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MGS WITH CURB AND OMITTED POST: EVALUATION TO MASH 2016 TEST NO. 3-11

Submitted by

Scott K. Rosenbaugh, M.S.C.E.
Research Engineer

Samantha J. Corey
Former Undergraduate Research Assistant

MIDWEST ROADSIDE SAFETY FACILITY
Nebraska Transportation Center
University of Nebraska-Lincoln

Main Office
Prem S. Paul Research Center at Whittier School
Room 130, 2200 Vine Street
Lincoln, Nebraska 68583-0853
(402) 472-0965

Outdoor Test Site
4630 N.W. 36th Street
Lincoln, Nebraska 68524

Submitted to

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16. Abstract

Curbs are often required along roadways for functions such as drainage control, right-of-way reduction, and sidewalk separation. However, when placed near guardrail systems, curbs can adversely affect the interaction of errant vehicles with roadside barriers and increase the propensity for vehicle underride, override, and instability increases. Further, curbed roadsides with soil backfill result in increased system stiffnesses and rail loads, which may lead to rail ruptures. Additionally, the presence of drainage features often interferes with the placement of guardrail posts, requiring a post to be omitted. Therefore, the system evaluated herein consisted of the Midwest Guardrail System (MGS) in conjunction with a curb and with an omitted post.

The test article consisted of an MGS installation with the rail mounted 31 in. above the roadway and the front face of the guardrail located 6 in. behind a 6-in. tall AASHTO Type B curb. A single post was omitted near the middle of the system and 37 ft – 6 in. of nested rail was incorporated around the 150-in. elongated span created by the omitted post. In test no. MGSCO-4, a 2270P pickup truck impacted the system at a speed of 62.0 mph and at an angle of 25.1 degrees. The vehicle was successfully contained and redirected with no evidence of rail tearing. The vehicle remained stable, and all vehicle decelerations were within the allowable limits. Thus, test no. MGSCO-4 met the safety performance criteria of MASH test designation no. 3-11. The same system configuration was previously crash tested with the 1100C vehicle during test no. MGSCO-2 and met the safety performance criteria of MASH test designation no. 3-10. Therefore, the MGS with nested W-beam rail placed 6 in. behind a 6-in. tall AASHTO Type B curb and with an omitted post has been assessed as crashworthy to MASH TL-3. Recommendations and installation guidance for the MGS with omitted post placed adjacent to curbs were provided.

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This material is based upon work supported by the Federal Highway Administration, U.S. Department of Transportation and the Midwest Pooled Fund Program under TPF-5(193) Supplement #140. The contents of this report reflect the views and opinions of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the University of Nebraska-Lincoln, state highway departments participating in the Midwest Pooled Fund Program, nor the Federal Highway Administration, U.S. Department of Transportation. This report does not constitute a standard, specification, or regulation. Trade or manufacturers' names, which may appear in this report, are cited only because they are considered essential to the objectives of the report. The United States (U.S.) government and the State of Nebraska do not endorse products or manufacturers.

UNCERTAINTY OF MEASUREMENT STATEMENT

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

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R.K. Faller, Ph.D., P.E., Research Professor & MwRSF Director
J.D. Reid, Ph.D., Professor
J.C. Holloway, M.S.C.E., Research Engineer & Assistant Director –Physical Testing Division
K.A. Lechtenberg, M.S.M.E., Research Engineer
R.W. Bielenberg, M.S.M.E., Research Engineer
J.D. Rasmussen, Ph.D., P.E., Former Research Assistant Professor
C.S. Stolle, Ph.D., Research Assistant Professor
J.S. Steelman, Ph.D., P.E., Associate Professor
M. Asadollahi Pajouh, Ph.D., P.E., Research Assistant Professor
A.T. Russell, B.S.B.A., Testing and Maintenance Technician II
E.W. Krier, B.S., Construction and Testing Technician II
S.M. Tighe, Construction and Testing Technician I
D.S. Charroin, Construction and Testing Technician I
R.M. Novak, Construction and Testing Technician I
T.C. Donahoo, Construction and Testing Technician I
J.T. Jones, Construction and Testing Technician I
J.E. Kohtz, B.S.M.E., Former CAD Technician
E.L. Urbank, B.A., Research Communication Specialist
Z.Z. Jabr, Engineering Technician
J.R. Revell, Research Communication Assistant
Undergraduate and Graduate Research Assistants

California Department of Transportation
Bob Meline, Chief, Roadside Safety Research Branch
David Whitesel, P.E., Transportation Engineer
John Jewell, P.E., Senior Transportation Engineer, Specialist

Florida Department of Transportation
Derwood C. Sheppard, Jr., P.E., Design Standards Publication Manager, Roadway Design Engineer

Georgia Department of Transportation
Christopher Rudd, P.E., State Design Policy Engineer
Frank Flanders IV, P.E., Assistant State Design Policy Engineer

Hawaii Department of Transportation
James Fu, P.E., State Bridge Engineer
Dean Takiguchi, P.E., Engineer, Bridge Design Section
Kimberly Okamura, Engineer, Bridge Design Section

Illinois Department of Transportation
Filiberto Sotelo, P.E., Engineering Policy Unit Chief
Martha Brown, P.E., Safety Evaluation Unit Chief

Indiana Department of Transportation
Katherine Smutzer, P.E., Standards Engineer
Elizabeth Phillips, P.E., Highway Design Director

Iowa Department of Transportation
Chris Poole, P.E., Roadside Safety Engineer
Brian Smith, P.E., Methods Engineer
Daniel Harness, P.E., Transportation Engineer Specialist
Stuart Nielsen, P.E., Transportation Engineer Administrator, Design
Elijah Gansen, P.E., Geometrics Engineer

Kansas Department of Transportation
Ron Seitz, P.E., Director of Design
Scott King, P.E., Road Design Bureau Chief
Thomas Rhoads, P.E., Road Design Leader, Bureau of Road Design
Brian Kierath Jr., Engineering Associate III, Bureau of Road Design

Kentucky Department of Transportation
Jason J. Siwula, P.E., Assistant State Highway Engineer
Kevin Martin, P.E., Transportation Engineer Specialist
Gary Newton, Engineering Tech III, Design Standards

Minnesota Department of Transportation
Michael Elle, P.E., Design Standards Engineer
Michelle Moser, P.E., Assistant Design Standards Engineer

Missouri Department of Transportation
Sarah Kleinschmit, P.E., Policy and Innovations Engineer

Nebraska Department of Transportation
Phil TenHulzen, P.E., Design Standards Engineer
Jim Knott, P.E., Construction Engineer
Mick Syslo, P.E., State Roadway Design Engineer
Brandon Varilek, P.E., Materials and Research Engineer & Division Head
Mark Fischer, P.E., PMP, Research Program Manager
Lieska Halsey, Research Project Manager
Angela Andersen, Research Coordinator
David T. Hansen, Internal Research Coordinator
Jodi Gibson, Former Research Coordinator

New Jersey Department of Transportation
Hung Tang, P.E., Principal Engineer, Transportation
Joseph Warren, Assistant Engineer, Transportation

North Carolina Department of Transportation
Neil Mastin, P.E., Manager, Transportation Program Management – Research and Development
D. D. "Bucky" Galloway, P.E., CPM, Field Operations Engineer
Brian Mayhew, P.E., State Traffic Safety Engineer
Joel Howerton, P.E., Plans and Standards Engineer

Ohio Department of Transportation
Don Fisher, P.E., Roadway Standards Engineer

South Carolina Department of Transportation
J. Adam Hixon, P.E., Design Standards Associate
Mark H. Anthony, P.E., Letting Preparation Engineer
Henry Cross, P.E., Design Standards Engineer
Jason Hall, P.E., Engineer

South Dakota Department of Transportation
David Huft, P.E., Research Engineer
Randy Brown, P.E., Standards Engineer

Utah Department of Transportation
Shawn Debenham, Traffic and Safety Specialist
Glenn Blackwelder, Operations Engineer

Virginia Department of Transportation
Charles Patterson, P.E., Standards/Special Design Section Manager
Andrew Zickler, P.E., Complex Bridge Design and ABC Support Program Manager

Wisconsin Department of Transportation
Erik Emerson, P.E., Standards Development Engineer
Rodney Taylor, P.E., Roadway Design Standards Unit Supervisor

Wyoming Department of Transportation
William Wilson, P.E., Architectural and Highway Standards Engineer

Federal Highway Administration
David Mraz, Division Bridge Engineer, Nebraska Division Office

SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in.	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1,000 L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short ton (2,000 lb)	0.907	megagrams (or “metric ton”)	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela per square meter	cd/m^2
		FORCE & PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in.
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yard	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliter	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or “metric ton”)	1.103	short ton (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela per square meter	0.2919	foot-Lamberts	fl
		FORCE & PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

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1 INTRODUCTION

1.1 Background

Curbs are often required along roadways for functions such as drainage control, right-of-way reduction, and sidewalk separation. However, when placed near guardrail systems, curbs can adversely affect the interaction of errant vehicles with roadside barriers and increase the propensity for vehicle underride, override, and instability. Further, curbed roadsides with soil backfill result in increased system stiffnesses and rail loads, which may lead to rail ruptures. Fortunately, the Midwest Guardrail System (MGS) has remained crashworthy when installed adjacent to curbs.

In early development, the MGS was crash tested in combination with a 6-in. tall, AASHTO Type B curb offset 6 in. from the front face of the guardrail, as shown in Figure 1 [1-3]. The test met the criteria of National Cooperative Highway Research Program (NCHRP) Report 350 test designation no. 3-11[4].

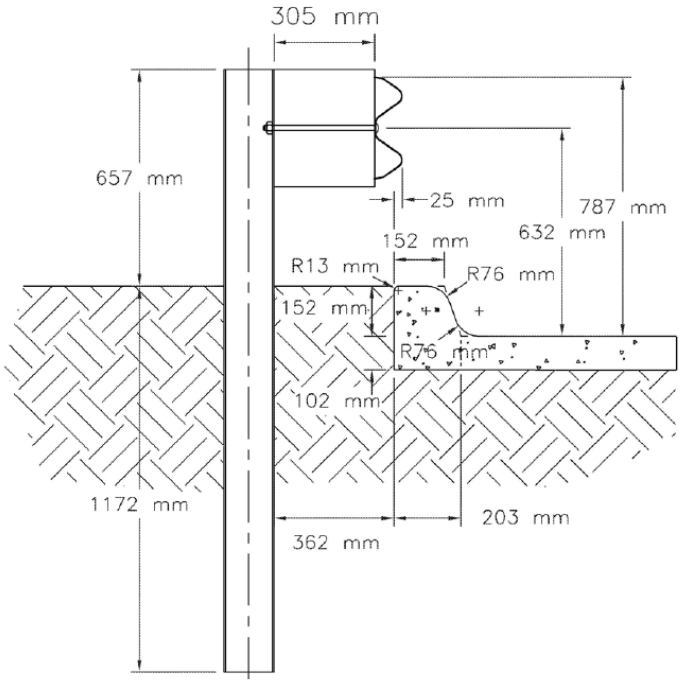


Figure 1. MGS Offset 6 in. from 6-in. AASHTO Type B Curb [1-3]

In 2020, the MGS placed 6 in. behind a 6-in. tall curb was crash tested to the Test Level 3 (TL-3) criteria found in the *Manual for Assessing Safety Hardware, Second Edition* (MASH) [5]. In full-scale crash testing, the MGS safely redirected both the small car and pickup truck and met the safety performance criteria of MASH test designation nos. 3-10 and 3-11 [6]. Thus, the MGS placed within 6 in. of a curb was deemed crashworthy to MASH TL-3.

The roadside features commonly used in combination with roadway curbs, such as drainage flumes or culverts, can prevent proper post placement within a run of guardrail. To avoid these obstructions, it is often desired to omit a post at the location of the obstruction. However, omitting a guardrail post can lead to increased deflections, high rail loads, barrier pocketing, and vehicle

instability. To evaluate the performance of the MGS with a single omitted post, a full-scale crash test was performed according to MASH test designation no. 3-11. During the test, the 2270P pickup truck was contained and smoothly redirected, and test no. MGSMP-1 met the MASH safety criteria [7].

Following the successful evaluation of the MGS with an omitted post and the MGS adjacent to a curb, it was desired to evaluate the MGS in combination with both a curb and an omitted post. In 2017, the Midwest Pooled Fund sponsored a research project to conduct full-scale crash testing on the MGS with a curb and an omitted post according to the evaluation criteria of MASH TL-3. As in the previous curb tests, the guardrail was located 6 in. behind a 6-in. tall curb. During the first full-scale test, test no. MGSCO-1, the front of the 1100C small car wedged under the W-beam rail causing combined lateral and vertical loading to the guardrail [8]. Ultimately, the rail ruptured at the splice located within the elongated span, and the vehicle penetrated behind the system, as shown in Figure 2.

Figure 2. Rail Rupture Resulting from Test No. MGSCO-1

Subsequently, the system design was modified, and 37 ft − 6 in. of nested W-beam was incorporated around the omitted post location to prevent rail rupture. The nested rail was positioned to extend at least one post spacing upstream and downstream from the elongated span created by the omitted post. During test no. MGSCO-2, the modified system captured and redirected the 1100C vehicle without any observed rail tearing [8]. The vehicle remained stable and the occupant risk measures were within the MASH limits. Thus, test no. MGSCO-2 passed the safety performance criteria of MASH test designation no. 3-10.

At the time test no. MGSCO-2 was completed, MASH test designation no. 3-11 with the 2270P pickup truck was still needed to complete the MASH TL-3 evaluation of the modified MGS. However, the original project budget only included funds for two full-scale crash tests. Thus, a continuation project was necessary to conduct the pickup truck test on the nested MGS in combination with a 6-in. tall curb and an omitted post.

1.2 Objective

The objective of this research project was to evaluate the performance of the nested MGS in combination with a curb and an omitted post according to MASH TL-3. Full-scale crash testing and evaluation were conducted according to MASH test designation no. 3-11 with the 2270P pickup truck. In prior full-scale crash testing, the system met the safety performance criteria of MASH test designation no. 3-10 [8], and the test documented herein completed the MASH TL-3 test matrix required for evaluation of the barrier system.

1.3 Scope

The research objective was achieved through the completion of several tasks. CAD details of the nested MGS with a curb and an omitted post were created. Barrier VII software was used to identify the critical impact point of the system based on the likelihood for rail rupture and rail pocketing. Full-scale crash testing was conducted according to MASH test designation no. 3-11. Next, the test results were analyzed, evaluated, and documented. Conclusions and recommendations were then made pertaining to the safety performance of the nested MGS with a curb and an omitted post.

2 TEST REQUIREMENTS AND EVALUATION CRITERIA

2.1 Test Requirements

Longitudinal barriers, such as W-beam guardrails, must satisfy impact safety standards in order to be declared eligible for federal reimbursement by the Federal Highway Administration for use on the National Highway System. For new hardware, these safety standards consist of the guidelines and procedures published in MASH [5]. According to TL-3 of MASH, longitudinal barrier systems must be subjected to two full-scale vehicle crash tests, as summarized in Table 1.

Table 1. 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 are explained in Table 3.

The nested MGS with a curb and an omitted post was crash tested in the previous phase of this study, and test no. MGSCO-2 met the safety performance criteria of MASH test designation no. 3-10 [8]. To complete the MASH TL-3 longitudinal barrier test matrix, MASH test designation no. 3-11 was required.

Test no. MGSCO-3 was conducted with a 2270P vehicle impacting the MGS with a curb and an omitted post. The pickup truck was safely contained and redirected. However, the soil around the test installation was later found to be below the minimum MASH requirements for strong soils. Subsequently, the test was deemed non-compliant to MASH testing conditions. Details on this non-compliance were discussed with the project sponsors in an email dated 9/11/2019 [9], and it was agreed to retest the system using MASH compliant soil. Test no. MGSCO-4 was then conducted as detailed herein. Details from the non-compliant test, test no. MGSCO-3, were not included in this report to save project funds and to focus on the MASH compliant test.

2.2 Critical Impact Point

The BARRIER VII computer program [10] was utilized to select the critical impact point, as recommended in Section 2.3.1 of MASH. An existing model of the MGS with a curb and an omitted post, created and validated as part of the previous small car testing and evaluation [8], was modified to include 37 ft − 6 in. of nested W-beam guardrail at the location of the omitted post. Impacts were then simulated on the model according to the impact conditions of MASH test 3-11, with a 2270P pickup truck impacting the system at 62 mph and a 25-degree angle.

Simulated impacts were conducted at 9.375-in. intervals along the length of the barrier system. For each simulated impact point, maximum dynamic deflections, maximum pocketing angles, and the extent of wheel snag on post no. 14 were documented. Note, similar to the test installation described in Chapter 3, post no.14 refers to the post at the downstream end of the

elongated span created by the omitted post. Deflections were measured at the center of the guardrail splice located within the elongated span, 37.5 in. upstream from post no. 14. Pocketing angles were measured at the downstream end of the elongated span, between the guardrail splice and post no. 14. Vehicle snag was measured as the lateral extent of the front tire beyond the face of the post at the time of tire-to-post contact. The analysis results are summarized in Table 2, where the impact points are identified as a distance upstream from post no. 14.

Table 2. Barrier VII Critical Impact Point Study Results

Impact Point Distance Upstream from Post No. 14 in.	Maximum Deflection* in.	Maximum Pocketing Angle deg.	Wheel Snag on Post No. 14 in.
300	18.28	14.73	-
290.625	20.56	15.55	-
281.25	22.79	16.5	0.60
271.875	25.49	17.54	2.35
262.5	28.8	17.07	3.46
253.125	30.24	17.14	5.46
243.75	27.08	16.83	4.02
234.375	29.32	16.6	5.05
225	31.16	16.5	5.61
215.625	32.94	16.52	5.92
206.25	34.15	16.45	6.51
196.875	35.09	16.53	6.47
187.5	**35.7**	**16.51**	**6.57**
178.125	35.73	16.62	6.31
168.75	32.3	15.61	6.12
159.375	32.34	15.54	6.25
150	32.06	15.44	6.31
140.625	31.57	15.2	5.93
131.25	30.98	14.79	5.89
121.875	30.24	14.35	5.37
112.5	29.26	13.79	4.87
103.125	28.18	12.89	4.07
93.75	27.3	12.28	2.61
84.375	26.23	11.28	1.39
75	25.25	9.63	0.08

*Deflections measured at the rail splice located within the elongated span length, 37.5 in. upstream from post no. 14.

The maximum wheel overlap on the post, i.e., vehicle snag, occurred in the simulation with the impact point located 187.5 in. upstream from post no. 14. This impact location also resulted in the second highest dynamic deflection at the guardrail splice, and a pocketing angle that was only 1 degree smaller than the highest pocketing angle of all the impact points. Therefore, the critical impact point for MASH test. 3-11 on the nested MGS with a curb and an omitted post was determined to be 187.5 in. upstream from the post at the downstream end of the elongated span.

Similar methods had been utilized to select the critical impact points for the previous small car tests on the system [8].

2.3 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 longitudinal barrier to contain and redirect impacting vehicles. In addition, controlled lateral deflection of the test article is acceptable. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Post-impact vehicle trajectory is a measure of the potential of the vehicle to result in a secondary collision with other vehicles and/or fixed objects, thereby increasing the risk of injury to the occupants of the impacting vehicle and/or other vehicles. These evaluation criteria are summarized in Table 3 and defined in greater detail in MASH. The full-scale vehicle crash test was conducted and reported in accordance with the procedures provided in MASH.

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

Table 3. MASH Evaluation Criteria for Longitudinal Barriers

<table>
<tr><td>Structural Adequacy</td><td colspan="4">A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td></tr>
<tr><td rowspan="8">Occupant Risk</td><td colspan="4">D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.</td></tr>
<tr><td colspan="4">F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td></tr>
<tr><td colspan="4">H. Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s</td><td>40 ft/s</td></tr>
<tr><td colspan="4">I. The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
</table>

2.4 Soil Strength Requirements

In accordance with Chapter 3 and Appendix B of MASH, 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 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.

3 DESIGN DETAILS

The barrier system consisted of an MGS with a curb and an omitted post, as shown in Figures 3 through 17. Photographs of the test installation are shown in Figure 18. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix A. The test installation consisted of 12-gauge, AASHTO M180 standard W-beam guardrail, W6x8.5 steel posts with timber blockouts, and MGS end anchorages. The total system length was 182 ft – 3½ in. The system was installed with the face of the guardrail located 6 in. behind a 6-in. tall, AASHTO Type B curb. A single post was omitted from the system near the middle of the test installation, and 37 ft – 6 in. of nested rail was placed at the omitted post location.

The test installation was constructed using 28 guardrail posts. Post nos. 3 through 26 were standard, 72-in. long, W6x8.5, ASTM A992 steel guardrail posts. The posts were each embedded to a depth of 46 in., which corresponded to the nominal 40-in. embedment plus the soil fill depth of 6 in. behind the curb. Post nos. 1, 2, 27, and 28 were part of the MGS end anchorages. All posts were embedded in coarse, crushed limestone and were spaced 75 in. on center. The omitted post location was between post nos. 13 and 14, creating a 150-in. elongated span. Timber blockouts measuring 12 in. deep were used to block the rail away from the front flange of each steel post. The W-beam guardrail was mounted with a top-rail height of 31 in. measured from the surface of the roadway. Guardrail splices were located at the mid-span between posts and oriented to prevent vehicle snag, as shown in Figure 5.

The 37 ft – 6 in. of nested W-beam rail around the omitted post location was incorporated to increase the rail strength and prevent premature rail rupture. The rails were nested such that the two upstream rails were placed in front of the two downstream rails.

A 6-in. tall, AASHTO Type B curb spanned from post nos. 9 through 19. The curb was located 6 in. in front of the face of the rail, as measured from the face of curb at mid-height. Soil was backfilled behind the curb bringing the ground line flush with the top of the curb. The soil backfill extended a minimum of 5 ft behind the curb. A replica concrete gutter was created by casting a 4-in. deep by 48-in. wide concrete slab in front of the curb. The curb and gutter concrete had a minimum compressive strength of 4,000 psi and the curb was reinforced by a single longitudinal #4 rebar.

The upstream and downstream ends of the guardrail installation were configured with a non-proprietary end anchorage system [11-14]. The guardrail anchorage system had a comparable strength to other crashworthy end terminals. The anchorage system consisted of timber posts, foundation tubes, anchor cables, bearing plates, rail brackets, and channel struts.

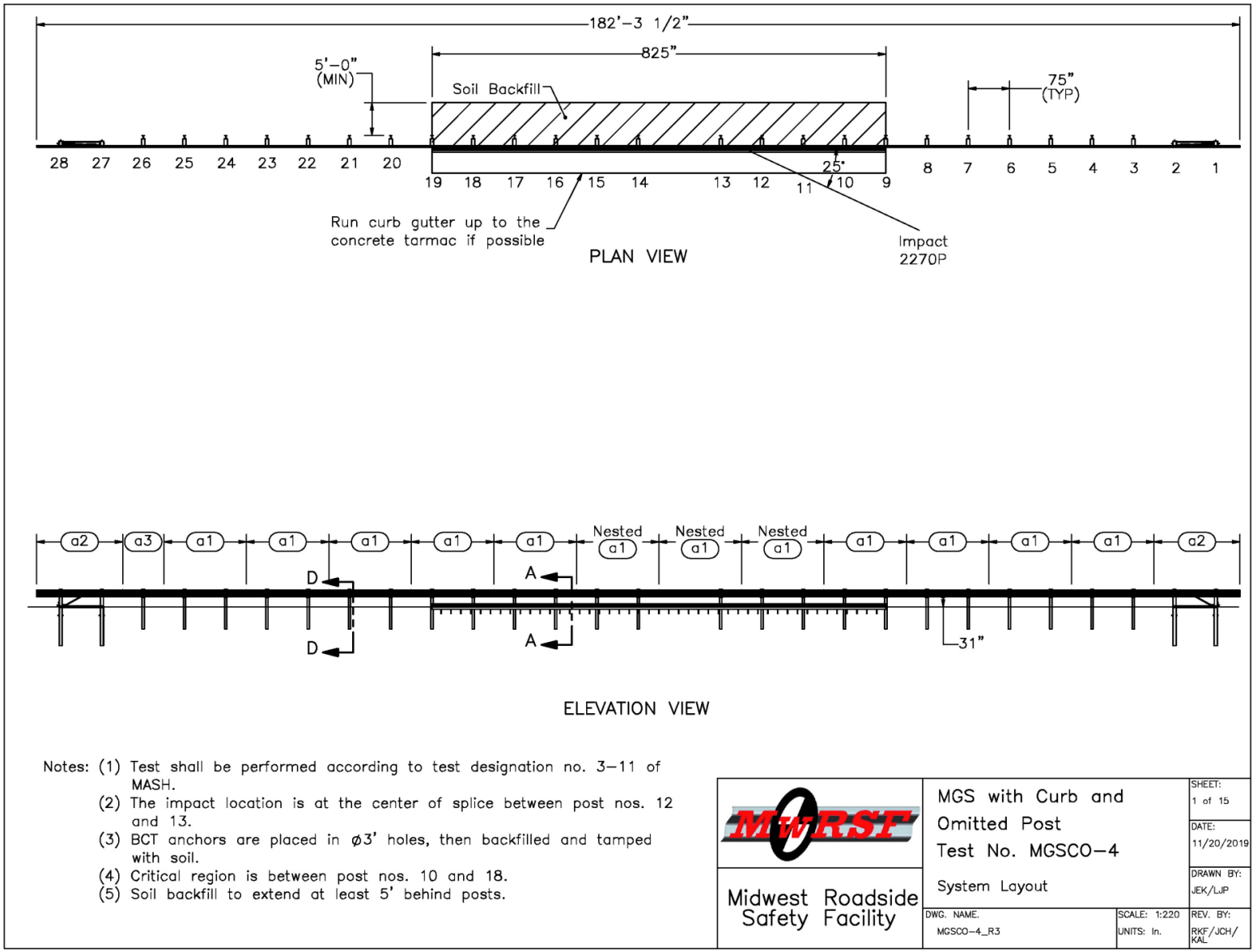


Figure 3. System Layout, Test No. MGSCO-4

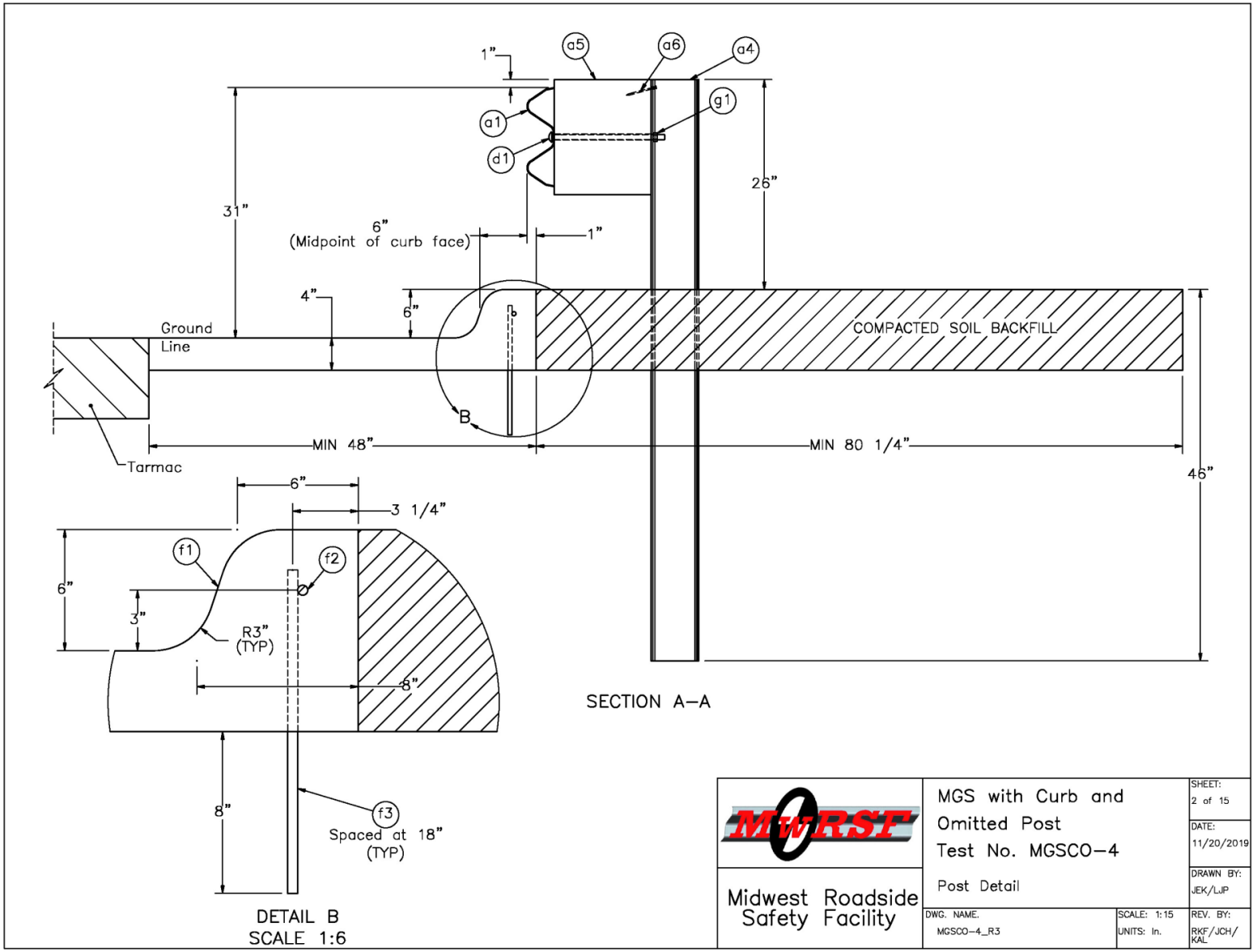


Figure 4. System Profile, Curb Geometry, and Reinforcement Details, Test No. MGSCO-4

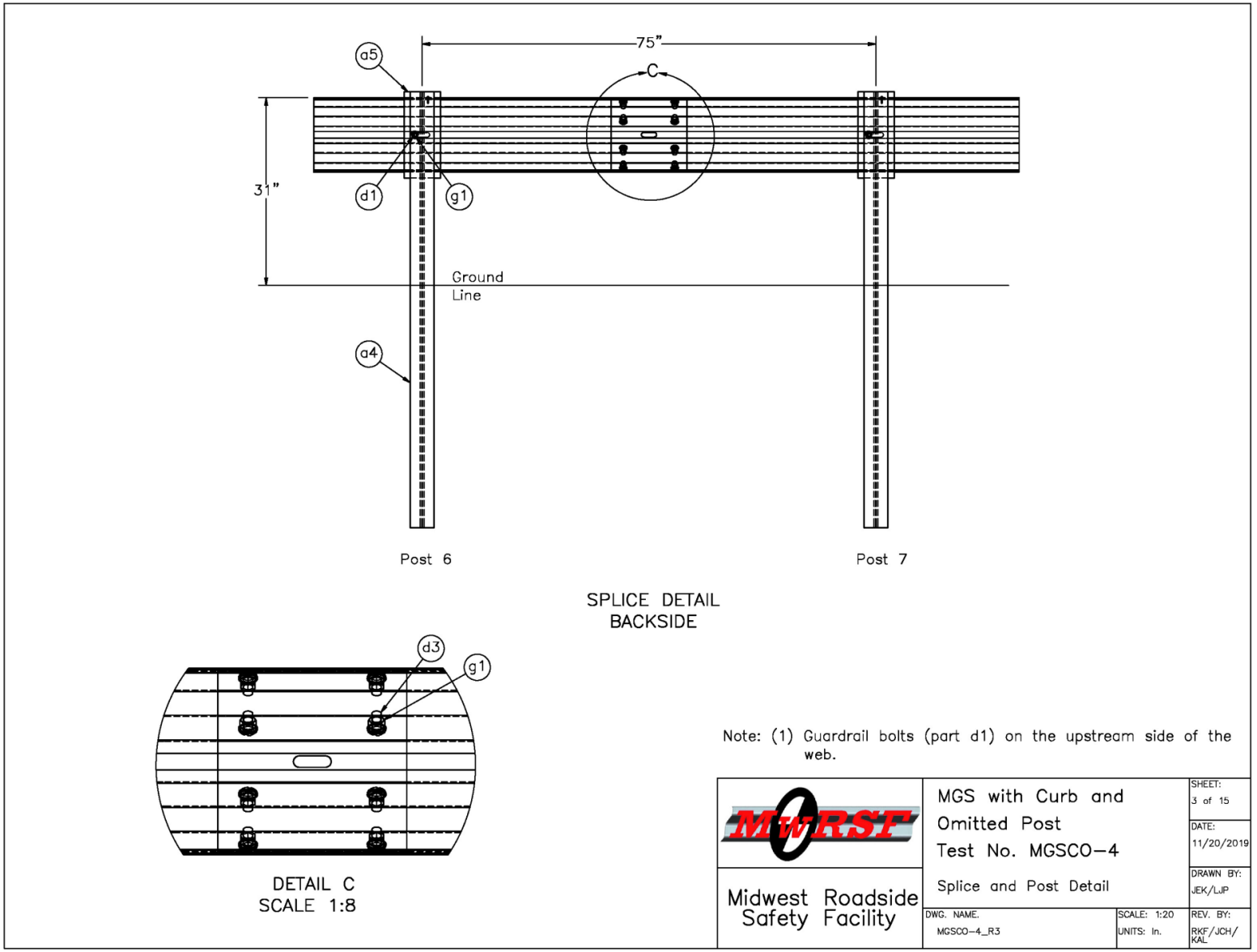


Figure 5. Splice and Post Details, Test No. MGSCO-4

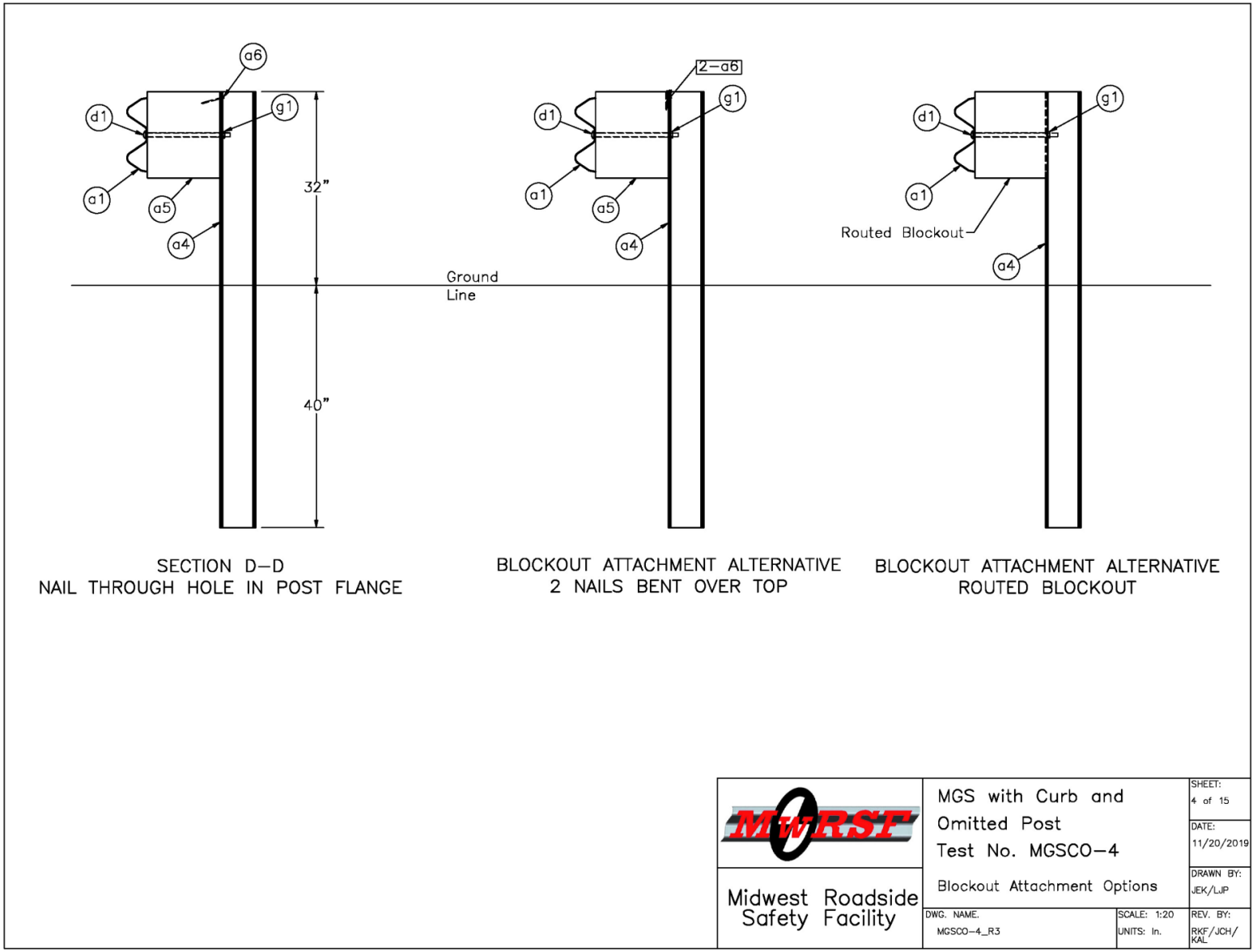


Figure 6. Blockout Attachment Details, Test No. MGSCO-4

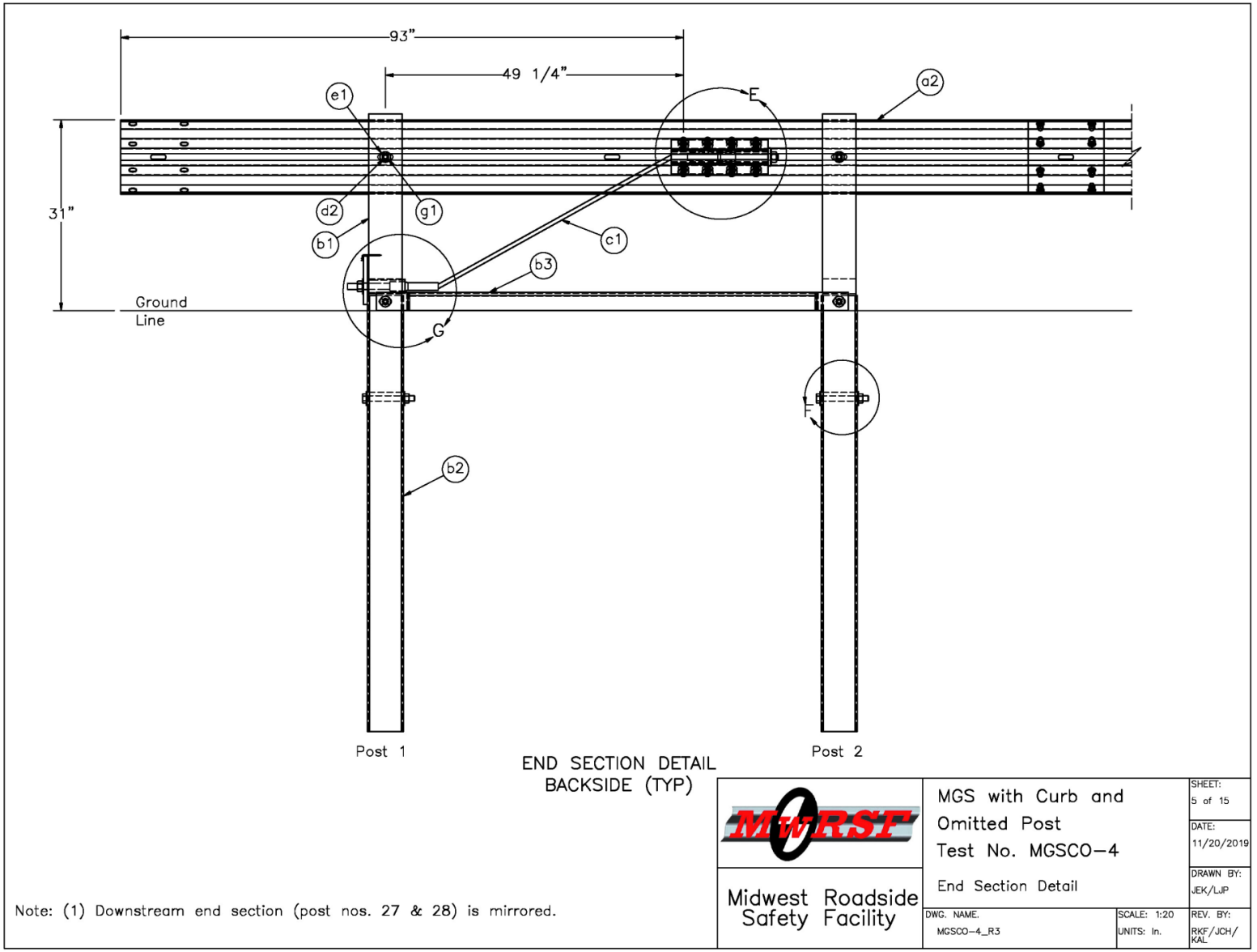


Figure 7. End Anchorage Details, Test No. MGSCO-4

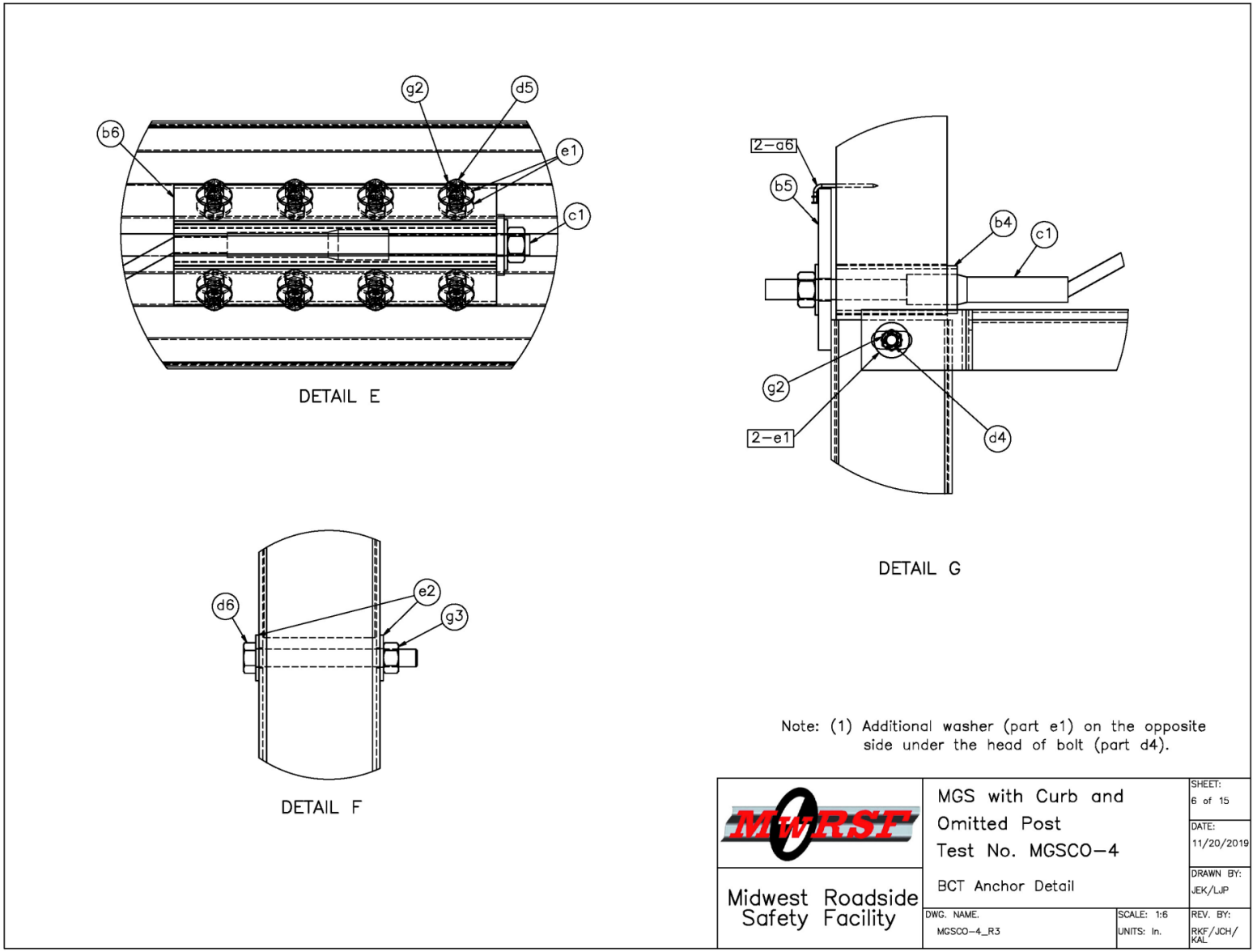


Figure 8. MGS End Anchorage Details, Test No. MGSCO-4

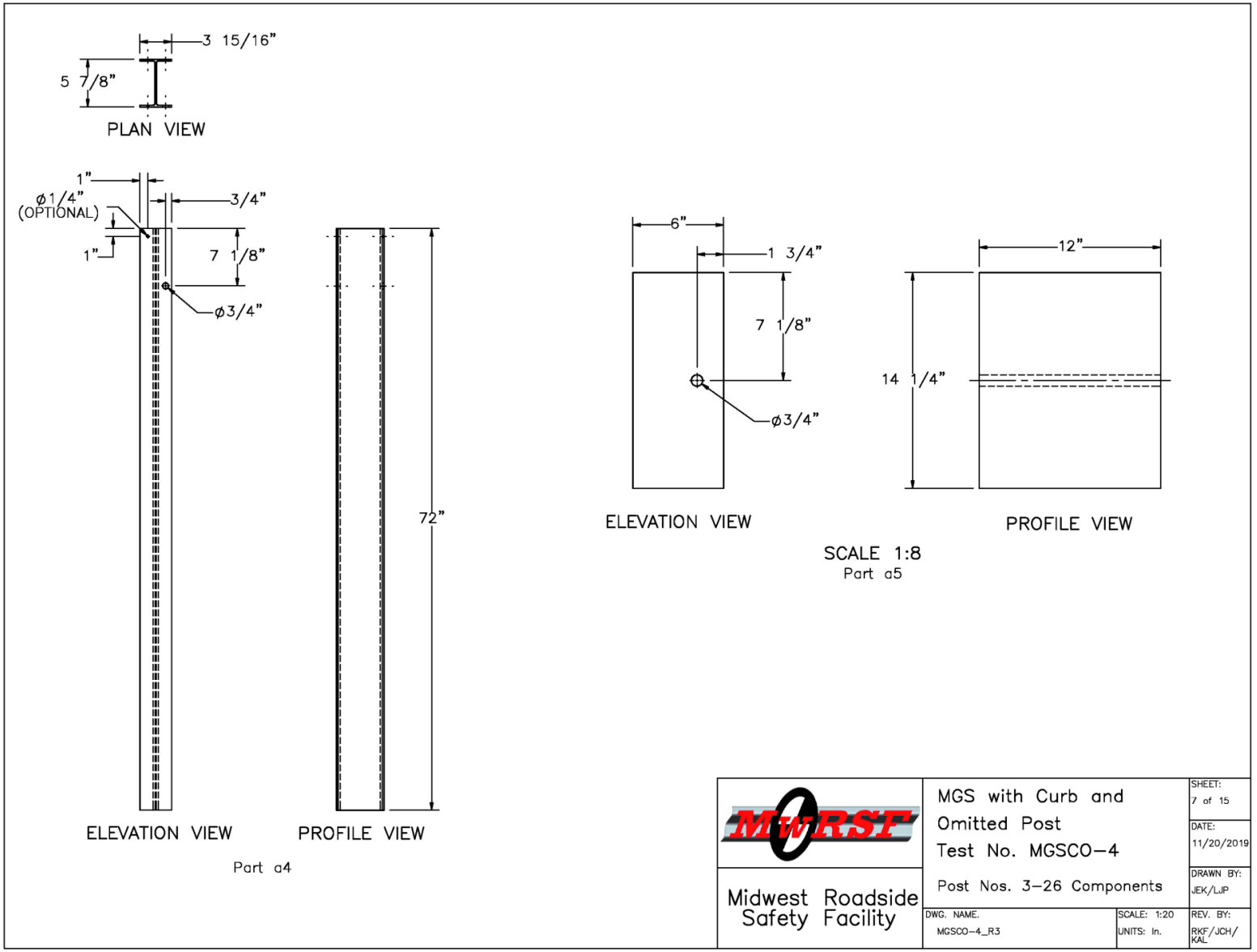


Figure 9. Post Nos. 3 through 26 Component Details, Test No. MGSCO-4

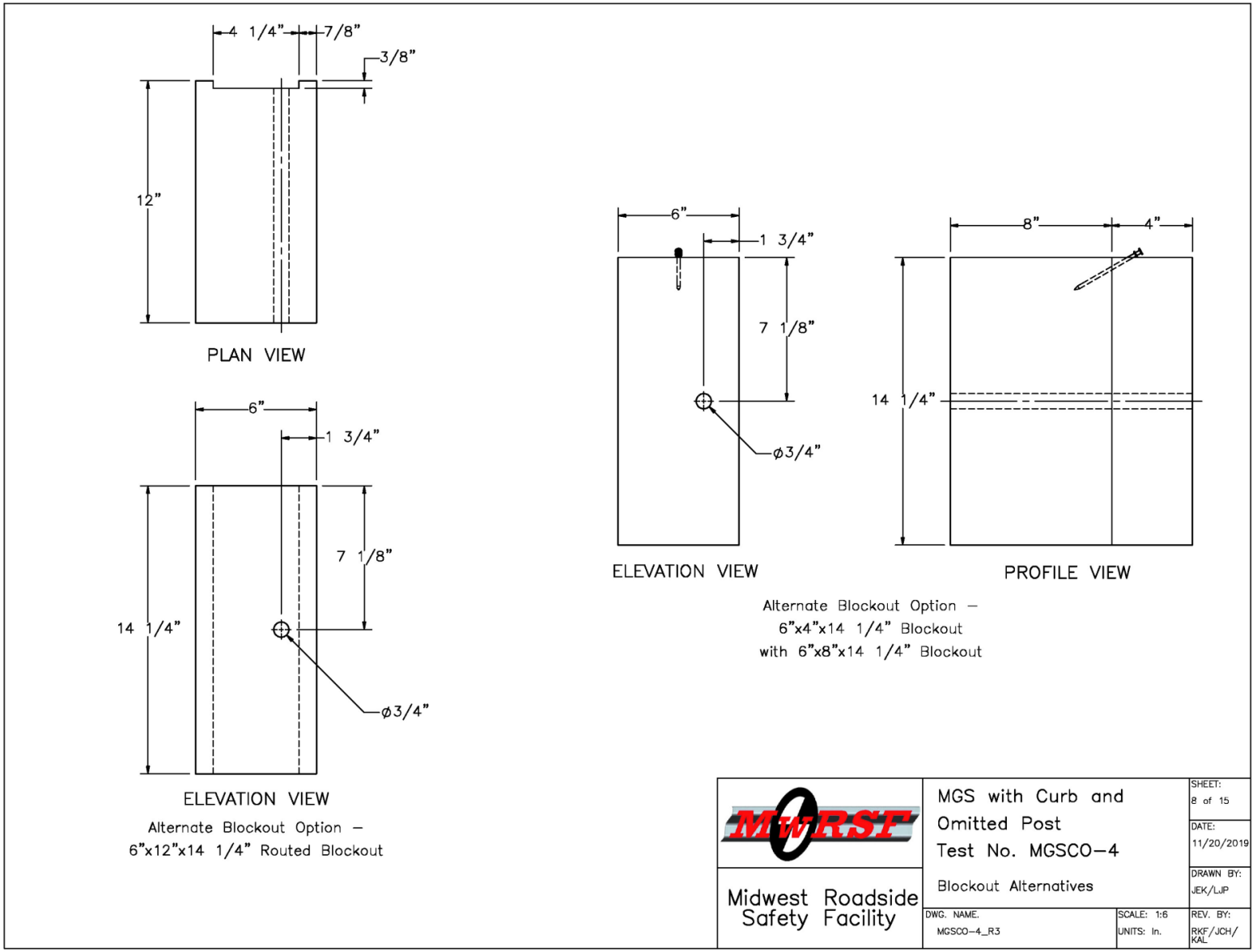


Figure 10. Post Blockout Alternatives, Test No. MGSCO-4

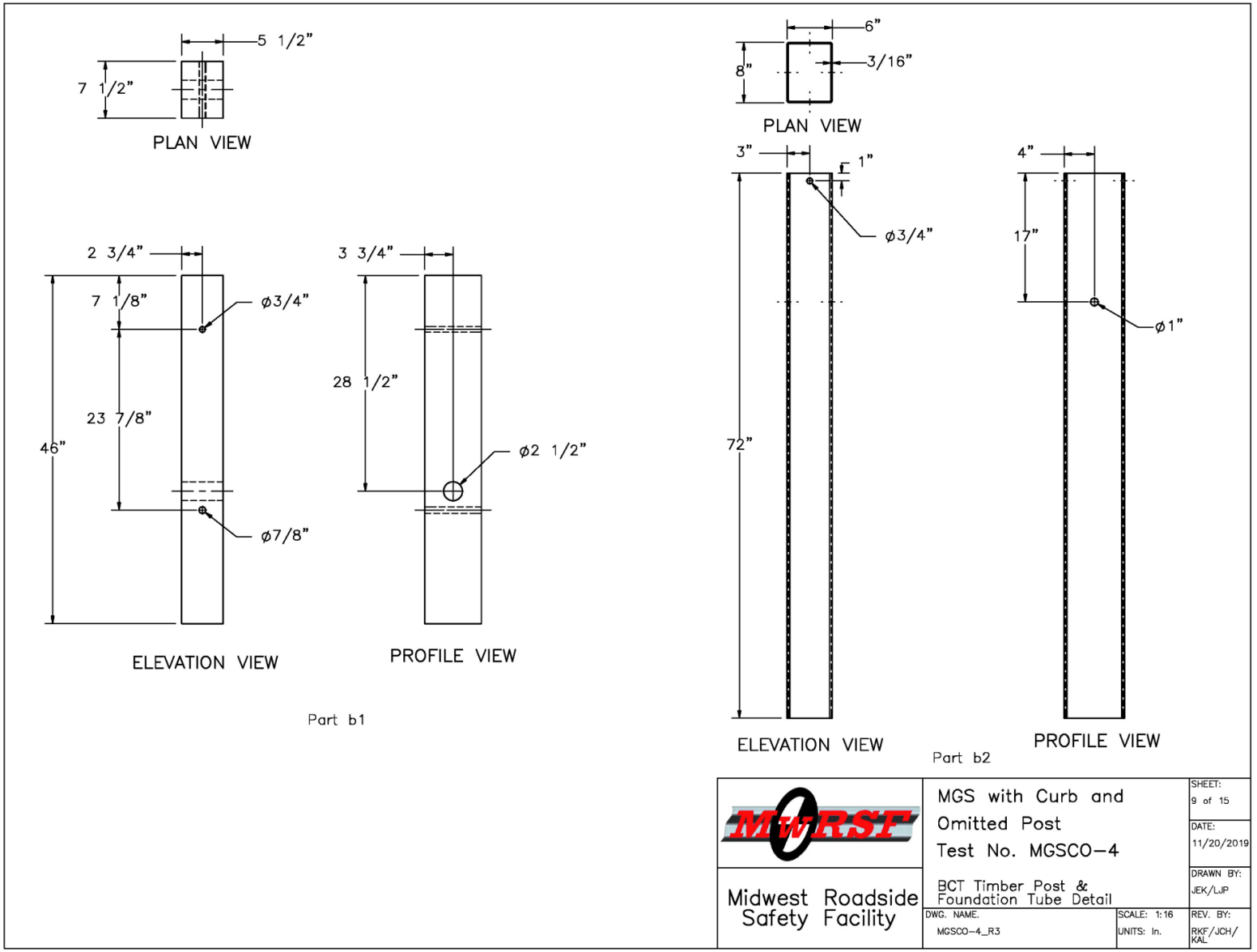


Figure 11. MGS BCT Timber Post and Foundation Tube Details, Test No. MGSCO-4

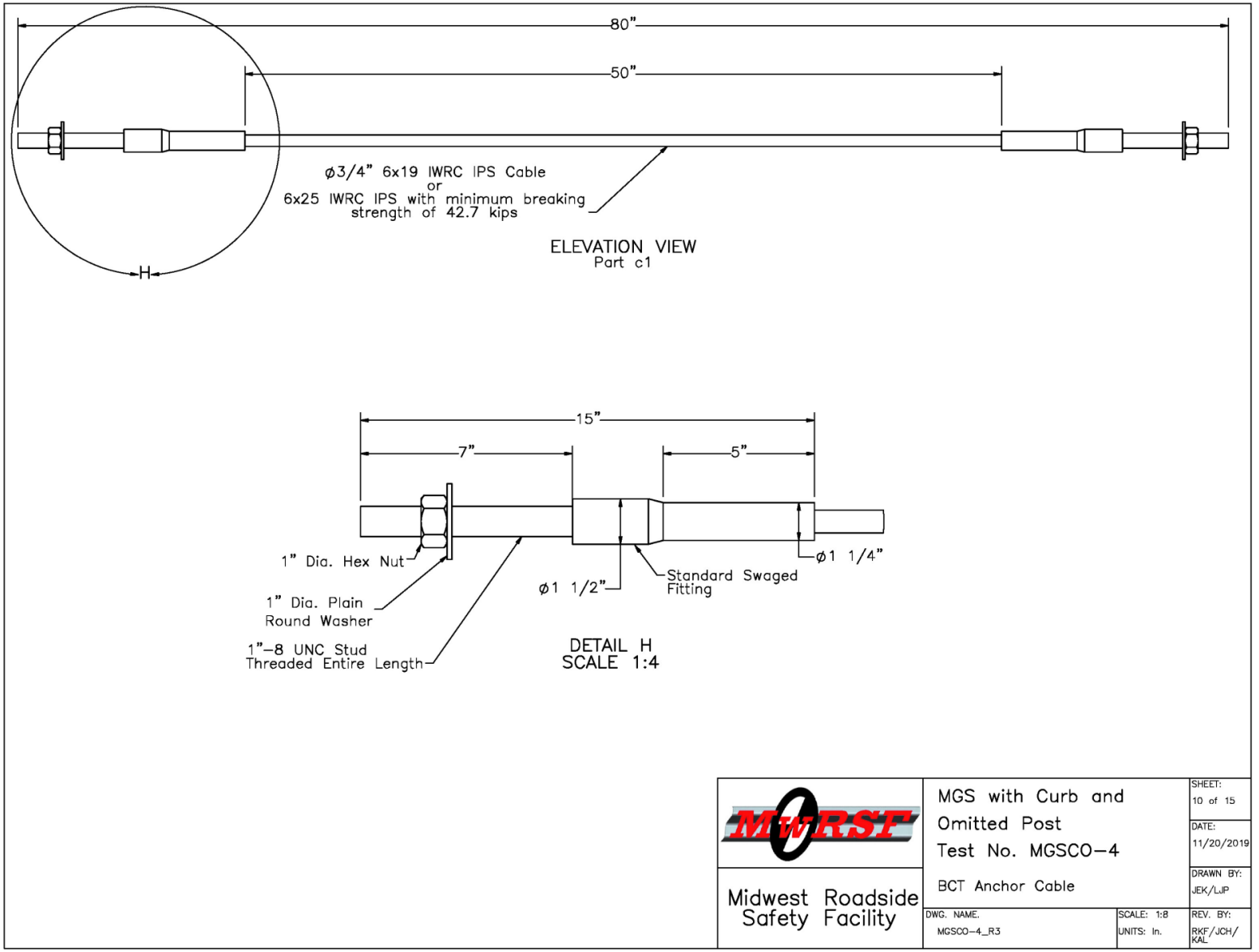


Figure 12. MGS BCT Anchor Cable, Test No. MGSCO-4

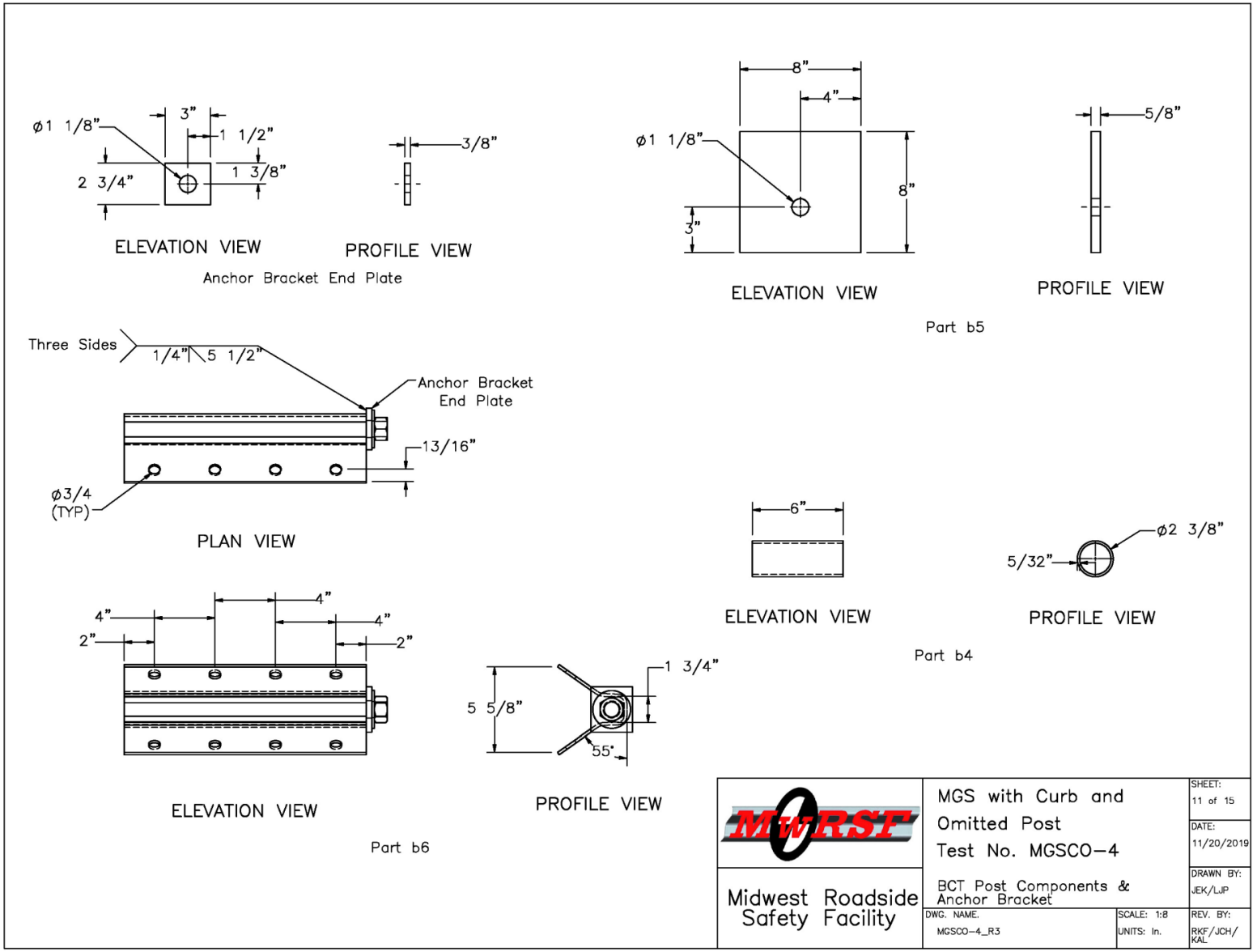


Figure 13. MGS BCT Post Components and Anchor Bracket, Test No. MGSCO-4

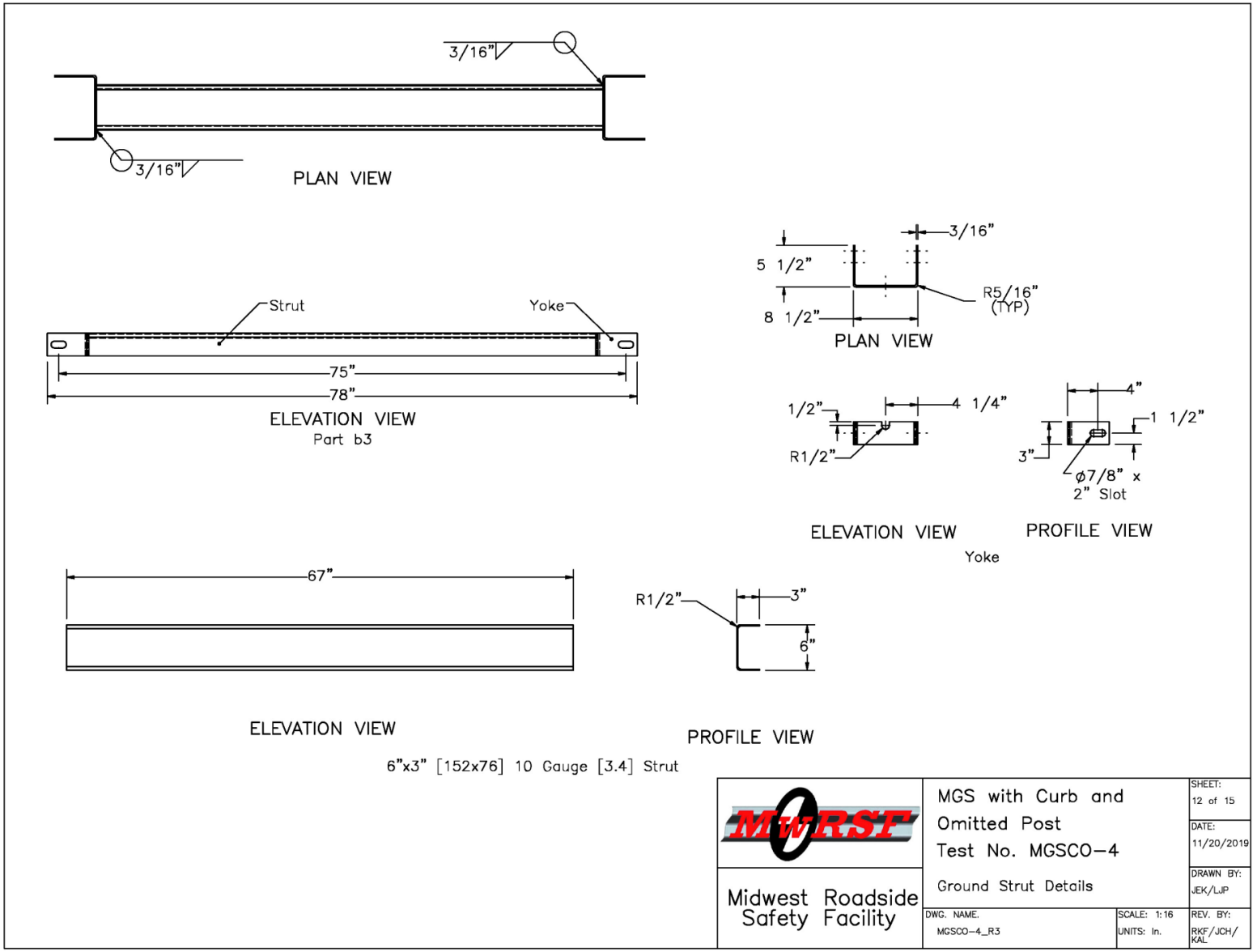


Figure 14. Ground Line Strut Details, Test No. MGSCO-4

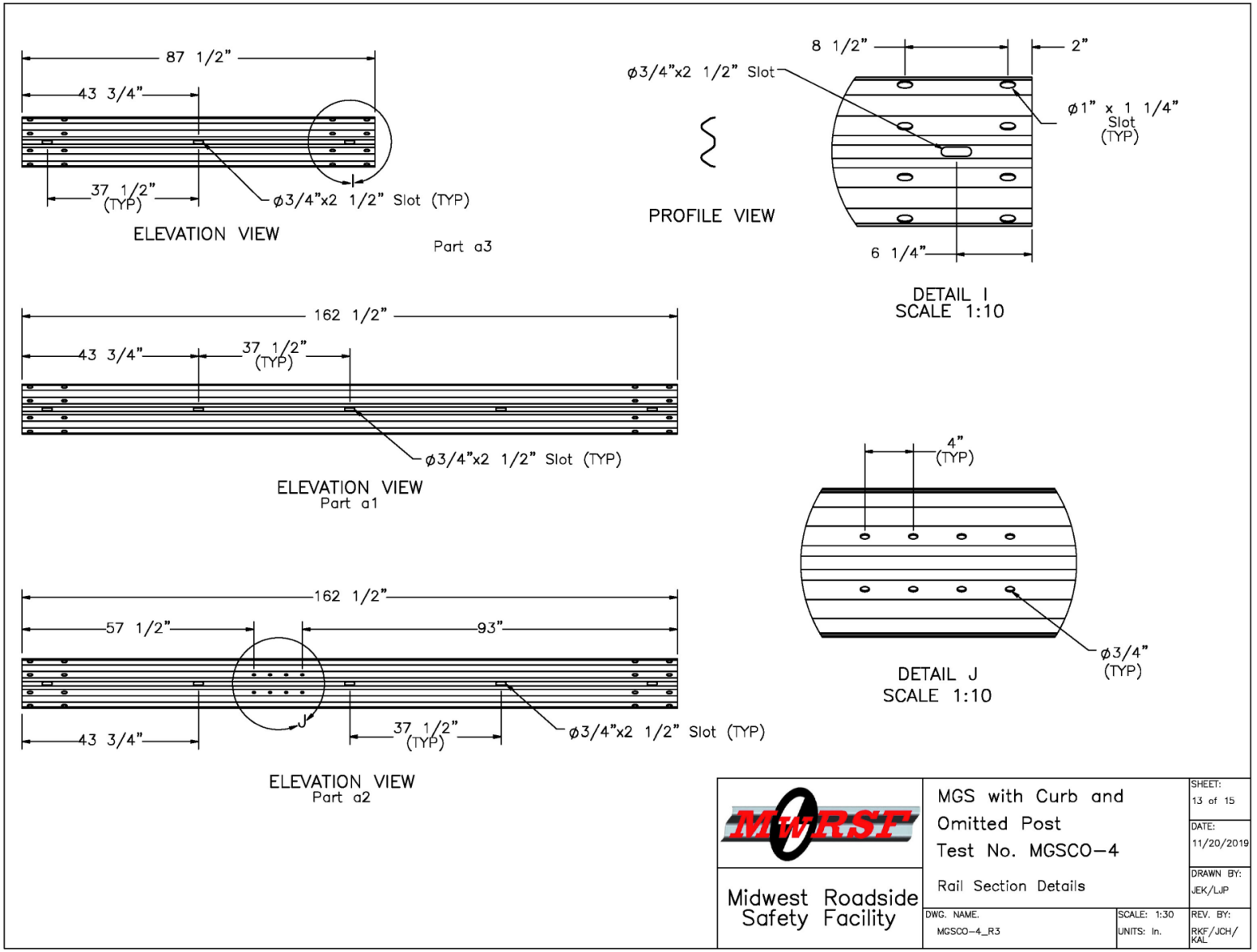


Figure 15. Rail Details, Test No. MGSCO-4

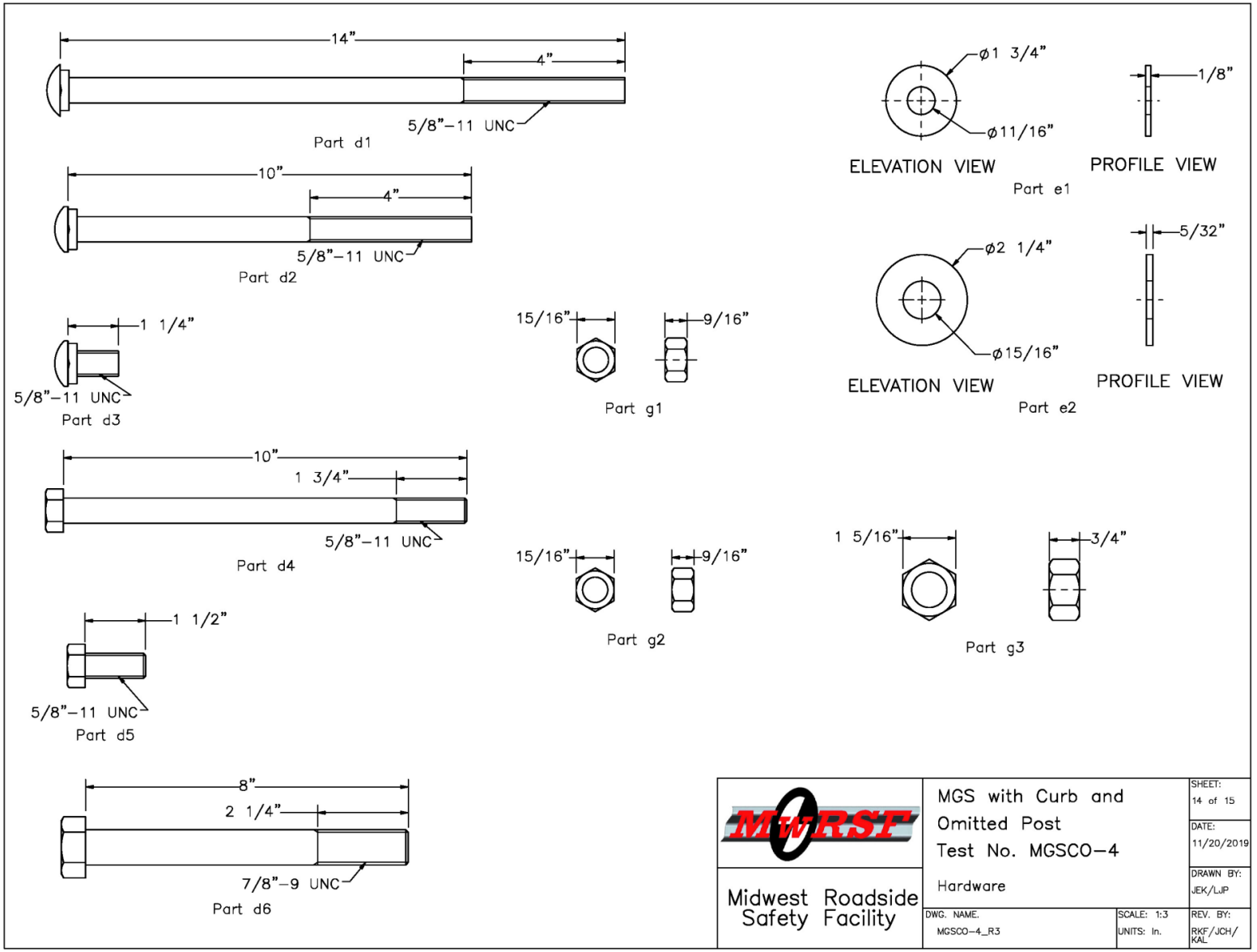


Figure 16. Attachment and Connection Hardware, Test No. MGSCO-4

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	–	Soil	–	–	–
a1	15	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	24	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992 Min. 50 ksi	ASTM A123	PWE06
a5	24	6"x12"x14 1/4" Timber Blockout for Steel Posts	AASHTO M168 or SYP Grade No.1 or better	AASHTO M133	PDB10a
a6	28	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	Ground Strut Assembly	ASTM A36	ASTM A123	PFP02
b4	2	2 3/8" O.D. x 6" Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	ASTM A123	FMM02
b5	2	8"x8"x5/8" Anchor Bearing Plate	ASTM A36	ASTM A123	FPB01
b6	2	Anchor Bracket Assembly	ASTM A36	ASTM A123	FPA01
c1	2	BCT Anchor Cable	–	–	FCA01
d1	24	5/8" Dia. UNC, 14" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F1941 or F2329	FBB06
d2	4	5/8" Dia. UNC, 10" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F1941 or F2329	FBB03
d3*	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
d4	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
d5	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
d6	4	7/8" Dia. UNC, 8" Long Hex Head Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F1941 or F2329	–
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	–
f1	1	Curb	f'c = 4,000 psi	–	–
f2	1	#4 Rebar 819" Long	ASTM A615 Gr. 60	–	–
f3	45	#4 Rebar 16" Long	ASTM A615 Gr. 60	–	–
g1	140	5/8" Dia. Heavy Hex Nut	ASTM A563A	ASTM A153 or B695 Class 55 or F1941 or F2329	–
g2	20	5/8" Dia. Hex Nut	ASTM A563A	ASTM A153 or B695 Class 55 or F1941 or F2329	FNX16a
g3	4	7/8" Dia. Hex Nut	ASTM A563A	ASTM A153 or B695 Class 55 or F1941 or F2329	–

* 2" Long Guardrail Bolts (FBB02) may be used in place of part d3 at nested splice locations.

Midwest Roadside Safety Facility

MGS with Curb and Omitted Post
Test No. MGSCO–4
Bill of Materials

SHEET: 15 of 15
DATE: 11/20/2019
DRAWN BY: JEK/LJP
REV. BY: RKF/JCH/KAL
DWG. NAME. MGSCO–4_R3
SCALE: None
UNITS: In.

Figure 17. Bill of Materials, Test No. MGSCO-4

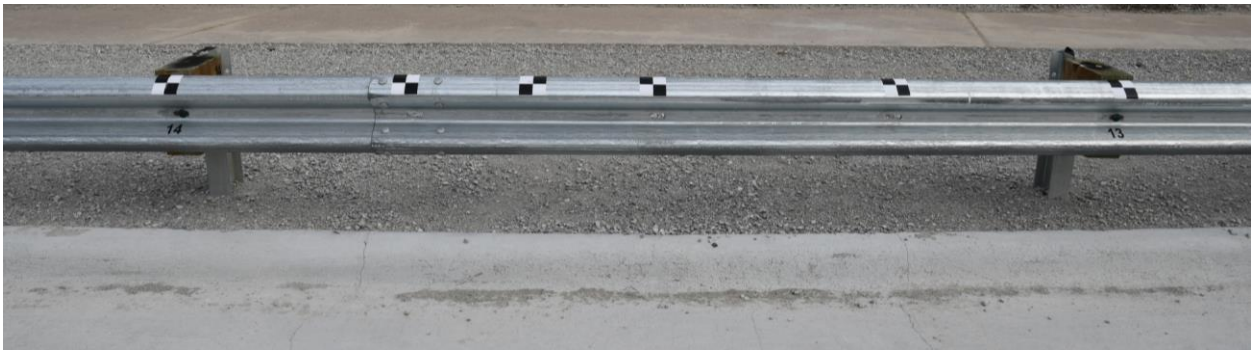


Figure 18. Test Installation Photographs, Test No. MGSCO-4

4 TEST CONDITIONS

4.1 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.

4.2 Vehicle Tow and Guidance System

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

A vehicle guidance system developed by Hinch [15] 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.

4.3 Test Vehicle

For test no. MGSCO-4, a 2013 Dodge RAM 1500 crew cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,146 lb, 5,000 lb, and 5,162 lb, respectively. The test vehicle is shown in Figures 19 and 20, and vehicle dimensions are shown in Figure 21.

Figure 19. Test Vehicle, Test No. MGSCO-4

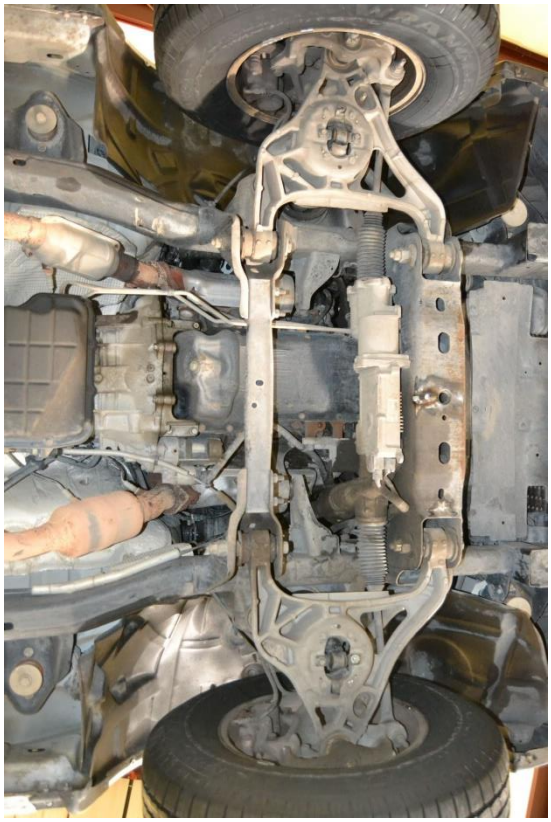
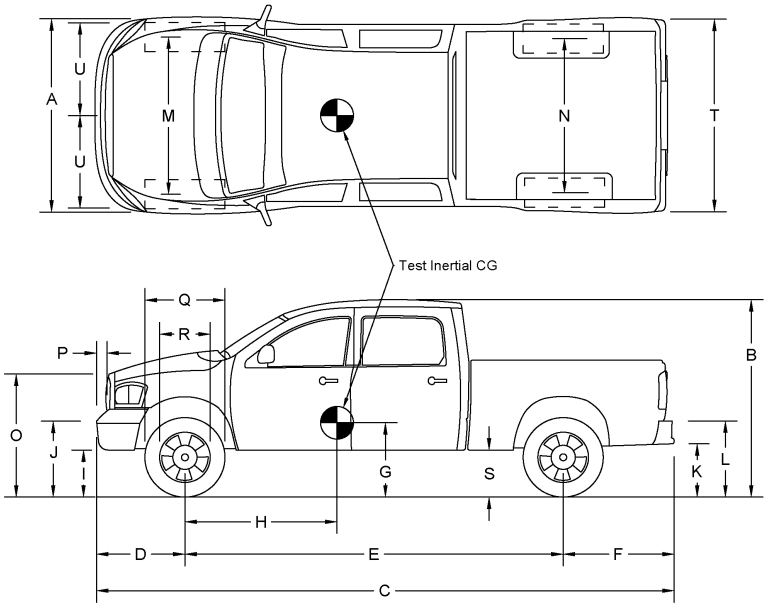


Figure 20. Test Vehicle's Interior Floorboards and Undercarriage, Test No. MGSCO-4

Test Name:	MGSCO-4			**VIN No:**	1C6RR6KP7DS679213
Model Year:	2013	**Make:**	Dodge	**Model:**	RAM 1500
Tire Size:	P265/70R17	**Tire Inflation Pressure:**	40 psi	**Odometer:**	238601



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

A:	77 5/16 (1964) 78±2 (1950±50)	**B:**	75 (1905)
C:	229 3/8 (5826) 237±13 (6020±325)	**D:**	40 (1016) 39±3 (1000±75)
E:	140 1/4 (3562) 148±12 (3760±300)	**F:**	49 1/8 (1248)
G:	28 15/16 (735) min: 28 (710)	**H:**	62 3/16 (1580) 63±4 (1575±100)
I:	13 1/2 (343)	**J:**	55 9/16 (1411)
K:	20 9/16 (522)	**L:**	29 (737)
M:	68 1/4 (1734) 67±1.5 (1700±38)	**N:**	67 1/2 (1715) 67±1.5 (1700±38)
O:	45 (1143) 43±4 (1100±75)	**P:**	3 1/2 (89)
Q:	31 1/2 (800)	**R:**	18 1/2 (470)
S:	16 (406)	**T:**	77 1/4 (1962)

U (impact width): 36 11/16 (932)

Mass Distribution - lb (kg)

Gross Static	**LF**	1416 (642)	**RF**	1463 (664)
	LR	1149 (521)	**RR**	1134 (514)

Weights lb (kg)	**Curb**	**Test Inertial**	**Gross Static**
W-front	2866 (1300)	2783 (1262)	2879 (1306)
W-rear	2280 (1034)	2217 (1006)	2283 (1036)
W-total	5146 (2334)	5000 (2268) 5000±110 (2270±50)	5162 (2341) 5165±110 (2343±50)

Wheel Center Height (Front):	15 1/4 (387)
Wheel Center Height (Rear):	15 1/2 (394)
Wheel Well Clearance (Front):	35 1/2 (902)
Wheel Well Clearance (Rear):	38 (965)
Bottom Frame Height (Front):	12 (305)
Bottom Frame Height (Rear):	13 1/2 (343)
Engine Type:	Gasoline
Engine Size:	4.7l v8
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Crew Cab
Bed Length:	67"

GVWR Ratings - lb

Front	3700
Rear	3900
Total	6800

Surrogate Occupant Data

Type:	Hybrid II
Mass:	162 lb
Seat Position:	Passenger

Note any damage prior to test: None

Figure 21. Vehicle Dimensions, Test No. MGSCO-4

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [16] was used to determine the vertical component of the c.g. for the 2270P 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 location of the final c.g. is shown in Figure 21. Data used to calculate the location of the c.g. and ballast information are shown in Appendix B.

Square, black-and-white checkered targets were placed on the vehicle, as shown in Figure 22, to serve as a reference in the high-speed digital video and aid in 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 vehicle were aligned to vehicle standards except the toe-in value was adjusted to zero such that the vehicle would track properly along the guide cable. A 5B flash bulb was mounted under the vehicle's right-side windshield wiper and was fired by a pressure tape switch mounted at the impact corner of the front 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.

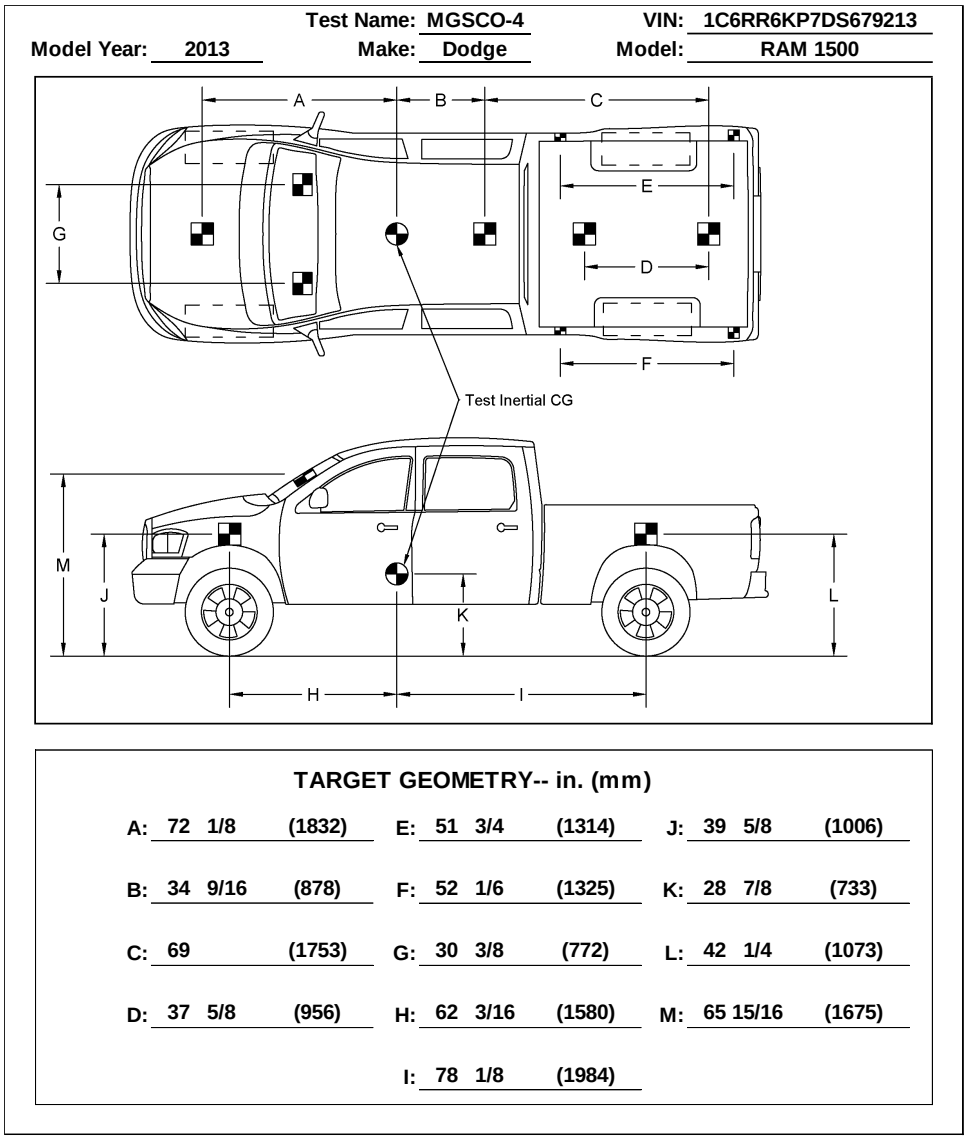


Figure 22. Target Geometry, Test No. MGSCO-4

4.4 Simulated Occupant

For test no. MGSCO-4, A Hybrid II 50th-Percentile, Adult Male Dummy equipped with footwear was placed in the right-front seat of the test vehicle with the seat belt fastened. The simulated occupant had a final weight of 162 lb. As recommended by MASH, the simulated occupant was not included in calculating the c.g. location.

4.5 Data Acquisition Systems

4.5.1 Accelerometers

Two environmental shock and vibration sensor/recorder systems were used to measure the accelerations in the longitudinal, lateral, and vertical directions. Both accelerometer systems were mounted near the c.g. of the test vehicle. The electronic accelerometer data obtained in dynamic

testing was filtered using the SAE Class 60 and the SAE Class 180 Butterworth filter conforming to the SAE J211/1 specifications [17].

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

4.5.2 Rate Transducers

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

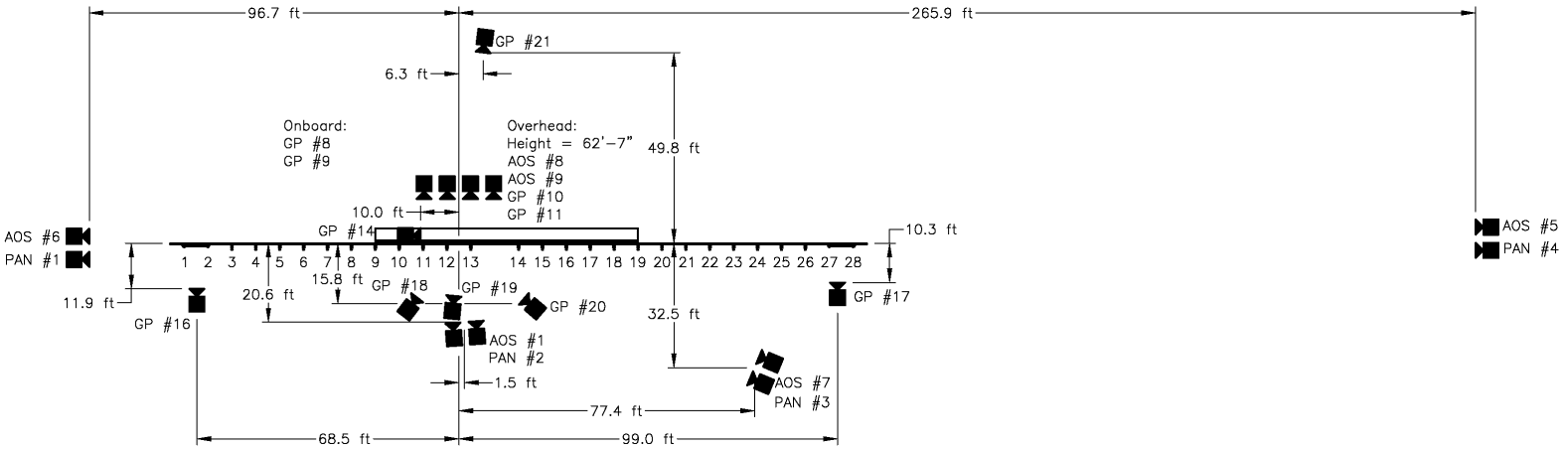
4.5.3 Retroreflective Optic Speed Trap

A retroreflective optic speed trap was used to determine the speed of the vehicle before impact. Five retroreflective targets, spaced approximately at 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.

4.5.4 Digital Photography

Six AOS high-speed digital video cameras, 11 GoPro digital video cameras, and four Panasonic digital video cameras were utilized to film test no. MGSCO-4. Note that four of the GoPro cameras did not record the test due to technical difficulties. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 23

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



No.	Type	Operating Speed frames/sec	Lens	Lens Setting
AOS-1	AOS Vitcam	500	KOWA 25mm	-
AOS-5	AOS X-PRI	500	100mm	-
AOS-6	rAOS X-PRI	500	Fujinon 50mm	-
AOS-7	AOS X-PRI	500	Fujinon 75mm	-
AOS-8	AOS S-VIT 1531	500	KOWA 16mm	-
AOS-9	AOS TRI-VIT 2236	500	KOWA 12mm	-
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-10	GoPro Hero 4	240		
GP-11	GoPro Hero 4	120		
GP-14	GoPro Hero 4	240		
GP-16	GoPro Hero 4	240		
GP-17	GoPro Hero 4	240		
GP-18*	GoPro Hero 6	240		
GP-19*	GoPro Hero 6	240		
GP-20*	GoPro Hero 6	240		
GP-21*	GoPro Hero 6	240		
PAN-1	Panasonic HC-V770	120		
PAN-2	Panasonic HC-V770	120		
PAN-3	Panasonic HC-V770	120		
PAN-4	Panasonic HC-V770	120		

* Camera did not record the impact event due to technical difficulties.

Figure 23. Camera Locations, Speeds, and Lens Settings, Test No. MGSCO-4

5 FULL-SCALE CRASH TEST NO. MGSCO-4

5.1 Static Soil Test

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

5.2 Weather Conditions

Test no. MGSCO-4 was conducted on November 26, 2019 at approximately 10:00 a.m. The weather conditions as reported by the National Oceanic and Atmospheric Administration (station 14939/KLNK) are shown in Table 4.

Table 4. Weather Conditions, Test No. MGSCO-4

Temperature	35°F
Humidity	78%
Wind Speed	13 mph
Wind Direction	30° from True North
Sky Conditions	Overcast
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.37 in.

5.3 Test Description

Initial vehicle impact was to occur 187.5 in. upstream from post no. 14, as shown in Figure 24. The impact point was selected using BARRIER VII analysis software, as discussed in Section 2.2. The 5,000-lb pickup truck impacted the MGS with curb and omitted post at a speed of 62.0 mph and at an angle of 25.1 degrees. The actual point of impact was 1.2 in. downstream from the target location. After brakes were applied, the vehicle came to rest 189.4 ft downstream and 34.1 ft in front of the system and was angled slightly toward the system.

A detailed description of the sequential impact events is contained in Table 5. Sequential photographs are shown in Figures 25 and 26. Documentary photographs of the crash test are shown in Figure 27. The vehicle trajectory and final position are shown in Figure 28.

Figure 24. Target Impact Location, Test No. MGSCO-4

Table 5. Sequential Description of Impact Events, Test No. MGSCO-4

Time sec	Event
0.000	Vehicle's front bumper contacted rail between post nos. 12 and 13. Vehicle's right-front tire contacted curb.
0.008	Post no. 12 deflected backward. Vehicle's right-front wheel contacted rail between post nos. 12 and 13.
0.016	Post no. 13 deflected backward.
0.024	Post no. 12 twisted clockwise.
0.044	Post no. 14 deflected backward.
0.054	Post no. 13 twisted counterclockwise.
0.058	Vehicle began yawing away from system.
0.074	Vehicle began rolling toward system.
0.082	Post no. 15 deflected backward.
0.094	Rail disengaged from bolt at post no. 13.
0.128	Post no. 14 twisted counterclockwise and bent backward.
0.138	Vehicle's right-rear tire contacted curb.
0.150	Vehicle's rear bumper contacted rail.
0.164	Rail disengaged from bolt at post no. 14.
0.168	Post no. 15 bent backward.
0.176	Vehicle's right-rear wheel contacted rail.
0.178	Vehicle's left-front tire became airborne.
0.206	Post no. 11 deflected backward. Blockout disengaged from post no. 14.
0.220	Vehicle’s right-front tire impacted post 14.
0.230	Vehicle's left-rear tire became airborne.
0.238	Post no. 15 twisted counterclockwise.
0.242	Vehicle was parallel to the system at a speed of 47.8 mph.
0.256	Post no. 16 deflected backward.
0.274	Rail disengaged from bolt at post no. 15.
0.298	Vehicle pitched downward slightly.
0.372	Vehicle's right-front tire became airborne.
0.412	Post no. 16 bent downstream.
0.626	Vehicle exited system at a speed of 44.0 mph and at an angle of -14.7 degrees.
0.632	Vehicle's right-front tire regained contact with ground.
0.722	Vehicle reached maximum roll angle of 21 degrees and began to roll away from system.
0.880	Vehicle's left-front tire regained contact with ground.
0.926	System came to a rest.
0.950	Vehicle's left-rear tire regained contact with ground.


0.000 sec


0.000 sec


0.050 sec


0.100 sec


0.100 sec


0.200 sec


0.150 sec


0.300 sec


0.200 sec


0.400 sec

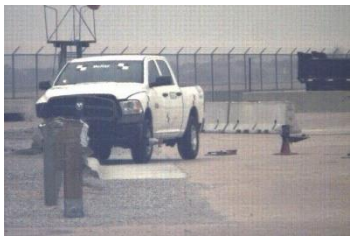

0.250 sec


0.500 sec

Figure 25. Sequential Photographs, Test No. MGSCO-4


0.000 sec


0.000 sec


0.150 sec


0.150 sec


0.300 sec


0.300 sec


0.450 sec


0.450 sec


0.600 sec


0.600 sec


0.750 sec


0.750 sec

Figure 26. Sequential Photographs, Test No. MGSCO-4

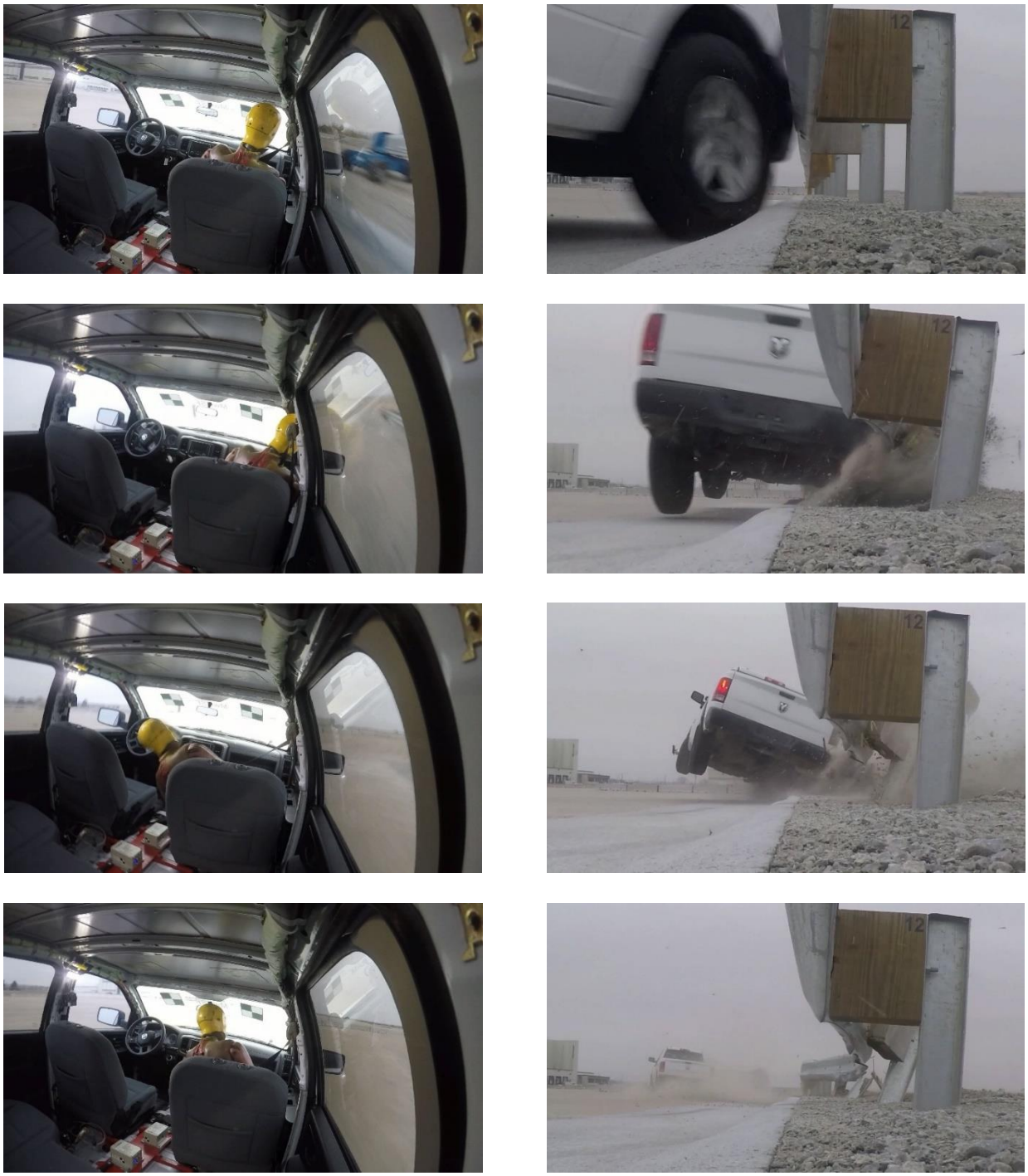


Figure 27. Documentary Photographs, Test No. MGSCO-4

Figure 28. Vehicle Final Position and Trajectory Marks, Test No. MGSCO-4

5.4 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 29 through 35. Barrier damage consisted of contact marks along with deformed W-beam rail, posts, post-to-rail attachment hardware, and timber blockouts. The length of vehicle contact along the rail was approximately 28 ft – 9 in., which spanned from 29 in. downstream from the center of post no. 12 to 4 in. downstream from the center of post no. 16.

At the upstream anchorage, post no. 2 had bolt pullout from the rail and the timber post fractured through the bottom hole. Post nos. 3 through 11 twisted clockwise. The guardrail was detached from post nos. 12 through 16 and the blockout detached from post no. 14. There were numerous kinks and dents on the W-beam rail between post nos. 12 and 16. Soil heaves and craters formed at the base of post nos. 12 through 16. Post nos. 12 and 13 rotated backward and twisted clockwise. Post no. 14 rotated downstream and twisted counterclockwise and the front flange buckled. Post no. 15 twisted counterclockwise and bent backward and downstream. Post no. 16 bent backward.

Figure 29. System Damage, Test No. MGSCO-4

Figure 30. System Damage, Test No. MGSCO-4

Figure 31. System Damage, Test No. MGSCO-4

Figure 32. System Damage, Post Nos. 12 and 13, Test No. MGSCO-4

Figure 33. System Damage, Post Nos. 14 and 15, Test No. MGSCO-4

The permanent set of the barrier system was measured in the field using GPS. The maximum lateral permanent set, inclusive of both guardrail and post deflections, was 25.3 in. at the midspan between post nos. 13 and 14. The maximum lateral dynamic barrier deflection was 38.6 in. at the splice upstream from post no. 14. This was determined from high-speed digital video analysis and included deformation of the MGS along the top surface. The working width of the system was found to be 41.8 in., also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 34.

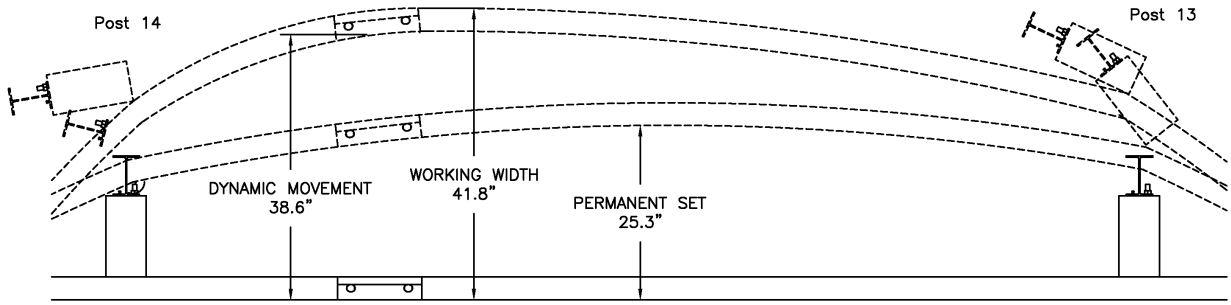


Figure 34. Permanent Set, Dynamic Deflection, and Working Width, Test No. MGSCO-4

5.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 35 through 37. The maximum occupant compartment intrusions are listed in Table 6 along with the intrusion limits established in MASH for various areas of the occupant compartment. Complete occupant compartment and vehicle deformations and their corresponding locations are provided in Appendix D. MASH 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 deformation limits were violated. Outward deformations, which are denoted as negative numbers in Appendix D, are not considered crush toward the occupant.

The majority of damage was concentrated on the right-front corner where the impact occurred as well as the front of the vehicle. The grille and right headlight disengaged from the vehicle. The right-front bumper was dented inward, and the right-front corner of the bumper was deformed and partly disengaged. The right-front fender panel was deformed outward. Part of the right-front tire rim was chipped off. Contact marks and scratches were observed throughout the right side of the vehicle. Both right-side doors were deformed slightly. The right-rear corner of the truck was dented below the taillight and on the rear bumper. The roof, windshield, and window glass remained undamaged.

Undercarriage damage was minimal. The right-front shock was bent outward and toward the rear of the vehicle. The right-front sway bar linkage was disconnected. The right lower control arm was disconnected and broken at the cross member mounts. The right outer tie rod was bent. Additionally, the right side steering knuckle assembly and streering gear box had minor scraping.

Figure 35. Vehicle Damage, Test No. MGSCO-4

Figure 36. Vehicle Damage, Test No. MGSCO-4

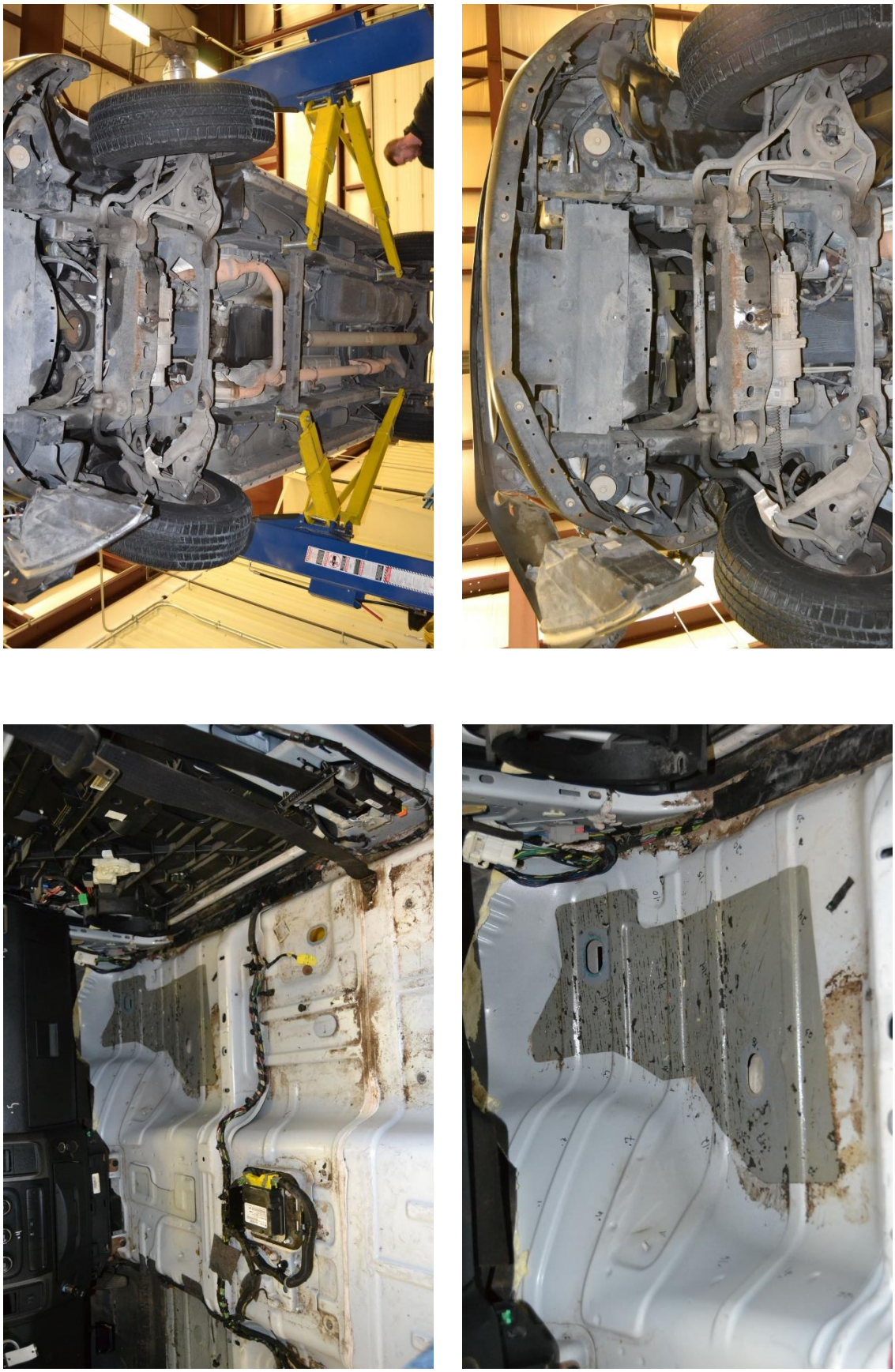


Figure 37. Occupant Compartment and Undercarriage Damage, Test No. MGSCO-4

Table 6. Maximum Occupant Compartment Intrusion by Location, Test No. MGSCO-4

Location	Maximum Intrusion in.	MASH Allowable Intrusion in.
Wheel Well & Toe Pan	0.0	≤ 9
Floor Pan & Transmission Tunnel	0.1	≤ 12
A-Pillar	0.2	≤ 5
A-Pillar (Lateral)	0.0	≤ 3
B-Pillar	0.1	≤ 5
B-Pillar (Lateral)	0.0	≤ 3
Side Front Panel (in Front of A-Pillar)	0.1	≤ 12
Side Door (Above Seat)	0.0*	≤ 9
Side Door (Below Seat)	0.2	≤ 12
Roof	0.1	≤ 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 criteria exist for this location.
* Negative value reported as 0.0. See Appendix D for further information.

5.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from accelerometer data, are shown in Table 7. Note that the OIVs and ORAs were within suggested limits, as provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 7. The recorded data from the accelerometers and the rate transducers is shown graphically in Appendix E.

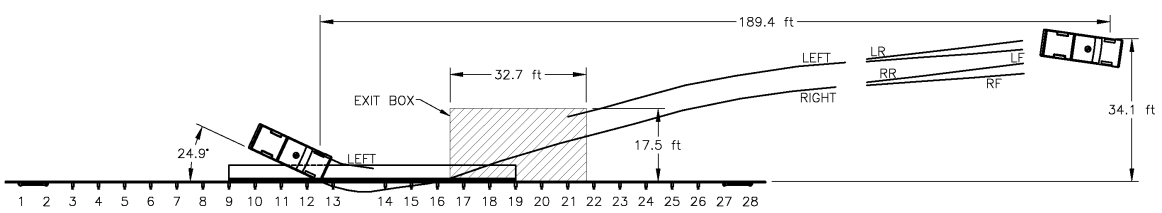
Table 7. Summary of Occupant Risk Values, Test No. MGSCO-4

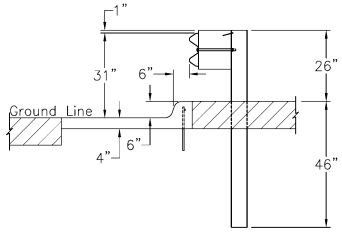
Evaluation Criteria		Transducer		MASH Limits
		SLICE-1	SLICE-2 (primary)	
OIV (ft/s)	Longitudinal	-12.02	-11.18	±40
	Lateral	-14.96	-16.04	±40
ORA (g's)	Longitudinal	-6.26	-6.72	±20.49
	Lateral	-9.10	-8.46	±20.49
Maximum Angular Displacement deg.	Roll	25.0	20.9	±75
	Pitch	-2.2	-4.0	±75
	Yaw	-46.0	-45.9	not required
THIV – ft/s		18.36	19.03	not required
PHD – g's		10.69	10.68	not required
ASI		0.87	0.81	not required

5.7 Discussion

The analysis of the test results for test no. MGSCO-4 showed that the system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. Sequential photographs and a summary of the test results are shown in Figure 38. 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 -14.7 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. MGSCO-4 was determined to be acceptable according to the MASH safety performance criteria for test designation no. 3-11.

0.000 sec 0.100 sec 0.250 sec 0.400 sec 0.600 sec





- Test Agency ..... MwRSF
- Test Number MGSCO-4
- Date 11/26/2019
- MASH Test No. 3-11
- Test Article ..... MGS with Curb and Omitted Post
- Total Length ..... 182 ft – 3½ in.
- Key Component – Steel W-beam Guardrail
  - Thickness ..... Nested 12 gauge
  - Top Mounting Height ..... 31 in. from roadway surface
- Key Component – Steel Post
  - Shape W6x8.5
  - Length ..... 72 in.
  - Post Nos. 1-12, 15-28 Spacing ..... 75 in.
  - Post Nos. 13-14 Spacing ..... 150 in.
  - Embedment Depth ..... 46 in.
- Key Component – Timber Blockout (Post Nos. 3-26)
  - Size ..... 6 in. x 14¼ in. x 12 in.
- Soil Type ..... Coarse, Crushed Limestone (Well-Graded Gravel)
- Vehicle Make /Model ..... 2013 Dodge Ram
  - Curb ..... 5,146 lb
  - Test Inertial ..... 5,000 lb (MASH Limit 5,000 ± 110 lb)
  - Gross Static ..... 5,162 lb
- Impact Conditions
  - Speed ..... 62.0 mph (MASH Limit 62 ± 2.5 mph)
  - Angle ..... 25.1 deg. (MASH Limit 25 ± 1.5 deg.)
  - Impact Location ..... 186.3 in. upstream from post no. 14
- Impact Severity ..... 115.9 kip-ft >106 kip-ft limit from MASH
- Exit Conditions
  - Speed ..... 44.0 mph
  - Angle ..... -14.7 deg.
- Exit Box Criterion ..... Pass
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 189.4 ft downstream
  34.1 ft laterally in front
- Vehicle Damage ..... Moderate
  - VDS [18] 1-FR-4
  - CDC [19] 01-FREW-3
  - Maximum Interior Deformation ..... 0.2 in. at A-Pillar ≤ 5 in. MASH Limit
- Test Article Damage ..... Moderate
- Maximum Test Article Deflections
  - Permanent Set ..... 25.3 in.
  - Dynamic ..... 38.6 in.
  - Working Width ..... 41.8 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH Limits
		SLICE-1	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-12.02	-11.18	±40
	Lateral	-14.96	-16.04	±40
ORA g's	Longitudinal	-6.26	-6.72	±20.49
	Lateral	-9.10	-8.46	±20.49
Maximum Angular Displacement deg.	Roll	25.0	20.9	±75
	Pitch	-2.2	-4.0	±75
	Yaw	-46.0	-45.9	not required
THIV – ft/s		18.36	19.03	not required
PHD – g's		10.69	10.68	not required
ASI		0.87	0.81	not required

Figure 38. Summary of Test Results and Sequential Photographs, Test No. MGSCO-4

6 SUMMARY AND CONCLUSIONS

The objective of this project was to evaluate the nested MGS with an omitted post placed adjacent to a curb in accordance with MASH test 3-11 criteria. The test article utilized for full-scale crash testing consisted of the MGS placed with the face of the rail offset 6 in. behind a 6-in tall AASHTO Type B curb, an omitted post in the middle of the barrier system, and 37 ft – 6 in. of nested W-beam guardrail placed in the region of the 150-in. elongated span.

In test no. MGSCO-4, the 5,000-lb pickup truck impacted the MGS test installation at a speed of 62.0 mph and an angle of 25.1 degrees, resulting in an impact severity of 115.9 kip-ft. Initial impact occurred 186.3 in. upstream from post no. 14 in an attempt to maximize system deflections, rail loading, and the potential for vehicle snag on system posts. The vehicle was captured, safely redirected, and exited the system at a speed of 44.0 mph at an angle of -14.7 degrees. The vehicle remained upright and stable throughout the test, and all vehicle decelerations and occupant compartment deformations were within the allowable MASH limits. There was no evidence of rail tearing. Therefore, test no. MGSCO-4 satisfied the safety performance criteria for MASH test designation no. 3-11. A summary of the test evaluation is shown in Table 8.

Previously, this same MGS configuration was crash tested with the 1100C vehicle in test no. MGSCO-2, and the system met the safety performance criteria for MASH test 3-10 [8]. Test no. MGSCO-4 completed the MASH TL-3 longitudinal barrier test matrix. Therefore, the nested MGS with a curb and an omitted post has been assessed as crashworthy to MASH TL-3. Chapter 7 provides recommendations and installation guidance for the MGS with a curb and an omitted post.

Table 8. Summary of Safety Performance Evaluation

<table>
<tr><th>Evaluation Factors</th><th>Evaluation Criteria</th><th>Test No. MGSCO-4</th></tr>
<tr><td>Structural Adequacy</td><td>A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td><td>S</td></tr>
<tr><td rowspan="4">Occupant Risk</td><td>D 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.
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.</td><td>S
S</td></tr>
<tr><td>F. 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></tr>
<tr><td>H. Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits:
<table>
<tr><th colspan="3">Occupant Impact Velocity Limits</th></tr>
<tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s</td><td>40 ft/s</td></tr>
</table></td><td>S</td></tr>
<tr><td>I. The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits:
<table>
<tr><th colspan="3">Occupant Ridedown Acceleration Limits</th></tr>
<tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
</table></td><td>S</td></tr>
<tr><td colspan="2">MASH Test Designation No.</td><td>3-11</td></tr>
<tr><td colspan="2">Final Evaluation (Pass or Fail)</td><td>Pass</td></tr>
</table>

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

7 RECOMMENDATIONS AND IMPLEMENTATION GUIDANCE

The following sections provide implementation guidance and/or recommendations regarding the installation of the nested MGS in combination with a curb and an omitted post. These recommendations are intended to ensure consistent safety performance of guardrail installations and are based on the full-scale testing and associated research available at the conclusion of this project. Although some installation sites will require systems outside the bounds of these recommendations, the reasoning behind these recommendations should still be considered along with other roadside treatments when selecting the final site-specific design.

The system tested and evaluated herein is a combination of two special MGS applications: the MGS adjacent to a curb and the MGS with an omitted post. Although the combination of these two configurations necessitated nested guardrail in the omitted post region, the implementation recommendations previously provided for the MGS adjacent to a curb and the MGS with an omitted post still apply. In other words, the nested MGS adjacent to curb and with an omitted post system evaluated herein should be installed under the same conditions previously recommended for both individual systems. These recommendations were not repeated herein but can be found in the project reports for each individual MGS configuration [6-7].

7.1 Minimum Length of Nested Rail

The initial test of the MGS with a curb and omitted post used standard, single-ply W-beam rail throughout the system. Rail tearing occurred during test no. MGSCO-1 and the system failed to meet MASH criteria. The system was then modified to incorporate nested rail around the omitted post. Testing of the modified system, test nos. MGSCO-2 with the small car and test no. MGSCO-4 with the pickup truck, satisfied MASH safety performance criteria. Based on the previously reported results of test nos. MGSCO-1 and MGSCO-2 [8], and test no. MGSCO-4 documented herein, it is recommended to install a minimum of 37 ft – 6 in. of nested W-beam rail at any omitted post location within an installation of MGS placed adjacent to curb. The nested rail should be installed over the elongated 150-in. span resulting from the omitted post and should extend a minimum of 112½ in. both upstream and downstream of the elongated span, which corresponds to at least two posts on each side of the omitted post, as shown in Figure 39. Note, unless 6-ft-3-in. long guardrail sections are utilized within the system, the nested rail section will not be centered about the omitted post location. The resulting offset configuration will not affect system performance. In fact, both test nos. MGSCO-2, and MGSCO-4 were conducted with the non-symmetrical layout shown in Figure 39.

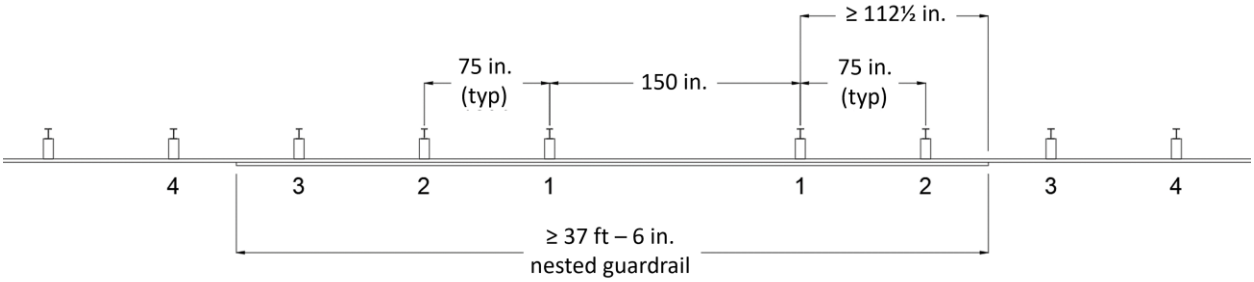


Figure 39. Minimum Length and Position for Nested Guardrail

7.2 Multiple Omitted Posts

The evaluation and conclusions provided herein relate to the omission of a single support post within the MGS adjacent to a curb. Omitting consecutive posts increases concerns for excessive pocketing, vehicle snag, and rail rupture. Although the MGS long-span system has been successfully crash tested to MASH TL-3 while omitting three consecutive posts, the long-span system has not been evaluated with a curb, and it is not currently recommended for use with a culvert headwall that extends more than 2 in. above the ground surface [20]. Thus, omitting two or more consecutive posts within the MGS adjacent to curb is not recommended until further evaluation is conducted.

Though not evaluated as part of this study, the omission of multiple non-consecutive posts within an MGS instillation may also lead to increased deflections, increased rail loads, and increased pocketing. Therefore, sufficient distance between omitted posts within an MGS instillation is necessary to ensure proper system performance. To conform with the recommendations provided for omitted posts within standard MGS [7], a minimum distance of 56 ft – 3 in. is recommended between omitted posts, as shown in Figure 40. This distance is equivalent to saying a single post may be omitted at every 9th post along an MGS installation.

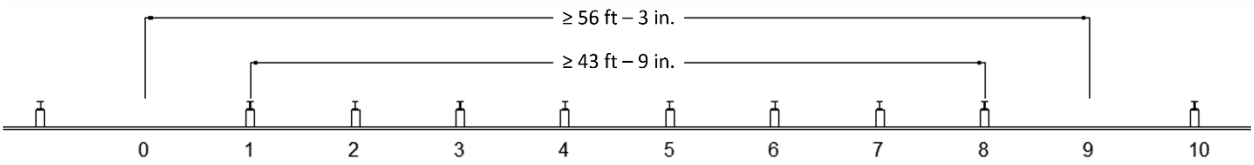


Figure 40. Minimum Recommended Distance between Omitted Posts

7.3 MGS Stiffness Transition

The MGS stiffness transition was previously developed to connect the MGS to various thrie beam, approach guardrail transitions. Both steel post and wood post versions of the MGS stiffness transition have been developed as well as a configuration for use adjacent to roadside curbs [21-23]. These previous studies recommended that 25 ft of guardrail be utilized between the upstream end of the asymmetrical W-to-thrie transition element and any guardrail flares, terminals, or variations in post spacing. Accounting for the 37½-in. post spacing required to transition between full- and half-post spacing, it is recommended to have a minimum distance of 28 ft – 1½ in. between the asymmetrical rail element and the elongated span created by an omitted post. Thus, an omitted post should be at least 34 ft – 4½ in. away from the upstream end of the W-to-thrie transition element, as shown in Figure 41.

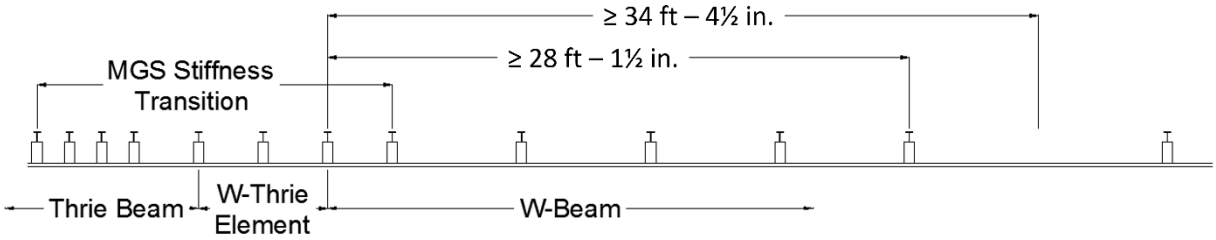


Figure 41. Recommended Distance between Omitted Posts and MGS Stiffness Transition

When the MGS upstream stiffness transition is installed adjacent to curb, 12 ft – 6 in. of nested W-beam rail is required on the upstream side of the W-to-thrie transition rail segment to strengthen the rail against premature failure [23]. Additionally, omitting a post within an MGS installation adjacent to curb requires at least 9 ft – 4½ in. of nested rail on each side of the omitted post location. If a post is omitted near the MGS stiffness transition, it may be beneficial to extend nested guardrail from the W-to-thrie transition segment to beyond the omitted post location to prevent alternating between nested and single ply guardrail.

To date, the MGS upstream stiffness transition with curb has only been evaluated with a 4-in. tall, triangular shaped curb. Accordingly, the MGS stiffness transition is only recommended for use with curbs with a height of 4 in. or lower due to concerns that taller curbs may accentuate vehicle wedging below the rail and lead to premature rail failure. Curb shape and/or height transitions (e.g., from a 4-in. tall curb to a 6-in. tall AASHTO Type B curb) should occur at least 12 ft – 6 in. upstream from the W-to-thrie transition rail segment. Further, curb shape transitions are recommended to use transition lengths of at least 3 ft to mitigate vehicle wedging or instabilities. Two-inch curb height transitions near omitted post locations are not anticipated to negatively affect the safety performance of the system.

7.4 Guardrail Terminals and Anchorages

Multiple W-beam guardrail end terminals have been developed for use with the MGS. However, to date, no guardrail end terminations or anchorages have been evaluated to MASH criteria when placed adjacent to curbs. Additionally, no guardrail terminals or anchorages have been evaluated to MASH with one or more omitted posts within the terminal stroke length. Thus, it is recommended to extend guardrail systems an adequate distance beyond roadside curbs and the location of any omitted posts prior to terminating/anchoring the system to avoid negatively affecting the safety performance of the guardrail terminal. Further guidance may be found within the installation manual or guidance provided for each specific guardrail terminal.

8 MASH EVALUATION

The MGS with a curb and a single omitted post was evaluated in accordance with MASH TL-3 criteria. The test article utilized for full-scale crash testing consisted of the MGS placed with the face of the guardrail 6 in. behind the face of a 6-in tall AASHTO Type B curb. An omitted post in the middle of the barrier system created a single elongated rail span of 150 in., and 37 ft – 6 in. of nested W-beam guardrail was placed in the region of the elongated span. The MGS was given a nominal rail height of 31 in. measured from the roadway surface, and soil backfill was placed behind the curb to maintain a ground line even with the top of the curb. As such, the nominal post embedment depth was increased by 6 in. to 46 in.

The nested MGS with a curb and an omitted post was subjected to two crash tests in accordance with MASH TL-3 evaluation criteria. In test no. MGSCO-2, the 1100C small car was contained and safely redirected. All occupant risk criteria were satisfied, and the test satisfied MASH test designation no. 3-10 criteria. During test no. MGSCO-4, the 2270P pickup was captured and smoothly redirected, and all occupant risk values were below MASH limits. Thus, test no. MGSCO-4 satisfied MASH test designation no. 3-11 criteria.

With the successful completion of both crash tests within the TL-3 testing matrix, nested MGS offset 6 in. behind the face of a 6-in. tall AASHTO Type B curb in combination with a single omitted post was assessed as crashworthy to MASH TL-3 criteria. Note, the guardrail should be nested for a minimum length of 37 ft – 6 in. , and the nested rail should be extended a minimum of 112.5 in. beyond each side of the elongated span. This ensures the nested rail extends across at least two posts upstream and downstream from the omitted post location.

A reduced offset between the barrier and the face of the curb is generally considered to improve system performance as it reduces the curb's effect on vehicle trajectory. Thus, the nested MGS with an omitted post should be considered crashworthy for curb-to-guardrail offsets between 0 in. and 6 in. Lower height curbs and curbs with sloped faces are also expected to reduce the vertical trajectory of impacting vehicles. Since the nested MGS with an omitted post was evaluated with a critical curb shape, the MGS is expected to remain crashworthy in combination with any standard AASHTO curb shape at or below a maximum height of 6 in.

9 REFERENCES

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10 APPENDICES

Appendix A. Material Specifications

Table A-1. Bill of Materials, Test No. MGSCO-4

Item No.	Description	Material Specification	Reference No.
a1	12'-6" 12-gauge W-Beam MGS Section	AASHTO M180	H#C85187 H#9411949
a2	12'-6" 12-gauge W-Beam MGS End Section	AASHTO M180	H#C85187 H#9411949
a3	6'-3" 12-gauge W-Beam MGS Section	AASHTO M180	H#31631800
a4	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992 Min. 50 ksi	Post Nos. 3-17: H#55062363 H#55062364 H#55062370 H#55059251 Post Nos.18-26: H#1702406
a5	6"x12"x14¼" Timber Blockout for Steel Posts	SYP Grade No.1 or better	Ch#18379 Ch#23888 Ch#23888 Ch#21327
a6	16D Double Head Nail	-	Certificate of Compliance for PO E000548963 McMaster Carr
b1	BCT Timber Post - MGS Height	SYP Grade No. 1 or better (No knots 18" above or below ground tension face)	Ch# 269
b2	72" Long Foundation Tube	ASTM A500 Gr. B	H#811T08220
b3	Ground Strut Assembly	ASTM A36	H#195070
b4	2⅜" O.D. x 6" Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	H#B712810
b5	8"x8"x⅝" Anchor Bearing Plate	ASTM A36	H#4181496
b6	Anchor Bracket Assembly	ASTM A36	H#A87581 H#JK16101488
c1	BCT Anchor Cable	-	Assembly Specialty Products Inc. Certificate of Conformance
d1	⅝" Dia. UNC, 14" Long Guardrail Bolt	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	H#DL17100590
d2	⅝" Dia. UNC, 10" Long Guardrail Bolt	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	H#1721198
d3	⅝" Dia. UNC, 1¼" Long Guardrail Bolt	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	H#10553090
d4	⅝" Dia. UNC, 10" Long Hex Head Bolt	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	H#JK18104124
d5	⅝" Dia. UNC, 1½" Long Hex Head Bolt	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	H#5-010570

Table A-2. Bill of Materials, Test No. MGSCO-4, Cont.

d6	⅞" Dia. UNC, 8" Long Hex Head Bolt	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	H#489517
e1	⅝" Dia. Plain USS Washer	ASTM F844	P#1133185 L#1845511
e2	⅞" Dia. Plain USS Washer	ASTM F844	P#33187 L#1844804
f1	Curb	f'c = 4,000 psi	Ticket#1237834 Report#2147371499
f2	#4 Rebar 819" Long	ASTM A615 Gr. 60	H#58033918
f3	#4 Rebar 16" Long	ASTM A615 Gr. 60	H#602934
g1	⅝" Dia. Heavy Hex Nut	ASTM A563A	H#10508780 H#62144802 H#20479830 H#20550810
g2	⅝" Dia. Hex Nut	ASTM A563A	H#331608011
g3	⅞" Dia. Hex Nut	ASTM A563A	H#18108473-3

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: Customer P O: Shipped to: Project: GHP Order No.:	 1/26/2018 36263 UNIVERSITY OF NEBRASKA-LINCOLN 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.

Jeffery L Grover

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, Test No. MGSCO-4 (Item Nos. a1 and a2)

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

H E A T M A S T E R L I S T I N G

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-2. 12-ft 6-in. 12-Gauge W-Beam, Test No. MGSCO-4 (Item Nos. a1 and a2)

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

Test Report

Customer:	GUARDRAIL SYSTEMS	Ship Date;	10/12/2016
	8000 SERUM AVE.	Customer P O	EMAIL 6-21-2016
		Shipped to:	GUARDRAIL SYSTEMS
	RALSTON,NE,68127-4213	Project:	STOCK
		GHP Order No.:	9386AJ

HT # code	Heat #	C.	MN.	P.	S.	Si.	Tensile	Yield	Elong.	Quanity	Class	Type	Description
9760	31631800	0.2	0.85	0.01	0.001	0.04	79600	62100	25	6	A	1	12GA 15FT7 5IN WB T13FT1.5IN
9761	4152233	0.22	0.74	0.011	0.006	0.01	79057	59958	25.33	6	A	1	12 GA 12FT6IN WB T1 FLEAT-SKT COMBO PAN
9760	31631800	0.2	0.85	0.01	0.001	0.04	79600	62100	25	5	A	1	12GA 25FT0IN 3FT1 1/2IN WB T1
9692	31629790	0.2	0.82	0.012	0.002	0.04	81442	58556	17.56	1	A	1	12GA 25FT0IN 3FT1 1/2IN WB T1
9760	31631800	0.2	0.85	0.01	0.001	0.04	79600	62100	25	40	A	1	12GA 6FT 3IN WB T1 HS@ 3FT 1.5IN

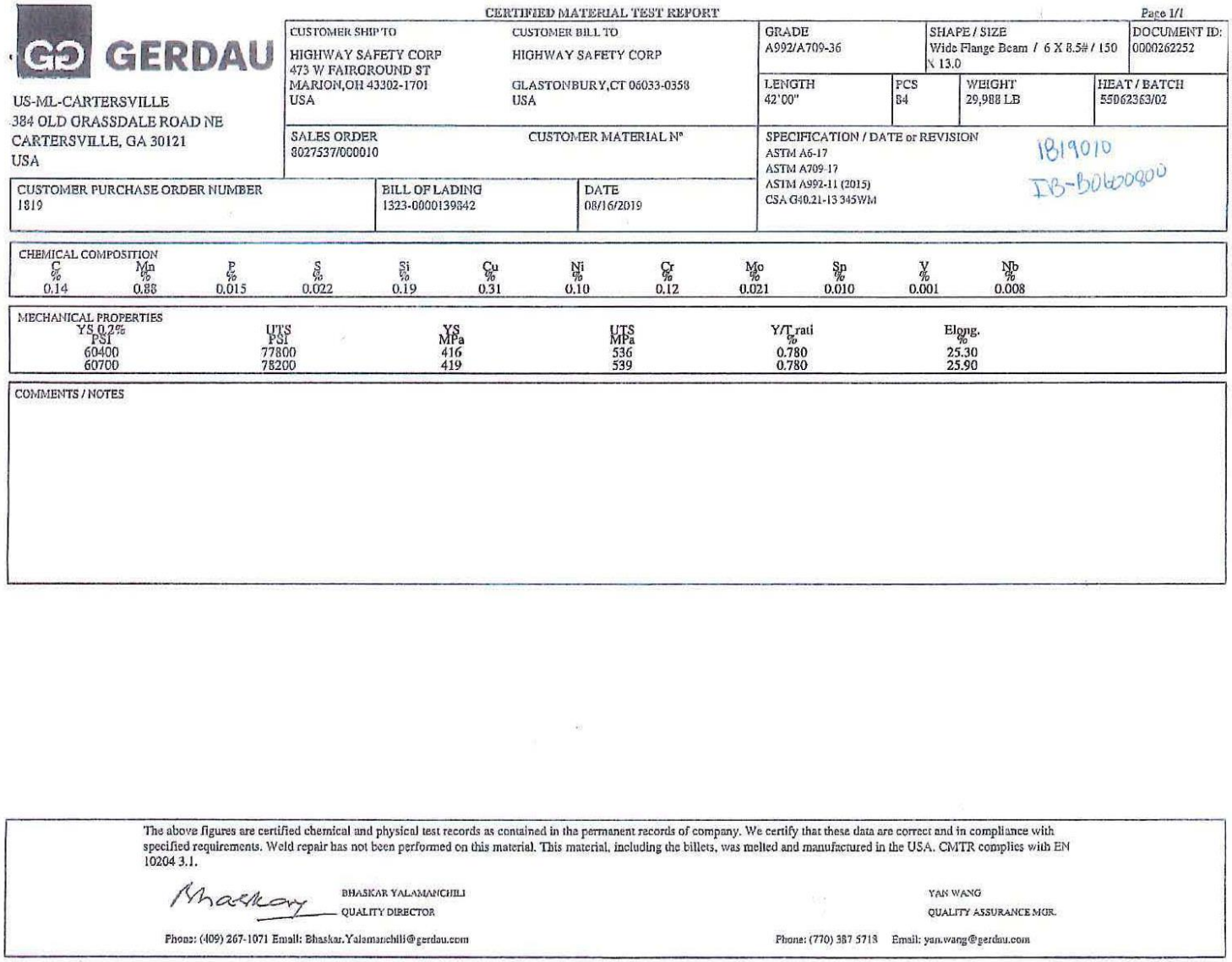
Bolts comply with ASTM A-307 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated
Nuts comply with ASTM A-563 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated
All other galvanized material conforms with ASTM-123 & ASTM-653
All 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 & Iowa 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 13 day of October, 2016

_____
Notary Public, State of Ohio

Figure A-3. 6-ft 3-in. 12-Gauge W-Beam, Test No. MGSCO-4 (Item No. a3)



CERTIFIED MATERIAL TEST REPORT

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GERDAU

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

CUSTOMER SHIP TO	CUSTOMER BILL TO
HIGHWAY SAFETY CORP 473 W FAIRGROUND ST MARION,OH 43302-1701 USA	HIGHWAY SAFETY CORP GLASTONBURY,CT 06033-0358 USA

GRADE	SHAPE / SIZE	DOCUMENT ID:
A992/A709-36	Wide Flange Beam / 6 X 8.5# / 150 N 13.0	0000262252

LENGTH	PCS	WEIGHT	HEAT / BATCH
42'00"	84	29,988 LB	55062363/02

SALES ORDER	CUSTOMER MATERIAL N°
8027537/000010	

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

1819010
IB-B0620800

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
1819	1323-0000139842	08/16/2019

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %
0.14	0.88	0.015	0.022	0.19	0.31	0.10	0.12	0.021	0.010	0.001	0.008

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	Y/T rati %	Elong. %
60400	77800	416	536	0.780	25.30
60700	78200	419	539	0.780	25.90

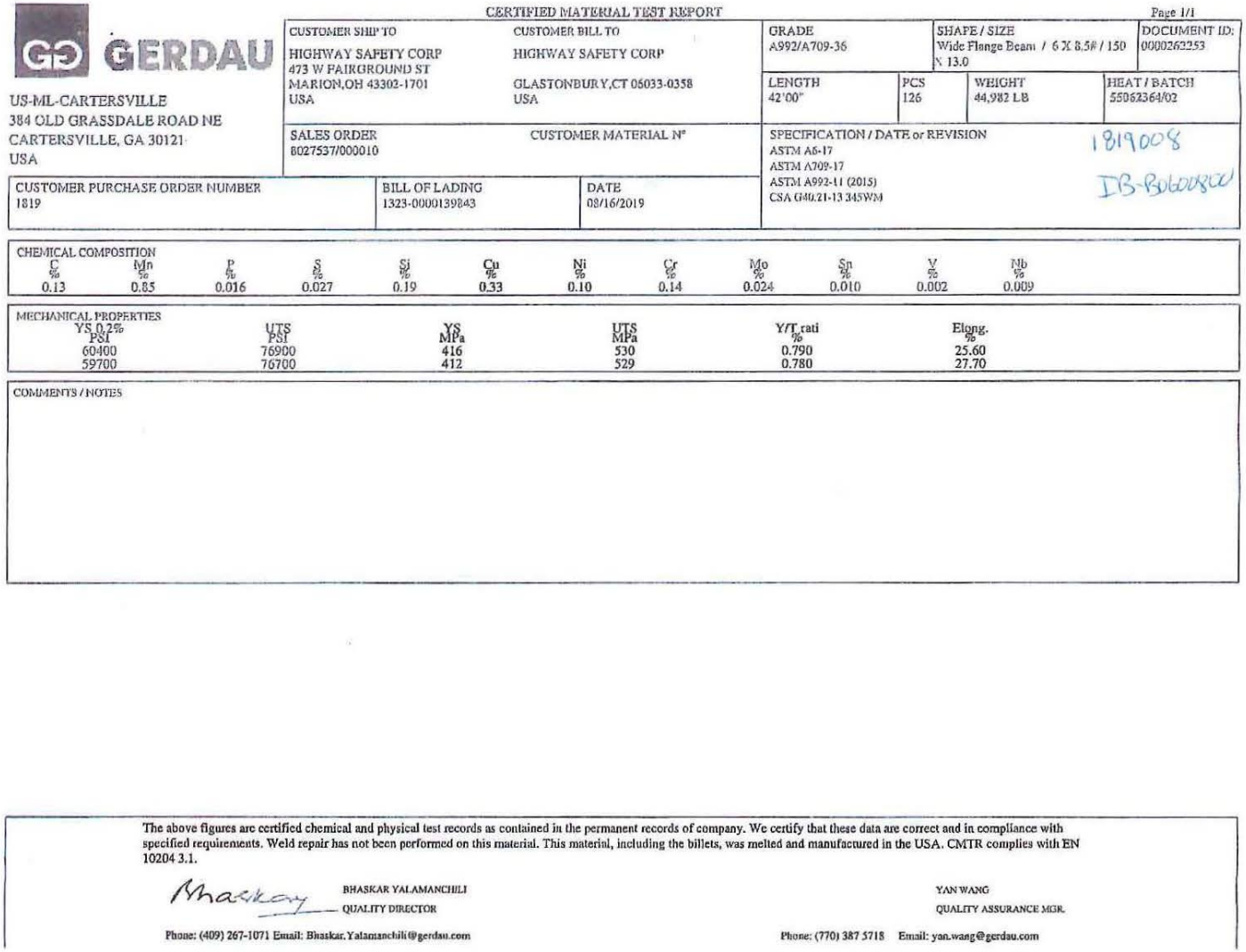
COMMENTS / NOTES

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 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-4. W6x8.5 Steel Post, Test No. MGSCO-4 (Item No. a4)



GERDAU

CERTIFIED MATERIAL TEST REPORT

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

CUSTOMER SHIP TO	CUSTOMER BILL TO
HIGHWAY SAFETY CORP 473 W FAIRGROUND ST MARION,OH 43302-1701 USA	HIGHWAY SAFETY CORP GLASTONBURY,CT 06033-0358 USA

GRADE	SHAPE / SIZE	DOCUMENT ID:
A992/A709-36	Wide Flange Beam / 6 X 8.5# / 150 X 13.0	0000262253

LENGTH	PCS	WEIGHT	HEAT / BATCH
42'00"	126	44,982 LB	55062364/02

SALES ORDER	CUSTOMER MATERIAL N°
8027537/000010	

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

1819008
IB-B060820

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
1819	1323-0000139843	08/16/2019

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %
0.13	0.85	0.016	0.027	0.19	0.33	0.10	0.14	0.024	0.010	0.002	0.009

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	Y/T rati %	Elong. %
60400	76900	416	530	0.790	25.60
59700	76700	412	529	0.780	27.70

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. 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.

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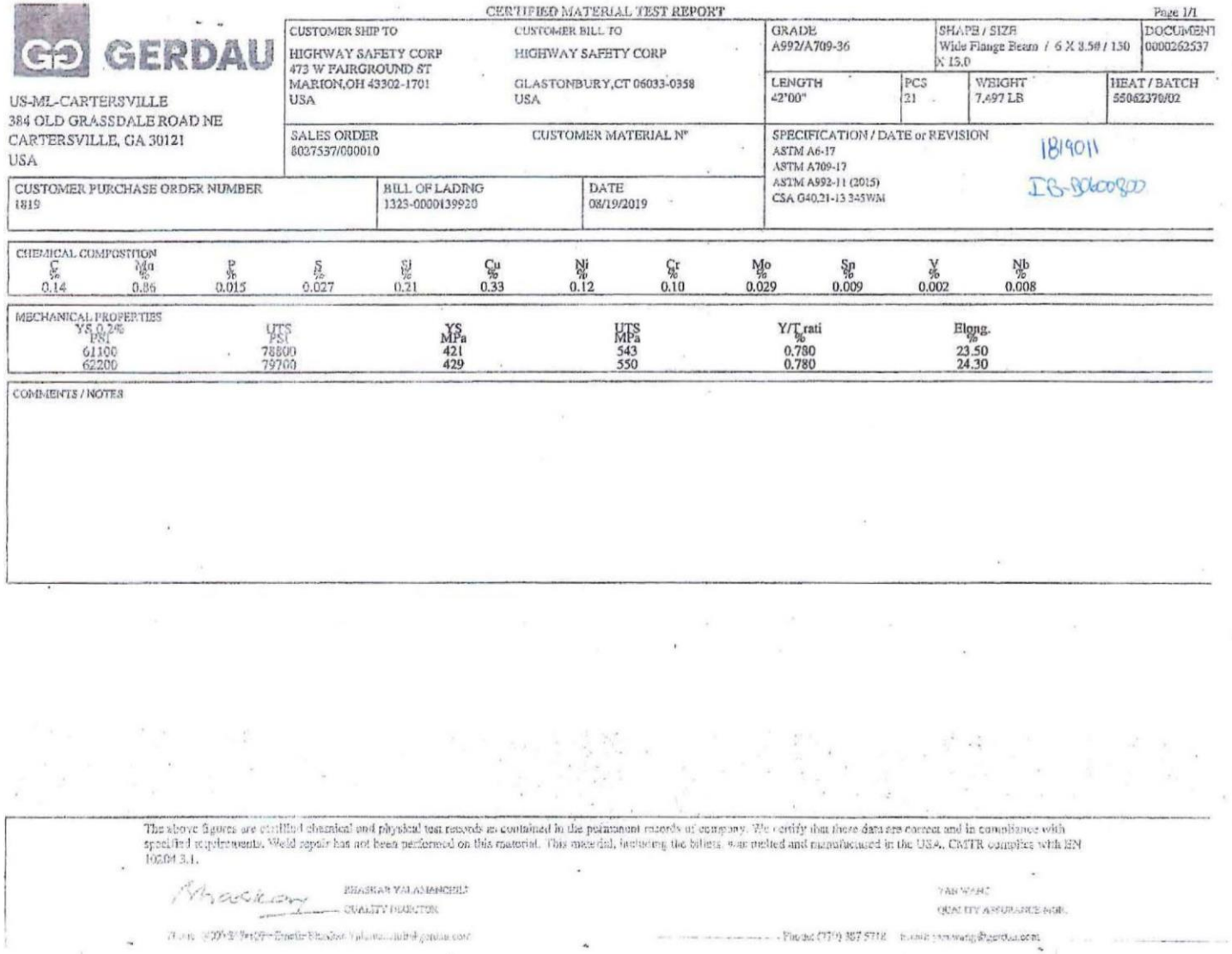
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

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

Figure A-5. W6x8.5 Steel Post, Test No. MGSCO-4 (Item No. a4)



GERDAU

CERTIFIED MATERIAL TEST REPORT

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

CUSTOMER SHIP TO	CUSTOMER BILL TO
HIGHWAY SAFETY CORP 473 W FAIRGROUND ST MARION,OH 43302-1701 USA	HIGHWAY SAFETY CORP GLASTONBURY,CT 06033-0358 USA

GRADE	SHAPE / SIZE	DOCUMENT
A992/A709-36	Wide Flange Beam / 6 X 8.50 / 150 X 15.0	0000262537

LENGTH	PCS	WEIGHT	HEAT / BATCH
42'00"	21	7,497 LB	55062370/02

SALES ORDER	CUSTOMER MATERIAL N°
8027537/000010	

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

1819011
IG-B5600800

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
1819	1323-0000139920	08/19/2019

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %
0.14	0.86	0.015	0.027	0.21	0.33	0.12	0.10	0.029	0.009	0.002	0.008

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	Y/T rati %	Elong. %
61100	78800	421	543	0.780	23.50
62200	79700	429	550	0.780	24.30

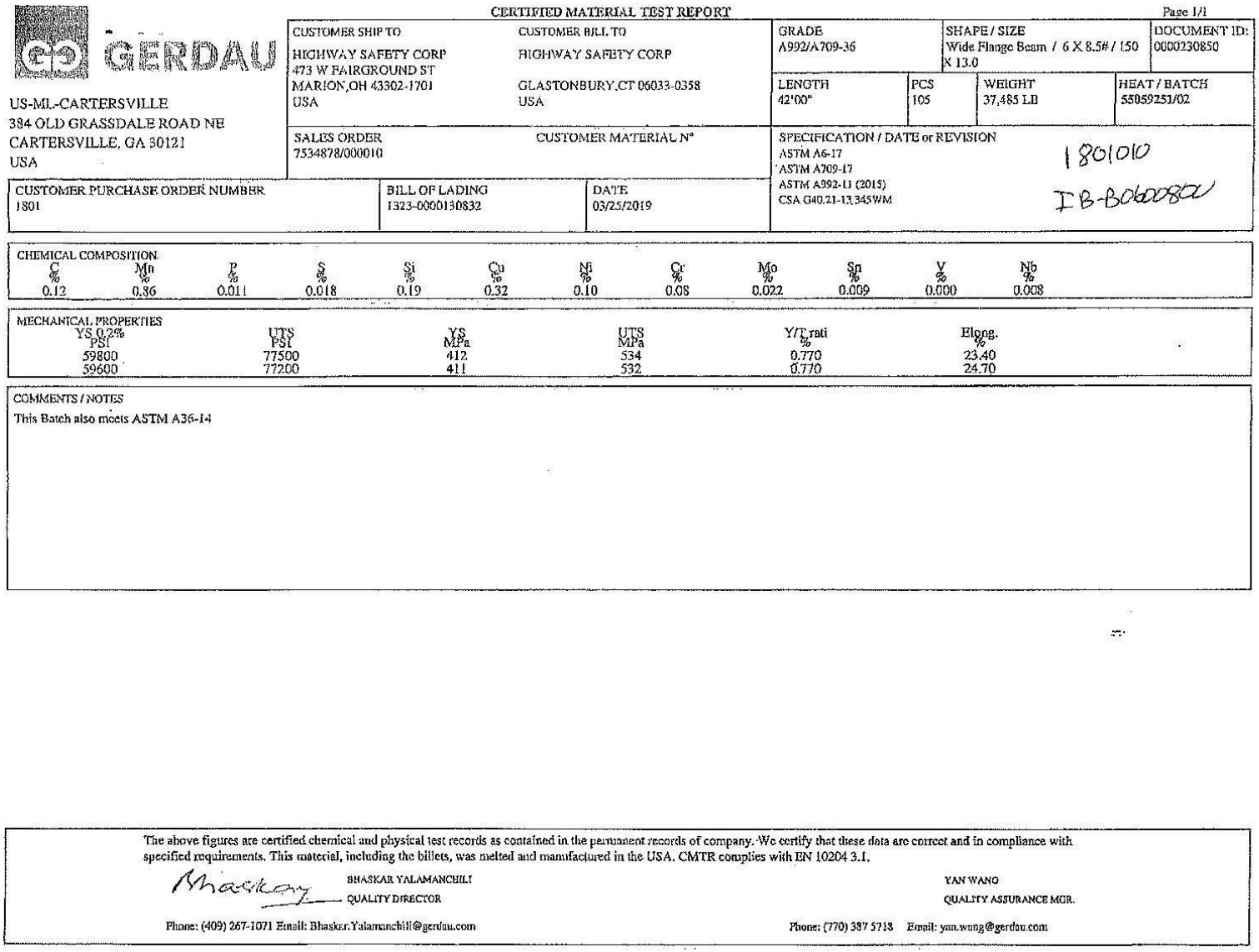
COMMENTS / NOTES

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 VALAMANCHILI
QUALITY DIRECTOR

YAN WANG
QUALITY ASSURANCE MGR.

Figure A-6. W6x8.5 Steel Post, Test No. MGSCO-4 (Item No. a4)



CERTIFIED MATERIAL TEST REPORT

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GERDAU

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

CUSTOMER SHIP TO	CUSTOMER BILL TO
HIGHWAY SAFETY CORP 473 W FAIRGROUND ST MARION,OH 43302-1701 USA	HIGHWAY SAFETY CORP GLASTONBURY,CT 06033-0358 USA

GRADE	SHAPE / SIZE	DOCUMENT ID:
A992/A709-36	Wide Flange Beam / 6 X 8.5# / 150 X 13.0	0000230850

LENGTH	PCS	WEIGHT	HEAT / BATCH
42'00"	105	37,485 LB	55059251/02

SALES ORDER
7534878/000010

CUSTOMER MATERIAL N°

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

1801010
IB-B060082

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
1801	1323-0000130832	03/25/2019

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %
0.12	0.86	0.011	0.018	0.19	0.32	0.10	0.08	0.022	0.009	0.000	0.008

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	Y/T rati %	Elong. %
59800	77500	412	534	0.770	23.40
59600	77200	411	532	0.770	24.70

COMMENTS / NOTES
This Batch also meets ASTM A36-14

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

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

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

Figure A-7. W6x8.5 Steel Post, Test No. MGSCO-4 (Item No. a4)

NUCOR STEEL - BERKELEY
P.O. Box 2259
Mt. Pleasant, S.C. 29464
Phone: (843) 336-6000

CERTIFIED MILL TEST REPORT

3/09/17 16:15:20

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

H#1702406

Stamped "A"

Sold To: HIGHWAY SAFETY CORP
PO BOX 358

GLASTONBURY, CT 06033

Ship To: HIGHWAY SAFETY CORP
473 WEST FAIRGROUND STREET

MARION, OH 43301

Customer #.: 352 - 3
Customer PO: 1722007
B.o.L. #...: 1255973

MOS: T

SPECIFICATIONS: Tested in accordance with ASTM specification A6/A6M-16a and A370. Quality Manual Rev H10 (12-13-16).
AASHTO : M270-345M270-50-10
ASME : SA-36 13
ASTM : A992-11(15:/A36-14/A529-14-50/A572 5015/A709-5016a
CSA : G40.21-50W/G40.2150WM/G402150WMI

IB-B0600800

Description / Part #	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
W6X8.5	1702434	.82	60300	73200	27.74	.07	.86	.007	.015	.19	.14	.05	.24
042' 00.00'	A992-11(15		416	505		.05	.01	.0086	.0002	.003	.016		.2701
W150X12.6		.83	59900	72300	27.83		.001			.0042		3.66	.1288
012.8016m	ANS		413		84 Pc(s)	29,988 lbs						Inv#:	0
W6X8.5	*1702406	.83	59000	71200	28.19	.07	.86	.006	.022	.20	.11	.03	.23
042' 00.00'	A992-11(15		407	491		.04	.01	.0056	.0002	.003	.015		.2652
W150X12.6		.83	58900	71100	28.26		.001			.0056		3.07	.1260
012.8016m	ANS		406	490	42 Pc(s)	14,994 lbs						Inv#:	0

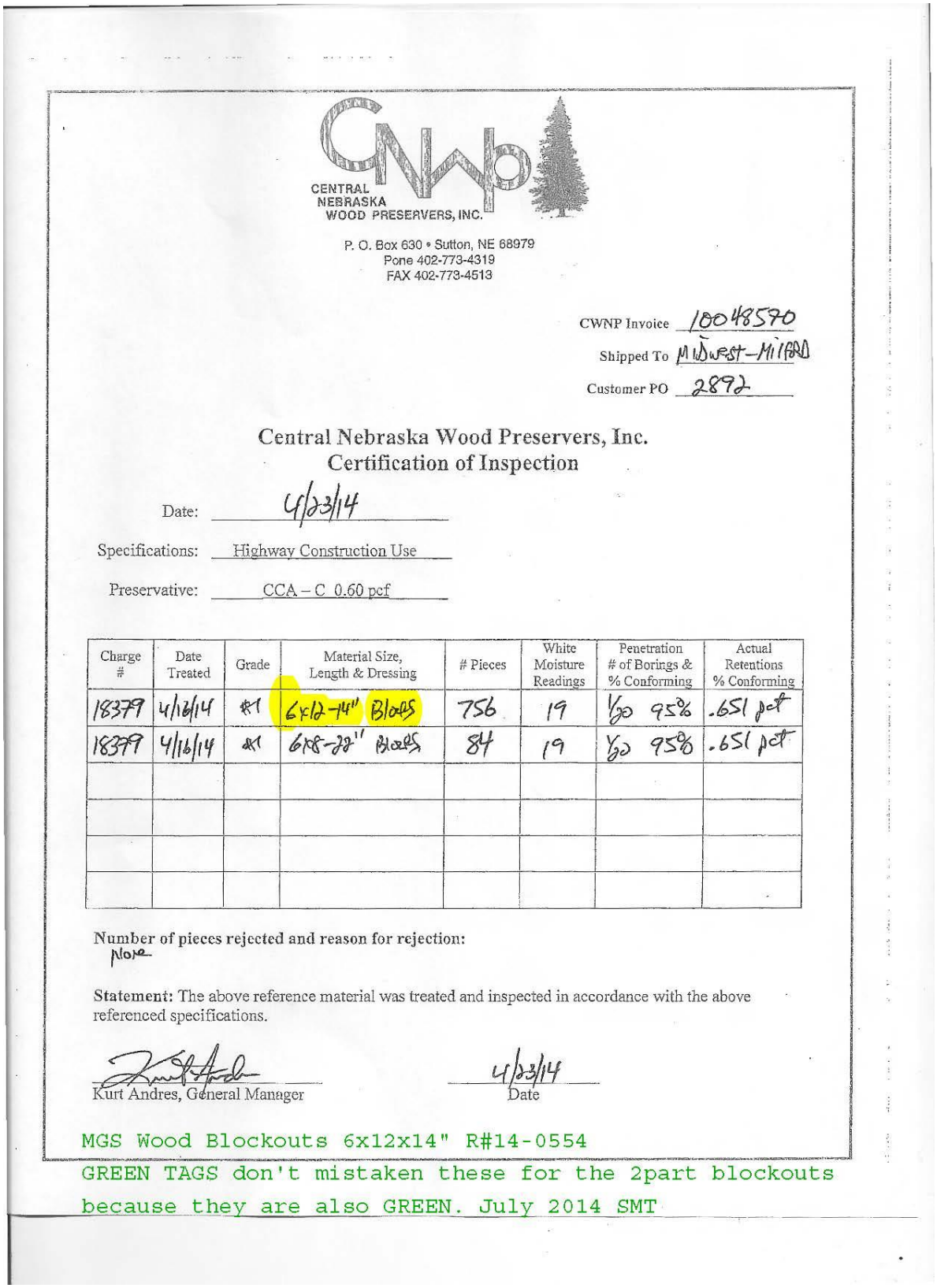
2 Heat(s) for this MTR.

Elongation based on 8" (20.32cm) gauge length, 'No Weld Repair' was peformed.
CI = 26.01Cu+3.88Ni+1.20Cr+1.49Si+17.28P-(7.29Cu*Ni)-(9.10Ni*P)-33.39(Cu*Cu)
Pcm = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B
CE1 = C+(Mn/6)+((Cr+Mo+V)/5)+((Ni+Cu)/15)
CE2 = C+((Mn+Si)/6)+((Cr+Mo+V+Cb)/5)+((Ni+Cu)/15)

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

Bruce A. Work
Metallurgist

Figure A-8. W6x8.5 Steel Post, Test No. MGSCO-4 (Item No. a4)



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-9. Timber Blockout, Test No. MGSCO-4 (Item No. a5)

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

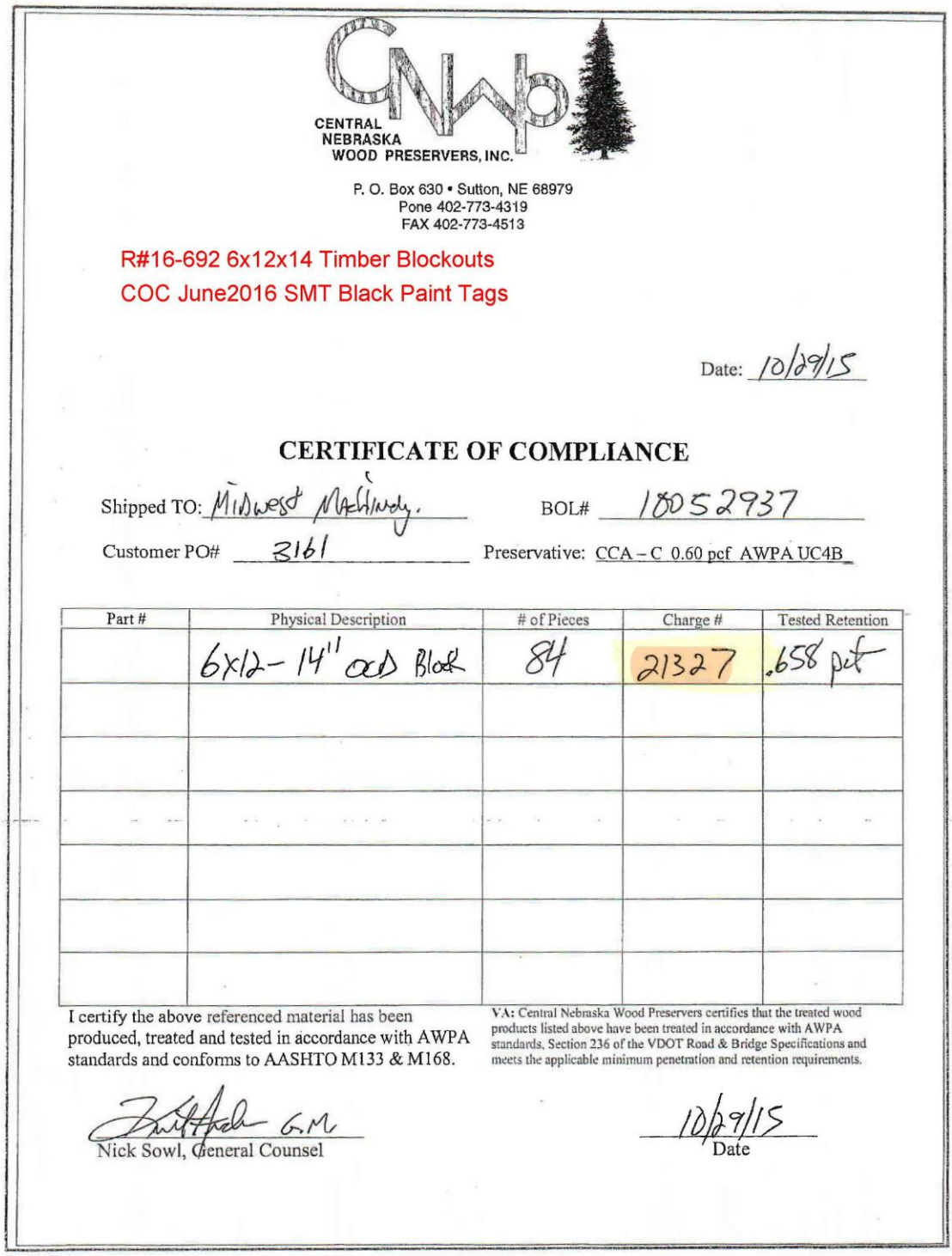
I certify the above referenced material has been produced, treated and tested in accordance with and conforms to AASHTO M133 & M168 standards.

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-10. Timber Blockout, Test No. MGSCO-4 (Item No. a5)



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' ccd Block	84	21327	.658 pct

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

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

Nick Sowl, General Counsel

10/29/15
Date

Figure A-11. Timber Blockout, Test No. MGSCO-4 (Item No. a5)

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

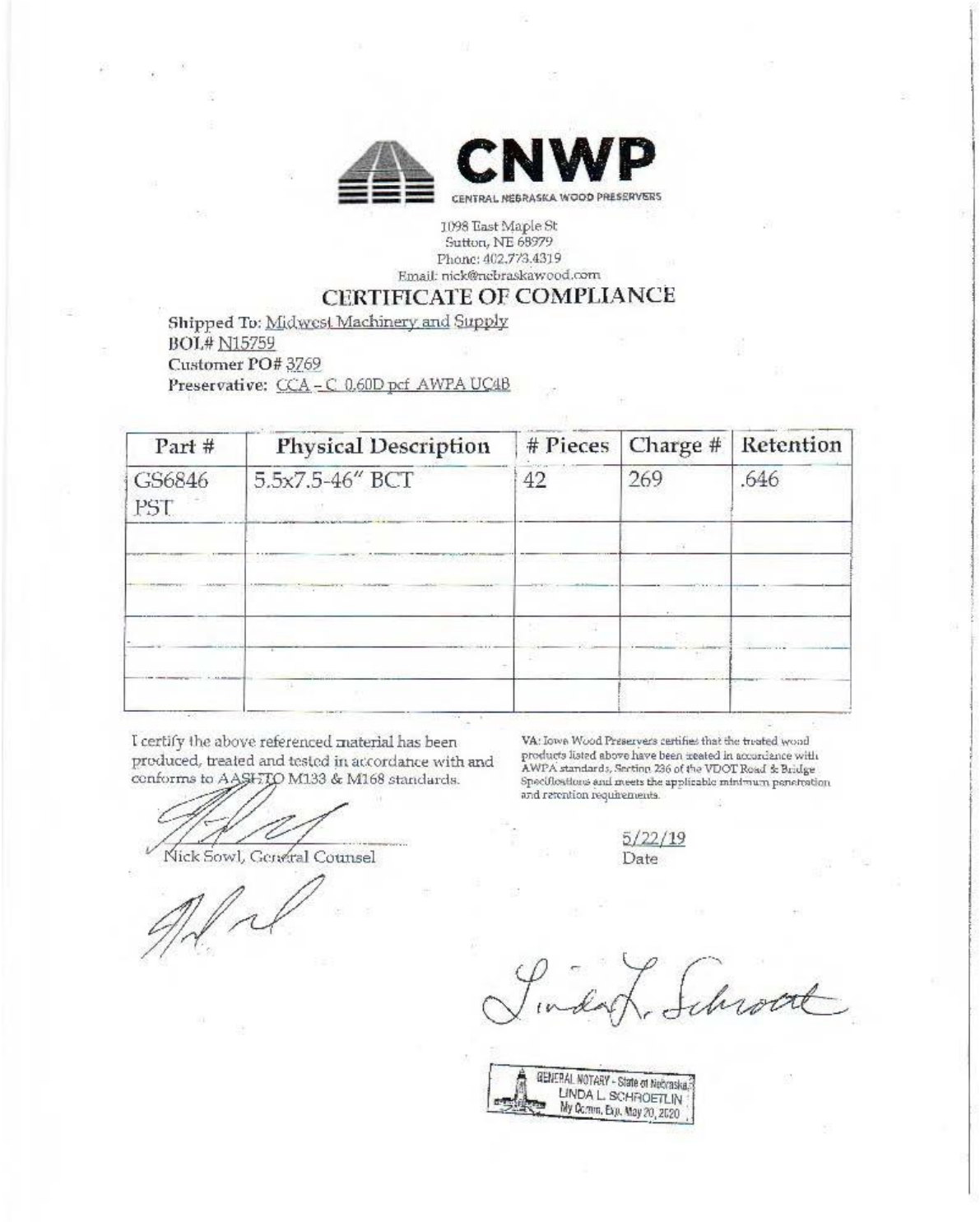
Line		Product	Ordered	Shipped
1	**97812A109**	Raised-Head Removable Nails, 16D Penny Size, 3" Long, Packs of 5	**5 Packs**	**5**

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 No. MGSCO-4 (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# N15759
Customer PO# 3769
Preservative: CCA – C 0.60D pcf AWPA UC4B

Part #	Physical Description	# Pieces	Charge #	Retention
GS6846 PST	5.5x7.5-46" BCT	42	269	.646

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

Nick Sowl, General Counsel

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.

5/22/19
Date

Linda L. Schroetlin

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

Figure A-13. BCT Timber Post, Test No. MGSCO-4 (Item No. b1)

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

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

MILFORD,NE,68405

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

HT # code	LOT#	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
616137		0.21	0.93	0.011	0.003	0.02	73148	58210	32	15		2	3/16IN X 6IN X 8IN X 5FT0IN TUBE SLEEVE
811T08220		0.22	0.81	0.013	0.006	0.005	71412	56323	35	10		2	3/16IN X 6IN X 8IN X 6FT0IN TUBE SLEEVE
214482		0.04	0.83	0.014	0.005	0.02	75275	68023	28.6	25			10GA MGS TB TRAN APPROACH END-RIGHT
214143		0.04	0.81	0.015	0.006	0.02	75565	69618	29.7	18			10GA MGS TB TRAN DEPARTURE END-LEFT

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 31 day of October, 2017

_____
Notary Public, State of Ohio

Figure A-14. Foundation Tube, Test No. MGSCO-4 (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

2 of 4

Figure A-15. Ground Strut Assembly, Test No. MGSCO-4 (Item No. b3)

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

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

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

MATERIAL TEST REPORT

Sold to

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

Shipped to

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

Material: 3.0x2.0x188x40'0"0(5x4). Material No: 0300201884000-B Made in: USA
Melted in: USA
Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 6630020018840

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

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

Material Note:
Sales Or.Note:

Material: 2.375x154x42'0"0(34x1). Material No: R023751544200 Made in: USA
Melted in: USA
Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 642004042

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

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

Material Note:
Sales Or.Note:

Material: 2.375x154x42'0"0(34x1). Material No: R023751544200 Made in: USA
Melted in: USA
Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 642004042

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

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

Material Note:
Sales Or.Note:

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

Steel Tube Institute

Page : 3 Of 4

Metals Service Center Institute

Figure A-16. BCT Post Sleeve, Test No. MGSCO-4 (Item No. b4)`

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-17. Anchor Bearing Plate, Test No. MGSCO-4 (Item No. b5)

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: 2/1/2019
Customer P.O.: 3691
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project: INVENTORY
GHP Order No: 2031AA

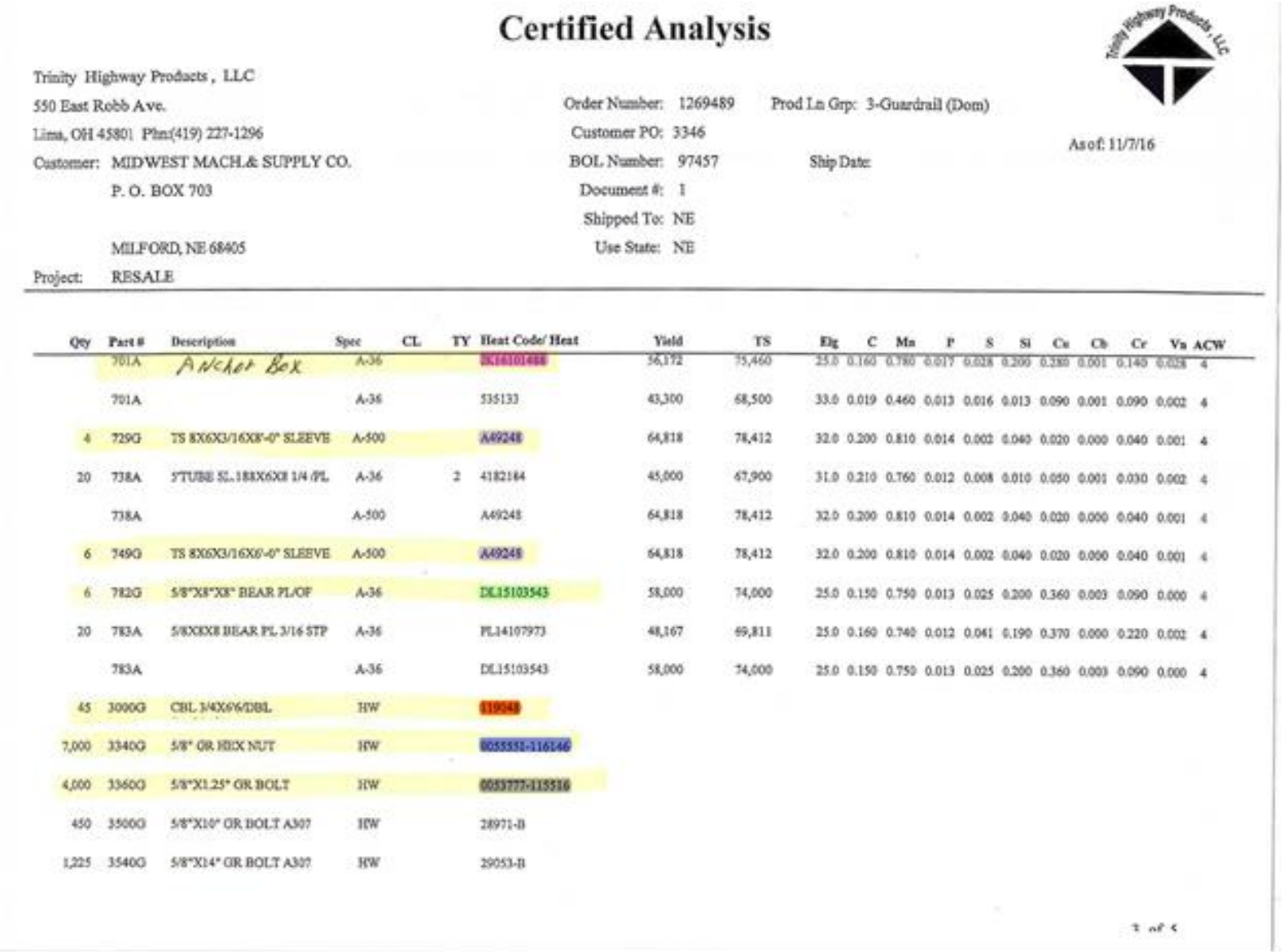
HT # code	LOT#	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
C88984		0.2	0.47	0.007	0.003	0.03	79300	59900	25.6	25	B	2	10GA BRIDGE SHOE
C88986		0.19	0.47	0.009	0.02	0.03	76600	58500	24.6	45	B	2	10GA TB BRIDGE SHOE
DL18105747		0.15	0.68	0.008	0.026	0.2	72000	55000	26	14		2	5/8IN X 8IN X 8IN BRG. PL.
A87581		0.18	0.48	0.01	0.002	0.02	72900	53100	28.7	20		2	CABLE AB
1813614		0.07	0.83	0.005	0.027	0.21	69800	57400	26	14		2	SKT/FLEAT UNIVERSAL POST #2 UPPER
1813611		0.07	0.8	0.006	0.025	0.21	69900	57900	25			2	SKT/FLEAT UNIVERSAL POST #2 UPPER
13894		0.13	0.78	0.024	0.033	0.28	71000	49000	25.8			2	SKT/FLEAT UNIVERSAL POST #2 UPPER
1813618		0.07	0.8	0.009	0.03	0.16	69500	57800	26	14		2	BOTTOM POST ASSEMBLY #2
A89297		0.08	0.35	0.007	0.003	0.03	59600	42060	38			2	BOTTOM POST ASSEMBLY #2
229860		0.04	0.83	0.01	0.004	0.02	75710	69618	28.5	25	B		10GA MGS TB TRAN APPROACH END-RIGHT
230751		0.2	0.73	0.013	0.002	0.02	84080	66730	25.7	15	B		10GA MGS TB TRAN DEPARTURE END-LEFT

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.

Jeffery L Grover

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

Figure A-18. Anchor Bracket Assembly, Test No. MGSCO-4 (Item No. b6)



Certified Analysis

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

MILFORD, NE 68405
Project: RESALE

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

As of: 11/7/16

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Va	ACW
	701A	Anchor Box	A-36			DL16101488	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	5/8XBX8 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													

1 of 1

Figure A-19. Anchor Bracket Assembly, Test No. MGSCO-4 (Item No. b6)

ASSEMBLY SPECIALTY PRODUCTS INC.
PH 216.676.5600
FX 216.676.6761
www.assemblyspecialty.com
ISO 9001:2008
14700 Brookpark Rd
Cleveland, OH 44135-5166
customerservice@assemblyspecialty.com

Certificate of Conformance

Date: October 10, 2017

To: Gregory Industries, Inc.
Gregory Galv. & Metal Processing
4100 13th St. SW
Canton, OH 44710

We certify that our system and procedures for the control of quality assures that all items furnished on the order will meet applicable tests, requirements and inspection requirements as required by the purchase order and applicable specifications and drawings.

PURCHASE ORDER #: 38684
DATE SHIPPED: 10/09/17
ASPI SALES ORDER #: 119183
MANUFACTURER: ASSEMBLY SPECIALTY PRODUCTS, INC.

QTY	CUST P/N	ASPI P/N	ASPI LOT#	DESCRIPTION
250	3012G	C-2028	80626	6' 6" BCT Cable Assembly
250	3012G	C-2028	80627	6' 6" BCT Cable Assembly
250	3012G	C-2028	80828	6' 6" BCT Cable Assembly
250	3012G	C-2028	80829	6' 6" BCT Cable Assembly
250	3012G	C-2028	80830	6' 6" BCT Cable Assembly
250	3012G	C-2028	80956	6' 6" BCT Cable Assembly
250	3012G	C-2028	80957	6' 6" BCT Cable Assembly
250	3012G	C-2028	80958	6' 6" BCT Cable Assembly
250	3012G	C-2028	81129	6' 6" BCT Cable Assembly
250	3012G	C-2028	81130	6' 6" BCT Cable Assembly

continued on page 2

REMARKS: NOMINAL BREAKING STRENGTH: 46,000 lbs
WIRE ROPE MANUFACTURED IN ACCORDANCE WITH AASHTO DESIGNATION: M30-02 and ASTM A741 TYPE 2, CLASS A
FITTINGS GALVANIZED IN ACCORDANCE WITH ASTM A-153 CLASS C.

STEEL USED TO MANUFACTURE THESE ITEMS WAS MELTED AND MANUFACTURED IN THE U.S.A
ALL MANUFACTURING PROCESSES SUPPLIED OR PERFORMED BY ASSEMBLY SPECIALTY PRODUCTS, INC. TOOK PLACE IN THE U.S.A.

Signature:
Certification and Compliance Manager

Figure A-20. BCT Anchor Cable, Page 1 of 2, Test No. MGSCO-4 (Item No. c1)

ASSEMBLY SPECIALTY PRODUCTS INC.
PH 216.676.5600
FX 216.676.6761
www.assemblyspecialty.com
ISO 9001:2008
14700 Brookpark Rd
Cleveland, OH 44135-5166
customerservice@assemblyspecialty.com

Lots continued):

QTY	CUST P/N	ASPI P/N	ASPI LOT#	DESCRIPTION
250	3012G	C-2028	81131	6' 6" BCT Cable Assembly
250	3012G	C-2028	81132	6' 6" BCT Cable Assembly
250	3012G	C-2028	81305	6' 6" BCT Cable Assembly
250	3012G	C-2028	81306	6' 6" BCT Cable Assembly
250	3012G	C-2028	81310	6' 6" BCT Cable Assembly

Figure A-21. BCT Anchor Cable, Page 2 of 2, Test No. MGSCO-4 (Item No. c1)

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, 2017

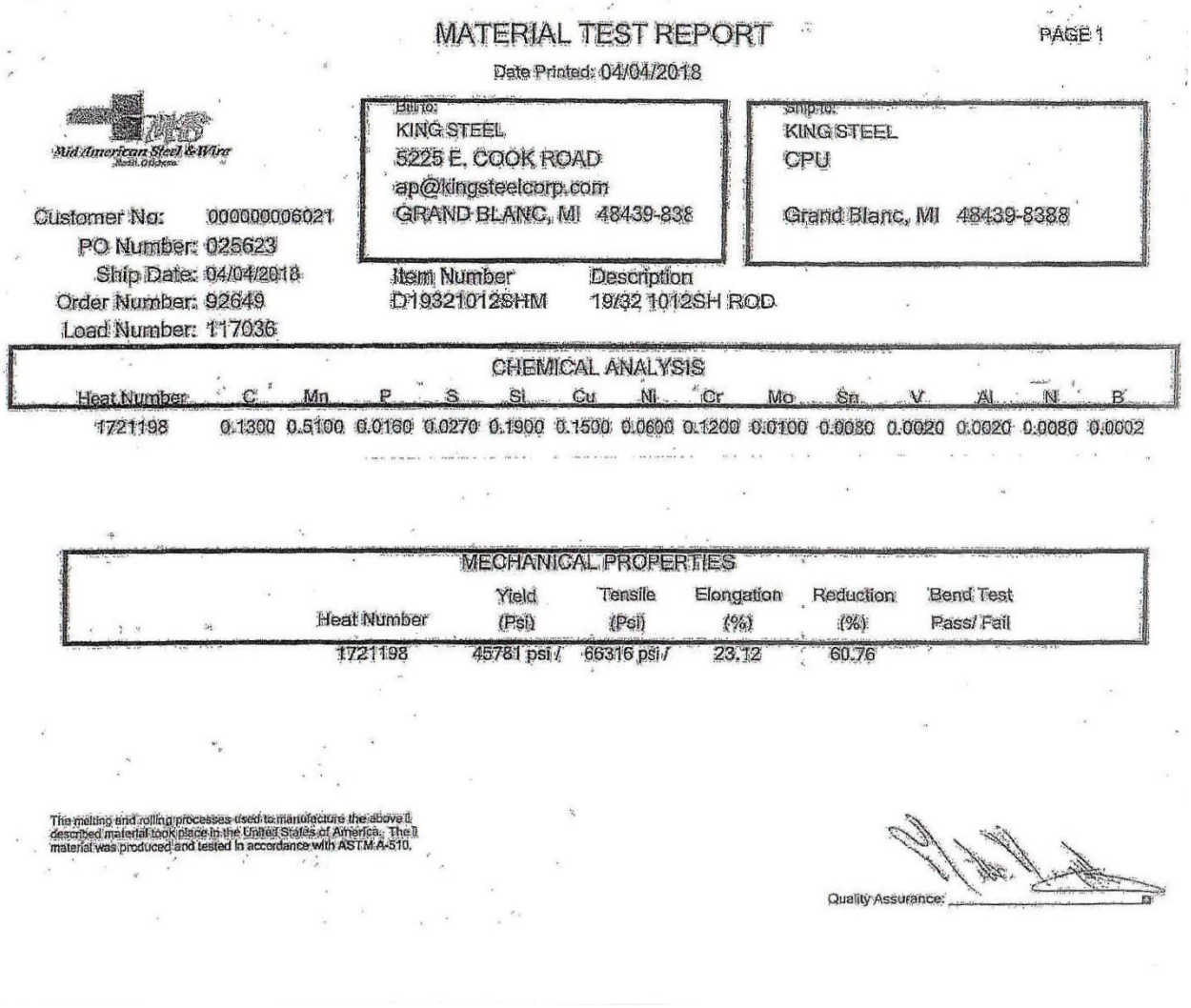
Merry F. Shane

Linda McComas
APPROVED SIGNATORY

11/6/17
DATE

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

Figure A-22. 14-in. Long Guardrail Bolt, Test No. MGSCO-4 (Item No. d1)



MATERIAL TEST REPORT

PAGE 1

Date Printed: 04/04/2018

Mid American Steel & Wire

Bill To:
KING STEEL
5225 E. COOK ROAD
ap@kingsteelcorp.com
GRAND BLANC, MI 48439-838

Ship To:
KING STEEL
CPU

Grand Blanc, MI 48439-8388

Customer No: 000000006021
PO Number: 025623
Ship Date: 04/04/2018
Order Number: 92649
Load Number: 117036

Item Number	Description
D19321012SHM	19/32 1012SH ROD

CHEMICAL ANALYSIS

Heat Number	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	V	Al	N	B
1721198	0.1300	0.5100	0.0160	0.0270	0.1900	0.1500	0.0600	0.1200	0.0100	0.0080	0.0020	0.0020	0.0080	0.0002

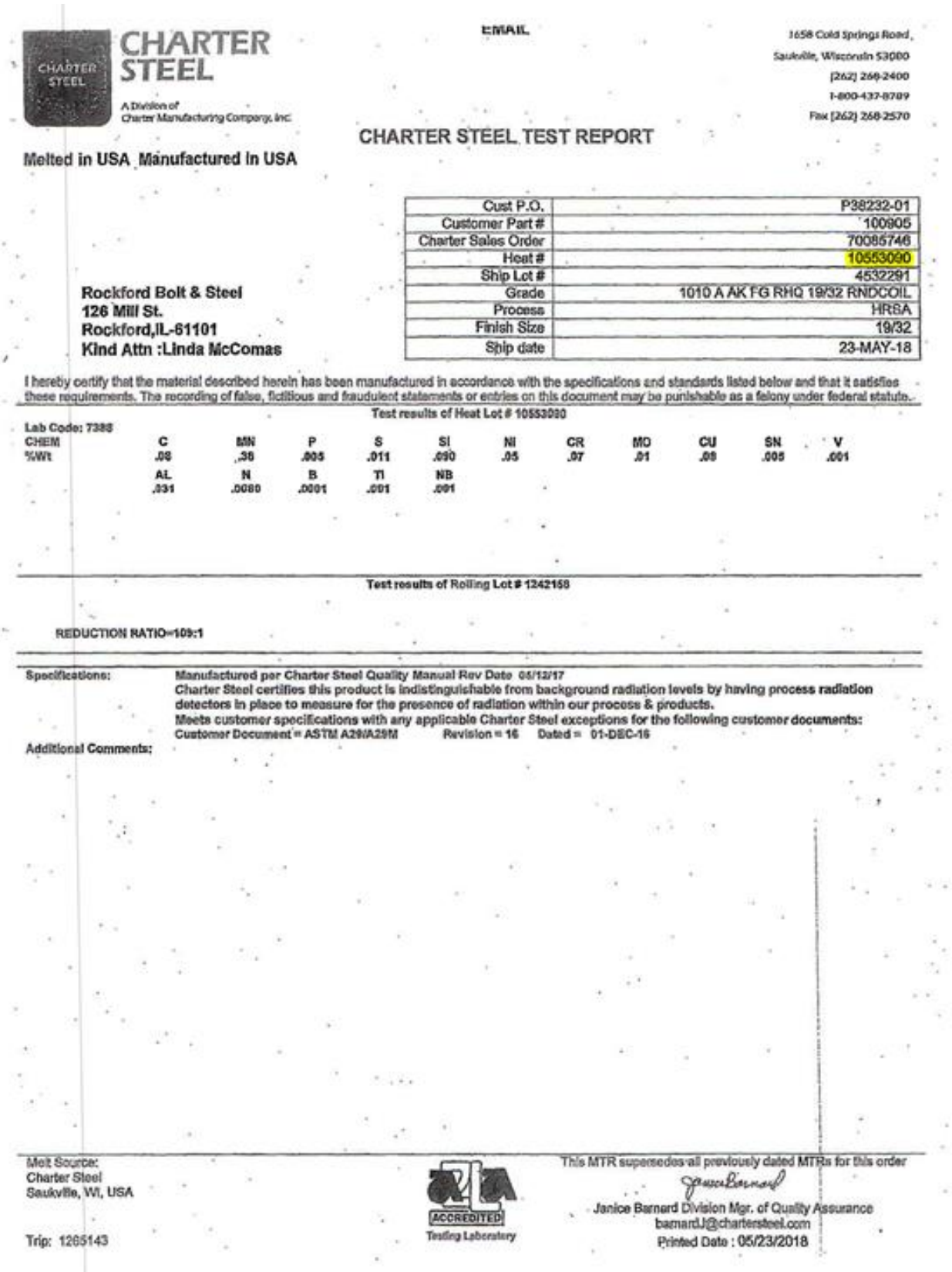
MECHANICAL PROPERTIES

Heat Number	Yield (Psi)	Tensile (Psi)	Elongation (%)	Reduction (%)	Bend Test Pass/ Fail
1721198	45781 psi /	66316 psi /	23.12	60.76	

The melting and rolling processes used to manufacture the above ll described material took place in the United States of America. The ll material was produced and tested in accordance with ASTM A-510.

Quality Assurance:

Figure A-23. 10-in. Long Guardrail Bolt, Test No. MGSCO-4 (Item No. d2)



EMAIL

CHARTER STEEL
A Division of Charter Manufacturing Company, Inc.

1658 Cold Springs Road
Saukville, Wisconsin 53080
(262) 269-2400
1-800-437-8789
Fax (262) 268-2570

CHARTER STEEL TEST REPORT

Melted in USA Manufactured in USA

Cust P.O.	P38232-01
Customer Part #	100905
Charter Sales Order	70085746
Heat #	10553090
Ship Lot #	4532291
Grade	1010 A AK FG RHQ 19/32 RNDCOIL
Process	HR&A
Finish Size	19/32
Ship date	23-MAY-18

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

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 # 10553090

Lab Code: 7388

CHEM	C	MN	P	S	SI	NI	CR	MO	CU	SN	V
%Wt	.08	.38	.005	.011	.090	.05	.07	.01	.09	.005	.001
	AL	N	B	TI	NB						
	.031	.0080	.0001	.001	.001						

Test results of Rolling Lot # 1242158

REDUCTION RATIO=109:1

Specifications: Manufactured per Charter Steel Quality Manual Rev Date 06/12/17
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 = 16 Dated = 01-DEC-16

Additional Comments:

Melt Source:
Charter Steel
Saukville, WI, USA

Trip: 1265143

ACCREDITED
Testing Laboratory

This MTR supersedes all previously dated MTRs for this order

Janice Barnard Division Mgr. of Quality Assurance
barnardJ@chartersteel.com
Printed Date : 05/23/2018

Figure A-24. 1¼-in. Long Guardrail Bolt, Test No. MGSCO-4 (Item No. d3)

Certificate of Compliance

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

Customer	Midwest Machinery & Supply	**Date Shipped**	11/28/2018
Customer Order Number	3664	**BFM Order Number**	1553751

Item Description

Description	5/8"-11 x 10" Hex Bolt			**Qty**	298
Lot #	81342	**Specification**	ASTM A307-14 Gr A	**Finish**	ASTM F2329

Raw Material Analysis

Heat# JK18104124

Chemical Composition (wt% Heat Analysis) By Material Supplier

C	Mn	P	S	Si	Cu	Ni	Cr	Mo
0.18	1.19	0.012	0.034	0.20	0.29	0.13	0.11	0.04

Mechanical Properties

Sample #	Hardness	Tensile Strength (lbs)	Tensile Strength (psi)
1	93 HRBW	22,049	99,410
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: _____ **Date:** 11/29/2018

Brian Hughes
Quality Assurance

Figure A-25. ⅝-in. Dia., 10-in. Long Hex Head Bolt, Test No. MGSCO-4 (Item No. d4)

CERTIFIED MATERIAL TEST REPORT
FOR ASTM A307, GRADE A - MACHINE BOLTS

FACTORY: IFI & MORGAN LTD.
ADDRESS: No.583-28, Chang'an North Road, Wuyuan Town, Haiyan, Zhejiang, China

REPORT DATE:2019/4/2
MANUFACTURE DATE:2019/3/14

CUSTOMER: FASTENAL
SAMPE SIZE: ACC. TO ASME B18.18 CATEGORY 2-2011; ASTM F1470-12 TABLE 3
MANU QTY: 2450PCS
SIZE: 5/8-11X1 1/2 HDG
HEADMARKS: 307A PLUS NY

MFG LOT NUMBER:M-2019HT138-5
SHIPPED QTY:2400PCS
PO NUMBER:210179696
PART NO:1191919

STEEL PROPERTIES:
MATERIAL TYPE:Q195C

HEAT NUMBER:5-01570

CHEMISTRY SPEC:	C %*100	Mn%*100	P %*1000	S %*1000
Grade A ASTM A307-12	0.29max	1.20 max	0.04max	0.15max
TEST:	0.07	0.33	0.015	0.022

DIMENSIONAL INSPECTIONS	Unit:inch	SPECIFICATION: ASME B18.2.1 - 2012		
CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
VISUAL	ASTM F788-2013	PASSED	18	0
THREAD	ASME B1.1-2003, 3A GO, 2A NO GO	PASSED	13	0
WIDTH A/F	0.906-0.938	0.916-0.928	3	0
WIDTH A/C	1.033-1.083	1.048-1.057	3	0
HEAD HEIGHT	0.378-0.444	0.394-0.428	3	0
BODY DIA.	0.605-0.642	0.617-0.634	3	0
THREAD LENGTH	1.420-1.560	1.436-1.543	13	0
LENGTH	1.420-1.560	1.436-1.543	13	0

MECHANICAL PROPERTIES:		SPECIFICATION: ASTM A307 - 14e1 GR.A			
CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS :	ASTM F606/F606M-2016	69-100 HRB	75-80 HRB	3	0
WEDGE TENSILE:	ASTM F606/F606M-2016	Min 60 KSI	65-69 KSI	3	0
CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
COATINGS OF ZINC:		SPECIFIATION: ASTM F2329/F2329M-2015			
HOT DIP GALVANIZED	ASTM B568-98(2014)	Min 0.0017"	0.0017" -0.0018"	3	0

We hereby certify that above products supplied are in compliance with all the requirements of the order.
We here by certify that this MTR is in compliance to DIN EN 10204 3.1 content.
ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.
Maker's ISO 9001:2015 SGS Certificate # HK04/0105

IFI & MORGAN LTD. 检验专用章

(SIGNATURE OF Q.A. LAB MGR.)
(NAME OF MANUFACTURER)

Figure A-26. ⅝-in. Dia., 1½-in. Long Hex Head Bolt, Test No. MGSCO-4 (Item No. d5)

Portland Bolt
& MANUFACTURING COMPANY

Phone: 800-547-6758 | Fax: 503-227-4634
3441 NW Guam Street, Portland, OR 97210
Web: www.portlandbolt.com | Email: sales@portlandbolt.com

CERTIFICATE OF CONFORMANCE

For: MIDWEST ROADSIDE SAFETY FACIL
PB Invoice#: 119891
Cust PO#: 70ACCT
Date: 4/17/2019
Shipped: 4/25/2019

We certify that the following items were manufactured and tested in accordance with the chemical, mechanical, dimensional and thread fit requirements of the specifications referenced.

Description: 7/8 X 8 GALV ASTM A307A HEX BOLT

Heat#: 489517 **Base Steel:** A36 **Diam:** 7/8

Source: CASCADE STEEL RLG MILL **Proof Load:** 0

C :	.180	**Mn:** .680	**P :** .013	**Hardness:**	0		
S :	.015	**Si:** .240	**Ni:** .080	**Tensile:**	72,500 PSI	**RA:**	42.00%
Cr:	.130	**Mo:** .028	**Cu:** .240	**Yield:**	48,800 PSI	**Elon:**	24.00%
Pb:	.000	**V :** .000	**Cb:** .000	**Sample Length:**	8 INCH		
N :	.000		**CE:** .3157	**Charpy:**		**CVN Temp:**	

Coatings:
ITEMS HOT DIP GALVANIZED PER ASTM F2329/A153C

By: _____
Certification Department Quality Assurance
Dane McKinnon

Figure A-27. ⅞-in. Dia. Hex Head Bolt, Test No. MGSCO-4 (Item No. d6)

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 : 2019/04/23

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 210167591
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 7/8-9 NC O/T 0.56MM
LOT NO : 1N1880113
SHIP QUANTITY : 2,250 PCS
LOT QUANTITY 31,764 PCS
HEADMARKS :

PACKING NO : GEM181128011
INVOICE NO : GEM/FNL-181212ED-1
PART NO : 36717
SAMPLING PLAN : ASME B18.18-2017(Category.2)/ASTM F1470-2018
HEAT NO : 18108473-3
MATERIAL : X1008A
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

MANUFACTURE DATE : 2018/10/12
COUNTRY OF ORIGIN : CHINA

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2015

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0.5800		0.1300	0.2300	
Test Value	0.0300	0.0600	0.2800	0.0160	0.0060	0.0300

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2015

SAMPLED BY : WANGYAN

INSPECTIONS ITEM	SAMPLE	SPECIFIED		ACTUAL RESULT	ACC.	REJ.
WIDTH ACROSS CORNERS	4 PCS		1.4470-1.5160 inch	1.4650-1.4690 inch	4	0
FIM	15 PCS	ASME B18.2.2-2015	Max. 0.0250 inch	0.0040-0.0060 inch	15	0
THICKNESS	4 PCS		0.7240-0.7760 inch	0.7430-0.7460 inch	4	0
WIDTH ACROSS FLATS	4 PCS		1.2690-1.3120 inch	1.2830-1.2840 inch	4	0
SURFACE DISCONTINUITIES	29 PCS		ASTM F812-2012	PASSED	29	0
THREAD	15 PCS		GAGING SYSTEM 21	PASSED	15	0
MINOR DIAMETER	15 PCS		0.7890-0.7970 inch	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2015

SAMPLED BY : GDAN LIAN

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	13 PCS	ASTM F606-2014		116-302 HRB	81-82 HRB	13	0
PROOF LOAD	3 PCS	ASTM F606-2014		Min. 90 KSI	OK	3	0
PLATING THICKNESS(μm)	5 PCS	ASTM B568-1998		>=53	72.03-95.08	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:

page 1 of 1

Figure A-28. Nut for ⅞-in. Dia. Hex Head Bolt, Test No. MGSCO-4 (Item No. d6)

CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS HDG

FACTORY: IFI & Morgan Ltd
ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan,Zhejiang, China

REPORT DATE: 21/5/2019
MFG LOT NUMBER: 1845511
PO NUMBER: 210167255
PART NO: 1133185

SAMPLING PLAN PER ASME B18.18-11
SIZE: USS 5/8 HDG QNTY(Lot size): 6000PCS
HEADMARKS: NO MARK

DIMENSIONAL INSPECTIONS — SPECIFICATION: ASTM B18.21.1-2011

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F844	PASSED	100	0
OUTSIDE DIA	1.743-1.780	1.746-1.754	10	0
INSIDE DIA	0.681-0.718	0.707-0.715	10	0
THICKNESS	0.108-0.160	0.108-0.126	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-29. ⅝-in. Dia. Plain USS Washer, Test No. MGSCO-4 (Item No. e1)

CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS HDG

FACTORY: IFI & Morgan Ltd
ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan,Zhejiang, China

REPORT DATE: 23/4/2019
MFG LOT NUMBER: 1844804
PO NUMBER: 170089822
PART NO: 33187

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

DIMENSIONAL INSPECTIONS — SPECIFICATION: ASTM B18.21.1-2011

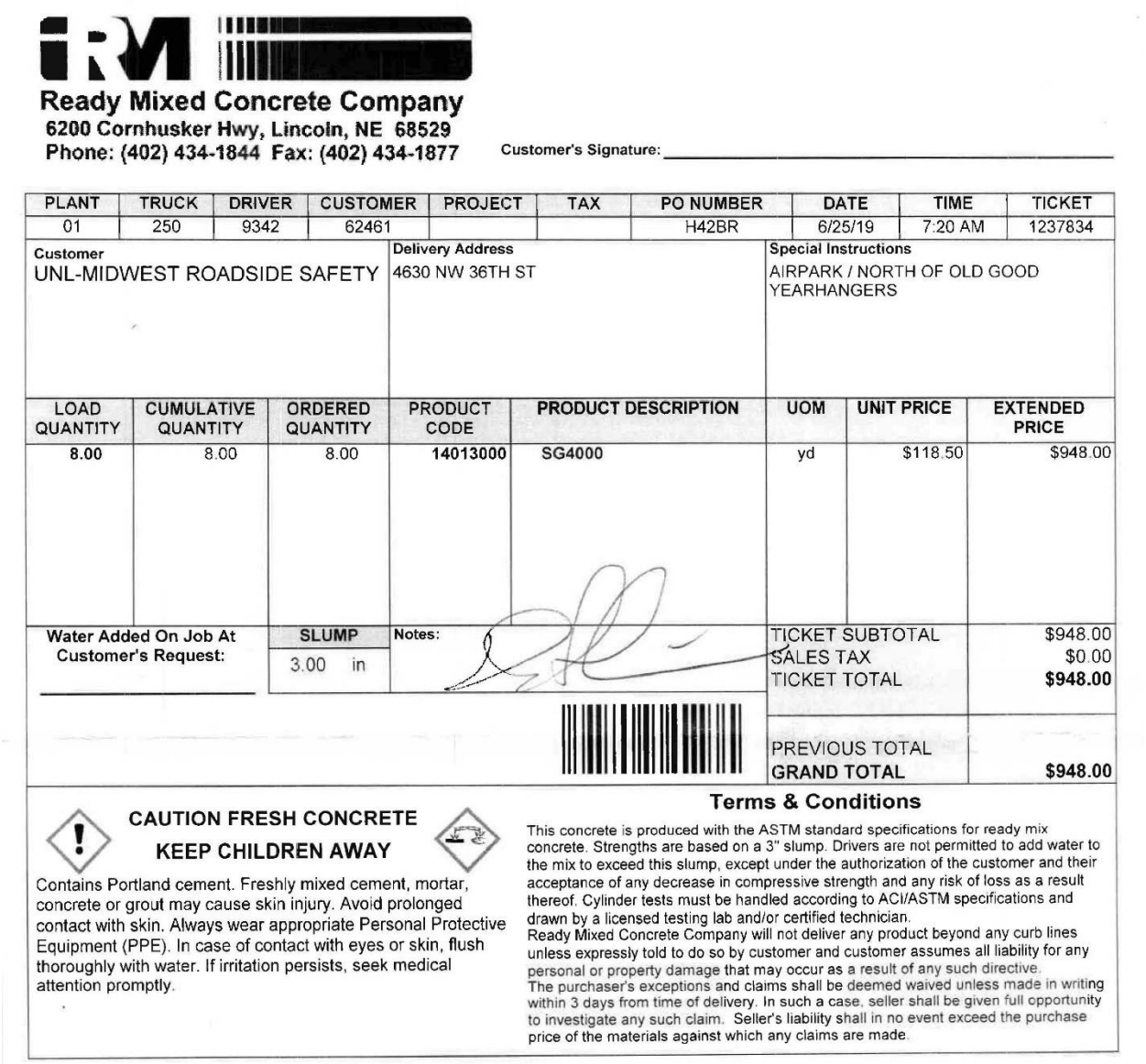
CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F844	PASSED	100	0
OUTSIDE DIA	2.243-2.280	2.246-2.254	10	0
INSIDE DIA	0.931-0.968	0.956-0.965	10	0
THICKNESS	0.136-0.192	0.136-0.157	10	0

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-30. ⅞-in. Dia. Plain USS Washer, Test No. MGSCO-4 (Item No. e2)



Ready Mixed Concrete Company
6200 Cornhusker Hwy, Lincoln, NE 68529
Phone: (402) 434-1844 Fax: (402) 434-1877

Customer's Signature: _____

PLANT	TRUCK	DRIVER	CUSTOMER	PROJECT	TAX	PO NUMBER	DATE	TIME	TICKET
01	250	9342	62461			H42BR	6/25/19	7:20 AM	1237834

Customer	Delivery Address	Special Instructions
UNL-MIDWEST ROADSIDE SAFETY	4630 NW 36TH ST	AIRPARK / NORTH OF OLD GOOD YEARHANGERS

LOAD QUANTITY	CUMULATIVE QUANTITY	ORDERED QUANTITY	PRODUCT CODE	PRODUCT DESCRIPTION	UOM	UNIT PRICE	EXTENDED PRICE
8.00	8.00	8.00	14013000	SG4000	yd	$118.50	$948.00

Water Added On Job At Customer's Request: _____

SLUMP: 3.00 in

Notes:

TICKET SUBTOTAL	$948.00
SALES TAX	$0.00
TICKET TOTAL	**$948.00**
PREVIOUS TOTAL	
GRAND TOTAL	**$948.00**

CAUTION FRESH CONCRETE
KEEP CHILDREN AWAY

Contains Portland cement. Freshly mixed cement, mortar, concrete or grout may cause skin injury. Avoid prolonged contact with skin. Always wear appropriate Personal Protective Equipment (PPE). In case of contact with eyes or skin, flush thoroughly with water. If irritation persists, seek medical attention promptly.

Terms & Conditions

This concrete is produced with the ASTM standard specifications for ready mix concrete. Strengths are based on a 3" slump. Drivers are not permitted to add water to the mix to exceed this slump, except under the authorization of the customer and their acceptance of any decrease in compressive strength and any risk of loss as a result thereof. Cylinder tests must be handled according to ACI/ASTM specifications and drawn by a licensed testing lab and/or certified technician.
Ready Mixed Concrete Company will not deliver any product beyond any curb lines unless expressly told to do so by customer and customer assumes all liability for any personal or property damage that may occur as a result of any such directive.
The purchaser's exceptions and claims shall be deemed waived unless made in writing within 3 days from time of delivery. In such a case, seller shall be given full opportunity to investigate any such claim. Seller's liability shall in no event exceed the purchase price of the materials against which any claims are made.

Figure A-31. Concrete Mix, Curb, Test No. MGSCO-4 (Item No. f1)

benesch
engineers · scientists · planners

LINCOLN OFFICE
825 "M" Street Suite 100
Lincoln, NE 68508
Phone: (402) 479-2200
Fax: (402) 479-2276

COMPRESSION TEST OF CYLINDRICAL CONCRETE SPECIMENS - 6x12

ASTM Designation: C 39

Client Name: Midwest Roadside Safety Facility
Project Name: Miscellaneous Concrete Testing
Placement Location: MGSCO-3

Date 20-Aug-19

Mix Designation:

Required Strength:

Laboratory Test Data

Laboratory Identification	Field Identification	Date Cast	Date Received	Date Tested	Days Cured in Field	Days Cured in Laboratory	Age of Test, Days	Length of Specimen, in.	Diameter of Specimen, in.	Cross-Sectional Area, sq.in.	Maximum Load, lbf	Compressive Strength, psi.	Required Strength, psi.	Type of Fracture	ASTM Practice for Capping Specimen
URR-129	A	6/25/2019	8/20/2019	8/20/2019	56	0	56	12	6.01	28.37	146,017	5,150		5	C 1231
URR-130	B	6/25/2019	8/20/2019	8/20/2019	56	0	56	12	6.01	28.37	148,068	5,220		5	C 1231

1 cc: Ms. Karla Lechtenberg
Midwest Roadside Safety Facility

Remarks:

Concrete test specimens along with documentation and test data were submitted by Midwest Roadside Safety Facility.

Test results presented relate only to the concrete specimens as received from Midwest Roadside Safety

This report shall not be reproduced except in full, without the written approval of Alfred Benesch & Company.

Report Number 2147371499
Page 1

Sketches of Types of Fractures

Type 1: Reasonably well-formed cones on both ends, less than 1 in. [25 mm] of cracking through caps

Type 2: Well-formed cone on one end, vertical cracks running through caps, no well-defined cone on other end

Type 3: Columnar vertical cracking through both ends, no well-formed cones

Type 4: Diagonal fracture with no cracking through ends; tap with hammer to distinguish from Type 1

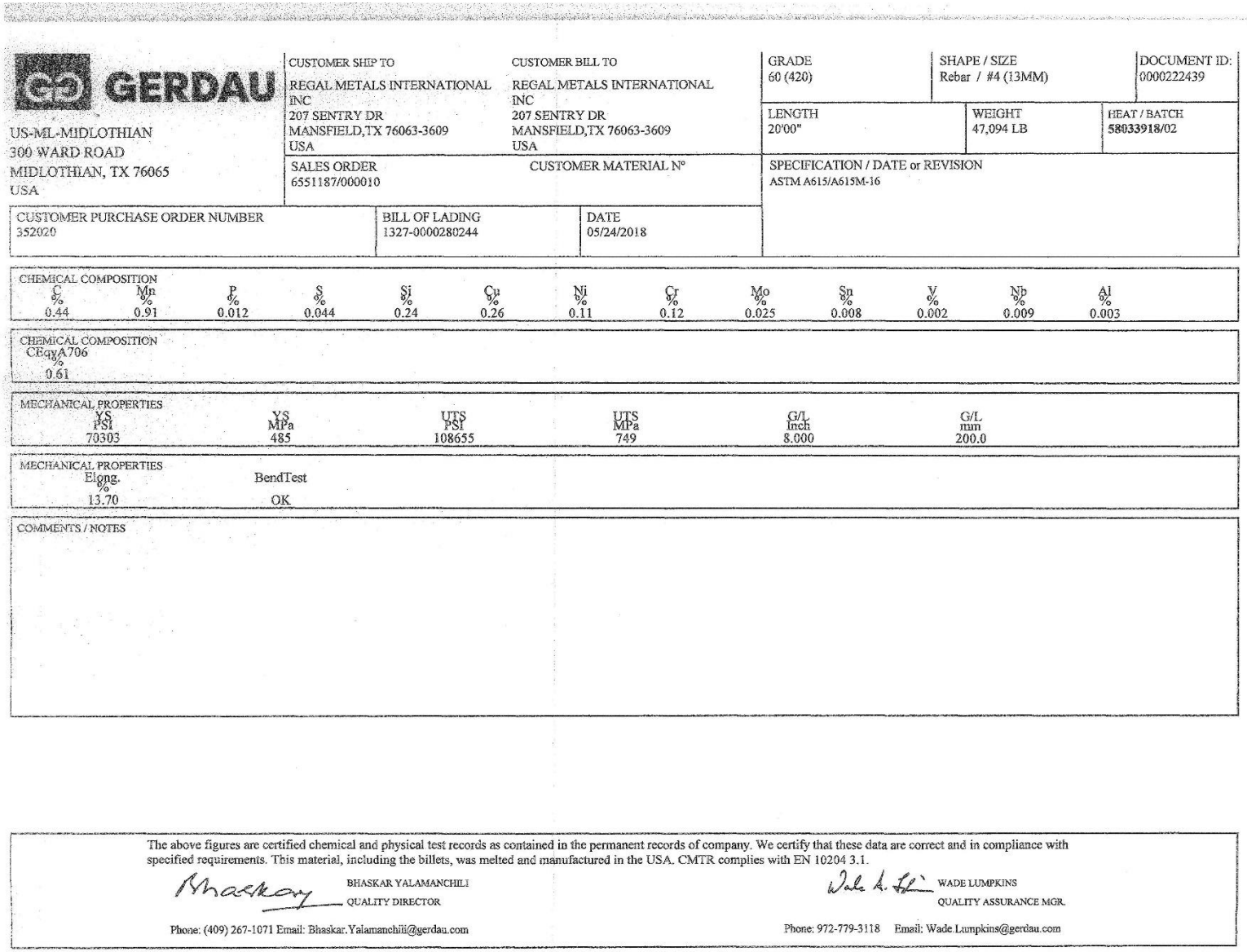
Type 5: Side fractures at top or bottom (occur commonly with unbonded caps)

Type 6: Similar to Type 5 but end of cylinder is pointed

ALFRED BENESCH & COMPANY
CONSTRUCTION MATERIALS LABORATORY

By Matt Rowler

Figure A-32. Concrete Strength Test, Curb, Test No. MGSCO-4 (Item No. f1)



GERDAU

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

CUSTOMER SHIP TO
REGAL METALS INTERNATIONAL INC
207 SENTRY DR
MANSFIELD,TX 76063-3609
USA

CUSTOMER BILL TO
REGAL METALS INTERNATIONAL INC
207 SENTRY DR
MANSFIELD,TX 76063-3609
USA

SALES ORDER
6551187/000010

CUSTOMER MATERIAL N°

GRADE
60 (420)

SHAPE / SIZE
Rebar / #4 (13MM)

DOCUMENT ID:
0000222439

LENGTH
20'00"

WEIGHT
47,094 LB

HEAT / BATCH
58033918/02

SPECIFICATION / DATE or REVISION
ASTM A615/A615M-16

CUSTOMER PURCHASE ORDER NUMBER
352020

BILL OF LADING
1327-0000280244

DATE
05/24/2018

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.44	0.91	0.012	0.044	0.24	0.26	0.11	0.12	0.025	0.008	0.002	0.009	0.003

CHEMICAL COMPOSITION
CEqvA706 %
0.61

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L inch	G/L mm
70303	485	108655	749	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
13.70	OK

COMMENTS / NOTES

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

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

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

Figure A-33. #4 Rebar, Test No. MGSCO-4 (Item No. f2)

EVRAZ ROCKY MOUNTAIN STEEL
A DIVISION OF EVRAZ INC. NA

2100 S. Freeway
Pueblo, CO 81004 USA

MATERIAL TEST REPORT

Date Printed: 02-OCT-18

Date Shipped: 02-OCT-18 | Product: DEF #4 (1/2") | Specification: ASTM A706/A615 GR 60

FWIP: 52815348 | Customer: CONCRETE INDUSTRIES INC | Cust. PO: 132759

P O BOX 29529
LINCOLN, NE 68529

CHEMICAL ANALYSIS (In Weight %, uncertainty of measurement 0.005%) (Heat cast 09/27/18)

Heat Number	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al	V	B	Cb	Sn	N	Ti
602934	0.27	1.23	0.014	0.018	0.25	0.23	0.07	0.16	0.015	0.003	0.038	0.0002	0.000	0.010	0.0086	0.001

Carbon Equivalent = 0.496

MECHANICAL PROPERTIES (Tensiles test date 10/01/18)

Heat Number	Sample No.		Yield (Psi)	Ultimate (Psi)	Elongation (%)	Reduction (%)	Bend	Wt/ft
602934	01		64366	96340	15.9		OK	0.648
		(MPa)	443.8	664.2				
602934	02		62315	95610	15.5		OK	0.645
		(MPa)	429.6	659.2				

All melting and manufacturing processes of the material subject to this test certificate occurred in the United States of America.
ERMS also certifies this material to be free from Mercury contamination.

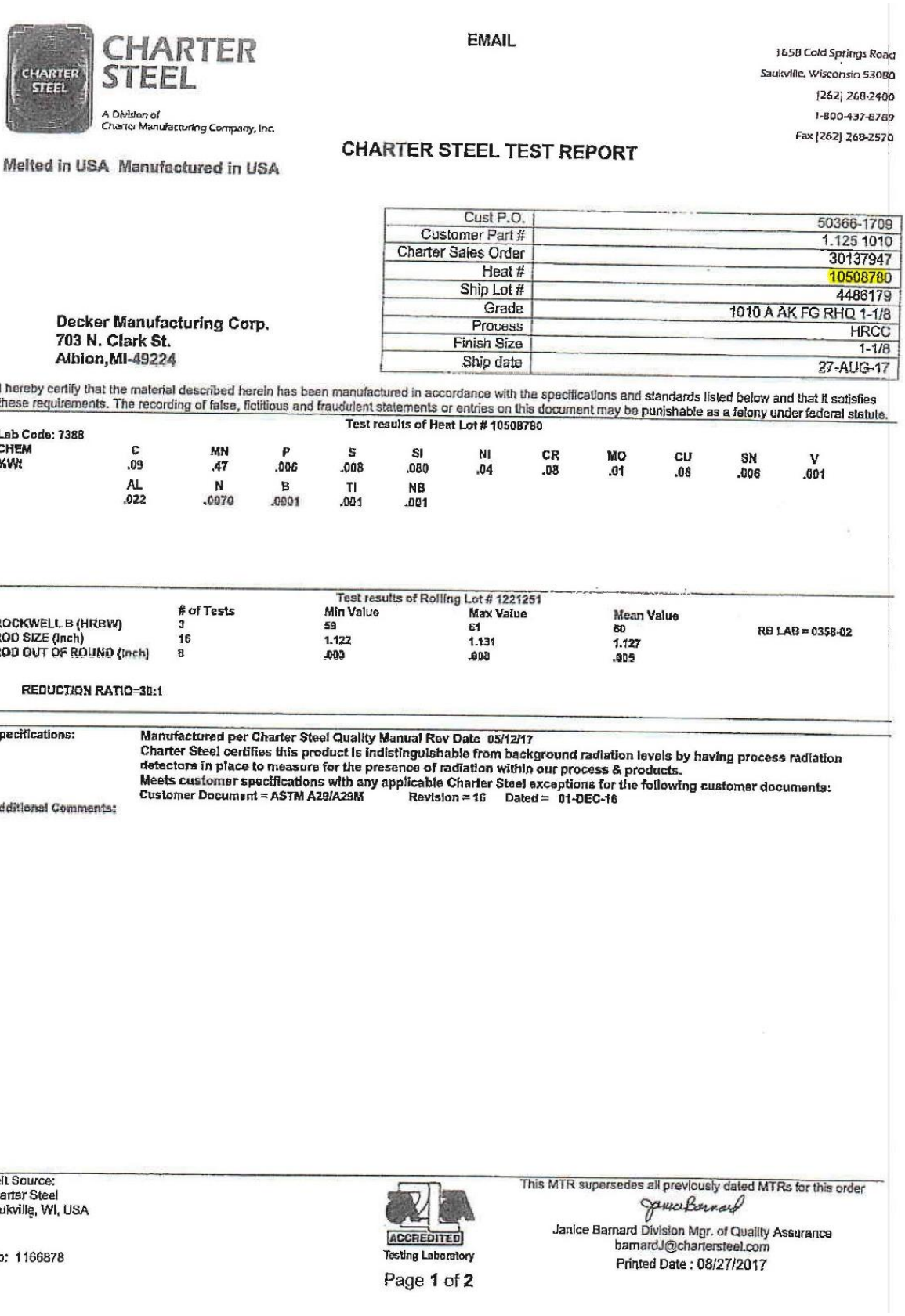
This material has been produced, tested and conforms to the requirements of the applicable specifications. We hereby certify that the above test results represent those contained in the records of the Company.

Methods used: ASTM A370, A510, A615, A706.

Material test report shall not be reproduced except in full, without approval of the company.

Bryce Lakamp
Process Control Engineer

Figure A-34. #4 Rebar, Test No. MGSCO-4 (Item No. f3)



CHARTER STEEL
A Division of Charter Manufacturing Company, Inc.

EMAIL

1658 Cold Springs Road
Saukville, Wisconsin 53080
(262) 268-2400
1-800-437-8769
Fax (262) 268-2570

Melted in USA Manufactured in USA

CHARTER STEEL TEST REPORT

Cust P.O.	50366-1709
Customer Part #	1.125 1010
Charter Sales Order	30137947
Heat #	10508780
Ship Lot #	4486179
Grade	1010 A AK FG RHQ 1-1/8
Process	HRCC
Finish Size	1-1/8
Ship date	27-AUG-17

Decker Manufacturing Corp.
703 N. Clark St.
Albion,MI-49224

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 # 10508780

Lab Code: 7388

CHEM	C	MN	P	S	SI	NI	CR	MO	CU	SN	V
%Wt	.09	.47	.006	.008	.080	.04	.08	.01	.08	.006	.001
	AL	N	B	TI	NB						
	.022	.0070	.0001	.001	.001						

Test results of Rolling Lot # 1221251

	# of Tests	Min Value	Max Value	Mean Value	
ROCKWELL B (HRBW)	3	59	61	60	RB LAB = 0358-02
ROD SIZE (Inch)	16	1.122	1.131	1.127	
ROD OUT OF ROUND (Inch)	8	.003	.008	.005	

REDUCTION RATIO=30:1

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 = 16 Dated = 01-DEC-16

Additional Comments:

Melt Source:
Charter Steel
Saukville, WI, USA

Trip: 1166878

ACCREDITED
Testing Laboratory

This MTR supersedes all previously dated MTRs for this order

Janice Barnard Division Mgr. of Quality Assurance
barnardJ@chartersteel.com
Printed Date : 08/27/2017

Page 1 of 2

Figure A-35. ⅝-in. Dia. Heavy Hex Nut, Test No. MGSCO-4 (Item No. g1)

GERDAU

CERTIFIED MATERIAL TEST REPORT

Page 1/1

US-ML-ST PAUL
1678 RED ROCK ROAD
SAINT PAUL, MN 55119
USA

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
UNYTITE INC LASALLE PLANT 325 CIVIC ROAD LA SALLE,IL 61301 USA	UNYTITE INC 1 UNYTITE DR PERU,IL 61354-9710 USA	1045M23FJZN	Round Bar / 1"	0000013175
		LENGTH 25'01.5"	WEIGHT 47330 LB	HEAT / BATCH 62144802/05

SALES ORDER	CUSTOMER MATERIAL Nº	SPECIFICATION / DATE or REVISION
5603810/000010	B1045SCL0000 S	ASTM A29-15 ASTM A576-90b(2012)

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
P007133	1532-0000056122	12/05/2017

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %
0.44	0.75	0.006	0.026	0.22	0.14	0.09	0.16	0.035	0.014	0.031	0.001

METALLURGICAL CHARACTERISTICS

Macro	E381 S	E381 R	E381 C
	1	1	1

HARDENABILITY

DI A255 Inch
1.39

COMMENTS / NOTES

Material 100% melted and rolled in the USA. Manufacturing processes for this steel, which may include scrap melted in an electric arc furnace and hot rolling, have been performed at Gerdau St. Paul Mill, 1678 Red Rock Road, Saint Paul, Minnesota, USA. All product produced from strand cast billets. [illegible] No weld repair was performed. Steel not exposed to mercury or any liquid alloy which is liquid at ambient temperatures during processing or while in Gerdau St. Paul Mill's possession. Any Modification to this certification as provided by Gerdau St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill negates the validity of this test report. This report shall not be reproduced except in full, without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill is not responsible for the inability of this material to meet specific applications.

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

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

ALEA BRANDENBURG
QUALITY ASSURANCE MGR.
Phone: (651) 731-5602 Email: Alea.Brandenburg@gerdau.com

Figure A-36. ⅝-in. Dia. Heavy Hex Nut, Test No. MGSCO-4 (Item No. g1)

CHARTER STEEL

A Division of Charter Manufacturing Company, Inc.

EMAIL

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

Melted in USA Manufactured in USA

CHARTER STEEL TEST REPORT

Cust P.O.	91693
Customer Part #	AXA18CB-5/16
Charter Sales Order	30124802
Heat #	20479830
Ship Lot #	2117839
Grade	1018 X AK FG RHQ 5/16
Process	HR
Finish Size	5/16
Ship date	13-JAN-17

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

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

Test results of Heat Lot # 20479830

Lab Code: 125544

CHEM	C	MN	P	S	SI	NI	CR	MO	CU	SN	V
%Wt	.16	.64	.008	.004	.060	.03	.05	.01	.04	.003	.001
	AL	N	B	TI	NB						
	.051	.0050	.0001	.001	.001						

CAT DI=.36

Test results of Rolling Lot # 2117839

	# of Tests	Min Value	Max Value	Mean Value	
TENSILE (KSI)	1	68.6	68.6	68.6	TENSILE LAB = 0358-04
REDUCTION OF AREA (%)	1	72	72	72	RA LAB = 0358-04

NUM DECARB=1
REDUCTION RATIO=637:1

AVE DECARB (inch)=.000

Specifications: Manufactured per Charter Steel Quality Manual Rev Date 12/12/13
Charter Steel certifies this product is indistinguishable from background radiation levels by having process radiation detectors in place to measure for the presence of radiation within our process & products.
Meets customer specifications with any applicable Charter Steel exceptions for the following customer documents:
Customer Document = RW007-RW100 Revision = Dated = 08-NOV-13

Additional Comments:

Melt Source:
Charter Steel
Cuyahoga Heights, OH, USA

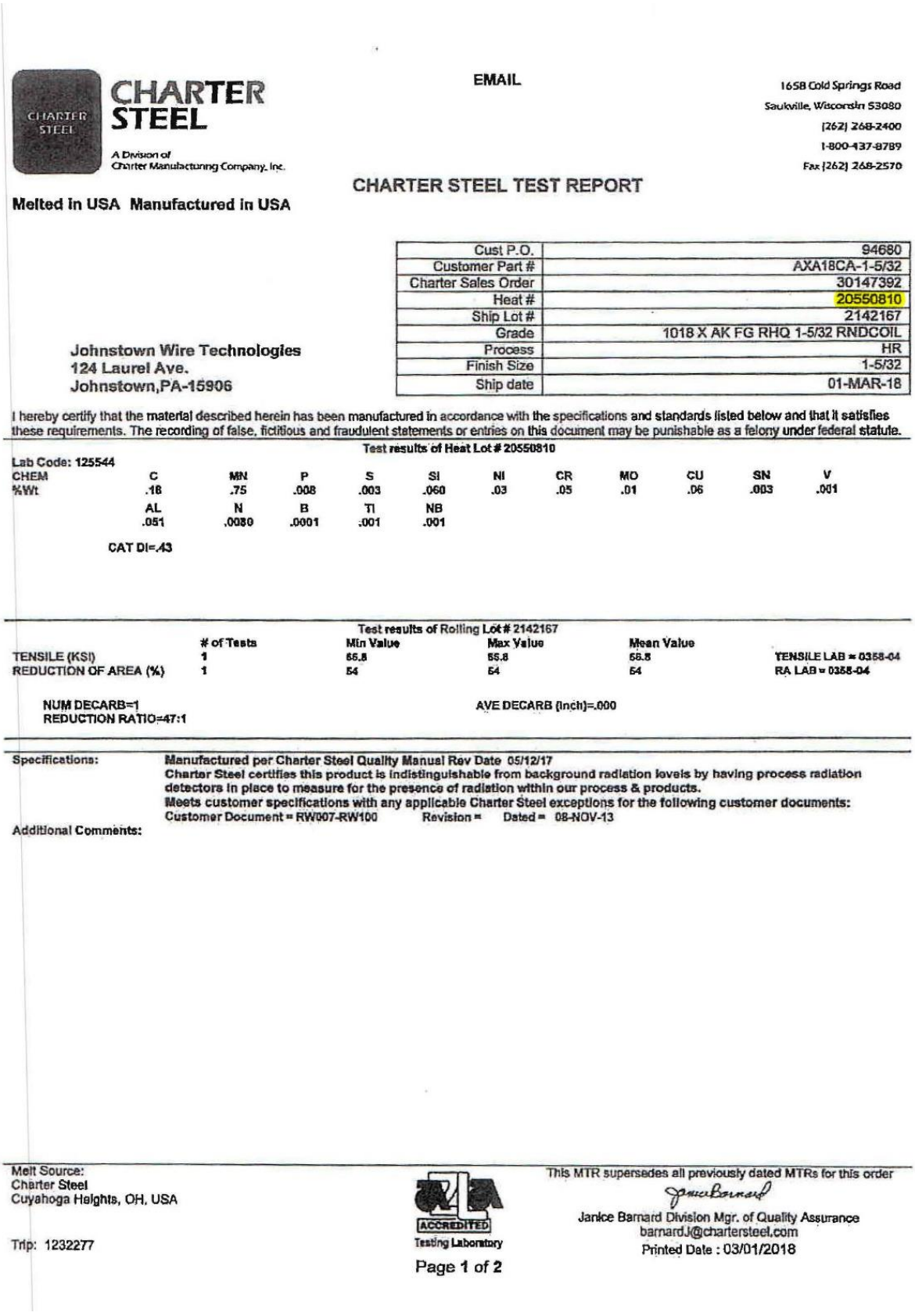
Rem: Load1,Fax0,Mail0

Testing Laboratory

This MTR supersedes all previously dated MTRs for this order

Janice Barnard Division Mgr. of Quality Assurance
barnard.j@chartersteel.com
Printed Date : 01/13/2017

Figure A-37. ⅝-in. Dia. Heavy Hex Nut, Test No. MGSCO-4 (Item No. g1)



CHARTER STEEL
A Division of Charter Manufacturing Company, Inc.

EMAIL

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

CHARTER STEEL TEST REPORT

Melted in USA Manufactured in USA

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

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

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

Test results of Heat Lot # 20550810

Lab Code: 125544

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

CAT DI=.43

Test results of Rolling Lot # 2142167

	# of Tests	Min Value	Max Value	Mean Value	
TENSILE (KSI)	1	68.8	68.8	68.8	TENSILE LAB = 0358-04
REDUCTION OF AREA (%)	1	54	54	54	RA LAB = 0358-04

NUM DECARB=1
REDUCTION RATIO=47:1

AVE DECARB (inch)=.000

Specifications: Manufactured per Charter Steel Quality Manual Rev Date 05/12/17
Charter Steel certifies this product is indistinguishable from background radiation levels by having process radiation detectors in place to measure for the presence of radiation within our process & products.
Meets customer specifications with any applicable Charter Steel exceptions for the following customer documents:
Customer Document = RW007-RW100 Revision = Dated = 08-NOV-13

Additional Comments:

Melt Source:
Charter Steel
Cuyahoga Heights, OH, USA

Trip: 1232277

ACCREDITED
Testing Laboratory

This MTR supersedes all previously dated MTRs for this order

Janice Barnard Division Mgr. of Quality Assurance
barnardJ@chartersteel.com
Printed Date : 03/01/2018

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Figure A-38. ⅝-in. Dia. Heavy Hex Nut, Test No. MGSCO-4 (Item No. g1)

ISO/TS 16949 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER : GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA
Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2017/03/23

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

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

MANUFACTURE DATE : 2016/08/26
COUNTRY OF ORIGIN : CHINA

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

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2007

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

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2010

SAMPLED BY : DWTING

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

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2007

SAMPLED BY : GDAN LIAN

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

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

Quality Supervisor:

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Figure A-39. ⅝-in. Dia. Hex Nut, Test No. MGSCO-4 (Item No. g2)

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 : 2019/04/23

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 210167591
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 7/8-9 NC O/T 0.56MM
LOT NO : 1N18BC001
SHIP QUANTITY : 2,250 PCS
LOT QUANTITY 3,910 PCS
HEADMARKS :

PACKING NO : GEM181128011
INVOICE NO : GEM/FNL-181212ED-1
PART NO : 36717
SAMPLING PLAN :
ASME B18.18-2017(Category.2)/ASTM F1470-2018
HEAT NO : 18108472-3
MATERIAL : X1008A
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

MANUFACTURE DATE : 2018/11/05
COUNTRY OF ORIGIN : CHINA

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2015

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0.5800		0.1300	0.2300	
Test Value	0.0300	0.0700	0.2700	0.0080	0.0050	0.0300

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2015

SAMPLED BY : YUQIAN

INSPECTIONS ITEM	SAMPLE	SPECIFIED		ACTUAL RESULT	ACC.	REJ.
WIDTH ACROSS CORNERS	4PCS		1.4470-1.5160 inch	1.4730-1.4770 inch	4	0
FIM	15PCS	ASME B18.2.2-2015	Max. 0.0250 inch	0.0010-0.0050 inch	15	0
THICKNESS	4PCS		0.7240-0.7760 inch	0.7280-0.7480 inch	4	0
WIDTH ACROSS FLATS	4PCS		1.2690-1.3120 inch	1.2840-1.2990 inch	4	0
SURFACE DISCONTINUITIES	22PCS		ASTM F812-2012	PASSED	22	0
THREAD	15PCS		GAGING SYSTEM 21	PASSED	15	0
MINOR DIAMETER	15PCS		0.7890-0.7970 inch	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2015

SAMPLED BY : GDAN LIAN

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REP	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	13 PCS	ASTM F606-2014		116-302 HRB	81-82 HRB	13	0
PROOF LOAD	3 PCS	ASTM F606-2014		Min. 90 KSI	OK	3	0
PLATING THICKNESS(μm)	5 PCS	ASTM B568-1998		>=53	70.22-75.66	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:

page 1 of 1

Figure A-40. ⅞-in. Dia. Hex Nut, Test No. MGSCO-4 (Item No. g3)

Appendix B. Vehicle Center of Gravity Determination

		Test Name:	**MGSCO-4**	**VIN:**	**1C6RR6KP7DS679213**
Model Year:	**2013**	**Make:**	**Dodge**	**Model:**	**RAM 1500**

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	5146	28.86011	148514.13
+	Hub	19	15.25	289.75
+	Brake activation cylinder & frame	8	30	240
+	Pneumatic tank (Nitrogen)	30	28	840
+	Strobe/Brake Battery	5	24	120
+	Brake Receiver/Wires	6	53	318
+	CG Plate including DAQ	38	32	1216
-	Battery	-38	41 1/4	-1567.5
-	Oil	-13	12	-156
-	Interior	-93	30 1/2	-2836.5
-	Fuel	-195	18	-3510
-	Coolant	-10	37 1/4	-372.5
-	Washer fluid	-1	27	-27
+	Water Ballast (In Fuel Tank)	90	14	1260
+	Onboard Supplemental Battery	5	24	120
				0
				0
Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle				144448.38

Estimated Total Weight (lb)	4997
Vertical CG Location (in.)	28.907

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.25 in. Front Track Width: 68.25 in.
Rear Track Width: 67.5 in.

Center of Gravity	**2270P MASH Targets**	**Test Inertial**	**Difference**
Test Inertial Weight (lb)	5000 ± 110	5000	0.0
Longitudinal CG (in.)	63 ± 4	62.18685	-0.81315
Lateral CG (in.)	NA	-0.46155	NA
Vertical CG (in.)	28 or greater	28.91	0.90702

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	1444	1422	
Rear	1180	1100	
FRONT	2866	lb	
REAR	2280	lb	
TOTAL	5146	lb	

TEST INERTIAL WEIGHT (lb)

	Left	Right	
Front	1404	1379	
Rear	1130	1087	
FRONT	2783	lb	
REAR	2217	lb	
TOTAL	5000	lb	

Figure B-1. Vehicle Mass Distribution, Test No. MGSCO-4

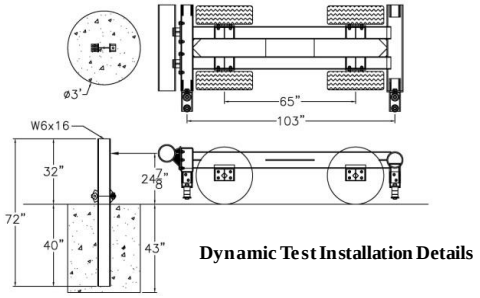
Appendix C. Static Soil Tests

Dynamic Set up

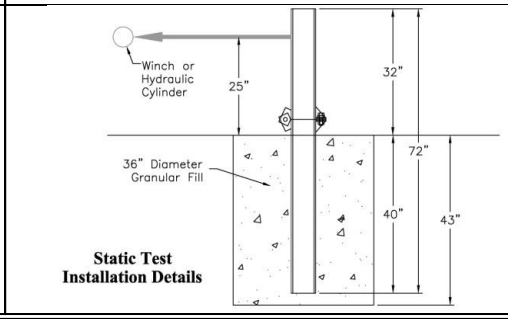
Post-Test Photo of Post

Static Load Test

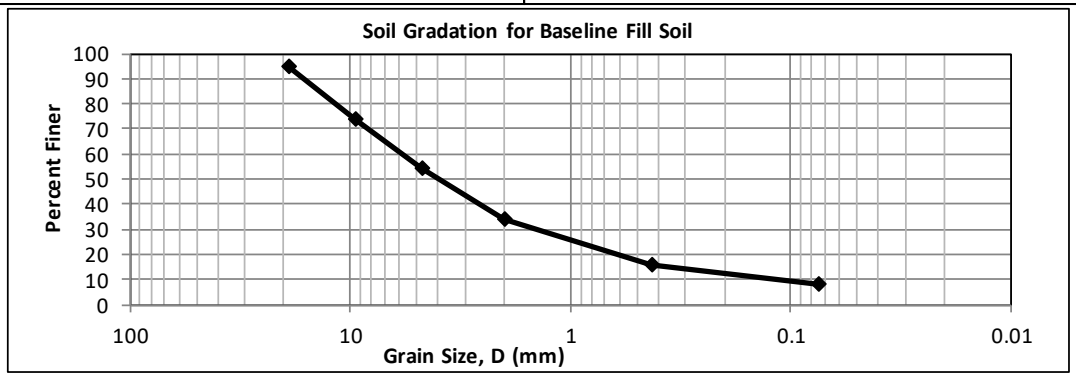
Post-Test Photo of Post

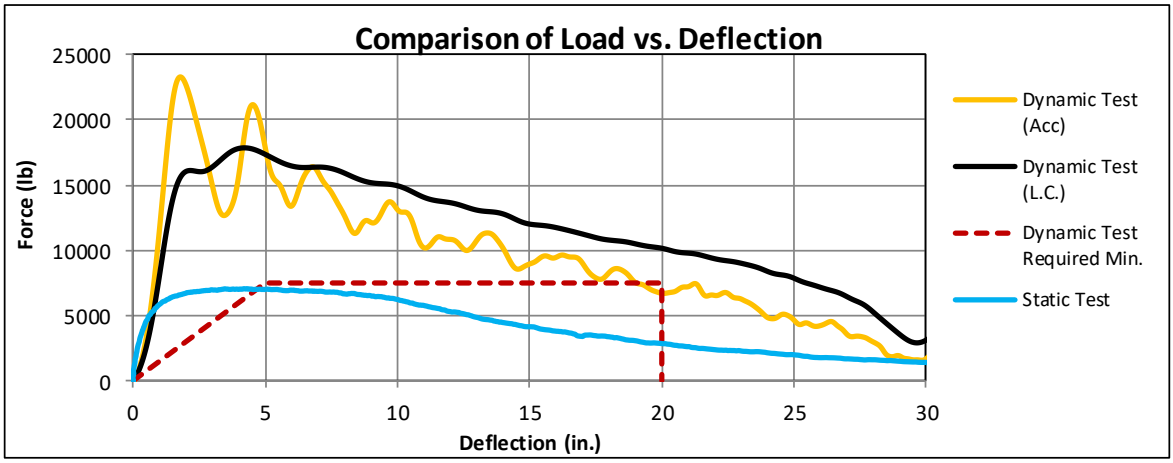


Dynamic Test Installation Details



Static Test Installation Details

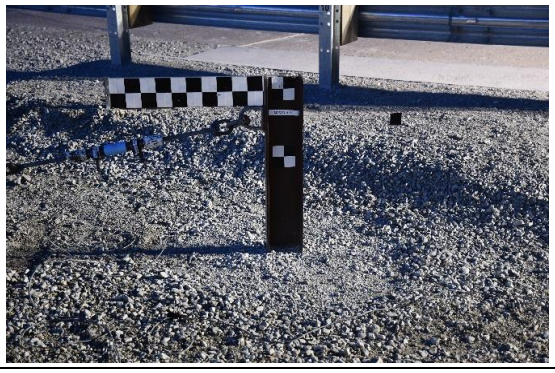




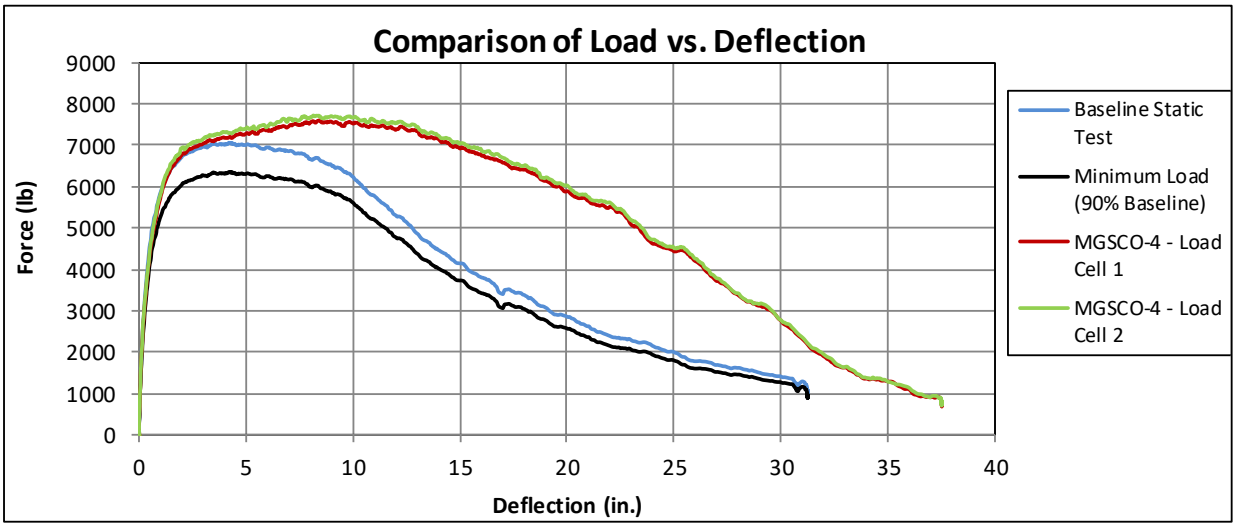
Date	4/4/2019		
Test Facility & Site Location	Midwest Roadside Safety Facility		
In situ soil description (ASTM D2487)	Well-Graded Gravel (GW)		
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)		
Description of fill placement procedure	HE 8		
Bogie Weight	1794	lb	814 kg
Impact Velocity	20.9	mph	33.6 km/h

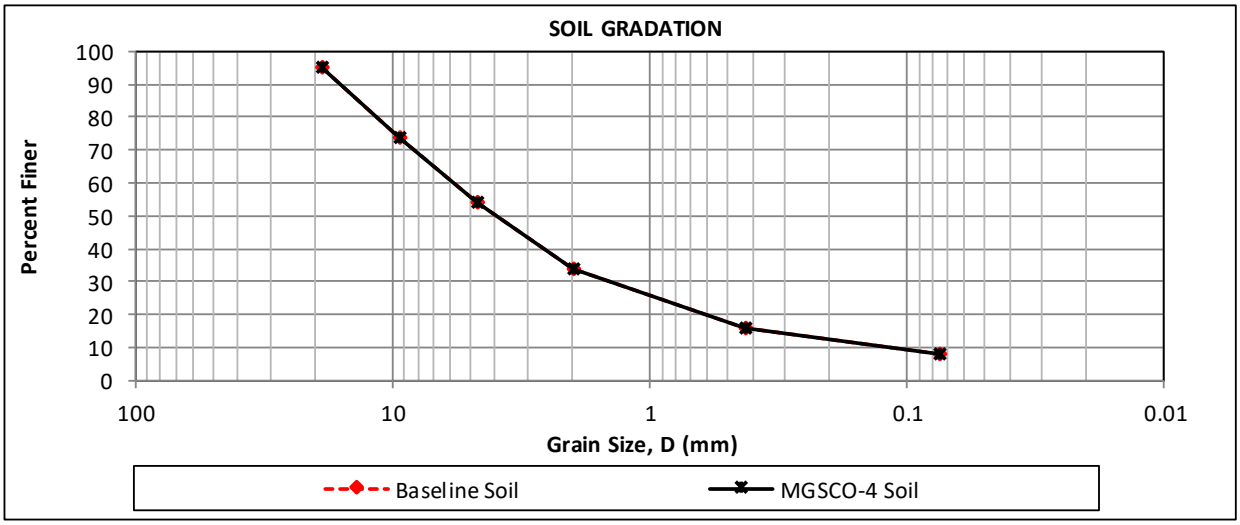
Figure C-1. Soil Strength, Initial Calibration Test

Static Load Test Setup



Post-Test Photo of Post





Date	11/26/2019
Test Facility & Site Location	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)	Well-Graded Gravel (GW)
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure	8-inch lifts tamped with a pneumatic compactor

Figure C-2. Static Soil Test, Test No. MGSCO-4

Appendix D. Vehicle Deformation Records

The following figures and tables describe all occupant compartment measurements taken on the test vehicles used in the full-scale crash testing herein. MASH 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 criteria.

Test Name: MGSCO-4 VIN: 1C6RR6KP7DS679213
Model Year: 2013 Make: Dodge Model: RAM 1500

VEHICLE DEFORMATION
PASSENGER SIDE FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	57.1793	15.2717	-2.3243	57.1756	15.5216	-2.3603	0.0037	-0.2499	0.0360	0.2525	0.0362	X, Z
	2	57.8326	18.2993	-0.5575	57.8195	18.5405	-0.5872	0.0131	-0.2412	0.0297	0.2434	0.0325	X, Z
	3	59.0335	21.8786	2.9780	59.0441	22.0805	2.9366	-0.0106	-0.2019	0.0414	0.2064	0.0414	Z
	4	59.3253	26.0649	3.1675	59.3038	26.2354	3.1402	0.0215	-0.1705	0.0273	0.1740	0.0347	X, Z
	5	59.4803	31.1623	3.1193	59.4803	31.3676	3.0812	0.0000	-0.2053	0.0381	0.2088	0.0381	X, Z
	6	53.9579	14.7742	-0.4366	53.9481	14.9936	-0.4706	0.0098	-0.2194	0.0340	0.2222	0.0354	X, Z
	7	54.8029	18.2908	1.9155	54.7833	18.5335	1.9259	0.0196	-0.2427	-0.0104	0.2437	0.0196	X
	8	55.9203	22.0711	5.0270	55.8733	22.2869	5.0227	0.0470	-0.2158	0.0043	0.2209	0.0472	X, Z
	9	55.9231	26.6334	5.0744	55.9189	26.8631	5.0381	0.0042	-0.2297	0.0363	0.2326	0.0365	X, Z
	10	56.1669	31.6464	4.9897	56.1664	31.8835	4.9538	0.0005	-0.2371	0.0359	0.2398	0.0359	X, Z
FLOOR PAN (Z)	11	50.8536	14.1332	1.4959	50.8423	14.3657	1.4893	0.0113	-0.2325	0.0066	0.2329	0.0066	Z
	12	52.0219	18.0176	4.9970	52.0903	18.2289	4.9327	-0.0684	-0.2113	0.0643	0.2312	0.0643	Z
	13	52.4075	21.7186	5.4538	52.4138	21.9447	5.4213	-0.0063	-0.2261	0.0325	0.2285	0.0325	Z
	14	52.4979	27.1739	5.4553	52.5089	27.2938	5.4274	-0.0110	-0.1199	0.0279	0.1236	0.0279	Z
	15	52.5938	32.1148	5.4793	52.6319	32.2646	5.4586	-0.0381	-0.1498	0.0207	0.1559	0.0207	Z
	16	47.3195	13.2460	2.2192	47.2678	13.4676	2.1833	0.0517	-0.2216	0.0359	0.2304	0.0359	Z
	17	47.8500	18.2551	5.4578	47.9235	18.5272	5.4279	-0.0735	-0.2721	0.0299	0.2834	0.0299	Z
	18	48.2125	23.0379	5.4647	48.2258	23.2990	5.4366	-0.0133	-0.2611	0.0281	0.2629	0.0281	Z
	19	48.8569	27.7996	5.4609	48.8697	28.0234	5.4498	-0.0128	-0.2238	0.0111	0.2244	0.0111	Z
	20	49.1629	32.8538	5.4937	49.1872	33.0446	5.4859	-0.0243	-0.1908	0.0078	0.1925	0.0078	Z
	21	43.4472	13.3536	2.5960	43.4402	13.5853	2.5684	0.0070	-0.2317	0.0276	0.2334	0.0276	Z
	22	44.1518	17.5869	5.4568	44.1534	17.7594	5.4285	-0.0016	-0.1725	0.0283	0.1748	0.0283	Z
	23	44.5119	23.2713	5.4543	44.4675	23.4774	5.4347	0.0444	-0.2061	0.0196	0.2117	0.0196	Z
	24	44.8140	28.3992	5.4692	44.7917	28.5930	5.4694	0.0223	-0.1938	-0.0002	0.1951	-0.0002	Z
	25	44.7773	33.1528	5.4911	44.7671	33.3287	5.4783	0.0102	-0.1759	0.0128	0.1767	0.0128	Z
	26	38.9549	13.3968	2.5868	38.9951	13.6272	2.5527	-0.0402	-0.2304	0.0341	0.2364	0.0341	Z
	27	39.0095	16.9181	4.6702	39.0282	17.1202	4.6527	-0.0187	-0.2021	0.0175	0.2037	0.0175	Z
	28	39.0875	22.6263	4.6669	39.0975	22.8814	4.6486	-0.0100	-0.2551	0.0183	0.2560	0.0183	Z
	29	39.0444	28.6038	4.6849	39.0333	28.8664	4.6694	0.0111	-0.2626	0.0155	0.2633	0.0155	Z
	30	38.7466	31.9290	4.6965	38.7821	32.1502	4.6803	-0.0355	-0.2212	0.0162	0.2246	0.0162	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. MGSCO-4

Model Year: 2013 Test Name: MGSCO-4 Make: Dodge VIN: 1C6RR6KP7DS679213 Model: RAM 1500

VEHICLE DEFORMATION
PASSENGER SIDE FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	58.8722	-0.0228	-6.9858	58.8800	0.0222	-6.8525	-0.0078	0.0450	-0.1333	0.1409	0.0000	NA
	2	59.4626	3.0165	-5.2168	59.4529	3.0580	-5.0836	0.0097	-0.0415	-0.1332	0.1399	0.0097	X
	3	60.5975	6.6173	-1.6814	60.5980	6.6307	-1.5662	-0.0005	-0.0134	-0.1152	0.1160	0.0000	NA
	4	60.7892	10.8090	-1.4852	60.7545	10.7910	-1.3669	0.0347	0.0180	-0.1183	0.1246	0.0347	X
	5	60.8207	15.9087	-1.5242	60.8027	15.9259	-1.4307	0.0180	-0.0172	-0.0935	0.0968	0.0180	X
	6	55.6749	-0.6014	-5.0803	55.6715	-0.5843	-4.9538	0.0034	0.0171	-0.1265	0.1277	0.0034	X
	7	56.4486	2.9303	-2.7262	56.4244	2.9775	-2.5626	0.0242	-0.0472	-0.1636	0.1720	0.0242	X
	8	57.4926	6.7307	0.3862	57.4285	6.7598	0.5281	0.0641	-0.0291	-0.1419	0.1584	0.0641	X
	9	57.3855	11.2916	0.4427	57.3599	11.3358	0.5394	0.0256	-0.0442	-0.0967	0.1094	0.0256	X
	10	57.5076	16.3092	0.3665	57.4818	16.3607	0.4502	0.0258	-0.0515	-0.0837	0.1016	0.0258	X
FLOOR PAN (Z)	11	52.5985	-1.3208	-3.1310	52.5876	-1.2878	-2.9851	0.0109	0.0330	-0.1459	0.1500	-0.1459	Z
	12	53.6932	2.5843	0.3709	53.7478	2.6085	0.4516	-0.0546	-0.0242	-0.0807	0.1004	-0.0807	Z
	13	53.9920	6.2926	0.8328	53.9797	6.3317	0.9362	0.0123	-0.0391	-0.1034	0.1112	-0.1034	Z
	14	53.9505	11.7485	0.8446	53.9412	11.6815	0.9374	0.0093	0.0670	-0.0928	0.1148	-0.0928	Z
	15	53.9272	16.6902	0.8779	53.9402	16.6539	0.9640	-0.0130	0.0363	-0.0861	0.0943	-0.0861	Z
	16	49.0912	-2.2945	-2.3888	49.0384	-2.2741	-2.2808	0.0528	0.0204	-0.1080	0.1219	-0.1080	Z
	17	49.5195	2.7200	0.8566	49.5762	2.8033	0.9576	-0.0567	-0.0833	-0.1010	0.1427	-0.1010	Z
	18	49.7664	7.5101	0.8708	49.7593	7.5811	0.9614	0.0071	-0.0710	-0.0906	0.1153	-0.0906	Z
	19	50.2956	12.2860	0.8727	50.2850	12.3201	0.9688	0.0106	-0.0341	-0.0961	0.1025	-0.0961	Z
	20	50.4797	17.3461	0.9138	50.4772	17.3477	0.9997	0.0025	-0.0016	-0.0859	0.0860	-0.0859	Z
	21	45.2196	-2.2812	-1.9892	45.2101	-2.2517	-1.8857	0.0095	0.0295	-0.1035	0.1080	-0.1035	Z
	22	45.8386	1.9626	0.8758	45.8264	1.9416	0.9689	0.0122	0.0210	-0.0931	0.0962	-0.0931	Z
	23	46.0613	7.6540	0.8824	45.9976	7.6656	0.9693	0.0637	-0.0116	-0.0869	0.1084	-0.0869	Z
	24	46.2395	12.7877	0.9058	46.1942	12.7878	0.9988	0.0453	-0.0001	-0.0930	0.1034	-0.0930	Z
	25	46.0881	17.5390	0.9373	46.0514	17.5214	1.0036	0.0367	0.0176	-0.0663	0.0778	-0.0663	Z
	26	40.7277	-2.3466	-1.9721	40.7653	-2.3207	-1.8897	-0.0376	0.0259	-0.0824	0.0942	-0.0824	Z
	27	40.7095	1.1712	0.1179	40.7167	1.1739	0.2071	-0.0072	-0.0027	-0.0892	0.0895	-0.0892	Z
	28	40.6496	6.8796	0.1255	40.6422	6.9350	0.1979	0.0074	-0.0554	-0.0724	0.0915	-0.0724	Z
	29	40.4621	12.8543	0.1556	40.4286	12.9166	0.2137	0.0335	-0.0623	-0.0581	0.0915	-0.0581	Z
	30	40.0842	16.1712	0.1756	40.0956	16.1931	0.2225	-0.0114	-0.0219	-0.0469	0.0530	-0.0469	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. MGSCO-4

Model Year: 2013 Test Name: MGSCO-4 Make: Dodge VIN: 1C6RR6KP7DS679213 Model: RAM 1500

VEHICLE DEFORMATION
PASSENGER SIDE INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	50.0244	3.9302	-27.7810	50.0686	3.9943	-27.6709	-0.0442	-0.0641	0.1101	0.1348	0.1348	X, Y, Z
	2	50.0556	14.5867	-27.4470	50.1646	14.6743	-27.3829	-0.1090	-0.0876	0.0641	0.1538	0.1538	X, Y, Z
	3	51.0682	29.5388	-26.4482	51.1137	29.5634	-26.3321	-0.0455	-0.0246	0.1161	0.1271	0.1271	X, Y, Z
	4	43.3119	3.7062	-16.6852	43.3741	3.7704	-16.5820	-0.0622	-0.0642	0.1032	0.1365	0.1365	X, Y, Z
	5	45.5774	15.0709	-16.5042	45.6505	15.1117	-16.3289	-0.0731	-0.0408	0.1753	0.1943	0.1943	X, Y, Z
	6	46.5256	30.5258	-16.8836	46.5870	30.5220	-16.8127	-0.0614	0.0038	0.0709	0.0939	0.0939	X, Y, Z
SIDE PANEL (Y)	7	55.5843	36.1871	0.3136	55.5879	36.0994	0.3985	-0.0036	0.0877	0.0849	0.1221	0.0877	Y
	8	58.3771	36.1309	-1.8631	58.3157	36.0738	-1.7763	0.0614	0.0571	0.0868	0.1207	0.0571	Y
	9	55.6205	36.2097	-3.0523	55.6792	36.0982	-2.9140	-0.0587	0.1115	0.1383	0.1871	0.1115	Y
IMPACT SIDE DOOR (Y)	10	24.6915	38.4473	-19.6006	24.6777	38.5349	-19.5705	0.0138	-0.0876	0.0301	0.0936	-0.0876	Y
	11	30.6401	38.3924	-19.3629	30.5998	38.4399	-19.2469	0.0403	-0.0475	0.1160	0.1317	-0.0475	Y
	12	36.6361	38.3511	-19.5227	36.5529	38.3709	-19.5157	0.0832	-0.0198	0.0070	0.0858	-0.0198	Y
	13	24.7364	38.9405	-3.0494	24.5807	38.8745	-3.0572	0.1557	0.0660	-0.0078	0.1693	0.0660	Y
	14	33.6972	39.0063	-3.6246	33.6066	38.8699	-3.6058	0.0906	0.1364	0.0188	0.1648	0.1364	Y
	15	40.1099	39.5417	-3.2104	40.0425	39.3745	-3.1022	0.0674	0.1672	0.1082	0.2103	0.1672	Y
ROOF - (Z)	16	35.8250	4.3803	-45.4166	35.9833	4.4247	-45.3230	-0.1583	-0.0444	0.0936	0.1892	0.0936	Z
	17	35.5958	9.2895	-45.4145	35.7764	9.3276	-45.3199	-0.1806	-0.0381	0.0946	0.2074	0.0946	Z
	18	34.8377	14.8427	-45.3808	34.9929	14.8798	-45.2973	-0.1552	-0.0371	0.0835	0.1801	0.0835	Z
	19	34.0135	20.1777	-45.2125	34.1433	20.2320	-45.1313	-0.1298	-0.0543	0.0812	0.1624	0.0812	Z
	20	32.6067	25.2269	-45.0253	32.7262	25.2584	-44.9525	-0.1195	-0.0315	0.0728	0.1434	0.0728	Z
	21	31.4235	4.5833	-46.1707	31.5696	4.5871	-46.0880	-0.1461	-0.0038	0.0827	0.1679	0.0827	Z
	22	30.3911	9.1976	-46.2435	30.5175	9.1914	-46.1665	-0.1264	0.0062	0.0770	0.1481	0.0770	Z
	23	29.4286	14.1254	-46.1355	29.6018	14.1964	-46.0534	-0.1732	-0.0710	0.0821	0.2044	0.0821	Z
	24	28.4958	19.8458	-46.0216	28.6439	19.8319	-45.9448	-0.1481	0.0139	0.0768	0.1674	0.0768	Z
	25	26.9828	24.6637	-45.8049	27.1014	24.6975	-45.7289	-0.1186	-0.0338	0.0760	0.1449	0.0760	Z
	26	27.0622	4.5148	-46.5820	27.2148	4.5489	-46.5142	-0.1526	-0.0341	0.0678	0.1704	0.0678	Z
	27	25.8177	8.6876	-46.6281	26.0258	8.6405	-46.5585	-0.2081	0.0471	0.0696	0.2244	0.0696	Z
	28	23.7277	13.0516	-46.5716	23.9784	13.0211	-46.5037	-0.2507	0.0305	0.0679	0.2615	0.0679	Z
	29	22.5232	18.4727	-46.4145	22.7089	18.4663	-46.3573	-0.1857	0.0064	0.0572	0.1944	0.0572	Z
	30	20.3786	23.9331	-46.2396	20.5484	23.9777	-46.1742	-0.1698	-0.0446	0.0654	0.1873	0.0654	Z
A-PILLAR Maximum (X, Y, Z)	31	53.8536	34.5856	-29.8914	53.9125	34.5688	-29.7256	-0.0589	0.0168	0.1658	0.1768	0.1666	Y, Z
	32	50.9340	33.9154	-32.2840	50.9666	33.9013	-32.1582	-0.0326	0.0141	0.1258	0.1307	0.1266	Y, Z
	33	48.6821	33.5890	-34.1774	48.7735	33.5973	-34.0287	-0.0914	-0.0083	0.1487	0.1747	0.1487	Z
	34	45.9556	33.0237	-36.0823	46.0772	33.0491	-35.9522	-0.1216	-0.0254	0.1301	0.1799	0.1301	Z
	35	42.7501	32.3857	-38.3149	42.8882	32.4153	-38.1776	-0.1381	-0.0296	0.1373	0.1970	0.1373	Z
	36	39.1561	31.6432	-40.2973	39.2568	31.6638	-40.1669	-0.1007	-0.0206	0.1304	0.1660	0.1304	Z
A-PILLAR Lateral (Y)	31	53.8536	34.5856	-29.8914	53.9125	34.5688	-29.7256	-0.0589	0.0168	0.1658	0.1768	0.0168	Y
	32	50.9340	33.9154	-32.2840	50.9666	33.9013	-32.1582	-0.0326	0.0141	0.1258	0.1307	0.0141	Y
	33	48.6821	33.5890	-34.1774	48.7735	33.5973	-34.0287	-0.0914	-0.0083	0.1487	0.1747	-0.0083	Y
	34	45.9556	33.0237	-36.0823	46.0772	33.0491	-35.9522	-0.1216	-0.0254	0.1301	0.1799	-0.0254	Y
	35	42.7501	32.3857	-38.3149	42.8882	32.4153	-38.1776	-0.1381	-0.0296	0.1373	0.1970	-0.0296	Y
	36	39.1561	31.6432	-40.2973	39.2568	31.6638	-40.1669	-0.1007	-0.0206	0.1304	0.1660	-0.0206	Y
B-PILLAR Maximum (X, Y, Z)	37	14.3698	31.7067	-40.6413	14.4424	31.7381	-40.5629	-0.0726	-0.0314	0.0784	0.1114	0.0784	Z
	38	11.7080	33.1053	-36.8938	11.7413	33.0871	-36.9371	-0.0333	0.0182	-0.0433	0.0576	0.0182	Y
	39	14.9646	34.3782	-33.3939	15.0243	34.3837	-33.3784	-0.0597	-0.0055	0.0155	0.0619	0.0155	Z
	40	12.0660	35.6207	-29.2232	12.1635	35.6412	-29.1652	-0.0975	-0.0205	0.0580	0.1153	0.0580	Z
B-PILLAR Lateral (Y)	37	14.3698	31.7067	-40.6413	14.4424	31.7381	-40.5629	-0.0726	-0.0314	0.0784	0.1114	-0.0314	Y
	38	11.7080	33.1053	-36.8938	11.7413	33.0871	-36.9371	-0.0333	0.0182	-0.0433	0.0576	0.0182	Y
	39	14.9646	34.3782	-33.3939	15.0243	34.3837	-33.3784	-0.0597	-0.0055	0.0155	0.0619	-0.0055	Y
	40	12.0660	35.6207	-29.2232	12.1635	35.6412	-29.1652	-0.0975	-0.0205	0.0580	0.1153	-0.0205	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. MGSCO-4

Model Year: 2013 Test Name: MGSCO-4 Make: Dodge VIN: 1C6RR6KP7DS679213 Model: RAM 1500

VEHICLE DEFORMATION
PASSENGER SIDE INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	51.9168	-11.7400	-32.3318	52.0022	-11.7148	-32.1360	-0.0854	0.0252	0.1958	0.2151	0.2151	X, Y, Z
	2	51.6937	-1.0863	-31.9811	51.8302	-1.0353	-31.8644	-0.1365	0.0510	0.1167	0.1867	0.1867	X, Y, Z
	3	52.3509	13.8842	-30.9622	52.4067	13.8746	-30.8383	-0.0558	0.0096	0.1239	0.1362	0.1362	X, Y, Z
	4	45.2492	-12.1414	-21.2139	45.3427	-12.0897	-21.0302	-0.0935	0.0517	0.1837	0.2125	0.2125	X, Y, Z
	5	47.2423	-0.7260	-21.0226	47.3335	-0.6944	-20.7998	-0.0912	0.0316	0.2228	0.2428	0.2428	X, Y, Z
	6	47.8184	14.7477	-21.3809	47.8807	14.7339	-21.3091	-0.0623	0.0138	0.0718	0.0961	0.0961	X, Y, Z
SIDE PANEL (Y)	7	56.7970	20.5989	-4.2053	56.7805	20.5630	-4.1288	0.0165	0.0359	0.0765	0.0861	0.0359	Y
	8	59.5830	20.6130	-6.3913	59.5026	20.6027	-6.3104	0.0804	0.0103	0.0809	0.1145	0.0103	Y
	9	56.8212	20.6274	-7.5712	56.8636	20.5589	-7.4415	-0.0424	0.0685	0.1297	0.1527	0.0685	Y
IMPACT SIDE DOOR (Y)	10	25.7916	22.1476	-24.0122	25.7699	22.1885	-24.0245	0.0217	-0.0409	-0.0123	0.0479	-0.0409	Y
	11	31.7406	22.2349	-23.7946	31.6933	22.2431	-23.7154	0.0473	-0.0082	0.0792	0.0926	-0.0082	Y
	12	37.7354	22.3376	-23.9746	37.6456	22.3235	-23.9990	0.0898	0.0141	-0.0244	0.0941	0.0141	Y
	13	25.8808	22.6170	-7.4605	25.7048	22.5515	-7.5115	0.1760	0.0655	-0.0510	0.1946	0.0655	Y
	14	34.8354	22.8984	-8.0656	34.7267	22.7732	-8.0826	0.1087	0.1252	-0.0170	0.1667	0.1252	Y
	15	41.2348	23.5868	-7.6721	41.1490	23.4404	-7.5957	0.0858	0.1464	0.0764	0.1861	0.1464	Y
ROOF - (Z)	16	37.6510	-11.6041	-49.9190	37.8674	-11.6667	-49.7536	-0.2164	-0.0626	0.1654	0.2795	0.1654	Z
	17	37.3042	-6.7018	-49.9084	37.5372	-6.7706	-49.7575	-0.2330	-0.0688	0.1509	0.2860	0.1509	Z
	18	36.4133	-1.1685	-49.8634	36.6143	-1.2398	-49.7412	-0.2010	-0.0713	0.1222	0.2458	0.1222	Z
	19	35.4621	4.1450	-49.6840	35.6306	4.0896	-49.5811	-0.1685	0.0554	0.1029	0.2051	0.1029	Z
	20	33.9353	9.1588	-49.4841	34.0879	9.0790	-49.4064	-0.1526	0.0798	0.0777	0.1889	0.0777	Z
	21	33.2433	-11.5056	-50.6581	33.4491	-11.6166	-50.5079	-0.2058	-0.1110	0.1502	0.2779	0.1502	Z
	22	32.1004	-6.9172	-50.7201	32.2813	-7.0404	-50.5908	-0.1809	-0.1232	0.1293	0.2542	0.1293	Z
	23	31.0205	-2.0141	-50.6011	31.2402	-2.0598	-50.4829	-0.2197	-0.0457	0.1182	0.2536	0.1182	Z
	24	29.9512	3.6821	-50.4751	30.1411	3.5499	-50.3804	-0.1899	0.1322	0.0947	0.2500	0.0947	Z
	25	28.3239	8.4620	-50.2458	28.4771	8.3755	-50.1679	-0.1532	0.0865	0.0779	0.1924	0.0779	Z
	26	28.8836	-11.6780	-51.0548	29.0956	-11.7651	-50.9233	-0.2120	-0.0871	0.1315	0.2642	0.1315	Z
	27	27.5393	-7.5361	-51.0902	27.8039	-7.7047	-50.9708	-0.2646	-0.1686	0.1194	0.3357	0.1194	Z
	28	25.3455	-3.2236	-51.0198	25.6471	-3.3769	-50.9174	-0.3016	-0.1533	0.1024	0.3535	0.1024	Z
	29	24.0119	2.1668	-50.8501	24.2413	2.0348	-50.7761	-0.2294	0.1320	0.0740	0.2748	0.0740	Z
	30	21.7376	7.5740	-50.6594	21.9432	7.4904	-50.5959	-0.2056	0.0836	0.0635	0.2309	0.0635	Z
A-PILLAR Maximum (X, Y, Z)	31	55.0029	19.0015	-34.4067	55.0704	18.9435	-34.2463	-0.0675	0.0580	0.1604	0.1834	0.1706	Y, Z
	32	52.0921	18.2650	-36.7907	52.1362	18.1983	-36.6705	-0.0441	0.0667	0.1202	0.1444	0.1375	Y, Z
	33	49.8423	17.8876	-38.6769	49.9469	17.8362	-38.5352	-0.1046	0.0514	0.1417	0.1835	0.1507	Y, Z
	34	47.1237	17.2599	-40.5737	47.2605	17.2173	-40.4511	-0.1368	0.0426	0.1226	0.1886	0.1298	Y, Z
	35	43.9268	16.5486	-42.7964	44.0831	16.5000	-42.6676	-0.1563	0.0486	0.1288	0.2083	0.1377	Y, Z
	36	40.3450	15.7231	-44.7680	40.4669	15.6542	-44.6467	-0.1219	0.0689	0.1213	0.1853	0.1395	Y, Z
A-PILLAR Lateral (Y)	31	55.0029	19.0015	-34.4067	55.0704	18.9435	-34.2463	-0.0675	0.0580	0.1604	0.1834	0.0580	Y
	32	52.0921	18.2650	-36.7907	52.1362	18.1983	-36.6705	-0.0441	0.0667	0.1202	0.1444	0.0667	Y
	33	49.8423	17.8876	-38.6769	49.9469	17.8362	-38.5352	-0.1046	0.0514	0.1417	0.1835	0.0514	Y
	34	47.1237	17.2599	-40.5737	47.2605	17.2173	-40.4511	-0.1368	0.0426	0.1226	0.1886	0.0426	Y
	35	43.9268	16.5486	-42.7964	44.0831	16.5000	-42.6676	-0.1563	0.0486	0.1288	0.2083	0.0486	Y
	36	40.3450	15.7231	-44.7680	40.4669	15.6542	-44.6467	-0.1219	0.0689	0.1213	0.1853	0.0689	Y
B-PILLAR Maximum (X, Y, Z)	37	15.5633	15.1929	-45.0288	15.6576	15.1034	-44.9811	-0.0943	0.0895	0.0477	0.1385	0.1014	Y, Z
	38	12.8815	16.5217	-41.2702	12.9322	16.3897	-41.3506	-0.0507	0.1320	-0.0804	0.1627	0.1320	Y
	39	16.1184	17.8670	-37.7793	16.1903	17.7741	-37.8021	-0.0719	0.0929	-0.0228	0.1197	0.0929	Y
	40	13.2050	19.0335	-33.5970	13.3091	18.9658	-33.5836	-0.1041	0.0677	0.0134	0.1249	0.0690	Y, Z
B-PILLAR Lateral (Y)	37	15.5633	15.1929	-45.0288	15.6576	15.1034	-44.9811	-0.0943	0.0895	0.0477	0.1385	0.0895	Y
	38	12.8815	16.5217	-41.2702	12.9322	16.3897	-41.3506	-0.0507	0.1320	-0.0804	0.1627	0.1320	Y
	39	16.1184	17.8670	-37.7793	16.1903	17.7741	-37.8021	-0.0719	0.0929	-0.0228	0.1197	0.0929	Y
	40	13.2050	19.0335	-33.5970	13.3091	18.9658	-33.5836	-0.1041	0.0677	0.0134	0.1249	0.0677	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. MGSCO-4

Test Name: MGSCO-4 VIN: 1C6RR6KP7DS679213

Model Year: 2013 Make: Dodge Model: RAM 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	0.1	≤ 4	Z	Roof	0.2	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.2	≤ 5	Y, Z	A-Pillar Maximum	0.2	≤ 5	Y, Z
A-Pillar Lateral	0.0	≤ 3	Y	A-Pillar Lateral	0.1	≤ 3	Y
B-Pillar Maximum	0.1	≤ 5	Z	B-Pillar Maximum	0.1	≤ 5	Y
B-Pillar Lateral	0.0	≤ 3	Y	B-Pillar Lateral	0.1	≤ 3	Y
Toe Pan - Wheel Well	0.0	≤ 9	X, Z	Toe Pan - Wheel Well	0.1	≤ 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)	0.0	≤ 9	Y
Side Door (below seat)	0.2	≤ 12	Y	Side Door (below seat)	0.1	≤ 12	Y
Floor Pan	0.1	≤ 12	Z	Floor Pan	-0.1	≤ 12	Z
Dash - no MASH requirement	0.2	NA	X, Y, Z	Dash - no MASH requirement	0.2	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.

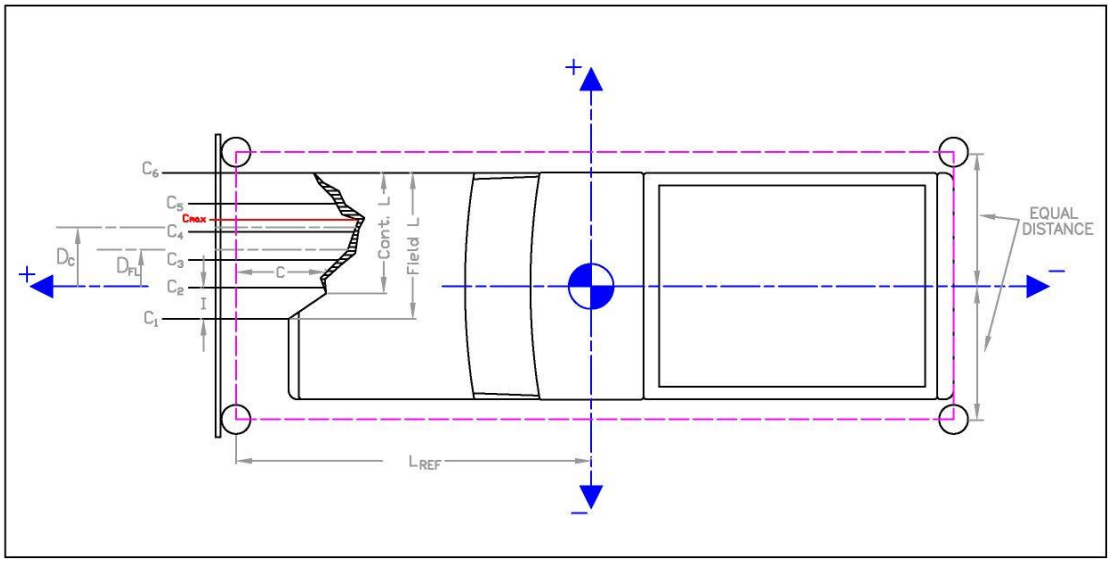
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

Notes on vehicle interior crush:

Figure D-5. Maximum Occupant Compartment Deformation by Location, Test No. MGSCO-4

Date Measured: 12/2/2019 Test Name: MGSCO-4 VIN: 1C6RR6KP7DS679213

Model Year: 2013 Make: Dodge Model: RAM 1500



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	108	(2743)
Total Vehicle Width:	77 1/3	(1964)
Width of contact and induced crush - Field L:	77 1/3	(1964)
Crush measurement spacing interval (L/5) - I:	15 1/2	(394)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	24	(610)
Distance from center of vehicle to center of contact damage - D_C:	29 3/4	(756)

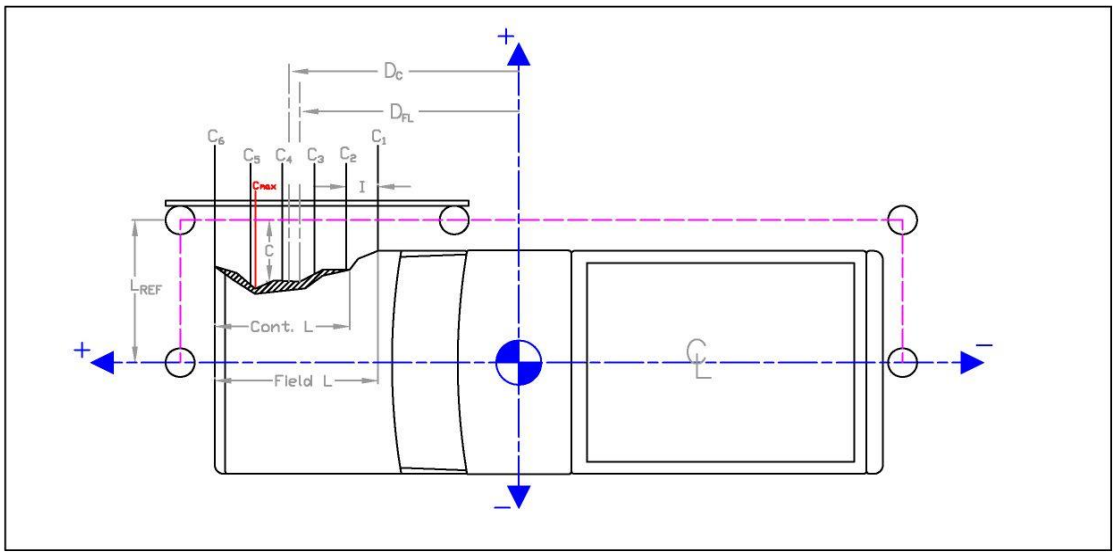
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)

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	NA	N/A	-38 5/8	-(981)	22 1/2	(572)	1 4/7	(40)	N/A	N/A
C_2	7 1/8	(181)	-23 1/8	-(587)	6 1/2	(165)			-1	-(24)
C_3	5 1/8	(130)	-7 5/8	-(194)	4 1/4	(108)			- 2/3	-(17)
C_4	5 1/4	(133)	7 7/8	(200)	4 1/4	(108)			- 4/7	-(14)
C_5	16	(406)	23 3/8	(594)	6 1/4	(159)			8 1/5	(208)
C_6	NA	N/A	38 7/8	(987)	20 1/2	(521)			N/A	N/A
C_{MAX}	16	(406)	23 3/8	(594)	6 1/4	(159)			8 1/5	(208)

Figure D-6. Exterior Vehicle Crush (NASS) – Front, Test No. MGSCO-4

Date Measured:	12/2/2019	**Test Name:**	MGSCO-4	**VIN:**	1C6RR6KP7DS679213
Model Year:	2013	**Make:**	Dodge	**Model:**	RAM 1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	43	(1092)
Total Vehicle Length:	229 3/8	(5826)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-3 3/8	-(86)
Width of contact and induced crush - Field L:	229 3/8	(5826)
Crush measurement spacing interval (L/5) - I:	45 7/8	(1165)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-3 3/8	-(86)
Width of Contact Damage:	229 3/8	(5826)
Distance from vehicle c.g. to center of contact damage - D_C:	-3 3/8	-(86)

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	NA	N/A	-118 1/8	-(3000)	33 1/2	(851)	-1	-(25)	N/A	N/A
C_2	NA	N/A	-72 1/4	-(1835)	5 1/4	(133)			N/A	N/A
C_3	4 3/4	(121)	-26 3/8	-(670)	5 5/8	(143)			1/8	(3)
C_4	4 3/4	(121)	19 1/2	(495)	5 1/8	(130)			5/8	(16)
C_5	NA	N/A	65 3/8	(1661)	5	(127)			N/A	N/A
C_6	NA	N/A	111 1/4	(2826)	30	(762)			N/A	N/A
C_{MAX}	17 1/2	(445)	89	(2261)	5 7/8	(149)			12 5/8	(321)

Figure D-7. Exterior Vehicle Crush (NASS) – Side, Test No. MGSCO-4

Appendix E. Accelerometer and Rate Transducer Data Plots

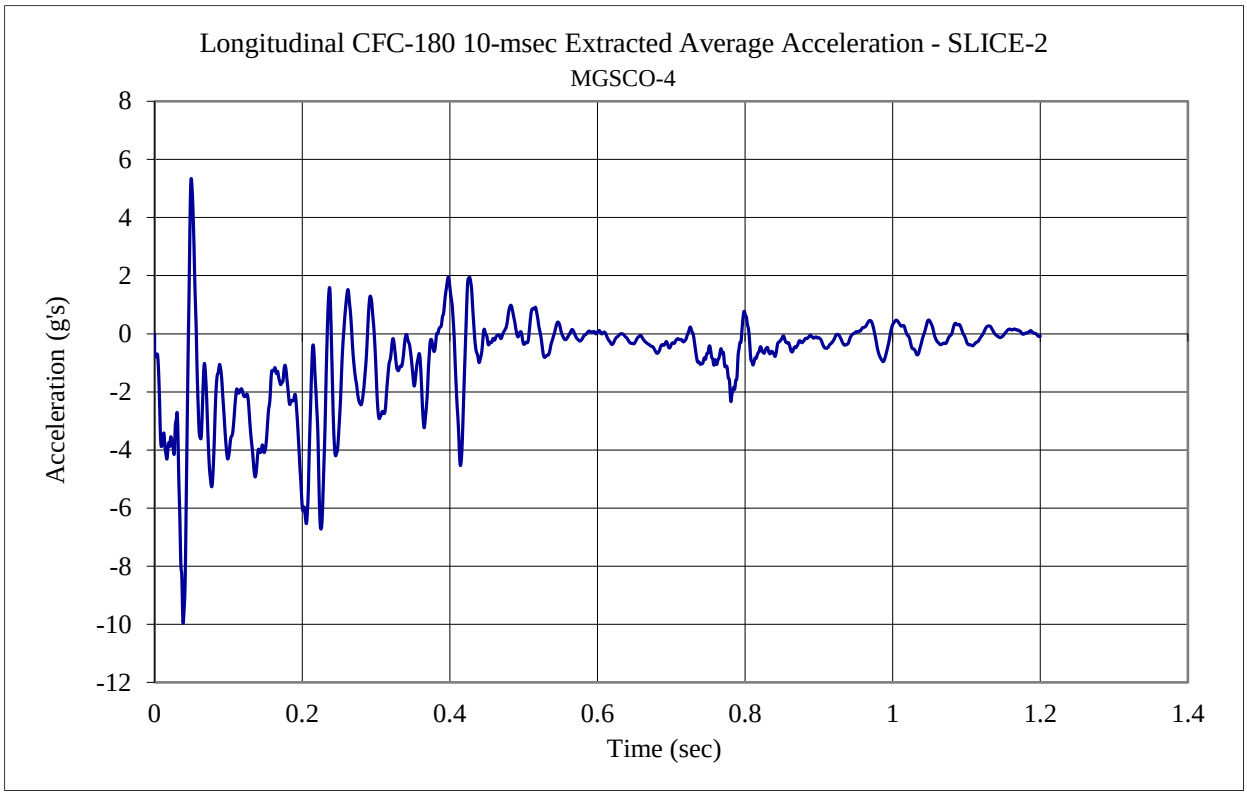


Figure E-1. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. MGSCO-4

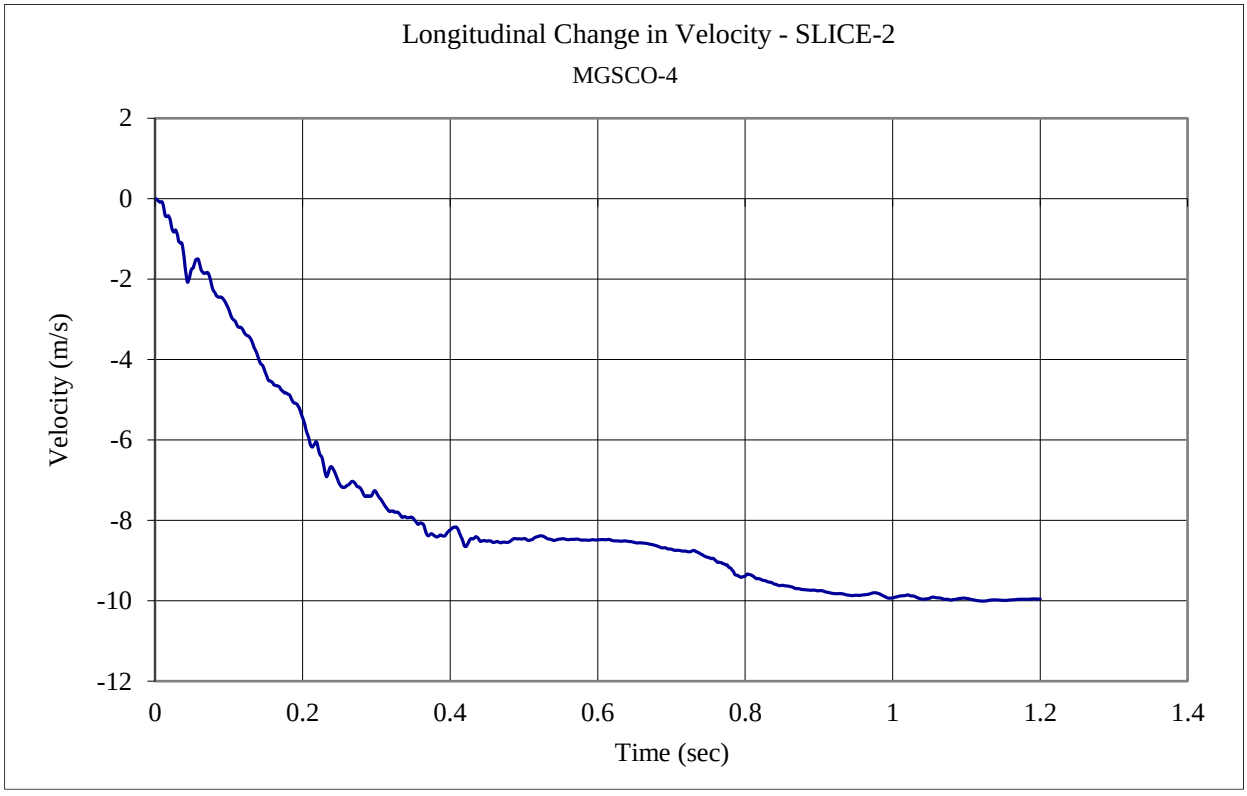


Figure E-2. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. MGSCO-4

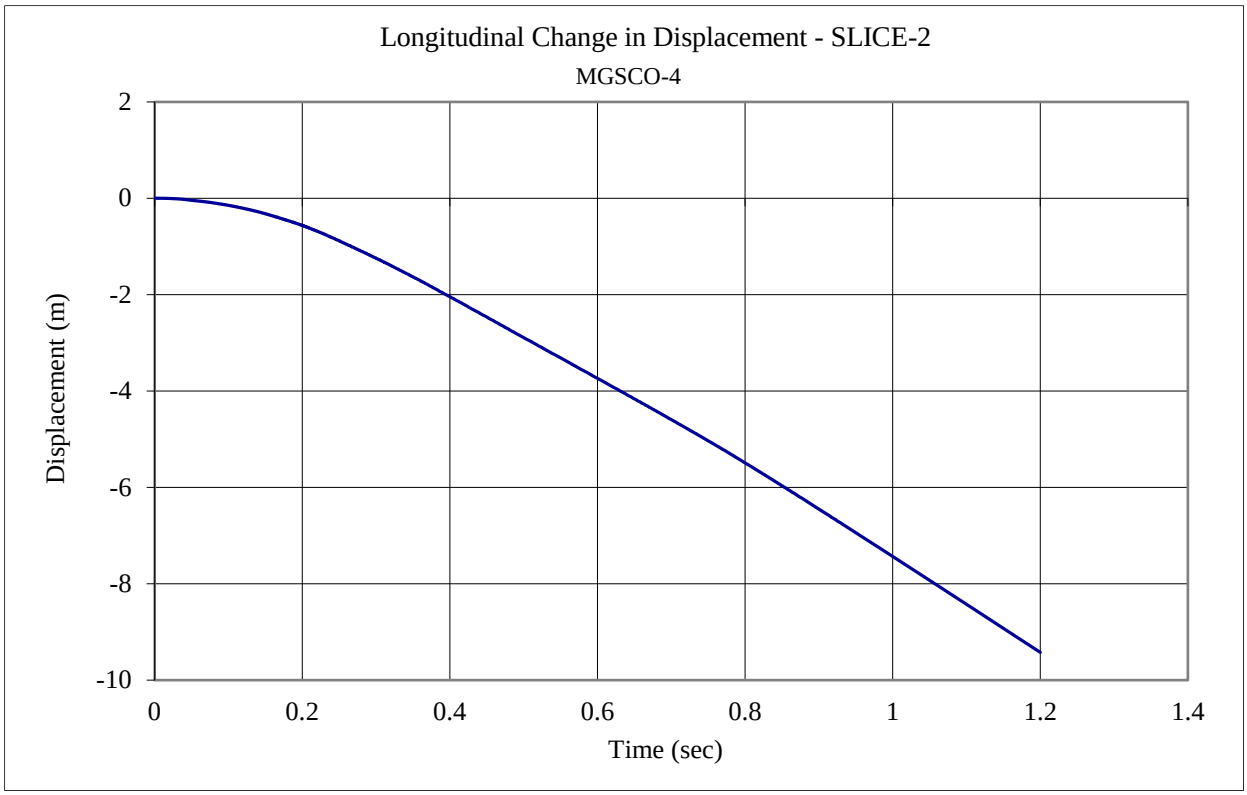


Figure E-3. Longitudinal Occupant Displacement (SLICE-2), Test No. MGSCO-4

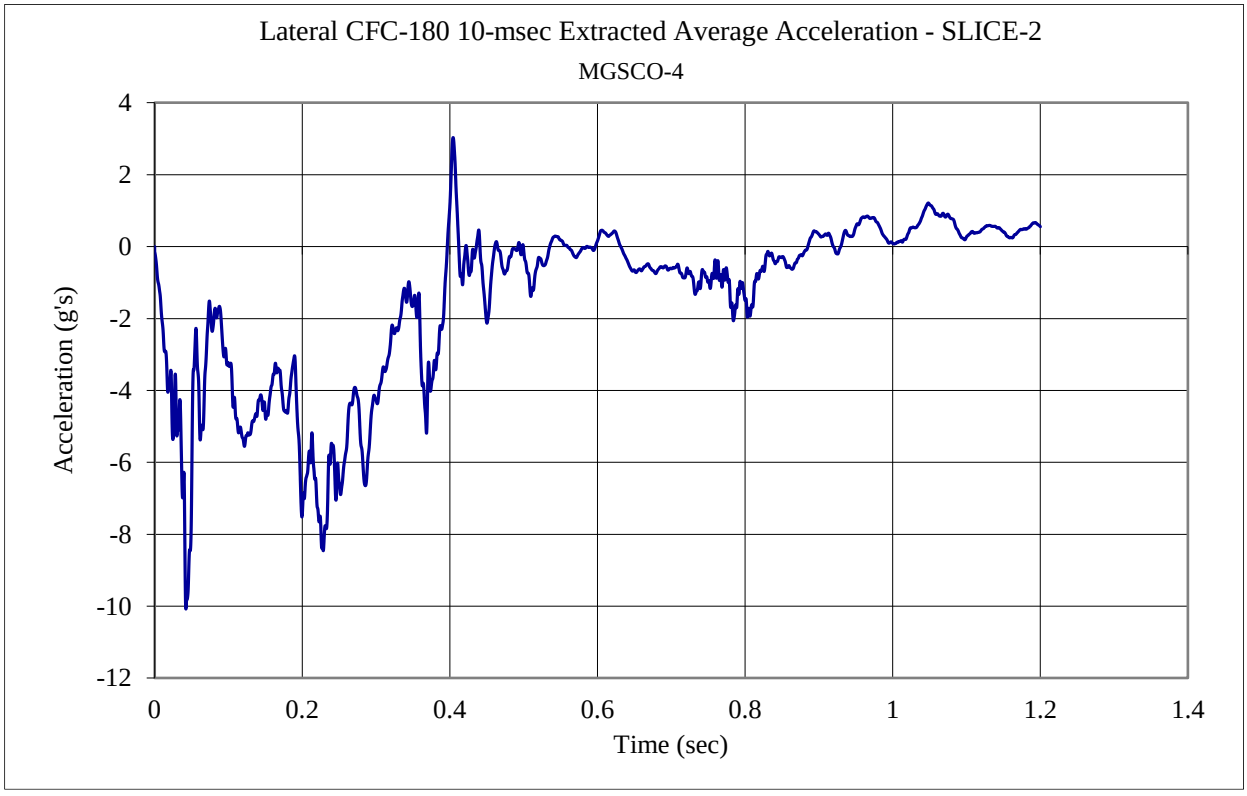


Figure E-4. 10-ms Average Lateral Deceleration (SLICE-2), Test No. MGSCO-4

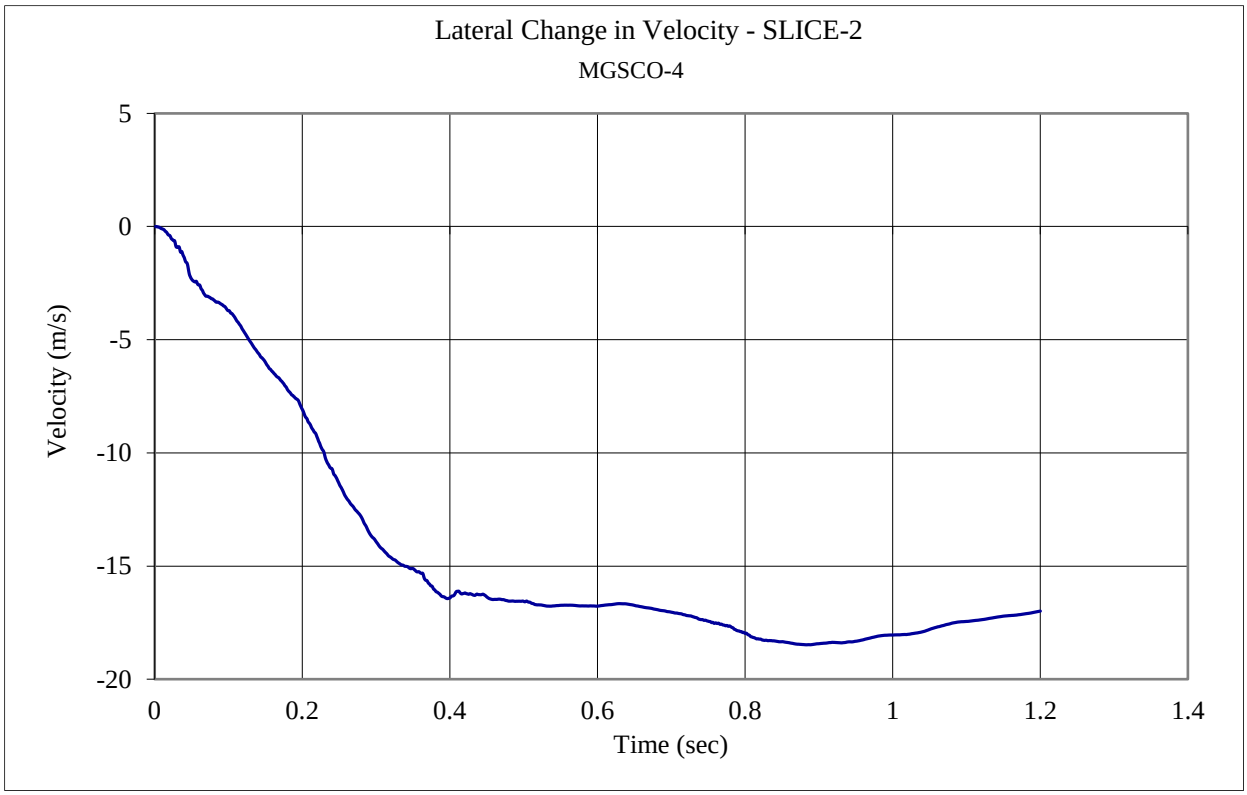


Figure E-5. Lateral Occupant Impact Velocity (SLICE-2), Test No. MGSCO-4

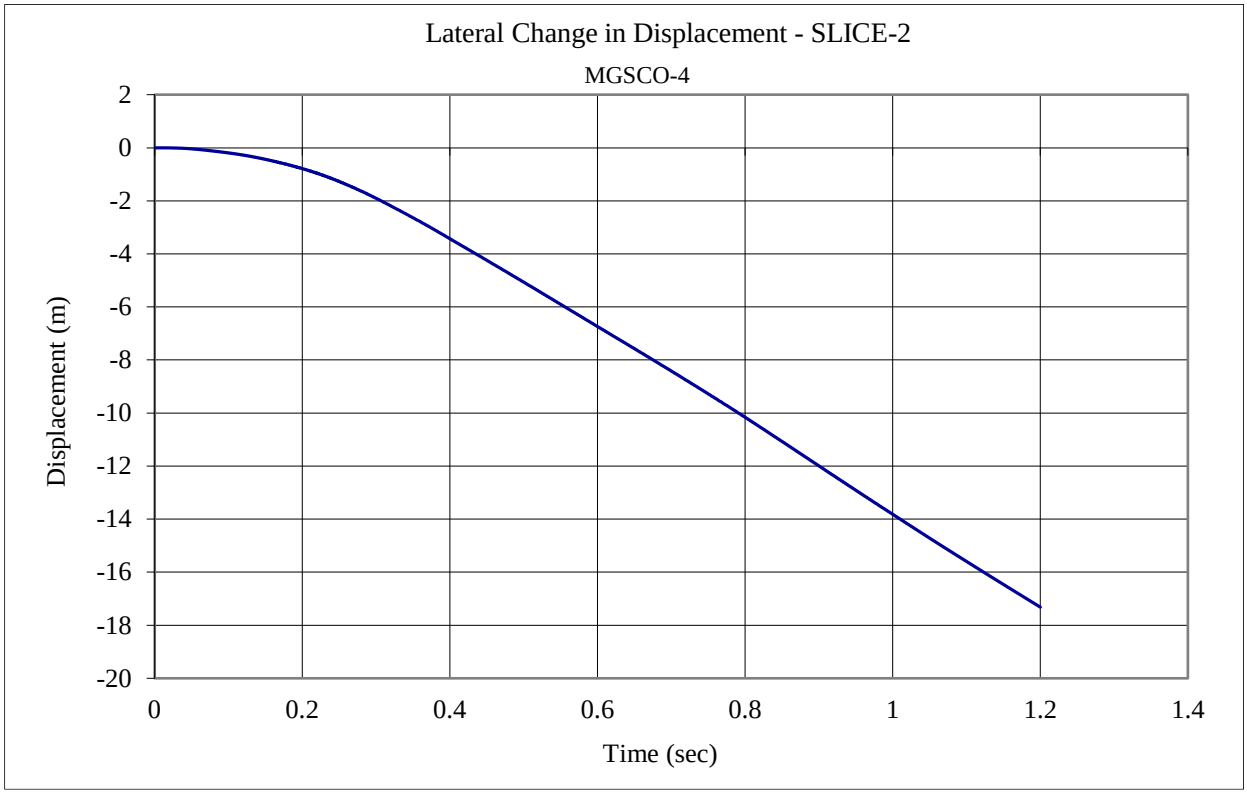


Figure E-6. Lateral Occupant Displacement (SLICE-2), Test No. MGSCO-4

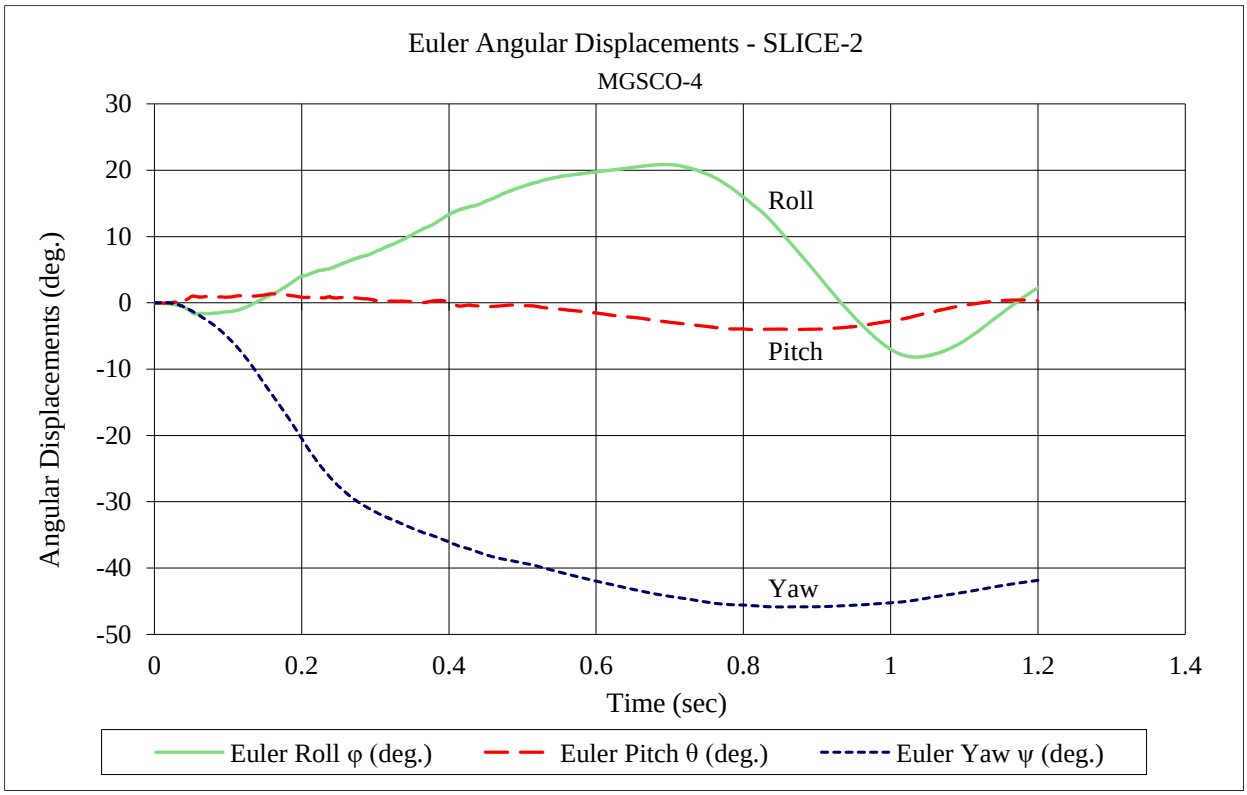


Figure E-7. Vehicle Angular Displacements (SLICE-2), Test No. MGSCO-4

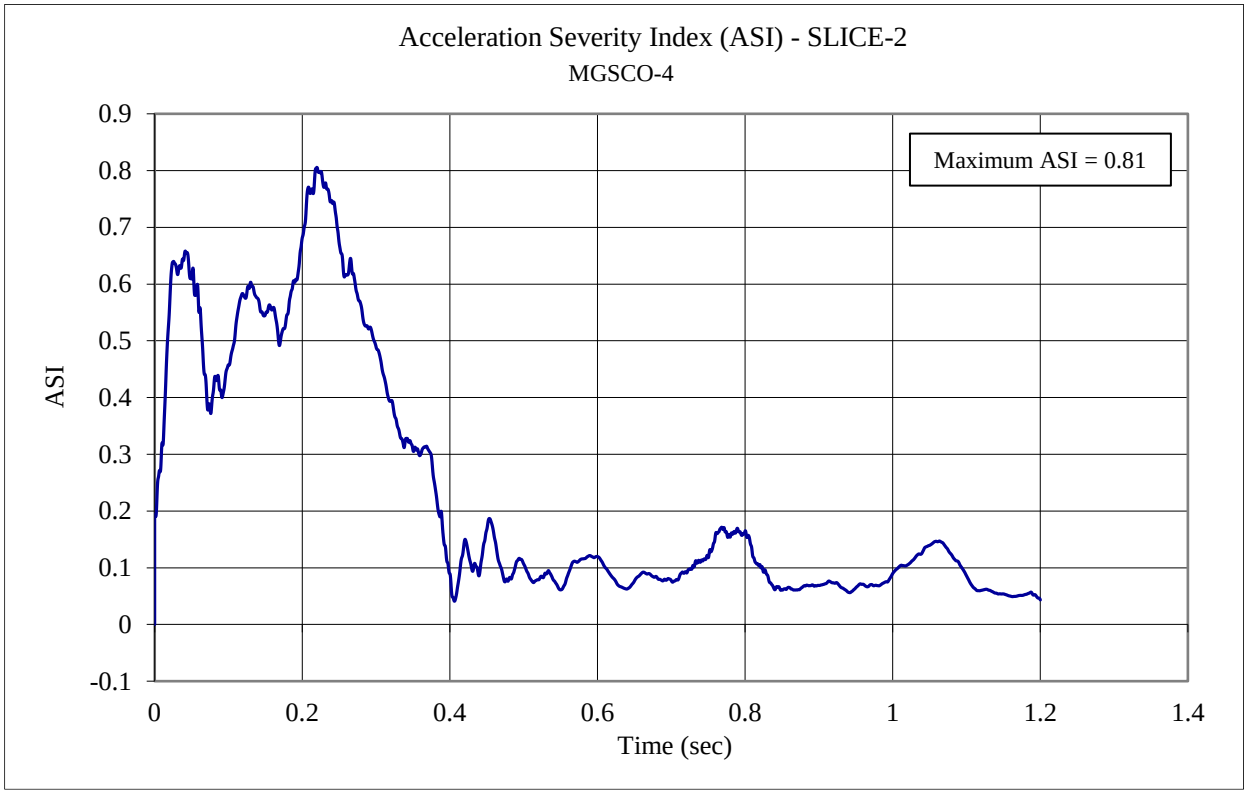


Figure E-8. Acceleration Severity Index (SLICE-2), Test No. MGSCO-4

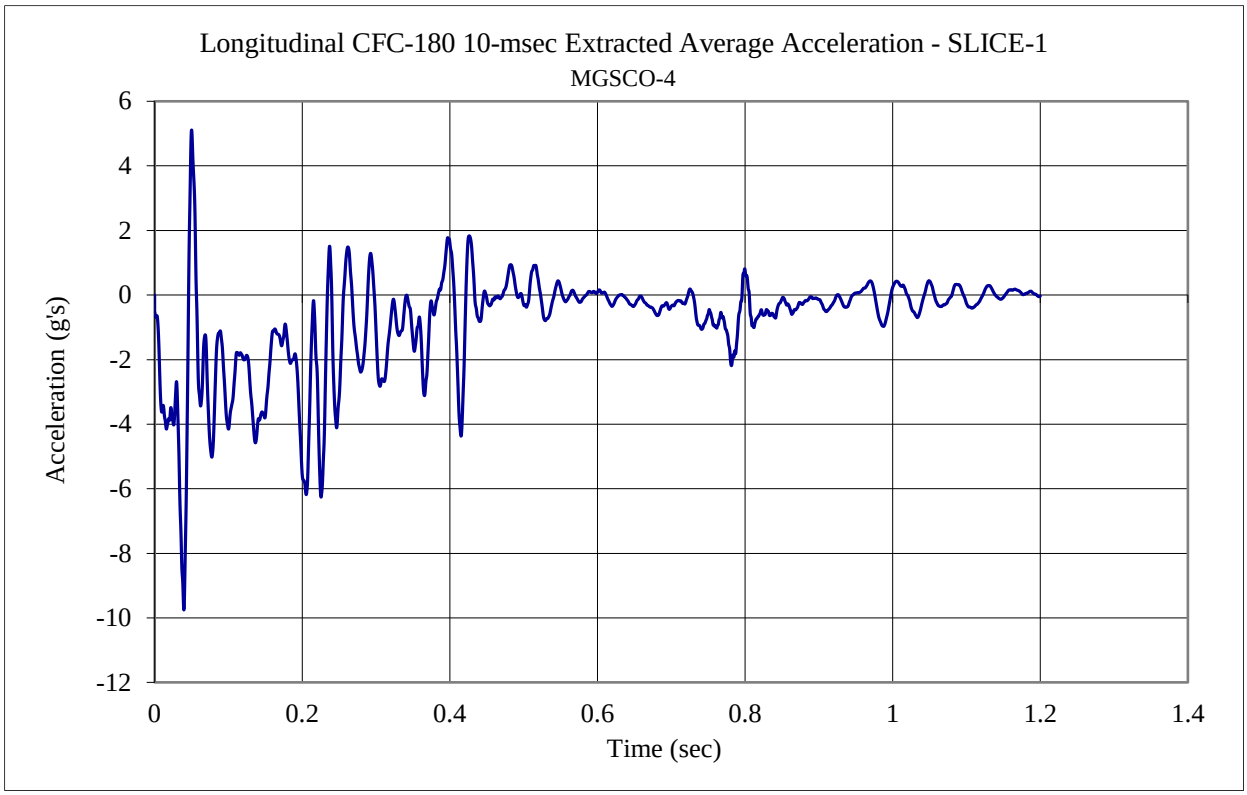


Figure E-9. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. MGSCO-4

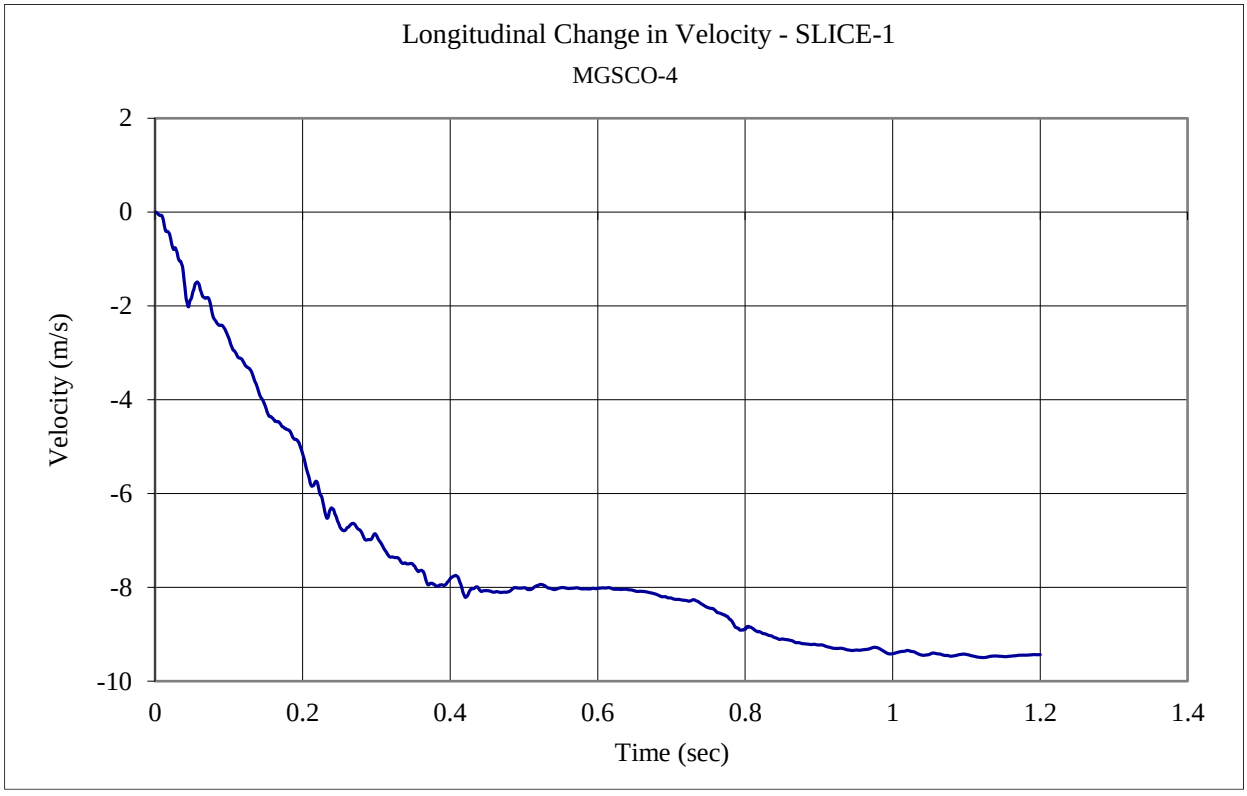


Figure E-10. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. MGSCO-4

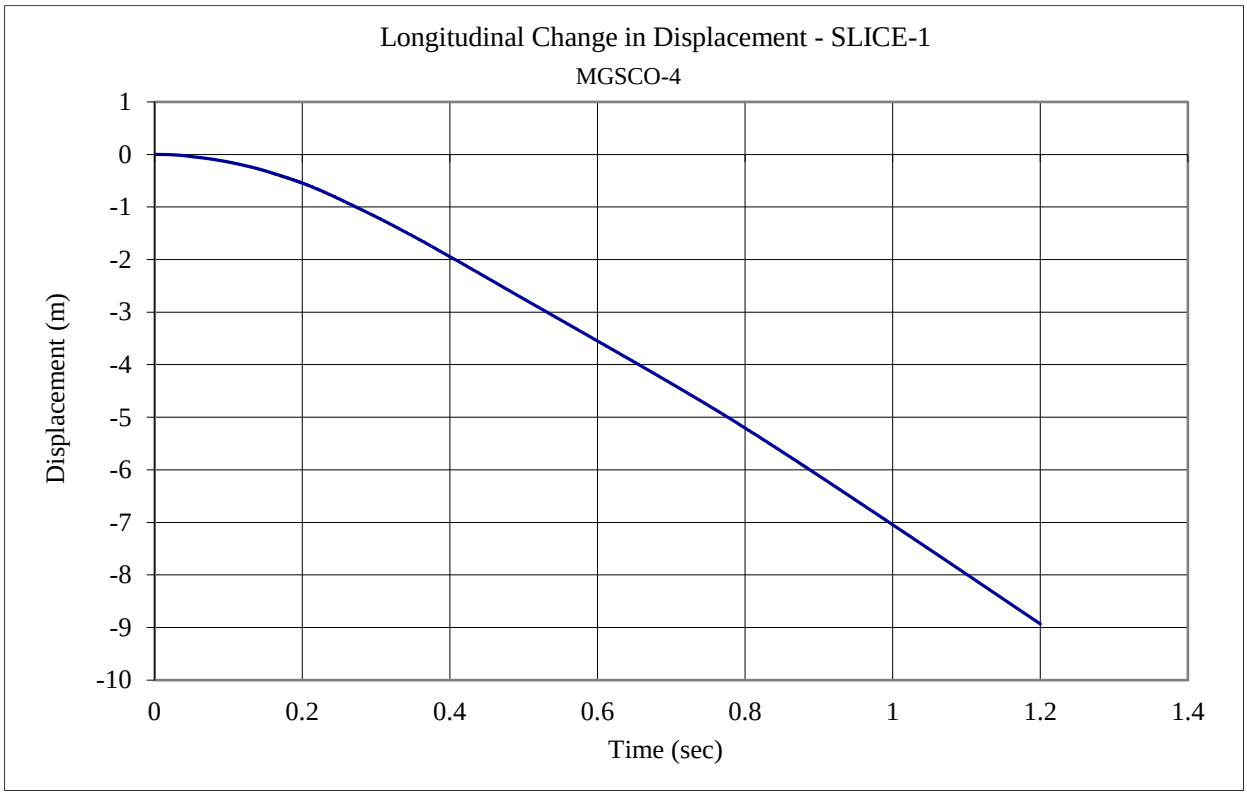


Figure E-11. Longitudinal Occupant Displacement (SLICE-1), Test No. MGSCO-4

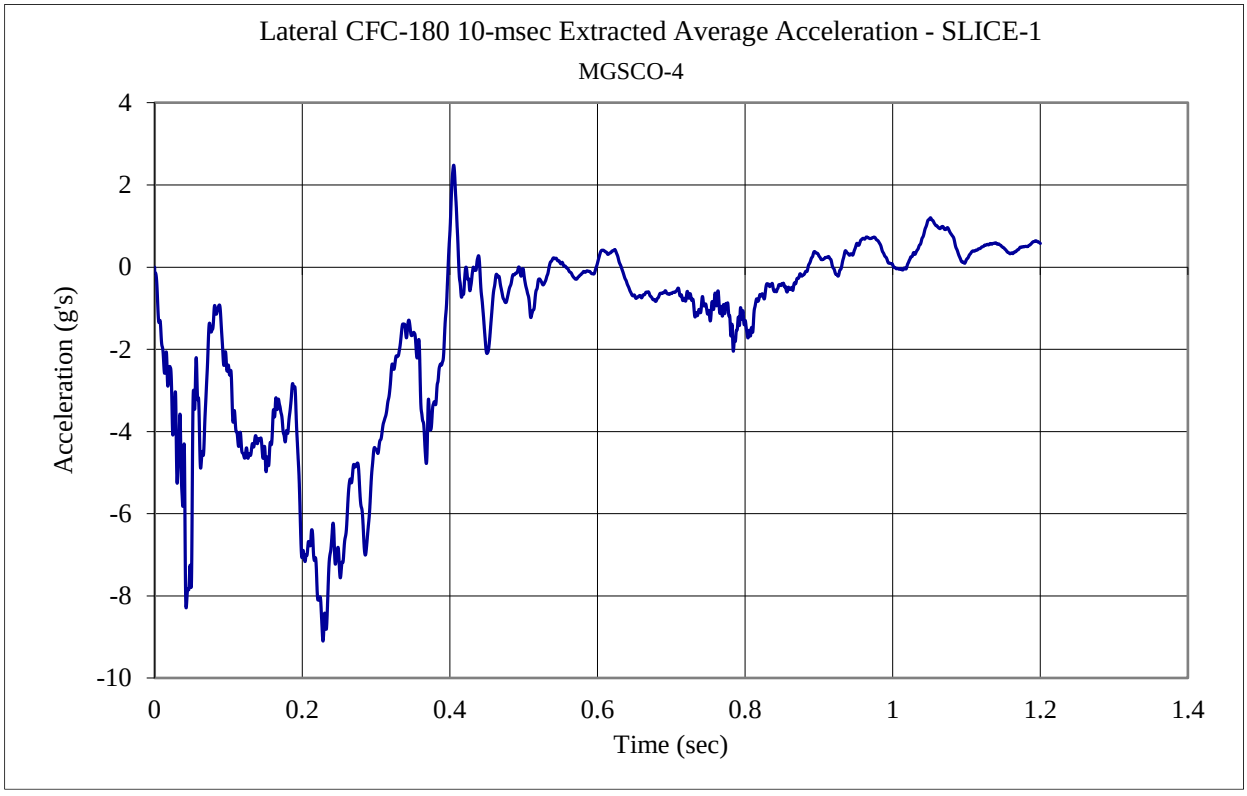


Figure E-12. 10-ms Average Lateral Deceleration (SLICE-1), Test No. MGSCO-4

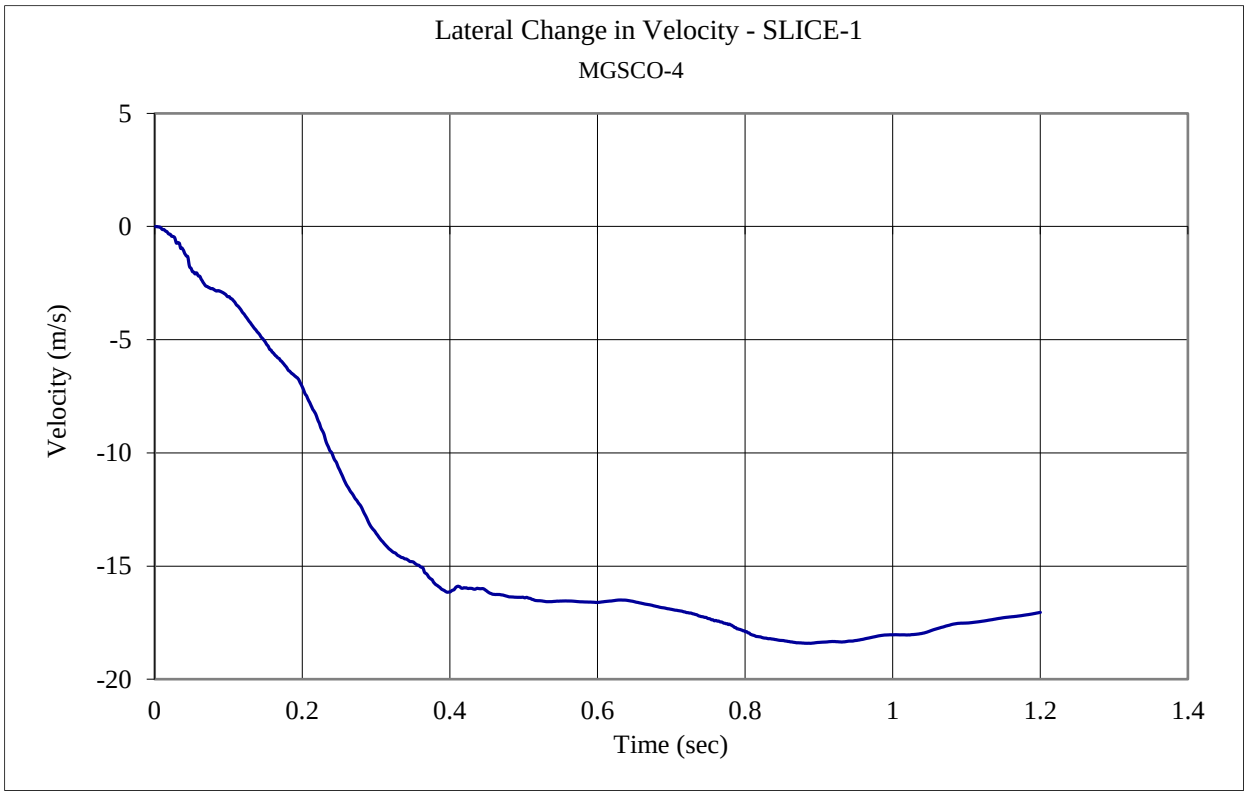


Figure E-13. Lateral Occupant Impact Velocity (SLICE-1), Test No. MGSCO-4

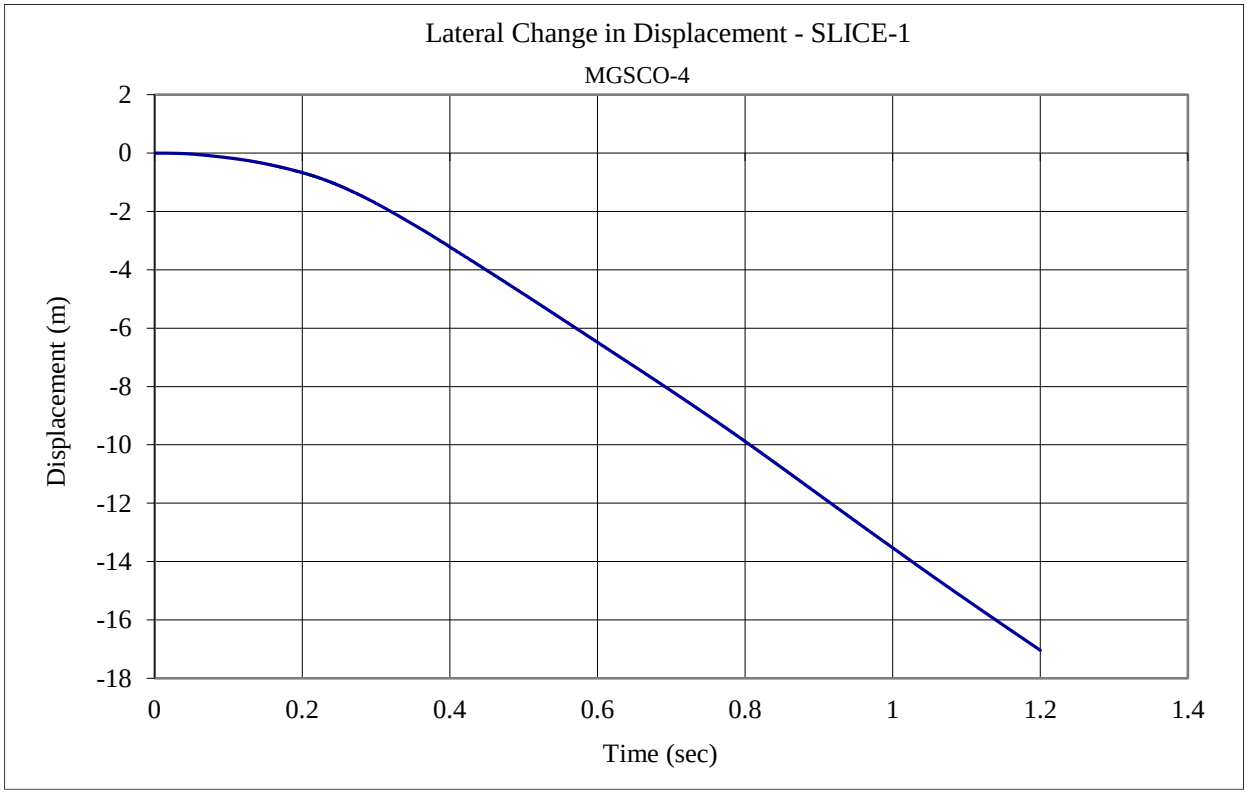


Figure E-14. Lateral Occupant Displacement (SLICE-1), Test No. MGSCO-4

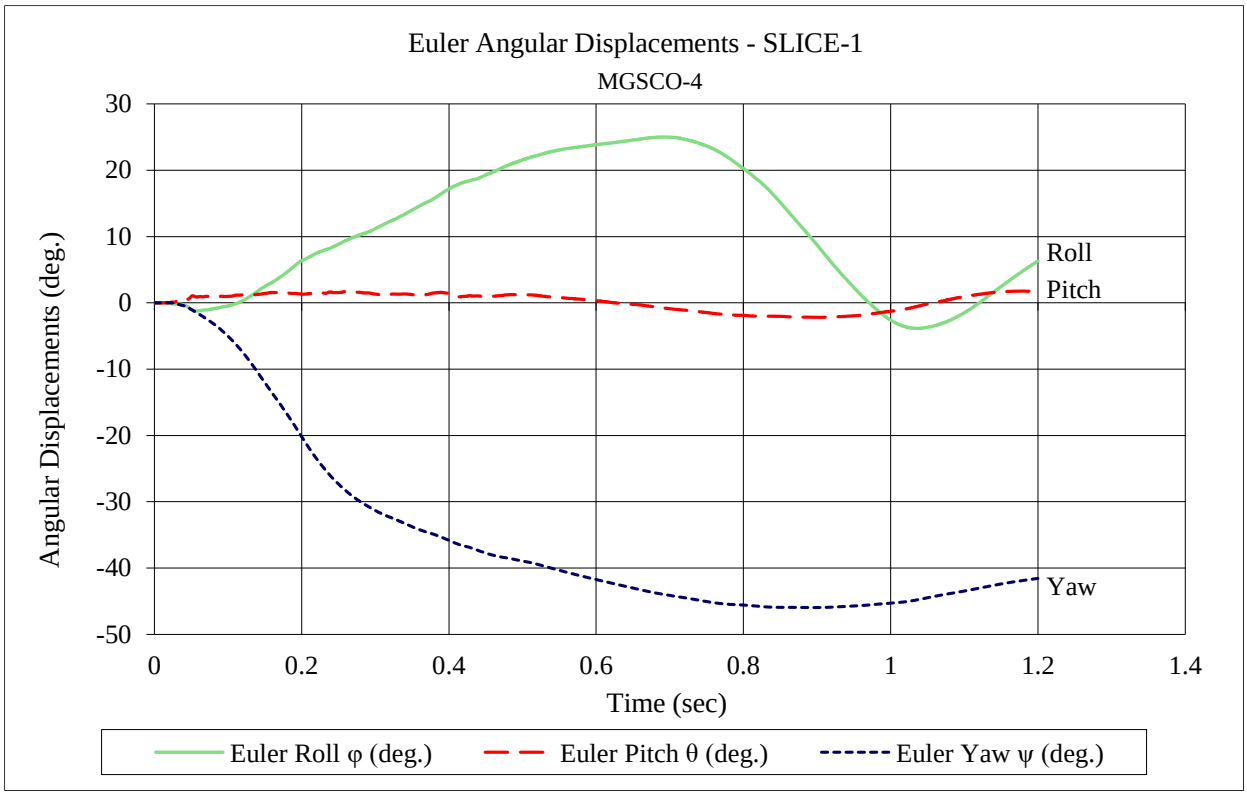


Figure E-15. Vehicle Angular Displacements (SLICE-1), Test No. MGSCO-4

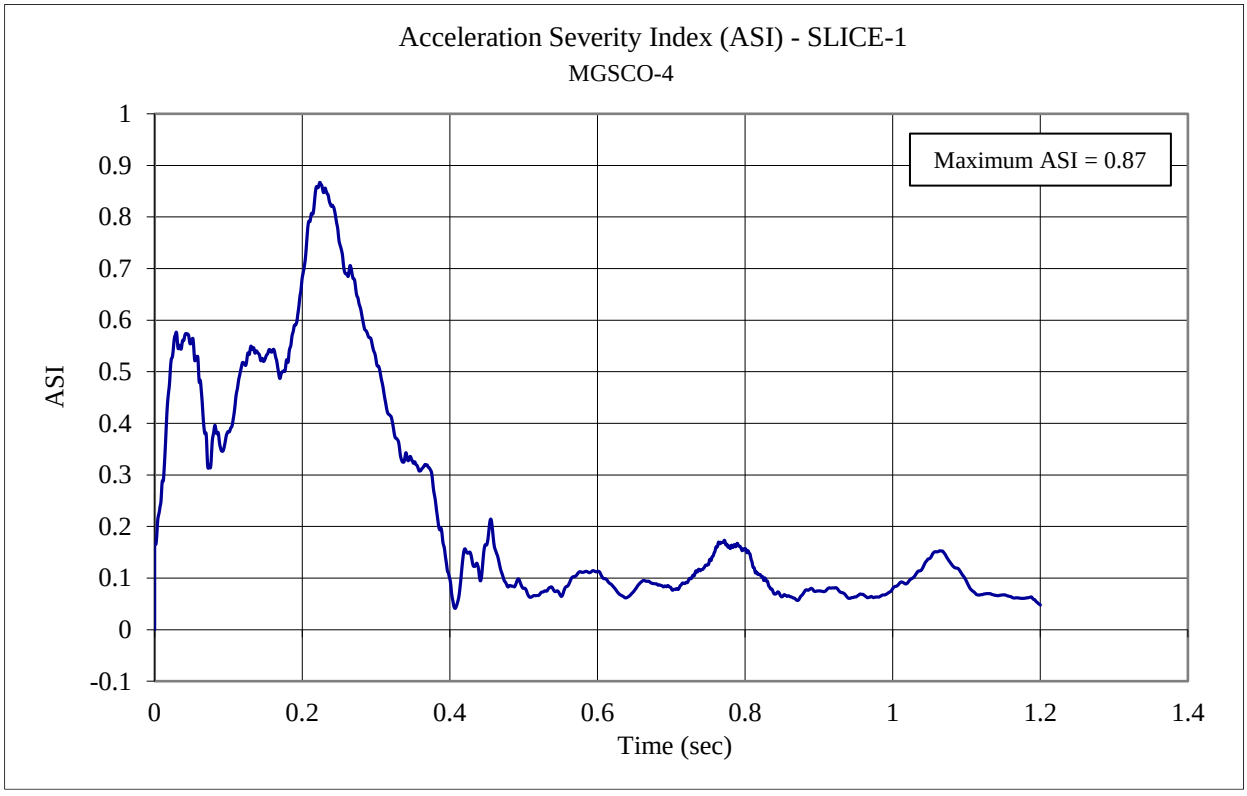


Figure E-16. Acceleration Severity Index (SLICE-1), Test No. MGSCO-4

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