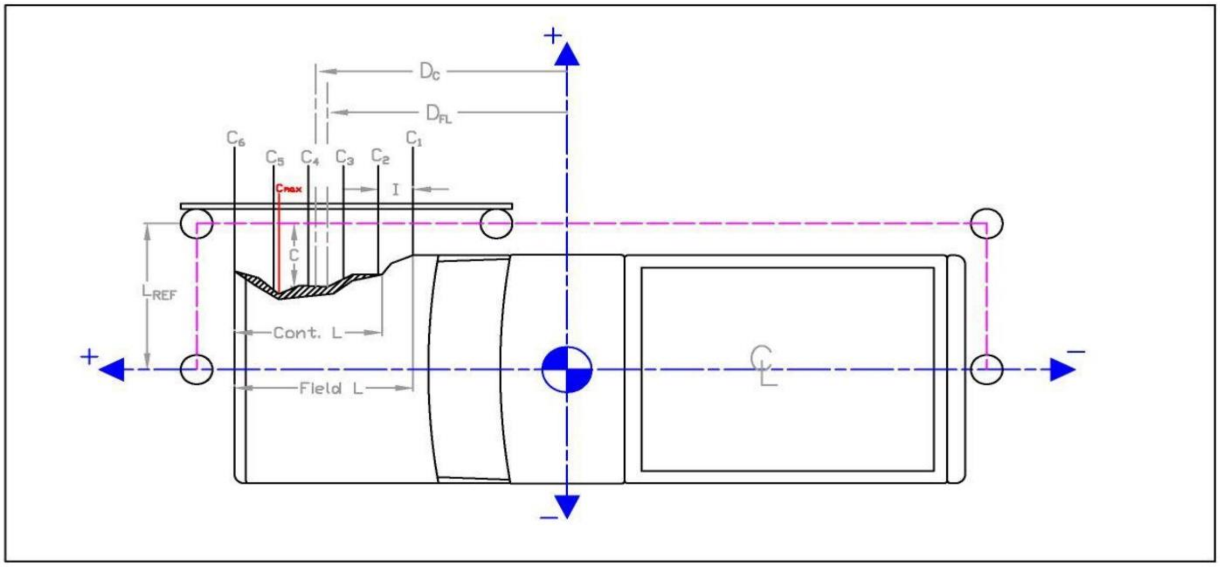
	in.	(mm)
Distance from centerline to reference line - L_{REF}:	45 1/2	(1156)
Total Vehicle Length:	229 3/4	(5836)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-6 1/3	-(160)
Width of contact and induced crush - Field L:	115 3/4	(2940)
Crush measurement spacing interval (L/5) - I:	23 1/8	(587)
Distance from vehicle c.g. to center of Field L - D_{FL}:	53	(1346)
Width of Contact Damage:	45 1/2	(1156)
Distance from vehicle c.g. to center of contact damage - D_C:	18	(457)

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual	Crush
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	6 7/8	(175)	-4 7/8	-(124)	5	(127)	1 1/2	(38)	3/8	(10)
C_2	9	(229)	18 1/4	(464)	5 1/8	(130)			2 3/8	(60)
C_3	7 1/8	(181)	41 3/8	(1051)	5 1/8	(130)			1/2	(13)
C_4	N/A	#VALUE!	64 1/2	(1638)	5 1/4	(133)			#VALUE!	#VALUE!
C_5	18 1/2	(470)	87 5/8	(2226)	5 7/8	(149)			11 1/8	(283)
C_6	N/A	#VALUE!	110 3/4	(2813)	33 1/2	(851)			#VALUE!	#VALUE!
C_{MAX}	18 1/2	(470)	87 5/8	(2226)	5 7/8	(149)			11 1/8	(283)

Figure D-42. Exterior Vehicle Crush (NASS) – Left Side, Test No. MSPBN-7

Date:	6/7/2018	Test Name:	MSPBN7	VIN:	1C6RD6KT4CS197048
Year:	2012	Make:	Dodge	Model:	Ram 1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	50 1/2	(1283)
Total Vehicle Length:	229 3/4	(5836)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-6 1/3	-(160)
Width of contact and induced crush - Field L:	157	(3988)
Crush measurement spacing interval (L/5) - I:	31 3/8	(797)
Distance from vehicle c.g. to center of Field L - D_{FL}:	17	(432)
Width of Contact Damage:	115	(2921)
Distance from vehicle c.g. to center of contact damage - D_C:	2 1/2	(64)

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual	Crush
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	14 3/4	(375)	-61 1/2	-(1562)	5 7/8	(149)	6 1/2	(165)	2 3/8	(60)
C_2	12 1/4	(311)	-30 1/8	-(765)	5 3/4	(146)			0	()
C_3	12 1/4	(311)	1 1/4	(32)	5	(127)			3/4	(19)
C_4	12 1/4	(311)	32 5/8	(829)	5 1/8	(130)			5/8	(16)
C_5	N/A	#VALUE!	64	(1626)	5 1/8	(130)			#VALUE!	#VALUE!
C_6	27 1/2	(699)	95 3/8	(2423)	6 7/8	(175)			14 1/8	(359)
C_{MAX}	14 3/4	(375)	-61 1/2	-(1562)	5 7/8	(149)			2 3/8	(60)

Figure D-43. Exterior Vehicle Crush (NASS) – Right Side, Test No. MSPBN-7

Date:	8/28/2018	Test Name:	MSPBN-8	VIN:	kmhcn4ac3bu533692
Year:	2011	Make:	Hyundai	Model:	Accent

VEHICLE DEFORMATION
FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	61.6958	-15.2448	5.7122	61.8209	-15.5074	5.6127	-0.1251	-0.2626	0.0995	0.3074	0.0995	Z
	2	61.9355	-18.1844	5.1426	62.0792	-18.2811	4.9892	-0.1437	-0.0967	0.1534	0.2314	0.1534	Z
	3	62.0256	-21.2641	5.2284	62.2735	-21.3781	5.0767	-0.2479	-0.1140	0.1517	0.3122	0.1517	Z
	4	61.8469	-23.9119	5.0500	61.9805	-24.0387	4.9181	-0.1336	-0.1268	0.1319	0.2265	0.1319	Z
	5	62.0327	-27.4894	5.0658	62.1832	-27.5989	4.9019	-0.1505	-0.1095	0.1639	0.2480	0.1639	Z
	6	58.7967	-15.0416	7.3984	58.9580	-15.2313	7.3132	-0.1613	-0.1897	0.0852	0.2632	0.0852	Z
	7	58.5842	-18.2065	7.3803	58.7592	-18.3095	7.2470	-0.1750	-0.1030	0.1333	0.2429	0.1333	Z
	8	58.2943	-21.8170	7.4637	58.4117	-21.9240	7.3472	-0.1174	-0.1070	0.1165	0.1970	0.1165	Z
	9	57.7521	-24.7580	7.4071	57.8532	-24.8889	7.2362	-0.1011	-0.1309	0.1709	0.2378	0.1709	Z
	10	57.7783	-27.5765	7.6407	57.9352	-27.6243	7.4405	-0.1569	-0.0478	0.2002	0.2588	0.2002	Z
FLOOR PAN (Z)	11	52.8999	-14.8118	8.3198	53.0436	-14.9373	8.2570	-0.1437	-0.1255	0.0628	0.2009	0.0628	Z
	12	52.7739	-17.2691	8.4588	52.9669	-17.3208	8.4639	-0.1930	-0.0517	-0.0051	0.1999	-0.0051	Z
	13	52.2937	-21.1600	8.2434	52.3899	-21.2993	8.0958	-0.0962	-0.1393	0.1476	0.2246	0.1476	Z
	14	51.8295	-25.9273	8.2429	52.0150	-26.1221	8.0706	-0.1855	-0.1948	0.1723	0.3194	0.1723	Z
	15	52.0030	-30.2236	8.4919	52.0653	-30.3150	8.2955	-0.0623	-0.0914	0.1964	0.2254	0.1964	Z
	16	48.0598	-14.8993	8.8603	48.2710	-14.9763	8.7691	-0.2112	-0.0770	0.0912	0.2426	0.0912	Z
	17	47.7905	-19.1277	8.5146	47.9546	-19.3019	8.3609	-0.1641	-0.1742	0.1537	0.2844	0.1537	Z
	18	47.6383	-22.6410	8.3802	47.8210	-22.7875	8.2119	-0.1827	-0.1465	0.1683	0.2884	0.1683	Z
	19	47.4865	-25.9398	8.3013	47.6046	-26.0449	8.1263	-0.1181	-0.1051	0.1750	0.2358	0.1750	Z
	20	47.5751	-29.8525	8.9567	47.6937	-30.0253	8.7426	-0.1186	-0.1728	0.2141	0.2996	0.2141	Z
	21	43.3160	-14.7396	8.8541	43.5054	-14.8782	8.7803	-0.1894	-0.1386	0.0738	0.2460	0.0738	Z
	22	43.1457	-18.3493	8.8117	43.2576	-18.5221	8.6652	-0.1119	-0.1728	0.1465	0.2527	0.1465	Z
	23	42.8826	-22.4357	8.4289	42.9756	-22.5673	8.2608	-0.0930	-0.1316	0.1681	0.2329	0.1681	Z
	24	42.9185	-26.2165	8.3263	42.9378	-26.3256	8.1451	-0.0193	-0.1091	0.1812	0.2124	0.1812	Z
	25	43.0224	-30.3998	8.8938	43.1601	-30.4331	8.6610	-0.1377	-0.0333	0.2328	0.2725	0.2328	Z
	26	39.4916	-14.6307	8.2553	39.6171	-14.7948	8.1685	-0.1255	-0.1641	0.0868	0.2241	0.0868	Z
	27	39.3076	-18.5902	8.4829	39.4702	-18.7359	8.3133	-0.1626	-0.1457	0.1696	0.2765	0.1696	Z
	28	39.1217	-22.4583	8.3762	39.2689	-22.6125	8.1959	-0.1472	-0.1542	0.1803	0.2792	0.1803	Z
	29	39.2287	-26.6735	8.3501	39.4319	-26.7866	8.2080	-0.2032	-0.1131	0.1421	0.2725	0.1421	Z
	30	39.4451	-29.9764	8.5523	39.5830	-30.0656	8.3766	-0.1379	-0.0892	0.1757	0.2405	0.1757	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Pretest Floor Pan

Posttest Floor Pan

Figure D-44. Floor Pan Deformation Data – Set 1 Left, Test No. MSPBN-8

Date: 8/28/2018 Test Name: MSPBN-8 VIN: kmhcn4ac3bu533692
Year: 2011 Make: Hyundai Model: Accent

VEHICLE DEFORMATION
INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	49.2420	-30.0432	-19.8175	49.3485	-30.1581	-19.9139	-0.1065	-0.1149	-0.0964	0.1839	0.1839	X, Y, Z
	2	47.6039	-19.3682	-22.9497	47.8582	-19.2224	-23.2228	-0.2543	0.1458	-0.2731	0.4006	0.4006	X, Y, Z
	3	50.3644	-6.6919	-20.8146	50.6084	-6.5540	-21.0583	-0.2440	0.1379	-0.2437	0.3714	0.3714	X, Y, Z
	4	47.9293	-32.6169	-8.0176	47.8731	-32.4825	-8.2343	0.0562	0.1344	-0.2167	0.2611	0.2611	X, Y, Z
	5	49.0716	-17.7171	-7.4492	49.1917	-17.6882	-7.6156	-0.1201	0.0289	-0.1664	0.2072	0.2072	X, Y, Z
	6	45.1094	-7.6814	-8.0445	44.9400	-7.7226	-8.4844	0.1694	-0.0412	-0.4399	0.4732	0.4732	X, Y, Z
SIDE PANEL (Y)	7	52.8602	-34.9446	0.0386	52.8153	-34.8114	-0.1371	0.0449	0.1332	-0.1757	0.2250	0.1332	Y
	8	52.9538	-35.7018	3.9618	52.8697	-35.7703	3.8236	0.0841	-0.0685	-0.1382	0.1757	-0.0685	Y
	9	56.5270	-35.8089	3.4579	56.4383	-35.8793	3.2752	0.0887	-0.0704	-0.1827	0.2149	-0.0704	Y
IMPACT SIDE DOOR (Y)	10	46.1632	-35.9383	-16.0245	45.9493	-35.3081	-16.1609	0.2139	0.6302	-0.1364	0.6793	0.6302	Y
	11	34.5752	-35.6265	-16.3660	34.3771	-35.3076	-16.5924	0.1981	0.3189	-0.2264	0.4384	0.3189	Y
	12	20.9642	-35.1546	-17.1668	20.6956	-35.1294	-17.4375	0.2686	0.0252	-0.2707	0.3822	0.0252	Y
	13	42.7570	-35.9596	-0.3628	42.3920	-36.0891	-0.6612	0.3650	-0.1295	-0.2984	0.4889	-0.1295	Y
	14	35.1984	-35.8791	0.2440	34.9056	-36.0806	0.0174	0.2928	-0.2015	-0.2266	0.4215	-0.2015	Y
	15	26.8278	-35.5688	0.2851	26.4298	-35.7501	-0.0675	0.3980	-0.1813	-0.3526	0.5618	-0.1813	Y
ROOF - (Z)	16	30.9242	-24.6323	-35.5124	31.2296	-24.6975	-35.6275	-0.3054	-0.0652	-0.1151	0.3328	-0.1151	Z
	17	31.5071	-21.6371	-35.7681	31.7632	-21.6307	-35.8885	-0.2561	0.0064	-0.1204	0.2831	-0.1204	Z
	18	32.0825	-18.6987	-35.7726	32.2752	-18.7095	-35.8996	-0.1927	-0.0108	-0.1270	0.2310	-0.1270	Z
	19	32.7068	-14.1758	-35.8741	33.0042	-14.1592	-35.9303	-0.2974	0.0166	-0.0562	0.3031	-0.0562	Z
	20	32.9453	-9.5763	-36.2830	33.2079	-9.5436	-36.3290	-0.2626	0.0327	-0.0460	0.2686	-0.0460	Z
	21	26.3846	-24.1050	-37.8254	26.6488	-23.9900	-37.9864	-0.2642	0.1150	-0.1610	0.3301	-0.1610	Z
	22	26.8203	-20.4528	-38.1003	27.1629	-20.4338	-38.2259	-0.3426	0.0190	-0.1256	0.3654	-0.1256	Z
	23	27.3908	-17.3953	-38.2244	27.7720	-17.3854	-38.2957	-0.3812	0.0099	-0.0713	0.3879	-0.0713	Z
	24	28.1027	-13.1945	-38.3063	28.5426	-13.1480	-38.3601	-0.4399	0.0465	-0.0538	0.4456	-0.0538	Z
	25	28.8298	-8.5343	-38.2820	29.3535	-8.4280	-38.3094	-0.5237	0.1063	-0.0274	0.5351	-0.0274	Z
	26	21.9525	-23.1964	-38.4610	22.3443	-23.1885	-38.6030	-0.3918	0.0079	-0.1420	0.4168	-0.1420	Z
	27	22.5962	-18.6350	-38.7668	23.0379	-18.5066	-38.8890	-0.4417	0.1284	-0.1222	0.4759	-0.1222	Z
	28	23.1134	-13.9350	-38.9656	23.6558	-13.8439	-39.0188	-0.5424	0.0911	-0.0532	0.5526	-0.0532	Z
	29	23.6735	-10.6130	-38.9995	24.2054	-10.5107	-39.0329	-0.5319	0.1023	-0.0334	0.5427	-0.0334	Z
	30	24.2643	-7.0319	-38.9602	24.8152	-6.9334	-38.9699	-0.5509	0.0985	-0.0097	0.5597	-0.0097	Z
A-PILLAR Maximum (X, Y, Z)	31	51.4560	-33.5550	-23.6506	51.5331	-33.5685	-23.6725	-0.0771	-0.0135	-0.0219	0.0813	0.0000	NA
	32	48.0129	-32.7288	-25.7938	48.1033	-32.7449	-25.8681	-0.0904	-0.0161	-0.0743	0.1181	0.0000	NA
	33	44.5086	-31.8352	-27.9181	44.6149	-31.8445	-28.0346	-0.1063	-0.0093	-0.1165	0.1580	0.0000	NA
	34	41.9764	-31.1736	-29.3825	42.1176	-31.1786	-29.4532	-0.1412	-0.0050	-0.0707	0.1580	0.0000	NA
	35	39.7947	-30.6160	-30.4832	40.0439	-30.6277	-30.6237	-0.2492	-0.0117	-0.1405	0.2863	0.0000	NA
	36	37.8441	-30.0934	-31.5817	38.0599	-30.1104	-31.6913	-0.2158	-0.0170	-0.1096	0.2426	0.0000	NA
A-PILLAR Lateral (Y)	31	51.4560	-33.5550	-23.6506	51.5331	-33.5685	-23.6725	-0.0771	-0.0135	-0.0219	0.0813	-0.0135	Y
	32	48.0129	-32.7288	-25.7938	48.1033	-32.7449	-25.8681	-0.0904	-0.0161	-0.0743	0.1181	-0.0161	Y
	33	44.5086	-31.8352	-27.9181	44.6149	-31.8445	-28.0346	-0.1063	-0.0093	-0.1165	0.1580	-0.0093	Y
	34	41.9764	-31.1736	-29.3825	42.1176	-31.1786	-29.4532	-0.1412	-0.0050	-0.0707	0.1580	-0.0050	Y
	35	39.7947	-30.6160	-30.4832	40.0439	-30.6277	-30.6237	-0.2492	-0.0117	-0.1405	0.2863	-0.0117	Y
	36	37.8441	-30.0934	-31.5817	38.0599	-30.1104	-31.6913	-0.2158	-0.0170	-0.1096	0.2426	-0.0170	Y
B-PILLAR Maximum (X, Y, Z)	37	13.7909	-27.7554	-34.5223	14.1873	-27.6263	-34.8311	-0.3964	0.1291	-0.3088	0.5188	0.1291	Y
	38	12.0007	-30.7466	-28.1923	12.3064	-30.6408	-28.4741	-0.3057	0.1058	-0.2818	0.4290	0.1058	Y
	39	15.7413	-32.7059	-23.3404	15.9324	-32.6577	-23.6344	-0.1911	0.0482	-0.2940	0.3539	0.0482	Y
	40	13.2280	-33.0422	-17.6982	13.4843	-32.9827	-18.0172	-0.2563	0.0595	-0.3190	0.4135	0.0595	Y
B-PILLAR Lateral (Y)	37	13.7909	-27.7554	-34.5223	14.1873	-27.6263	-34.8311	-0.3964	0.1291	-0.3088	0.5188	0.1291	Y
	38	12.0007	-30.7466	-28.1923	12.3064	-30.6408	-28.4741	-0.3057	0.1058	-0.2818	0.4290	0.1058	Y
	39	15.7413	-32.7059	-23.3404	15.9324	-32.6577	-23.6344	-0.1911	0.0482	-0.2940	0.3539	0.0482	Y
	40	13.2280	-33.0422	-17.6982	13.4843	-32.9827	-18.0172	-0.2563	0.0595	-0.3190	0.4135	0.0595	Y

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

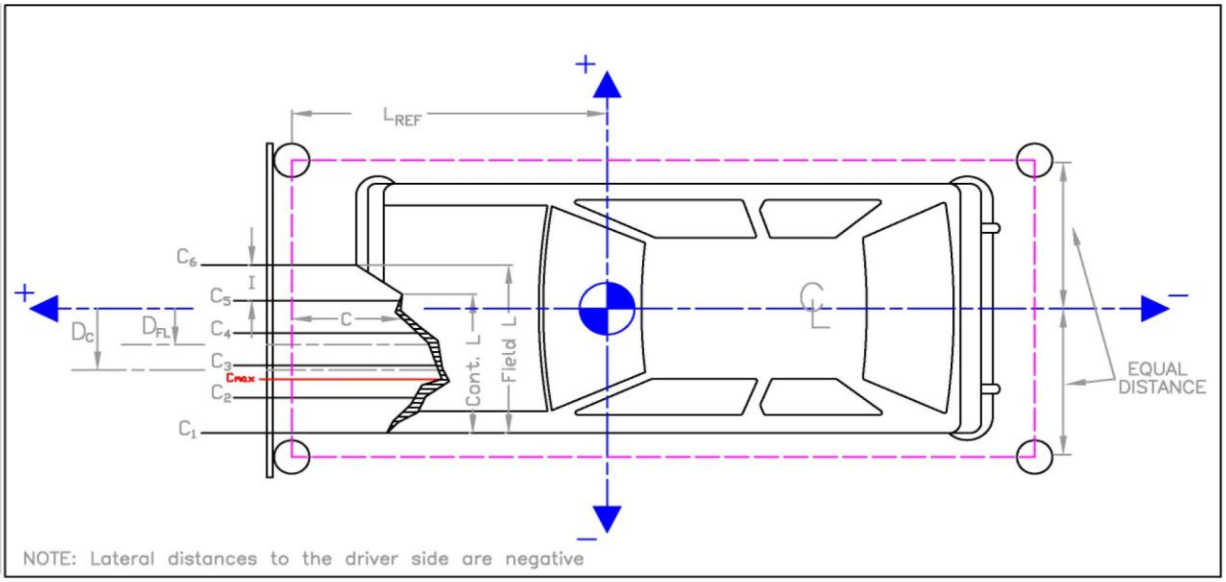
[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-45. Occupant Compartment Deformation Data – Set 1 Left, Test No. MSPBN-8

Date: 8/28/2018 Test Name: MSPBN-8 VIN: kmhcn4ac3bu533692

Year: 2011 Make: Hyundai Model: Accent



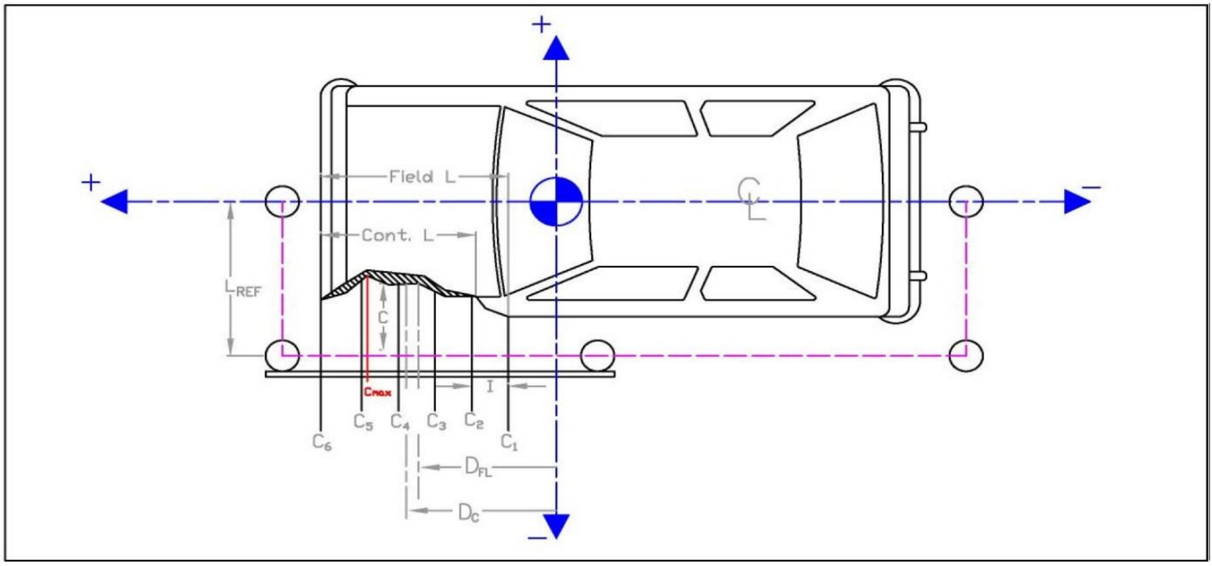
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	91	(2311)
Total Width of Vehicle:	65 1/2	(1664)
Width of contact and induced crush - Field L:	65 1/2	(1664)
Crush measurement spacing interval (L/5) - I:	13 1/8	(333)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	65 1/2	(1664)
Distance from center of vehicle to center of contact damage - D_C:	0	()

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/a	######	-32 3/4	-(832)	20 1/4	(514)	19 1/3	(491)	#VALUE!	#VALUE!
C_2	24 1/4	(616)	-19 5/8	-(498)	4 3/4	(121)			1/5	(5)
C_3	21 1/4	(540)	-6 1/2	-(165)	2 3/8	(60)			- 4/9	-(11)
C_4	21	(533)	6 5/8	(168)	2 3/8	(60)			- 2/3	-(17)
C_5	39	(991)	19 3/4	(502)	4 3/4	(121)			15	(379)
C_6	n/a	######	32 7/8	(835)	19 7/8	(505)			#VALUE!	#VALUE!
C_{MAX}	39	(991)	19 3/4	(502)	4 3/4	(121)			15	(379)

Figure D-46. Exterior Vehicle Crush (NASS) - Front, Test No. MSPBN-8

Date:	8/28/2018	Test Name:	MSPBN-8	VIN:	kmhcn4ac3bu533692
Year:	2011	Make:	Hyundai	Model:	Accent



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	36	(914)
Total Vehicle Length:	168 1/4	(4274)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-11 4/9	-(291)
Width of contact and induced crush - Field L:	168 1/4	(4274)
Crush measurement spacing interval (L/5) - I:	33 5/8	(854)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-11 4/9	-(291)
Width of Contact Damage:	168 1/4	(4274)
Distance from vehicle c.g. to center of contact damage - D_C:	-11 4/9	-(291)

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	n/a	#VALUE!	-95 5/8	-(2429)	16	(406)	0	()	#VALUE!	#VALUE!
C_2	n/a	#VALUE!	-62	-(1575)	4	(102)			#VALUE!	#VALUE!
C_3	3	(76)	-28 3/8	-(721)	3 3/8	(86)			- 3/8	-(10)
C_4	3 3/4	(95)	5 1/4	(133)	3 1/4	(83)			1/2	(13)
C_5	3 1/2	(89)	38 7/8	(987)	3 1/2	(89)			0	()
C_6	n/a	#VALUE!	72 1/2	(1842)	36	(914)			#VALUE!	#VALUE!
C_{MAX}	12 1/2	(318)	63	(1600)	9 1/4	(235)			3 1/4	(83)

Figure D-47. Exterior Vehicle Crush (NASS) – Left Side, Test No. MSPBN-8

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

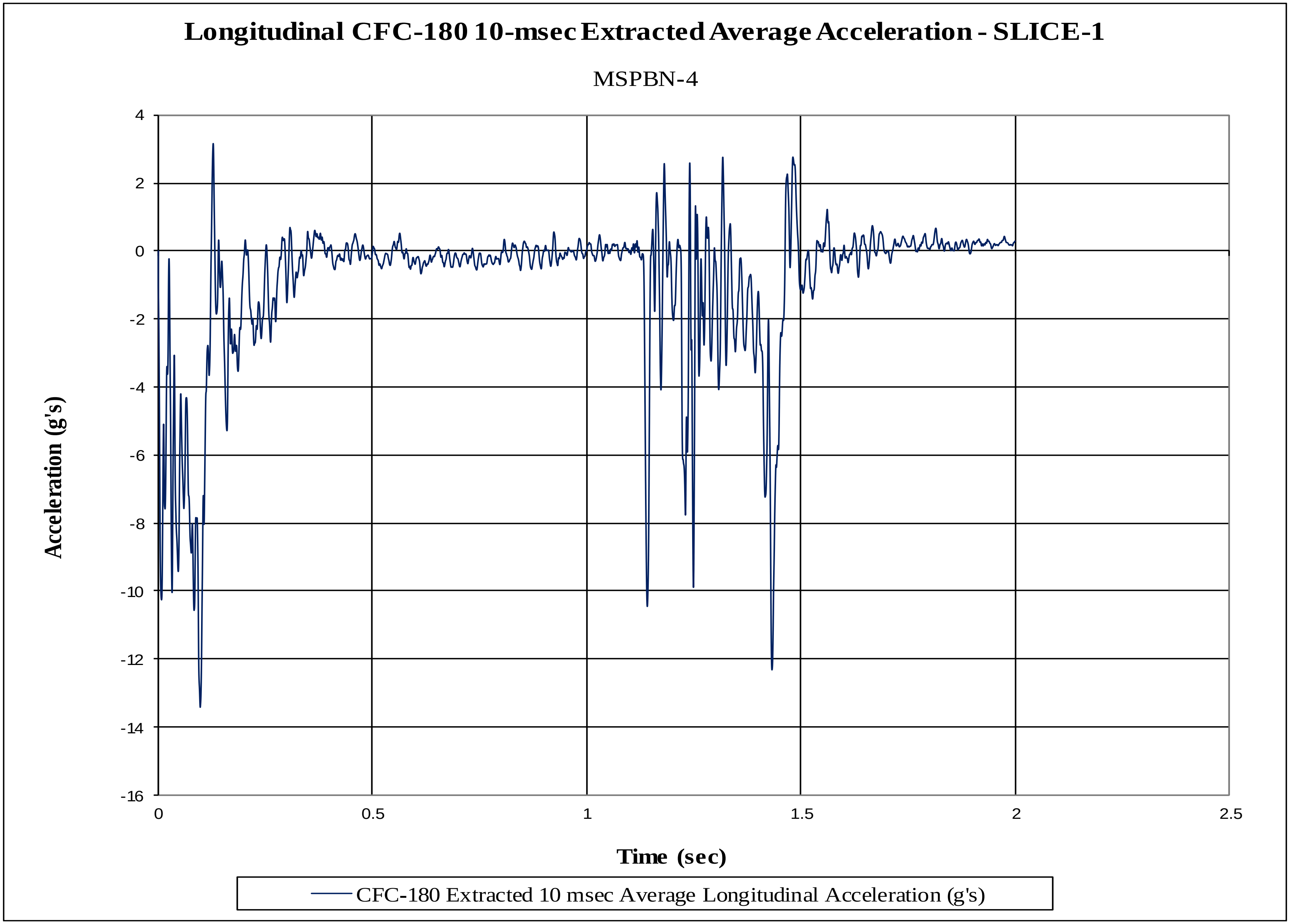


Figure E-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. MSPBN-4

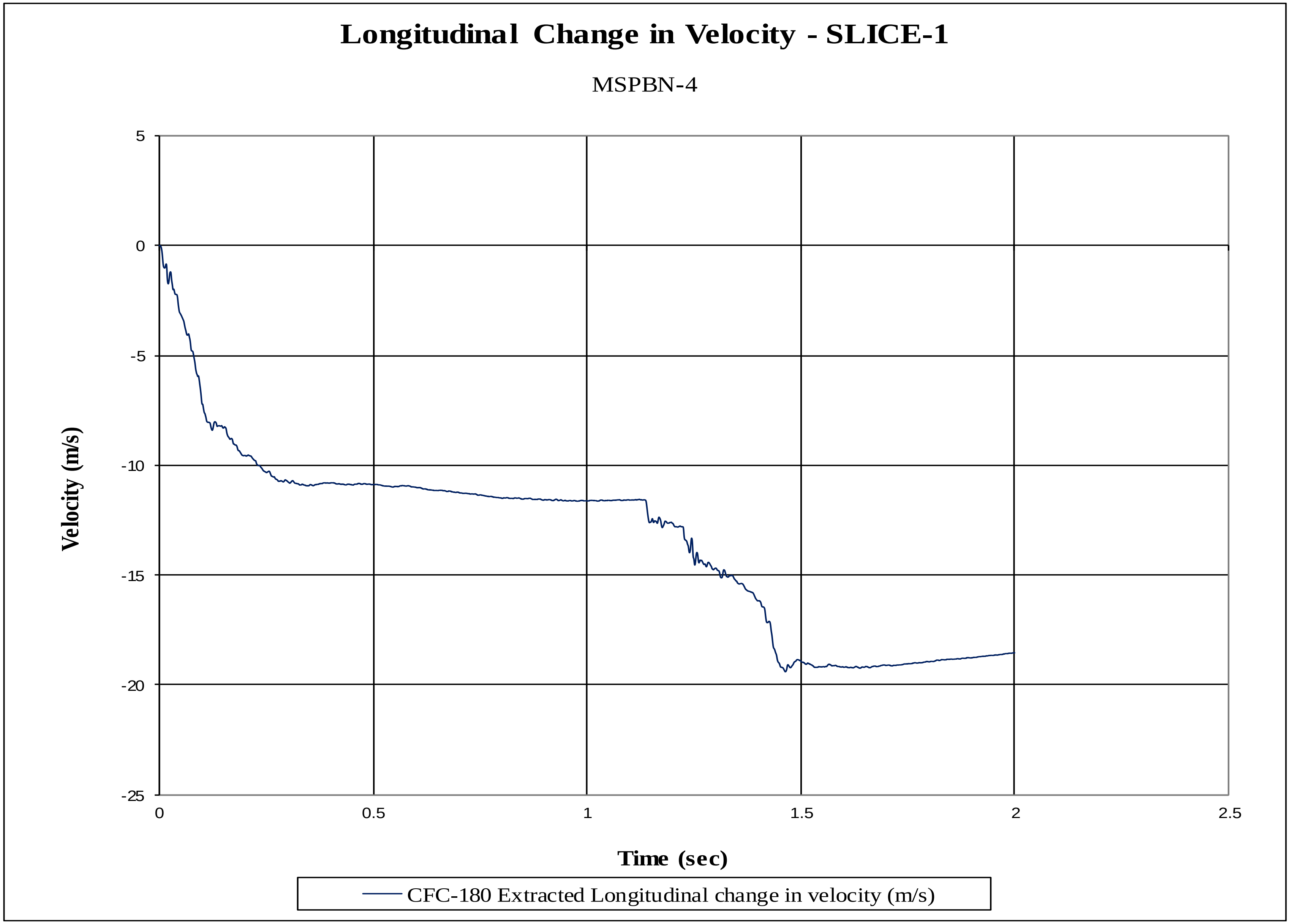


Figure E-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. MSPBN-4

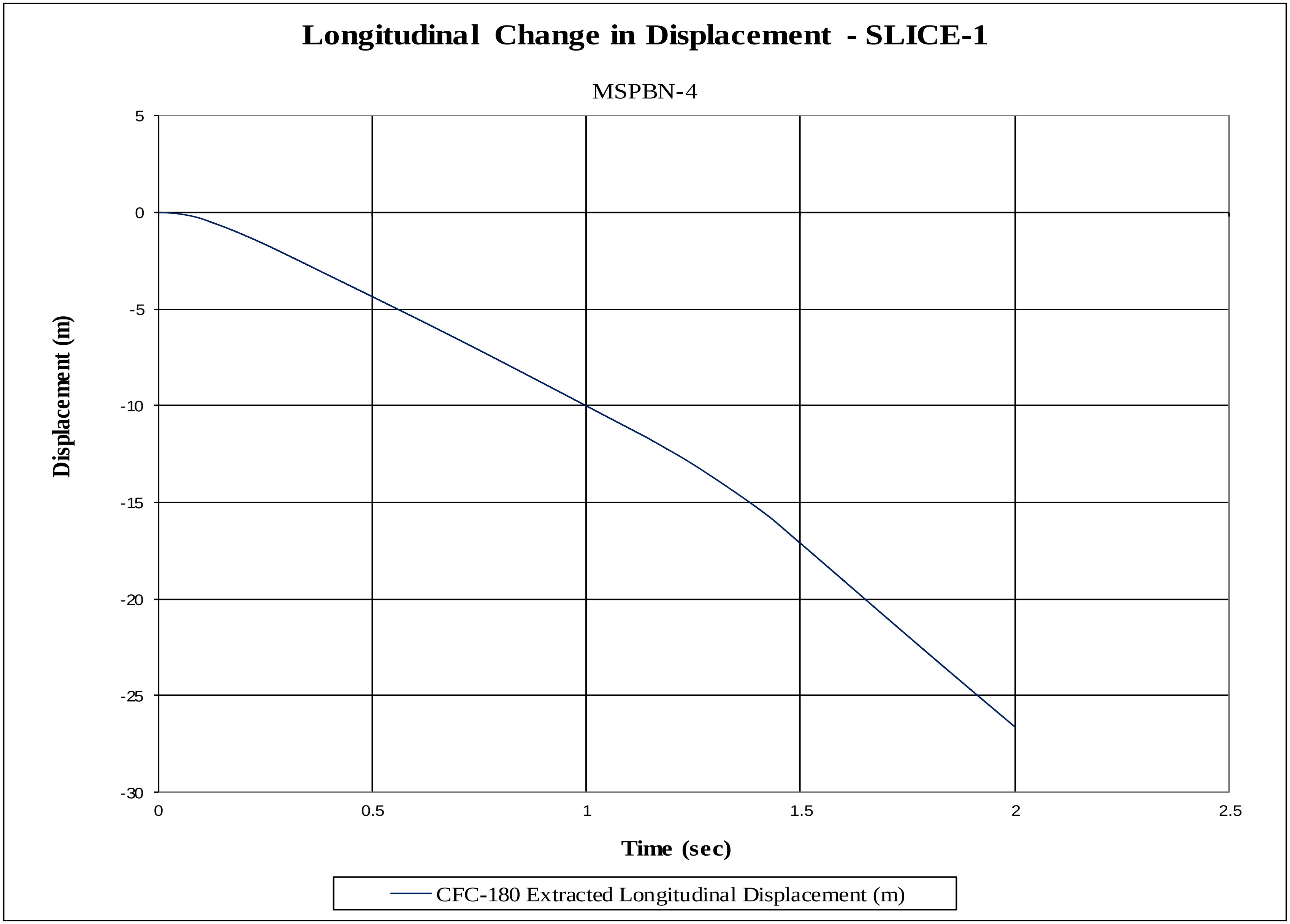


Figure E-3. Longitudinal Occupant Displacement (SLICE-1), Test No. MSPBN-4

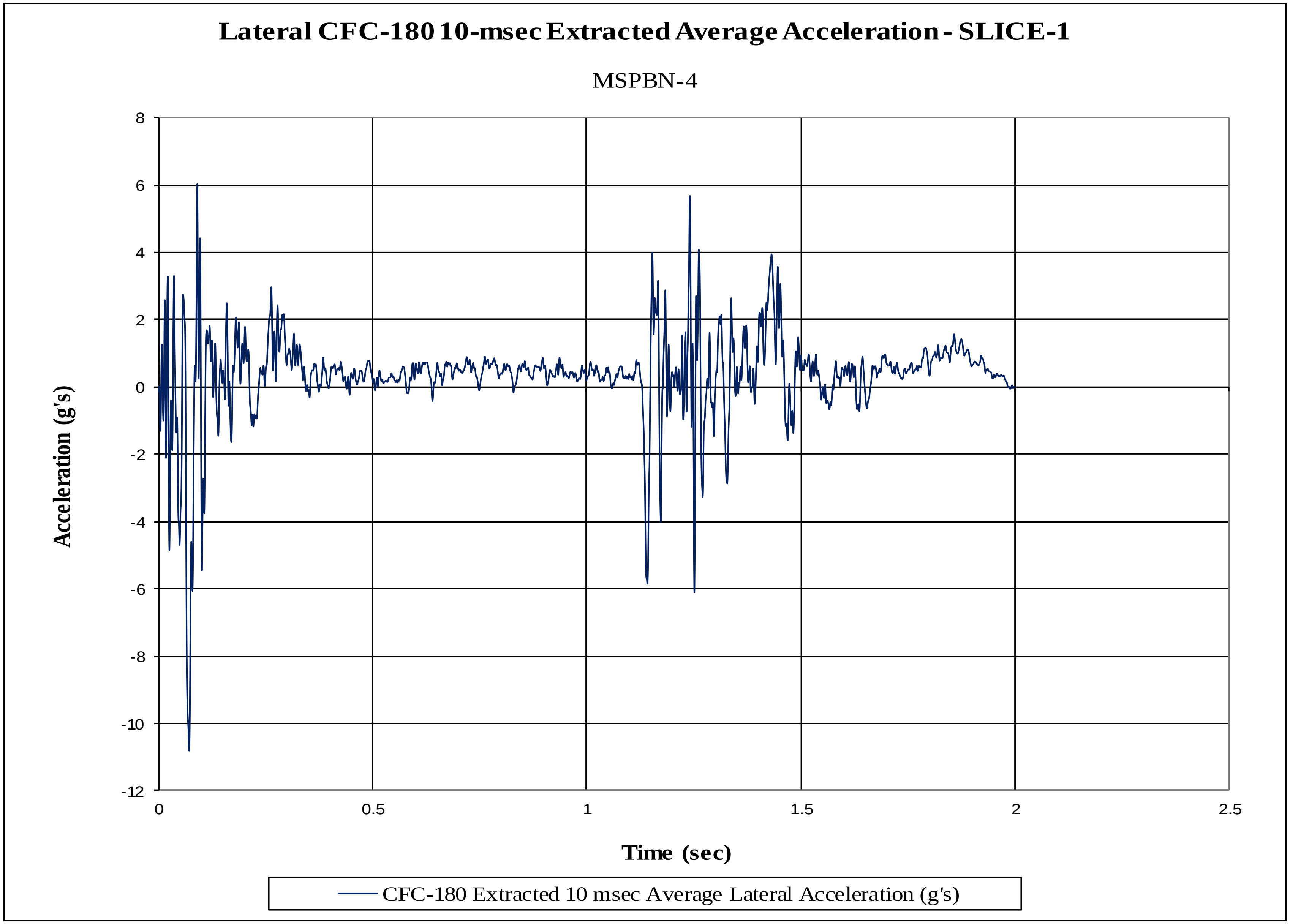


Figure E-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. MSPBN-4

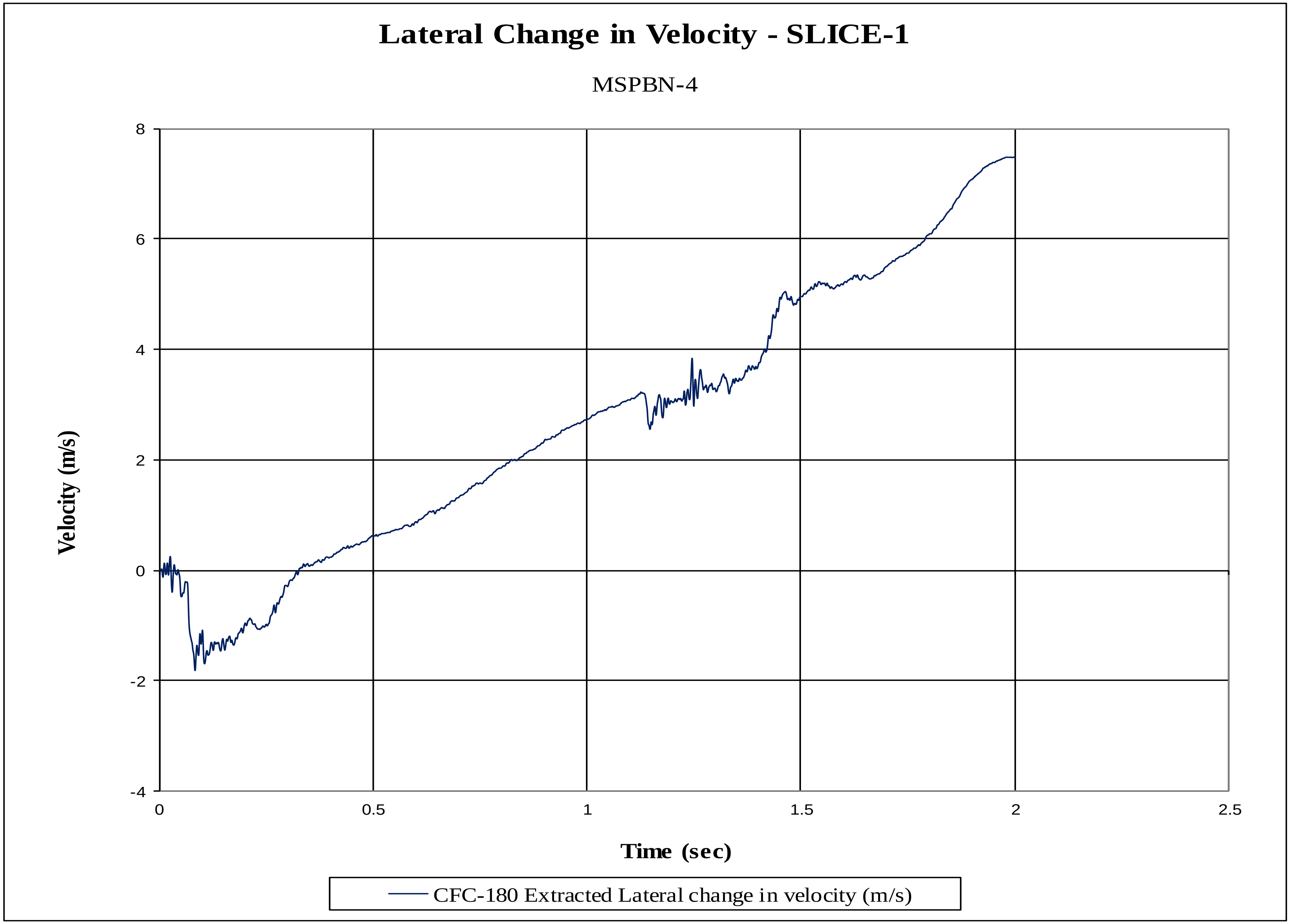


Figure E-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. MSPBN-4

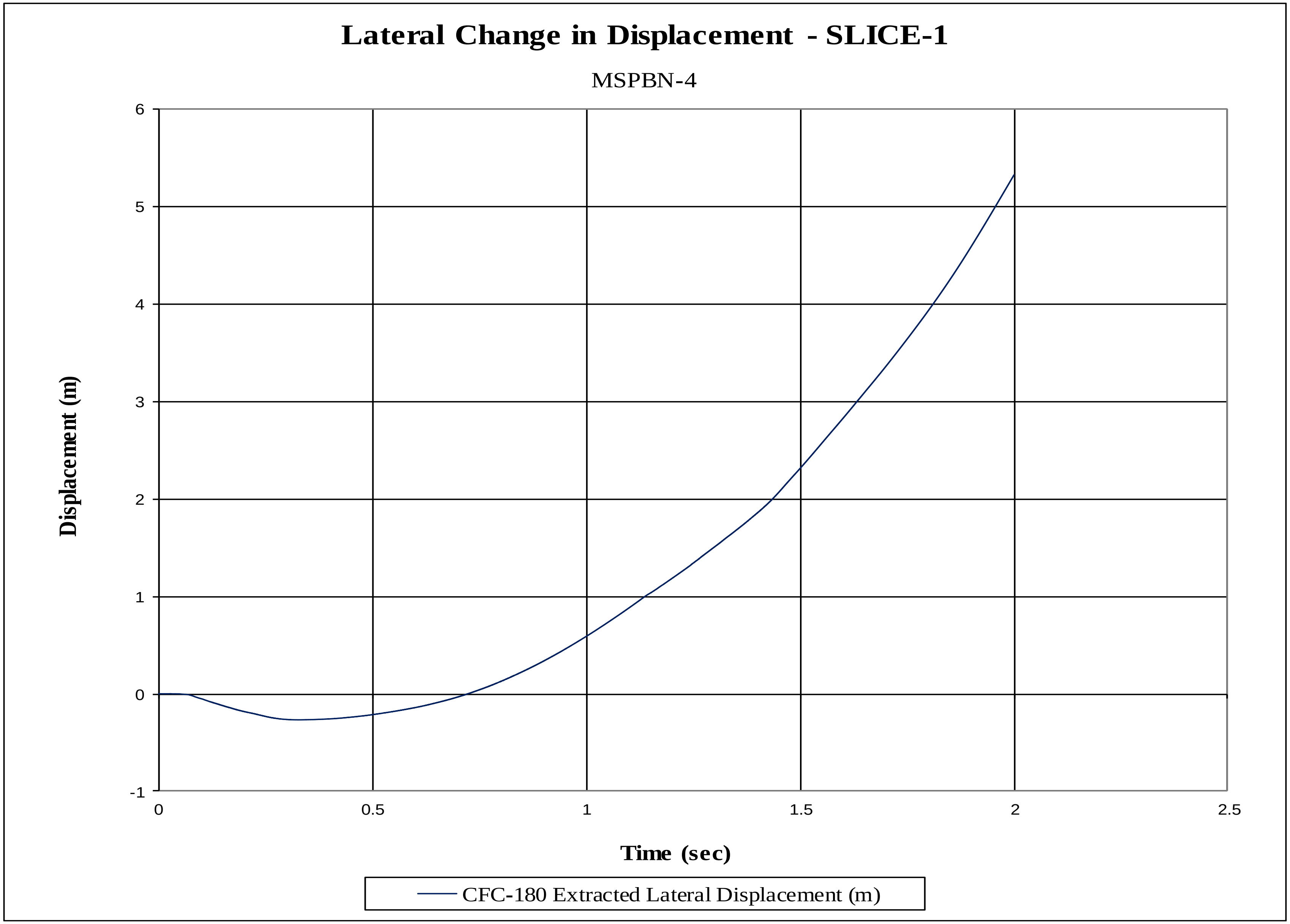


Figure E-6. Lateral Occupant Displacement (SLICE-1), Test No. MSPBN-4

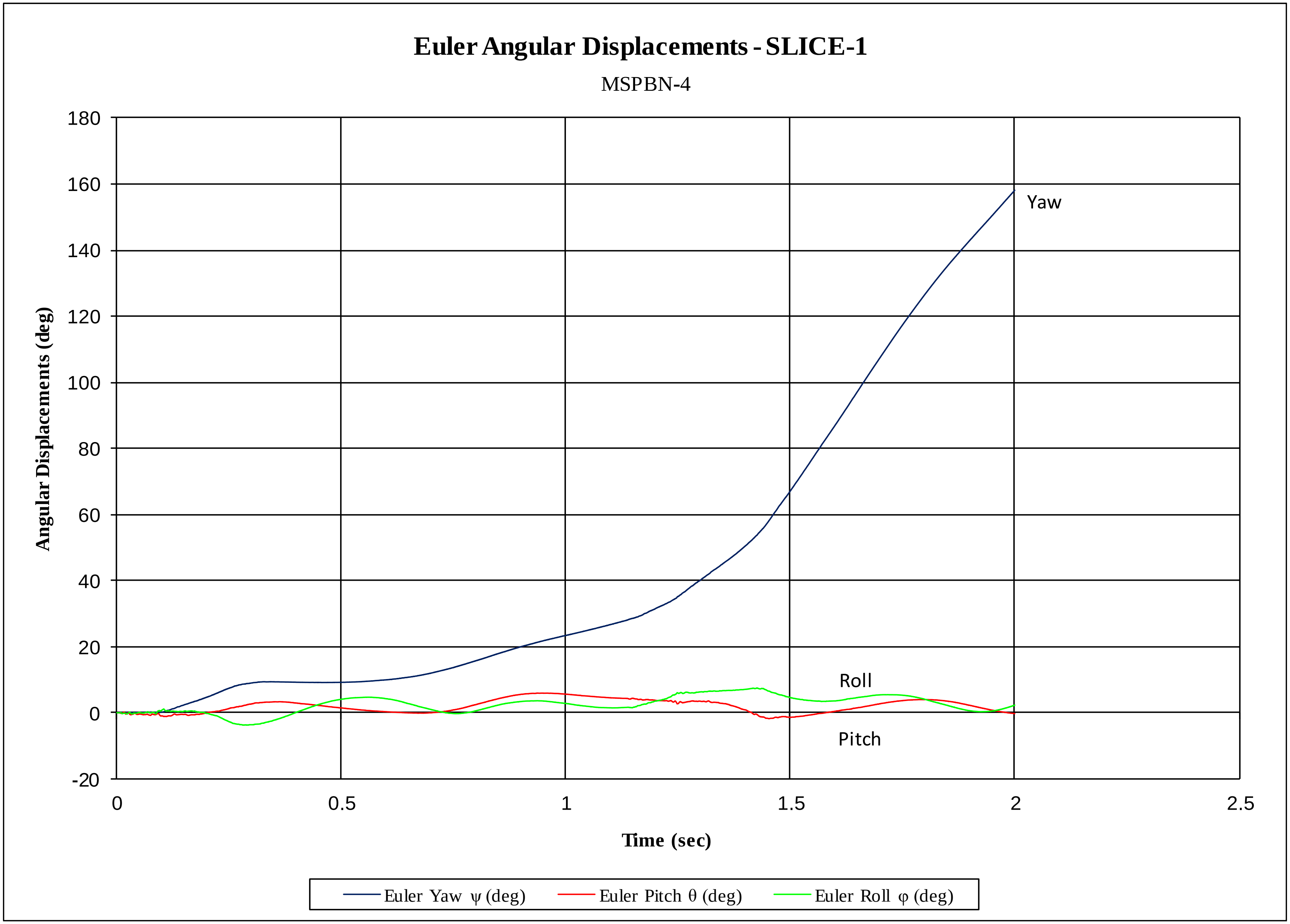


Figure E-7. Vehicle Angular Displacements (SLICE-1), Test No. MSPBN-4

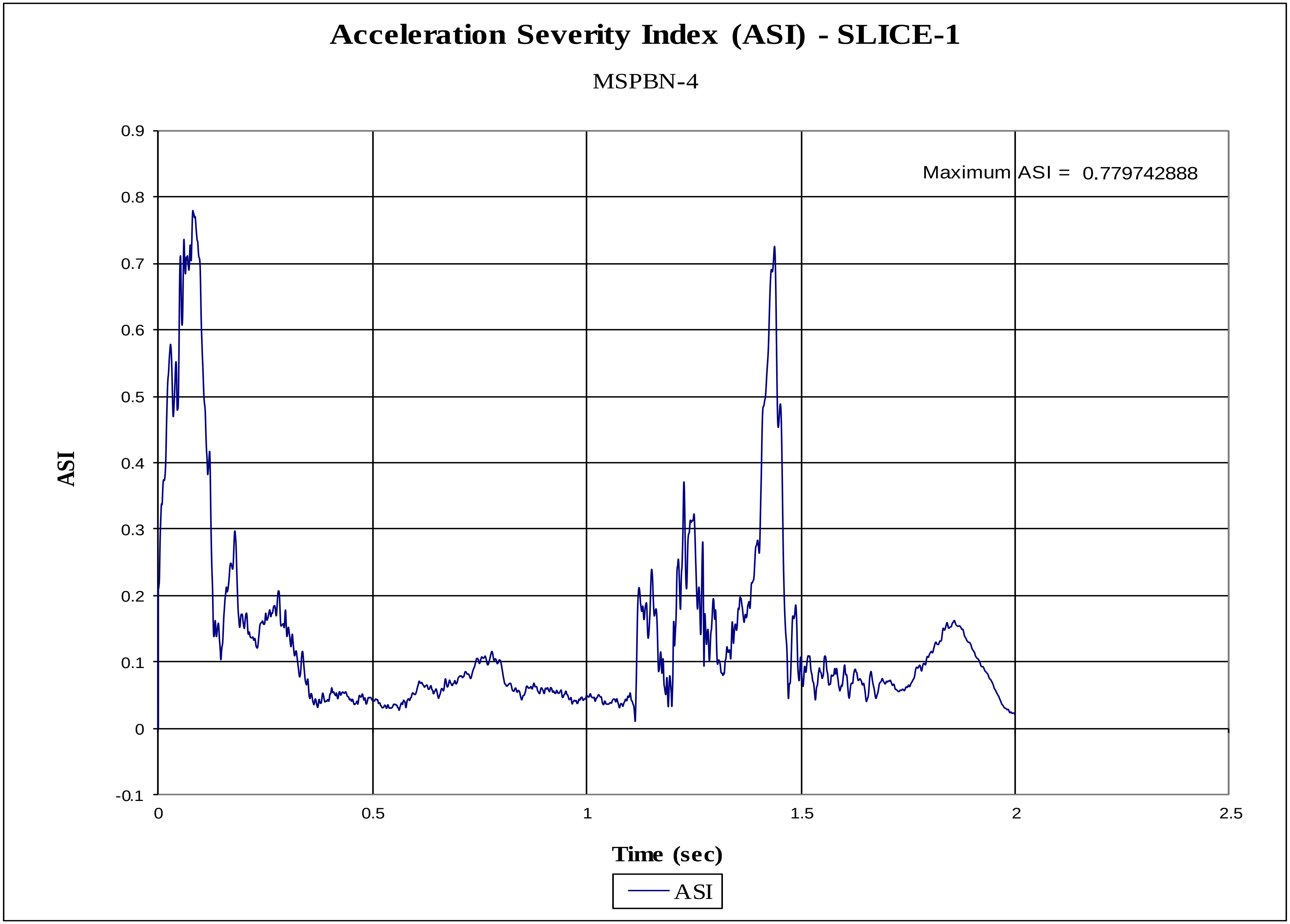


Figure E-8. Acceleration Severity Index (SLICE-1), Test No. MSPBN-4

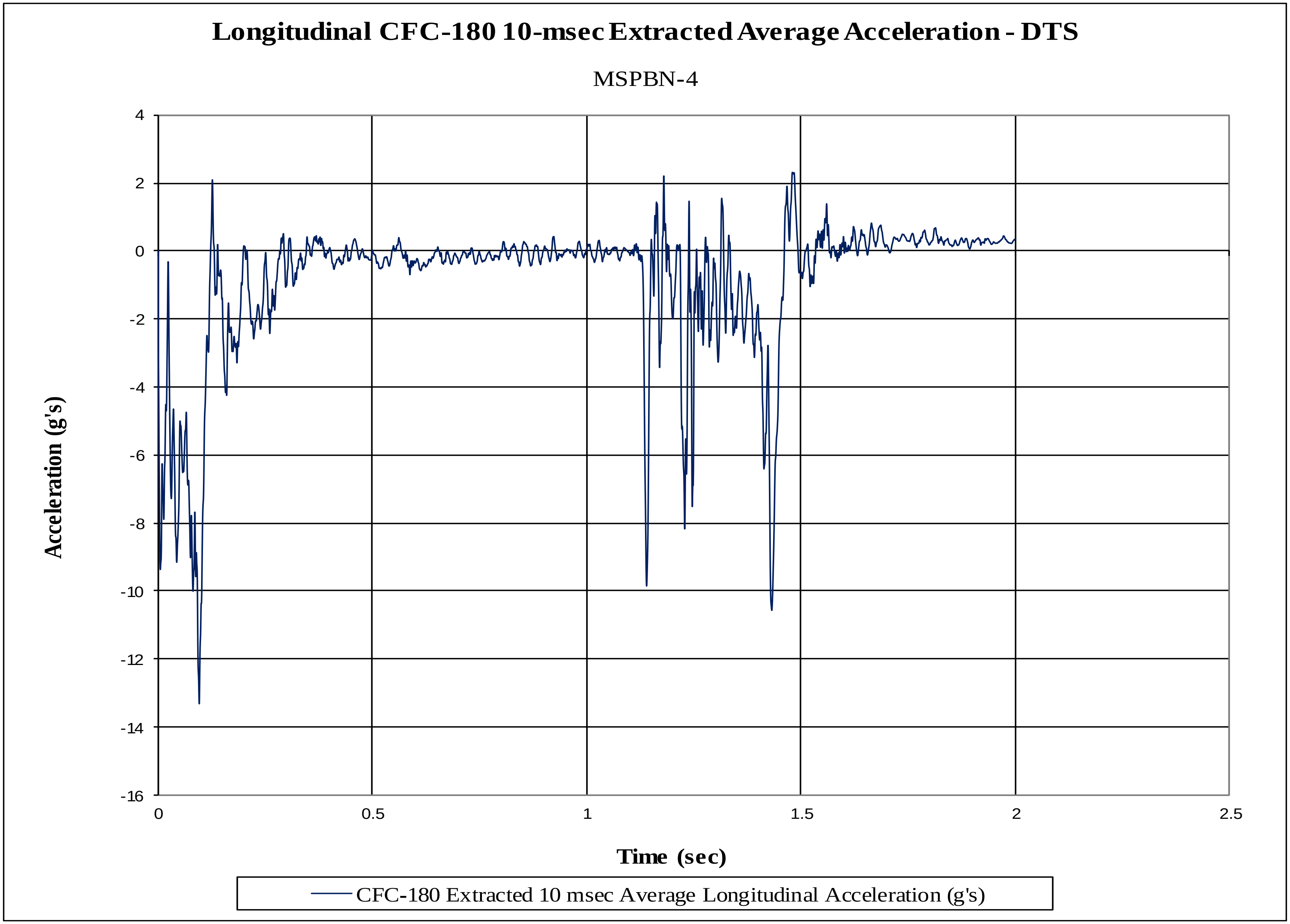


Figure E-9. 10-ms Average Longitudinal Deceleration (DTS), Test No. MSPBN-4

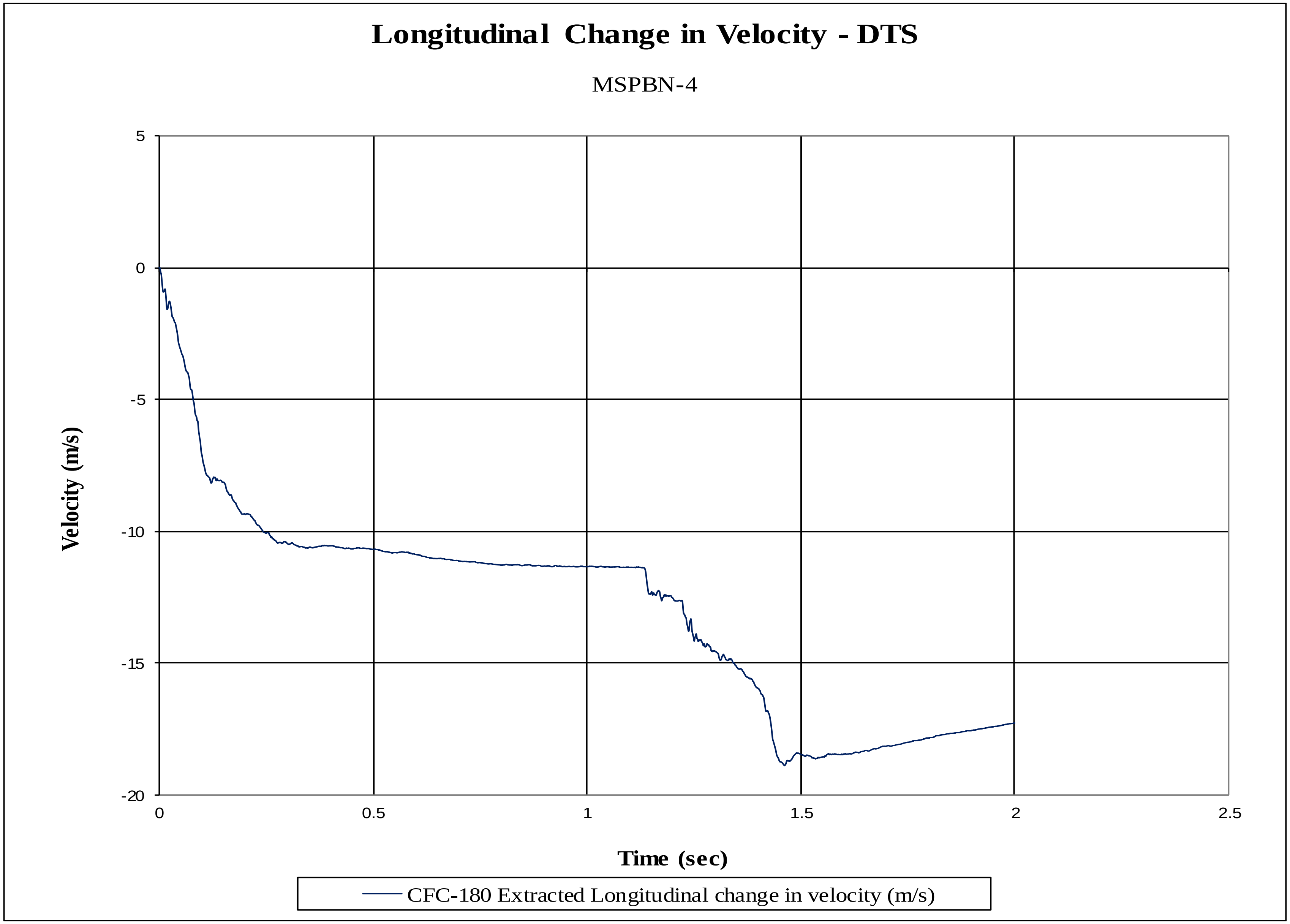


Figure E-10. Longitudinal Occupant Impact Velocity (DTS), Test No. MSPBN-4

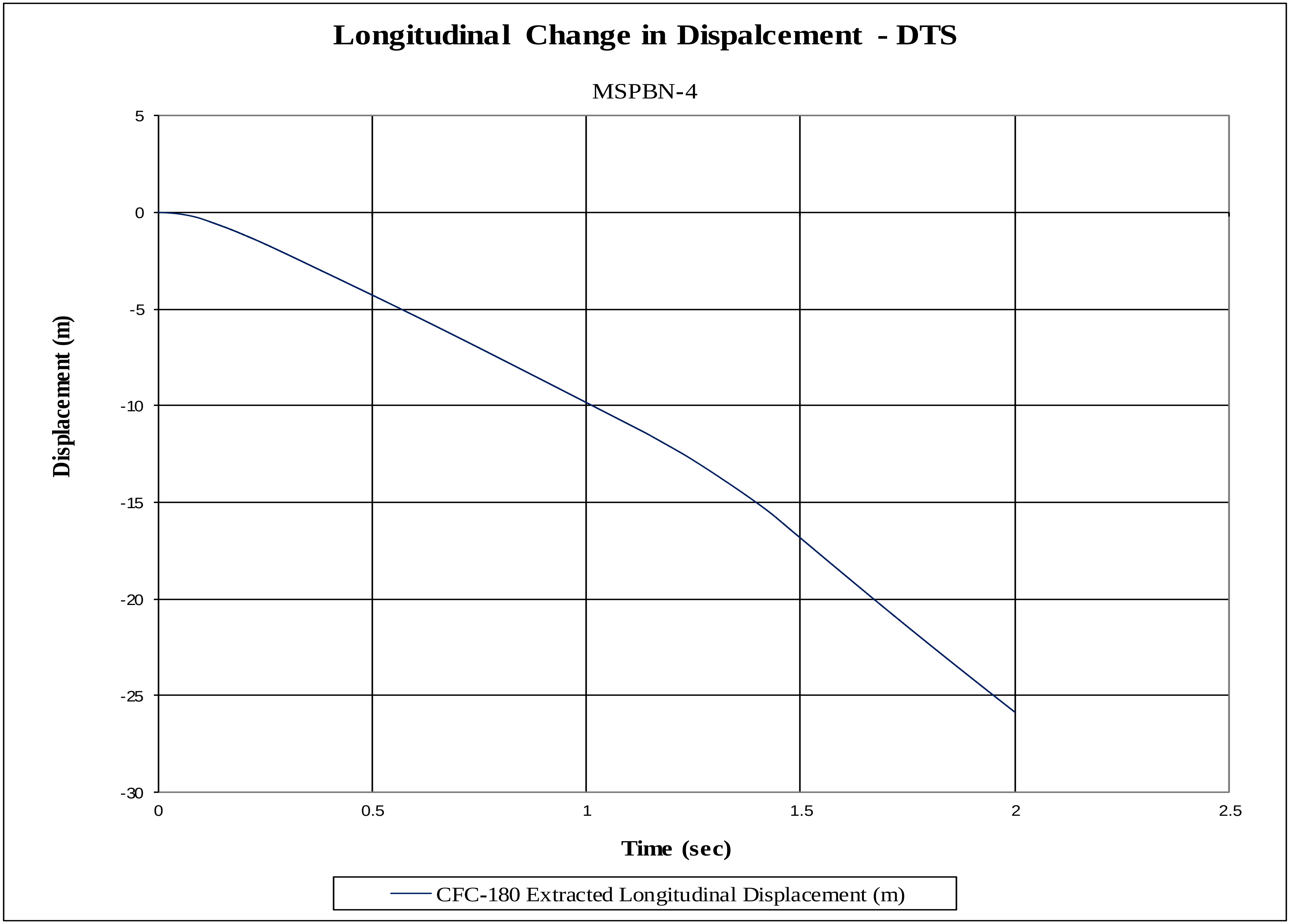


Figure E-11. Longitudinal Occupant Displacement (DTS), Test No. MSPBN-4

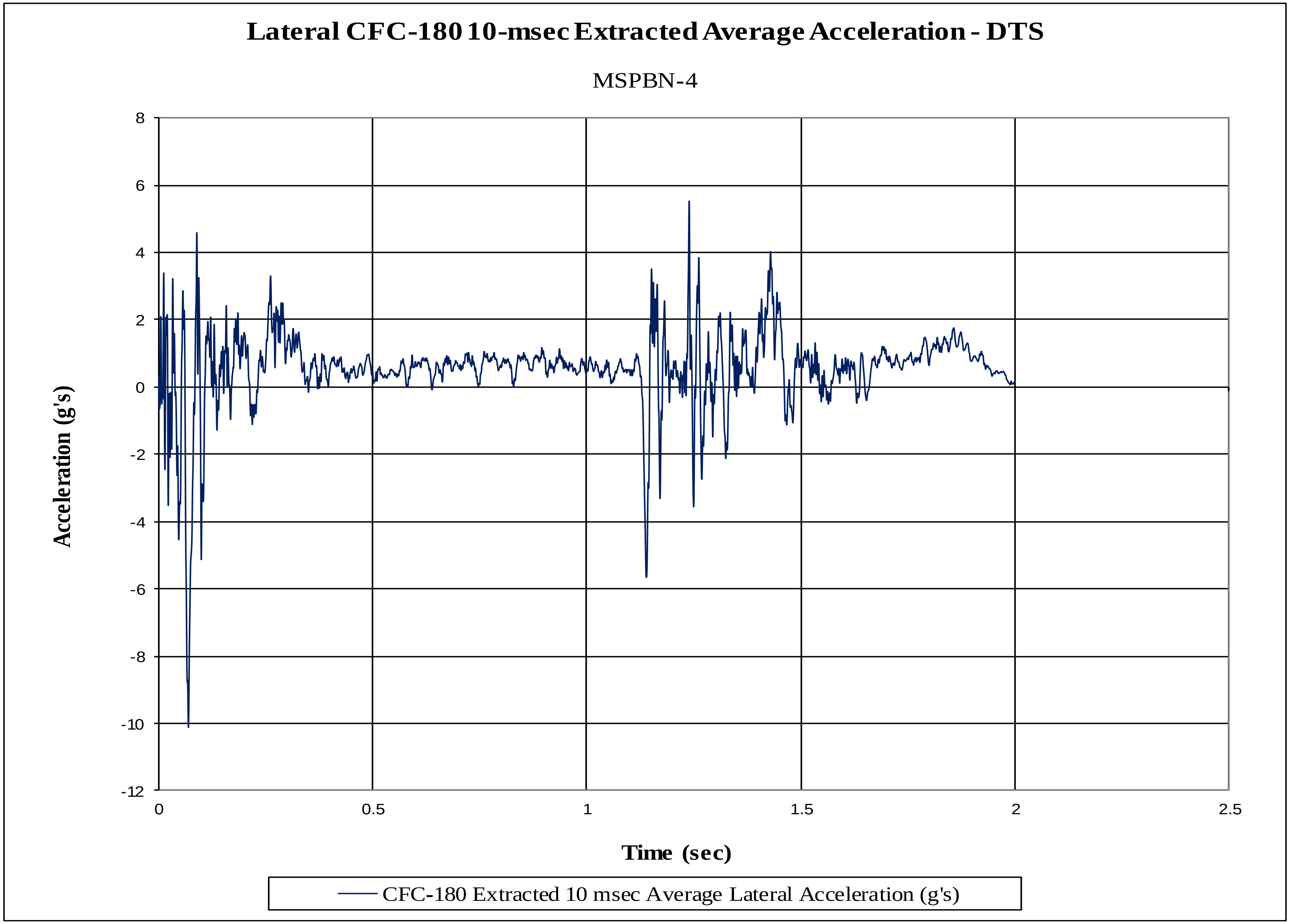


Figure E-12. 10-ms Average Lateral Deceleration (DTS), Test No. MSPBN-4

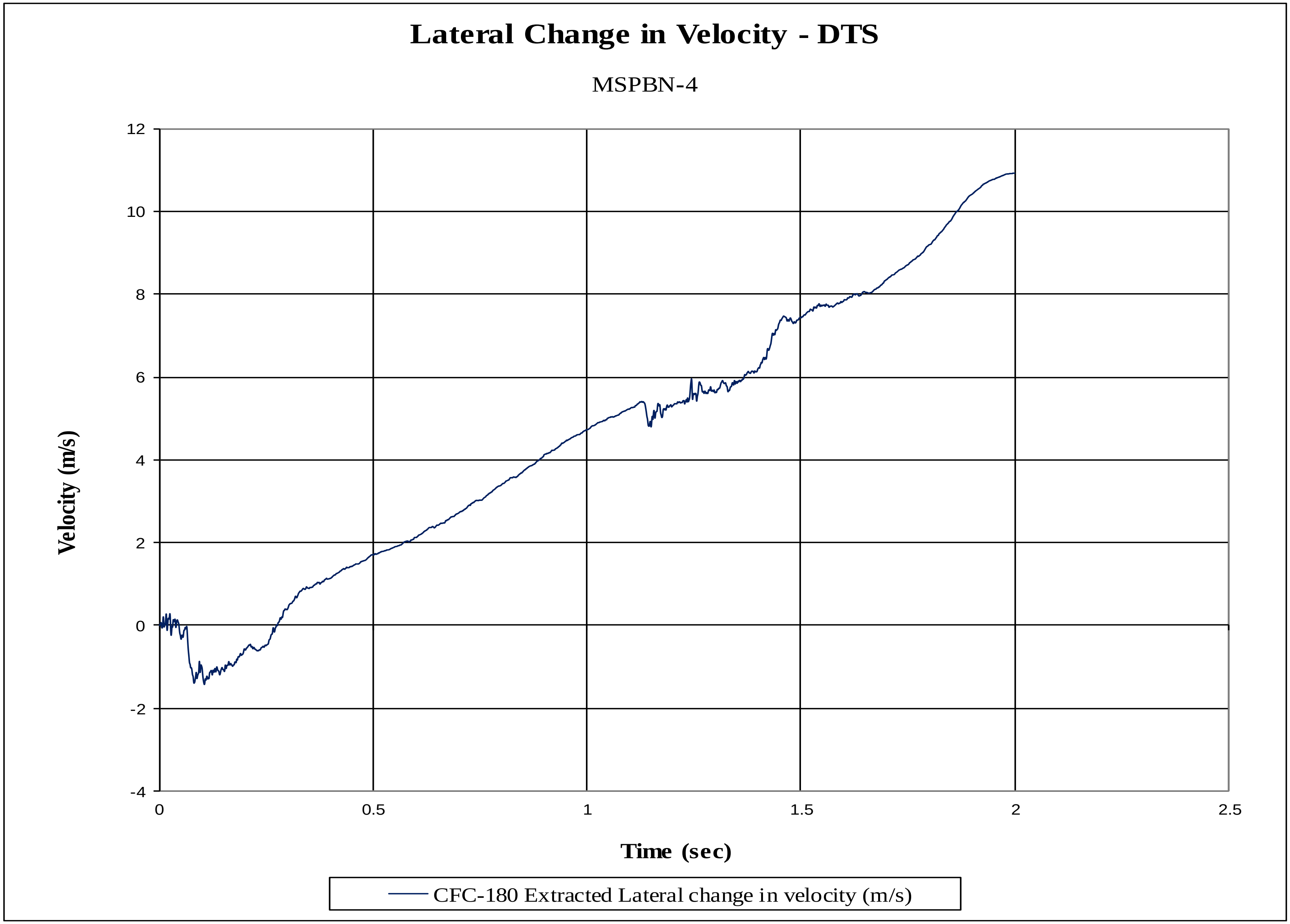


Figure E-13. Lateral Occupant Impact Velocity (DTS), Test No. MSPBN-4

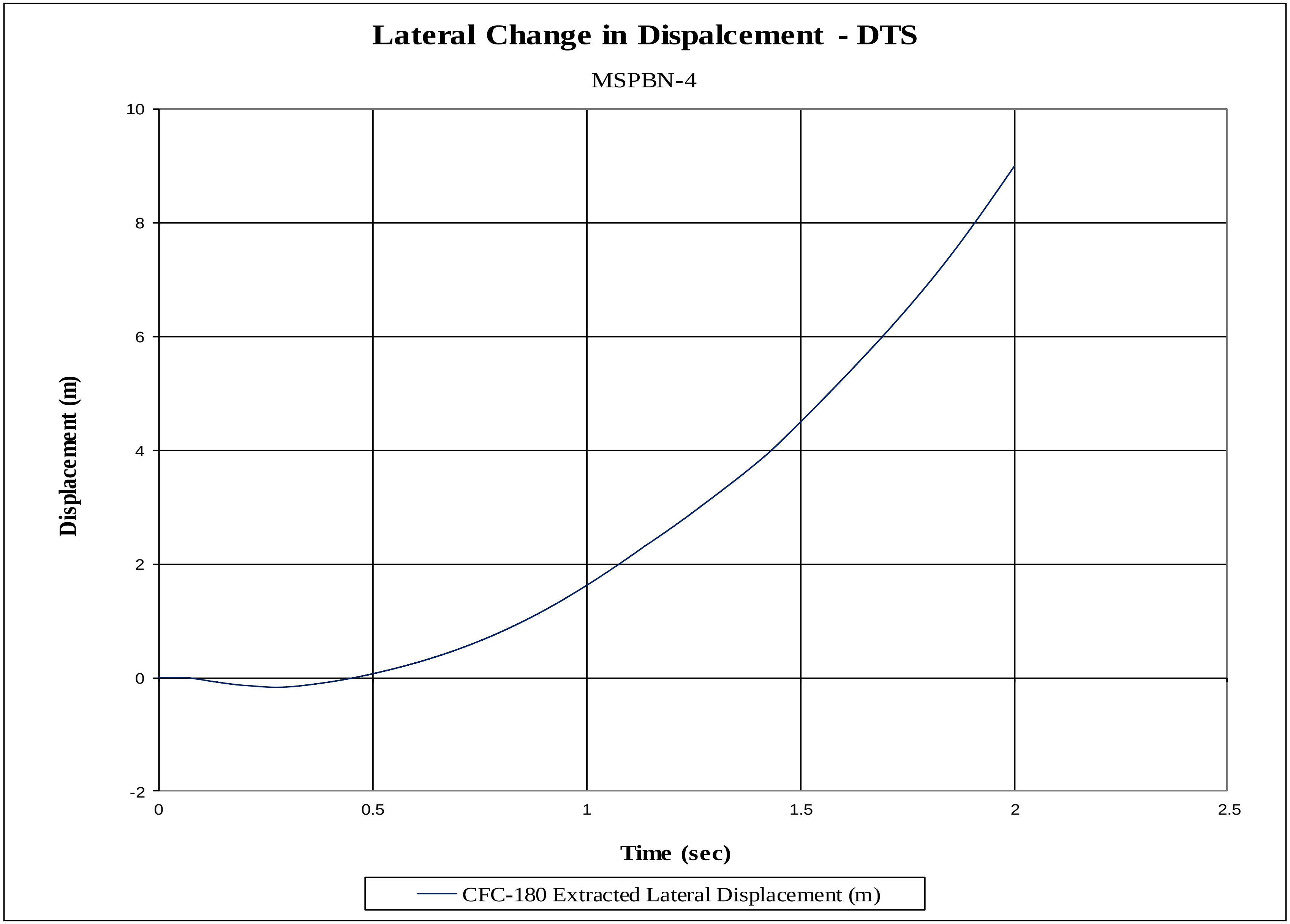


Figure E-14. Lateral Occupant Displacement (DTS), Test No. MSPBN-4

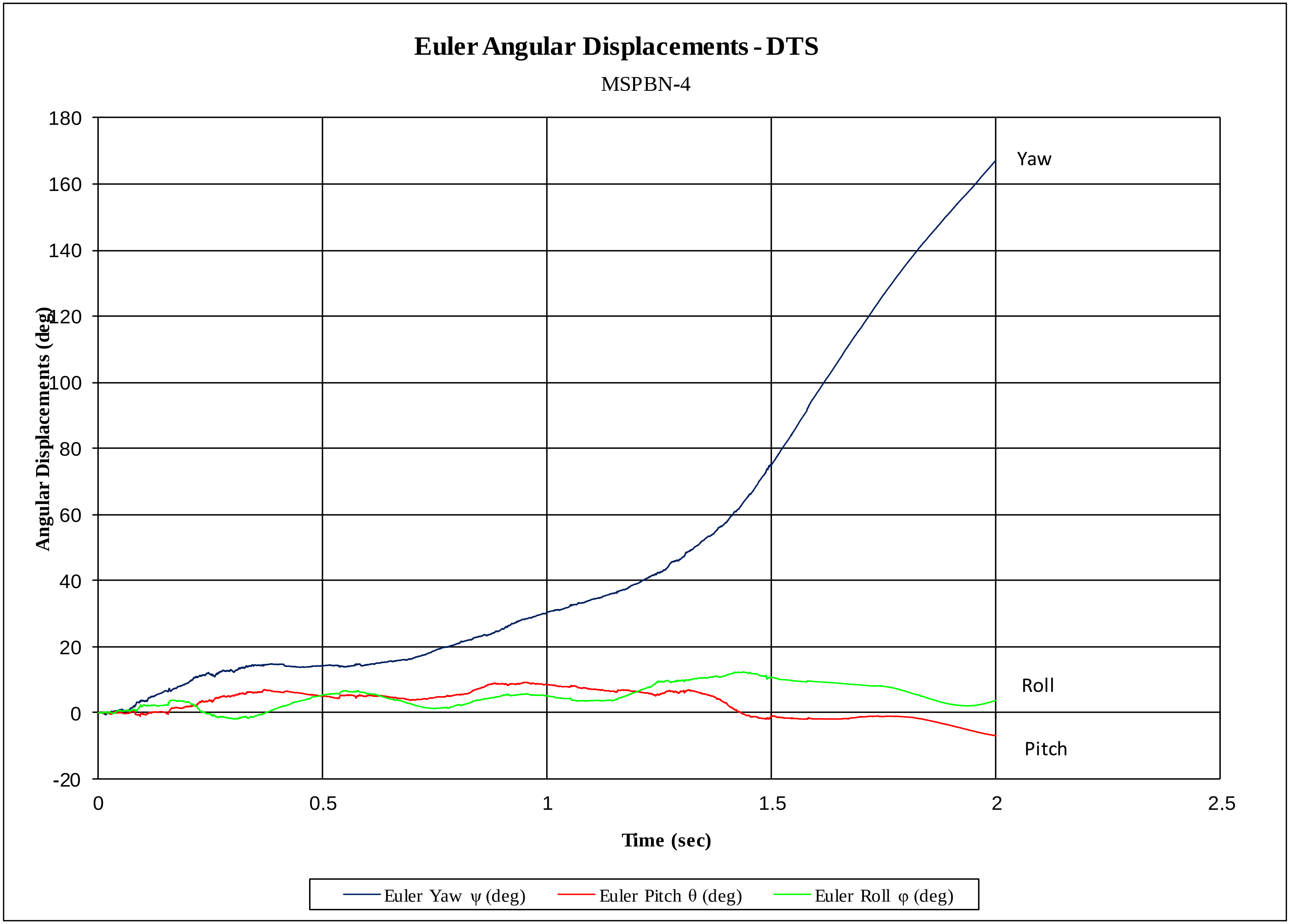


Figure E-15. Vehicle Angular Displacements (DTS), Test No. MSPBN-4

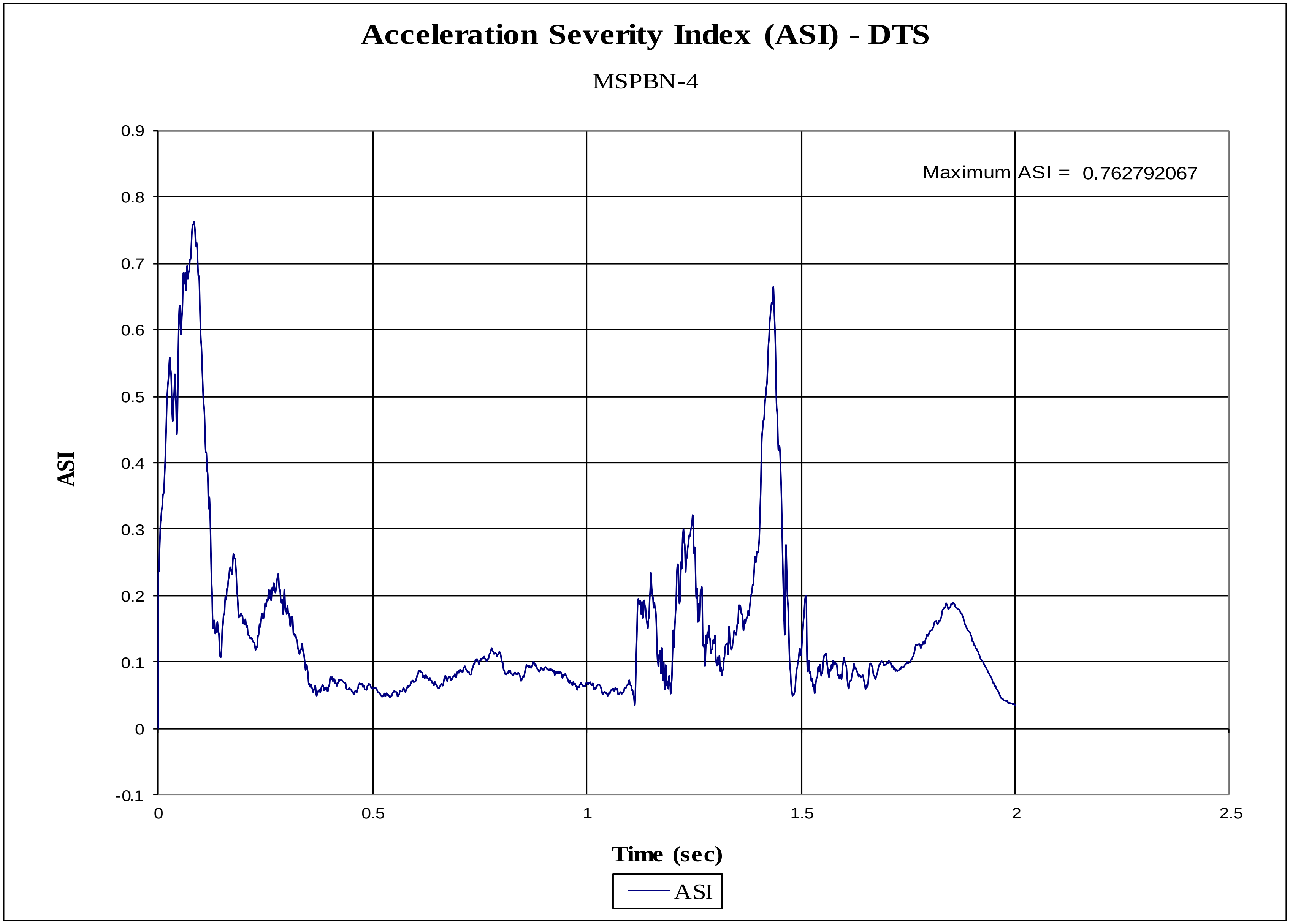


Figure E-16. Acceleration Severity Index (DTS), Test No. MSPBN-4

Appendix F. Accelerometer and Rate Transducer Data Plots, Test No. MSPBN-5

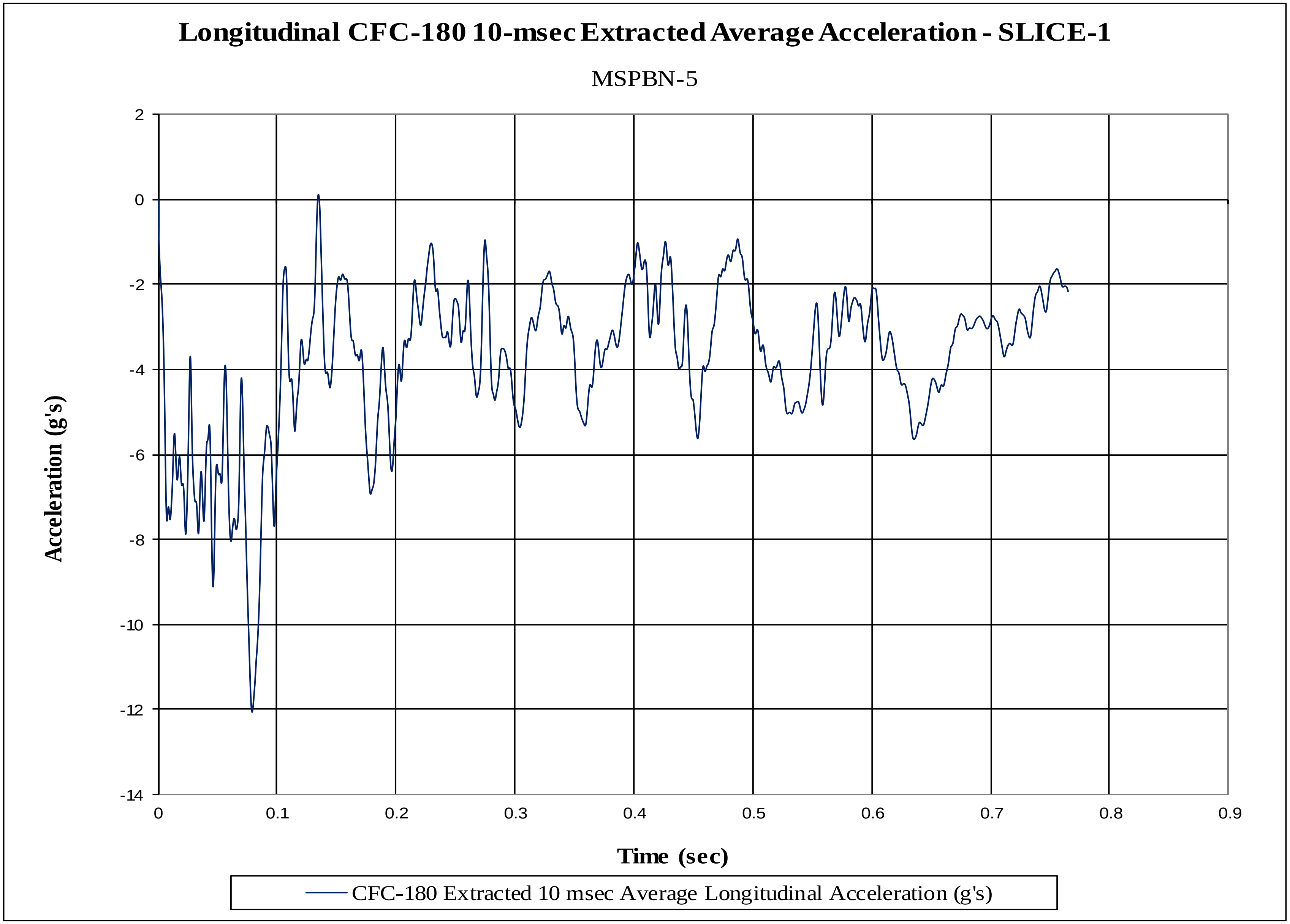


Figure F-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. MSPBN-5

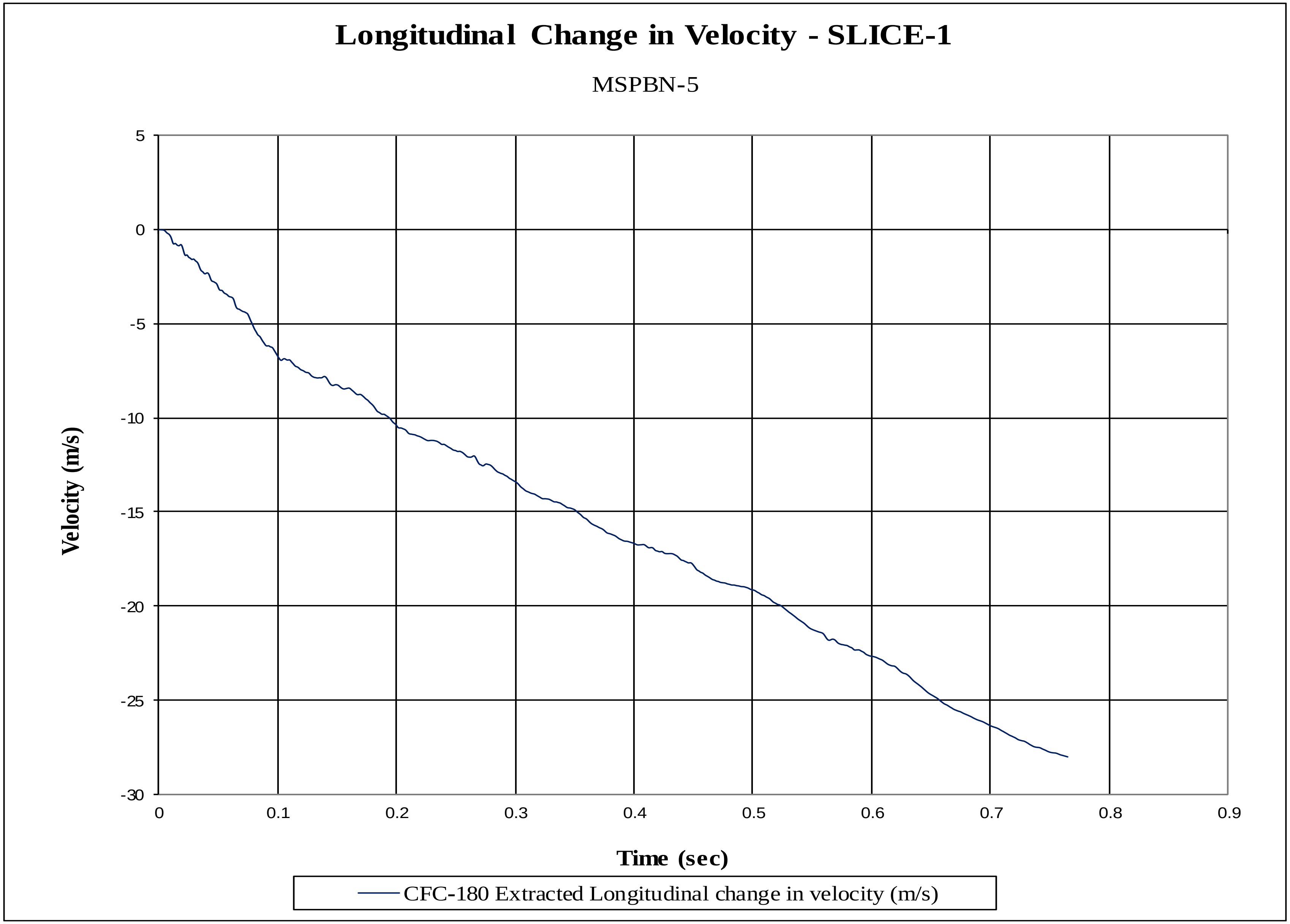


Figure F-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. MSPBN-5

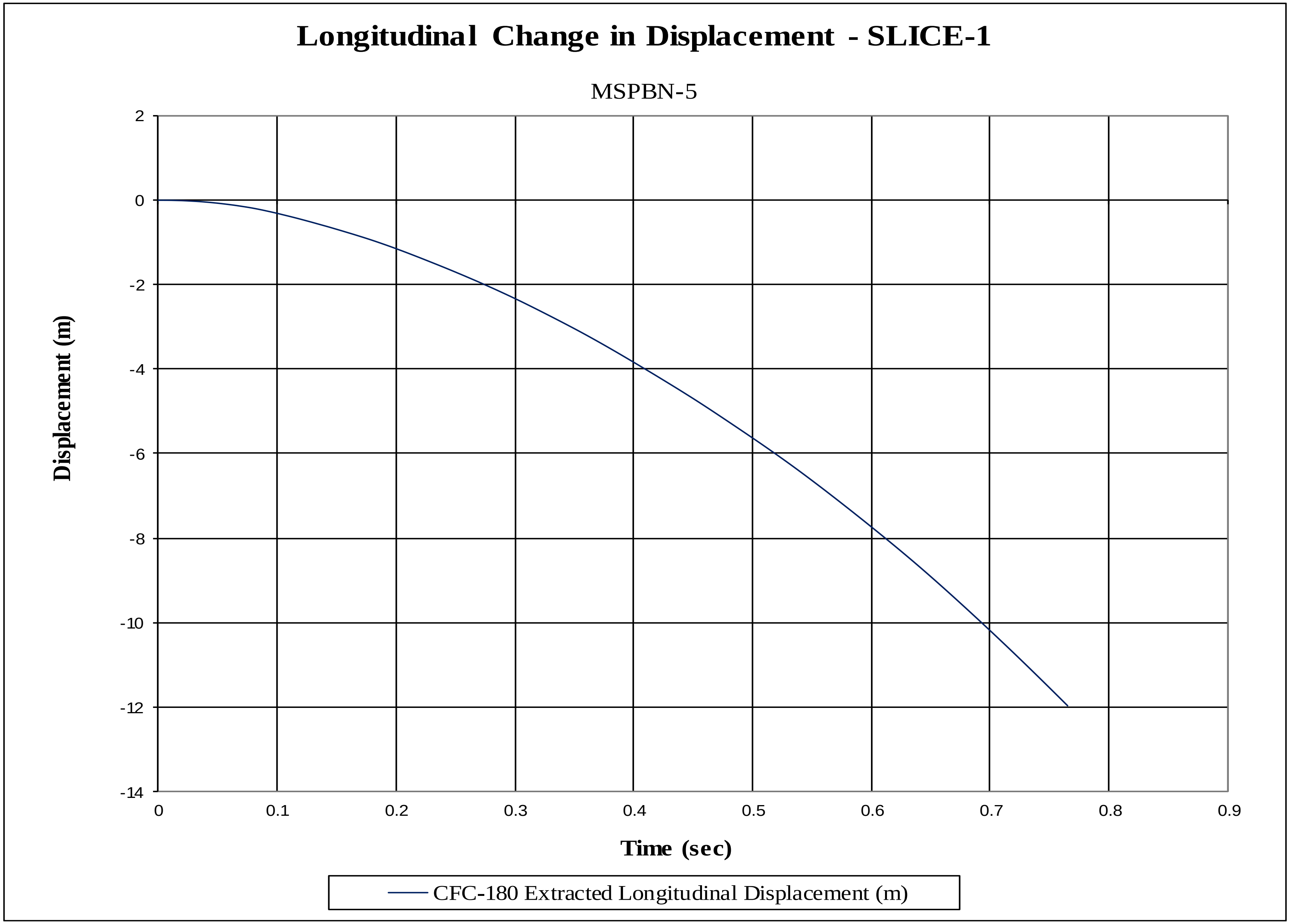


Figure F-3. Longitudinal Occupant Displacement (SLICE-1), Test No. MSPBN-5

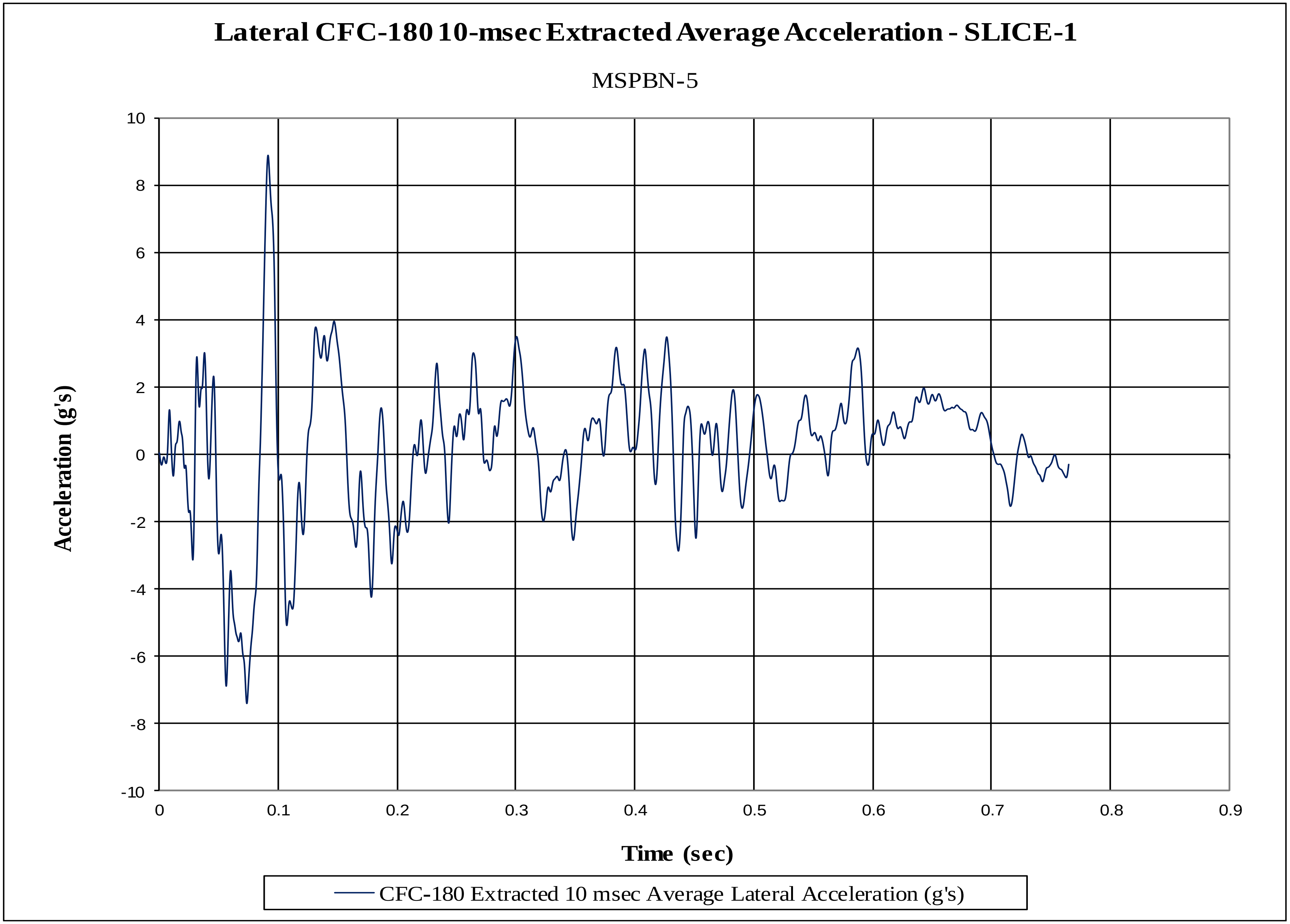


Figure F-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. MSPBN-5

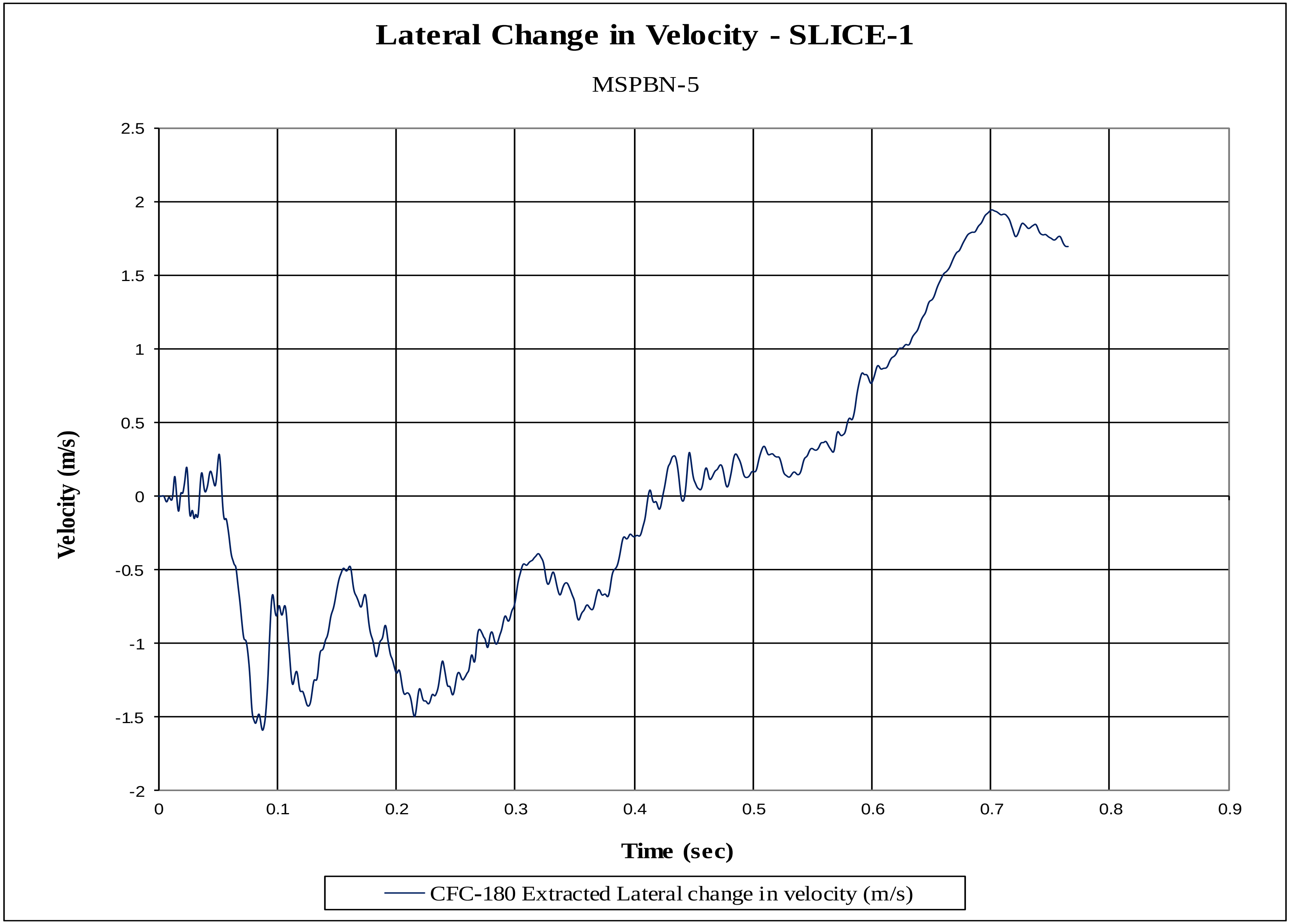


Figure F-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. MSPBN-5

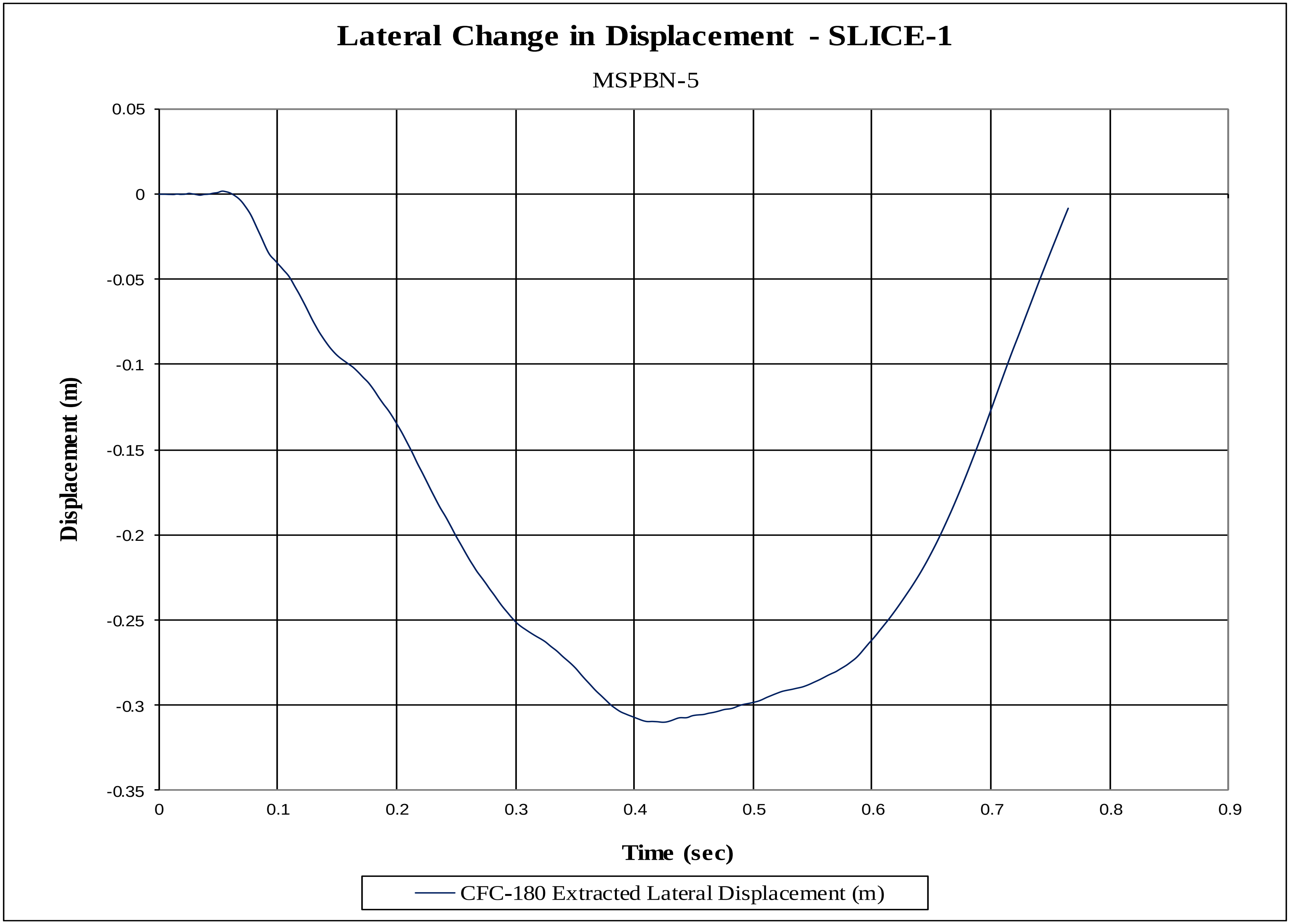


Figure F-6. Lateral Occupant Displacement (SLICE-1), Test No. MSPBN-5

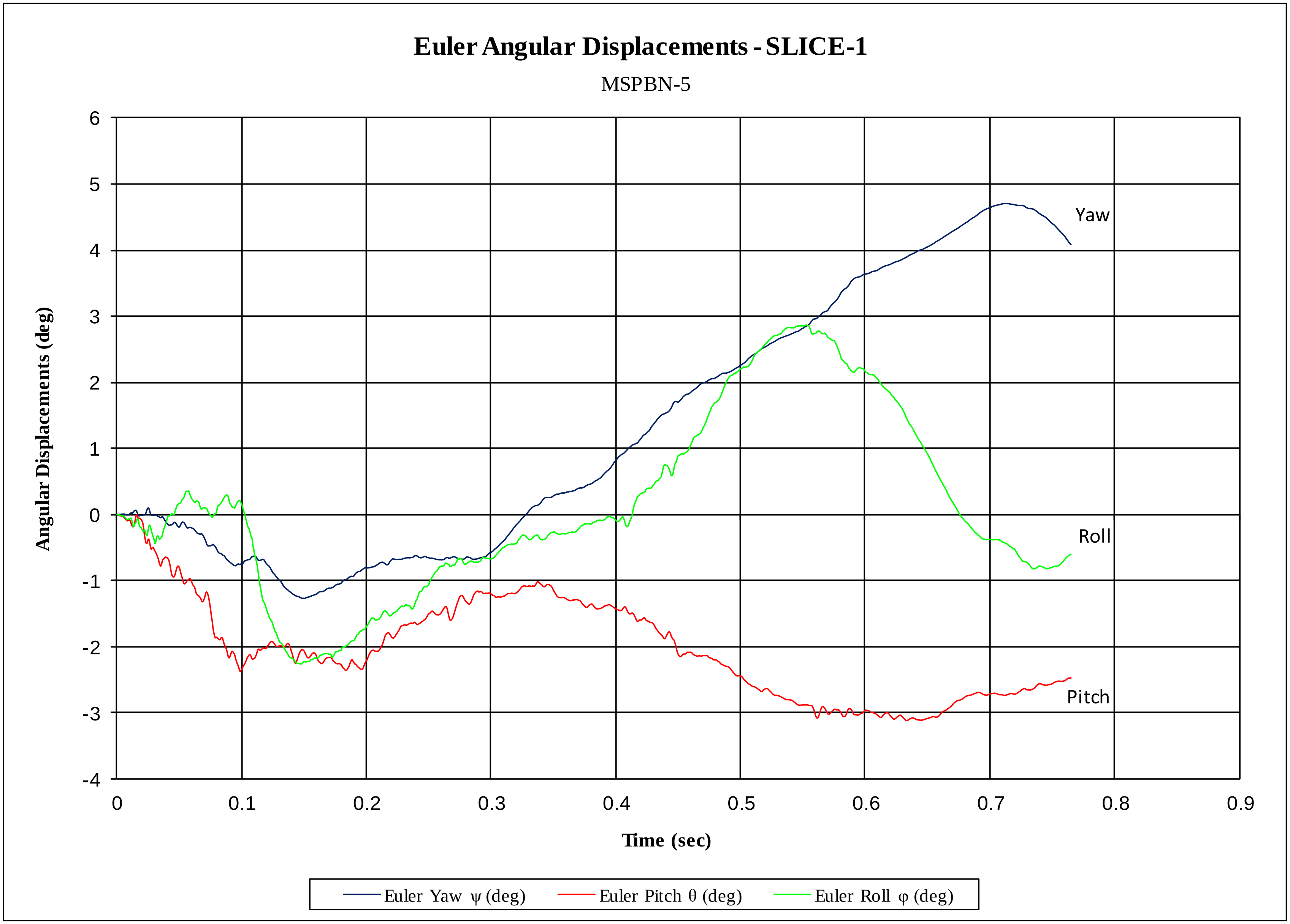


Figure F-7. Vehicle Angular Displacements (SLICE-1), Test No. MSPBN-5

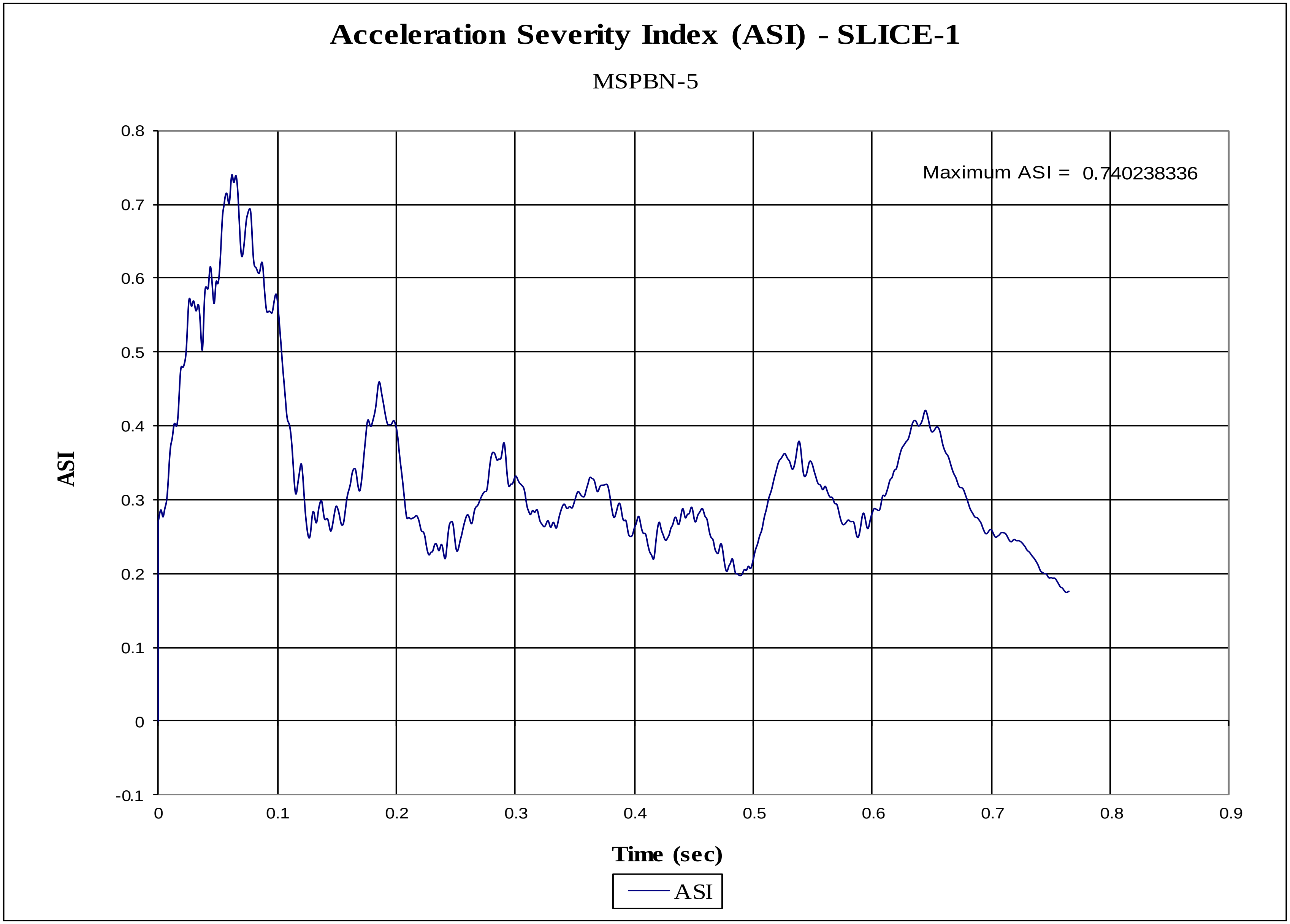


Figure F-8. Acceleration Severity Index (SLICE-1), Test No. MSPBN-5

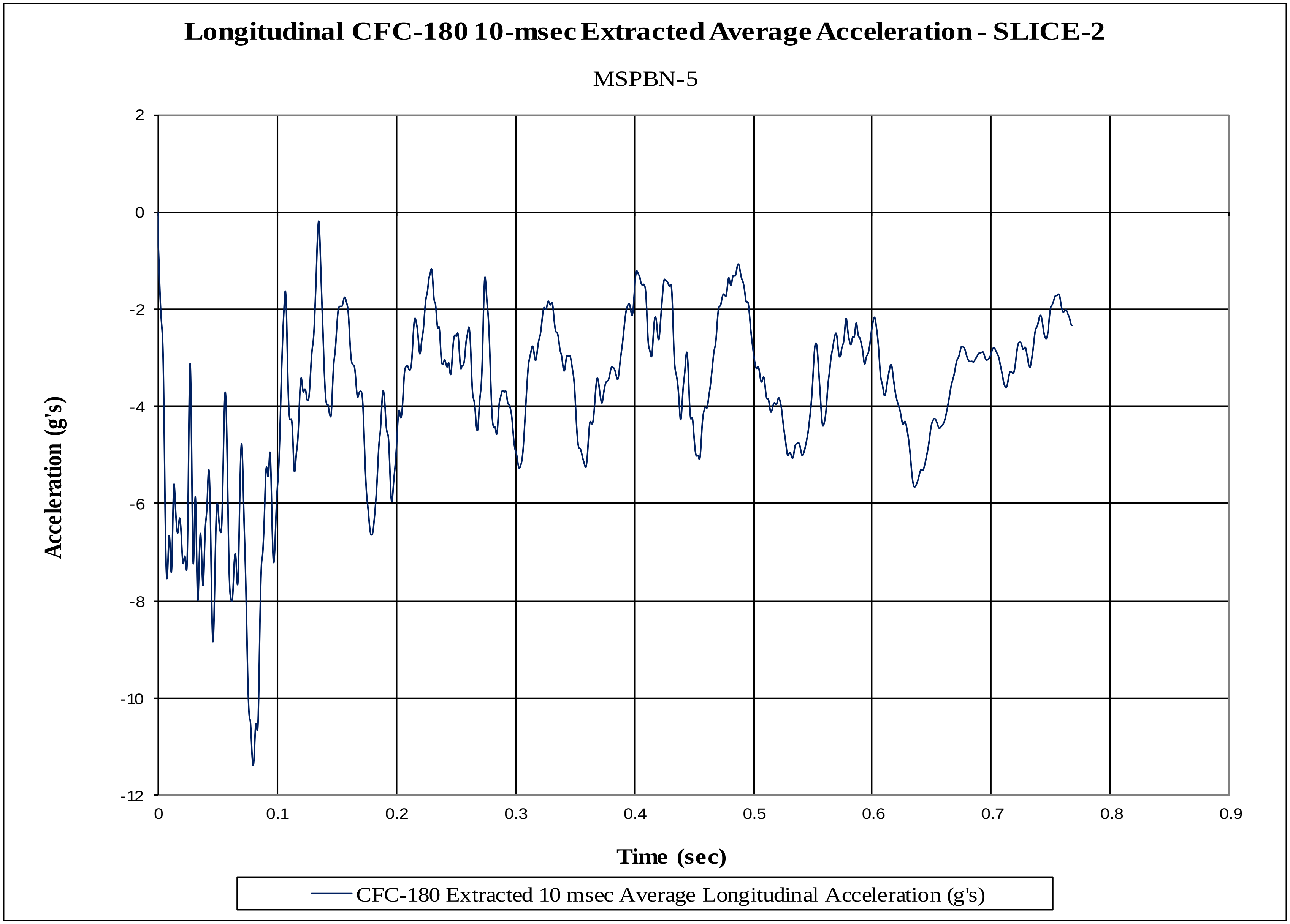


Figure F-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. MSPBN-5

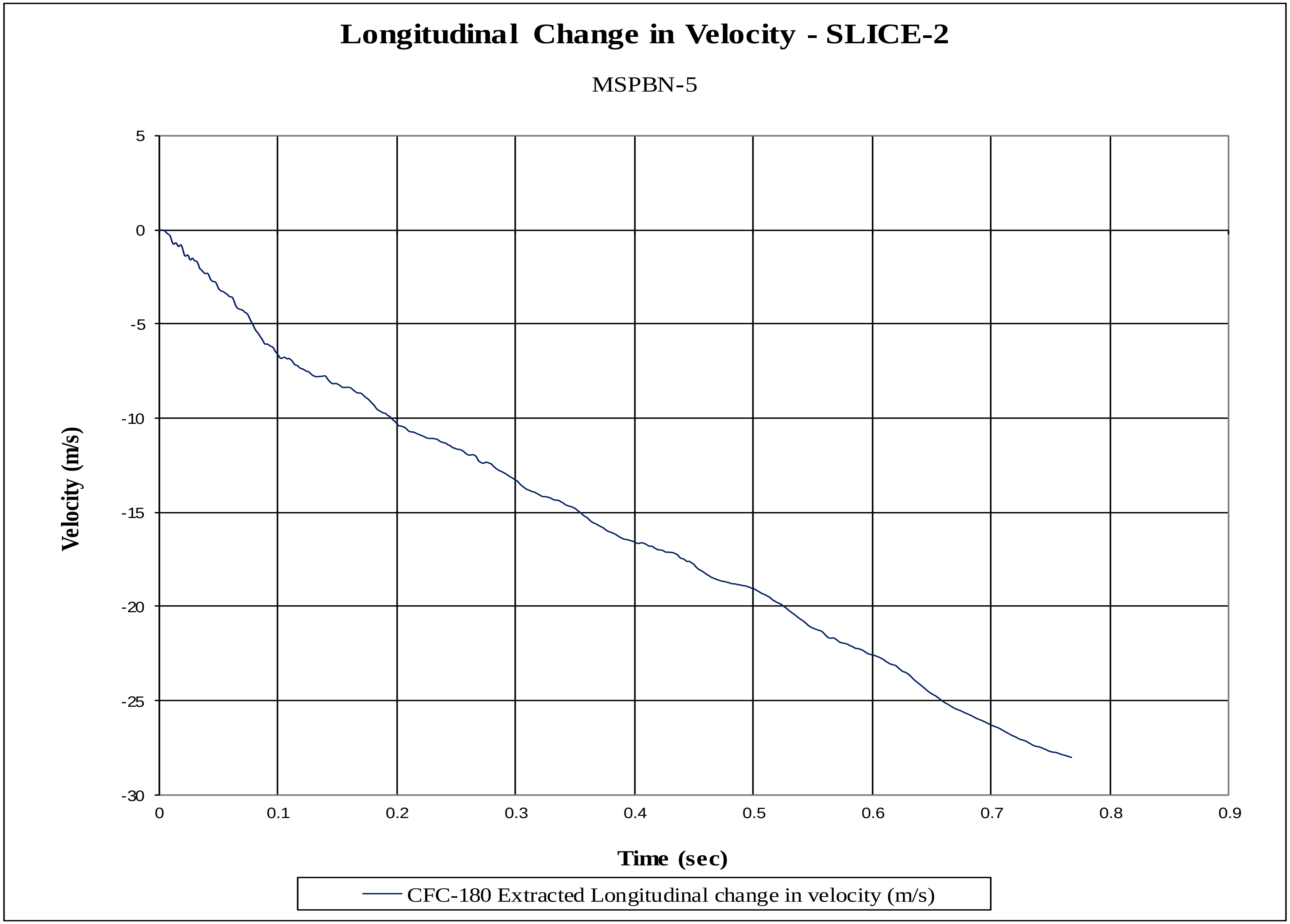


Figure F-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. MSPBN-5

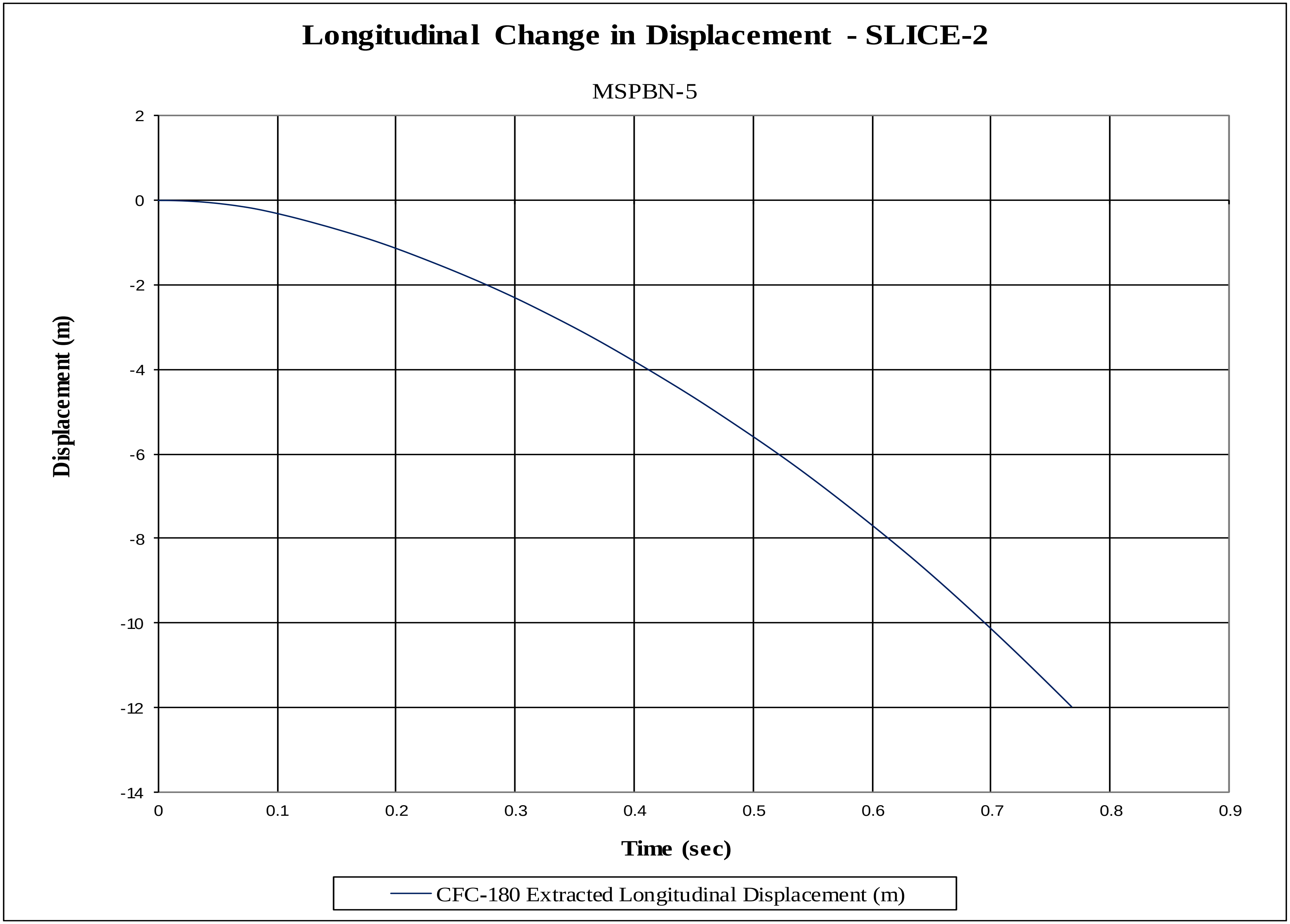


Figure F-11. Longitudinal Occupant Displacement (SLICE-2), Test No. MSPBN-5

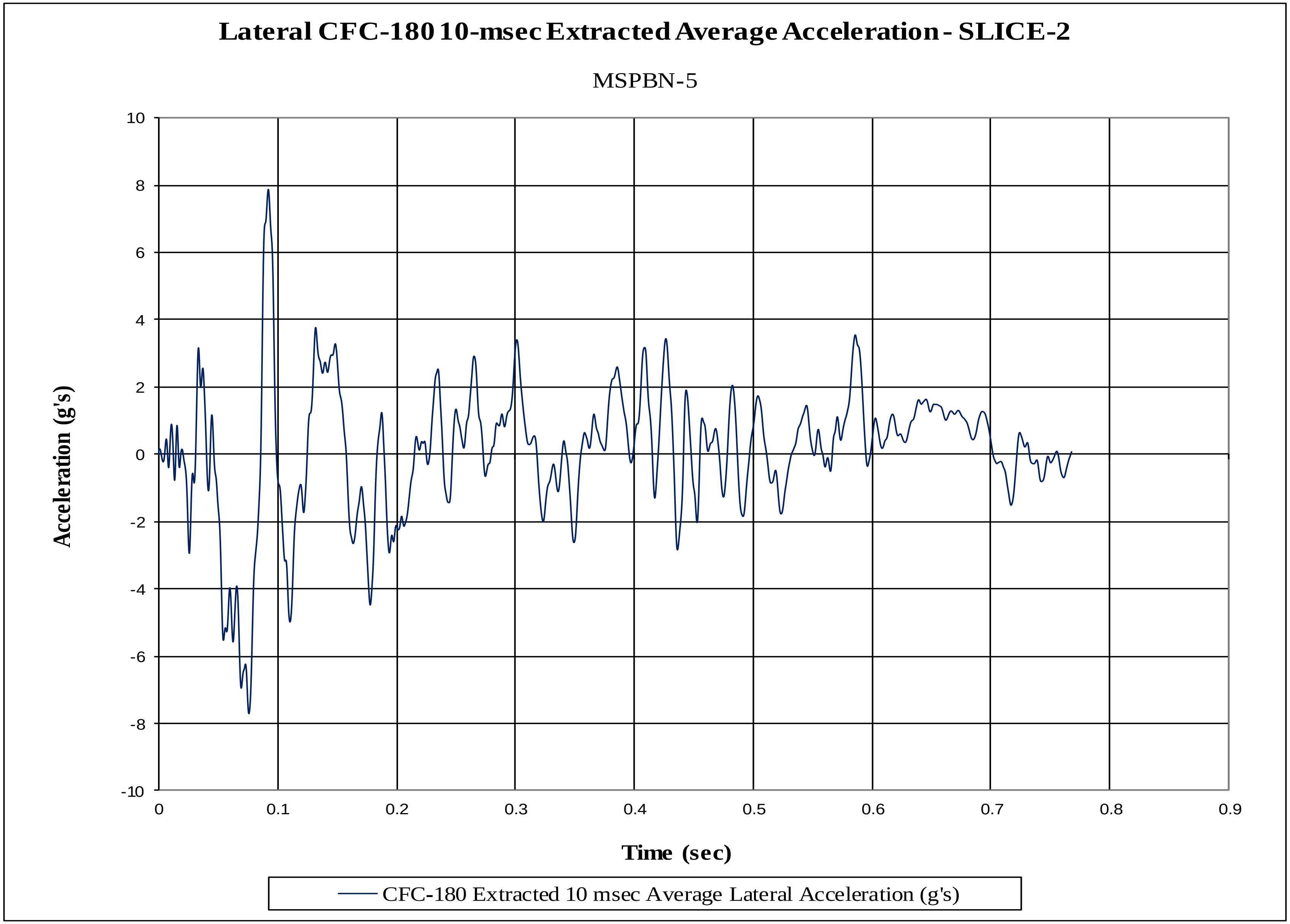


Figure F-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. MSPBN-5

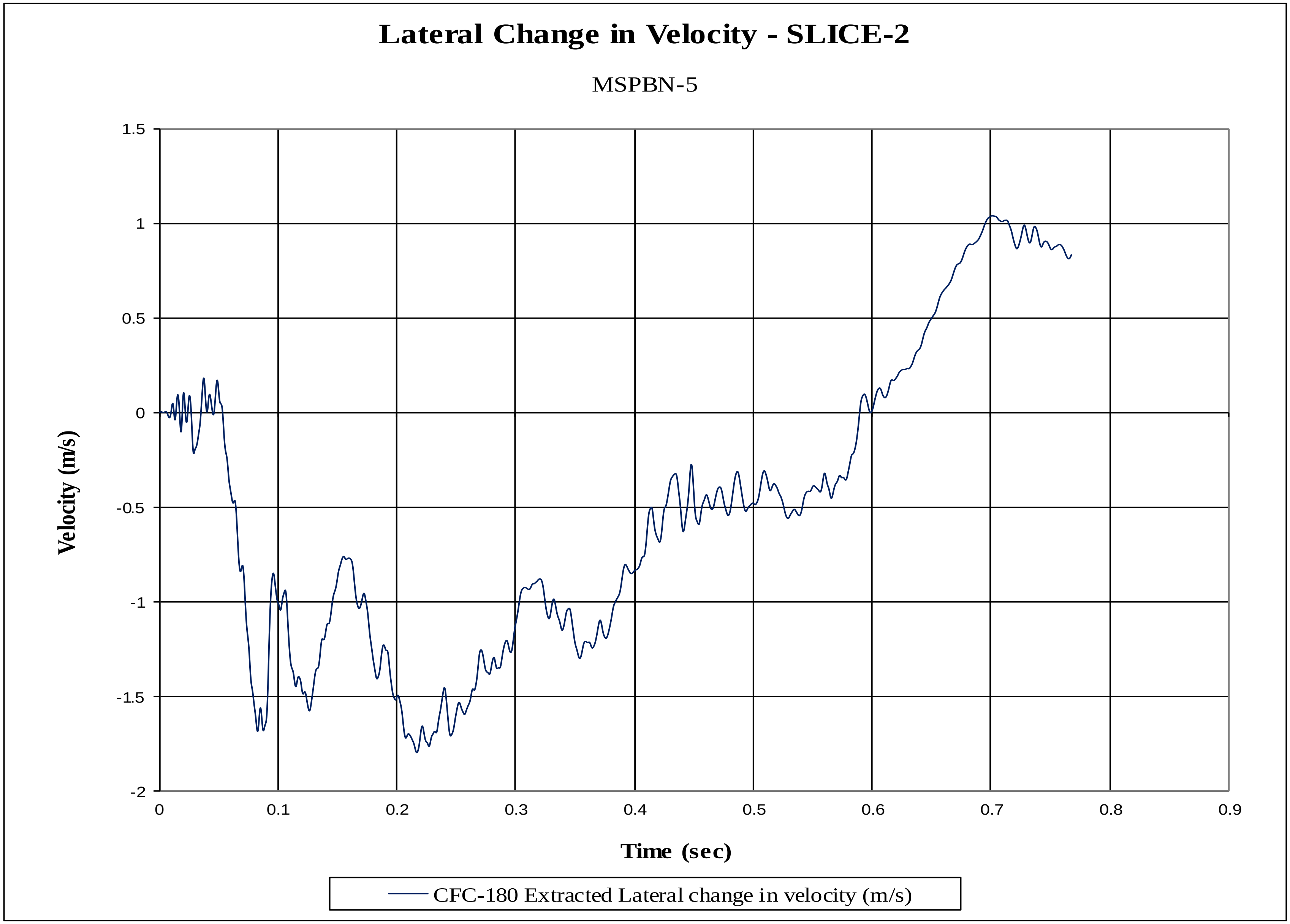


Figure F-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. MSPBN-5

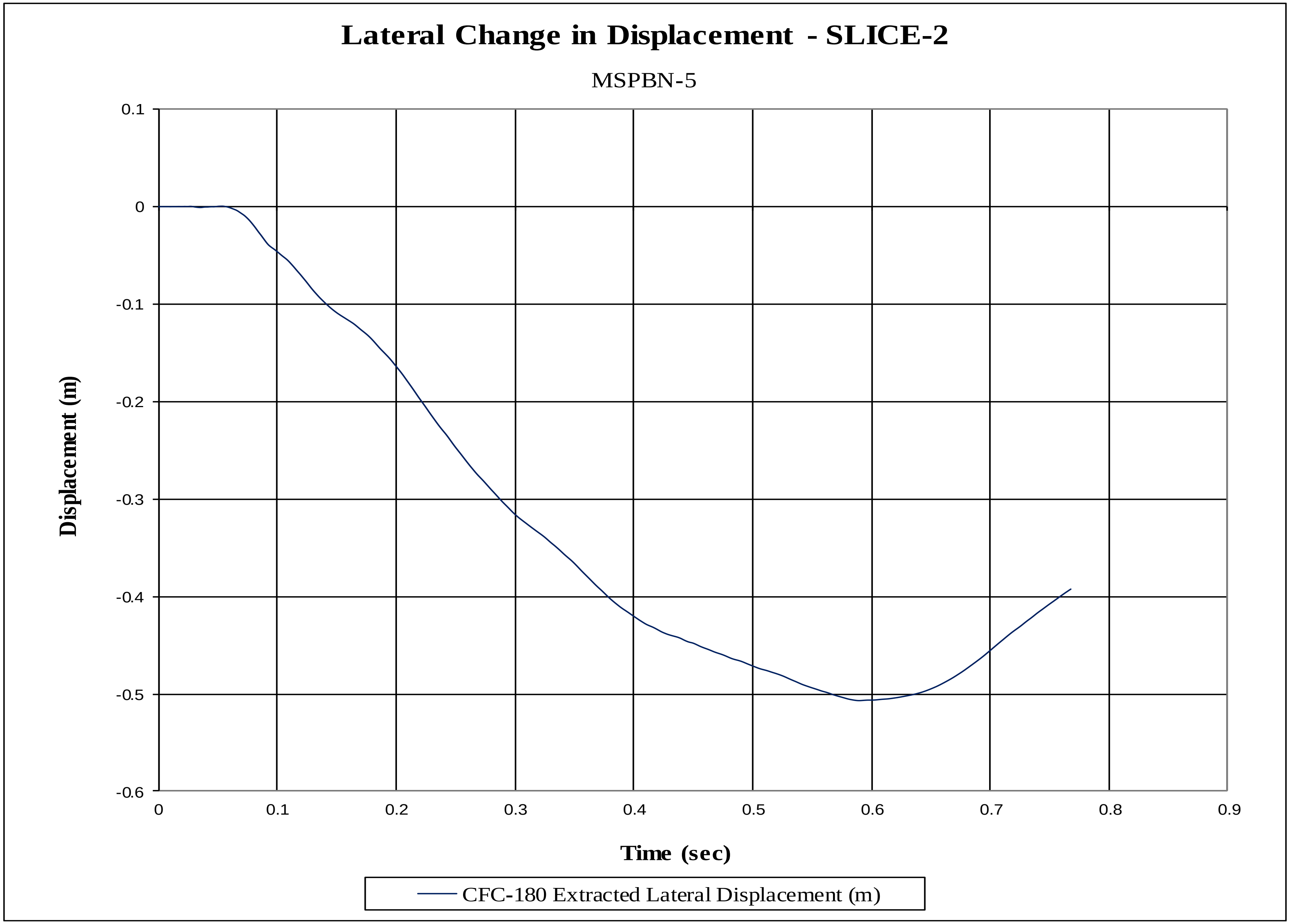


Figure F-14. Lateral Occupant Displacement (SLICE-2), Test No. MSPBN-5

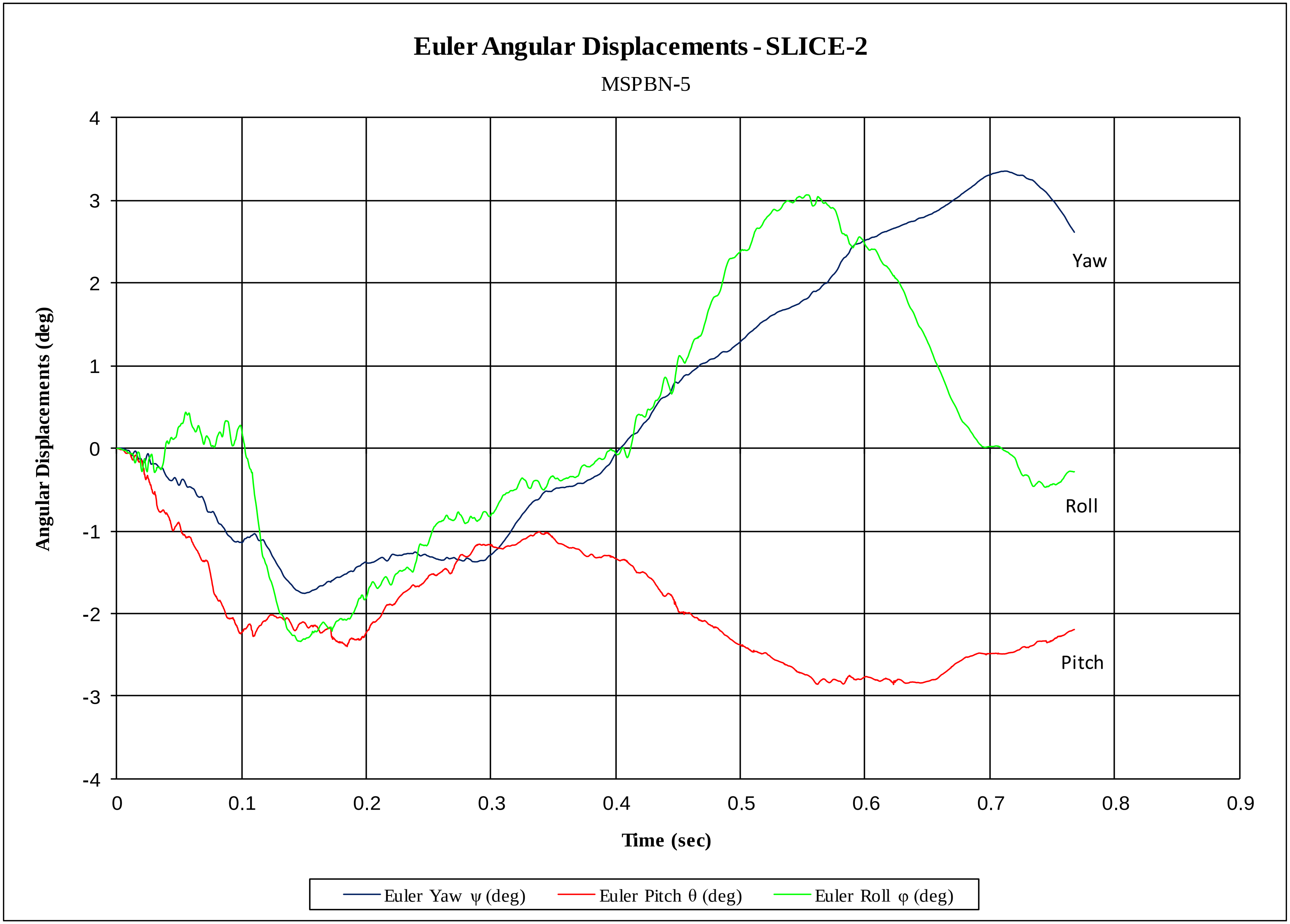


Figure F-15. Vehicle Angular Displacements (SLICE-2), Test No. MSPBN-5

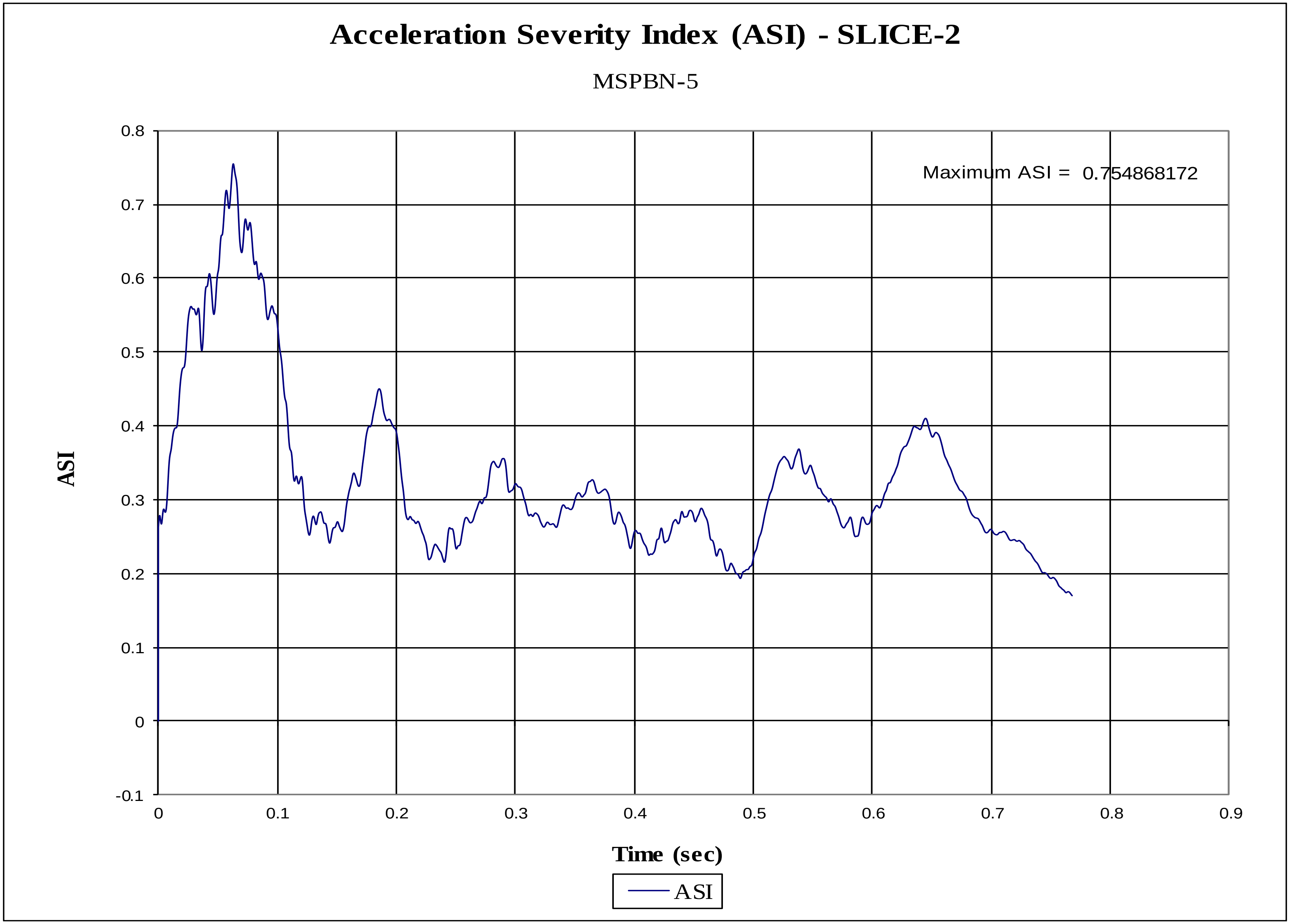


Figure F-16. Acceleration Severity Index (SLICE-2), Test No. MSPBN-5

Appendix G. Accelerometer and Rate Transducer Data Plots, Test No. MSPBN-6

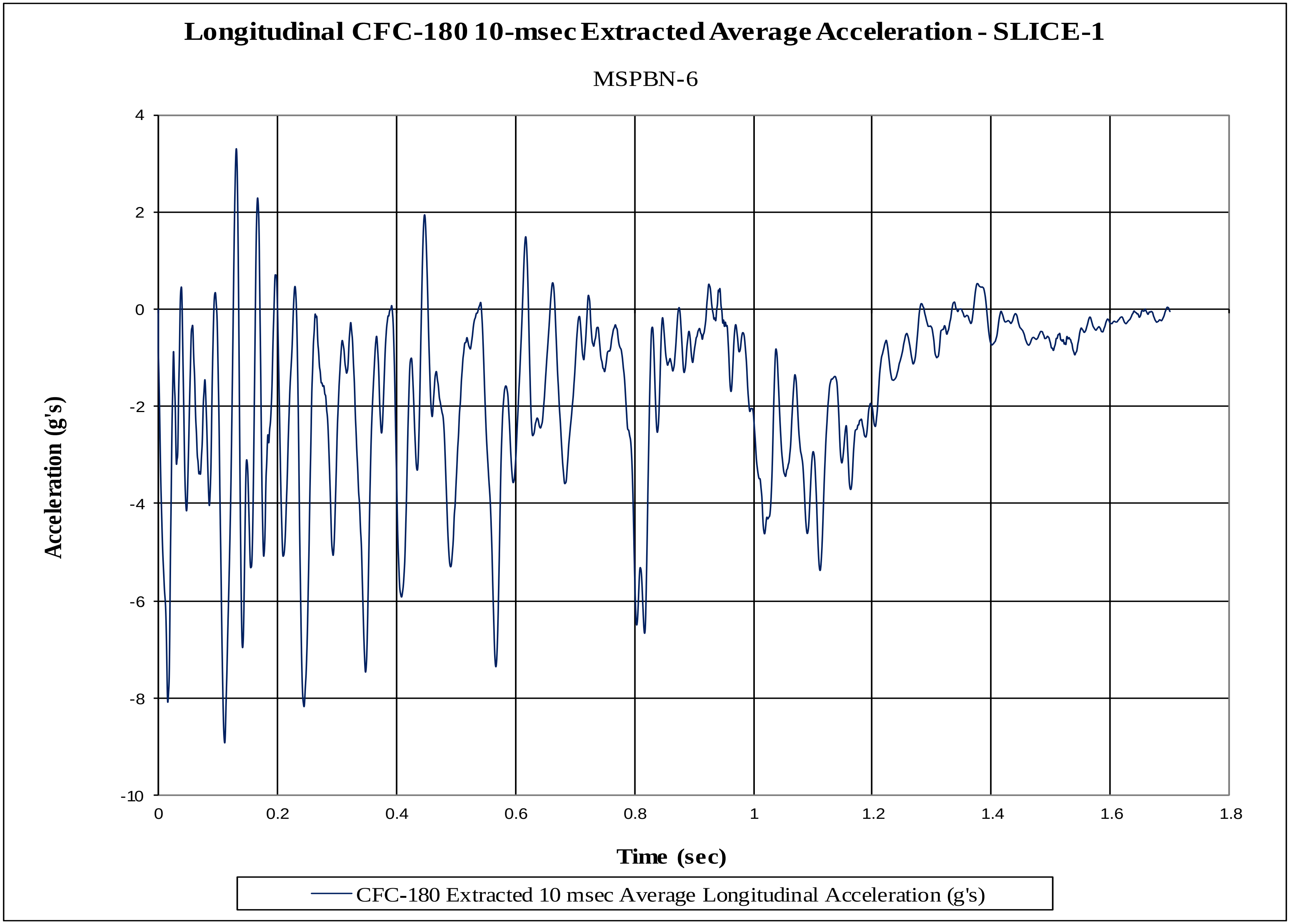


Figure G-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. MSPBN-6

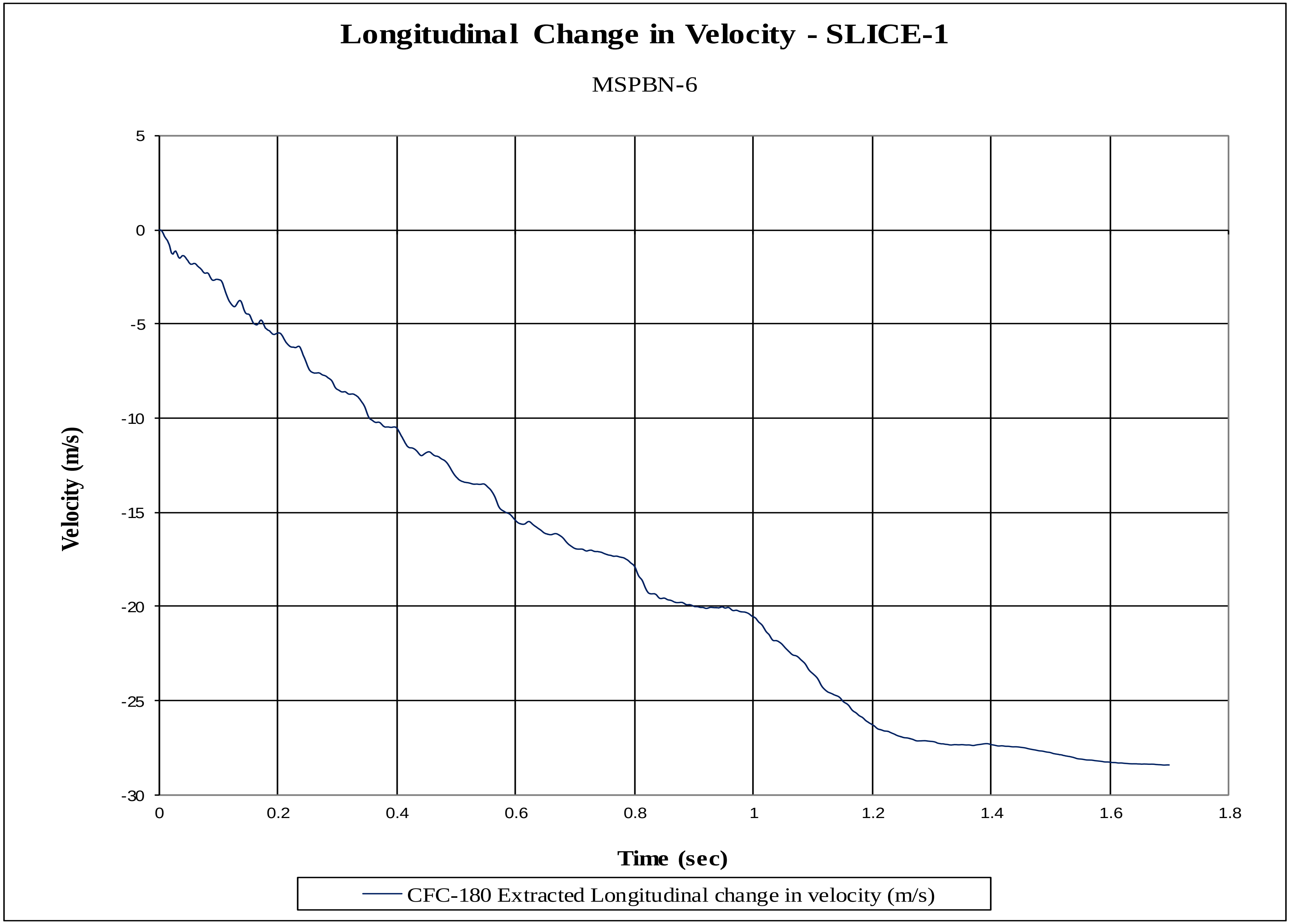


Figure G-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. MSPBN-6

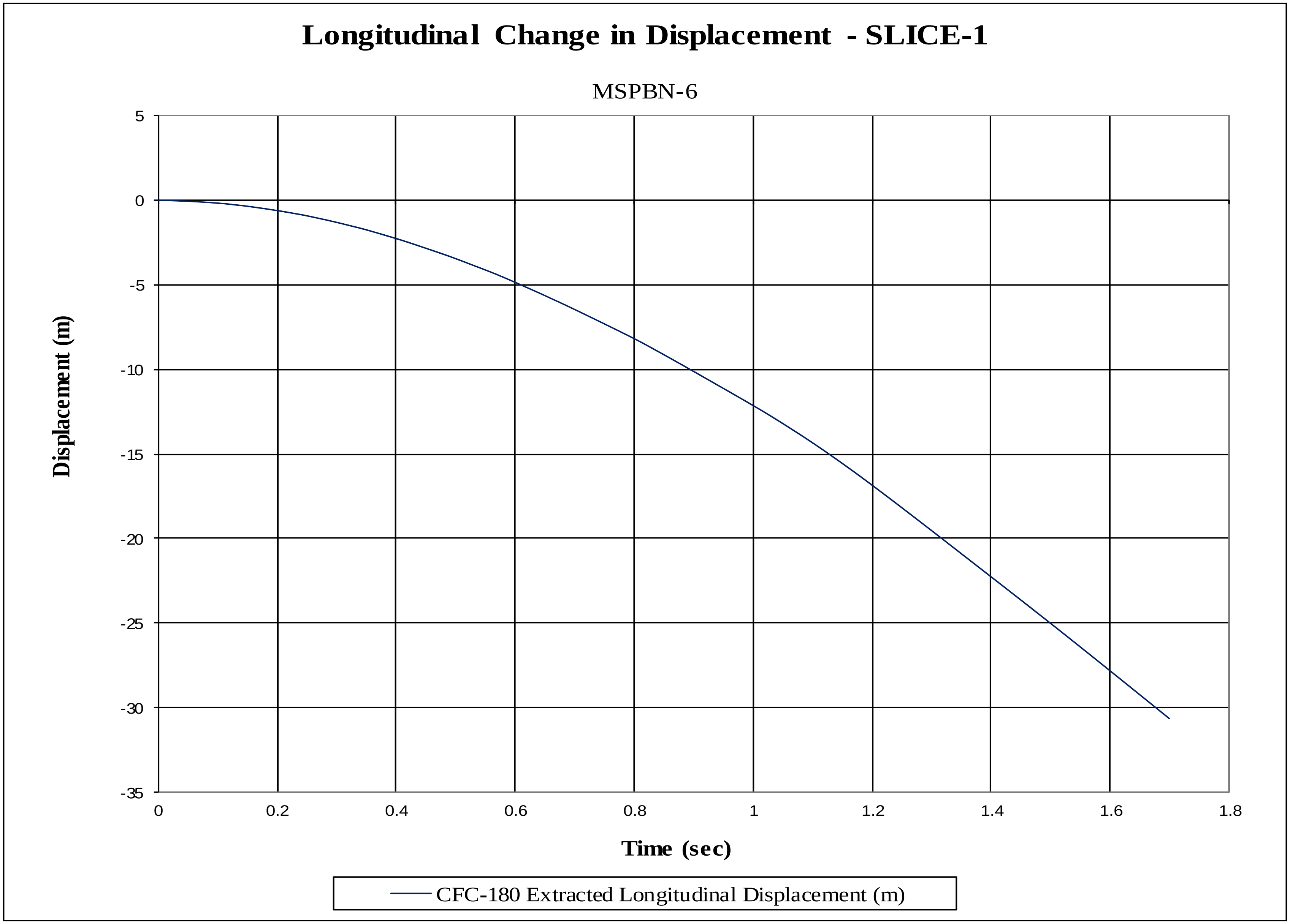


Figure G-3. Longitudinal Occupant Displacement (SLICE-1), Test No. MSPBN-6

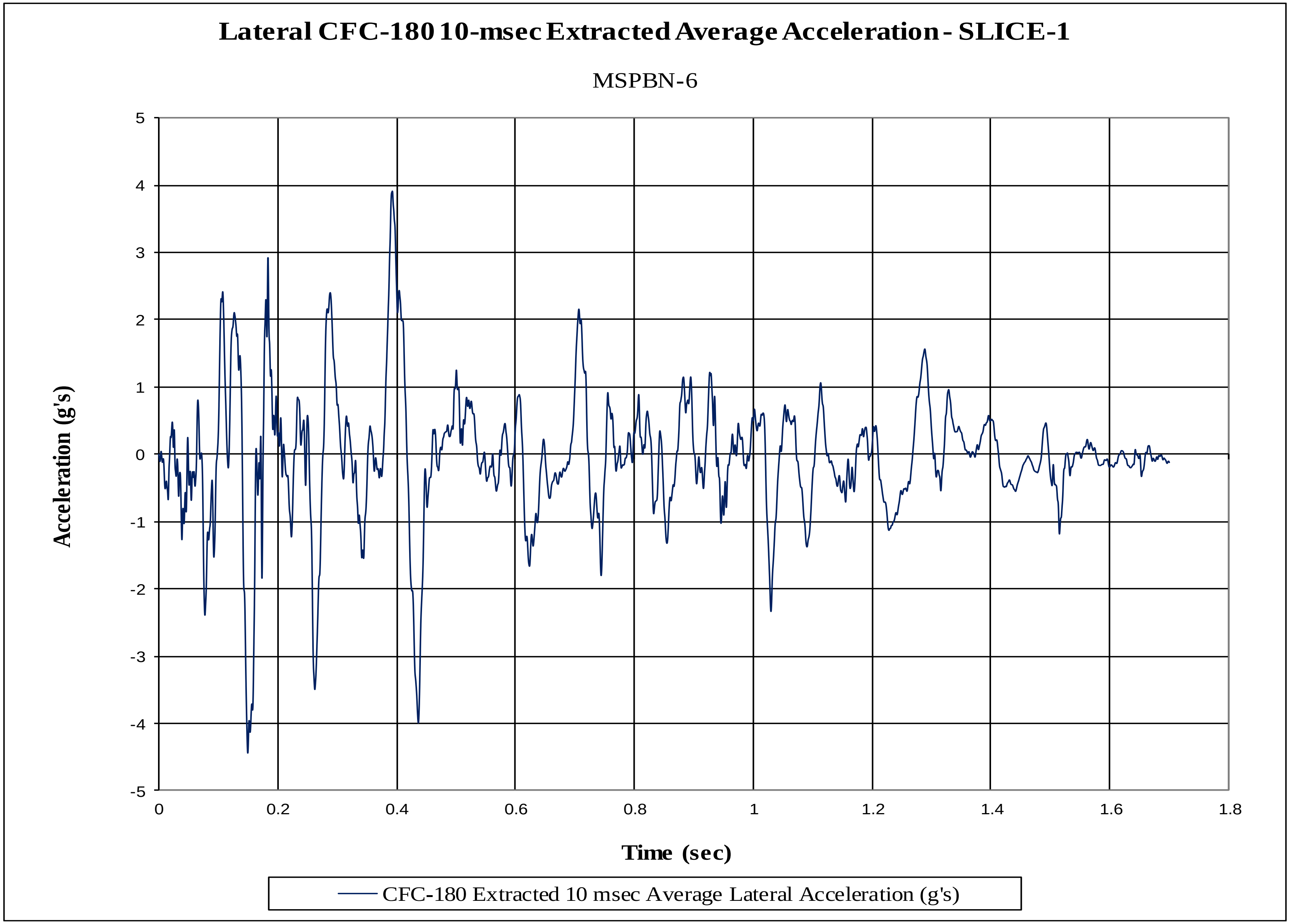


Figure G-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. MSPBN-6

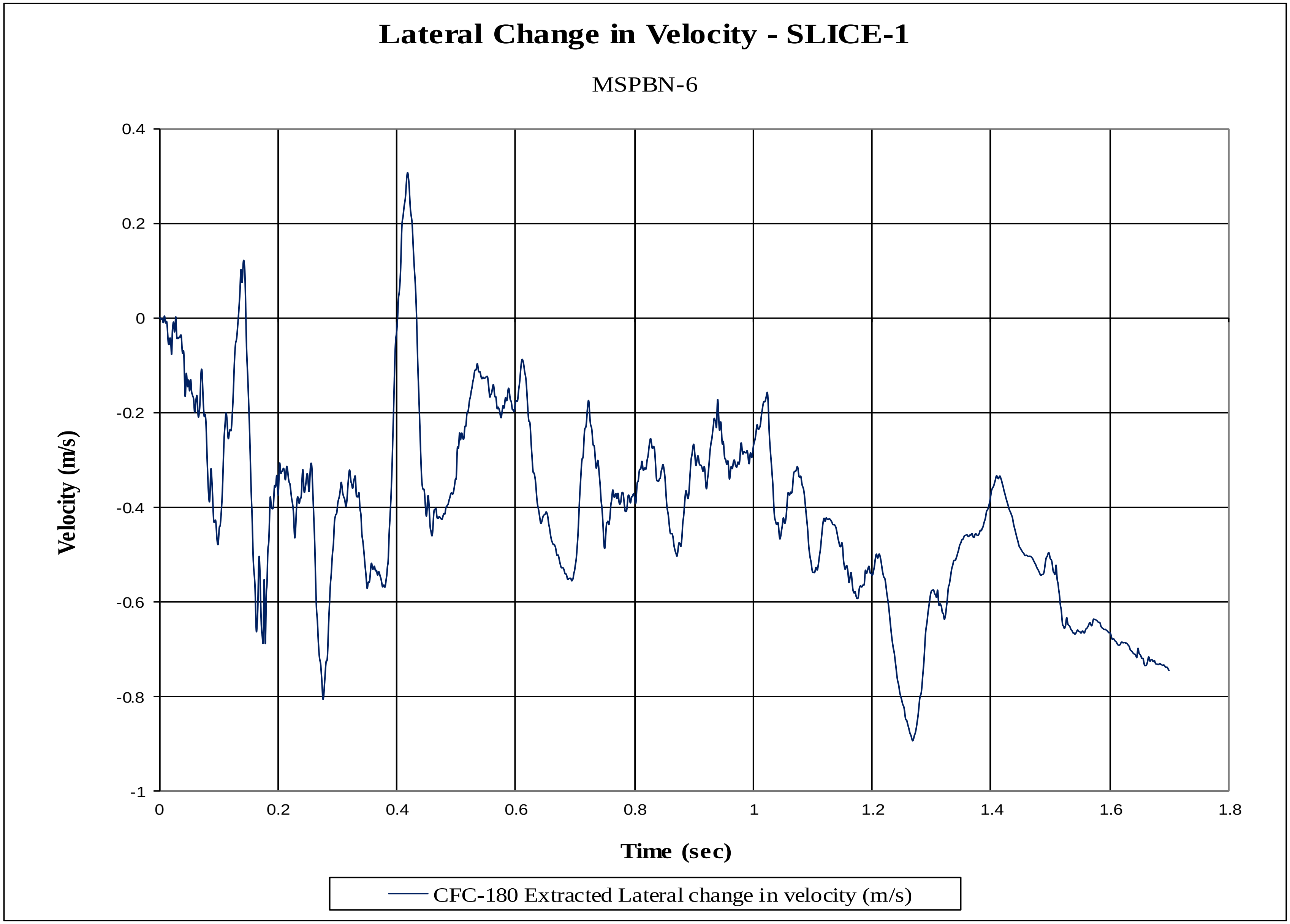


Figure G-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. MSPBN-6

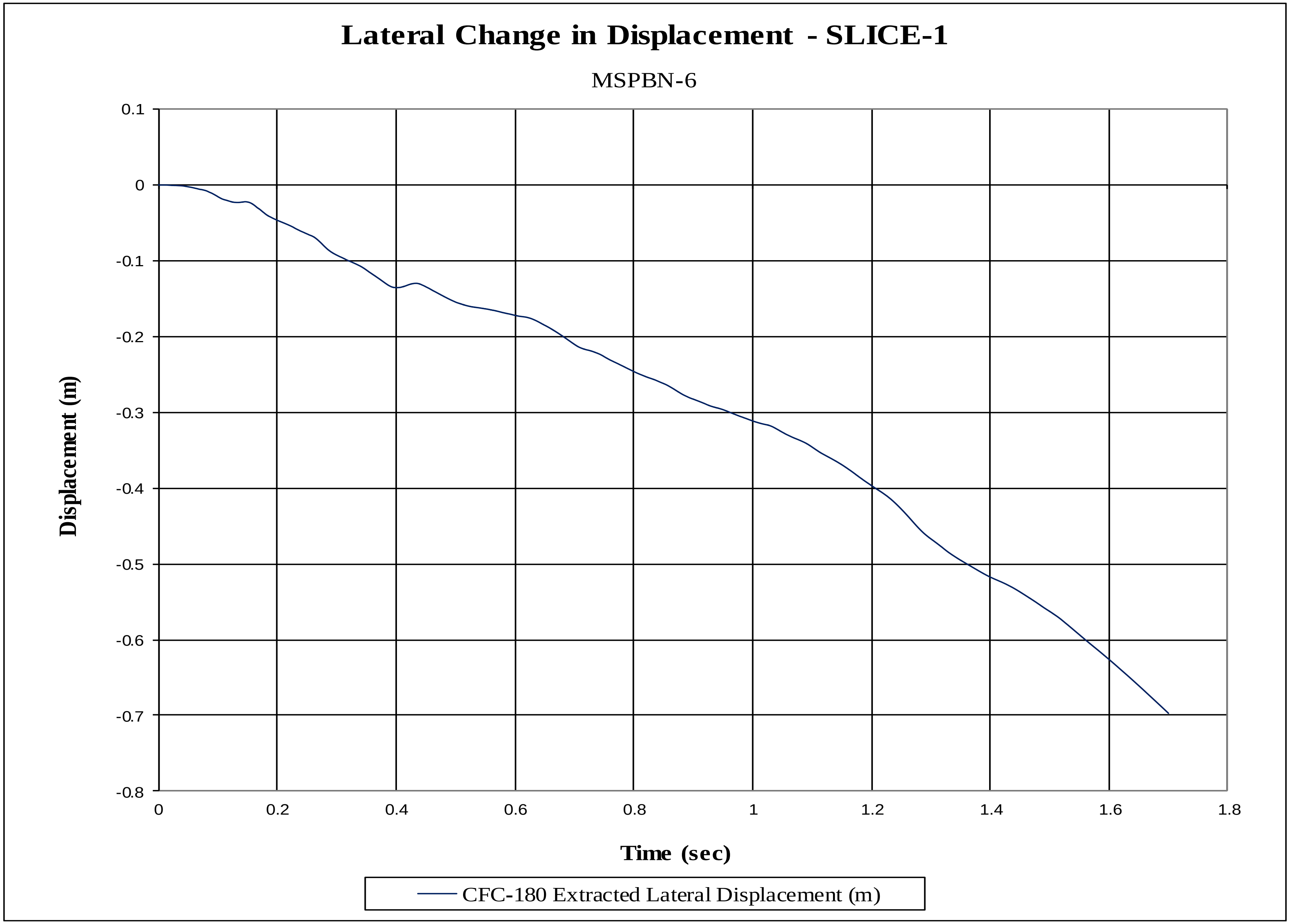


Figure G-6. Lateral Occupant Displacement (SLICE-1), Test No. MSPBN-6

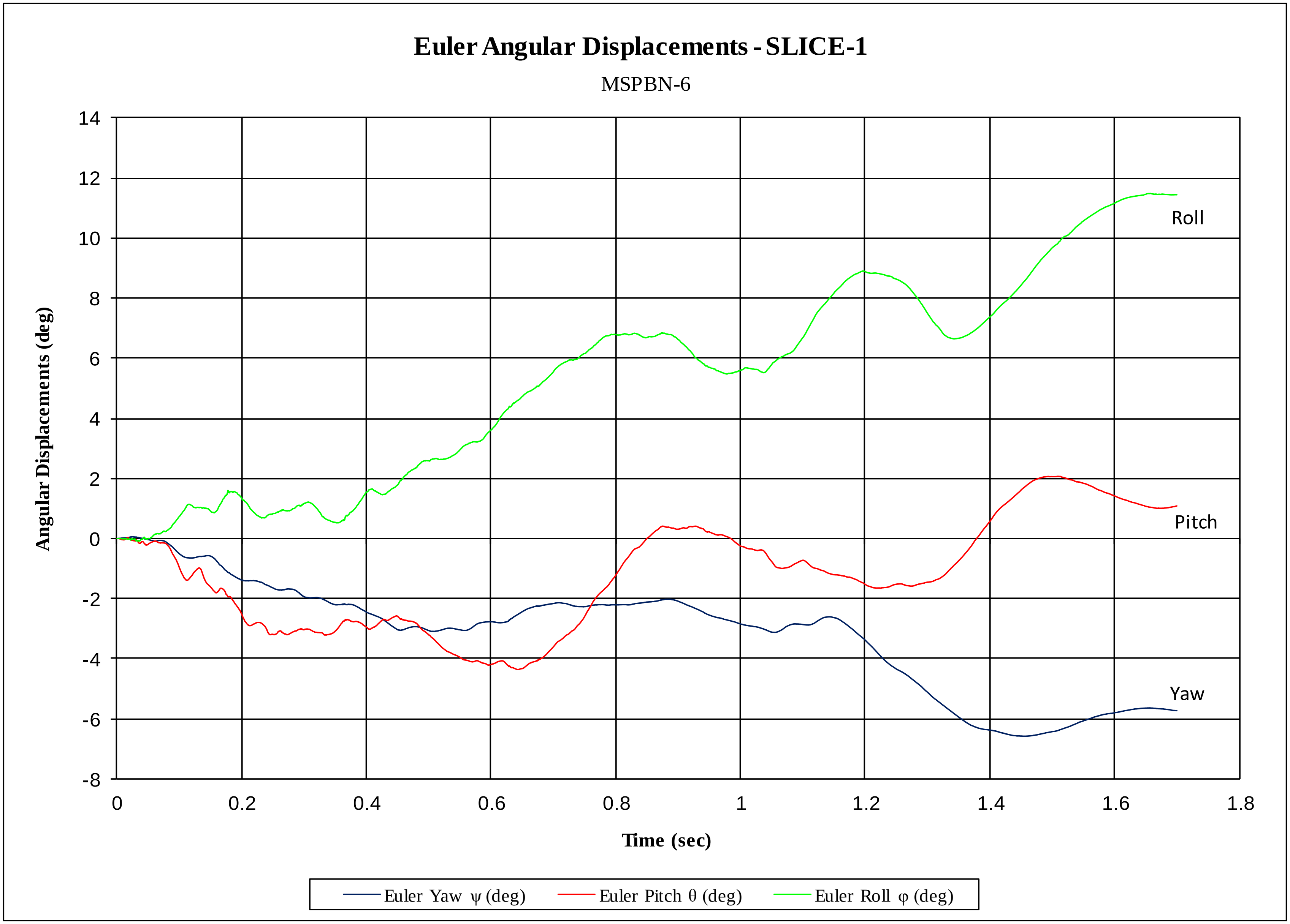


Figure G-7. Vehicle Angular Displacements (SLICE-1), Test No. MSPBN-6

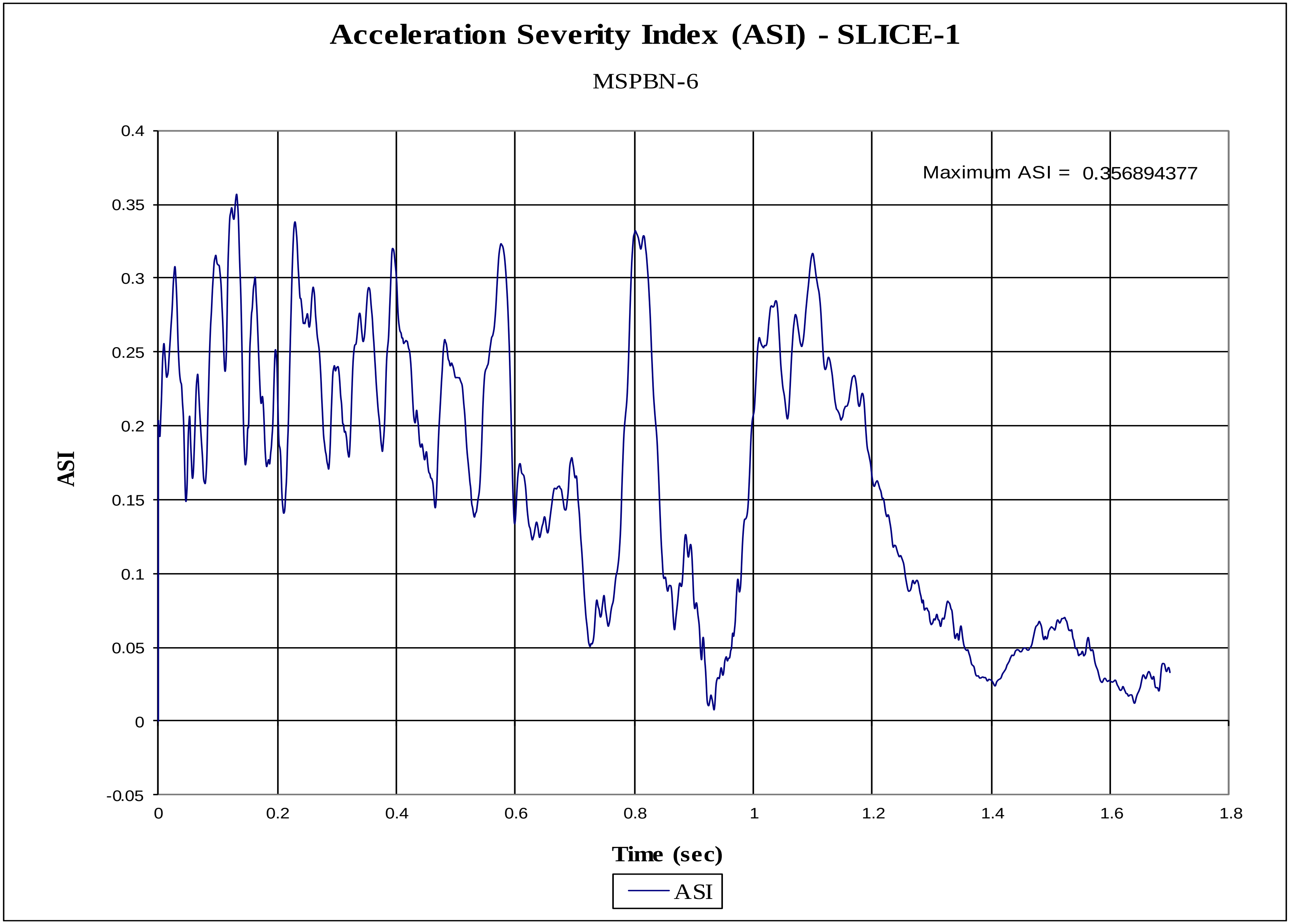


Figure G-8. Acceleration Severity Index (SLICE-1), Test No. MSPBN-6

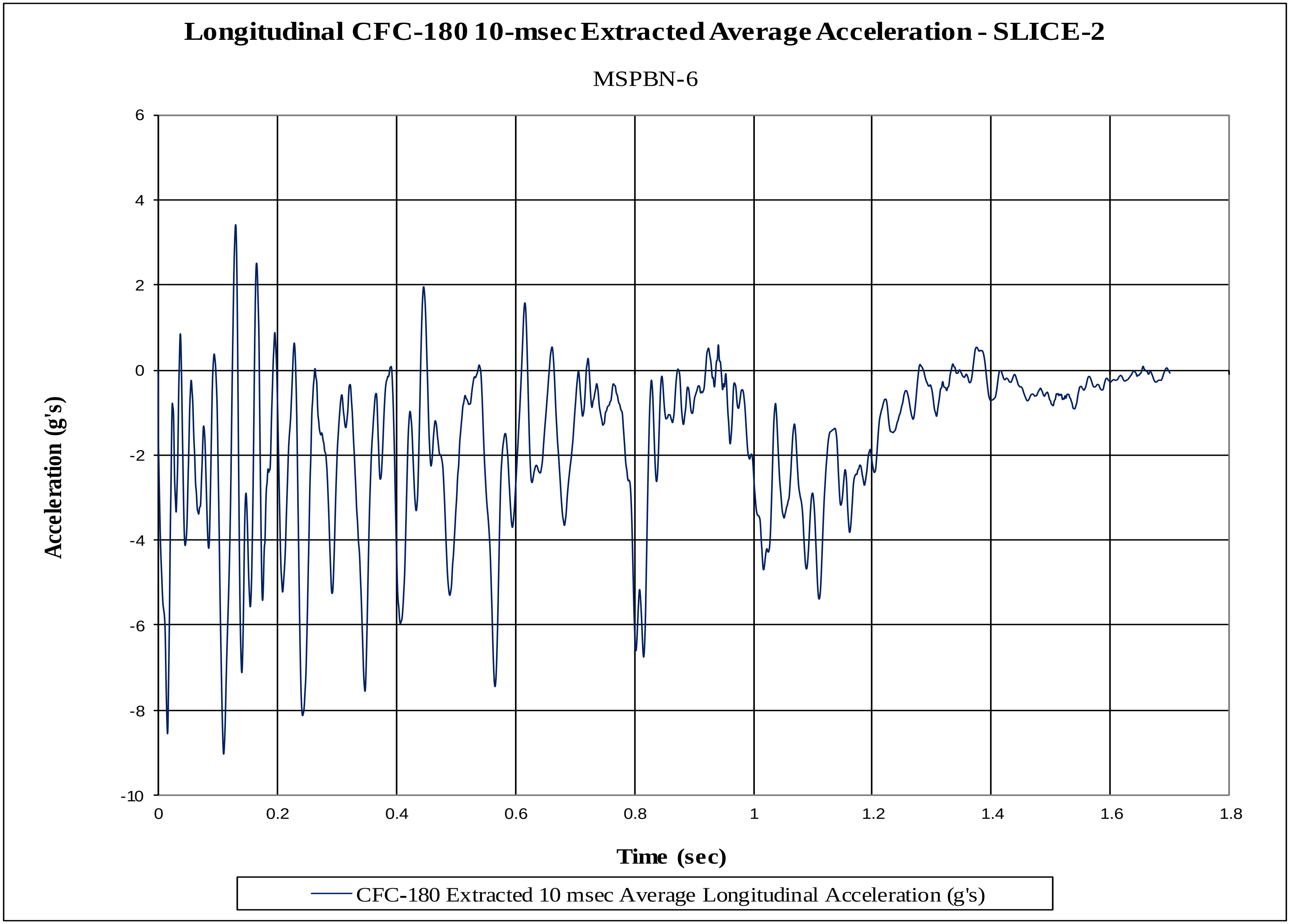


Figure G-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. MSPBN-6

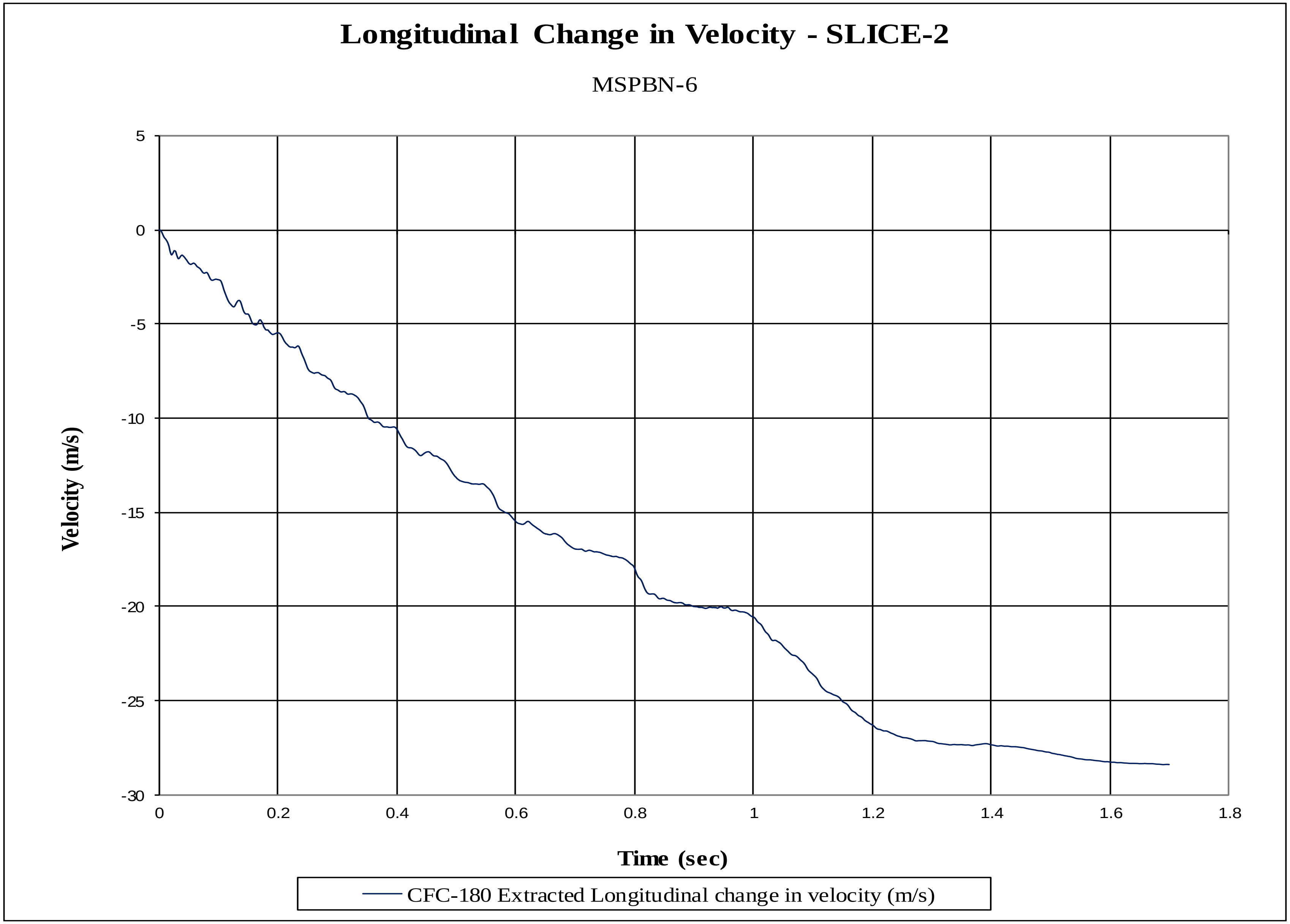


Figure G-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. MSPBN-6

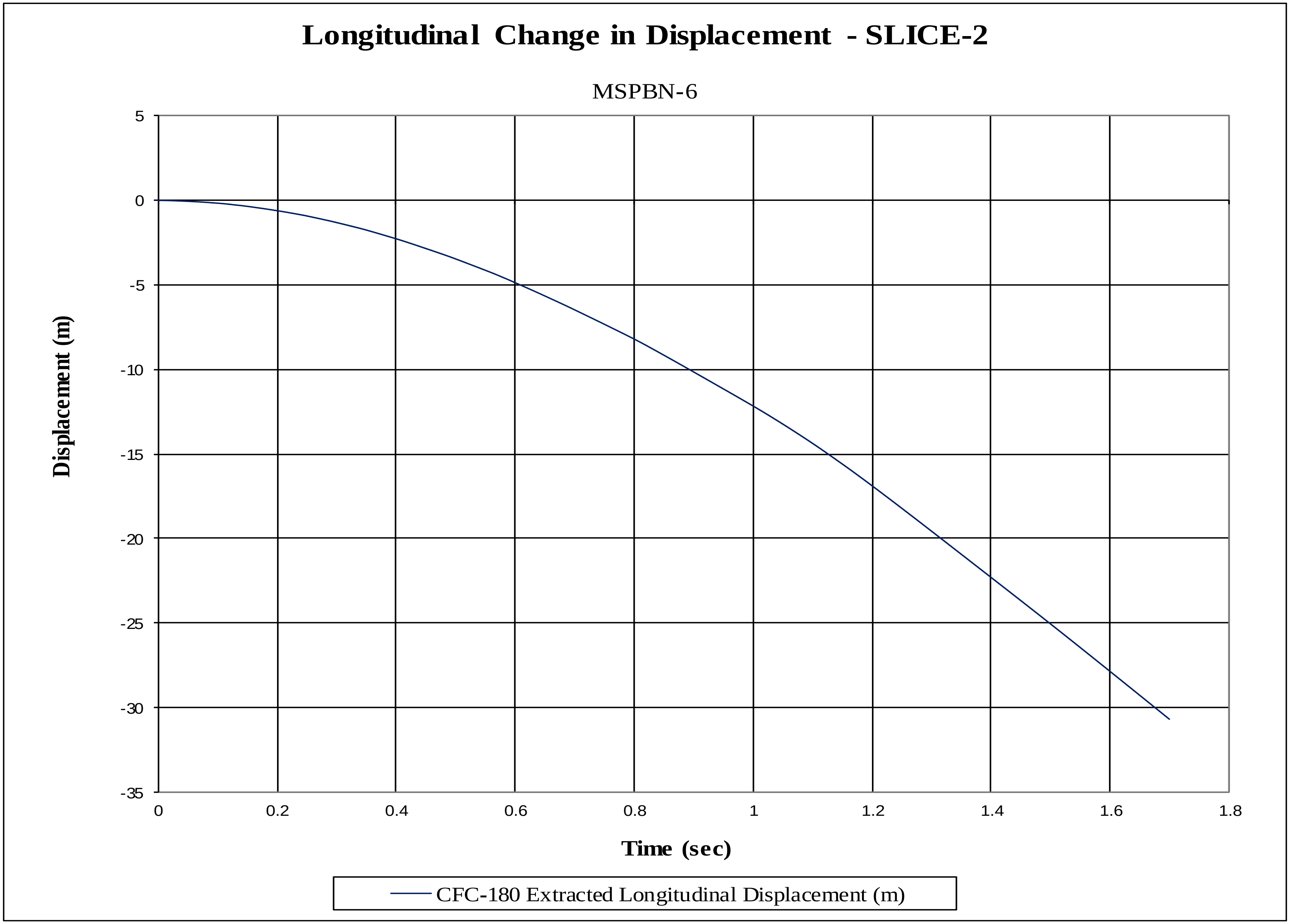


Figure G-11. Longitudinal Occupant Displacement (SLICE-2), Test No. MSPBN-6

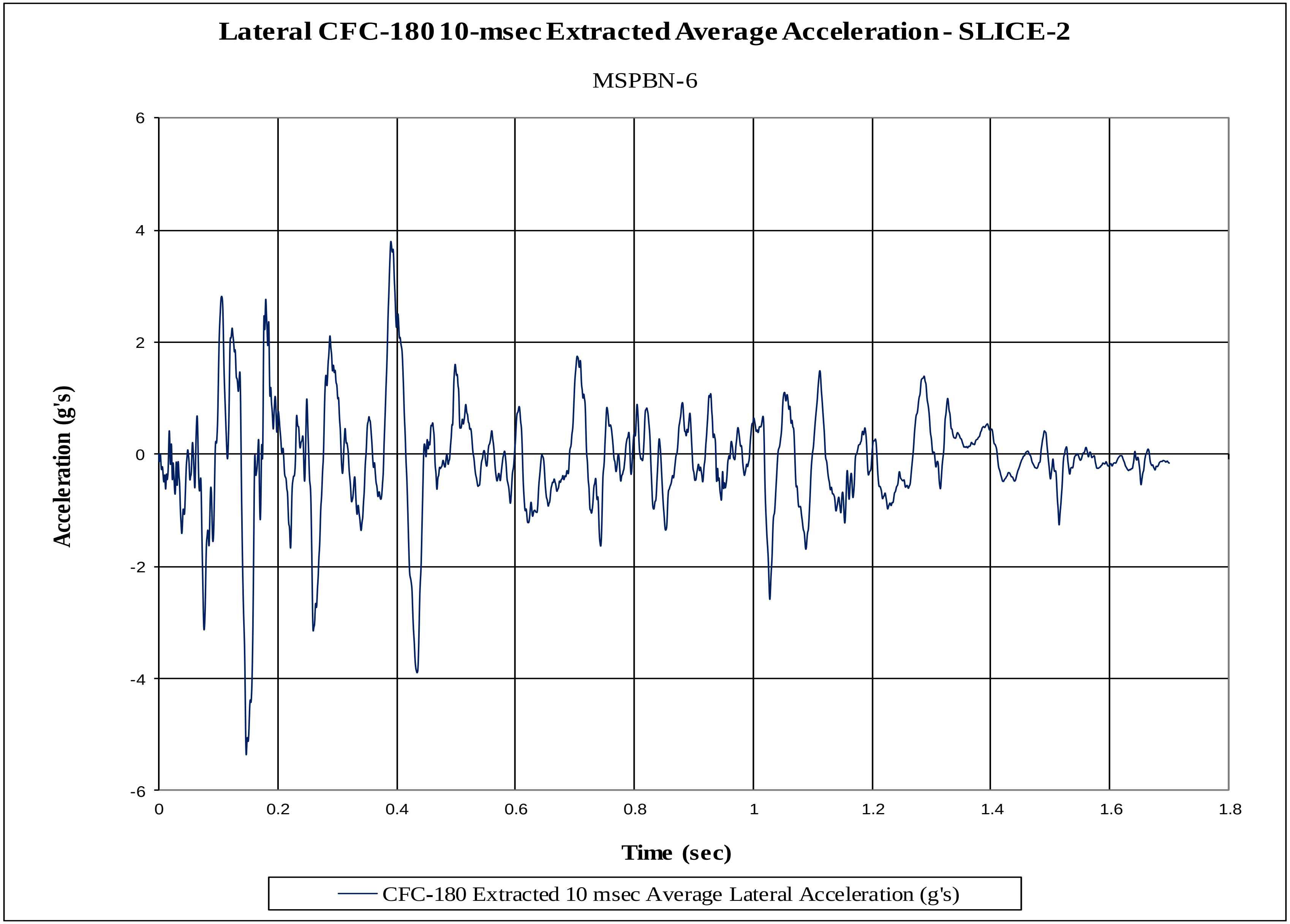


Figure G-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. MSPBN-6

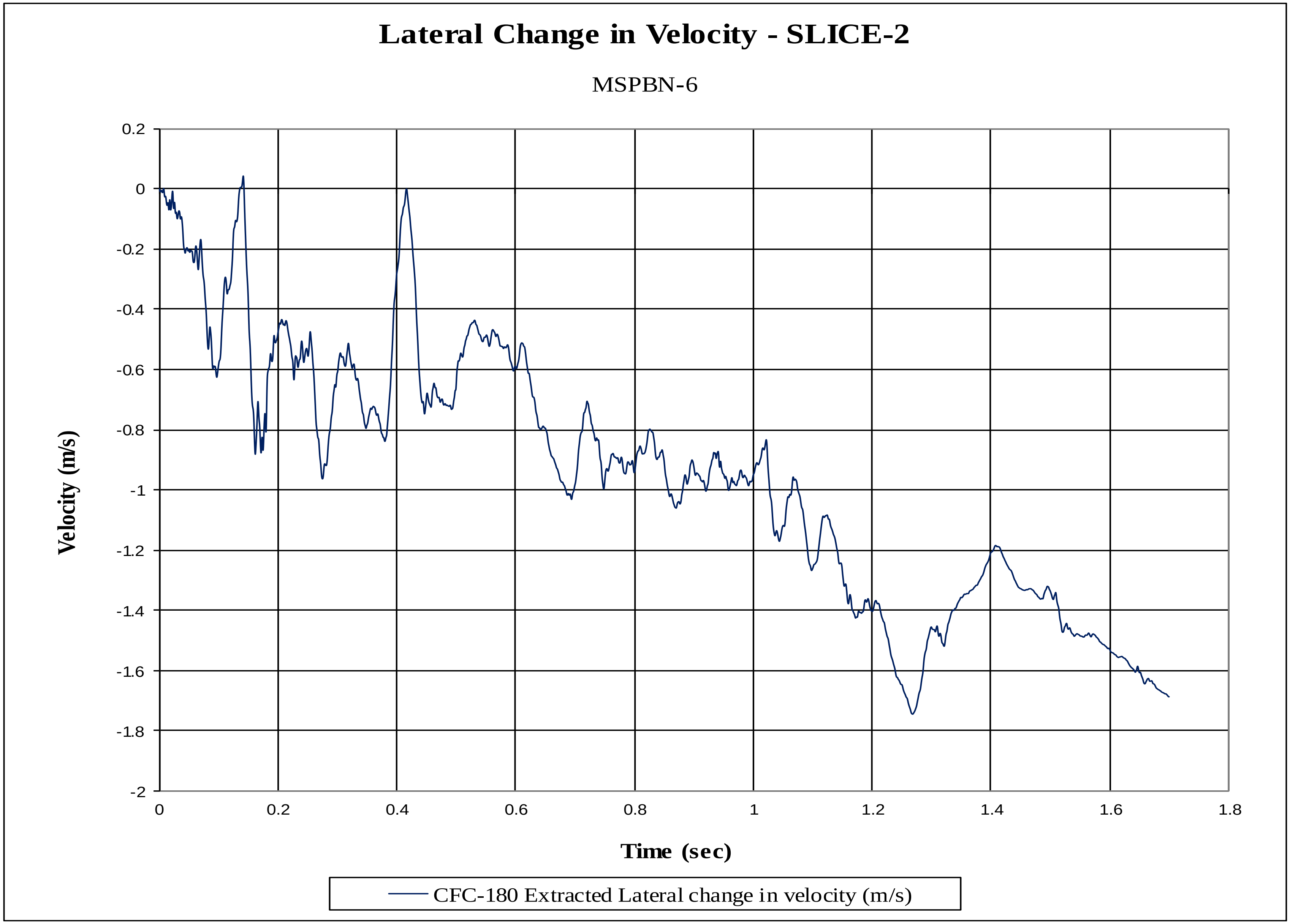


Figure G-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. MSPBN-6

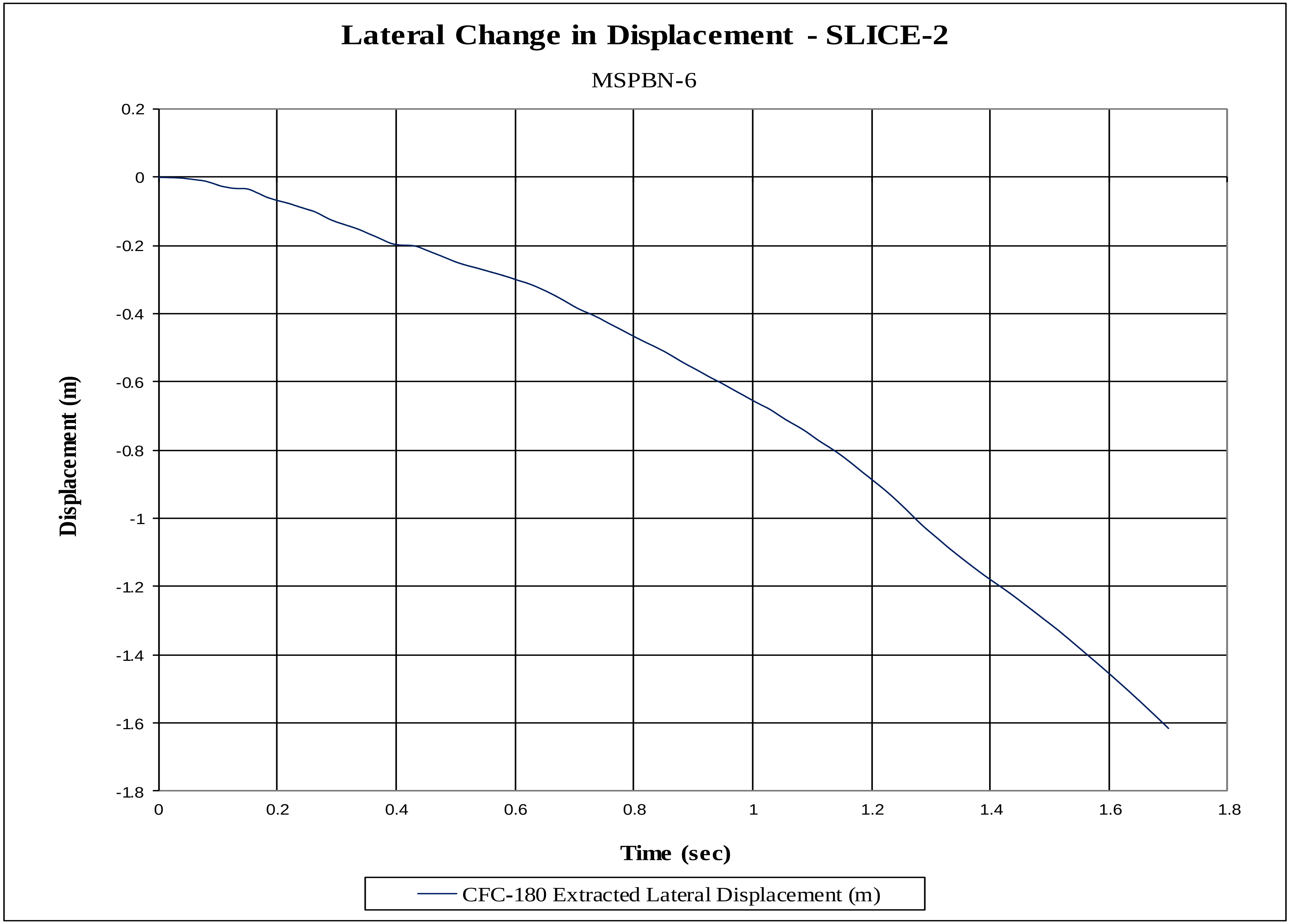


Figure G-14. Lateral Occupant Displacement (SLICE-2), Test No. MSPBN-6

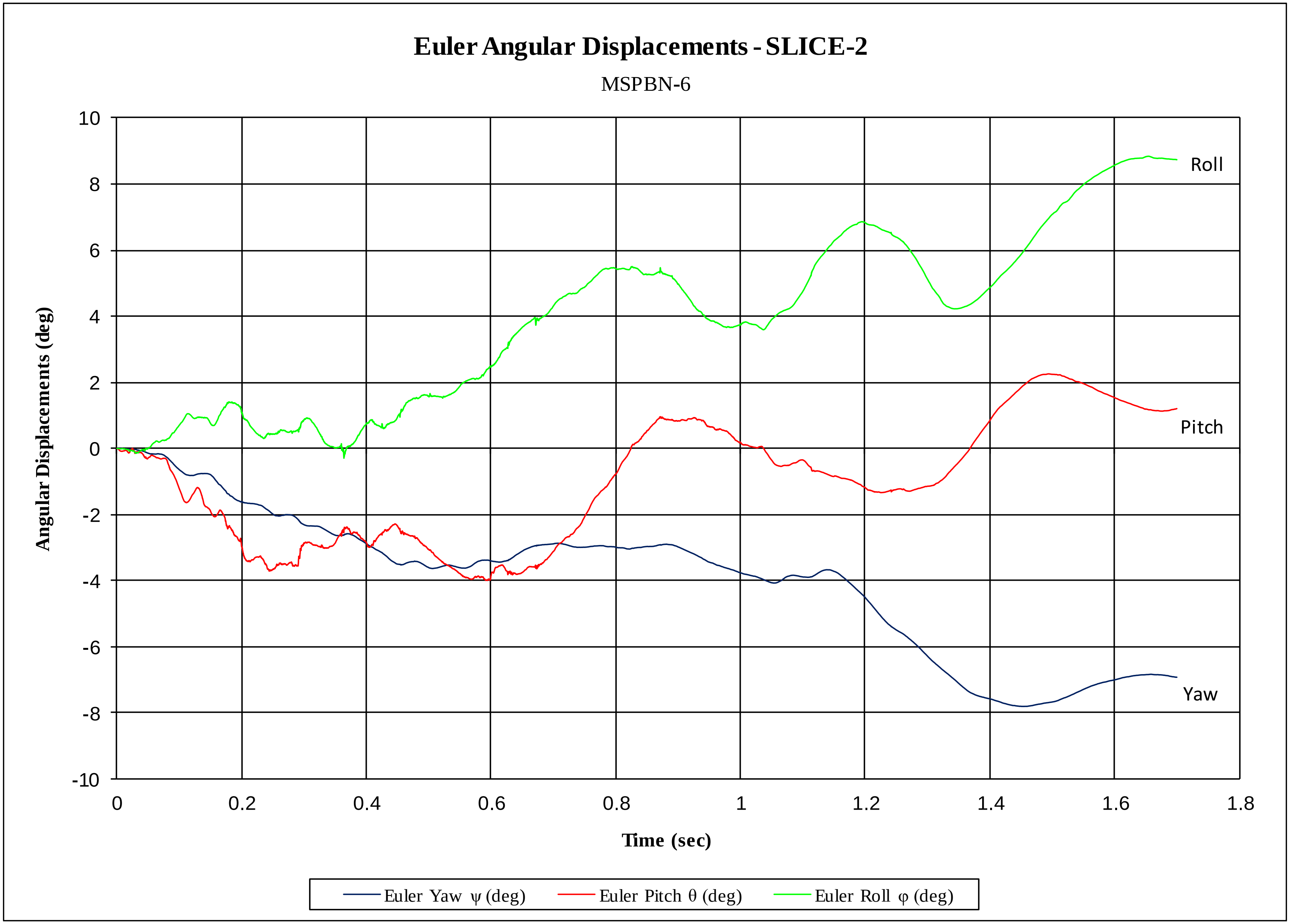


Figure G-15. Vehicle Angular Displacements (SLICE-2), Test No. MSPBN-6

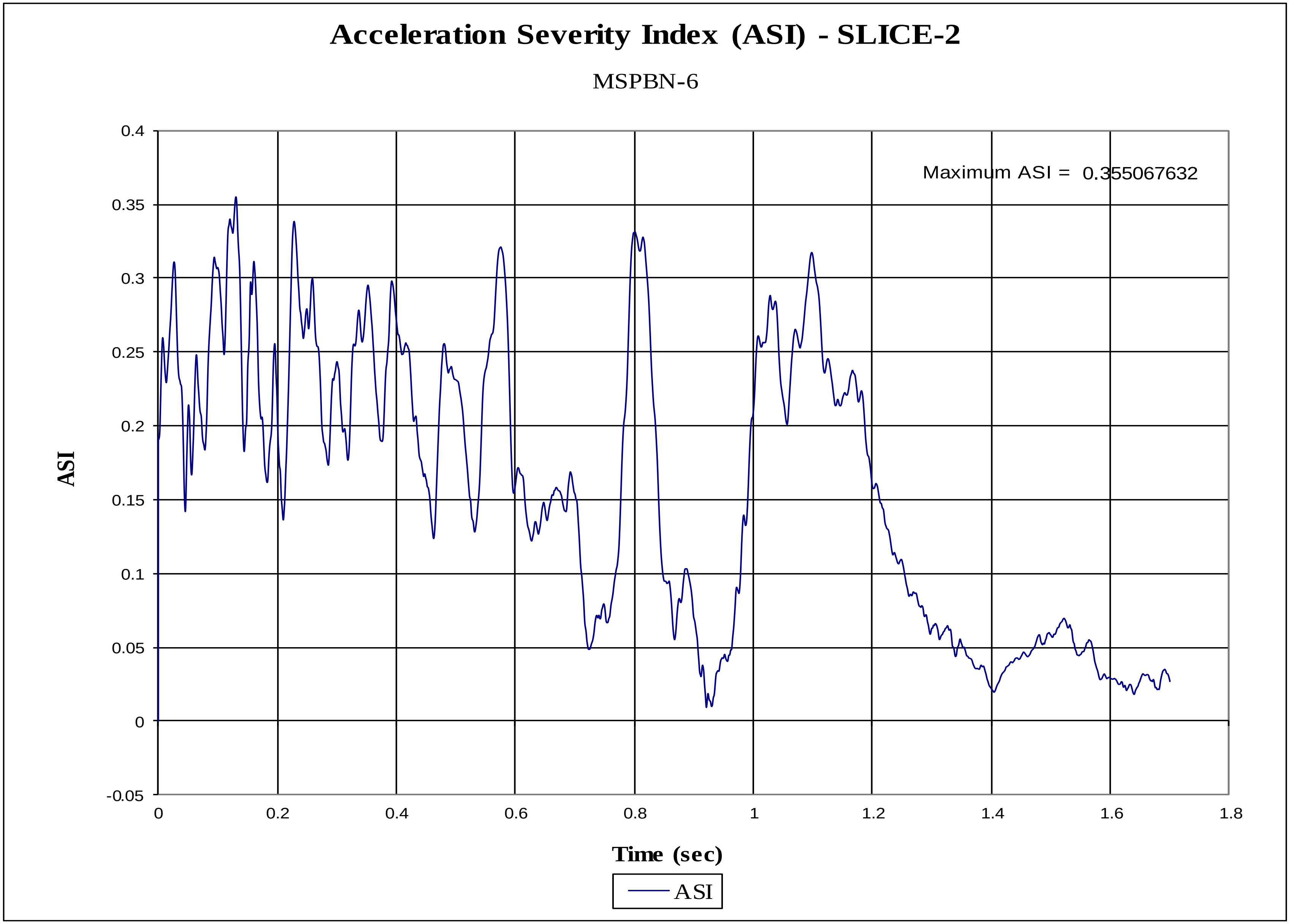


Figure G-16. Acceleration Severity Index (SLICE-2), Test No. MSPBN-6

Appendix H. Accelerometer and Rate Transducer Data Plots, Test No. MSPBN-7

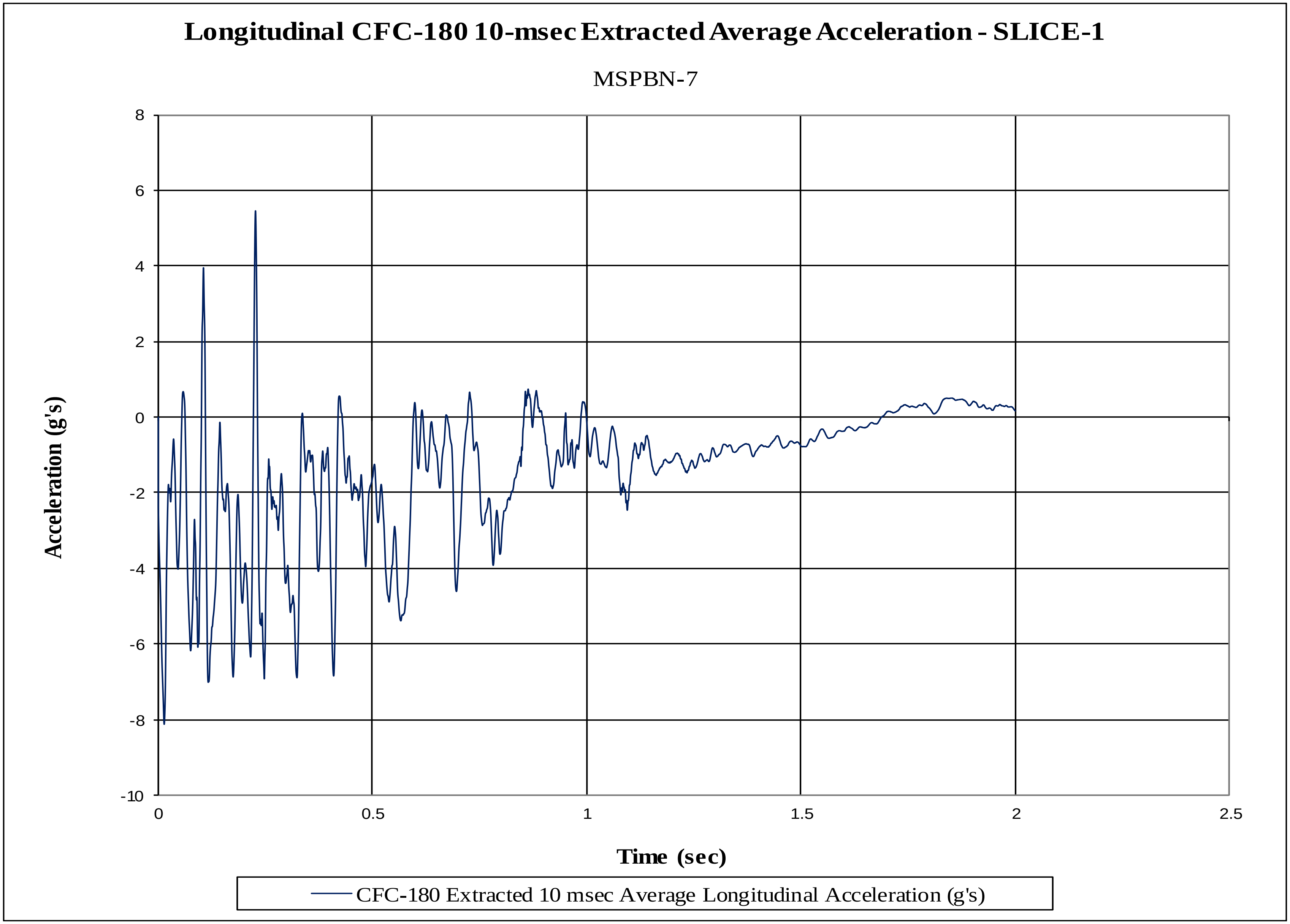


Figure H-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. MSPBN-7

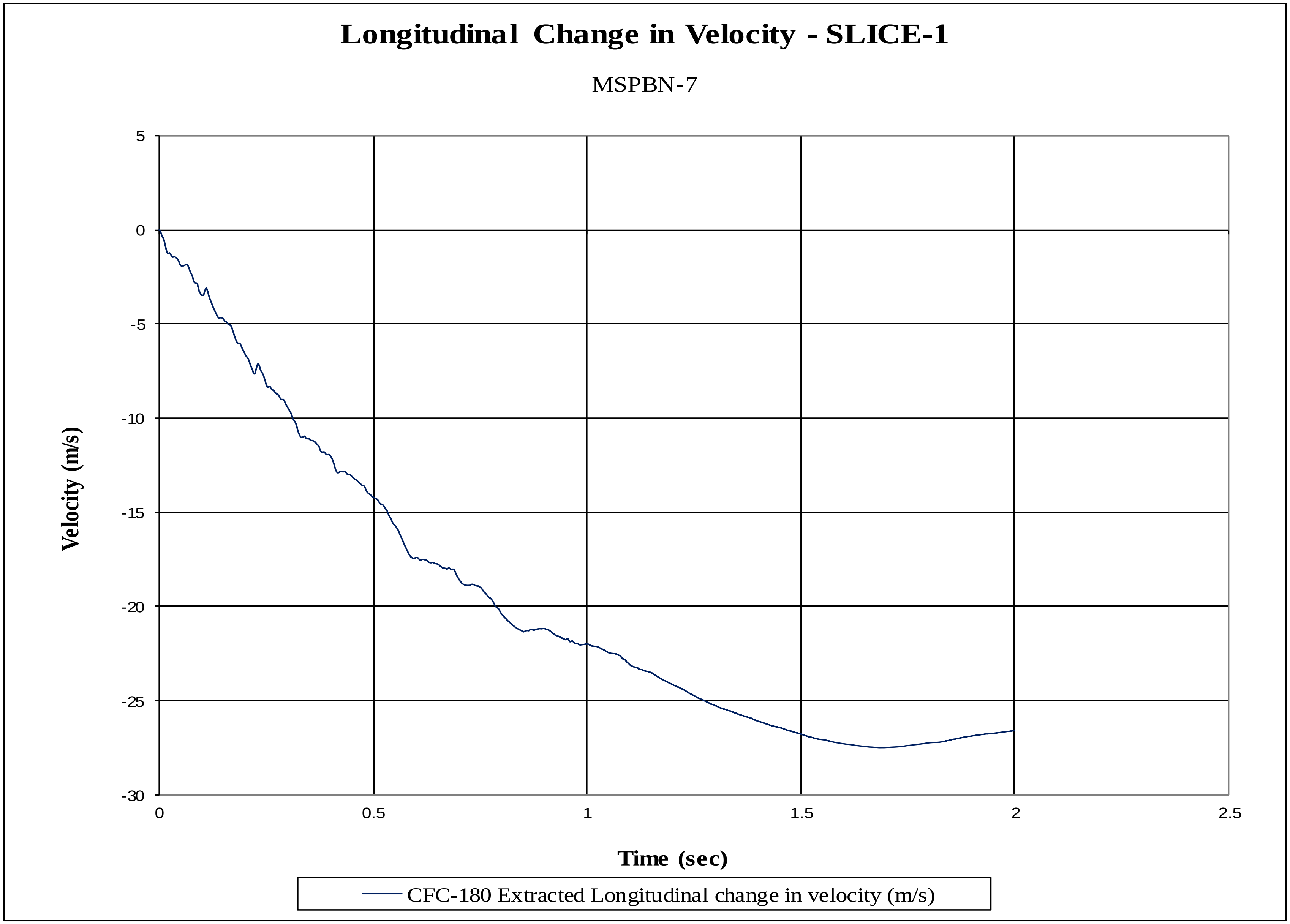


Figure H-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. MSPBN-7

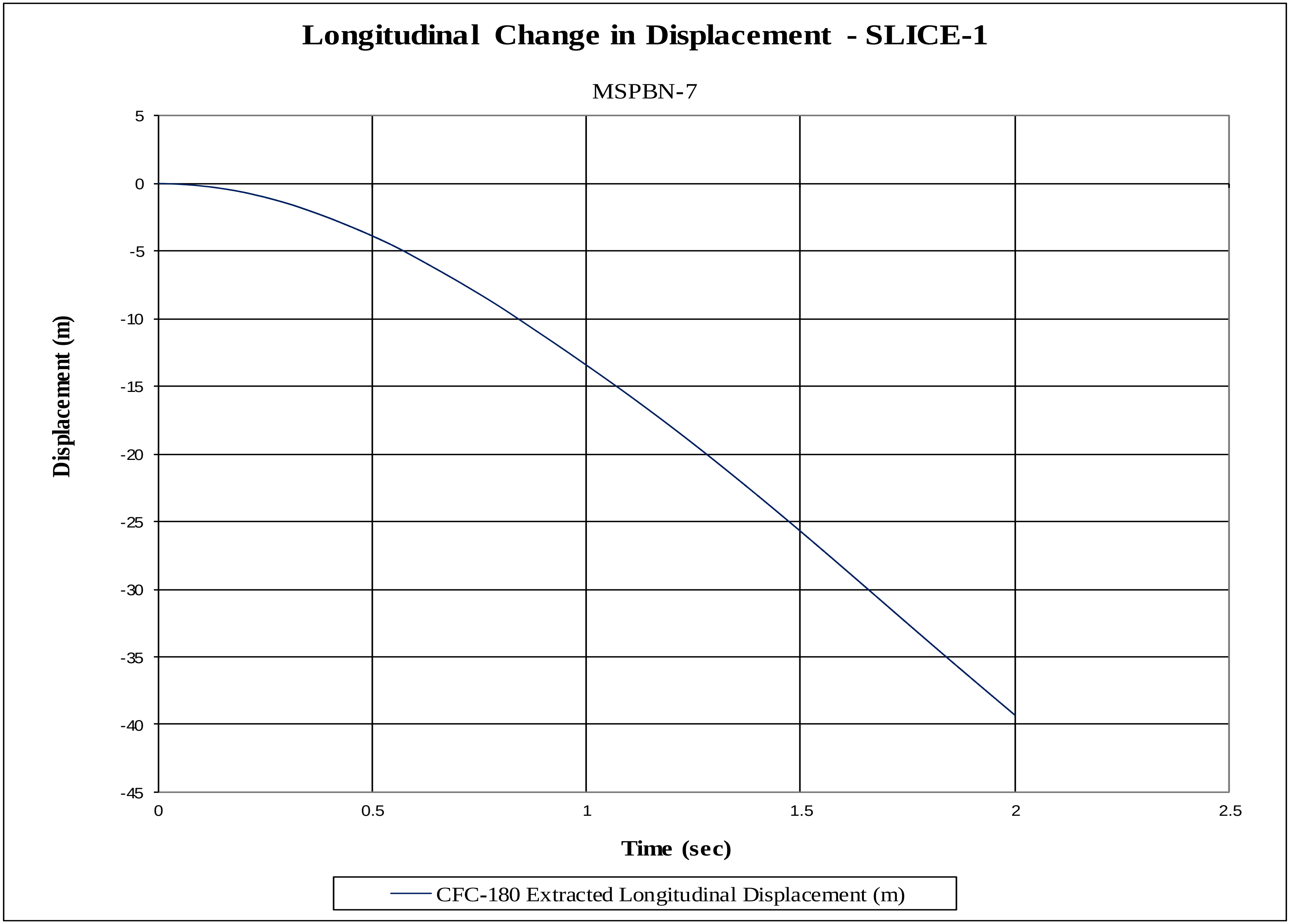


Figure H-3. Longitudinal Occupant Displacement (SLICE-1), Test No. MSPBN-7

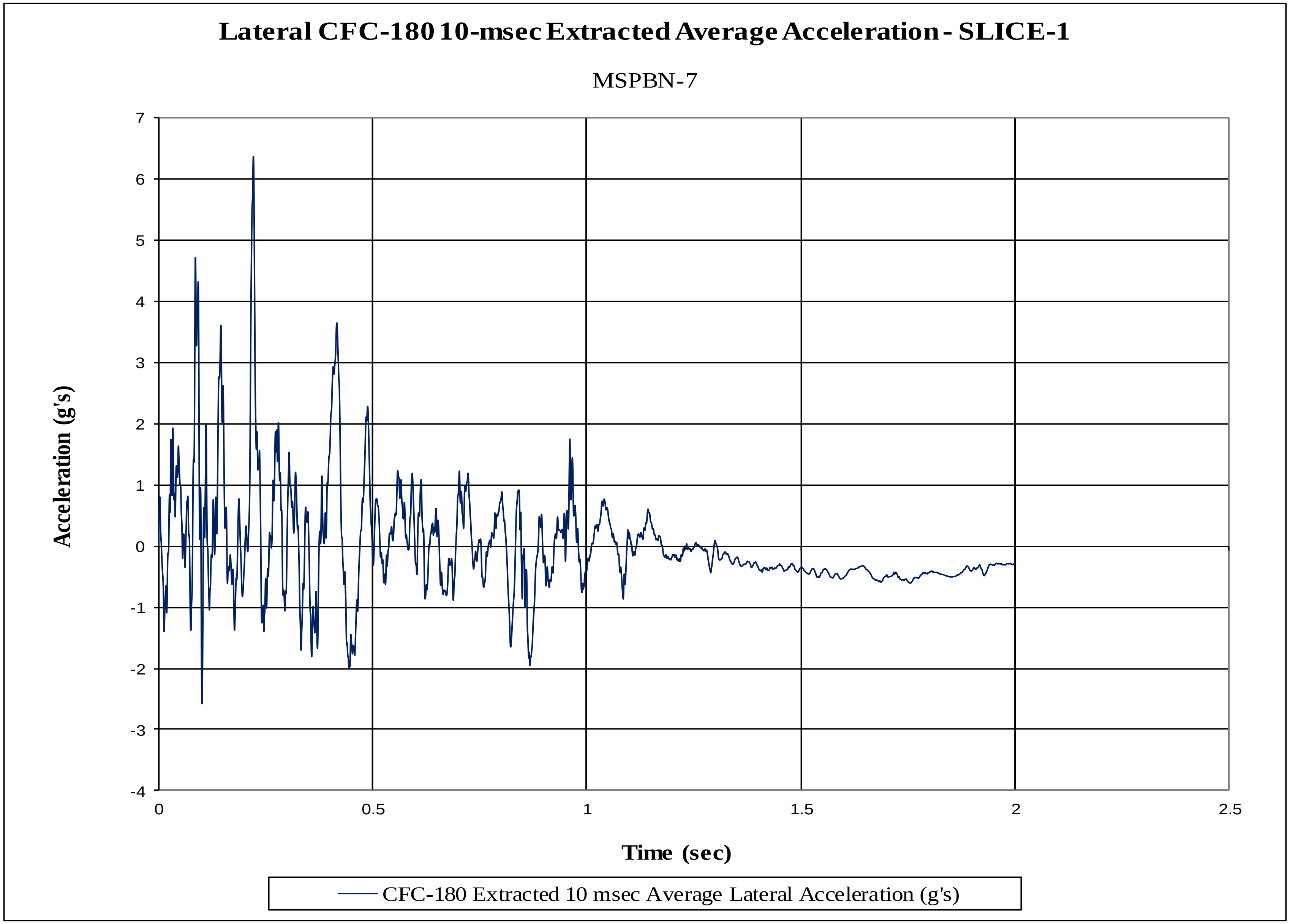


Figure H-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. MSPBN-7

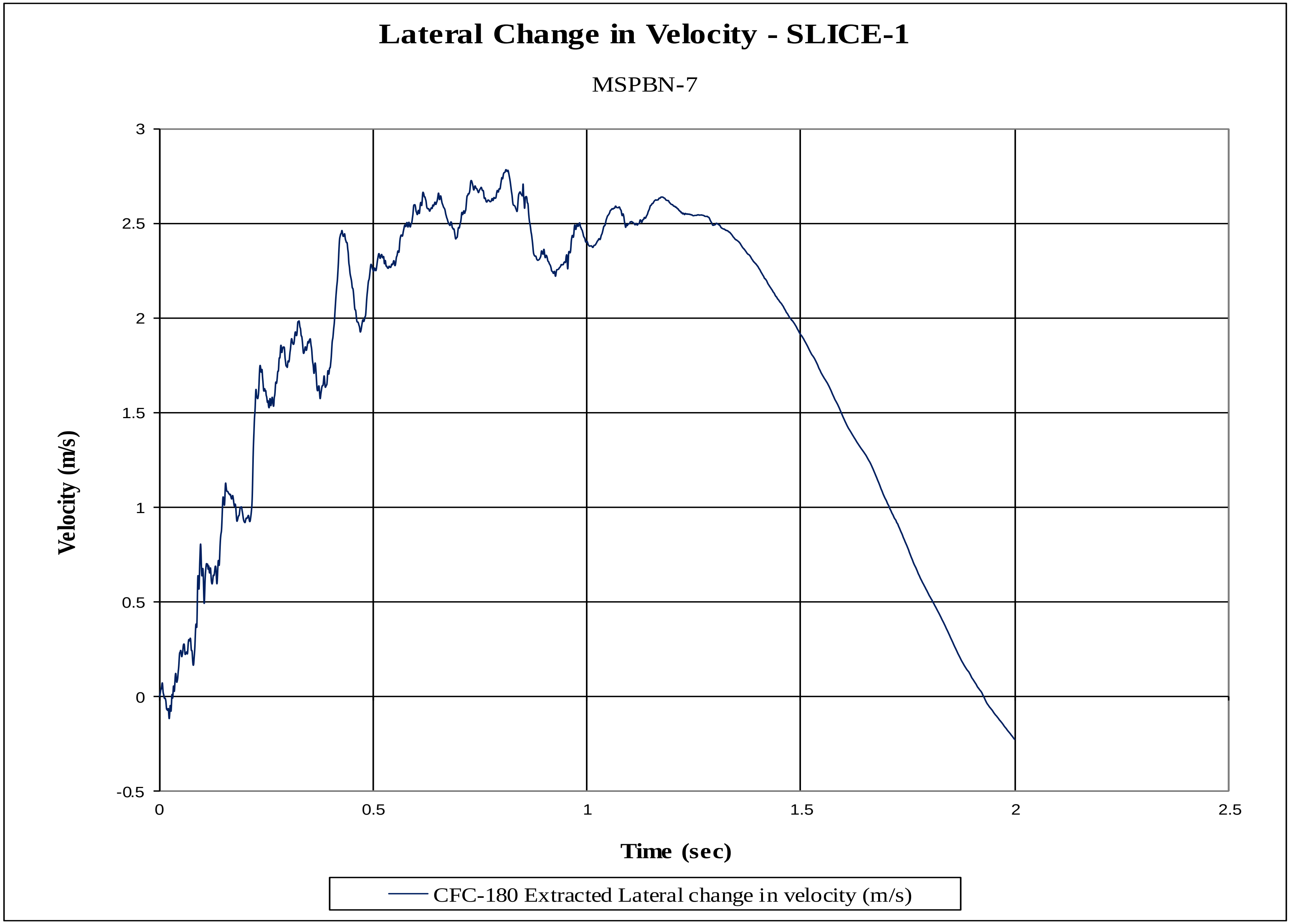


Figure H-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. MSPBN-7

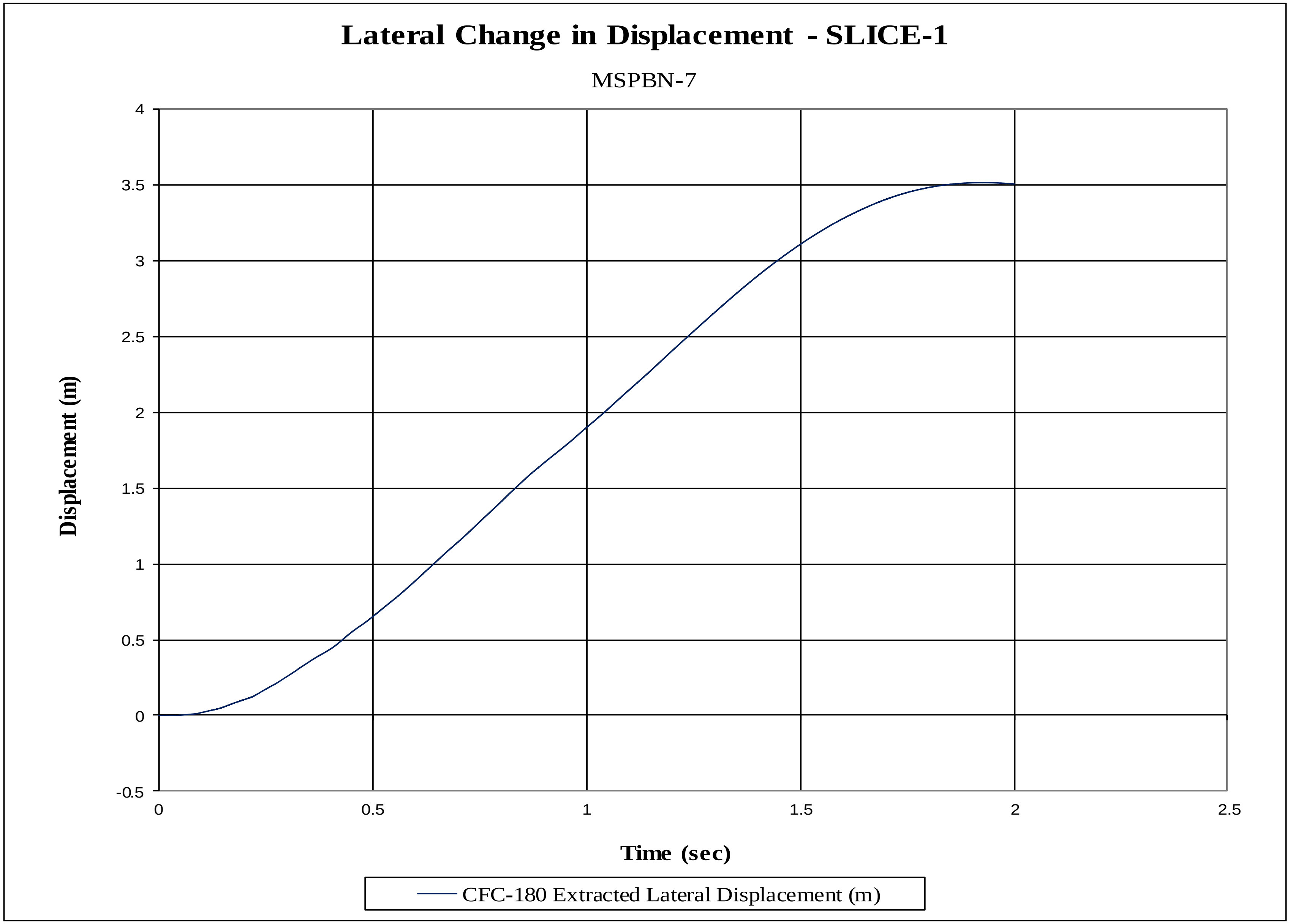


Figure H-6. Lateral Occupant Displacement (SLICE-1), Test No. MSPBN-7

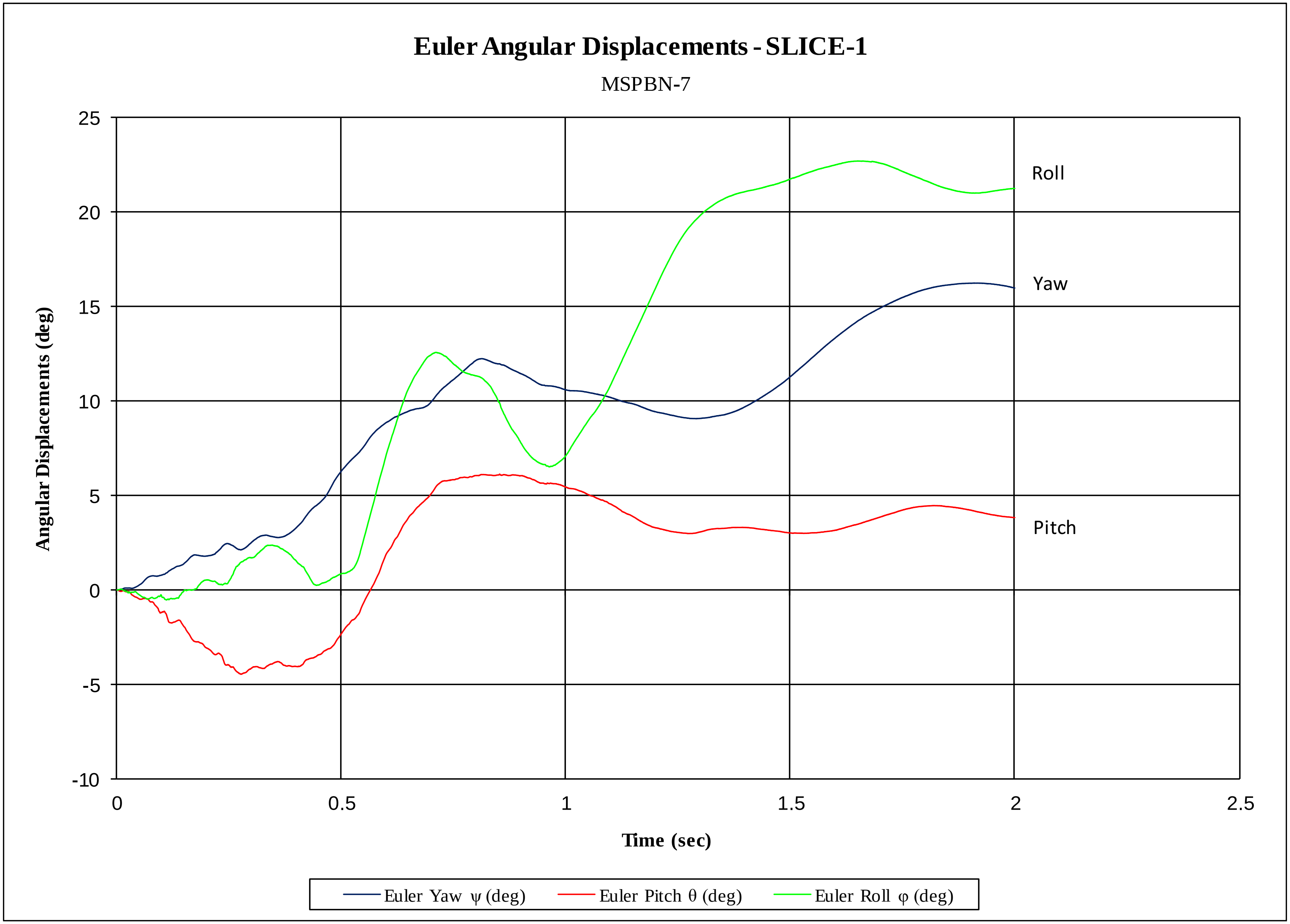


Figure H-7. Vehicle Angular Displacements (SLICE-1), Test No. MSPBN-7

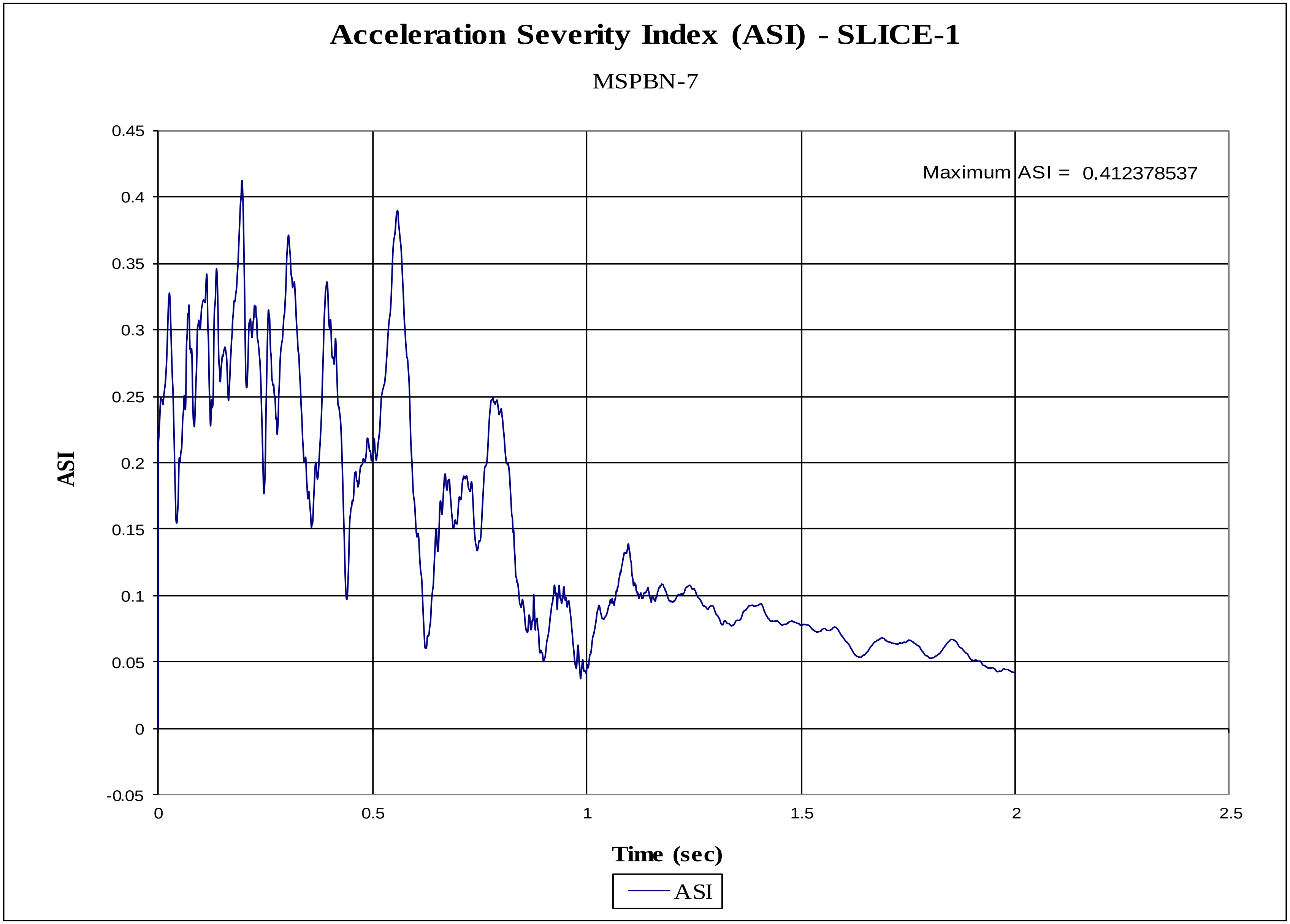


Figure H-8. Acceleration Severity Index (SLICE-1), Test No. MSPBN-7

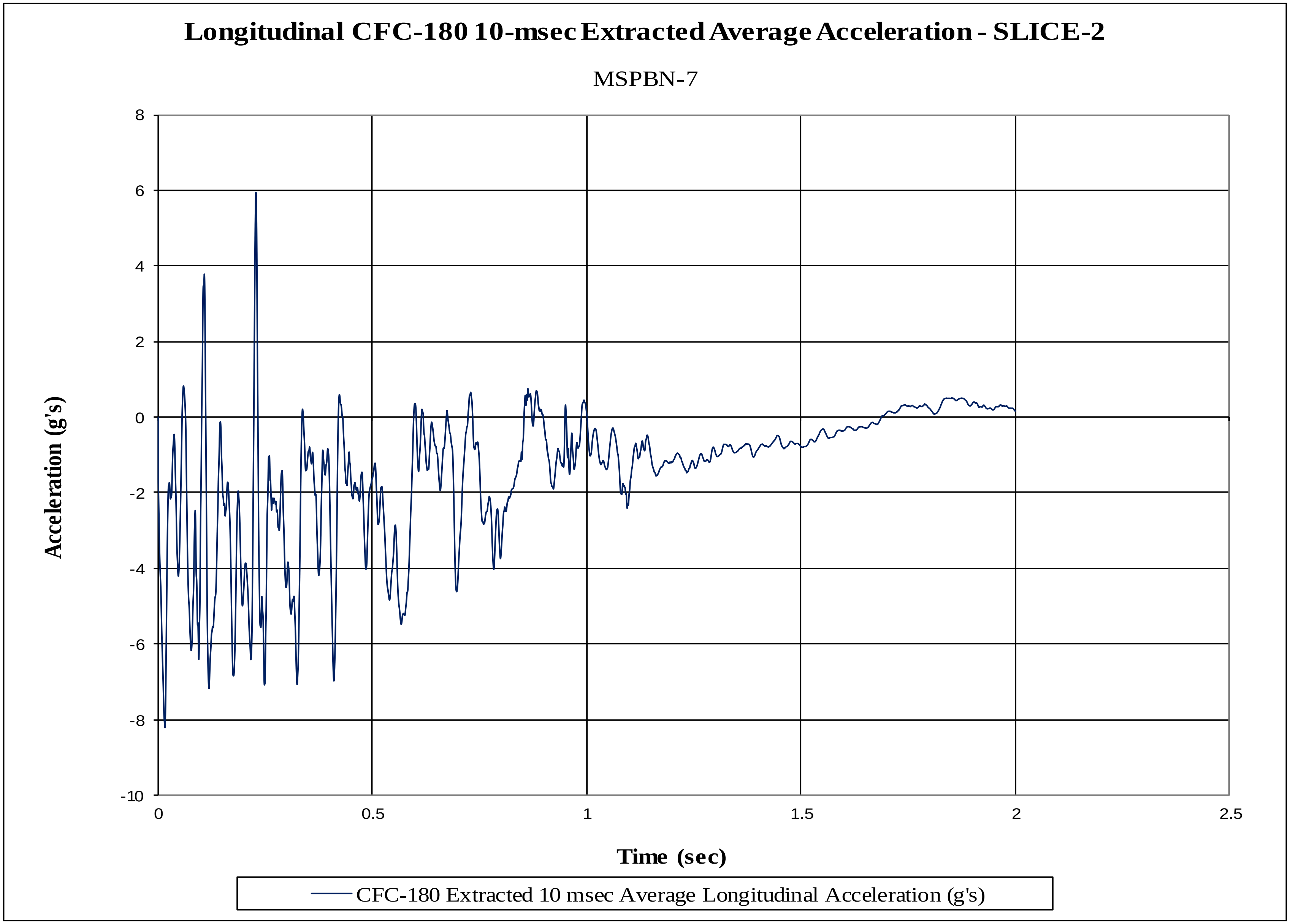


Figure H-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. MSPBN-7

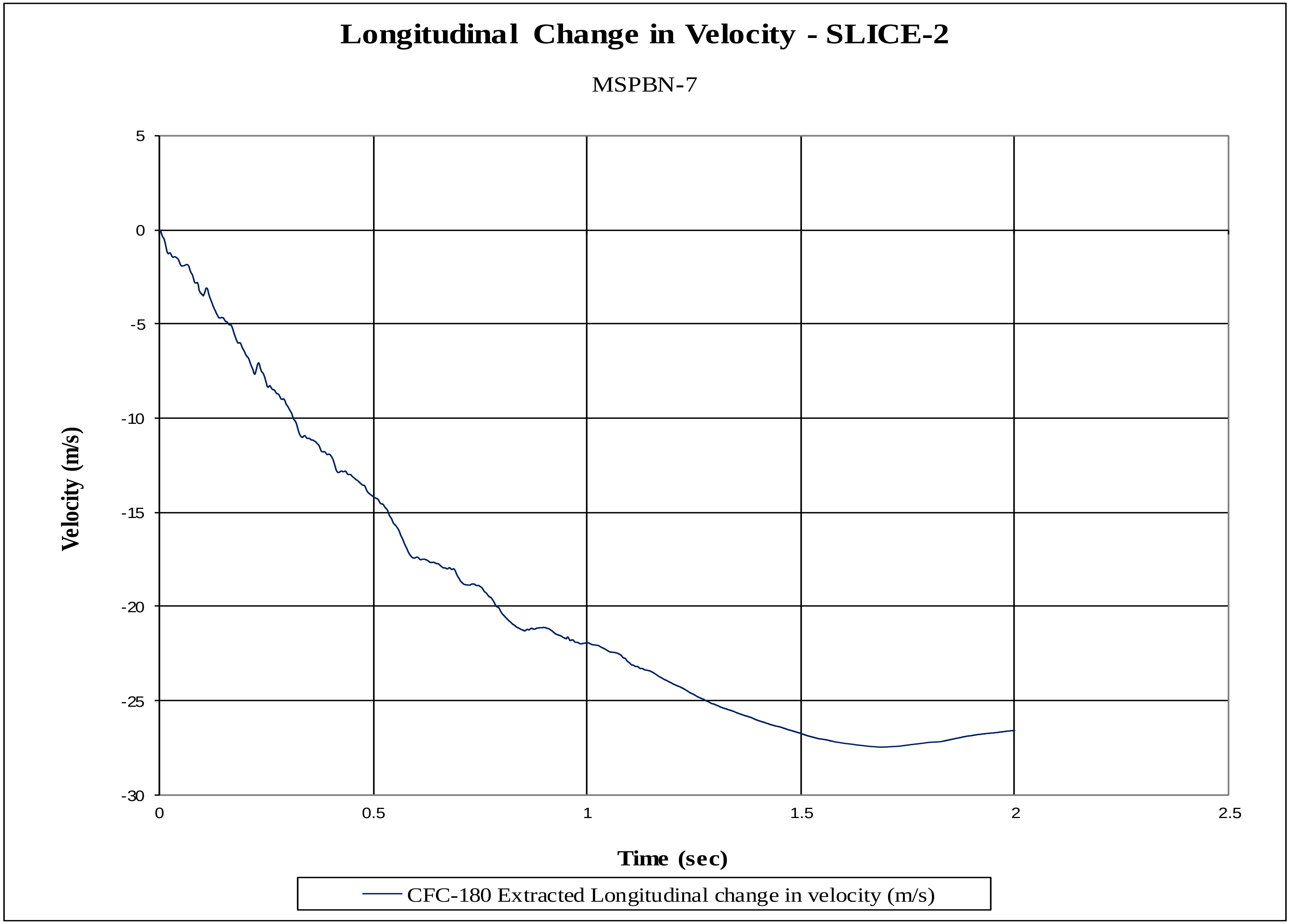


Figure H-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. MSPBN-7

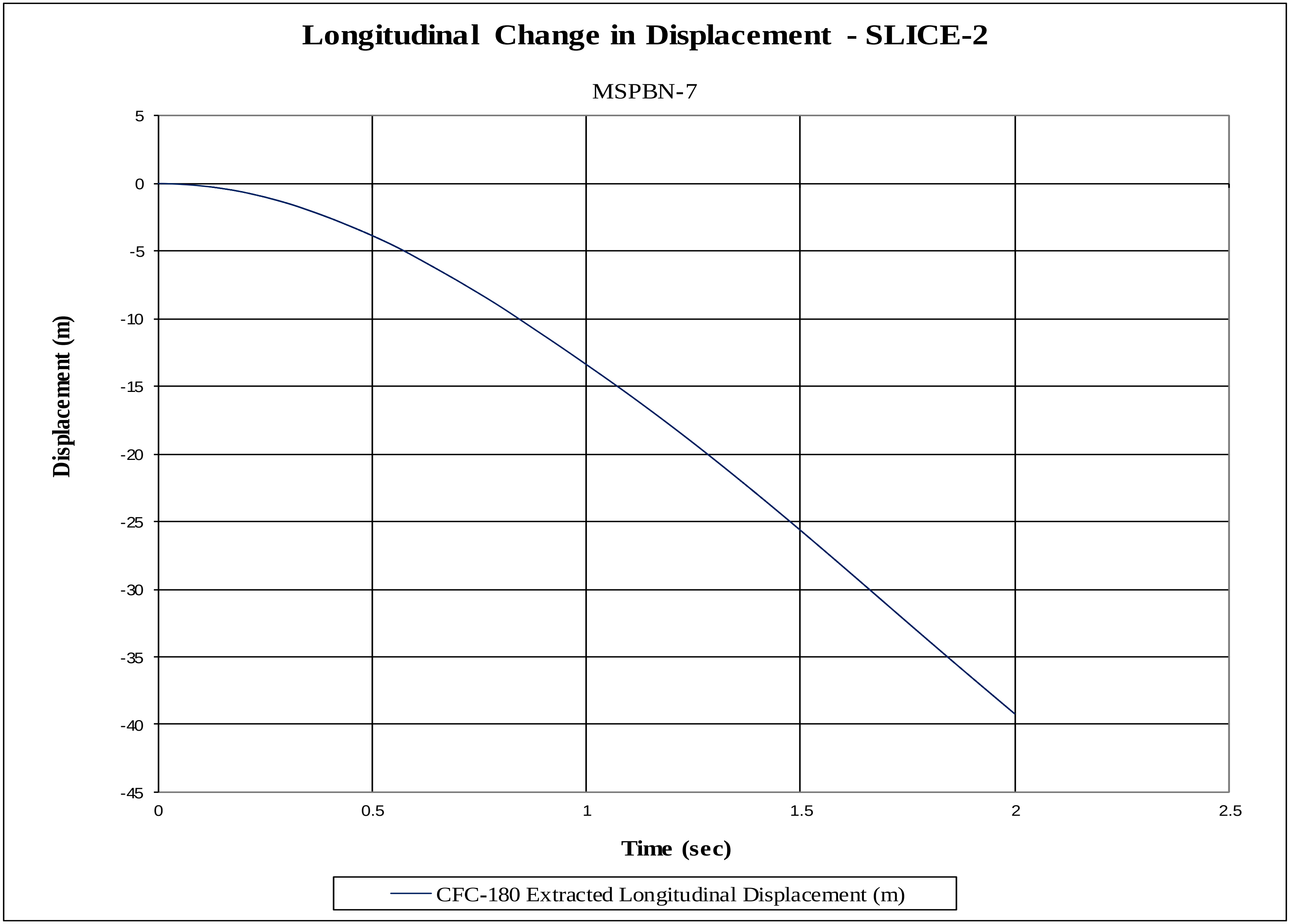


Figure H-11. Longitudinal Occupant Displacement (SLICE-2), Test No. MSPBN-7

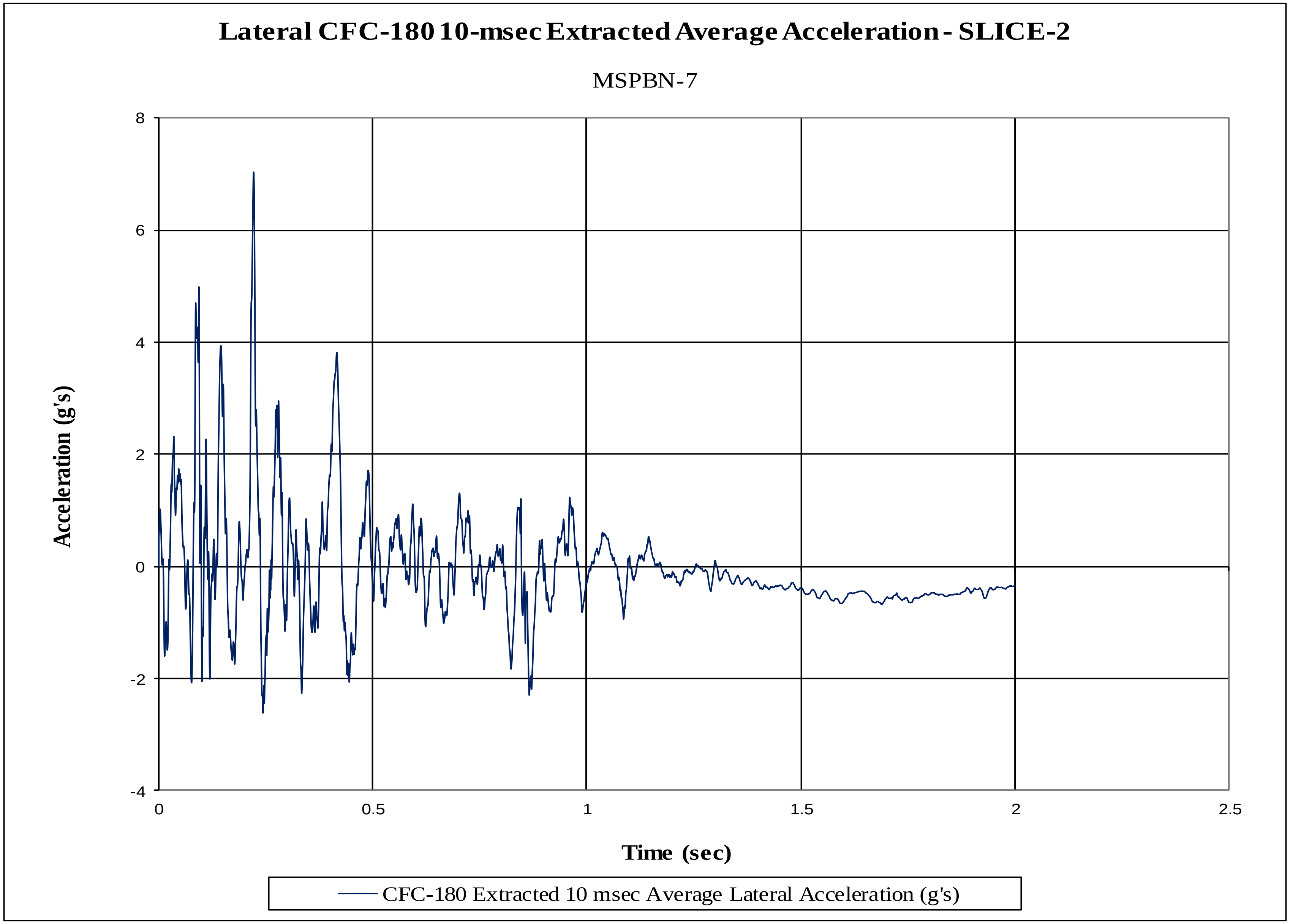


Figure H-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. MSPBN-7

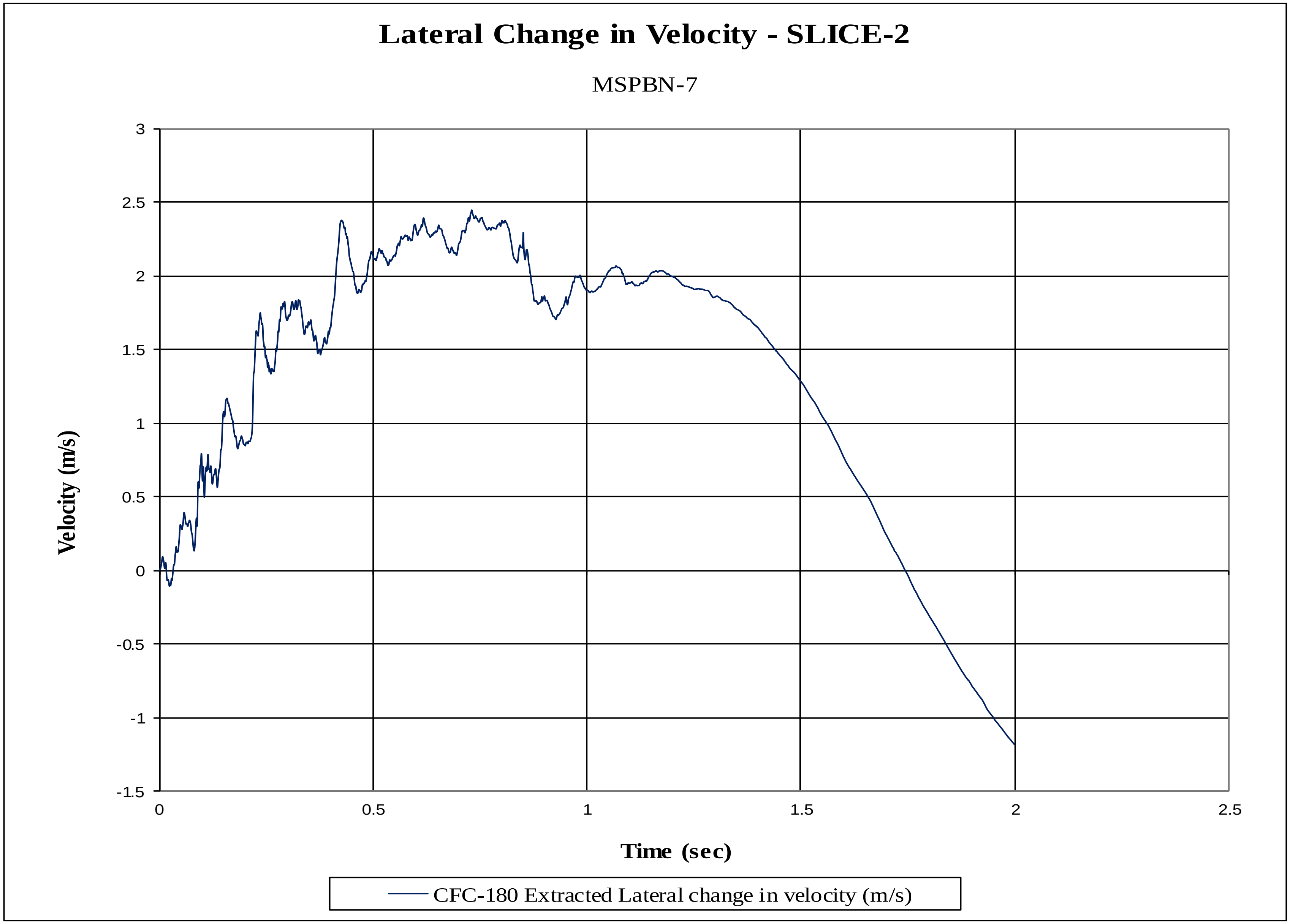


Figure H-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. MSPBN-7

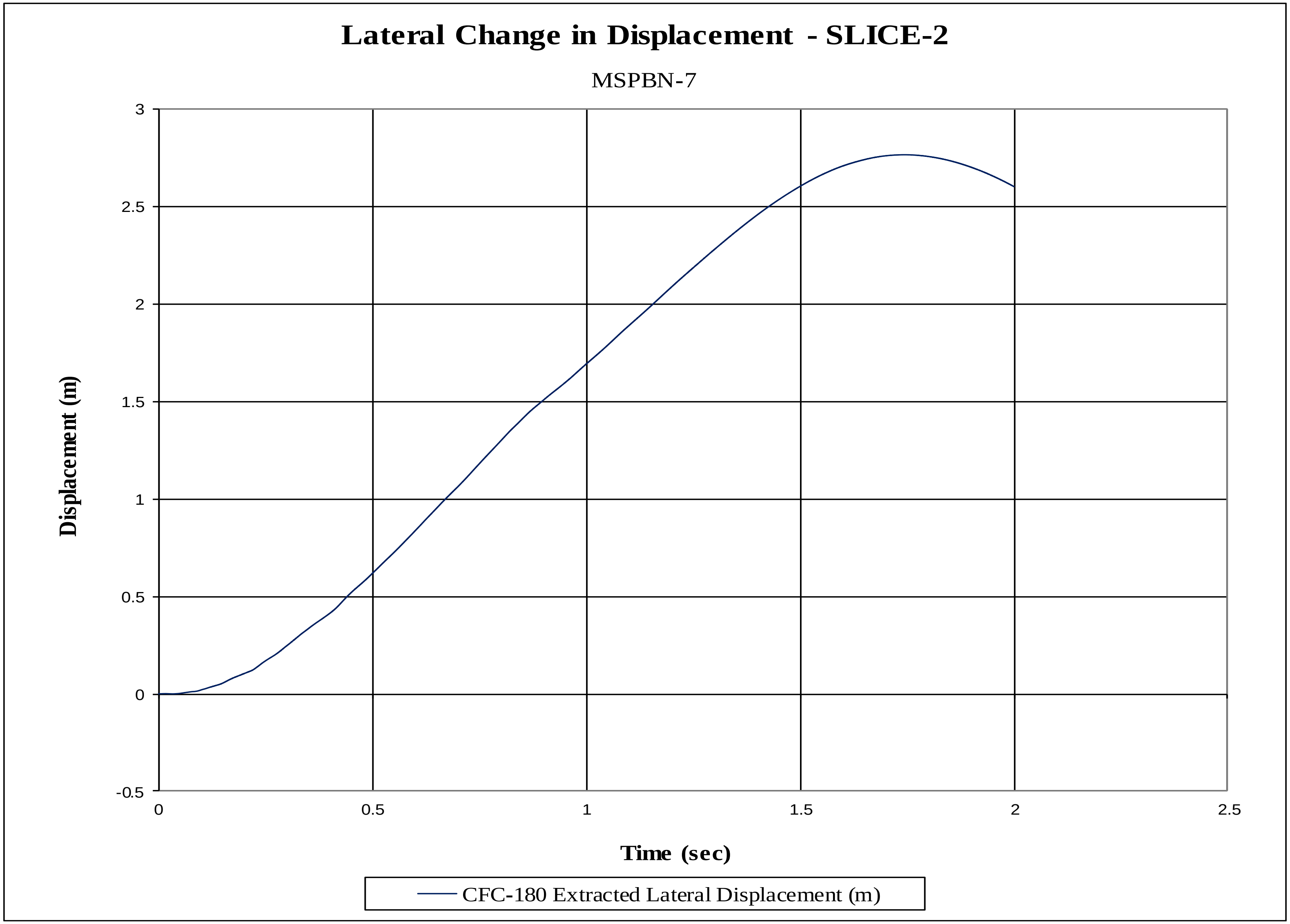


Figure H-14. Lateral Occupant Displacement (SLICE-2), Test No. MSPBN-7

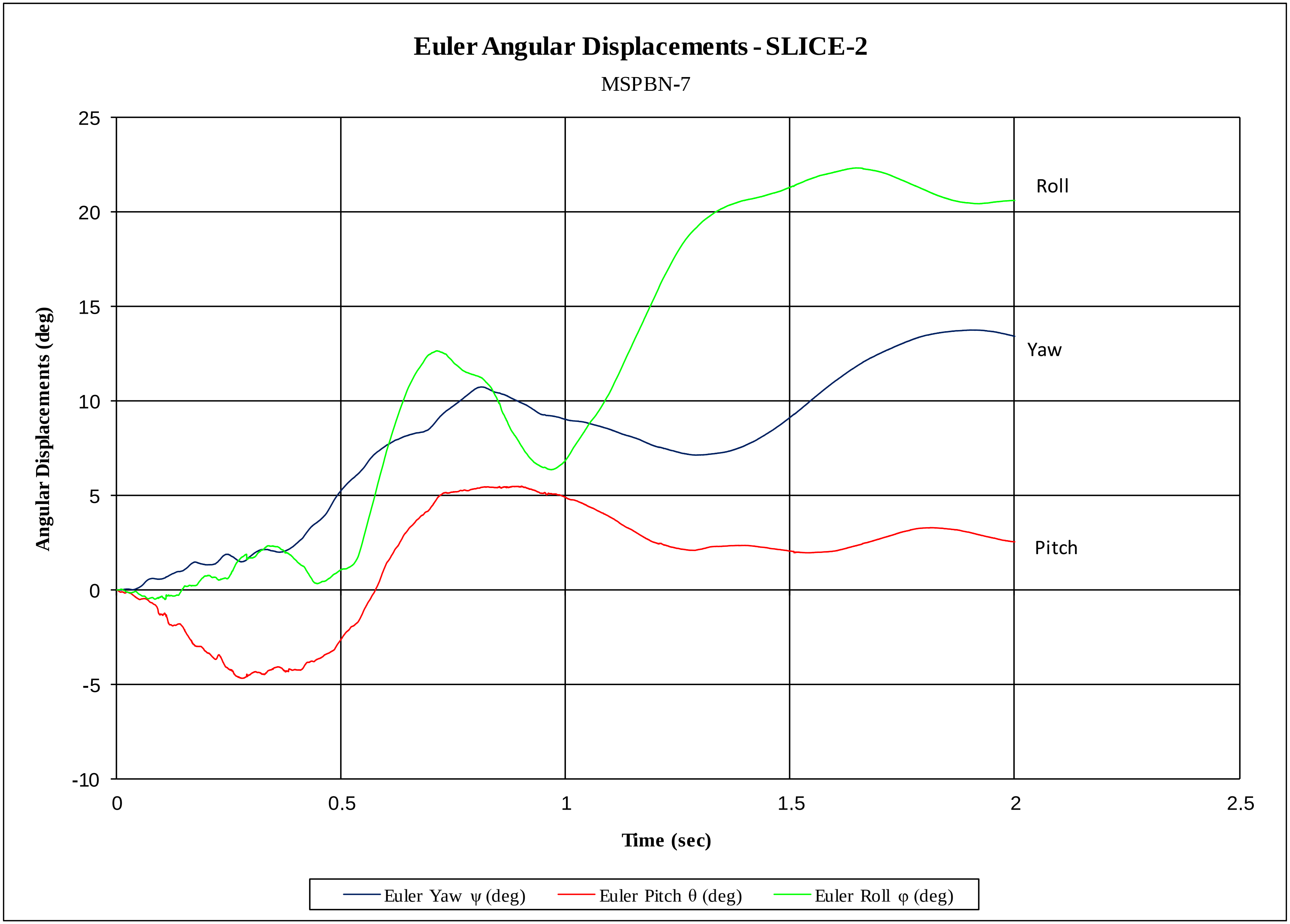


Figure H-15. Vehicle Angular Displacements (SLICE-2), Test No. MSPBN-7

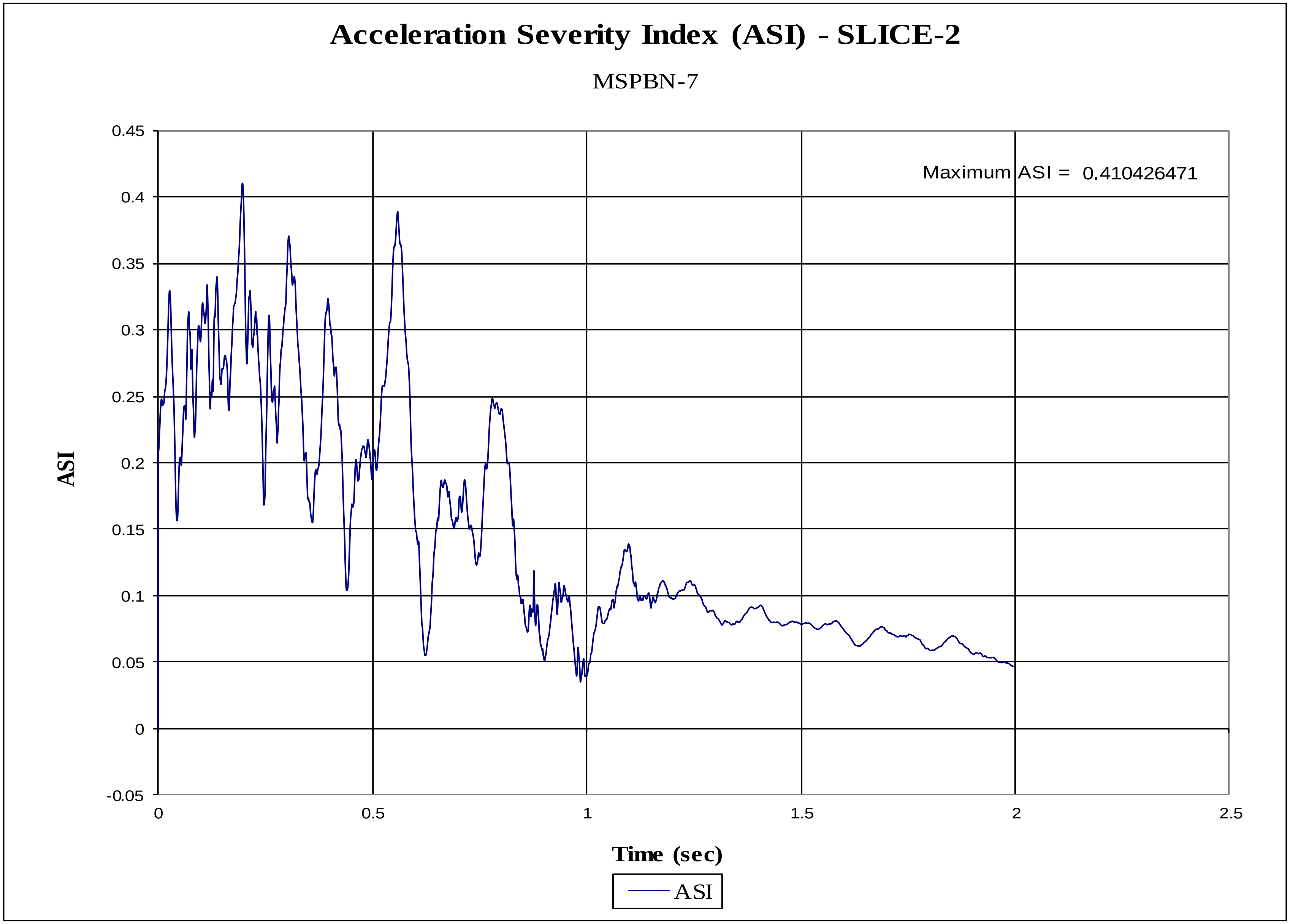


Figure H-16. Acceleration Severity Index (SLICE-2), Test No. MSPBN-7

Appendix I. Accelerometer and Rate Transducer Data Plots, Test No. MSPBN-8

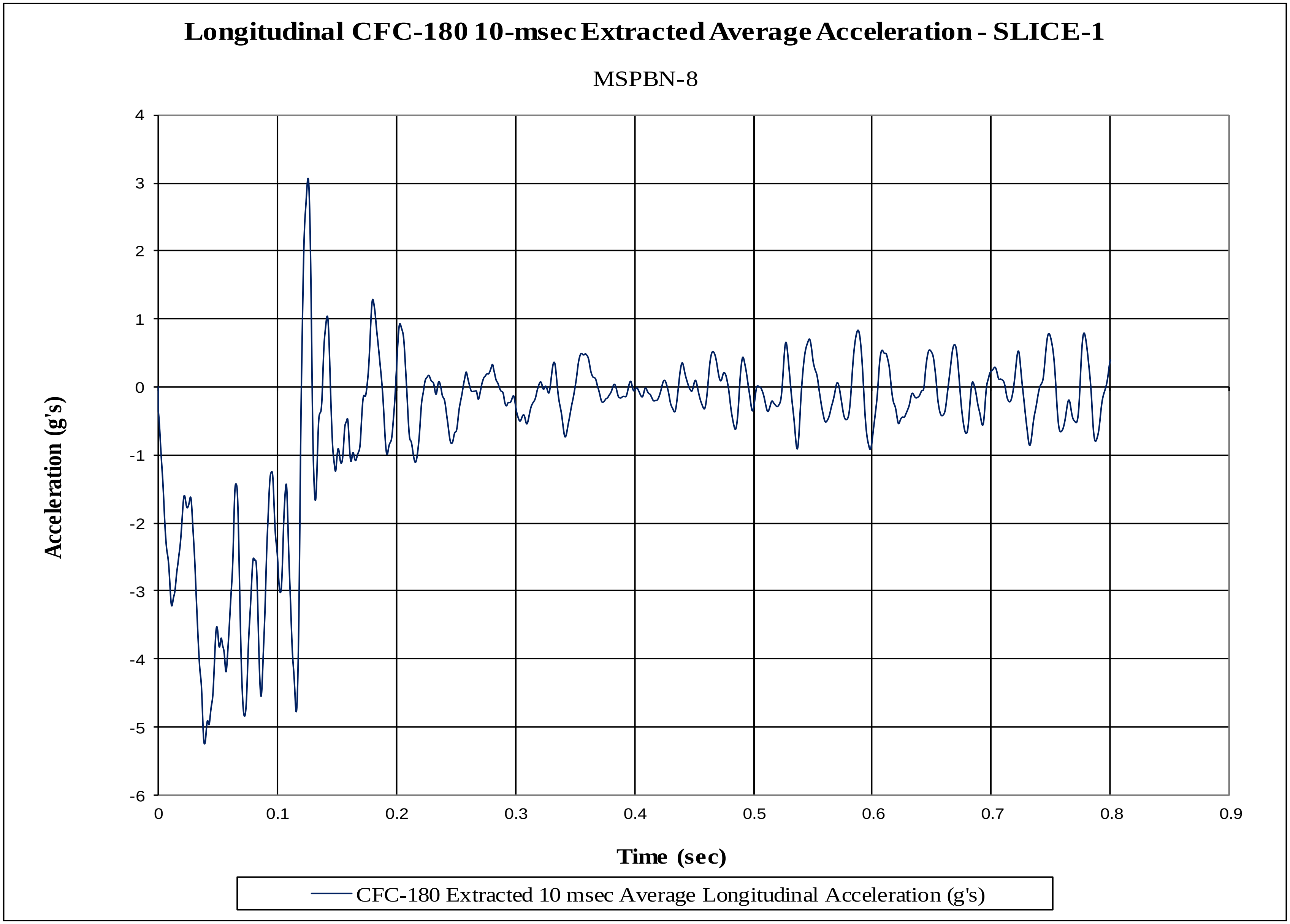


Figure I-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. MSPBN-8

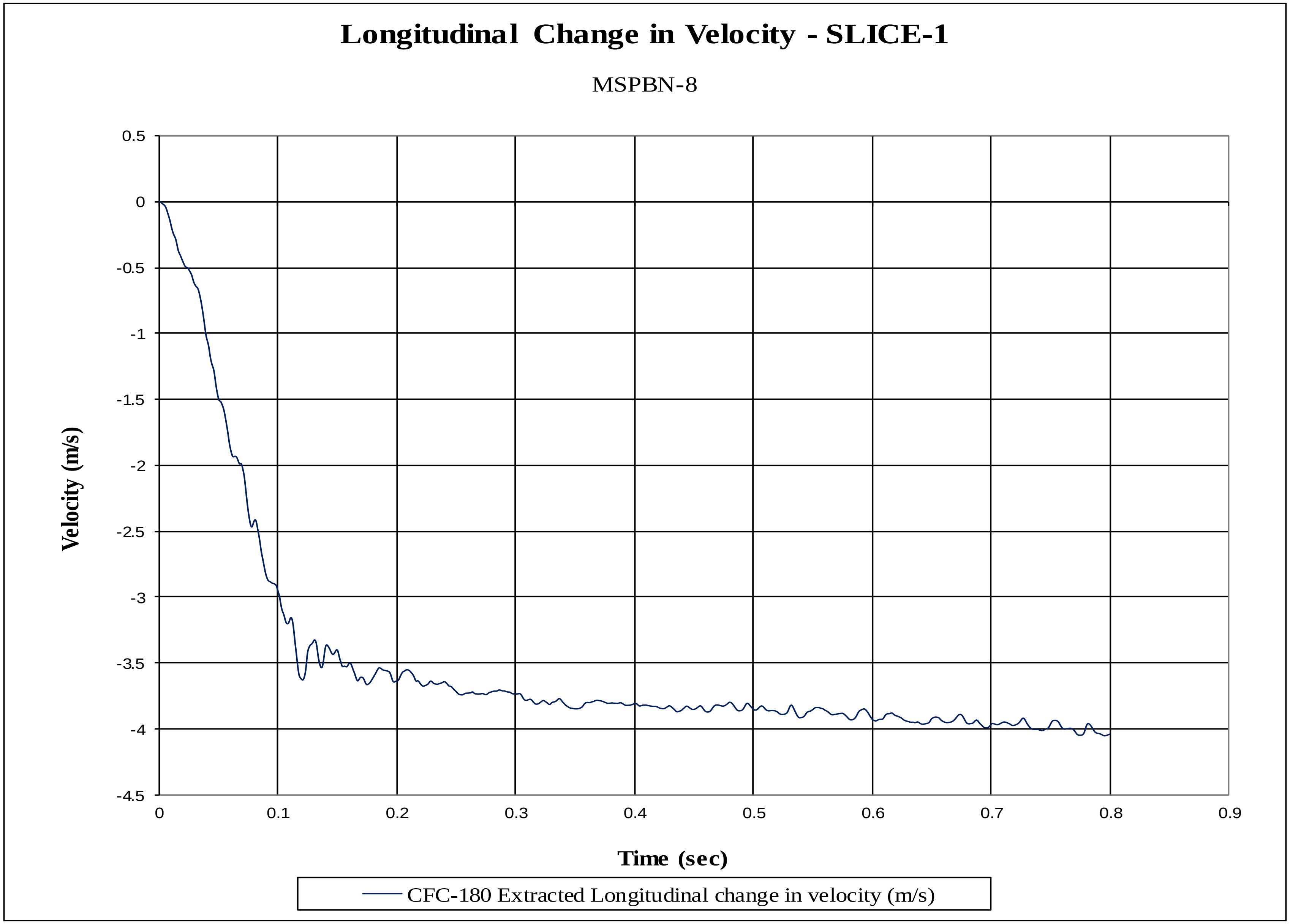


Figure I-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. MSPBN-8

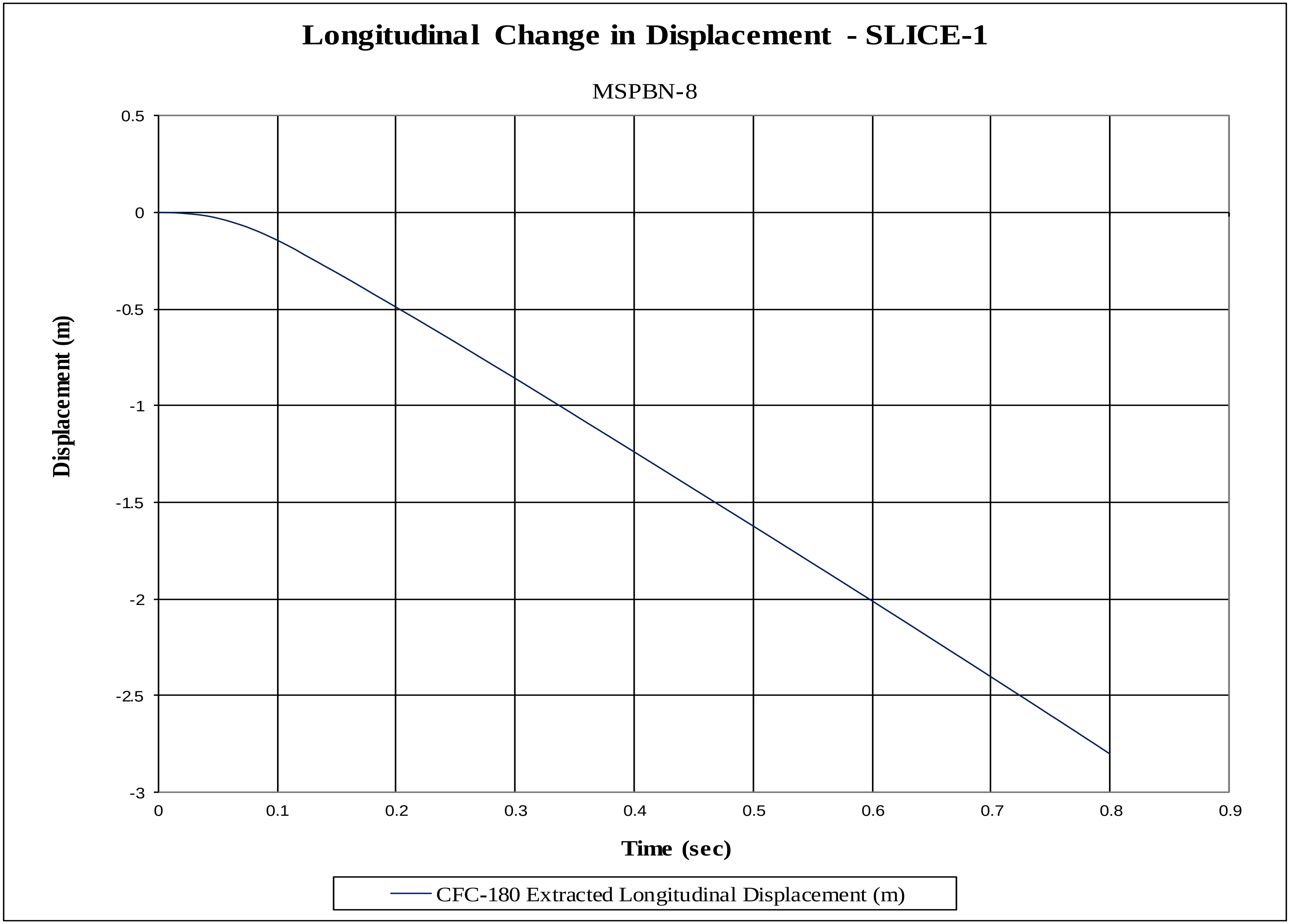


Figure I-3. Longitudinal Occupant Displacement (SLICE-1), Test No. MSPBN-8

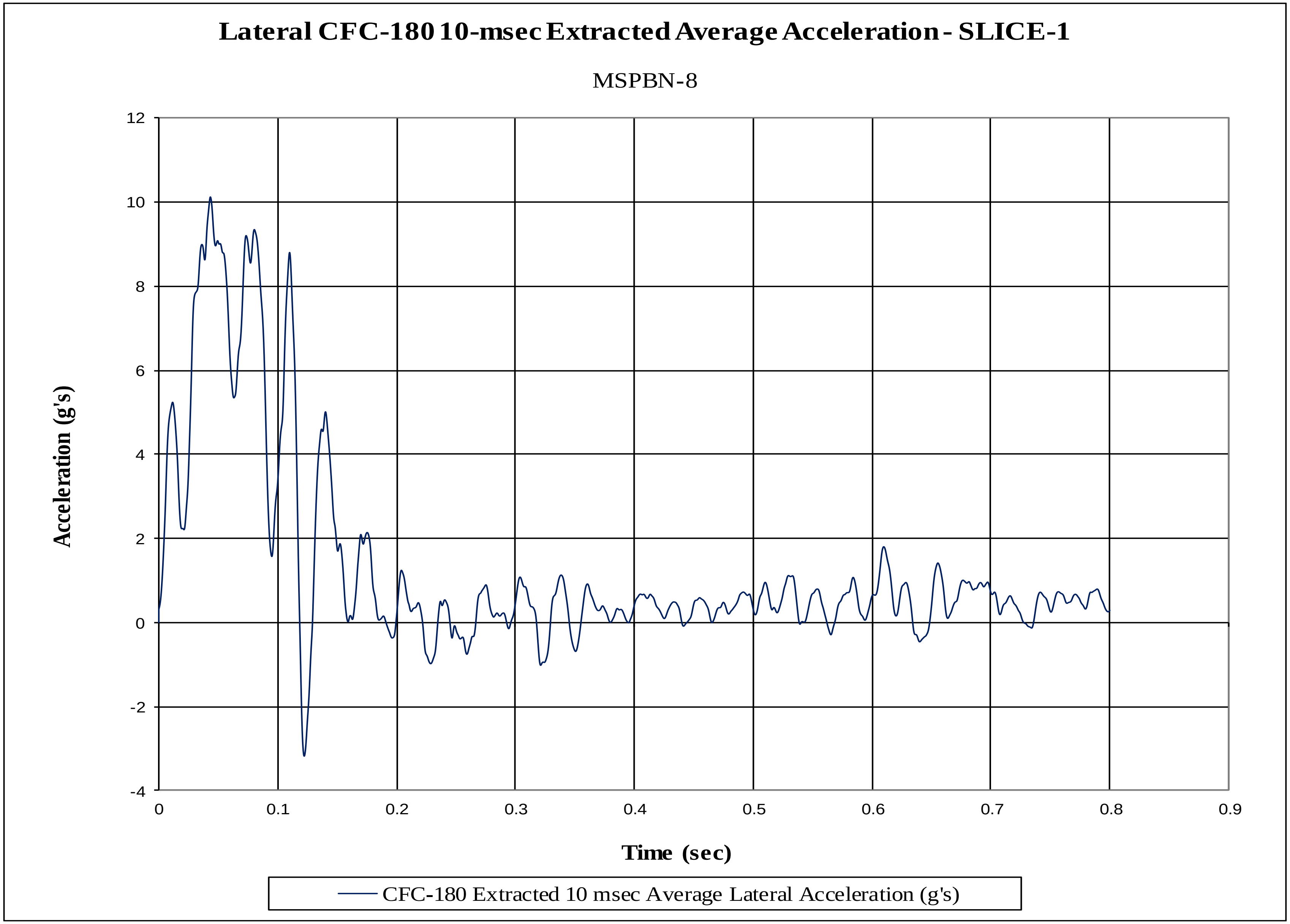


Figure I-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. MSPBN-8

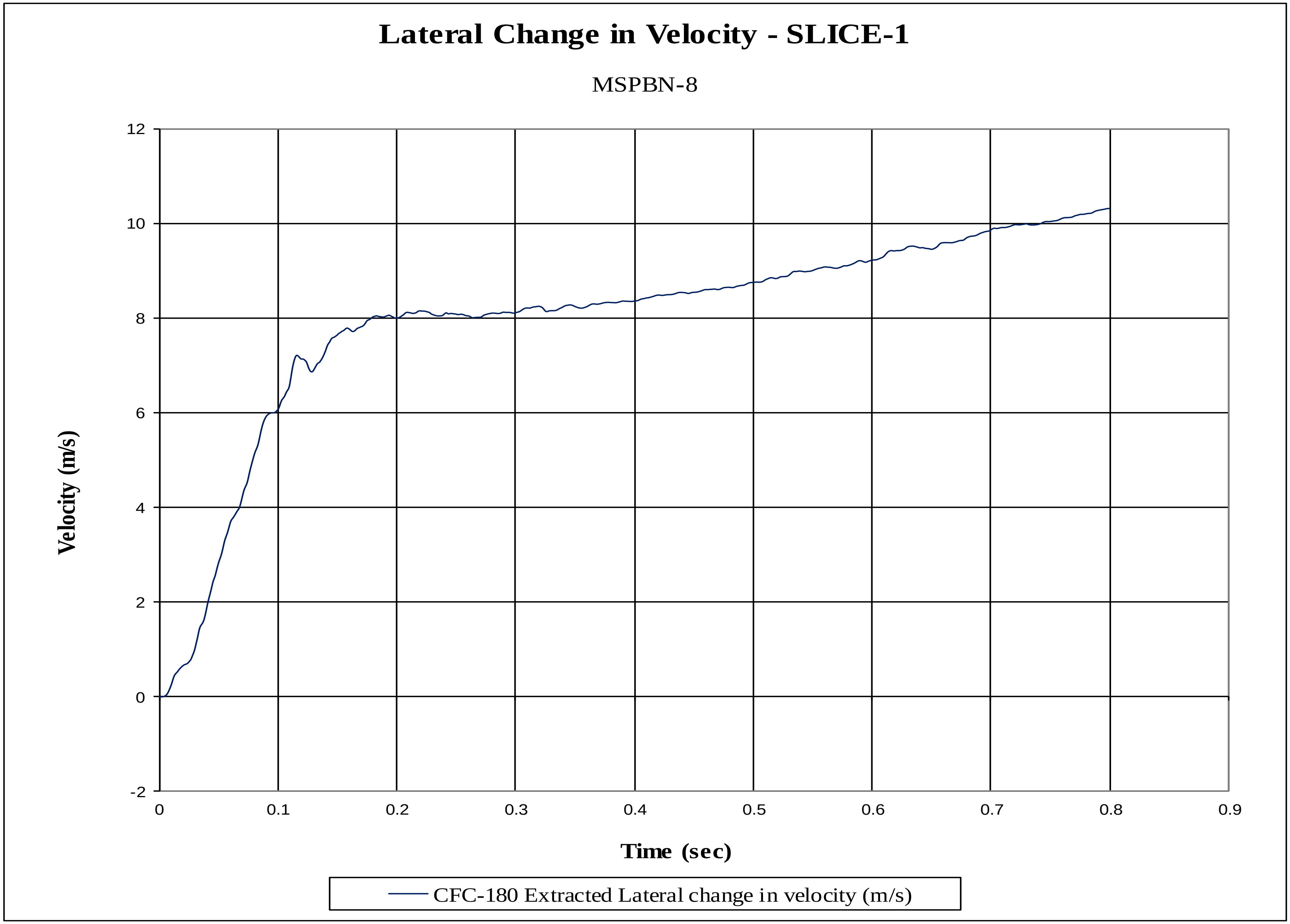


Figure I-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. MSPBN-8

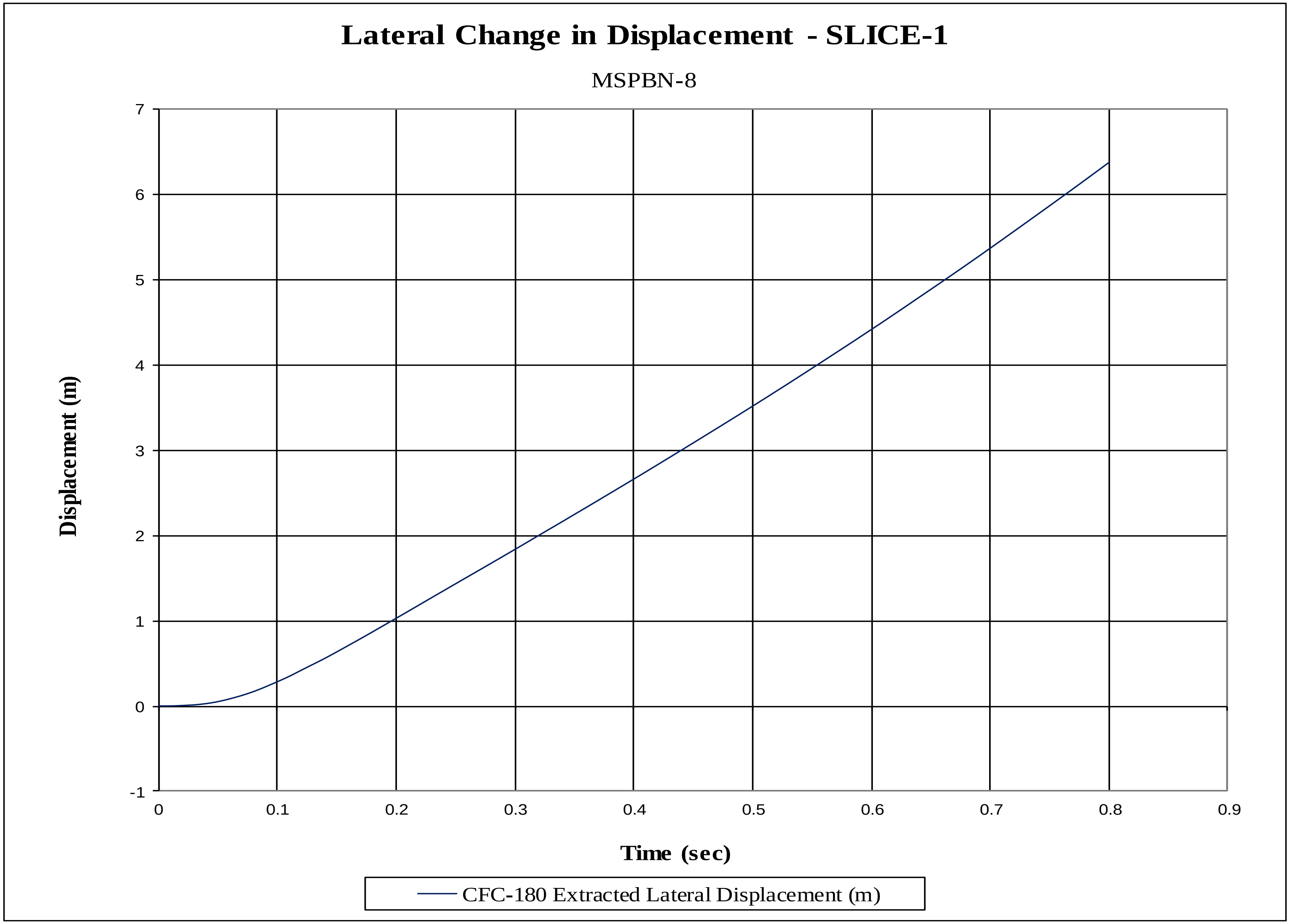


Figure I-6. Lateral Occupant Displacement (SLICE-1), Test No. MSPBN-8

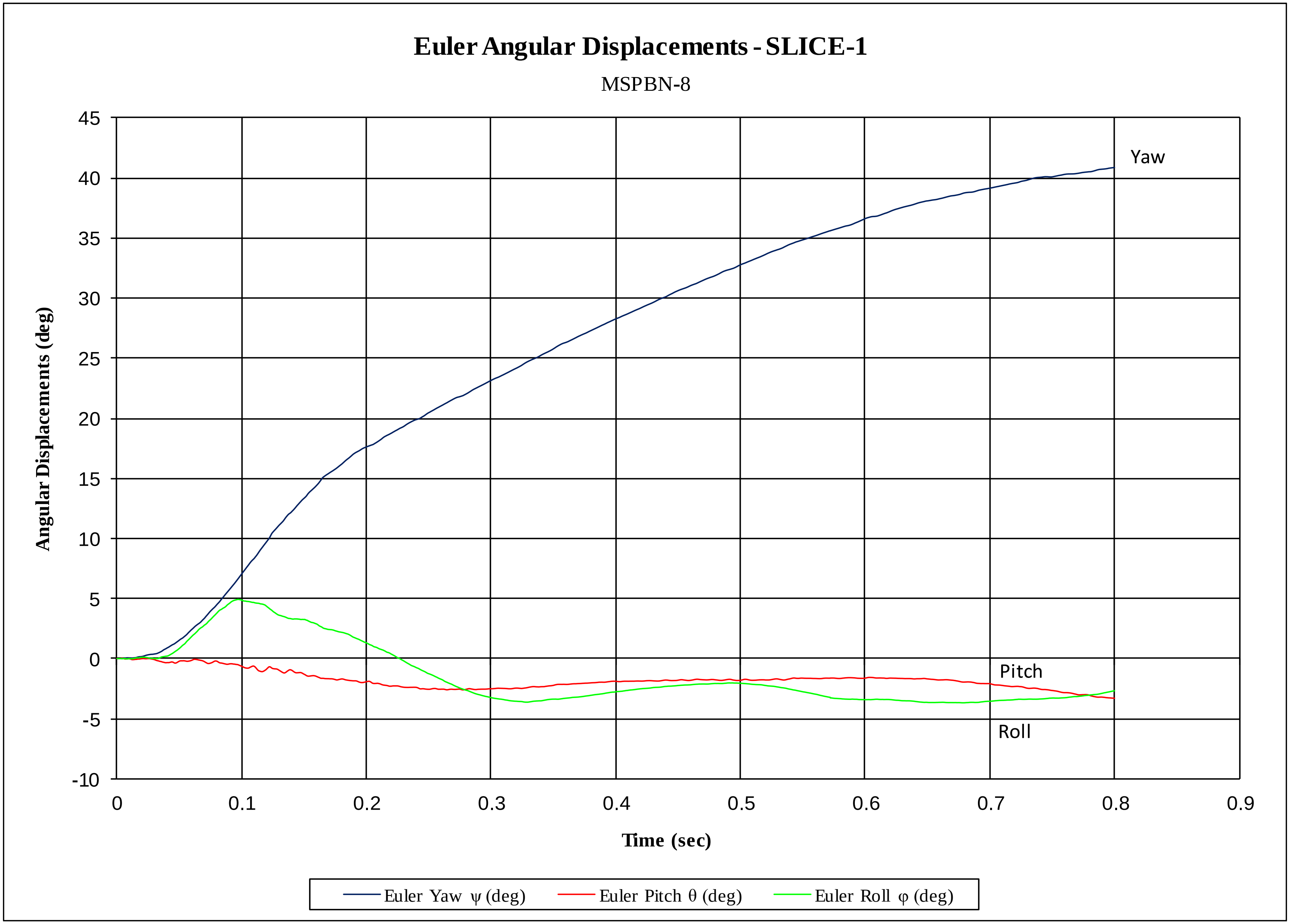


Figure I-7. Vehicle Angular Displacements (SLICE-1), Test No. MSPBN-8

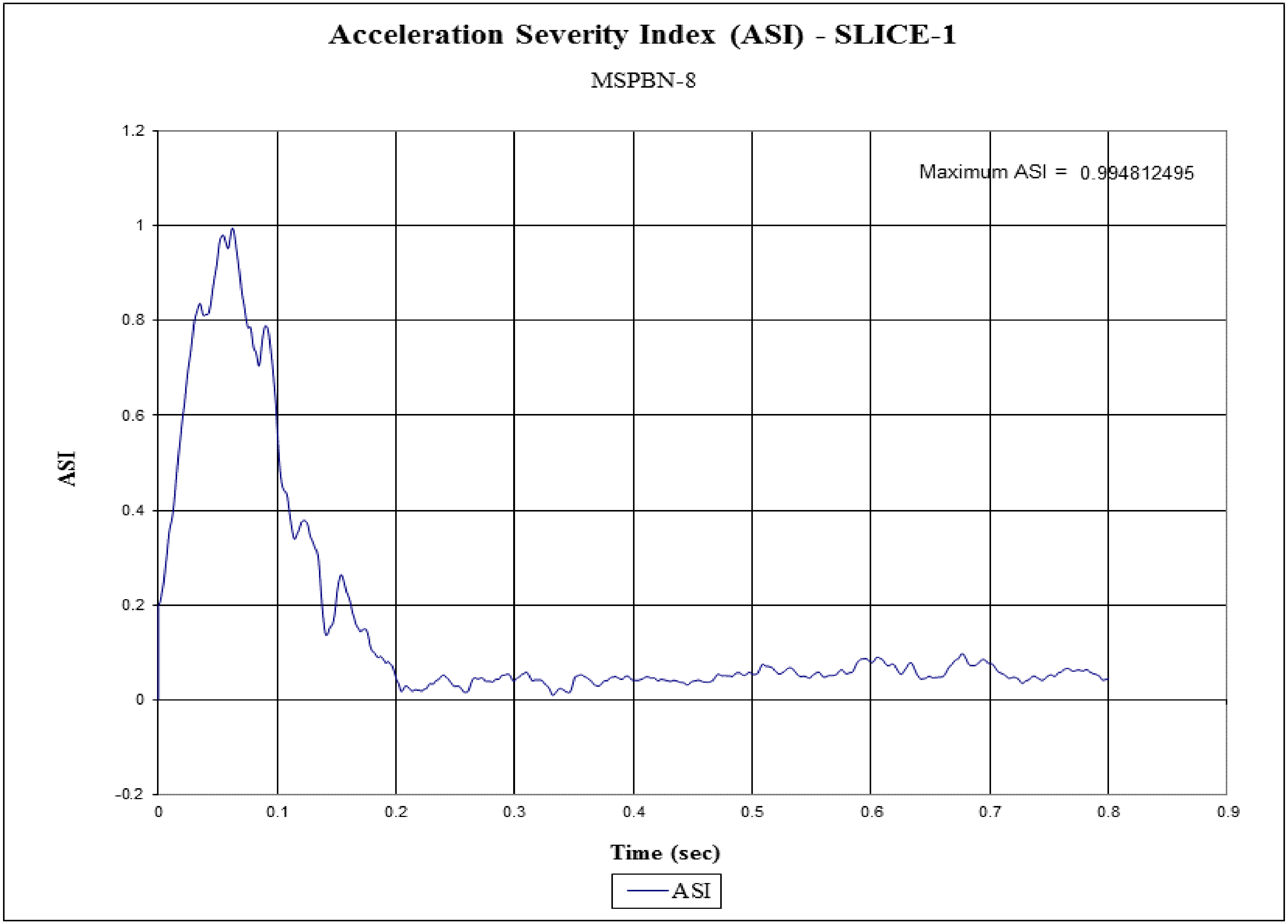


Figure I-8. Acceleration Severity Index (SLICE-1), Test No. MSPBN-8

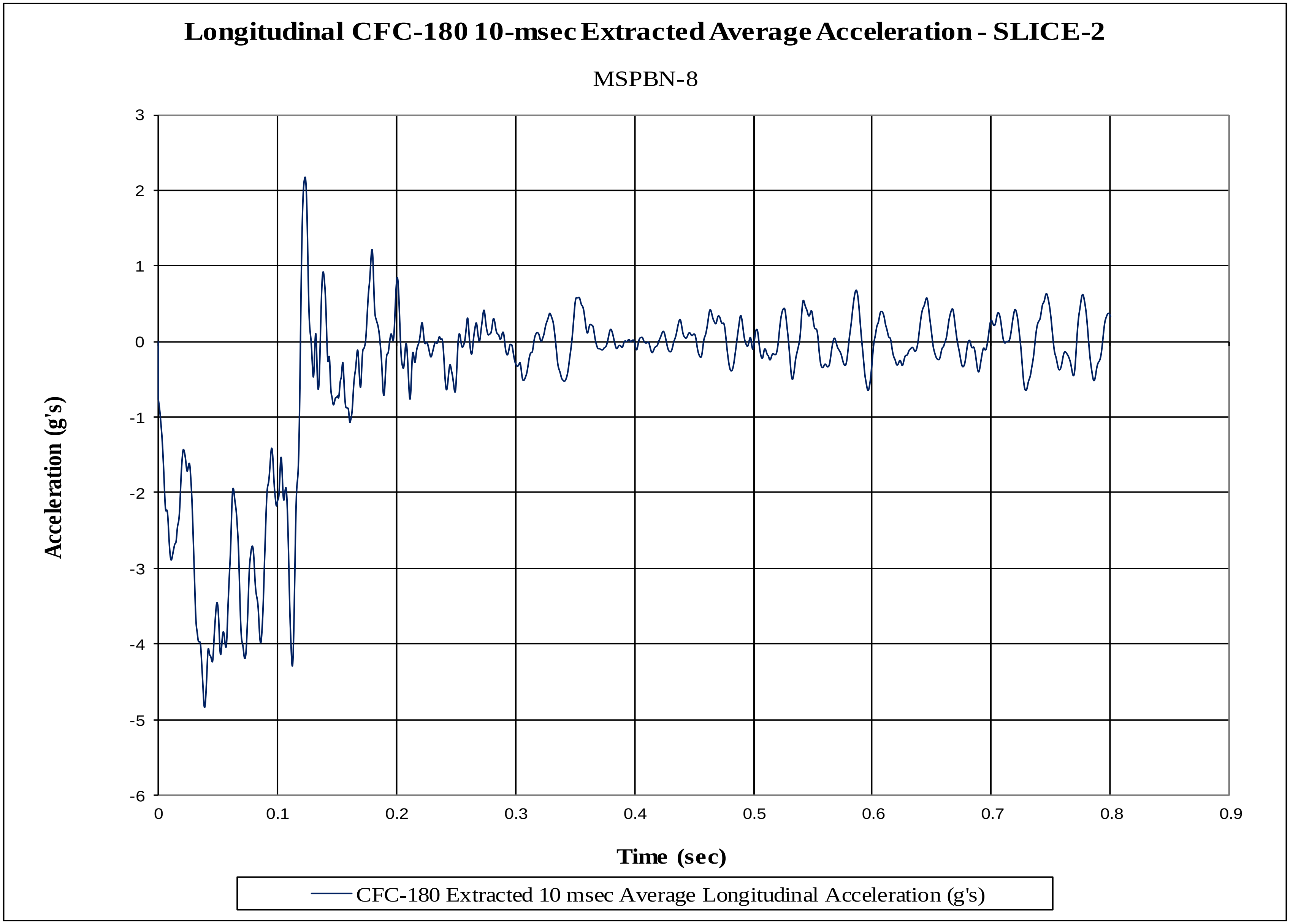


Figure I-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. MSPBN-8

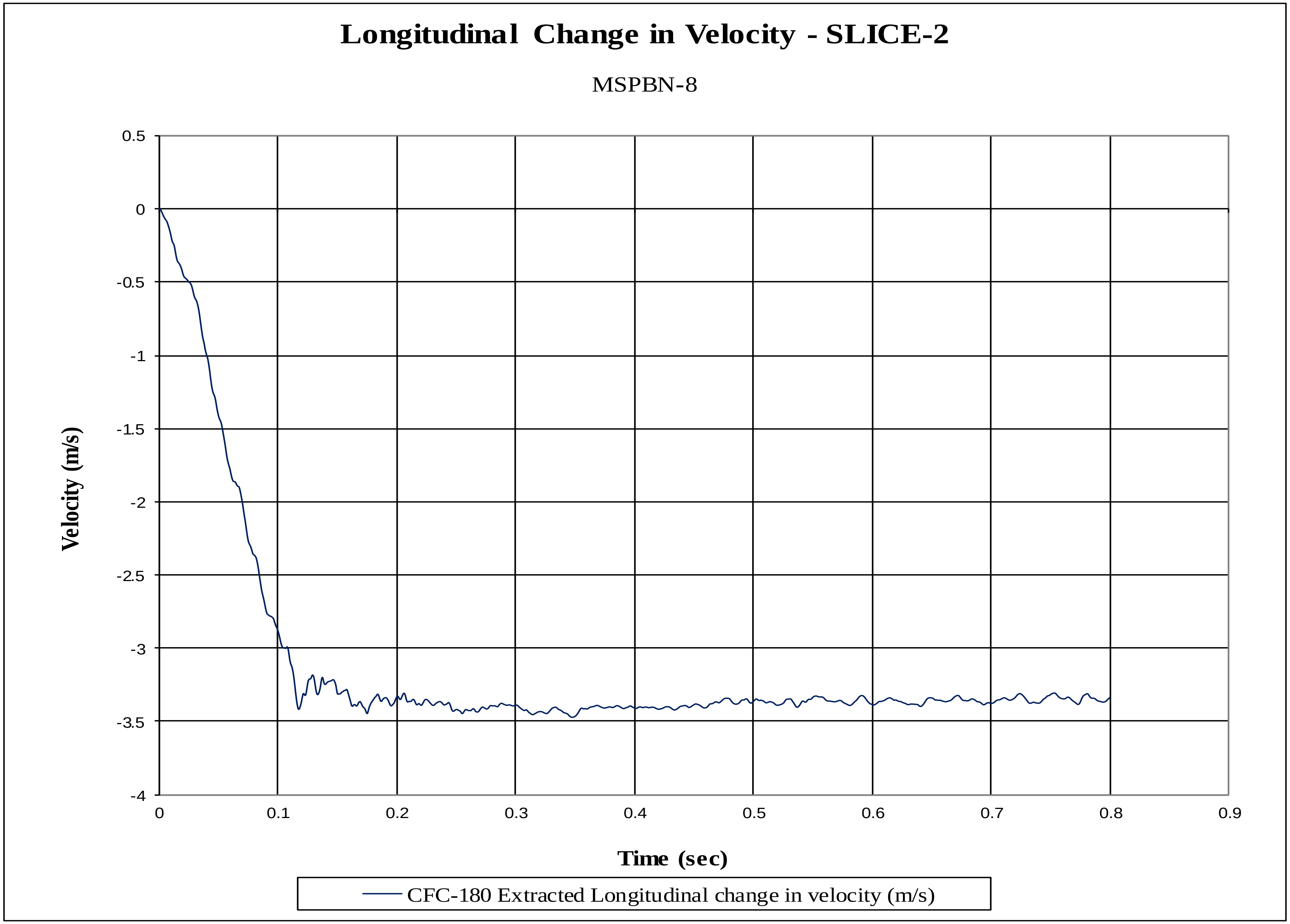


Figure I-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. MSPBN-8

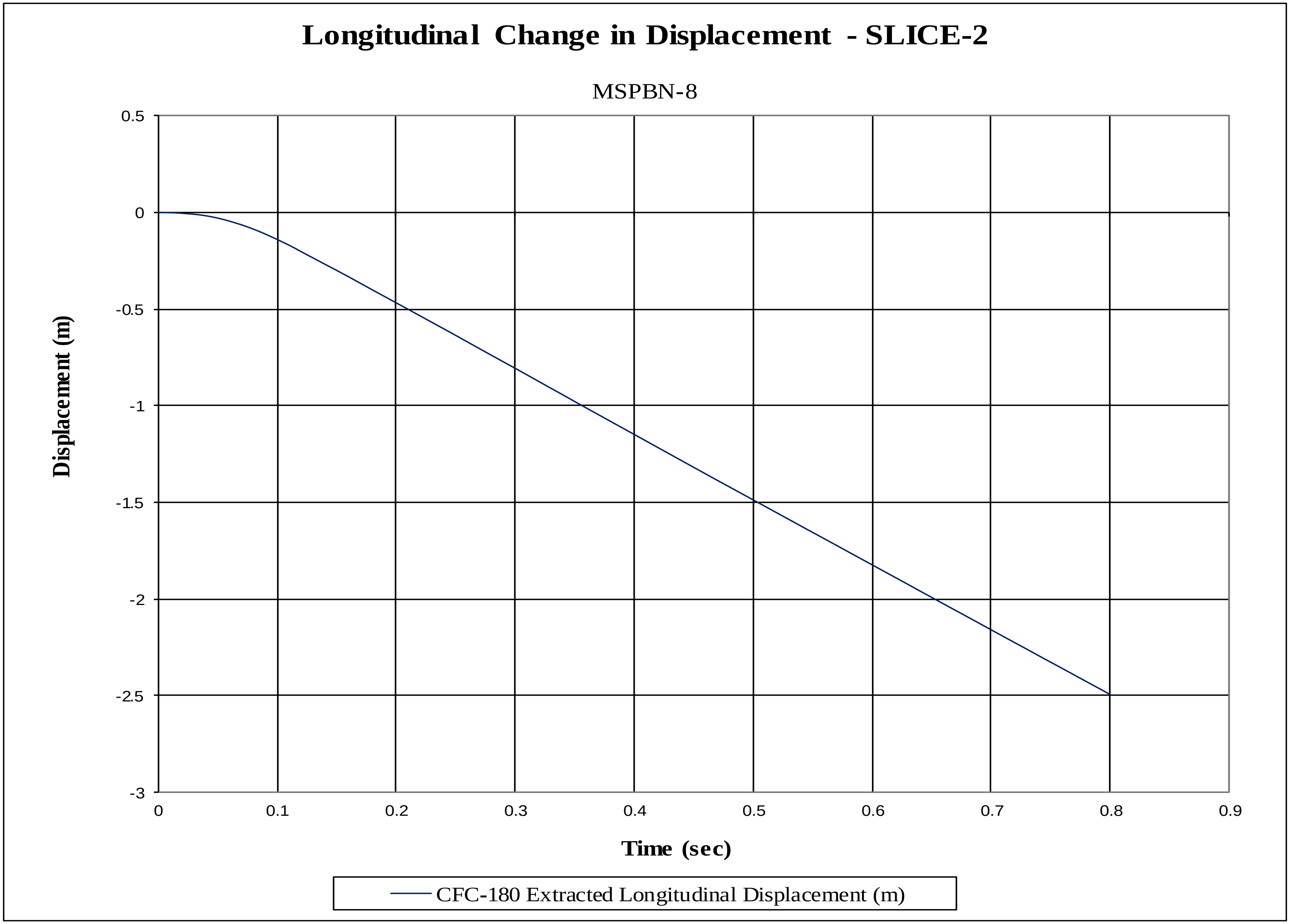


Figure I-11. Longitudinal Occupant Displacement (SLICE-2), Test No. MSPBN-8

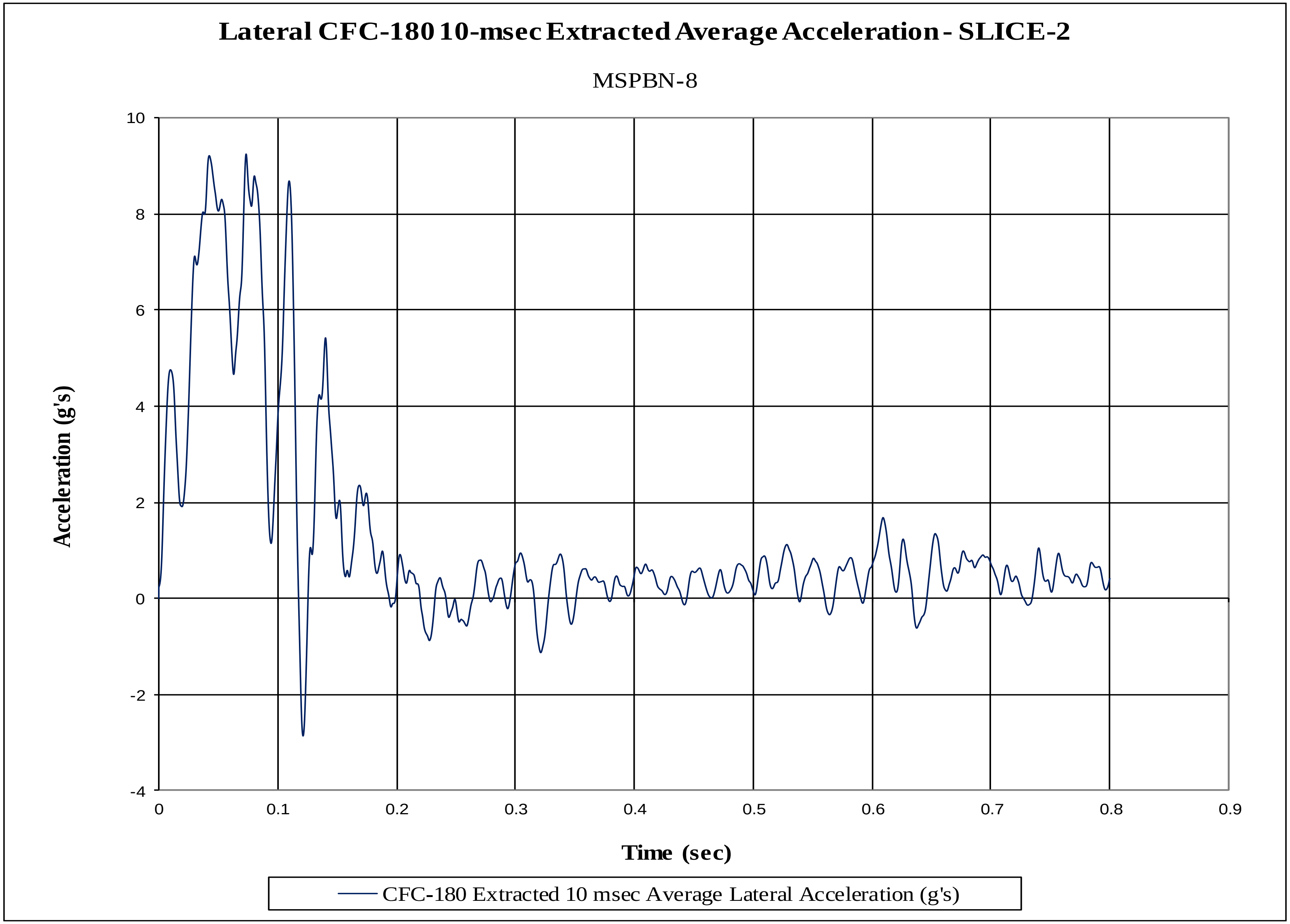


Figure I-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. MSPBN-8

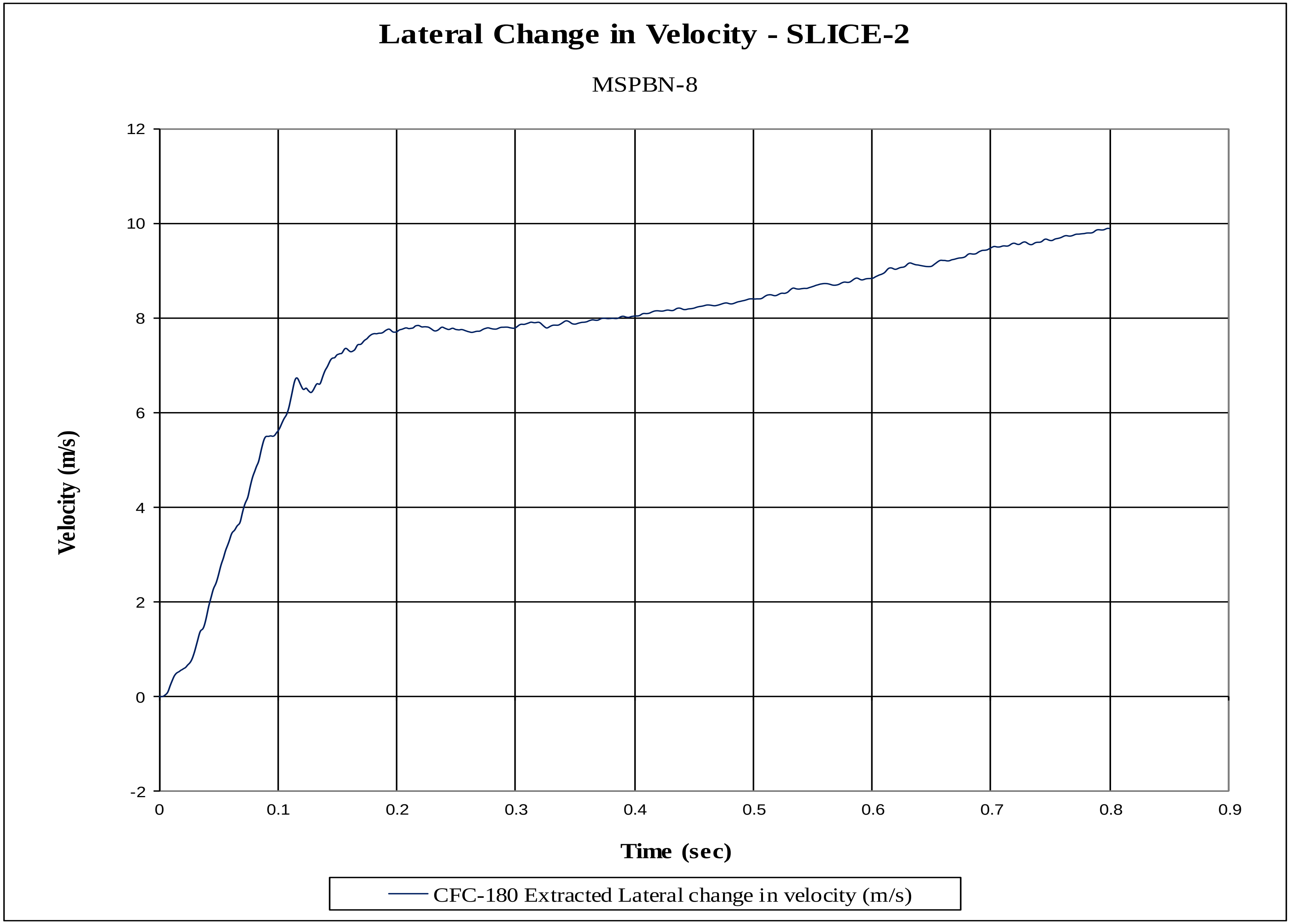


Figure I-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. MSPBN-8

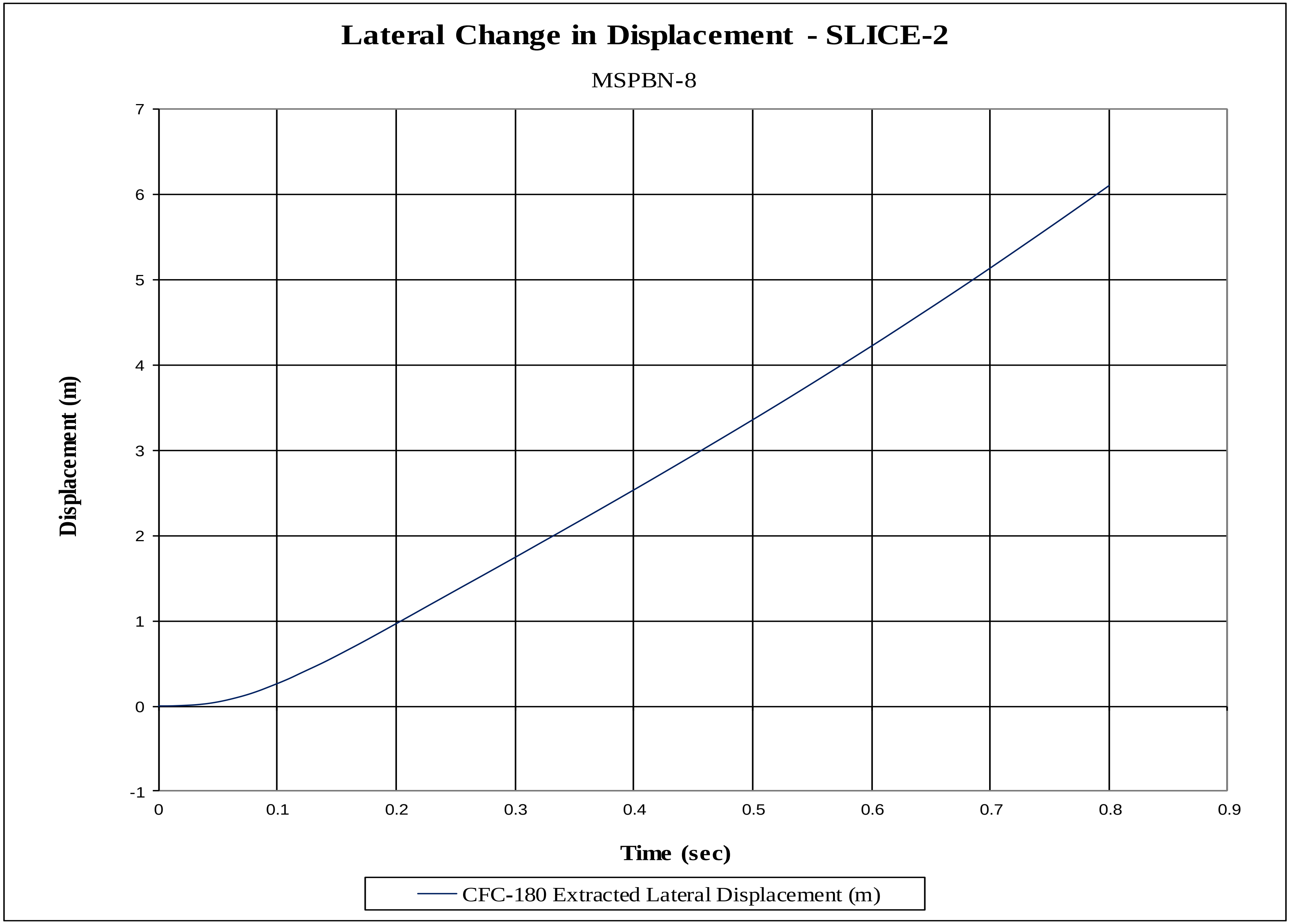


Figure I-14. Lateral Occupant Displacement (SLICE-2), Test No. MSPBN-8

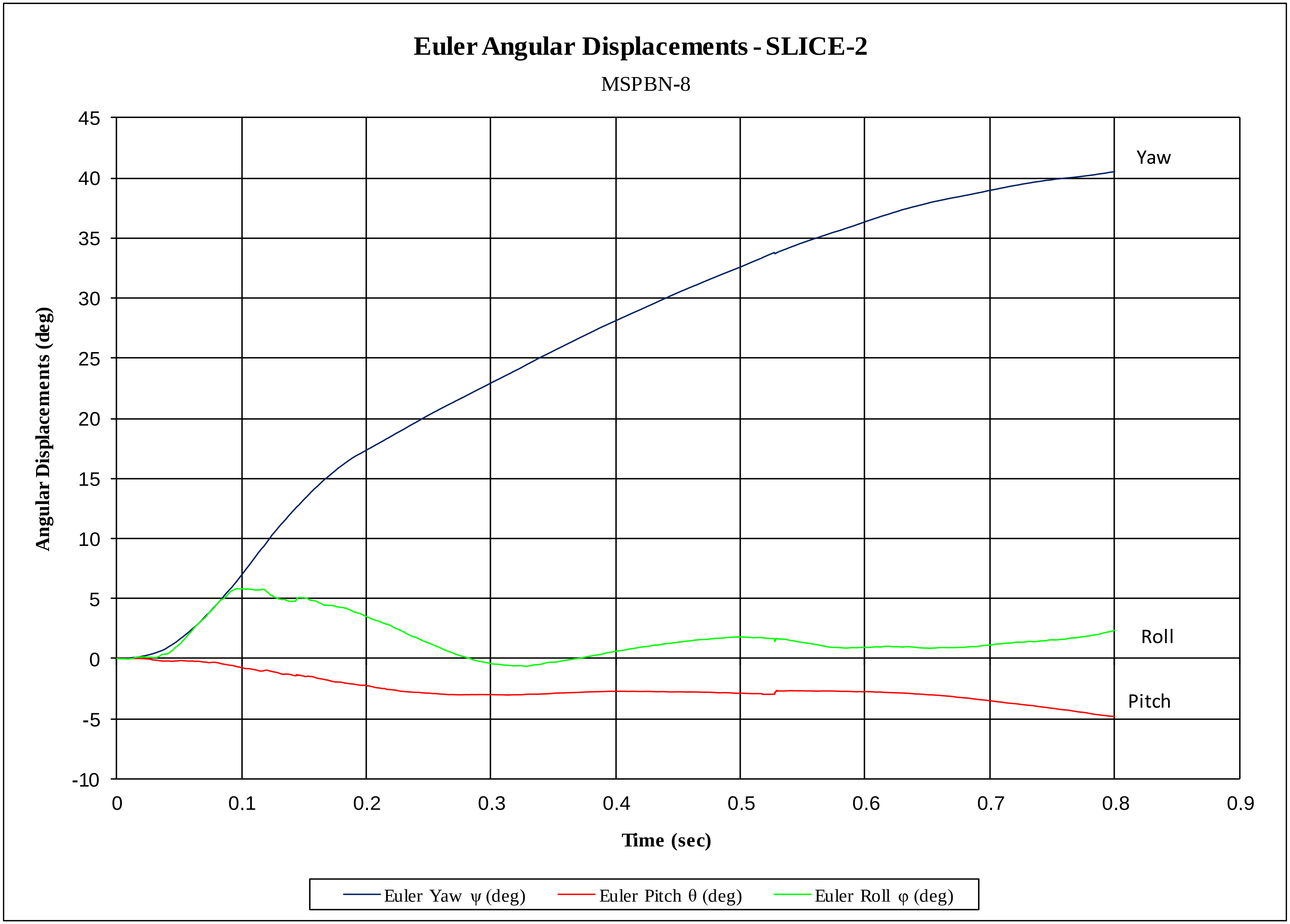


Figure I-15. Vehicle Angular Displacements (SLICE-2), Test No. MSPBN-8

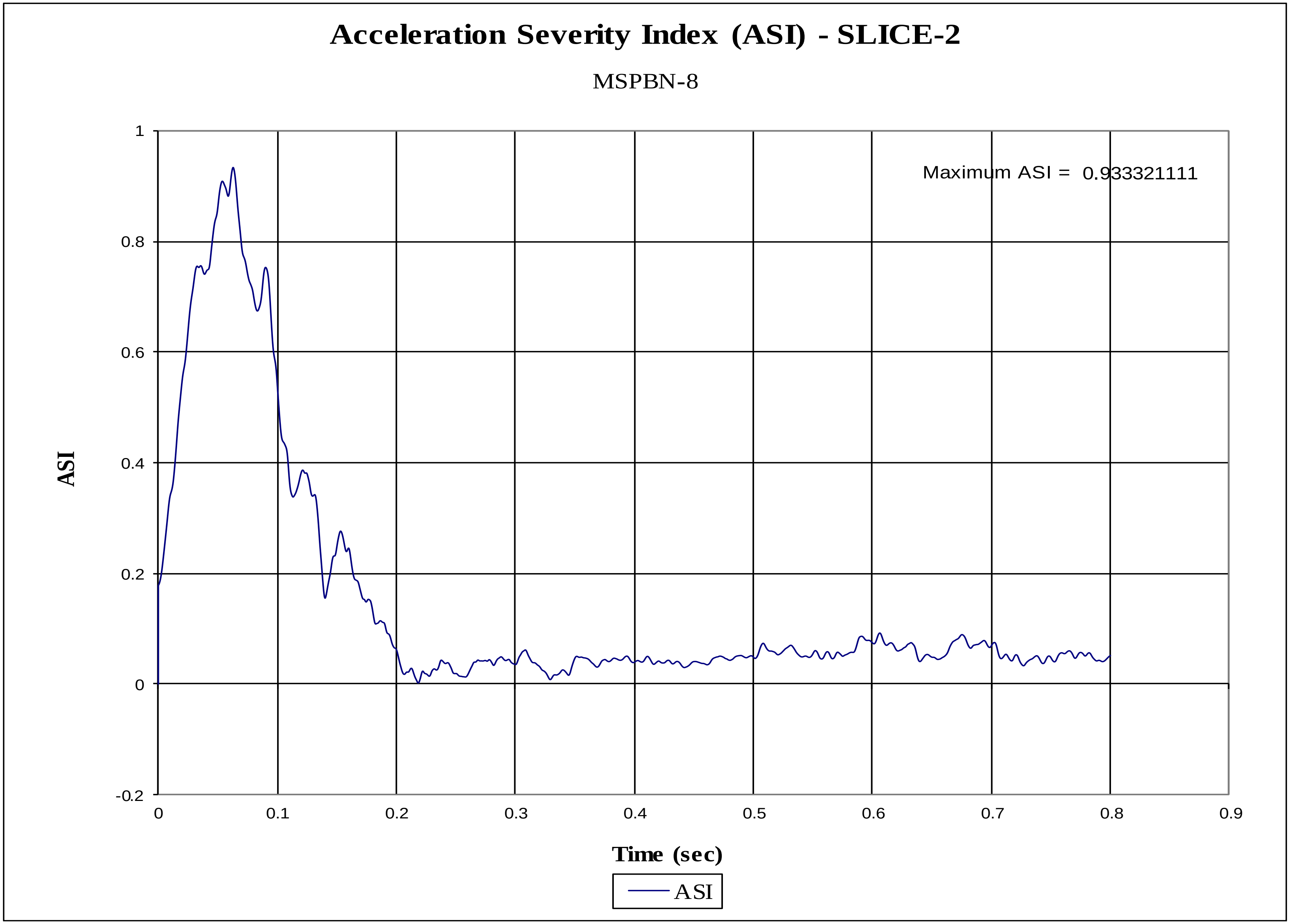


Figure I-16. Acceleration Severity Index (SLICE-2), Test No. MSPBN-8

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