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MIDWEST GUARDRAIL SYSTEM (MGS) WITH SOUTHERN YELLOW PINE POSTS

Submitted by

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16. Abstract (Limit: 200 words)

The Midwest Guardrail System (MGS) has previously been approved for use with various alternative species of wood posts. However, Southern Yellow Pine (SYP) is the most common wood guardrail post material in the United States. The goal of this research was to evaluate the MGS with rectangular SYP posts. In a previous test, the 6-in. x 8-in. x 72-in. long (152-mm x 203-mm x 1,829-mm) rectangular White Pine post was found to have 39 percent lower capacity than the 6-in. x 8-in. x 72-in. long (152-mm x 203-mm x 1,829-mm) Southern Yellow Pine post. This result indicated that the MGS with SYP posts would likely be successful, but full-scale crash testing was deemed useful to verify satisfactory safety performance and obtain dynamic deflection and working width data under Manual for Assessing Safety Hardware (MASH) TL-3 test conditions.

The MGS was crash tested with 6-in. x 8-in. x 72-in. long (152-mm x 203-mm x 1,829-mm) Southern Yellow Pine posts. This system also used a 6-in. x 12-in. x 14¼-in. long (152-mm x 305-mm x 362-mm) blockout as well as 12-gauge (2.66-mm) guardrail sections. The design was evaluated using a small car (test no. 3-10) and a pickup truck (test no. 3-11) according to the testing standards established in the MASH. The MGS with Southern Yellow Pine posts met the MASH safety requirements for both full-scale crash tests. Following the full-scale crash testing, recommendations were given regarding the use of SYP posts in special MGS applications.

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UNCERTAINTY OF MEASUREMENT STATEMENT

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

INDEPENDENT APPROVING AUTHORITY

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

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1 INTRODUCTION

1.1 Problem Statement

The Midwest Guardrail System (MGS) is a non-proprietary, strong post, W-beam barrier composed of W6x9 or W6x8.5 steel posts or wood guardrail posts, 12-gauge (2.66-mm) W-beam rail, and a 12-in. (305-mm) deep blockout. The MGS has been evaluated under the safety criteria of both the National Cooperative Highway Research Program (NCHRP) Report No. 350 [1] and the *Manual for Assessing Safety Hardware (MASH)* [2] under Test Level 3 (TL-3) impact conditions. Subsequently, the Federal Highway Administration (FHWA) deemed the MGS eligible for reimbursement under the Federal-Aid Highway Program. However, the MGS had never been tested with rectangular Southern Yellow Pine (SYP) wood posts to evaluate the working width and dynamic deflection of the system. Being that rectangular SYP posts are the most commonly used wood guardrail posts in the United States, it was proposed that an evaluation of the MGS with SYP posts would prove beneficial for many State Departments of Transportation (DOTs).

The MGS was previously tested and approved for use with several wood post variations. The MGS has been successfully tested with both alternative wood species round posts [3] and 6-in. x 8-in. x 72-in. long (152-mm x 203-mm x 1829-mm) rectangular White Pine (WP) posts [4]. WP posts have approximately 39 percent lower capacity than standard SYP wood posts [5]. The Midwest Roadside Safety Facility (MwRSF) performed a crash test under MASH test designation no. 3-11 on the MGS with WP posts. The 2270P vehicle was smoothly redirected in test no. MGSWP-1, and six posts fractured or split [5]. Although test no. MGSWP-1 was a good indicator that the MGS would perform well with SYP posts, the Midwest Pooled Fund Program members desired to obtain the actual system behavior (e.g., dynamic deflection and working width) for a SYP wood post MGS.

1.2 Objective

The objective of this research effort was to evaluate the safety performance of the MGS with 6-in. x 8-in. x 72-in. long (152-mm x 203-mm x 1829-mm) SYP posts according to the TL-3 full-scale crash testing criteria set forth in MASH.

1.3 Scope

The research objective was achieved through the completion of several tasks. First, two full-scale crash tests were conducted on the MGS with SYP wood posts. The crash tests utilized a pickup truck and a small car, weighing approximately 5,000 lb (2,268 kg) and 2,425 lb (1,100 kg), respectively. The target impact conditions for both tests were an impact speed of 62 mph (100 km/hr) and an impact angle of 25 degrees. Next, the test results were analyzed, evaluated, and documented. Finally, conclusions and recommendations were made that pertain to the safety performance of the MGS with SYP posts.

2 DESIGN DETAILS

The test installation consisted of 181 ft – 3 in. (55.3 m) of standard 12-gauge (2.66-mm) W-beam supported by SYP wood posts, as shown in Figure 1. Anchorage systems similar to those used on tangent guardrail terminals were utilized on both the upstream and downstream ends of the guardrail system. Design details are shown in Figures 1 through 10. Photographs of the test installations are shown in Figures 11 and 12. Material specifications, mill certifications, and certificates of conformity for the component materials are shown in Appendix A.

The system was constructed with twenty-nine wood posts spaced at 75 in. (1,905 mm) on center, as shown in Figures 1 and 2. Post nos. 3 through 27 were 6-in. x 8-in. x 72-in. long (152-mm x 203-mm x 1,829-mm) Grade 1 SYP wood posts with a soil embedment depth of 40 in. (1,016 mm). A 6-in. wide x 12-in. deep x 14¼-in. long (152-mm x 305-mm x 362-mm) wood spacer blockout was used to block the rail away from the front face of each steel post. A 16D double head nail was also driven through a hole in the front flange of the post into the top of the blockout assembly to prevent rotation of the blockout. Post nos. 1, 2, 28, and 29 were breakaway cable terminal (BCT) timber posts measuring 5½ in. wide x 7½ in. deep x 46 in. long (140 mm x 191 mm x 1,168 mm) and were placed in 6-ft (1.8-m) long foundation tubes, as shown in Figure 6. A tangent anchorage system was utilized on the upstream and downstream ends of the guardrail system in order to develop the barrier's tensile capacity. The anchorage system consisted of timber posts, foundation tubes, anchor cables, bearing plates, rail brackets, and channel struts, which closely resembled the hardware used in the Modified BCT system. As such, this system is believed to be representative of existing guardrail terminal end anchorages. All posts were placed in a compacted coarse, crushed limestone material.

Standard 12-ft 6-in. (3.81-m) long 12-gauge (2.66-mm) W-beam rails with additional post bolt slots at half-post spacings were placed between post nos. 1 and 29, as shown in Figures

1, 2, and 9. Standard splice bolts, ⅝ x 22 in. (M16x559) long guardrail bolt and nuts, were used to attach the rail to the posts. The W-beam's top rail height for MGSSYP-1 was 31 in. (787 mm) with a 24⅞-in. (632-mm) center mounting height. The rail splices were placed at midspan locations, as shown in Figures 1 and 2. All lap-splice connections between the rail sections were configured with the upstream segment in front to minimize vehicle snag at the splice during the crash test.

The installation for test no. MGSSYP-2 was raised 1 in. (25 mm) such that the height to the top of the guardrail was 32 in. (813 mm), as shown in Figures 13 through 22. Photographs of the test installation for test no. MGSSYP-2 are shown in Figure 23.

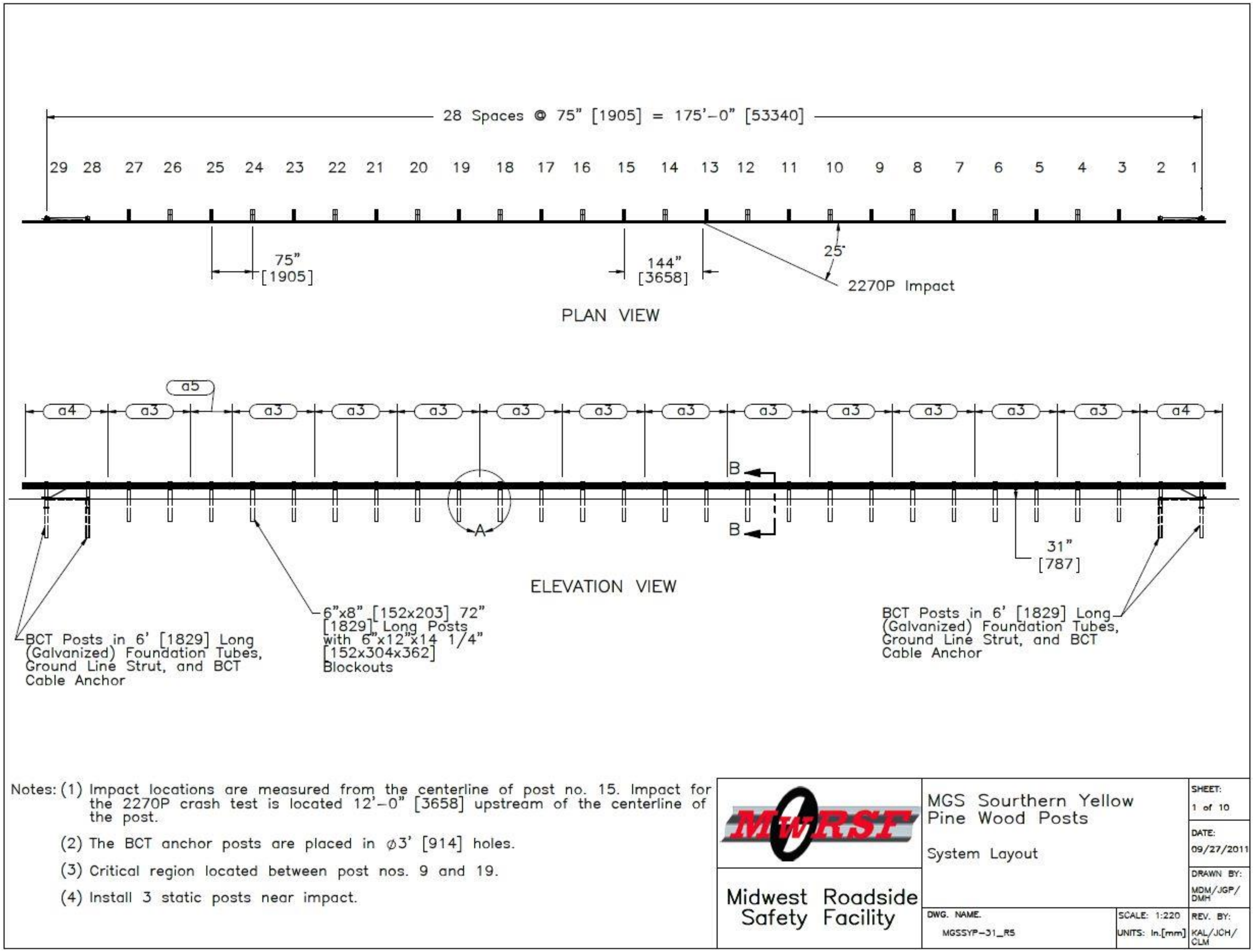


Figure 1. Test Installation Layout, Test No. MGSSYP-1

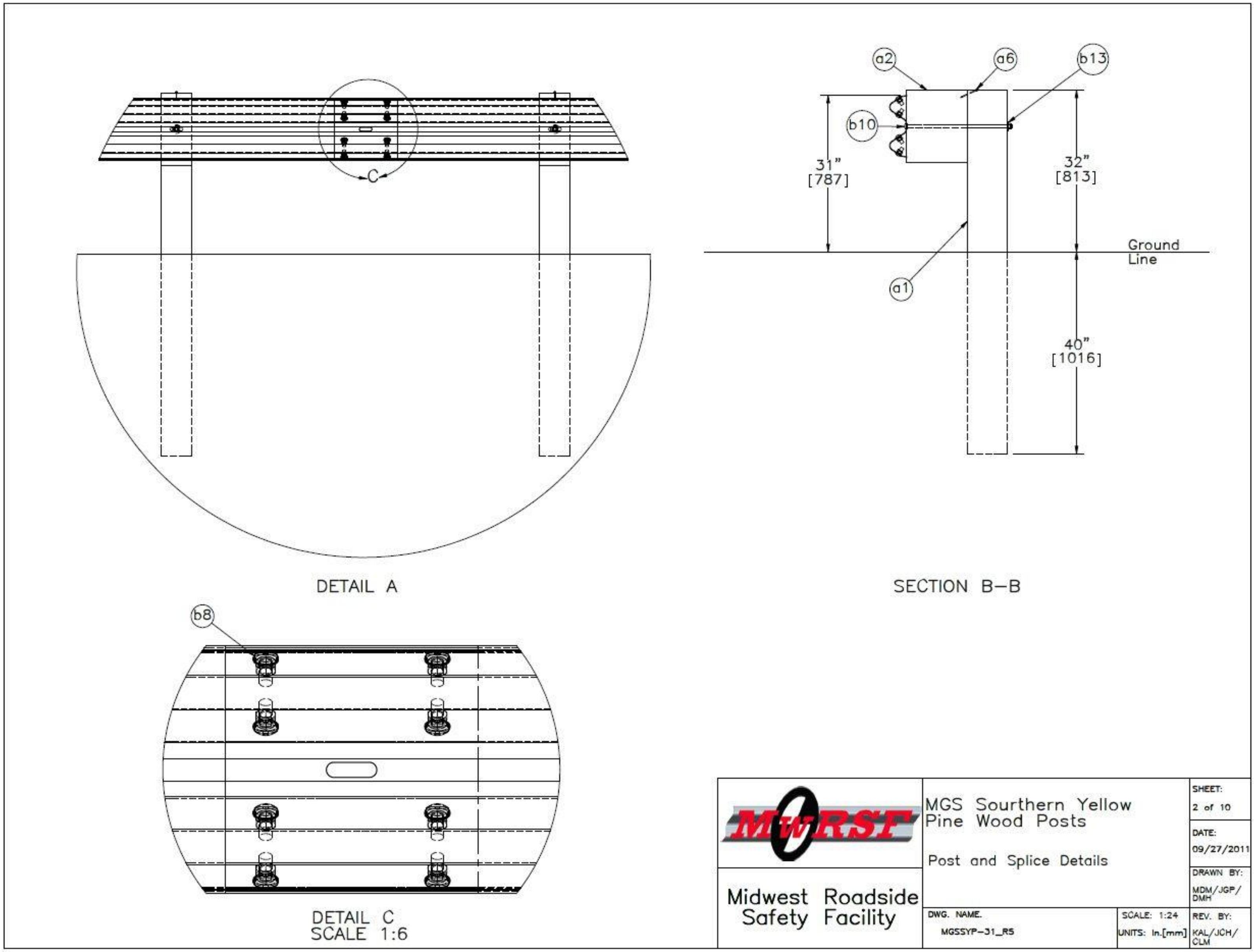


Figure 2. Post and Splice Details, Test No. MGSSYP-1

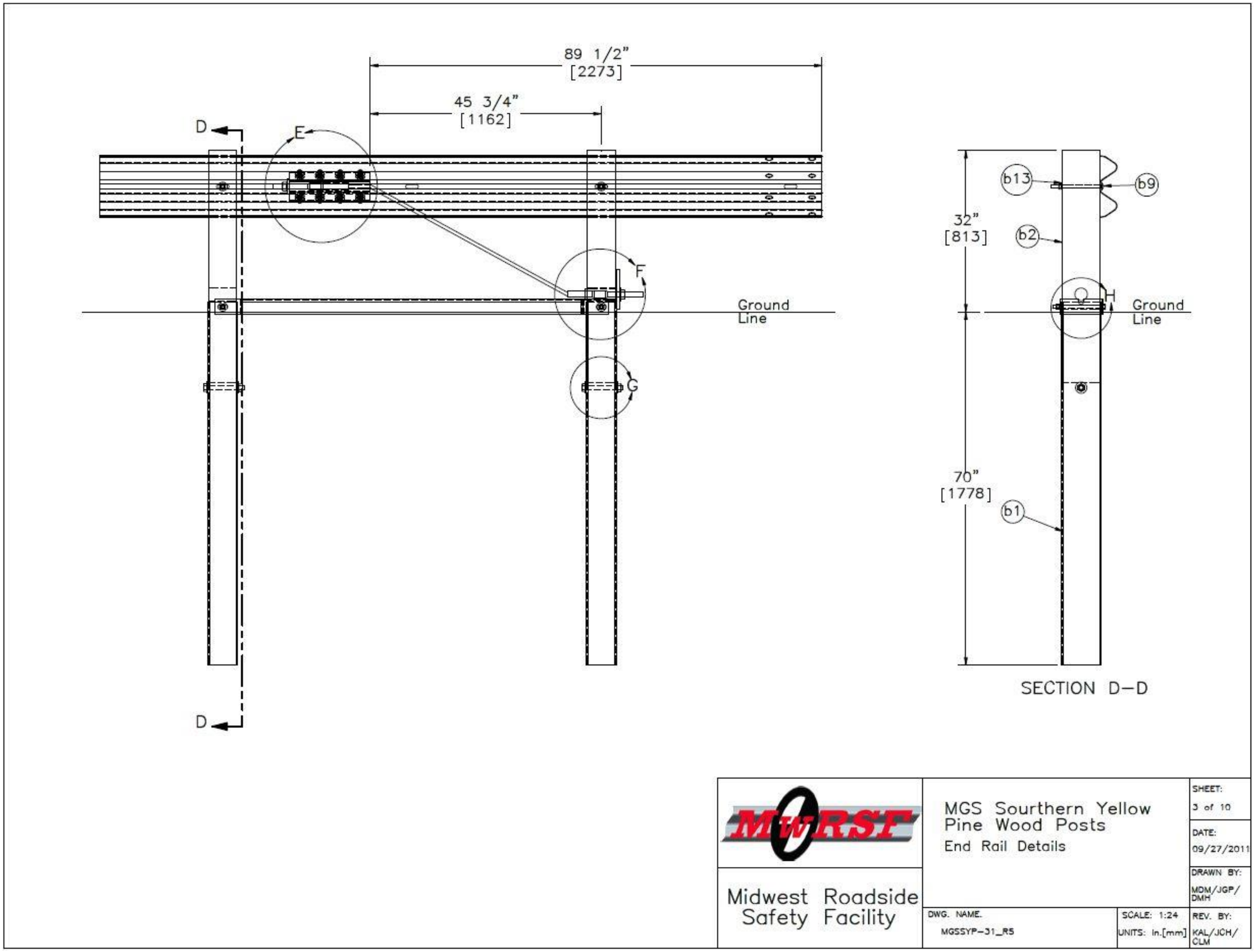


Figure 3. Anchorage Layout, Test No.MGSSYP-1

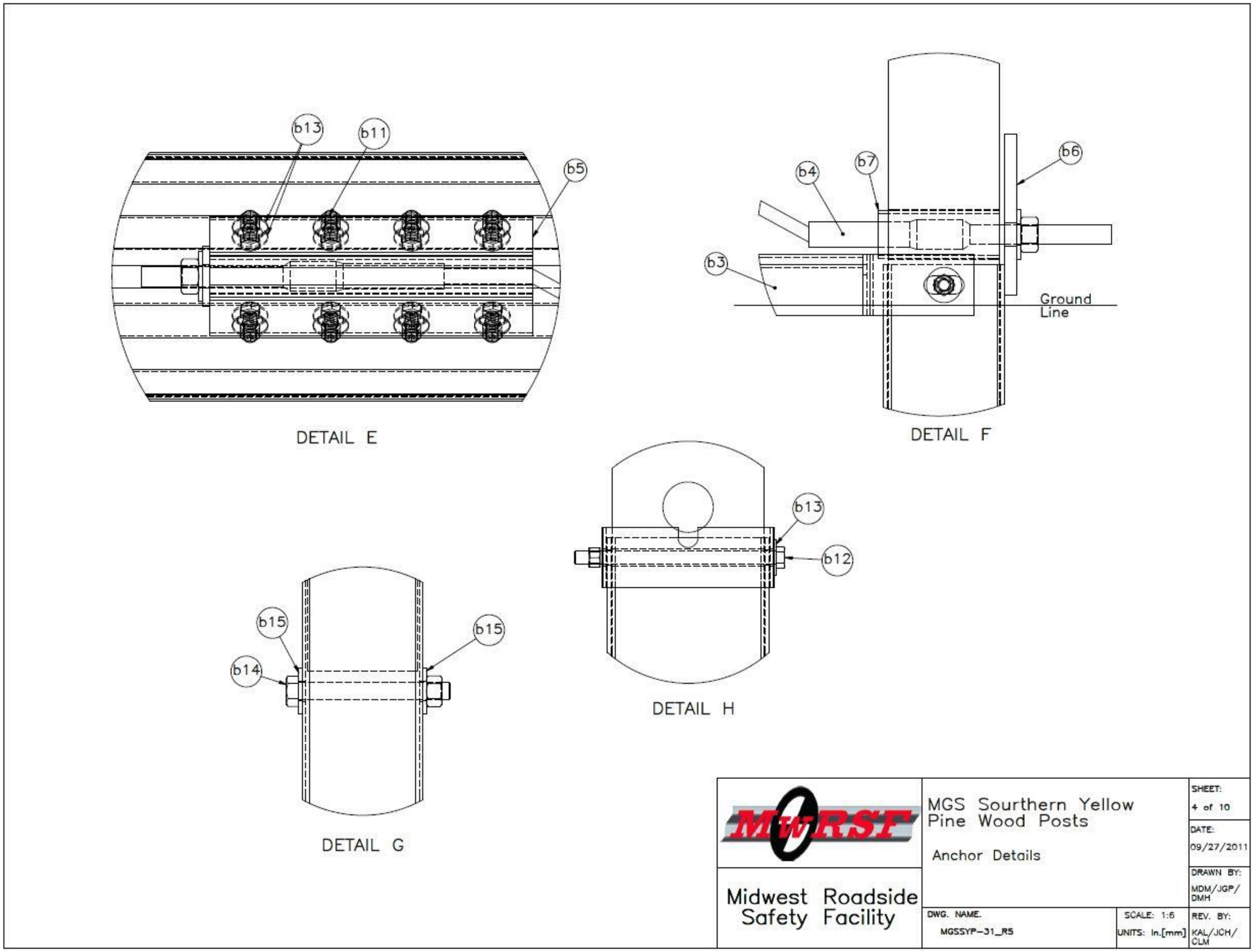


Figure 4. Anchorage Component Details, Test No. MGSSYP-1

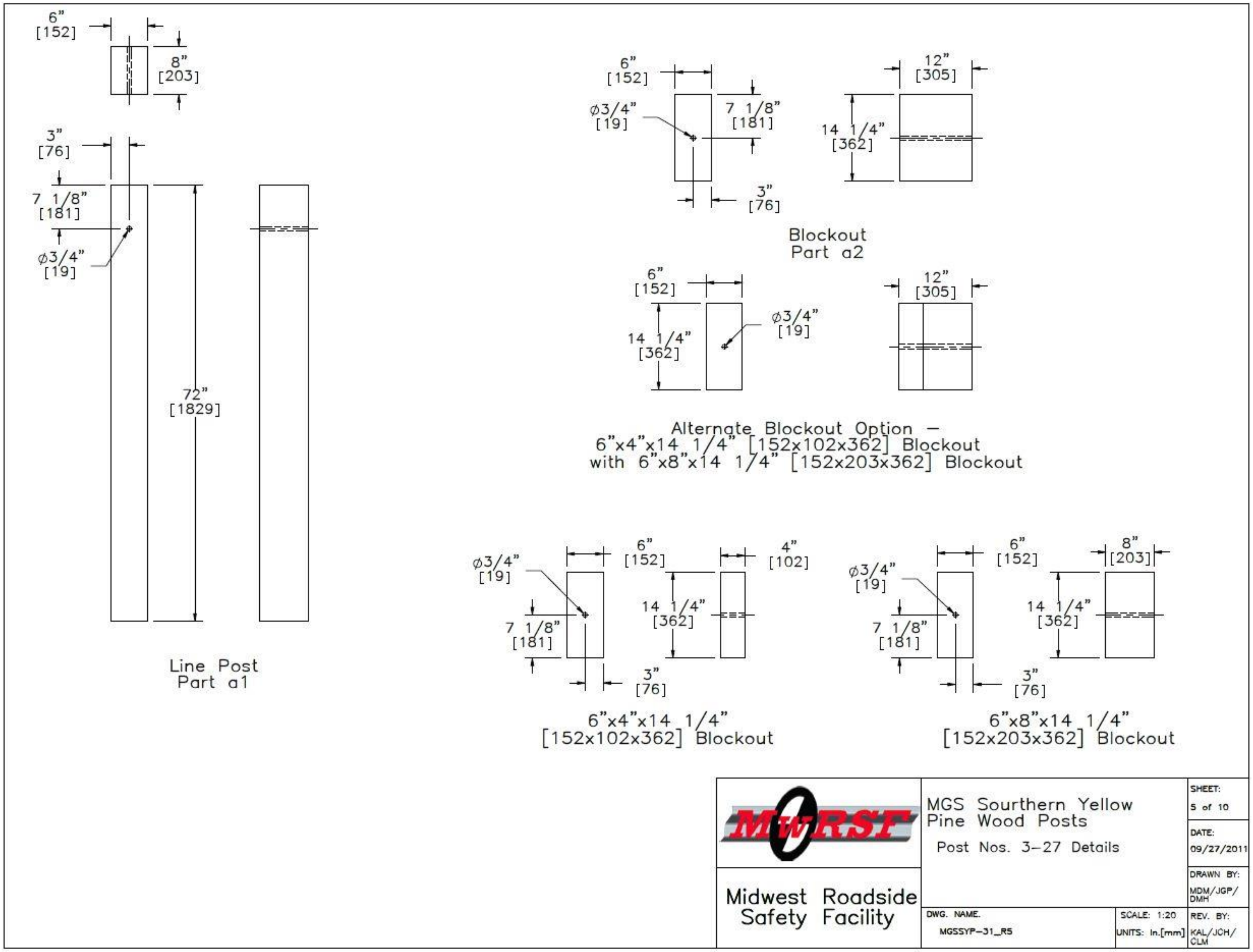


Figure 5. Post nos. 3 through 27 and Blockout Details, Test No. MGSSYP-1

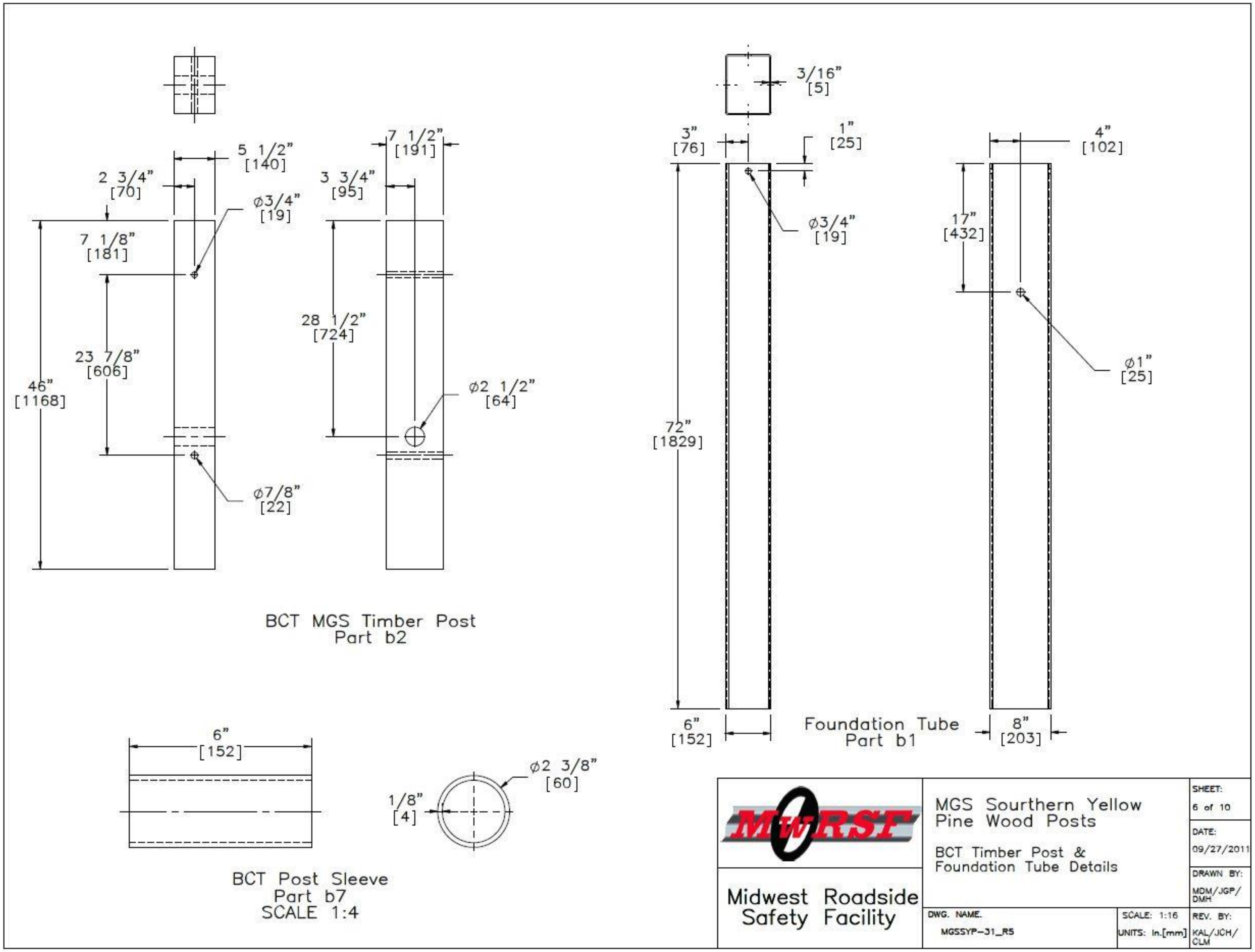


Figure 6. BCT Timber Post and Foundation Tube Details, Test No. MGSSYP-1

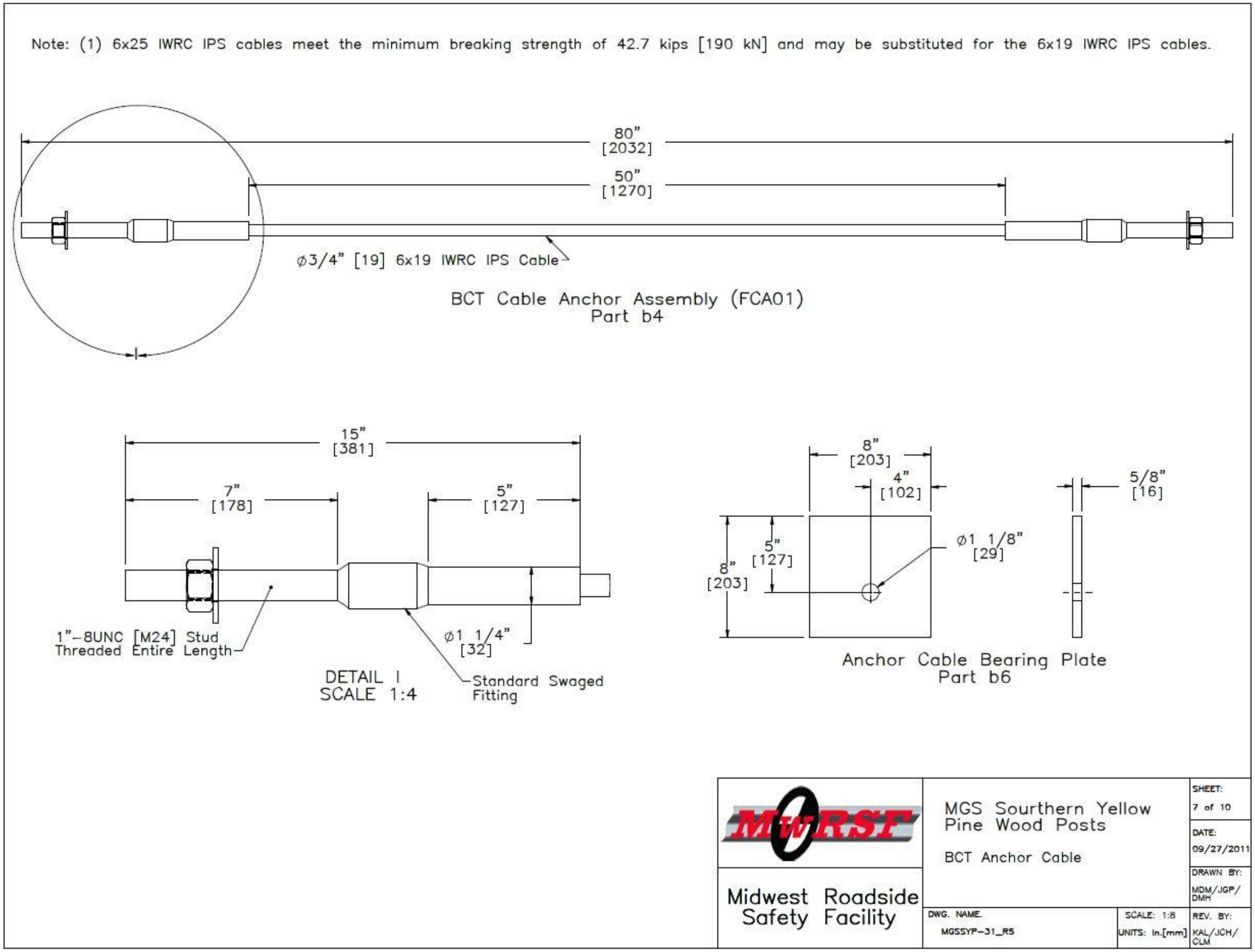


Figure 7. BCT Anchor Cable Details, Test No. MGSSYP-1

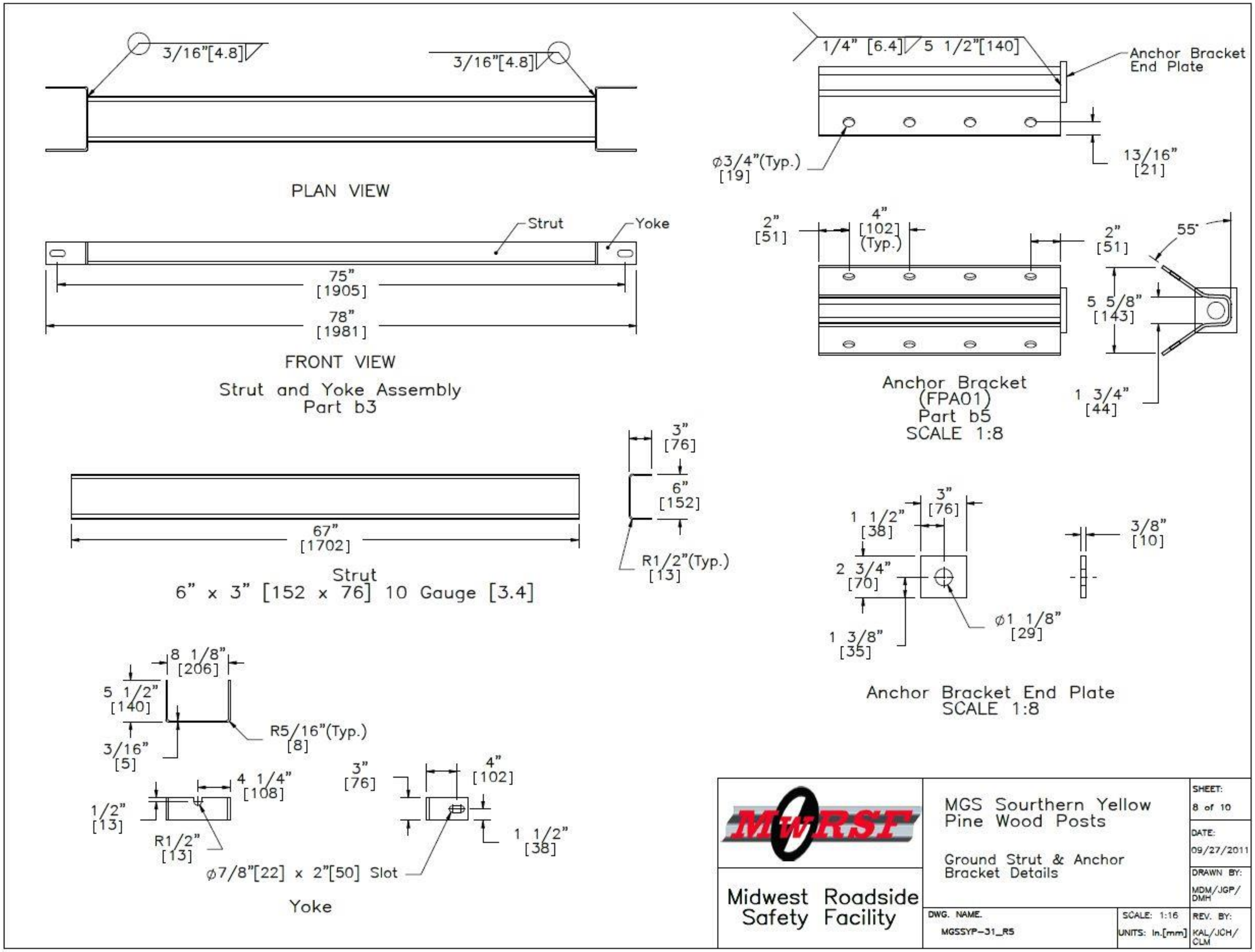


Figure 8. Ground Strut and Anchor Bracket Details, Test No. MGSSYP-1

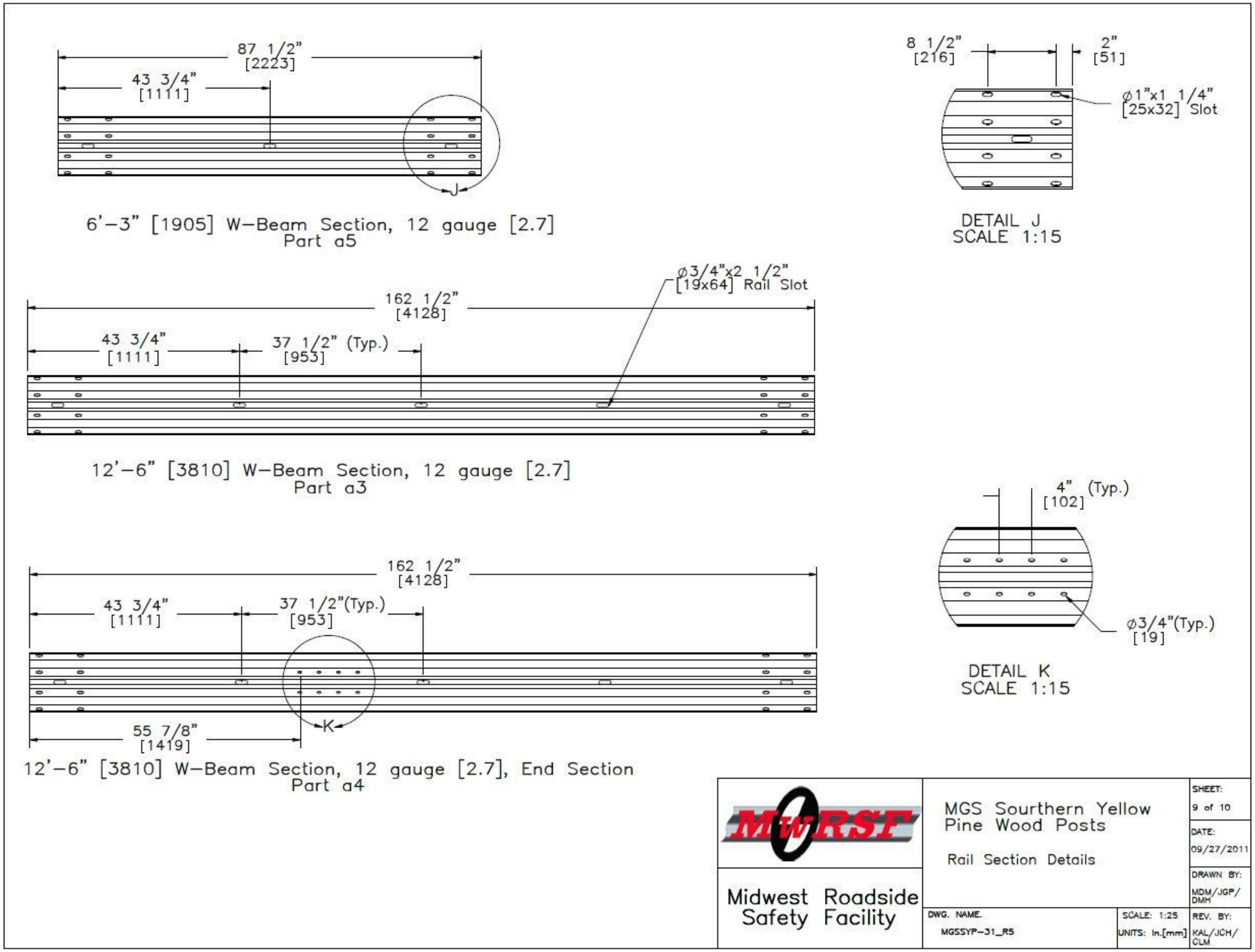


Figure 9. Rail Section Details, Test No. MGSSYP-1

Item No.	QTY.	Description	Material Specification	Hardware Guide
a1	25	6"x8"x72" [152x203x1829] Southern Yellow Pine Wood Post	SYP Grade No.1 or better	PDE02
a2	25	6"x12"x14 1/4" [152x305x362] MGS Timber Blockout	SYP Grade No.1 or better	PDB11a
a3	12	12'–6" [3810] 4–Space W–Beam Guardrail	12 gauge [2.7] AASHTO M180	RWM04a
a4	2	12'–6" [3810] BCT Terminal Rail Section	12 gauge [2.7] AASHTO M180	–
a5	1	6'–3" [1905] W–Beam Spacer Guardrail	12 gauge [2.7] AASHTO M180	RWM01a
a6	25	16D Double Head Nail	–	–
b1	4	72" [1829] Long Foundation Tube	ASTM A500 Gr. B	PTE06
b2	4	BCT Timber Post–MGS Height	SYP Grade No.1 or better	PDF01
b3	2	Strut and Yoke Assembly	ASTM A36 Steel Galvanized	–
b4	2	BCT Cable Anchor Assembly	ϕ3/4" 6x19 IWRC IPS Galvanized Wire Rope	FCA01–02
b5	2	Guardrail Anchor Bracket	ASTM A36 Steel	FPA01
b6	2	8"x8"x5/8" [203x203x16] BCT Bearing Plate	ASTM A36 Steel	FPB01
b7	2	2 3/8" [60] O.D.x 6" [152] Long BCT Post Sleeve	ASTM A53 Grade B Schedule 40	FMM02
b8	112	5/8" Dia. x 1 1/4" [M16x32] Long Guardrail Bolt and Double Recessed Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 A	FBB01
b9	4	5/8" Dia. x 10" [M16x254] Long Guardrail Bolt and Double Recessed Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 A	FBB03
b10	25	5/8" Dia. x 22" [M16x559] Long Guardrail Bolt and Double Recessed Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 A	FBB07
b11	16	5/8" Dia. x 1 1/2" [M16x38] Long Hex Bolt and Double Recessed Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 A	FBX16a
b12	4	5/8" Dia. x 9 1/2" [M16x241] Long Hex Bolt and Double Recessed Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 A	FBX16a
b13	69	5/8" [16] Dia. Plain Round Washer	ASTM F844 or Grade 2 Steel	FWC16a
b14	4	7/8" Dia. x 7 1/2" [M22x191] Long Hex Bolt and Double Recessed Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 A	FBX22a
b15	8	7/8" [22] Dia. Plain Round Washer	ASTM F844 or Grade 2 Steel	FWC22a

Midwest Roadside Safety Facility

MGS Sourthern Yellow Pine Wood Posts

Bill of Materials

SHEET: 10 of 10
DATE: 09/27/2011
DRAWN BY: MDM/JGP/DMH
DWG. NAME. MGSSYP–31_R5
SCALE: None
UNITS: in.[mm]
REV. BY: KAL/JCH/CLM

Figure 10. Bill of Materials, Test No. MGSSYP-1

Figure 11. Test Installation Photographs, Test No. MGSSYP-1

Figure 12. Test Installation Photographs, Test No. MGSSYP-1

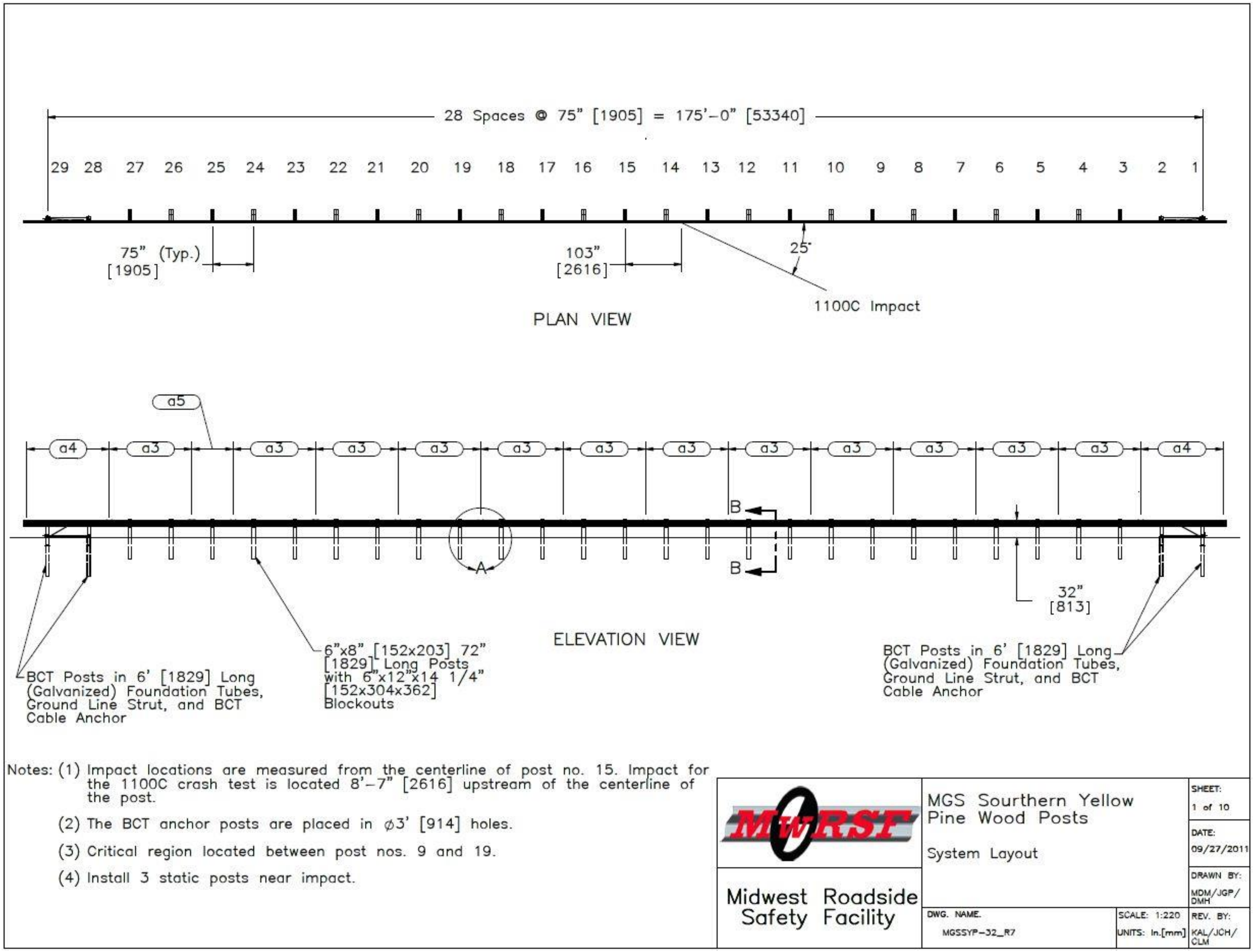


Figure 13. Test Installation Layout, Test No. MGSSYP-2

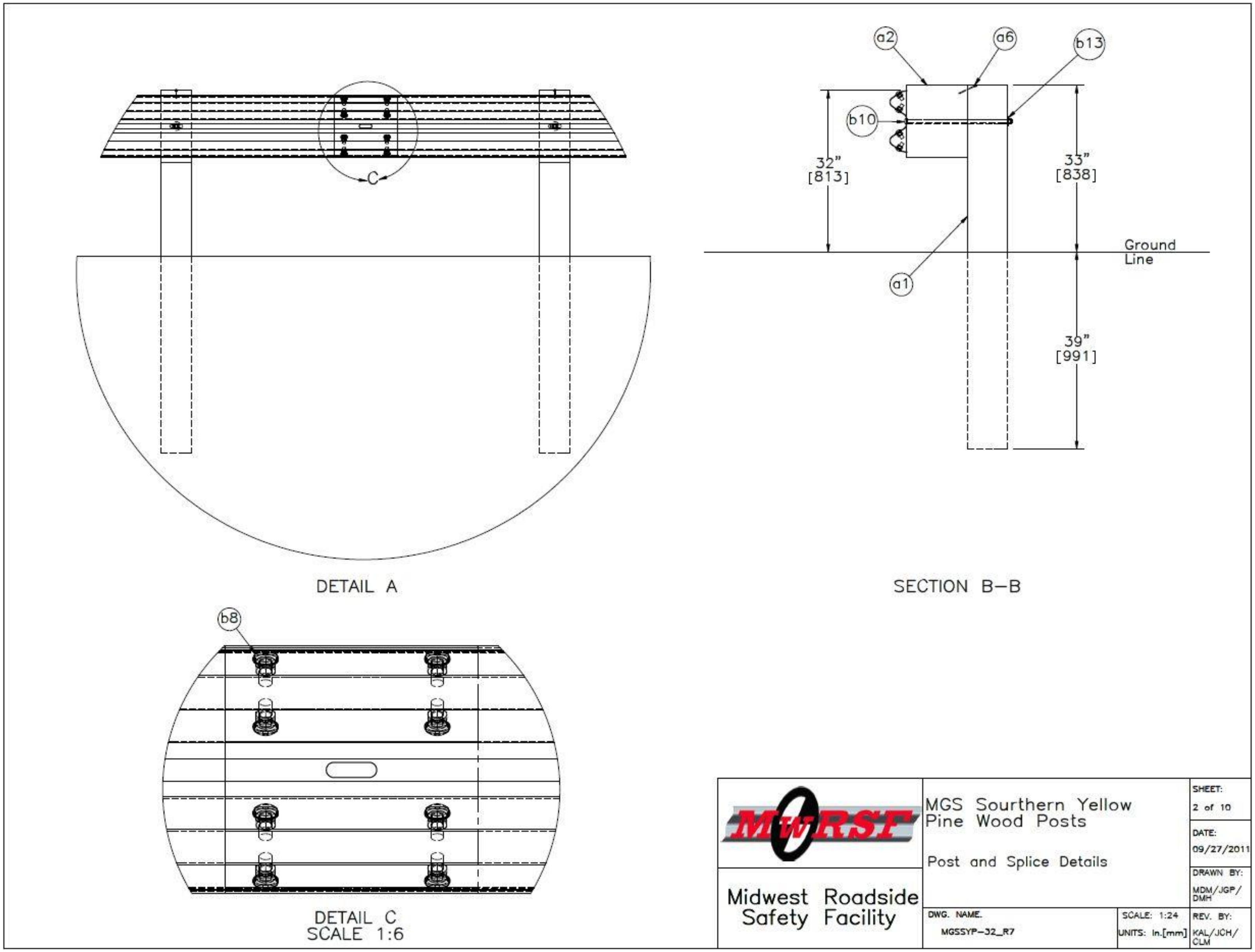


Figure 14. Post and Splice Details, Test No. MGSSYP-2

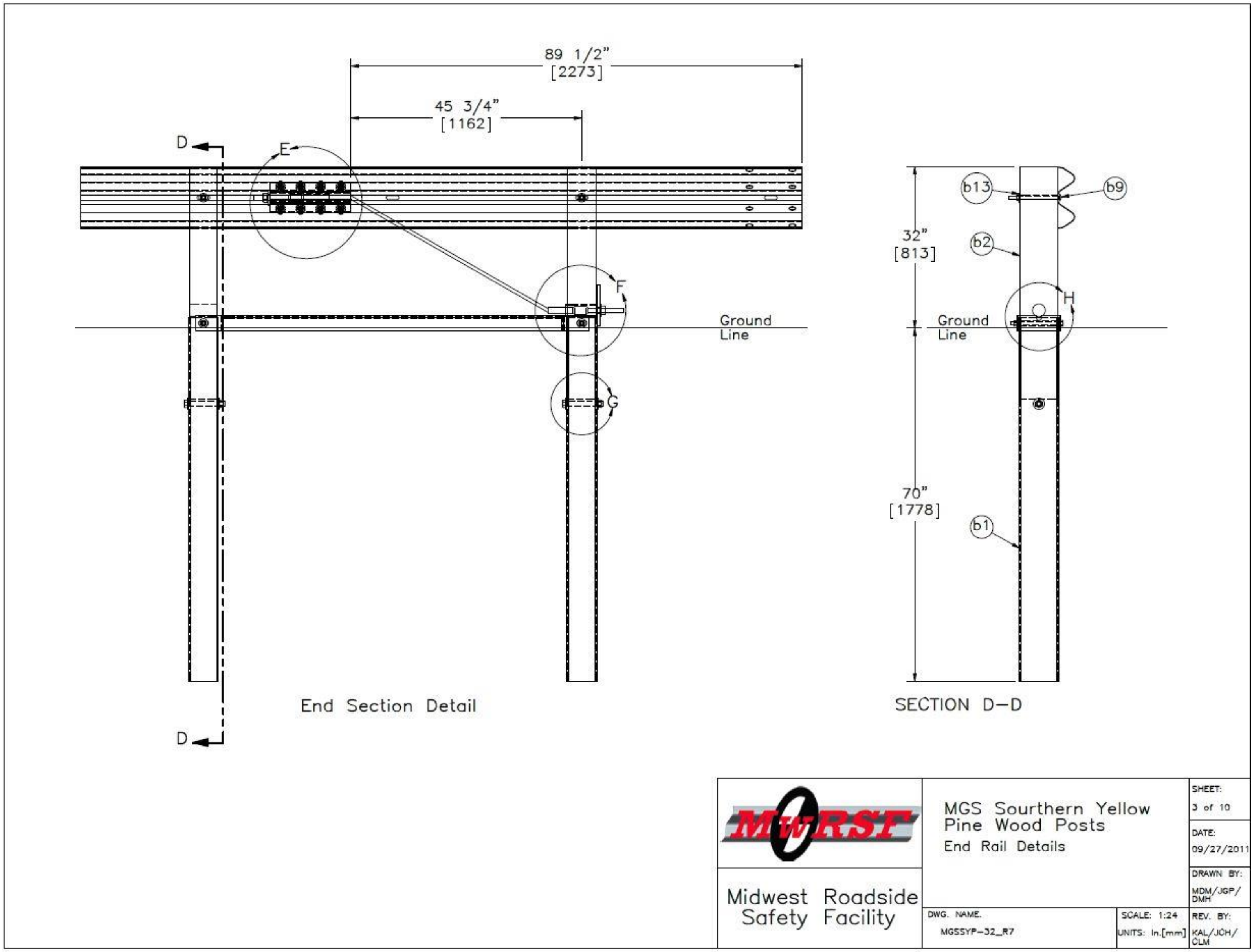


Figure 15. Anchorage Layout, Test No. MGSSYP-2

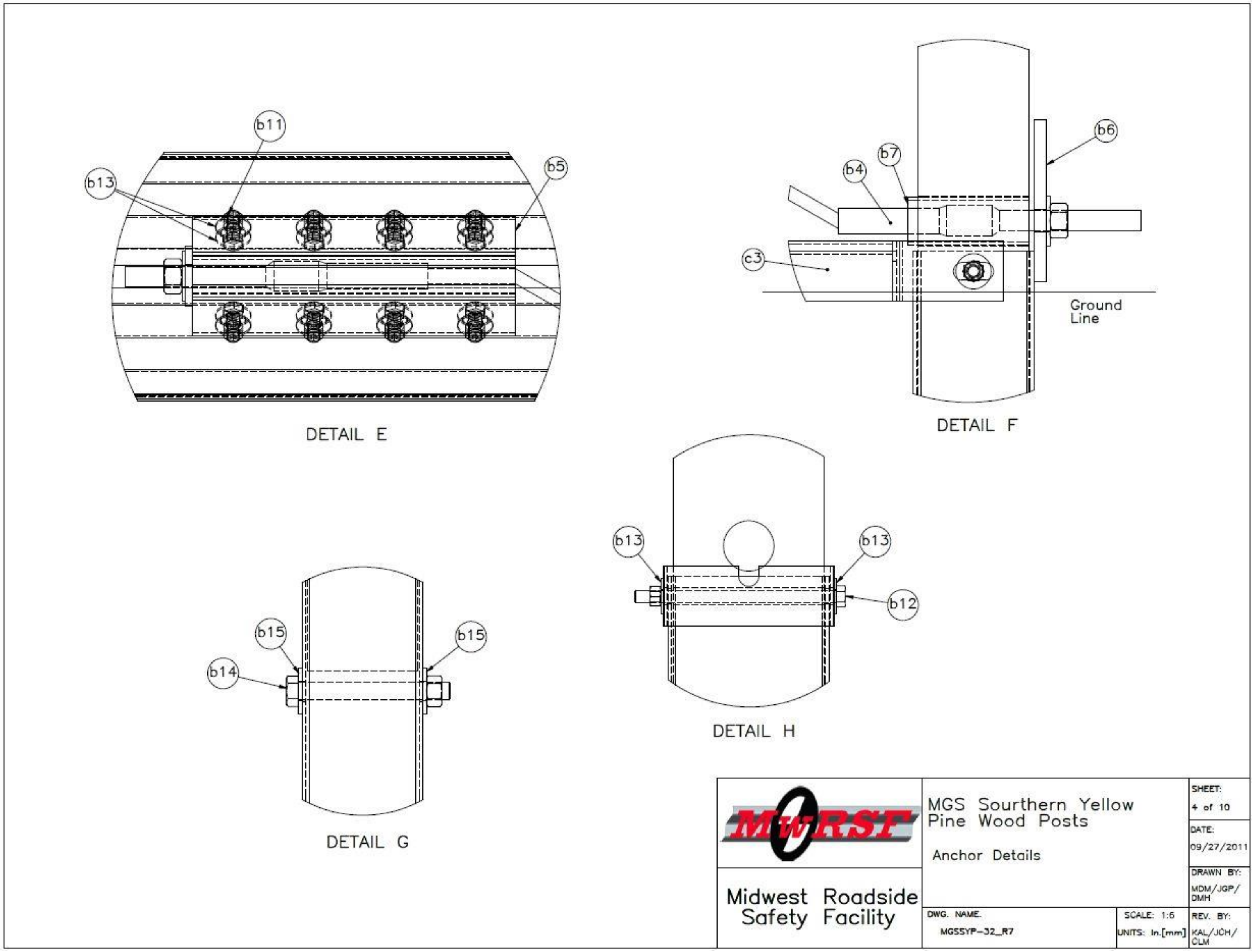


Figure 16. Anchorage Component Details, Test No. MGSSYP-2

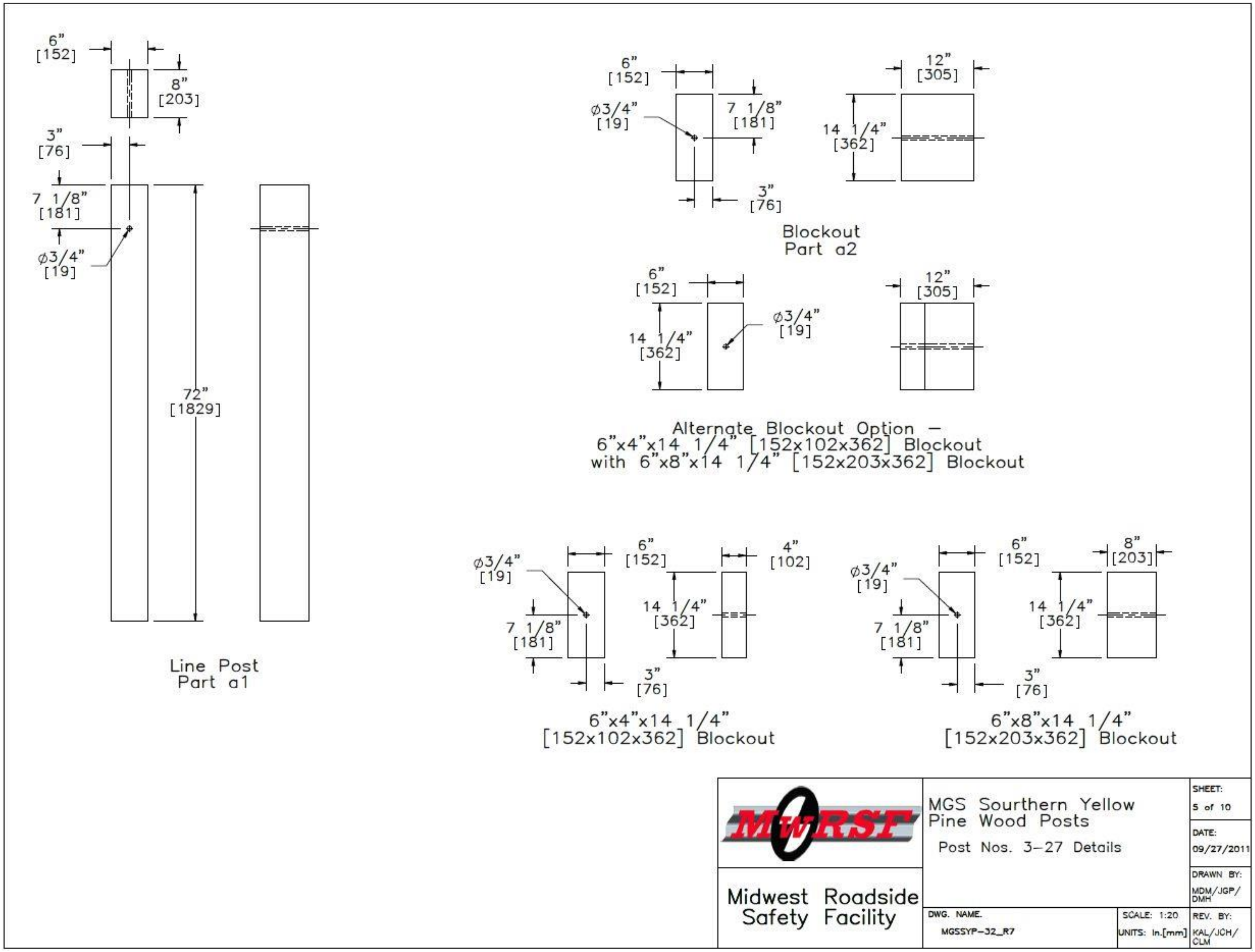


Figure 17. Post nos. 3 through 27 and Blockout Details, Test No. MGSSYP-2

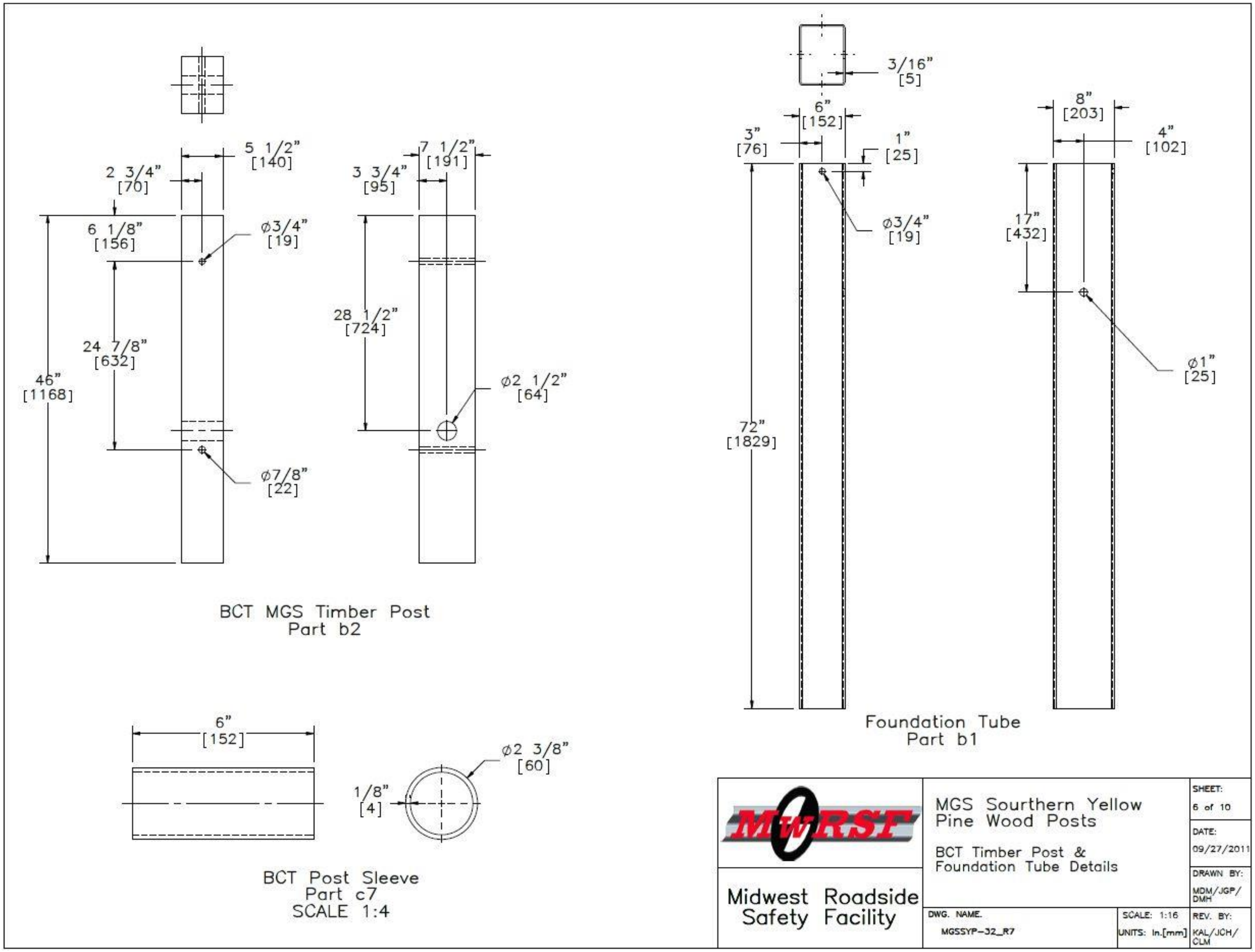


Figure 18. BCT Timber Post and Foundation Tube Details, Test No. MGSSYP-2

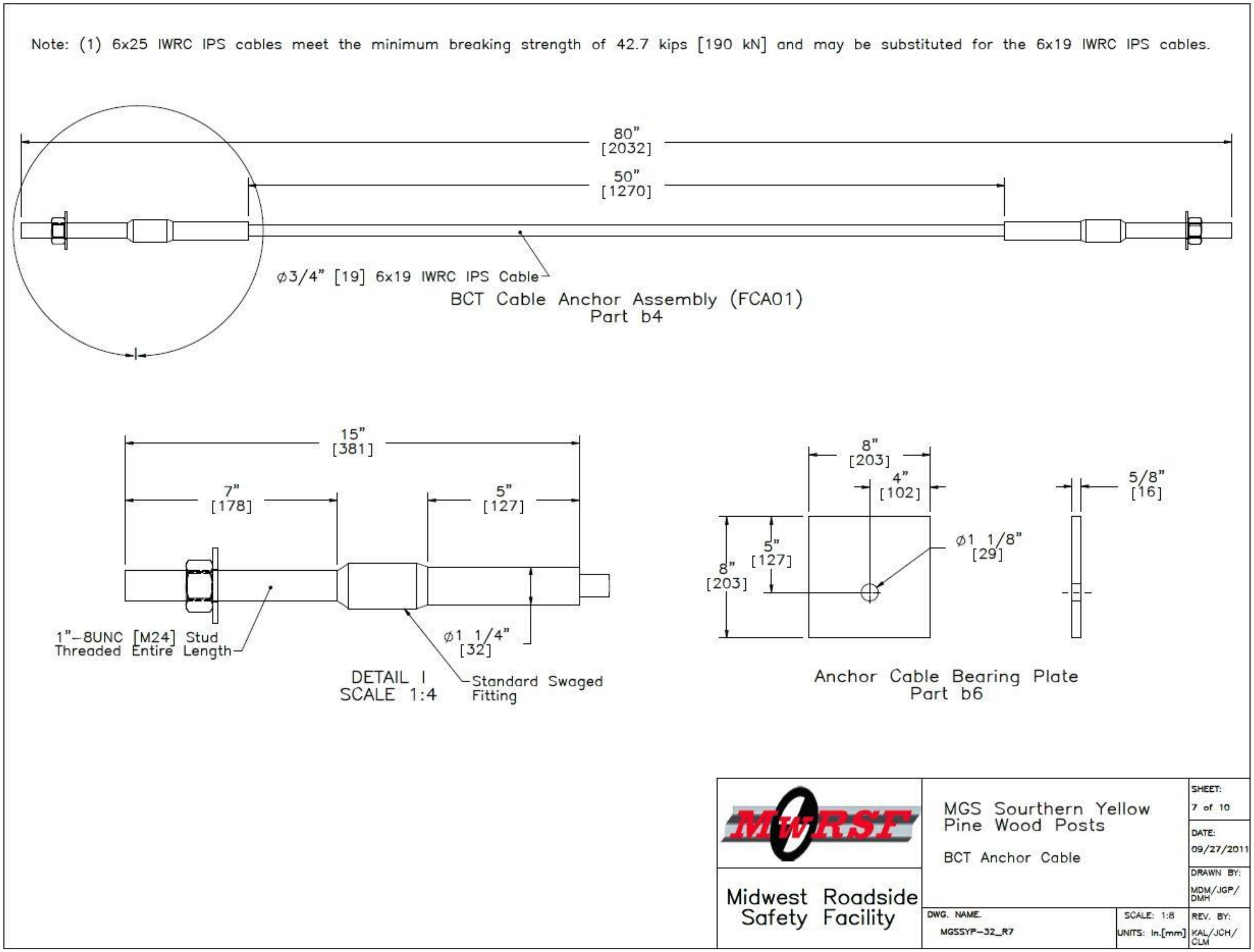


Figure 19. BCT Anchor Cable Details, Test No. MGSSYP-2

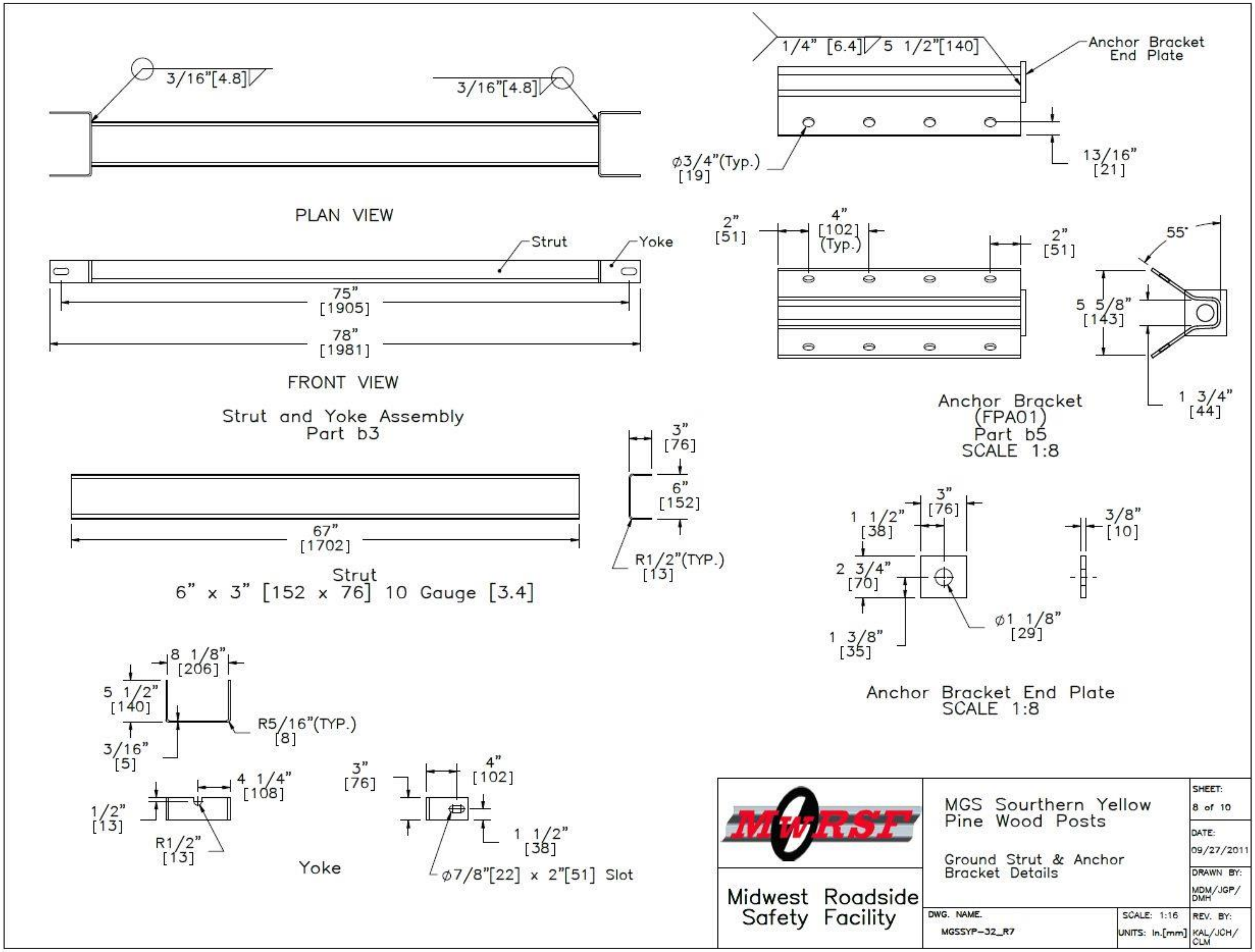


Figure 20. Ground Strut and Anchor Bracket Details, Test No. MGSSYP-2

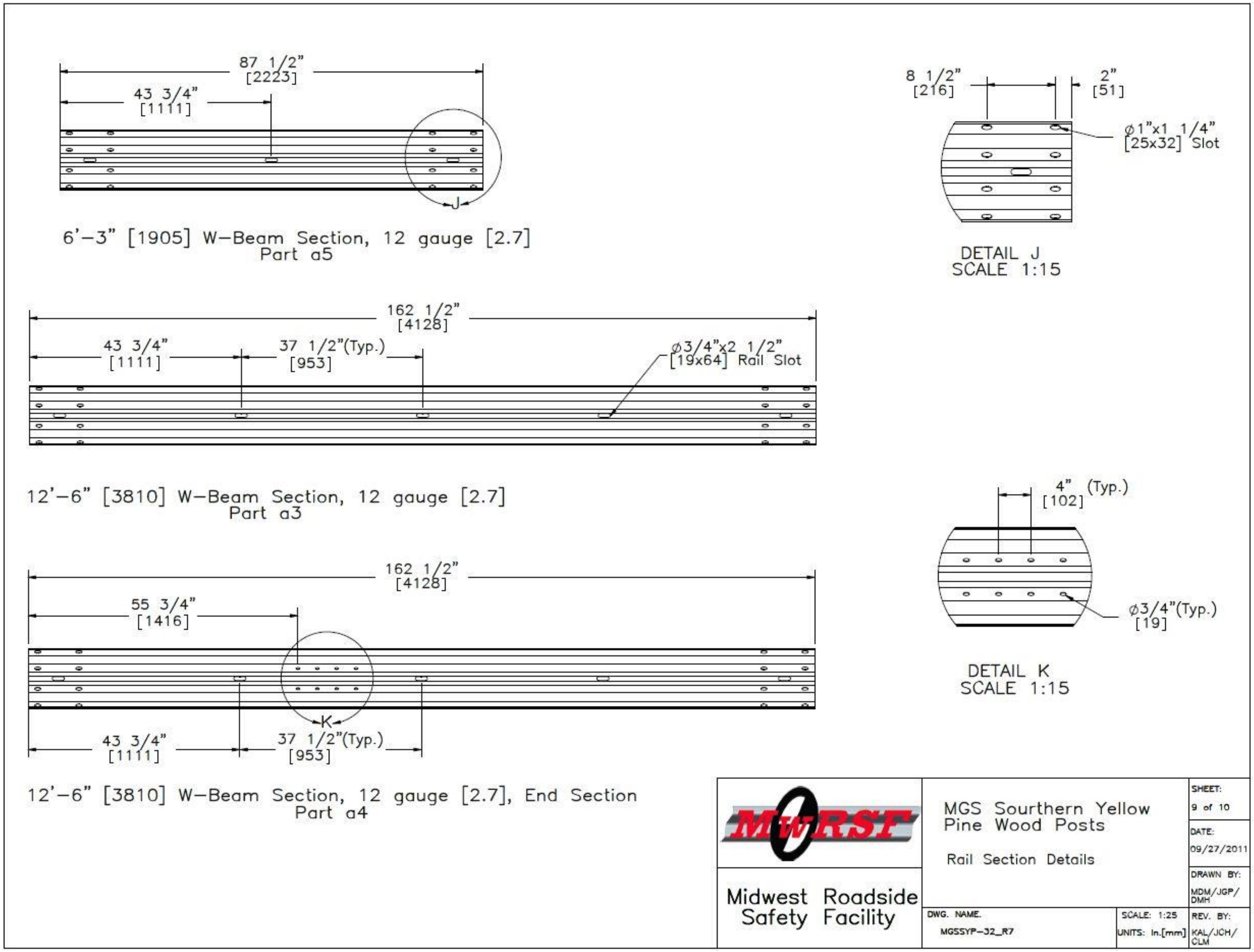


Figure 21. Rail Section Details, Test No. MGSSYP-2

Item No.	QTY.	Description	Material Specification	Hardware Guide
a1	25	6"x8"x72" [152x203x1829] Southern Yellow Pine Wood Post	SYP Grade No.1 or better	PDE02
a2	25	6"x12"x14 1/4" [152x305x362] MGS Timber Blockout	SYP Grade No.1 or better	PDB11a
a3	12	12'–6" [3810] 4–Space W–Beam Guardrail	12 gauge [2.7] AASHTO M180	RWM04a
a4	2	12'–6" [3810] BCT Terminal Rail Section	12 gauge [2.7] AASHTO M180	–
a5	1	6'–3" [1905] W–Beam Spacer Guardrail	12 gauge [2.7] AASHTO M180	RWM01a
a6	25	16D Double Head Nail	–	–
b1	4	72" [1829] Long Foundation Tube	ASTM A500 Gr. B	PTE06
b2	4	BCT Timber Post–MGS Height	SYP Grade No.1 or better	PDF01
b3	2	Strut and Yoke Assembly	ASTM A36 Steel Galvanized	–
b4	2	BCT Cable Anchor Assembly	ϕ3/4" 6x19 IWRC IPS Galvanized Wire Rope	FCA01–02
b5	2	Guardrail Anchor Bracket	ASTM A36 Steel	FPA01
b6	2	8"x8"x5/8" [203x203x16] BCT Bearing Plate	ASTM A36 Steel	FPB01
b7	2	2 3/8" [60] O.D.x 6" [152] Long BCT Post Sleeve	ASTM A53 Grade B Schedule 40	FMM02
b8	112	5/8" Dia. x 1 1/4" [M16x32] Long Guardrail Bolt and Double Recessed Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 A	FBB01
b9	4	5/8" Dia. x 10" [M16x254] Long Guardrail Bolt and Double Recessed Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 A	FBB03
b10	25	5/8" Dia. x 22" [M16x559] Long Guardrail Bolt and Double Recessed Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 A	FBB07
b11	16	5/8" Dia. x 1 1/2" [M16x38] Long Hex Bolt and Double Recessed Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 A	FBX16a
b12	4	5/8" Dia. x 9 1/2" [M16x241] Long Hex Bolt and Double Recessed Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 A	FBX16a
b13	69	5/8" [16] Dia. Plain Round Washer	ASTM F844 or Grade 2 Steel	FWC16a
b14	4	7/8" Dia. x 7 1/2" [M22x191] Long Hex Bolt and Double Recessed Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 A	FBX22a
b15	8	7/8" [22] Dia. Plain Round Washer	ASTM F844 or Grade 2 Steel	FWC22a

Midwest Roadside Safety Facility

MGS Southern Yellow Pine Wood Posts

Bill of Materials

SHEET:	10 of 10
DATE:	09/27/2011
DRAWN BY:	MDM/JGP/DMH
REV. BY:	KAL/JCH/CLM
DWG. NAME.	MGSSYP–32_R7
SCALE:	None
UNITS:	in.[mm]

Figure 22. Bill of Materials, Test No. MGSSYP-2

Figure 23. Test Installation Photographs, Test No. MGSSYP-2

3 TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 Test Requirements

Longitudinal barriers, such as W-beam guardrails, must satisfy impact safety standards in order to be accepted by the Federal Highway Administration (FHWA) for use on the National Highway System (NHS). For new hardware, these safety standards consist of the guidelines and procedures published in MASH [2]. According to TL-3 of MASH, longitudinal barrier systems must be subjected to two full-scale vehicle crash tests. The two full-scale crash tests are noted below:

1. Test Designation No. 3-10 consists of a 2,425-lb (1,100-kg) passenger car impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 25 degrees, respectively.

2. Test Designation No. 3-11 consists of a 5,000-lb (2,268-kg) pickup truck impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 25 degrees, respectively.

The test conditions of TL-3 longitudinal barriers are summarized in Table 1.

Table 1. MASH TL-3 Crash Test Conditions

Test Article	Test Designation No.	Test Vehicle	Impact Conditions			Evaluation Criteria [1]
			Speed		Angle (deg)	
			mph	km/h		
Longitudinal Barrier	3-10	1100C	62	100	25	A,D,F,H,I
	3-11	2270P	62	100	25	A,D,F,H,I

[1] Evaluation criteria explained in Table 2.

3.2 Evaluation Criteria

Evaluation criteria for full-scale vehicle crash testing are based on three appraisal areas: (1) structural adequacy; (2) occupant risk; and (3) vehicle trajectory after collision. Criteria for structural adequacy are intended to evaluate the ability of the 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. The full-scale vehicle crash test was conducted and reported in accordance with the procedures provided in MASH.

In addition to the standard occupant risk measures, the Post-Impact Head Deceleration (PHD), the Theoretical Head Impact Velocity (THIV), and the Acceleration Severity Index (ASI) were determined and reported on the test summary sheet. Additional discussion on PHD, THIV and ASI is provided in MASH. Note that ASI values were calculated according to MASH as developed by TTI.

3.3 Soil Strength Requirements

In order to limit the variation of soil strength among testing agencies, foundation soil must satisfy the recommended performance characteristics set forth in Chapter 3 and Appendix B of MASH. Testing facilities must first subject the designated soil to a dynamic post test to demonstrate a minimum dynamic load of 7.5 kips (33.4 kN) at deflections between 5 and 20 in. (127 and 508 mm). If satisfactory results are observed, a static test is conducted using an identical test installation. The results from this static test become the baseline requirement for soil strength in future full-scale crash testing in which the designated soil is used. An additional post installed near the impact point is statically tested on the day of full-scale crash test in the same manner as used in the baseline static test. The full-scale crash test can be conducted only if the static test results show a soil resistance equal to or greater than 90 percent of the baseline static test at deflections of 5, 10, and 15 in. (127, 254, and 381 mm) or if a dynamic test shows a soil resistance of at least 7.5 kips (33.4 kN) at deflections between 5 and 20 in. (127 and 508 mm). Otherwise, the crash test must be postponed until the soil demonstrates adequate post-soil strength.

Table 2. MASH 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="12">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 5.3 and Appendix E of MASH.</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.3 of MASH for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s
(9.1 m/s)</td><td>40 ft/s
(12.2 m/s)</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.3 of MASH 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>

4 TEST CONDITIONS

4.1 Test Facility

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

4.2 Vehicle Tow and Guidance System

A reverse cable tow system with a 1:2 mechanical advantage was used to propel the test 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 [6] 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. (9.5-mm) diameter guide cable was tensioned to approximately 3,500 lb (15.6 kN) and supported both laterally and vertically every 100 ft (30.5 m) by hinged stanchions. The hinged stanchions stood upright while holding up the guide cable, but as the vehicle was towed down the line, the guide flag struck and knocked each stanchion to the ground.

4.3 Test Vehicles

For test no. MGSSYP-1, a 2004 Dodge Ram Quad Cab 1500 pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,130 lb (2,327 kg), 5,029 lb (2,281 kg), and 5,199 lb (2,358 kg), respectively. The test vehicle is shown in Figure 24, and vehicle dimensions are shown in Figure 25.

For test no. MGSSYP-2, a 2004 Kia Rio sedan was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,402 lb (1,090 kg), 2,442 lb (1,108 kg), 2,612

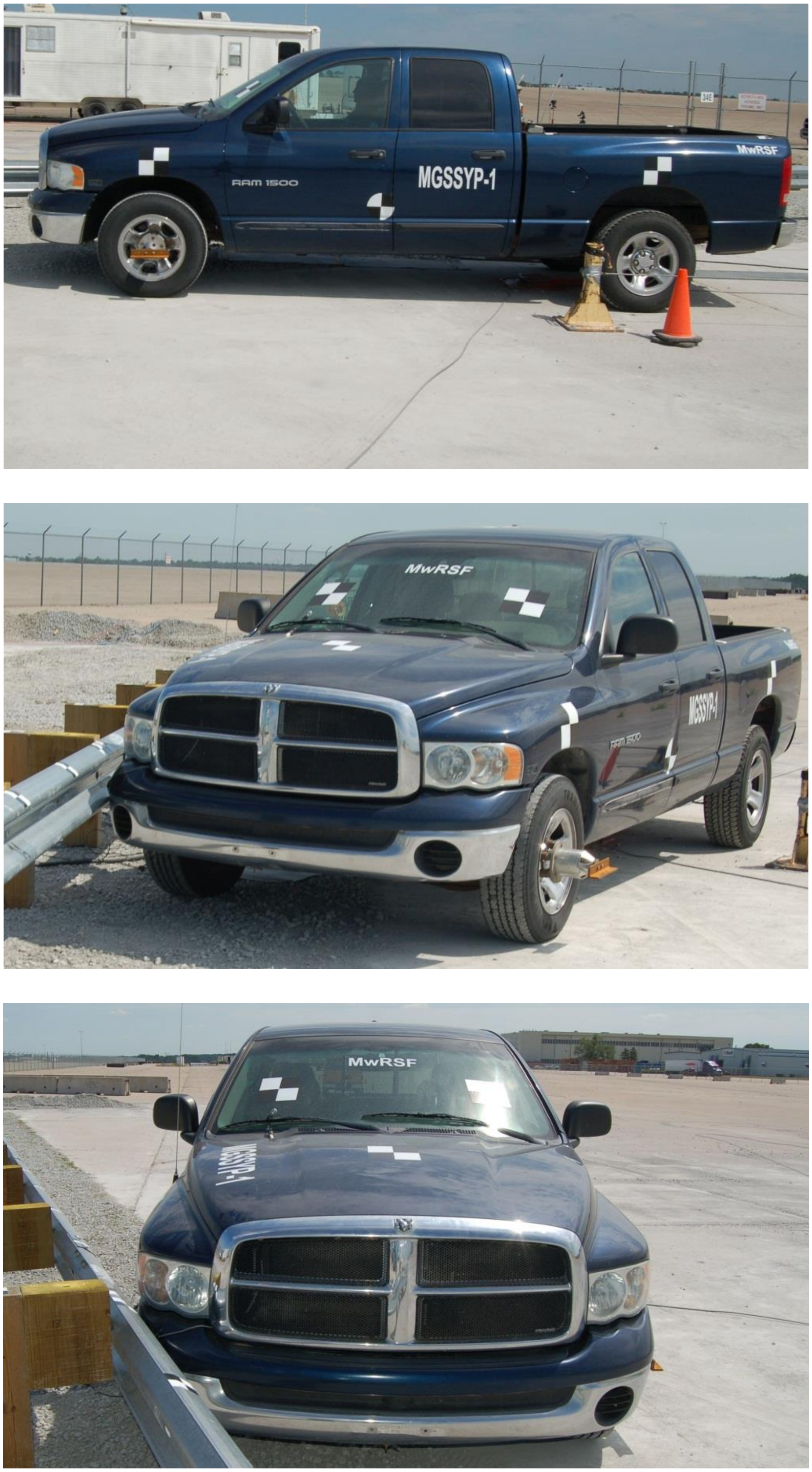


Figure 24. Test Vehicle, Test No. MGSSYP-1

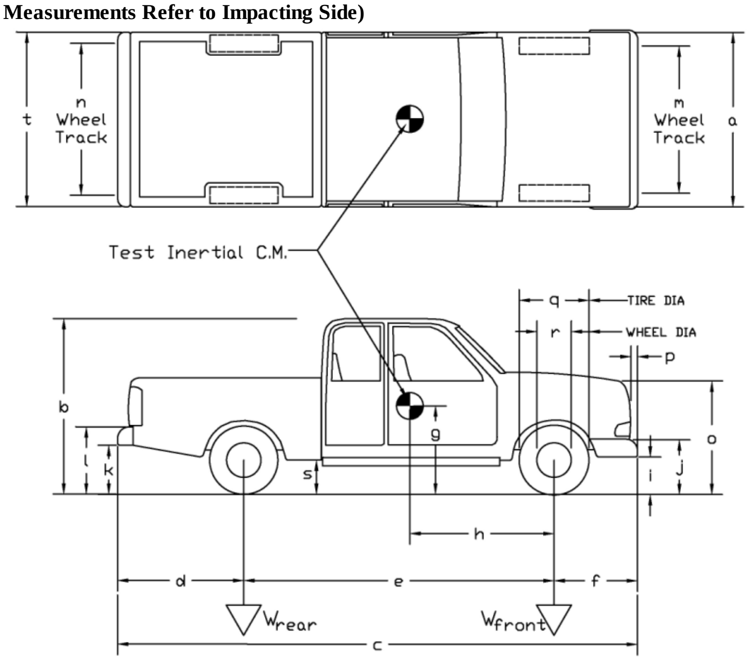
Date: 8/3/2011 **Test Number:** MGSSYP-1 **Model:** 2270P/Ram 1500

Make: Dodge **Vehicle I.D.#:** 1D7HA18DX4J254351

Tire Size: LT245/70 R17 **Year:** 2004 **Odometer:** 223763

Tire Inflation Pressure: 35 Psi

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



Vehicle Geometry -- in. (mm)

a	78 (1981)	b	74 (1880)
c	227 3/4 (5785)	d	47 (1194)
e	140 1/2 (3569)	f	40 1/4 (1022)
g	28 1/8 (716)	h	62 1/2 (1588)
i	14 (356)	j	26 (660)
k	20 (508)	l	28 1/2 (724)
m	67 7/8 (1724)	n	67 1/2 (1715)
o	44 (1118)	p	3 (76)
q	30 (762)	r	18 1/2 (470)
s	14 (356)	t	75 1/2 (1918)

Wheel Center Height Front	14 1/4 (362)
Wheel Center Height Rear	14 1/2 (368)
Wheel Well Clearance (F)	33 3/4 (857)
Wheel Well Clearance (R)	36 1/2 (927)
Frame Height (F)	16 1/4 (413)
Frame Height (R)	24 (610)
Engine Type	8Cyl. GAS
Engine Size	5.7L 345CI

Transmition Type: (Automatic) Manual

FWD (RWD) 4WD

Mass Distribution lb (kg)

Gross Static	LF	1437 (652)	RF	1466 (665)
	LR	1113 (505)	RR	1183 (537)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2856 (1295)	2798 (1269)	2903 (1317)
W-rear	2274 (1031)	2231 (1012)	2296 (1041)
W-total	5130 (2327)	5029 (2281)	5199 (2358)

GVWR Ratings

Front	3650
Rear	3900
Total	6650

Dummy Data

Type: Hybrid II

Mass: 170 lbs

Seat Position: Passenger

Note any damage prior to test: None

Figure 25. Vehicle Dimensions, Test No. MGSSYP-1

lb (1,185 kg) respectively. The test vehicle is shown in Figure 26, and the vehicle dimensions are shown in Figure 27.

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [7] was used to determine the vertical component of the c.g. for the pickup truck. This method is based on the principle that the c.g. of any freely suspended body is in the vertical plane through the point of suspension. The vehicle was suspended successively in three positions, and the respective planes containing the c.g. were established. The intersection of these planes pinpointed the final c.g. location for the test inertial condition. The vertical component of the c.g. for the 1100C vehicle was based on historical c.g. height measurements. The location of the final c.g. is shown in Figures 25 through 29. Data used to calculate the location of the c.g. and ballast information are shown in Appendix B.

Square, black- and white-checkered targets were placed on the vehicles for reference to be viewed from the high-speed digital video cameras and aid in the video analysis, as shown in Figures 28 and 29. Round, checkered targets were placed on the center of gravity on the left-side door, the right-side door, and the roof of the vehicle.

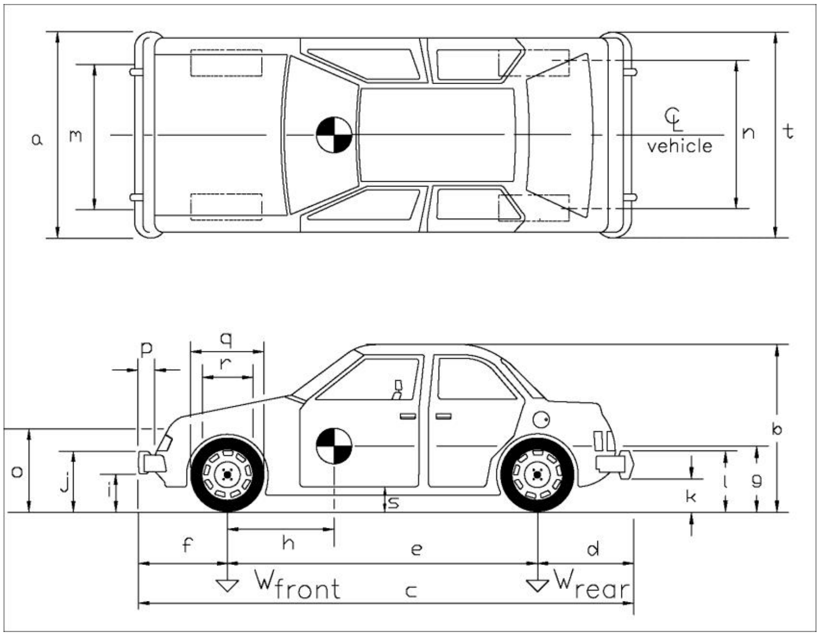
The front wheels of the test vehicles were aligned to vehicle standards except the toe-in value was adjusted to zero so that the vehicles would track properly along the guide cable. A 5B flash bulb was mounted on the right side of the vehicle’s dash for both tests and was fired by a pressure tape switch mounted at the impact corner of the bumper. The flash bulb was fired upon initial impact with the test article to create a visual indicator of the precise time of impact on the high-speed videos. A remote controlled brake system was installed in the test vehicles so the vehicles could be brought safely to a stop after the test.

Figure 26. Test Vehicle, Test No. MGSSYP-2

Date:	9/13/2011	**Test Number:**	MGSSYP-2	**Model:**	1100C
Make:	Kia	**Vehicle I.D.#:**	KNADC125046350879		
Tire Size:	175/65 R14	**Year:**	2004	**Odometer:**	85056

Tire Inflation Pressure: 30psi

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



Vehicle Geometry -- in. (mm)

a	65 1/4	(1657)	b	55	(1397)
c	167	(4242)	d	38 1/2	(978)
e	95 3/4	(2432)	f	32 3/4	(832)
g	17	(432)	h	37	(942)
i	8 1/2	(216)	j	21	(533)
k	11 1/2	(292)	l	22	(559)
m	56 1/8	(1426)	n	56 3/4	(1441)
o	27 3/8	(695)	p	3	(76)
q	22 1/2	(572)	r	15 1/4	(387)
s	11	(279)	t	60 1/4	(1530)

Wheel Center Height Front	10 3/4	(273)
Wheel Center Height Rear	10 7/8	(276)
Wheel Well Clearance (F)	23 7/8	(606)
Wheel Well Clearance (R)	24	(610)
Frame Height (F)	6 3/4	(171)
Frame Height (R)	16 1/2	(419)
Engine Type	4cyl gas	
Engine Size	1.4L	

Transmition Type:

Automatic (circled) Manual

FWD (circled) RWD 4WD

Mass Distribution lb (kg)

Gross Static	**LF**	783 (355)	**RF**	797 (362)
	LR	482 (219)	**RR**	550 (249)

Weights lb (kg)	**Curb**	**Test Inertial**	**Gross Static**
W-front	1517 (688)	1496 (679)	1580 (717)
W-rear	885 (401)	946 (429)	1032 (468)
W-total	2402 (1090)	2442 (1108)	2612 (1185)

GVWR Ratings

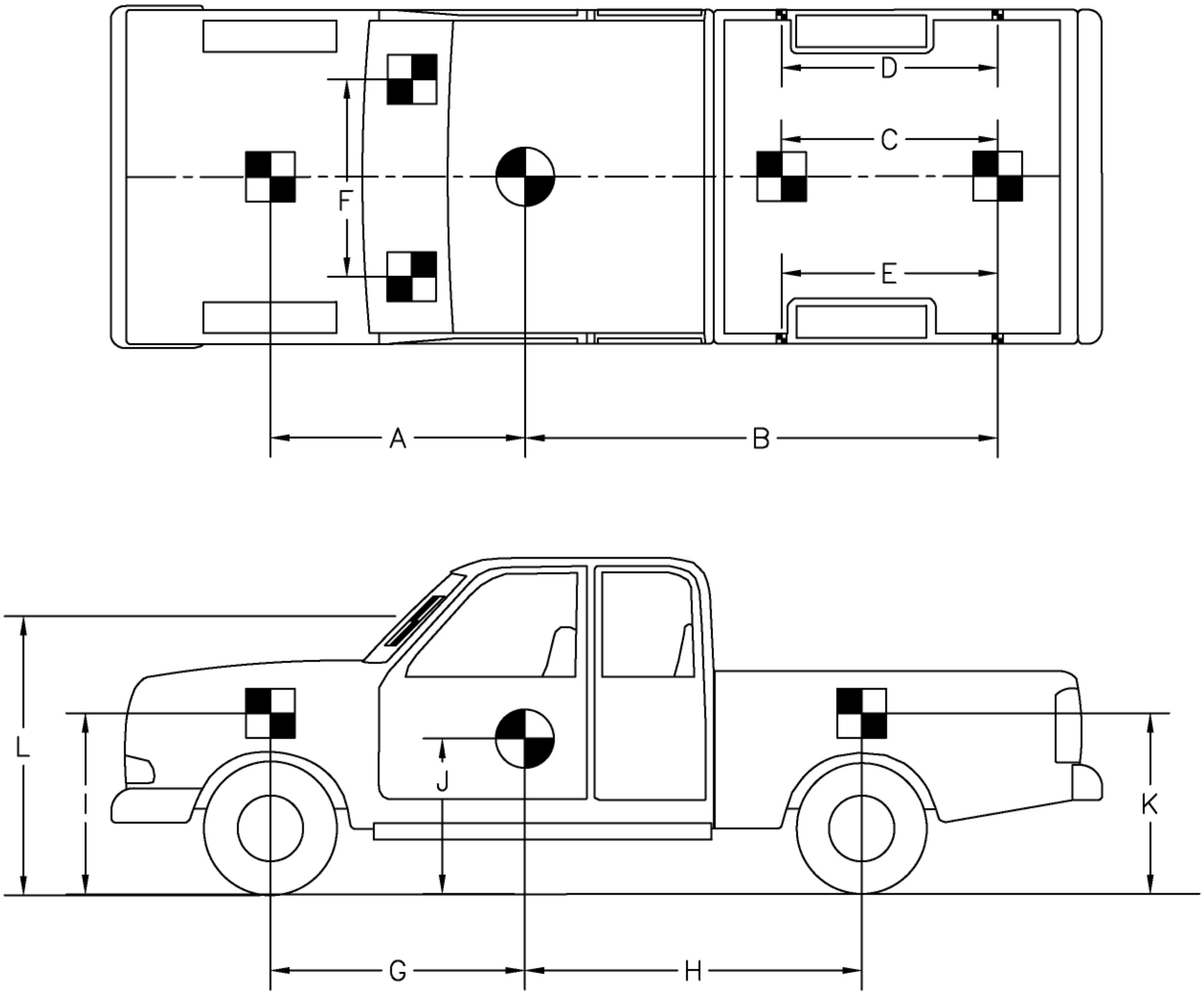
Front	1808
Rear	1742
Total	3399

Dummy Data

Type: Hybrid 1
Mass: 170 lbs.
Seat Position: Passenger

Note any damage prior to test: Minor Hail Damage

Figure 27. Vehicle Dimensions, Test No. MGSSYP-2

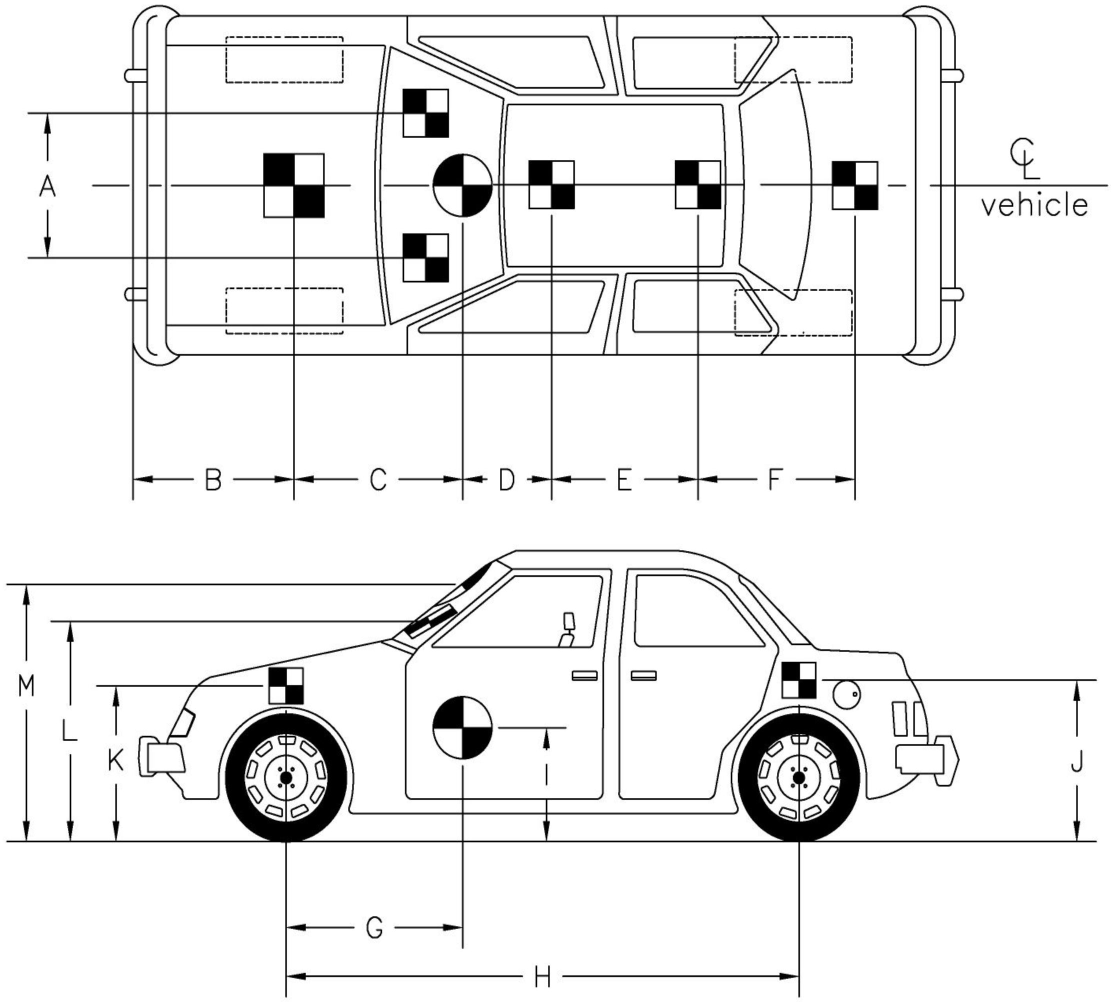


TEST #: MGSSYP-1

TARGET GEOMETRY-- in. (mm)

A	**72**	**(1829)**	**E**	**64**	**(1626)**	**I**	**38**	**(965)**
B	**104 1/2**	**(2654)**	**F**	**41**	**(1041)**	**J**	**28 1/8**	**(716)**
C	**48**	**(1219)**	**G**	**62 1/2**	**(1588)**	**K**	**41**	**(1041)**
D	**64**	**(1626)**	**H**	**78**	**(1981)**	**L**	**58 3/4**	**(1492)**

Figure 28. Target Geometry, Test No. MGSSYP-1



TEST #: MGSSYP-2

TARGET GEOMETRY-- in. (mm)

A	**31 1/2**	**(800)**	**E**	**42**	**(1067)**	**I**	**17**	**(432)**
B	**21 3/4**	**(552)**	**F**	**33 1/4**	**(845)**	**J**	**28 1/4**	**(718)**
C	**48**	**(1219)**	**G**	**37 1/9**	**(942)**	**K**	**28**	**(711)**
D	**9 1/8**	**(232)**	**H**	**95 3/4**	**(2432)**	**L**	**43**	**(1092)**
						M	**52**	**(1321)**

Figure 29. Target Geometry, Test No. MGSSYP-2

4.4 Simulated Occupant

For test nos. MGSSYP-1 and MGSSYP-2, a Hybrid II 50th-Percentile, Adult Male Dummy, equipped with clothing and footwear, was placed in the right-front seat of the test vehicle with the seat belt fastened. The dummy, which had a final weight of 170 lb (77 kg), was represented by model no. 572, serial no. 451, and was manufactured by Android Systems of Carson, California. As recommended by MASH, the dummy was not included in calculating the c.g. location.

4.5 Data Acquisition Systems

4.5.1 Accelerometers

Two environmental shock and vibration sensor/recorder systems were used to measure the accelerations in the longitudinal, lateral, and vertical directions. All of the accelerometers were mounted near the center of gravity 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 [8].

The first accelerometer system was a two-arm piezoresistive accelerometer system manufactured by Endevco of San Juan Capistrano, California. Three accelerometers were used to measure each of the longitudinal, lateral, and vertical accelerations independently at a sample rate of 10,000 Hz. Two additional accelerometers were used to measure longitudinal and lateral accelerations independently at the same rate. The accelerometers were configured and controlled using a system developed and manufactured by Diversified Technical Systems, Inc. (DTS) of Seal Beach, California. More specifically, data was collected using a DTS Sensor Input Module (SIM), Model TDAS3-SIM-16M. The SIM was configured with 16 MB SRAM and 8 sensor input channels with 250 kB SRAM/channel. The SIM was mounted on a TDAS3-R4 module rack. The module rack was configured with isolated power/event/communications, 10BaseT

Ethernet and RS232 communication, and an internal backup battery. Both the SIM and module rack were crashworthy. The "DTS TDAS Control" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

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

4.5.2 Rate Transducers

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

4.5.3 Pressure Tape Switches

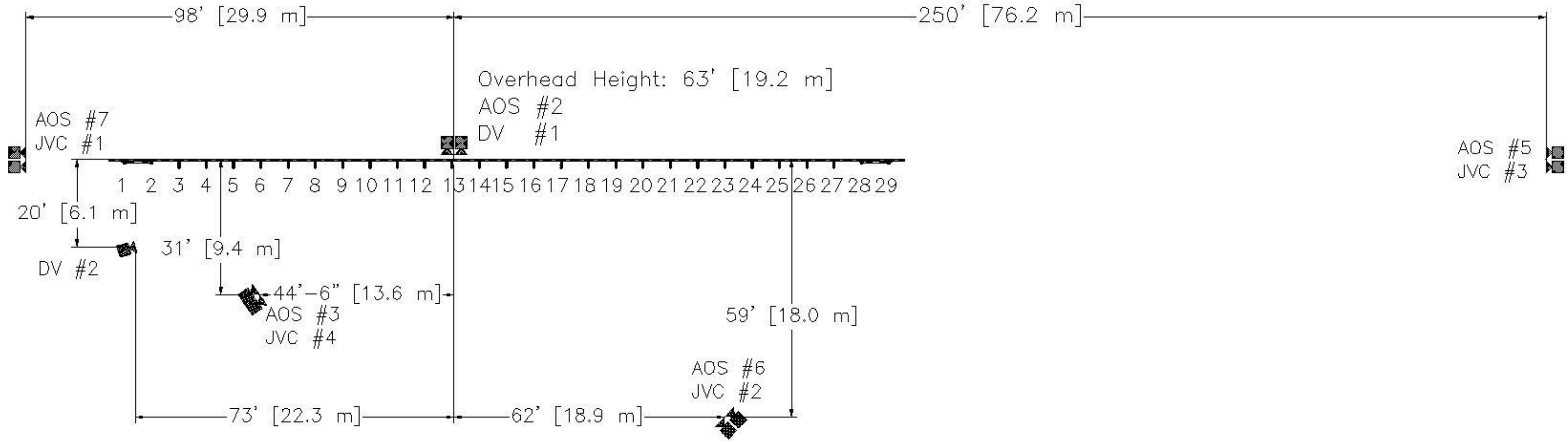
For test nos. MGSSYP-1 and MGSSYP-2, five pressure-activated tape switches, spaced at approximately 6.56-ft (2-m) intervals, were used to determine the speed of the vehicle before impact. Each tape switch fired a strobe light which sent an electronic timing signal to the data acquisition system as the right-front tire of the test vehicle passed over it. Test vehicle speeds were determined from electronic timing mark data recorded using TestPoint and LabVIEW computer software programs. Strobe lights and high-speed video analysis are used only as a backup in the event that vehicle speed cannot be determined from the electronic data.

4.5.4 Digital Photography

Two AOS VITcam high-speed digital video cameras, three AOS X-PRI high-speed digital video cameras, four JVC digital video cameras, and two Canon digital video cameras were utilized to film test no. MGSSYP-1. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 30.

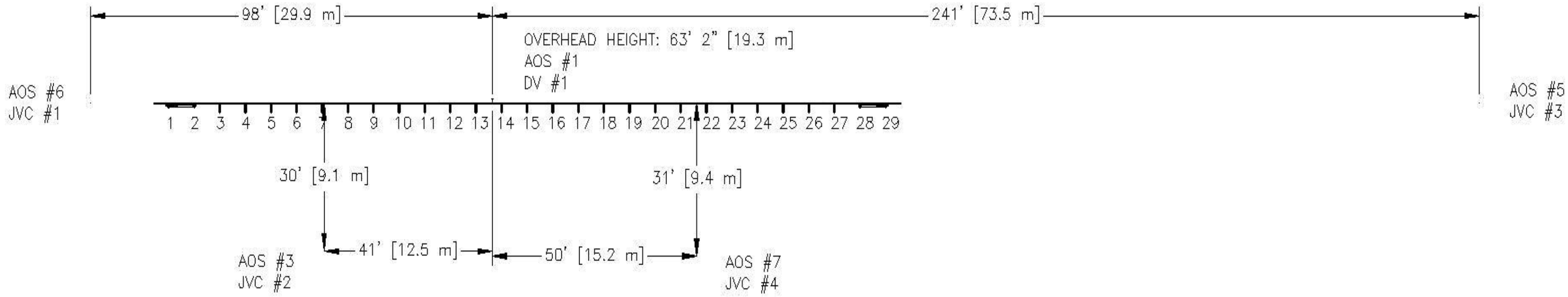
Three AOS VITcam high-speed digital video cameras, three AOS X-PRI high-speed digital video cameras, four JVC digital video cameras, and two Canon digital video cameras were utilized to film test no. MGSSYP-2. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 31.

The high-speed videos were analyzed using ImageExpress, MotionPlus, and RedLake MotionScope software programs. Actual camera speed and camera divergence factors were considered in the analysis of the high-speed videos. A Nikon D50 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
High-Speed Video	2	AOS Vitcam	500	8 mm fixed	-
	3	AOS Vitcam	500	Sigma 50 mm fixed	-
	5	AOS X-PRI	500	TV Zoom 17-102 mm	102
	6	AOS X-PRI	500	Fuji 50 mm fixed	-
	7	AOS X-PRI	500	Sigma 24-70 mm	50
Digital Video	1	JVC – GZ-MC500 (Everio)	29.97		
	2	JVC – GZ-MG27u (Everio)	29.97		
	3	JVC – GZ-MG27u (Everio)	29.97		
	4	JVC – GZ-MG27u (Everio)	29.97		
	1	Canon ZR90	29.97		
	2	Canon ZR10	29.97		

Figure 30. Camera Locations, Speeds, and Lens Settings, Test No. MGSSYP-1



	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	1	AOS Vitcam CTM	500	Cosmicar 12.5 mm fixed	-
	3	AOS Vitcam	500	Sigma 24-70 mm	35
	4	AOS Vitcam	500	-	-
	5	AOS X-PRI	500	Canon 17-102 mm	102
	6	AOS X-PRI	500	Fujinon 50 mm fixed	-
	7	AOS X-PRI	500	Sigma 50 mm fixed	-
Digital Video	1	JVC – GZ-MC500 (Everio)	29.97		
	2	JVC – GZ-MG27u (Everio)	29.97		
	3	JVC – GZ-MG27u (Everio)	29.97		
	4	JVC – GZ-MG27u (Everio)	29.97		
	1	Canon ZR90	29.97		
	2	Canon ZR10	29.97		

Figure 31. Camera Locations, Speeds, and Lens Settings, Test No. MGSSYP-2

5 FULL-SCALE CRASH TEST NO. MGSSYP-1

5.1 Dynamic Soil Test

Before full-scale crash test no. MGSSYP-1 was conducted, the strength of the foundation soil was evaluated with a dynamic test, as described in MASH [2]. The dynamic test results are shown in Appendix C. The force vs. deflection curve for the dynamic soil test was determined using the acceleration data from the bogie vehicle to determine both the load and deflection of the post in the soil. While Appendix B of MASH requires the use of load cells for determination of post-soil forces, MwRSF has demonstrated through previous bogie tests of posts in soil that the load versus deflection as determined by accelerometers on the bogie vehicle compares well with data obtained from load cells mounted on an impacted post. There are minor differences in the load and deflection as measured by the accelerometer versus a dedicated transducer. First, loads measured by the load cell are expected to be slightly higher than those measured by the accelerometer due to the accelerometer only capturing the longitudinal component of the impact force as the post rotates backward. The vertical component of the impact load, which increases in magnitude as the rotation angle increases, is not reflected in the accelerometer data. Thus, utilizing accelerometers to obtain force data would be a conservative estimate of soil strength.

The soil strength test conducted prior to test no. MGSSYP-1 demonstrated that the soil for the test generated relatively high initial force levels, but the force level between 19 and 20 in. (483 and 508 mm) was slightly lower than the MASH requirement of 7,500 lb (33.4 kN). It was reasoned that the soil strength was sufficient even though the end of the post-soil force vs. deflection curve dipped slightly below the required threshold. First, the initial loading of the soil was significantly higher than the 7,500 lb (33.4 kN) force limit for the initial 10 in. (254 mm) of deflection. This indicated that the soil stiffness was high and that the soil was absorbing a significant amount of energy. Second, as noted above, the force data measured by the accelerometer is conservative and was likely underestimating the soil resistance near the end of the post deflection. Third, the post-soil forces were only below the threshold for a limited deflection near the end of the 20 in. (508 mm) deflection limit. As such, the effect on overall post behavior was determined to be negligible.

5.2 Test No. MGSSYP-1

The 5,199-lb (2,358-kg) pickup truck impacted the MGS with SYP wood posts at a speed of 62.2 mph (100.1 km/h) and at an angle of 24.9 degrees. A summary of the test results and sequential photographs are shown in Figure 32. Additional sequential photographs are shown in Figures 33 and 34.

5.3 Weather Conditions

Test no. MGSSYP-1 was conducted on August 3, 2011 at approximately 4:45 pm. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 3 [9].

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

Temperature	85° F
Humidity	55 %
Wind Speed	11 mph
Wind Direction	30° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.14 in.

5.4 Test Description

Initial vehicle impact was to occur 12 ft (3.7 m) upstream of the center line of post no. 15, as shown in Figure 35, which was selected using the CIP plots found in Section 2.3 of MASH to maximize pocketing and the propensity of wheel snag. The actual point of impact was 12 ft – 6 in. (3.8 m) upstream of post no. 15. A sequential description of the impact event is contained in Table 4. The vehicle came to rest 209 ft (63.7 m) downstream of the impact point and 56 ft – 10 in. (17.3 m) laterally behind the barrier system, and its trajectory did not violate the bounds of the exit box. The vehicle trajectory and final position are shown in Figures 32 and 36.

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

TIME (sec)	EVENT
0.000	The right-front corner of vehicle impacted rail 12 ft – 6 in. (3.8 m) upstream from post no. 15.
0.004	Post no. 13 deflected backward.
0.022	The right-front fender of vehicle deformed, post no. 14 deflected backward, and rail kinked downstream of post no. 14.
0.030	The upstream terminal deflected downstream, post no. 1 was moved upward, and post no. 12 deflected backward.
0.038	The right-front headlight shattered, downstream terminal rail deflected upstream, post no. 15 deflected backward, and rail kinked upstream of post no. 15.
0.060	The rail kinked downstream of post no. 15, and vehicle began to yaw counterclockwise.
0.066	The rail released from post no. 14.
0.074	Post no. 16 deflected backward.
0.080	Post no. 14 began to fracture.
0.095	The posts upstream of impact rotated toward impact point, and right-front wheel snagged on post no. 14 and disengaged from vehicle.
0.100	Post no. 15 fractured.
0.112	The rail released from post no. 15.
0.118	A kink formed in rail downstream of post no. 16, post no. 16 fractured approximately 1 ft (305 mm) above ground level, and right-front door of vehicle became slightly ajar.
0.136	Post nos. 17 and 18 deflected backward, and the vehicle rolled away from system.
0.144	The rail released from post no. 16.
0.154	The rail kinked at post no. 18.
0.228	The vehicle rolled slightly toward system.
0.238	The undercarriage of vehicle impacted remaining 1 ft (305 mm) of post no. 16.
0.290	The vehicle was parallel to system with a speed of 46.8 mph (75.3 km/h).
0.300	The upstream terminal was at maximum deflection, post no. 19 deflected backward, and post no. 17 fractured.

0.308	The rail released from post no. 17.
0.652	The vehicle exited system with a speed of 37.8 mph (60.8 km/h) and at an angle of 15.7 degrees.
0.892	The right-front brake disk contacted ground.
0.966	The right-front bumper contacted ground.

5.5 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 37 through 38 . Barrier damage consisted of deformed guardrail, fractured posts, and contact marks on the front face of the W-beam guardrail. The length of vehicle contact along the barrier was approximately 34 ft – 4 in. (10.5 m) which spanned from 4 in. (102 mm) upstream of the centerline of post no. 13 and extended to 33 in. (838 mm) downstream of post no. 18.

The rail disengaged from several posts both upstream and downstream of impact. The guardrail bolt pulled through the rail at post nos. 3 through 5, 7 through 9, and 14 through 17. A ¼-in. (6-mm) tear was found in the rail on the upstream end of the slot at post no 3. A ¼-in. (6-mm) tear also occurred at the bottom center of the slot at post no. 7. A ½-in. (13-mm) tear occurred on the bottom downstream edge of the slot at post no. 14.

Deformations in the rail occurred from post no. 12 to post no. 18. The top of the rail kinked at post no. 12. The rail buckled 2½ in. (64 mm) downstream of the downstream side of the slot at post no. 13. The bottom corrugation began to fold at post no. 13. Folding of the bottom corrugation also occurred from 52 in. (1,321 mm) downstream of post no. 13 and extended to 33 in. (838 mm) downstream of post no. 14. The rail kinked 4 in. (102 mm) upstream of post no. 13. Flattening of the rail began 1 in. (25 mm) downstream of post no. 13 and extended to 52 in. (1,321 mm) downstream of post no. 13. Flattening occurred again from 33 in. (838 mm) downstream of post no. 14 and extended to 5 in. (127 mm) upstream of post no. 17. Flattening also occurred from 23 in. (584 mm) upstream of post no. 18 and extended to 10 in. (254 mm) downstream of post no. 18. The bottom corrugation of the rail kinked at 31 in. (787 mm) downstream of post no. 18. The rail also buckled at post no. 18.

The top of the blockouts of post nos. 3 through 5 were twisted upstream. The top of the blockouts of post nos. 6 and 7 were twisted downstream. The front of the blockouts for post nos. 6 and 10 were rotated downstream. The top of the blockouts for post nos. 9 and 11 were twisted downstream.

Damage to the posts began at post no. 6, which split on the front face downstream corner. Post no. 10 split at the center of the top of the post from the front to the back. This split started at the top of the post and extended 8½ in. (216 mm) down the post. Post no. 11 split at the center of the post from the front to the back. The split started at the top of the post and extended to the groundline. Post nos. 12 and 13 rotated backwards and split at the center of the post from the front of the post to the back of the post. The splits on both posts started at the top of the post and continued to the groundline. Post nos. 14 through 17 were fractured at the groundline. Post no. 14 came to rest 9 ft – 6 in. (2,896 mm) behind the barrier. Post no. 15 came to rest 9 ft – 3 in. (2,819 mm) behind the barrier. Post no. 16 came to rest 14 ft – 6 in. (4,420 mm) behind the barrier. Post no. 17 came to rest 1 ft – 1 in. (330 mm) behind the barrier. Tire contact marks were found 21 in. (533 mm) down from the top of the front face of post no. 14. Post no. 16 was split into 3 pieces due to contact with the vehicle, and contact marks were also found on the front face of the post. Soil gaps, heaves, and craters can be found in Table 5.

The maximum permanent set of the barrier system was 30¼ in. (768 mm) at the midspan between post nos. 15 and 16, as measured in the field. The maximum lateral dynamic rail and post deflections were 40.0 in. (1,016 mm) at post no. 15 and 28.1 in. (714 mm) at post no. 17, respectively, as determined from high-speed digital video analysis. The working width of the system was found to be 53.8 in. (1,367 mm), also determined from high-speed digital video analysis.

Table 5. Soil Gap, Soil Heave, and Soil Crater Measurements, Test No. MGSSYP-1

Soil Gap Location[1], in. (mm)					**Soil Heave, in. (mm)**		**Soil Crater, in. (mm)**	
Post No.	Upstream	Downstream	Front	Back	Diameter	Height	Diameter	Depth
1	1½ (38)	0	0	0	28 (711)	3 (76)	0	0
2	¼ (6)	¼ (6)	0	0	0	0	0	0
12	½ (13)	0	½ (13)	0	0	0	0	0
13	¾ (19)	0	2¼ (57)	¾ (19)	27 (686)	3 (76)	0	0
14	0	0	1¾ (44)	2 (51)	17 (432)	2 (51)	13 (330)	4 (102)
15	0	0	0	0	0	0	42 (1,067)	3 (76)
16	0	0	0	0	24 (610)	3 (76)	0	0
17	0	0	4 (102)	0	20 (508)	4 (102)	0	0
18	0	0	1¼ (32)	2½ (64)	18 (457)	4 (102)	0	0
19	0	0	¼ (6)	¼ (6)	0	0	0	0
29	0	¼ (6)	0	0	0	0	0	0

[1] If a post is omitted in the table, there were no soil disturbances at that post location

5.6 Vehicle Damage

The damage to the vehicle was minimal, as shown in Figures 47 and 48. The maximum occupant compartment deformations are listed in Table 6 along with the deformation limits established in MASH for various areas of the occupant compartment. Note that none of the MASH established deformation limits were violated. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D.

Table 6. Maximum Occupant Compartment Deformations by Location

LOCATION	MAXIMUM DEFORMATION in. (mm)	MASH ALLOWABLE DEFORMATION in. (mm)
Wheel Well & Toe Pan	½ (13)	≤ 9 (229)
Floor Pan & Transmission Tunnel	½ (13)	≤ 12 (305)
Side Front Panel (in Front of A-Pillar)	¾ (19)	≤ 12 (305)
Side Door (Above Seat)	¾ (19)	≤ 9 (229)
Side Door (Below Seat)	1 (25)	≤ 12 (305)
Roof	0	≤ 4 (102)
Windshield	0	≤ 3 (76)

The majority of the damage was concentrated on the right-front corner and right side of the vehicle where the impact occurred. The front bumper was bent on the right lower side approximately 8 in. (203 mm) from the centerline of the vehicle. There was also a kink on the top of the front bumper approximately 19 in. (483 mm) from the centerline of the vehicle. There were contact marks on the right side of the front bumper cover. The front bumper cover also had a 5-in. (127-mm) tear along the right quarter panel. The grill of the vehicle was deformed backward 2½ in. (64 mm) on the bottom right side. The right quarter panel was folded inward 7 in. (178 mm). The right headlight fractured, and the right-front tire detached from the vehicle at the wheel bearing. The right-front upper control arm and disc brake assembly detached. Contact marks extended the entire length of the right side of the vehicle. Both of the doors on the right side were slightly ajar. The top of the right-front door separated 1 in. (25 mm) from the cab of the vehicle, while the bottom of the right rear door separated ¾ in. (19 mm) from the cab. The right-front door also had flattening that extended the entire length of the door 17 in. (432 mm) up from the bottom of the door. The right-rear door had contact marks that extended the length of the door. Flattening occurred at the bottom of the door and at the rear corner of the cab. The right side of the rear bumper was flattened and had a kink 12 in. (305 mm) from the right fender. The right-rear taillight separated approximately 2½ in. (64) mm from the fender. A 35 in. (889 mm) long crack was found down the center of the windshield.

5.7 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 are shown in Table 7. Note that the OIVs and ORAs were within the suggested limits provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 7.

The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 32. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix E.

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

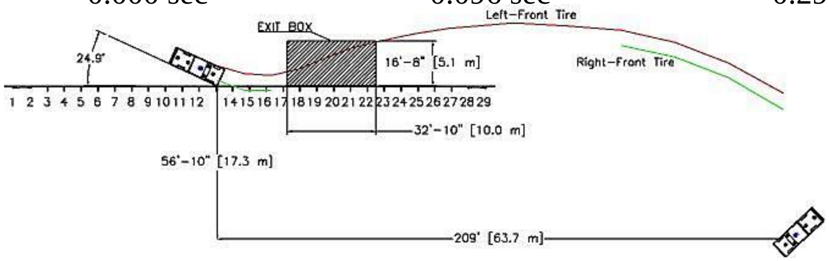
Evaluation Criteria		**Transducer**		**MASH Limits**
		EDR-3	**DTS**	
OIV ft/s (m/s)	Longitudinal	-14.20 (-4.33)	-13.25 (-4.04)	≤ 40 (12.2)
	Lateral	-14.77 (-4.50)	-14.74 (-4.50)	≤40 (12.2)
ORA g's	Longitudinal	8.39 -7.56	-8.14	≤ 20.49
	Lateral	-7.65	-8.51	≤ 20.49
THIV ft/s (m/s)		NA	19.82 (6.04)	not required
PHD g's		NA	11.36	not required
ASI[1]		0.70	0.70	not required

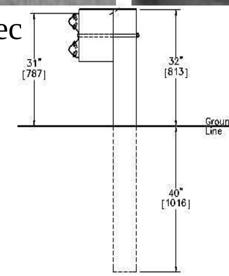
[1]ASI procedures based on MASH Appendix F

5.8 Discussion

The analysis of the test results for test no. MGSSYP-1 showed that the system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. There were no detached elements nor fragments which showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix E, were deemed acceptable because they did not adversely influence occupant risk safety criteria nor cause rollover. After impact, the vehicle exited the barrier at an angle of 15.7 degrees. Therefore, test no. MGSSYP-1 was determined to be acceptable according to the MASH safety performance criteria for test designation no. 3-11.

0.000 sec 0.096 sec 0.290 sec 0.402 sec 0.602 sec





- Test Agency.......MwRSF
- Test Number.......MGSSYP-1
- Date.......8/3/2011
- MASH Test Designation No.......3-11
- Test Article.......MGS with SYP Posts
- Total Length.......181 ft – 3 in. (55.2 m)
- Key Component – Steel W-Beam Guardrail
  - Thickness.......12 gauge (2.66 mm)
  - Top Mounting Height.......31 in. (787 mm)
- Key Component – Southern Yellow Pine Posts
  - Dimension.......6 x 8 x 72 in. (152 x 203 x 1,829 mm)
  - Post Spacing.......75 in. (1,905 mm)
  - Embedment Depth.......40 in. (1,016 mm)
- Key Component – Wood Blockout
  - Post Nos. 3-27.......6 x 12 x 14¼ in. (152 x 305 x 362 mm)
- Vehicle Make /Model.......2004 Dodge Ram 1500 Quad Cab
  - Curb.......5,130 lb (2,327 kg)
  - Test Inertial.......5,029 lb (2,281 kg)
  - Gross Static.......5,199 lb (2,358 kg)
- Impact Conditions
  - Speed.......62.2 mph (100.2 km/h)
  - Angle (Trajectory).......24.9 deg
  - Impact Location.......12 ft – 6 in. (3.8 m) Upstream of Post No. 15
- Impact Severity.......115.5 kip-ft (156.6 kJ) > 106 kip-ft (144 kJ)
- Exit Conditions
  - Speed.......37.8 mph (60.8 km/h)
  - Angle (Trajectory).......15.7 deg
  - Angle (Orientation).......16.1 deg
- Exit Box Criterion.......Pass
- Vehicle Stability.......Satisfactory
- Vehicle Stopping Distance.......209 ft (63.7 m) downstream
  56 ft – 10 in. (17.3) laterally behind

- Vehicle Damage.......Minimal
  - VDS[11].......01-RFQ-4
  - CDC[12].......01-RYEW-3
  - Maximum Interior Deformation.......1 in. (25 mm)
- Test Article Damage.......Moderate
- Maximum Test Article Deflections
  - Permanent Set.......30¼ in. (768 mm)
  - Dynamic.......40.0 in. (1,016 mm)
  - Working Width.......53.8 in. (1,367 mm)
- Maximum Angular Displacements
  - Roll.......5.6° < 75°
  - Pitch.......4.4° < 75°
  - Yaw.......-44.1°
- Transducer Data

Evaluation Criteria		Transducer		MASH Limit
		EDR-3	DTS	
OIV ft/s (m/s)	Longitudinal	-14.20 (-4.33)	-13.25 (-4.04)	≤ 40 (12.2)
	Lateral	-14.77(-4.50)	-14.74 (-4.50)	≤ 40 (12.2)
ORA g's	Longitudinal	8.39 -7.56	-8.14	≤ 20.49
	Lateral	-7.65	-8.51	≤ 20.49
THIV – ft/s (m/s)		NA	19.82 (6.04)	not required
PHD – g's		NA	11.36	not required
ASI		0.70	0.70	not required

Figure 32. Summary of Test Results and Sequential Photographs, Test No. MGSSYP-1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0.094 sec


0.122 sec


0.252 sec

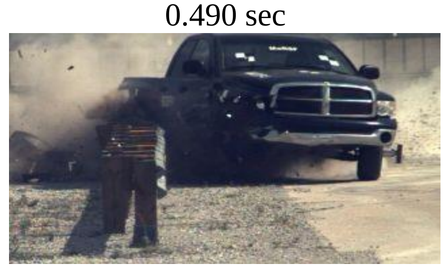

0.352 sec


0.000 sec


0.138 sec


0.290 sec


0.490 sec


0.790 sec


0.892 sec

Figure 33. Additional Sequential Photographs, Test No. MGSSYP-1

0.000 sec

0.022 sec

0.118 sec

0.218 sec

0.338 sec

0.438 sec

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0.030 sec

0.136 sec

0.330 sec

0.500 sec

0.600 sec

Figure 34. Additional Sequential Photographs, Test No. MGSSYP-1

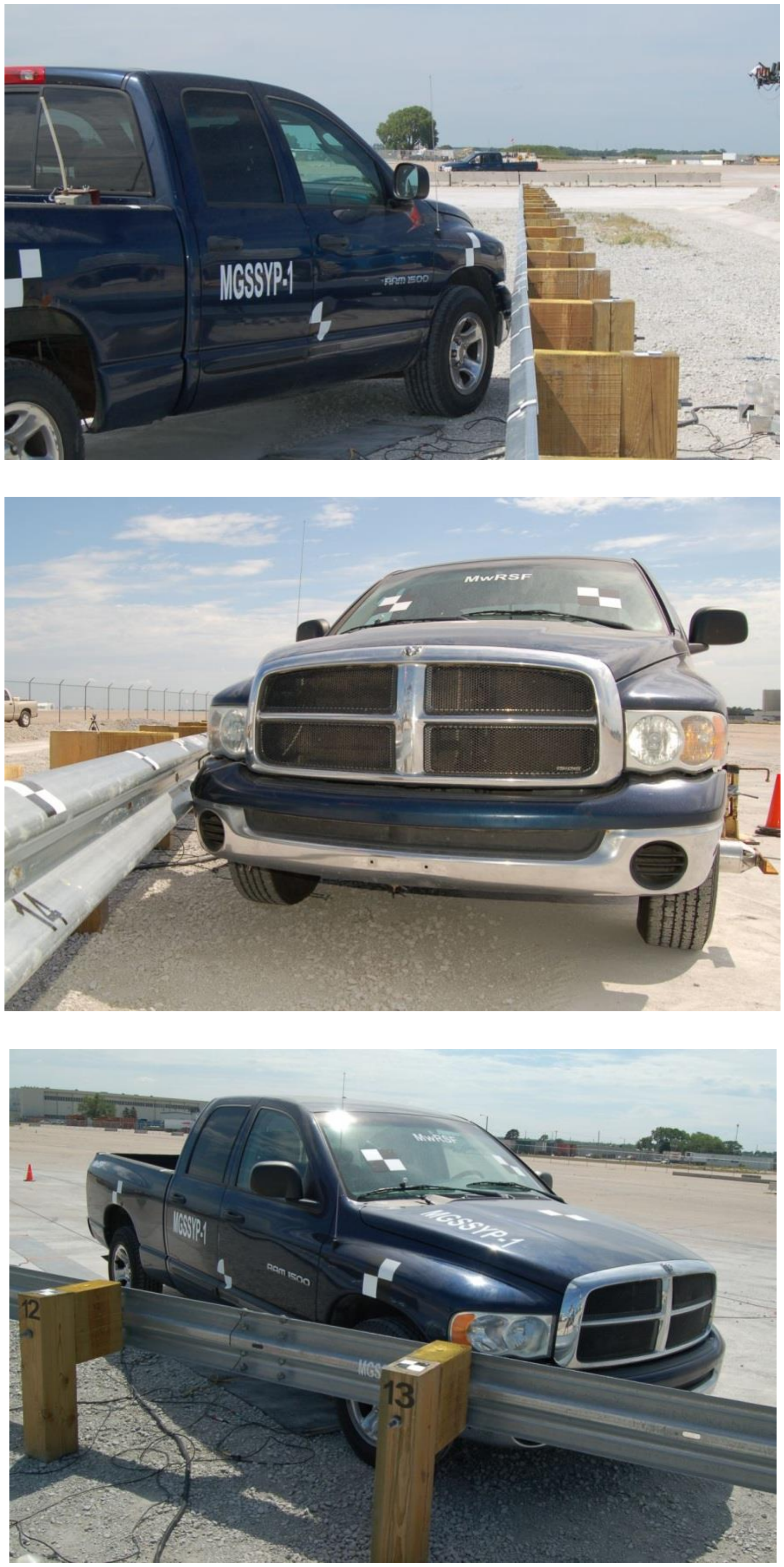


Figure 35. Impact Location, Test No. MGSSYP-1

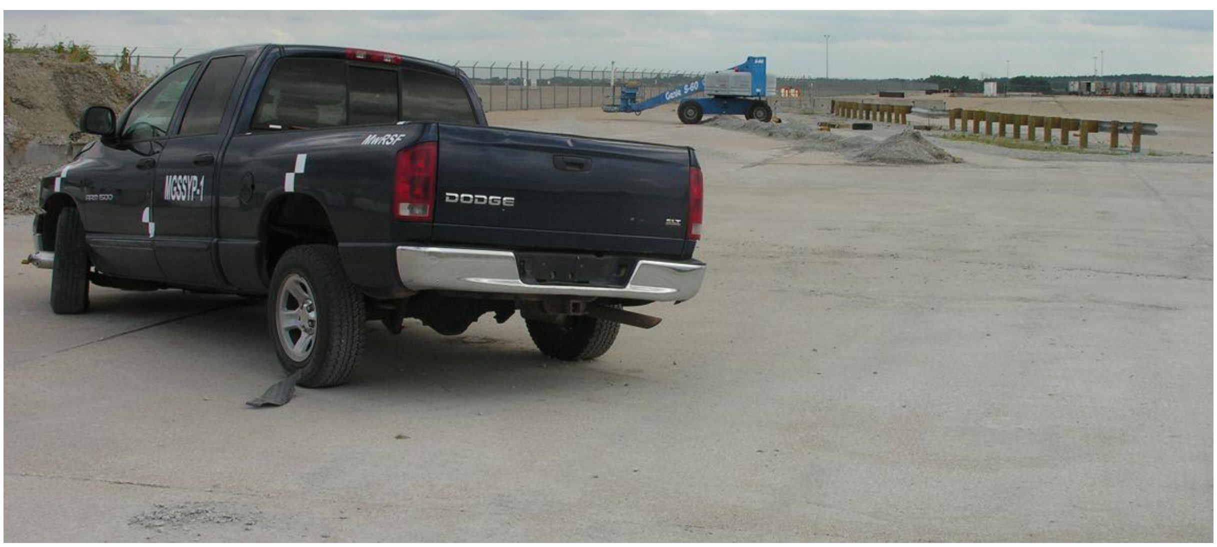


Figure 36. Vehicle Final Position and Trajectory Marks, Test No. MGSSYP-1

Figure 37. System Damage, Test No. MGSSYP-1

Figure 38. Rail Damage Between Post Nos. 13 and 18, Test No. MGSSYP-1

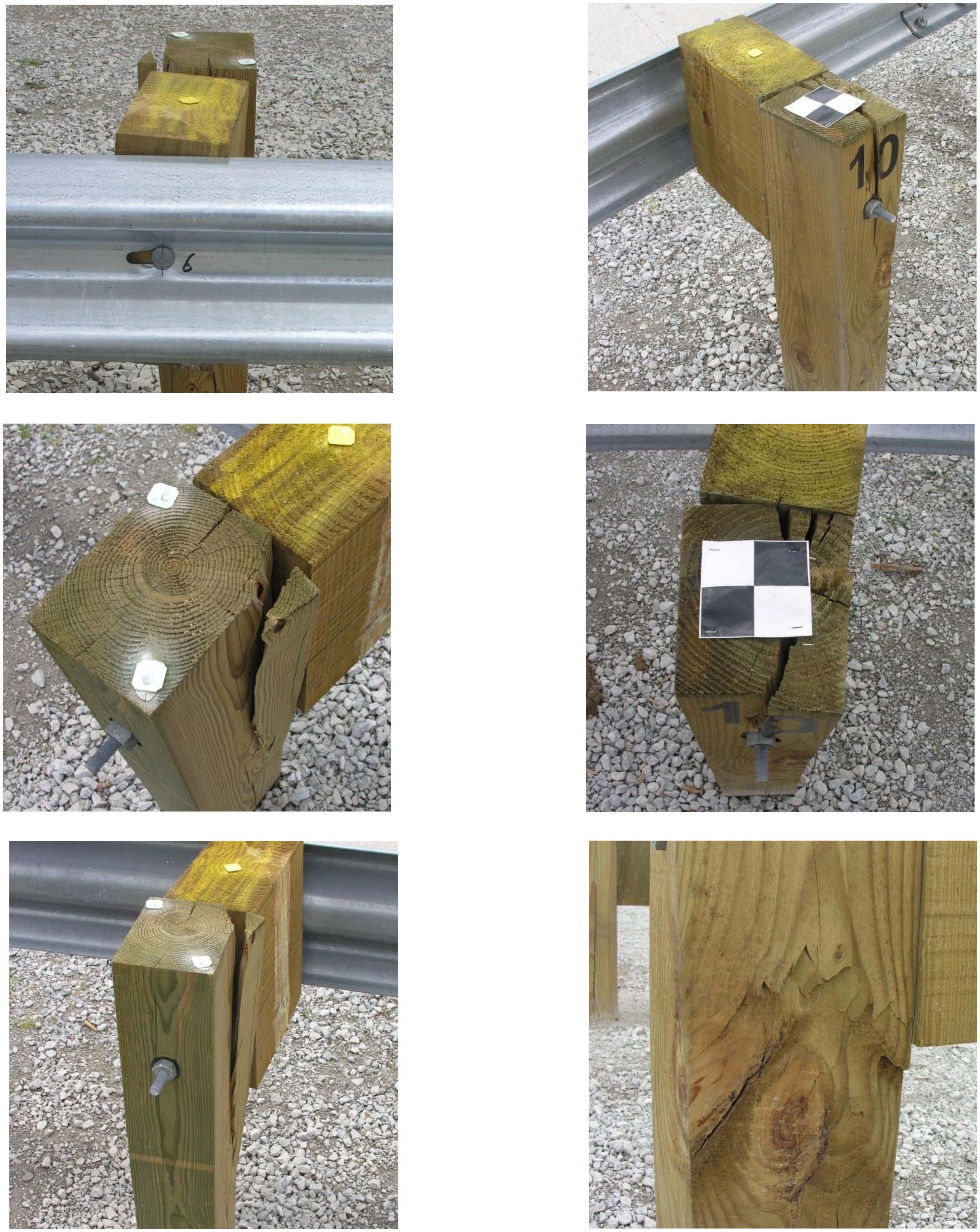


Figure 39. Post Nos. 6 and 10 Damage, Test No. MGSSYP-1

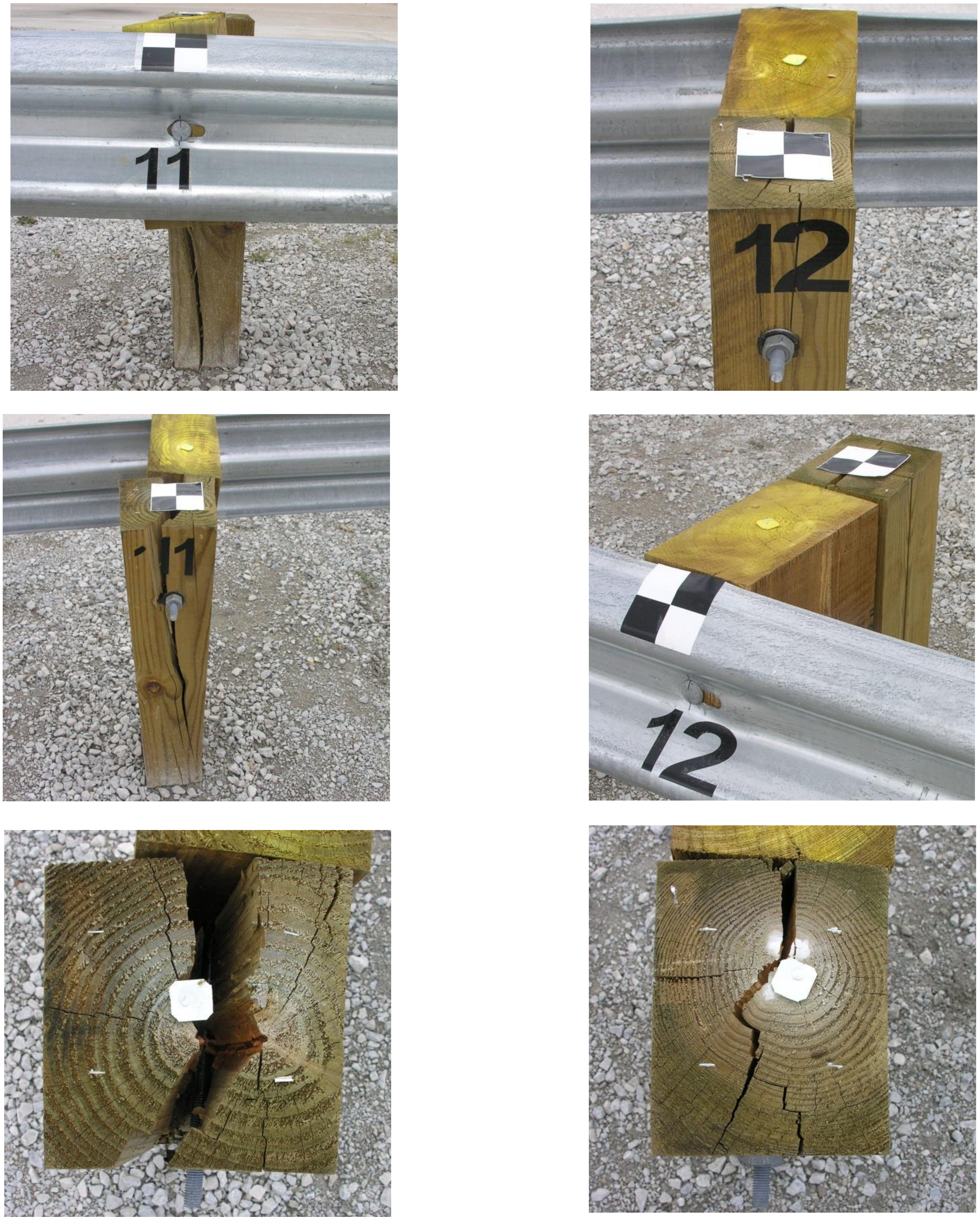


Figure 40. Post Nos. 11 and 12 Damage, Test No. MGSSYP-1.

Figure 41. Post Nos. 13 and 14 Damage, Test No. MGSSYP-1

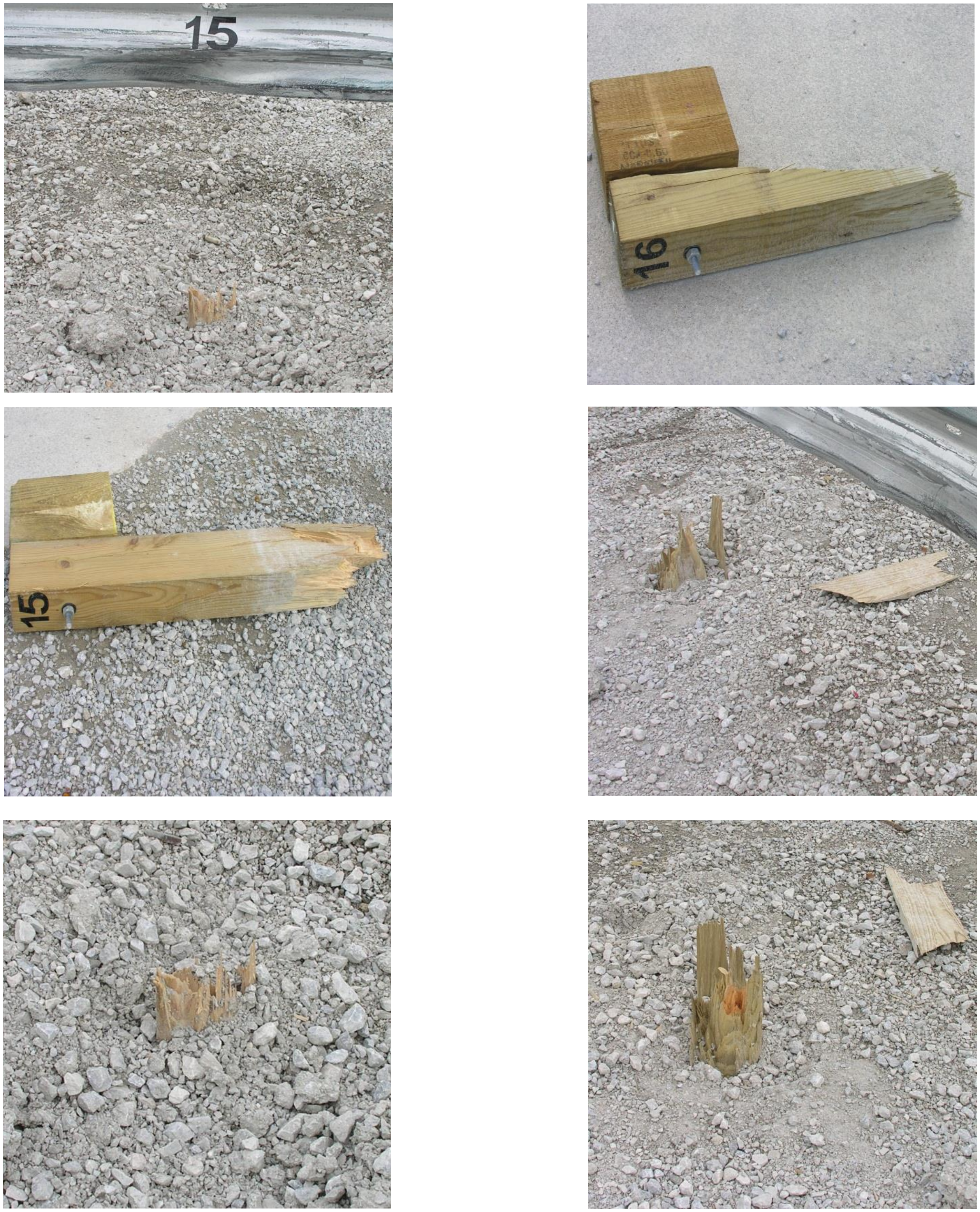


Figure 42. Post Nos. 15 and 16 Damage, Test No. MGSSYP-1

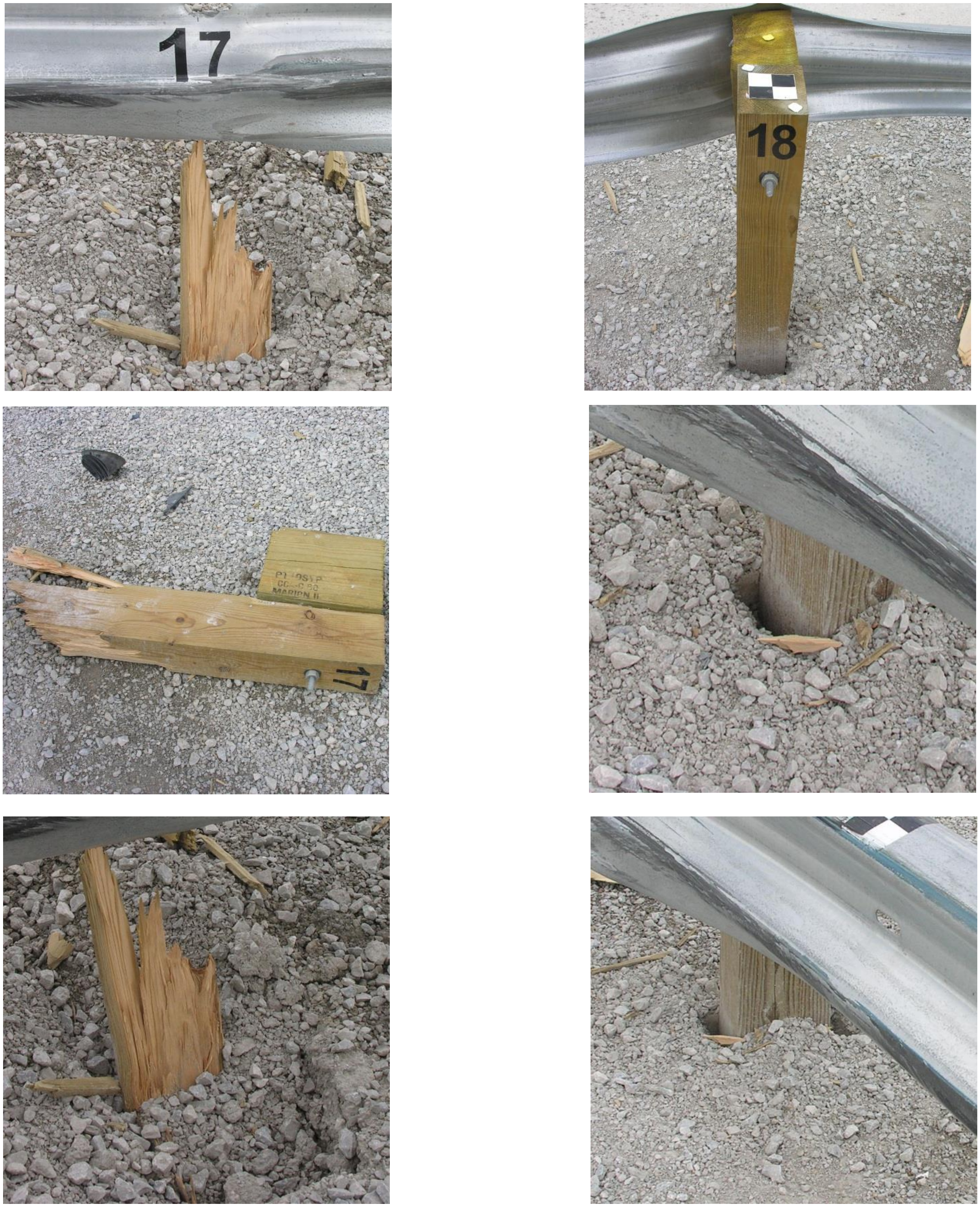


Figure 43. Post Nos. 17 and 18 Damage, Test No. MGSSYP-1

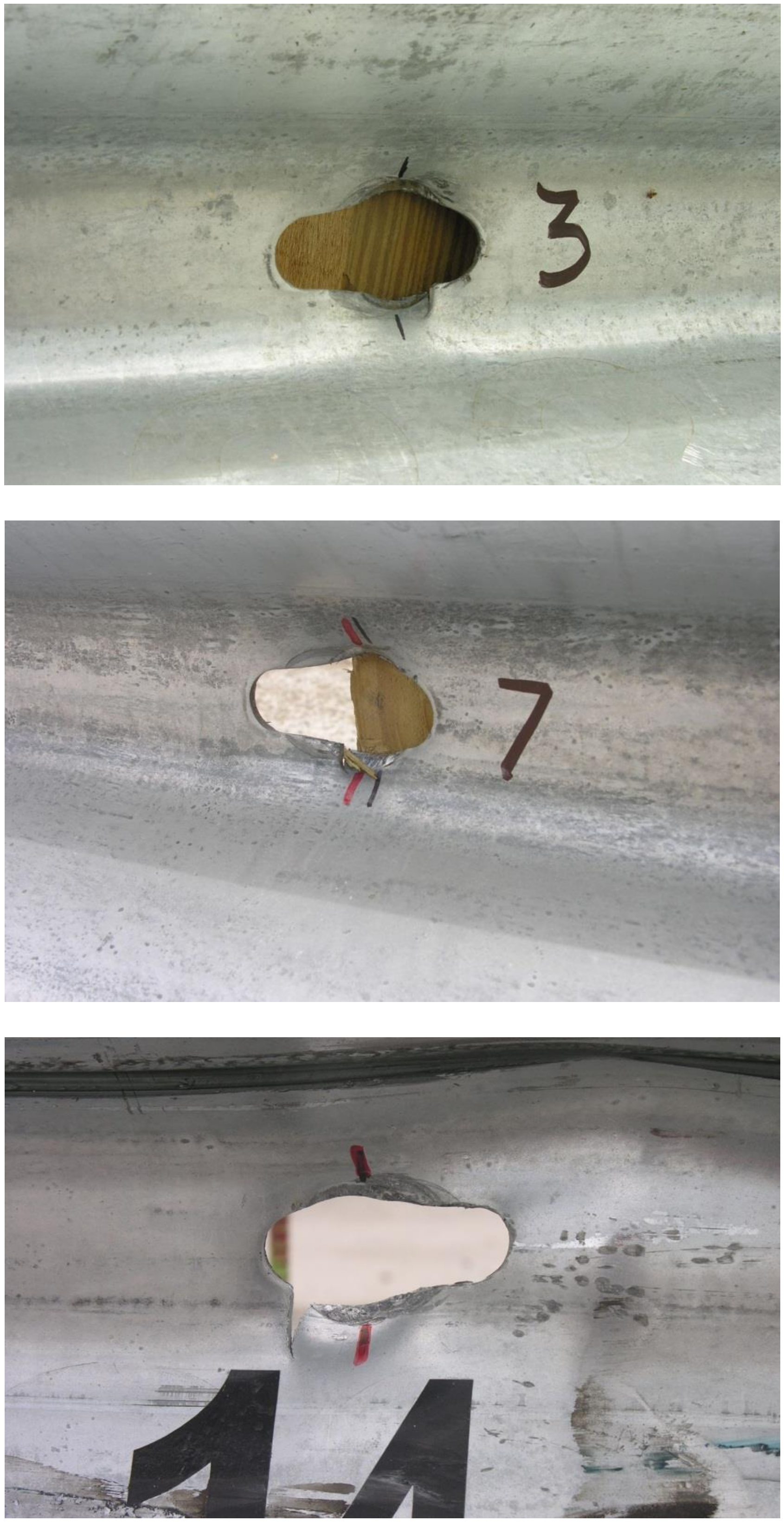


Figure 44. Local Rail Tearing at Post Nos. 3, 7, and 14, Test No. MGSSYP-1

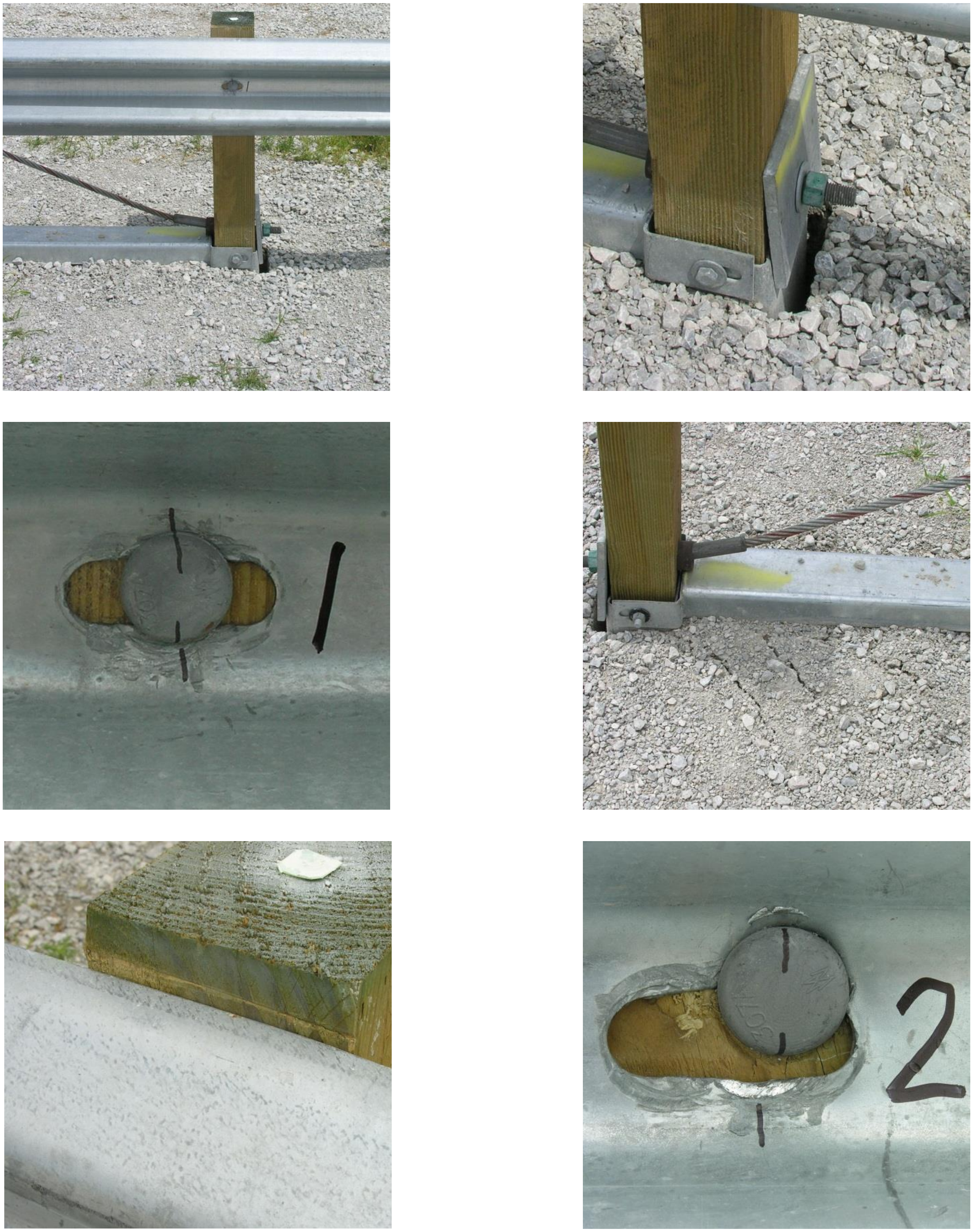


Figure 45. Upstream Anchor Damage, Test No. MGSSYP-1

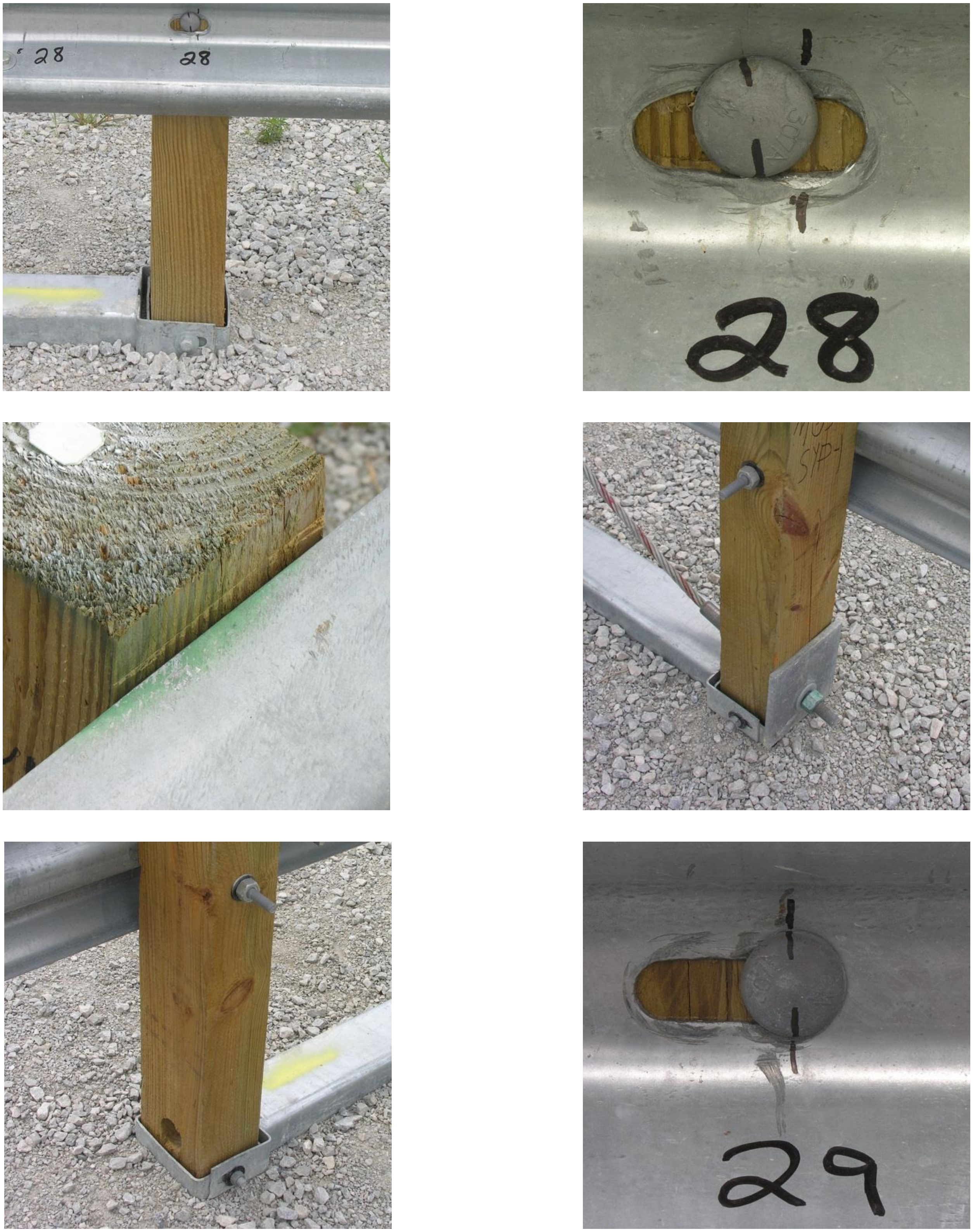


Figure 46. Downstream Anchor Damage, Test No. MGSSYP-1

Figure 47. Vehicle Damage, Test No. MGSSYP-1

Figure 48. Vehicle Damage, Test No. MGSSYP-1

6 FULL-SCALE CRASH TEST NO. MGSSYP-2

6.1 Static Soil Test

Before full-scale crash test no. MGSSYP-2 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH. The post-soil resistance was measured at deflections of 5 in., 10 in., and 15 in. (127 mm, 254 mm, and 381 mm) using load cells during a static test, as shown in Table 8. The complete force versus deflection curves for the static post test are shown in Appendix C.

Table 8. Soil Resistance

Displacement in. [mm]	Test Day Load lb [kN]		Minimum Load (90% Baseline) lb [kg]
	Load Cell #1	Load Cell #2	
5 [127]	7,814 [34.8]	7,899 [35.1]	5,547 [24.7]
10 [254]	7,899 [35.1]	8,013 [35.6]	6,650 [29.6]
15 [381]	6,852 [30.5]	6,845 [30.4]	6,973 [31.0]

At 5 in. (127 mm) of deflection, the static post-soil resistance was approximately 41 percent higher than the baseline minimum. As the post rotated through the 10 in. (254 mm) was approximately 19 percent greater than the baseline minimum. At 15 in. (381 mm) of deflection, the post-soil resistance was less than 2 percent lower than the baseline minimum value. However, it should be noted that the static baseline capacity was excessively high, as shown in Figure C-2, and it corresponded to a soil strength with significant dynamic post-soil resistance, ranging between 10,000 lb (44.5 kN) and 11,000 lb (48.9 kN). As such, the test day dynamic soil strength would have easily surpassed the 7,500-lb (33.4-kN) limit. Therefore, the soil was determined to provide adequate strength for embedded wood guardrail posts, and full-scale crash testing was then conducted on the barrier system.

6.2 Test No. MGSSYP-2

The 2,612-lb (1,185-kg) small car impacted the MGS with SYP wood posts at a speed of 61.5 mph (99.0 km/h) and at an angle of 25.3 degrees. A summary of the test results and sequential photographs are shown in Figure 49. Additional sequential photographs are shown in Figures 50 and 51.

6.3 Weather Conditions

Test no. MGSSYP-2 was conducted on September 13, 2011 at approximately 4:30 pm. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 9 [9].

Table 9. Weather Conditions, Test No. MGSSYP-2

Temperature	70° F
Humidity	53 %
Wind Speed	10 mph
Wind Direction	10° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.00 in.

6.4 Test Description

Initial vehicle impact was to occur 8 ft – 7 in. (2.6 m) upstream of the center line of post no. 15, as shown in Figure 52, which was selected using the CIP plots found in Section 2.3 of MASH to maximize pocketing and the propensity of wheel snag. The actual point of impact was 8 ft – 4 in. (2.5 m) upstream of post no. 15. A sequential description of the impact events is contained in Table 10. The vehicle came to a rest 168 ft – 2 in. (51.3 m) downstream of the impact location and 17 ft – 11 in. (5.5 m) laterally in front of the barrier system, and its trajectory did not violate the bounds of the exit box. The vehicle trajectory and final position are shown in Figure 53.

Table 10. Sequential Description of Impact Events, Test No. MGSSYP-2

TIME (sec)	EVENT
0.000	The right-front corner of vehicle impacted rail 8 ft – 4 in. (2.5 m) upstream of post no. 15.
0.008	The hood of vehicle separated and began to override rail.
0.030	Post nos. 14 and 15 rotated backward.
0.062	The rail penetrated front of vehicle to center point.
0.082	The blockout of post no. 15 twisted.
0.084	The vehicle impacted post no. 15.
0.088	The front bumper of vehicle started detaching.
0.090	Post no. 16 rotated backward.
0.096	The right-front door became ajar.
0.112	The rail detached from post no. 15.
0.120	The surrogate occupant’s head impacted right-front window and shattered it.
0.136	Post no. 15 fractured near groundline.
0.150	The right side of front bumper detached from vehicle.
0.164	Post no. 15 became airborne, and vehicle impacted blockout of post no. 16, causing it to twist.
0.166	The vehicle impacted post no. 16.
0.186	The maximum deflection of system occurred.
0.194	The right-front tire impacted post no. 16, causing it to split vertically and fracture near groundline.
0.222	The blockout of post no. 16 detached from post no. 16
0.258	The detached portion of front bumper impacted ground.
0.260	The vehicle was parallel with system at a speed of 41.2 mph (66.3 km/h).
0.262	The vehicle impacted blockout of post no. 17.
0.280	The vehicle redirected away from system.
0.290	The right-front tire impacted post no. 17.
0.320	Post no. 17 rotated slightly back toward traffic.
0.370	The front of vehicle lost contact with rail.
0.484	The vehicle exited system at a speed of 35.7 mph (57.4 km/h) and at an angle of 13.6 degrees.

6.5 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 54 through 56. Barrier damage consisted of deformed guardrail, rotated and fractured posts, and contact marks on the guardrail and posts. The length of vehicle contact along the barrier was approximately 23 ft – 1 in. (7.0 m) which spanned from 2 ft – 6½ in. (775 mm) upstream of post no. 14 to 1 ft – 9½ in. (546 mm) downstream of post no. 17.

The guardrail bolt pulled through the rail at post nos. 15 through 17. A 1-in. (25-mm) tear was found in the bolt slot of the rail at post no. 15. The rail kinked at the downstream edge of post no. 13. The rail kinked at the top of the rail at the midspan between post nos. 13 and 14. The rail buckled at the downstream edge of the blockout at post no. 14. Flattening occurred from post no. 14 and extended to the splice downstream from post no. 16. The rail buckled at post no. 17 and kinked at post no. 18.

Post no. 15 fractured at the groundline and splintered on the upstream corner of the front face. Contact marks were found on the front of post no. 15. Post no. 16 fractured at the groundline, and tire gouging was found on the front face of the post. Post no. 17 deflected backwards. The top of post no. 17 split at the nail location, and a 6½-in. (165-mm) gouge was found on the upstream side of the front face. Soil gaps, heaves, and craters can be found in Table 11.

The maximum permanent set of the barrier system measured from the back of the posts was 11 in. (279 mm) at post no. 17, as measured in the field. The maximum permanent set of the rail was 16¼ in. (413 mm) at the midspan between post nos. 15 and 16, as measured in the field. The maximum lateral dynamic barrier deflection was 22.2 in. (564 mm) at the midspan between post nos. 15 and 16, as determined from high-speed digital video analysis. The working width of the system was found to be 39.7 in. (1,008 mm), also determined from high-speed digital video analysis.

Table 11. Soil Gap, Soil Heave, Soil Crater Measurements, Test No. MGSSYP-2

Soil Gap Location[1], in. (mm)					**Soil Heave, in. (mm)**		**Soil Crater, in. (mm)**	
Post No.	Upstream	Downstream	Front	Back	Diameter	Height	Diameter	Depth
13	0	0	½ (13)	0	0	0	0	0
14	0	0	2½ (64)	1 (25)	13 (330)	3 (76)	0	0
15	0	0	2 (51)	0	0	0	20 (508)	3½ (89)
16	0	0	0	0	22 (559)	2 (51)	19 (483)	3 (76)
17	1½ (38)	0	4 (102)	0	22 (559)	4 (102)	0	0
18	0	0	¾ (19)	0	0	0	0	0
29	0	½ (13)	0	0	0	0	0	0

[1] If a post is omitted in the table, there were no soil disturbances at that post location

6.6 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 61 and 62. The maximum occupant compartment deformations are listed in Table 12 along with the deformation limits established in MASH for various areas of the occupant compartment. Note that none of the MASH established deformation limits were violated. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D.

Table 12. Maximum Occupant Compartment Deformations by Location

LOCATION	MAXIMUM DEFORMATION in. (mm)	MASH ALLOWABLE DEFORMATION in. (mm)
Wheel Well & Toe Pan	½ (13)	≤ 9 (229)
Floor Pan & Transmission Tunnel	¼ (6)	≤ 12 (305)
Side Front Panel (in Front of A-Pillar)	¾ (19)	≤ 12 (305)
Side Door (Above Seat)	1 ¼ (32)	≤ 9 (229)
Side Door (Below Seat)	¼ (6)	≤ 12 (305)
Roof	0	≤ 4 (102)
Windshield	0	≤ 3 (76)

The majority of the damage was concentrated on the right-front corner and right side of the vehicle where the impact occurred. The right-front of the vehicle was folded under. The right-front quarter panel crushed inward 13 in. (330 mm) and into the shock absorber. Contact marks and gouging were found on the right-front fender. The right-front wheel dented and crushed severely. The right-front tire was punctured and deflated. The tie-rod on the right-front side fractured. The right-front control arm bent and disengaged from the vehicle. The door on the right-front of the vehicle was dented, ajar from the vehicle, and crushed inward. The mirror on the right side disengaged from the vehicle. The windshield cracked on the right side from the right A – pillar and extended 21 in. (533 mm) toward the center and the entire height of the windshield. Tears were found along the bottom of the right-front fender behind the wheel well. The bottom of the door frame crushed inward for 1 ft (305 mm) behind the right-front wheel well. The front bumper disengaged from the vehicle and had contact marks and dents on the right side. The radiator fan disengaged from the vehicle, and brake fluid leaked from the front-left of the vehicle. Contact marks extended the entire length of the right side of the vehicle.

6.7 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 13. Note that the OIVs and ORAs were within the suggested limits provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 13.

The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 49. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix F.

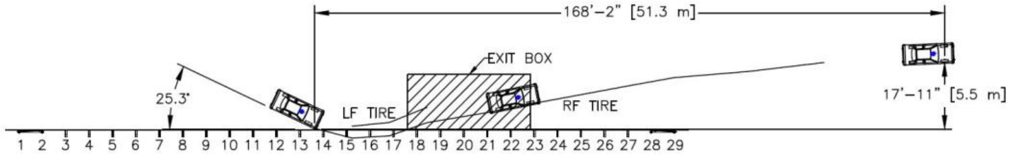
Table 13. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. MGSSYP-2

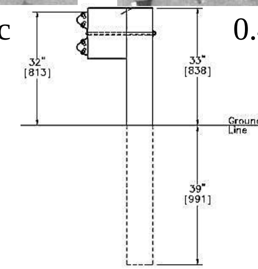
Evaluation Criteria		Transducer		MASH Limits
		EDR-3	DTS	
OIV ft/s (m/s)	Longitudinal	-17.13 (-5.22)	-15.70 (-4.79)	≤ 40 (12.2)
	Lateral	-19.52 (-5.95)	-20.92 (-6.38)	≤40 (12.2)
ORA g's	Longitudinal	-13.05	-13.34	≤ 20.49
	Lateral	-7.42	-9.30	≤ 20.49
THIV ft/s (m/s)		NA	27.92 (8.51)	not required
PHD g's		NA	14.38	not required
ASI[1]		0.91	0.99	not required

[1]ASI procedures based on MASH Appendix F

6.8 Discussion

The analysis of the test results for test no. MGSSYP-2 showed that the system adequately contained and redirected the 1100C vehicle with controlled lateral displacements of the barrier. There were no detached elements or fragments which showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix F, were deemed acceptable because they did not adversely influence occupant risk safety criteria nor cause rollover. After impact, the vehicle exited the barrier at an angle of 13.6 degrees. Therefore, test no. MGSSYP-2 was determined to be acceptable according to the MASH safety performance criteria for test designation no. 3-10.





- Test Agency....................MwRSF
- Test Number....................MGSSYP-2
- Date 9/13/2011
- MASH Test Designation No....................3-10
- Test Article....................MGS with SYP Posts
- Total Length ....181 ft – 3 in. (55.3 m)
- Key Component – Steel W-Beam Guardrail
  - Thickness....................12 gauge (2.66 mm)
  - Top Mounting Height....................32 in. (813 mm)
- Key Component – Southern Yellow Pine Posts
  - Dimension....................6 x 8 x 72 in. (152 x 203 x 1,829 mm)
  - Post Spacing....................75 in. (1,905 mm)
  - Embedment Depth ....39 in. (991 mm)
- Key Component – Wood Blockout
  - Post Nos. 3-27....................6 x 12 x 14¼ in. (152 x 305 x 362 mm)
- Vehicle Make /Model ....2004 Kia Rio
  - Curb ....2,402 lb (1,090 kg)
  - Test Inertial....................2,442 lb (1,108 kg)
  - Gross Static....................2,612 lb (1,185 kg)
- Impact Conditions
  - Speed ....61.5 mph (98.9 km/h)
  - Angle (Trajectory) ....25.3 deg
  - Angle (Orientation)....................24.9 deg
  - Impact Location ....8 ft – 4 in. (2.5 m) Upstream of Post No. 15
- Impact Severity (IS)....................56.4 kip-ft (76.4 kJ) > 51 kip-ft (69.7 kJ)
- Exit Conditions
  - Speed ....35.7 mph (57.4 km/h)
  - Angle (Trajectory) ....13.6 deg
  - Angle (Orientation)....................9.0 deg
- Exit Box Criterion ....Pass
- Vehicle Stability....................Satisfactory
- Vehicle Stopping Distance....................168 ft – 2 in. (51.3 m) downstream
  17 ft – 11 in. (5.5 m) laterally in front
- Vehicle Damage....................Moderate
  - VDS[11]....................01-RFQ-6
  - CDC[12]....................01-RYEW-5
  - Maximum Interior Deformation....................1¼ in. (31.8 mm)
- Test Article Damage ....Moderate
- Maximum Test Article Deflections
  - Permanent Set....................16¼ in. (413 mm)
  - Dynamic ....22.2 in. (564 mm)
  - Working Width....................39.7 in. (1,008 mm)
- Maximum Angular Displacements
  - Roll....................-10.7 ° < 75°
  - Pitch....................-6.7° < 75°
  - Yaw ....-32.9 °
- Transducer Data

Evaluation Criteria		Transducer		MASH Limit
		EDR-3	DTS	
OIV ft/s (m/s)	Longitudinal	-17.13 (-5.22)	-15.72 (-4.79)	≤ 40 (12.2)
	Lateral	-19.52(-5.95)	-20.93 (-6.38)	≤ 40 (12.2)
ORA g's	Longitudinal	-13.05	-13.04	≤ 20.49
	Lateral	-7.42	-9.30	≤ 20.49
THIV – ft/s (m/s)		NA	27.92 (8.51)	not required
PHD – g's		NA	14.38	not required
ASI		0.91	0.99	not required

Figure 49. Summary of Test Results and Sequential Photographs, Test No. MGSSYP-2

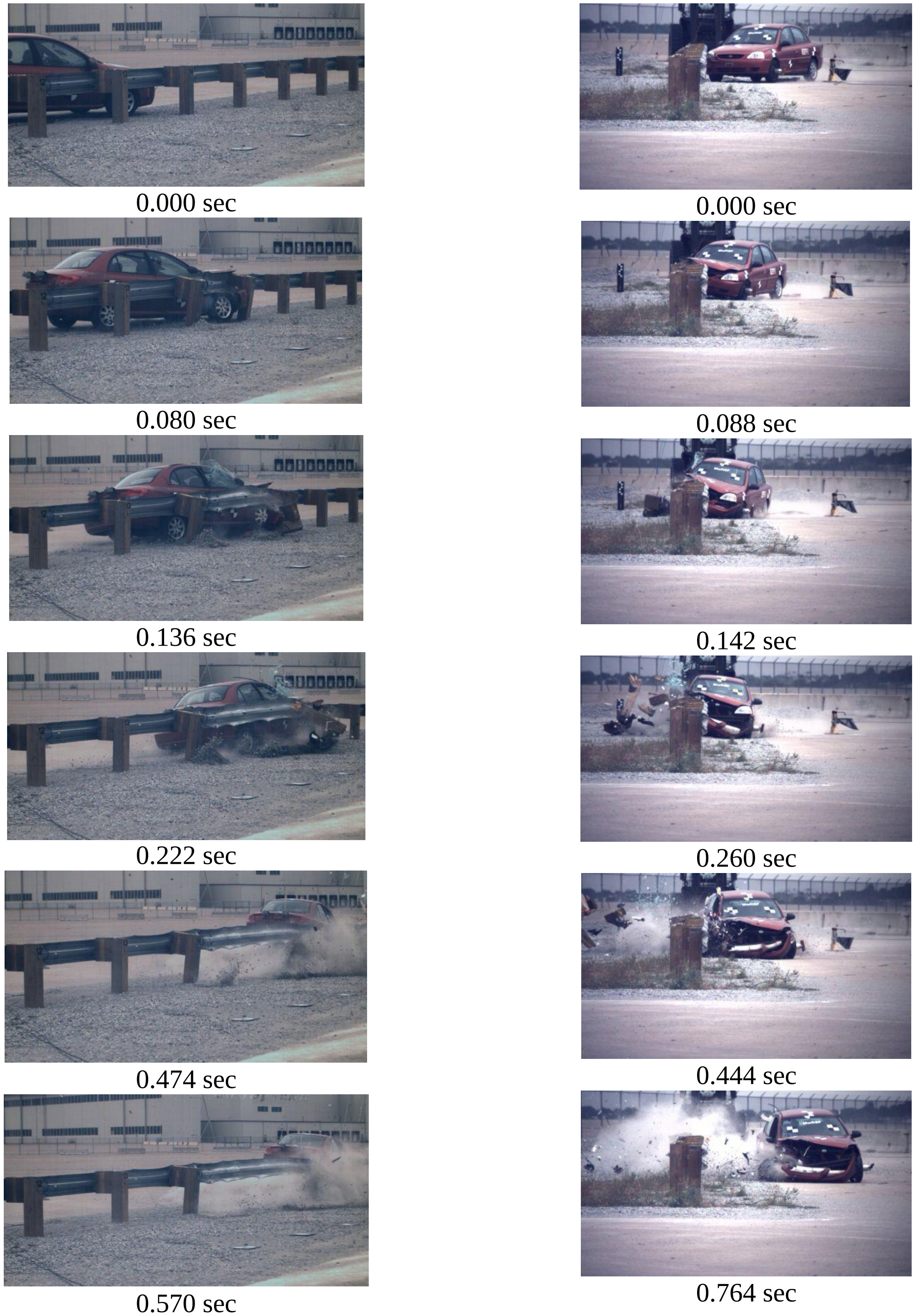


Figure 50. Additional Sequential Photographs, Test No. MGSSYP-2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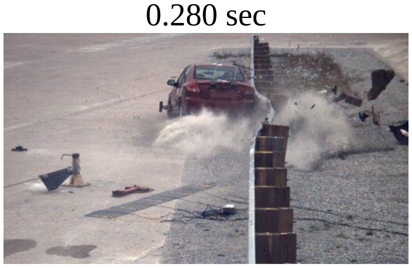
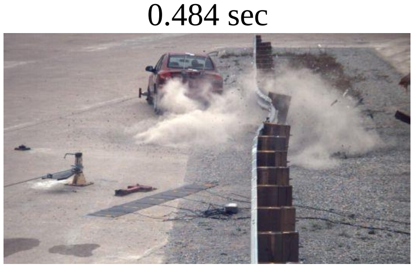
0.084 sec


0.142 sec


0.280 sec


0.484 sec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0.236 sec


0.288 sec

Figure 51. Additional Sequential Photographs, Test No. MGSSYP-2

Figure 52. Impact Location, Test No. MGSSYP-2

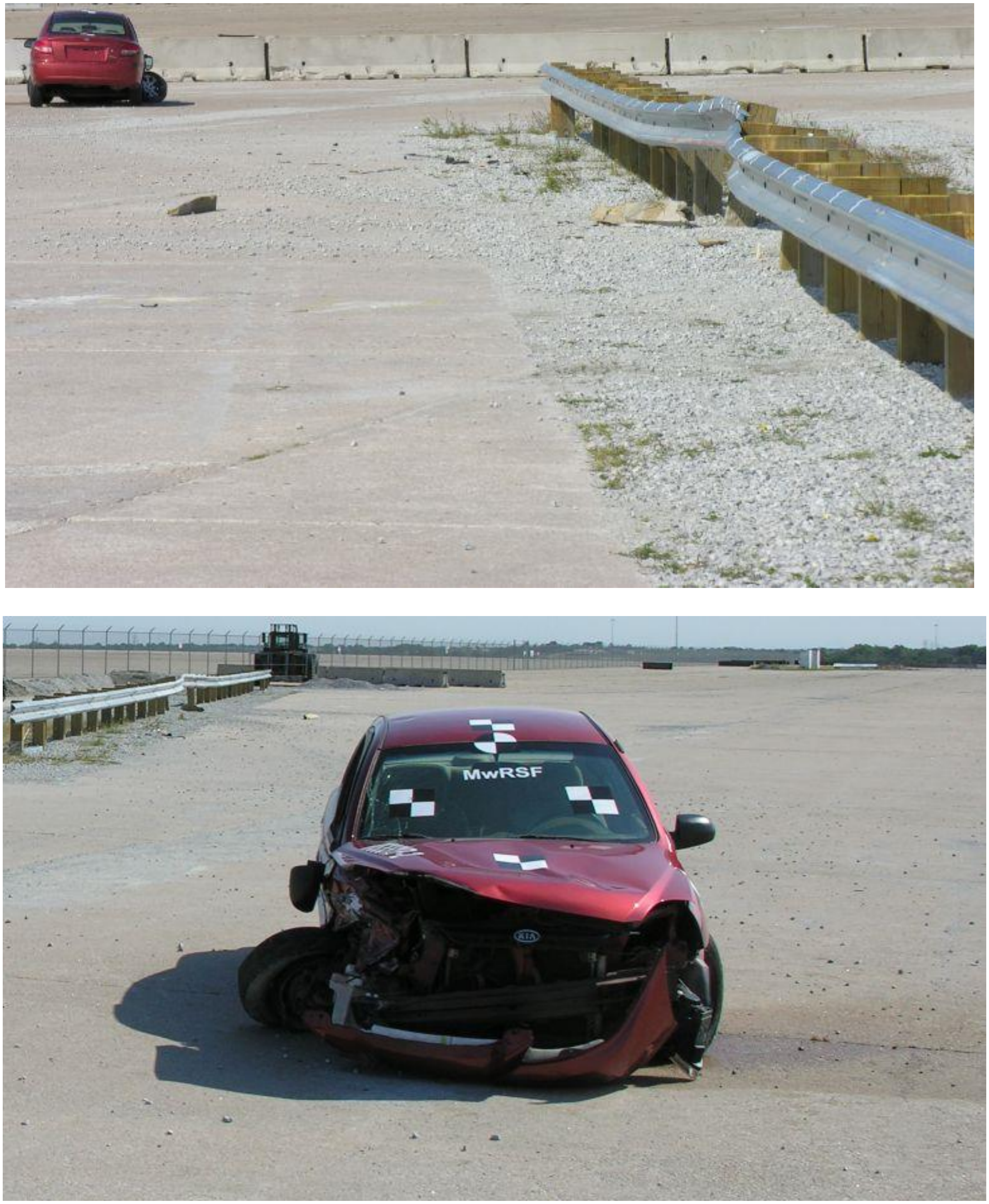


Figure 53. Vehicle Final Position and Trajectory Marks, Test No. MGSSYP-2

Figure 54. System Damage, Test No. MGSSYP-2

Figure 55. Rail Damage Between Post Nos. 13 and 15, Test No. MGSSYP-2

Figure 56. Rail Damage Between Post Nos. 16 and 18, Test No. MGSSYP-2

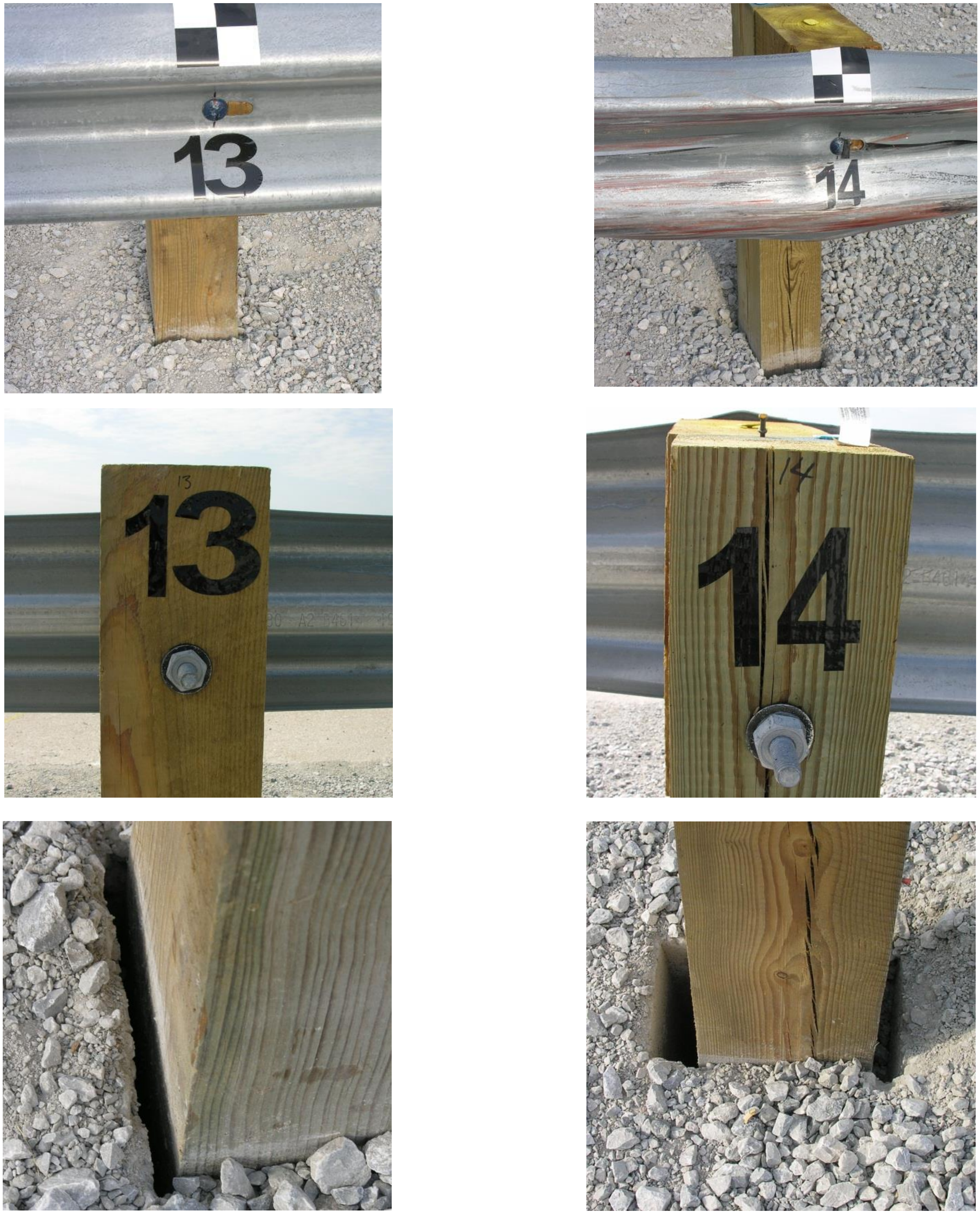


Figure 57. Post Nos. 13 and 14 Damage, Test No. MGSSYP-2

Figure 58. Post Nos. 15 and 16 Damage, Test No. MGSSYP-2

Figure 59. Post Nos. 17 and 18 Damage, Test No. MGSSYP-2

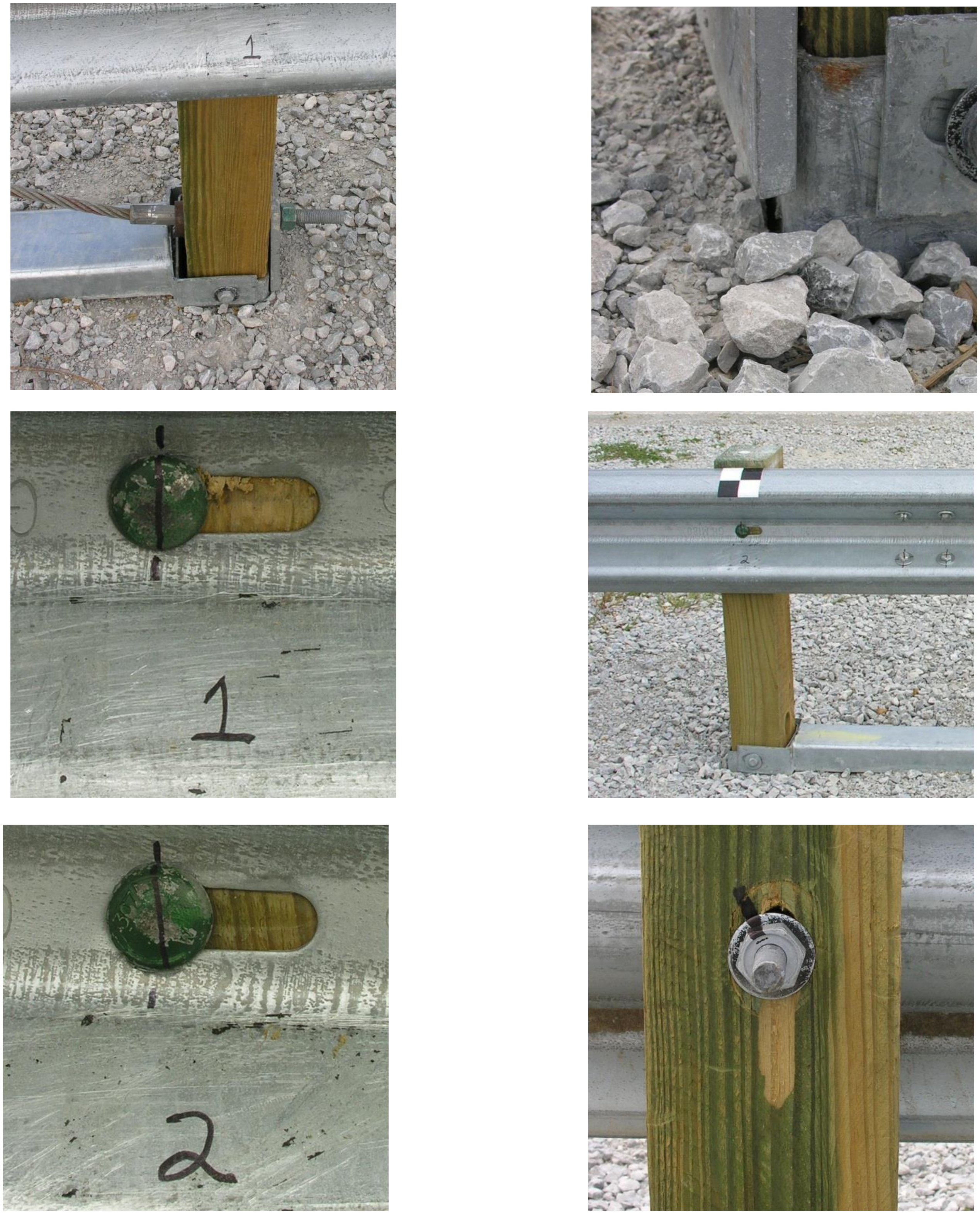


Figure 60. Upstream Anchor Damage, Test No. MGSSYP-2

Figure 61. Vehicle Damage, Test No. MGSSYP-2

Figure 62. Vehicle Damage, Test No. MGSSYP-2

7 SUMMARY AND CONCLUSIONS

A non-proprietary, Southern Yellow Pine wood post, W-beam guardrail system was developed and crash tested according to MASH. The wood post MGS utilized 6-in. x 8-in. x 72-in. (152-mm x 203-mm x 1,829-mm) Southern Yellow Pine posts instead of the standard W6x8.5x72 in. (W152x216x1,829 mm) steel posts. Two full-scale crash tests were performed according to the TL-3 safety performance criteria, as defined in MASH. Test no. MGSSYP-1 (test designation no. 3-11) consisted of a 5,199-lb (2,358-kg) pickup truck impacting the MGS with Southern Yellow Pine posts at a speed of 62.2 mph (100.1 km/h) and at an angle of 24.9 degrees. The vehicle was contained and smoothly redirected. Test no. MGSSYP-2 (test designation no. 3-10) consisted of a 2,612-lb (1,185-kg) small car impacting the wood post MGS at a speed of 61.5 mph (99.0 km/h) and at an angle of 25.3 degrees. The vehicle was contained and smoothly redirected. Thus, the MGS with Southern Yellow Pine posts was judged to be acceptable according to the safety performance criteria presented in MASH. A summary of the safety performance evaluation is provided in Table 14. The successful evaluation of the MGS with Southern Yellow Pine posts as a non-proprietary system may prevent State DOTs that already have an inventory of Southern Yellow Pine posts from having to invest in an inventory of specialized components for use in other systems.

The standard MGS has demonstrated acceptable safety performance when configured with either standard W6x9 (W152x13.4) or W6x8.5 (W152x12.6) steel posts [13-15], round wood posts [3], 6-in. x 8-in. (152-mm x 203-mm) White Pine wood posts [4], and now 6-in. x 8-in. (152-mm x 203-mm) Southern Yellow Pine wood posts. The different configurations have exhibited similar performance, as shown in Table 15. Therefore, the MGS configured with standard-sized, Southern Yellow Pine wood posts is an acceptable alternative to the previously-recommended, steel post, round wood post, and rectangular White Pine wood post configurations.

Table 14. Summary of Safety Performance Evaluation Results

<table>
<tr><th>Evaluation Factors</th><th colspan="4">Evaluation Criteria</th><th>Test No. MGSSYP-1</th><th>Test No. MGSSYP-2</th></tr>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td><td>S</td><td>S</td></tr>
<tr><td rowspan="10">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment 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>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td><td>S</td><td>S</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">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 colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s (9.1 m/s)</td><td>40 ft/s (12.2 m/s)</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.3 of MASH for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td><td rowspan="4">S</td></tr>
<tr><td 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

Table 15. Comparison of MGS with Steel and Wood Post

Performance Criteria	MGS											
	7¼-in. Diameter Douglas Fir Posts		8-in. Diameter Ponderosa Pine Posts		W6x9 Steel Posts		W6x9 Steel Posts		6-in. x 8-in. White Pine Posts		6-in. x 8-in. Southern Yellow Pine Posts	
Test Criteria	NCHRP 350		NCHRP 350		NCHRP 350		MASH		MASH		MASH	
Test Designation No.	3-11	3-10	3-11	3-10	3-11	3-10	3-11	3-10	3-11	3-10	3-11	3-10
Test Vehicle	2000P [3]	820C[1]	2000P [3]	820C[1]	2000P [13]	820C [13]	2270P [14]	1100C [15]	2270P [4]	1100C[1]	2270P	1100C
Impact Severity kip-ft (kJ)	106.4 (144.3)	-	107.2 (145.3)	-	101.5 (137.7)	31.2 (42.3)	122.3 (165.8)	58.8 (79.7)	131.5 (178.3)	-	115.5 (156.6)	56.4 (76.4)
Permanent Set Deflections in. (mm)	35.5 (902)	-	27.8 (705)	-	26.0 (652)	9.4 (238)	31⅝ (803)	19.9 (505)	33¾ (857)	-	30¼ (768)	16¼ (413)
Dynamic Deflections in. (mm)	60.2 (1,529)	-	37.6 (956)	-	43.1 (1,094)	17.4 (443)	43.9 (1,115)	35.9 (913)	46.3 (1,176)	-	40.0 (1,016)	22.2 (564)
Working Width in. (mm)	60.3 (1,531)	-	48.6 (1,234)	-	49.6 (1,260)	40.3 (1,023)	48.6 (1,234)	48.3 (1,227)	58.4 (1,483)	-	53.8 (1,367)	39.7 (1,008)
OIV ft/s (m/s) Longitudinal	13.22 (4.03)	-	22.47 (6.85)	-	18.32 (5.58)	11.55 (3.52)	15.32 (4.67)	14.83 (4.52)	-15.27 (-4.65)	-	-13.25 (-4.04)	-15.72 (-4.79)
OIV ft/s (m/s) Lateral	13.22 (4.03)	-	23.56 (7.18)	-	12.87 (3.89)	18.64 (5.68)	15.62 (4.76)	17.13 (5.22)	-16.14 (-4.92)	-	-14.74 (-4.50)	-20.93 (-6.38)
ORA g's Longitudinal	8.76	-	5.90	-	9.50	6.13	8.23	16.14	-8.25	-	-8.14	-13.04
ORA g's Lateral	5.69	-	4.09	-	6.94	7.97	6.93	8.37	-10.13	-	-8.51	-9.30

[1]This test was not conducted.

8 IMPLEMENTATION GUIDANCE

8.1 Background

As previously noted, the research detailed herein demonstrated that the MGS utilizing 6-in. x 8-in. x 72-in. (152-mm x 203-mm x 1,829-mm) Southern Yellow Pine posts, performed in an acceptable manner according to test designation nos. 3-10 and 3-11 of the MASH impact safety standards. However, several variations of the MGS system have been developed for special applications, which may be more sensitive to the use of wood posts. These special applications would include the MGS long-span system, MGS adjacent to 2:1 fill slopes, MGS on 8:1 approach slopes, MGS adjacent to a curb, MGS stiffness transition to approach guardrail transitions, MGS with reduced post spacing, and MGS without blockouts. Since several MGS variations are available, recommendations regarding the use SYP wood posts will likely vary depending on the nature and behavior of the special applications listed above. Implementation guidance and/or recommendations regarding the use SYP wood posts in these special applications are discussed below.

8.2 MGS Long-Span Guardrail

The MGS long-span guardrail system was successfully full-scale crash tested using an unsupported length of 25 ft (7.62 m) and three CRT posts with 12-in. (305-mm) deep blockouts adjacent to each end of the unsupported span [16]. These CRT posts were incorporated into the system in order to mitigate concerns for wheel snag on posts adjacent to the unsupported span when traversing from the unsupported span to the downstream standard guardrail. Adjacent to the CRT posts, the standard MGS utilized 12-in. (305-mm) deep blockouts. The MGS long-span guardrail system was installed with the back of the CRT posts positioned flush with the front face of the culvert headwall. The posts upstream and downstream from the culvert were installed 2 ft (610 mm) away from the slope break point of a 3:1 fill slope.

Occasionally, it may be desirable to attach a SYP wood post version of the MGS to the MGS long-span guardrail system. There are no concerns regarding the use of SYP wood posts in the MGS long-span guardrail system. The SYP wood-post version of the MGS performed in an acceptable manner when using the standard post spacing on level terrain and full-scale crash tested under the MASH TL-3 safety performance criteria using both the 1100C and 2270P vehicles. The maximum dynamic deflections of the MGS with W6x8.5 (W152x12.6) steel posts and SYP wood posts under MASH designation no. 3-11 were found to be 43.9 in. (1,115 mm) and 40.0 in. (1,016 mm), respectively. These results indicate that the relative deflection and stiffness of the wood and steel post versions of the MGS are very similar. As such, the SYP wood post version of the MGS system would not be expected to significantly alter the safety performance of the MGS long-span guardrail system when attached to guardrail beyond the upstream and downstream CRT wood posts. Therefore, it would seem reasonable to allow for the SYP wood post MGS to be attached to the MGS long-span guardrail system, as shown in Figure 63.

8.3 MGS Adjacent to 2:1 Fill Slopes

Previously, the 31-in. (787-mm) tall Midwest Guardrail System with 9-ft (2.74-m) long W6x8.5 (W152x12.6) steel posts was successfully crash tested under the MASH TL-3 criteria when installed at the slope break point of a 2:1 fill slope using standard post spacing and blockouts [17]. However, similar crash testing was not successful for the minimum recommended MGS mounting height of 27¾ in. (705 mm). As such, the minimum recommended top mounting height is unknown for the MGS adjacent to 2:1 fill slopes. Later and based on dynamic component testing, a wood post version of the MGS system was configured with 7.5-ft (2,286-mm) long, SYP posts and for use in shielding a 2:1 fill slope, as shown in Figure 64. For the SYP wood post variation, the embedment depth was 58 in. (1,473 mm). Based on this previous research, it is highly recommended that the MGS with 7.5-ft (2,286-mm) long SYP wood posts adjacent to 2:1 fill slopes utilize a minimum top mounting height of 31 in. (787 mm).

8.4 MGS on 8:1 Approach Slopes

Previously, full-scale crash testing was successfully performed on the steel-post version of the MGS installed on an 8:1 approach slope with the W-beam positioned 5 ft (1.52 m) laterally behind the slope break point [18]. This testing program was conducted according to the NCHRP Report No. 350 impact safety standards using both an 820C small car and a 2000P pickup truck. From the crash testing program, the mounting height of the blocked MGS relative to the airborne trajectory of the front bumper and impact-side wheels was deemed critical for satisfactorily containing the 2000P pickup truck. Arguably, the test results may have also demonstrated that the 31-in. (787-mm) top railing height greatly contributed to adequate vehicle containment and stable redirection.

Based on the similar performance of the steel and wood post versions of the MGS system when tested on level terrain, there is little concern that the use of SYP wood posts would adversely affect the performance of the MGS on 8:1 approach slopes. Therefore, it is believed to be acceptable to install SYP wood posts with the MGS on an 8:1 approach slope using the previously-evaluated offset values, as shown in Figure 65.

8.5 MGS Adjacent to Curb

The steel post MGS was successfully crash tested and evaluated with the front face of the W-beam rail placed 6 in. (152 mm) behind the front face of a 6-in. (152-mm) tall concrete curb according to the NCHRP Report No. 350 TL-3 criteria using a 2000P pickup truck [19]. Based on the similar performance of the steel and wood post versions of the MGS system when tested on level terrain, there is little concern that the use of SYP wood posts would adversely affect the performance of the MGS installed adjacent to a curb. Therefore, it is believed to be acceptable to install a SYP wood post MGS with the front face of the W-beam rail placed 6 in. (152 mm) behind the front face of a 6-in. (152-mm) tall concrete curb, as shown in Figure 66.

8.6 MGS Stiffness Transition to Approach Guardrail Transitions

Several options for approach guardrail transitions for the MGS system have been developed. As part of those efforts, a research project was conducted with the objective of identifying a wood-post MGS approach transition system that was equivalent to a previously-designed and full-scale crash tested steel-post MGS stiffness transition that utilized W6x9 and W6x15 steel posts [10]. A literature study on previous bogie testing and comparisons between wood and steel guardrail posts suggested that 6-ft (1.8-m) long, 6-in. x 8-in. (152-mm x 203-mm) wood posts and W6x9 (W152x13.4) steel posts have similar force versus displacement characteristics. However, very little component testing had been previously conducted on larger transition posts. Thus, a bogie testing program was undertaken to determine the behavior of W6x15 (W152x22.3) steel posts and wood posts of various cross sections and embedment depths. Early in this bogie-testing program, the propensity for wood-post fracture in stiff soil was observed. As a result, the wood-post replacements were conservatively selected such that the cross section had excess strength capacity to minimize the risk of post fracture. Ultimately, 6.5 ft (2.0 m) long 8-in. x 10-in. (203-mm x 254-mm) wood posts provided similar resistance to rotation and were selected as the replacement for the 7-ft (2.1-m) long W6x15 (W152x22.3) steel transition posts.

The steel-post MGS stiffness transition was found to satisfy all of the TL-3 safety performance criteria of MASH through a full-scale crash testing program. Since BARRIER VII analysis showed the proposed wood-post transition system behaved similarly and without increases in deflections, pocketing, or snag, it was believed that the wood-post transition system would also satisfy the TL-3 performance criteria of MASH. Therefore, the wood-post MGS stiffness transition was recommended for use as a TL-3 safety barrier. Full details on the wood post approach transition and recommendations for its use can be found in MwRSF research report no. TRP-03-243-11. In addition, it is believed that the use of the MGS with SYP wood posts in standard MGS guardrail upstream of the approach guardrail transition would be acceptable as well.

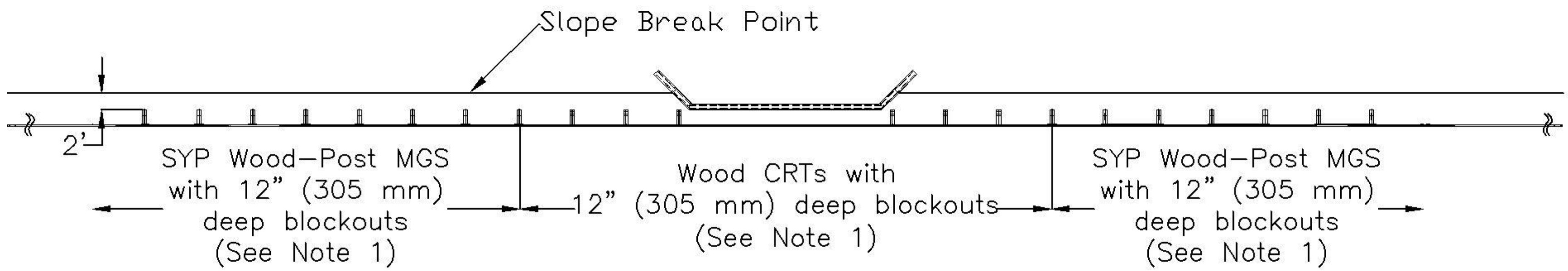
8.7 MGS with Reduced Post Spacing

A steel-post version of the MGS with quarter-post spacing was successfully full-scale crash tested and evaluated using a 2000P pickup truck according to the TL-3 criteria found in NCHRP Report No. 350 [19]. Subsequent analysis of the barrier system with BARRIER VII was used to develop details for a half-post spacing version of the MGS as well. As noted previously, the performance of the steel and wood post versions of the MGS system were found to be very similar in terms of stiffness and dynamic deflection. Thus, it is reasonable to assume that a SYP wood post MGS with reduced post spacing would provide similar performance to the previously evaluated steel post system.

8.8 MGS without Blockouts

Over the years, MwRSF has crash tested several wood-post MGS systems with blockouts, including the rectangular, SYP wood posts evaluation detailed herein. These wood-post MGS systems provided acceptable safety performance without concerns for vehicular instabilities, excessive occupant ridedown decelerations, or critical occupant impact velocities. Based on the similar performance observed for the wood- and steel-post MGS systems with blockouts, there may be a desire for end users to install a non-blocked, wood post MGS. Unfortunately, no crash tests have been performed on non-blocked versions of the wood-post MGS.

Wood and steel guardrail posts can provide slightly different behaviors when loaded through the W-beam rail and about the strong and weak axis of bending. Typical steel guardrail posts may rotate in soil, bend about one of the strong and weak axes near the ground line, or plastically deform from a combination of eccentric loading and/or lateral torsional buckling. Typical wood posts may also rotate in soil or fracture near the ground line. Based on these slight differences in post-soil behavior, there are some concerns that the removal of the blockout from the wood-post MGS may potentially lead to: (1) increased propensity for wheel snag on wood posts; (2) increased vehicle decelerations; and/or (3) greater risk of vehicular instabilities upon redirection. Thus, these outcomes could potentially result in degraded barrier performance. As such, it is not recommended to remove the blockouts from the wood-post MGS without further analysis and crash testing.



Note: (1) Back of post must be installed on level or mostly level soil grading 2 ft (0.6 m) away from the slope break point of a 3:1 or steeper fill slope. The back of the CRT posts can be flush with the headwall. The headwall cannot extend higher than 2 in. (51mm) above the ground line. The wingwall must match the fill slope.

Figure 63. MGS Long-Span System with SYP Wood Post MGS

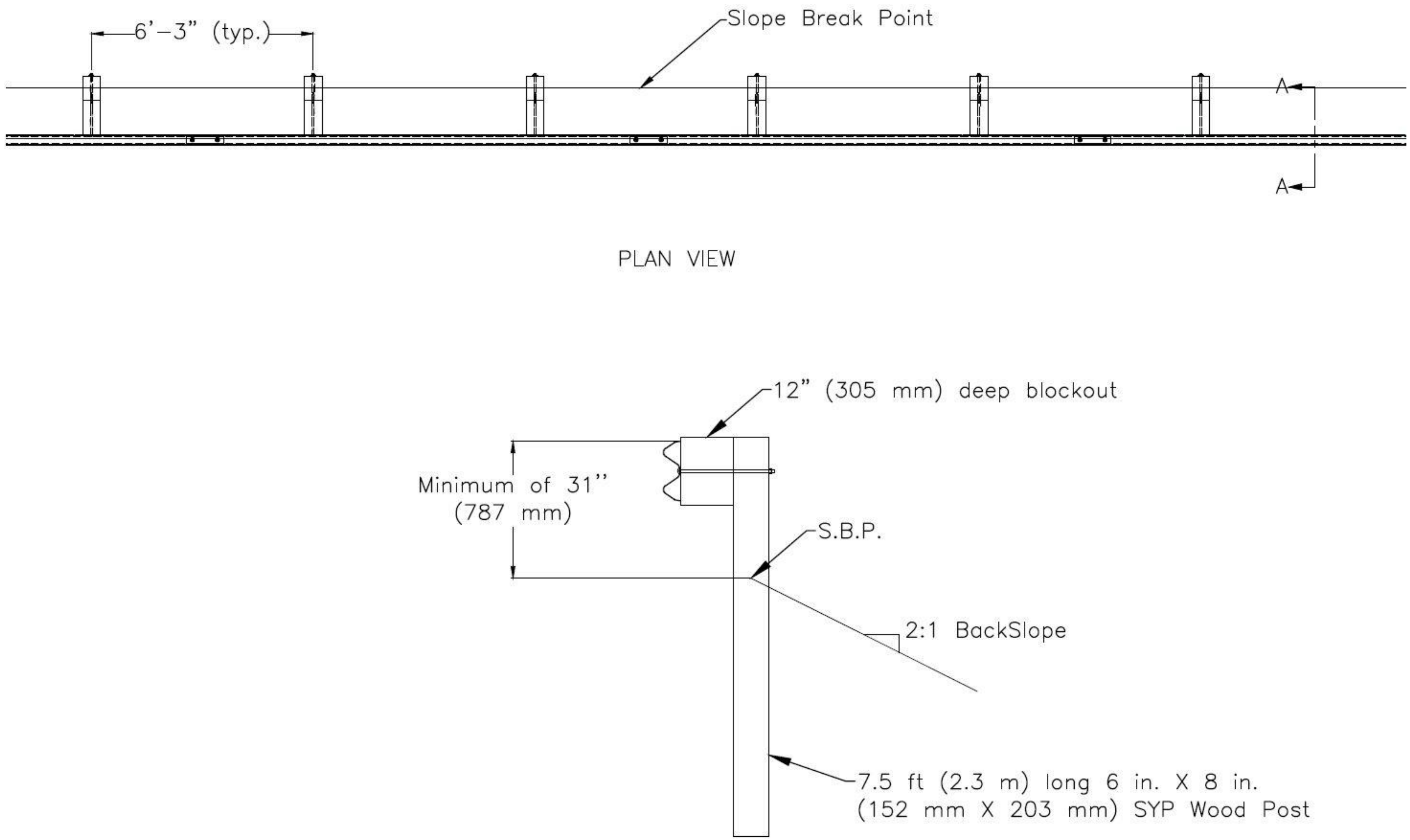


Figure 64. SYP Wood Post MGS Adjacent to 2:1 Fill-Slope

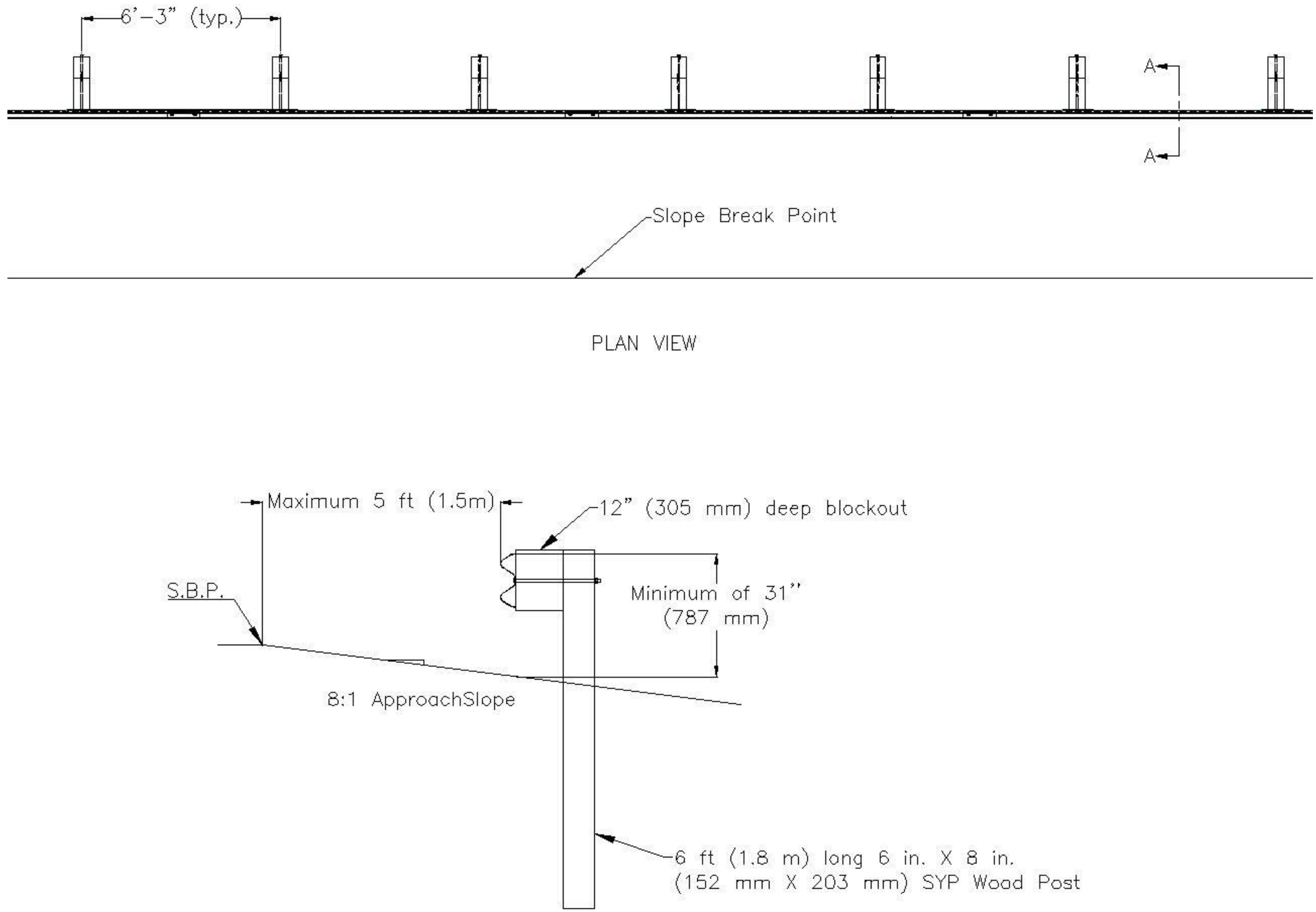


Figure 65. Use of SYP Wood Post MGS on 8:1 Approach Slope

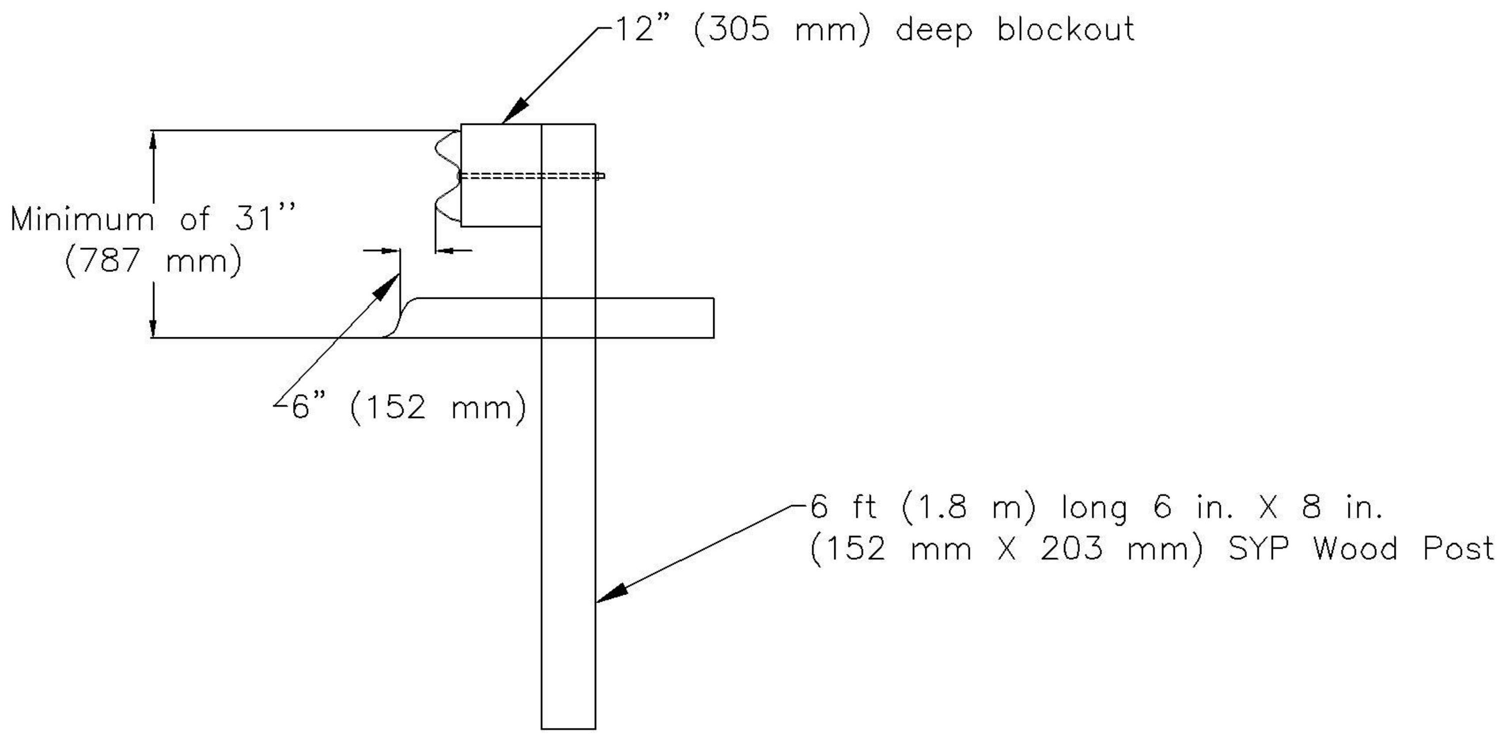


Figure 66. SYP Wood Post MGS Adjacent to Curb Cross-Section

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10 APPENDICES

Appendix A. Material Specifications

MGSSYP-1		
Description	Material Specification	Reference
6"x8"x72" [152x203x1829] Southern Yellow Pine Wood Post	SYP Grade No.1 or better	White Tag
6"x12"x14 1/4" [152x305x362] Blockout	SYP Grade No.1 or better	Yellow Tag
12'-6" [3810] W-Beam MGS Section	12 gauge [2.7] AASHTO M180	4614
12'-6" [3810] W-Beam MGS End Section	12 gauge [2.7] AASHTO M180	4614
6'-3" [1905] W-Beam MGS Section	12 gauge [2.7] AASHTO M180	10-0142-5
16D Double Head Nail	-	N/A
72" [1829] Long Foundation Tube	ASTM A500 Gr. B	090458-7
BCT Timber Post-MGS Height	SYP Grade No.1 or better	10-0282
Strut and Yoke Assembly	ASTM A36 Steel Galvanized	090453-8
BCT Cable Anchor Assembly	⌀ 3/4" 6x19 IWRC IPS Galvanized Wire Rope	Black Paint "A1"
Anchor Bracket Assembly	ASTM A36 Steel	090453-10
8"x8"x5/8" [203x203x16] Anchor Cable Bearing Plate	ASTM A36 Steel	090453-9
2 3/8" [60] O.D.x 6" [152] Long BCT Post Sleeve	ASTM A53 Grade B Schedule 40	90458
5/8" Dia. x 1 1/4" [M16x32] Long Guardrail Bolt and Nut	ASTM A307 Steel/ Nut ASTM A563 DH	100144-1,3
5/8" Dia. x 10" [M16x254] Long Guardrail Bolt and Nut	ASTM A307 Steel/ Nut ASTM A563 DH	Black Paint
5/8" Dia. x 22" [M16x559] Long Guardrail Bolt and Nut	ASTM A307 Steel/ Nut ASTM A563 DH	Black Paint
5/8" Dia. x 1 1/2" [M16x38] Long Hex Head Bolt	ASTM A307 Steel/ Nut ASTM A563 DH	11-0006-3
5/8" Dia. x 9 1/2" [M16x241] Long Hex Head Bolt and Nut	ASTM A307 Steel/ Nut ASTM A563 DH	090453-11
5/8" [16] Dia. Flat Washer	ASTM A307 Steel	N/A
7/8" Dia. x 7 1/2" [M22x191] Long Hex Head Bolt and Nut	ASTM A307 Steel / Nut ASTM A563 DH	N/A
7/8" [22] Dia. Flat Washer	ASTM A307 Steel	N/A

Figure A-1. Bill of Materials, Test No. MGSSYP-1

MGSSYP–2		
Description	Material Specification	Reference
6"x8"x72" [152x203x1829] Southern Yellow Pine Wood Post	SYP Grade No.1 or better	(TAGGED SPA BLUE PAINT) / (TAGGED WHITE PAINT)
6"x12"x14 1/4" [152x305x362] MGS Timber Blockout	SYP Grade No.1 or better	TAGGED GLOSS SUN YELLOW PAINT
12'–6" [3810] 4–Space W–Beam Guardrail	12 gauge [2.7] AASHTO M180	4614
12'–6" [3810] BCT Terminal Rail Section	12 gauge [2.7] AASHTO M180	4614 AND 3390
6'–3" [1905] W–Beam Spacer Guardrail	12 gauge [2.7] AASHTO M180	10–0142–5
16D Double Head Nail	–	SCAN 16d–1
72" [1829] Long Foundation Tube	ASTM A500 Gr. B	090453–7 AND 09–0458
BCT Timber Post–MGS Height	SYP Grade No.1 or better	TAGGED WHITE PAINT
Strut and Yoke Assembly	ASTM A36 Steel Galvanized	09–0453–8
BCT Cable Anchor Assembly	∅ 3/4" 6x19 IWRC IPS Galvanized Wire Rope	STAMPED "A1" AND BLACK PAINT
Guardrail Anchor Bracket	ASTM A36 Steel	090453–10
8"x8"x5/8" [203x203x16] BCT Bearing Plate	ASTM A36 Steel	090453–9
2 3/8" [60] O.D.x 6" [152] Long BCT Post Sleeve	ASTM A53 Grade B Schedule 40	09–0458
5/8" Dia. x 1 1/4" [M16x32] Long Guardrail Bolt and Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 DH	100144–1 (BOLTS)/ 10–0144–3 (NUTS) AND 12–0033 (NUTS)
5/8" Dia. x 10" [M16x254] Long Guardrail Bolt and Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 DH	09–0453–2 (Green Paint) / 12–0033 (NUTS)
5/8" Dia. x 22" [M16x559] Long Guardrail Bolt and Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 DH	10–0143(GLOSS NAVY BLUE PAINT) and 11-0490 (BLACK PAINT)/12–0033 (NUTS)
5/8" Dia. x 1 1/2" [M16x38] Long Hex Bolt and Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 DH	11–0006–3 (HEX BOLTS)/ 12–0030 (nuts)
5/8" Dia. x 9 1/2" [M16x241] Long Hex Bolt and Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 DH	BLACK PAINT (bolt)/12–0030 (nut)
5/8" [16] Dia. Plain Round Washer	ASTM A307 or Grade 2 Steel	09–0453–15/ N/A
7/8" Dia. x 7 1/2" [M22x191] Long Hex Bolt and Nut	Bolt ASTM A307 or Grade 2 Steel/ Nut ASTM A563 DH	11––0492 (bolts and nuts)/12–0037(BOLT) and (NUT)12–0030
7/8" [22] Dia. Plain Round Washer	ASTM A307 or Grade 2 Steel	1JY82/12–0037
SOIL	350 SOIL	6222011

Figure A-2. Bill of Materials, Test No. MGSSYP-2

S.I. Storey
LUMBER COMPANY, INC.

CERTIFICATE OF COMPLIANCE

JULY 20, 2010

MIDWEST MACHINERY & SUPPLY
MILFORD, NE

THE FOLLOWING MATERIAL DELIVERED ON 7/20/10 ON BILL OF LADING NUMBER 20254 HAS BEEN INSPECTED BEFORE AND AFTER TREATMENT AND IS IN FULL COMPLIANCE WITH APPLICABLE NEBRASKA DEPARTMENT OF ROADS REQUIREMENTS FOR SOUTHERN YELLOW PINE TIMBER GUARDRAIL COMPONENTS, PRESERVATIVE TREATED WITH CHROMATED-COPPER-ARSENATE (CCA-C) TO A MINIMUM RETENTION OF .60 LBS/CU.FT. THE ACCEPTANCE OF EACH PIECE BY COMPANY QUALITY CONTROL IS INDICATED BY A HAMMER BRAND ON THE END OF EACH PIECE.

MATERIAL	CHARGE #	DATE	RETENTION	QUANTITY
6x8x6' Line Post	10-342	7/1/10	0.62	105

THIS CERTIFICATE APPLIES TO MATERIAL ORDERED FOR your order no.: 2333

FOR ANY INQUIRIES, PLEASE RETAIN THIS DOCUMENT FOR FUTURE REFERENCE.

THANK YOU FOR YOUR ORDER.

SINCERELY,

Karen Storey

SIGNED BEFORE ME THIS 20 DAY OF JULY 2010.

Notary:
Notary Public Floyd County Georgia
My Commission Expires Oct. 19, 2010

WILLIAM S. HOUSTON NOTARY PUBLIC Exp. Oct. 19, 2010 FLOYD COUNTY, GA

Phone: 706-234-1605 P.O. Box 99, Armuchee, GA 30105 Fax: 706-235-8132

Figure A-3. Southern Yellow Pine Posts, Test Nos. MGSSYP-1 and MGSSYP-2

S.I. Storey
LUMBER COMPANY, INC.

SEP 17 2010

CERTIFICATE OF COMPLIANCE

SEPTEMBER 10, 2010

MIDWEST MACHINERY & SUPPLY
MILFORD, NE

THE FOLLOWING MATERIAL DELIVERED ON 9/10/10 ON BILL OF LADING NUMBER 20374 HAS BEEN INSPECTED BEFORE AND AFTER TREATMENT AND IS IN FULL COMPLIANCE WITH APPLICABLE NEBRASKA DEPARTMENT OF ROADS REQUIREMENTS FOR SOUTHERN YELLOW PINE TIMBER GUARDRAIL COMPONENTS, PRESERVATIVE TREATED WITH CHROMATED-COPPER-ARSENATE (CCA-C) TO A MINIMUM RETENTION OF .60 LBS/CU.FT. THE ACCEPTANCE OF EACH PIECE BY COMPANY QUALITY CONTROL IS INDICATED BY A HAMMER BRAND ON THE END OF EACH PIECE.

MATERIAL		CHARGE #	DATE	RETENTION	QUANTITY
6x8x14"	OCD Blockout	10-456	8/31/10	0.75	280
5½X7½X42½"	BCT Post	10-192	4/15/10	0.64	48
6x8x18"	Blockout	10-456	8/31/10	0.75	70
6x8x22"	Blockout	10-456	8/31/10	0.75	140

THIS CERTIFICATE APPLIES TO MATERIAL ORDERED FOR your order no.: 2355

FOR ANY INQUIRIES, PLEASE RETAIN THIS DOCUMENT FOR FUTURE REFERENCE.

THANK YOU FOR YOUR ORDER.

SINCERELY,

Karen Storey

SIGNED BEFORE ME THIS 10 DAY OF SEPTEMBER 2010.

Notary: Notary Public Floyd County Georgia
My Commission Expires Oct. 19, 2010

WILLIAM S. HOUSTON NOTARY PUBLIC Exp. Oct. 19, 2010 FLOYD COUNTY, GA

Phone: 706-234-1605 P.O. Box 99, Armuchee, GA 30105 Fax: 706-235-8132

Figure A-4. Southern Yellow Pine Posts, Test Nos. MGSSYP-1 and MGSSYP-2 (cont.)

PERMA-TREAT OF ILLINOIS, INC.

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

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

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

Company:

Bill of Lading:

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

Perma-Treat of Illinois, Inc

By:

Title: President

Date: 5/10/11

NOTARIZED

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

By: Sara Bond

Official Seal

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

Figure A-5. Wood Blockouts, Test Nos. MGSSYP-1 and MGSSYP-2

GREGORY HIGHWAY PRODUCTS, INC.
4100 13th St. P.O. Box 80508
Canton, Ohio 44708

MAY 14 2009

Customer: UNIVERSITY OF NEBRASKA-LINCOLN
401 CANFIELD ADMIN BLDG
P O BOX 880439
LINCOLN, NE. 68588-0439

Test Report
B.O.L. # 39963
Customer P.O. 4500204081/ 04/06/2009
Shipped to: UNIVERSITY OF NEBRASKA-LINCOLN
Project : TEST PANELS
GHP Order No 105271

DATE SHIPPED: 05/07/09

HT # code	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
4614	0.21	0.84	0.011	0.003	0.03	89432	67993	19.8	160	A	2	12GA 12FT6IN/3FT1 1/2IN WB T2

Bolts comply with ASTM A-307 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
Nuts comply with ASTM A-563 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
All other galvanized material conforms with ASTM-123 & ASTM-525
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
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
Andrew Artar
Vice President of Sales & Marketing
Gregory Highway Products, Inc.

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by Andrew Artar this 8th day of May, 2009.
Cynthia K Crawford
Notary Public, State of Ohio

NOTARIAL SEAL
STATE OF OHIO

CYNTHIA K. CRAWFORD
Notary Public, State of Ohio
My Commission Expires 09-16-2012

Figure A-6. 12-ft 6-in. Long W-Beam, Test Nos. MGSSYP-1 and MGSSYP-2

RECEIVED
OCT 0 5 2005
UNL FMP

03/09/2009 14:21 4024722022 MwRSF PAGE 01

GREGORY HIGHWAY PRODUCTS, INC.
4100 13th St. P.O. Box 80508
Canton, Ohio 44708

Test Report

Customer: UNIVERSITY OF NEBRASKA-LINCOLN
401 CANFIELD ADMIN BLDG
P O BOX 880439
LINCOLN, NE 68588-0439

B.O.L. # 15808
Customer P.O.: VERBAL JOHN ROHDE
Shipped to: UNIVERSITY OF NEBRASKA-LINCOLN
Project: STOCK
GHP Order No.: 44822

DATE SHIPPED: 09/27/05

HEAT #	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
3390	0.21	0.8	0.013	0.007	0.01	81660	62520	20.76	160		2	12GA 12FT6IN/3FT1 1/2IN WB T2

Bolts comply with ASTM A-307 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
Nuts comply with ASTM A-563 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
All other galvanized material conforms with ASTM-123 & ASTM-525
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
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

By: [signature]
Andrew Artar
Vice President of Sales and Marketing
Gregory Highway Products, Inc.

RECEIVED
OCT - 3 2005
UNL ACCOUNTING

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by Andrew Artar this 28th day of September, 2005
[signature]
Dawn R. Batton
Notary Public, State of Ohio
My Commission Expires February 24, 2008

Figure A-7. Figure A-10. 12-ft 6-in. Long W-Beam, Test No. MGSSYP-2

Trinity Highw roducts , LLC
25-8 N.E. 28th St.
Ft Worth, TX

Customer: MIDWEST MACH.& SUPPLY CO. P. O. BOX 81097 LINCOLN, NE 68501-1097	Sales Order: 1112249 Customer PO: 2188 BOL # 28104 Document # 1	Print Date: 8/4/09 Project: RESALE Shipped To: NE Use State: KS

Trinity Highway Products, LLC
Certificate Of Compliance For Trinity Industries, Inc.
NCHRP Report 350 Compliant

Pieces	Description
X 40	12/6'3/S

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

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL OTHER GALVANIZED MATERIAL CONFORMS WITH ASTM-123.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 49100 LB

State of Texas, County of Tarrant. Sworn and subscribed before me this 4th day of August, 2009

RACHEL MEDINA
Notary Public, State of Texas
My Commission Expires
July 13, 2013

Notary Public:
Commission Expires: / /

Trinity Highway Products, LLC
Certified By: Stefanie Inglet
Quality Assurance

1 of 1

Figure A-8. 6-ft 3-in. Long W-Beam, Test Nos. MGSSYP-1 and MGSSYP-2

MATERIAL TEST REPORT

ATE: 09/25/07
PAGE: 1
BILL OF LADING: 164358

LEAVIT UBE COMPANY, LLC

LEAVITT
The Tube People

Leavitt Tube Co., LLC
1717 W. 115th St.
Chicago, IL 60643

Phone: 773-239-7700
Phone: 1-800-LEAVITT
Fax: 773-239-1023
www.leavitt-tube.com
QA1002-0003 Rev. 0

CUST: STEEL & PIPE SUPPLY - CATOOSA OK
1050 FORT GIBSON ROAD
CATOOSA OK 74015

TUBING MANUFACTURED IN USA

ATTN: * Test Report Desk

106201 8027185

ITEM NO.	PIECES	SIZE, GAUGE,LENGTH	QTY. SHIPPED	CUSTOMER P.O.	ORDER NUMBER	CUSTOMER PART NBR	ASTM SPECIFICATION	GRADE
1	7	8.625-322HRB 252	147	4500088611	1015580 1.000		A500-03b	B
2	6	12X2-188HRB 480	240	4500088813	1016034 1.000		A500-03b	B
3 - 4	28	8.625-322HRB 504	1,176	4500091471	1025579 1.000		A500-03b	B
5	9	8X6-188HRB 480	360	4500092386	1029189 1.000		A500-03b	B

ITEM NO.	1	2	3	4	5
COIL NO.	395453	395532	395813	395460	391232
HEAT NO.	722562	722551	722564	722564	A13386
CORRECTED COIL					
CARBON	.210	.210	.210	.210	.220
MANGANESE	.820	.860	.820	.820	.700
PHOSPHORUS	.004	.006	.004	.004	.006
SULFUR	.006	.004	.006	.006	.003
ALUMINUM	.047	.050	.047	.047	.024
SILICON	.020	.030	.020	.020	.030
WELD TESTING	FLATTEN	FLARE	FLATTEN	FLATTEN	FLARE
YIELD STRENGTH (PSI)	47,297			52,000	55,056
TENSILE STRENGTH (PSI)	62,162			70,666	70,787
ELONGATION IN 2" (%)	29.0			31.0	27.0

Item(s)- 1 2 3 4 5 Are
Made and Melted
In The U.S.A.

I HEREBY CERTIFY THAT THE ABOVE IS CORRECT AS CONTAINED IN THE RECORDS OF THE COMPANY.

[redacted]

Figure A-9. Foundation Tube, Test Nos. MGSSYP-1 and MGSSYP-2

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: STOCK

Order Number: 1108107
Customer PO: 2132
BOL Number: 48341
Document #: 1
Shipped To: NE
Use State: KS

As of: 5/22/09

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	C49037	64,600	88,600	21.2	0.210	0.880	0.010	0.000	0.030	0.080	0.000	0.060	0.010	4
25	736G	5'/TUBE SL/.188"X6"X8"FLA	A-500			Y85912	56,500	72,980	37.0	0.210	0.770	0.009	0.006	0.016	0.010	0.00	0.020	0.001	4
6	742G	6'0 TUBE SL/.188X8X6	A-500			Y85912	56,500	72,980	37.0	0.210	0.770	0.009	0.006	0.016	0.010	0.00	0.020	0.001	4
26	764G	1/4"X24"X24"SOIL PLATE	A-36			120039	46,660	73,630	26.9	0.190	0.520	0.012	0.003	0.020	0.090	0.00	0.040	0.000	4
12	923G	BRONSTAD 98" W/O	M-180	A	2	122209	63,590	82,010	26.6	0.190	0.730	0.015	0.004	0.020	0.110	0.00	0.040	0.000	4
4	927G	10/END SHOE/EXT	M-180	B	2	A814375	59,770	78,641	27.4	0.210	0.750	0.017	0.005	0.030	0.090	0.00	0.030	0.002	4

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

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123, UNLESS OTHERWISE STATED.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH -- 49100 LB

State of Ohio, County of Allen. Sworn and subscribed before me this 22nd day of May, 2009
Notary Public: [signature]
Commission Expires 11 28 2012

Trinity Highway Products , LLC
Certified By: [signature]
Quality Assurance

4 of 7

Figure A-10. Foundation Tube, Test No. MGSSYP-2

AMERICAN TIMBER AND STEEL

FORMERLY MIDWESTERN WHOLESALERS, INC.

This is to certify that the materials shipped, as indicated, conform to the State of Nebraska specifications.

Order Number: 89198

Project Number:

QUANTITY	DESCRIPTION	CHARGE NO.	TREATMENT	TREATER
50	6x8-46" DSS SYP S4S BCT Post	38040	CCA	MWT

MWT - MIDWEST WOOD TREATING, INC., NORWALK, OH
MWT-OK - MIDWEST WOOD TREATING, INC., CHICKASHA, OK

Made & Treated in the USA. Meets AASHTO Specs M133 & M168.

AMERICAN TIMBER AND STEEL

By Heather L. Seward

Title Sales Assistant

Date April 13, 2010

NOTARIZED

Sworn to and subscribed before me

this 13th day of April 2010.

by Hope Wilhelm

Hope Wilhelm
Resident Huron County
Notary Public, State Of Ohio
My Commission Expires
March 9, 2014

American Timber And Steel Corp 4832 Plank Rd / PO Box 767 Norwalk, OH 44857 Ph: 419.668.7610 Fax: 419.663.1077

" THE TIMBER SPECIALISTS "

Figure A-11. BCT Timber Post, Test Nos. MGSSYP-1 and MGSSYP-2

425 E. O'Connor
Lima, OH

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

LINCOLN, NE 68501-1097

Sales Order: 1093497
Customer PO: 2030
BOL # 43073
Document # 1

Print Date: 6/30/08
Project: RESALE
Shipped To: NE
Use State: KS

Trinity Highway Products, LLC

Certificate Of Compliance For Trinity Industries, Inc. ** SLOTTED RAIL TERMINAL **

NCHRP Report 350 Compliant

Pieces	Description
64	5/8"X10" GR BOLT A307
192	5/8"X18" GR BOLT A307
32	1" ROUND WASHER F844
64	1" HEX NUT A563
192	WD 6'0 POST 6X8 CRT
192	WD BLK 6X8X14 DR
64	NAIL 16d SRT
64	WD 3'9 POST 5.5X7.5 BAND
32	STRUT & YOKE ASSY
128	SLOT GUARD '98
32	3/8 X 3 X 4 PL WASHER

MGSBR

Ground Strut

090453-8

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

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL OTHER GALVANIZED MATERIAL CONFORMS WITH ASTM-123.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM449 AASHTO M30, TYPE II BREAKING STRENGTH – 49100 LB

State of Ohio, County of Allen. Sworn and Subscribed before me this 30th day of June, 2008

Notary Public:
Commission Expires

Trinity Highway Products, LLC
Certified By:

2 of 4

05/04/2009 16:36 402-761-3288

Figure A-12. Strut and Yoke Assembly, Test Nos. MGSSYP-1 and MGSSYP-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: 1145215
Customer PO: 2441
BOL Number: 61905
Document #: 1
Shipped To: NE
Use State: KS

As of: 4/15/11

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
25	980G	T10/END SHOE/SLANT	A-1011-SS			A57723	49,000	64,500	34.8	0.080	0.350	0.018	0.005	0.020	0.090	0.00	0.060	0.001	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.
ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT"
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123, UNLESS OTHERWISE STATED.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
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 – 49100 LB

State of Ohio, County of Allen: Sworn and subscribed before me this 15th day of April, 2011

Notary Public:
Commission Expires 1/23/2016

STATE OF OHIO ANGELA COUNTS NOTARY PUBLIC ID# 2011NT0014 Commission Expires January 23, 2016 AUGLAIZE COUNTY

Certified By: Trinity Highway Products , LLC
Quality Assurance

2 of 2

Figure A-13. BCT Cable Anchor Assembly, Test Nos. MGSSYP-1 and MGSSYP-2

Certified Analysis

Trinity Highway Products, LLC
2548 N.E. 28th St.
Ft Worth, TX

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

LINCOLN, NE 68501-1097

Project: RESALE

Order Number: 1095199
Customer PO: 2041
BOL Number: 24481
Document #: 1
Shipped To: NE
Use State: KS

As of: 6/20/08

Qty	Part#	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
25	6G	12/6'3/S	M-180	A		84964	64,230	81,300	25.4	0.180	0.720	0.012	0.001	0.040	0.080	0.000	0.060	0.000	4
20	701A	.25X11.75X16 CAB ANC	A-36			4153095	44,900	60,800	34.0	0.240	0.750	0.012	0.003	0.020	0.020	0.000	0.040	0.002	4
10	742G	6'0 TUBE SL/.188X8X6	A-500			A8F1160	74,000	87,000	25.2	0.050	0.670	0.013	0.005	0.030	0.220	0.000	0.060	0.021	4
20	782G	5/8"X8"X8" BEAR PL/OF	A-36			6106195	46,700	69,900	23.5	0.190	0.830	0.010	0.005	0.020	0.230	0.000	0.070	0.006	4
40	907G	12/BUFFER/ROLLED	M-180	A		L0049	54,200	73,500	25.0	0.160	0.700	0.011	0.008	0.020	0.200	0.000	0.100	0.000	4

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

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

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

State of Texas, County of Tarrant. Sworn and subscribed before me this 20th day of June, 2008

Notary Public:
Commission Expires

RACHEL R. MEDINA
Notary Public
State of Texas
My Commission Expires

Trinity Highway Products, LLC
Certified By: Stefanie Orr...

Figure A-14. Anchor Bracket Assembly, Test Nos. MGSSYP-1 and MGSSYP-2

PAGE 52/52

Certified Analysis

Trinity Highway Products , LLC
2548 N.E. 28th St.
Ft Worth, TX
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097
Project: RESALE

Order Number: 1095199
Customer PO: 2041
BOL Number: 34481
Document #: 1
Shipped To: NE
Use State: KS

As of: 6/10/08

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
25	60	150608	M-180	A		89564	60,[illegible]	81,300	25.4	0.180	0.730	0.012	0.001	0.040	0.100	0.100	0.060	0.000	4
20	701A	.25X11.75X18 CAB ANC	A-36			4133093	44,900	68,000	34.0	0.240	0.730	0.012	0.020	0.020	0.020	0.000	0.040	0.002	4
10	749G	6'0 TUBE SL/.188X8X6	A-500			A8P1140	58,000	87,000	21.5	0.058	0.670	0.013	0.005	0.030	0.320	0.000	0.060	0.021	4
20	782G	5/8"X8"X8" BEAR PL/OF	A-36			6106195	46,700	69,900	33.5	0.190	0.830	0.010	0.005	0.020	0.330	0.060	0.030	0.066	4
40	907G	12/6'3/S/R/ROLLED	M-180	A		L0949	54,205	73,500	25.0	0.160	0.780	0.011	0.008	0.020	0.200	0.000	0.100	0.003	4

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

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

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

State of Texas, County of Tarrant. Sworn and subscribed before me this 20th day of June, 2008

Notary Public:
Commission Expires

RACHEL R. MEDINA
Notary Public
State of Texas
My Commission Expires

Trinity Highway Products , LLC
Certified By:

Stefanie Oneal

MIDWEST MACHINERY
402-761-3288
06/04/2009 16:36

Figure A-15. Anchor Cable Bearing Plate, Test Nos. MGSSYP-1 and MGSSYP-2

905 ATLANTIC STREET, NORTH KANSAS CITY, MO 64116 1-816-474-5210 TOLL FREE 1-800-892-TUBE

STEEL VENTURES, LLC dba EXLTUBE

CERTIFIED TEST REPORT

Customer:	Size:	Spec No:	Date:
SPS - New Century 401 New Century Parkway New Century KS 66031	02.875	ASTM A500-07, A53B-07	06/22/2009
	Gauge: .154	Grade: A500B,C, A53BNT	Customer Order No: 4500104158
			B/L No: 81163893

Heat No	Yield P.S.I.	Tensile P.S.I.	Elongation % 2 Inch
280638	61,500	88,400	23.00

SLEEVE MAT
CRT

Heat No	C	MN	P	S	SI	CU	NI	CR	MO	V
280638	0.040	0.330	0.010	0.000	0.034	0.088	0.039	0.042	0.015	0.003

We hereby certify that the above material was manufactured in the U.S.A and that all test results shown in this report are correct as contained in the records of our company. All testing and manufacturing is in accordance to A.S.T.M. parameters encompassed within the scope of the specifications denoted in the specification and grade titles above.

BNT - Grade B not tested - meets tensile properties ONLY.

STEEL VENTURES, LLC dba EXLTUBE

Steve Frerichs
Quality Assurance Manager

104158

Figure A-16. BCT Post Sleeve, Test Nos. MGSSYP-1 and MGSSYP-2

11/04/2009 06:10 402-761-3288 MIDWEST MACHINERY PAGE 04/10

1009418

Republic

1807 EAST 28TH ST.
PHONE: 330-438-5694
LORAIN, OH 44055
FAX: 330-438-5695

CERTIFICATE OF TESTS
REPUBLIC ENGINEERED PRODUCTS
May 6, 2009
PAGE 1 OF 2

PURCHASE ORD:	130063M	PURCHASE ORDER DATE:	4/1/2009
PART NUMBER:	1009418	ACCOUNT NUMBER:	5580-3007-01
ORDER NUMBER:	1408019 - 01	SCHEDULE:	5063-86
HEAT:	5072014	REVISION:	1

CHARGE ADDRESS — SHIP TO

TRINITY INDUSTRIES INC
HIGHWAY SAFETY PRODUCTS INC
P O BOX 568887 4TH FLOOR
DALLAS, TX 75356-0887

TRINITY INDUSTRIES INC
C/O SCS METALS PREP
5806 STERLING AVE
MAPLE HEIGHTS, OH 44137

MATERIAL DESCRIPTION

HOT ROLLED STEEL COILS CARBON AISI-1015 AK AL KILLED FINE GRAIN COLD WORKING QUALITY TEST REPORTS OF MECHANICAL PROPERTIES FOR INFO ONLY EXTRA TESTING
SIZE: RDS .6390 DIAM X COIL
RDS 16.2306MM DIAM X COIL

LADLE CHEMISTRY %

C	MN	P	S	SI	CU	NI	CR
0.15	0.47	0.006	0.003	0.09	0.05	0.06	0.05
V	MO	SN	AL	CB	N		
0.009	0.02	0.005	0.046	0.000	0.0063		

CALCULATED TESTS

REDUCTION RATIO 112.1 TO 1

AUSTENITIC GRAIN SIZE 5 OR FINER BASED ON A TOTAL ALUMINUM CONTENT EQUAL TO OR GREATER THAN .020% PER ASTM A29.

SEMI - FINISHED RESULTS

FINISHED SIZE RESULTS

TENSILE TEST STANDARD FORMAT

	TENSILE PSI	YIELD(0.2%) PSI	RA %	E %
PCE 2728	63100	44200	65.4	39.0

HARDNESS TEST ASTM E10/ASTM A370 HBW AS-RLD/CD RBW

	MID-RADIUS
PCE 2723	116

NOTES

CHEMICAL ANALYSIS CONFORMS TO APPLICABLE SPECS: ASTM E415, LBL10129, LBL10130, ASTM E1019, LBL10150, LBL10114, AND ASTM E1085, LBL10184, LBL10189.

REPUBLIC ENGINEERED PRODUCTS HEREBY CERTIFY THAT THE MATERIAL LISTED HEREIN HAS BEEN INSPECTED AND TESTED IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE GOVERNING SPECIFICATIONS AND BASED UPON THE RESULTS OF SUCH INSPECTION AND TESTING HAS BEEN APPROVED FOR CONFORMANCE TO THE SPECIFICATIONS.

CERTIFICATE OF TESTS SHALL NOT BE REPRODUCED EXCEPT IN FULL.

ALL TESTING HAS BEEN PERFORMED USING THE CURRENT REVISION OF THE TESTING SPECIFICATIONS.

RECORDING OF FALSE, FICTITIOUS OR FRAUDULENT STATEMENTS OR ENTRIES ON THIS DOCUMENT MAY BE PUNISHED AS A FELONY UNDER FED STATUES TITLE 18 CHAPTER 47.

THE MATERIAL WAS NOT EXPOSED TO MERCURY OR ANY METAL ALLOY THAT IS LIQUID AT AMBIENT TEMPERATURE DURING PROCESSING OR WHILE IN OUR POSSESSION.

NO WELD OR WELD REPAIR WAS PERFORMED ON THIS MATERIAL.

R. A. SZELIGA
MANAGER TECH. SERVICES
R.A. Szeliga

BY HILDA BEGUE

Figure A-17. ⅝-in. x 1¼-in. Bolts, Test Nos. MGSSYP-1 and MGSSYP-2

11/04/2009 06:10 402-761-3288 MIDWEST MACHINERY PAGE 02/10

TRINITY HIGHWAY PRODUCTS, LCC.
Plant #55
425 E. O' CONNOR AVENUE
Lima, OH 45801
419-227-1296

MATERIAL CERTIFICATION

CUSTOMER: STOCK	DATE: JULY29, 2009
	INVOICE #
	LOT NUMBER: 090703B
PART NUMBER: 3360G	QUANTITY: 110,765
DESCRIPTION: 5/8"x 1 ¼" GR BOLT	DATE SHIPPED:
SPECIFICATIONS: ASTM A307-A /A153	HEAT#: 5072014

MATERIAL CHEMISTRY

C	MN	P	S	SI	NI	CR	MO	CU	SN	V	AL	N	B	TI	NB
.15	.47	.006	.003	.09	.06	.05	.02	.05	.005	.000	.046	.0063	.000	.000	.000

PLATING AND/OR PROTECTIVE COATING

HOT DIP GALVANIZED (OZ. PER SQ. FT.)		1.25 Avg.

****THIS PRODUCT WAS MANUFACTURED IN THE UNITED STATES OF AMERICA****

THE MATERIAL USED IN THIS PRODUCT WAS MELTED AND MANUFACTURED IN THE U.S.A

WE HEREBY CERTIFY THAT TO THE BEST OF OUR KNOWLEDGE ALL INFORMATION CONTAINED HEREIN IS CORRECT.

TRINITY HIGHWAY PRODUCTS, LLC.

STATE OF OHIO, COUNTY OF ALLEN
SWORN AND SUBSCRIBED BEFORE ME
THIS 29TH DAY OF JULY, 2009

NOTARY PUBLIC

425 E. O 'CONNOR AVENUE LIMA, OH 45801 419-227-1296

Figure A-18. ⅝-in. x 1¼-in. Bolts, Test Nos. MGSSYP-1 and MGSSYP-2 (cont.)

11/04/2009 06:10 402-761-3288 MIDWEST MACHINERY PAGE 09/10

Rec'd 6-7-09

Republic

3049 LAKESHORE-GATE 6 BUFFALO, NY 14219
PHONE: 330-438-5694 FAX: 330-438-5695

CERTIFICATE OF TESTS REPUBLIC ENGINEERED PRODUCTS June 3, 2009
PAGE 1 OF 2

PURCHASE ORD:	130969M	PURCHASE ORDER DATE:	4/15/2009
PART NUMBER:	100944B	ACCOUNT NUMBER:	5550-3007-01
ORDER NUMBER:	1409650 - 01	SCHEDULE:	8877-68
HEAT:	6072080	REVISION:	1

CHARGE ADDRESS — SHIP TO

TRINITY INDUSTRIES INC
HIGHWAY SAFETY PRODUCTS INC
P O BOX 568887 4TH FLOOR
DALLAS, TX 75356-8887

TRINITY INDUSTRIES INC
C/O BCS METALS PREP
5800 STERLING AVE
MAPLE HEIGHTS, OH 44137

MATERIAL DESCRIPTION

HOT ROLLED STEEL COILS CARBON AISI-1015 AK AL KILLED FINE GRAIN COLD WORKING QUALITY TEST REPORTS OF MECHANICAL PROPERTIES FOR INFO ONLY EXTRA TESTING
SIZE: RDS 1.2190 DIAM X COIL
RDS 30.9626MM DIAM X COIL

LADLE CHEMISTRY %

C	MN	P	S	SI	CU	NI	CR
0.14	0.45	0.013	0.003	0.16	0.05	0.05	0.07
V	MO	SN	AL	CB	N		
0.002	0.02	0.006	0.037	0.000	0.0060		

CALCULATED TESTS

REDUCTION RATIO 39.1 TO 1

AUSTENITIC GRAIN SIZE 5 OR FINER BASED ON A TOTAL ALUMINUM CONTENT EQUAL TO OR GREATER THAN .020% PER ASTM A29.

SEMI - FINISHED RESULTS

FINISHED SIZE RESULTS

TENSILE TEST STANDARD FORMAT

	TENSILE PSI	YIELD(0.2%) PSI	RA %	E %
TCB 01	64530	38930	64.2	33.0

HARDNESS TEST ASTM E10/ASTM A370 HBW AS-RLD/CD HBW
MID-RADIUS
AVG 112

NOTES

REPUBLIC ENGINEERED PRODUCTS HEREBY CERTIFY THAT THE MATERIAL LISTED HEREIN HAS BEEN INSPECTED AND TESTED IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE GOVERNING SPECIFICATIONS AND BASED UPON THE RESULTS OF SUCH INSPECTION AND TESTING HAS BEEN APPROVED FOR CONFORMANCE TO THE SPECIFICATIONS.

CERTIFICATE OF TESTS SHALL NOT BE REPRODUCED EXCEPT IN FULL.

ALL TESTING HAS BEEN PERFORMED USING THE CURRENT REVISION OF THE TESTING SPECIFICATIONS.

RECORDING OF FALSE, FICTITIOUS OR FRAUDULENT STATEMENTS OR ENTRIES ON THIS DOCUMENT MAY BE PUNISHED AS A FELONY UNDER FED STATUTES TITLE 18 CHAPTER 47.

THE MATERIAL WAS NOT EXPOSED TO MERCURY OR ANY METAL ALLOY THAT IS LIQUID AT AMBIENT TEMPERATURE DURING PROCESSING OR WHILE IN OUR POSSESSION.

NO WELD OR WELD REPAIR WAS PERFORMED ON THIS MATERIAL.

THE RESULTS REPORTED RELATE ONLY TO THE ITEMS TESTED

MELTED AND MANUFACTURED IN THE U.S.A.

R. A. BULLOCK BY HILDA BRGUZ
DIRECTOR QUAL. ASSURANCE
R A Bullock

Figure A-19. ⅝ in. Nut, Test Nos. MGSSYP-1 and MGSSYP-2

11/04/2009 06:10 402-761-3288 MIDWEST MACHINERY PAGE 07/10

Trinity Metals Laboratory
A DIVISION OF TRINITY INDUSTRIES
4001 IRVING BLVD. 75247 - P.O. BOX 568887
DALLAS, TX 75356-8887
Phone: 214.589.7591 FAX: 214.589.7594

NVLAP LAB CODE 200084-0

Lab No: 9080059F
SUE HENLINE
TRINITY HWY PRODUCTS, LLC #55
ROLLFORM
LIMA, OH 45801

Received Date: 08/07/2009
Heat Code:
Heat Number: 5072060
PO or Work Order: 55-80083
Test Spec: F606 ASTM METHODS
Other Information: Lot # 080717N2

Completion Date: 08/10/2009
Weld Spec:
Material Type: A 563 A
Material Size: 5/8" GR Nuts 3340B

HARDNESS TEST:

Hardness Type: HARDNESS ROCKWELL BW
Hardness Location: SURFACE of WRENCH FLAT - A
Hardness Average: 88.5

Measured Value	Measured Amt
Measured Value	89
Measured Value	88

PASSED

Hardness Type: HARDNESS ROCKWELL BW
Hardness Location: SURFACE of WRENCH FLAT - B
Hardness Average: 92

Measured Value	Measured Amt
Measured Value	92
Measured Value	92

PASSED

Hardness Type: HARDNESS ROCKWELL BW
Hardness Location: SURFACE of WRENCH FLAT - C
Hardness Average: 87.5

Measured Value	Measured Amt
Measured Value	88
Measured Value	87

PASSED

Hardness Type: HARDNESS ROCKWELL BW
Hardness Location: SURFACE of WRENCH FLAT - D
Hardness Average: 89.5

Measured Value	Measured Amt
Measured Value	90
Measured Value	89

PASSED

We certify the above results to be a true and accurate representation of the sample(s) submitted. Alteration or partial reproduction of this report will void certification. NVLAP Certificate of Accreditation effective through 12-31-09. This report may not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the federal government.

Lab Director, Michael B. Beaton, PE

Page 1 of 2

Figure A-20. ⅝ in. Nut, Test Nos. MGSSYP-1 and MGSSYP-2 (cont.)

11/04/2009 06:10 402-761-3288 MIDWEST MACHINERY

Trinity Metals Laboratory
A DIVISION OF TRINITY INDUSTRIES
4001 IRVING BLVD, 75247 - P.O. BOX 568887
DALLAS, TX 75356-8887
Phone: 214.589.7591 FAX: 214.589.7594

NVLAP LAB CODE 200864-0

Lab No: 9080059F
SUE HENLINE
TRINITY HWY PRODUCTS, LLC #55
ROLLFORM
LIMA, OH 45801

Received Date: 08/07/2009
Heat Code:
Heat Number: 5072080
PO or Work Order: 55-50083
Test Spec: F606 ASTM METHODS
Other Information: Lot # 090717N2

Completion Date: 08/10/2009
Weld Spec:
Material Type: A 563 A
Material Size: 5/8" GR Nuts 3340B

PASSED

Hardness Type: HARDNESS ROCKWELL BW
Hardness Location: SURFACE of WRENCH FLAT - E
Hardness Average: 88

Measured Value	Measured Amt
Measured Value	88
Measured Value	88

OTHER TEST:

Type: NUT PROOF LOAD — Quantity amount: 5
Samples PASSED proof loads of 16,950 LBS.

Type: HEAD MARKINGS — Quantity amount: 1
TRN L

We certify the above results to be a true and accurate representation of the sample(s) submitted. Alteration or partial reproduction of this report will void certification. NVLAP Certificate of Accreditation effective through 12-31-09. This report may not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the federal government.

Lab Director, Michael S. Benton, PE

Page 2 of 2

Figure A-21. ⅝ in. Nut, Test Nos. MGSSYP-1 and MGSSYP-2 (cont.)

11/04/2009 06:10 402-761-3288 MIDWEST MACHINERY PAGE 06/10

TRINITY HIGHWAY PRODUCTS, LLC.
425 E. O'CONNOR AVENUE
LIMA, OHIO 45801
419-227-1296

MATERIAL CERTIFICATION

CUSTOMER: STOCK	DATE: JULY 27, 2009
	INVOICE #:
	LOT #: 090717N2
PART NUMBER: 3340G	QUANTITY: 62,000
DESCRIPTION: 5/8" GR NUT	DATE SHIPPED
SPECIFICATIONS: ASTM A563-A/A153	HEAT 5072080

MATERIAL CHEMISTY

C	MN	P	S	SI	CU	NI	CR	V	MO	SN	AL	CB	N		
.14	.45	.013	.003	.14	.05	.05	.07	.002	.02	.006	.037	.000	.006		

PLATING AND/OR PROTECTIVE COATING

HOT DIP GALVANIZING (OZ. PER SQ. FT.)	2.81 AVG.

****THIS PRODUCT WAS MANUFACTURED IN THE UNITED STATES OF AMERICA***

THE MATERIAL USED IN THIS PRODUCT WAS MELTED AND MANUFACTURED IN THE U.S.A.

WE HEREBY CERTIFY THAT TO THE BEST OF OUR KNOWLEDGE ALL INFORMATION CONTAINED HEREIN IS CORRECT.

TRINITY HIGHWAY PRODUCTS, LLC.

STATE OF OHIO, COUNTY OF ALLEN
SWORN AND SUBSCRIBED BEFORE ME
THIS 27TH DAY OF JULY, 2009

NOTARY PUBLIC

425 E. O'CONNOR AVENUE LIMA, OHIO 45801 419-227-1296

Figure A-22. ⅝ in. Nut, Test Nos. MGSSYP-1 and MGSSYP-2 (cont.)

3340G

TRINITY HIGHWAY PRODUCTS, LLC.
425 E. O'CONNOR AVENUE
LIMA, OHIO 45801
419-227-1296

MATERIAL CERTIFICATION

CUSTOMER: STOCK	DATE: MARCH 31, 2011
	INVOICE #:
	LOT #: 110318N2
PART NUMBER: 3340G	QUANTITY: 106,000
DESCRIPTION: 5/8" GR NUT	DATE SHIPPED
SPECIFICATIONS: ASTM A563-A/A153	HEAT # 20131470 & 20131460

MATERIAL CHEMISTY

C	MN	P	S	SI	NI	CR	MO	CU	SN	V	AL	N	B	TI	NB
.08	.35	.007	.004	.07	.05	.05	.02	.09	.007	.004	.023	.008	.0001	.001	.001
09	.36	.008	.004	.05	.04	.06	.01	.09	.006	.004	.025	.006	.0002	.001	.001

PLATING AND/OR PROTECTIVE COATING

HOT DIP GALVANIZING (OZ. PER SQ. FT.)	2.52 AVG.

****THIS PRODUCT WAS MANUFACTURED IN THE UNITED STATES OF AMERICA***

THE MATERIAL USED IN THIS PRODUCT WAS MELTED AND MANUFACTURED IN THE U.S.A.

WE HEREBY CERTIFY THAT TO THE BEST OF OUR KNOWLEDGE ALL INFORMATION CONTAINED HEREIN IS CORRECT.

TRINITY HIGHWAY PRODUCTS, LLC.

STATE OF OHIO, COUNTY OF ALLEN
SWORN AND SUBSCRIBED BEFORE ME
THIS 31ST DAY OF MARCH, 2011

Sheri L. Dorig/Mann NOTARY PUBLIC

425 E. O'CONNOR AVENUE LIMA, OHIO 45801 419-227-1296

Figure A-23. ⅝ in. Nut, Test No. MGSSYP-2

rinity Metals Laboratory
A DIVISION OF TRINITY INDUSTRIES
4001 IRVING BLVD. 75247 - P.O. BOX 568887
DALLAS, TX 75356-8887
Phone: 214.589.7591 FAX: 214.589.7594

NVLAP LAB CODE 200054-0

Lab No: 11040021F

KEITH HAMBURG
TRINITY HWY PRODUCTS, LLC #55
ROLLFORM
LIMA, OH 45801

Received Date: 04/04/2011
Heat Code:
Heat Number: 20131460 & 20131470
PO or Work Order: 110318N2
Test Spec: F606 ASTM METHODS
Other Information: 55-61587

Completion Date: 04/04/2011
Weld Spec:
Material Type: A 563 A
Material Size: 5/8" GR Nut

HARDNESS TEST:

Hardness Type: HARDNESS ROCKWELL BW
Hardness Location: Surface of Wrench Flat A
Hardness Average: 86.5

Measured Value	Measured Amt
Measured Value	86
Measured Value	87

PASSED

Hardness Type: HARDNESS ROCKWELL BW
Hardness Location: Surface of Wrench Flat B
Hardness Average: 84

Measured Value	Measured Amt
Measured Value	84
Measured Value	84

PASSED

Hardness Type: HARDNESS ROCKWELL BW
Hardness Location: Surface of Wrench Flat C
Hardness Average: 87

Measured Value	Measured Amt
Measured Value	87
Measured Value	87

PASSED

Hardness Type: HARDNESS ROCKWELL BW
Hardness Location: Surface of Wrench Flat D
Hardness Average: 87.5

Measured Value	Measured Amt
Measured Value	87
Measured Value	88

PASSED

4-04-11 CG

We certify the above results to be a true and accurate representation of the sample(s) submitted. Alteration or partial reproduction of this report will void certification. NVLAP Certificate of Accreditation effective through 12-31-11. This report may not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the federal government.

Lab Director, Michael S. Beaton, PE

Page 1 of 2

Figure A-24. ⅝ in. Nut, Test No. MGSSYP-2 (cont.)

Trinity Metals Laboratory
A DIVISION OF TRINITY INDUSTRIES
4001 IRVING BLVD. 75247 - P.O. BOX 568887
DALLAS, TX 75356-8887
Phone: 214.589.7591 FAX: 214.589.7594

NVLAP LAB CODE 200854-0

Lab No: 11040021F
KEITH HAMBURG
TRINITY HWY PRODUCTS, LLC #55
ROLLFORM
LIMA, OH 45801

Received Date: 04/04/2011
Heat Code:
Heat Number: 20131460 & 20131470
PO or Work Order: 110318N2
Test Spec: F606 ASTM METHODS
Other Information: 55-61597

Completion Date: 04/04/2011
Weld Spec:
Material Type: A 563 A
Material Size: 5/8" GR Nuts

PASSED

Hardness Type: HARDNESS ROCKWELL BW
Hardness Location: Surface of Wrench Flat E
Hardness Average: 86.5

Measured Value	Measured Amt
Measured Value	87
Measured Value	86

OTHER TEST:

Type: NUT PROOF LOAD (to 30K) — Quantity amount: 5
Samples PASSED proof loads of 16,950 lbs.

Type: HEAD MARKINGS — Quantity amount: 1
TRN N

We certify the above results to be a true and accurate representation of the sample(s) submitted. Alteration or partial reproduction of this report will void certification. NVLAP Certificate of Accreditation effective through 12-31-11. This report may not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the federal government.

Lab Director, Michael S. Bexton, PE

Page 2 of 2

Figure A-25. ⅝ in. Nut, Test No. MGSSYP-2 (cont.)

06/04/2009 16:36 402-761-3288 MIDWEST MACHINERY PAGE [illegible]

08/14/2008 12:38 KREMER_STEEL → 17086814433 NO.807 [illegible]

#6

Republic Engineered Products [illegible] EAST [illegible] ST. LORAIN, [illegible]
PHONE: 330-438-5494 FAX: 330-438-[illegible]

CERTIFICATE OF TESTS REPUBLIC ENGINEERED PRODUCTS August 5, 2008
PAGE 1

P 1

CUSTOMER ORD: 17438		PURCHASE ORDER DATE:	6/20/2008
PART NUMBER: 40764		ACCOUNT NUMBER:	[illegible]
ORDER NUMBER: 1390626 - 01		SCHEDULE:	5125-85
HEAT: 7261611		REVISION:	1

CHARGE ADDRESS ---- SHIP TO

KREMER STEEL COMPANY LLC
1880 N 25TH AVE
MELROSE PARK, IL 60160

KREMER STEEL COMPANY LLC
[illegible]
C/O MID WEST FABRICATING
313 JOHNS ST
AMANDA, OH 43102

MATERIAL DESCRIPTION
HOT ROLLED STEEL COILS CARBON AISI-1018 SI KILLED FINE GRAIN COLD WORKING QUALITY
SIZE: [illegible] .5790 DIAM X COIL
[illegible] 14.[illegible] DIAM X COIL

LADLE CHEMISTRY %

C	MN	P	S	SI	CU	NI	CR
0.18	0.82	0.008	0.003	0.25	0.04	0.06	0.10
V	MO	SN	AL	CB	N		
0.002	0.04	0.002	0.042	0.001	0.0040		

CALCULATED TESTS
REDUCTION RATIO 137.3 TO 1

AUSTENITIC GRAIN SIZE 5 OR FINER BASED ON A TOTAL ALUMINUM CONTENT EQUAL TO OR GREATER THAN .020% PER ASTM A29.

SEMI - FINISHED RESULTS

FINISHED SIZE RESULTS

NOTES
CHEMICAL ANALYSIS CONFORMS TO APPLICABLE SPECS: ASTM E415, [illegible], [illegible], ASTM E1019, [illegible], [illegible], AND ASTM E1086, [illegible], [illegible].

REPUBLIC ENGINEERED PRODUCTS HEREBY CERTIFY THAT THE MATERIAL LISTED HEREIN HAS BEEN INSPECTED AND TESTED IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE GOVERNING SPECIFICATIONS AND BASED UPON THE RESULTS OF SUCH INSPECTION AND TESTING HAS BEEN APPROVED FOR CONFORMANCE TO THE SPECIFICATIONS.

CERTIFICATE OF TESTS SHALL NOT BE REPRODUCED EXCEPT IN FULL.

ALL TESTING HAS BEEN PERFORMED USING THE CURRENT REVISION OF THE TESTING SPECIFICATIONS.

RECORDING OF FALSE, FICTITIOUS OR FRAUDULENT STATEMENTS OR ENTRIES ON THIS DOCUMENT MAY BE PUNISHED AS A FELONY UNDER THE STATUTE TITLE 18 CHAPTER 47.

THE MATERIAL WAS NOT EXPOSED TO MERCURY OR ANY METAL ALLOY THAT IS LIQUID AT AMBIENT TEMPERATURE DURING PROCESSING OR WHILE IN OUR POSSESSION.

NO WELD OR WELD REPAIR WAS PERFORMED ON THIS MATERIAL.

THE RESULTS REPORTED RELATE ONLY TO THE ITEMS TESTED

SOURCE INFORMATION
MELT SOURCE: LORAIN BILLET MELT COUNTRY: U.S.A HOT ROLL SOURCE: LORAIN [illegible], U.S.A
MELT METHOD: BOF BILLET RED. RATIO: 137.3

END OF DATA CC END OF DATA

[illegible] SHIP TO	1 COPY	ATTENTION [illegible]	[illegible]
[illegible] SHIPMENT	1 COPY	PRINTED AT SHIPPING AREA	
[illegible]	1 COPY		

[illegible] A. [illegible]
[illegible] TECH. SERVICES
[signature]

BY [illegible]

Figure A-26. ⅝ in. x 10 in. Bolt, Test Nos. MGSSYP-1 and MGSSYP-2

06/04/2009 16:36 402-761-3288 MIDWEST MACHINERY

Mid West Fabricating Company
Rockmill Division
3115 West Fair Avenue
Lancaster, OH 43130
(740) 681-4411

Lab Test Report

Data Results

Date:	24-Sep-08	*Sample 1:*	2.65
Part Number:	10-5	*Sample 2:*	2.84
Description:	10" POST BOLT W/6" THRD	*Sample 3:*	2.63
Lot Number:	85217	*Sample 4:*	2.95
Customer:	Trinity	*Sample 5:*	3.28
Test Type:	Permiscope	*Sample 6:*	2.19
Heat Number:	7261611	*Sample 7:*	3.12
Processor:	Columbus	*Sample 8:*	2.64
Testing Standard:	ASTM=A153-A153/98	*Sample 9:*	3.50
Requirement:	1.77 Mil	*Sample 10:*	3.71
Sample Qty:	20	*Sample 11:*	2.16
Disposition:	Ship	*Sample 12:*	2.73
Ship ID:	X99	*Sample 13:*	3.01
		Sample 14:	2.70
		Sample 15:	2.86
		Sample 16:	3.28
		Sample 17:	3.12
		Sample 18:	2.39
		Sample 19:	2.44
		Sample 20:	2.58
		Average:	2.94

✓ Conformance

Non-Conformance

Performed By: D.Smith

This report shall not be reproduced, except in full, without the written approval of Mid West Fabricating Company's Quality Department.

Figure A-27. ⅝ in. x 10 in. Bolt, Test Nos. MGSSYP-1 and MGSSYP-2 (cont.)

06/04/2009 16:36 402-761-3288 MIDWEST MACHINERY

Mid West Fabricating Company
Rockmill Division
3115 West Fair Avenue
Lancaster, OH 43130
(740) 681-4411

Lab Test Report

Date:	24-Sep-08
Part Number:	10-6
Description:	10" POST BOLT W/6" THRD
Lot Number:	85217
Customer:	Trinity
Test Type:	Rockwell
Heat Number:	7261611
Processor:	Columbus
Testing Standard:	ASTM=E18-98
Requirement:	69-100 "B"
Sample Qty:	5
Disposition:	Scrap
Ship ID:	

Data Results

Sample 1:	85.20
Sample 2:	86.80
Sample 3:	85.40
Sample 4:	85.00
Sample 5:	86.60
Sample 6:	0.00
Sample 7:	0.00
Sample 8:	0.00
Sample 9:	0.00
Sample 10:	0.00
Sample 11:	0.00
Sample 12:	0.00
Sample 13:	0.00
Sample 14:	0.00
Sample 15:	0.00
Sample 16:	0.00
Sample 17:	0.00
Sample 18:	0.00
Sample 19:	0.00
Sample 20:	0.00
Average:	85.80

✔ Conformance

Non-Conformance

Performed By: D.Smith

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Figure A-28. ⅝ in. x 10 in. Bolt, Test Nos. MGSSYP-1 and MGSSYP-2 (cont.)

06/04/2009 16:36 402-761-3288 MIDWEST MACHINERY

Mid West Fabricating Company
Rockmill Division
3115 West Fair Avenue
Lancaster, OH 43130
(740) 681-4411

Lab Test Report

Date:	24-Sep-08
Part Number:	10-6
Description:	10" POST BOLT W/6" THRD
Lot Number:	85217
Customer:	Trinity
Test Type:	Rockwell
Heat Number:	7261611
Processor:	Columbus
Testing Standard:	ASTM=F606-95B
Requirement:	13,590 lbf
Sample Qty:	5
Disposition:	Scrap
Ship ID:	

Data Results

Sample 1:	16,850.00
Sample 2:	17,370.00
Sample 3:	17,190.00
Sample 4:	17,500.00
Sample 5:	17,300.00
Sample 6:	0.00
Sample 7:	0.00
Sample 8:	0.00
Sample 9:	0.00
Sample 10:	0.00
Sample 11:	0.00
Sample 12:	0.00
Sample 13:	0.00
Sample 14:	0.00
Sample 15:	0.00
Sample 16:	0.00
Sample 17:	0.00
Sample 18:	0.00
Sample 19:	0.00
Sample 20:	0.00
Average:	17,242.00

✓ Conformance

Non-Conformance

Performed By: D.Smith

Figure A-29. ⅝ in. x 10 in. Bolt, Test Nos. MGSSYP-1 and MGSSYP-2 (cont.)

06/14/11 03:40 PM 315-689-3999 via VSI-FAX Page 2 of 7 #2120

INSPECTION CERTIFICATE

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

CUSTOMER NAME: BENNETT BOLT WORKS

CUSTOMER P.O. : 6008015

INVOICE #: 945308 **DATE SHIPPED:** 2/3/11

LOT #: 21306

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

	SPECIFICATION	ACTUAL	
TENSILE RESULTS:	60,000 min.	77,730	75,314
		77,787	75,367
HARDNESS RESULTS:	SPECIFICATION 100 MAX	88.80	85.46
		90.83	86.83

COATING: ASTM SPECIFICATION F2329 HOT DIP GALVANIZE

STEEL SUPPLIER: NUCOR, NUCOR

HEAT NO. NF1010253801, NF1020257001

QUANTITY AND DESCRIPTION:

500 PCS 5/8" X 22" GUARD RAIL BOLT

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE U.S.A.. WE FURTHER CERTIFY 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 REQUIREMENTS PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS 4 DAY OF February 20 11
Diana Ahsmann

Linda McComas 2/4/11
APPROVED SIGNATORY DATE

Figure A-30. ⅝ in. x 22 in. Bolts, Test Nos. MGSSYP-1 and MGSSYP-2

06/14/11 03:40 PM 315-689-3999 via VSI-FAX Page 3 of 7 #2120

Mill Certification Details

NUCOR

NUCOR CORPORATION
NUCOR STEEL NEBRASKA

Mill Certification Details - 8/19/2010 8:47 AM

Customer: KING STEEL CORP - GRAND BLANC
Bill of Lading #: 178801
Chief Metallurgist : Jim Hill **Date :** 7/13/2010
Heat # : NF1010253801 **Tag # :** NF1011097050
Product : WIRE **Size :** .594-19/32 Wire Rod
Grade: 1010 **Division :** Norfolk, NE
Comments : **Billet Heat #:** NF10102538

Chemical Properties -Wt.%

0.11 0.58 0.20 0.030 0.015 0.27 0.09 0.09 0.02 0.032 0.000 0.000 0.000 0.011 0.0005

0.0000 0.001

Physical Properties

Tensile:
Yield:
Elongation (in 8 inches):
Elongation (in 2 inches):

The testing was conducted in accordance with the requirements of this specification. All melting and manufacturing processes were performed in the United States of America.

Jim Hill
Division Metallurgist

Figure A-31. ⅝ in. x 22 in. Bolts, Test Nos. MGSSYP-1 and MGSSYP-2 (cont.)

06/14/11 03:40 PM 315-689-3999 via VSI-FAX Page 5 of 7 #2120

Mill Certification Details

NUCOR

NUCOR CORPORATION
NUCOR STEEL NEBRASKA

Mill Certification Details - 8/5/2010 11:22 AM

Customer: KRUEGER & CO - ELMHURST
Bill of Lading #: 179281
Chief Metallurgist: Jim Hill **Date:** 7/13/2010
Heat #: NF10202570D1 **Tag #:** NF1011097111
Product: WIRE **Size:** .594-19/32 Wire Rod
Grade: 1010 **Division:** Norfolk, NE
Comments: **Billet Heat #:** NF10202570

Chemical Properties -Wt.%

0.12 0.50 0.20 0.032 0.012 0.23 0.07 0.09 0.04 0.003 0.000 0.000 0.000 0.009 0.0002

0.0000 0.001

Physical Properties

Tensile:
Yield:
Elongation (in 8 inches):
Elongation (in 2 inches):

The testing was conducted in accordance with the requirements of this specification. All melting and manufacturing processes were performed in the United States of America.

Jim Hill
Division Metallurgist

Figure A-32. ⅝ in. x 22 in. Bolts, Test Nos. MGSSYP-1 and MGSSYP-2 (cont.)

10-05-09;04:15PM;Bennett-Bolt-Works   Midwest Machinery :3156893999   # 5/ 10

INSPECTION CERTIFICATE

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

CUSTOMER NAME: BENNETT BOLT WORKS

CUSTOMER P.O. : 6006874

INVOICE #: 941845   **DATE SHIPPED:** 7/24/09

LOT #: 19934

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

	SPECIFICATION	ACTUAL			
TENSILE RESULTS:	60,000 min.	76,513	75,053	77,617	76,876
		76,796	74,899	77,828	76,938
HARDNESS RESULTS:	100 MAX	81.22	88.80	86.98	81.62
		81.80	85.25	87.10	81.00

COATING: ASTM SPECIFICATION F2329 HOT DIP GALVANIZE

STEEL SUPPLIER: NUCOR, NUCOR, NUCOR, NUCOR

HEAT NO. 848653, 749237, 849289, 848672

QUANTITY AND DESCRIPTION:

600 PCS 5/8" X 22" GUARD RAIL BOLT

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE U.S.A. WE FURTHER CERTIFY 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 REQUIREMENTS PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS
27th DAY OF July 2009
Lisa A. Berg

OFFICIAL SEAL
LISA A. BERG
Notary Public - State of Illinois
My Commission Expires Dec 11, 2011

Linda Melomas   7/27/09
APPROVED SIGNATORY   DATE

Figure A-33. ⅝ in. x 22 in. Bolts, Test No. MGSSYP-2

10-05-09;04:15PM;Bennett-Bolt-Works Midwest Machinery :3156893999 # 6/ 10

NUCOR
BAR MILL GROUP

KING STEEL

Mill Certification Details - 2/11/2009 9:43 AM

Customer: KING STEEL
Bill of Lading #:
Chief Metallurgist : Jim Hill
Heat # : 848653
Product : Wire Rod
Grade: 1010

Date : 1/11/2009
Tag # : 12172921A
Size : .594-19/32
Division : Norfolk, NE

Comments : Test conform to ASTM A29, ASTM E415 and ASTM E1019-resulphurized grades.
Certificate: 0780-01 Expires: 02/28/09
Coarse Grain Practice

Chemical Properties -Wt.%

.12	.54	.16	.034	.010	.21	.05	.08	.02

Physical Properties

Tensile:	66,201	456
Yield:	47,546	328
Elongation (in 8 inches):	28 %	26
Elongation (in 2 inches):		

Reduction Ratio: 159:1

The testing was conducted in accordance with the requirements of this specification. All melting and manufacturing processes were performed in the United States of America.

Jim Hill
Division Metallurgist

Figure A-34. ⅝ in. x 22 in. Bolts, Test No. MGSSYP-2 (cont.)

10-05-09;04:15PM;Bennett-Bolt-Works Midwest Machinery ;3156893999 # 7/ 10

www.kingsteelcorp.com

From: support@nucorbar.com [mailto:support@nucorbar.com]
Sent: Wednesday, January 14, 2009 2:23 PM
To: Sutherland, Don
Subject: Mill Certifications - 1/14/2009

NUCOR BAR MILL GROUP

KING STEEL

Mill Certification Details - 1/14/2009 2:23 PM

Customer: KING STEEL
Bill of Lading #:
Chief Metallurgist : Jim Hill
Heat # : 749237
Product : Wire Rod
Grade: 1010
Date : 8/13/2008
Tag # : 12116840
Size : .594-19/32
Division : Norfolk, NE
Comments : Test conforms to ASTM A29, ASTM E415 and ASTM E1019-resulphurized grades.
Certificate: 0780-01 Expires: 12/31/08
Coarse Grain Practice

Chemical Properties -Wt.%

C	Mn	Si	S	P	Cu	Cr	Ni	Mo
.12	.56	.14	.021	.014	.24	.07	.08	.02

Physical Properties

	Imperial - psi	Metric - mpa
Tensile:	64,790	447
Yield:	46,264	319
Elongation (in 8 inches):	25 %	25
Elongation (in 2 inches):		

Reduction Ratio: 199:1

The testing was conducted in accordance with the requirements of this specification. All melting and manufacturing processes were performed in the United States of America.

Jim Hill
Division Metallurgist

Figure A-35. ⅝ in. x 22 in. Bolts, Test No. MGSSYP-2 (cont.)

10-05-09;04:15PM;Bennett-Bolt-Works Midwest Machinery ;3156893999 # 8/ 10

Date: 2/17/09

Nucor Corporation

Heat Number: 849289

Nucor Steel Division
Post Office Box 309 Norfolk, Nebraska 68702 Phone (402) 644-0200
Mill Certification

Chemical Testing
Certificate: 0780-01 *Chemical Analysis
Expires: 11/30/10

Test conform to ASTM A29-05, ASTM E415 and ASTM E1019-resulphurized grades
Spec: 1010 Size: .594-19/32 Rounds

C	.12	P	.015	Mo	.03
Mn	.54	Cu	.32	Pb	.001
Si	.18	Cr	.12		
S	.026	Ni	.11		

Physical Properties

	Imperial			Metric	
Yield	49,471	psi	341	MPA
Tensile	67,947	psi	468	MPA
% Elongation	28	% in 8"	28	% in 203.3 mm

Strand Cast

Reduction Ratio: 159:1
Coarse Grain Practice

KING STEEL
5225 EAST COOK ROAD
GRAND BLANC,MI 48439

Jim Hill Division Metallurgist

All Manufacturing processes, including melting have been performed in the U.S.A. Mercury, in any form, has not been used in the production or testing of this material. Welding or weld repair was not performed on this material. This material conforms to the specifications described on this document and may not be reproduced except in full, without written approval of Nucor Corporation. This product is NAFTA certified under Paragraph "B" of the NAFTA rules of origin.

*Within Our A2LA Accreditation Scope HT3000R

Figure A-36. ⅝ in. x 22 in. Bolts, Test No. MGSSYP-2 (cont.)

10-05-09;04:15PM;Bennett-Bolt-Works Midwest Machinery ;3156893999 # 9/ 10

Nucor Bar Mill Group - Mill Certification Details Page 1 of 1

Mill Certification Details

Nucor Bar Mill Group

KRUEGER & CO.

Mill Certification Details - 7/14/2008 5:02 PM

Customer: KRUEGER & CO.
Bill of Lading #: 293611
Chief Metallurgist : Jim Hill — Date : 7/1/2008
Heat # : 846672 — Tag # : 12095061
Product : Wire Rod — Size : .594-19/32
Grade: 1010 — Division : Norfolk, NE
Comments : Test conform to ASTM A29, ASTM E415 and ASTM E1019-resulphurized grades. Certificate: 0780-01 Expires: 11/30/08 Coarse Grain Practice

Chemical Properties -Wt.%

C	Mn	Si	S	P	Cu	Cr	Ni	Mo	Al	V	Nb	Ti
.11	.53	.17	.026	.014	.23	.08	.08	.02	.001	.001	.001	.0008

Physical Properties

	Imperial -psi	Metric -mpa
Tensile:	63,969	441
Yield:	41,456	286
Elongation (in 8 inches):	27 %	27
Elongation (in 2 inches):		
Reduction Ratio:	159:1	

The testing was conducted in accordance with the requirements of this specification. All melting and manufacturing processes were performed in the United States of America.

file://C:\Documents and Settings\lmccomas\Local Settings\Temp\Ht. #846672.htm 7/14/2008

Figure A-37. ⅝ in. x 22 in. Bolts, Test No. MGSSYP-2 (cont.)

TRINITY HIGHWAY PRODUCTS, LLC.
425 E. O'CONNOR AVENUE
LIMA, OHIO 45801
419-227-1296

MATERIAL CERTIFICATION

CUSTOMER: STOCK	DATE: SEPTEMBER 29, 2009
	INVOICE #:
	LOT #: 090123B
PART NUMBER: 3380G	QUANTITY: 119,201
DESCRIPTION: 5/8" X 1 ½ HH BOLT	DATE SHIPPED:
SPECIFICATIONS: ASTM A307-A/A153	HEAT #: 7367052, 7366484,7368369

MATERIAL CHEMISTY

C	MN	P	S	SI	CU	NI	CR	MO	AL	V	N	CB	SN	B	TI	NB
.15	.49	.008	.002	.06	.03	.02	.05	.01	.029	.002	.005	.001	.001	.000	.000	.000
.13	.38	.007	.002	.10	.03	.04	.06	.02	.037	.002	.004	.001	.001	.000	.000	.000
.14	.43	.006	.008	.06	.04	.02	.06	.02	.034	.002	.005	.001	.001	.000	.000	.000

PLATING AND/OR PROTECTIVE COATING

HOT DIP GALVANIZING (OZ. PER SQ. FT.)	2.74 AVG.

****THIS PRODUCT WAS MANUFACTURED IN THE UNITED STATES OF AMERICA***

THE MATERIAL USED IN THIS PRODUCT WAS MELTED AND MANUFACTURED IN THE U.S.A.

WE HEREBY CERTIFY THAT TO THE BEST OF OUR KNOWLEDGE ALL INFORMATION CONTAINED HEREIN IS CORRECT.

TRINITY HIGHWAY PRODUCTS, LLC.

STATE OF OHIO, COUNTY OF ALLEN
SWORN AND SUBSCRIBED BEFORE ME
THIS 29TH DAY SEPTEMBER, 2009

NOTARY PUBLIC

425 E. O'CONNOR AVENUE LIMA, OHIO 45801 419-227-1296

Figure A-38. ⅝ in. x 1½ in. Hex Bolts, Test Nos. MGSSYP-1 and MGSSYP-2

Trinity Metals Laboratory
A DIVISION OF TRINITY INDUSTRIES
4001 IRVING BLVD. 75247 - P.O. BOX 568887
DALLAS, TX 75356-8887
Phone: 214.589.7591 FAX: 214.589.7594

NVLAP LAB CODE 200654-0

Lab No: 9010250F

SUE HENLINE
TRINITY HWY PRODUCTS, LLC #55
ROLLFORM
LIMA, OH 45801

Received Date: 01/27/2009
Heat Code:
Heat Number: 7367052, 7368484, and 7368886
PO or Work Order: Lot#: 090123B
Test Spec: F606 ASTM METHODS
Other Information: SO#: 55-46502

Completion Date: 01/29/2009
Weld Spec:
Material Type: A 307 A
Material Size: 5/8" x 1-1/2" HHB

OTHER TEST:

Type: HARDNESS ROCKWELL BW — Quantity amount: 20

A) 90-91-90-89

B) 88-90-91-91

C) 89-91-91-91

D) 89-89-91-91

E) 91-91-90-88

Type: HEAD MARKINGS — Quantity amount: 0

TRN 307A USA

We certify the above results to be a true and accurate representation of the sample(s) submitted. Alteration or partial reproduction of this report will void certification. NVLAP Certificate of Accreditation effective through 12-31-09. This report may not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the federal government.

Lab Director, Michael S. Baxter, PE

Page 1 of 1

Figure A-39. ⅝ in. x 1½ in. Hex Bolts, Test Nos. MGSSYP-1 and MGSSYP-2 (cont.)

07/10/2008 11:19 330-670-3198 REPUBLIC ENGINEER PAGE 03/04

ATTN Carina Smith

Republic ENGINEERED PRODUCTS 1807 EAST 28TH ST. LORAIN, OH 4405
PHONE: 330-438-5694 FAX: 330-438-561

CERTIFICATE OF TESTS REPUBLIC ENGINEERED PRODUCTS July 9, 2008
PAGE 1
OF 2

PURCHASE ORD:	127595M	PURCHASE ORDER DATE:	4/14/2008
PART NUMBER:	1009418	ACCOUNT NUMBER:	5550-3007-01
ORDER NUMBER:	1379747 - 01	SCHEDULE:	4116-85
HEAT:	7356484	REVISION:	1

CHARGE ADDRESS / SHIP TO

CHARGE ADDRESS	SHIP TO
TRINITY INDUSTRIES INC	TRINITY INDUSTRIES INC
HIGHWAY SAFETY PRODUCTS INC	C/O BCS METALS PREP
P O BOX 568887 4TH FLOOR	5800 STERLING AVE
DALLAS, TX 75356-8887	MAPLE HTS, OH 44137

MATERIAL DESCRIPTION

HOT ROLLED STEEL COILS CARBON AISI-1015 AK AL KILLED FINE GRAIN COLD WORKING QUALITY TEST REPORTS OF MECHANICAL PROPERTIES FOR INFO ONLY EXTRA TESTING
SIZE: RDS .6390 DIAM X COIL
RDS 16.2306MM DIAM X COIL

LADLE CHEMISTRY %

C	MN	P	S	SI	CU	NI	CR
0.13	0.38	0.007	0.002	0.10	0.03	0.04	0.06
V	MO	SN	AL	CB	N		
0.002	0.02	0.001	0.037	0.001	0.0040		

CALCULATED TESTS

REDUCTION RATIO 132.3 TO 1

AUSTENITIC GRAIN SIZE 5 OR FINER BASED ON A TOTAL ALUMINUM CONTENT EQUAL TO OR GREATER THAN .020% PER ASTM A29.

SBMI - FINISHED RESULTS

FINISHED SIZE RESULTS

TENSILE TEST STANDARD FORMAT

	TENSILE PSI	YIELD(0.2%) PSI	RA %	E %
PCE 10427	59700	422000	72.4	49.0

HARDNESS TEST ASTM E10/ASTM A370 HBW AS-RLD/CD HBW

	MID-RADIUS
PCE 10428	107

NOTES

CHEMICAL ANALYSIS CONFORMS TO APPLICABLE SPECS: ASTM E415, LBL10129, LBL10130, ASTM E1019, LBL10158, LBL10114, AND ASTM E1085, LBL10184, LBL10188.

REPUBLIC ENGINEERED PRODUCTS HEREBY CERTIFY THAT THE MATERIAL LISTED HEREIN HAS BEEN INSPECTED AND TESTED IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE GOVERNING SPECIFICATIONS AND BASED UPON THE RESULTS OF SUCH INSPECTION AND TESTING HAS BEEN APPROVED FOR CONFORMANCE TO THE SPECIFICATIONS

CERTIFICATE OF TESTS SHALL NOT BE REPRODUCED EXCEPT IN FULL.

ALL TESTING HAS BEEN PERFORMED USING THE CURRENT REVISION OF THE TESTING SPECIFICATIONS.

RECORDING OF FALSE, FICTITIOUS OR FRAUDULENT STATEMENTS OR ENTRIES ON THIS DOCUMENT MAY BE PUNISHED AS A FELONY UNDER FED STATUES TITLE 18 CHAPTER 47.

THE MATERIAL WAS NOT EXPOSED TO MERCURY OR ANY METAL ALLOY THAT IS LIQUID AT AMBIENT TEMPERATURE DURING PROCESSING OR WHILE IN OUR POSSESSION.

NO WELD OR WELD REPAIR WAS PERFORMED ON THIS MATERIAL.

R. A. SZELIGA BY JANET K. HARTLINE
MANAGER TECH. SERVICES
R. A. Szeliga

Figure A-40. ⅝ in. x 1½ in. Hex Bolts, Test Nos. MGSSYP-1 and MGSSYP-2 (cont.)

Republic
1807 EAST 28TH ST. LORAIN, OH 44055
PHONE: 330-438-5694 FAX: 330-438-5695

CERTIFICATE OF TESTS
REPUBLIC ENGINEERED PRODUCTS
September 17, 2008
PAGE 1 OF 2

PURCHASE ORD:	127595M	PURCHASE ORDER DATE:	4/14/2008
PART NUMBER:	1003418	ACCOUNT NUMBER:	5550-3007-01
ORDER NUMBER:	1379747 - 01	SCHEDULE:	7327-85
HEAT:	7367052	REVISION:	1

CHARGE ADDRESS / SHIP TO

TRINITY INDUSTRIES INC
HIGHWAY SAFETY PRODUCTS INC
P O BOX 568887 4TH FLOOR
DALLAS, TX 75356-8887

TRINITY INDUSTRIES INC
C/O BCS METALS PREP
5800 STERLING AVE
MAPLE HEIGHTS, OH 44137

MATERIAL DESCRIPTION

HOT ROLLED STEEL COILS CARBON AISI-1015 AK AL KILLED FINE GRAIN COLD WORKING QUALITY TEST REPORTS OF MECHANICAL PROPERTIES FOR INFO ONLY EXTRA TESTING
SIZE: RDS .6390 DIAM X COIL
RDS 16.2306MM DIAM X COIL

LADLE CHEMISTRY %

C	MN	P	S	SI	CU	NI	CR
0.15	0.49	0.008	0.002	0.06	0.03	0.02	0.05
V	MO	SN	AL	CB	N		
0.002	0.01	0.001	0.029	0.001	0.0050		

CALCULATED TESTS

REDUCTION RATIO 132.3 TO 1

AUSTENITIC GRAIN SIZE 5 OR FINER BASED ON A TOTAL ALUMINUM CONTENT EQUAL TO OR GREATER THAN .020% PER ASTM A29.

SEMI - FINISHED RESULTS

FINISHED SIZE RESULTS

TENSILE TEST STANDARD FORMAT

	TENSILE PSI	YIELD(0.2%) PSI	RA %	E %
PCE 14133	60850	45000	64.4	44.0

HARDNESS TEST ASTM E10/ASTM A370 HBN AS-RLD/CD HBN

	MID-RADIUS
PCE 14134	116

NOTES

CHEMICAL ANALYSIS CONFORMS TO APPLICABLE SPECS: ASTM E415, LBL10129, LBL10130, ASTM E1019, LBL10158, LBL10134, AND ASTM E1085, LBL10184, LBL10188.

REPUBLIC ENGINEERED PRODUCTS HEREBY CERTIFY THAT THE MATERIAL LISTED HEREIN HAS BEEN INSPECTED AND TESTED IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE GOVERNING SPECIFICATIONS AND BASED UPON THE RESULTS OF SUCH INSPECTION AND TESTING HAS BEEN APPROVED FOR CONFORMANCE TO THE SPECIFICATIONS.

CERTIFICATE OF TESTS SHALL NOT BE REPRODUCED EXCEPT IN FULL.

ALL TESTING HAS BEEN PERFORMED USING THE CURRENT REVISION OF THE TESTING SPECIFICATIONS.

RECORDING OF FALSE, FICTITIOUS OR FRAUDULENT STATEMENTS OR ENTRIES ON THIS DOCUMENT MAY BE PUNISHED AS A FELONY UNDER FED STATUES TITLE 18 CHAPTER 47.

THE MATERIAL WAS NOT EXPOSED TO MERCURY OR ANY METAL ALLOY THAT IS LIQUID AT AMBIENT TEMPERATURE DURING PROCESSING OR WHILE IN OUR POSSESSION.

NO WELD OR WELD REPAIR WAS PERFORMED ON THIS MATERIAL.

R. A. SZELIGA
MANAGER TECH. SERVICES
R. A. Szeliga

BY JANET K. HARTLINE

Figure A-41. ⅝ in. x 1½ in. Hex Bolts, Test Nos. MGSSYP-1 and MGSSYP-2 (cont.)

Republic 1807 EAST 28TH ST. PHONE: 330-438-5694 LORAIN, OH 44055 FAX: 330-438-5695

CERTIFICATE OF TESTS REPUBLIC ENGINEERED PRODUCTS October 31, 2008 PAGE 1 OF 2

PURCHASE ORD:	129120M	PURCHASE ORDER DATE:	8/27/2008
PART NUMBER:	300941B	ACCOUNT NUMBER:	5550-3007-01
ORDER NUMBER:	1396303 - 01	SCHEDULE:	9510-85
HEAT:	7366369	REVISION:	1

CHARGE ADDRESS

TRINITY INDUSTRIES INC
HIGHWAY SAFETY PRODUCTS INC
P O BOX 568887 4TH FLOOR
DALLAS, TX 75356-8887

SHIP TO

TRINITY INDUSTRIES INC
C/O BCS METALS PREP
5800 STERLING AVE
MAPLE HEIGHTS, OH 44137

MATERIAL DESCRIPTION

HOT ROLLED STEEL COILS CARBON AISI-1015 AK AL KILLED FINE GRAIN COLD WORKING QUALITY TEST REPORTS OF MECHANICAL PROPERTIES FOR INFO ONLY EXTRA TESTING

SIZE: RDS .6390 DIAM X COIL
RDS 16.2306MM DIAM X COIL

LADLE CHEMISTRY %

C	MN	P	S	SI	CU	NI	CR
0.14	0.43	0.006	0.008	0.06	0.04	0.03	0.06
V	MO	SN	AL	CB	N		
0.002	0.02	0.001	0.034	0.001	0.0050		

CALCULATED TESTS

REDUCTION RATIO 112.3 TO 1

AUSTENITIC GRAIN SIZE 5 OR FINER BASED ON A TOTAL ALUMINUM CONTENT EQUAL TO OR GREATER THAN .020% PER ASTM A29.

SEMI - FINISHED RESULTS

FINISHED SIZE RESULTS

TENSILE TEST STANDARD FORMAT

	TENSILE PSI	YIELD(0.2%) PSI	RA %	E %
PCE 15910	58600	43200	63.9	47.0

HARDNESS TEST ASTM E10/ASTM A370 HBW AS-RLD/CD HBW

	MID-RADIUS
PCE 15911	111

NOTES

CHEMICAL ANALYSIS CONFORMS TO APPLICABLE SPECS: ASTM E415, LBL10129, LBL10130, ASTM E1019, LBL10158, LBL10114 AND ASTM E1085, LBL10184, LBL10188.

REPUBLIC ENGINEERED PRODUCTS HEREBY CERTIFY THAT THE MATERIAL LISTED HEREIN HAS BEEN INSPECTED AND TESTED IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE GOVERNING SPECIFICATIONS AND BASED UPON THE RESULTS OF SUCH INSPECTION AND TESTING HAS BEEN APPROVED FOR CONFORMANCE TO THE SPECIFICATIONS.

CERTIFICATE OF TESTS SHALL NOT BE REPRODUCED EXCEPT IN FULL.

ALL TESTING HAS BEEN PERFORMED USING THE CURRENT REVISION OF THE TESTING SPECIFICATIONS.

RECORDING OF FALSE, FICTITIOUS OR FRAUDULENT STATEMENTS OR ENTRIES ON THIS DOCUMENT MAY BE PUNISHED AS A FELONY UNDER FED STATUTES TITLE 18 CHAPTER 47.

THE MATERIAL WAS NOT EXPOSED TO MERCURY OR ANY METAL ALLOY THAT IS LIQUID AT AMBIENT TEMPERATURE DURING PROCESSING OR WHILE IN OUR POSSESSION.

NO WELD OR WELD REPAIR WAS PERFORMED ON THIS MATERIAL.

R. A. SZELIGA BY JANET K. HARTLINE
MANAGER TECH. SERVICES

R. A. Szeliga

Figure A-42. ⅝ in. x 1½ in. Hex Bolts, Test Nos. MGSSYP-1 and MGSSYP-2 (cont.)

425 E. O'Connor
Lima, OH

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

LINCOLN, NE 68501-1097

Sales Order: 1093497
Customer PO: 2030
BOL # 43073
Document # 1

Print Date: 6/30/08
Project: RESALE
Shipped To: NE
Use State: KS

Trinity Highway Products. LLC

Certificate Of Compliance For Trinity Industries, Inc. ** SLOTTED RAIL TERMINAL **

NCHRP Report 350 Compliant

Pieces	Description
32	12/12'6/S SRT-1
32	12/25'0/SPEC/S SRT-2
32	3/16X12.5X16 CAB ANC BRKT
32	2" X 5 1/2" PIPE (LONG)
64	6'0 TUBE SL/.188X8X6
32	5/8 X 6 X 8 BEARING PLATE
32	12/BUFFER/ROLLED
32	CBL 3/4X6'6/DBL SWG/NOHWD
640	5/8" RD WASHER 1 3/4 OD
1,728	5/8" GR HEX NUT
1,152	5/8"X1.25" GR BOLT
256	5/8"X1.5" HEX BOLT A307
64	5/8"X9.5" HEX BOLT A307

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

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL OTHER GALVANIZED MATERIAL CONFORMS WITH ASTM-123.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 49100 LB

State of Ohio, County of Allen. Sworn and Subscribed before me this 30th day of June, 2008

Notary Public:
Commission Expires

Trinity Highway Products, LLC
Certified By:

Figure A-43. ⅝ in. x 9½ in. Hex Bolt, Test No. MGSSYP-1

Southeastern Bolt & Screw, Inc.
1037 16th Avenue West
Birmingham, AL 35204

Certification Of Compliance

DATE: September 28, 2010

CUSTOMER: Midwest Machinery & Supply
P.O. Box 703
Milford, NE 68405

RE: Purchase Order No. 2351
SBS Shop Order No. 1093439

QTY	DESCRIPTION	SPECIFICATION	HEAT/LOT NO.
150	5/8-11 X 10 Hex Bolt	A307 Grade A	DL10101333405 1077688-1
100	5/8-11 X 12 Hex Bolt	A307 Grade A	DL10101333405 1077688-2
500	5/8-11 X 19 Hex Bolt	A307 Grade A	DL10101333405 1077688-3
150	3/4-10 X 8 Hex Bolt	A307 Grade A	11893810 1077688-4
500	7/8-9 X 14 Hex Bolt	A307 Grade A	DL1010333403 1077688-5
100	7/8-9 X 16 Hex Bolt	A307 Grade A	DL1010333403 1077688-6

Surface coating: A153 Grade C

We certify the materials listed meet or exceed the latest ASTM specification as shown.

Jim Waddell
Quality Assurance Manager

402 701 3288

10/07/2010 08:52 2052634851 ACCOUNTING PAGE 01/10

Figure A-44. ⅝ in. x 10 in. Hex Bolt, Test No. MGSSYP-2

NUCOR
NUCOR CORPORATION
NUCOR STEEL SOUTH CAROLINA

Mill Certification
9/8/2010

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

Sold To: SOUTHEASTERN BOLT & SCREW INC
1037 16TH AVE W
PO BOX 758
BIRMINGHAM, AL 35201-0000
(205) 328-4551
Fax: (205) 458-1527

Ship To: SOUTHEASTERN BOLT & SCREW INC
1037 16TH AVE W
PO BOX 758
BIRMINGHAM, AL 35201-0000
(205) 328-4551
Fax: (205) 458-1527

Customer P.O.	95947	Sales Order	120158.1
Product Group	Merchant Bar Quality	Part Number	300005624805740
Grade	ASTM A572/A572M-07 GR 50 TY2 / 30	Lot ID	DL10103334
Size	.5615" Round	Heat ID	DL1010333405
Product	.5615" Round 40' A572-55	B.L. Number	C1-507010
Description	A572-55 - ASTM A572-03	Load Number	C1-223418
Customer Spec		Customer Part #	

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Cb
0.24%	1.26%	0.007%	0.036%	0.18%	0.34%	0.09%	0.12%	0.030%	0.015%	0.006%

Yield 1: 63000psi (434MPa) | Tensile 1: 91000psi (627MPa) | Elongation: 18% in 8"(% in 203.3mm)

Yield 2: 63000psi (434MPa) | Tensile 2: 91000psi (627MPa) | Elongation 19% in 8"(% in 203.3mm)

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

QMG-10 May 12, 2009

Page 2 of 3

Figure A-45. ⅝ in. x 10 in. Hex Bolt, Test No. MGSSYP-2 (cont.)

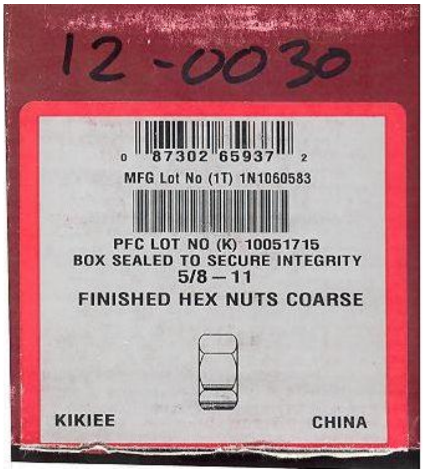


Figure A-46. ⅝ in. Hex Nut, Test Nos. MGSSYP-1 and MGSSYP-2

Figure A-47. ⅝ in. Flat Washer, Test Nos. MGSSYP-1 and MGSSYP-2

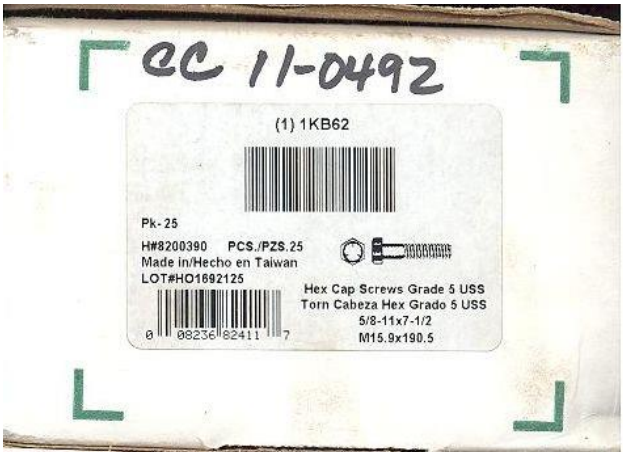


Figure A-48. ⅝ in. x 7½ in. Hex Bolts, Test Nos. MGSSYP-1 and MGSSYP-2

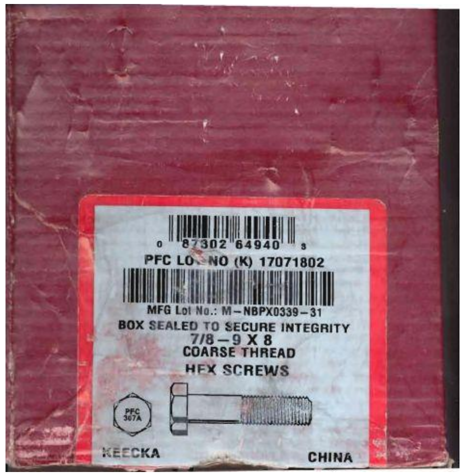


Figure A-49. ⅞ in. x 8 in. Hex Bolts, Test Nos. MGSSYP-1 and MGSSYP-2

Figure A-50. ⅞ in. Flat Washer, Test Nos. MGSSYP-1 and MGSSYP-2

Figure A-51. Double Head Nail, Test Nos. MGSSYP-1 and MGSSYP-2

Appendix B. Vehicle Center of Gravity Determination

Test: MGSSYP-1 Vehicle: 2270P/Ram 1500

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb)	[redacted]	Vert CG (in.)	[redacted]	Vert M (lb-in.)
+	Unbalasted Truck(Curb)	5130	[redacted]	28.14805	[redacted]	144399.5
+	Brake receivers/wires	6		49		294
+	Brake Frame	5		24		120
+	Brake Cylinder (Nitrogen)	22		26		572
+	Strobe/Brake Battery	6		31		186
+	Hub	26		14.4375		375.375
+	CG Plate (EDRs)	7.5		32		240
-	Battery	-37		41		-1517
-	Oil	-8		16		-128
-	Interior	-59		22		-1298
-	Fuel	-165		19		-3135
-	Coolant	-21		33.5		-703.5
-	Washer fluid	-3		34		-102
BALLAST	Water	100		19		1900
	Misc.					0
	Misc.					0

			313208.5	496.125	141203.4
TOTAL WEIGHT	5009.5 lb	CG location (in.)	62.5229	0.099037	28.18712

wheel base 140.5

Calculated Test Inertial Weight

MASH Targets	Targets	CURRENT	Difference
Test Inertial Weight (lb)	5000 ± 110	5009.5	9.5
Long CG (in.)	63 ± 4	62.52	-0.47710
Lat CG (in.)	NA	0.10	NA
Vert CG (in.)	≥ 28	28.19	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	1470	1386
Rear	1097	1177
FRONT	2856 lb	
REAR	2274 lb	
TOTAL	5130 lb	

Actual test inertial weight (lb)
(from scales)

	Left	Right
Front	1424	1374
Rear	1090	1141
FRONT	2798 lb	
REAR	2231 lb	
TOTAL	5029 lb	

Figure B-1. Vehicle Mass Distribution, Test No. MGSSYP-1

Test: MGSSYP-2 Vehicle: 1100C

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb)	Long CG (in.)	Lat CG (in.)	Long M (lb-in.)	Lat M (lb-in.)
+	Unbalasted Car (curb)	2402	35.27841	0.211464	84738.75	507.9375
+	Brake receivers/wires	6	129.25	0	775.5	0
+	Brake Frame	5	27	-12	135	-60
+	Brake Cylinder	22	62.5	-15	1375	-330
+	Strobe Battery	6	56.75	0	340.5	0
+	Hub	20	0	-35.5	0	-710
+	CG Plate (EDRs)	7.5	39	0	292.5	0
+	DTS	18	63	9.5	1134	171
-	Battery	-29	-8.5	-15	246.5	435
-	Oil	-3	-6.5	10	19.5	-30
-	Interior	-38	40	0	-1520	0
-	Fuel	-6	81	-4	-486	24
-	Coolant	-8	-17	0	136	0
-	Washer fluid	-7	-14	22	98	-154
BALLAST	Water	25	81	-4	2025	-100
	Misc.				0	0
	Misc.				0	0

				TEMP	89310.25	-246.063
	Estimated Total Weight	2420.5	lb	CG location	36.89744	-0.10166

wheel base 95.75 in.

MASH targets			**Test Inertial**	
Test Inertial Wt (lb)	2420	(+/-)55	2442	22.0
Long CG (in.)	39	(+/-)4	37.09	-1.90766
Lateral CG (in.)	N/A		-0.02311	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	778	739
Rear	414	471

FRONT	1517	lb
REAR	885	lb
TOTAL	2402	lb

Dummy = 166lbs.

TEST INERTIAL WEIGHT (lb)
(from scales)

	Left	Right
Front	765	731
Rear	457	489

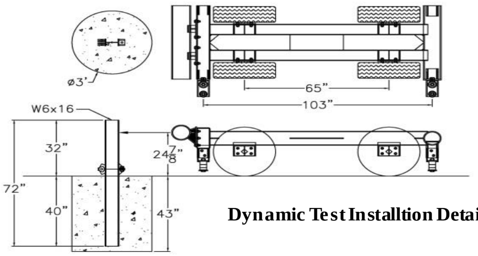
FRONT	1496	lb
REAR	946	lb
TOTAL	2442	lb

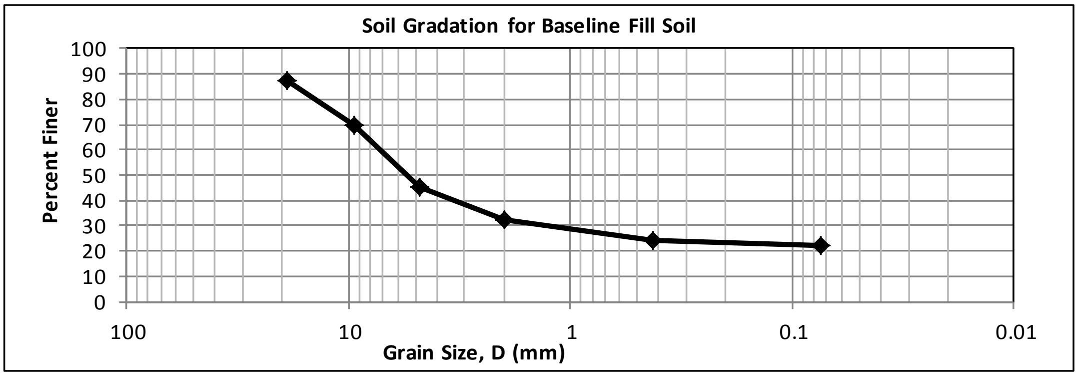
Figure B-2. Vehicle Mass Distribution, Test No. MGSSYP-2

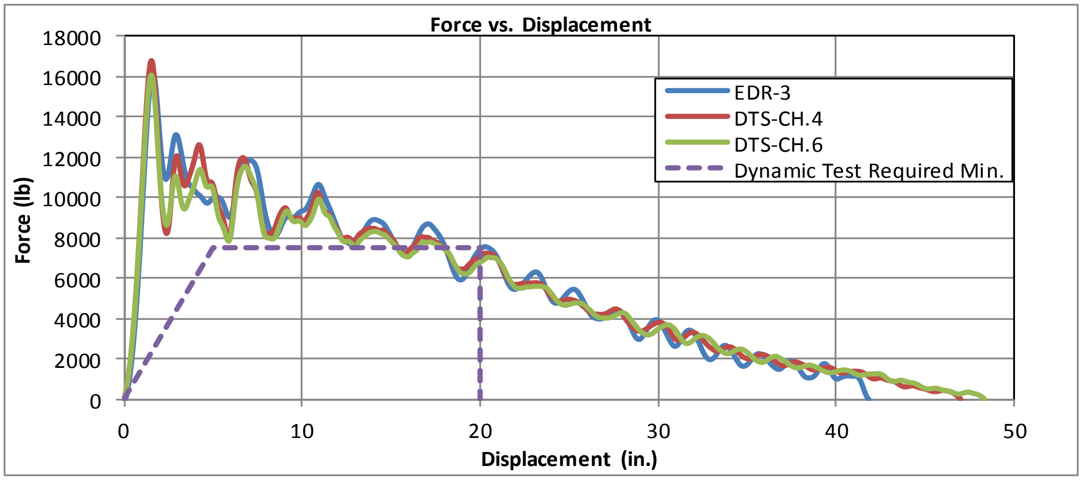
Appendix C. Dynamic and Static Soil Tests

Dynamic Set up

Post-Test Photo of Post







Date..	8/3/2011
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..	1,724 lb
Impact Velocity..	20.5 mph

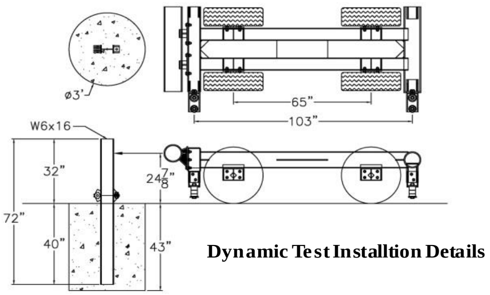
Figure C-1. Test Day Dynamic Soil Test, Test No. MGSSYP-1

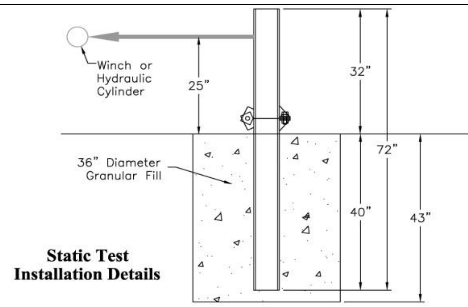
Dynamic Set up

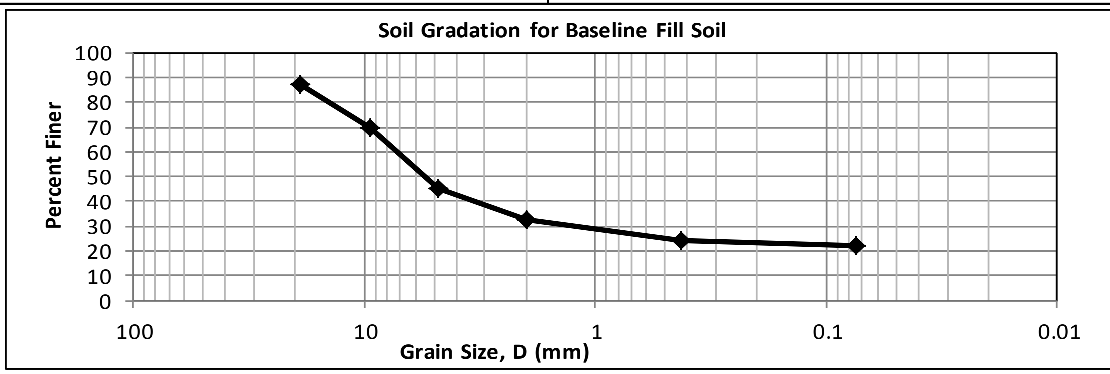
Post-Test Photo of Post

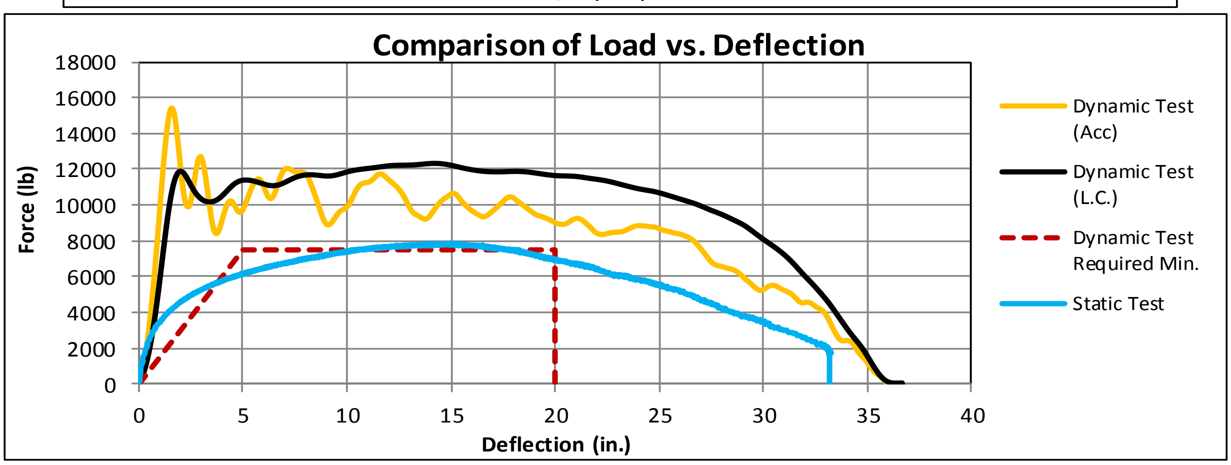
Static Load Test

Post-Test Photo of Post





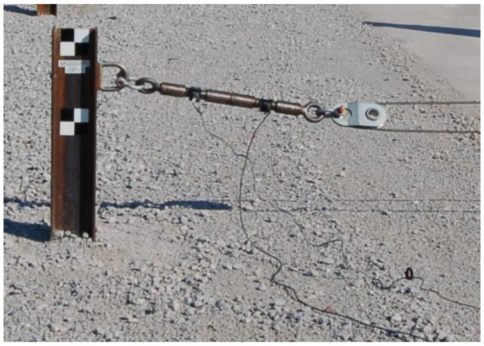




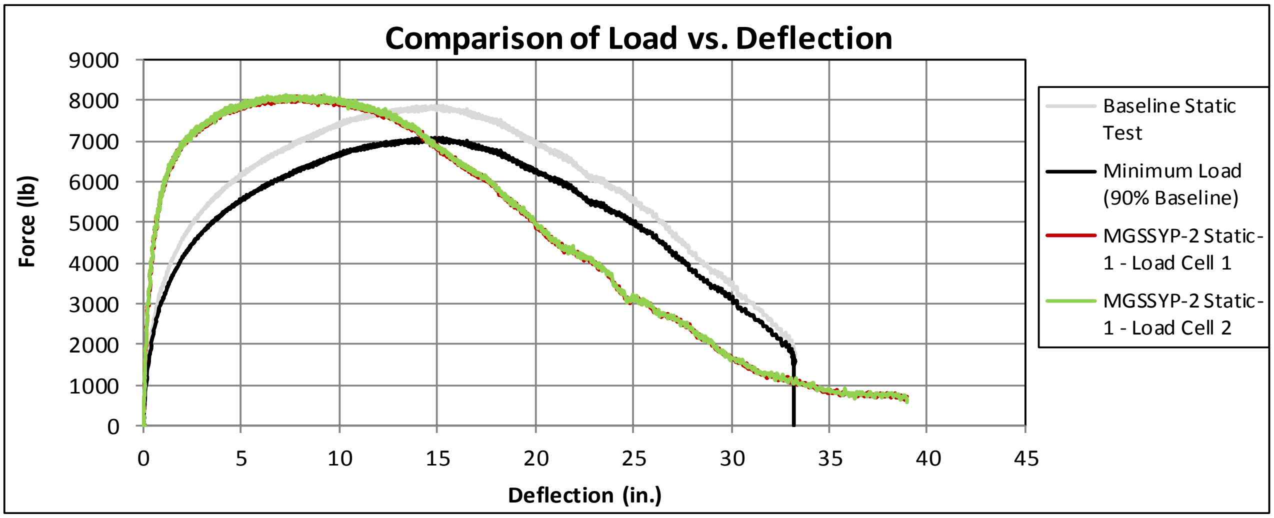
Date..	7/8/2011
Test Facility & Site Location.....................	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487).........	Well Graded Gravel (GW)
Fill material description (ASTM D2487)......	Well Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure.....	H.E. - 8
Bogie Weight...	1,726 lb
Impact Velocity..	22.03 mph

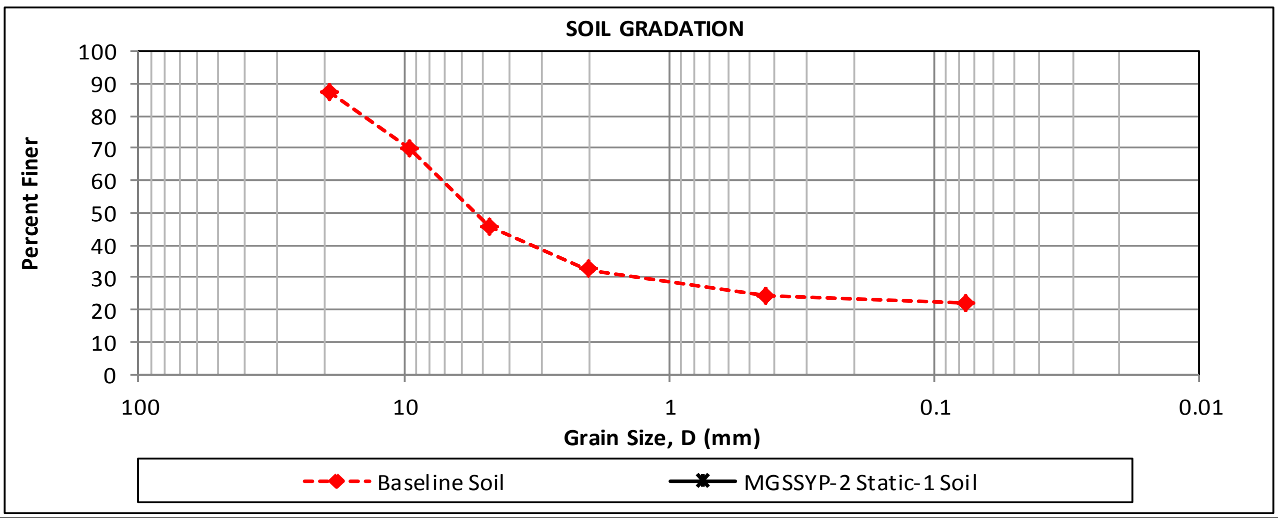
Figure C-2. Summary Sheet for Strong Soil Test Results, Test No. MGSSYP-2

Static Load Test Setup



Post-Test Photo of Post





Date..	9/13/2011
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 C-3. Test Day Static Soil Test, Test No. MGSSYP-2

Appendix D. Vehicle Deformation Records

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 1

TEST: MGSSYP-1
VEHICLE: 2270P/Ram 1500

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

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
1	25	12 3/4	-1	25	13	- 1/2	0	1/4	1/2
2	30	19 1/4	-4	30	19 1/2	-3 3/4	0	1/4	1/4
3	30	25	-3	30	25	-2 1/2	0	0	1/2
4	28 3/4	29	-1 1/4	28 1/2	29	-1	- 1/4	0	1/4
5	21	10	-1 1/4	21 1/4	10	-1	1/4	0	1/4
6	22	14 1/2	-3 3/4	22	14 1/2	-3 1/2	0	0	1/4
7	23 1/2	21 1/2	-7	23 1/4	21 1/2	-7	- 1/4	0	0
8	23 3/4	29 1/4	-6 3/4	23 1/2	29 3/4	-6 1/2	- 1/4	1/2	1/4
9	12 1/2	3 3/4	-2 1/2	12 1/2	3 3/4	-2 1/4	0	0	1/4
10	18	9	-2 3/4	18	9 1/4	-2 3/4	0	1/4	0
11	19	13 3/4	-5 1/2	19	13 1/2	-5 1/4	0	- 1/4	1/4
12	20 1/2	18	-8 3/4	20 1/2	18	-8 1/2	0	0	1/4
13	20 3/4	24 1/4	-8 1/2	20 1/2	24	-8 1/4	- 1/4	- 1/4	1/4
14	20 3/4	28 3/4	-8 1/2	20 3/4	28 3/4	-8 1/4	0	0	1/4
15	11	6	-2 3/4	11	6	-2 1/2	0	0	1/4
16	16 3/4	15	-8 3/4	16 3/4	15	-8 3/4	0	0	0
17	16 3/4	21 1/2	-8 1/2	16 1/2	21 1/2	-8 1/2	- 1/4	0	0
18	17	29 1/4	-8 1/2	17	28 3/4	-8 1/4	0	- 1/2	1/4
19	8	6 1/2	-3	8	6 1/4	-2 3/4	0	- 1/4	1/4
20	11	13	-8 3/4	11	12 3/4	-8 1/2	0	- 1/4	1/4
21	11 3/4	19	-8 1/2	11 1/2	18	-8 1/4	- 1/4	-1	1/4
22	11 1/2	24 1/2	-8 1/4	11 1/4	24 1/4	-8	- 1/4	- 1/4	1/4
23	11 1/4	29 1/2	-8	11 1/4	29 1/4	-8	0	- 1/4	0
24	1 1/2	6 1/2	-2 1/2	1 1/2	6 1/2	-2 1/4	0	0	1/4
25	3/4	13 1/4	-4 1/2	3/4	13 1/4	-4 1/2	0	0	0
26	1	20 3/4	-4 1/4	1	20 1/2	-4	0	- 1/4	1/4
27	1	27 1/2	-4	1	27 3/4	-4	0	1/4	0
28							0	0	0
29							0	0	0
30							0	0	0
31							0	0	0

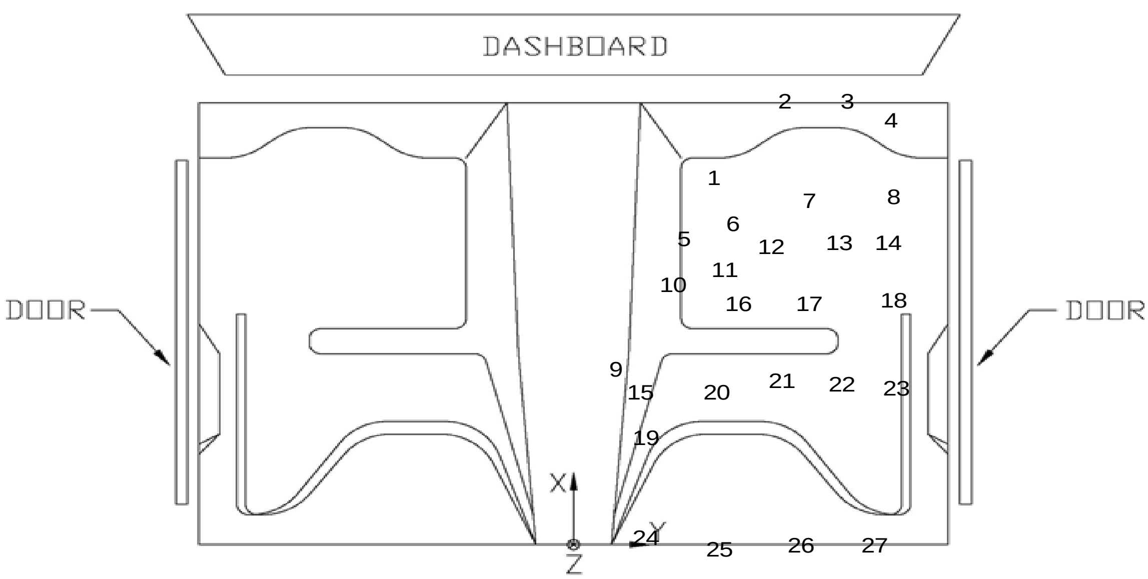


Figure D-1. Floor Pan Deformation Data – Set 1, Test No. MGSSYP-1

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 2

TEST: MGSSYP-1
VEHICLE: 2270P/Ram 1500

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

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
1	40 3/4	19 1/4	- 1/4	40 1/2	19 3/4	0	- 1/4	1/2	1/4
2	46	25 1/2	-3 1/4	46	25 1/4	-3	0	- 1/4	1/4
3	46	31 3/4	-2	46	31 1/2	-1 1/2	0	- 1/4	1/2
4	44 1/2	35 3/4	0	44	35 1/2	1/4	- 1/2	- 1/4	1/4
5	37 1/4	16 3/4	- 3/4	37	16 1/4	- 1/2	- 1/4	- 1/2	1/4
6	38	21	-3	38	21	-2 3/4	0	0	1/4
7	39 1/2	28	-6 1/4	39 1/2	28	-6	0	0	1/4
8	39 3/4	35 1/2	-5 1/2	39 3/4	35 1/2	-5 1/2	0	0	0
9	28 1/2	10 1/2	-2 1/4	28 1/2	10 1/2	-2	0	0	1/4
10	34	16	-2 1/2	34	16	-2 1/4	0	0	1/4
11	35 1/4	20 1/4	-4 3/4	35	20 1/4	-4 1/2	- 1/4	0	1/4
12	36 3/4	24 1/4	-8	36 1/2	24 1/2	-8	- 1/4	1/4	0
13	37	30 3/4	-7 1/2	36 3/4	30 3/4	-7 1/2	- 1/4	0	0
14	37	35 1/4	-7 1/4	37	35	-7	0	- 1/4	1/4
15	27	12 3/4	-2 1/4	27	12 3/4	-2 1/4	0	0	0
16	33	21 3/4	-8 1/4	33	21 1/4	-8 1/4	0	- 1/2	0
17	32 3/4	28 1/4	-7 3/4	32 3/4	28	-7 1/2	0	- 1/4	1/4
18	33 1/4	35 1/4	-7 1/4	33	35	-7	- 1/4	- 1/4	1/4
19	24 1/4	13 1/2	-2 1/2	24	13 1/2	-2 1/4	- 1/4	0	1/4
20	27 1/2	19 1/4	-8	27	18 3/4	-8	- 1/2	- 1/2	0
21	27 3/4	25 1/2	-7 3/4	27 1/2	25	-7 1/2	- 1/4	- 1/2	1/4
22	27 1/2	31 1/4	-7 1/4	27 1/2	31	-7	0	- 1/4	1/4
23	27 1/2	36 1/2	-7	27 1/4	36	-6 3/4	- 1/4	- 1/2	1/4
24	17 1/2	13 1/4	-2	17 1/2	13 1/4	-1 3/4	0	0	1/4
25	17	20 1/4	-4	16 3/4	20	-3 3/4	- 1/4	- 1/4	1/4
26	17	27 1/2	-3 1/4	17	27 1/2	-3 1/4	0	0	0
27	17	34 1/2	-3	17	34 1/4	-2 3/4	0	- 1/4	1/4
28							0	0	0
29							0	0	0
30							0	0	0
31							0	0	0

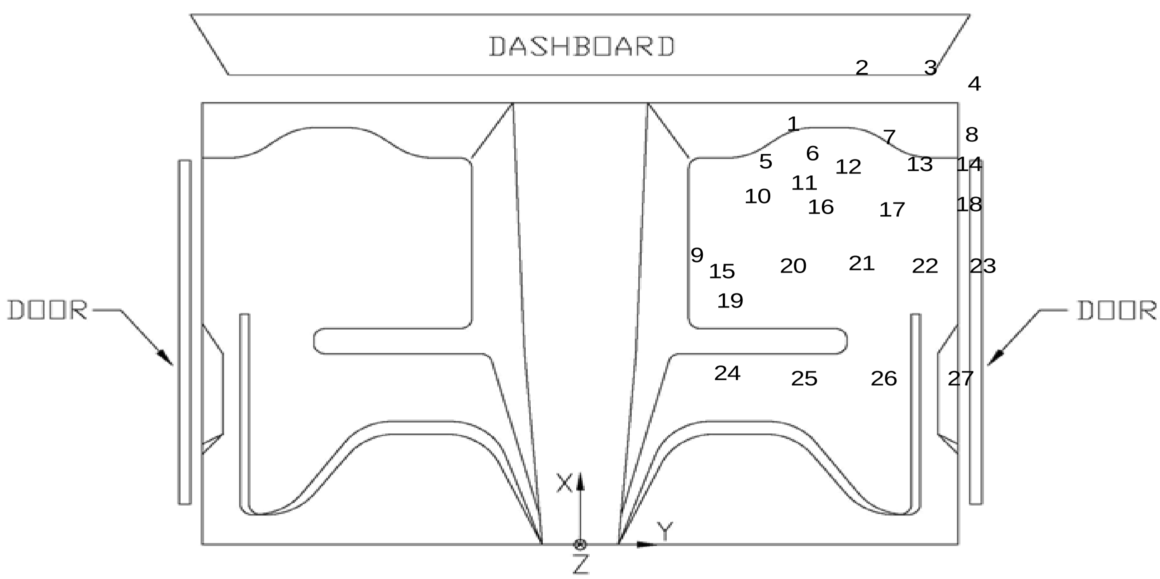


Figure D-2. Floor Pan Deformation Data – Set 2, Test No. MGSSYP-1

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1

TEST: MGSSYP-1
VEHICLE: 2270P/Ram 1500

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

	POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
DASH	A1	40 3/4	41 1/4	22 1/2	40 3/4	41	23	0	- 1/4	1/2
	A2	40 1/2	48 3/4	22 3/4	40 3/4	48 3/4	23	1/4	0	1/4
	A3	40	58	22 1/2	40	57 3/4	22 1/2	0	- 1/4	0
	A4	32 3/4	43 1/2	13 1/2	32 3/4	43 1/4	13 1/2	0	- 1/4	0
	A5	33 1/4	51 1/2	14 1/4	33 1/4	51 1/2	14 1/2	0	0	1/4
	A6	33	60 1/4	14 1/2	33	60 1/4	14 3/4	0	0	1/4
SIDE PANEL	B1	22	27 1/2	-2	22	27 1/4	-2	0	- 1/4	0
	B2	20	27 1/2	-1 1/2	20	26 3/4	-1 1/2	0	- 3/4	0
	B3	20 1/2	27 3/4	-5	20 1/2	27 1/2	-5	0	- 1/4	0
IMPACT SIDE DOOR	C1	29 3/4	39 1/2	18 3/4	29	39 3/4	19 1/4	- 3/4	1/4	1/2
	C2	18 1/2	39 1/2	18 1/2	17 3/4	40	19	- 3/4	1/2	1/2
	C3	5 3/4	40	19	5	41	19 1/4	- 3/4	1	1/4
	C4	26	34	1 1/4	25	34	1 1/2	-1	0	1/4
	C5	18 1/4	33 3/4	3/4	17 1/2	34	1	- 3/4	1/4	1/4
	C6	5	34 1/4	2	4 1/2	35	2 1/4	- 1/2	3/4	1/4
ROOF	D1							0	0	0
	D2							0	0	0
	D3							0	0	0
	D4							0	0	0
	D5							0	0	0
	D6		Omitted due to low probability of damage					0	0	0
	D7							0	0	0
	D8							0	0	0
	D9							0	0	0
	D10							0	0	0
	D11							0	0	0
	D12							0	0	0
	D13							0	0	0
	D14							0	0	0
	D15							0	0	0

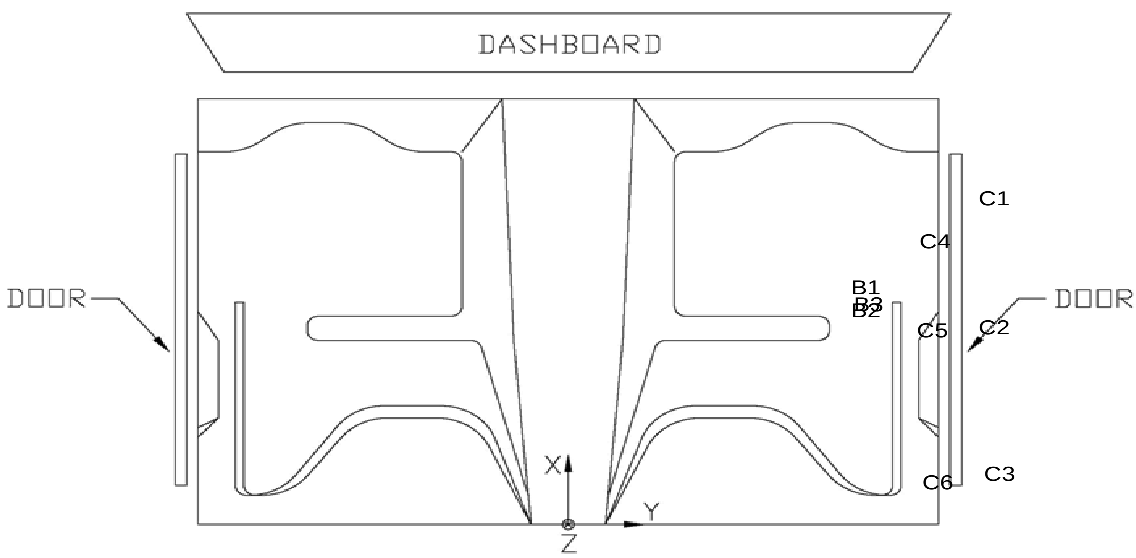


Figure D-3. Occupant Compartment Deformation Data – Set 1, Test No. MGSSYP-1

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2

TEST: MGSSYP-1
VEHICLE: 2270P/Ram 1500

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

	POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
DASH	A1	53 3/4	41	23 1/4	54	41	23 3/4	1/4	0	1/2
	A2	53 3/4	48 3/4	23 1/2	54	49	24	1/4	1/4	1/2
	A3	58 1/4	58	23 3/4	58	58	24	- 1/4	0	1/4
	A4	47 1/4	43	14	47 1/2	43	14 1/4	1/4	0	1/4
	A5	47 3/4	51 1/4	15 1/4	48	51 1/4	15 1/2	1/4	0	1/4
	A6	52 3/4	60 1/2	15 3/4	52 1/2	60	16	- 1/4	- 1/2	1/4
SIDE PANEL	B1	38 3/4	24 1/2	- 3/4	38 1/2	24	- 3/4	- 1/4	- 1/2	0
	B2	36 1/4	24 1/2	0	36 1/2	24	0	1/4	- 1/2	0
	B3	37 1/4	25	-3 3/4	37 1/4	24 1/2	-3 1/2	0	- 1/2	1/4
IMPACT SIDE DOOR	C1	33 1/2	45 1/2	20	32 3/4	46	20 1/2	- 3/4	1/2	1/2
	C2	22	45 3/4	19 3/4	21 1/2	46	20 1/4	- 1/2	1/4	1/2
	C3	8 3/4	46 1/4	20 1/4	8 1/4	47	20 1/2	- 1/2	3/4	1/4
	C4	32	41	3	31	41	3 1/4	-1	0	1/4
	C5	24	41	2	23 1/4	41 1/4	2 1/2	- 3/4	1/4	1/2
	C6	10 1/2	41 1/4	3 1/4	10	42	3 1/2	- 1/2	3/4	1/4
ROOF	D1							0	0	0
	D2							0	0	0
	D3							0	0	0
	D4							0	0	0
	D5							0	0	0
	D6		Omitted due to low probability of damage					0	0	0
	D7							0	0	0
	D8							0	0	0
	D9							0	0	0
	D10							0	0	0
	D11							0	0	0
	D12							0	0	0
	D13							0	0	0
	D14							0	0	0
	D15							0	0	0

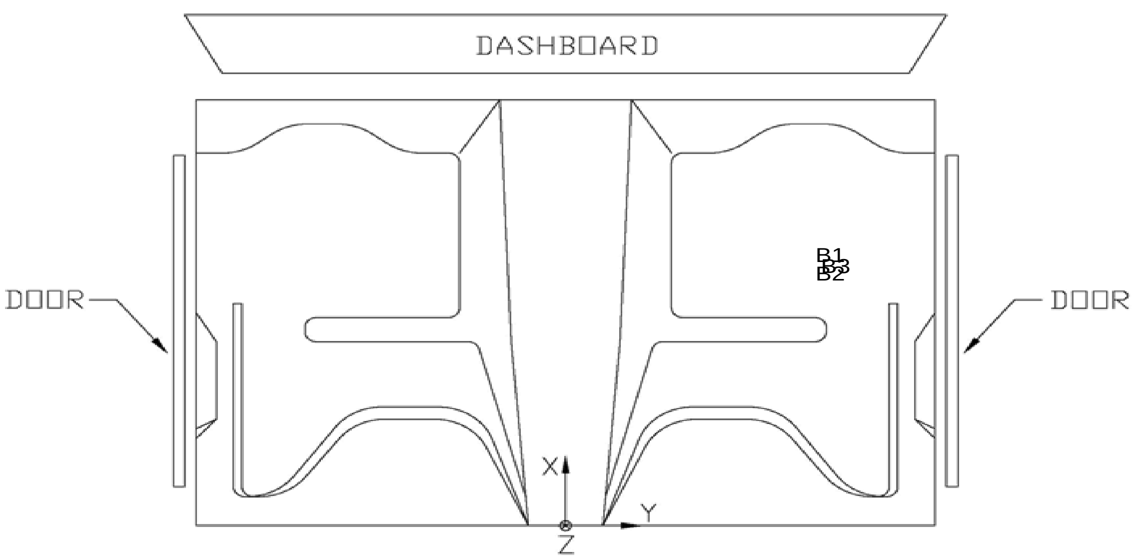
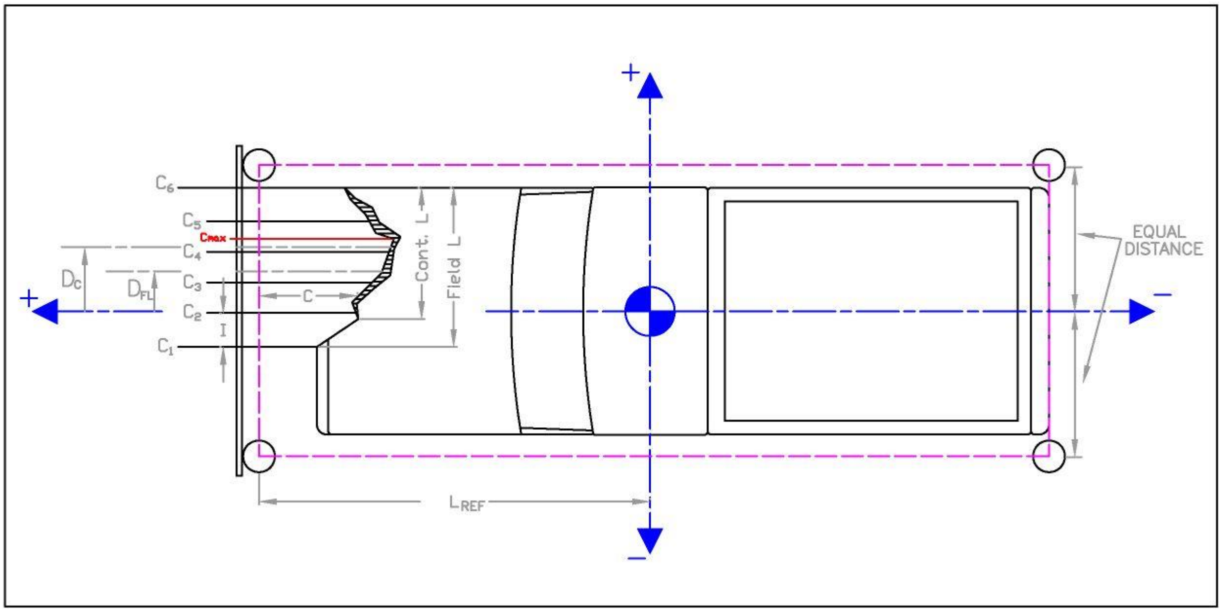


Figure D-4. Occupant Compartment Deformation Data – Set 2, Test No. MGSSYP-1

Date: 9/30/2011 **Test Number:** MGSSYP-1

Make: Dodge **Model:** 2270P/Ram 1500 **Year:** 2004



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	106.5	(2705)
Width of contact and induced crush - Field L:	39	(991)
Crush measurement spacing interval (L/5) - I:	7.8	(198)
Distance from center of vehicle to center of Field L - D_{FL}:	19.5	(495)
Width of Contact Damage:	22	(559)
Distance from center of vehicle to center of contect damage - D_C:	28	(711)

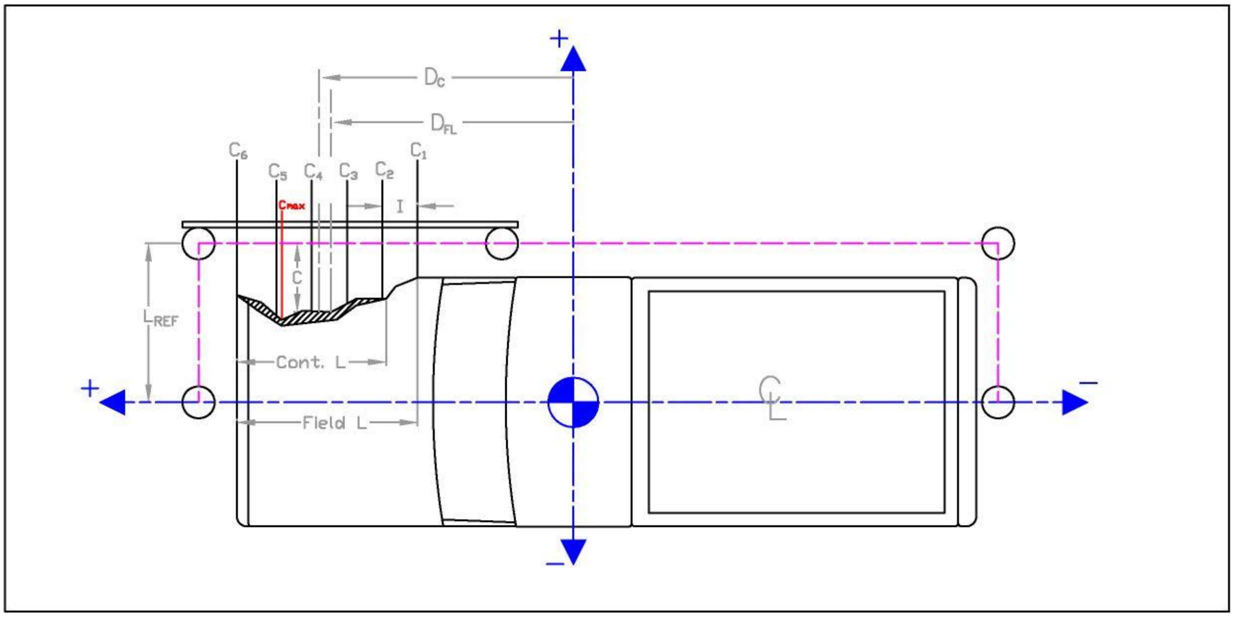
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)

	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	4.24	(108)	0	()	10.25	(260)	-5.52	-(140)	-0.5	-(12)
C_2	5	(127)	7.8	(198)	10.48	(266)			0.0	(1)
C_3	6	(152)	15.6	(396)	11.66	(296)			-0.1	-(3)
C_4	10.75	(273)	23.4	(594)	13.39	(340)			2.9	(73)
C_5	NA	NA	31.2	(792)	16.81	(427)			NA	NA
C_6	NA	NA	39	(991)	29.00	(737)			NA	NA
C_{MAX}	14	(356)	25	(635)	14.06	(357)			5.5	(139)

Figure D-5. Exterior Vehicle Crush (NASS) - Front, Test No. MGSSYP-1

Date: 9/30/2011 **Test Number:** MGSSYP-1

Make: Dodge **Model:** 2270P/Ram 1500 **Year:** 2004



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	48.25	(1226)
Width of contact and induced crush - Field L:	227.75	(5785)
Crush measurement spacing interval (L/5) - I:	45.55	(1157)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-11.125	-(283)
Width of Contact Damage:	227.75	(5785)
Distance from vehicle c.g. to center of contect damage - D_C:	11.125	(283)

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 remeoved)

	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	12	(305)	-125	-(3175)	16.00	(406)	-1.75	-(44)	-2.3	-(57)
C_2	11	(279)	-79.45	-(2018)	10.50	(267)			2.3	(57)
C_3	9.5	(241)	-33.9	-(861)	11.63	(295)			-0.4	-(10)
C_4	11.5	(292)	11.65	(296)	11.25	(286)			2.0	(51)
C_5	NA	NA	57.2	(1453)	10.50	(267)			NA	NA
C_6	NA	NA	102.75	(2610)	35.25	(895)			NA	NA
C_{MAX}	22.5	(572)	83	(2108)	11.50	(292)			12.8	(324)

Figure D-6. Exterior Vehicle Crush (NASS) - Side, Test No. MGSSYP-1

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 1

TEST: MGSSYP-2
VEHICLE: 1100C

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

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
F1	28 3/4	3 3/4	- 1/4	28 1/2	4 1/4	0	- 1/4	1/2	1/4
2	30	11 1/4	-1	29 1/2	11	- 3/4	- 1/2	- 1/4	1/4
3	28 1/2	16	-1 1/2	28 1/4	16	-1 1/2	- 1/4	0	0
4	25 1/2	21 1/2	0	25 1/4	21 3/4	0	- 1/4	1/4	0
5	24 3/4	4	-3 1/4	24 3/4	4 1/4	-3 1/4	0	1/4	0
6	27	8 3/4	-3 3/4	27	8 3/4	-3 1/2	0	0	1/4
7	26 1/2	13	-3 3/4	26 1/2	13 1/4	-3 3/4	0	1/4	0
8	24 3/4	19 1/4	-3	24 3/4	19 3/4	-3	0	1/2	0
9	22	5 1/2	-6	22	5 1/2	-6 1/4	0	0	- 1/4
10	22 1/2	11	-5 1/2	22 1/2	11 1/4	-5 1/2	0	1/4	0
11	22 1/4	16	-5 1/2	22 1/2	16 1/4	-5 1/2	1/4	1/4	0
12	21 3/4	21	-6	21 3/4	20 3/4	-6	0	- 1/4	0
13	17 1/2	5 1/4	-6 1/4	17 1/2	5 1/2	-6 1/4	0	1/4	0
14	18	11 1/4	-5 3/4	18	11 1/2	-5 3/4	0	1/4	0
15	19	15 3/4	-6	19	15 3/4	-6	0	0	0
16	18 1/2	21	-6	18 1/2	21	-6	0	0	0
17	13	3	-6	12 3/4	3	-6	- 1/4	0	0
18	14	9 3/4	-6	14	9 1/2	-6	0	- 1/4	0
19	14 1/2	14 1/2	-5 3/4	14 1/2	14 1/2	-5 3/4	0	0	0
20	15	20 3/4	-6	15	20 3/4	-6	0	0	0
21	8 1/4	5	-6 1/4	8 1/4	5 1/4	-6 1/4	0	1/4	0
22	7 3/4	9 3/4	-6 1/4	7 3/4	9 1/2	-6 1/4	0	- 1/4	0
23	7 1/4	14 1/2	-6	7 1/4	14 3/4	-6	0	1/4	0
24	8 1/4	19 3/4	-6	8 1/4	20	-6 1/4	0	1/4	- 1/4
25	1 1/2	3 3/4	-2 3/4	1 1/2	3 3/4	-2 3/4	0	0	0
26	1	8 1/2	-3 1/2	1	8 1/2	-3 1/2	0	0	0
27	1	13 3/4	-3 1/2	1 1/4	13 3/4	-3 3/4	1/4	0	- 1/4
28	1 1/2	20 1/2	-3 1/4	1 1/2	20 1/2	-3 1/4	0	0	0
29							0	0	0
30							0	0	0
31							0	0	0

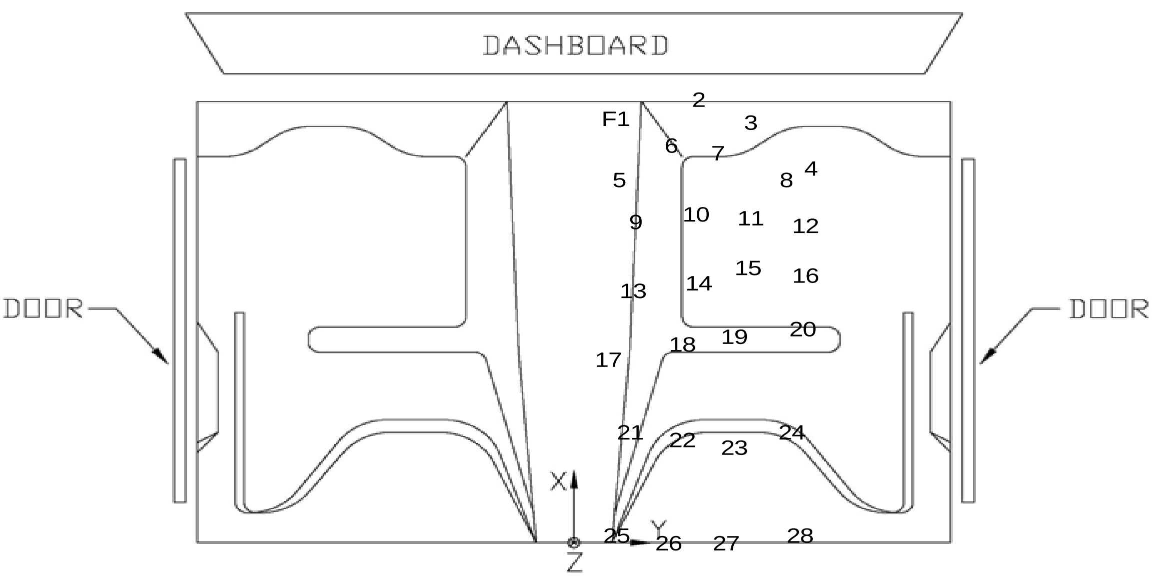


Figure D-7. Floor Pan Deformation Data – Set 1, Test No. MGSSYP-2

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 2

TEST: MGSSYP-2
VEHICLE: 1100C

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

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
1	37 1/4	9 3/4	0	37 1/4	9 3/4	0	0	0	0
2	38 1/2	16 3/4	-1	38 1/4	16 1/2	- 3/4	- 1/4	- 1/4	1/4
3	37 1/4	21 1/2	-1 3/4	36 3/4	21 1/2	-1 1/2	- 1/2	0	1/4
4	34	27 1/4	- 1/4	33 3/4	26 3/4	0	- 1/4	- 1/2	1/4
5	33 1/4	8 3/4	-3	33 1/2	9 1/2	-3	1/4	3/4	0
6	35 3/4	14 1/4	-3 1/2	35 3/4	14 1/2	-3 1/2	0	1/4	0
7	35 1/4	18 1/2	-4	35 1/4	19	-3 3/4	0	1/2	1/4
8	33 1/2	25 1/4	-3 1/4	33 1/2	24 3/4	-3 1/2	0	- 1/2	- 1/4
9	31	10 1/4	-6	30 3/4	10 3/4	-6	- 1/4	1/2	0
10	31 1/4	15 3/4	-5 1/2	31 1/4	16 1/4	-5 1/2	0	1/2	0
11	31 1/4	21	-5 3/4	31 1/4	21 1/2	-5 3/4	0	1/2	0
12	30 1/2	26 1/4	-6 1/4	30 1/2	26	-6 1/4	0	- 1/4	0
13	26 1/4	10 1/4	-6	26 1/4	10 1/2	-6	0	1/4	0
14	27	16 1/2	-5 3/4	26 3/4	16 3/4	-5 3/4	- 1/4	1/4	0
15	28	20 3/4	-6	28	21 1/4	-6	0	1/2	0
16	27 1/4	26 1/2	-6 1/4	27 1/4	26 1/2	-6 1/4	0	0	0
17	21 1/2	8	-6	21 1/2	8	-6	0	0	0
18	22 3/4	14 3/4	-6 1/4	22 3/4	14 3/4	-6 1/4	0	0	0
19	23 1/2	20	-6	23 1/2	20 1/2	-6	0	1/2	0
20	23 3/4	26 1/4	-6 1/2	24	26	-6 1/2	1/4	- 1/4	0
21	17	10 1/4	-6 1/4	17	10 3/4	-6 1/4	0	1/2	0
22	16 3/4	14 1/2	-6 1/2	16 3/4	15	-6 1/2	0	1/2	0
23	16	19 1/2	-6 1/4	16 1/4	20	-6 1/4	1/4	1/2	0
24	17 1/4	25 1/4	-6 1/2	17 1/4	25 1/2	-6 1/2	0	1/4	0
25	10 1/4	9	-3	10 1/4	9	-2 3/4	0	0	1/4
26	9 3/4	14	-3 3/4	10	13 3/4	-3 3/4	1/4	- 1/4	0
27	10	19 1/4	-4	10	19 1/4	-4	0	0	0
28	10 1/4	25 3/4	-3 1/2	10 1/2	26	-3 1/2	1/4	1/4	0
29							0	0	0
30							0	0	0
31							0	0	0

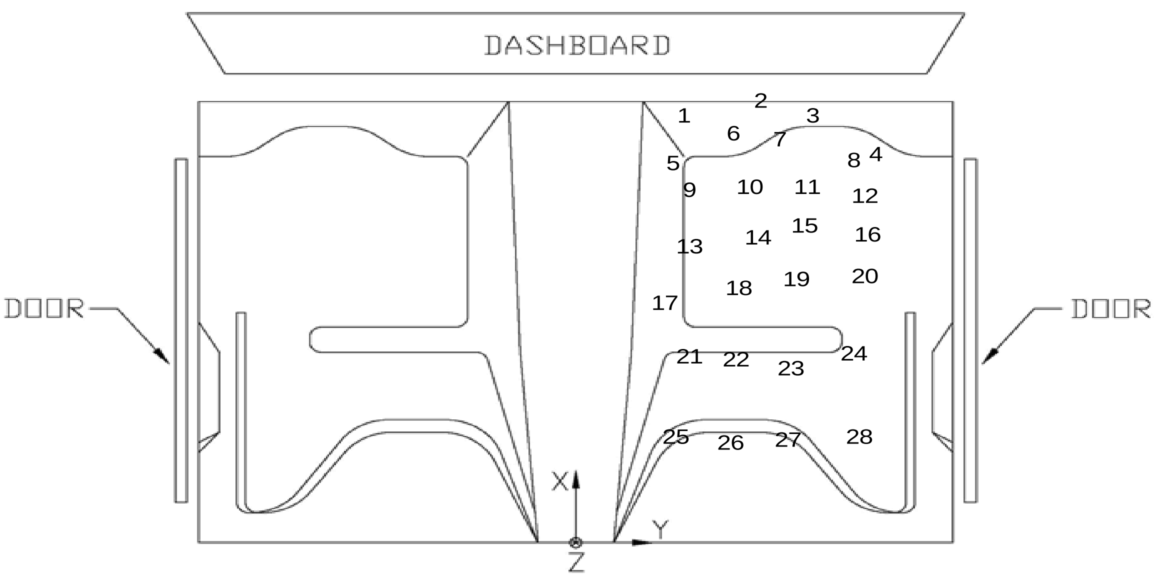


Figure D-8. Floor Pan Deformation Data – Set 2, Test No. MGSSYP-2

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1

TEST: MGSSYP-2
VEHICLE: 1100C

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

	POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
DASH	A1	35 1/4	32 3/4	22 1/4	34 3/4	32 1/2	22 1/2	- 1/2	- 1/4	1/4
	A2	35 1/4	39 1/2	22	34 3/4	39 1/2	22	- 1/2	0	0
	A3	35 1/4	46 1/4	21 3/4	34 3/4	46 1/4	22	- 1/2	0	1/4
	A4	28 1/2	33 1/2	16 3/4	28 1/4	34	16 3/4	- 1/4	1/2	0
	A5	28 1/2	40	16 1/2	28 1/4	39 3/4	16 1/2	- 1/4	- 1/4	0
	A6	28 1/2	46 1/2	16 1/4	28 1/4	46 1/2	16 1/2	- 1/4	0	1/4
SIDE PANEL	B1	34	24 1/2	3	34 1/4	24	2 3/4	1/4	- 1/2	- 1/4
	B2	33 1/2	23 3/4	- 1/4	33 1/2	23 1/2	0	0	- 1/4	1/4
	B3	36 3/4	24 1/2	- 1/2	36 3/4	24	- 1/2	0	- 1/2	0
IMPACT SIDE DOOR	C1	26 1/4	33	18 1/4	26 1/4	33	18 1/4	0	0	0
	C2	17	32 3/4	18 3/4	17	33 1/2	18 3/4	0	3/4	0
	C3	7 1/2	33 3/4	19 1/4	8	34	19 1/2	1/2	1/4	1/4
	C4	21 3/4	26	1 1/2	21 3/4	26 1/4	1 3/4	0	1/4	1/4
	C5	15	25 1/4	1/4	14 3/4	25	0	- 1/4	- 1/4	- 1/4
	C6	3	25 3/4	3	3 1/4	25 1/2	3 1/4	1/4	- 1/4	1/4
ROOF	D1							0	0	0
	D2							0	0	0
	D3							0	0	0
	D4							0	0	0
	D5							0	0	0
	D6							0	0	0
	D7							0	0	0
	D8							0	0	0
	D9							0	0	0
	D10							0	0	0
	D11							0	0	0
	D12							0	0	0
	D13							0	0	0
	D14							0	0	0
	D15							0	0	0

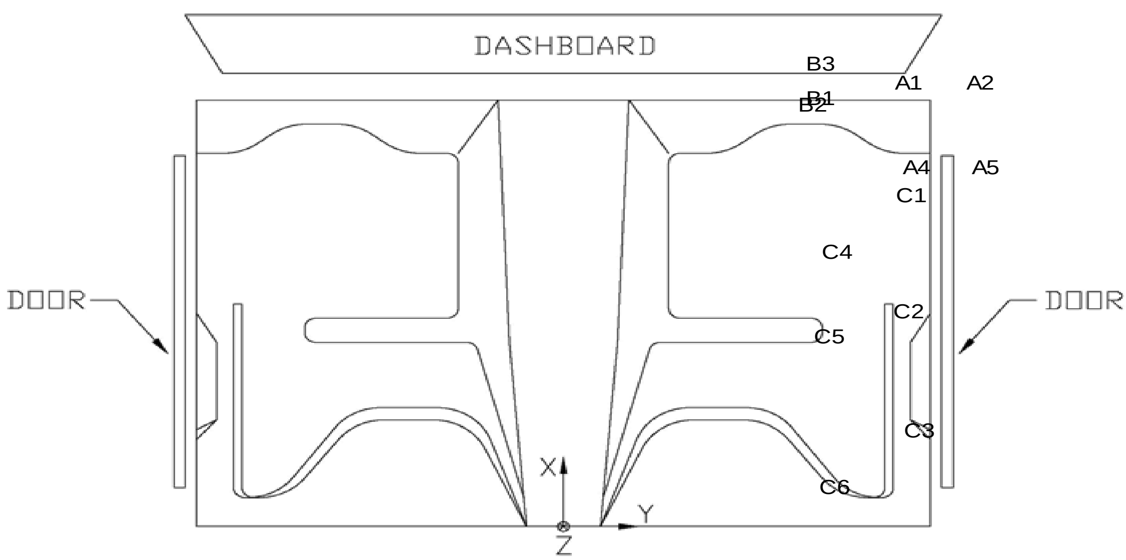


Figure D-9. Occupant Compartment Deformation Data – Set 1, Test No. MGSSYP-2

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2

TEST: MGSSYP-2
VEHICLE: 1100C

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

	POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
DASH	A1	50 3/4	34 1/2	22 1/2	50	34 1/2	22	- 3/4	0	- 1/2
	A2	50 3/4	40 1/2	22	50	40 3/4	21 1/2	- 3/4	1/4	- 1/2
	A3	51 1/2	46 3/4	21 1/2	50 3/4	47	21 1/2	- 3/4	1/4	0
	A4	45	35	16 3/4	44 3/4	35 1/4	16 3/4	- 1/4	1/4	0
	A5	45	41	16 1/2	45	40 1/2	16 1/2	0	- 1/2	0
	A6	45 1/2	47	16	45 1/4	47	16 1/4	- 1/4	0	1/4
SIDE PANEL	B1	38 1/2	25 3/4	2 3/4	38 1/4	25	2 1/2	- 1/4	- 3/4	- 1/4
	B2	37 3/4	24 3/4	- 3/4	38	24 1/2	- 1/4	1/4	- 1/4	1/2
	B3	41	25 3/4	- 1/2	41	25 3/4	- 3/4	0	0	- 1/4
IMPACT SIDE DOOR	C1	29 3/4	36 1/2	18	29 3/4	36 3/4	17 3/4	0	1/4	- 1/4
	C2	20 3/4	37	18 1/4	20 1/2	37 1/2	18 1/4	- 1/4	1/2	0
	C3	11 1/4	37 1/4	19	11 1/2	38 1/2	19	1/4	1 1/4	0
	C4	26 1/4	30 3/4	1 1/4	26	30 3/4	1 1/4	- 1/4	0	0
	C5	19 1/4	30 1/2	- 3/4	19	30 3/4	- 1/2	- 1/4	1/4	1/4
	C6	7 1/2	30 3/4	2 1/2	7 1/2	31	2 3/4	0	1/4	1/4
ROOF	D1							0	0	0
	D2							0	0	0
	D3							0	0	0
	D4							0	0	0
	D5							0	0	0
	D6							0	0	0
	D7							0	0	0
	D8							0	0	0
	D9							0	0	0
	D10							0	0	0
	D11							0	0	0
	D12							0	0	0
	D13							0	0	0
	D14							0	0	0
	D15							0	0	0

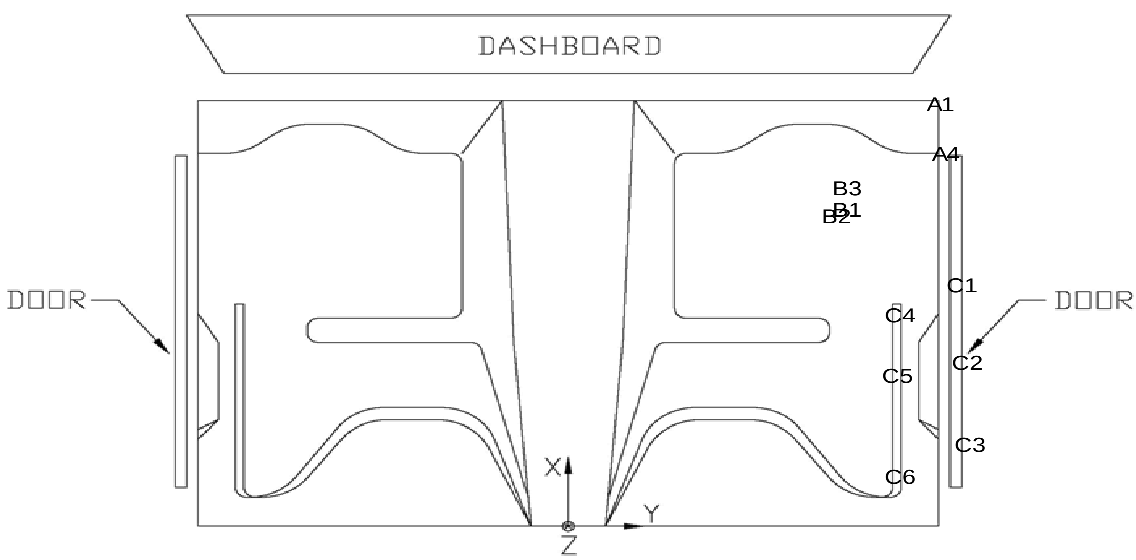
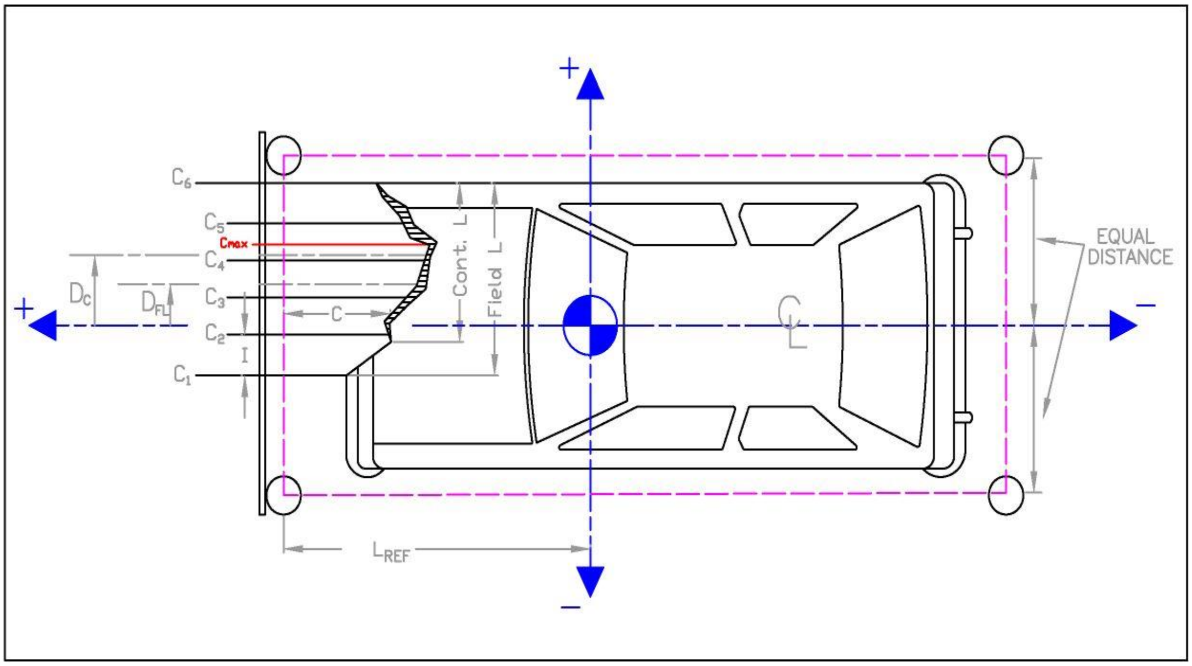


Figure D-10. Occupant Compartment Deformation Data – Set 2, Test No. MGSSYP-2

Date: 6/7/2012 **Test Number:** MGSSYP-2

Make: Kia **Model:** 1100C **Year:** 2004



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	74 1/2	(1892)
Width of contact and induced crush - Field L:	65 1/4	(1657)
Crush measurement spacing interval (L/5) - I:	13	(331)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	25 1/8	(638)
Distance from center of vehicle to center of contect damage - D_C:	20	(510)

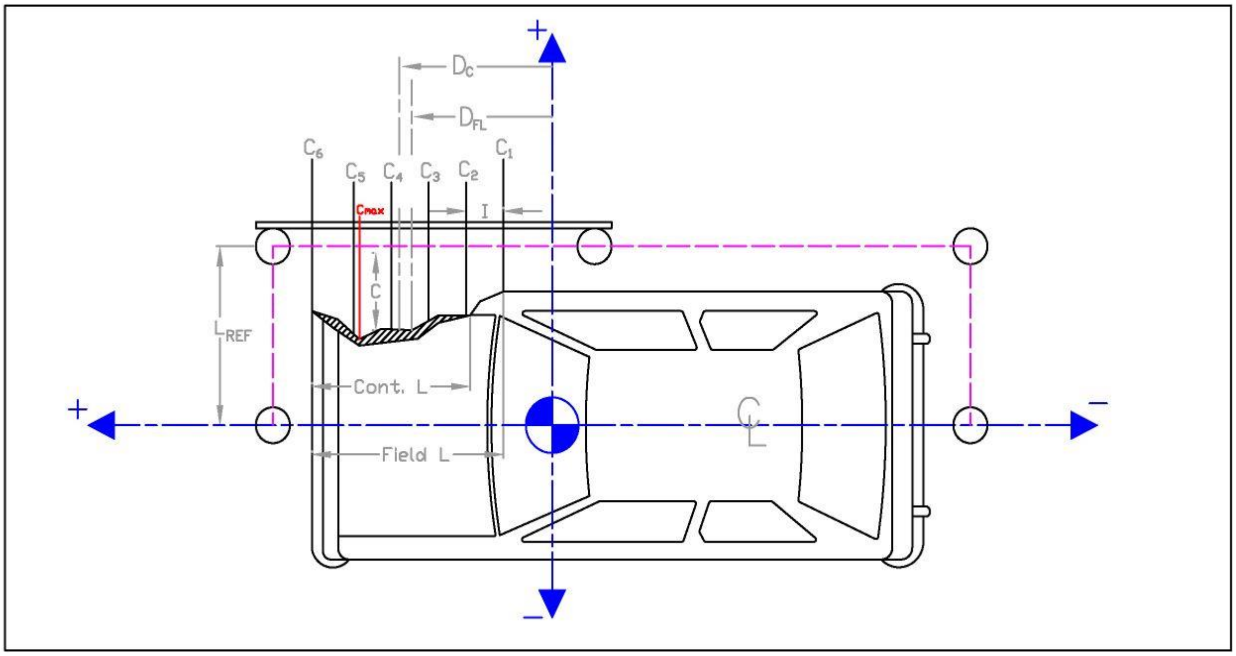
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)

	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	NA	NA	-32 5/8	(-829)	29 1/2	(749)	-4 1/3	(-110)	NA	NA
C_2	9 1/2	(241)	-19 4/7	(-497)	11 2/3	(296)			2 1/6	(55)
C_3	8 1/4	(210)	-6 1/2	(-166)	9 3/7	(239)			3 1/6	(81)
C_4	8 1/2	(216)	6 1/2	(166)	9 2/5	(239)			3 3/7	(87)
C_5	10 1/2	(267)	19 4/7	(497)	11 3/5	(294)			3 1/4	(83)
C_6	NA	NA	32 5/8	(829)	29 1/2	(749)			NA	NA
C_{MAX}	15	(381)	26 1/4	(667)	14 5/9	(369)			4 4/5	(122)

Figure D-11. Exterior Vehicle Crush (NASS) - Front, Test No. MGSSYP-2

Date: 6/7/2012 **Test Number:** MGSSYP-2

Make: Kia **Model:** 1100C **Year:** 2004



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	42.5	(1080)
Width of contact and induced crush - Field L:	89	(2261)
Crush measurement spacing interval (L/5) - I:	17.8	(452)
Distance from vehicle c.g. to center of Field L - D_{FL}:	25.25	(641)
Width of Contact Damage:	89	(2261)
Distance from vehicle c.g. to center of contect damage - D_C:	25.25	(641)

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 remeoved)

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	10.25	(260)	-19.25	(-489)	3.13	(79)	6.5	(165)	0.6	(16)
C_2	10.25	(260)	-1.45	(-37)	3.13	(79)			0.6	(16)
C_3	10.75	(273)	16.35	(415)	3.13	(79)			1.1	(29)
C_4	NA	NA	34.15	(867)	4.00	(102)			NA	NA
C_5	21	(533)	51.95	(1320)	4.13	(105)			10.4	(264)
C_6	NA	NA	69.75	(1772)	23.50	(597)			NA	NA
C_{MAX}	21	(533)	51.95	(1320)	4.13	(105)			10.4	(264)

Figure D-12. Exterior Vehicle Crush (NASS) - Side, Test No. MGSSYP-2

Appendix E. Accelerometer and Rate Transducer Data Plots, Test No. MGSSYP-1

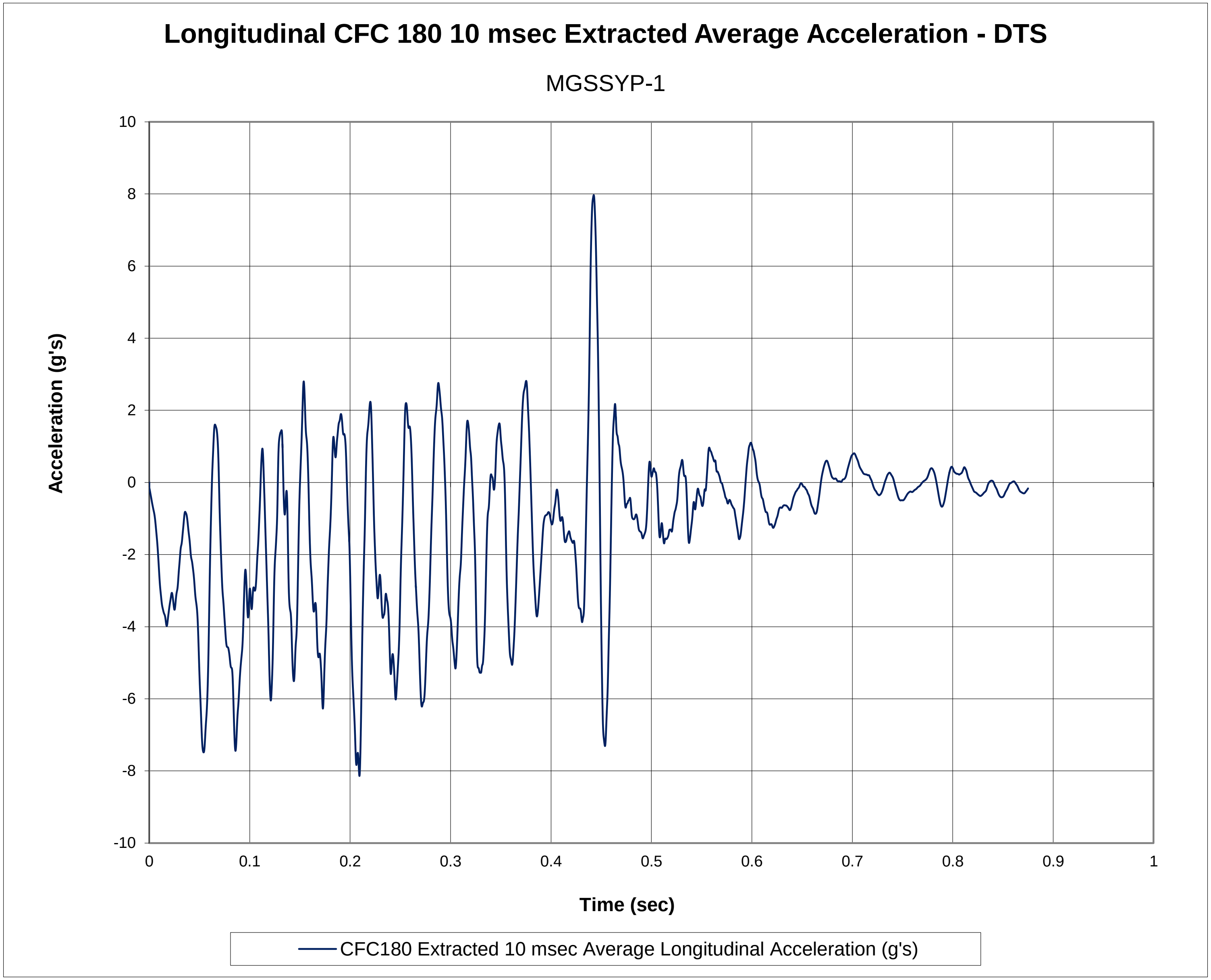


Figure E-1. 10-ms Average Longitudinal Deceleration (DTS), Test No. MGSSYP-1

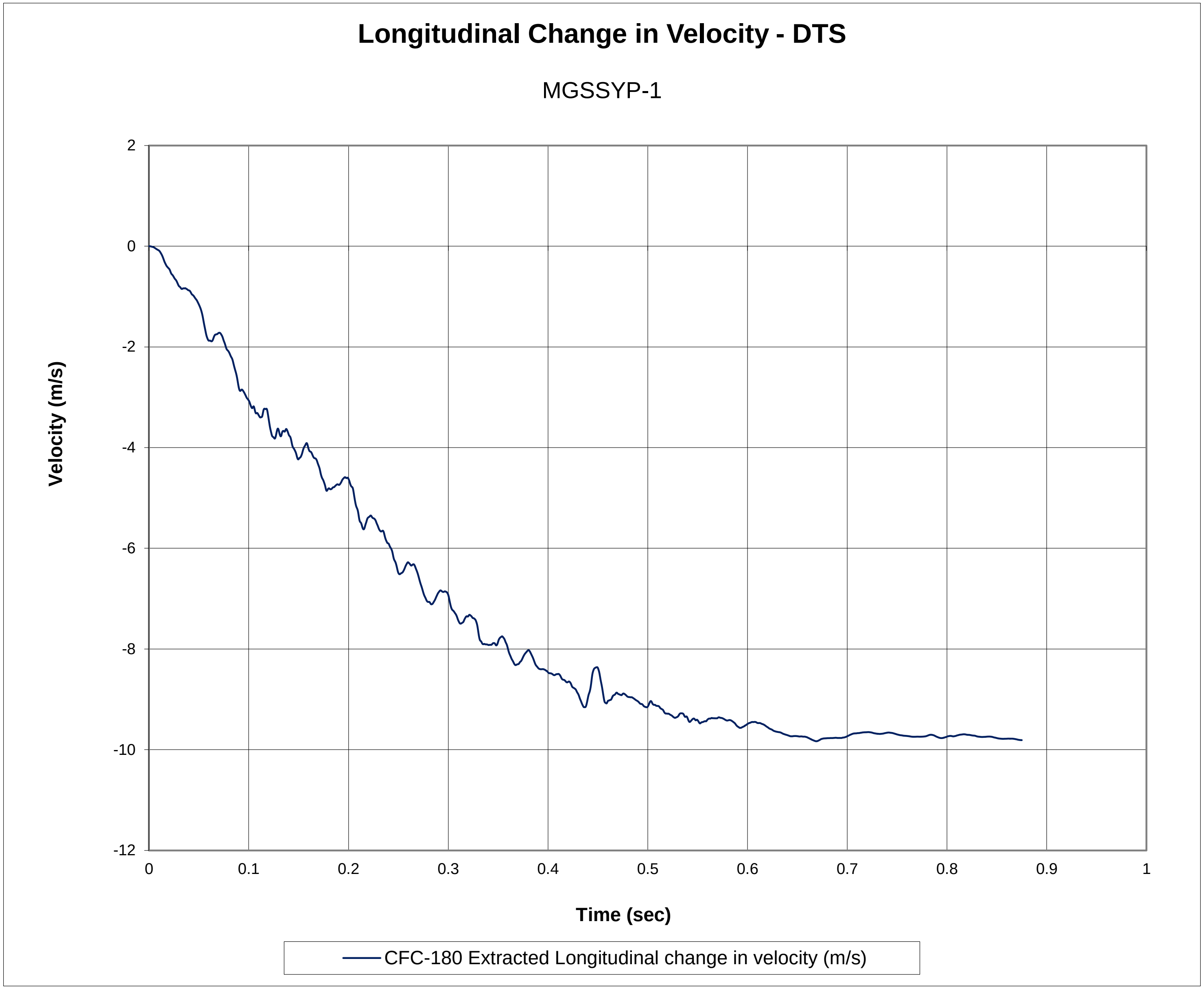


Figure E-2. Longitudinal Occupant Impact Velocity (DTS), Test No. MGSSYP-1

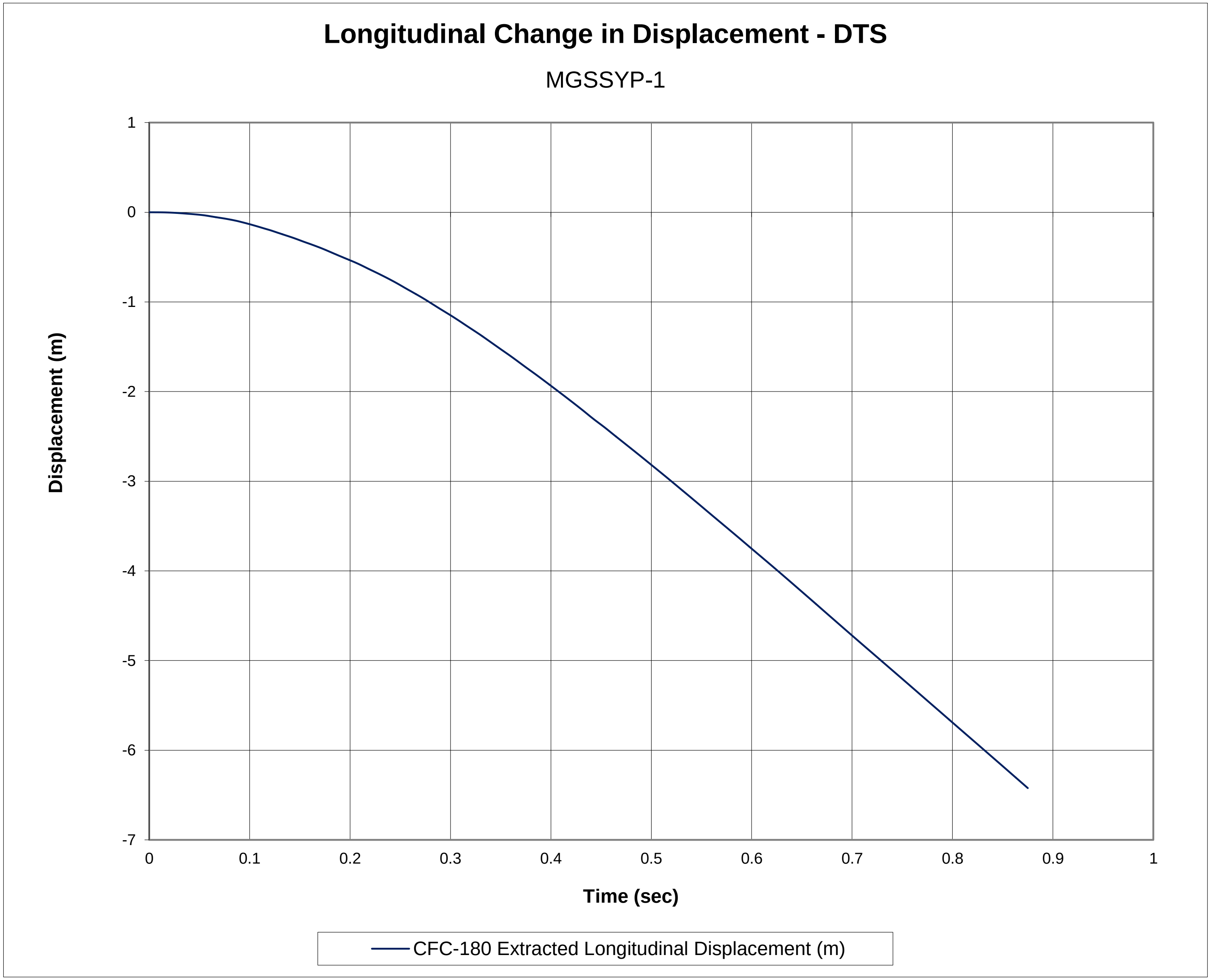


Figure E-3. Longitudinal Occupant Displacement (DTS), Test No. MGSSYP-1

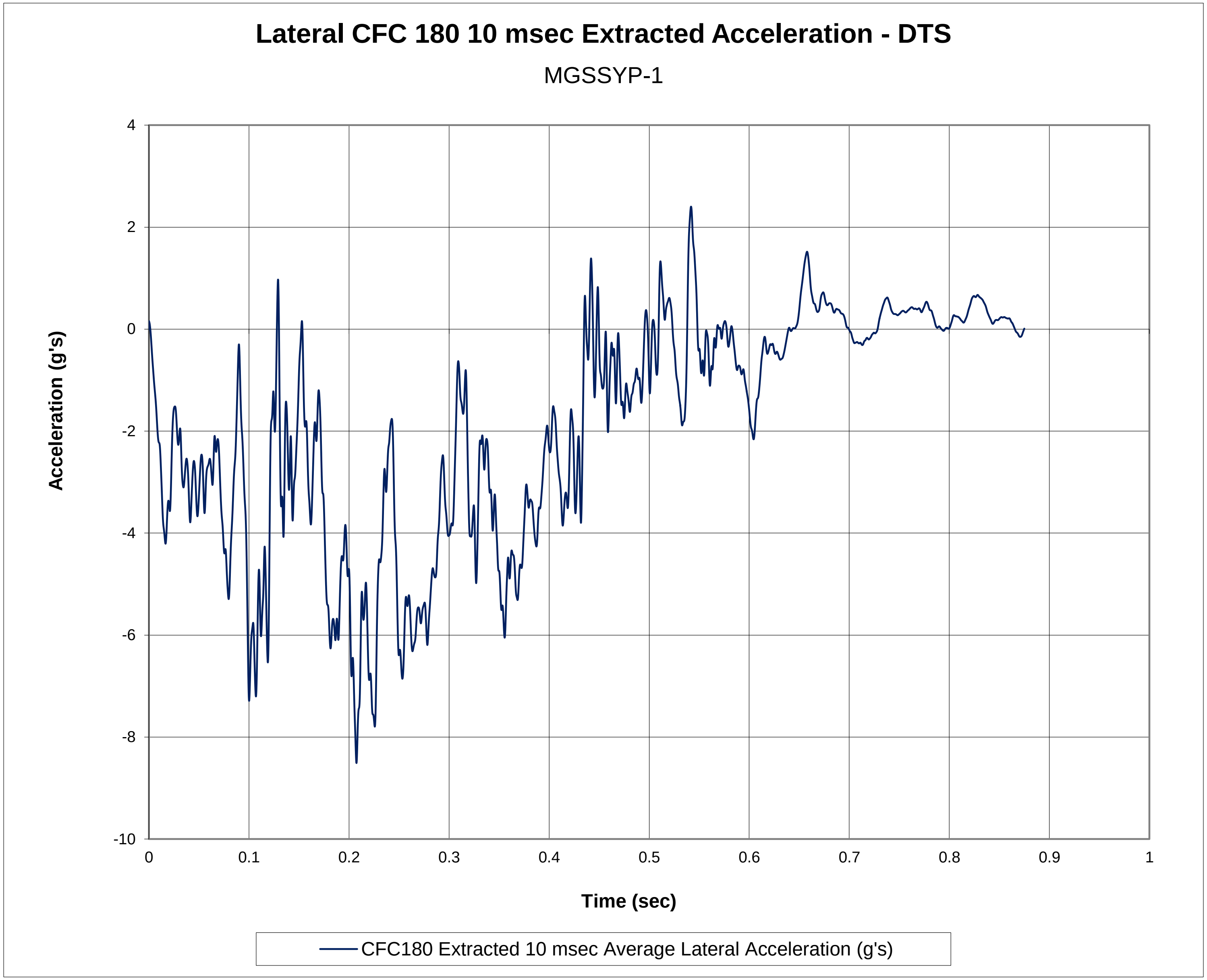


Figure E-4. 10-ms Average Lateral Deceleration (DTS), Test No. MGSSYP-1

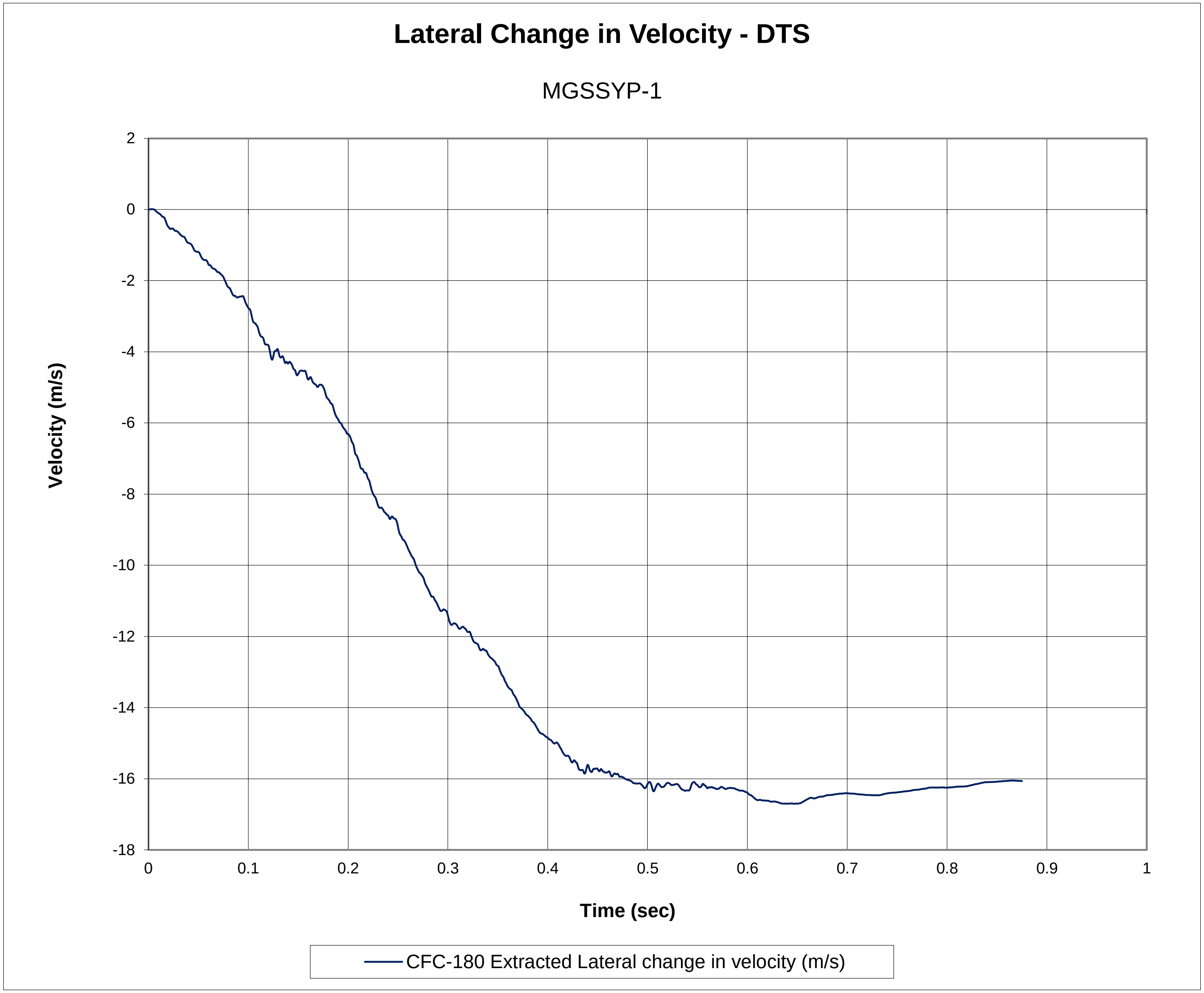


Figure E-5. Lateral Occupant Impact Velocity (DTS), Test No. MGSSYP-1

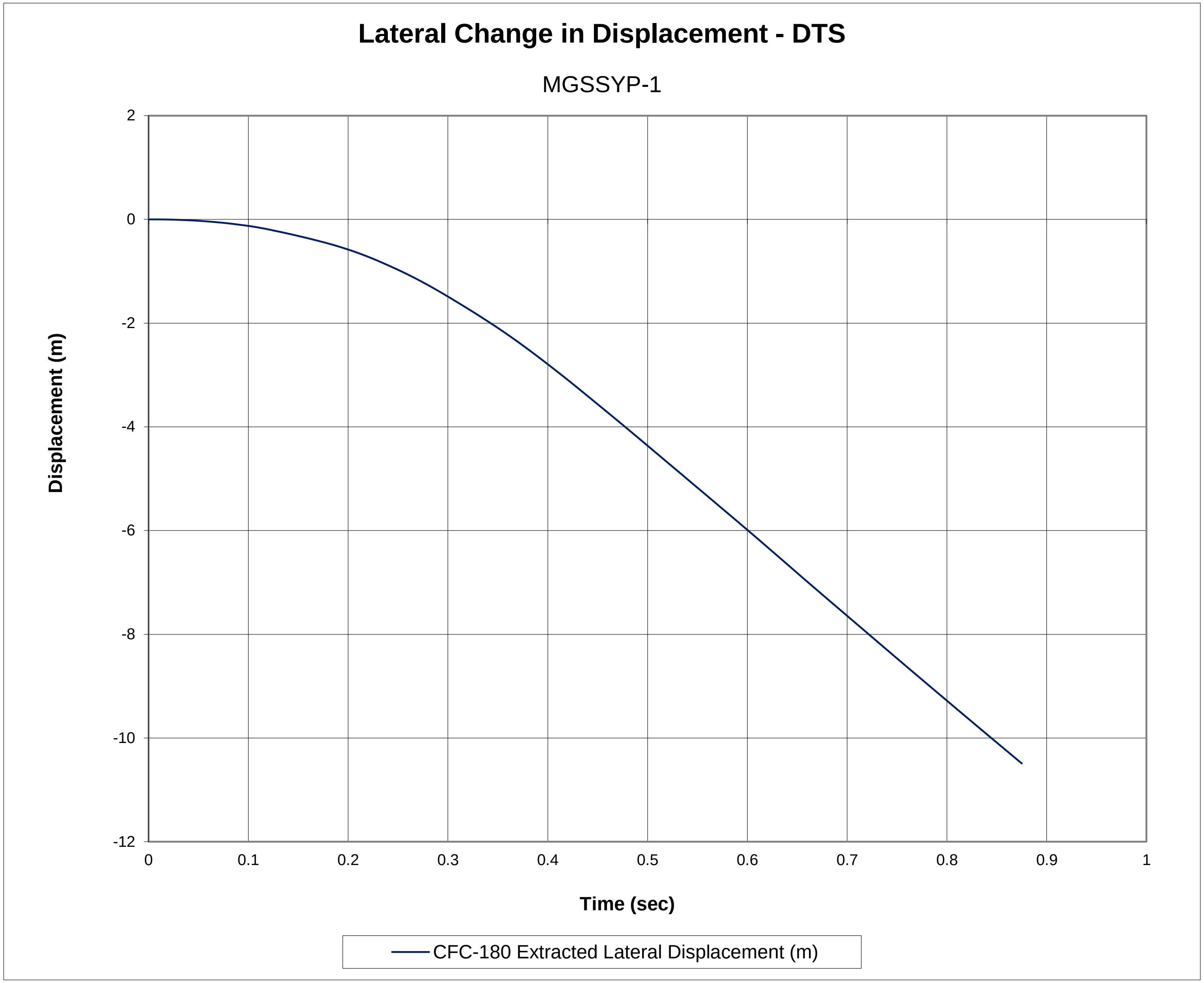


Figure E-6. Lateral Occupant Displacement (DTS), Test No. MGSSYP-1

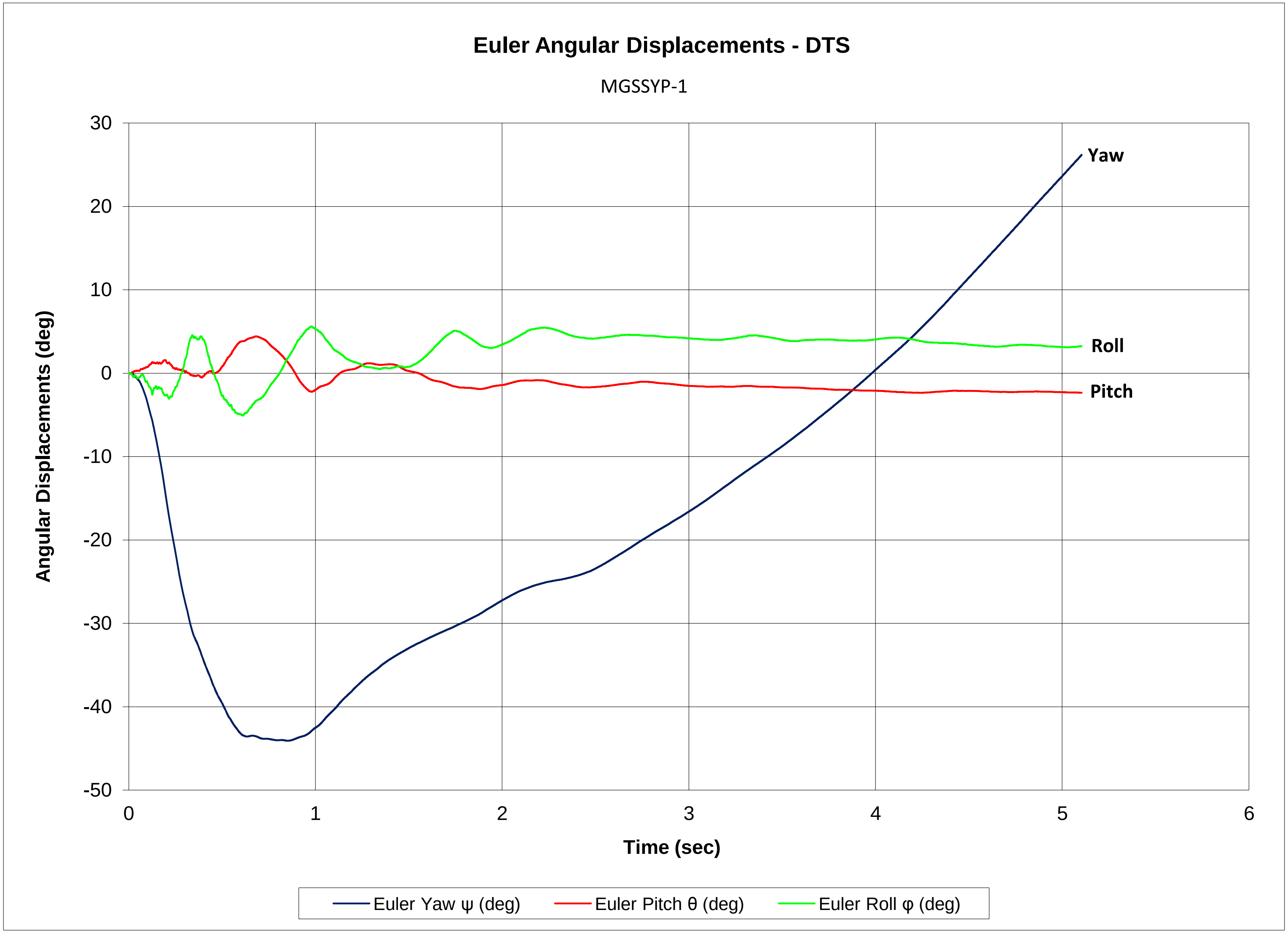


Figure E-7. Vehicle Angular Displacements (DTS), Test No. MGSSYP-1

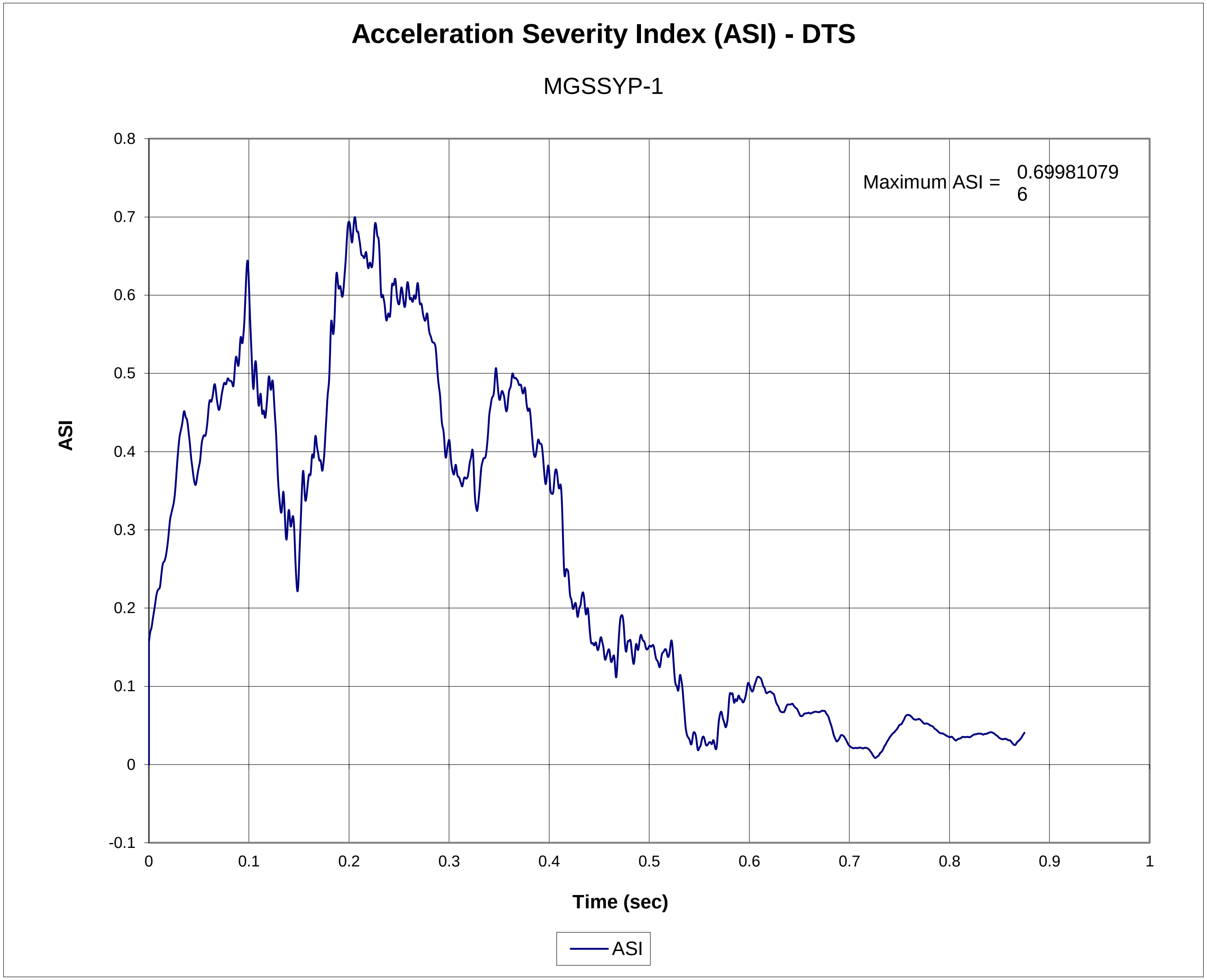


Figure E-8. Acceleration Severity Index (DTS), Test No. MGSSYP-1

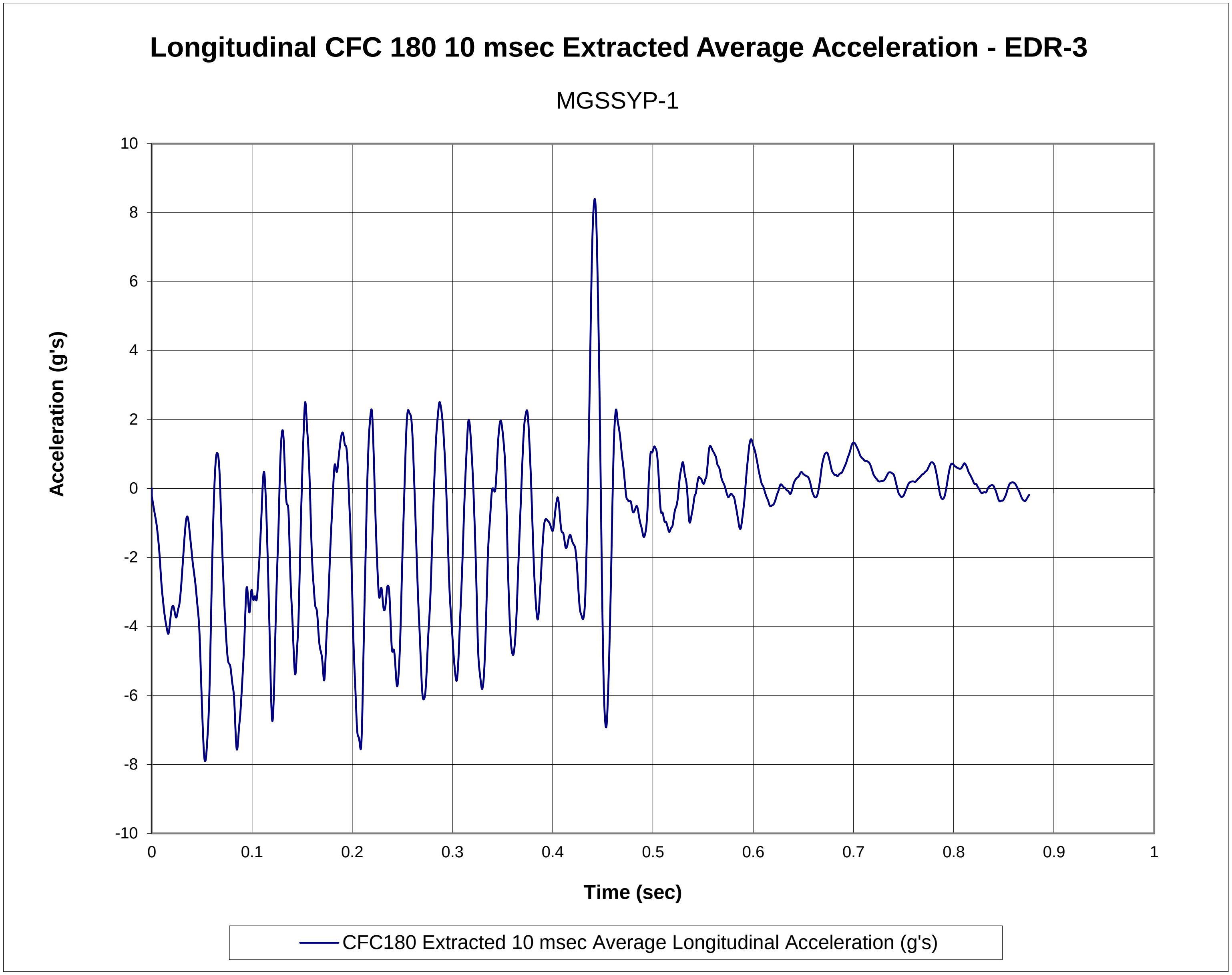


Figure E-9. 10-ms Average Longitudinal Deceleration (EDR-3), Test No. MGSSYP-1

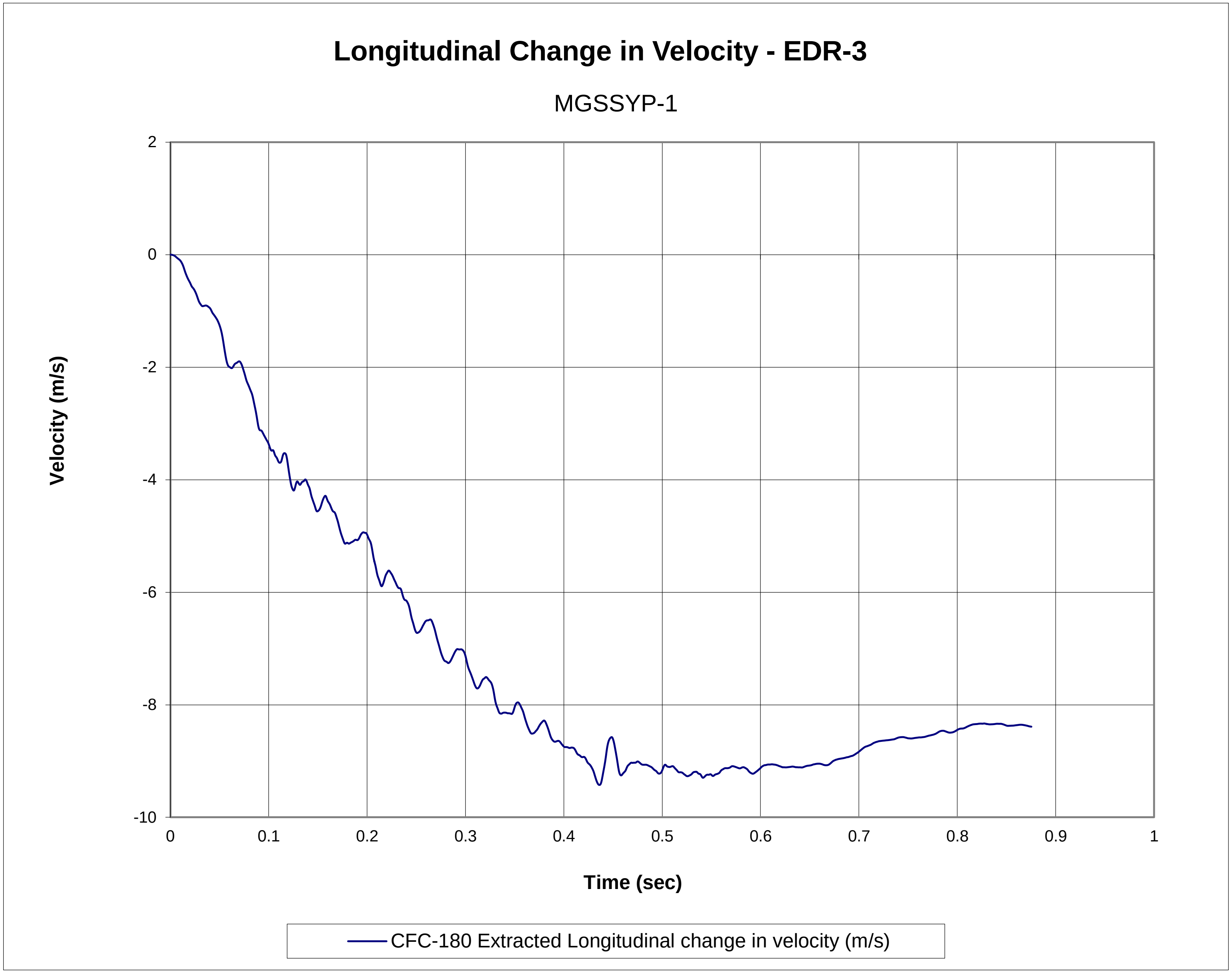


Figure E-10. Longitudinal Occupant Impact Velocity (EDR-3), Test No. MGSSYP-1

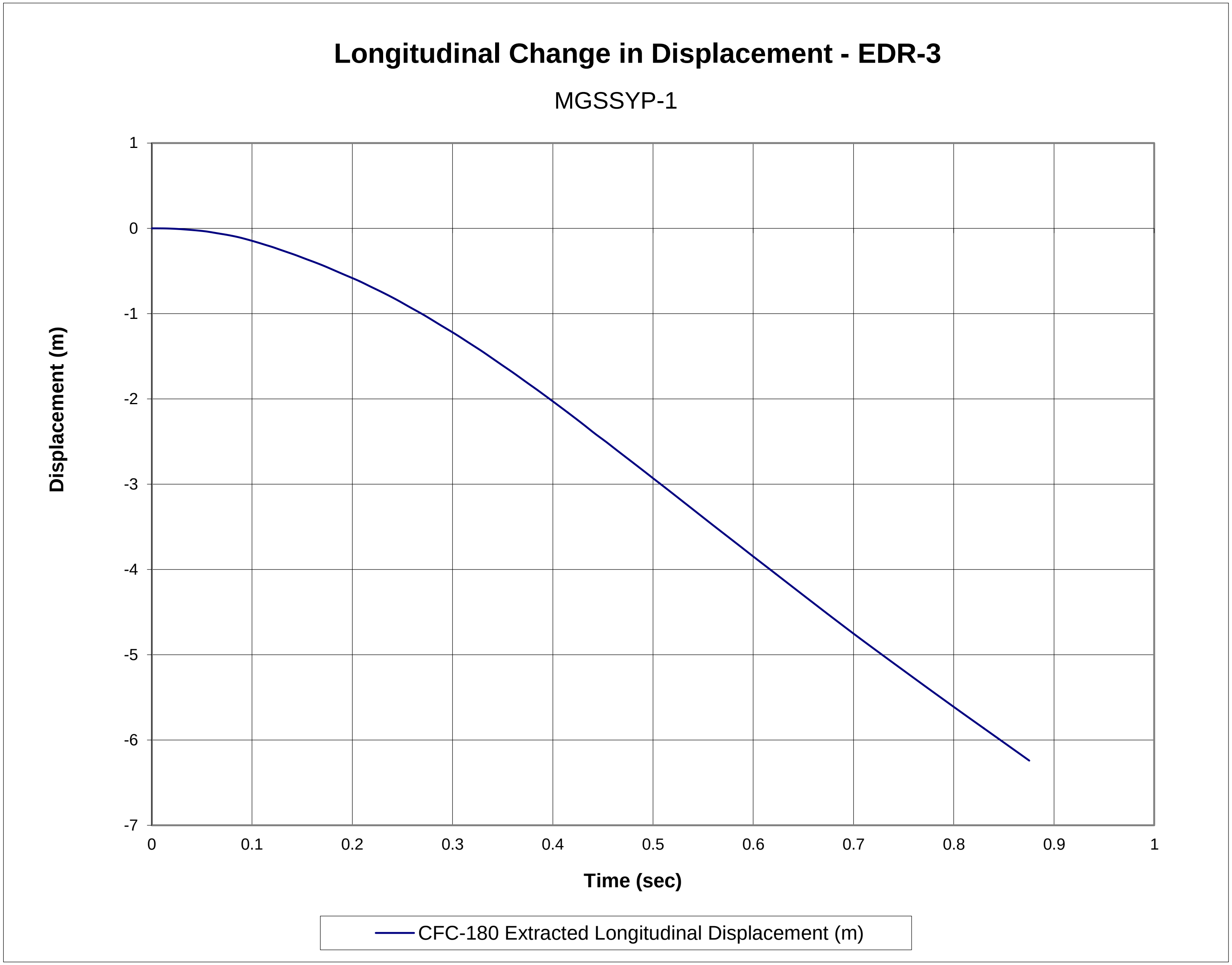


Figure E-11. Longitudinal Occupant Displacement (EDR-3), Test No. MGSSYP-1

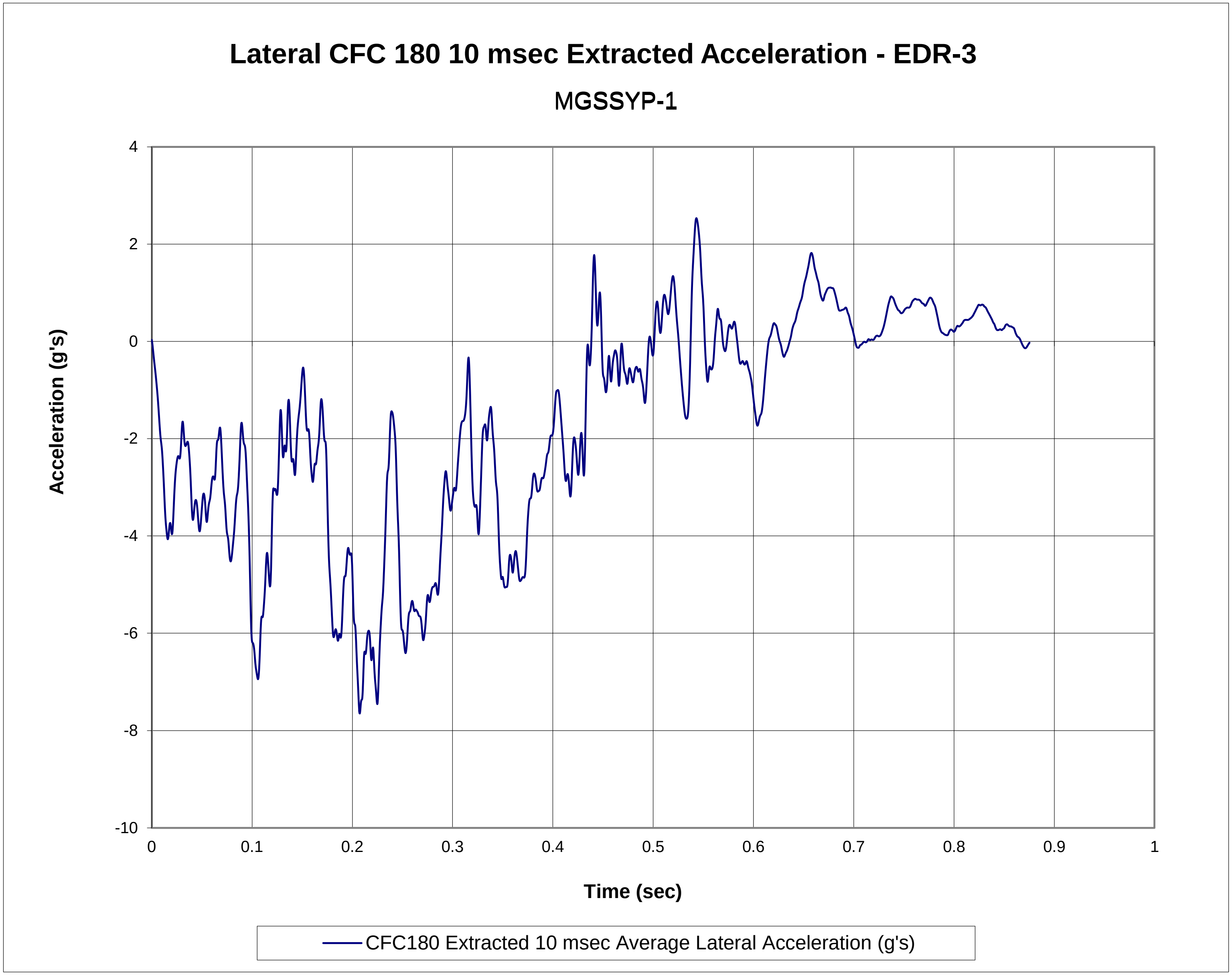


Figure E-12. 10-ms Average Lateral Deceleration (EDR-3), Test No. MGSSYP-1

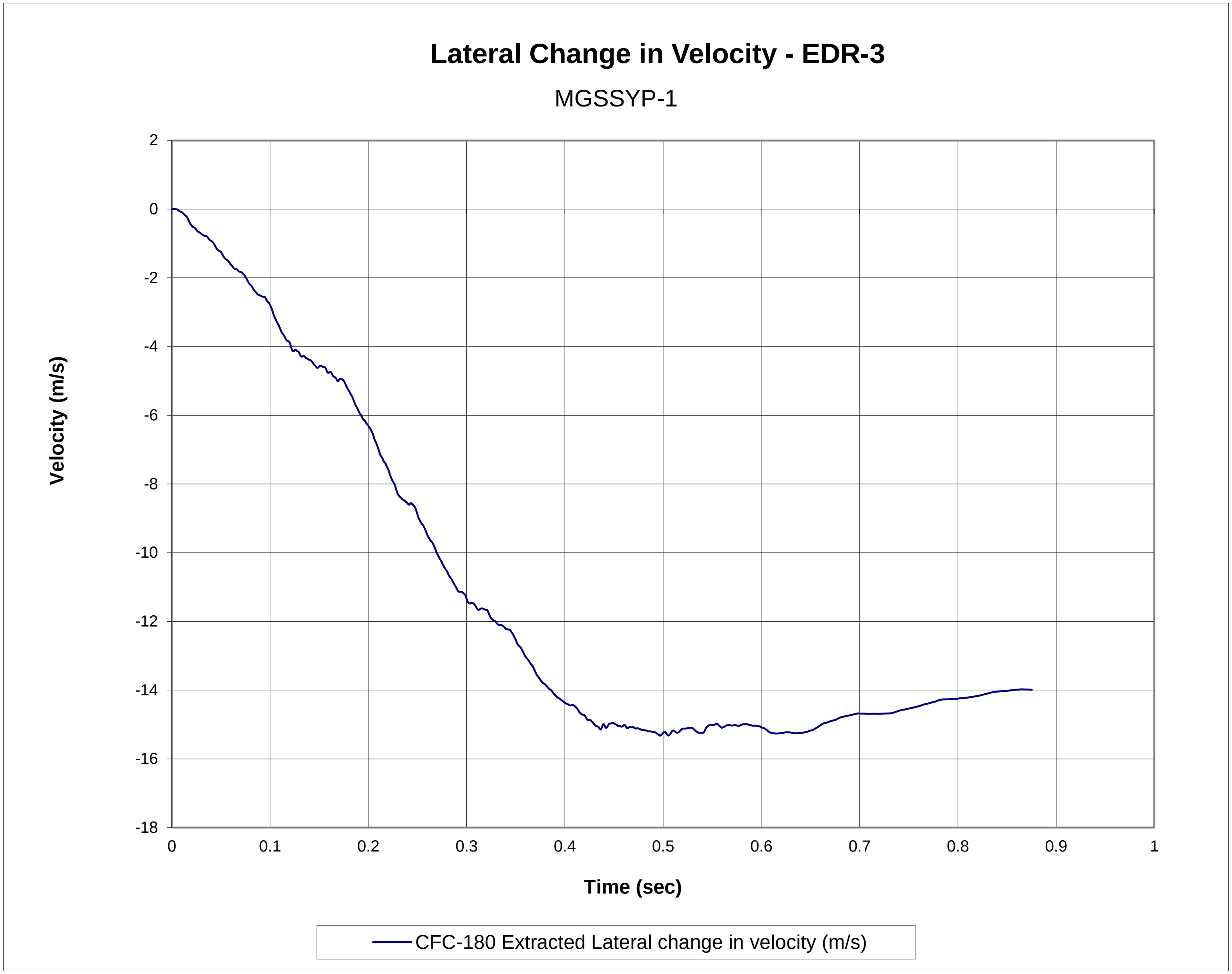


Figure E-13. Lateral Occupant Impact Velocity (EDR-3), Test No. MGSSYP-1

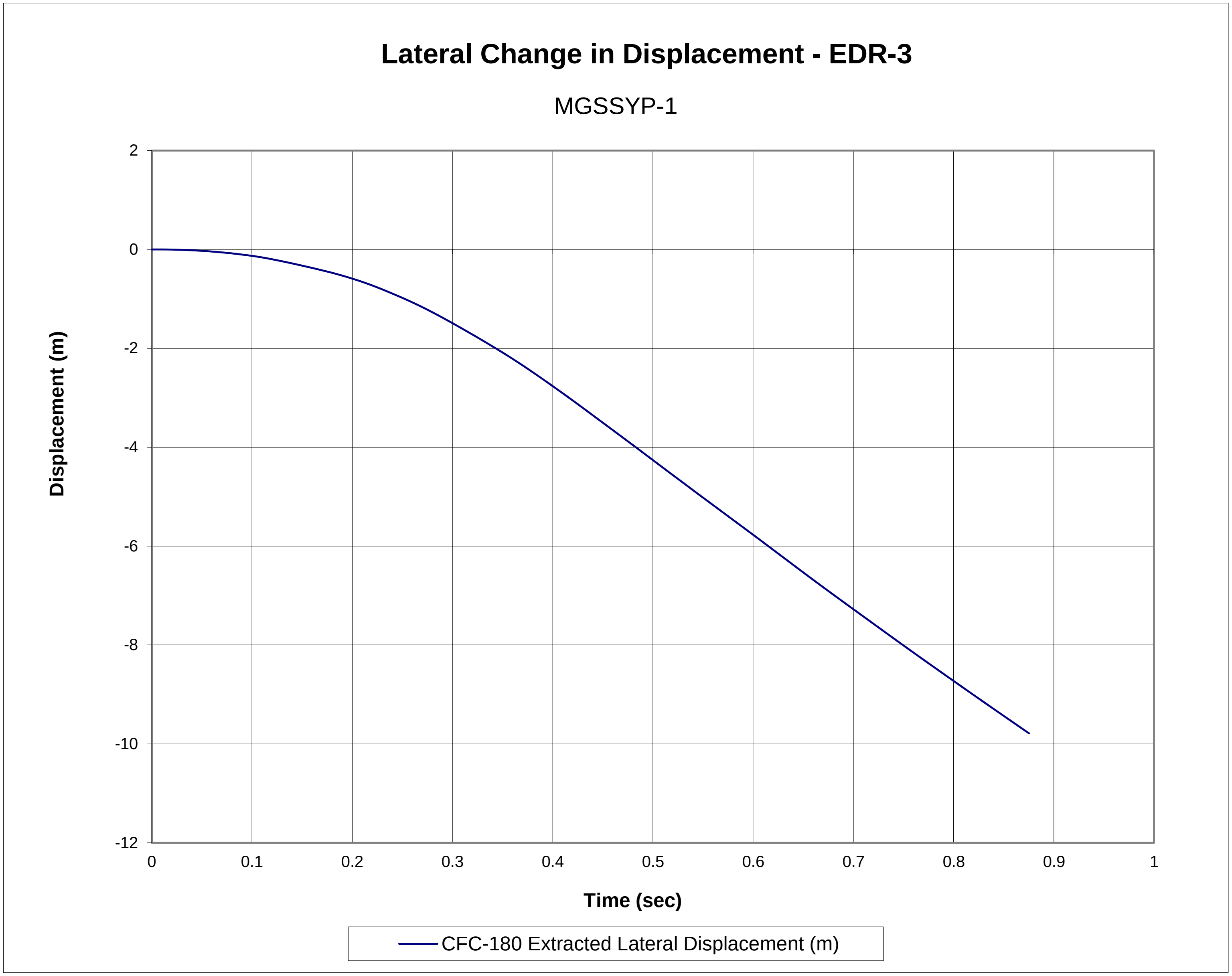


Figure E-14. Lateral Occupant Displacement (EDR-3), Test No. MGSSYP-1

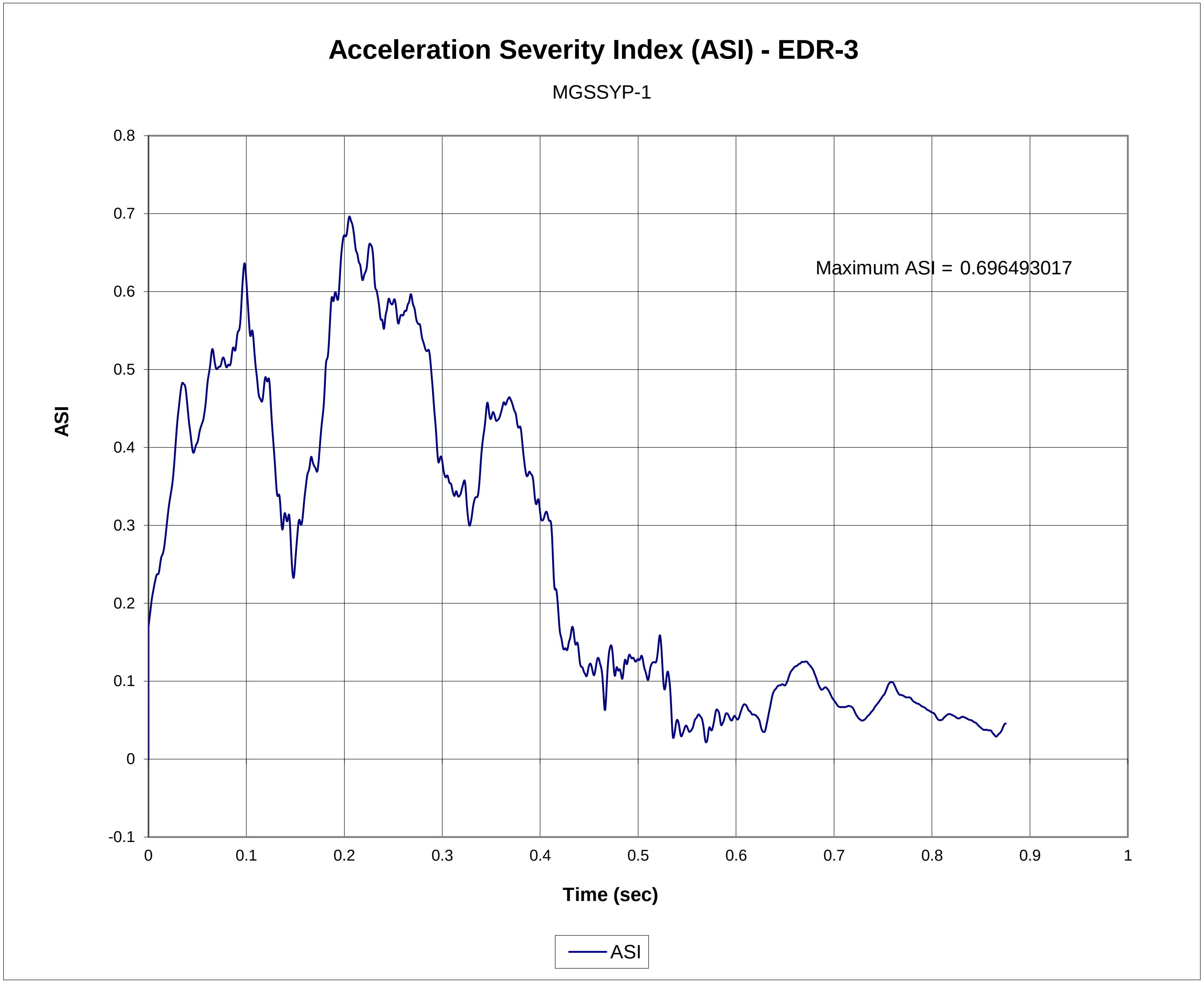


Figure E-15. Acceleration Severity Index (EDR-3), Test No. MGSSYP-1

Appendix F. Accelerometer and Rate Transducer Data Plots, Test No. MGSSYP-2

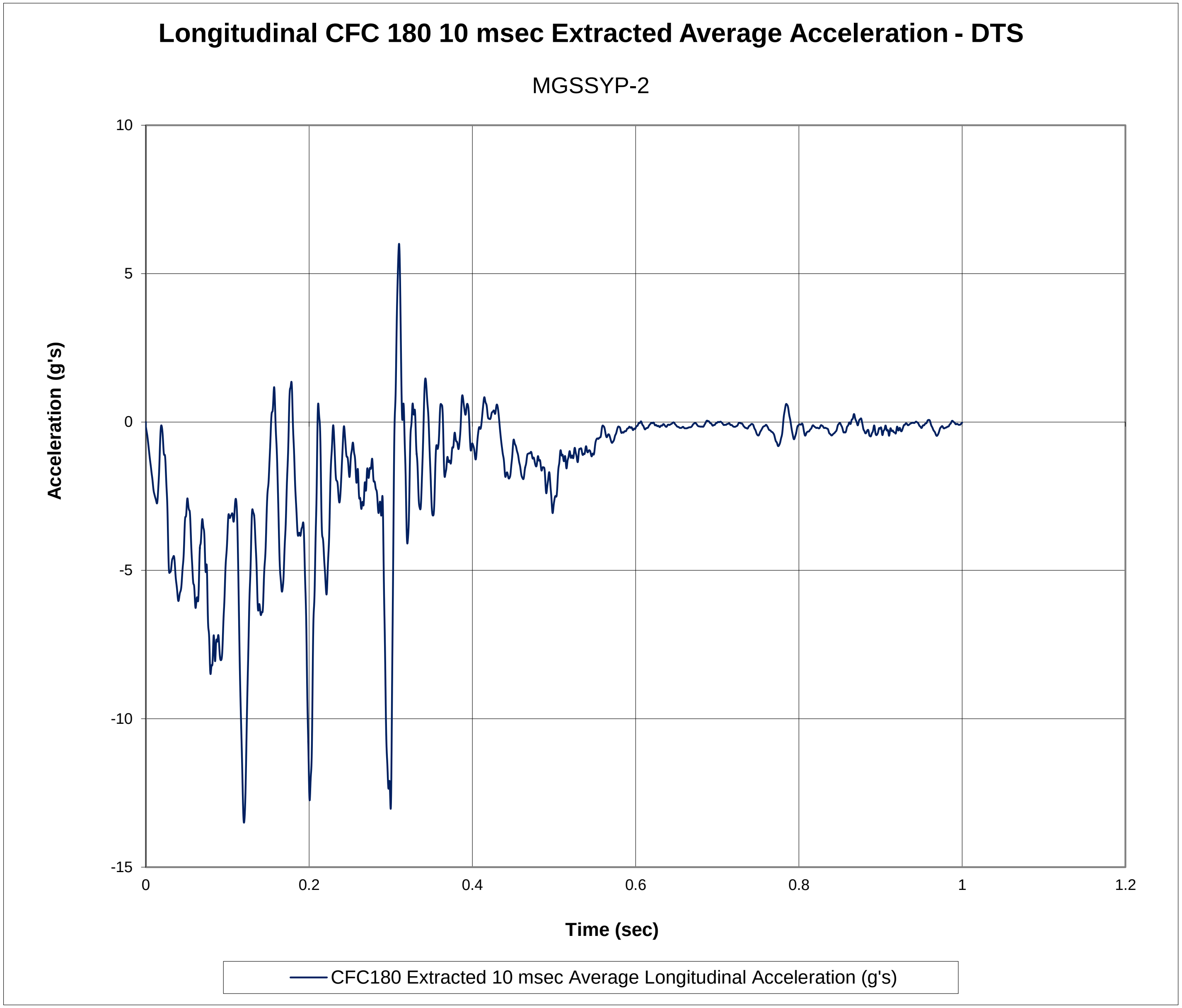


Figure F-1. 10-ms Average Longitudinal Deceleration (DTS), Test No. MGSSYP-2

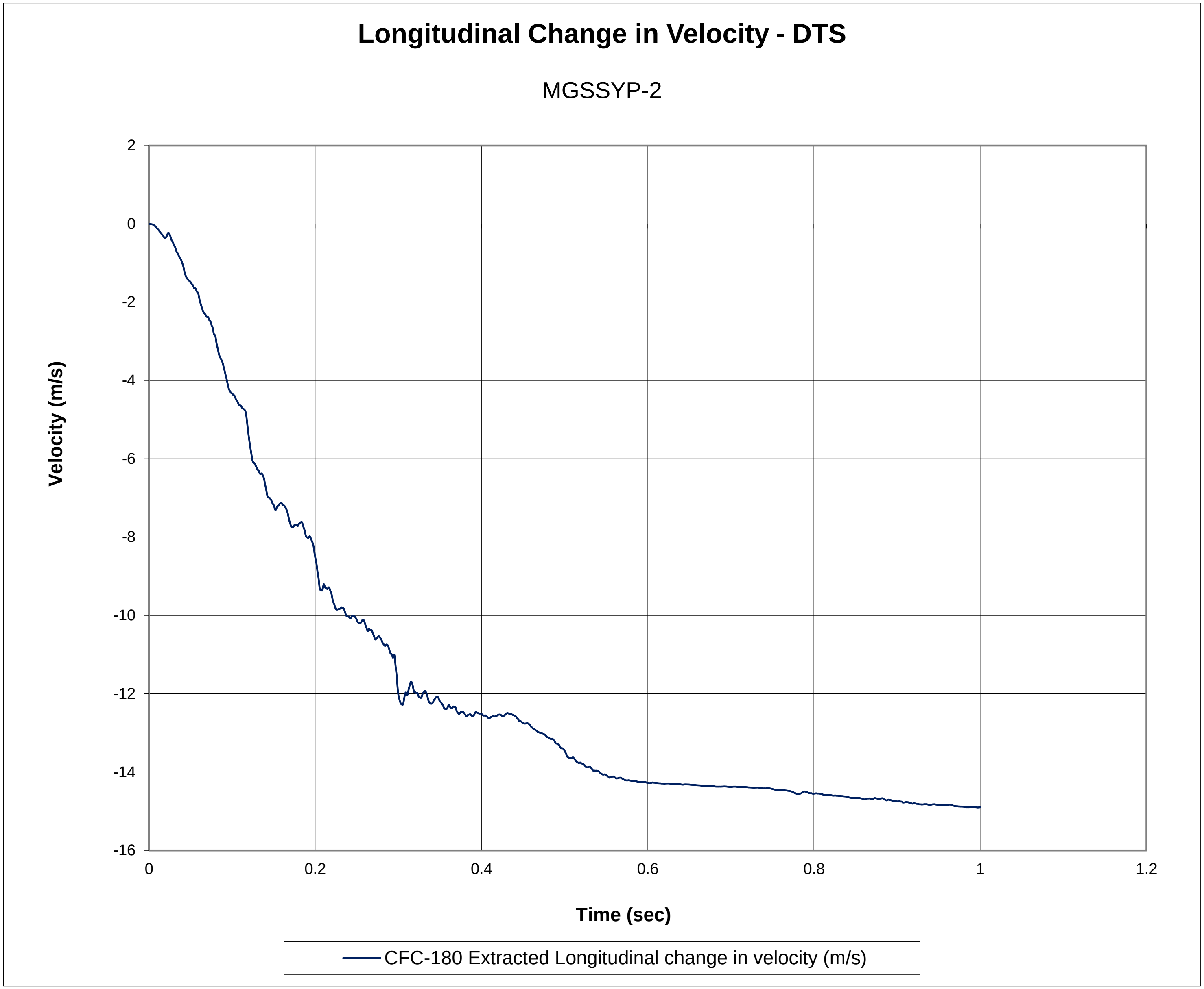


Figure F-2. Longitudinal Occupant Impact Velocity (DTS), Test No. MGSSYP-2

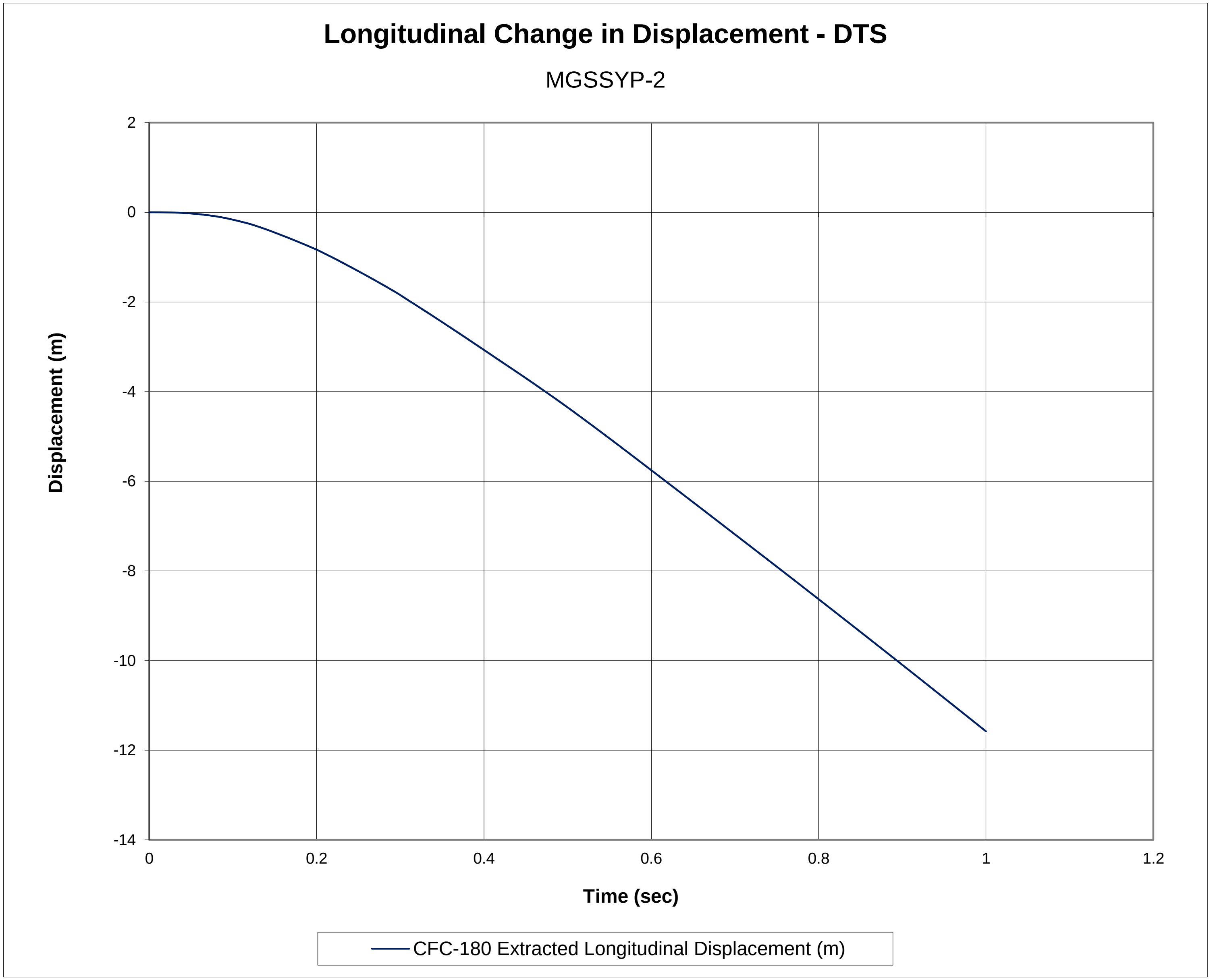


Figure F-3. Longitudinal Occupant Displacement (DTS), Test No. MGSSYP-2

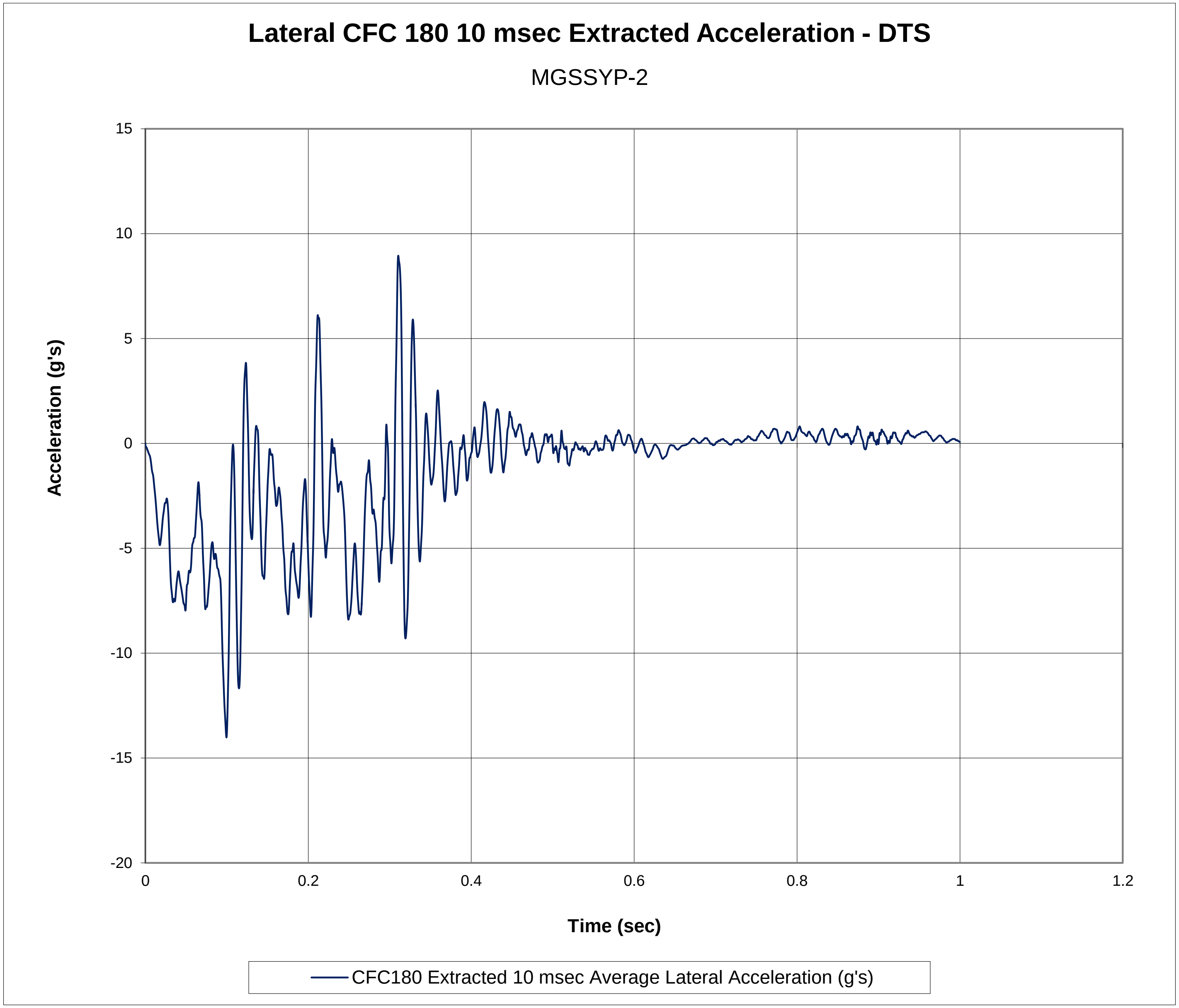


Figure F-4. 10-ms Average Lateral Deceleration (DTS), Test No. MGSSYP-2

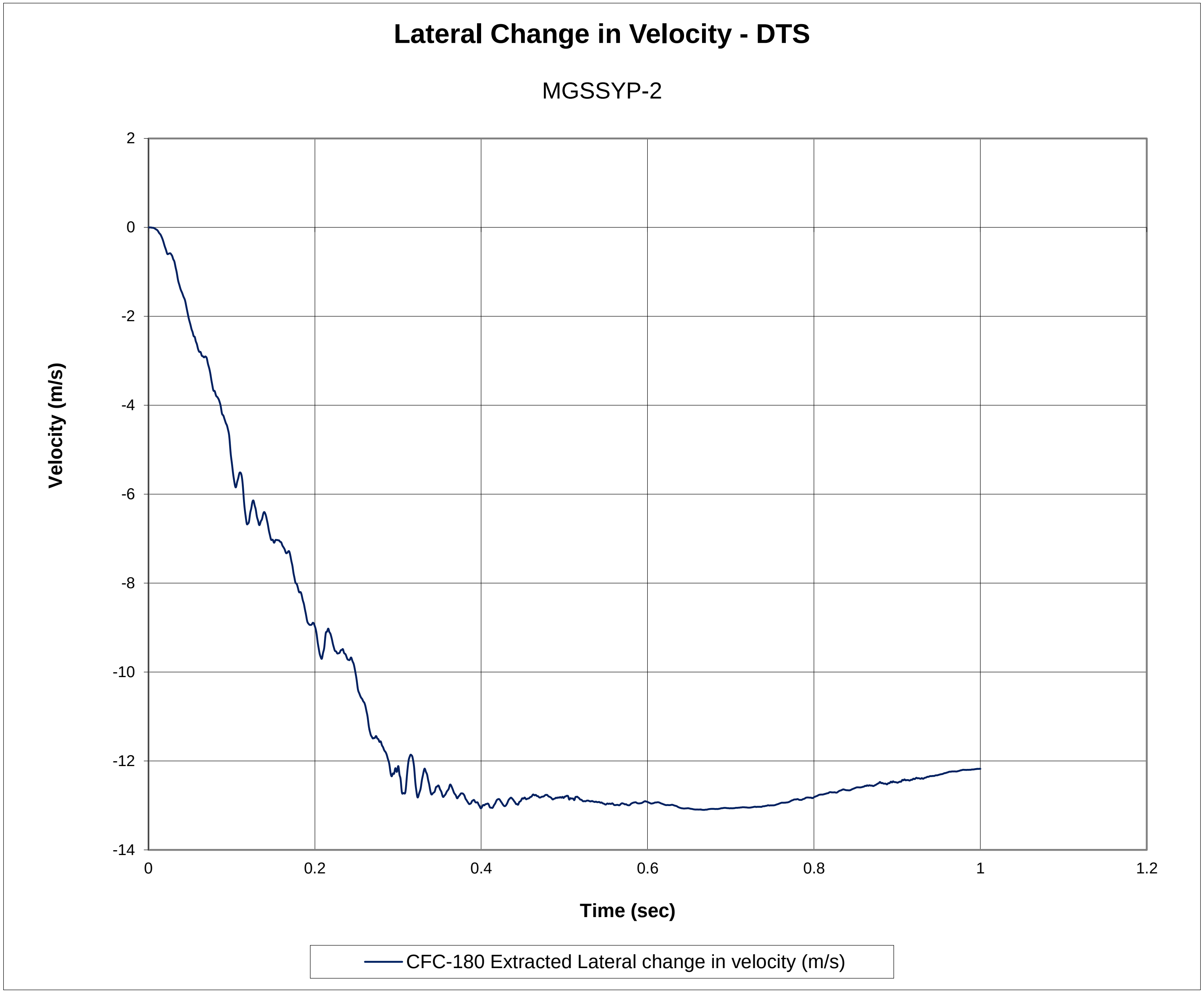


Figure F-5. Lateral Occupant Impact Velocity (DTS), Test No. MGSSYP-2

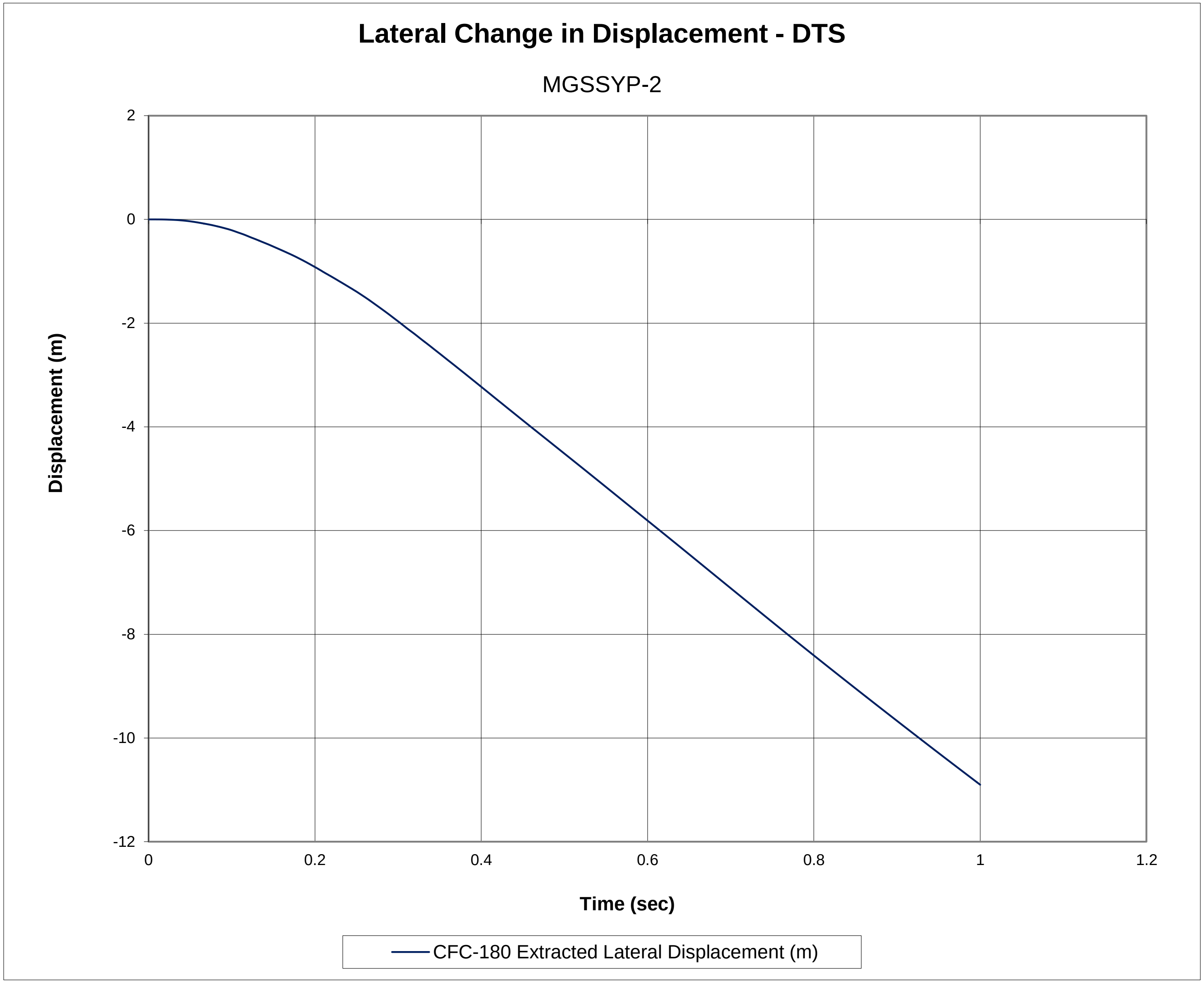


Figure F-6. Lateral Occupant Displacement (DTS), Test No. MGSSYP-2

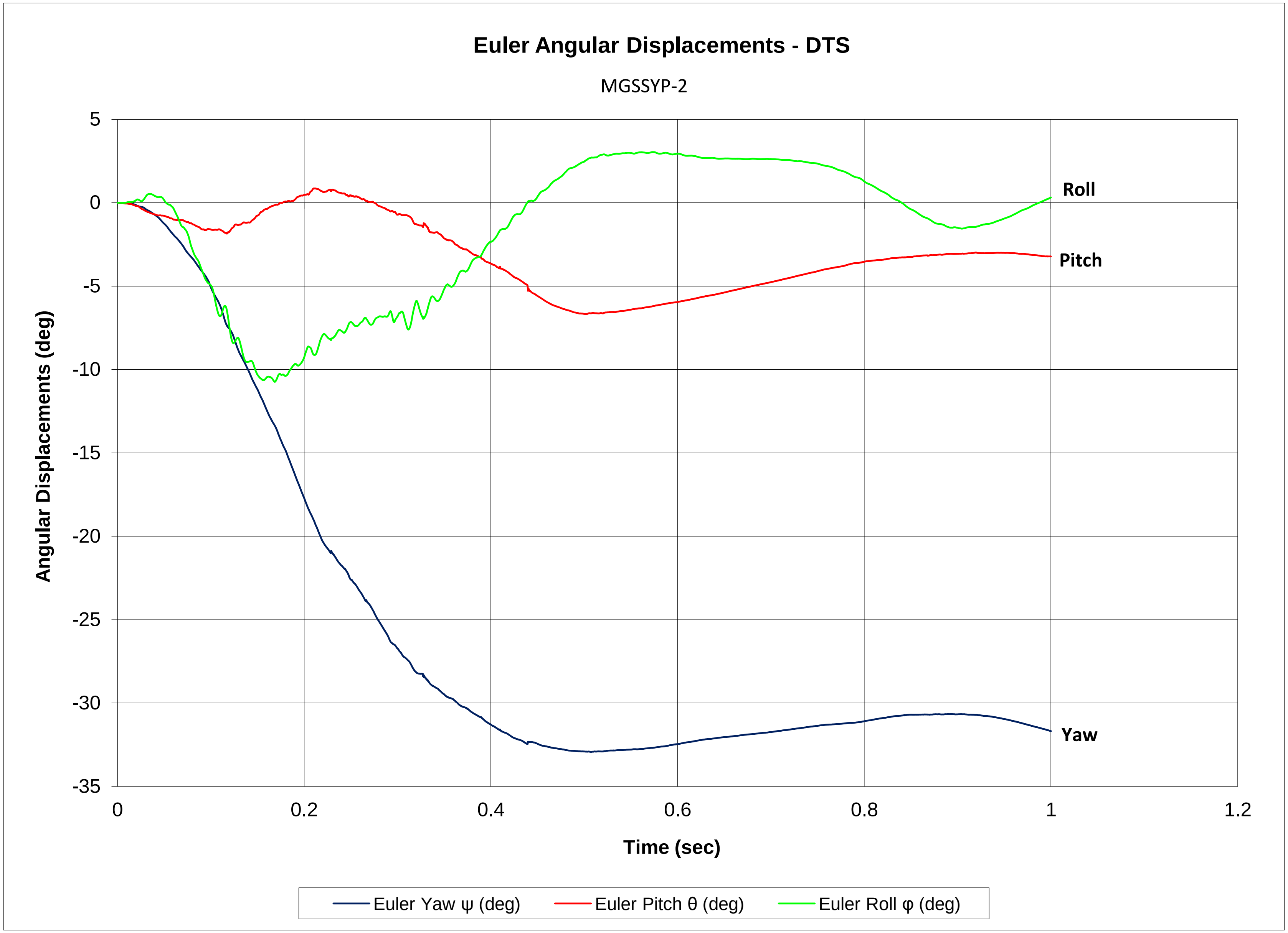


Figure F-7. Vehicular Angular Displacement (DTS), Test No. MGSSYP-2

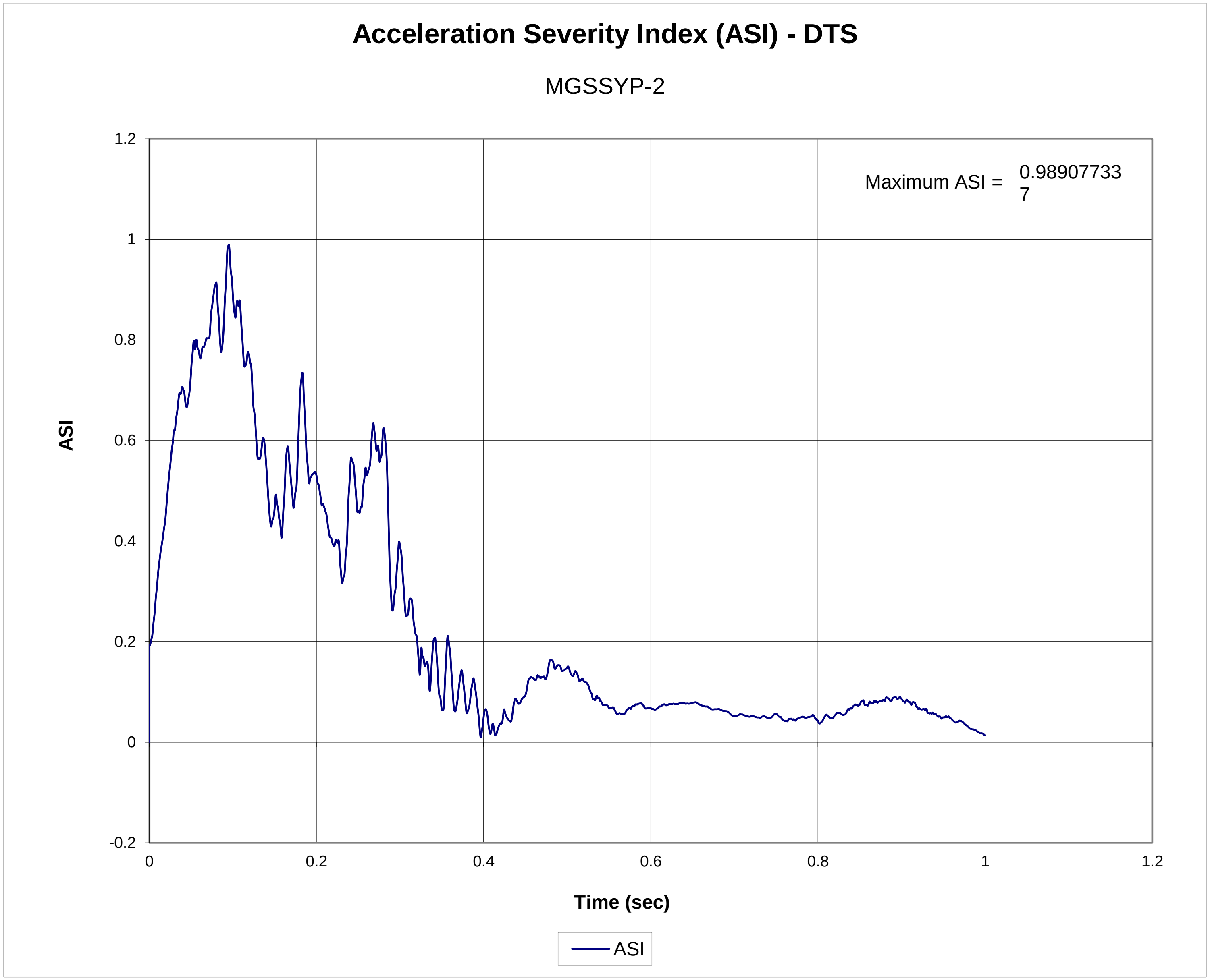


Figure F-8. Acceleration Severity Index (DTS), Test No. MGSSYP-2

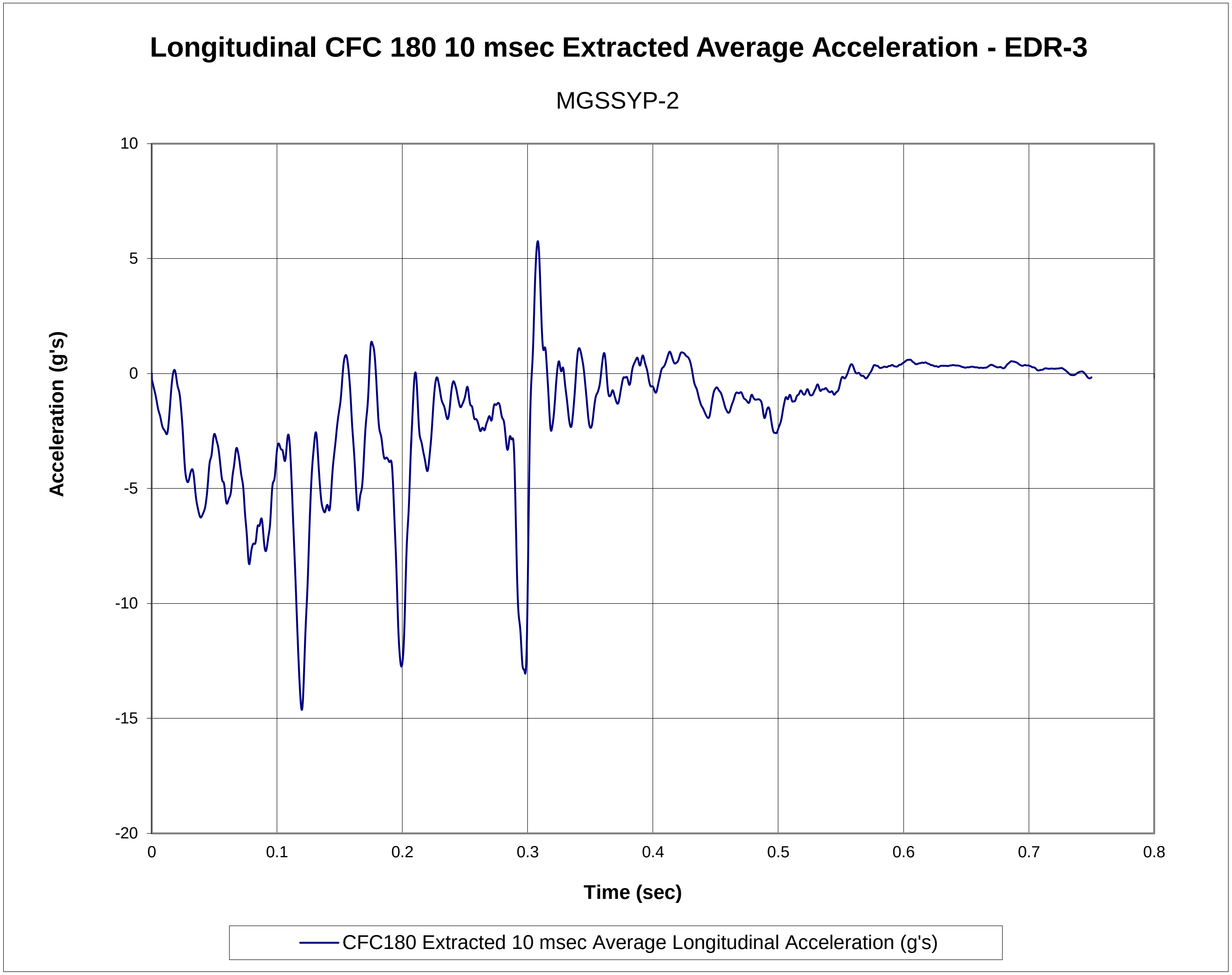


Figure F-9. 10-ms Average Longitudinal Deceleration (EDR-3), Test No. MGSSYP-2

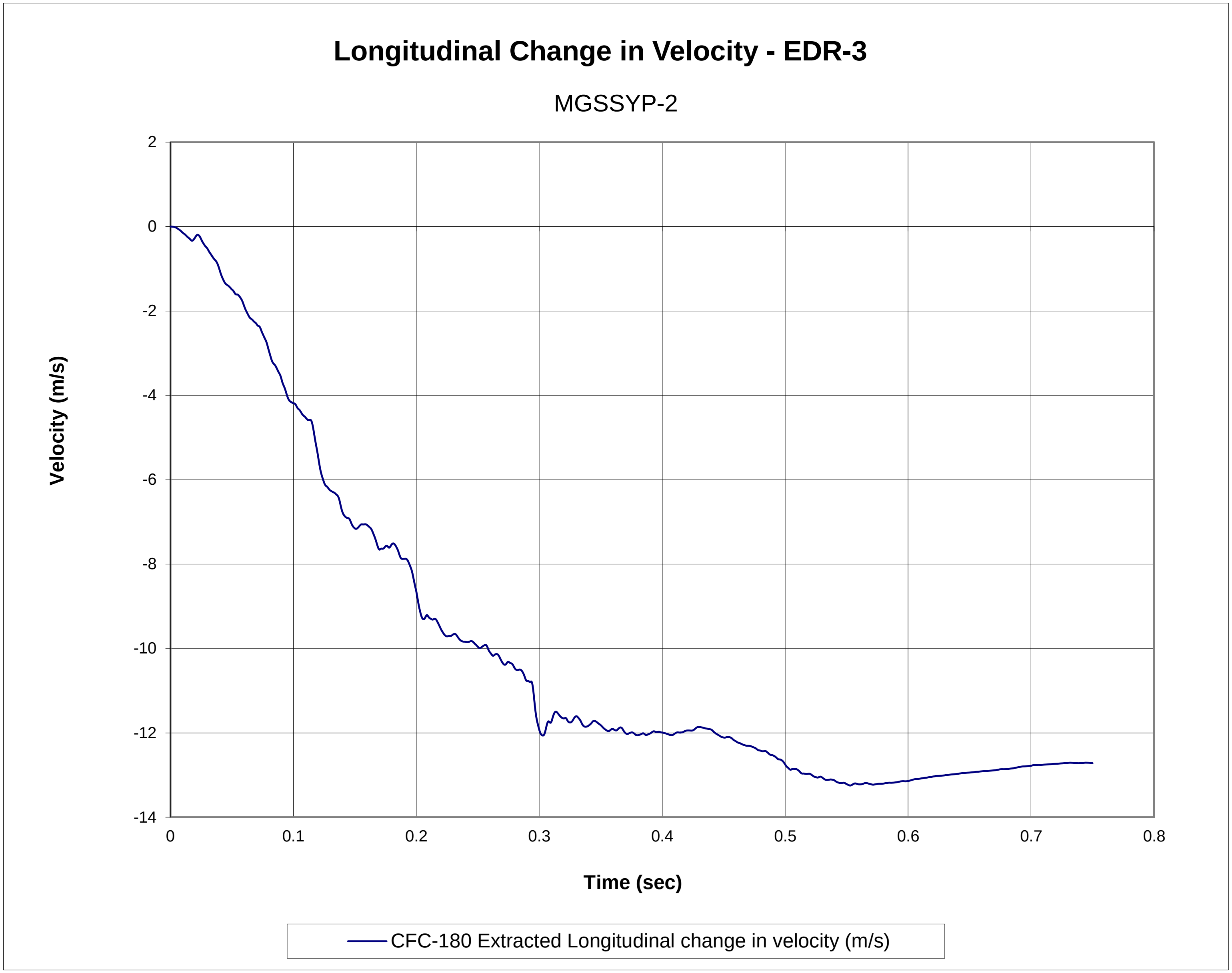


Figure F-10. Longitudinal Occupant Impact Velocity (EDR-3), Test No. MGSSYP-2

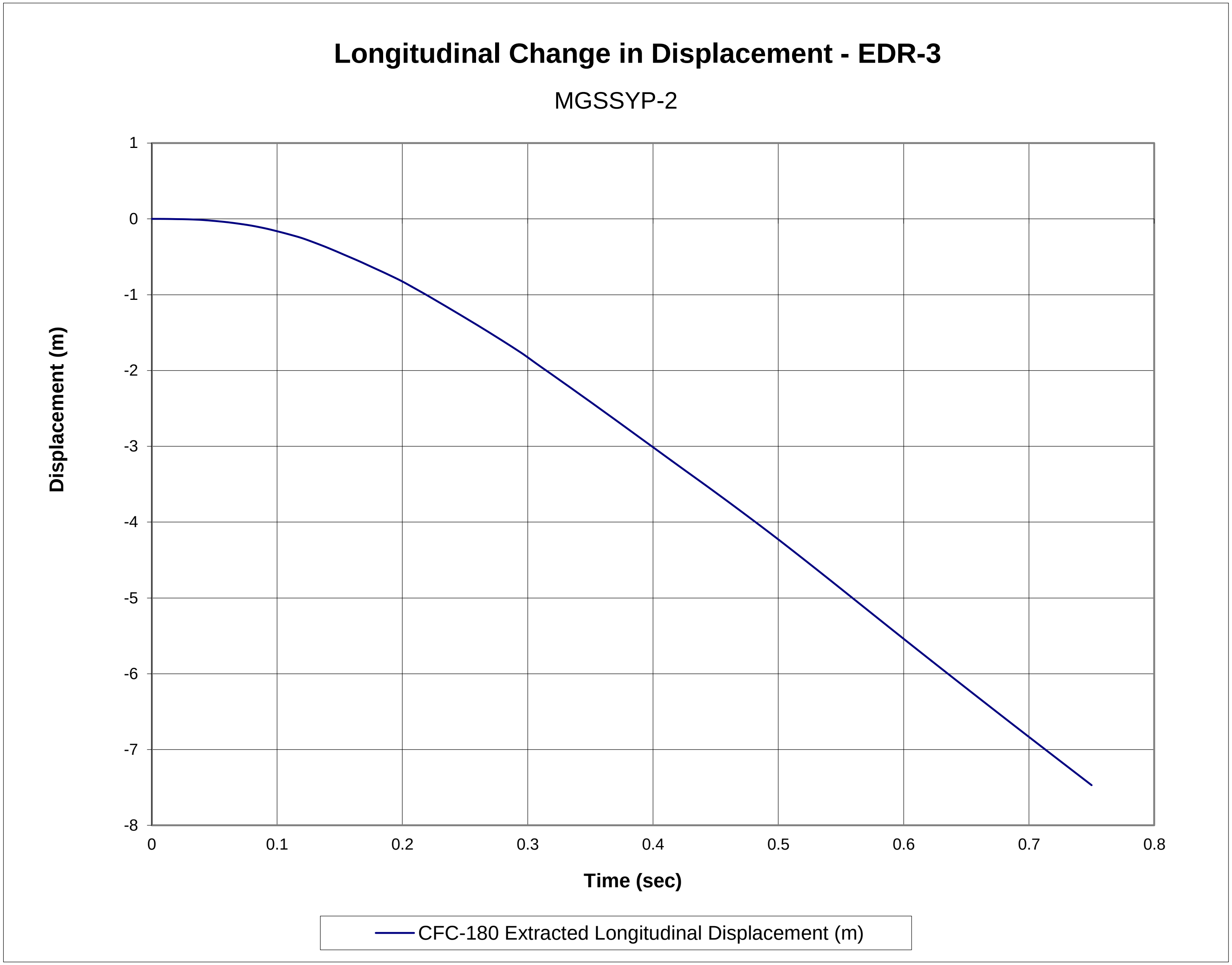


Figure F-11. Longitudinal Occupant Displacement (EDR-3), Test No. MGSSYP-2

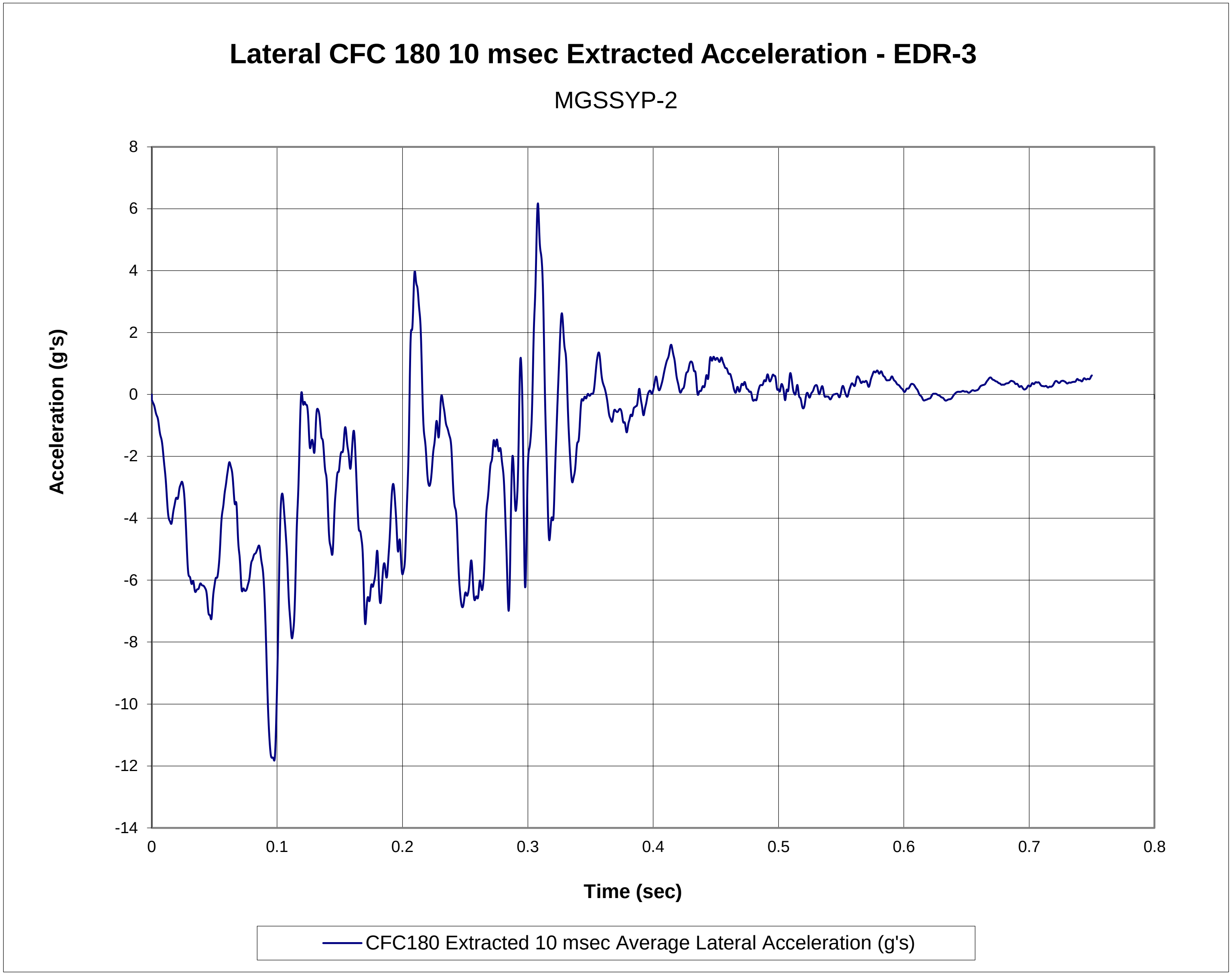


Figure F-12. 10-ms Average Lateral Deceleration (EDR-3), Test No. MGSSYP-2

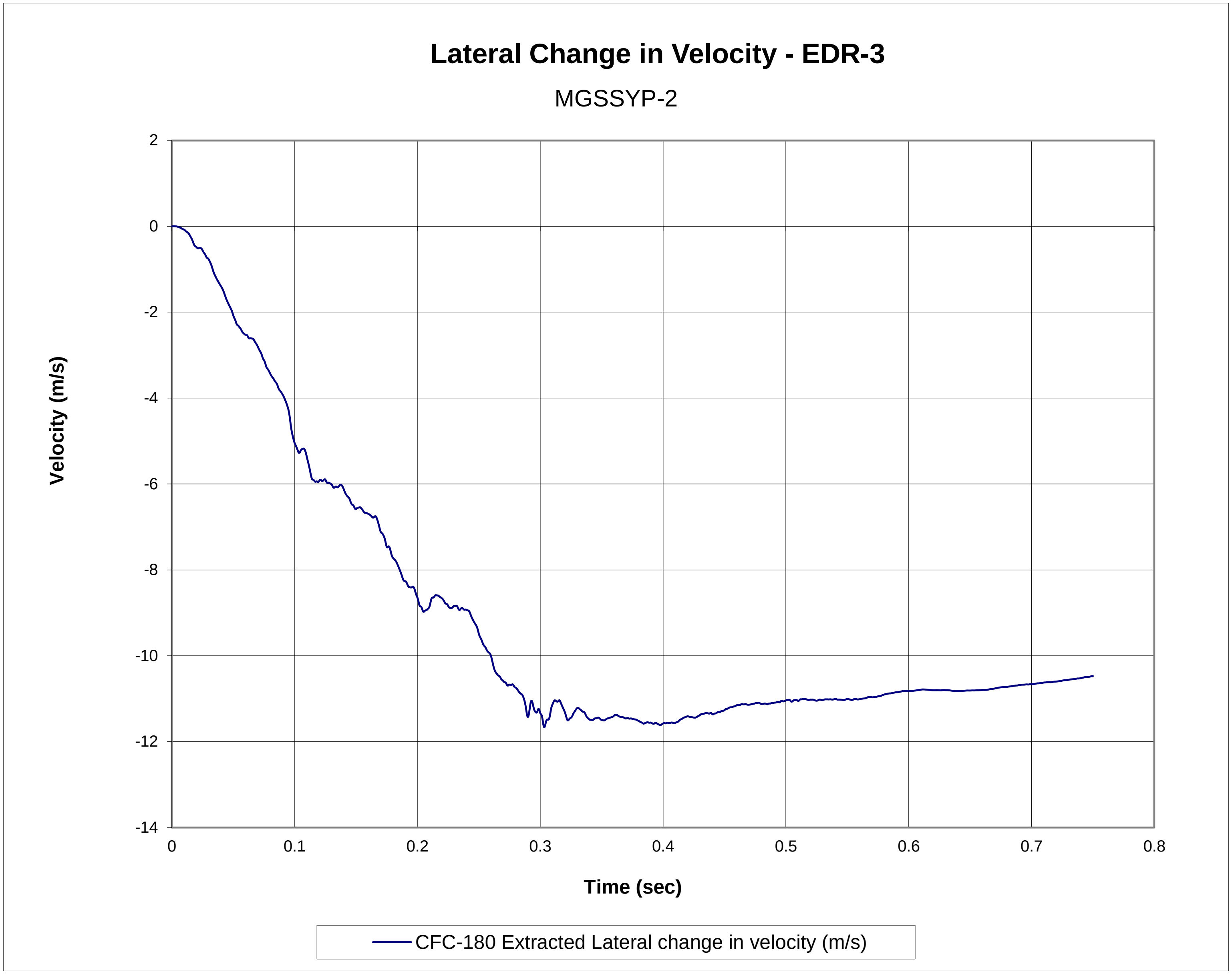


Figure F-13. Lateral Occupant Impact Velocity (EDR-3), Test No. MGSSYP-2

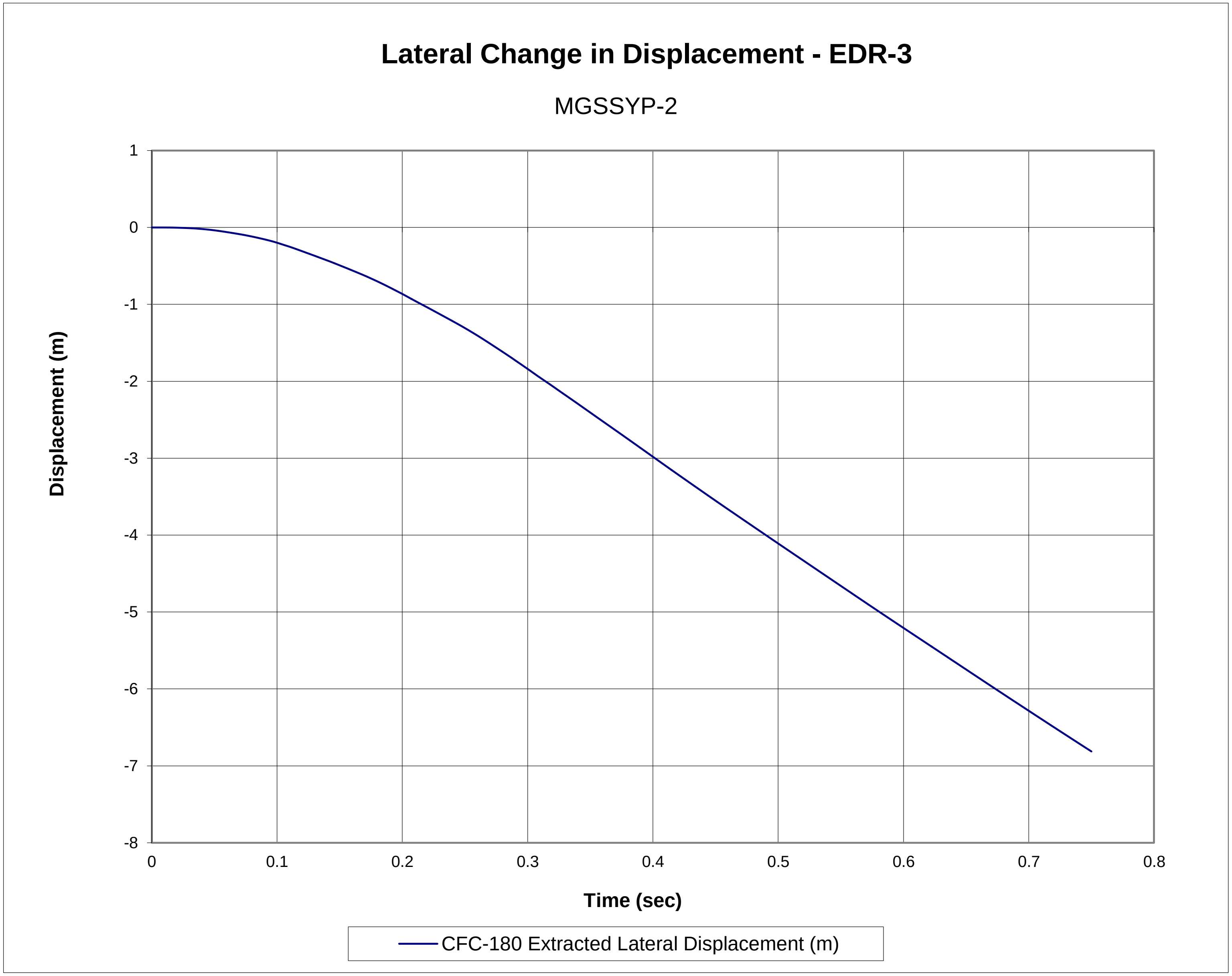


Figure F-14. Lateral Occupant Displacement (EDR-3), Test No. MGSSYP-2

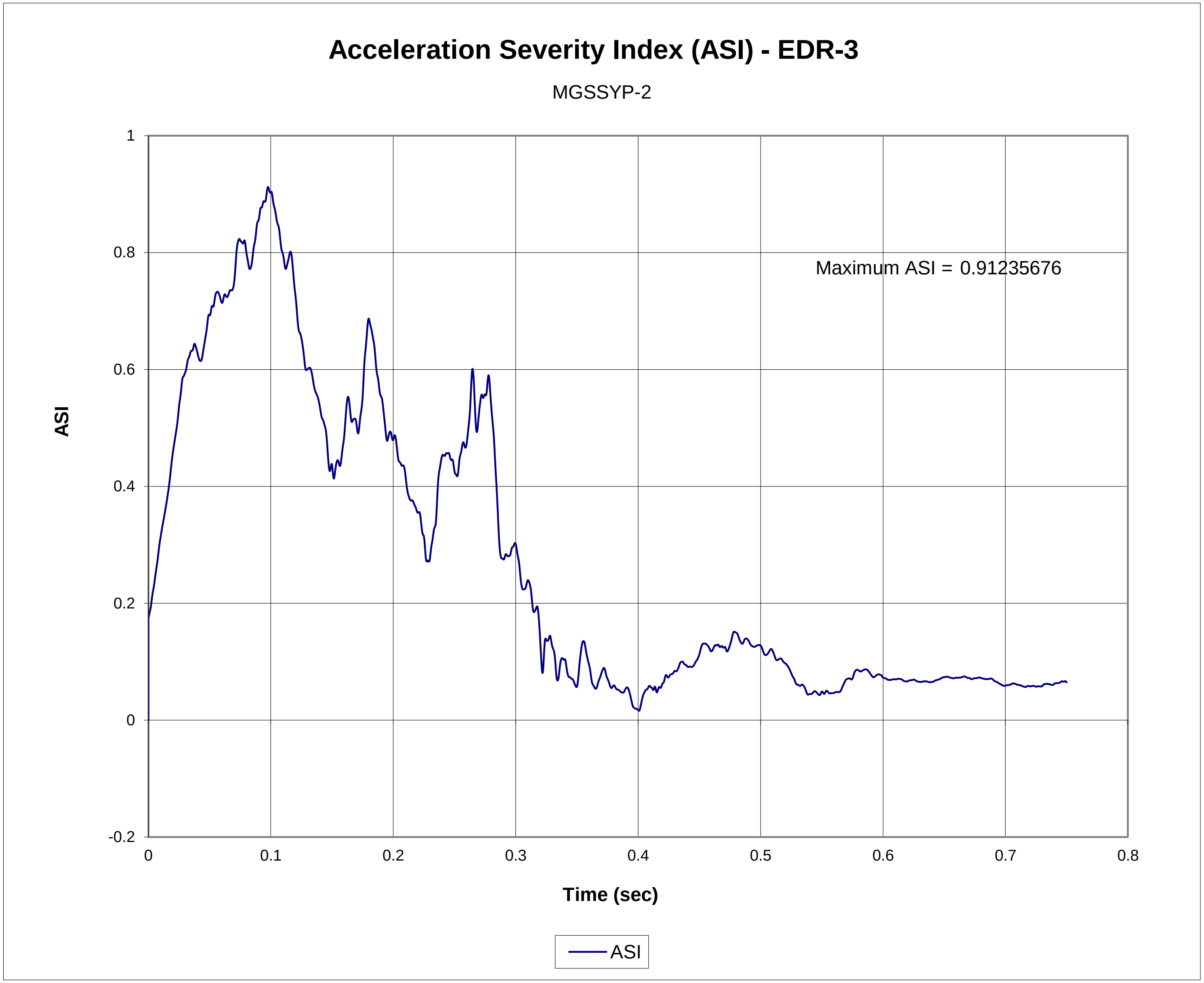


Figure F-15. Acceleration Severity Index (EDR-3), Test No. MGSSYP-2

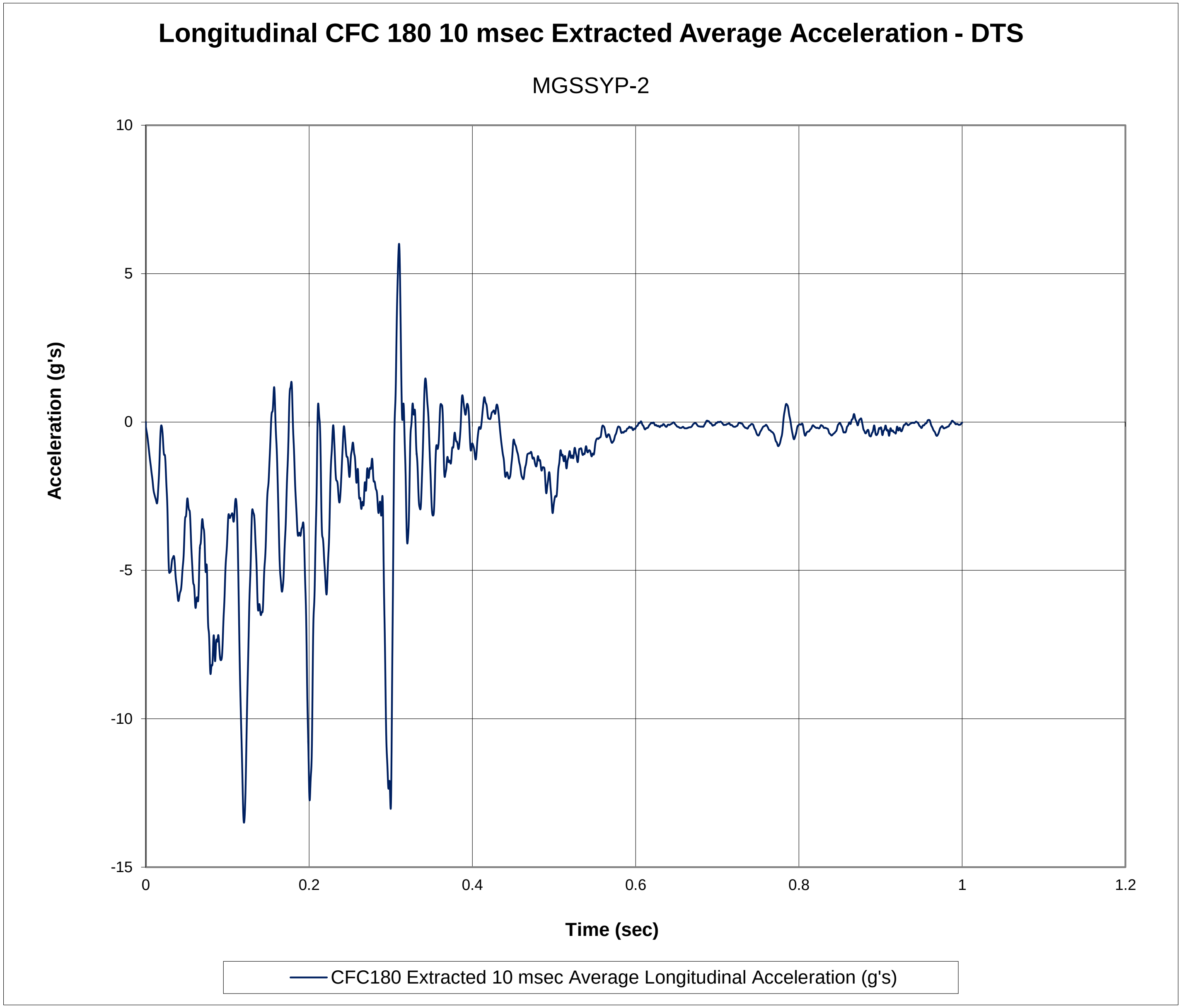


Figure F-16. 10-ms Average Longitudinal Deceleration (DTS), Test No. MGSSYP-2

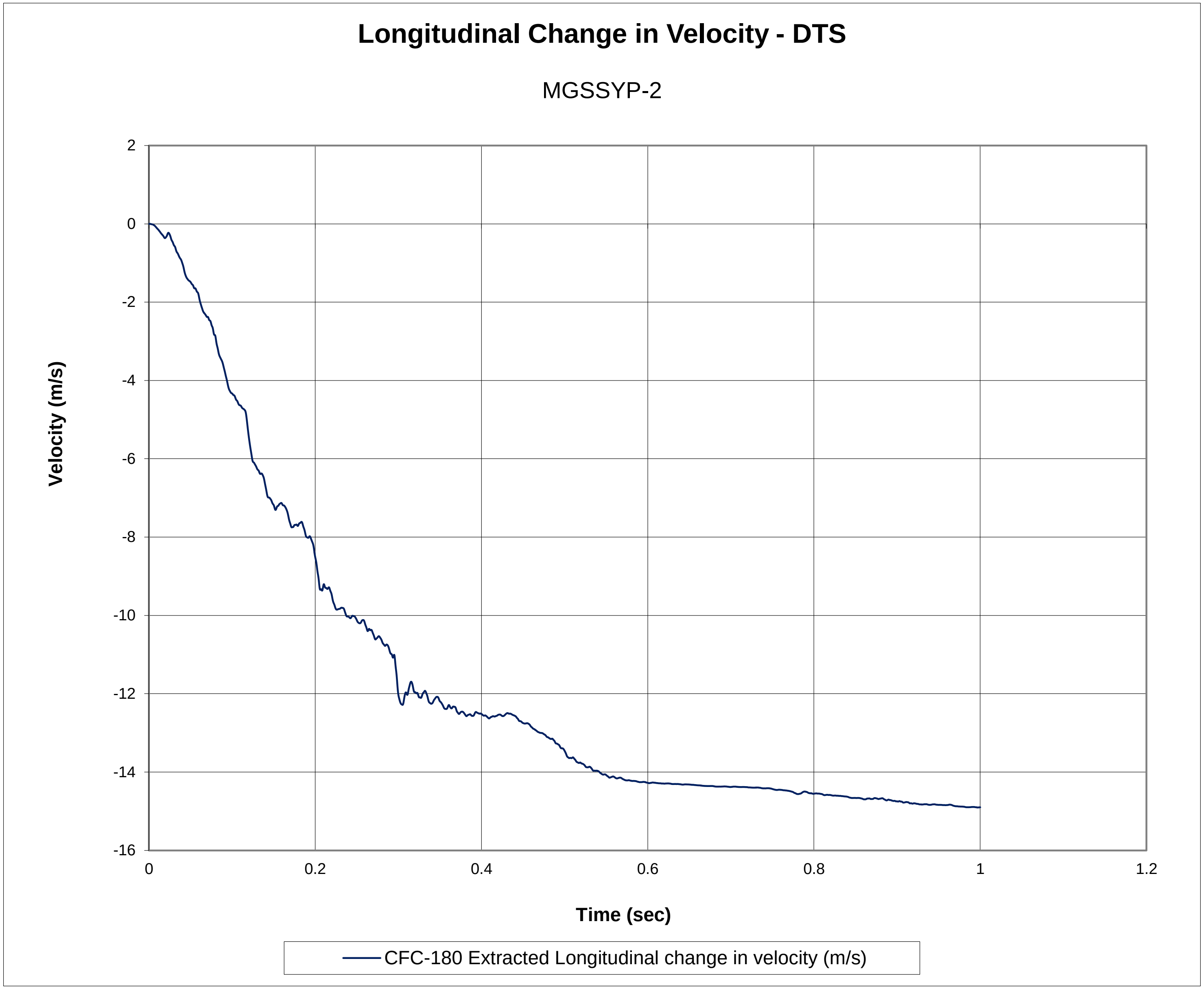


Figure F-17. Longitudinal Occupant Impact Velocity (DTS), Test No. MGSSYP-2

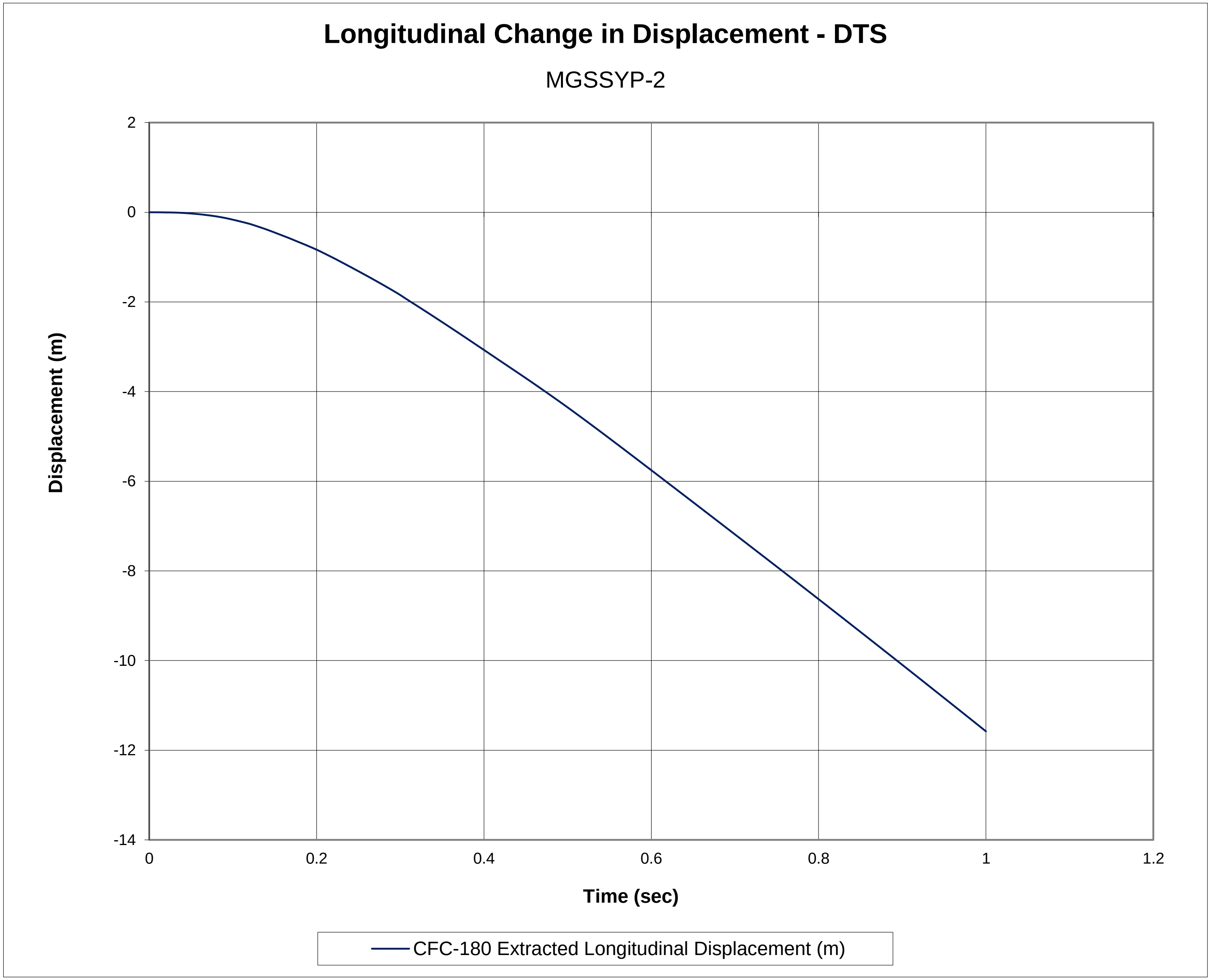


Figure F-18. Longitudinal Occupant Displacement (DTS), Test No. MGSSYP-2

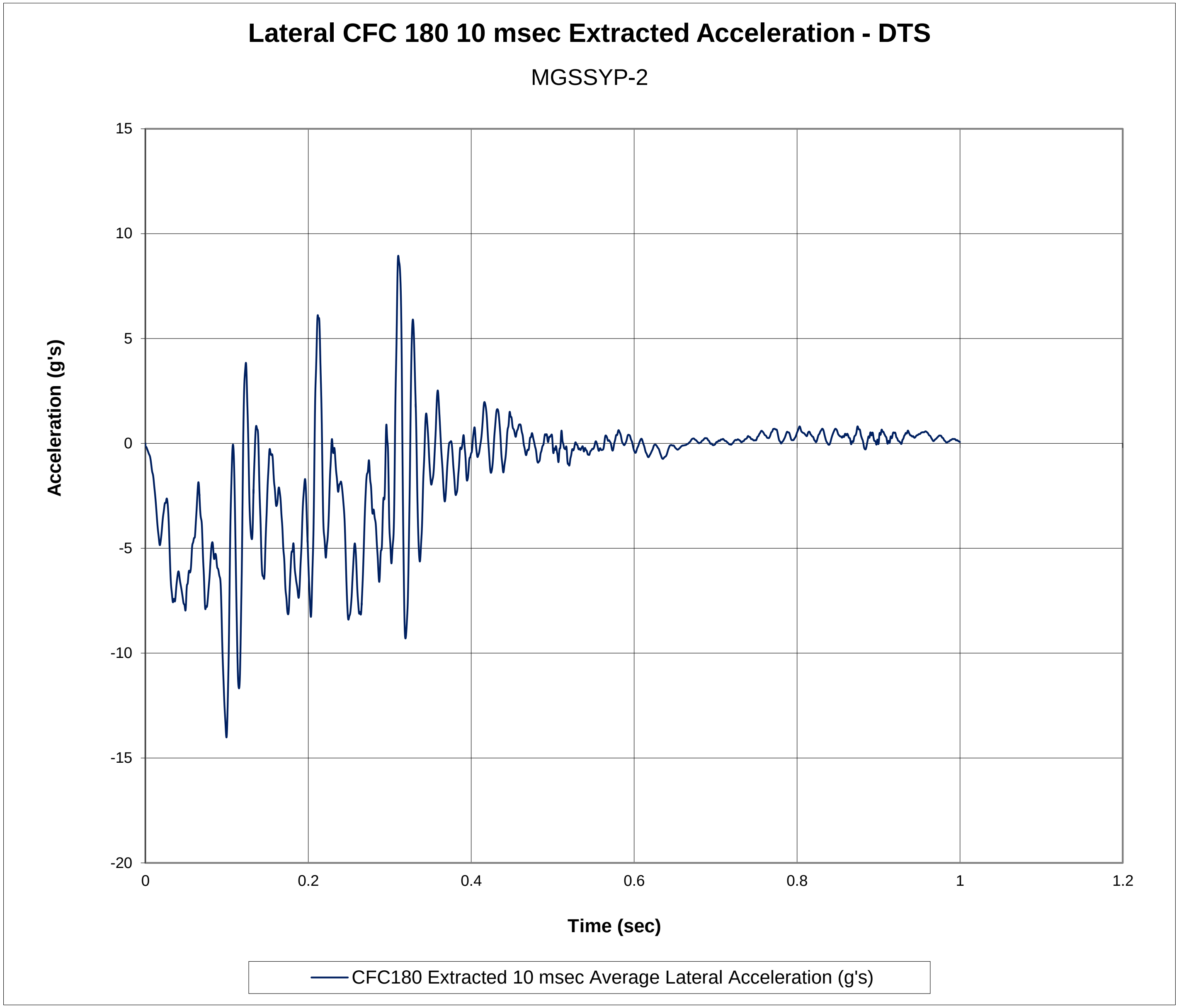


Figure F-19. 10-ms Average Lateral Deceleration (DTS), Test No. MGSSYP-2

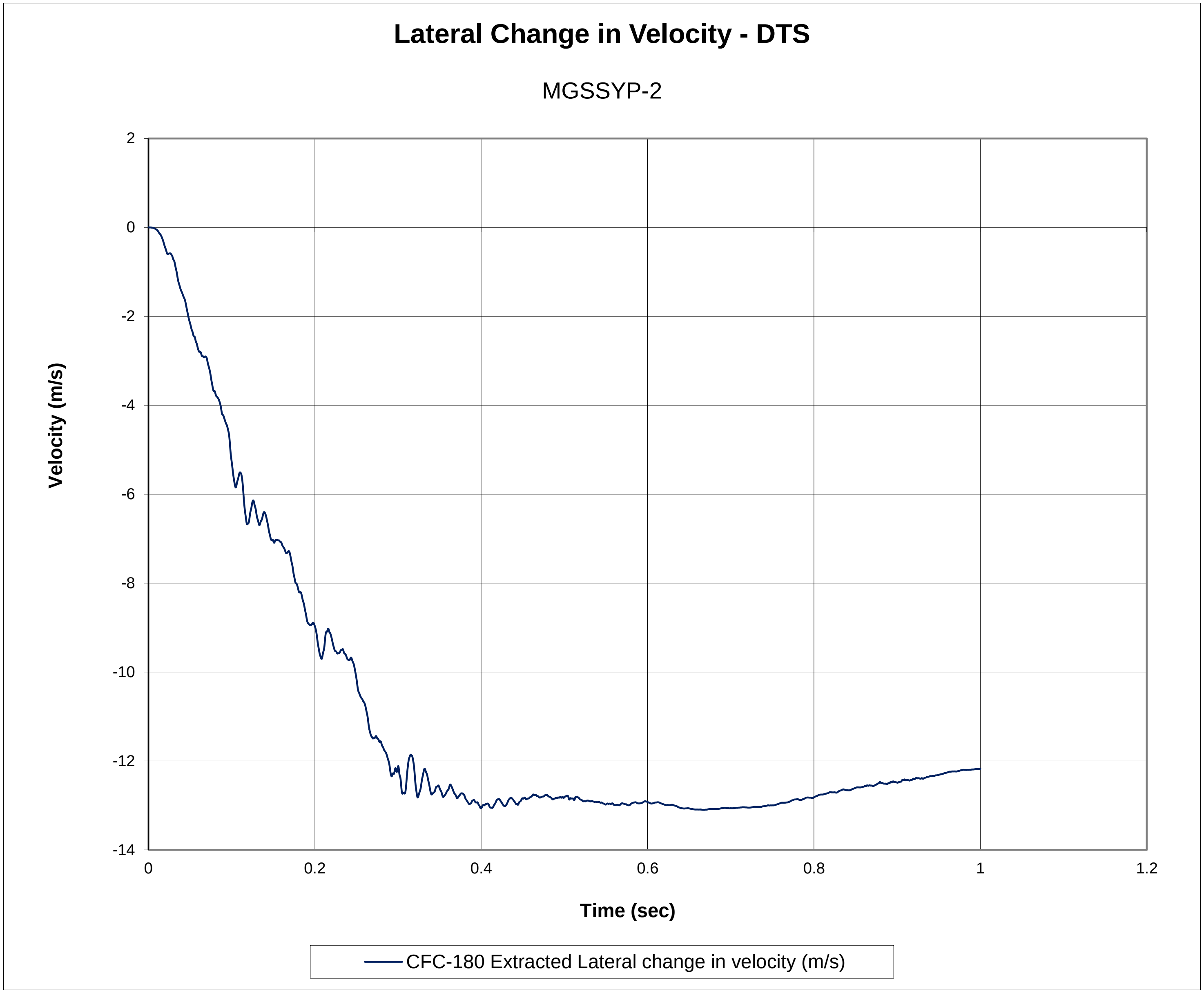


Figure F-20. Lateral Occupant Impact Velocity (DTS), Test No. MGSSYP-2

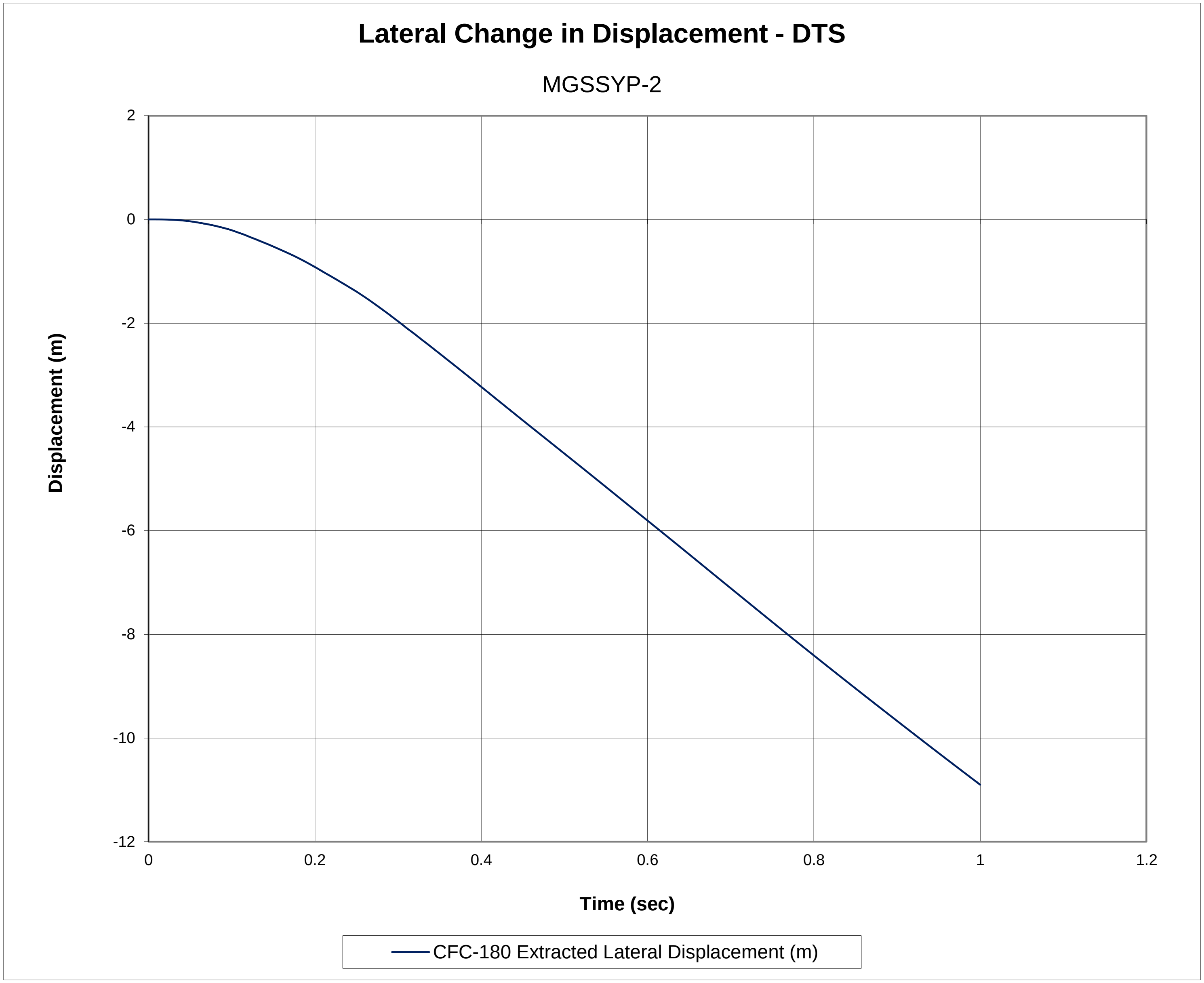


Figure F-21. Lateral Occupant Displacement (DTS), Test No. MGSSYP-2

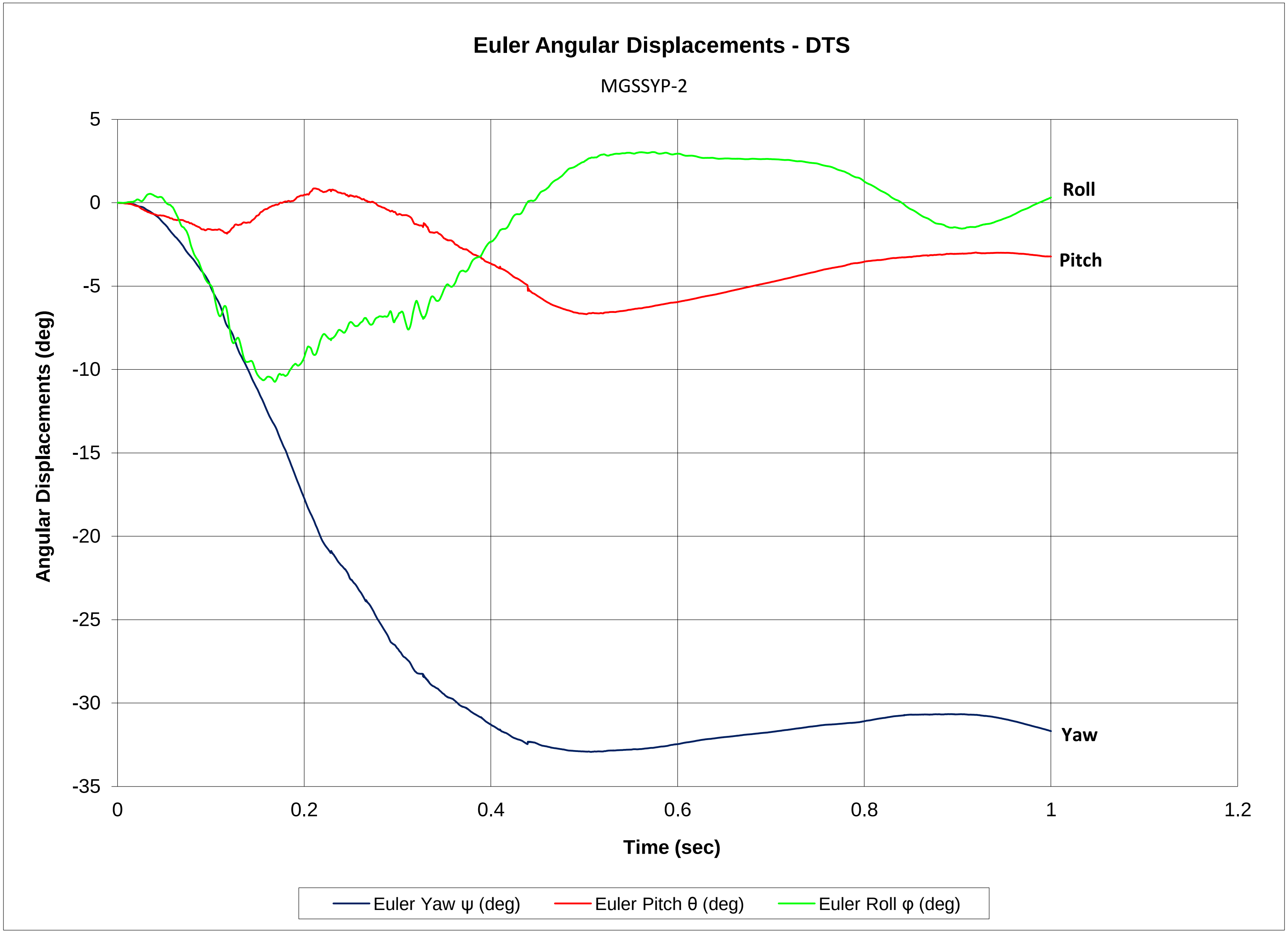


Figure F-22. Vehicular Angular Displacement (DTS), Test No. MGSSYP-2

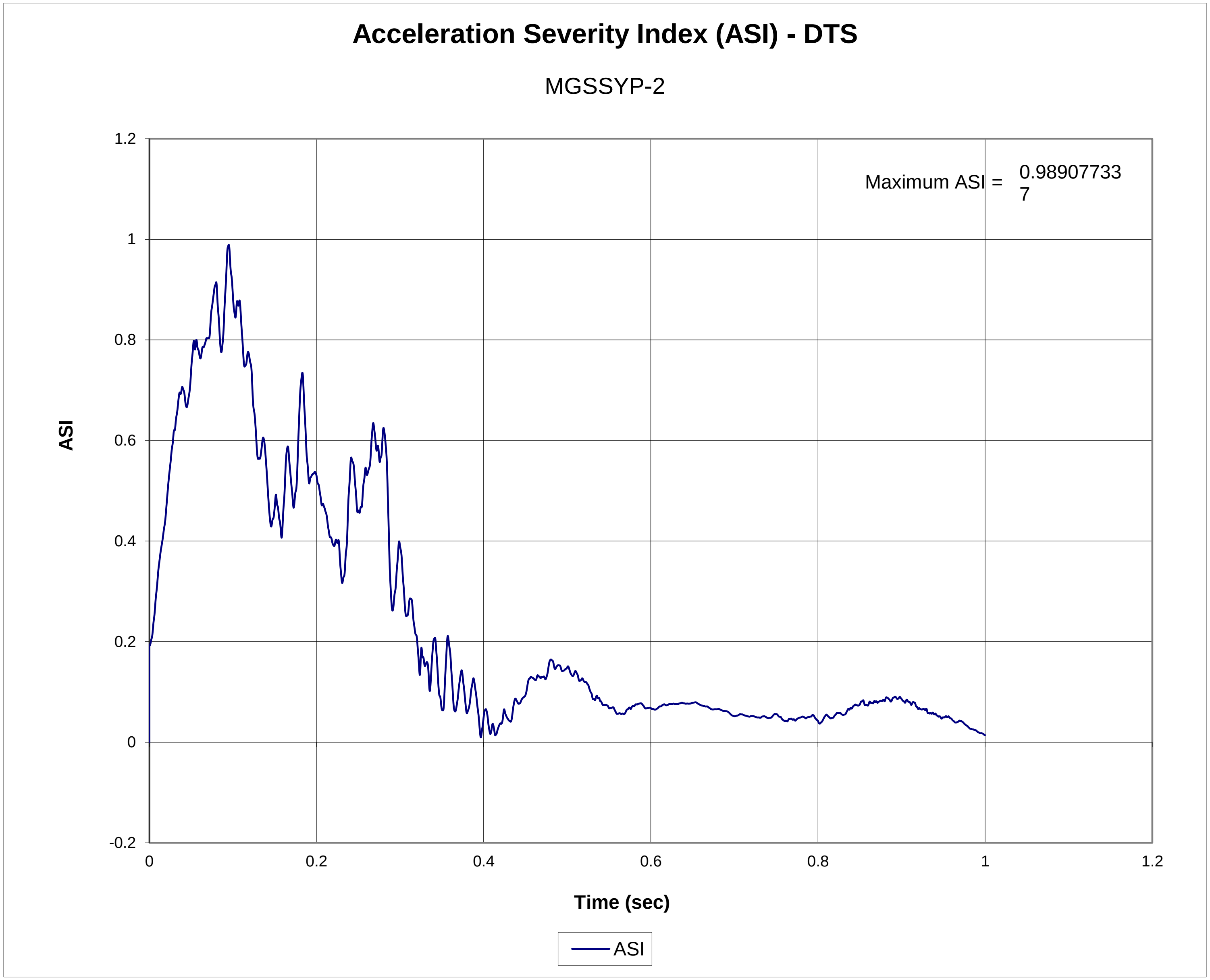


Figure F-23. Acceleration Severity Index (DTS), Test No. MGSSYP-2

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