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MASH 2016 EVALUATION OF THE MODIFIED THRIE BEAM SYSTEM

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16. Abstract

This report documents the evaluation of the New Jersey Department of Transportation (NJDOT) modified thrie beam (MTB) system in both a single-sided roadside configuration and a dual-sided median configuration under *Manual for Assessing Safety Hardware 2016* (MASH 2016) Test-Level 3 (TL-3) criteria. The MTB system was previously tested and approved under National Cooperative Highway Research Program Report No. 350 TL-3 impact conditions. Two full-scale crash tests, test nos. MTB-1 and MTB-2, were conducted according to test designation nos. 3-11 and 3-10, respectively.

In test no. MTB-1, a single-sided roadside barrier configuration was constructed using 81-in. long W6x8.5 steel posts at 75-in. post spacing, W14x22 blockouts, and 12-gauge guardrail sections. A 5,003-lb quad cab pickup truck impacted the critical impact point of the system at a speed of 62.9 mph and an angle of 25.4 deg. The test vehicle was satisfactorily captured and smoothly redirected. Therefore, test no. MTB-1 was deemed successful according to MASH 2016 TL-3 safety performance criteria.

Test no. MTB-2 was conducted on a dual-sided median barrier configuration of the modified thrie beam. A 2,415-lb small car impacted the critical impact point of the system at a speed of 63.1 mph and an angle of 24.9 deg. The test vehicle was satisfactorily captured and smoothly redirected. Therefore, test no. MTB-2 was deemed successful according to MASH 2016 TL-3 safety performance criteria.

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This material is based upon work supported by the New Jersey Department of Transportation (NJDOT) and the California Department of Transportation (Caltrans) under TPF-5(193) Supplement #132. The contents of this report reflect views and opinions of the authors who are responsible for the facts and the accuracy of the data represented herein. The contents do not necessarily reflect the official views or policies of the University of Nebraska-Lincoln, NJDOT, Caltrans nor the Federal highway Administration, U.S. Department of Transportation. This report does not constitute a standard, specification, or regulation. Trade or manufacturers' names, which may appear in this report are cited only because they are considered essential to the objectives of the report. The United States (U.S.) government and the State of Nebraska do not endorse products or manufacturers.

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. Cody Stolle, 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 2016, the American Association of State Highway and Transportation Officials (AASHTO) implemented an updated standard for the evaluation of roadside hardware. The standard, called the *Manual for Assessing Safety Hardware 2016* (MASH 2016) [1], improved the criteria for evaluating roadside hardware beyond the previous National Cooperative Highway Research Program (NCHRP) Report No. 350 [2] standard through updates to the test vehicles, test matrices, and impact conditions. In an effort to encourage state departments of transportation and hardware developers to advance their hardware designs, the Federal Highway Administration (FHWA) and AASHTO have collaborated to develop a MASH implementation policy that includes sunset dates for various categories of roadside hardware. The new policy will require that devices installed on federal aid roadways after the sunset dates must have been evaluated to MASH 2016.

The New Jersey Department of Transportation (NJDOT) and the California Department of Transportation (Caltrans) currently use roadside hardware systems that were originally developed and evaluated under NCHRP Report No. 350 criteria. This includes modified thrie beam guardrail which was previously evaluated to NCHRP Report No. 350 Test Levels 3 (TL-3) and 4 (TL-4). Additionally, these states desire to use a dual-sided version of the system for median applications that has yet to be evaluated to MASH or NCHRP Report No. 350. It was determined to be acceptable under NCHRP Report No. 350 by the FHWA based on crash testing of the single-sided system.

The original evaluation and testing of the modified thrie beam guardrail was performed by the Texas A&M Transportation Institute (TTI) [3]. The original development of the modified thrie beam rail stemmed from a desire to develop a barrier capable of safely redirecting bus-type vehicles while still providing safe performance for passenger car impacts. Testing of standard thrie beam guardrail during early research found that the performance of the standard thrie beam was marginal, as it captured and redirected the bus but allowed the vehicle to roll over. Thus, a modified thrie beam guardrail was developed that utilized 14-in. deep M14x17.2 blockouts with an angled cutout and increased the top rail height to 34 in. A thrie beam backup plate was included between the thrie beam and the blockout at posts where the splice did not occur to reduce the potential for stress concentrations that could arise as the thrie beam wrapped around the edge of the blockout during the impact. The modified thrie beam was evaluated by impacting the barrier with a 20,040-lb International school bus at 55.8 mph and an angle of 15.0 degrees. The modified thrie beam safely redirected the bus with a dynamic deflection of 2.87 ft. A subsequent test was conducted to evaluate the performance of small car on the system in terms of vehicle snag and capture. A 2,276-lb Honda Civic was used to impact the barrier at 62.5 mph and an angle of 15.0 degrees. The small car was safely redirected with a dynamic deflection of 0.8 ft. No snagging of the vehicle on the system posts was noted. A second test of a Honda Civic vehicle impacting at 61.6 mph and 18.1 degrees on the repaired barrier from the first test demonstrated very similar performance.

Several previous research efforts have evaluated modified thrie beam guardrail under NCHRP Report No. 350. In 1995, TTI performed test designation no. 3-11 on a modified thrie beam guardrail similar to the system detailed above except the blockout section was changed to a W14x22 section [4]. The modified thrie-beam guardrail system successfully contained and redirected the vehicle and met all evaluation criteria set forth in NCHRP Report No. 350 for TL-3. The maximum dynamic deflection of the guardrail was 3.4 ft. The relatively large dynamic deflection sustained by the guardrail system and snagging of the left wheel assembly on post no. 17 was somewhat unexpected given the stiffness of the thrie-beam rail element and the 14-in. deep blockout. Review of the high-speed film showed that post nos. 16 through 18 were severely twisted from the vehicle impact as the thrie-beam rail element deflected. The added moment arm from the deep blockout aggravated the torsional moment acting on the posts. As the posts twisted, the resistance to rail motion provided by the posts decreased which increased the dynamic deflection of the guardrail. The torsional collapse of the posts allowed the left-front wheel assembly of the vehicle to come into direct contact with post no. 17.

Finally, two tests have been conducted on modified thrie beam under NCHRP Report No. 350 TL-4 impact criteria. TTI tested the modified thrie beam with W14x22 blockouts with an impact of a 17,636-lb single-unit truck at a speed of 49.0 mph and an angle of 15.7 degrees [5]. The 8000S single-unit truck was safely and stably redirected with a maximum dynamic deflection of 2.33 ft. A subsequent test of the modified thrie beam was conducted according to NCHRP Report No. 350 TL-4 for Trinity Industries that used a slightly modified blockout with a different shape for the angled cutout [6]. In this test, a 17,380-lb single-unit truck impacted the barrier at a speed of 50.2 mph and an angle of 14.9 degrees. The test resulted in a successful redirection of the 8000S vehicle with a dynamic deflection of 2.18 ft.

Review of previous testing of the modified thrie beam system suggested the barrier may potentially meet MASH TL-3 criteria. However, the increased mass and kinetic energy of the MASH 2270P test vehicle has been shown to increase impact loading and dynamic deflection of guardrail systems, and no MASH testing has been conducted on the modified thrie beam system with a small car. Additionally, no testing has been conducted on a dual-sided modified thrie beam system. Thus, a need exists to evaluate the modified thrie beam system under MASH 2016 criteria to determine its dynamic deflection, working width, and crashworthiness under MASH TL-3. If the modified thrie beam system proves successful under TL-3 impact conditions, further study regarding its performance under TL-4 impacts with the 10000S vehicle may be warranted.

1.2 Objective

The objective of this research is to conduct full-scale crash testing on the modified thrie beam guardrail system according to TL-3 of the MASH 2016 impact safety standards. The effort will seek to evaluate both the single-sided and dual-sided median versions of the design through full-scale crash testing with both the 1100C and 2270P vehicles.

1.3 Scope

Two full-scale crash tests were conducted on the modified thrie beam guardrail according to MASH 2016 test designation nos. 3-10 and 3-11. The system was constructed following NJDOT's schematic drawings, which are shown in Appendix A. Because the sponsors desired to evaluate both the single-sided and dual-sided median versions of modified thrie beam guardrail, MwRSF proposed conducting MASH test designation nos. 3-10 and 3-11 on the critical configuration of the barrier such that only two tests were required. Test designation no. 3-10 was conducted on the dual-sided, median version of the modified thrie beam and test designation no. 3-11 was conducted on the single-sided configuration. The test results were analyzed, evaluated, and documented, and conclusions and recommendations were made pertaining to the safety performance of the system. Specific recommendations will also be made regarding transitioning of the modified thrie beam to crashworthy thrie beam approach guardrail transitions and transitioning the modified thrie beam transition from its 34-in. height to the 31-in. height of the Midwest Guardrail System (MGS).

2 TEST REQUIREMENTS AND EVALUATION CRITERIA

2.1 Test Requirements

Longitudinal barriers, such as the modified thrie beam guardrail, must satisfy impact safety standards in order to be declared eligible for federal reimbursement by the FHWA for use on the National Highway System (NHS). For new hardware, these safety standards consist of the guidelines and procedures published in MASH 2016. Note that there is no difference between MASH 2009 [7] and MASH 2016 for longitudinal barriers, except that additional occupant compartment deformation measurements, photographs, and documentation are required by MASH 2016. According to TL-3 of MASH 2016, longitudinal barrier systems must be subjected to two full-scale vehicle crash tests, as summarized in Table 1.

Table 1. MASH 2016 TL-3 Crash Test Conditions for Longitudinal Barriers

Test Article	Test Designation No.	Test Vehicle	Vehicle Weight lb	Impact Conditions		Evaluation Criteria [1]
				Speed mph	Angle deg.	
Longitudinal Barrier	3-10	1100C	2,425	62	25	A,D,F,H,I
	3-11	2270P	5,000	62	25	A,D,F,H,I

[1] Evaluation criteria explained in Table 2

Because NJDOT and Caltrans would like to evaluate both the single-sided roadside and dual-sided median versions of the modified thrie beam guardrail, MwRSF proposed to run test designation nos. 3-10 and 3-11 on the critical configuration of the barrier such that only two tests were required. Test designation no. 3-10 (test no. MTB-2) was conducted on the dual-sided, median version of the modified thrie beam as this system configuration would tend to increase loading and occupant risk values for the small car vehicle and increase the propensity for vehicle snag on the post due to the higher stiffness and reduced dynamic deflection of the dual-sided system. Conversely, test designation no. 3-11 (test no. MTB-1) was conducted on the single-sided configuration because the 2270P vehicle will impart increased barrier loading on the components of a single-sided system. Additionally, the potential for the torsional buckling of the system posts that led to increased barrier deflection and post snag as occurred in the original test designation no. 3-11 testing of the modified thrie beam would be more prevalent in the single-sided configuration. Finally, evaluation of the single-sided modified thrie beam configuration with the 2270P vehicle would also produce the maximum dynamic deflection and working width values for the barrier system. Previous evaluation of the T-39 thrie beam barrier for both roadside and median versions followed a similar methodology [8].

Evaluation of the length of need for guardrail systems has traditionally been conducted near the midpoint of 175-ft long systems. This has shown to be sufficiently far from the system anchors to simulate the performance and dynamic deflection of longer barrier systems and limit the sensitivity of the results to the proximity of the end anchorages. MwRSF evaluated the MTB guardrail using a similar length. It should be noted that 175 ft typically becomes the minimal functional system length, since any reduction affects barrier performance and anchorage requirements. Thus, further analysis and testing is usually required to justify barrier systems shorter than that length, or the length of the system in its full-scale crash test. MwRSF may be able to provide guidance based on previous MGS research, but actual determination of minimum system lengths and effects on performance are outside the scope of this effort and would require further study.

Test nos. MTB-1 and MTB-2 were conducted, documented, and evaluated by MwRSF personnel in accordance with the MASH TL-3 guidelines. The tests were conducted to MwRSF's list of accredited testing services granted by the A2LA laboratory accreditation body (A2LA Cert. No. 2937.01).

Table 2. MASH 2016 Evaluation Criteria for Longitudinal Barrier

<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="11">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 deg.</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</td><td>40 ft/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>

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 longitudinal barrier 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 documented herein 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 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 posts are installed near the impact region using 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 at post deflections between 5 and 20 in. measured at a height of 25 in. 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 percent of the static baseline test at deflections of 5, 10, and 15 in. 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 five miles 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 [13] was used to steer the test vehicle. A guide flag, attached to the left-front wheel and the guide cable, was sheared off before impact with the barrier system. The ⅜-in. diameter guide cable was tensioned to approximately 3,500 lb and supported both laterally and vertically every 100 ft 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. MTB-1, 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 5,089 lb, 5,003 lb, and 5,162 lb, respectively. The test vehicle is shown in Figures 1 and 2 and vehicle dimensions are shown in Figure 3.

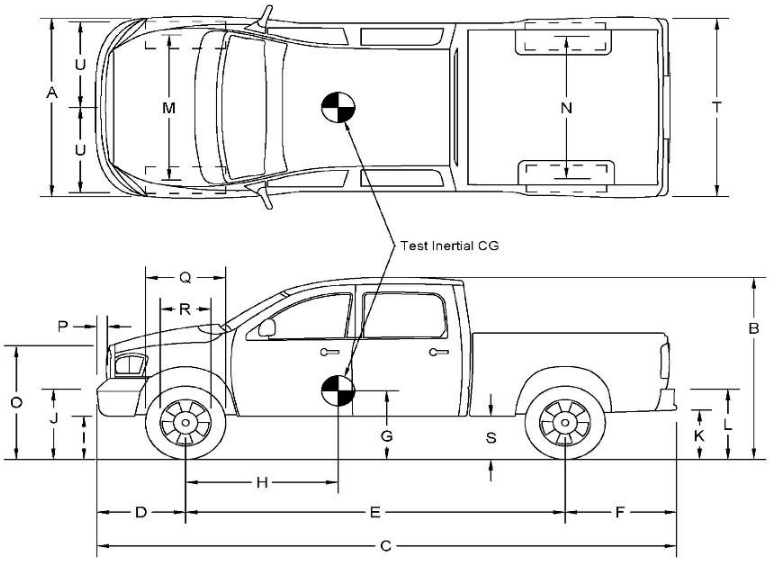
For test no. MTB-2, a 2009 Kia Rio was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,497 lb, 2,415 lb, and 2,579 lb, respectively. The test vehicle is shown in Figures 4 and 5 and vehicle dimensions are shown in Figure 6.

MASH 2016 requires test vehicles used in crash testing to be no more than six model years old. A 2009 model was used for this test 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 [14].

Figure 1. Test Vehicle, Test No. MTB-1

Figure 2. Test Vehicle’s Interior Floorboards and Undercarriage, Test No. MTB-1

Date: 11/7/2018	Test Name: MTB-1	VIN No: 1C6RD6FT1CS307273
Year: 2012	Make: Dodge	Model: Ram 1500
Tire Size: 265/77/17	Tire Inflation Pressure: 35 Psi	Odometer: 197759



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

A: 77 (1956) 78±2 (1950±50)	B: 74 (1880)
C: 229 (5817) 237±13 (6020±325)	D: 39 3/4 (1010) 39±3 (1000±75)
E: 140 5/8 (3572) 148±12 (3760±300)	F: 48 (1219)
G: 28 3/16 (716) min: 28 (710)	H: 61 5/8 (1565) 63±4 (1575±100)
I: 11 1/2 (292)	J: 29 1/8 (740)
K: 20 3/4 (527)	L: 30 (762)
M: 67 (1702) 67±1.5 (1700±38)	N: 67 (1702) 67±1.5 (1700±38)
O: 43 1/2 (1105) 43±4 (1100±75)	P: 4 1/4 (108)
Q: 30 1/2 (775)	R: 18 1/2 (470)
S: 13 7/8 (352)	T: 77 1/8 (1959)
	U (impact width): 70 3/4 (1797)

Wheel Center Height (Front):	14 7/8 (378)
Wheel Center Height (Rear):	15 (381)
Wheel Well Clearance (Front):	34 1/4 (870)
Wheel Well Clearance (Rear):	37 7/8 (962)
Bottom Frame Height (Front):	11 (279)
Bottom Frame Height (Rear):	13 (330)
Engine Type:	gasoline
Engine Size:	5.7L V8 Hemi
Transmission Type:	automatic
Drive Type:	RWD
Cab Style:	quad cab
Bed Length:	76"

Mass Distribution lb (kg)

Gross Static				
	LF	1453 (659)	RF	1453 (659)
	LR	1111 (504)	RR	1145 (519)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2869 (1301)	2811 (1275)	2906 (1318)
W-rear	2220 (1007)	2192 (994)	2256 (1023)
W-total	5089 (2308)	5003 (2269) 5000±110 (2270±50)	5162 (2341) 5165±110 (2343±50)

GVWR Ratings lb

Front	3700
Rear	3900
Total	6700

Surrogate Occupant Data

Type:	Hybrid II
Mass:	159 lb
Seat Position:	Right/Passenger

Note any damage prior to test:

Figure 3. Vehicle Dimensions, Test No. MTB-1

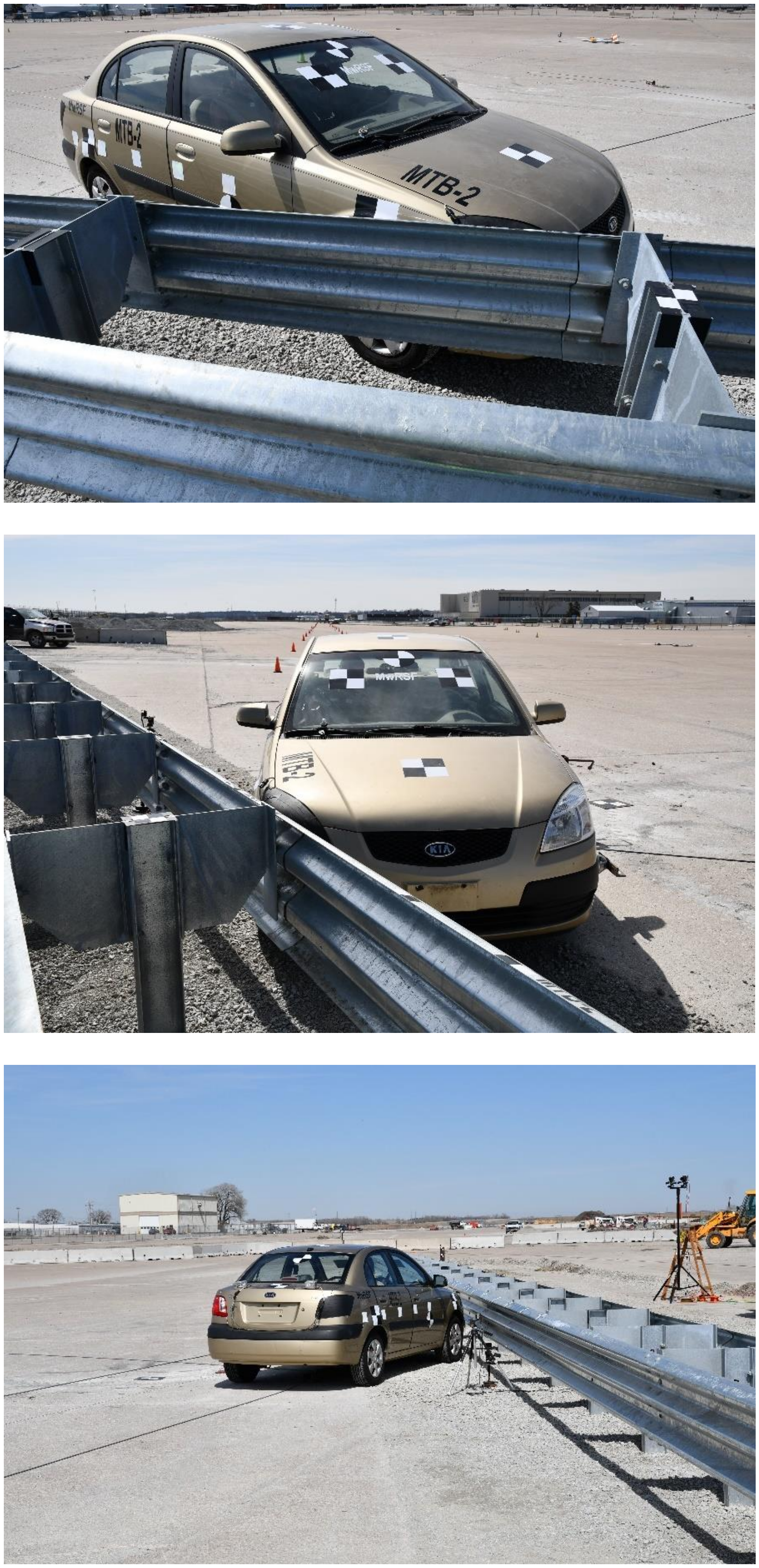
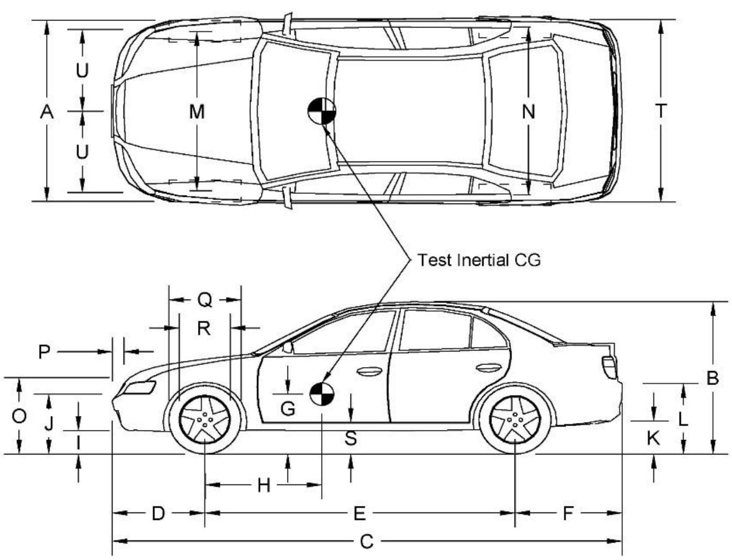


Figure 4. Test Vehicle, Test No. MTB-2

Figure 5. Test Vehicle’s Interior Floorboards and Undercarriage, Test No. MTB-2

Date:	9/20/2018	**Test Name:**	MTB-2	**VIN No:**	KNADE223596440731
Year:	2009	**Make:**	Kia	**Model:**	Rio
Tire Size:	185/65R14	**Tire Inflation Pressure:**	32 Psi	**Odometer:**	209189



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

A:	65 3/4	(1670)	B:	57 3/8	(1457)
	65±3 (1650±75)				
C:	167 1/4	(4248)	D:	33	(838)
	169±8 (4300±200)			35±4 (900±100)	
E:	98 1/2	(2502)	F:	35	(889)
	98±5 (2500±125)				
G:	22 3/4	(578)	H:	36 3/16	(919)
				39±4 (990±100)	
I:	7 1/2	(191)	J:	22	(559)
K:	11	(279)	L:	24 1/4	(616)
M:	58	(1473)	N:	57 1/2	(1461)
	56±2 (1425±50)			56±2 (1425±50)	
O:	27 1/2	(699)	P:	4 1/4	(108)
	24±4 (600±100)				
Q:	22 1/2	(572)	R:	15 1/4	(387)
S:	7 1/4	(184)	T:	64 1/2	(1638)

U (impact width):	29	(737)
Top of radiator core support:	29 1/2	(749)
Wheel Center Height (Front):	10 3/4	(273)
Wheel Center Height (Rear):	11	(279)
Wheel Well Clearance (Front):	25 5/8	(651)
Wheel Well Clearance (Rear):	25 1/2	(648)
Bottom Frame Height (Front):	7 1/4	(184)
Bottom Frame Height (Rear):	7 1/4	(184)
Engine Type:	Gasoline	
Engine Size:	1.4 L 4 cyl	
Transmission Type:	Automatic	
Drive Type:	FWD	

Mass Distribution lb (kg)

Gross Static	LF	805	(365)	RF	808	(367)
	LR	476	(216)	RR	490	(222)

Weights lb (kg)	Curb		Test Inertial		Gross Static	
W-front	1574	(714)	1528	(693)	1613	(732)
W-rear	923	(419)	887	(402)	966	(438)
W-total	2497	(1133)	2415	(1095)	2579	(1170)
			2420±55 (1100±25)		2585±55 (1175±50)	

GVWR Ratings lb	
Front	1918
Rear	1874
Total	3638

Surrogate Occupant Data	
Type:	Hybrid II
Mass:	161 lb
Seat Position:	164

Note any damage prior to test:

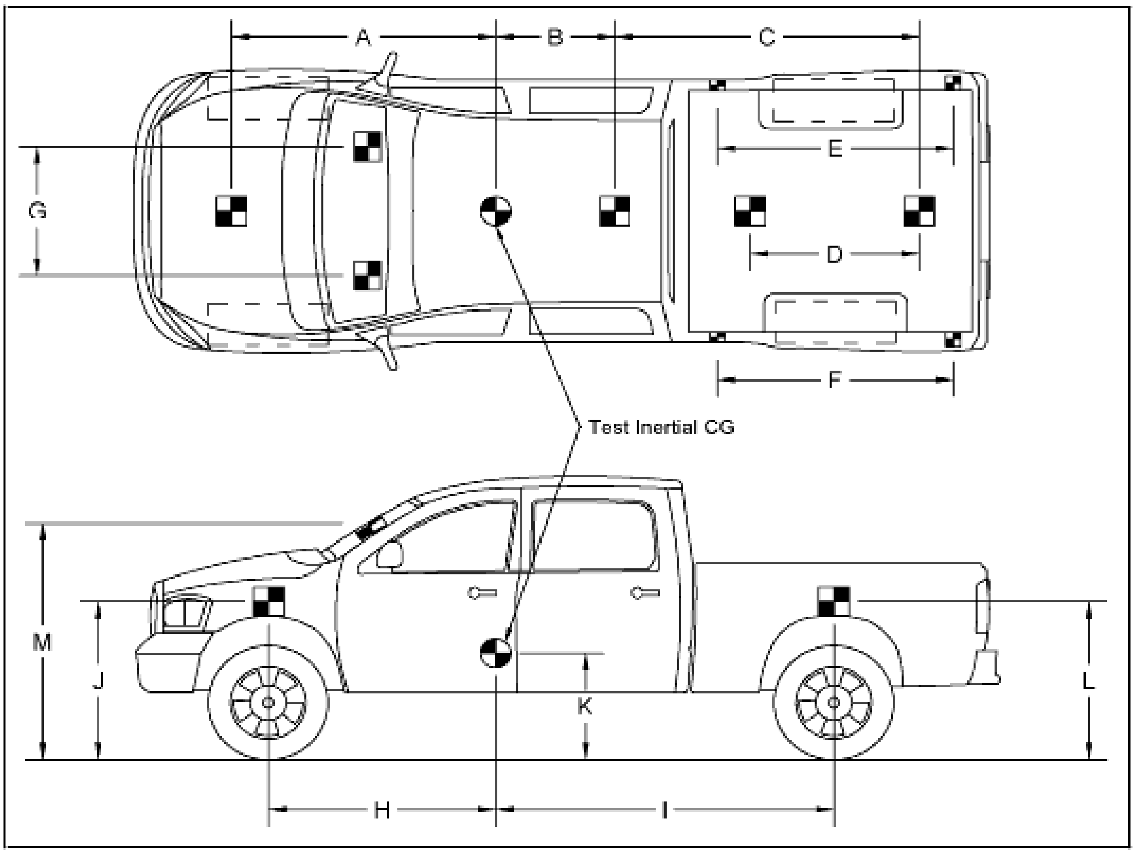
Figure 6. Vehicle Dimensions, Test No. MTB-2

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [15] was used to determine the vertical component of the c.g. for the pickup truck used in test no. MTB-1. 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 location of the final c.g. for test no. MTB-1 is shown in Figure 7. The vertical component of the c.g. for the 1100C vehicle was determined using a procedure published by SAE [16]. The location of the final c.g. for test no. MTB-2 is shown in Figure 8. Data used to calculate the locations of the c.g. and ballast information are shown in Appendix C.

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 video analysis, as shown in Figures 7 and 8. Round, checkered targets were placed at the c.g. on the left- and right-side doors 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 on the vehicle’s left-side dash for both tests and 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 radio-controlled brake system was installed in the test vehicles so the vehicles could be brought safely to a stop after the test.

Date:	11/7/2018	Test Name:	MTB-1	VIN:	1C6RD6FT1CS307273
Year:	2012	Make:	Dodge	Model:	Ram 1500

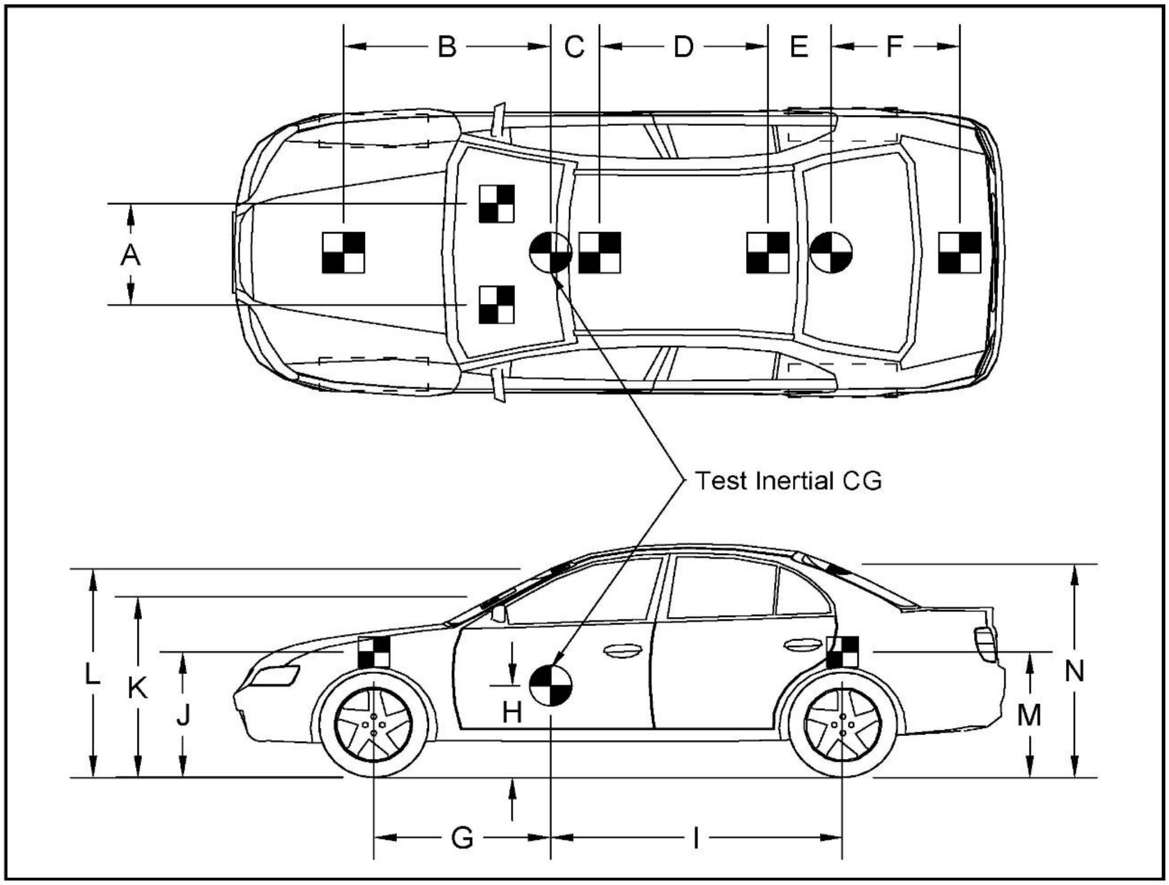


TARGET GEOMETRY-- in. (mm)

A:	78 1/4	(1988)	E:	63 5/8	(1616)	J:	38 1/2	(978)
B:	25 1/4	(641)	F:	63 1/2	(1613)	K:	28 1/4	(718)
C:	72 1/2	(1842)	G:	31 1/4	(794)	L:	41 7/8	(1064)
D:	32 3/4	(832)	H:	61 1/2	(1562)	M:	63 1/4	(1607)
			I:	78 7/8	(2003)			

Figure 7. Target Geometry, Test No. MTB-1

Date:	9/20/2018	Test Name:	MTB-2	VIN:	KNADE223596440731
Year:	2009	Make:	Kia	Model:	Rio



TARGET GEOMETRY-- in. (mm)

A:	25 3/8	(645)	F:	22	(559)	K:	48 1/4	(1226)
						Windshield Target		
B:	46 5/8	(1184)	G:	36 1/8	(918)	L:	52 1/8	(1324)
						Front round CG target		
C:	17	(432)	H:	22 3/4	(578)	M:	29 1/4	(743)
D:	27	(686)	I:	62 3/8	(1584)	N:	52 3/8	(1330)
						Rear Round target		
E:	19 15/16	(506)	J:	29 1/8	(740)			

Figure 8. Target Geometry, Test No. MTB-2

3.4 Simulated Occupant

For test nos. MTB-1 and MTB-2, a Hybrid II 50th-Percentile, Adult Male Dummy, equipped with footwear, was placed in the right-front seat of the test vehicle for both tests with the seat belt fastened. The simulated occupant had a final weight of 159 lb and 161 lb for test nos. MTB-1 and MTB-2, respectively. As recommended by MASH 2016, the simulated occupant was not included in calculating the c.g. locations.

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. Both accelerometer 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 SAE J211/1 specifications [17].

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-2 unit was designated as the primary system for test no. MTB-1, and the SLICE-1 unit was designated as the primary system for test no. MTB-2. 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.

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 deg./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.

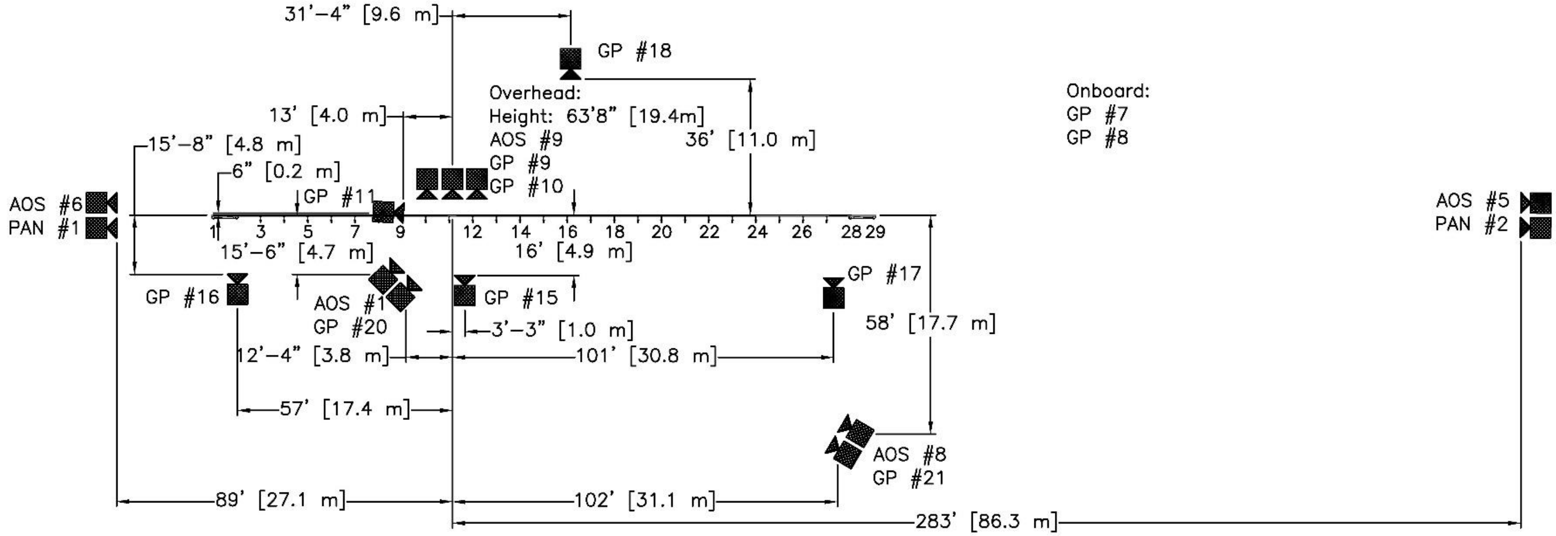
3.5.3 Retroreflective Optic Speed Trap

The retroreflective optic speed trap was used to determine the speed of the test vehicles before impact. Five retroreflective targets, spaced at approximately 18-in. 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

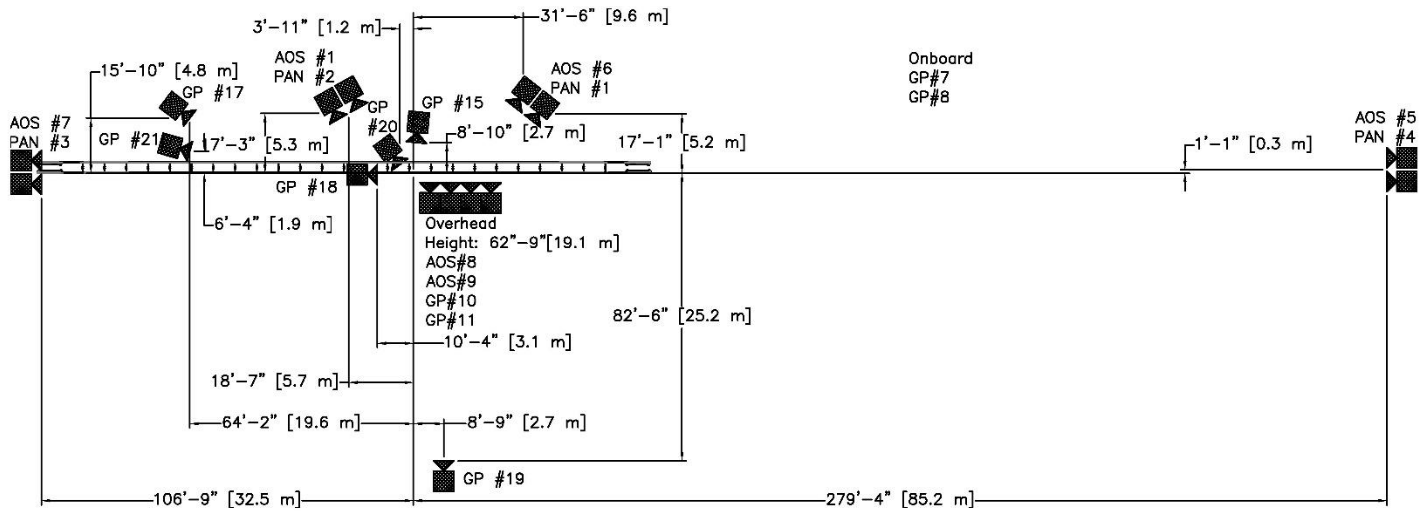
Five AOS high-speed digital video cameras, eleven GoPro digital video cameras, and two Panasonic digital video cameras were used to film test no. MTB-1. Seven AOS high-speed digital video cameras, ten GoPro digital video cameras, and four Panasonic digital video cameras were used to film test no. MTB-2. Camera details and operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figures 9 and 10, respectively.

The high-speed videos were analyzed using TEMA Motion and Red lake 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-1	AOS Vitcam	500	Sigma 28-70 mm	28
AOS-5	AOS X-PRI	500	100 mm Fixed	
AOS-6	AOS X-PRI	500	Fujinon 50 mm Fixed	
AOS-8	AOS S-VIT 1531	500	Fujinon 75 mm Fixed	
AOS-9	AOS TRI-VIT 2236	500	Kowa 12 mm Fixed	
GP-7	GoPro Hero 4	120		
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	240		
GP-10	GoPro Hero 4	120		
GP-11	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	240		
GP-20	GoPro Hero 6	240		
GP-21	GoPro Hero 6	240		
PAN-1	Panasonic HC-V770	60		
PAN-2	Panasonic HC-V770	120		

Figure 9. Camera Locations, Speeds, and Lens Settings, Test No. MTB-1



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-1	AOS Vitcam CTM	500	Kowa 25 mm	
AOS-5	AOS X-PRI Gigabit	500	100 mm Fixed	
AOS-6	AOS X-PRI Gigabit	500	Sigma 28-70 mm	35
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	500	Kowa 12 mm Fixed	
AOS MINI	Smize		Kowa 35 mm Fixed	
GP-7	GoPro Hero 4	120		
GP-8	GoPro Hero 4	120		
GP-10	GoPro Hero 4	120		
GP-11	GoPro Hero 4	240		
GP-15	GoPro Hero 4	120		
GP-17	GoPro Hero 4	240		
GP-18	GoPro Hero 6	240		
GP-19	GoPro Hero 6	240		
GP-20	GoPro Hero 6	240		
GP-21	GoPro Hero 6	240		
PAN-1	Panasonic – HC-V770	60		
PAN-2	Panasonic – HC-V770	60		
PAN-3	Panasonic – HC-V770	60		
PAN-4	Panasonic – HC-V770	60		

Figure 10. Camera Locations, Speeds, and Lens Settings, Test No. MTB-2

4 DESIGN DETAILS, TEST NO. MTB-1

The test installation consisted of a 176-ft – $^9/_{16}$-in. long modified thrie beam guardrail supported by 29 posts. Design details for test no. MTB-1 are shown in Figure 11 through Figure 23. Photographs of the system for test no. MTB-1 are shown in Figure 24 and Figure 25. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

The modified thrie beam test article was constructed based on the NJDOT standard plans. It was noted previously that two similar blockout designs were evaluated with the modified thrie beam system under NCHRP Report No. 350. Because these two blockouts are very similar, NJDOT elected to evaluate the system with the original W14x22 blockout rather than the Trinity alternative. Similarly, the NJDOT plans denoted the use of W6x9 or W6x8.5 posts with A709 Grade 36 steel. After discussion with the sponsors regarding available steel grades for W6x9 and W6x8.5 posts, W6x8.5 posts fabricated from A36 steel were selected for the tested system.

For test no. MTB-1, post nos. 3 through 27 were 81-in. long W6x8.5 steel posts spaced 75 in. apart with W14x22 blockouts and an embedment depth of 46 in. The blockouts were attached with two diagonally opposed ⅝-in. diameter bolts and the thrie beam rail elements were attached to the blockout with one ⅝-in. diameter button head bolt. Post nos. 1, 2, 28, and 29 were 5½-in. x 7½-in. x 46-in. breakaway cable terminal (BCT) timber posts placed into 6-in. x 8-in. x 72-in. ASTM A53 Grade B, steel foundation tubes. Post nos. 3 through 27 featured 12-gauge thrie-beam rails with additional post bolt slots at half-post spacing intervals. The mounting height was 34 in. to the top of the thrie-beam rail. Rail splices were located at posts, as shown in Figure 13. The lap splice connections between the rail sections were configured to reduce vehicle snag potential at the splice. The modified thrie beam guardrail utilized 12-in. long, 12-gauge thrie-beam backup plates at each post location without a rail splice.

The upstream and downstream ends of the guardrail installation were configured with a non-proprietary end anchorage system [8-12]. The guardrail anchorage system had a comparable strength to other crashworthy end terminals. The anchorage system consisted of timber posts, foundation tubes, anchor cables, bearing plates, rail brackets, and channel struts. Due to the 34-in. height of the modified thrie-beam guardrail, a 10-gauge, symmetric W-beam to thrie beam transition section was used to transition down to a 12-gauge, W-beam rail segment with a top mounting height of 30⅛ in. at each end of the system. This allowed for anchorage of the system using typical trailing end anchorage hardware. The only modification required was altering the hole location for the post bolt in the BCT posts to adjust for the ⅞-in. height difference.

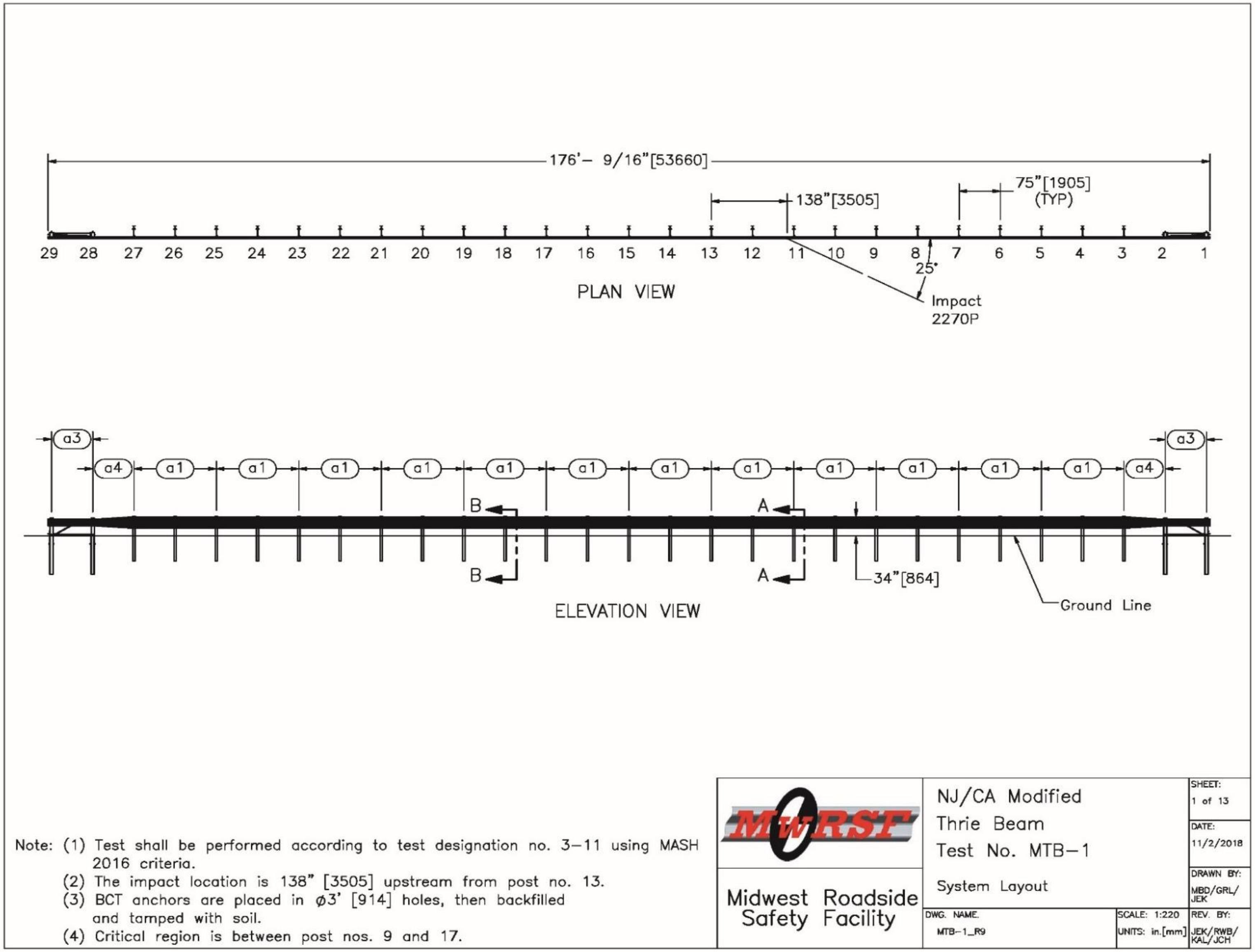


Figure 11. System Layout, Test No. MTB-1

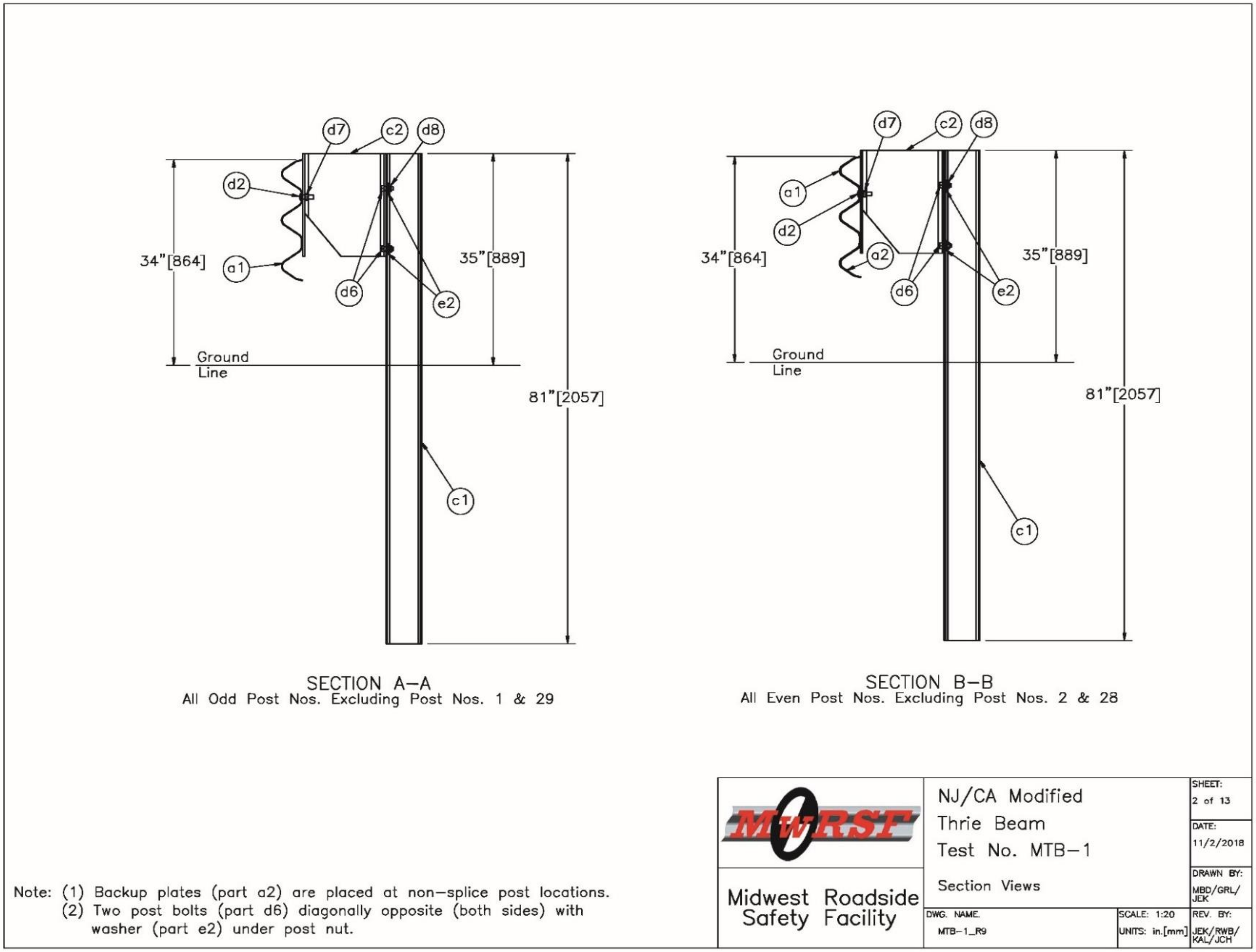


Figure 12. Section Views, Test No. MTB-1

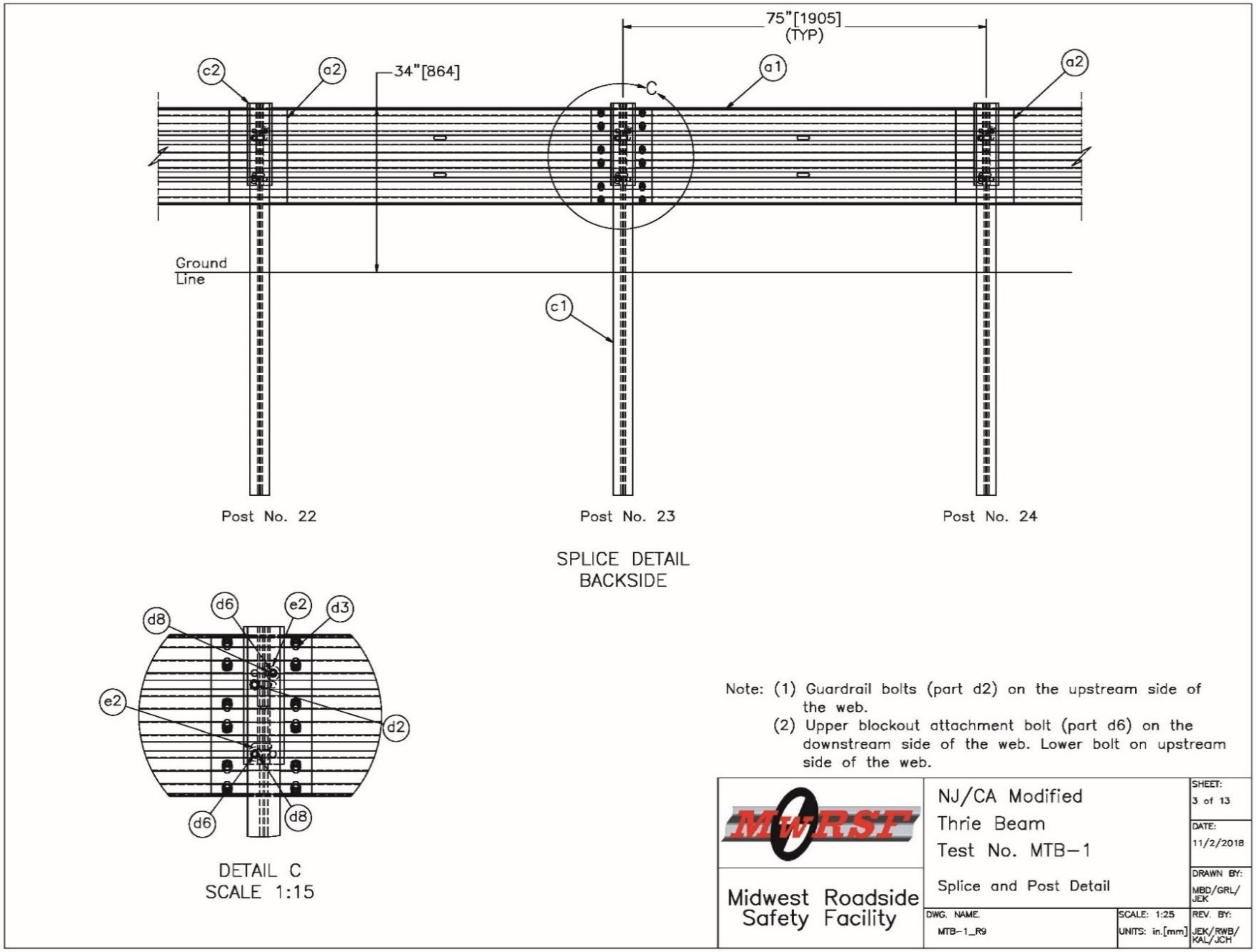


Figure 13. Splice and Post Detail, Test No. MTB-1

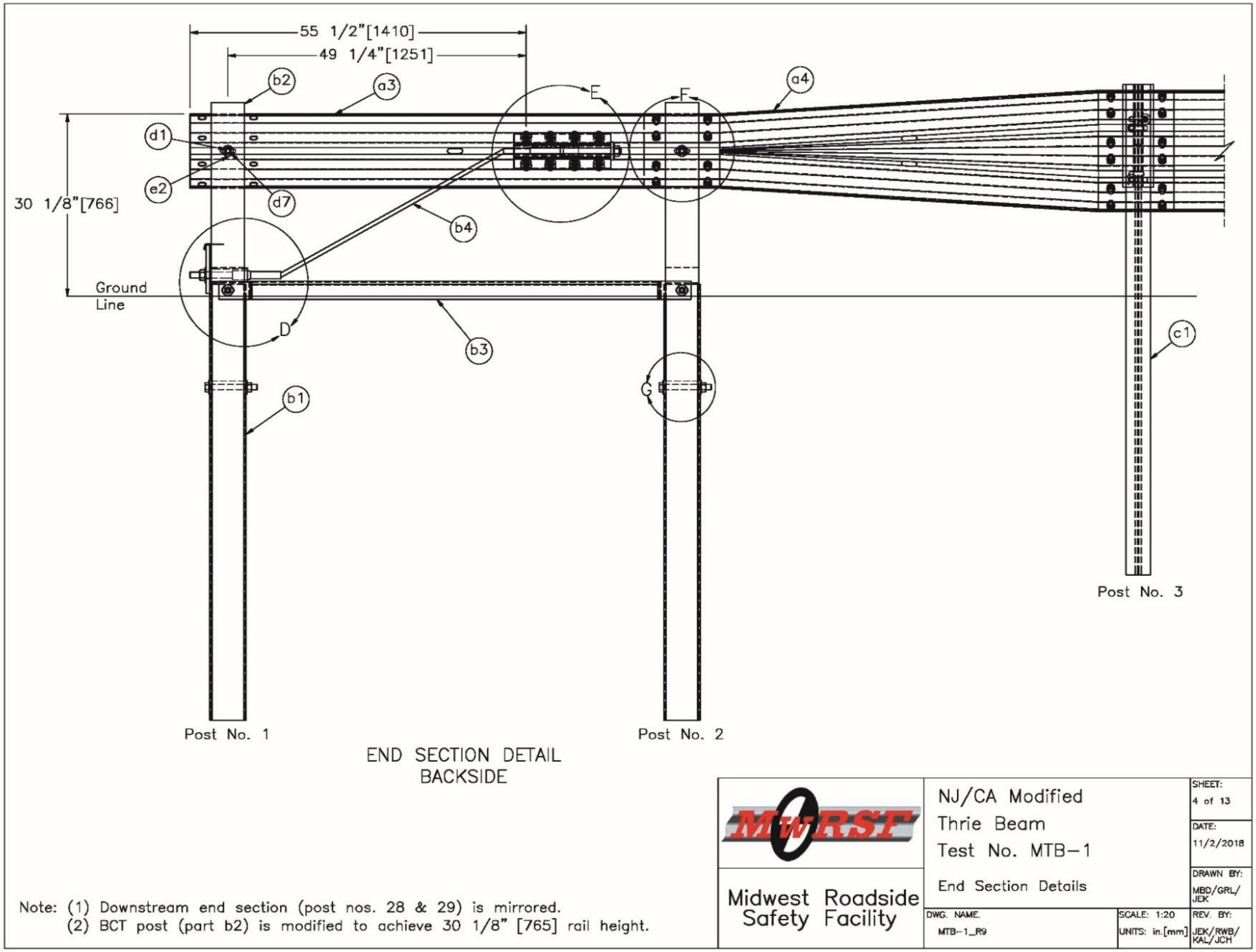


Figure 14. End Section Details, Test No. MTB-1

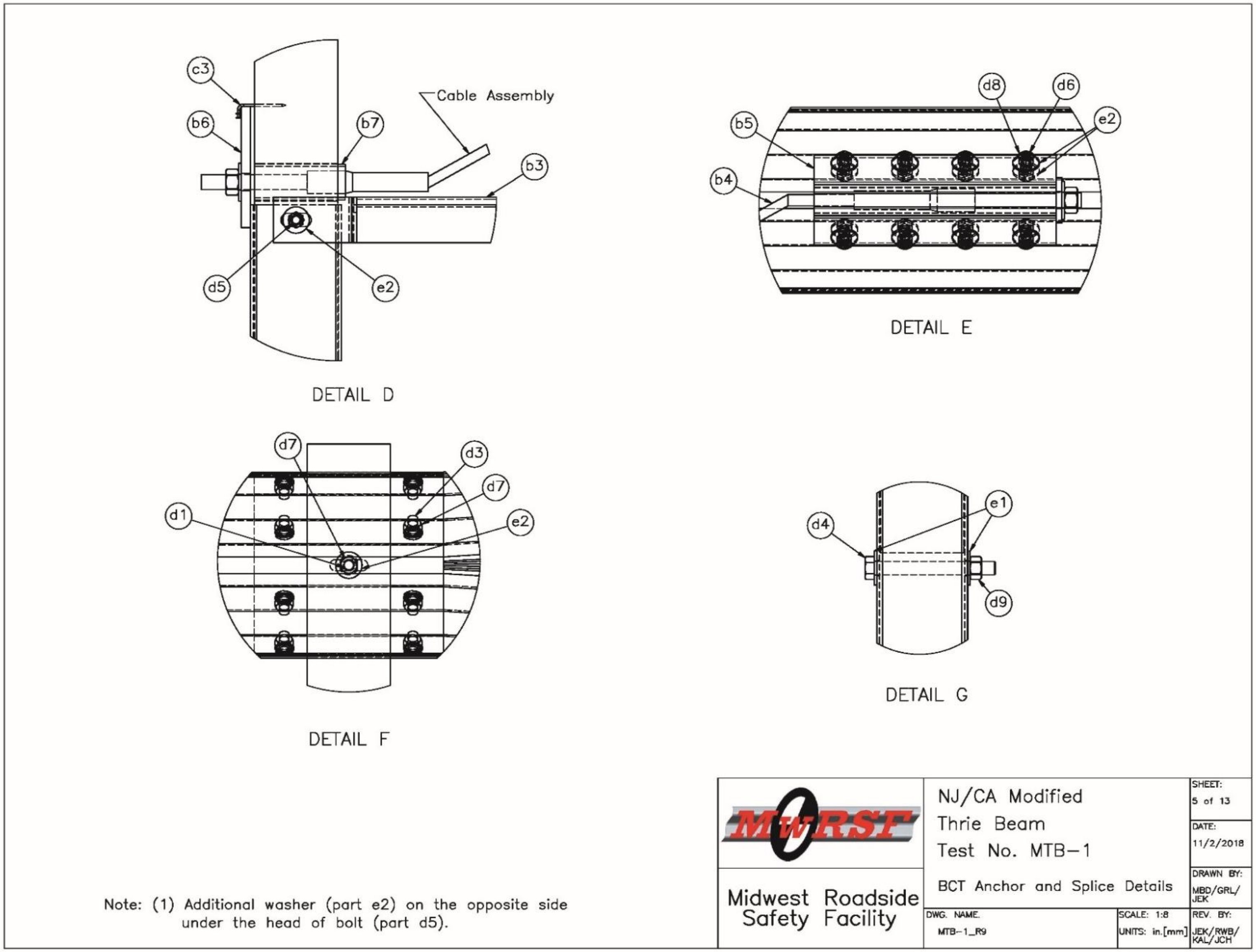


Figure 15. BCT Anchor and Splice Details, Test No. MTB-1

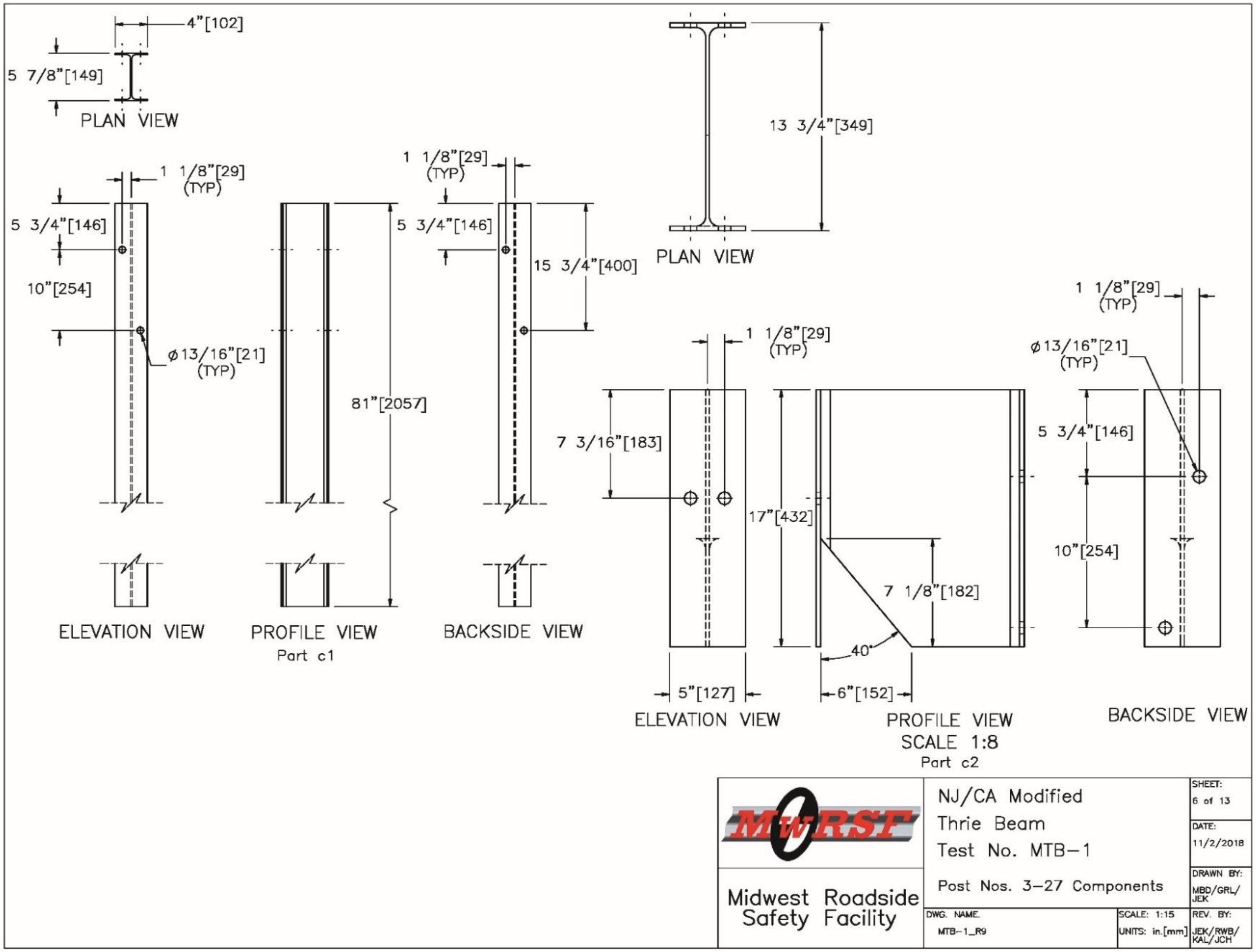


Figure 16. Post Nos. 3 through 27 Components, Test No. MTB-1

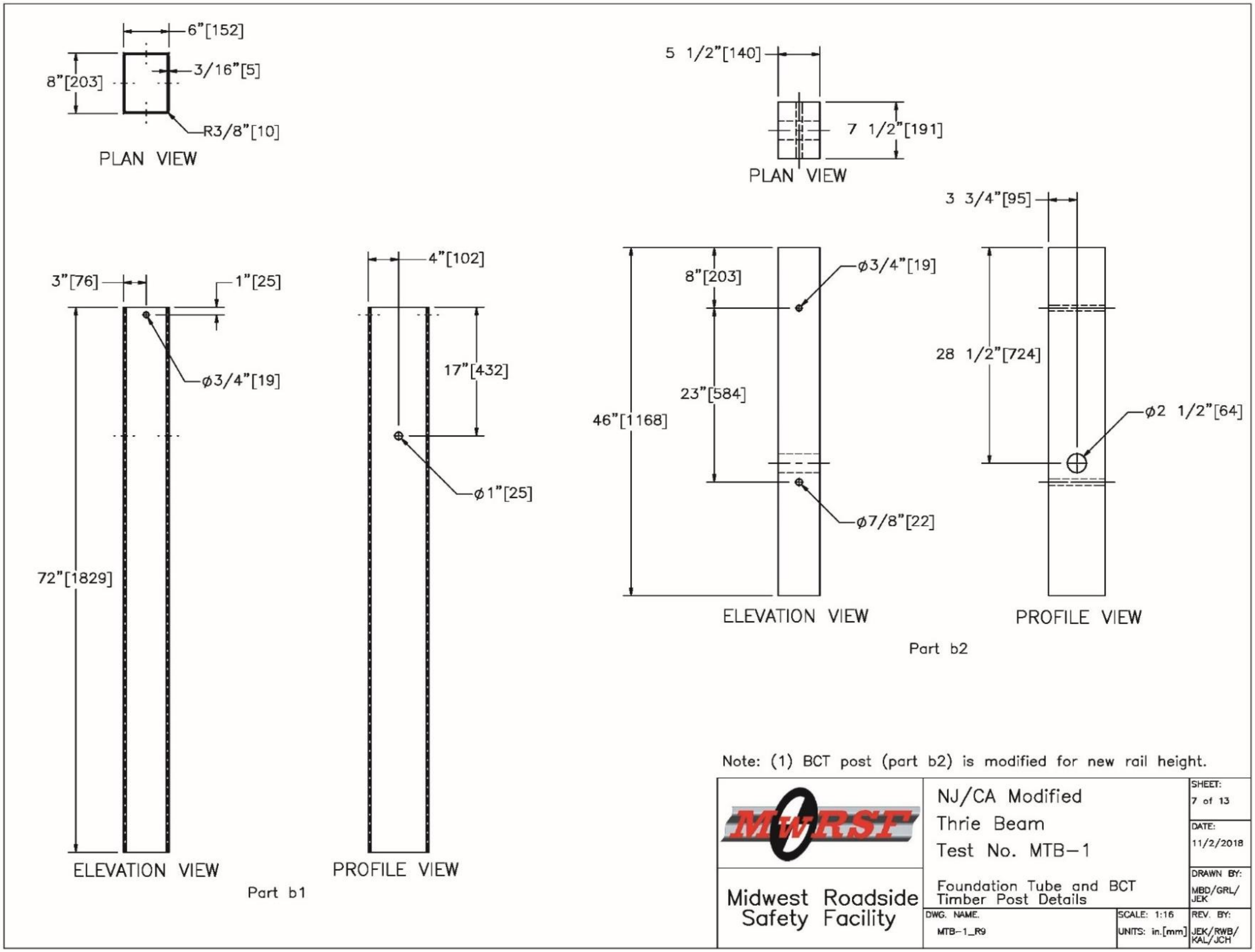


Figure 17. Foundation Tube and BCT Timber Post Details, Test No. MTB-1

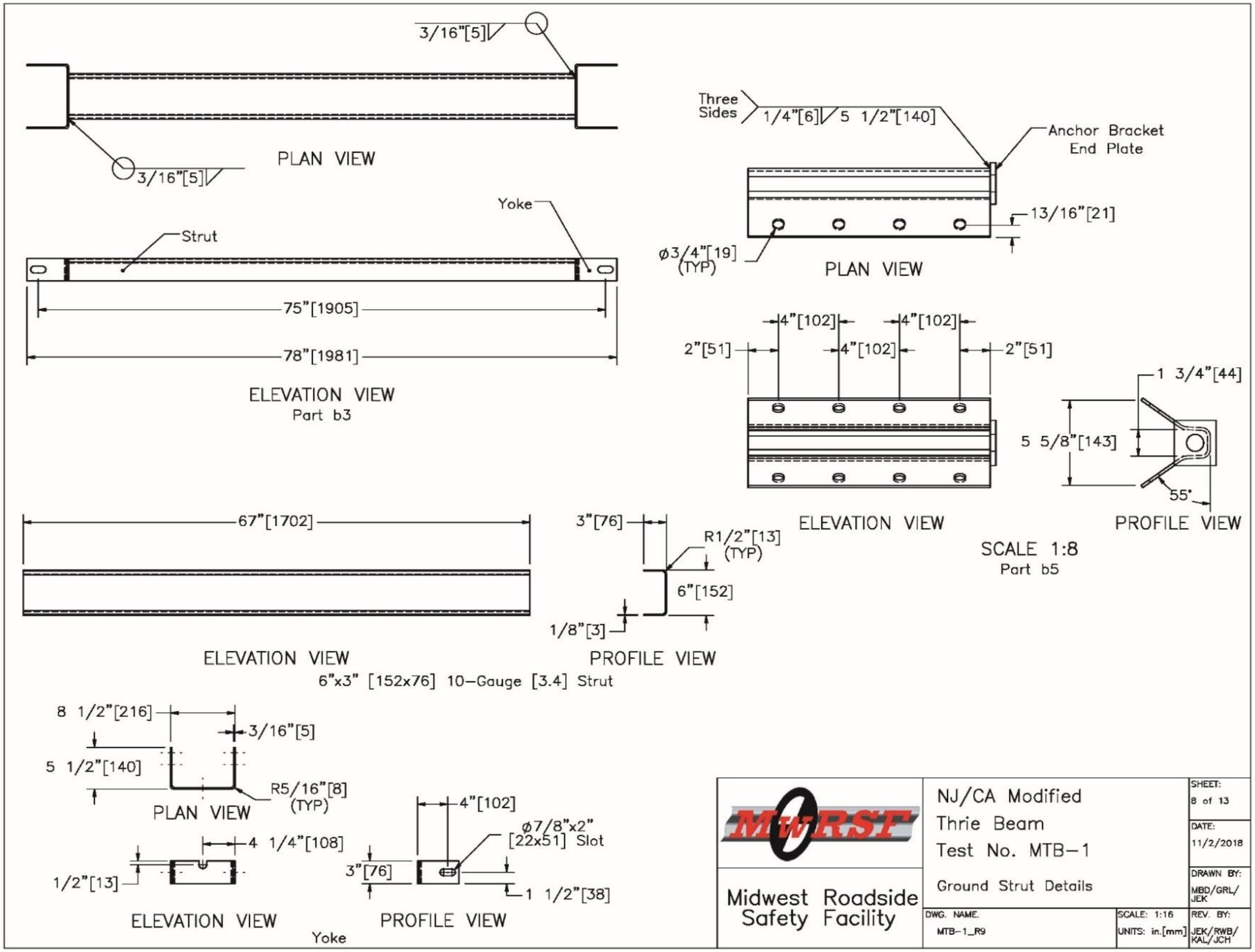
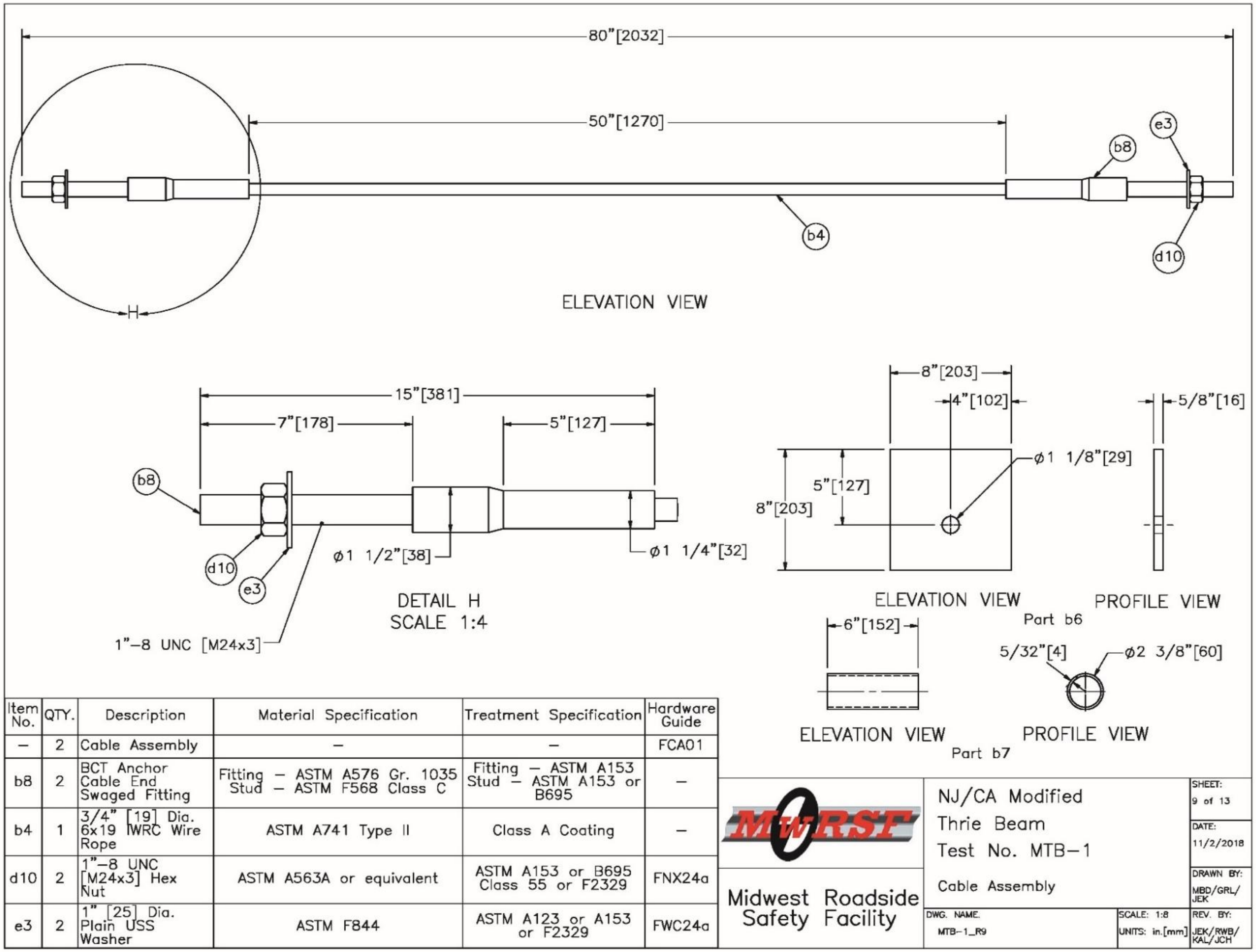


Figure 18. Ground Strut Details, Test No. MTB-1



Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	2	Cable Assembly	–	–	FCA01
b8	2	BCT Anchor Cable End Swaged Fitting	Fitting – ASTM A576 Gr. 1035 Stud – ASTM F568 Class C	Fitting – ASTM A153 Stud – ASTM A153 or B695	–
b4	1	3/4" [19] Dia. 6x19 IWRC Wire Rope	ASTM A741 Type II	Class A Coating	–
d10	2	1"-8 UNC [M24x3] Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX24a
e3	2	1" [25] Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC24a

Figure 19. Cable Assembly, Test No. MTB-1

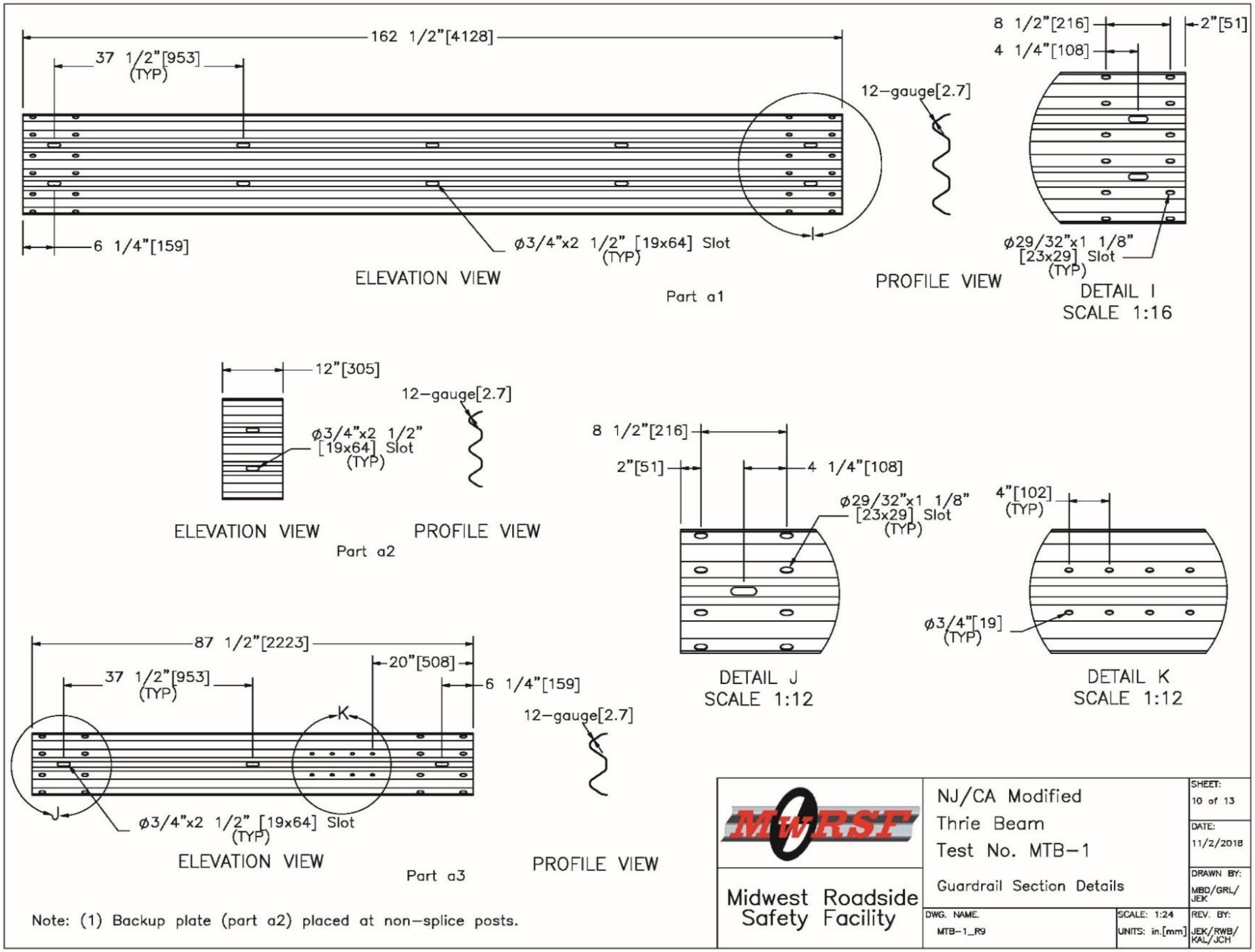


Figure 20. Guardrail Section Details, Test No. MTB-1

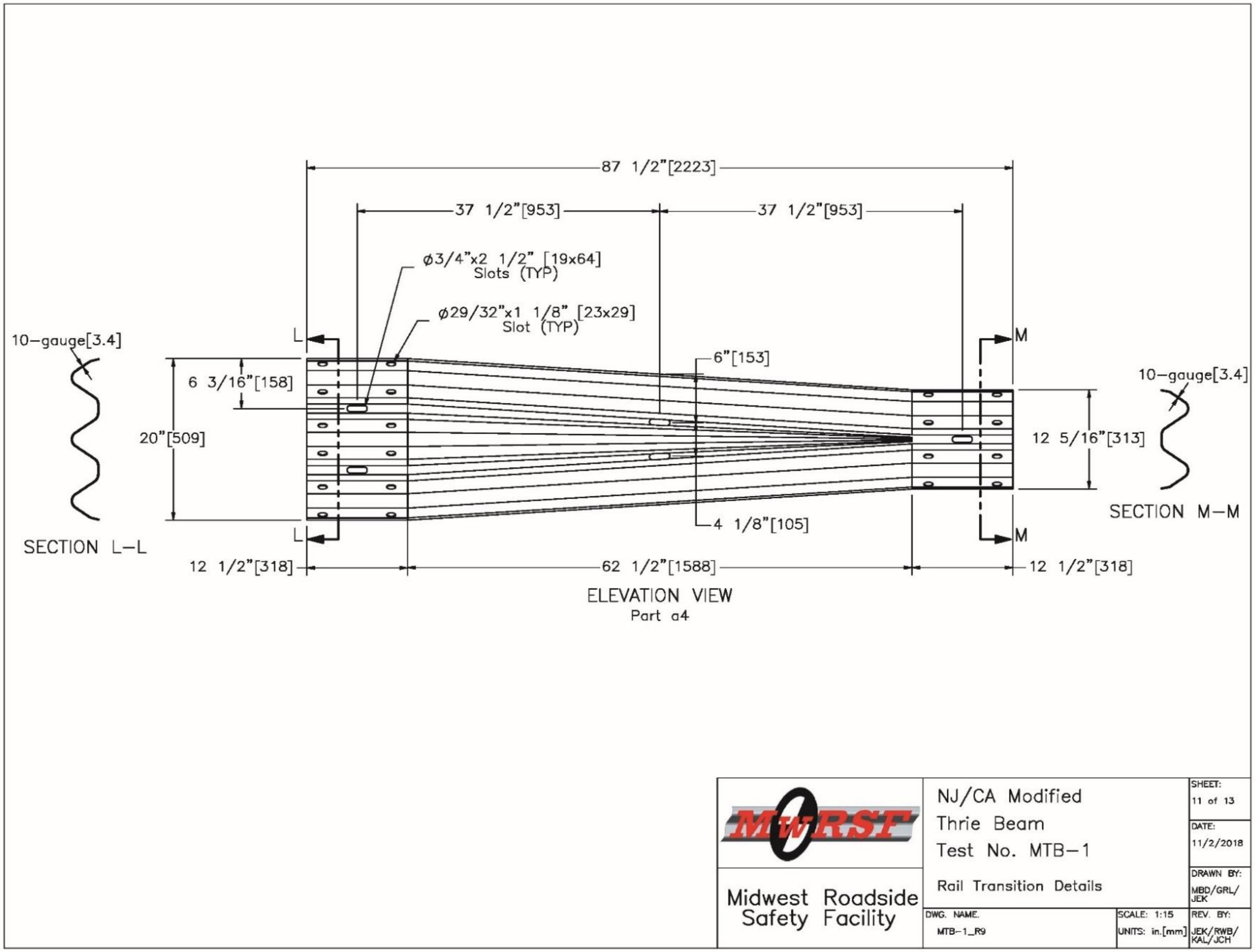


Figure 21. Rail Transition Details, Test No. MTB-1

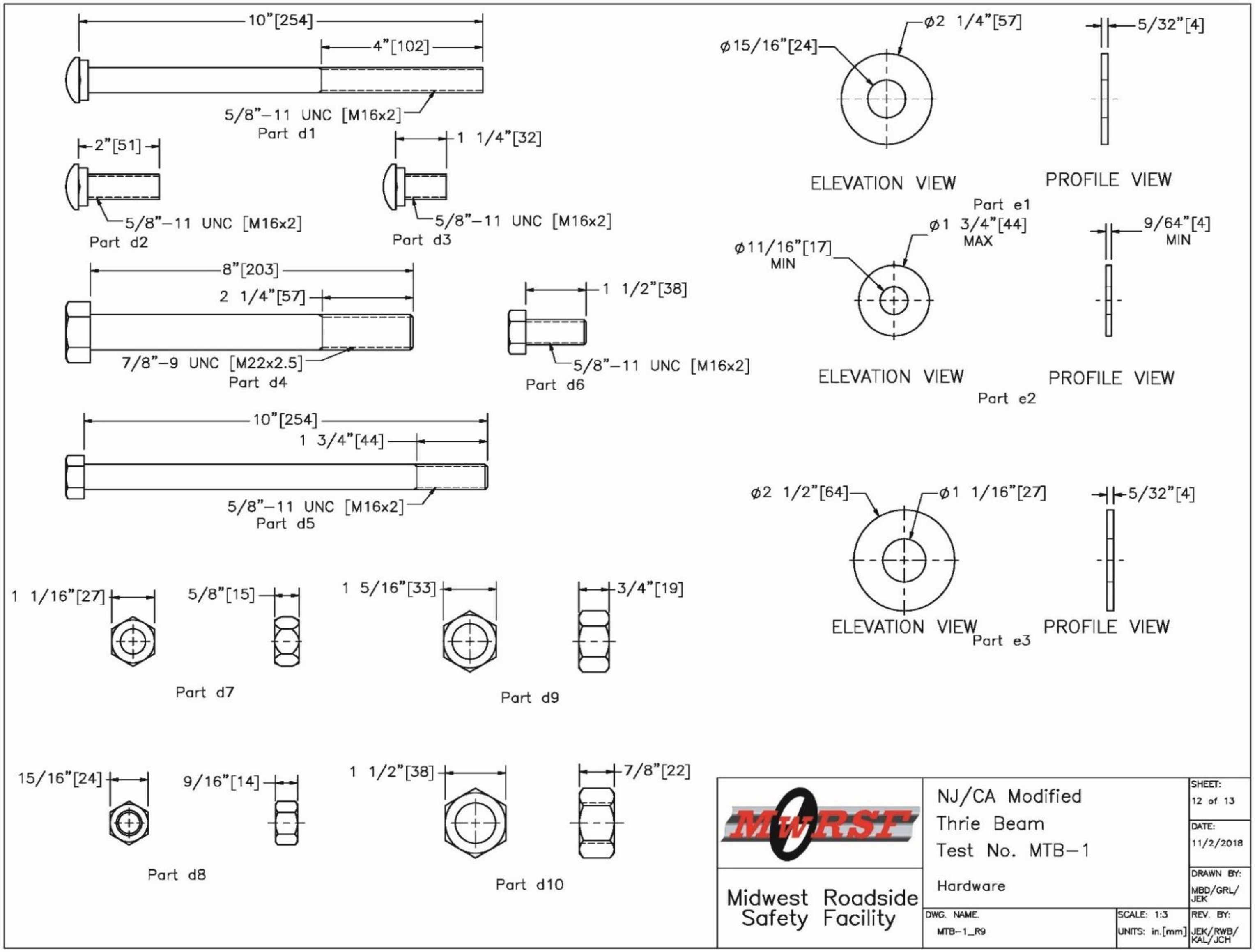


Figure 22. Hardware, Test No. MTB-1

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	12	12'–6" [3,810] 12–gauge [2.7] Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM04a
a2	12	12" [305] 12–gauge [2.7] Thrie Beam Backup Plate	AASHTO M180	ASTM A123 or A653	RTB01a
a3	2	6'–3" [3,810] 12–gauge [2.7] W–Beam MGS End Section	AASHTO M180	ASTM A123 or A653	–
a4	2	10–gauge [3.4] Symmetrical W–beam to Thrie Beam Transition	AASHTO M180	ASTM A123 or A653	RWT01b
b1	4	72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	ASTM A123	PTE06
b2	4	BCT Timber Post – MGS Height – Not Standard	SYP Grade No. 1 or better (No knots 18" [457] above or below ground tension face)	–	–
b3	2	Ground Strut Assembly	ASTM A36	ASTM A123	PFP01
b4	2	3/4" [19] Dia. 6x19 IWRC Wire Rope	ASTM A741 Type II	Class A Coating	–
b5	2	Anchor Bracket Assembly	ASTM A36	ASTM A123	FPA01
b6	2	8"x8"x5/8" [203x203x16] Anchor Bearing Plate	ASTM A36	ASTM A123	FPB01
b7	2	2 3/8" [60] O.D. x 6" [152] Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	ASTM A123	FMM02
b8	4	BCT Anchor Cable End Swaged Fitting	Fitting – ASTM A576 Gr. 1035 Stud – ASTM F568 Class C	Fitting – ASTM A153 Stud – ASTM A153 or B695	–
c1	25	W6x8.5 [W152x12.6], 81" [2,057] Long Steel Post	ASTM A36	ASTM A123	–
c2	25	W14x22 [356x32.7], 17" [432] Long Steel Blockout	ASTM A992	ASTM A123	–
c3	2	16D Double Head Nail	–	–	–
d1	4	5/8"–11 UNC [M16x2], 10" [254] Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB03
d2	25	5/8"–11 UNC [M16x2], 2" [51] Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB02
d3	172	5/8"–11 UNC [M16x2], 1 1/4" [32] Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB01
d4	4	7/8"–9 UNC [M22x2.5], 8" [203] Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	–
d5	4	5/8"–11 UNC [M16x2], 10" [254] Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
d6	66	5/8"–11 UNC [M16x2], 1 1/2" [38] Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
d7	201	5/8"–11 UNC [M16x2] Heavy Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX16b
d8	70	5/8"–11 UNC [M16x2] Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX16a
d9	4	7/8"–9 UNC [M22x2.5] Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX22a
d10	4	1"–8 UNC [M24x3] Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX24a
e1	8	7/8" [22] Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	–
e2	94	5/8" [16] Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC16a
e3	4	1" [25] Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC24a

Midwest Roadside Safety Facility

NJ/CA Modified
Thrie Beam
Test No. MTB–1

Bill of Materials

SHEET: 13 of 13
DATE: 11/2/2018
DRAWN BY: MBD/GRL/JEK
REV. BY: JEK/RWB/KAL/JCH
DWG. NAME. MTB–1_R9
SCALE: 1:384
UNITS: in.[mm]

Figure 23. Bill of Materials, Test No. MTB-1

Figure 24. Test Installation Photographs, Test No. MTB-1

Figure 25. Additional Test Installation Photographs, Test No. MTB-1

5 FULL-SCALE CRASH TEST NO. MTB-1

5.1 Static Soil Test

Before full-scale crash test no. MTB-1 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. The static test results, shown in Appendix D, 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. MTB-1 was conducted on November 17, 2018 at approximately 2:30 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 3.

Table 3. Weather Conditions, Test No. MTB-1

Temperature	25 deg. F
Humidity	80 percent
Wind Speed	19 mph
Wind Direction	10 deg. from True North
Sky Conditions	Sunny
Visibility	1.50 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0 in.
Previous 7-Day Precipitation	0 in.

5.3 Test Description

Test no. MTB-1 was conducted under the MASH TL-3 guidelines for test designation no. 3-11. Test designation no. 3-11 is an impact of the 2270P vehicle at 62 mph and 25 degrees on the system. The critical impact point for this test was selected to maximize vehicle snag on the system posts and splice loading. Initial vehicle impact was to occur 11 ft – 6 in. upstream from post no. 13, as shown in Figure 26, which was selected using the critical impact point plots found in Section 2.3 of MASH 2016. The 5,003-lb quad cab pickup truck impacted the modified thrie beam guardrail at a speed of 62.9 mph and an angle of 25.4 deg. The actual point of impact was 0.3 in. downstream from the target location. During the test, the pickup truck was captured and redirected by the thrie beam system. During the redirection of the vehicle, torsional collapse of some of the W-section blockouts was observed. The torsional collapse of the blockouts did not compromise the overall test result, but it allowed increased wheel snag on the posts and disengagement of the vehicle's right-front wheel. Additionally, the collapse of the blockouts allowed the lower portion of the thrie beam guardrail to contact the flange and web of the blockout and post flanges at post no. 13. The contact at post no. 13 was sufficient to cause a small tear downstream from the thrie beam splice at that post. However, this tear did not adversely affect the barrier system performance. The stability and trajectory of the vehicle were acceptable. Prior to coming to a stop, the test vehicle impacted portable barriers used to shield other areas of the test facility downstream from the barrier. This contact was well after vehicle exit and resulted in minor damage to the front of the test vehicle. The vehicle came to rest 282 ft – 3 in. downstream from the impact point and 14 ft – 7 in. laterally in front of the barrier after brakes were applied.

A detailed description of the sequential impact events is contained in Table 4. Sequential photographs are shown in Figures 27 and 28. Documentary photographs of the crash test are shown in Figure 29. The vehicle trajectory and final position are shown in Figure 30.

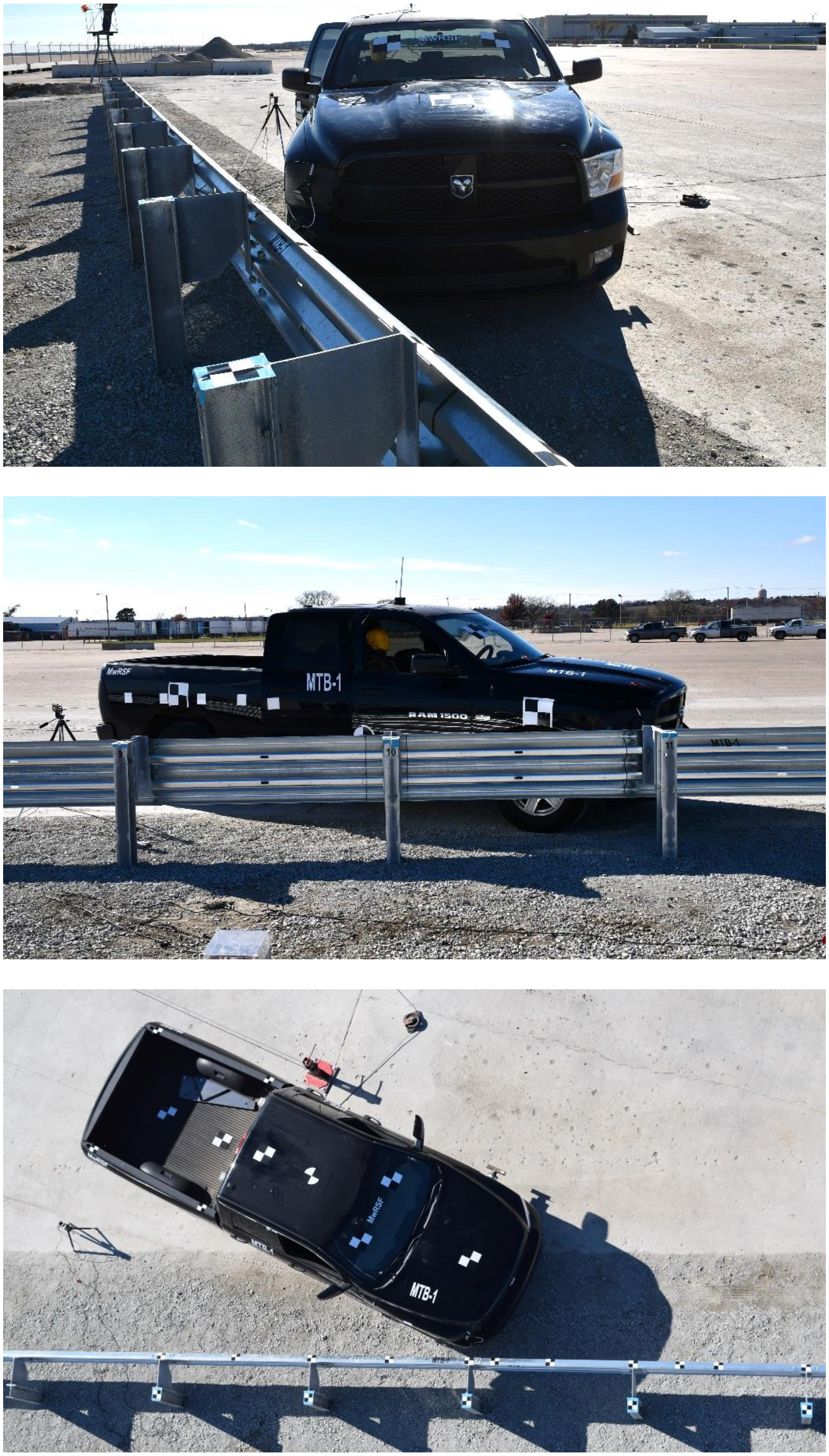


Figure 26. Impact Location, Test No. MTB-1

Table 4. Sequential Description of Impact Events, Test No. MTB-1

TIME (sec)	EVENT
0.000	Vehicle’s right-front bumper contacted the rail between post nos. 11 and 12 at a speed of 62.9 mph and angle of 25.4 deg.
0.004	Vehicle’s right fender contacted rail.
0.008	Vehicle’s right headlight contacted rail.
0.010	Post no. 11 deflected backward.
0.012	Post no. 12 deflected backward.
0.016	Vehicle’s right-front tire contacted rail.
0.024	Vehicle’s grille contacted rail.
0.028	Post no. 10 deflected backward and post no. 2 deflected downstream.
0.038	Post nos. 3 through 10 rotated clockwise due to rail movement.
0.044	Post no. 16 rotated counterclockwise.
0.046	Post no. 13 deflected backward.
0.048	Post nos. 17 through 27 rotated counterclockwise due to rail movement.
0.050	Post no. 29 deflected upstream.
0.052	Post no. 12 rotated backward.
0.060	Post no. 12 twisted counterclockwise.
0.064	Post no. 12 deflected downstream.
0.072	Vehicle’s right-front door contacted rail.
0.074	Post no. 12 bent backward and post no. 13 rotated backward.
0.090	Vehicle’s right-front tire contacted post no. 12.
0.108	Blockout no. 13 deflected backward and torsionally buckled.
0.112	Post no. 13 deflected downstream.
0.122	Post no. 14 deflected backward and vehicle’s right-rear door contacted rail.
0.136	Post no. 14 rotated backward.
0.140	Rail disengaged from bolt at post no. 13.
0.142	Post flange at post no. 13 contacted rail splice at post no. 13 initiating small tear in splice
0.146	Post no. 15 deflected backward.
0.154	Blockout at post no. 13 contacted lower portion of thrie bream downstream from splice at post no.13.
0.160	Post no. 13 bent downstream.
0.164	Vehicle’s right-front tire contacted post no. 13.
0.166	Post no. 14 twisted counterclockwise.

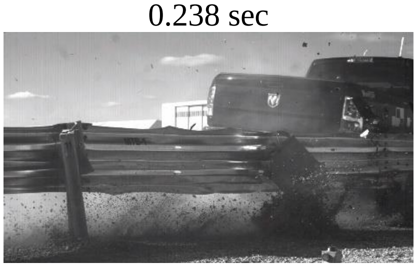
Table 5. Sequential Description of Impact Events, Test No. MTB-1, Cont.

TIME (sec)	EVENT
0.168	Vehicle's right-front wheel snagged on post no. 13.
0.180	Vehicle's right quarter panel contacted rail.
0.184	Vehicle's right-rear bumper contacted rail.
0.188	Vehicle's right taillight contacted rail.
0.190	Post no. 11 twisted clockwise.
0.194	Post no. 10 rotated backward.
0.206	Post no. 13 deflected forward.
0.208	Post no. 10 twisted clockwise.
0.210	Post no. 16 deflected backward
0.218	Post no. 15 rotated backward.
0.236	Vehicle was parallel to system at a speed of 45.7 mph.
0.248	Vehicle's right-front tire contacted post no. 14.
0.256	Vehicle's right-front wheel became disengaged.
0.258	Rail disengaged from bolt at post no. 14 and vehicle's left-rear tire became airborne.
0.270	Post no. 14 bent backward and post no. 13 deflected upstream.
0.276	Post no. 11 rotated counterclockwise.
0.290	Post no. 15 twisted counterclockwise.
0.302	Post nos. 3 through 9 rotated counterclockwise due to rail movement.
0.306	Post no. 14 deflected forward.
0.310	Post no. 15 rotated downstream.
0.336	Post nos. 17 through 27 rotated clockwise due to rail movement.
0.446	Vehicle's right-rear tire contacted the disengaged tire.
0.470	Vehicle's left-rear tire regained contact with ground.
0.502	Post no. 15 deflected forward.
0.524	Vehicle's left-rear tire became airborne.
0.530	Vehicle's right-rear tire became airborne.
0.588	Vehicle exited system with a speed of 40.6 mph.
0.632	Vehicle's right-rear tire regained contact with ground.
0.638	Vehicle's left-rear tire regained contact with ground.
0.924	Vehicle came to a rest.

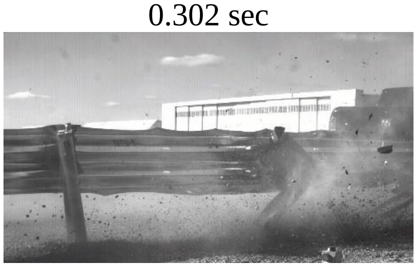
0.000 sec

0.100 sec

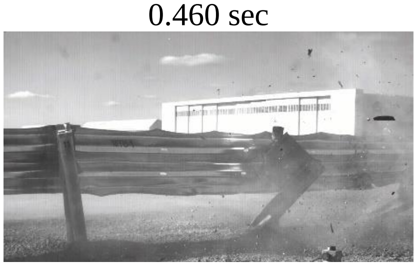
0.238 sec



0.302 sec



0.460 sec



0.878 sec

0.000 sec

0.118 sec

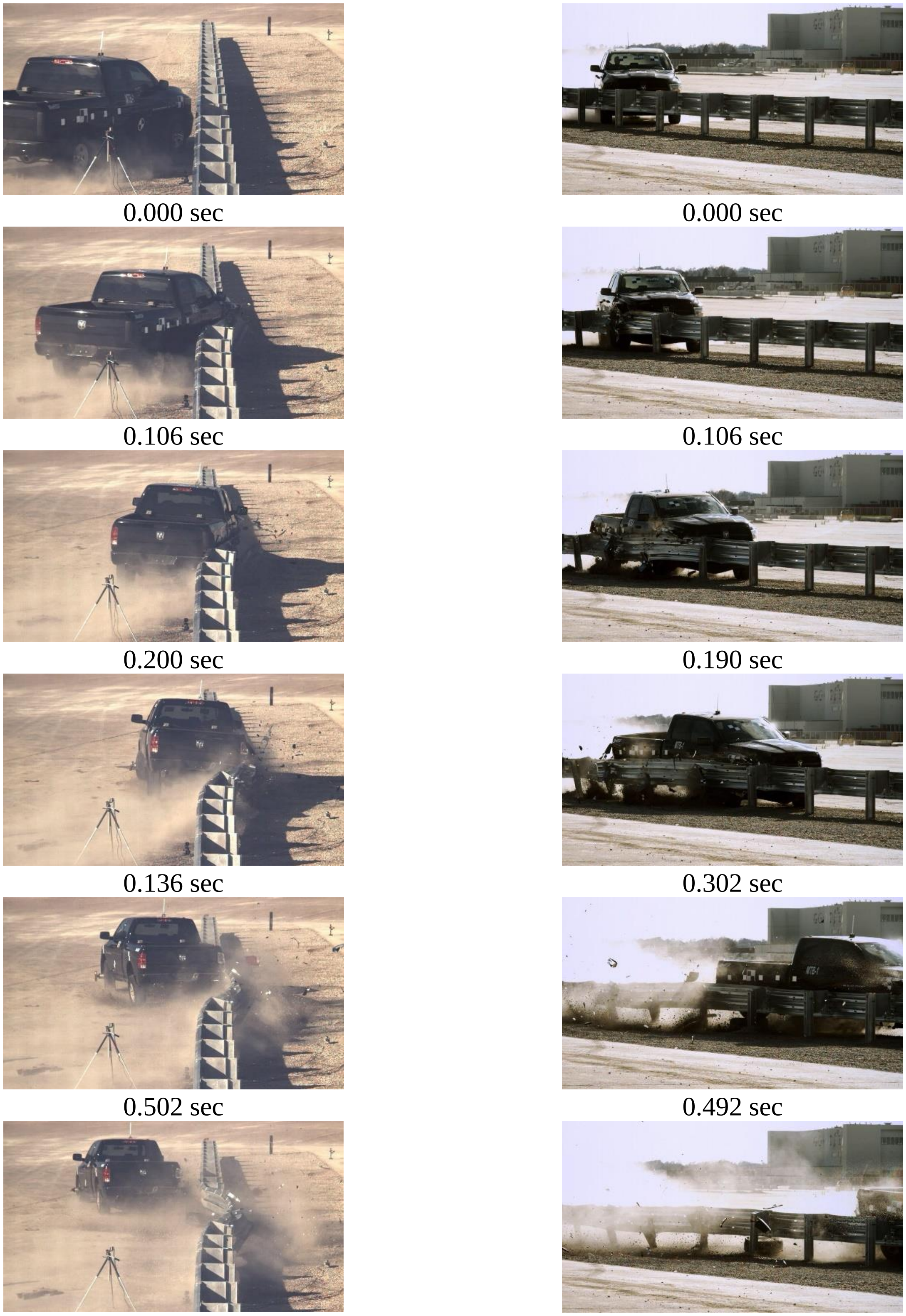
0.202 sec

0.320 sec

0.514 sec

0.706 sec

Figure 27. Sequential Photographs, Test No. MTB-1



0.000 sec | 0.000 sec

0.106 sec | 0.106 sec

0.200 sec | 0.190 sec

0.136 sec | 0.302 sec

0.502 sec | 0.492 sec

0.726 sec | 0.712 sec

Figure 28. Additional Sequential Photographs, Test No. MTB-1

Figure 29. Documentary Photographs, Test No. MTB-1

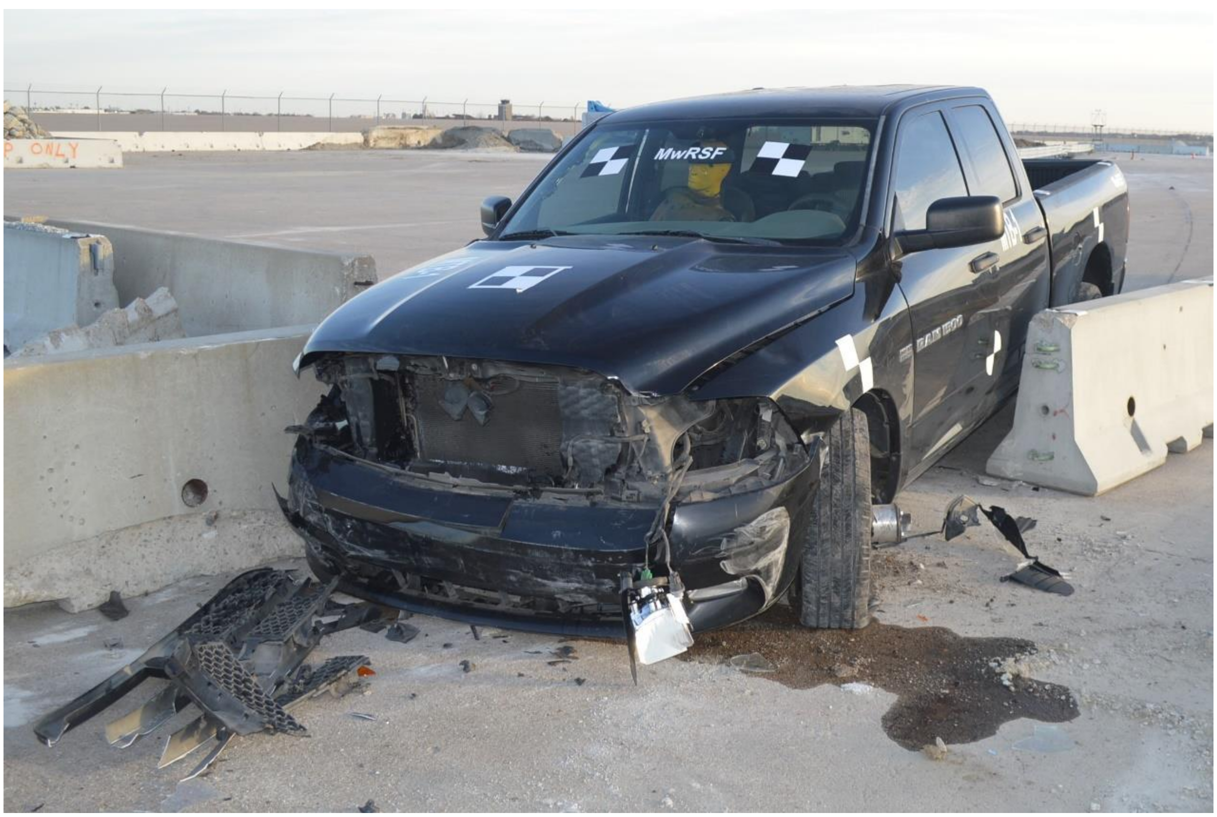


Figure 30. Vehicle Final Position and Trajectory Marks, Test No. MTB-1

5.4 Barrier Damage

Barrier damage was moderate, as shown in Figures 31 through 33, consisting of contact marks, deformation, disengaged rail elements, and bending, kinking, rotation, and twisting of the steel posts. The total length of vehicle contact along the barrier was approximately 37 ft – 10½ in., which spanned from 2 in. upstream from post no. 10 to 2½ in. downstream from post no. 16. All measurements were taken from post centerlines.

The most significant damage occurred between post nos. 11 and 13 where impact occurred. A 19-in. long contact mark was found on the top of the rail, beginning 13 in. upstream from post no. 11. A 23-in. long contact mark was found on the middle corrugation, beginning 18 in. upstream from post no. 11. A 24-ft 7-in. long contact mark was found across the entire front face of the rail, beginning 7½ in. downstream from post no. 11 and ending 5 in. downstream of post no. 15. The top slot at post no. 12, used to attach the blockout to the guardrail, was torn as a result of bolt pull out. The bottom rail corrugation was flattened from 17 in. upstream from post no. 12 to 7½ in. upstream from post no. 15. The top slot at post no. 13 and the top and bottom slots at post no. 14 were indented as a result of bolt pull out. A 4-in. long tear was found at the bottom edge of the rail 8 in. downstream from post no. 13. A 17-in. long contact mark was found on the top edge of the rail, beginning 8 in. downstream from post no. 15. Various kinks and dents were observed on the rail between post no. 9 and post no. 17.

The front flange of the blockouts at post nos. 3 through 11 twisted clockwise. The lower front flange of the blockout at post no. 10 bent inward, 7 in. from the bottom. The lower front flange of the blockout at post no. 11 bent inward 6 in. from the bottom. The front flange of post no. 12 twisted counter-clockwise, 35 in. from the top, and the back flange twisted clockwise 24 in. from the top. The blockout at post no. 12 bent clockwise 3½ in. from the front face, and the lower front flange of the blockout bent inward 7 in. from the bottom. The backing plate at post no. 12 bent inward 11 in. from the top and twisted clockwise 11 in. from the bottom. A 9-in. tall contact mark was found on the front flange of post no. 12, 29 in. from the top of the post. The front flange of post no. 13 was bent 17 in. from the top. The blockout at post no. 13 bent 4 in. upstream from the back of the blockout. The front flange of the blockout at post no. 13 bent clockwise, and the base of the blockout bent inward 7 in. from the bottom. A 10-in. tall contact mark was found on the upstream side of the front flange of post no. 13, 27 in. from the top. The front flange of post no. 14 was bent 18 in. from the top. The front flange of the blockout at post no. 14 bent clockwise, and the base of the blockout was bent 7 in. from the bottom. The stiffener at post no. 14 bent inward 7 in. from the bottom. A 6-in. tall contact mark was found 26½ in. from the top of post no. 14. Post no. 15 twisted counterclockwise 35 in. from the top. The front flange of the blockout at post no. 15 bent clockwise, and the base of the blockout bent inward 7 in. from the bottom. The front flange of the blockout at post no. 16 bent inward 6 in. from the bottom. Post no. 15 twisted counter-clockwise 35 in. from the top. The base of the front flange bent inward 7 in. from the bottom of the post. The blockout of post no. 16 was bent inward 6 in. from the bottom of the post. The blockout web of post no. 23 was bent 7 in. downstream from the front flange. No damage was observed on post nos. 1 and 2, 17 through 22, and 24 through 29.

Figure 31. System Damage, Test No. MTB-1

Figure 32. Damage between Post Nos. 10 and 12, Test No. MTB-1

Figure 33. Damage between Post Nos. 13 and 15, Test No. MTB-1

The maximum lateral permanent set deflection was 27.7 in. at post no. 13, as measured via GPS. The maximum lateral dynamic rail and barrier deflections were 34.4 in. at the midspan of rail no. 12, and 38 in. at post no. 13, respectively, as determined from high-speed digital video analysis. The working width of the system was found to be 49.3 in. at post no. 13, also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 34.

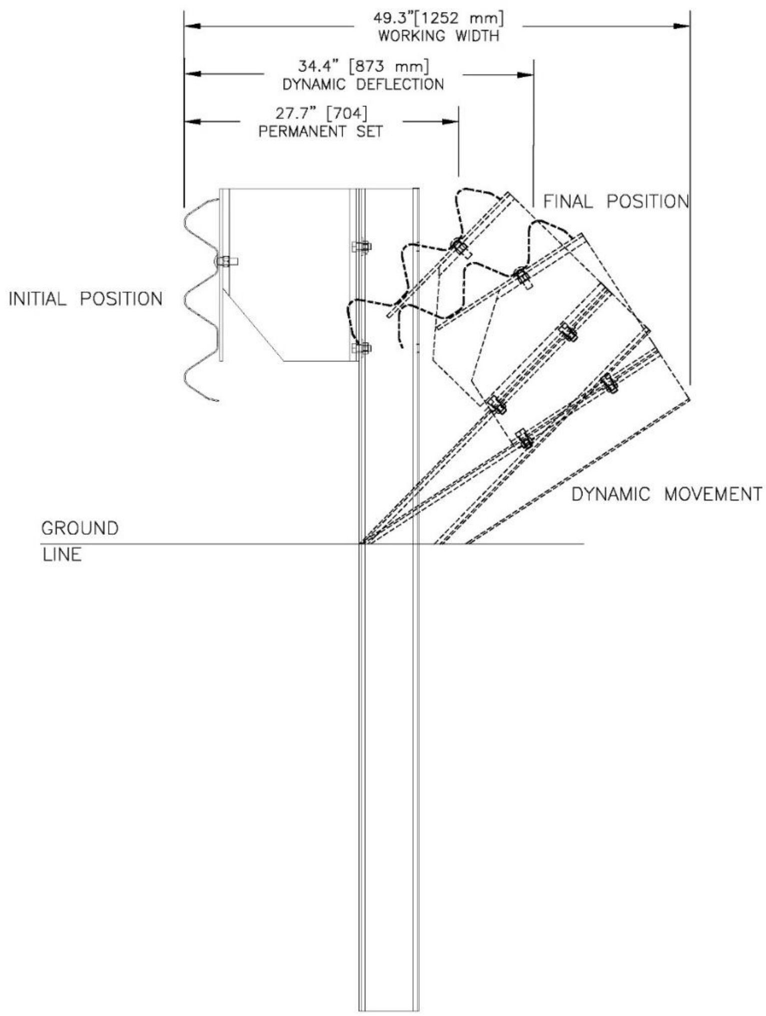


Figure 34. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. MTB-1

5.5 Vehicle Damage

Damage to the vehicle was moderate, as shown in Figures 35 through 39. The maximum occupant compartment intrusions are listed in Table 6 along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. There were no penetrations into the occupant compartment and none of the established MASH 2016 intrusion limits were violated. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix E.

Figure 35. Vehicle Damage, Test No. MTB-1

Figure 36. Vehicle Damage, Test No. MTB-1

Figure 37. Vehicle Damage, Test No. MTB-1

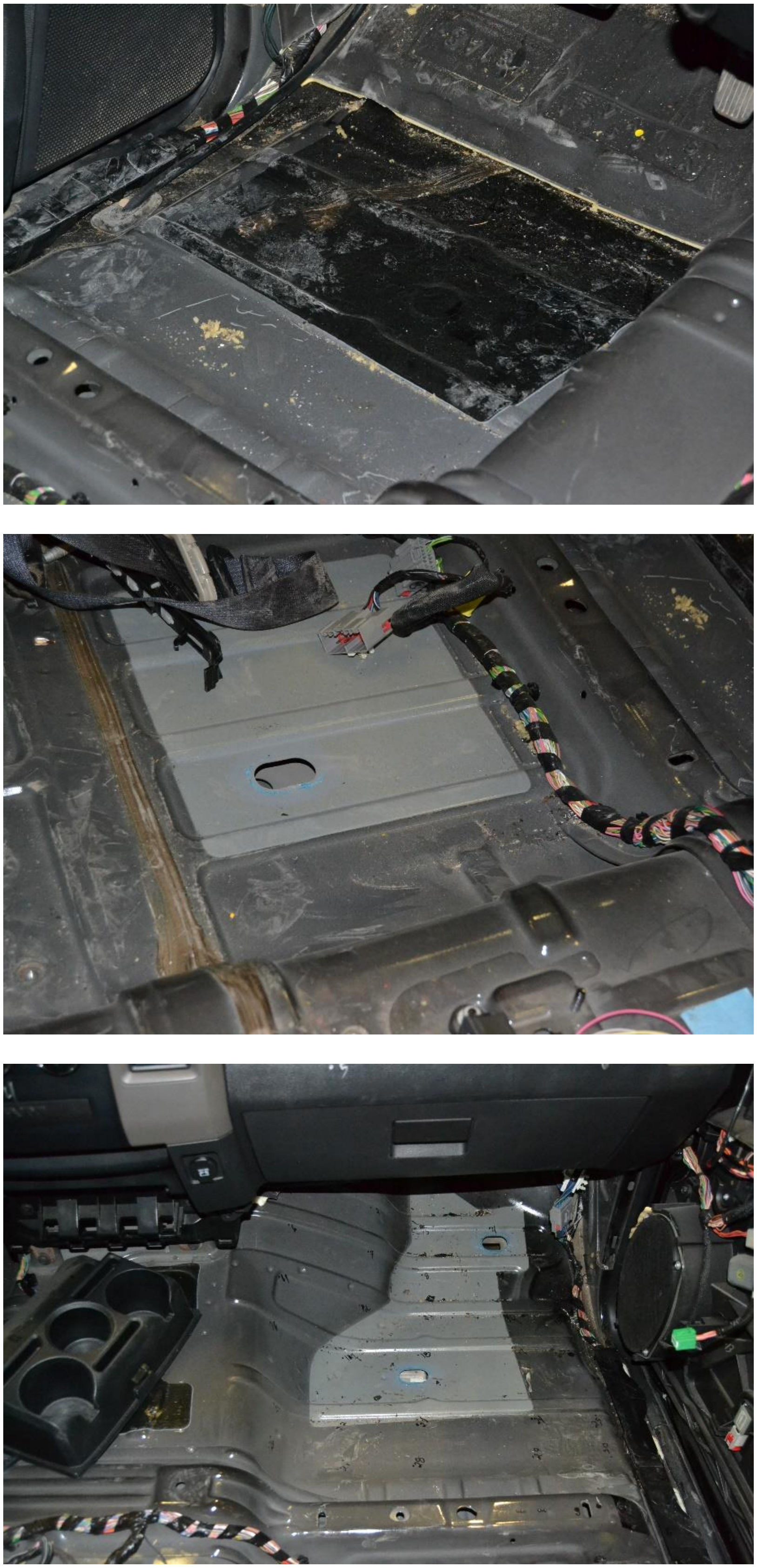


Figure 38. Occupant Compartment Damage, Test No. MTB-1

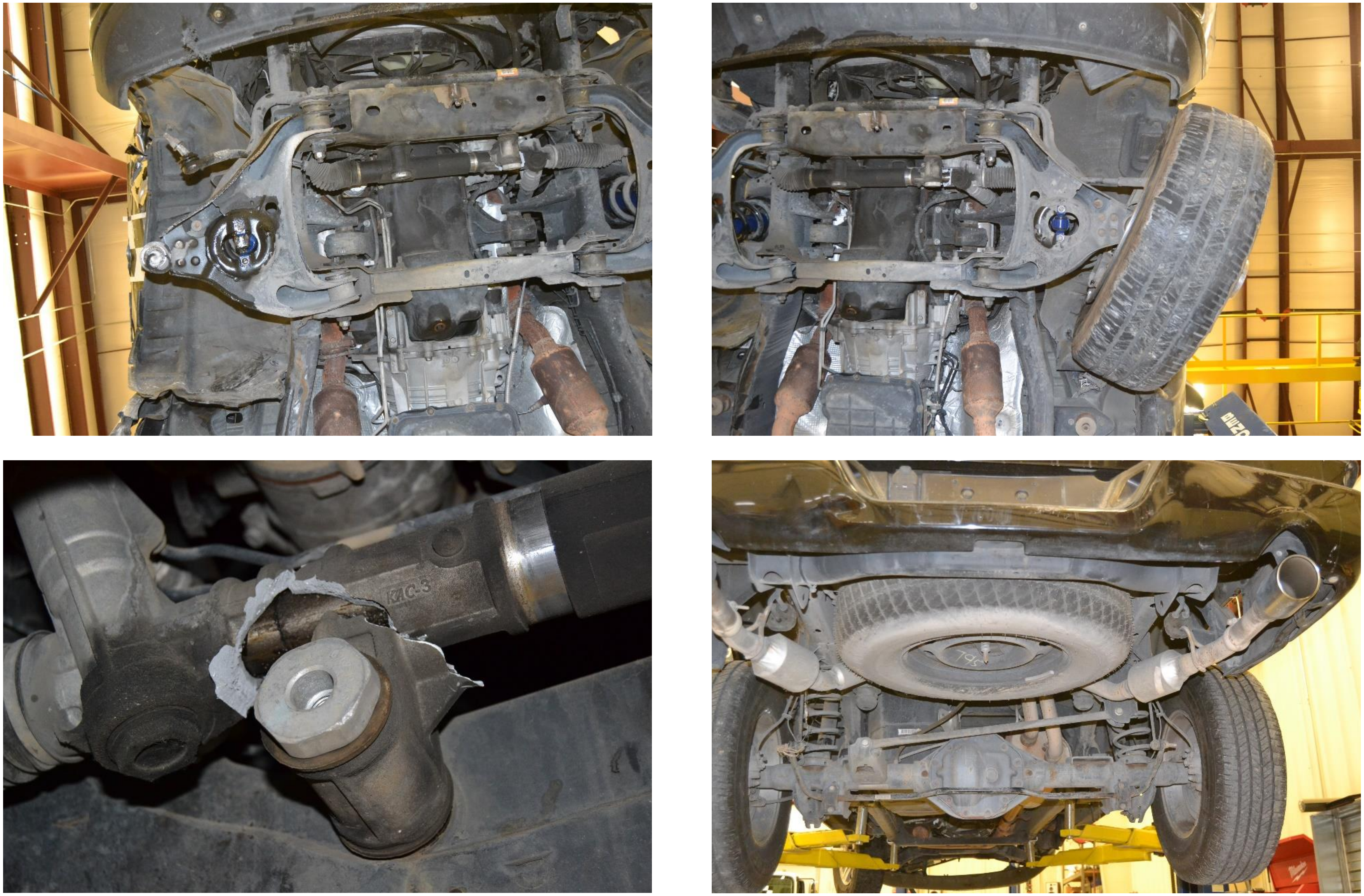


Figure 39. Vehicle Undercarriage Damage, Test No. MTB-1

Table 6. Maximum Occupant Compartment Intrusions by Location, Test No. MTB-1

LOCATION	MAXIMUM INTRUSION in.	MASH 2016 ALLOWABLE INTRUSION in.
Wheel Well & Toe Pan	0.1	≤ 9
Floor Pan & Transmission Tunnel	−0.5	N/A[1]
A-Pillar	0.6	≤ 5
A-Pillar (Lateral)	−0.5	N/A[2]
B-Pillar	0.3	≤ 5
B-Pillar (Lateral)	−0.5	N/A[1]
Side Front Panel (in Front of A-Pillar)	0.3	≤ 12
Side Door (Above Seat)	−1.0	N/A[1]
Side Door (Below Seat)	0.1	≤ 12
Roof	0.4	≤ 4
Windshield	0	≤ 3
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	0.8	N/A[2]

Note: Negative values denote outward deformation
N/A[1] – MASH 2016 criteria are not applicable when deformation is outward
N/A[2] – No MASH 2016 criteria exist for this location

The majority of damage was concentrated on the right-front corner and right side of the vehicle where impact occurred. The front bumper cover was crushed in and partially torn from the vehicle. The grille and both headlights were disengaged from the vehicle. The right-front wheel assembly was torn from the vehicle. The front and side of the right-front fender were crushed inward. The right side of vehicle was deformed or scratched along its entirety. The right tail light was crushed. The right-side shocks bent backward. The right-side sway bar end link was disconnected from the lower control arm. The right-side steering knuckle disengaged from the vehicle. The right-side lower control arm broke and the upper control arm bent backward. The steering gear box broke apart and the right-side tie rod was bent. The front bumper mounts were bent backward.

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 7. 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 7. The results of the occupant risk analysis are summarized in Figure 40. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix F.

Table 7. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. MTB-1

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1	SLICE-2 (primary)	
OIV ft/s	Longitudinal	−14.97	−14.34	±40
	Lateral	−15.74	−16.84	±40
ORA g’s	Longitudinal	−10.35	−10.76	±20.49
	Lateral	−9.55	−9.56	±20.49
MAX. ANGULAR DISPL. deg.	Roll	4.1	−6.1	±75
	Pitch	−1.3	−2.0	±75
	Yaw	−39.8	−39.5	not required
THIV ft/s		20.73	21.21	not required
PHD g’s		13.44	13.79	not required
ASI		0.73	0.75	not required

5.7 Discussion

The analysis of the test results for test no. MTB-1 showed that the system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown in Figure 40. 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. After impact, the vehicle exited the barrier at an angle of 15.0 deg., and its trajectory did not violate the bounds of the exit box. Therefore, test no. MTB-1 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-11.

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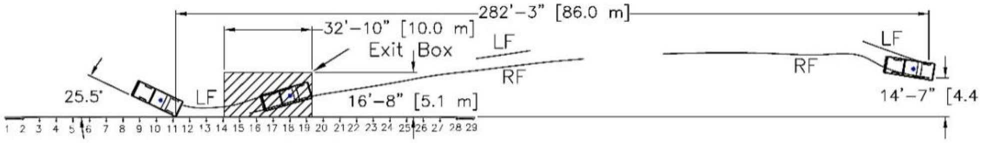
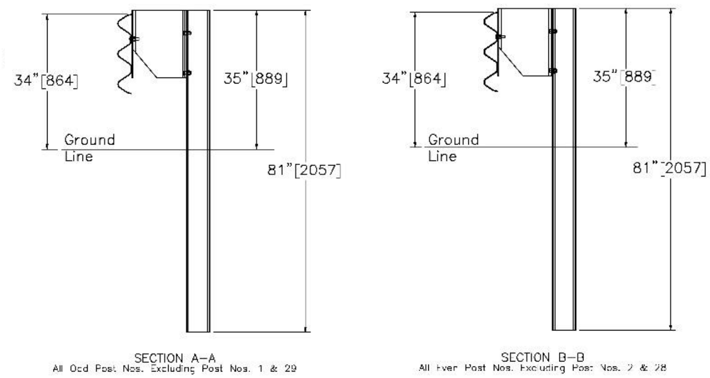




- Test Agency .... MwRSF
- Test Number MTB-1
- Date .... November 7, 2018
- MASH 2016 Test Designation No. 3-11
- Test Article .... NJDOT-Caltrans Modified Thrie Beam
- Total Length .... 176 ft – $^{9}/_{16}$ in.
- Key Component – Steel Thrie Beam Guardrail
  - Thickness .... 12 gauge
  - Top Mounting Height .... 34 in.
- Key Component – Steel Post
  - Shape W6x8.5
  - Length .... 81 in.
  - Embedment Depth .... 46 in.
  - Spacing .... 75 in.
- Key Component – Steel Blockout (Post Nos. 3-27)
  - Shape W14x22
- Soil Type .... Coarse, Crushed Limestone
- Vehicle Make / Model .... 2012 Dodge Ram 1500
  - Curb .... 5,089 lb
  - Test Inertial .... 5,003 lb
  - Gross Static .... 5,162 lb
- Impact Conditions
  - Speed .... 62.9 mph
  - Angle .... 25.4 deg.
  - Impact Location .... 11 ft – 5.7 in. upstream from post no. 13
- Impact Severity .... 121.8 kip-ft > 105.6 kip-ft limit from MASH 2016
- Exit Conditions
  - Speed .... 40.6 mph
  - Angle .... 15.0 deg.
- Exit Box Criterion .... Pass
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 282 ft – 3 in.
- Vehicle Damage .... Moderate
  - VDS [18] 1-RFQ-3
  - CDC [19] 01-FYEW-3
  - Maximum Interior Deformation .... 0.6 in.
- Test Article Damage .... Moderate
- Maximum Test Article Deflections
  - Permanent Set .... 27.7 in.
  - Dynamic Deflection .... 34.4 in.
  - Working Width .... 49.3 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limit
		SLICE-1	**SLICE-2 (primary)**	
OIV ft/s	Longitudinal	−14.97	−14.34	±40
	Lateral	−15.74	−16.84	±40
ORA g's	Longitudinal	−10.35	−10.76	±20.49
	Lateral	−9.55	−9.56	±20.49
MAX ANGULAR DISP. deg.	Roll	4.1	−6.1	±75
	Pitch	−1.3	−2.0	±75
	Yaw	−39.8	−39.5	not required
THIV – ft/s		20.73	21.21	not required
PHD – g's		13.44	13.79	not required
ASI		0.73	0.75	not required

Figure 40. Summary of Test Results and Sequential Photographs, Test No. MTB-1

6 DESIGN DETAILS, TEST NO. MTB-2

The test installation for test no. MTB-2 consisted of a 176-ft – ½-in. long, dual-sided modified thrie beam guardrail supported by 33 posts. Design details for the test no. MTB-2 system are shown in Figures Figure 41 through Figure 53. Photographs of the system for test no. MTB-2 are shown in Figure 54 and Figure 55. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

The dual-sided modified thrie beam test article was constructed based on the NJDOT standard plans. The system was nearly identical to the single-sided modified thrie beam system with the exception of a second set of blockouts and thrie beam rails installed on the backside of the barrier line posts. In addition, the upstream and downstream ends of the guardrail installation were configured with a dual, non-proprietary end anchorage systems [8-12]. The guardrail anchorage system had a comparable strength to other crashworthy end terminals. The anchorage system consisted of timber posts, foundation tubes, anchor cables, bearing plates, rail brackets, and channel struts. Due to the 34-in. height of the modified thrie-beam guardrail, a 10-gauge, symmetric W-beam to thrie beam transition section was used to transition down to a 12-gauge, W-beam rail segment with a top mounting height of 30⅛ in. at each end of the system. This allowed for anchorage of the system using typical trailing end anchorage hardware. The only modification required was altering the hole location for the post bolt in the BCT posts to adjust for the ⅞-in. height difference.

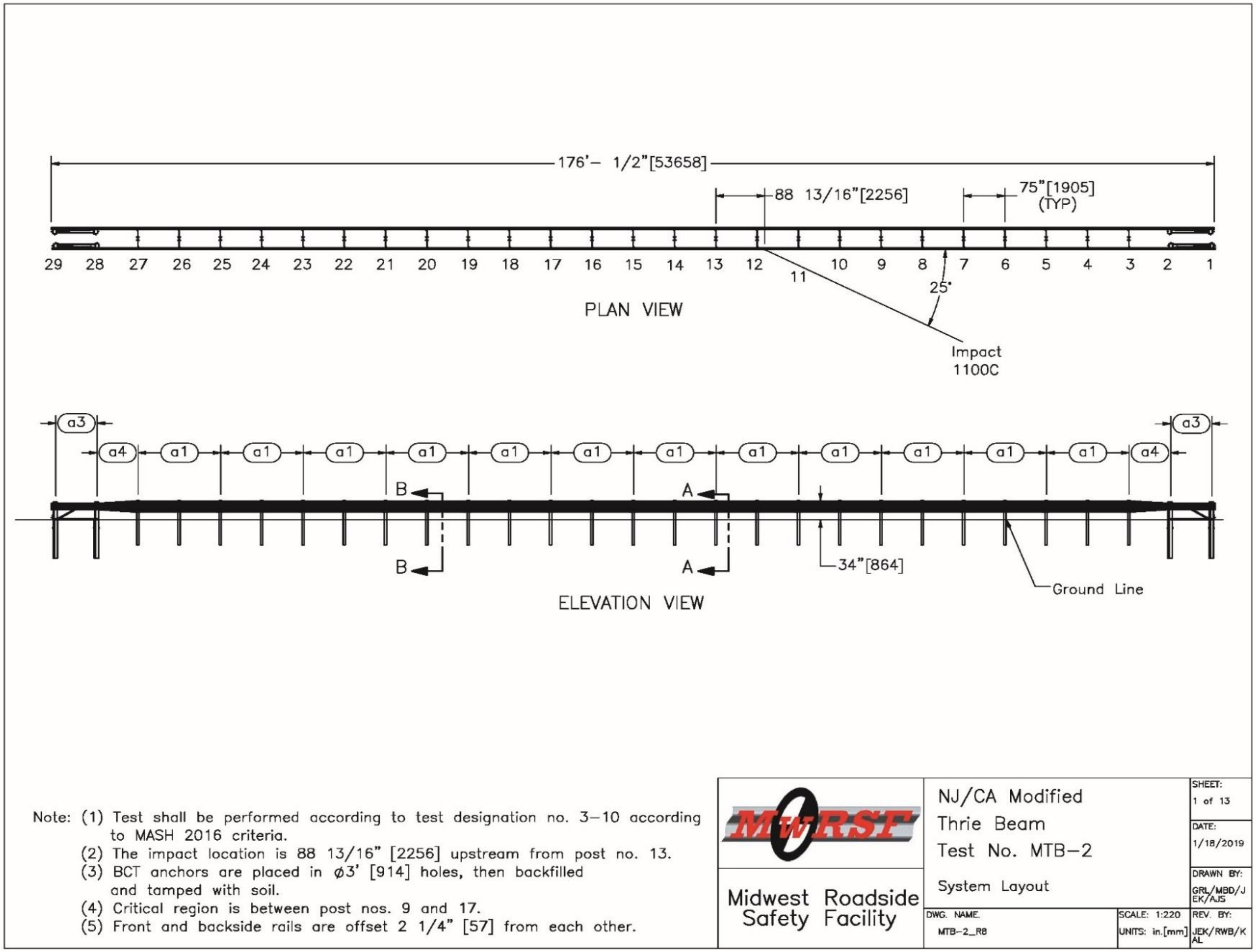


Figure 41. System Layout, Test No. MTB-2

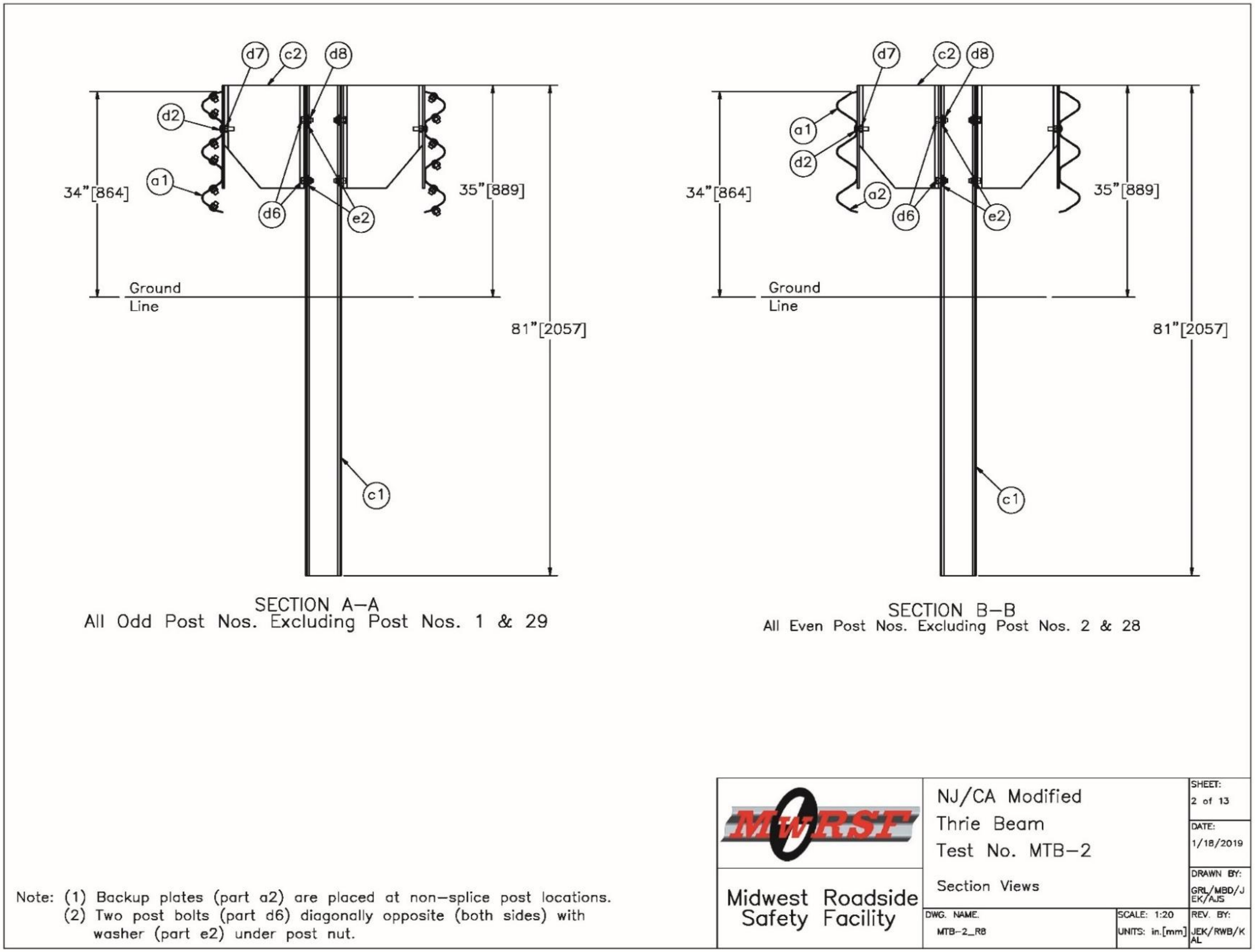


Figure 42. Section Views, Test No. MTB-2

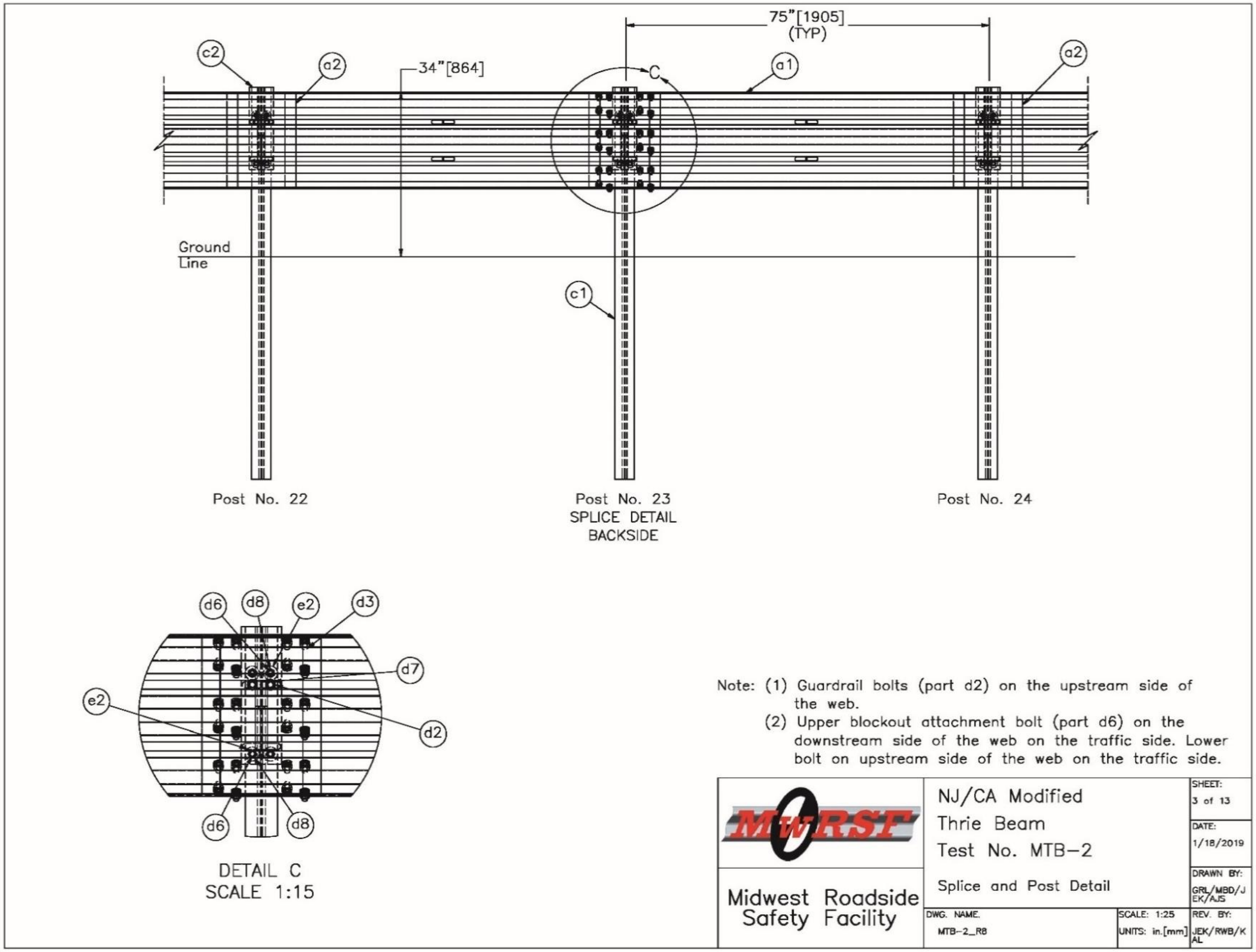


Figure 43. Splice and Post Detail, Test No. MTB-2

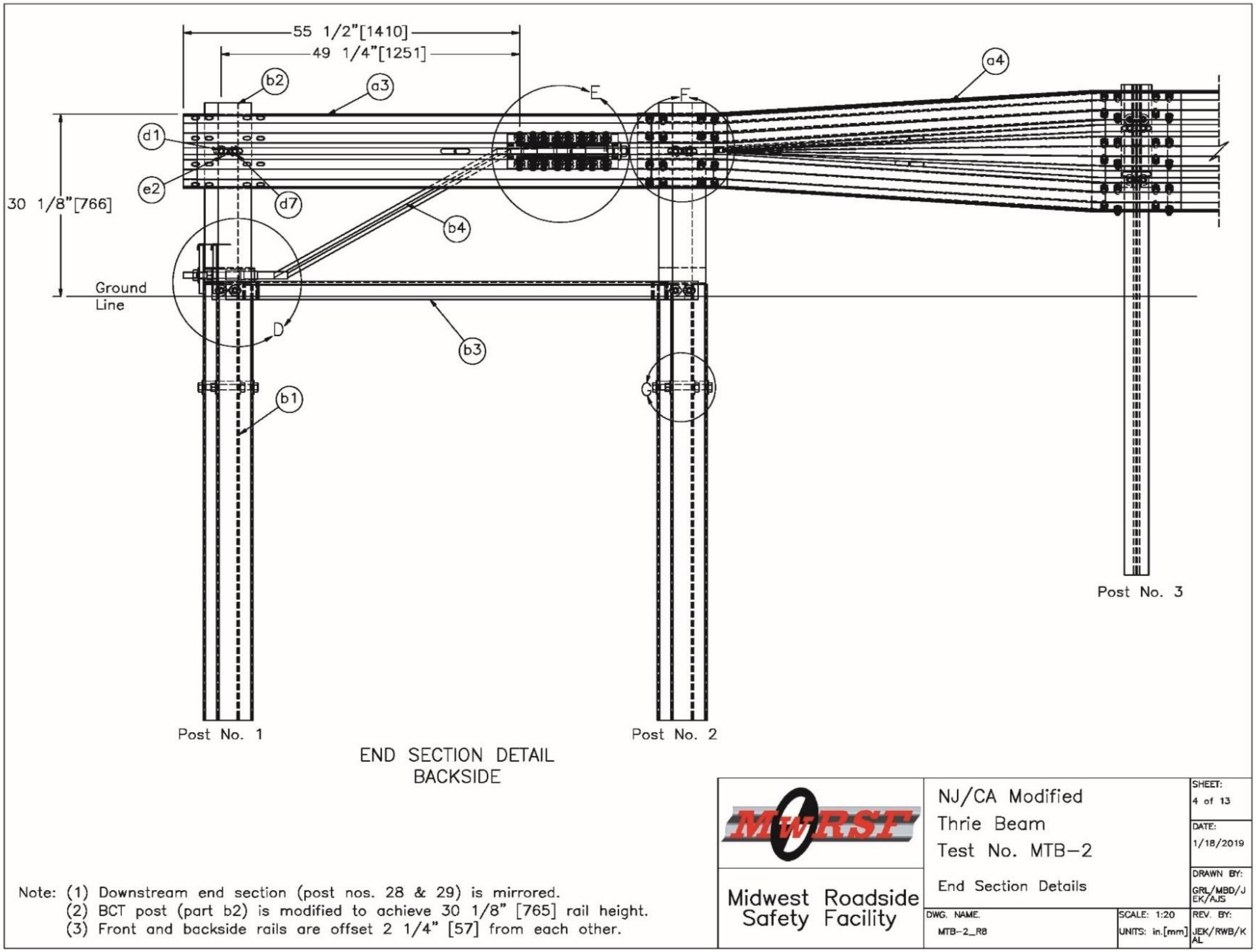


Figure 44. End Section Details, Test No. MTB-2

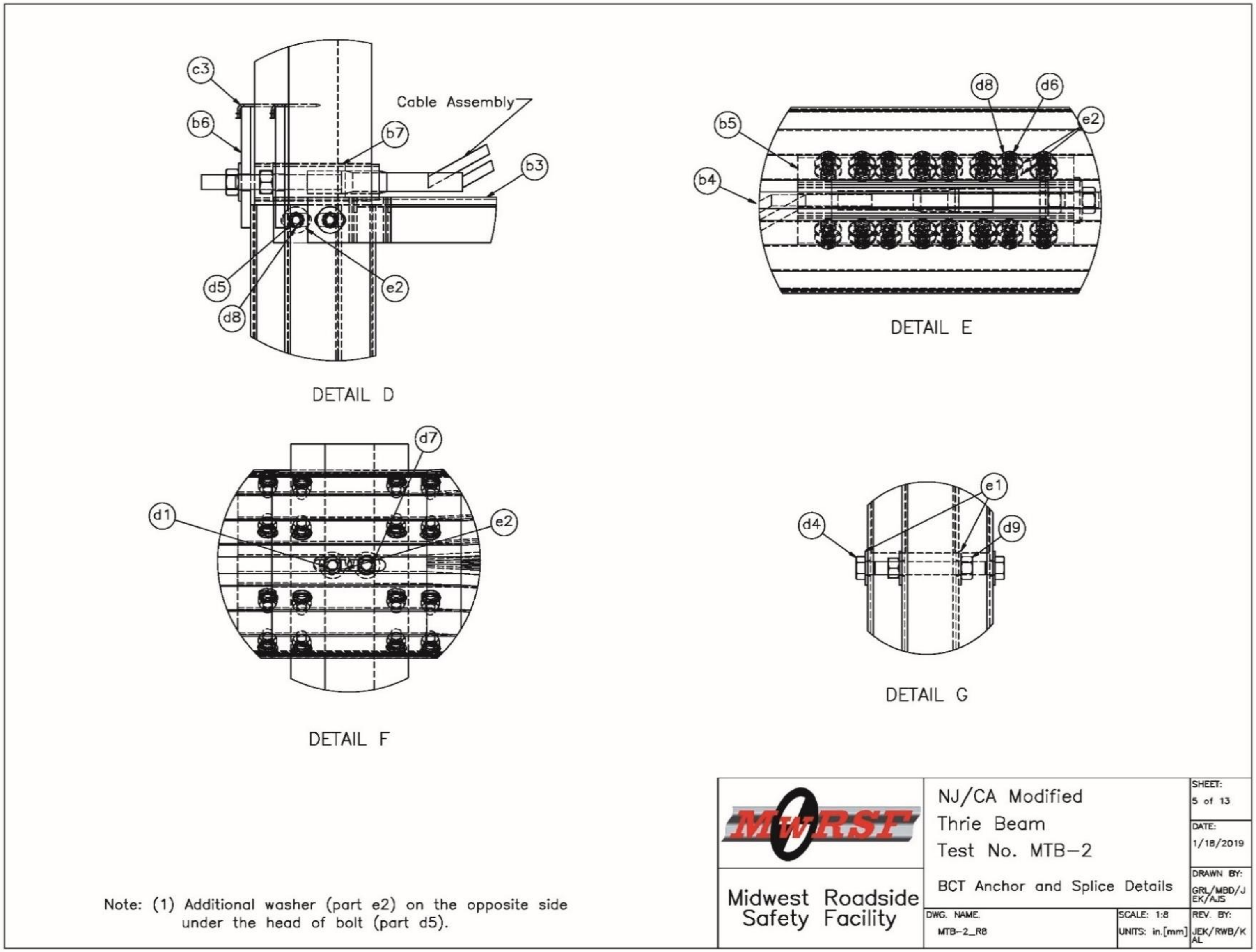


Figure 45. BCT Anchor and Splice Details, Test No. MTB-2

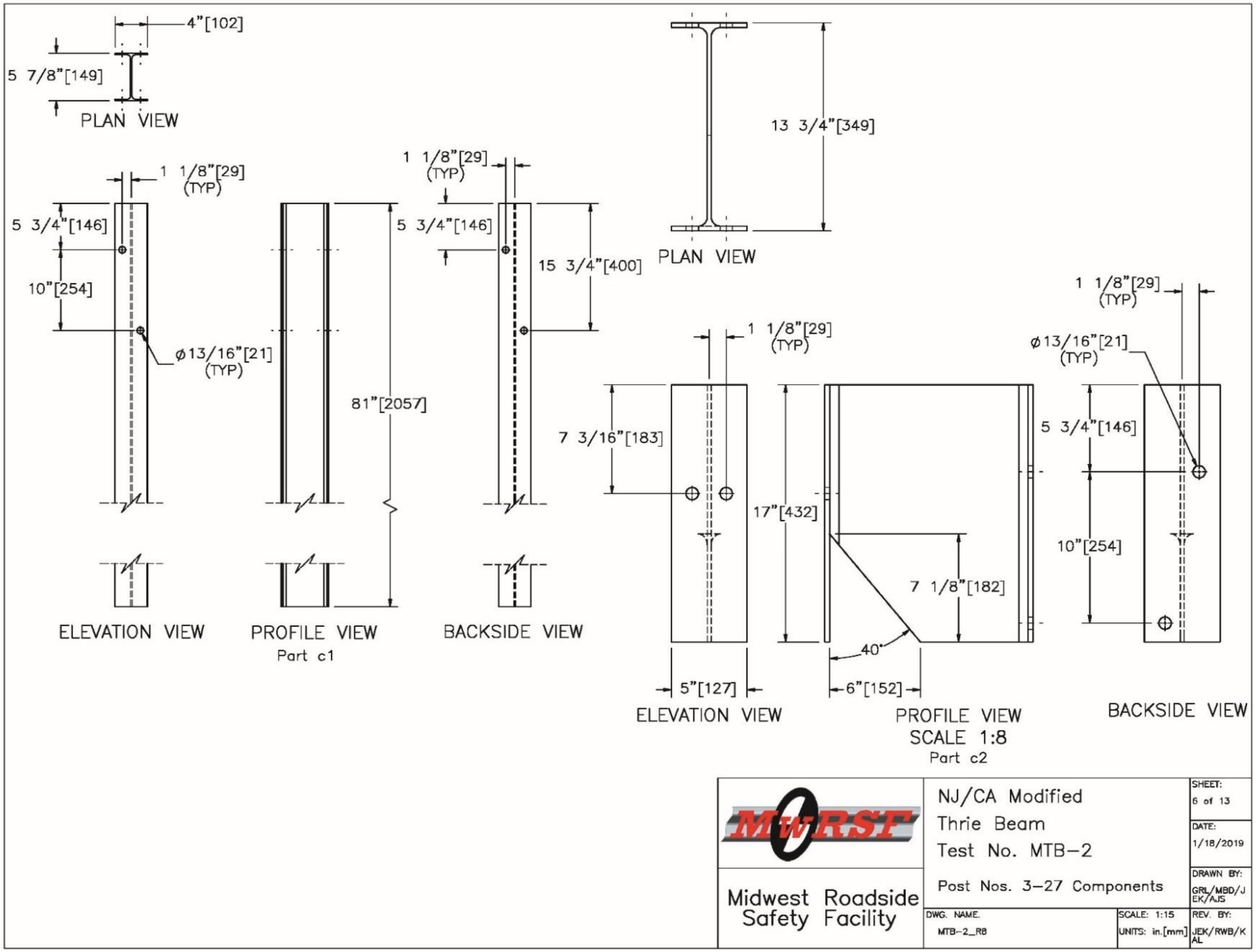


Figure 46. Post Nos. 3 through 27 Components, Test No. MTB-2

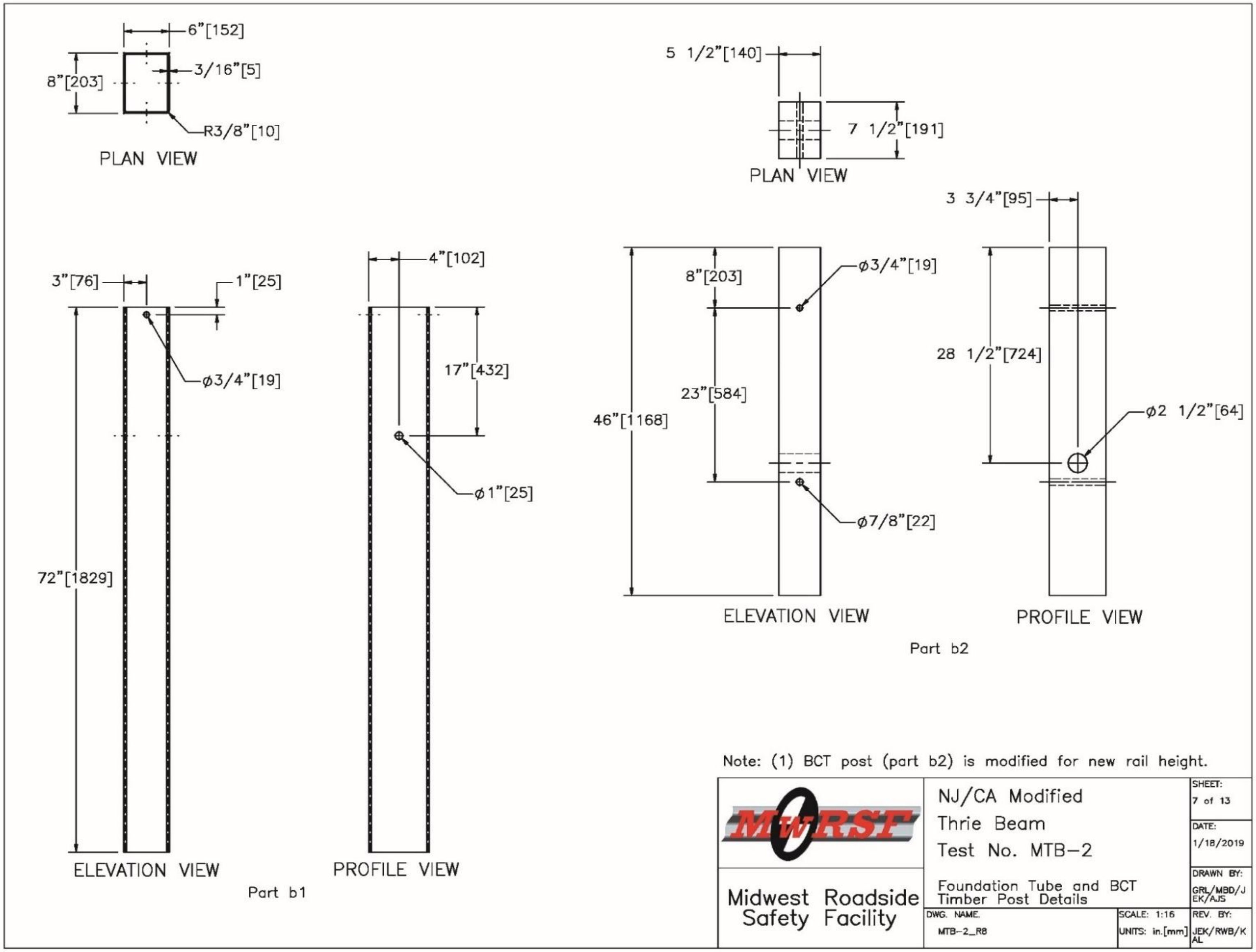


Figure 47. Foundation Tube and BCT Timber Post Details, Test No. MTB-2

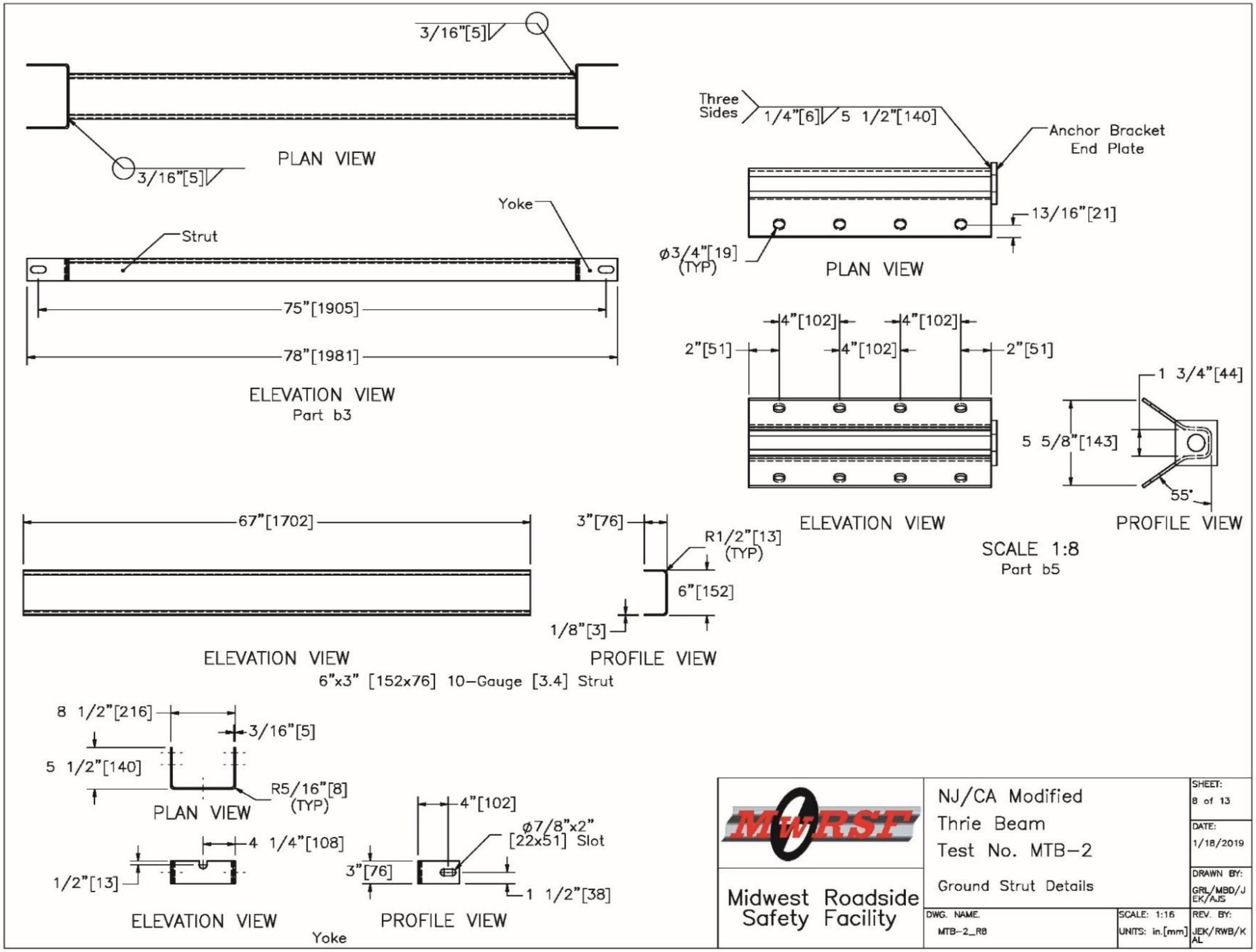
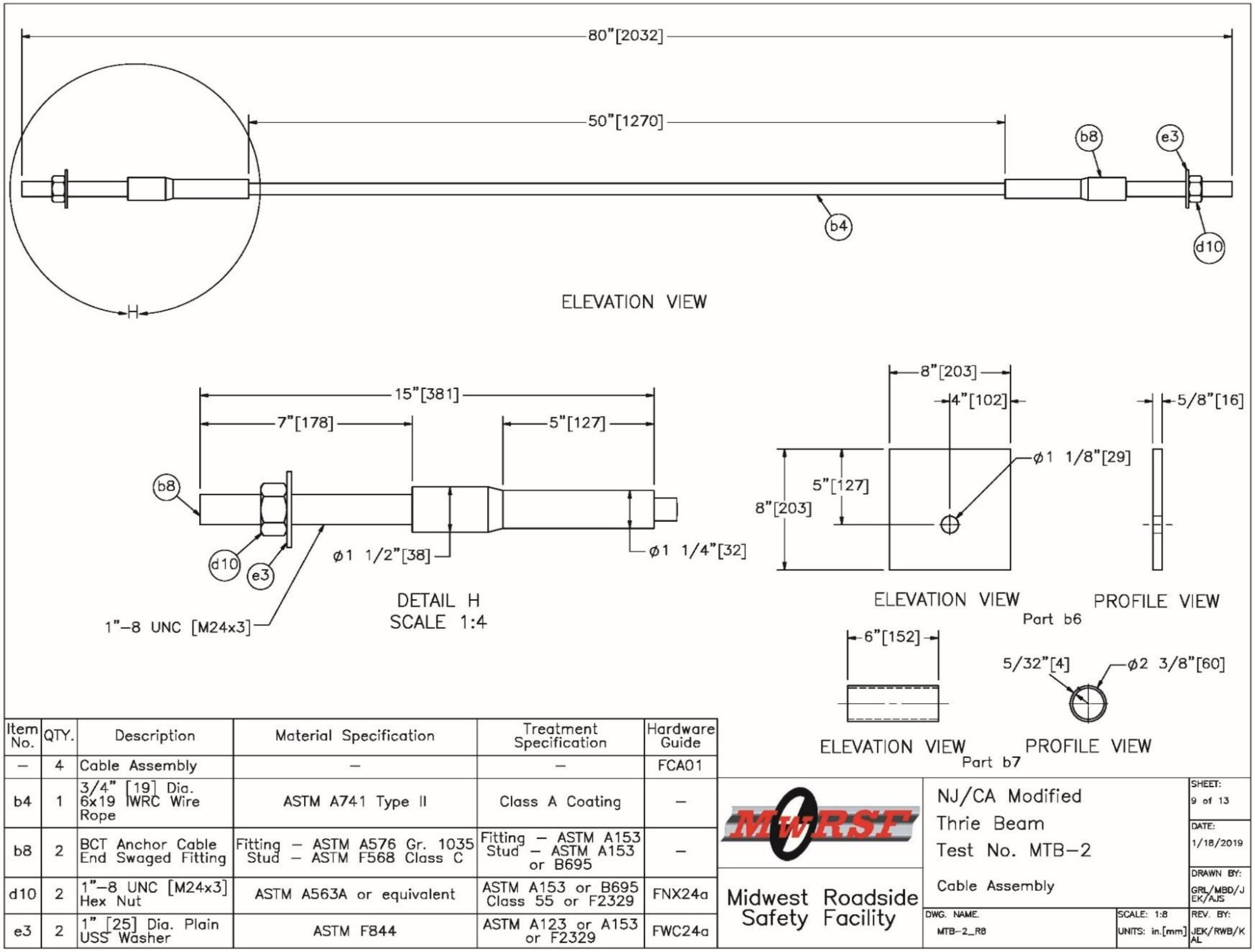


Figure 48. Ground Strut Details, Test No. MTB-2



Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	4	Cable Assembly	–	–	FCA01
b4	1	3/4" [19] Dia. 6x19 IWRC Wire Rope	ASTM A741 Type II	Class A Coating	–
b8	2	BCT Anchor Cable End Swaged Fitting	Fitting – ASTM A576 Gr. 1035 Stud – ASTM F568 Class C	Fitting – ASTM A153 Stud – ASTM A153 or B695	–
d10	2	1"-8 UNC [M24x3] Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX24a
e3	2	1" [25] Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC24a

Figure 49. Cable Assembly, Test No. MTB-2

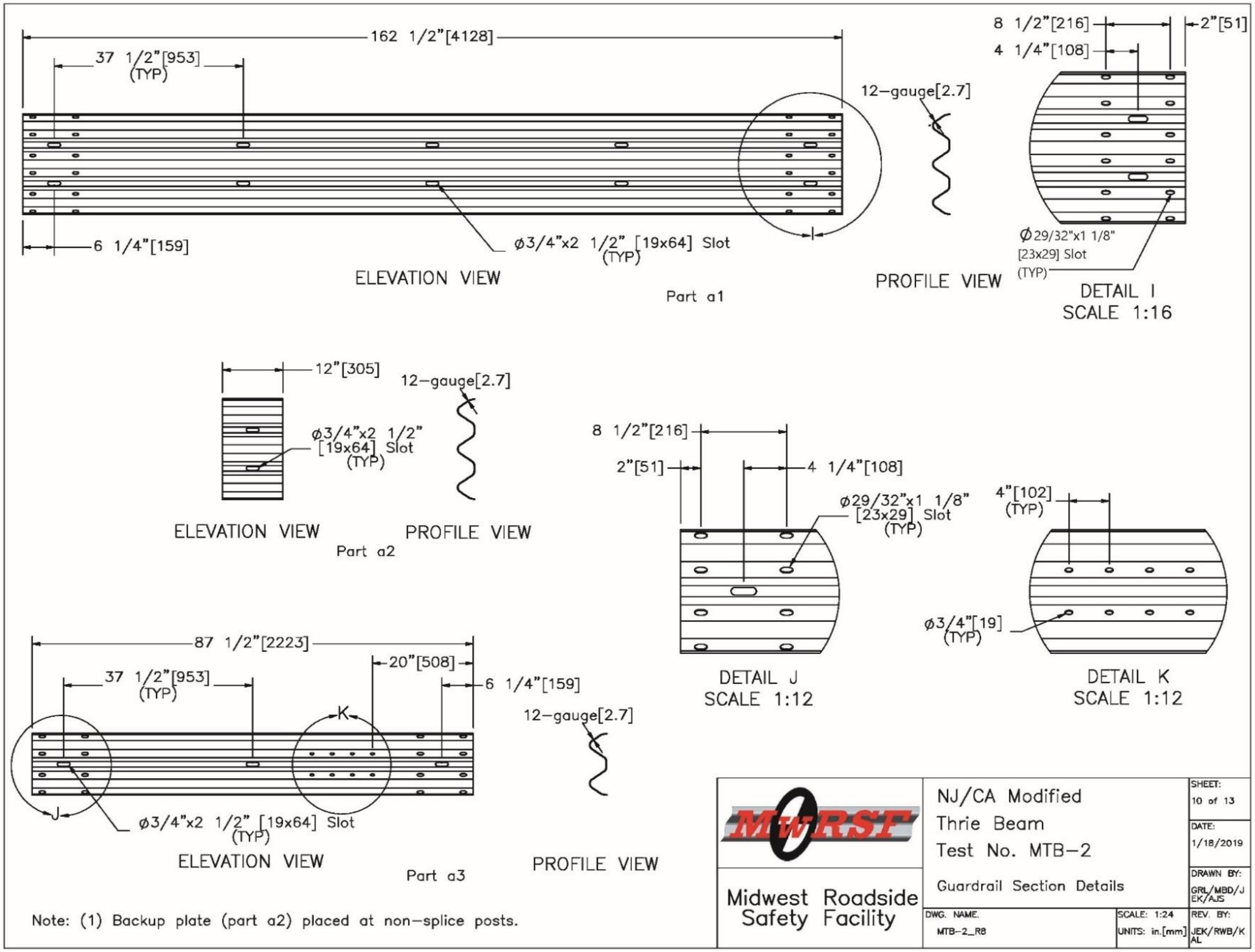


Figure 50. Guardrail Section Details, Test No. MTB-2

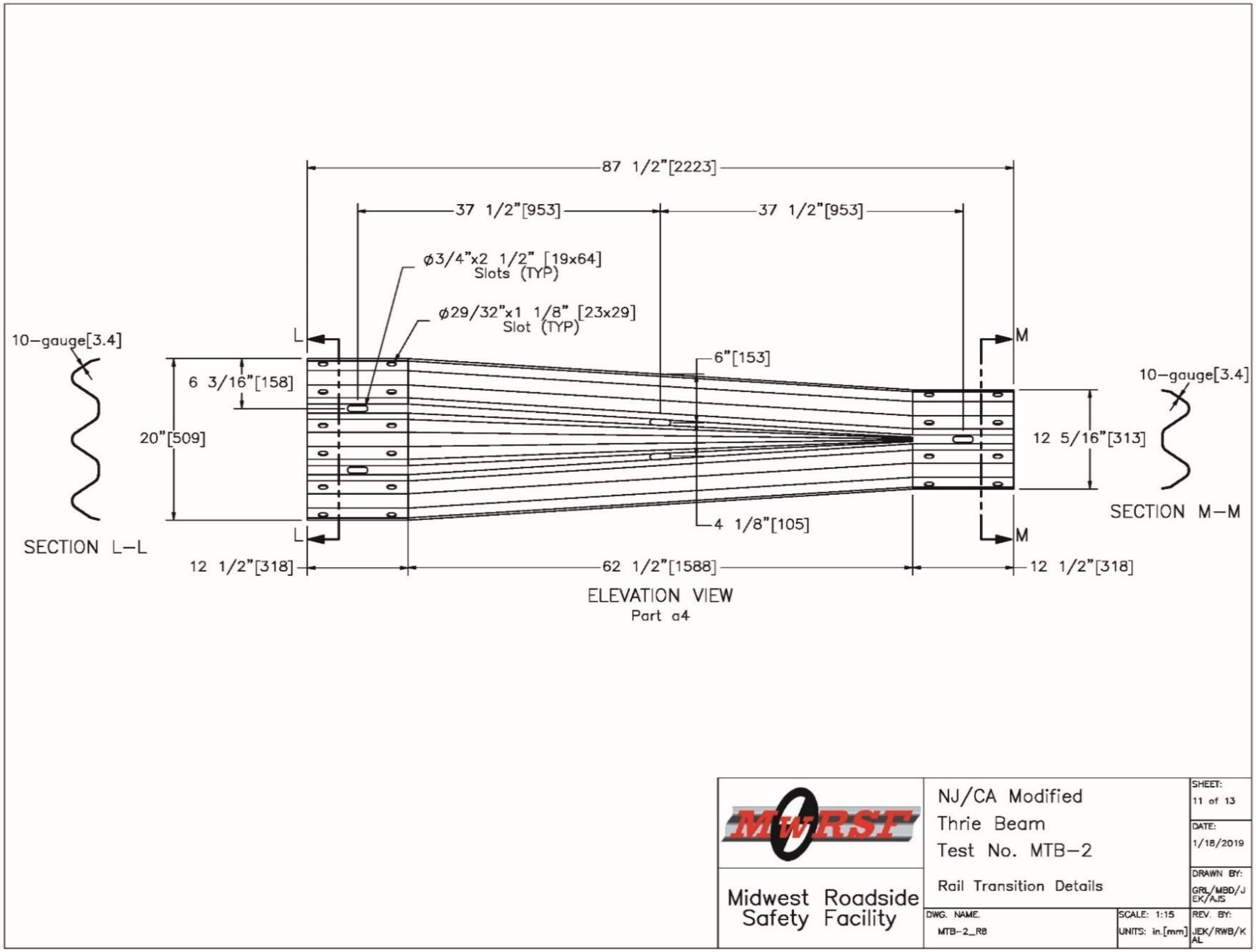


Figure 51. Rail Transition Details, Test No. MTB-2

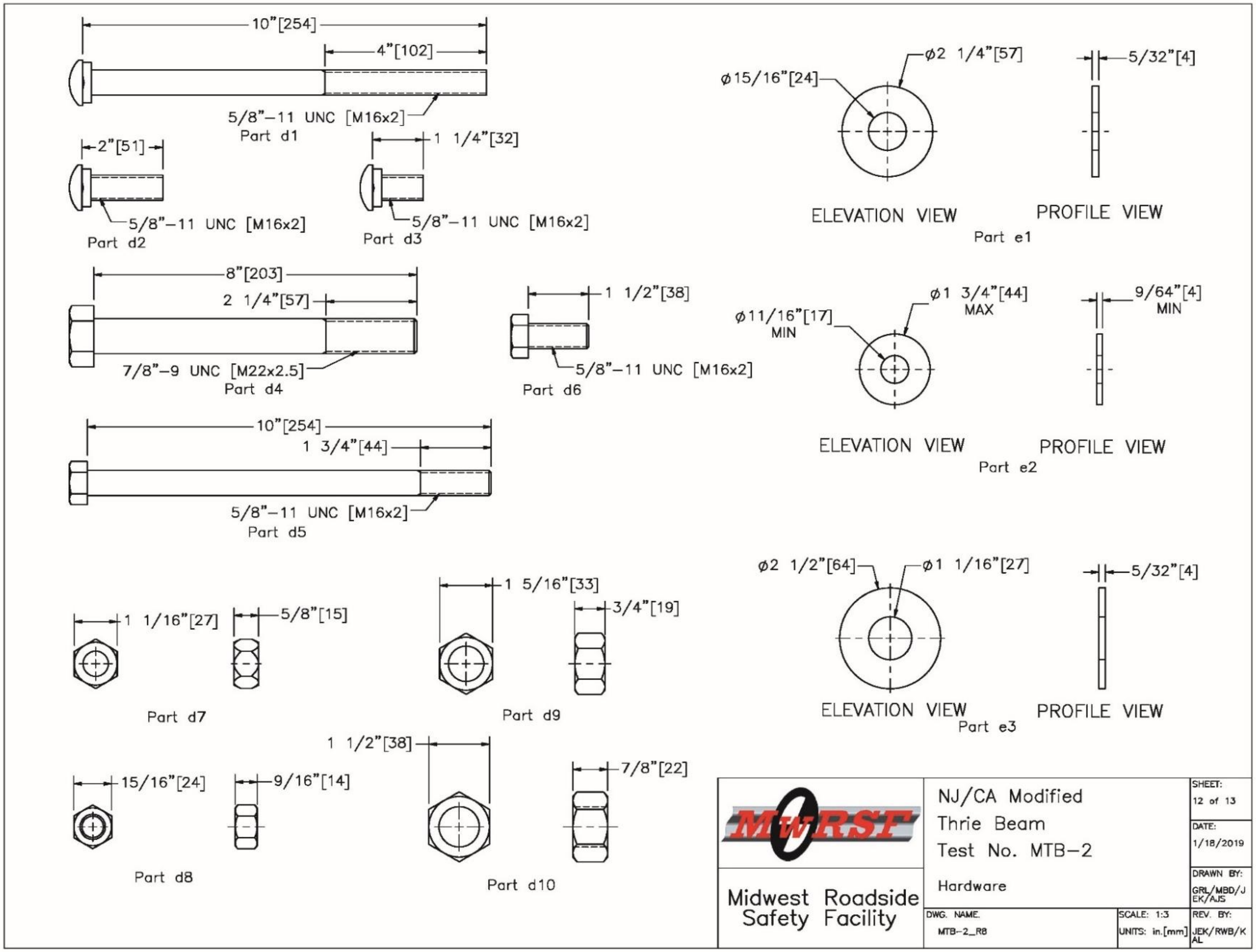


Figure 52. Hardware, Test No. MTB-2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	24	12'–6" [3,810] 12–gauge [2.7] Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM04a
a2	24	12" [305] 12–gauge [2.7] Thrie Beam Backup Plate	AASHTO M180	ASTM A123 or A653	RTB01a
a3	4	6'–3" [3,810] 12–gauge [2.7] W–Beam MGS End Section	AASHTO M180	ASTM A123 or A653	–
a4	4	10–gauge [3.4] Symmetrical W–beam to Thrie Beam Transition	AASHTO M180	ASTM A123 or A653	RWT01b
b1	8	72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	ASTM A123	PTE06
b2	8	BCT Timber Post – MGS Height – Not Standard	SYP Grade No. 1 or better (No knots 18" [457] above or below ground tension face)	–	–
b3	4	Ground Strut Assembly	ASTM A36	ASTM A123	PFP01
b4	4	3/4" [19] Dia. 6x19 IWRC Wire Rope	ASTM A741 Type II	Class A Coating	–
b5	4	Anchor Bracket Assembly	ASTM A36	ASTM A123	FPA01
b6	4	8"x8"x5/8" [203x203x16] Anchor Bearing Plate	ASTM A36	ASTM A123	FPB01
b7	4	2 3/8" [60] O.D. x 6" [152] Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	ASTM A123	FMM02
b8	8	BCT Anchor Cable End Swaged Fitting	Fitting – ASTM A576 Gr. 1035 Stud – ASTM F568 Class C	Fitting – ASTM A153 Stud – ASTM A153 or B695	–
c1	25	W6x8.5 [W152x12.6], 81" [2,057] Long Steel Post	ASTM A36	ASTM A123	–
c2	50	W14x22 [356x32.7], 17" [432] Long Steel Blockout	ASTM A992	ASTM A123	–
c3	4	16D Double Head Nail	–	–	–
d1	8	5/8"–11 UNC [M16x2], 10" [254] Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB03
d2	50	5/8"–11 UNC [M16x2], 2" [51] Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB02
d3	344	5/8"–11 UNC [M16x2], 1 1/4" [32] Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB01
d4	8	7/8"–9 UNC [M22x2.5], 8" [203] Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	–
d5	8	5/8"–11 UNC [M16x2], 10" [254] Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
d6	132	5/8"–11 UNC [M16x2], 1 1/2" [38] Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
d7	402	5/8"–11 UNC [M16x2] Heavy Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX16b
d8	140	5/8"–11 UNC [M16x2] Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX16a
d9	8	7/8"–9 UNC [M22x2.5] Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX22a
d10	8	1"–8 UNC [M24x3] Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX24a
e1	16	7/8" [22] Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	–
e2	188	5/8" [16] Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC16a
e3	8	1" [25] Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC24a

MwRSF
Midwest Roadside Safety Facility

NJ/CA Modified
Thrie Beam
Test No. MTB–2
Bill of Materials

SHEET: 13 of 13
DATE: 1/18/2019
DRAWN BY: GRL/MBD/JEK/AJS
DWG. NAME. MTB–2_R8
SCALE: 1:384
UNITS: in.[mm]
REV. BY: JEK/RWB/KAL

Figure 53. Bill of Materials, Test No. MTB-2

Figure 54. Test Installation Photographs, Test No. MTB-2

Figure 55. Test Installation Photographs, Test No. MTB-2

7 FULL-SCALE CRASH TEST NO. MTB-2

7.1 Static Soil Test

Before full-scale crash test no. MTB-2 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. The static test results, shown in Appendix D, 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. MTB-2 was conducted on March 22, 2019 at approximately 2:30 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 8.

Table 8. Weather Conditions, Test No. MTB-2

Temperature	63 deg. F
Humidity	31 percent
Wind Speed	6 mph
Wind Direction	200 deg. from True North
Sky Conditions	Partly cloudy
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.42 in.

7.3 Test Description

Test no. MTB-2 was conducted under the MASH TL-3 guidelines for test designation no. 3-10. Test designation no. 3-10 is an impact of the 1100C vehicle at 62 mph and 25 degrees on the system. The critical impact point for this test was selected to maximize vehicle snag on the system posts and splice loading. Initial vehicle impact was to occur 7 ft – $4^{13}/_{16}$ in. upstream from post no. 13, as shown in Figure 56, which was selected using the critical impact point plots found in Section 2.3 of MASH 2016. The 2,415-lb small car impacted the MTB guardrail at a speed of 63.1 mph and an angle of 24.9 deg. The actual point of impact was 1.6 in. upstream from the target location. During the test, the vehicle was captured and redirected by the thrie beam guardrail. As the vehicle was redirected, the right-front wheel and tire of the vehicle snagged on post no. 13 in the system. However, the wheel snag did not adversely affect vehicle stability or the occupant risk values. After exiting the system, the vehicle came to rest 187 ft – 7 in. downstream from the impact point and 51 ft – 11 in. laterally in front of the barrier after brakes were applied.

A detailed description of the sequential impact events is contained in Table 9. Sequential photographs are shown in Figures 57 and 58. Documentary photographs of the crash test are shown in Figures 59 through 61. The vehicle trajectory and final position are shown in Figure 62.

Figure 56. Vehicle Impact Point, Test No. MTB-2

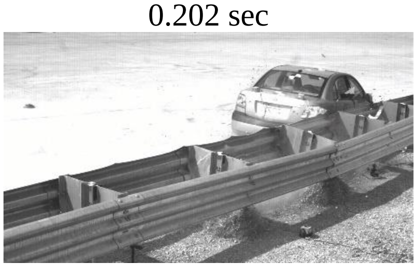
Table 9. Sequential Description of Impact Events, Test No. MTB-2

TIME (sec)	EVENT
0.000	Vehicle’s front bumper contacted rail between post nos. 11 and 12 at a speed of 63.1 mph and an angle of 24.9 deg.
0.006	Vehicle’s right headlight contacted rail.
0.018	Post no. 12 deflected backward, vehicle’s right fender deformed, and vehicle’s hood and right fender contacted rail.
0.022	Post no. 13 deflected backward.
0.024	Post no. 11 deflected backward.
0.040	Post no. 14 deflected backward and soil heave formed on the downstream side of post no. 13.
0.042	Vehicle’s right headlight shattered.
0.058	Vehicle’s right mirror contacted rail.
0.067	Vehicle’s right-front tire contacted post no. 13.
0.074	Vehicle’s right-front door contacted rail.
0.100	Post no. 15 deflected backward.
0.102	Rail disengaged from bolt at post no. 14 on non-traffic side.
0.124	Post no. 16 deflected backward, soil heave formed on the non-traffic flange of post no. 15.
0.130	Rail disengaged from bolt at post no. 15 on non-traffic side.
0.144	Vehicle’s right-rear door contacted rail.
0.146	Vehicle’s right quarter panel contacted rail.
0.164	Vehicle was parallel to the system at a speed of 46.0 mph.
0.172	Post no. 16 deflected forward.
0.174	Vehicle’s right taillight contacted rail.
0.184	Vehicle’s right taillight became disengaged.
0.196	Post no. 12 deflected forward.
0.216	Post no. 13 deflected forward.
0.244	Post nos. 11 and 14 deflected forward.
0.300	Post no. 15 deflected forward.
0.334	Vehicle exited system at a speed of 45.9 mph and an angle of 13.4 deg.
0.912	System came to a rest.


0.000 sec


0.106 sec


0.202 sec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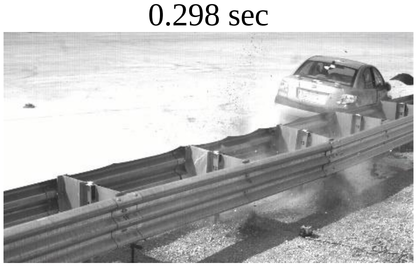
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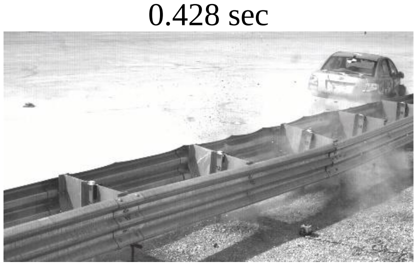
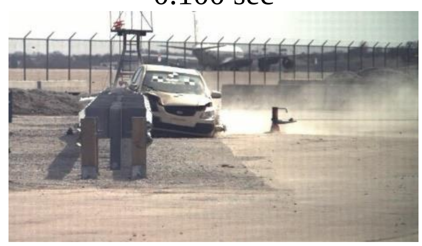

0.520 sec


0.000 sec


0.100 sec


0.180 sec


0.300 sec


0.400 sec


0.500 sec

Figure 57. Sequential Photographs, Test No. MTB-2

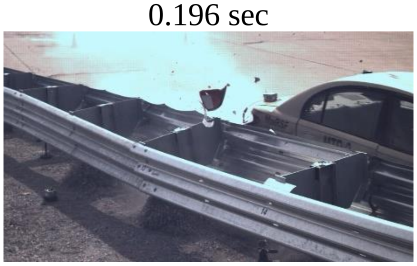

0.000 sec


0.046 sec


0.106 sec


0.146 sec


0.196 sec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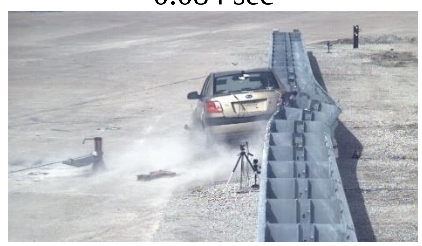
0.000 sec


0.084 sec


0.164 sec


0.294 sec


0.404 sec


0.564 sec

Figure 58. Additional Sequential Photographs, Test No. MTB-2

Figure 59. Documentary Photographs, Test No. MTB-2

Figure 60. Documentary Photographs, Test No. MTB-2

Figure 61. Documentary Photographs, Test No. MTB-2

Figure 62. Vehicle Trajectory and Final Position, Test No. MTB-2

7.4 Barrier Damage

Barrier damage was moderate, as shown in Figures 63 through 65, mainly consisting of bending, kinking, denting, and contact marks on the front face of the rail. The length of vehicle contact along the barrier was approximately 17 ft – 3 in., which spanned from 22 in. upstream from post no. 12 to 38 in. downstream from post no. 14.

A 17 ft – 3-in. long contact mark was found on the bottom corrugation beginning 22 in. upstream from post no. 12. A 13-ft – 5-in. long contact mark was found on the middle corrugation, beginning 22 in. upstream from post no. 12. A 12-ft – 7-in. long contact mark was found on the top corrugation, beginning 12 in. upstream from post no. 12. A small contact mark was found on the top front face of the blockout at post no. 12. Dents were found on the middle corrugation 22 in. and 33 in. downstream from post no. 12. The rail bent backward and was slightly flattened between post nos. 12 and 14. The bottom corrugation at post no. 12 bent outward 1 in. The bottom corrugation at post no. 14 bent outward ¾ in. and the backing plate on the non-traffic side detached as a result of bolt pull out. A 1-in. long gap between the guardrail and backing plate was found on the non-traffic side blockout at post no. 16. Various kinks were found on the rail between post nos. 10 and 15.

Post nos. 10 and 12 rotated clockwise. The lower front flange on the traffic-side blockouts at post nos. 11 through 14 were bent inward 10 in. from the top. The non-traffic-side blockouts at post nos. 12 and 13 bent slightly near the bottom. Contact marks were noted on the flanged of post no. 13 due to wheel and tire contact. Bolt pullout occurred on the non-traffic side at post nos. 14 and 15, and at post no. 15 the bolt was removed entirely. The traffic-side blockout at post no. 15 bent 11 in. from its top. The front flange of the traffic-side blockout at post no. 16 bent slightly at the top. Soil gaps were found around post nos. 11 through 16. Soil heave formed around post nos. 12 thorough 15. No damage was observed on the remainder of the posts.

Figure 63. System Damage, Test No. MTB-2

Figure 64. Traffic-Side Damage, Post Nos. 12 through 15, Test No. MTB-2

Figure 65. Damage between Post Nos. 12 through 15, Test No. MTB-2

The maximum lateral permanent set of the barrier system was 7.6 in., which occurred at post no. 13, as measured via GPS. The maximum lateral dynamic barrier deflection, was 16.1 in. at post no. 13, as determined from high-speed digital video analysis. The working width of the system was found to be 56.0 in., also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 66.

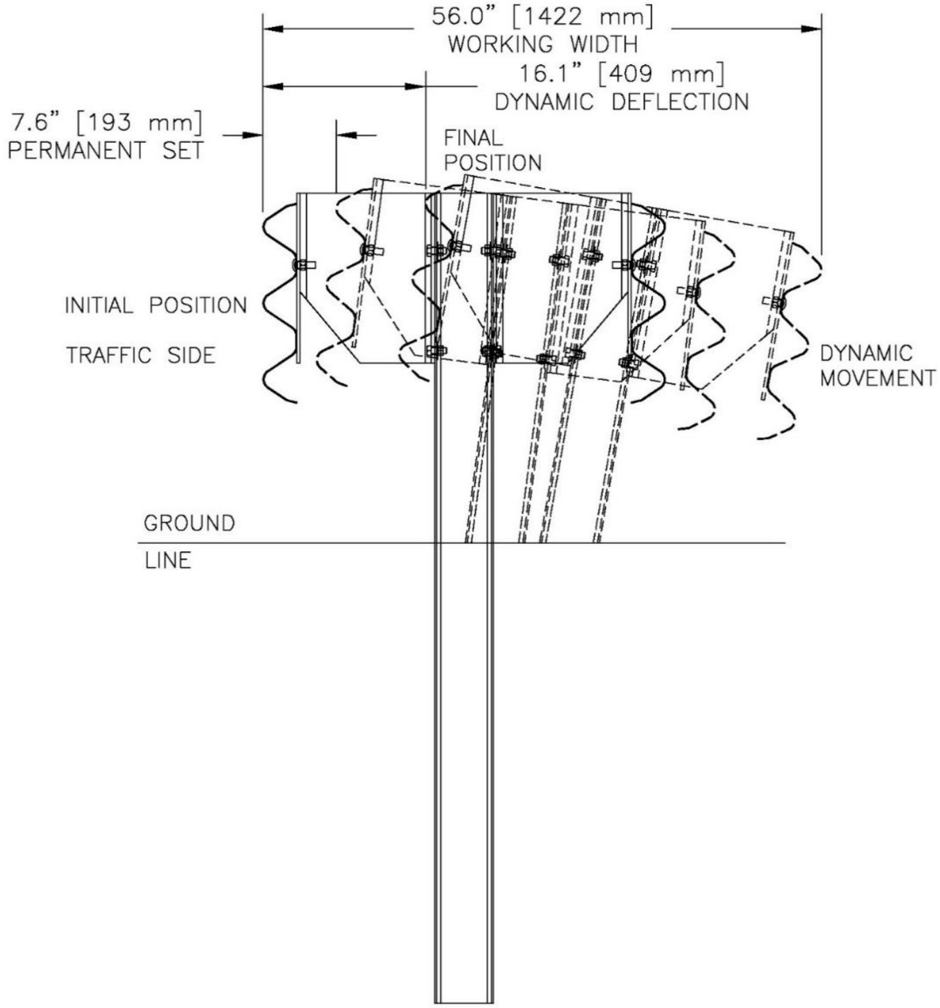


Figure 66. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. MTB-2

7.5 Vehicle Damage

Damage to the vehicle was moderate, as shown in Figures 67 through 70. The maximum occupant compartment intrusions are listed in Table 10, along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. There were no penetrations into the occupant compartment and none of the established MASH 2016 deformation limits were violated. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix E.

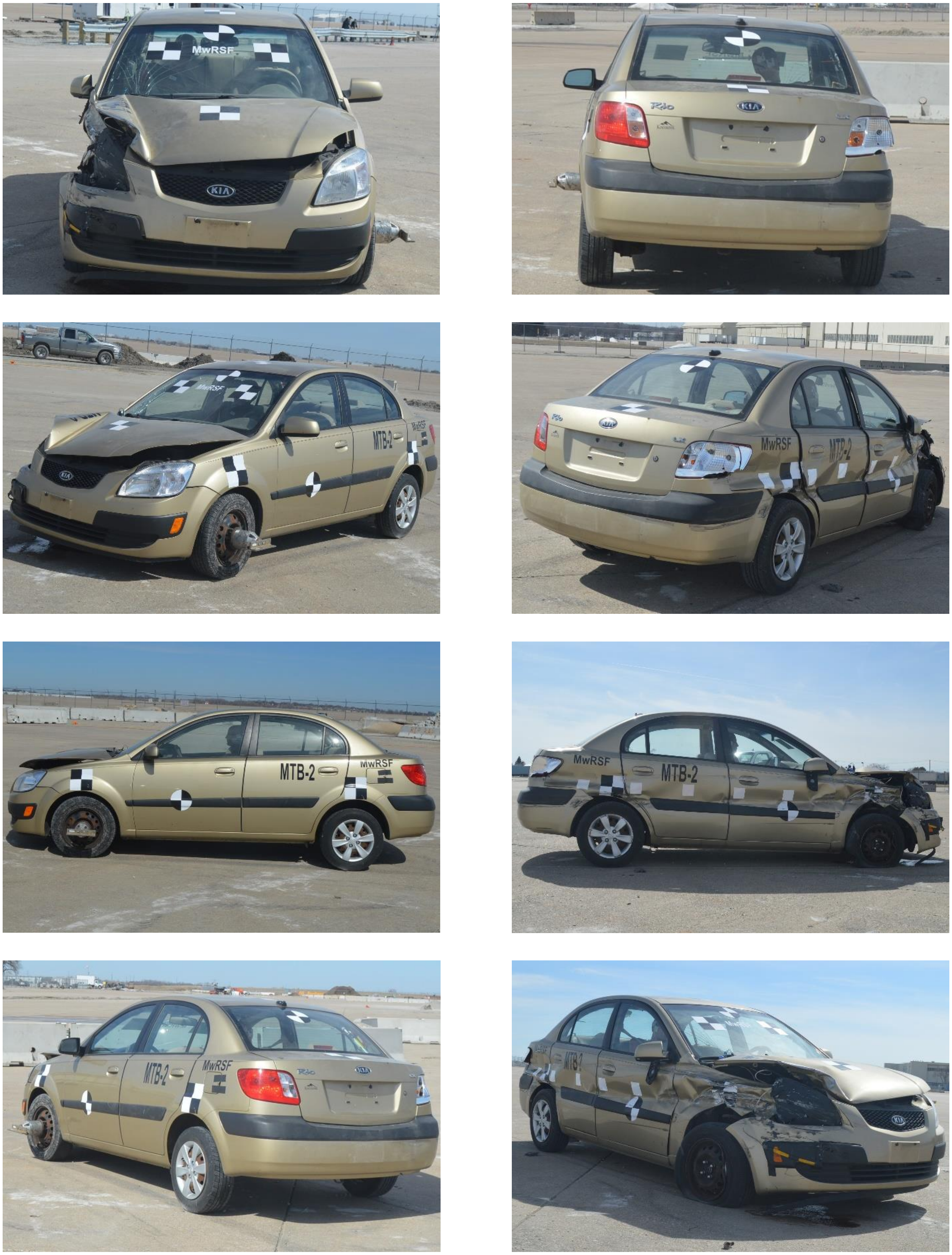


Figure 67. Vehicle Damage, Test No. MTB-2

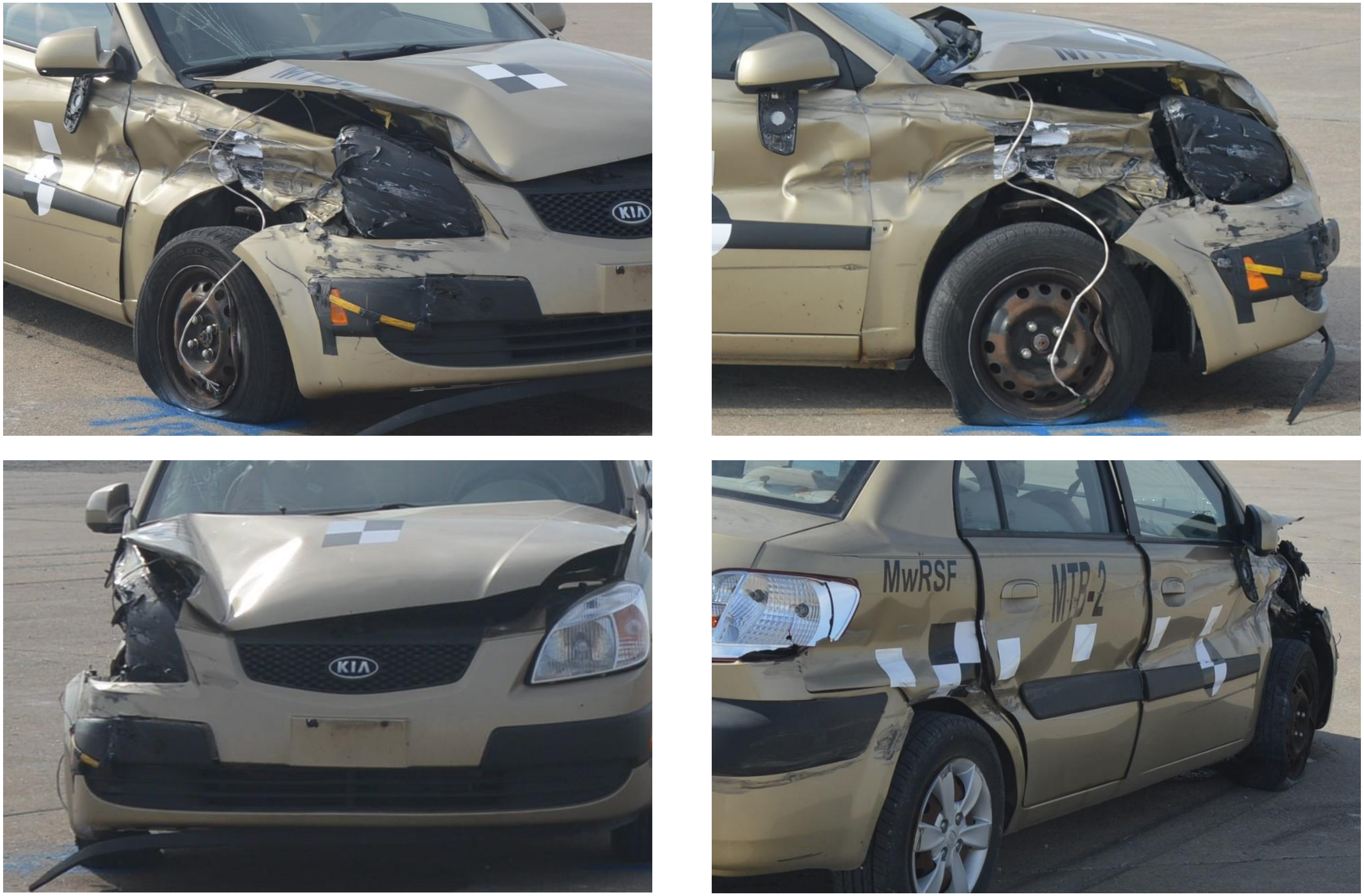


Figure 68. Vehicle Damage, Test No. MTB-2

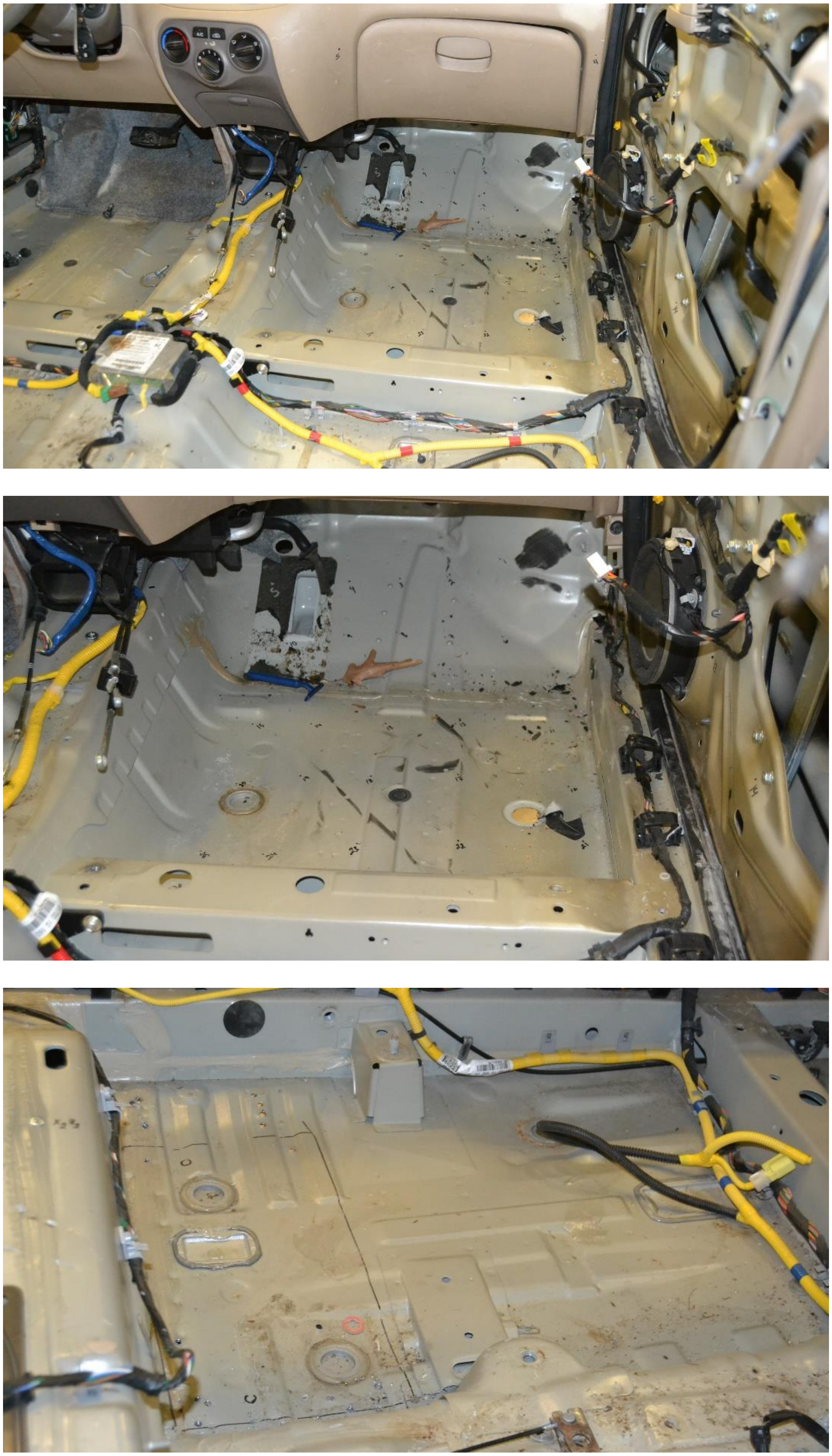


Figure 69. Occupant Compartment Damage, Test No. MTB-2

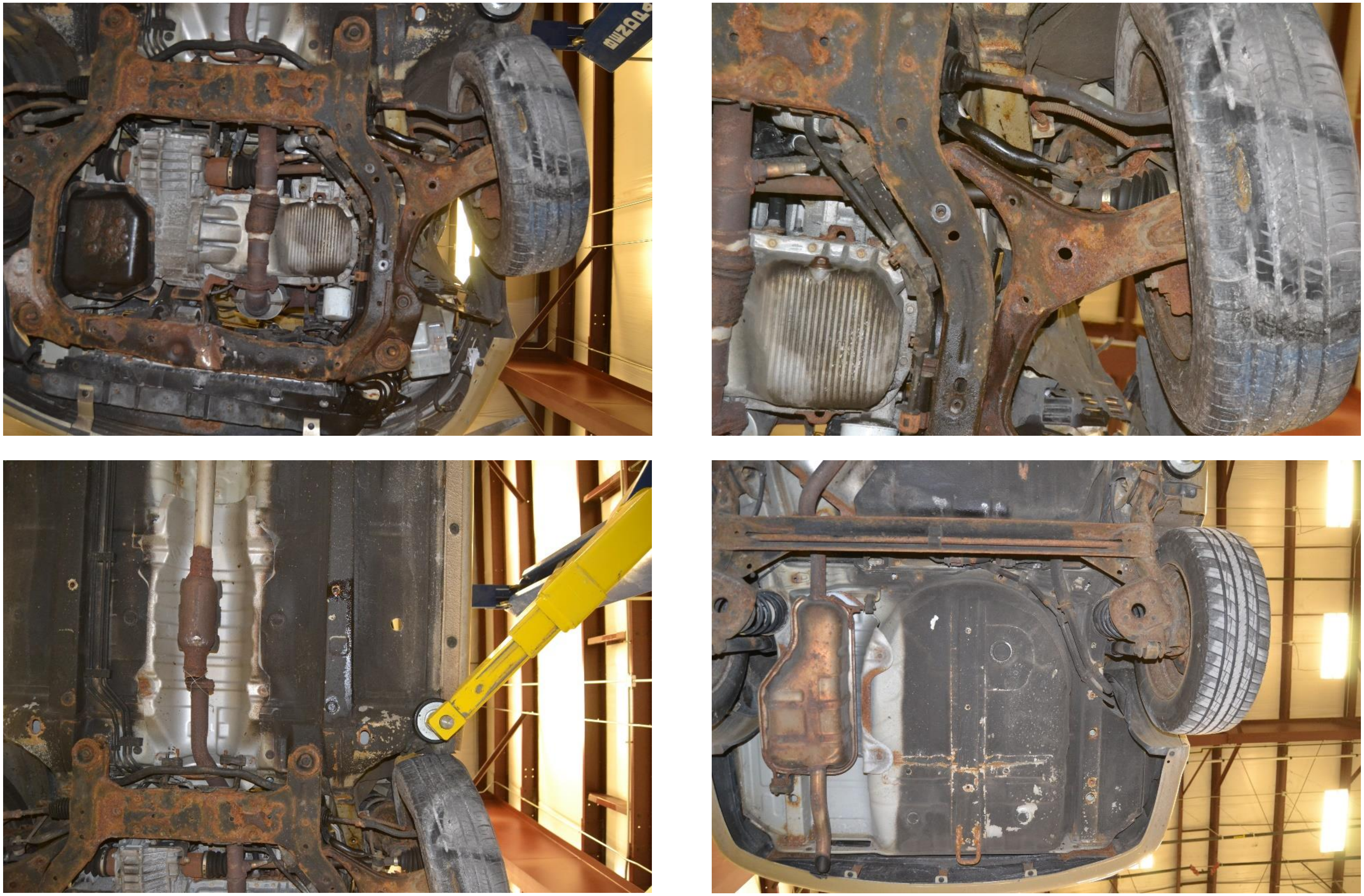


Figure 70. Vehicle Undercarriage Damage, Test No. MTB-2

Table 10. Maximum Occupant Compartment Intrusions by Location, Test No. MTB-2

LOCATION	MAXIMUM INTRUSION in.	MASH 2016 ALLOWABLE INTRUSION in.
Wheel Well & Toe Pan	0.5	≤ 9
Floor Pan & Transmission Tunnel	0.3	≤ 12
A-Pillar	0.2	≤ 5
A-Pillar (Lateral)	−0.2	N/A[2]
B-Pillar	0.2	≤ 5
B-Pillar (Lateral)	0.2	≤ 3
Side Front Panel (in Front of A-Pillar)	0.1	≤ 12
Side Door (Above Seat)	0.1	≤ 9
Side Door (Below Seat)	−0.7	N/A[2]
Roof	0.1	≤ 4
Windshield	0	≤ 3
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	0.4	N/A[1]

Note: Negative values denote outward deformation
N/A[1] – No MASH 2016 criteria exist for this location
N/A[2] – MASH 2016 criteria are not applicable when deformation is outward

The majority of the damage was concentrated on the right-front corner and the right side where impact occurred. The hood kinked on the right side. The front bumper detached, and the right-front quarter panel was deformed inward and scraped. The right-front door was deformed inward along its length and dented near the handle. The right-rear door was dented and scraped along its length. The right-rear quarter panel was crushed inward and scraped along its length. The right-rear wheel well was crushed inward, and the right-front wheel was dented due to contact with post no. 13. The right taillight was broken, and the cover was disengaged. The windshield was cracked and buckled outward. The rest of the window glass and roof were undamaged. The right-side spring perch was bent. The right lower control arm was bent backward. The front cross member of the vehicle was bent upward near the mid point.

7.6 Occupant Risk

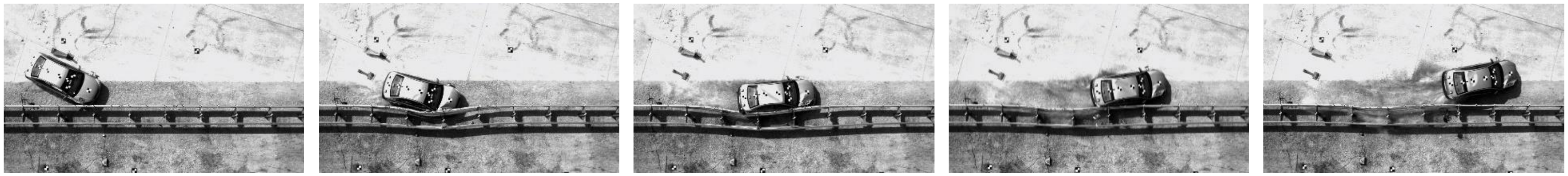
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 11. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 11. The results of the occupant risk analysis are summarized in Figure 71. The recorded data from the accelerometers and rate transducers are shown graphically in Appendix F.

Table 11. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. MTB-2

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (primary)	SLICE-2	
OIV ft/s	Longitudinal	−16.73	−17.76	±40
	Lateral	−24.18	−23.39	±40
ORA g's	Longitudinal	−7.27	−5.45	±20.49
	Lateral	−10.62	−10.93	±20.49
MAX. ANGULAR DISPL. deg.	Roll	6.9	−8.9	±75
	Pitch	−3.7	−4.3	±75
	Yaw	−35.6	−36.2	not required
THIV ft/s		27.31	25.15	not required
PHD g's		11.20	11.46	not required
ASI		1.29	1.21	not required

7.7 Discussion

The analysis of the test results for test no. MTB-2 showed that the system adequately contained and redirected the 1100C vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown in Figure 71. 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. After impact, the vehicle exited the barrier at an angle of 13.4 deg., and its trajectory did not violate the bounds of the exit box. Therefore, test no. MTB-2 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-10.



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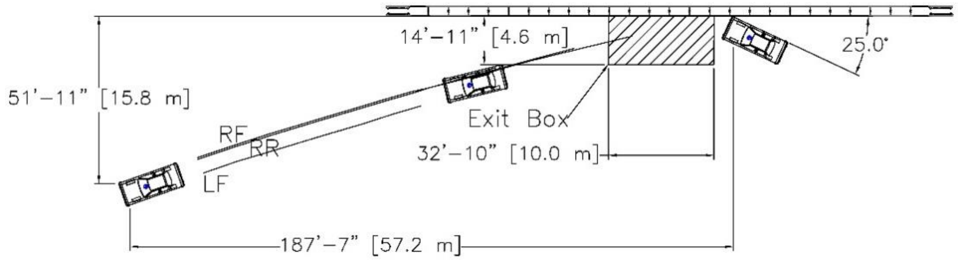

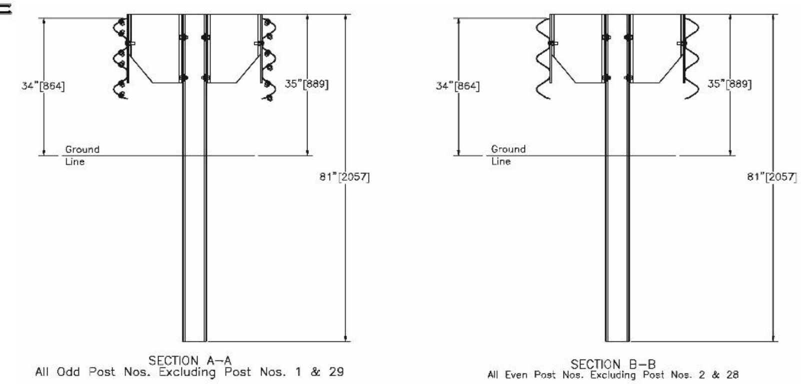

- Test Agency .... MwRSF
- Test Number MTB-2
- Date .... March 22, 2019
- MASH 2016 Test Designation No. 3-10
- Test Article .... NJDOT-Caltrans Modified Thrie Beam
- Total Length .... 176 ft – ½ in.
- Key Component – Steel Thrie Beam Guardrail
  - Thickness .... 12 gauge
  - Top Mounting Height .... 34 in.
- Key Component – Steel Post
  - Shape W6x8.5
  - Length .... 81 in.
  - Embedment Depth .... 46 in.
  - Spacing .... 75 in.
- Key Component – Steel Blockout (Post Nos. 3-27)
  - Shape W14x22
- Soil Type .... Coarse, Crushed Limestone
- Vehicle Make / Model .... 2009 Kia Rio
  - Curb .... 2,497 lb
  - Test Inertial .... 2,415 lb
  - Gross Static .... 2,579 lb
- Impact Conditions
  - Speed .... 63.1 mph
  - Angle .... 24.9 deg.
  - Impact Location .... 7 ft – 6.4 in. upstream from post no. 13
- Impact Severity .... 57.2 kip-ft > 51 kip-ft limit from MASH 2016
- Exit Conditions
  - Speed .... 45.9 mph
  - Angle .... 13.4 deg.
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 187 ft – 7 in.
- Exit Box Criterion .... Pass
- Vehicle Damage .... Moderate
  - VDS [18] 1-FRQ-3
  - CDC [19] 01-FDEW-9
  - Maximum Interior Deformation .... 0.5 in.
- Test Article Damage .... Moderate
- Maximum Test Article Deflections
  - Permanent Set .... 7.6 in.
  - Dynamic .... 16.1 in.
  - Working Width .... 56.0 in.
- Transducer Data

Evaluation Criteria		**Transducer**		**MASH 2016 Limit**
		SLICE-1 (primary)	**SLICE-2**	
OIV ft/s	Longitudinal	−16.73	−17.76	±40
	Lateral	−24.18	−23.39	±40
ORA g's	Longitudinal	−7.27	−5.45	±20.49
	Lateral	−10.62	−10.93	±20.49
MAX ANGULAR DISP. deg.	Roll	6.9	−8.9	±75
	Pitch	−3.7	−4.3	±75
	Yaw	−35.6	−36.2	not required
THIV – ft/s		27.31	25.15	not required
PHD – g's		11.20	11.46	not required
ASI		1.29	1.21	not required

Figure 71. Summary of Test Results and Sequential Photographs, Test No. MTB-2

8 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The research detailed in the report describes the full-scale crash testing and evaluation of the modified thrie beam guardrail system to MASH TL-3 in both a single-sided roadside configuration and a dual-sided median barrier configuration. Two full-scale crash tests are required to evaluate a longitudinal barrier such as the modified thrie beam guardrail. Review of the system configurations and test requirements led the researchers to determine that test designation no. 3-11 was critical for evaluation of the single-sided roadside configuration in order to maximize structural loading of the barrier system, evaluate the potential for collapse of the wide flange of the blockouts, and determine the maximum dynamic deflection and working width. Test designation no. 3-10 was selected to evaluate the dual-sided median barrier configuration as this configuration would tend to produce increased loading and occupant risk values for the small car and increase the propensity for vehicle snag on the post due to the higher stiffness and reduced dynamic deflection of the dual-sided configuration. Previous evaluation of the T-39 thrie beam barrier for both roadside and median versions followed a similar methodology [8]. Thus, two full-scale crash tests were conducted for evaluation of the modified thrie-beam guardrail.

Test no. MTB-1 consisted of test designation no. 3-11, in which a 5,003-lb quad cab pickup truck impacted the MTB guardrail at a speed of 62.9 mph and an angle of 25.4 deg., resulting in an impact severity of 121.8 kip-ft. Impact occurred 11 ft – 5.7 in. upstream from post no. 13, and the vehicle exited the system at a speed of 40.7 mph and an angle of 15.0 deg. The vehicle was contained and smoothly redirected with moderate damage to both the system and vehicle. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH 2016. Therefore, test no. MTB-1 was successful according to the safety criteria of MASH 2016 test designation no. 3-11.

Test no. MTB-2 consisted of test designation no. 3-10, in which a 2,415-lb small car impacted the MTB guardrail at a speed of 63.1 mph and an angle of 24.9 deg., resulting in an impact severity of 57.2 kip-ft. Impact occurred 7 ft – 6.4 in. upstream from post no. 13, and the vehicle exited the system at a speed of 45.9 mph and an angle of 13.4 deg. The vehicle was contained and smoothly redirected with moderate damage to both the system and vehicle. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH 2016. Therefore, test no. MTB-2 was successful according to the safety criteria of MASH 2016 test designation no. 3-10. A summary of the safety performance evaluation for both tests is provided in Table 12.

Based on the results of the two successful full-scale crash tests conducted in this study, the modified thrie-beam guardrail system meets all safety requirements for MASH 2016 TL-3 for both single-sided roadside and dual-sided median configurations.

Table 12. Summary of Safety Performance Evaluation

<table>
<tr><th>Evaluation Factors</th><th colspan="4">Evaluation Criteria</th><th>Test No. MTB-1</th><th>Test No. MTB-2</th></tr>
<tr><td>Structural Adequacy</td><td colspan="4">A. 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>S</td><td>S</td></tr>
<tr><td rowspan="11">Occupant Risk</td><td colspan="4">D. 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 5.3 and Appendix E of MASH.</td><td>S</td><td>S</td></tr>
<tr><td colspan="4">F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 deg.</td><td>S</td><td>S</td></tr>
<tr><td colspan="4">H. Occupant Impact Velocity (OIV) (see Appendix A, Section A5.3 of MASH for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td><td rowspan="4">S</td></tr>
<tr><td rowspan="3"></td><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</td><td>40 ft/s</td></tr>
<tr><td colspan="4">I. The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.3 of MASH for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td><td rowspan="4">S</td></tr>
<tr><td rowspan="3"></td><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 Test Designation Number</td><td>3-11</td><td>3-10</td></tr>
<tr><td colspan="5">Pass/Fail</td><td>Pass</td><td>Pass</td></tr>
</table>

S – Satisfactory U – Unsatisfactory NA – Not Applicable

9 RECOMMENDATIONS

The MASH TL-3 modified thrie beam guardrail systems detailed herein was evaluated using a basic test configuration on level terrain in both roadside and median configurations. Real-world installations will have other considerations for the application of the design that should be considered. The following sections provide recommendations for implementation of the modified thrie beam guardrail.

9.1 MASH TL-4

The modified thrie beam guardrail system was previously successfully tested to NCHRP Report No. 350 TL-4. Based on its previous use as a TL-4 system, users may desire to use the modified thrie beam guardrail as a TL-4 barrier under MASH as well. While the design of the modified thrie beam guardrail system may have increased capacity as compared to standard W-beam guardrails due to its mounting height and use of thrie beam rail elements, there are concerns with its ability to meet MASH TL-4 safety criteria. Test designation no. 4-12 required for MASH TL-4 consists of a 22,000-lb single unit truck (SUT) impacting the barrier at 56 mph and an angle of 15 degrees. This test differs significantly from test designation no. 4-12 in NCHRP Report No. 350, which consists of a 17,637-lb SUT vehicle impacting the barrier at 49.7 mph and an angle of 15 degrees. The increased mass and speed required in MASH test designation no. 4-12 has led to increased barrier loads during crash testing of TL-4 barriers. Additionally, rigid barrier heights required to meet MASH TL-4 have increased to 36 in. in order to capture and contain the SUT vehicle. Based on the increased MASH TL-4 requirements, it is unknown if the modified thrie beam guardrail can effectively meet MASH TL-4 without full-scale crash testing.

9.2 Transitioning to the MGS

For certain applications, such as terminating the barrier system, end users may wish to transition the modified thrie beam guardrail to the MGS. This transition requires both a transition in the beam section, a guardrail height transition, and a transition of the splices to the midspan between posts. It is recommended that a 10-gauge symmetrical W-to-thrie transition section be used to accomplish the rail section transition from thrie beam to W-beam. The symmetrical W-to-thrie transition section will also transition the rail height from a 34-in. tall thrie beam down to a 30⅛-in. tall W-beam guardrail. In order to reach the nominal 31-in. height of the MGS, it is recommended that the height of the W-beam rail be transitioned up ⅞ in. over one 12½-ft long W-beam segment.

If transitioning to the MGS, there is a need to transition the splices to the midspan as well. It is recommended that this be accomplished by placing the first post downstream from the symmetrical W-to-thrie transition piece at ½ post spacing and then using standard spacing from that point on. A schematic of the recommended transition is shown in Figure 72. The total length of the transition is 18.75 ft.

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 verify the performance of the transition.

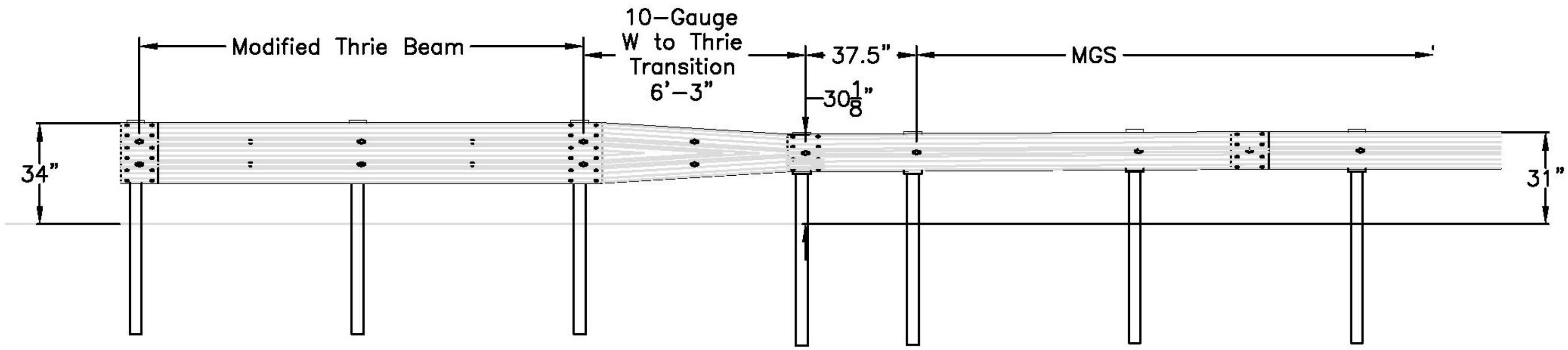

Figure 72. Modified Thrie Beam Transition to MGS

9.3 Guardrail Terminals and Anchorages

It should also be noted that the modified thrie beam guardrail system constructed for use in this testing program utilized trailing end cable anchorages installed on each end of the barrier system. The function of these cable anchorages was to develop the appropriate rail tension required to simulate a typical field installation of the barrier which would typically be longer than a standard test installation and have some form of anchorage on each end. Note that these anchors were installed after transitioning to W-beam guardrail such that a standard trailing end anchorage could be employed. No current trailing end anchorage or end terminal design has been full-scale tested for use with modified thrie beam guardrail. Thus, it is recommended that field installations of the modified thrie beam guardrail transition to MGS guardrail at the end of the system and then employ a MASH tested trailing end anchorage or end terminal design. Details on transitioning to the MGS are contained in the previous section.

Guardrail terminals are sensitive systems that have been carefully designed to satisfy safety performance standards. Thus, installation of the modified thrie beam guardrail within the length that a terminal requires to function properly could degrade the system's crashworthiness. Thus, for energy absorbing terminals, it is recommended to have a minimum length of 12.5 ft of standard MGS between the inner end of a guardrail terminal, identified by system stroke length, and the transition to the modified thrie beam guardrail, as shown in Figure 73.

Non-energy absorbing terminals typically flare away from the roadway utilizing either an angled or parabolic geometry. Both geometric layouts result in increased effective impact angles, which result in increased system deflections for impacts on or near the flared terminal. Due to the increase in system deflections associated with guardrail flares, at least 25 ft of tangent MGS should be used to separate a flared guardrail terminal and the transition to the modified thrie beam guardrail, as shown in Figure 73.

Installation of the modified thrie beam guardrail near W-beam guardrail trailing end anchorages may also affect system performance. Guidance has been previously provided for length-of-need and working width for MGS trailing-end anchorages [9-10]. However, modified thrie beam guardrail near W-beam trailing end anchorages would likely change system performance and make previous recommendations for the trailing end terminal behavior invalid. From the noted study, impacts beyond 43.75 ft from the end post resulted in consistent redirection and working width. In order to ensure that the modified thrie beam does not affect the performance of the W-beam trailing end anchorage, it would be conservative to place the modified thrie beam and associated transition to the MGS outside of the region 43.75 ft from the end post of the anchorage. Thus, it is recommended that the modified thrie beam guardrail and the associated transition to the MGS be located a minimum of 46 ft 10-½ in. from the downstream end of the trailing end anchorage, as shown in Figure 73.

Note that the dual-sided median version of the modified thrie beam guardrail would require a MASH TL-3 crashworthy median terminal for the W-beam guardrail. Trailing end terminals may not be applicable for the dual-sided median version of the modified thrie beam guardrail due to the potential for impact from reverse direction traffic unless the end of the system is outside the clear zone for both traffic directions. Similarly, there are no non-energy absorbing, median end terminals. Thus, implementation of energy-absorbing guardrail terminals with the dual-sided median version of the modified thrie beam guardrail should follow similar guidance as the roadside version in terms of the transitioning to the MGS and the location of terminal relative to the modified thrie beam.

End users may also want to consult with the manufacturers of the end terminal systems for any additional guidance or information that they can provide.

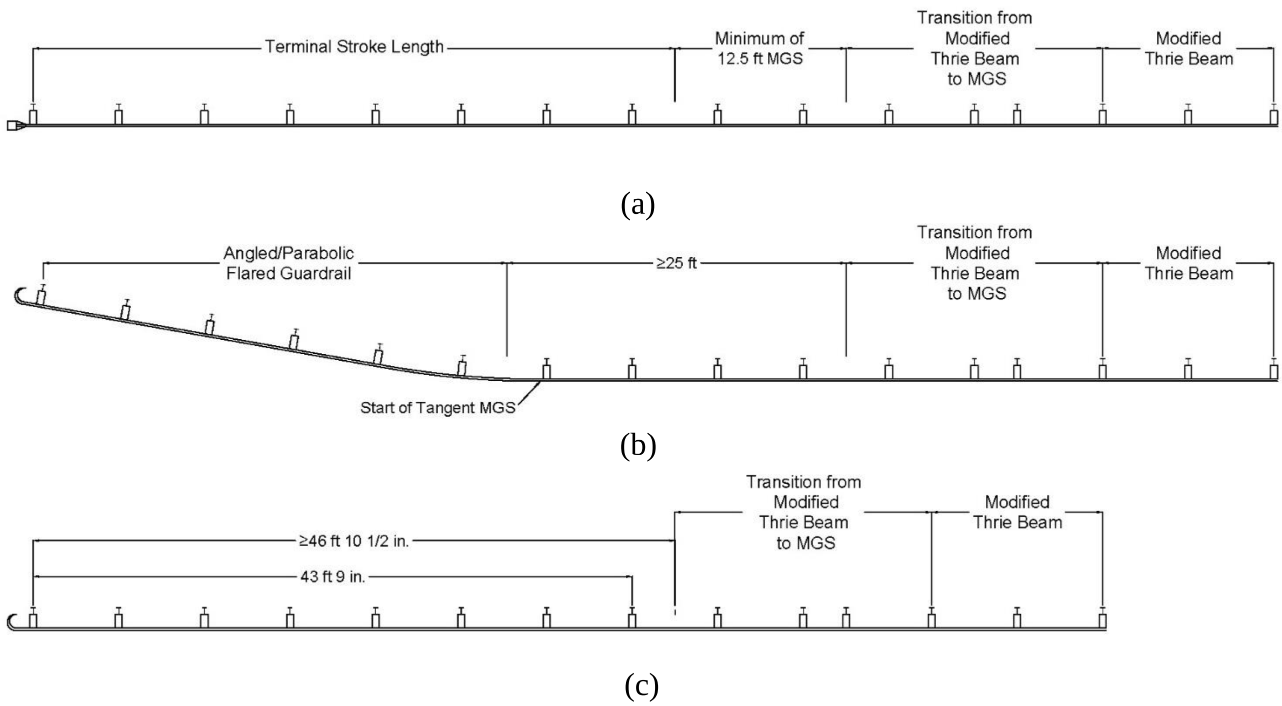

Figure 73. Recommended Distance between Modified Thrie Beam and (a) Energy-Absorbing Terminals, (b) Flared Terminals, and (c) Trailing-End Guardrail Anchorages

9.4 Transitioning to Thrie-Beam AGTs

Another consideration for implementation of the modified thrie beam guardrail system is the attachment of the system directly to a thrie-beam approach guardrail transition (AGT). It is recommended that the modified thrie beam guardrail be attached to a MASH-compliant thrie beam AGT that is crashworthy at both the upstream stiffness transition and the attachment to the bridge rail or parapet. MwRSF has previously developed an upstream stiffness transition for use when transitioning between the MGS and thrie beam AGTs [20-21]. This upstream stiffness transition should be applicable to the modified thrie beam as well because the barrier system would have similar or greater stiffness than the MGS system. Details on attachment of the upstream stiffness transition from the MGS to a variety of crashworthy thrie beam AGTs were described in the original research reports.

A schematic outlining the basic parts of a thrie beam AGT and upstream stiffness transition to the MGS is shown in Figure 74. Application of the MGS upstream stiffness transition to the connection of the modified thrie beam to a MASH compliant thrie beam AGT should not require transitioning of the rail element as the modified thrie beam and the AGT both use thrie beam rail elements. However, in order to apply the previously developed upstream stiffness transition to a crashworthy thrie beam AGT, several minor adjustments to the basic schematic in Figure 74 are needed.

1. The MASH TL-3 thrie beam AGT region on the downstream end of the transition can use the post spacing and rail configuration of any MASH TL-3 compliant AGT. It should be noted that the selected MASH TL-3 compliant AGT should be compatible with the bridge rail/end buttress being used.

2. In the upstream stiffness transition region, the 6.25-ft long, 10-gauge W- to thrie transition section and the 6.25-ft long, 12-gauge thrie beam are replaced by a single 12.5-ft long thrie beam section.

3. In the upstream stiffness transition region, it is recommended to use the same W6x8.5 or W6x9 posts at the same spacing used in the original MASH-tested design. Note that end users could elect to use up to 81-in. long posts in that region as well if it was desired to limit the number of post types in the system. For example, many thrie beam AGTs use 78-in. long posts at reduced post spacing and the modified thrie beam uses 81-in. long posts. As such, it may be desired to use one of these post alternatives to limit the number of post types in inventory. It is believed that this increase in the post depth would not negatively affect the upstream stiffness transition region as the modified thrie beam is already using 81-in. long posts.

4. In the upstream stiffness transition region, it is recommended to use 6-in. x 12-in. x 19-in. southern yellow pine blockouts. These blockouts are required in the upstream stiffness transition to reduce vehicle snag on the posts in that region. During MASH TL-3 testing of the upstream stiffness transition, researchers observed significant wheel snag with the small car and pickup truck on the posts in the upstream stiffness transition area where the vehicle engaged in the ½ post spacing. As such, there is concern with reducing blockout depth in that region. Additionally, it is not recommended to use the W14x22 blockouts from the modified thrie beam in that region due to their tendency to collapse in the web and potentially reduce their effective depth which may similarly increase the snag concern. MwRSF has also previously recommended the use of an alternative HSS 12x4x¼ by 17.5-in. long blockout for the upstream stiffness transition [22], as shown in Figure 75. Note that Figure 75 also depicts a 6-in. x 12-in. x 18-in. southern yellow pine blockout. This slightly shorter timber blockout is also acceptable for use in the upstream stiffness transition region.

5. The first post on the upstream end of the upstream stiffness transition can be removed. This post exists in the transition from MGS to a bridge rail to provide an improved stiffness transition and aid in aligning the splices with the posts for the AGT. Because the modified thrie beam system has splices at the posts by default, the need to transition the splice location is eliminated. Additionally, the consistent post spacing and the increased stiffness and reduced deflection of the modified thrie beam system on the upstream end of the transition eliminate the need for this post to provide an adequate transition in stiffness.

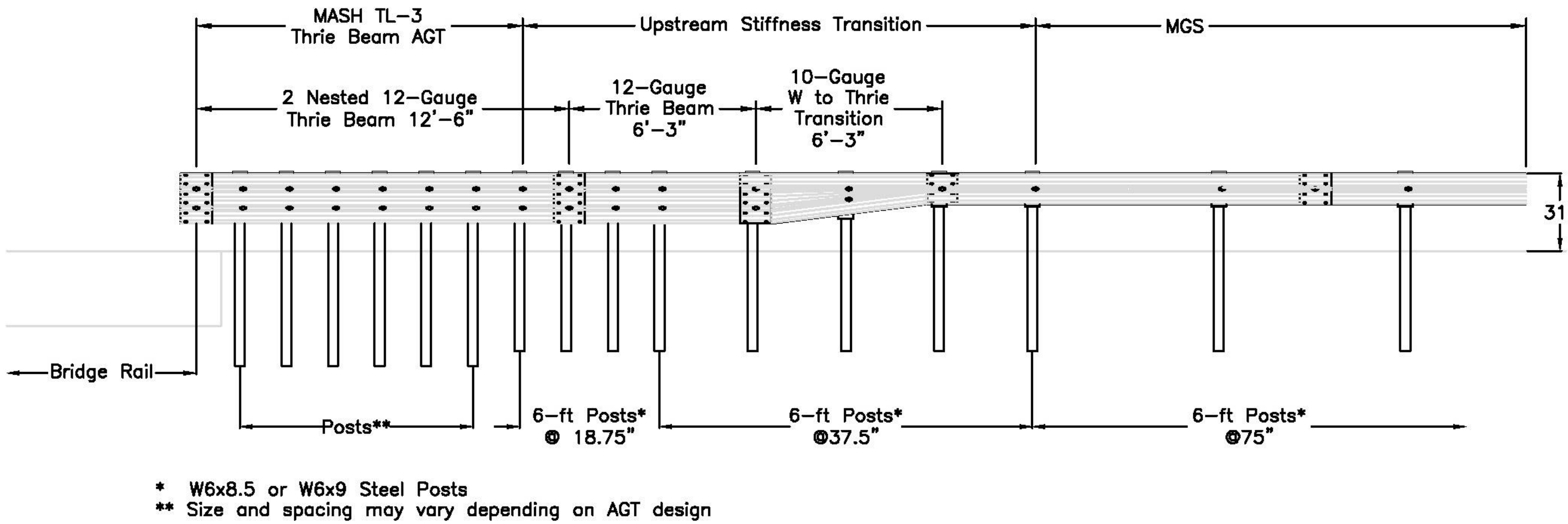

Figure 74. Schematic of Upstream Stiffness Transition from MGS to MASH TL-3 Thrie Beam AGT

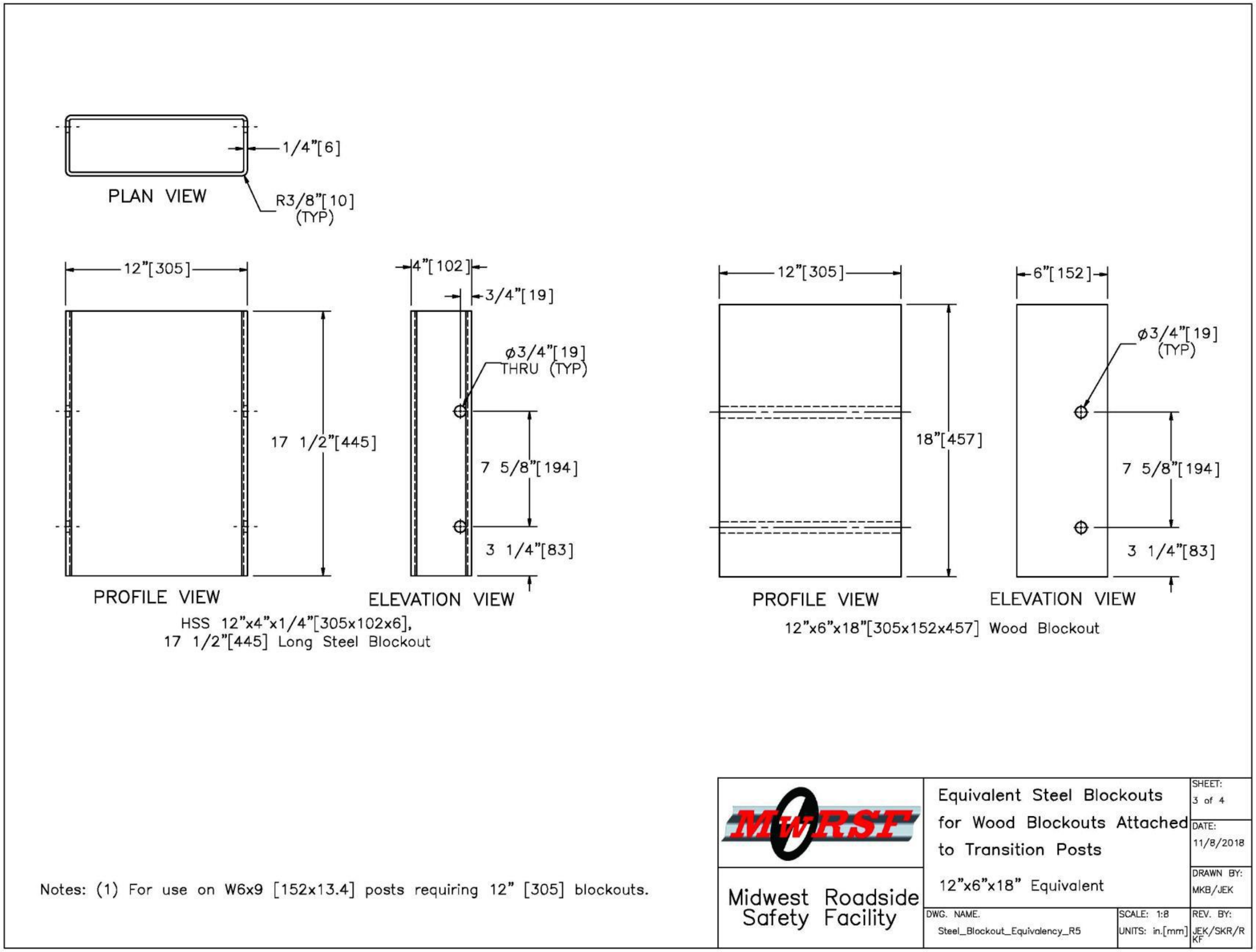

Figure 75. Alternative Steel Tube Blockout

6. Following the single 12.5-ft long thrie beam section, the modified thrie beam can be attached. The modified thrie beam will start at the 31-in. mounting height of the AGT and then transition to the standard modified thrie beam height of 34 in. over a distance of 25 ft to 50 ft. MwRSF and FHWA have previously had recommended height transitions for the MGS over similar lengths.

7. Following the height transition for the modified thrie beam, standard modified thrie beam as evaluated in this research study is applied.

8. Note that the use of curbs within the transition region would follow guidance published previously relative to AGTs and curbs [23].

As an example, a conversion from an existing AGT from MGS to a bridge rail has been completed in Figure 76. The existing AGT design consisted of the MGS guardrail, the MASH TL-3 tested upstream stiffness transition, and a MASH TL-3 compliant thrie beam transition to bridge rail, commonly called the "Iowa Transition," that utilizes 6.5-ft long, W6x8.5 or W6x9 posts at ¼ post spacing [24]. The conversion shown implements the transition conversion guidance above to an existing AGT design.

Note that the design shown in Figure 76 is very similar to the typical AGT design used by the New Jersey Department of Transportation with the exceptions that the New Jersey system uses a curb in the region adjacent to the bridge rail and uses slightly longer 86-in. long posts in the nested thrie beam region adjacent to the bridge rail. Both of these variations used by the New Jersey Department of Transportation would be acceptable within the recommendations for transitioning from modified thrie beam to existing AGTs.

Alternatively, MwRSF has evaluated a 34-in. tall AGT that uses the standardized end buttress developed through the Midwest Pooled Fund Program [25]. If desired, end users could apply this AGT design to attach to the modified thrie beam without a height transition. The basic configuration of the transition would be the same as the 31-in. tall transition detailed previously, except that there would be no height transition and the 34-in. tall modified thrie beam would be attached directly following the single 12.5-ft long thrie beam section. In order to use this alternative, the AGT would have to be attached to the standardized end buttress designed for 34-in. tall AGTs.

End users may also be interested in attachment of the modified thrie beam to MASH TL-2 compliant thrie beam approach guardrail transitions. Currently, only one thrie beam approach guardrail transition has been evaluated to MASH TL-2. The thrie beam approach guardrail transition shown in Figure 77 was evaluated to MASH TL-2 through three full-scale crash tests at TTI [26]. This TL-2 thrie beam AGT was identical to the previous MASH TL-3 upstream stiffness transition for thrie beam AGTs developed at MwRSF upstream of the downstream end of the W-to-thrie transition section. As such, the basic guidance provided previously for transitioning from modified thrie beam to MASH TL-3 AGTs would also apply to transitioning to the MASH TL-2 AGT system. However, there are three additional points that should be made with respect to attachment to the MASH TL-2 AGT design.

1. The MASH TL-2 AGT design evaluated at TTI utilized 8-in. deep blockouts in the AGT rather than 12-in. deep blockouts. As such, the use of 8-in. deep blockouts or 12-in. deep blockouts would be appropriate for the attachment of the modified thrie beam to the MASH TL-2 AGT.

2. The MASH TL-2 AGT design evaluated at TTI used a 37 ½-in. long, 10-gauge thrie beam section between the W-to-thrie transition section and the end shoe attachment to the parapet. Thus, it is recommended that the W-to-thrie transition section and the 37 ½-in. long, 10-gauge thrie beam section be replaced with a single 112 ½-in. long, 10-gauge or nested 12 gauge thrie beam section.

3. The MASH TL-2 AGT design evaluated at TTI was attached to a 36-in tall, single-slope parapet with a vertical taper over the final 3 ft of the parapet to reduce snag. It is believed that either this parapet shape or other parapet shapes that have been utilized with MASH TL-3 thrie beam AGTs could be applied for the TL-2 approach guardrail transition.

As an example, a conversion from the existing MASH TL-2 AGT has been completed in Figure 78.

A final note should be made with respect to transitioning from the downstream end of a bridge back to the modified thrie beam. If the downstream end of the bridge is within the clear zone for opposing traffic, then attachment of modified thrie beam should follow the guidance listed above for approach guardrail transitions. If the downstream end of the bridge is not within the clear zone for opposing traffic, it is often desirable to attached guardrail directly to the downstream end of the bridge parapet without a transition. In this scenario, the transition from a rigid parapet to the semi-flexible guardrail poses less of a risk for pocketing or snagging. As a result, the departing transition is typically designed to be much simpler (i.e., using only W-beam guardrail at standard post spacing rather than the post configurations used in typical approach guardrail transition systems).

The main concern with this type of simplified downstream transition from bridge rails is increased rail loading. The rigid concrete barrier will not deflect, thus potentially producing high tensile and/or shear forces in the rail at the edge of the rigid parapet that may result in tearing or rupture. This concern could be mitigated somewhat by the location of the first post downstream of the bridge rail. By placing the first downstream post closer to the end of the bridge rail, the propensity for the rail to be bent around the end of the bridge would be lowered. Thus, it may be worth considering placement of the first post 3.125 ft (quarter post spacing) or less from the end of the downstream bridge end. Additionally, modified thrie beam has considerably more cross-sectional area and capacity than W-beam guardrail. While W-beam guardrail ruptures have been observed in crash testing of stiffened barrier systems, thrie beam ruptures are relatively rare. This would indicate that the propensity for potential rail failure would be significantly less for a modified thrie beam guardrail transitioning directly off the downstream end of a bridge rail.

As such, the following recommendations can be made with respect to transitioning from the downstream end of a bridge rail to modified thrie beam. First, if the bridge end/modified thrie beam is within the clear zone of opposing traffic, then the recommendations for approach guardrail transitioning of modified thrie beam guardrail should be used on the downstream end of the bridge rail. Second, if the bridge end/modified thrie beam is outside of the clear zone of opposing traffic, it is believed that modified thrie beam can safely be attached directly to the end of the bridge rail as long as the following factors are met: first, standard thrie beam end connection hardware is used to attach the thrie beam rail to the parapet (terminal connectors, anchorage, etc.); and second, the first post downstream of the bridge rail should be 3.125 ft or less from the end of the parapet to limit rail loads.

It should be noted that the proposed transition designs recommended herein are based on the best currently available transition research and engineering judgment. Further analysis and full-scale crash testing would be required to fully verify the performance of the transitions.

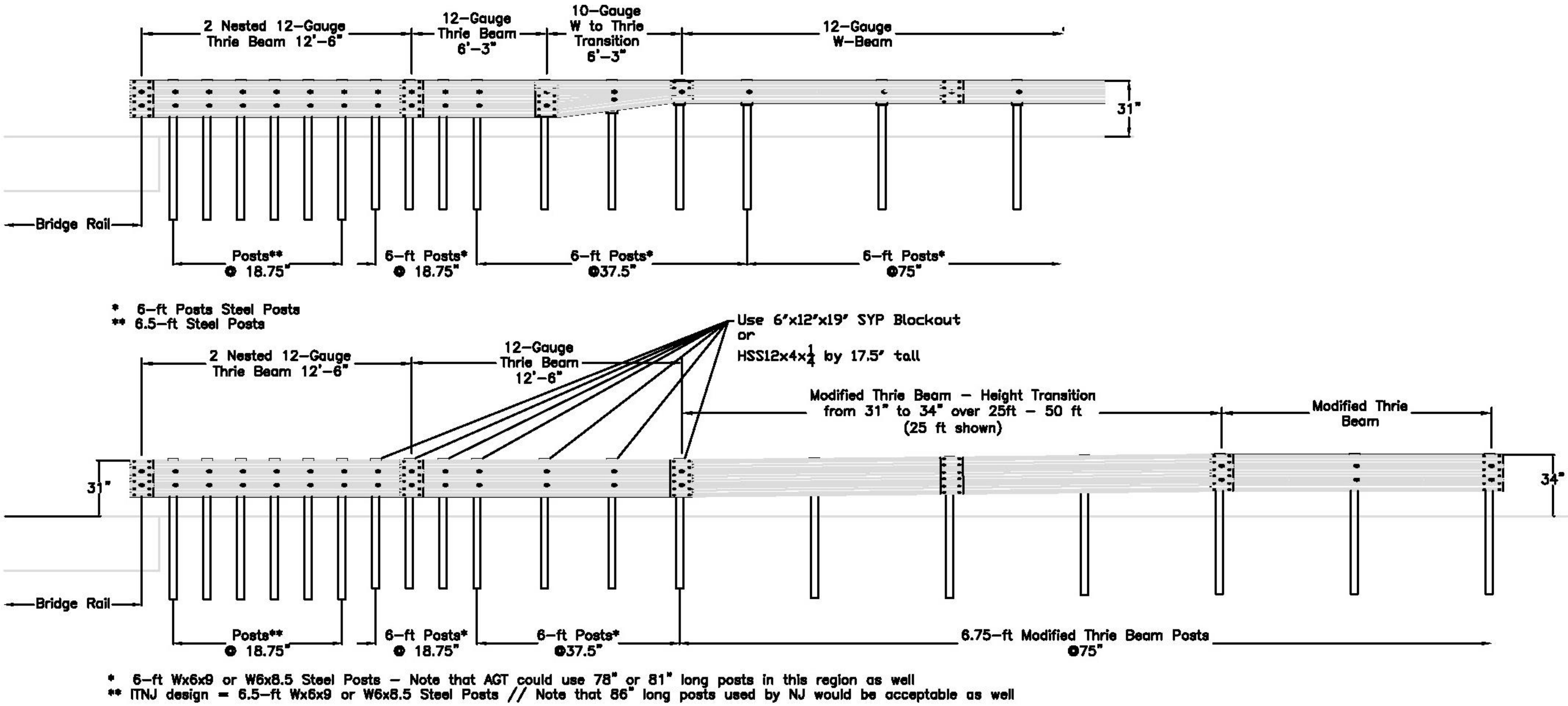

Figure 76. Modified Thrie Beam Transition to Thrie-Beam AGTs

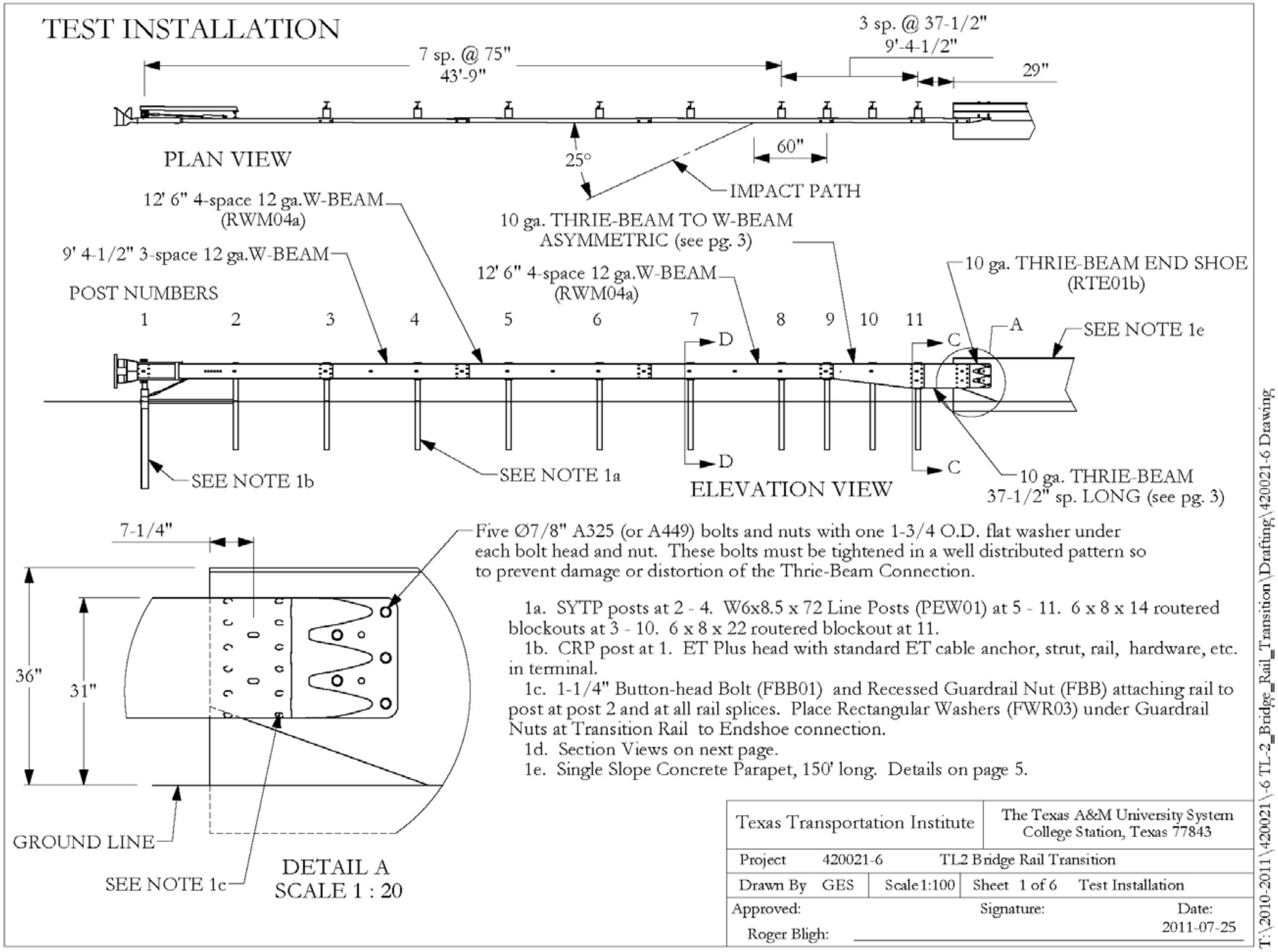

Figure 77. MASH TL-2 Thrie Beam Approach Guardrail Transition

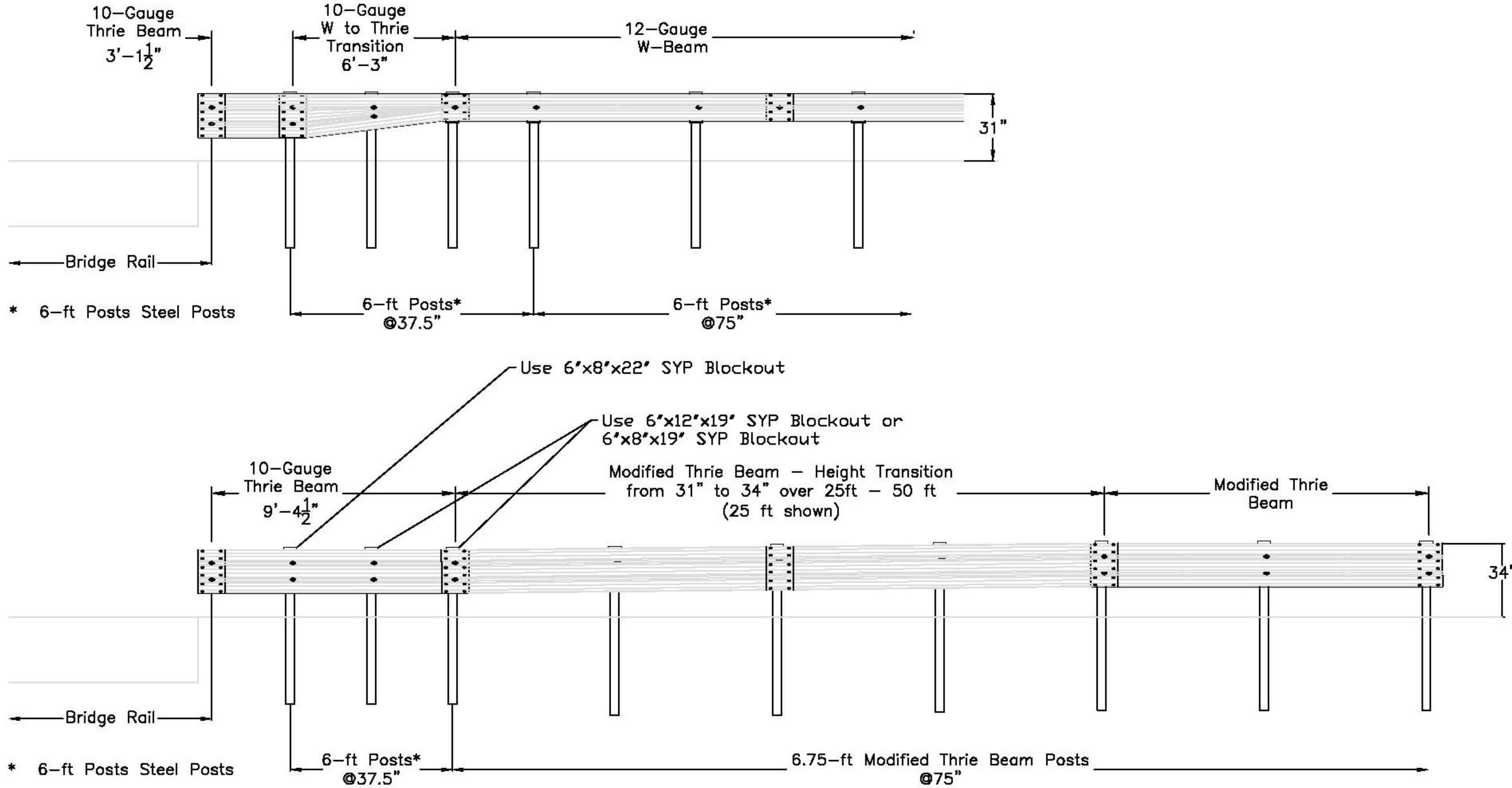

Figure 78. Modified Thrie Beam Transition to MASH TL-2 Thrie-Beam AGT

9.5 Working Width – Lateral Offset

During the crash testing program, test designation no. 3-11, test no. MTB-1, was conducted on the single sided roadside configuration of the modified thrie beam guardrail as this combination was expected to generate the maximum dynamic deflection for the barrier system. Working width of the system would be affected differently as the width of the overall particular version of the barrier factors into its determination. For example, the working width of the median version of the barrier is at least 40-1/8 in. based on the width of the system. The maximum dynamic deflection and working width observed in test no. MTB-1 were 34.4 in. and 49.3 in., respectively. These values should be applied to determine acceptable lateral offsets for the single-sided roadside version of the modified thrie beam system. While it is likely that the median barrier configuration would exhibit reduced dynamic deflection under test designation no. 3-11 than the single-sided roadside configuration, determination of the dynamic deflection and working width for the median barrier configuration would require further research and analysis through simulation or full-scale crash testing. As such, it is recommended that the dynamic deflection from test no. 3-11 on single-sided modified thrie beam be combined with the overall system width of the dual-sided barrier to estimate the working width for the dual-sided modified thrie beam under MASH TL-3 impacts. This would yield a conservative estimated working width value of 74 ½ in. for the dual-sided modified thrie beam system under MASH TL-3. As noted above, actual working widths would likely be considerably lower.

9.6 Grading Requirements

As with any barrier system, grading of the terrain adjacent to the modified thrie beam guardrail is an important aspect of its installation to ensure proper function of the system. The modified thrie beam guardrail should be installed on a maximum grade of 10H:1V as noted in the *Roadside Design Guide* [27]. Previous research under NCHRP Report No. 350 indicated that approach slopes as steep as 8H:1V could be accommodated by the MGS for limited offsets [28]. This may suggest that the increased rail height and thrie beam coverage provided by modified thrie beam guardrail could potentially allow for the use of steeper approach slopes than the 10H:1V slope recommended above. However, additional research and testing would be required to confirm and define performance limits of the barrier with respect to steeper approach slopes.

Installation of the median barrier configuration of the modified thrie beam guardrail in v-ditches or flat-bottom ditches with slopes greater than 10H:1V is not recommended at this time. Research and full-scale crash testing of cable median barriers has indicated that traversal of v-ditches with 6H:1V and 4H:1V slopes can significantly affect barrier performance in terms of vehicle capture and stability. Thus, it is anticipated that similar issues with barrier performance may occur if the median modified thrie beam guardrail is installed in ditches with slopes greater than 10H:1V.

End users also often use longitudinal barrier systems to shield steep slopes. Typically, 2 ft of level terrain is recommended to be placed behind W-beam guardrail systems to ensure development of adequate post-soil forces. A similar offset would be 2 ft recommended for the modified thrie beam guardrail evaluated herein. Note that the MGS has been successfully evaluated at MASH TL-3 when installed at the slope break point of 2H:1V slopes or flatter slopes with 6-ft long posts at standard 75-in. post spacing [29]. Modified thrie beam guardrail uses the same posts section as the MGS with 6-in. deeper embedment. The top rail height of the modified thrie beam is 3 in. higher than the MGS, but the thrie beam rail element on modified thrie beam guardrail extends $4^{11}/_{16}$ in. lower than the MGS. As such, modified thrie beam would be expected to have similar or improved vehicle capture and increased post-soil restive forces as compared to the standard MGS installed at the slope break point of a 2H:1V slope. Thus, it is believed that modified thrie beam would perform acceptably under MASH TL-3 impact conditions when installed at the slope break point of 2H:1V or shallower slopes. It should be noted that this recommendation is based on the best currently available research and engineering judgment. Further analysis and full-scale crash testing would be required to fully verify the performance of the modified thrie beam adjacent to slopes.

9.7 Curbs

There may be a desire to install the modified thrie beam guardrail adjacent to a curb and gutter to address water flow and drainage issues. It is known that vehicle traversal of curbs can affect vehicle trajectory, including vehicle pitch and the height of the vehicle bumper and front-end structure. Thus, impacts that include a traversal of the curb prior to impact with the barrier may affect the vehicle trajectory and capture. Additionally, previous full-scale testing of guardrail with curbs had indicated the potential for increased rail loads and rail rupture due to increased post embedment and wedging of the vehicle underneath the guardrail. Previous testing of the MGS with curbs has indicated that the MGS is capable of meeting MASH TL-3 if the curb offset for a 6-in. tall AASHTO Type B curb is less than or equal to 6 in. in front of the face of rail [30]. However, no full-scale testing has been conducted on thrie-beam guardrail adjacent to curb to prove that it provides similar performance.

There are concerns with using modified thrie beam guardrail adjacent to curbs. Previous testing of upstream stiffness transitions for thrie beam AGTs have shown a tendency for small car vehicles to become wedged between the curb and the bottom of the rail segment, which increases the deceleration of the small car and increases the loading of the rail element [23]. There is an additional concern with respect to impacts on modified thrie beam guardrail adjacent to curb with the 2270P pickup truck vehicle in terms of vehicle capture. Because the use of the curb reduces the clear space between the bottom of the guardrail and the ground or curb, there is potential for the pickup truck wheel to ride up the curb and then continue to ride up the rail. This may lead to poor vehicle capture and vaulting of the vehicle. A similar behavior was observed in early testing of the thrie beam bullnose barrier under NCHRP Report No. 350 [31-33].

As such, the use of modified thrie beam guardrail adjacent to curbs is not recommended at this time, and further research would be required to determine the effect curbs adjacent to the barrier. If the modified thrie beam guardrail were transitioned to a thrie-beam AGT or the MGS, curbs could be used with those regions in accordance with previous crash testing and guidance.

9.8 Flaring

Flaring of the modified thrie beam guardrail may also be desired in certain applications. The flare rates used for the modified thrie beam guardrail should be obtained based on guidelines set forth in the AASHTO *Roadside Design Guide*, or other applicable research. Currently, there is no MASH TL-3 guidance for flare rates for the thrie beam guardrail system outside of the recommendation in the AASHTO *Roadside Design Guide*.

9.9 Blockout Types

The modified thrie beam guardrail evaluated in this study used a W14x22 blockout that has a 7⅛-in. x 6-in. triangular region of the web cut away near the lower front flange. A previous test of the modified thrie beam was conducted according to NCHRP Report No. 350 TL-4 for Trinity Industries that used the same blockout section with a slightly different shape for the angled cutout [6], as shown in Figure 79. In this test, a 17,380-lb SUT impacted the barrier at a speed of 50.2 mph and an angle of 14.9 degrees. The test resulted in a successful redirection of the 8000S vehicle with a dynamic deflection of 2.18 ft. Based on the similarities between the blockout tested herein and the alternative blockout tested by Trinity Industries, it is believed that either blockout is acceptable for use with the MASH TL-3 modified thrie beam system.

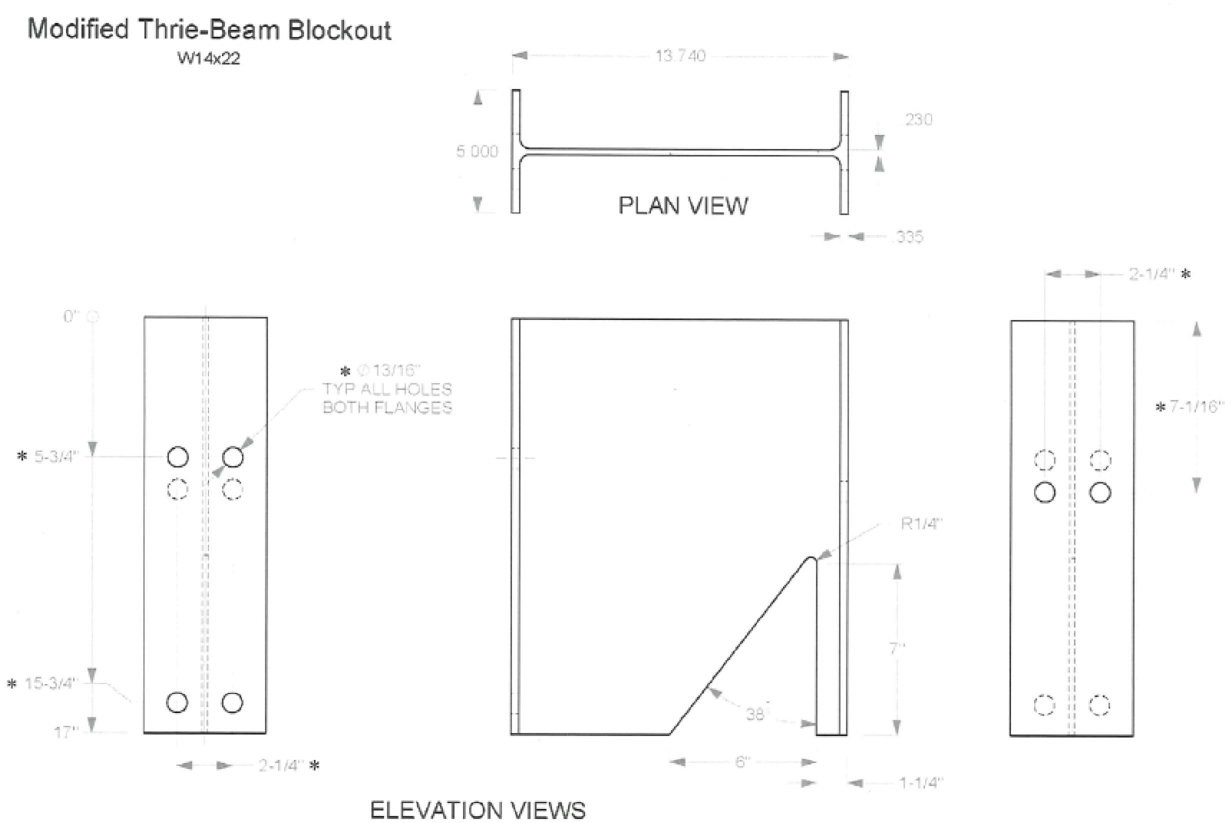

Figure 79. Trinity Industries Alternative Modified Thrie Beam Blockout [6]

10 MASH EVALUATION

The modified thrie-beam guardrail system was evaluated to determine its compliance with MASH 2016 TL-3 evaluation criteria in both a single-sided roadside configuration and a dual-sided median configuration. The single-sided roadside configuration of the modified thrie-beam guardrail consisted of a 12-gauge thrie-beam panels mounted at a height of 34 in. and supported by 81-in. long W6x8.5 posts and W14x22 blockouts with an angled cutout in the web. The dual-sided modified thrie-beam guardrail was largely identical to the single-sided configuration except that the blockouts and thrie beam guardrail panels are mirrored on the backside of the system. Both configurations were transitioned to the W-beam guardrail at each end and anchored with standard trailing end anchorages.

10.1 Test Matrix

The modified thrie-beam guardrail system is classified as a longitudinal barrier for the purposes of evaluation. In MASH 2016, two full-scale crash tests are potentially required to evaluate this type of hardware, as shown in Table 13.

Table 13. MASH 2016 TL-3 Crash Test Conditions for Longitudinal Barriers

Test Article	Test Designation No.	Test Vehicle	Vehicle Weight (lb)	Impact Conditions		Evaluation Criteria [1]
				Speed (mph)	Angle (deg.)	
Longitudinal Barrier	3-10	1100C	2,425	62	25	A,D,F,H,I
	3-11	2270P	5,000	62	25	A,D,F,H,I

NJDOT and Caltrans desired to evaluate both the single-sided roadside and dual-sided median versions of the modified thrie beam guardrail. MwRSF reviewed the system designs and elected to conduct test designation nos. 3-10 and 3-11 on the critical configuration of the barrier such that only two tests were required. Test designation no. 3-11 (test no. MTB-1) was conducted on the single-sided configuration because the 2270P vehicle will impart increased barrier loading on the components of a single-sided system. Additionally, the potential for the torsional buckling of the system posts that led to increased barrier deflection and post snag in the original test designation no. 3-11 testing of the modified thrie beam would be more prevalent in the single-sided configuration. Finally, evaluation of the single-sided modified thrie beam configuration with the 2270P vehicle would also produce the maximum dynamic deflection and working width values for the barrier system. Test designation no. 3-10 (test no. MTB-2) was conducted on the dual-sided, median version of the modified thrie beam as this system configuration would tend to increase loading and occupant risk values for the small car vehicle and increase the propensity for vehicle snag on the post due to the higher stiffness and reduced dynamic deflection of the dual-sided system. Previous evaluation of the T-39 thrie beam barrier in for both roadside and median versions followed a similar methodology [8]. Thus, a total of two tests were conducted to complete the MASH TL-3 test matrix for evaluation of the single-sided roadside and dual-sided median versions of the modified thrie beam guardrail.

10.2 Full-Scale Crash Test Results

The results of the MASH TL-3 full-scale crash testing of the modified thrie beam guardrail system are summarized below.

1. Test no. MTB-1 was conducted under the MASH TL-3 guidelines for test designation no. 3-11. Test designation no. 3-11 is an impact of the 2270P vehicle into the system at 62 mph and an angle of 25 degrees. The critical impact point for this test was selected to maximize vehicle snag on the system posts and splice loading. The 5,003-lb quad cab pickup truck impacted the MTB guardrail at a speed of 62.9 mph, an angle of 25.4 deg, and at an impact point 11 ft – 5.7 in. upstream from post no. 13. During the test, the pickup truck was captured and redirected by the thrie beam. During the redirection of the vehicle, torsional collapse of some of the W-section blockouts was observed similar to that seen in the original NCHRP Report No. 350 testing of the system. The torsional collapse of the blockouts did not compromise the overall test result. However, it may have led to increased wheel snag on the posts and disengagement of the right-front wheel. Additionally, the collapse of the blockouts appeared to allow the lower portion of the thrie beam guardrail to contact the flange and web of the blockout and the post flanges at post nos. 12 and 13. The contact at post no. 13 was sufficient to cause a small tear just downstream of the thrie beam splice at that post. However, this tear did not adversely affect the barrier system performance. The stability and trajectory of the vehicle were acceptable. Prior to coming to a stop, the test vehicle impacted portable barriers used to shield other areas of the test facility downstream from the barrier. This contact was well after vehicle exit and resulted in minor damage to the front of the test vehicle. The vehicle came to rest 282 ft – 3 in. downstream from the impact point and 14 ft – 7 in. laterally in front of the barrier after brakes were applied. Test no. MTB-1 met all of the safety requirements for MASH TL-3.

2. Test no. MTB-2 was conducted under the MASH TL-3 guidelines for test designation no. 3-10. Test designation no. 3-10 is an impact of the 1100C vehicle into the system at 62 mph and an angle of 25 degrees. The critical impact point for this test was selected to maximize vehicle snag on the system posts and splice loading. The 2,415-lb small car impacted the MTB guardrail at a speed of 63.1 mph, an angle of 24.9 deg, and at an impact point 7 ft – 6.4 in. upstream from post no. 13. During the test, the vehicle was captured and redirected by the thrie beam. As the vehicle was redirected, the right-front wheel and tire of the vehicle snagged on post no. 13 in the system. However, the wheel snag did not adversely affect vehicle stability or the occupant risk values. After exiting the system, the vehicle came to rest 187 ft – 7 in. downstream from the impact point and 51 ft – 11 in. laterally in front of the barrier after brakes were applied. Test no. MTB-2 met all of the safety requirements for MASH TL-3.

10.3 MASH Evaluation

Based on the results of the two successful full-scale crash tests conducted in this study, the modified thrie beam guardrail system meets all of the safety requirements for MASH TL-3 in both a single-sided roadside configuration and a dual-sided median configuration.

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12 APPENDICES

Appendix A. NJDOT Modified Thrie Beam Drawings

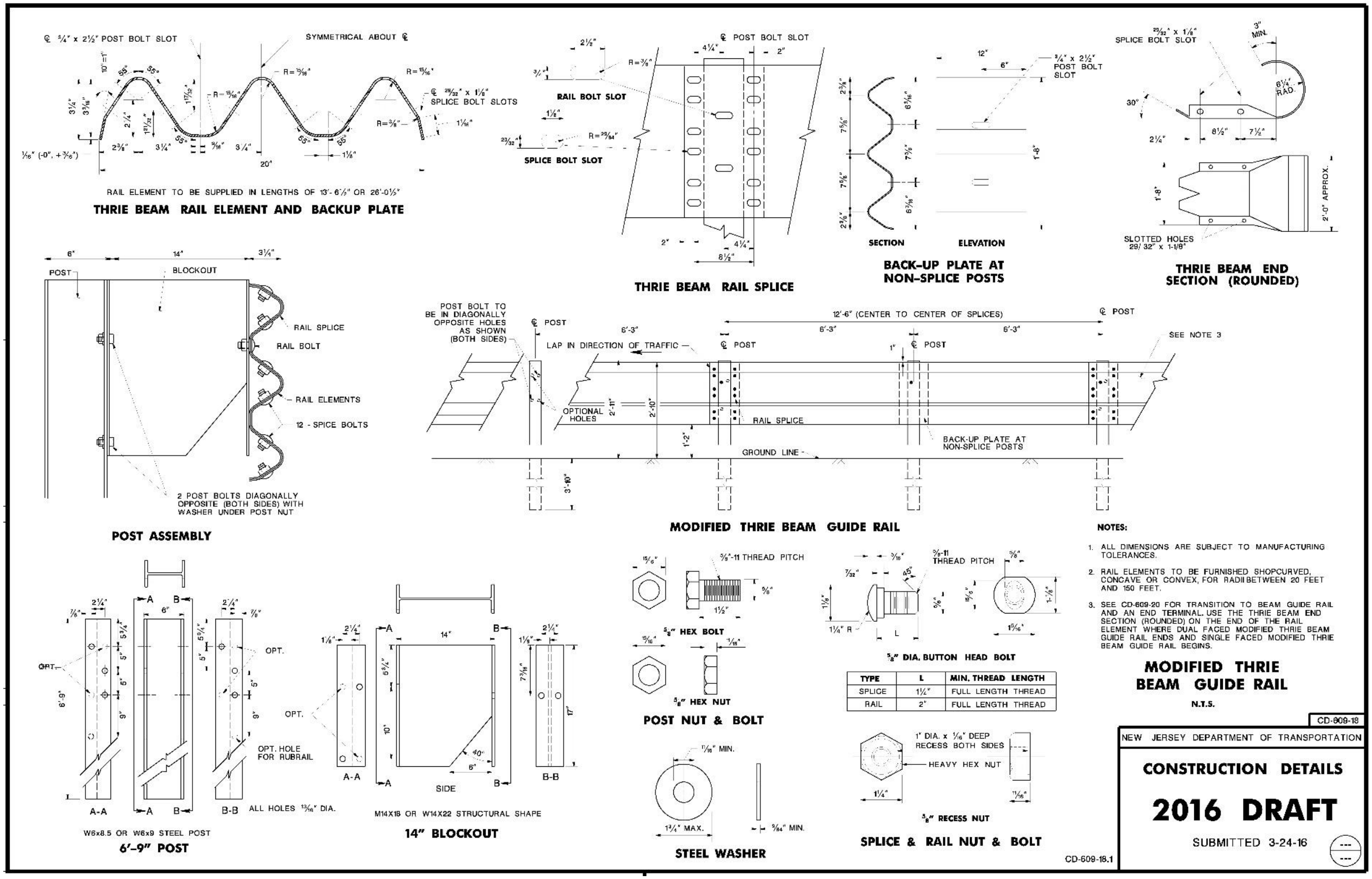


Figure A-1. NJDOT Modified Thrie Beam Details, Test No. MTB-1

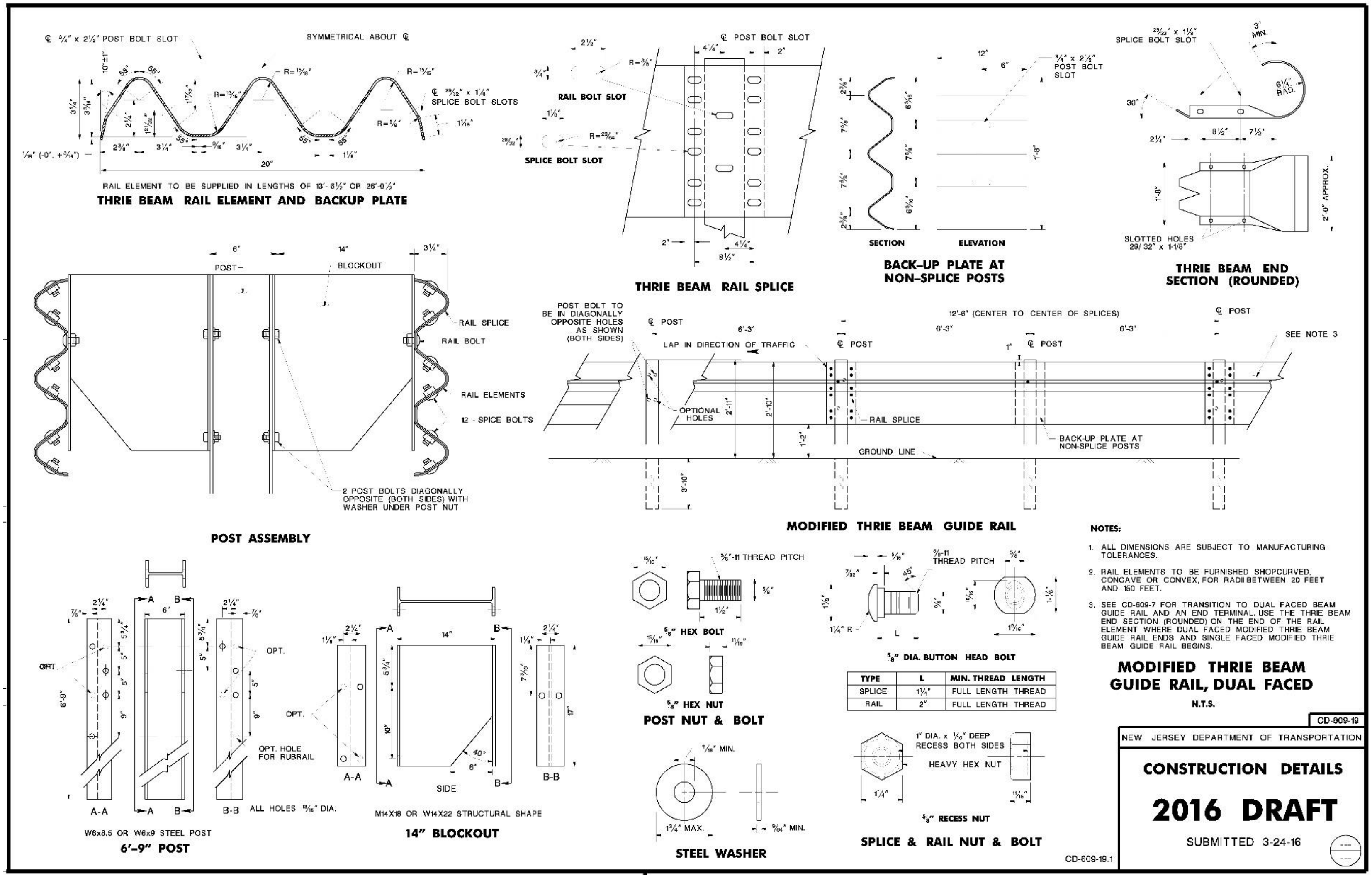


Figure A-2. NJDOT Modified Thrie Beam Details, Test No. MTB-2

Appendix B. Material Specifications

Table B-1. Bill of Materials, Test Nos. MTB-1 and MTB-2

Item No.	Description	Material Specification	Reference
a1	12 ft – 6 in. 12-gauge Thrie Beam Section	AASHTO M180	H#130217 H#L33118
a2	12 in. 12-gauge Thrie Beam Backup Plate	AASHTO M180	H#L31018 H#L33118
a3	6 ft – 3 in. 12-gauge W-Beam MGS End Section	AASHTO M180	H#9513565 H#515691
a4	10-gauge Symmetrical W-beam to Thrie Beam Transition	AASHTO M180	H#191871 H#A80344 H#265388
b1	72-in. Long Foundation Tube	ASTM A500 Gr. B	H#A49248
b2	BCT Timber Post - MGS Height - Not Standard	SYP Gr. No. 1 or better (No knots 18 in. above or below ground tension face)	Ch#25729
b3	Ground Strut Assembly	ASTM A36	
b4	BCT Cable Anchor Assembly	-	
b5	Anchor Bracket Assembly	ASTM A36	H#JK16101488
b6	8 in. x 8 in. x $^{5}/_{8}$ in. Anchor Bearing Plate	ASTM A36	H#4181496
b7	$2^{3}/_{8}$-in. O.D. x 6-in. Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	H#B712810
c1	W6x8.5, 81-in. Long Steel Post	ASTM A36	H#13897 H#26236
c2	W14x22, 17-in. Long Steel Blockout	ASTM A992	H#B138445
c3	16D Double Head Nails	-	
d1	$^{5}/_{8}$ in.-11 UNC, 10-in. Long Guardrail Bolt and Heavy Hex Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolt: H#20351510 Nut: H#20550810
d2	$^{5}/_{8}$ in.-11 UNC, 2-in. Long Guardrail Bolt and Heavy Hex Nut	Bolt - ASTM A307 Gr. A or equivalent Nut - ASTM A563A or equivalent	Bolt: H#10439100 Nut: H#20550810
d3	$^{5}/_{8}$ in.-11 UNC, 1¼-in. Long Guardrail Bolt and Heavy Hex Nut	Bolt - ASTM A307 Gr. A or equivalent Nut - ASTM A563A or equivalent	Bolt: H#10553090 Nut: H#20550810
d4	$^{7}/_{8}$ in.-9 UNC, 8-in. Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A or equivalent Nut - ASTM A563A or equivalent	Bolt: H#2038622 Nut: H#12101054

Table B-2. Bill of Materials, Test Nos. MTB-1 and MTB-2, Cont.

Item No.	Description	Material Specification	Reference
d5	5/8 in.-11 UNC, 10-in. Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A or equivalent Nut - ASTM A563A or equivalent	Bolt: H#DL15107048 Nut: P#36713 C#210101523
d6	5/8 in.-11 UNC, 1½-in. Long Hex Head Bolt and Nut"	Bolt - ASTM A307 Gr. A or equivalent Nut - ASTM A563A or equivalent	Bolt: H#816070039 Nut: P#36713 C#210101523
e1	7/8-in. Dia. Plain Round Washer	ASTM F844	P#33188 C#210151571
e2	5/8-in. Dia. Plain Round Washer	ASTM F844	P#33188 C#210151571

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-1. 12 ft – 6 in. Thrie Beam Section, Test Nos. MTB-1 and MTB-2

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: 1298970 Prod Ln Grp: 0-OE2.0
Customer PO: 3624
BOL Number: 106000 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 9/7/18

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	227752	60,970	79,700	24.9	0.190	0.730	0.014	0.004	0.010	0.120	0.000	0.060	0.002	4
			M-180	A	2	228143	62,240	80,850	26.3	0.190	0.740	0.012	0.002	0.020	0.120	0.000	0.060	0.002	4
			M-180	A	2	228144	57,980	78,970	27.3	0.190	0.730	0.015	0.003	0.020	0.120	0.000	0.050	0.001	4
			M-180	A	2	228145	56,880	76,080	28.9	0.190	0.730	0.013	0.004	0.020	0.120	0.000	0.060	0.008	4
	205G				2	L33418													
			M-180	A	2	230047	63,610	83,360	25.8	0.180	0.720	0.011	0.004	0.010	0.060	0.000	0.060	0.001	4
			M-180	A	2	95812	63,610	83,360	25.8	0.190	0.740	0.010	0.002	0.020	0.100	0.000	0.060	0.002	4
60	211G	T12/12'6/3'1.5/S			2	L33118													
			M-180	A	2	227752	60,970	79,700	24.9	0.190	0.730	0.014	0.004	0.010	0.120	0.000	0.060	0.002	4
			M-180	A	2	227753	61,750	80,930	24.3	0.190	0.730	0.013	0.004	0.020	0.090	0.000	0.050	0.001	4
			M-180	A	2	228143	62,240	80,850	26.3	0.190	0.740	0.012	0.002	0.020	0.120	0.000	0.060	0.002	4
			M-180	A	2	228144	57,980	78,970	27.3	0.190	0.730	0.015	0.003	0.020	0.120	0.000	0.050	0.001	4
			M-180	A	2	228145	56,880	76,080	28.9	0.190	0.730	0.013	0.004	0.020	0.120	0.000	0.060	0.008	4
	211G				2	L32818													
			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	227752	60,970	79,700	24.9	0.190	0.730	0.014	0.004	0.010	0.120	0.000	0.060	0.002	4
			M-180	A	2	228143	62,240	80,850	26.3	0.190	0.740	0.012	0.002	0.020	0.120	0.000	0.060	0.002	4
			M-180	A	2	228145	56,880	76,080	28.9	0.190	0.730	0.013	0.004	0.020	0.120	0.000	0.060	0.008	4
60	261G	T12/25/3'1.5/S			2	L33418													
			M-180	A	2	230047	63,610	83,360	25.8	0.180	0.720	0.011	0.004	0.010	0.060	0.000	0.060	0.001	4
			M-180	A	2	95812	63,610	83,360	25.8	0.190	0.740	0.010	0.002	0.020	0.100	0.000	0.060	0.002	4
	261G				2	L32818													
			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	227752	60,970	79,700	24.9	0.190	0.730	0.014	0.004	0.010	0.120	0.000	0.060	0.002	4
			M-180	A	2	228143	62,240	80,850	26.3	0.190	0.740	0.012	0.002	0.020	0.120	0.000	0.060	0.002	4
			M-180	A	2	228145	56,880	76,080	28.9	0.190	0.730	0.013	0.004	0.020	0.120	0.000	0.060	0.008	4

2 of 4

Figure B-2. 12 ft – 6 in. Thrie Beam Section, Test Nos. MTB-1 and MTB-2

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: 1293172 Prod Ln Grp: 0-OE2.0
Customer PO: 3572
BOL Number: 104228 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 5/1/18

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
1	111G	10/12'6/3'1.5/S	RHC		2	L10518T													4
			M-180	B	2	217849	60,890	79,570	28.0	0.180	0.720	0.014	0.002	0.030	0.140	0.000	0.100	0.001	4
			M-180	B	2	218811	63,570	83,180	24.6	0.190	0.710	0.012	0.002	0.020	0.110	0.000	0.050	0.002	4
			M-180	B	2	217849	60,890	79,570	28.0	0.180	0.720	0.014	0.002	0.030	0.140	0.000	0.100	0.001	4
			M-180	B	2	218811	63,570	83,180	24.6	0.190	0.710	0.012	0.002	0.020	0.110	0.000	0.050	0.002	4
40	211G	T12/12'6/3'1.5/S			2	L31018													
			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
50	261G	T12/25/3'1.5/S			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
			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
12	736G	5'/TUBE SL/.188"X6"X8"FLA	A-500			A712224	79,860	80,000	25.8	0.050	0.810	0.008	0.002	0.030	0.090	0.000	0.050	0.003	4
9	738A	5'TUBE SL.188X6X8 1/4 /PL	A-36		2	749231	50,400	73,800	29.0	0.170	0.770	0.010	0.004	0.020	0.030	0.008	0.020	0.008	4
	738A		A-500		2	822Y34060	54,505	68,028	29.0	0.200	0.790	0.010	0.003	0.011	0.014	0.002	0.020	0.001	4
	738A		HW		2	15616848													
6	957G	T12/BUFFER/ROLLED	A-36			9412222	54,100	72,900	31.0	0.200	0.400	0.008	0.005	0.010	0.020	0.000	0.040	0.001	4
600	3320G	3/16"X1.75"X3" WASHER	HW			P37836													
12	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
	9852A		A-36		2	645887	39,900	62,500	32.0	0.190	0.400	0.009	0.015	0.009	0.054	0.001	0.038	0.001	4

1 of 2

Figure B-3. 12 in. Thrie Beam Backup Plates, Test Nos. MTB-1 and MTB-2

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; 11/15/2016
Customer P O 3356
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project INVENTORY
GHP Order No.: 202136

HT # code	Heat #	C.	MN.	P.	S.	Si.	Tensile	Yield	Elong.	Quanity	Class	Type	Description
9830	9513565	0.21	0.3	0.01	0.008	0.01	76639	56644	25.65	80	A	1	12GA 12FT6IN/3FT1 1/2IN WB T1
9827	9513566	0.22	0.76	0.011	0.008	0.01	79453	59412	28.02	3	A	2	12GA 12FT6IN/3FT1 1/2IN WB T2
9816	31639313	0.19	0.82	0.01	0.005	0.03	77300	56000	27	3	A	2	12 GA 12FT6IN WB T2 FLEAT-SKT COMBO PAN
9828	9513569	0.23	0.78	0.009	0.008	0.01	78281	58917	24.96	170	A	1	12GA 25FT0IN 3FT1 1/2IN WB T1
9818	31639313	0.19	0.82	0.01	0.005	0.03	77300	56000	27	3	A	2	12GA 9FT4 1/2IN 3FT1 1/2IN WB T2
9830	9513565	0.21	0.3	0.01	0.008	0.01	76639	56644	25.65	40	A	1	12GA 6FT 3IN WB T1 HS@ 3FT 1.5IN

R#17-410 HT Code#9830 H#9513565
6'3" W-Beam Yellow Paint Feb 2017 SMT

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.

NOTARIAL SEAL
STATE OF OHIO

KARA J CARPENTER
Notary Public
In and for the State of Ohio
My Commission Expires
February 16, 2021

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by Andrew Artar this 16 day of November, 2016
Notary Public, State of Ohio

Figure B-4. 6 ft – 3 in. W-Beam MGS End Section, Test Nos. MTB-1 and MTB-2

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: RESALE

Order Number: 1164746
Customer PO: 2563
BOL Number: 69500
Document #: 1
Shipped To: NE
Use State: KS

As of: 5/16/12

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
50	6G	12/6'3/S	M-180	A	2	515691	64,000	72,300	27.0	0.060	0.740	0.009	0.008	0.010	0.021	0.04	0.032	0.000	4
			M-180	A	2	4111321	63,100	80,200	29.0	0.210	0.710	0.009	0.007	0.010	0.030	0.000	0.030	0.000	4
			M-180	A	2	515659	67,000	75,200	26.0	0.064	0.790	0.012	0.008	0.008	0.022	0.000	0.025	0.000	4
			M-180	A	2	515660	66,800	74,300	27.0	0.064	0.740	0.012	0.006	0.009	0.017	0.000	0.025	0.000	4
			M-180	A	2	515662	63,900	72,900	28.0	0.064	0.770	0.010	0.006	0.009	0.016	0.000	0.025	0.000	4
			M-180	A	2	515663	64,900	76,500	21.0	0.064	0.740	0.009	0.007	0.007	0.023	0.000	0.026	0.000	4
			M-180	A	2	515668	66,700	75,500	27.0	0.063	0.770	0.014	0.007	0.010	0.024	0.000	0.030	0.000	4
			M-180	A	2	515668	70,200	80,800	21.0	0.063	0.770	0.014	0.007	0.010	0.024	0.000	0.030	0.000	4
			M-180	A	2	515669	64,500	74,100	26.0	0.063	0.790	0.014	0.007	0.009	0.017	0.000	0.028	0.000	4
			M-180	A	2	515687	63,400	74,100	30.0	0.068	0.750	0.012	0.010	0.008	0.025	0.000	0.060	0.000	4
			M-180	A	2	515687	65,100	74,400	28.0	0.068	0.750	0.012	0.010	0.008	0.025	0.000	0.060	0.000	4
			M-180	A	2	515690	63,000	71,800	27.0	0.059	0.720	0.010	0.008	0.013	0.024	0.000	0.042	0.000	4
			M-180	A	2	515696	62,900	72,500	28.0	0.058	0.740	0.013	0.008	0.011	0.029	0.000	0.046	0.000	4
			M-180	A	2	515696	63,900	73,400	29.0	0.058	0.740	0.013	0.008	0.011	0.029	0.000	0.046	0.000	4
			M-180	A	2	515700	67,800	77,700	28.0	0.065	0.800	0.013	0.009	0.012	0.036	0.000	0.035	0.000	4
			M-180	A	2	616068	62,900	71,600	27.0	0.061	0.740	0.013	0.010	0.012	0.027	0.000	0.064	0.000	4
			M-180	A	2	616068	66,700	74,200	30.0	0.061	0.740	0.013	0.010	0.012	0.027	0.000	0.064	0.000	4
			M-180	A	2	616071	64,000	74,000	28.0	0.061	0.760	0.016	0.007	0.011	0.021	0.000	0.028	0.000	4
			M-180	A	2	616072	63,800	74,200	29.0	0.066	0.750	0.014	0.009	0.010	0.026	0.000	0.039	0.000	4
			M-180	A	2	616073	63,900	73,300	27.0	0.064	0.760	0.016	0.009	0.012	0.024	0.000	0.041	0.000	4
			M-180	A	2	616073	65,000	74,500	28.0	0.064	0.760	0.016	0.009	0.012	0.024	0.000	0.041	0.000	4
30	60G	12/25/6'3/S	M-180	A	2	4111321	63,100	80,200	29.0	0.210	0.710	0.009	0.007	0.010	0.030	0.00	0.030	0.000	4
			M-180	A	2	515656	63,600	73,600	27.0	0.066	0.720	0.012	0.006	0.011	0.021	0.000	0.026	0.000	4
			M-180	A	2	515658	64,800	74,300	26.0	0.069	0.740	0.010	0.006	0.011	0.022	0.000	0.021	0.000	4
			M-180	A	2	515659	67,000	75,200	26.0	0.064	0.790	0.012	0.008	0.008	0.022	0.000	0.025	0.000	4
			M-180	A	2	515663	64,900	76,500	21.0	0.064	0.740	0.009	0.007	0.007	0.023	0.000	0.026	0.000	4

1 of 4

Figure B-5. 6 ft – 3 in. W-Beam MGS End Section, Test Nos. MTB-1 and MTB-2

Certified Analysis

Trinity Highway Products , LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499
Customer: GORDON'S SPECIALTIES INC
dba GSI HIGHWAY PRODUCTS
720 WEST WINTERGREEN

HUTCHINS, TX 75141
Project: RESALE

Order Number: 1277693 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 35079
BOL Number: 66287 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 4/12/17

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
2	977G	T10/TRANS RAIL/6'3"/3'1.5	M-180	B	2	191871	62,020	80,610	26.6	0.190	0.720	0.012	0.004	0.020	0.090	0.000	0.060	0.000	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

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

State of Texas, County of Tarrant. Sworn and subscribed before me this 12nd day of April, 2017 .

Notary Public:
Commission Expires:

JOMARY LUGINSLAND
Notary Public, State of Texas
My Commission Expires
May 28, 2019

Certified By: Trinity Highway Products, LLC
Quality Assurance

1 of 1

Figure B-6. 10-gauge Symmetrical W-Beam to Thrie Beam Transition, Test Nos. MTB-1 and MTB-2

Certified Analysis

Trinity Highway Products , LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499
Customer: GORDON'S SPECIALTIES INC
dba GSI HIGHWAY PRODUCTS
720 WEST WINTERGREEN

HUTCHINS, TX 75141
Project: RESALE

Order Number: 1267955 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 33653
BOL Number: 63907 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 10/4/16

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
175	11G	12/12'6/3'1.5/S				F14016													
			M-180	A		1264666	61,000	79,800	26.0	0.190	0.790	0.009	0.001	0.030	0.120	0.003	0.060	0.003	4
			M-180	A		A80569	64,100	84,300	25.6	0.210	0.840	0.016	0.004	0.020	0.140	0.000	0.090	0.001	4
			M-180	A		C78738	66,800	85,800	22.5	0.210	0.840	0.011	0.003	0.030	0.140	0.003	0.060	0.001	4
			M-180	A		C79057	64,200	87,100	20.9	0.220	0.850	0.013	0.004	0.030	0.160	0.002	0.080	0.001	4
100	61G	12/25/3'1.5/S				F13716													
			M-180	A		1164306	56,300	77,700	29.0	0.190	0.780	0.010	0.002	0.020	0.120	0.002	0.050	0.003	4
			M-180	A		1264315	58,500	80,400	21.0	0.200	0.750	0.007	0.001	0.020	0.100	0.001	0.040	0.003	4
			M-180	A		1264669	56,100	76,900	26.0	0.180	0.770	0.012	0.002	0.020	0.120	0.002	0.060	0.004	4
			M-180	A		C78738	66,800	85,800	22.5	0.210	0.840	0.011	0.003	0.030	0.140	0.003	0.060	0.001	4
50	850G	12/BUFFER/ROLLED	A-36			635238	51,500	72,500	30.0	0.190	0.440	0.021	0.018	0.011	0.077	0.001	0.069	0.001	4
200	901G	12/FLARE/8 HOLE	M-180	A	2	193147	62,430	81,280	26.2	0.190	0.730	0.014	0.003	0.020	0.110	0.000	0.060	0.001	4
15	926G	10/END SHOE/EXTRA HOLE	M-180	B	2	193144	59,120	78,090	29.2	0.190	0.720	0.013	0.004	0.010	0.120	0.000	0.040	0.000	4
50	32218G	T10/TRAN/TB:WB/ASYM/R	M-180	B	2	A78617	51,300	72,300	30.2	0.200	0.697	0.009	0.002	0.030	0.070	0.002	0.050	0.002	4
50	32219G	T10/TRAN/TB:WB/ASYM/LT	M-180	B	2	A80344	63,200	85,600	19.9	0.200	0.700	0.009	0.003	0.030	0.130	0.002	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.

Figure B-7. 10-gauge Symmetrical W-Beam to Thrie Beam Transition, Test Nos. MTB-1 and MTB-2

Certified Analysis

Trinity Highway Products , LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499
Customer: GORDON'S SPECIALTIES INC
dba GSI HIGHWAY PRODUCTS
720 WEST WINTERGREEN

HUTCHINS, TX 75141
Project: RESALE

Order Number: 1266784 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 33512
BOL Number: 63626 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 9/14/16

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
53	975G	T10/END SHOE	M-180	B	2	265388	39,700	56,600	37.0	0.045	0.350	0.007	0.000	0.020	0.087	0.000	0.049	0.004	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

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

State of Texas, County of Tarrant. Sworn and subscribed before me this 14th day of September, 2016 .

Notary Public:
Commission Expires:

JOMARY LUGINSLAND
Notary Public, State of Texas
My Commission Expires
May 28, 2019

Trinity Highway Products, LLC
Certified By:
Quality Assurance

Figure B-8. 10-gauge Symmetrical W-Beam to Thrie Beam Transition, Test Nos. MTB-1 and MTB-2

/2016

TESTING CERT # 2914.01

CERTIFIED REPORT OF CHEMICAL ANALYSIS AND MECHANICAL TESTS

ArcelorMittal

Page 1 of 1

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	ORDERING 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-9. 72-in. Long Foundation Tube, Test Nos. MTB-1 and MTB-2

CCA Charge Report

Central Nebrasl
105 N. Owen
Sutton, NE 68979
Tel: (402) 773-4319 F

Charge	C1-25729/U0	Recipe	Default	Start Time	7/27/18 10:1
Tally	25729/U26826	Preset	GuardRail	End Time	7/27/18 11:5
Cylinder	CYL_1	Operator	Larry	Duration	

				FLW	INJ	MNT	MXT	PRS	VAC
1	Initial Vacuum	Time	SP ACT				7.00 11.53		2 2
2	Vacuum Fill	Vacuum	SP ACT				4.45		2
3	Atm Absorption	Time	SP ACT				1.00 1.00		
4	Pressure	Time	SP ACT	0.00	4.10 11.87	25.00 25.00	25.00 25.00	140.00 147.95	
5	Release Pressure	Pressure	SP ACT				6.00 6.62	10.00 9.95	
6	Emptying	Cylinder Empty	SP ACT				5.38		
7	Final Vacuum	Time	SP ACT			40.00 40.00	40.00 40.00		
8	Drain Cylinder	Cylinder Empty	SP ACT				5.98		

OXFORD LAB-X CCA
WOOD ANALYSIS
30/7/2018 9:59
Calibration title: SAWDUST-pcf

SAMPLE ID: 25729
****
DENSITY = 32.0 pcf
****

	%WT OXIDES	%BALANCE
CRO3 =	1.030 %	48.5
OUO =	0.380 %	17.9
AS205 =	0.716 %	33.7
TOTAL =	2.126 %WT	100.0

****

RETENTION

CRO3 = 0.330 pcf
OUO = 0.121 pcf
AS205 = 0.229 pcf
TOTAL= 0.680 pcf
****

Tank Information for T02 CCA

Phase	FT	GAL	LBS
Initial Vacuum	9.3	7878	66698
Vacuum Fill	2.7	2260	19134
Pressure	0.6	532	4501
End of Charge	7.6	6393	54131

Charge Data

Solution Concentration	1.90%	Volume Basis	Tally
Calculated Chemical Use (Lbs)	238.91	Disp. Volume (CuFT)	480.89
Net Injection (Gal/CuFt)	3.09	Target Assay Retention	0.60
Estimated Heartwood (%)		Assay (Lbs/CuFT) / NC	/
Calculated Retention	0.60		
Total Gallons Used (Gal)	1,485.16		

Tally BF/SF 5,767.35 Total Volume 480.61 CuFt

Designation	Description	Qty	Specie	Grade	Lot	MC %	Dressing	CuFt	BdFt
Stock	T004140B	126	SYP	1				144.38	1,732.50
Stock	T006115B	42	SYP	1				46.12	553.43
Stock	T006120B	336	SYP	1				196.00	2,352.01
Stock	T006118B	126	SYP	1				49.00	588.00
Stock	6x8x46\" ~~8'6"~~ BCT	42	SYP	1				45.12	541.41

Generated by Treat Right® on 7/27/2018.

Figure B-10. BCT Timber Post – MGS Height – Not Standard, Test Nos. MTB-1 and MTB-2

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: 1275017 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3400
BOL Number: 99202 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 3/22/17

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
400	3380G	5/8"X1.5" HEX BOLT A307	HW			0052429-113200													
600	3400G	5/8"X2" GR BOLT	HW			29221													
500	3480G	5/8"X8" GR BOLT A307	HW			29369													
450	3500G	5/8"X10" GR BOLT A307	HW			29550-B													
700	3540G	5/8"X14" GR BOLT A307	HW			29567													
300	3580G	5/8"X18" GR BOLT A307	HW			29338													
600	4235G	3/16"X1.75"X3" WSHR	HW			C7001													
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
	9852A		A-36			A82292	54,000	73,300	31.0	0.200	0.460	0.010	0.003	0.020	0.150	0.000	0.060	0.001	4
	9852A		A-36			645887	39,900	62,500	32.0	0.190	0.400	0.009	0.015	0.009	0.054	0.001	0.038	0.001	4
	9852A		A-36			645887	39,900	62,500	32.0	0.190	0.400	0.009	0.015	0.009	0.054	0.001	0.038	0.001	4
	9852A		HW			15056184													
20	12173G	T12/6'3/4@1'6.75"/S			2	L35216													
			M-180	A	2	209331	62,090	81,500	28.1	0.190	0.720	0.013	0.002	0.020	0.110	0.000	0.070	0.002	4
			M-180	A	2	209332	61,400	81,290	25.3	0.190	0.730	0.014	0.003	0.020	0.120	0.000	0.060	0.001	4
			M-180	A	2	209333	61,200	80,050	25.8	0.200	0.740	0.016	0.005	0.010	0.120	0.000	0.070	0.002	4

2 of 4

Figure B-11. Ground Strut Assembly, Test Nos. MTB-1 and MTB-2

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: 1275956 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3415
BOL Number: 99204 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 3/22/17

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	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
			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
			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
			M-180	A	2	208676	62,920	82,040	25.4	0.190	0.720	0.012	0.004	0.010	0.100	0.000	0.060	0.002	4
	12365G				2	L35216													
			M-180	A	2	209331	62,090	81,500	28.1	0.190	0.720	0.013	0.002	0.020	0.110	0.000	0.070	0.002	4
			M-180	A	2	209332	61,400	81,290	25.3	0.190	0.730	0.014	0.003	0.020	0.120	0.000	0.060	0.001	4
			M-180	A	2	209333	61,200	80,050	25.8	0.200	0.740	0.016	0.005	0.010	0.120	0.000	0.070	0.002	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

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

Figure B-12. Ground Strut Assembly, Test Nos. MTB-1 and MTB-2

WireCo WorldGroup

24150 Oak Grove Lane
Sedalia MO. 65302-0844
660-829-6721(P)
660-829-6780(F)

Date: 1/8/18
Sold to: The Commercial Group
12801 Universal Drive
Taylor, MI 48180
Order: 214425

Certificate of Compliance

Report of Chemical Analysis and Physical Tests

Order No. 196002 **Reel number** 428-724681-2 **Rope Description** 3/4 6x19W-WSC CL-ZA

Item No.	Description	Tensile Strength Lbs.	Tensile Strength Lbs. per sq. in.		Wt. Coat	Torsion Test 8"	Heat No.	C	Mn	P	S	Si
001	.0395" Galvanized Wire											
	.0395	341	278,000		.385	65	17R590203	.81	.54	.011	.009	.20
	.0395	330	269,000		.372	71	17R594359	.80	.58	.015	.010	.24
							17R591720	.82	.53	.008	.009	.18
002	.0460" Galvanized Wire											
	.0460	415	250,000		.417	71	17R591720	.82	.53	.008	.009	.18
003	.0540" Galvanized Wire											
	.054	580	253,000		.410	55	17R590203	.81	.54	.011	.009	.20
							17R591077	.81	.53	.006	.008	.21
							17R593340	.82	.54	.009	.015	.21
							17R591720	.82	.53	.008	.009	.18
							17R594796	.83	.49	.005	.005	.18
004	.0610" Galvanized Wire											
	0.061	751	257,000		.489	45	16R585888	.80	.72	.007	.017	.23
							17R591077	.81	.53	.006	.008	.21
							16KY73253	.84	.61	.006	.013	.24

The material covered by this certification was manufactured and tested in accordance with specifications as listed above. We certify that representative samples of the material have been tested and the results conform to the requirements outlined in these specifications.

The chemical, physical, or mechanical tests reported above are correct as contained in the records of the corporation.

Signed: Michele Johnson

SHEILA DOWDY
Notary Public - Notary Seal
State of Missouri, Pettis County
Commission Number 00464267
My Commission Expires Jun 6, 2020

Sheila Dowdy
January 8, 2018

Page 2 of 2

Figure B-13. BCT Cable Anchor Assembly, Test Nos. MTB-1 and MTB-2

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
	701A	Anchor Box	A-36			JK16101488	56,172	75,460	25.0	0.160	0.780	0.017	0.028	0.200	0.280	0.001	0.140	0.028	4
	701A		A-36			535133	43,300	68,500	33.0	0.019	0.460	0.013	0.016	0.013	0.090	0.001	0.090	0.002	4
4	729G	TS 8X6X3/16X8'-0" SLEEVE	A-500			A49248	64,818	78,412	32.0	0.200	0.810	0.014	0.002	0.040	0.020	0.000	0.040	0.001	4
20	738A	5'TUBE SL.188X6X8 1/4 /PL	A-36		2	4182184	45,000	67,900	31.0	0.210	0.760	0.012	0.008	0.010	0.050	0.001	0.030	0.002	4
	738A		A-500			A49248	64,818	78,412	32.0	0.200	0.810	0.014	0.002	0.040	0.020	0.000	0.040	0.001	4
6	749G	TS 8X6X3/16X6'-0" SLEEVE	A-500			A49248	64,818	78,412	32.0	0.200	0.810	0.014	0.002	0.040	0.020	0.000	0.040	0.001	4
6	782G	5/8"X8"X8" BEAR PL/OF	A-36			DL15103543	58,000	74,000	25.0	0.150	0.750	0.013	0.025	0.200	0.360	0.003	0.090	0.000	4
20	783A	5/8X8X8 BEAR PL 3/16 STP	A-36			PL14107973	48,167	69,811	25.0	0.160	0.740	0.012	0.041	0.190	0.370	0.000	0.220	0.002	4
	783A		A-36			DL15103543	58,000	74,000	25.0	0.150	0.750	0.013	0.025	0.200	0.360	0.003	0.090	0.000	4
45	3000G	CBL 3/4X6'6/DBL	HW			119048													
7,000	3340G	5/8" GR HEX NUT	HW			0055551-116146													
4,000	3360G	5/8"X1.25" GR BOLT	HW			0053777-115516													
450	3500G	5/8"X10" GR BOLT A307	HW			28971-B													
1,225	3540G	5/8"X14" GR BOLT A307	HW			29053-B													

Figure B-14. Anchor Bracket Assembly, Test Nos. MTB-1 and MTB-2

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-15. 8 in. x 8 in. x $^5/_8$ in. Anchor Bearing Plate, Test Nos. MTB-1 and MTB-2

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

Page : 3 Of 4

Metals Service Center Institute

Figure B-16. $2^{3}/_{8}$ in. O.D. x 6-in. Long BCT Post Sleeve, Test Nos. MTB-1 and MTB-2

SWVA, INC.
A Subsidiary of
STEEL OF WEST VIRGINIA
Phone (304)696-8200

PACKING LIST/MTR

CUSTOMER ORDER NO.	DATED	OUR ORDER NO.	FREIGHT PMT	CUSTOMER NO.	CHANGE DATE	DATE SHIPPED	LOAD NUMBER
36011	7/13/18	86956-1	COLLXXX	28300001	F 8/07/18	8 28 18	8-342

F.O.B HUNTINGTON

ROUTE REQUESTED	TERMS
RAILCAR	NET 30 DAYS

ROUTING VIA TTPX81662 B.O.L.# 273825

SOLD TO:
D I HWY SIGN CORP
P O BOX 123
NEW YORK MILLS NY 13417

SHIP TO:
DI-HIGHWAY SIGN CORP.
CSXT UTICA NEW YORK NYSW
STCC 33125XX
NEW YORK MILLS NY 13502

This is to certify that the material specification is a true and correct report as contained in the records of this company.

XXX

Steve Fisher - Metallurgist

PROD. CODE	DESCRIPTION	LENGTH ORDERED	QUANTITY ORDERED	ESTIMATED WEIGHT	BUNDLES SHIPPED	QUANTITY THIS SHIPMENT PIECES	LIN FEET	POUNDS
2759	6" X 8.5# WF BEAM NO_HOLES, BARE							
	NO CLIPS SWV 67 ASTM = ASTM A36-08							
	A36 SHIP BY RAILCAR							
	MELTED & MANUFACTURED IN USA							
	275942	42'	147 PCS	52,479#	5 of 21	105 TARP MATERIAL	42'	37,485
						SHIPPED WITH:	83776-2	88005-1

All melting and manufacturing processes for these materials occurred in the U.S.A.

HEATNO	Strength (P.S.I) Yield	Tensile	Elongation %	Lth	Cu	Cr	Ni	Mo	Nb
13897	49000	71000	26.2	8	.28	.19	.09	.03	.002
26236	48000	70000	25.3	8	.20	.20	.10	.03	.002

HEAT NO.	C	MN	P	S	SI	V	SN	CE
13897	.15	.66	.016	.032	.20	.006	.013	.33
26236	.15	.69	.018	.023	.21	.005	.009	.33

Figure B-17. W6x8.5, 81-in. Long Steel Post, Test Nos. MTB-1 and MTB-2

Steel Dynamics, Inc.
Long Products Group
Structural and Rail Division

(260) 625-8100 (260) 625-8950 FAX
Quality Steel 100% EAF Melted and Manufactured in the USA
Recycled content: PC = 79.6%, PI = 18.0%
ISO 9001:2008 and ABS Certified

CERTIFIED MILL TEST REPORT

Printed: **12 / 27 / 2017**
Produced: **08 / 21 / 2017**

Ship to:
Steel & Pipe Supply
401 New Century Parkway
New Century KS, 66031 US
Attn: Receiving

Customer # 000058

Bill to:
Steel & Pipe Supply - Kansas
555 Poyntz Avenue
PO Box 1688
Manhattan KS, 66505 US
Attn: Kaycia VanSickle

GENERAL INFORMATION

Product Wide Flange Beam
Size W14X22
W360X32.9
Heat Number B138445
Condition(s) As-Rolled
Fine Grained
Fully Killed
No Weld Repair

SPECIFICATIONS

Standards	Grades*
ASTM A6/A6M - 17	
» ASTM A992/A992M - 11	A992 / A992M
ASTM A572/A572M - 15	A572 gr50/gr345
AASHTO M270M/M270 - 12	M270 gr345/gr50
CSA G40.21-13	50WM/345WM
ASTM A36/A36M - 14	A36 / A36M

*SDI-MULTI meets the requirements of ASTM A992, A572-50, A529-50, A709-50, M270-50, A36, A709-36, M270-36, CSA300W, CSA345WM, CSA350W.

SHIPMENT DETAILS

BOL # 0000481210 - 7040.00 lbs

Bundle / ASN #	Length	pcs	Cust PO | Recv PO | Job
060810140	40' 0"	8	4500299792

CHEMICAL ANALYSIS (weight percent)

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	V	Nb/Cb	Al	N	B	*C1	*C2	*C3	*PC	*I	Analysis Type
.09	.94	.008	.016	.27	.24	.08	.09	.03	.012	.036	.001	.001	.0122	.0004	.30	.34	.29	.17	5.13	Heat

MECHANICAL TESTING

Test	Yield (fy) Strength ksi / MPa	Tensile (fu) Strength ksi / MPa	fy / fu ratio	% Elong. (8" gage)
1	62 / 427	77 / 531	.81	26
2	63 / 434	77 / 531	.82	28
3				
4				

CHARPY IMPACT TESTS (available only when specified at time of order)

Test	Temp F / C	Absorbed Energy ft-lbf / J Specimen 1	Specimen 2	Specimen 3	Average	Minimum
1						
2						
3						
4						
5						
6						
7						

Notes: *Calculated Chemistry Values: Carbon Equivalents (C1, C2, C3, PC), Corrosion Index (I) (ASTM G101)= 26.01(Cu)+3.88(Ni)+1.20(Cr)+1.49(Si)+17.29(P)-7.29(Cu)(Ni)-9.10(Ni)(P)-33.39(Cu²) Pcm(AWS) = C+Si/30+Mn/20+Cu/20+Ni/60+Cr/20+mo/15+V/10+5B CE1 (IIW)=C+Mn/6+(Cr+Mo+V)/5+(Ni+Cu)/15 CE2 (AWS)=C+(Mn+Si)/6+(Cr+Mo+V)/5+(Ni+Cu)/15 CE3 (CET) = C + (Mn/6) + (Si/24) + (Cr/5) + (Ni/40) +(Mo/4) + (V/14)

I hereby certify that the material described herein has been made to the applicable specification by the electric arc furnace/continuous cast process and tested in accordance with the requirements of American Bureau of Shipping Rules with satisfactory results.

Signed:

ABS CERTIFICATION

I hereby certify that the content of this report are accurate and correct. All tests and operations performed by this material manufacturer are in compliance with the requirements of the material specifications and applicable purchaser designated requirements.

Signed: **Todd Bashford**
Quality Manager

State of Indiana, County of Whitley Sworn to and subscribed before me

this __________ day of ______________________

Signed: ______________________ My commission expires:__________
Notary Public

Form F-6100-002-054 rev 8

ASTM A6 - 14.6: A signature is not required on the test report; however, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report

Page 2 of 6

Figure B-18. W14x22, 17-in. Long Steel Blockout, Test Nos. MTB-1 and MTB-2

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-19. 16D Double Head Nails, Test Nos. MTB-1 and MTB-2

3500b

CHARTER STEEL
A Division of Charter Manufacturing Company, Inc

EMAIL

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

Trinity Industries Inc.
2525 Stemmons Frwy, 4th Floor
Dallas,TX-75207
Kind Attn : Material Certifications Dept.

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

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	.06	.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-20. $^5/_8$ in.-11 UNC, 10-in. Long Guardrail Bolt, Test Nos. MTB-1 and MTB-2

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

Cust P.O.	94680
Customer Part #	AXA18CA-1-5/32
Charter Sales Order	30147392
Heat #	20550810
Ship Lot #	2142167
Grade	1018 X AK FG RHQ 1-5/32 RNDCOIL
Process	HR
Finish Size	1-5/32
Ship date	01-MAR-18

Johnstown Wire Technologies
124 Laurel Ave.
Johnstown,PA-15906

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 # 20550810

Lab Code: 125544

CHEM	C	MN	P	S	SI	NI	CR	MO	CU	SN	V
%Wt	.18	.75	.008	.003	.060	.03	.05	.01	.06	.003	.001
	AL	N	B	TI	NB						
	.051	.0080	.0001	.001	.001						

CAT DI=.43

Test results of Rolling Lot # 2142167

	# of Tests	Min Value	Max Value	Mean Value	
TENSILE (KSI)	1	66.8	66.8	66.8	TENSILE LAB = 0358-04
REDUCTION OF AREA (%)	1	54	54	54	RA LAB = 0358-04

NUM DECARB=1
REDUCTION RATIO=47:1

AVE DECARB (inch)=.000

Specifications: Manufactured per Charter Steel Quality Manual Rev Date 05/12/17
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

Trip: 1232277

ACCREDITED 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 : 03/01/2018

Figure B-21. ⅝-in.-11 UNC, Heavy Hex Nut, Test Nos. MTB-1 and MTB-2

CERTIFICATE OF COMPLIANCE

34006

ROCKFORD BOLT & STEEL CO.
126 MILL STREET
ROCKFORD, IL 61101
815-968-0514 FAX# 815-968-3111

CUSTOMER NAME: TRINITY INDUSTRIES

CUSTOMER PO: 182402

SHIPPER #: 059943
DATE SHIPPED: 03/07/2017

LOT#: 29221

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE: SPEC: 60,000 psi*min RESULTS: 68,460 66,327

HARDNESS: 100 max 71.30 71.60

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
ROGERS GALVANIZE: 29221

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
CHARTER	1010	10439100	.09	.40	.008	.011	.090

QUANTITY AND DESCRIPTION:

10,400 PCS 5/8" X 2" GUARD RAIL BOLT
P/N 3400G

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 March, 20 17

Merry F. Shane

Linda McComas 3/7/17
APPROVED SIGNATORY DATE

OFFICIAL SEAL
MERRY F. SHANE
NOTARY PUBLIC – STATE OF ILLINOIS
MY COMMISSION EXPIRES OCTOBER 3, 2018

Figure B-22. ⅝ in.-11 UNC, 2-in. Long Guardrail Bolt, Test Nos. MTB-1 and MTB-2

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: 40787

SHIPPER #: 063741
DATE SHIPPED: 06/29/2018

LOT#: 30934-B

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE: SPEC: 60,000 psi*min RESULTS: 66,100 65,400

HARDNESS: 100 max 65.60 65.20

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
AZZ GALVANIZING: 30934-B

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
CHARTER STEEL	1010	10553090	.08	.38	.005	.011	.090

QUANTITY AND DESCRIPTION:

7,000 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

3rd DAY OF July, 2018 Linda Metomas 7/3/18
APPROVED SIGNATORY DATE

Merry F. Shane

OFFICIAL SEAL
MERRY F. SHANE
NOTARY PUBLIC – STATE OF ILLINOIS
MY COMMISSION EXPIRES OCTOBER 3, 2018

Figure B-23. $^5/_8$ in.-11 UNC, 1¼-in. Long Guardrail Bolt, Test Nos. MTB-1 and MTB-2

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

	SOLD TO	SHIP TO	
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	Infra-Metals - Mars 1601 Broadway St Marseilles IL US 61341-9326 8009875283	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-24. $^7/_8$ in.-9 UNC, 8-in. Long Hex Head Bolt, Test Nos. MTB-1 and MTB-2

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	-

Shape & Dimension	
Inspection	ANSI B18.2.2 GOOD
Thread Precision Inspection	ANSI B1.1 CLASS 2B GOOD
Appearance Inspection	GOOD

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 Results GOOD	n - Results -	29.4 28.9 29.7 29.7 29.5 29.4	5 Piece Average After Heat Treament Hardness Treatment After 24 Hr.X °F(°C)	at °F(°C)	Q: FORGING Q (W.Q.) T: 1058 F/45M. (W.C.) Q: Quenching T: Tempering ST: Solution Treatment

OFFICIAL SEAL
JEAN MARGHERIO
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES 10/18/13
07-10-12

Remarks:

"DH U"

Production Quantity
22,391 pcs.

BCT Foundation Tube
Keeper Bolt Nuts
R#15-0600 June 2015 SMT

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-25. ⅞-in.-9 UNC, Nut, Test Nos. MTB-1 and MTB-2

NUCOR
NUCOR CORPORATION
NUCOR STEEL SOUTH CAROLINA

Mill Certification
3/11/2016

MTR #: C1-366222
300 Steel Mill Road
DARLINGTON, SC 29540
(843) 393-5841
Fax: (843) 395-8701

Sold To: BIRMINGHAM FASTENER & SUPPLY
PO BOX 10323
BIRMINGHAM, AL 35202-0323
(205) 595-3511
Fax: (205) 591-0244

Ship To: BIRMINGHAM FASTENER & SUPPLY
931 AVE W
PO BOX 10323
BIRMINGHAM, AL 35202-0000
(205) 595-3511
Fax: (205) 591-0244

Customer P.O.	M7812	Sales Order	238747.1
Product Group	Merchant Bar Quality	Part Number	30000562480DES0
Grade	ASTM A307-55, F1554-07a gr 55, S1, AASHTO M314 GR 55, S1	Lot #	DL1510704804
Size	9/16" (.5625) Round	Heat #	DL15107048
Product	9/16" (.5625) Round 40' A307-55	B.L. Number	C1-686488
Description	A307-55	Load Number	C1-366222
Customer Spec		Customer Part #	

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: 1/28/2016 Melt Date: 12/5/2015 Qty Shipped LBS: 17,494 Qty Shipped Pcs: 517

Melt Date: 12/5/2015

C	Mn	V	Si	S	P	Cu	Cr	Ni	Mo	Cb	CE1554
0.22%	0.82%	0.0410%	0.27%	0.010%	0.007%	0.20%	0.10%	0.06%	0.015%	0.001%	0.37%

CE1554: CE per F1554 GR55, S1

Roll Date: 1/28/2016

Yield 1: 67,000psi	Tensile 1: 87,000psi	Elongation: 21% in 8"(% in 203.3mm)
Yield 2: 66,000psi	Tensile 2: 88,000psi	Elongation 21% in 8"(% in 203.3mm)
Reduction of Area: 50.43%	Reduction of Area #2: 53.52%	

Specification Comments:

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 2

Figure B-26. ⅝-in.-11 UNC, 10-in. Long Hex Head Bolt, Test Nos. MTB-1 and MTB-2

R#16-0217
BCT Hex Nuts
December 2015 SMT
Fastenal part#36713
Control# 210101523

STELFAST® INC.

22979 Stelfast Parkway
Strongsville, Ohio 44149

CERTIFICATE OF CONFORMANCE

DESCRIPTION OF MATERIAL AND SPECIFICATIONS

- Sales Order #: 129980
- Part No: AFH2G0625C
- Cust Part No: 36713
- Quantity (PCS): 1200
- Description: 5/8-11 Fin Hx Nut Gr2 HDG/TOS 0.020
- Specification: SAE J995(99) - GRADE 2 / ANSI B18.2.2
- Stelfast I.D. NO: 595689-O201087
- Customer PO: 210101523
- Warehouse: DAL

The data in this report is a true representation of the information provided by the material supplier certifying that the product meets the mechanical and material requirements of the listed specification. This certificate applies to the product shown on this document, as supplied by STELFAST INC. Alterations to the product by our customer or a third party shall render this certificate void.

This document may only be reproduced unaltered and only for certifying the same or lesser quantity of the product specified herein. Reproduction or alteration of this document for any other purpose is prohibited.

Stelfast certifies parts to the above description. The customer part number is only for reference purposes.

David Biss
Quality Manager

December 07, 2015

Page 1 of 1

Figure B-27. ⅝-in.-11 UNC, Nut, Test Nos. MTB-1 and MTB-2

ZENITH 中天钢铁

产品质量证明书
INSPECTION CERTIFICATE

中天钢铁集团有限公司
地址：常州市中吴大道1号
电话：+86-0519-88771501
传真：+86-0519-88772849

品质记录编号：JL/ZG-207-A

客户名称 SOLD TO	宁波包杭钢铁物资有限公司	产品名称 PRODUCT	
收货单位 CONSIGNEE	宁波包杭钢铁物资有限公司	提货编单号 DELIVERY NO.	LT16077883
		证明书编号 CERTIFICATE NO.	160713H00617
执行标准 SPEC.	GB/T 701-2008	客户编号 CUSTOMER NO.	0210547
牌号	Q195	订单编号 ORDER NO.	O1607130075
		客户采购案号 CUST ORDER NO.	
		证明书日期 ISSUE DATE	20160713
生产许可证号 APPROVAL CERT NO.		交货状态 Cond. Of Supply	热轧
钢筋标识 BAR MARK		车船号 TRAIN/SHIP NO.	皖L82035

项次 ITEM NO.	轧制序号 LOT NO.	炉号 HEAT NO.	尺寸及规格MATERIAL DESCRIPTION 产品尺寸 PRODUCT SIZE	数量 QTY	重量 WEIGHT t	化学成份 % CHEMICAL ANALYSIS C X10²	Si X10²	Mn X10²	P X10³	S X10³	拉伸试验 G.L.=A11.3 *A01 屈服 N/mm2	*A02 抗拉 N/mm2	*A03 伸长 %	*B01 弯曲试验	*O01 冷顶锻	备注 REMARKS
			规格 SPECIFICATION			0 12	30 MAX	25 50	35 MAX	40 MAX	INF	400 MAX	25 MIN	180	1/2 0 MIN	
002	G1606201005	816070039	Φ16mm	16	37.932	7	9	28	16	3	/	362	28.5	OK	OK	
											/	370	30.5	OK	OK	
											/	369	31.0	/	/	
			TOTAL:	16	37.932											

*B01=弯曲180度 Bend Test

注释 NOTES

外观、形状、尺寸和标识依据中间检查记录判定为合格ACCORDING TO PROCESS INSPECTION RECORD,VISUAL INSPECTION(SURFACE&SHAPE) AND CHECK OF DIMENSION&MARK: OK

注：产品牌号以质保证明书为准

1、兹证明本表所列产品，均依材料规格制造及试验，并且符合规范之要求。所列产品不含任何有害及辐射物质。
It is to certify that the products described herein have been manufactured and tested with satisfactory results in accordance with the requirements of the material specification.The product described herein does not contain any harmful materials and is free of radiation.

2、品质证明书影本不作有效证明文件。The copy of this Certificate is invalid except stamped.

3、用户验收后使用，如有异议应详细告知其牌号，炉号，并保留实物及标志。Please inform us the steel grade and the heat number of under qualified material(s) found in inspection on time, and keep the material(s) and the marking card.

质量管理处 GENERAL MANAGER-REASEARCH and DEVELOPMENT DEPARTMENT:

质检专用章

综合判定 Comprehensive judgment: 合格

20160713-190132

Figure B-28. ⅝-in.-11 UNC, 1½-in. Long Hex Head Bolt, Test Nos. MTB-1 and MTB-2

CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS HDG

FACTORY: IFI & Morgan Ltd REPORT DATE: 22/10/2018
ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan,Zhejiang, China

SAMPLING PLAN PER ASME B18.18-11 PO NUMBER: 210151571
SIZE: USS 1 HDG QNTY(Lot size): 3240PCS
HEADMARKS: NO MARK PART NO: 33188

DIMENSIONAL INSPECTIONS SPECIFICATION: ASTM B18.21.1-2011

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
**********************	***********************************	******************	********	********
APPEARANCE	ASTM F844	PASSED	100	0
OUTSIDE DIA	2.492-2.529	2.496-2.504	10	0
INSIDE DIA	1.055-1.092	1.080-1.089	10	0
THICKNESS	0.135-0.192	0.135-0.157	10	0

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
*********************	******************	******************	******************	********	********
HOT DIP GALVANIZED	ASTM F2329-13	Min 0.0017"	0.0017-0.0020 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.
ISO 9001:2015 SGS Certificate # HK04/0105

IFI & MORGAN LTD. 检验专用章 QUANLITY CONTROL

(SIGNATURE OF Q.A. LAB MGR.)

Figure B-29. Plain Round Washers, Test Nos. MTB-1 and MTB-2

Appendix C. Vehicle Center of Gravity Determination

Date:	**11/7/2018**	**Test Name:**	**MTB-1**	**VIN:**	**1C6RD6FT1CS307273**
Year:	**2012**	**Make:**	**Dodge**	**Model:**	**Ram 1500**

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	5089	28.22933	143659.06
+	Hub	20	14.875	297.5
+	Brake activation cylinder & frame	8	28 3/4	230
+	Pneumatic tank (Nitrogen)	31	28 1/2	883.5
+	Strobe/Brake Battery	5	28	140
+	Brake Receiver/Wires	5	51 1/4	256.25
+	CG Plate including DAS	30	33 1/4	997.5
-	Battery	-42	39 1/2	-1659
-	Oil	-10	15 7/8	-158.75
-	Interior	-97	31 5/8	-3067.625
-	Fuel	-186	14 3/4	-2743.5
-	Coolant	-3	37 1/4	-111.75
-	Washer fluid	-5	33 5/8	-168.125
+	Water Ballast (In Fuel Tank)	122	14 1/8	1723.25
+	Onboard Supplemental Battery	13	25 3/8	329.875
+	Smart Barrier	9	2 3/8	21.375
				0
				140629.56

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

Estimated Total Weight (lb)	4989
Vertical CG Location (in.)	28.1879

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.625 in.
Front Track Width: 67 in.
Rear Track Width: 67 in.

Center of Gravity	**2270P MASH Targets**	**Test Inertial**	**Difference**
Test Inertial Weight (lb)	5000 ± 110	5003	3.0
Longitudinal CG (in.)	63 ± 4	61.613032	-1.38697
Lateral CG (in.)	NA	-0.448631	NA
Vertical CG (in.)	28 or greater	28.19	0.18793

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	1472	1397
Rear	1113	1107

FRONT	2869	lb
REAR	2220	lb
TOTAL	5089	lb

TEST INERTIAL WEIGHT (lb)

	Left	Right
Front	1442	1369
Rear	1093	1099

FRONT	2811	lb
REAR	2192	lb
TOTAL	5003	lb

Figure C-1. Vehicle Mass Distribution, Test No. MTB-1

Date:	**9/20/2018**	**Test Name:**	**MTB-2**	**VIN:**	**KNADE223596440731**
Year:	**2009**	**Make:**	**Kia**	**Model:**	**Rio**

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)
+	Unballasted Car (Curb)	2497
+	Hub	19
+	Brake activation cylinder & frame	8
+	Pneumatic tank (Nitrogen)	30
+	Strobe/Brake Battery	5
+	Brake Receiver/Wires	5
+	CG Plate including DAS	13
-	Battery	-31
-	Oil	-11
-	Interior	-56
-	Fuel	-38
-	Coolant	-7
-	Washer fluid	-2
+	Water Ballast (In Fuel Tank)	0
+	Onboard Supplemental Battery	0
+	Trunk Contents	-13

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

Estimated Total Weight (lb) 2419

Vehicle Dimensions for C.G. Calculations

Wheel Base:	98.5	in.	Front Track Width:	58.0	in.
Roof Height:	57.375	in.	Rear Track Width:	57.5	in.

Center of Gravity	**1100C MASH Targets**	**Test Inertial**	**Difference**
Test Inertial Weight (lb)	2420 ± 55	2415	-5.0
Longitudinal CG (in.)	39 ± 4	36.178	-2.822
Lateral CG (in.)	NA	-0.777	NA
Vertical CG (in.)	NA	22.746	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	805	769
Rear	466	457

FRONT	1574	lb
REAR	923	lb
TOTAL	2497	lb

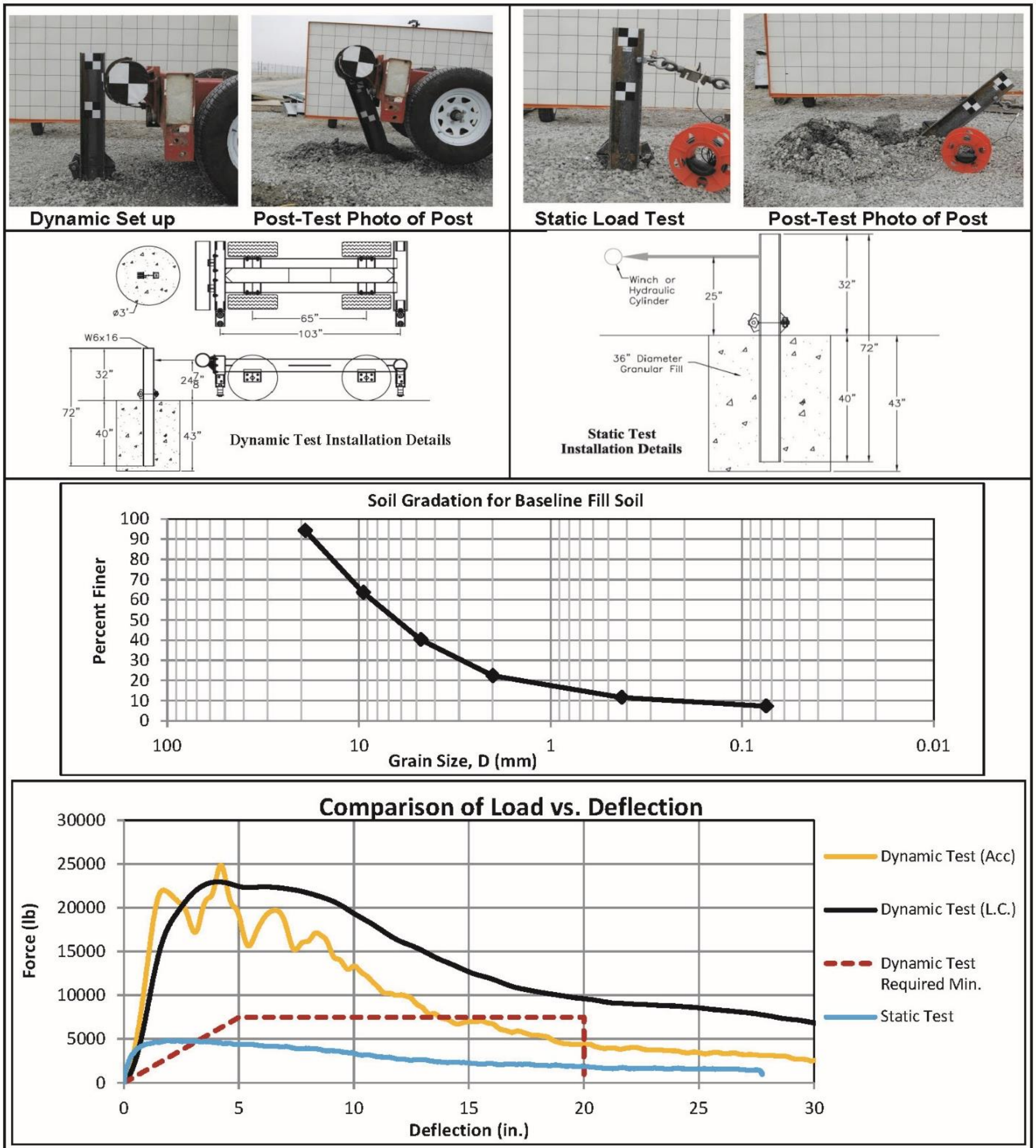
TEST INERTIAL WEIGHT (lb)

	Left	Right
Front	789	739
Rear	451	436

FRONT	1528	lb
REAR	887	lb
TOTAL	2415	lb

Figure C-2. Vehicle Mass Distribution, Test No. MTB-2

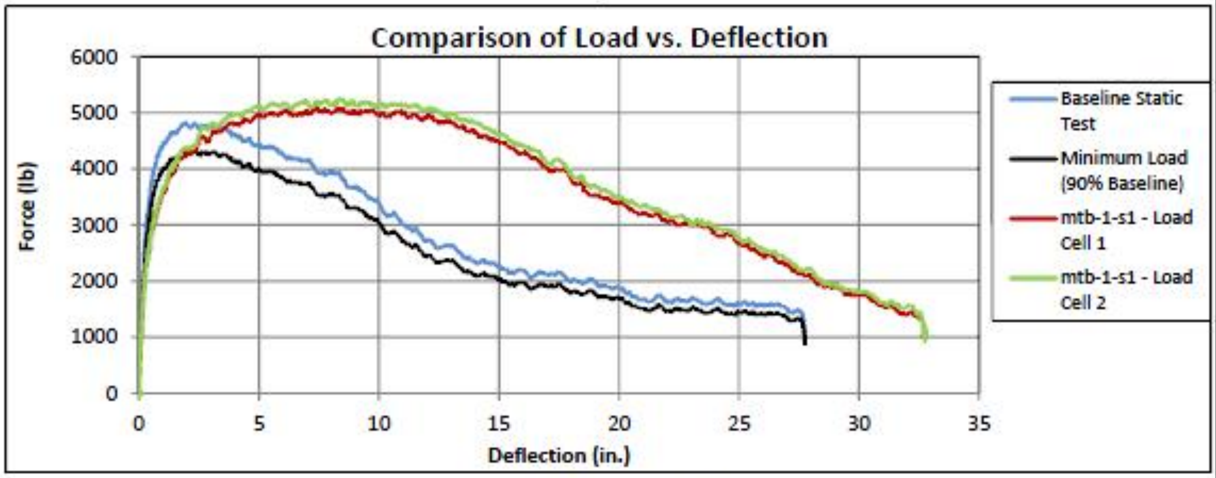
Appendix D. Static Soil Tests

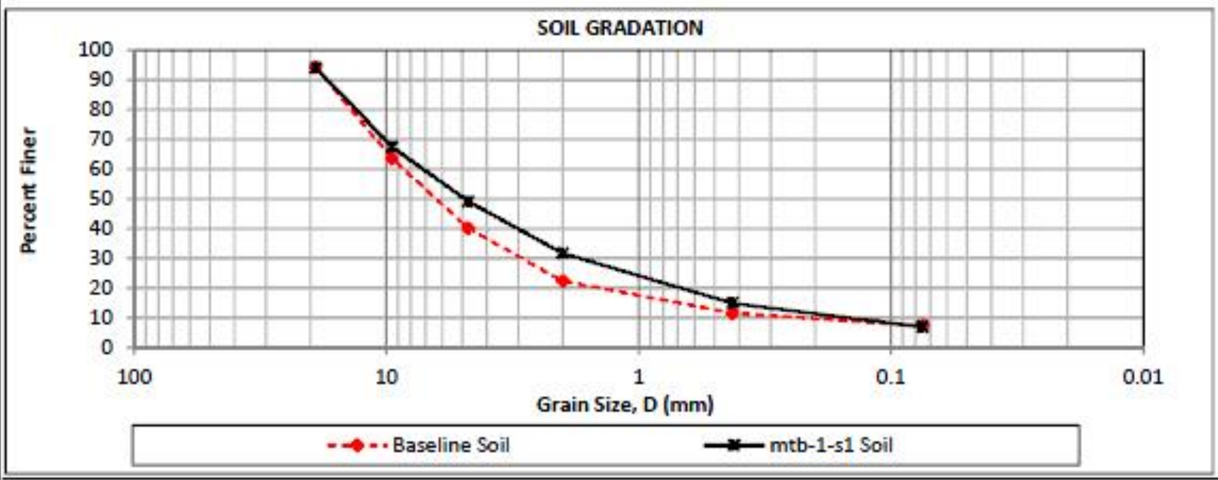


Date	2/16/2018			
Test Facility & Site Location	Midwest Roadside Safety Facility			
In situ soil description (ASTM D2487)	Well-Graded Gravel (GW)			
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)			
Description of fill placement procedure	H.E.-8			
Bogie Weight	1786	lb	810	kg
Impact Velocity	20.9	mph	33.7	km/h

Figure D-1. Soil Strength, Initial Calibration Tests, Test No. MTB-1

Static Load Test Setup	Post-Test Photo of Post
	



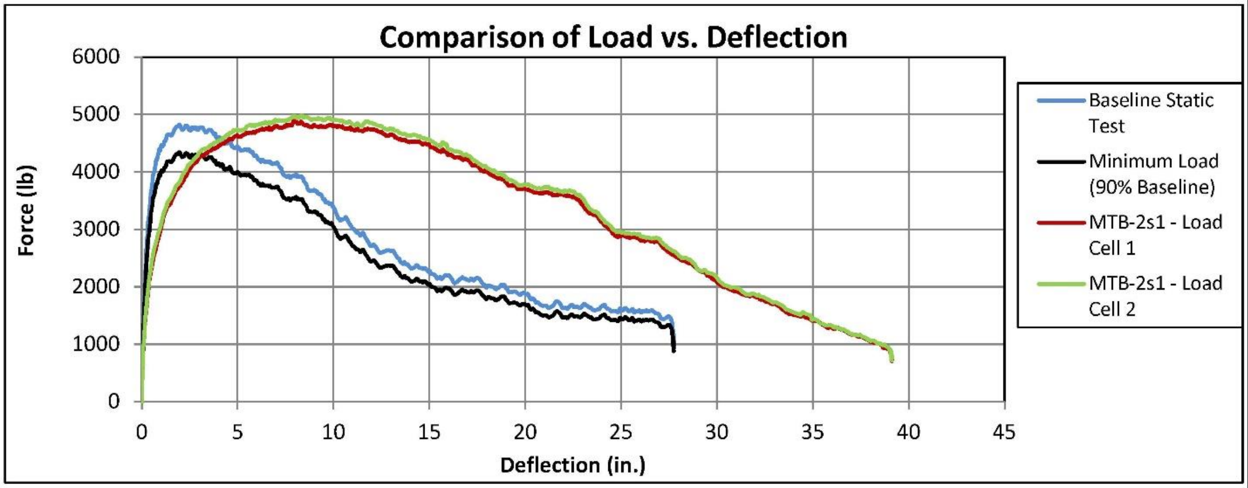


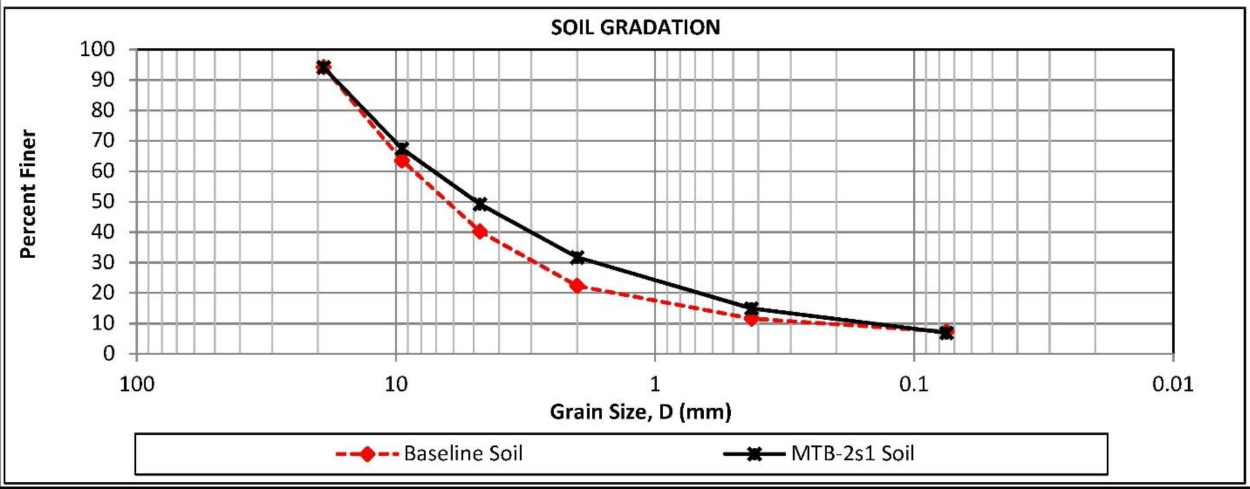
Date..	11/7/2018
Test Facility & Site Location.......................	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)...........	Well-Graded Gravel (GW)
Fill material description (ASTM D2487).........	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure........	8-inch lifts tamped with a pneumatic compactor

Figure D-2. Static Soil Test, Test No. MTB-1

Static Load Test Setup

Post-Test Photo of Post





Date...	3/22/2019
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........	8-inch lifts tamped with a pneumatic compactor

Figure D-3. Static Soil Test, Test No. MTB-2

Appendix E. Vehicle Deformation Records

Date: 11/7/2018 Test Name: MTB-1 VIN: 1C6RD6FT1CS307273
Year: 2012 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE 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	51.5257	14.6096	-3.8444	51.5273	14.8611	-3.6810	-0.0016	-0.2515	-0.1634	0.2999	0.0000	NA
	2	52.5304	19.6218	-1.0359	52.4918	19.8606	-0.8078	0.0386	-0.2388	-0.2281	0.3325	0.0386	X
	3	53.9030	23.6886	2.0925	53.8792	23.9474	2.3642	0.0238	-0.2588	-0.2717	0.3760	0.0238	X
	4	53.9742	28.9421	1.9718	53.9237	29.1164	2.2966	0.0505	-0.1743	-0.3248	0.3721	0.0505	X
	5	54.0180	33.3217	1.7587	53.9577	33.4736	2.0916	0.0603	-0.1519	-0.3329	0.3709	0.0603	X
	6	48.5429	13.9429	-2.3869	48.5073	14.2479	-2.1646	0.0356	-0.3050	-0.2223	0.3791	0.0356	X
	7	49.6394	19.3528	0.8089	49.5272	19.5119	1.0500	0.1122	-0.1591	-0.2411	0.3099	0.1122	X
	8	50.7453	23.4015	3.8701	50.7128	23.5922	4.1360	0.0325	-0.1907	-0.2659	0.3288	0.0325	X
	9	50.6567	29.2493	3.9234	50.6469	29.4256	4.1666	0.0098	-0.1763	-0.2432	0.3005	0.0098	X
	10	50.7768	33.4389	3.8765	50.6986	33.5619	4.1932	0.0782	-0.1230	-0.3167	0.3486	0.0782	X
FLOOR PAN (Z)	11	45.1167	13.4608	-0.5185	45.1597	13.6867	-0.3698	-0.0430	-0.2259	-0.1487	0.2738	-0.1487	Z
	12	46.6227	18.6887	3.3997	46.5579	18.8418	3.5847	0.0648	-0.1531	-0.1850	0.2487	-0.1850	Z
	13	47.5095	22.9923	5.2481	47.5124	23.1888	5.4702	-0.0029	-0.1965	-0.2221	0.2966	-0.2221	Z
	14	47.5131	29.3534	5.2607	47.4164	29.5388	5.5312	0.0967	-0.1854	-0.2705	0.3419	-0.2705	Z
	15	47.4558	33.3166	5.2687	47.3628	33.4533	5.5519	0.0930	-0.1367	-0.2832	0.3279	-0.2832	Z
	16	41.8222	13.0427	0.4688	41.7762	13.2659	0.6142	0.0460	-0.2232	-0.1454	0.2703	-0.1454	Z
	17	43.3180	17.3631	5.1874	43.2353	17.5590	5.4008	0.0827	-0.1959	-0.2134	0.3013	-0.2134	Z
	18	43.5494	22.6040	5.2823	43.4585	22.8192	5.5016	0.0909	-0.2152	-0.2193	0.3204	-0.2193	Z
	19	43.6456	29.4993	5.2796	43.8582	29.4550	5.4189	-0.2126	0.0443	-0.1393	0.2580	-0.1393	Z
	20	43.6612	33.3642	5.2911	43.6343	33.5592	5.5582	0.0269	-0.1950	-0.2671	0.3318	-0.2671	Z
	21	36.6006	13.5421	2.2672	36.5762	13.7538	2.3525	0.0244	-0.2117	-0.0853	0.2295	-0.0853	Z
	22	36.9026	16.9131	5.2942	36.9348	17.0812	5.4655	-0.0322	-0.1681	-0.1713	0.2422	-0.1713	Z
	23	37.3450	22.1040	5.2800	37.2867	22.3113	5.4744	0.0583	-0.2073	-0.1944	0.2901	-0.1944	Z
	24	37.5360	29.4770	5.2816	37.5874	29.6292	5.5091	-0.0514	-0.1522	-0.2275	0.2785	-0.2275	Z
	25	37.7588	33.6904	5.2956	37.7058	33.8710	5.5481	0.0530	-0.1806	-0.2525	0.3149	-0.2525	Z
	26	33.3596	13.5454	2.2432	33.3855	13.7710	2.3460	-0.0259	-0.2256	-0.1028	0.2493	-0.1028	Z
	27	34.0670	17.0360	5.2506	33.9606	17.2588	5.4027	0.1064	-0.2228	-0.1521	0.2900	-0.1521	Z
	28	34.2094	21.6562	5.2615	34.1175	21.8122	5.4424	0.0919	-0.1560	-0.1809	0.2559	-0.1809	Z
	29	34.5784	28.9410	5.2851	34.4938	29.1276	5.5090	0.0846	-0.1866	-0.2239	0.3035	-0.2239	Z
	30	34.3919	33.7939	5.2878	34.3646	33.9406	5.5316	0.0273	-0.1467	-0.2438	0.2858	-0.2438	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 E-1. Floor Pan Deformation Data – Set 1, Test No. MTB-1

Date: 11/7/2018 Test Name: MTB-1 VIN: 1C6RD6FT1CS307273
Year: 2012 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE 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	54.7174	33.9907	-7.6017	54.9837	33.9953	-7.4317	-0.2663	-0.0046	-0.1700	0.3160	0.0000	NA
	2	55.7386	39.0001	-4.7943	55.9669	38.9907	-4.5577	-0.2283	0.0094	-0.2366	0.3289	0.0000	NA
	3	57.1185	43.0620	-1.6627	57.3640	43.0705	-1.3808	-0.2455	-0.0085	-0.2819	0.3739	0.0000	NA
	4	57.2287	48.3147	-1.7914	57.4489	48.2389	-1.4541	-0.2202	0.0758	-0.3373	0.4099	0.0000	NA
	5	57.3058	52.6935	-2.0113	57.5180	52.5954	-1.6639	-0.2122	0.0981	-0.3474	0.4187	0.0000	NA
	6	51.7196	33.3480	-6.1644	51.9486	33.4072	-5.9353	-0.2290	-0.0592	-0.2291	0.3293	0.0000	NA
	7	52.8327	38.7552	-2.9697	52.9870	38.6671	-2.7199	-0.1543	0.0881	-0.2498	0.3065	0.0000	NA
	8	53.9462	42.8008	0.0928	54.1829	42.7418	0.3695	-0.2367	0.0590	-0.2767	0.3689	0.0000	NA
	9	53.8998	48.6492	0.1360	54.1618	48.5756	0.3929	-0.2620	0.0736	-0.2569	0.3742	0.0000	NA
	10	54.0507	52.8377	0.0833	54.2453	52.7114	0.4151	-0.1946	0.1263	-0.3318	0.4049	0.0000	NA
FLOOR PAN (Z)	11	48.2768	32.8939	-4.3197	48.5845	32.8740	-4.1631	-0.3077	0.0199	-0.1566	0.3458	-0.1566	Z
	12	49.7930	38.1173	-0.3993	49.9953	38.0229	-0.2049	-0.2023	0.0944	-0.1944	0.2960	-0.1944	Z
	13	50.6979	42.4174	1.4485	50.9704	42.3647	1.6821	-0.2725	0.0527	-0.2336	0.3628	-0.2336	Z
	14	50.7476	48.7783	1.4508	50.9230	48.7153	1.7351	-0.1754	0.0630	-0.2843	0.3399	-0.2843	Z
	15	50.7191	52.7419	1.4520	50.8994	52.6302	1.7509	-0.1803	0.1117	-0.2989	0.3665	-0.2989	Z
	16	44.9724	32.5014	-3.3551	45.1912	32.4805	-3.2018	-0.2188	0.0209	-0.1533	0.2680	-0.1533	Z
	17	46.4660	36.8187	1.3671	46.6505	36.7680	1.5898	-0.1845	0.0507	-0.2227	0.2936	-0.2227	Z
	18	46.7349	42.0579	1.4551	46.9135	42.0264	1.6860	-0.1786	0.0315	-0.2309	0.2936	-0.2309	Z
	19	46.8812	48.9523	1.4420	47.3651	48.6588	1.5984	-0.4839	0.2935	-0.1564	0.5872	-0.1564	Z
	20	46.9249	52.8170	1.4474	47.1719	52.7648	1.7314	-0.2470	0.0522	-0.2840	0.3800	-0.2840	Z
	21	39.7419	33.0417	-1.5947	39.9833	33.0107	-1.5000	-0.2414	0.0310	-0.0947	0.2612	-0.0947	Z
	22	40.0469	36.4155	1.4290	40.3462	36.3389	1.6115	-0.2993	0.0766	-0.1825	0.3588	-0.1825	Z
	23	40.5272	41.6030	1.4096	40.7384	41.5661	1.6168	-0.2112	0.0369	-0.2072	0.2982	-0.2072	Z
	24	40.7718	48.9744	1.4006	41.0954	48.8815	1.6452	-0.3236	0.0929	-0.2446	0.4161	-0.2446	Z
	25	41.0251	53.1860	1.4095	41.2462	53.1224	1.6801	-0.2211	0.0636	-0.2706	0.3552	-0.2706	Z
	26	36.5014	33.0685	-1.6416	36.7930	33.0524	-1.5285	-0.2916	0.0161	-0.1131	0.3132	-0.1131	Z
	27	37.2127	36.5588	1.3650	37.3740	36.5394	1.5281	-0.1613	0.0194	-0.1631	0.2302	-0.1631	Z
	28	37.3887	41.1779	1.3695	37.5657	41.0914	1.5636	-0.1770	0.0865	-0.1941	0.2766	-0.1941	Z
	29	37.8104	48.4599	1.3840	37.9980	48.4038	1.6243	-0.1876	0.0561	-0.2403	0.3100	-0.2403	Z
	30	37.6959	53.2727	1.1464	37.9058	53.2177	1.6406	-0.2099	0.0550	-0.4942	0.5397	-0.4942	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 E-2. Floor Pan Deformation Data – Set 2, Test No. MTB-1

Date: 11/7/2018 Test Name: MTB-1 VIN: 1C6RD6FT1CS307273
Year: 2012 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE 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	43.0808	4.8155	-27.6487	43.2224	5.1506	-27.5653	-0.1416	-0.3351	0.0834	0.3732	0.3732	X, Y, Z
	2	43.1884	17.0808	-27.2086	43.3424	17.3845	-27.1263	-0.1540	-0.3037	0.0823	0.3503	0.3503	X, Y, Z
	3	44.0136	28.1918	-26.5694	44.1984	28.4643	-26.4911	-0.1848	-0.2725	0.0783	0.3384	0.3384	X, Y, Z
	4	36.7431	3.8529	-16.9854	36.7755	4.1823	-16.9864	-0.0324	-0.3294	-0.0010	0.3310	0.3310	X, Y, Z
	5	38.8227	17.6079	-16.8430	38.9472	17.9385	-16.7738	-0.1245	-0.3306	0.0692	0.3600	0.3600	X, Y, Z
	6	39.5334	29.4624	-16.6148	39.6319	29.7491	-16.5470	-0.0985	-0.2867	0.0678	0.3106	0.3106	X, Y, Z
SIDE PANEL (Y)	7	48.7867	36.2034	-0.0067	48.7712	36.0147	0.2376	0.0155	0.1887	0.2443	0.3091	0.1887	Y
	8	48.7739	36.2331	-4.6263	48.7665	35.9250	-4.4110	0.0074	0.3081	0.2153	0.3759	0.3081	Y
	9	51.9033	36.4185	-3.7095	51.8926	36.3789	-3.5484	0.0107	0.0396	0.1611	0.1662	0.0396	Y
IMPACT SIDE DOOR (Y)	10	35.3501	37.6596	-22.4691	35.0356	38.0095	-22.4320	0.3145	-0.3499	0.0371	0.4719	-0.3499	Y
	11	27.7268	37.7989	-22.6470	27.4952	38.3408	-22.6316	0.2316	-0.5419	0.0154	0.5895	-0.5419	Y
	12	15.8089	38.0035	-22.8603	15.5316	38.8813	-22.7399	0.2773	-0.8778	0.1204	0.9284	-0.8778	Y
	13	35.9172	38.8657	-2.8145	35.5220	38.7343	-2.6561	0.3952	0.1314	0.1584	0.4456	0.1314	Y
	14	27.6250	39.5106	-2.7259	27.3116	39.6529	-2.6790	0.3134	-0.1423	0.0469	0.3474	-0.1423	Y
	15	17.4570	38.7824	-2.9868	17.1444	39.1925	-2.9602	0.3126	-0.4101	0.0266	0.5163	-0.4101	Y
ROOF - (Z)	16	34.1250	5.0209	-42.7340	34.1679	5.3439	-42.7032	-0.0429	-0.3230	0.0308	0.3273	0.0308	Z
	17	34.3596	11.2836	-42.8801	34.4693	11.6690	-42.8191	-0.1097	-0.3854	0.0610	0.4053	0.0610	Z
	18	33.8543	17.4593	-42.7948	33.8544	17.8768	-42.7521	-0.0001	-0.4175	0.0427	0.4197	0.0427	Z
	19	32.5738	21.6233	-42.3331	32.6292	22.0068	-42.2590	-0.0554	-0.3835	0.0741	0.3945	0.0741	Z
	20	31.9251	25.6571	-42.4815	32.0557	26.0563	-42.3617	-0.1306	-0.3992	0.1198	0.4368	0.1198	Z
	21	29.2240	5.3214	-45.4392	29.3361	5.6914	-45.3978	-0.1121	-0.3700	0.0414	0.3888	0.0414	Z
	22	28.5778	10.7588	-45.4812	28.6769	11.1830	-45.4241	-0.0991	-0.4242	0.0571	0.4393	0.0571	Z
	23	28.0769	16.7830	-45.3112	28.1308	17.1898	-45.2441	-0.0539	-0.4068	0.0671	0.4158	0.0671	Z
	24	27.3489	20.6836	-45.1800	27.3654	21.1243	-45.1058	-0.0165	-0.4407	0.0742	0.4472	0.0742	Z
	25	26.0778	25.0955	-45.0160	26.1564	25.4750	-44.9231	-0.0786	-0.3795	0.0929	0.3985	0.0929	Z
	26	20.7886	6.2880	-46.6138	20.9358	6.6442	-46.5780	-0.1472	-0.3562	0.0358	0.3871	0.0358	Z
	27	20.2564	11.3403	-46.5616	20.3150	11.8282	-46.5142	-0.0586	-0.4879	0.0474	0.4937	0.0474	Z
	28	20.0231	16.8409	-46.3754	20.1246	17.2092	-46.3136	-0.1015	-0.3683	0.0618	0.3870	0.0618	Z
	29	20.0842	21.0613	-46.1393	20.0882	21.4911	-46.0676	-0.0040	-0.4298	0.0717	0.4358	0.0717	Z
	30	20.1520	24.7814	-45.8442	20.2922	25.2074	-45.7492	-0.1402	-0.4260	0.0950	0.4584	0.0950	Z
A-PILLAR Maximum (X, Y, Z)	31	46.6759	34.6230	-29.1394	46.6962	34.8745	-28.9190	-0.0203	-0.2515	0.2204	0.3350	0.2204	Z
	32	44.2202	34.2384	-30.7691	44.3320	34.4872	-30.5603	-0.1118	-0.2488	0.2088	0.3435	0.2088	Z
	33	41.7002	32.5483	-32.1704	41.7418	32.8162	-32.0302	-0.0416	-0.2679	0.1402	0.3052	0.1402	Z
	34	38.7663	32.5624	-34.3839	38.7712	32.8831	-34.2398	-0.0049	-0.3207	0.1441	0.3516	0.1441	Z
	35	36.7535	32.1396	-35.6941	36.8688	32.4550	-35.5311	-0.1153	-0.3154	0.1630	0.3733	0.1630	Z
	36	33.7742	30.9216	-37.2756	33.8900	31.2585	-37.1291	-0.1158	-0.3369	0.1465	0.3852	0.1465	Z
A-PILLAR Lateral (Y)	31	46.6759	34.6230	-29.1394	46.6962	34.8745	-28.9190	-0.0203	-0.2515	0.2204	0.3350	-0.2515	Y
	32	44.2202	34.2384	-30.7691	44.3320	34.4872	-30.5603	-0.1118	-0.2488	0.2088	0.3435	-0.2488	Y
	33	41.7002	32.5483	-32.1704	41.7418	32.8162	-32.0302	-0.0416	-0.2679	0.1402	0.3052	-0.2679	Y
	34	38.7663	32.5624	-34.3839	38.7712	32.8831	-34.2398	-0.0049	-0.3207	0.1441	0.3516	-0.3207	Y
	35	36.7535	32.1396	-35.6941	36.8688	32.4550	-35.5311	-0.1153	-0.3154	0.1630	0.3733	-0.3154	Y
	36	33.7742	30.9216	-37.2756	33.8900	31.2585	-37.1291	-0.1158	-0.3369	0.1465	0.3852	-0.3369	Y
B-PILLAR Maximum (X, Y, Z)	37	8.3737	35.4867	-28.3133	8.4186	35.7684	-28.2167	-0.0449	-0.2817	0.0966	0.3012	0.0966	Z
	38	5.6136	35.5314	-28.6694	5.7059	35.8121	-28.6061	-0.0923	-0.2807	0.0633	0.3022	0.0633	Z
	39	7.2524	31.6100	-40.2919	7.3221	31.9056	-40.2198	-0.0697	-0.2956	0.0721	0.3121	0.0721	Z
	40	4.0336	31.7389	-40.0495	4.0499	32.0399	-39.9839	-0.0163	-0.3010	0.0656	0.3085	0.0656	Z
B-PILLAR Lateral (Y)	37	8.3737	35.4867	-28.3133	8.4186	35.7684	-28.2167	-0.0449	-0.2817	0.0966	0.3012	-0.2817	Y
	38	5.6136	35.5314	-28.6694	5.7059	35.8121	-28.6061	-0.0923	-0.2807	0.0633	0.3022	-0.2807	Y
	39	7.2524	31.6100	-40.2919	7.3221	31.9056	-40.2198	-0.0697	-0.2956	0.0721	0.3121	-0.2956	Y
	40	4.0336	31.7389	-40.0495	4.0499	32.0399	-39.9839	-0.0163	-0.3010	0.0656	0.3085	-0.3010	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 E-3. Occupant Compartment Deformation Data – Set 1, Test No. MTB-1

Date: 11/7/2018 Test Name: MTB-1 VIN: 1C6RD6FT1CS307273
Year: 2012 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE 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	46.3180	24.0781	-31.6149	46.7984	24.5308	-31.3348	-0.4804	-0.4527	0.2801	0.7171	0.7171	X, Y, Z
	2	46.5141	36.3448	-31.2507	46.9886	36.8025	-30.8851	-0.4745	-0.4577	0.3656	0.7539	0.7539	X, Y, Z
	3	47.4183	47.4532	-30.6767	47.8910	47.9354	-30.2225	-0.4727	-0.4822	0.4542	0.8138	0.8138	X, Y, Z
	4	39.9215	23.2290	-20.9771	40.2604	23.6783	-20.7571	-0.3389	-0.4493	0.2200	0.6043	0.6043	X, Y, Z
	5	42.1021	36.9690	-20.9102	42.5320	37.4052	-20.5825	-0.4299	-0.4362	0.3277	0.6946	0.6946	X, Y, Z
	6	42.8992	48.8191	-20.7523	43.3134	49.2064	-20.4104	-0.4142	-0.3873	0.3419	0.6622	0.6622	X, Y, Z
SIDE PANEL (Y)	7	52.1212	55.5958	-4.1413	52.3956	55.4282	-3.4724	-0.2744	0.1676	0.6689	0.7422	0.1676	Y
	8	52.1311	55.5966	-8.7610	52.4203	55.3340	-8.1552	-0.2892	0.2626	0.6058	0.7208	0.2626	Y
	9	55.2573	55.7646	-7.8300	55.0147	55.9305	-7.1002	0.2426	-0.1659	0.7298	0.7868	-0.1659	Y
IMPACT SIDE DOOR (Y)	10	38.8051	57.0101	-26.6780	38.8354	57.4830	-26.2368	-0.0303	-0.4729	0.4412	0.6475	-0.4729	Y
	11	31.1841	57.2043	-26.8943	31.2511	57.8828	-26.4688	-0.0670	-0.6785	0.4255	0.8037	-0.6785	Y
	12	19.2692	57.4954	-27.1673	19.3021	58.4933	-26.7863	-0.0329	-0.9979	0.3810	1.0687	-0.9979	Y
	13	39.2855	58.3350	-7.0288	39.1889	58.2299	-6.5312	0.0966	0.1051	0.4976	0.5177	0.1051	Y
	14	30.9980	59.0416	-6.9850	30.9226	59.2028	-6.5499	0.0754	-0.1612	0.4351	0.4701	-0.1612	Y
	15	20.8263	58.3866	-7.2913	20.7505	58.8226	-6.9385	0.0758	-0.4360	0.3528	0.5660	-0.4360	Y
ROOF - (Z)	16	37.4374	24.2549	-46.7450	37.9155	24.8546	-46.4874	-0.4781	-0.5997	0.2576	0.8091	0.2576	Z
	17	37.7190	30.5146	-46.9289	38.1870	31.1105	-46.6265	-0.4680	-0.5959	0.3024	0.8158	0.3024	Z
	18	37.2589	36.6944	-46.8846	37.7517	37.3343	-46.5360	-0.4928	-0.6399	0.3486	0.8797	0.3486	Z
	19	36.0070	40.8705	-46.4551	36.4322	41.5477	-46.0957	-0.4252	-0.6772	0.3594	0.8767	0.3594	Z
	20	35.3889	44.9079	-46.6318	35.8858	45.5210	-46.2261	-0.4969	-0.6131	0.4057	0.8874	0.4057	Z
	21	32.5520	24.5745	-49.4760	33.1095	25.1550	-49.2214	-0.5575	-0.5805	0.2546	0.8442	0.2546	Z
	22	31.9462	30.0162	-49.5551	32.5061	30.6235	-49.2608	-0.5599	-0.6073	0.2943	0.8769	0.2943	Z
	23	31.4891	36.0448	-49.4251	31.9808	36.6802	-49.1019	-0.4917	-0.6354	0.3232	0.8660	0.3232	Z
	24	30.7893	39.9514	-49.3218	31.2685	40.6245	-48.9725	-0.4792	-0.6731	0.3493	0.8971	0.3493	Z
	25	29.5500	44.3735	-49.1915	30.0563	44.9875	-48.8110	-0.5063	-0.6140	0.3805	0.8821	0.3805	Z
	26	24.1298	25.5958	-50.6980	24.6680	26.2150	-50.4807	-0.5382	-0.6192	0.2173	0.8487	0.2173	Z
	27	23.6347	30.6521	-50.6800	24.1236	31.3359	-50.4314	-0.4889	-0.6838	0.2486	0.8766	0.2486	Z
	28	23.4412	36.1554	-50.5292	23.9377	36.7545	-50.2404	-0.4965	-0.5991	0.2888	0.8300	0.2888	Z
	29	23.5323	40.3766	-50.3191	24.0316	40.9855	-49.9977	-0.4993	-0.6089	0.3214	0.8505	0.3214	Z
	30	23.6262	44.0979	-50.0468	24.1403	44.7685	-49.6903	-0.5141	-0.6706	0.3565	0.9171	0.3565	Z
A-PILLAR Maximum (X, Y, Z)	31	50.1406	53.8484	-33.2736	50.5516	54.2652	-32.6514	-0.4110	-0.4168	0.6222	0.8543	0.6222	Z
	32	47.6901	53.4717	-34.9129	48.0551	53.9190	-34.3314	-0.3650	-0.4473	0.5815	0.8194	0.5815	Z
	33	45.1645	51.7915	-36.3160	45.5042	52.2371	-35.8263	-0.3397	-0.4456	0.4897	0.7442	0.4897	Z
	34	42.2416	51.8133	-38.5440	42.6106	52.2667	-38.1007	-0.3690	-0.4534	0.4433	0.7337	0.4433	Z
	35	40.2321	51.3971	-39.8614	40.7394	51.8341	-39.4100	-0.5073	-0.4370	0.4514	0.8075	0.4514	Z
	36	37.2515	50.1912	-41.4498	37.7126	50.7170	-41.0046	-0.4611	-0.5258	0.4452	0.8290	0.4452	Z
A-PILLAR Lateral (Y)	31	50.1406	53.8484	-33.2736	50.5516	54.2652	-32.6514	-0.4110	-0.4168	0.6222	0.8543	-0.4168	Y
	32	47.6901	53.4717	-34.9129	48.0551	53.9190	-34.3314	-0.3650	-0.4473	0.5815	0.8194	-0.4473	Y
	33	45.1645	51.7915	-36.3160	45.5042	52.2371	-35.8263	-0.3397	-0.4456	0.4897	0.7442	-0.4456	Y
	34	42.2416	51.8133	-38.5440	42.6106	52.2667	-38.1007	-0.3690	-0.4534	0.4433	0.7337	-0.4534	Y
	35	40.2321	51.3971	-39.8614	40.7394	51.8341	-39.4100	-0.5073	-0.4370	0.4514	0.8075	-0.4370	Y
	36	37.2515	50.1912	-41.4498	37.7126	50.7170	-41.0046	-0.4611	-0.5258	0.4452	0.8290	-0.5258	Y
B-PILLAR Maximum (X, Y, Z)	37	11.8423	54.9992	-32.6410	12.2389	55.4295	-32.3200	-0.3966	-0.4303	0.3210	0.6675	0.3210	Z
	38	9.0843	55.0620	-33.0109	9.5228	55.5046	-32.6924	-0.4385	-0.4426	0.3185	0.6997	0.3185	Z
	39	10.7505	51.0559	-44.6006	11.1750	51.5514	-44.3089	-0.4245	-0.4955	0.2917	0.7147	0.2917	Z
	40	7.5317	51.2101	-44.3749	7.9700	51.7147	-44.0601	-0.4383	-0.5046	0.3148	0.7388	0.3148	Z
B-PILLAR Lateral (Y)	37	11.8423	54.9992	-32.6410	12.2389	55.4295	-32.3200	-0.3966	-0.4303	0.3210	0.6675	-0.4303	Y
	38	9.0843	55.0620	-33.0109	9.5228	55.5046	-32.6924	-0.4385	-0.4426	0.3185	0.6997	-0.4426	Y
	39	10.7505	51.0559	-44.6006	11.1750	51.5514	-44.3089	-0.4245	-0.4955	0.2917	0.7147	-0.4955	Y
	40	7.5317	51.2101	-44.3749	7.9700	51.7147	-44.0601	-0.4383	-0.5046	0.3148	0.7388	-0.5046	Y

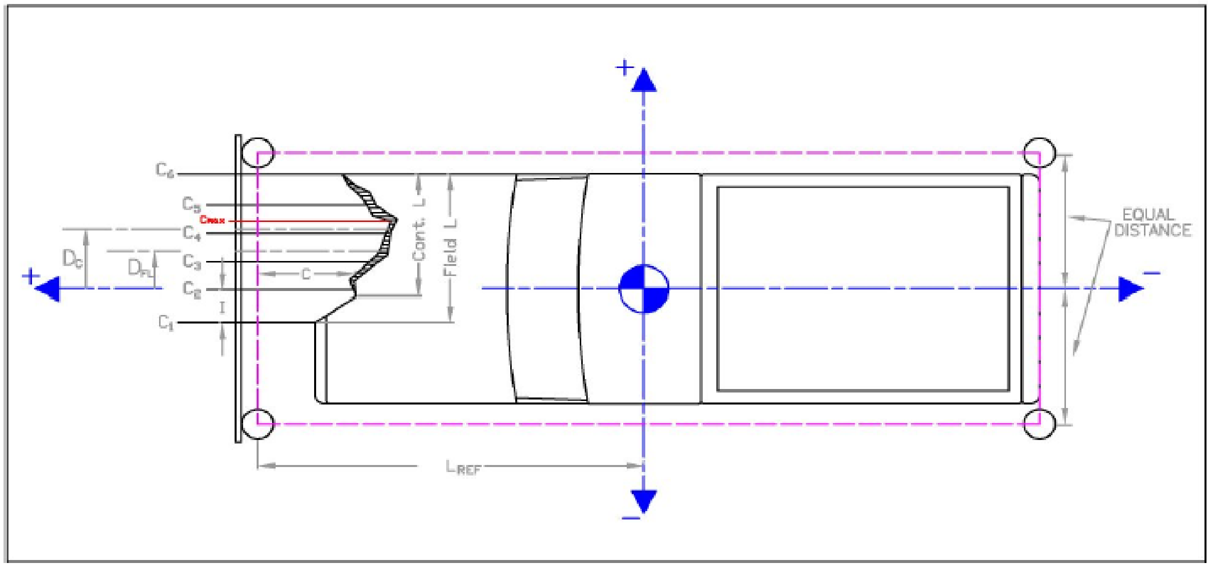
[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[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 E-4. Occupant Compartment Deformation Data – Set 2, Test No. MTB-1

Date: 1/12/2018	Test Name: MTB-1	VIN: 1C6RD6FT1CS307273
Year: 2012	Make: Dodge	Model: Ram 1500



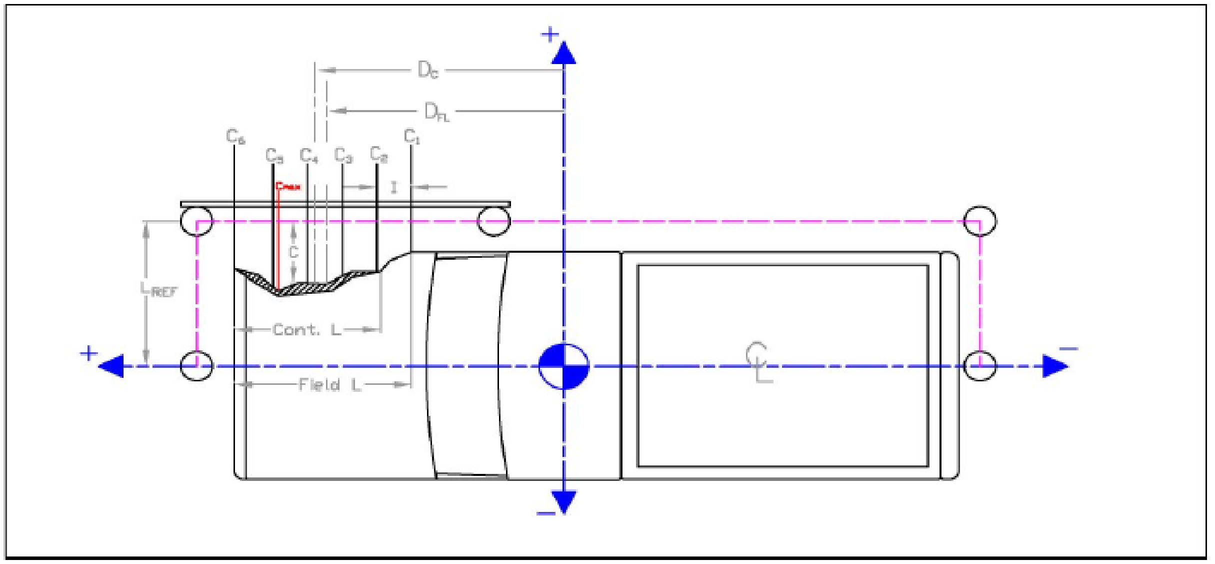
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	108 1/4	(2750)
Total Vehicle Width:	77	(1956)
Width of contact and induced crush - Field L:	77	(1956)
Crush measurement spacing interval (L/5) - I:	15 3/8	(391)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	24	(610)
Distance from center of vehicle to center of contact damage - D_C:	23	(584)

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 1/2	-(978)	22 1/2	(572)	2 3/4	(70)	#VALUE!	#VALUE!
C_2	14 1/2	(368)	-23 1/8	-(587)	6 1/2	(165)			5 1/4	(133)
C_3	12 1/4	(311)	-7 3/4	-(197)	4 1/4	(108)			5 1/4	(133)
C_4	13 1/8	(333)	7 5/8	(194)	4 1/4	(108)			6 1/8	(156)
C_5	11 1/4	(286)	23	(584)	6 1/8	(156)			2 3/8	(60)
C_6	n/a	#VALUE!	38 3/8	(975)	20 1/2	(521)			#VALUE!	#VALUE!
C_{MAX}	13 1/8	(333)	7 5/8	(194)	4 1/4	(108)			6 1/8	(156)

Figure E-5. Exterior Vehicle Crush (NASS) – Front, Test No. MTB-1

Date:	1/12/2018	Test Name:	MTB-1	VIN:	1C6RD6FT1CS307273
Year:	2012	Make:	Dodge	Model:	Ram 1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	44 1/2	(1130)
Total Vehicle Length:	229	(5817)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-4 7/8	-(124)
Width of contact and induced crush - Field L:	229	(5817)
Crush measurement spacing interval (L/5) - I:	45 3/4	(1162)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-13 1/8	-(333)
Width of Contact Damage:	229	(5817)
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	n/a	#VALUE!	-127 5/8	-(3242)	33 1/2	(851)	1/2	(13)	#VALUE!	#VALUE!
C_2	n/a	#VALUE!	-81 7/8	-(2080)	5 1/2	(140)			#VALUE!	#VALUE!
C_3	6 1/4	(159)	-36 1/8	-(918)	5 3/4	(146)			0	()
C_4	6 3/8	(162)	9 5/8	(244)	5	(127)			7/8	(22)
C_5	n/a	#VALUE!	55 3/8	(1407)	5 3/4	(146)			#VALUE!	#VALUE!
C_6	n/a	#VALUE!	101 1/8	(2569)	9 3/4	(248)			#VALUE!	#VALUE!
C_{MAX}	21	(533)	95 3/4	(2432)	6 3/4	(171)			13 3/4	(349)

Figure E-6. Exterior Vehicle Crush (NASS) – Side, Test No. MTB-1

Date: 9/20/2018 Test Name: MTB-2 VIN: KNADE223596440731
Year: 2009 Make: Kia Model: Rio

VEHICLE DEFORMATION
PASSENGER SIDE 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	63.9964	9.6915	2.8727	64.2097	9.6791	2.5636	-0.2133	0.0124	0.3091	0.3758	0.3091	Z
	2	64.7593	6.7154	4.4410	64.9206	6.6287	4.0926	-0.1613	0.0867	0.3484	0.3936	0.3484	Z
	3	64.3797	3.9877	4.5218	64.5442	3.8593	4.1561	-0.1645	0.1284	0.3657	0.4211	0.3657	Z
	4	63.9188	1.0276	4.7348	64.0987	0.9976	4.3342	-0.1799	0.0300	0.4006	0.4402	0.4006	Z
	5	63.2835	-3.5260	4.8933	63.4690	-3.5592	4.5124	-0.1855	-0.0332	0.3809	0.4250	0.3809	Z
	6	61.5904	10.2711	6.5347	61.8135	10.2128	6.2511	-0.2231	0.0583	0.2836	0.3655	0.2836	Z
	7	61.1647	7.0646	6.6375	61.3577	6.9173	6.2983	-0.1930	0.1473	0.3392	0.4171	0.3392	Z
	8	61.0593	4.1293	6.5156	61.2762	4.1301	6.1244	-0.2169	-0.0008	0.3912	0.4473	0.3912	Z
	9	60.7574	1.1937	6.7030	60.9216	1.1347	6.3898	-0.1642	0.0590	0.3132	0.3585	0.3132	Z
	10	59.9345	-2.0022	7.0942	60.1167	-2.0364	6.7643	-0.1822	-0.0342	0.3299	0.3784	0.3299	Z
FLOOR PAN (Z)	11	54.7532	13.1964	8.3216	54.9655	13.1615	8.0790	-0.2123	0.0349	0.2426	0.3243	0.2426	Z
	12	54.2065	8.2978	8.2070	54.5153	8.2608	7.9292	-0.3088	0.0370	0.2778	0.4170	0.2778	Z
	13	53.7921	4.7251	8.2498	54.0213	4.7019	7.9567	-0.2292	0.0232	0.2931	0.3728	0.2931	Z
	14	53.2865	0.8012	8.3692	53.5118	0.7838	8.0255	-0.2253	0.0174	0.3437	0.4113	0.3437	Z
	15	53.1102	-2.2816	8.4945	53.3420	-2.3354	8.1818	-0.2318	-0.0538	0.3127	0.3929	0.3127	Z
	16	49.8547	14.1525	8.6947	50.1307	14.1123	8.4686	-0.2760	0.0402	0.2261	0.3590	0.2261	Z
	17	49.5381	8.8817	8.2836	49.7655	8.8645	8.0690	-0.2274	0.0172	0.2146	0.3131	0.2146	Z
	18	48.8525	4.7636	8.3284	49.0896	4.7218	8.0997	-0.2371	0.0418	0.2287	0.3321	0.2287	Z
	19	48.8790	1.2165	8.6729	49.0923	1.1774	8.4137	-0.2133	0.0391	0.2592	0.3380	0.2592	Z
	20	48.2836	-1.8277	9.0314	48.5468	-1.8735	8.7792	-0.2632	-0.0458	0.2522	0.3674	0.2522	Z
	21	45.3584	14.8436	8.6065	45.6031	14.8328	8.4138	-0.2447	0.0108	0.1927	0.3117	0.1927	Z
	22	44.3741	9.4074	8.4142	44.6585	9.3825	8.2446	-0.2844	0.0249	0.1696	0.3321	0.1696	Z
	23	43.5115	4.9677	8.3911	43.7573	4.9601	8.1993	-0.2458	0.0076	0.1918	0.3119	0.1918	Z
	24	42.6536	0.8974	8.7863	42.8871	0.8819	8.5953	-0.2335	0.0155	0.1910	0.3021	0.1910	Z
	25	42.6379	-1.8945	8.8774	42.8894	-1.8921	8.6728	-0.2515	0.0024	0.2046	0.3242	0.2046	Z
	26	40.5826	15.4805	8.3749	40.8025	15.5124	8.2049	-0.2199	-0.0319	0.1700	0.2798	0.1700	Z
	27	39.8059	9.3941	8.3789	40.0616	9.3602	8.2235	-0.2557	0.0339	0.1554	0.3011	0.1554	Z
	28	39.7096	4.9618	8.4028	39.9809	5.0099	8.2352	-0.2713	-0.0481	0.1676	0.3225	0.1676	Z
	29	39.6290	1.4827	8.4774	39.8806	1.4742	8.3096	-0.2516	0.0085	0.1678	0.3025	0.1678	Z
	30	39.1689	-2.1222	8.2797	39.4107	-2.1102	8.0988	-0.2418	0.0120	0.1809	0.3022	0.1809	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 E-7. Floor Pan Deformation Data – Set 1, Test No. MTB-2

Date: 9/20/2018 Test Name: MTB-2 VIN: KNADE223596440731
Year: 2009 Make: Kia Model: Rio

VEHICLE DEFORMATION
PASSENGER SIDE 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	61.4391	33.9345	3.0030	61.0349	34.7120	2.9765	0.4042	-0.7775	0.0265	0.8767	0.4051	X, Z
	2	62.5701	31.0752	4.5661	62.1226	31.7271	4.5724	0.4475	-0.6519	-0.0063	0.7907	0.4475	X
	3	62.5378	28.3212	4.6409	62.0706	29.0502	4.6801	0.4672	-0.7290	-0.0392	0.8667	0.4672	X
	4	62.4541	25.3261	4.8472	62.0877	26.0099	4.8371	0.3664	-0.6838	0.0101	0.7758	0.3665	X, Z
	5	62.3985	20.7285	4.9957	62.0778	21.4305	5.0401	0.3207	-0.7020	-0.0444	0.7731	0.3207	X
	6	58.9756	34.1978	6.6630	58.5635	34.9210	6.6521	0.4121	-0.7232	0.0109	0.8324	0.4122	X, Z
	7	58.9580	30.9630	6.7588	58.5825	31.6369	6.6987	0.3755	-0.6739	0.0601	0.7738	0.3803	X, Z
	8	59.2241	28.0381	6.6308	58.8468	28.8089	6.5834	0.3773	-0.7708	0.0474	0.8595	0.3803	X, Z
	9	59.2951	25.0875	6.8118	58.9452	25.8212	6.8212	0.3499	-0.7337	-0.0094	0.8129	0.3499	X
	10	58.8818	21.8124	7.1954	58.5327	22.5236	7.2357	0.3491	-0.7112	-0.0403	0.7933	0.3491	X
FLOOR PAN (Z)	11	51.8220	36.2326	8.4474	51.4144	36.9067	8.3775	0.4076	-0.6741	0.0699	0.7908	0.0699	Z
	12	51.8982	31.3044	8.3221	51.5503	31.9690	8.2701	0.3479	-0.6646	0.0520	0.7520	0.0520	Z
	13	51.9381	27.7080	8.3570	51.5900	28.3903	8.3124	0.3481	-0.6823	0.0446	0.7673	0.0446	Z
	14	51.9318	23.7514	8.4678	51.5910	24.4888	8.3986	0.3408	-0.7374	0.0692	0.8153	0.0692	Z
	15	52.1460	20.6707	8.5866	51.8331	21.3681	8.5805	0.3129	-0.6974	0.0061	0.7644	0.0061	Z
	16	46.8416	36.5619	8.8162	46.4083	37.2040	8.7272	0.4333	-0.6421	0.0890	0.7797	0.0890	Z
	17	47.1934	31.2942	8.3939	46.8138	31.9174	8.3396	0.3796	-0.6232	0.0543	0.7317	0.0543	Z
	18	47.0331	27.1224	8.4295	46.6663	27.7503	8.3979	0.3668	-0.6279	0.0316	0.7279	0.0316	Z
	19	47.5068	23.6062	8.7668	47.2037	24.2569	8.7314	0.3031	-0.6507	0.0354	0.7187	0.0354	Z
	20	47.3002	20.5105	9.1183	47.0287	21.1219	9.1141	0.2715	-0.6114	0.0042	0.6690	0.0042	Z
	21	42.2941	36.6801	8.7238	41.8505	37.2871	8.6075	0.4436	-0.6070	0.1163	0.7608	0.1163	Z
	22	42.0042	31.1634	8.5191	41.6159	31.7526	8.4608	0.3883	-0.5892	0.0583	0.7080	0.0583	Z
	23	41.7090	26.6505	8.4858	41.3626	27.2527	8.4353	0.3464	-0.6022	0.0505	0.6966	0.0505	Z
	24	41.3714	22.5036	8.8717	41.0630	23.1277	8.8625	0.3084	-0.6241	0.0092	0.6962	0.0092	Z
	25	41.7082	19.7319	8.9571	41.3936	20.3377	8.9576	0.3146	-0.6058	-0.0005	0.6826	-0.0005	Z
	26	37.4764	36.7094	8.4874	36.9476	37.2436	8.3632	0.5288	-0.5342	0.1242	0.7619	0.1242	Z
	27	37.4743	30.5737	8.4780	37.0726	31.1306	8.4114	0.4017	-0.5569	0.0666	0.6899	0.0666	Z
	28	37.9382	26.1647	8.4928	37.5846	26.7739	8.4521	0.3536	-0.6092	0.0407	0.7056	0.0407	Z
	29	38.2974	22.7030	8.5602	38.0132	23.2474	8.5527	0.2842	-0.5444	0.0075	0.6142	0.0075	Z
	30	38.2963	19.0693	8.3546	38.0755	19.6596	8.3571	0.2208	-0.5903	-0.0025	0.6302	-0.0025	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 E-8. Floor Pan Deformation Data – Set 2, Test No. MTB-2

Date:	9/20/2018	Test Name:	MTB-2	VIN:	KNADE223596440731
Year:	2009	Make:	Kia	Model:	Rio

VEHICLE DEFORMATION
PASSENGER SIDE 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	51.2837	12.1913	-19.2225	51.2843	12.3961	-19.5374	-0.0006	-0.2048	-0.3149	0.3756	0.3756	X, Y, Z
	2	50.3047	0.1942	-19.9689	50.3004	0.3968	-20.3172	0.0043	-0.2026	-0.3483	0.4030	0.4030	X, Y, Z
	3	49.5053	-9.0843	-20.1348	49.5993	-8.8368	-20.4925	-0.0940	0.2475	-0.3577	0.4450	0.4450	X, Y, Z
	4	48.5213	14.6351	-10.2523	48.4908	14.7856	-10.5668	0.0305	-0.1505	-0.3145	0.3500	0.3500	X, Y, Z
	5	46.3795	-1.6337	-9.9550	46.5311	-1.4495	-10.3063	-0.1516	0.1842	-0.3513	0.4246	0.4246	X, Y, Z
	6	43.7414	-9.7829	-10.5271	43.8952	-9.6071	-10.8436	-0.1538	0.1758	-0.3165	0.3934	0.3934	X, Y, Z
SIDE PANEL (Y)	7	55.5771	16.1899	2.4092	55.6114	16.4252	2.1464	-0.0343	-0.2353	-0.2628	0.3544	-0.2353	Y
	8	60.2355	15.8969	2.7153	60.2315	16.2588	2.3960	0.0040	-0.3619	-0.3193	0.4826	-0.3619	Y
	9	56.4666	15.9940	-1.9363	56.4365	15.8910	-2.2200	0.0301	0.1030	-0.2837	0.3033	0.1030	Y
IMPACT SIDE DOOR (Y)	10	48.8938	18.0171	-15.0724	48.5050	17.9606	-15.4060	0.3888	0.0565	-0.3336	0.5154	0.0565	Y
	11	34.3809	19.4425	-15.5836	34.0888	19.8538	-15.7558	0.2921	-0.4113	-0.1722	0.5331	-0.4113	Y
	12	23.7882	20.0012	-16.3140	23.4120	20.6997	-16.4757	0.3762	-0.6985	-0.1617	0.8097	-0.6985	Y
	13	44.9866	18.4507	-0.6730	44.8121	19.1967	-0.9314	0.1745	-0.7460	-0.2584	0.8085	-0.7460	Y
	14	37.6867	19.2898	0.0957	37.5181	19.9533	-0.1476	0.1686	-0.6635	-0.2433	0.7265	-0.6635	Y
	15	28.7236	19.6589	0.5578	28.5874	20.2029	0.4069	0.1362	-0.5440	-0.1509	0.5807	-0.5440	Y
ROOF - (Z)	16	30.4175	8.1879	-37.0564	30.3635	8.3195	-37.3460	0.0540	-0.1316	-0.2896	0.3226	-0.2896	Z
	17	30.8037	3.0216	-37.3385	30.6950	3.1129	-37.6174	0.1087	-0.0913	-0.2789	0.3129	-0.2789	Z
	18	30.8772	-0.8440	-37.4888	30.7829	-0.6778	-37.7507	0.0943	0.1662	-0.2619	0.3242	-0.2619	Z
	19	29.6237	-4.0714	-37.8205	29.5107	-4.0187	-38.0757	0.1130	0.0527	-0.2552	0.2840	-0.2552	Z
	20	29.4922	-8.1152	-37.8465	29.4454	-7.9428	-38.0634	0.0468	0.1724	-0.2169	0.2810	-0.2169	Z
	21	19.2233	8.1474	-38.5457	18.9827	8.2573	-38.7771	0.2406	-0.1099	-0.2314	0.3514	-0.2314	Z
	22	19.1485	4.2840	-38.8351	18.9537	4.3204	-39.0470	0.1948	-0.0364	-0.2119	0.2901	-0.2119	Z
	23	18.6453	0.4562	-39.0657	18.4789	0.5182	-39.2588	0.1664	-0.0620	-0.1931	0.2623	-0.1931	Z
	24	18.2319	-2.7917	-39.2012	18.0608	-2.7712	-39.3731	0.1711	0.0205	-0.1719	0.2434	-0.1719	Z
	25	17.4661	-6.4113	-39.3038	17.3027	-6.3501	-39.4555	0.1634	0.0612	-0.1517	0.2312	-0.1517	Z
	26	9.2178	9.2690	-38.8457	9.0100	9.3410	-38.9756	0.2078	-0.0720	-0.1299	0.2554	-0.1299	Z
	27	9.1627	5.5344	-39.1496	8.9085	5.5998	-39.2716	0.2542	-0.0654	-0.1220	0.2894	-0.1220	Z
	28	9.2087	1.4984	-39.3853	9.0524	1.5863	-39.4979	0.1563	-0.0879	-0.1126	0.2117	-0.1126	Z
	29	9.5103	-2.2098	-39.5239	9.3083	-2.2322	-39.6247	0.2020	-0.0224	-0.1008	0.2269	-0.1008	Z
	30	9.7442	-5.1882	-39.5795	9.5435	-5.1719	-39.6683	0.2007	0.0163	-0.0888	0.2201	-0.0888	Z
A-PILLAR Maximum (X, Y, Z)	31	54.3458	15.0277	-22.4646	54.1704	15.1155	-22.8705	0.1754	-0.0878	-0.4059	0.4508	0.1754	X
	32	51.9399	14.7222	-24.0407	51.8587	14.8478	-24.4191	0.0812	-0.1256	-0.3784	0.4069	0.0812	X
	33	49.5159	14.4057	-25.6361	49.4273	14.5432	-26.0270	0.0886	-0.1375	-0.3909	0.4237	0.0886	X
	34	47.1912	14.0856	-27.0036	47.0488	14.2301	-27.4101	0.1424	-0.1445	-0.4065	0.4543	0.1424	X
	35	44.1689	13.6351	-28.7740	43.9814	13.7987	-29.1513	0.1875	-0.1636	-0.3773	0.4520	0.1875	X
	36	40.5082	13.1106	-30.7138	40.3686	13.2797	-31.0757	0.1396	-0.1691	-0.3619	0.4231	0.1396	X
A-PILLAR Lateral (Y)	31	54.3458	15.0277	-22.4646	54.1704	15.1155	-22.8705	0.1754	-0.0878	-0.4059	0.4508	-0.0878	Y
	32	51.9399	14.7222	-24.0407	51.8587	14.8478	-24.4191	0.0812	-0.1256	-0.3784	0.4069	-0.1256	Y
	33	49.5159	14.4057	-25.6361	49.4273	14.5432	-26.0270	0.0886	-0.1375	-0.3909	0.4237	-0.1375	Y
	34	47.1912	14.0856	-27.0036	47.0488	14.2301	-27.4101	0.1424	-0.1445	-0.4065	0.4543	-0.1445	Y
	35	44.1689	13.6351	-28.7740	43.9814	13.7987	-29.1513	0.1875	-0.1636	-0.3773	0.4520	-0.1636	Y
	36	40.5082	13.1106	-30.7138	40.3686	13.2797	-31.0757	0.1396	-0.1691	-0.3619	0.4231	-0.1691	Y
B-PILLAR Maximum (X, Y, Z)	37	16.1162	14.3694	-33.1190	16.0114	14.3377	-33.3691	0.1048	0.0317	-0.2501	0.2730	0.1095	X, Y
	38	14.4216	17.3353	-26.5745	14.4289	17.2408	-26.7510	-0.0073	0.0945	-0.1765	0.2003	0.0945	Y
	39	19.0891	18.4520	-20.1435	19.1990	18.3050	-20.3775	-0.1099	0.1470	-0.2340	0.2974	0.1470	Y
	40	15.8428	19.0213	-16.2147	15.9354	18.8685	-16.4237	-0.0926	0.1528	-0.2090	0.2750	0.1528	Y
B-PILLAR Lateral (Y)	37	16.1162	14.3694	-33.1190	16.0114	14.3377	-33.3691	0.1048	0.0317	-0.2501	0.2730	0.0317	Y
	38	14.4216	17.3353	-26.5745	14.4289	17.2408	-26.7510	-0.0073	0.0945	-0.1765	0.2003	0.0945	Y
	39	19.0891	18.4520	-20.1435	19.1990	18.3050	-20.3775	-0.1099	0.1470	-0.2340	0.2974	0.1470	Y
	40	15.8428	19.0213	-16.2147	15.9354	18.8685	-16.4237	-0.0926	0.1528	-0.2090	0.2750	0.1528	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 E-9. Occupant Compartment Deformation Data – Set 1, Test No. MTB-2

Date: 9/20/2018 Test Name: MTB-2 VIN: KNADE223596440731
Year: 2009 Make: Kia Model: Rio

VEHICLE DEFORMATION
PASSENGER SIDE 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	48.3307	35.0901	-19.5630	48.2897	35.3224	-19.3604	0.0410	-0.2323	0.2026	0.3110	0.3110	X, Y, Z
	2	48.8901	23.0649	-20.2893	48.8559	23.2953	-20.1259	0.0342	-0.2304	0.1634	0.2845	0.2845	X, Y, Z
	3	49.2840	13.7600	-20.4394	49.3454	14.0478	-20.2899	-0.0614	-0.2878	0.1495	0.3301	0.3301	X, Y, Z
	4	45.3461	37.1783	-10.5742	45.1770	37.3429	-10.4042	0.1691	-0.1646	0.1700	0.2908	0.2908	X, Y, Z
	5	45.3072	20.7698	-10.2433	45.3144	20.9909	-10.1267	-0.0072	-0.2211	0.1166	0.2501	0.2501	X, Y, Z
	6	43.7299	12.3487	-10.7865	43.7486	12.5620	-10.6619	-0.0187	-0.2133	0.1246	0.2477	0.2477	X, Y, Z
SIDE PANEL (Y)	7	52.2404	39.6492	2.0305	51.9775	39.8950	2.3338	0.2629	-0.2458	0.3033	0.4707	-0.2458	Y
	8	56.9001	39.9556	2.3007	56.5798	40.3227	2.6014	0.3203	-0.3671	0.3007	0.5725	-0.3671	Y
	9	53.1148	39.5600	-2.3215	52.8818	39.4666	-2.0286	0.2330	0.0934	0.2929	0.3857	0.0934	Y
IMPACT SIDE DOOR (Y)	10	45.2460	40.5703	-15.4005	44.8033	40.4887	-15.2480	0.4427	0.0816	0.1525	0.4753	0.0816	Y
	11	30.6666	40.1250	-15.8005	30.2649	40.5171	-15.6561	0.4017	-0.3921	0.1444	0.5796	-0.3921	Y
	12	20.0844	39.3216	-16.4492	19.5707	39.9861	-16.4184	0.5137	-0.6645	0.0308	0.8405	-0.6645	Y
	13	41.4246	40.5294	-0.9717	40.9244	41.2555	-0.7897	0.5002	-0.7261	0.1820	0.9003	-0.7261	Y
	14	34.0834	40.4286	-0.1472	33.5905	41.0712	-0.0351	0.4929	-0.6426	0.1121	0.8176	-0.6426	Y
	15	25.1505	39.6481	0.3841	24.6994	40.1741	0.4848	0.4511	-0.5260	0.1007	0.7002	-0.5260	Y
ROOF - (Z)	16	28.0144	28.4122	-37.2301	28.1360	28.5787	-37.2431	-0.1216	-0.1665	-0.0130	0.2066	-0.0130	Z
	17	29.0567	23.3373	-37.5098	29.1335	23.4574	-37.5053	-0.0768	-0.1201	0.0045	0.1426	0.0045	Z
	18	29.6233	19.5126	-37.6567	29.7073	19.7090	-37.6326	-0.0840	-0.1964	0.0241	0.2150	0.0241	Z
	19	28.7910	16.1507	-37.9753	28.8754	16.2323	-37.9574	-0.0844	-0.0816	0.0179	0.1188	0.0179	Z
	20	29.1780	12.1232	-37.9961	29.3138	12.3322	-37.9394	-0.1358	-0.2090	0.0567	0.2556	0.0567	Z
	21	16.9065	26.9359	-38.6324	16.8629	27.0561	-38.7178	0.0436	-0.1202	-0.0854	0.1538	-0.0854	Z
	22	17.3248	23.0942	-38.9173	17.3401	23.1476	-38.9818	-0.0153	-0.0534	-0.0645	0.0851	-0.0645	Z
	23	17.3141	19.2331	-39.1400	17.3577	19.3158	-39.1898	-0.0436	-0.0827	-0.0498	0.1059	-0.0498	Z
	24	17.3189	15.9587	-39.2689	17.3653	15.9998	-39.3007	-0.0464	-0.0411	-0.0318	0.0697	-0.0318	Z
	25	17.0221	12.2706	-39.3617	17.0728	12.3532	-39.3807	-0.0507	-0.0826	-0.0190	0.0988	-0.0190	Z
	26	6.8378	26.7669	-38.8559	6.8344	26.8517	-38.9562	0.0034	-0.0848	-0.1003	0.1314	-0.1003	Z
	27	7.2590	23.0553	-39.1555	7.2147	23.1280	-39.2471	0.0443	-0.0727	-0.0916	0.1251	-0.0916	Z
	28	7.8195	19.0580	-39.3874	7.8731	19.1659	-39.4667	-0.0536	-0.1079	-0.0793	0.1442	-0.0793	Z
	29	8.5924	15.4186	-39.5244	8.6171	15.4116	-39.5867	-0.0247	0.0070	-0.0623	0.0674	-0.0623	Z
	30	9.2052	12.4946	-39.5787	9.2274	12.5263	-39.6250	-0.0222	-0.0317	-0.0463	0.0603	-0.0463	Z
A-PILLAR Maximum (X, Y, Z)	31	50.9798	38.2885	-22.8318	50.8166	38.3862	-22.6865	0.1632	-0.0977	0.1453	0.2394	0.2185	X, Z
	32	48.6209	37.6744	-24.3888	48.5646	37.8227	-24.2435	0.0563	-0.1483	0.1453	0.2151	0.1558	X, Z
	33	46.2455	37.0469	-25.9650	46.1987	37.2071	-25.8603	0.0468	-0.1602	0.1047	0.1970	0.1147	X, Z
	34	43.9706	36.4291	-27.3141	43.8856	36.5903	-27.2521	0.0850	-0.1612	0.0620	0.1925	0.1052	X, Z
	35	41.0174	35.5918	-29.0605	40.9058	35.7673	-29.0044	0.1116	-0.1755	0.0561	0.2154	0.1249	X, Z
	36	37.4395	34.5991	-30.9712	37.3972	34.7873	-30.9418	0.0423	-0.1882	0.0294	0.1951	0.0515	X, Z
A-PILLAR Lateral (Y)	31	50.9798	38.2885	-22.8318	50.8166	38.3862	-22.6865	0.1632	-0.0977	0.1453	0.2394	-0.0977	Y
	32	48.6209	37.6744	-24.3888	48.5646	37.8227	-24.2435	0.0563	-0.1483	0.1453	0.2151	-0.1483	Y
	33	46.2455	37.0469	-25.9650	46.1987	37.2071	-25.8603	0.0468	-0.1602	0.1047	0.1970	-0.1602	Y
	34	43.9706	36.4291	-27.3141	43.8856	36.5903	-27.2521	0.0850	-0.1612	0.0620	0.1925	-0.1612	Y
	35	41.0174	35.5918	-29.0605	40.9058	35.7673	-29.0044	0.1116	-0.1755	0.0561	0.2154	-0.1755	Y
	36	37.4395	34.5991	-30.9712	37.3972	34.7873	-30.9418	0.0423	-0.1882	0.0294	0.1951	-0.1882	Y
B-PILLAR Maximum (X, Y, Z)	37	13.0696	32.7200	-33.1883	13.1148	32.7106	-33.3304	-0.0452	0.0094	-0.1421	0.1494	0.0094	Y
	38	11.0588	35.4578	-26.6339	11.1466	35.3934	-26.7229	-0.0878	0.0644	-0.0890	0.1406	0.0644	Y
	39	15.5934	37.1758	-20.2405	15.7152	37.0670	-20.3326	-0.1218	0.1088	-0.0921	0.1875	0.1088	Y
	40	12.3308	37.3329	-16.2872	12.3905	37.2113	-16.3923	-0.0597	0.1216	-0.1051	0.1715	0.1216	Y
B-PILLAR Lateral (Y)	37	13.0696	32.7200	-33.1883	13.1148	32.7106	-33.3304	-0.0452	0.0094	-0.1421	0.1494	0.0094	Y
	38	11.0588	35.4578	-26.6339	11.1466	35.3934	-26.7229	-0.0878	0.0644	-0.0890	0.1406	0.0644	Y
	39	15.5934	37.1758	-20.2405	15.7152	37.0670	-20.3326	-0.1218	0.1088	-0.0921	0.1875	0.1088	Y
	40	12.3308	37.3329	-16.2872	12.3905	37.2113	-16.3923	-0.0597	0.1216	-0.1051	0.1715	0.1216	Y

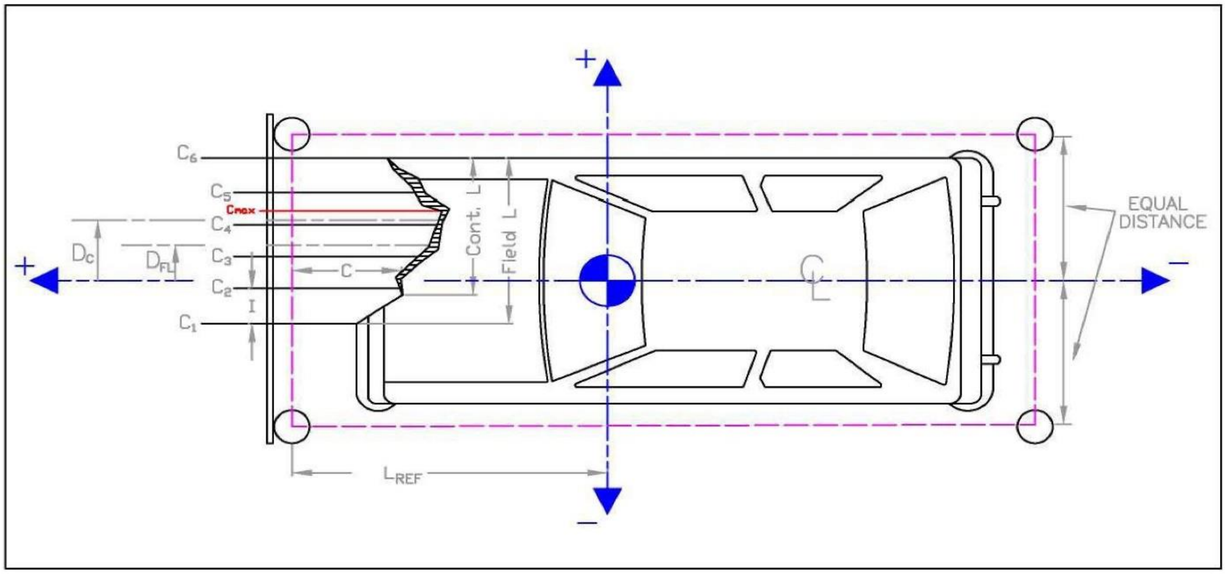
[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[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 E-10. Occupant Compartment Deformation Data – Set 2, Test No. MTB-2

Date:	**9/20/2018**	**Test Name:**	**MTB-2**	**VIN:**	**KNADE223596440731**
Year:	**2009**	**Make:**	**Kia**	**Model:**	**Rio**



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	**80**	**(2032)**
Total Width of Vehicle:	**65 3/4**	**(1670)**
Width of contact and induced crush - Field L:	**32 5/8**	**(829)**
Crush measurement spacing interval (L/5) - I:	**6 1/2**	**(165)**
Distance from center of vehicle to center of Field L - D_{FL}:	**16 4/9**	**(418)**
Width of Contact Damage:	**21 7/8**	**(556)**
Distance from center of vehicle to center of contact damage - D_C:	**21 2/3**	**(551)**

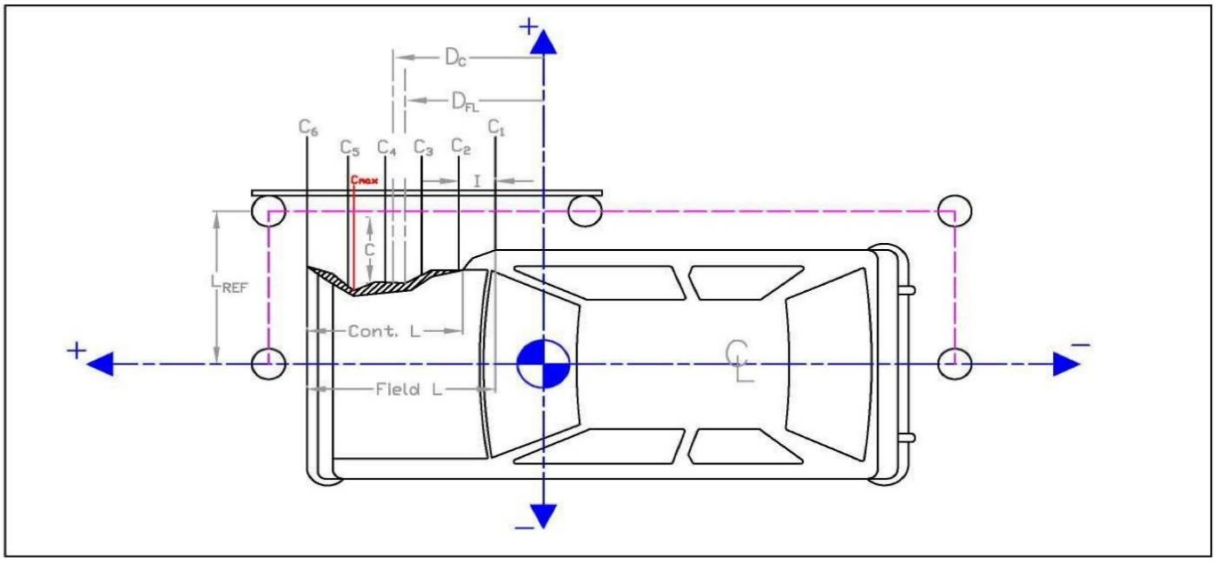
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	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	11	(279)	1/8	(3)	6	(152)	4 4/5	(122)	1/5	(5)
C_2	11 1/4	(286)	6 5/8	(168)	6 1/8	(156)			1/3	(8)
C_3	12 1/4	(311)	13 1/8	(333)	7	(178)			4/9	(11)
C_4	12 7/8	(327)	19 5/8	(498)	8 3/8	(213)			- 1/3	-(8)
C_5	17	(432)	26 1/8	(664)	11 3/8	(289)			4/5	(21)
C_6	28	(711)	32 5/8	(829)	24	(610)			- 4/5	-(21)
C_{MAX}	28	(711)	32 5/8	(829)	24	(610)			- 4/5	-(21)

Figure E-11. Exterior Vehicle Crush (NASS) – Front, Test No. MTB-2

Date: 9/20/2018 Test Name: MTB-2 VIN: KNADE223596440731

Year: 2009 Make: Kia Model: Rio



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	48	(1219)
Total Vehicle Length:	167 1/4	(4248)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-12 4/9	-(316)
Width of contact and induced crush - Field L:	167 1/4	(4248)
Crush measurement spacing interval (L/5) - I:	33 1/2	(851)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-12 4/9	-(316)
Width of Contact Damage:	167 1/4	(4248)
Distance from vehicle c.g. to center of contact damage - D_C:	-12 4/9	-(316)

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	NA	-96 1/8	-(2442)	23 3/4	(603)	12	(305)	NA	NA
C_2	n/a	NA	-62 5/8	-(1591)	4	(102)			NA	NA
C_3	15 1/4	(387)	-29 1/8	-(740)	3 5/8	(92)			- 3/8	-(10)
C_4	14 3/4	(375)	4 3/8	(111)	3 3/4	(95)			-1	-(25)
C_5	n/a	NA	37 7/8	(962)	3 1/4	(83)			NA	NA
C_6	n/a	NA	71 3/8	(1813)	21 3/4	(552)			NA	NA
C_{MAX}	16 1/2	(419)	18 1/4	(464)	3 3/4	(95)			3/4	(19)

Figure E-12. Exterior Vehicle Crush (NASS) – Side, Test No. MTB-2

Appendix F. Accelerometer and Rate Transducer Data Plots, Test No. MTB-1

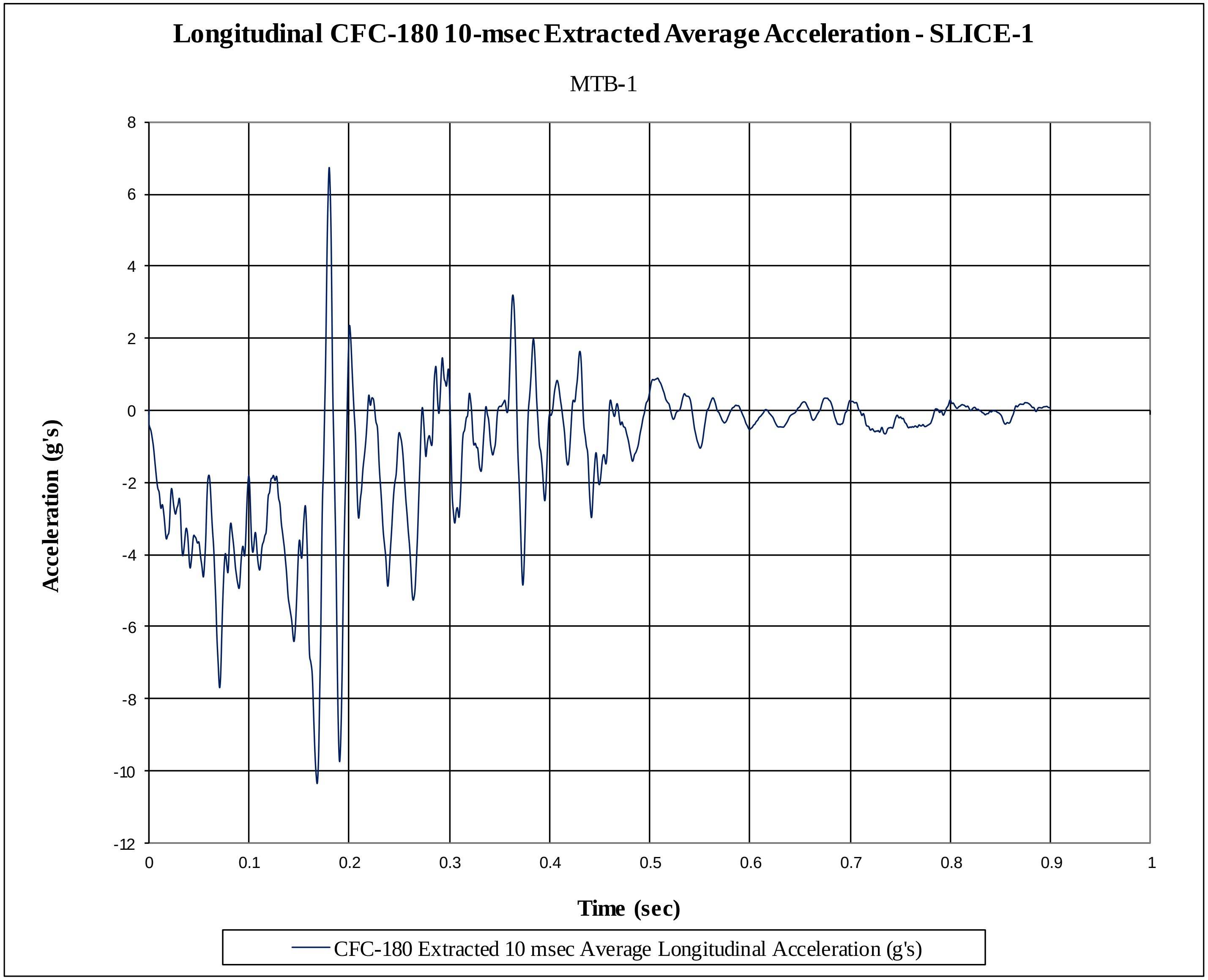


Figure F-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. MTB-1

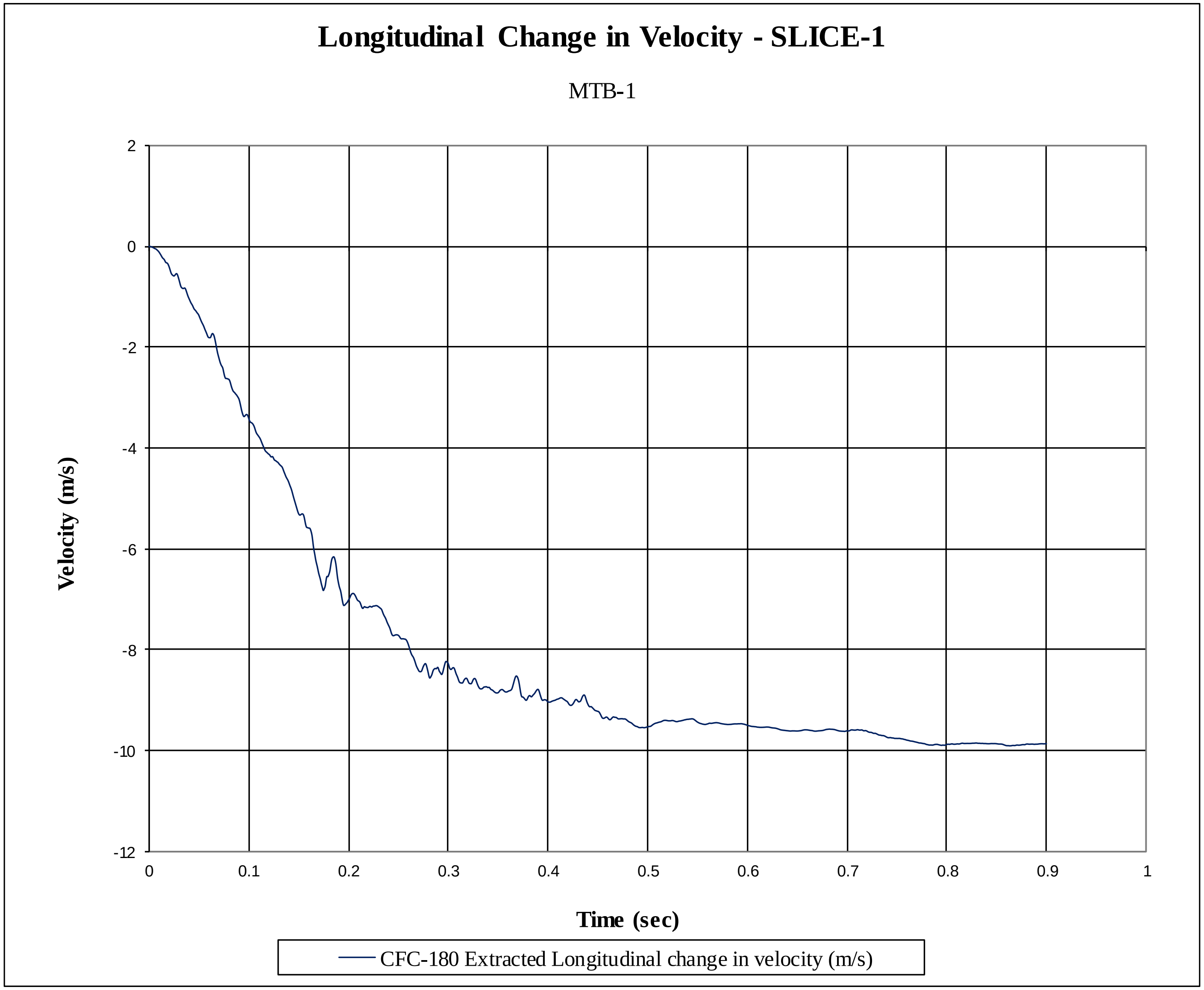


Figure F-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. MTB-1

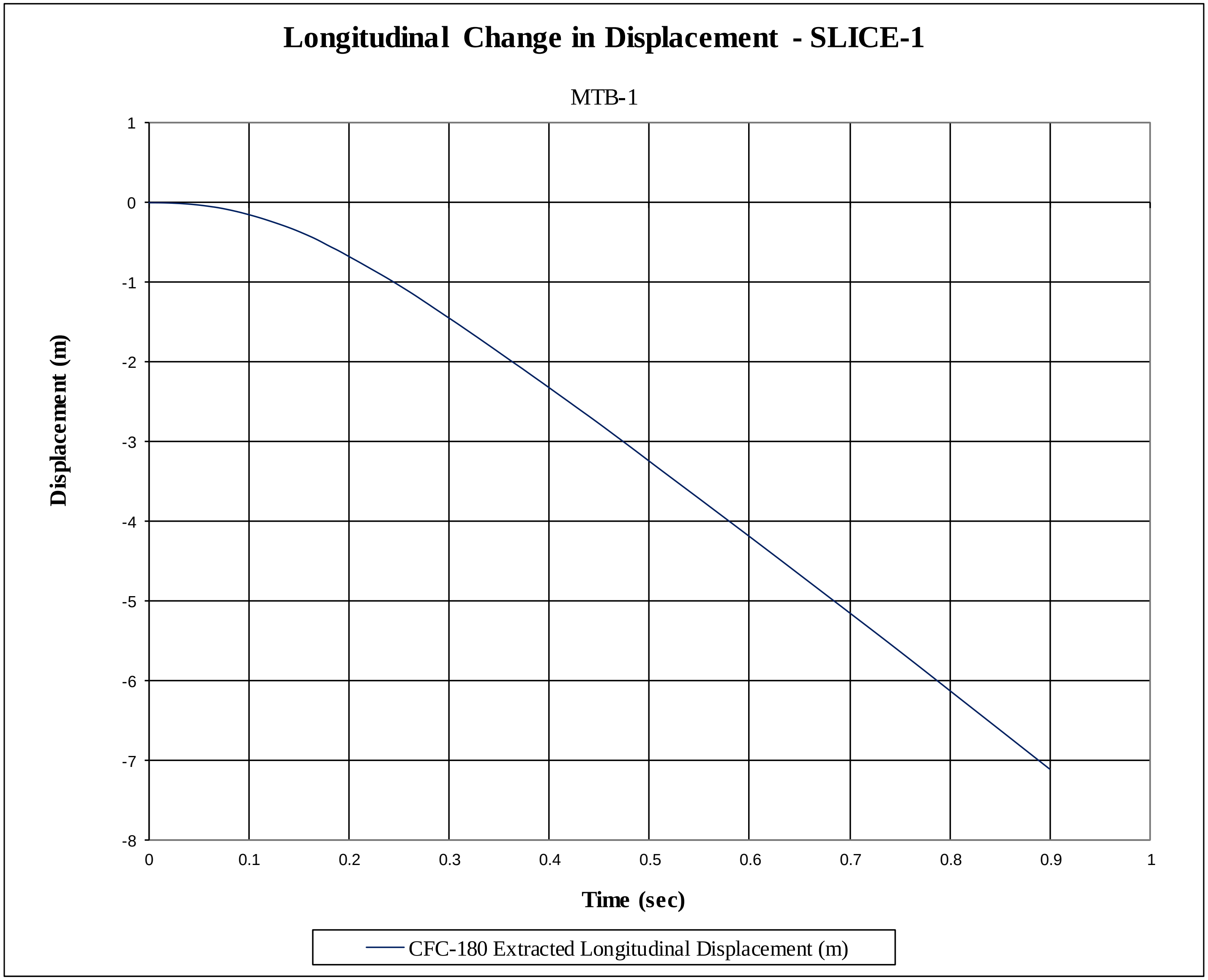


Figure F-3. Longitudinal Occupant Displacement (SLICE-1), Test No. MTB-1

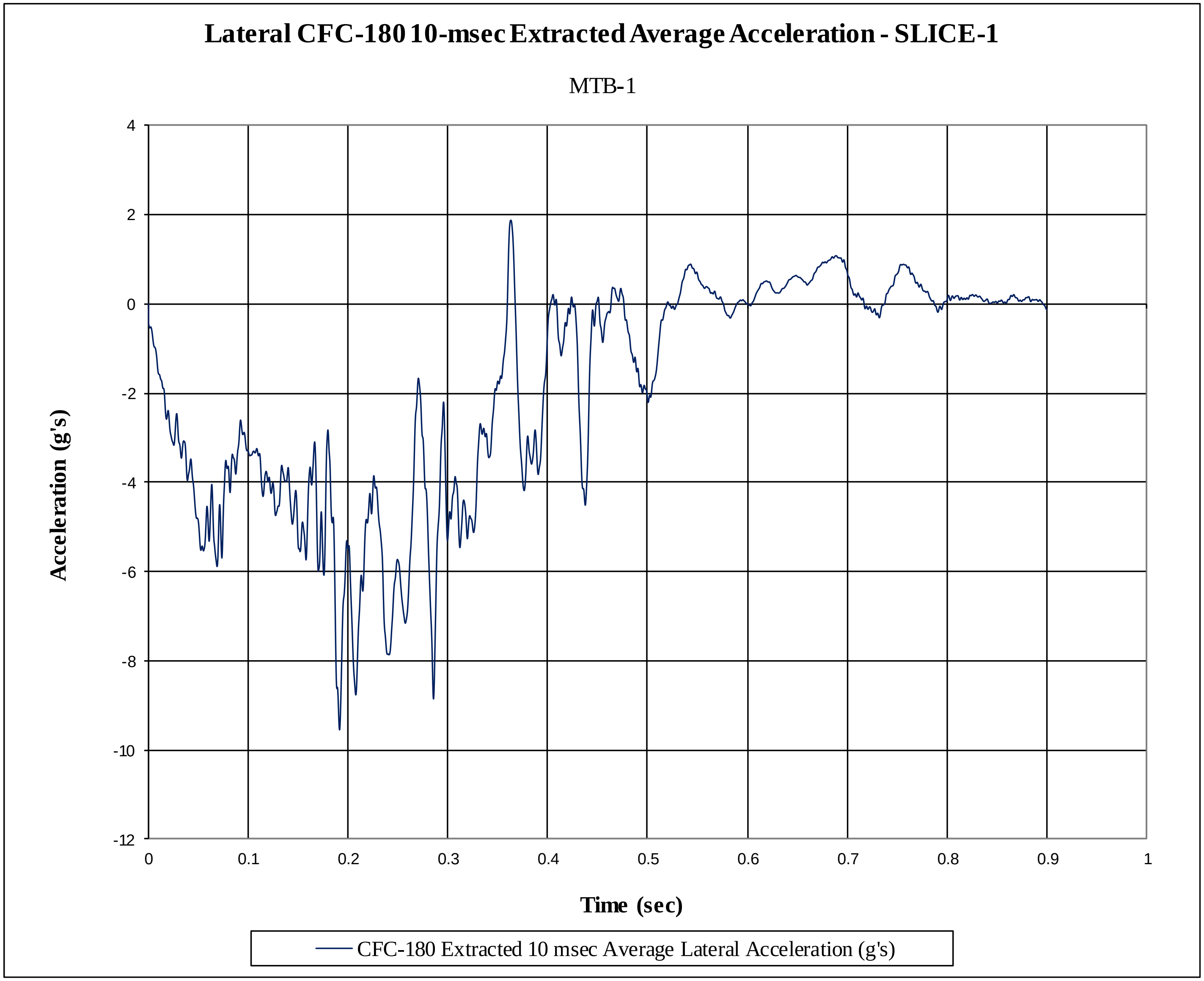


Figure F-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. MTB-1

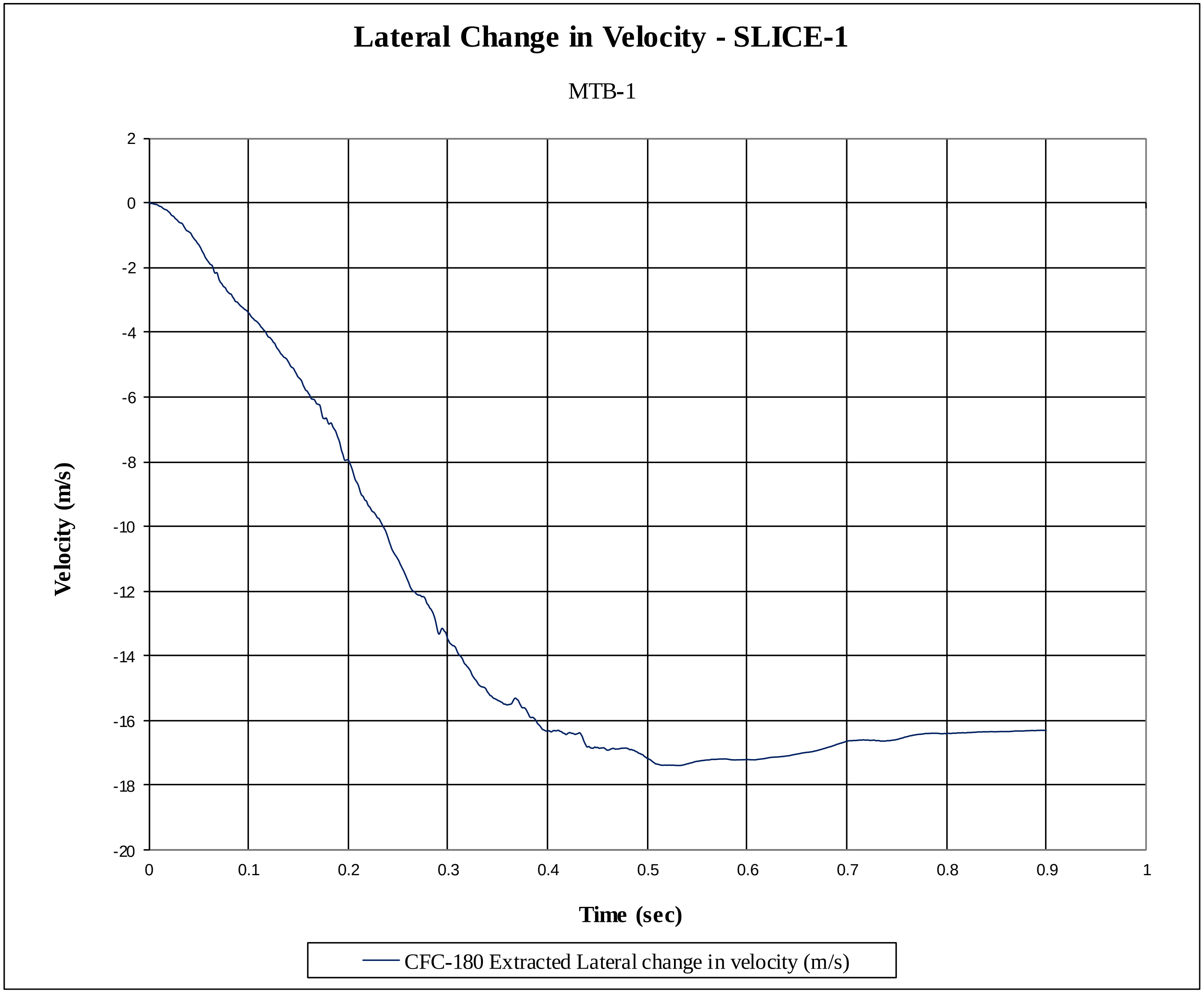


Figure F-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. MTB-1

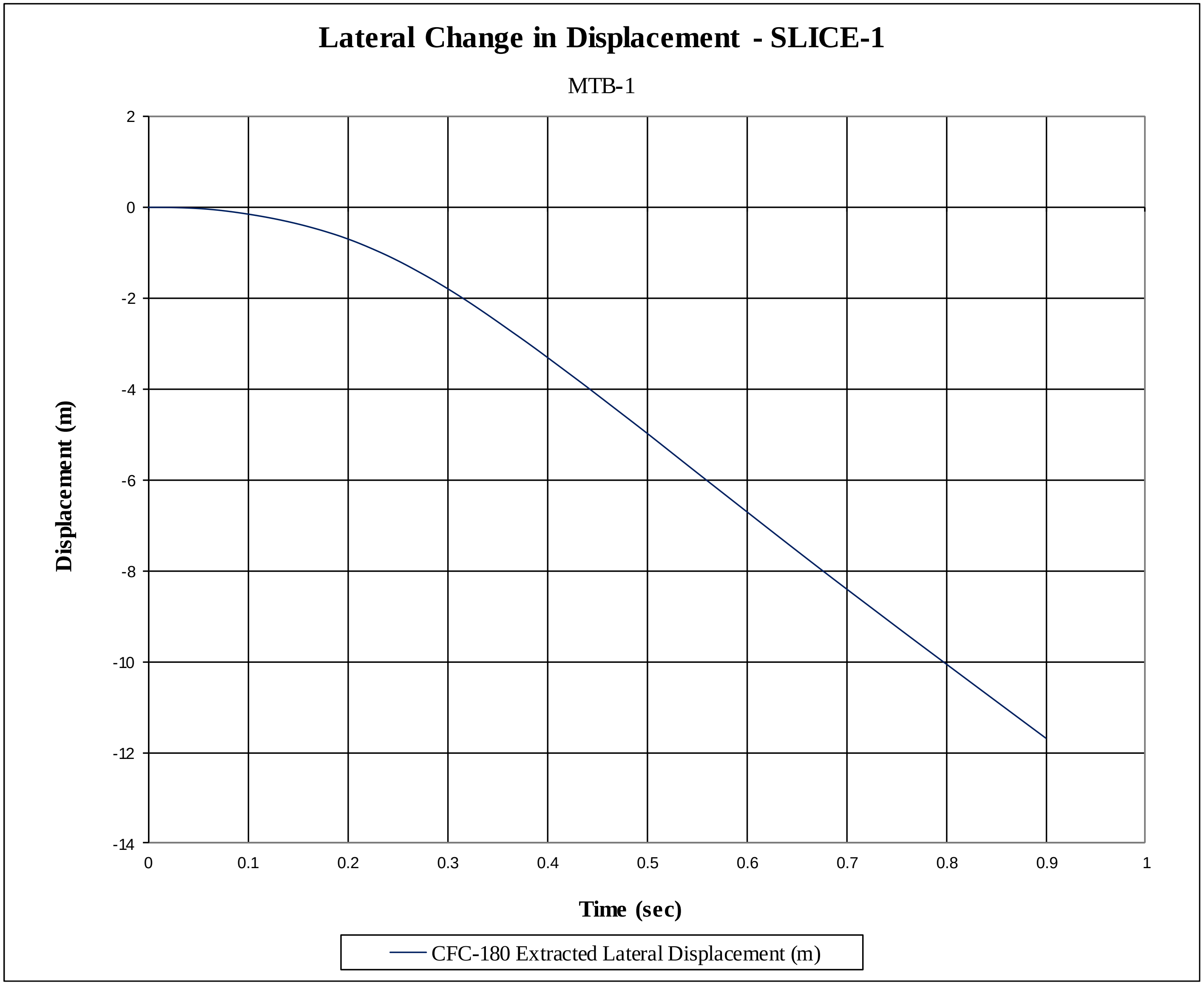


Figure F-6. Lateral Occupant Displacement (SLICE-1), Test No. MTB-1

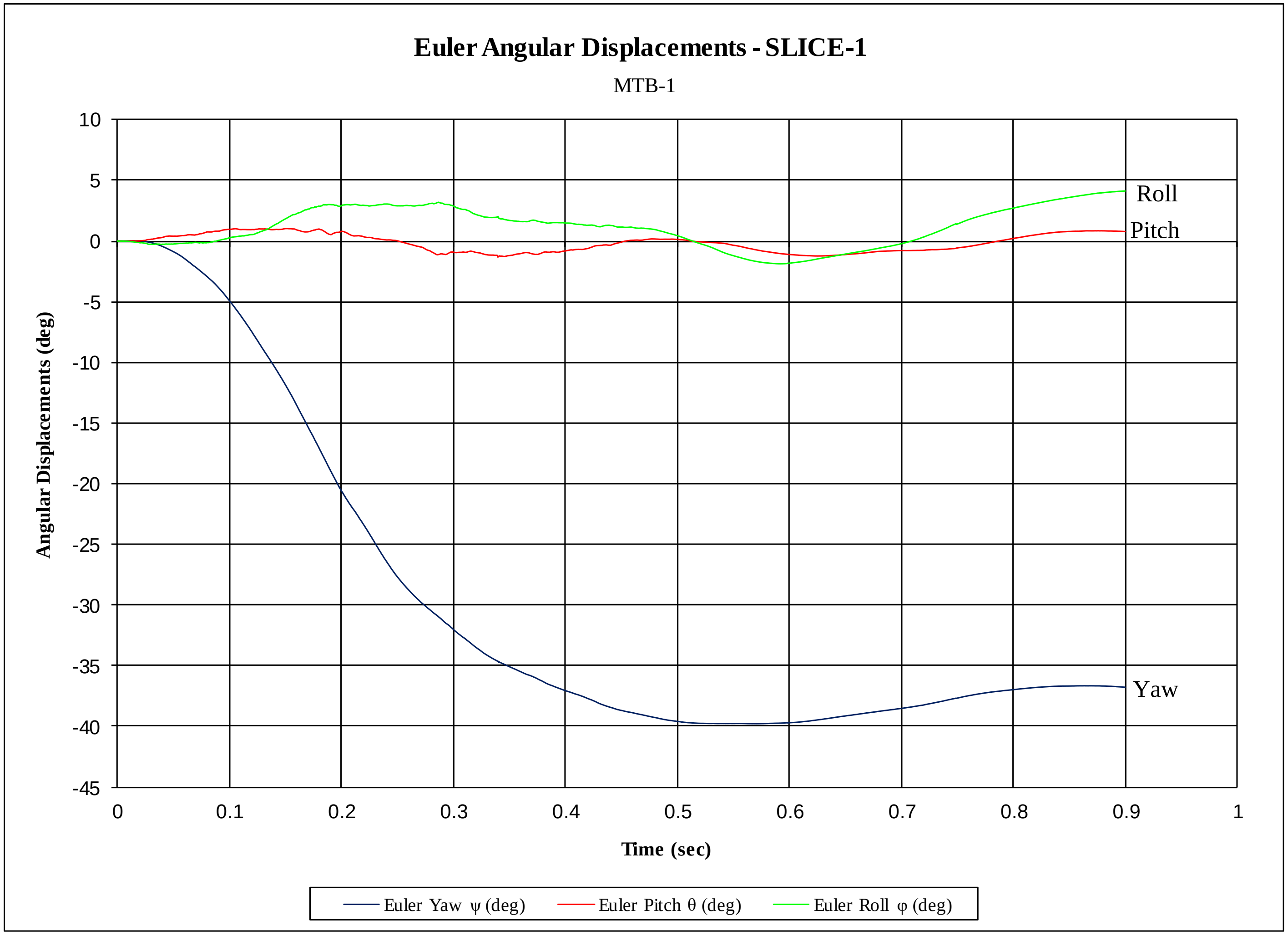


Figure F-7. Vehicle Angular Displacements (SLICE-1), Test No. MTB-1

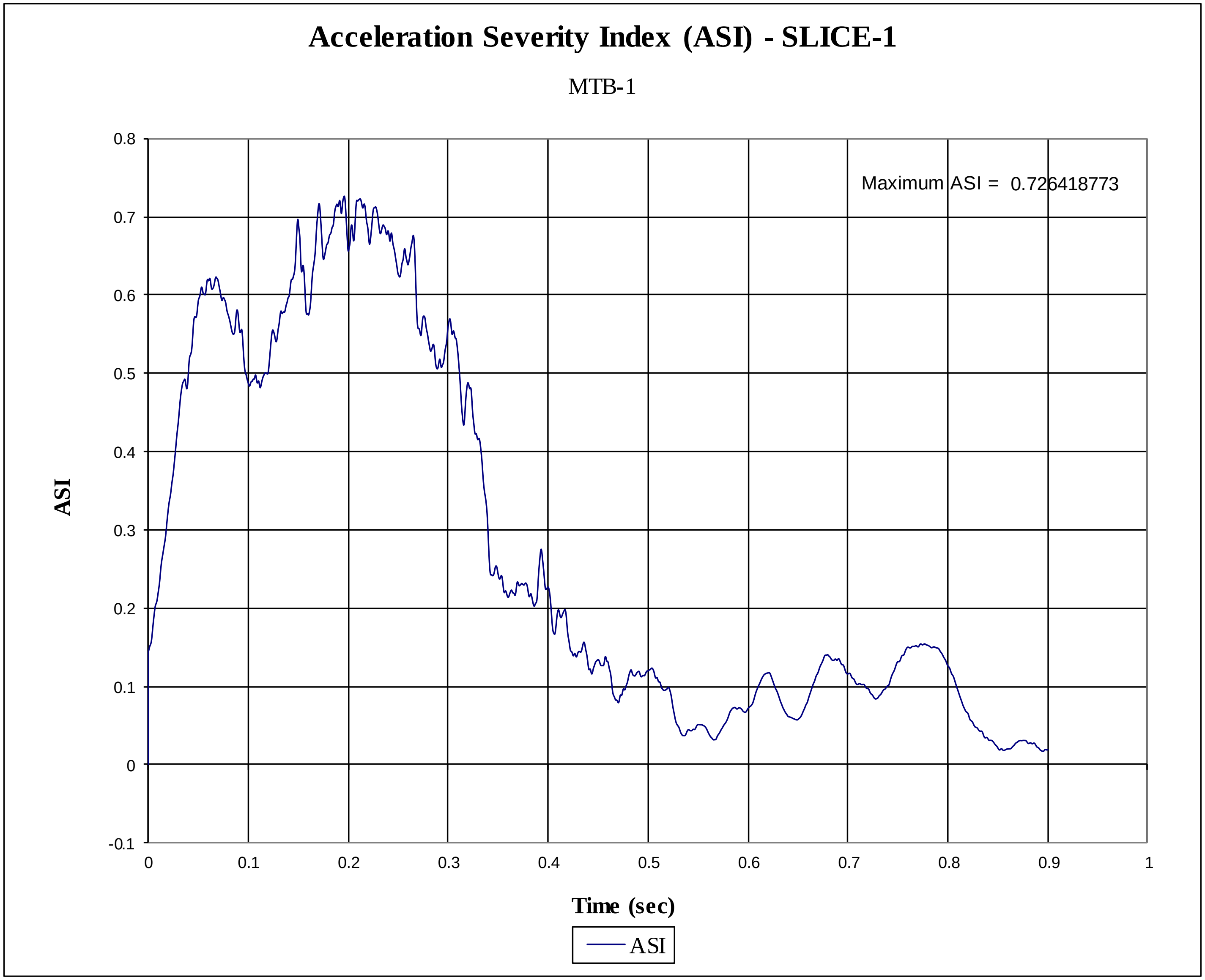


Figure F-8. Acceleration Severity Index (SLICE-1), Test No. MTB-1

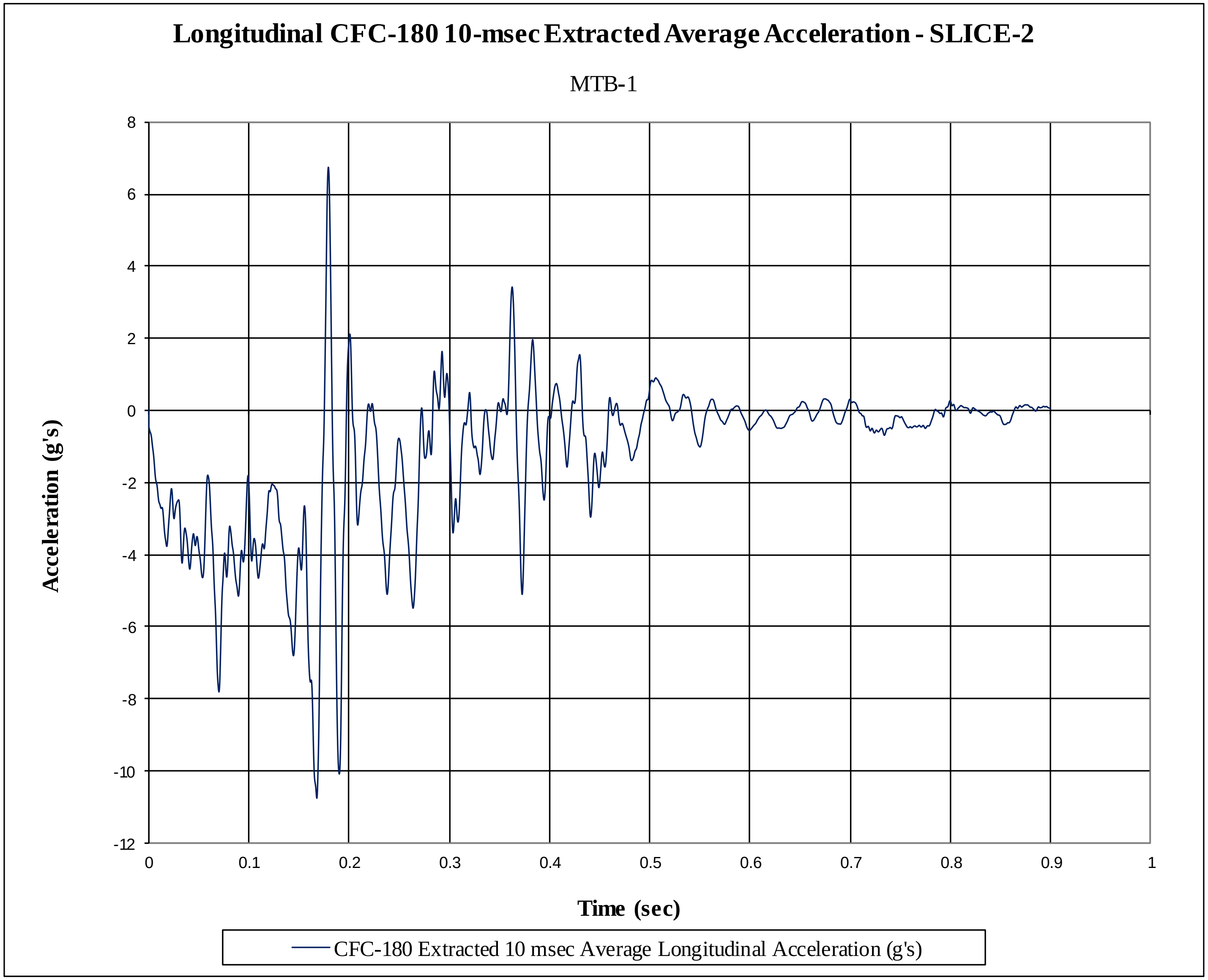


Figure F-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. MTB-1

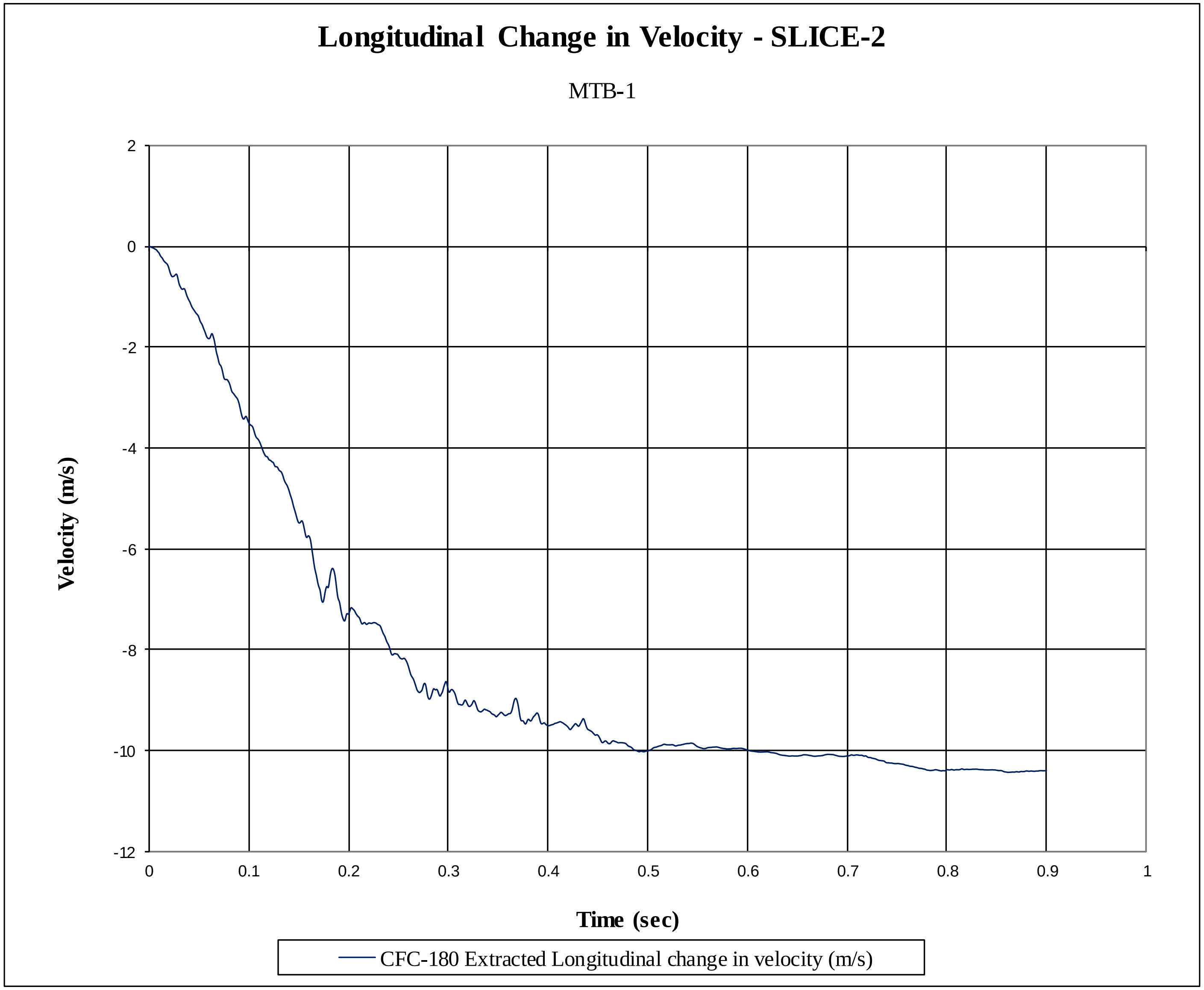


Figure F-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. MTB-1

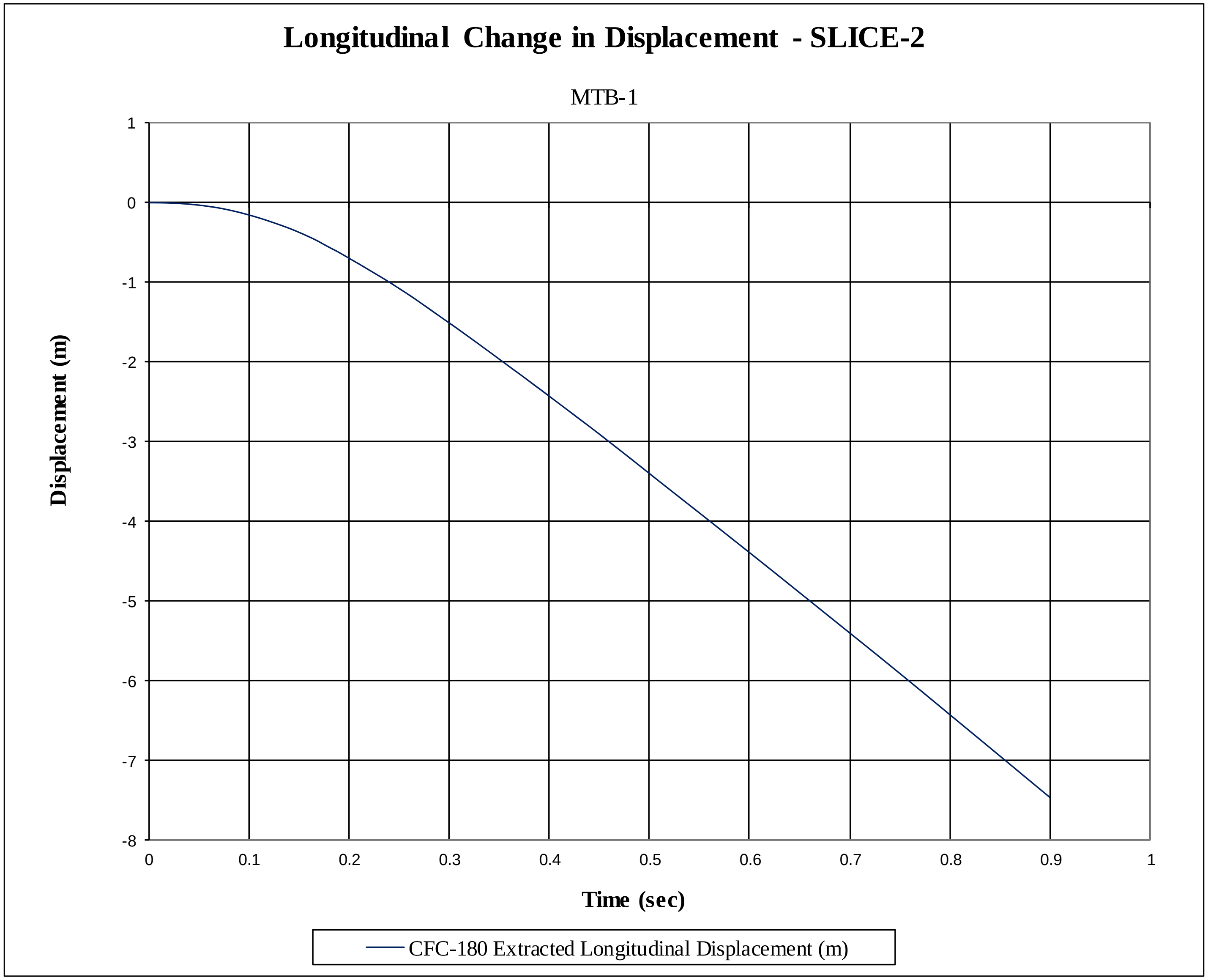


Figure F-11. Longitudinal Occupant Displacement (SLICE-2), Test No. MTB-1

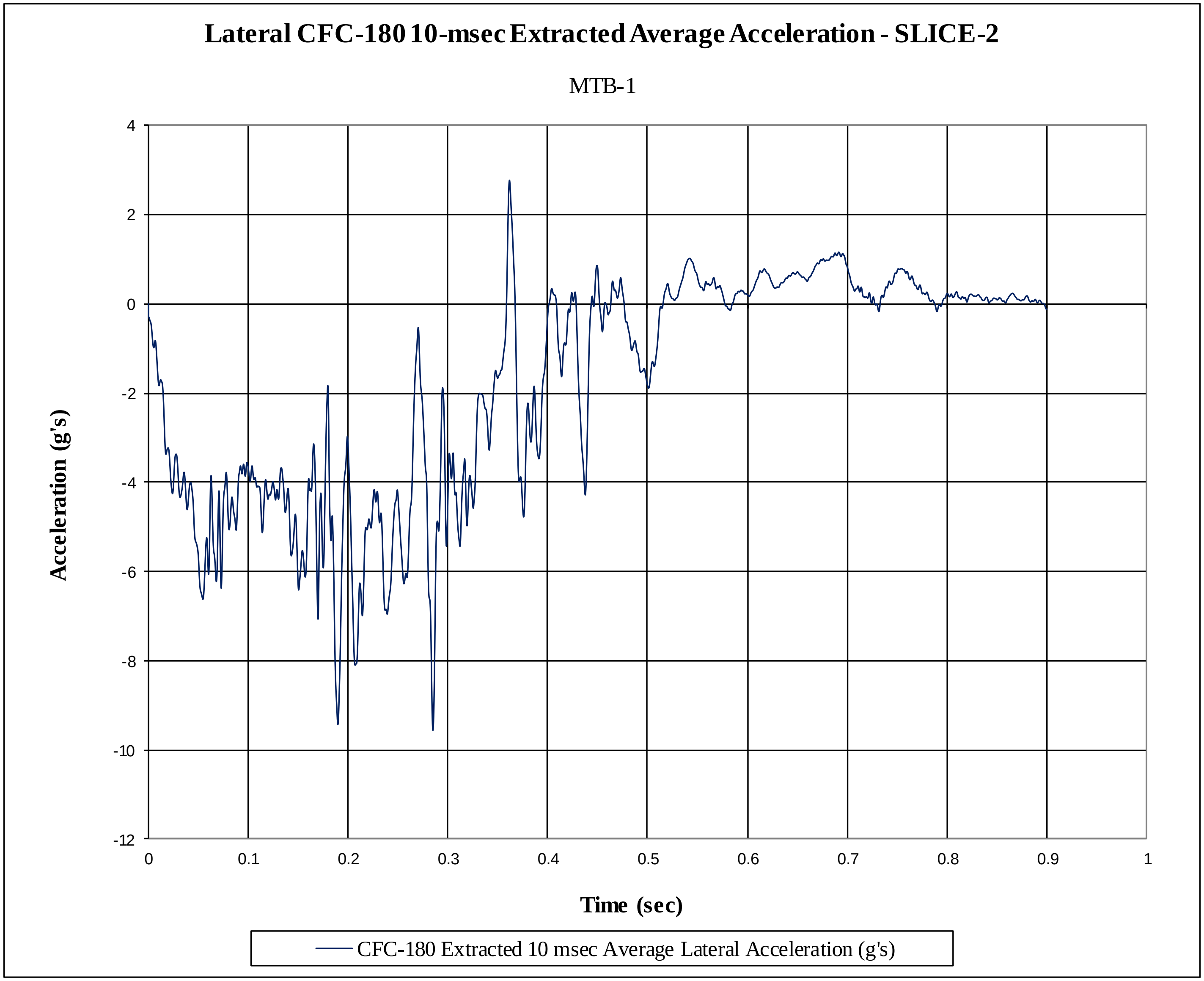


Figure F-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. MTB-1

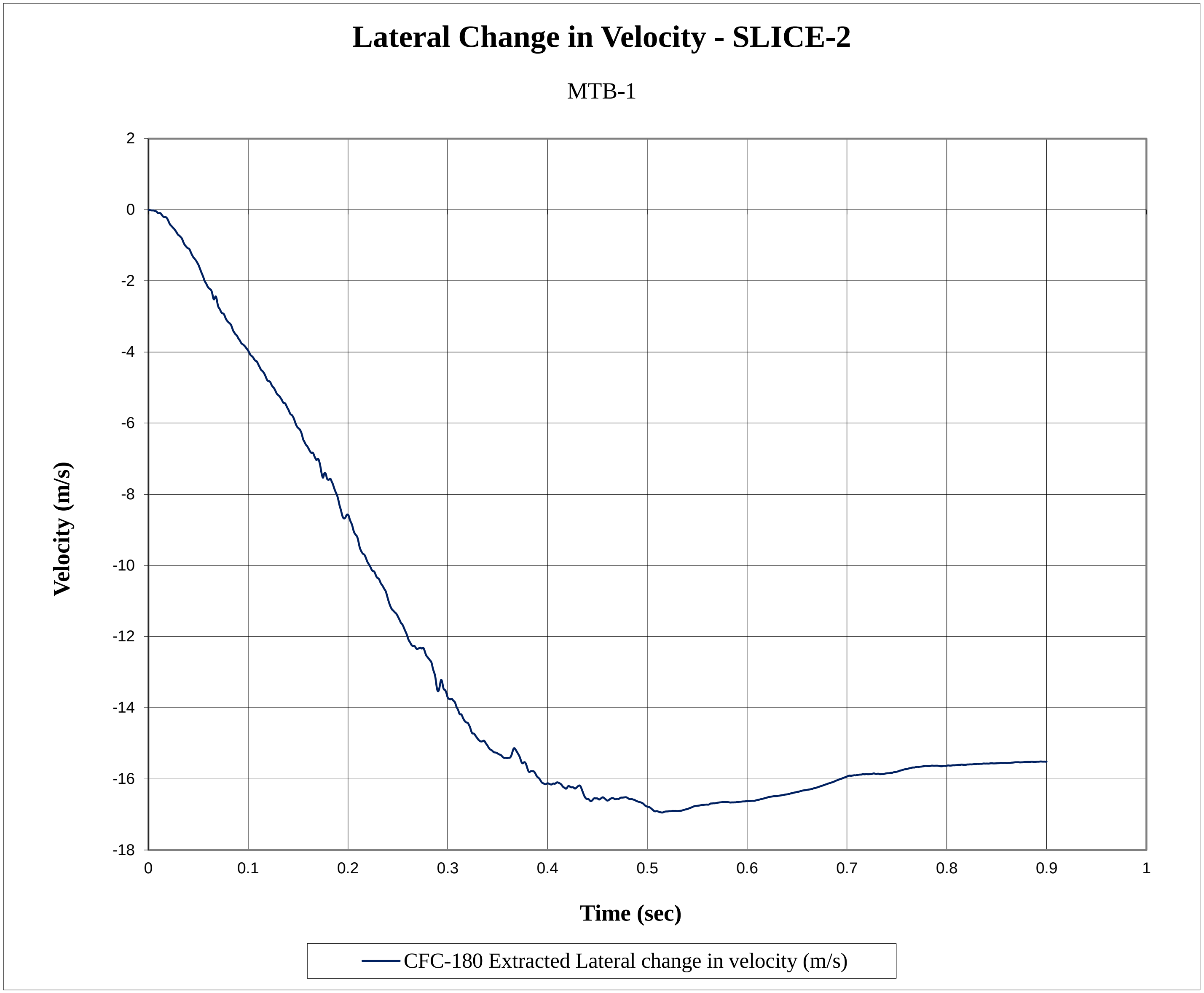


Figure F-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. MTB-1

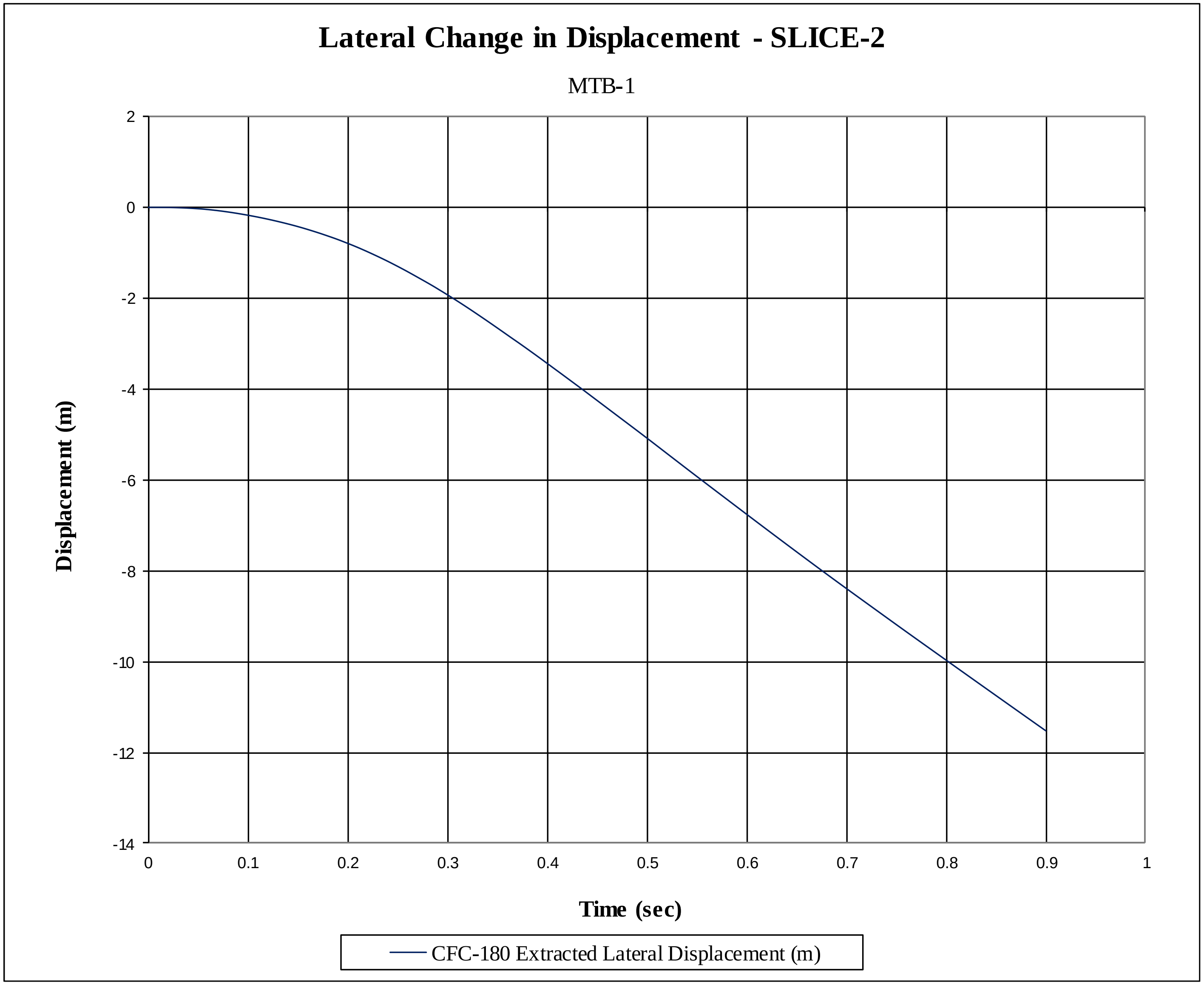


Figure F-14. Lateral Occupant Displacement (SLICE-2), Test No. MTB-1

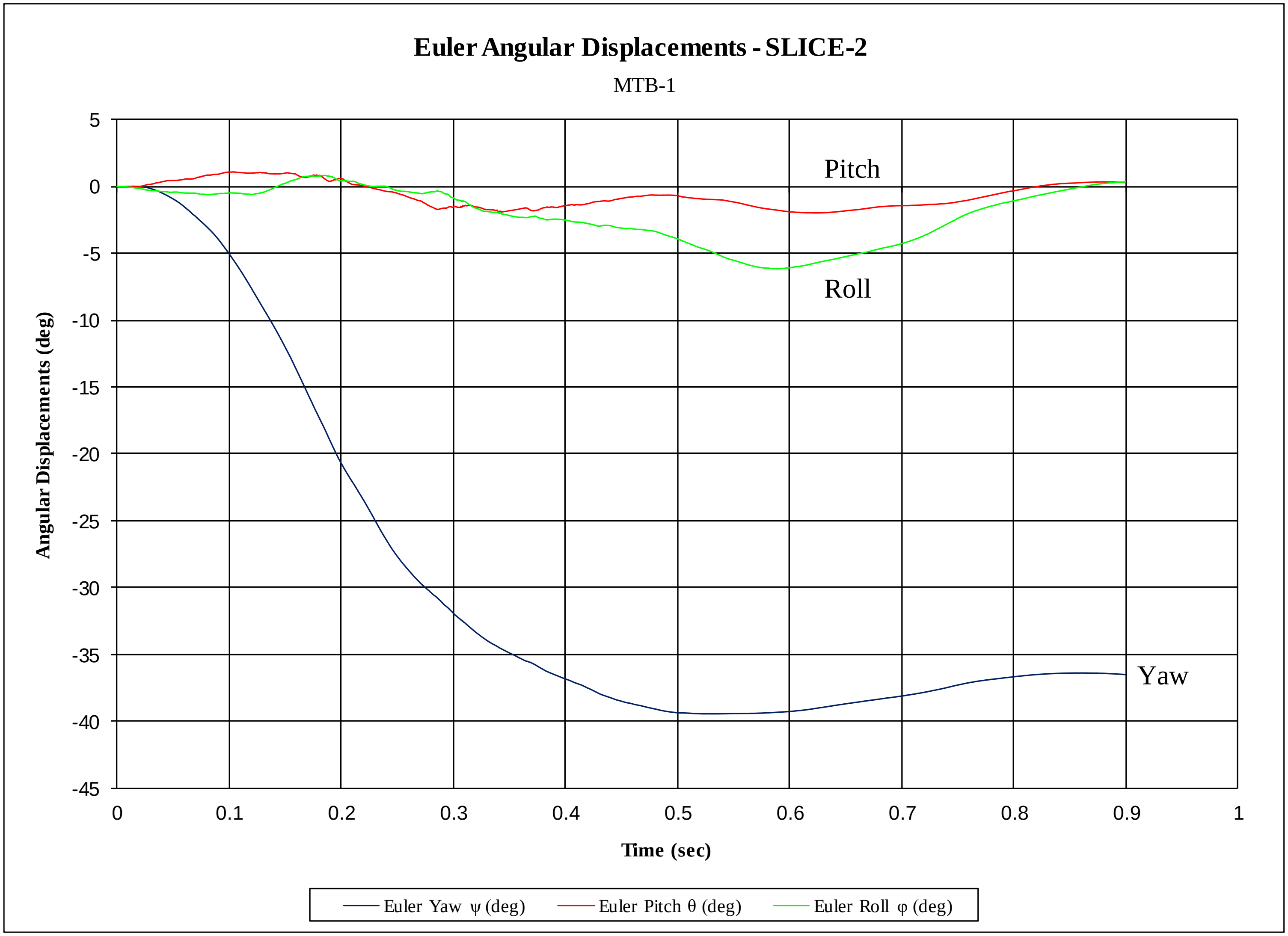


Figure F-15. Vehicle Angular Displacements (SLICE-2), Test No. MTB-1

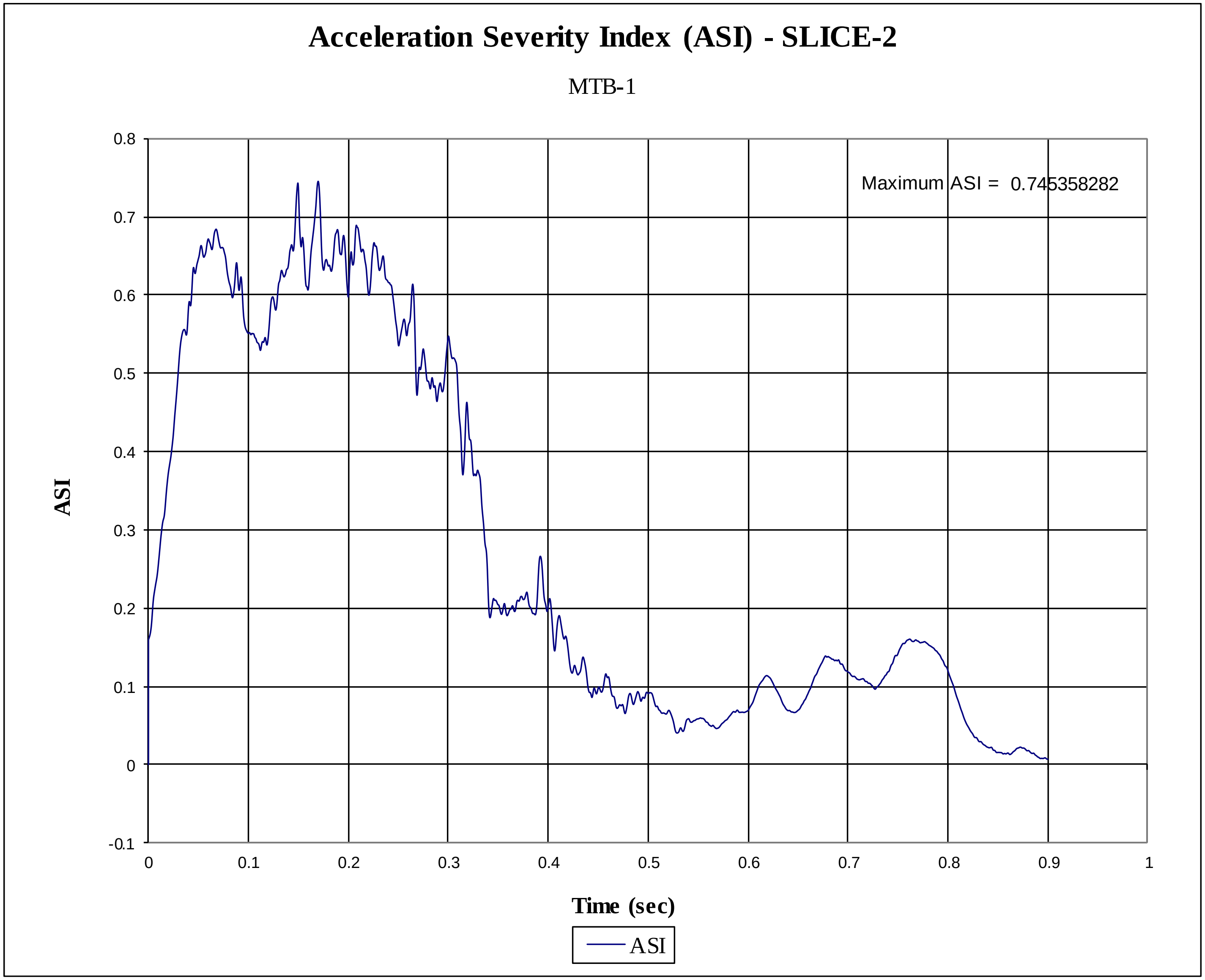


Figure F-16. Acceleration Severity Index (SLICE-2), Test No. MTB-1

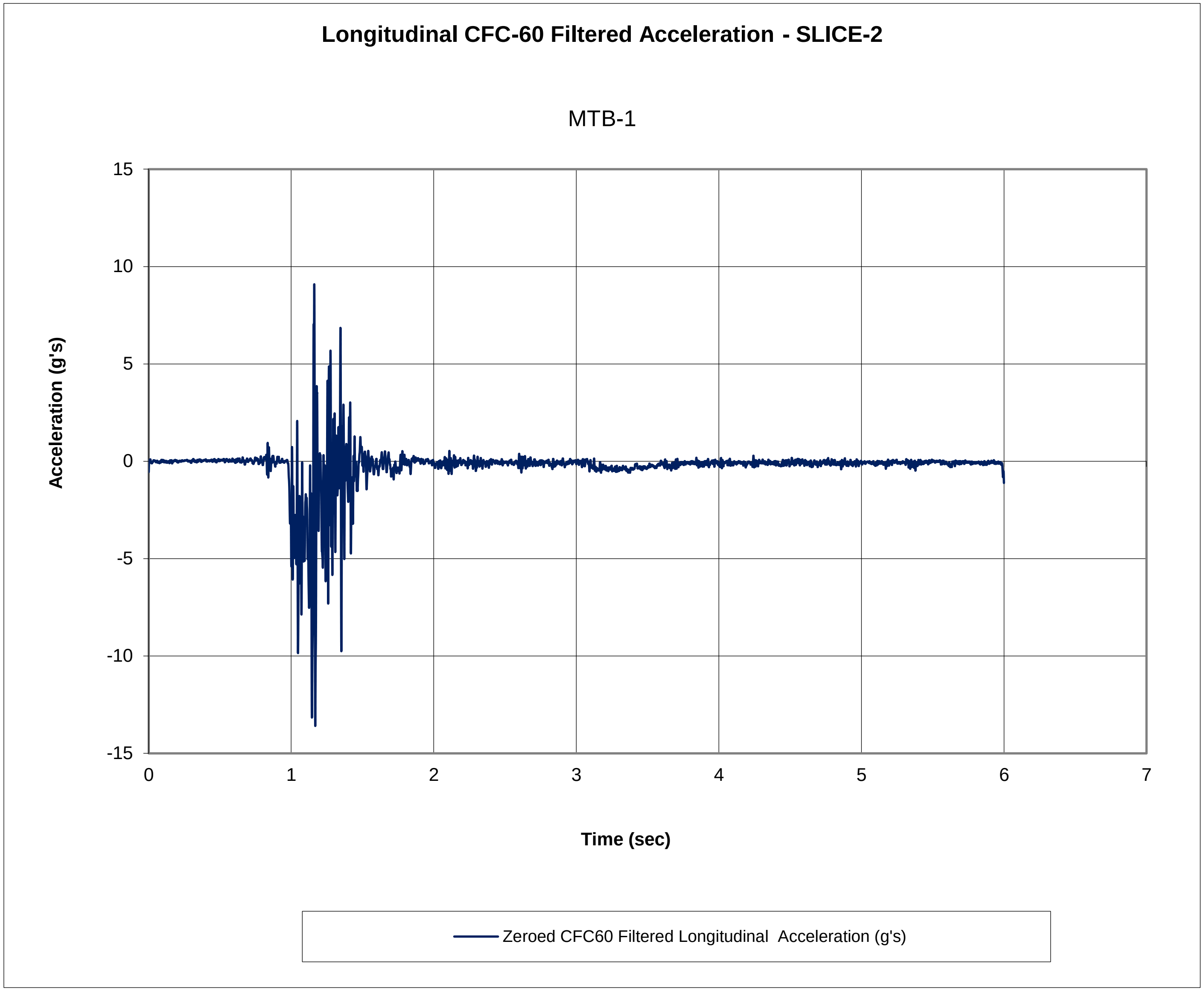


Figure F-17. Longitudinal Filtered Acceleration, Test No. MTB-1

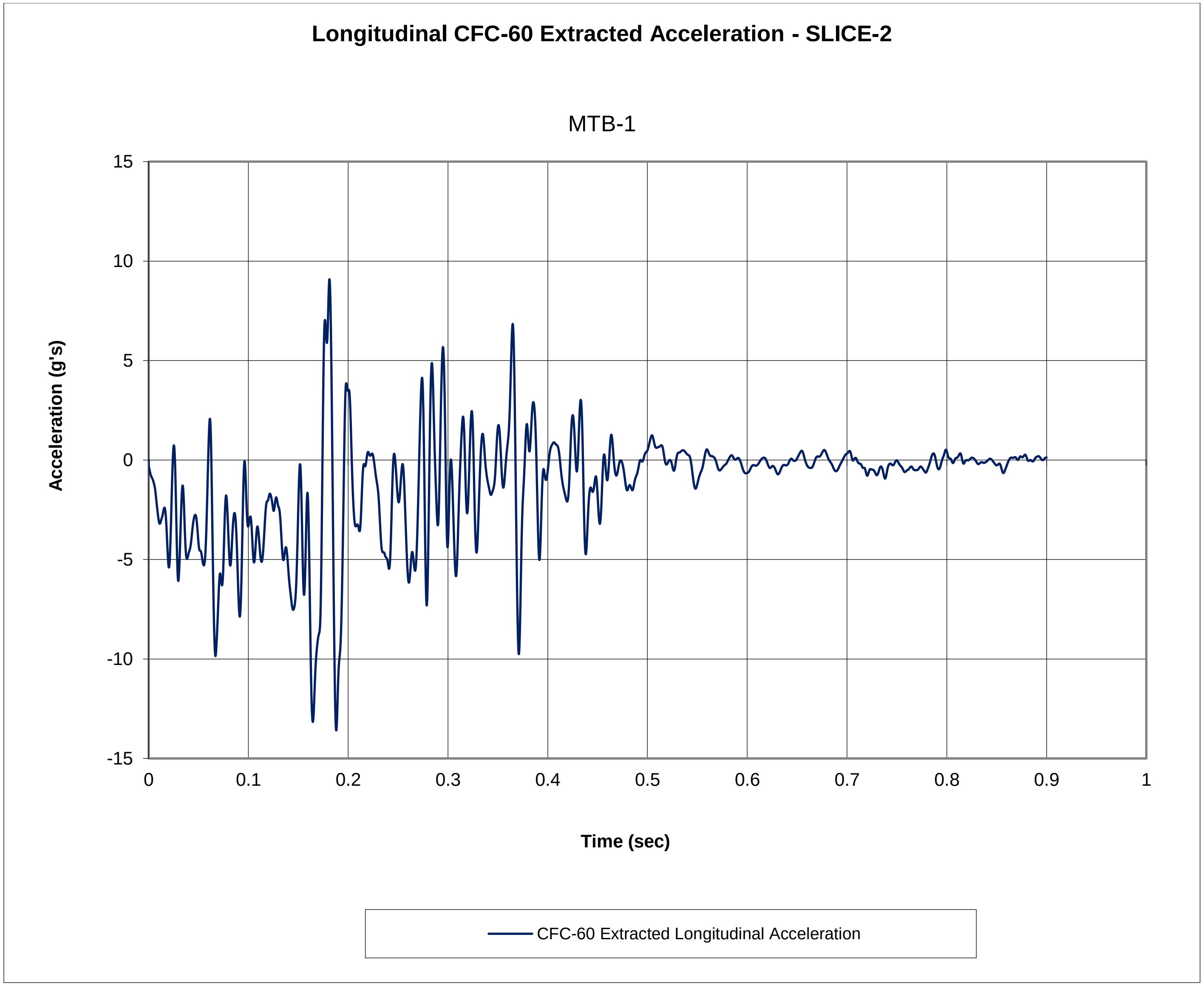


Figure F-18. Longitudinal Extracted Acceleration, Test No. MTB-1

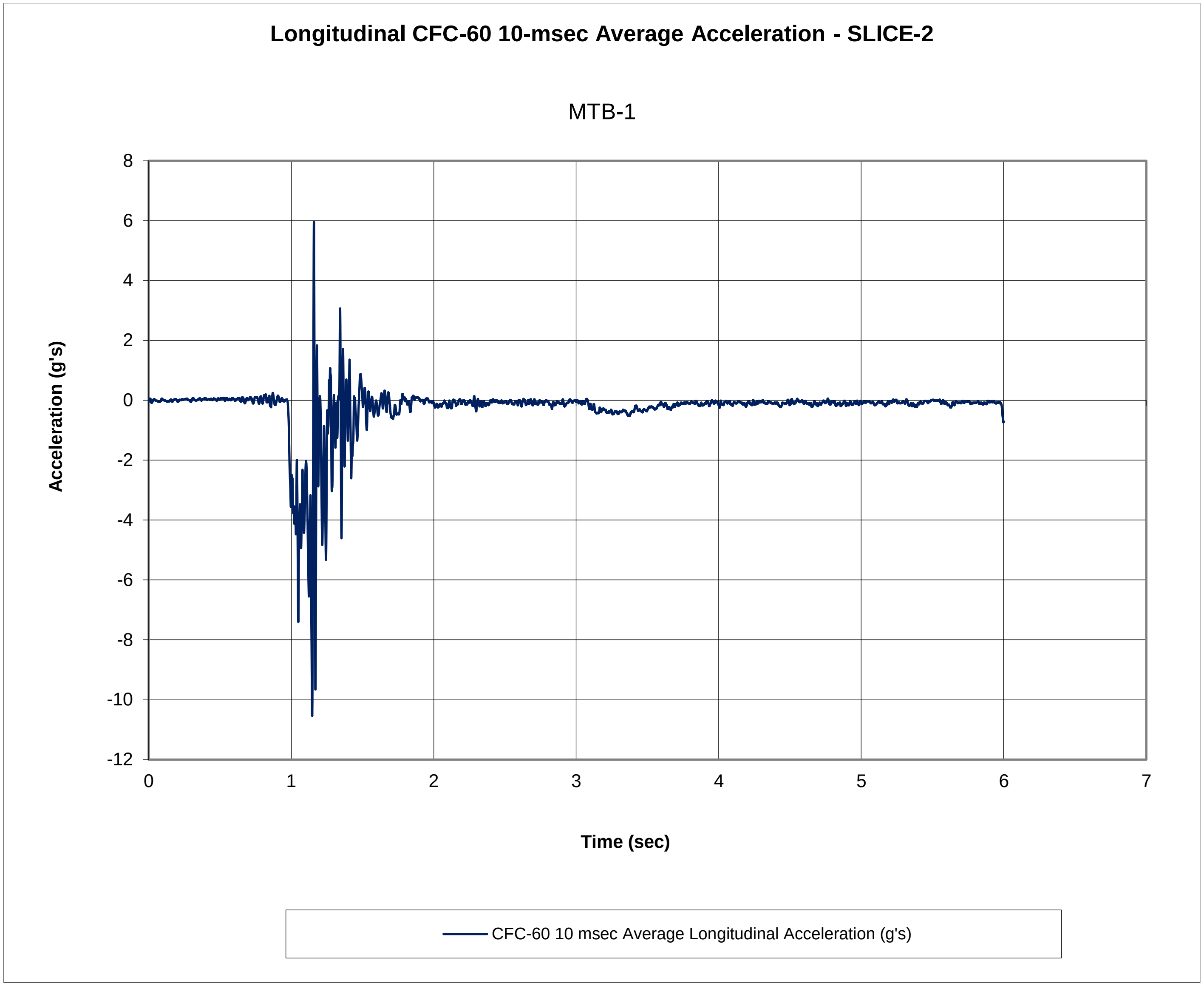


Figure F-19. Longitudinal Average Acceleration, Test No. MTB-1

Appendix G. Accelerometer and Rate Transducer Data Plots, Test No. MTB-2

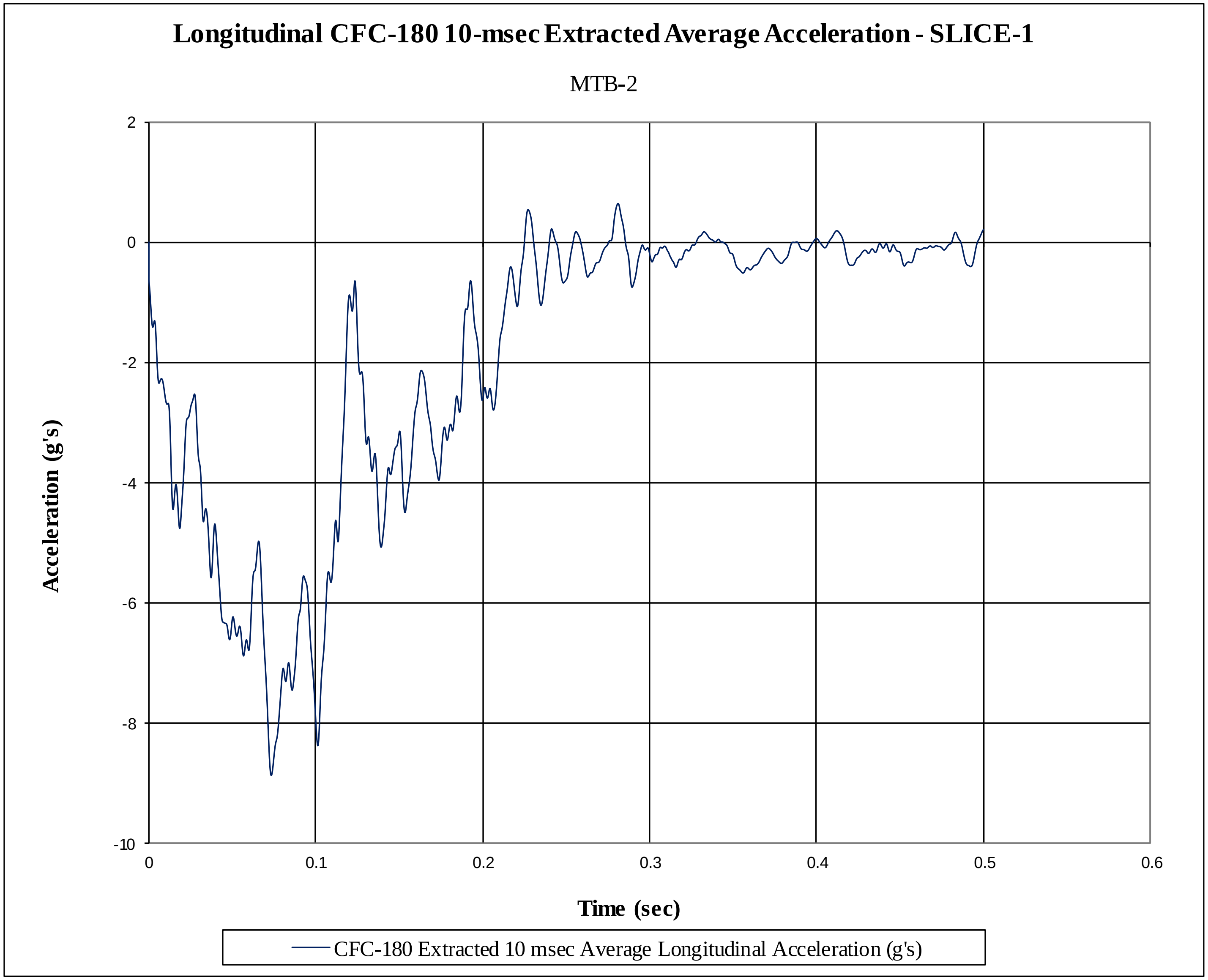


Figure G-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. MTB-2

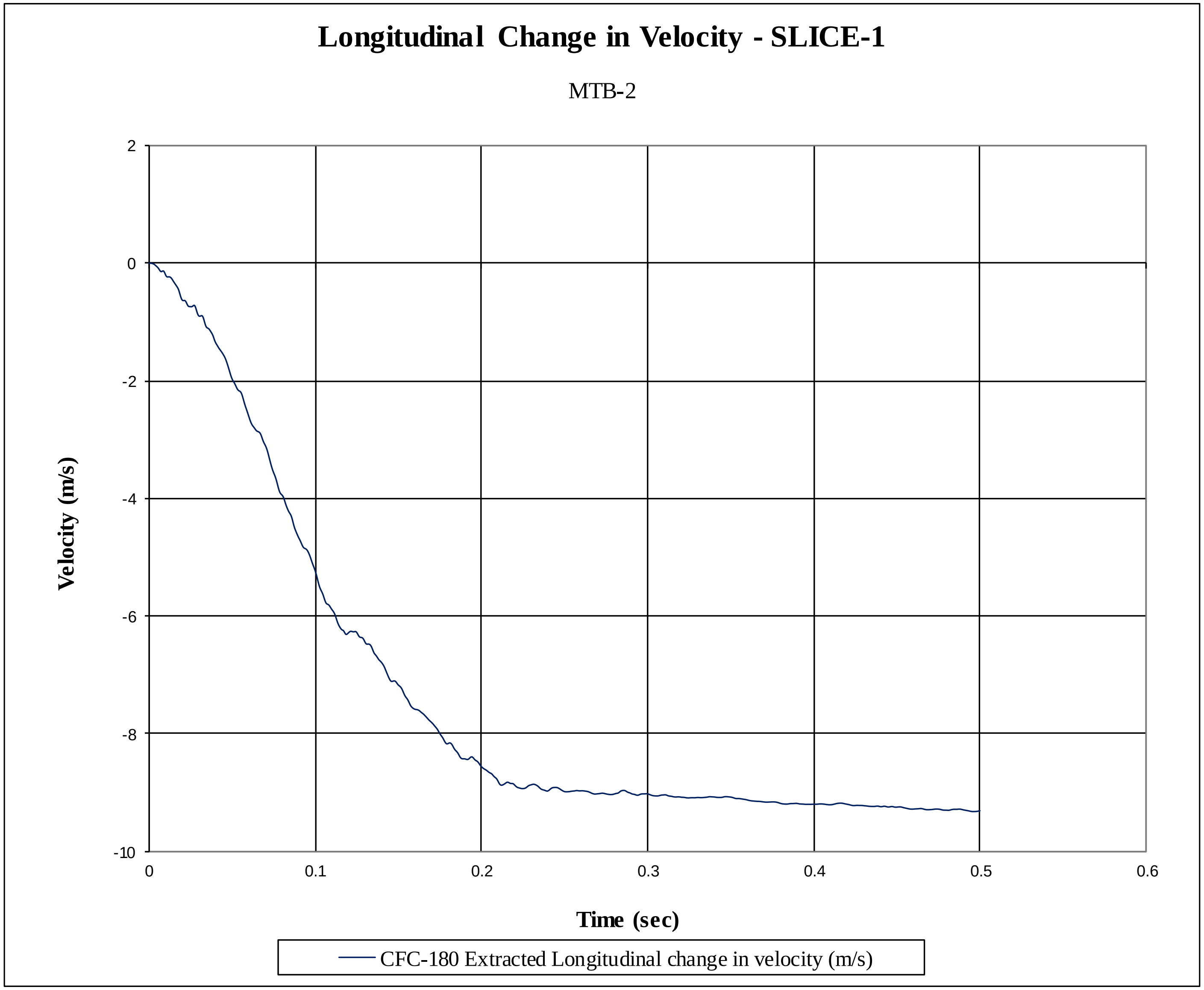


Figure G-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. MTB-2

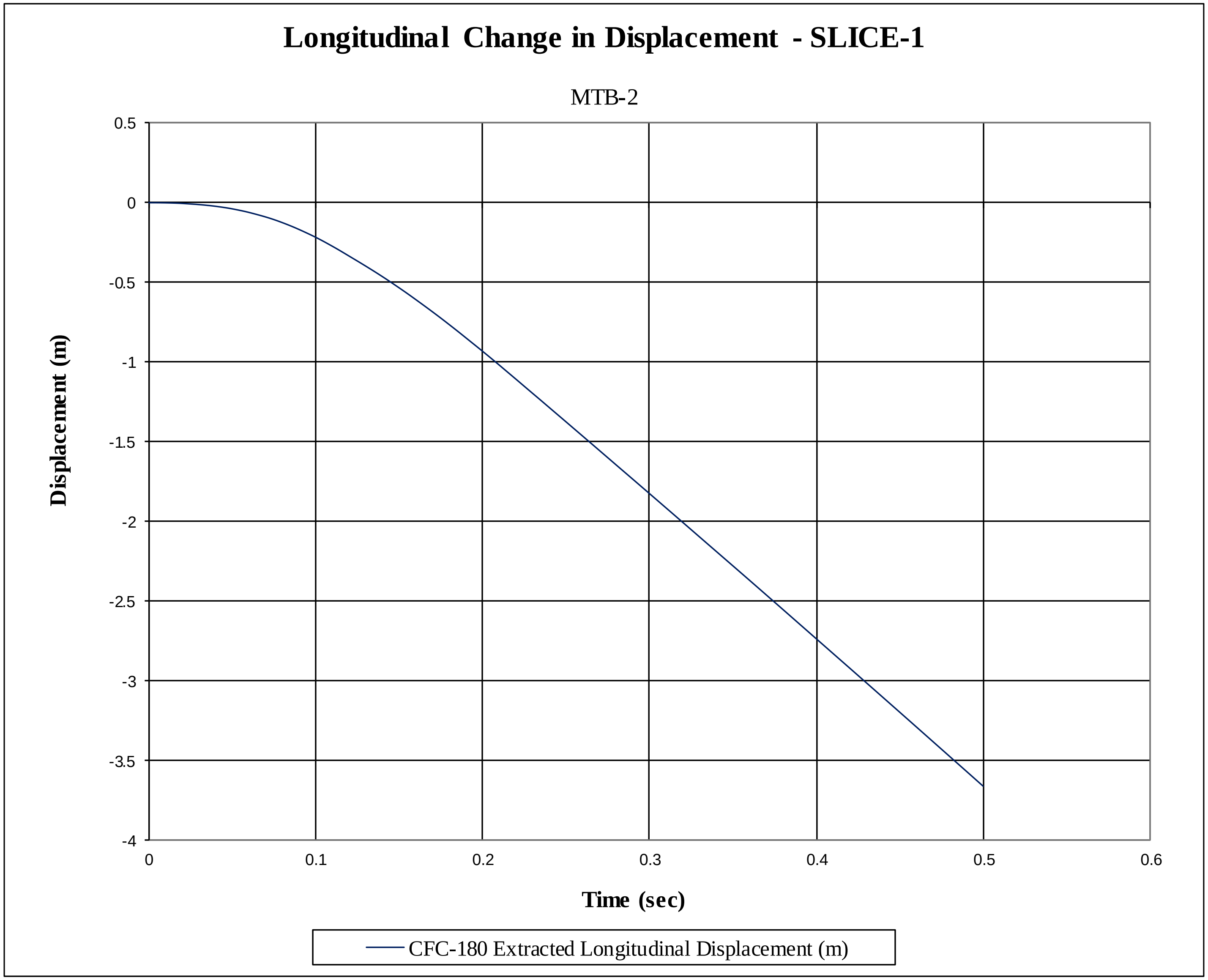


Figure G-3. Longitudinal Occupant Displacement (SLICE-1), Test No. MTB-2

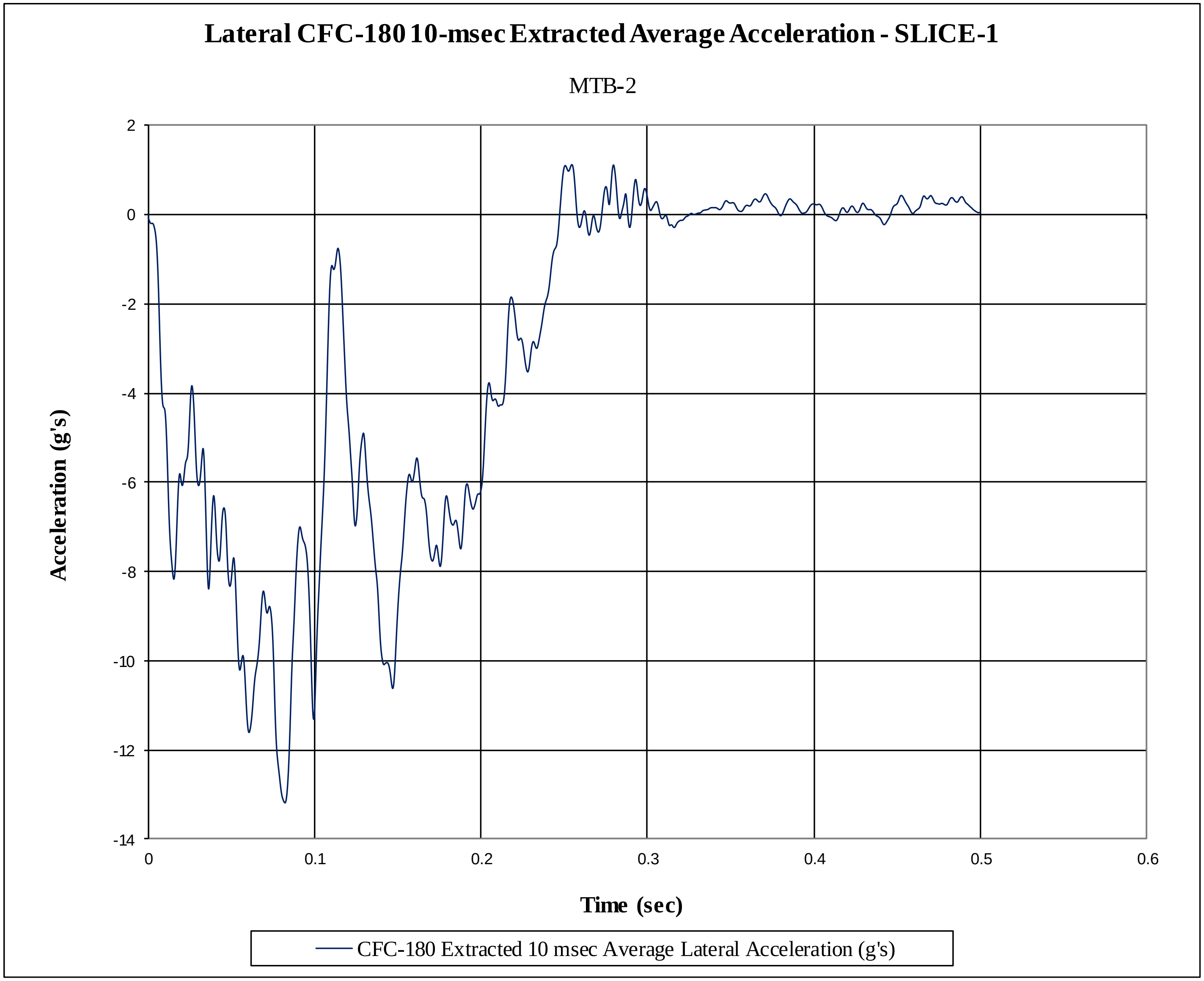


Figure G-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. MTB-2

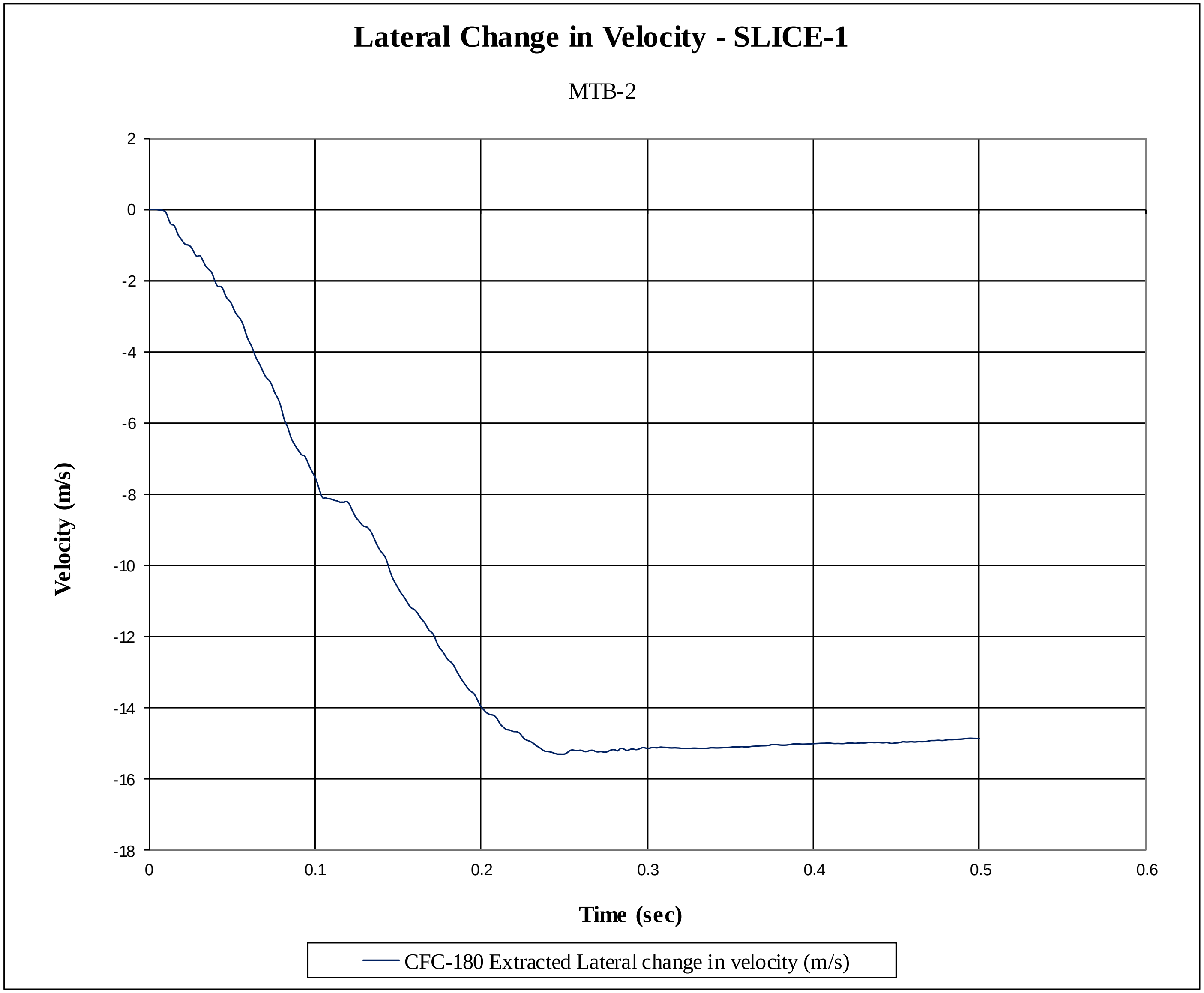


Figure G-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. MTB-2

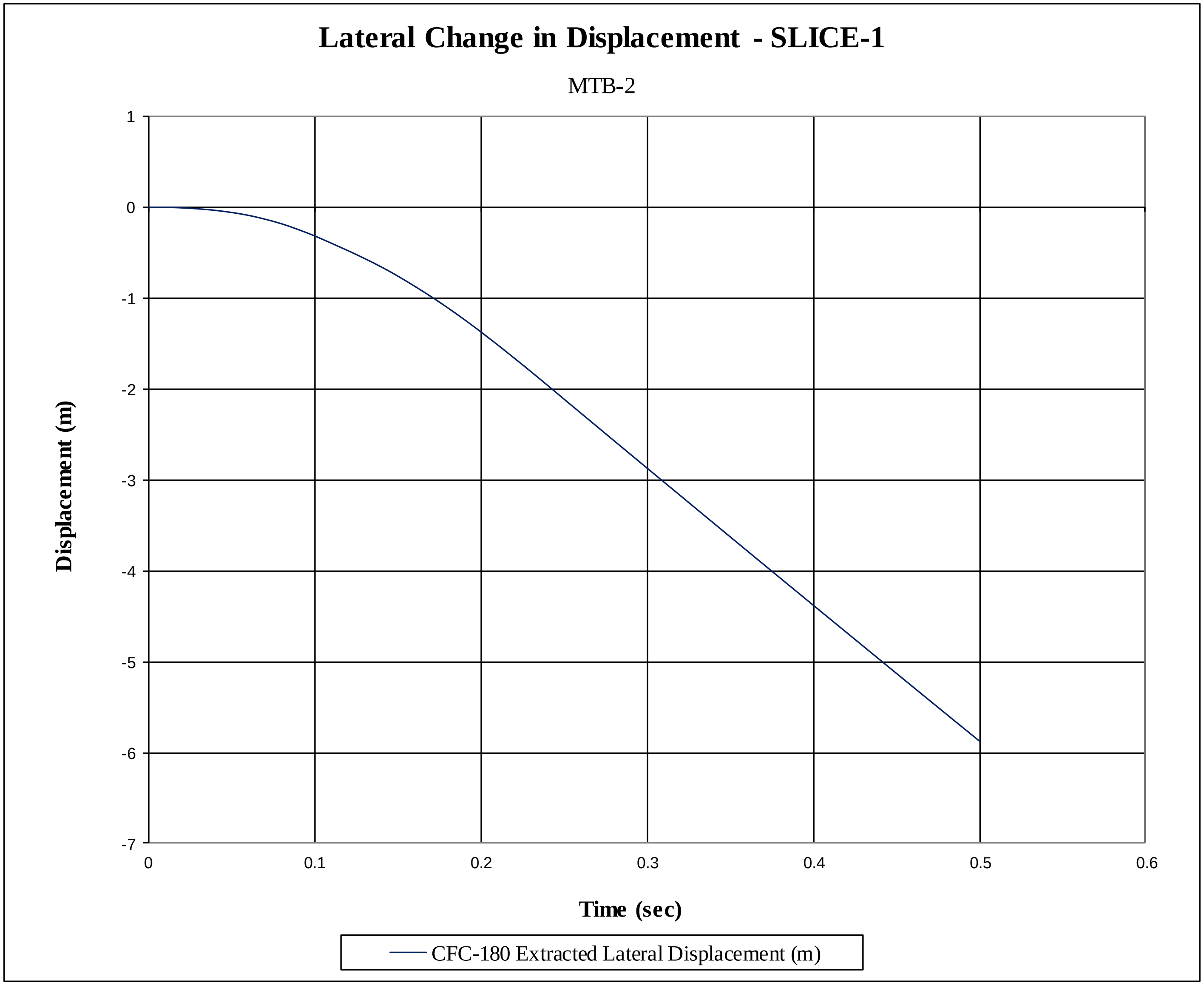


Figure G-6. Lateral Occupant Displacement (SLICE-1), Test No. MTB-2

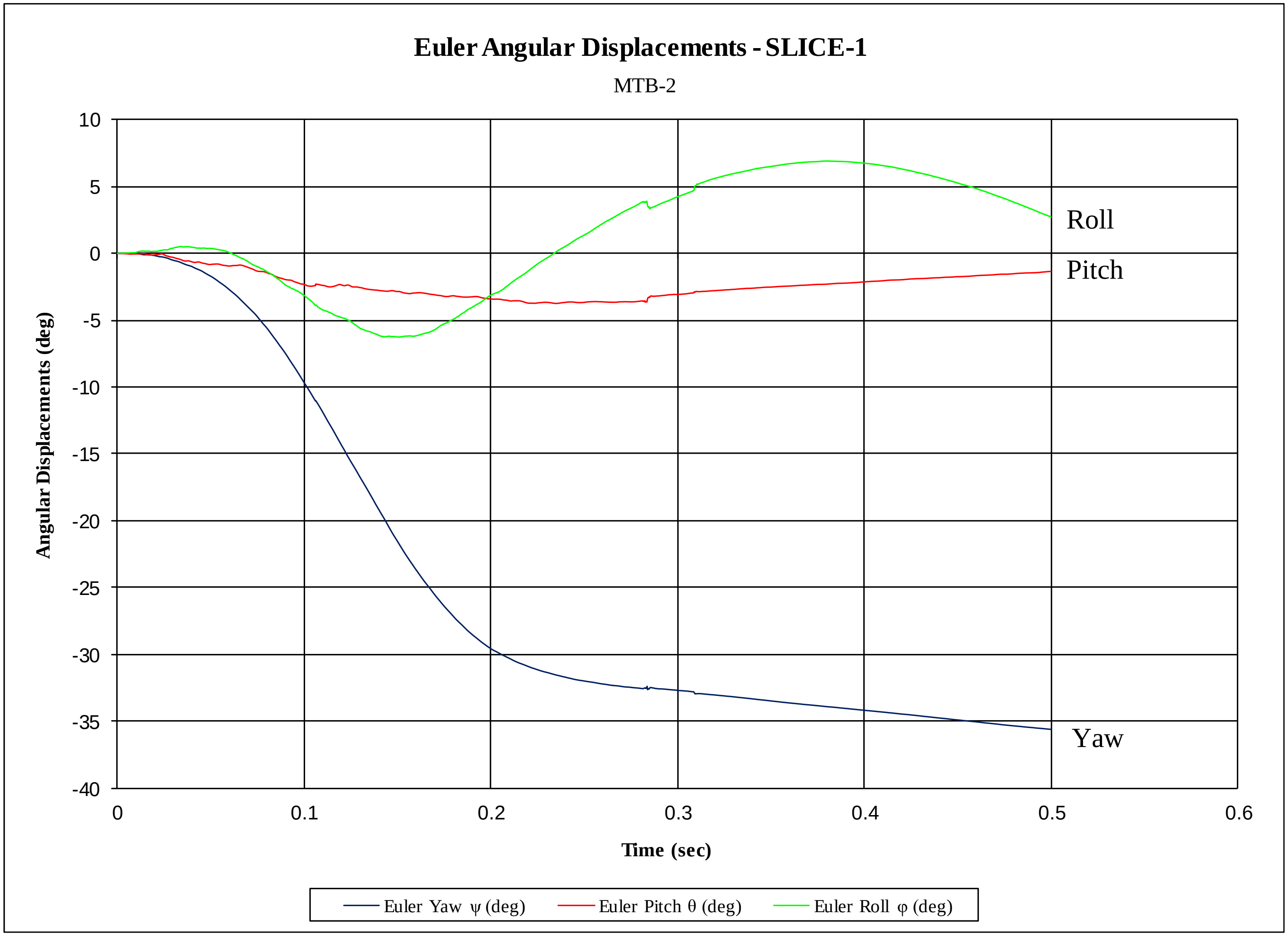


Figure G-7. Vehicle Angular Displacements (SLICE-1), Test No. MTB-2

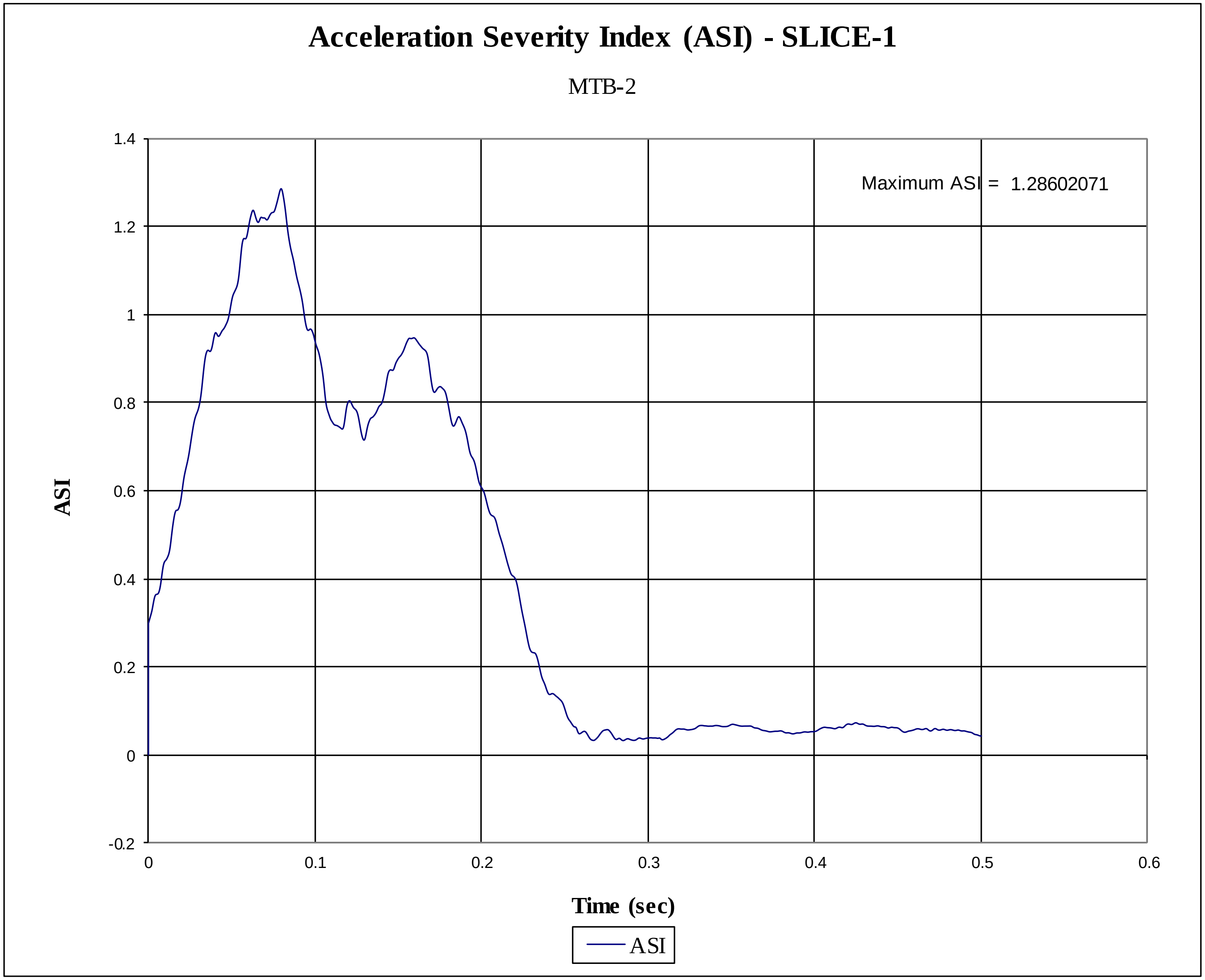


Figure G-8. Acceleration Severity Index (SLICE-1), Test No. MTB-2

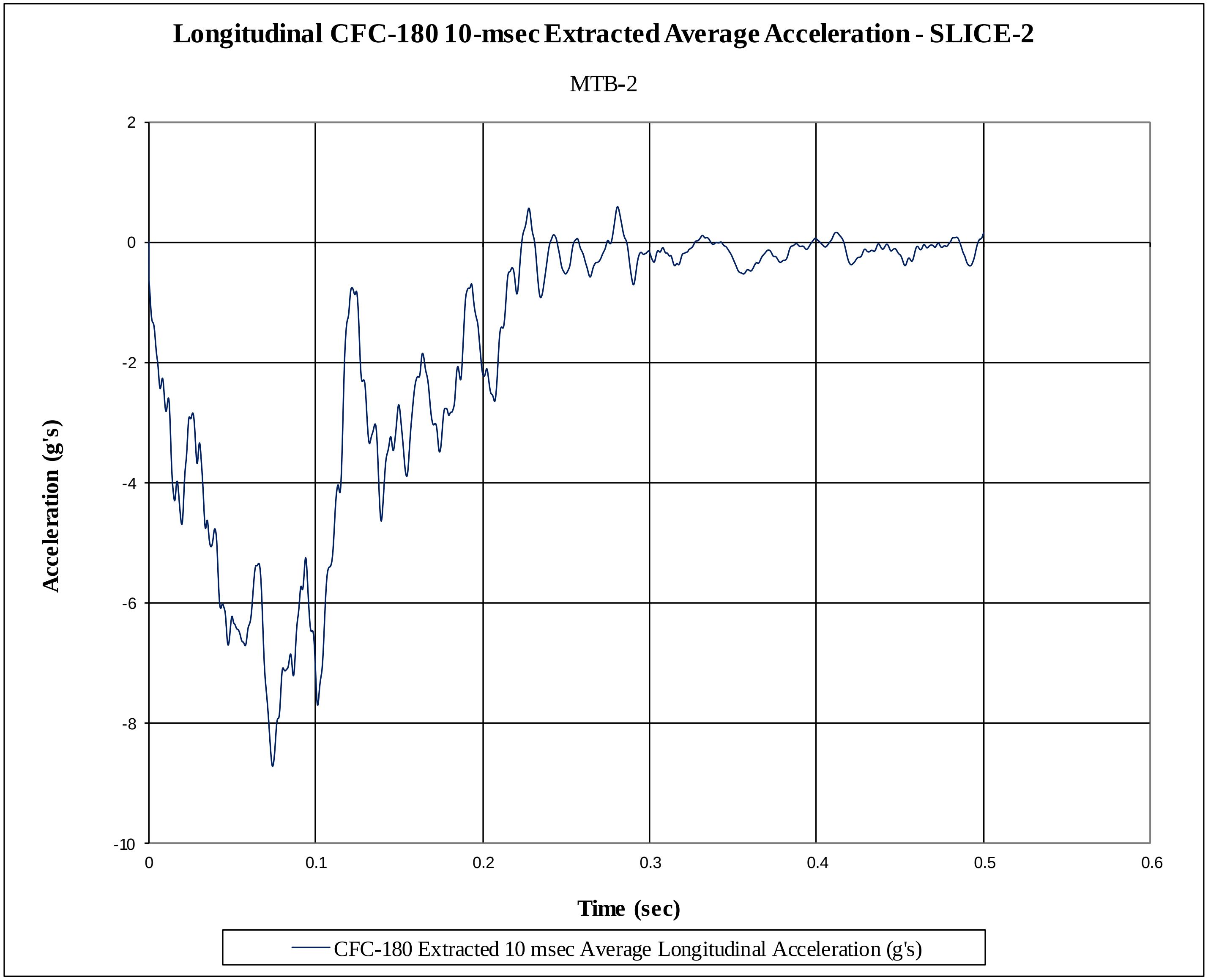


Figure G-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. MTB-2

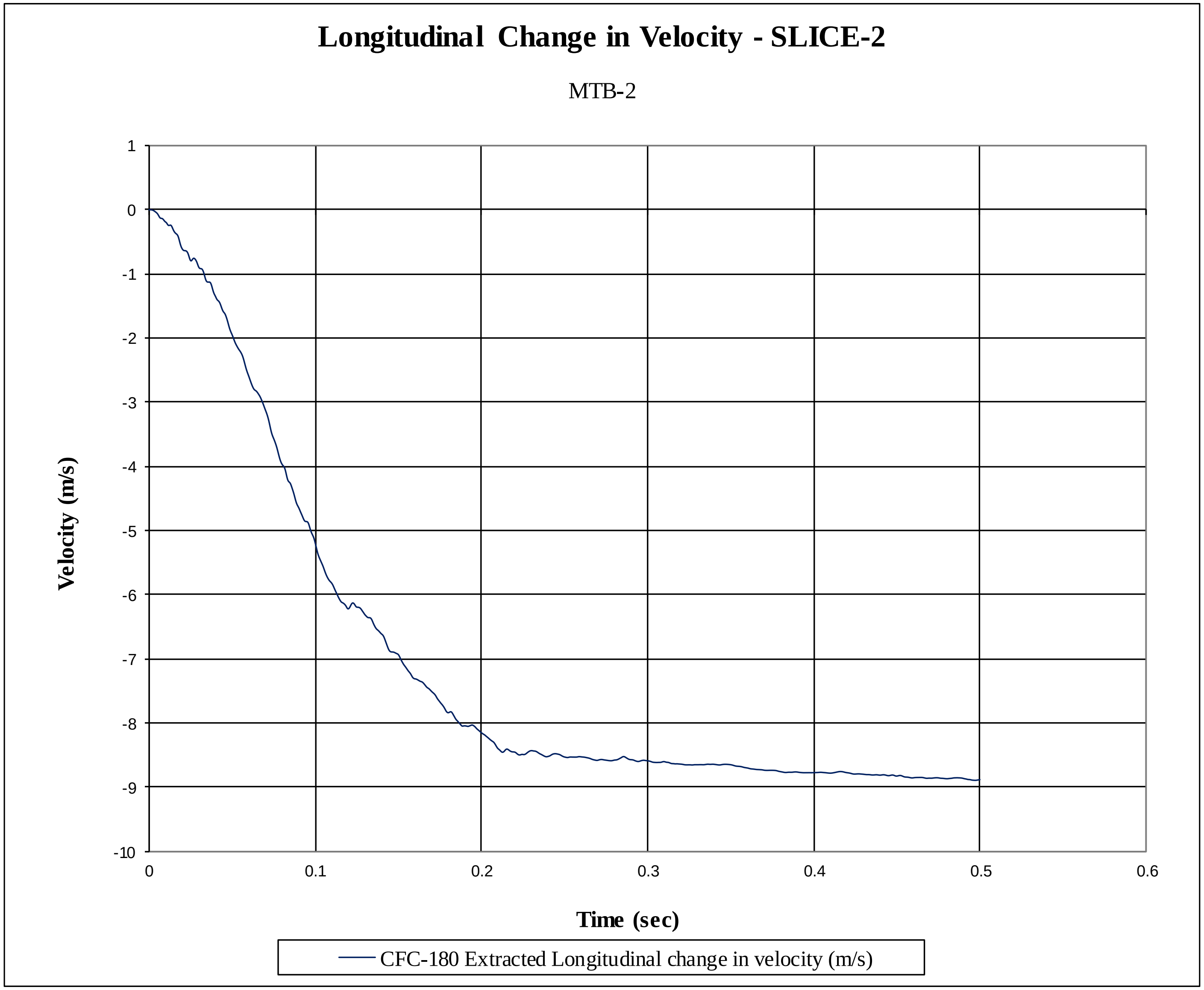


Figure G-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. MTB-2

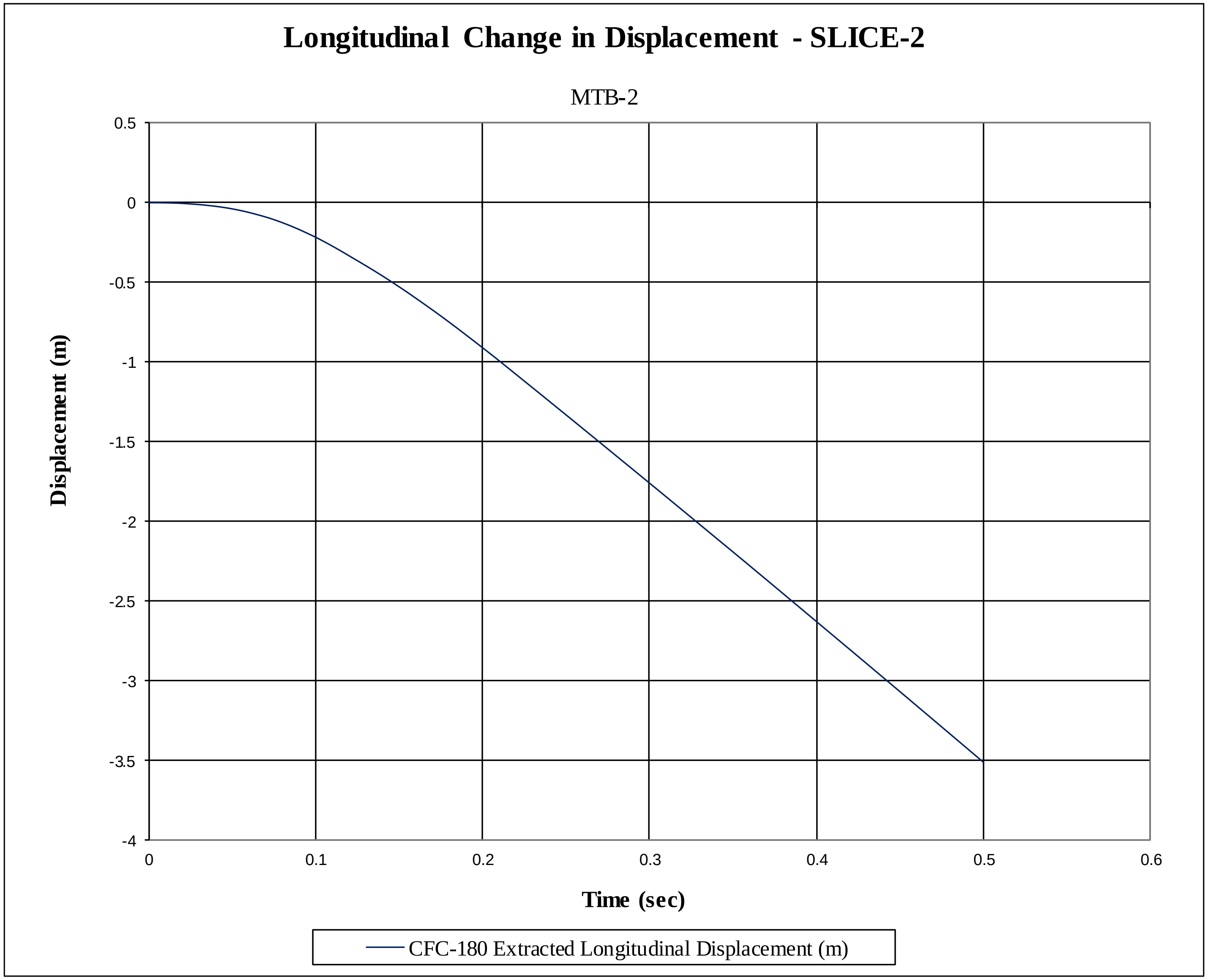


Figure G-11. Longitudinal Occupant Displacement (SLICE-2), Test No. MTB-2

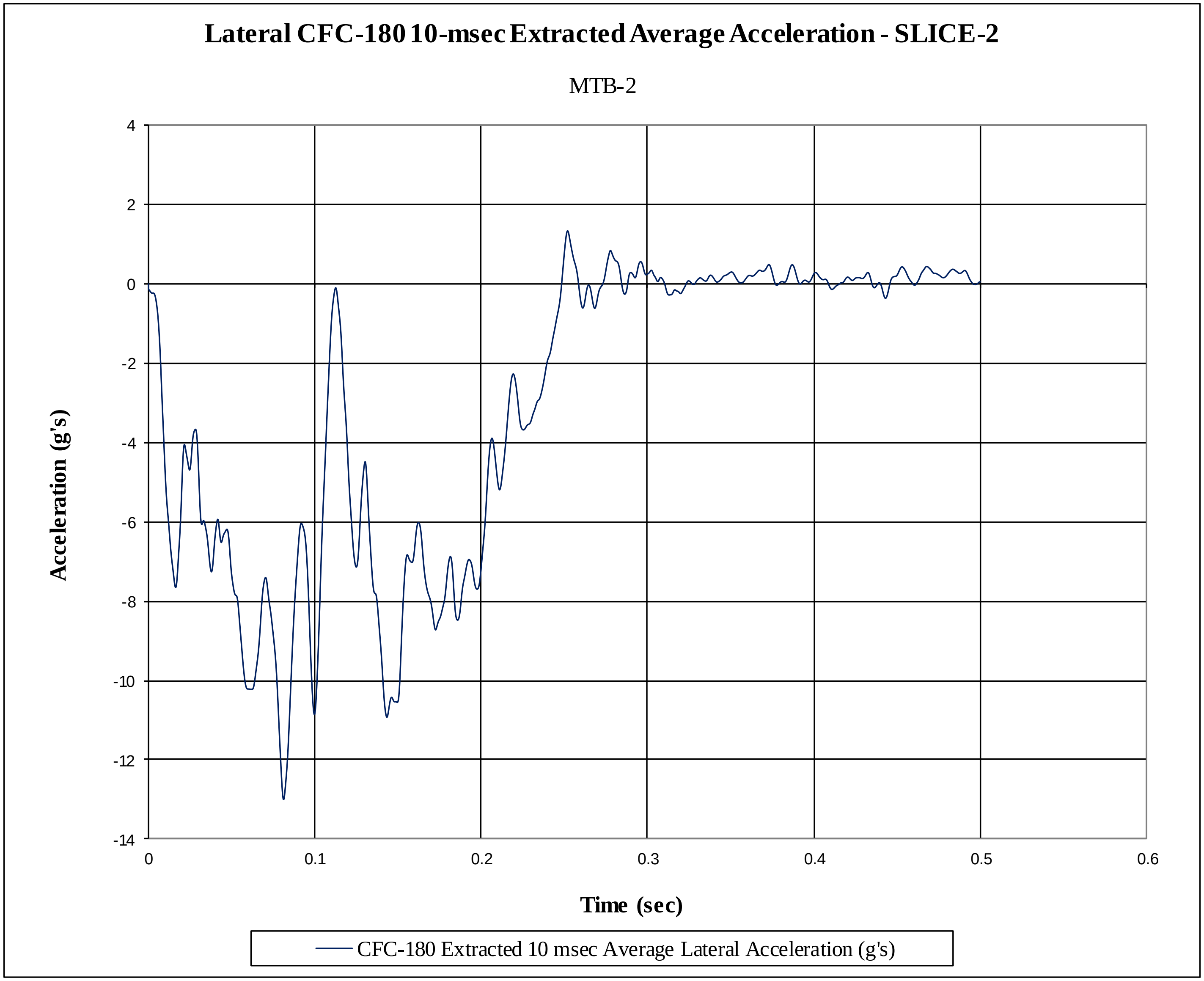


Figure G-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. MTB-2

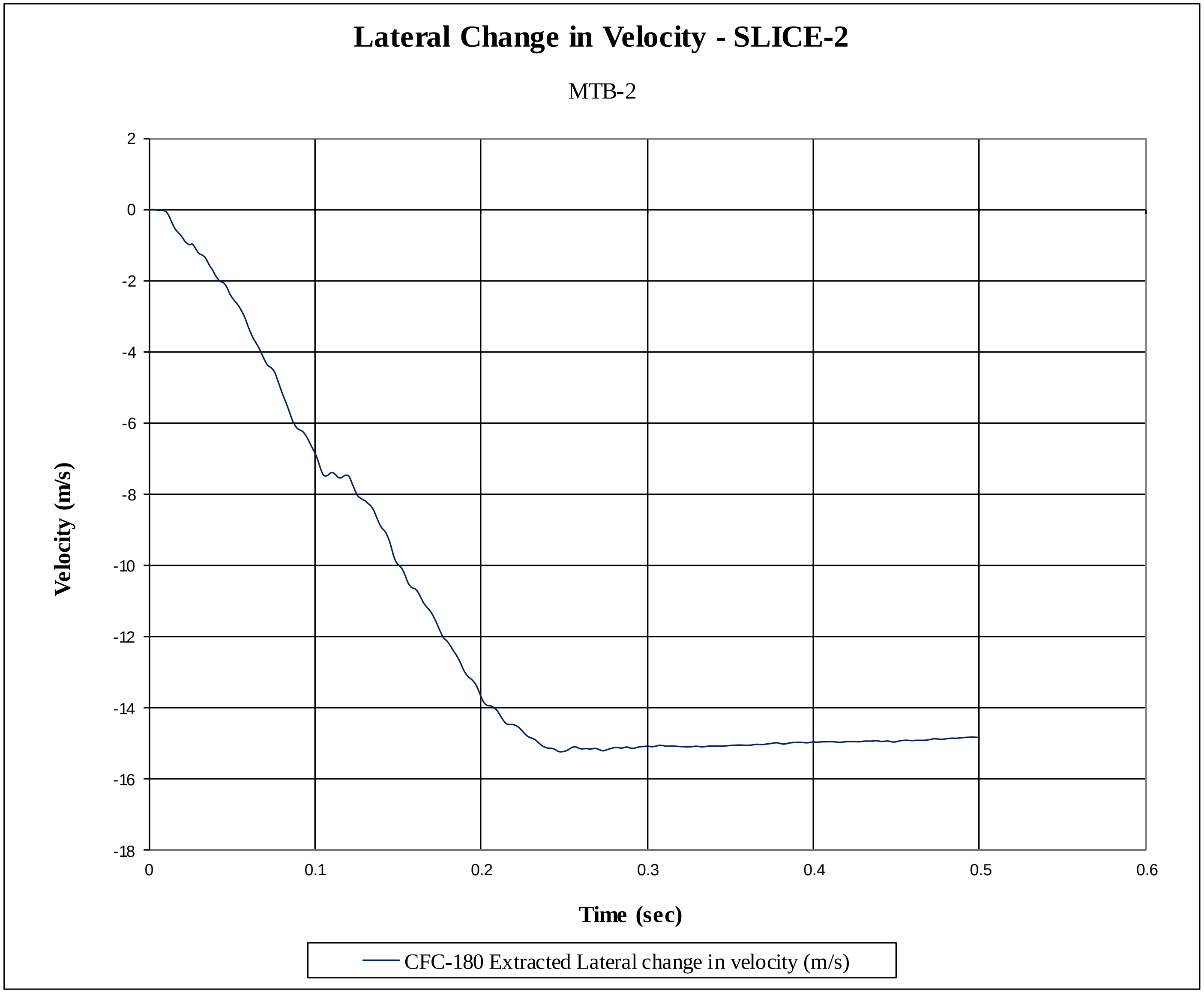


Figure G-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. MTB-2

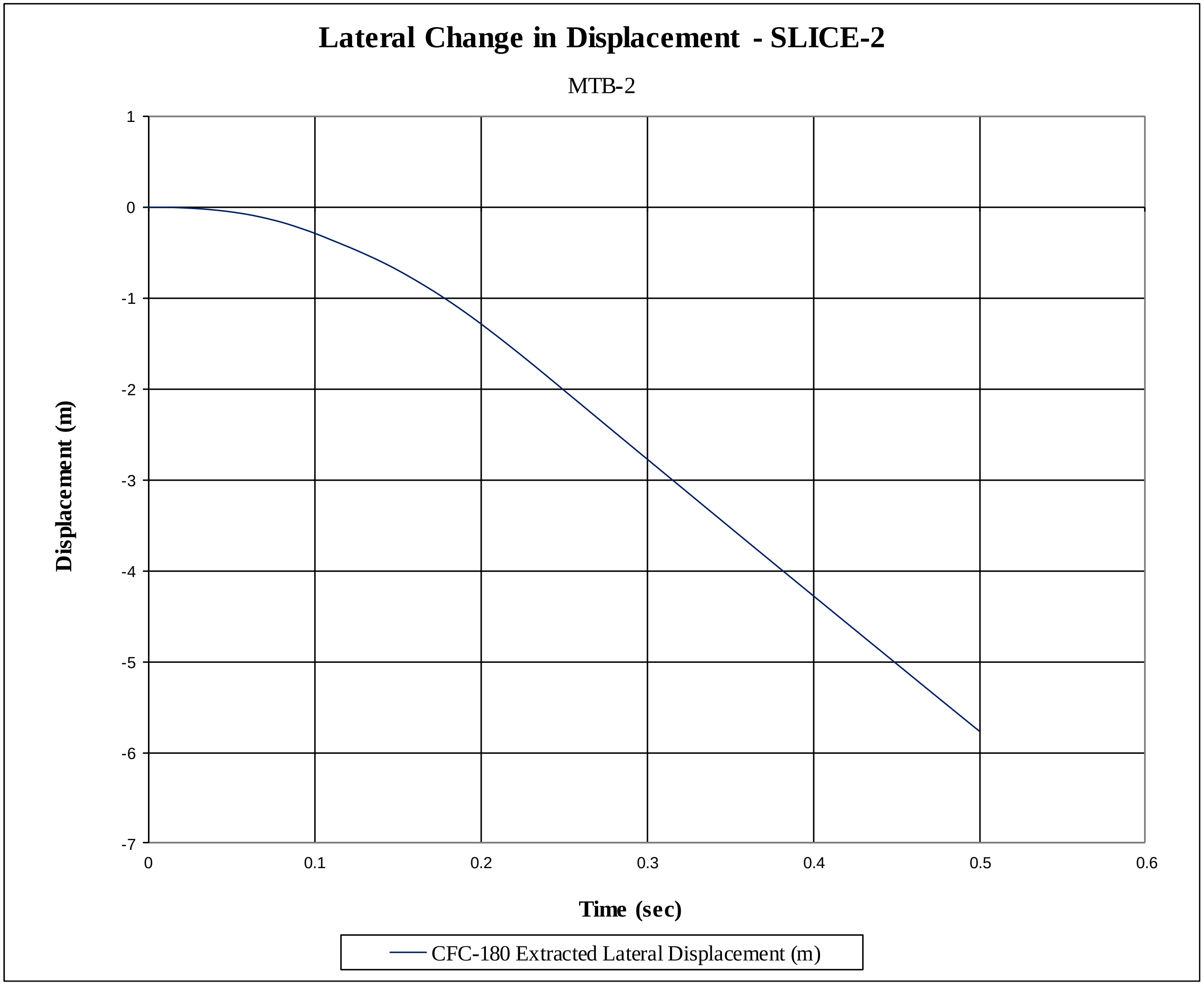


Figure G-14. Lateral Occupant Displacement (SLICE-2), Test No. MTB-2

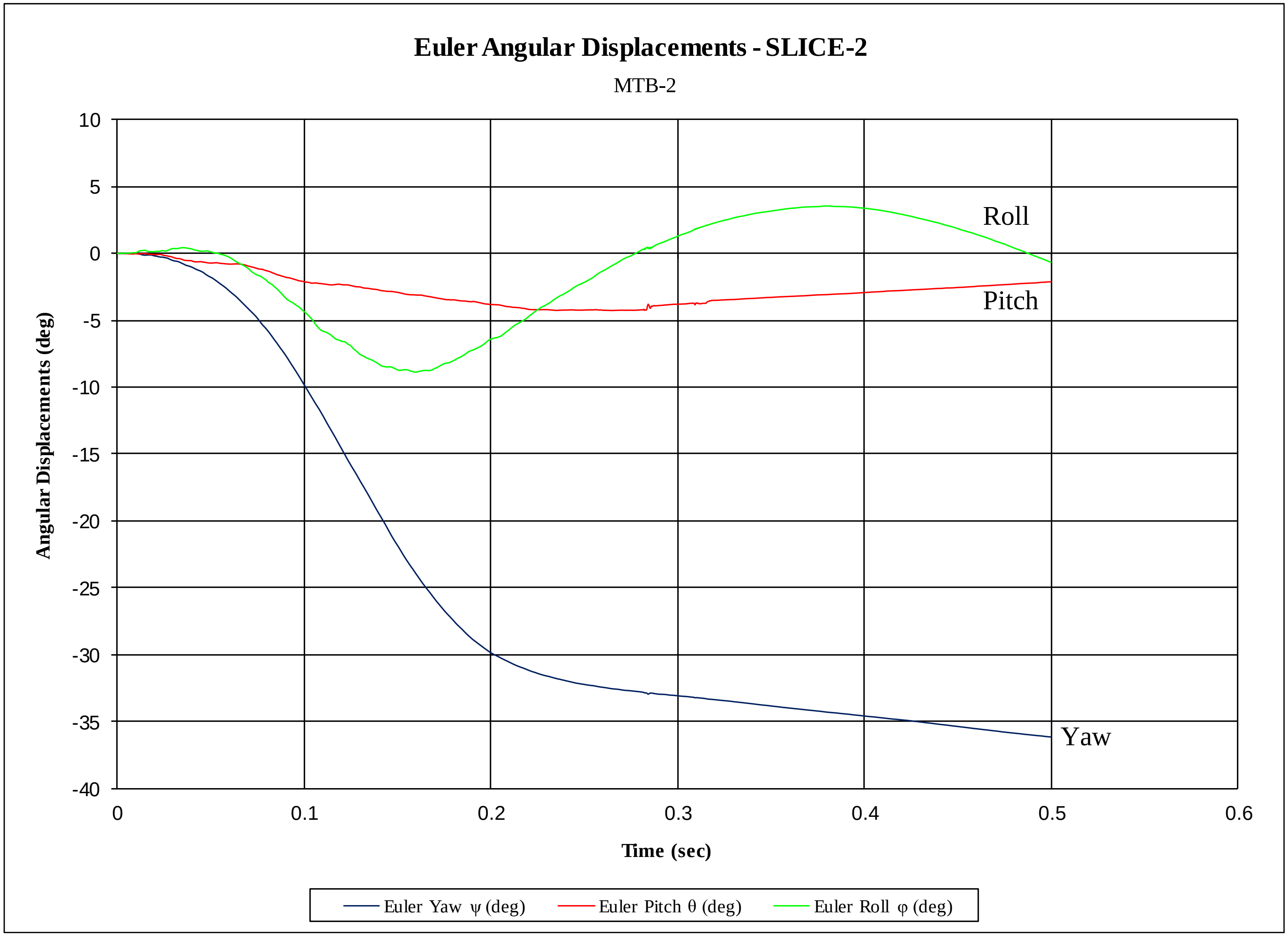


Figure G-15. Vehicle Angular Displacements (SLICE-2), Test No. MTB-2

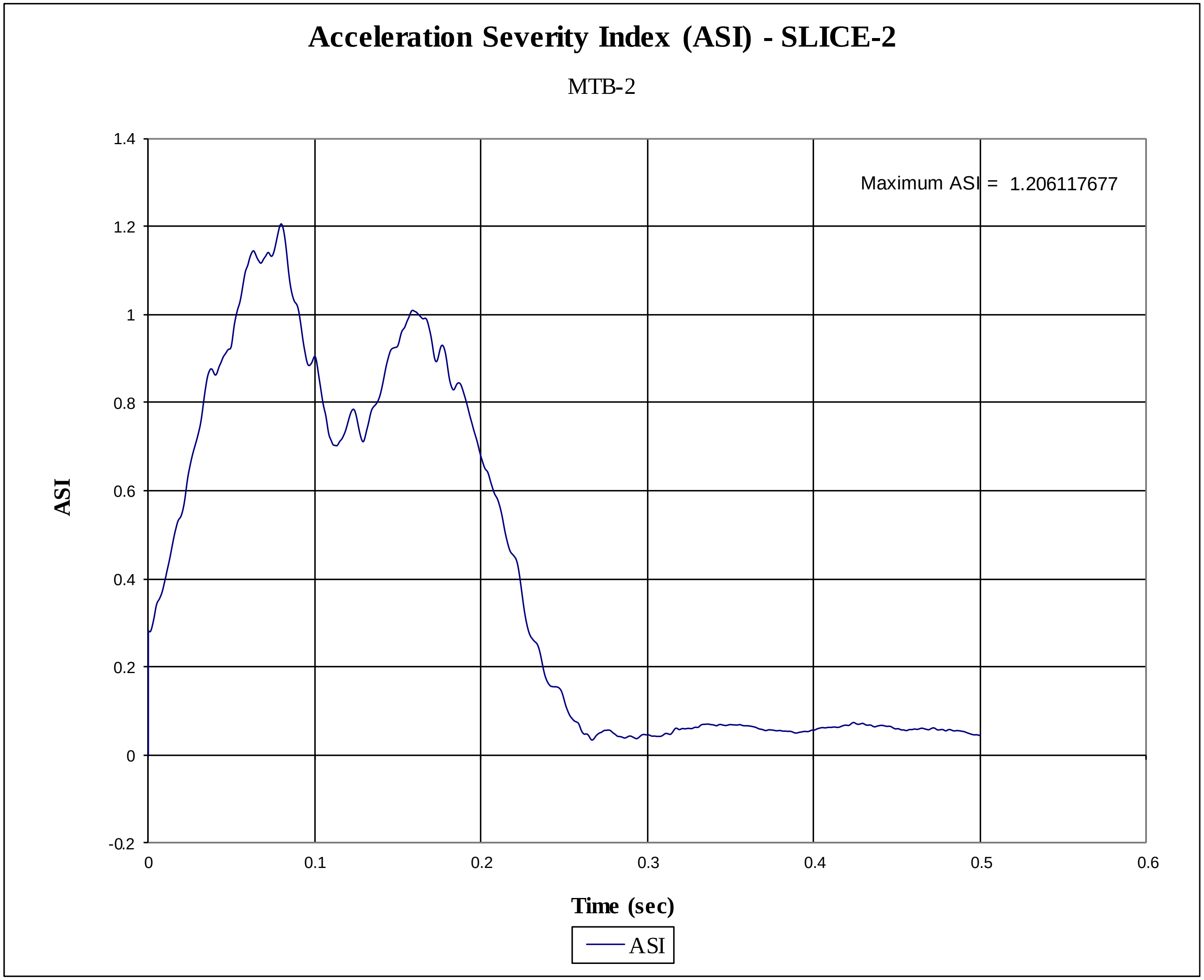


Figure G-16. Acceleration Severity Index (SLICE-2), Test No. MTB-2

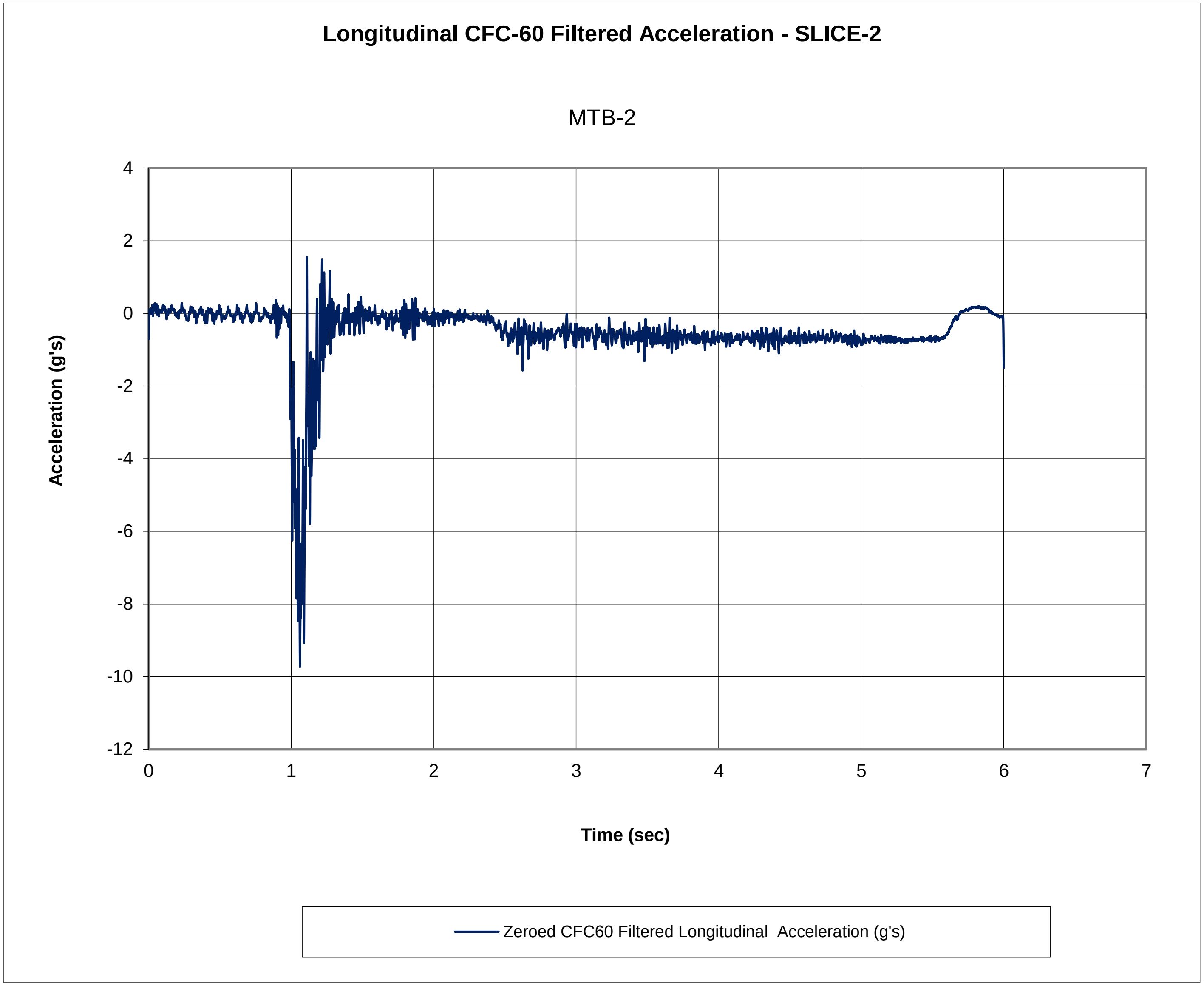


Figure G-17. Longitudinal Filtered Acceleration, Test No. MTB-2

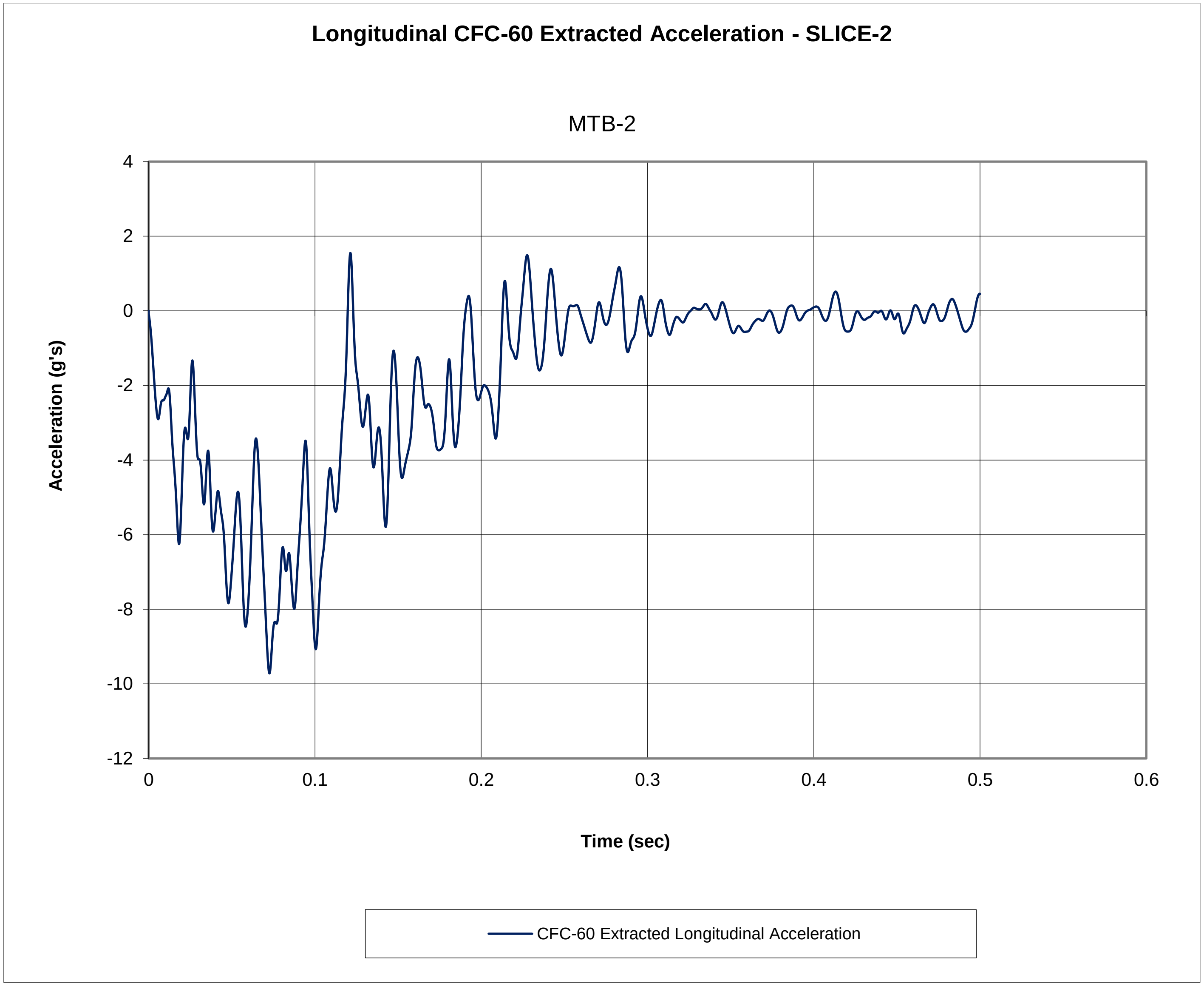


Figure G-18. Longitudinal Extracted Acceleration, Test No. MTB-2

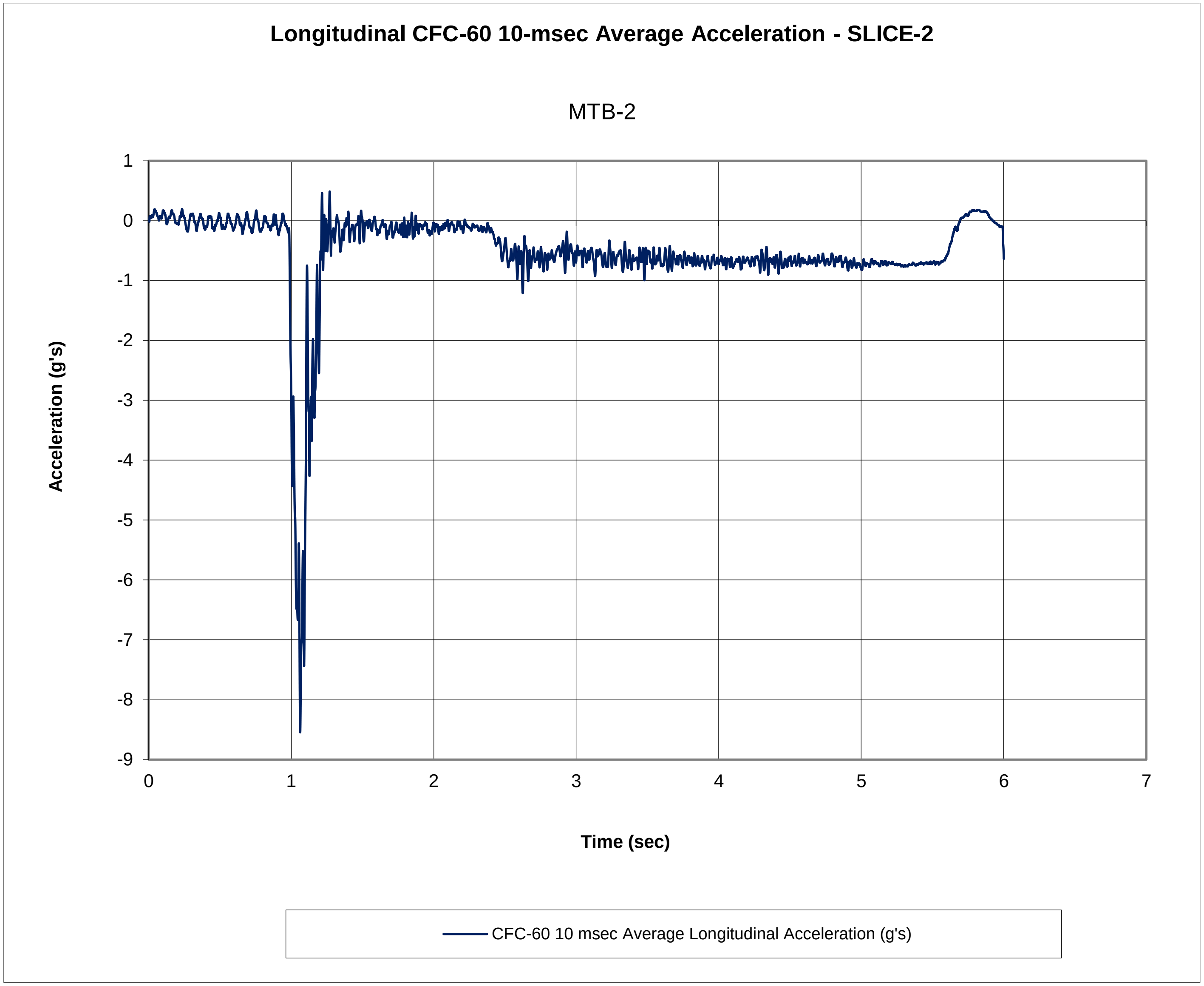


Figure G-19. Longitudinal Average Acceleration, Test No. MTB-2

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