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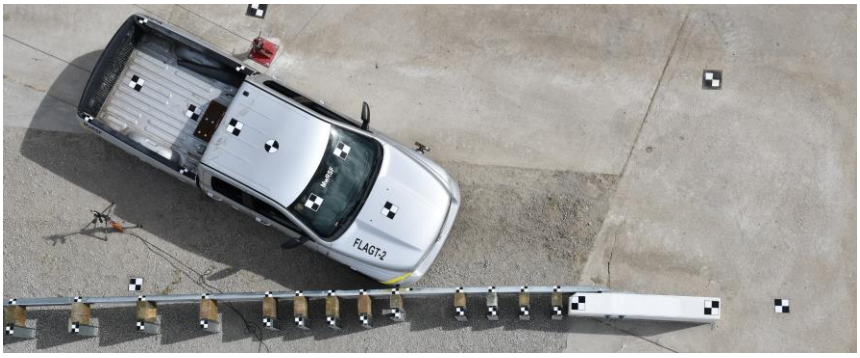
EVALUATION OF FLARED APPROACH GUARDRAIL TRANSITIONS: TEST NO. FLAGT-2



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16. Abstract

Approach guardrail transitions (AGTs) are typically installed tangent to the roadway. However, there was a desire to install AGTs flared away from the roadway to satisfy geometry constraints or to shorten system lengths. Previously, LS-DYNA simulations were used to explore the performance of AGTs flared away from the roadway, and a 15:1 flare rate was identified as the critical maximum flare rate. A crash test on a flared AGT was conducted in accordance with the Test Level 3 (TL-3) criteria of the American Association of State and Highway and Transportation Officials' (AASHTO) *Manual for Assessing Safety Hardware* (MASH). Test no. FLAGT-1, a MASH test designation no. 3-21 test, was conducted with the 2270P pickup impacting an AGT flared away from the roadway at a 15:1 rate. The selected AGT configuration had previously passed MASH TL-3 in a tangent layout. However, the 15:1 flared AGT test resulted in vehicle snag at the upstream end of the concrete buttress, which caused excessive occupant compartment deformations and excessive longitudinal ORAs. Thus, the test failed to meet MASH standards.

As documented herein, the research project continued by redesigning the flared AGT to strengthen the barrier, reduce system deflections, and mitigate vehicle snag at the end of the buttress. The redesigned system continued the use of a 15:1 flare, but the 6.5-ft long W6x9 posts on the downstream end of the AGT were replaced with larger 7.5-ft long W6x15 posts. MASH test designation no. 3-21 was then re-run on the downstream end of the redesigned system.

In test no. FLAGT-2, the 5,000-lb pickup truck impacted the system at 62.6 mph and angle of 25.4 degrees relative to the roadway (effectively 29.2 degrees relative to the flared system). The vehicle was successfully contained and redirected. Vehicle decelerations, ORAs, and OVIs all fell within the MASH limits. However, deformations to the toe pan area were 9.9 in., which exceeded MASH limits. Therefore, test no. FLAGT-2 failed to satisfy the safety criteria for MASH test designation no. 3-21.

17. Key Words Highway Safety, Crash Test, Roadside Appurtenances, Compliance Test, MASH 2016, Test Level 3, Approach Guardrail Transition, AGT, Flare, Flared Guardrail		**18. Distribution Statement** No restrictions. This document is available through the National Technical Information Service. 5285 Port Royal Road Springfield, VA 22161	
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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.

INDEPENDENT APPROVING AUTHORITY

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

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.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

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

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in.
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yard	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliter	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or “metric ton”)	1.103	short ton (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela per square meter	0.2919	foot-Lamberts	fl
		FORCE & PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

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1 INTRODUCTION

1.1 Background

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 safe transition in lateral stiffness between semi-rigid guardrail and rigid bridge rail installations. 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 driver 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] had been established in accordance with NCHRP Report 350 Test Level 3 (TL-3) criteria [3]. Due to the need to reduce guardrail length 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 has been conducted on flared AGTs.

Several concerns for flaring AGTs have arisen due to 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 wheel 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].

The Midwest Pooled Fund Program sponsored the Phase I research effort to identify the critical flare rate for a thrie-beam AGT, which would provide the greatest reduction in length of

need (LON) while maintaining acceptable barrier safety performance [5]. The computer simulation study identified a flare rate of 15:1 (3.81 degrees from roadway) as the maximum critical flare rate to pass MASH TL-3 safety performance criteria. LS-DYNA simulations were also conducted to identify downstream critical impact points (CIPs) for both the 2270P and 1100C test vehicles with the 15:1 flared AGT.

The subsequent phases of the research effort included crash testing and evaluation of flared AGT installations to MASH TL-3 conditions. Test no. FLAGT-1 was conducted in accordance with MASH test designation no. 3-21 on an AGT with a 15:1 flare rate [6]. The AGT consisted of nested, 12-gauge thrie beam supported by W6x9 posts spaced at 18¾-in. intervals. The downstream end of the AGT was connected to a concrete parapet with the geometry of the Standardized Transition Buttress [1] oriented tangent to the roadway. In test no. FLAGT-1, the pickup truck impacted the AGT 90 in. upstream of the buttress at speed of 63.2 mph and at an angle of 25.4 degrees (29.2 degrees relative to the guardrail).

The vehicle was contained and redirected by the flared AGT. However, increased impact severity resulting from the flare caused excessive guardrail deflections and led to a large kink in the nested thrie beam at the upstream end of the buttress. The 2270P vehicle snagged on this kink, 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 [6]. Subsequently, the flared AGT needed to be modified to limit system deflections and create a crashworthy barrier.

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 Phases II through IV was to evaluate the safety performance of flared AGTs in accordance with MASH TL-3 criteria. Test no. FLAGT-2, documented herein, was conducted with the 2270P pickup truck impacting the downstream end of the modified, flared AGT to evaluate the potential for vehicle snag on the rigid buttress.

1.3 Scope

After the failure observed in test no. FLAGT-1 on an AGT with a 15:1 flare rate, the project was rescoped to include identifying and implementing system modifications that would increase the safety performance of the flared AGT. The redesigned AGT was then retested to the same impact conditions as the failed test (FLAGT-1) to evaluate the barrier system modifications. Note, the complete evaluation of the flared AGT required MASH test designation nos. 3-20 and 3-21 at both the downstream end of the AGT to evaluate the snag on the buttress and the upstream end of the AGT to evaluate pocketing, snag, and capture at the W-to-thrie transition section.

2 FLARED AGT DESIGN MODIFICATIONS

The previous crash test on a flared AGT, test no. FLAGT-1, failed to satisfy MASH safety performance criteria 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 upstream end of the buttress and the large kink in the guardrail that formed adjacent to the buttress. The large kink in the nested thrie beam was a damage characteristic not observed in previous MASH testing of AGTs. Additionally, a large soil crack formed along the front flange of the AGT posts, as shown in Figure 2, which was not typical of previous AGT crash testing.


Figure 2. System Damage, Test No. FLAGT-1

These unusual damage characteristics were the result of excessive guardrail deflections within the downstream region of the AGT. System deflections were expected to be higher than previous MASH AGTs due to the 30 percent increase in impact severity associated with the 15:1 flare. However, the lateral deflections of the flared AGT in test no. FLAGT-1 were significantly higher than predicted by the Phase I numerical simulations. To prevent vehicle snag, the system deflections needed to be reduced.

It was noted that the AGT posts did not plastically bend during the impact. Instead, the soil behind the posts shifted, opening the large soil crack along the front of the posts and allowing the

posts to rotate back. Installing larger and deeper embedded posts would result in more soil resistance, increased lateral stiffness to the AGT, and reduced deflections during impact. Therefore, the 6.5-ft long W6x9 posts in the nested thrie beam region of the AGT were replaced with 7.5-ft long W6x15 posts, as shown in Figure 3. Note, all other barrier components were identical to the system configuration evaluated in test no. FLAGT-1, including the 15:1 flare rate.

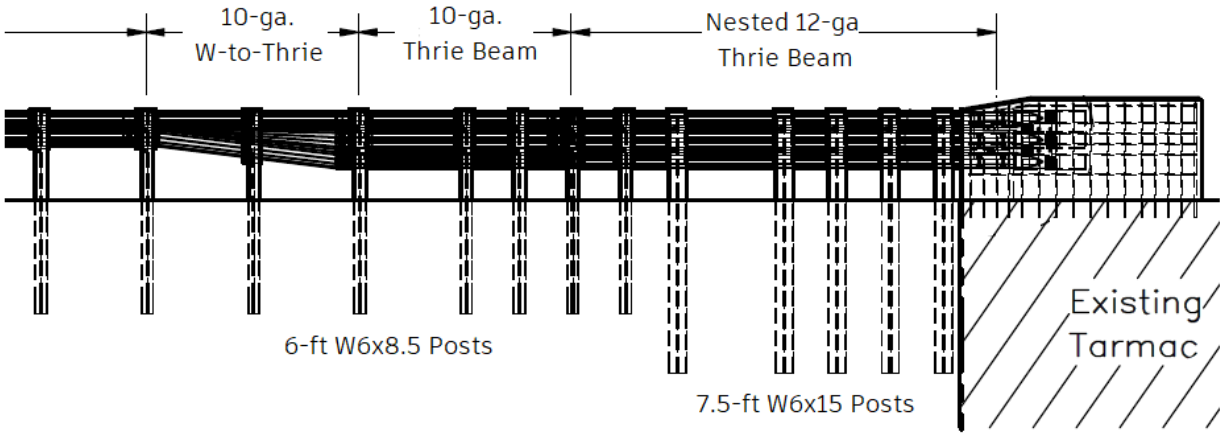


Figure 3. Modified AGT Posts, Test No. FLAGT-2

3 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) a flared AGT connector plate. Design details for test no. FLAGT-2 are shown in Figures 4 through 31. Photographs of the test installation are shown in Figures 32 through 34. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix A. Note, the test installation was identical to the one evaluated previously in test no. FLAGT-1 except the posts supporting the nested thrie beam (post nos. 16 through 20).

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 13. 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 14 through 17, and the vertical steel in the buttress was anchored to the tarmac using an epoxy adhesive, as detailed in Figure 14.

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 height of 31 in. to the top of the guardrail. Post nos. 3 through 15 and were 6-ft long W6x8.5 steel posts embedded 40 in. into the soil, while post nos. 16 through 20 were 7.5-ft long W6x15 steel posts embedded 61 in. in the soil. Spacing between posts varied, as show in Figure 5.

The upstream stiffness transition, or the W-beam to nested thrie beam transition, was previously full-scale crash tested to MASH TL-3 [7]. 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 [8].

The upstream end of the guardrail installation, post nos. 1 and 2, were configured with a trailing-end anchorage system. The guardrail anchorage system was utilized to simulate the strength of other crashworthy end terminals. The anchorage system consisted of timber posts, foundation tubes, anchor cables, bearing plates, rail brackets, and channel struts, which closely resembled the hardware used in the Modified Breakaway Cable Terminal (BCT) system and is now part of a crashworthy, downstream trailing end terminal [9-12].

Finally, 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 7 and

detailed in Figures 24 through 26. 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 28, 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.

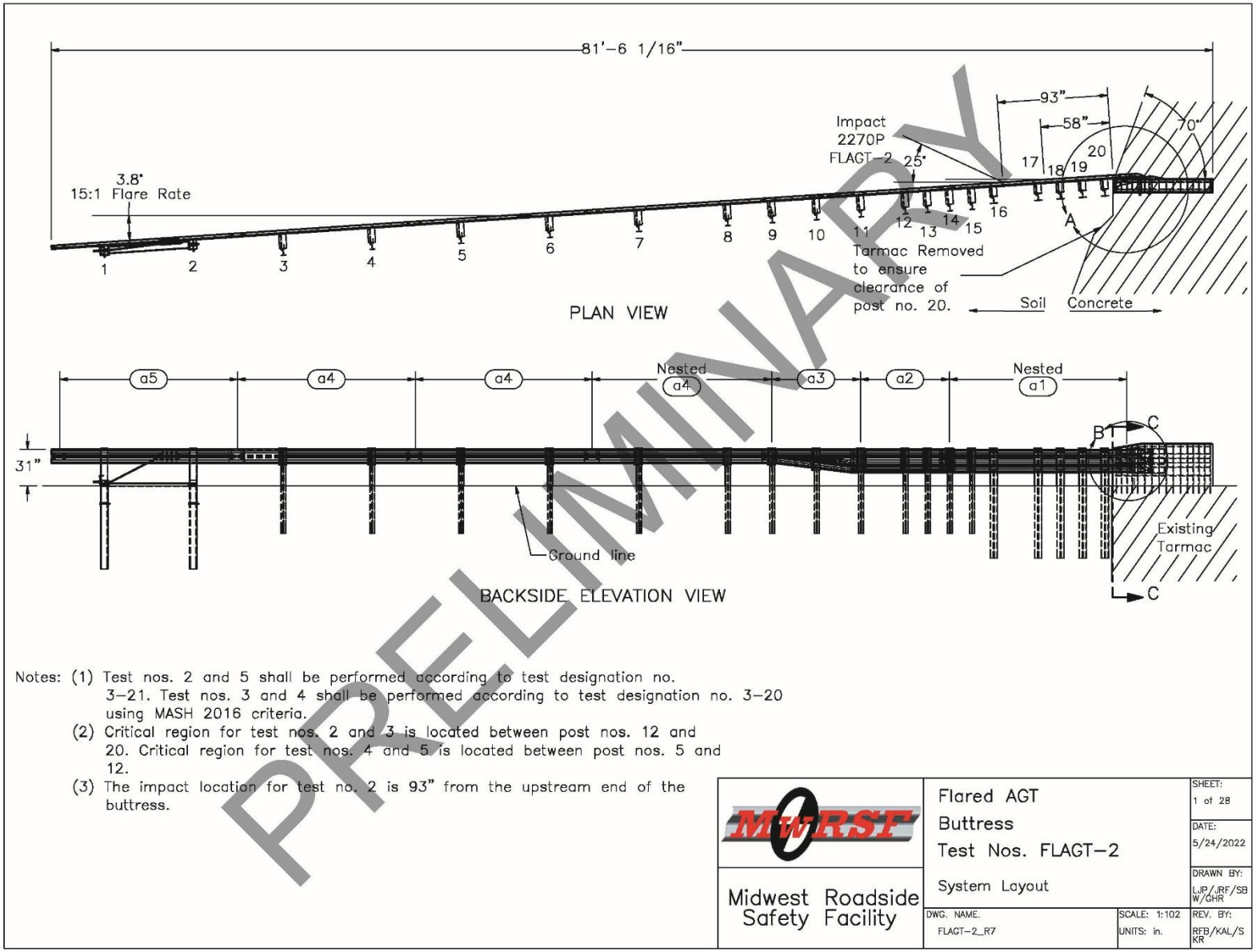


Figure 4. Test Installation Layout, Test No. FLAGT-2

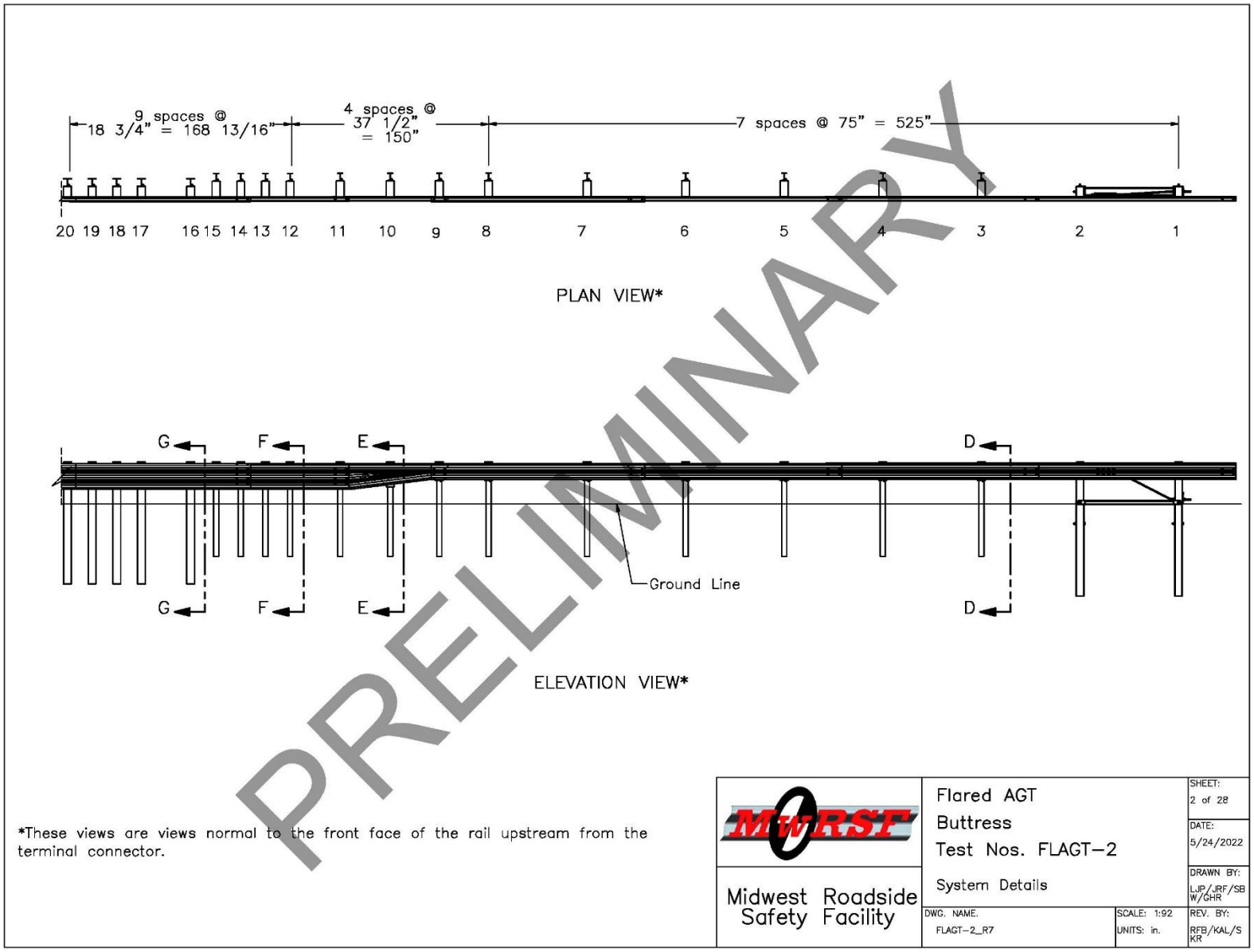


Figure 5. System Details, Test No. FLAGT-2

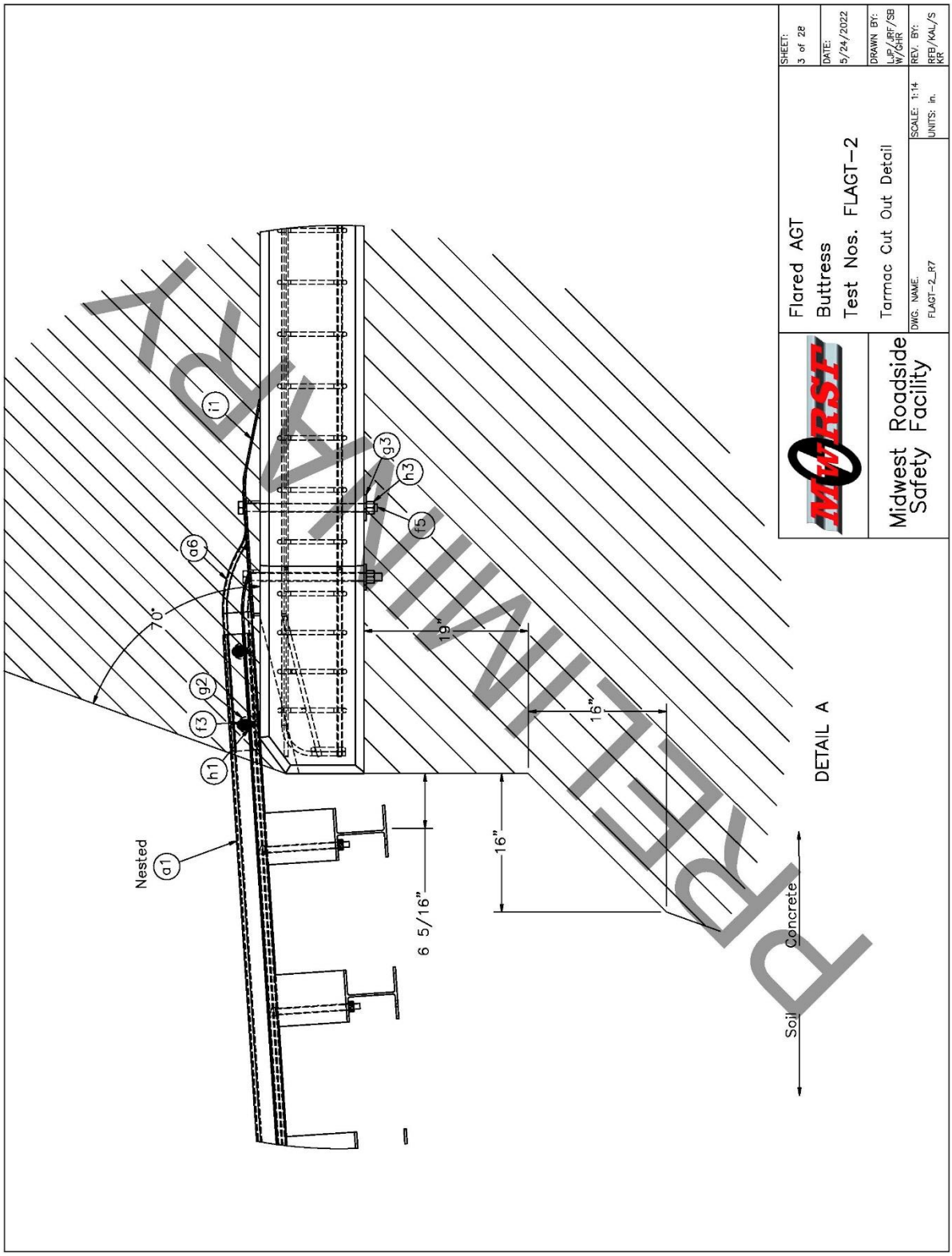


Figure 6. Tarmac Cut Out Detail, Test No. FLAGT-2

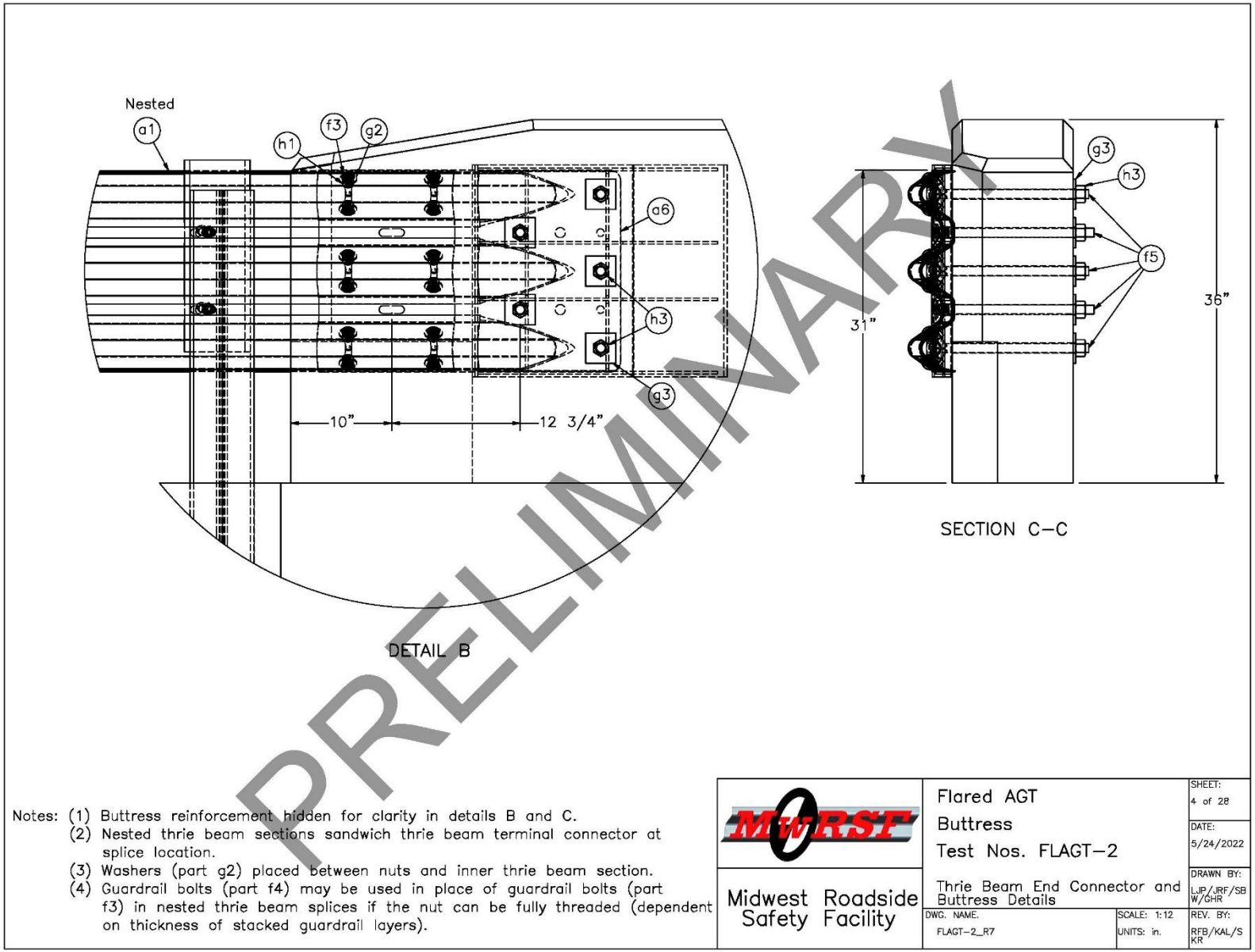


Figure 7. Thrie-Beam End Connector and Buttress Details, Test No. FLAGT-2

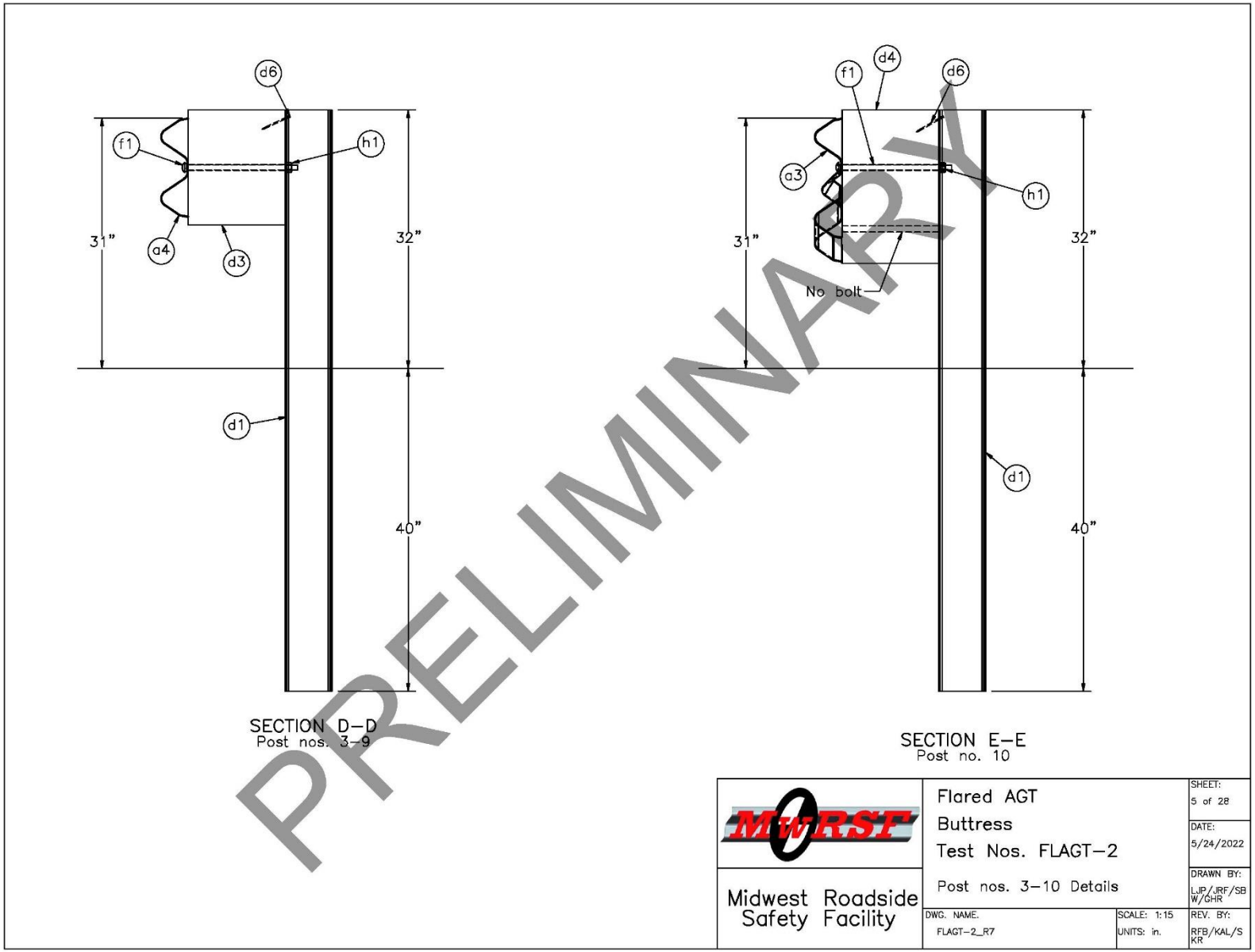


Figure 8. Post Nos. 3 through 10 Details, Test No. FLAGT-2

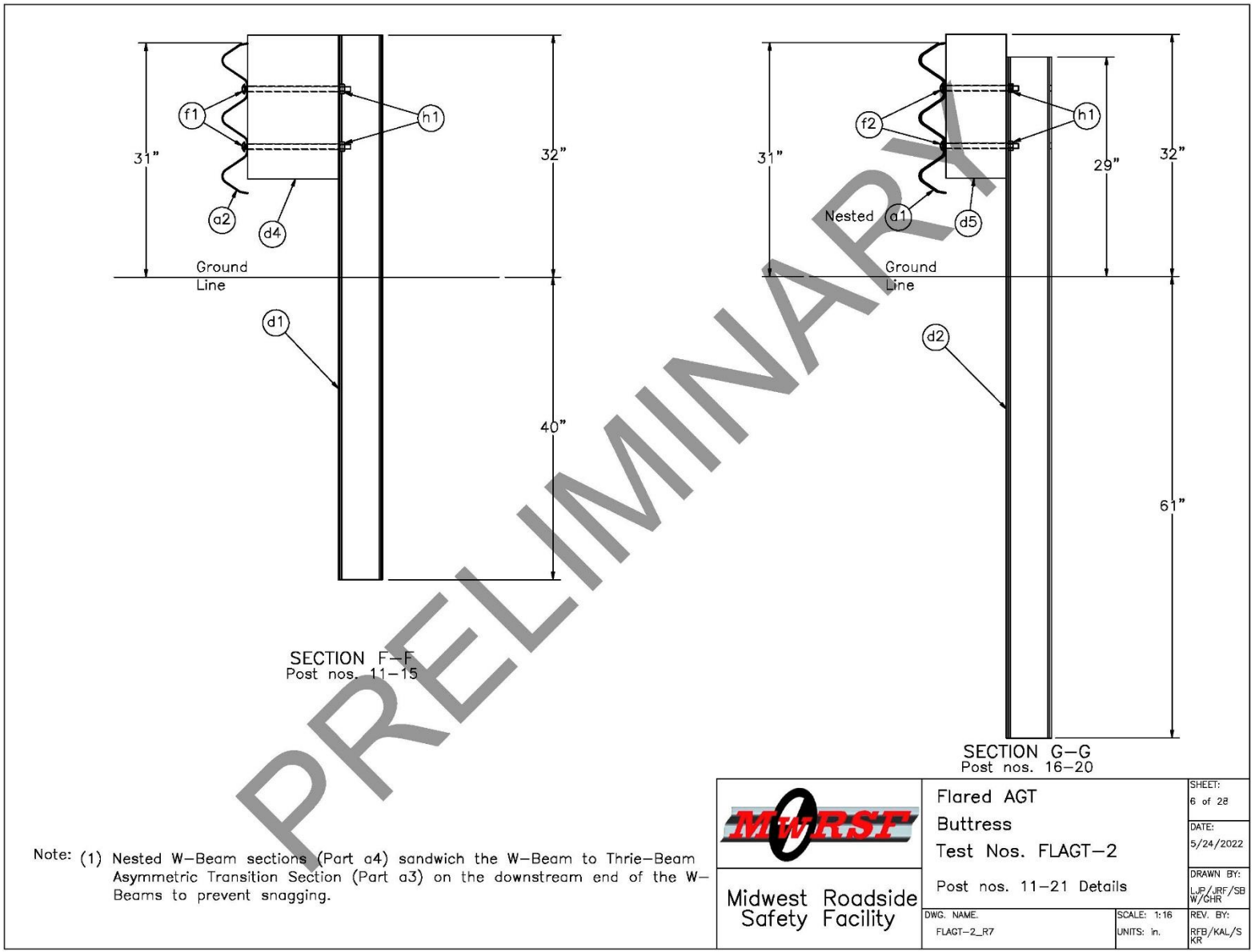


Figure 9. Post Nos. 11 through 20 Details, Test No. FLAGT-2

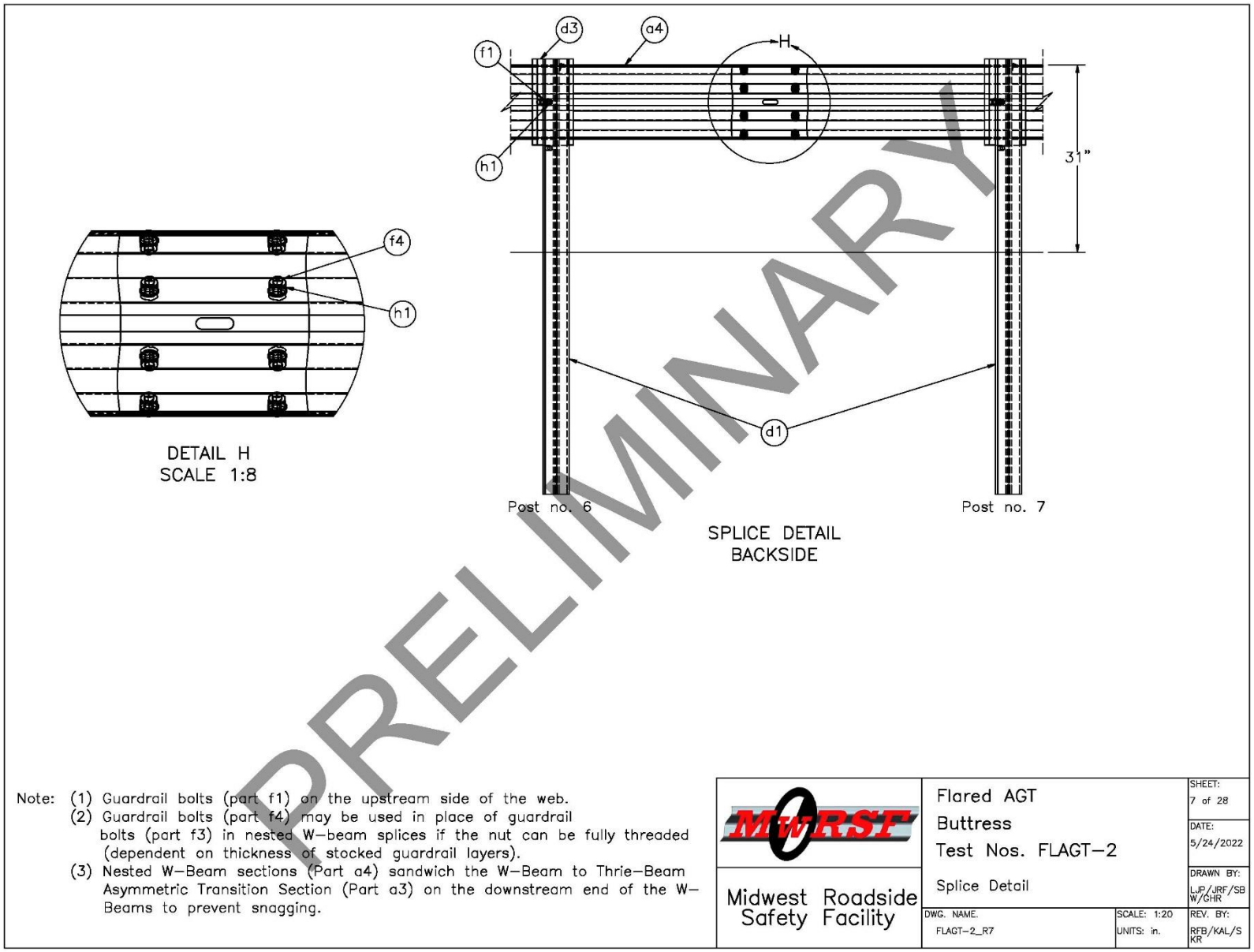


Figure 10. Splice Detail, Test No. FLAGT-2

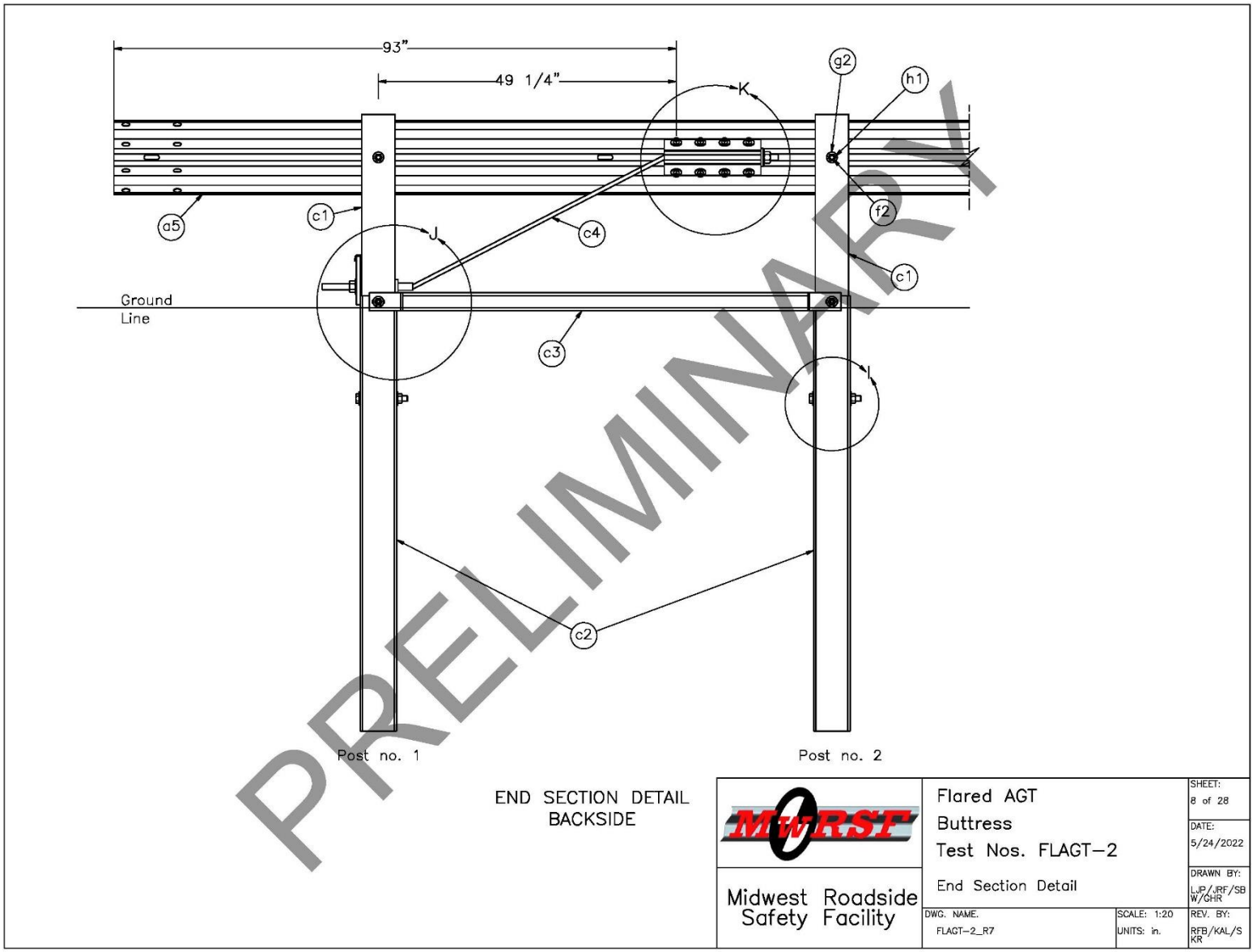


Figure 11. End Section Detail, Test No. FLAGT-2

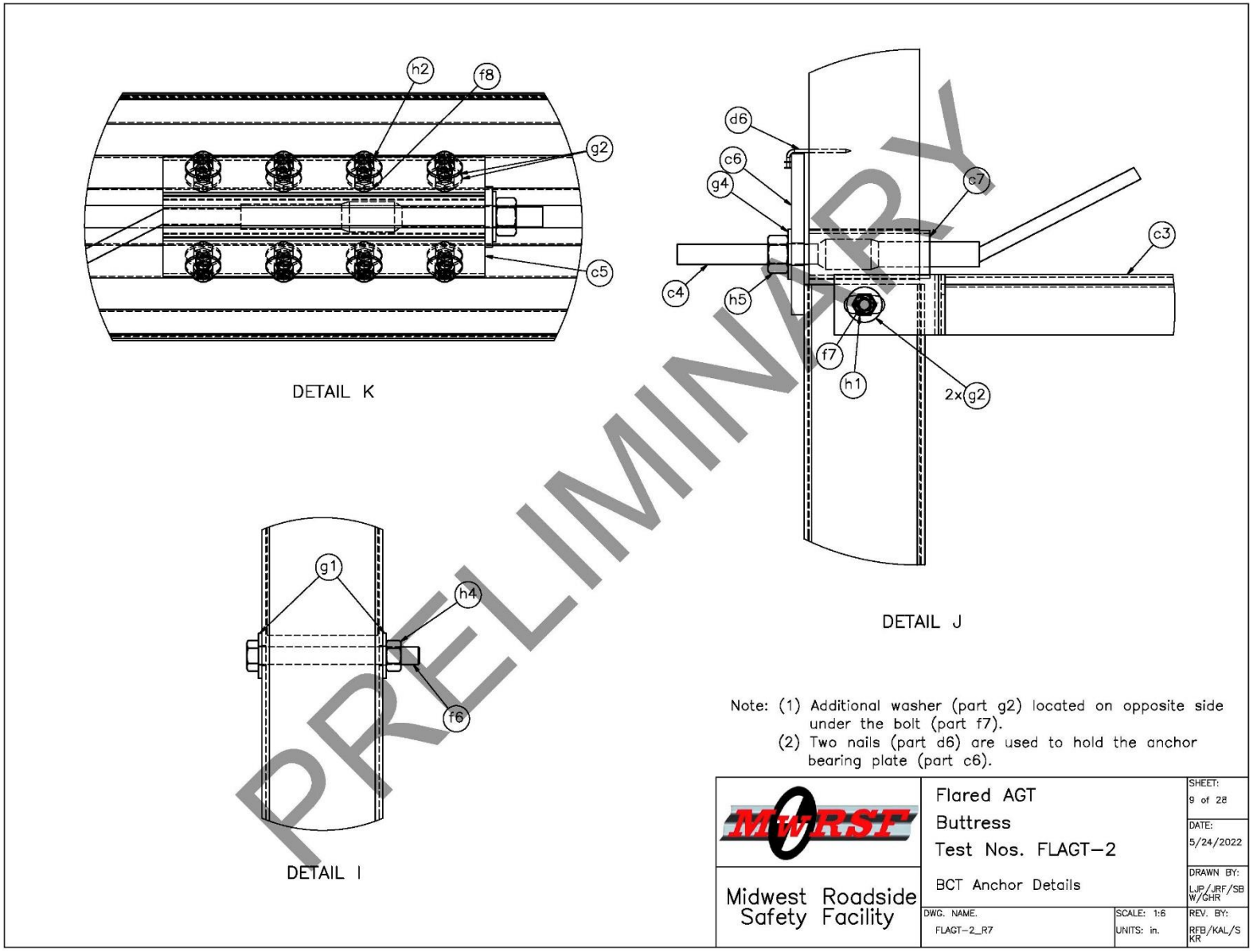


Figure 12. BCT Anchor Details, Test No. FLAGT-2

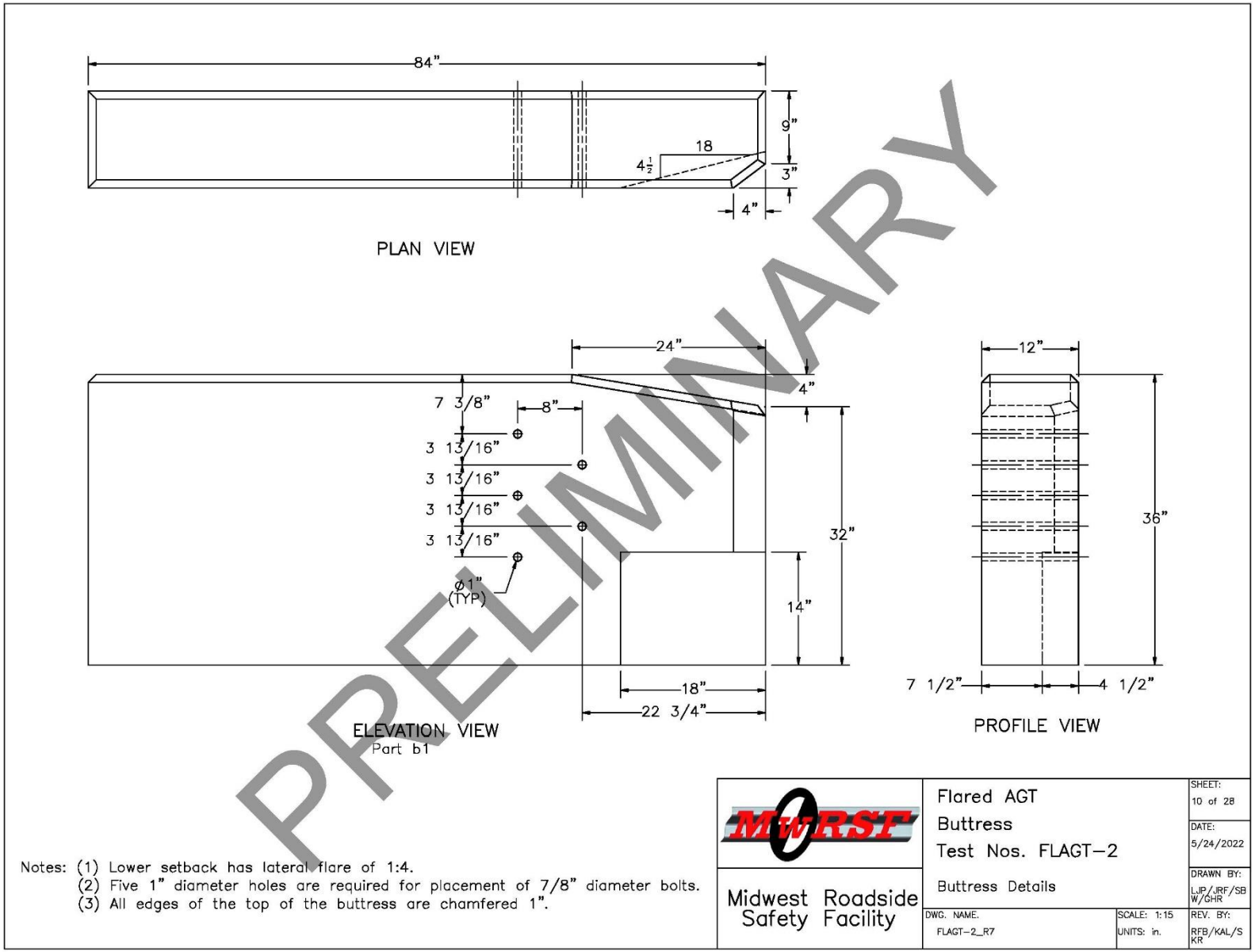


Figure 13. Buttress Details, Test No. FLAGT-2

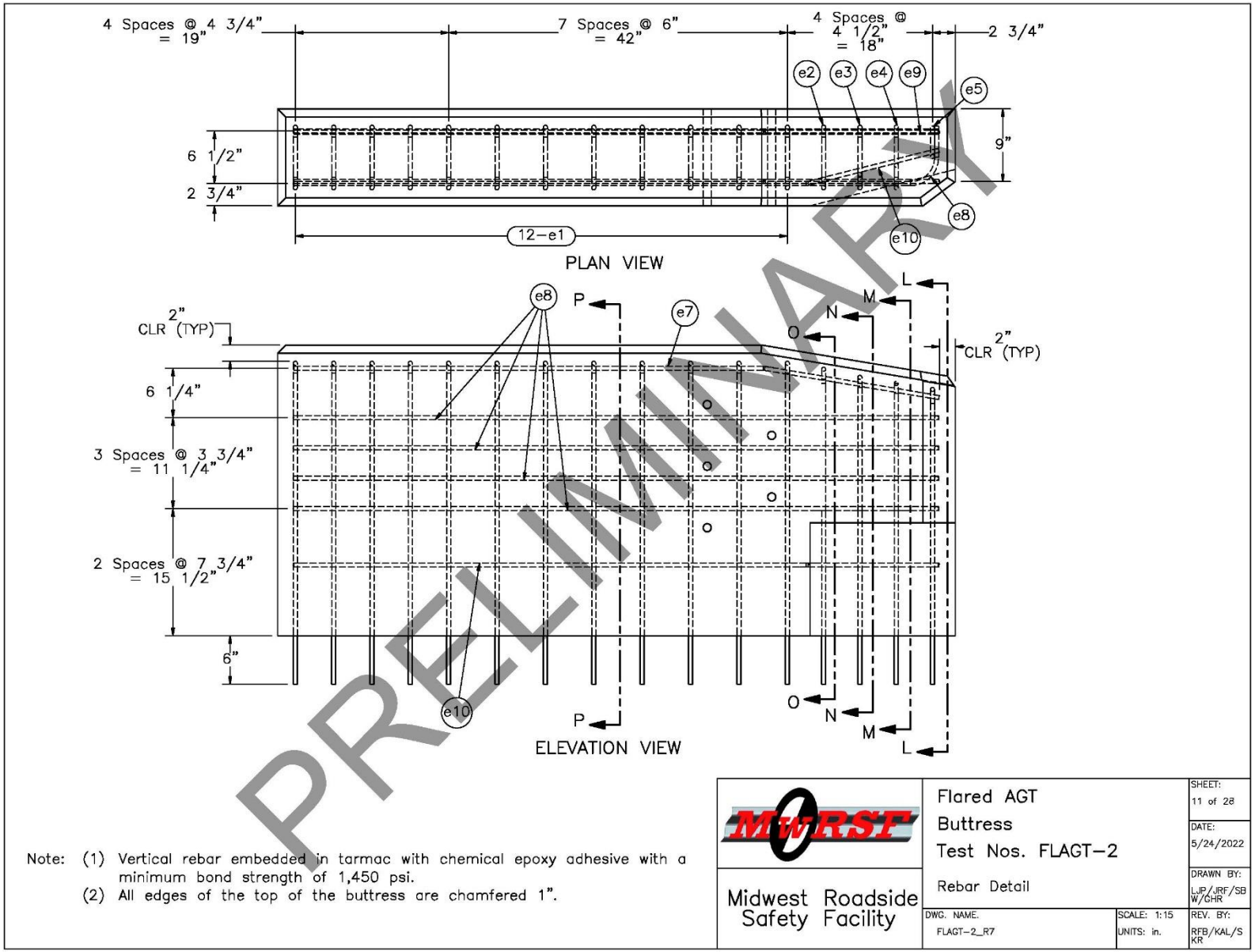


Figure 14. Buttress Rebar Detail, Test No. FLAGT-2

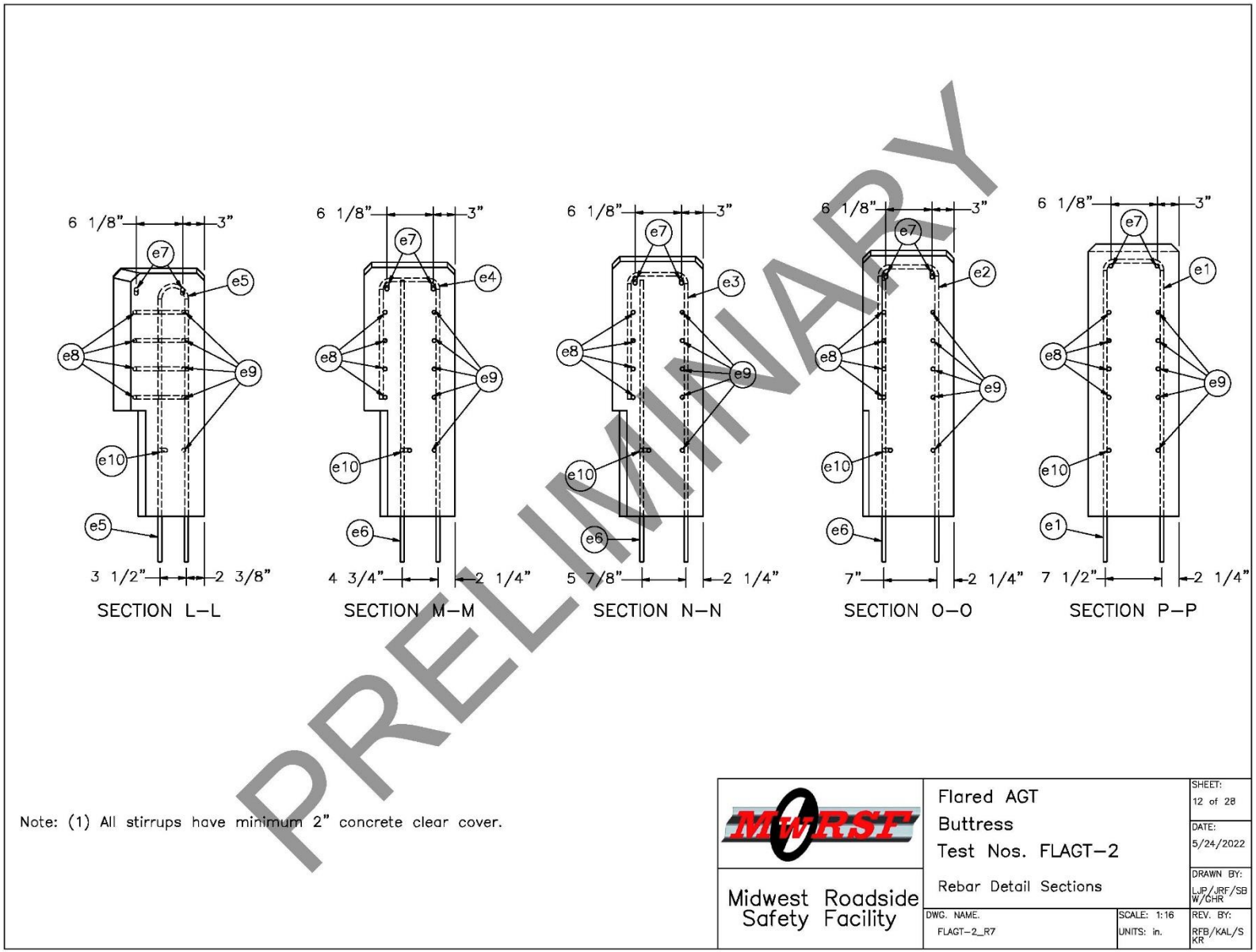
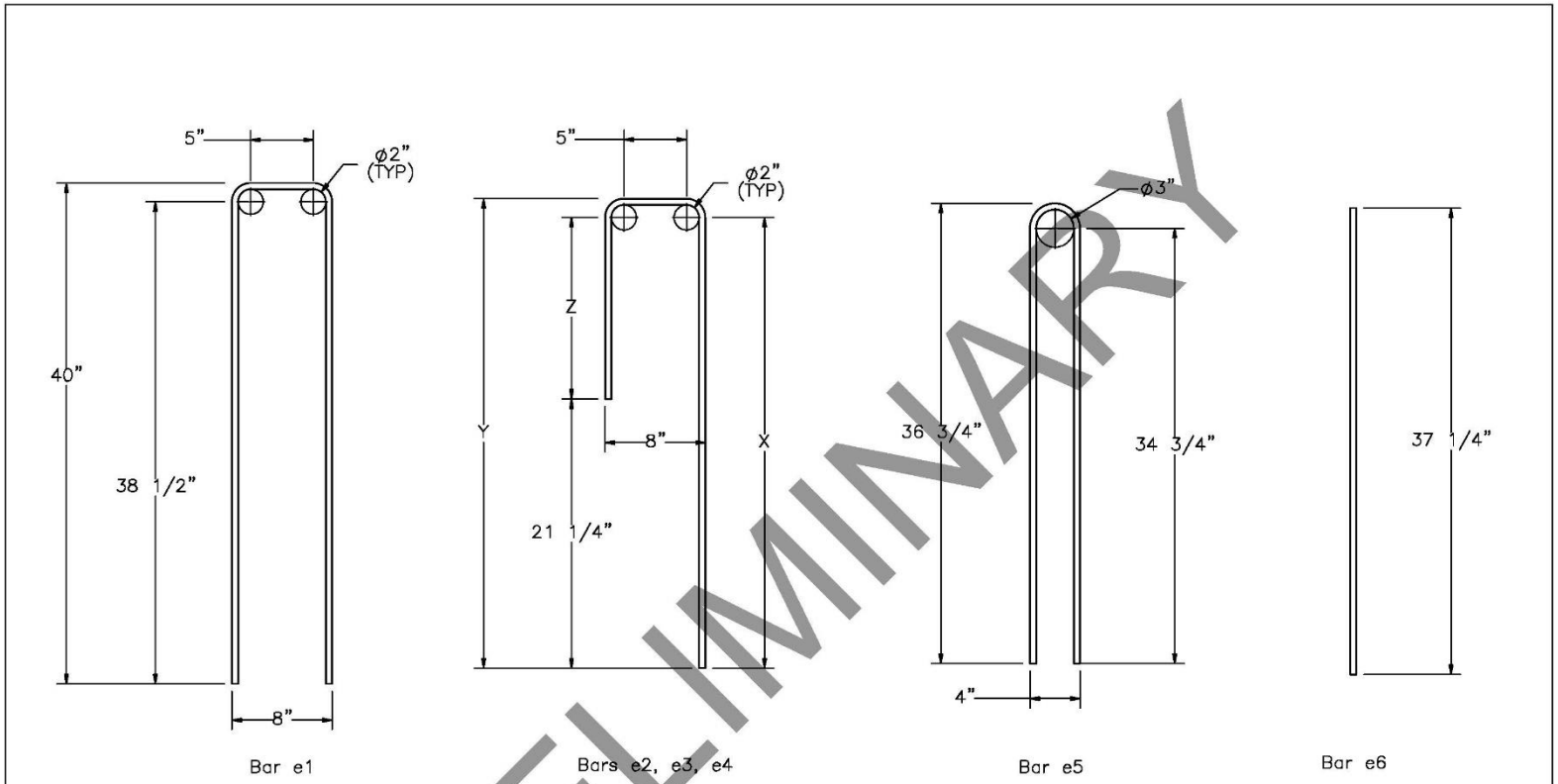


Figure 15. Buttress Rebar Detail Sections, Test No. FLAGT-2



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"

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Flared AGT Buttress
Test Nos. FLAGT-2
Vertical Bar Details

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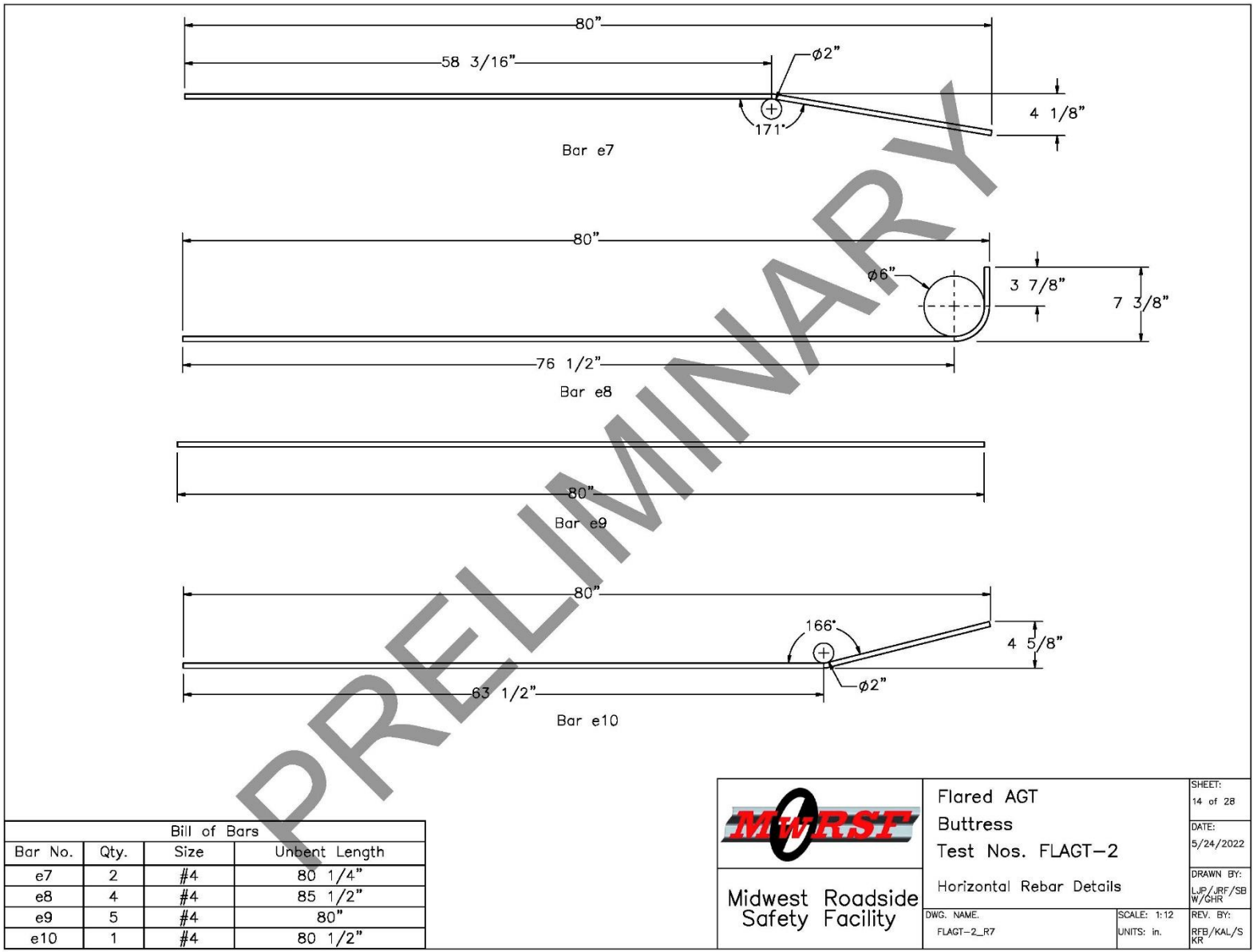
REV. BY: RFB/KAL/S KR
DWG. NAME. FLAGT-2_R7
SCALE: 1:12
UNITS: in.

Figure 16. Vertical Rebar Details, Test No. FLAGT-2



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 17. Horizontal Rebar Details, Test No. FLAGT-2

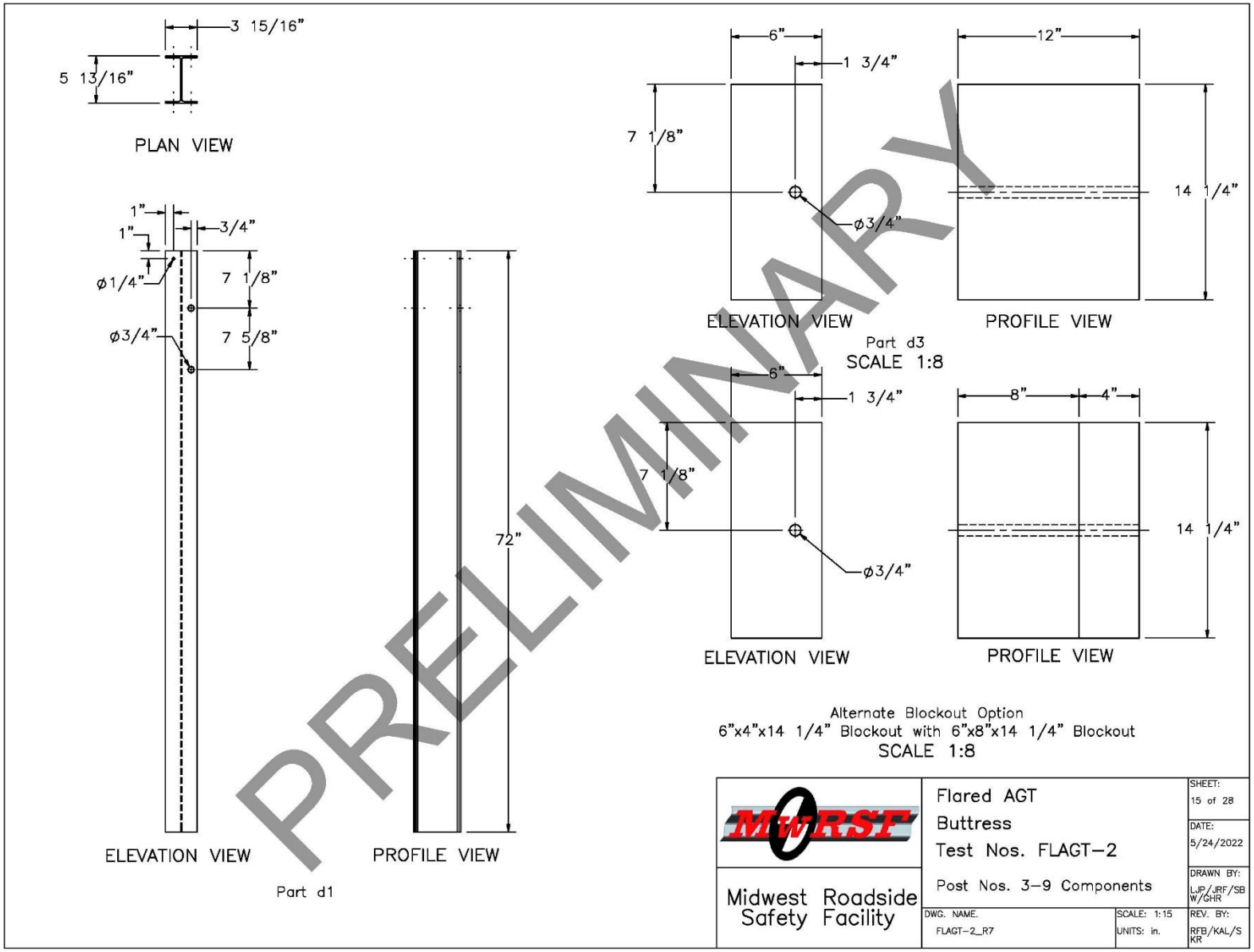


Figure 18. Post Nos. 3 through 9 Components, Test No. FLAGT-2

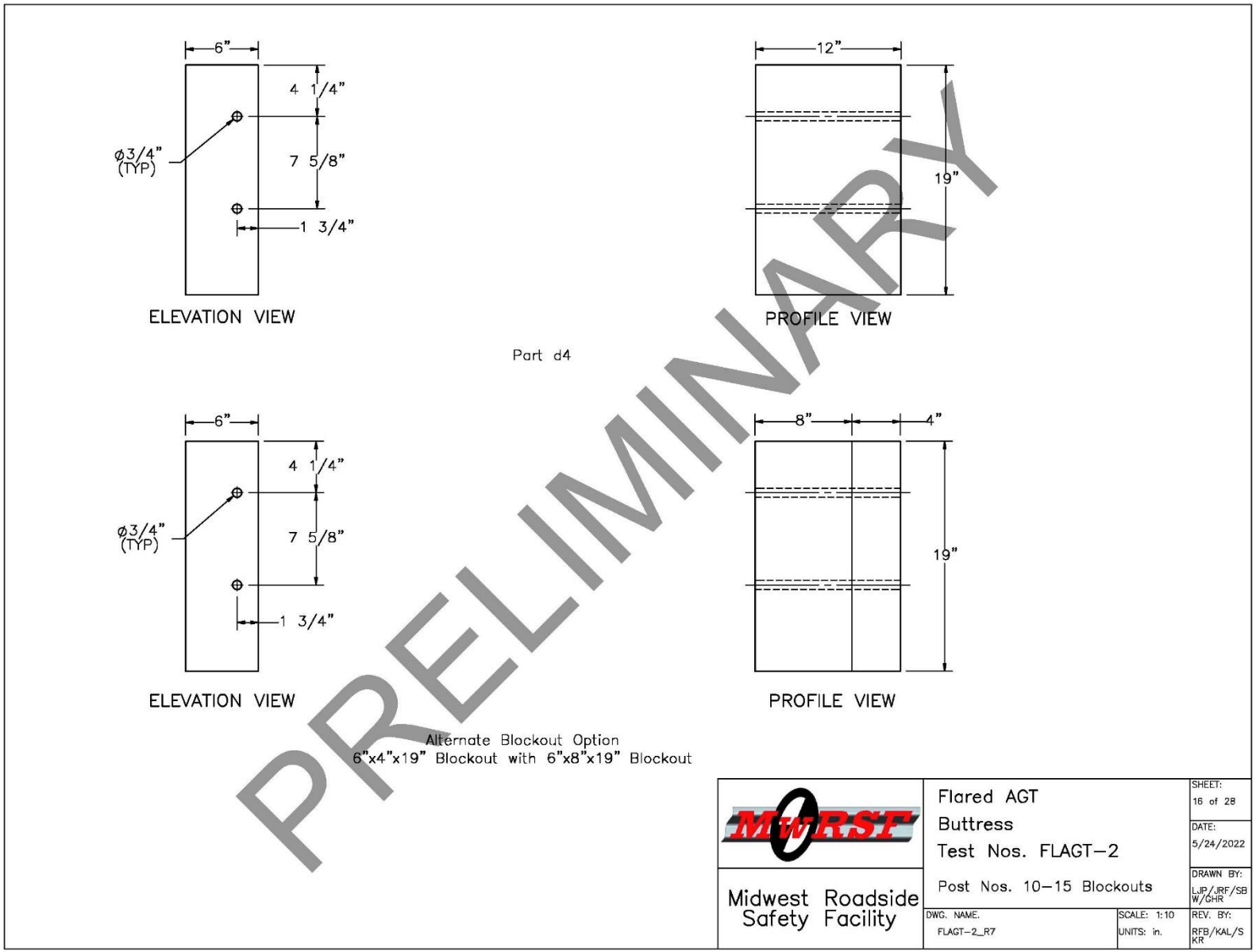


Figure 19. Post Nos. 10 through 15 Blockouts, Test No. FLAGT-2

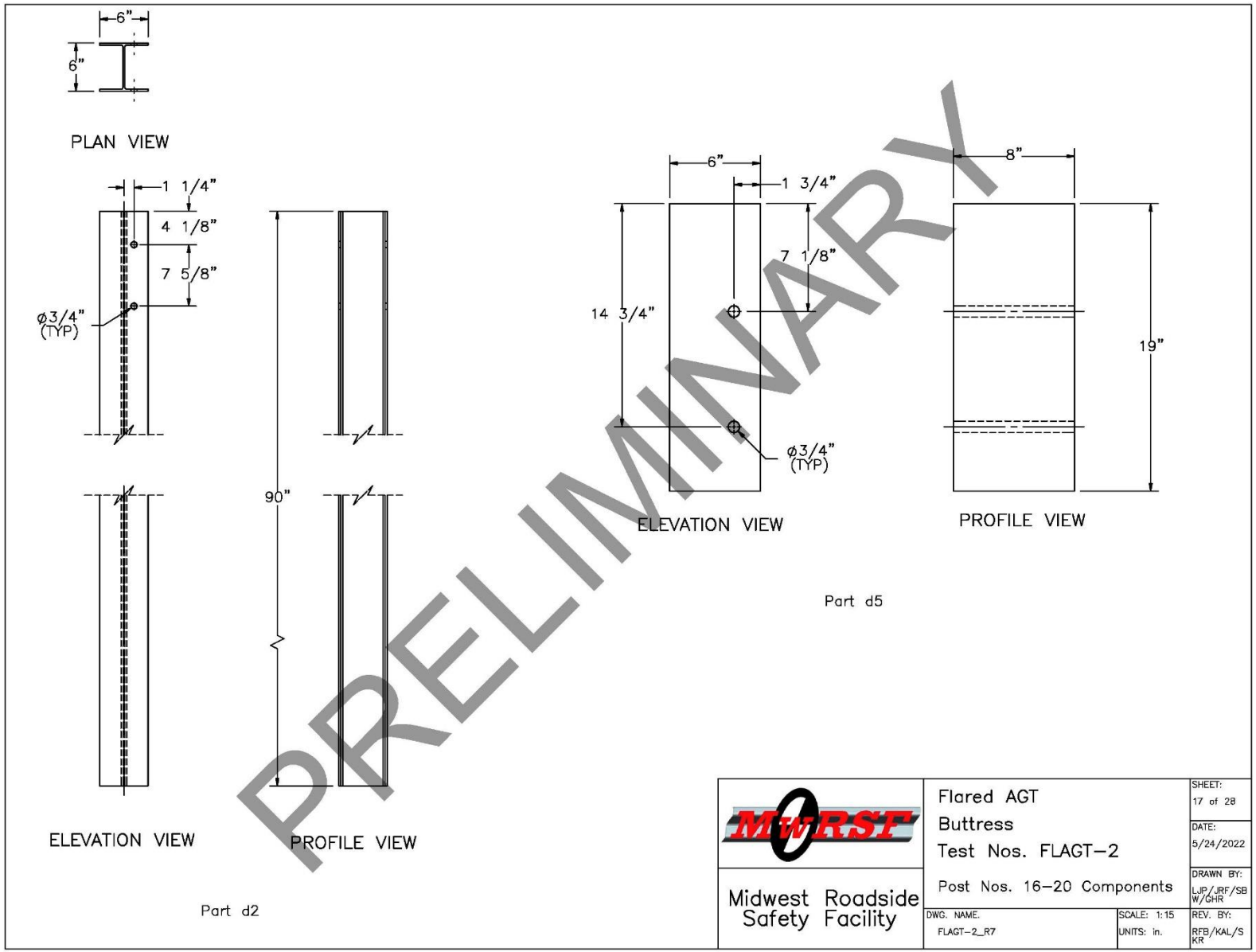


Figure 20. Post Nos. 16 through 20 Components, Test No. FLAGT-2

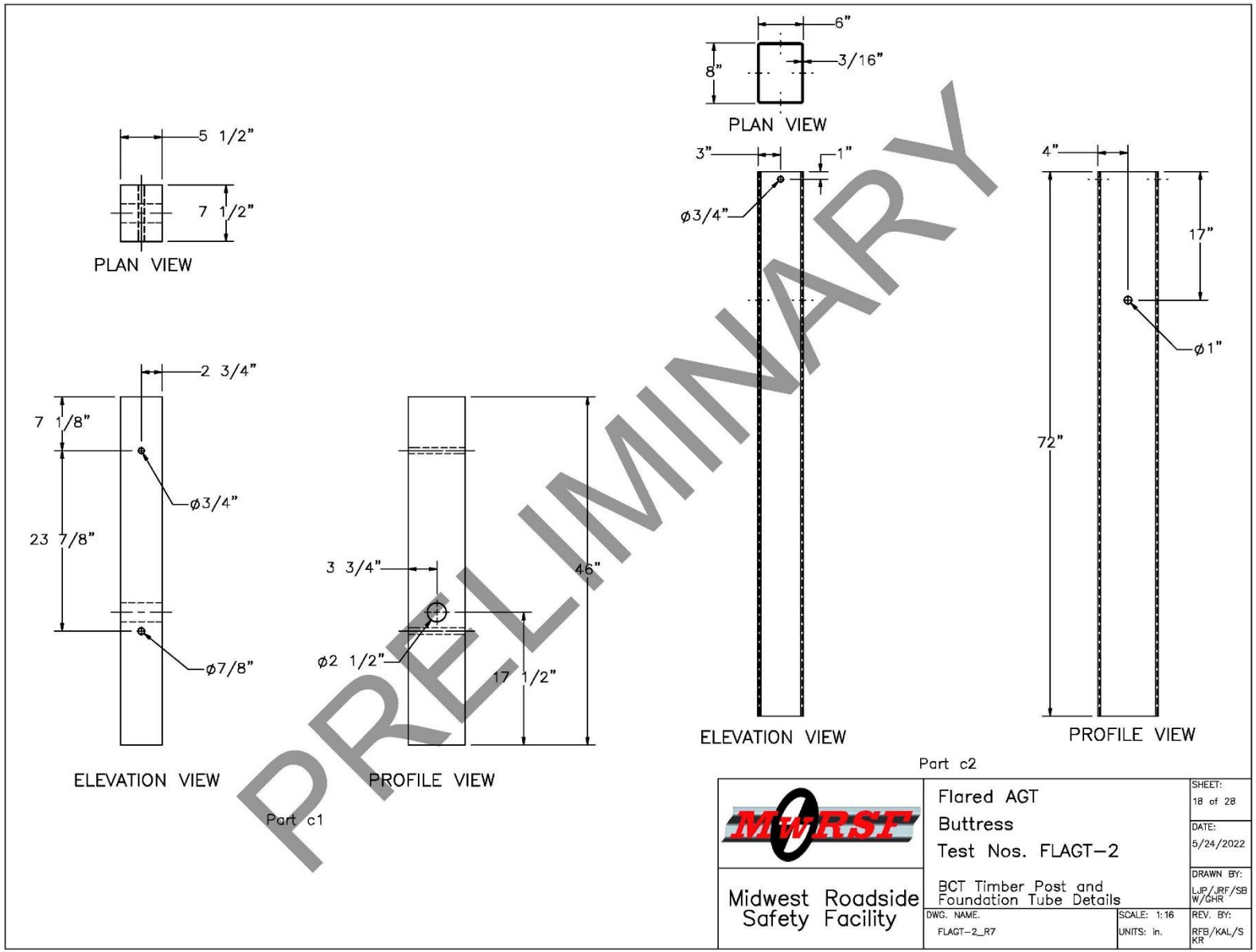


Figure 21. BCT Timber Post and Foundation Tube Details, Test No. FLAGT-2

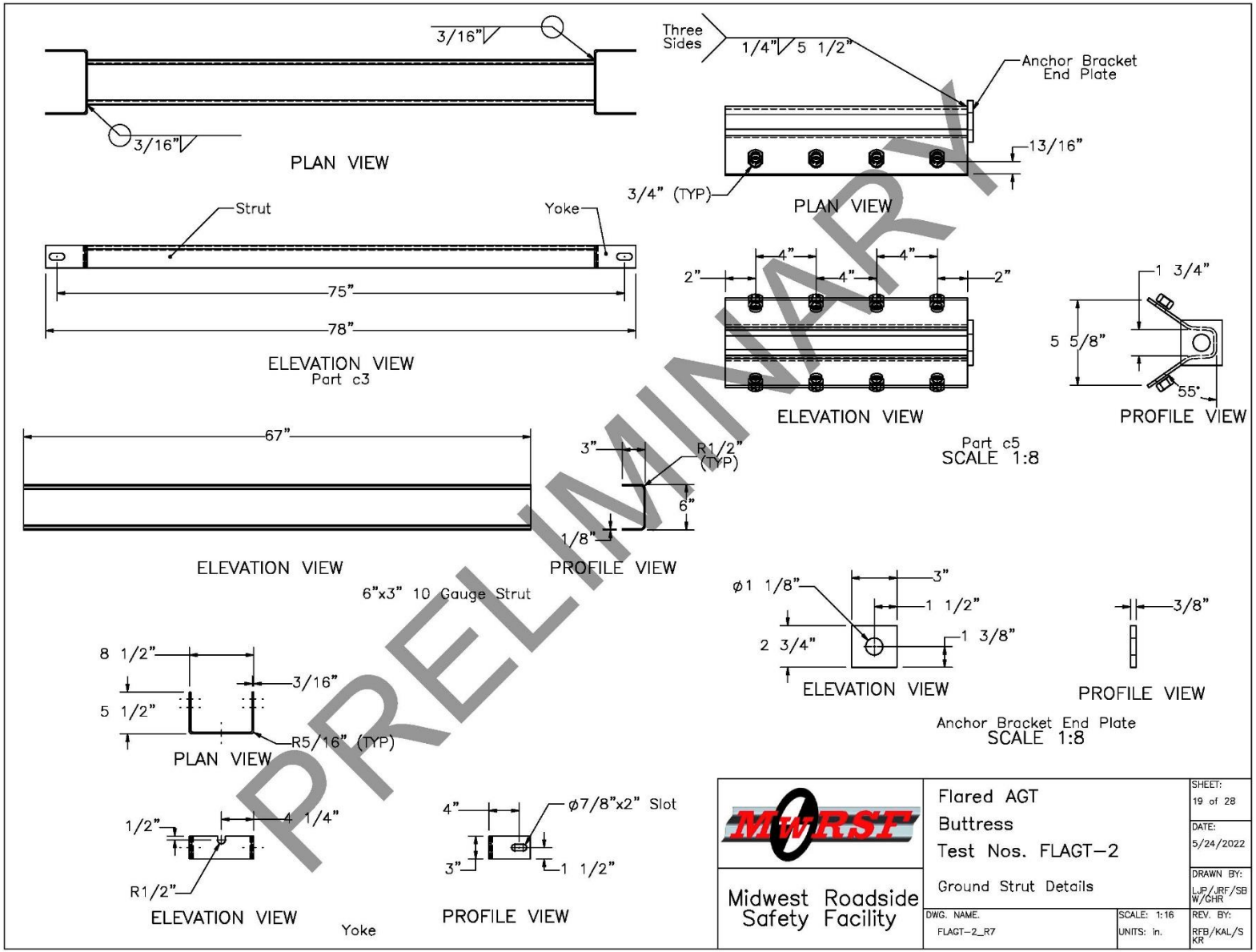


Figure 22. Ground Strut Details, Test No. FLAGT-2

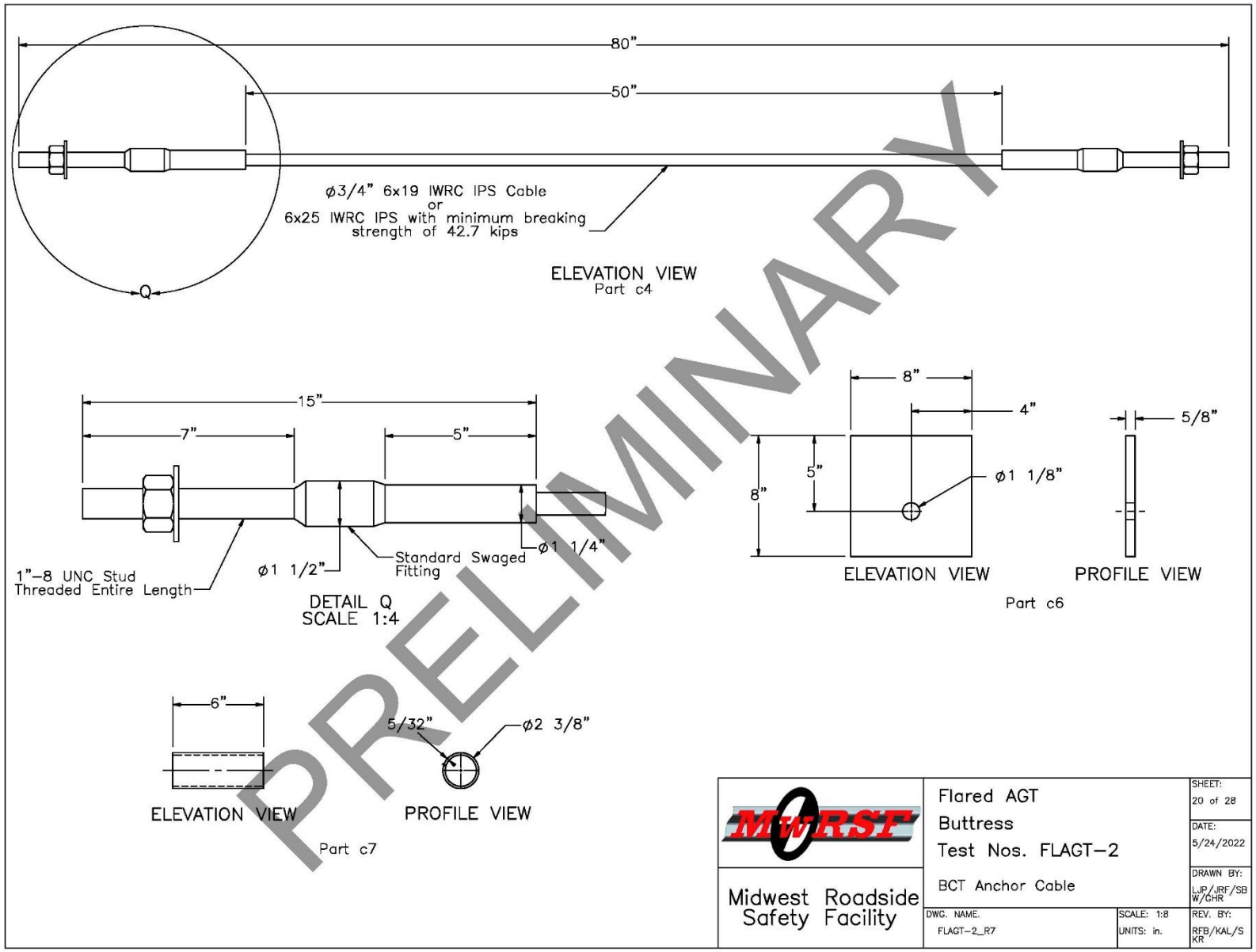
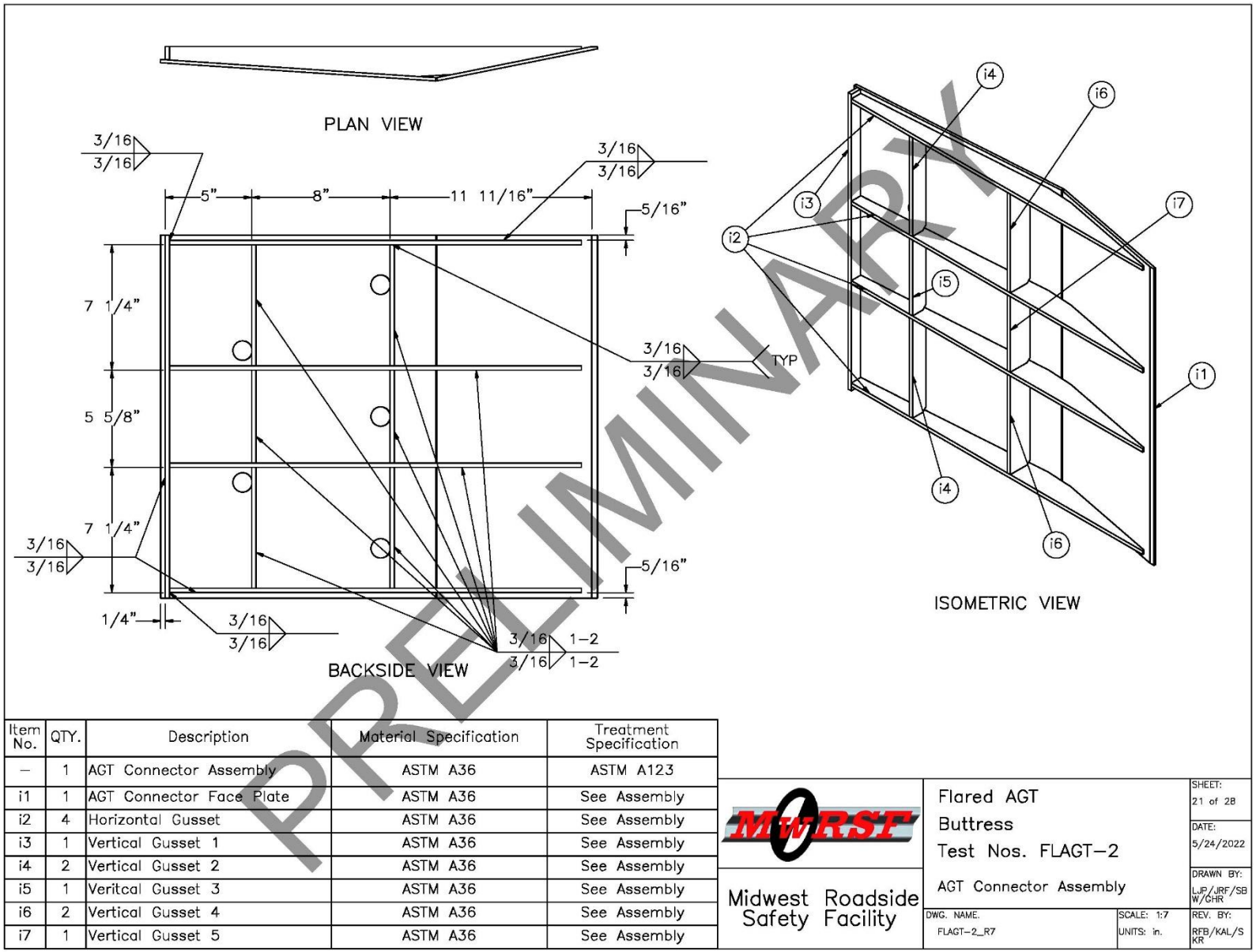


Figure 23. BCT Anchor Cable, Test No. FLAGT-2



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

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AGT Connector Assembly

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DRAWN BY: LJP/JRF/SB W/CHR
REV. BY: RFB/KAL/S KR
DWG. NAME. FLAGT–2_R7
SCALE: 1:7
UNITS: in.

Figure 24. AGT Connector Assembly, Test No. FLAGT-2

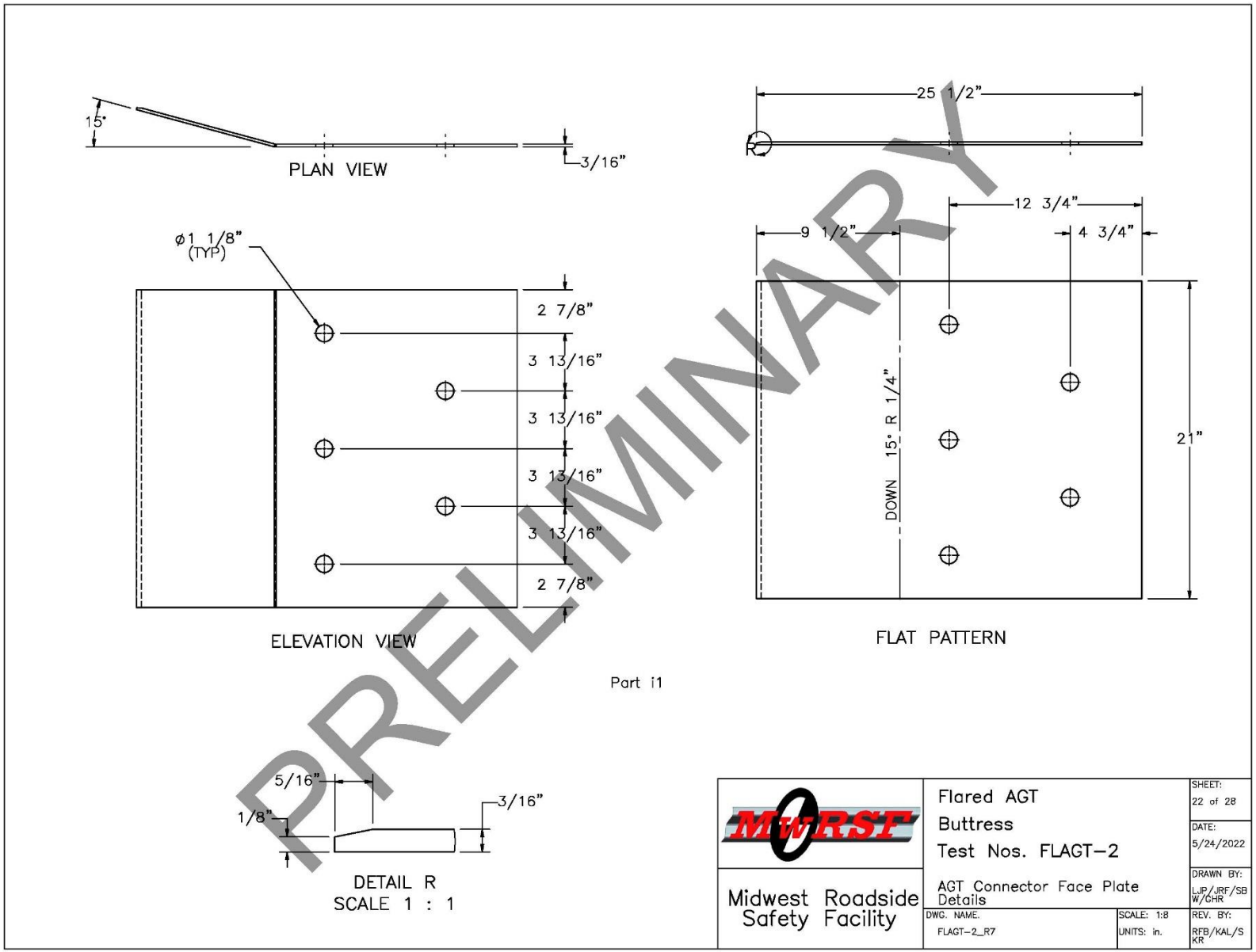

Figure 25. AGT Connector Face Plate Details, Test No. FLAGT-2

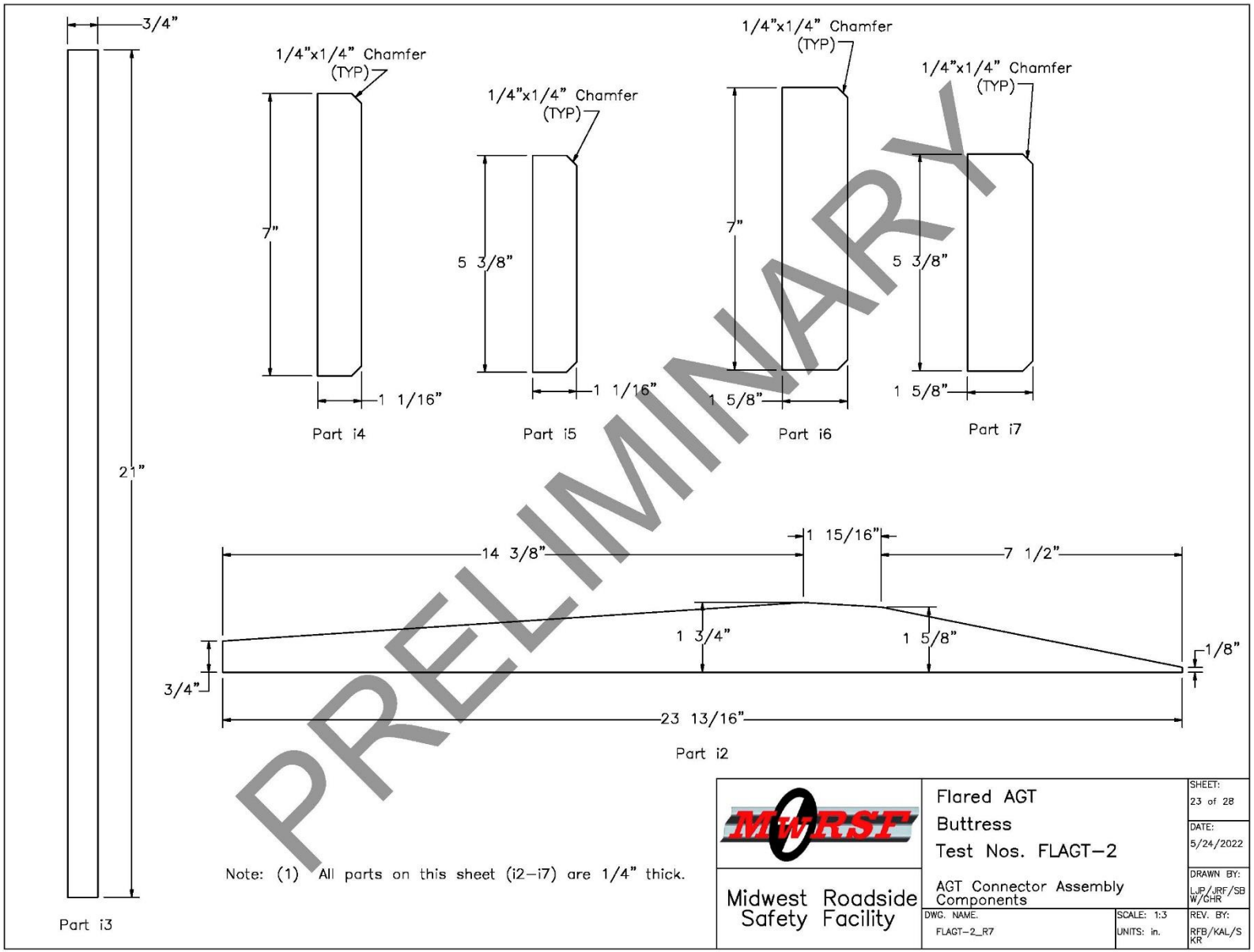

Figure 26. AGT Connector Assembly Components, Test No. FLAGT-2

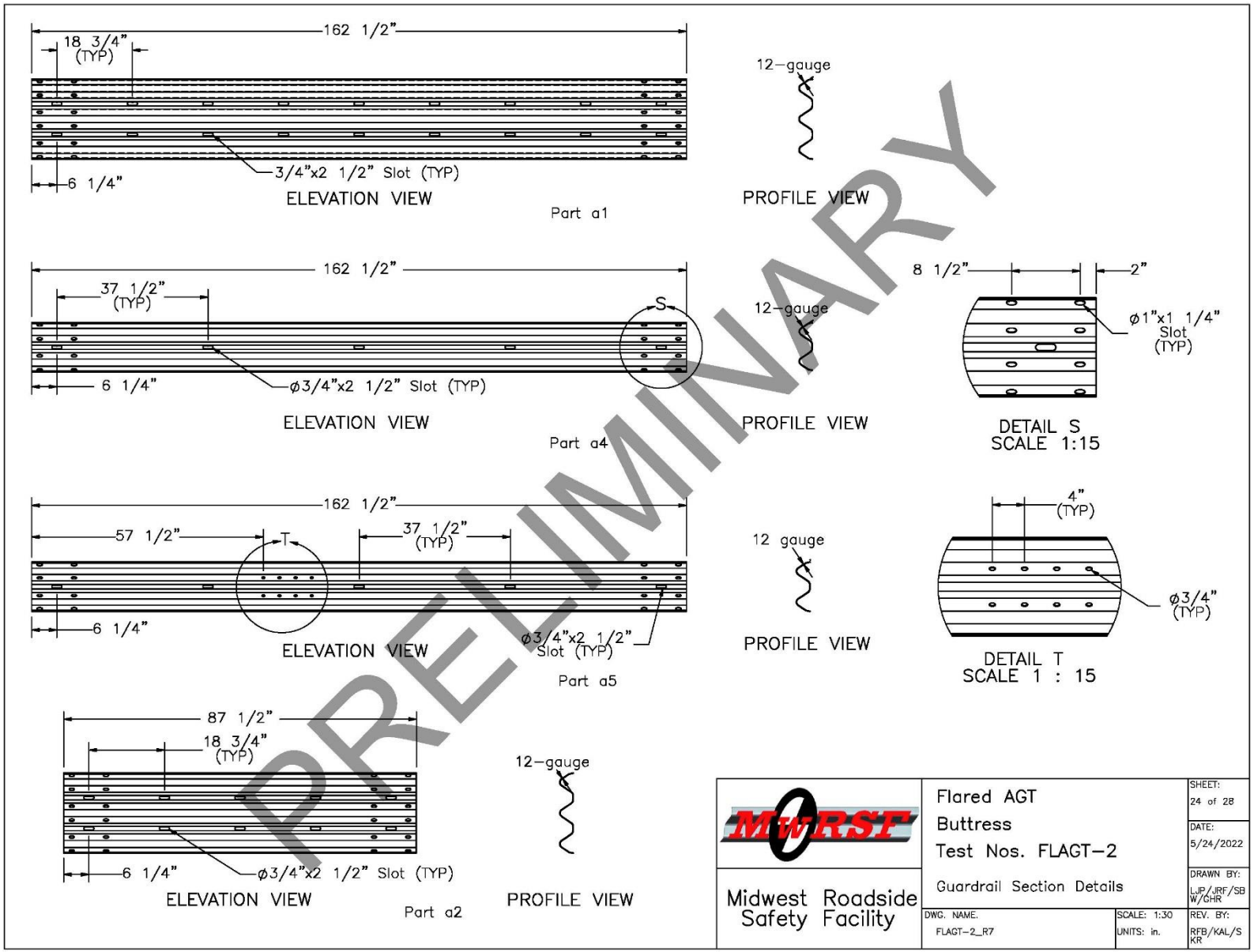

Figure 27. Guardrail Section Details, Test No. FLAGT-2

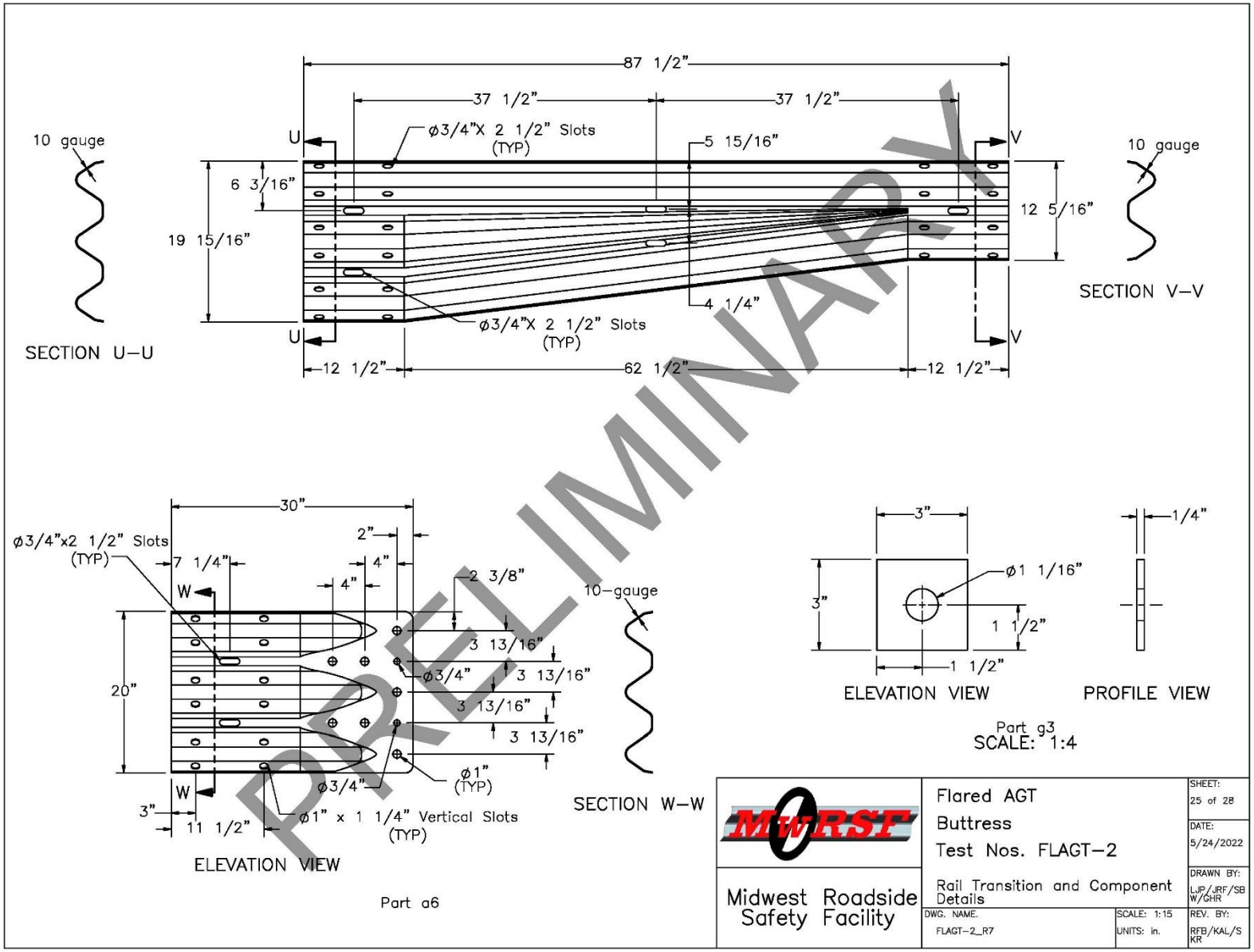

Figure 28. Rail Transition and Component Details, Test No. FLAGT-2

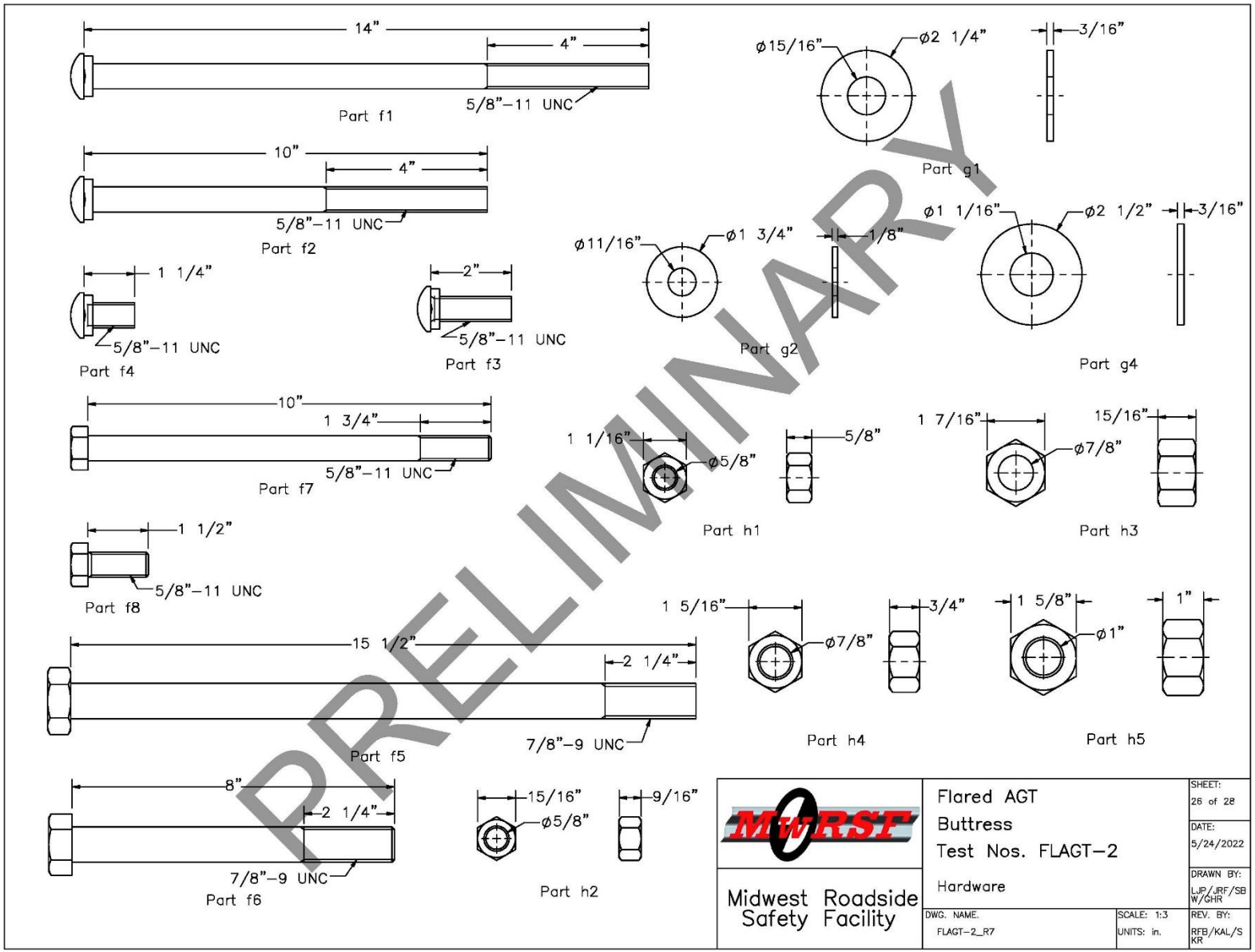

Figure 29. Hardware, Test No. FLAGT-2

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 Asymmetric 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	RTE01b
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	–
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	13	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992	*ASTM A123	PWE06
d2	5	W6x15, 90" Long Steel Post	ASTM A992	*ASTM A123	–
d3	7	6"x12"x14 1/4" Timber Blockout	SYP Grade No.1 or better	–	PDB10a
d4	6	6"x12"x19" Timber Blockout	SYP Grade No.1 or better	–	–
d5	5	6"x8"x19" Timber Blockout	SYP Grade No.1 or better	–	–
d6	10	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.

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Flared AGT Buttress
Test Nos. FLAGT–2
Bill of Materials

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DWG. NAME. FLAGT–2_R7
SCALE: None
UNITS: in.
REV. BY: RFB/KAL/SKR

Figure 30. Bill of Materials, Test No. FLAGT-2

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	12	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	44	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	FBX22a
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	8	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	FWC20a
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	100	5/8" Dia. Heavy Hex Nut	ASTM A563A	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	FNX16b
h2	8	5/8" Dia. Hex Nut	ASTM A563A	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	FNX16a
h3	5	7/8" Dia. UNC Heavy Hex Nut	ASTM A563DH or A194 Gr. 2H	–	FNX22b
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.

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Flared AGT Buttress
Test Nos. FLAGT-2
Bill of Materials

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REV. BY: RFB/KAL/SKR
DWG. NAME. FLAGT-2_R7
SCALE: None
UNITS: in.

Figure 31. Bill of Material, Test No. FLAGT-2, Cont.

Figure 32. Test Installation Photos, Test No. FLAGT-2

Figure 33. Test Installation Photos, Test No. FLAGT-2

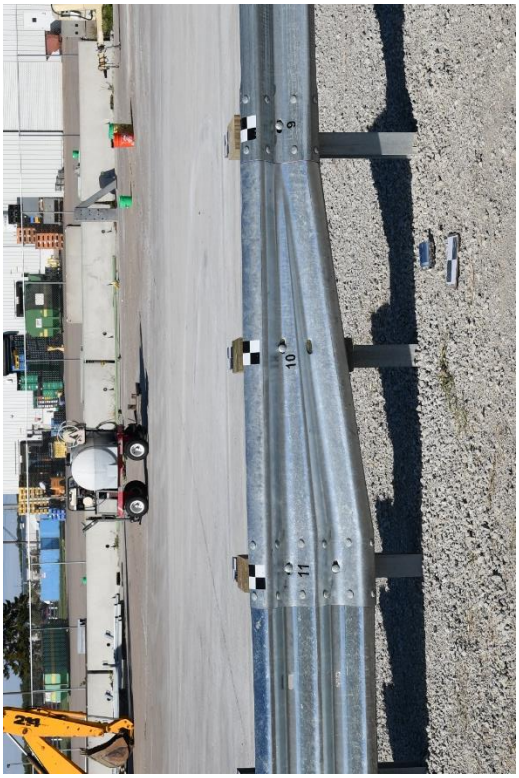


Figure 34. Test Installation Photos, Test No. FLAGT-2

4 TEST REQUIREMENTS AND EVALUATION CRITERIA

4.1 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 MASH [4]. According to TL-3 of MASH, longitudinal barriers 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 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 full-scale crash tests are required to evaluate the flared AGT, as summarized in Table 1.

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

Test Article	Test Designation No.	Test Vehicle	Vehicle Weight lb	Impact Conditions		Evaluation Criteria [1]	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.

4.2 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. 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="6">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="3">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="3">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>

4.3 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].

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

5.3 Test Vehicles

For test no. FLAGT-2, a 2015 Ram 1500 quad cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 4,900 lb, 5,000 lb, and 5,161 lb, respectively. The test vehicle is shown in Figures 35 and 36, and vehicle dimensions are shown in Figure 37.

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [15] was used to determine the vertical component of the c.g. for the pickup truck. 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 37 and 38. 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 38. 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 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 remote-controlled brake system was installed in the test vehicle so the vehicle could be brought safely to a stop after the test.

Figure 35. Test Vehicle, Test No. FLAGT-2

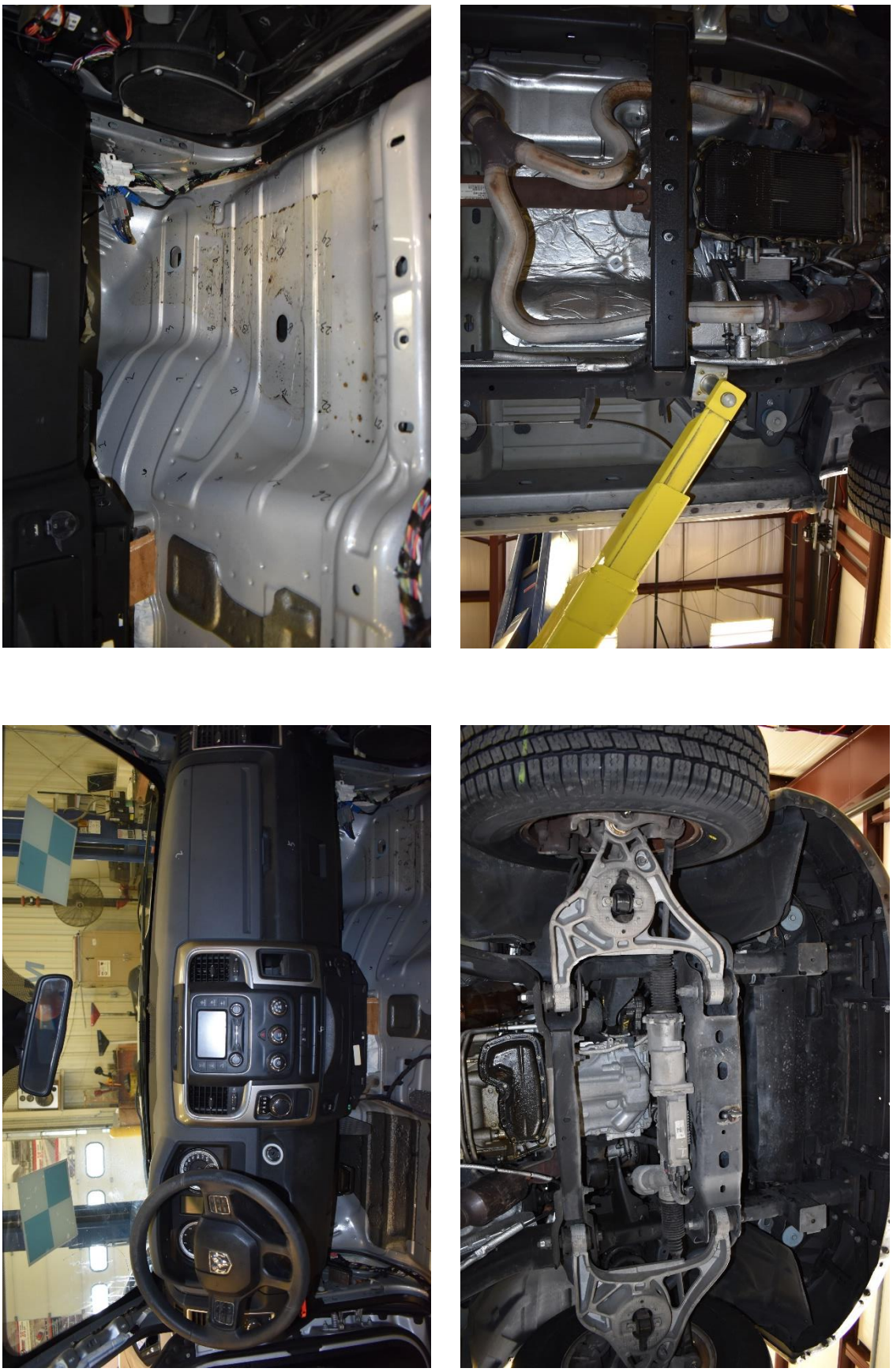
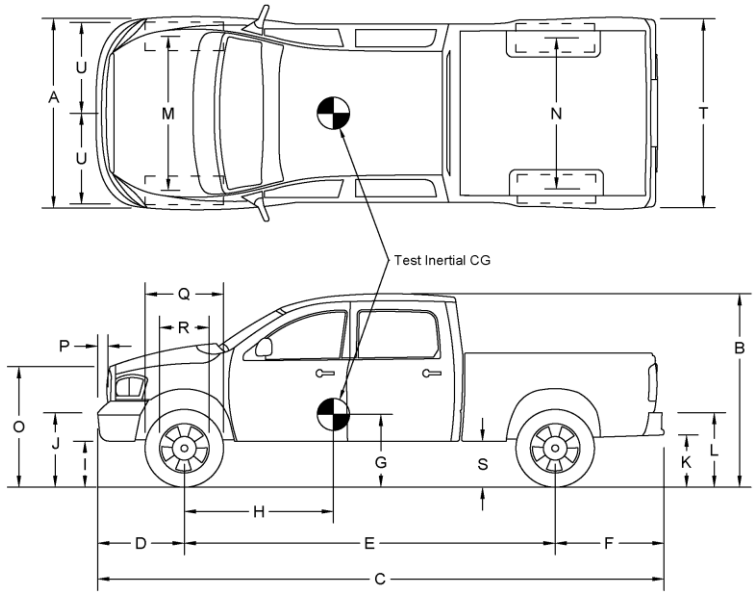


Figure 36. Test Vehicle's Interior Floorboards and Undercarriage, Test No. FLAGT-2

Test Name:	FLAGT-2		**VIN No:**	1C6RR6GG1FS646171	
Model Year:	2015	**Make:**	Dodge	**Model:**	Ram 1500
Tire Size:	265/70 R17	**Tire Inflation Pressure:**	40 psi	**Odometer:**	253218.9



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

A:	79 (2007)	**B:**	74 1/2 (1892)
	78±2 (1950±50)		
C:	228 7/8 (5813)	**D:**	39 1/4 (997)
	237±13 (6020±325)		39±3 (1000±75)
E:	140 1/2 (3569)	**F:**	46 (1168)
	148±12 (3760±300)		
G:	28 3/16 (716)	**H:**	65 13/16 (1672)
	min: 28 (710)		63±4 (1575±100)
I:	12 1/2 (318)	**J:**	26 (660)
K:	20 3/4 (527)	**L:**	29 3/4 (756)
M:	68 1/4 (1734)	**N:**	67 3/4 (1721)
	67±1.5 (1700±38)		67±1.5 (1700±38)
O:	44 3/4 (1137)	**P:**	5 (127)
	43±4 (1100±75)		
Q:	31 1/2 (800)	**R:**	18 1/2 (470)
S:	15 (381)	**T:**	74 1/2 (1892)
U (impact width):	36 11/16 (932)		

Mass Distribution - lb (kg)

Gross Static	**LF**	1389 (630)	**RF**	1368 (621)
	LR	1198 (543)	**RR**	1206 (547)

Wheel Center Height (Front):	14 3/4 (375)
Wheel Center Height (Rear):	15 (381)
Wheel Well Clearance (Front):	34 7/8 (886)
Wheel Well Clearance (Rear):	37 5/8 (956)
Bottom Frame Height (Front):	18 (457)
Bottom Frame Height (Rear):	25 1/4 (641)
Engine Type:	Gasoline
Engine Size:	3/6L V6
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Quad Cab
Bed Length:	76"

Weights lb (kg)	**Curb**	**Test Inertial**	**Gross Static**
W-front	2699 (1224)	2658 (1206)	2757 (1251)
W-rear	2201 (998)	2342 (1062)	2404 (1090)
W-total	4900 (2223)	5000 (2268)	5161 (2341)
		5000±110 (2270±50)	5165±110 (2343±50)

GVWR Ratings - lb

Front	3700
Rear	3900
Total	6800

Surrogate Occupant Data

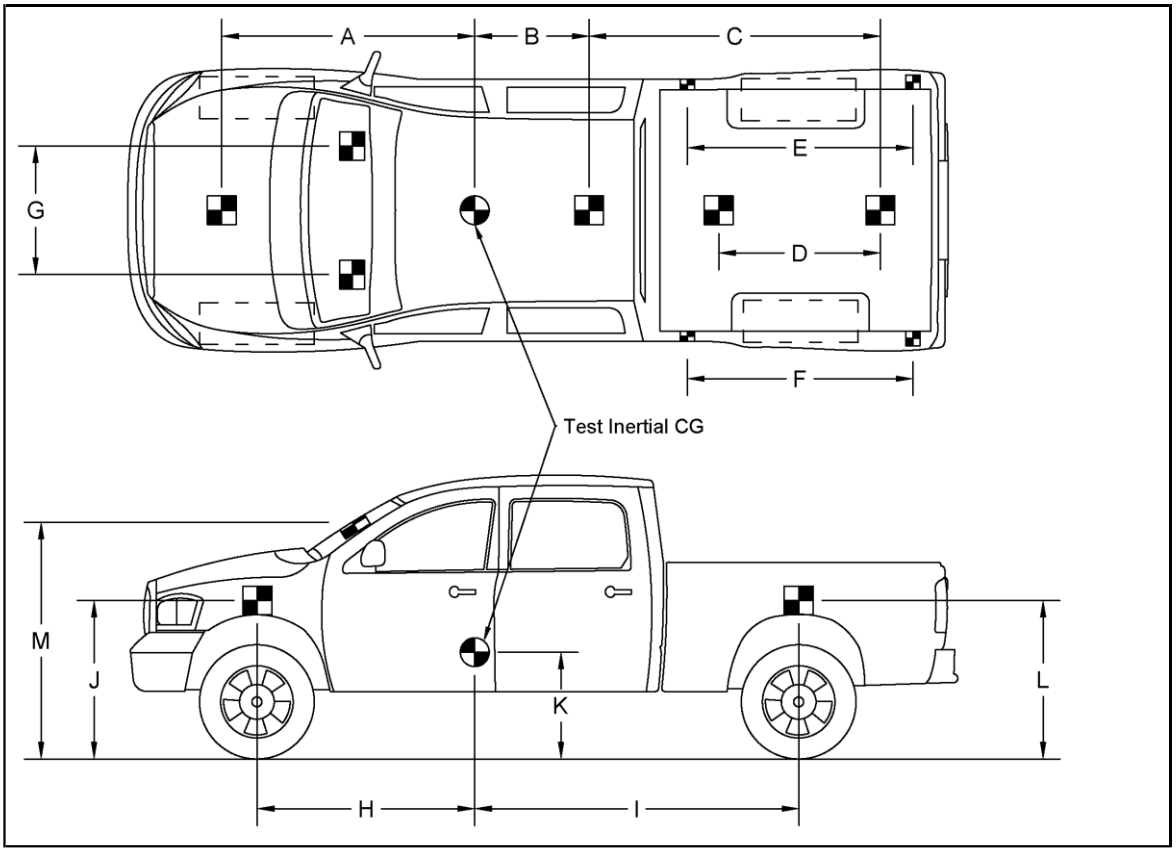
Type:	Hybrid II
Mass:	161 lb
Seat Position:	Right/Passenger

Note any damage prior to test: None

Figure 37. Vehicle Dimensions, Test No. FLAGT-2

Test Name: FLAGT-2 VIN: 1C6RR6GG1FS646171

Model Year: 2015 Make: Dodge Model: Ram 1500



TARGET GEOMETRY-- in. (mm)

A:	72 7/8	(1851)	E:	63 3/8	(1610)	J:	39 1/16	(992)
B:	23 13/16	(605)	F:	63 1/2	(1613)	K:	28 3/16	(716)
C:	78 1/2	(1994)	G:	33 1/2	(851)	L:	41 7/8	(1064)
D:	38 7/8	(987)	H:	65 13/16	(1672)	M:	65 1/4	(1657)
			I:	75	(1905)			

Figure 38. Target Geometry, Test No. FLAGT-2

5.4 Simulated Occupant

For test no. FLAGT-2, 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 and Rate Transducers

The accelerometer and rate transducer systems used in the full-scale crash testing were the SLICE-1 and SLICE-2 units described below. The units were positioned near the c.g. of the test vehicle and the SLICE-2 unit was designated as primary. Data obtained in dynamic testing was filtered using the SAE Class 60 and the SAE Class 180 Butterworth filter conforming to the SAEJ211/1 specifications [16].

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

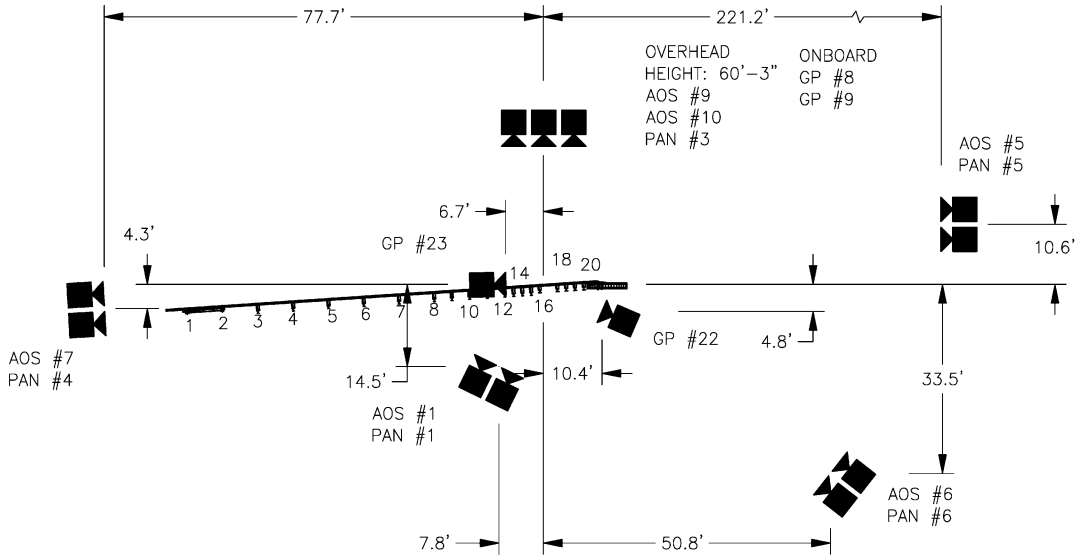
5.5.2 Retroreflective Optic Speed Trap

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.

5.5.3 Digital Photography

Six AOS high-speed digital video cameras, four GoPro digital video cameras, and five Panasonic digital video cameras were utilized to film test no. FLAGT-2. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 39. Due to technical difficulties, camera AOS-10 did not record the impact event.

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



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-1	AOS Vitcam	500	KOWA 25mm Fixed	-
AOS-5	AOS X-PRI Gigabit	500	100mm Fixed	-
AOS-6	AOS X-PRI Gigabit	500	Fujinon 50mm Fixed	-
AOS-7	AOS X-PRI Gigabit	500	Fujinon 35mm Fixed	-
AOS-9	AOS TRI-VIT 2236	1000	KOWA 12mm Fixed	-
AOS-10*	AOS TRI-VIT 2236	500	KOWA 16mm Fixed	-
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-22	GoPro Hero 7	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		

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

Figure 39. Camera Locations, Speeds and Lens Settings, Test No. FLAGT-2

6 FULL-SCALE CRASH TEST NO. FLAGT-2

6.1 Static Soil Test

Before full-scale crash test no. FLAGT-2 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-2 was conducted on September 21, 2021 at approximately 2:00 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-2

Temperature	73° F
Humidity	30%
Wind Speed	11 mph
Wind Direction	350° from True North
Sky Conditions	Overcast
Visibility	10.00 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.02 in.
Previous 7-Day Precipitation	0.05 in.

6.3 Test Description

Similar to previous test no. FLAGT-1, initial vehicle impact was to occur 93 in. from the upstream end of the concrete buttress, as shown in Figure 40, which was selected during Phase I of this project using computer simulations to maximize the probability of vehicle snag [5]. In test no. FLAGT-2, the 5,000-lb quad cab pickup truck impacted the 15:1 flared AGT at a speed of 62.6 mph and at an angle of 25.4 degrees, which corresponded to 29.2 degrees relative to the flared guardrail. The actual point of impact was 91.5 in. from the upstream end of the buttress.

The vehicle was contained and redirected by the AGT with a 15:1 flare and enlarged transition posts located within the nested thrie beam region of the AGT. The larger posts helped reduce the system deflections to roughly half of those observed during the previous test, test no. FLAGT-1. During redirection, contact with the guardrail caused the front wheel to disengage from the vehicle and be pushed backward against the vehicle's toe pan, causing significant occupant compartment deformations. After the vehicle exited the system, the absence of a front wheel allowed the pickup truck to continue rolling toward the barrier as it traveled away from the test installation. The vehicle eventually stabilized and returned to an upright position without rolling over. The brakes were applied remotely, and the vehicle came to rest 120.7 ft downstream from the impact location and 35 ft front of the barrier.

A detailed description of the sequential impact events is contained in Table 4. Sequential photographs are shown in Figures 41 and 42. Documentary photographs of the crash test are shown in Figure 43. The vehicle trajectory and final position are shown in Figure 44

Figure 40. Impact Location, Test No. FLAGT-2

Table 4. Sequential Description of Impact Events, Test No. FLAGT-2

TIME (sec)	EVENT
0.000	Vehicle's front bumper contacted rail from the target impact location.
0.012	Vehicle's right fender, right headlight contacted rail and deformed. Vehicle's right-front tire contacted rail.
0.016	Rail deformed between post nos. 16 and 17. Post nos. 14 through 20 rotated backward.
0.018	Vehicle's grille contacted rail and deformed, vehicle's hood deformed, and vehicle's right-front tire deflated.
0.036	Vehicle's front bumper detached from left fender. Vehicle yawed away from barrier and rolled toward barrier.
0.046	Vehicle's right-front door contacted rail and bent.
0.050	Vehicle’s right-front wheel disengaged from vehicle.
0.062	Blockouts at post nos. 17 and 18 fractured.
0.078	Vehicle's roof deformed and vehicle's right headlight disengaged.
0.086	Vehicle's windshield cracked.
0.102	Vehicle pitched downward and right-front wheel disengaged from the vehicle.
0.122	Concrete spalled on upstream end of terminal and vehicle's right-front window glass shattered.
0.126	Vehicle’s left-front wheel became airborne.
0.155	Vehicle's grille disengaged.
0.170	Vehicle's left headlight disengaged. Vehicle pitched upward.
0.214	Vehicle was parallel to system at a speed of 41.7 mph.
0.242	Vehicle's right quarter panel and rear bumper contacted rail and deformed.
0.365	Vehicle exited system at a speed of 36.9 mph and an angle of −6.6 degrees.
1.148	Vehicle reached its maximum roll position and began to roll away from barrier. Vehicle slid on its front-right fender.
2.920	Vehicle’s left wheels contacted ground.
4.258	Vehicle came to rest


0.000 sec


0.000 sec


0.100 sec


0.100 sec


0.200 sec


0.200


0.300 sec


0.300 sec


0.400 sec


0.400 sec


0.500 sec


0.500 sec

Figure 41. Sequential Photographs, Test No. FLAGT-2


0.000 sec


0.000 sec


0.100 sec


0.050 sec


0.200 sec


0.100 sec


0.300 sec


0.150 sec


0.400 sec


0.200 sec


0.500 sec


0.250 sec

Figure 42. Sequential Photographs, Test No. FLAGT-2

Figure 43. Documentary Photographs, Test No. FLAGT-2

Figure 44. Vehicle Final Position and Trajectory Marks, Test No. FLAGT-2

6.4 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 45 through 49. Barrier damage consisted of contacts marks, deformation to the thrie-beam rail, post rotations, and blockout fracture. The length of vehicle contact along the barrier was 12 ft – 4 in., beginning 4 in. downstream from post no. 16 and extending downstream. Contact marks were observed on the top surface of the concrete buttress beginning at the upstream end and continuing downstream for 47 in., as shown in Figure 46. No contact marks were observed on the lower chamfer of the buttress below the guardrail.

The thrie beam was displaced laterally between post no. 16 and the buttress, and localized kinking, bending, denting, and flattening of the thrie beam were present throughout this region, as show in Figure 47. The bottom corrugation of the rail was flattened and bent backward between post nos. 16 and 19. The middle corrugation of the guardrail was gouged and sharply dented at various locations between post nos. 16 and 20 due to contact with the front wheel rim. An 11-in. long tear through both thrie beam segments was present on the bottom corrugations near post no. 18. It was believed that this tear was caused by the vehicle's upper control arm punching through the guardrail after the front wheel disengaged.

Post nos. 15 through 20 were displaced backward and a small crack in the soil formed along the front flanges of these posts. A soil heave formed behind the posts. Post nos. 18 and 19 were also twisted and deflected downstream. The wooden blockouts at post nos. 17 and 18 were fractured and the attachment bolts at these posts were bent. Contact marks were found on the upstream front flanges of post nos. 17 and 19 and the upstream face of the blockout at post no. 19 above the guardrail.

Figure 45. Overall System Damage, Test No. FLAGT-2

Figure 46. Concrete and Thrie-Beam Damage, Test No. FLAGT-2

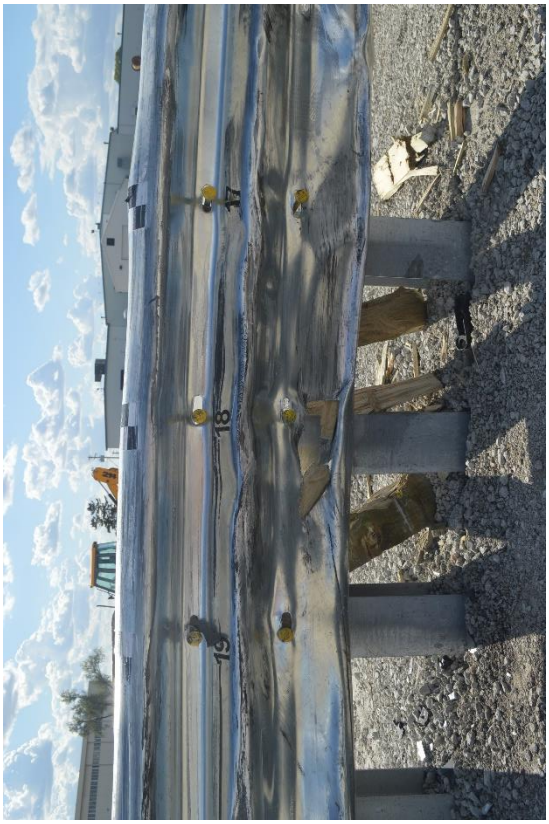


Figure 47. Thrie-Beam Damage, Test No. FLAGT-2

Figure 48. Post and Blockout Damage, Test No. FLAGT-2

Figure 49. Soil Disturbance, Test No. FLAGT-2

The maximum lateral permanent set of the barrier system was 4.7 in., which occurred at the rail at post no. 17, as measured in the field. The maximum lateral dynamic barrier deflection was 7.9 in. located at the rail at post no. 17, as determined from high-speed video analysis. The working width of the system was found to be 25.0 in., also determined from high-speed video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 50.

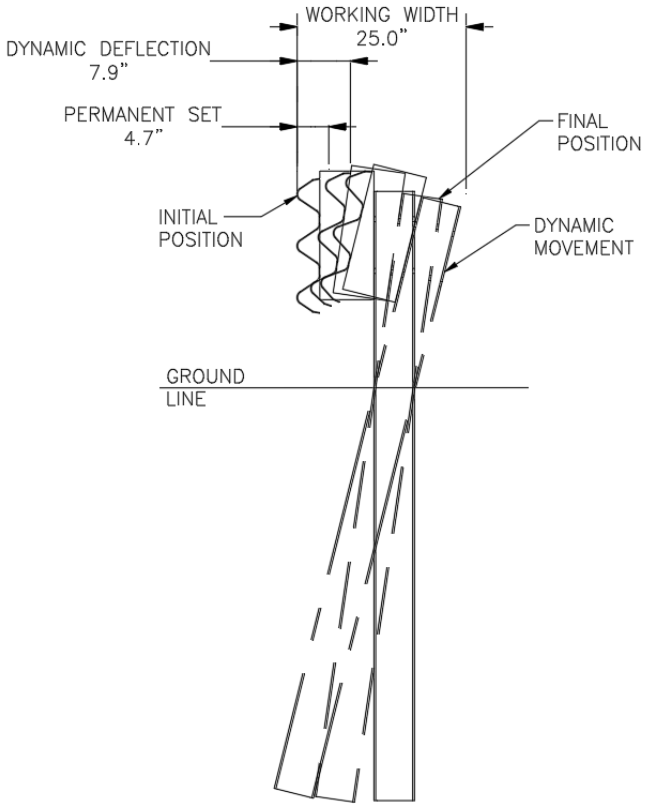


Figure 50. Permanent Set, Dynamic Deflection, and Working Width, Test No. FLAGT-2

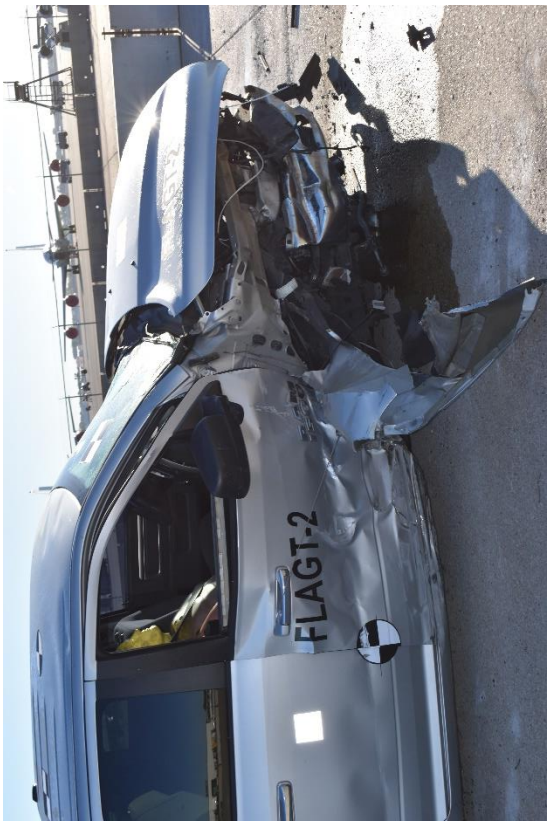
6.5 Vehicle Damage

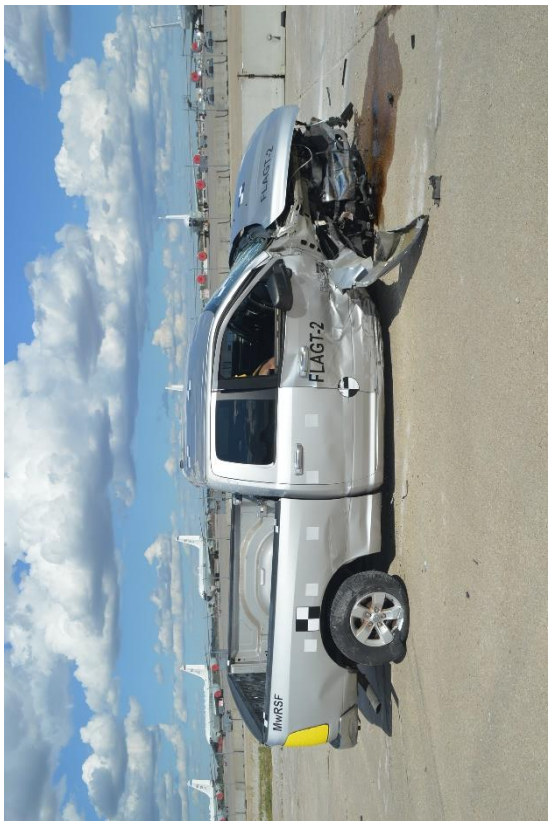
The damage to the vehicle was severe, as shown in Figures 51 through 53. The maximum occupant compartment intrusions are listed in Table 5, along with the intrusion limits established in MASH for various areas of the occupant compartment. There were no penetrations into the occupant compartment, however, the toe pan/wheel well deformation of 9.9 in. violated the MASH limit of 9.0 in. 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.

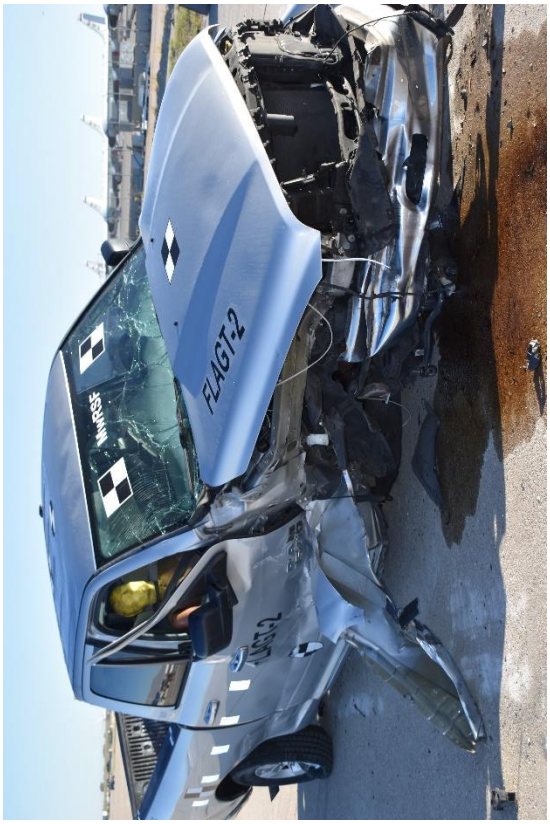
The majority of the damage was concentrated on the right-front corner and right side of the vehicle where the impact had occurred. The bumper cover was disengaged on the right end and the radiator was crushed inward on the right side. The right fender was barely attached to the vehicle after impact, and the frame was completely crushed inward approximately 1 ft at the front

of the vehicle. The right-front door was crushed, and both right-side doors were scraped. The right-rear fender was scraped and gouged. The front end of the left fender was bent outward slightly.

The undercarriage was damaged as well. The right-front shock and spring were disengaged, and the rear shock was dented slightly. The sway bar was shifted to the right side, and there was a scrape on the outside of the right sway bar. The right passenger control arm was fractured and disengaged from the vehicle. The right passenger steering knuckle was disengaged at the ball joint, while the left side steering knuckle was scraped. The right tie rod was disengaged from the vehicle. The gear box was detached from the frame and steering shaft, and the gear box was cracked in several places. The rear axle was bent, and there was a puncture in the oil pan. There were several bends and kinks in the right side of the frame, and the entire frame appeared twisted. There was scraping on the bottom of every cross member on the right side, and the middle cross member appeared to be buckled in the middle. The right-front cab mount was crushed and disengaged. The toe pan was visibly damaged, and there was a small gouge on the right side of the gas tank from contact with the drive shaft.







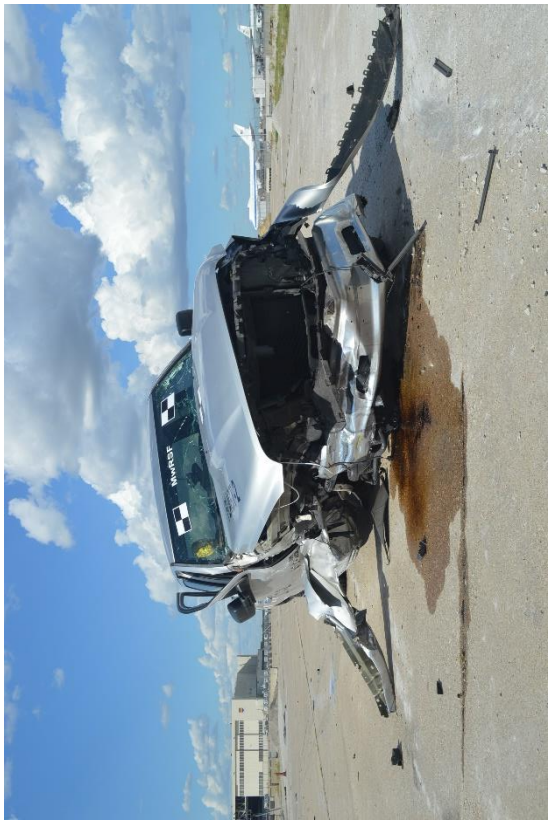


Figure 51. Vehicle Damage, Test No. FLAGT-2

Figure 52. Vehicle Damage, Test No. FLAGT-2

Figure 53. Vehicle Interior and Undercarriage Damage, Test No. FLAGT-2

Table 5. Maximum Occupant Compartment Intrusion by Location, Test No. FLAGT-2

LOCATION	Maximum Intrusion in.	MASH Allowable Intrusion in.
Wheel Well & Toe Pan	9.9	≤ 9
Floor Pan & Transmission Tunnel	6.5	≤ 12
A-Pillar	0.1	≤ 5
A-Pillar (Lateral)	0.0*	≤ 3
B-Pillar	0.0	≤ 5
B-Pillar (Lateral)	0.0*	≤ 3
Side Front Panel (in Front of A-Pillar)	8.1	≤ 12
Side Door (Above Seat)	0.0*	≤ 9
Side Door (Below Seat)	1.2	≤ 12
Roof	0.0*	≤ 4
Windshield	2.5	≤ 3
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	4.3	N/A

* Negative values (outward deformation) reported as 0.0. See Appendix E for further information.
N/A – No MASH criteria exist for this location.

6.6 Occupant Risk

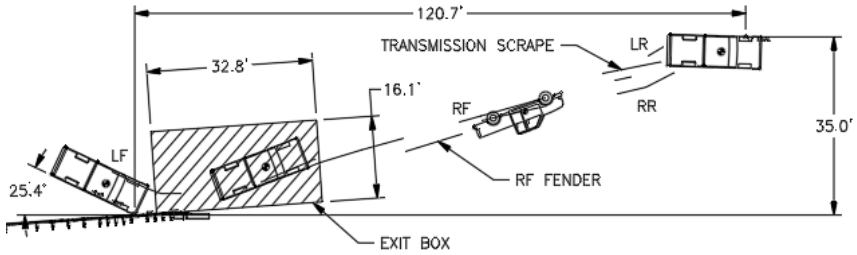
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 6. Note that the OIVs and ORAs were within suggested limits, as provided in MASH. 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-2

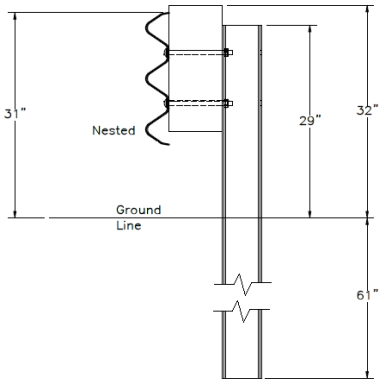
Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (backup)	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-31.65	-30.38	±40
	Lateral	-23.43	-25.56	±40
ORA g's	Longitudinal	11.41	11.74	±20.49
	Lateral	-12.12	-11.48	±20.49
Maximum Angular Displacement deg.	Roll	76.0	72.7	±75
	Pitch	-9.3	-10.6	±75
	Yaw	-58.9	-59.3	not required
THIV – ft/s		37.80	38.29	not required
PHD – g's		14.67	16.07	not required
ASI		1.45	1.57	not required

6.7 Discussion

Analysis of the results from test no. FLAGT-2 showed that the system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. The test vehicle did not penetrate nor ride over the barrier. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix F, were deemed acceptable because they did not adversely influence occupant risk nor cause rollover. The vehicle rolled significantly after exiting the system with a maximum roll angle of 73 degrees recorded by the primary data recorder, but the vehicle remained upright and within the 75-degree maximum roll angle allowed by MASH. After impact, the vehicle exited the barrier at an angle of −6.6 degrees, and its trajectory did not violate the bounds of the exit box. 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. However, deformations of the wheel well and toe pan area of 9.9 in. exceeded the MASH deformation limit of 9 in. Therefore, test no. FLAGT-2 failed to satisfy the safety performance criteria for MASH test designation no. 3-21. A summary of the test results and sequential photographs are shown in Figure 54.



- Test Agency ..... MwRSF
- Test Number FLAGT-2
- Date 9/20/2021
- 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 ..... W6x15, 90-in. length
  - Spacing Post Nos. 16 to 17 ..... 37.5 in.
  - Spacing Post Nos. 17 to 20 ..... 18.75 in.
  - Embedment Post Nos. 16 through 20 ..... 61 in.
- Key Component –Buttress
  - Shape ..... Standardized Transition Buttress
- Soil Type ..... Coarse, crushed limestone (well-graded gravel)
- Vehicle Make /Model ..... 2015 Dodge Ram 1500 Quad Cab
  - Curb ..... 4,900 lb
  - Test Inertial ..... 5,000 lb (5,000 ± 110 lb MASH limit)
  - Gross Static ..... 5,161 lb (5,165 ± 110 lb MASH limit)
- Impact Conditions
  - Speed ..... 62.6 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 ..... 91.5 in. upstream from end of buttress
- Impact Severity ..... 120.9 kip-ft > 106 kip-ft limit from MASH
- Exit Conditions
  - Speed ..... 36.9 mph
  - Angle ..... −6.6 deg.
- Exit Box Criterion ..... Pass
- Vehicle Stability ..... Pass
- Vehicle Stopping Distance ..... 120.7 ft downstream, 35 ft laterally in front



- Vehicle Damage ..... Severe
  - VDS [17] 1-RFQ-6
  - CDC [18] 1-FREW-4
  - Maximum Interior Deformation ..... 9.9 in. at toe pan > 9 in. MASH limit
- Test Article Damage ..... Moderate
- Maximum Test Article Deflections
  - Permanent Set ..... 4.7 in.
  - Dynamic ..... 7.9 in.
  - Working Width ..... 25.0 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH Limits
		SLICE-1	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-31.65	-30.38	±40
	Lateral	-23.43	-25.56	±40
ORA g's	Longitudinal	11.41	11.74	±20.49
	Lateral	-12.12	-11.48	±20.49
Maximum Angular Displacement deg.	Roll	76.0	72.7	±75
	Pitch	-9.3	-10.6	±75
	Yaw	-58.9	-59.3	not required
THIV – ft/s		37.80	38.29	not required
PHD – g's		14.67	16.07	not required
ASI		1.45	1.57	not required

Figure 54. Summary of Test Results and Sequential Photographs, Test No. FLAGT-2

7 SUMMARY AND CONCLUSIONS

The main research objective for this project was to develop guidelines for flaring approach guardrail transitions. Previously, an LS-DYNA simulation study selected a maximum flare rate of 15:1 and a critical AGT to evaluate to MASH TL-3 criteria [5]. However, test no. FLAGT-1 resulted in the 2270P vehicle snagging on the concrete buttress, a longitudinal ORA value exceeding the MASH limits, and occupant compartment deformations that exceeded MASH limits for the toe pan and floorboard regions of the vehicle [6]. Thus, the research efforts documented herein focused on redesigning the flared AGT and retesting the modified barrier system to MASH test designation no. 3-21 criteria.

An analysis of test no. FLAGT-1 revealed the main reason for the test failure was excessive deflections of the AGT posts, which allowed the vehicle to snag on the upstream end of the buttress. To stiffen the AGT, the 6.5-ft long W6x9 posts located within the nested thrie beam area were replaced by 7.5-ft long W6x15 posts. The new posts had increased cross sectional strength and an increased embedment depth to create higher soil resistance in the system. No other modifications were made to the 15:1 flared AGT installation.

In test no. FLAGT-2, the 5,000-lb quad pickup truck impacted the modified, flared AGT 91.5 in. upstream from the end of the buttress at a speed of 62.6 mph and an angle of 25.4 degrees. The flared AGT contained and redirected the 2270P vehicle, and all ORA and OIV values were within MASH recommended limits. However, during the impact event, the front wheel was disengaged from the vehicle and pushed backward toward the occupant compartment. Maximum deformations to the toe pan and floorboard area of the vehicle measured 9.9 in., which exceeded the MASH limit of 9.0 in. for this region of the occupant compartment. Thus, test no. FLAGT-2 failed to satisfy MASH TL-3 safety performance criteria. After the vehicle exited the system, the absence of the front wheel allowed the vehicle to continue to roll toward the test installation, ultimately reaching a maximum roll angle of 73 degrees prior to returning to its upright position. Note, this maximum roll angle remained within the MASH limit of 75 degrees. A summary of the test evaluation is shown in Table 7.

A review of the high-speed video from test no. FLAGT-2 showed that the front wheel had disengaged from the vehicle early in the impact event. The wheel stopped rotating and was pushed backward against the wheel well when the wheel was located between post nos. 16 and 17 of the AGT. Inspection of the guardrail between post nos. 16 and 17 revealed sharp denting or gouging to the middle corrugation. Researchers believe the front wheel rim gouged into the middle corrugation, thus causing rim snag and high longitudinal forces to be imparted to the wheel and ultimately disengaging the wheel from the vehicle. The disengaged wheel remained within the wheel well and pressed against the guardrail. Gouging of the middle corrugation of the thrie beam was found at various locations between post nos. 17 and 20, indicating that the wheel rim continued to gouge and snag on the guardrail after it had disengaged form the vehicle. This continued rim snag likely led to increased loading and deformation to the toe pan region of the occupant compartment. Based on this test failure analysis, it was determined that the severity of the rim-to-guardrail gouging and snag within the flared AGT must be reduced in order to reduce the occupant compartment deformation and satisfy MASH TL-3 safety performance criteria.

Table 7. Summary of Safety Performance Evaluation

<table>
<tr><th>Evaluation Factors</th><th colspan="4">Evaluation Criteria</th><th>Test No. FLAGT-2</th></tr>
<tr><td>Structural Adequacy</td><td colspan="4">A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td><td>S</td></tr>
<tr><td rowspan="4">Occupant Risk</td><td colspan="4">D. 1. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.
2. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.</td><td>S
U</td></tr>
<tr><td colspan="4">F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td><td>S</td></tr>
<tr><td colspan="4">H. Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits:
<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 colspan="4">I. The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits:
<table><tr><th colspan="3">Occupant Ridedown Acceleration Limits</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr></table></td><td>S</td></tr>
<tr><td colspan="5">MASH Test Designation No.</td><td>3-21</td></tr>
<tr><td colspan="5">Final Evaluation (Pass or Fail)</td><td>Fail</td></tr>
</table>

S – Satisfactory U – Unsatisfactory NA - Not Applicable

8 REFERENCES

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9 APPENDICES

Appendix A. A2LA Accreditation Certificates

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-2

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 Asymetric Transition Section	AASHTO M180	H#250344
a4	12'-6" 12-gauge W-Beam Section	AASHTO M180	H#C85187
a5	12'-6" 12-gauge W-Beam End Section	AASHTO M180	H#9411949
a6	10-ga Thrie Beam Terminal Connector	AASHTO M180 Gr. 50	H#833M66260
b1	Concrete - 21.9 cubic ft	Min. f'c = 4,000 psi	Sample #011, FLAGT1, FLAGT2
c1	BCT Timber Post - MGS Height	SYP Grade No. 1 or better	C.o.C. 9/21/2020
c2	72" Long Foundation Tube	ASTM A500 Gr. B	H#821T08220
c3	Ground Strut Assembly	ASTM A36	H#163375
c4	BCT Cable Anchor Assembly	-	C.o.C. 9/24/2018
c5	Anchor Bracket Assembly	ASTM A36	H#V911470
c6	8"x8"x5/8" Anchor Bearing Plate	ASTM A36	H#4181496
c7	2 3/8" O.D. x 6" Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	H#8712810
d1	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992	H#55066501/03
d2	W6x15, 90" Long Steel Post	ASTM A992	H#59098849/03
d3	6"x12"x14 1/4" Timber Blockout	SYP Grade No.1 or better	C.o.C. 4/1/2020
d4	6"x12"x19" Timber Blockout	SYP Grade No.1 or better	C.o.C. 9/24/2020
d5	6"x8"x19" Timber Blockout	SYP Grade No.1 or better	C.o.C. 6/21/2021
d6	16D Double Head Nail	-	C.o.C. for PO E000548963
e1	86" Unbent Length #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e2	62 3/4" Unbent Length #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e3	60 1/2" Unbent Length #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e4	59 1/4" Unbent Length #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e5	74¾" Unbent Length #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e6	37¼ " Long #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e7	80¼ " Unbent Length #4 Rebar	ASTM A615 Gr. 60	H#3600014740

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

Item No.	Description	Material Specification	Reference
e8	85½ " Unbent Length #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e9	80" Long #4 Rebar	ASTM A615 Gr. 60	H#3600014740
e10	80½ " 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#10666100
f3	⅝" Dia. UNC, 2" Long Guardrail Bolt	ASTM A307 Gr. A	H#10439100
f4	⅝Dia. UNC, 1 1/4" Long Guardrail Bolt	ASTM A307 Gr. A	H#10634210
f5	⅞” Dia. UNC, 15 1/2" Long Heavy Hex Bolt	ASTM F3125 Gr. 120 (A325)	H#3093334
f6	⅞" Dia. UNC, 8" Long Hex Bolt	ASTM A307 Gr. A	FASTENAL C.o.C. 04/12/2018
f7	⅝" Dia. UNC, 10" Long Hex Bolt	ASTM A307 Gr. A	H#JK18104124
f8	⅝" Dia. UNC, 1 1/2" Long Hex 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
g4	1" Dia. Plain Round Washer	ASTM F844	P#33188
h1	⅝" Dia. Heavy Hex Nut	ASTM A563A	H#10640980
h2	⅝" Dia. Hex Nut	ASTM A563A	H#331608011
h3	⅞" Dia. UNC Heavy Hex Nut	ASTM A563DH or A194 Gr. 2H	H#190841
h4	⅞" Dia. Hex Nut	ASTM A307	H#331704677
h5	1"-8 UNC Heavy Hex Nut	ASTM A563DH	FASTENAL C.o.C. 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	Veritcal 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-2 (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

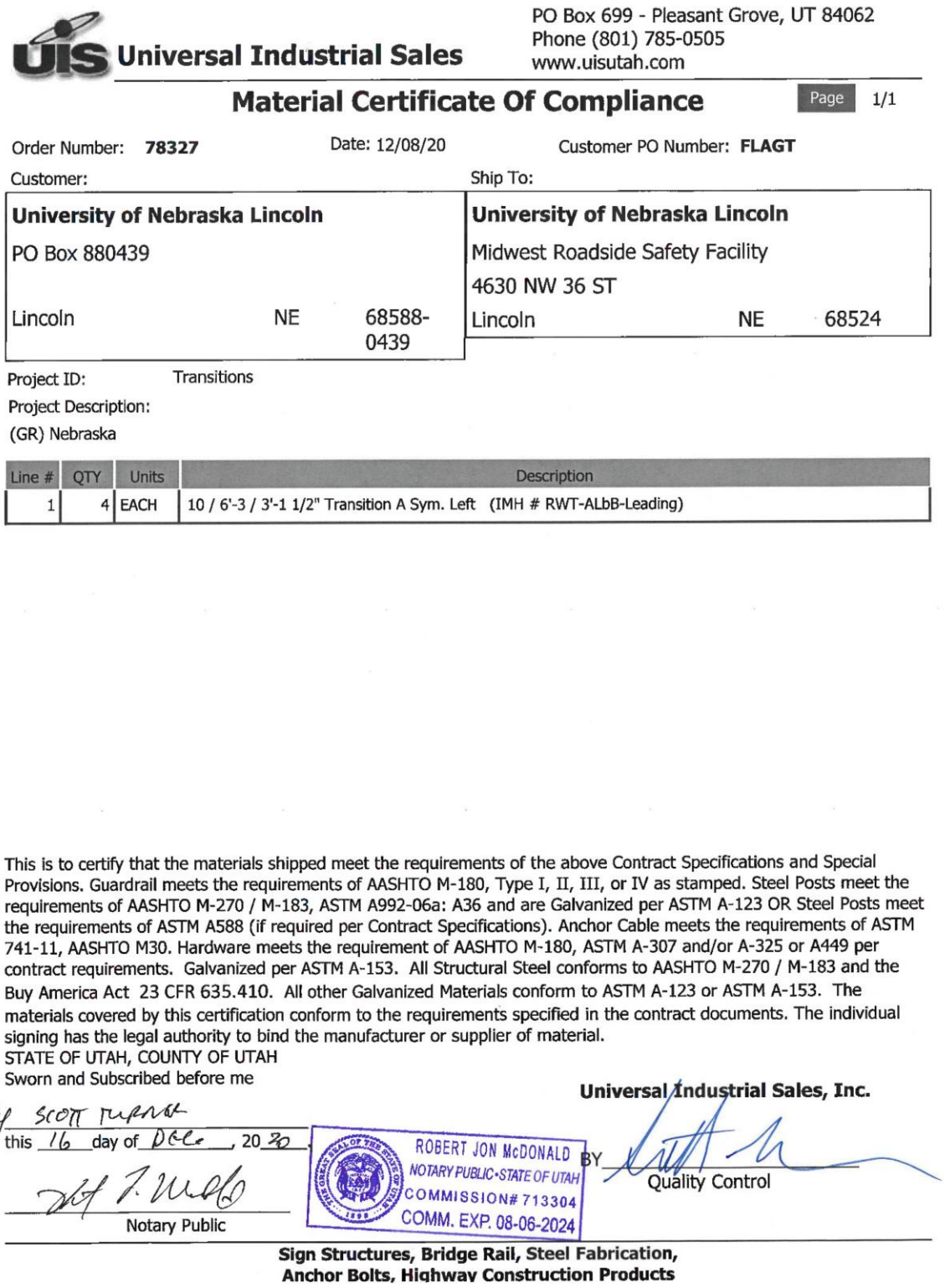
Order Number: 1328797 Prod Ln Grp: 0-OE2.0
Customer PO: 4006
BOL Number: 113647 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

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-2 (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 PO Box 880439 Lincoln NE 68588-0439	**University of Nebraska Lincoln** Midwest Roadside Safety Facility 4630 NW 36 ST 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-2 (Item No. a3)

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

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

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

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

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

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

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

NOTARIAL SEAL
STATE OF OHIO

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

Figure B-4. 12.5-ft W-beam Guardrail, Test No. FLAGT-2 (Item No. a4)

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

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

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

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.

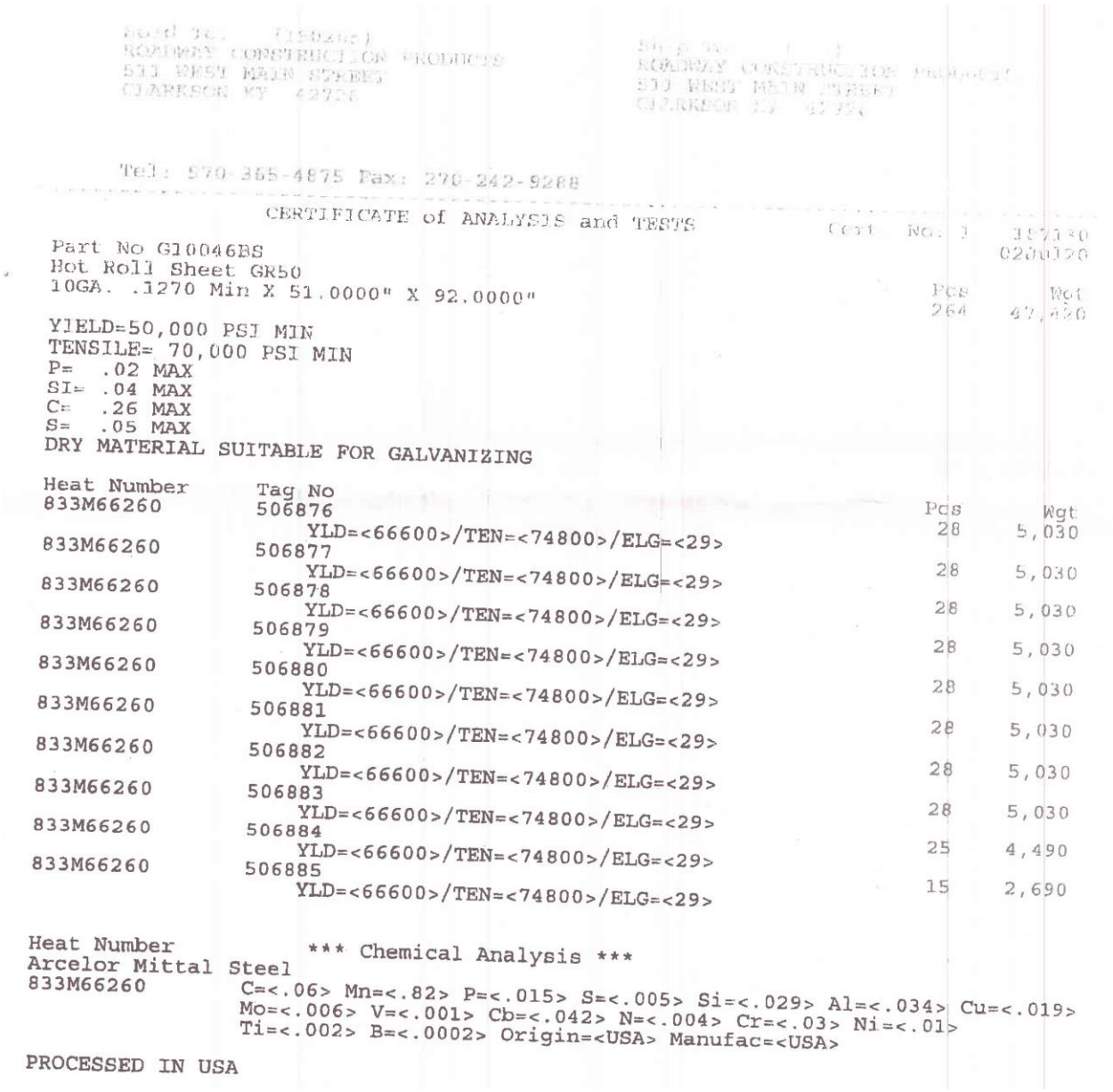
STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by
Andrew Artar this 17 day of July, 2015

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-2 (Item No. a5)



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

CERTIFICATE of ANALYSIS and TESTS

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

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>	25	4,490
833M66260	506884 YLD=<66600>/TEN=<74800>/ELG=<29>	15	2,690
833M66260	506885 YLD=<66600>/TEN=<74800>/ELG=<29>	264	47,420

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-2 (Item No. a6)

benesch

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)

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

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: ☒ Standard ☐ Field
ASTM C511
Submitted by: Matt Roeuler

Distribution:

Report Date: 1/5/21

825 M Street Suite 100
Lincoln, NE 68508

Alfred Benesch & Company

Figure B-7. Buttress Concrete, Test No. FLAGT-2 (Item No. b1)

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

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

CERTIFICATE OF COMPLIANCE

Shipped To: Midwest Machinery and Supply
BOL# 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-2 (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

Jeffery L Grover

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

Figure B-9. BCT Foundation Tube, Test No. FLAGT-2 (Item No. c2)

Certified Analysis

Trinity Highway Products, LLC

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-2 (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:
Certification and Compliance Manager

Figure B-11. BCT Anchor Cable Assembly, Test No. FLAGT-2 (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

As of 4/15/11

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Ve	aCV
10	206G	T12/6'3/8	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	T12/25/8'3/8	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	0.002	
			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	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	
			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	0.000	
	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	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	
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	
	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	
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-2 (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		76000	74000	25			2	350 STRUT & YOKE
E22985		0.17	0.51	0.013	0.008	0.008	72510	64310	29.5	4		2	2IN X 5 1/2IN PIPE SLEEVE
811T08220		0.22	0.81	0.013	0.006	0.005	71412	56323	35	8		2	3/16IN X 6IN X 8IN X 6FTOIN TUBE SLEEVE

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

By: _____

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

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

Notary Public, State of Ohio

Figure B-13. Anchor Bearing Plate, Test No. FLAGT-2 (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:

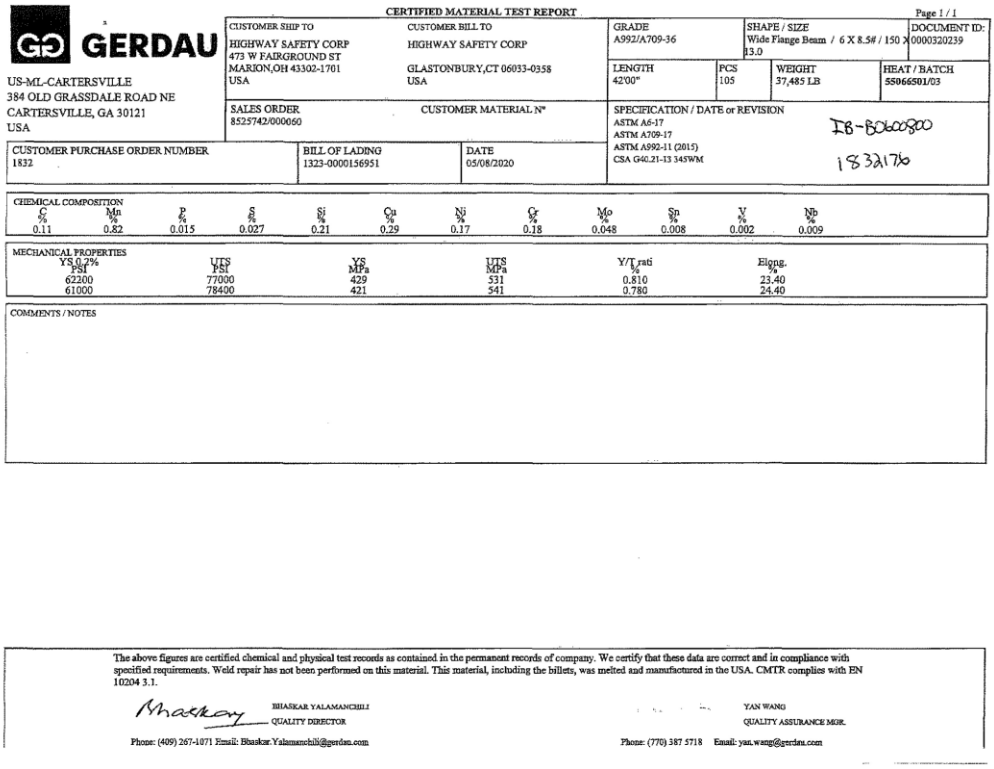
Authorized by Quality Assurance:
The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
[illegible] using the AWS D1.1 method.

Steel Tube Institute

Page : 3 Of 4

Metals Service Center Institute

Figure B-14. BCT Post Sleeve, Test No. FLAGT-2 (Item No. c7)



GERDAU

CERTIFIED MATERIAL TEST REPORT

Page 1 / 1

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

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

GRADE	SHAPE / SIZE	DOCUMENT ID:
A992/A709-36	Wide Flange Beam / 6 X 8.5# / 150 X 13.0	0000320239

LENGTH	PCS	WEIGHT	HEAT / BATCH
42'00"	105	37,485 LB	550665501/03

SALES ORDER	CUSTOMER MATERIAL N°
8525742/000060	

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

IB-B0600300
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

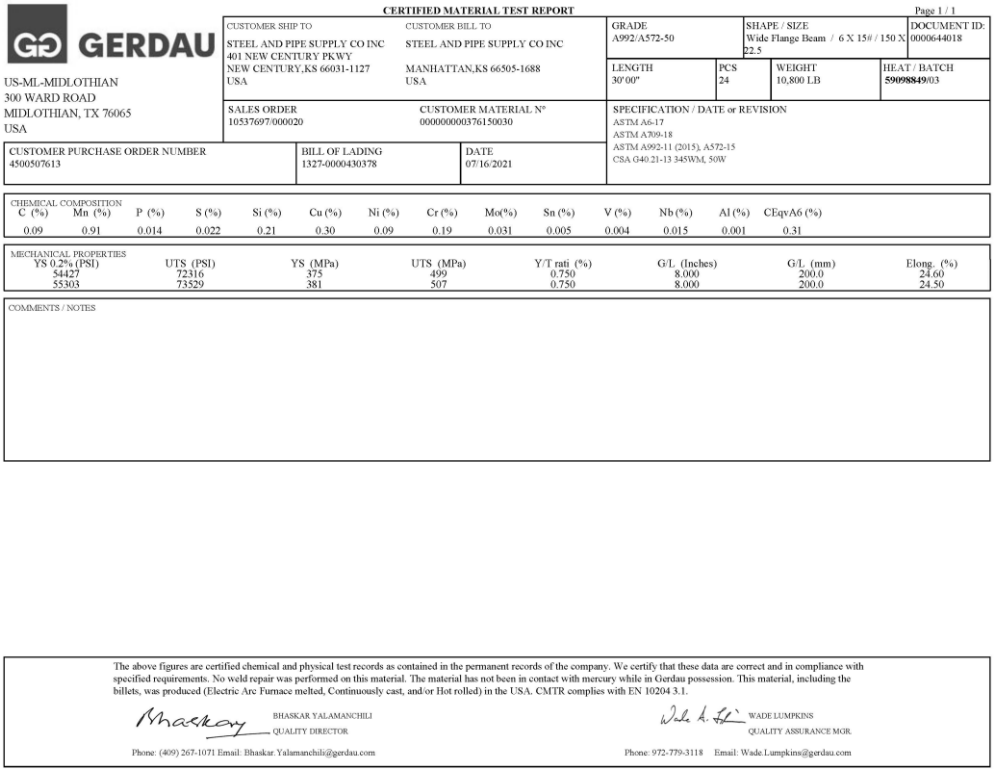
COMMENTS / NOTES

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-2 (Item No. d1)



GERDAU

CERTIFIED MATERIAL TEST REPORT

Page 1 / 1

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

CUSTOMER SHIP TO	CUSTOMER BILL TO
STEEL AND PIPE SUPPLY CO INC 401 NEW CENTURY PKWY NEW CENTURY,KS 66031-1127 USA	STEEL AND PIPE SUPPLY CO INC MANHATTAN,KS 66505-1688 USA

GRADE	SHAPE / SIZE	DOCUMENT ID:
A992/A572-50	Wide Flange Beam / 6 X 15# / 150 X 22.5	0000644018

LENGTH	PCS	WEIGHT	HEAT / BATCH
30'00"	24	10,800 LB	59098849/03

SALES ORDER	CUSTOMER MATERIAL N°
10537697/000020	000000000376150030

SPECIFICATION / DATE or REVISION
ASTM A6-17
ASTM A709-18
ASTM A992-11 (2015), A572-15
CSA G40.21-13 345WM, 50W

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
4500507613	1327-0000430378	07/16/2021

CHEMICAL COMPOSITION

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cu (%)	Ni (%)	Cr (%)	Mo(%)	Sn (%)	V (%)	Nb (%)	Al (%)	CEqvA6 (%)
0.09	0.91	0.014	0.022	0.21	0.30	0.09	0.19	0.031	0.005	0.004	0.015	0.001	0.31

MECHANICAL PROPERTIES

YS 0.2% (PSI)	UTS (PSI)	YS (MPa)	UTS (MPa)	Y/T rati (%)	G/L (Inches)	G/L (mm)	Elong. (%)
54427	72316	375	499	0.750	8.000	200.0	24.60
55303	73529	381	507	0.750	8.000	200.0	24.50

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of the company. We certify that these data are correct and in compliance with specified requirements. No weld repair was performed on this material. The material has not been in contact with mercury while in Gerdau possession. This material, including the billets, was produced (Electric Arc Furnace melted, Continuously cast, and/or Hot rolled) in the USA. CMTR complies with EN 10204 3.1.

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

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

Figure B-16. 7.5-ft W6x15 Posts, Test No. FLAGT-2 (Item No. d2)

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-2 (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# N34266
Customer PO# 4008
Preservative: CCA – C 0.60D pcf AWPA UC4B

Part #	Physical Description	# Pieces	Charge #	Retention
GR6819 BLK	6x8-19″ OCD Block	168	2580	.632
GR61219 BLK	6x12-19″ OCD Block	504	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

9/24/20
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-2 (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# N42634
Customer PO# 5011
Preservative: CCA – C 0.50D pcf AWPA UC4

Part #	Physical Description	# Pieces	Charge #	Retention
GR6819 BLK	6x8-19" Thrie OCD Block	252	4369	.623

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

6/21/21
Date

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

Figure B-19. 6-in. x 8-in. x 19-in. Timber Blockout, Test No. FLAGT-2 (Item No. d5)

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-2 (Item No. d6)

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-2 (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
				89.20
HARDNESS:	100 max			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

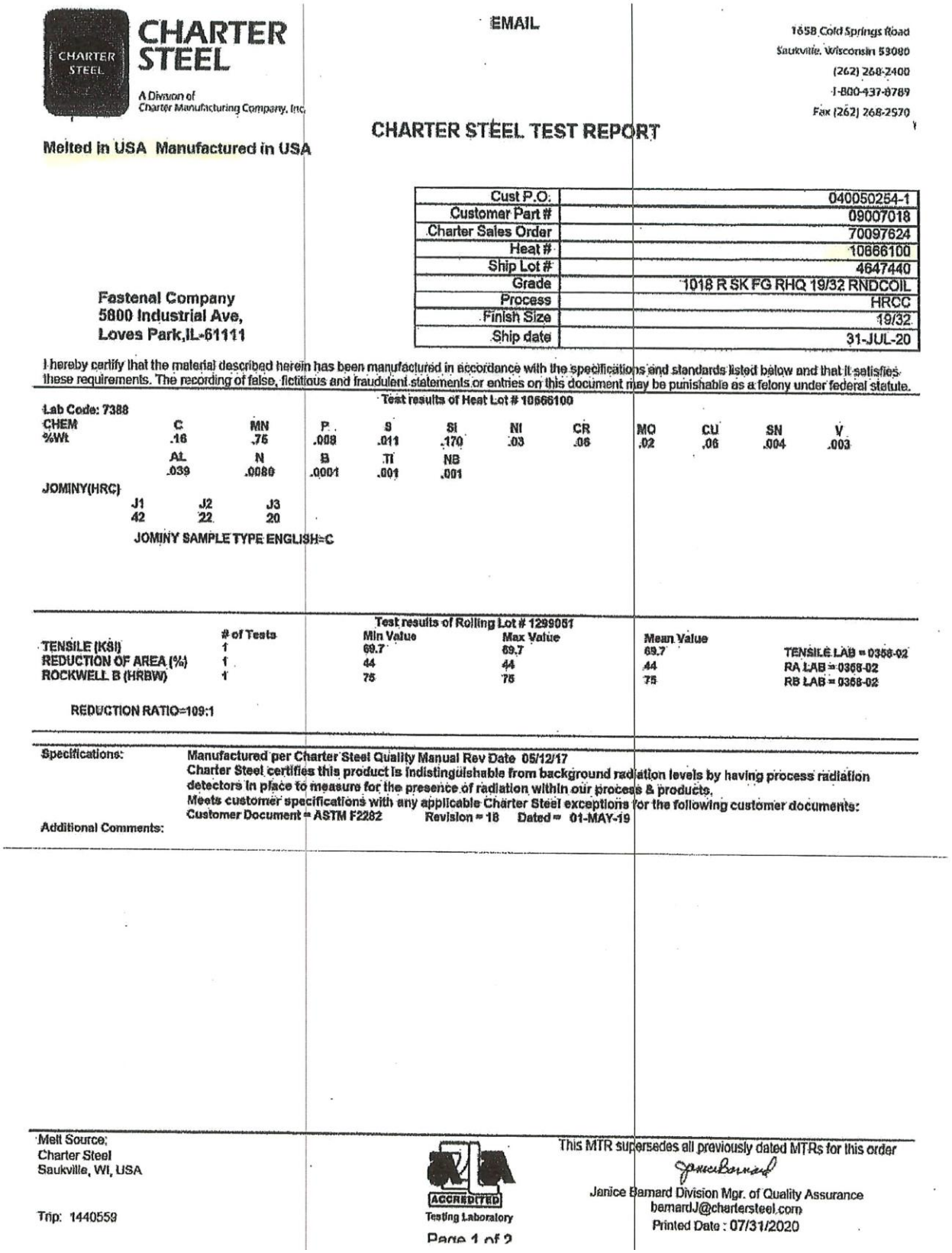
Merry F Shane

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

Linda Melomas
APPROVED SIGNATORY

8/20/19
DATE

Figure B-22. ⅝-in. x 14-in. Guardrail Bolt, Test No. FLAGT-2 (Item No. f1)



CHARTER STEEL

A Division of Charter Manufacturing Company, Inc.

EMAIL

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

Melted in USA Manufactured in USA

CHARTER STEEL TEST REPORT

Cust P.O.	040050254-1
Customer Part #	09007018
Charter Sales Order	70097624
Heat #	10666100
Ship Lot #	4647440
Grade	1018 R SK FG RHQ 19/32 RNDCOIL
Process	HRCC
Finish Size	19/32
Ship date	31-JUL-20

Fastenal Company
5800 Industrial Ave,
Loves Park,IL-61111

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

Test results of Heat Lot # 10666100

Lab Code: 7388

CHEM	C	MN	P	S	SI	NI	CR	MO	CU	SN	V
%Wt	.16	.75	.008	.011	.170	.03	.06	.02	.06	.004	.003
	AL	N	B	TI	NB						
	.039	.0080	.0001	.001	.001						

JOMINY(HRC)

J1	J2	J3
42	22	20

JOMINY SAMPLE TYPE ENGLISH=C

Test results of Rolling Lot # 1299051

	# of Tests	Min Value	Max Value	Mean Value	
TENSILE (KSI)	1	69.7	69.7	69.7	TENSILE LAB = 0368-02
REDUCTION OF AREA (%)	1	44	44	44	RA LAB = 0368-02
ROCKWELL B (HRBW)	1	75	75	75	RB LAB = 0368-02

REDUCTION RATIO=109:1

Specifications: Manufactured per Charter Steel Quality Manual Rev Date 05/12/17
Charter Steel certifies this product is indistinguishable from background radiation levels by having process radiation detectors in place to measure for the presence of radiation within our process & products.
Meets customer specifications with any applicable Charter Steel exceptions for the following customer documents:
Customer Document = ASTM F2282 Revision = 18 Dated = 01-MAY-19

Additional Comments:

Melt Source:
Charter Steel
Saukville, WI, USA

Trip: 1440559

ACCREDITED
Testing Laboratory

This MTR supersedes all previously dated MTRs for this order

Janice Bernard Division Mgr. of Quality Assurance
bernardJ@chartersteel.com
Printed Date : 07/31/2020

Page 1 of 2

Figure B-23. ⅝-in. x 10-in. Guardrail Bolt, Test No. FLAGT-2 (Item No. f2)

3400G

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: 182402

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

LOT#: 29221

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE:	SPEC:	60,000 psi*min	RESULTS:	68,460 66,327
HARDNESS:		100 max		71.30 71.60

*Pounds Per Square Inch.

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

CHEMICAL COMPOSITION

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

QUANTITY AND DESCRIPTION:

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

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

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS

7th DAY OF March, 20 17

Merry F Shane

Linda McThomas
APPROVED SIGNATORY

3/7/17
DATE

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

Figure B-24. ⅝-in. x 2-in. Guardrail Bolt, Test No. FLAGT-2 (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 McComas
APPROVED SIGNATORY

2/5/2020
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-2 (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-2 (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 lline35042 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 lline35042 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 lline35042 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 lline35042 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

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-2 (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: **Date:** 11/29/2018

Brian Hughes
Quality Assurance

Figure B-28. ⅝-in. x 10-in. Hex Bolt, Test No. FLAGT-2 (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.
ADDRESS: No.583-28, Chang'an North Road, Wuyuan Town, Haiyan, Zhejiang, China

REPORT DATE:2019/4/9
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-2 (Item No. f8)

CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS HDG

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

REPORT DATE: 23/4/2019

MFG LOT NUMBER: 1844804

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

PO NUMBER: 170089822

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-2 (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**

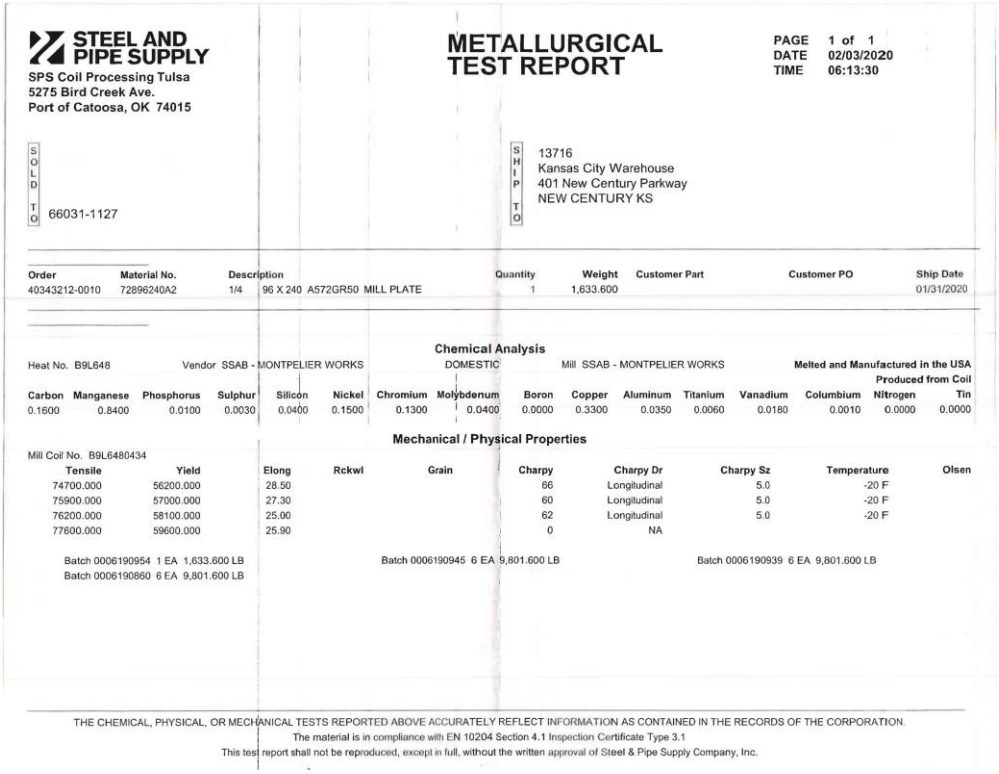
Test Item	Spec.	Sampling	Remark	Test Result
Plating thickness	min.3 μm	5	OK	4.573 μm - 5.328 μm
SST	2 hours no white corrosion and 12 hours no red rust	5	OK	OK

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-2 (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

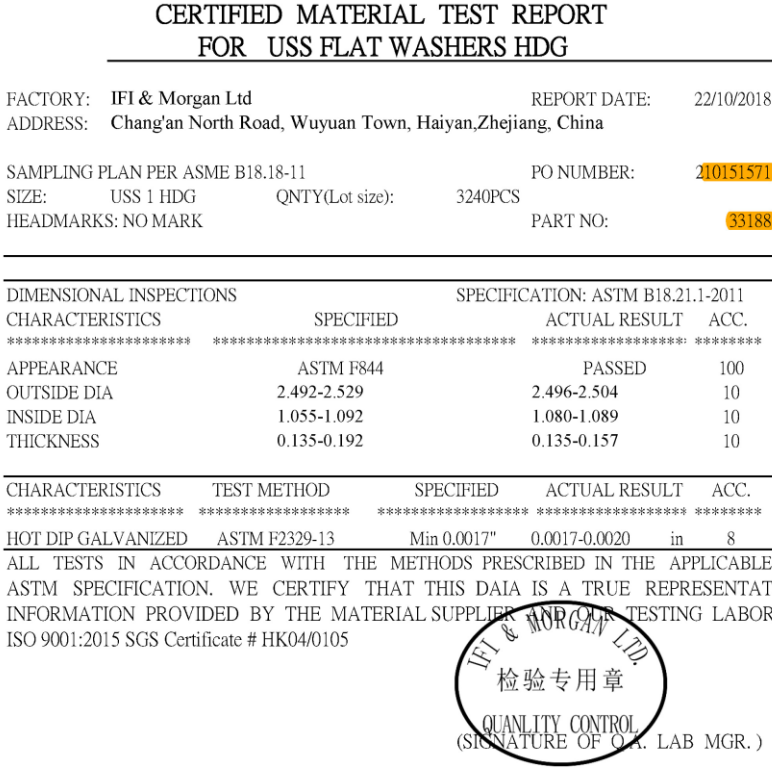
Mill Coil No. B9L6480434

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-2 (Item No. g3)



CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS HDG

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

REPORT DATE: 22/10/2018

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

PO NUMBER: 210151571
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-2 (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. CONNELLY 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 89 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)	86.2	(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-2 (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 :

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

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

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

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2007

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

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2010

SAMPLED BY : DWTING

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

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2007

SAMPLED BY : GDAN LIAN

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

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

Quality Supervisor:

Figure B-35. ⅝-in. Hex Nut, Test No. FLAGT-2 (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:09/18/21

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-2 (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	5 PCS		1.4470-1.5160 inch	1.4850-1.4930 inch	5	0
FIM	15 PCS	ASME B18.2.2-2015	Max. 0.0250 inch	0.0110-0.0200 inch	15	0
THICKNESS	5 PCS		0.7240-0.7760 inch	0.7460-0.7570 inch	5	0
WIDTH ACROSS FLATS	5 PCS		1.2690-1.3120 inch	1.2930-1.2980 inch	5	0
SURFACE DISCONTINUITIES	29 PCS		ASTM F812-2012	PASSED	29	0
THREAD	15 PCS		GAGING SYSTEM 21	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2015

SAMPLED BY : TANGHAO

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

Figure B-37. ⅞-in. Hex Nut, Test No. FLAGT-2 (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.

Fastenal Account Representative Signature

Ashly Stanczyk

Printed Name

11/29/18

Date

Please check current revision to avoid using obsolete copies.

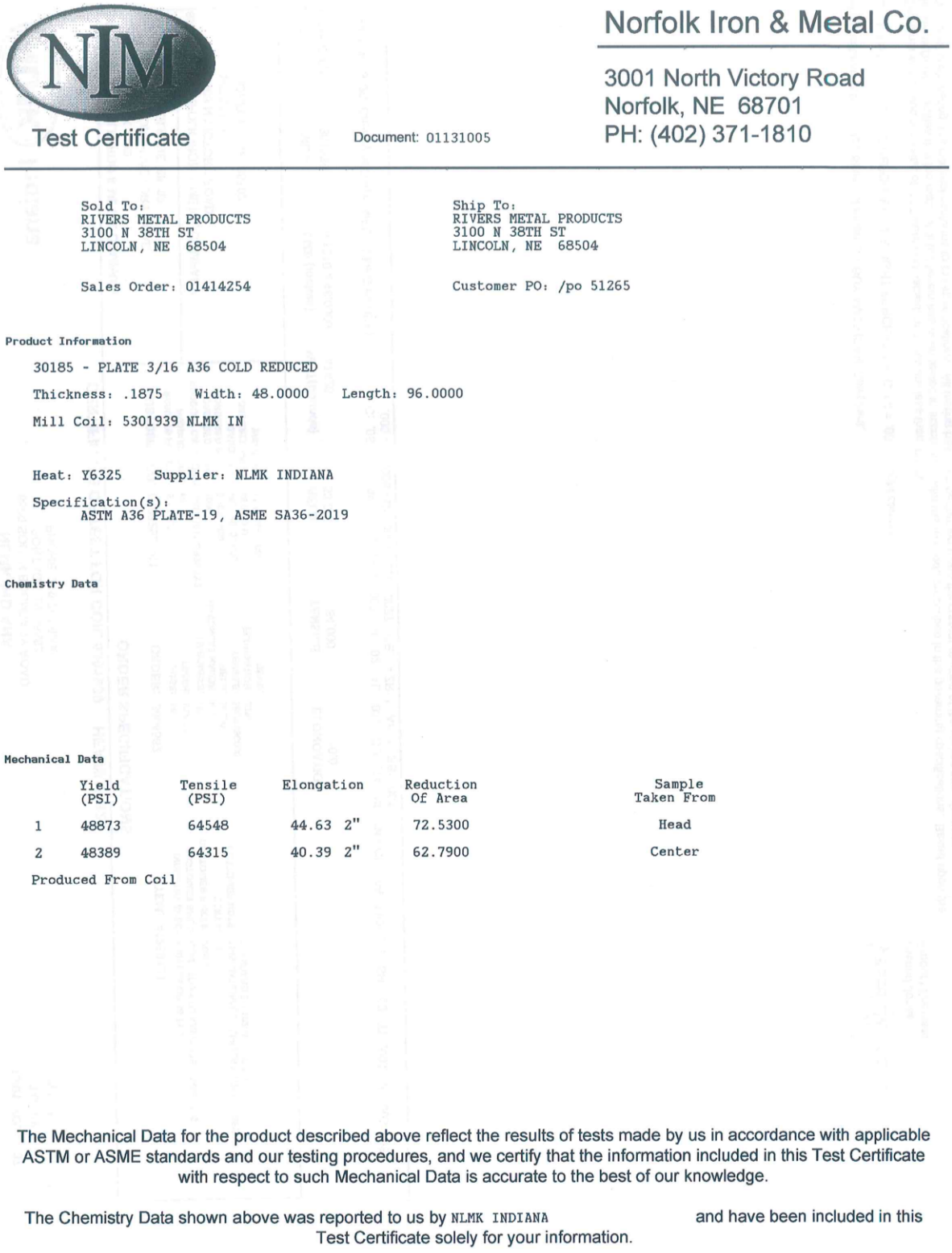
This document was printed on 11/26/2018 and was current at that time.

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-2 (Item No. h5)



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

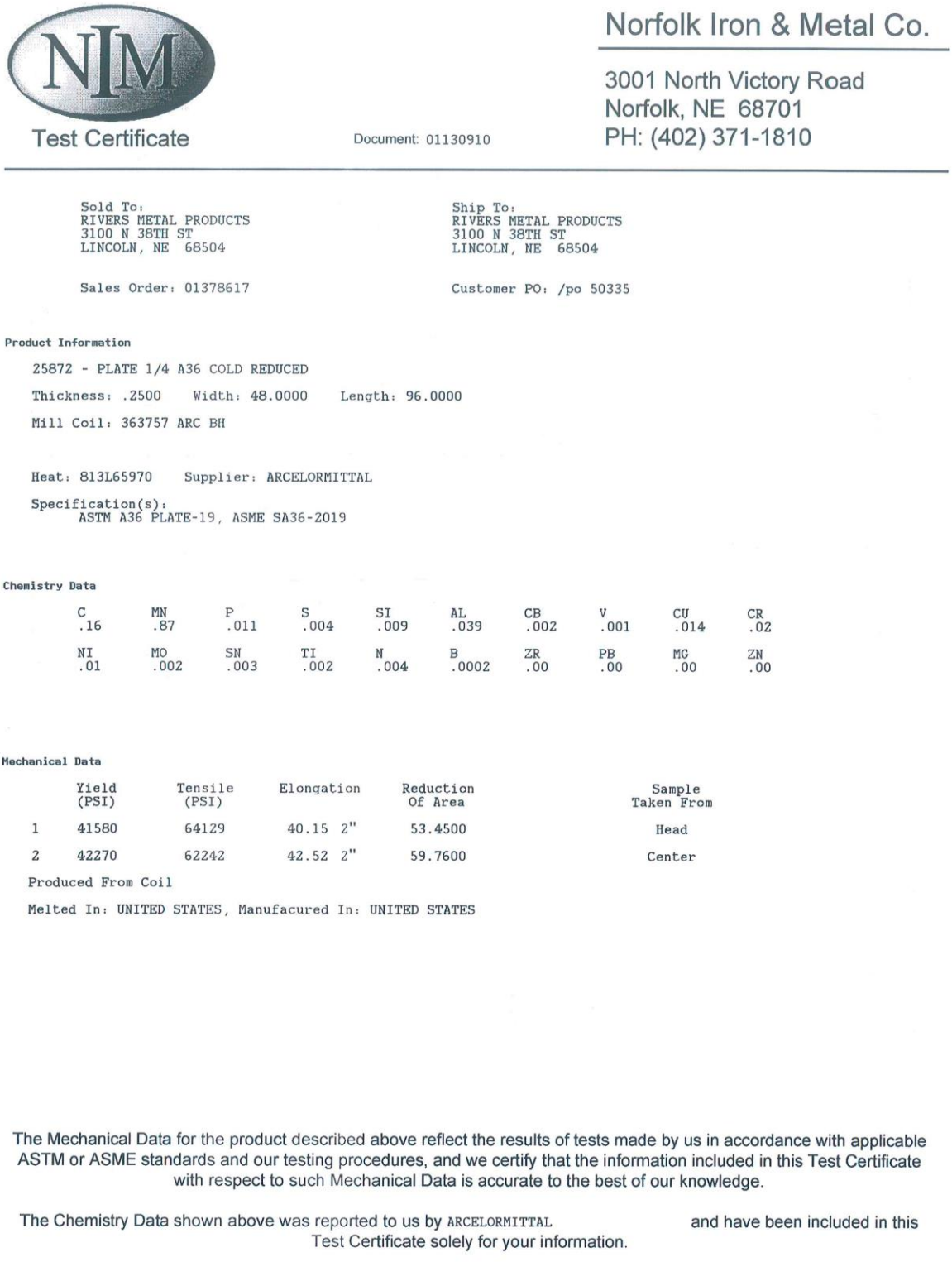
	Yield (PSI)	Tensile (PSI)	Elongation	Reduction Of Area	Sample Taken From
1	48873	64548	44.63 2"	72.5300	Head
2	48389	64315	40.39 2"	62.7900	Center

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-2 (Item No. i1)



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-2 (Item Nos. i2 through i7)

Appendix C. Vehicle Center of Gravity Determination

		Test Name:	**FLAGT-2**	**VIN:**	**1C6RR6GG1FS646171**
Model Year:	**2015**	**Make:**	**Dodge**	**Model:**	**Ram 1500**

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	4900	28.379184	139058
+	Hub	19	14.75	280.25
+	Brake activation cylinder & frame	7	28.25	197.75
+	Pneumatic tank (Nitrogen)	30	28	840
+	Strobe/Brake Battery	10	27.75	277.5
+	Brake Receiver/Wires	6	53.25	319.5
+	CG Plate including DAQ	30	30.25	907.5
-	Battery	-42	42.25	-1774.5
-	Oil	-19	15.25	-289.75
-	Interior	-96	38.75	-3720
-	Fuel	-176	19.75	-3476
-	Coolant	-10	35.5	-355
-	Washer fluid	-4	32.75	-131
+	Water Ballast (In Fuel Tank)	195	19	3705
+	Onboard Supplemental Battery			0
+	Steel Ballast	133	35.75	4754.75
				0
	Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle			140594

Estimated Total Weight (lb)	4983
Vertical CG Location (in.)	28.21473

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.5 in. Front Track Width: 68.25 in.
Rear Track Width: 67.75 in.

Center of Gravity	**2270P MASH Targets**	**Test Inertial**	**Difference**
Test Inertial Weight (lb)	5000 ± 110	5000	0.0
Longitudinal CG (in.)	63 ± 4	65.8102	2.81020
Lateral CG (in.)	NA	-0.68	NA
Vertical CG (in.)	28 or greater	28.21	0.21473

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	1374	1325	
Rear	1105	1096	
FRONT	2699		lb
REAR	2201		lb
TOTAL	4900		lb

TEST INERTIAL WEIGHT (lb)

	Left	Right	
Front	1373	1285	
Rear	1177	1165	
FRONT	2658		lb
REAR	2342		lb
TOTAL	5000		lb

Figure C-1. Vehicle Mass Distribution, Test No. FLAGT-2

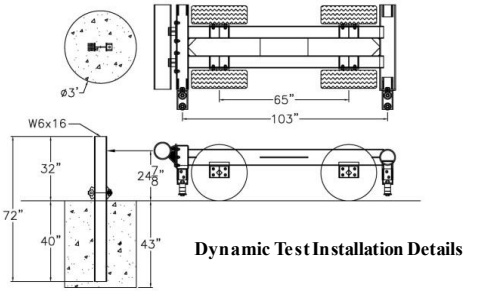
Appendix D. Static Soil Tests

Dynamic Set up

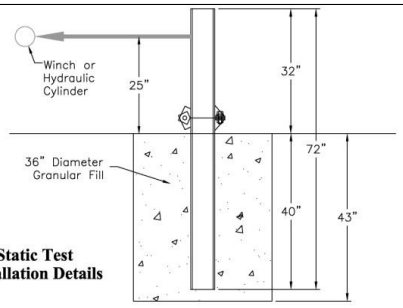
Post-Test Photo of Post

Static Load Test

Post-Test Photo of Post



Dynamic Test Installation Details



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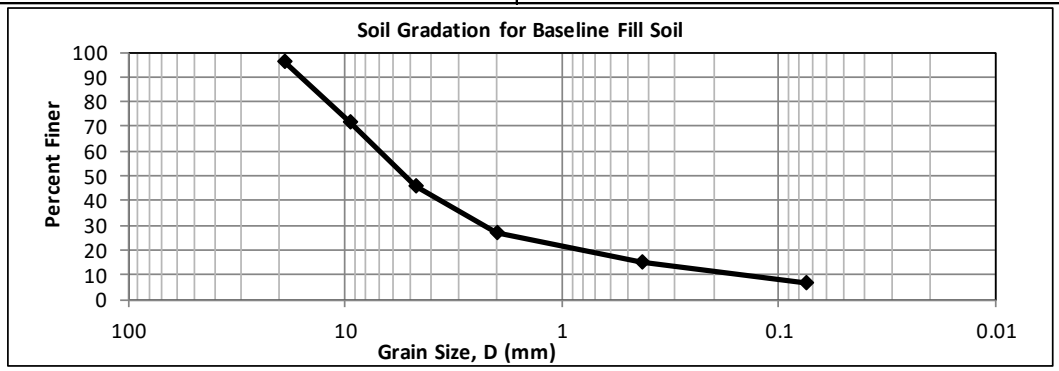
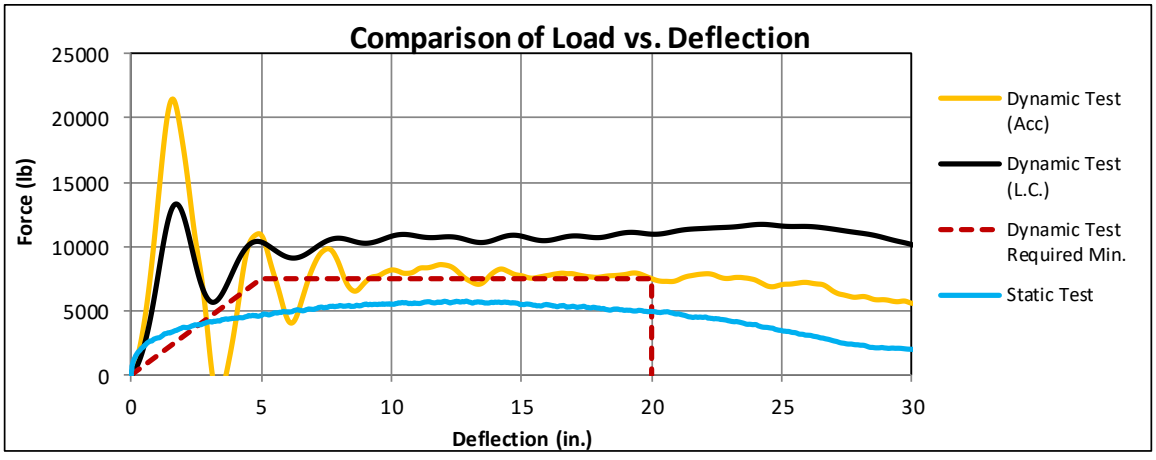
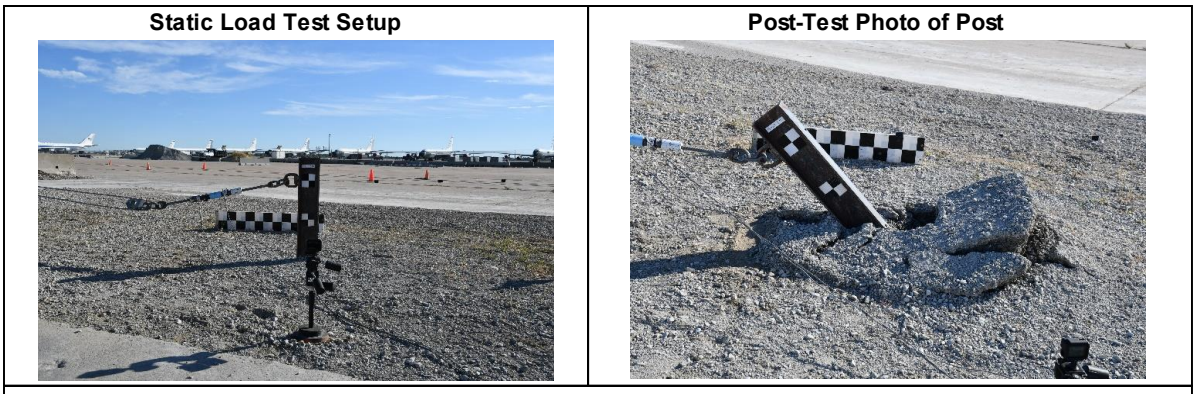
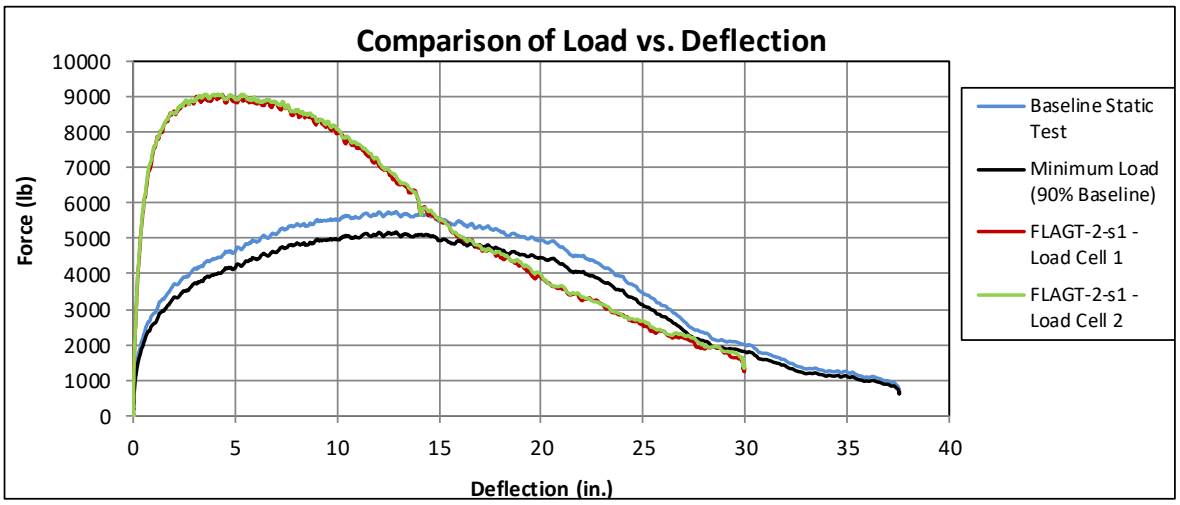


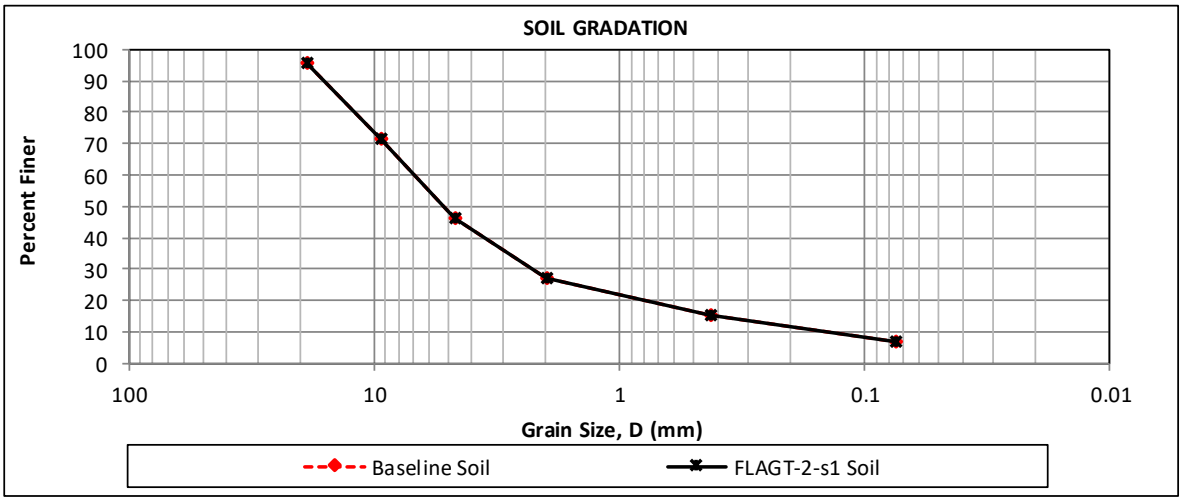


Date	5/24/2021		
Test Facility & Site Location	Midwest Roadside Safety Facility		
In situ soil description (ASTM D2487)	Well-Graded Gravel (GW)		
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)		
Description of fill placement procedure	LE-8 - 4 times around	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

Figure D-1. Soil Strength, Initial Calibration Tests, Test No. FLAGT-2







Date	9/21/2021
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. Soil Strength, Initial Calibration Tests, Test No. FLAGT-2

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.

Test Name: FLAGT-2 VIN: 1C6RR6GG1FS646171
Model Year: 2015 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	53.5043	32.2987	-8.2422	51.7693	31.6227	-11.0980	1.7350	0.6760	2.8558	3.4092	3.3415	X, Z
	2	54.4983	37.5048	-5.8078	51.1808	37.5369	-10.3241	3.3175	-0.0321	4.5163	5.6039	5.6038	X, Z
	3	55.7276	41.8300	-1.6980	50.1126	38.8441	-6.5177	5.6150	2.9859	4.8197	7.9796	7.3998	X, Z
	4	55.8571	46.7938	-1.5774	49.1222	41.9654	-8.1601	6.7349	4.8284	6.5827	10.5832	9.4176	X, Z
	5	56.0314	51.5521	-1.6715	48.5438	45.6075	-7.7679	7.4876	5.9446	6.0964	11.3388	9.6556	X, Z
	6	49.3907	30.9471	-6.4452	48.5483	30.5320	-8.3598	0.8424	0.4151	1.9146	2.1325	2.0917	X, Z
	7	50.9718	37.6328	-3.0213	47.2119	37.3359	-8.2992	3.7599	0.2969	5.2779	6.4870	6.4802	X, Z
	8	52.0696	41.6561	0.4883	46.7832	39.5512	-5.0595	5.2864	2.1049	5.5478	7.9470	7.6632	X, Z
	9	51.8156	47.5672	0.6746	45.7551	43.2220	-5.2305	6.0605	4.3452	5.9051	9.5121	8.4617	X, Z
	10	51.8293	52.3221	0.6694	44.3843	45.2958	-5.8725	7.4450	7.0263	6.5419	12.1488	9.9108	X, Z
FLOOR PAN (Z)	11	45.8851	31.2525	-5.5707	45.5052	30.9626	-6.8795	0.3799	0.2899	1.3088	1.3933	1.3088	Z
	12	47.8350	36.6860	0.0450	44.2675	36.6049	-5.0271	3.5675	0.0811	5.0721	6.2016	5.0721	Z
	13	48.3024	41.2820	1.2559	43.3963	40.3120	-4.2991	4.9061	0.9700	5.5550	7.4745	5.5550	Z
	14	48.2137	47.6428	1.2703	44.5368	45.0486	-2.7262	3.6769	2.5942	3.9965	6.0184	3.9965	Z
	15	48.2192	52.5581	1.2924	42.6289	48.1872	-5.2537	5.5903	4.3709	6.5461	9.6544	6.5461	Z
	16	42.7456	31.6399	-4.5480	42.4920	31.5176	-5.5491	0.2536	0.1223	1.0011	1.0399	1.0011	Z
	17	43.4819	36.6510	1.2606	42.3633	37.5563	-2.0949	1.1186	-0.9053	3.3555	3.6511	3.3555	Z
	18	43.0909	40.9241	1.2514	41.2924	41.1864	-2.7472	1.7985	-0.2623	3.9986	4.3923	3.9986	Z
	19	43.9895	46.4592	1.2596	41.5854	45.6139	-0.8510	2.4041	0.8453	2.1106	3.3089	2.1106	Z
	20	44.4702	52.7128	1.2980	41.0584	49.8454	-2.3211	3.4118	2.8674	3.6191	5.7411	3.6191	Z
	21	38.4214	31.9696	-3.7231	38.1458	32.3734	-4.6096	0.2756	-0.4038	0.8865	1.0124	0.8865	Z
	22	39.3849	35.8622	1.2441	39.1422	36.3223	-0.0757	0.2427	-0.4601	1.3198	1.4186	1.3198	Z
	23	39.2211	40.7360	1.2435	38.0036	40.9792	-1.1594	1.2175	-0.2432	2.4029	2.7047	2.4029	Z
	24	39.2249	46.3939	1.2554	38.0966	46.4350	0.0455	1.1283	-0.0411	1.2099	1.6549	1.2099	Z
	25	39.4934	52.8125	1.2784	38.3809	51.7373	0.0241	1.1125	1.0752	1.2543	1.9917	1.2543	Z
	26	34.6309	31.9493	-3.6257	34.5097	32.1849	-4.1654	0.1212	-0.2356	0.5397	0.6012	0.5397	Z
	27	34.7147	35.2391	0.4648	34.6491	35.4162	0.2706	0.0656	-0.1771	0.1942	0.2709	0.1942	Z
	28	34.6963	41.0112	0.4538	34.5037	41.0107	-0.1777	0.1926	0.0005	0.6315	0.6602	0.6315	Z
	29	34.6425	46.1564	0.4646	34.5383	46.2180	-0.1864	0.1042	-0.0616	0.6510	0.6622	0.6510	Z
	30	34.6440	52.4057	0.2724	34.5107	52.4230	0.0671	0.1333	-0.0173	0.2053	0.2454	0.2053	Z

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.
[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.
[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Pretest Floor Pan	Posttest Floor Pan
	

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

Test Name: FLAGT-2 VIN: 1C6RR6GG1FS646171
Model Year: 2015 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	45.2611	53.6665	-29.3848	44.6186	52.7321	-32.5680	0.6425	0.9344	-3.1832	3.3792	3.3792	X, Y, Z
	2	45.5987	40.8392	-30.4802	45.2934	39.9588	-32.9395	0.3053	0.8804	-2.4593	2.6299	2.6299	X, Y, Z
	3	42.4432	23.1615	-30.7978	42.3731	22.2010	-32.6415	0.0701	0.9605	-1.8437	2.0801	2.0801	X, Y, Z
	4	42.4587	53.5511	-19.9059	40.5556	52.7242	-23.6335	1.9031	0.8269	-3.7276	4.2662	4.2662	X, Y, Z
	5	41.6188	41.3442	-19.7923	40.4706	40.5005	-22.7835	1.1482	0.8437	-2.9912	3.3132	3.3132	X, Y, Z
	6	40.0342	23.2954	-17.4752	38.6523	23.0779	-19.7194	1.3819	0.2175	-2.2442	2.6445	2.6445	X, Y, Z
SIDE PANEL (Y)	7	51.9551	55.5381	-6.2285	46.2810	49.4208	-10.3035	5.6741	6.1173	-4.0750	9.2856	6.1173	Y
	8	51.5503	55.4167	-2.1767	46.4096	47.8325	-6.0060	5.1407	7.5842	-3.8293	9.9303	7.5842	Y
	9	53.2878	55.4568	-2.7630	48.0798	47.4030	-6.6191	5.2080	8.0538	-3.8561	10.3371	8.0538	Y
IMPACT SIDE DOOR (Y)	10	39.6004	57.8119	-19.3037	37.5905	60.8442	-20.5386	2.0099	-3.0323	-1.2349	3.8418	-3.0323	Y
	11	29.3356	57.9904	-18.7124	27.6276	62.9776	-19.3953	1.7080	-4.9872	-0.6829	5.3156	-4.9872	Y
	12	17.6257	57.6315	-18.7427	16.5893	60.6874	-19.2281	1.0364	-3.0559	-0.4854	3.2632	-3.0559	Y
	13	37.9698	58.5002	-5.0032	36.1863	57.3070	-6.8460	1.7835	1.1932	-1.8428	2.8285	1.1932	Y
	14	30.3807	58.1575	-3.7490	28.6960	57.8092	-5.1370	1.6847	0.3483	-1.3880	2.2104	0.3483	Y
	15	21.6148	57.5923	-4.3966	19.9018	58.9134	-5.1981	1.7130	-1.3211	-0.8015	2.3070	-1.3211	Y
ROOF - (Z)	16	34.2907	47.3781	-46.0864	34.4105	47.6771	-47.0911	-0.1198	-0.2990	-1.0047	1.0551	-1.0047	Z
	17	37.0563	37.3240	-46.5814	37.0954	37.5987	-47.1691	-0.0391	-0.2747	-0.5877	0.6499	-0.5877	Z
	18	38.3519	23.2377	-46.8594	38.4314	23.4196	-46.9731	-0.0795	-0.1819	-0.1137	0.2288	-0.1137	Z
	19	27.3436	44.7990	-49.3613	27.3092	44.8846	-50.2054	0.0344	-0.0856	-0.8441	0.8491	-0.8441	Z
	20	29.6701	35.5137	-49.7344	29.6973	35.6110	-50.3712	-0.0272	-0.0973	-0.6368	0.6448	-0.6368	Z
	21	31.0914	22.3133	-49.8308	31.1636	22.5245	-50.0495	-0.0722	-0.2112	-0.2187	0.3125	-0.2187	Z
	22	12.1595	43.1085	-50.6700	12.1659	43.0594	-51.3706	-0.0064	0.0491	-0.7006	0.7023	-0.7006	Z
	23	12.3199	34.2152	-51.1617	12.4631	34.1711	-51.6156	-0.1432	0.0441	-0.4539	0.4780	-0.4539	Z
	24	12.0609	21.4999	-51.4063	12.2081	21.5193	-51.7730	-0.1472	-0.0194	-0.3667	0.3956	-0.3667	Z
	25	-1.8397	42.7698	-50.9864	-1.8069	42.7805	-51.5073	-0.0328	-0.0107	-0.5209	0.5220	-0.5209	Z
	26	-1.9267	34.9123	-51.3634	-1.7868	34.8050	-51.7955	-0.1399	0.1073	-0.4321	0.4667	-0.4321	Z
	27	-1.8197	20.4053	-51.5829	-1.6386	20.2959	-51.8910	-0.1811	0.1094	-0.3081	0.3738	-0.3081	Z
	28	-18.2937	43.2251	-50.7755	-18.2594	43.0403	-51.2144	-0.0343	0.1848	-0.4389	0.4775	-0.4389	Z
	29	-17.8241	32.8556	-51.1965	-17.6995	32.6406	-51.5947	-0.1246	0.2150	-0.3982	0.4694	-0.3982	Z
	30	-17.3041	20.7433	-51.3169	-17.1845	20.5058	-51.6420	-0.1196	0.2375	-0.3251	0.4200	-0.3251	Z
A-PILLAR Maximum (X, Y, Z)	31	53.2569	54.8108	-31.1890	53.1602	55.5662	-32.6322	0.0967	-0.7554	-1.4432	1.6318	0.0967	X
	32	49.6730	53.9555	-33.8205	50.2512	54.5300	-36.0113	-0.5782	-0.5745	-2.1908	2.3375	0.0000	NA
	33	44.3189	52.7881	-38.0165	44.7588	53.4900	-39.6803	-0.4399	-0.7019	-1.6638	1.8586	0.0000	NA
	34	40.7036	52.0293	-40.8258	40.9815	52.5957	-42.4156	-0.2779	-0.5664	-1.5898	1.7104	0.0000	NA
	35	38.0849	51.4320	-42.3903	38.3281	51.9126	-43.7704	-0.2432	-0.4806	-1.3801	1.4815	0.0000	NA
	36	34.8623	50.7276	-44.2701	35.0454	51.1116	-45.5729	-0.1831	-0.3840	-1.3028	1.3705	0.0000	NA
A-PILLAR Lateral (Y)	31	53.2569	54.8108	-31.1890	53.1602	55.5662	-32.6322	0.0967	-0.7554	-1.4432	1.6318	-0.7554	Y
	32	49.6730	53.9555	-33.8205	50.2512	54.5300	-36.0113	-0.5782	-0.5745	-2.1908	2.3375	-0.5745	Y
	33	44.3189	52.7881	-38.0165	44.7588	53.4900	-39.6803	-0.4399	-0.7019	-1.6638	1.8586	-0.7019	Y
	34	40.7036	52.0293	-40.8258	40.9815	52.5957	-42.4156	-0.2779	-0.5664	-1.5898	1.7104	-0.5664	Y
	35	38.0849	51.4320	-42.3903	38.3281	51.9126	-43.7704	-0.2432	-0.4806	-1.3801	1.4815	-0.4806	Y
	36	34.8623	50.7276	-44.2701	35.0454	51.1116	-45.5729	-0.1831	-0.3840	-1.3028	1.3705	-0.3840	Y
B-PILLAR Maximum (X, Y, Z)	37	10.1177	51.6254	-41.3322	10.0966	51.7204	-41.8631	0.0211	-0.0950	-0.5309	0.5397	0.0211	X
	38	7.6464	53.2392	-37.1858	7.6410	53.2931	-37.6808	0.0054	-0.0539	-0.4950	0.4980	0.0054	X
	39	10.9721	54.2783	-33.1808	10.9227	54.3665	-33.6810	0.0494	-0.0882	-0.5002	0.5103	0.0494	X
	40	8.2207	54.8427	-28.6862	8.1799	54.8783	-29.2245	0.0408	-0.0356	-0.5383	0.5410	0.0408	X
B-PILLAR Lateral (Y)	37	10.1177	51.6254	-41.3322	10.0966	51.7204	-41.8631	0.0211	-0.0950	-0.5309	0.5397	-0.0950	Y
	38	7.6464	53.2392	-37.1858	7.6410	53.2931	-37.6808	0.0054	-0.0539	-0.4950	0.4980	-0.0539	Y
	39	10.9721	54.2783	-33.1808	10.9227	54.3665	-33.6810	0.0494	-0.0882	-0.5002	0.5103	-0.0882	Y
	40	8.2207	54.8427	-28.6862	8.1799	54.8783	-29.2245	0.0408	-0.0356	-0.5383	0.5410	-0.0356	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 1, Test No. FLAGT-2

Model Year: 2015 Test Name: FLAGT-2 Make: Dodge VIN: 1C6RR6GG1FS646171 Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	50.5209	12.6277	-5.1699	48.8957	12.2944	-7.8344	1.6252	0.3333	2.6645	3.1388	3.1210	X, Z
	2	51.5730	17.8369	-2.7665	48.3206	18.1910	-6.9273	3.2524	-0.3541	4.1608	5.2930	5.2811	X, Z
	3	52.8892	22.1683	1.3095	47.3410	19.4196	-3.0713	5.5482	2.7487	4.3808	7.5848	7.0692	X, Z
	4	53.0333	27.1321	1.4162	46.3098	22.5722	-4.6266	6.7235	4.5599	6.0428	10.1249	9.0400	X, Z
	5	53.2175	31.8897	1.3077	45.7377	26.2049	-4.1472	7.4798	5.6848	5.4549	10.8637	9.2576	X, Z
	6	46.4382	11.2905	-3.2934	45.7407	11.1444	-5.0440	0.6975	0.1461	1.7506	1.8901	1.8844	X, Z
	7	48.0993	17.9800	0.0848	44.4006	17.9440	-4.8144	3.6987	0.0360	4.8992	6.1387	6.1386	X, Z
	8	49.2723	22.0086	3.5639	44.0462	20.0928	-1.5214	5.2261	1.9158	5.0853	7.5394	7.2919	X, Z
	9	49.0363	27.9207	3.7412	43.0113	23.7650	-1.5939	6.0250	4.1557	5.3351	9.0572	8.0476	X, Z
	10	49.0617	32.6756	3.7246	41.6241	25.8496	-2.1615	7.4376	6.8260	5.8861	11.6858	9.4849	X, Z
FLOOR PAN (Z)	11	42.9503	11.6068	-2.3545	42.7329	11.5411	-3.4843	0.2174	0.0657	1.1298	1.1524	1.1298	Z
	12	45.0178	17.0482	3.2112	41.5343	17.1433	-1.4896	3.4835	-0.0951	4.7008	5.8516	4.7008	Z
	13	45.5190	21.6458	4.4025	40.6774	20.8338	-0.6665	4.8416	0.8120	5.0690	7.0566	5.0690	Z
	14	45.4463	28.0067	4.4037	41.8506	25.5390	0.9747	3.5957	2.4677	3.4290	5.5477	3.4290	Z
	15	45.4644	32.9220	4.4142	39.8814	28.7256	-1.4433	5.5830	4.1964	5.8575	9.1154	5.8575	Z
	16	39.8313	12.0044	-1.2745	39.7512	12.0652	-2.0726	0.0801	-0.0608	0.7981	0.8044	0.7981	Z
	17	40.6880	17.0269	4.5077	39.6987	18.0327	1.5051	0.9893	-1.0058	3.0026	3.3175	3.0026	Z
	18	40.3074	21.3009	4.4958	38.6098	21.6739	0.9516	1.6976	-0.3730	3.5442	3.9474	3.5442	Z
	19	41.2198	26.8338	4.4743	38.9436	26.0625	2.9297	2.2762	0.7713	1.5446	2.8569	1.5446	Z
	20	41.7165	33.0862	4.4892	38.3788	30.3221	1.5583	3.3377	2.7641	2.9309	5.2317	2.9309	Z
	21	35.5240	12.3468	-0.3700	35.4276	12.8962	-1.0144	0.0964	-0.5494	0.6444	0.8523	0.6444	Z
	22	36.5895	16.2483	4.5693	36.5269	16.7540	3.5739	0.0626	-0.5057	0.9954	1.1182	0.9954	Z
	23	36.4378	21.1226	4.5604	35.3594	21.4303	2.6116	1.0784	-0.3077	1.9488	2.2484	1.9488	Z
	24	36.4557	26.7804	4.5590	35.4761	26.8608	3.9241	0.9796	-0.0804	0.6349	1.1701	0.6349	Z
	25	36.7405	33.1984	4.5620	35.7556	32.1628	4.0034	0.9849	1.0356	0.5586	1.5344	0.5586	Z
	26	31.7360	12.3363	-0.2020	31.8031	12.6940	-0.4889	-0.0671	-0.3577	0.2869	0.4634	0.2869	Z
	27	31.9041	15.6352	3.8786	32.0440	15.8352	4.0071	-0.1399	-0.2000	-0.1285	0.2758	-0.1285	Z
	28	31.8997	21.4073	3.8544	31.8834	21.4374	3.6756	0.0163	-0.0301	0.1788	0.1820	0.1788	Z
	29	31.8589	26.5527	3.8542	31.9135	26.6439	3.7715	-0.0546	-0.0912	0.0827	0.1347	0.0827	Z
	30	31.8722	32.8014	3.6474	31.8868	32.8425	4.1510	-0.0146	-0.0411	-0.5036	0.5055	-0.5036	Z

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

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

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

Pretest Floor Pan	Posttest Floor Pan
	

Figure E-3. Floor Pan Deformation Data – Set 2, Test No. FLAGT-2

Test Name: FLAGT-2 VIN: 1C6RR6GG1FS646171
Model Year: 2015 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	41.9396	33.9781	-26.1864	41.2364	33.8208	-28.6923	0.7032	0.1573	-2.5059	2.6074	2.6074	X, Y, Z
	2	42.2216	21.1482	-27.2670	41.9127	21.0585	-29.3373	0.3089	0.0897	-2.0703	2.0951	2.0951	X, Y, Z
	3	39.0130	3.4787	-27.4954	39.0146	3.2945	-29.3302	-0.0016	0.1842	-1.8348	1.8440	1.8440	X, Y, Z
	4	39.3184	33.8853	-16.6555	37.3822	33.6274	-19.6677	1.9362	0.2579	-3.0122	3.5901	3.5901	X, Y, Z
	5	38.4479	21.6809	-16.5059	37.3270	21.3890	-19.0631	1.1209	0.2919	-2.5572	2.8073	2.8073	X, Y, Z
	6	36.8592	3.6402	-14.1294	35.5946	3.9058	-16.3101	1.2646	-0.2656	-2.1807	2.5348	2.5348	X, Y, Z
SIDE PANEL (Y)	7	49.0795	35.8681	-3.1651	43.4188	30.0632	-6.5438	5.6607	5.8049	-3.3787	8.7838	5.8049	Y
	8	48.7519	35.7542	0.8938	43.6486	28.3887	-2.2834	5.1033	7.3655	-3.1772	9.5073	7.3655	Y
	9	50.4779	35.7886	0.2744	45.3044	27.9738	-2.9437	5.1735	7.8148	-3.2181	9.9092	7.8148	Y
IMPACT SIDE DOOR (Y)	10	36.4836	38.1549	-16.0058	34.4833	41.6795	-16.3414	2.0003	-3.5246	-0.3356	4.0665	-3.5246	Y
	11	26.2325	38.3623	-15.2189	24.5479	43.7766	-14.9241	1.6846	-5.4143	0.2948	5.6780	-5.4143	Y
	12	14.5232	38.0352	-15.0250	13.5184	41.4694	-14.5467	1.0048	-3.4342	0.4783	3.6100	-3.4342	Y
	13	35.1282	38.8702	-1.6779	33.4008	37.8651	-2.6941	1.7274	1.0051	-1.0162	2.2421	1.0051	Y
	14	27.5636	38.5502	-0.2785	25.9519	38.3230	-0.8017	1.6117	0.2272	-0.5232	1.7097	0.2272	Y
	15	18.7854	38.0079	-0.7577	17.1578	39.4169	-0.6362	1.6276	-1.4090	0.1215	2.1562	-1.4090	Y
ROOF - (Z)	16	30.6353	27.6931	-42.6651	30.6974	29.0468	-43.0733	-0.0621	-1.3537	-0.4082	1.4153	-0.4082	Z
	17	33.3638	17.6307	-43.1964	33.3880	18.9754	-43.4173	-0.0242	-1.3447	-0.2209	1.3629	-0.2209	Z
	18	34.6159	3.5406	-43.4760	34.7397	4.7970	-43.5389	-0.1238	-1.2564	-0.0629	1.2641	-0.0629	Z
	19	23.6200	25.1278	-45.8025	23.5279	26.3085	-46.0776	0.0921	-1.1807	-0.2751	1.2158	-0.2751	Z
	20	25.9139	15.8356	-46.2048	25.9190	17.0432	-46.4861	-0.0051	-1.2076	-0.2813	1.2399	-0.2813	Z
	21	27.2975	2.6313	-46.3068	27.4030	3.9548	-46.4630	-0.1055	-1.3235	-0.1562	1.3369	-0.1562	Z
	22	8.4092	23.4766	-46.8184	8.3631	24.4877	-46.9272	0.0461	-1.0111	-0.1088	1.0180	-0.1088	Z
	23	8.5363	14.5821	-47.2985	8.6617	15.6066	-47.3586	-0.1254	-1.0245	-0.0601	1.0339	-0.0601	Z
	24	8.2383	1.8672	-47.5173	8.4135	2.9602	-47.7655	-0.1752	-1.0930	-0.2482	1.1344	-0.2482	Z
	25	-5.5944	23.1756	-46.8669	-5.6089	24.1937	-46.7449	0.0145	-1.0181	0.1220	1.0255	0.1220	Z
	26	-5.7097	15.3177	-47.2293	-5.5890	16.2257	-47.1945	-0.1207	-0.9080	0.0348	0.9166	0.0348	Z
	27	-5.6460	0.8102	-47.4271	-5.4312	1.7217	-47.5865	-0.2148	-0.9115	-0.1594	0.9499	-0.1594	Z
	28	-22.0400	23.6760	-46.3426	-22.0503	24.4264	-46.0646	0.0103	-0.7504	0.2780	0.8003	0.2780	Z
	29	-21.6065	13.3047	-46.7555	-21.4910	14.0373	-46.6678	-0.1155	-0.7326	0.0877	0.7468	0.0877	Z
	30	-21.1215	1.1908	-46.8661	-20.9673	1.9066	-46.9722	-0.1542	-0.7158	-0.1061	0.7399	-0.1061	Z
A-PILLAR Maximum (X, Y, Z)	31	49.9026	35.0977	-28.1448	49.7718	36.6666	-28.8976	0.1308	-1.5689	-0.7528	1.7451	0.1308	X
	32	46.2667	34.2480	-30.7060	46.7859	35.6950	-32.2285	-0.5192	-1.4470	-1.5225	2.1637	0.0000	NA
	33	40.8304	33.0886	-34.7970	41.2105	34.7222	-35.7891	-0.3801	-1.6336	-0.9921	1.9487	0.0000	NA
	34	37.1600	32.3352	-37.5355	37.3714	33.8784	-38.4534	-0.2114	-1.5432	-0.9179	1.8080	0.0000	NA
	35	34.5103	31.7426	-39.0488	34.6878	33.2194	-39.7597	-0.1775	-1.4768	-0.7109	1.6486	0.0000	NA
	36	31.2506	31.0439	-40.8656	31.3647	32.4507	-41.5013	-0.1141	-1.4068	-0.6357	1.5480	0.0000	NA
A-PILLAR Lateral (Y)	31	49.9026	35.0977	-28.1448	49.7718	36.6666	-28.8976	0.1308	-1.5689	-0.7528	1.7451	-1.5689	Y
	32	46.2667	34.2480	-30.7060	46.7859	35.6950	-32.2285	-0.5192	-1.4470	-1.5225	2.1637	-1.4470	Y
	33	40.8304	33.0886	-34.7970	41.2105	34.7222	-35.7891	-0.3801	-1.6336	-0.9921	1.9487	-1.6336	Y
	34	37.1600	32.3352	-37.5355	37.3714	33.8784	-38.4534	-0.2114	-1.5432	-0.9179	1.8080	-1.5432	Y
	35	34.5103	31.7426	-39.0488	34.6878	33.2194	-39.7597	-0.1775	-1.4768	-0.7109	1.6486	-1.4768	Y
	36	31.2506	31.0439	-40.8656	31.3647	32.4507	-41.5013	-0.1141	-1.4068	-0.6357	1.5480	-1.4068	Y
B-PILLAR Maximum (X, Y, Z)	37	6.5691	32.0138	-37.4573	6.5083	32.9525	-37.2013	0.0608	-0.9387	0.2560	0.9749	0.2631	X, Z
	38	4.1818	33.6409	-33.2671	4.1495	34.4374	-32.9321	0.0323	-0.7965	0.3350	0.8647	0.3366	X, Z
	39	7.5861	34.6773	-29.3280	7.5224	35.4340	-28.9888	0.0637	-0.7567	0.3392	0.8317	0.3451	X, Z
	40	4.9225	35.2563	-24.7826	4.8835	35.8524	-24.4603	0.0390	-0.5961	0.3223	0.6788	0.3247	X, Z
B-PILLAR Lateral (Y)	37	6.5691	32.0138	-37.4573	6.5083	32.9525	-37.2013	0.0608	-0.9387	0.2560	0.9749	-0.9387	Y
	38	4.1818	33.6409	-33.2671	4.1495	34.4374	-32.9321	0.0323	-0.7965	0.3350	0.8647	-0.7965	Y
	39	7.5861	34.6773	-29.3280	7.5224	35.4340	-28.9888	0.0637	-0.7567	0.3392	0.8317	-0.7567	Y
	40	4.9225	35.2563	-24.7826	4.8835	35.8524	-24.4603	0.0390	-0.5961	0.3223	0.6788	-0.5961	Y

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

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

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

Figure E-4. Occupant Compartment Deformation Data – Set 2, Test No. FLAGT-2

Test Name: FLAGT-2 VIN: 1C6RR6GG1FS646171

Model Year: 2015 Make: Dodge Model: Ram 1500

Passenger Side Maximum Deformation

Reference Set 1				Reference Set 2			
Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]	Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	-1.0	≤ 4	Z	Roof	0.3	≤ 4	Z
Windshield[D]	2.5	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.1	≤ 5	X	A-Pillar Maximum	0.1	≤ 5	X
A-Pillar Lateral	-0.8	≤ 3	Y	A-Pillar Lateral	-1.6	≤ 3	Y
B-Pillar Maximum	0.0	≤ 5	X	B-Pillar Maximum	0.3	≤ 5	X, Z
B-Pillar Lateral	-0.1	≤ 3	Y	B-Pillar Lateral	-0.9	≤ 3	Y
Toe Pan - Wheel Well	9.9	≤ 9	X, Z	Toe Pan - Wheel Well	9.5	≤ 9	X, Z
Side Front Panel	8.1	≤ 12	Y	Side Front Panel	7.8	≤ 12	Y
Side Door (above seat)	-5.0	≤ 9	Y	Side Door (above seat)	-5.4	≤ 9	Y
Side Door (below seat)	1.2	≤ 12	Y	Side Door (below seat)	1.0	≤ 12	Y
Floor Pan	6.5	≤ 12	Z	Floor Pan	5.9	≤ 12	Z
Dash - no MASH requirement	4.3	NA	X, Y, Z	Dash - no MASH requirement	3.6	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.

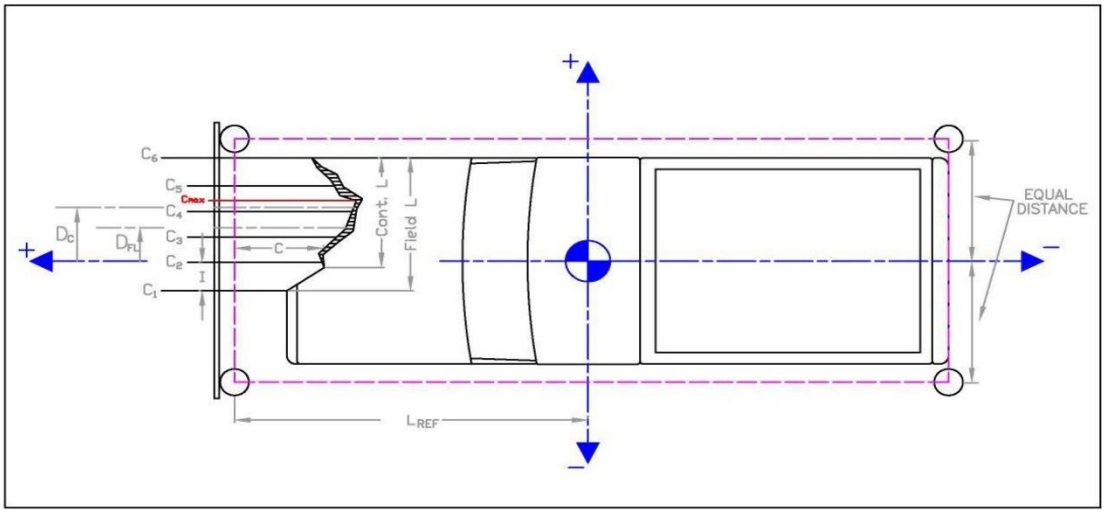
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

Notes on vehicle interior crush:

Figure E-5. Maximum Occupant Compartment Deformations by Location, Test No. FLAGT-2

Test Name: FLAGT-2 VIN: 1C6RR6GG1FS646171

Model Year: 2015 Make: Dodge Model: Ram 1500



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	136	(3454)
Total Vehicle Width:	79	(2007)
Width of contact and induced crush - Field L:	79	(2007)
Crush measurement spacing interval (L/5) - I:	15 3/4	(400)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	79	(2007)
Distance from center of vehicle to center of contact damage - D_C:	0	()

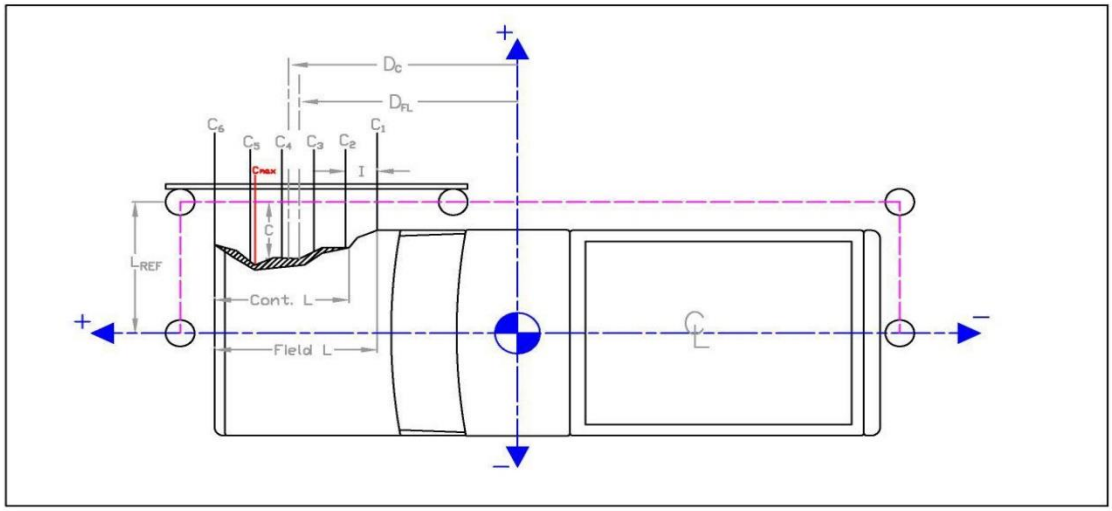
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	35	(889)	-39 1/2	-(1003)	22 1/2	(572)	26 1/5	(665)	-13 2/3	-(348)
C_2	30 1/2	(775)	-23 3/4	-(603)	6 3/4	(171)			-2 4/9	-(62)
C_3	29 1/2	(749)	-8	-(203)	4 1/4	(108)			-1	-(24)
C_4	47 3/8	(1203)	7 3/4	(197)	4 1/4	(108)			17	(430)
C_5	N/A	N/A	23 1/2	(597)	6 1/4	(159)			N/A	N/A
C_6	N/A	N/A	39 1/4	(997)	20 1/2	(521)			N/A	N/A
C_{MAX}	64	(1626)	18 7/8	(479)	5 3/8	(137)			32 4/9	(824)

Figure E-6. Exterior Vehicle Crush (NASS) - Front, Test No. FLAGT-2

Test Name: FLAGT-2 VIN: 1C6RR6GG1FS646171

Model Year: 2015 Make: Dodge Model: Ram 1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	56	(1422)
Total Vehicle Length:	228 7/8	(5813)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-9 3/8	-(238)
Width of contact and induced crush - Field L:	228 7/8	(5813)
Crush measurement spacing interval (L/5) - I:	45 3/4	(1162)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-9 3/8	-(238)
Width of Contact Damage:	228 7/8	(5813)
Distance from vehicle c.g. to center of contact damage - D_C:	-9 3/8	-(238)

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

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual	Crush
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/A	N/A	-123 7/8	-(3146)	33 1/2	(851)	12	(305)	N/A	N/A
C_2	N/A	N/A	-78 1/8	-(1984)	5 1/2	(140)			N/A	N/A
C_3	15 1/2	(394)	-32 3/8	-(822)	5 7/8	(149)			-2 3/8	-(60)
C_4	13 5/8	(346)	13 3/8	(340)	5	(127)			-3 3/8	-(86)
C_5	N/A	N/A	59 1/8	(1502)	5 7/8	(149)			N/A	N/A
C_6	N/A	N/A	104 7/8	(2664)	11 3/8	(289)			N/A	N/A
C_{MAX}	44 3/4	(1137)	95	(2413)	6 1/4	(159)			26 1/2	(673)

Figure E-7. Exterior Vehicle Crush (NASS) - Side, Test No. FLAGT-2

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

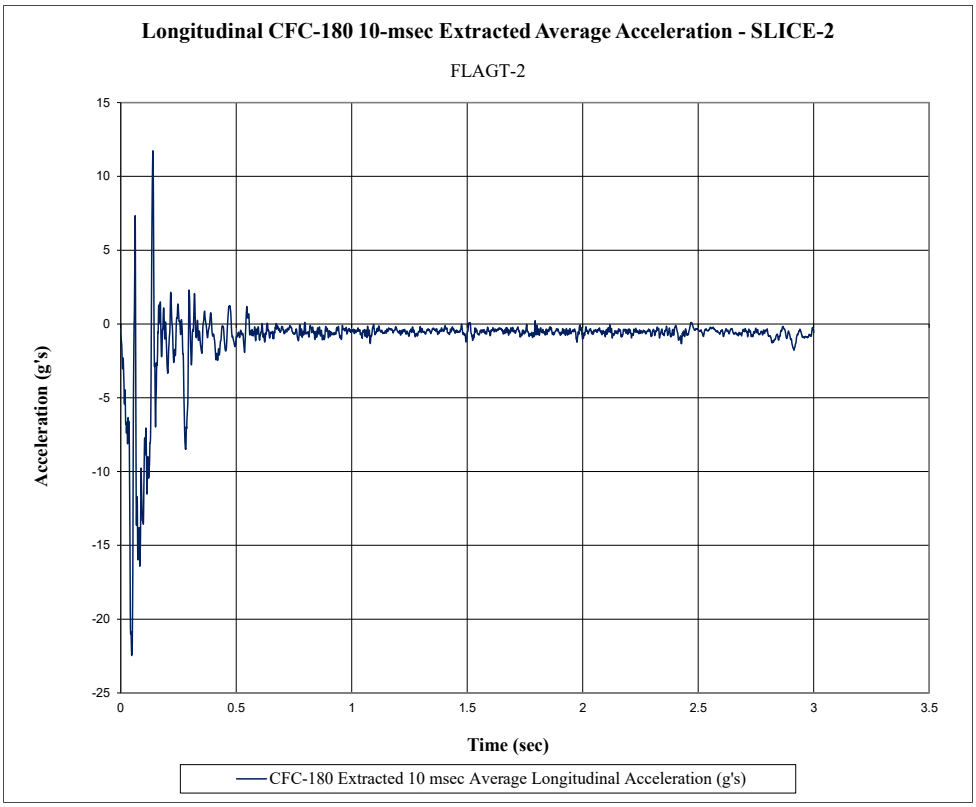


Figure F-1. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. FLAGT-2

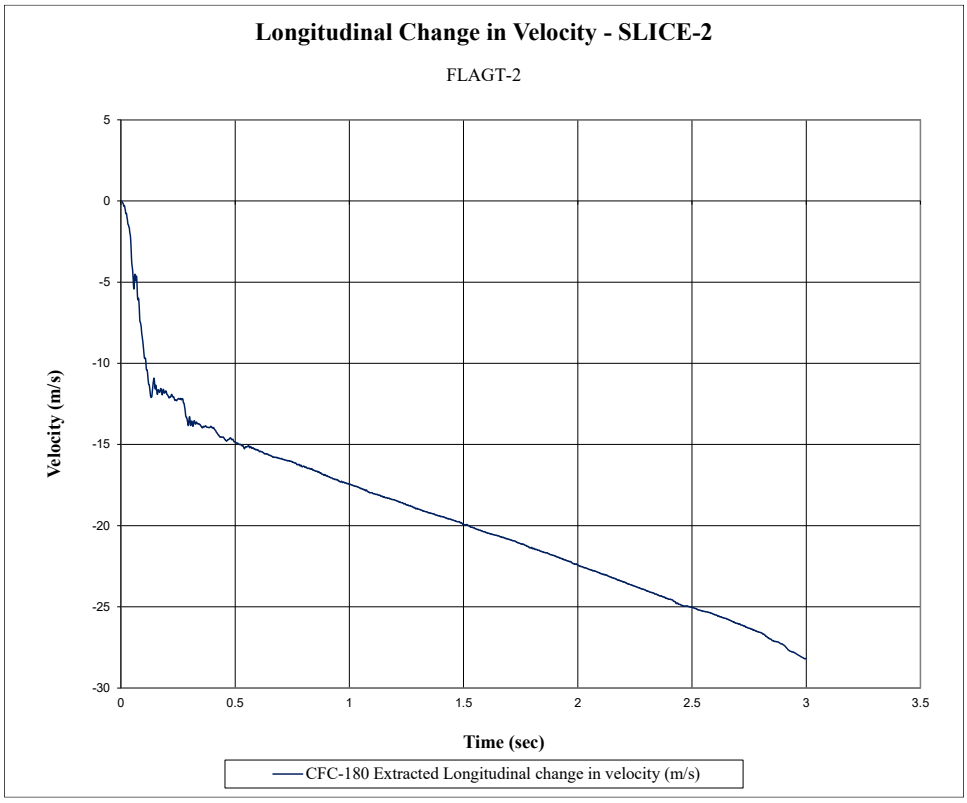


Figure F-2. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. FLAGT-2

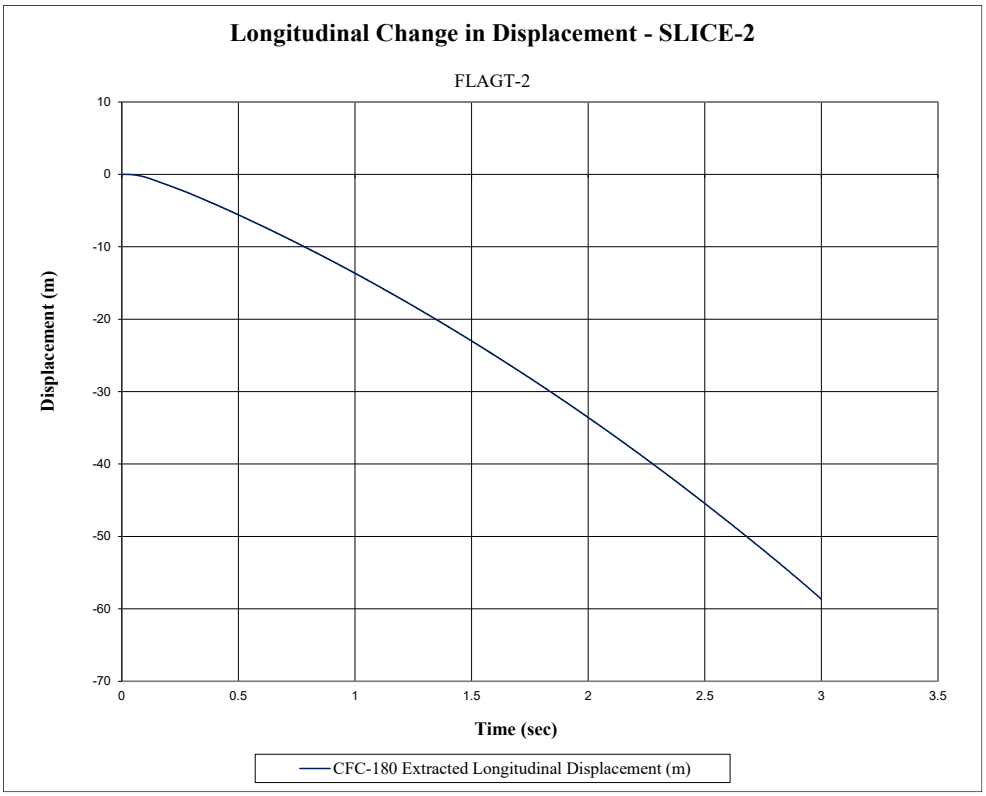


Figure F-3. Longitudinal Occupant Displacement (SLICE-2), Test No. FLAGT-2

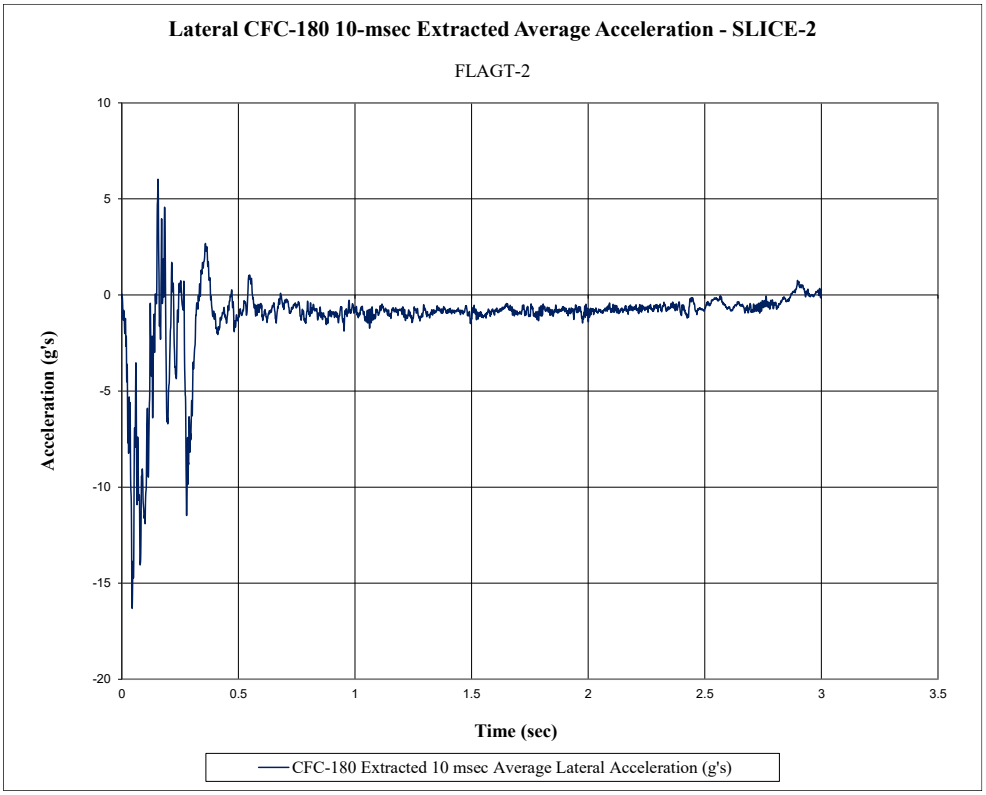


Figure F-4. 10-ms Average Lateral Deceleration (SLICE-2), Test No. FLAGT-2

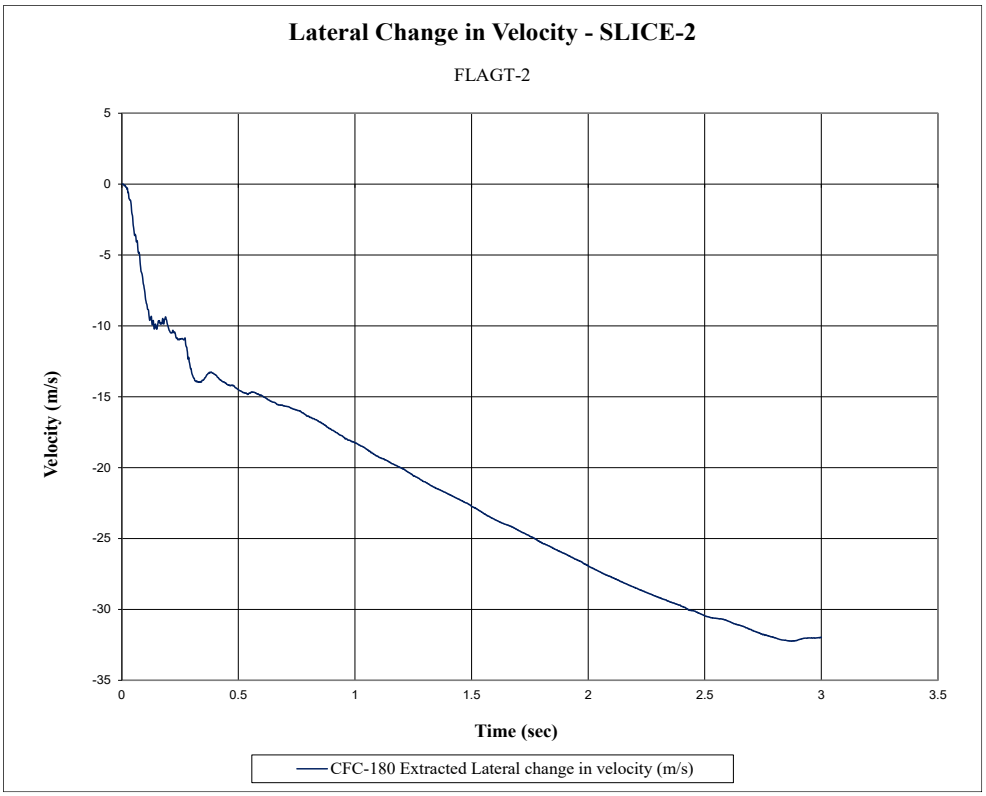


Figure F-5. Lateral Occupant Impact Velocity (SLICE-2), Test No. FLAGT-2

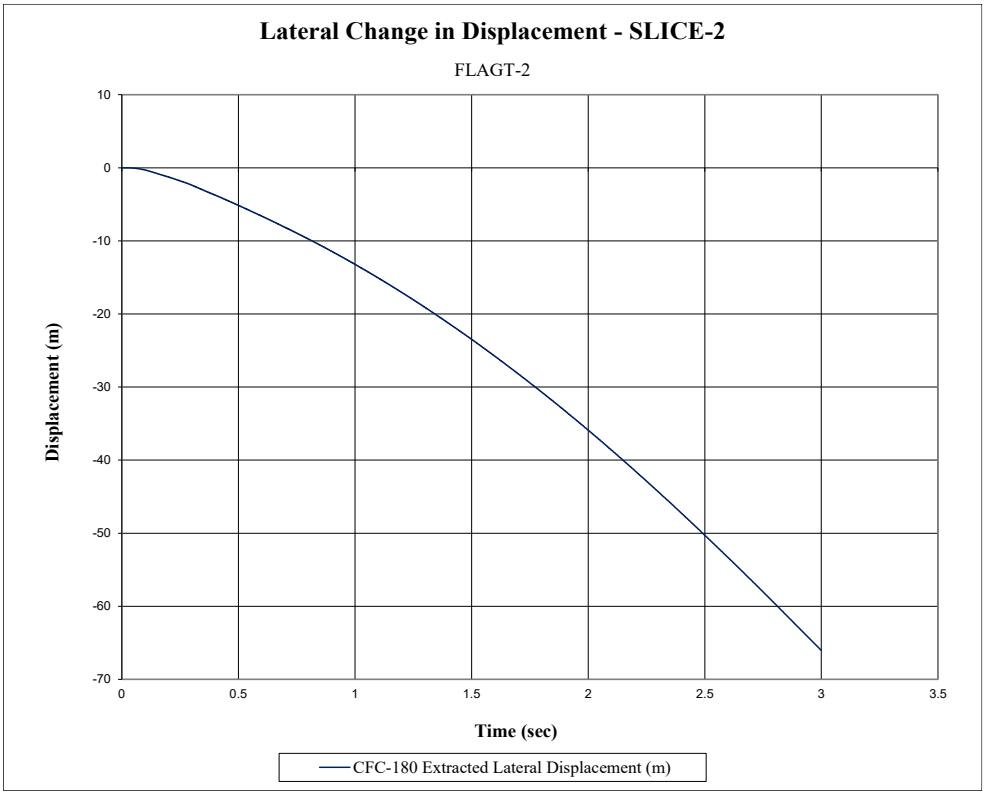


Figure F-6. Lateral Occupant Displacement (SLICE-2), Test No. FLAGT-2

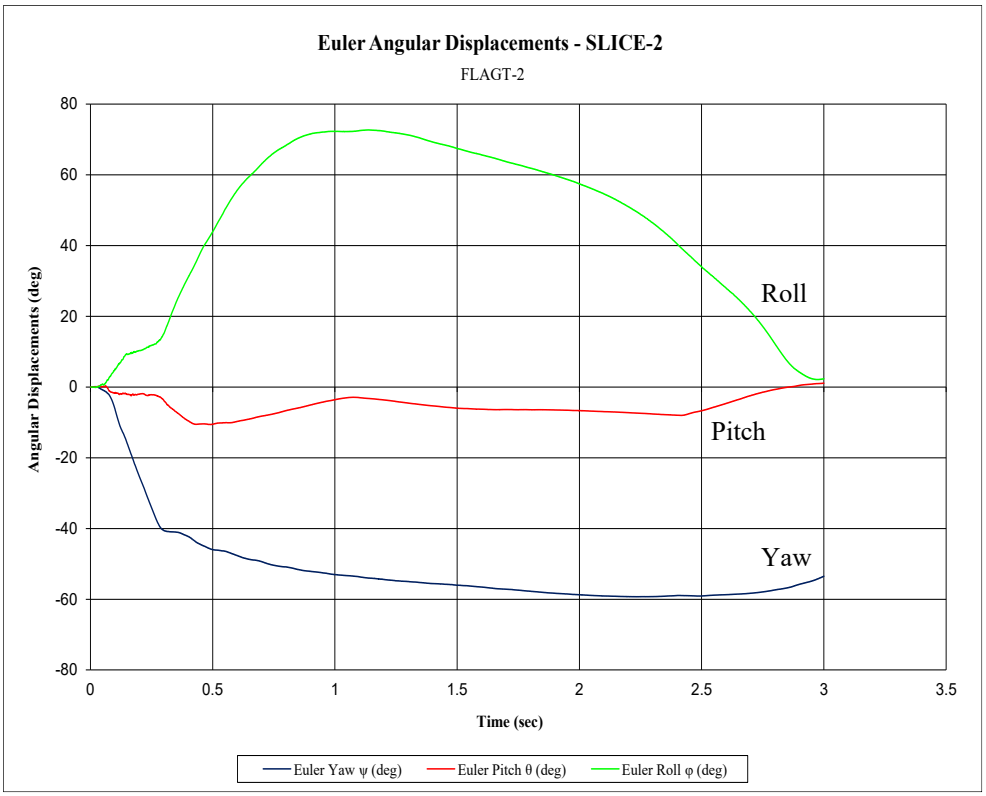


Figure F-7. Vehicle Angular Displacements (SLICE-2), Test No. FLAGT-2

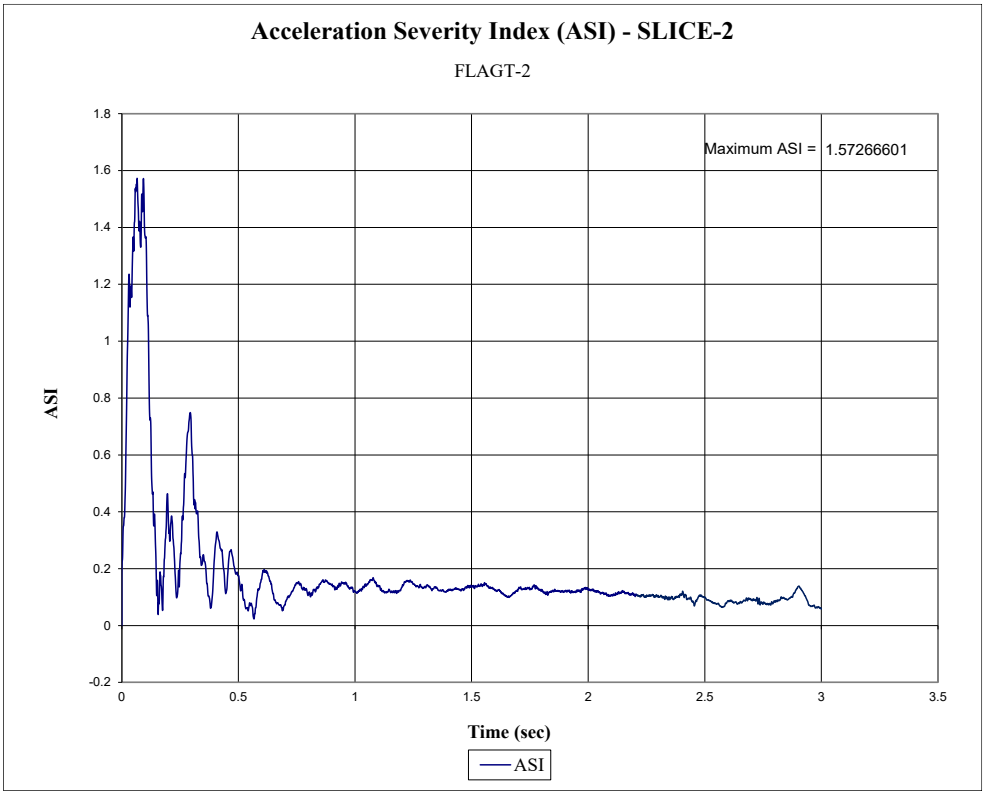


Figure F-8. Acceleration Severity Index (SLICE-2), Test No. FLAGT-2

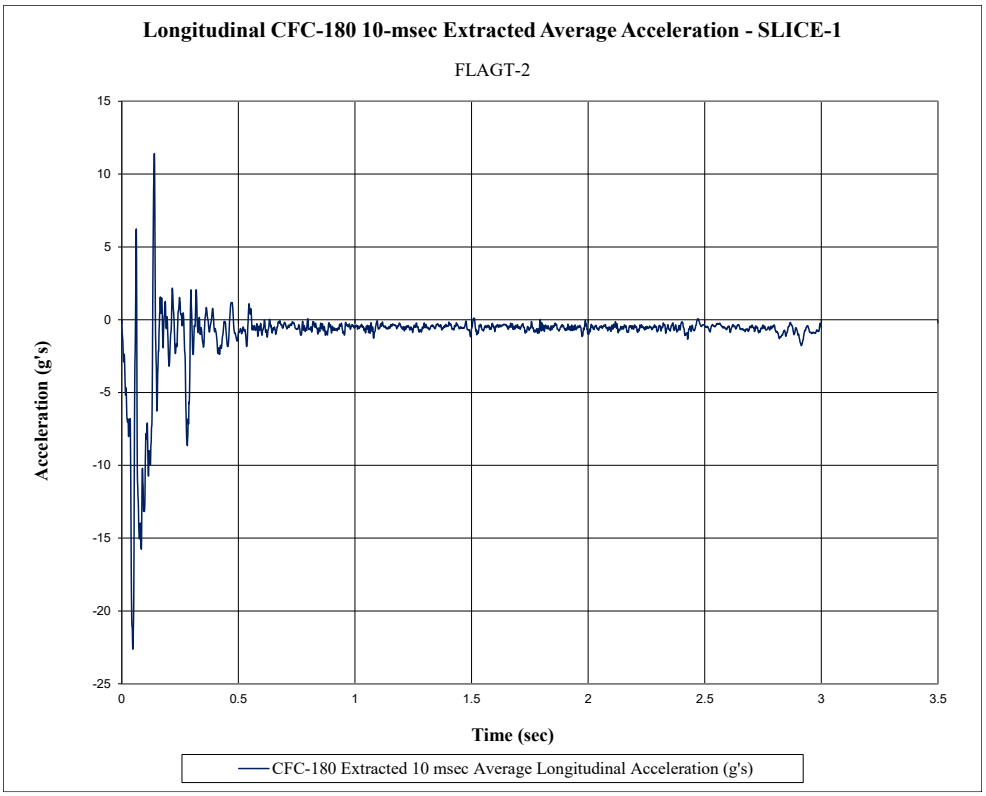


Figure F-9. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. FLAGT-2

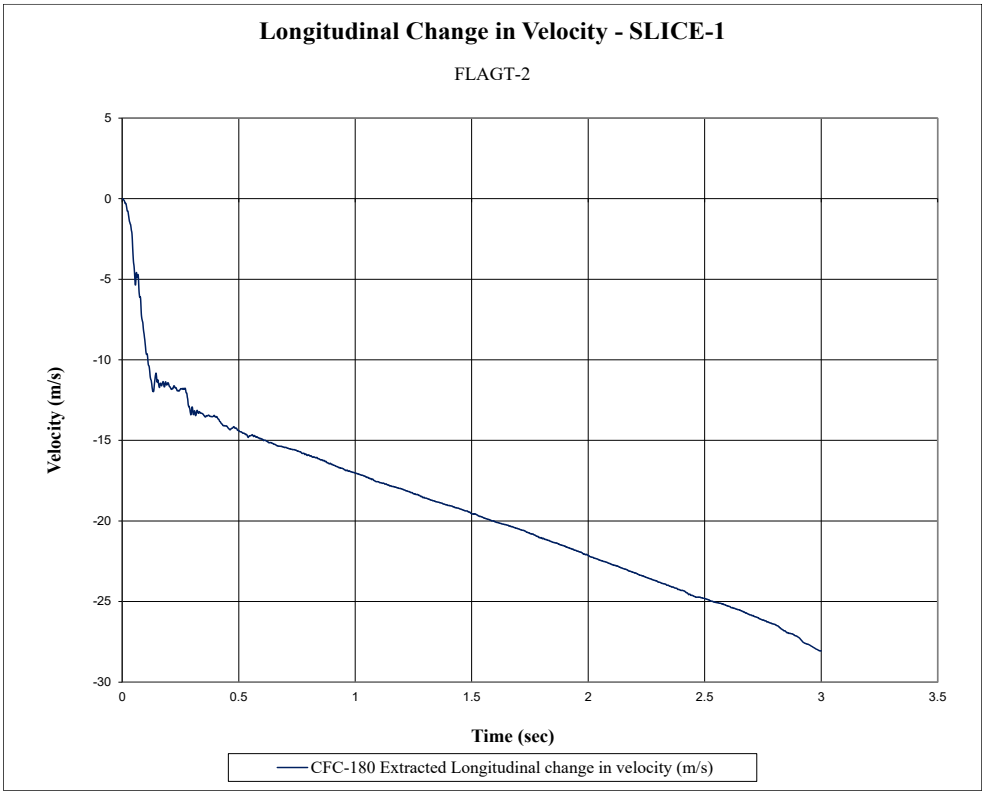


Figure F-10. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. FLAGT-2

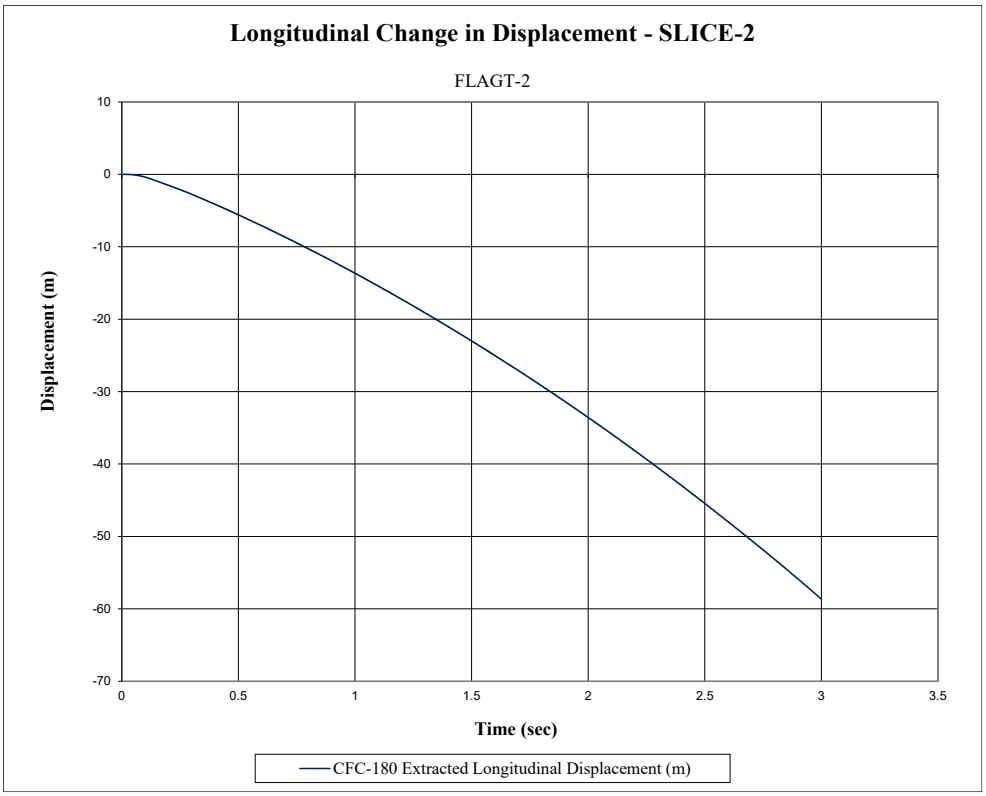


Figure F-11. Longitudinal Occupant Displacement (SLICE-2), Test No. FLAGT-2

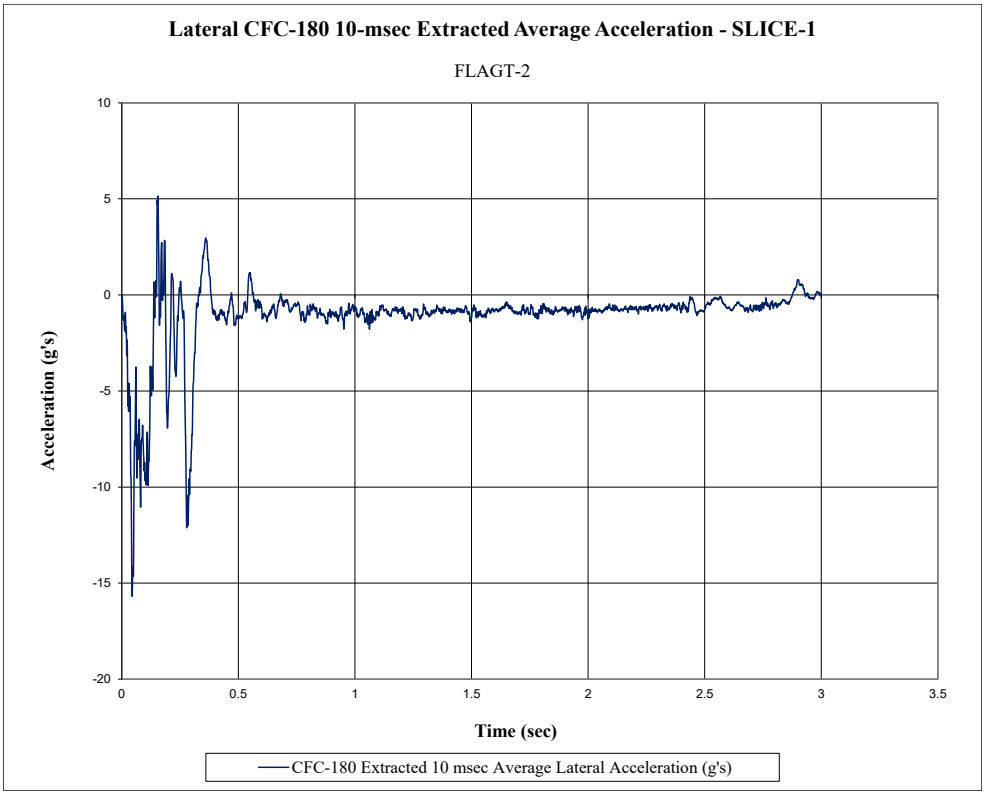


Figure F-12. 10-ms Average Lateral Deceleration (SLICE-1), Test No. FLAGT-2

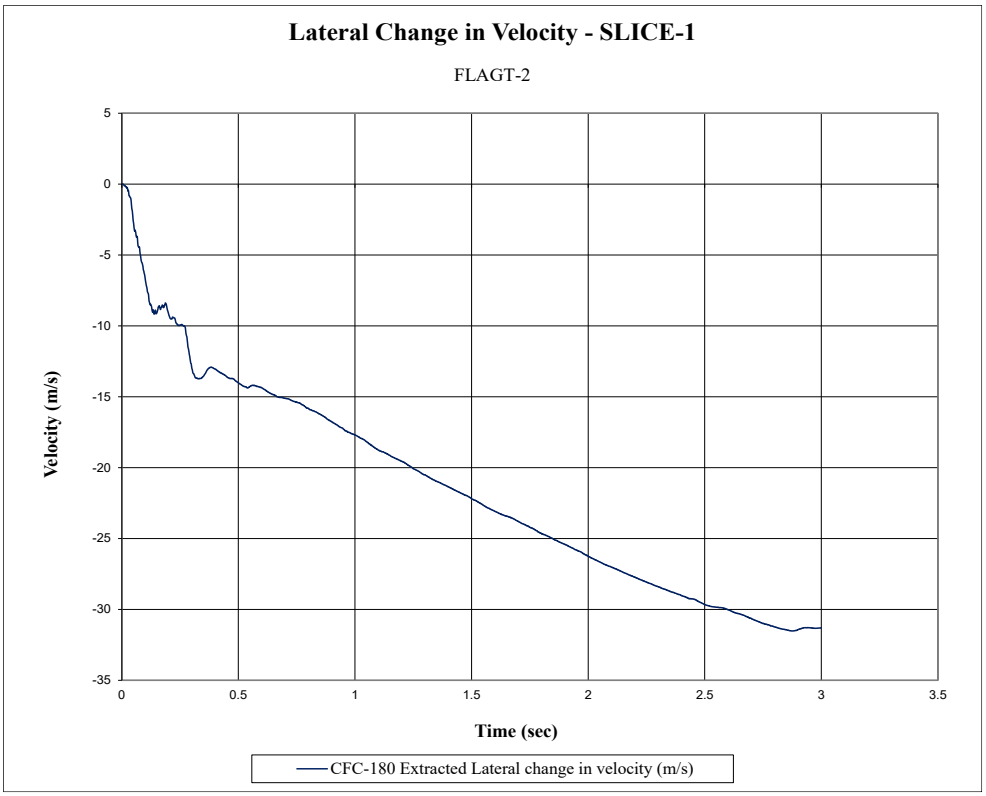


Figure F-13. Lateral Occupant Impact Velocity (SLICE-1), Test No. FLAGT-2

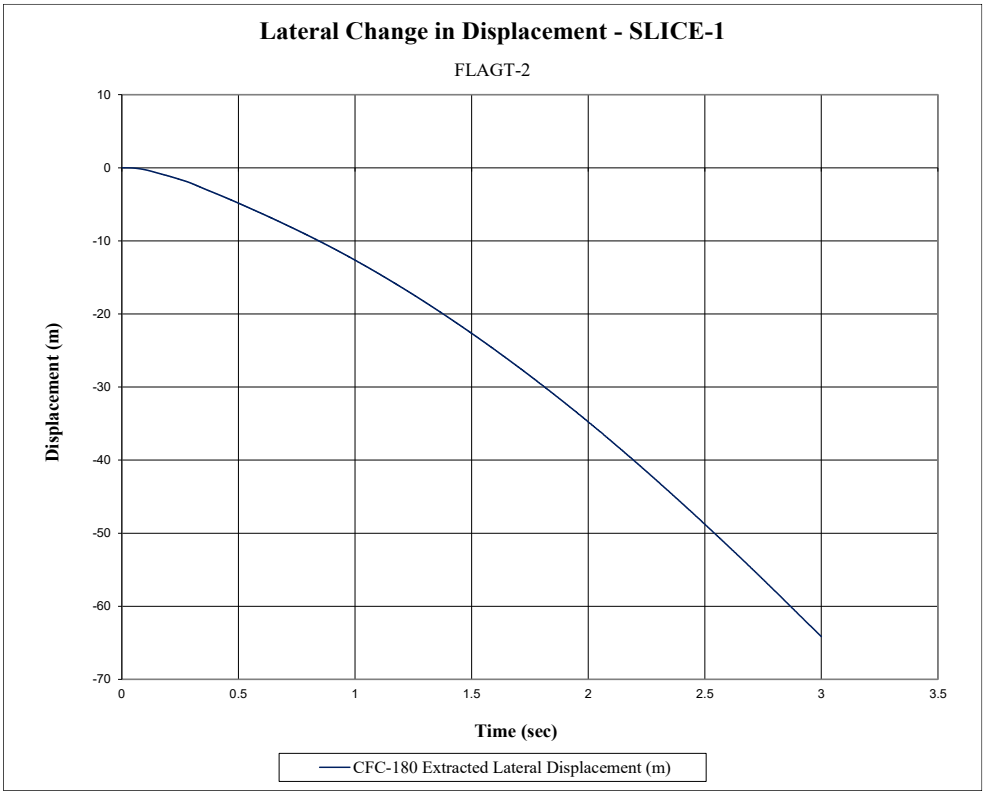


Figure F-14. Lateral Occupant Displacement (SLICE-1), Test No. FLAGT-2

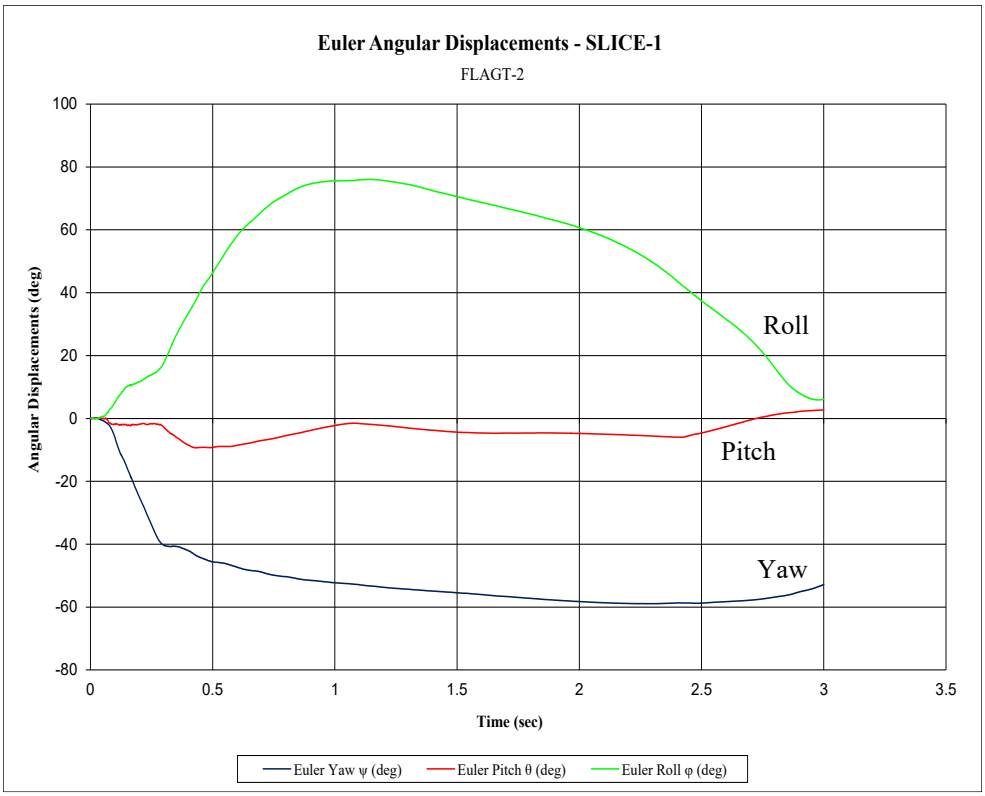


Figure F-15. Vehicle Angular Displacements (SLICE-1), Test No. FLAGT-2

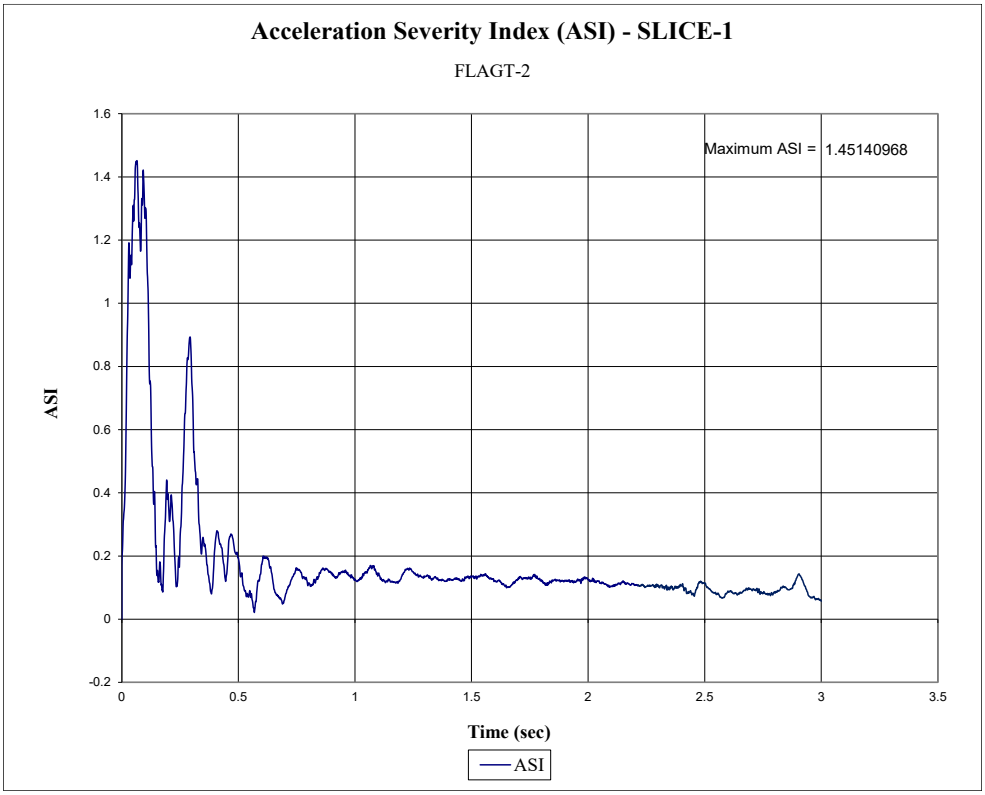


Figure F-16. Acceleration Severity Index (SLICE-1), Test No. FLAGT-2

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