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EVALUATION OF FLARED APPROACH GUARDRAIL TRANSITIONS: TEST NO. FLAGT-1

Submitted by

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

Ryan F. Bickhaus, B.S.
Former Graduate Research Assistant

Ronald K. Faller, Ph.D., P.E.
Research Professor & MwRSF Director

Jennifer D. Rasmussen, Ph.D., P.E.
Former Research Associate Professor

Robert W. Bielenberg, M.S.M.E.
Research Engineer

John D. Reid, Ph.D.
Former Professor

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

MIDWEST POOLED FUND PROGRAM
Nebraska Department of Transportation
1500 Nebraska Highway 2
Lincoln, Nebraska 68502

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Prem S. Paul Research Center at Whittier School
Room 130, 2200 Vine Street
Lincoln, Nebraska 68583-0853</td><td colspan="2">Outdoor Test Site:
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Approach guardrail transitions (AGTs) are used to safely connect guardrail to rigid parapets, such as bridge rails. Ideally, AGTs are installed tangent to the roadway and the bridge rail. However, there was a desire to install AGTs flared away from the roadway to satisfy geometry constraints or to shorten system lengths. Phase I of this study used LS-DYNA simulation to explore the performance of AGTs flared away from the roadway. Ultimately, a 15:1 flare rate was identified as the critical maximum flare rate for AGTs that would remain crashworthy.
Phase II of this project consisted of full-scale crash testing in accordance with Test Level 3 (TL-3) criteria of the American Association of State and Highway and Transportation Officials' (AASHTO) Manual for Assessing Safety Hardware (MASH). In test no. FLAGT-1, the 2270P vehicle impacted the system at an angle 25.4 degrees relative to the roadway and a speed of 63.3 mph. The 2270P pickup truck was contained and redirected by the flared AGT. However, the vehicle snagged on the system at the upstream edge of the concrete buttress, which resulted in excessive occupant compartment deformations to the toe pan and wheel well, as well as an excessive longitudinal acceleration of -24.2 g's. Thus, test no. FLAGT-1 failed to satisfy the safety performance criteria of MASH test designation no. 3-11.</td></tr>
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DISCLAIMER STATEMENT

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(430) Supplement #3. 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.

A2LA ACCREDITATION

The test reported herein is within the scope of MwRSF's A2LA Accreditation. MwRSF's accreditation documentation can be found in Appendix A.

INDEPENDENT APPROVING AUTHORITY

The Independent Approving Authority for the data contained herein was Dr. Andrew Loken, Research Assistant Professor.

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Midwest Roadside Safety Facility
J.C. Holloway, M.S.C.E., Research Engineer & Assistant Director –Physical Testing Division
K.A. Lechtenberg, M.S.M.E., Research Engineer
C.S. Stolle, Ph.D., Research Associate Professor
J.S. Steelman, Ph.D., P.E., Associate Professor
M. Asadollahi Pajouh, Ph.D., P.E., Research Assistant Professor
B.J. Perry, M.E.M.E., Research Engineer
A.E. Loken, Ph.D., Research Assistant Professor
T.Y. Yosef, Ph.D., Research Assistant Professor
A.T. Russell, B.S.B.A., Testing and Maintenance Technician II
E.W. Krier, B.S., Former Engineering Testing Technician II
D.S. Charroin, Engineering Testing Technician II
R.M. Novak, Engineering Testing Technician II
T.C. Donahoo, Engineering Testing Technician I
J.T. Jones, Engineering Testing Technician II
E.L. Urbank, Research Communication Specialist
Z.Z. Jabr, Engineering Technician
J.J. Oliver, Solidworks Drafting Coordinator
Undergraduate and Graduate Research Assistants

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

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
Daniel Harness, P.E., Transportation Engineer Specialist
Stuart Nielsen, P.E., Methods Engineer
Mike Thiel, P.E., Transportation Engineer Specialist

Kansas Department of Transportation
Ron Seitz, P.E., Director of Design
Scott King, P.E., Road Design Bureau Chief

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

Nebraska Department of Transportation, Cont.
Mark Fischer, P.E., PMP, Research Program 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

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.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Background

Approach guardrail transitions (AGTs) are commonly used to safeguard rigid hazards, including bridge railings and concrete parapets. A typical AGT is shown in Figure 1 [1]. AGT installations provide a gradual transition in lateral stiffness between semi-rigid guardrail and rigid bridge rail in order to prevent vehicle snag and pocketing within the barrier. Often, intersecting roadways or other roadside obstacles create space constraints that limit the ability to install an AGT within the desired area. Thus, a need exists to minimize the length of AGTs tangent to the roadway.

Figure 1. AGT Installation [1]

Installing an AGT with a flare away from the roadway would reduce the system length along the primary roadway, as the guardrail would intercept the vehicle runout path closer to the hazard, when compared to a tangent installation. Additionally, the flared AGT configuration would result in a greater lateral offset between the guardrail and the traveled roadway. Thus, the flared AGT configuration would move the hazard posed by impacts with the guardrail farther away from the traveled road and increase the area for the drivers to regain control of the vehicle. As a result, flared AGT installations would reduce both accident frequency and the overall installation maintenance and material costs.

Previously, guidance for flaring the Midwest Guardrail System (MGS) away from the roadway [2] was established in accordance with NCHRP Report 350 Test Level 3 (TL-3) criteria [3]. Due to the need to reduce the length of the guardrail adjacent to the rigid parapet, initiating the flare in the transition region rather than the upstream MGS is more desirable as it would provide a greater reduction in barrier length along the primary road than flaring the W-beam section of guardrail at the upstream end of the transition. Unfortunately, minimal research and full-scale crash testing have been conducted on flared AGTs.

Several concerns have arisen about flaring AGTs resulting from previous flare rate studies. Flaring a guardrail system away from the roadway increases the vehicle impact angle with the barrier installation, which increases the chance for pocketing and vehicle snag. The increased impact angle also results in larger loads imparted to the barrier system, which could lead to component failure or rail rupture. Thus, a need exists to evaluate and establish guidance for flaring AGT installations under the American Association of State and Highway and Transportation Officials' (AASHTO) *Manual for Assessing Safety Hardware* (MASH) safety performance criteria [4].

Phase I of this research effort was conducted to identify the critical flare rate for a thrie-beam AGT, which would provide the greatest reduction in length of need (LON) while ensuring the system remained crashworthy to MASH Test Level 3 (TL-3) [5-6]. Phase I efforts included a literature review of existing AGTs and flared guardrail installations, validation of a tangent AGT LS-DYNA model, and determination of the critical flare rate for an AGT installation using the validated LS-DYNA model. Computer simulations identified a 15:1 flare rate (3.81 degrees from the roadway) as the maximum critical flare rate for full-scale testing, as steeper flare rates showed increased risks of snag and vehicle instabilities.

Phase I of the study concluded with computer simulations to identify critical impact points (CIPs) for both MASH test designation nos. 3-20 and 3-21 impacting the 15:1 flared AGT [5]. However, no funding was allocated for the full-scale crash testing and evaluation of the flared AGT installation during the Phase I research effort. Thus, a need existed to full-scale crash test and evaluate flared AGTs according to the MASH TL-3 safety performance criteria.

1.2 Objective

The objective of the research study was to identify the critical flare rate for flaring AGTs away from the primary roadway. Research focused on determining the maximum allowable flare rate that could safely be applied to 31-in. tall thrie-beam AGTs without curbs below the guardrail. Additionally, the standardized buttress was targeted for use at the downstream end of the AGT because it included chamfers intended to mitigate tire snag.

The objective of Phase II of the research project was to evaluate the safety performance of AGTs flared away from the roadway using full-scale crash testing according to the TL-3 criteria of MASH. Both MASH test designation nos. 3-20 and 3-21 were to be conducted on both the upstream and downstream ends of the AGT. Test no. FLAGT-1, documented herein, was conducted with the 2270P pickup truck impacting the downstream end of the flared AGT to evaluate the potential for vehicle snag on the rigid buttress.

1.3 Scope

The research objective was achieved through the completion of several tasks. First, a sponsor survey was conducted to identify the preferred connection method to facilitate the 15:1 flare away from the roadway. CAD details for the 15:1 flared AGT were developed, and the test installation was constructed. One full-scale crash test was conducted on the 15:1 flared AGT according to MASH test designation no. 3-21. The crash test results were analyzed, evaluated, and documented. Conclusions and recommendations were then made pertaining to the safety performance of the 15:1 flared AGT.

2 FLARED AGT CONNECTION OPTIONS

A special connection design was necessary to attach an AGT with a 15:1 flare rate to a rigid buttress installed tangent to the roadway. Four options for connecting the flared AGT to the rigid buttress were explored:

- Option 1: Flared Concrete Buttress
- Option 2: Tapered Concrete Buttress
- Option 3: Angled Connector Plate Assembly
- Option 4: Radiused Thrie-Beam Guardrail

The four options are discussed in the following sections.

2.1 Option 1: Flared Concrete Buttress

The first option was to modify the geometry of the upstream end of the concrete buttress to match the flare rate of the AGT. As shown in Figure 2, the upstream 3 ft of the buttress was flared back at 3.8 degrees (matching the 15:1 flare rate) through the entire thickness of the standardized buttress. While this option would require alteration of the standardized buttress and a new standard detail, it would achieve the desired flare rate without requiring additional connection hardware and would utilize standard (unbent) thrie-beam guardrail.

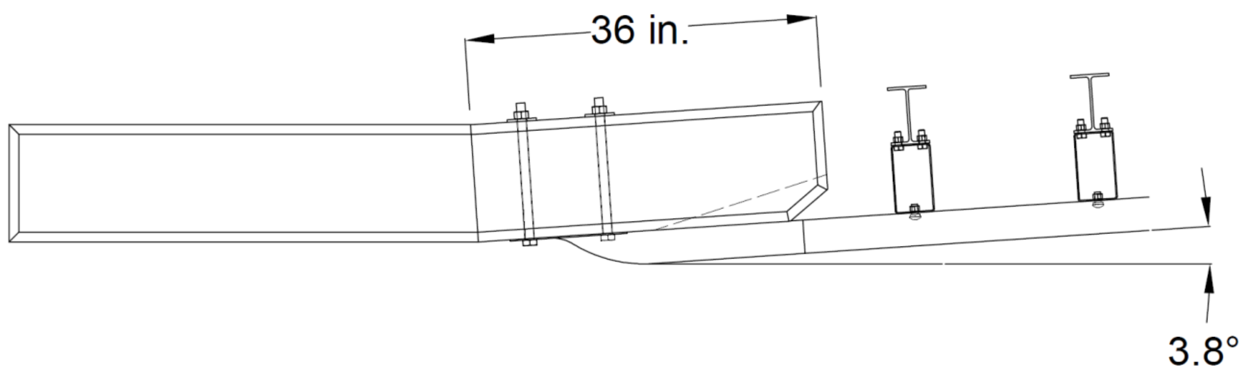


Figure 2. Option 1 – Flared Concrete Buttress

2.2 Option 2: Tapered Concrete Buttress

Option 2 was similar to Option 1, but only the front face of the concrete buttress was tapered at 3.8 degrees to match the 15:1 flare rate. The back side of the buttress would remain tangent to the roadway, as shown in Figure 3. Thus, the upstream end of the standardized buttress would be tapered to facilitate the 15:1 flare. Option 2 would require alteration of the standardized buttress geometry and a new standard detail, but like Option 1, would not require additional components and would utilize standard (unbent) thrie-beam guardrail to achieve the 15:1 flare rate.

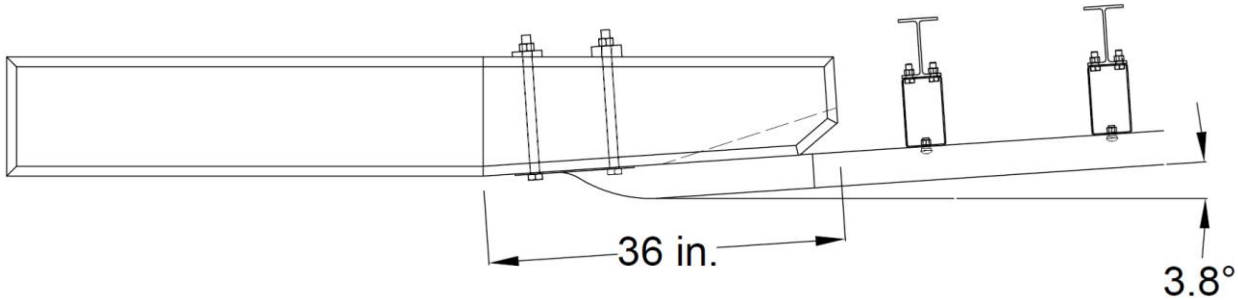


Figure 3. Option 2 – Tapered Concrete Buttress

2.3 Option 3: Angled Connector Plate Assembly

Option 3 included a wedge-shaped connector plate installed between the thrie-beam terminal connector and the standardized concrete buttress, as shown in Figures 4 and 5. Similar connection plates have been used to connect vertical thrie beam to the sloped faces of safety shape and single slope parapets [7-8]. However, this angled connector plate assembly would be used to fill the gap between the angled thrie beam and the vertical buttress face.

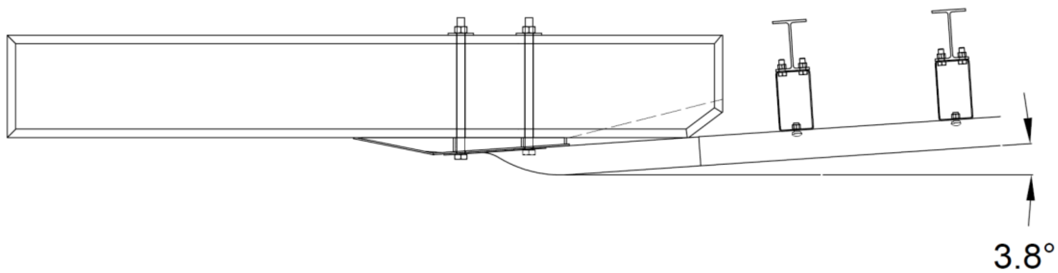


Figure 4. Option 3 – Angled Connector Plate Assembly

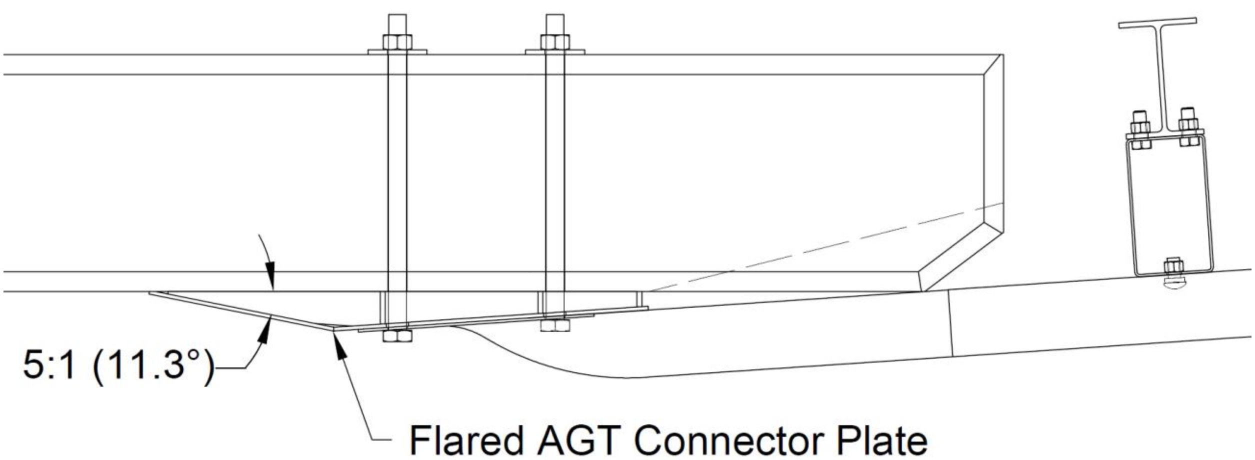


Figure 5. Option 3 – Angled Connector Plate Assembly, Enlarged

Use of an angled connector plate assembly would enable the use of standard AGT components (i.e., the standardized transition buttress and unbent thrie beam segments). However, the connector plate assembly would be an additional required component and the plate would extend 2 in. from the face of the buttress into the traveled way, which could result in a snag hazard in the reverse direction. To mitigate the snag hazard, the downstream end of the connector plate would transition back to the traffic-side face of the standardized concrete buttress with a 5:1 taper. Steel connection plates with a 5:1 taper/slope have demonstrated acceptable safety performance in previous MASH TL-3 crash testing [9].

2.4 Option 4: Radiused Thrie-Beam Guardrail

Option 4 would utilize bent, or radiused, guardrail to achieve the 15:1 flare away from the roadway, as shown in Figures 6 and 7. The bend in the thrie beams would initiate 13½ in. from the downstream end of the thrie-beam segments, which would coincide with the upstream end of the thrie-beam terminal connector. Rather than bending the guardrail at a single point, the radiused guardrail would achieve the 15:1 flare rate over a 16-in. long bend with a 240-in. radius. Only the first post immediately upstream from the standardized buttress would be located within the radiused section. This option would require the fabrication of radiused thrie-beam guardrail sections, but the thrie-beam terminal connector would be mounted flush with the traffic-side face of the buttress and the standardized transition buttress geometry would be unchanged. Fabrication of a radiused thrie beam guardrail has previously been done for other guardrail systems, such as the bullnose crash cushion [10]. However, nesting of bent guardrail sections may prove to be difficult as the bent sections may not perfectly line up to fit together.

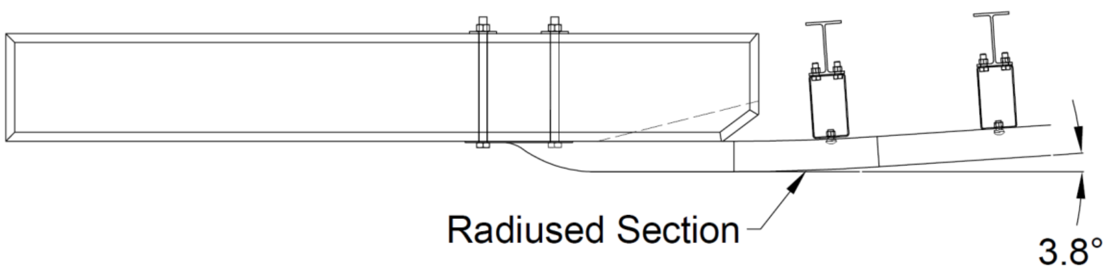


Figure 6. Option 4 – Radiused Thrie-Beam

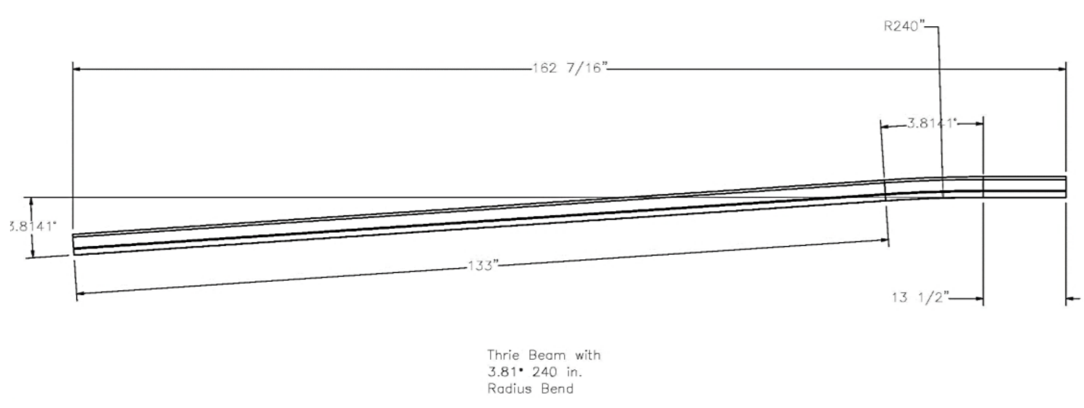


Figure 7. 12.5-ft Long Radiused Thrie-Beam Section

2.5 Discussion

Each of the connection concepts were considered viable options for connecting a flared AGT to a tangent buttress. Further, all four options were expected to perform similarly and provide MASH crashworthy solutions, but the angled connector plate (Option 3) may have a slightly higher risk for snag underneath the thrie-beam guardrail. As shown in Figure 8, the flared AGT connector plate geometry results in a ¼-in. reduction in the offset distance from the front face of the guardrail to the edge of the lower chamfer on the buttress. In each of the other three options (Options 1, 2, and 4) the thrie-beam terminal connector would be bolted flush with the face of the buttress, so the guardrail immediately upstream from the buttress would have the same offset as the tangent AGT installation. Thus, Option 3 was selected as the critical connection design for full-scale crash testing. If the angled connector plate configuration was found to perform acceptably during crash testing, the other three connection options would also be considered crashworthy.

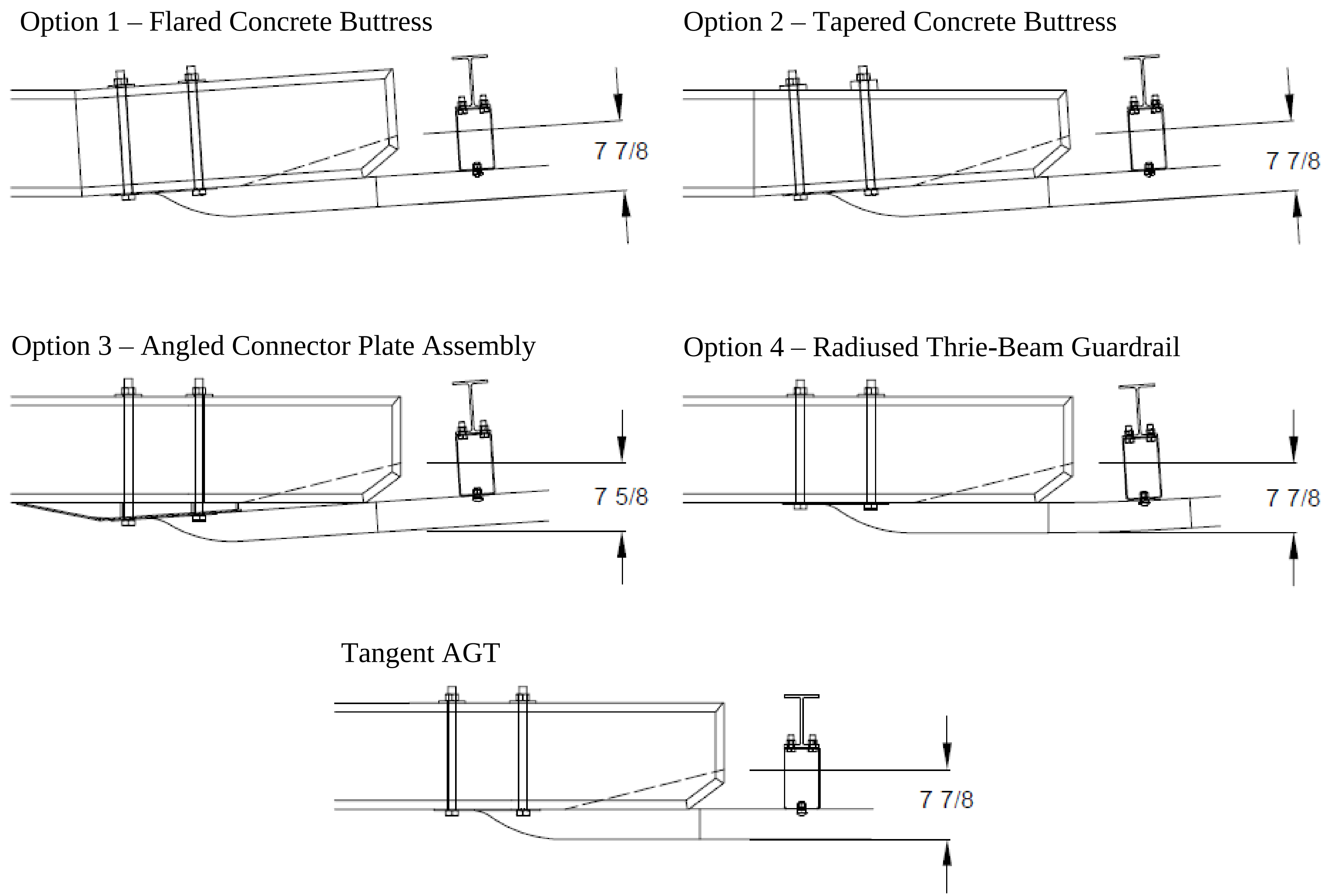


Figure 8. Comparison of Guardrail Offset from Buttress Lower Chamfer

2.6 Vertical Slotted Terminal Connector

Thrie-beam terminal connectors are used at the downstream end of a thrie-beam AGT to connect the thrie-beam guardrail to a rigid bridge rail, buttress, or concrete parapet. Alignment issues often occur at the splice between the terminal connection and the nested thrie beam segments that result in difficulties installing the splice bolts.

In 2017, the Texas A&M Transportation Institute (TTI) evaluated existing thrie-beam terminal connector designs and developed design improvements to improve constructability and reduce or eliminate the need for rail modifications in the field [11]. The research study recommended the use of splice slots oriented in the vertical direction, as this splice slot orientation demonstrated adequate strength during component testing and improved the constructability of the nested connection. Thus, a thrie-beam terminal connector with 1-in. wide by 1¼-in. tall splice slots oriented in the vertical direction was selected for use during the evaluation of the flared AGT and would be recommended for use with any of the four connection options. The vertical slotted terminal connector is shown in Figure 9.

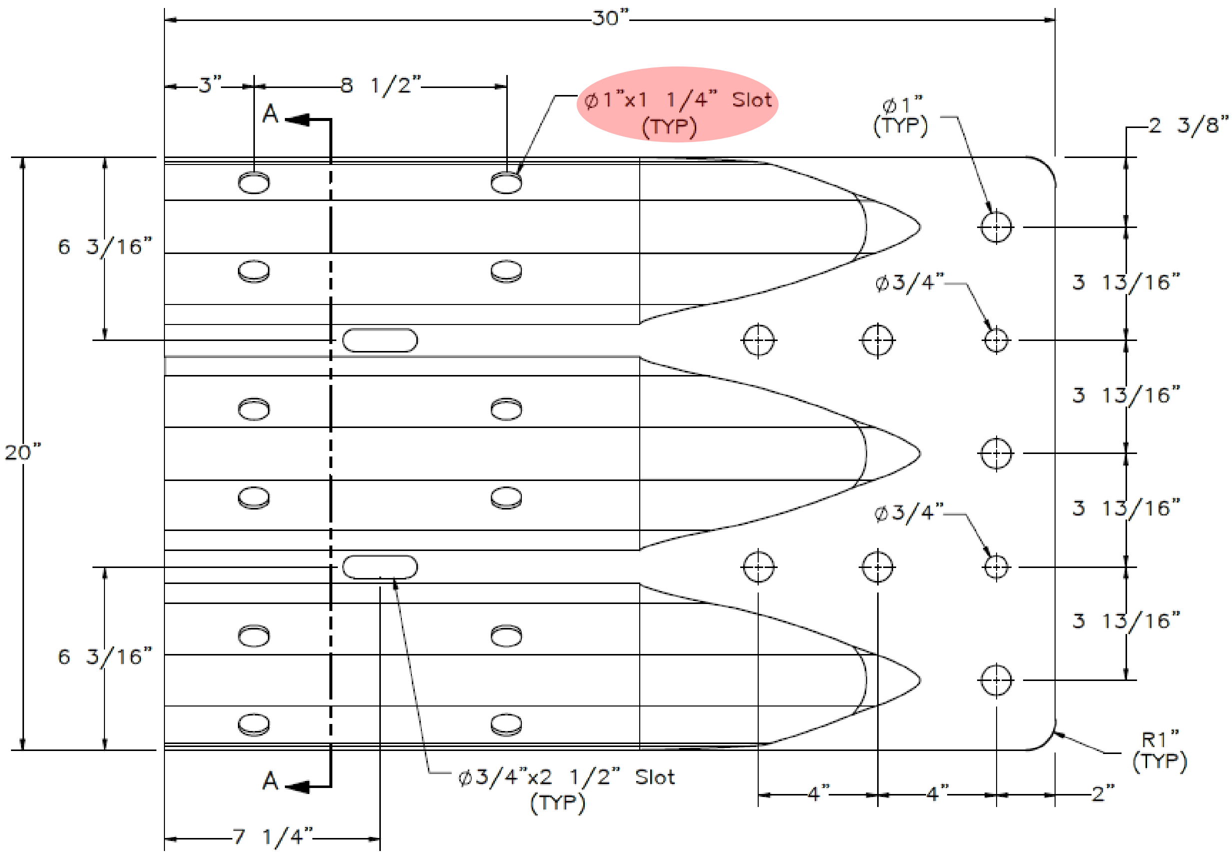


Figure 9. Vertical Slotted Terminal Connector

3 TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 Test Requirements

Longitudinal barriers, such as AGTs, must satisfy impact safety standards in order to be declared eligible for federal reimbursement by the Federal Highway Administration (FHWA) for use on the National Highway System. For new hardware, these safety standards consist of the guidelines and procedures published in the 2016 edition of MASH [4]. Note, for longitudinal barriers, there is no difference between the 2009 edition of MASH [12] and the current 2016 edition except that additional occupant compartment deformation measurements, photographs, and documentation are required. According to TL-3 of MASH, longitudinal barrier systems must be subjected to two full-scale vehicle crash tests, MASH test designation no. 3-20 with the 1100C small car and MASH test designation no. 3-21 with the 2270P pickup truck. However, recent testing has demonstrated that there are two CIPs for an AGT: (1) near the downstream end of the AGT to maximize snagging on the buttress and (2) near the upstream end to maximize snagging and pocketing at the W-to-thrie transition section. Thus, four crash tests were required to evaluate the flared AGT, as summarized in Table 1.

Table 1. MASH TL-3 Crash Test Matrix for AGT

Test Article	Test Designation No.	Test Vehicle	Vehicle Weight lb	Impact Conditions		Evaluation Criteria [1]	Impact Point
				Speed mph	Angle deg.		
Longitudinal Barrier	3-20	1100C	2,420	62	25	A,D,F,H,I	Downstream AGT
	3-21	2270P	5,000	62	25	A,D,F,H,I	Downstream AGT
	3-20	1100C	2,420	62	25	A,D,F,H,I	Upstream AGT
	3-21	2270P	5,000	62	25	A,D,F,H,I	Upstream AGT

[1] Evaluation criteria explained in Table 2.

3.2 Evaluation Criteria

Evaluation criteria for full-scale vehicle crash testing are based on three appraisal areas: (1) structural adequacy; (2) occupant risk; and (3) vehicle trajectory after collision. Criteria for structural adequacy are intended to evaluate the ability of the flared AGT to contain and redirect impacting vehicles. In addition, controlled lateral deflection of the test article is acceptable. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Post-impact vehicle trajectory is a measure of the potential of the vehicle to result in a secondary collision with other vehicles and/or fixed objects, thereby increasing the risk of injury to the occupants of the impacting vehicle and/or other vehicles. These evaluation criteria are summarized in Table 2 and defined in greater detail in MASH [4]. Each 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 [4].

Table 2. MASH Evaluation Criteria for Longitudinal Barrier

<table>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td></tr>
<tr><td rowspan="12">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 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 rowspan="4">I.</td><td colspan="3">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>

3.3 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% of the static baseline test at deflections of 5, 10, and 15 in. Further details can be found in Appendix B of MASH [4].

4 DESIGN DETAILS

The flared AGT test installation was approximately 81 ft – 6 in. long and consisted of five main components: (1) a concrete buttress, (2) a thrie-beam AGT, (3) standard MGS, (4) a guardrail anchorage system, and (5) the flared AGT connector plate. Design details for test no. FLAGT-1 are shown in Figures 10 through 36. Photographs of the test installation are shown in Figures 37 and 38. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

The downstream end of the installation consisted of a concrete parapet with dimensions matching those of the standardized concrete buttress [1]. The buttress was 84 in. long and 36 in. tall. To prevent vehicle snag on the buttress above the thrie-beam rail, the upstream end of the buttress was 32 in. tall and incorporated a 24-in. long slope to bring the barrier height up to 36 in. The upstream end of the standardized buttress utilized a dual tapered design, or dual chamfer, as shown in Figure 18. The lower tire chamfer was 18 in. long by 4½ in. wide by 14 in. tall and was designed to reduce the propensity for wheel snag on the buttress. The upper chamfer measured 4 in. long by 3 in. wide and extended vertically 18 in. along the remaining height of the buttress. The upper chamfer was designed to limit vehicle snag on the buttress, prevent the guardrail from bending around a rigid corner, and to limit the unsupported span length of the rail upstream from the buttress. The buttress was reinforced with Grade 60 rebar, as detailed in Figures 19 through 22, and the vertical steel in the buttress was anchored to the tarmac using an epoxy adhesive, as detailed in Figure 19.

The AGT consisted of a 12½-ft section of nested 12-gauge thrie-beam, a 6¼-ft section of 12-gauge thrie-beam, a 6¼-ft long 10-gauge W-to-thrie transition section, and a 12½-ft section of nested 12-gauge W-beam guardrail. Upstream from the AGT was 37½ ft of 12-gauge W-beam guardrail, which included the MGS and a guardrail anchor. All guardrail sections were mounted with a top guardrail height of 31 in. and were supported by W6x8.5 ASTM A992 steel guardrail posts. Posts. 3 through 15 were 72 in. long and embedded 40 in. into the soil, while the six posts adjacent to the buttress, post nos. 16 through 21, were 78 in. long and embedded at a depth of 49 in. As shown in Figure 11, post nos. 1 through 8 were spaced at 75 in., post nos. 8 through 12 were spaced at 37½ in., and post nos. 12 through 21 were spaced at 18¾ in.

The nested thrie beam AGT utilized herein was previously shown to be MASH TL-3 crashworthy via full-scale crash testing [1, 13]. The AGT configuration was selected for use in this flared AGT study because it was a common AGT configuration that had a lower lateral stiffness than other crashworthy AGTs (i.e., it allowed higher system displacements than other MASH TL-3 AGTs). Thus, this AGT configuration represented a critical configuration to evaluate vehicle snag on the buttress.

The upstream stiffness transition, or the W-beam to nested thrie beam transition, was also previously full-scale crash tested to MASH TL-3 [14]. Nested W-beam was placed adjacent to the W-to-thrie transition segment to strengthen the AGT and prevent rupture of the W-beam, as was previously done to strength the upstream stiffness transition installed behind a curb [15].

All guardrail segments were installed with a 15:1 flare rate relative to the face of the concrete buttress. An angled connector plate assembly was placed between the thrie-beam terminal connector and the buttress to connect the guardrail at a 15:1 flare rate, as shown in Figure 12 and detailed in Figures 29 through 31. The angled connector plate assembly was constructed with a $^{3}/_{16}$-in. thick steel face plate and ¼-in. thick steel gussets. The plate extended 2 in. laterally from the traffic-side face of the buttress and the downstream end of the plate tapered flush with the face of the buttress via a 5:1 slope to mitigate snag in the reverse direction. As shown in Figure 33, the 10-gauge thrie-beam terminal connector had 1¼-in. tall by 1-in. wide splice slots oriented in the vertical direction to improve constructability of the nested thrie-beam splice connection. Five ⅞-in. diameter ASTM F3125, Grade 120 heavy hex head bolts were used to connect the guardrail and connector assembly to the buttress.

The upstream end of the guardrail installation was configured with a non-proprietary guardrail anchorage system. The anchorage system consisted of timber posts, foundation tubes, anchor cables, bearing plates, rail brackets, and channel struts. The guardrail anchorage system had a strength comparable to other crashworthy end terminals. This anchorage system was successfully crash tested to MASH TL-3 as a downstream, trailing-end, guardrail terminal [16-19].

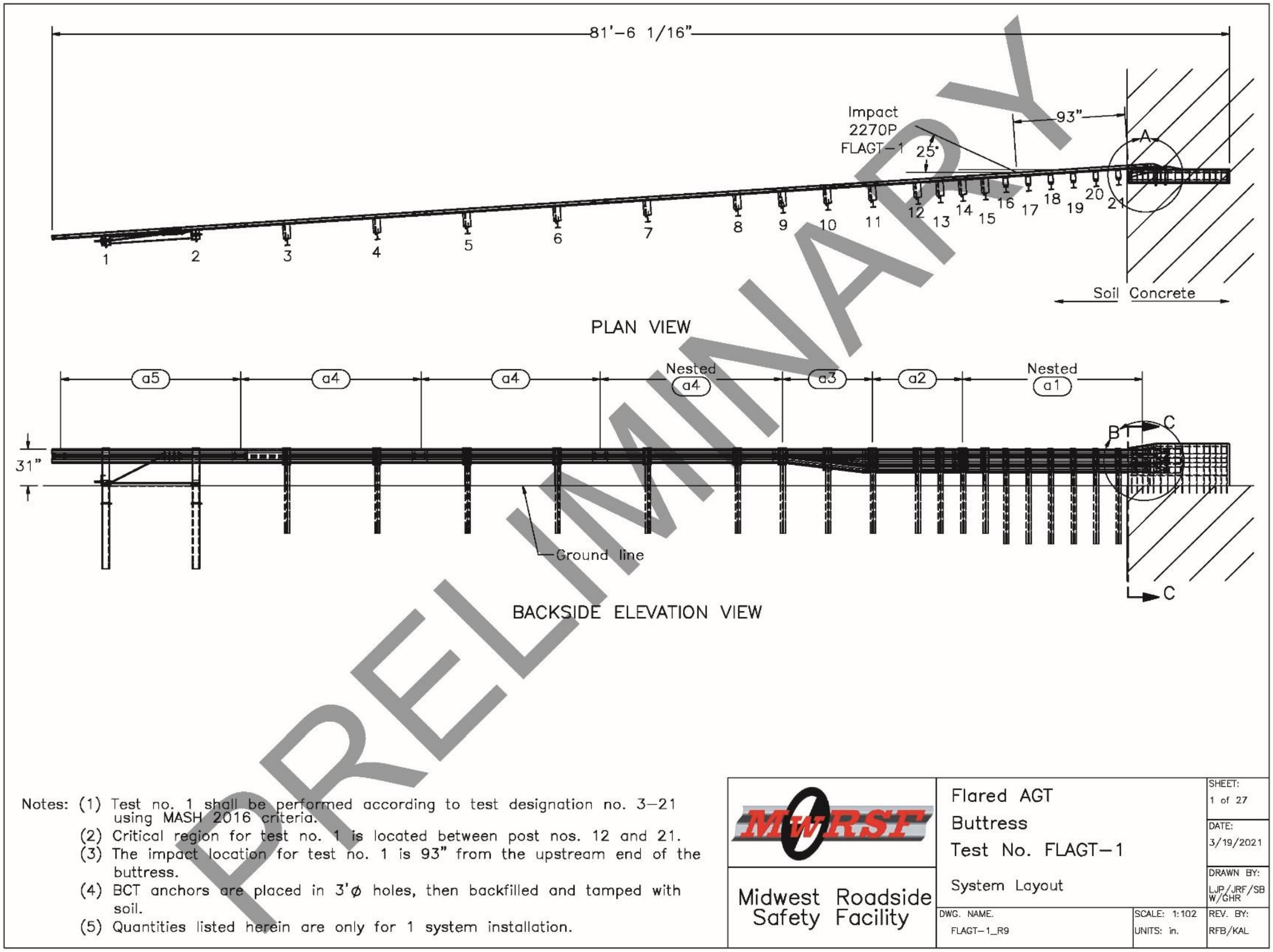


Figure 10. Test Installation Layout, Test No. FLAGT-1

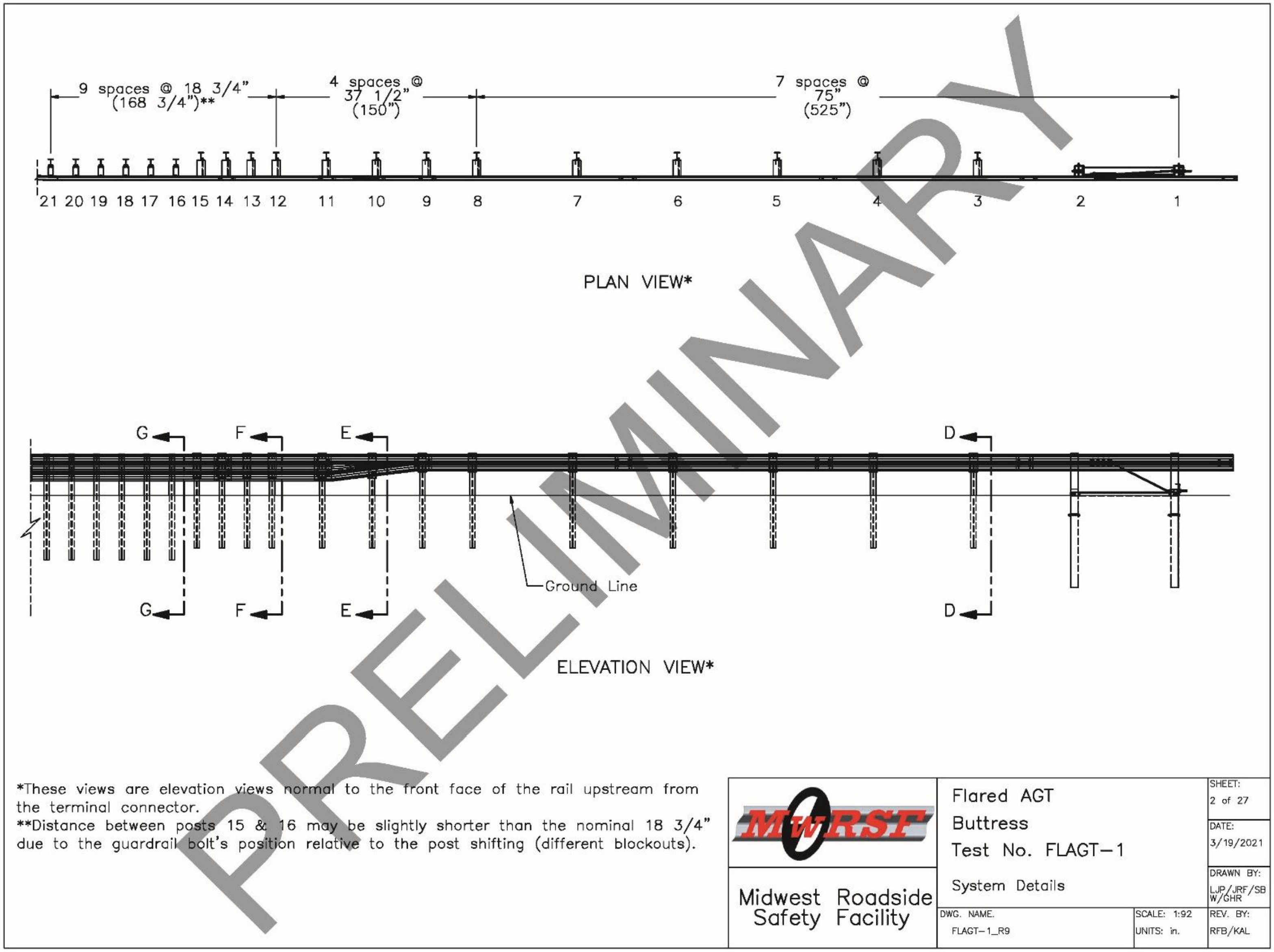


Figure 11. System Details, Test No. FLAGT-1

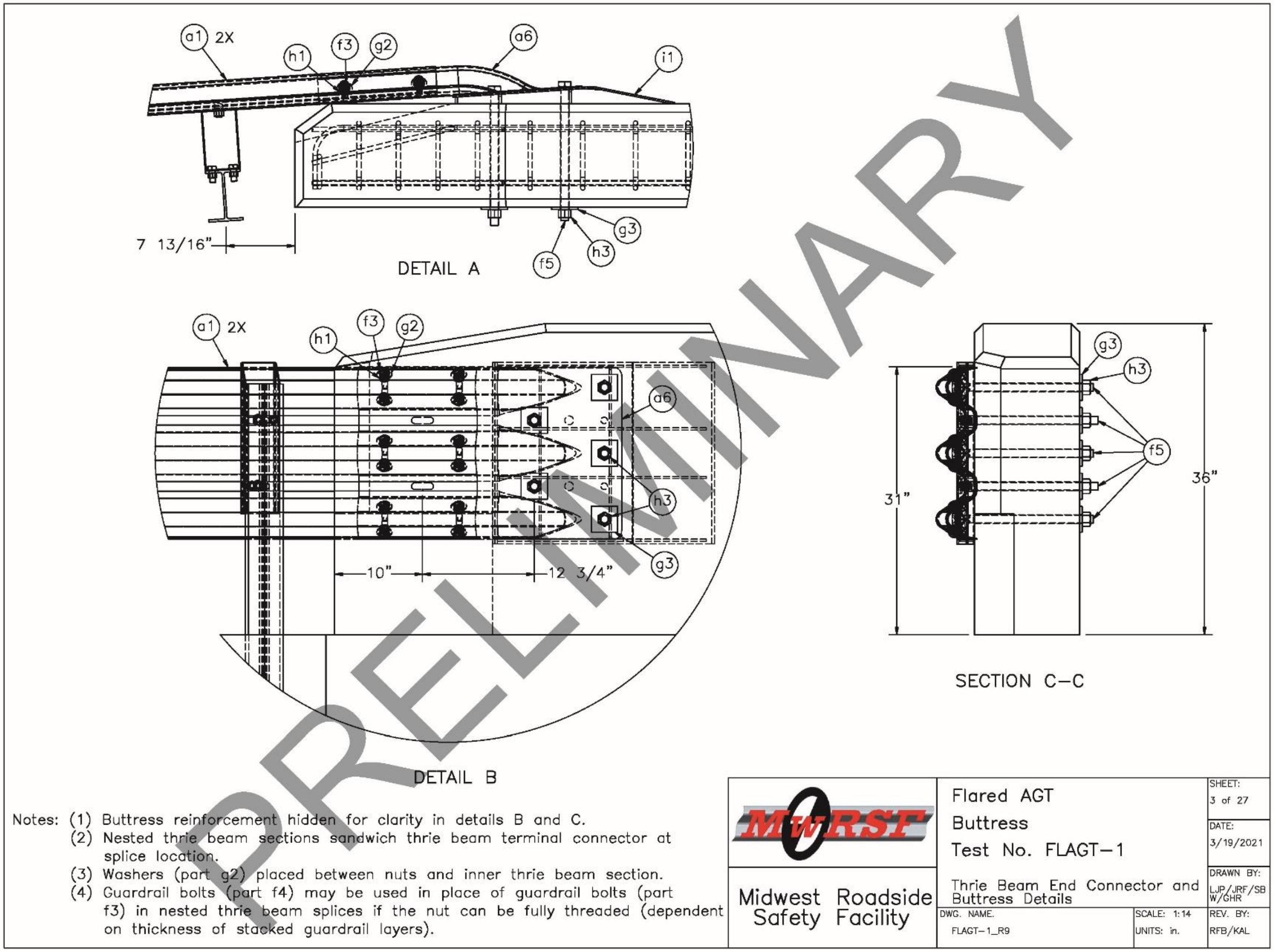


Figure 12. Thrie-beam End Connector and Buttress Details, Test No. FLAGT-1

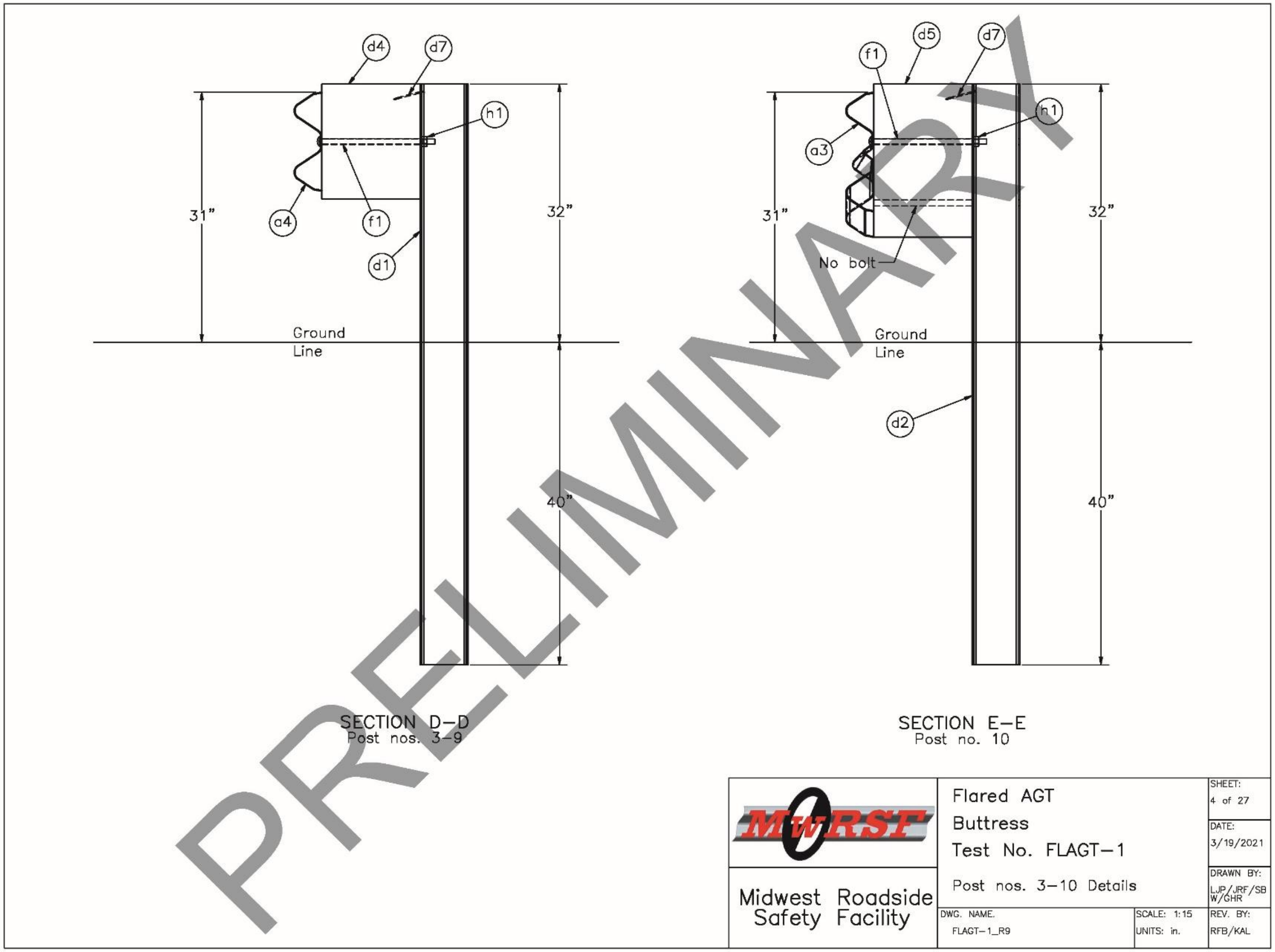


Figure 13. Post Nos. 3-10 Details, Test No. FLAGT-1

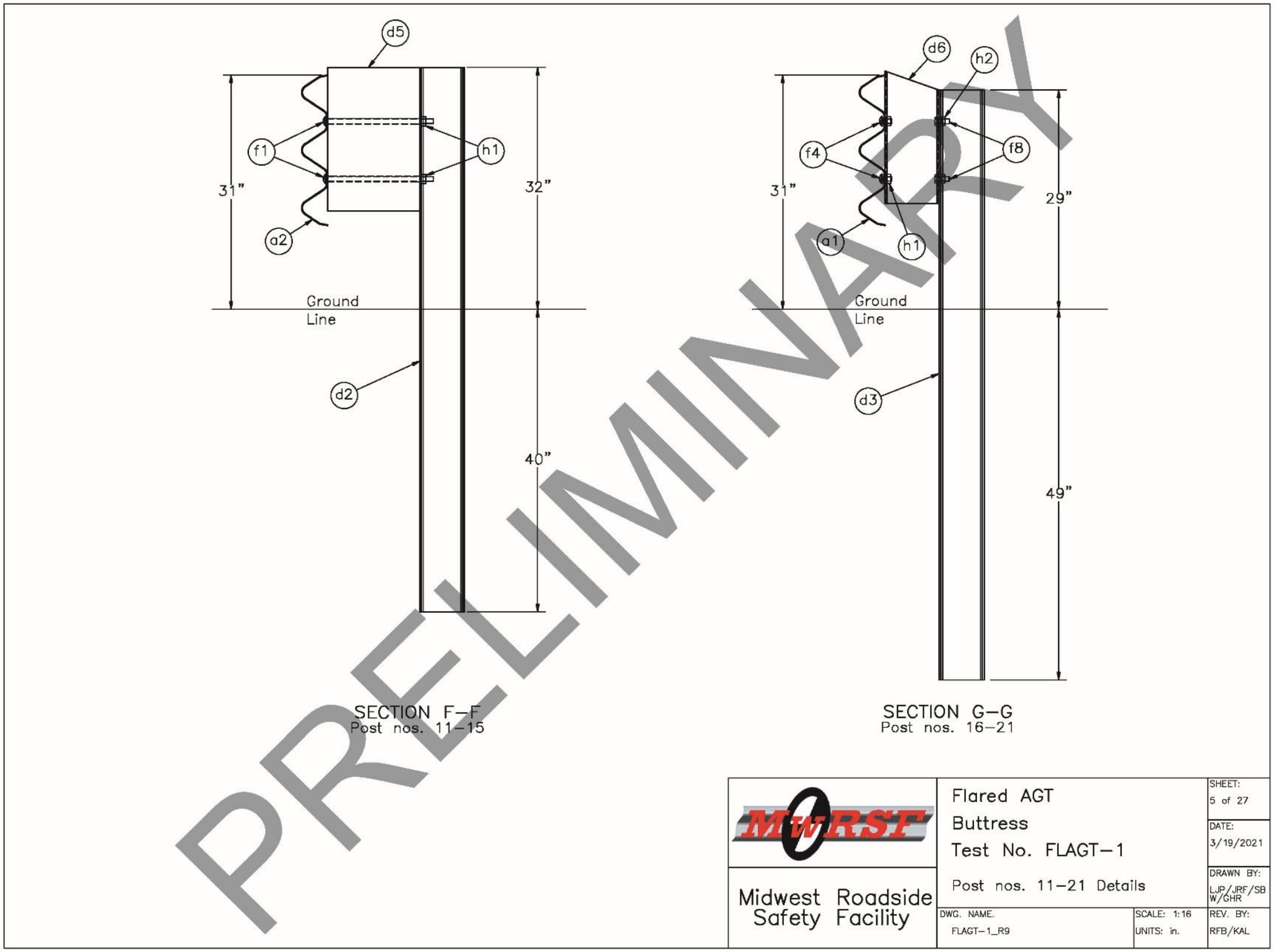


Figure 14. Post Nos. 11-21 Details, Test No. FLAGT-1

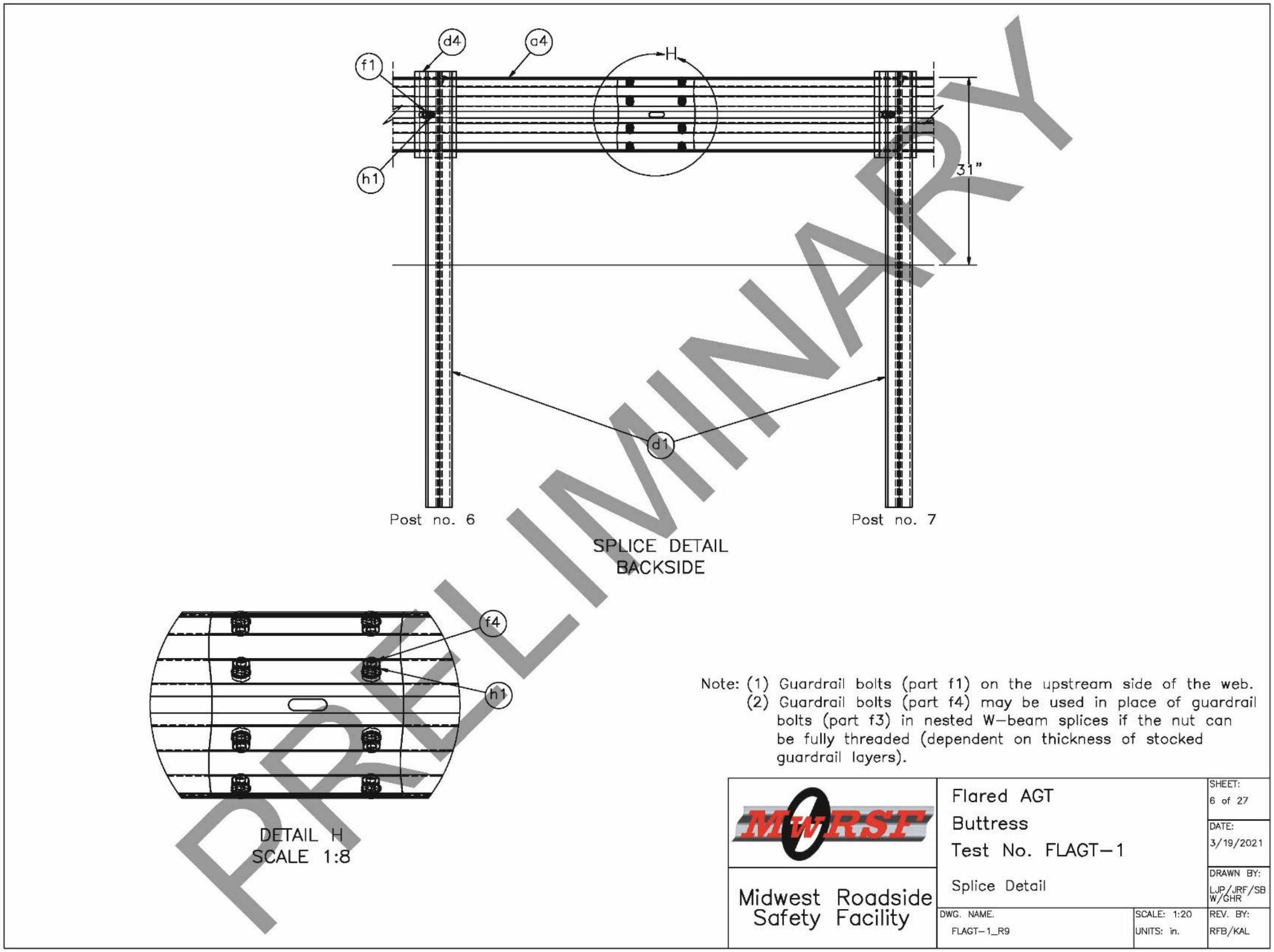


Figure 15. Splice Detail, Test No. FLAGT-1

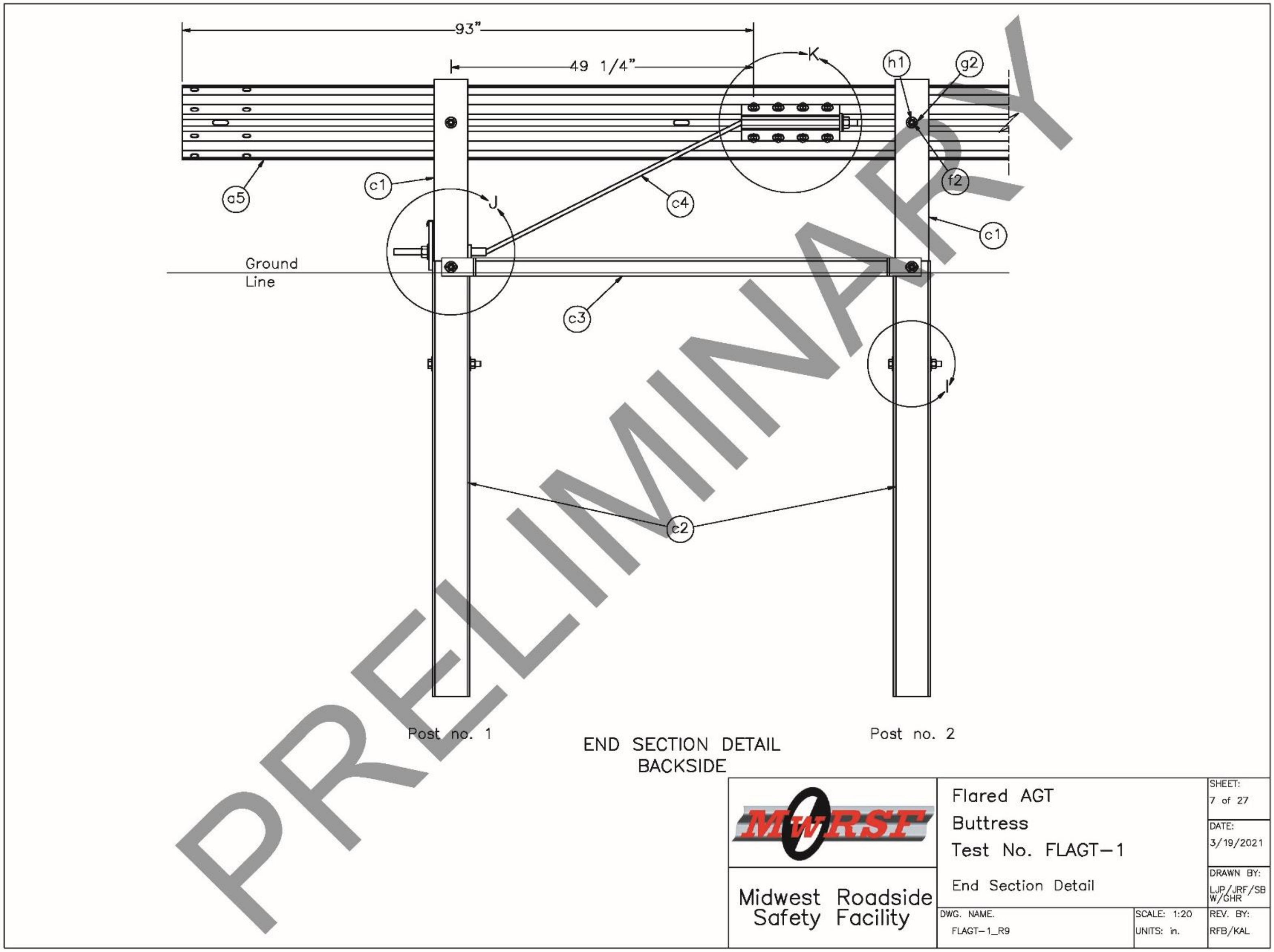


Figure 16. End Section Detail, Test No. FLAGT-1

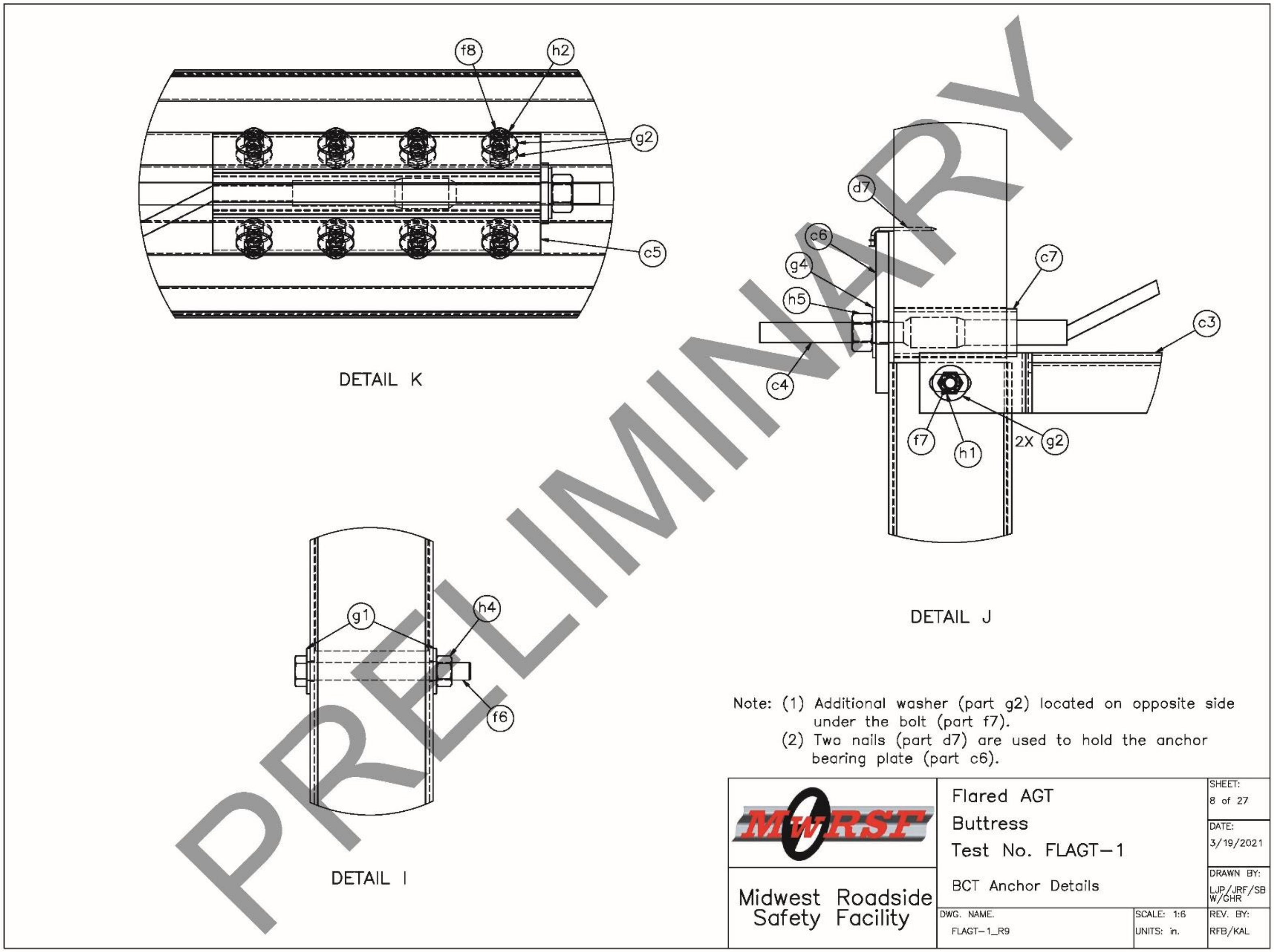


Figure 17. BCT Anchor Details, Test No. FLAGT-1

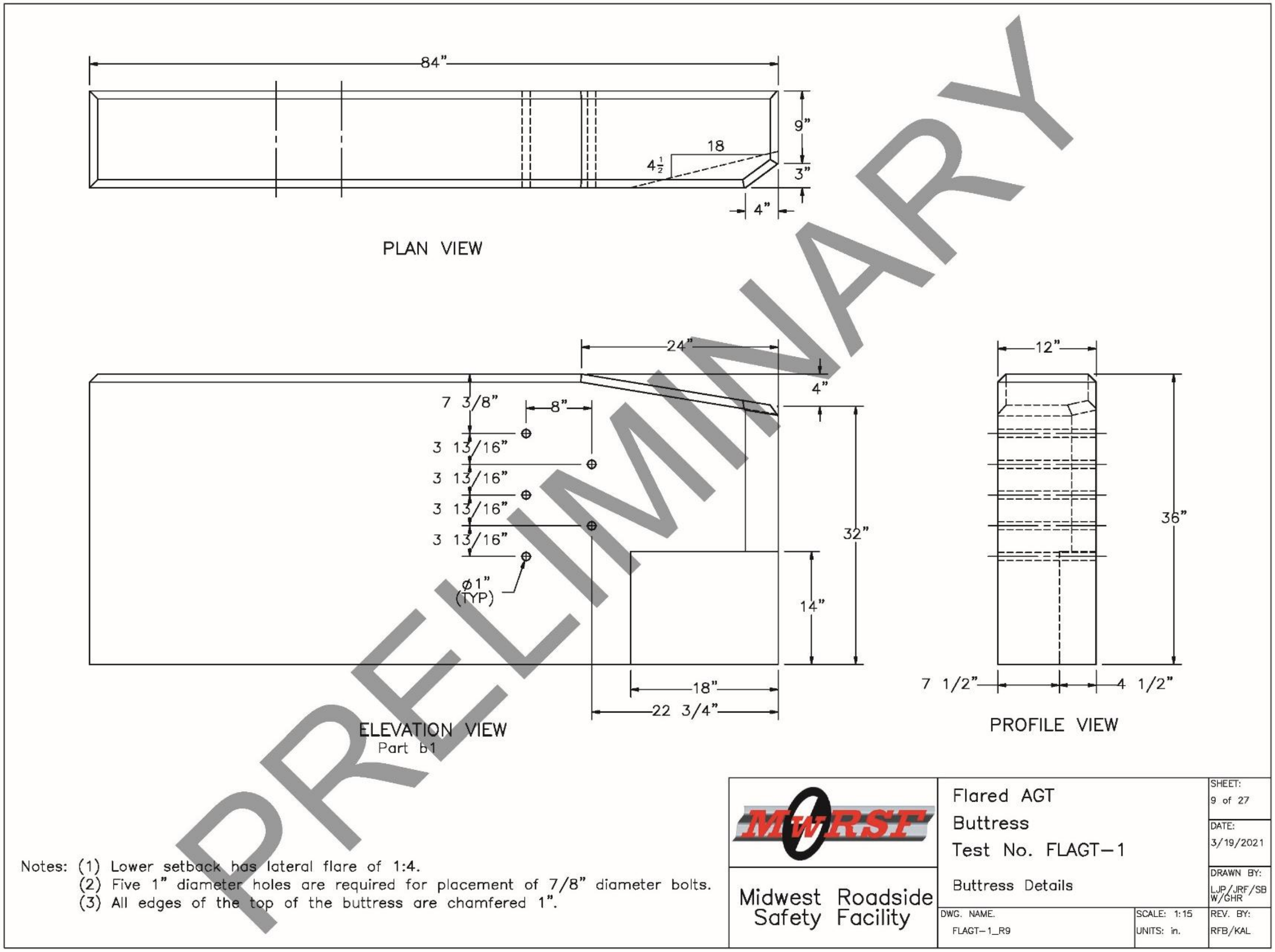


Figure 18. Buttress Details, Test No. FLAGT-1

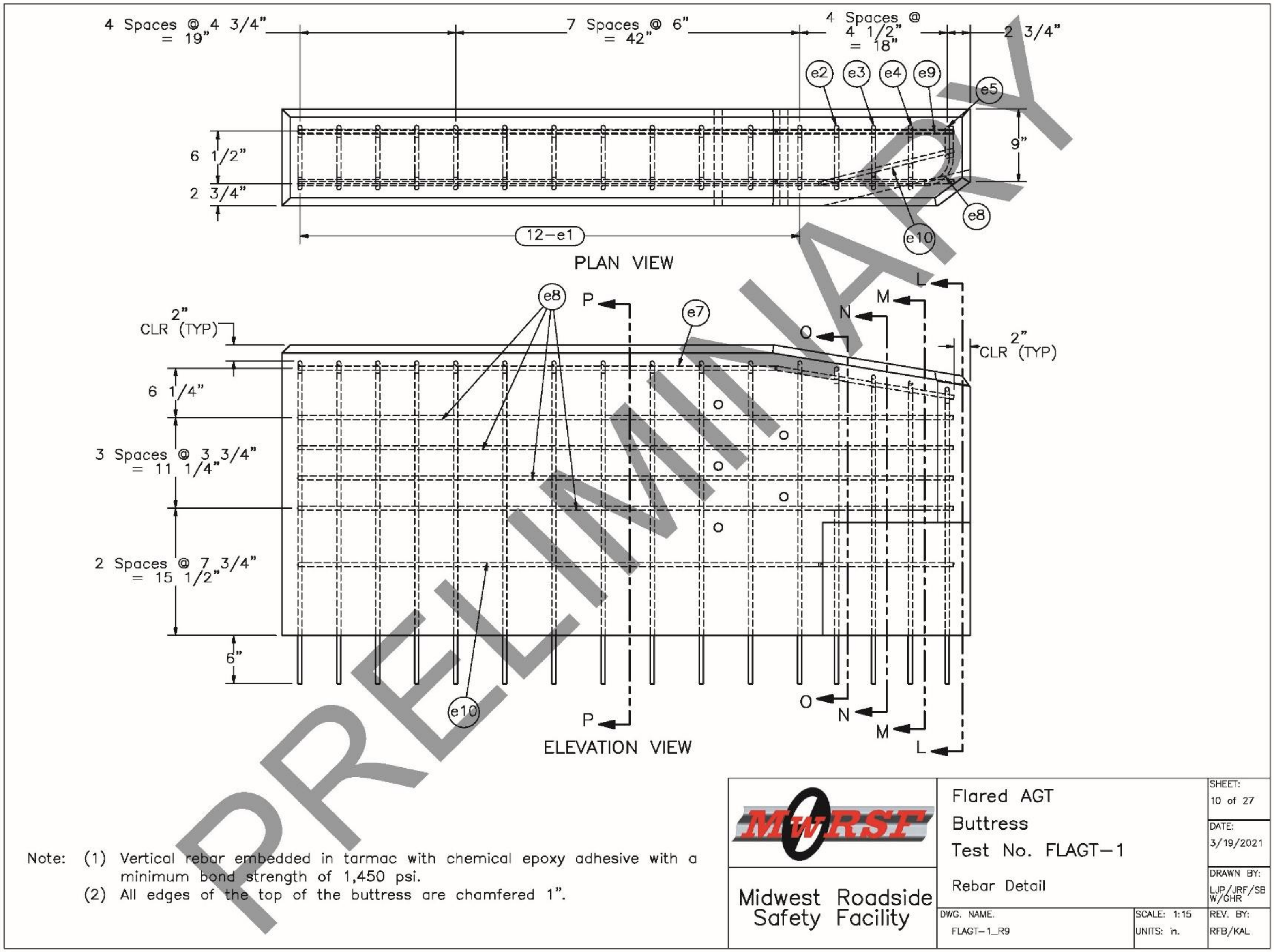


Figure 19. Rebar Detail, Test No. FLAGT-1

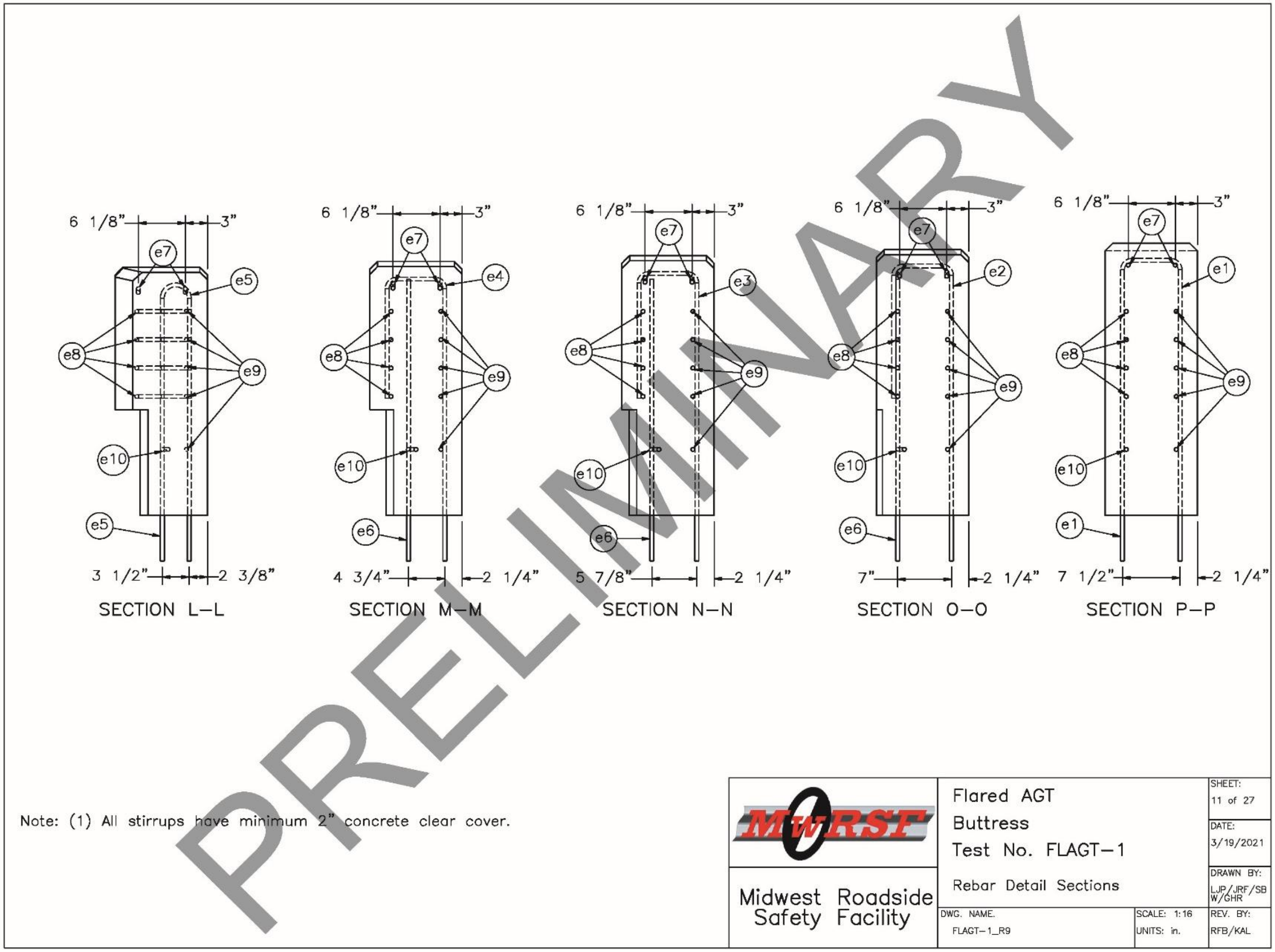
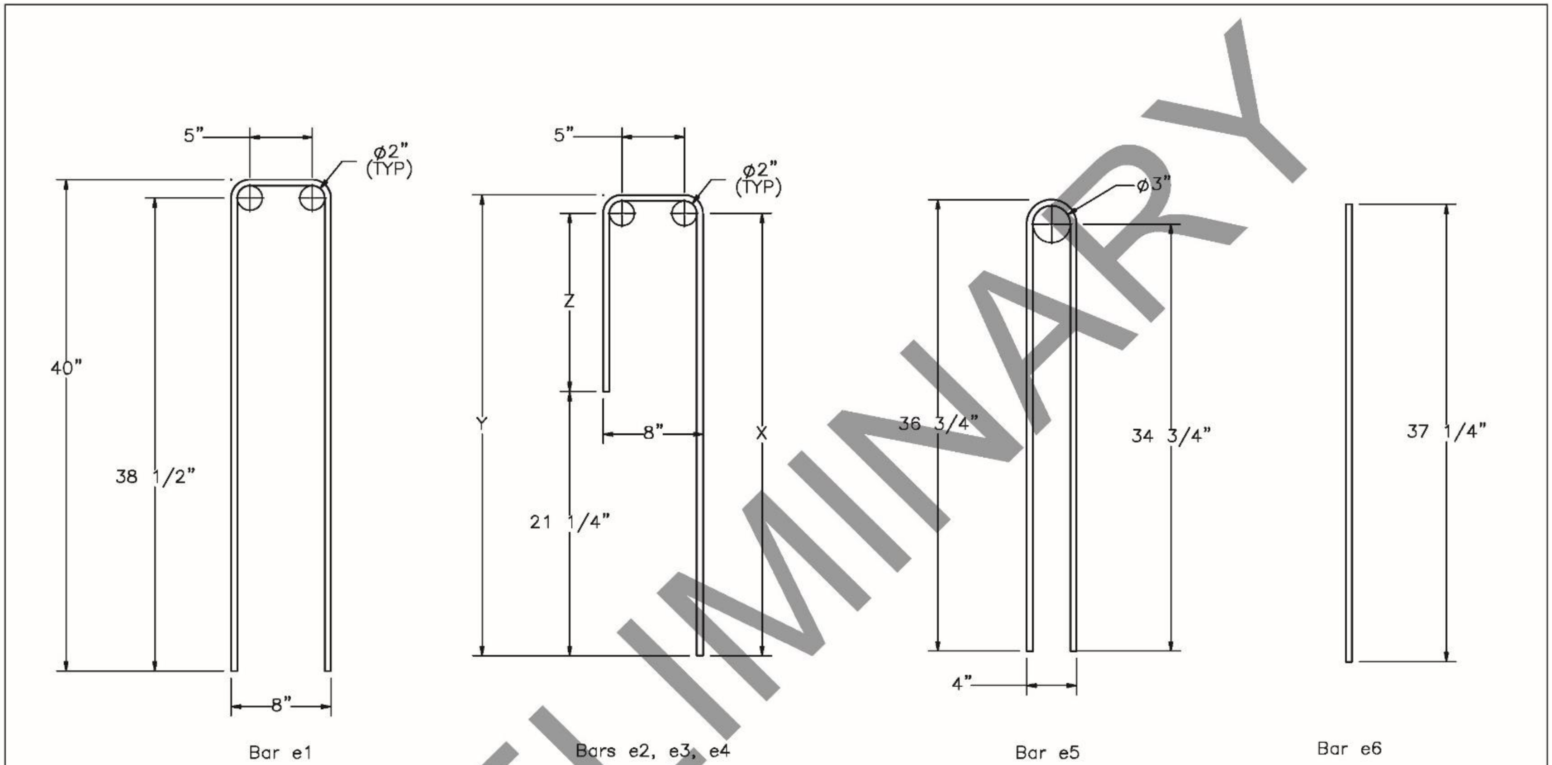


Figure 20. Rebar Detail Sections, Test No. FLAGT-1



Bill of Bars

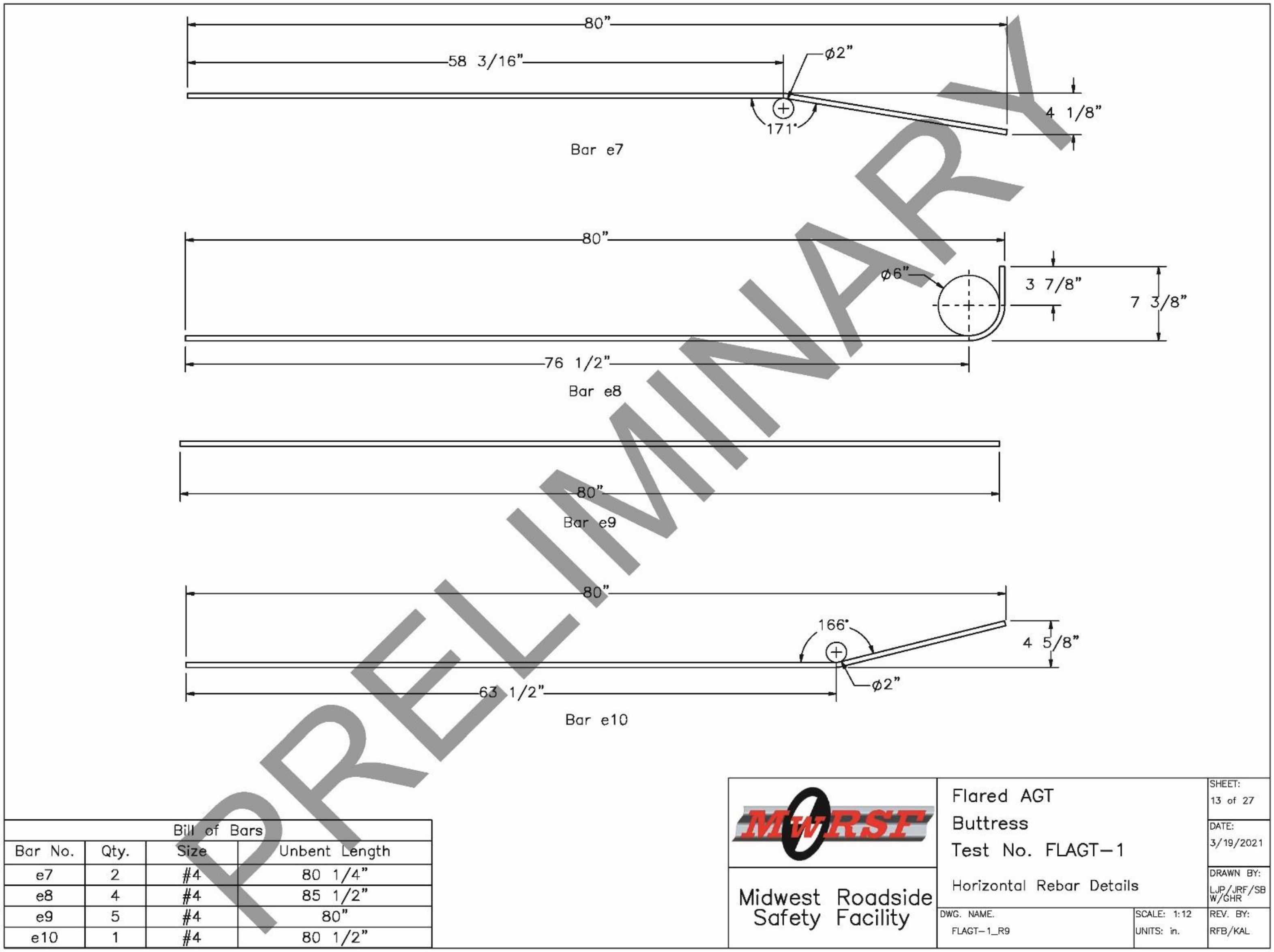
Bar No.	QTY	Size	X	Y	Z	Unbent Length
e1	12	#4	38 1/2"	40"	–	86"
e2	1	#4	37 1/2"	39"	16 1/4"	62 3/4"
e3	1	#4	36 1/2"	38"	15 1/4"	60 1/2"
e4	1	#4	35 3/4"	37 1/4"	14 1/2"	59 1/4"
e5	1	#4	34 3/4"	36 3/4"	–	74 3/4"
e6	3	#4	–	–	–	37 1/4"

MwRSF
Midwest Roadside Safety Facility

Flared AGT Buttress
Test No. FLAGT-1
Vertical Bar Details

SHEET: 12 of 27
DATE: 3/19/2021
DRAWN BY: LJP/JRF/SB W/GHR
DWG. NAME. FLAGT-1_R9
SCALE: 1:12
UNITS: in.
REV. BY: RFB/KAL

Figure 21. Vertical Rebar Details, Test No. FLAGT-1



Bill of Bars

Bar No.	Qty.	Size	Unbent Length
e7	2	#4	80 1/4"
e8	4	#4	85 1/2"
e9	5	#4	80"
e10	1	#4	80 1/2"

Figure 22. Horizontal Rebar Details, Test No. FLAGT-1

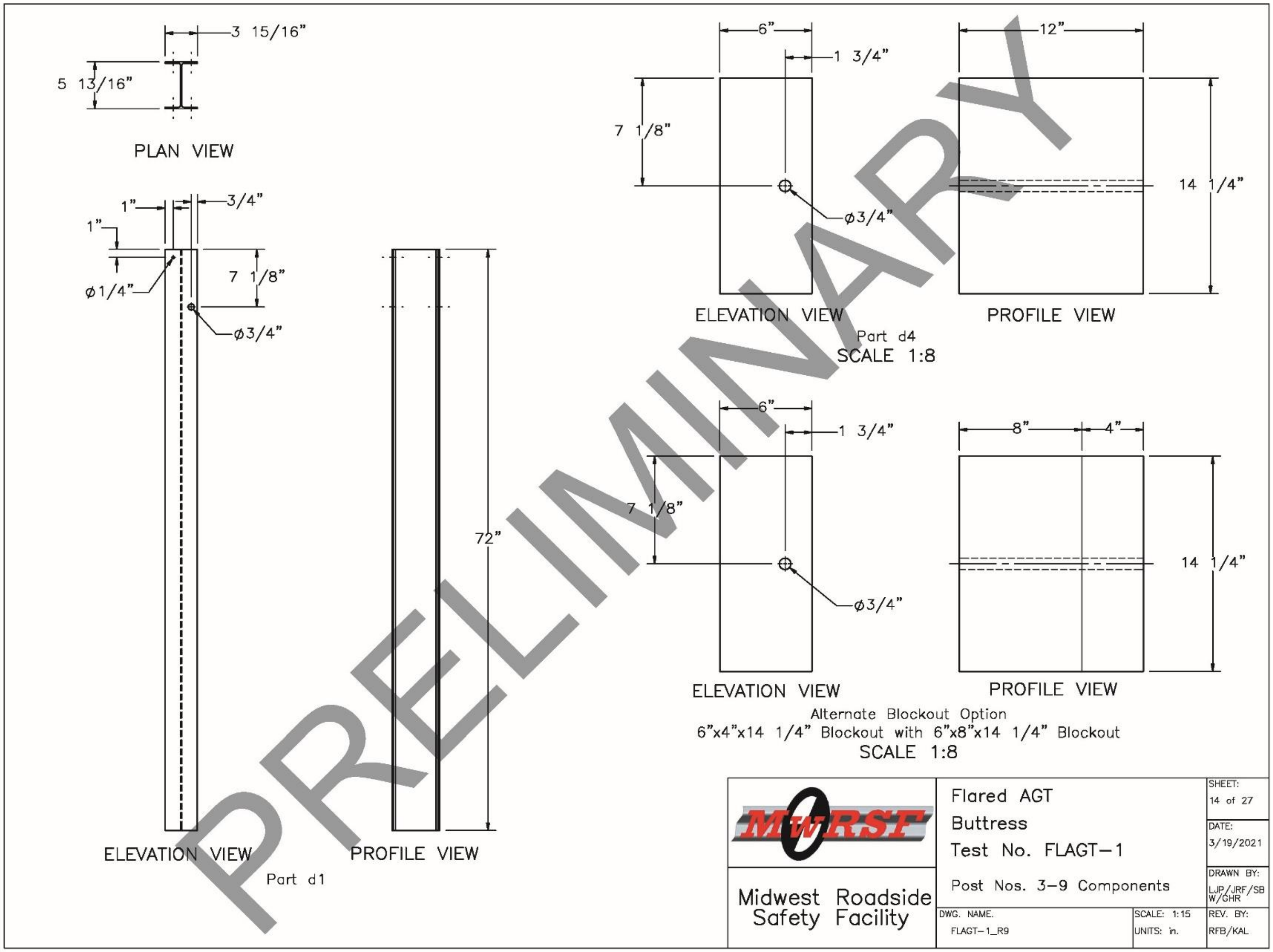


Figure 23. Post Nos. 3 through 9 Components, Test No. FLAGT-1

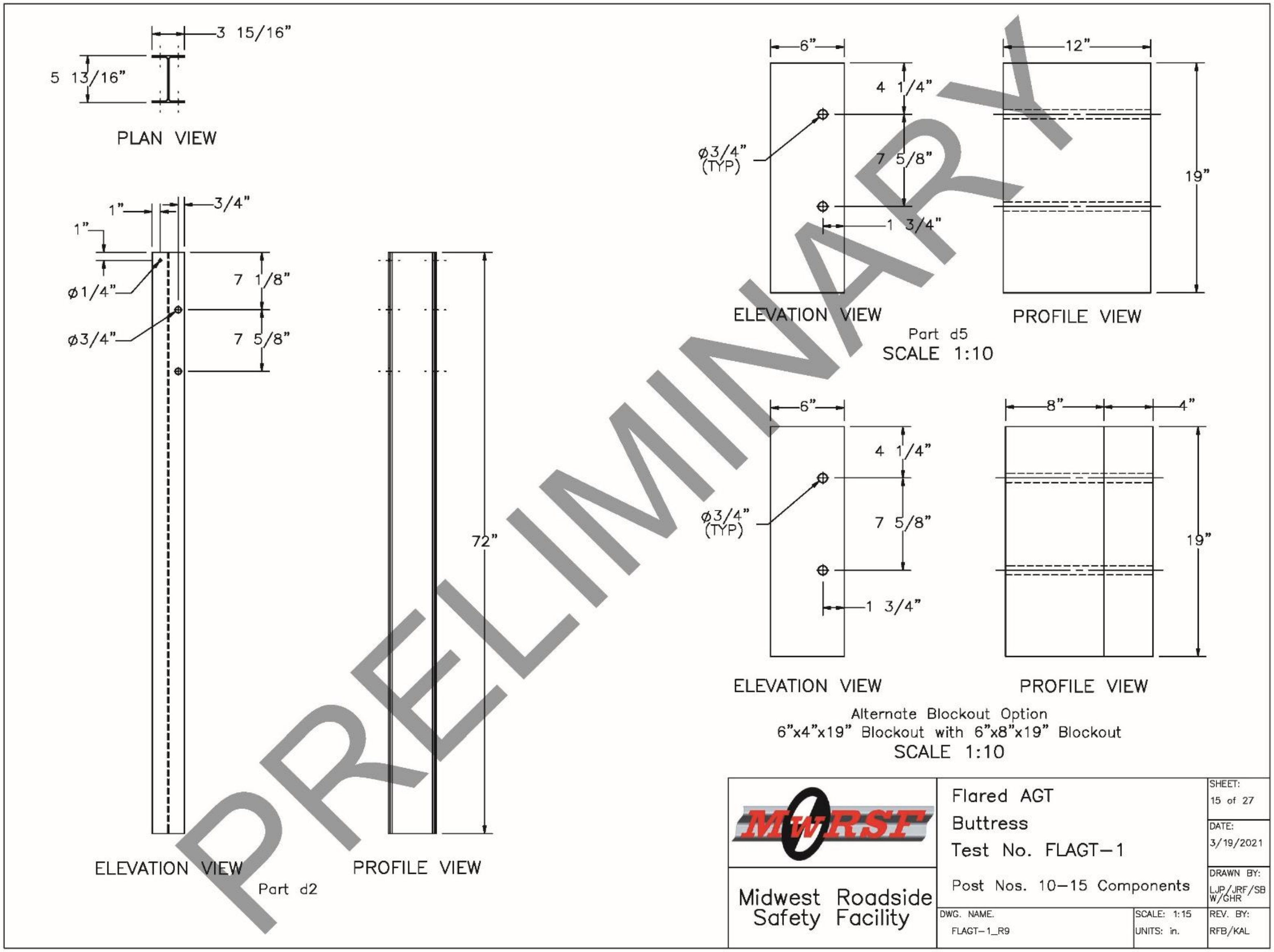


Figure 24. Post Nos. 10 through 15 Components, Test No. FLAGT-1

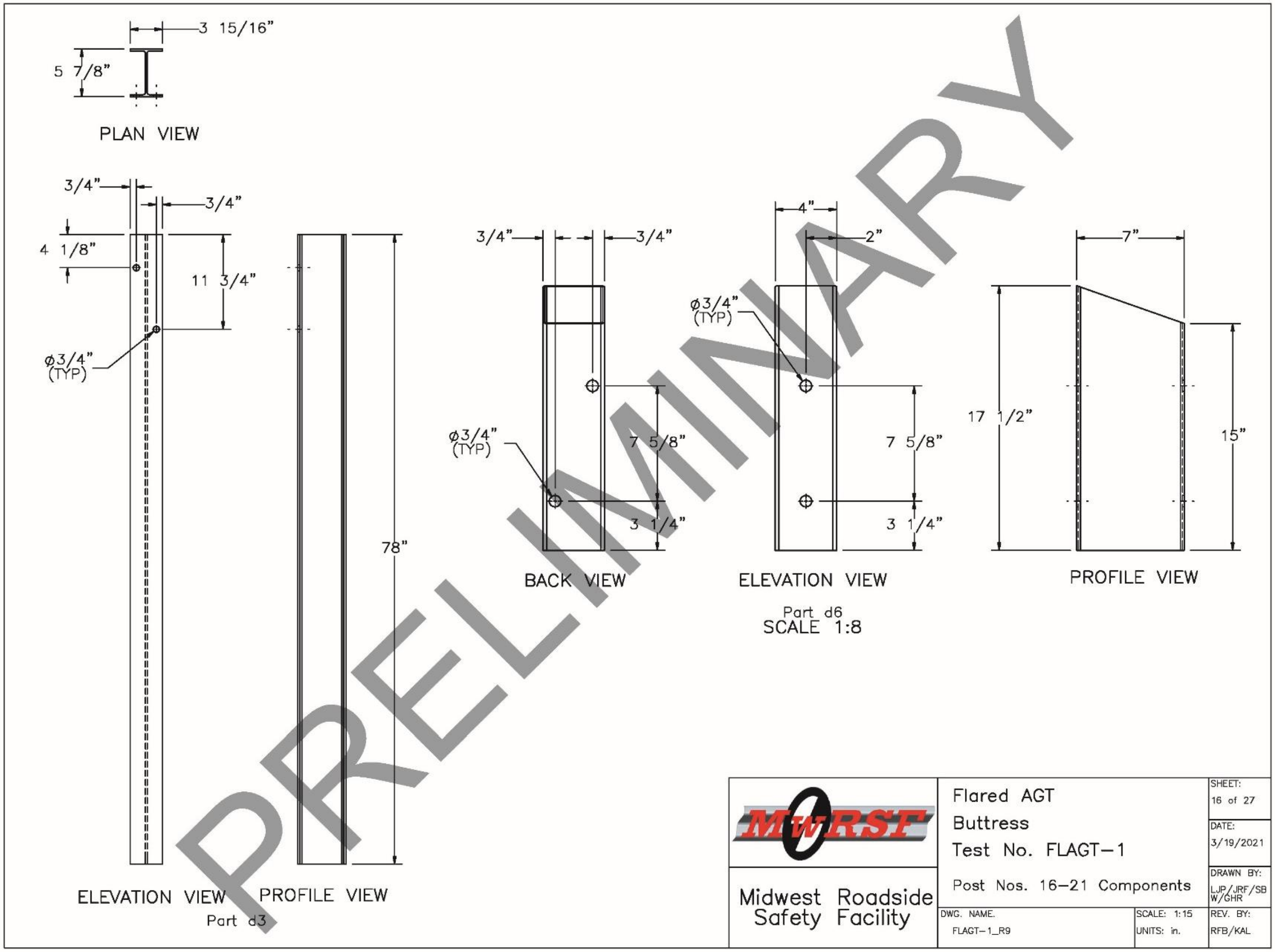


Figure 25. Post Nos. 16 through 21 Components, Test No. FLAGT-1

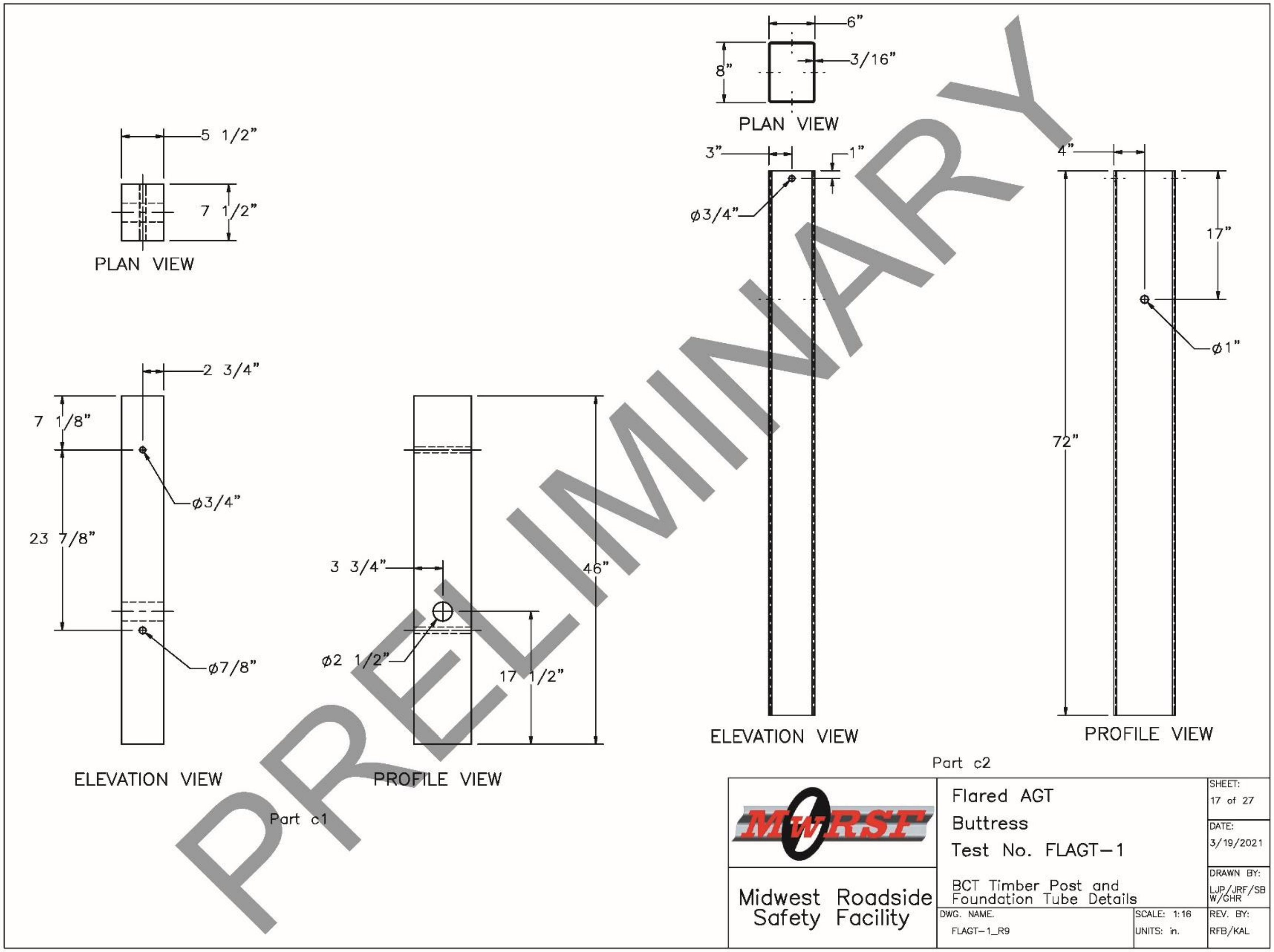


Figure 26. BCT Timber Post and Foundation Tube Details, Test No. FLAGT-1

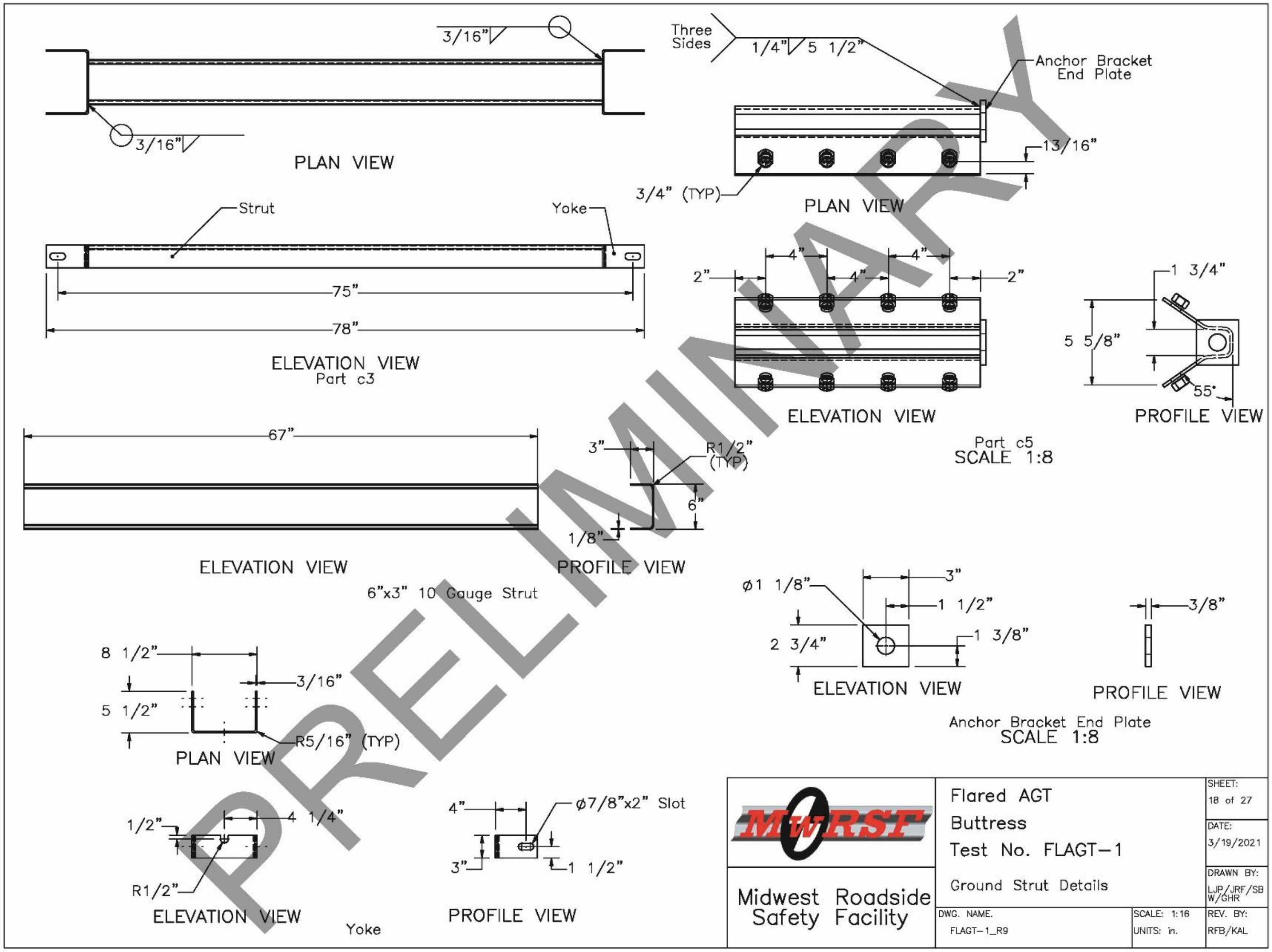


Figure 27. Ground Strut Details, Test No. FLAGT-1

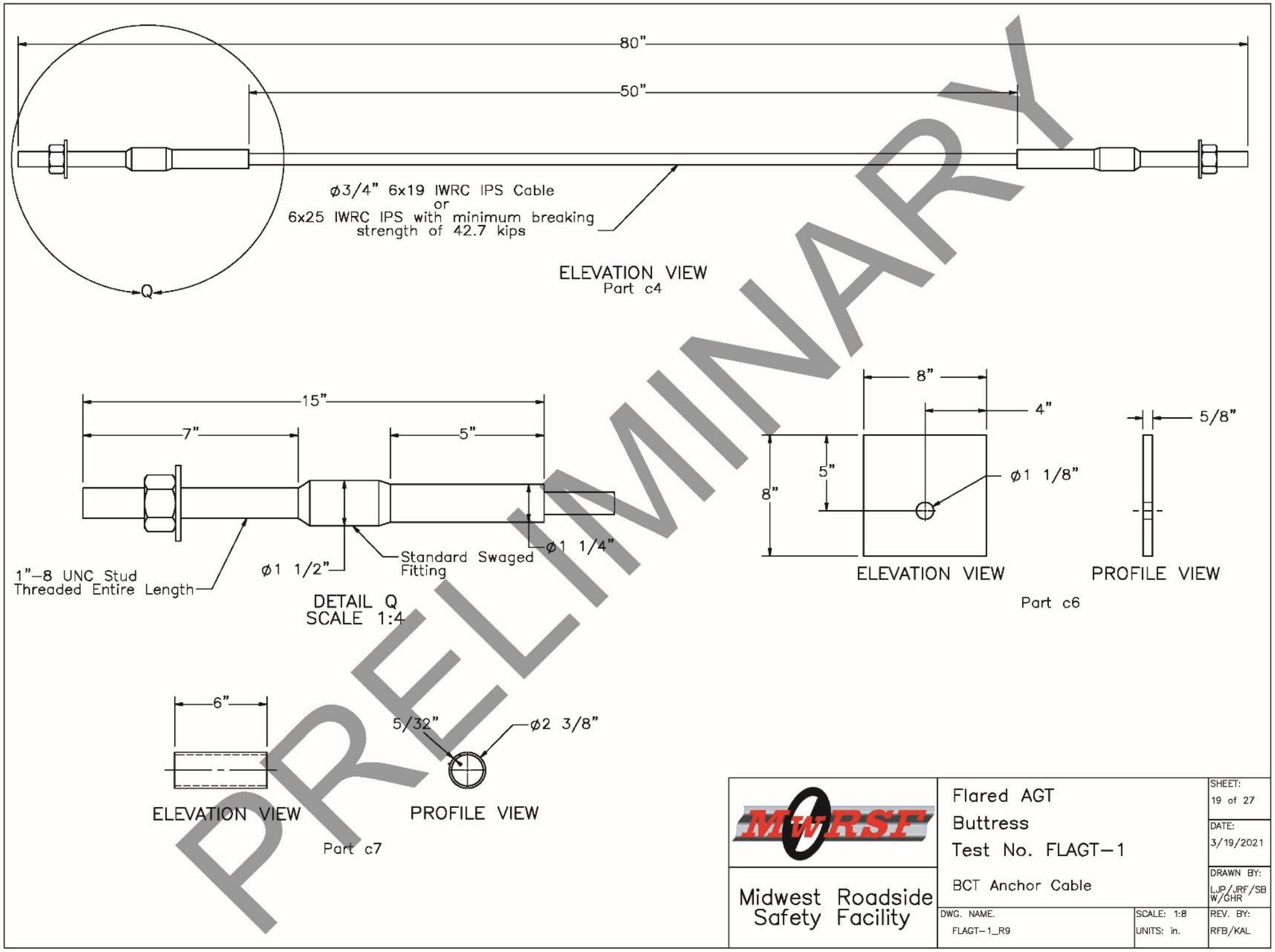
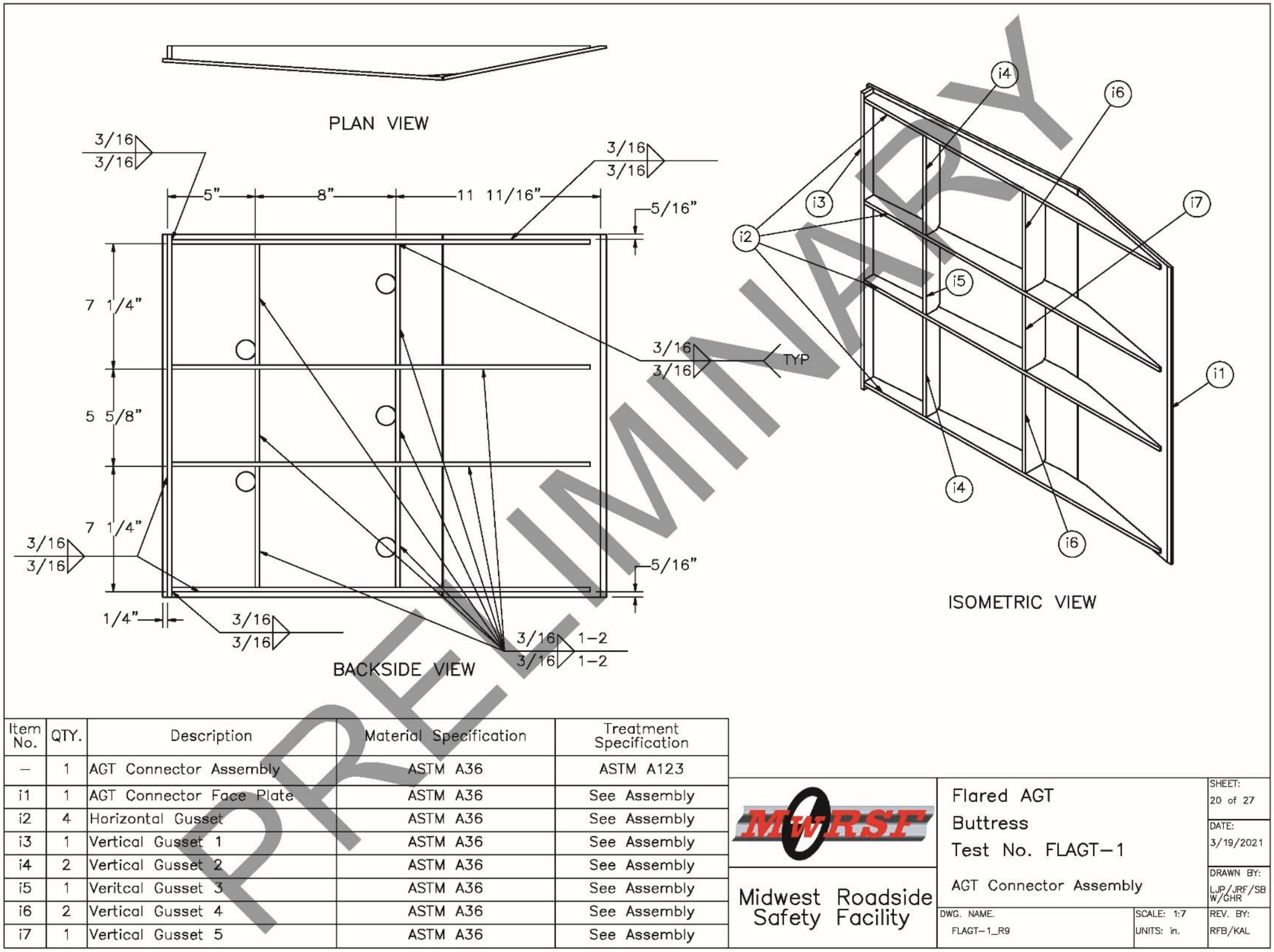


Figure 28. BCT Anchor Cable, Test No. FLAGT-1



Item No.	QTY.	Description	Material Specification	Treatment Specification
–	1	AGT Connector Assembly	ASTM A36	ASTM A123
i1	1	AGT Connector Face Plate	ASTM A36	See Assembly
i2	4	Horizontal Gusset	ASTM A36	See Assembly
i3	1	Vertical Gusset 1	ASTM A36	See Assembly
i4	2	Vertical Gusset 2	ASTM A36	See Assembly
i5	1	Veritcal Gusset 3	ASTM A36	See Assembly
i6	2	Vertical Gusset 4	ASTM A36	See Assembly
i7	1	Vertical Gusset 5	ASTM A36	See Assembly

Figure 29. AGT Connector Plate Assembly, Test No. FLAGT-1

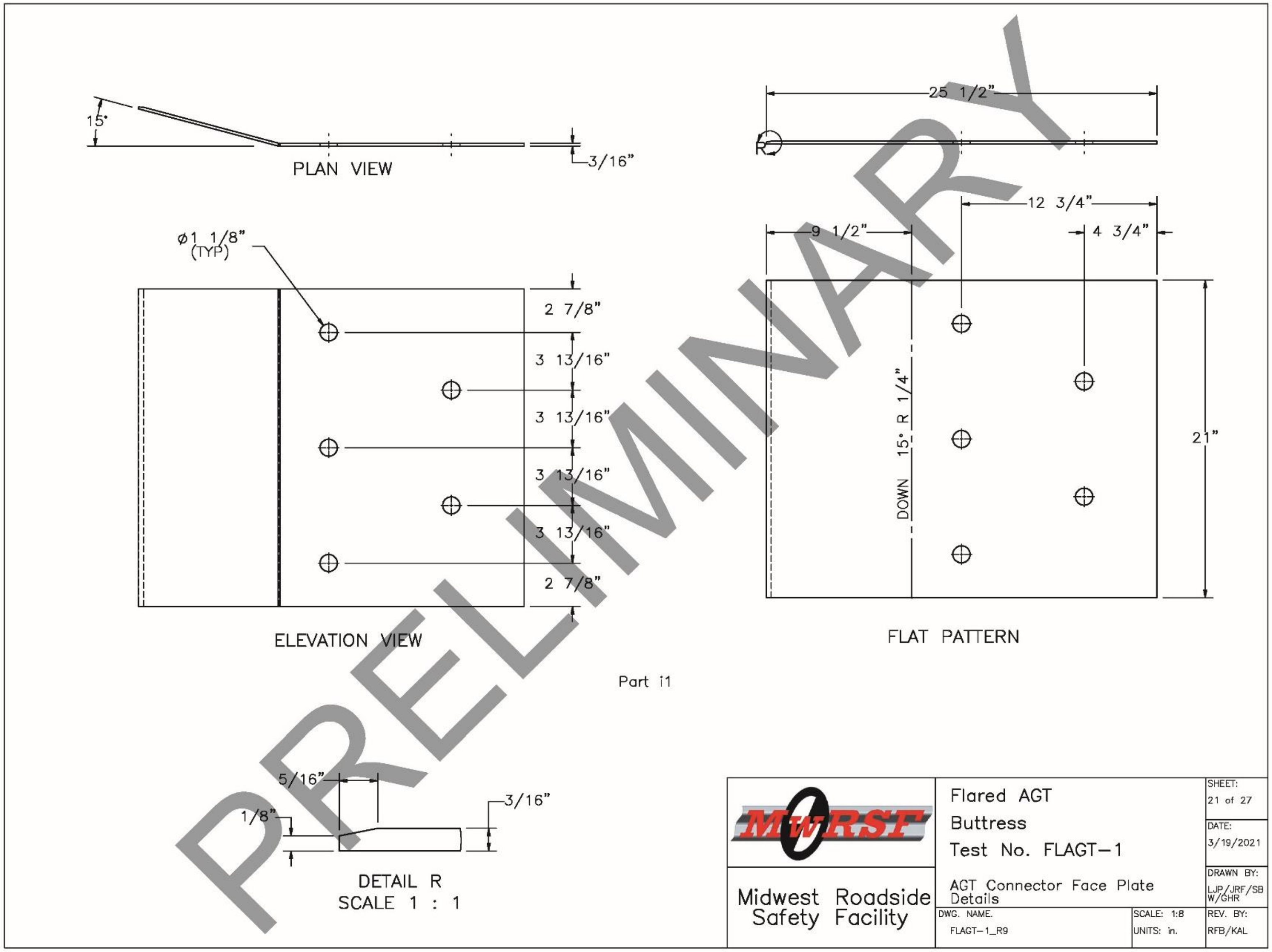


Figure 30. AGT Connector Plate Assembly Face Plate Details, Test No. FLAGT-1

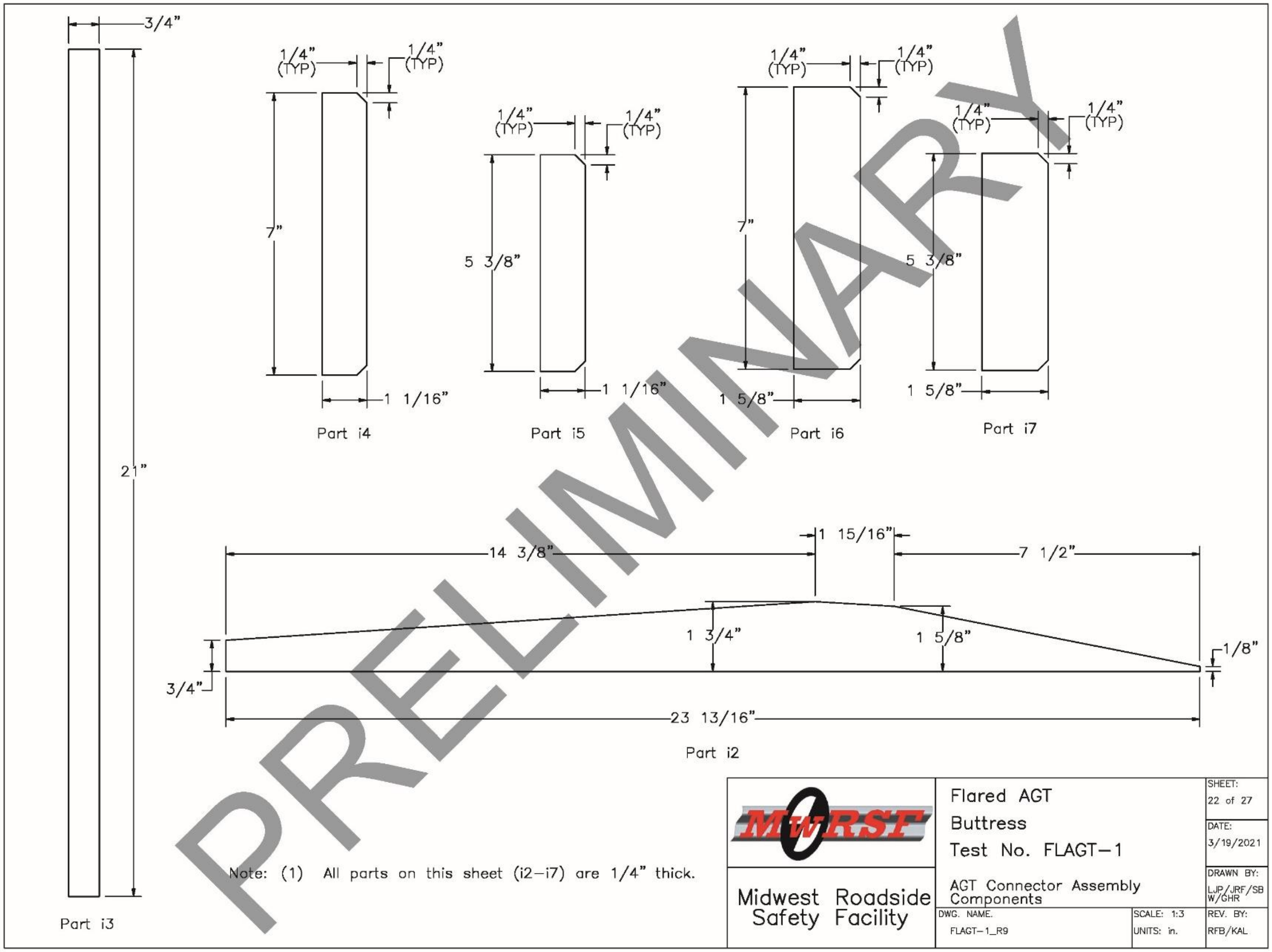


Figure 31. AGT Connector Assembly Components, Test No. FLAGT-1

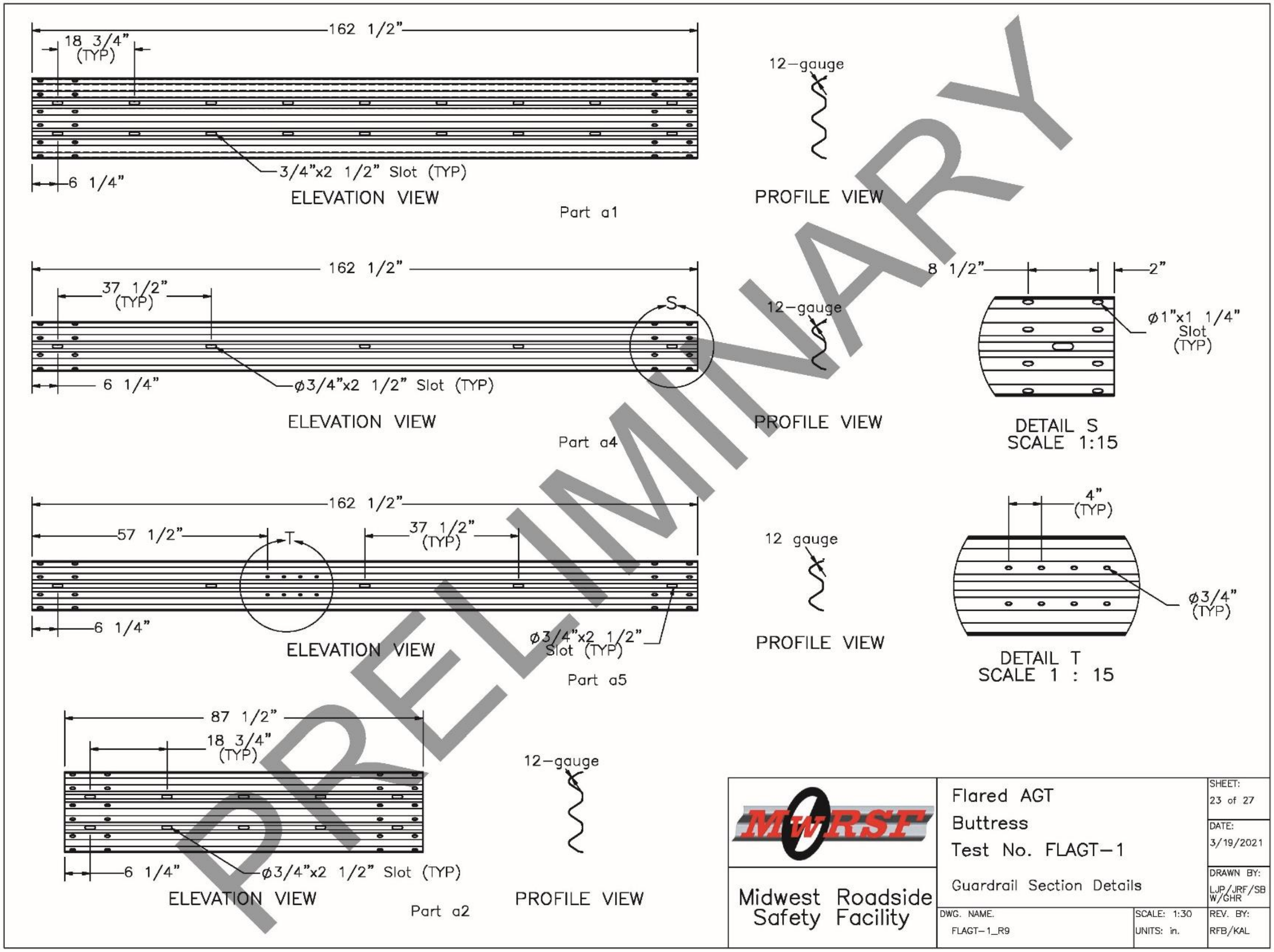


Figure 32. Guardrail Section Details, Test No. FLAGT-1

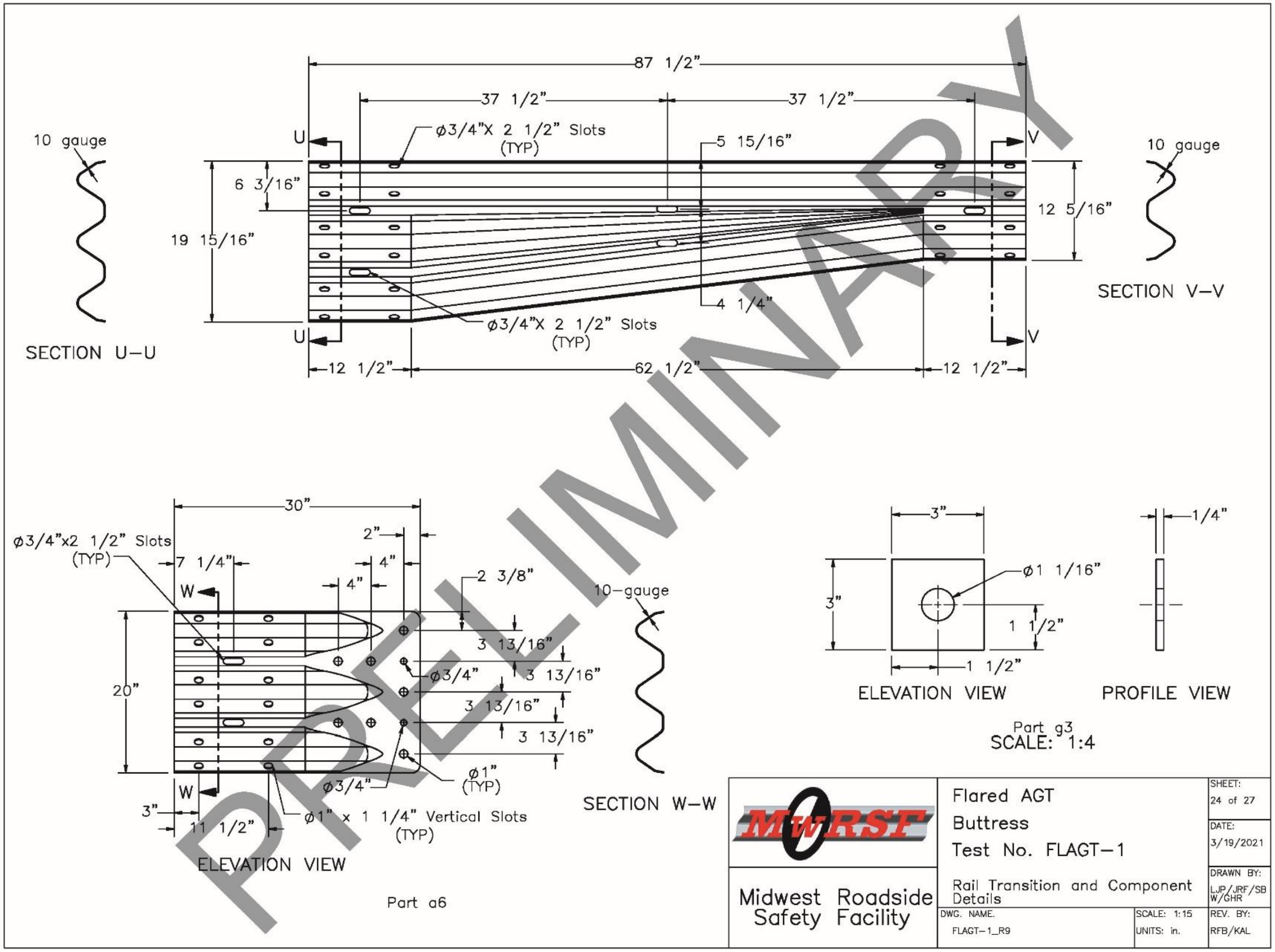


Figure 33. Rail Transition and Component Details, Test No. FLAGT-1

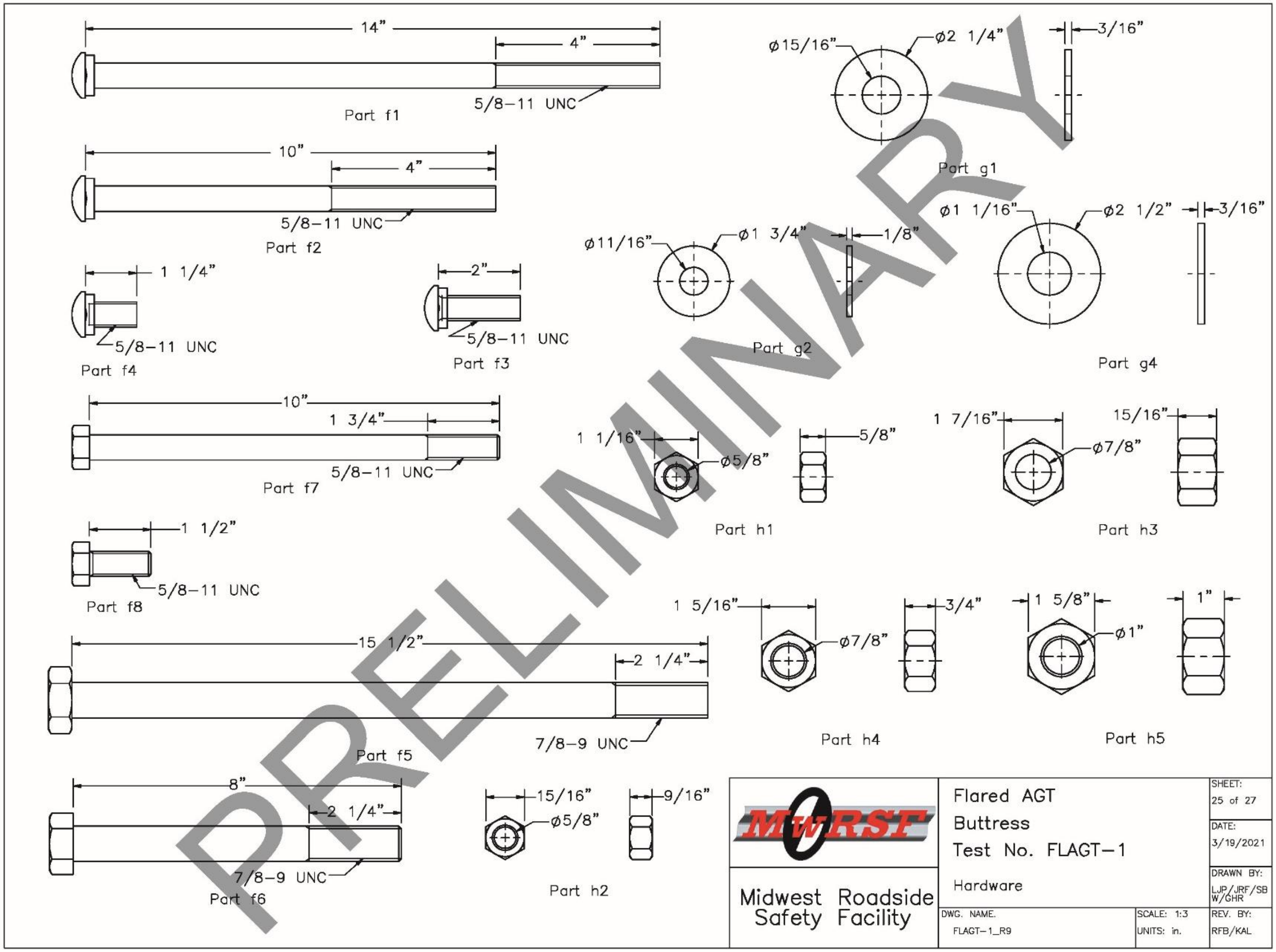


Figure 34. Hardware, Test No. FLAGT-1

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	2	12'–6" 12–gauge Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM08a
a2	1	6'–3" 12–gauge Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM19a
a3	1	6'–3" 10–gauge W–Beam to Thrie–Beam Asymetric Transition Section	AASHTO M180	ASTM A123 or A653	RWT02
a4	4	12'–6" 12–gauge W–Beam MGS Section	AASHTO M180	ASTM A123 or A653	RWM04a
a5	1	12'–6" 12–gauge W–Beam MGS End Section	AASHTO M180	ASTM A123 or A653	RWM14a
a6	1	10–gauge Thrie Beam Terminal Connector	AASHTO M180 Gr. 50 Min. yield strength = 50 ksi Min. ultimate strength = 70 ksi	ASTM A123 or A653	–
b1	1	Concrete – 21.9 cubic ft	Min. f'c = 4,000 psi	–	–
c1	2	BCT Timber Post – MGS Height	SYP Grade No. 1 or better (No knots +/– 18" from ground on tension face)	–	PDF01
c2	2	72" Long Foundation Tube	ASTM A500 Gr. B	*ASTM A123	PTE06
c3	1	Ground Strut Assembly	ASTM A36	*ASTM A123	PFP02
c4	1	BCT Cable Anchor Assembly	–	–	FCA01
c5	1	Anchor Bracket Assembly	ASTM A36	*ASTM A123	FPA01
c6	1	8"x8"x5/8" Anchor Bearing Plate	ASTM A36	*ASTM A123	FPB01
c7	1	2 3/8" O.D. x 6" Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	*ASTM A123	FMM02
d1	7	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992	*ASTM A123	PWE06
d2	6	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992	*ASTM A123	PWE06
d3	6	W6x8.5 or W6x9, 78" Long Steel Post	ASTM A992	*ASTM A123	–
d4	7	6"x12"x14 1/4" Timber Blockout	SYP Grade No.1 or better	–	PDB10a
d5	6	6"x12"x19" Timber Blockout	SYP Grade No.1 or better	–	–
d6	6	17 1/2" Long, 7"x4"x3/16" Iowa Steel Blockout	ASTM A500 Gr. B	*ASTM A123	–
d7	9	16D Double Head Nail	–	–	–
e1	12	86" Unbent Length #4 Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e2	1	62 3/4" Unbent Length #4 Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e3	1	60 1/2" Unbent Length #4 Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e4	1	59 1/4" Unbent Length #4 Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e5	1	74 3/4" Unbent Length #4 Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e6	3	37 1/4" Long #4 Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e7	2	80 1/4" Unbent Length #4 Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e8	4	85 1/2" Unbent Length #4 Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–

* Component does not need to be galvanized for testing purposes.
** Rebar does not need to be epoxy–coated for testing purposes.

Note: (1) Quantities listed herein are only for 1 system installation.
(2) For testing purposes part b1 used NE Mix 47B1S/1PF4000HW.

Midwest Roadside Safety Facility

Flared AGT Buttress Test No. FLAGT–1

Bill of Materials

SHEET: 26 of 27
DATE: 3/19/2021
DRAWN BY: LJP/JRF/SB W/GHR
DWG. NAME. FLAGT–1_R9
SCALE: None
UNITS: in.
REV. BY: RFB/KAL

Figure 35. Bill of Materials, Test No. FLAGT-1

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
e9	5	80" Long #4 Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e10	1	80 1/2" Unbent Length #4 Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
f1	18	5/8" Dia. UNC, 14" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB06
f2	2	5/8" Dia. UNC, 10" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB03
f3	24	5/8" Dia. UNC, 2" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB02
f4	56	5/8" Dia. UNC, 1 1/4" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB01
f5	5	7/8 Dia. UNC, 15 1/2" Long Heavy Hex Head Bolt	ASTM F3125 Gr. 120 (A325) or A354 Gr. BC	ASTM A153 or B695 Class 55 or F1136 Gr. 3 or F2329 or F2833 Gr. 1	FBX22b
f6	2	7/8" Dia. UNC, 8" Long Hex Head Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	–
f7	2	5/8" Dia. UNC, 10" Long Hex Head Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBX16a
f8	20	5/8" Dia. UNC, 1 1/2" Long Hex Head Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBX16a
g1	4	7/8" Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	–
g2	46	5/8" Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC16a
g3	5	3"x3"x1/4" or 3 1/2"x3 1/2"x1/4" Square Washer Plate	ASTM A572 Gr. 50	*ASTM A123	–
g4	2	1" Dia. Plain Round Washer	ASTM F844	ASTM A153 (AASHTO M232) for Class D or ASTM B695 (AASHTO M298) for Class 50	FWC24a
h1	102	5/8" Dia. Heavy Hex Nut	ASTM A563A	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	–
h2	20	5/8" Dia. Hex Nut	ASTM A563A	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	–
h3	5	7/8" Dia. UNC Heavy Hex Nut	ASTM A563DH or A194 Gr. 2H	–	–
h4	2	7/8" Dia. Hex Nut	ASTM A307	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	–
h5	2	1"-8 UNC Heavy Hex Nut	ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX24b
i1	1	AGT Connector Face Plate	ASTM A36	See Assembly	–
i2	4	Horizontal Gusset	ASTM A36	See Assembly	–
i3	1	Vertical Gusset 1	ASTM A36	See Assembly	–
i4	2	Vertical Gusset 2	ASTM A36	See Assembly	–
i5	1	Veritcal Gusset 3	ASTM A36	See Assembly	–
i6	2	Vertical Gusset 4	ASTM A36	See Assembly	–
i7	1	Vertical Gusset 5	ASTM A36	See Assembly	–

* Component does not need to be galvanized for testing purposes.
** Rebar does not need to be epoxy-coated for testing purposes.

Midwest Roadside Safety Facility

Flared AGT Buttress Test No. FLAGT-1

Bill of Materials

SHEET: 27 of 27

DATE: 3/19/2021

DRAWN BY: LJP/JRF/SB W/GHR

DWG. NAME. FLAGT-1_R9

SCALE: None UNITS: in.

REV. BY: RFB/KAL

Figure 36. Bill of Materials, Cont., Test No. FLAGT-1

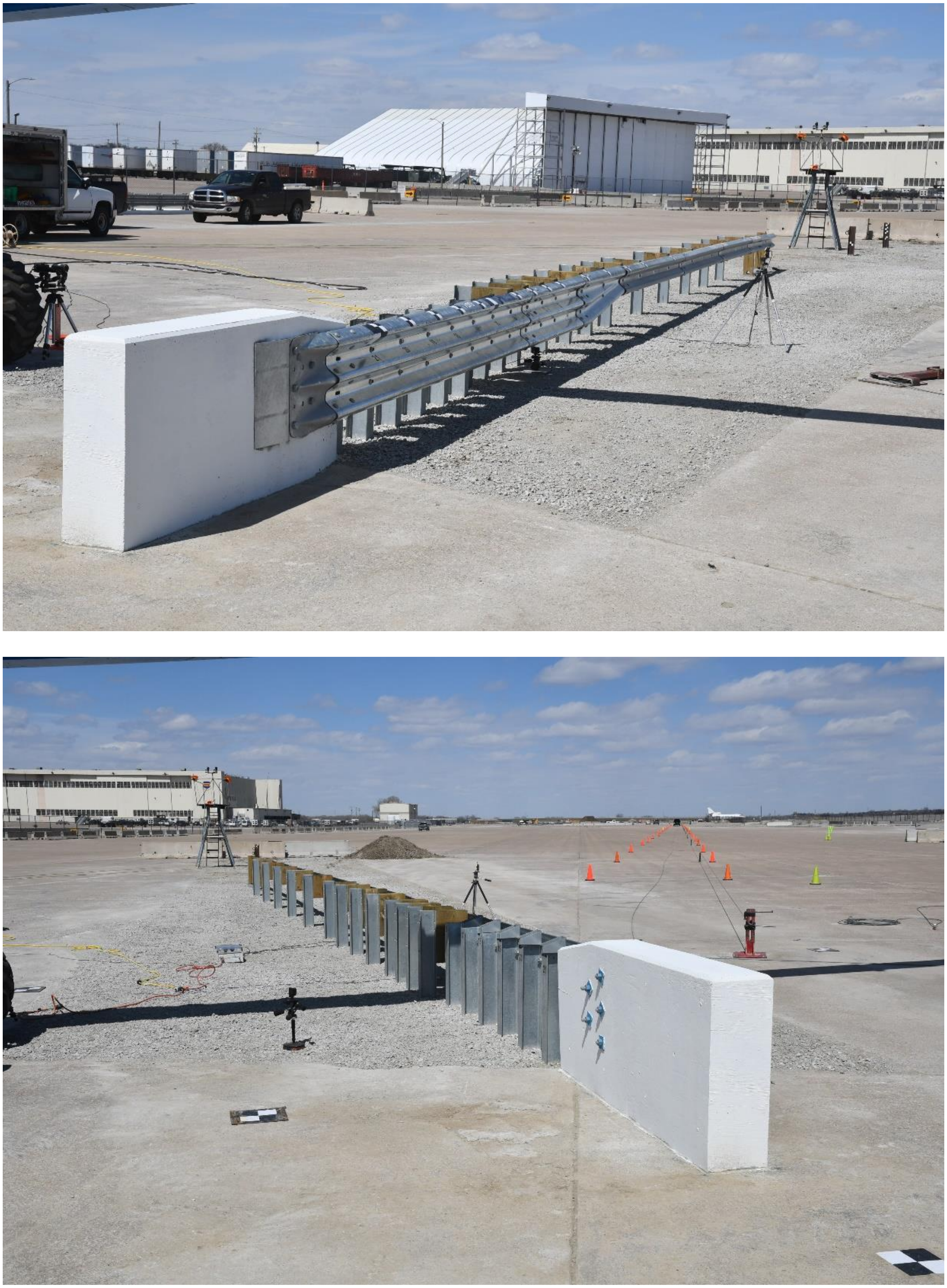


Figure 37. Test Installation Photographs

Figure 38. Test Installation Photographs

5 TEST CONDITIONS

5.1 Test Facility

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

5.2 Vehicle Tow and Guidance System

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

A vehicle guidance system developed by Hinch [20] was used to steer the test vehicle. A guide flag, attached to the left-front wheel and the guide cable, was sheared off before impact with the barrier system. The ⅜-in. diameter guide cable was tensioned to approximately 3,500 lb and supported both laterally and vertically every 100 ft by hinged stanchions. The hinged stanchions stood upright while holding up the guide cable, but as the vehicle was towed down the line, the guide flag struck and knocked each stanchion to the ground.

5.3 Test Vehicle

For test no. FLAGT-1, a 2016 Ram 1500 quad cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 4,910 lb, 5,003 lb, and 5,163 lb, respectively. The test vehicle is shown in Figures 39 and 40, and vehicle dimensions are shown in Figure 41. The rear track width of the vehicle (69 in.) was 0.5 in. greater than the maximum value specified in MASH (67 in. ± 1.5 in.).

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [21] was used to determine the vertical component of the c.g. for the pickup truck. This method is based on the principle that the c.g. of any freely suspended body is in the vertical plane through the point of suspension. The vehicle was suspended successively in three positions, and the respective planes containing the c.g. were established. The intersection of these planes pinpointed the final c.g. location for the test inertial condition. The location of the final c.g. is shown in Figures 41 and 42. Data used to calculate the location of the c.g. and ballast information are shown in Appendix C.

Square, black- and white-checkered targets were placed on the vehicle for reference to be viewed from the high-speed digital video cameras and aid in the video analysis, as shown in Figure 42. 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 vehicles 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 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.

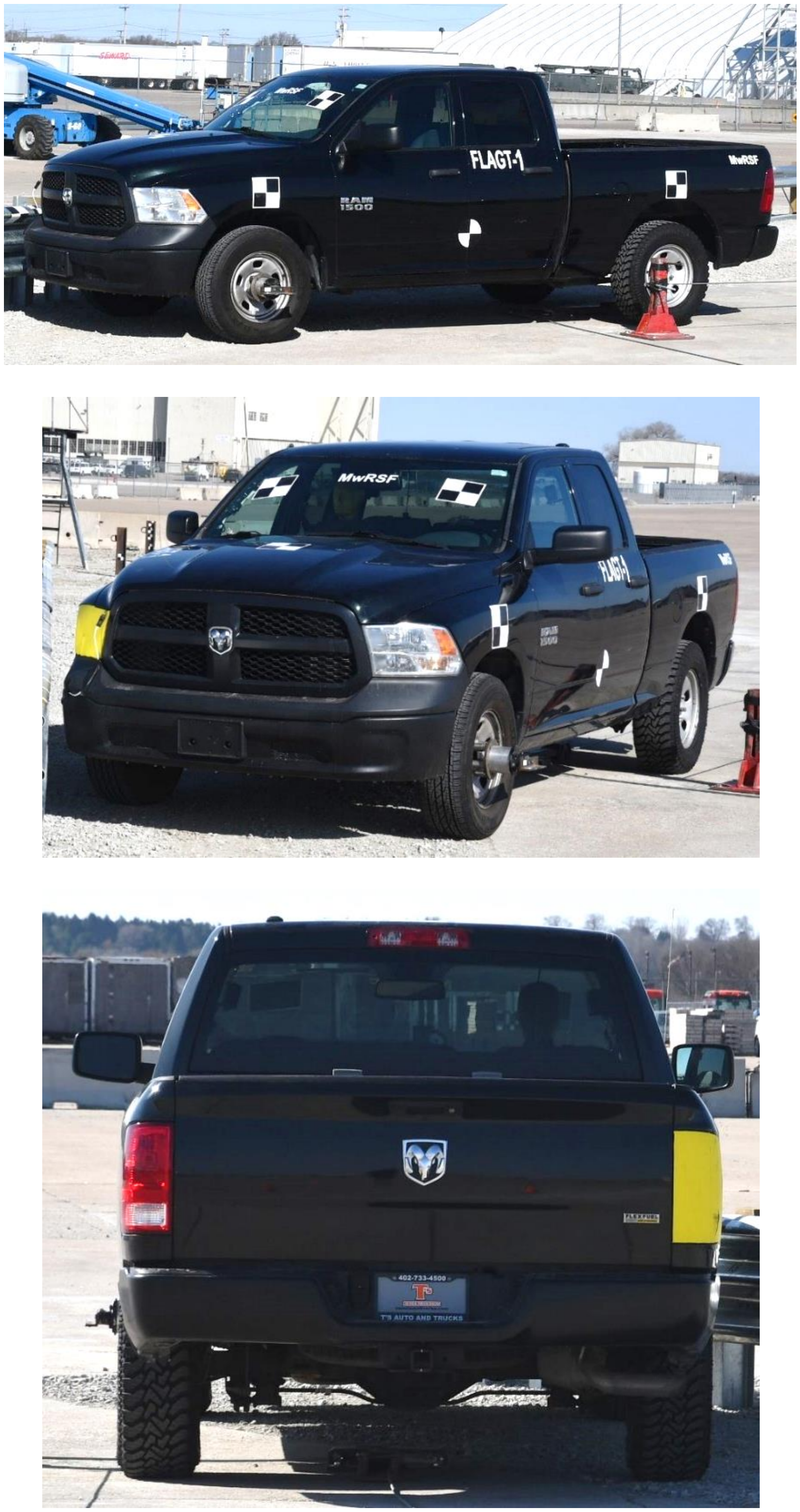
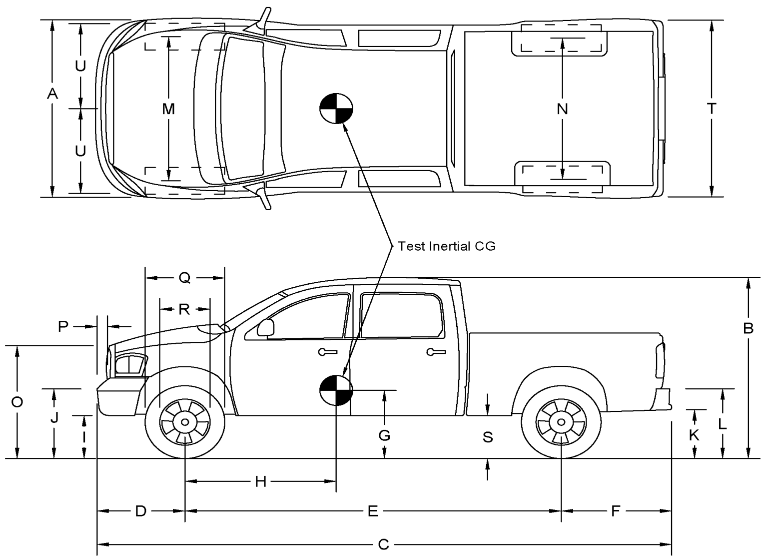


Figure 39. Test Vehicle, Test No. FLAGT-1

Figure 40. Test Vehicle’s Interior Floorboards and Undercarriage, Test No. FLAGT-1

		Test Name:	FLAGT-1	**VIN No:**	1C6RR6FGXGS284280
Model Year:	2016	**Make:**	RAM	**Model:**	1500 Quad Cab
Tire Size:	265/70R17	**Tire Inflation Pressure:**	40 psi	**Odometer:**	119027.6



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

A:	77 3/8	(1965)	B:	74	(1880)
	78±2 (1950±50)				
C:	229 1/4	(5823)	D:	41 1/4	(1048)
	237±13 (6020±325)			39±3 (1000±75)	
E:	140 5/8	(3572)	F:	47 3/8	(1203)
	148±12 (3760±300)				
G:	28 3/16	(716)	H:	66 1/16	(1678)
	min: 28 (710)			63±4 (1575±100)	
I:	13	(330)	J:	25	(635)
K:	20	(508)	L:	28 7/8	(733)
M:	68 1/2	(1740)	N:	69	(1753)
	67±1.5 (1700±38)			67±1.5 (1700±38)	
O:	45	(1143)	P:	4 7/8	(124)
	43±4 (1100±75)				
Q:	32	(813)	R:	18 1/2	(470)
S:	14 3/4	(375)	T:	78 5/8	(1997)
			U (impact width):	36 5/8	(930)

Wheel Center Height (Front):	15	(381)
Wheel Center Height (Rear):	15 3/8	(391)
Wheel Well Clearance (Front):	35 1/4	(895)
Wheel Well Clearance (Rear):	37 1/4	(946)
Bottom Frame Height (Front):	11 3/4	(298)
Bottom Frame Height (Rear):	12 7/8	(327)
Engine Type:	Gasoline	
Engine Size:	3.6L V6	
Transmission Type:	Automatic	
Drive Type:	RWD	
Cab Style:	Quad Cab	
Bed Length:	76"	

Mass Distribution - lb (kg)

Gross Static	LF	1388	(630)	RF	1369	(621)
	LR	1200	(544)	RR	1206	(547)

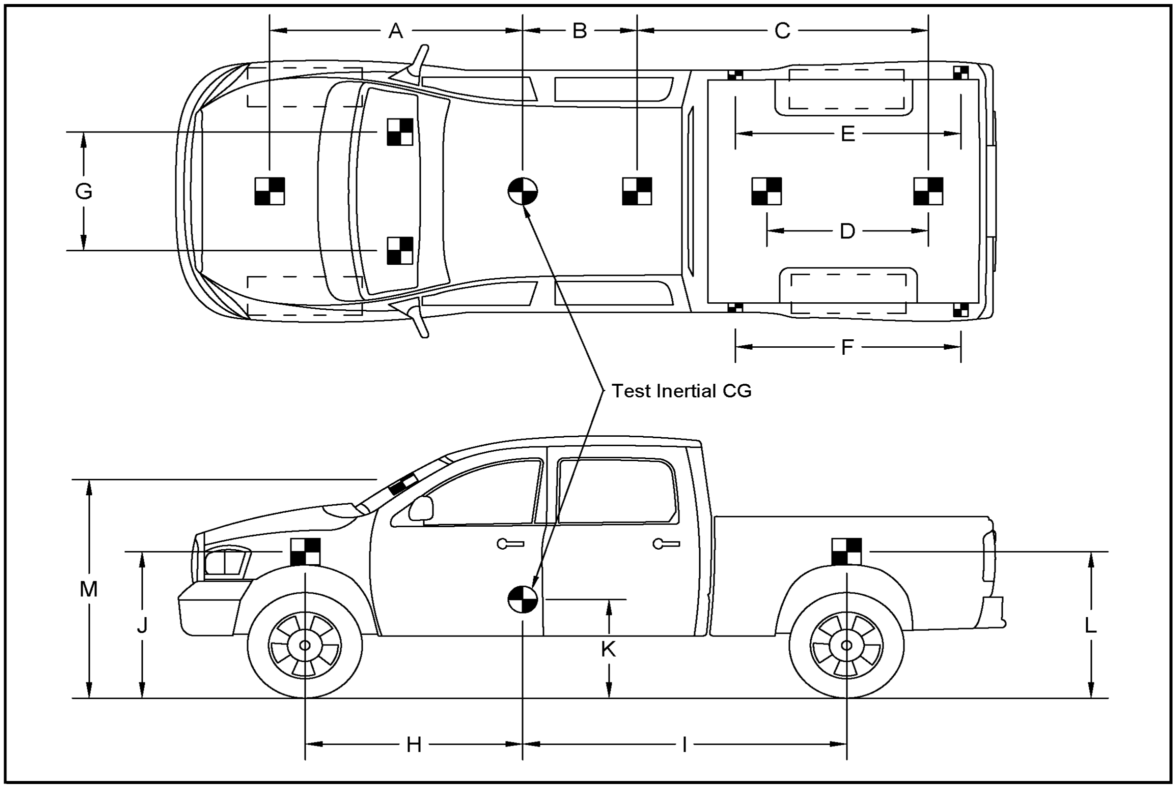
Weights lb (kg)	**Curb**	**Test Inertial**	**Gross Static**
W-front	2695 (1222)	2652 (1203)	2757 (1251)
W-rear	2215 (1005)	2351 (1066)	2406 (1091)
W-total	4910 (2227)	5003 (2269) 5000±110 (2270±50)	5163 (2342) 5165±110 (2343±50)

GVWR Ratings - lb		**Surrogate Occupant Data**	
Front	3700	**Type:**	Hybrid II
Rear	3900	**Mass:**	160 lb
Total	6800	**Seat Position:**	Right/Passenger

Note any damage prior to test: None

Figure 41. Vehicle Dimensions, Test No. FLAGT-1

		Test Name:	FLAGT-1	VIN:	1C6RR6FGXGS284280
Model Year:	2016	Make:	RAM	Model:	1500 Quad Cab



TARGET GEOMETRY-- in. (mm)

A:	76 5/8	(1946)	E:	63 1/4	(1607)	J:	39 1/4	(997)
B:	24	(610)	F:	63 13/16	(1621)	K:	28 3/16	(716)
C:	70 5/16	(1786)	G:	40	(1016)	L:	41 3/8	(1051)
D:	30 1/4	(768)	H:	66 1/16	(1678)	M:	63 1/2	(1613)
			I:	73 15/16	(1878)			

Figure 42. Target Geometry, Test No. FLAGT-1

5.4 Simulated Occupant

For test no. FLAGT-1, 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 160 lb. As recommended by MASH, the simulated occupant weight was not included in calculating the c.g. location.

5.5 Data Acquisition Systems

5.5.1 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 [22].

The two systems, the SLICE-1 and SLICE-2 units, were modular data acquisition systems manufactured by Diversified Technical Systems, Inc. (DTS) of Seal Beach, California. The SLICE-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.

5.5.2 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.

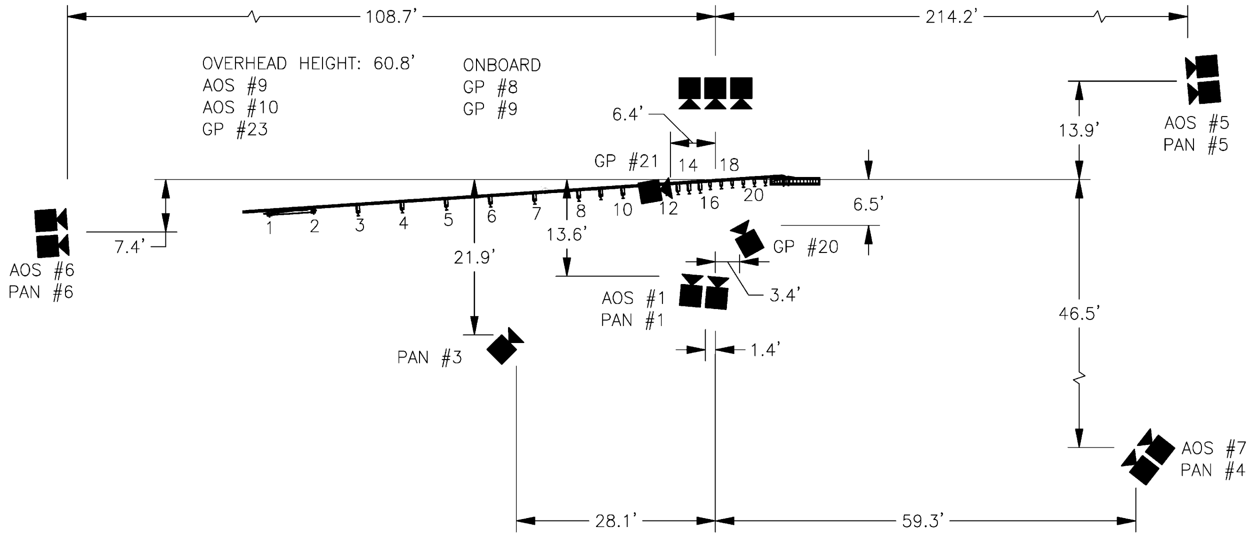
5.5.3 Retroreflective Optic Speed Trap

The retroreflective optic speed trap was used to determine the speed of the test vehicle before impact. Five retroreflective targets, spaced at approximately 18-in. 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 only used as a backup in the event that vehicle speeds cannot be determined from the electronic data.

5.5.4 Digital Photography

Six AOS high-speed digital video cameras, five GoPro digital video cameras, and five Panasonic digital video cameras were utilized to film test no. FLAGT-1. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 43. A digital still camera was also used to document pre- and post-test conditions.

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.



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-1	AOS Vitcam	500	Kowa 25mm	-
AOS-5	AOS X-PRI Gigabit	500	100 mm	-
AOS-6	AOS X-PRI Gigabit	500	Fujinon 50mm	-
AOS-7	AOS X-PRI Gigabit	500	Fujinon 50mm	-
AOS-9	AOS TRI-VIT 2236	1000	Kowa 12mm	-
AOS-10	AOS TRI-VIT 2236	1000	Kowa 16mm	-
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-20	GoPro Hero 6	240		
GP-21	GoPro Hero 6	240		
GP-23	GoPro Hero 7	240		
PAN-1	Panasonic HC-V770	120		
PAN-3	Panasonic HC-V770	120		
PAN-4	Panasonic HC-V770	120		
PAN-5	Panasonic HC-VX981	120		
PAN-6	Panasonic HC-VX981	120		

Figure 43. Camera Locations, Speeds, and Lens Settings, Test No. FLAGT-1

6 FULL-SCALE CRASH TEST NO. FLAGT-1

6.1 Static Soil Test

Before full-scale crash test no. FLAGT-1 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 D, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and full-scale crash testing could be conducted on the barrier system.

6.2 Weather Conditions

Test no. FLAGT-1 was conducted on March 31, 2021 at approximately 2:15 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/KLNK) were reported and are shown in Table 3.

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

Temperature	51° F
Humidity	17 %
Wind Speed	20 mph
Wind Direction	300° from True North
Sky Conditions	Scattered Clouds
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.00 in.

6.3 Test Description

Initial vehicle impact was to occur 93 in. upstream from the upstream edge of the concrete buttress, as shown in Figure 44, which was selected during Phase I of this project using computer simulations to maximize the probability of vehicle snag [5]. The 5,003-lb quad cab pickup truck impacted the 15:1 flared AGT at a speed of 63.2 mph and at an angle of 25.4 degrees relative to the roadway, which corresponded to 29.2 degrees relative to the flared guardrail. The actual point of impact was 90 in. upstream from the edge of the concrete buttress.

The vehicle was contained and redirected by the flared AGT, and the vehicle remained stable throughout the impact event. However, the increased effective impact severity associated with the flared installation resulted in increased system deflections as compared to other MASH TL-3 AGTs. The nested thrie beam kinked at the end of the concrete buttress, and the vehicle snagged on the kink and the buttress as it was being redirected, causing high magnitude decelerations to the vehicle. After exiting the system, the brakes were applied remotely, and the vehicle came to rest approximately 76.6 ft downstream from the upstream end of the concrete buttress and 3.6 ft in front of the system. A detailed description of the sequential impact events is contained in Table 4. Sequential photographs are shown in Figures 45 and 46. Documentary photographs of the crash test are shown in Figures 47 and 48. The vehicle trajectory and final position are shown in Figure 49.

Figure 44. Impact Location, Test No. FLAGT-1

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

TIME (sec)	EVENT
0.000	Vehicle's front bumper contacted rail 3 in. downstream from target impact location.
0.010	Vehicle's right headlight contacted rail.
0.016	Vehicle's right fender contacted rail.
0.020	Vehicle's grille contacted rail.
0.030	Vehicle's hood deformed.
0.036	Post nos. 14 through 18 deflected backward and vehicle yawed away from system.
0.056	Vehicle's right headlight shattered and grille disengaged.
0.060	Post no. 19 deflected backward.
0.066	Vehicle's left fender deformed.
0.070	Vehicle's right-front door contacted rail.
0.078	Post no. 20 deflected backward, vehicle's right-front corner contacted upstream end of concrete buttress.
0.088	Vehicle rolled toward system.
0.098	Post no. 21 deflected backward.
0.118	Vehicle's right-front door deformed. Top of door became ajar. Vehicle's left headlight disengaged.
0.136	Vehicle's windshield cracked and roof deformed.
0.140	Vehicle's right-front door window shattered.
0.144	Vehicle's left-front tire became airborne.
0.152	Vehicle's left-rear tire became airborne.
0.168	Occupant’s head contacted right-front door.
0.192	Vehicle pitched upward.
0.240	Vehicle was parallel to system at a speed of 33.0 mph.
0.317	Vehicle's right quarter panel contacted concrete buttress.
0.432	Vehicle pitched downward, vehicle yawed toward system, and vehicle exited system at a speed of 28.6 mph and an angle of -11 degrees.
0.458	Vehicle's left-front tire regained contact with ground.
3.124	Vehicle came to rest.


0.000 sec


0.100 sec


0.200 sec


0.300 sec


0.400 sec

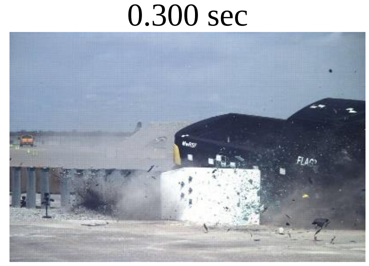

0.600 sec


0.000 sec


0.100 sec

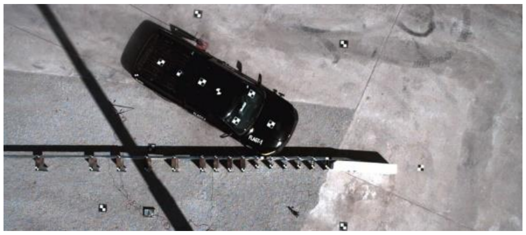

0.200 sec


0.300 sec


0.400 sec


0.600 sec

Figure 45. Sequential Photographs, Test No. FLAGT-1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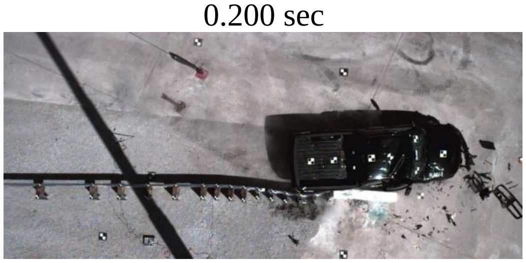
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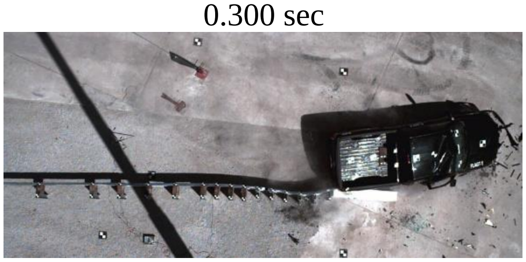
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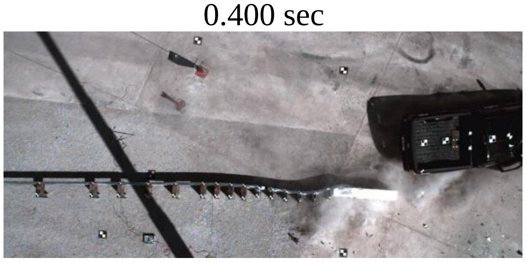
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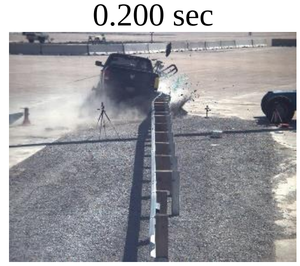
0.200 sec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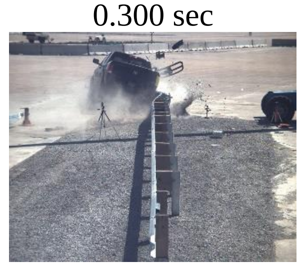
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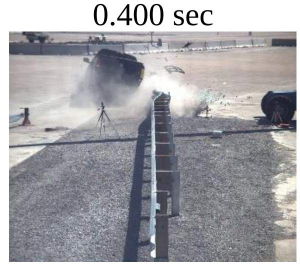
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Figure 46. Additional Sequential Photographs, Test No. FLAGT-1

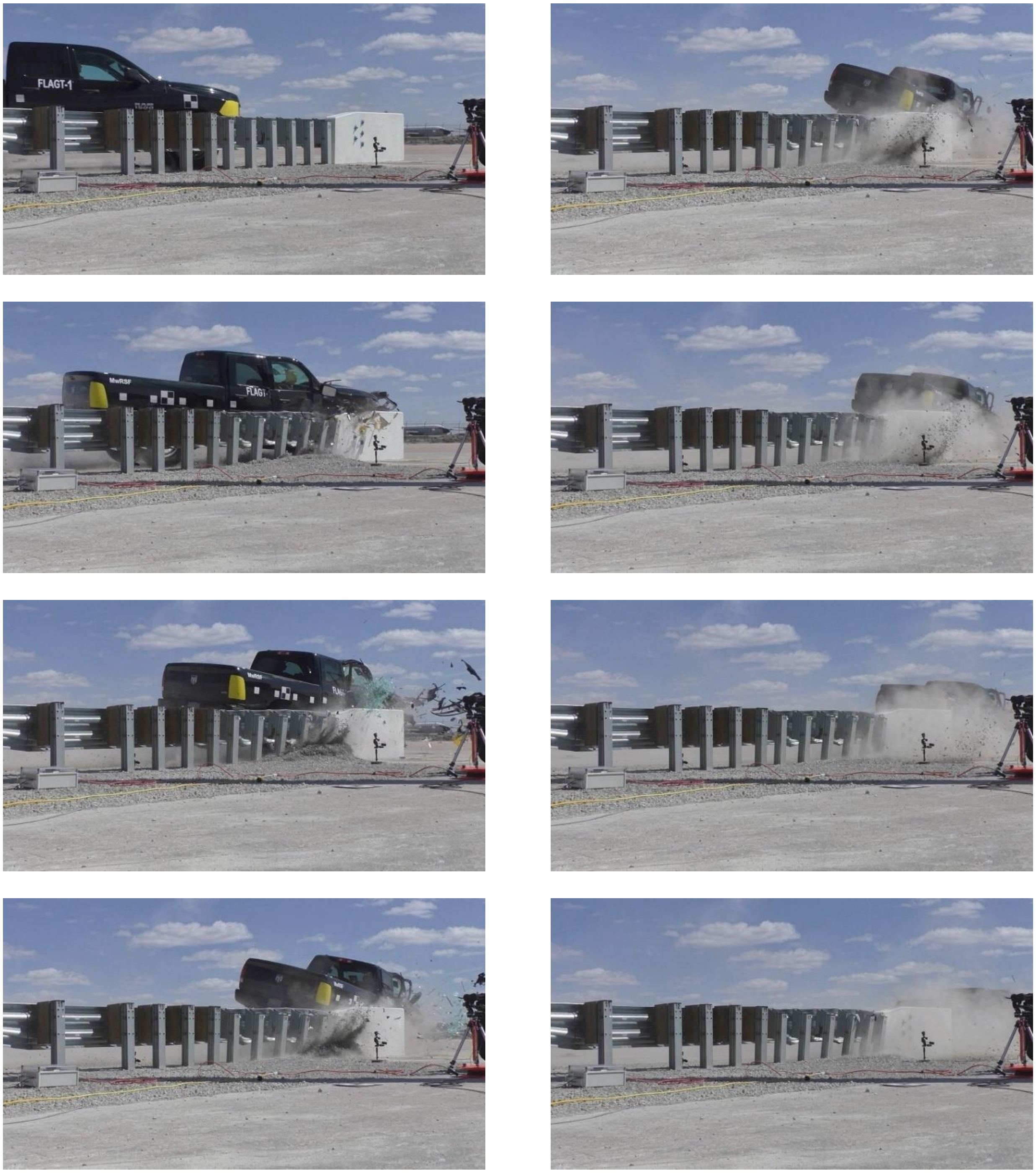


Figure 47. Additional Documentary Photographs, Test No. FLAGT-1

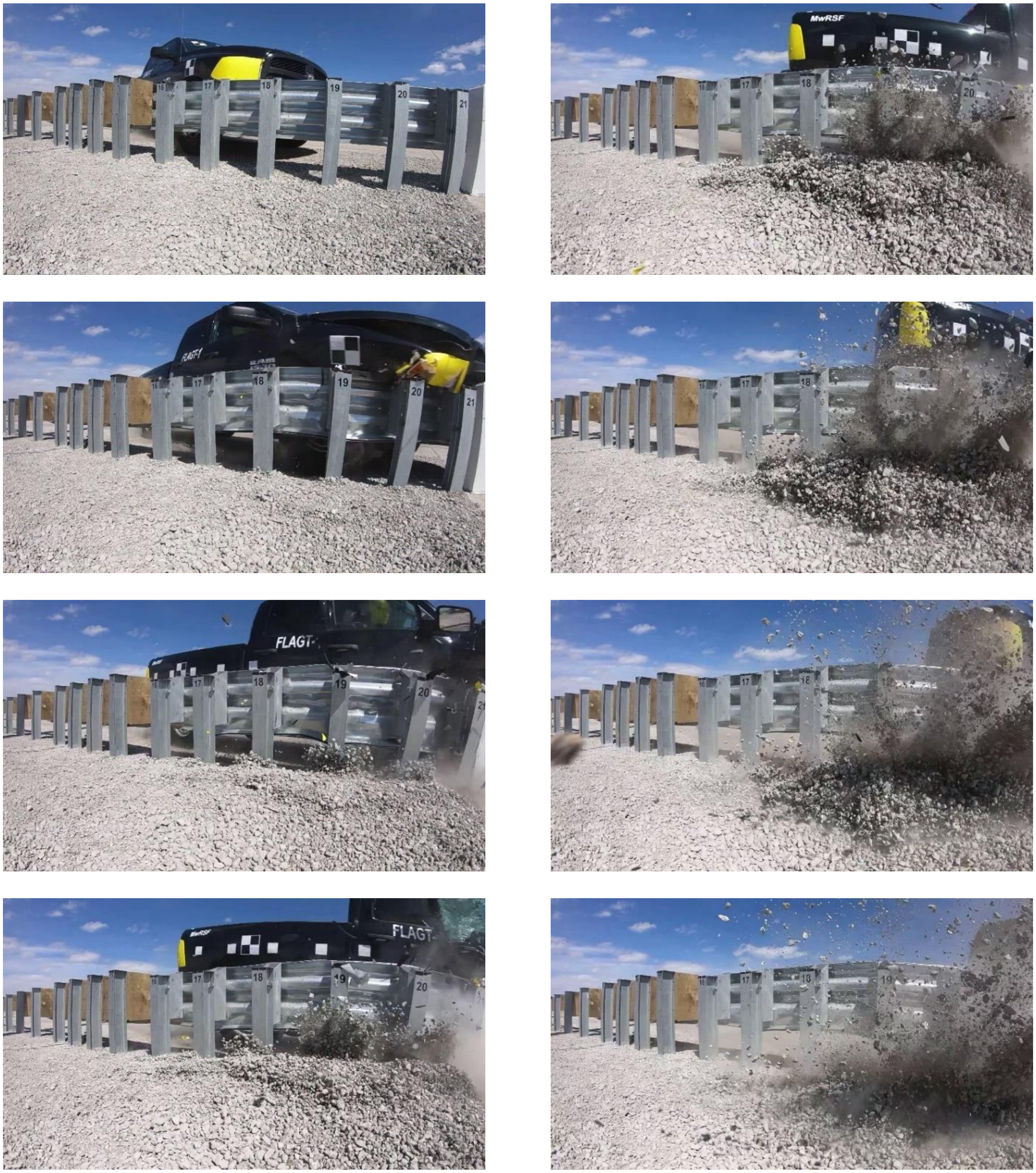


Figure 48. Additional Documentary Photographs, Test No. FLAGT-1

Figure 49. Vehicle Final Position and Trajectory Marks, Test No. FLAGT-1

6.4 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 50 through 54. The overall length of vehicle contact along the barrier was approximately 12 ft – 3 in. and began 10 in. upstream from the center line of post no. 17. Contact marks in this region were found along the face of the thrie-beam rail, the sloped top surface of the concrete buttress, and along the front of the buttress. Additionally, tire marks were observed on the lower taper of the buttress and extended 1½ in. laterally onto the upstream face of the buttress.

Damage to the rail segments consisted of various dents, kinks, gouges, and flattening of the nested thrie beam rails. The majority of the dents and gouges were on the middle corrugation, while the bottom corrugation of the guardrail was flattened beginning at post no. 17. Small kinks were present on the top and bottom corrugations of the guardrail near post nos. 14 through 20. A large kink through the entire cross section of the thrie beam was found at the edge of the concrete buttress.

Post nos. 1 through 15 all twisted slightly to face downstream (toward impact). Post nos. 14 through 21 rotated backward, and a large soil crack had formed along the front flanges of post nos. 17 though 20. The soil crack had a depth of at least 15 in. and maximum width of 4 in. near post no. 19. Various contact marks were observed on the blockouts of post nos. 18 through 20, and localized buckling and deformations were found on the front flanges of post nos. 19 and 20.

Figure 50. System Damage, Test No. FLAGT-1

Figure 51. System Damage, Test No. FLAGT-1

Figure 52. Post Nos. 18 through 21 Damage, Test No. FLAGT-1

Figure 53. Post Nos. 15 through 17 Damage, Test No. FLAGT-1

Figure 54. Soil Gaps, Test No. FLAGT-1

The maximum lateral permanent set of the barrier system was 10.8 in., which occurred in the guardrail between post nos. 19 and 20, as measured in the field. The maximum lateral dynamic barrier deflection was 16.8 in. located at post no. 19, as determined from high-speed digital video analysis. The working width of the system was found to be 36.5 in., determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 55.

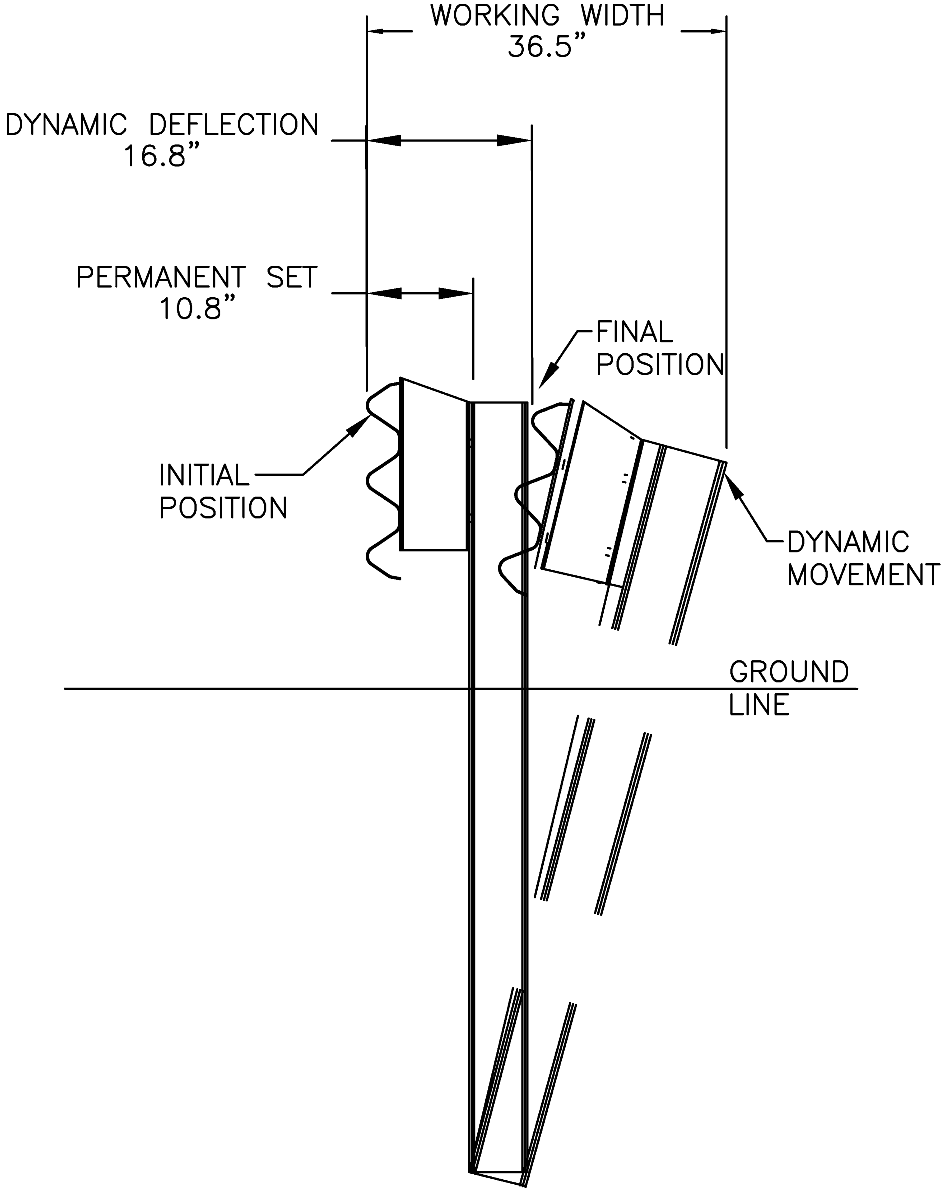


Figure 55. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. FLAGT-1

6.5 Vehicle Damage

The damage to the vehicle was severe, as shown in Figures 56 and 57. Majority of the exterior damage was concentrated on the right-front area of the vehicle where the impact had occurred. The right-front corner of the vehicle and the right-front door were both crushed inward. The grille was disengaged, the right side of the front bumper was crushed inward, and the left side of the bumper was pushed out slightly. The right-front fender panel was completely crushed inward. There were scrapes, dents and gouges present along the entire right side of the vehicle, but they were concentrated on the bottom half of the right-side doors. Both right-side wheels were deflated.

The front right and left front shocks and springs were bent rearward, and the front-right bump stop disengaged. The rear right spring was also disengaged. The sway bar shifted and the right-front steering knuckle was scraped. The right lower control arm disconnected from the cross member, the right tie rod was bent, and the gearbox was cracked. The right side axle tube was bent severely and the engine mounts completely disengaged. The oil pan was punctured and crushed on the right side, and the casting was fractured on the pan.

The chassis of the vehicle was severely deformed around the contact area. The right-side engine cross members were bent backward, and scrapes were found along the right side of the transmission cross member. The right frame horn was completely crushed inward and the left frame horn was facing slightly outward. The windshield was severely cracked due to loading and displacement of the A-pillar, but the windshield remained in place. The front-right window was shattered and disengaged from the vehicle due to contact with the simulated occupant.

The maximum occupant compartment intrusions are listed in Table 5, along with the intrusion limits established in MASH for various areas of the occupant compartment. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix E. MASH defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. Outward deformations, which are denoted as negative numbers in Appendix E, are not considered crush toward the occupant, and are not evaluated by MASH criteria. The maximum occupant compartment deformation was 12.0 in. in the wheel well and toe pan, which exceeded MASH limits. Significant deformations were also observed to the side front panel and the right-side A-pillar, though these deformations did not violate MASH limits.

Figure 56. Vehicle Damage, Test No. FLAGT-1

Figure 57. Vehicle Damage, Undercarriage and Occupant Compartment, Test No. FLAGT-1

Table 5. Maximum Occupant Compartment Intrusion by Location, Test No. FLAGT-1

Location	Maximum Intrusion In.	MASH Allowable Intrusion in.
Wheel Well & Toe Pan	12.0	≤ 9
Floor Pan & Transmission Tunnel	7.8	≤ 12
A-Pillar	4.1	≤ 5
A-Pillar (Lateral)	1.5	≤ 3
B-Pillar	1.8	≤ 5
B-Pillar (Lateral)	1.0	≤ 3
Side Front Panel (in Front of A-Pillar)	8.6	≤ 12
Side Door (Above Seat)	0.0*	≤ 9
Side Door (Below Seat)	2.6	≤ 12
Roof	2.1	≤ 4
Windshield	**	≤ 3
Side Window	Shattered due to contact with simulated occupant's head	No shattering resulting from contact with structural member of test article
Dash	6.0	N/A

*Negative value reported as 0.0. See Appendix E for further information.
**The windshield was cracked and deformed but no intrusion into the cab was present. The right-side A-pillar's inward movement caused the windshield to crush and bow outward. Therefore, no measurements were taken.
N/A – No MASH criteria exist for this location.

6.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 6. Note that the longitudinal ORA measured by the primary accelerometer exceeded MASH limits. The calculated THIV, PHD, and ASI values are also shown in Table 6. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix F.

Table 6. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. FLAGT-1

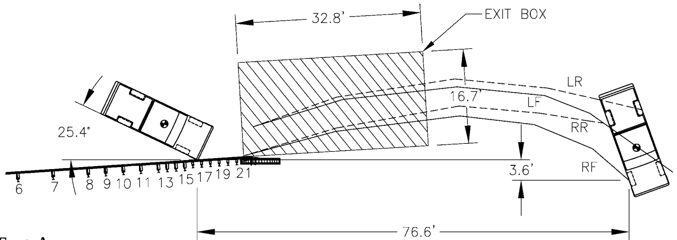
Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (backup)	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-35.62	-29.06	±40
	Lateral	-23.30	-24.12	±40
ORA g's	Longitudinal	-17.22	-24.23	±20.49
	Lateral	-7.68	-12.46	±20.49
Maximum Angular Displacement deg.	Roll	20.9	19.4	±75
	Pitch	-10.2	-11.6	±75
	Yaw	-40.4	-39.6	not required
THIV – ft/s		36.52	36.20	not required
PHD – g's		25.27	30.05	not required
ASI		1.61	1.68	not required

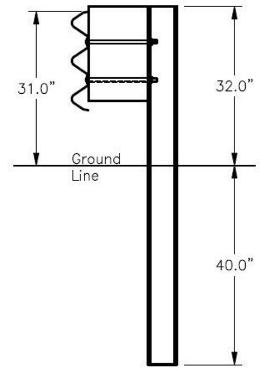
6.7 Discussion

The analysis of test no. FLAGT-1 showed that the system adequately contained and redirected the 2270P vehicle. A summary of the test results and sequential photographs are shown in Figure 58. The test vehicle remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix F, were deemed acceptable. 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. After impact, the vehicle exited the barrier at an angle of -11 degrees, and its trajectory did not violate the bounds of the exit box. Note, exit box criteria is difficult to apply to any longitudinal barrier system that changes direction within the impact region as the face of the system would have multiple tangent lines. However, in Figure 58 the exit box is drawn relative to the flared AGT since the majority of contact was with the AGT.

However, increased system deflections lead to a large kink forming the nested thrie beam at the upstream end of the concrete buttress, and the test vehicle snagged on the kink as it was being redirected. This snag caused excessive vehicle deformation and decelerations. The maximum occupant compartment intrusion measurement at the wheel well and toe pan location of 12.0 in. exceeded the MASH limit of 9 in., and the longitudinal ORA value of -24.23 g's exceeded the MASH limit of ± 20.49 g's. Thus, due to the excessive occupant compartment deformation and longitudinal ORA value, test no. FLAGT-1 was determined to be unacceptable according to the MASH safety performance criteria for test designation no. 3-21.

0.000 sec | 0.100 sec | 0.200 sec | 0.400 sec | 0.600 sec





- Test Agency .... MwRSF
- Test Number FLAGT-1
- Date 3/31/2021
- MASH Test Designation No. 3-21
- Test Article .... 15:1 Flared Approach Guardrail Transition
- Total Length .... 81 ft – $6^{1}/_{16}$ in.
- Key Component – Thrie-Beam Guardrail
  - Thickness .... Nested 12 Gauge
  - Top Guardrail Height .... 31 in.
- Key Component –Steel Post
  - Shape W6x8.5
  - Embedment Posts 3 through 15 .... 40 in.
  - Embedment Posts 16 through 21 .... 49 in.
- Key Component –Buttress
  - Shape .... Standardized Transition Buttress
- Soil Type .... AASHTO M147 Grade B
- Vehicle Make /Model .... 2016 Ram 1500 Quad Cab
  - Curb .... 4,910 lb
  - Test Inertial .... 5,003 lb (5,000 ±110 lb MASH Limit)
  - Gross Static .... 5,163 lb (5,165 ±110 lb MASH Limit)
- Impact Conditions
  - Speed .... 63.2 mph (62 ±2.5 mph MASH Limit)
  - Angle .... 25.4 deg (25±1.5 deg MASH Limit
  - .... 29.2 deg. (relative to flared AGT)
  - Impact Location .... 90 in. upstream from end of the buttress
- Impact Severity .... 122.9 kip-ft > 106 kip-ft limit from MASH
  - Relative to Flared AGT .... 158.9 kip-ft
- Exit Conditions
  - Speed .... 28.6 mph
  - Angle .... 169.3 deg
- Exit Box Criterion .... Pass
- Vehicle Stability .... Pass

Vehicle Stopping Distance .... 76 ft – 7 in. downstream, 3 ft – 7 in. laterally in front

- Vehicle Damage .... Severe
  - VDS [23] 1-RFQ-6
  - CDC [24] 21-FREW-4
  - Maximum Interior Deformation .... 12.0 in. at toe pan > 9-in. MASH limit
- Test Article Damage .... Moderate
- Maximum Test Article Deflections
  - Permanent Set .... 10.8 in.
  - Dynamic .... .16.8 in.
  - Working Width .... 36.5 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH Limits
		SLICE-1	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-35.62	-29.06	±40
	Lateral	-23.30	-24.12	±40
ORA g's	Longitudinal	-17.22	-24.23	±20.49
	Lateral	-7.68	-12.46	±20.49
Maximum Angular Displacement deg.	Roll	20.9	19.4	±75
	Pitch	-10.2	-11.6	±75
	Yaw	-40.4	-39.6	not required
THIV – ft/s		36.52	36.20	not required
PHD – g's		25.27	30.05	not required
ASI		1.61	1.68	not required

Figure 58. Summary of Test Results and Sequential Photographs, Test No. FLAGT-1

7 TEST NO. FLAGT-1 FAILURE ANALYSIS

Test no. FLAGT-1 was determined to be unacceptable according to the safety performance criteria for MASH test designation no. 3-21 for two reasons: (1) the longitudinal ORA of −24.23 g's exceeded the MASH limit of ±20.49 g's, and (2) the 12.0-in. intrusion into the toe pan area of the occupant compartment exceeded the MASH limit of 9 in. After examining all available data for this test, it became evident that both the excessive decelerations and excessive occupant compartment crush were the result of the vehicle snagging on the system during redirection. Recall, a large kink formed in the rail at the upstream end of the concrete buttress. This kink and the rigid buttress located directly behind it were responsible for causing the vehicle snag.

A review of the longitudinal acceleration data showed a high-magnitude spike centered about 95 ms after initial impact. As shown in Figure 59, this spike was well above the accelerations observed during the rest of the impact and a departure from the acceleration observed in previous MASH evaluations of AGTs. Shown in Figure 59, the "AGTB-2" [1] data represents a MASH test designation no. 3-21 impact into the same AGT tested herein, only installed tangent to the roadway (i.e., without a flare), and the "15:1 Simulation" data was taken from the simulation analysis conducted on the 15:1 flared AGT during Phase I of this project [5]. Neither of these previous analyses showed vehicle snagging nor had test curves with high acceleration spikes. At 95 ms into test no. FLAGT-1, the vehicle was in direct contact with the guardrail kink and the upstream end of the concrete buttress, as shown in Figure 60.

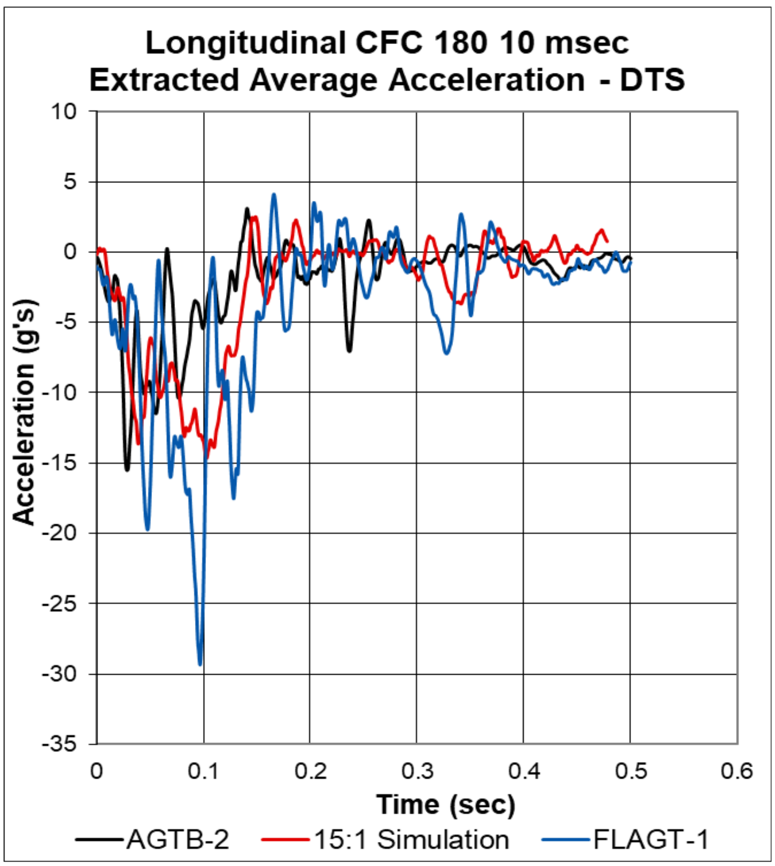


Figure 59. Comparison of Longitudinal CFC 180 10-msec Extracted Average Accelerations

Figure 60. Overhead View of Test No. FLAGT-1, 95 ms after Impact

As noted previously in Section 6.4, tire contact marks were found on the lower taper and upstream end of the concrete buttress. However, this is not uncommon for MASH tests on AGTs with the standardized transition buttress. The amount of lateral overlap of the tire on the buttress in test no. FLAGT-1 was estimated to be 6 in., as measured from the front face of the buttress. This tire overlap fell between two other MASH test designation no. 3-21 tests on tangent AGTs with the standardized transition buttress. Test no. AGTB-2 [1] had 5 in. of tire overlap, while test no. 34AGT-1 [25] had 6.5 in. of tire overlap. This indicated that the wheel snag on the buttress was similar to previous successful MASH tests. Thus, the excessive decelerations and occupant compartment crush were not the result of wheel snag, but instead were caused by the vehicle snagging on the kink and the concrete buttress behind the guardrail.

The large kink that formed in the nested thrie beam was a damage characteristic not observed in previous MASH testing of AGTs. It is believed that excessive guardrail deflections within the nested thrie beam region of the AGT led to the formation of this kink. System deflections were expected to be higher than previous MASH AGTs due to the increase in impact severity associated with the flared guardrail. However, the lateral deflections of the flared AGT in test no. FLAGT-1 were significantly higher than predicted.

The maximum dynamic deflections for each post in the impact region from test no. FLAGT-1 are listed in Table 7 and compared to the deflections in the simulated crash test for the 15:1 flared AGT [5] and test no. AGTB-2 [1], which evaluated a tangent installation of the AGT evaluated herein. The simulation analysis predicted deflection increases of about 1.5 to 2 times the observed post deflections from test no. AGTB-2. However, the dynamic deflections from test no. FLAGT-1 were over 3 times that of the tangent system and over 50 percent higher than the simulation results. Specifically, the maximum dynamic deflection was 3.7 times higher in test no. FLAGT-1 as compared to test no. AGTB-2. These trends were also observed in the permanent set displacements of the AGTs, shown in Table 8.

The unusually high deflections within the AGT posts were also evident by the large soil crack that opened up along the front flanges of the transition posts. This was another damage characteristic not observed in previous successful MASH testing of AGTs. The posts themselves did not plastically bend during the impact, rather, the soil behind the posts shifted and allowed the posts to rotate back to achieve high system deflections. Design changes to increase the post-soil strength and reduce the system deflections may be necessary to create a crashworthy AGT flared at a 15:1 rate. These design changes will be explored in the next phase of the project.

Table 7. Maximum Lateral Dynamic Deflections in AGT Posts

Test	**Maximum Dynamic Deflection (in.)**					
	Post No. 21	Post No. 20	Post No. 19	Post No. 18	Post No. 17	Post No. 16
FLAGT-1 15:1 Flare	4.6	13.1	16.8	10.4	7.2	4.3
Simulation 15:1 Flare	2.4	8.1	10.7	8.8	4.9	2.0
AGTB-2 Tangent	1.4	3.9	4.5	3.9	2.8	1.9

Table 8. Permanent Set Comparison, Test No. FLAGT-1, Simulation, and Test No. AGTB-2

Test	**Permanent Set (in.)**					
	Post No. 21	Post No. 20	Post No. 19	Post No. 18	Post No. 17	Post No. 16
FLAGT-1	4.1	9.3	10.4	8.4	5.1	3.3
Simulation	2.0	7.2	9.2	7.6	4.2	1.6
AGTB-2	1.0	1.6	2.3	2.5	1.9	1.1

8 SUMMARY AND CONCLUSIONS

The main research objective for this project was to develop guidelines for flaring approach guardrail transitions. A critical AGT design, the critical flare rate of 15:1, and critical impact points were identified during Phase I of this project. The research documented in this report focused on the full-scale crash testing and evaluation of the 15:1 flared AGT according to MASH TL-3 criteria. A summary of the test evaluation is shown in Table 9.

In test no. FLAGT-1, the 5,003-lb pickup truck impacted the AGT at a 25.4-degree angle relative to the roadway (29.2 degrees relative to the guardrail) and at a speed of 63.2 mph, resulting in an impact severity of 122.9 kip-ft (158.9 kip-ft relative to the guardrail). The actual impact location was 90 in. upstream from the end of the concrete buttress. The pickup truck was captured and redirected in a stable manner and came to rest 76.6 ft downstream from the buttress after brakes were applied. Permanent set, dynamic deflection, and working width were measured at 10.8 in., 16.8 in., and 36.5 in., respectively.

However, the vehicle toe pan area was crushed inward 12 in., which exceeded the MASH limit of 9 in. for this region of the occupant compartment. Additionally, the longitudinal ORA value of −24.23 g's exceeded the MASH limit of ±20.49 g's. Because of these two factors, test no. FLAGT-1 was deemed unsuccessful according to the safety criteria of MASH.

Detailed evaluation of test no. FLAGT-1 revealed that excessive guardrail deflections resulted in a large kink forming in the nested thrie beam rails at the upstream end of the concrete buttress. The pickup truck snagged on this guardrail kink and the rigid buttress directly behind it, which caused excessive occupant compartment intrusion and decelerations. The flared AGT will need to be redesigned to limit system deflections and create a crashworthy barrier.

Table 9. Summary of Safety Performance Evaluation

<table>
<tr><th>Evaluation Factors</th><th colspan="2">Evaluation Criteria</th><th>Test No. FLAGT-1</th></tr>
<tr><td>Structural Adequacy</td><td>A.</td><td>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="5">Occupant Risk</td><td rowspan="2">D.</td><td>1. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.</td><td>S</td></tr>
<tr><td>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>U</td></tr>
<tr><td>F.</td><td>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.</td><td>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.</td><td>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>U</td></tr>
<tr><td colspan="3">MASH Test Designation No.</td><td>3-21</td></tr>
<tr><td colspan="3">Final Evaluation (Pass or Fail)</td><td>Fail</td></tr>
</table>

S – Satisfactory U – Unsatisfactory NA - Not Applicable

9 REFERENCES

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10 APPENDICES

Appendix A. A2LA Accreditation Certificates

Accredited Laboratory

A2LA has accredited

MIDWEST ROADSIDE SAFETY FACILITY (MwRSF)

Lincoln, NE

for technical competence in the field of

Mechanical Testing

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017 *General requirements for the competence of testing and calibration laboratories*. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (*refer to joint ISO-ILAC-IAF Communiqué dated April 2017*).

AMERICAN ASSOCIATION FOR LABORATORY ACCREDITATION
CORPORATE SEAL 1978 DISTRICT OF COLUMBIA
A2LA

Presented this 12th day of February 2020.

Vice President, Accreditation Services
For the Accreditation Council
Certificate Number 2937.01
Valid to November 30, 2021

For the tests to which this accreditation applies, please refer to the laboratory's Mechanical Scope of Accreditation.

Figure A-1. Midwest Roadside Safety Facility A2LA Accreditation Certificate No. 2937.01

SCOPE OF ACCREDITATION TO ISO/IEC 17025:2017

MIDWEST ROADSIDE SAFETY FACILITY (MwRSF)[1]
University of Nebraska-Lincoln
4630 NW 36th Street
Lincoln, NE 68524
Ms. Karla Lechtenberg Phone: 402 472 9070

MECHANICAL

Valid To: November 30, 2021 Certificate Number: 2937.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following tests:

Tests	**Test Methods[2]**
Full-Scale Vehicle Crash Tests of Highway Safety Features	NCHRP Report 350; MASH; EN 1317
Full-Scale Vehicle Crash Tests of Perimeter Protection Systems and Access Control Devices	ASTM F2656; SD-STD-02.01 Revision A
Bogie Dynamic Tests of Highway Safety Features	Non-Standard Test Method: Dynamic Testing of Steel Post and Rigid Foundation; Non-Standard Test Method: Dynamic Testing of Post in Soil; Non-Standard Test Method: Dynamic Testing of Spacer Blocks
Crushable Nose Bogie Testing for Breakaway Supports	Non-Standard Test Method: Dynamic Testing of Breakaway Supports; AASHTO Breakaway Poles and Supports; NCHRP Report 350

On the following types of products, materials, and/or structures:
Metal, Wood, Concrete and Plastic Structures, Components of Structures, Fasteners, and Roadway Pavements.

[1] Administrative office located at: 2200 Vine Street, 130 Whittier Building, Lincoln, NE 68583-0853.

[2] This laboratory meets A2LA R104 – *General Requirements: Accreditation of Field Testing and Field Calibration Laboratories* for these tests.

(A2LA Cert. No. 2937.01) 02/12/2020 Page 1 of 1

5202 Presidents Court, Suite 220 | Frederick, MD 21703-8515 | Phone: 301 644 3248 | Fax: 240 454 9449 | www.A2LA.org

Figure A-2. Midwest Roadside Safety Facility Scope of Accreditation to ISO/IEC 17025

Appendix B. Material Specifications

Table B-1. Bill of Materials, Test No. FLAGT-1

Item No.	Description	Material Specification	Reference
a1	12'-6" 12-gauge Thrie-Beam Section	AASHTO M180	H#L33120
a2	6'-3" 12-gauge Thrie-Beam Section	AASHTO M180	H#L33720
a3	6'-3" 10-gauge W-Beam to Thrie-Beam Asymmetric Transition Section	AASHTO M180	H#250344
a4	12'-6" 12-gauge W-Beam MGS Section	AASHTO M180	H#C85187
a5	12'-6" 12-gauge W-Beam MGS End Section	AASHTO M180	H#9411949
a6	10-gauge Thrie-Beam Terminal Connector	AASHTO M180 Gr. 50 Min. yield strength=50 ksi Min. ultimate strength=70 ksi	H#833M66260
b1	Concrete - 21.9 cubic ft	Min. f'c = 4,000 psi	Sample #011 Set # FLAGT1,FLAGT2
c1	BCT Timber Post - MGS Height	SYP Grade No. 1 or better (No knots +/- 18" from ground on tension face)	C#2538 P#GS6846
c2	72" Long Foundation Tube	ASTM A500 Gr. B	H#821T08220
c3	Ground Strut Assembly	ASTM A36	H#163375
c4	BCT Cable Anchor Assembly	-	PO#40299 ASPI#122160
c5	Anchor Bracket Assembly	ASTM A36	H#V911470
c6	⅝"x8"x8" Anchor Bearing Plate	ASTM A36	H#4181496
c7	2⅜" O.D. x 6" Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	H#8712810
d1	W6x8.5, 72" Long Steel Post	ASTM A992	H#55066501/03
d2	W6x8.5, 72" Long Steel Post	ASTM A992	H#55066501/03
d3	W6x8.5, 78" Long Steel Post	ASTM A992	H#55068023/02
d4	6"x12"x14" Timber Blockout	SYP Grade No.1 or better	C#1695 P#GR61214
d5	6"x12"x19" Timber Blockout	SYP Grade No.1 or better	C#2580 P#GR61219
d6	17 ½" Long, 7"x4"x$^{3}/_{16}$" Iowa Steel Blockout	ASTM A500 Gr. B	H#Y0521/Y0523

Table B-2. Bill of Materials, Test No. FLAGT-1, Cont.

Item No.	Description	Material Specification	Reference
d7	16D Double Head Nail	-	PO#E000548963 P#97812A109
e1	86" Unbent Length, #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e2	62 ¾" Unbent Length, #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e3	60 ½" Unbent Length, #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e4	59 ¼" Unbent Length, #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e5	74 ¾" Unbent Length, #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e6	37 ¼" Long, #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e7	80 ¼" Unbent Length, #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e8	85 ½" Unbent Length, #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e9	80" Long, #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e10	80 ½" Unbent Length, #4 Rebar	ASTM A615 Gr. 60	H#3600014740
f1	⅝" Dia. UNC, 14" Long Guardrail Bolt	ASTM A307 Gr. A	H#100897520
f2	⅝" Dia. UNC, 10" Long Guardrail Bolt	ASTM A307 Gr. A	H#1721198
f3	⅝" Dia. UNC, 2" Long Guardrail Bolt	ASTM A307 Gr. A	H#20303430
f4	⅝" Dia. UNC, 1 ¼" Long Guardrail Bolt	ASTM A307 Gr. A	H#10634210
f5	⅞" Dia. UNC, 15 ½" Long Heavy Hex Head Bolt	ASTM F3125 Gr. 120 (A325) or A354 Gr. BC	H#3093334
f6	⅞" Dia. UNC, 8" Long Hex Head Bolt	ASTM A307 Gr. A	FASTENAL COC 04/12/2018
f7	⅝" Dia. UNC, 10" Long Hex Head Bolt	ASTM A307 Gr. A	H#JK18104124
f8	⅝" Dia. UNC, 1½" Long Hex Head Bolt	ASTM A307 Gr. A	H#5-01571
g1	⅞" Dia. Plain Round Washer	ASTM F844	L#1844804 PO#170089822
g2	⅝" Dia. Plain Round Washer	ASTM F844	L#20200515 C#000825
g3	3"x3"x¼" or 3½"x3½"x¼" Square Washer Plate	ASTM A572 Gr. 50	H#B9L648

Table B-3. Bill of Materials, Test No. FLAGT-1, Cont.

Item No.	Description	Material Specification	Reference
g4	1" Dia. Plain Round Washer	ASTM F844	PO#210151571 P#33188
h1	5/8" Dia. Heavy Hex Nut	ASTM A563A	H#10640980
h2	5/8" Dia. Hex Nut	ASTM A563A	H#331608011
h3	7/8" Dia. UNC Heavy Hex Nut	ASTM A563DH or A194 Gr. 2H	H#190841
h4	7/8" Dia. Hex Nut	ASTM A563A	H#331704677
h5	1" Dia. Heavy Hex Nut	ASTM A563A	FASTENAL COC 11/29/2018
i1	AGT Connector Face Plate	ASTM A36	H#Y6325
i2	Horizontal Gusset	ASTM A36	H#813L65970
i3	Vertical Gusset 1	ASTM A36	H#813L65970
i4	Vertical Gusset 2	ASTM A36	H#813L65970
i5	Vertical Gusset 3	ASTM A36	H#813L65970
i6	Vertical Gusset 4	ASTM A36	H#813L65970
i7	Vertical Gusset 5	ASTM A36	H#813L65970

Certified Analysis

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

MILFORD, NE 68405
Project: STOCK

Order Number: 1327401 Prod Ln Grp: 0-OE2.0
Customer PO: 3986
BOL Number: 113190 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 8/14/20

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
2	974G	T12/TRANS RAIL/6'3"/3'1.5	M-180	A	2	208675	62,100	81,170	22.7	0.190	0.730	0.012	0.004	0.020	0.090	0.000	0.050	0.001	4
50	980G	T10/END SHOE/SLANT	A-1011			95839	50,900	628,000	35.4	0.060	0.490	0.010	0.001	0.030	0.110	0.000	0.070	0.001	4
1,000	3340G	5/8" GR HEX NUT	FAST			20-42-016													4
450	3500G	5/8"X10" GR BOLT A307	A307-3500			921743-10													4
175	3580G	5/8"X18" GR BOLT A307	A307-3580			32915-G													4
48	12173G	T12/6'3/4@1'6.75"/S			2	L34919													
			M-180	A	2	245021	64,480	83,940	22.2	0.190	0.700	0.013	0.004	0.020	0.060	0.000	0.060	0.001	4
			M-180	A	2	245984	62,860	80,840	26.2	0.190	0.720	0.008	0.003	0.010	0.080	0.000	0.050	0.000	4
95	12365G	T12/12'6/8@1'6.75/S			2	L32520													
			M-180	A	2	251386	62,920	81,060	24.4	0.200	0.720	0.010	0.002	0.020	0.100	0.000	0.070	0.002	4
			M-180	A	2	252079	63,050	81,000	26.3	0.190	0.720	0.015	0.003	0.020	0.130	0.000	0.070	0.002	4
	12365G				2	L33120													
			M-180	A	2	2101328	55,100	80,800	23.0	0.220	0.770	0.008	0.001	0.030	0.070	0.002	0.030	0.004	4
			M-180	A	2	2101329	60,300	84,000	21.0	0.210	0.770	0.010	0.001	0.020	0.070	0.001	0.040	0.000	4
			M-180	A	2	2200763	55,900	80,400	25.0	0.210	0.780	0.008	0.017	0.030	0.100	0.000	0.040	0.002	4
			M-180	A	2	251387	61,400	80,020	24.9	0.200	0.720	0.010	0.003	0.020	0.110	0.000	0.080	0.000	4
			M-180	A	2	252078	62,860	81,150	25.1	0.190	0.720	0.015	0.003	0.020	0.130	0.000	0.070	0.001	4
			M-180	A	2	253966	60,100	79,330	27.0	0.190	0.710	0.011	0.003	0.020	0.120	0.000	0.060	0.002	4
20	32218G	T10/TRAN/TB:WB/ASYM/R	M-180	B	2	42014850	50,000	70,000	28.0	0.040	0.770	0.014	0.001	0.040	0.120	0.000	0.070	0.003	4
20	32219G	T10/TRAN/TB:WB/ASYM/LT	M-180	B	2	248834	59,940	78,890	27.2	0.210	0.720	0.013	0.003	0.020	0.100	0.000	0.050	0.000	4

1 of 2

Figure B-1. 12.5-ft Thrie Beam Guardrail, Test No. FLAGT-1 (Item No. a1)

Certified Analysis

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

MILFORD, NE 68405
Project: STOCK

Order Number: 1328797 Prod Ln Grp: 0-OE2.0
Customer PO: 4006
BOL Number: 113647 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 9/30/20

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
30	261G	T12/25/3'1.5/S			2	L33820													
			M-180	A	2	255300	62,065	80,722	24.9	0.200	0.730	0.008	0.004	0.010	0.060	0.000	0.040	0.002	4
10	738A	5'TUBE SL.188X6X8 1/4 /PL	A-500			823L69130	56,796	75,727	31.0	0.150	0.850	0.013	0.004	0.007	0.017	0.002	0.030	0.001	4
20	749G	TS 8X6X3/16X6'-0" SLEEVE	A-500			A712224	79,860	80,000	25.8	0.050	0.810	0.008	0.002	0.030	0.090	0.000	0.050	0.003	4
12	929G	10/END SHOE/KS/2 EXT			2	L13520													
			M-180	A	2	251391	62.050	80,960	23.0	0.200	0.730	0.011	0.001	0.020	0.100	0.000	0.070	0.000	4
			M-180	A	2	251392	62,580	81,450	21.6	0.190	0.730	0.009	0.003	0.020	0.100	0.000	0.070	0.002	4
			M-180	A	2	253045	67,090	84,510	24.6	0.190	0.720	0.012	0.002	0.020	0.120	0.000	0.070	0.023	4
			M-180	A	2	253236	64,040	81,570	24.1	0.190	0.710	0.014	0.020	0.020	0.110	0.000	0.080	0.000	4
			M-180	A	2	253968	62,900	80,220	25.1	0.190	0.730	0.013	0.002	0.020	0.120	0.000	0.060	0.002	4
			M-180	B	2	253972	62,480	79,220	25.9	0.190	0.730	0.016	0.001	0.020	0.080	0.000	0.080	0.002	4
20	950A	T12/FLARE/12 HOLE ASS'Y			2	L23820													
			M-180	A	2	254834	62,484	81,174	25.8	0.190	0.730	0.010	0.003	0.020	0.120	0.000	0.060	0.001	4
			M-180	A	2	254835	62,594	81,284	23.3	0.190	0.730	0.012	0.005	0.010	0.140	0.000	0.070	0.002	4
			M-180	A	2	254836	65,000	84,343	26.6	0.190	0.720	0.013	0.001	0.020	0.130	0.000	0.070	0.001	4
			M-180	A	2	255522	62,070	79,830	24.9	0.190	0.720	0.010	0.004	0.010	0.100	0.000	0.050	0.002	4
			M-180	A	2	255523	61,380	79,990	22.0	0.200	0.730	0.013	0.003	0.020	0.100	0.000	0.080	0.001	4
			M-180	A	2	255524	62,050	81,610	26.4	0.190	0.730	0.010	0.002	0.010	0.110	0.000	0.050	0.002	4
6	957G	T12/BUFFER/ROLLED	A-36			31847970	48,400	62,300	35.0	0.060	0.450	0.015	0.001	0.030	0.090	0.001	0.070	0.002	4
78	12173G	T12/6'3/4@1'6.75"/S			2	L33720													
			M-180	A	2	254833	62,344	82,251	25.5	0.190	0.720	0.015	0.002	0.020	0.150	0.000	0.070	0.002	4
			M-180	A	2	255300	62,065	80,722	24.9	0.200	0.730	0.008	0.004	0.010	0.060	0.000	0.040	0.002	4
	12173G				2	L34919													

1 of 3

Figure B-2. 6.25-ft Thrie Beam Guardrail, Test No. FLAGT-1 (Item No. a2)

Universal Industrial Sales

PO Box 699 - Pleasant Grove, UT 84062
Phone (801) 785-0505
www.uisutah.com

Material Certificate Of Compliance

Page 1/1

Order Number: **78327** Date: 12/08/20 Customer PO Number: **FLAGT**

Customer:	Ship To:
University of Nebraska Lincoln	**University of Nebraska Lincoln**
PO Box 880439	Midwest Roadside Safety Facility
	4630 NW 36 ST
Lincoln NE 68588-0439	Lincoln NE 68524

Project ID: Transitions
Project Description:
(GR) Nebraska

Line #	QTY	Units	Description
1	4	EACH	10 / 6'-3 / 3'-1 1/2" Transition A Sym. Left (IMH # RWT-ALbB-Leading)

This is to certify that the materials shipped meet the requirements of the above Contract Specifications and Special Provisions. Guardrail meets the requirements of AASHTO M-180, Type I, II, III, or IV as stamped. Steel Posts meet the requirements of AASHTO M-270 / M-183, ASTM A992-06a: A36 and are Galvanized per ASTM A-123 OR Steel Posts meet the requirements of ASTM A588 (if required per Contract Specifications). Anchor Cable meets the requirements of ASTM 741-11, AASHTO M30. Hardware meets the requirement of AASHTO M-180, ASTM A-307 and/or A-325 or A449 per contract requirements. Galvanized per ASTM A-153. All Structural Steel conforms to AASHTO M-270 / M-183 and the Buy America Act 23 CFR 635.410. All other Galvanized Materials conform to ASTM A-123 or ASTM A-153. The materials covered by this certification conform to the requirements specified in the contract documents. The individual signing has the legal authority to bind the manufacturer or supplier of material.

STATE OF UTAH, COUNTY OF UTAH
Sworn and Subscribed before me

by Scott Turner
this 16 day of Dec, 20 20

ROBERT JON McDONALD
NOTARY PUBLIC•STATE OF UTAH
COMMISSION# 713304
COMM. EXP. 08-06-2024

Notary Public

Universal Industrial Sales, Inc.

BY
Quality Control

Sign Structures, Bridge Rail, Steel Fabrication, Anchor Bolts, Highway Construction Products

Figure B-3. 10-ga. W-to-Thrie Transition Segment, Test No. FLAGT-1 (Item No. a3)

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

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

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

HT # code	Heat #	C.	MN.	P.	S.	Si.	Tensile	Yield	Elong.	Quanity	Class	Type	Description
1207	C85187	0.2	0.48	0.008	0.003	0.03	80433	59371	16.35	150	A	2	12GA 12FT6IN/3FT1 1/2IN WB T2

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

By: Jeffery L. Grover
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 B-4. 12.5-ft W-beam Guardrail, Test No. FLAGT-1 (Item No. a4)

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

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

Test Report
Ship Date: 7/9/2015
Customer P.O.: 4500274709/ 07/07/2015
Shipped to: UNIVERSITY OF NEBRASKA-LINCOLN
Project: TESTING COIL
GHP Order No.: 183306

HT # code	Heat #	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
8534	9411949	0.21	0.75	0.01	0.006	0.01	75774	56527	27.15	10	A	2	12GA 25FT WB T2 MGS ANCHOR PANEL
8534	9411949	0.21	0.75	0.01	0.006	0.01	75774	56527	27.15	100	A	2	12GA 12FT6IN/3FT1 1/2IN WB T2
8534	9411949	0.21	0.75	0.01	0.006	0.01	75774	56527	27.15	20	A	2	12GA 25FT0IN 3FT1 1/2IN WB T2

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

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

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

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

Figure B-5. 12.5-ft W-beam End Section, Test No. FLAGT-1 (Item No. a5)

[illegible]
ROADWAY CONSTRUCTION PRODUCTS
511 WEST MAIN STREET
CLARKSON KY 42726

[illegible]
ROADWAY CONSTRUCTION PRODUCTS
511 WEST MAIN STREET
CLARKSON KY 42726

Tel: 570-365-4875 Fax: 270-242-9288

CERTIFICATE of ANALYSIS and TESTS

Cert No: 197130
020120

Part No G10046BS
Hot Roll Sheet GR50
10GA. .1270 Min X 51.0000" X 92.0000"

Pcs	Wgt
264	47,420

YIELD=50,000 PSI MIN
TENSILE= 70,000 PSI MIN
P= .02 MAX
SI= .04 MAX
C= .26 MAX
S= .05 MAX
DRY MATERIAL SUITABLE FOR GALVANIZING

Heat Number	Tag No	Pcs	Wgt
833M66260	506876 YLD=<66600>/TEN=<74800>/ELG=<29>	28	5,030
833M66260	506877 YLD=<66600>/TEN=<74800>/ELG=<29>	28	5,030
833M66260	506878 YLD=<66600>/TEN=<74800>/ELG=<29>	28	5,030
833M66260	506879 YLD=<66600>/TEN=<74800>/ELG=<29>	28	5,030
833M66260	506880 YLD=<66600>/TEN=<74800>/ELG=<29>	28	5,030
833M66260	506881 YLD=<66600>/TEN=<74800>/ELG=<29>	28	5,030
833M66260	506882 YLD=<66600>/TEN=<74800>/ELG=<29>	28	5,030
833M66260	506883 YLD=<66600>/TEN=<74800>/ELG=<29>	28	5,030
833M66260	506884 YLD=<66600>/TEN=<74800>/ELG=<29>	25	4,490
	506885 YLD=<66600>/TEN=<74800>/ELG=<29>	15	2,690

Heat Number *** Chemical Analysis ***
Arcelor Mittal Steel
833M66260 C=<.06> Mn=<.82> P=<.015> S=<.005> Si=<.029> Al=<.034> Cu=<.019>
Mo=<.006> V=<.001> Cb=<.042> N=<.004> Cr=<.03> Ni=<.01>
Ti=<.002> B=<.0002> Origin=<USA> Manufac=<USA>

PROCESSED IN USA

Figure B-6. 10-ga Thrie Beam Terminal Connector, Test No. FLAGT-1 (Item No. a6) benesch

Page 1 of 1

Concrete Sample Test Report
Cylinder Compressive Strength

Project Name:	Midwest Roadside Safety - Misc Testing
Project Number:	00110546.00
Client:	Midwest Roadside Safety Facility
Location:	MNPD
Sample:	011
Description:	FLAGT

Field Data (ASTM C172, C143, C173/C231, C138, C1064)

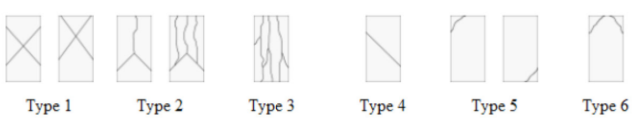
		Property	Test Result
Supplier:		Slump (in):	
Mix Name:		Air Content (%):	
Ticket Number:		Unit Weight (lb/ft³):	
Truck Number:		Air Temp (°F):	
Load Volume (yd³):		Mix Temp (°F):	
Mold Date:	12/16/2020	Min Temp (°F):	
Molded By:		MaxTemp (°F):	
Initial Cure Method:			

Laboratory Test Data (ASTM C39)

Sample Number:	011	011				
Set Number:	FLAGT1	FLAGT2				
Specimen Number:	1	1				
Age:	20	20				
Length (in):	8	12				
Diameter (in):	3.99	5.98				
Area (in²):	12.50	28.09				
Test Date:	01/05/2021	01/05/2021				
Break Type:	3	5				
Max Load (lbf):	72,045	142,222				
Strength (psi):	5,760	5,060				
Spec Strength (psi):						

Remarks:
Average 20-day Compressive Strength (psi): **5,410**

Date received: 01/05/2021
Curing: [x] Standard [ ] Field
ASTM C511
Submitted by: Matt Roesler



Distribution:

Report Date: 1/5/21

This report shall not be reproduced, except in full, without prior approval of Alfred Benesch & Company. Results relate only to items tested.

825 M Street Suite 100
Lincoln, NE 68508

Alfred Benesch & Company

Figure B-7. Buttress Concrete, Test No. FLAGT-1 (Item No. b1)

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

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

CERTIFICATE OF COMPLIANCE

Shipped To: Midwest Machinery and Supply
BOL# N32346
Customer PO# 3988
Preservative: CCA - C 0.60D pcf AWPA UC4B

Part #	Physical Description	# Pieces	Charge #	Retention
GS6846 PST	5.5x7.5-46" BCT	42	2538	.716
GR6819 BLK	6x8-19" Block	84	2580	.632

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

9/21/20
Date

GENERAL NOTARY-State of Nebraska
LINDA L. SCHROETLIN
My Comm. Exp. May 20, 2024

Figure B-8. BCT Timber Posts, Test No. FLAGT-1 (Item No. c1)

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

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

MILFORD,NE,68405

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

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

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

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

Figure B-9. BCT Foundation Tube, Test No. FLAGT-1 (Item No. c2)

Certified Analysis

Trinity Highway Products, LLC
550 East Robb Ave.
Lima, OH 45801
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: STOCK

Order Number: 1214903 Prod Ln Grp: 9-End Terminals (Dom)
Customer PO: 2878
BOL Number: 80278 Ship Date:
Document #: 1
Shipped To: NE
Use State: KS

As of: 3/7/14

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
36	749G	TS 8X6X3/16X6'-0" SLEEVE	A-500			0173175	55,871	74,495	31.0	0.160	0.610	0.012	0.009	0.010	0.030	0.000	0.030	0.000	4
20	3000G	CBL 3/4X6'6/DBL	HW			98790													
22	9852A	STRUT & YOKE ASSY	A-1011-SS			163375	48,380	64,020	32.9	0.190	0.520	0.011	0.003	0.030	0.110	0.000	0.050	0.000	4
	9852A		A-36			11237730	45,500	70,000	30.0	0.170	0.500	0.010	0.008	0.020	0.080	0.000	0.070	0.001	4

Ground Strut Green Paint
R#15-0157 September 2014 SMT

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.
ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT"
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A123 & ISO 1461 (INTERNATIONAL SHIPMENTS)
FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 46000 LB

Figure B-10. Strut and Yoke Assembly, Test No. FLAGT-1 (Item No. c3)

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: September 24, 2018

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 #: 40299

DATE SHIPPED: 09/24/18

ASPI SALES ORDER #: 122160

MANUFACTURER: ASSEMBLY SPECIALTY PRODUCTS, INC.

QTY	CUST P/N	ASPI P/N	ASPI LOT#	DESCRIPTION
250	3012G	C-2028	89315	6' 6" BCT Cable Assembly
250	3012G	C-2028	89316	6' 6" BCT Cable Assembly
250	3012G	C-2028	89318	6' 6" BCT Cable Assembly
250	3012G	C-2028	89864	6' 6" BCT Cable Assembly
250	3012G	C-2028	89865	6' 6" BCT Cable Assembly
250	3012G	C-2028	89866	6' 6" BCT Cable Assembly
250	3012G	C-2028	89929	6' 6" BCT Cable Assembly
250	3012G	C-2028	89930	6' 6" BCT Cable Assembly
250	3012G	C-2028	89931	6' 6" BCT Cable Assembly
250	3012G	C-2028	89932	6' 6" BCT Cable Assembly

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: [signature]
Certification and Compliance Manager

Figure B-11. BCT Anchor Cable Assembly, Test No. FLAGT-1 (Item No. c4)

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: RESALE

Order Number: 1145215
Customer PO: 2441
BOL Number: 61905
Document #: 1
Shipped To: NE
Use State: KS

Asof: 4/15/11

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Va	ACW
10	206G	T12/6'3/S	M-180	A	2	140734	64,240	82,640	26.4	0.190	0.740	0.015	0.006	0.010	0.110	0.00	0.060	0.000	
			M-180	A	2	139587	64,220	81,750	28.5	0.190	0.720	0.014	0.003	0.020	0.130	0.000	0.060	0.002	
			M-180	A	2	139588	63,850	82,080	24.9	0.200	0.730	0.012	0.004	0.020	0.140	0.000	0.050	0.003	
			M-180	A	2	139589	55,670	74,810	27.7	0.190	0.720	0.012	0.003	0.020	0.130	0.000	0.060	0.002	
			M-180	A	2	140733	59,000	78,200	28.1	0.190	0.740	0.015	0.006	0.010	0.120	0.000	0.070	0.001	
55	260G	T12/25/6'3/S	M-180	A	2	139588	63,850	82,080	24.9	0.200	0.730	0.012	0.004	0.020	0.140	0.00	0.050	0.000	
			M-180	A	2	139206	61,730	78,580	26.0	0.180	0.710	0.012	0.004	0.020	0.140	0.000	0.050	0.001	
			M-180	A	2	139587	64,220	81,750	28.5	0.190	0.720	0.014	0.003	0.020	0.130	0.000	0.060	[illegible]	
			M-180	A	2	140733	59,000	78,200	28.1	0.190	0.740	0.015	0.006	0.010	0.120	0.000	0.070	0.001	
			M-180	A	2	140734	64,240	82,640	26.4	0.190	0.740	0.015	0.006	0.010	0.110	0.000	0.060	[illegible]	
	260G		M-180	A	2	140734	64,240	82,640	26.4	0.190	0.740	0.015	0.006	0.010	0.110	0.00	0.060	0.000	
			M-180	A	2	139587	64,220	81,750	28.5	0.190	0.720	0.014	0.003	0.020	0.130	0.000	0.060	0.002	
			M-180	A	2	139588	63,850	82,080	24.9	0.200	0.730	0.012	0.004	0.020	0.140	0.000	0.050	[illegible]	
			M-180	A	2	139589	55,670	74,810	27.7	0.190	0.720	0.012	0.003	0.020	0.130	0.000	0.060	[illegible]	
			M-180	A	2	140733	59,000	78,200	28.1	0.190	0.740	0.015	0.006	0.010	0.120	0.000	0.070	[illegible]	
26	701A	.25X11.75X16 CAB ANC	A-36			V911470	51,460	71,280	27.5	0.120	0.800	0.015	0.030	0.190	0.300	0.00	0.090	0.023	4
	701A		A-36			N3540A	46,200	65,000	31.0	0.120	0.380	0.010	0.019	0.010	0.180	0.00	0.070	0.001	4
24	729G	TS 8X6X3/16X8'-0" SLEEVE	A-500			N4747	63,548	85,106	27.0	0.150	0.610	0.013	0.001	0.040	0.160	0.00	0.160	0.004	
24	749G	TS 8X6X3/16X6'-0" SLEEVE	A-500			N4747	63,548	85,106	27.0	0.150	0.610	0.013	0.001	0.040	0.160	0.00	0.160	0.004	
22	782G	5/8"X8"X8" BEAR PL/OF	A-36			18486	49,000	78,000	25.1	0.210	0.860	0.021	0.036	0.250	0.260	0.00	0.170	0.014	
25	974G	T12/TRANS RAIL/6'3"/3'1.5	M-180	A	2	140735	61,390	80,240	27.1	0.200	0.740	0.014	0.005	0.010	0.120	0.00	0.070	0.001	

Figure B-12. Anchor Bracket, Test No. FLAGT-1 (Item No. c5)

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		78000	74000	25			2	350 STRUT & YOKE
E22985		0.17	0.51	0.013	0.008	0.008	72510	64310	29.5	4		2	2IN X 5 1/2IN PIPE SLEEVE
811T08220		0.22	0.81	0.013	0.006	0.005	71412	56323	35	8		2	3/16IN X 6IN X 8IN X 6FT0IN TUBE SLEEVE

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

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

By: ____________

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

Notary Public, State of Ohio

Figure B-13. Anchor Bearing Plate, Test No. FLAGT-1 (Item No. c6)

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

Steel Tube Institute

Page : 3 Of 4

Metals Service Center Institute

Figure B-14. BCT Post Sleeve, Test No. FLAGT-1 (Item No. c7)

GERDAU

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

CERTIFIED MATERIAL TEST REPORT — Page 1 / 1

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
HIGHWAY SAFETY CORP 473 W FAIRGROUND ST MARION,OH 43302-1701 USA	HIGHWAY SAFETY CORP GLASTONBURY,CT 06033-0358 USA	A992/A709-36	Wide Flange Beam / 6 X 8.5# / 150 X 13.0	0000320239

LENGTH	PCS	WEIGHT	HEAT / BATCH
42'00"	105	37,485 LB	55066501/03

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
8525742/000060		ASTM A6-17 ASTM A709-17 ASTM A992-11 (2015) CSA G40.21-13 345WM

IB-B0600800
1832176

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
1832	1323-0000156951	05/08/2020

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %
0.11	0.82	0.015	0.027	0.21	0.29	0.17	0.18	0.048	0.008	0.002	0.009

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	Y/T rati %	Elong. %
62200	77000	429	531	0.810	23.40
61000	78400	421	541	0.780	24.40

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 B-15. 6-ft W6x8.5 Posts, Test No. FLAGT-1 (Item Nos. d1 and d2)

GERDAU

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

CERTIFIED MATERIAL TEST REPORT — Page 1 / 1

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
HIGHWAY SAFETY CORP 473 W FAIRGROUND ST MARION,OH 43302-1701 USA	HIGHWAY SAFETY CORP GLASTONBURY,CT 06033-0358 USA	A36/A709/A992G	Wide Flange Beam / 6 X 8.5# / 150 X 13.0	0000347199

LENGTH	PCS	WEIGHT	HEAT / BATCH
39'00"	126	41,766 LB	55068023/02

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
9070390/000170	8/6 GA	ASTM A6-17, A36-14 ASTM A709-17 ASTM A992-11 (2015), A572-15 CSA G40.21-13 345WM, 50W

1852216
IB-B0600800

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
1852	1323-0000163828	08/26/2020

CHEMICAL COMPOSITION

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cu (%)	Ni (%)	Cr (%)	Mo(%)	Sn (%)	V (%)	Nb (%)
0.12	0.81	0.010	0.019	0.19	0.33	0.10	0.11	0.029	0.009	0.001	0.007

MECHANICAL PROPERTIES

YS 0.2% (PSI)	UTS (PSI)	YS (MPa)	UTS (MPa)	Y/T rati (%)	G/L (Inches)	Elong. (%)
59800	76500	412	527	0.780	8.000	25.30
59900	76600	413	528	0.780	8.000	26.40

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 B-16. 6.5-ft W6x8.5 Posts, Test No. FLAGT-1 (Item No. d3)

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# N26219
Customer PO# 3930
Preservative: CCA – C 0.60D pcf AWPA UC4B

Part #	Physical Description	# Pieces	Charge #	Retention
6117b	6x8-6.5′ CRT	35	1413	.626
GR6814 BLK	6x8-14″ OCD Block	126	1696	.621
GR61214 BLK	6x12-14″ OCD Block	168	1695	.625
GR61222 BLK	6x12-22″ OCD Block	168	1695	.625

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

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

Nick Sowl, General Counsel

4/1/20
Date

Figure B-17. 6-in. x 12-in. x 14-in. Timber Blockout, Test No. FLAGT-1 (Item No. d4)

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# N32346
Customer PO# 3988
Preservative: CCA – C 0.60D pcf AWPA UC4B

Part #	Physical Description	# Pieces	Charge #	Retention
GS6846 PST	5.5x7.5-46" BCT	42	2538	.716
GR6819 BLK	6x8-19" Block	84	2580	.632

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

9/21/20
Date

GENERAL NOTARY-State of Nebraska
LINDA L. SCHROETLIN
My Comm. Exp. May 20, 2024

Figure B-18. 6-in. x 12-in. x 19-in. Timber Blockout, Test No. FLAGT-1 (Item No. d5)

CERTIFICATE OF TEST

Page 01 of 02

Certification Date
8-MAY-2020

CUSTOMER ORDER NUMBER
50375

CUSTOMER PART NUMBER
0001 121076

EARLE M. JORGENSEN COMPANY
1800 N UNIVERSAL AVENUE
KANSAS CITY MO 64120

Invoice Number
S719292

SOLD TO: RIVERS METAL PRODUCTS
3100 N 38TH
LINCOLN NE 68504

SHIP TO: RIVERS METAL PRODUCTS
3100 NORTH 38TH
LINCOLN NE 68504

Description: ASTM A500 GR B
4 X 7 X .188 WALL X 24'
HEAT: Y0521/Y0523 ITEM: 121076

Line Total: 48 FT

Specifications:
ASTM A500 GR B 18 C

CHEMICAL ANALYSIS

C	MN	P	S	SI	AL	CU	CB
0.19	0.64	0.012	0.01	0.02	0.039	0.13	0.001

MO	NI	CR	V	TI	CE	CA
0.01	0.04	0.07	0.002	0.002	0.0029	0.0029

C	MN	P	S	SI	AL	CU	CB
0.19	0.62	0.014	0.01	0.01	0.038	0.13	0.001

MO	NI	CR	V	TI	N	CA	CE
0.01	0.05	0.08	0.002	0.002	0.006	0.003	0.33

RCPT: R858184
VENDOR: ATLAS TUBE COUNTRY OF ORIGIN : USA

MECHANICAL PROPERTIES

DESCRIPTION	YLD STR PSI	ULT TEN PSI	%ELONG IN 02 IN	%RED IN AREA	HARDNESS
	57688.0	74730.0	29.0		
	54794.0	73439.0	31.0		

The above data were transcribed from the manufacturer's Certificate of Test after verification for completeness and specification requirements of the information on the certificate. All test results remain on file subject to examination.

We hereby certify that the material covered by this report will meet the applicable requirements described herein, including any specification forming a part of the description.

The willful recording of false, fictitious, or fraudulent statements in connection with test results may be punishable as a felony under federal statutes.

Material did not come in contact with mercury while in our possession.

LARRY BUSICK

Larry A. Busick

Manager, Quality Assurance

Figure B-19. HSS4x7x$^{3}/_{16}$ Steel Blockout, Test No. FLAGT-1 (Item No. d6)

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 B-20. 16D Nail, Test No. FLAGT-1 (Item No. d7)

NUCOR

Mill Certification
09/02/2020

MTR#:458890-2
Lot #:360001474020
ONE NUCOR WAY
BOURBONNAIS, IL 60914 US
815 937-3131
Fax: 815 939-5599

Sold To: SIMCOTE INC
1645 RED ROCK RD
ST PAUL, MN 55119 US

Ship To: SIMCOTE INC
1645 RED ROCK RD
ST PAUL, MN 55119 US

Customer PO	MN-3748	Sales Order #	36013225 - 1.31
Product Group	Rebar	Product #	2110206
Grade	A615 Gr 60/AASHTO M31	Lot #	360001474020
Size	#4	Heat #	3600014740
BOL #	BOL-567414	Load #	458890
Description	Rebar #4/13mm A615 Gr 60/AASHTO M31 60' 0" [720"] 6001-10000 lbs	Customer Part #	
Production Date	08/12/2020	Qty Shipped LBS	22725
Product Country Of Origin	United States	Qty Shipped EA	567
Original Item Description		Original Item Number	

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

Melt Country of Origin : United States — Melting Date: 08/07/2020

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Nb (%)
0.34	0.90	0.015	0.043	0.198	0.18	0.23	0.06	0.40	0.012	0.002

Other Test Results
Yield (PSI) : 66100 — Tensile (PSI) : 99200 — Average Deformation Height (IN) : 0.036
Elongation in 8" (%) : 14.5 — Bend Test : Pass — Weight Percent Variance (%) : -4.00

Comments:

All manufacturing processes of the steel materials in this product, including melting, have occurred within the United States. Products produced are weld free. Mercury, in any form, has not been used in the production or testing of this material.

Figure B-21. #4 Rebar, Test No. FLAGT-1 (Item Nos. e1 through e10)

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: 200208

SHIPPER #: 067063
DATE SHIPPED: 08/21/2019

LOT#: 32086-B

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE: SPEC: 60,000 psi*min RESULTS: 74,700
74,000

HARDNESS: 100 max 89.20
88.60

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
AZZ GALVANIZING: 32086-B

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
NUCOR	1010	100897520	.11	.51	.012	.007	.18

10,650 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

20th DAY OF August 2019
Merry F Shane

Linda McLomas
APPROVED SIGNATORY

8/20/19
DATE

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

Figure B-22. ⅝-in. x 14-in. Guardrail Bolt, Test No. FLAGT-1 (Item No. f1)

CERTIFICATE OF COMPLIANCE

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

CUSTOMER NAME: GREGORY INDUSTRIES

CUSTOMER PO: 39864

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

LOT#: 30920-B

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE:	SPEC:	60,000 psi*min	RESULTS:	79,300 76,800
HARDNESS:		100 max		90.00 90.80

*Pounds Per Square Inch.

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

CHEMICAL COMPOSITION

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

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

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

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS

31st DAY OF May, 20 18

Merry F Shane

Linda McTomas
APPROVED SIGNATORY

5/31/18
DATE

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

Figure B-23. ⅝-in. x 10-in. Guardrail Bolt, Test No. FLAGT-1 (Item No. f2)

5/8"x2" Splice Bolt
AGT Buttress
R#16-0009 L#140812B H#20303430
July 2015 SMT

3400G

TRINITY HIGHWAY PRODUCTS, LLC
425 East O'Connor Ave.
Lima, Ohio 45801
419-227-1296

MATERIAL CERTIFICATION

NOV 2 1 2014
PASSED & CERTIFIED

Customer: Stock

Date: November 20,2014

Invoice Number:

Lot Number: 140812B

Part Number: 3400G

Quantity: 118,821

Description: 5/8" x 2" G.R. Bolt

Heat Number(s): 20303430 | 118821

Specification: ASTM A307-A / A153 / F2329

MATERIAL CHEMISTRY

Heat	C	MN	P	S	SI	NI	CR	MO	CU	SN	V	AL	N	B	TI	NB
20303430	.08	.34	.007	.002	.06	.04	.05	.02	.08	.005	.001	.032	.009	.0001	.001	.001

PLATING OR PROTECTIVE COATING

HOT DIP GALVANIZED (Lot Ave.Thickness / Mils) 2.55 (2.0 Mils Minimum)

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

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

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

TRINITY HIGHWAY PRODUCTS LLC

STATE OF OHIO, COUNTY OF ALLEN
SWORN AND SUBSCRIBED BEFORE ME THIS 20th day of Nov 2014

Sherri Braun NOTARY PUBLIC

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

SHERRI BRAUN
Notary Public, State of Ohio
My Commission Expires
April 20, 2019

Figure B-24. ⅝-in. x 2-in. Guardrail Bolt, Test No. FLAGT-1 (Item No. f3)

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: 203160

SHIPPER #: 068184
DATE SHIPPED: 02/06/2020

LOT#: 32539-P

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE: SPEC: 60,000 psi*min RESULTS: 69,000 69,300

HARDNESS: 100 max 68.60 68.30

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
AZZ GALVANIZING: 32539-P

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
CHARTER STEEL	1010	10634210	.10	.52	.008	.009	.08

QUANTITY AND DESCRIPTION:

12,000 PCS 5/8" X 1.25" GUARD RAIL BOLT
P/N 3360G

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

5th DAY OF February 20 20 — Linda McLomas — 2/5/2020

APPROVED SIGNATORY — DATE

Merry F Shane

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

Figure B-25. ⅝-in. x 1¼-in. Guardrail Bolt, Test No. FLAGT-1 (Item No. f4)

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#: 136724
Cust PO#: FL AGT ITEM#F5/H
Date: 11/13/2020
Shipped: 11/16/2020

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 15-1/2 GALV ASTM F3125 GRADE A325 HEAVY HEX BOLT

Heat#: 3093334 **Base Steel:** 4140 **Diam:** 7/8

Source: COMMERCIAL METALS CO **Proof Load:** 39,250 LBF

C :	.400	**Mn:**	.810	**P :**	.016	**Hardness:**	293 HBN		
S :	.019	**Si:**	.240	**Ni:**	.190	**Tensile:**	67,180 LBF	**RA:**	.00%
Cr:	.870	**Mo:**	.208	**Cu:**	.320	**Yield:**	0	**Elon:**	.00%
Pb:	.000	**V :**	.024	**Cb:**	.000	**Sample Length:**	0		
N :	.000			**CE:**	.6329	**Charpy:**		**CVN Temp:**	

LOT#19878

Nuts:
ASTM A563DH HVY HX

Coatings:
ITEMS HOT DIP GALVANIZED PER ASTM F2329/A153C

By:
Certification Department Quality Assurance
Dane McKinnon

Figure B-26. ⅞-in. x 15½-in. Heavy Hex Bolt, Test No. FLAGT-1 (Item No. f5)

Apr. 12. 2018 4:32PM Fastenal-NELIN No. 4682 P. 3

FASTENAL®

Certificate of Compliance

Sold To:

UNL TRANSPORTATION

Purchase Order:

Job: TL-2 and Bullnose

Invoice Date: 03/27/2018

THIS IS TO CERTIFY THAT WE HAVE SUPPLIED YOU WITH THE FOLLOWING PARTS.
THESE PARTS WERE PURCHASED TO THE FOLLOWING SPECIFICATIONS.

5 PCS 7/8"-9 x 8" ASTM A307 Grade A Hot Dipped Galvanized Hex Bolt SUPPLIED UNDER OUR TRACE NUMBER lIne35042 AND UNDER PART NUMBER 92005

20 PCS 7/8"-9 Hot Dip Galvanized Finish Grade A Finished Hex Nut SUPPLIED UNDER OUR TRACE NUMBER 110254885 AND UNDER PART NUMBER 36717

5 PCS 7/8"-9 x 8" ASTM A307 Grade A Hot Dipped Galvanized Hex Bolt SUPPLIED UNDER OUR TRACE NUMBER lIne35042 AND UNDER PART NUMBER 92005

5 PCS 7/8"-9 x 8" ASTM A307 Grade A Hot Dipped Galvanized Hex Bolt SUPPLIED UNDER OUR TRACE NUMBER lIne35042 AND UNDER PART NUMBER 92005

5 PCS 7/8"-9 x 8" ASTM A307 Grade A Hot Dipped Galvanized Hex Bolt SUPPLIED UNDER OUR TRACE NUMBER lIne35042 AND UNDER PART NUMBER 92005

This is to certify that the above document is true and accurate to the best of my knowledge.

Fastenal Account Representative Signature

Jeremiah Moorhead

Printed Name

4/12/18

Date

Please check current revision to avoid using obsolete copies.

This document was printed on 04/12/2018 and was current at that time.

Fastenal Store Location/Address

3201 N. 23rd Street STE 1
LINCOLN, NE 68521
Phone #: (402)476-7900
Fax #: 402/476-7958

Page 1 of 1

Figure B-27. ⅞-in. x 8-in. Hex Bolt, Test No. FLAGT-1 (Item No. f6)

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: Brian Hughes, Quality Assurance

Date: 11/29/2018

Figure B-28. ⅝-in. x 10-in. Hex Bolt, Test No. FLAGT-1 (Item No. f7)

CERTIFIED MATERIAL TEST REPORT TO DIN EN 10204-2005 3.1
FOR ASTM A307, GRADE A - MACHINE BOLTS

FACTORY: IFI & MORGAN LTD.
REPORT DATE:2019/4/9
ADDRESS: No.583-28, Chang'an North Road, Wuyuan Town, Haiyan, Zhejiang, China
MANUFACTURE DATE:2019/3/28

CUSTOMER: FASTENAL
MFG LOT NUMBER:M-2019HT200-9
SAMPE SIZE: ACC. TO ASME B18.18 CATEGORY 2-2011; ASTM F1470-12 TABLE 3
MANU QTY: 28130PCS
SHIPPED QTY:28080PCS
SIZE: 5/8-11X1 1/2 HDG
HEADMARKS: 307A PLUS NY
PO NUMBER:180170611
PART NO:91919

STEEL PROPERTIES:
MATERIAL TYPE:Q195C
HEAT NUMBER:5-01571

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:	0.08	0.33	0.016	0.024

DIMENSIONAL INSPECTIONS **Unit:inch** SPECIFICATION: ASME B18.2.1 - 2012

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
**********************	************************************	******************	********	********
VISUAL	ASTM F788-2013	PASSED	29	0
THREAD	ASME B1.1-2003, 3A GO, 2A NO GO	PASSED	15	0
WIDTH A/F	0.906-0.938	0.915-0.929	4	0
WIDTH A/C	1.033-1.083	1.048-1.057	4	0
HEAD HEIGHT	0.378-0.444	0.395-0.411	4	0
THREAD LENGTH	1.420-1.560	1.434-1.486	15	0
LENGTH	1.420-1.560	1.434-1.486	15	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	76-80 HRB	4	0
WEDGE TENSILE:	ASTM F606/F606M-2016	Min 60 KSI	65-69 KSI	4	0

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
COATINGS OF ZINC:		SPECIFIATION: ASTM F2329/F2329M-15			
HOT DIP GALVANIZED	ASTM B568-98(2014)	Min 0.0020"	0.0021" -0.0022"	4	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 QUALITY CONTROL

Mike Chen

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

Figure B-29. ⅝-in. x 1½-in. Hex Bolt, Test No. FLAGT-1 (Item No. f8)

CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS HDG

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

MFG LOT NUMBER: 1844804

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

DIMENSIONAL INSPECTIONS SPECIFICATION: ASTM B18.21.1-2011

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

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

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

IFI & MORGAN LTD.
检验专用章
QUANLITY CONTROL

(SIGNATURE OF Q.A. LAB MGR.)

Figure B-30. ⅞-in. Round Washer, Test No. FLAGT-1 (Item No. g1)

SSF INDUSTRIAL CO., LIMITED

MILL TEST CERTIFICATION

Certification Conforms to EN1024 3.1B

Supplier: SSF INDUSTRIAL CO.,LIMITED
Buyer: FASTENAL COMPANY PURCHASING

Certificate No.: 000825
Invoice No.: FASTCO2020051501

Product Description: 5/8 USS F/W GALV
Product Size: 5/8
Quality Acceptance: ISO 3269

Shipped Q'ty: 12 MPCS
Lot No.: **20200515**

RAW MATERIAL scrap

Element	C	Si	Mn	S	P	Ni	Cr	Cu

SURFACE

Test Item	Spec.	Standard	Remark
Appearance	Flawless	/	OK

DIMENSION MEASUREMENT(U According to : USS

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

MACHANICAL PROPERTIES According to : ISO 6507

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

COATING According to : ISO 4042

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

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

Inspector: QC Chen **Inspc. Date:** 2020.11.16

For and on behalf of
SSF INDUSTRIAL CO., LIMITED
Authorized Signature(s)

Figure B-31. ⅝-in. Round Washer, Test No. FLAGT-1 (Item No. g2)

STEEL AND PIPE SUPPLY
SPS Coil Processing Tulsa
5275 Bird Creek Ave.
Port of Catoosa, OK 74015

METALLURGICAL TEST REPORT

PAGE 1 of 1
DATE 02/03/2020
TIME 06:13:30

SOLD TO: 66031-1127

SHIP TO: 13716
Kansas City Warehouse
401 New Century Parkway
NEW CENTURY KS

Order	Material No.	Description	Quantity	Weight	Customer Part	Customer PO	Ship Date
40343212-0010	72896240A2	1/4 96 X 240 A572GR50 MILL PLATE	1	1,633.600			01/31/2020

Chemical Analysis

Heat No. B9L648 Vendor SSAB - MONTPELIER WORKS DOMESTIC Mill SSAB - MONTPELIER WORKS **Melted and Manufactured in the USA**
Produced from Coil

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.1600	0.8400	0.0100	0.0030	0.0400	0.1500	0.1300	0.0400	0.0000	0.3300	0.0350	0.0060	0.0180	0.0010	0.0000	0.0000

Mechanical / Physical Properties

Mill Coil No. B9L6480434

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
74700.000	56200.000	28.50			66	Longitudinal	5.0	-20 F	
75900.000	57000.000	27.30			60	Longitudinal	5.0	-20 F	
76200.000	58100.000	25.00			62	Longitudinal	5.0	-20 F	
77600.000	59600.000	25.90			0	NA			

Batch 0006190954 1 EA 1,633.600 LB
Batch 0006190860 6 EA 9,801.600 LB
Batch 0006190945 6 EA 9,801.600 LB
Batch 0006190939 6 EA 9,801.600 LB

THE CHEMICAL, PHYSICAL, OR MECHANICAL TESTS REPORTED ABOVE ACCURATELY REFLECT INFORMATION AS CONTAINED IN THE RECORDS OF THE CORPORATION.
The material is in compliance with EN 10204 Section 4.1 Inspection Certificate Type 3.1
This test report shall not be reproduced, except in full, without the written approval of Steel & Pipe Supply Company, Inc.

Figure B-32. Square Washer Plate, Test No. FLAGT-1 (Item No. g3)

CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS HDG

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

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

DIMENSIONAL INSPECTIONS SPECIFICATION: ASTM B18.21.1-2011

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

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

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

IFI & MORGAN LTD. 检验专用章 QUANLITY CONTROL

(SIGNATURE OF Q.A. LAB MGR.)

Figure B-33. 1-in. Round Washer, Test No. FLAGT-1 (Item No. g4)

DECKER
SINCE 1927 www.deckernut.com

DECKER MANUFACTURING CORPORATION
703 N. Clark Street
Albion, Michigan 49224
P: 517.629.3955 • F: 517.629.3535

LABORATORY AND TESTING FACILITY
Reaffirmed to be in compliance to current Rev Level. Form 8.0
ORIGINAL LABORATORY AND/OR INSPECTION REPORT
THIS IS A LEGAL DOCUMENT

NAME AND ADDRESS OF CLIENT: ______

PAGE 1 OF 2 DATE OF MANUFACTURE: 3-5-2020
LAB FILE ID NUMBER/LOT NUMBER: 20-42-001
DMC PART NUMBER #: 035-1031-26
ITEM DESCRIPTION: 5/8 X 11 +.031 2B GUARD RAIL NUT
GRADE ID MARK AND INSIGNIA: DMC
NAME (S) OF PERSON (S) SAMPLING M. Ortiz / J. Conley SAMPLING PROCEDURES ARE UNDER THE SUPERVISION OF DECKER MANUFACTURING CORPORATION'S QUALITY DEPARTMENT.
PRODUCTION LOT SIZE: <200M SUITABILITY/CONDITION OF TEST SPECIMENS: ACCEPTABLE
TOTAL NO. OF SAMPLES INSPECTED AND/OR TESTED (8) EIGHT

INSPECTIONS AND/OR TESTS:

INSPECTION/TEST DATE (S):	3-6-2020	3-19-2020
DESCRIPTION (S):	ROCKWELL HRB	PROOFLOAD
SPECIFICATION (S):	ASTM E18	ASTM F606
REQUIREMENTS:	ASTM-A563 GRADE B @ HRB 69 MIN &HRC 32 MAX.	ASTM A563 GRADE B Zn @ 20,340 LBF.
EQUIPMENT ID: #	FH10000120120012	# 184280

INSPECTION / TEST RESULTS:

UNIT OF MEASUREMENT: HRB W				UNIT OF MEASUREMENT: LBF			
(1)	88.2	(5)	85.55	(1)	21,300	(5)	21,300
(2)	88.7	(6)	87.0	(2)	21,300	(6)	21,100
(3)	88.05	(7)	88.2	(3)	21,200	(7)	21,300
(4)	85.8	(8)	86.3	(4)	21,200	(8)	21,300

RESULTS OBTAINED FROM: WRENCH FLATS
SPECIFICATION OR MATERIAL GRADE AS EVIDENCED: C-1010 HEAT # 10640980
REMARKS OR DEVIATIONS: MEET AND EXCEED ASTM A563 (09) GRADE A REQUIREMENTS
PER ASTM F606 SECTION 4 THE HARDNESS OF EACH SAMPLE IS THE AVERAGE OF TWO READINGS.

HEAT TREAT, SURFACE TREATMENT, COATING, ETC.,: PROOFLOAD SAMPLES WERE GALVANIZED.
TO THE SPECIFICATIONS ABOVE, THE SAMPLES INSPECTED AND/OR TESTED

CONFORM: X ARE RESULTS ONLY: ______ DO NOT CONFORM: ______

APPROVED SIGNATORY
QUALITY MANAGER
Russell L. Wilson

INSPECTED AND/OR TESTED BY:
Authorized Lab Technician

I CERTIFY THAT THE ABOVE TEST(S) WERE CONDUCTED IN ACCORDANCE WITH THE ABOVE STATED SPECIFICATION(S) AND THAT THE RESULTS ARE CORRECT AS ENTERED. THE ABOVE RESULTS ONLY PERTAIN TO THE SAMPLE ITEMS TESTED, SEE THE QUALITY MANUAL FOR MANDATORY REPORT CONTENT. THIS DOCUMENT SHALL NOT BE REPRODUCED IN FULL WITHOUT THE APPROVAL OF DECKER MANUFACTURING CORPORATION. DO NOT ERASE OR ALTER ANY ERRORS DRAW A STRAIGHT LINE THROUGH AND INITIAL. SEE REVERSE OF THIS DOCUMENT FOR THE TERMS AND CONDITIONS OF THIS TEST REPORT. THE DECISION RULE IS SIMPLE EXCEPTANCE.

ACCREDITED
TESTING CERT # 0499-01

Figure B-34. ⅝-in. Heavy Hex Nut, Test No. FLAGT-1 (Item No. h1)

ISO/TS 16949
BUREAU VERITAS
Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

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

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

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

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

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

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2007

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

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2010

SAMPLED BY : DWTING

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

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2007

SAMPLED BY : GDAN LIAN

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

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

Quality Supervisor: Erin

Figure B-35. ⅝-in. Hex Nut, Test No. FLAGT-1 (Item No. h2)

UNYTITE INC.
INNOVATIVE FASTENING SYSTEMS

Unytite, Inc.
One Unytite Drive
Peru, IL 61354
Tel 815-224-2221
Fax 815-224-3434

INSPECTION CERTIFICATE

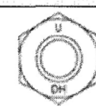
Job No: 31846 **Job Information** **Certified Date:** 1/7/20

Customer:
Customer Part No:
Customer PO No:
Lot Number: 31846-190841

Ship To:
Shipped Qty:

Part Information

Part No: A563 7/8-9 +0.022 DH HHN HDG BLUE DYE-0



Description: ASTM A563 HHN, Grade DH, Hot Dipped Galv, Blue Dye

Manufactured Quantity: 77,514

Applicable Specifications

Specification	Amend	Specification	Amend
ASME B1.1	2003	ASME B18.2.2	2015
ASME B18.2.6	2011	ASTM A563	2015
ASTM F2329/F2329M	2015	ASTM F606/606M	2016
ASTM F812	2017		

Test Results
Test No: 21162 **Test:** A563 DH Mechanical Properties

Description	Hardness (HRC)	Tempering Temp (800 degree F Min)	Proof Load (Pass ASTM Min LBS)	Shape & Dimension ASME B18.2.2	Thread Precision ASME B18.1.1	Visual ASTM F812
Sample Inspection	29.85	1,193	69,300	Pass	Pass	Pass

Certified Chemical Analysis

Heat No	Grade	Manufacturer	Origin	C	Mn	P	S	Si	Cr	Ni	Cu
190841	1045	Alton Steel Inc.	USA	0.4400	0.7300	0.0070	0.0260	0.2100	0.1290	0.0780	0.1700

Notes

All tests are in accordance with the latest revisions of the methods prescribed in the applicable SAE and ASTM Specifications.

The samples tested conform the specifications as described/listed above and were manufactured free of mercury contamination and there is no welding performed in the production of the products. No heats to which Bismuth, Selenium, Tellurium, or Lead was intentionally added have been used to produce products.
The steel was melted and manufactured in the U.S.A. and the product was manufactured and tested in the U.S.A.

We certify that this data is true representation of information provided by the material supplier and our testing laboratory. This certified material test report relates only to the items listed on this document and may not be reproduced except in full.

OFFICIAL SEAL
JEAN E MARGHERIO
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES:08/18/21

Thorsen, Chris - Supervisor, Quality — 1/7/20 Date

Plex 1/7/20 2:39 PM cthorsen Page 1

Figure B-36. ⅞-in. Heavy Hex Nut, Test No. FLAGT-1 (Item No. h3)

ISO/TS 16949
BUREAU VERITAS
Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

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

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2018/03/28

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 110254885
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 7/8-9 NC O/T 0.56MM
LOT NO : 1N1810005
SHIP QUANTITY : 9,000 PCS
LOT QUANTITY 55,748 PCS
HEADMARKS :

PACKING NO : GEM180115010
INVOICE NO : GEM/FNL-180201WI-1
PART NO : 36717
SAMPLING PLAN : ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : 331704677
MATERIAL : XGML08
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

MANUFACTURE DATE : 2018/01/05
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	0.0360	0.0600	0.4500	0.0140	0.0030	0.0300

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2015

SAMPLED BY : WDANDAN

INSPECTIONS ITEM	SAMPLE	SPECIFIED		ACTUAL RESULT	ACC.	REJ.
WIDTH ACROSS CORNERS	5PCS	ASME B18.2.2-2015	1.4470-1.5160 inch	1.4850-1.4930 inch	5	0
FIM	15PCS		Max. 0.0250 inch	0.0110-0.0200 inch	15	0
THICKNESS	5PCS		0.7240-0.7760 inch	0.7460-0.7570 inch	5	0
WIDTH ACROSS FLATS	5PCS		1.2690-1.3120 inch	1.2930-1.2980 inch	5	0
SURFACE DISCONTINUITIES	29PCS		ASTM F812-2012	PASSED	29	0
THREAD	15PCS		GAGING SYSTEM 21	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2015

SAMPLED BY : TANGHAO

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15PCS	ASTM F606-2014		68-107 HRB	86-90 HRB	15	0
PROOF LOAD	5PCS	ASTM F606-2014		Min. 31,416 LBF	OK	5	0
PLATING THICKNESS(μm)	29PCS	ASTM B568-1998		>=53	62.38-62.57	29	0

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

Quality Supervisor: [signature]

Figure B-37. ⅞-in. Hex Nut, Test No. FLAGT-1 (Item No. h4)

Nov. 26. 2018 3:47PM Fastenal-NELIN No. 5947 P. 2

FASTENAL®

Certificate of Compliance

Sold To: UNL TRANSPORTATION

Purchase Order: STBR

Job: Item# f3, h1 and i1

Invoice Date: 11/8/2018

THIS IS TO CERTIFY THAT WE HAVE SUPPLIED YOU WITH THE FOLLOWING PARTS.
THESE PARTS WERE PURCHASED TO THE FOLLOWING SPECIFICATIONS.

80 PCS 1"-8 Hot Dipped Galvanized A563 Grade DH Heavy Hex Nut Made In USA SUPPLIED UNDER OUR TRACE NUMBER 210157128 AND UNDER PART NUMBER 38210

450 PCS 3/4"-10 Hot Dipped Galvanized A563 Grade DH Heavy Hex Nut Made In USA SUPPLIED UNDER OUR TRACE NUMBER 210169774 AND UNDER PART NUMBER 38208

80 PCS 1"-8 Hot Dipped Galvanized A563 Grade DH Heavy Hex Nut Made In USA SUPPLIED UNDER OUR TRACE NUMBER 210157128 AND UNDER PART NUMBER 38210

This is to certify that the above document is true and accurate to the best of my knowledge.

[signature]

Fastenal Account Representative Signature

Ashly Stanczyk

Printed Name

11/29/18

Date

Please check current revision to avoid using obsolete copies.

This document was printed on 11/26/2018 and was current at that time.

Fastenal Store Location/Address

3201 N. 23rd Street STE 1
LINCOLN, NE 68521
Phone #: (402)476-7900
Fax #: 402/476-7958

Page 1 of 1

Figure B-38. 1-in. Heavy Hex Nut, Test No. FLAGT-1 (Item No. h5)

NIM
Test Certificate

Document: 01131005

Norfolk Iron & Metal Co.

3001 North Victory Road
Norfolk, NE 68701
PH: (402) 371-1810

Sold To:
RIVERS METAL PRODUCTS
3100 N 38TH ST
LINCOLN, NE 68504

Ship To:
RIVERS METAL PRODUCTS
3100 N 38TH ST
LINCOLN, NE 68504

Sales Order: 01414254

Customer PO: /po 51265

Product Information

30185 - PLATE 3/16 A36 COLD REDUCED

Thickness: .1875 Width: 48.0000 Length: 96.0000

Mill Coil: 5301939 NLMK IN

Heat: Y6325 Supplier: NLMK INDIANA

Specification(s):
ASTM A36 PLATE-19, ASME SA36-2019

Chemistry Data

Mechanical Data

	Yield (PSI)	Tensile (PSI)	Elongation	Reduction Of Area	Sample Taken From
1	48873	64548	44.63 2"	72.5300	Head
2	48389	64315	40.39 2"	62.7900	Center

Produced From Coil

The Mechanical Data for the product described above reflect the results of tests made by us in accordance with applicable ASTM or ASME standards and our testing procedures, and we certify that the information included in this Test Certificate with respect to such Mechanical Data is accurate to the best of our knowledge.

The Chemistry Data shown above was reported to us by NLMK INDIANA and have been included in this Test Certificate solely for your information.

Figure B-39. $^{3}/_{16}$-in. AGT Connector Face Plate, Test No. FLAGT-1 (Item No. i1)

NIM

Test Certificate

Document: 01130910

Norfolk Iron & Metal Co.

3001 North Victory Road
Norfolk, NE 68701
PH: (402) 371-1810

Sold To:
RIVERS METAL PRODUCTS
3100 N 38TH ST
LINCOLN, NE 68504

Ship To:
RIVERS METAL PRODUCTS
3100 N 38TH ST
LINCOLN, NE 68504

Sales Order: 01378617

Customer PO: /po 50335

Product Information

25872 - PLATE 1/4 A36 COLD REDUCED

Thickness: .2500 Width: 48.0000 Length: 96.0000

Mill Coil: 363757 ARC BH

Heat: 813L65970 Supplier: ARCELORMITTAL

Specification(s):
ASTM A36 PLATE-19, ASME SA36-2019

Chemistry Data

C	MN	P	S	SI	AL	CB	V	CU	CR
.16	.87	.011	.004	.009	.039	.002	.001	.014	.02
NI	MO	SN	TI	N	B	ZR	PB	MG	ZN
.01	.002	.003	.002	.004	.0002	.00	.00	.00	.00

Mechanical Data

	Yield (PSI)	Tensile (PSI)	Elongation	Reduction Of Area	Sample Taken From
1	41580	64129	40.15 2"	53.4500	Head
2	42270	62242	42.52 2"	59.7600	Center

Produced From Coil

Melted In: UNITED STATES, Manufacured In: UNITED STATES

The Mechanical Data for the product described above reflect the results of tests made by us in accordance with applicable ASTM or ASME standards and our testing procedures, and we certify that the information included in this Test Certificate with respect to such Mechanical Data is accurate to the best of our knowledge.

The Chemistry Data shown above was reported to us by ARCELORMITTAL and have been included in this Test Certificate solely for your information.

Figure B-40. ¼-in. AGT Connector Gusset Plates, Test No. FLAGT-1 (Item Nos. i2 through i7)

Appendix C. Vehicle Center of Gravity Determination

	Test Name: FLAGT-1	VIN:	1C6RR6FGXGS284280
Model Year: 2016	Make: RAM	Model:	1500 Quad Cab

Vehicle CG Determination

Vehicle Equipment		Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	4910	28.536214	140112.81
+	Hub	19	15	285
+	Brake activation cylinder & frame	7	29 7/8	209.125
+	Pneumatic tank (Nitrogen)	22	27 4/7	606.375
+	Strobe/Brake Battery	5	26	130
+	Brake Receiver/Wires	5	53	265
+	CG Plate including DAQ	30	29	870
-	Battery	-44	42 1/4	-1859
-	Oil	-12	19	-228
-	Interior	-91	36	-3276
-	Fuel	-143	19	-2717
-	Coolant	-12	32 1/2	-390
-	Washer fluid	-8	32 1/2	-260
+	Water Ballast (In Fuel Tank)	228	19	4332
+	Onboard Supplemental Battery	5	26	130
	Steel Plate	67	33 5/8	2252.875
				0
Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle				140463.19

Estimated Total Weight (lb)	4988
Vertical CG Location (in.)	28.1602

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.625 in. Front Track Width: 68.5 in.
Rear Track Width: 69 in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb)	5000 ± 110	5003	3.0
Longitudinal CG (in.)	63 ± 4	66.082226	3.08223
Lateral CG (in.)	NA	-0.721442	NA
Vertical CG (in.)	28 or greater	28.16	0.16022

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	1376	1319
Rear	1129	1086

FRONT	2695	lb
REAR	2215	lb
TOTAL	4910	lb

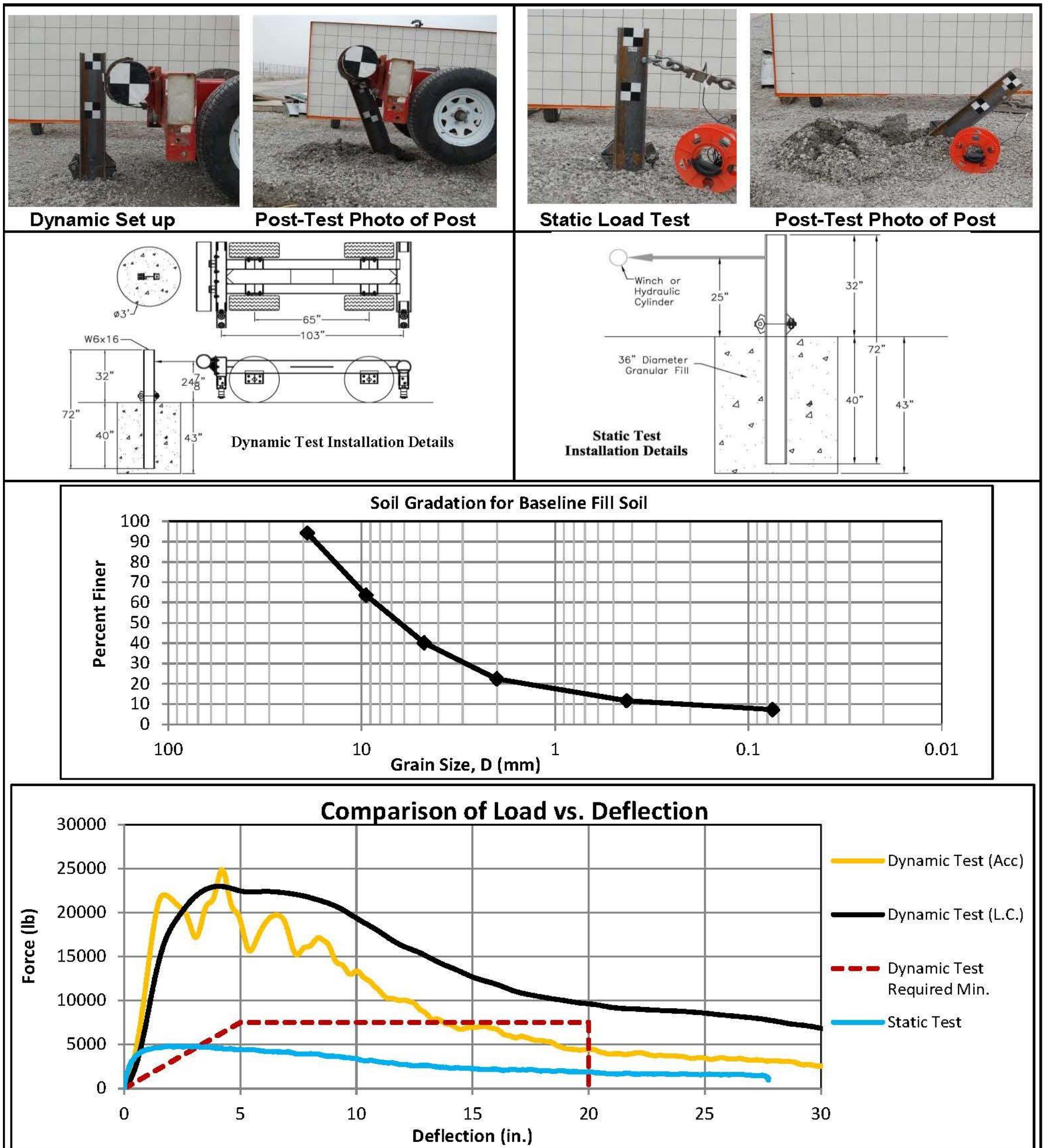
TEST INERTIAL WEIGHT (lb.)

	Left	Right
Front	1373	1279
Rear	1181	1170

FRONT	2652	lb
REAR	2351	lb
TOTAL	5003	lb

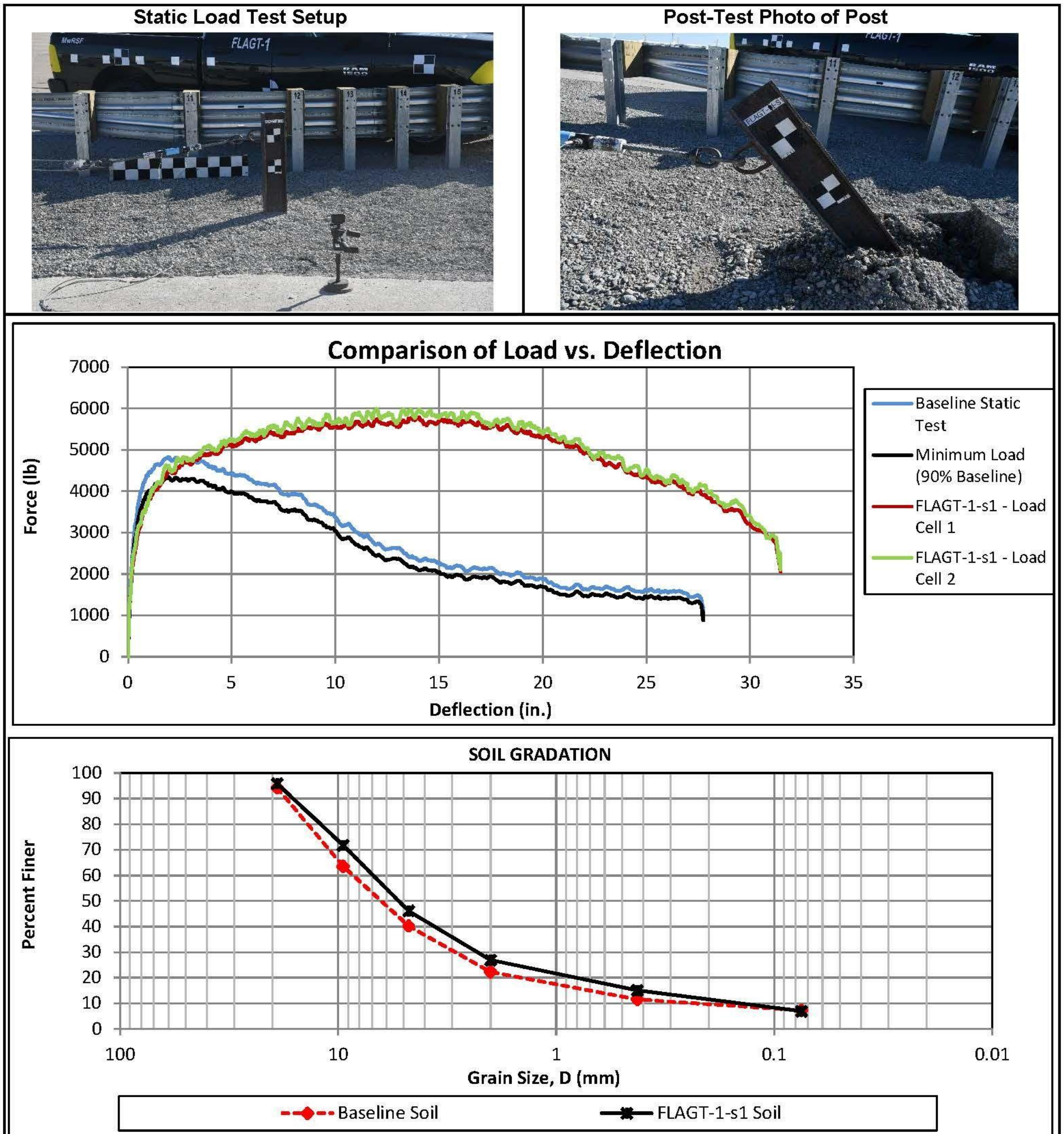
Figure C-1. Vehicle Mass Distribution, Test No. FLAGT-1

Appendix D. Static Soil Tests



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

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



Date	3/31/2021
Test Facility & Site Location	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)	Well-Graded Gravel (GW)
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure	8-inch lifts tamped with a pneumatic compactor

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

Appendix E. Vehicle Deformation Records

The following figures and tables describe all occupant compartment measurements taken on the test vehicles used in 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.

Model Year: 2016 | Test Name: FLAGT-1 | VIN: 1C6RR6FGXGS284280
Make: RAM | Model: 1500 Quad Cab

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	52.5478	32.6316	-7.1908	N/a	N/a	N/a	#VALUE!	#VALUE!	#VALUE!	NA	NA	#VALUE!
	2	53.6385	36.5714	-5.1093	47.8097	35.4114	-9.5232	5.8288	1.1600	4.4139	7.4029	7.3115	X, Z
	3	54.7467	41.5102	-1.6958	47.9035	36.9411	-4.6330	6.8432	4.5691	2.9372	8.7369	7.4469	X, Z
	4	55.3417	46.8894	-2.2714	44.4622	39.9821	-7.4000	10.8795	6.9073	5.1286	13.8700	12.0277	X, Z
	5	54.7380	50.7480	-1.9434	45.7057	42.6574	-5.9780	9.0323	8.0906	4.0346	12.7796	9.8924	X, Z
	6	49.3102	30.3283	-6.4779	N/a	N/a	N/a	#VALUE!	#VALUE!	#VALUE!	NA	NA	#VALUE!
	7	50.2384	35.0131	-3.9381	44.2854	33.9749	-10.1793	5.9530	1.0382	6.2412	8.6873	8.6250	X, Z
	8	51.5779	40.5391	0.0543	44.9338	36.7037	-3.6019	6.6441	3.8354	3.6562	8.4984	7.5837	X, Z
	9	51.6064	46.0474	0.0166	43.5474	40.2226	-2.8338	8.0590	5.8248	2.8504	10.3441	8.5482	X, Z
	10	51.4276	50.5666	0.1318	43.3624	43.1802	-2.9840	8.0652	7.3864	3.1158	11.3717	8.6461	X, Z
FLOOR PAN (Z)	11	45.7751	29.6318	-5.2667	42.8688	28.3552	-8.0436	2.9063	1.2766	2.7769	4.2175	2.7769	Z
	12	46.9725	34.1169	-1.5718	40.2057	33.0980	-9.3245	6.7668	1.0189	7.7527	10.3408	7.7527	Z
	13	48.0209	40.1839	1.3141	41.2095	37.2978	-3.6025	6.8114	2.8861	4.9166	8.8824	4.9166	Z
	14	48.0937	45.7289	1.3275	42.2586	40.8073	0.3628	5.8351	4.9216	0.9647	7.6942	0.9647	Z
	15	47.9001	50.3799	1.3407	41.9406	44.5043	-0.5223	5.9595	5.8756	1.8630	8.5737	1.8630	Z
	16	42.3108	29.8014	-3.7243	40.2300	29.2059	-5.5110	2.0808	0.5955	1.7867	2.8065	1.7867	Z
	17	43.6580	33.4900	1.1486	38.4309	34.0034	-6.2914	5.2271	-0.5134	7.4400	9.1071	7.4400	Z
	18	44.0169	39.7450	1.2965	37.5569	38.0640	-3.8515	6.4600	1.6810	5.1480	8.4297	5.1480	Z
	19	44.1033	46.4285	1.3124	38.6434	42.8407	0.5514	5.4599	3.5878	0.7610	6.5774	0.7610	Z
	20	44.0693	50.4249	1.3250	38.7357	45.4254	0.9497	5.3336	4.9995	0.3753	7.3201	0.3753	Z
	21	38.0583	30.0018	-3.5626	36.3453	29.1957	-3.7137	1.7130	0.8061	0.1511	1.8992	0.1511	Z
	22	39.6803	33.3762	1.0421	37.0015	34.2955	-2.7025	2.6788	-0.9193	3.7446	4.6950	3.7446	Z
	23	39.6934	40.0794	1.0204	33.8438	39.8391	-4.4534	5.8496	0.2403	5.4738	8.0149	5.4738	Z
	24	39.5391	45.8373	1.0331	35.1194	44.2515	-0.8228	4.4197	1.5858	1.8559	5.0490	1.8559	Z
	25	39.5235	50.0241	1.0496	35.1853	47.0588	2.1557	4.3382	2.9653	-1.1061	5.3700	-1.1061	Z
	26	34.2159	30.0742	-2.5885	32.9958	30.0847	-1.9923	1.2201	-0.0105	-0.5962	1.3580	-0.5962	Z
	27	34.3557	33.1591	0.8753	33.7174	34.1056	0.8128	0.6383	-0.9465	0.0625	1.1433	0.0625	Z
	28	34.2595	39.6990	0.8578	33.0026	40.5266	0.6149	1.2569	-0.8276	0.2429	1.5244	0.2429	Z
	29	34.2291	45.6846	0.8924	31.0290	45.9300	-0.0707	3.2001	-0.2454	0.9631	3.3509	0.9631	Z
	30	34.2888	49.8939	0.9822	N/a	N/a	N/a	#VALUE!	#VALUE!	#VALUE!	NA	NA	Z

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

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

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

Pretest Floor Pan	Posttest Floor Pan
	

Figure E-1. Floor Pan Deformation Data – Set 2, Test No. FLAGT-1

Model Year: 2016 | Test Name: FLAGT-1 | Make: RAM | VIN: 1C6RR6FGXGS284280 | Model: 1500 Quad Cab

VEHICLE DEFORMATION
PASSENGER SIDE INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	46.2479	50.2141	-30.7012	41.9370	48.0129	-32.9524	4.3109	2.2012	-2.2512	5.3383	5.3383	X, Y, Z
	2	44.0204	37.5314	-30.1476	40.6783	35.2630	-32.5884	3.3421	2.2684	-2.4408	4.7194	4.7194	X, Y, Z
	3	41.1750	20.5048	-30.7039	38.8772	17.8674	-32.9284	2.2978	2.6374	-2.2245	4.1454	4.1454	X, Y, Z
	4	40.9373	50.8392	-19.7193	36.2363	48.0538	-22.2961	4.7010	2.7854	-2.5768	6.0413	6.0413	X, Y, Z
	5	40.1948	38.6811	-20.0835	36.3364	35.8747	-22.6852	3.8584	2.8064	-2.6017	5.4343	5.4343	X, Y, Z
	6	38.0422	20.4905	-20.4788	35.3816	17.8537	-22.9086	2.6606	2.6368	-2.4298	4.4649	4.4649	X, Y, Z
SIDE PANEL (Y)	7	49.9066	53.3107	-6.0084	42.9208	45.8149	-8.0659	6.9858	7.4958	-2.0575	10.4509	7.4958	Y
	8	50.1667	53.3149	-9.8343	43.1509	46.3736	-12.0212	7.0158	6.9413	-2.1869	10.1087	6.9413	Y
	9	53.5214	53.2351	-5.6343	46.2280	44.6561	-8.1285	7.2934	8.5790	-2.4942	11.5332	8.5790	Y
IMPACT SIDE DOOR (Y)	10	16.5802	55.1470	-23.6893	12.0382	60.1802	-21.2792	4.5420	-5.0332	2.4101	7.1952	-5.0332	Y
	11	29.4850	54.9409	-23.6816	24.1992	59.4069	-23.1466	5.2858	-4.4660	0.5350	6.9405	-4.4660	Y
	12	41.1025	55.1701	-23.2067	34.8253	55.4122	-24.2086	6.2772	-0.2421	-1.0019	6.3613	-0.2421	Y
	13	16.7220	55.1792	-7.1085	N/a	N/a	N/a	#VALUE!	#VALUE!	#VALUE!	NA	NA	Y
	14	25.2677	55.9609	-8.1587	19.0089	56.7599	-8.3018	6.2588	-0.7990	-0.1431	6.3112	-0.7990	Y
	15	36.9107	55.7373	-6.9771	30.3820	53.1157	-7.8754	6.5287	2.6216	-0.8983	7.0925	2.6216	Y
ROOF - (Z)	16	33.5150	43.0529	-46.3404	33.6745	41.5732	-50.3429	-0.1595	1.4797	-4.0025	4.2702	-4.0025	Z
	17	36.1385	33.1055	-46.6144	36.2455	31.5709	-49.7271	-0.1070	1.5346	-3.1127	3.4721	-3.1127	Z
	18	37.3060	20.9809	-46.8191	37.1526	19.4842	-48.9948	0.1534	1.4967	-2.1757	2.6452	-2.1757	Z
	19	27.4083	42.9246	-49.0587	27.3379	41.3084	-51.7789	0.0704	1.6162	-2.7202	3.1649	-2.7202	Z
	20	30.3254	32.3000	-49.3595	30.2431	30.6744	-51.6596	0.0823	1.6256	-2.3001	2.8178	-2.3001	Z
	21	31.2878	20.8878	-49.4910	31.1842	19.3019	-51.5382	0.1036	1.5859	-2.0472	2.5917	-2.0472	Z
	22	21.3382	42.5442	-49.9646	21.4347	40.9596	-50.2895	-0.0965	1.5846	-0.3249	1.6204	-0.3249	Z
	23	22.8164	32.6754	-50.4381	23.1220	30.9588	-49.5590	-0.3056	1.7166	0.8791	1.9527	0.8791	Z
	24	23.8092	21.2270	-50.6818	23.8288	19.7992	-51.7753	-0.0196	1.4278	-1.0935	1.7985	-1.0935	Z
	25	14.7631	42.1954	-50.4204	15.1863	40.6154	-48.2829	-0.4232	1.5800	2.1375	2.6915	2.1375	Z
	26	16.6528	32.5732	-50.9241	16.9620	31.2041	-50.7479	-0.3092	1.3691	0.1762	1.4146	0.1762	Z
	27	17.3962	21.9850	-51.1325	17.4641	20.7896	-50.6301	-0.0679	1.1954	0.5024	1.2985	0.5024	Z
	28	10.2152	41.7249	-50.6783	10.6871	40.5127	-49.7209	-0.4719	1.2122	0.9574	1.6152	0.9574	Z
	29	10.3178	32.4585	-51.2254	10.5885	31.3605	-50.1958	-0.2707	1.0980	1.0296	1.5294	1.0296	Z
	30	10.4432	22.4787	-51.4470	10.6304	21.2987	-50.4622	-0.1872	1.1800	0.9848	1.5483	0.9848	Z
A-PILLAR Maximum (X, Y, Z)	31	49.8368	52.0262	-32.3206	46.0375	50.5464	-33.6997	3.7993	1.4798	-1.3791	4.3042	4.0773	X, Y
	32	47.0144	51.3208	-34.3679	43.9347	49.9353	-36.5195	3.0797	1.3855	-2.1516	4.0042	3.3770	X, Y
	33	43.0848	50.5493	-38.2487	41.5095	49.1214	-41.4440	1.5753	1.4279	-3.1953	3.8380	2.1261	X, Y
	34	39.4660	49.7038	-40.8526	38.9288	48.3714	-45.0671	0.5372	1.3324	-4.2145	4.4526	1.4366	X, Y
	35	35.8978	48.8791	-43.1443	36.2421	47.5782	-48.3074	-0.3443	1.3009	-5.1631	5.3356	1.3009	Y
	36	32.4710	47.7751	-44.6398	33.1849	46.4064	-49.2252	-0.7139	1.3687	-4.5854	4.8383	1.3687	Y
A-PILLAR Lateral (Y)	31	49.8368	52.0262	-32.3206	46.0375	50.5464	-33.6997	3.7993	1.4798	-1.3791	4.3042	1.4798	Y
	32	47.0144	51.3208	-34.3679	43.9347	49.9353	-36.5195	3.0797	1.3855	-2.1516	4.0042	1.3855	Y
	33	43.0848	50.5493	-38.2487	41.5095	49.1214	-41.4440	1.5753	1.4279	-3.1953	3.8380	1.4279	Y
	34	39.4660	49.7038	-40.8526	38.9288	48.3714	-45.0671	0.5372	1.3324	-4.2145	4.4526	1.3324	Y
	35	35.8978	48.8791	-43.1443	36.2421	47.5782	-48.3074	-0.3443	1.3009	-5.1631	5.3356	1.3009	Y
	36	32.4710	47.7751	-44.6398	33.1849	46.4064	-49.2252	-0.7139	1.3687	-4.5854	4.8383	1.3687	Y
B-PILLAR Maximum (X, Y, Z)	37	9.4304	47.3202	-46.4760	9.9402	46.3537	-44.9099	-0.5098	0.9665	1.5661	1.9096	1.8403	Y, Z
	38	8.3713	48.3468	-43.3440	8.8529	47.4326	-41.8299	-0.4816	0.9142	1.5141	1.8331	1.7687	Y, Z
	39	6.5271	49.7915	-39.0853	6.7443	48.8641	-37.6194	-0.2172	0.9274	1.4659	1.7482	1.7346	Y, Z
	40	9.4939	51.6467	-33.7235	9.4780	50.8447	-32.1685	0.0159	0.8020	1.5550	1.7497	1.7497	X, Y, Z
B-PILLAR Lateral (Y)	37	9.4304	47.3202	-46.4760	9.9402	46.3537	-44.9099	-0.5098	0.9665	1.5661	1.9096	0.9665	Y
	38	8.3713	48.3468	-43.3440	8.8529	47.4326	-41.8299	-0.4816	0.9142	1.5141	1.8331	0.9142	Y
	39	6.5271	49.7915	-39.0853	6.7443	48.8641	-37.6194	-0.2172	0.9274	1.4659	1.7482	0.9274	Y
	40	9.4939	51.6467	-33.7235	9.4780	50.8447	-32.1685	0.0159	0.8020	1.5550	1.7497	0.8020	Y

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

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

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

Figure E-2. Occupant Compartment Deformation Data – Set 2, Test No. FLAGT-1

		Test Name:	FLAGT-1	VIN:	1C6RR6FGXGS284280
Model Year:	2016	Make:	RAM	Model:	1500 Quad Cab

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	0.0	≤ 4	Z	Roof	2.1	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.0	≤ 5	NA	A-Pillar Maximum	4.1	≤ 5	X, Y
A-Pillar Lateral	0.0	≤ 3	Y	A-Pillar Lateral	1.5	≤ 3	Y
B-Pillar Maximum	0.0	≤ 5	NA	B-Pillar Maximum	1.8	≤ 5	Y, Z
B-Pillar Lateral	0.0	≤ 3	Y	B-Pillar Lateral	1.0	≤ 3	Y
Toe Pan - Wheel Well	0.0	≤ 9	NA	Toe Pan - Wheel Well	12.0	≤ 9	X, Z
Side Front Panel	0.0	≤ 12	Y	Side Front Panel	8.6	≤ 12	Y
Side Door (above seat)	0.0	≤ 9	Y	Side Door (above seat)	-5.0	≤ 9	Y
Side Door (below seat)	0.0	≤ 12	Y	Side Door (below seat)	2.6	≤ 12	Y
Floor Pan	0.0	≤ 12	Z	Floor Pan	7.8	≤ 12	Z
Dash - no MASH requirement	0.0	NA	X, Y, Z	Dash - no MASH requirement	6.0	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.

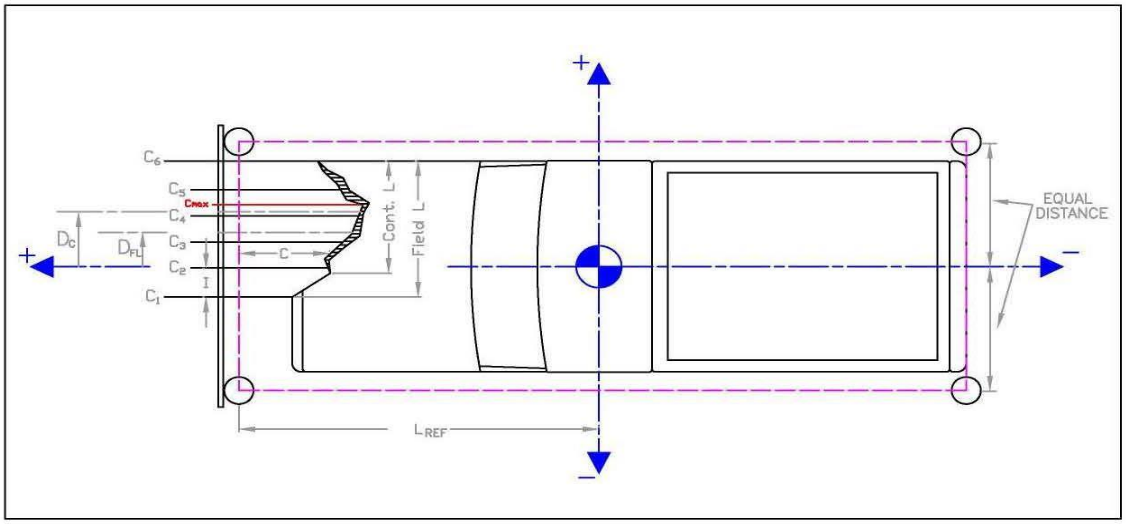
[C] For Toe Pan - Wheel Well the direction of defromation may include X and Z direction. For A-Pillar Maximum and B-Pillar Maximum the direction of deformation may include X, Y, and Z directions. The direction of deformation for Toe Pan -Wheel Well, A-Pillar Maximum, and B-Pillar Maximum only include 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 E-3. Maximum Occupant Compartment Deformations by Location, Test No. FLAGT-1

Date Measured:	4/8/2021	Test Name:	FLAGT-1	VIN:	1C6RR6FGXGS284280
Model Year:	2016	Make:	RAM	Model:	1500 Quad Cab



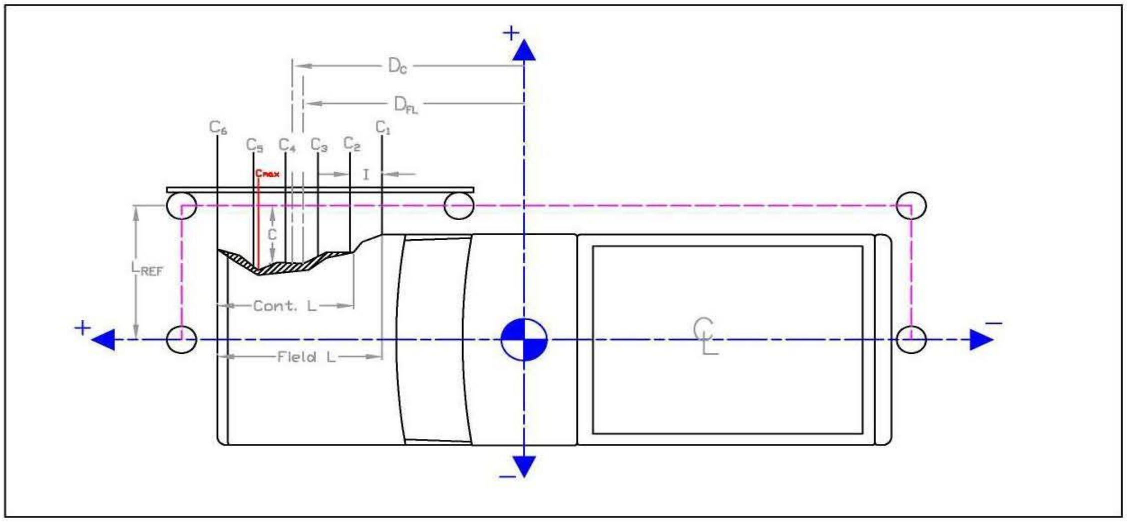
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	121	(3073)
Total Vehicle Width:	77 3/8	(1965)
Width of contact and induced crush - Field L:	77 3/8	(1965)
Crush measurement spacing interval (L/5) - I:	15 1/2	(394)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	38 2/3	(983)
Distance from center of vehicle to center of contact damage - D_C:	19 1/3	(491)

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	19 5/8	(498)	-38 3/4	-(984)	22 1/2	(572)	11	(281)	-14	-(354)
C_2	14	(354)	-23 1/4	-(591)	6 1/2	(165)			-3 5/8	-(92)
C_3	16	(406)	-7 3/4	-(197)	4 1/4	(108)			2/3	(17)
C_4	31 1/2	(800)	7 3/4	(197)	4 1/4	(108)			16 1/5	(411)
C_5	54 3/4	(1391)	23 1/4	(591)	6 1/4	(159)			37 4/9	(951)
C_6	NA	N/A	38 3/4	(984)	20 1/2	(521)			N/A	N/A
C_{MAX}	60	(1524)	19	(483)	5 1/2	(140)			43 4/9	(1103)

Figure E-4. Exterior Vehicle Crush (NASS) - Front, Test No. FLAGT-1

Date Measured:	4/8/2021	Test Name:	FLAGT-1	VIN:	1C6RR6FGXGS284280
Model Year:	2016	Make:	RAM	Model:	1500 Quad Cab



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	47	(1194)
Total Vehicle Length:	229 1/4	(5823)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-1 1/5	-(30)
Width of contact and induced crush - Field L:	229 1/4	(5823)
Crush measurement spacing interval (L/5) - I:	45 7/8	(1165)
Distance from vehicle c.g. to center of Field L - D_{FL}:	7 1/3	(186)
Width of Contact Damage:	229 1/4	(5823)
Distance from vehicle c.g. to center of contact damage - D_C:	7 1/3	(186)

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	11 3/4	(298)	-107 3/8	-(2727)	6 5/8	(168)	3	(76)	2 1/8	(54)
C_2	NA	N/A	-61 1/2	-(1562)	5 3/8	(137)			N/A	N/A
C_3	8 1/2	(216)	-15 5/8	-(397)	5 1/8	(130)			3/8	(10)
C_4	16 3/4	(425)	30 1/4	(768)	5 1/8	(130)			8 5/8	(219)
C_5	38	(965)	76 1/8	(1934)	6	(152)			29	(737)
C_6	n/a	N/A	122	(3099)	33 1/2	(851)			N/A	N/A
C_{MAX}	38	(965)	76 1/8	(1934)	6	(152)			29	(737)

Figure E-5. Exterior Vehicle Crush (NASS) - Side, Test No. FLAGT-1

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

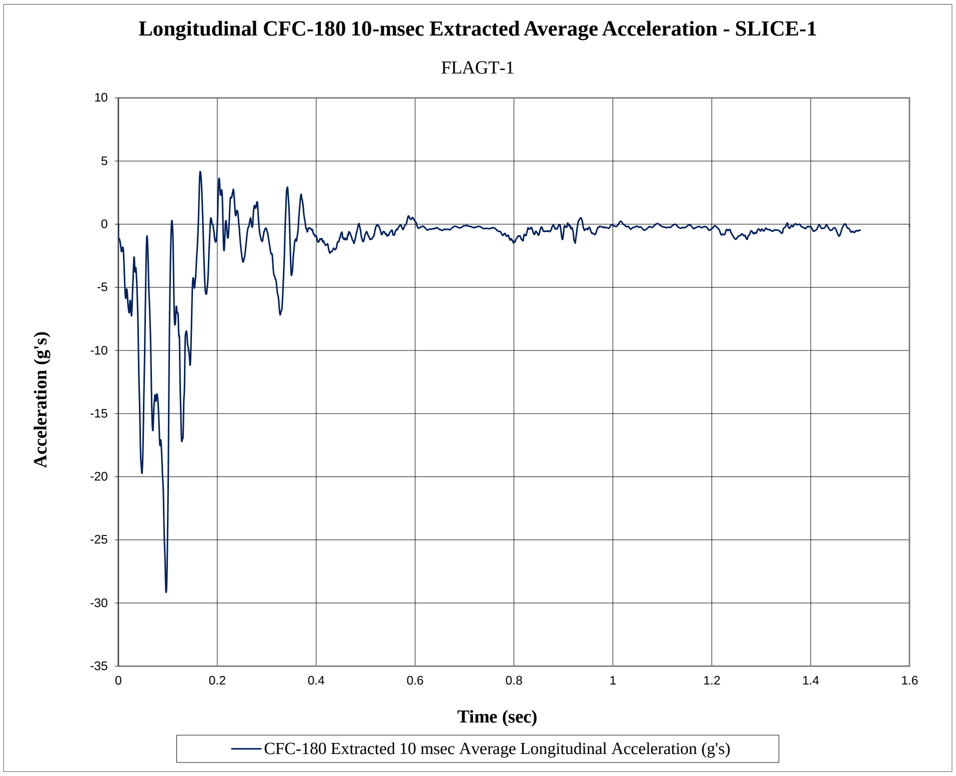


Figure F-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. FLAGT-1

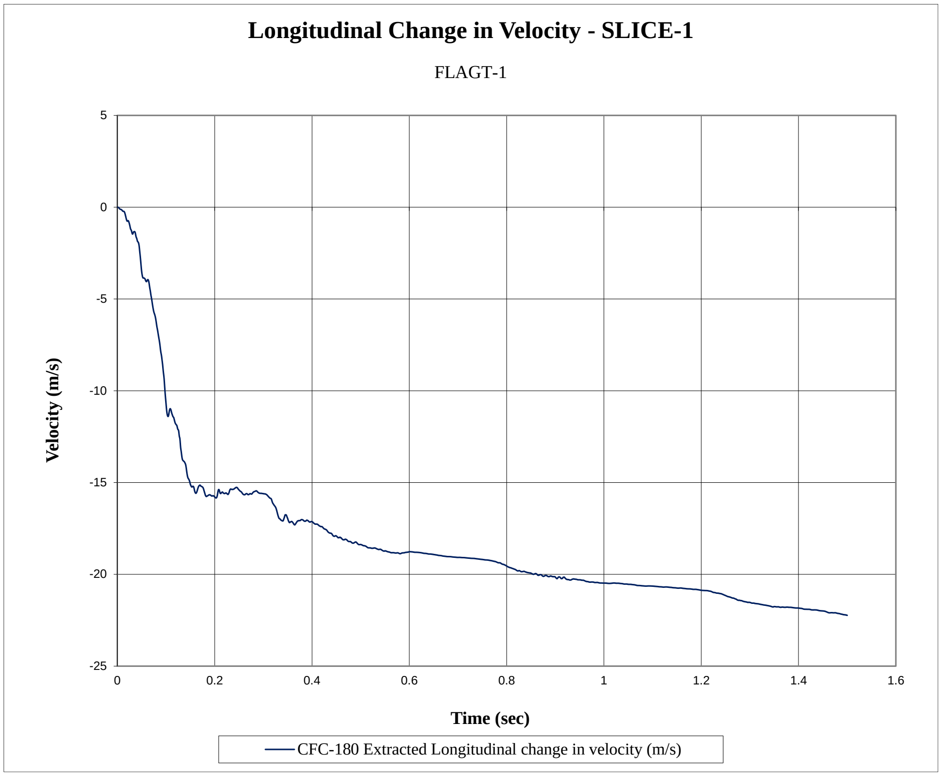


Figure F-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. FLAGT-1

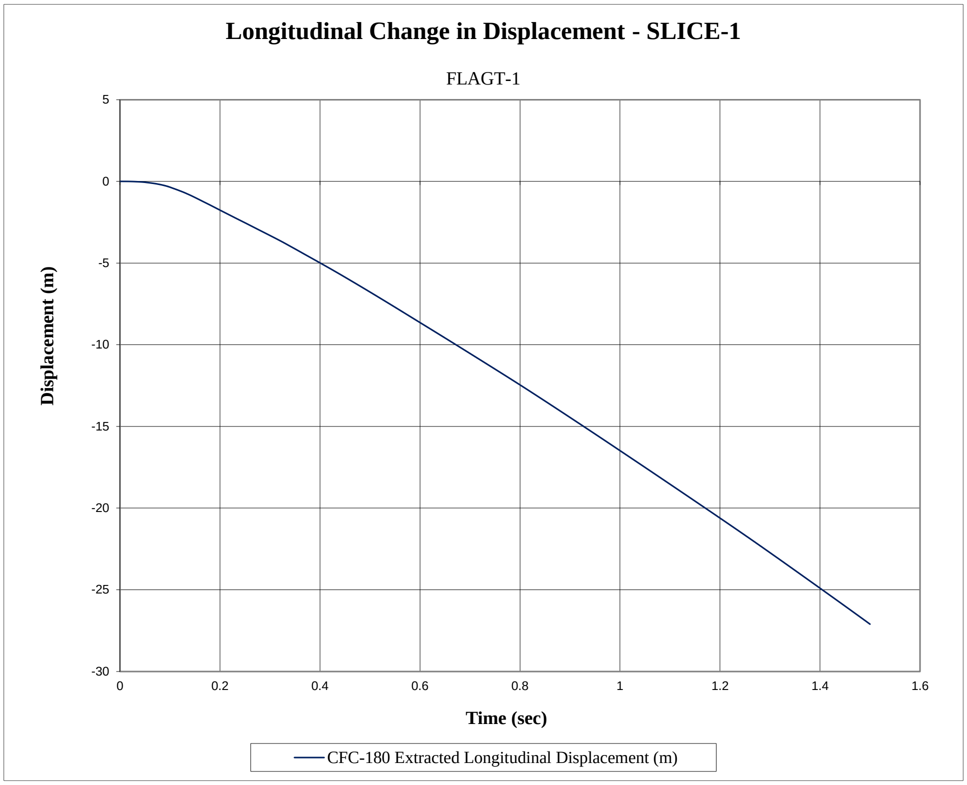


Figure F-3. Longitudinal Occupant Displacement (SLICE-1), Test No. FLAGT-1

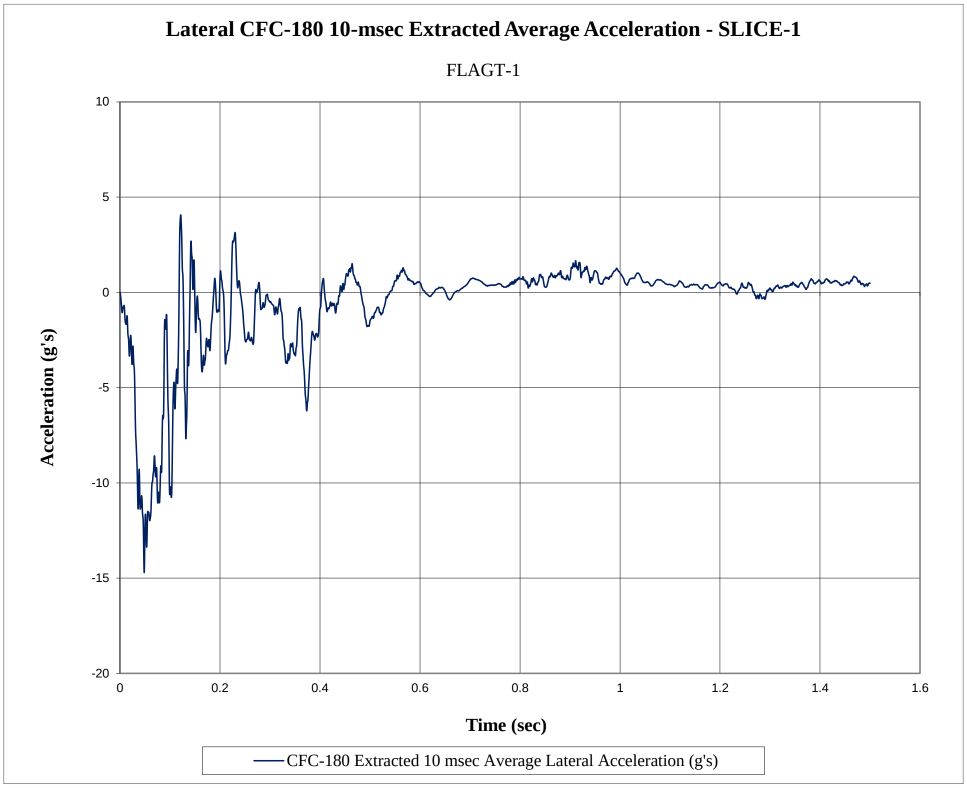


Figure F-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. FLAGT-1

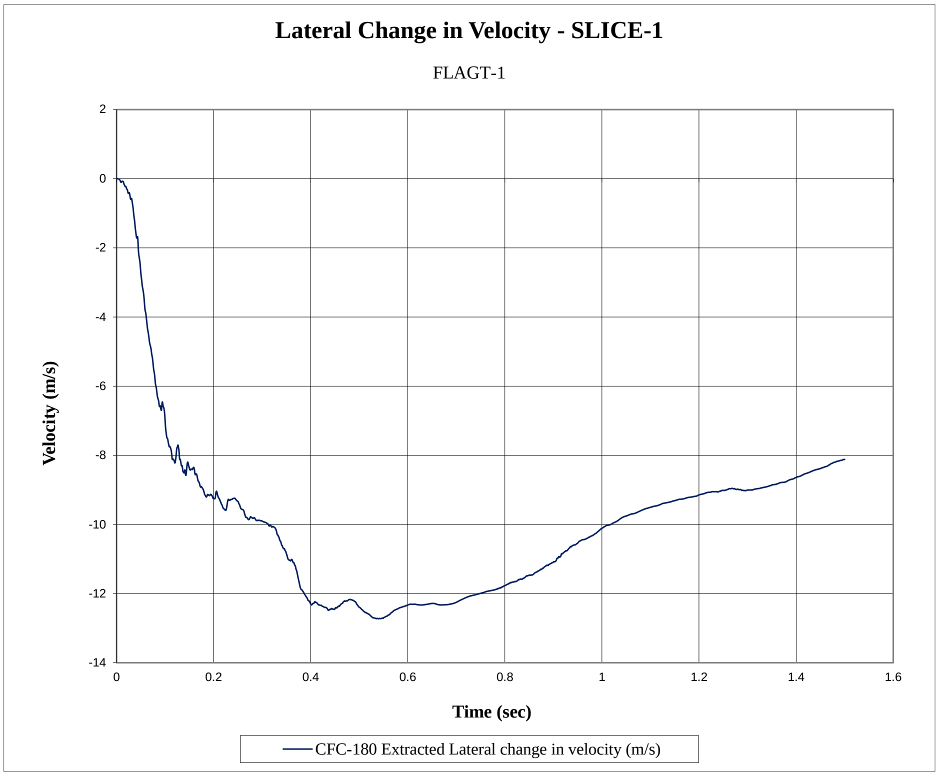


Figure F-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. FLAGT-1

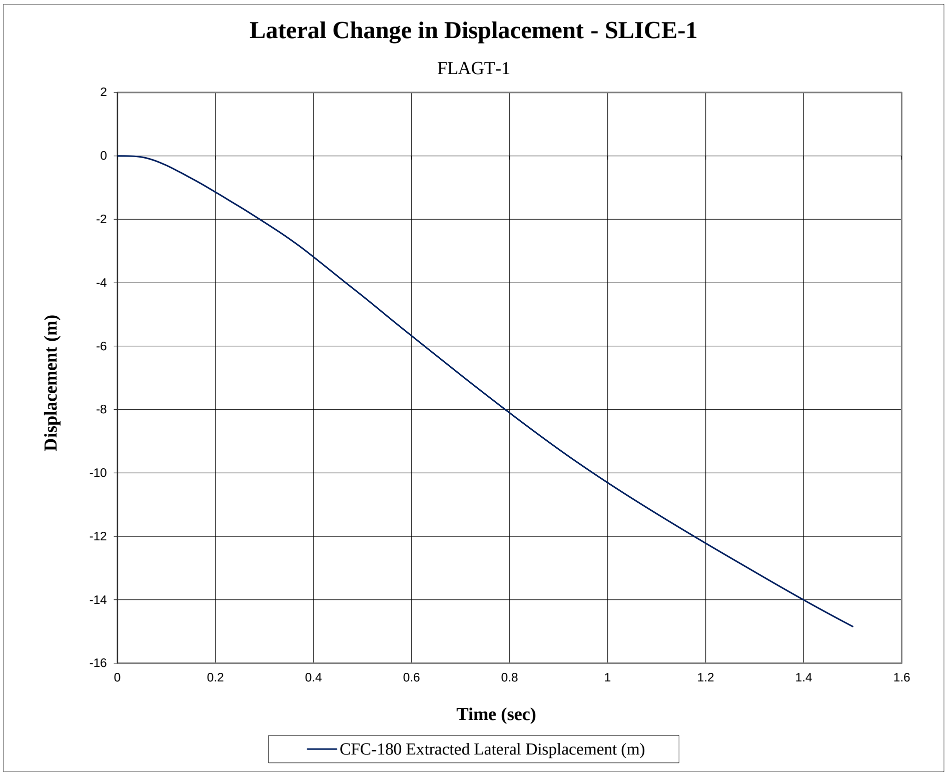


Figure F-6. Lateral Occupant Displacement (SLICE-1), Test No. FLAGT-1

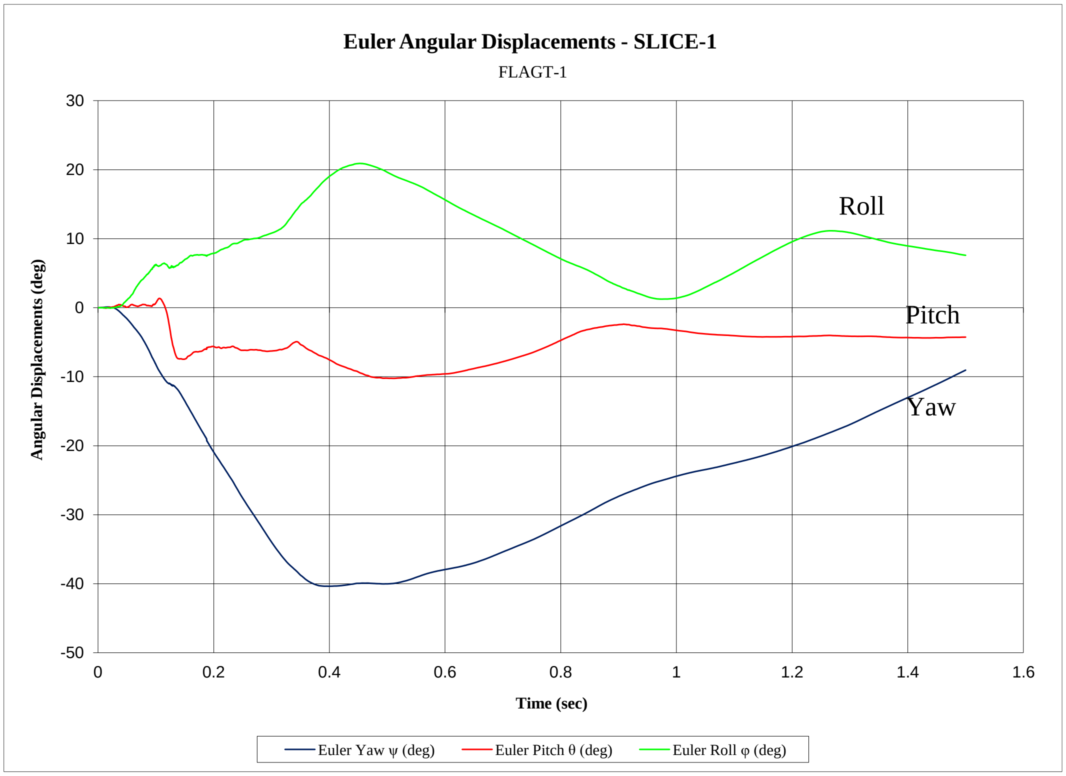


Figure F-7. Vehicle Angular Displacements (SLICE-1), Test No. FLAGT-1

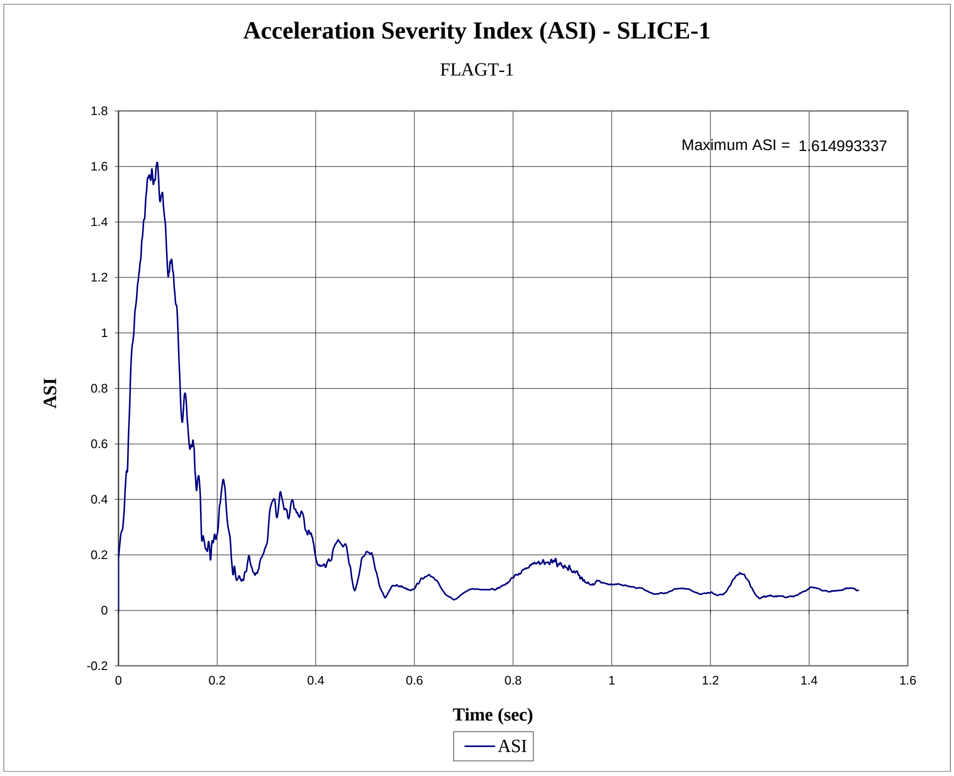


Figure F-8. Acceleration Severity Index (SLICE-1), Test No. FLAGT-1

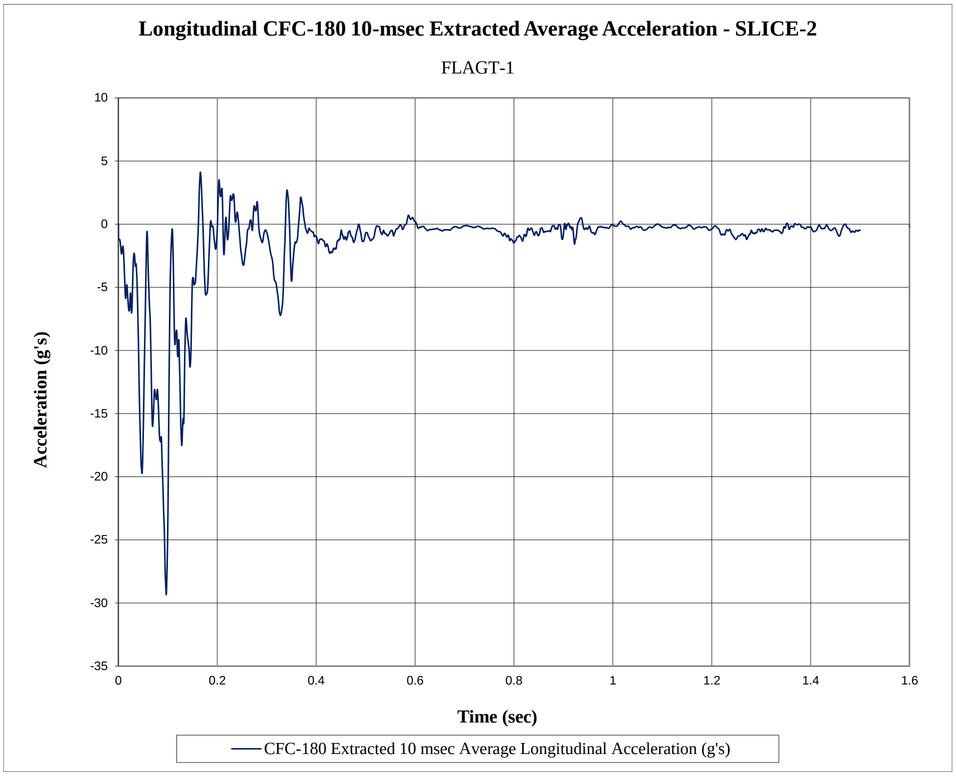


Figure F-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. FLAGT-1

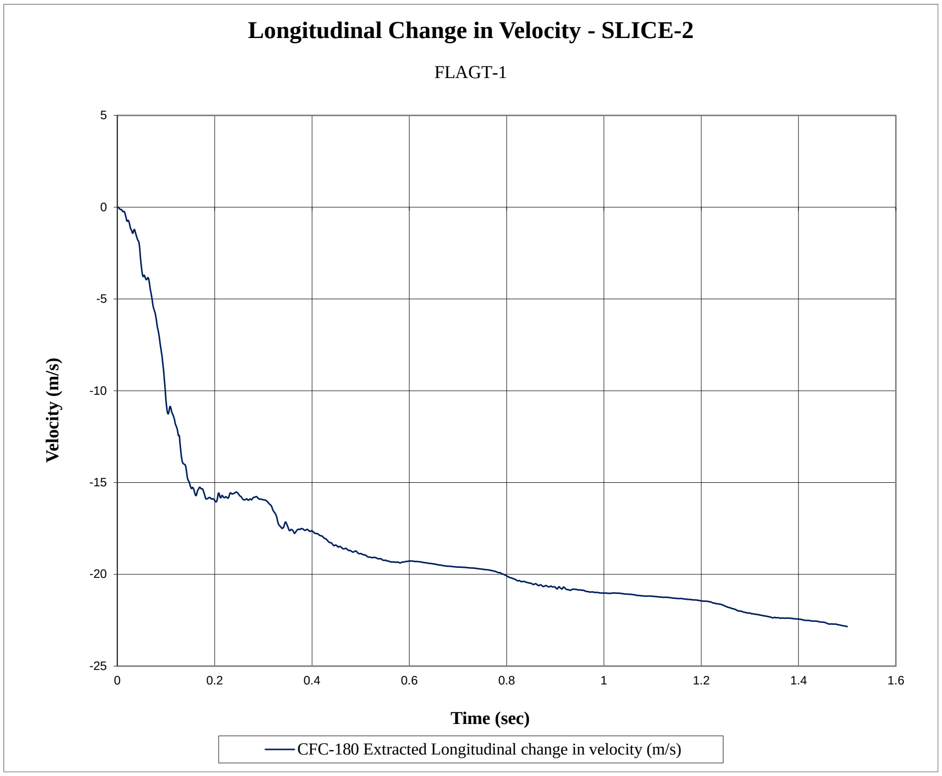


Figure F-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. FLAGT-1

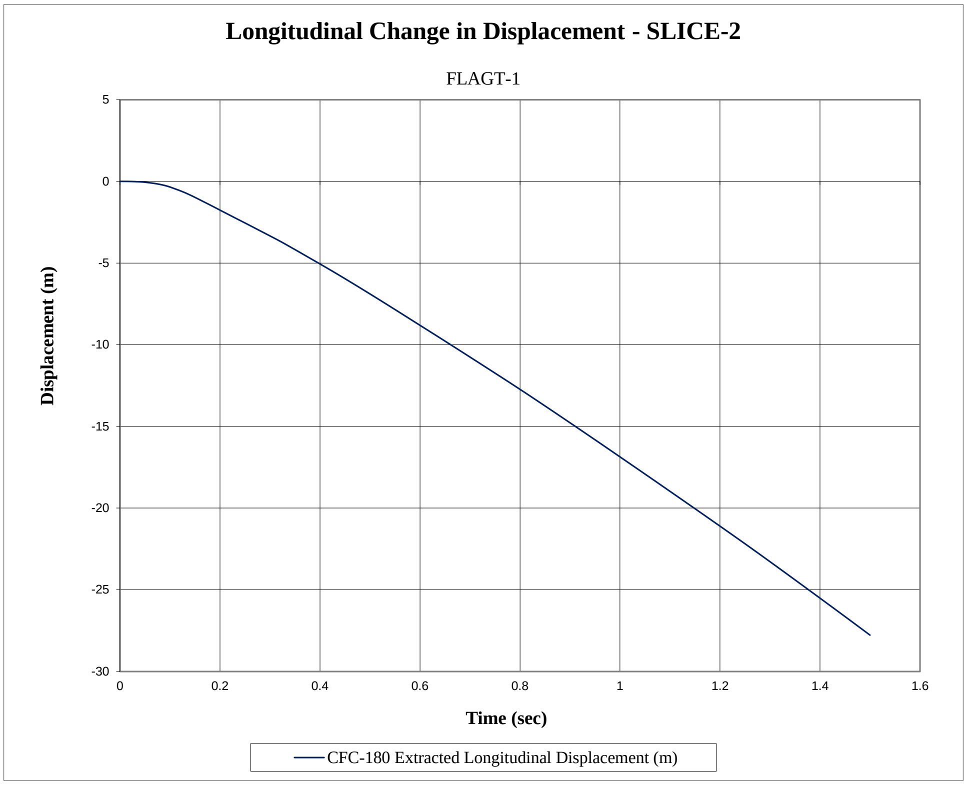


Figure F-11. Longitudinal Occupant Displacement (SLICE-2), Test No. FLAGT-1

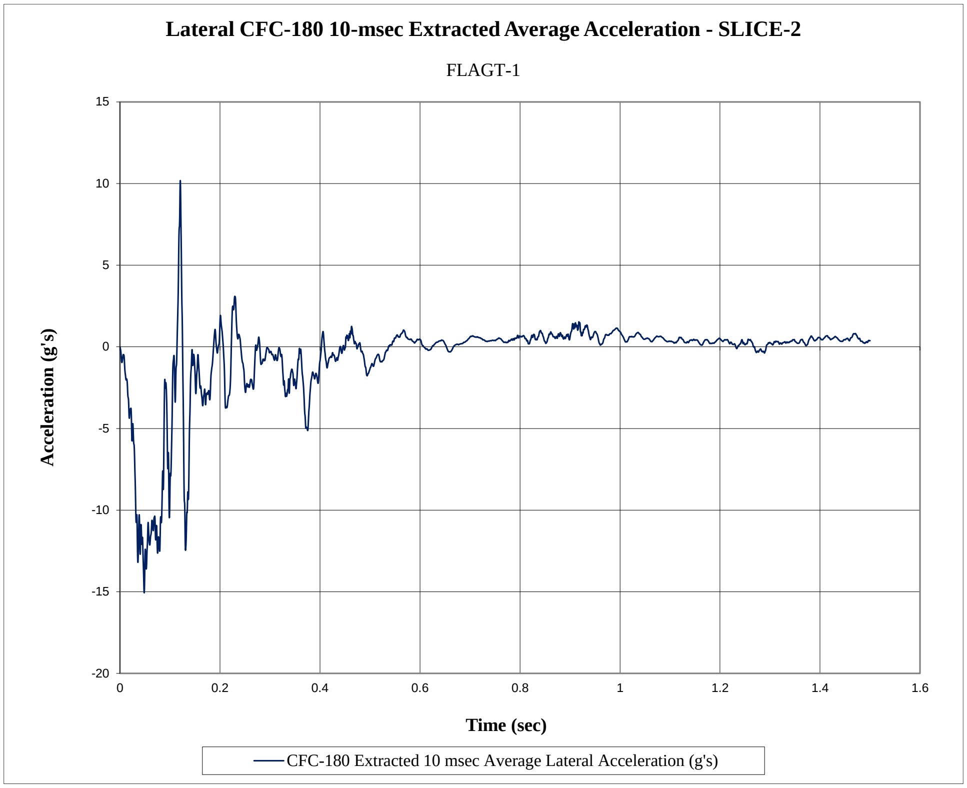


Figure F-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. FLAGT-1

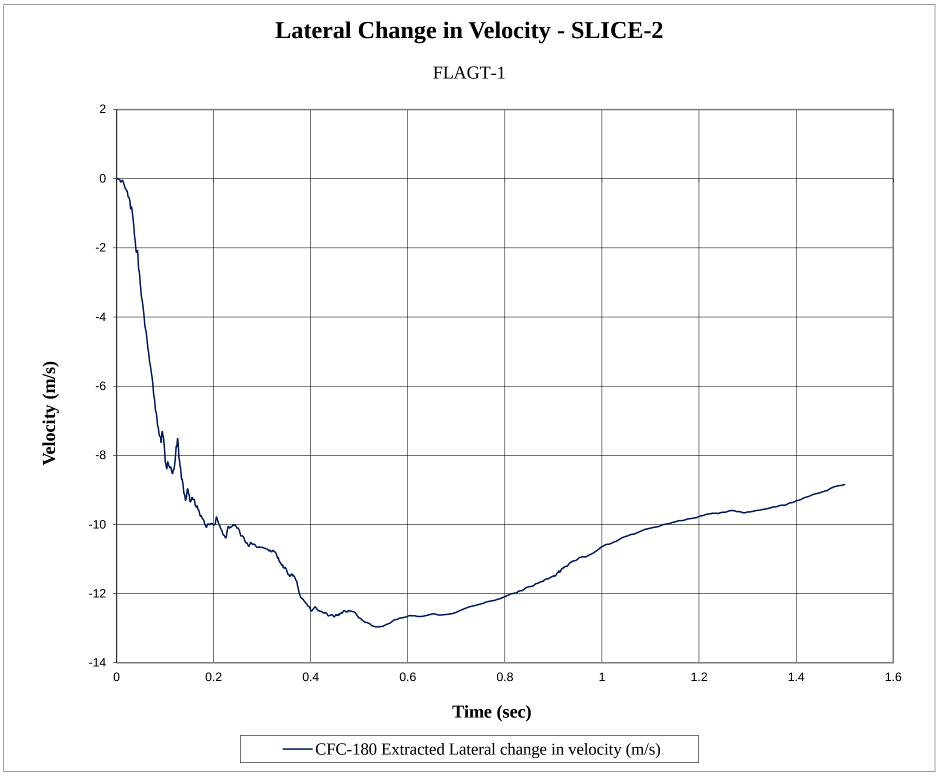


Figure F-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. FLAGT-1

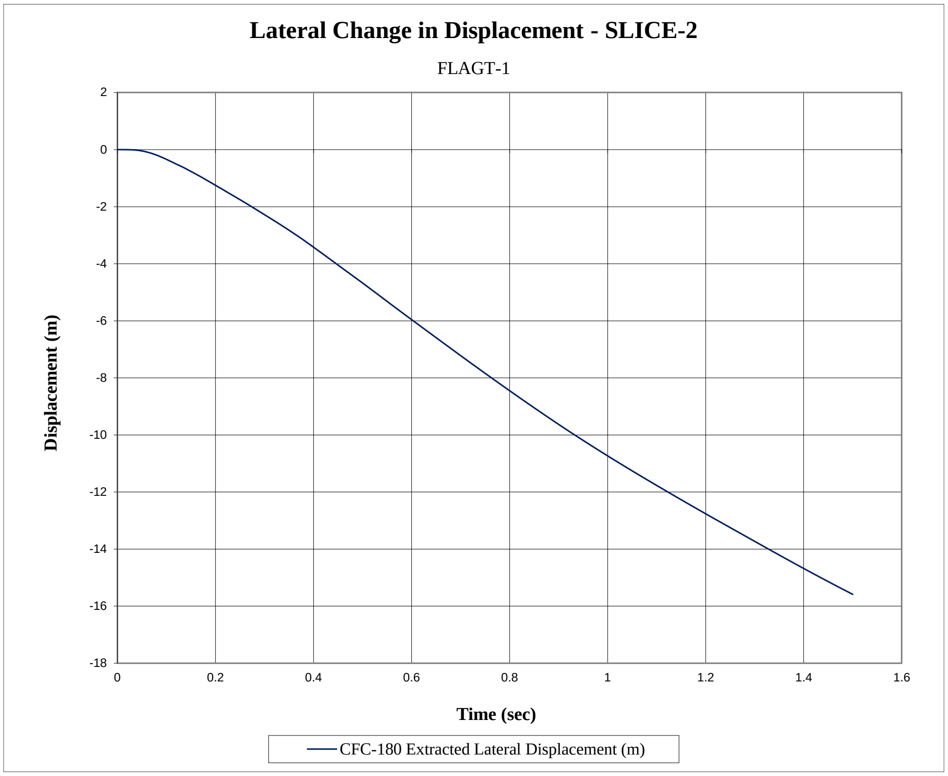


Figure F-14. Lateral Occupant Displacement (SLICE-2), Test No. FLAGT-1

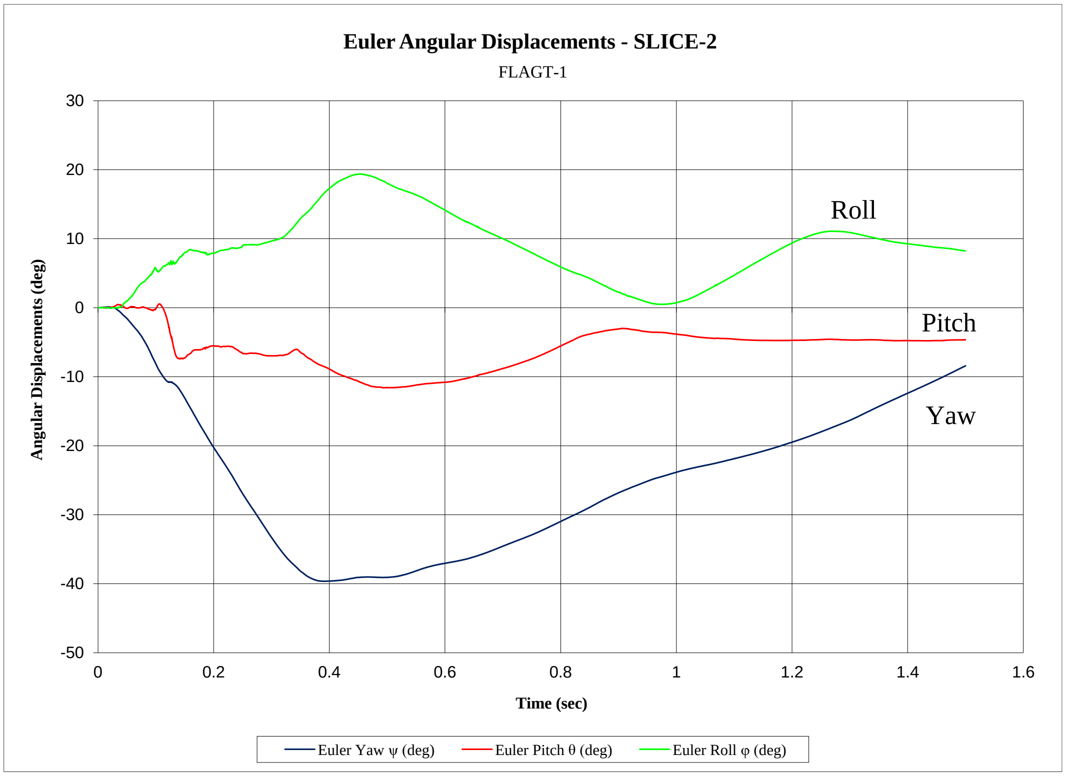


Figure F-15. Vehicle Angular Displacements (SLICE-2), Test No. FLAGT-1

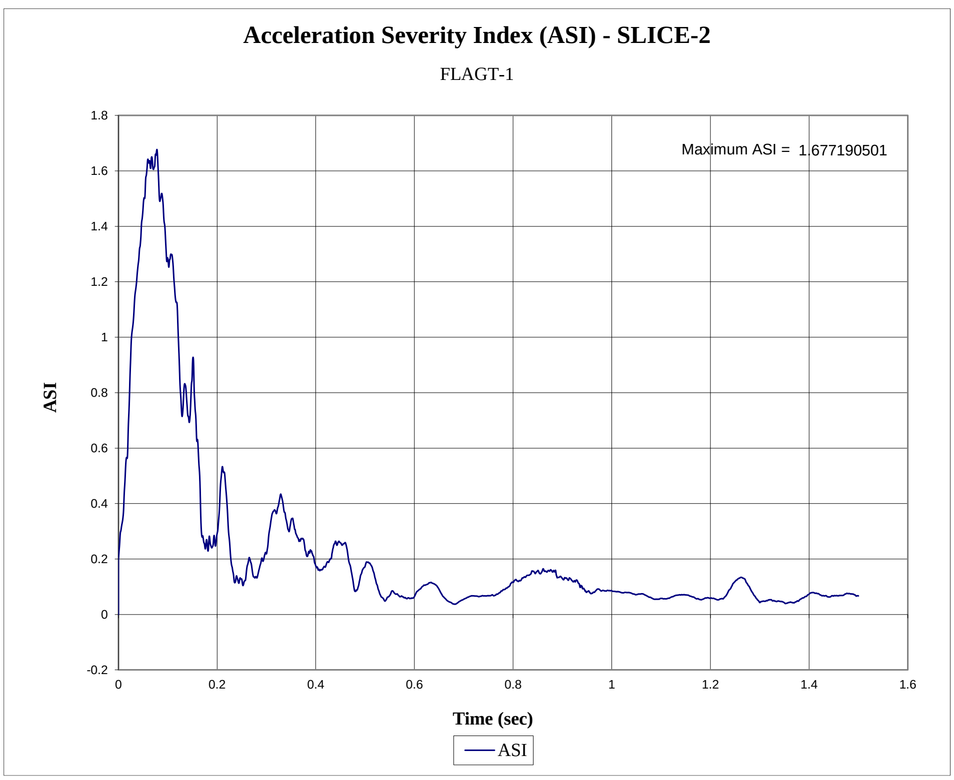


Figure F-16. Acceleration Severity Index (SLICE-2), Test No. FLAGT-1

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