Research Project Number TPF-5(430) – Supplement #10

EVALUATION OF THE MGS WITH HALF POST SPACING AND 7-FT POSTS ADJACENT TO SLOPE

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16. Abstract
This report documents two full-scale crash tests conducted in support of a study to investigate the safety performance of Wisconsin Department of Transportation's (WisDOT's) Midwest Guardrail System (MGS) with half-post spacing adjacent to a 2H:1V slope. The test installation consisted of 175-ft long MGS with 75-ft long section of the barrier installed with ½ post spacing with 7-ft long W6x9 posts adjacent to a 2H:1V slope. The full-scale crash tests were conducted according to Manual for Assessing Safety Hardware 2016 (MASH 2016) criteria using Test-Level 3 (TL-3) test designation nos. 3-10 and 3-11, respectively.

In test no. MGS7S-1, an 1100C small car impacted the barrier at a speed of 62.8 mph and an angle of 25.2 degrees. In the test no. MGS7S-2, a 2270P quad cab pickup truck impacted the barrier at a speed of 62.6 mph and an angle of 25.4 degrees. In both tests, the guardrail successfully contained and redirected the vehicle, and it did not penetrate or show potential for debris to penetrate the occupant compartment. All occupant risk measurements were below the maximum thresholds. Thus, test nos. MGS7S-1 and MGS7S-2 successfully met the TL-3 safety performance criteria defined in MASH 2016.

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DISCLAIMER STATEMENT

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 for the data contained herein was Brandon Perry, Research Engineer.

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1 INTRODUCTION

1.1 Background

W-beam guardrail is often used to protect motorists from steep roadside slopes adjacent to high-speed roadways. A roadside slope placed immediately behind a guardrail system significantly reduces the soil resistance associated with lateral deflection of the barrier. This reduction in the post-soil forces reduces the barrier system's energy-absorption capability, increases dynamic rail deflections, and can potentially produce issues with vehicle capture or vehicle override. Further, when the guardrail extends over the embankment, the gap between the bottom of the rail and the ground will be magnified and thereby increase the risk of severe wheel snag.

Guardrail placed adjacent to slopes has been a common concern for state departments of transportation (DOTs). In the past, several states have requested guidance regarding safe guardrail offsets or modification to guardrail post spacing and/or embedment when placed directly adjacent to steep fill slopes. Under National Cooperative Highway Research Program (NCHRP) Report 350 [1], Midwest Roadside Safety Facility (MwRSF) developed and evaluated a variation of the G4(1S) guardrail system for use adjacent to slopes as steep a 2H:1V. The test installation consisted of W-beam guardrail supported by 7-ft long, W6x9 steel guardrail posts spaced 37½ in. on center and installed with the center of the posts at the slope break point (SBP), as shown in Figure 1. The rail height of the system was 27¾ in. to the top of the rail. For the full-scale test, test no. MOSW-1, a 4,462-lb, ¾-ton pickup truck impacted the system 9⅜ in. downstream from the centerline of post no. 17, located within the half-post spacing region, at a speed of 62.6 mph and at an angle of 28.5 degrees. The vehicle was safely redirected, and the test was determined to be acceptable according to the TL-3 safety performance criteria presented in NCHRP Report 350.

Since the development of that system, the Midwest Guardrail System (MGS) has replaced the G4(1S) guardrail system as the standard guardrail design used by highway transportation agencies [2], and the evaluation of roadside hardware is currently governed by the *Manual for Assessing Safety Hardware, Second Edition* (MASH 2016) [3]. The Wisconsin Department of Transportation (WisDOT) has previously used the G4(1S) W-beam barrier configuration with half-post spacing with 7-ft long W6x9 posts adjacent to slopes and desired that this configuration be adopted to the MGS system and evaluated under MASH 2016 Test Level 3 (TL-3).

Figure 1. W-beam Guardrail Adjacent to a 2:1 Foreslope, Test No. MOSW-1 [2]

1.2 Objective

The objective of this research effort is to evaluate a MASH TL-3 compliant variation of the MGS adjacent to slopes as steep as 2H:1V through full-scale crash testing. The modified MGS system utilized half-post spacing with 7-ft long W6x9 posts installed at the SBP of a 2H:1V slope. The system was evaluated according to the TL-3 criteria of MASH 2016 [3].

1.3 Scope

The research objective was achieved through the completion of several tasks. First, the researchers developed CAD details for the modified MGS system adjacent to steep slopes. These CAD drawings were then utilized to construct the full-scale test installation, which consisted of a modified MGS system adjacent to steep slopes utilizing half-post spacing with 7-ft long W6x9 posts installed at the SBP of a 2H:1V slope. Two full-scale crash tests were conducted on the MGS with half-post spacing adjacent to steep slopes according to MASH 2016 test designation nos. 3-10 and 3-11. The full-scale vehicle crash test results were analyzed, evaluated, and documented. Conclusions and recommendations were then made pertaining to the safety performance of the MGS with half-post spacing adjacent to steep slopes.

2 LITERATURE REVIEW

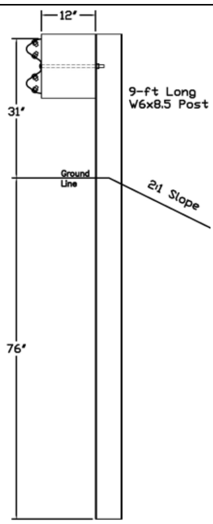
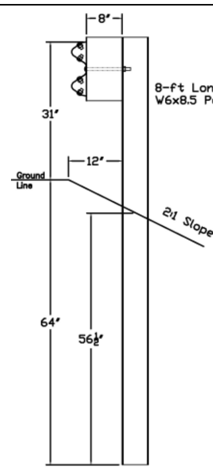
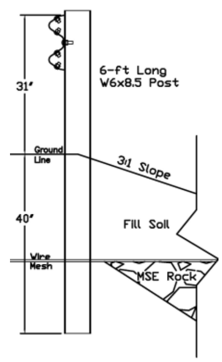
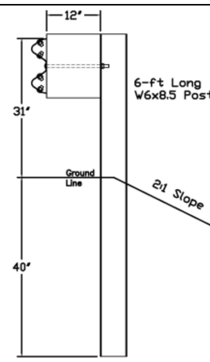
The strength and stiffness of W-beam guardrail is heavily dependent on post-soil resistance forces. Placing the system on or adjacent to a slope reduces the amount of soil behind the post, lowers the post-soil resistance, and can negatively affect the performance of the system. Thus, it is recommended for guardrail posts to be installed with at least 2 ft of level terrain behind the system to ensure the system performs as initially developed and evaluated. However, there are instances where placing guardrail adjacent to slopes is necessary due to limited roadside widths.

To date, there have been four different W-beam guardrail configurations adjacent to slopes successfully developed and crash tested according to MASH TL-3 evaluation criteria [4]. Although all four systems utilized 31-in. tall W-beam rail, they had varying post lengths, blockouts, allowable slopes, and placements relative to the SBP, as detailed in Table 1. None of the MASH-evaluated MGS guardrail systems adjacent to slope utilized reduced post spacing.

Based on the existing MASH TL-3 full-scale crash tests adjacent to slope, MwRSF also developed generalized guidance for placement of the MGS adjacent to steep slopes [4]. That research noted that end users may desire to further reduce the dynamic deflection and working width of installations adjacent to slopes through increased post length and/or reduced post spacing. However, recent full-scale crash testing of stiffened or reduced deflection MGS resulted in rail ruptures. Texas A&M Transportation Institute (TTI) recently conducted testing on the MGS with reduced post spacing and transitions from standard post spacing to reduced post spacing. TTI researchers first evaluated a quarter-post spacing system (18¾ in.) with MASH test designation nos. 3-11 and 3-10. The quarter-post spacing system successfully passed both MASH tests. TTI researchers also tested a transition between quarter- (18¾ in.) and full- (75 in.) post spacing according to MASH test designation no. 3-21 impact conditions. This transition used single W-beam rail elements and did not incorporate any nested rail sections. In this test, the pickup truck ruptured the rail and penetrated beyond the barrier. TTI researchers attributed the failure to rail pocketing caused by the short transition in lateral barrier stiffness. Finally, TTI researchers tested a half-post spacing (37½ in.) variation of the MGS under this project in which the pickup truck ruptured the rail and penetrated beyond the barrier. The recent test failures involving 2270P impacts into the MGS with reduced post spacing suggested that there was potential for rail failure during impacts into stiffened MGS applications and/or applications where increased localized rail deflection and pocketing may occur. The use of increased post length and embedment and/or reduced post spacing MGS configurations at the SBP outside of those that have been full-scale crash tested may result in similar W-beam rail loading and the potential for rail rupture. As such, the application of reduced post spacing and/or increased post length and embedment depth for the MGS installed at the SBP was not recommended without further research and crash testing.

Finally, a comment should be made regarding stiffness transitions between the proposed MGS with 7-ft long posts at half post spacing adjacent to slope and the standard MGS on level terrain. Typically, the use of reduced post spacing and increased embedment depth results in increased barrier stiffness. The increased stiffness of the barrier can result in the need for a stiffness transition to prevent degradation of the barrier performance at the junction between the barrier configurations. Conversely, the use of posts installed at the SBP of a steep slope can reduce post-soil resistive forces and lower the stiffness and increase the deflection of a barrier system, creating a transition in stiffness when it is attached to standard guardrail. The modified MGS adjacent to slope evaluated herein would have both a stiffness reduction due to its placement adjacent to slope and a stiffness increase due to the post spacing and embedment when compared with the standard MGS on level terrain. It was not known what the net effect of these factors on the overall barrier stiffness and deflection would be nor whether a stiffness transition would be required between standard MGS and the modified MGS adjacent to slope proposed herein. Additionally, an ongoing research effort at TTI is investigating the use of reduced post spacing with W-beam guardrail and the need for stiffness transitions between standard guardrail and reduced post spacing. Thus, it was recommended that the results of that study, full-scale crash testing of other stiffened W-beam guardrail systems, and the full-scale crash tests on the system proposed herein be reviewed to determine if further transition research and design is needed following the full-scale crash testing.

Table 1. MASH TL-3 Details for 31-in. W-Beam Guardrail on Slopes [4]

System	A (9-ft MGS)	B (TTI)	C (Gabion Wall)	D (6-ft MGS)
Layout				
Performance Level	MASH TL-3	MASH TL-3	MASH TL-3	MASH TL-3
Full-Scale Tests	MASH 3-11	MASH 3-10 MASH 3-11	MASH 3-10 MASH 3-11	MASH 3-11
Post	9-ft W6x8.5	8-ft W6x8.5	6-ft W6x8.5	6-ft W6x8.5
Post Spacing	75 in.	75 in.	75 in.	75 in.
Blockout	12-in. Blockout	8-in. Blockout	Non-Blocked	12-in. Blockout
Slope	2:1	2:1	3:1	2:1
Post Locations	Centered on SBP	Centered 15 in. Down Slope	Centered on SBP	Centered on SBP
Working Width	62.4 in.	55.2 in.	45.2 in.	77.4 in.
Alternative Posts	8-ft W6x8.5 or 7.5-ft 6"x8" Timber*	-	-	6-ft 6"x8" Timber*
Alternative Blockouts	Non-Blocked or 8" Blockout	12-in. Blockout	-	Non-Blocked or 8" Blockout
Allowable Slopes	2:1 or Flatter	2:1 or Flatter	-	2:1 or Flatter

* Timber Posts should have strength equal to or greater than SYP grade 1

3 TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 Test Requirements

Longitudinal barriers, such as W-beam guardrails like the MGS, must satisfy impact safety standards in order to be declared eligible for federal reimbursement by the Federal Highway Administration (FHWA) for use on the National Highway System. For new hardware, these safety standards consist of the guidelines and procedures published in MASH 2016 [3]. Note that there is no difference between MASH 2009 and MASH 2016 for longitudinal barriers such as the system tested in this project, except that additional occupant compartment deformation measurements, photographs, and documentation are required by MASH 2016. According to TL-3 of MASH 2016, longitudinal barrier systems must be subjected to two full-scale vehicle crash tests, as summarized in Table 2.

Table 2. MASH 2016 TL-3 Crash Test Conditions for Longitudinal Barriers

Test Article	Test Designation No.	Test Vehicle	Vehicle Weight lb	Impact Conditions		Evaluation Criteria [1]
				Speed mph	Angle deg.	
Longitudinal Barrier	3-10	1100C	2,420	62	25	A,D,F,H,I
	3-11	2270P	5,000	62	25	A,D,F,H,I

[1] Evaluation criteria explained in Table 4.

MwRSF proposed that both test designation nos. 3-10 and 3-11 be conducted to evaluate the modified MGS system adjacent to steep slopes. Test designation no. 3-10 has not always been conducted for evaluation of guardrail adjacent to slope due to the reduced impact loading of the small car vehicle. However, recent MASH TL-3 crash testing of 1100C vehicles on guardrails with reduced post spacing or increased stiffness due to the presence of curbs have indicated the potential for combined loading of the guardrail splice by the small car vehicle that can lead to partial rail tears and even complete rail rupture. As such, test designation no. 3-10 was recommended for the evaluation of the barrier system. Test designation no. 3-11 with the 2270P vehicle represents the highest impact barrier loading during 2270P impacts, evaluates potential vehicle extension over the slope and the potential for vehicle instability, and determines dynamic deflection and working width. Thus, test designation no. 3-11 was also recommended for the evaluation of the barrier system.

The critical impact point for both tests were selected to maximize vehicle snag on the system posts and splice loading based on the guidance provide in Section 2.3 of MASH 2016. For test designation no. 3-10, initial vehicle impact was to occur 8 ft upstream from a post with a splice, which was selected using the critical impact point plots found in Section 2.3 of MASH 2016. Similarly, initial vehicle impact for test designation no. 3-11 was to occur 11 ft – 6 in. upstream from a post with a splice, which was selected using the critical impact point plots found in Section 2.3 of MASH 2016. These impact points were denoted on the test plans for the full-scale crash testing. During installation of the barrier system, the barrier orientation was flipped from the original test plan to better accommodate the site conditions and vehicle tow and guidance. When this change was made, the impact points for test designation nos. 3-10 and 3-11 were not properly adjusted to maintain their location relative to a guardrail splice. Thus, the full-scale crash tests were conducted at a critical location relative to vehicle snag on the system posts, but a guardrail splice was not located at the critical post location as intended.

In order to evaluate whether or not this error had an effect on the evaluation of the barrier system, MwRSF researchers compared the results of test designation nos. 3-10 and 3-11 on modified MGS adjacent to a 2H:1V slope with 7-ft long posts at ½-post spacing with previous testing of the strong post MGS with ½-post spacing mounted to a low-fill culvert that was evaluated to MASH TL-3 [5]. The strong post MGS with ½-post spacing mounted to a low-fill culvert utilized posts that were mounted directly to the top of the culvert slab at a depth of 9 in. below grade. The culvert mounted posts would be expected to provide similar or greater barrier stiffness as compared to the modified MGS adjacent to a 2H:1V slope with 7-ft long posts at ½-post spacing. This expectation seems consistent with comparison of dynamic deflection values for test designation nos. 3-10 and 3-11 conducted on both of these barrier systems, as shown in Table 3. The culvert-mounted MGS system produced lower dynamic rail deflections for test designation nos. 3-10 and 3-11 as compared to the modified MGS adjacent to a 2H:1V slope with 7-ft long posts at ½-post spacing. Dynamic post deflections for the culvert mounted MGS system were also similar or less than the modified MGS adjacent to a 2H:1V slope with 7-ft long posts at ½-post spacing. The potential for rail splice rupture tends to increase with increased barrier stiffness. Thus, the successful containment and redirection observed in the full-scale testing of the strong post, culvert-mounted MGS system would suggest that splice loading for the modified MGS adjacent to a 2H:1V slope with 7-ft long posts at ½-post spacing should pose a performance concern.

Additionally, it was noted previously that 1100C rail rupture has been associated with combined loading of the rail splice due to rail tension, lateral deflection and bending, and vertical bending of the rail due to the vehicle wedging underneath the guardrail element. Wedging of the 1100C vehicle underneath the rail element should be less pronounced for a barrier system installed adjacent to a 2H:1V slope as the ground should be falling away from the vehicle as the barrier deflects. Thus, concerns for rail splice failure should be further mitigated. Based on this analysis, it was believed that the error in the critical impact point relative to the splice location did not adversely affect full-scale testing and evaluation of the barrier system detailed herein.

Table 3. MASH 2016 TL-3 Dynamic Deflection and Working Width Comparison for Strong Post, Culvert Mounted MGS and Modified MGS Adjacent to 2H:1V Slope

Test Article	Test Designation No.	Impact Conditions		Dynamic Rail Deflection (in.)	Dynamic Post Deflection (in.)
		Speed (mph)	Angle (deg.)		
Strong Post, Culvert Mounted MGS	3-10	61.3	25.1	11.7	12.0
	3-11	62.8	25.7	22.4	29.6
Modified MGS Adjacent to 2H:1V Slope	3-10	62.8	25.2	21.8	30.4
	3-11	62.6	25.4	27.2	26.5

3.2 Evaluation Criteria

Evaluation criteria for full-scale vehicle crash testing are based on three factors: (1) structural adequacy, (2) occupant risk, and (3) vehicle trajectory after collision. Criteria for structural adequacy are intended to evaluate the ability of the MGS 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 4 and defined in greater detail in MASH 2016. The full-scale vehicle crash test was conducted and reported in accordance with the procedures provided in MASH 2016.

In addition to the standard occupant risk measures, the Post-Impact Head Deceleration (PHD), the Theoretical Head Impact Velocity (THIV), and the Acceleration Severity Index (ASI) were determined and reported. Additional discussion on PHD, THIV and ASI is provided in MASH 2016.

Table 4. MASH 2016 Evaluation Criteria for Longitudinal Barrier

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

3.3 Soil Strength Requirements

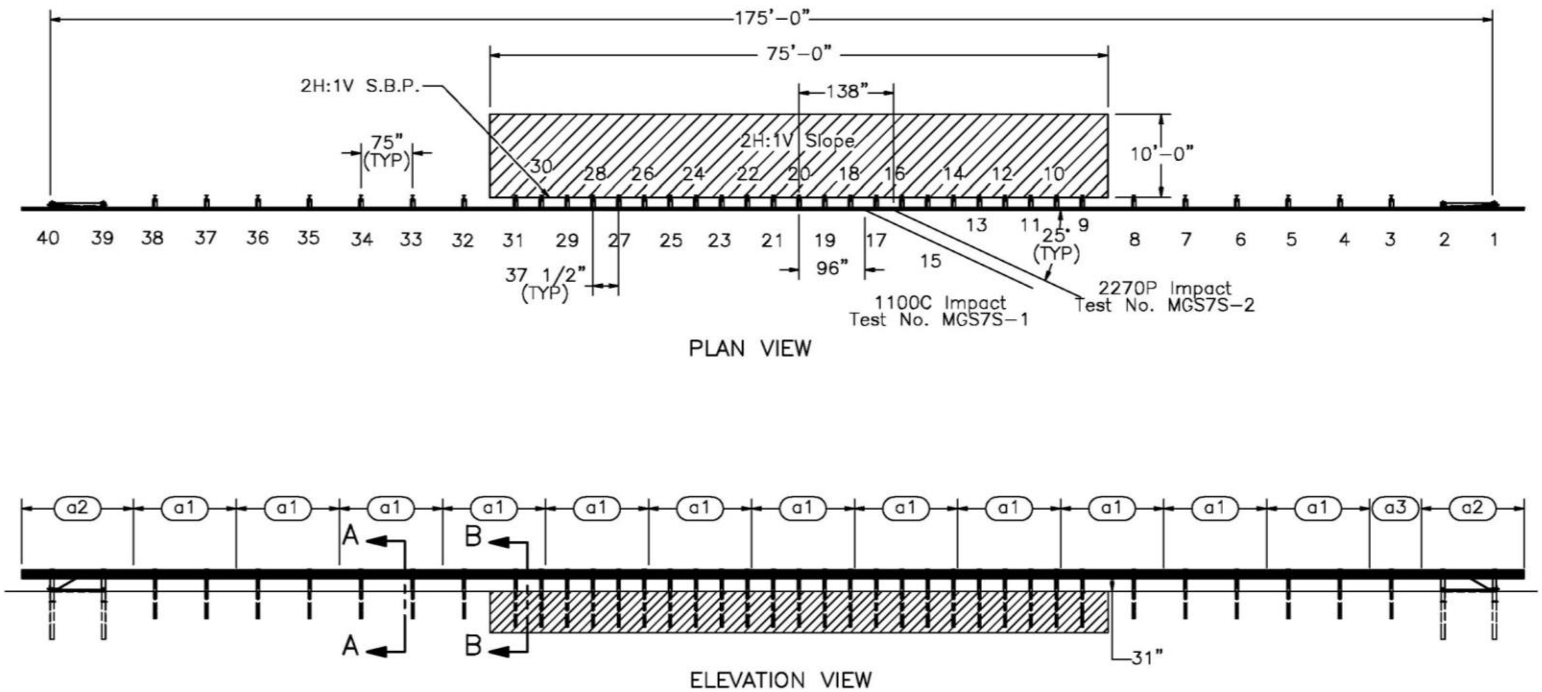
In accordance with Chapter 3 and Appendix B of MASH 2016, foundation soil strength must be verified before any full-scale crash testing can occur. During the installation of a soil dependent system, W6x16 posts are installed near the impact region utilizing the same installation procedures as the system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

4 DESIGN DETAILS

The test installation for the modified MGS adjacent to a 2H:1V slope consisted of a 175-ft long modified MGS that utilized 12-gauge W-beam guardrail supported by 40 posts. System design details for test nos. MGS7S-1 and MGS7S-2 are shown in Figures 2 through 14. Photographs of the test installation are shown in Figures 15 through 17. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix A.

The modified MGS was installed on level terrain for 50 ft on each end of the system, while the middle of the barrier was installed adjacent to a 5-ft deep by 75-ft long 2H:1V slope. The slope started at the centerline of the post and extended 10 ft behind the post. Post nos. 3 through 8 and 32 through 38 were ASTM A992 W6x8.5 steel posts that measured 72-in. long and were spaced 75 in. apart with an embedment depth of 40 in. Post nos. 9 through 31 were ASTM A992 W6x8.5 steel posts that measured 84 in. long, were spaced 37½ in. apart with W14x22 blockouts, and had an embedment depth of 52 in. The posts were placed in a compacted, coarse, crushed limestone material with a strength that satisfied MASH 2016 criteria. Post nos. 3 through 38 used 6-in. x 12-in. x 14¼-in. wood blockouts to offset the rail away from the front face of the steel posts.

The upstream and downstream ends of the guardrail installation were configured with a trailing-end anchorage system. The guardrail anchorage system was utilized to simulate the strength of other crashworthy end terminals. 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 Breakaway Cable Terminal (BCT) system and is now part of a crashworthy, downstream trailing end terminal [6-8].



Notes:
(1) Test No. MGS7S-1 shall be performed according to test designation no. 3-10 of MASH criteria.
(2) Test No. MGS7S-2 shall be performed according to test designation no. 3-11 of MASH criteria.
(3) The impact locations are 8' upstream of post no. 20 (MGS7S-1) and 11'-6" upstream of post no. 20 (MGS7S-2).
(4) BCT anchors are placed in ϕ 3' holes, then backfilled and tamped with soil.
(5) Critical region is between post nos. 9 and 31 (ϕ3' holes). All posts on slope (post nos. 9 through 31) need to be spaced at 37 1/2".
(6) The compacted slope shall be constructed prior to installing the posts. Auger holes and place the posts at the slope break point. Backfill and compact soil around the posts, recreating the 2H:1V fill slope.

Midwest Roadside Safety Facility	WI MGS with Half Post Spacing Test Nos. MGS7S-1-2 System Layout	SHEET: 1 of 13 DATE: 1/20/2022 DRAWN BY: MJM/JRF/GHR
	DWG. NAME. MGS7S_R5	SCALE: 1:220 UNITS: in.	REV. BY: RWB/JCH

Figure 2. Test Installation Layout, Test Nos. MGS7S-1 and MGS7S-2

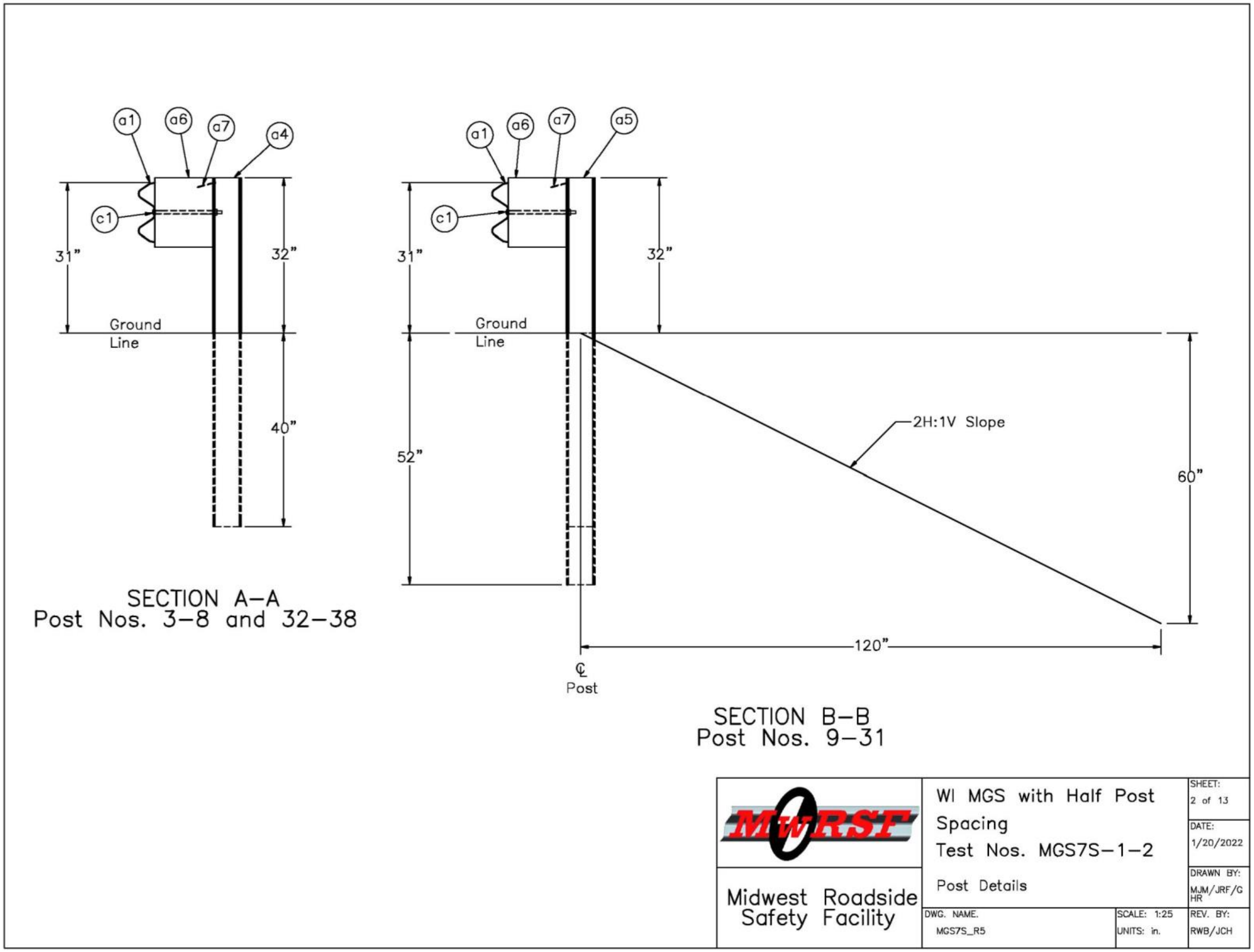


Figure 3. Post Details, Test Nos. MGS7S-1 and MGS7S-2

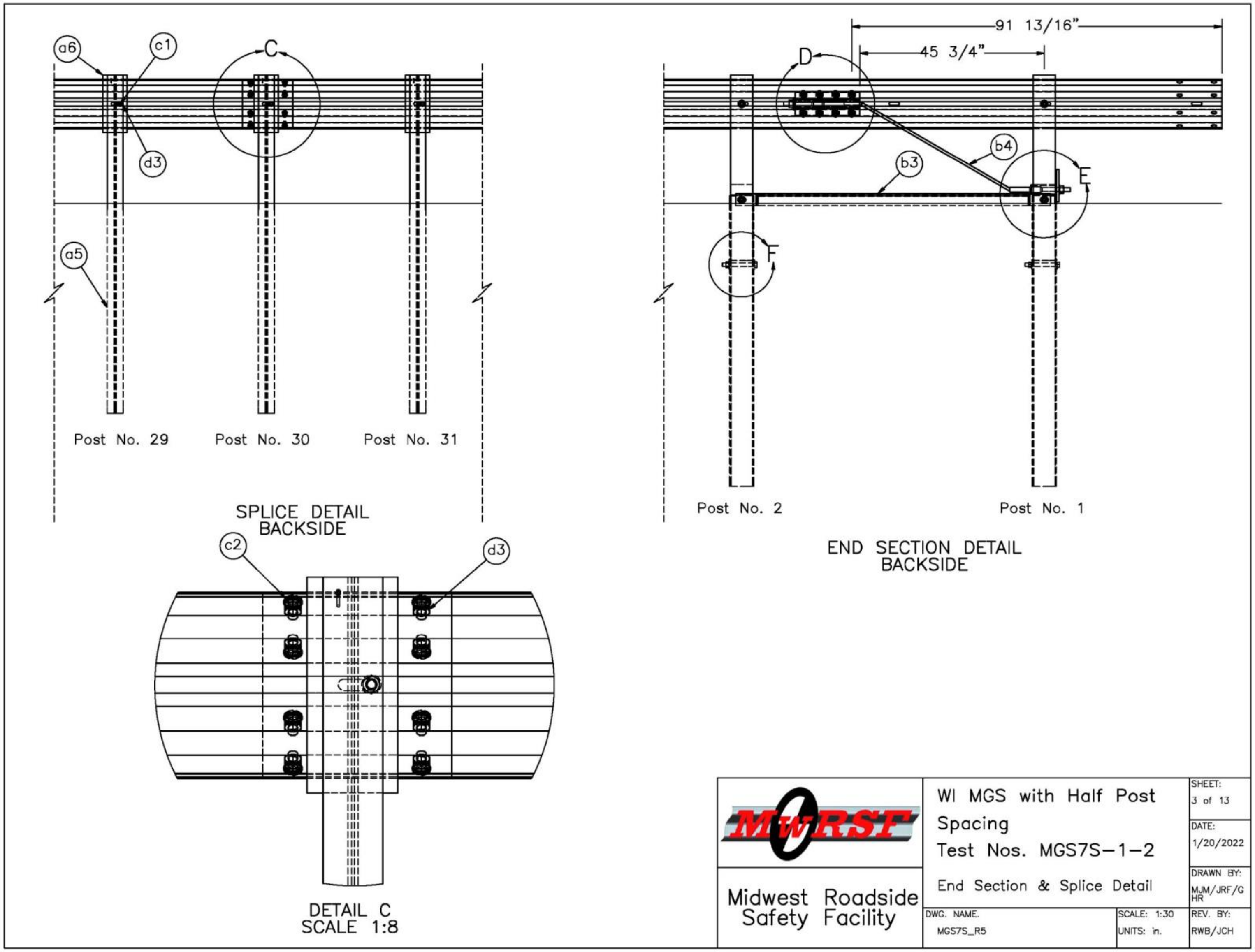


Figure 4 End Section and Splice Detail, Test Nos. MGS7S-1 and MGS7S-2

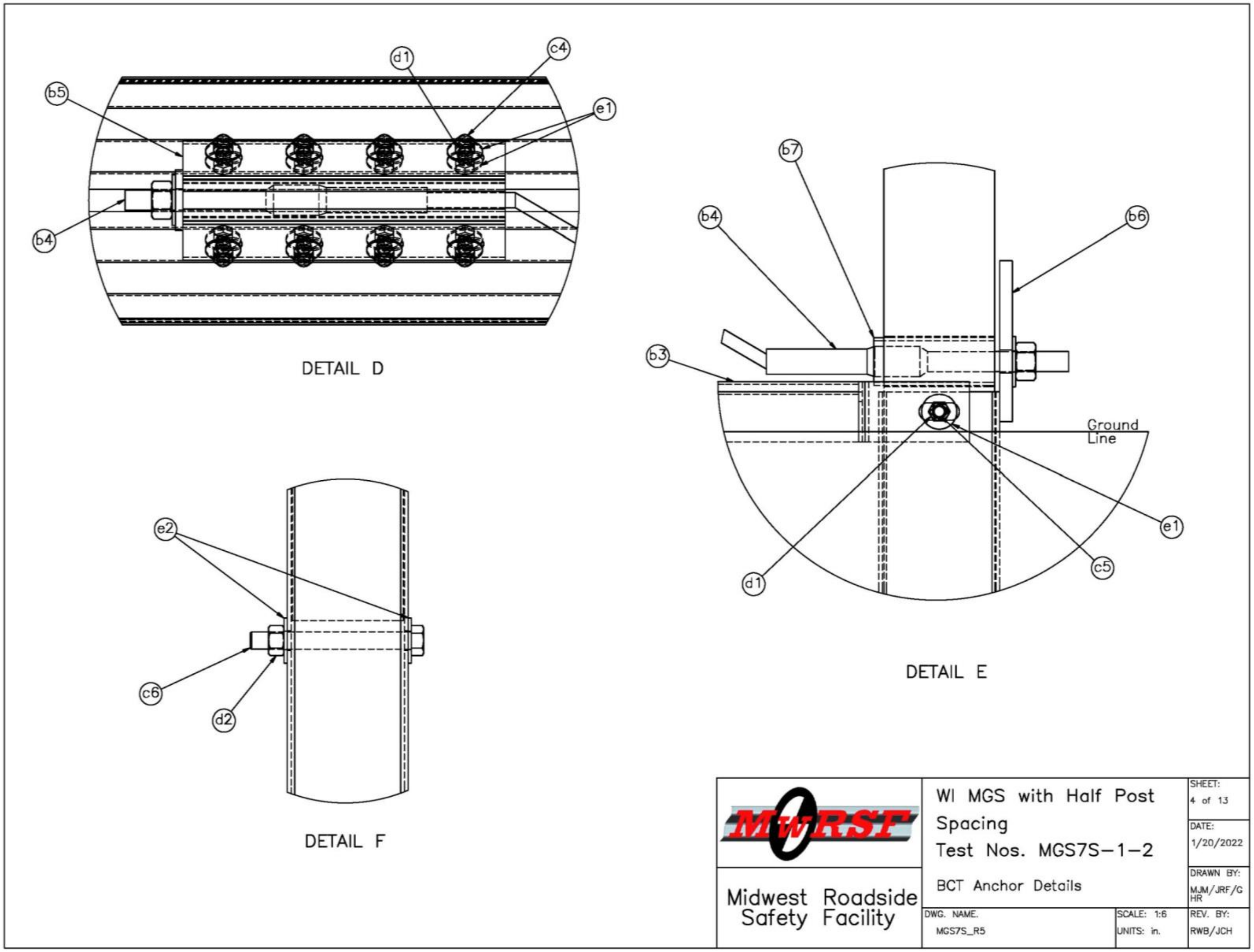


Figure 5. BCT Anchor Details, Test No. MGS7S-1 and MGS7S-2

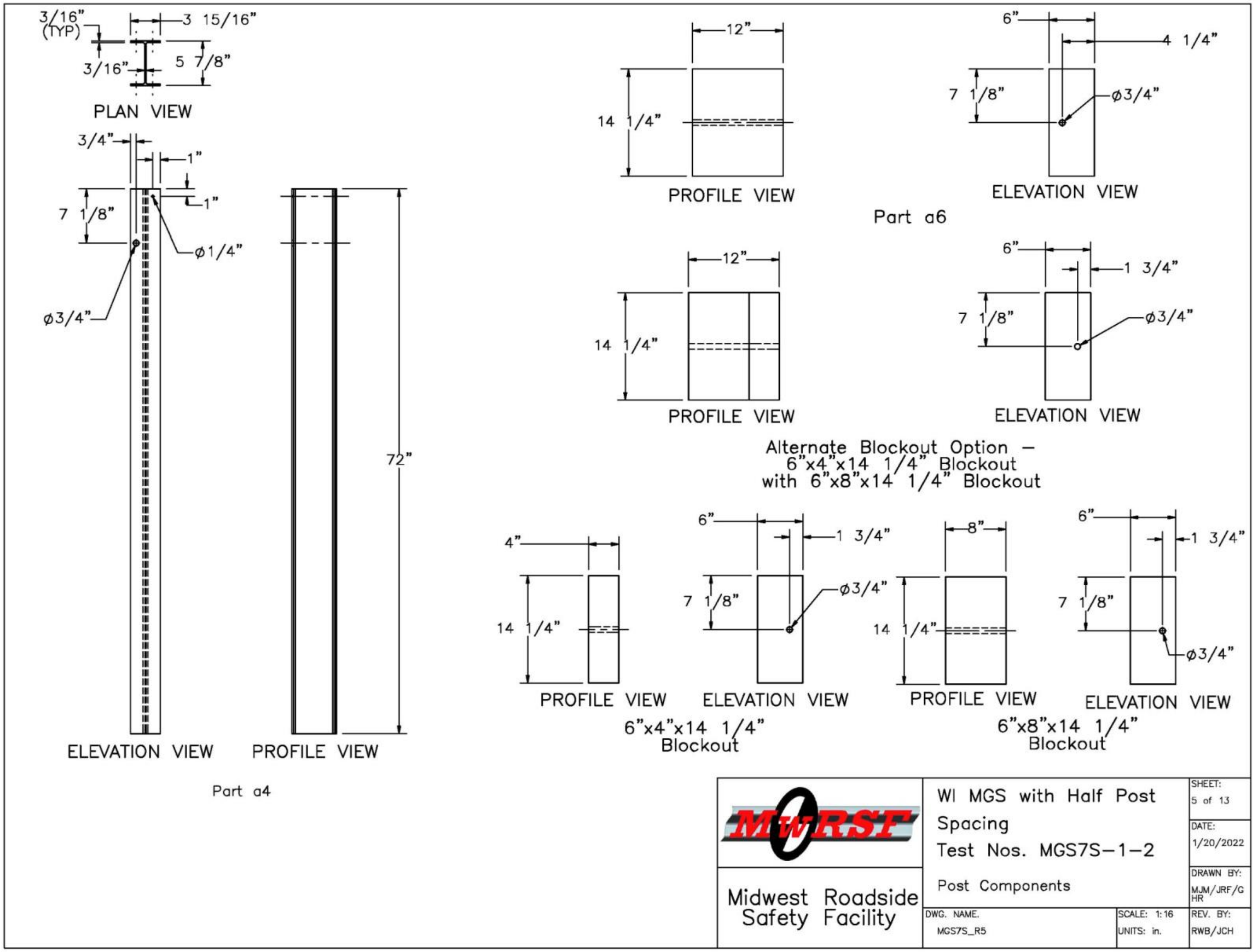


Figure 6. Post Components, Test No. MGS7S-1 and MGS7S-2

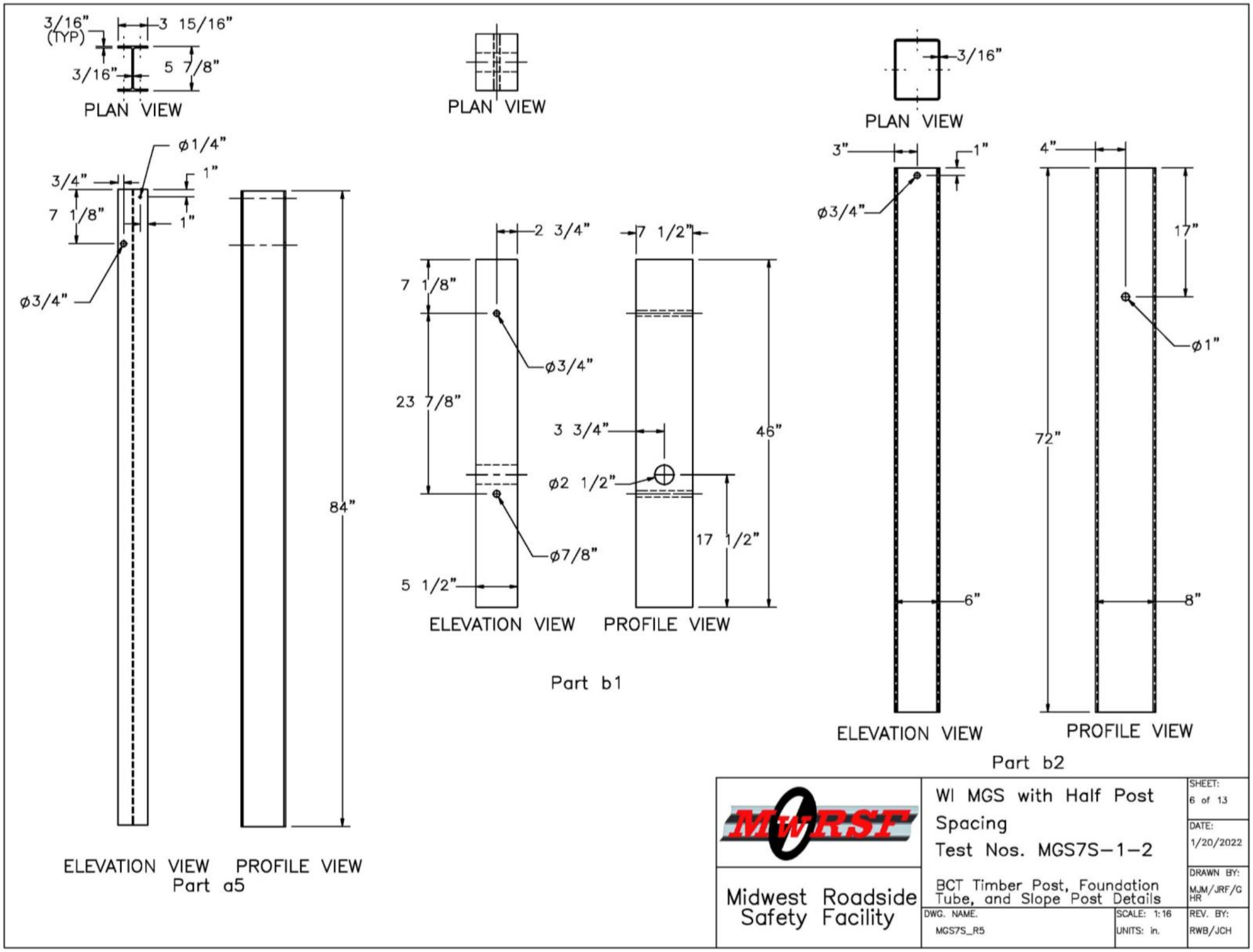


Figure 7. BCT Timber Post, Foundation Tube and Slope Post Details, Test Nos. MGS7S-1 and MGS7S-2

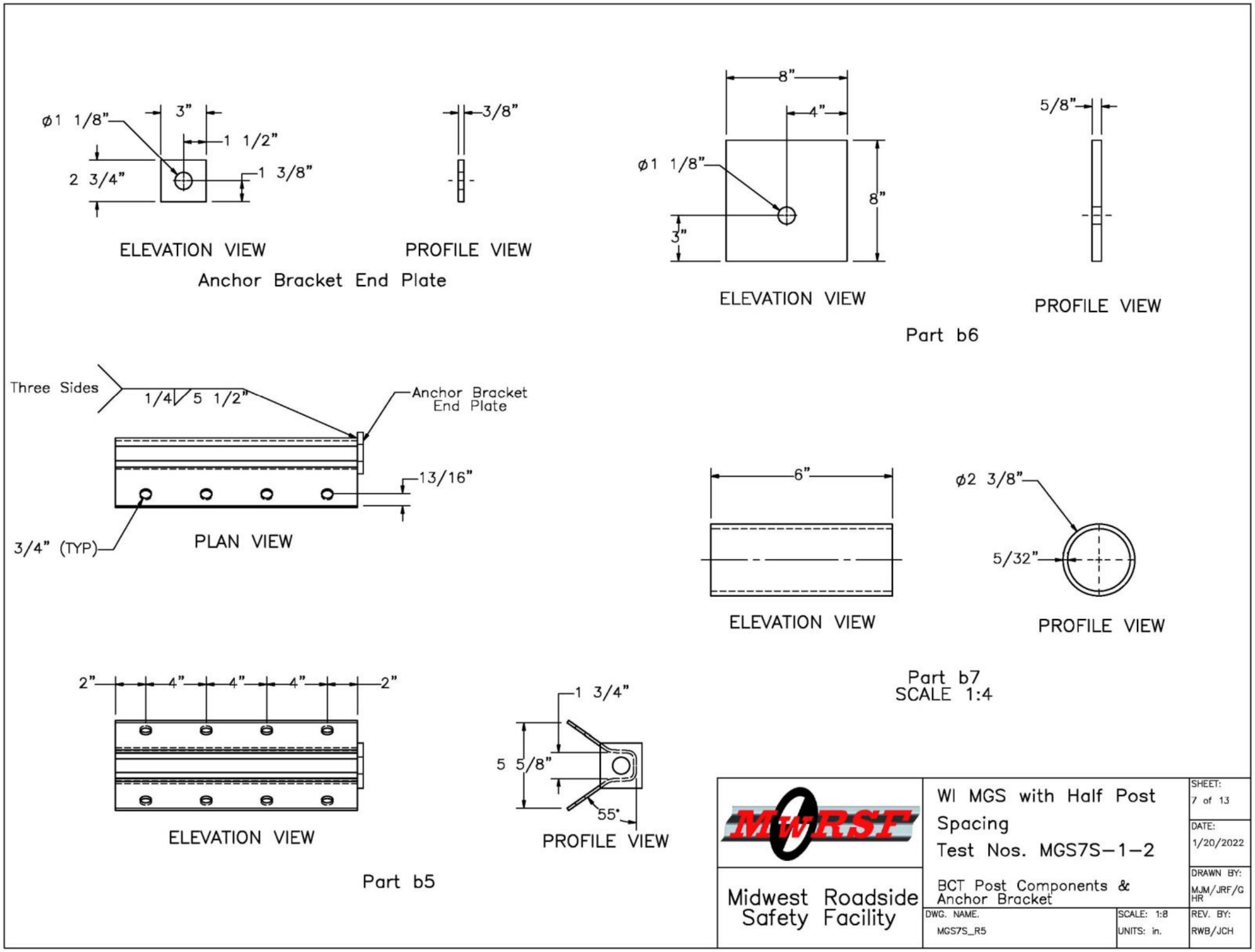


Figure 8. BCT Post Components, Test Nos. MGS7S-1 and MGS7S-2

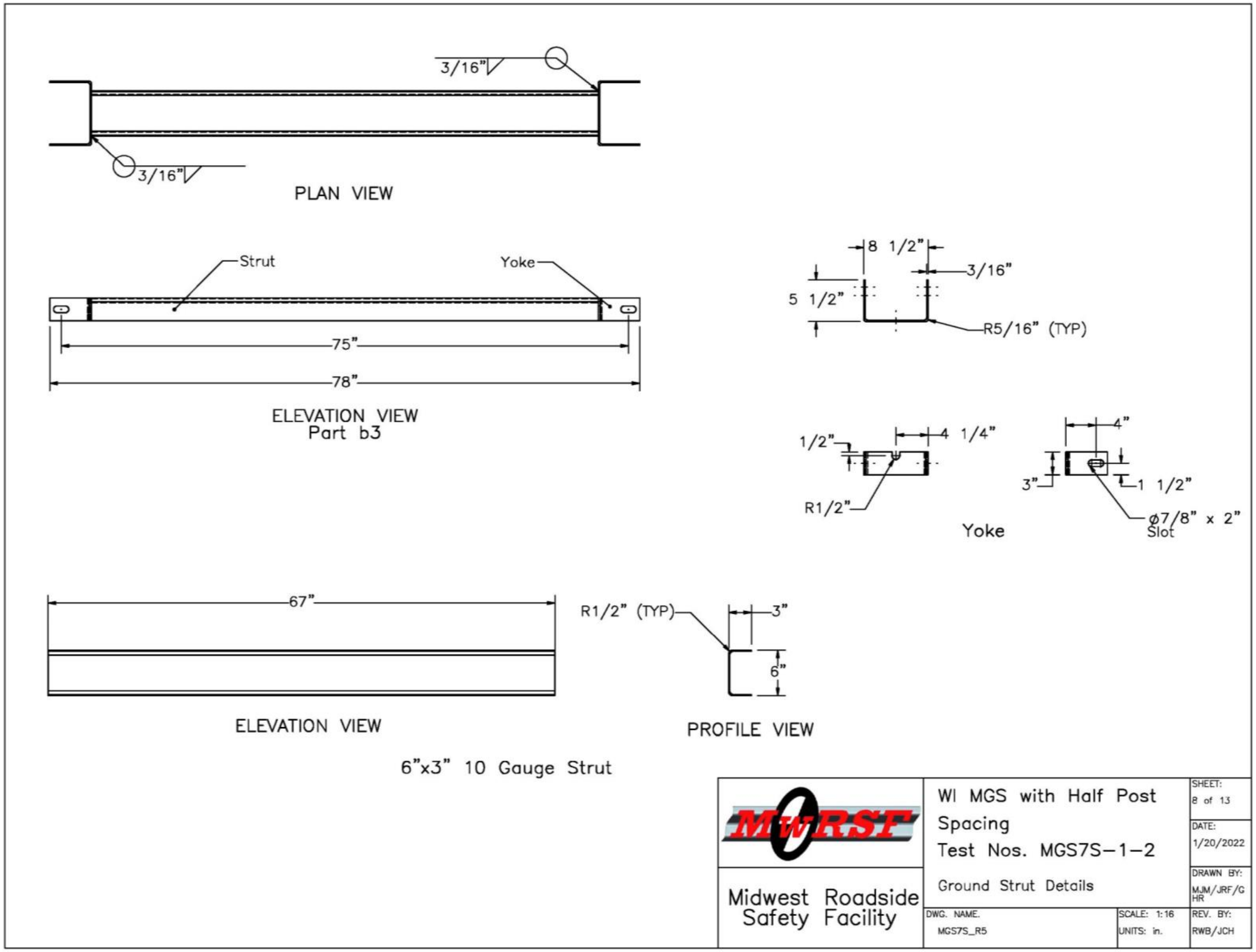


Figure 9. Ground Strut Details, Test Nos. MGS7S-1 and MGS7S-2

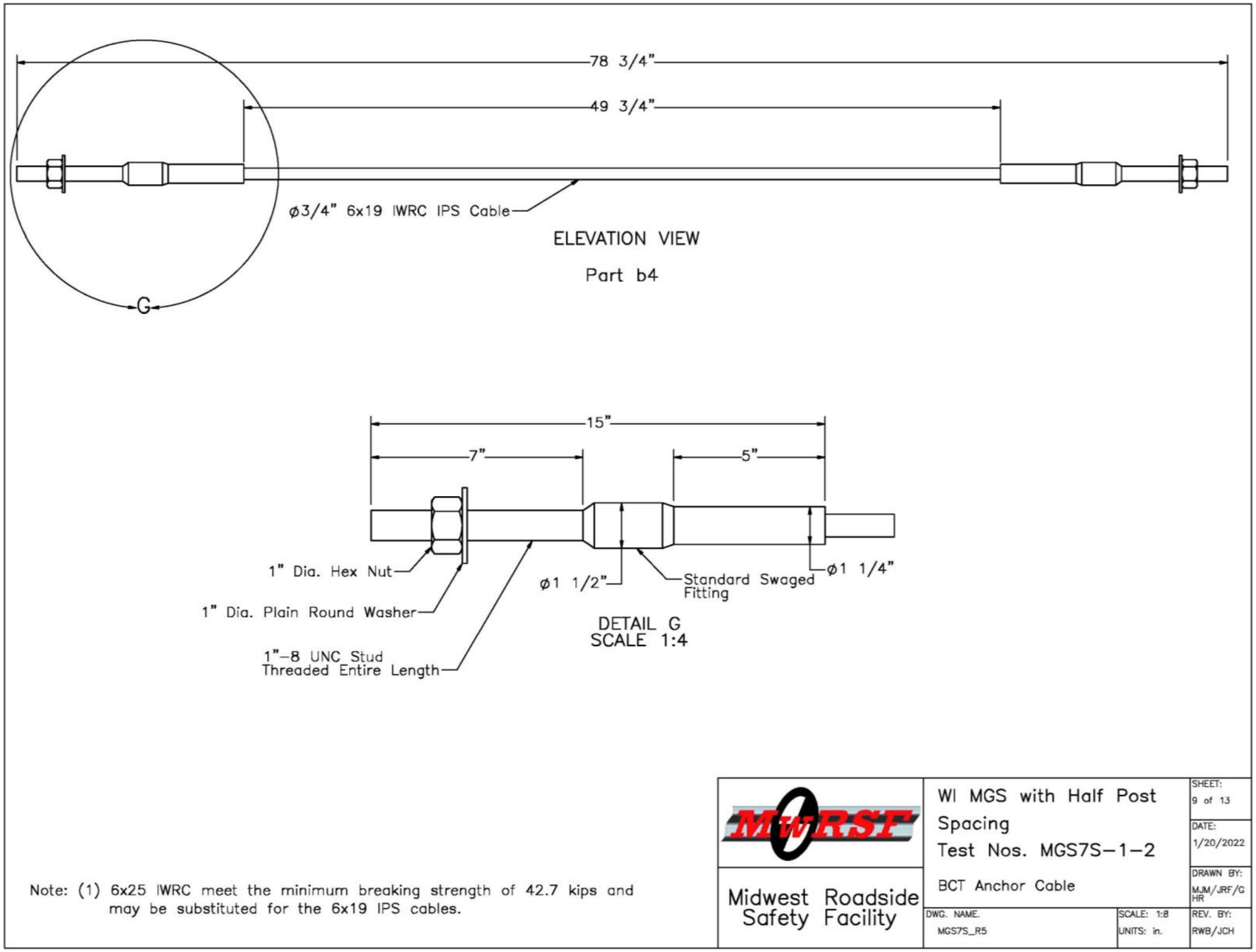


Figure 10. BCT Anchor Cable, Test Nos. MGS7S-1 and MGS7S-2

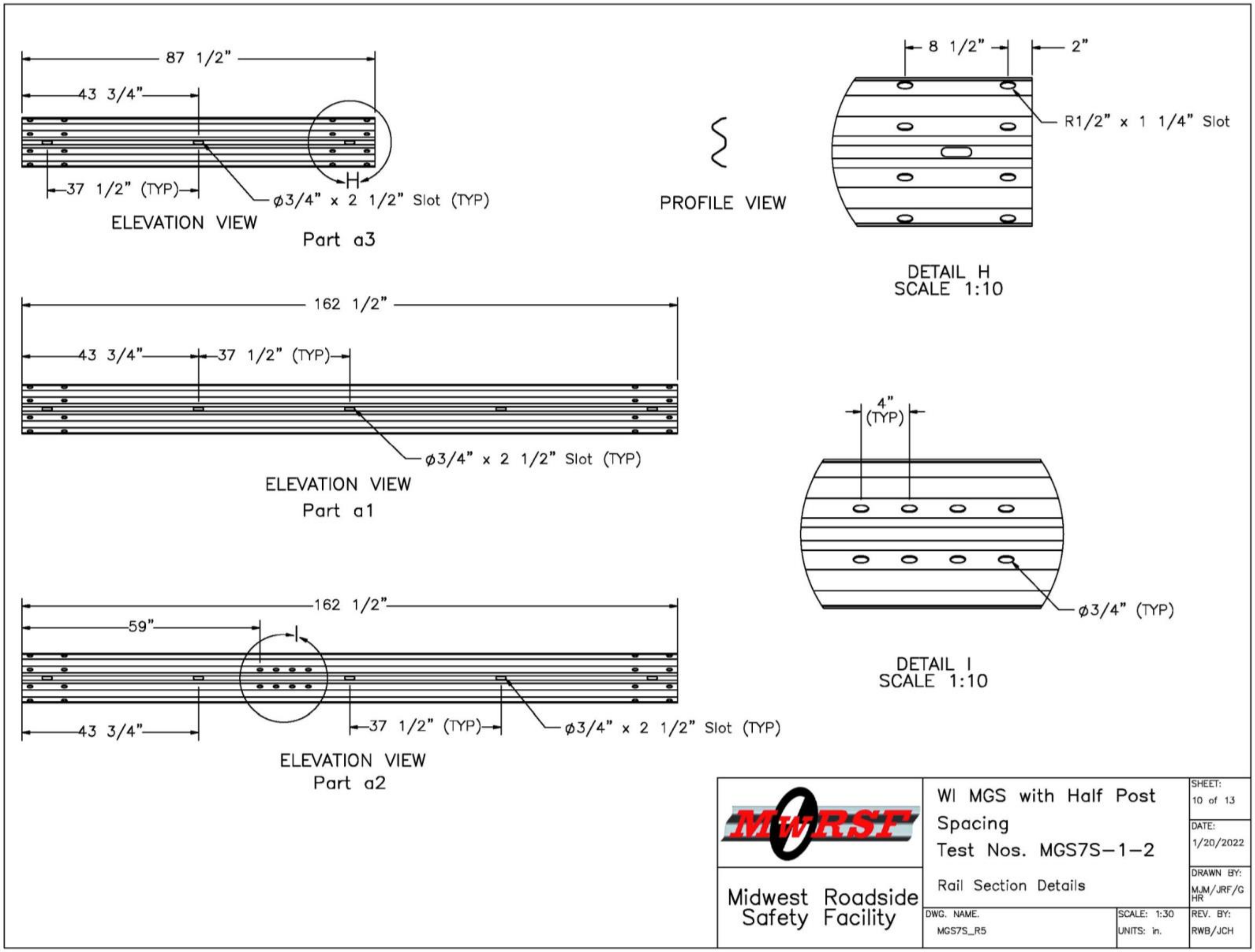


Figure 11. Rail Section Details, Test Nos. MGS7S-1 and MGS7S-2

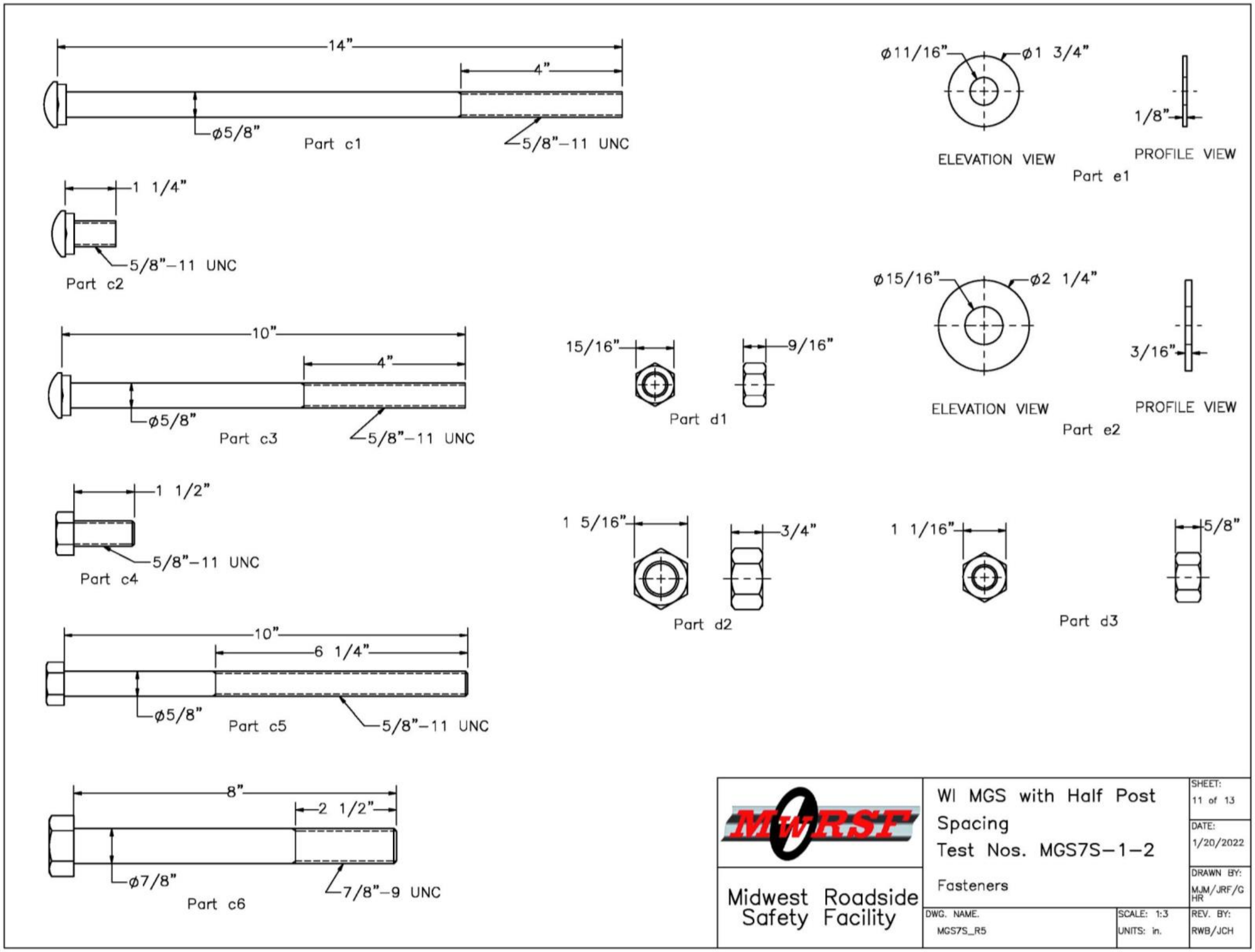


Figure 12. Fasteners, Test Nos. MGS7S-1 and MGS7S-2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	12	12'–6" 12–gauge W–Beam MGS Section	AASHTO M180	ASTM A123 or A653	RWM04a
a2	2	12'–6" 12–gauge W–Beam MGS End Section	AASHTO M180	ASTM A123 or A653	RWM14a
a3	1	6'–3" 12–gauge W–Beam MGS Section	AASHTO M180	ASTM A123 or A653	RWM04a
a4	13	W6x9 or W6x8.5, 72" Long Steel Post	ASTM A992 Min. 50 ksi or ASTM A36 Min. 36 ksi	ASTM A123	PWE06
a5	23	W6x9 or W6x8.5, 84" Long Steel Post	ASTM A992 Min. 50 ksi or ASTM A36 Min. 36 ksi	ASTM A123	PWE07
a6	36	6x12x14 1/4" Timber Blockout for Steel Posts	AASHTO M168 or SYP Grade No.1 or better	AASHTO M133	PDB10a
a7	36	16D Double Head Nail	–	–	–
b1	4	BCT Timber Post – MGS Height	AASHTO M168 or SYP Grade No. 1 or better	AASHTO M133	PDF01
b2	4	72" Long Foundation Tube	ASTM A500 Gr. B	ASTM A123	PTE06
b3	2	Strut and Yoke Assembly	ASTM A36	ASTM A123	PFP02
b4	2	BCT Cable Anchor Assembly	–	–	FCA01
b5	2	Anchor Bracket Assembly	ASTM A36	ASTM A123	FPA01
b6	2	8"x8"x5/8" Anchor Bearing Plate	ASTM A36	ASTM A123	FPB01
b7	2	2 3/8" O.D. x 6" Long BCT Post Sleeve	ASTM A53 Gr. B	ASTM A123	FMM02
c1	36	5/8" Dia. UNC, 14" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F1941 or F2329	FBB06
c2	112	5/8" Dia. UNC, 1 1/4" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F1941 or F2329	FBB01
c3	4	5/8" Dia. UNC, 10" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F1941 or F2329	FBB03
c4	16	5/8" Dia. UNC, 1 1/2" Long Hex Head Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F1941 or F2329	FBX16a
c5	4	5/8" Dia. UNC, 10" Long Hex Head Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F1941 or F2329	FBX16a
c6	4	7/8" Dia. UNC, 8" Long Hex Head Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F1941 or F2329	–

Midwest Roadside Safety Facility

WI MGS with Half Post Spacing
Test Nos. MGS7S–1–2

Bill of Materials

SHEET: 12 of 13
DATE: 1/20/2022
DRAWN BY: MJM/JRF/GHR
REV. BY: RWB/JCH
DWG. NAME. MGS7S_R5
SCALE: None
UNITS: in.

Figure 13. Bill of Materials, Test Nos. MGS7S-1 and MGS7S-2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
d1	24	5/8" Dia. Hex Nut	ASTM A563A	ASTM A153 or B695 Class 55 or F1941 or F2329	FNX16a
d2	4	7/8" Dia. Hex Nut	ASTM A563A	ASTM A153 or B695 Class 55 or F1941 or F2329	–
d3	148	5/8" Dia. Heavy Hex Nut	ASTM A563A	ASTM A153 or B695 Class 55 or F1941 or F2329	FNX16b
e1	44	5/8" Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC16a
e2	8	7/8" Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC20a

MwRSF
Midwest Roadside Safety Facility

WI MGS with Half Post Spacing
Test Nos. MGS7S-1-2

Bill of Materials

SHEET: 13 of 13
DATE: 1/20/2022
DRAWN BY: MJM/JRF/GHR
REV. BY: RWB/JCH
DWG. NAME. MGS7S_R5
SCALE: None
UNITS: in.

Figure 14. Bill of Materials, Test No. MGS7S-1 and MGS7S-2

Figure 15. Test Installation Photographs, Test Nos. MGS7S-1 and MGS7S-2

Figure 16. Test Installation Photographs, Test Nos. MGS7S-1 and MGS7S-2

Figure 17. Test Installation Photographs, Test Nos. MGS7S-1 and MGS7S-2

5 TEST CONDITIONS

5.1 Test Facility

The Outdoor Test Site is located at the Lincoln Air Park on the northwest side of the Lincoln Municipal Airport and is approximately 5 miles northwest of the University of Nebraska-Lincoln.

5.2 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 [9] was used to steer the test vehicle. A guide flag, attached to the left-front wheel and the guide cable, was sheared off before impact with the barrier system. The ⅜-in. diameter guide cable was tensioned to approximately 3,500 lb and supported both laterally and vertically every 100-ft by hinged stanchions. The hinged stanchions stood upright while holding up the guide cable, but as the vehicle was towed down the line, the guide flag struck and knocked each stanchion to the ground.

5.3 Test Vehicles

For test no. MGS7S-1, a 2016 Hyundai Accent Sedan was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,484 lb, 2,431 lb, and 2,592 lb, respectively. The test vehicle is shown in Figures 18 and 19, and vehicle dimensions are shown in Figure 20.

For test no. MGS7S-2, a 2016 Ram 1500 Quad Cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 4,958 lb, 5,022 lb, and 5,185 lb, respectively. The test vehicle is shown in Figures 21 and 22, and vehicle dimensions are shown in Figure 23.

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. For test no. MGS7S-1, the vertical component of the c.g. for the 1100C vehicle was determined utilizing a procedure published by SAE [10]. Test No. MGS7S-2 utilized the Suspension Method [11]. This method was used to determine the vertical component of the c.g. for the 2270P vehicle. 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 final c.g. location of MGS7S-1 is shown in Figure 24. The final c.g. location of MGS7S-2 is shown in Figure 25. Ballast information and data used to calculate the location of the c.g. for the tests are shown in Appendix B.

Square, black-and-white checkered targets were placed on the vehicle for reference, as shown in Figure 24, to serve as a reference in the high-speed digital video and aid in the video analysis. Round, checkered targets were placed at the c.g. 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 such that the vehicles would track properly along the guide cable. For both tests a 5B flash bulb was mounted under the vehicles' right-side windshield wiper 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 digital videos. A radio-controlled brake system was installed in the test vehicle so the vehicle could be brought safely to a stop after the test.

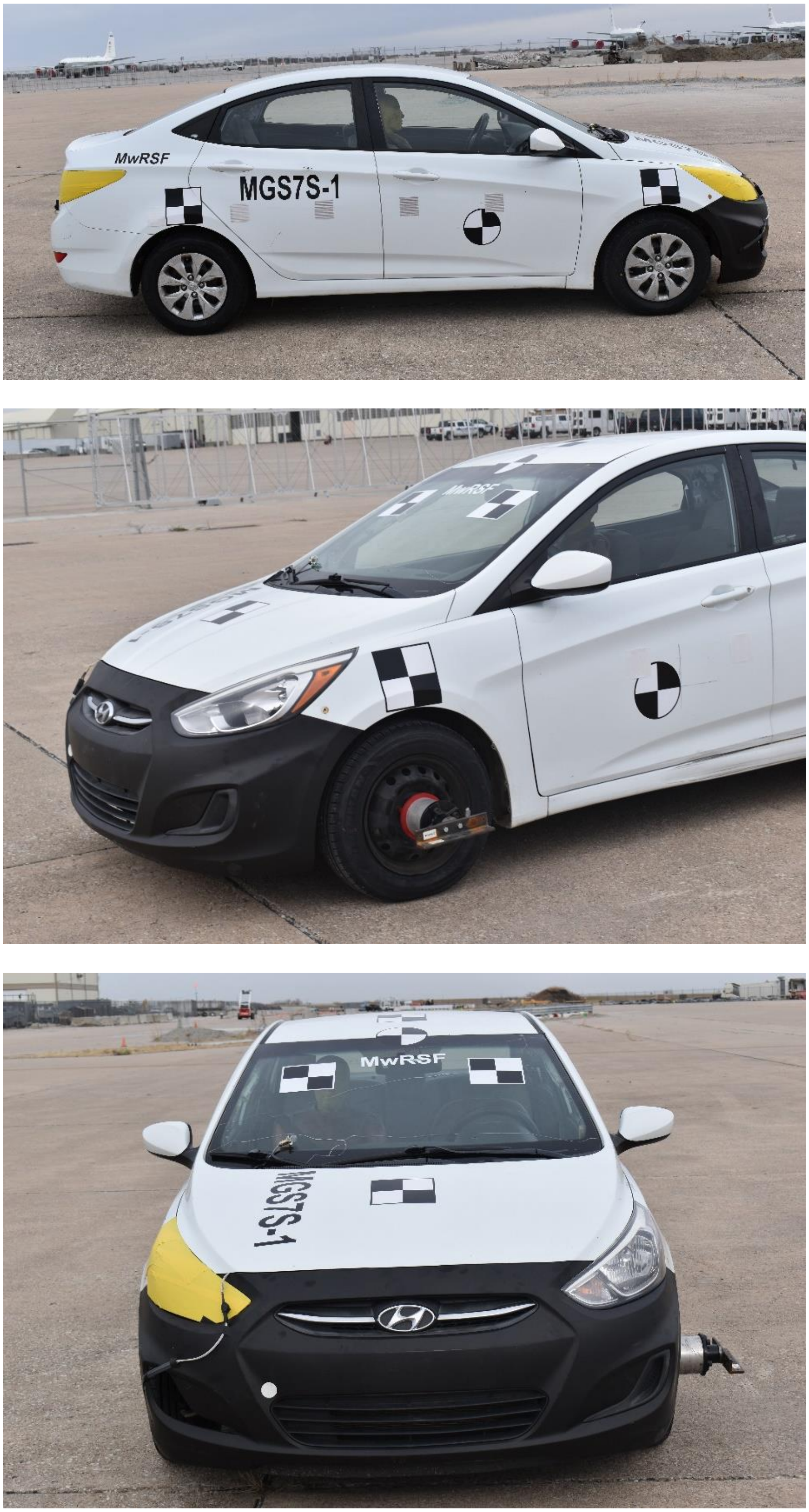


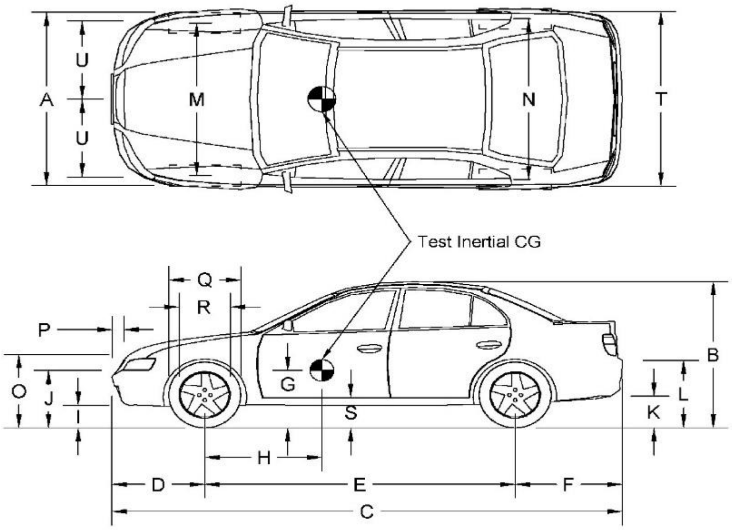
Figure 18. Test Vehicle, Test No. MGS7S-1

Figure 19. Test Vehicle’s Interior Floorboards and Undercarriage, Test No. MGS7S-1

Test Name: MGS7S-1 VIN No: KMHTC4AEXGU059917

Model Year: 2016 Make: Hyundai Model: Accent Sedan

Tire Size: 175/70R15 Tire Inflation Pressure: 32 psi Odometer: 118712



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

A:	66 3/8 (1686) 65±3 (1650±75)	B:	56 5/8 (1438)
C:	171 1/2 (4356) 169±8 (4300±200)	D:	32 3/8 (822) 35±4 (900±100)
E:	101 1/4 (2572) 98±5 (2500±125)	F:	37 7/8 (962)
G:	21 7/8 (556)	H:	38 1/4 (972) 39±4 (990±100)
I:	6 1/4 (159)	J:	23 1/2 (597)
K:	11 (279)	L:	26 1/4 (667)
M:	59 3/8 (1508) 59±2 (1498±50)	N:	59 1/2 (1511) 59±2 (1425±50)
O:	29 5/8 (752) 28±4 (711±100)	P:	6 (152)
Q:	23 1/4 (591)	R:	15 1/4 (387)
S:	11 (279)	T:	66 1/2 (1689)

U (impact width):	30 1/2 (775)
Top of radiator core support:	28 3/16 (716)
Wheel Center Height (Front):	11 (279)
Wheel Center Height (Rear):	11 1/2 (292)
Wheel Well Clearance (Front):	24 3/4 (629)
Wheel Well Clearance (Rear):	25 3/16 (640)
Bottom Frame Height (Front):	15 (381)
Bottom Frame Height (Rear):	15 3/4 (400)
Engine Type:	4cyl. Gas
Engine Size:	1.6L
Transmission Type:	Automatic
Drive Type:	FWD

Mass Distribution - lb (kg)

Gross Static	LF	832 (377)	RF	766 (347)
	LR	476 (216)	RR	518 (235)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	1564 (709)	1513 (686)	1598 (725)
W-rear	920 (417)	918 (416)	994 (451)
W-total	2484 (1127)	2431 (1103) 2420±55 (1100±25)	2592 (1176) 2585±55 (1175±50)

GVWR Ratings lb

Front	1874
Rear	1852
Total	3527

Surrogate Occupant Data

Type:	Hybrid II
Mass:	161 lb
Seat Position:	Right/passenger

Note any damage prior to test: Minor hail damage to roof/hood/trunk. Driver side rocker panel is scraped. Windshield cracks.

Figure 20. Vehicle Dimensions, Test No. MGS7S-1

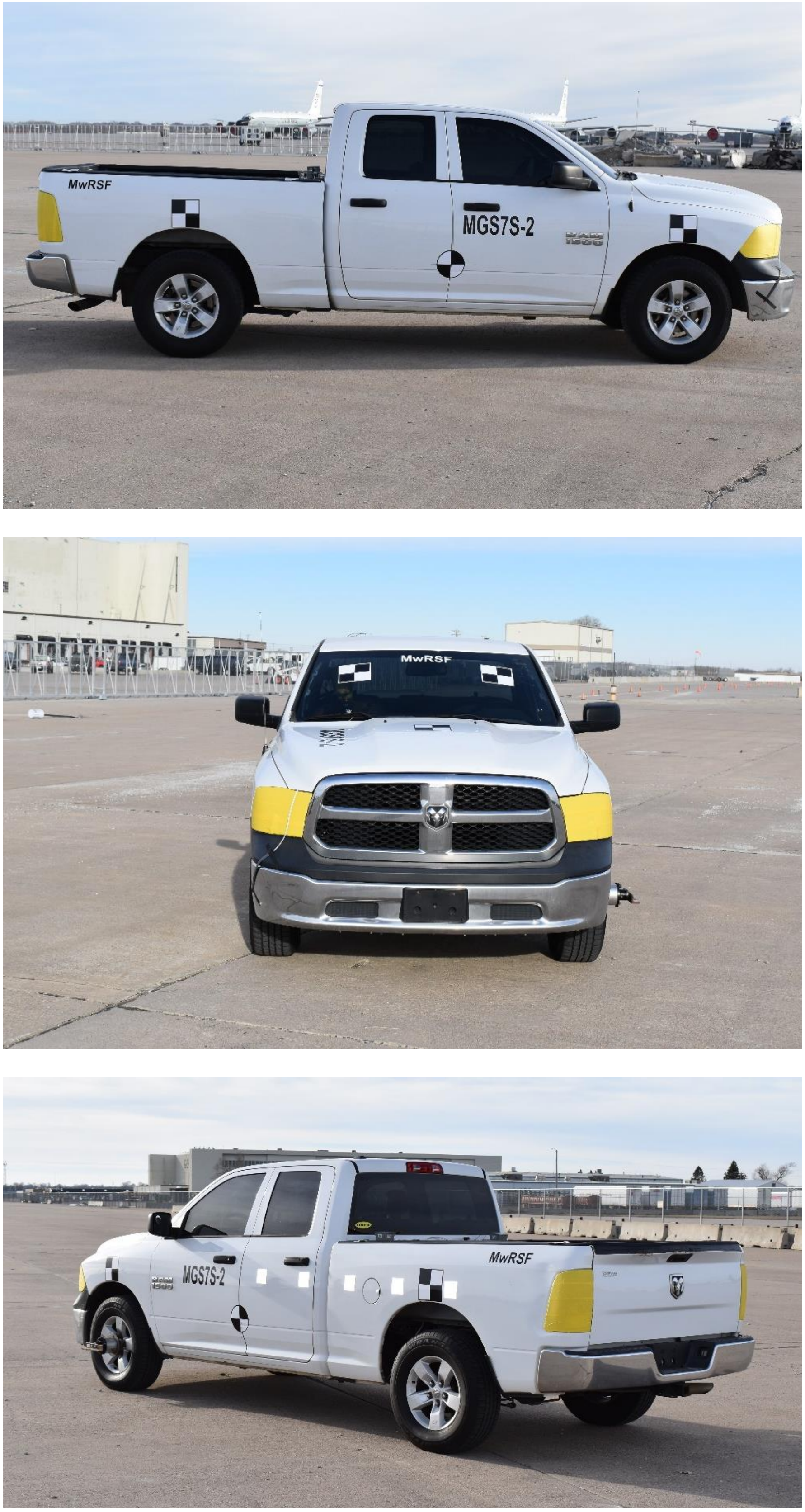


Figure 21 Test Vehicle, Test No. MGS7S-2

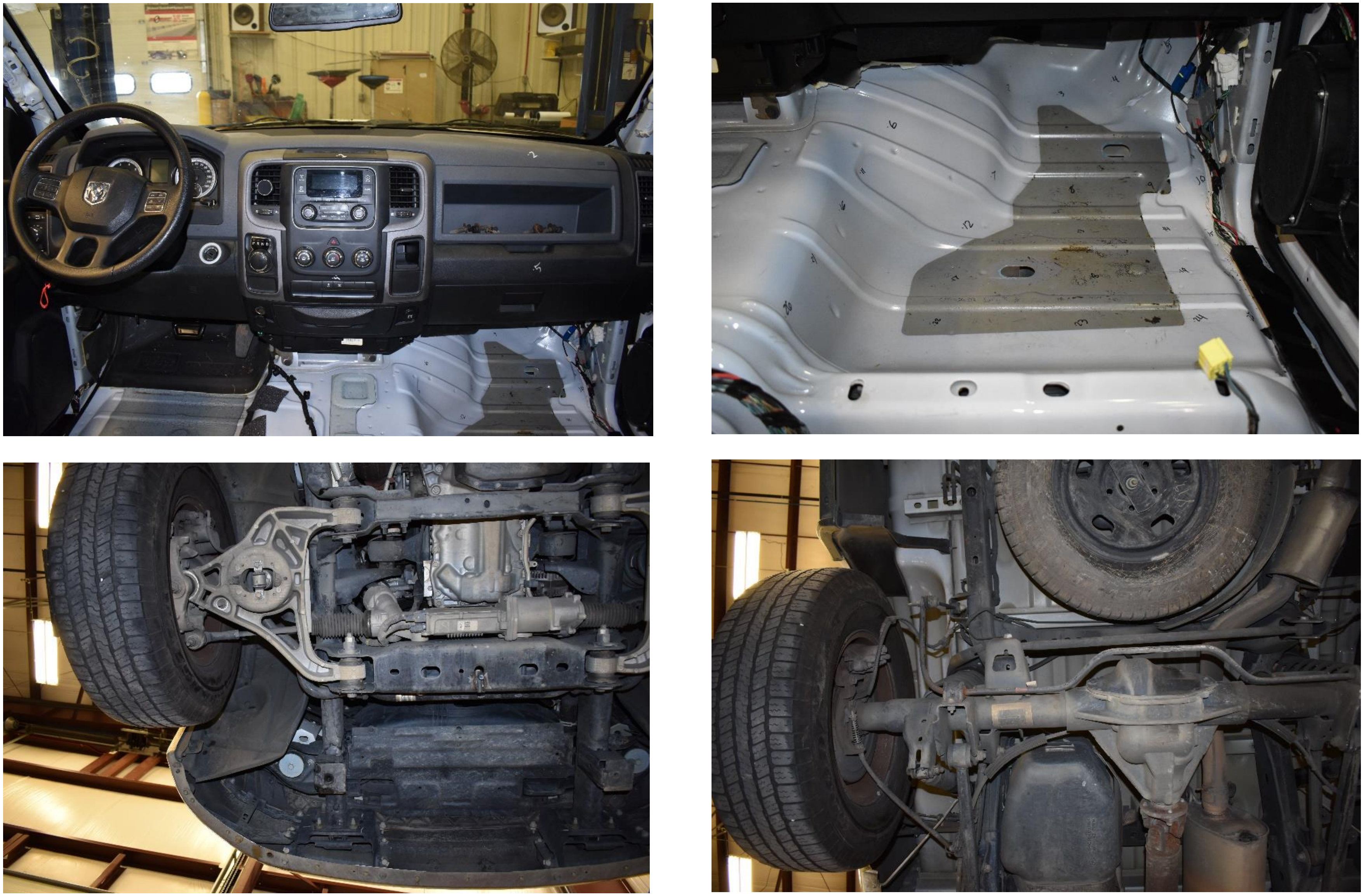
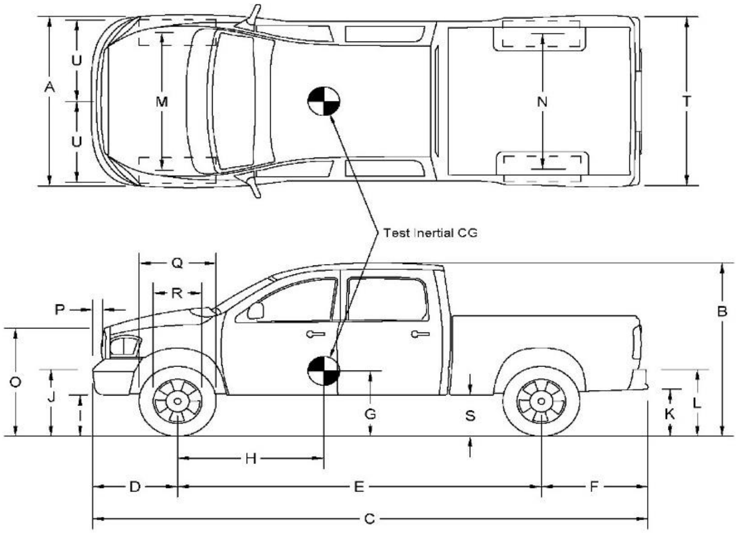


Figure 22. Test Vehicle’s Interior Floorboards and Undercarriage, Test No. MGS7S-2

		Test Name: MGS7S-2	VIN No: 1C6RR6FGXGS128241
Model Year: 2016		Make: Ram	Model: 1500
Tire Size: P265/70R17		Tire Inflation Pressure: 40 psi	Odometer: 269493



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

A: 78 1/8 (1984)	78±2 (1950±50)	B: 74 1/4 (1886)	
C: 229 1/2 (5829)	237±13 (6020±325)	D: 41 3/8 (1051)	39±3 (1000±75)
E: 140 1/2 (3569)	148±12 (3760±300)	F: 47 5/8 (1210)	
G: 28 1/8 (714)	min: 28 (710)	H: 65 3/4 (1670)	63±4 (1575±100)
I: 13 (330)		J: 25 1/8 (638)	
K: 19 1/2 (495)		L: 28 (711)	
M: 68 1/4 (1734)	67±1.5 (1700±38)	N: 67 7/8 (1724)	67±1.5 (1700±38)
O: 45 (1143)	43±4 (1100±75)	P: 4 1/2 (114)	
Q: 30 1/2 (775)		R: 18 1/2 (470)	
S: 14 3/4 (375)		T: 76 3/4 (1949)	
U (impact width): 36 1/2 (927)			

Mass Distribution - lb (kg)

Gross Static	LF 1425 (646)	RF 1345 (610)
	LR 1183 (537)	RR 1232 (559)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2713 (1231)	2671 (1212)	2770 (1256)
W-rear	2245 (1018)	2351 (1066)	2415 (1095)
W-total	4958 (2249)	5022 (2278) 5000±110 (2270±50)	5185 (2352) 5165±110 (2343±50)

Wheel Center Height (Front):	14 3/4 (375)
Wheel Center Height (Rear):	15 (381)
Wheel Well Clearance (Front):	34 7/8 (886)
Wheel Well Clearance (Rear):	37 (940)
Bottom Frame Height (Front):	18 3/8 (467)
Bottom Frame Height (Rear):	25 (635)
Engine Type:	Gasoline
Engine Size:	3.6L V6
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Quad Cab
Bed Length:	76"

GVWR Ratings - lb

Front	3700
Rear	3900
Total	6800

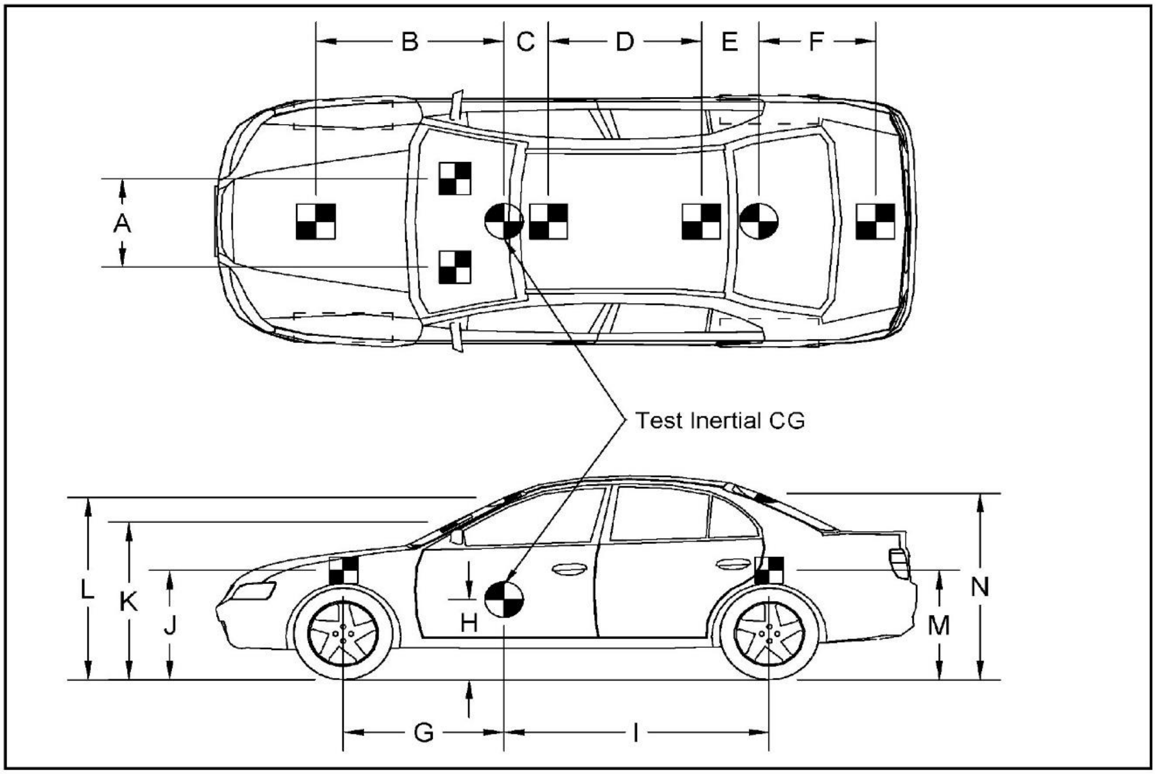
Surrogate Occupant Data

Type:	Hybrid II
Mass:	161 lb
Seat Position:	Right

Note any damage prior to test: None

Figure 23. Vehicle Dimensions, Test No. MGS7S-2

		Test Name:	MGS7S-1	VIN:	KMHTC4AEXGU059917
Model Year:	2016	Make:	Hyundai	Model:	Accent Sedan

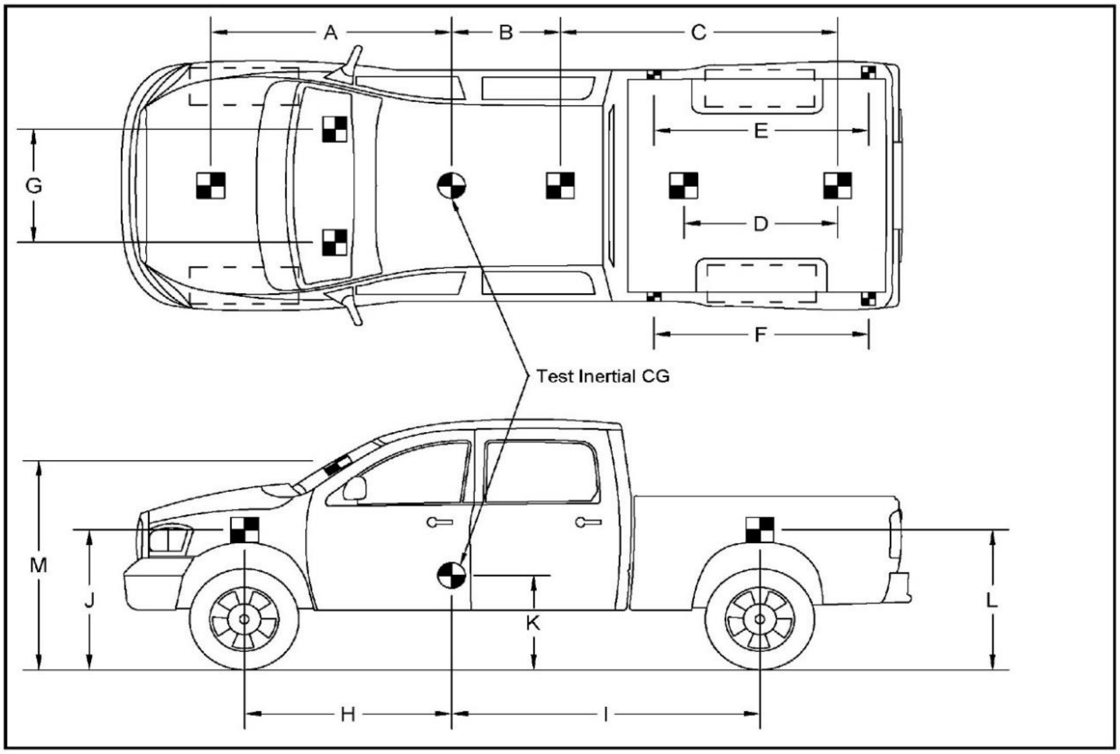


TARGET GEOMETRY-- in. (mm)

A:	27 1/2 (699)	F:	33 3/4 (857)	K:	48 (1219) Windshield Target
B:	46 15/16 (1192)	G:	38 1/4 (972)	L:	53 1/4 (1353) Front round CG target
C:	12 1/16 (306)	H:	21 7/8 (556)	M:	29 3/16 (741)
D:	26 7/8 (683)	I:	63 3/8 (1610)	N:	53 1/4 (1353) Rear Round target
E:	16 13/16 (427)	J:	28 13/16 (732)		

Figure 24. Target Geometry, Test No. MGS7S-1

Test Name: MGS7S-2 VIN: 1C6RR6FGXGS128241
Model Year: 2016 Make: Ram Model: 1500



TARGET GEOMETRY-- in. (mm)

A:	75 1/8 (1908)	E:	63 3/8 (1610)	J:	39 (991)
B:	25 3/8 (645)	F:	63 3/8 (1610)	K:	28 1/8 (714)
C:	44 3/8 (1127)	G:	35 1/4 (895)	L:	41 1/4 (1048)
D:	44 5/16 (1126)	H:	65 3/4 (1670)	M:	63 3/4 (1619)
		I:	74 5/8 (1895)		

Figure 25. Target Geometry, Test No. MGS7S-2

5.4 Simulated Occupant

For test nos. MGS7S-1 and MGS7S-2, a Hybrid II 50th-Percentile, Adult Male Dummy equipped with footwear was placed in the right-front seat of the test vehicles with the seat belt fastened. The simulated occupant had a final weight of 161 lb for both tests. As recommended by MASH 2016, the simulated occupant weights were not included in calculating the c.g. location.

5.5 Data Acquisition Systems

5.5.1 Accelerometers and Rate Transducers

The accelerometer and rate transducer systems used in the full-scale crash testing were the SLICE-1 and SLICE-2 units described below. Units were positioned near the c.g. of the test vehicle and the SLICE-1 unit was designated as primary for test no. MGS7S-1. The SLICE-2 unit was designated as primary for MGS7S-2. Data obtained in dynamic testing was filtered using the SAE Class 60 and the SAE Class 180 Butterworth filter conforming to the SAEJ211/1 specifications [12].

The SLICE-1 and SLICE-2 units were modular data acquisition systems manufactured by Diversified Technical Systems, Inc. of Seal Beach, California. Triaxial acceleration and angular rate sensor modules were mounted inside the bodies of custom-built SLICE 6DX event data recorders equipped with 7GB of non-volatile flash memory and recorded data at 10,000 Hz to the onboard microprocessor. The accelerometers had a range of ±500 g's in each of three directions (longitudinal, lateral, and vertical) and a 1,650 Hz (CFC 1000) anti-aliasing filter. The SLICE MICRO Triax ARS had a range of 1,500 degrees/sec in each of three directions (roll, pitch, and yaw). The raw angular rate measurements were downloaded, converted to the proper Euler angles for analysis, and plotted. The "SLICEWare" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot both the accelerometer and angular rate sensor data.

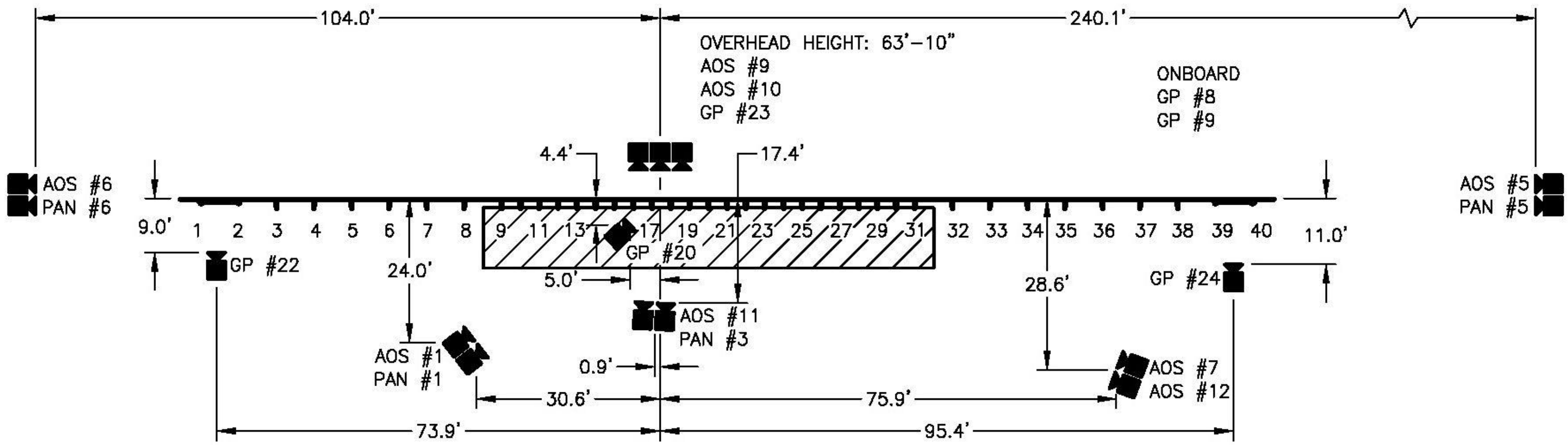
5.5.2 Retroreflective Optic Speed Trap

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

5.5.3 Digital Photography

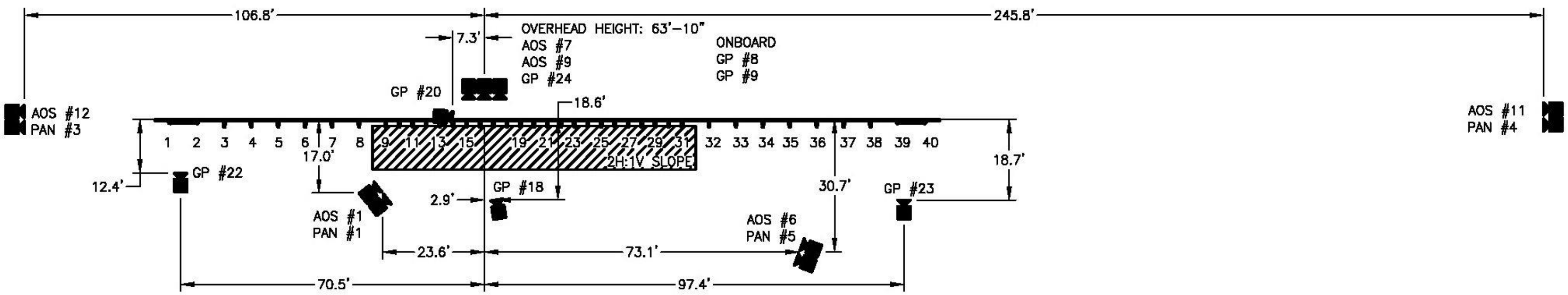
Eight AOS high-speed digital video cameras, six GoPro digital video cameras, and four Panasonic digital video cameras were utilized to film test no. MGS7S-1. Six AOS high-speed digital video cameras, seven GoPro digital video cameras, and four Panasonic digital video cameras were utilized to film test no. MGS7S-2. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figures 26 and 27, respectively.

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



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-1	AOS Vitcam CTM	500	KOWA 25mm Fixed	
AOS-5	AOS X-PRI Gigabit	500	100mm Fixed	
AOS-6	AOS X-PRI Gigabit	500	Fujinon 50mm Fixed	
AOS-7	AOS X-PRI Gigabit	500	Fujinon 35mm Fixed	
AOS-9	AOS TRI-VIT 2236	1000	KOWA 12mm Fixed	
AOS-10	AOS TRI-VIT 2236	500	KOWA 16mm Fixed	
AOS-11	AOS J-PRI	500	Nikon 20mm Fixed	
AOS-12	AOS J-PRI	500	Signia 24-135	100
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-20	GoPro Hero 6	120		
GP-22	GoPro Hero 7	240		
GP-23	GoPro Hero 7	240		
GP-24	GoPro Hero 7	60		
PAN-1	Panasonic HC-V770	120		
PAN-3	Panasonic HC-V770	120		
PAN-5	Panasonic HC-VX981	120		
PAN-6	Panasonic HC- VX981	120		

Figure 26. Camera Locations, Speeds, and Lens Settings, Test No. MGS7S-1



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-1	AOS Vitcam CTM	500	KOWA 25mm Fixed	
AOS-6	AOS X-PRI Gigabit	500	Fujinon 50mm Fixed	
AOS-7	AOS X-PRI Gigabit	500	KOWA 16mm Fixed	
AOS-9	AOS TRI-VIT 2236	1000	KOWA 12mm Fixed	
AOS-11	AOS J-PRI	500	Sigma 24-135	135
AOS-12	AOS J-PRI	500	Sigma 2-70	42 ½
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-18	GoPro Hero 6	240		
GP-20	GoPro Hero 6	120		
GP-22	GoPro Hero 7	240		
GP-23	GoPro Hero 7	240		
GP-24	GoPro Hero 7	240		
PAN-1	Panasonic HC-V770	120		
PAN-3	Panasonic HC-V770	120		
PAN-4	Panasonic HC-V770	120		
PAN-5	Panasonic HC-VX981	120		

Figure 27. Camera Locations, Speeds, and Lens Settings, Test No. MGS7S-2

6 FULL-SCALE CRASH TEST NO. MGS7S-1

6.1 Static Soil Test

Before full-scale crash test no. MGS7S-1 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. The static test results, as shown in Appendix C, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and full-scale crash testing could be conducted on the longitudinal barrier system.

6.2 Weather Conditions

Test no. MGS7S-1 was conducted on November 24th, 2021 at approximately 2:30 p.m. The weather conditions as reported by the National Oceanic and Atmospheric Administration (station 14939/KLNK) are shown in Table 5.

Table 5. Weather Conditions, Test No. MGS7S-1

Temperature	45°F
Humidity	48%
Wind Speed	21 mph
Wind Direction	360° from True North
Sky Conditions	Overcast
Visibility	10.00 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.0 in.
Previous 7-Day Precipitation	0.0 in.

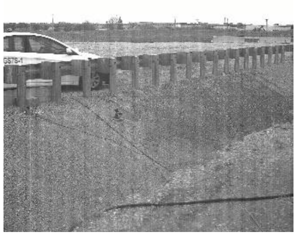
6.3 Test Description

Test no. MGS7S-1 was conducted according to MASH 2016 criteria for test designation no. 3-10 and consisted of an 1100C vehicle impacting the MGS installed adjacent to a 2H:1V slope with 7-ft long posts at ½-post spacing with a target speed of 62 mph and a target angle of 25 degrees. Initial vehicle impact was to occur 8 ft upstream from post no. 20, as shown in Figure 28, which was selected using the CIP plots found in Section 2.3 of MASH 2016. The 2,431-lb small car impacted the longitudinal barrier at a speed of 62.8 mph and at an angle of 25.2 degrees. The actual point of impact was 1.9 in. upstream from the targeted point of impact, or 8 ft – 1.9 in. upstream from post no. 20. After initial impact, the 1100C vehicle began to be redirected. During redirection, the right front wheel of the vehicle extended beneath the rail and impacted and snagged post nos. 20 and 21. The wheel snag did not adversely affect vehicle stability or lead to occupant risk concerns. The closely spaced, 7-ft long posts also generated a significant amount of soil displacement as the guardrail deflected. The vehicle exited the barrier and continued downstream until brakes were applied, and the vehicle came to rest 80.5 ft downstream and 13 ft in front of the system from the impact point as measured to the right front wheel of the vehicle. A detailed description of the sequential impact events is contained in Table 6. Sequential photographs are shown in Figures 29 through 31. Documentary photographs of the crash test are shown in Figures 32 and 33. The vehicle trajectory and final position are shown in Figure 34.

Figure 28. Impact Location, Test No. MGS7S-1

Table 6. Sequential Description of Impact Events, Test No. MGS7S-1

Time (sec)	Event
0.000	Vehicle's front bumper contacted rail 1.9 in. upstream from targeted impact location and deformed.
0.006	Vehicle's right headlight contacted rail and shattered. Vehicle's right fender contacted rail and was crushed inward.
0.014	Post nos. 18 and 19 rotated backward. Vehicle's hood contacted rail and right side severely crushed inward to a downward "U" shape.
0.028	Post nos. 17 and 20 rotated backward.
0.038	Vehicle's right-front door contacted rail and deformed. Vehicle rolled and yawed away from barrier.
0.048	Vehicle's front bumper cover detached on right end. Post nos. 16 and 21 rotated backward. Post no. 19 rotated downstream.
0.064	Vehicle's right-front tire contacted rail and blockout at post no. 19 fractured.
0.078	Post nos. 14 and 15 rotated downstream. Vehicle's right-front tire deflated.
0.086	Post no. 20 rotated downstream and disengaged from rail. Post no. 22 rotated backward.
0.096	Vehicle’s right-front wheel contacted and snagged post no. 20.
0.101	Bottom of right vehicle’s A-pillar and vehicle’s right mirror contacted rail and deformed. Post nos. 23 and 24 rotated backward.
0.117	Surrogate occupant’s head contacted right-front door window glass. Post no. 21 rotated downstream.
0.122	Vehicle’s right-front wheel contacted and snagged post no. 21.
0.130	Post no. 21 disengaged from rail. Vehicle rolled toward barrier.
0.154	Vehicle's right-side mirror detached.
0.168	Post no. 25 rotated backward. Vehicle's left-front tire deflated.
0.194	Post 22 rotated downstream. Post no. 22 disengaged from rail.
0.292	Vehicle became parallel to system at a speed of 27.8 mph.
0.370	Vehicle's right-rear door contacted rail and deformed.
0.414	Vehicle's right quarter panel contacted rail and deformed.
0.441	Vehicle's rear bumper contacted rail and deformed.
0.526	Vehicle exited system at a speed of 28.6 mph and an angle of 15.1 degrees.
0.538	System came to rest.
3.158	Vehicle came to rest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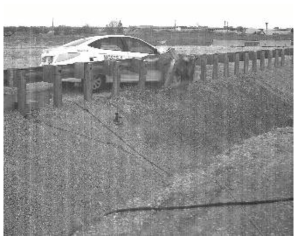
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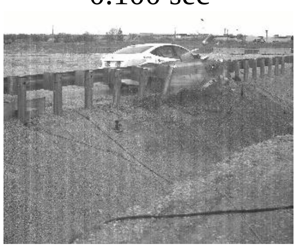
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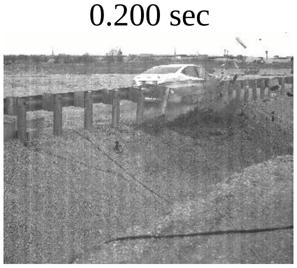
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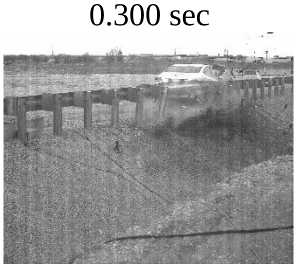
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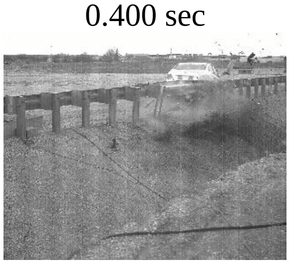
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Figure 29. Sequential Photographs, Test No. MGS7S-1


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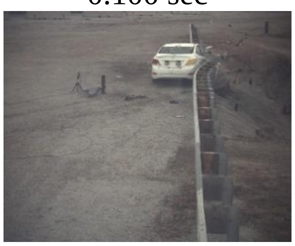
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Figure 30. Sequential Photographs, Test No. MGS7S-1


0.000 sec


0.050 sec


0.100 sec


0.150 sec


0.200 sec


0.250 sec


0.000 sec


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0.100 sec


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Figure 31. Sequential Photographs, Test No. MGS7S-1

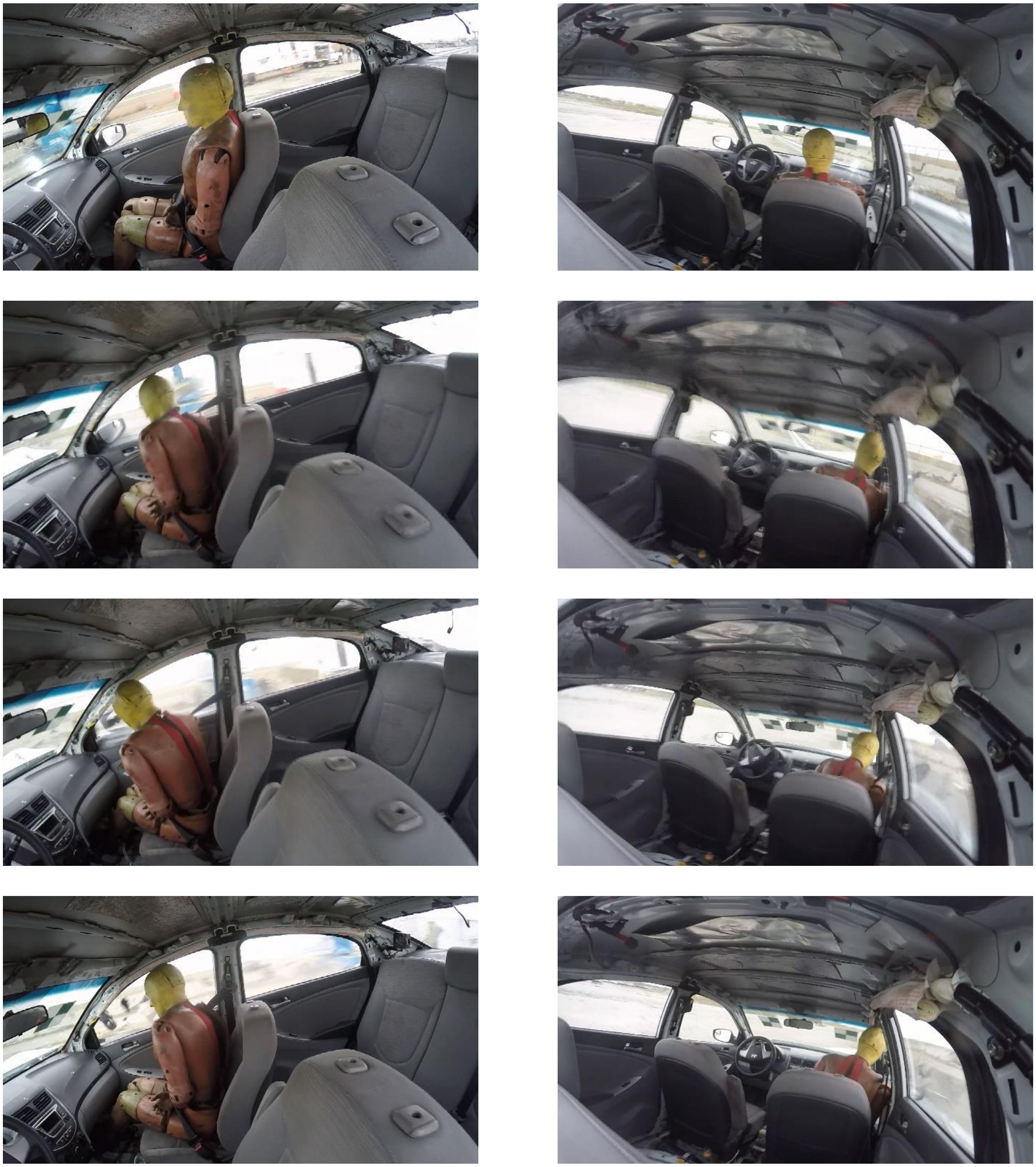

Figure 32. Documentary Photographs, Test No. MGS7S-1

Figure 33. Documentary Photographs, Test No. MGS7S-1

Figure 34. Vehicle Final Position and Trajectory Marks, Test No. MGS7S-1

6.4 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 35 through 41. Barrier damage consisted of contact marks on the guardrail sections and posts, guardrail and post deformations, and post damage. The primary length of vehicle contact along the barrier was approximately 19 ft – 1 in. which spanned 14¼ in. downstream from post no. 17 to approximately 18¼ in. downstream from post no. 23. Contact marks were located on post nos. 17 through 23, spanning different lengths.

The W-beam guardrail configuration experienced rail kinking between post nos. 16 and 26. Minor rail flattening also occurred at post no. 18. Intermittent soil heaving was observed spanning from post nos. 19 through 23 which led to displacement of a portion of the 2H:1V slope behind the system.

The most significant post deformation occurred at posts nos. 19 to 22. Posts nos. 20 and 21 bent downstream while deflecting downstream. Post nos. 19 and 22 deflected downstream. Posts nos. 19 and 20 were twisted due to the counter-clockwise rotation caused by impact and snagging of the vehicle’s right-front wheel. Posts nos. 19 through 21 were also rotated counter-clockwise. Both post nos. 19 through 22 deflected backwards. In addition, minor to moderate damage was experienced by post nos. 15 to 18 and 23 to 24, in which no permanent deformation occurred. Post nos. 15 to 18, 23, and 24 deflected backward at different angles; the angles were larger closer impact. Posts nos. 23 and 24 also experienced slight clockwise rotation.

The guardrail was detached from the post at post nos. 20 through 22. Post no. 19 experienced blockout fracture on the downstream half of the blockout and buckling occurred on the back side of the flange. Post no. 20 experienced blockout fracture on the downstream half of the blockout, and a bent bolt at the post flange. The post was no longer in contact with the rail due to the post bolt releasing from the guardrail. Post no. 21 was also disengaged from the rail resulting from bolt shear at the nut on the backside of the flange. At post nos. 20 through 22, the upstream front flange was bent twice, on the top half of the post. The block at post no. 21 was detached from the post and the block at post no. 22 was dented, both following impact with the vehicle. The bolt bent at mid length on post no. 21, while the bolt on post no. 22 was bent at the flange hole. As result of the damage experienced by post nos. 20 through 22, the bolt holes became warped. Post no. 21’s flange curled backward at the upper downstream corner. The back flange was then bent forward at the upstream edge. The web of the post was bent on the front half. The front flange tore on the lower bolt hole of the downstream side.

Figure 35. System Damage, Test No. MGS7S-1

Figure 36. System Damage, Test No. MGS7S-1

Figure 37. Damage to Post Nos. 19 and 20, Test No. MGS7S-1

Figure 38. Damage to Post Nos. 21 and 22, Test No. MGS7S-1

Figure 39. Post and Flange Damage, Test No. MGS7S-1

Figure 40. Bolt Hole and Bolt Damage, Post No. 20, Test No, MGS7S-1

Figure 41. Bolt Hole and Bolt Damage, Test No. MGS7S-1

The maximum lateral permanent set of the barrier system, including post and rail deflection, was 22.1 in. at post no. 20, as measured in the field. The maximum lateral dynamic barrier deflection, was 31.2 in. located at post no. 20, as determined from high-speed digital video analysis. The working width of the system was found to be 52.5 in. also located at post no. 20, also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 42.

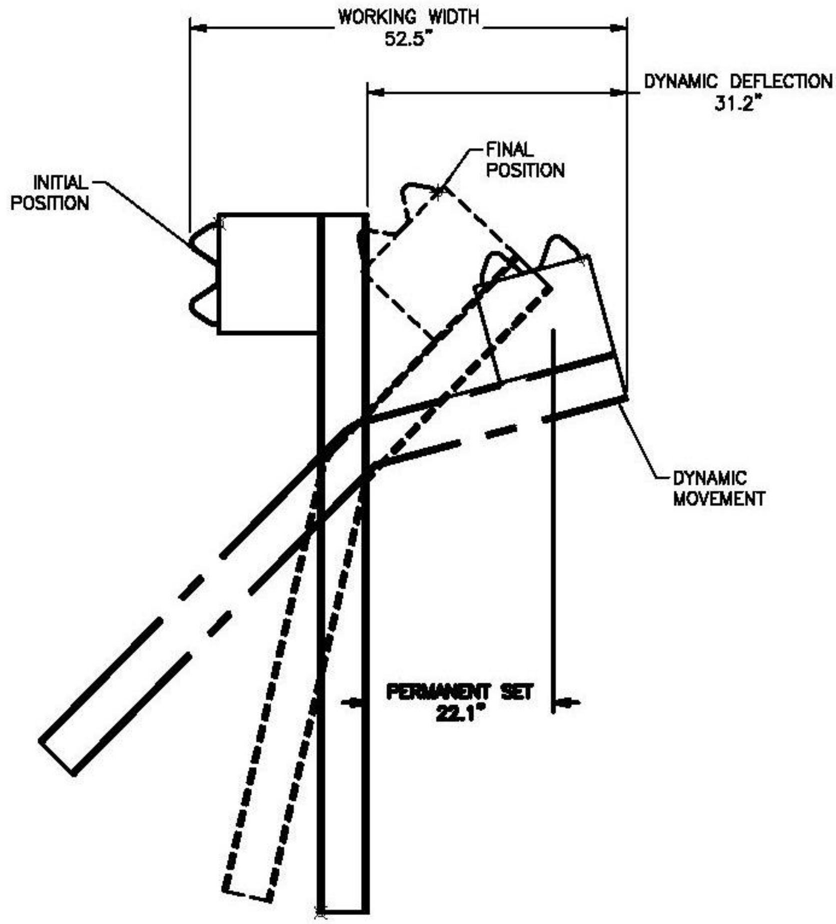

Figure 42. Permanent Set, Dynamic Deflection, and Working Width, Test No. MGS7S-1

6.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 43 and 44. The maximum occupant compartment intrusions are listed in Table 7, along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. There were no penetrations into the occupant compartment and none of the established MASH 2016 deformation limits were violated. Outward deformations, which are denoted as negative numbers in Appendix D, are not considered crush toward the occupant, and are not evaluated by MASH 2016 criteria.

Majority of the vehicle damage was concentrated on the right front corner and the right side of the vehicle where impact had occurred. One quarter of the front bumper cover, on the right side, was detached. The furthest right frame horn was crushed inwards. The hood was crushed inwards near the right side. This resulted in the hood bending into a downward "U" shape. The right fender was crushed inwards upon impact, damage was concentrated upon the front end. Significant scraping occurred throughout the crushed area. Inward crushing occurred at the leading edge of the front-right door. Scraping spanned the entire width of both right-side doors. The right quarter panel underwent rearward scrapes spanning its length. The left-side front bumper cover was deformed. Scraping was also found along the leading edge of the right-side rear bumper cover.

Similar to the vehicle body damage, the vehicle's undercarriage was concentrated upon the right-side. The right-side control arm detached at the front most cross member of the vehicle; the strut remained attached with minor deformation. The right side of the steering rack detached at the steering rack. The right shock/spring bent outwards with a damaged steering knuckle. The right side of the front sway bar bent upwards with damaged steering knuckle. The right steering knuckle assemblies were pushed outwards with the wheel it was attached to, but all components remained intact. The right tie rod remained connected to the steering knuckle. The left-side tie rod was slightly bent at the steering knuckle connection.

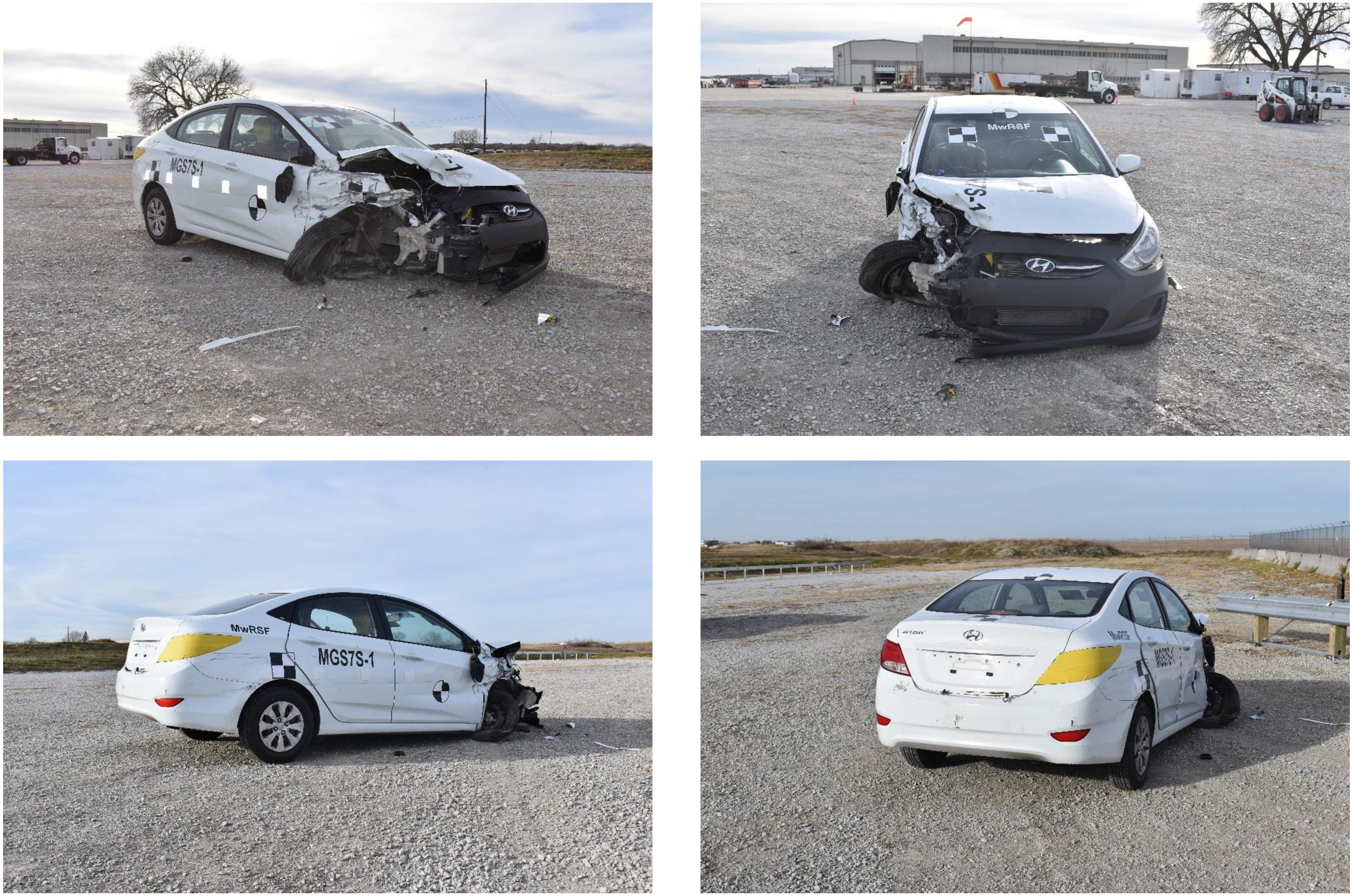

Figure 43. Vehicle Damage. Test No. MGS7S-1

Figure 44. Vehicle Undercarriage and Occupant Compartment Damage, Test No. MGS7S-1

Table 7. Maximum Occupant Compartment Intrusion by Location, Test No. MGS7S-1

Location	Maximum Intrusion in.	MASH 2016 Allowable Intrusion in.
Wheel Well & Toe Pan	0.3	≤ 9
Floor Pan & Transmission Tunnel	0.1	≤ 12
A-Pillar	0.1	≤ 5
A-Pillar (Lateral)	0.1	≤ 3
B-Pillar	0.1	≤ 5
B-Pillar (Lateral)	0.1	≤ 3
Side Front Panel (in Front of A-Pillar)	0.1	≤ 12
Side Door (Above Seat)	0.1	≤ 9
Side Door (Below Seat)	0.0*	≤ 12
Roof	0.0	≤ 4
Windshield	0.0	≤ 3
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	0.2	N/A

N/A – No MASH 2016 criteria exist for this location.
*Negative value reported as 0.0. See Appendix D for further information.

6.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 8. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 8. The recorded data from the accelerometers and the rate transducers is shown graphically in Appendix E.

Table 8. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. MGS7S-1

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (primary)	SLICE-2 (backup)	
OIV ft/s	Longitudinal	-20.81	-22.08	±40
	Lateral	-19.59	-18.00	±40
ORA g's	Longitudinal	-14.56	-14.11	±20.49
	Lateral	-10.17	-12.43	±20.49
Maximum Angular Displacement deg.	Roll	-5.9	-6.9	±75
	Pitch	-2.6	-2.8	±75
	Yaw	-43.3	-43.9	not required
THIV – ft/s		26.96	29.79	not required
PHD – g's		15.11	16.17	not required
ASI		1.03	0.99	not required

6.7 Discussion

The analysis of the test results for test no. MGS7S-1 showed that the system adequately contained and redirected the 1100C vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown in Figure 45. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix E, were deemed acceptable because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the barrier at an angle of 15.1 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. MGS7S-1 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-10.


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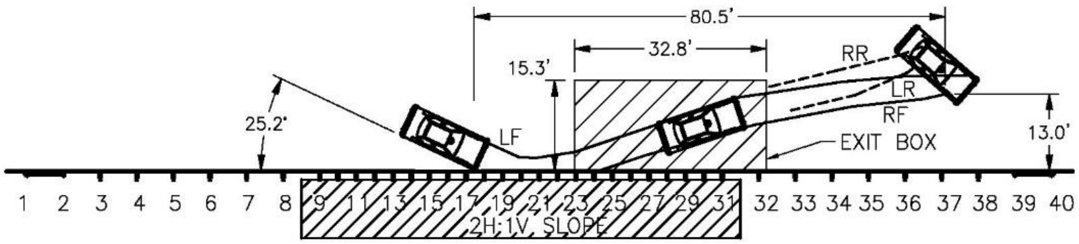
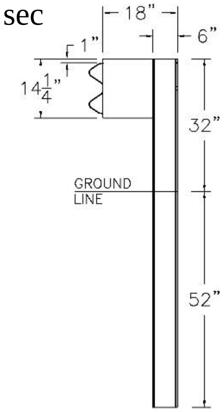




- Test Agency .... MwRSF
- Test Number.. MGS7S-1
- Date.. 11/24/2021
- MASH 2016 Test Designation No.. 3-10
- Test Article.. MGS Half-Post Adjacent to Slope
- Total Length .... 175 ft
- Key Component - Rail
  - Length .... 175 ft
  - Width.. 3.25 in.
  - Depth.. 14.25 in.
- Key Component - Post
  - Length .... 7 ft
  - Width.. 4 in.
  - Spacing.. 37.5 in.
- Soil Type.. Coarse, Crushed Limestone
- Vehicle Make /Model.. 2016 Hyundai Accent Sedan
  - Curb.. 2,484 lb
  - Test Inertial.. 2,431 lb (MASH 2016 Limit 2,420 ± 25 lb)
  - Gross Static.. 2,592 lb
- Impact Conditions
  - Speed .... 62.8 mph
  - Angle .... 25.2 deg
  - Impact Location.. 8 ft – 1.9 in. Upstream from Post No. 20
- Impact Severity/Kinetic Energy .... 59.3 kip-ft > 50 kip-ft MASH 2016 limit
- Exit Conditions
  - Speed .... 28.6 mph
  - Angle .... 15.1 deg.
- Exit Box Criterion .... Pass
- Vehicle Stability.. Satisfactory
- Vehicle Stopping Distance .... 85 ft – 1 in. downstream, 16 ft – 4 in. laterally in front
- Vehicle Damage.. Moderate
  - VDS [13] 1-RFQ-6
  - CDC [14].. 1-RFER-5
  - Maximum Interior Deformation .... 0.4 in. at A-Pillar ≤ 5.0 in. MASH 2016 limit
- Test Article Damage .... Moderate
- Maximum Test Article Deflections
  - Permanent Set.. 22.1 in.
  - Dynamic .... 31.2 in.
  - Working Width.. 52.5 in.
- Transducer Data

Evaluation Criteria		Transducer SLICE-1 (primary)	Transducer SLICE-2 (backup)	MASH 2016 Limits
OIV ft/s	Longitudinal	-20.81	-22.08	±40
	Lateral	-19.59	-18.00	±40
ORA g's	Longitudinal	-14.56	-14.11	±20.49
	Lateral	-10.17	-12.43	±20.49
Maximum Angular Displacement deg.	Roll	-5.9	-6.9	±75
	Pitch	-2.6	-2.8	±75
	Yaw	-43.3	-43.9	not required
THIV – ft/s		26.96	29.79	not required
PHD – g's		15.11	16.17	not required
ASI		1.03	0.99	not required

Figure 45. Summary of Test Results and Sequential Photographs, Test No. MGS7S-1

7 FULL-SCALE CRASH TEST NO. MGS7S-2

7.1 Static Soil Test

Before full-scale crash test no. MGS7S-2 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. The static test results, as shown in Appendix C, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and full-scale crash testing could be conducted on the longitudinal barrier system.

7.2 Weather Conditions

Test no. MGS7S-2 was conducted on December 21, 2021 at approximately 1:30 p.m. The weather conditions as reported by the National Oceanic and Atmospheric Administration (station 14939/KLNK) are shown in Table 9.

Table 9. Weather Conditions, Test No. MGS7S-2

Temperature	49°F
Humidity	32%
Wind Speed	11 mph
Wind Direction	330° from True North
Sky Conditions	Sunny
Visibility	10.00 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.0 in.
Previous 7-Day Precipitation	0.2 in.

7.3 Test Description

Test no. MGS7S-2 was conducted according to MASH 2016 criteria for test designation no. 3-11 and consisted of a 2270P vehicle impacting the MGS installed adjacent to a 2H:1V slope with 7-ft long posts at ½-post spacing at a target speed of 62 mph and target angle of 25 degrees. Initial vehicle impact was to occur 138 in. upstream from post no. 20, as shown in Figure 46, which was selected using the CIP plots found in Section 2.3 of MASH 2016. The 5,022-lb quad cab pickup truck impacted the guardrail system at a speed of 62.6 mph and at an angle of 25.4 degrees. The actual point of impact was at the targeted impact location. After initial impact, the 2270P vehicle began to be redirected. During redirection, the right front wheel of the vehicle extended beneath the rail and impacted and snagged on post nos. 18 through 21. The wheel snag did not adversely affect vehicle stability or lead to occupant risk concerns. The closely spaced, 7-ft long posts also generated a significant amount of soil displacement as the guardrail deflected. The vehicle exited the barrier and continued downstream in a stable manner until brakes were applied and the vehicle came to rest. The vehicle came to rest 117.3 ft downstream and 7.1 ft laterally in front of the system with respect to the impact point as measured to the right front wheel of the vehicle. A detailed description of the sequential impact events is contained in Table 10. Sequential photographs are shown in Figures 47 through 48. Documentary photographs of the crash test are shown in Figures 49 and 50. The vehicle trajectory and final position are shown in Figure 51.

Figure 46. Impact Location, Test No. MGS7S-2

Table 10. Sequential Description of Impact Events, Test No. MGS7S-2

Time (sec)	Event
0.000	Vehicle's front bumper contacted rail 138 in. upstream from post no. 20 and deformed.
0.008	Vehicle's right-front tire, right headlight, and right fender. Vehicle’s right headlight shattered and right fender deformed.
0.018	Vehicle's grille contacted rail and deformed. Post nos. 16 and 17 rotated backward.
0.024	Post no. 18 rotated backward and flange bent.
0.038	Post no. 19 rotated backward. Vehicle yawed away from barrier. Vehicle's hood deformed. Vehicle's right-front door contacted rail and deformed.
0.052	Vehicle's left headlight disengaged. Post no. 20 rotated downstream.
0.064	Post no. 21 rotated downstream.
0.084	Post no. 19 bent downstream.
0.086	Vehicle’s right-front wheel snagged post no. 18.
0.098	Post no. 18 blockout fractured and disengaged from rail. Post no. 19 disengaged from rail. Surrogate occupant’s head contacted right-front door's window glass.
0.106	Vehicle's right-front tire deflated. Post no. 22 rotated downstream.
0.132	Vehicle’s right-front wheel snagged post 19.
0.134	Vehicle's grille disengaged. Post no. 20 disengaged from rail.
0.148	Post no. 23 rotated downstream.
0.156	Vehicle's right-rear door contacted rail causing minor crushing. Vehicle's right quarter panel contacted rail causing crush along entire length.
0.172	Vehicle's roof deformed. Post no. 21 blockout disengaged from rail.
0.188	Vehicle's rear bumper contacted rail and crushed inward.
0.194	Vehicle's right taillight contacted rail and fractured.
0.258	Vehicle became parallel to system at a speed of 41.1 mph.
0.270	Vehicle’s right-front wheel snagged post no. 20.
0.330	Vehicle’s right-front wheel snagged post no. 21.
0.612	Vehicle exited system at a speed of 38.8 mph and an angle of 27.5 degrees.
0.776	System came to rest.
3.576	Vehicle came to rest.

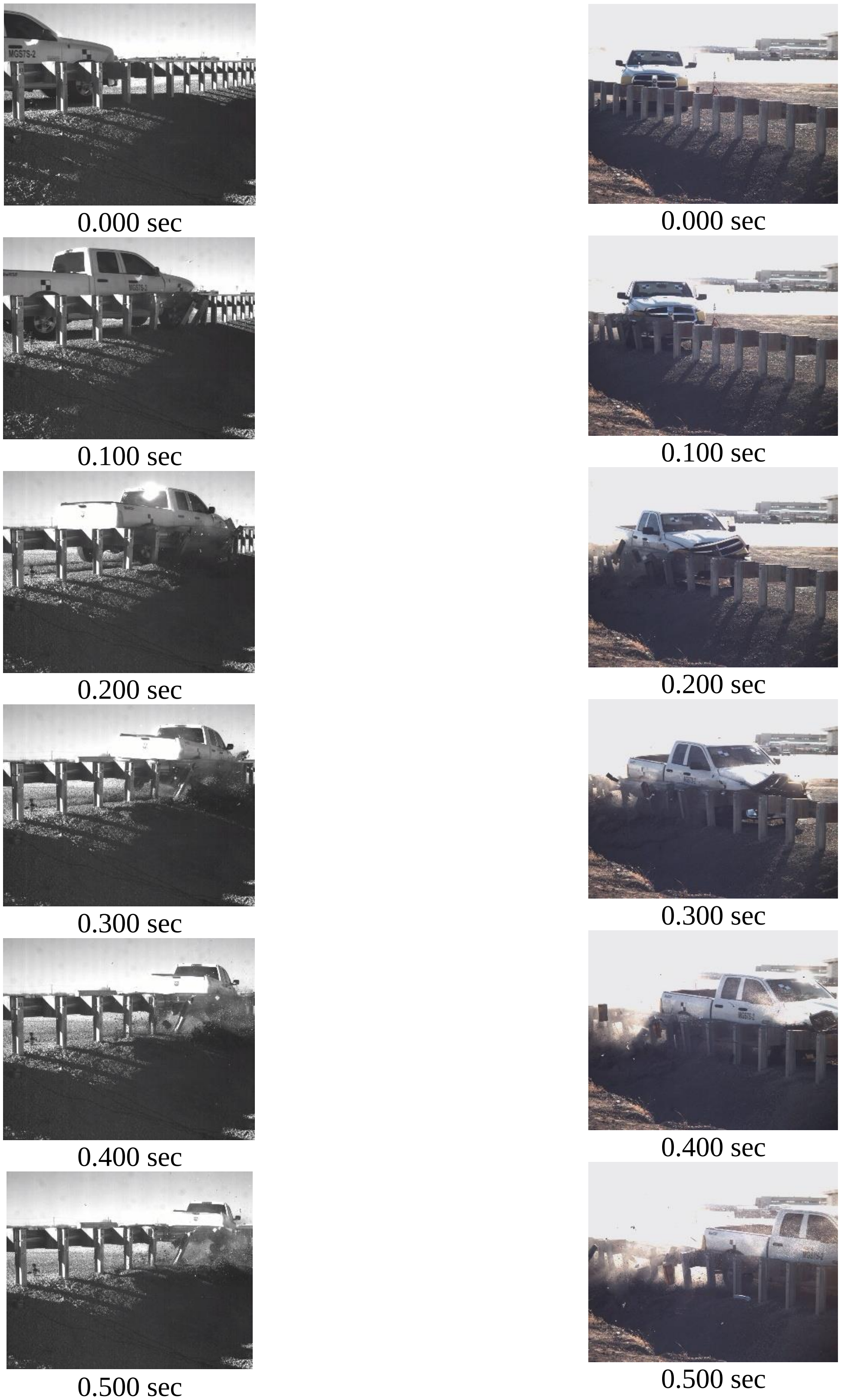


Figure 47. Sequential Photographs, Test No. MGS7S-2

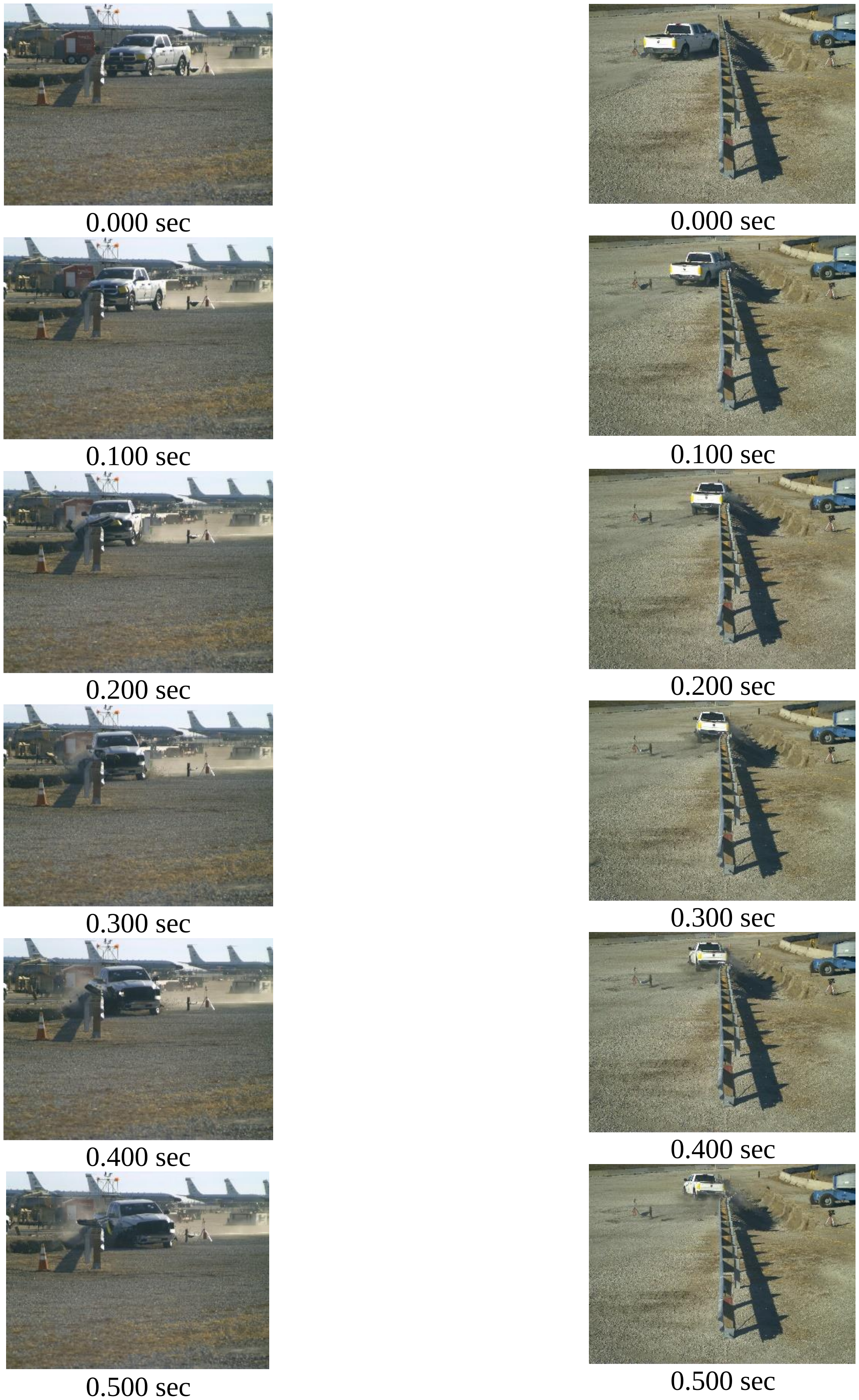


Figure 48. Sequential Photographs, Test No. MGS7S-2

Figure 49. Documentary Photographs, Test No. MGS7S-2

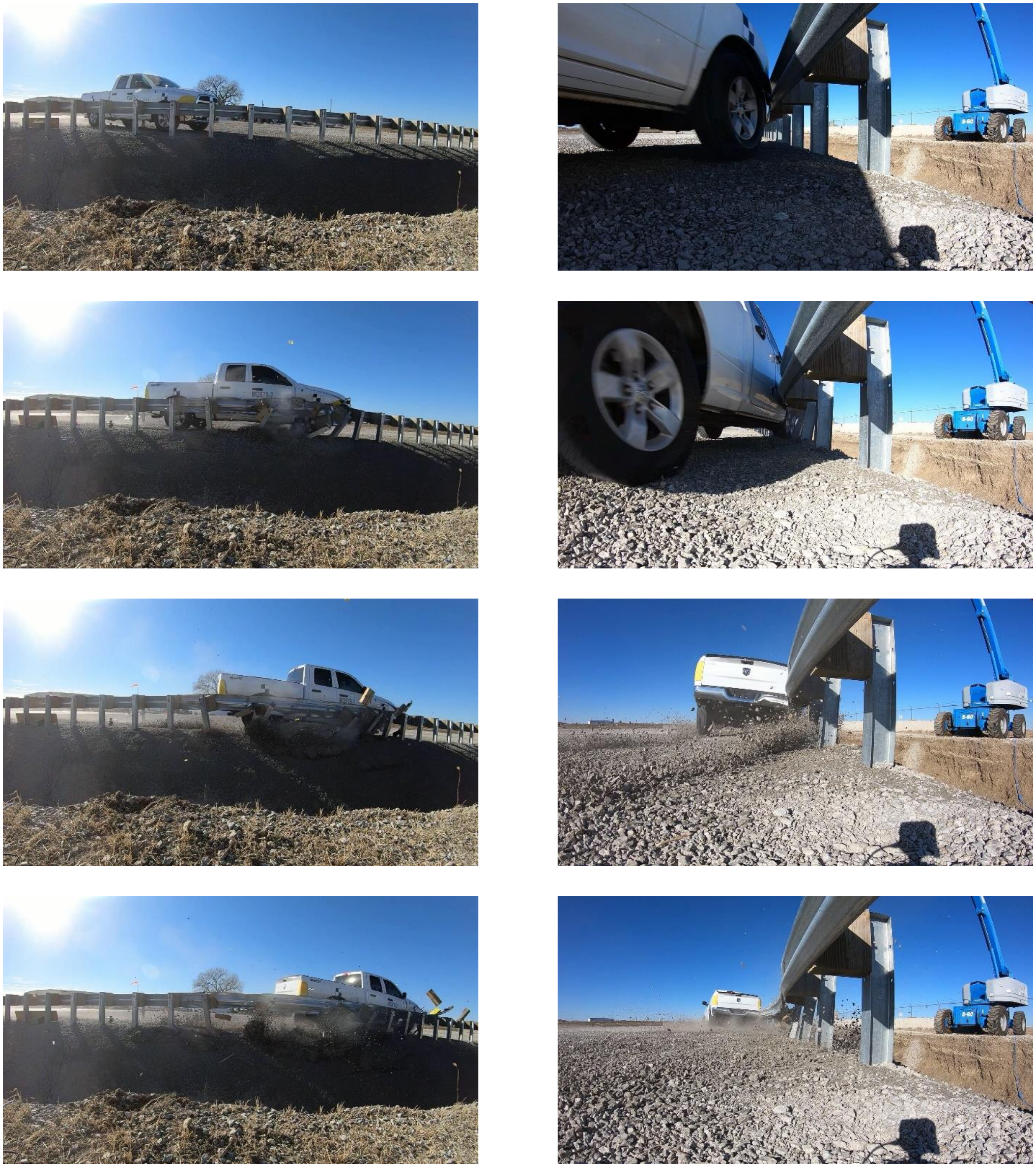


Figure 50. Documentary Photographs, Test No. MGS7S-2

Figure 51. Vehicle Final Position and Trajectory Marks, Test No. MGS7S-2

7.4 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 52 through 57. Barrier damage consisted of contact marks on the guardrail sections and posts, guardrail and post deformation, and post damage. The length of vehicle contact along the barrier was approximately 25 ft – 8 in. which spanned from 10½ in. upstream from the center of post no. 16 to approximately 2½ in. upstream of post no. 24. Additional contact marks were located on post nos. 18 through 23 and the blockouts of post nos. 17, 19, 22, and 23.

The W-beam guardrail configuration experienced rail kinking on the top corrugation ranging from upstream of post nos. 15 to 18. Kinking on the top and bottom corrugation occurred from upstream of post no. 23 to downstream of post no. 24. Intermittent kinks were located on the rail from post nos. 18 through 22. Two indentations were located upstream and downstream of post no. 16, respectively. The upstream dent occurred on the top corrugation while the downstream dent occurred on the bottom corrugation. Rail flattening occurred on the guardrail, starting 11 in. upstream of post no. 17 spanning approximately 17 ft downstream.

The majority of post deformation was concentrated on post nos. 17 through 22. The posts deflected backward upon impact. Post nos. 18 to 22 also experienced deflection in the downstream direction. Post nos. 18 to 21 were bent due to the deflection. In addition, post nos. 17 through 19 rotated clockwise while post nos. 20 through 22 rotated counter-clockwise. Torsional deformation occurred at these posts due to the specified rotation. Less critical damage was observed at post nos. 13 through 16, 23, and 24. Post nos. 15, 16, 23, and 24 deflected laterally backwards at lower levels. Post nos. 13 through 16 underwent clockwise rotation while post no. 24 experienced counter-clockwise rotation. Post nos. 18 and 19 displayed contact marks and flange deformation indicative of tire and wheel snag on the upstream flange of the posts.

The bolt hole was deformed on post nos. 17 through 24. The blockout at post no. 18 was fractured and disengaged. Post nos. 18 through 21 were no longer connected to the rail due to the post bolt releasing through the guardrail slot. Soil fissures occurred from post no. 18 to post no. 22. Large segments of soil were pushed backwards behind the posts in the impact region which disengaged sections of the 2H:1V slope behind the system and formed a line of soil disengagement in front of post nos. 16 through 23.

Figure 52. System Damage, Test No. MGS7S-2

Figure 53. Damage to Post Nos. 17 and 18, Test No. MGS7S-2

Figure 54. Damage to Post Nos. 19 and 20, Test No. MGS7S-2

Figure 55. Damage to Post Nos. 21 and 22, Test No. MGS7S-2 Description

Figure 56. Bolt Damage. Test No. MGS7S-2

Figure 57. Blockout Damage and Post Buckling, Test No. MGS7S-2

The maximum lateral permanent set of the barrier system was 25.8 in. at post no. 19 as measured in the field. The maximum lateral dynamic barrier deflection was found to be 27.2 on the guardrail at post no. 21 as determined from high-speed digital video analysis. The working width of the system was found to be 47.7 in. at post 20, also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 58.

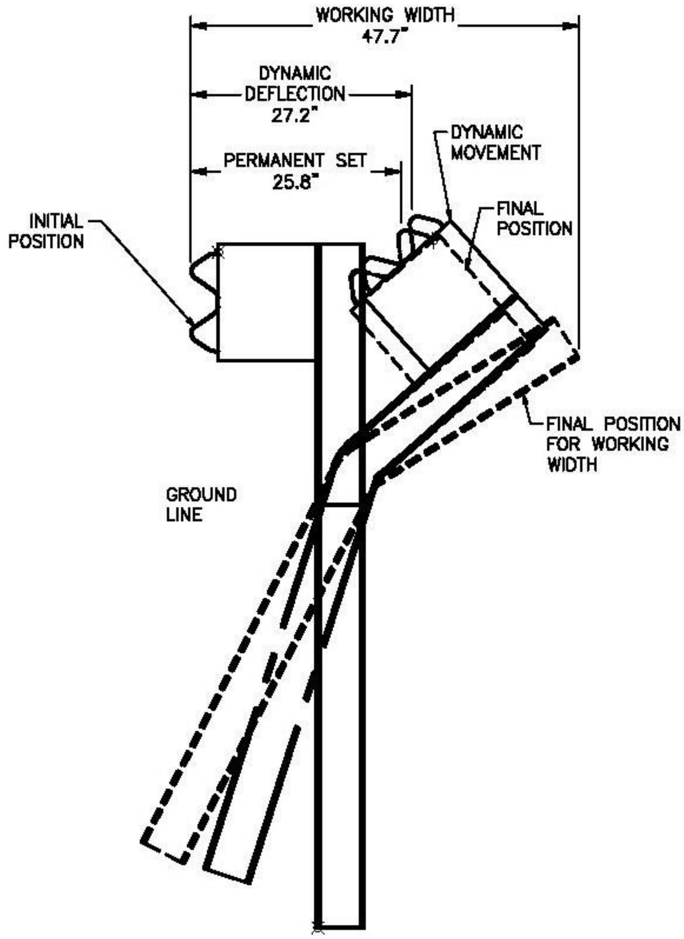


Figure 58. Permanent Set, Dynamic Deflection, and Working Width, Test No. MGS7S-2

7.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 59 and 60. The maximum occupant compartment intrusions are listed in Table 11, along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Table 11. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. There were no penetrations into the occupant compartment and none of the established MASH 2016 deformation limits were violated. Outward deformations, which are denoted as negative numbers in Table 11, are not considered crush toward the occupant, and are not evaluated by MASH 2016 criteria.

The majority of vehicle damage was concentrated on the right-front corner and right side of the vehicle. Both headlights and the grille were disengaged from the vehicle. The bumper was bent inward and slightly crushed on the right side of the bumper. The right-front fender was dented and scraped along the entire length. The right-front door was scraped and dented along the entire length. Damage to the door was concentrated upon the leading edge and lower half of the panel. The right rear door was slightly dented and scraped located around the vertical center of the panel. The right side of the truck box was dented and scraped along the entire length with the majority of the damage at the back end near the taillight. Damage was also located around the vertical center of the panel. The right end of the rear bumper was dented and scraped.

Vehicle undercarriage damage was also concentrated on the right side. The right lower control arm inner joints failed and detached at the control arm. The right-side inner tie rod also detached from the steering rack. The right-side frame horn was bent inward 3 in. The right-side frame rail was slightly bent inward around the second engine cross member. The right-front sway bar end link was bent at the upper mount. The right-front shock dust cover was slightly bent.

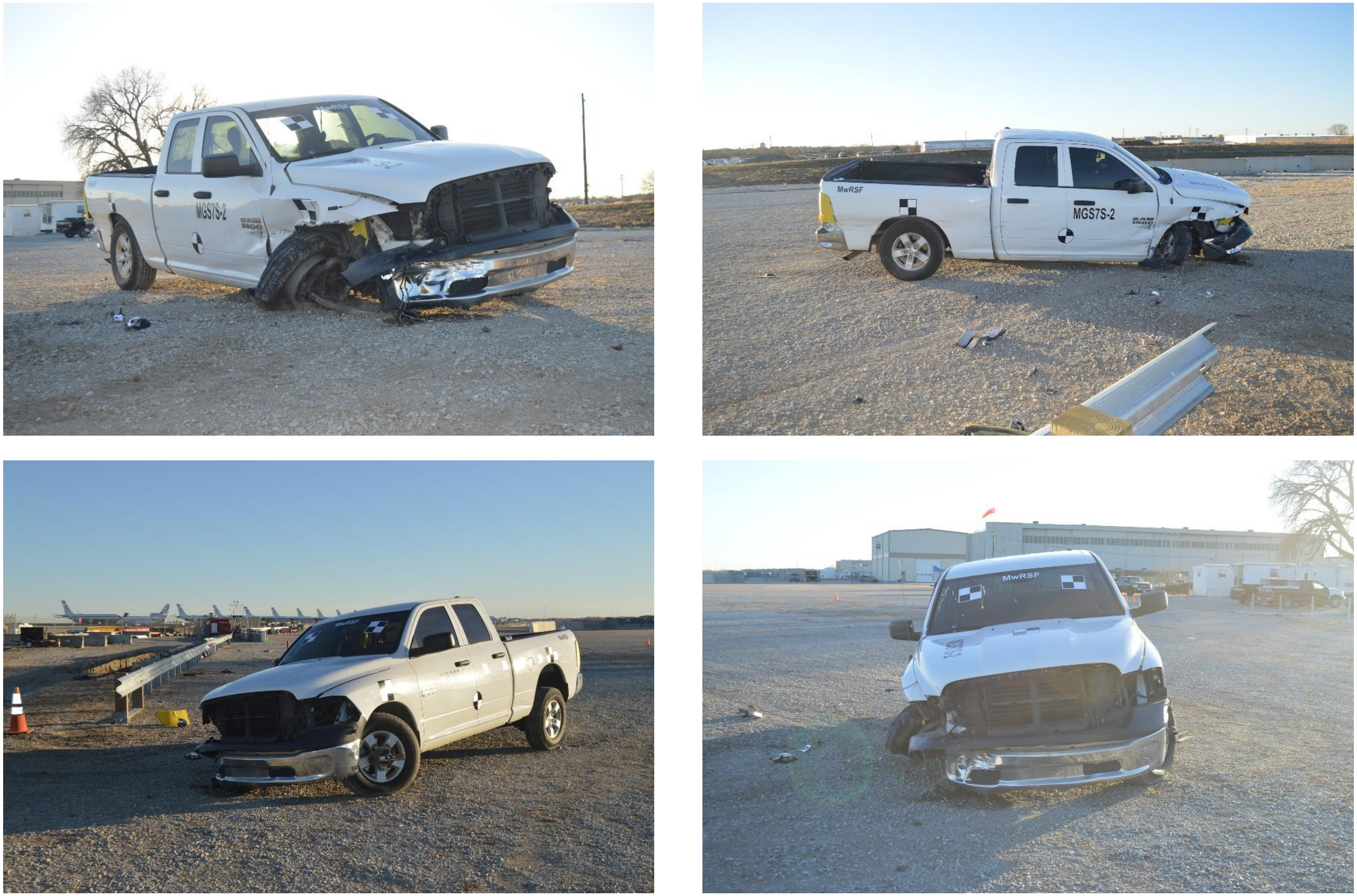


Figure 59. Vehicle Damage, Test No. MGS7S-2

Figure 60. Vehicle Undercarriage and Occupant Compartment Damage, Test No. MGS7S-2

Table 11. Maximum Occupant Compartment Intrusion by Location, Test No. MGS7S-2

Location	Maximum Intrusion in.	MASH 2016 Allowable Intrusion in.
Wheel Well & Toe Pan	0.6	≤ 9
Floor Pan & Transmission Tunnel	0.5	≤ 12
A-Pillar	0.6	≤ 5
A-Pillar (Lateral)	0.0*	≤ 3
B-Pillar	0.5	≤ 5
B-Pillar (Lateral)	0.0*	≤ 3
Side Front Panel (in Front of A-Pillar)	0.4	≤ 12
Side Door (Above Seat)	0.3	≤ 9
Side Door (Below Seat)	0.3	≤ 12
Roof	0.2	≤ 4
Windshield	0.0	≤ 3
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	0.6	N/A

N/A – No MASH 2016 criteria exist for this location.
*Negative value reported as 0.0. See Appendix D for further information.

7.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 12. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 12. The recorded data from the accelerometers and the rate transducers is shown graphically in Appendix F.

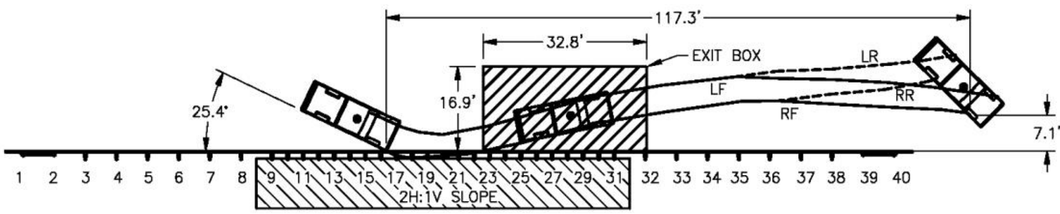
Table 12. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. MGS7S-2

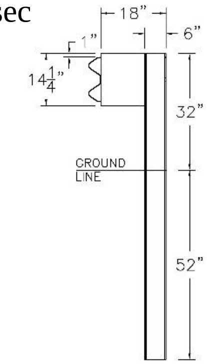
Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (backup)	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-18.02	-18.48	±40
	Lateral	-15.76	-17.29	±40
ORA g's	Longitudinal	-9.80	-10.24	±20.49
	Lateral	-11.31	-9.55	±20.49
Maximum Angular Displacement deg.	Roll	10.5	5.7	±75
	Pitch	-2.5	-3.8	±75
	Yaw	-42.1	-41.8	not required
THIV – ft/s		23.80	23.08	not required
PHD – g's		13.43	13.50	not required
ASI		0.85	0.81	not required

7.7 Discussion

The analysis of the test results for test no. MGS7S-2 showed that the system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown in Figure 61. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix F, were deemed acceptable because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the barrier at an angle of 27.5 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. MGS7S-2 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-11.

0.000 sec | 0.100 sec | 0.200 sec | 0.300 sec | 0.400 sec





- Test Agency .... MwRSF
- Test Number MGS7S-2
- Date 12/21/2021
- MASH 2016 Test Designation No. 3-11
- Test Article .... MGS Half-Post Adjacent to Slope
- Total Length .... 175 ft
- Key Component - Rail
  - Length .... 175 ft
  - Width .... 3.25 in.
  - Depth .... 14.25 in.
- Key Component - Post
  - Length .... 7 ft
  - Width .... 4 in.
  - Spacing .... 37.5 in.
- Soil Type .... Coarse, Crushed Limestone
- Vehicle Make /Model .... 2016 Ram 1500 Quad Cab Pickup Truck
  - Curb .... 4,958 lb
  - Test Inertial .... 5,022 lb (MASH 2016 Limit 5000 ± 110 lb)
  - Gross Static .... 5,185 lb
- Impact Conditions
  - Speed .... 62.6 mph
  - Angle .... 25.4 deg.
  - Impact Location .... 11 ft – 6 in. upstream from Post No. 20
- Impact Severity/Kinetic Energy .... 120.3 kip-ft > 106 kip-ft MASH 2016 Limit
- Exit Conditions
  - Speed .... 38.8 mph
  - Angle .... 27.5 deg.
- Exit Box Criterion .... Pass
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 117 ft – 4 in. downstream, 7 ft – 1 in. laterally in front
- Vehicle Damage .... Moderate
  - VDS [13] 1-RFQ-5
  - CDC [14] 1-RFER-5
  - Maximum Interior Deformation .... 3.6 in. at the roof ≤ 4.0 in. MASH 2016 Limit
- Test Article Damage .... Moderate
- Maximum Test Article Deflections
  - Permanent Set .... 25.8 in.
  - Dynamic .... 27.2 in.
  - Working Width .... 47.7 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (backup)	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-18.02	-18.48	±40
	Lateral	-15.76	-17.29	±40
ORA g's	Longitudinal	-9.80	-10.24	±20.49
	Lateral	-11.31	-9.55	±20.49
Maximum Angular Displacement deg.	Roll	10.48	5.67	±75
	Pitch	-2.45	-3.80	±75
	Yaw	-42.	-41.80	not required
THIV – ft/s		23.80	23.08	not required
PHD – g's		13.43	13.50	not required
ASI		0.85	0.81	not required

Figure 61. Summary of Test Results and Sequential Photographs, Test No. MGS7S-2

8 STIFFNESS TRANSITION GUIDANCE

Following two successful full-scale crash tests on the modified MGS system utilizing half-post spacing with 7-ft long W6x9 posts installed at the slope break point of a 2H:1V slope, it was desired to evaluate the performance of the transition between the standard MGS and the modified MGS.

The standard MGS consists of steel W6x8.5 guardrail posts measuring 6 ft long and W-beam guardrail with a top mounting height of 31 in. The posts are spaced at 75 in. on center with a soil embedment depth of 40 in. Each post within the MGS utilizes 6-in. wide x 12-in. deep x 14¼-in. long timber spacer blockouts to offset the rail away from the front face of the steel posts. The standard MGS has been previously successfully crash tested to MASH TL-3 criteria [15-17]. In these previous MASH TL-3 tests, the MGS displayed dynamic barrier deflections during test designation no. 3-11 with the 2270P vehicle ranging between 44.1 in for test no. ILT-1 and 48.6 in. for test no. 2214MG-2. Full-scale crash testing of the modified MGS in this research yielded a dynamic barrier deflection of 27.2 in. The reduced deflection of the modified MGS indicated that a stiffness transition may be warranted between standard MGS and the MGS utilizing half-post spacing with 7-ft long W6x9 posts installed at the slope break point of a 2H:1V slope.

Two related efforts were reviewed to gain insight on an appropriate stiffness transition between the standard and modified MGS. The first research effort dealt with a similar half-post spacing MGS installed on low-fill culverts [18]. In this research, the safety performance of the MGS installed on a culvert with a strong-post attachment using W6x9 steel posts welded to anchored baseplates at half-post spacing and offset 12 in. from the back of the post to the culvert headwall was evaluated through full-scale crash testing. The system consisted of strong post MGS mounted on a simulated four-cell concrete box culvert system. Anchorage systems were utilized at both the upstream and downstream ends of the guardrail system. Steel post nos. 3 through 12 and 27 through 39 were embedded in soil at a depth of 40 in. Post nos. 13 through 26 were embedded at a depth of 9 in. and anchored to the top of the concrete culvert using welded steel baseplates. Post nos. 13 through 15, 17 through 22, and 24 through 26 were anchored to the top concrete slab using four through-bolts, and post nos. 16 and 26 were anchored using 10-in. long epoxied threaded rods with an 8-in. embedded length due to the presence of the culvert's interior wall support. This system was evaluated with MASH test designation nos. 3-10 and 3-11. In the test designation no. 3-11 evaluation of the system, test no. MGS7S-2, a 5,013-lb pickup truck impacted the system at a speed of 62.8 mph and at an angle of 25.7 degrees. The vehicle was successfully contained and smoothly redirected. The maximum dynamic barrier deflection was 29.6 in.

The half-post spacing MGS system installed on low-fill culverts had very similar dynamic deflection to the half-post spacing MGS installed adjacent to slope evaluated in this research. Thus, it was believed that these two systems were reasonable equivalents based on their similar barrier configuration with respect to the guardrail layout and post spacing and their similar lateral stiffness. As part of the research effort for the half-post spacing MGS system installed on low-fill culverts, MwRSF researchers evaluated the need for a stiffness transition from standard MGS to the culvert mounted system [18]. For the transition from standard MGS to half-posts spacing MGS, LS-DYNA analysis and comparison with previous approach guardrail transition testing was used to determine the transition design. Based on this analysis, it was recommended that a transition region of a minimum of five posts at half-post spacing in soil (five 37½-in. post spacings) prior to the culvert mounted posts was needed between the standard MGS and the half-post spacing MGS.

Parallel research related to this issue was also performed at TTI, where researchers investigated and full-scale crash tested the MGS with both half- and quarter-post spacing under MASH TL-3 impact conditions [19]. During that research, TTI full-scale crash tested the MGS with quarter-post spacing under MASH TL-3 impact conditions for test designation nos. 3-10 and 3-11. Both tests met all relevant MASH requirements, and the maximum lateral dynamic deflection of the system during test designation no. 3-11 was 19.5 in. As part of that research effort, TTI developed and full-scale crash tested a transition from the standard, full-post spacing MGS to the MGS with quarter-post spacing. Initial design of the transition section utilized three posts at half-post spacing in the approach to the quarter-post spacing MGS. Full-scale crash testing of the three-post transition section under MASH test designation no. 3-21 impact conditions led to pocketing of the guardrail and eventual rail rupture and penetration of the barrier system. TTI researchers reviewed the failed test and used computer simulation modeling to determine an improved transition design. The revised transition design consisted of four posts at half-post spacing (four 37½-in. post spacings) prior to the quarter-post spacing MGS. The four-post transition design was also full-scale crash tested to MASH TL-3 under MASH test designation no. 3-21 impact conditions. The test of the four-post transition design successfully met all TL-3 MASH requirements. Full-scale testing of the transition with the 1100C vehicle was deemed unnecessary based on 1100C full-scale crash testing of the MGS at quarter-post spacing during the research effort and previous 1100C full-scale crash testing of the non-blocked MGS performed by MwRSF.

The results of the previous evaluation of a transition from the standard, full-post spacing MGS to the MGS with quarter-post spacing would suggest that a similar transition design could be utilized for the MGS with half-post spacing adjacent to steep slope. Because the lateral dynamic deflection of the MGS with half-post spacing adjacent to steep slope was 39.5 percent greater than that of the MGS with quarter-post spacing, the transition in stiffness would be less severe between standard MGS and the MGS with half-post spacing adjacent to steep slope as compared to a transition to the MGS with quarter-post spacing. As the stiffness transition to the MGS with half-post spacing adjacent to steep slope was less critical than the transition from the standard, full-post spacing MGS to the MGS with quarter-post spacing, it was believed that a transition of four posts at half-post spacing (four 37½-in. post spacings) prior to the MGS with half-post spacing adjacent to steep slope would perform as well or better than the transition tested at TTI. Thus, the researchers recommend a transition of four posts at half-post spacing (four 37½-in. post spacings) when transitioning from standard MGS to the MGS with half-post spacing adjacent to steep slope.

9 SUMMARY AND CONCLUSIONS

The objective of this research was to evaluate the safety performance of the MGS with half-post spacing installed adjacent to a steep slope and determine a stiffness transition design for transitioning from standard MGS to the modified system adjacent to slope if one was needed. The MGS with half-post spacing installed adjacent to a steep slope evaluated herein consisted of the MGS with 6-ft long W6x8.5 posts installed at 37½-in. spacing at the break point of a 2H:1V slope. Test nos. MGS7S-1 and MGS7S-2 were conducted on this modified MGS according to MASH 2016 test designation nos. 3-10 and 3-11, respectively. A summary of the test evaluation is shown in Table 13.

In test no. MGS7S-1, a 2,484-lb small car impacted the MGS long-span system at a speed of 62.8 mph, an angle of 25.2 degrees, and at a location 8 ft – 1.9 in. upstream from post no. 20, thus resulting in an impact severity of 59.3 kip-ft. After impacting the barrier, the vehicle exited the system at a speed of 28.6 mph and an angle of 15.1 degrees. The vehicle was successfully contained and smoothly redirected with moderate damage to both the barrier system and the vehicle. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH 2016. Therefore, test no. MGS7S-1 was successful according to the safety criteria of MASH 2016 test designation no. 3-10.

In test no. MGS7S-2 the 5,022-lb quad-cab pickup truck impacted the MGS long-span system at a speed of 62.6 mph, an angle of 25.4 degrees, and at a location 11 ft – 6 in. upstream from post no. 20, thus resulting in an impact severity of 120.3 kip-ft. After impacting the barrier, the vehicle exited the system at a speed of 27.5 mph and an angle of 38.8 degrees. The vehicle was successfully contained and smoothly redirected with moderate damage to both the barrier system and the vehicle. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH 2016. Therefore, test no. MGS7S-2 was successful according to the safety criteria of MASH 2016 test designation no. 3-11.

Following the successful full-scale crash testing of the MGS with half-post spacing installed adjacent to a steep slope, the researchers compared the performance of the modified MGS with standard MGS guardrail. The modified MGS had significantly lower dynamic deflection than the standard MGS, and it was believed that a stiffness transition would be required to connect standard MGS approach guardrail to the MGS with half-post spacing installed adjacent to a steep slope. Previous relevant research was reviewed for the transition design including MASH full-scale crash testing of the MGS mounted to culverts with half-post spacing, the MGS with half-post and quarter-post spacing, and stiffness transition recommendations for those respective systems. Based on that analysis, a stiffness transition of four posts at half-post spacing (four 37½-in. post spacings) was recommended when transitioning from standard MGS to the MGS with half-post spacing adjacent to steep slope.

Finally, installations of the MGS with half-post spacing adjacent to steep slope should be implemented with the guardrail terminals (or end anchorages) located a sufficient distance from the sloped region to prevent the slope from interfering with the proper performance of one another. As such, the following implementation guidelines should be considered in addition to guardrail length of need requirements:

1. A recommended minimum length of 12 ft – 6 in. of standard MGS between the first post at half-post spacing and the interior end of an acceptable TL-3 guardrail end terminal. The interior end of a TL-3 guardrail terminal is defined as the greater of the pay length of the terminal or the maximum stroke of the terminal observed in MASH test no. 3-31. This provides for a minimum of one section of standard MGS guardrail between any end terminal and the reduced post spacing.

2. A recommended minimum barrier length of 50 ft before the first post at half-post spacing, which includes standard MGS and a crashworthy guardrail end terminal. This guidance applies to the downstream end as well. This provides for a minimum overall distance from any end anchorage of the terminal.

3. For flared guardrail applications, a minimum length of 25 ft is recommended between the first post at half-post spacing and the start of the flared section (i.e., bend between flared and tangent sections).

Table 13. Summary of Safety Performance Evaluation

<table>
<tr><th>Evaluation Factors</th><th colspan="4">Evaluation Criteria</th><th>Test No. MGS7S-1</th><th>Test No. MGS7S-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 rowspan="2">D.</td><td colspan="3">1. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.</td><td>S</td><td>S</td></tr>
<tr><td colspan="3">2. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.</td><td>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 A5.2.2 of MASH 2016 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</td><td>40 ft/s</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td><td rowspan="4">S</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
<tr><td colspan="5">MASH 2016 Test Designation No.</td><td>3-10</td><td>3-11</td></tr>
<tr><td colspan="5">Final Evaluation (Pass or Fail)</td><td>Pass</td><td>Pass</td></tr>
</table>

S – Satisfactory U – Unsatisfactory N/A – Not Applicable

10 MASH EVALUATION

A modified guardrail system consisting of the Midwest Guardrail System (MGS) with half-post spacing adjacent to a steep slope was evaluated according to MASH TL-3 performance criteria. The system consisted of standard MGS installed on level terrain for 50 ft on each end of the system, while the middle of the barrier was installed adjacent to a 5-ft deep by 75-ft long, 2H:1V slope. The slope started at the centerline of the post and extended 10 ft behind the post. Post nos. 3 through 8 and 32 through 38 were ASTM A992 W6x8.5 steel posts that measured 72-in. long and were spaced 75 in. apart and had an embedment depth of 40 in. Post nos. 9 through 31 were ASTM A992 W6x8.5 steel posts that measured 84-in. long and were spaced 37½ in. apart with W14x22 blockouts and had an embedment depth of 52 in. The posts were placed in a compacted, coarse, crushed limestone material with a strength that satisfied MASH 2016 criteria. Post nos. 3 through 38 used 6-in. x 12-in. x 14¼-in. wood blockouts to offset the rail away from the front face of the steel posts. Additionally, each end of the system was anchored by a trailing end anchorage system, to simulate the strength of other crashworthy end terminals.

10.1 Test Matrix

The modified MGS was classified as a longitudinal barrier for the purposes of evaluation. According to TL-3 of MASH, longitudinal barrier systems must be subjected to two full-scale vehicle crash tests, as summarized in Table 14.

Table 14. MASH TL-3 Crash Test Conditions for Longitudinal Barriers

Test Article	Test Designation No.	Test Vehicle	Vehicle Weight lb	Impact Conditions		Evaluation Criteria [1]
				Speed mph	Angle deg.	
Longitudinal Barrier	3-10	1100C	2,420	62	25	A,D,F,H,I
	3-11	2270P	5,000	62	25	A,D,F,H,I

[1] Evaluation criteria explained in Table 4.

Both test designation nos. 3-10 and 3-11 were conducted to evaluate the modified MGS adjacent to steep slopes. Test designation no. 3-10 has not always been conducted for evaluation of guardrail adjacent to slope due to the reduced impact loading of the small car vehicle. However, recent MASH TL-3 crash testing of 1100C vehicles on guardrail with reduced post spacing or increased stiffness due to the presence of curbs have indicated the potential for combined loading of the guardrail splice by the small car vehicle that can lead to partial rail tears and even complete rail rupture. As such, test designation no. 3-10 was recommended for the evaluation of the barrier system. Test designation no. 3-11 with the 2270P vehicle represents the highest impact barrier loading during 2270P impacts, evaluates potential vehicle extension over the slope and the potential for vehicle instability, and determines dynamic deflection and working width. Thus, test designation no. 3-11 was also recommended for the evaluation of the barrier system.

10.2 Full-Scale Crash Test Results

The results of the MASH TL-3 full-scale crash testing of the MGS with half-post spacing adjacent to a steep slope are summarized below. A summary of the full-scale crash testing is provided in Table 15. A plan and elevation view of the final system and a system photo are shown in Figure 62.

1. Test no. MGS7S-1 was conducted according to MASH 2016 criteria for test designation no. 3-10 and consisted of an 1100C vehicle impacting the MGS installed adjacent to a 2H:1V slope with 7-ft long posts at ½ post spacing at a target speed of 62 mph and a target angle of 25 degrees. Initial vehicle impact was to occur 96 in. upstream from post no. 20, which was selected using the CIP plots found in Section 2.3 of MASH 2016. The 2,431-lb small car impacted the longitudinal barrier at a speed of 62.8 mph and at an angle of 25.2 degrees. The actual point of impact was 1.9 in. upstream from the targeted point of impact, or 8 ft – 1.9 in. upstream from post no. 20. After the initial impact, the 1100C vehicle began to be redirected. During redirection, the right front wheel of the vehicle extended beneath the rail and impacted and snagged post nos. 20 and 21 of the system. The wheel snag did not adversely affect vehicle stability or lead to occupant risk concerns. The closely spaced, 7-ft long posts also generated a significant amount of soil displacement as the guardrail deflected. The vehicle exited the barrier and continued downstream in a stable manner until brakes were applied and the vehicle came to rest 80.5 ft downstream and 13 ft in front of the system from impact.

2. Test no. MGS7S-2 was conducted according to MASH 2016 criteria for test designation no. 3-11 and consisted of a 2270P vehicle impacting the MGS installed adjacent to a 2H:1V slope with 7-ft long posts at ½ post spacing at a target speed of 62 mph and a target angle of 25 degrees. Initial vehicle impact was to occur 138 in. upstream from post no. 20, which was selected using the CIP plots found in Section 2.3 of MASH 2016. The 5,022-lb quad cab pickup truck impacted the guiderail system at a speed of 62.6 mph and at an angle of 25.4 degrees. The actual point of impact was at the targeted impact location. After initial impact, the 2270P vehicle began to be redirected. During redirection, the right front wheel of the vehicle extended beneath the rail and impacted and snagged post nos. 18 through 21 of the system. The wheel snag did not adversely affect vehicle stability or lead to occupant risk concerns. The closely spaced, 7-ft long posts also generated a significant amount of soil displacement as the guardrail deflected. The vehicle exited the barrier and continued downstream in a stable manner until brakes were applied and the vehicle came to rest. The vehicle came to rest 117.3 ft downstream and 7.1 ft laterally in front of the system.

Table 15. MASH TL-4 Crash Test Summary for Open Concrete Bridge Rail

MwRSF Test No.	MASH Test Designation No.	MwRSF Report No.	Test Date	Pass/Fail	System Version
OCBR-1	3-10	TRP-03-452-23	11/24/21	Pass	Modified MGS Adjacent to 2H:1V Slope
OCBR-2	3-11	TRP-03-452-23	12/21/21	Pass	Modified MGS Adjacent to 2H:1V Slope

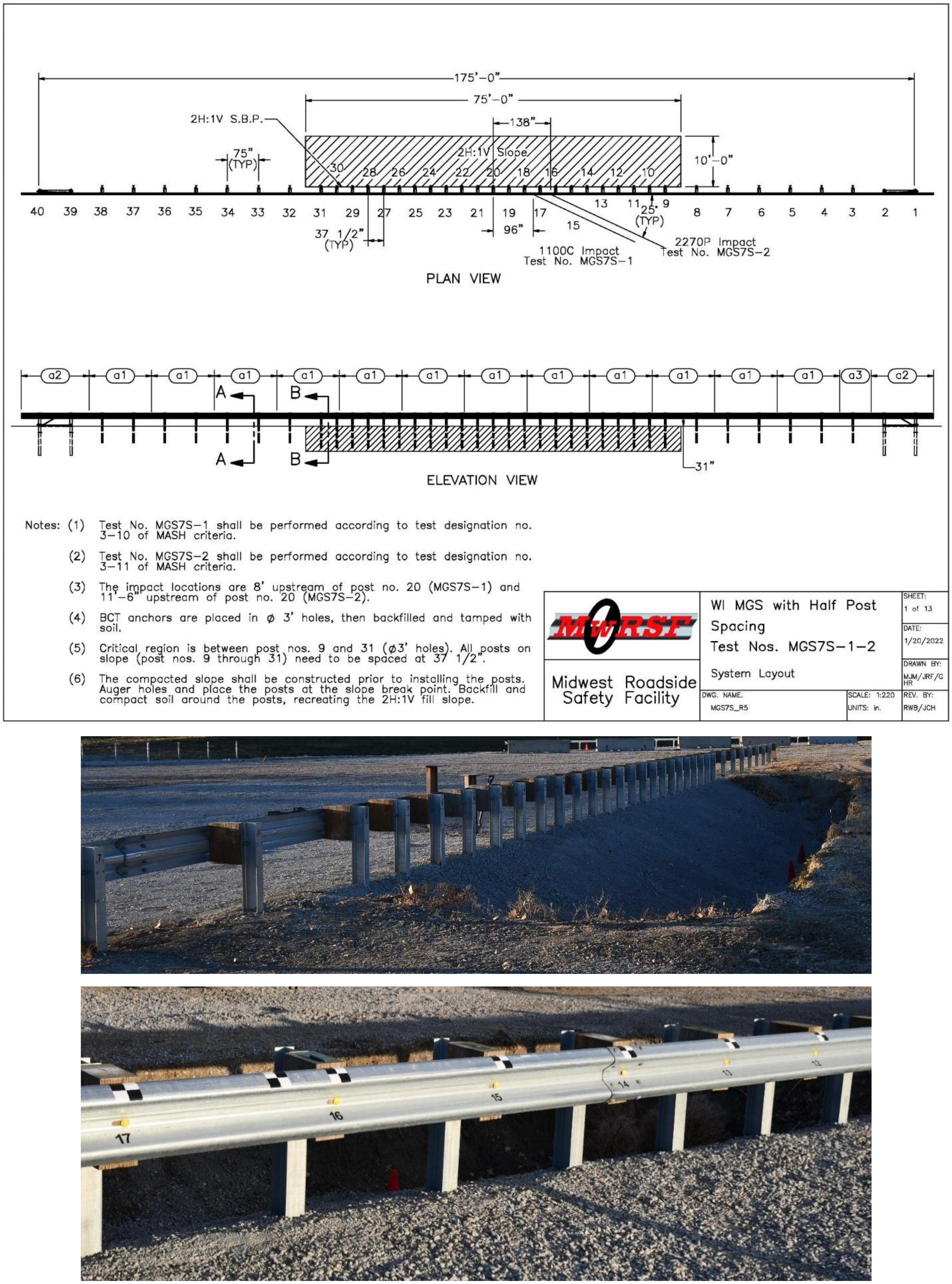


Figure 62. MASH TL-3 MGS with Half-Post Spacing Adjacent to a Steep Slope

10.3 MASH 2016 Evaluation

Based on the results of the two successful full-scale crash tests conducted in this research effort, the MGS with half-post spacing adjacent to a steep slope meets all the safety requirements for MASH TL-3.

11 REFERENCES

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12 APPENDICES

Appendix A. Material Specifications

Table A-1. Bill of Materials, Test Nos. MGS7S-1 and MGS7S-2

Item No.	Description	Material Specification	Reference
a1	12'-6" 12-gauge W-Beam MGS Section	AASHTO M180	H#C85187
a2	12'-6" 12-gauge W-Beam MGS End Section	AASHTO M180	H#9411949
a3	6'-3" 12-gauge W-Beam MGS Section	AASHTO M180	H#4143340
a4	W6x9 or W6x8.5, 72" Long Steel Post	ASTM A992 Min. 50 ksi or ASTM A36 Min. 36 ksi	H#55064803
a5	W6x9 or W6x8.5, 84" Long Steel Post	ASTM A992 Min. 50 ksi or ASTM A36 Min. 36 ksi	H#2909166
a6	6x12x14¼" Timber Blockout for Steel Posts	AASHTO M168 or SYP Grade No.1 or better	Ch#23422, Ch#18379, Ch#23888, Ch#21327
a7	16D Double Head Nail	-	PO E000548963
b1	BCT Timber Post - MGS Height	AASHTO M168 or SYP Grade No. 1 or better	Ch#1488 Ch#652
b2	72" Long Foundation Tube	ASTM A500 Gr. B	H#821T08220
b3	Strut and Yoke Assembly	ASTM A36	H#195070
b4	BCT Cable Anchor Assembly	-	R#22-107
b5	Anchor Bracket Assembly	ASTM A36	H#JK16101488
b6	8"x8"x⅝" Anchor Bearing Plate	ASTM A36	H#4181496
b7	2⅜" O.D. x 6" Long BCT Post Sleeve	ASTM A500-13 Gr. B&C	H#B712810
c1	⅝" Dia. UNC, 14" Long Guardrail Bolt	ASTM A307 Gr. A	H#DL17100590
c2	⅝" Dia. UNC, 1 1/4" Long Guardrail Bolt	ASTM A307 Gr. A	H#10684020
c3	⅝" Dia. UNC, 10" Long Guardrail Bolt	ASTM A307 Gr. A	H#1721198
c4	⅝" Dia. UNC, 1 1/2" Long Hex Head Bolt	ASTM A307 Gr. A	H#1731059-3
c5	⅝" Dia. UNC, 10" Long Hex Head Bolt	ASTM A307 Gr. A	H#JK17100352
c6	⅞" Dia. UNC, 8" Long Hex Head Bolt	ASTM A307 Gr. A	P#92005
d1	⅝" Dia. Hex Nut	ASTM A563A	H#331608011
d2	⅞" Dia. Hex Nut	ASTM A563A	P#33187 L#1844804
d3	⅝" Dia. Heavy Hex Bolt	ASTM A563A	H#10553090
e1	⅝" Dia. Plain USS Washer	ASTM F844	L#20200831 P#1133185
e2	⅞" Dia. Plain USS Washer	ASTM F844	P#33187 C#170077928

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

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

Test Report
Ship Date: 1/26/2018
Customer P O: 36263
Shipped to: UNIVERSITY OF NEBRASKA-LINCOLN
Project:
GHP Order No.: 319AA

HT # code	Heat #	C.	MN.	P.	S.	Si.	Tensile	Yield	Elong.	Quanity	Class	Type	Description
1207	C85187	0.2	0.48	0.008	0.003	0.03	80433	59371	16.35	150	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-653
All Galvanizing has occurred in the United States
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Steel used meets Title 23CFR 635.410 - Buy America
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All controlled oxidized/corrosion resistant Guardrail and terminal sections meet ASTM A606, Type 4.

By:
Jeffery Grover, VP of Highway Products Sales & Marketing
Gregory Highway Products, Inc.

NOTARIAL SEAL — STATE OF OHIO

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

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by
Jeffery Grover this 29 day of January, 2018

Notary Public, State of Ohio

Figure A-1. 12-ft 6-in. 12-gauge W-Beam MGS Section, Test Nos. MGS7S-1 and MGS7S-2 (Item No. a1)

NUCOR
NUCOR STEEL GALLATIN

Nucor Steel Gallatin
4831 U.S. Highway 42 West
Ghent, KY 41045-9704
Phone: 1(800)581-3853 Fax: (859)567-3165

METALLURGICAL TEST REPORT

Invoice To: Gregory Industries
4100 13th Street SW
Canton, OH 44710

Ship To: Gregory Industries
4100 13th Street SW
Canton, OH 44710

Date: 1/21/2018
Customer No: 10019
Customer P.O.: 39620

Mill Order No: 214078-1 **Customer Reference No:** 39620 **Load No:** 736148

This product was melted and manufactured in the USA to meet the requirements of: 1020 steel for SS 50 grade for Guard Rails - 50 ksi min yield, 70 ksi min tensile, 0.10% max Si, and 0.06% Cr max
HR Sheet Steel Bands

Ordered Size: Min 0.095 (In.) X 56.88 (In.) X Coil
Min 2.413 (mm) X 1445 (mm) X Coil

Coil Number(s): 1465177

CHEMICAL ANALYSIS (Weight %)

Heat No	C	Mn	P	S	Si	Cu	Ni	Cr	Mo
C85187	0.20	0.48	0.008	0.003	0.03	0.06	0.02	0.05	0.01
	Al	Ca	Nb	V	B	Ti	N	Sn	
	0.029	0.0017	0.000	0.001	0.0001	0.001	0.0080	0.003	

MECHANICAL PROPERTIES

Coil Tested								
Yield Strength(ksi)								
Yield Strength(mpa)								
Tensile Strength(ksi)								
Tensile Strength(mpa)								
% Elongation								
N-Value								
N-Value Range								
Hardness(HRBW)								
Test Section								
Orientation								
Test Method								

BEND TEST RESULTS

Coil ID #	Orientation	Diameter/radius of mandrel	No. of cracks	Size of cracks	Pass/Fail

Ht code
1207

Hot rolled coils manufactured through Nucor Steel Gallatin do not contain welds or weld repairs at the time of shipment (fca mill).
Mercury was not added during production of this material. The material was produced using a fully killed fine grain practice with a grain size of 6 or finer according to ASTM E112.

This product is in compliance with DFARS 252.225, the Buy American Act.

Above tests performed in accordance to ASTM standards E8 (yield strength determined using 0.2% offset method and elongation determined using at fracture method) or JIS Z2241, E18, E415, and E1019 and are correct as contained in the records of the company.

The elongation original gauge length is 2 inches for ASTM test method and 1.97 inches for JIS test method.
Above test results were performed in accordance to EN 10204 3.1

Bend tests were conducted in accordance with ISO 7438, ASTM E290, or JIS Z2248 using the press, guided, two support and a mandrel bend method at a 180 degree bend. Bend test specimen is longer than 6" and wider than 0.8"

This report shall not be reproduced, except in full, without written approval of the undersigned laboratory managers.
* This mechanical property has been tested at a subcontractor's laboratory.

Stephen S. Sipple

Stephen S. Sipple
Chemical Laboratory
Mechanical Laboratory
steve.sipple@nucor.com

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Page 1 of 1

Figure A-2. 12-ft 6-in. 12-gauge W-Beam MGS Section, Test Nos. MGS7S-1 and MGS7S-2 (Item No. a1)

Gregory Industries 13:54:11 Jun 24 2015 Page 1

HEAT MASTER LISTING

Heat No.	Mill#	Name	YR	Primary Grade	Secondary Grade	CODE	Original Heat Number
9411949	ARC03	ARCELOR MITTAL USA, LLC	15	1021		8534	

******* Chemistry *******

Cr	Si	P	C	Mn	S	Cu	Ni	Mo	Sn	Al	V	Cb	N	Ti
0.0400	0.0100	0.0100	0.2100	0.7500	0.0060	0.0200	0.0100	0.0100	0.0020	0.0580	0.0020	0.0020	0.0042	0.0020

Ca
0.0003

******* Mechanical Test *******

YIELD	TENSILE	ELONGATION	ROCKWELL
56527	75774	27.15	78

Guardrail W-Beam

20ct/25'

100ct/12'

10ct/25ft w/MGS Anchor Panel

July 2015 SMT

Figure A-3. 12-ft 6-in. 12-gauge W-Beam MGS End Section, Test Nos. MGS7S-1 and MGS7S-2 (Item No. a2)

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

Customer:	UNIVERSITY OF NEBRASKA-LINCOLN 401 CANFIELD ADMIN BLDG P O BOX 880439 LINCOLN,NE,68588-0439	Test Report	
		Ship Date:	7/9/2015
		Customer P.O.:	4500274709/ 07/07/2015
		Shipped to:	UNIVERSITY OF NEBRASKA-LINCOLN
		Project:	TESTING COIL
		GHP Order No.:	183306

HT # code	Heat #	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
8534	9411949	0.21	0.75	0.01	0.006	0.01	75774	56527	27.15	10	A	2	12GA 25FT WB T2 MGS ANCHOR PANEL
8534	9411949	0.21	0.75	0.01	0.006	0.01	75774	56527	27.15	100	A	2	12GA 12FT6IN/3FT1 1/2IN WB T2
8534	9411949	0.21	0.75	0.01	0.006	0.01	75774	56527	27.15	20	A	2	12GA 25FT0IN 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-653
All Galvanizing has occurred in the United States
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Steel used meets Title 23CFR 635.410 - Buy America
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All controlled oxidized/corrosion resistant Guardrail and terminal sections meet ASTM A606, Type 4.

By:
Andrew Artar, VP of Sales & Marketing
Gregory Highway Products, Inc.

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by Andrew Artar this 17 day of July 2015.

Notary Public, State of Ohio

NOTARIAL SEAL
STATE OF OHIO

DAWN R. BATTON
NOTARY PUBLIC
STATE OF OHIO
Comm. Expires
March 03, 2018
Recorded in
Portage County

Figure A-4. 12-ft 6-in. 12-gauge W-Beam MGS End Section, Test Nos. MGS7S-1 and MGS7S-2 (Item No. a2)

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

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

MILFORD,NE,68405

Test Report
Ship Date:
Customer P.O.:
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project:
GHP Order No:

HT # code	Heat #	C.	MN.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
5818	4143340	0.2	0.76	0.013	0.007	0.02	79874	62737	22.77	1	A	2	12GA 6FT 3IN WB

Bolts comply with ASTM A-307 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
Nuts comply with ASTM A-563 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
All other galvanized material conforms with ASTM-123 & ASTM-653
All Galvanizing has occurred in the United States
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Steel used meets Title 23CFR 635.410 - Buy America
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All controlled oxidized/corrosion resistant Guardrail and terminal sections meet ASTM A606, Type 4.

GREGORY HIGHWAY

By: Jeffery L. Grover
Jeffery Grover, Vice President Gregory Highway
Gregory Highway

Figure A-5. 6-ft 3-in. 12-gauge W-Beam MGS Section, Test Nos. MGS7S-1 and MGS7S-2 (Item No. a3)

CERTIFIED MATERIAL TEST REPORT

Page 1 / 1

GERDAU

US-ML-CARTERSVILLE
384 OLD GRASSDALE ROAD NE
CARTERSVILLE, GA 30121
USA

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
HIGHWAY SAFETY CORP 473 W FAIRGROUND ST MARION,OH 43302-1701 USA	HIGHWAY SAFETY CORP GLASTONBURY,CT 06033-0358 USA	A992/A709-36	Wide Flange Beam / 6 X 8.5# / 150 X 13.0	0000307083

LENGTH	PCS	WEIGHT	HEAT / BATCH
42'00"	63	22,491 LB	55064803/02

SALES ORDER	CUSTOMER MATERIAL N°
8525742/000010	

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
1832	1323-0000153422	03/02/2020

SPECIFICATION / DATE or REVISION
ASTM A6-17
ASTM A709-17
ASTM A992-11 (2015)
CSA G40.21-13 345WM

1832138
IB-60080

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %
0.14	0.81	0.012	0.029	0.21	0.31	0.09	0.09	0.025	0.008	0.002	0.009

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	Y/T ratio %	Elong. %
58300	76400	402	527	0.760	27.50
55900	73900	385	510	0.760	24.80

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. Weld repair has not been performed on this material. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

Bhaskar
BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

YAN WANG
QUALITY ASSURANCE MGR.
Phone: (770) 387 5718 Email: yan.wang@gerdau.com

Figure A-6. W6x8.5, 72-in. Long Steel Post, Test Nos. MGS7S-1 and MGS7S-2 (Item No. a4)

JCOR STEEL - BERKELEY
155 Hagan Avenue
1ger, SC 29450
1one: (843) 336-6000

CERTIFIED MILL TEST REPORT

8/05/19 7:11:19

100% EAF MELTED AND MANUFACTURED IN THE USA
Structural sections produced by Nucor-Berkeley are cast
and hot rolled to a fully killed and fine grain practice.
Mercury has not been used in the direct manufacturing of this material.

Sold To: RG STEEL CORP
PO BOX 356

PULASKI, PA 16143

Ship To: R.G. STEEL
ROUTE 551

PULASKI, PA 16143

Customer #.: 711 - 1
Customer PO: 11894
B.O.L. #...: 1425833

MOS: I

?ECIFICATIONS: Tested in accordance with ASTM specification A6/A6M-17a and A370. Quality Manual Rev #10 (3-14-19).
AASHIO : m270-345M270-50-15
ASME : SA-36 13
ASTM : A992-11(15:/A36-19/A529-19-50/A5725018T1/A7093618/A7095018
CSA : G40.21-44w/G40.2150WM

RG-196

ascription art #	Heat# Grade(s) Test/Heat JW	Yield/ Tensile Ratio	Yield (PSI) (MPa)	Tensile (PSI) (MPa)	Elong %	C Cr XXXXXX	Mn Mo Ti	P Sn XXXXXX	S B XXXXXX	Si V N	Cu Nb XXXXXX	Ni XXXXXX CI	CE1 CE2 Pcm
5X8.5	2909166	.81	55700	68600	25.20	.07	.86	.010	.014	.23	.12	.04	.23
042' 00.00"	A992-11(15		384	473		.04	.01	.0060	.0001	.004	.016		.2762
/150X12.6		.82	55800	68400	29.10		.001			.0053		3.26	.1290
012.8016m	ANSW		385	472	84 Pc(s)	29,988 lbs		Customer PO: 11894				InvH:	0
5X8.5	2909165	.81	55500	68800	28.50	.07	.84	.007	.021	.22	.11	.04	.23
042' 00.00"	A992-11(15		383	474		.03	.01	.0058	.0002	.004	.015		.2701
/150X12.6		.80	54700	68200	30.00		.001			.0049		3.00	.1293
012.8016m	ANSW		377	470	42 Pc(s)	14,994 lbs		Customer PO: 11894				InvH:	0

2 Heat(s) for this MTR.

.ongation based on 8" (20.32cm) gauge length. 'No Weld Repair' was peformed.
: = 26.01Cu+3.88Ni+1.20Cr+1.49Si+17.28P-(7.29CuXNi)-(9.10NiXP)-33.39(CuXCu)
:m = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B
:1 = C+(Mn/6)+((Cr+Mo+V)/5)+((Ni+Cu)/15)

'All mechanical testing is performed by the Quality testing lab, which is independent of the production departments'
CE2 = C+((Mn+Si)/6)+((Cr+Mo+V+Cb)/5)+((Ni+Cu)/15)

hereby certify that the contents of this report are accurate and
irrect. All test results and operations performed by the material
ianufacturer are in compliance with material specifications, and
ien designated by the Purchaser, meet applicable specifications.

Bruce A. Work
Metallurgist
Quality Control

Figure A-7. W6x8.5, 84-in. Long Steel Post, Test Nos. MGS7S-1 and MGS7S-2 (Item No. a5)

CENTRAL NEBRASKA WOOD PRESERVERS, INC.

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

CWNP Invoice 10048570
Shipped To MIDWEST-MILFORD
Customer PO 2892

Central Nebraska Wood Preservers, Inc.
Certification of Inspection

Date: 4/23/14

Specifications: Highway Construction Use

Preservative: CCA – C 0.60 pcf

Charge #	Date Treated	Grade	Material Size, Length & Dressing	# Pieces	White Moisture Readings	Penetration # of Borings & % Conforming	Actual Retentions % Conforming
18379	4/16/14	#1	6x12-14" Blocks	756	19	1/20 95%	.651 pcf
18379	4/16/14	#1	6x8-22" Blocks	84	19	1/20 95%	.651 pcf

Number of pieces rejected and reason for rejection:
None

Statement: The above reference material was treated and inspected in accordance with the above referenced specifications.

Kurt Andres, General Manager

4/23/14
Date

MGS Wood Blockouts 6x12x14" R#14-0554
GREEN TAGS don't mistaken these for the 2part blockouts because they are also GREEN. July 2014 SMT

Figure A-8. Timber Blockout for Steel Posts, Test Nos. MGS7S-1 and MGS7S-2 (Item No. a6)

CENTRAL
NEBRASKA
WOOD PRESERVERS, INC.

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

R#16-692 6x12x14 Timber Blockouts
COC June2016 SMT Black Paint Tags

Date: 10/29/15

CERTIFICATE OF COMPLIANCE

Shipped TO: Midwest Machinery. BOL# 18052937

Customer PO# 3161 Preservative: CCA – C 0.60 pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
	6x12- 14'' ocd Blok	84	21327	.658 pcf

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

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

[signature] G.M
Nick Sowl, General Counsel

10/29/15
Date

Figure A-9. Timber Blockout for Steel Posts, Test Nos. MGS7S-1 and MGS7S-2 (Item No. a6)

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

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

CERTIFICATE OF COMPLIANCE

Shipped To: Midwest Machinery and Supply
BOL# 10057873
Customer PO# 3475
Preservative: CCA – C 0.60D pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
GR61219 BLK	6x12-19" TRANS Hole BLK	56	24245	.616
GR6819 BLK	6x8-19" OCD BLOCK	168	24253	.611
GR61214 BLK	6x12-14" Thrie Hole BLK OCD	84	23422	.660

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

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

Nicholas Sowl, General Counsel

9/1/2017
Date

Figure A-10. Timber Blockout for Steel Posts, Test Nos. MGS7S-1 and MGS7S-2 (Item No. a6)

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

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

CERTIFICATE OF COMPLIANCE

Shipped To: Midwest Machinery and Supply
BOL# 100588715
Customer PO# 3528
Preservative: CCA - C 0.60D pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
4075b	6x8-14" Block	126	24683	.665
6120b	6x12-14" Block	84	23888	.678
GS6806.5 PST	5.5x7.5-6.5' Rub Post	84	24604	.652
GS6806.5 PST	5.5x7.5-6.5' Rub Post	42	24603	.643
GS6814 BLK	5.5x7.5-14' Block	126	24194	.633

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

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

Nick Sowl, General Counsel

1/11/2018
Date

Figure A-11. Timber Blockout for Steel Posts, Test Nos. MGS7S-1 and MGS7S-2 (Item No. a6)

McMASTER-CARR®

Certificate of Compliance

600 N County Line Rd
Elmhurst IL 60126-2081
630-600-3600
chi.sales@mcmaster.com

University of Nebraska
Midwest Roadside Safety Facility
M W R S F
4630 Nw 36TH St
Lincoln NE 68524-1802
Attention: Shaun M Tighe
Midwest Roadside Safety Facility

Purchase Order
E000548963

Order Placed By
Shaun M Tighe

McMaster-Carr Number
7204107-01

Page 1 of 1

08/02/2018

Line		Product	Ordered	Shipped
1	**97812A109**	Raised-Head Removable Nails, 16D Penny Size, 3" Long, Packs of 5	**5 Packs**	**5**

Certificate of compliance

This is to certify that the above items were supplied in accordance with the description and as illustrated in the catalog. Your order is subject only to our terms and conditions, available at www.mcmaster.com or from our Sales Department.

Sarah Weinberg
Compliance Manager

Figure A-12. 16D Double Head Nail, Test Nos. MGS7S-1 and MGS7S-2 (Item No. a7)

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

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

CERTIFICATE OF COMPLIANCE

Shipped To: Midwest Machinery and Supply
BOL# N24824
Customer PO# 3901
Preservative: CCA – C 0.60D pcf AWPA UC4B

Part #	Physical Description	# Pieces	Charge #	Retention
6115b	5.5x7.5.46″ BCT	42	1488	.607
GS6843.5 PST	5.5x7.5-43.5″ BCT	42	1488	.607

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

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

Nick Sowl, General Counsel

3/6/20
Date

Figure A-13. BCT Timber Post – MGS Height, Test Nos. MGS7S-1 and MGS7S-2 (Item No. b1)

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

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

CERTIFICATE OF COMPLIANCE

Shipped To: Midwest Machinery and Supply
BOL# N18798
Customer PO# 3801
Preservative: CCA – C 0.60D pcf AWPA UC4B

Part #	Physical Description	# Pieces	Charge #	Retention
GR6806 PST	6x8-6′ Post	35 35	694 695	.763 .707
GS6846 PST	5.5x7.5-46″ BCT	42	652	.608
GR61222 BLK	6x12-22″ OCD BLock	56	612	.619

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

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

Nick Sowl, General Counsel

8/20/19
Date

GENERAL NOTARY - State of Nebraska
LINDA L. SCHROETLIN
My Comm. Exp. May 20, 2020

Figure A-14. BCT Timber Post – MGS Height, Test Nos. MGS7S-1 and MGS7S-2 (Item No. b1)

3046HD6

Atlas Tube Corp (Chicago)
1855 East 122nd Street
Chicago, Illinois, USA
60633
Tel: 773-646-4500
Fax: 773-646-6128

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

Ref.B/L: 80728203
Date: 08.17.2016
Customer: 2908

MATERIAL TEST REPORT

Sold to

Gregory Industries Inc.
4100 13th Street SW.
CANTON OH 44710
USA

Shipped to

Tru-Form Steel & Wire
1204 Gilkey Ave
HARTFORD CITY IN 47348
USA

Material: 8.0x6.0x188x27'0"0(2x2)SILDOMUS **Material No:** 80060188 **Made in:** USA **Melted in:** USA

Sales order: 1105121 **Purchase Order:** 35569 **Cust Material #:** TRB3/16-8-6-27

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
616137	0.210	0.930	0.011	0.003	0.020	0.041	0.020	0.008	0.020	0.020	0.030	0.008	0.001	0.000	0.003

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800650076	4	058210 Psi	073148 Psi	32 %	ASTM A500-13 GRADE B&C	0.38

Material Note:
Sales Or.Note:

Material: 8.0x6.0x188x30'0"0(2x3)SILDOMUS **Material No:** 80060188 **Made in:** USA **Melted in:** USA

Sales order: 1105121 **Purchase Order:** 35569 **Cust Material #:** TRB3/16-8-6-30

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
821T08220	0.220	0.810	0.013	0.006	0.006	0.041	0.160	0.002	0.005	0.010	0.020	0.002	0.002	0.000	0.007

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800650038	6	057275 Psi	070934 Psi	32 %	ASTM A500-13 GRADE B&C	0.37

Material Note:
Sales Or.Note:

Material: 8.0x6.0x188x30'0"0(2x3)SILDOMUS **Material No:** 80060188 **Made in:** USA **Melted in:** USA

Sales order: 1105121 **Purchase Order:** 35569 **Cust Material #:** TRB3/16-8-6-30

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
821T08220	0.220	0.810	0.013	0.006	0.006	0.041	0.160	0.002	0.005	0.010	0.020	0.002	0.002	0.000	0.007

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800650039	6	057275 Psi	070934 Psi	32 %	ASTM A500-13 GRADE B&C	0.37

Material Note:
Sales Or.Note:

Jason Richard

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

Steel Tube Institute OF NORTH AMERICA

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Metals Service Center Institute

Figure A-15. 72-in. Long Foundation Tube, Test Nos. MGS7S-1 and MGS7S-2 (Item No. b2)

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

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

MILFORD,NE,68405

Test Report
Ship Date: 10/26/2017
Customer P.O.: 3501
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
PROJECT: STOCK
GHP Order No: 7044AA

HT CODE	Lot #	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
616137		0.21	0.93	0.011	0.003	0.02	73148	58210	32	15		2	3/16 X 6IN X 8IN X 5FT0IN TUBE SLEEVE
821T08220		0.22	0.81	0.013	0.006	0.006	70934	57275	32	10		2	3/16IN X 6IN X 8IN X 6FT0IN TUBE SLEEVE
214482		0.04	0.83	0.014	0.005	0.02	75275	68023	28.6	25	B		10GA MGS TB TRAN APPROACH END-RIGHT
214143		0.04	0.81	0.015	0.006	0.02	75565	69618	29.7	18	B		10GA MGS TB TRAN DEPARTURE END-LEFT

Bolts comply with ASTM A-307 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
Nuts comply with ASTM A-563 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
All other galvanized material conforms with ASTM-123 & ASTM-653
All Galvanizing has occurred in the United States
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Steel used meets Title 23CFR 635.410 - Buy America
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All sheet, zinc-coated or zinc-iron alloy-coated by the hot dip process that meets ASTM Specifications A653

By: Jeffey L Grover
Jeffery L Grover, VP of Highway Products Sales & Marketing
Gregory Highway Products, Inc.

Figure A-16. 72-in. Long Foundation Tube, Test Nos. MGS7S-1 and MGS7S-2 (Item No. b2)

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: RESALE

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

As of: 3/22/17

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
400	3380G	5/8"X1.5" HEX BOLT A307	HW			0052429-113200													
600	3400G	5/8"X2" GR BOLT	HW			29221													
500	3480G	5/8"X8" GR BOLT A307	HW			29369													
450	3500G	5/8"X10" GR BOLT A307	HW			29550-B													
700	3540G	5/8"X14" GR BOLT A307	HW			29567													
300	3580G	5/8"X18" GR BOLT A307	HW			29338													
600	4235G	3/16"X1.75"X3" WSHR	HW			C7001													
10	9852A	STRUT & YOKE ASSY	A-36			195070	52,940	69,970	31.1	0.190	0.520	0.014	0.004	0.020	0.110	0.000	0.050	0.000	4
	9852A		A-36			A82292	54,000	73,300	31.0	0.200	0.460	0.010	0.003	0.020	0.150	0.000	0.060	0.001	4
	9852A		A-36			645887	39,900	62,500	32.0	0.190	0.400	0.009	0.015	0.009	0.054	0.001	0.038	0.001	4
	9852A		A-36			645887	39,900	62,500	32.0	0.190	0.400	0.009	0.015	0.009	0.054	0.001	0.038	0.001	4
	9852A		HW			15056184													
20	12173G	T12/6'3/4@1'6.75"/S			2	L35216													
			M-180	A	2	209331	62,090	81,500	28.1	0.190	0.720	0.013	0.002	0.020	0.110	0.000	0.070	0.002	4
			M-180	A	2	209332	61,400	81,290	25.3	0.190	0.730	0.014	0.003	0.020	0.120	0.000	0.060	0.001	4
			M-180	A	2	209333	61,200	80,050	25.8	0.200	0.740	0.016	0.005	0.010	0.120	0.000	0.070	0.002	4

Figure A-17. Strut and Yoke Assembly, Test Nos. MGS7S-1 and MGS7S-2 (Item No. b3)

Wirerope Works, Inc. 100 Maynard St Williamsport, PA 17701
Manufacturer of Bethlehem Wire Rope ®
"Our Quality Management Systems are registered to ISO 9001: 2015 and API-Q1"

CERTIFICATE OF COMPLIANCE

CUSTOMER: MAZZELLA LIFTING TECHNOLOGIES
ORD# 267872
CUST. PO P202954 **WW FILE NAME 267872ORD**

REEL# 0243493

DESCRIPTION: 3/4" 0619 W GA IPS RR SAC GALVANIZED WIRE ROPE IN ACCORDANCE WITH AASHTO DESIGNATION M30-02

ACTUAL TEST RESULTS
ACTUAL BREAKING STRENGTH: 63,400 LBS
REQUIRED BREAKING STRENGTH: 42,800 LBS

MINIMUM MASS OF COATING:
WIRE DIAMETER MAINWIRES
.054" MINIMUM CLASS A COATING .40- ACTUAL RANGE .55/.66 oz/fl2
.040" MINIMUM CLASS A COATING .40- ACTUAL RANGE .52/.53 oz/fl2

STEEL CERTIFICATES FOR ROD MANUFACTURER ARE ATTACHED
The following are heat numbers and wire diameters as shown on the Steel Certificates

.054" HEAT #	**OT0016343**	**20676920**	
.040" HEAT #	**614442**	**OT0013913**	
.061" HEAT #	**20676920**	**20643620**	**OT0009792**
.046" HEAT #	**531380084/02**		

ALL MATERIALS " MELTED AND MANUFACTURED IN THE USA"

Patti Watkins **DATE: 09/08/2020 CERTIFICATE# AA30816**
PATTI WATKINS, Inv. Control/QA Customer Coordinator
Per the authority of, **ROGER GILLILAND, DIRECTOR OF ENGINEERING**

Figure A-18. BCT Cable Anchor Assembly, Test Nos. MGS7S-1 and MGS7S-2 (Item No. b4)

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: RESALE

Order Number: 1269489 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3346
BOL Number: 97457 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 11/7/16

H#JK16101488 R#17-282 Anchor Bracket Assembly

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

Figure A-19. Anchor Bracket Assembly, Test Nos. MGS7S-1 and MGS7S-2 (Item No. b5)

NUCOR
NUCOR STEEL JACKSON, INC.

Mill Certification
7/27/2016

MTR #: M1-150903
NUCOR STEEL JACKSON, INC.
3630 Fourth Street
Flowood, MS 39232
(601) 939-1623
Fax: (601) 936-6202

Sold To: O'NEAL STEEL INC
ATTN ACCOUNTS PAYABLE
PO BOX 98
BIRMINGHAM, AL 35202-0098
(205) 599-8000
Fax: (205) 599-8052

Ship To: O'NEAL STEEL INC
4530 MESSER-AIRPORT HWY
BIRMINGHAM, AL 35222
(205) 599-8000
Fax: (205) 599-8052

Customer P.O.	00771356	Sales Order	343125.6
Product Group	Merchant Bar Quality	Part Number	6350030024010W0
Grade	NUCOR MULTIGRADE	Lot #	JK1610148801
Size	1/2x3" Flat	Heat #	JK16101488
Product	1/2x3" Flat 20' NUCOR MULTIGRADE	B.L. Number	M1-429896
Description	NUCOR MULTIGRADE	Load Number	M1-150903
Customer Spec		Customer Part #	00777557

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

Roll Date: 4/5/2016 Melt Date: 3/30/2016 Qty Shipped LBS: 4,900 Qty Shipped Pcs: 48

Melt Date: 3/30/2016

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Cb	Sn
0.16%	0.78%	0.017%	0.028%	0.20%	0.28%	0.08%	0.14%	0.020%	0.0280%	0.001%	0.010%
CE4020	CEA529										
0.35%	0.39%										

CE4020: C. E. CSA G4020, AASHTO M270
CEA529: A529 CARBON EQUIVALENT

Roll Date: 4/5/2016

Yield 1: 56,172psi	Tensile 1: 75,460psi	Elongation: 25% in 8"(% in 203.3mm)
Yield 2: 56,126psi	Tensile 2: 76,500psi	Elongation 25% in 8"(% in 203.3mm)

Specification Comments: NUCOR MULTIGRADE MEETS THE REQUIREMENTS OF: ASTM A36/36M, ASTM A529/529M GR50 ASTM A572/572M GR50 ASTM709/709M GR36/GR50 CSA G40.21 GR44W(300W)/GR50W(350W) AASHTO M270/M270M GR36/GR50 ASME SA36/SA36M MEETS EN10204 SEC 3.1 REPORTING REQUIREMENTS

ALL MANUFACTURING PROCESSES OF THE STEEL MATERIALS IN THIS PRODUCT, INCLUDING MELTING, HAVE OCCURRED WITHIN THE UNITED STATES. ALL PRODUCTS PRODUCED ARE WELD FREE. MERCURY, IN ANY FORM, HAS NOT BEEN USED IN THE PRODUCTION OR TESTING OF THIS MATERIAL.

QA Approved
SI# 777557

Christopher Smith
Division Metallurgist

NBMG-10 January 1, 2012

Page 1 of 1

Figure A-20. Anchor Bracket Assembly, Test Nos. MGS7S-1 and MGS7S-2 (Item No. b5)

H#4181496 R#18-642 Black Paint

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

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

MILFORD,NE,68405

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

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

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

By:

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

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

Notary Public, State of Ohio

Figure A-21. 8-in. x 8-in. x ⅝-in. Anchor Bearing Plate, Test Nos. MGS7S-1 and MGS7S-2 (Item No. b6)

Atlas Tube (Alabama), Inc.
171 Cleage Dr
Birmingham, Alabama, USA
35217
Tel:
Fax:

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

Ref.B/L: 80791452
Date: 11.10.2017
Customer: 179

MATERIAL TEST REPORT

Sold to

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

Shipped to

Steel & Pipe Supply Compan
401 New Century Parkway
NEW CENTURY KS 66031
USA

H#712810 R#18-773 2 3/8" O.D. x 6" Long BCT Post Sleeve

Material: 3.0x2.0x188x40'0"0(5x4). Material No: 0300201884000-B Made in: USA Melted in: USA

Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 6630020018840

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
B704212	0.200	0.450	0.010	0.004	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.28
40867002	20	064649 Psi	087652 Psi	24 %	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

Material: 2.375x154x42'0"0(34x1). Material No: R023751544200 Made in: USA Melted in: USA

Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 642004042

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
B712810	0.210	0.460	0.012	0.002	0.020	0.024	0.100	0.002	0.020	0.030	0.060	0.004	0.002	0.000	0.008

Bundle No	PCs	Yield	Tensile	Eln.2in	Rb	Certification	CE: 0.32
MC00006947	34	063688 Psi	083220 Psi	25 %	91	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

Material: 2.375x154x42'0"0(34x1). Material No: R023751544200 Made in: USA Melted in: USA

Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 642004042

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
17037261	0.210	0.810	0.005	0.004	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.35
41532001	34	066144 Psi	082159 Psi	27 %	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

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

Steel Tube Institute

Page : 3 Of 4

Metals Service Center Institute

Figure A-22. 2⅜-in. O.D. x 6-in. Long BCT Post Sleeve, Test Nos. MGS7S-1 and MGS7S-2 (Item No. b7)

CERTIFICATE OF COMPLIANCE

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

CUSTOMER NAME: TRINITY INDUSTRIES

CUSTOMER PO: 187087

SHIPPER #: 061972
DATE SHIPPED: 11/06/2017

LOT#: 30361-P

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE:	SPEC:	60,000 psi*min	RESULTS:	66,566 66,832
HARDNESS:		100 max		82.60 82.70

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
ROGERS GALVANIZE: 30361-P

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
NUCOR	1010	DL17100590	.10	.41	.005	.005	.05

QUANTITY AND DESCRIPTION:

4,825 PCS 5/8" X 14" GUARD RAIL BOLT
P/N 3540G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS

6th DAY OF November, 20 17 — Linda Mcthomas (APPROVED SIGNATORY) — 11/6/17 (DATE)

Merry F. Shane

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

Figure A-23. ⅝-in. Dia. UNC, 14-in. Long Guardrail Bolt, Test Nos. MGS7S-1 and MGS7S-2 (Item No. c1)

CERTIFICATE OF COMPLIANCE

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

CUSTOMER NAME: GREGORY INDUSTRIES

CUSTOMER PO: 49996

SHIPPER #: 071888
DATE SHIPPED: 07/29/2021

LOT#: 33278-P

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE: SPEC: 60,000 psi*min RESULTS: 70,400 71,400

HARDNESS: 100 max 71.80 72.30

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
AZZ GALVANIZING: 33278-P

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
CHARTER STEEL	1010	10684020	.11	.43	.006	.010	.09

QUANTITY AND DESCRIPTION:

6,000 PCS 5/8" X 1.25" GUARD RAIL BOLT
P/N 1001G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS

24th DAY OF August, 20 21

Merry F Shane

APPROVED SIGNATORY

8-24-2021
DATE

Official Seal
Merry F Shane
Notary Public State of Illinois
My Commission Expires 10/03/2022

Figure A-24. ⅝-in. Dia. UNC 1¼-in. Long Guardrail Bolt, Test Nos. MGS7S-1 and MGS7S-2 (Item No. c2)

CHARTER STEEL

A Division of Charter Manufacturing Company, Inc.

LOAD

1658 Cold Springs Road
Saukville, Wisconsin 53080
(262) 268-2400
1-800-437-8789
Fax (262) 268-2570

CHARTER STEEL TEST REPORT

Melted in USA Manufactured in USA

Rockford Bolt & Steel
126 Mill St.
Rockford,IL-61101
Kind Attn :Linda McComas

Cust P.O.	P39618-4
Customer Part #	100905
Charter Sales Order	70098700
Heat #	10684020
Ship Lot #	4664211
Grade	1010 A AK FG RHQ 19/32 RNDCOIL
Process	HRSA
Finish Size	19/32
Ship date	02-DEC-20

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed below and that it satisfies these requirements. The recording of false, fictitious and fraudulent statements or entries on this document may be punishable as a felony under federal statute.

Test results of Heat Lot # 10684020

Lab Code: 7388

CHEM	C	MN	P	S	SI	NI	CR	MO	CU	SN	V
%Wt	.11	.43	.006	.010	.090	.04	.07	.01	.07	.005	.002
	AL	N	B	TI	NB						
	.038	.0080	.0001	.001	.001						

Test results of Rolling Lot # 1306546

REDUCTION RATIO=109:1

Specifications: Manufactured per Charter Steel Quality Manual Rev Date 05/12/17
Charter Steel certifies this product is indistinguishable from background radiation levels by having process radiation detectors in place to measure for the presence of radiation within our process & products.
Meets customer specifications with any applicable Charter Steel exceptions for the following customer documents:
Customer Document = ASTM A29/A29M Revision = 20 Dated = 01-JUL-20

Additional Comments:

Melt Source:
Charter Steel
Saukville, WI, USA

Trip: 1465603

This MTR supersedes all previously dated MTRs for this order

Douglas Jones Division Mgr. of Quality Assurance
jonesdo@chartersteel.com
Printed Date : 12/02/2020

Figure A-25. ⅝-in. Dia. UNC, 1¼-in. Long Guardrail Bolt, Test Nos. MGS7S-1 and MGS7S-2 (Item No. c2)

CERTIFICATE OF COMPLIANCE

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

CUSTOMER NAME: GREGORY INDUSTRIES

CUSTOMER PO: 39864

SHIPPER #: 063466
DATE SHIPPED: 05/24/2018

LOT#: 30920-B

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE: SPEC: 60,000 psi*min RESULTS: 79,300
76,800

HARDNESS: 100 max 90.00
90.80

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
AZZ GALVANIZING: 30920-B

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
MID AMERICAN STEEL & WIRE	1012	1721198	.13	.51	.016	.027	.19

20,700 PCS 5/8" X 10" GUARD RAIL BOLT
P/N 1010G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS
31st DAY OF May, 20 18
Merry F Shane

Linda McComas — APPROVED SIGNATORY
5/31/18 — DATE

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

Figure A-26. ⅝-in. Dia. UNC, 10-in. Long Guardrail Bolt, Test Nos. MGS7S-1 and MGS7S-2 (Item No. c3)

IATF 16949:2016
BUREAU VERITAS
Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER : GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2020/06/05

PURCHASER : FASTENAL
PO. NUMBER : 220027055
COMMODITY : HEX MACHINE BOLT GR-A
SIZE : 5/8-11X1-1/2 NC
LOT NO : 1B17C3611
SHIP QUANTITY : 4, 800 PCS
LOT QUANTITY 410 PCS
HEADMARKS : CYI & 307A
MANUFACTURE DATE : 2018/04/13
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM180426006
INVOICE NO : GEM/FNL-180510IN-2
PART NO : 1191919
SAMPLING PLAN : ASME B18. 18-2017(Category. 2)/ASTM F1470-2018
HEAT NO : 17310569-3
MATERIAL : X1008A
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A307-14E1

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0. 3300	1. 2500	0. 0410		
Test Value	0. 0300	0. 0600	0. 2700	0. 0160	0. 0090	0. 0300

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18. 2. 1-2012

SAMPLED BY : FCHUN

INSPECTIONS ITEM	SAMPLE	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
MAJOR DIAMETER	9 PCS	0. 6110-0. 6230 inch	0. 6130-0. 6220 inch	9	0
WIDTH ACROSS CORNERS	3 PCS	1. 0330-1. 0830 inch	1. 0700-1. 0700 inch	3	0
HEIGHT	3 PCS	0. 3780-0. 4440 inch	0. 4270-0. 4390 inch	3	0
NOMINAL LENGTH	9 PCS	1. 4200-1. 5600 inch	1. 4350-1. 5210 inch	9	0
WIDTH ACROSS FLATS	3 PCS	0. 9060-0. 9380 inch	0. 9110-0. 9370 inch	3	0
SURFACE DISCONTINUITIES	11 PCS	ASTM F788-2013	PASSED	11	0
AND IS MATCHED WITH THE REAMING NUT AFTER PLATING	11 PCS	nut	PASSED	11	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A307-14E1

SAMPLED BY : GDAN LIAN

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15 PCS	ASTM F606-2016		69-100 HRB	82-84 HRB	15	0
TENSILE STRENGTH	4 PCS	ASTM F606-2016		Min. 60 KSI	76-78 KSI	4	0
PLATING THICKNESS(μm)	5 PCS	ASTM B568-1998		>=53	80. 07-81. 18	5	0

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER
WE CERTIFY THAT ALL PRODUCTS WE SUPPLIED ARE IN COMPLIANCE WITH DIN EN 10204 3.1 CONTENT

Quality Supervisor: [signature]

Figure A-27. ⅝-in. Dia. UNC, 1½-in. Long Hex Head Bolt, Test Nos. MGS7S-1 and MGS7S-2 (Item No. c4)

Certificate of Compliance

Birmingham Fastener Manufacturing
PO Box 10323
Birmingham, AL 35202
(205) 595-3512

Customer Midwest Machinery & Supply **Date Shipped** 06/26/2017

Customer Order Number 3443 **BFM Order Number** 1425884

Item Description

Description 5/8"-11 x 10" HEX BOLT **Qty** 157

Lot # 213833 **Specification** ASTM A307-14 Gr A **Finish** ASTM F2329

Raw Material Analysis

Heat# JK17100352

Chemical Composition (wt% Heat Analysis) By Material Supplier

C	Mn	P	S	Si	Cu	Ni	Cr	Mo
0.16	1.14	0.022	0.040	0.26	0.30	0.13	0.25	0.031

Mechanical Properties

Sample #	Hardness	Tensile Strength (lbs)	Tensile Strength (psi)
1	89 HRBW	21,500	96,770
2			
3			
4			
5			

This information represents the most recent analysis of the product supplied on the stated customer order. The samples tested conform to the ASTM standard listed above.
All steel melted and manufactured in the U.S.A.

Authorized Signature: [signature] **Date:** 7/7/2017

Brian Hughes
Quality Assurance

Figure A-28. ⅝-in. Dia. UNC, 10-in. Long Hex Head Bolt, Test Nos. MGS7S-1 and MGS7S-2 (Item No. c5)

FASTENAL®

Fastenal Company
P.O Box 1286
WINONA, MN 55987-1286

Invoice

Date: 3/27/18
Reference No.: NELIN314987
Page: 1
DUE DATE: 04/26/2018

Cust. No. NELIN2067
Cust. P.O.
Job No. TL-2 and Bullnose

The store serving you is
3201 N. 23rd Street STE 1

LINCOLN, NE 68521
Phone #: (402)476-7900
Fax #: 402/476-7958

Contract No: 1862 & 14284 OC

Sold To
UNL TRANSPORTATION
1931 NORTH ANTELOPE VALLEY PKWY
LINCOLN, NE 68588
402-472-7937; 402-472-8660(Fax)

Ship To
UNL TRANSPORTATION
4630 NW 36th Street

LINCOLN, NE 68524
402-580-8095; 402-472-0071(Fax)

Authorized Purchaser: Jim Holloway

This Order and Document are subject to the "Terms of Purchase" posted on www.fastenal.com.

Line No.	Quantity Ordered	Quantity Shipped	Quantity Backorder	Description	Control No.	Part No.	Price / Hundred	Amount
1	5	5 TS	0	7/8-9x8 A307A HDG	llne35042	92005	509.5500	25.48 G
2	20	20 TS	0	7/8"-9 HX NUT GALV	110254885	36717	72.2400	14.45 G
3	5	5 TS	0	7/8-9x8 A307A HDG	llne35042	92005	509.5500	25.48 G
4	5	5 TS	0	7/8-9x8 A307A HDG	llne35042	92005	509.5500	25.48 G
5	5	5 TS	0	7/8-9x8 A307A HDG	llne35042	92005	509.5500	25.48 G

Visa Account # XXXXXXXXXXX6926 Exp XX/XX
Cardmember acknowledges receipt of goods or services in the amount of the total shown hereon and agrees to perform the obligations set forth by the cardmember's agreement with the issuer.

X ______________________
Card Member Signature

Received By

Comments
Contact: WEBORD CONTRACT:1862 & 14284 OC

Tax Exemption
Government NE

Subtotal	116.37
Shipping & Handling	0.00
State Tax	0.00
County Tax	0.00
City Tax	0.00
TOTAL USD	116.37

If you re-package or re-sell this product, you are required to maintain integrity of Country of Origin to the consumer of this product.

Reasonable collection and attorneys fees will be assessed to all accounts placed for collection
No materials accepted for return without our permission.
X indicates part is a hazardous material
** indicates part was sold at a promotional or special discount price*

This is your invoice.
All discrepancies must be reported within 10 days. *0*

Thank You !

Figure A-29. ⅞-in. Dia. UNC, 8-in. Long Hex Head Bolt, Test Nos. MGS7S-1 and MGS7S-2 (Item No. c6)

ISO/TS 16949
BUREAU VERITAS
Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER : GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2017/03/23

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 110216407
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 5/8-11 NC O/T 0.51MM
LOT NO : 1N1680027
SHIP QUANTITY : 23,400 PCS
LOT QUANTITY 170,278 PCS
HEADMARKS :
MANUFACTURE DATE : 2016/08/26
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM160919007
INVOICE NO : GEM/FNL-160929WI
PART NO : 36713
SAMPLING PLAN : ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : 331608011
MATERIAL : ML08
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

R#17-507 H#331608011
BCT Cable Bracket Nuts

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2007

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0.5800		0.1300	0.2300	
Test Value	0.0350	0.0700	0.4100	0.0160	0.0060	0.0500

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2010

SAMPLED BY : DWTING

INSPECTIONS ITEM	SAMPLE	SPECIFIED		ACTUAL RESULT	ACC.	REJ.
WIDTH ACROSS CORNERS	6PCS	ASME B18.2.2-2010	1.0510-1.0830 inch	1.0560-1.0690 inch	6	0
FIM	15PCS		Max. 0.0210 inch	0.0020-0.0040 inch	15	0
THICKNESS	6PCS		0.5350-0.5590 inch	0.5390-0.5570 inch	6	0
WIDTH ACROSS FLATS	6PCS		0.9220-0.9380 inch	0.9240-0.9340 inch	6	0
SURFACE DISCONTINUITIES	29PCS		ASTM F812-2012	PASSED	29	0
THREAD	15PCS		GAGING SYSTEM 21	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2007

SAMPLED BY : GDAN LIAN

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15PCS	ASTM F606-2014		68-107 HRB	79-81 HRB	15	0
PROOF LOAD	4PCS	ASTM F606-2014		Min. 90 KSI	OK	4	0
PLATING THICKNESS(μm)	5PCS	ASTM B568-1998		>=53	70.02-75.81	5	0

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER

Quality Supervisor: Grin

Figure A-30. ⅝-in. Dia. Hex Nut, Test Nos. MGS7S-1 and MGS7S-2 (Item No. d1)

CERTIFICATE OF COMPLIANCE

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

CUSTOMER NAME: GREGORY INDUSTRIES

CUSTOMER PO: 40787

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

LOT#: 30934-B

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

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

HARDNESS: 100 max 65.60
65.20

*Pounds Per Square Inch.

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

CHEMICAL COMPOSITION

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

QUANTITY AND DESCRIPTION:

7,000 PCS 5/8" X 1.25" GUARD RAIL BOLT
P/N 1001G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS

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

Merry F Shane

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

Figure A-31. ⅝-in. Dia. Heavy Hex Bolt, Test Nos. MGS7S-1 and MGS7S-2 (Item No. d3)

L#20200831 P#1133185 C#120403777 Inv#384753 R#21-153

SSF INDUSTRIAL CO., LIMITED

MILL TEST CERTIFICATION

Certification Conforms to EN1024 3.1B

Supplier: SSF INDUSTRIAL CO.,LIMITED
Buyer: FASTENAL COMPANY PURCHASING
Certificate No.: 000826
Invoice No.: FASTCO2020083101

Product Description: 5/8 USS F/W GALV
Product Size: 5/8
Quality Acceptance: ISO 3269
Shipped Q'ty: 6 MPCS
Lot No.: 20200831

RAW MATERIAL scrap

Element	C	Si	Mn	S	P	Ni	Cr	Cu

SURFACE

Test Item	Spec.	Standard	Remark
Appearance	Flawless	/	OK

DIMENSION MEASUREMENT(UNI According to : USS

Test Item	Standard (mm)		Sampling	Remark	Test Result
	Min	Max			
INNER DIAMETER (d1)	17.3	18.23	80	OK	
OUTTER DIAMETER (d2)	44.28	45.21	80	OK	
THICKNESS (h)	2.75	4.06	80	OK	

MACHANICAL PROPERTIES According to : ISO 6507

Test Item	Spec.	Sampling	Remark	Test Result
HARDNESS (HRC/HV)	HV10 140 ~ HV10 250	10	OK	HV10 145 ~ HV10 150

COATING According to : ISO 4042

Test Item	Spec.	Sampling	Remark	Test Result
Plating thickness	min.3 μm	5	OK	4.573 μm - 5.328 μm
SST	2 hours no white corrosion and 12 hours no red rust	5	OK	OK

We hereby certify that all the above material were manufactured , sampled, tested, and inspected in accordance with the relevant specification and any supplementary requirements or other requirements designated in the purchase order and was found to meet those requirements.

Inspector: QC Chen
Inspc. Date: 2020.11.16

Figure A-32. ⅝-in. Dia. Plain USS Washer, Test Nos. MGS7S-1 and MGS7S-2 (Item No. e1)

CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS HDG

FACTORY: IFI & Morgan Ltd REPORT DATE: 23/4/2019
ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan,Zhejiang, China

MFG LOT NUMBER: 1844804

SAMPLING PLAN PER ASME B18.18-11 PO NUMBER: 170089822
SIZE: USS 7/8 HDG QNTY(Lot size): 7200PCS
HEADMARKS: NO MARK PART NO: 33187

DIMENSIONAL INSPECTIONS SPECIFICATION: ASTM B18.21.1-2011

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F844	PASSED	100	0
OUTSIDE DIA	2.243-2.280	2.246-2.254	10	0
INSIDE DIA	0.931-0.968	0.956-0.965	10	0
THICKNESS	0.136-0.192	0.136-0.157	10	0

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
HOT DIP GALVANIZED	ASTM F2329-13	Min 0.0017"	0.0017-0.0020 in	8	0

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.
ISO 9001:2015 SGS Certificate # HK04/0105

IFI & MORGAN LTD.
检验专用章
QUANLITY CONTROL

(SIGNATURE OF Q.A. LAB MGR.)

Figure A-33. ⅞-in. Dia. Plain USS Washer, Test Nos. MGS7S-1 and MGS7S-2 (Item No. e2)

Appendix B. Vehicle Center of Gravity Determination

		Test Name:	MGS7S-1	VIN:	KMHTC4AEXGU059917
Model Year:	2016	Make:	Hyundai	Model:	Accent Sedan

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)
+	Unballasted Car (Curb)	2484
+	Hub	19
+	Brake activation cylinder & frame	7
+	Pneumatic tank (Nitrogen)	22
+	Strobe/Brake Battery	5
+	Brake Receiver/Wires	5
+	CG Plate including DAQ	20
-	Battery	-37
-	Oil	-12
-	Interior	-72
-	Fuel	-5
-	Coolant	-6
-	Washer fluid	-3
+	Water Ballast (In Fuel Tank)	
+	Onboard Supplemental Battery	

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

Estimated Total Weight (lb) 2427

Vehicle Dimensions for C.G. Calculations

Wheel Base:	101.25 in.	Front Track Width:	59.375 in.
Roof Height:	56.625 in.	Rear Track Width:	59.5 in.

Center of Gravity	1100C MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb)	2420 ± 55	2431	11.0
Longitudinal CG (in.)	39 ± 4	38.234	-0.766
Lateral CG (in.)	NA	-1.161	NA
Vertical CG (in.)	NA	21.879	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	820	744
Rear	449	471

FRONT	1564	lb
REAR	920	lb
TOTAL	2484	lb

TEST INERTIAL WEIGHT (lb)

	Left	Right
Front	812	701
Rear	451	467

FRONT	1513	lb
REAR	918	lb
TOTAL	2431	lb

Figure B-1. Vehicle Mass Distribution, Test No. MGS7S-1

		Test Name: MGS7S-2	**VIN:** 1C6RR6FGXGS128241
Model Year: 2016		**Make:** Ram	**Model:** 1500

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	4958	28.347078	140544.81
+	Hub	19	14.75	280.25
+	Brake activation cylinder & frame	7	27 1/4	190.75
+	Pneumatic tank (Nitrogen)	22	27	594
+	Strobe/Brake Battery	10	26	260
+	Brake Receiver/Wires	5	52	260
+	CG Plate including DAQ	42	29 7/8	1254.75
-	Battery	-52	42	-2184
-	Oil	-10	15	-150
-	Interior	-112	35	-3920
-	Fuel	-173	17	-2941
-	Coolant	-9	34 1/2	-310.5
-	Washer fluid	-7	33	-231
+	Water Ballast (In Fuel Tank)	202	16	3232
+	Onboard Supplemental Battery			0
+	Steel Plate Ballast	100	36 5/8	3662.5
				0
				140542.56

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

Estimated Total Weight (lb)	5002
Vertical CG Location (in.)	28.09727

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.5 in. Front Track Width: 68.25 in.
Rear Track Width: 67.875 in.

Center of Gravity	**2270P MASH Targets**	**Test Inertial**	**Difference**
Test Inertial Weight (lb)	5000 ± 110	5022	22.0
Longitudinal CG (in.)	63 ± 4	65.773696	2.77370
Lateral CG (in.)	NA	-0.840278	NA
Vertical CG (in.)	28 or greater	28.10	0.09727

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	1410	1303
Rear	1102	1143

FRONT	2713	lb
REAR	2245	lb
TOTAL	4958	lb

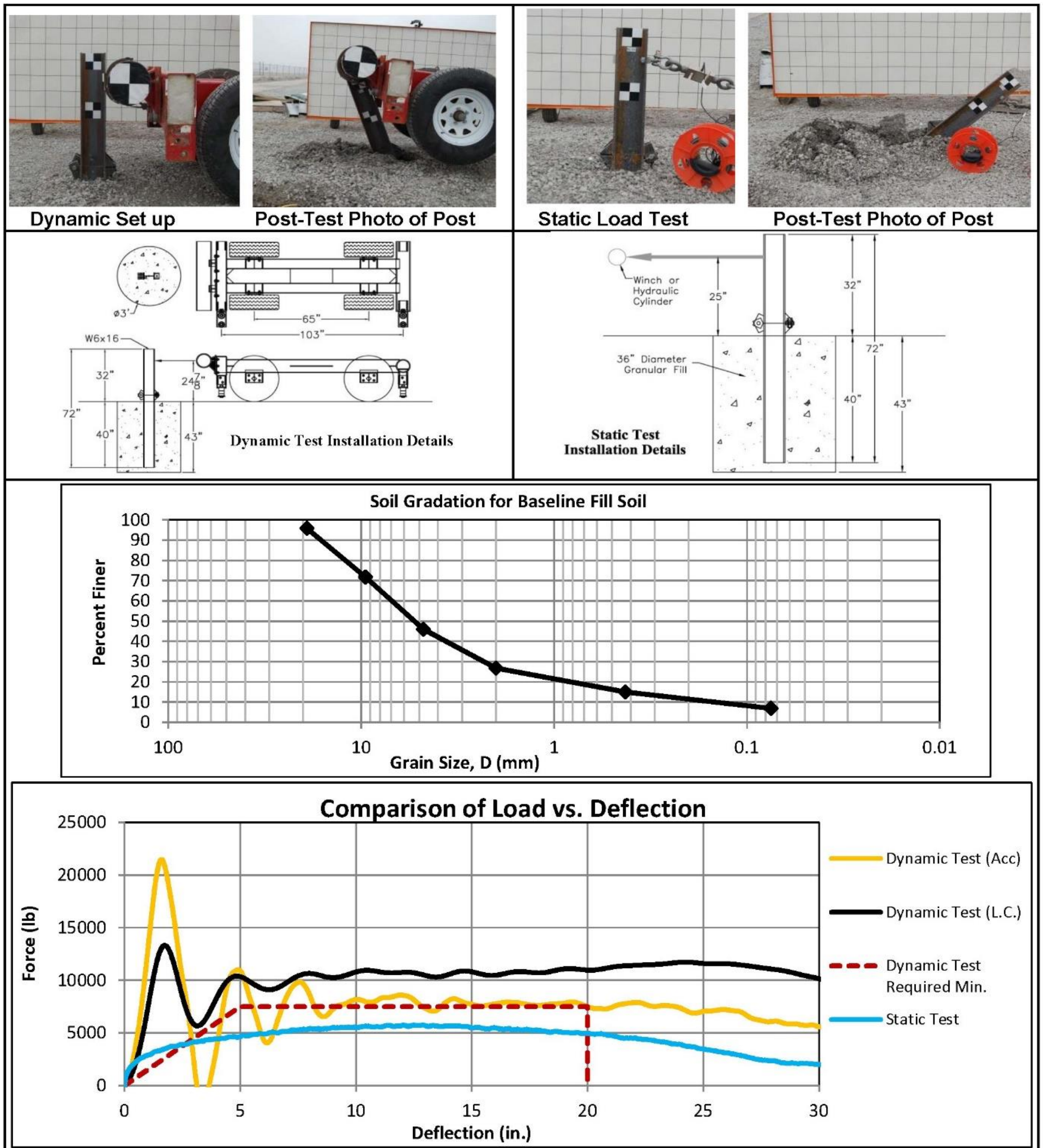
TEST INERTIAL WEIGHT (lb)

	Left	Right
Front	1412	1259
Rear	1161	1190

FRONT	2671	lb
REAR	2351	lb
TOTAL	5022	lb

Figure B-2. Vehicle Mass Distribution, Test No. MGS7S-2

Appendix C. Static Soil Tests

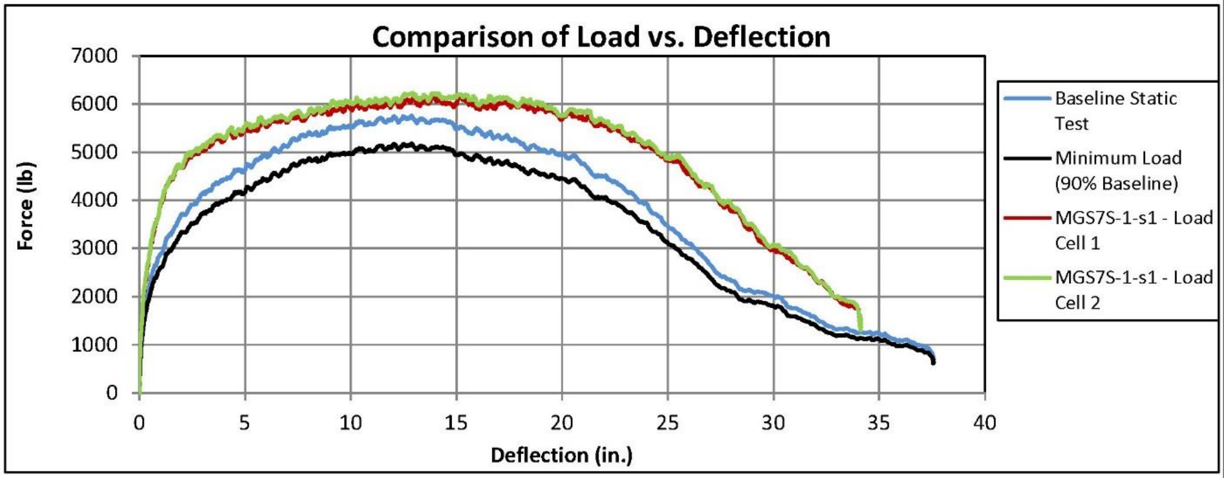


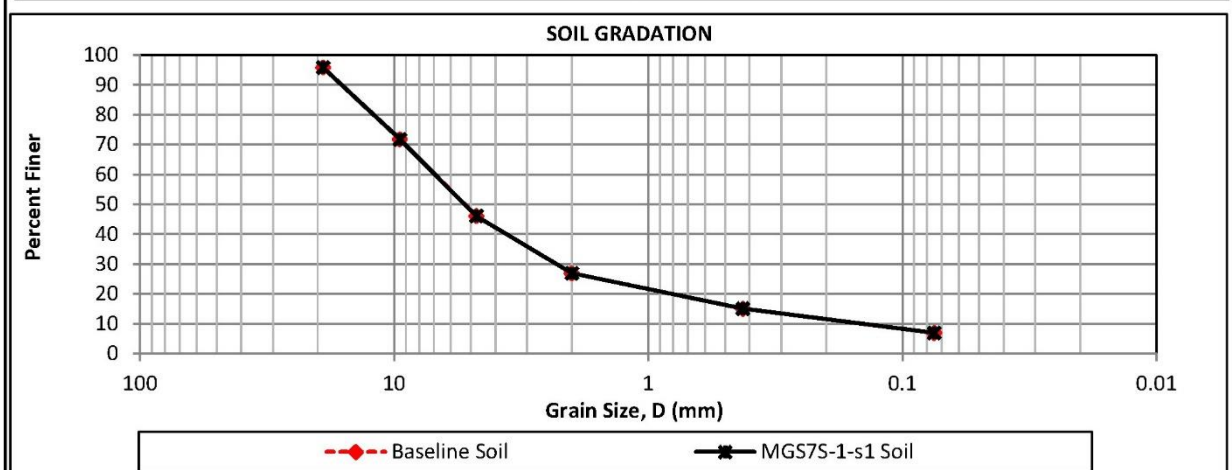
Date……	5/24/2021		
Test Facility & Site Location……	Midwest Roadside Safety Facility		
In situ soil description (ASTM D2487)……	Well-Graded Gravel (GW)		
Fill material description (ASTM D2487)……	Well-Graded Gravel (GW) (see sieve analyses above)		
Description of fill placement procedure……	LE-8 - 4 times around		
Bogie Weight……	1878 lb		852 kg
Impact Velocity……	20.9 mph		33.6 km/h

Figure C-1. Soil Strength, Initial Calibration Test, Test Nos. MGS7S-1 and MGS7S-2

Static Load Test Setup

Post-Test Photo of Post



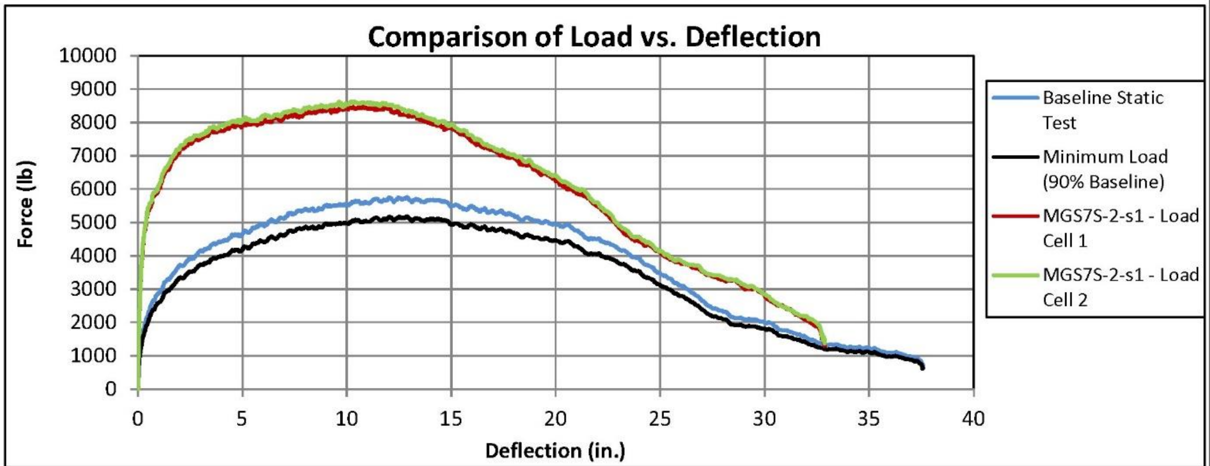


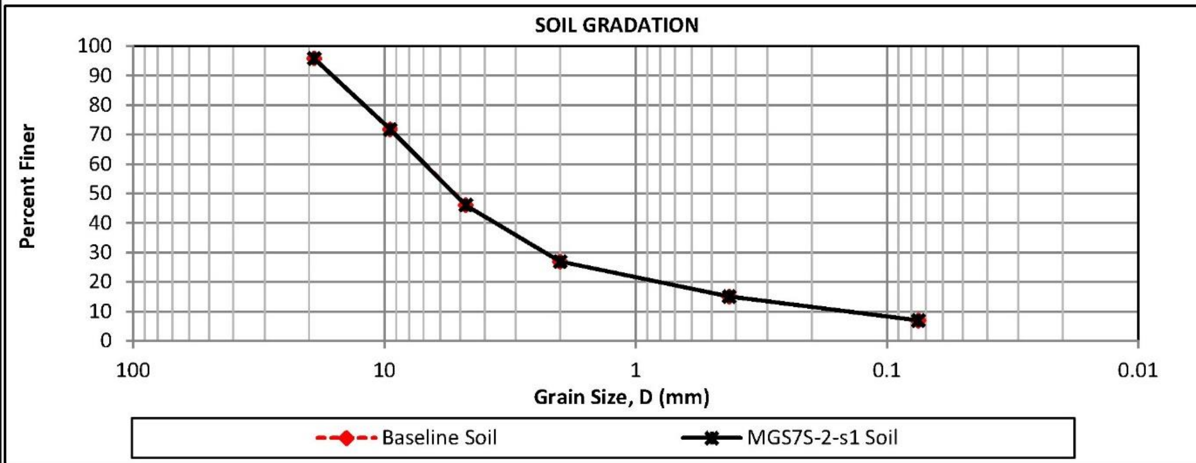
Date..	11/24/2021
Test Facility & Site Location........................	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)...........	Well-Graded Gravel (GW)
Fill material description (ASTM D2487).........	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure........	8-inch lifts tamped with a pneumatic compactor

Figure C-2. Static Soil Test, Test No. MGS7S-1

Static Load Test Setup

Post-Test Photo of Post





Date..	12/20/2021
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. Static Soil Test, Test No. MGS7S-2

Appendix D. Vehicle Deformation Records, Test No. MGS7S-1

The following figures and tables describe all occupant compartment measurements taken on the test vehicles used in full-scale crash testing herein. MASH 2016 defines intrusion as the occupant compartment being deformed and reduced in size with no penetration. Outward deformations, which are denoted as negative numbers within this Appendix, are not considered as crush toward the occupant, and are not subject to evaluation by MASH 2016 criteria.

Model Year: 2016 | Test Name: MGS7S-1 | Make: Hyundai | VIN: KMHTC4AEXGU059917 | Model: Accent Sedan

VEHICLE DEFORMATION
PASSENGER SIDE FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	74.5709	8.7363	0.7329	74.5867	8.6610	0.6643	-0.0158	0.0753	0.0686	0.1031	0.0686	Z
	2	75.3590	10.8486	2.0838	75.3345	10.8198	2.0340	0.0245	0.0288	0.0498	0.0625	0.0555	X, Z
	3	76.0956	17.4835	1.7695	76.0748	17.4512	1.6779	0.0208	0.0323	0.0916	0.0993	0.0939	X, Z
	4	76.3815	22.8590	0.9932	76.3199	22.7929	0.9162	0.0616	0.0661	0.0770	0.1187	0.0986	X, Z
	5	73.8528	26.9330	-1.5215	73.6081	26.7663	-1.6807	0.2447	0.1667	0.1592	0.3362	0.2919	X, Z
	6	67.5811	8.6776	3.3659	67.5919	8.5805	3.3124	-0.0108	0.0971	0.0535	0.1114	0.0535	Z
	7	67.6062	12.1267	6.5967	67.6336	12.1226	6.5275	-0.0274	0.0041	0.0692	0.0745	0.0692	Z
	8	67.4940	17.0726	6.3863	67.4892	17.0384	6.3329	0.0048	0.0342	0.0534	0.0636	0.0536	X, Z
	9	67.9566	24.6147	5.8391	67.9822	24.5660	5.8164	-0.0256	0.0487	0.0227	0.0595	0.0227	Z
	10	68.1434	28.6809	5.6003	68.1253	28.5955	5.6128	0.0181	0.0854	-0.0125	0.0882	0.0181	X
FLOOR PAN (Z)	11	64.5478	8.4514	3.2850	64.5695	8.3821	3.3050	-0.0217	0.0693	-0.0200	0.0753	-0.0200	Z
	12	64.3496	11.9425	7.1622	64.3484	11.9680	7.1099	0.0012	-0.0255	0.0523	0.0582	0.0523	Z
	13	64.1539	17.0746	7.0613	64.2006	17.0379	7.0277	-0.0467	0.0367	0.0336	0.0682	0.0336	Z
	14	64.0060	25.3137	6.8143	64.0011	25.2911	6.8014	0.0049	0.0226	0.0129	0.0265	0.0129	Z
	15	64.6623	29.1179	6.4396	64.6706	29.0536	6.4273	-0.0083	0.0643	0.0123	0.0660	0.0123	Z
	16	59.3088	8.2518	3.2772	59.2871	8.1935	3.2495	0.0217	0.0583	0.0277	0.0681	0.0277	Z
	17	58.9718	12.5196	7.1605	58.9638	12.4765	7.1039	0.0080	0.0431	0.0566	0.0716	0.0566	Z
	18	58.4857	17.0913	7.0463	58.5053	17.0295	7.0308	-0.0196	0.0618	0.0155	0.0667	0.0155	Z
	19	59.4758	25.0806	6.5483	59.4438	25.0282	6.5471	0.0320	0.0524	0.0012	0.0614	0.0012	Z
	20	59.5214	28.2328	6.4509	59.5366	28.1792	6.4399	-0.0152	0.0536	0.0110	0.0568	0.0110	Z
	21	54.4306	7.9965	3.2240	54.3910	7.9494	3.1884	0.0396	0.0471	0.0356	0.0711	0.0356	Z
	22	54.2937	12.7813	7.4390	54.2619	12.7548	7.3882	0.0318	0.0265	0.0508	0.0655	0.0508	Z
	23	54.3710	18.1114	7.1390	54.3497	18.0287	7.1476	0.0213	0.0827	-0.0086	0.0858	-0.0086	Z
	24	54.0504	24.6967	6.6811	54.0440	24.6131	6.6778	0.0064	0.0836	0.0033	0.0839	0.0033	Z
	25	54.0145	28.0447	6.6059	54.0347	27.9703	6.6143	-0.0202	0.0744	-0.0084	0.0775	-0.0084	Z
	26	49.9786	7.7213	3.2767	50.0253	7.6858	3.2041	-0.0467	0.0355	0.0726	0.0933	0.0726	Z
	27	50.3678	12.6822	7.4194	50.3821	12.6234	7.3670	-0.0143	0.0588	0.0524	0.0800	0.0524	Z
	28	50.3300	18.1933	7.2727	50.4170	18.1661	7.2652	-0.0870	0.0272	0.0075	0.0915	0.0075	Z
	29	50.2772	24.6030	7.0577	50.3440	24.6270	7.0439	-0.0668	-0.0240	0.0138	0.0723	0.0138	Z
	30	50.3848	28.3688	6.9817	50.4154	28.3863	6.9647	-0.0306	-0.0175	0.0170	0.0391	0.0170	Z

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

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Pretest Floor Pan	Posttest Floor Pan
	

Figure D-1. Floor Pan Deformation Data – Set 1, Test No. MGS7S-1

Model Year: 2016 | Test Name: MGS7S-1 | VIN: KMHTC4AEXGU059917
Make: Hyundai | Model: Accent Sedan

VEHICLE DEFORMATION
PASSENGER SIDE FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	53.2208	7.0264	-6.6158	53.2486	7.0019	-6.4453	-0.0278	0.0245	-0.1705	0.1745	0.0000	NA
	2	54.0524	9.1130	-5.2513	54.0377	9.1206	-5.0365	0.0147	-0.0076	-0.2148	0.2154	0.0147	X
	3	54.8215	15.7478	-5.4809	54.8130	15.7544	-5.2387	0.0085	-0.0066	-0.2422	0.2424	0.0085	X
	4	55.1219	21.1329	-6.1811	55.0769	21.1123	-5.8690	0.0450	0.0206	-0.3121	0.3160	0.0450	X
	5	52.5607	25.2596	-8.5742	52.3388	25.1667	-8.3084	0.2219	0.0929	-0.2658	0.3585	0.2219	X
	6	46.2930	6.9666	-3.8236	46.3082	6.8948	-3.6587	-0.0152	0.0718	-0.1649	0.1805	0.0000	NA
	7	46.4131	10.3652	-0.5419	46.4373	10.3533	-0.3559	-0.0242	0.0119	-0.1860	0.1879	0.0000	NA
	8	46.3258	15.3143	-0.6739	46.3204	15.2732	-0.4224	0.0054	0.0411	-0.2515	0.2549	0.0054	X
	9	46.8212	22.8612	-1.1161	46.8511	22.8085	-0.7571	-0.0299	0.0527	-0.3590	0.3641	0.0000	NA
	10	47.0269	26.9295	-1.2968	47.0158	26.8409	-0.8610	0.0111	0.0886	-0.4358	0.4449	0.0111	X
FLOOR PAN (Z)	11	43.2574	6.7589	-3.8381	43.2851	6.7145	-3.6098	-0.0277	0.0444	-0.2283	0.2342	-0.2283	Z
	12	43.1692	10.1907	0.0957	43.1635	10.2031	0.2889	0.0057	-0.0124	-0.1932	0.1937	-0.1932	Z
	13	43.0022	15.3249	0.0778	43.0466	15.2742	0.3387	-0.0444	0.0507	-0.2609	0.2695	-0.2609	Z
	14	42.8982	23.5674	-0.0395	42.8953	23.5316	0.3266	0.0029	0.0358	-0.3661	0.3679	-0.3661	Z
	15	43.5687	27.3732	-0.3710	43.5812	27.2985	0.0349	-0.0125	0.0747	-0.4059	0.4129	-0.4059	Z
	16	38.0185	6.5891	-3.7283	38.0015	6.5585	-3.5628	0.0170	0.0306	-0.1655	0.1692	-0.1655	Z
	17	37.7964	10.7983	0.2266	37.7833	10.7433	0.4051	0.0131	0.0550	-0.1785	0.1872	-0.1785	Z
	18	37.3353	15.3739	0.1937	37.3526	15.2993	0.4572	-0.0173	0.0746	-0.2635	0.2744	-0.2635	Z
	19	38.3618	23.3642	-0.2045	38.3322	23.3021	0.1582	0.0296	0.0621	-0.3627	0.3692	-0.3627	Z
	20	38.4241	26.5172	-0.2548	38.4430	26.4542	0.1294	-0.0189	0.0630	-0.3842	0.3898	-0.3842	Z
	21	33.1389	6.3623	-3.6729	33.1037	6.3448	-3.5308	0.0352	0.0175	-0.1421	0.1474	-0.1421	Z
	22	33.1276	11.0821	0.6169	33.0900	11.0419	0.7918	0.0376	0.0402	-0.1749	0.1834	-0.1749	Z
	23	33.2300	16.4157	0.3969	33.2066	16.3196	0.6837	0.0234	0.0961	-0.2868	0.3034	-0.2868	Z
	24	32.9387	23.0090	0.0473	32.9336	22.9155	0.3879	0.0051	0.0935	-0.3406	0.3532	-0.3406	Z
	25	32.9212	26.3579	0.0243	32.9445	26.2732	0.4100	-0.0233	0.0847	-0.3857	0.3956	-0.3857	Z
	26	28.6877	6.1115	-3.5219	28.7377	6.1065	-3.4332	-0.0500	0.0050	-0.0887	0.1019	-0.0887	Z
	27	29.2018	11.0056	0.6862	29.2097	10.9338	0.8460	-0.0079	0.0718	-0.1598	0.1754	-0.1598	Z
	28	29.1938	16.5184	0.6249	29.2780	16.4771	0.8846	-0.0842	0.0413	-0.2597	0.2761	-0.2597	Z
	29	29.1746	22.9308	0.5093	29.2419	22.9418	0.8292	-0.0673	-0.0110	-0.3199	0.3271	-0.3199	Z
	30	29.3031	26.6967	0.4885	29.3358	26.7015	0.8443	-0.0327	-0.0048	-0.3558	0.3573	-0.3558	Z

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

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Pretest Floor Pan

Posttest Floor Pan

Figure D-2. Floor Pan Deformation Data – Set 2, Test No. MGS7S-1

Model Year: 2016 | Test Name: MGS7S-1 | VIN: KMHTC4AEXGU059917
Make: Hyundai | Model: Accent Sedan

VEHICLE DEFORMATION
PASSENGER SIDE INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	61.6074	4.4837	-21.9299	61.5071	4.4335	-22.0587	0.1003	0.0502	-0.1288	0.1708	0.1708	X, Y, Z
	2	62.3371	18.1980	-20.3875	62.1805	18.0906	-20.4804	0.1566	0.1074	-0.0929	0.2114	0.2114	X, Y, Z
	3	62.1199	28.3890	-21.2090	62.0141	28.3220	-21.3374	0.1058	0.0670	-0.1284	0.1794	0.1794	X, Y, Z
	4	56.3050	4.4153	-12.6943	56.2557	4.3251	-12.8337	0.0493	0.0902	-0.1394	0.1732	0.1732	X, Y, Z
	5	59.4551	19.2078	-16.1929	59.3841	19.1400	-16.3491	0.0710	0.0678	-0.1562	0.1845	0.1845	X, Y, Z
	6	59.0129	27.4118	-17.0698	58.9749	27.3543	-17.1892	0.0380	0.0575	-0.1194	0.1379	0.1379	X, Y, Z
SIDE PANEL (Y)	7	66.2935	31.0101	-2.7782	66.3172	30.9237	-2.8740	-0.0237	0.0864	-0.0958	0.1312	0.0864	Y
	8	65.7260	31.0565	-0.6095	65.7440	30.9827	-0.7684	-0.0180	0.0738	-0.1589	0.1761	0.0738	Y
	9	68.9737	31.1697	0.8267	69.0516	31.0945	0.6364	-0.0779	0.0752	-0.1903	0.2189	0.0752	Y
IMPACT SIDE DOOR (Y)	10	53.3022	31.4356	-16.3088	53.2893	31.3855	-16.3934	0.0129	0.0501	-0.0846	0.0992	0.0501	Y
	11	44.3082	32.0148	-17.6741	44.2301	31.9849	-17.7854	0.0781	0.0299	-0.1113	0.1392	0.0299	Y
	12	33.2214	31.5459	-18.7437	33.2008	31.6311	-18.7742	0.0206	-0.0852	-0.0305	0.0928	-0.0852	Y
	13	57.2659	32.3914	-0.4646	57.2175	32.4873	-0.5786	0.0484	-0.0959	-0.1140	0.1566	-0.0959	Y
	14	49.3136	32.8036	-0.7357	49.1903	32.9474	-0.8206	0.1233	-0.1438	-0.0849	0.2076	-0.1438	Y
	15	36.4554	31.9055	-2.7031	36.4431	31.9986	-2.8181	0.0123	-0.0931	-0.1150	0.1485	-0.0931	Y
ROOF - (Z)	16	47.6835	22.5533	-36.7122	47.6388	22.4309	-36.8572	0.0447	0.1224	-0.1450	0.1949	-0.1450	Z
	17	49.4824	12.9444	-36.7447	49.4615	12.9102	-36.8638	0.0209	0.0342	-0.1191	0.1257	-0.1191	Z
	18	50.2392	3.0250	-36.5194	50.1028	2.9914	-36.6678	0.1364	0.0336	-0.1484	0.2043	-0.1484	Z
	19	36.8809	20.3691	-39.7543	36.7882	20.2761	-39.8580	0.0927	0.0930	-0.1037	0.1673	-0.1037	Z
	20	36.9996	11.1348	-40.0503	36.9037	11.0894	-40.1416	0.0959	0.0454	-0.0913	0.1400	-0.0913	Z
	21	37.3909	0.5770	-39.8726	37.3353	0.5075	-39.9488	0.0556	0.0695	-0.0762	0.1172	-0.0762	Z
	22	26.9568	19.4900	-40.4437	26.8555	19.3995	-40.5355	0.1013	0.0905	-0.0918	0.1639	-0.0918	Z
	23	27.0429	10.2862	-40.7130	27.0264	10.1992	-40.7838	0.0165	0.0870	-0.0708	0.1134	-0.0708	Z
	24	27.5877	-0.8019	-40.5028	27.5271	-0.8610	-40.5624	0.0606	-0.0591	-0.0596	0.1035	-0.0596	Z
	25	10.6053	19.0957	-39.9096	10.5375	19.0527	-39.9473	0.0678	0.0430	-0.0377	0.0887	-0.0377	Z
	26	10.7518	8.8784	-40.1909	10.7074	8.8580	-40.2220	0.0444	0.0204	-0.0311	0.0579	-0.0311	Z
	27	10.9599	0.2032	-40.0467	10.9821	0.1552	-40.0729	-0.0222	0.0480	-0.0262	0.0590	-0.0262	Z
	28	-2.5171	18.0886	-37.9215	-2.5587	18.0409	-37.9296	0.0416	0.0477	-0.0081	0.0638	-0.0081	Z
	29	-3.1665	9.2691	-38.0736	-3.2020	9.2495	-38.0710	0.0355	0.0196	0.0026	0.0406	0.0026	Z
	30	-2.8953	1.8686	-38.0271	-2.9830	1.8332	-38.0088	0.0877	0.0354	0.0183	0.0963	0.0183	Z
A-PILLAR Maximum (X, Y, Z)	31	70.3241	30.1578	-24.1218	70.3732	30.0403	-24.2792	-0.0491	0.1175	-0.1574	0.2025	0.1175	Y
	32	64.2042	28.9009	-27.0294	64.2897	28.7749	-27.1745	-0.0855	0.1260	-0.1451	0.2103	0.1260	Y
	33	60.3540	27.8983	-29.7248	60.3639	27.7711	-29.8671	-0.0099	0.1272	-0.1423	0.1911	0.1272	Y
	34	55.0837	26.6455	-32.8420	55.1710	26.5461	-32.9922	-0.0873	0.0994	-0.1502	0.2002	0.0994	Y
	35	51.3194	25.7118	-34.3862	51.3139	25.5977	-34.5738	0.0055	0.1141	-0.1876	0.2196	0.1142	X, Y
	36	48.4171	25.1809	-35.9507	48.4589	25.0765	-36.0840	-0.0418	0.1044	-0.1333	0.1744	0.1044	Y
A-PILLAR Lateral (Y)	31	70.3241	30.1578	-24.1218	70.3732	30.0403	-24.2792	-0.0491	0.1175	-0.1574	0.2025	0.1175	Y
	32	64.2042	28.9009	-27.0294	64.2897	28.7749	-27.1745	-0.0855	0.1260	-0.1451	0.2103	0.1260	Y
	33	60.3540	27.8983	-29.7248	60.3639	27.7711	-29.8671	-0.0099	0.1272	-0.1423	0.1911	0.1272	Y
	34	55.0837	26.6455	-32.8420	55.1710	26.5461	-32.9922	-0.0873	0.0994	-0.1502	0.2002	0.0994	Y
	35	51.3194	25.7118	-34.3862	51.3139	25.5977	-34.5738	0.0055	0.1141	-0.1876	0.2196	0.1141	Y
	36	48.4171	25.1809	-35.9507	48.4589	25.0765	-36.0840	-0.0418	0.1044	-0.1333	0.1744	0.1044	Y
B-PILLAR Maximum (X, Y, Z)	37	26.2661	25.4581	-33.2348	26.2375	25.3867	-33.3550	0.0286	0.0714	-0.1202	0.1427	0.0769	X, Y
	38	23.6038	25.9183	-32.0138	23.6243	25.8926	-32.0464	-0.0205	0.0257	-0.0326	0.0463	0.0257	Y
	39	26.7236	26.9654	-29.8876	26.6902	26.9039	-29.9909	0.0334	0.0615	-0.1033	0.1248	0.0700	X, Y
	40	24.0050	28.2169	-26.2626	23.9851	28.1677	-26.3509	0.0199	0.0492	-0.0883	0.1030	0.0531	X, Y
B-PILLAR Lateral (Y)	37	26.2661	25.4581	-33.2348	26.2375	25.3867	-33.3550	0.0286	0.0714	-0.1202	0.1427	0.0714	Y
	38	23.6038	25.9183	-32.0138	23.6243	25.8926	-32.0464	-0.0205	0.0257	-0.0326	0.0463	0.0257	Y
	39	26.7236	26.9654	-29.8876	26.6902	26.9039	-29.9909	0.0334	0.0615	-0.1033	0.1248	0.0615	Y
	40	24.0050	28.2169	-26.2626	23.9851	28.1677	-26.3509	0.0199	0.0492	-0.0883	0.1030	0.0492	Y

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

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-3. Occupant Compartment Deformation Data – Set 1, Test No. MGS7S-1

Model Year: 2016

Test Name: MGS7S-1
Make: Hyundai

VIN: KMHTC4AEXGU059917
Model: Accent Sedan

VEHICLE DEFORMATION
PASSENGER SIDE INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	39.6687	3.2375	-29.1072	39.6882	3.4326	-29.0008	-0.0195	-0.1951	0.1064	0.2231	0.2231	X, Y, Z
	2	40.5077	16.9227	-27.3735	40.4829	17.0401	-27.0862	0.0248	-0.1174	0.2873	0.3114	0.3114	X, Y, Z
	3	40.3235	27.1260	-28.0333	40.3663	27.2910	-27.6764	-0.0428	-0.1650	0.3569	0.3955	0.3955	X, Y, Z
	4	34.5946	3.0522	-19.7457	34.6231	3.1177	-19.6769	-0.0285	-0.0655	0.0688	0.0992	0.0992	X, Y, Z
	5	37.7349	17.8815	-23.0942	37.7772	17.9993	-22.8733	-0.0423	-0.1178	0.2209	0.2539	0.2539	X, Y, Z
	6	37.3141	26.1001	-23.8342	37.4050	26.2349	-23.4936	-0.0909	-0.1348	0.3406	0.3774	0.3774	X, Y, Z
SIDE PANEL (Y)	7	44.9625	29.4422	-9.6730	45.0575	29.3891	-9.2435	-0.0950	0.0531	0.4295	0.4431	0.0531	Y
	8	44.4487	29.4578	-7.4905	44.5273	29.3971	-7.1258	-0.0786	0.0607	0.3647	0.3780	0.0607	Y
	9	47.7313	29.5332	-6.1333	47.8633	29.4526	-5.7862	-0.1320	0.0806	0.3471	0.3800	0.0806	Y
IMPACT SIDE DOOR (Y)	10	31.6450	30.1393	-22.8712	31.7632	30.2784	-22.4791	-0.1182	-0.1391	0.3921	0.4325	-0.1391	Y
	11	22.6232	30.7830	-24.0052	22.6820	30.9683	-23.6709	-0.0588	-0.1853	0.3343	0.3867	-0.1853	Y
	12	11.5112	30.3844	-24.8082	11.6328	30.7068	-24.4443	-0.1216	-0.3224	0.3639	0.5012	-0.3224	Y
	13	36.0017	30.8313	-7.1167	36.0165	30.9478	-6.7243	-0.0148	-0.1165	0.3924	0.4096	-0.1165	Y
	14	28.0475	31.2862	-7.1853	27.9892	31.4624	-6.7913	0.0583	-0.1762	0.3940	0.4355	-0.1762	Y
	15	15.1403	30.4808	-8.8486	15.1983	30.6425	-8.5531	-0.0580	-0.1617	0.2955	0.3418	-0.1617	Y
ROOF - (Z)	16	25.4802	21.6002	-43.2633	25.6428	21.8896	-43.0473	-0.1626	-0.2894	0.2160	0.3960	0.2160	Z
	17	27.2276	11.9843	-43.4873	27.4025	12.3613	-43.3355	-0.1749	-0.3770	0.1518	0.4425	0.1518	Z
	18	27.9379	2.0591	-43.4326	27.9826	2.4371	-43.4075	-0.0447	-0.3780	0.0251	0.3815	0.0251	Z
	19	14.5949	19.5155	-46.0712	14.7201	19.8785	-45.8814	-0.1252	-0.3630	0.1898	0.4283	0.1898	Z
	20	14.6580	10.2864	-46.5115	14.7696	10.7017	-46.4033	-0.1116	-0.4153	0.1082	0.4434	0.1082	Z
	21	14.9985	-0.2747	-46.5051	15.1355	0.1159	-46.4912	-0.1370	0.3906	0.0139	0.4142	0.0139	Z
	22	4.6523	18.6952	-46.5292	4.7702	19.0797	-46.3793	-0.1179	-0.3845	0.1499	0.4292	0.1499	Z
	23	4.6838	9.4964	-46.9414	4.8757	9.8880	-46.8673	-0.1919	-0.3916	0.0741	0.4423	0.0741	Z
	24	5.1757	-1.5962	-46.9144	5.3082	-1.1770	-46.9404	-0.1325	0.4192	-0.0260	0.4404	-0.0260	Z
	25	-11.6829	18.3719	-45.5982	-11.5345	18.8164	-45.4688	-0.1484	-0.4445	0.1294	0.4862	0.1294	Z
	26	-11.5967	8.1595	-46.0394	-11.4371	8.6314	-46.0088	-0.1596	-0.4719	0.0306	0.4991	0.0306	Z
	27	-11.4304	-0.5177	-46.0332	-11.2166	-0.0739	-46.0890	-0.2138	0.4438	-0.0558	0.4958	-0.0558	Z
	28	-24.7575	17.3978	-43.3028	-24.5938	17.8319	-43.2121	-0.1637	-0.4341	0.0907	0.4727	0.0907	Z
	29	-25.4565	8.5849	-43.5738	-25.2975	9.0512	-43.5664	-0.1590	-0.4663	0.0074	0.4927	0.0074	Z
	30	-25.2229	1.1833	-43.6474	-25.1259	1.6345	-43.6992	-0.0970	-0.4512	-0.0518	0.4644	-0.0518	Z
A-PILLAR Maximum (X, Y, Z)	31	48.4628	28.8998	-31.1201	48.6756	29.0342	-30.7423	-0.2128	-0.1344	0.3778	0.4540	0.3778	Z
	32	42.2668	27.7176	-33.8947	42.5267	27.8807	-33.5449	-0.2599	-0.1631	0.3498	0.4653	0.3498	Z
	33	38.3463	26.7754	-36.5095	38.5410	26.9705	-36.1822	-0.1947	-0.1951	0.3273	0.4279	0.3273	Z
	34	32.9945	25.5963	-39.5146	33.2782	25.8580	-39.2316	-0.2837	-0.2617	0.2830	0.4786	0.2830	Z
	35	29.1886	24.7048	-40.9796	29.3839	24.9741	-40.7584	-0.1953	-0.2693	0.2212	0.3995	0.2212	Z
	36	26.2460	24.2122	-42.4800	26.4957	24.5093	-42.2232	-0.2497	-0.2971	0.2568	0.4654	0.2568	Z
A-PILLAR Lateral (Y)	31	48.4628	28.8998	-31.1201	48.6756	29.0342	-30.7423	-0.2128	-0.1344	0.3778	0.4540	-0.1344	Y
	32	42.2668	27.7176	-33.8947	42.5267	27.8807	-33.5449	-0.2599	-0.1631	0.3498	0.4653	-0.1631	Y
	33	38.3463	26.7754	-36.5095	38.5410	26.9705	-36.1822	-0.1947	-0.1951	0.3273	0.4279	-0.1951	Y
	34	32.9945	25.5963	-39.5146	33.2782	25.8580	-39.2316	-0.2837	-0.2617	0.2830	0.4786	-0.2617	Y
	35	29.1886	24.7048	-40.9796	29.3839	24.9741	-40.7584	-0.1953	-0.2693	0.2212	0.3995	-0.2693	Y
	36	26.2460	24.2122	-42.4800	26.4957	24.5093	-42.2232	-0.2497	-0.2971	0.2568	0.4654	-0.2971	Y
B-PILLAR Maximum (X, Y, Z)	37	4.1702	24.5547	-39.2149	4.3363	24.8831	-39.0362	-0.1661	-0.3284	0.1787	0.4091	0.1787	Z
	38	1.5411	25.0088	-37.9218	1.7534	25.3708	-37.6622	-0.2123	-0.3620	0.2596	0.4935	0.2596	Z
	39	4.7177	26.0079	-35.8574	4.8667	26.3101	-35.6442	-0.1490	-0.3022	0.2132	0.3987	0.2132	Z
	40	2.0955	27.2164	-32.1477	2.2438	27.4958	-31.9186	-0.1483	-0.2794	0.2291	0.3906	0.2291	Z
B-PILLAR Lateral (Y)	37	4.1702	24.5547	-39.2149	4.3363	24.8831	-39.0362	-0.1661	-0.3284	0.1787	0.4091	-0.3284	Y
	38	1.5411	25.0088	-37.9218	1.7534	25.3708	-37.6622	-0.2123	-0.3620	0.2596	0.4935	-0.3620	Y
	39	4.7177	26.0079	-35.8574	4.8667	26.3101	-35.6442	-0.1490	-0.3022	0.2132	0.3987	-0.3022	Y
	40	2.0955	27.2164	-32.1477	2.2438	27.4958	-31.9186	-0.1483	-0.2794	0.2291	0.3906	-0.2794	Y

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

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-4. Occupant Compartment Deformation Data – Set 2, Test No. MGS7S-1

Test Name:	MGS7S-1	VIN:	KMHTC4AEXGU059917
Model Year: 2016	Make: Hyundai	Model:	Accent Sedan

Passenger Side Maximum Deformations							
Reference Set 1				**Reference Set 2**			
Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]	Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	0.0	≤ 4	Z	Roof	0.2	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.1	≤ 5	Y	A-Pillar Maximum	0.4	≤ 5	Z
A-Pillar Lateral	0.1	≤ 3	Y	A-Pillar Lateral	-0.3	≤ 3	Y
B-Pillar Maximum	0.1	≤ 5	X, Y	B-Pillar Maximum	0.3	≤ 5	Z
B-Pillar Lateral	0.1	≤ 3	Y	B-Pillar Lateral	-0.4	≤ 3	Y
Toe Pan - Wheel Well	0.3	≤ 9	X, Z	Toe Pan - Wheel Well	0.2	≤ 9	X
Side Front Panel	0.1	≤ 12	Y	Side Front Panel	0.1	≤ 12	Y
Side Door (above seat)	0.1	≤ 9	Y	Side Door (above seat)	-0.3	≤ 9	Y
Side Door (below seat)	-0.1	≤ 12	Y	Side Door (below seat)	-0.2	≤ 12	Y
Floor Pan	0.1	≤ 12	Z	Floor Pan	-0.4	≤ 12	Z
Dash - no MASH requirement	0.2	NA	X, Y, Z	Dash - no MASH requirement	0.4	NA	X, Y, Z

[A] Items highlighted in red do not meet MASH allowable deformations.

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

[C] For Toe Pan - Wheel Well the direction of defromation may include X and Z direction. For A-Pillar Maximum and B-Pillar Maximum the direction of deformation may include X, Y, and Z directions. The direction of deformation for Toe Pan -Wheel Well, A-Pillar Maximum, and B-Pillar Maximum only include components where the deformation is positive and intruding into the occupant compartment. If direction of deformation is "NA" then no intrusion is recorded and deformation will be 0.

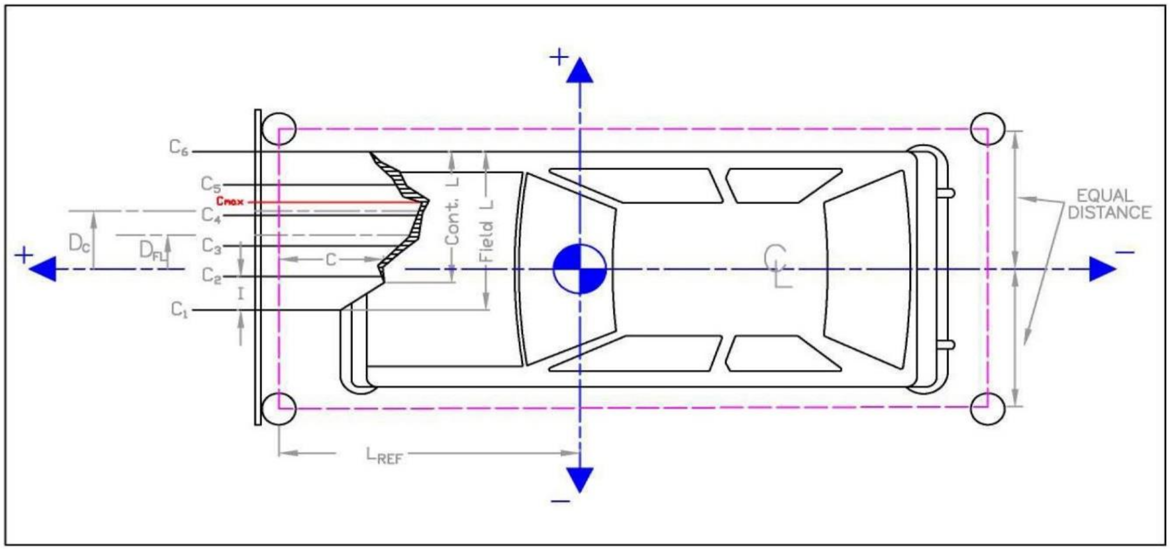
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

Notes on vehicle crush:

Figure D-5. Maximum Occupant Compartment Deformation by Location, Test No. MGS7S-1

Test Name: MGS7S-1 **VIN:** KMHTC4AEXGU059917

Model Year: 2016 **Make:** Hyundai **Model:** Accent Sedan



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	83	(2108)
Total Width of Vehicle:	66 3/8	(1686)
Width of contact and induced crush - Field L:	66 3/8	(1686)
Crush measurement spacing interval (L/5) - I:	13 1/4	(337)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	66 3/8	(1686)
Distance from center of vehicle to center of contact damage - D_C:	0	()

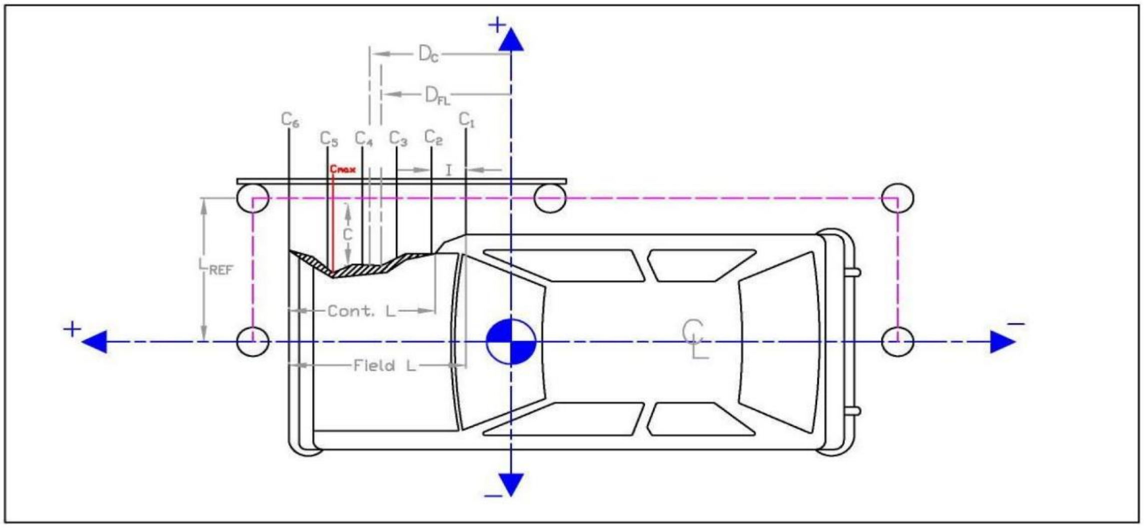
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/A	NA	-33 1/4	-(845)	15 5/8	(397)	8 1/2	(216)	NA	NA
C_2	13 1/4	(337)	-20	-(508)	6 7/8	(175)			-2 1/8	-(54)
C_3	12 3/4	(324)	-6 3/4	-(171)	4 3/8	(111)			- 1/8	-(3)
C_4	14 1/2	(368)	6 1/2	(165)	4 1/2	(114)			1 1/2	(38)
C_5	17 1/2	(445)	19 3/4	(502)	6 3/4	(171)			2 1/4	(57)
C_6	N/A	NA	33	(838)	15 5/8	(397)			NA	NA
C_{MAX}	23 1/2	(597)	25	(635)	9 1/4	(235)			5 3/4	(146)

Figure D-6. Exterior Vehicle Crush (NASS) – Front, Test No. MGS7S-1

Test Name: MGS7S-1 VIN: KMHTC4AEXGU059917

Model Year: 2016 Make: Hyundai Model: Accent Sedan



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	40	(1016)
Total Vehicle Length:	171 1/2	(4356)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-15 1/8	-(384)
Width of contact and induced crush - Field L:	171 1/2	(4356)
Crush measurement spacing interval (L/5) - I:	34 1/4	(870)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-15 1/8	-(384)
Width of Contact Damage:	171 1/2	(4356)
Distance from vehicle c.g. to center of contact damage - D_C:	-15 1/8	-(384)

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

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/A	NA	-100 7/8	-(2562)	41 1/4	(1048)	-1 1/4	-(32)	NA	NA
C_2	N/A	NA	-66 5/8	-(1692)	7	(178)			NA	NA
C_3	7 5/8	(194)	-32 3/8	-(822)	8 1/8	(206)			3/4	(19)
C_4	8 3/8	(213)	1 7/8	(48)	8 1/4	(210)			1 3/8	(35)
C_5	N/A	NA	36 1/8	(918)	7	(178)			NA	NA
C_6	N/A	NA	70 3/8	(1788)	25 5/8	(651)			NA	NA
C_{MAX}	16	(406)	59 1/2	(1511)	9 1/4	(235)			8	(203)

Figure D-7. Exterior Vehicle Crush (NASS) – Side, Test No. MGS7S-1

Model Year: 2016 | Test Name: MGS7S-2 | Make: Ram | VIN: 1C6RR6FGXGS128241 | Model: 1500

VEHICLE DEFORMATION
PASSENGER SIDE FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	57.2047	32.0386	-7.3886	57.0039	32.1307	-7.9444	0.2008	-0.0921	0.5558	0.5981	0.5910	X, Z
	2	59.4792	35.4428	-4.8308	59.3779	35.4461	-5.4589	0.1013	-0.0033	0.6281	0.6362	0.6362	X, Z
	3	60.7558	39.2457	-3.8178	60.6859	39.2703	-4.4407	0.0699	-0.0246	0.6229	0.6273	0.6268	X, Z
	4	60.7914	43.3386	-4.8691	60.7173	43.3053	-5.4733	0.0741	0.0333	0.6042	0.6096	0.6087	X, Z
	5	60.4376	46.9125	-7.7733	59.9950	45.5674	-7.9741	0.4426	1.3451	0.2008	1.4302	0.4860	X, Z
	6	50.3155	28.4959	-5.2753	50.2359	28.5149	-5.7952	0.0796	-0.0190	0.5199	0.5263	0.5260	X, Z
	7	51.9349	34.6680	-1.0418	51.8622	34.6433	-1.5615	0.0727	0.0247	0.5197	0.5253	0.5248	X, Z
	8	52.9824	39.8504	0.4419	52.9629	39.8495	-0.0753	0.0195	0.0009	0.5172	0.5176	0.5176	X, Z
	9	53.0929	45.2192	0.1507	53.0455	45.2385	-0.3674	0.0474	-0.0193	0.5181	0.5206	0.5203	X, Z
	10	53.6806	48.7645	0.1000	53.6478	48.7622	-0.4233	0.0328	0.0023	0.5233	0.5243	0.5243	X, Z
FLOOR PAN (Z)	11	46.7123	27.5349	-3.8963	46.6806	27.5156	-4.3688	0.0317	0.0193	0.4725	0.4740	0.4725	Z
	12	48.4946	32.9066	0.8506	48.5060	32.9272	0.3678	-0.0114	-0.0206	0.4828	0.4834	0.4828	Z
	13	48.9181	40.1331	1.3899	48.9142	40.2004	0.9251	0.0039	-0.0673	0.4648	0.4697	0.4648	Z
	14	49.3357	45.8191	1.3837	49.3220	45.8297	0.9167	0.0137	-0.0106	0.4670	0.4673	0.4670	Z
	15	49.4173	48.7650	1.8514	49.4496	48.8165	1.4114	-0.0323	-0.0515	0.4400	0.4442	0.4400	Z
	16	43.3765	27.1847	-3.3468	43.3464	27.1973	-3.7871	0.0301	-0.0126	0.4403	0.4415	0.4403	Z
	17	43.6731	32.7554	1.3691	43.6231	32.7208	0.9382	0.0500	0.0346	0.4309	0.4352	0.4309	Z
	18	43.8745	40.6058	1.3466	43.8379	40.6146	0.9432	0.0366	-0.0088	0.4034	0.4052	0.4034	Z
	19	44.4416	45.8977	1.3596	44.4315	45.8703	0.9548	0.0101	0.0274	0.4048	0.4059	0.4048	Z
	20	44.3972	48.5936	1.4453	44.4108	48.5281	1.0182	-0.0136	0.0655	0.4271	0.4323	0.4271	Z
	21	38.4923	27.2195	-3.3134	40.4053	29.6559	-3.1092	-1.9130	-2.4364	-0.2042	3.1044	-0.2042	Z
	22	39.7125	32.2217	1.3433	39.7149	32.2470	0.9522	-0.0024	-0.0253	0.3911	0.3919	0.3911	Z
	23	39.6427	39.4902	1.3126	39.6416	39.4825	0.9544	0.0011	0.0077	0.3582	0.3583	0.3582	Z
	24	39.9064	45.6779	1.3236	39.9332	45.6532	0.9639	-0.0268	0.0247	0.3597	0.3615	0.3597	Z
	25	40.0327	48.6997	1.3806	40.0745	48.7519	1.0408	-0.0418	-0.0522	0.3398	0.3463	0.3398	Z
	26	34.7108	27.3197	-3.1574	34.6816	27.3289	-3.5307	0.0292	-0.0092	0.3733	0.3746	0.3733	Z
	27	34.8172	32.0731	0.5266	34.8261	32.0494	0.1847	-0.0089	0.0237	0.3419	0.3428	0.3419	Z
	28	34.8170	39.3412	0.4957	34.8608	39.3410	0.1784	-0.0438	0.0002	0.3173	0.3203	0.3173	Z
	29	34.8553	45.1565	0.4993	34.8299	45.1719	0.1963	0.0254	-0.0154	0.3030	0.3045	0.3030	Z
	30	34.9308	48.3357	0.4313	34.8985	48.2662	0.0984	0.0323	0.0695	0.3329	0.3416	0.3329	Z

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

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Pretest Floor Pan

Posttest Floor Pan

Figure D-8. Floor Pan Deformation Data – Set 1, Test No. MGS7S-2

Model Year: 2016 | Test Name: MGS7S-2 | VIN: 1C6RR6FGXGS128241
Make: Ram | Model: 1500

VEHICLE DEFORMATION
PASSENGER SIDE FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	54.0949	17.0986	-3.5145	54.2595	17.3380	-3.4954	-0.1646	-0.2394	-0.0191	0.2912	0.0000	NA
	2	56.3395	20.5232	-0.9576	56.4784	20.7104	-0.9578	-0.1389	-0.1872	0.0002	0.2331	0.0002	Z
	3	57.5754	24.3385	0.0595	57.8459	24.5487	0.0601	-0.2705	-0.2102	-0.0006	0.3426	0.0000	NA
	4	57.5585	28.4341	-0.9820	57.8352	28.6103	-1.0061	-0.2767	-0.1762	0.0241	0.3289	0.0241	Z
	5	57.1509	32.0104	-3.8760	57.3711	32.1599	-3.8413	-0.2202	-0.1495	-0.0347	0.2684	0.0000	NA
	6	47.2566	13.4699	-1.3820	47.4667	13.6981	-1.3313	-0.2101	-0.2282	-0.0507	0.3143	0.0000	NA
	7	48.8203	19.6506	2.8599	49.0251	19.8493	2.8727	-0.2048	-0.1987	-0.0128	0.2856	0.0000	NA
	8	49.8127	24.8414	4.3519	50.0061	25.0785	4.3989	-0.1934	-0.2371	-0.0470	0.3096	0.0000	NA
	9	49.8589	30.2118	4.0734	50.0571	30.4798	4.0857	-0.1982	-0.2680	-0.0123	0.3336	0.0000	NA
	10	50.4045	33.7639	4.0288	50.6420	33.9764	4.0191	-0.2375	-0.2125	0.0097	0.3188	0.0097	Z
FLOOR PAN (Z)	11	43.6705	12.4633	0.0092	43.9421	12.6522	0.0422	-0.2716	-0.1889	-0.0330	0.3325	-0.0330	Z
	12	45.4087	17.8443	4.7619	45.6505	18.0785	4.7950	-0.2418	-0.2342	-0.0331	0.3382	-0.0331	Z
	13	45.7493	25.0740	5.3170	45.9528	25.3556	5.3471	-0.2035	-0.2816	-0.0301	0.3487	-0.0301	Z
	14	46.0999	30.7645	5.3230	46.3145	31.0011	5.3372	-0.2146	-0.2366	-0.0142	0.3197	-0.0142	Z
	15	46.1487	33.7100	5.7974	46.4060	34.0083	5.8318	-0.2573	-0.2983	-0.0344	0.3954	-0.0344	Z
	16	40.3413	12.0725	0.5713	40.5532	12.3061	0.6200	-0.2119	-0.2336	-0.0487	0.3191	-0.0487	Z
	17	40.5915	17.6351	5.2995	40.7560	17.8629	5.3295	-0.1645	-0.2278	-0.0300	0.2826	-0.0300	Z
	18	40.7004	25.4873	5.2952	40.9036	25.7303	5.3253	-0.2032	-0.2430	-0.0301	0.3182	-0.0301	Z
	19	41.2051	30.7854	5.3188	41.4262	30.9654	5.3347	-0.2211	-0.1800	-0.0159	0.2855	-0.0159	Z
	20	41.1294	33.4805	5.4111	41.3793	33.7309	5.4256	-0.2499	-0.2504	-0.0145	0.3541	-0.0145	Z
	21	35.4573	12.0496	0.6245	35.6872	12.3164	0.7074	-0.2299	-0.2668	-0.0829	0.3618	-0.0829	Z
	22	36.6374	17.0548	5.2883	36.8356	17.3450	5.3087	-0.1982	-0.2902	-0.0204	0.3520	-0.0204	Z
	23	36.4818	24.3220	5.2756	36.7457	24.5709	5.2970	-0.2639	-0.2489	-0.0214	0.3634	-0.0214	Z
	24	36.6727	30.5124	5.3005	36.9022	30.7458	5.3081	-0.2295	-0.2334	-0.0076	0.3274	-0.0076	Z
	25	36.7637	33.5353	5.3644	37.0143	33.8070	5.3770	-0.2506	-0.2717	-0.0126	0.3698	-0.0126	Z
	26	31.6755	12.1049	0.7960	31.9081	12.3468	0.8195	-0.2326	-0.2419	-0.0235	0.3364	-0.0235	Z
	27	31.7409	16.8504	4.4911	31.9460	17.0346	4.5051	-0.2051	-0.1842	-0.0140	0.2760	-0.0140	Z
	28	31.6550	24.1181	4.4778	31.9394	24.3471	4.4894	-0.2844	-0.2290	-0.0116	0.3653	-0.0116	Z
	29	31.6249	29.9334	4.4954	31.8153	30.1893	4.4976	-0.1904	-0.2559	-0.0022	0.3190	-0.0022	Z
	30	31.6626	33.1135	4.4347	31.8919	33.3235	4.4251	-0.2293	-0.2100	0.0096	0.3111	0.0096	Z

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

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Pretest Floor Pan	Posttest Floor Pan
	

Figure D-9. Floor Pan Deformation Data – Set 2, Test No. MGS7S-2

Model Year: 2016 | Test Name: MGS7S-2 | VIN: 1C6RR6FGXGS128241
Make: Ram | Model: 1500

VEHICLE DEFORMATION
PASSENGER SIDE INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	42.7699	18.4036	-30.6977	42.4673	18.4719	-31.2043	0.3026	-0.0683	-0.5066	0.5940	0.5940	X, Y, Z
	2	46.3906	36.5811	-30.4818	46.0996	36.6475	-31.0592	0.2910	-0.0664	-0.5774	0.6500	0.6500	X, Y, Z
	3	46.0695	48.6788	-29.3398	45.8246	48.7669	-29.8889	0.2449	-0.0881	-0.5491	0.6077	0.6077	X, Y, Z
	4	39.8121	18.1485	-20.0854	39.6229	18.2471	-20.5275	0.1892	-0.0986	-0.4421	0.4909	0.4909	X, Y, Z
	5	42.1235	36.7313	-20.3720	41.9653	36.7509	-20.8345	0.1582	-0.0196	-0.4625	0.4892	0.4892	X, Y, Z
	6	43.2027	48.7566	-19.8635	43.0005	48.8070	-20.3395	0.2022	-0.0504	-0.4760	0.5196	0.5196	X, Y, Z
SIDE PANEL (Y)	7	51.8664	50.4953	-7.2611	51.7710	50.0498	-7.7577	0.0954	0.4455	-0.4966	0.6739	0.4455	Y
	8	51.6951	50.3902	-2.0237	51.6516	50.2253	-2.5446	0.0435	0.1649	-0.5209	0.5481	0.1649	Y
	9	53.8661	50.3886	-3.1167	53.7799	50.2692	-3.6416	0.0862	0.1194	-0.5249	0.5452	0.1194	Y
IMPACT SIDE DOOR (Y)	10	40.3447	52.8759	-19.2213	39.8525	52.5540	-19.6343	0.4922	0.3219	-0.4130	0.7186	0.3219	Y
	11	30.4406	53.1446	-18.7989	29.9576	53.0382	-19.1474	0.4830	0.1064	-0.3485	0.6050	0.1064	Y
	12	20.2543	53.5601	-19.8762	19.7900	53.5874	-20.0432	0.4643	-0.0273	-0.1670	0.4942	-0.0273	Y
	13	38.6655	53.3686	-3.2752	38.4142	53.0863	-3.6762	0.2513	0.2823	-0.4010	0.5510	0.2823	Y
	14	30.3438	53.3512	-3.0655	30.0466	53.1582	-3.4520	0.2972	0.1930	-0.3865	0.5244	0.1930	Y
	15	22.0162	52.9271	-4.5852	21.6690	52.8406	-4.7881	0.3472	0.0865	-0.2029	0.4113	0.0865	Y
ROOF - (Z)	16	38.7702	18.0575	-46.8448	38.2247	18.1398	-47.2718	0.5455	-0.0823	-0.4270	0.6976	-0.4270	Z
	17	37.6229	33.2270	-46.4420	37.0588	33.2999	-46.8693	0.5641	-0.0729	-0.4273	0.7114	-0.4273	Z
	18	34.9779	42.8339	-45.9417	34.4406	42.8671	-46.3409	0.5373	-0.0332	-0.3992	0.6702	-0.3992	Z
	19	31.2195	16.4274	-49.7727	30.6653	16.4835	-50.1144	0.5542	-0.0561	-0.3417	0.6535	-0.3417	Z
	20	29.0049	31.0362	-49.8563	28.4417	31.0840	-50.1734	0.5632	-0.0478	-0.3171	0.6481	-0.3171	Z
	21	27.7754	41.2027	-49.2145	27.9681	41.0000	-49.0000	-0.1927	0.2027	0.2145	0.3525	0.2145	Z
	22	12.7303	17.1507	-51.3571	12.1473	17.2551	-51.4968	0.5830	-0.1044	-0.1397	0.6085	-0.1397	Z
	23	12.9243	30.0195	-51.1418	12.3148	30.0768	-51.2707	0.6095	-0.0573	-0.1289	0.6256	-0.1289	Z
	24	12.5087	39.6617	-50.6047	11.9681	39.7085	-50.7248	0.5406	-0.0468	-0.1201	0.5558	-0.1201	Z
	25	-1.4031	18.0644	-51.5761	-2.0384	18.1727	-51.5538	0.6353	-0.1083	0.0223	0.6449	0.0223	Z
	26	-2.4288	29.8917	-51.4587	-3.0044	29.9707	-51.4052	0.5756	-0.0790	0.0535	0.5835	0.0535	Z
	27	-1.7020	40.1342	-50.9218	-2.2656	40.2418	-50.8689	0.5636	-0.1076	0.0529	0.5762	0.0529	Z
	28	-17.6010	18.6616	-51.2952	-18.2026	18.7556	-51.0932	0.6016	-0.0940	0.2020	0.6415	0.2020	Z
	29	-17.3295	29.2165	-51.2502	-17.9432	29.3340	-51.0168	0.6137	-0.1175	0.2334	0.6670	0.2334	Z
	30	-16.5847	39.8922	-50.8935	-17.1758	39.9869	-50.6624	0.5911	-0.0947	0.2311	0.6417	0.2311	Z
A-PILLAR Maximum (X, Y, Z)	31	54.2349	49.8352	-30.9453	53.8273	49.8667	-31.4810	0.4076	-0.0315	-0.5357	0.6739	0.4076	X
	32	48.8402	48.6093	-34.9150	48.4200	48.6256	-35.4087	0.4202	-0.0163	-0.4937	0.6485	0.4202	X
	33	43.1057	47.4230	-39.3773	42.5557	47.4586	-39.8637	0.5500	-0.0356	-0.4864	0.7351	0.5500	X
	34	38.6223	46.5423	-42.8003	38.0296	46.5987	-43.2268	0.5927	-0.0564	-0.4265	0.7324	0.5927	X
	35	36.1001	45.8655	-44.0334	35.5280	45.9378	-44.4570	0.5721	-0.0723	-0.4236	0.7155	0.5721	X
	36	34.3110	45.1999	-44.8102	33.7125	45.2593	-45.2983	0.5985	-0.0594	-0.4881	0.7746	0.5985	X
A-PILLAR Lateral (Y)	31	54.2349	49.8352	-30.9453	53.8273	49.8667	-31.4810	0.4076	-0.0315	-0.5357	0.6739	-0.0315	Y
	32	48.8402	48.6093	-34.9150	48.4200	48.6256	-35.4087	0.4202	-0.0163	-0.4937	0.6485	-0.0163	Y
	33	43.1057	47.4230	-39.3773	42.5557	47.4586	-39.8637	0.5500	-0.0356	-0.4864	0.7351	-0.0356	Y
	34	38.6223	46.5423	-42.8003	38.0296	46.5987	-43.2268	0.5927	-0.0564	-0.4265	0.7324	-0.0564	Y
	35	36.1001	45.8655	-44.0334	35.5280	45.9378	-44.4570	0.5721	-0.0723	-0.4236	0.7155	-0.0723	Y
	36	34.3110	45.1999	-44.8102	33.7125	45.2593	-45.2983	0.5985	-0.0594	-0.4881	0.7746	-0.0594	Y
B-PILLAR Maximum (X, Y, Z)	37	10.9808	46.9421	-41.8116	10.4593	47.0208	-41.8591	0.5215	-0.0787	-0.0475	0.5295	0.5215	X
	38	8.3252	48.8627	-36.8958	7.9523	48.9166	-36.9581	0.3729	-0.0539	-0.0623	0.3819	0.3729	X
	39	11.8075	49.5715	-34.1772	11.4447	49.6229	-34.2605	0.3628	-0.0514	-0.0833	0.3758	0.3628	X
	40	8.7416	49.8949	-32.7600	8.3436	49.9408	-32.8316	0.3980	-0.0459	-0.0716	0.4070	0.3980	X
B-PILLAR Lateral (Y)	37	10.9808	46.9421	-41.8116	10.4593	47.0208	-41.8591	0.5215	-0.0787	-0.0475	0.5295	-0.0787	Y
	38	8.3252	48.8627	-36.8958	7.9523	48.9166	-36.9581	0.3729	-0.0539	-0.0623	0.3819	-0.0539	Y
	39	11.8075	49.5715	-34.1772	11.4447	49.6229	-34.2605	0.3628	-0.0514	-0.0833	0.3758	-0.0514	Y
	40	8.7416	49.8949	-32.7600	8.3436	49.9408	-32.8316	0.3980	-0.0459	-0.0716	0.4070	-0.0459	Y

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

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-10. Occupant Compartment Deformation Data – Set 1, Test No. MGS7S-2

Model Year: 2016 | Test Name: MGS7S-2 | VIN: 1C6RR6FGXGS128241
Make: Ram | Model: 1500

VEHICLE DEFORMATION
PASSENGER SIDE INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	39.7279	3.3391	-26.8043	40.0179	3.6056	-26.7296	-0.2900	-0.2665	0.0747	0.4009	0.4009	X, Y, Z
	2	43.1365	21.5572	-26.5633	43.4580	21.8140	-26.5532	-0.3215	-0.2568	0.0101	0.4116	0.4116	X, Y, Z
	3	42.6785	33.6478	-25.3936	43.0430	33.9386	-25.4078	-0.3645	-0.2908	-0.0142	0.4665	0.4665	X, Y, Z
	4	36.8165	3.0267	-16.1807	37.1270	3.3457	-16.1186	-0.3105	-0.3190	0.0621	0.4495	0.4495	X, Y, Z
	5	38.9091	21.6359	-16.4361	39.2469	21.8781	-16.4158	-0.3378	-0.2422	0.0203	0.4162	0.4162	X, Y, Z
	6	39.8496	33.6719	-15.9057	40.1318	33.9096	-15.9171	-0.2822	-0.2377	-0.0114	0.3691	0.3691	X, Y, Z
SIDE PANEL (Y)	7	48.5435	35.4850	-3.3346	48.8068	35.2823	-3.2430	-0.2633	0.2027	0.0916	0.3447	0.2027	Y
	8	48.3947	35.3667	1.9032	48.5991	35.4517	1.9895	-0.2044	-0.0850	0.0863	0.2376	-0.0850	Y
	9	50.5612	35.3929	0.8014	50.7201	35.5176	0.8141	-0.1589	-0.1247	0.0127	0.2024	-0.1247	Y
IMPACT SIDE DOOR (Y)	10	36.9462	37.7560	-15.2429	36.9205	37.6470	-15.2176	0.0257	0.1090	0.0253	0.1148	0.1090	Y
	11	27.0414	37.9078	-14.7799	27.0563	38.0043	-14.9020	-0.0149	-0.0965	-0.1221	0.1563	-0.0965	Y
	12	16.8466	38.2062	-15.8151	16.8631	38.4331	-15.7931	-0.0165	-0.2269	0.0220	0.2286	-0.2269	Y
	13	35.3262	38.1950	0.7109	35.3401	38.1554	0.7243	-0.0139	0.0396	0.0134	0.0441	0.0396	Y
	14	27.0062	38.0796	0.9541	26.9810	38.1252	0.9449	0.0252	-0.0456	-0.0092	0.0529	-0.0456	Y
	15	18.6780	37.5612	-0.5328	18.5952	37.7062	-0.5169	0.0828	-0.1450	0.0159	0.1677	-0.1450	Y
ROOF - (Z)	16	35.6668	2.9807	-42.9358	35.9345	3.2258	-42.8782	-0.2677	-0.2451	0.0576	0.3675	0.0576	Z
	17	34.3438	18.1348	-42.4953	34.6627	18.3582	-42.4503	-0.3189	-0.2234	0.0450	0.3920	0.0450	Z
	18	31.5885	27.7089	-41.9632	31.8290	27.8935	-41.9886	-0.2405	-0.1846	-0.0254	0.3042	-0.0254	Z
	19	28.1239	1.2685	-45.8367	28.4232	1.4958	-45.7771	-0.2993	-0.2273	0.0596	0.3805	0.0596	Z
	20	25.7382	15.8505	-45.8795	26.0352	16.0489	-45.8459	-0.2970	-0.1984	0.0336	0.3587	0.0336	Z
	21	24.3924	26.0004	-45.2105	24.6435	26.1840	-45.2044	-0.2511	-0.1836	0.0061	0.3111	0.0061	Z
	22	9.6212	1.7785	-47.3447	9.9499	2.0215	-47.3170	-0.3287	-0.2430	0.0277	0.4097	0.0277	Z
	23	9.6655	14.6482	-47.1021	9.9455	14.8505	-47.0954	-0.2800	-0.2023	0.0067	0.3455	0.0067	Z
	24	9.1393	24.2838	-46.5423	9.5129	24.4517	-46.5477	-0.3736	-0.1679	-0.0054	0.4096	-0.0054	Z
	25	-4.5227	2.5271	-47.5046	-4.2374	2.7485	-47.5147	-0.2853	-0.2214	-0.0101	0.3613	-0.0101	Z
	26	-5.6862	14.3413	-47.3572	-5.0070	17.6131	-43.8041	-0.6792	-3.2718	3.5531	4.8776	3.5531	Z
	27	-5.0772	24.5904	-46.8009	-4.7565	24.7987	-46.8316	-0.3207	-0.2083	-0.0307	0.3836	-0.0307	Z
	28	-20.7251	2.9339	-47.1568	-20.4368	3.1279	-47.1808	-0.2883	-0.1940	-0.0240	0.3483	-0.0240	Z
	29	-20.5770	13.4912	-47.0899	-20.2901	13.7245	-47.1053	-0.2869	-0.2333	-0.0154	0.3701	-0.0154	Z
	30	-19.9558	24.1741	-46.7129	-19.6825	24.3859	-46.7418	-0.2733	-0.2118	-0.0289	0.3470	-0.0289	Z
A-PILLAR Maximum (X, Y, Z)	31	50.8232	34.9033	-27.0296	51.0591	35.1228	-26.8799	-0.2359	-0.2195	0.1497	0.3553	0.1497	Z
	32	45.4271	33.6227	-30.9801	45.6889	33.8206	-30.9107	-0.2618	-0.1979	0.0694	0.3354	0.0694	Z
	33	39.6887	32.3789	-35.4218	39.9003	32.5806	-35.3882	-0.2116	-0.2017	0.0336	0.2943	0.0336	Z
	34	35.2021	31.4530	-38.8286	35.3733	31.6575	-38.8158	-0.1712	-0.2045	0.0128	0.2670	0.0128	Z
	35	32.6830	30.7494	-40.0530	32.8879	30.9695	-40.0723	-0.2049	-0.2201	-0.0193	0.3013	0.0000	NA
	36	30.8986	30.0645	-40.8239	31.1033	30.2707	-40.9180	-0.2047	-0.2062	-0.0941	0.3054	0.0000	NA
A-PILLAR Lateral (Y)	31	50.8232	34.9033	-27.0296	51.0591	35.1228	-26.8799	-0.2359	-0.2195	0.1497	0.3553	-0.2195	Y
	32	45.4271	33.6227	-30.9801	45.6889	33.8206	-30.9107	-0.2618	-0.1979	0.0694	0.3354	-0.1979	Y
	33	39.6887	32.3789	-35.4218	39.9003	32.5806	-35.3882	-0.2116	-0.2017	0.0336	0.2943	-0.2017	Y
	34	35.2021	31.4530	-38.8286	35.3733	31.6575	-38.8158	-0.1712	-0.2045	0.0128	0.2670	-0.2045	Y
	35	32.6830	30.7494	-40.0530	32.8879	30.9695	-40.0723	-0.2049	-0.2201	-0.0193	0.3013	-0.2201	Y
	36	30.8986	30.0645	-40.8239	31.1033	30.2707	-40.9180	-0.2047	-0.2062	-0.0941	0.3054	-0.2062	Y
B-PILLAR Maximum (X, Y, Z)	37	7.5620	31.5269	-37.7272									X, Y, Z
	38	4.9042	33.4058	-32.7965									X, Y, Z
	39	8.3890	34.1496	-30.0905									X, Y, Z
	40	5.3253	34.4339	-28.6602									X, Y, Z
B-PILLAR Lateral (Y)	37	7.5620	31.5269	-37.7272									Y
	38	4.9042	33.4058	-32.7965									Y
	39	8.3890	34.1496	-30.0905									Y
	40	5.3253	34.4339	-28.6602									Y

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

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure D-11. Occupant Compartment Deformation Data – Set 2, Test No. MGS7S-2

Test Name:	MGS7S-2	VIN:	1C6RR6FGXGS128241
Model Year: 2016	Make: Ram	Model:	1500

Passenger Side Maximum Deformation

Reference Set 1				Reference Set 2			
Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]	Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	0.2	≤ 4	Z	Roof	3.6	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.6	≤ 5	X	A-Pillar Maximum	0.1	≤ 5	Z
A-Pillar Lateral	-0.1	≤ 3	Y	A-Pillar Lateral	-0.2	≤ 3	Y
B-Pillar Maximum	0.5	≤ 5	X	B-Pillar Maximum	0.0	≤ 5	NA
B-Pillar Lateral	-0.1	≤ 3	Y	B-Pillar Lateral	0.0	≤ 3	Y
Toe Pan - Wheel Well	0.6	≤ 9	X, Z	Toe Pan - Wheel Well	0.0	≤ 9	Z
Side Front Panel	0.4	≤ 12	Y	Side Front Panel	0.2	≤ 12	Y
Side Door (above seat)	0.3	≤ 9	Y	Side Door (above seat)	0.1	≤ 9	Y
Side Door (below seat)	0.3	≤ 12	Y	Side Door (below seat)	0.0	≤ 12	Y
Floor Pan	0.5	≤ 12	Z	Floor Pan	0.0	≤ 12	Z
Dash - no MASH requirement	0.6	NA	X, Y, Z	Dash - no MASH requirement	0.5	NA	X, Y, Z

[A] Items highlighted in red do not meet MASH allowable deformations.

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

[C] For Toe Pan - Wheel Well the direction of defromation may include X and Z direction. For A-Pillar Maximum and B-Pillar Maximum the direction of deformation may include X, Y, and Z directions. The direction of deformation for Toe Pan -Wheel Well, A-Pillar Maximum, and B-Pillar Maximum only include components where the deformation is positive and intruding into the occupant compartment. If direction of deformation is "NA" then no intrusion is recorded and deformation will be 0.

[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

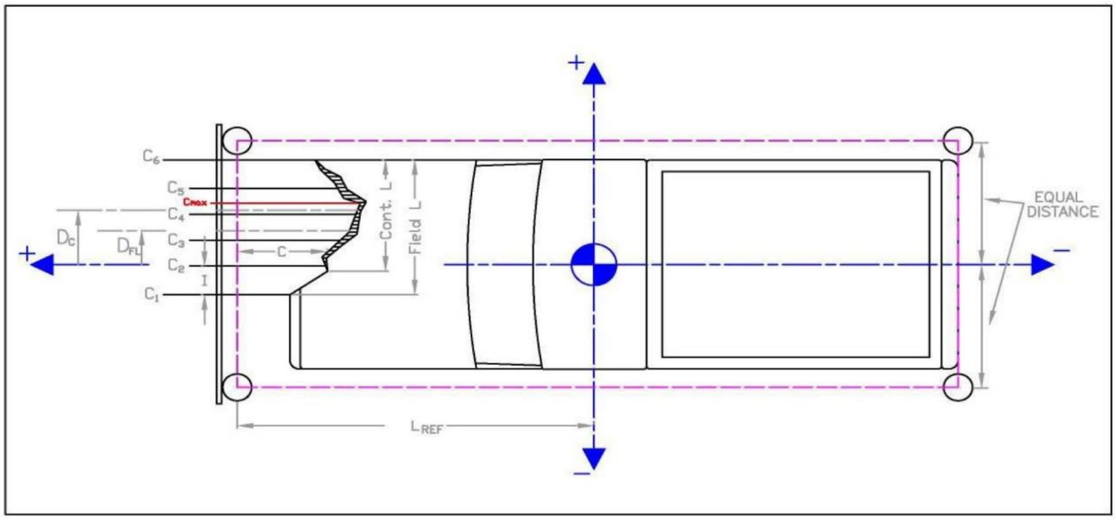
Notes on vehicle interior crush:

Interior crush set 2 (secondary) points are missing the B-pillar information due to bad data transfer.

Figure D-12. Maximum Occupant Compartment Deformation by Location, Test No. MGS7S-2

Test Name: MGS7S-2 | VIN: 1C6RR6FGXGS128241

Model Year: 2016 | Make: Ram | Model: 1500



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	115	(2921)
Total Vehicle Width:	78 1/8	(1984)
Width of contact and induced crush - Field L:	78 1/8	(1984)
Crush measurement spacing interval (L/5) - I:	15 5/8	(397)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	18	(456)
Distance from center of vehicle to center of contact damage - D_C:	21	(533)

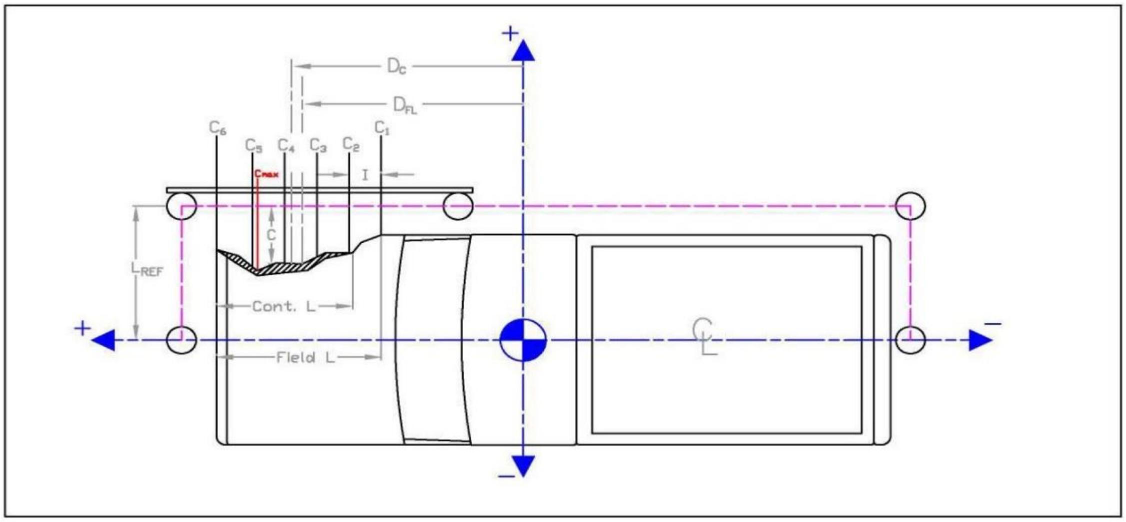
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	n/a	N/A	-39 1/8	-(994)	22 1/2	(572)	5 1/4	(133)	N/A	N/A
C_2	11 3/4	(298)	-23 1/2	-(597)	6 5/8	(168)			- 1/8	-(3)
C_3	9 1/8	(232)	-7 7/8	-(200)	4 1/4	(108)			- 3/8	-(10)
C_4	10	(254)	7 3/4	(197)	4 1/4	(108)			1/2	(13)
C_5	20 3/4	(527)	23 3/8	(594)	6 1/4	(159)			9 1/4	(235)
C_6	n/a	N/A	39	(991)	20 1/2	(521)			N/A	N/A
C_{MAX}	20 3/4	(527)	23 3/8	(594)	6 1/4	(159)			9 1/4	(235)

Figure D-13. Exterior Vehicle Crush (NASS) – Front, Test No. MGS7S-2

Test Name: MGS7S-2 VIN: 1C6RR6FGXGS128241

Model Year: 2016 Make: Ram Model: 1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	49	(1245)
Total Vehicle Length:	229 1/2	(5829)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-7 5/8	-(194)
Width of contact and induced crush - Field L:	229 1/2	(5829)
Crush measurement spacing interval (L/5) - I:	45 7/8	(1165)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-7 5/8	-(194)
Width of Contact Damage:	229 1/2	(5829)
Distance from vehicle c.g. to center of contact damage - D_C:	-7 5/8	-(194)

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

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual	Crush
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	n/a	N/A	-122 3/8	-(3108)	33 1/2	(851)	5	(127)	N/A	N/A
C_2	n/a	N/A	-76 1/2	-(1943)	5 1/2	(140)			N/A	N/A
C_3	9 3/8	(238)	-30 5/8	-(778)	5 7/8	(149)			-1 1/2	-(38)
C_4	9 1/4	(235)	15 1/4	(387)	5	(127)			- 3/4	-(19)
C_5	N/a	N/A	61 1/8	(1553)	5 7/8	(149)			N/A	N/A
C_6	N/a	N/A	107	(2718)	11 7/8	(302)			N/A	N/A
C_{MAX}	19 1/4	(489)	81	(2057)	5 1/4	(133)			9	(229)

Figure D-14. Exterior Vehicle Crush (NASS) – Side, Test No. MGS7S-2

Appendix E. Accelerometer and Rate Transducer Data Plots, Test No. MGS7S-1

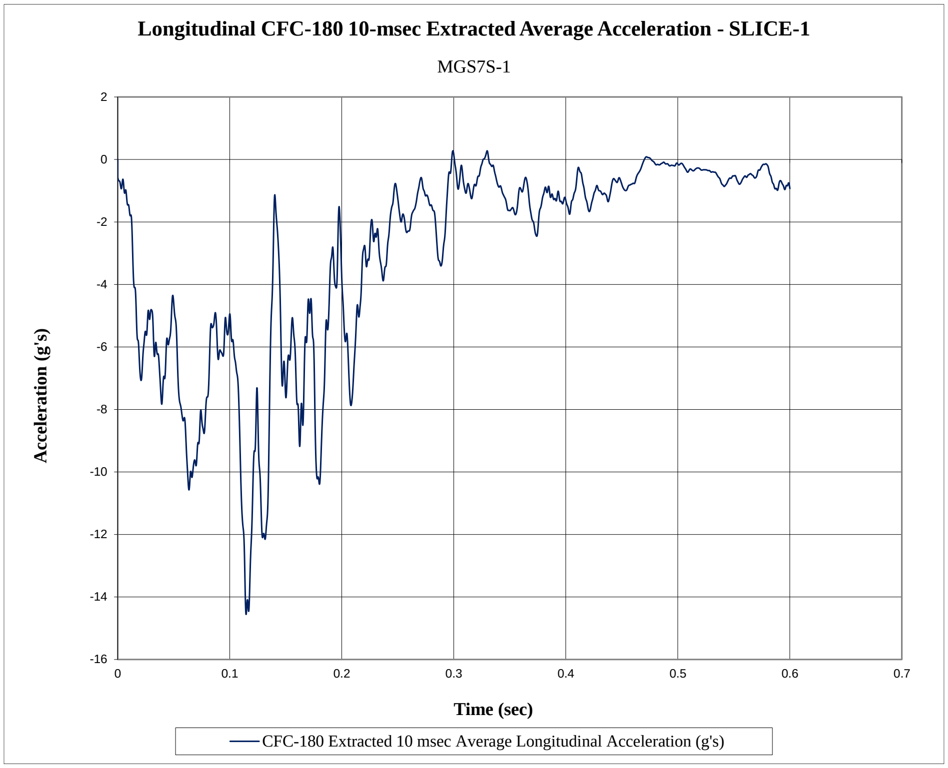


Figure E-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. MGS7S-1

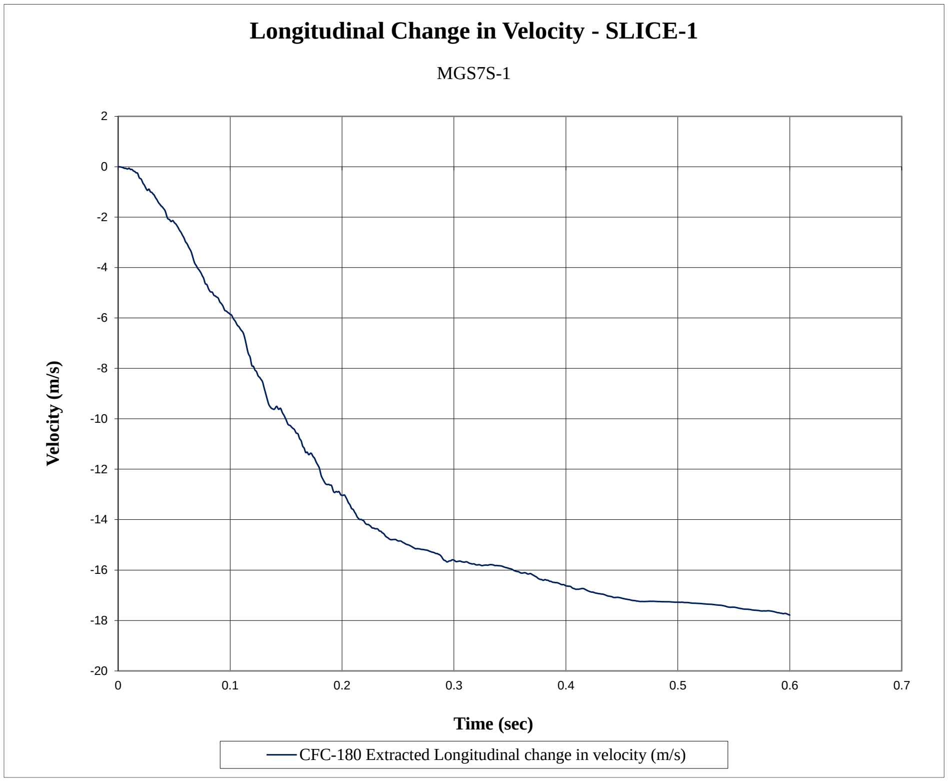


Figure E-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. MGS7S-1

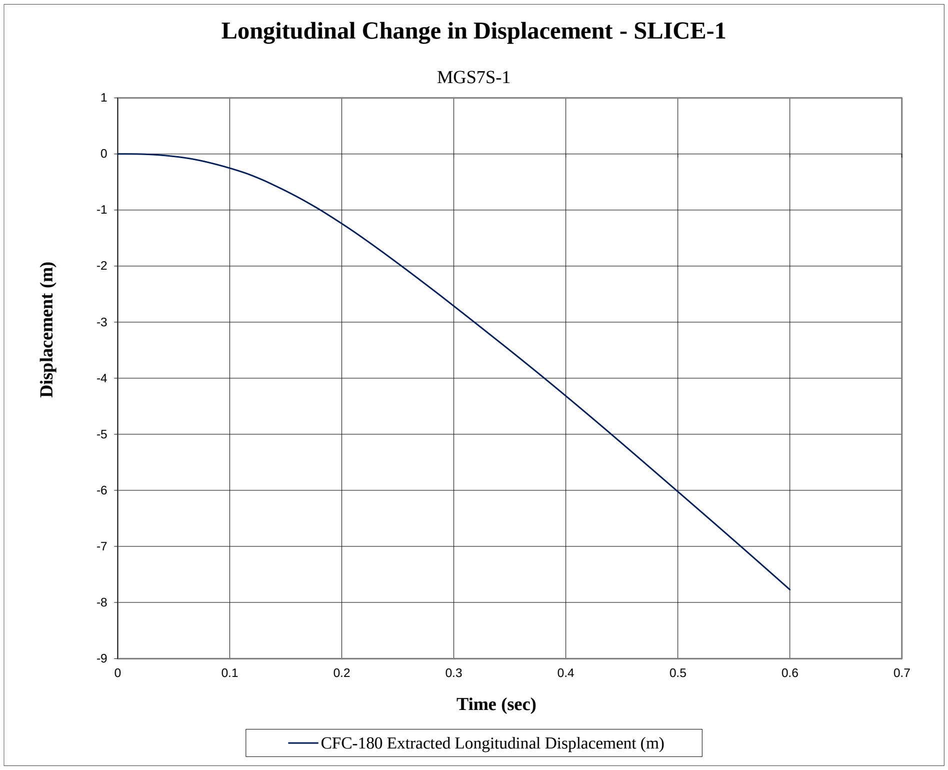


Figure E-3. Longitudinal Occupant Displacement (SLICE-1), Test No. MGS7S-1

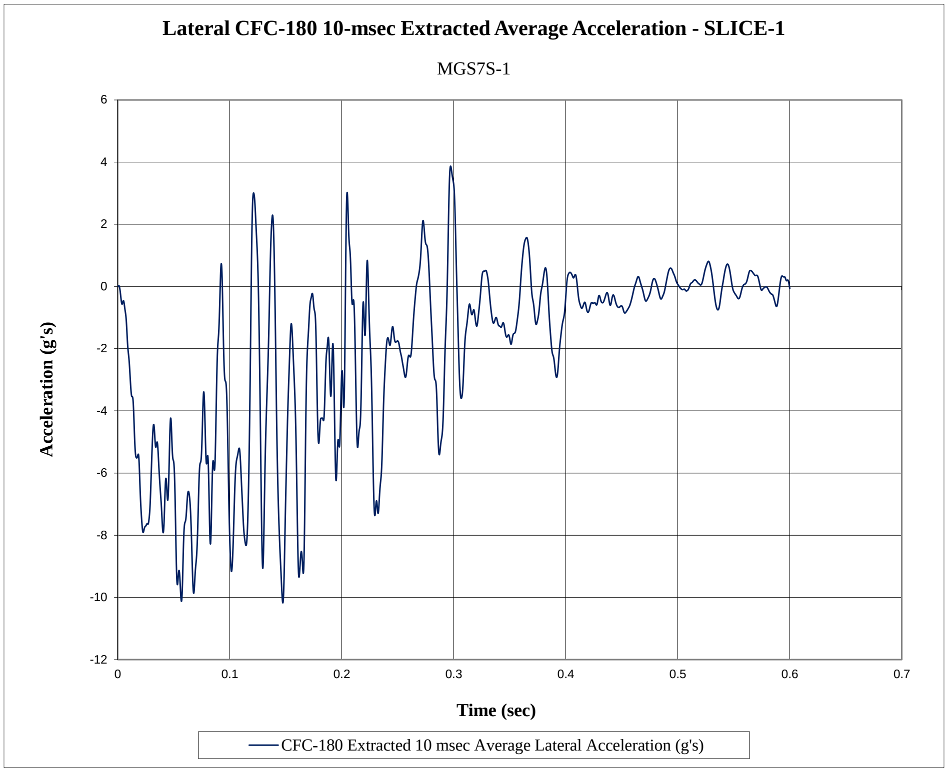


Figure E-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. MGS7S-1

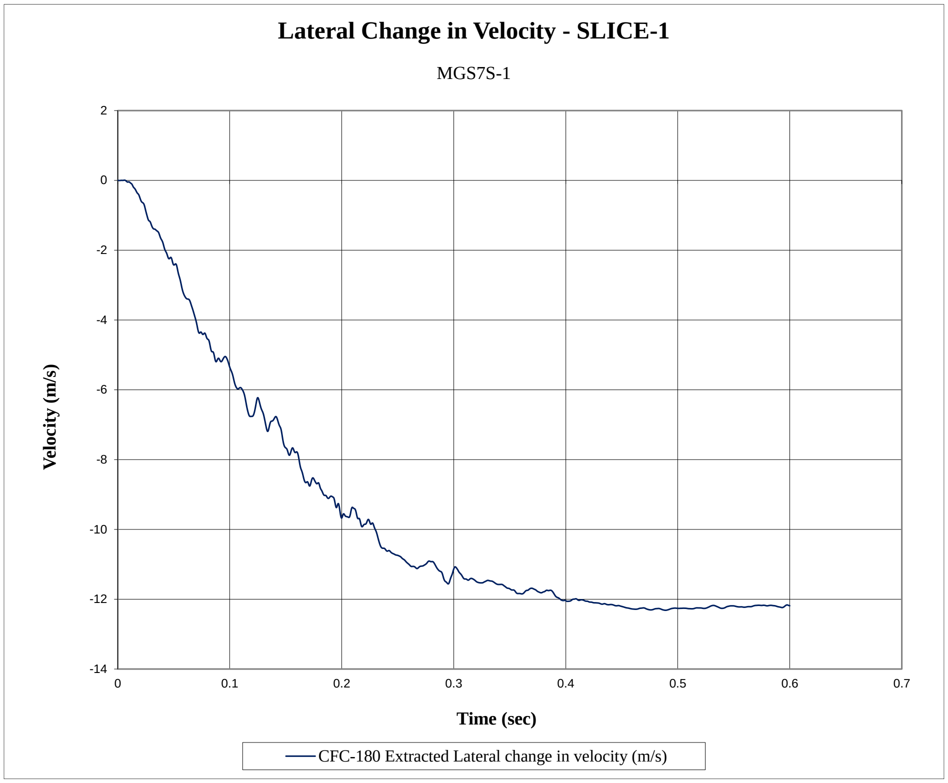


Figure E-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. MGS7S-1

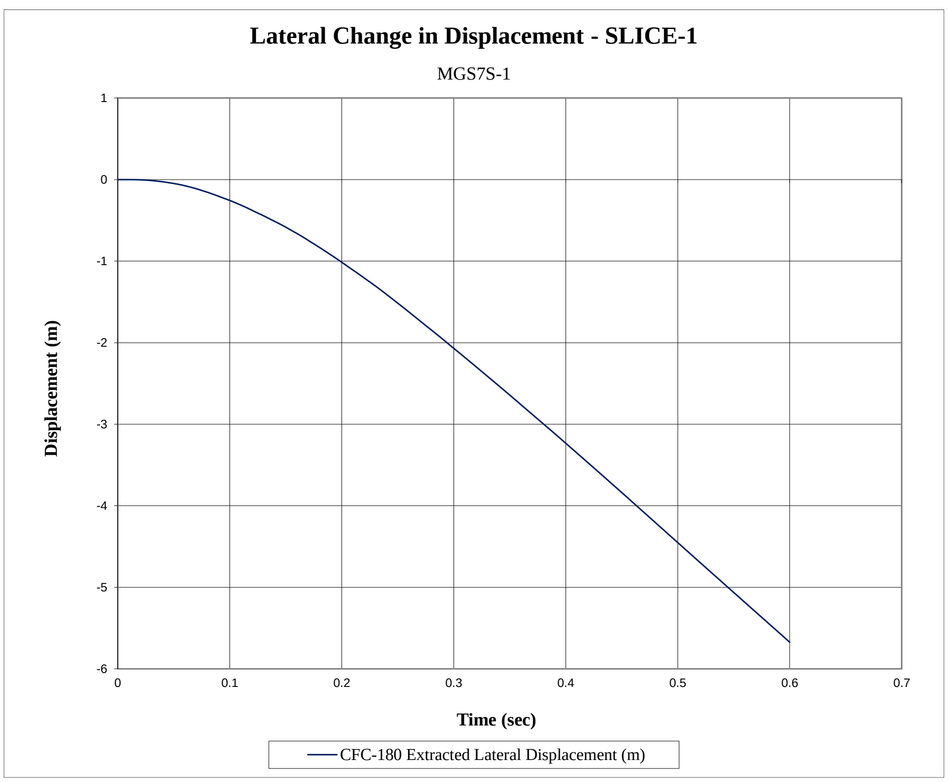


Figure E-6. Lateral Occupant Displacement (SLICE-1), Test No. MGS7S-1

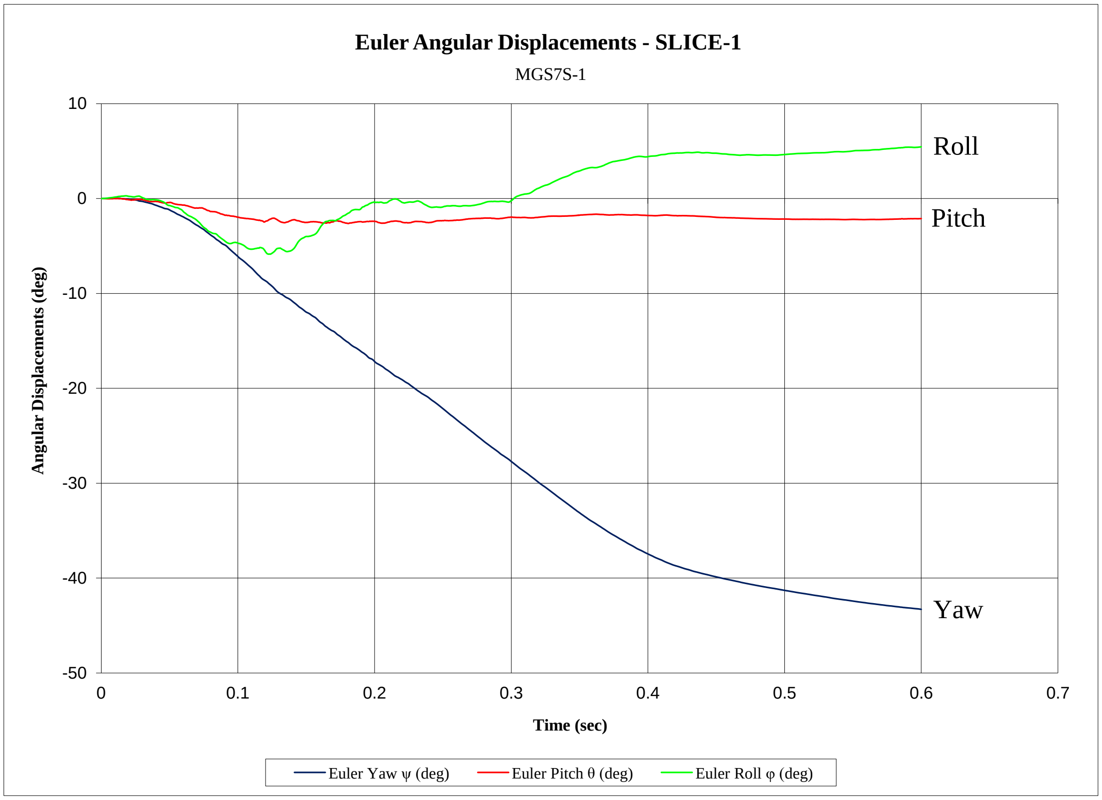


Figure E-7. Vehicle Angular Displacements (SLICE-1), Test No. MGS7S-1

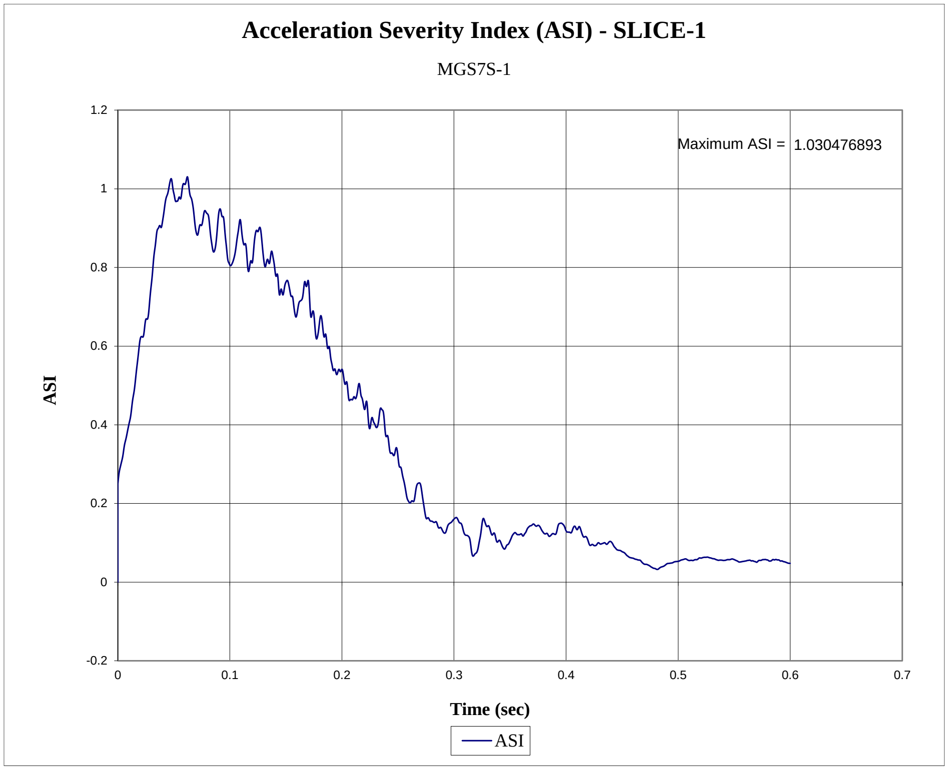


Figure E-8. Acceleration Severity Index (SLICE-1), Test No. MGS7S-1

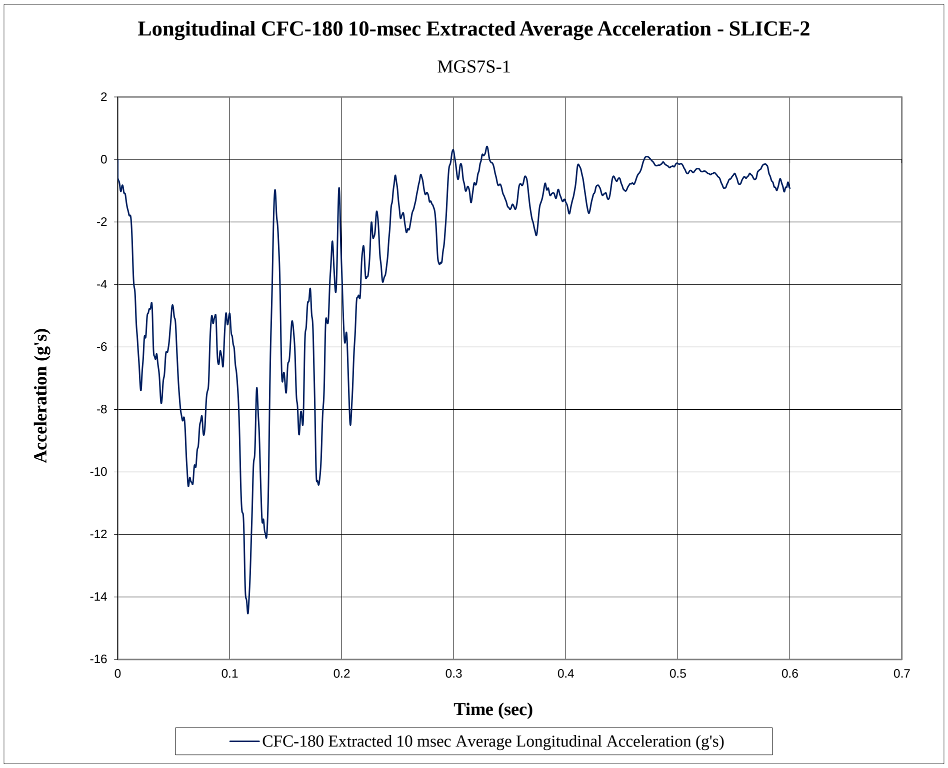


Figure E-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. MGS7S-1

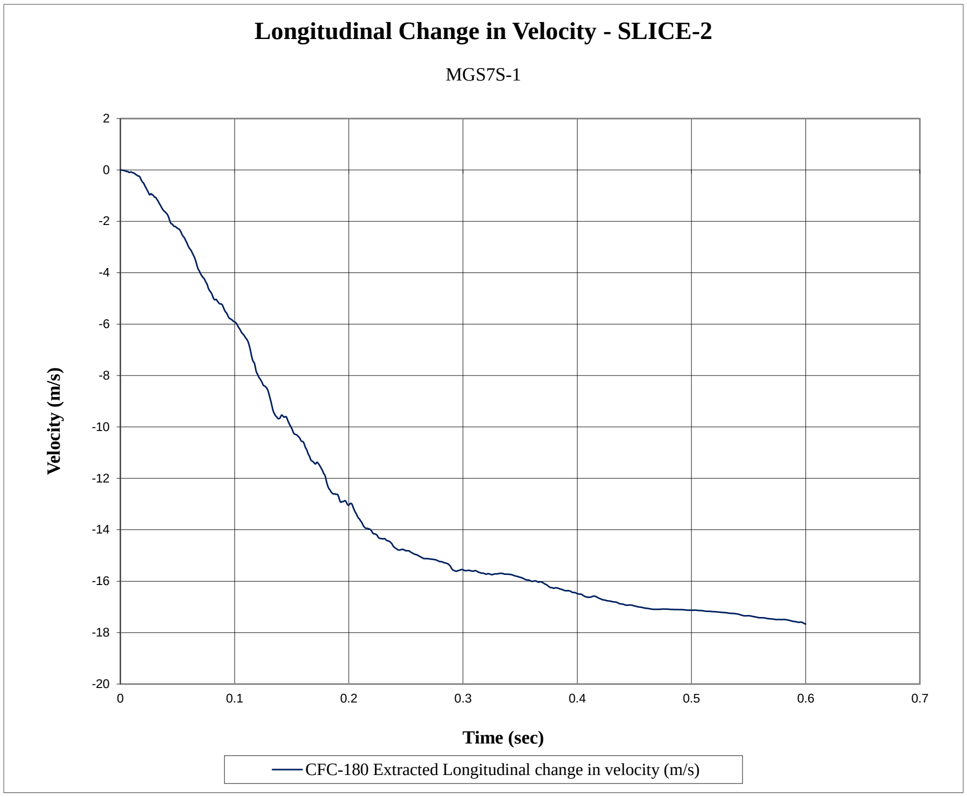


Figure E-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. MGS7S-1

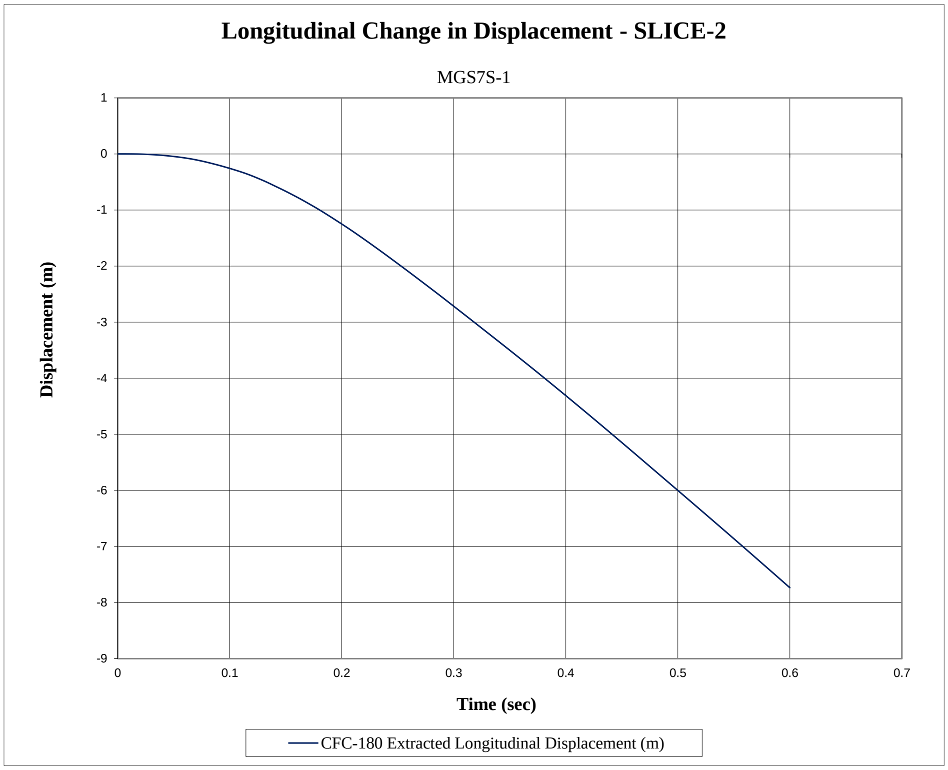


Figure E-11. Longitudinal Occupant Displacement (SLICE-2), Test No. MGS7S-1

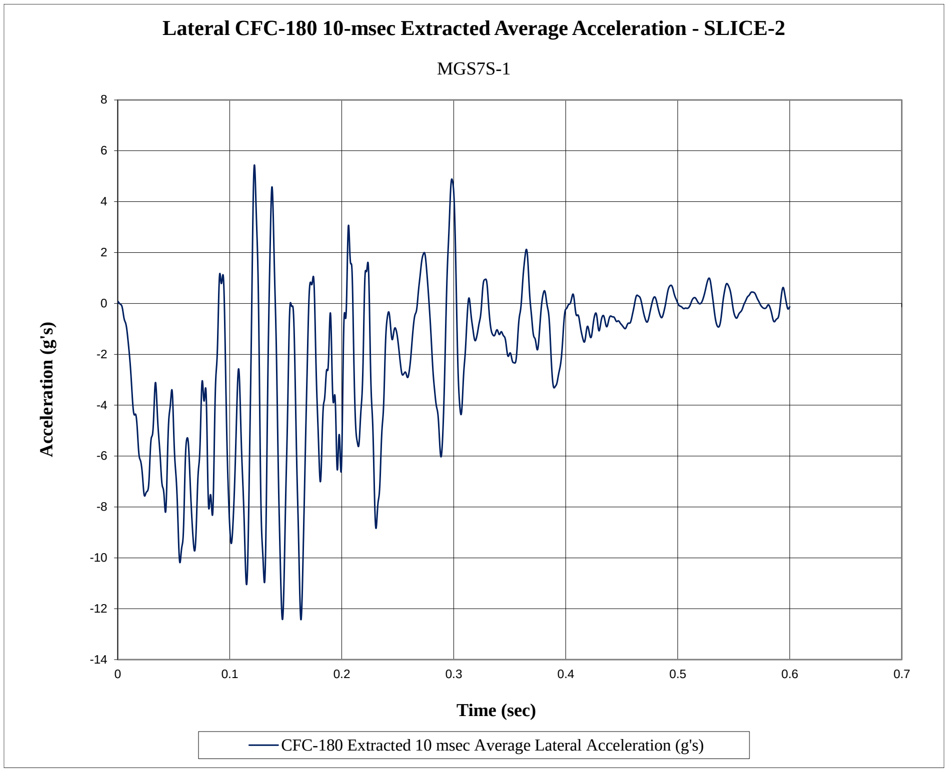


Figure E-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. MGS7S-1

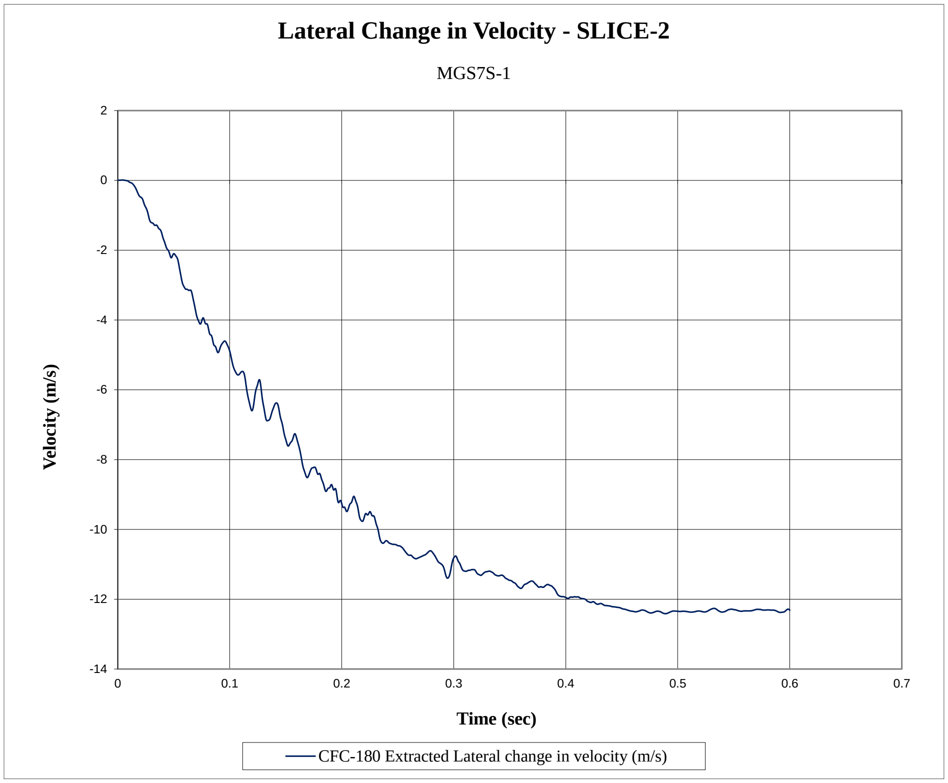


Figure E-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. MGS7S-1

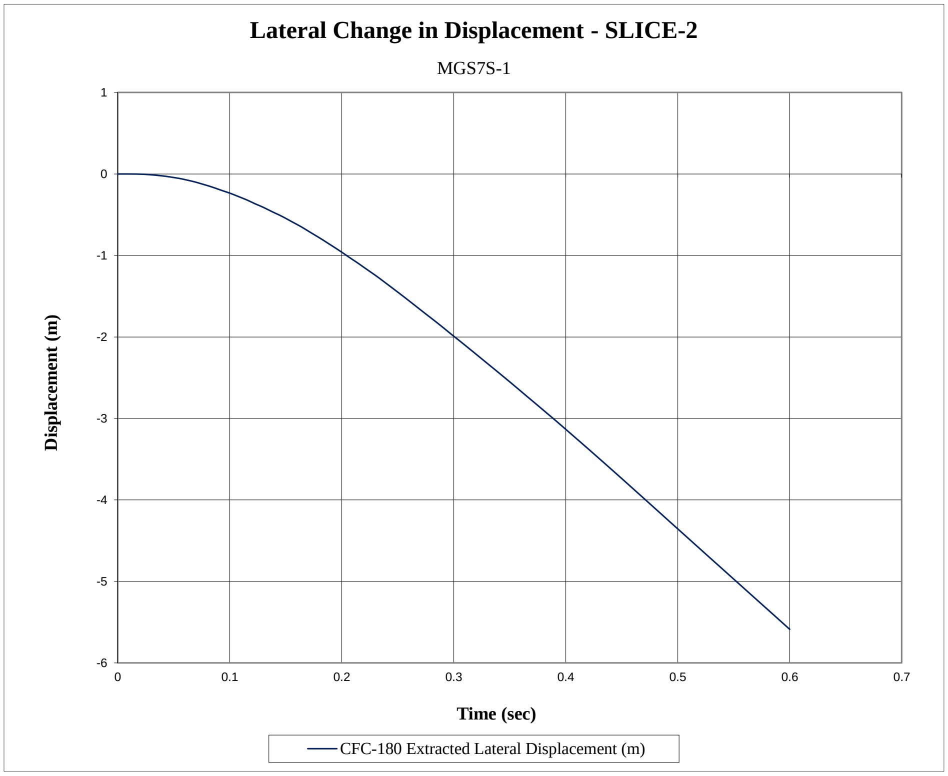


Figure E-14. Lateral Occupant Displacement (SLICE-2), Test No. MGS7S-1

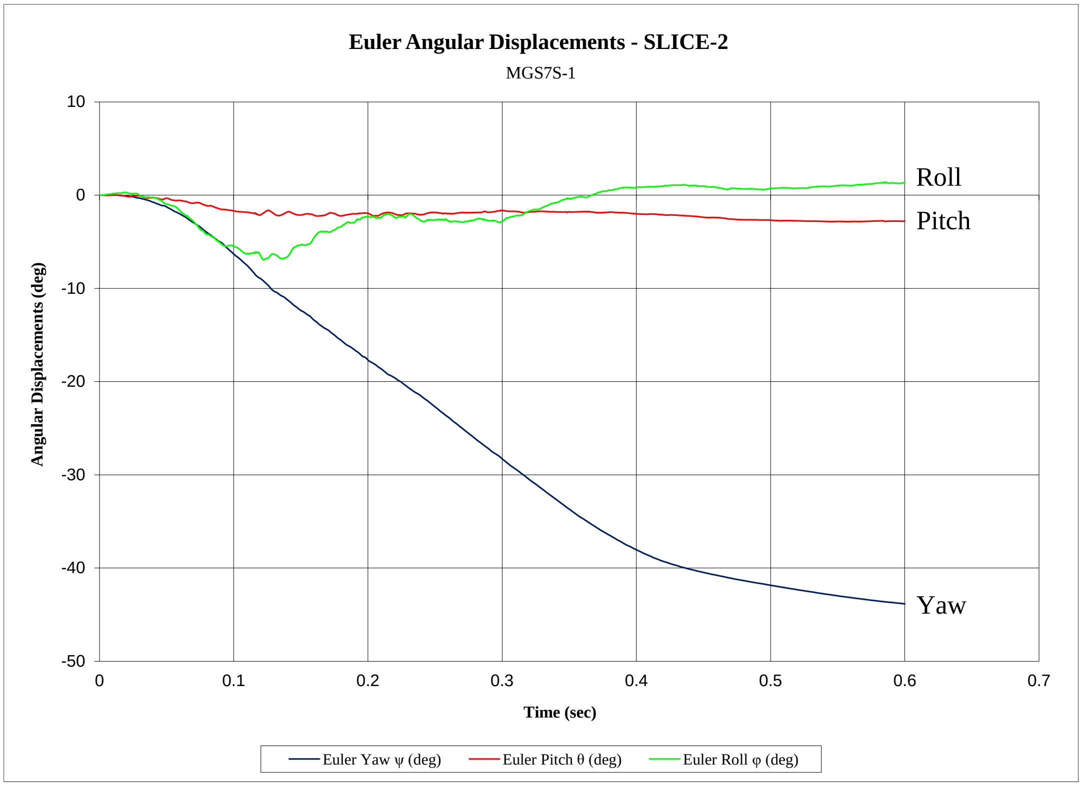


Figure E-15. Vehicle Angular Displacements (SLICE-2), Test No. MGS7S-1

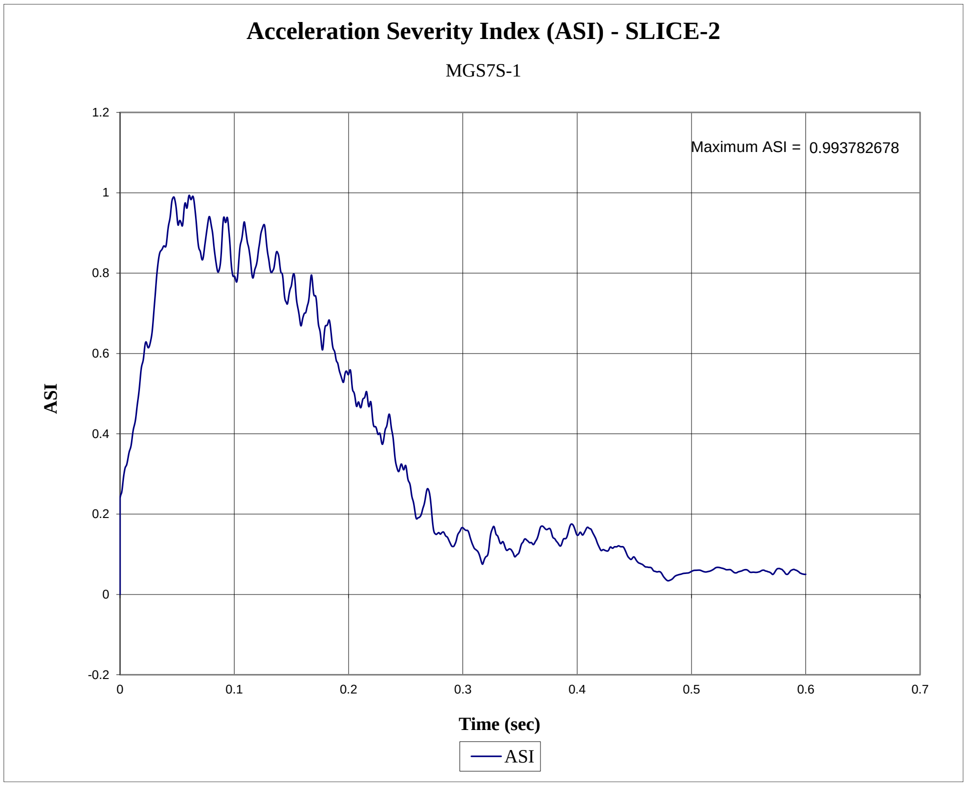


Figure E-16. Acceleration Severity Index (SLICE-2), Test No. MGS7S-1

Appendix F. Accelerometer and Rate Transducer Data Plots, Test No. MGS7S-2

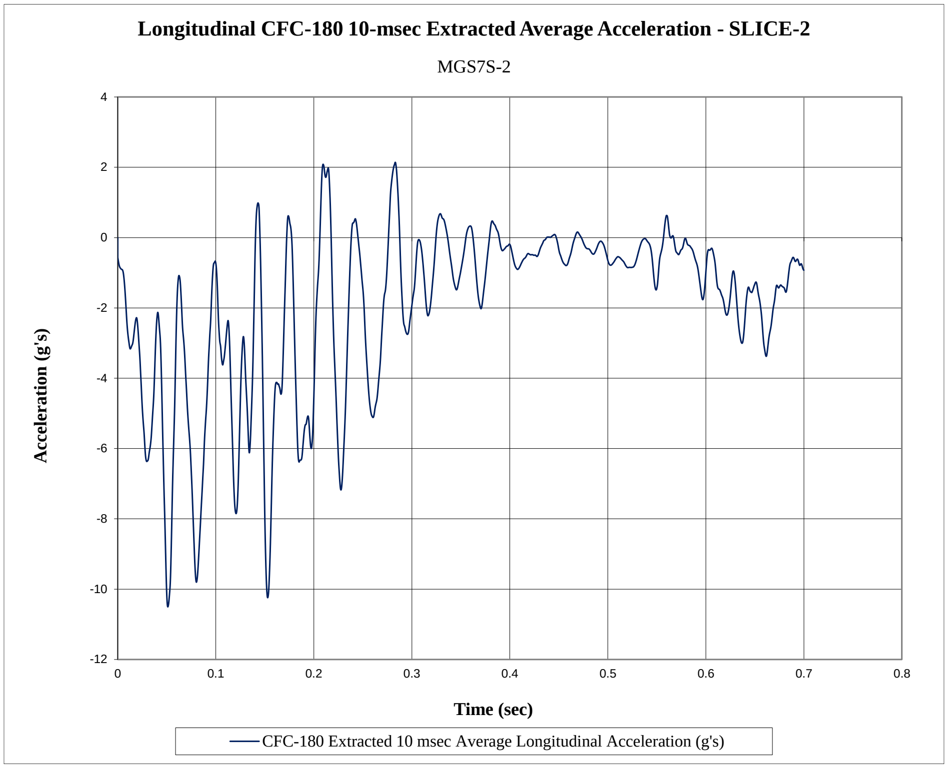


Figure F-1. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. MGS7S-2

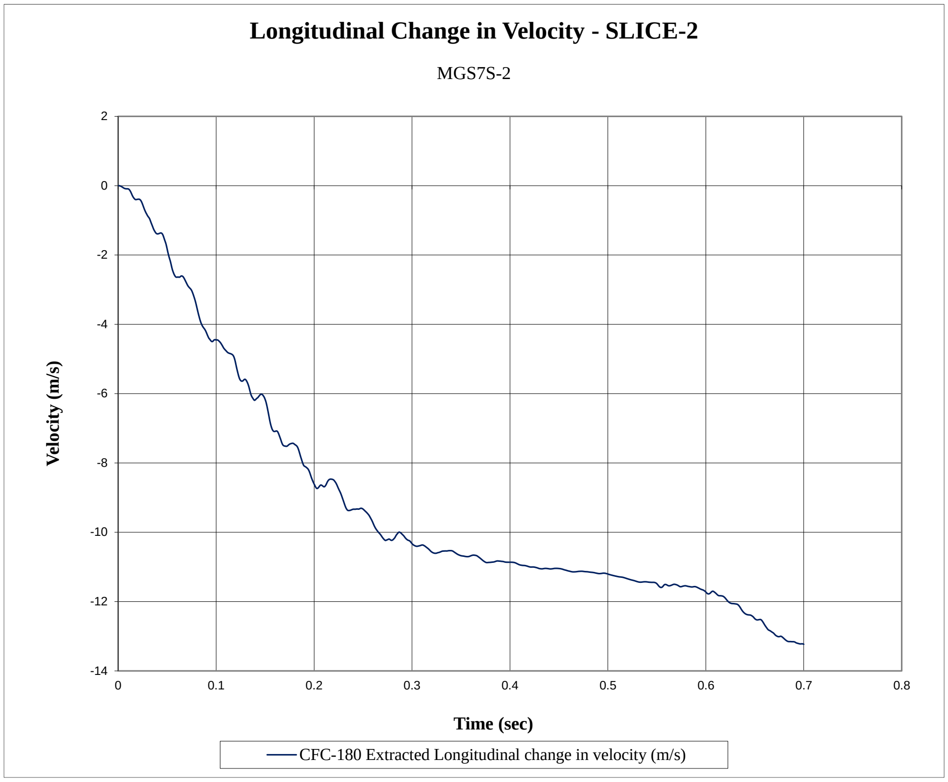


Figure F-2. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. MGS7S-2

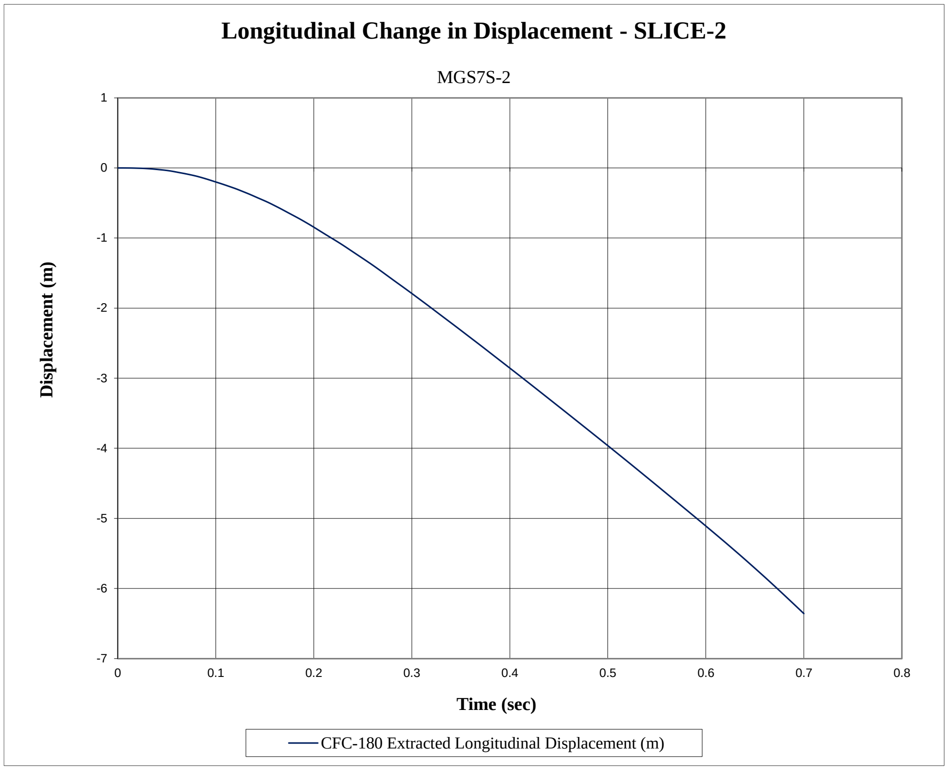


Figure F-3. Longitudinal Occupant Displacement (SLICE-2), Test No. MGS7S-2

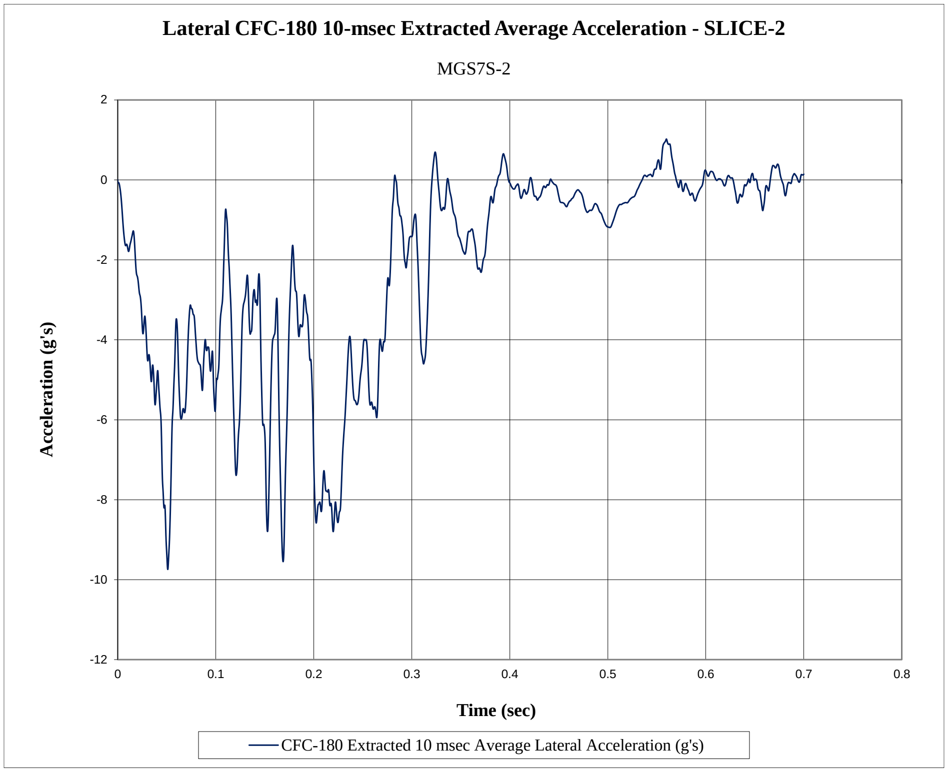


Figure F-4. 10-ms Average Lateral Deceleration (SLICE-2), Test No. MGS7S-2

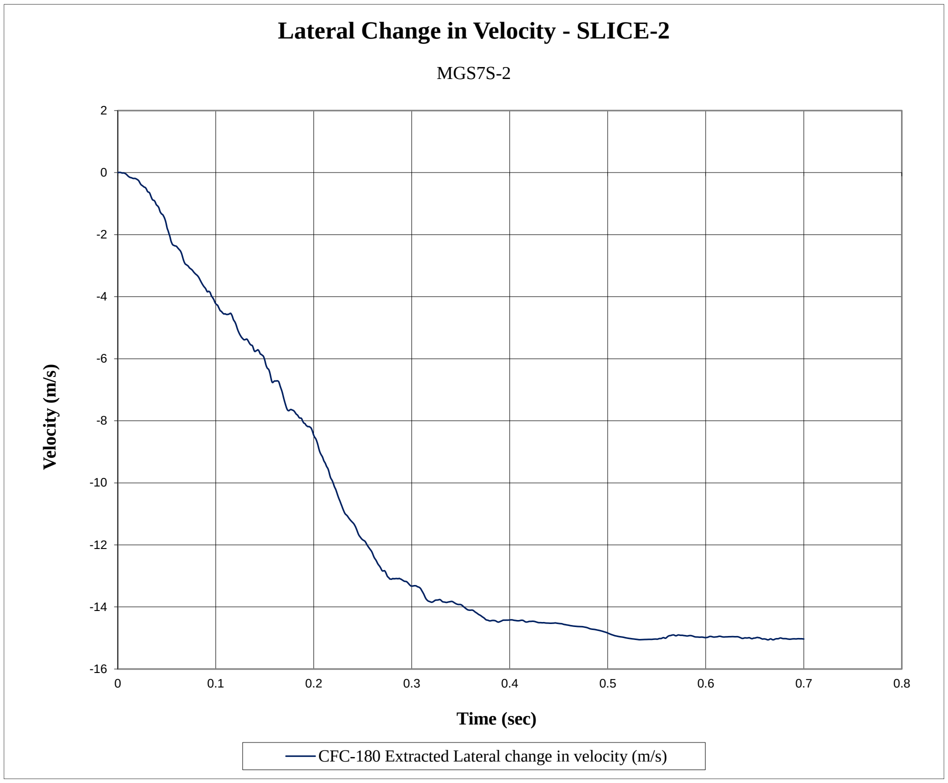


Figure F-5. Lateral Occupant Impact Velocity (SLICE-2), Test No. MGS7S-2

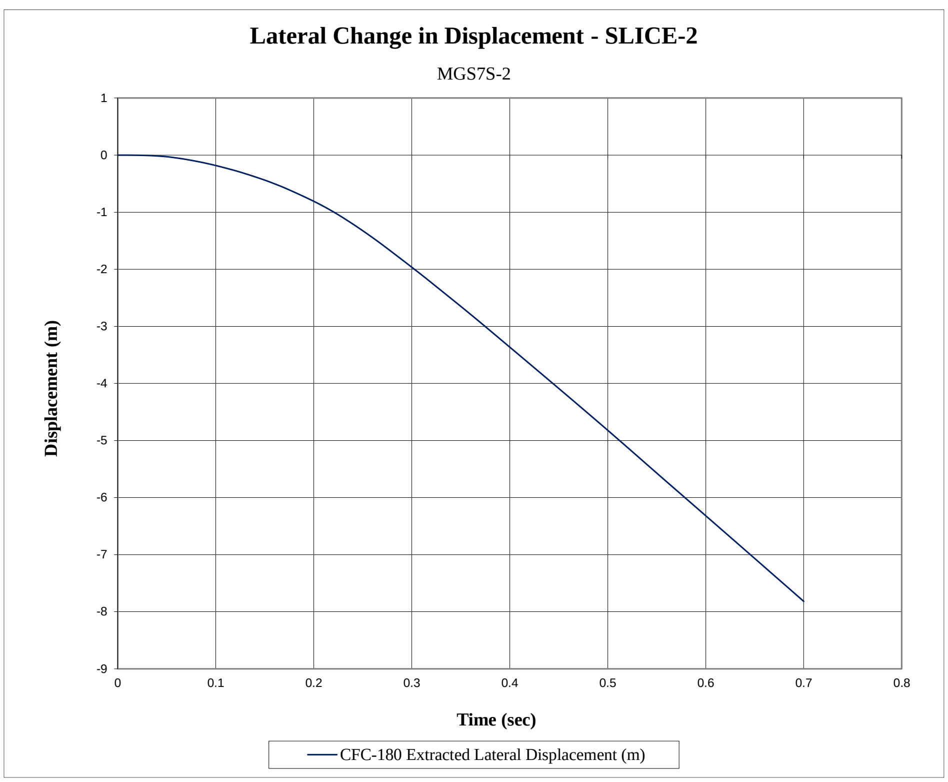


Figure F-6. Lateral Occupant Displacement (SLICE-2), Test No. MGS7S-2

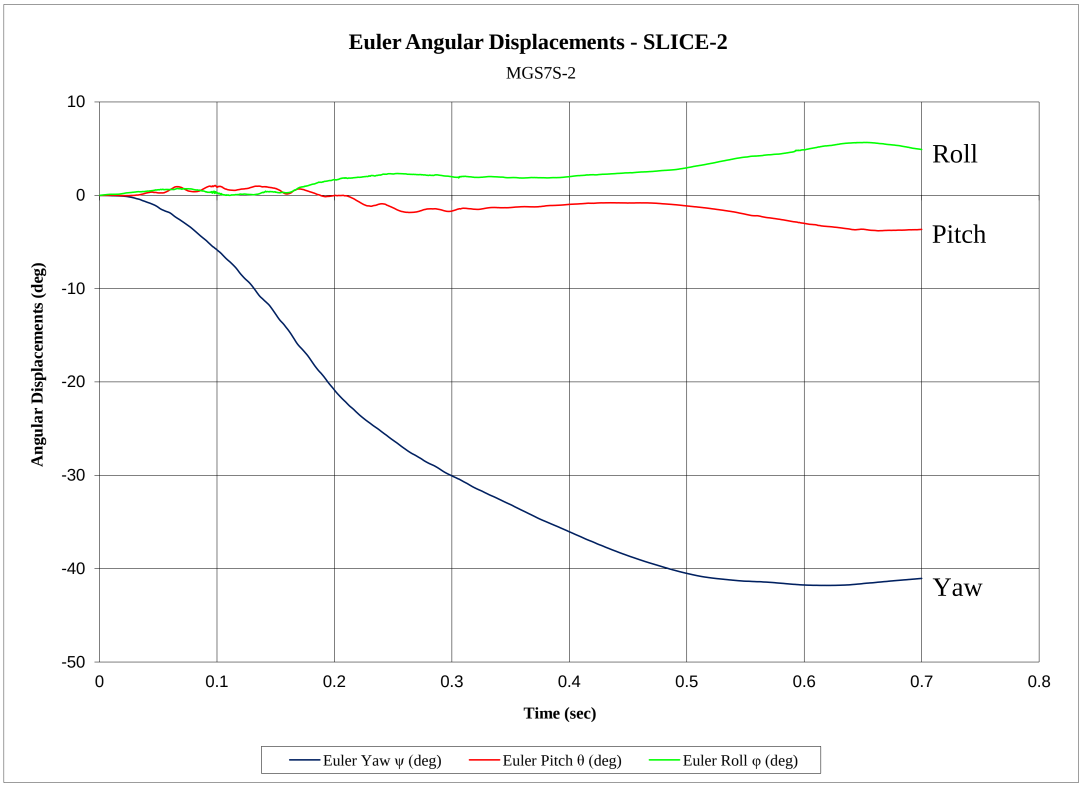


Figure F-7. Vehicle Angular Displacements (SLICE-2), Test No. MGS7S-2

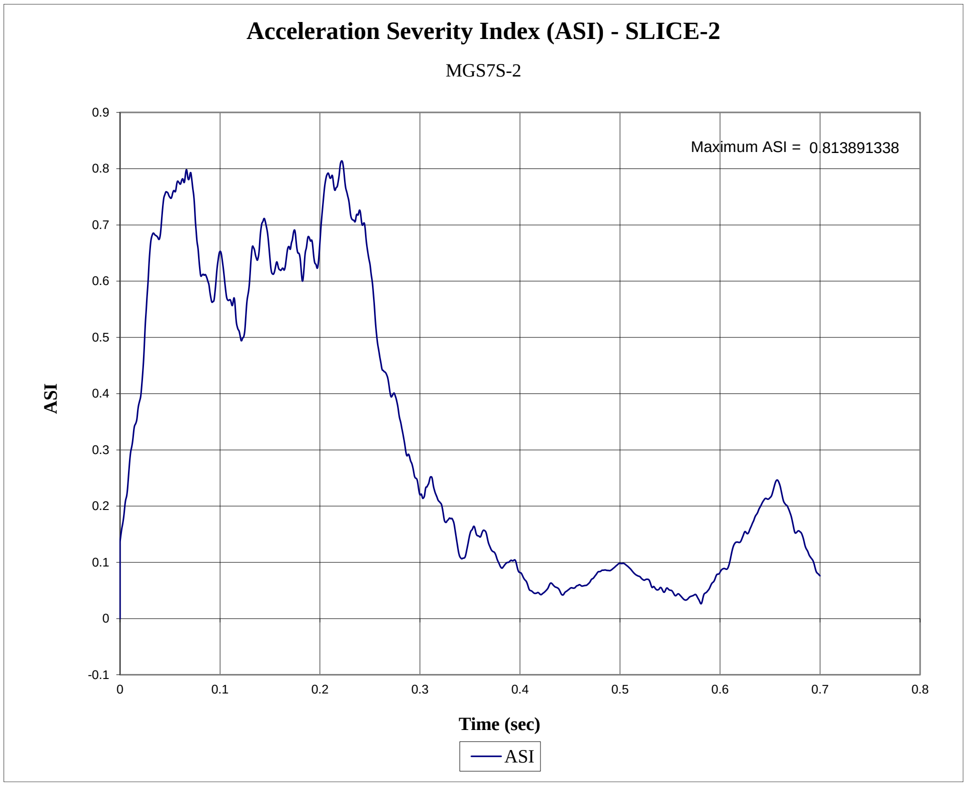


Figure F-8. Acceleration Severity Index (SLICE-2), Test No. MGS7S-2

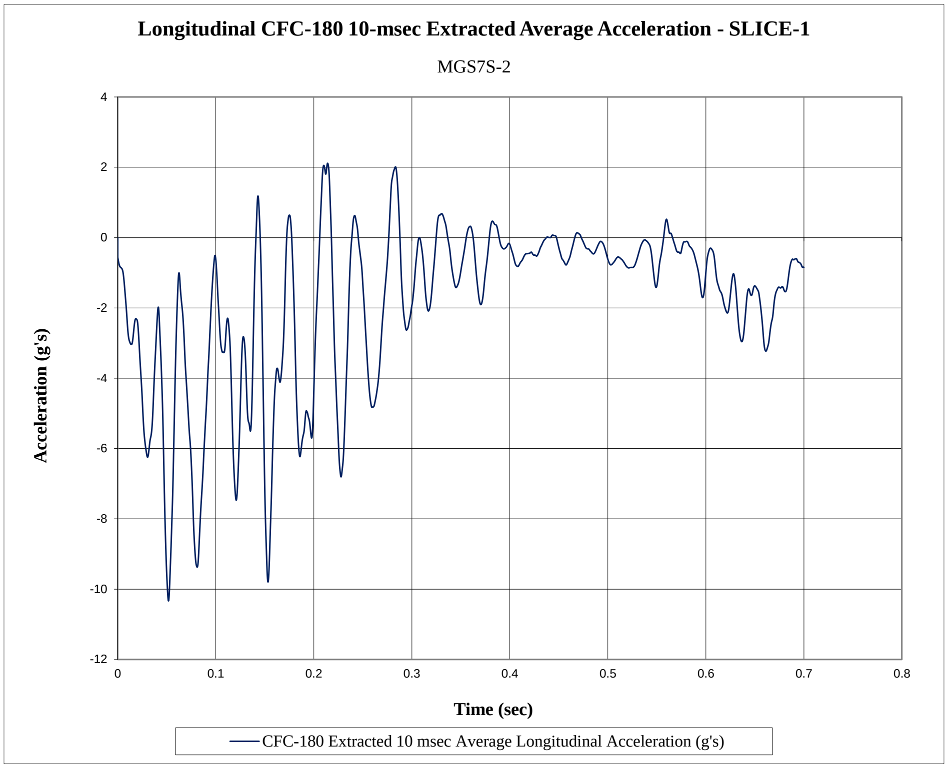


Figure F-9. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. MGS7S-2

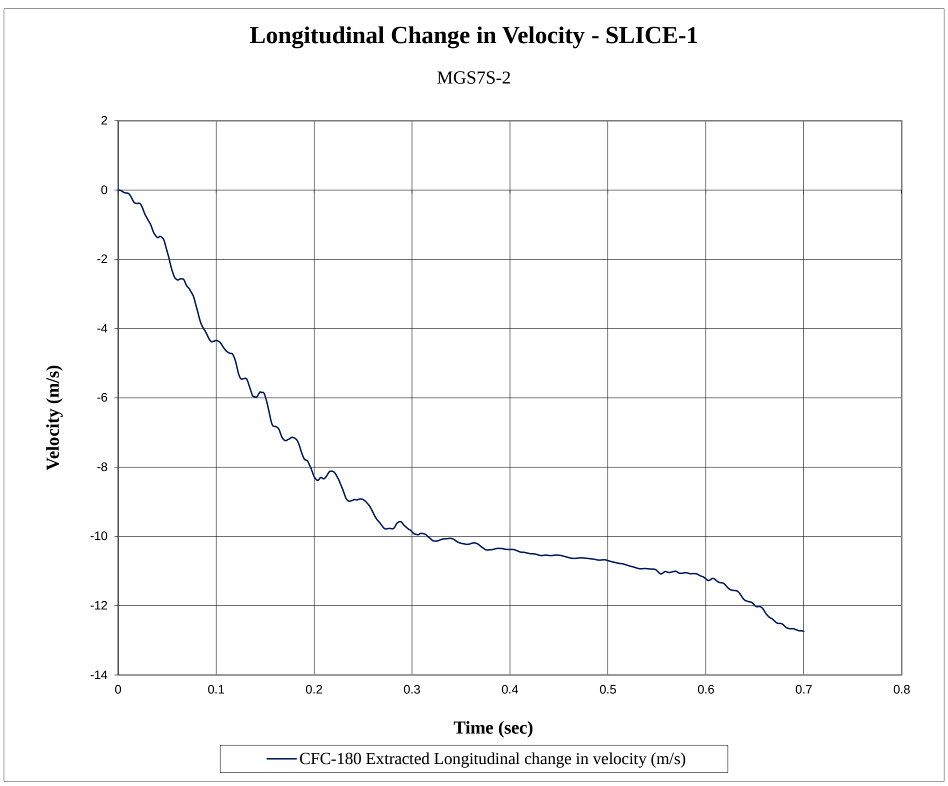


Figure F-10. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. MGS7S-2

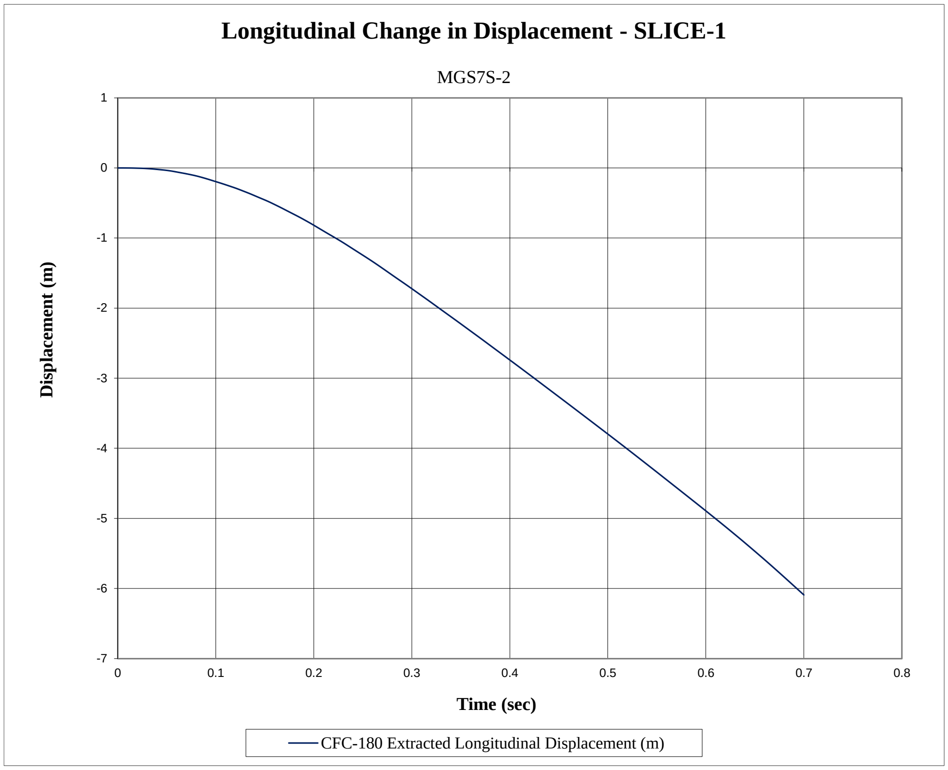


Figure F-11. Longitudinal Occupant Displacement (SLICE-1), Test No. MGS7S-2

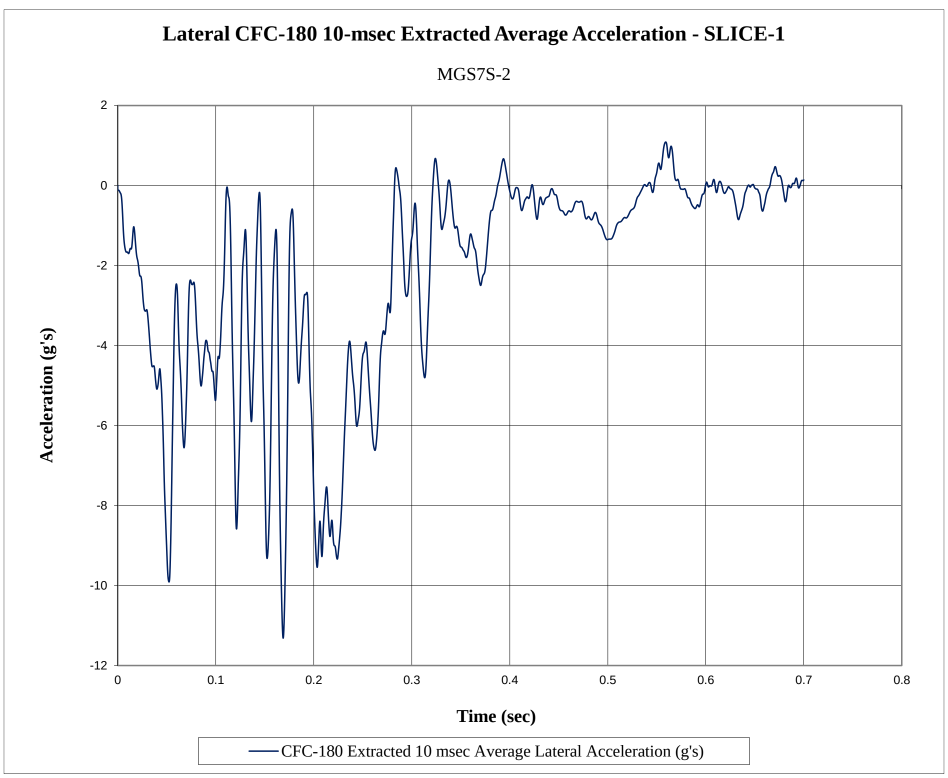


Figure F-12. 10-ms Average Lateral Deceleration (SLICE-1), Test No. MGS7S-2

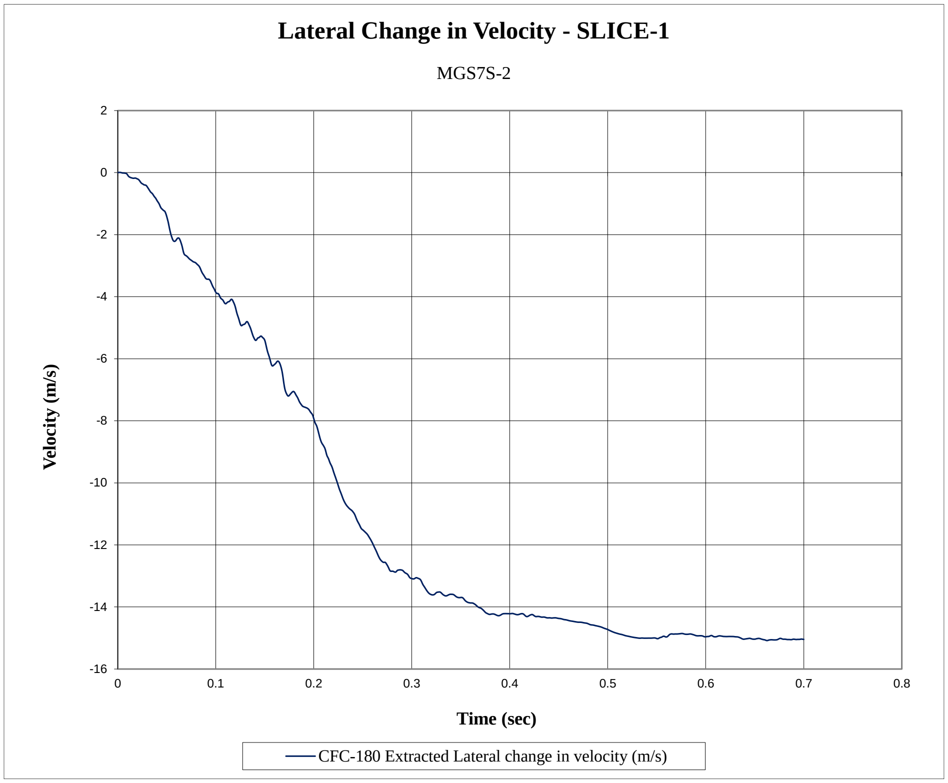


Figure F-13. Lateral Occupant Impact Velocity (SLICE-1), Test No. MGS7S-2

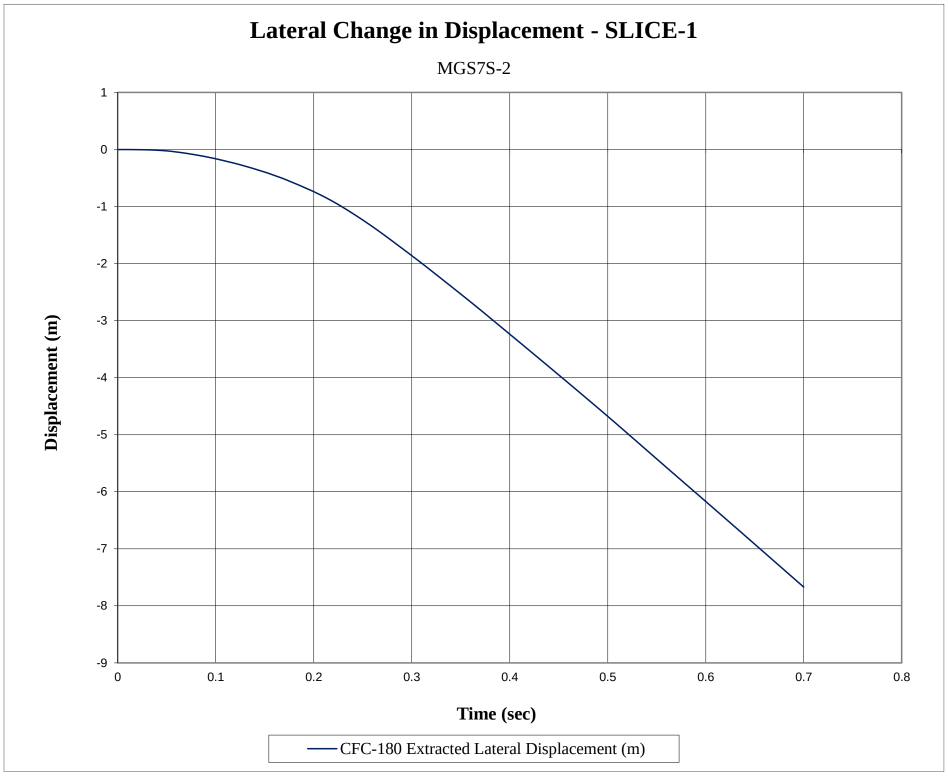


Figure F-14. Lateral Occupant Displacement (SLICE-1), Test No. MGS7S-2

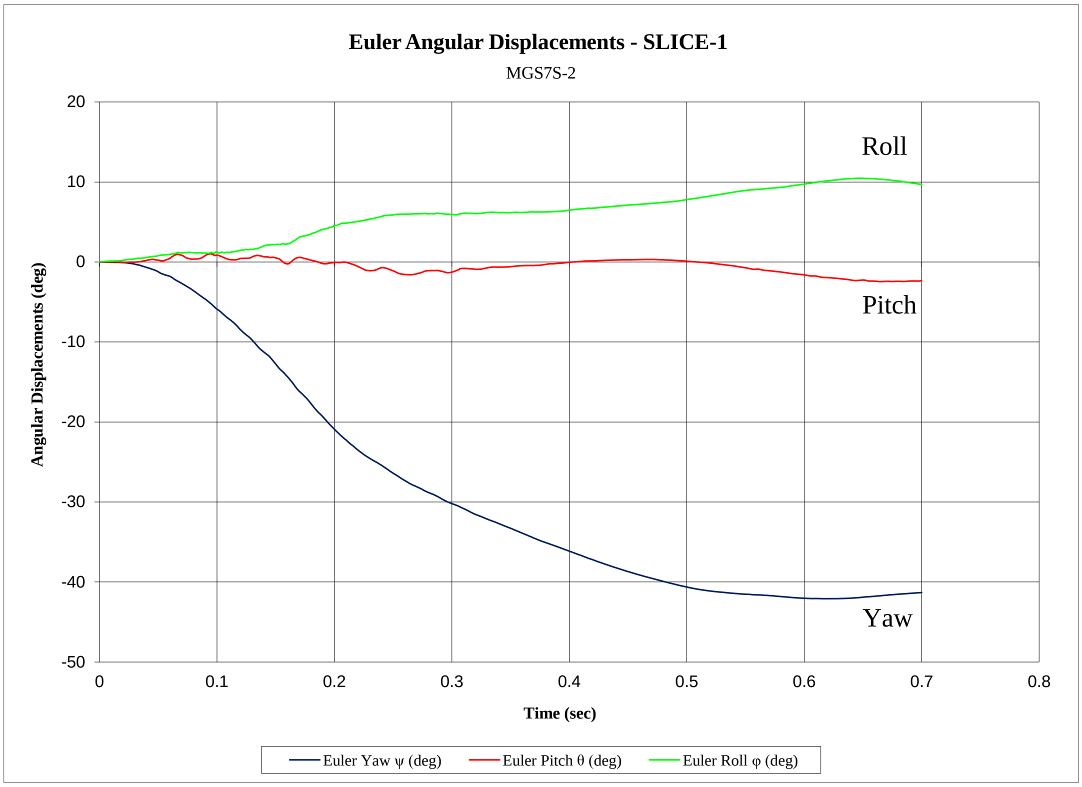


Figure F-15. Vehicle Angular Displacements (SLICE-1), Test No. MGS7S-2

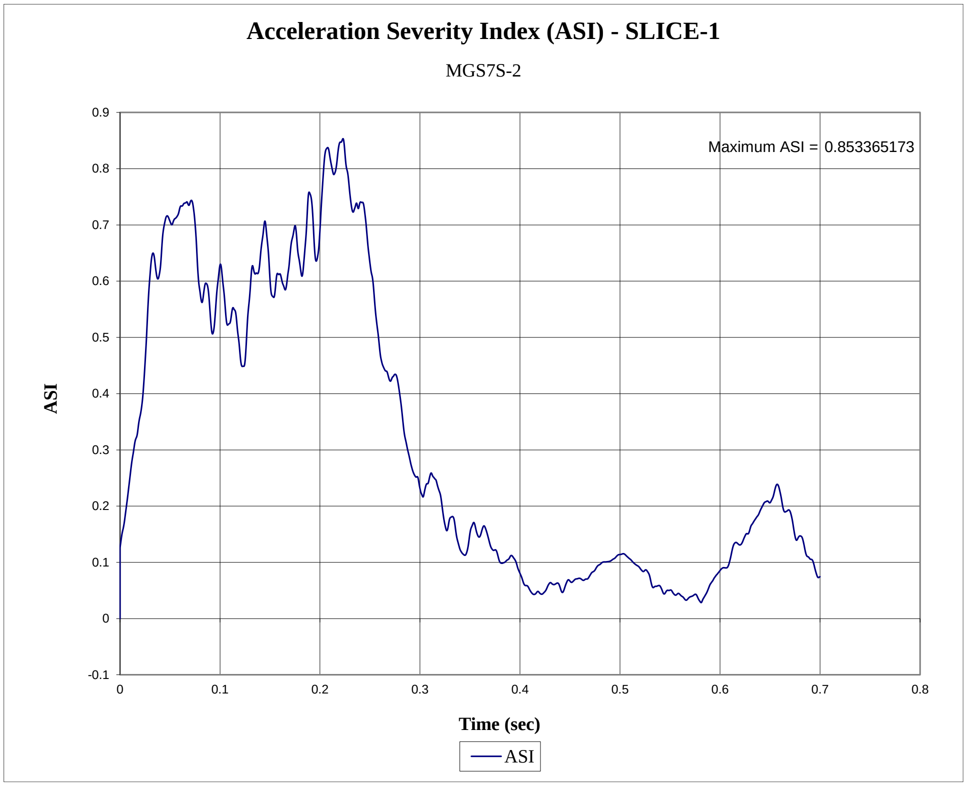


Figure F-16. Acceleration Severity Index (SLICE-1), Test No. MGS7S-2

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