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CRASH TESTING AND EVALUATION OF THE HAWAII MODIFIED DELAWARE RETROFIT THRIE-BEAM BRIDGE RAIL ON SIDEWALK: MASH TEST NOS. 3-10 AND 3-11

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16. Abstract

This report documents three full-scale crash tests conducted to evaluate the safety performance of the Hawaii Department of Transportation's Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail according to the *Manual for Assessing Safety Hardware, Second Edition* (MASH 2016) Test Level 3 (TL-3) crash test criteria. The bridge rail consisted of 10-gauge thrie-beam rail with 32-in. mounting height, supported by W6x25 steel posts, spaced at 75 in., and installed on a concrete sidewalk. Test no. HMDBR-1 was conducted using test designation no. 3-11 on a 9-in. tall sidewalk configuration. Test nos. HMDBR-2 and HMDBR-3 were conducted to test designation nos. 3-10 and 3-11, respectively, with a 6-in. tall sidewalk configuration.

In test no. HMDBR-1, a 2014 Dodge Ram pickup truck impacted the system at a speed of 63.1 mph and an angle of 25.5 degrees. In test no. HMDBR-2, a 2016 Hyundai Accent impacted the system at a speed of 62.5 mph and an angle of 24.5 degrees. In test no. HMDBR-3, a 2015 Dodge Ram pickup truck impacted the system at a speed of 63.3 mph and an angle of 25.5 degrees. In all tests, the bridge rail successfully contained and safely redirected the test vehicles. All occupant risk measurements were found to be within the established MASH 2016 limits. Therefore, test nos. HMDBR-1, HMDBR-2, and HMDBR-3 were deemed to have satisfied all safety performance criteria, and the Hawaii Modified Delaware Thrie-Beam Bridge Rail installed on a 6-in. to 9-in. tall concrete sidewalk was determined to be crashworthy according to MASH 2016 TL-3.

17. Key Words Highway Safety, Crash Test, Roadside Appurtenances, Bridge Rail, Compliance Test, MASH 2016, Test Level 3, and Modified Delaware Retrofit Thrie-Beam Bridge Rail.		**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 Hawaii Department of Transportation. 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 nor the Hawaii 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 Hawaii 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. Chen Fang.

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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.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Background

The Hawaii Department of Transportation (HDOT) utilizes the Hawaii Modified Delaware Thrie-Beam Bridge Rail to safely redirect vehicles on bridges. However, the crashworthiness of this bridge rail has not been investigated under current impact safety standards. This report documents three full-scale crash tests conducted in support of a study to evaluate the safety performance of the Hawaii Modified Delaware Thrie-Beam Bridge Rail installed on a concrete sidewalk according to the Test Level 3 (TL-3) criteria of the *Manual for Assessing Safety Hardware, Second Edition* (MASH 2016) [1].

The original HDOT standard plans of the Hawaii Modified Delaware Thrie-Beam Bridge Rail are shown in Figures 1 and 2. The bridge rail consisted of 10-gauge thrie-beam rail with a mounting height of 32 in. above finish grade, supported by W6x25 steel posts, spaced 6 ft – 3 in. apart, and installed on a concrete sidewalk. The W6x25 steel posts were welded to steel base plates countersunk into the top of the sidewalk, and the base plate's perimeter was backfilled with an epoxy grout. The base plates were secured to the top of the sidewalk using two 1¼-in. diameter by 14-in. long anchor rods at the traffic side of the plate and two ⅝-in. diameter by 8-in. long anchor rods at the non-traffic side of the plate.

The traffic face of the thrie-beam rail was set flush with the front face of the sidewalk, and the bridge rail was designed for use with 6-in. to 9-in. tall concrete sidewalks. The HDOT standard plans also include details to transition the thrie-beam bridge rail to the Midwest Guardrail System (MGS) using an Approach Guardrail Transition (AGT). Full-scale crash testing and evaluation of this HDOT AGT is part of a parallel MwRSF research effort that will be documented in a separate report [2].

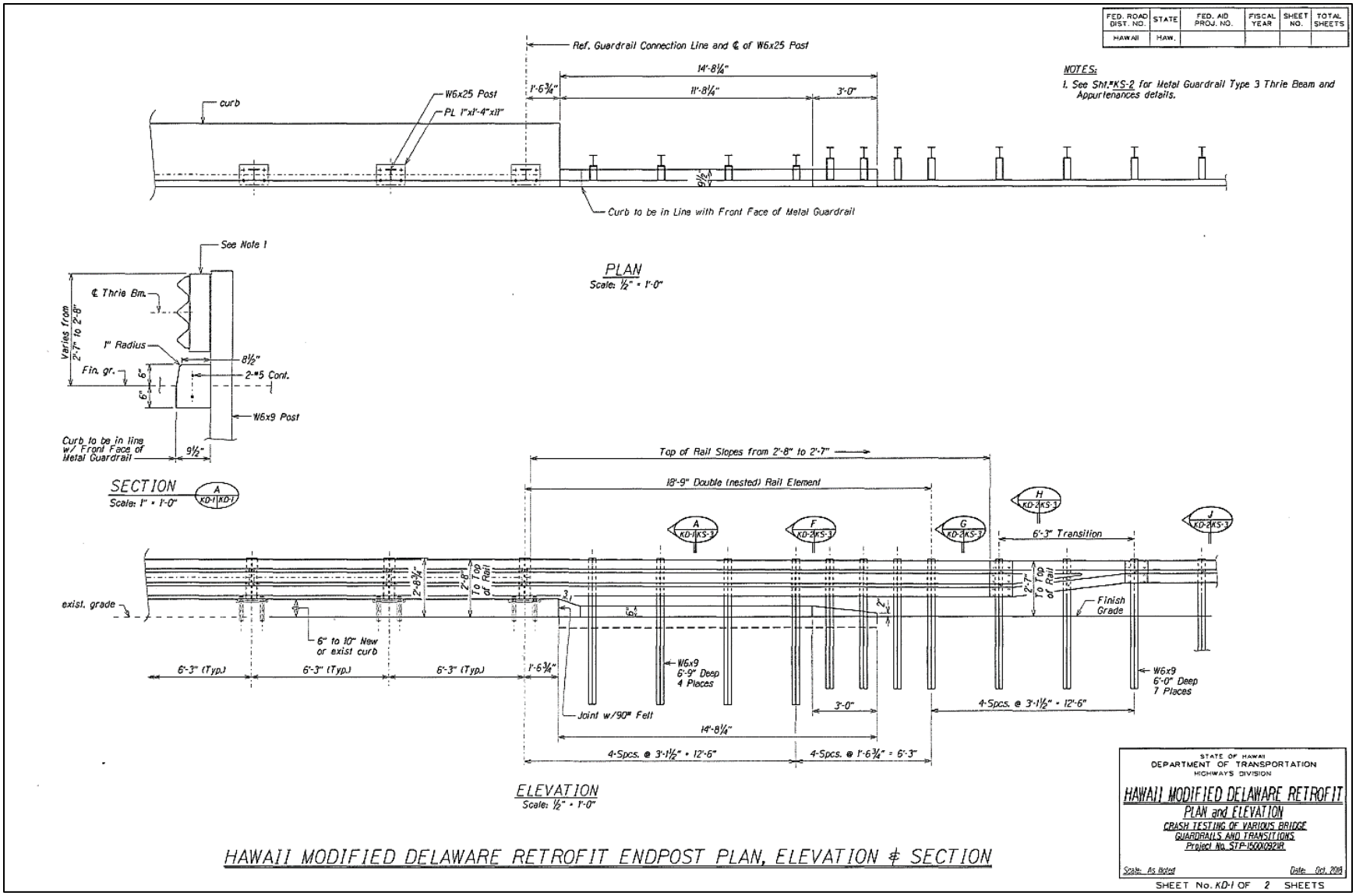


Figure 1. Hawaii Modified Delaware Retrofit Bridge Rail, Plan and Elevation

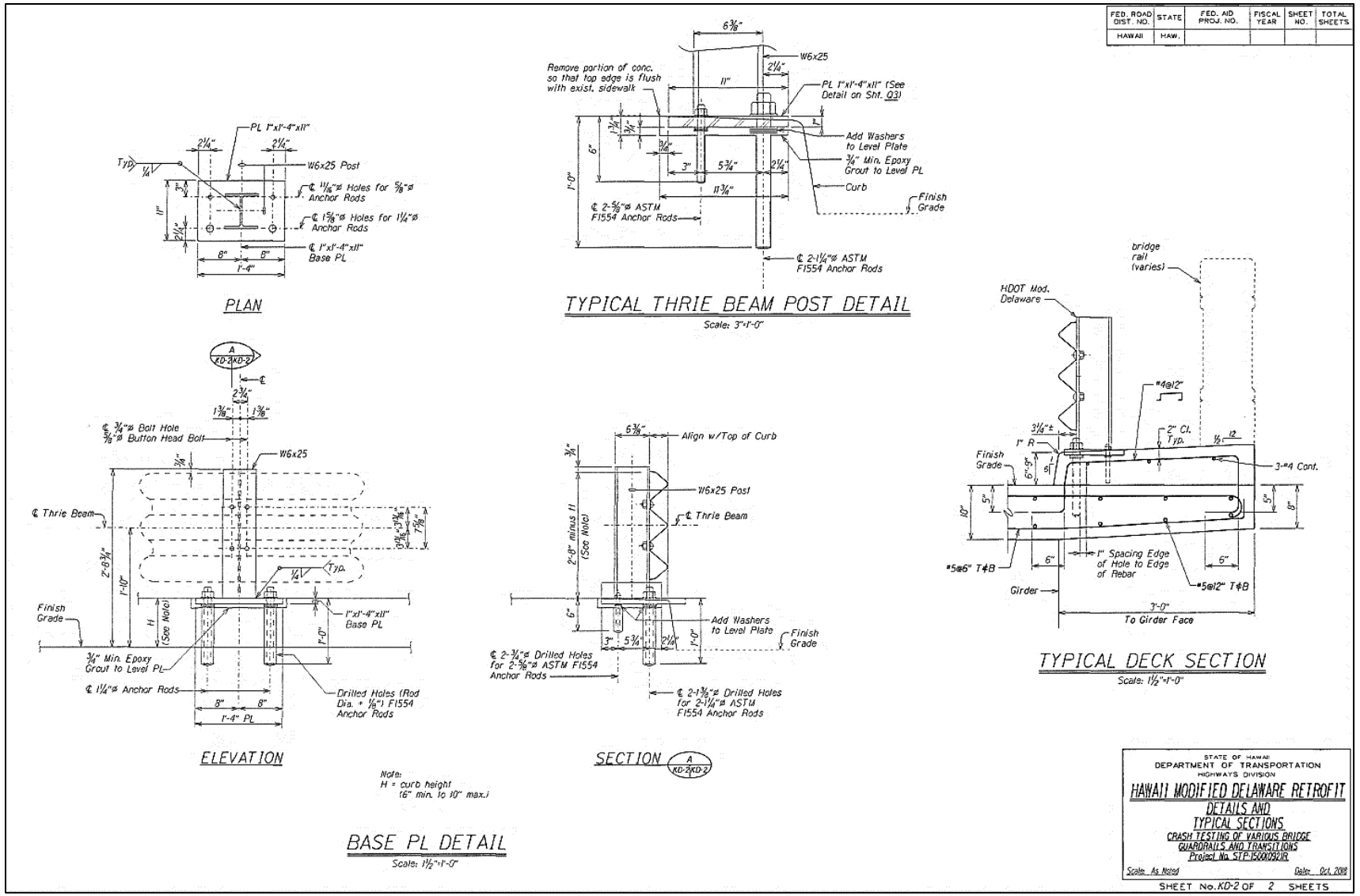


Figure 2. Hawaii Modified Delaware Retrofit Bridge Rail, Details and Typical Sections

1.2 Objective

The objective of this research included a safety performance evaluation of the Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail, installed on 9-in. and 6-in. tall concrete sidewalks. The system was to be evaluated according to the TL-3 criteria of MASH 2016 [1].

1.3 Scope

The research objective was achieved through the completion of several tasks. The first task included a review of HDOT's existing standard plans for the Hawaii Modified Delaware Retrofit Bridge Rail and its transition to the MGS, the identification of potential safety issues, and the recommendation of system modifications to improve the crashworthiness of the bridge rail and AGT. Three full-scale crash tests were conducted on the Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail according to MASH 2016 test designation nos. 3-10 and 3-11: one full-scale crash test was conducted on the 9-in. tall sidewalk configuration under test designation no. 3-11, and two full-scale crash tests were conducted on the 6-in. tall sidewalk configuration under test designation nos. 3-10 and 3-11. The 9-in. tall sidewalk configuration was tested with the HDOT AGT anchoring the upstream end of the system and a simulated tensile anchor on the downstream end, while the 6-in. tall sidewalk configuration was tested using simulated tensile anchors on both the upstream and downstream ends of the system. Following full-scale vehicle crash testing, the test results were analyzed, evaluated, and documented. Conclusions and recommendations were then made pertaining to the safety performance of the Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail.

2 TEST REQUIREMENTS AND EVALUATION CRITERIA

2.1 Test Requirements

Longitudinal barriers, such as bridge rails, must satisfy impact safety standards to be declared eligible for federal reimbursement by the Federal Highway Administration (FHWA) for use on the National Highway System. For new hardware, these safety standards consist of the guidelines and procedures published in MASH 2016 [1]. Note that there is no difference between MASH 2009 [3] and MASH 2016 for longitudinal barriers, except that additional occupant compartment deformation measurements, photographs, and documentation are required by MASH 2016. According to TL-3 of MASH 2016, longitudinal barrier systems must be subjected to two full-scale vehicle crash tests, as summarized in Table 1.

Table 1. MASH 2016 TL-3 Crash Test Conditions for Longitudinal Barriers

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

[1] Evaluation criteria are explained in Table 2.

Note that the test matrix detailed herein represents a practical worst-case condition with respect to the MASH 2016 safety requirements and a crashworthiness evaluation of the barrier system. Test designation no. 3-11, which utilizes a pickup truck (2270P vehicle), evaluates vehicle instability and pocketing during and after the impact with the bridge rail and sidewalk, and was deemed more critical for the bridge rail installed on a 9-in. tall concrete sidewalk. Therefore, a small car (1100C vehicle) crash test according to test designation no. 3-10 was not performed on the bridge rail installed on a 9-in. tall concrete sidewalk.

Both prescribed full-scale crash tests, test designation nos. 3-10 and 3-11, were deemed critical to evaluate the system performance of the bridge rail installed on a 6-in. tall concrete sidewalk. Test designation no. 3-10, which utilizes a small car, evaluates front end and wheel wedging below the thrie-beam rail as well as snag on the bridge rail posts in conjunction with the 6-in. tall sidewalk. If 1100C crash testing, which utilizes a small car, is successful for the bridge rail installed on a 6-in. tall sidewalk, then it would be believed to also perform satisfactorily when installed on a 9-in. tall sidewalk. Test designation no. 3-11, which utilizes a pickup truck, evaluates the system's safety performance and structural adequacy of the post anchorage when using the shorter sidewalk.

According to MASH 2016, the Hawaii Modified Delaware Thrie-Beam Retrofit Bridge Rail should be crash tested at a location that evaluates the greatest propensity for vehicle snag, and at a location that maximizes structural loading of the bridge rail at a critical section. For non-rigid longitudinal barriers, the critical impact points (CIPs) are primarily controlled by the post dynamic yield force, *Fp*, and the barrier rail plastic moment, *Mp*. For this bridge rail, the critical impact

points were selected using the calculated *Fp* and *Mp* values in conjunction with the CIP plots found in Section 2.3.2.1 of MASH 2016. The rail splice located at the centerline of the posts was selected as the reference point for the critical impact distance, *x*, in the MASH CIP plots. This CIP determination is provided in Appendix A.

Table 2. MASH 2016 Evaluation Criteria for Longitudinal Barriers

<table>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="4">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="4">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.</td></tr>
<tr><td>F.</td><td colspan="4">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="4">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s</td><td>40 ft/s</td></tr>
<tr><td rowspan="3">I.</td><td colspan="4">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
</table>

Note that the test matrix detailed herein represents the researchers’ best engineering judgement of which tests are necessary to assess system crashworthiness according to MASH 2016 safety requirements. However, future evaluation may be required due to revisions to the MASH criteria or additional knowledge gained over time.

2.2 Evaluation Criteria

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

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

3 DESIGN DETAILS, TEST NO. HMDBR-1

The 177-ft 6-in. long test installation featured a 100-ft long section of the Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail connected to the HDOT AGT at the upstream end and a thrie-beam anchorage system at the downstream end, as shown in Figures 3 through 38. Photographs of the test installation are shown in Figures 39 through 41. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B. Note that the drawing set includes details for the entire system, inclusive of the bridge rail, AGT, and W-beam rail installation. However, test conditions were such that the AGT would not influence the bridge rail performance, and therefore only the bridge rail details are described below and in Appendix B.

The Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail consisted of a 10-gauge thrie-beam rail with a mounting height of 32 in. above finish grade, supported by W6x25 steel posts, spaced at 75 in., and anchored to a 9-in. tall concrete sidewalk. The W6x25 steel posts were welded to 16-in. long x 11-in. wide x 1-in. thick ASTM A36 steel base plates. The base plates were countersunk into the top of the sidewalk, and the approximately ¾-in. wide gap remaining under the base plate and around the edges was backfilled with an epoxy grout following the specifications of ASTM C881, Type IV, Grade I, Class C epoxy filler recommended by HDOT. The base plates were secured to the sidewalk using two 1¼-in. diameter, 14-in. long anchor rods at the traffic side (front side) of the base plate and two ⅝-in. diameter, 8-in. long anchor rods at the non-traffic side (back side) of the base plate with heavy hex nuts and hardened washers. All anchor rods were epoxied into drilled out holes in the concrete sidewalk to develop their full tensile strength. The front rods were epoxied through the full depth of the concrete sidewalk and 2½ in. into the concrete tarmac, and the back anchor rods were epoxied 6 in. into the concrete sidewalk. All anchor rods were installed using Hilti RE-500, Class C881. ASTM F436, hardened washers were used to level the baseplates at the traffic side and non-traffic side of the base plates.

The thrie-beam rail splices located at the post installation utilized ⅝-in. diameter by 1¼-in. long guardrail bolts with heavy hex nuts and plain washers. The thrie-beam rail sections were attached to the posts using two ⅝-in. diameter by 2-in. long guardrail bolts with heavy hex nut and plain washers. Note that the ⅝-in. diameter washers (item no. g1) intended for use with the guardrail bolts connecting the thrie-beam rail to the posts were not installed, but this omission had no impact on rail performance in the crash test.

The traffic face of the sidewalk was aligned with the face of the thrie-beam rail and was sloped at 6V:1H to the ground. The top surface of the sidewalk was sloped at 1V:24H toward the traffic-side face. The concrete mix for the sidewalk required a minimum 28-day compressive strength of 4,000 psi, and the sidewalk was reinforced with a combination of transverse and longitudinal ASTM A615 Grade 60 rebar. The sidewalk reinforcement consisted of three no. 4 longitudinal bars that were vertically spaced 12 in. apart with an 18-in. minimum lap length. The sidewalk transverse reinforcement was vertical no. 4 stirrups formed from two L-shaped bars with a minimum lap length of 12 in. The bars were shaped to match the sidewalk profile and spaced at 12-in. on center along the full sidewalk length. The transverse reinforcing bars were epoxied into the concrete tarmac on both the traffic-side and non-traffic-side to a depth of 6 in. using Hilti HIT RE-500 epoxy to develop the full tensile strength of the rebars.

The downstream end of the system incorporated a thrie-beam end anchor assembly that developed the necessary tensile strength and consisted of a vertical HSS 6x12x¼ steel tube, a HSS6x4x⅝ steel tube angled at 55 degrees to the ground, and a 10-gauge thrie-beam terminal connector, as shown in Figure 29. This thrie-beam downstream end anchorage was successfully crash tested and reported in another project [4]. The upstream end of the bridge rail was connected to the HDOT thrie-beam AGT system. The design details of the AGT and its modifications from HDOT's original plans will be discussed in a subsequent report [2].

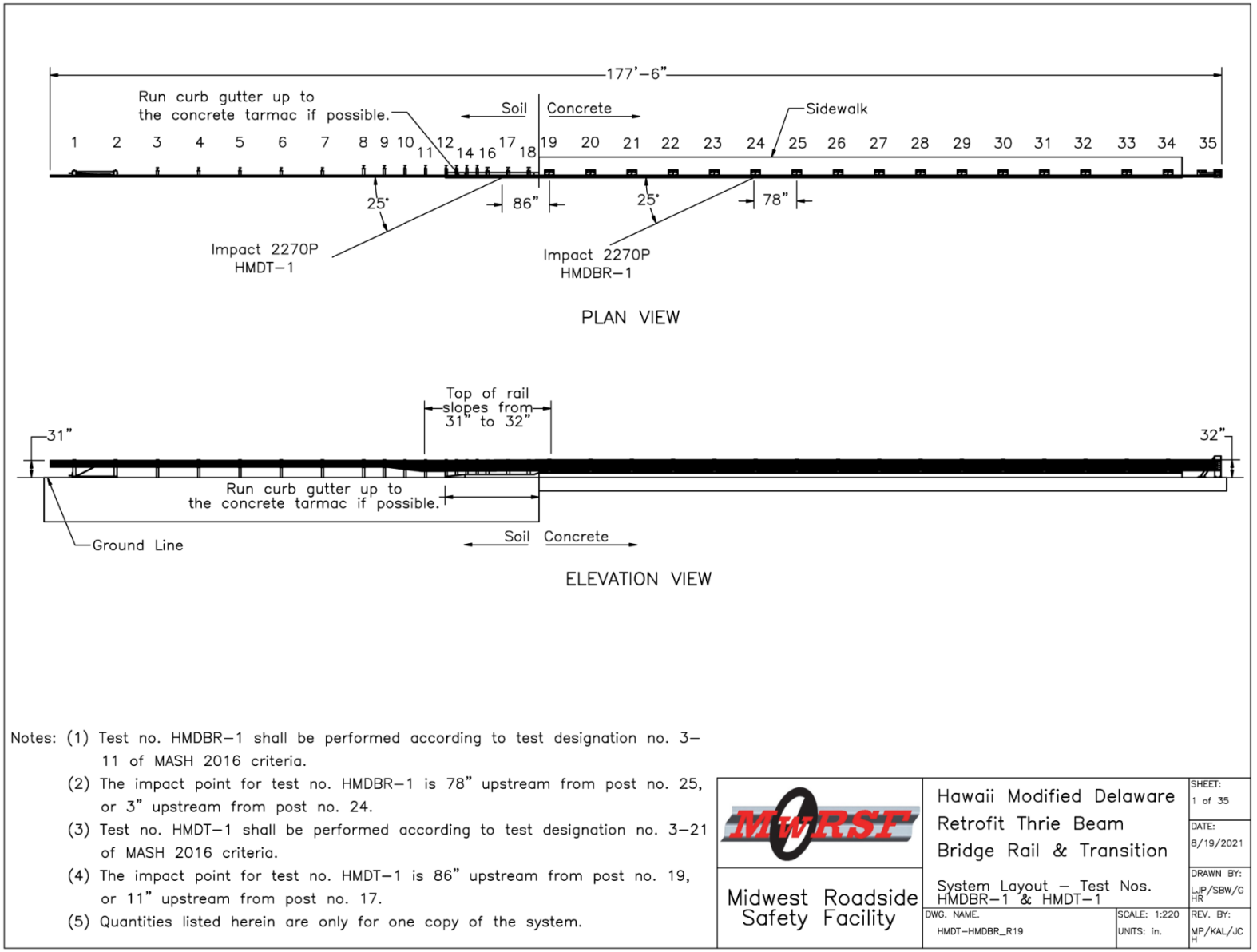


Figure 3. Test Installation Layout, Test No. HMDBR-1

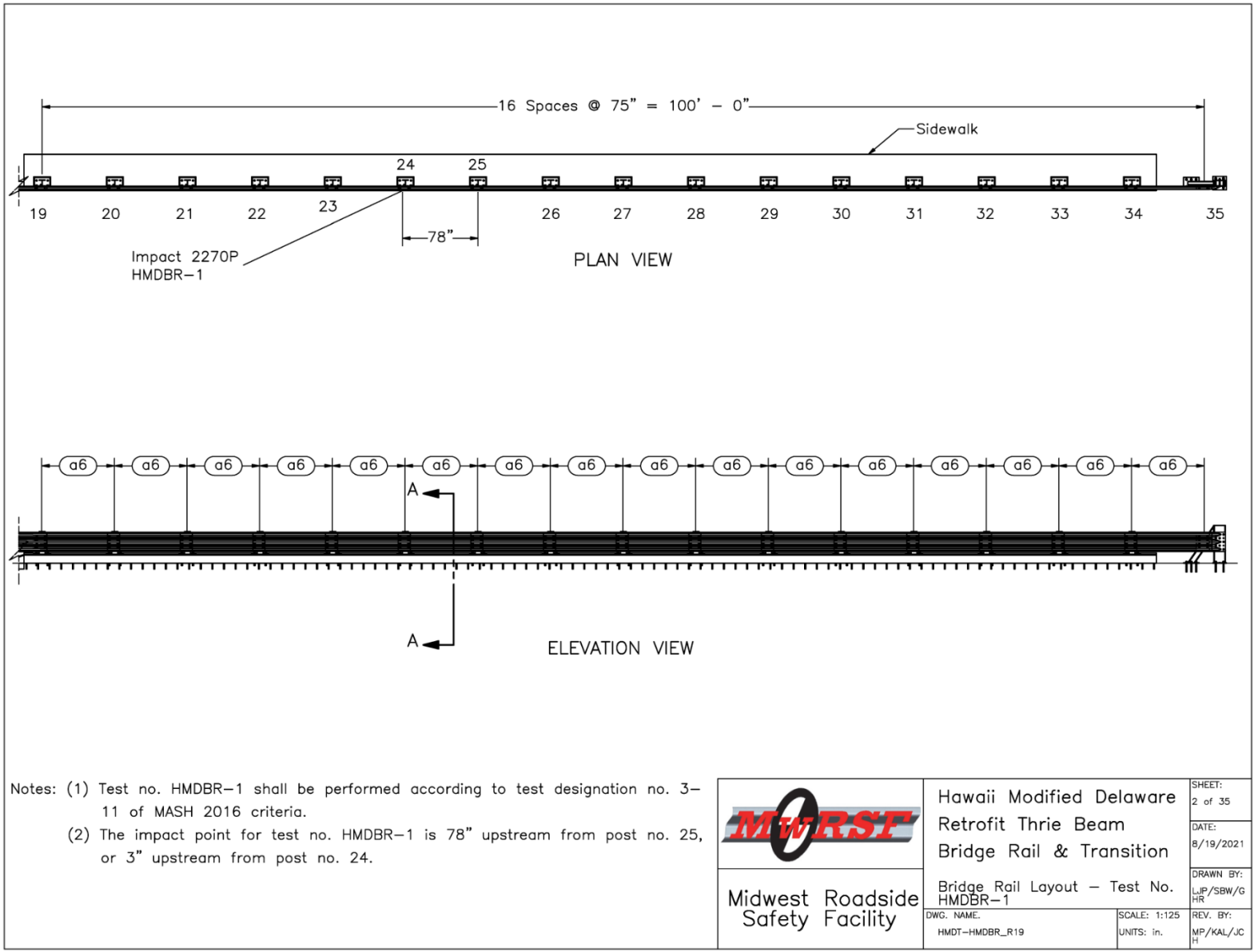


Figure 4. Bridge Rail Layout, Test No. HMDBR-1

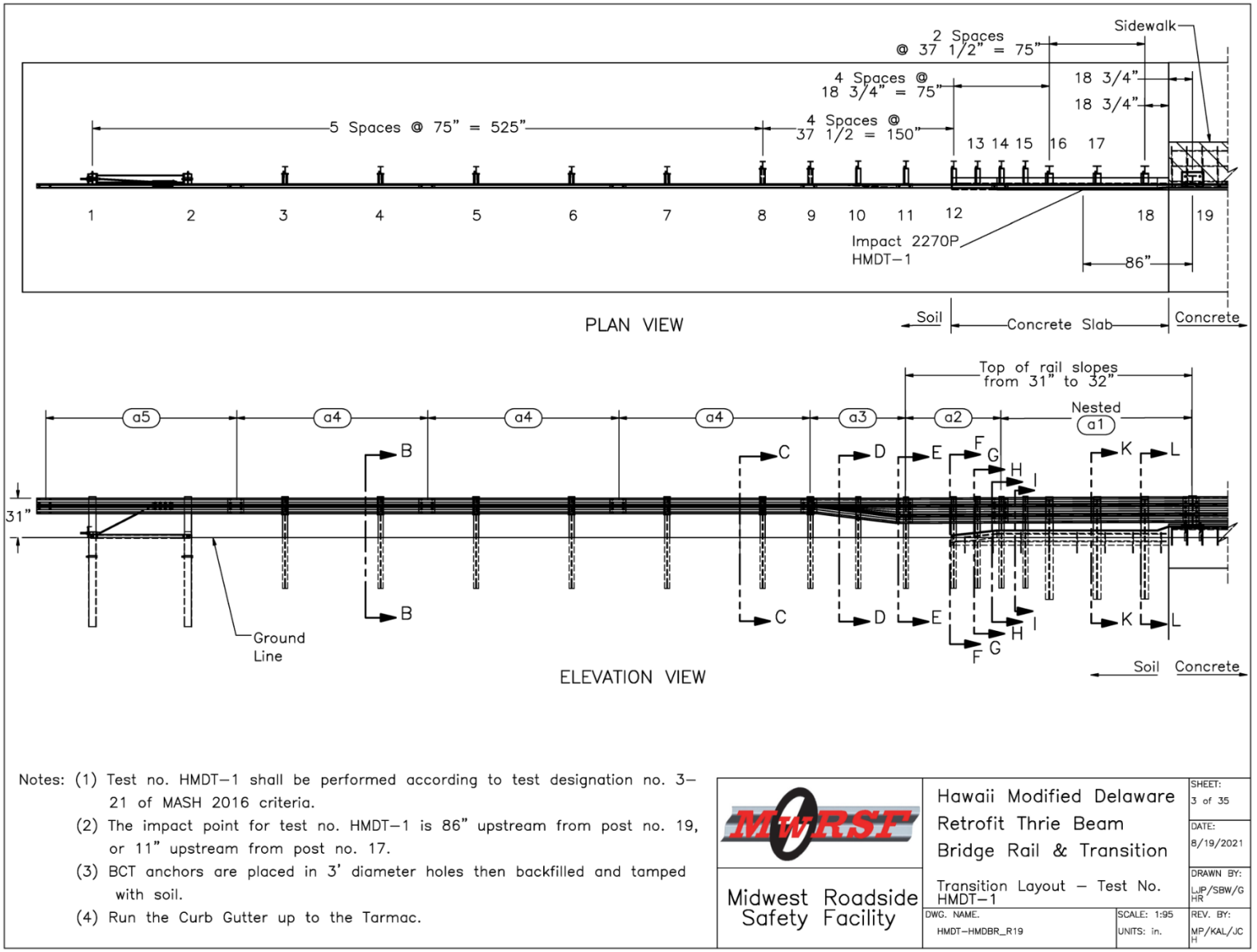


Figure 5. Rail Heights, Transition Layout, Test No. HMDBR-1

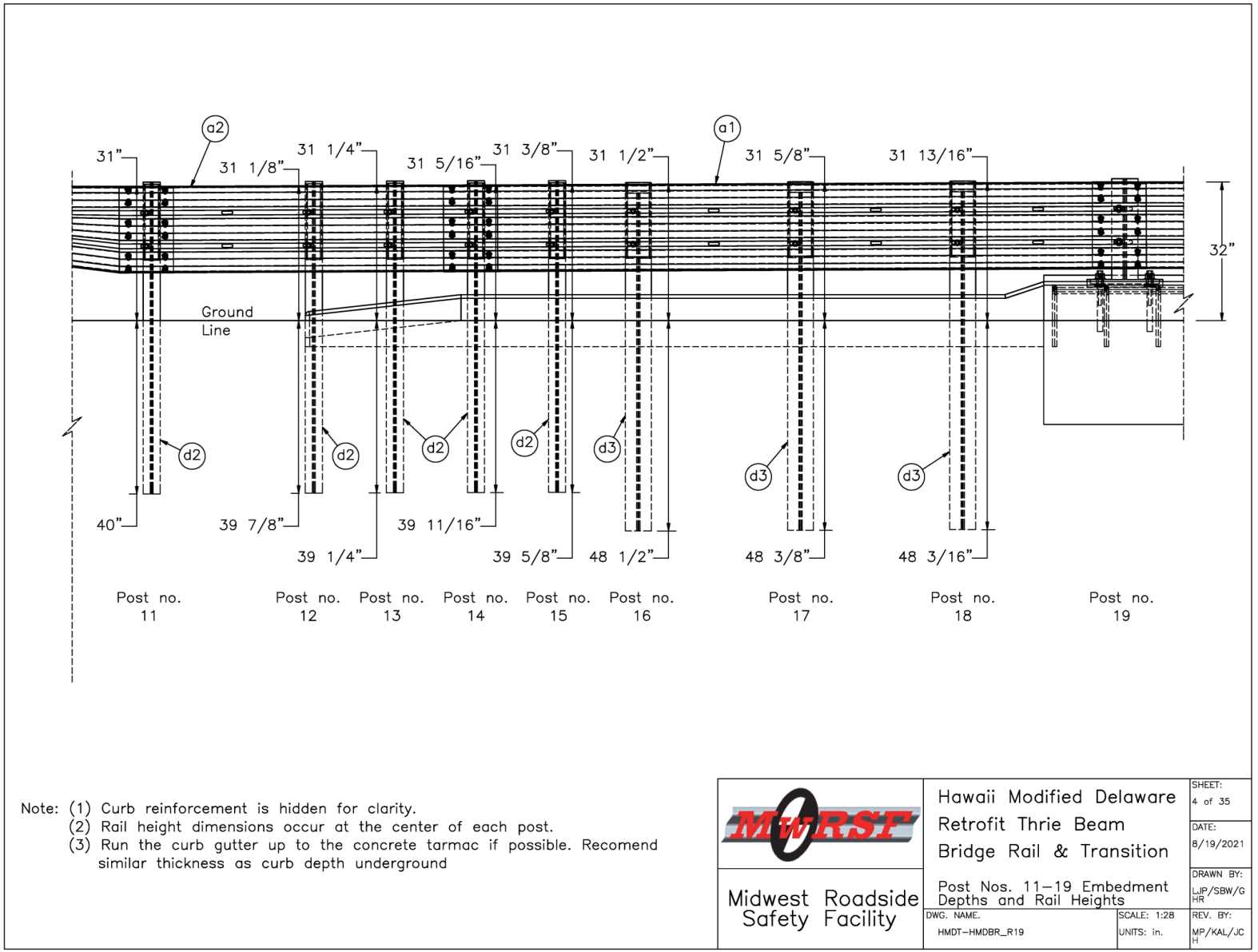


Figure 6. Rail Heights, Post Nos. 11 through 19, Test No. HMDBR-1

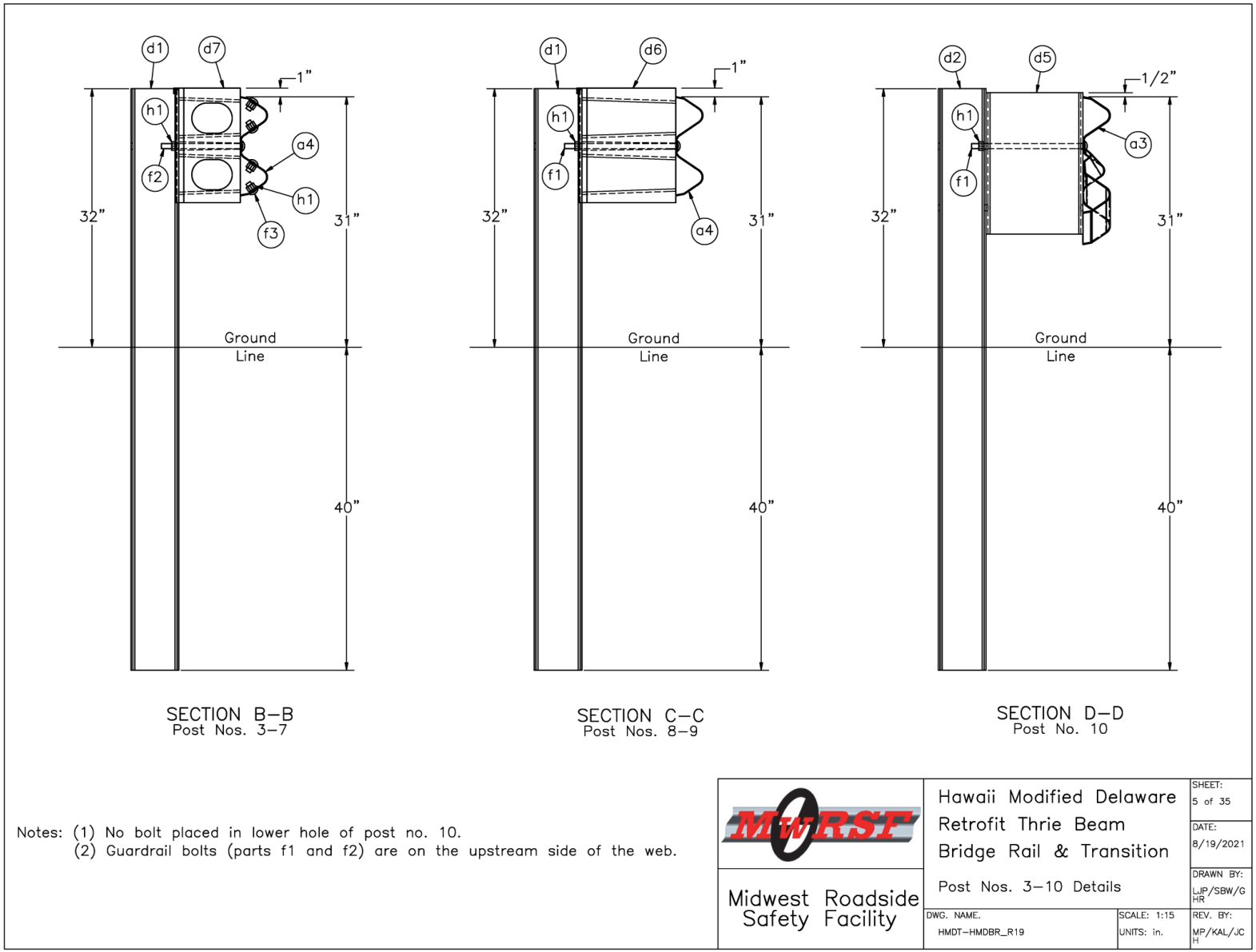


Figure 7. Post Details, Post Nos. 3 through 10, Test No. HMDBR-1

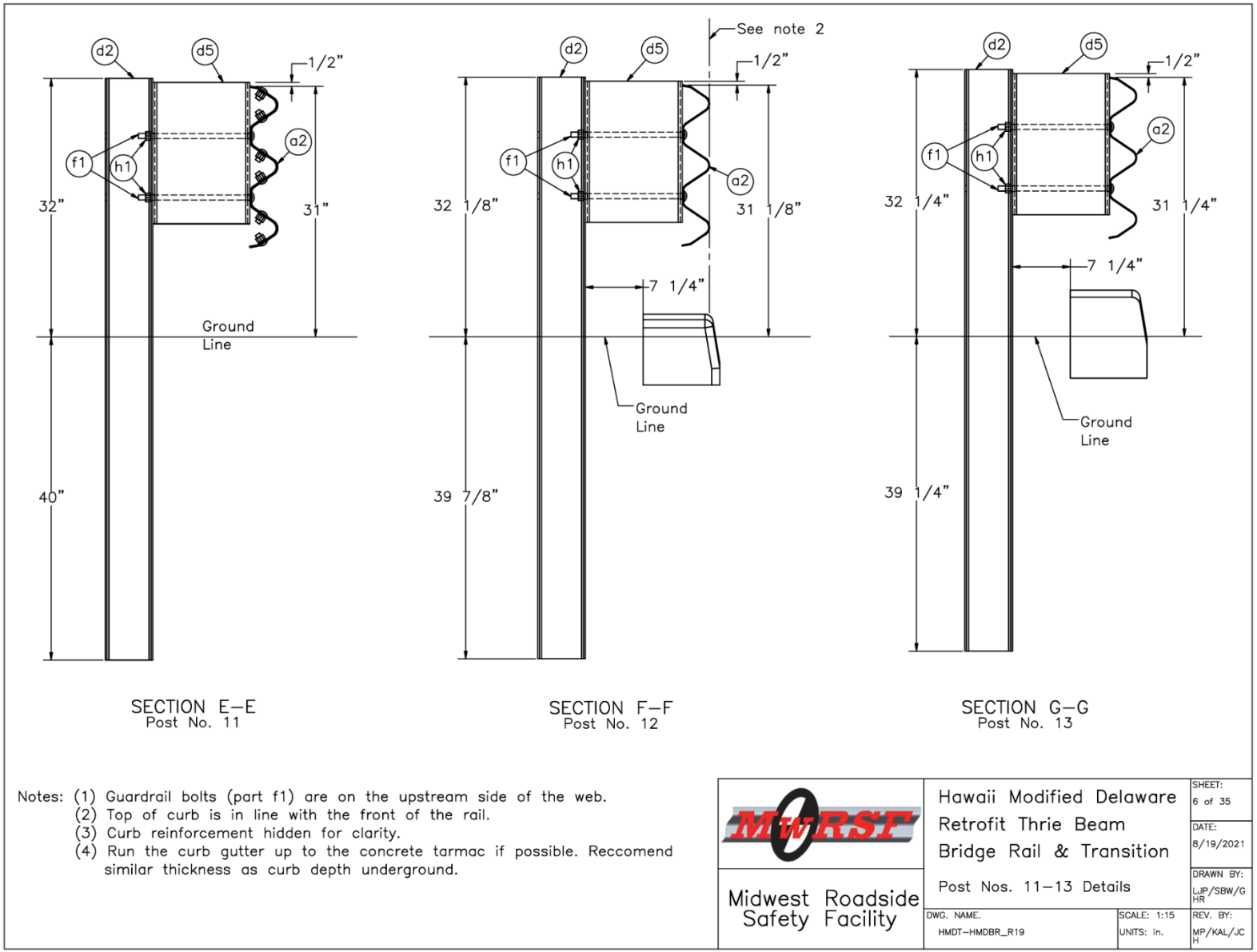


Figure 8. Post Details, Post Nos. 11 through 13, Test No. HMDBR-1

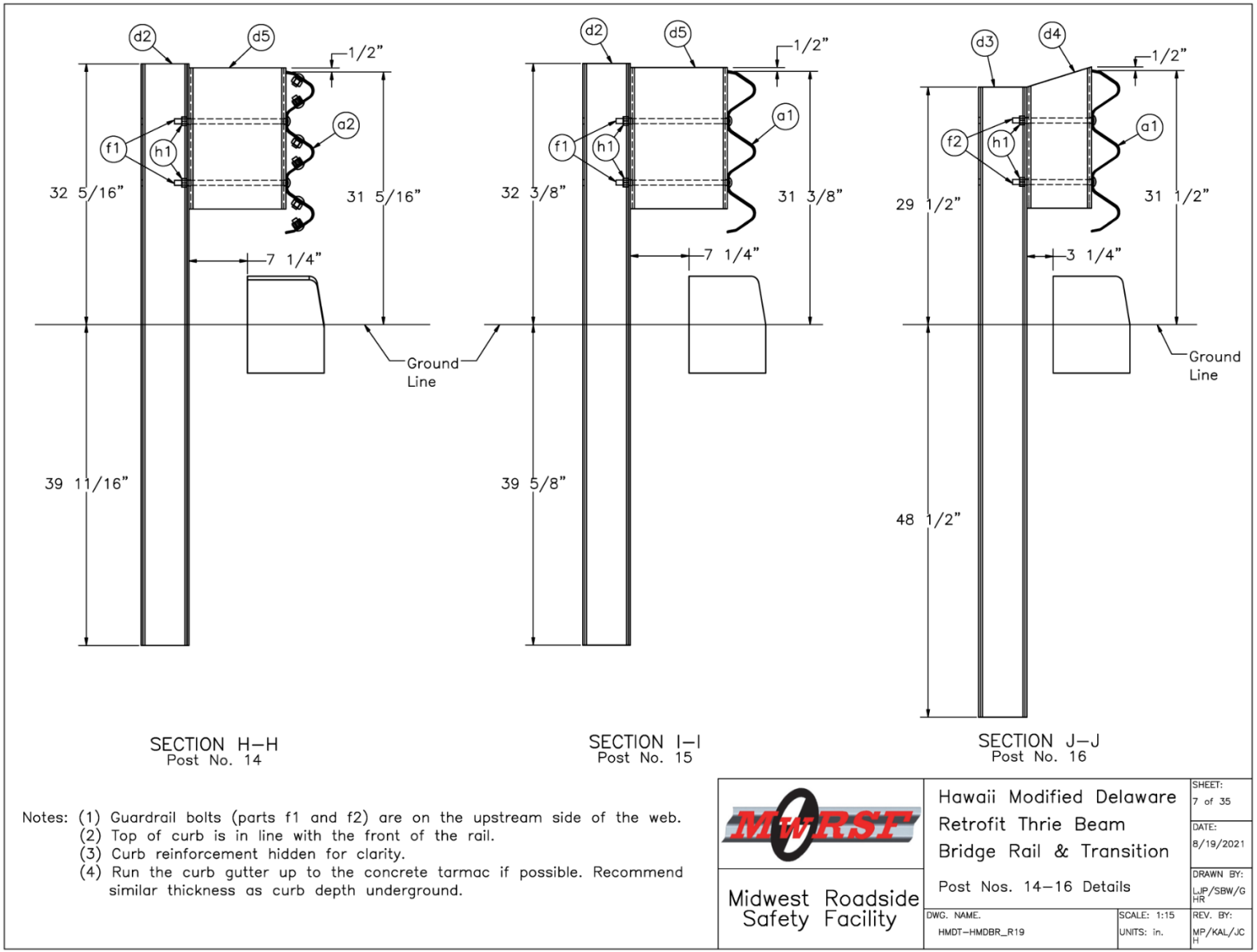


Figure 9. Post Details, Post Nos. 14 through 16, Test No. HMDBR-1

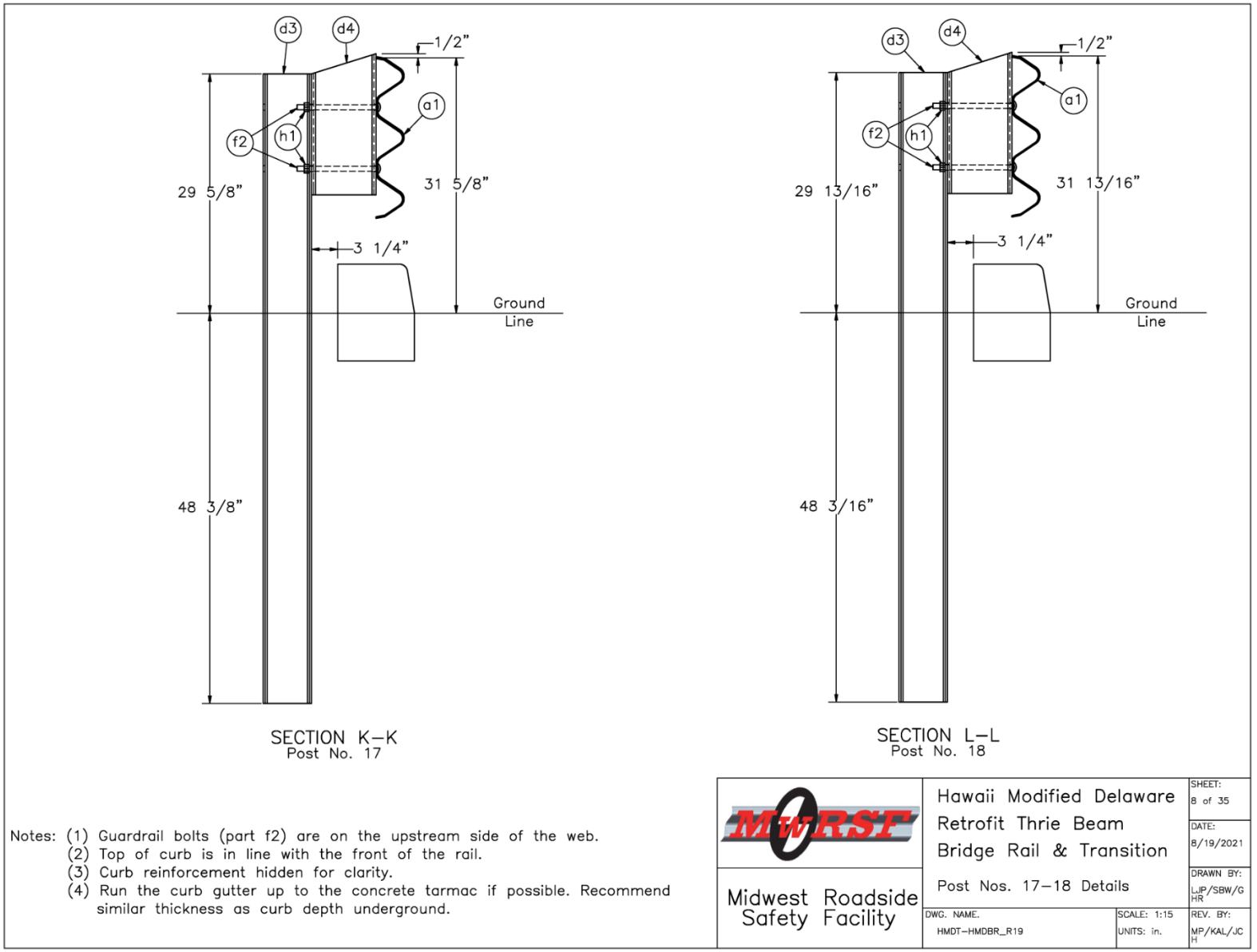


Figure 10. Post Details, Post Nos. 17 through 18, Test No. HMDBR-1

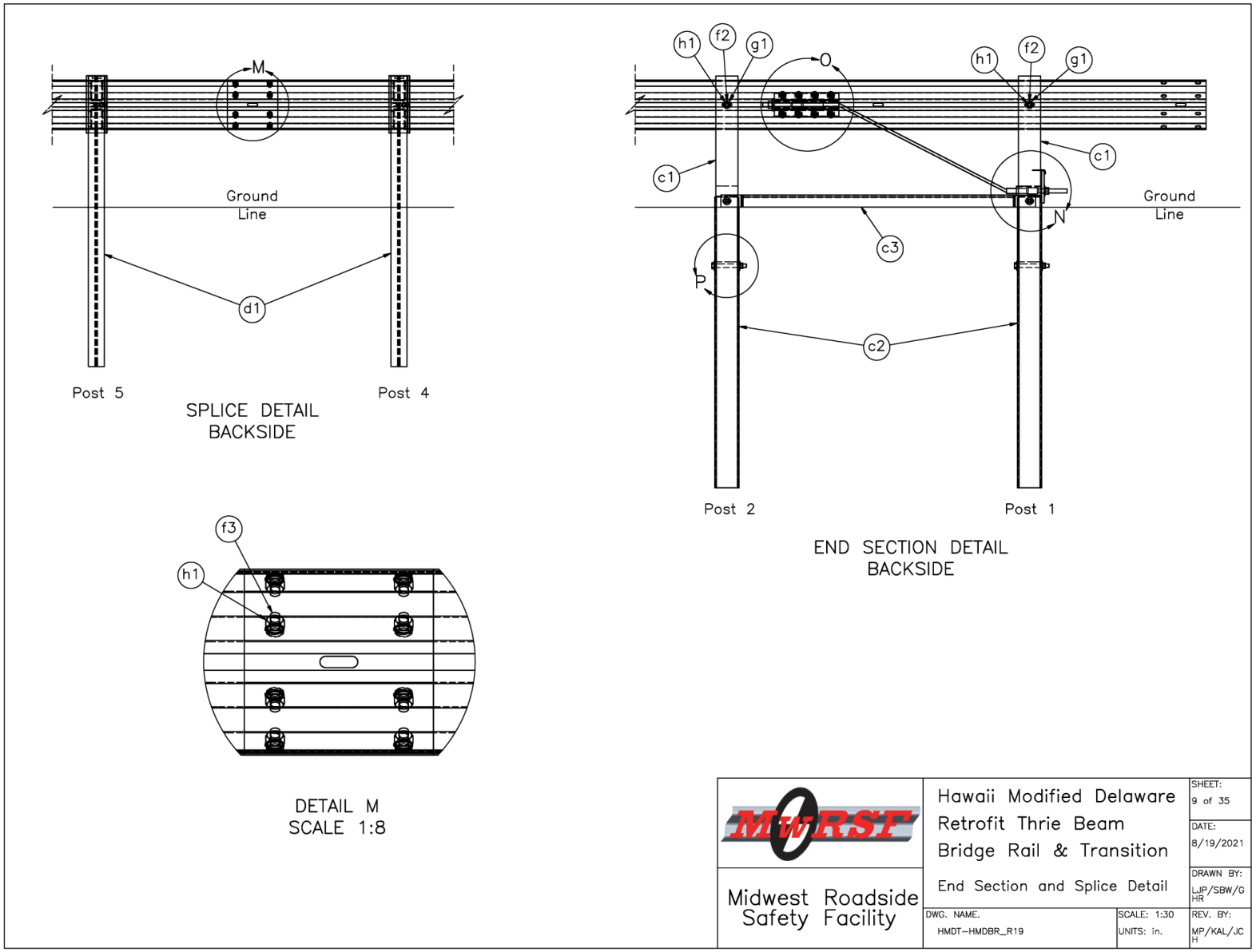


Figure 11. End Section and Splice Details, Test No. HMDBR-1

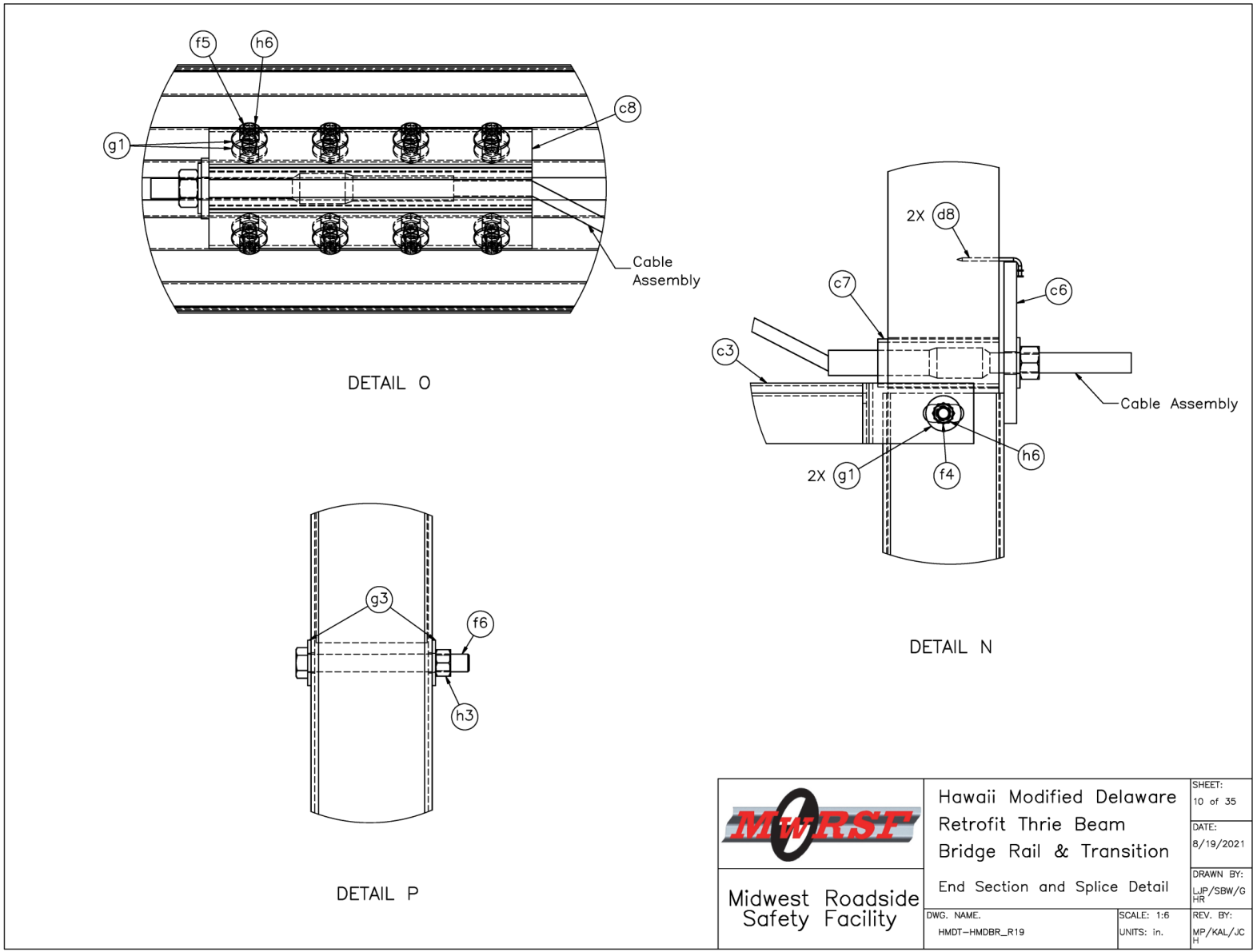


Figure 12. End Section and Splice Details, Cont., Test No. HMDBR-1

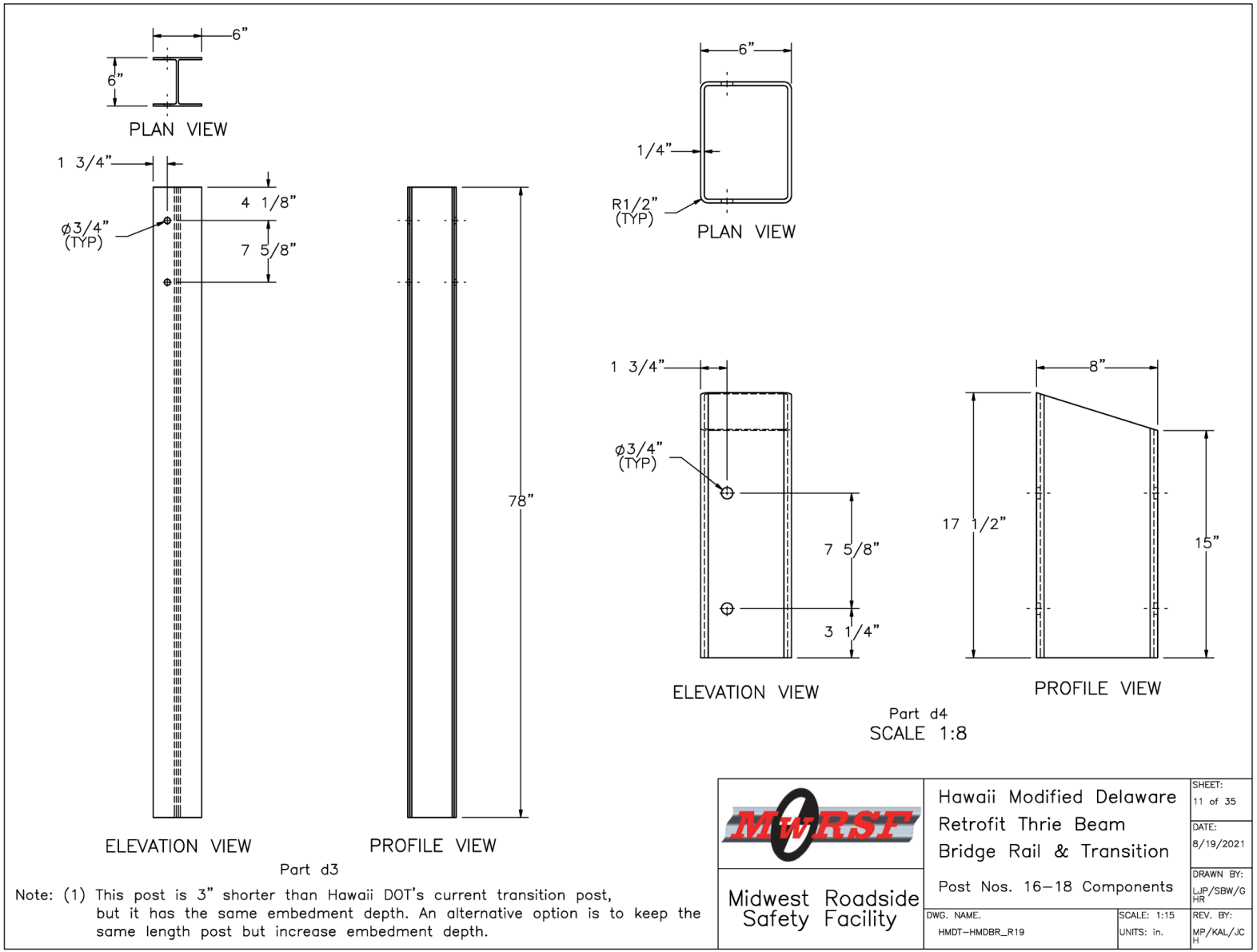


Figure 13. Post Nos. 16 through 18 Components, Test No. HMDBR-1

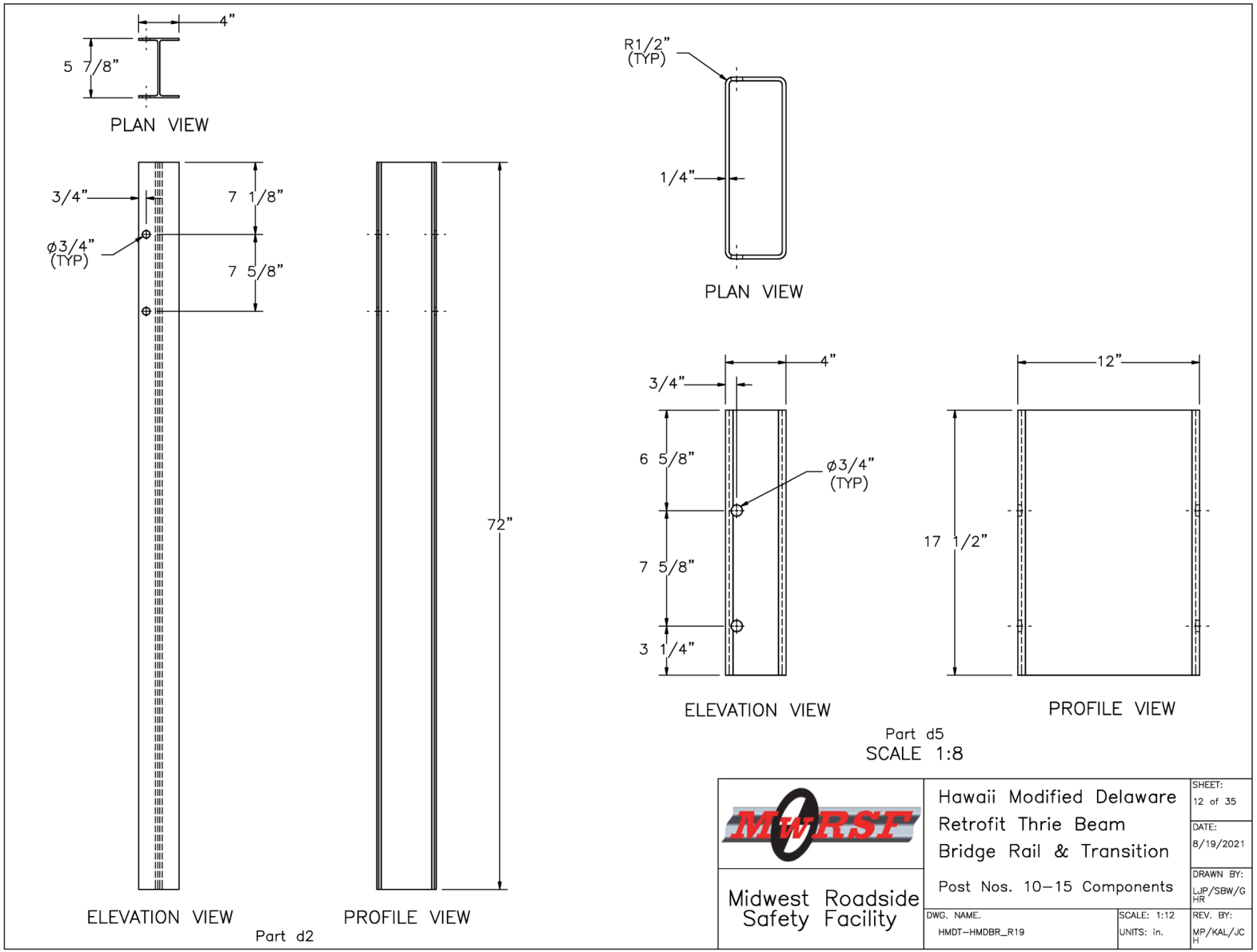


Figure 14. Post Nos. 10 through 15 Components, Test No. HMDBR-1

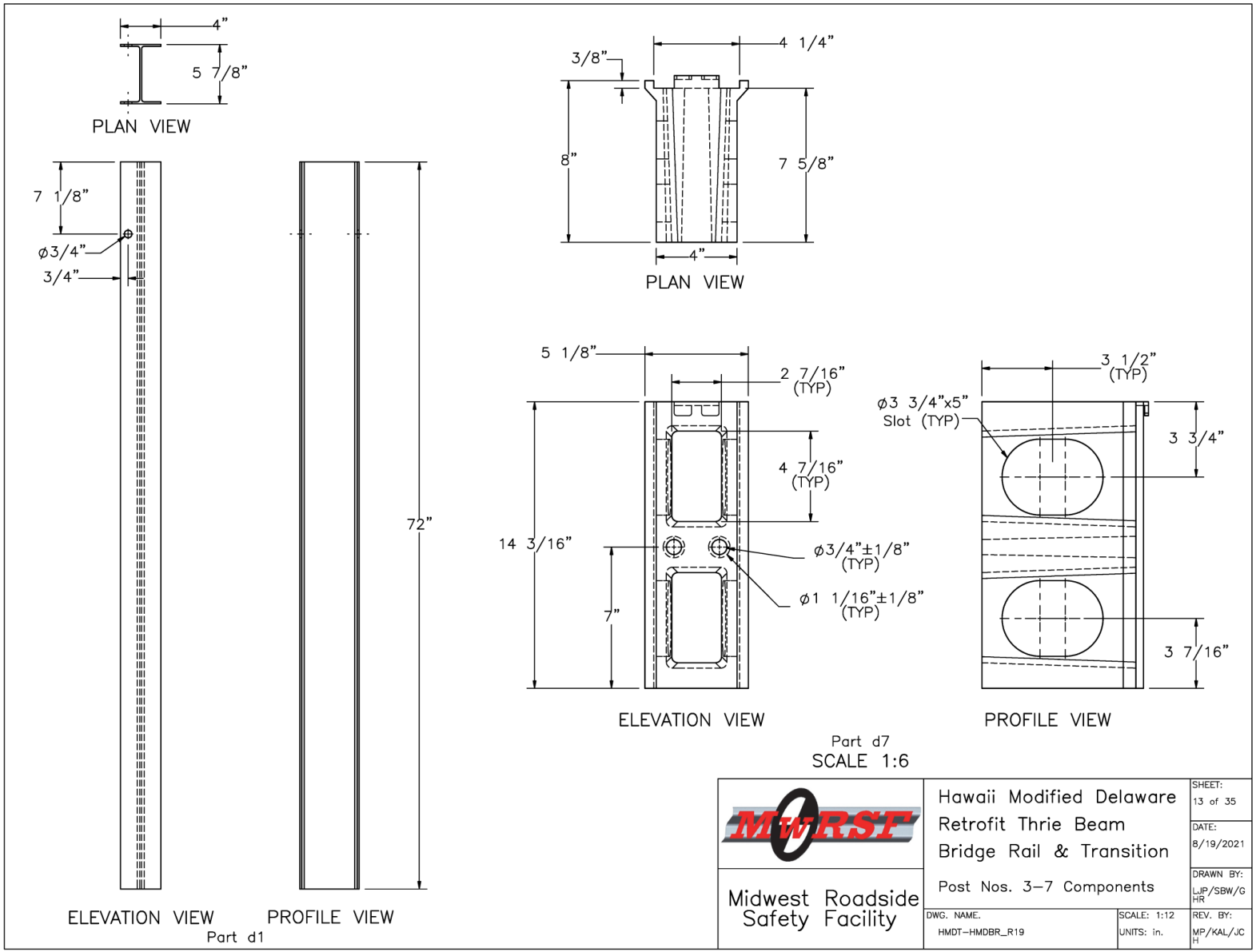


Figure 15. Post Nos. 3 through 7 Components, Test No. HMDBR-1

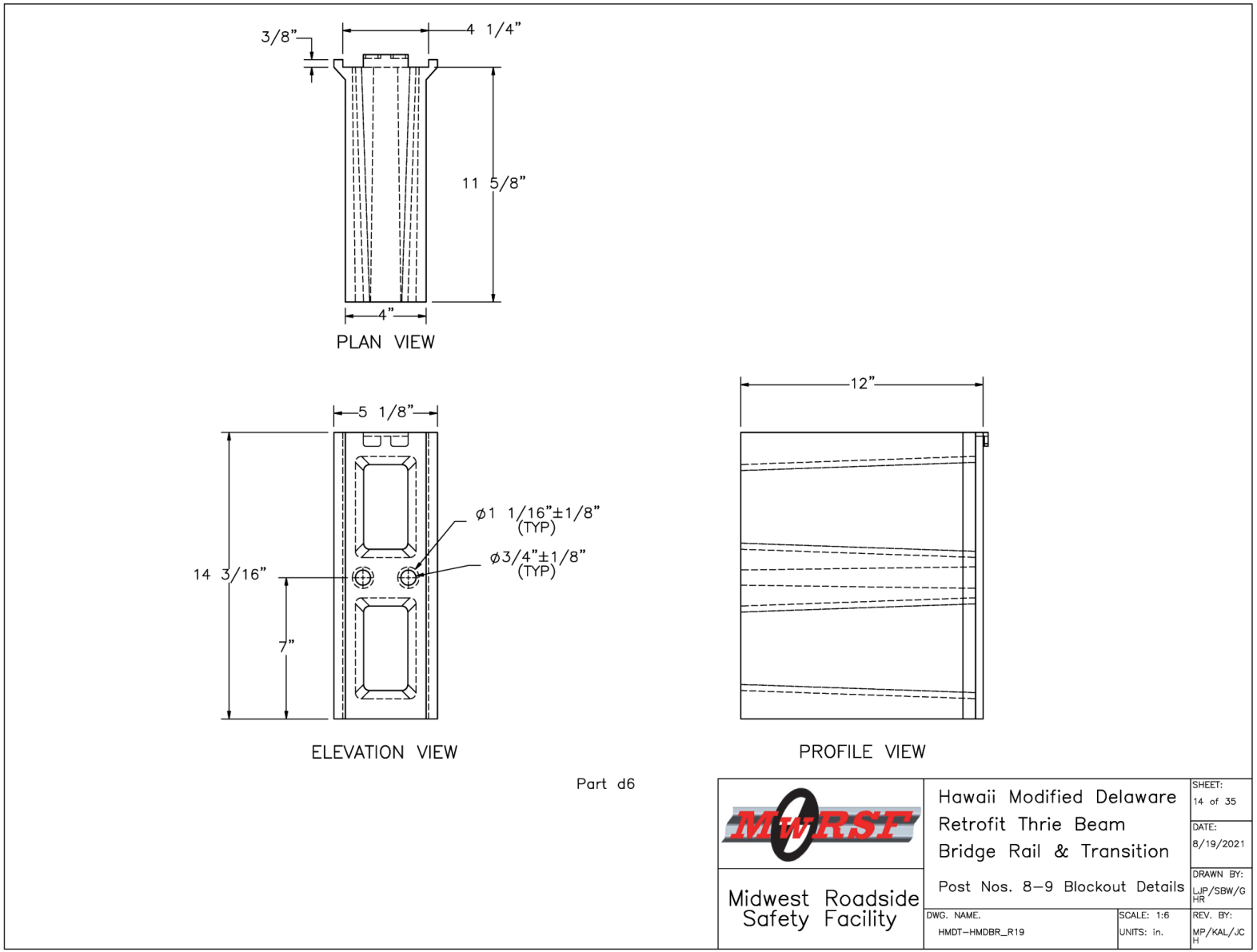


Figure 16. Post Nos. 8 and 9 Blockout Details, Test No. HMDBR-1

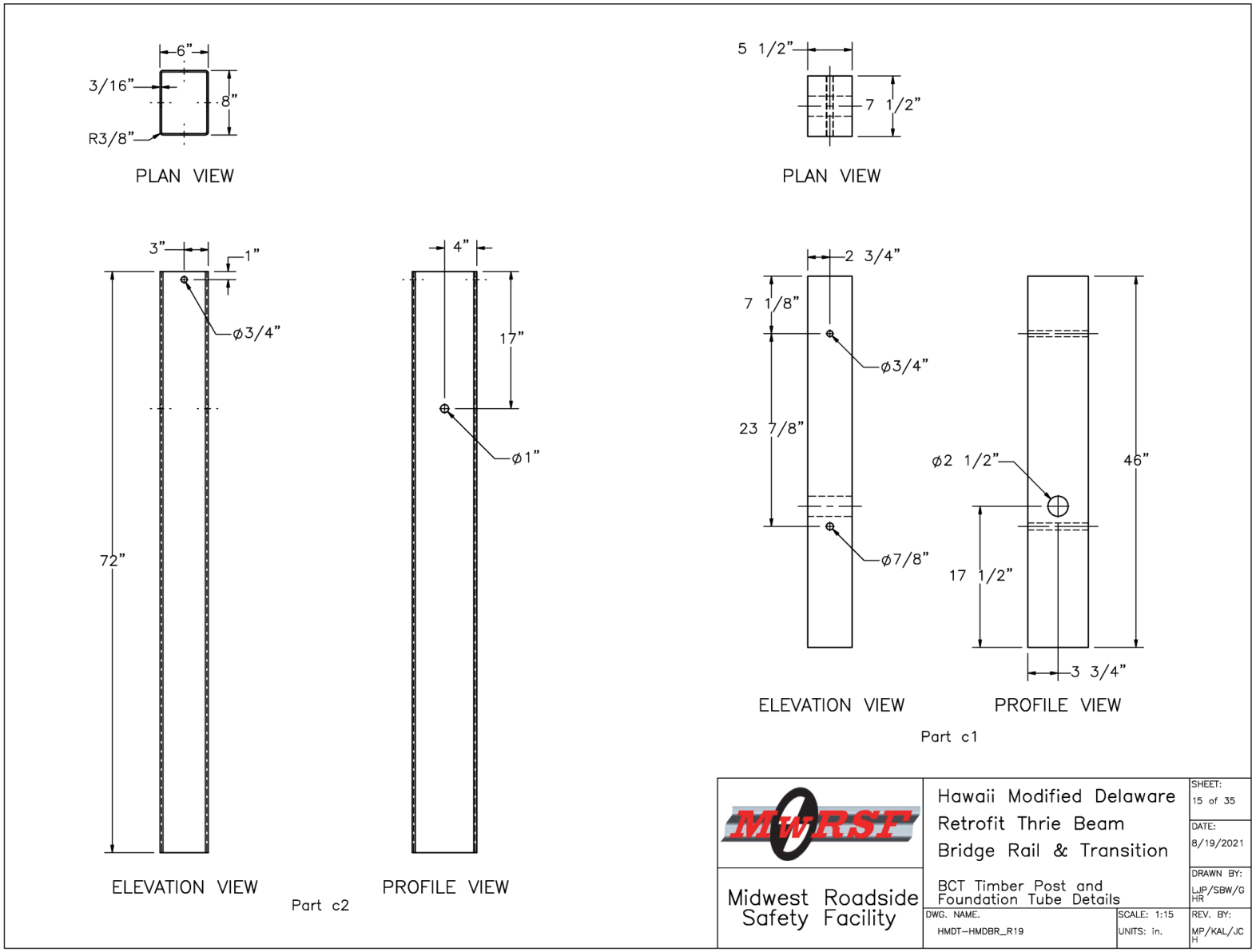


Figure 17. BCT Timber Post and Foundation Tube Details, Test No. HMDBR-1

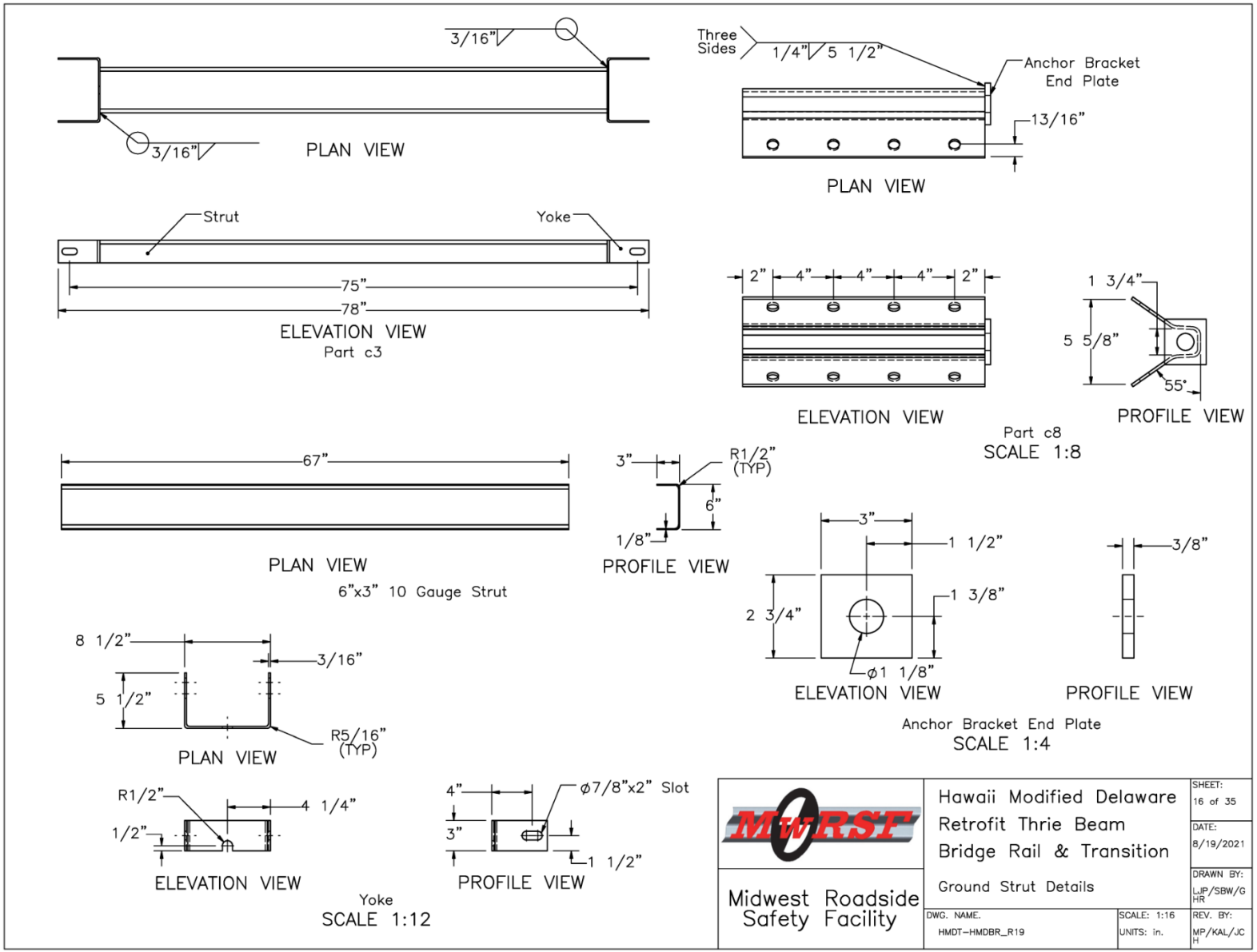
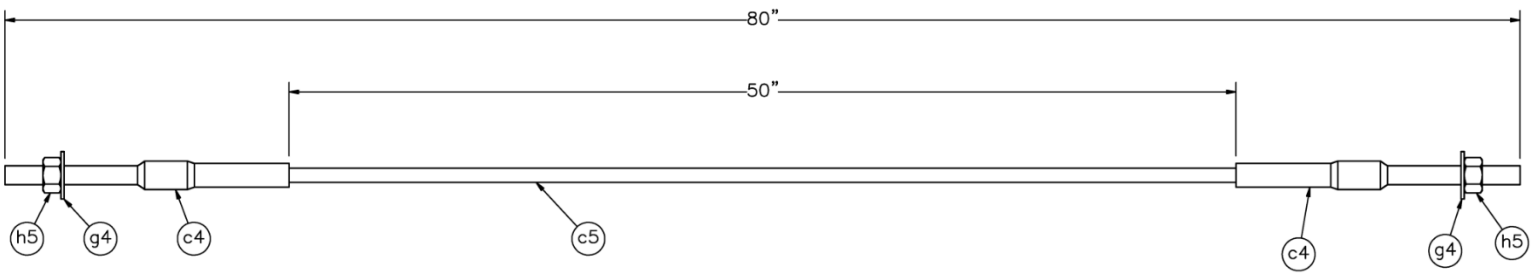


Figure 18. Ground Strut Details, Test No. HMDBR-1



Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	1	Cable Assembly	–	–	FCA01
c4	2	BCT Anchor Cable End Swaged Fitting	Fitting – ASTM A576 Gr. 1035 Stud – ASTM F568 Class C	Fitting – ASTM A153 Stud – ASTM A153 or B695	–
c5	1	3/4" Dia. 6x19 IWRC IPS Wire Rope	ASTM A741 Type 2	Class A Coating	–
h5	2	1"–8 UNC Heavy Hex Nut	ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX24b
g4	2	1" Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC24a

Midwest Roadside Safety Facility

Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail & Transition

BCT Anchor Cable

SHEET: 17 of 35
DATE: 8/19/2021
DRAWN BY: LJP/SBW/GHR
REV. BY: MP/KAL/JCH
DWG. NAME. HMDT–HMDBR_R19
SCALE: 1:8
UNITS: in.

Figure 19. BCT Anchor Cable, Test No. HMDBR-1

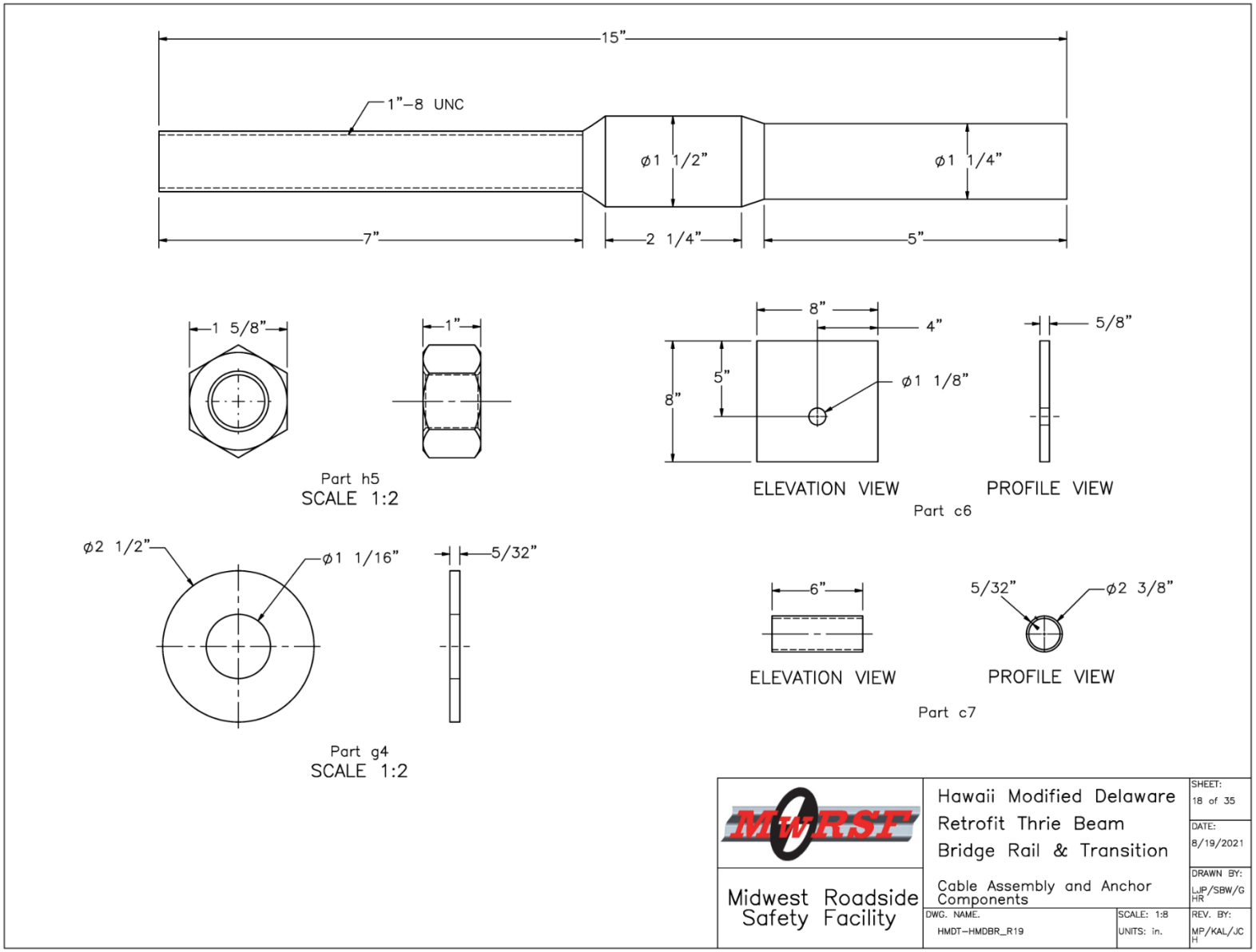


Figure 20. Cable Assembly and Anchor Components, Test No. HMDBR-1

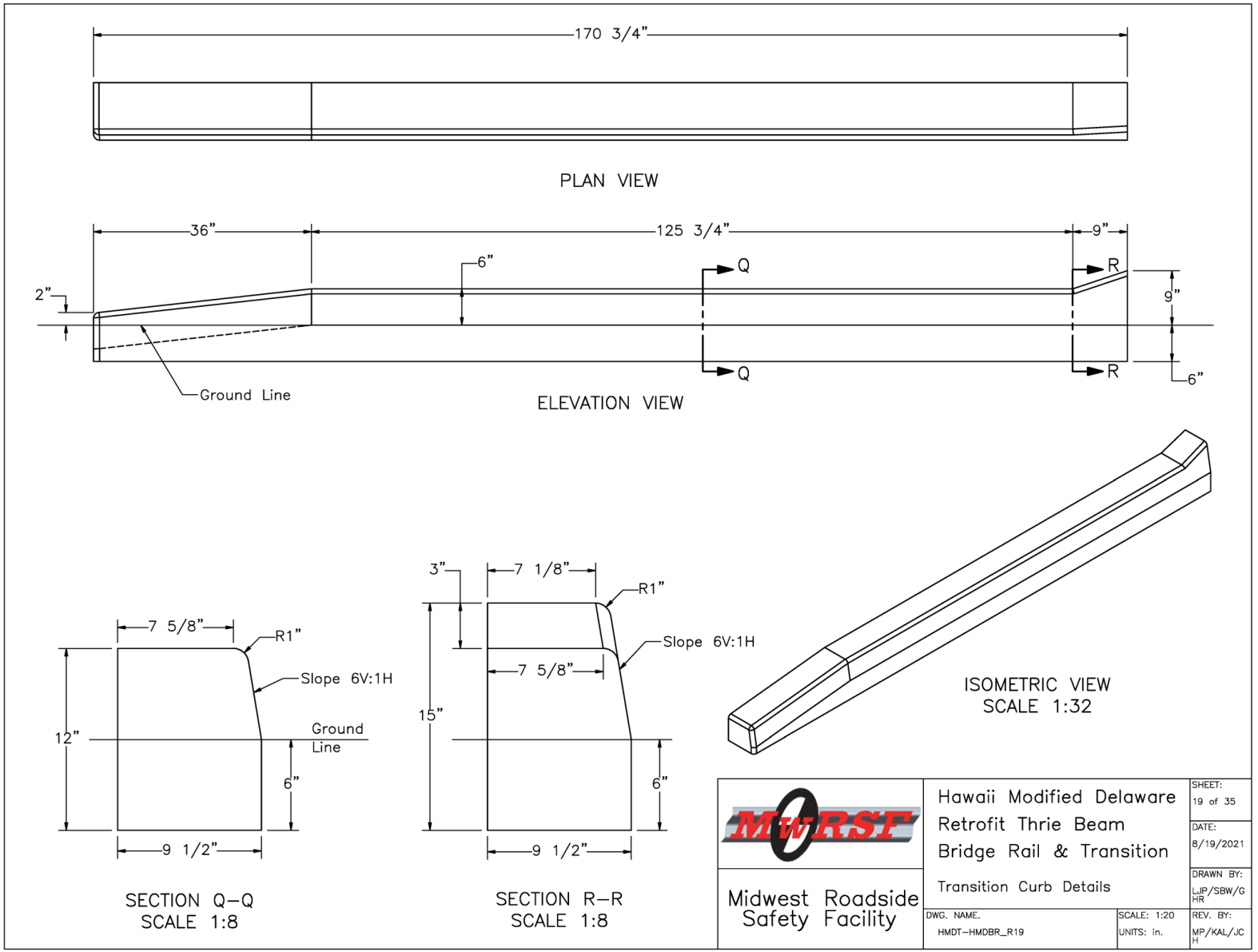


Figure 21. Transition Curb Details, Test No. HMDBR-1

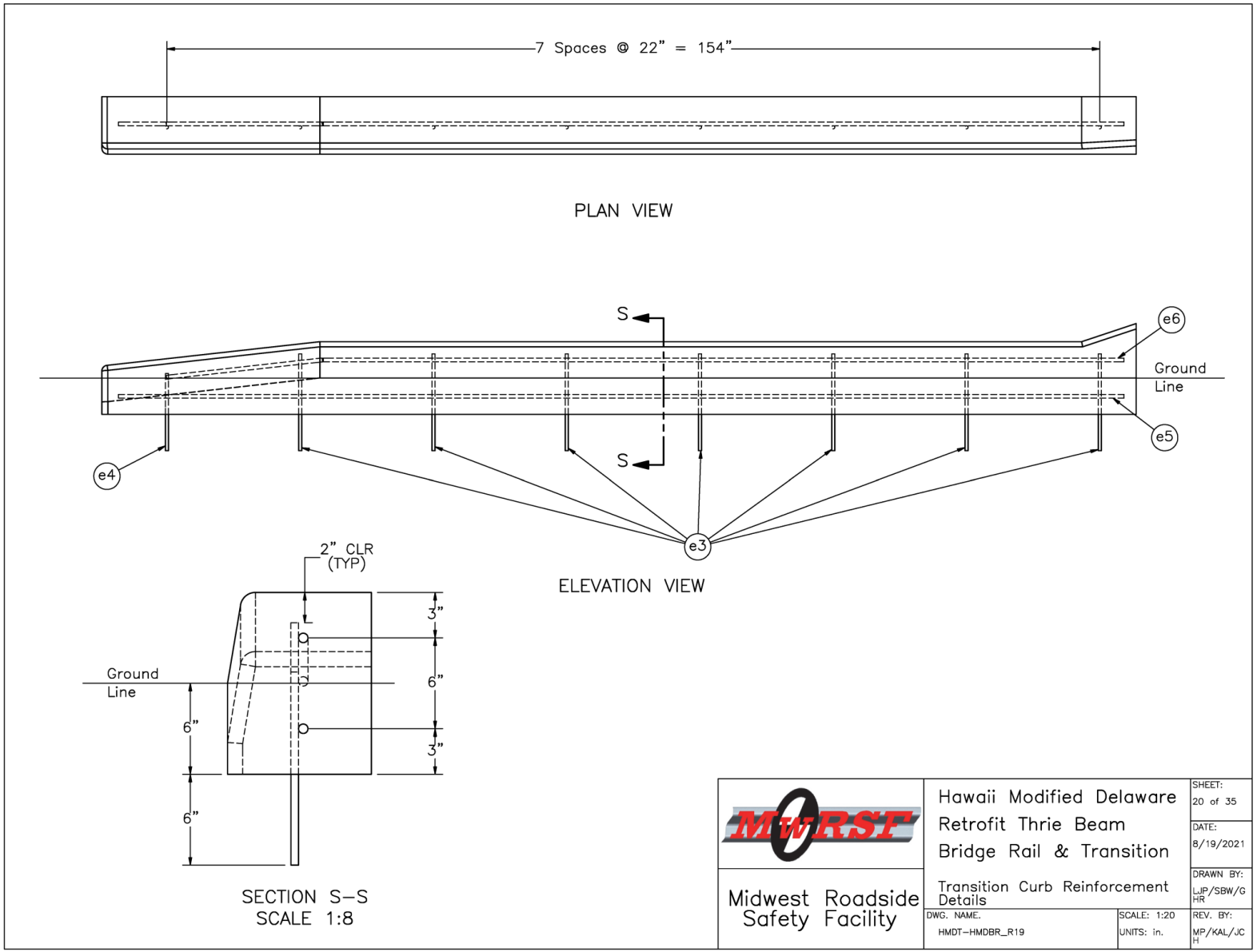


Figure 22. Transition Curb Reinforcement Details, Test No. HMDBR-1

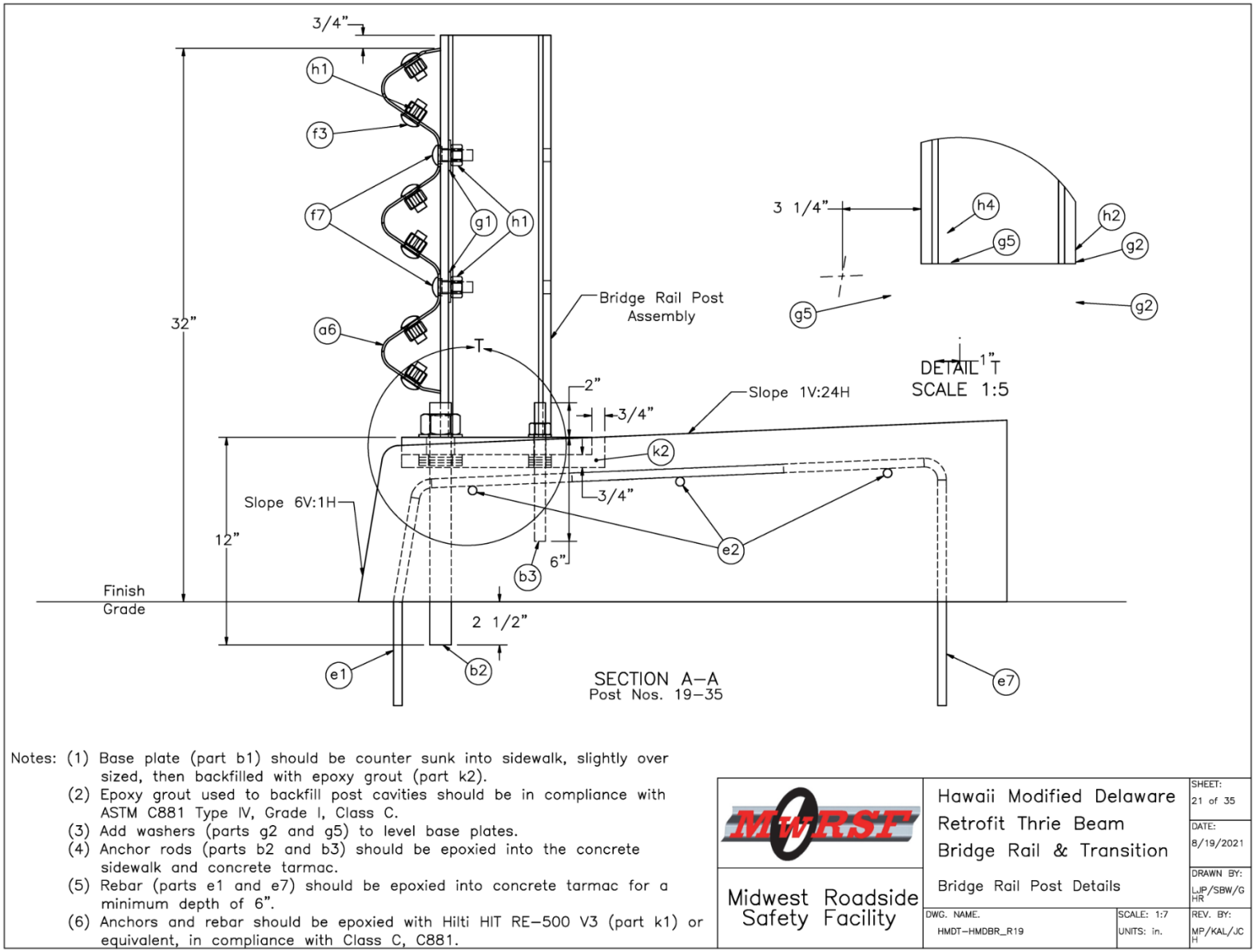


Figure 23. Bridge Rail Post Details, Test No. HMDBR-1

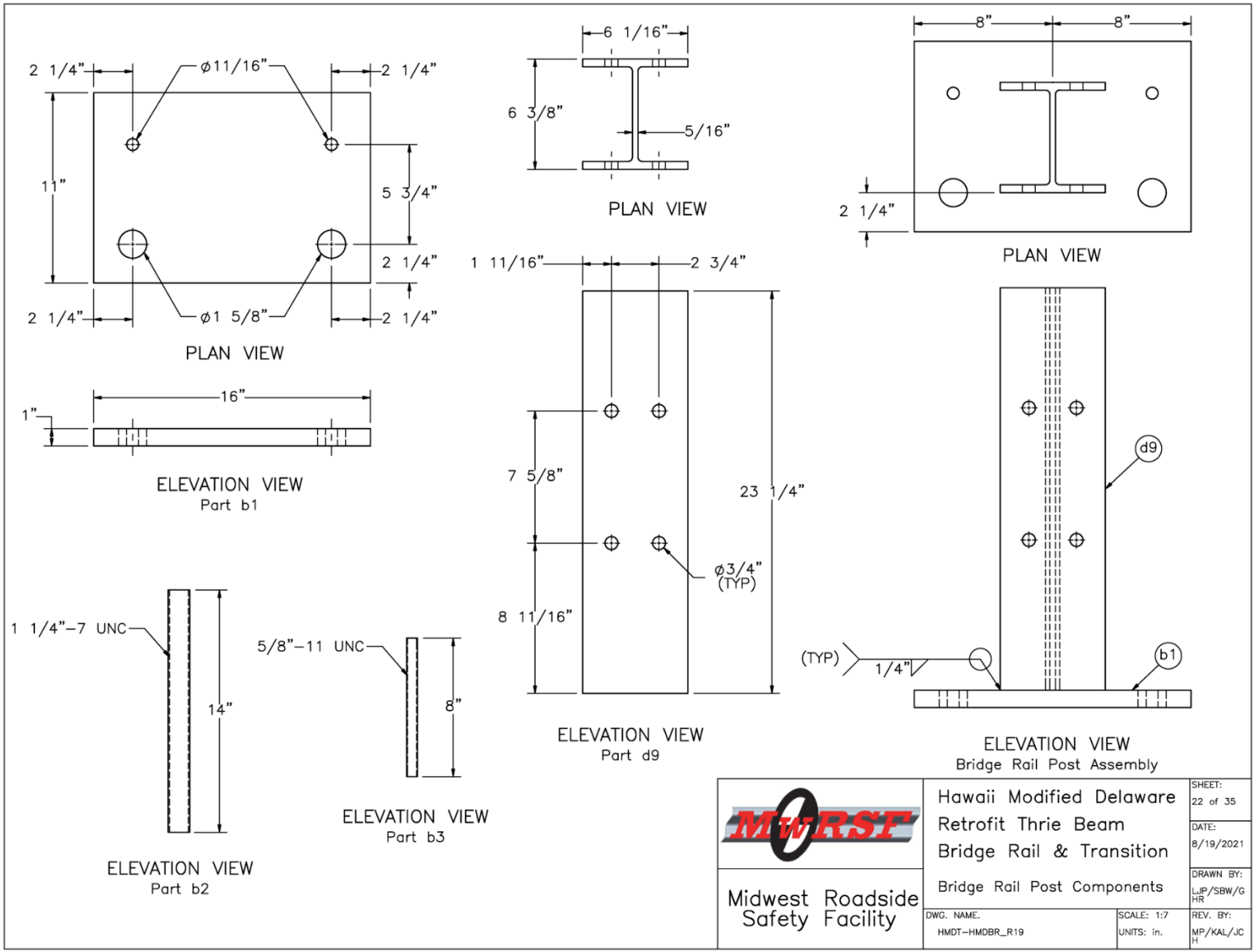


Figure 24. Bridge Rail Post Components, Test No. HMDBR-1

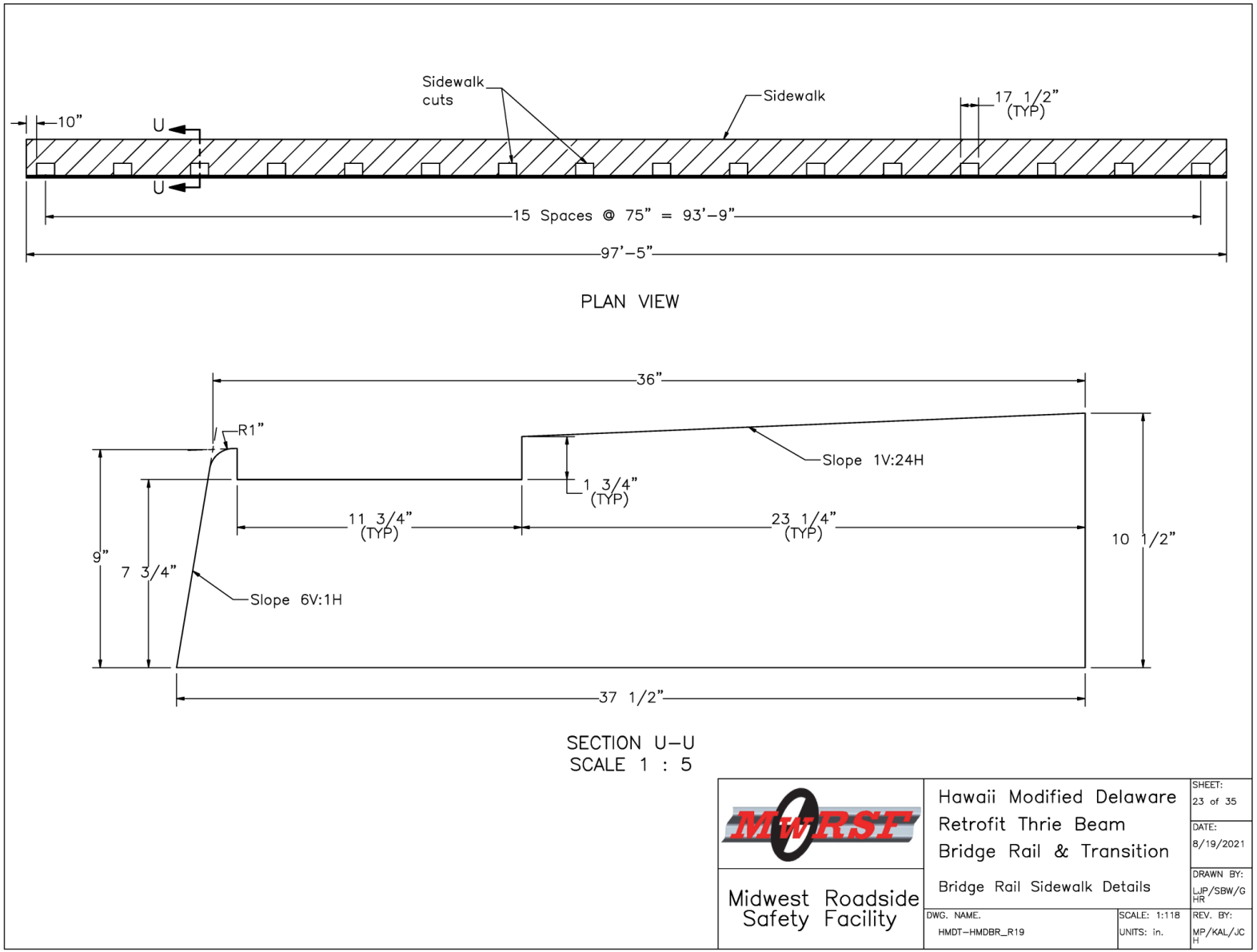


Figure 25. Bridge Rail Sidewalk Details, Test No. HMDBR-1

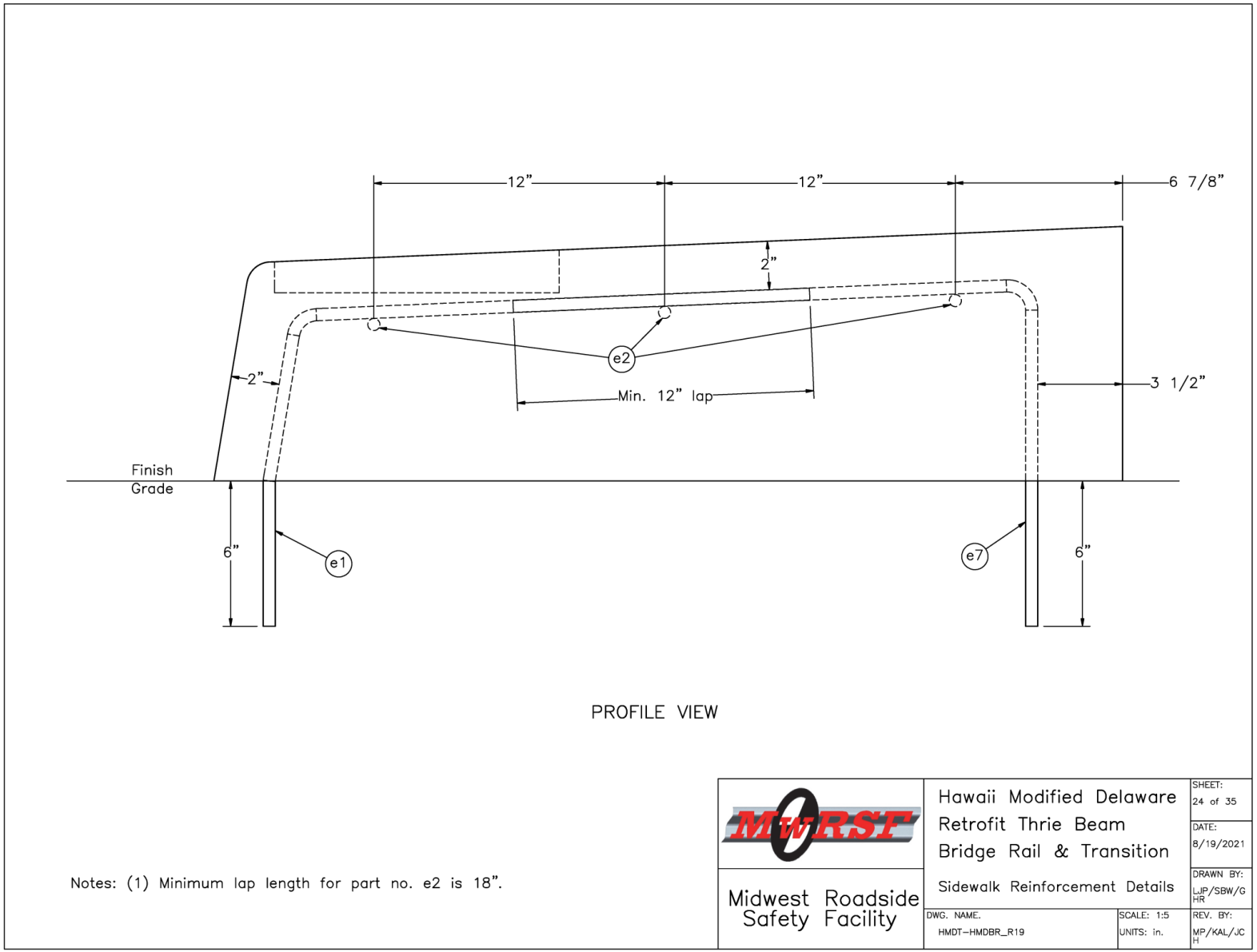


Figure 26. Sidewalk Reinforcement Details, Test No. HMDBR-1

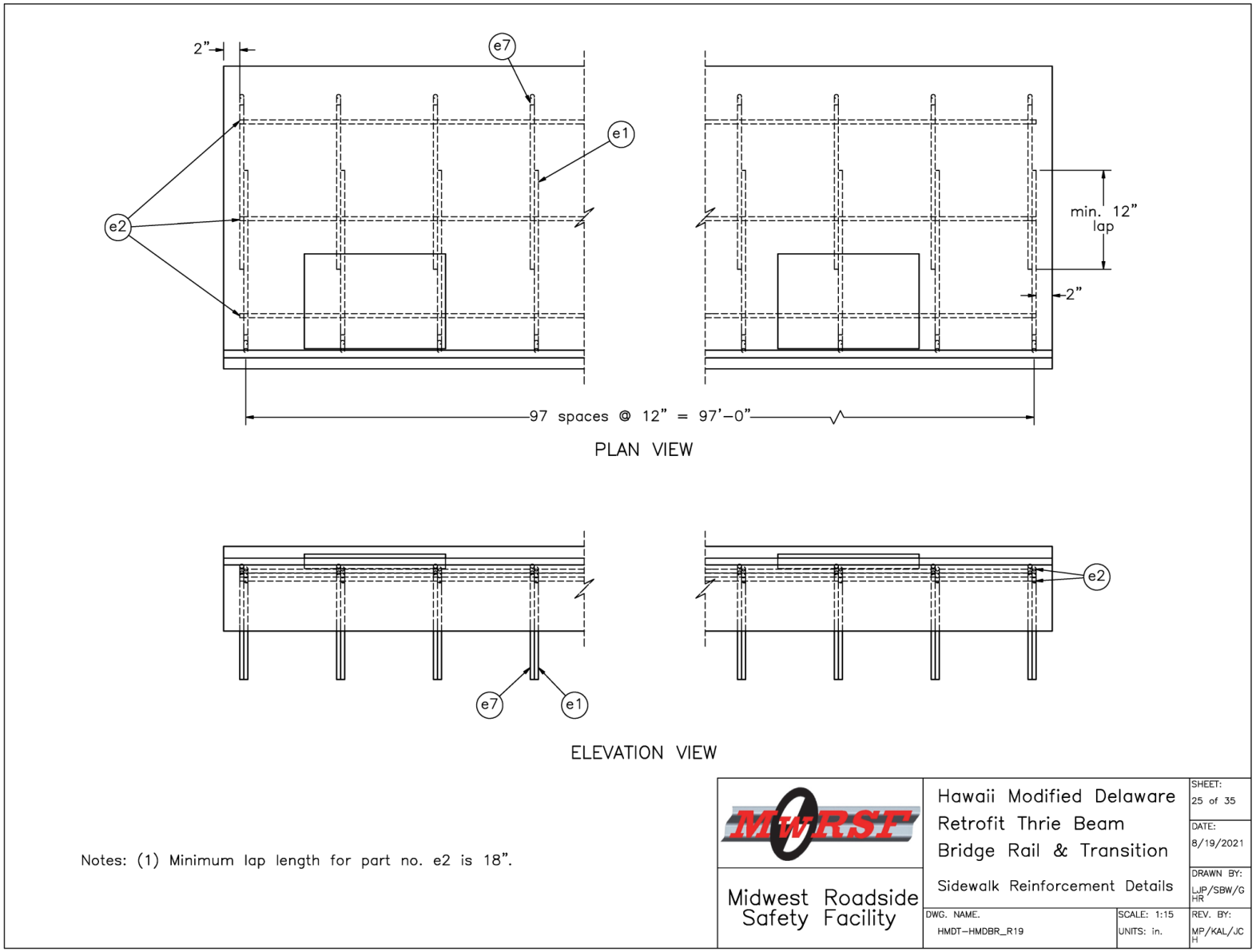
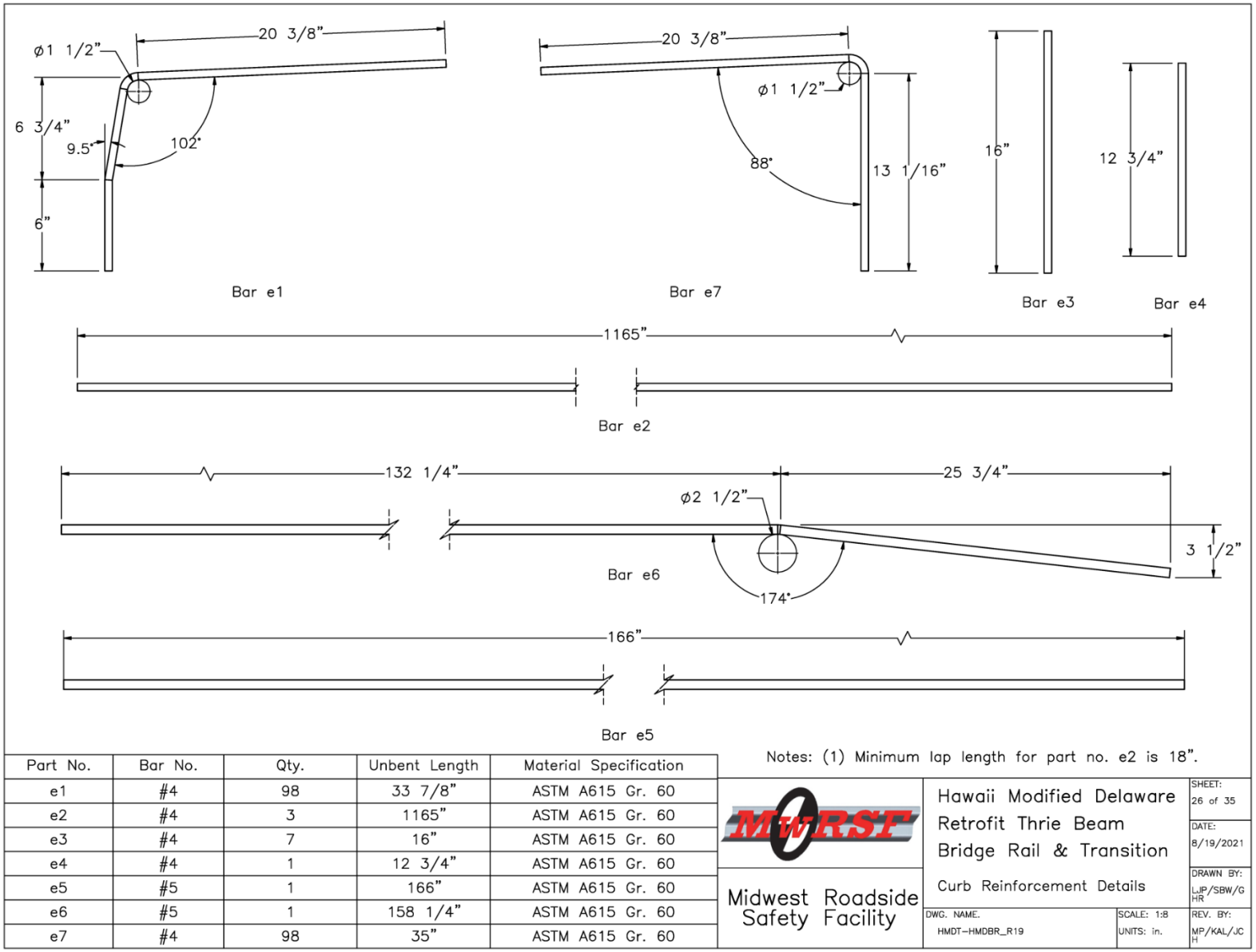


Figure 27. Sidewalk Reinforcement Details, Cont., Test No. HMDBR-1



Part No.	Bar No.	Qty.	Unbent Length	Material Specification
e1	#4	98	33 7/8"	ASTM A615 Gr. 60
e2	#4	3	1165"	ASTM A615 Gr. 60
e3	#4	7	16"	ASTM A615 Gr. 60
e4	#4	1	12 3/4"	ASTM A615 Gr. 60
e5	#5	1	166"	ASTM A615 Gr. 60
e6	#5	1	158 1/4"	ASTM A615 Gr. 60
e7	#4	98	35"	ASTM A615 Gr. 60

Figure 28. Curb Reinforcement Details, Test No. HMDBR-1

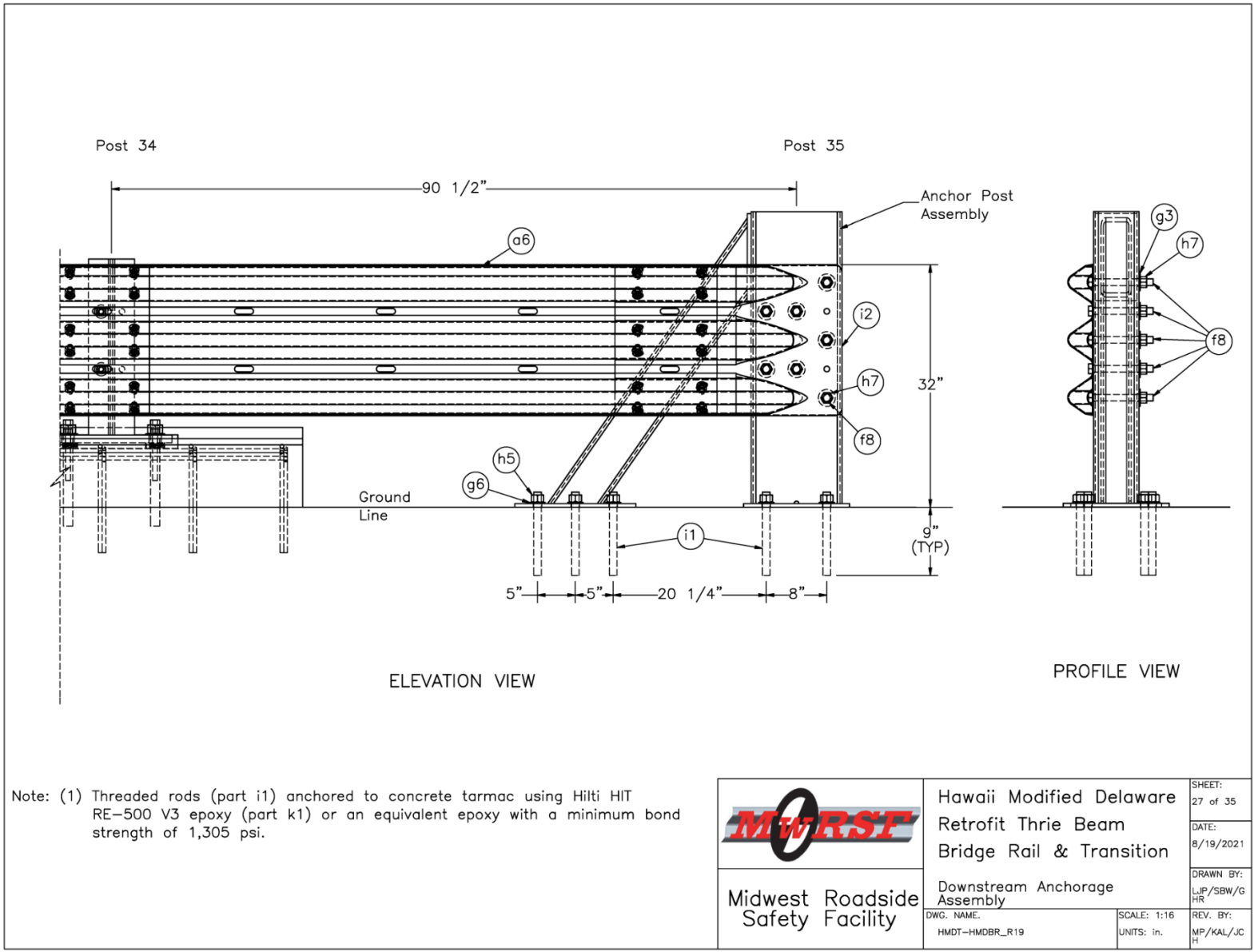


Figure 29. Downstream Anchorage Assembly, Test No. HMDBR-1

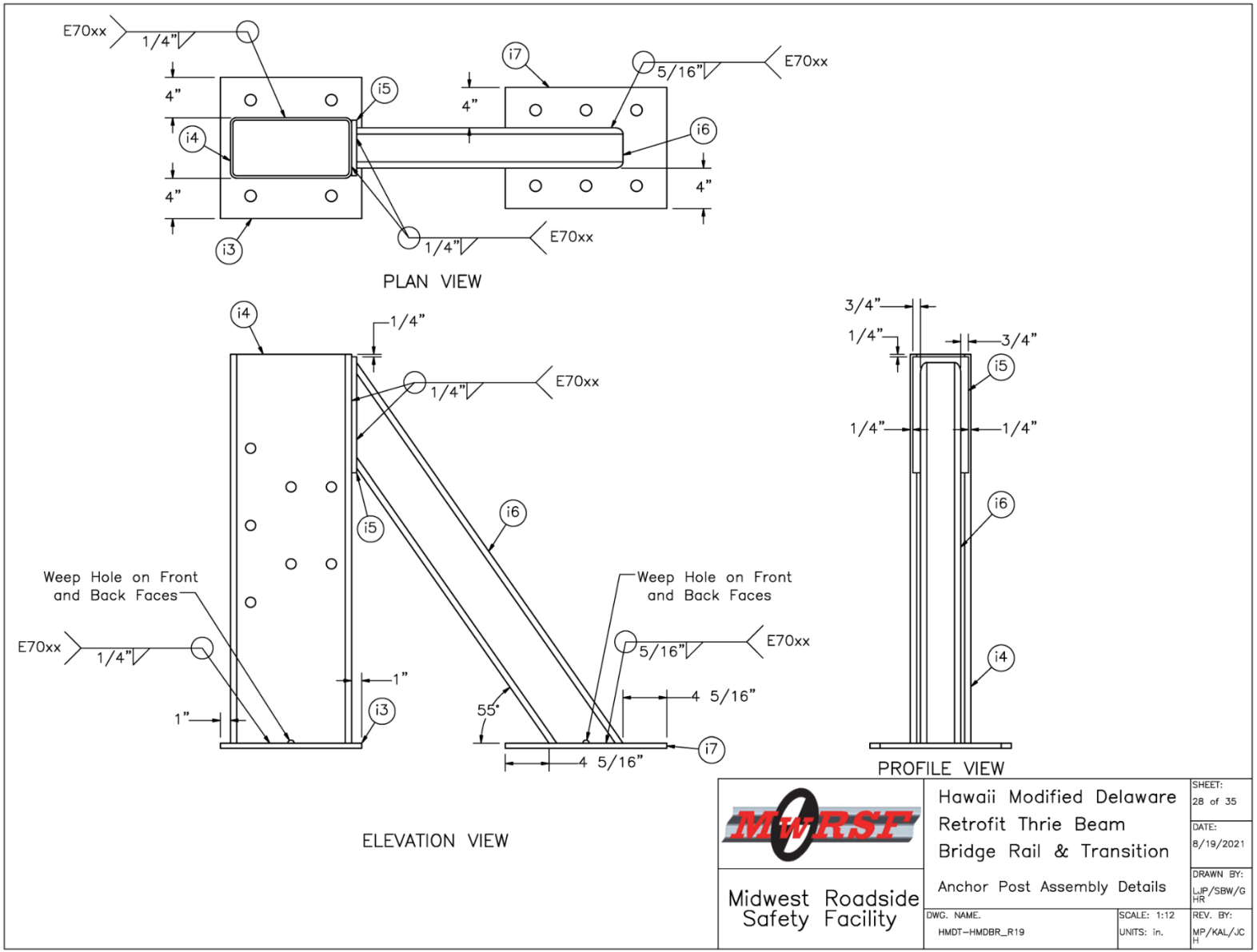


Figure 30. Anchor Post Assembly Details, Test No. HMDBR-1

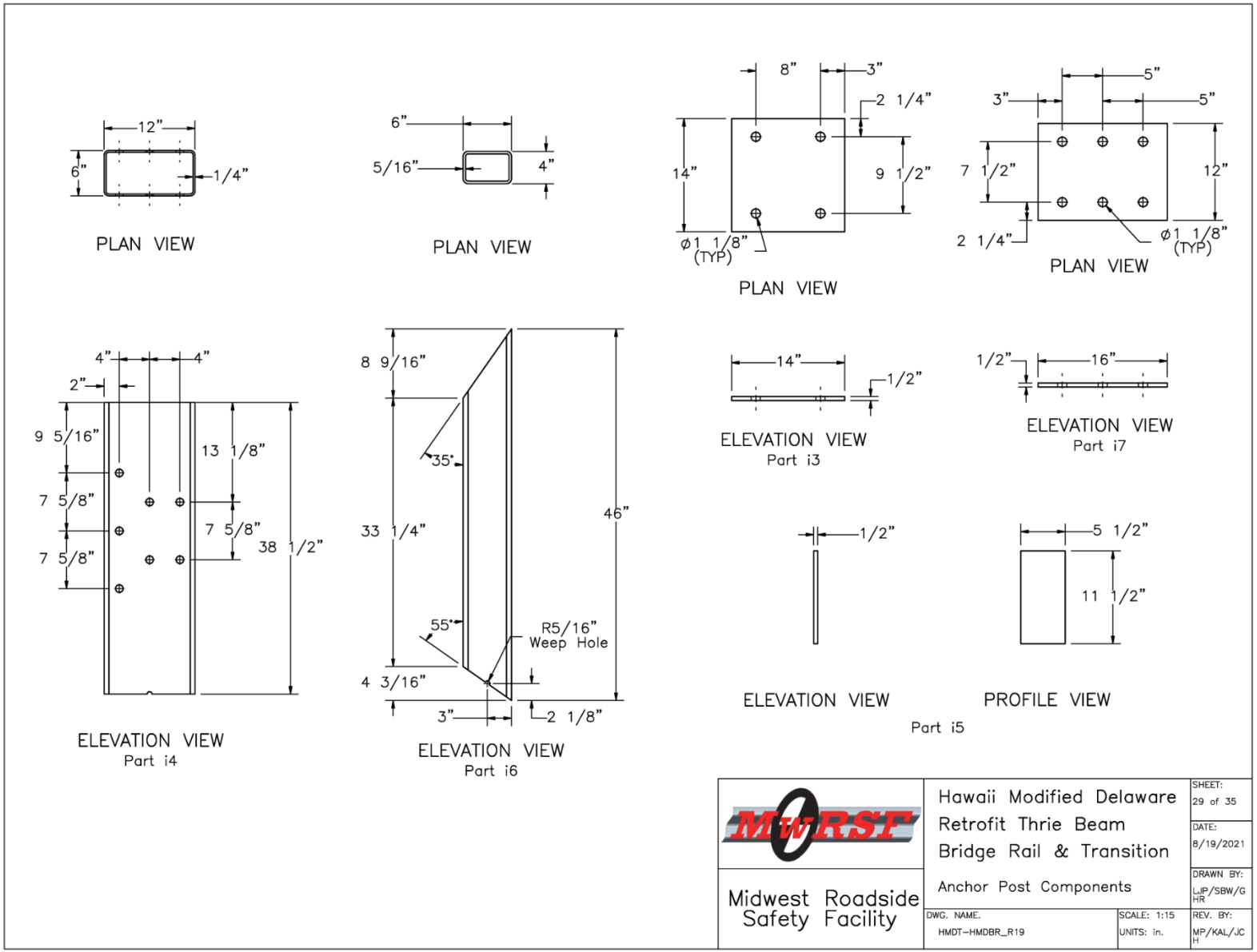


Figure 31. Anchor Post Components, Test No. HMDBR-1

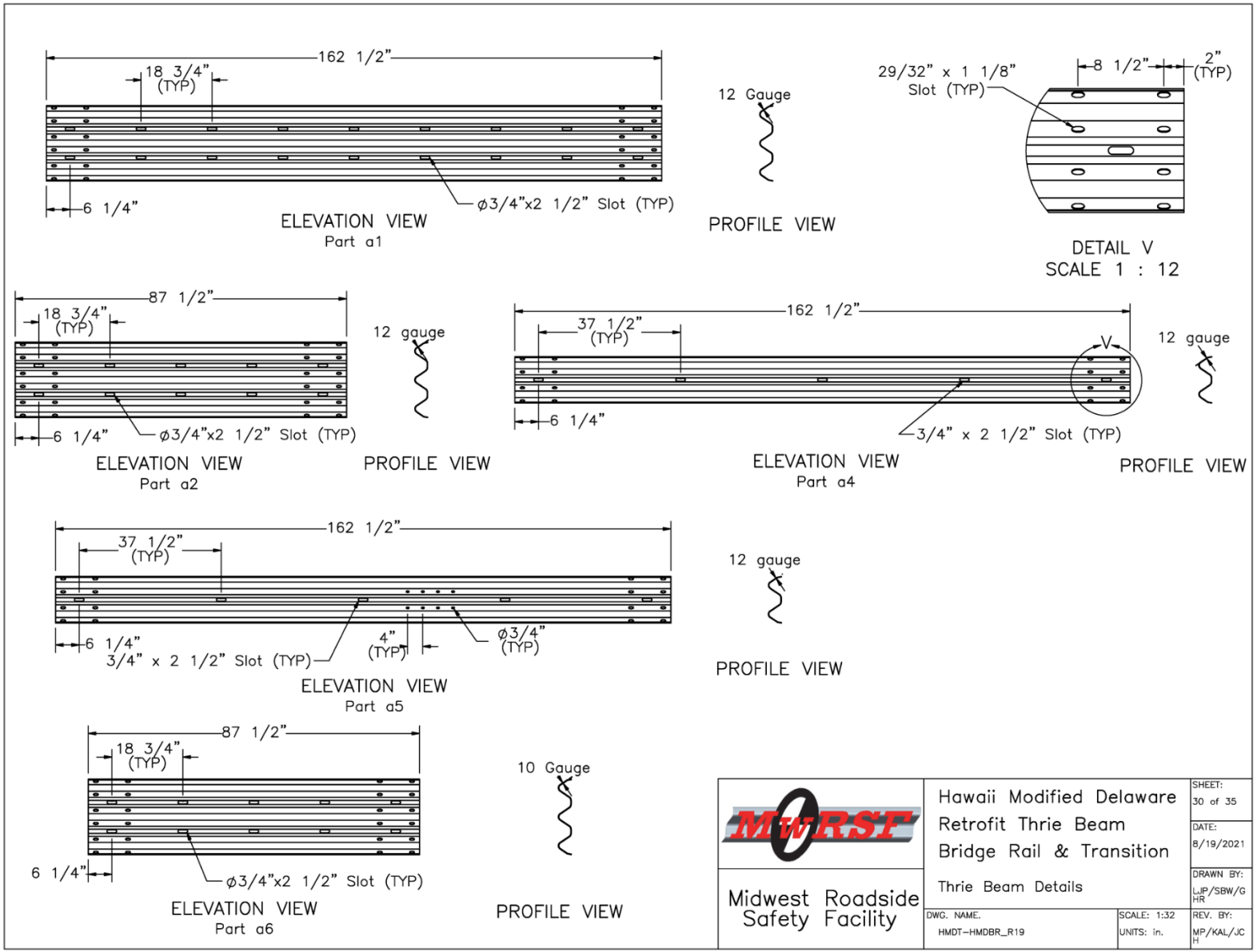


Figure 32. Thrie-Beam Details, Test No. HMDBR-1

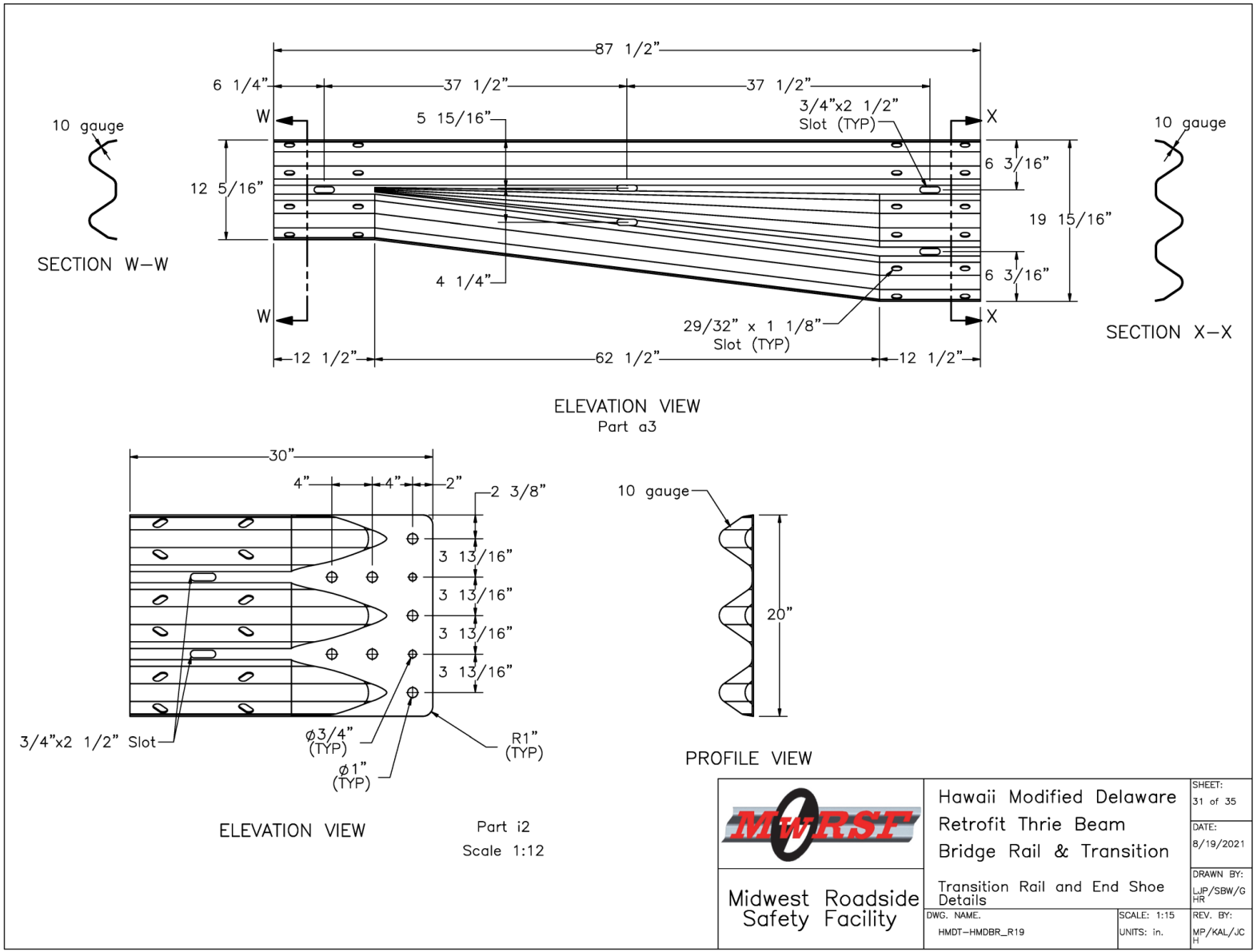


Figure 33. Transition Rail and End Shoe Details, Test No. HMDBR-1

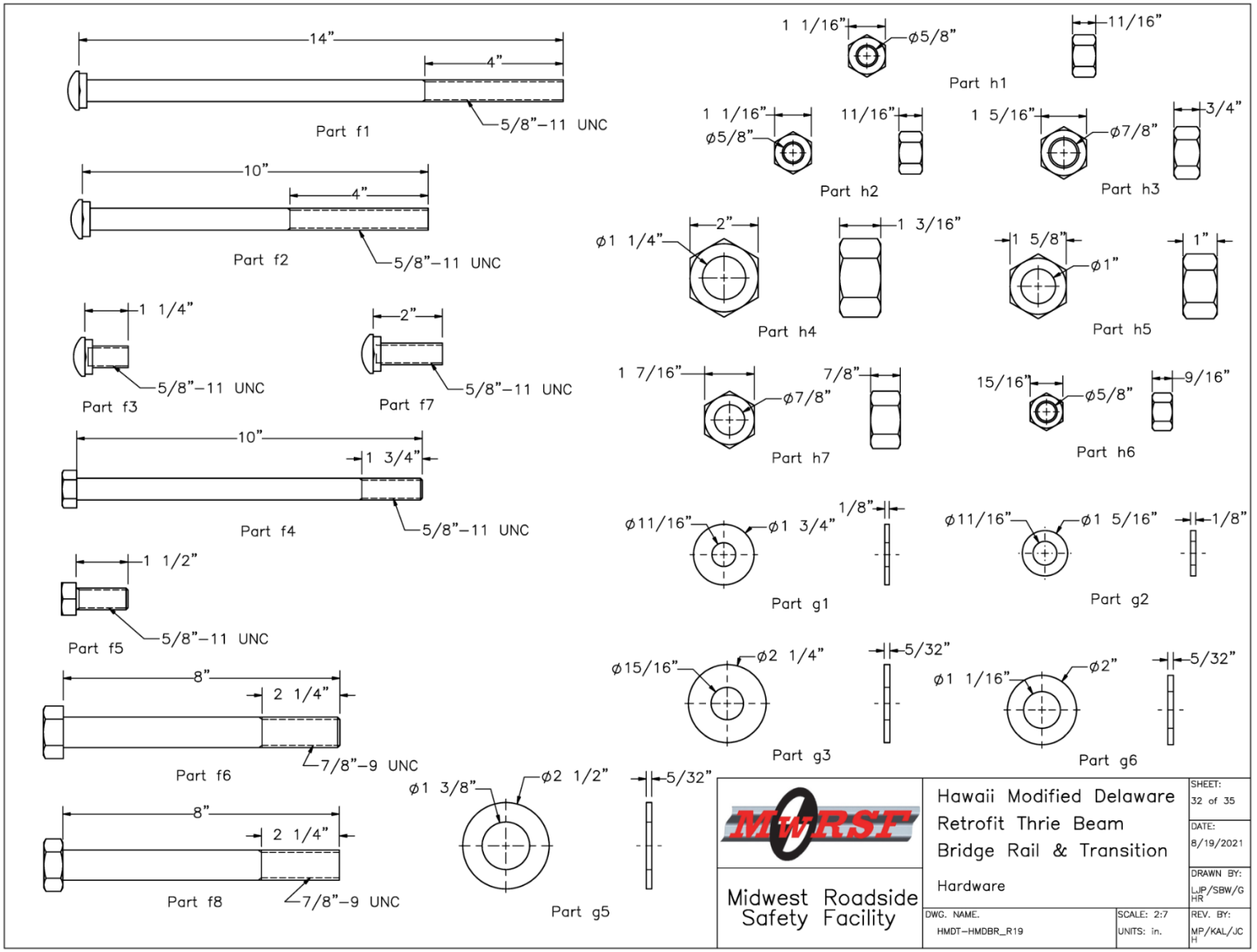


Figure 34. Hardware Details, Test No. HMDBR-1

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	2	12'–6" 12–gauge Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM08a
a2	1	6'–3" 12–gauge Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM19a
a3	1	6'–3" 10–gauge W–Beam to Thrie–Beam Asymmetric Transition Section	AASHTO M180	ASTM A653	RWT02
a4	3	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	16	6'–3" 10–gauge Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM19a
b1	16	16"x11"x1" Base Plate	ASTM A36	ASTM A123	–
b2	32	1 1/4" Dia., 14" Long Anchor Rod	ASTM F1554–15 Grade 105, Class 2A	ASTM F2329 / F2329M–15	–
b3	32	5/8" Dia., 8" Long Anchor Rod	ASTM F1554–15 Grade 105, Class 2A	ASTM F2329 / F2329M–15	–
c1	2	BCT Timber Post – MGS Height	SYP Grade No. 1 or better (No knots +/– 18" from ground on tension face)	–	PDF01
c2	2	72" Long Foundation Tube	ASTM A500 Gr. B	ASTM A123	PTE06
c3	1	Ground Strut Assembly	ASTM A36	ASTM A123	PFP02
c4	2	BCT Anchor Cable End Swaged Fitting	Fitting – ASTM A576 Gr. 1035 Stud – ASTM F568 Class C	Fitting – ASTM A153 Stud – ASTM A153 or B695	–
c5	1	BCT Cable Anchor Assembly	–	–	FCA01
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
c8	1	Anchor Bracket Assembly	ASTM A36	ASTM A123	FPA01
d1	7	W6x9 or W6x8.5, 72" Long Steel Post	ASTM A992	ASTM A123*	PWE06
d2	6	W6x9 or W6x8.5, 72" Long Steel Post	ASTM A992	ASTM A123*	PWE06
d3	3	W6x15, 78" Long Steel Post	ASTM A992	ASTM A123*	–
d4	3	17 1/2" Long, 8"x6"x1/4" Steel Blockout	ASTM A500 Gr. B	ASTM A123*	–
d5	6	17 1/2" Long, 12"x4"x1/4" Steel Blockout	ASTM A500 Gr. B	ASTM A123*	–
d6	2	14 3/16"x12"x5 1/8" Composite Recycled Blockout	Mondo Polymer MGS14SH or Equivalent	–	–
d7	5	14 3/16"x8"x5 1/8" Composite Recycled Blockout	Mondo Polymer GB14SH2 or Equivalent	–	–
d8	2	16D Double Head Nail	Galvanized	–	–
d9	16	W6x25, 23 1/4" Long Steel Post	ASTM A992	ASTM A123	–

* Component does not need to be galvanized for testing purposes

Notes: (1) Quantities listed herein are only for one copy of the system.
(2) Purchase additional materials to repair the barrier system following the first transition test, test no. HMDT–1.

MwRSF	Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail & Transition	SHEET: 33 of 35
		DATE: 8/19/2021
Midwest Roadside Safety Facility	Bill of Materials	DRAWN BY: LJP/SBW/GHR
	DWG. NAME. HMDT–HMDBR_R19 / SCALE: None / UNITS: in.	REV. BY: MP/KAL/JCH

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

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
e1	98	#4 Rebar, 33 7/8" Total Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e2	3	#4 Rebar, 97' 1" Total Length*	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e3	7	#4 Rebar, 16" Total Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e4	1	#4 Rebar, 12 3/4" Total Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e5	1	#5 Rebar, 166" Total Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e6	1	#5 Rebar, 158 1/4" Total Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e7	98	#4 Rebar, 35" Total Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
f1	13	5/8"-11 UNC, 14" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB06
f2	13	5/8"-11 UNC, 10" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB03
f3	260	5/8"-11 UNC, 1 1/4" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB01
f4	2	5/8"-11 UNC, 10" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f5	8	5/8"-11 UNC, 1 1/2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f6	2	7/8"-9 UNC, 8" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	–
f7	32	5/8"-11 UNC, 2" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM F2329	FBB01
f8	7	7/8" Dia., 8" Long Heavy Hex Head Bolt	ASTM F3125 Gr. A325 Type 1	ASTM A153 or B695 Class 55 or F1136 Gr. 3 or F2329 or F2833 Gr. 1	FBX22b
g1	54	5/8" Dia. Plain USS Washer	ASTM F844	ASTM F2329	FWC16a
g2	192	5/8" Dia. Hardened Washer	ASTM F436	ASTM F2329	FWC16a
g3	11	7/8" Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	–
g4	2	1" Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC24a
g5	160	1 1/4" Dia. Hardened Washer	ASTM F436	ASTM F2329	FWC30a
g6	10	1" Dia. Hardened Flat Washer	ASTM F436	ASTM A153 or B695 Class 55 or F1136 Gr. 3 or F2329	FWC24b
h1	318	5/8"-11 UNC Heavy Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX16b
h2	32	5/8"-11 UNC Heavy Hex Nut	ASTM A563-15 Grade DH	ASTM F2329 / F2329U-15	FNX16b
h3	2	7/8"-9 UNC Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	–
h4	32	1 1/4"-7 UNC Heavy Hex Nut	ASTM A563-15 Grade DH	ASTM F2329 / F2329U-15	–
h5	12	1" Dia. Heavy Hex Nut	ASTM A563DH or A194 Gr. 2H	ASTM A153 or B633 or B695 Class 55 or F1941 or F2329	FNX24b
h6	10	5/8"-11 UNC Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX16a
h7	7	7/8" Dia. UNC Heavy Hex Nut	ASTM A563DH or ASTM A194 Gr. 2H	ASTM A153 for Class C or ASTM B695 for Class 50	–

* Minimum lap length for part e2 is 18".

MwRSF

Midwest Roadside Safety Facility

Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail & Transition

Bill of Materials

SHEET: 34 of 35
DATE: 8/19/2021
DRAWN BY: LJP/SBW/GHR
REV. BY: MP/KAL/JCH
DWG. NAME. HMDT-HMDBR_R19
SCALE: None
UNITS: in.

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

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
i1	10	1" Dia. UNC, 11" Long Threaded Rod	ASTM A449 or A354 Gr. BC or A193 Gr. B7	ASTM A153 or B633 or B695 Class 55 or F1941 or F2329	FRR24b
i2	1	10–gauge Thrie Beam Terminal Connector	AASHTO M180 Min. yield strength = 50 ksi Min. tensile strength = 70 ksi	ASTM A123 or A653	RTE01b
i3	1	14"x14"x1/2" Steel Plate	ASTM A36 or A572 Gr. 50	ASTM A123*	–
i4	1	HSS 6"x12"x1/4" Tube, 38 1/2" Long	ASTM A500 Gr. B	ASTM A123*	–
i5	1	11 1/2"x5 1/2"x1/2" Steel Plate	ASTM A36 or A572 Gr. 50	ASTM A123*	–
i6	1	HSS 6"x4"x5/16" Tube, 46" Long	ASTM A500 Gr. B	ASTM A123*	–
i7	1	16"x12"x1/2" Steel Plate	ASTM A36 or A572 Gr. 50	ASTM A123*	–
j1	1	Concrete	Min. f'c = 4,000 psi NE Mix 47BD1S/1PF4000HW	–	–
k1	–	Hilti HIT RE–500 V3 Epoxy Adhesive	Class C 881	–	–
k2	–	SpecChem 500 Epoxy Filler	ASTM C881 Type IV, Grade I, Class C	–	–

* Component does not need to be galvanized for testing purposes

MwRSF Midwest Roadside Safety Facility	Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail & Transition Bill of Materials		SHEET: 35 of 35 DATE: 8/19/2021 DRAWN BY: LJP/SBW/GHR
	DWG. NAME. HMDT–HMDBR_R19	SCALE: None UNITS: in.	REV. BY: MP/KAL/JCH

Figure 37. Bill of Materials, Cont., Test No. HMDBR-1

Figure 38. Test Installation Photographs, Test No. HMDBR-1

(a)

(b)

Figure 39. Photographs of (a) Full Installation and (b) AGT with Transition Curb and MGS, Test No. HMDBR-1

Figure 40. Test Installation Photographs, Typical Post Installation, Test No. HMDBR-1

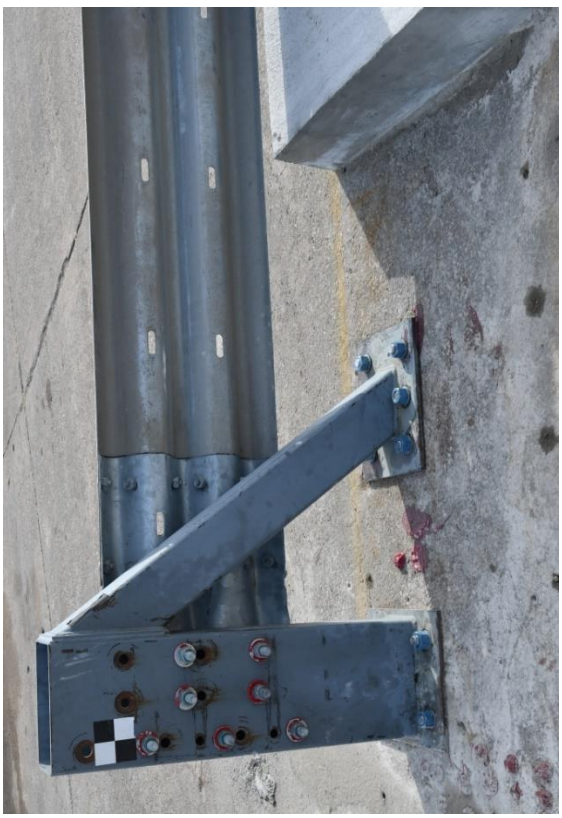


Figure 41. Test Installation Photographs, End Anchorage Assemblies, Test No. HMDBR-1

4 DESIGN DETAILS, TEST NOS. HMDBR-2 AND HMDBR-3

The test installation for test nos. HMDBR-2 and HMDBR-3 was the Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail with a total length of approximately 110 ft, as shown in Figures 42 through 57. These systems were identical installations to the system crash tested in test no. HMDBR-1, except that the bridge rail installation did not connect to an AGT, and the thrie-beam anchorage assembly was used at both the upstream and downstream ends of the installation. In addition, the sidewalk height was reduced from 9 in. to 6 in., thereby increasing the threaded rod embedment depth at the post anchorages by 3 in. Photographs of the test installation for test no. HMDBR-2 are shown in Figures 58 and 59. Photographs of the test installation for test no. HMDBR-3 are shown in Figures 60 and 61. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix C. Note that in test no. HMDBR-2, the ⅝-in. diameter washers (item no. g1) intended for use with the guardrail bolts connecting the thrie-beam rail to the posts were not installed, but this omission had no impact on rail performance in the crash test. Item no. g1 was included in the test no. HMDBR-3 installation.

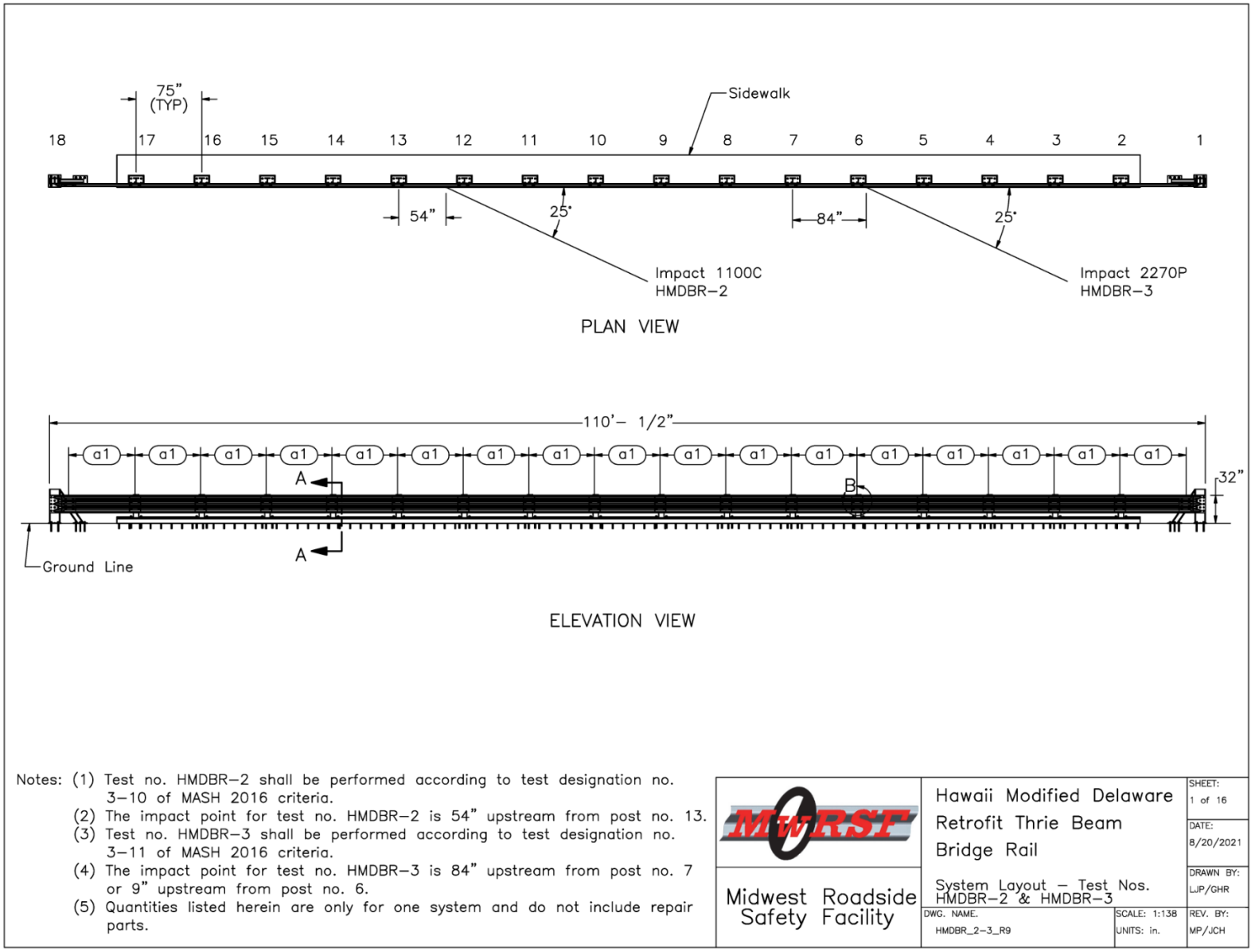


Figure 42. Test Installation Layout, Test Nos. HMDBR-2 and HMDBR-3

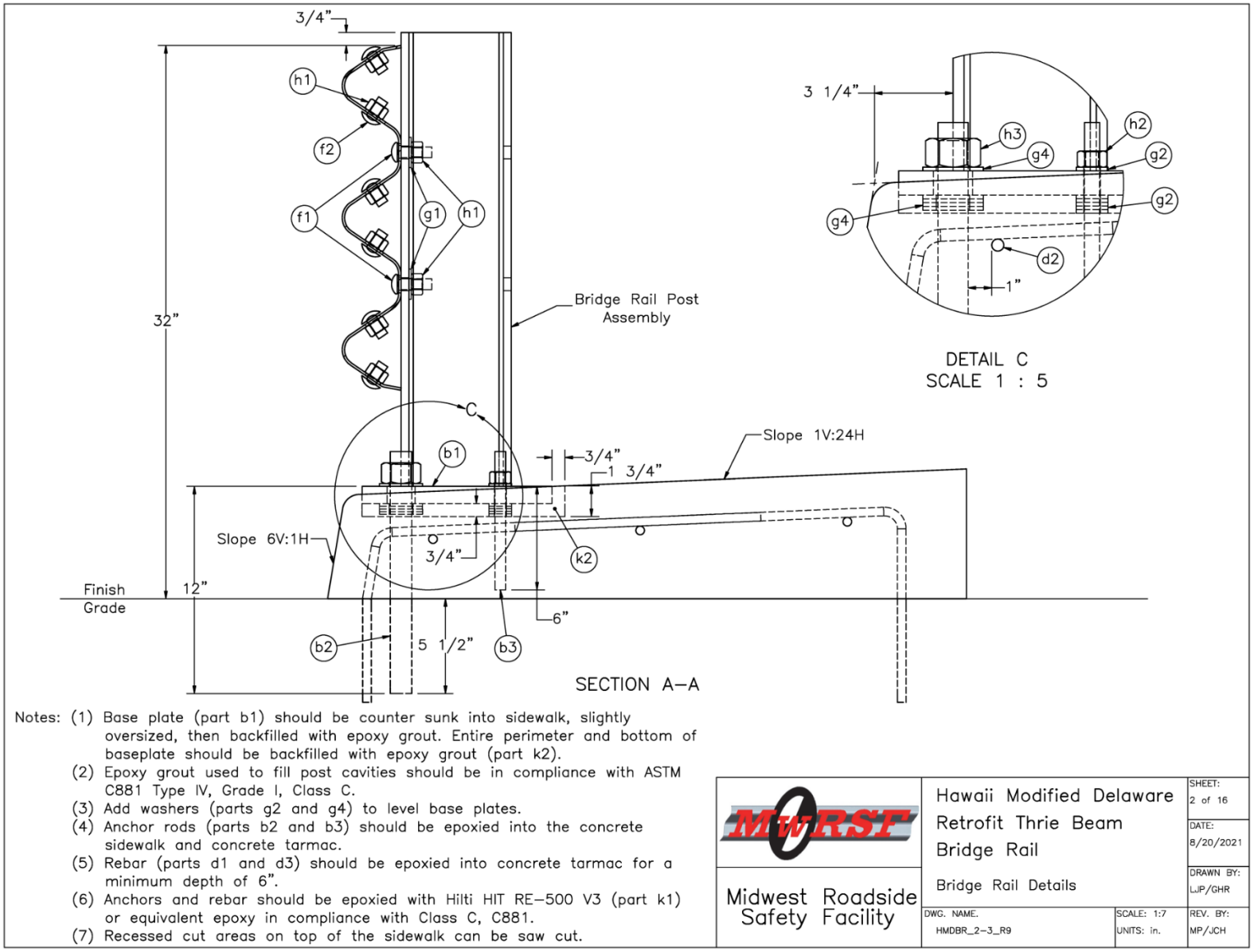


Figure 43. Bridge Rail Details, Test Nos. HMDBR-2 and HMDBR-3

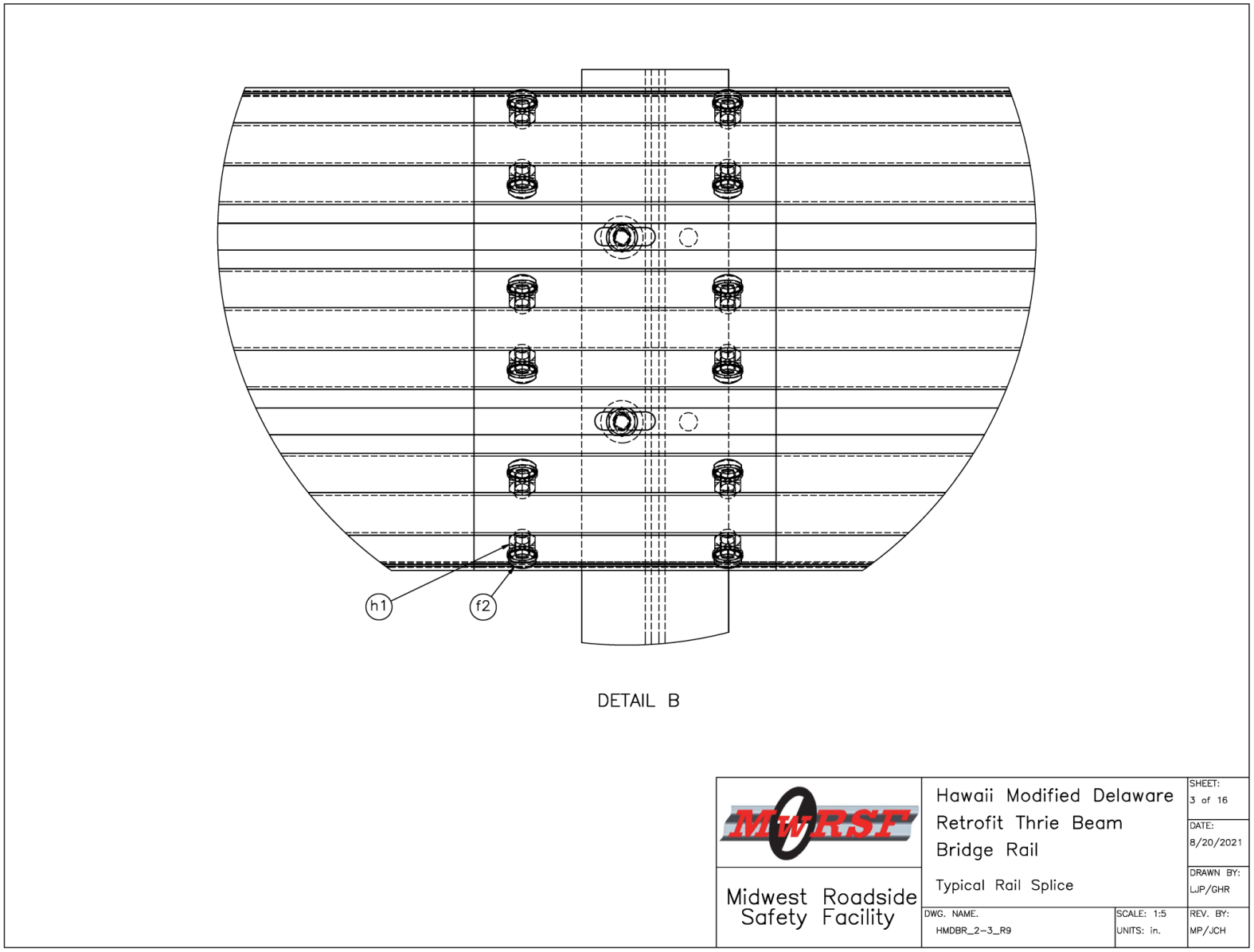


Figure 44. Typical Rail Splice, Test Nos. HMDBR-2 and HMDBR-3

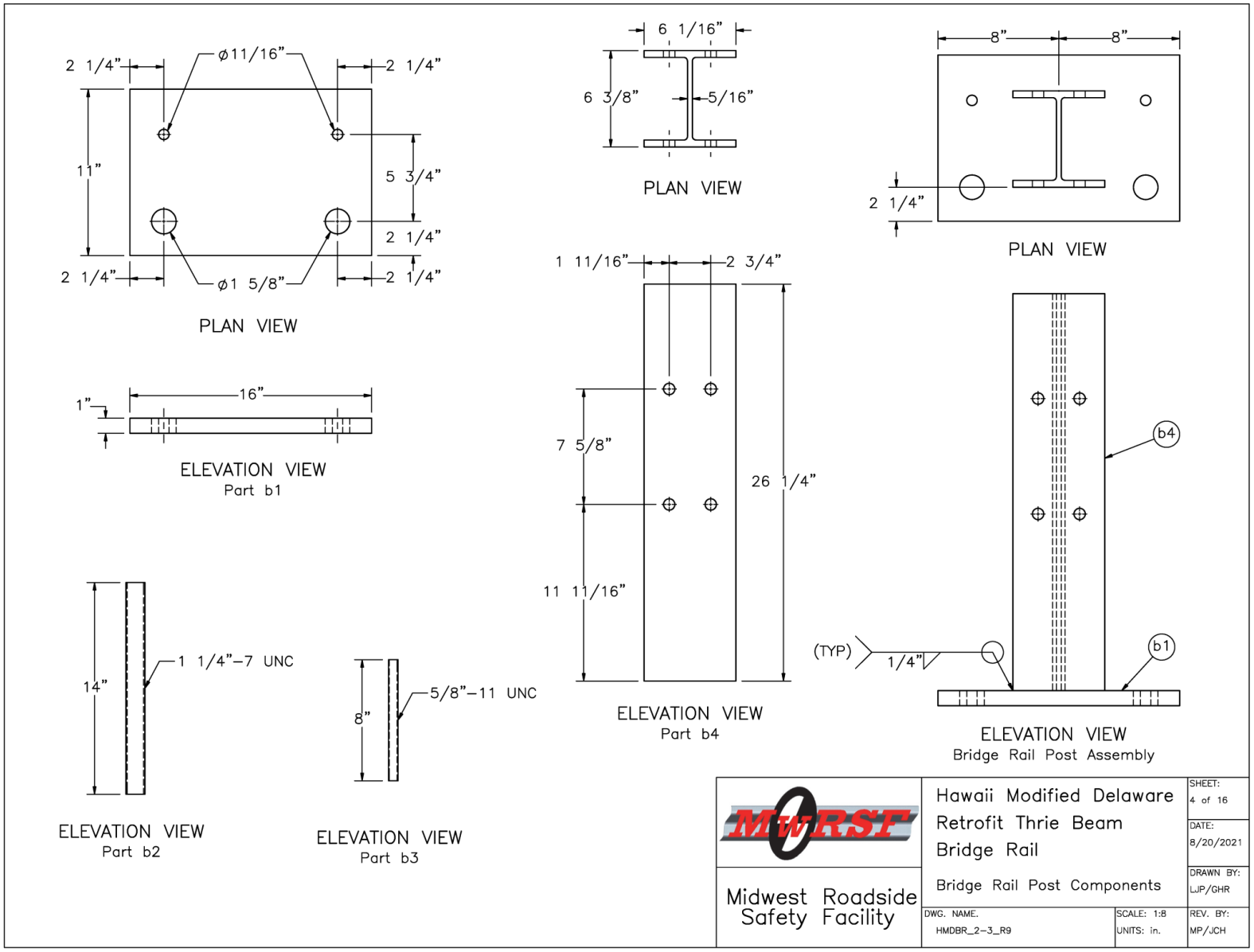


Figure 45. Bridge Rail Post Components, Test Nos. HMDBR-2 and HMDBR-3

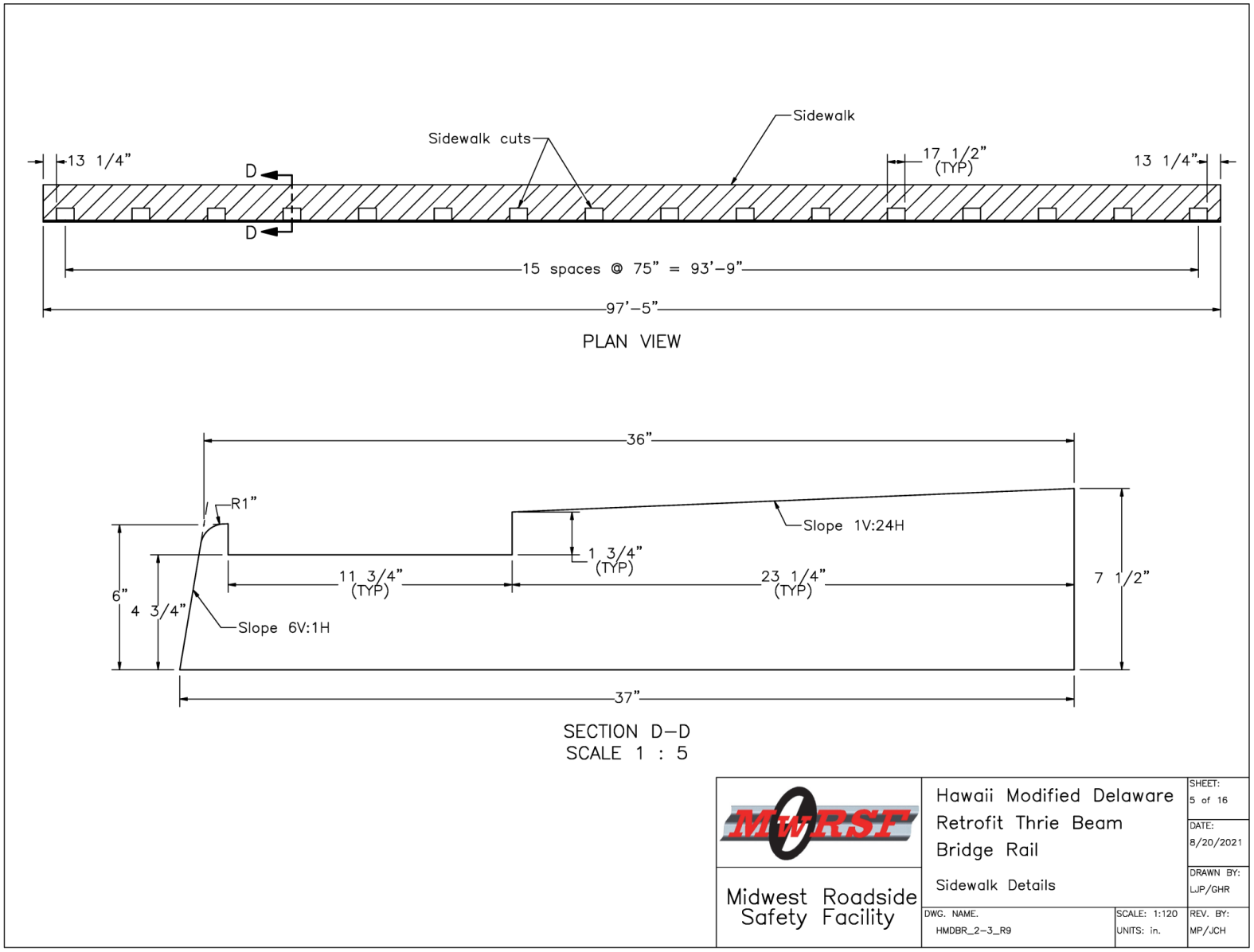


Figure 46. Sidewalk Details, Test Nos. HMDBR-2 and HMDBR-3

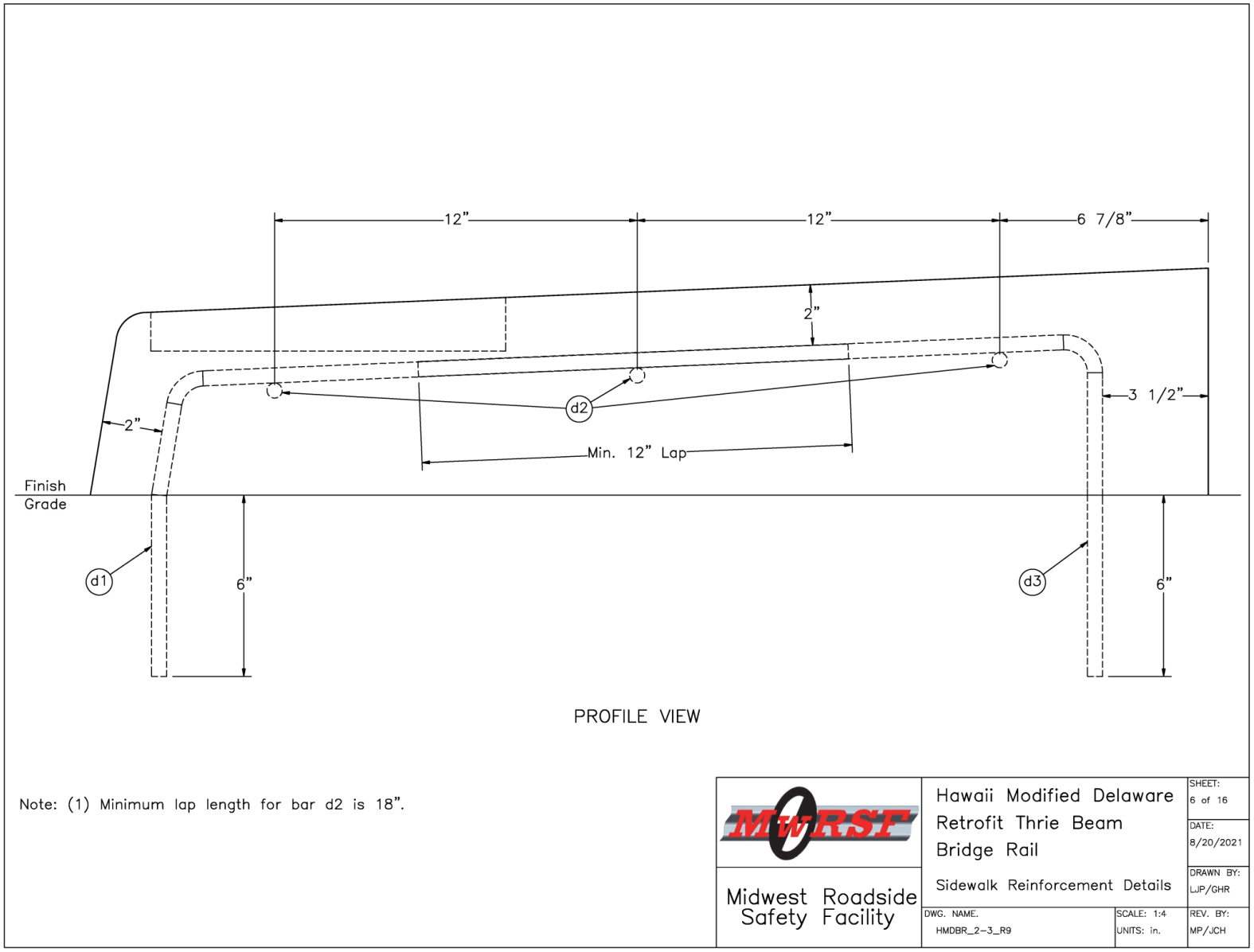


Figure 47. Sidewalk Reinforcement Details, Test Nos. HMDBR-2 and HMDBR-3

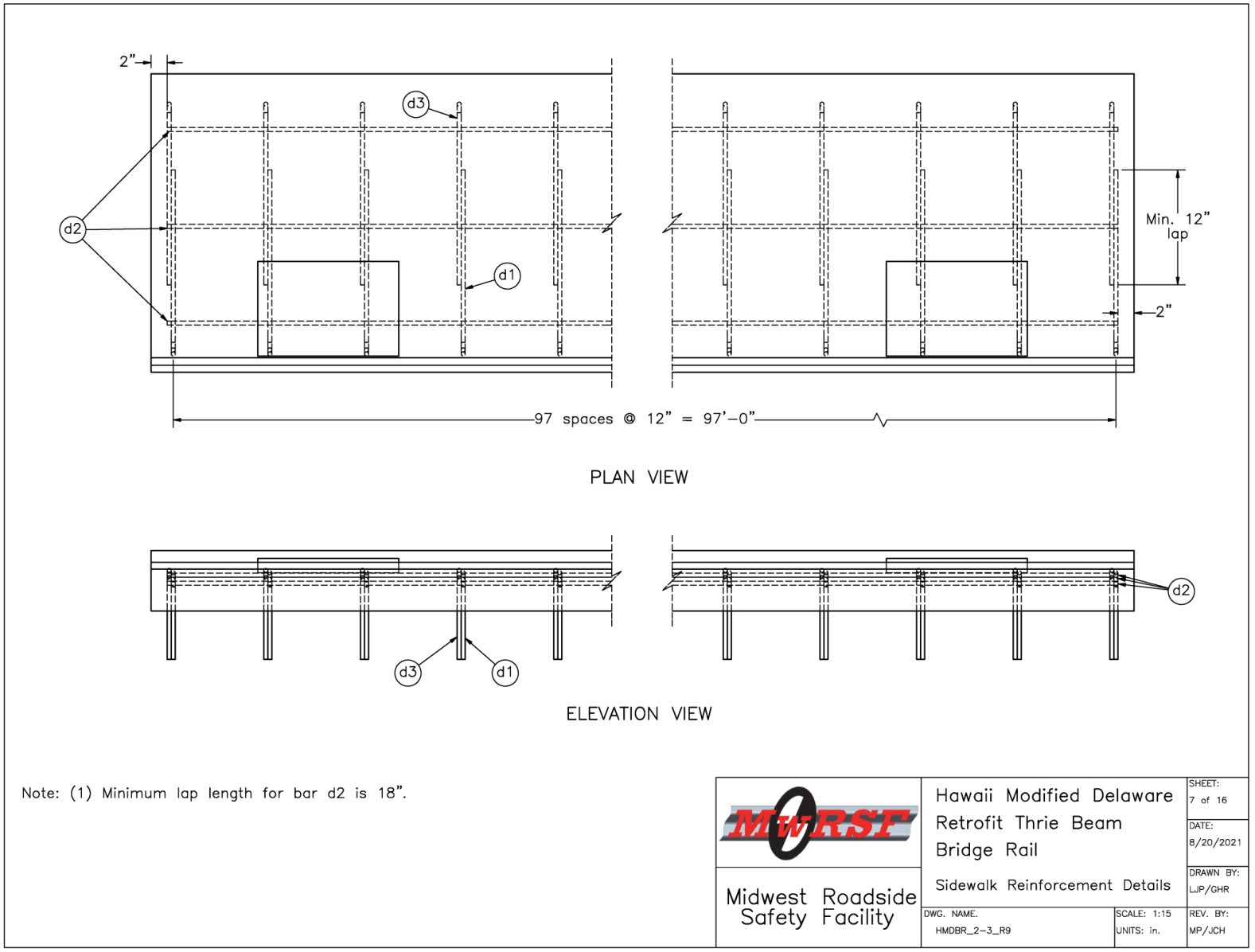


Figure 48. Sidewalk Reinforcement Details, Cont., Test Nos. HMDBR-2 and HMDBR-3

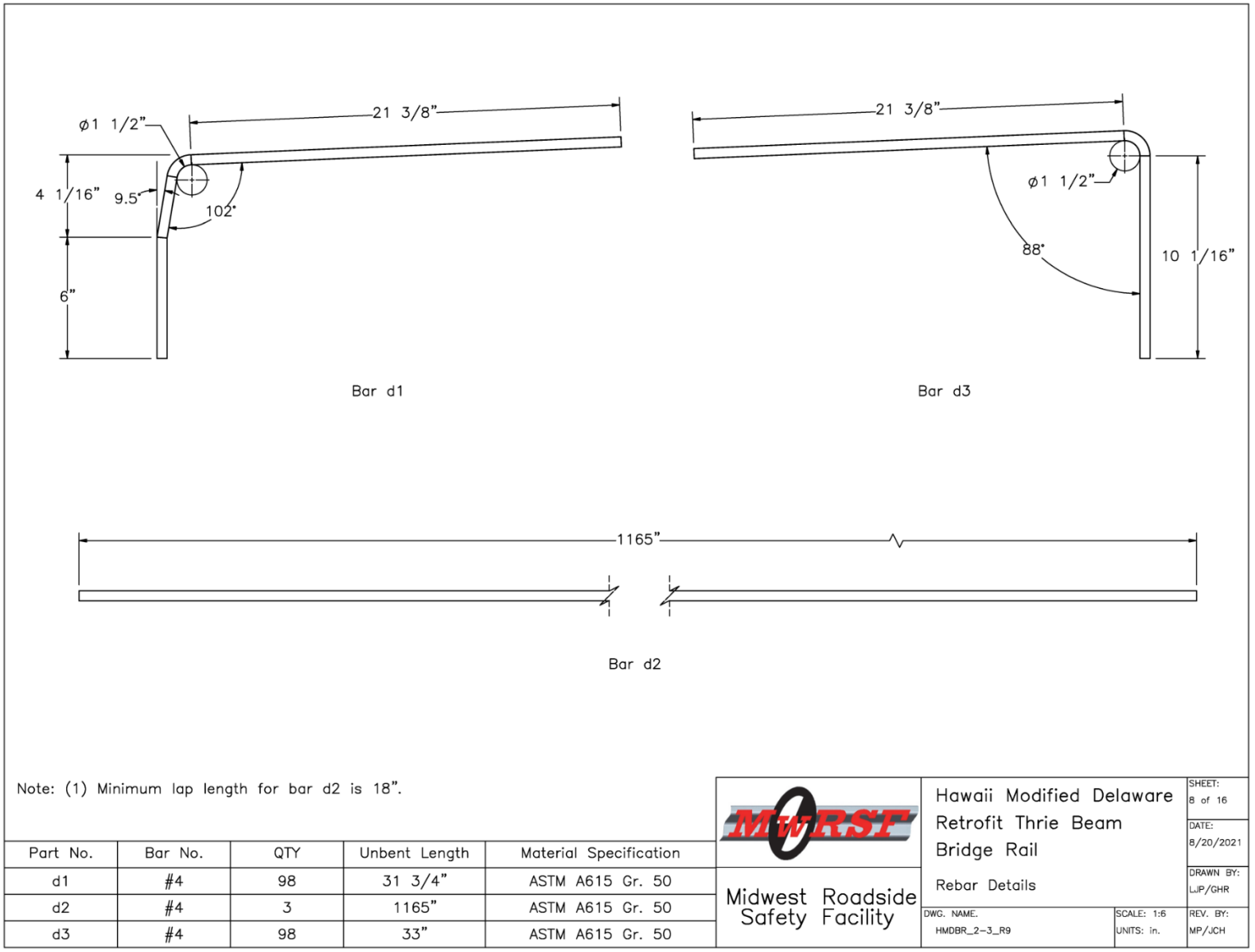


Figure 49. Rebar Details, Test Nos. HMDBR-2 and HMDBR-3

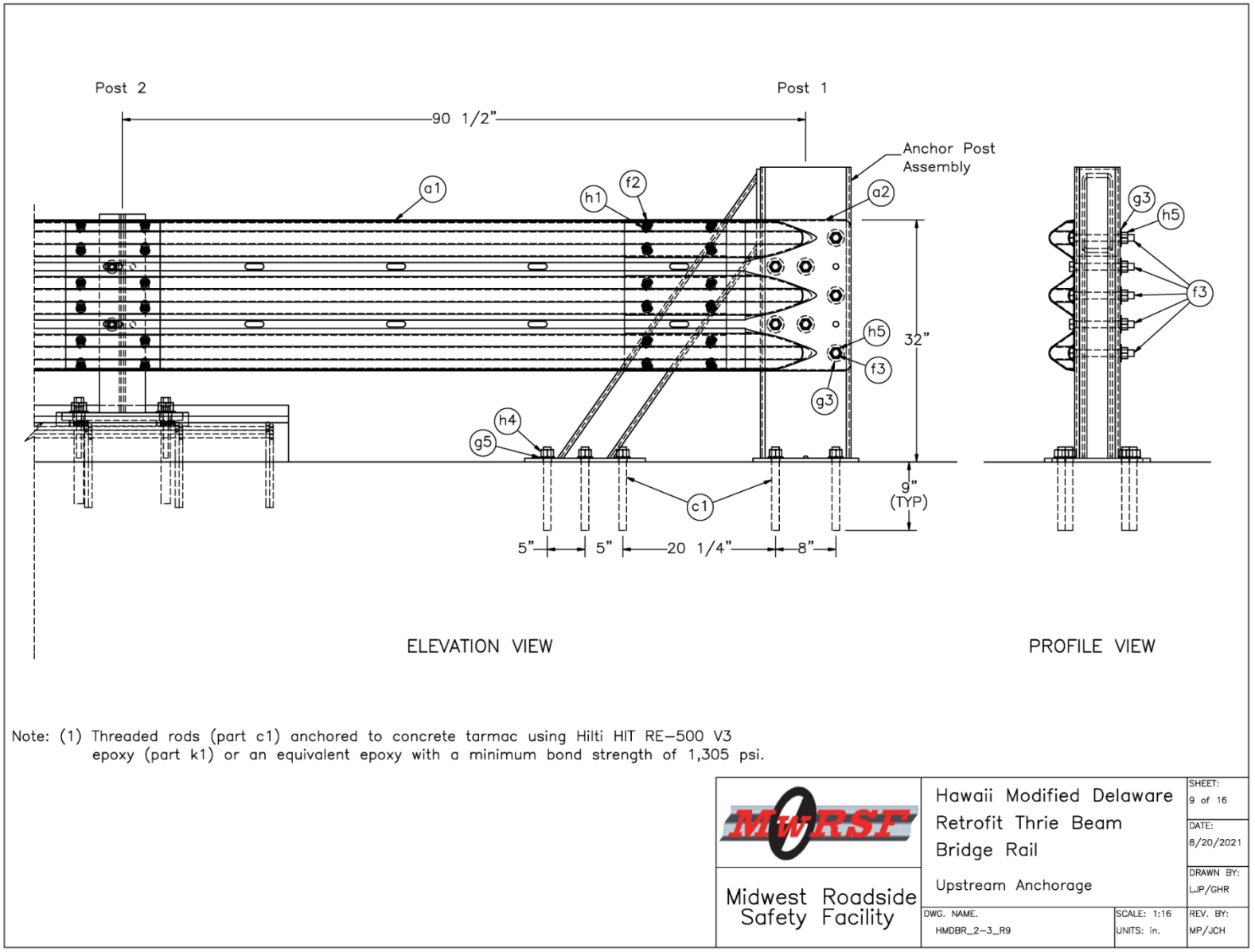


Figure 50. Upstream Anchorage, Test Nos. HMDBR-2 and HMDBR-3

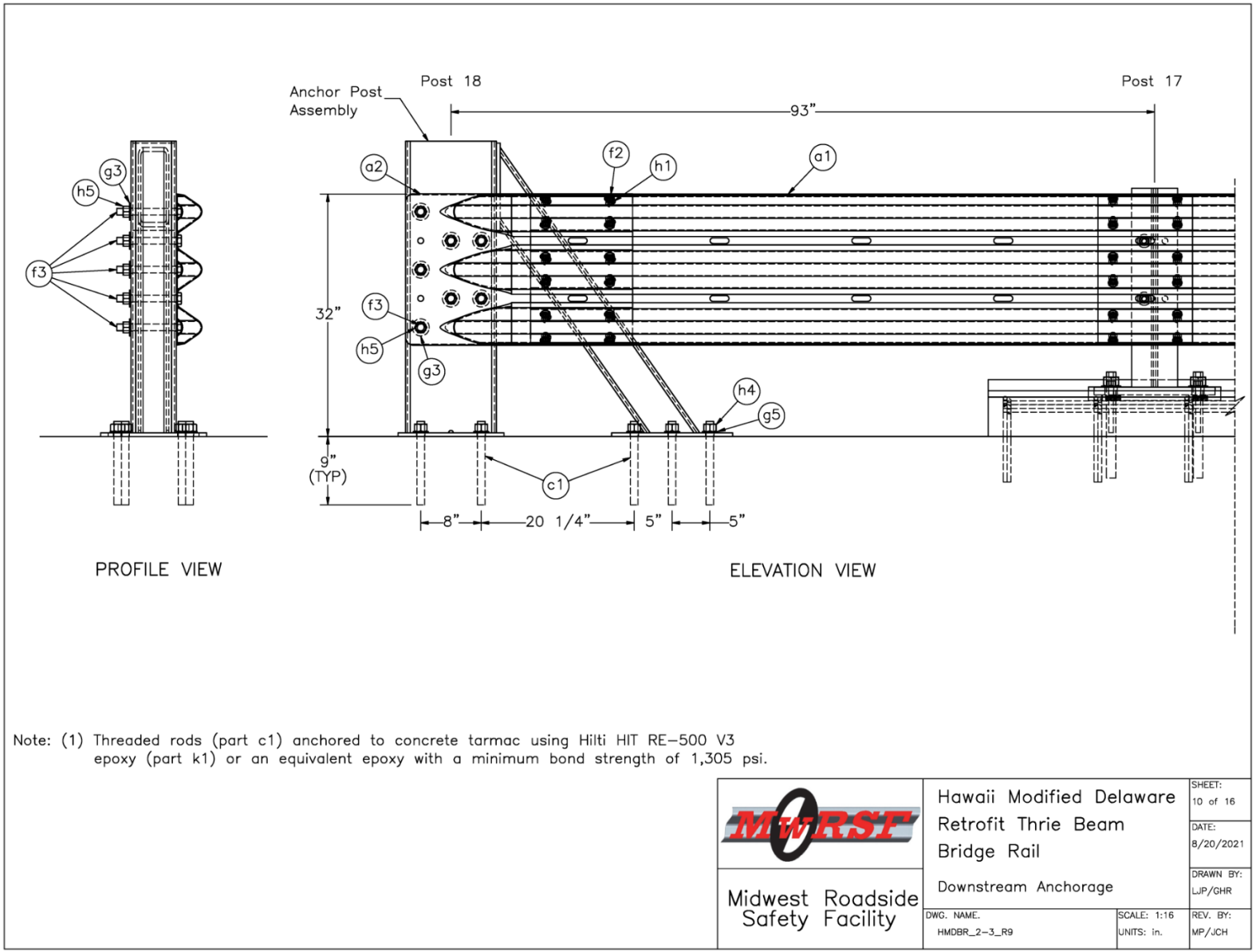


Figure 51. Downstream Anchorage, Test Nos. HMDBR-2 and HMDBR-3

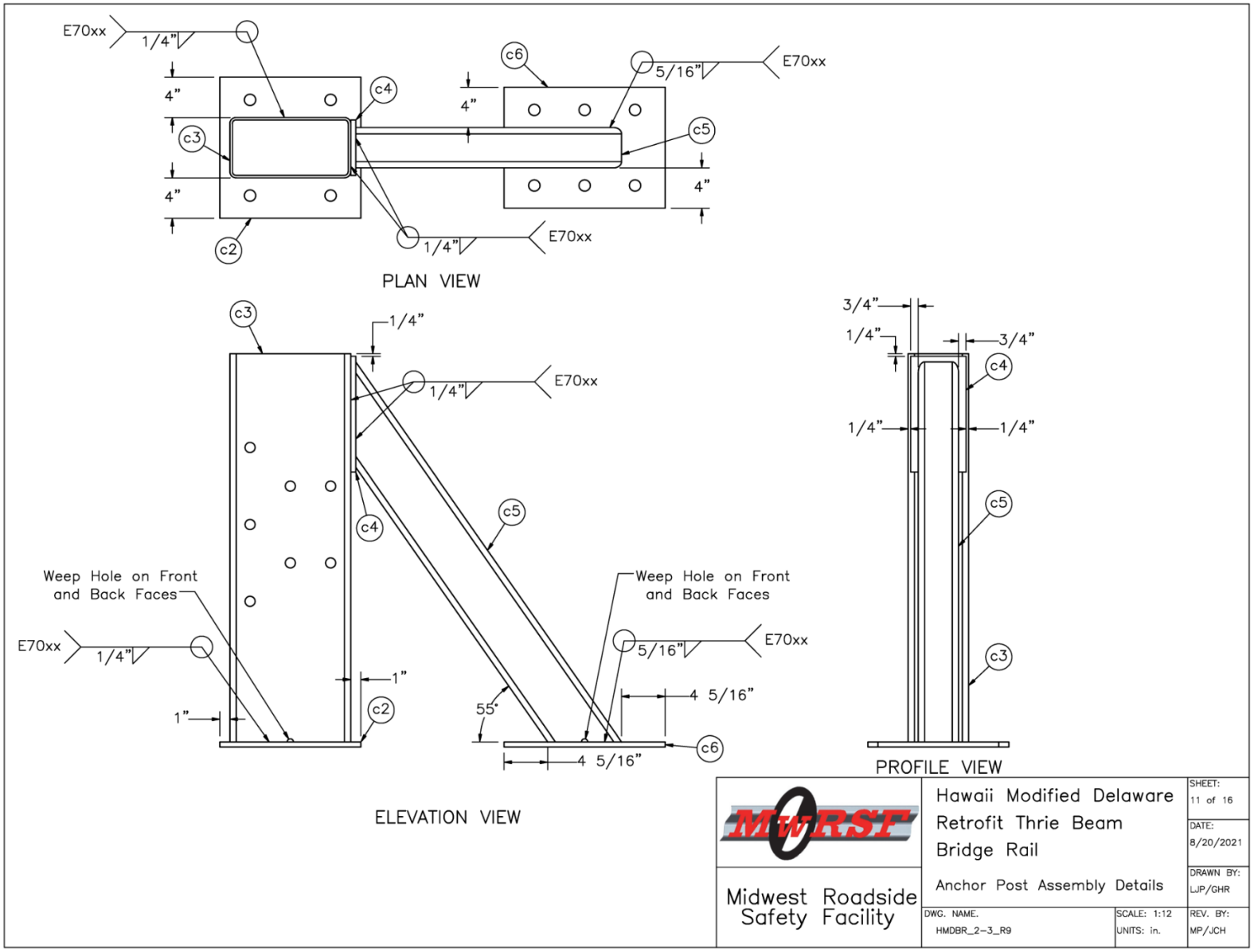


Figure 52. Anchor Post Assembly Details, Test Nos. HMDBR-2 and HMDBR-3

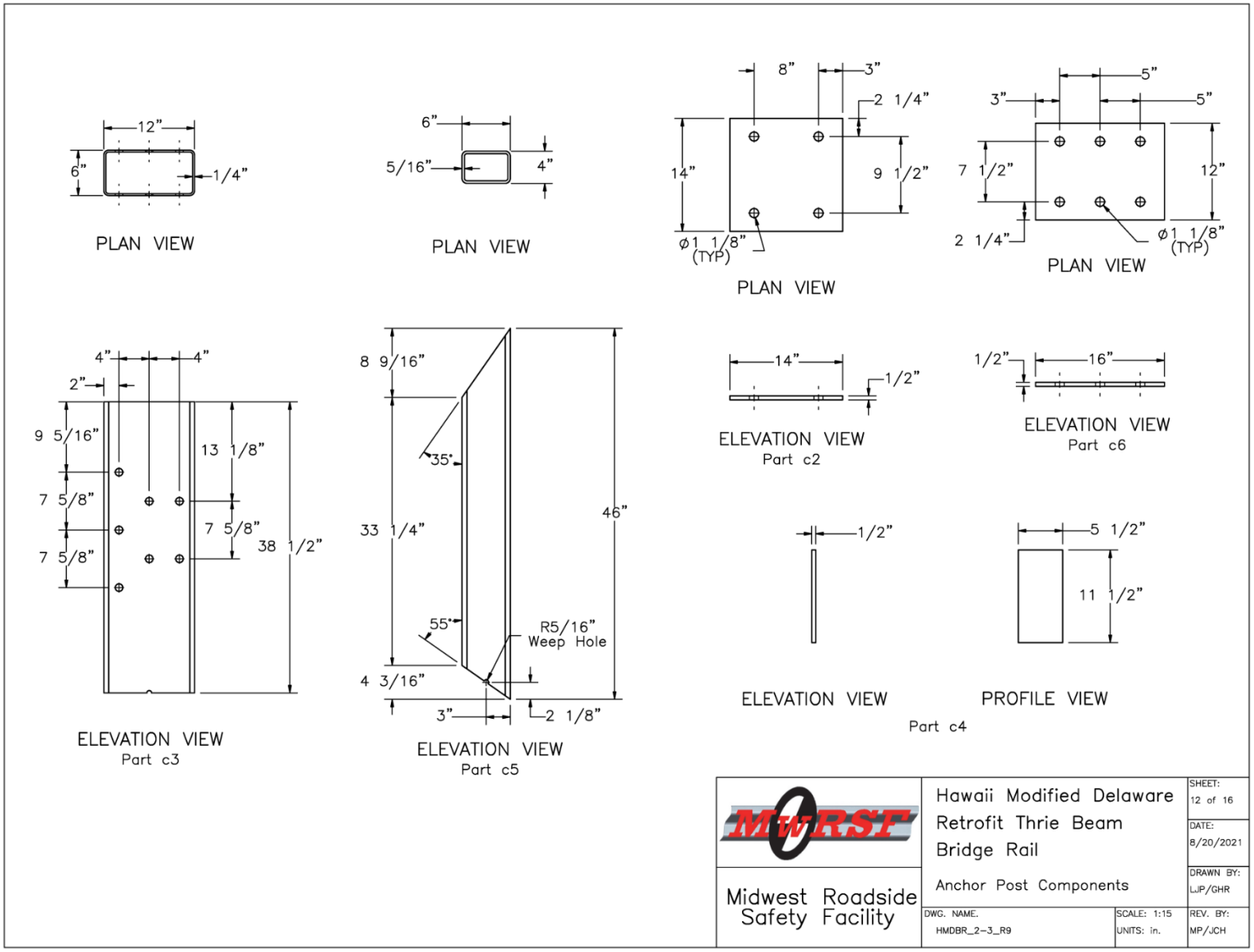


Figure 53. Anchor Post Components, Test Nos. HMDBR-2 and HMDBR-3

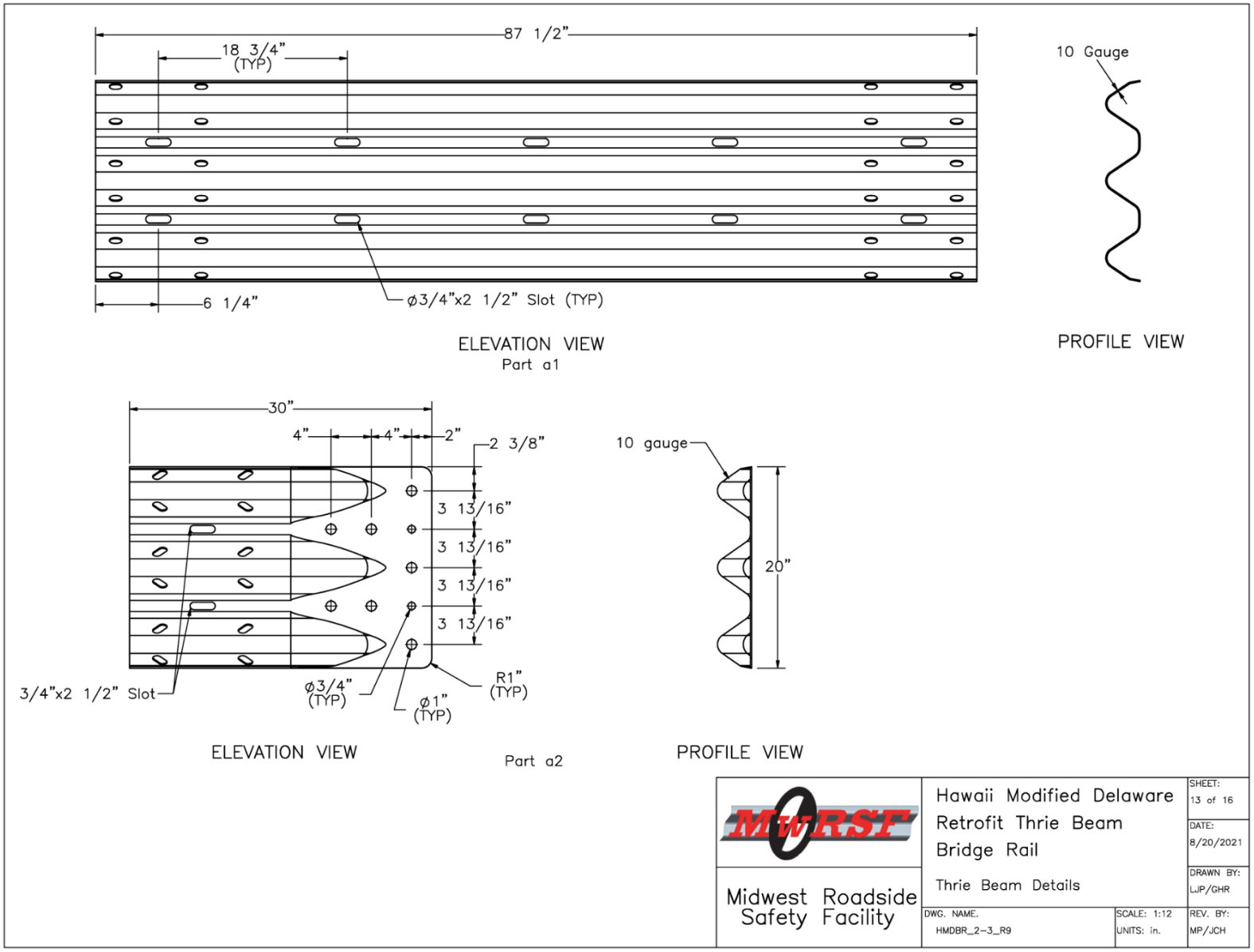


Figure 54. Thrie-Beam Details, Test Nos. HMDBR-2 and HMDBR-3

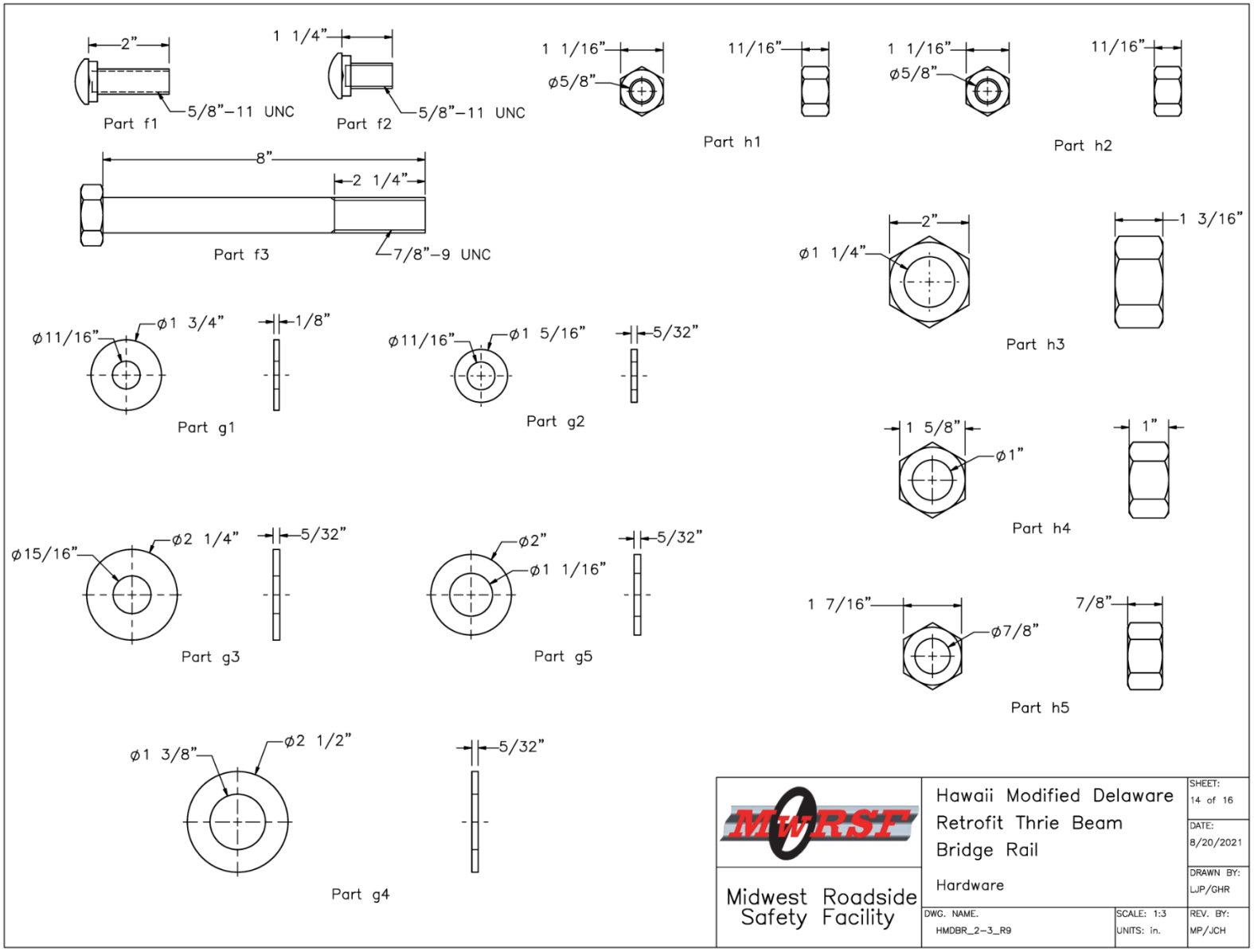


Figure 55. Hardware Details, Test Nos. HMDBR-2 and HMDBR-3

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	17	6'–3" 10–gauge Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM19a
a2	2	10–gauge Thrie Beam Terminal Connector	AASHTO M180 Min. yield strength = 50 ksi Min. tensile strength = 70 ksi	ASTM A123 or A653	RTE01b
b1	16	16"x11"x1" Base Plate	ASTM A36	ASTM A123	–
b2	32	1 1/4" Dia., 14" Long Anchor Rod	ASTM F1554–15 Grade 105, Class 2A	ASTM F2329 / F2329M–15	–
b3	32	5/8" Dia., 8" Long Anchor Rod	ASTM F1554–15 Grade 105, Class 2A	ASTM F2329 / F2329M–15	–
b4	16	W6x25, 26 1/4" Long Steel Post	ASTM A992	ASTM A123	–
c1	20	1" Dia. UNC, 11" Long Threaded Rod	ASTM A449 or A354 Gr. BC or A193 Gr. B7	ASTM A153 or B633 or B695 Class 55 or F1941 or F2329	FRR24b
c2	2	14"x14"x1/2" Steel Plate	ASTM A36 or A572 Gr. 50	ASTM A123*	–
c3	2	HSS 6"x12"x1/4" Tube, 38 1/2" Long	ASTM A500 Gr. B	ASTM A123*	–
c4	2	11 1/2"x5 1/2"x1/2" Steel Plate	ASTM A36 or A572 Gr. 50	ASTM A123*	–
c5	2	HSS 6"x4"x5/16" Tube, 46" Long	ASTM A500 Gr. B	ASTM A123*	–
c6	2	16"x12"x1/2" Steel Plate	ASTM A36 or A572 Gr. 50	ASTM A123*	–
d1	98	#4 Rebar, 31 3/4" Total Unbent Length	ASTM A615 Gr. 60	Epoxy–Coated (ASTM A775 or A934)	–
d2	3	#4 Rebar, 97' 1" Total Length, 18" Min. Lap Length	ASTM A615 Gr. 60	Epoxy–Coated (ASTM A775 or A934)	–
d3	98	#4 Rebar, 33" Total Unbent Length	ASTM A615 Gr. 60	Epoxy–Coated (ASTM A775 or A934)	–
e1	1	Reinforced Concrete	Min. f'c = 4,000 psi NE Mix 47B1S/1PF4000HW	–	–
f1	32	5/8"–11 UNC, 2" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM F2329	FBB01
f2	216	5/8"–11 UNC, 1 1/4" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM F2329	FBB01
f3	14	7/8"–9 UNC, 8" Long Heavy Hex Bolt	ASTM F3125 Gr. A325 Type 1	ASTM A153 or B695 Class 55 or F1136 Gr. 3 or F2329 or F2833 Gr. 1	FBX22b

*Component does not need to be galvanized for testing purposes.

Note: (1) Quantities listed herein are only for one system and do not include repair parts.

Midwest Roadside Safety Facility

Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail

Bill of Materials

SHEET: 15 of 16
DATE: 8/20/2021
DRAWN BY: LJP/GHR
REV. BY: MP/JCH
DWG. NAME. HMDBR_2–3_R9
SCALE: None
UNITS: in.

Figure 56. Bill of Materials, Test Nos. HMDBR-2 and HMDBR-3

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
g1	32	5/8" Dia. Plain Round Washer	ASTM F844	ASTM F2329	FWC16a
g2	192	5/8" Dia. Hardened Washer	ASTM F436	ASTM F2329	FWC16b
g3	14	7/8" Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC20a
g4	160	1 1/4" Dia. Hardened Washer	ASTM F436	ASTM F2329	FWC30b
g5	20	1" Dia. Hardened Round Washer	ASTM F436	ASTM A153 or B695 Class 55 or F1136 Gr. 3 or F2329	FWC24b
h1	248	5/8"–11 UNC Heavy Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX16b
h2	32	5/8"–11 UNC Heavy Hex Nut	ASTM A563–15 Grade DH	ASTM F2329 / F2329U–15	FNX16b
h3	32	1 1/4"–7 UNC Heavy Hex Nut	ASTM A563–15 Grade DH	ASTM F2329 / F2329U–15	FNX30b
h4	20	1" Dia. Heavy Hex Nut	ASTM A563DH or A194 Gr. 2H	ASTM A153 or B633 or B695 Class 55 or F1941 or F2329	FNX24b
h5	14	7/8" Dia. UNC Heavy Hex Nut	ASTM A563DH or ASTM A194 Gr. 2H	ASTM A153 for Class C or ASTM B695 for Class 50	FNX22b
k1	–	Hilti HIT RE–500 V3 Epoxy Adhesive	Class C, C881	–	–
k2	–	SpecChem 500 Epoxy Filler	ASTM C881 Type IV, Grade I, Class C	–	–

Midwest Roadside Safety Facility

Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail

Bill of Materials

SHEET: 16 of 16
DATE: 8/20/2021
DRAWN BY: LJP/GHR
REV. BY: MP/JCH
DWG. NAME. HMDBR_2–3_R9
SCALE: None
UNITS: in.

Figure 57. Bill of Materials, Cont., Test Nos. HMDBR-2 and HMDBR-3

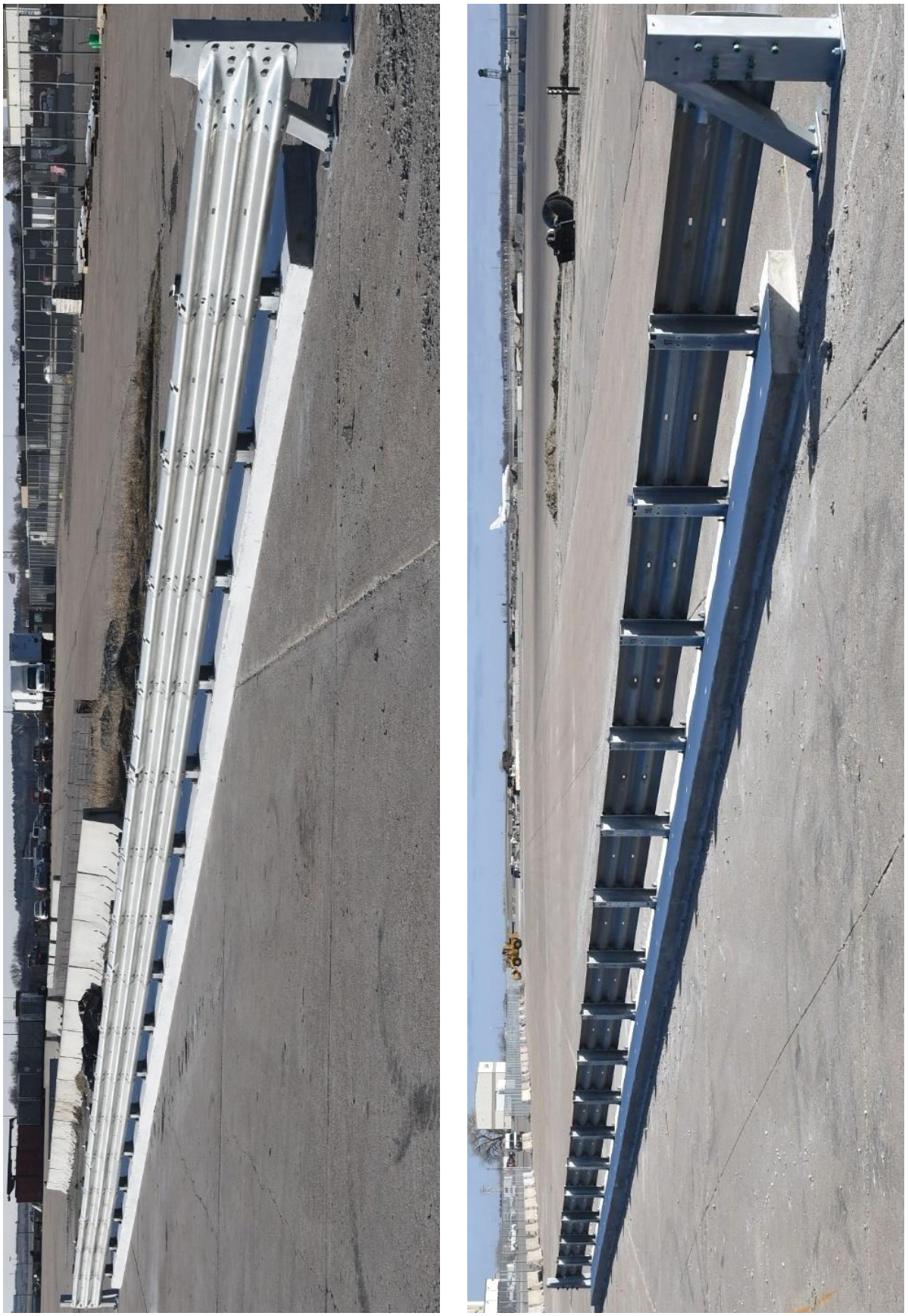


Figure 58. Test Installation, Test No. HMDBR-2

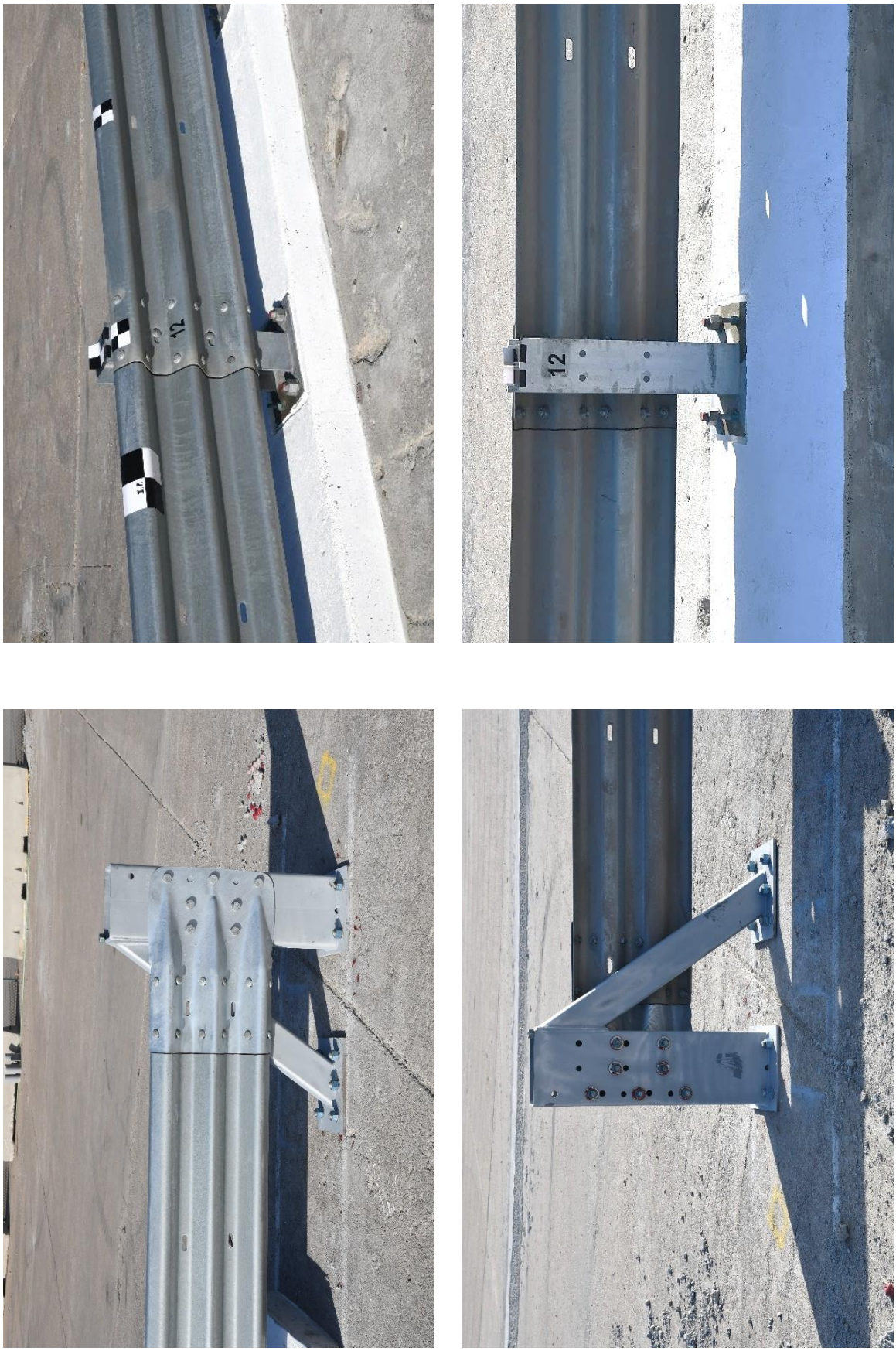


Figure 59. Test Installation, Upstream Anchor and Typical Post, Test No. HMDBR-2

Figure 60. Test Installation, Test No. HMDBR-3

Figure 61. Test Installation, Upstream Anchor and Typical Post, Test No. HMDBR-3

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 five 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 each 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 ⅜-in. diameter 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 [5] was used to steer the test vehicles. A guide flag, attached to the non-impact side 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. HMDBR-1, a 2014 Dodge Ram quad cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,104 lb, 5,001 lb, and 5,165 lb, respectively. The test vehicle is shown in Figures 62 and 63, and vehicle dimensions are shown in Figure 64.

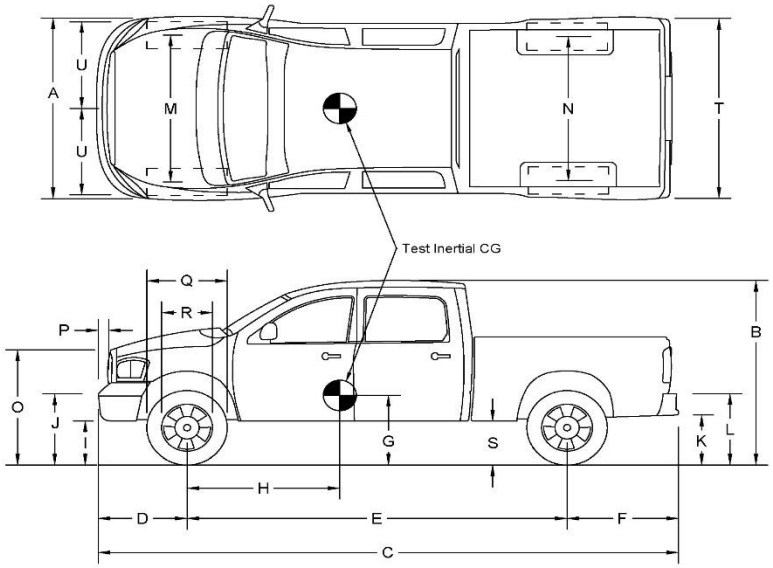
For test no. HMDBR-2, a 2016 Hyundai Accent was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,497 lb, 2,453 lb, and 2,616 lb, respectively. The test vehicle is shown in Figures 65 and 66, and vehicle dimensions are shown in Figure 67.

For test no. HMDBR-3, a 2015 Dodge Ram 1500 crew cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 4,963 lb, 5,001 lb, and 5,162 lb, respectively. The test vehicle is shown in Figures 68 and 69, and vehicle dimensions are shown in Figure 70.

Figure 62. Test Vehicle, Test No. HMDBR-1

Figure 63. Test Vehicle's Interior Floorboards and Undercarriage, Test No. HMDBR-1

Test Name:	HMDBR-1			VIN No:	1C6RRGT6ES314223
Model Year:	2014	Make:	Dodge	Model:	Ram
Tire Size:	P265/70R17	Tire Inflation Pressure:	40 psi	Odometer:	225539



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

A:	77 1/2 (1969)	B:	74 1/2 (1892)
	78±2 (1950±50)		
C:	228 1/2 (5804)	D:	40 (1016)
	237±13 (6020±325)		39±3 (1000±75)
E:	140 1/4 (3562)	F:	48 1/4 (1226)
	148±12 (3760±300)		
G:	28 7/16 (722)	H:	60 (1524)
	min: 28 (710)		63±4 (1575±100)
I:	12 1/4 (311)	J:	24 1/2 (622)
K:	21 (533)	L:	30 (762)
M:	67 7/8 (1724)	N:	67 5/8 (1718)
	67±1.5 (1700±38)		67±1.5 (1700±38)
O:	44 1/2 (1130)	P:	4 1/2 (114)
	43±4 (1100±75)		
Q:	31 (787)	R:	18 1/2 (470)
S:	15 3/8 (391)	T:	76 1/2 (1943)

U (impact width): 36 1/2 (927)

Mass Distribution - lb (kg)

Gross Static	LF	1480 (671)	RF	1481 (672)
	LR	1077 (489)	RR	1127 (511)

Wheel Center Height (Front):	15	(381)		
Wheel Center Height (Rear):	15 1/4	(387)		
Wheel Well Clearance (Front):	34 3/4	(883)		
Wheel Well Clearance (Rear):	38 1/5	(970)		
Bottom Frame Height (Front):	18 1/4	(464)		
Bottom Frame Height (Rear):	26 1/9	(663)		

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2932 (1330)	2862 (1298)	2961 (1343)
W-rear	2172 (985)	2139 (970)	2204 (1000)
W-total	5104 (2315)	5001 (2268)	5165 (2343)
		5000±110 (2270±50)	5165±110 (2343±50)

Engine Type:	Gasoline
Engine Size:	5.7L V8
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Quad Cab
Bed Length:	76"

GVWR Ratings - lb

Front	3700
Rear	3900
Total	6800

Surrogate Occupant Data

Type:	Hybrid II
Mass:	164 lb
Seat Position:	Left/Drivers

Note any damage prior to test: None

Figure 64. Vehicle Dimensions, Test No. HMDBR-1

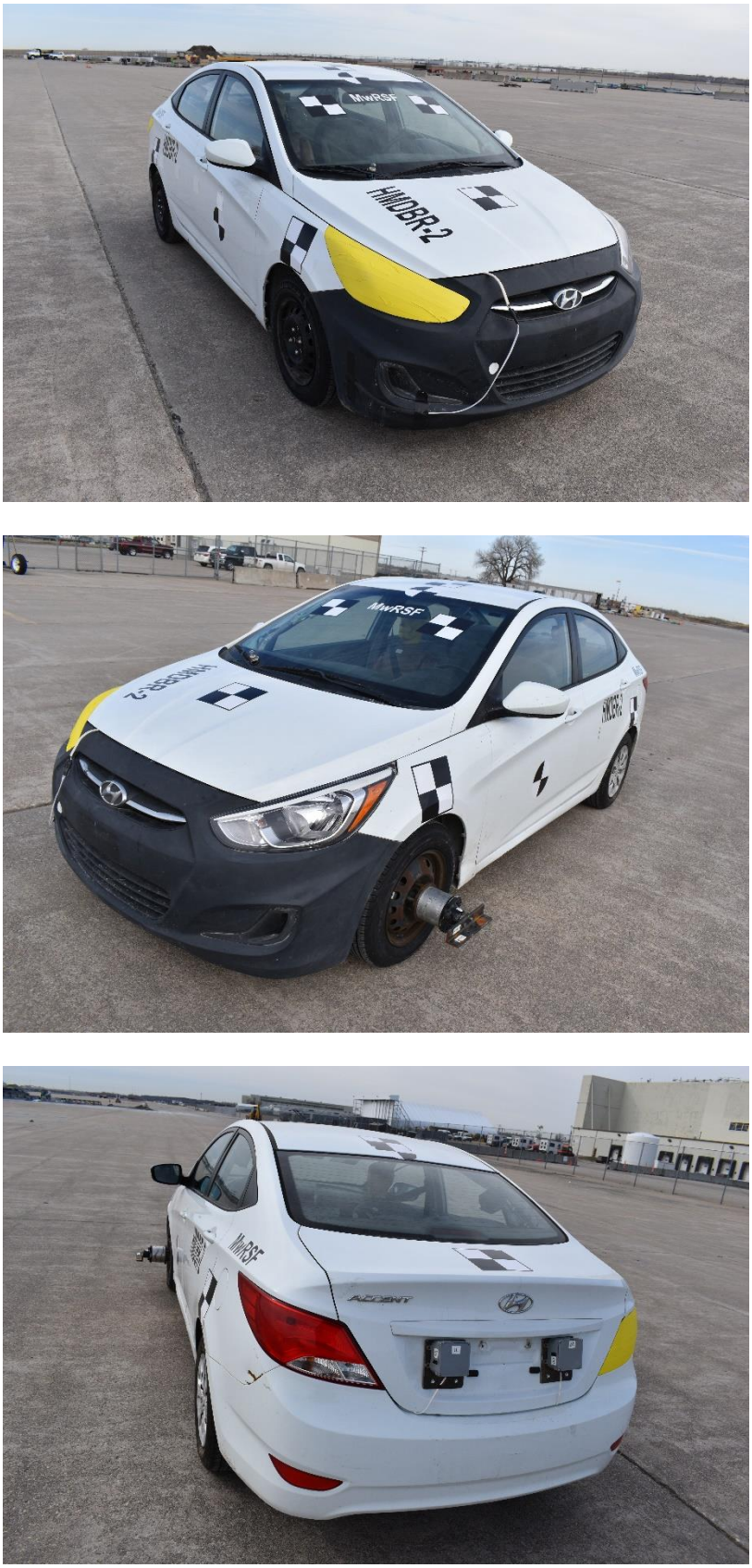


Figure 65. Test Vehicle, Test No. HMDBR-2

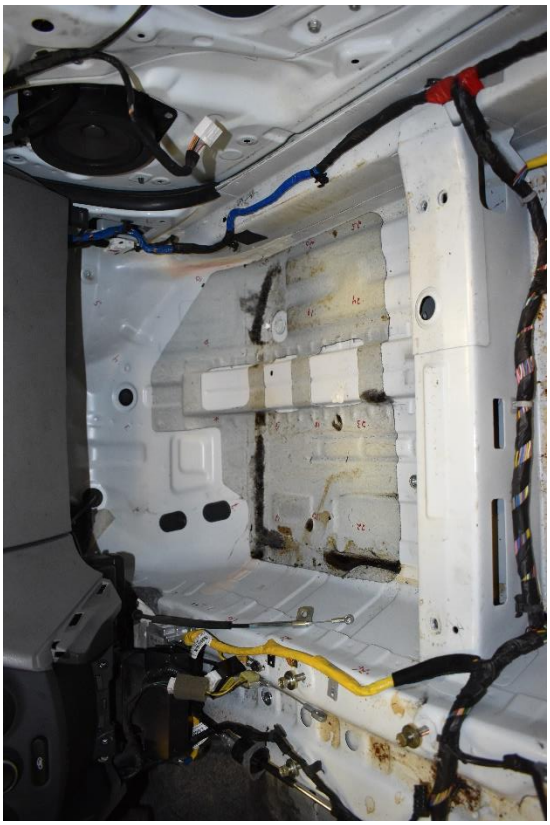
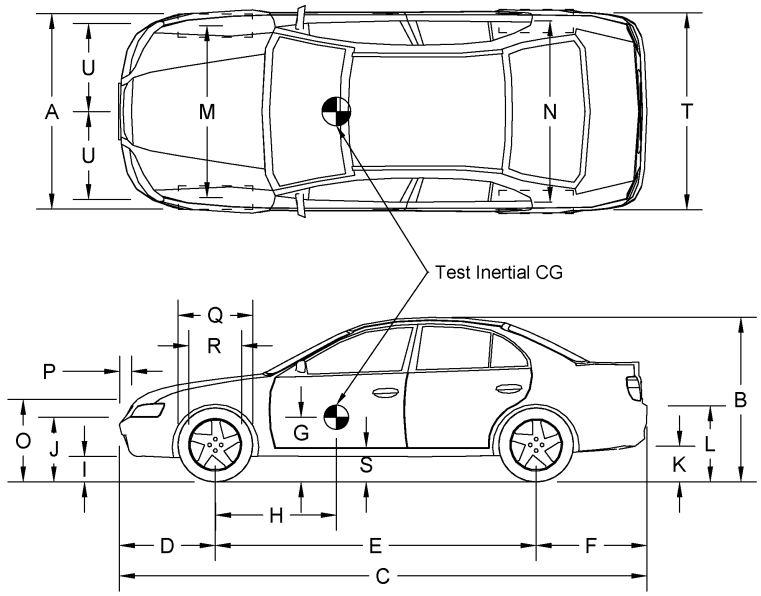



Figure 66. Test Vehicle's Interior Floorboards and Undercarriage, Test No. HMDBR-2

Test Name: HMDBR-2 **VIN No:** KMHCT4AE3GU979226

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

Tire Size: 175/70R14 **Tire Inflation Pressure:** 33 psi **Odometer:** 159468



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

A:	66 1/4 (1683)	**B:**	56 3/8 (1432)
	65±3 (1650±75)		
C:	171 3/4 (4362)	**D:**	23 7/8 (606)
	169±8 (4300±200)		35±4 (900±100)
E:	101 (2565)	**F:**	37 7/8 (962)
	98±5 (2500±125)		
G:	21 13/16 (554)	**H:**	39 1/16 (992)
			39±4 (990±100)
I:	7 (178)	**J:**	23 1/4 (591)
K:	10 1/4 (260)	**L:**	25 1/4 (641)
M:	59 (1499)	**N:**	59 1/2 (1511)
	59±2 (1498±50)		56±2 (1425±50)
O:	29 1/4 (743)	**P:**	6 1/4 (159)
	28±4 (711±100)		
Q:	23 1/2 (597)	**R:**	15 1/4 (387)
S:	10 5/8 (270)	**T:**	66 1/2 (1689)

U (impact width): 30 3/8 (772)

Mass Distribution - lb (kg)

Gross Static	**LF**	792 (359)	**RF**	803 (364)
	LR	515 (234)	**RR**	506 (230)

Weights lb (kg)	**Curb**	**Test Inertial**	**Gross Static**
W-front	1544 (700)	1505 (683)	1595 (723)
W-rear	953 (432)	948 (430)	1021 (463)
W-total	2497 (1133)	2453 (1113)	2616 (1187)
		2420±55 (1100±25)	2585±55 (1175±50)

Top of radiator core support:	29 1/2 (749)
Wheel Center Height (Front):	11 1/8 (283)
Wheel Center Height (Rear):	11 1/4 (286)
Wheel Well Clearance (Front):	24 3/4 (629)
Wheel Well Clearance (Rear):	25 (635)
Bottom Frame Height (Front):	14 /8 #######
Bottom Frame Height (Rear):	16 (406)
Engine Type:	Gasoline
Engine Size:	1.4L 4cyl
Transmission Type:	Automatic
Drive Type:	FWD

GVWR Ratings lb

Front	1874
Rear	1852
Total	3527

Surrogate Occupant Data

Type:	Hybrid II
Mass:	163 lb
Seat Position:	Right/Passenger

Note any damage prior to test: None

Figure 67. Vehicle Dimensions, Test No. HMDBR-2

Figure 68. Test Vehicle, Test No. HMDBR-3



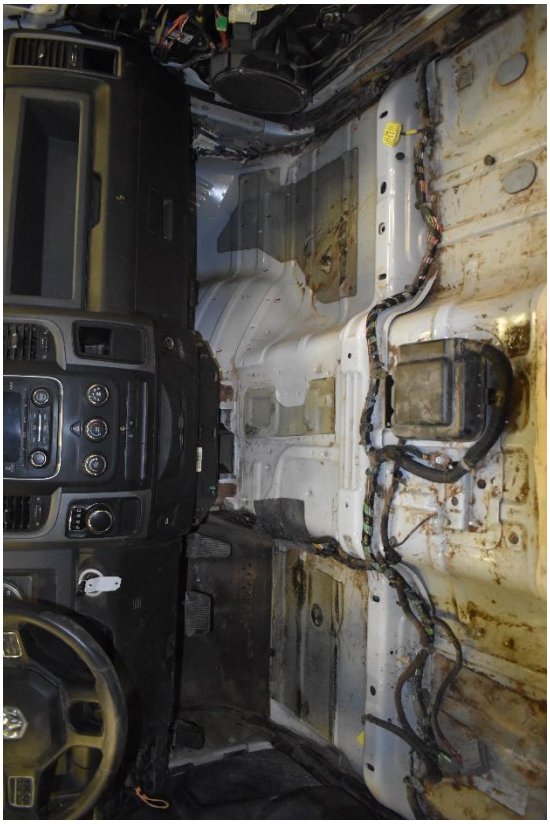
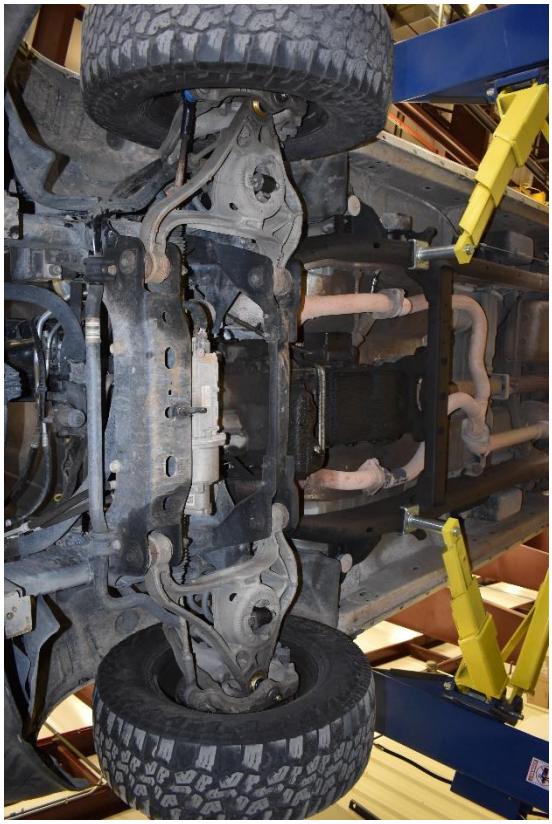
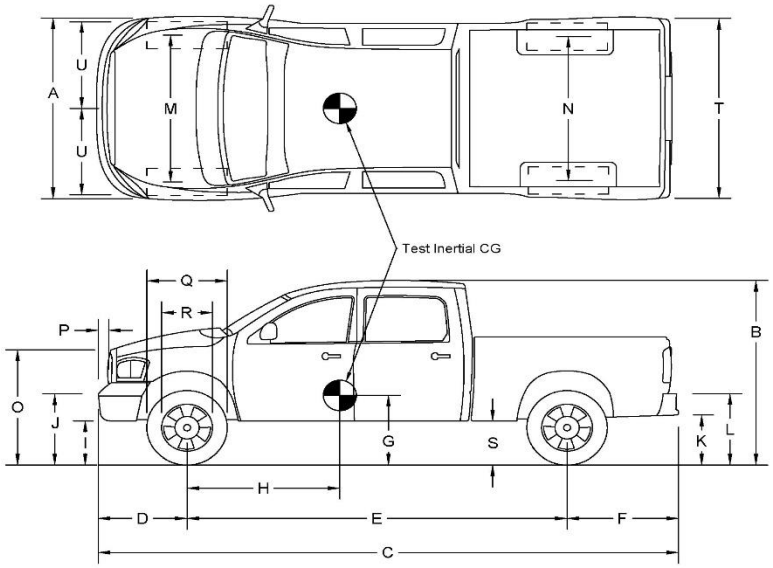



Figure 69. Test Vehicle's Interior Floorboards and Undercarriage, Test No. HMDBR-3

Test Name:	HMDBR-3			VIN No:	1C6RR6KG2FS506038
Model Year:	2015	Make:	Dodge	Model:	Ram 1500
Tire Size:	265/70R17	Tire Inflation Pressure:	40 psi	Odometer:	268247



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

A:	77 3/4 (1975)	B:	74 1/8 (1883)
	78±2 (1950±50)		
C:	229 (5817)	D:	41 1/2 (1054)
	237±13 (6020±325)		39±3 (1000±75)
E:	140 1/4 (3562)	F:	47 1/4 (1200)
	148±12 (3760±300)		
G:	28 1/16 (713)	H:	65 1/16 (1653)
	min: 28 (710)		63±4 (1575±100)
I:	13 1/2 (343)	J:	24 (610)
K:	19 1/4 (489)	L:	28 1/2 (724)
M:	68 (1727)	N:	68 (1727)
	67±1.5 (1700±38)		67±1.5 (1700±38)
O:	44 1/2 (1130)	P:	4 1/2 (114)
	43±4 (1100±75)		
Q:	30 1/2 (775)	R:	18 1/2 (470)
S:	14 3/4 (375)	T:	77 (1956)

U (impact width): 36 1/4 (921)

Mass Distribution - lb (kg)

Gross Static	LF	1419 (644)	RF	1357 (616)
	LR	1161 (527)	RR	1225 (556)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2704 (1227)	2682 (1217)	2776 (1259)
W-rear	2259 (1025)	2319 (1052)	2386 (1082)
W-total	4963 (2251)	5001 (2268)	5162 (2341)
		5000±110 (2270±50)	5165±110 (2343±50)

Wheel Center Height (Front):	15 (381)
Wheel Center Height (Rear):	15 1/4 (387)
Wheel Well Clearance (Front):	35 (889)
Wheel Well Clearance (Rear):	37 1/4 (946)
Bottom Frame Height (Front):	11 3/4 (298)
Bottom Frame Height (Rear):	12 3/4 (324)
Engine Type:	Gasoline
Engine Size:	3.6L v6
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Crew Cab
Bed Length:	67"

GVWR Ratings - lb

Front	3700
Rear	3900
Total	6800

Surrogate Occupant Data

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

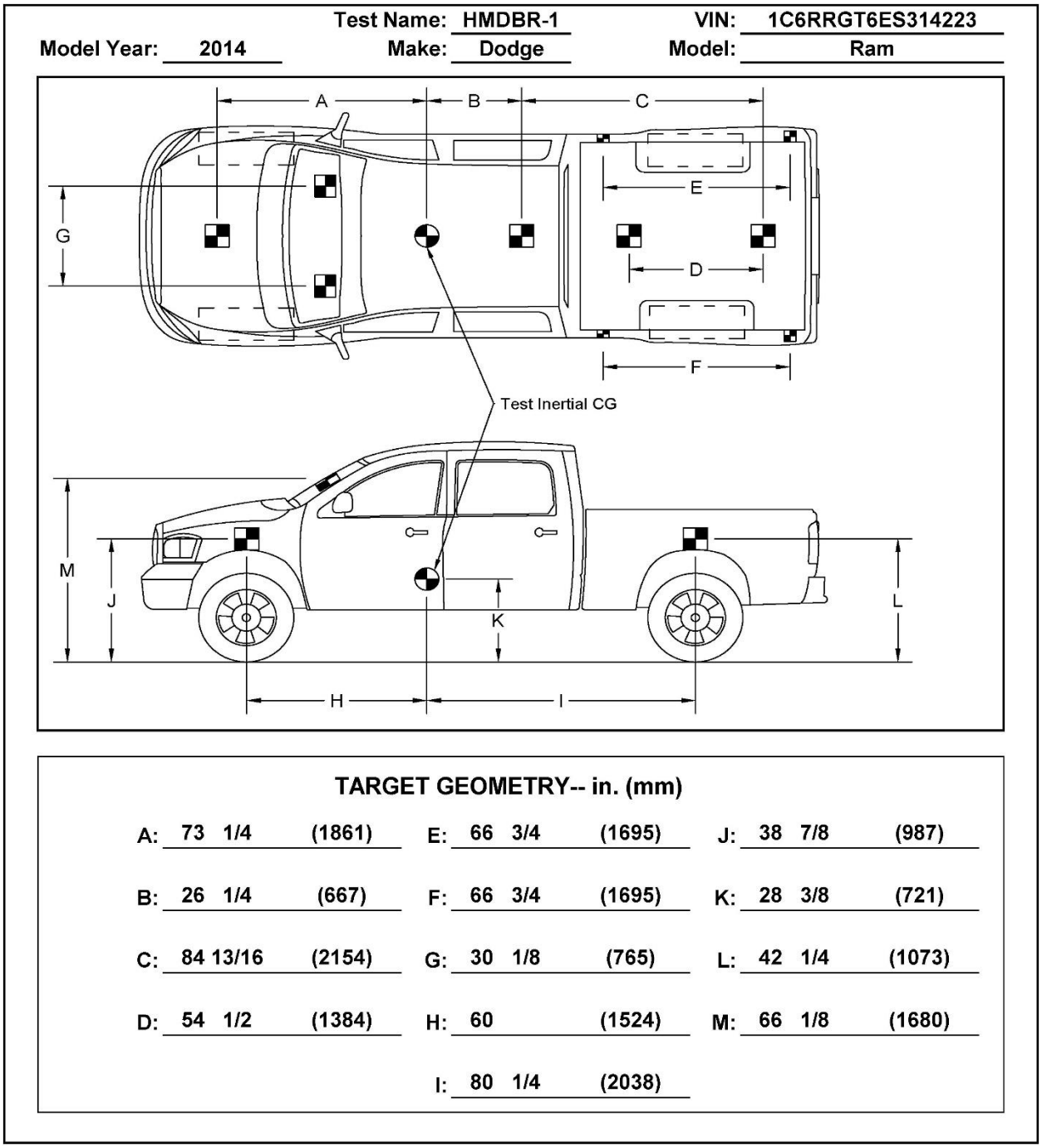
Note any damage prior to test: None

Figure 70. Vehicle Dimensions, Test No. HMDBR-3

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [6] was used to determine the vertical component of the c.g. for the 2270P vehicles. 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 vehicles were suspended successively in three positions, and the respective planes containing the c.g. were established. The intersection of these planes pinpointed the final c.g. location for the test inertial condition. The vertical component of the c.g. for the 1100C vehicle was determined utilizing a procedure published by the Society of Automotive Engineers (SAE) [7]. The location of the final c.g.'s are shown in Figures 64, 67, and 70. Data used to calculate the location of the c.g. and ballast information are shown in Appendix D.

Square, black-and-white, checkered targets were placed on the vehicles, as shown in Figures 71 through 73, to serve as a reference in the high-speed digital video and aid in the video analysis. Round, checkered targets were placed at the c.g. on the left-side door, the right-side door, and the roof of the vehicles.

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

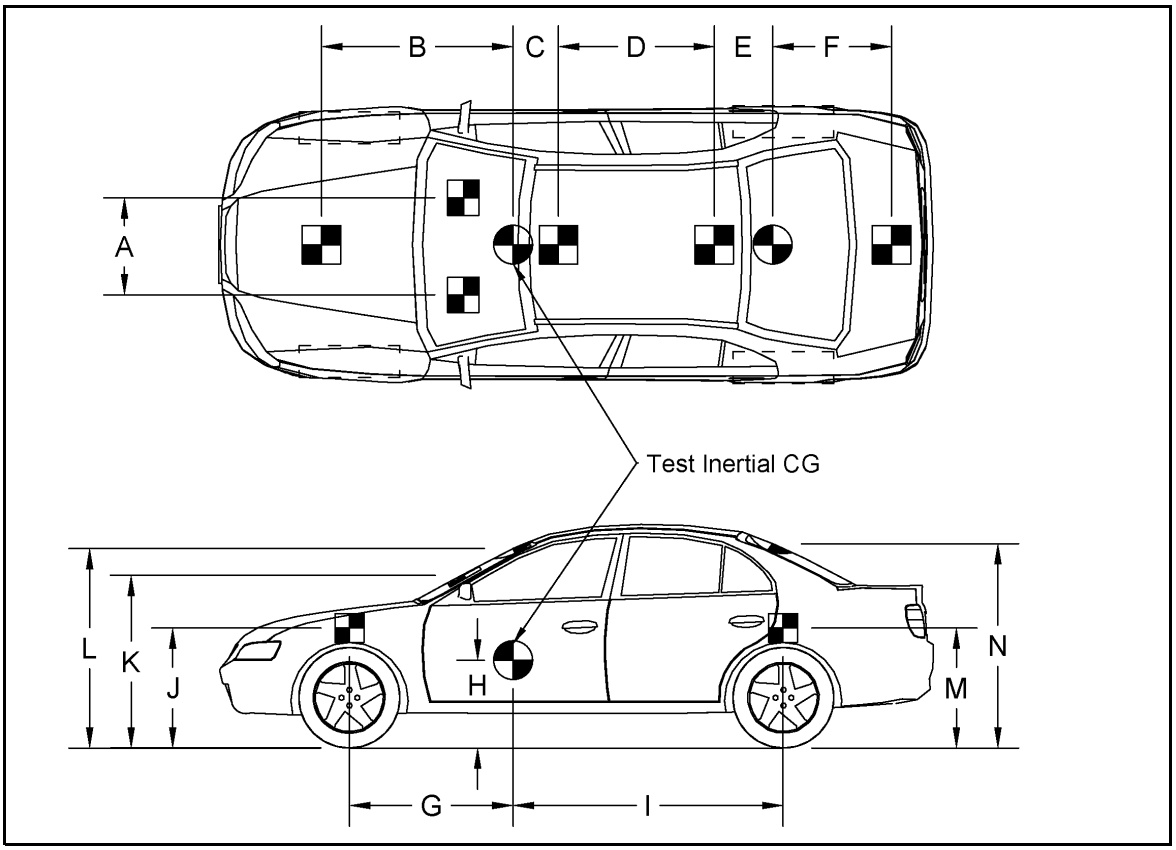


TARGET GEOMETRY-- in. (mm)

A:	73 1/4	(1861)	E:	66 3/4	(1695)	J:	38 7/8	(987)
B:	26 1/4	(667)	F:	66 3/4	(1695)	K:	28 3/8	(721)
C:	84 13/16	(2154)	G:	30 1/8	(765)	L:	42 1/4	(1073)
D:	54 1/2	(1384)	H:	60	(1524)	M:	66 1/8	(1680)
			I:	80 1/4	(2038)			

Figure 71. Target Geometry, Test No. HMDBR-1

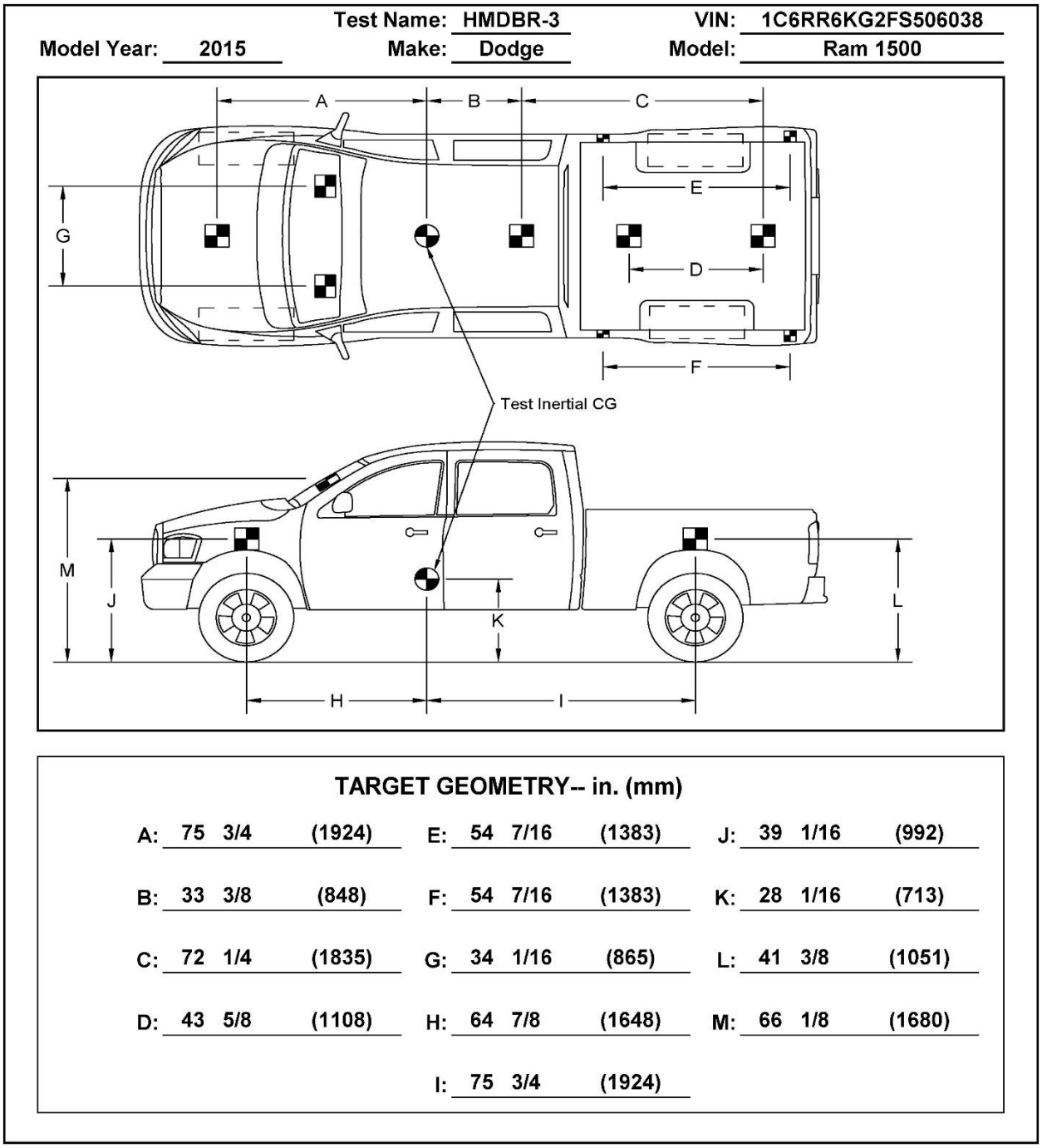
Test Name: HMDBR-2 **VIN:** KMHCT4AE3GU979226
Model Year: 2016 **Make:** Hyundai **Model:** Accent



TARGET GEOMETRY-- in. (mm)

A:	27 3/8	(695)	**F:**	34 7/8	(886)	**K:**	47 7/8	(1216)
						Windshield Target		
B:	47 3/4	(1213)	**G:**	39	(991)	**L:**	53 7/16	(1357)
						Front round CG target		
C:	9 11/16	(246)	**H:**	21 5/8	(549)	**M:**	28 13/16	(732)
D:	38 5/16	(973)	**I:**	62 1/16	(1576)	**N:**	53 7/16	(1357)
						Rear Round target		
E:	6	(152)	**J:**	28 9/16	(725)			

Figure 72. Target Geometry, Test No. HMDBR-2



TARGET GEOMETRY-- in. (mm)

A:	75 3/4	(1924)	E:	54 7/16	(1383)	J:	39 1/16	(992)
B:	33 3/8	(848)	F:	54 7/16	(1383)	K:	28 1/16	(713)
C:	72 1/4	(1835)	G:	34 1/16	(865)	L:	41 3/8	(1051)
D:	43 5/8	(1108)	H:	64 7/8	(1648)	M:	66 1/8	(1680)
			I:	75 3/4	(1924)			

Figure 73. Target Geometry, Test No. HMDBR-3

5.4 Simulated Occupant

In each test, a Hybrid II 50th-Percentile, Adult Male Dummy equipped with footwear was placed the test vehicle with the seat belt fastened. The simulated occupant was positioned in the impact-side front seat, which was the left-front seat for test no. HMDBR-1 and the right-front seat for test nos. HMDBR-2 and HMDBR-3. The final simulated occupant weights were 164 lb, 163 lb, and 161 lb in test nos. HMDBR-1 through HMDBR-3, respectively. As recommended by MASH 2016, the simulated occupant weight was not included in calculating the c.g. location.

5.5 Data Acquisition Systems

5.5.1 Accelerometers

In each test, two environmental shock and vibration sensor/recorder systems mounted near the c.g. of the test vehicle were used to measure the accelerations in the longitudinal, lateral, and vertical directions. The electronic accelerometer data obtained in dynamic testing was filtered using the SAE Class 60 and the SAE Class 180 Butterworth filter conforming to the SAE J211/1 specifications [8].

The two systems, the SLICE-1 and SLICE-2 units, were modular data acquisition systems manufactured by Diversified Technical Systems, Inc. of Seal Beach, California. The SLICE-2 unit was designated as the primary system for test nos. HMDBR-1 and HMDBR-3, and the SLICE-1 unit was designated as the primary system for test no. HMDBR-2. The acceleration sensors were mounted inside the bodies of custom-built, SLICE 6DX event data recorders and recorded data at 10,000 Hz to the onboard microprocessor. Each SLICE 6DX was configured with 7 GB of non-volatile flash memory, a range of ±500 g's, a sample rate of 10,000 Hz, and a 1,650 Hz (CFC 1000) anti-aliasing filter. The "SLICEWare" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

5.5.2 Rate Transducers

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

5.5.3 Retroreflective Optic Speed Trap

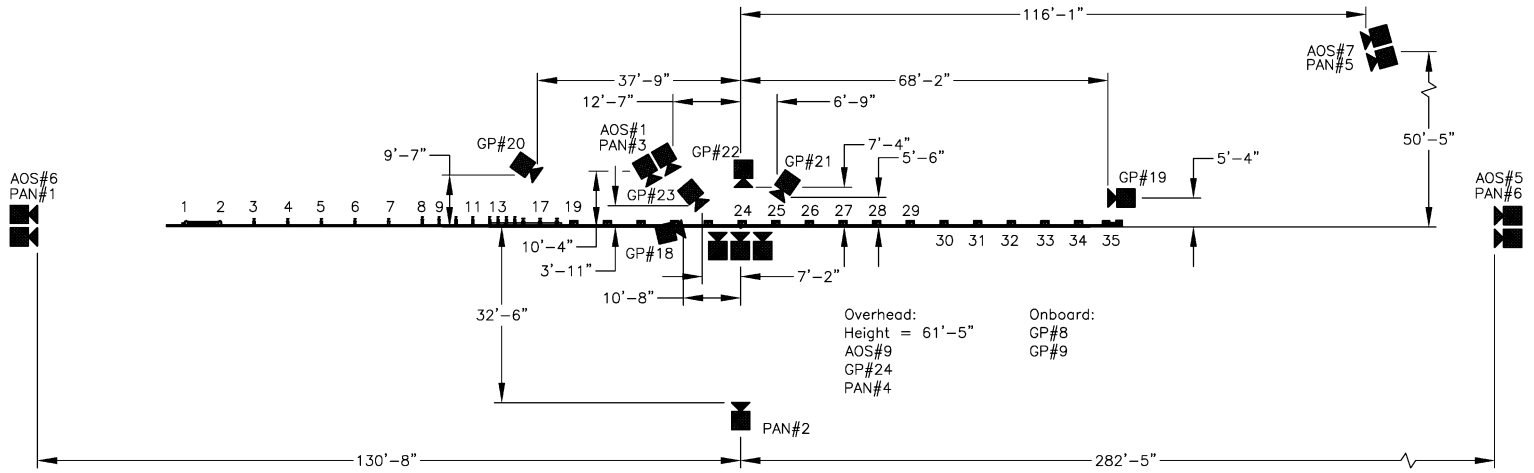
A retroreflective optic speed trap was used to determine the speed of the test vehicles before impact. Five retroreflective targets, spaced at approximately 18-in. intervals, were applied to the side of each vehicle. When the emitted beam of light was reflected by the targets and returned to the Emitter/Receiver, a signal was sent to the data acquisition computer, recording at 10,000 Hz, as well as the external LED box activating the LED flashes. The speed was then calculated using the spacing between the retroreflective targets and the time between the signals. LED lights and

high-speed digital video analysis are used as a backup if vehicle speeds cannot be determined from the electronic data.

5.5.4 Digital Photography

Five AOS high-speed digital video cameras, nine GoPro digital video cameras, and six Panasonic digital video cameras were utilized to film test no. HMDBR-1. Six AOS high-speed digital video cameras, six GoPro digital video cameras, and six Panasonic digital video cameras were utilized to film test no. HMDBR-2. Six AOS high-speed digital video cameras, five GoPro digital video cameras, and four Panasonic digital video cameras were utilized to film test no. HMDBR-3. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figures 74 through 76. Due to technical difficulties, one GoPro camera in test nos. HMDBR-1 and HMDBR-3 and two GoPro cameras in test no. HMDBR-2 did not capture the impact event.

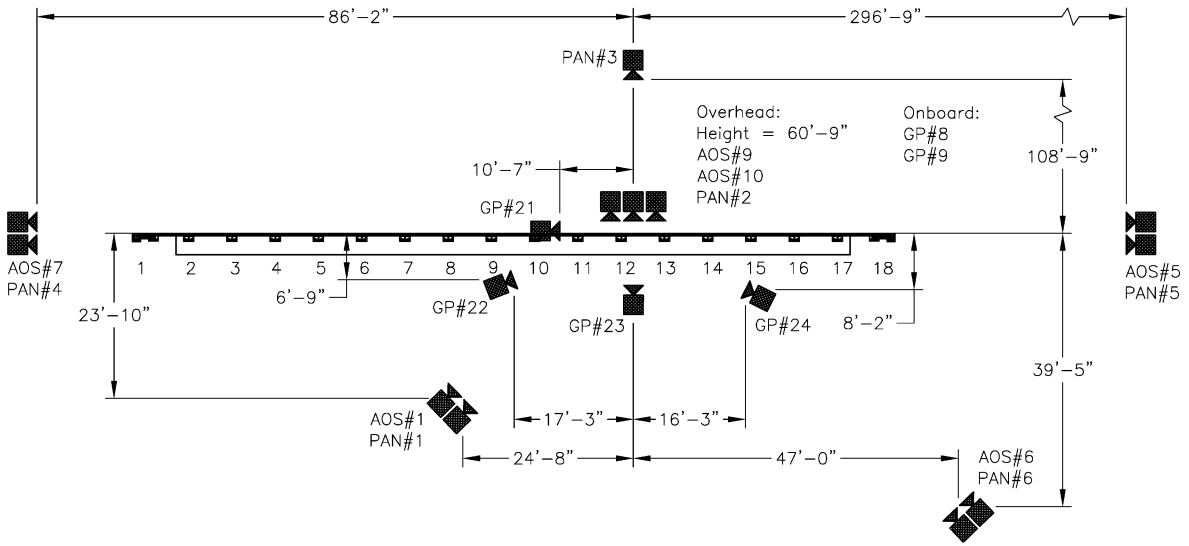
The high-speed videos were analyzed using TEMA Motion and Redlake MotionScope software programs. Actual camera speed and camera divergence factors were considered in the analysis of the high-speed videos. A digital still camera was also used to document pre- and post-test conditions for all tests.



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-1	AOS Vitcam CTM	500	Kowa 25mm Fixed	–
AOS-5	AOS X-PRI Gigabit	500	100mm Fixed	–
AOS-6	AOS X-PRI Gigabit	500	Fujinon 75mm Fixed	–
AOS-7	AOS X-PRI Gigabit	500	Fujinon 75mm Fixed	–
AOS-9	AOS TRI-VIT	1000	Kowa 12mm Fixed	–
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-18*	GoPro Hero 6	240		
GP-19	GoPro Hero 6	240		
GP-20	GoPro Hero 6	240		
GP-21	GoPro Hero 6	240		
GP-22	GoPro Hero 7	240		
GP-23	GoPro Hero 7	240		
GP-24	GoPro Hero 7	240		
PAN-1	Panasonic HC-V770	120		
PAN-2	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.

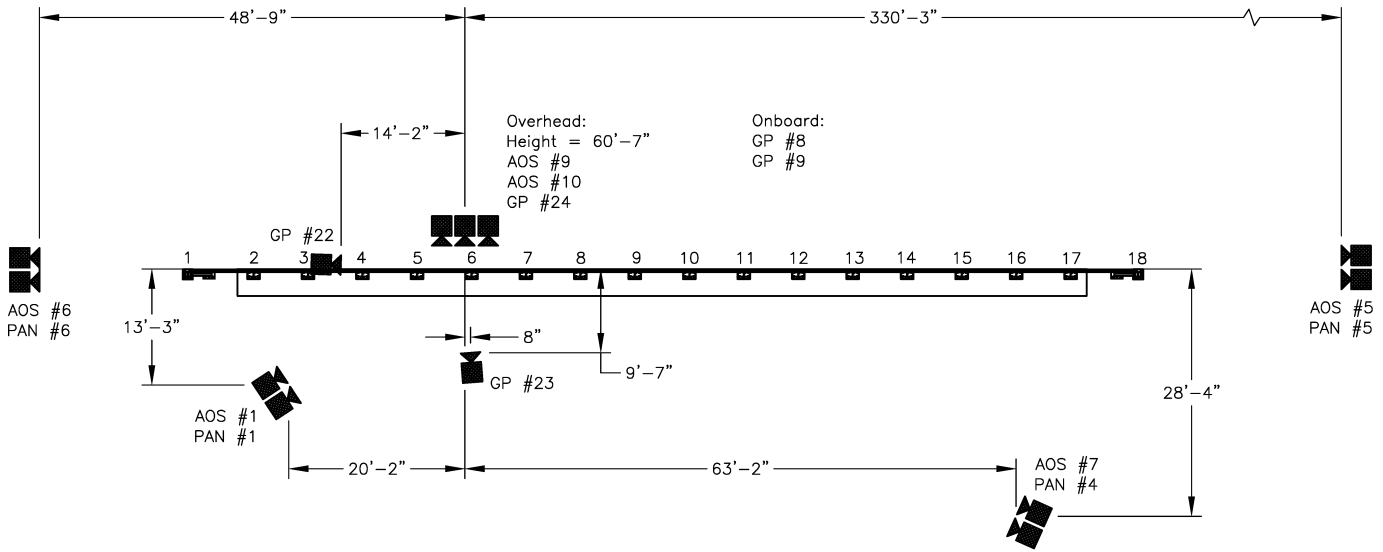
Figure 74. Camera Locations, Speeds, and Lens Settings, Test No. HMDBR-1



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-1	AOS Vitcam CTM	500	Nikon 28-70	50
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 50mm Fixed	–
AOS-9	AOS TRI-VIT	1000	Kowa 12mm Fixed	–
AOS-10	AOS TRI-VIT	1000	100mm Fixed	–
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-21	GoPro Hero 6	240		
GP-22*	GoPro Hero 7	240		
GP-23*	GoPro Hero 7	240		
GP-24	GoPro Hero 7	240		
PAN-1	Panasonic HC-V770	120		
PAN-2	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 75. Camera Locations, Speeds, and Lens Settings, Test No. HMDBR-2



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-1	AOS Vitcam CTM	500	Kowa 25mm Fixed	–
AOS-5	AOS X-PRI Gigabit	500	100mm Fixed	–
AOS-6	AOS X-PRI Gigabit	500	Fujinon 35mm Fixed	–
AOS-7	AOS X-PRI Gigabit	500	Fujinon 50mm Fixed	–
AOS-9	AOS TRI-VIT	1000	Kowa 12mm Fixed	–
AOS-10	AOS TRI-VIT	1000	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		
GP-24	GoPro Hero 7	240		
PAN-1	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 76. Camera Locations, Speeds, and Lens Settings, Test No. HMDBR-3

6 FULL-SCALE CRASH TEST NO. HMDBR-1

6.1 Weather Conditions

Test no. HMDBR-1 was conducted on December 18, 2020 at approximately 3:15 p.m. The weather conditions as reported by the National Oceanic and Atmospheric Administration (station 14939/KLNK) are shown in Table 3.

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

Temperature	47°F
Humidity	54%
Wind Speed	14 mph
Wind Direction	290° from True North
Sky Conditions	Clear
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.49 in.

6.2 Test Description

Initial vehicle impact was to occur 78 in. upstream from the centerline of post no. 25, as shown in Figure 77, which was selected using the CIP plots found in Figure 2-11 of MASH 2016 to maximize probability of vehicle snag as well as structural loading of the bridge rail. The 5,001-lb quad cab pickup truck impacted the Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail at a speed of 63.1 mph and an angle of 25.5 degrees. The actual point of impact was 2.9 in. downstream from the targeted impact location. The vehicle was captured and redirected by the bridge rail. During the redirection of the vehicle, the left-front fender and left-front wheel snagged on the bridge rail (post no. 25). The snag was sufficient to push the left-front wheel backward, which resulted in toe pan area deformation. However, the snag of the vehicle components did not pose a risk to the vehicle occupant compartment, nor did it pose a hazard due to the velocity change or deceleration of the vehicle.

The vehicle came to rest 141 ft – 3 in. downstream from impact and 39 ft – 3 in. laterally in front of the barrier after brakes were applied. Impact Severity (I.S.) is an additional limiting condition required in MASH 2016. The measured I.S. of test no. HMDBR-1 was 123.7 kip-ft, which fell into the acceptable range of greater than or equal to 106 kip-ft, as defined in MASH 2016 for test designation no. 3-11.

A detailed description of the sequential impact events is contained in Table 4. Sequential photographs are shown in Figures 78 and 79. Documentary photographs of the crash test are shown in Figures 80 and 81. The vehicle trajectory and final position are shown in Figure 82.

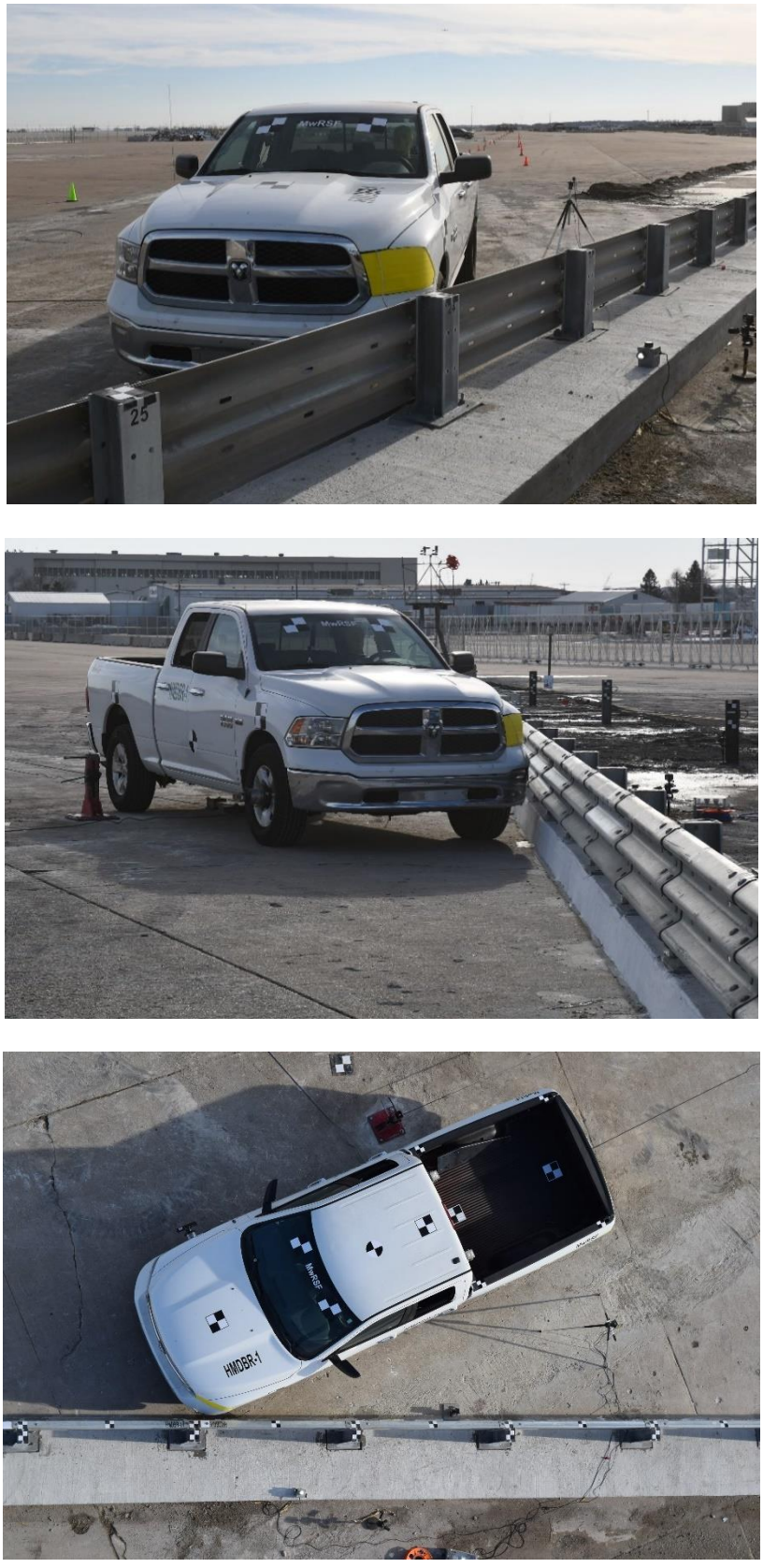


Figure 77. Target Impact Location, Test No. HMDBR-1

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

Time sec	Event
0.000	Vehicle's front bumper contacted rail 75.1 in. upstream from post no. 25.
0.002	Vehicle's front bumper deformed, and vehicle's left fender contacted rail between post nos. 24 and 25.
0.004	Vehicle's left fender deformed, and vehicle's left headlight contacted rail between post nos. 24 and 25.
0.008	Vehicle's left headlight deformed.
0.010	Vehicle's left-front tire contacted rail between post nos. 24 and 25.
0.018	Post nos. 24 and 25 deflected backward.
0.020	Vehicle's hood deformed, and vehicle's grille contacted rail. Vehicle's grille deformed.
0.026	Vehicle yawed away from system.
0.030	Vehicle's left headlight shattered. Vehicle rolled toward system.
0.036	Vehicle's left-front tire deflated.
0.040	Vehicle pitched upward.
0.044	Vehicle's left-front door contacted rail and deformed.
0.046	Vehicle's grille became disengaged.
0.048	Top of vehicle’s left-front door deformed.
0.051	Vehicle's roof deformed.
0.056	Concrete sidewalk at post no. 25 spalled on front side.
0.064	Vehicle's right headlight deformed, and vehicle's left headlight contacted post no. 25.
0.086	Post no. 25 bent backward.
0.090	Post no. 26 deflected backward.
0.120	Vehicle's right-front tire became airborne.
0.124	Vehicle's left fender contacted post no. 26, and vehicle's right-rear tire became airborne.
0.126	Vehicle's windshield cracked due to vehicle’s impact with barrier.
0.130	Vehicle's left-rear door contacted rail and deformed.
0.186	Vehicle's left quarter panel contacted rail and deformed.
0.196	Vehicle's left-rear tire contacted rail.
0.206	Post no. 27 slightly deflected backward.
0.207	Vehicle was parallel to system at a speed of 47.0 mph.
0.210	Vehicle's rear bumper and left taillight contacted rail, and vehicle's rear bumper deformed.
0.218	Vehicle's left-rear tire deflated.
0.224	Vehicle pitched downward, and vehicle’s tailgate deformed.
0.284	Vehicle's left taillight disengaged.
0.354	Vehicle's left A-pillar deformed.

Table 5. Sequential Description of Impact Events, Test No. HMDBR-1, Cont.

Time sec	Event
0.392	Vehicle's left-rear tire became airborne, and vehicle exited system at a speed of 46.8 mph and at angle of 5.9 degrees.
0.412	Vehicle's left-front wheel contacted ground and deformed.
0.728	Vehicle rolled away from system.
0.972	Vehicle's left-rear wheel contacted ground and deformed.
1.000	System came to a rest.
1.158	Vehicle's right headlight disengaged.
1.184	Vehicle's right-rear tire regained contact with ground.
1.210	Vehicle's right-front tire regained contact with ground.
1.238	Vehicle rolled toward system.
1.286	Vehicle pitched downward, and vehicle's right-rear tire became airborne.
1.867	Vehicle's right-rear tire regained contact with ground.
4.042	Vehicle came to rest 136 ft – 6 in. downstream from impact.

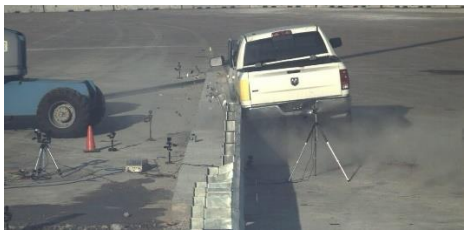

0.000 sec


0.000 sec

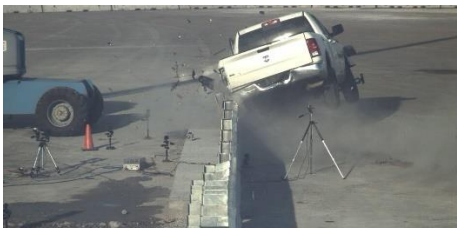

0.100 sec


0.100 sec


0.200 sec


0.200 sec


0.300 sec


0.300 sec


0.400 sec

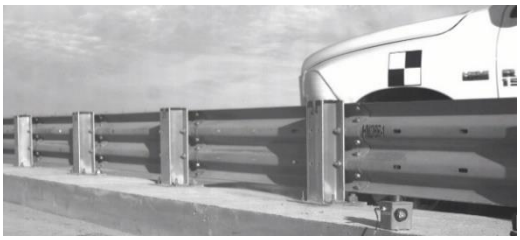

0.400 sec


0.500 sec


0.500 sec

Figure 78. Sequential Photographs, Test No. HMDBR-1


0.000 sec


0.000 sec


0.100 sec

0.100 sec

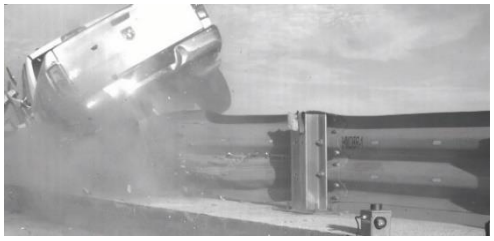

0.200 sec

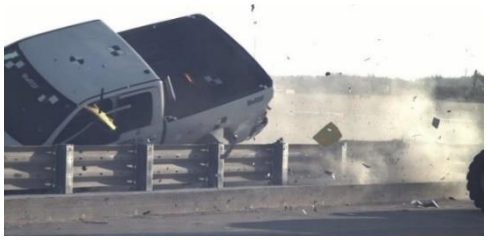
0.200 sec


0.300 sec


0.300 sec


0.400 sec


0.400 sec


0.500 sec


0.500 sec

Figure 79. Sequential Photographs, Test No. HMDBR-1

Figure 80. Documentary Photographs, Test No. HMDBR-1

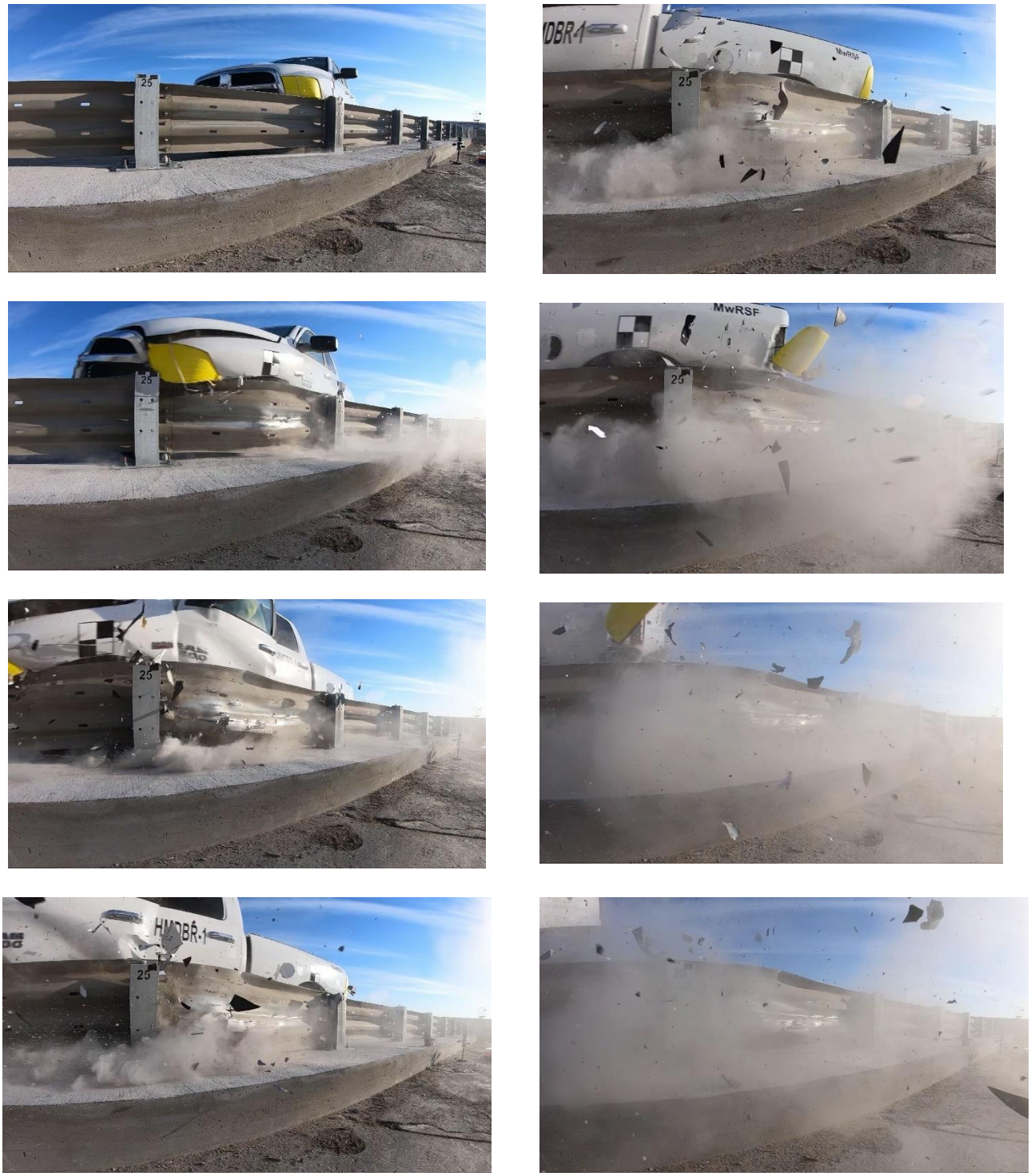


Figure 81. Documentary Photographs, Test No. HMDBR-1

Figure 82. Vehicle Final Position and Trajectory Marks, Test No. HMDBR-1

6.3 Barrier Damage

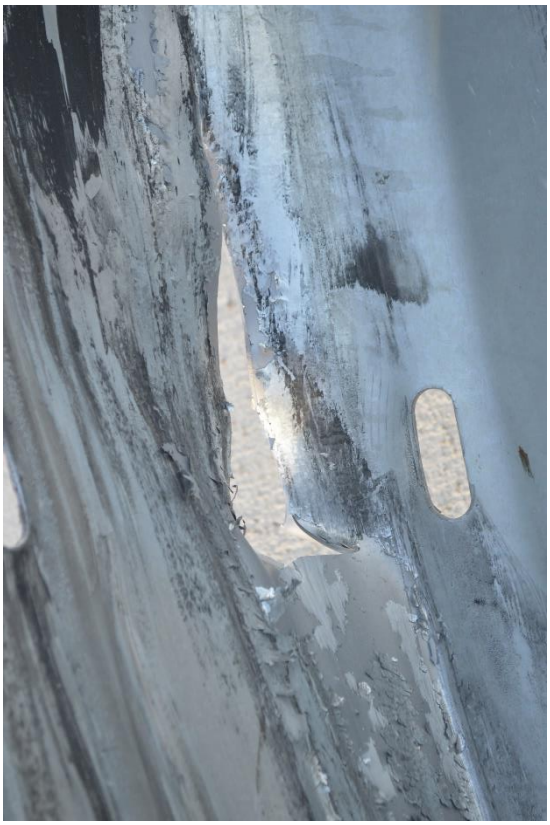
Damage to the barrier was moderate, as shown in Figures 83 through 85. Barrier damage was largely concentrated between post nos. 24 and 26 and consisted of contact marks, concrete spalling, anchor bolt pullout, and thrie-beam rail tearing. The length of vehicle contact along the barrier was approximately 15 ft – 1¾ in. and began slightly upstream from post no. 24.

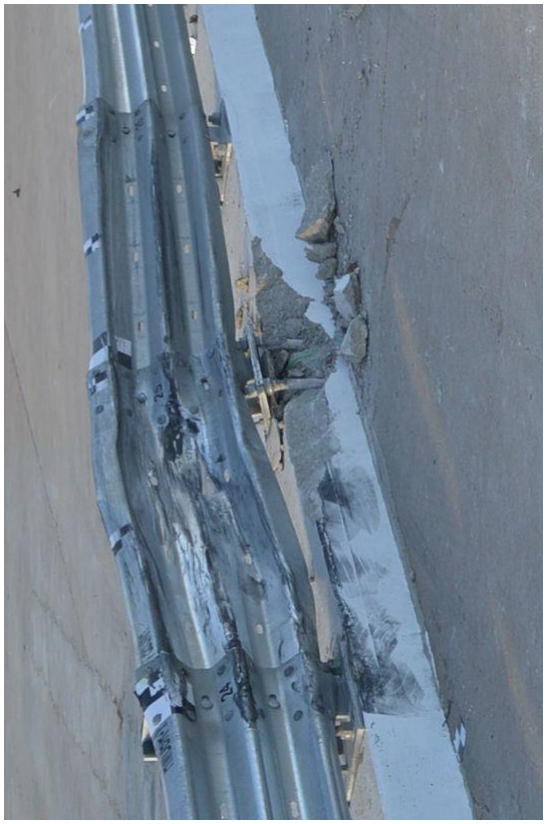
Concrete breakout and anchor rod pullout occurred at post no. 25. Concrete spalling was observed along 76½ in. of the traffic face of the sidewalk, centered about post no. 25. The concrete cone-shaped breakout with a maximum width of 15 in. extended 31¾ in. downstream from post no. 24 on the traffic face of the sidewalk and extended outward roughly 41¾ in. upstream from post no. 26. Contact marks were found on the traffic face of the sidewalk slightly upstream from post no. 24 and extended to the concrete breakout. The filler epoxy fractured and was removed from under the base plate of post no. 25.

Post no. 25 rotated backward about the back edge of the base plate, and the front edge of the base plate was lifted upward approximately 3⅞ in. from the original position. The upstream-front anchor rod was visibly bent at a point approximately 3½ in. below the top of the base plate. The front flange of post no. 25 deformed, and the lower guardrail connection bolt at post no. 25 sheared. Post nos. 24 and 26 deflected backward, and post nos. 5 and 18 twisted counterclockwise. Other bridge rail posts as well as the AGT installation remained undamaged. No movement was observed in the downstream and upstream anchorage systems.

Contact marks were visible over the full height of the thrie-beam rail between post nos. 24 and 26. The rail was bent and flattened between post nos. 24 and 25. A 9½-in. long by 2-in. wide tear formed in the middle corrugation of the thrie-beam rail, beginning approximately 20 in. upstream from post no. 25. At post nos. 19 through 24, post-to-rail bolts slid in their slots, which caused the rail to move slightly downstream.

Figure 83. System Damage, Test No. HMDBR-1





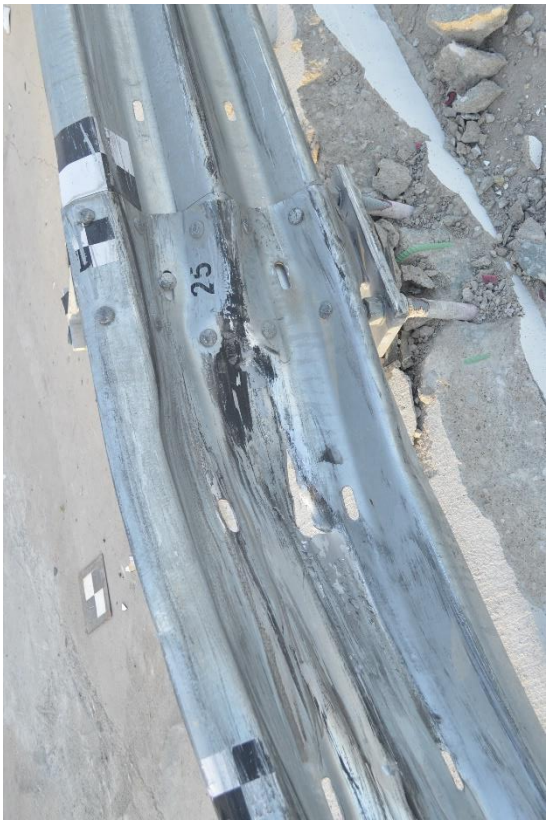


Figure 84. Rail Damage, Test No. HMDBR-1

Figure 85. System Damage, Post Nos. 24 and 25, Test No. HMDBR-1

The maximum lateral permanent set of the barrier system was 6.9 in. at post no. 25, as measured using GPS. The maximum lateral permanent set of the thrie-beam rail was 5.9 in., which occurred between post nos. 24 and 25. The maximum lateral dynamic barrier deflection was 10.2 in. at post no. 25. The maximum lateral dynamic deflection of the thrie-beam rail was 8.3 in., which occurred between post nos. 12 and 13. Exclusive of the sidewalk, the working width of the system was 21.6 in. and was controlled by vehicle overhang. Note that when including the sidewalk, the working width was the system width of 37.5 in. Both dynamic deflection and working width were determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 86.

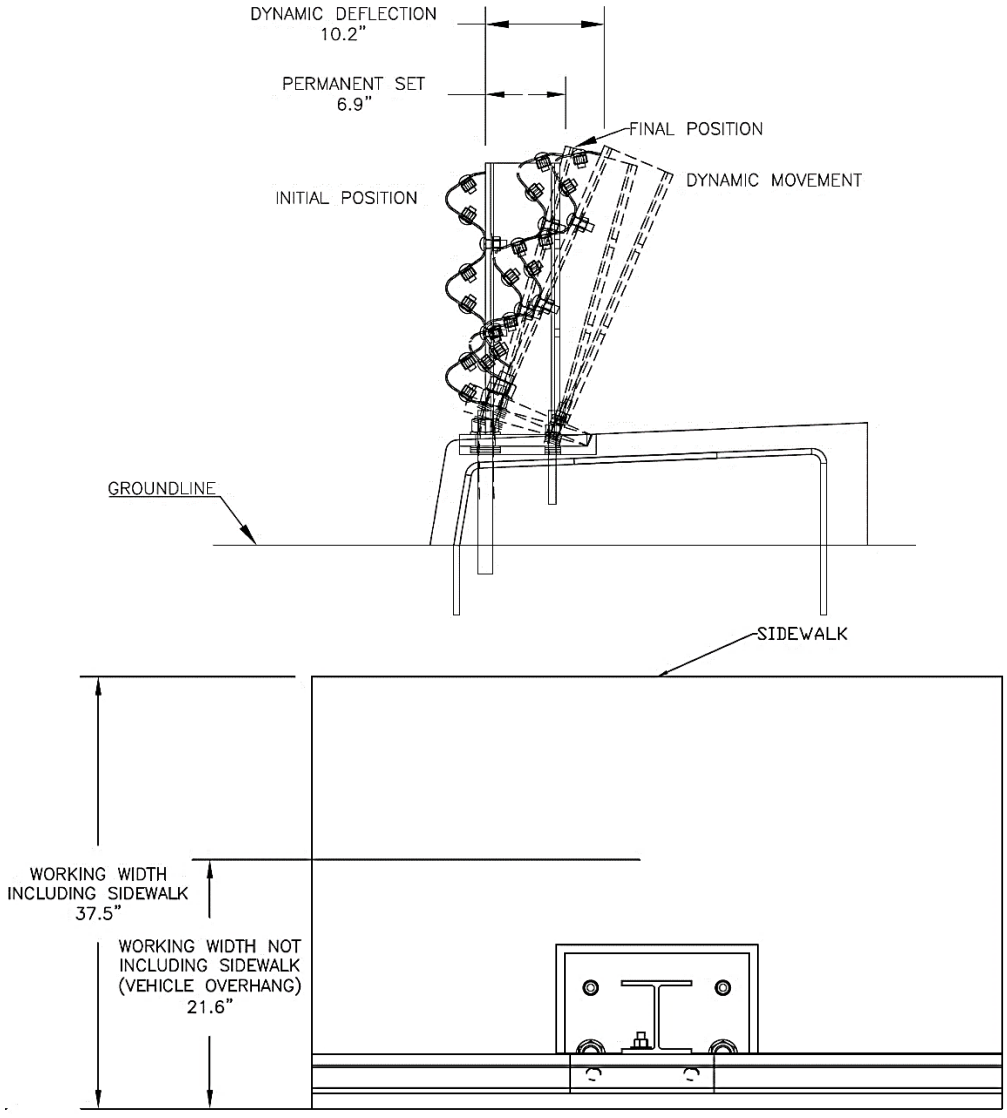


Figure 86. Permanent Set, Dynamic Deflection, and Working Width, Test No. HMDBR-1

6.4 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 87 through 89. The maximum occupant compartment intrusions are listed in Table 6, along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. The tabulated values reflect the maximum occupant compartment intrusions measured using two reference sets, as documented in Appendix E. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix E. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. There were no penetrations into the occupant compartment, and none of the established MASH 2016 deformation limits were violated. Outward deformations, which are denoted as negative numbers in Appendix E, are not considered crush toward the occupant and are not evaluated by the MASH 2016 criteria.

Majority of the damage was concentrated on the left-front corner and left side of the vehicle where the impact had occurred. Due to the vehicle wheel snag on post no. 25, the vehicle's left-front wheel was pushed inward and rearward. The vehicle's grille and left headlight were disengaged, and the left side of the front bumper was crushed. The left-front fender was crushed inward and rearward. Both left-side doors were dented at mid-height along their full length, and the left-front door was ajar. The left side of the rear bumper was dented, and both left-side tires were deflated. The left side of the windshield was cracked, which was not in violation of the MASH 2016 criteria. All other window glass remained intact and undamaged.

The lower-left control arm mounts fractured, and the upper-left control arm bent severely around the ball joint. The left-front sway bar link fractured and disengaged. The left inner tie rod disengaged from the steering rack, and the outer tie rod was bent slightly. The left-rear wheel bent, the left-front spring disengaged, and the left-front shock bent approximately 90 degrees. The bottom lower control arm mount fractured and disengaged. The left side of the frame horn leading edge bent inward and upward about 6 in. and 3 in., respectively.

Figure 87. Vehicle Damage, Test No. HMDBR-1

Figure 88. Vehicle Damage, Test No. HMDBR-1

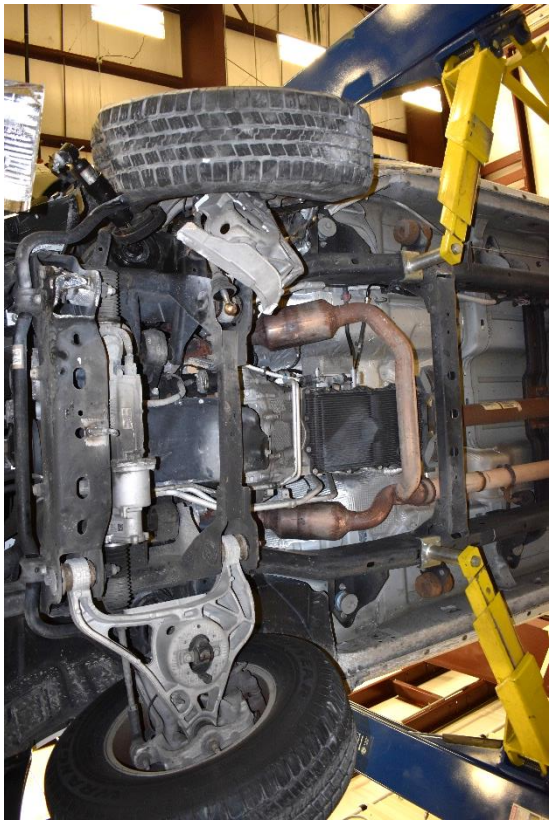


Figure 89. Interior and Undercarriage Damage, Test No. HMDBR-1

Table 6. Maximum Occupant Compartment Intrusion by Location, Test No. HMDBR-1

Location	Maximum Intrusion in.	MASH 2016 Allowable Intrusion in.
Wheel Well & Toe Pan	7.4	≤ 9
Floor Pan & Transmission Tunnel	3.5	≤ 12
A-Pillar	0.4	≤ 5
A-Pillar (Lateral)	0.4	≤ 3
B-Pillar	0.5	≤ 5
B-Pillar (Lateral)	0.5	≤ 3
Side Front Panel (in Front of A-Pillar)	4.1	≤ 12
Side Door (Above Seat)	0.0	≤ 9
Side Door (Below Seat)	0.0	≤ 12
Roof	0.3	≤ 4
Windshield	0.0	≤ 3
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	2.2	N/A

N/A – No MASH 2016 criteria exist for this location.

6.5 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 7. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 7. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix F.

Table 7. Summary of Occupant Risk Values, Test No. HMDBR-1

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-25.84	-25.07	±40
	Lateral	23.72	27.21	±40
ORA g's	Longitudinal	-13.22	-14.78	±20.49
	Lateral	13.67	-12.06	±20.49
Maximum Angular Displacement deg.	Roll	-42.2	-37.9	±75
	Pitch	-10.5	-12.6	±75
	Yaw	73.8	73.5	not required
THIV – ft/s		34.83	36.05	not required
PHD – g's		16.06	15.41	not required
ASI		1.53	1.64	not required

6.6 Barrier Loads

The longitudinal and lateral vehicle accelerations, as measured at the vehicle's c.g., were also processed using a SAE CFC-60 filter and a 50-msec moving average. The 50-msec moving average vehicle accelerations were then combined with the uncoupled yaw angle versus time data in order to estimate the vehicular loading applied to the barrier system. From the data analysis, the perpendicular impact forces were determined for the bridge rail, as shown in Figure 90. The maximum perpendicular (i.e., lateral) load imparted to the barrier was 75.4 kips, as determined by the SLICE-2 (primary) unit.

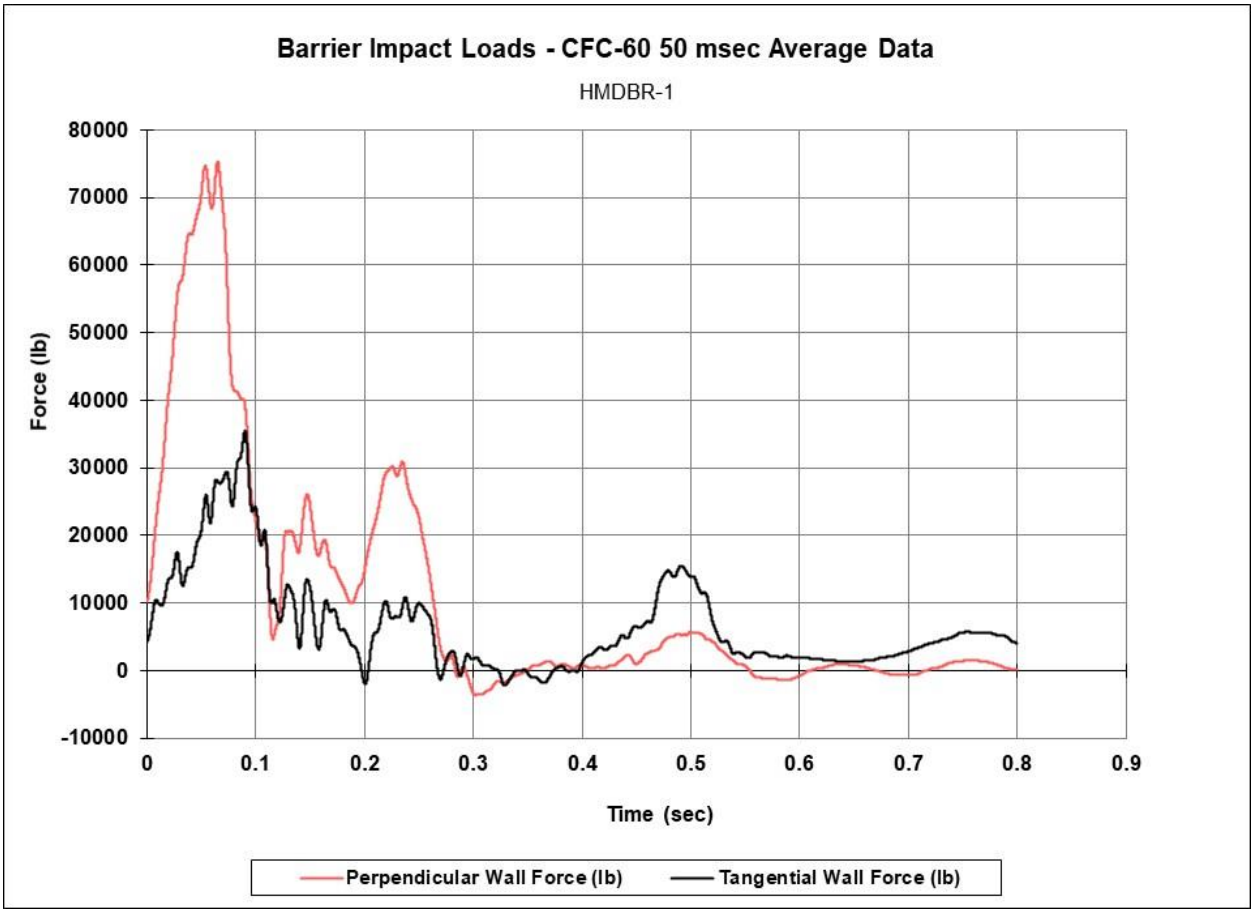
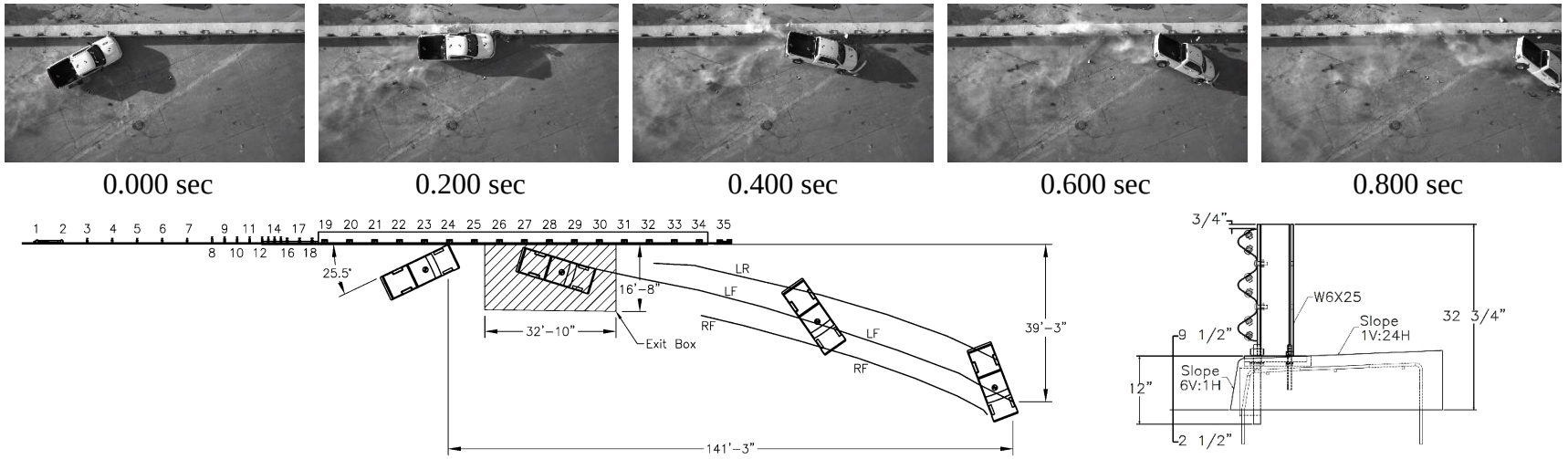


Figure 90. Perpendicular and Tangential Forces Imparted to the Barrier System (SLICE-2), Test No. HMDBR-1

6.7 Discussion

The analysis of the test results for test no. HMDBR-1 showed that the system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown in Figure 91. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix F, were deemed acceptable, because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the barrier at an angle of 5.9 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HMDBR-1 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-11.



- Test Agency ..... MwRSF
- Test Number HMDBR-1
- Date 12/18/2020
- MASH 2016 Test Designation No. 3-11
- Test Article ..... Hawaii Modified Delaware Thrie-Beam Bridge Rail
- Total Length ..... 177 ft – 6 in. (including 100 ft of Bridge Rail)
- Key Component – Thrie-Beam Guardrail
  - Thickness 10-gauge
  - Mounting Height ..... 32 in.
- Key Component – Steel Posts
  - Size W6x25
  - Spacing ..... 75 in.
  - Anchor Rods ..... two 1¼-in. dia., epoxied 2½ in. into concrete tarmac
two ⅝-in. dia., epoxied 6 in. into concrete sidewalk
- Key Component – Sidewalk
  - Height ..... 9 in.
  - Anchorage ..... #4 bars epoxied 6 in. into concrete tarmac
- Surface Type ..... Concrete tarmac
- Vehicle Make /Model ..... 2014 Dodge Ram 1500 quad cab
  - Curb ..... 5,104 lb
  - Test Inertial ..... 5,001 lb (MASH 2016 Limit 5,000 ± 110 lb)
  - Gross Static ..... 5,165 lb
- Impact Conditions
  - Speed ..... 63.1 mph (MASH 2016 Limit 62 ± 2.5 mph)
  - Angle ..... 25.5 deg. (MASH 2016 Limit 25 ± 1.5 deg.)
  - Impact Location ..... 75.1 in. upstream from the centerline of post no. 25
- Impact Severity ..... 123.7 kip-ft > 106 kip-ft limit from MASH 2016
- Exit Conditions
  - Speed ..... 46.8 mph
  - Angle ..... 5.9 deg.
- Exit Box Criterion ..... Pass
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 141 ft – 3 in. downstream
39 ft – 3 in. laterally in front of barrier
- Vehicle Damage ..... Moderate
  - VDS [9] 11-LFQ-5
  - CDC [10] 11-LFEW-3
  - Maximum Interior Deformation ..... 7.4 in. at Toe Pan ≤ 9 in. MASH 2016 limit
- Test Article Damage ..... Moderate
- Maximum Test Article Deflections
  - Permanent Set ..... 6.9 in.
  - Dynamic ..... 10.2 in.
  - Working Width (without sidewalk) ..... 20.1 in.
  - Working Width (with sidewalk) ..... 37.5 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-25.84	-25.07	±40
	Lateral	23.72	27.21	±40
ORA g's	Longitudinal	-13.22	-14.78	±20.49
	Lateral	13.67	-12.06	±20.49
Maximum Angular Displacement deg.	Roll	-42.2	-37.9	±75
	Pitch	-10.5	-12.6	±75
	Yaw	73.8	73.5	not required
THIV – ft/s		34.83	36.05	not required
PHD – g's		16.06	15.41	not required
ASI		1.53	1.64	not required

Figure 91. Summary of Test Results and Sequential Photographs, Test No. HMDBR-1

7 FULL-SCALE CRASH TEST NO. HMDBR-2

7.1 Weather Conditions

Test no. HMDBR-2 was conducted on March 12, 2021 at approximately 1:15 p.m. The weather conditions as reported by the National Oceanic and Atmospheric Administration (station 14939/KLNK) are shown in Table 8.

Table 8. Weather Conditions, Test No. HMDBR-2

Temperature	51°F
Humidity	32%
Wind Speed	11 mph
Wind Direction	110° from True North
Sky Conditions	Clear
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.00 in.

7.2 Test Description

Initial vehicle impact was to occur 54 in. upstream from post no. 13, as shown in Figure 92, which was selected using the CIP plots found in Figure 2-8 of MASH 2016 to maximize propensity for vehicle snag. The 2,453-lb small car impacted the Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail at a speed of 62.7 mph and an angle of 24.6 degrees. The actual point of impact was 6.4 in. upstream from the targeted impact location. The vehicle was captured and redirected safely by the bridge rail with minor deflections. The vehicle came to rest 146 ft – 6 in. downstream from impact and 1 ft laterally behind the barrier after brakes were applied. I.S. is an additional limiting condition required in MASH 2016. The measured I.S. for test no. HMDBR-1 was 55.9 kip-ft, which fell into the acceptable range of greater than or equal to 51.0 kip-ft as defined in MASH 2016 for test designation no. 3-10.

A detailed description of the sequential impact events is contained in Table 9. Sequential photographs are shown in Figures 93 and 94. Documentary photographs of the crash test are shown in Figures 95 and 96. The vehicle trajectory and final position are shown in Figure 97.

Figure 92. Target Impact Location, Test No. HMDBR-2

Table 9. Sequential Description of Impact Events, Test No. HMDBR-2

Time sec	Event
0.000	Vehicle's front bumper contacted rail 60.4 in. upstream from post no. 13 and deformed.
0.004	Vehicle's right-front tire contacted rail between post nos. 12 and 13.
0.007	Vehicle's right headlight contacted rail between post nos. 12 and 13 and shattered.
0.009	Vehicle's hood deformed, and vehicle pitched downward.
0.011	Vehicle's right fender contacted rail between post nos. 12 and 13.
0.018	Vehicle's hood contacted rail between post nos. 12 and 13. Vehicle's right-front tire deflated. Vehicle's grille deformed.
0.028	Vehicle's left headlight deformed, and vehicle pitched upward.
0.030	Vehicle's right-front door deformed, and vehicle yawed away from system.
0.037	Vehicle rolled away from system. Post no. 13 twisted counterclockwise, vehicle's windshield cracked, and vehicle's right-front door contacted rail.
0.042	Top of vehicle’s left-front door deformed.
0.058	Post no. 13 bent backward.
0.060	Vehicle's front bumper fractured into pieces.
0.077	Simulated occupant's head contacted vehicle’s right-front window and window shattered.
0.082	Vehicle rolled toward system.
0.104	Vehicle pitched downward, and vehicle’s right mirror shattered.
0.114	Vehicle's left-rear tire became airborne.
0.158	Vehicle was parallel to system at a speed of 46.1 mph.
0.196	Vehicle's right quarter panel contacted rail and deformed, and vehicle's trunk deformed.
0.201	Vehicle's left headlight disengaged. Vehicle's rear bumper contacted rail and deformed.
0.223	Vehicle's rear bumper fractured.
0.292	Vehicle exited system at a speed of 43.8 mph and at angle of 11.9 degrees.
0.301	System came to a rest.
0.526	Vehicle's left-rear tire regained contact with ground.
0.636	Vehicle yawed toward system.
0.778	Vehicle rolled away from system.
3.533	Vehicle came to rest 146 ft – 6 in. downstream from impact.

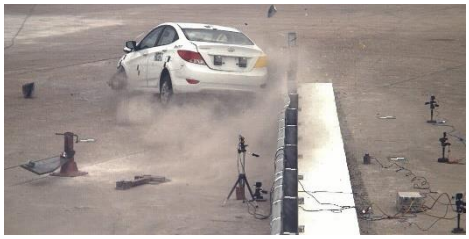

0.000 sec


0.300 sec


0.050 sec


0.350 sec


0.100 sec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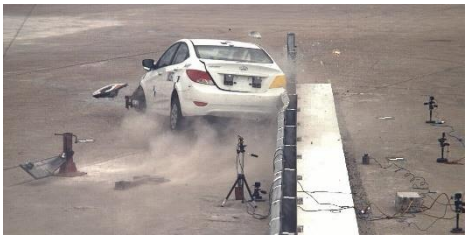
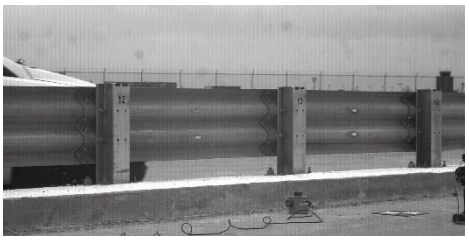

0.250 sec


0.550 sec

Figure 93. Sequential Photographs, Test No. HMDBR-2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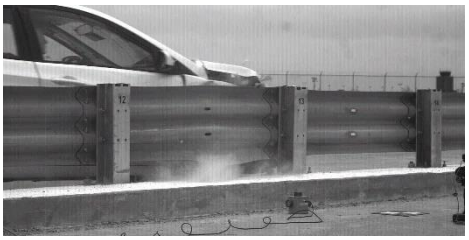
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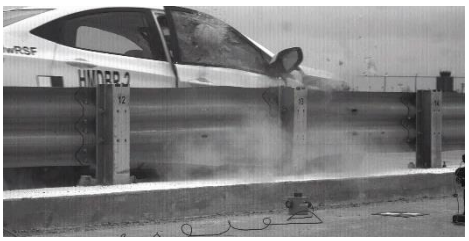
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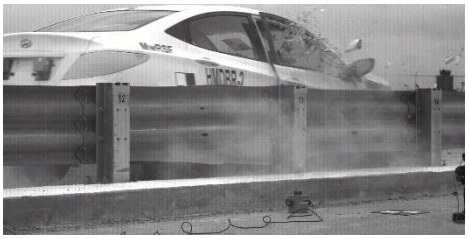
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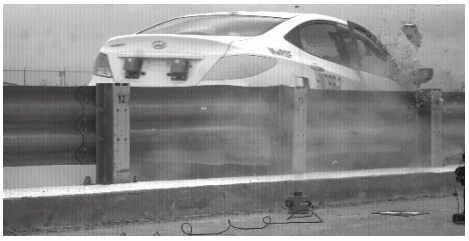
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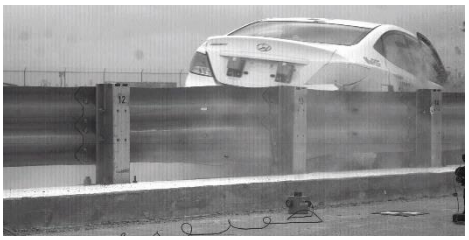

0.250 sec


0.250 sec

Figure 94. Sequential Photographs, Test No. HMDBR-2

Figure 95. Documentary Photographs, Test No. HMDBR-2

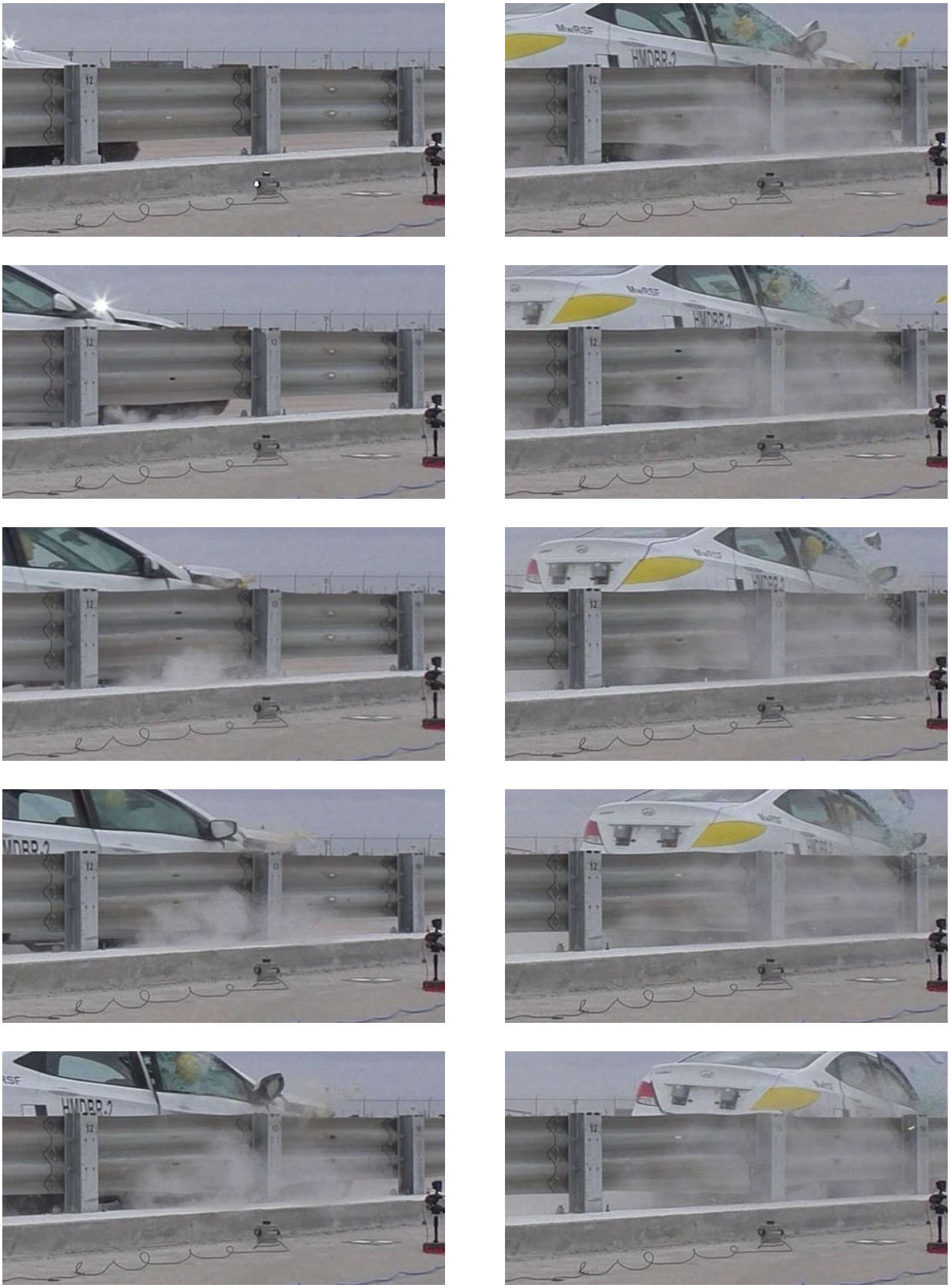


Figure 96. Documentary Photographs, Test No. HMDBR-2

Figure 97. Vehicle Final Position and Trajectory Marks, Test No. HMDBR-2

7.3 Barrier Damage

Damage to the barrier was minimal, as shown in Figures 98 through 101. Barrier damage consisted of contact marks, minor concrete sidewalk spalling, and deformed thrie-beam rail. The length of vehicle contact along the barrier was approximately 11 ft – 1½ in. and began 8½ in. downstream from post no. 12.

Contact marks were visible along the front face and top surface of the concrete sidewalk and along the full depth of the thrie-beam rail between post nos. 12 and 14. The front edge of the concrete sidewalk was spalled near the post no. 13 base plate. The thrie-beam rail was bent, and the bottom corrugation flattened between post nos. 12 and 13. Post no. 13 deformed slightly backward, and the upstream side of the front flange deformed 3½ in. above the base plate. Other bridge rail posts remained undamaged. No movement was observed in the downstream and upstream anchorage systems.

The maximum lateral permanent set of the barrier system was 2.6 in. which occurred in the thrie-beam rail between post nos. 12 and 13, as measured using GPS. The maximum post permanent set was 0.6 in. at post no. 13. The maximum lateral dynamic barrier deflection was 3.8 in., which also occurred in the thrie-beam rail between post nos. 12 and 13. The maximum lateral post dynamic deflection was 1.0 in. at post no. 13. Exclusive of the sidewalk, the working width of the system was 11.9 in. and was controlled by vehicle overhang. Note that when including the sidewalk, the working width was the system width of 37 in. Both dynamic deflection and working width were determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 102.

Figure 98. System Damage, Test No. HMDBR-2

Figure 99. Rail Damage, Test No. HMDBR-2

Figure 100. System Damage, Post No. 13, Test No. HMDBR-2

Figure 101. Sidewalk Damage and Contact Marks, Test No. HMDBR-2

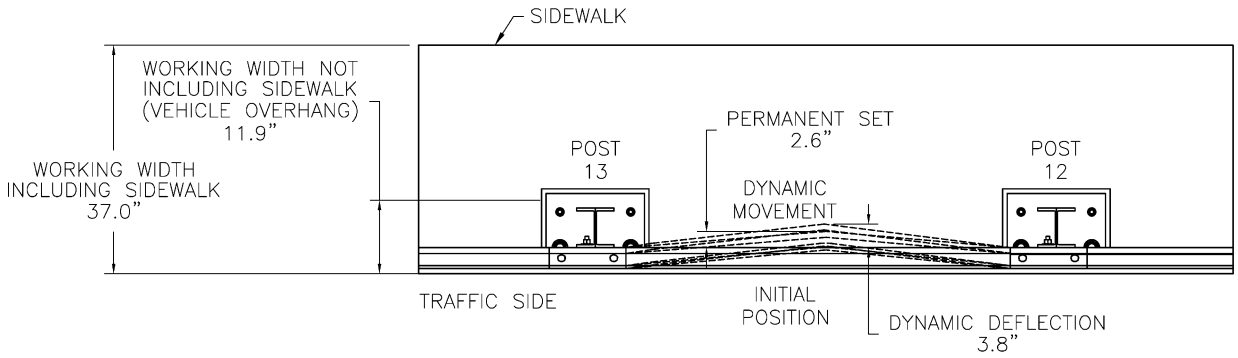


Figure 102. Permanent Set, Dynamic Deflection, and Working Width, Test No. HMDBR-2

7.4 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 103 through 105. The maximum occupant compartment intrusions are listed in Table 10, along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. As documented in Appendix E, the primary reference set was compromised, and the tabulated values reflect the maximum occupant compartment intrusions measured using the secondary reference set. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix E. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. There were no penetrations into the occupant compartment, and none of the established MASH 2016 deformation limits were violated. Outward deformations, which are denoted as negative numbers in Appendix E, are not considered crush toward the occupant and are not evaluated by the MASH 2016 criteria.

Damage was concentrated on the right-front corner and right side of the vehicle where the impact had occurred. The right side of the front bumper was crushed and pushed into the engine compartment. The right side of the engine hood was crushed, and the left side was deformed upward. The full length of the right-front quarter panel was pushed into the engine compartment, and the right-front door was shifted backward. Scrapes and dents were visible along the entire right side of the vehicle. The rear bumper was cracked and scraped, and a kink was visible on the left-front quarter panel. Both left-side tires were deflated. The lower-right side of the windshield was cracked, which did not violate the MASH 2016 criteria. The right-front window shattered due to contact with the simulated occupant's head. All other window glass remained intact and undamaged.

On the undercarriage, the lower right-side control arm buckled and was pushed rearward. The right-side front shock was pushed rearward. The front sway bar link and the right-side outer tie rod were bent. The engine cradle was bent upward at the right-side control arm mounting points. The right-side frame horn was bent inward and upward. A small dent was found on the right side of the floor pan, and the right-side drive shaft was bent.

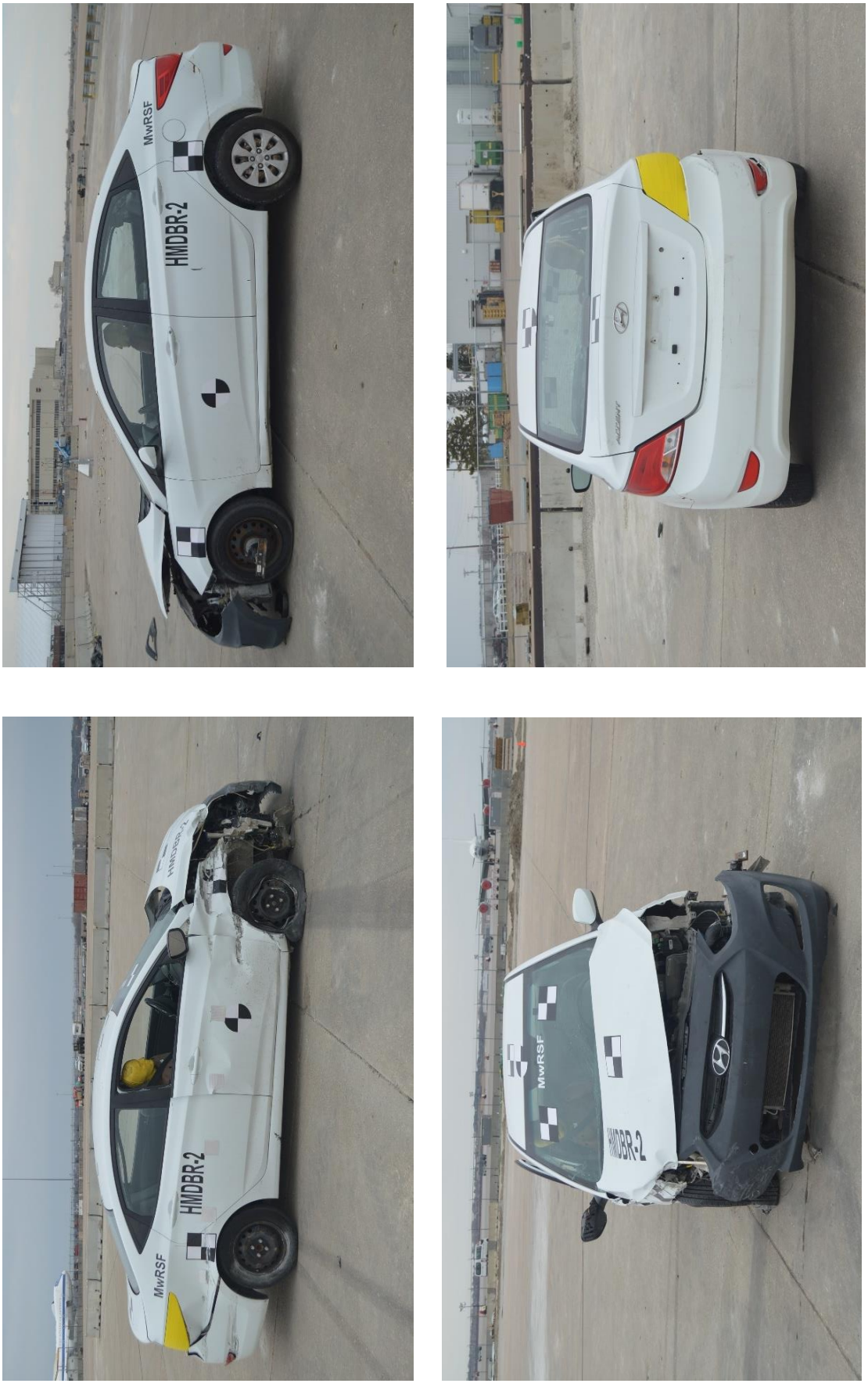


Figure 103. Vehicle Damage, Test No. HMDBR-2

Figure 104. Vehicle Damage, Test No. HMDBR-2

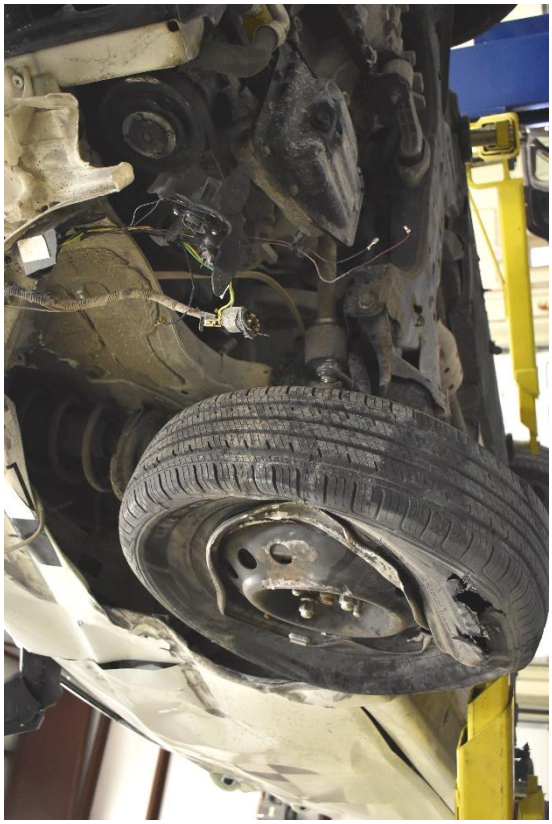


Figure 105. Interior and Undercarriage Damage, Test No. HMDBR-2

Table 10. Maximum Occupant Compartment Intrusion by Location, Test No. HMDBR-2

Location	Maximum Intrusion in.	MASH 2016 Allowable Intrusion in.
Wheel Well & Toe Pan	1.8	≤ 9
Floor Pan & Transmission Tunnel	0.5	≤ 12
A-Pillar	0.5	≤ 5
A-Pillar (Lateral)	0.0	≤ 3
B-Pillar	0.5	≤ 5
B-Pillar (Lateral)	0.0	≤ 3
Side Front Panel (in Front of A-Pillar)	1.7	≤ 12
Side Door (Above Seat)	0.0	≤ 9
Side Door (Below Seat)	0.0	≤ 12
Roof	0.0	≤ 4
Windshield	0.0	≤ 3
Side Window	Shattered due to contact with simulated occupant's head	No shattering resulting from contact with structural member of test article
Dash	1.2	N/A

N/A – No MASH 2016 criteria exist for this location.

7.5 Occupant Risk

The calculated OIVs and maximum 0.010-sec average ORAs in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 11. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 11. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix G.

Table 11. Summary of Occupant Risk Values, Test No. HMDBR-2

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (primary)	SLICE-2	
OIV ft/s	Longitudinal	-28.12	-30.45	±40
	Lateral	-39.56	-37.48	±40
ORA g's	Longitudinal	-12.89	-6.41	±20.49
	Lateral	16.11	20.12	±20.49
Maximum Angular Displacement deg.	Roll	-7.8	-9.9	±75
	Pitch	-4.7	-6.0	±75
	Yaw	-47.3	-48.0	not required
THIV – ft/s		0.20	0.07	not required
PHD – g's		36.16	34.91	not required
ASI		2.96	2.80	not required

7.6 Barrier Loads

The longitudinal and lateral vehicle accelerations, as measured at the vehicle's c.g., were also processed using a SAE CFC-60 filter and a 50-msec moving average. The 50-msec moving average vehicle accelerations were then combined with the uncoupled yaw angle versus time data in order to estimate the vehicular loading applied to the barrier system. From the data analysis, the perpendicular impact forces were determined for the bridge rail, as shown in Figure 106. The maximum perpendicular (i.e., lateral) load imparted to the barrier was 67.9 kips, as determined by the SLICE-1 (primary) unit.

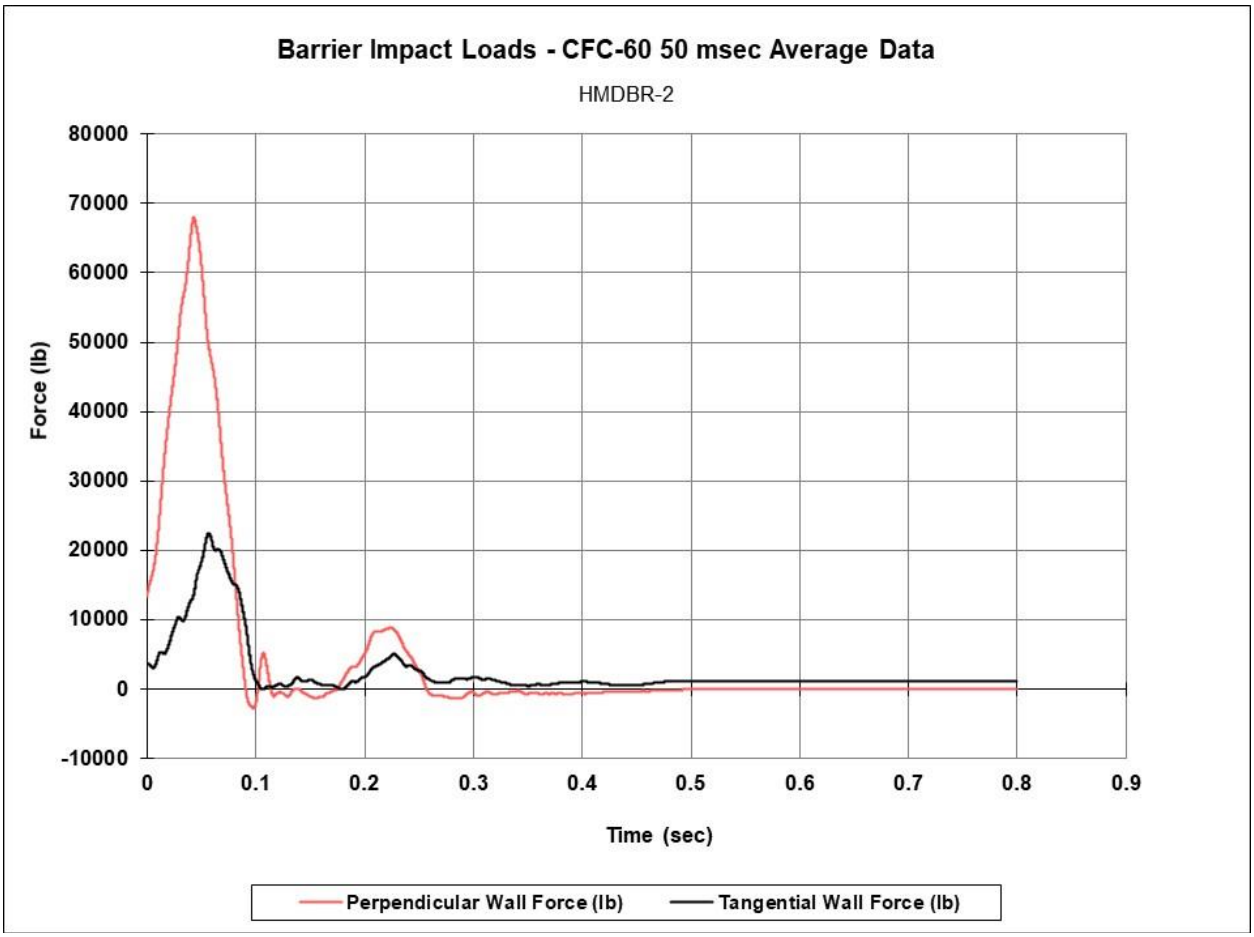
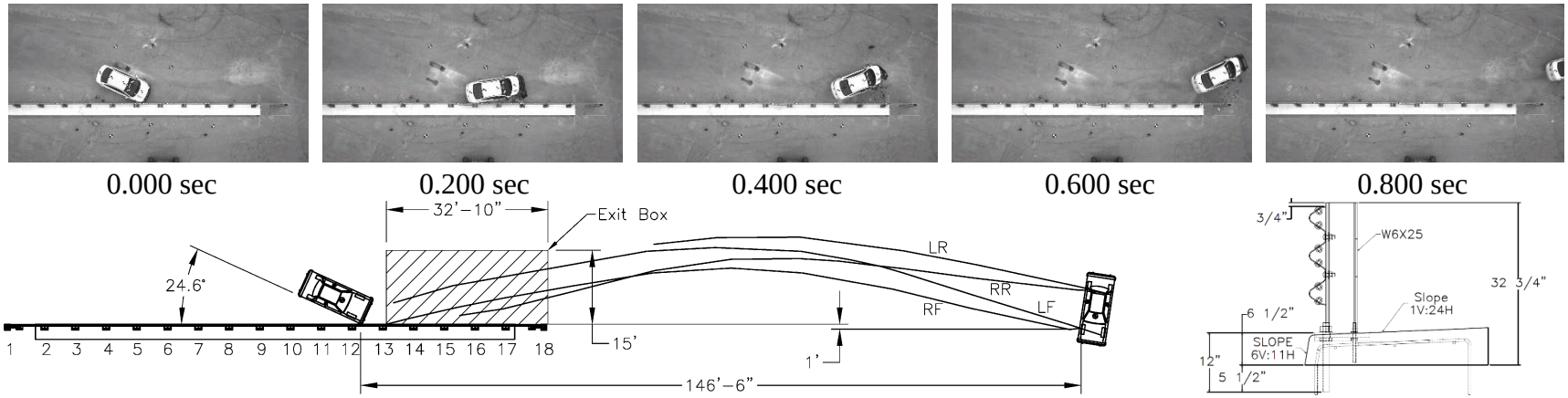


Figure 106. Perpendicular and Tangential Forces Imparted to the Barrier System (SLICE-1), Test No. HMDBR-2

7.7 Discussion

The analysis of the test results for test no. HMDBR-2 showed that the system adequately contained and redirected the 1100C vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown in Figure 107. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix G, were deemed acceptable, because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the barrier at an angle of 11.9 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HMDBR-2 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-10.



- Test Agency ..... MwRSF
- Test Number HMDBR-2
- Date 3/12/2021
- MASH 2016 Test Designation No. 3-10
- Test Article ..... Hawaii Modified Delaware Thrie-Beam Bridge Rail
- Total Length ..... 110 ft
- Key Component – Thrie-Beam Guardrail
  - Thickness 10-gauge
  - Mounting Height ..... 32 in.
- Key Component – Steel Posts
  - Size W6x25
  - Spacing ..... 75 in.
  - Anchor Rods ..... two 1¼-in. dia., epoxied 5½ in. into concrete tarmac
two ⅝-in. dia., epoxied 6 in. into concrete sidewalk
- Key Component – Sidewalk
  - Height ..... 6 in.
  - Anchorage ..... #4 bars epoxied 6 in. into concrete tarmac
- Surface Type ..... Concrete tarmac
- Vehicle Make /Model ..... 2016 Hyundai Accent
  - Curb ..... 2,497 lb
  - Test Inertial ..... 2,453 lb (MASH 2016 Limit 2,420 ± 55 lb)
  - Gross Static ..... 2,616 lb
- Impact Conditions
  - Speed ..... 62.7 mph (MASH 2016 Limit 62 ± 2.5 mph)
  - Angle ..... 24.6 deg. (MASH 2016 Limit 25 ± 1.5 deg.)
  - Impact Location ..... 60.4 in. upstream from the centerline of post no. 13
- Impact Severity ..... 55.9 kip-ft > 51 kip-ft MASH 2016 limit
- Exit Conditions
  - Speed ..... 43.8 mph
  - Angle ..... 11.9 deg.
- Exit Box Criterion ..... Pass
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 146 ft – 6 in. downstream
1 ft laterally behind barrier
- Vehicle Damage ..... Moderate
  - VDS [9] 1-RFQ-4
  - CDC [10] 1-RFEW-3
  - Maximum Interior Deformation ..... 1.8 in. at wheel well and toe pan area
≤ 9 in. MASH 2016 limit
- Test Article Damage ..... Minimal
- Maximum Test Article Deflections
  - Permanent Set ..... 2.6 in.
  - Dynamic ..... 3.8 in.
  - Working Width (without sidewalk) ..... 11.9 in.
  - Working Width (with sidewalk) ..... 37.0 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (primary)	SLICE-2	
OIV ft/s	Longitudinal	-28.12	-30.45	±40
	Lateral	-39.56	-37.48	±40
ORA g's	Longitudinal	-12.89	-6.41	±20.49
	Lateral	16.11	20.12	±20.49
Maximum Angular Displacement deg.	Roll	-7.8	-9.9	±75
	Pitch	-4.7	-6.0	±75
	Yaw	-47.3	-48.0	not required
THIV – ft/s		0.20	0.07	not required
PHD – g's		36.16	34.91	not required
ASI		2.96	2.80	not required

Figure 107. Summary of Test Results and Sequential Photographs, Test No. HMDBR-2

8 FULL-SCALE CRASH TEST NO. HMDBR-3

8.1 Weather Conditions

Test no. HMDBR-3 was conducted on April 6, 2021 at approximately 2:00 p.m. The weather conditions as reported by the National Oceanic and Atmospheric Administration (station 14939/KLNK) are shown in Table 12.

Table 12. Weather Conditions, Test No. HMDBR-3

Temperature	74°F
Humidity	56%
Wind Speed	29 mph
Wind Direction	160° from True North
Sky Conditions	Partly Cloudy
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.04 in.
Previous 7-Day Precipitation	0.04 in.

8.2 Test Description

Initial vehicle impact was to occur 84 in. upstream from the centerline of post no. 7, as shown in Figure 108, which was selected using the CIP plots found in Figure 2-11 of MASH 2016 to maximize propensity for vehicle snag as well as structural loading of the bridge rail. The 5,001-lb crew cab pickup truck impacted the Hawaii Modified Delaware Thrie-Beam Bridge Rail at a speed of 63.3 mph and an angle of 25.5 degrees. The actual point of impact was 3.4 in. downstream from the targeted impact location. The vehicle was captured and redirected safely by the bridge rail with minor deflections. The vehicle came to rest 200 ft – 7 in. downstream from the impact and 40 ft laterally behind the barrier after brakes were applied. I.S. is an additional limiting condition required in MASH 2016. The measured I.S. of test no. HMDBR-3 was 124.2 kip-ft, which fell into the acceptable range of greater than or equal to 106 kip-ft, as defined in MASH 2016 for test designation no. 3-11.

A detailed description of the sequential impact events is contained in Table 13. Sequential photographs are shown in Figures 109 and 110. Documentary photographs of the crash test are shown in Figures 111 and 112. The vehicle trajectory and final position are shown in Figure 113.

Figure 108. Target Impact Location, Test No. HMDBR-3

Table 13. Sequential Description of Impact Events, Test No. HMDBR-3

Time sec	Event
0.000	Vehicle's front bumper and right headlight contacted rail 80.5 in. upstream from post no. 7 and deformed.
0.008	Vehicle's right fender and tire contacted rail at post no. 6 and deformed.
0.016	Post no. 6 deflected backward, and vehicle's right headlight fractured.
0.018	Vehicle's hood deformed.
0.020	Vehicle's grille contacted rail between post nos. 6 and 7 and deformed.
0.026	Vehicle pitched upward.
0.032	Top of left-front door deformed.
0.040	Post no. 7 deflected backward. Vehicle's right-front door contacted rail and deformed.
0.048	Vehicle rolled toward system and yawed away from system.
0.050	Vehicle's right-rear door deformed.
0.072	Vehicle's grille fractured.
0.100	Vehicle's right-front window shattered during vehicle’s impact with barrier.
0.110	Vehicle's left-front tire became airborne.
0.124	Vehicle pitched downward.
0.134	Vehicle's right-front tire deflated.
0.140	Vehicle's left-rear tire became airborne.
0.170	Vehicle's right quarter panel contacted rail at post no. 6 and deformed.
0.176	Vehicle's right taillight and rear bumper contacted rail at post no. 6 and deformed.
0.178	Vehicle was parallel to system at a speed of 49.6 mph.
0.180	Post no. 8 deflected backward.
0.206	Vehicle's right taillight disengaged.
0.440	Vehicle exited system at a speed of 45.1 mph and at angle of 6.8 degrees.
0.458	System came to rest.
0.474	Vehicle pitched upward.
0.480	Vehicle's front bumper contacted ground.
0.672	Vehicle rolled away from system.
0.825	Vehicle yawed toward system.
1.148	Vehicle's left-front tire regained contact with ground.
1.354	Vehicle's left-rear tire regained contact with ground.
1.408	Vehicle pitched downward.
1.440	Vehicle rolled toward system.
6.183	Vehicle came to rest 200 ft – 7 in. downstream from impact.


0.000 sec


0.100 sec

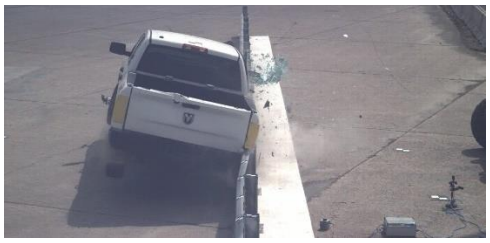

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Figure 109. Sequential Photographs, Test No. HMDBR-3


0.000 sec


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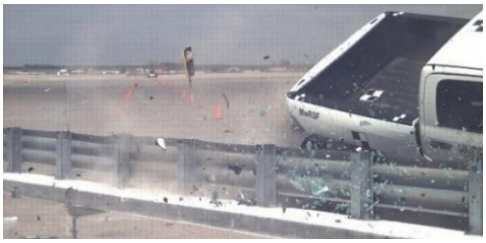
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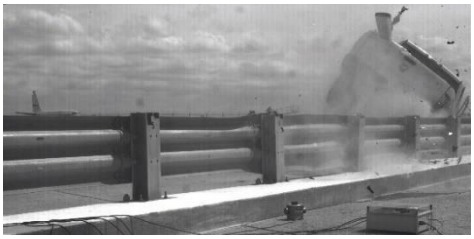

0.500 sec


0.500 sec

Figure 110. Sequential Photographs, Test No. HMDBR-3

Figure 111. Documentary Photographs, Test No. HMDBR-3

Figure 112. Documentary Photographs, Test No. HMDBR-3

Figure 113. Vehicle Final Position and Trajectory Marks, Test No. HMDBR-3

8.3 Barrier Damage

Damage to the barrier was minimal, as shown in Figures 114 through 117. Note that there was pre-existing damage on the system from a previous test, test no. HMBDR-2, that was reported in Chapter 7. The pre-existing damage included contact marks on the concrete curb between post nos. 12 and 14, and minor spalling on the front edge of the concrete curb near post no. 13. The thrie-beam rail between post nos. 12 and 13 that was flattened in the previous test, was replaced.

Barrier damage consisted of contact marks, minor concrete curb spalling and gouging, and deformed thrie-beam rail. The length of vehicle contact along the barrier was approximately 14 ft – 4 in. and began 29 in. upstream from post no. 6.

Contact marks were visible along the front face and top surface of the concrete sidewalk and the full depth of the thrie-beam rail between post nos. 6 and 8. The front edge of the concrete sidewalk was spalled near the post no. 6 base plate, starting 6½ in. upstream from post no. 6 and extending to 5¾ in. downstream from post no. 6. Minor gouging of the top traffic-side edge of the sidewalk occurred at several locations between post nos. 6 and 7. The thrie-beam rail between post nos. 6 and 7 was bent backward 3¼ in. for a length of 76¼ in. The lower thrie-beam corrugation was flattened between post nos. 6 and 7. Tire marks were visible on the base plate and the two front-side anchor rods at post nos. 6 and 7, but the anchor rods remained intact. Other bridge rail posts sustained no visible damage. No movement was observed in the downstream and upstream anchorage systems.

The maximum lateral permanent set of the barrier system was 3.7 in., which occurred in the thrie-beam rail between post nos. 6 and 7, as measured using GPS. The maximum post permanent set was 0.7 in. at post no. 7. The maximum lateral dynamic barrier deflection was 4.7 in., which occurred in the thrie-beam rail between post nos. 6 and 7. The maximum lateral post dynamic deflection was 1.1 in. at post no. 6. Exclusive of the curb, the working width of the system was 19.3 in. and was controlled by vehicle overhang. Note that when including the curb, the working width was the system width of 37 in. Both dynamic deflection and working width were determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 118.

Figure 114. System Damage, Test No. HMDBR-3

Figure 115. Rail Damage, Test No. HMDBR-3

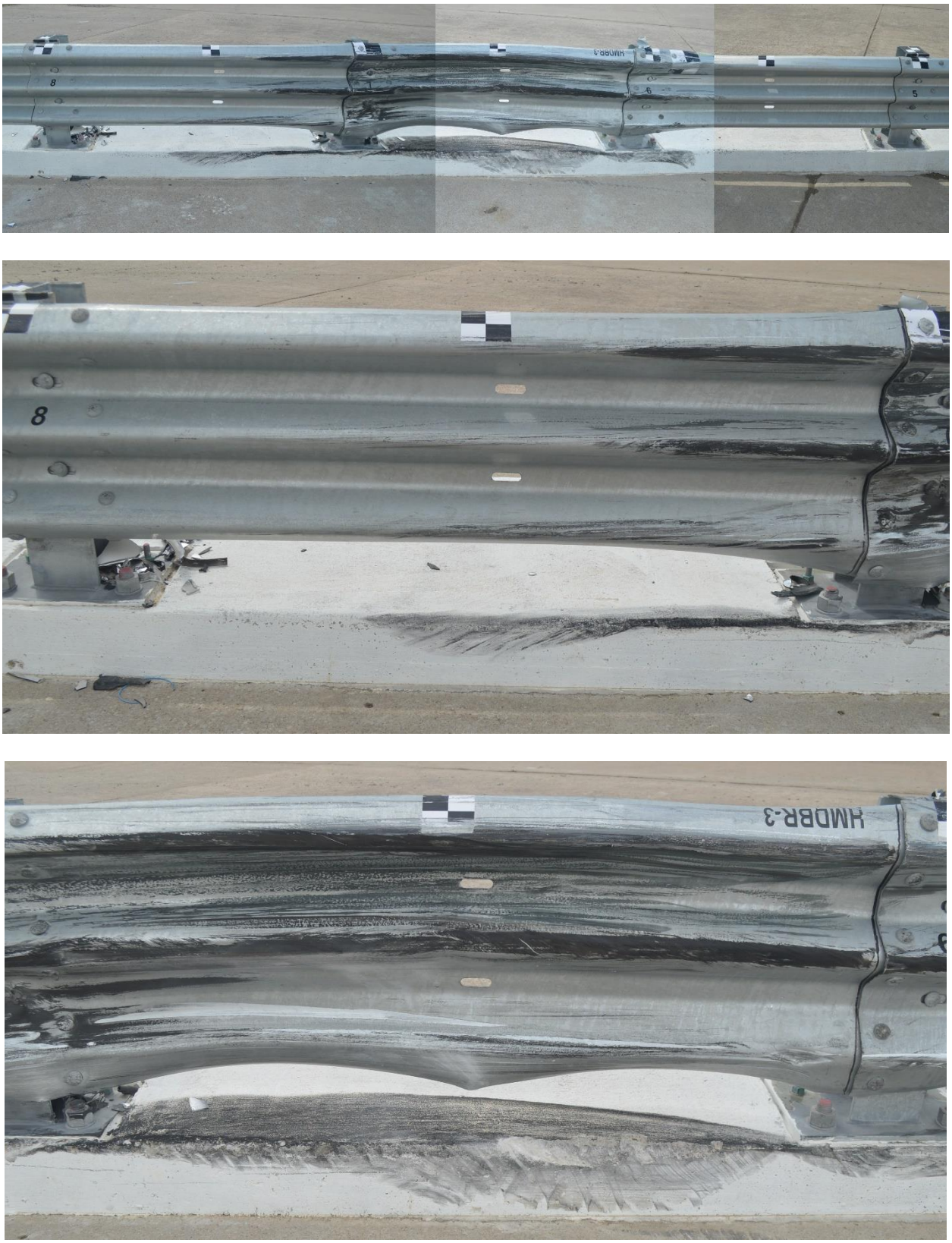


Figure 116. Curb Damage and Contact Marks, Test No. HMDBR-3

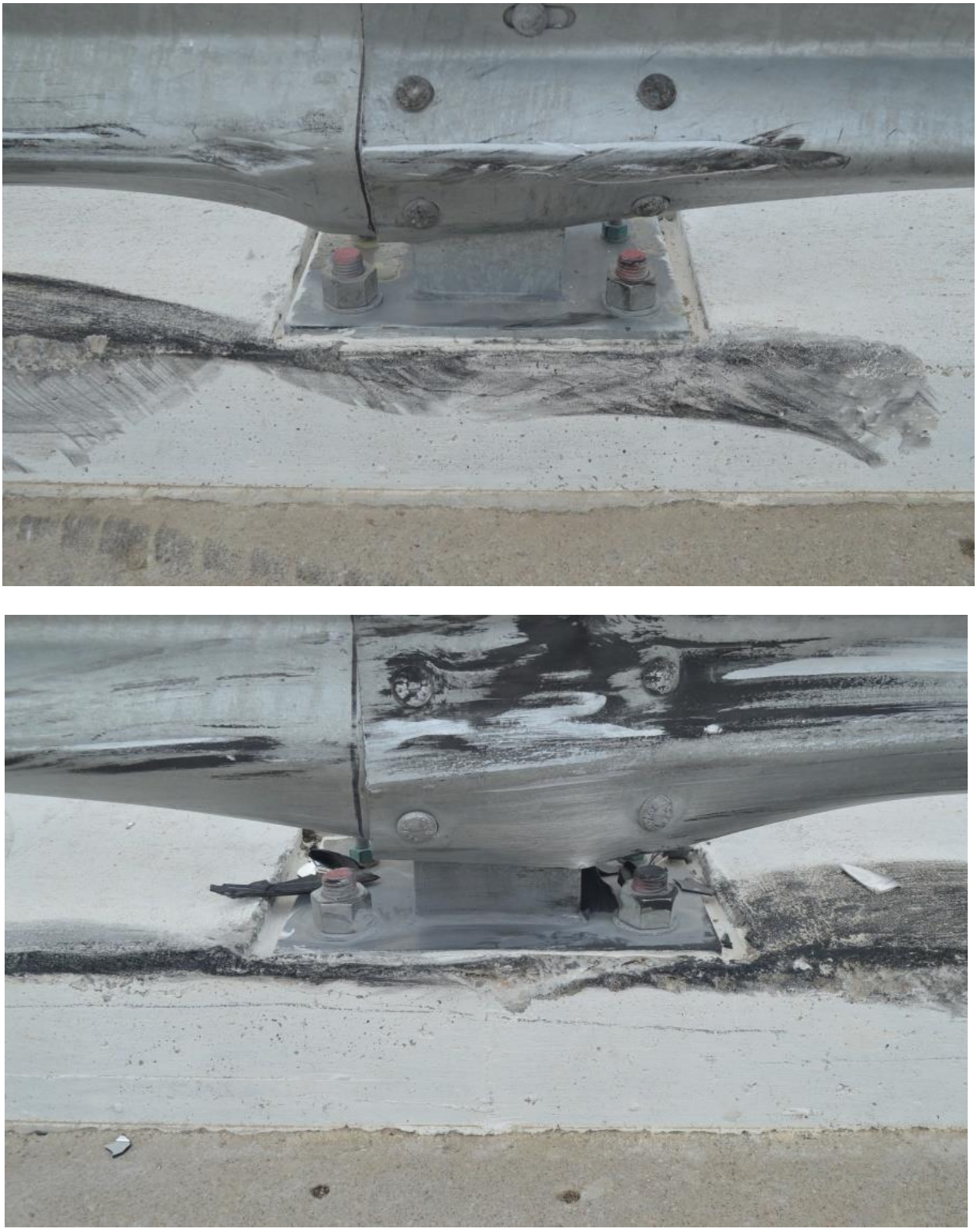


Figure 117. Curb Damage at Post No. 6 (Top) and Post No. 7 (Bottom), Test No. HMDBR-3

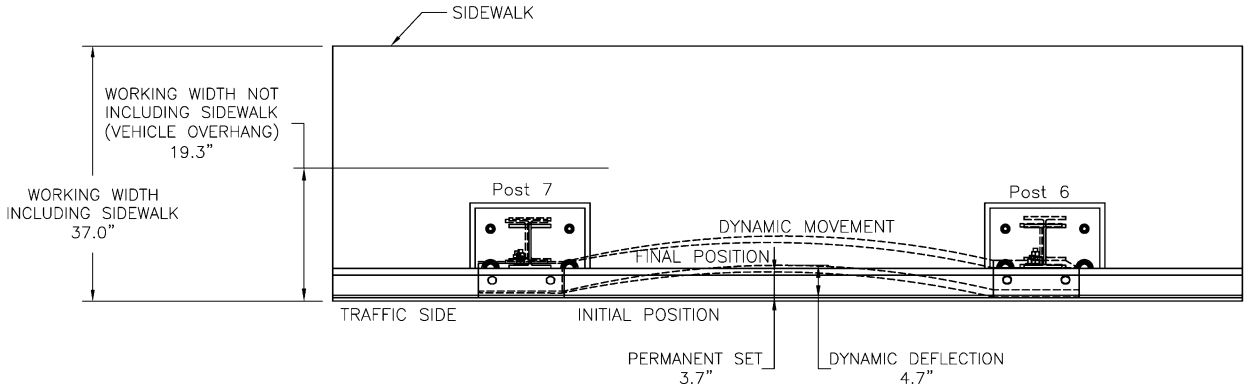


Figure 118. Permanent Set, Dynamic Deflection, and Working Width, Test No. HMDBR-3

8.4 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 119 through 121. Note that the test vehicle experienced two impacts: (1) the intended impact with the bridge rail system and (2) a secondary impact with PCBs placed downstream from the bridge rail to contain the vehicle after exiting the system. Vehicle damage after impacting the bridge rail was moderate, and the secondary impact caused slight additional damage to the front end of the vehicle. The maximum occupant compartment intrusions are listed in Table 14, along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. The tabulated values reflect the maximum occupant compartment intrusions measured using two reference sets, as documented in Appendix E. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix E. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. There were no penetrations into the occupant compartment, and none of the established MASH 2016 deformation limits were violated. Outward deformations, which are denoted as negative numbers in Appendix E, are not considered crush toward the occupant, and are not evaluated by MASH 2016 criteria.

Damage was concentrated on the right-front corner and right side of the vehicle where the impact had occurred. During impact, the vehicle's right-front wheel was pushed inward. The front of the engine hood was bent downward, and the right side of the hood was dented. The right corner of the front bumper was pushed inward and scraped on the right side. The grille was detached from the vehicle and the right-front fender was partially detached. The right-front door was deformed outward. Scrapes and dents were visible along the entire right side of the vehicle. The rear bumper was detached, and the left-front fender was bent. The right-front tire was deflated. The right-front window was shattered during the vehicle's impact with the barrier. The windshield and all other window glass remained intact and undamaged.

On the undercarriage, several suspension components on the right side of the vehicle were bent, including the front shock, spring, the sway bar end link, and the right-side outer tie rod. The right-front steering knuckle disconnected from the control arm. The lower control arm was fractured at both cross members. The steering gear box was cracked, and the left engine mount was disconnected. The right frame horn was bent and crushed, and the engine cross members were scraped.

Figure 119. Vehicle Damage, Test No. HMDBR-3

Figure 120. Vehicle Damage, Test No. HMDBR-3

Figure 121. Interior and Undercarriage Damage, Test No. HMDBR-3

Table 14. Maximum Occupant Compartment Intrusion by Location, Test No. HMDBR-3

Location	Maximum Intrusion in.	MASH 2016 Allowable Intrusion in.
Wheel Well & Toe Pan	4.8	≤ 9
Floor Pan & Transmission Tunnel	0.7	≤ 12
A-Pillar	0.0	≤ 5
A-Pillar (Lateral)	0.0	≤ 3
B-Pillar	0.1	≤ 5
B-Pillar (Lateral)	0.1	≤ 3
Side Front Panel (in Front of A-Pillar)	3.3	≤ 12
Side Door (Above Seat)	0.0	≤ 9
Side Door (Below Seat)	0.0	≤ 12
Roof	0.0	≤ 4
Windshield	0.0	≤ 3
Side Window	Shattered due to contact with simulated occupant's head	No shattering resulting from contact with structural member of test article
Dash	1.3	N/A

N/A – No MASH 2016 criteria exist for this location.

8.5 Occupant Risk

The calculated OIVs and maximum 0.010-sec average ORAs in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 15. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 15. The recorded data from the accelerometers and the rate transducers is shown graphically in Appendix H.

Table 15. Summary of Occupant Risk Values, Test No. HMDBR-3

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-21.58	-20.51	±40
	Lateral	-25.52	-26.55	±40
ORA g's	Longitudinal	-9.34	-9.78	±20.49
	Lateral	-12.75	-11.37	±20.49
Maximum Angular Displacement deg.	Roll	42.9	39.4	±75
	Pitch	-5.6	-7.8	±75
	Yaw	-50.6	-50.7	not required
THIV – ft/s		31.99	32.58	not required
PHD – g's		13.49	12.57	not required
ASI		1.52	1.61	not required

8.6 Barrier Loads

The longitudinal and lateral vehicle accelerations, as measured at the vehicle's c.g., were also processed using a SAE CFC-60 filter and a 50-msec moving average. The 50-msec moving average vehicle accelerations were then combined with the uncoupled yaw angle versus time data in order to estimate the vehicular loading applied to the barrier system. From the data analysis, the perpendicular impact forces were determined for the bridge rail, as shown in Figure 122. The maximum perpendicular (i.e., lateral) load imparted to the barrier was 75.8 kips, as determined by the SLICE-2 (primary) unit.

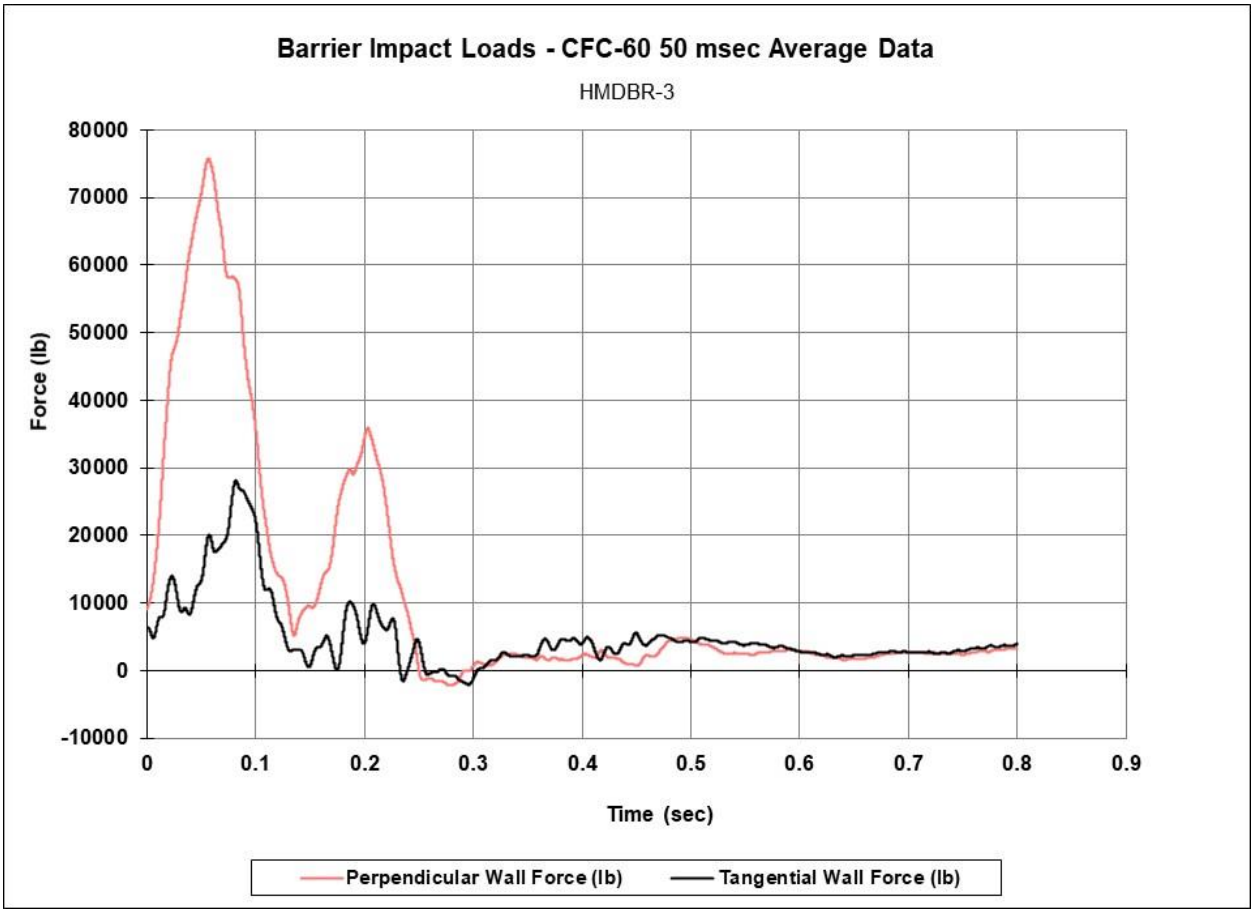
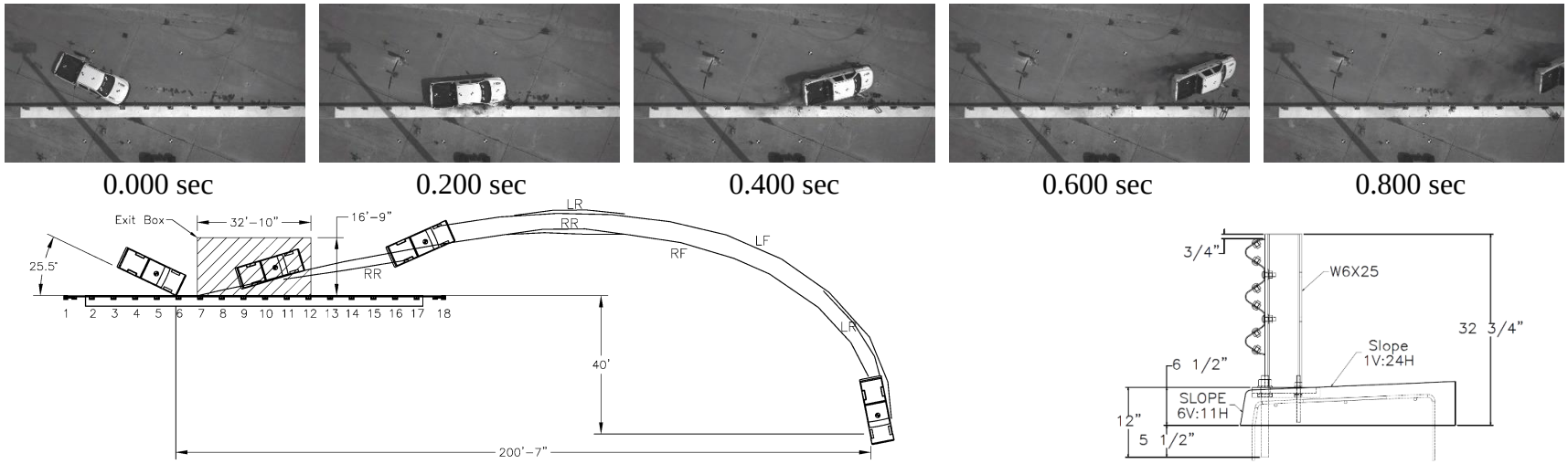


Figure 122. Perpendicular and Tangential Forces Imparted to the Barrier System (SLICE-2), Test No. HMDBR-3

8.7 Discussion

The analysis of the test results for test no. HMDBR-3 showed that the system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown in Figure 123. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix H, were deemed acceptable, because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the barrier at an angle of 6.8 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HMDBR-3 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-11.



- Test Agency ..... MwRSF
- Test Number HMDBR-3
- Date 4/6/2021
- MASH 2016 Test Designation No. 3-11
- Test Article ..... Hawaii Modified Delaware Thrie-Beam Bridge Rail
- Total Length ..... 110 ft
- Key Component – Thrie-Beam Guardrail
  - Thickness 10-gauge
  - Mounting Height ..... 32 in.
- Key Component – Steel Posts
  - Size W6x25
  - Spacing ..... 75 in.
  - Anchor Rods ..... two 1¼-in. dia., epoxied 5½ in. into concrete tarmac
two ⅝-in. dia., epoxied 6 in. into concrete curb
- Key Component – Curb
  - Height ..... 6 in.
  - Anchorage ..... #4 bars epoxied 6 in. into concrete tarmac
- Surface Type ..... Concrete tarmac
- Vehicle Make /Model ..... 2015 Dodge Ram 1500 crew cab
  - Curb ..... 4,963 lb
  - Test Inertial ..... 5,001 lb (MASH 2016 Limit 5,000 ± 110 lb)
  - Gross Static ..... 5,162 lb
- Impact Conditions
  - Speed ..... 63.3 mph (MASH 2016 Limit 62 ± 2.5 mph)
  - Angle ..... 25.5 deg. (MASH 2016 Limit 25 ± 1.5 deg.)
  - Impact Location ..... 80½ in. upstream from post no. 7
- Impact Severity ..... 124.2 kip-ft > 106 kip-ft MASH 2016 limit
- Exit Conditions
  - Speed ..... 45.1 mph
  - Angle ..... 6.8 deg.
- Exit Box Criterion ..... Pass
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 200 ft – 7 in. downstream
40 ft laterally behind barrier
- Vehicle Damage ..... Moderate
  - VDS [9] 1-RFQ-5
  - CDC [10] 1-RFEW-4
  - Maximum Interior Deformation ..... 4.8 in. at wheel well and toe pan area
≤ 9 in. MASH 2016 limit
- Test Article Damage ..... Minimal
- Maximum Test Article Deflections
  - Permanent Set ..... 3.7 in.
  - Dynamic ..... 4.7 in.
  - Working Width (without Sidewalk) ..... 19.3 in.
  - Working Width (with Sidewalk) ..... 37.0 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-21.58	-20.51	±40
	Lateral	-25.52	-26.55	±40
ORA g's	Longitudinal	-9.34	-9.78	±20.49
	Lateral	-12.75	-11.37	±20.49
Maximum Angular Displacement deg.	Roll	42.9	39.4	±75
	Pitch	-5.6	-7.8	±75
	Yaw	-50.6	-50.7	not required
THIV – ft/s		31.99	32.58	not required
PHD – g's		13.49	12.57	not required
ASI		1.52	1.61	not required

Figure 123. Summary of Test Results and Sequential Photographs, Test No. HMDBR-3

9 SUMMARY AND CONCLUSIONS

The Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail evaluated in this research study consisted of a 10-gauge thrie-beam rail with a mounting height of 32 in. above the finished grade, supported by W6x25 steel posts, spaced at 75 in., and anchored to a concrete curb. Both 6-in. and 9-in. tall curb configurations were tested and evaluated. The bridge rail is intended for use with an approach guardrail transition system. The bridge rail installation with the 9-in. tall curb was connected to the HDOT AGT and a W-beam guardrail system. The crash testing and evaluation of the AGT was conducted in a parallel study and documented in a separate report [2]. The 6-in. tall curb configuration was constructed as a standalone bridge rail installation with two end anchorages.

The Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail was subjected to three full-scale crash tests in accordance with the TL-3 evaluation criteria of MASH 2016. Test no. HMDBR-1 was conducted on the 9-in. tall sidewalk configuration according to MASH 2016 test designation no. 3-11. Test nos. HMDBR-2 and HMDBR-3 were conducted on the 6-in. tall sidewalk configuration according to MASH 2016 test designations nos. 3-10 and 3-11, respectively. The test evaluations are summarized in Table 16.

In test no. HMDBR-1, the 5,001-lb pickup truck impacted the Hawaii Modified Delaware Thrie-Beam Bridge Rail with 9-in. tall sidewalk at a speed of 63.1 mph and an angle of 25.5 degrees. The impact occurred 75.1 in. upstream from the centerline of post no. 25, and the impact severity was 123.4 kip-ft. After impacting the barrier system, the vehicle exited the system at a speed of 42.2 mph and an angle of 11.1 degrees. The vehicle was successfully contained and smoothly redirected with moderate damage to both the barrier system and the vehicle. All occupant risk values fell within the recommended safety limits established in MASH 2016. Therefore, test no. HMDBR-1 was successful according to the safety criteria of MASH 2016 test designation no. 3-11.

In test no. HMDBR-2, the 2,453-lb small car impacted the Hawaii Modified Delaware Thrie-Beam Bridge Rail with 6-in. tall sidewalk at a speed of 62.7 mph and an angle of 24.6 degrees. The impact occurred 60.4 in. upstream from post no. 13, and the impact severity was 55.9 kip-ft. After impacting the barrier system, the vehicle exited the system at a speed of 43.8 mph and an angle of 11.9 degrees. The vehicle was successfully contained and smoothly redirected with minimal damage to the barrier system and moderate damage to the vehicle. All occupant risk values fell within the recommended safety limits established in MASH 2016. Therefore, test no. HMDBR-2 was successful according to the safety criteria of MASH 2016 test designation no. 3-10.

In test no. HMDBR-3, the 5,001-lb pickup truck impacted the Hawaii Modified Delaware Thrie-Beam Bridge Rail with 6-in. tall sidewalk at a speed of 63.3 mph and an angle of 25.5 degrees. The impact occurred 80.5 in. upstream from post no. 7, and the impact severity was 124.2 kip-ft. After impacting the barrier system, the vehicle exited the system at a speed of 45.1 mph and an angle of 6.8 degrees. The vehicle was successfully contained and smoothly redirected with minimal damage to the barrier system and moderate damage to the vehicle. All occupant risk values fell within the recommended safety limits established in MASH 2016. Therefore, test no. HMDBR-3 was successful according to the safety criteria of MASH 2016 test designation no. 3-11.

Based on the successful completion of the three full-scale crash tests required for the evaluation of longitudinal barriers and bridge rails in MASH 2016, it is believed that the Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail installed on a concrete sidewalk with a height ranging between 6 in. and 9 in. meets the safety criteria for MASH 2016 TL-3.

Table 16. Summary of Safety Performance Evaluation

Evaluation Factors	Evaluation Criteria	Test No. HMDBR-1	Test No. HMDBR-2	Test No. HMDBR-3
Structural Adequacy	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.	S	S	S
Occupant Risk	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.	S	S	S
	2. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.	S	S	S
	F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	S	S	S
	H. Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:	S	S	S
	Occupant Impact Velocity Limits			
	Component: Longitudinal and Lateral — Preferred: 30 ft/s — Maximum: 40 ft/s			
	I. The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:	S	S	S
	Occupant Ridedown Acceleration Limits			
	Component: Longitudinal and Lateral — Preferred: 15.0 g's — Maximum: 20.49 g's			
MASH 2016 Test Designation No.		3-11	3-10	3-11
Final Evaluation (Pass or Fail)		Pass	Pass	Pass

S – Satisfactory U – Unsatisfactory NA – Not Applicable

10 REFERENCES

1. *Manual for Assessing Safety Hardware (MASH), Second Edition*, American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C., 2016.

2. Selva Kumar, G., Asadollahi Pajouh, M., Lechtenberg, K.A., Faller, R.K., Holloway, J.C., and Urbank, E.L., *Crash Testing and Evaluation of Hawaii Transition to Modified Delaware Retrofit Bridge Rail: MASH Test Nos. 3-20 and 3-21*, Draft Report No. TRP-03-449-21, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, in Progress.

3. *Manual for Assessing Safety Hardware*, American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C., 2009.

4. Stolle, C.S., Asselin, N., Schmidt, J.D., Faller, R.K., Holloway, J.C., Reid, J.D., and Rilett, L.R., *Development of a Non-Proprietary ASTM F2656-15 M30 and FS30 P1 Barrier*, Report No. TRP-03-365-17, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, December 18, 2017.

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7. MacInnis, D., Cliff, W., and Ising, K., *A Comparison of the Moment of Inertia Estimation Techniques for Vehicle Dynamics Simulation*, SAE Technical Paper Series – 970951, Society of Automotive Engineers, Inc., Warrendale, Pennsylvania, 1997.

8. Society of Automotive Engineers (SAE), *Instrumentation for Impact Test – Part 1 – Electronic Instrumentation*, SAE J211/1 MAR95, New York City, New York, July 2007.

9. *Vehicle Damage Scale for Traffic Investigators*, Second Edition, Technical Bulletin No. 1, Traffic Accident Data (TAD) Project, National Safety Council, Chicago, Illinois, 1971.

10. *Collision Deformation Classification*, SAE International Surface Vehicle Recommended Practice, SAE Standard J224_201702, Society of Automotive Engineers, Warrendale, PA, February 2017.

11 APPENDICES

Appendix A. Critical Impact Point Determination

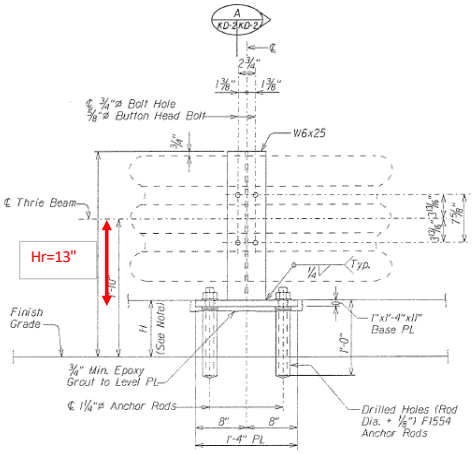
Name of System	Hawaii Modified Delaware Bridge Rail HMDR w/ 9" curb
Test Designation	MASH 3-11

A) Steel Post Fy

$$F_y = D\left(\frac{\sigma_y Z_p}{H_r}\right) \qquad \text{(Eq. A3-1)}$$

Where:

F_y = dynamic post yield force for a rigid anchor;
D = dynamic magnification factor;
σ_y = post yield stress;
Z_p = post plastic section modulus; and
H_r = height of highest rail above base of post.



	CIP-1 (published values with D=1.5)	CIP-2 (published values with D=1)	Comments
D	1.5	1	MASH recommends
Zp (in^3)	18.9	18.9	W6x25
σy (ksi)	50	50	A992
Hr (in)	13	13	
Fy (kips)	109.04	72.69	
Spacing (ft)	6.25	6.25	Full post spacing
Fp (kip/ft)	17.45	11.63	

B) Soil Forces Fs

$$F_s' = F_s \times \left(\frac{D_e'}{D_e}\right)^2 \qquad \text{(Eq. A3-2)}$$

Where:

D_e' = soil dynamic yield force at alternate embedment depth, D_e';
F_s = soil dynamic yield force shown in Table A-3;
D_e' = alternate embedment depth; and
D_e = post embedment depth shown in Table A-3.

		Commnets
Fs (kips)	NA	From MASH Table A-3 or MwRSF soil tests
De (in)	NA	
D'e (in)	NA	
F's (kips)	NA	

Smallest of Fy and Fs controls Fp	Fy	No soil is involved
Fp for CIP-1	17.45	with 1.5 factor
Fp for CIP-2	11.63	without 1.5 factor

C) Rail plastic Moment

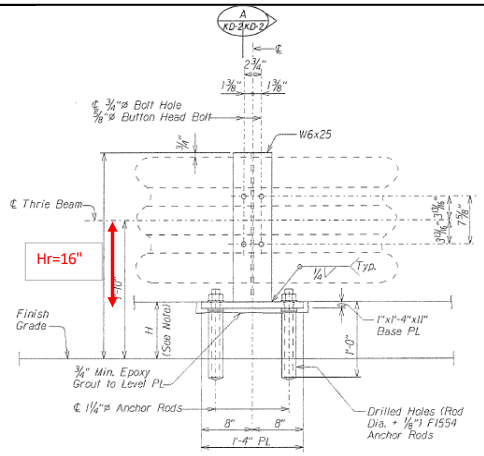
	MASH Table A-1	Using actual mill certs	Comments
Zp	3.92	3.92	10-gauge thrie beam
σy (ksi)	50		
Mp	16.33		

D) CIP

Test 3-11	Figure 2-11		From Post/splice no. 25
Fp	17.45	X=6.5ft =78 in (CIP1)	25
Mp	16.33		
Fp	11.63	X=7.5 ft =90 in (CIP2)	25
Mp	16.33		

Figure A-1. CIP Determination, Test No. HMDBR-1

Name of System	Hawaii Modified Delaware Bridge Rail HMDR w/ 6" curb
Test Designation	MASH 3-11 and 3-10



A) Steel Post Fy

$$F_y = D\left(\frac{\sigma_y Z_p}{H_r}\right) \qquad \text{(Eq. A3-1)}$$

Where:

F_y = dynamic post yield force for a rigid anchor;
D = dynamic magnification factor;
σ_y = post yield stress;
Z_p = post plastic section modulus; and
H_r = height of highest rail above base of post.

	CIP-1 (published values with D=1.5)	CIP-2 (published values with D=1)	Comments
D	1.5	1	MASH recommends
Zp (in^3)	18.9	18.9	W6x25
σy (ksi)	50	50	A992
Hr (in)	16	16	
Fy (kips)	88.59	59.06	
Spacing (ft)	6.25	6.25	Full post spacing
Fp (kip/ft)	14.18	9.45	

B) Soil Forces Fs

$$F_s' = F_s \times \left(\frac{D_e'}{D_e}\right)^2 \qquad \text{(Eq. A3-2)}$$

Where:

D_e' = soil dynamic yield force at alternate embedment depth, D_e';
F_s = soil dynamic yield force shown in Table A-3;
D_e' = alternate embedment depth; and
D_e = post embedment depth shown in Table A-3.

		Commnets
Fs (kips)	NA	From MASH Table A-3 or MwRSF soil tests
De (in)	NA	
D'e (in)	NA	
F's (kips)	NA	

Smallest of Fy and Fs controls Fp	Fy	No soil is involved
Fp for CIP-1	14.18	with 1.5 factor
Fp for CIP-2	9.45	without 1.5 factor

C) Rail plastic Moment

	MASH Table A-1	Using actual mill certs	Comments
Zp	3.92	3.92	10-gauge thrie beam
σy (ksi)	50		
Mp	16.33		

D) CIP

Test 3-11	Figure 2-11		From Post/splice no.
Fp	14.18	X=7 ft =84 in. (CIP1)	25
Mp	16.33		
Fp	9.45	X=8 ft = 96 in. (CIP2)	25
Mp	16.33		

Figure A-2. CIP Determination, Test No. HMDBR-2

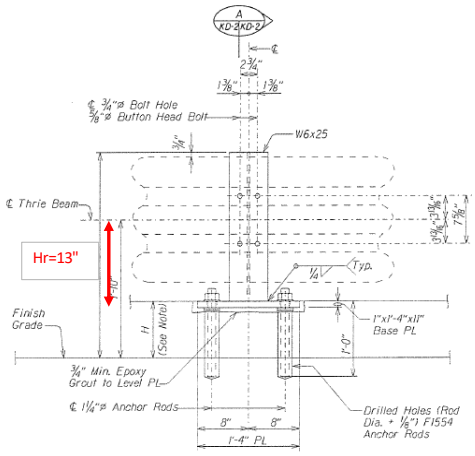
Name of System	Hawaii Modified Delaware Bridge Rail HMDR w/ 9" curb
Test Designation	MASH 3-11

A) Steel Post Fy

$$F_y = D\left(\frac{\sigma_y Z_p}{H_r}\right) \qquad \text{(Eq. A3-1)}$$

Where:

F_y = dynamic post yield force for a rigid anchor;
D = dynamic magnification factor;
σ_y = post yield stress;
Z_p = post plastic section modulus; and
H_r = height of highest rail above base of post.



	CIP-1 (published values with D=1.5)	CIP-2 (published values with D=1)	Comments
D	1.5	1	MASH recommends
Zp (in^3)	18.9	18.9	W6x25
σy (ksi)	50	50	A992
Hr (in)	13	13	
Fy (kips)	109.04	72.69	
Spacing (ft)	6.25	6.25	Full post spacing
Fp (kip/ft)	17.45	11.63	

B) Soil Forces Fs

$$F_s' = F_s \times \left(\frac{D_e'}{D_e}\right)^2 \qquad \text{(Eq. A3-2)}$$

Where:

D_e' = soil dynamic yield force at alternate embedment depth, D_e';
F_s = soil dynamic yield force shown in Table A-3;
D_e' = alternate embedment depth; and
D_e = post embedment depth shown in Table A-3.

		Commnets
Fs (kips)	NA	From MASH Table A-3 or MwRSF soil tests
De (in)	NA	
D'e (in)	NA	
F's (kips)	NA	

Smallest of Fy and Fs controls Fp	Fy	No soil is involved
Fp for CIP-1	17.45	with 1.5 factor
Fp for CIP-2	11.63	without 1.5 factor

C) Rail plastic Moment

	MASH Table A-1	Using actual mill certs	Comments
Zp	3.92	3.92	10-gauge thrie beam
σy (ksi)	50		
Mp	16.33		

D) CIP

Test 3-11	Figure 2-11		From Post/splice no. 25
Fp	17.45	X=6.5ft =78 in (CIP1)	25
Mp	16.33		
Fp	11.63	X=7.5 ft =90 in (CIP2)	25
Mp	16.33		

Figure A-3. CIP Determination, Test No. HMDBR-3

Appendix B. Material Specifications, Test No. HMDBR-1

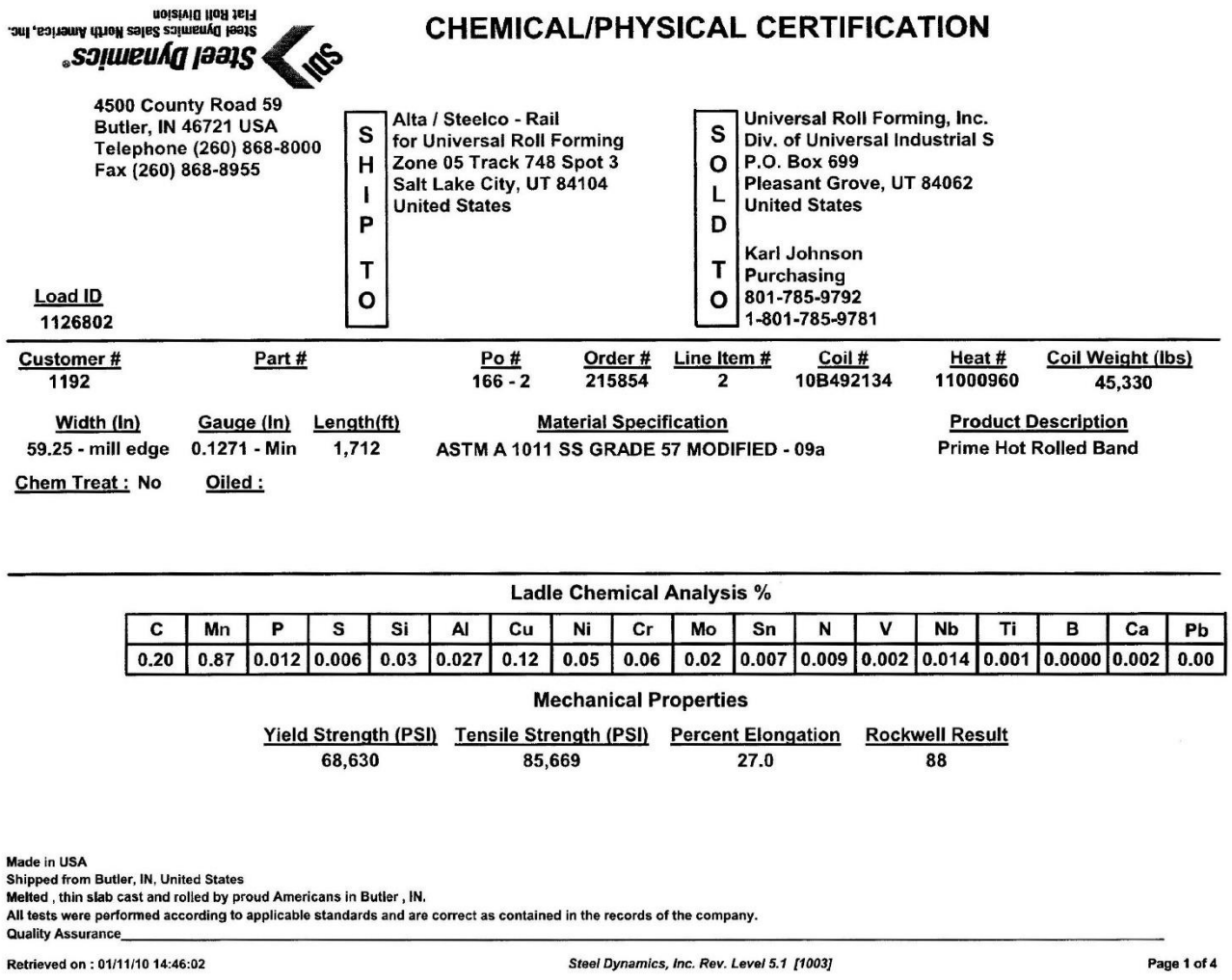
As discussed in Chapter 3, the drawing set for test no. HMDBR-1 included details for the entire system, inclusive of the AGT and bridge rail installation. However, the bridge rail alone was under evaluation in this test, and therefore, only the bridge rail components are documented in this appendix.

Table B-1. Bill of Materials, HMDBR-1

Item No.	Description	Material Specification	Reference
a6	6'-3" 10-gauge Thrie-Beam Section	AASHTO M180	H#1100960
b1	16"x11"x1" Base Plate	ASTM A36	H#B0H751
b2	1 1/4" Dia., 14" Long Anchor Rod	ASTM F1554-15 Grade 105, Class 2A	H#A194079
b3	5/8" Dia., 8" Long Anchor Rod	ASTM F1554-15 Grade 105, Class 2A	H#10543730
d9	W6x25, 23 1/4" Long Steel Post	ASTM A992	H#59089655/02
e1	#4 Rebar, 33 7/8" Total Unbent Length	ASTM A615 Gr. 60	H#7006848
e2	#4 Rebar, 97' 1" Total Length	ASTM A615 Gr. 60	H#7006848
e7	#4 Rebar, 35" Total Unbent Length	ASTM A615 Gr. 60	H#7006848
f3	5/8"-11 UNC, 1 1/4" Long Guardrail Bolt	ASTM A307 Gr. A	H#10657410
f7	5/8"-11 UNC, 2" Long Guardrail Bolt	ASTM A307 Gr. A	H#10439100
f8	7/8" Dia., 8" Long Heavy Hex Head Bolt	ASTM F3125 Gr. A325 Type 1	H#3093334
g1	5/8" Dia. Plain USS Washer	ASTM F844	L#M-SWE0412454-8
g2	5/8" Dia. Hardened Washer	ASTM F436	H#1P832
g3	7/8" Dia. Plain Round Washer	ASTM F844	L#1844804
g5	1 1/4" Dia. Hardened Washer	ASTM F436	H#182540
g6	1" Dia. Hardened Flat Washer	ASTM F436	H#105594
h1	5/8"-11 UNC Heavy Hex Nut	ASTM A563A or equivalent	H#62151324 H#62152527
h2	5/8"-11 UNC Heavy Hex Nut	ASTM A563-15 Grade DH	H#1100890711
h4	1 1/4"-7 UNC Heavy Hex Nut	ASTM A563-15 Grade DH	H#F19080206
h5	1" Dia. Heavy Hex Nut	ASTM A563DH or A194 Gr. 2H	H#621253305
h7	7/8" Dia. UNC Heavy Hex Nut	ASTM A563DH or ASTM A194 Gr. 2H	H#100203930

Table B-2. Bill of Materials, HMDBR-1, Cont.

Item No.	Description	Material Specification	Reference
i1	1" Dia. UNC, 11" Long Threaded Rod	ASTM A449 or A354 Gr. BC or A193 Gr. B7	H#A201673
i2	10-gauge Thrie-Beam Terminal Connector	AASHTO M180 Min. yield strength = 50 ksi Min. tensile strength = 70 ksi	H#A81568
i3	14"x14"x1/2" Steel Plate	ASTM A36 or A572 Gr. 50	H#B705783
i4	HSS 6"x12"x1/4" Tube, 38 1/2" Long	ASTM A500 Gr. B	H#17003401
i5	11 1/2"x5 1/2"x1/2" Steel Plate	ASTM A36 or A572 Gr. 50	H#B705783
i6	HSS 6"x4"x5/16" Tube, 46" Long	ASTM A500 Gr. B	H#A81506
i7	16"x12"x1/2" Steel Plate	ASTM A36 or A572 Gr. 50	H#B705783
j1	Concrete	Min. f'c = 4,000 psi NE Mix 47B1S384000HW or 47B1PF4000HW	Project#00110546.00
k1	Epoxy Adhesive	Hilti HIT RE-500 V3 Class C881	COC
k2	Epoxy Post Cavity Filler	ASTM C881 Type IV, Grade I, Class C	COC



Steel Dynamics Sales North America, Inc.
Flat Roll Division

CHEMICAL/PHYSICAL CERTIFICATION

Steel Dynamics®

4500 County Road 59
Butler, IN 46721 USA
Telephone (260) 868-8000
Fax (260) 868-8955

SHIP TO
Alta / Steelco - Rail
for Universal Roll Forming
Zone 05 Track 748 Spot 3
Salt Lake City, UT 84104
United States

SOLD TO
Universal Roll Forming, Inc.
Div. of Universal Industrial S
P.O. Box 699
Pleasant Grove, UT 84062
United States

Karl Johnson
Purchasing
801-785-9792
1-801-785-9781

Load ID
1126802

Customer #	Part #	Po #	Order #	Line Item #	Coil #	Heat #	Coil Weight (lbs)
1192		166 - 2	215854	2	10B492134	11000960	45,330

Width (In)	Gauge (In)	Length(ft)	Material Specification	Product Description
59.25 - mill edge	0.1271 - Min	1,712	ASTM A 1011 SS GRADE 57 MODIFIED - 09a	Prime Hot Rolled Band

Chem Treat : No Oiled :

Ladle Chemical Analysis %

C	Mn	P	S	Si	Al	Cu	Ni	Cr	Mo	Sn	N	V	Nb	Ti	B	Ca	Pb
0.20	0.87	0.012	0.006	0.03	0.027	0.12	0.05	0.06	0.02	0.007	0.009	0.002	0.014	0.001	0.0000	0.002	0.00

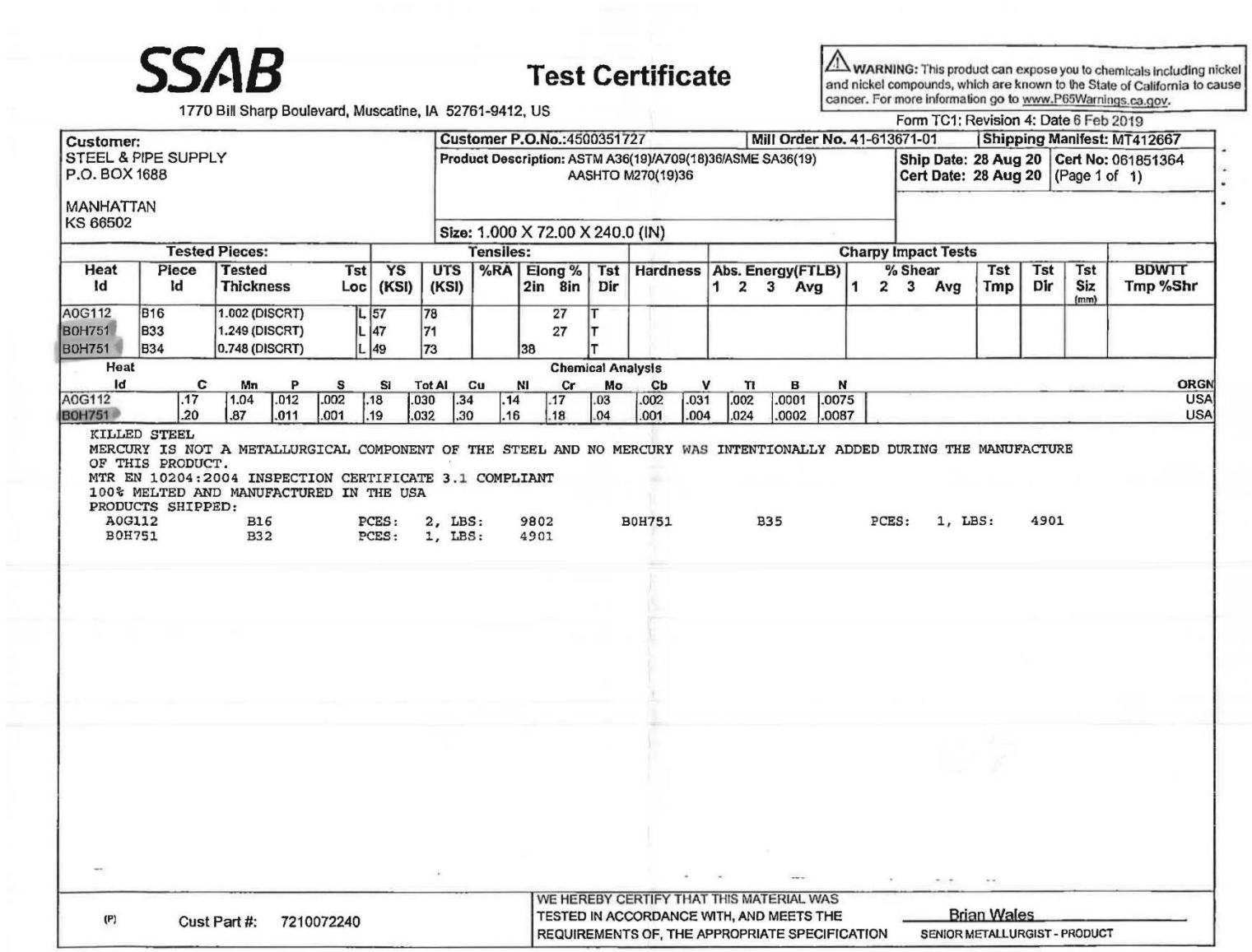
Mechanical Properties

Yield Strength (PSI)	Tensile Strength (PSI)	Percent Elongation	Rockwell Result
68,630	85,669	27.0	88

Made in USA
Shipped from Butler, IN, United States
Melted , thin slab cast and rolled by proud Americans in Butler , IN.
All tests were performed according to applicable standards and are correct as contained in the records of the company.
Quality Assurance

Retrieved on : 01/11/10 14:46:02 *Steel Dynamics, Inc. Rev. Level 5.1 [1003]* Page 1 of 4

Figure B-1. 10-gauge Thrie-Beam Section, Test No. HMDBR-1 (Item No. a6)



SSAB

1770 Bill Sharp Boulevard, Muscatine, IA 52761-9412, US

Test Certificate

WARNING: This product can expose you to chemicals including nickel and nickel compounds, which are known to the State of California to cause cancer. For more information go to www.P65Warnings.ca.gov.

Form TC1: Revision 4: Date 6 Feb 2019

Customer:
STEEL & PIPE SUPPLY
P.O. BOX 1688

MANHATTAN
KS 66502

Customer P.O.No.:4500351727 | Mill Order No. 41-613671-01 | Shipping Manifest: MT412667

Product Description: ASTM A36(19)/A709(18)36/ASME SA36(19)
AASHTO M270(19)36

Ship Date: 28 Aug 20 | Cert No: 061851364
Cert Date: 28 Aug 20 | (Page 1 of 1)

Size: 1.000 X 72.00 X 240.0 (IN)

Tested Pieces:				Tensiles:					Hardness	Charpy Impact Tests						
Heat Id	Piece Id	Tested Thickness	Tst Loc	YS (KSI)	UTS (KSI)	%RA	Elong % 2in 8in	Tst Dir		Abs. Energy(FTLB) 1 2 3 Avg	% Shear 1 2 3 Avg	Tst Tmp	Tst Dir	Tst Siz (mm)	BDWTT Tmp %Shr
A0G112	B16	1.002 (DISCRT)	L	57	78		27	T							
B0H751	B33	1.249 (DISCRT)	L	47	71		27	T							
B0H751	B34	0.748 (DISCRT)	L	49	73		38	T							

Heat Id	Chemical Analysis C	Mn	P	S	Si	Tot Al	Cu	Ni	Cr	Mo	Cb	V	Ti	B	N	ORGN
A0G112	.17	1.04	.012	.002	.18	.030	.34	.14	.17	.03	.002	.031	.002	.0001	.0075	USA
B0H751	.20	.87	.011	.001	.19	.032	.30	.16	.18	.04	.001	.004	.024	.0002	.0087	USA

KILLED STEEL
MERCURY IS NOT A METALLURGICAL COMPONENT OF THE STEEL AND NO MERCURY WAS INTENTIONALLY ADDED DURING THE MANUFACTURE OF THIS PRODUCT.
MTR EN 10204:2004 INSPECTION CERTIFICATE 3.1 COMPLIANT
100% MELTED AND MANUFACTURED IN THE USA
PRODUCTS SHIPPED:

A0G112	B16	PCES:	2,	LBS:	9802	B0H751	B35	PCES:	1,	LBS:	4901
B0H751	B32	PCES:	1,	LBS:	4901						

(P) Cust Part #: 7210072240

WE HEREBY CERTIFY THAT THIS MATERIAL WAS TESTED IN ACCORDANCE WITH, AND MEETS THE REQUIREMENTS OF, THE APPROPRIATE SPECIFICATION

Brian Wales
SENIOR METALLURGIST - PRODUCT

Figure B-2. Base Plate, Test No. HMDBR-1 (Item No. b1)

Job Material Certification

Vulcan
THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 647405 **Job Information** **Certified Date:** 10/29/19

Containers: S16189360 S16189496 S16190823 S16192677 S16192738

Customer: Conklin and Conklin **Ship To:** 34201 Seventh Street Union City, CA 94587

Vulcan Part No: BAR B7 1.1523x144 SC

Customer Part No: BAR B7 1.152x144

Customer PO No: 19595

Order No: 385750 **Shipped Qty:** 15028 lbs

Note: **Line No:** 5

Applicable Specifications

Type	Specification	Rev	Amend	Option
-	ASTM F1554 Gd 105 S4	2018		
Heat Treat	ASME SA-193/SA-193M B7	2013		
	ASTM A193 B7	2017		

Test Results

See following pages for tests

Certified Chemical Analysis

Heat No: A194079 Lot 1.218 Origin: USA

C	Mn	P	S	Si	Cr	Mo	Ni	V	Cu	Al
0.40	0.80	0.013	0.022	0.24	0.83	0.17	0.11	0.002	0.25	0.023
Cb	Sn	N	B	Ca	As	Sb	H, ppm	DI	RR	G.S.
0.001	0.009	0.0093	0.0002	0.0007	0.004	0.002	2.3	4.44	124.6:1	8
Macro S	Macro R	Macro C	J1	J2	J3	J4	J5	J6	J7	J8
1	1	2	56	56	56	56	56	53	51	49
J9	J10	J12	J14	J16	J18	J20	J24	J28	J32	
48	47	44	42	39	38	37	35	33	32	

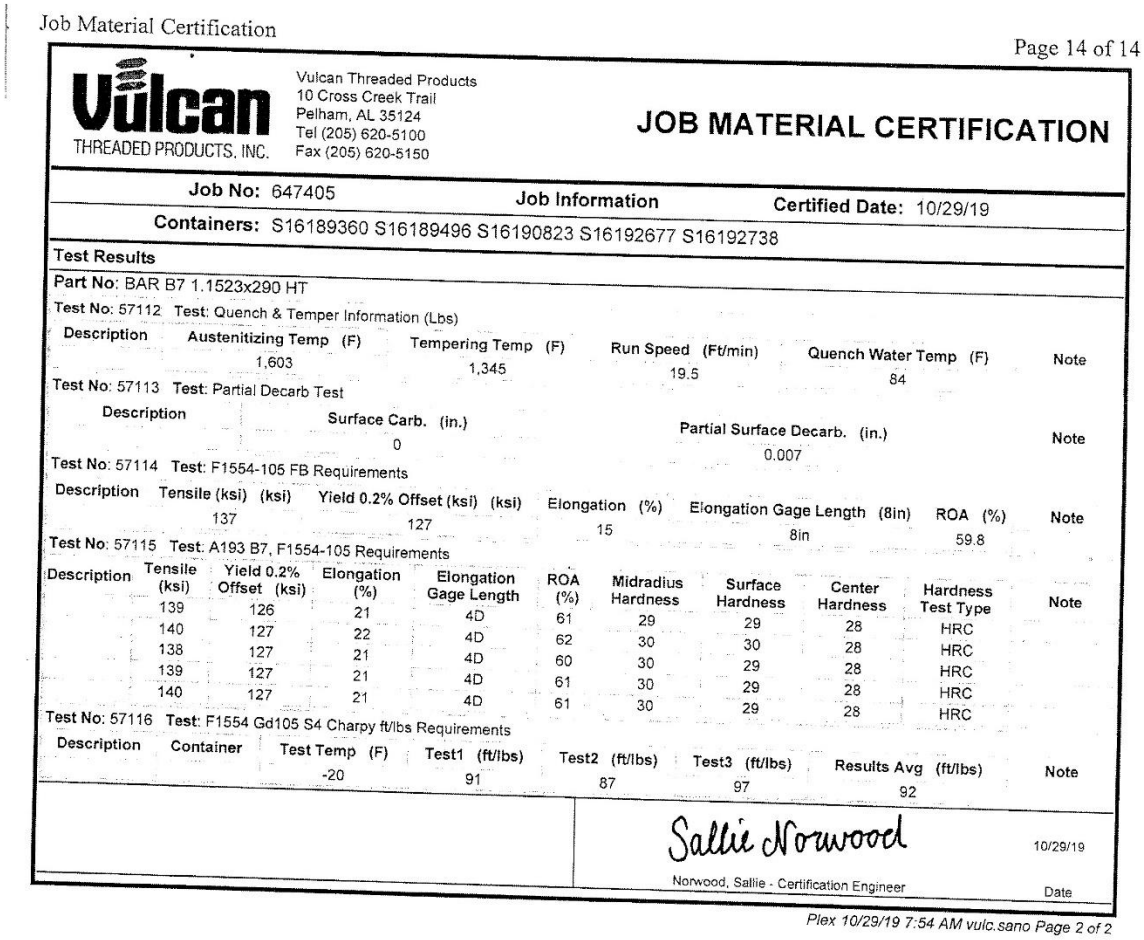
Notes

Material was manufactured, tested and inspected as required by the product standard and in accordance with Vulcan's ISO 9001:2015 Quality Management System registered June 30th, 2017. Processed material is Tempered - Stress Free. No weld repair performed on the material. No Mercury used in the production of this material. Melted and Manufactured in the USA.
Document is in accordance with EN 10204 - 3.1B of 2004 (3.1).
Grade - 4140
EAF Melted

PORTLAND BOLT
PO 45740
INV 80296
50 1-1/4" X 144" B7 ATR, H.D.G. 1OF2
MAY 13, 2020

01-0454

Figure B-3. 1¼-in. Dia. Anchor Rod, Test No. HMDBR-1 (Item No. b2), Page 1 of 2



Job Material Certification

Page 14 of 14

Vulcan
THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 647405 **Job Information** **Certified Date:** 10/29/19

Containers: S16189360 S16189496 S16190823 S16192677 S16192738

Test Results

Part No: BAR B7 1.1523x290 HT

Test No: 57112 **Test:** Quench & Temper Information (Lbs)

Description	Austenitizing Temp (F)	Tempering Temp (F)	Run Speed (Ft/min)	Quench Water Temp (F)	Note
	1,603	1,345	19.5	84	

Test No: 57113 **Test:** Partial Decarb Test

Description	Surface Carb. (in.)	Partial Surface Decarb. (in.)	Note
	0	0.007	

Test No: 57114 **Test:** F1554-105 FB Requirements

Description	Tensile (ksi) (ksi)	Yield 0.2% Offset (ksi) (ksi)	Elongation (%)	Elongation Gage Length (8in)	ROA (%)	Note
	137	127	15	8in	59.8	

Test No: 57115 **Test:** A193 B7, F1554-105 Requirements

Description	Tensile (ksi)	Yield 0.2% Offset (ksi)	Elongation (%)	Elongation Gage Length	ROA (%)	Midradius Hardness	Surface Hardness	Center Hardness	Hardness Test Type	Note
	139	126	21	4D	61	29	29	28	HRC	
	140	127	22	4D	62	30	30	28	HRC	
	138	127	21	4D	60	30	29	28	HRC	
	139	127	21	4D	61	30	29	28	HRC	
	140	127	21	4D	61	30	29	28	HRC	

Test No: 57116 **Test:** F1554 Gd105 S4 Charpy ft/lbs Requirements

Description	Container	Test Temp (F)	Test1 (ft/lbs)	Test2 (ft/lbs)	Test3 (ft/lbs)	Results Avg (ft/lbs)	Note
		-20	91	87	97	92	

Sallie Norwood 10/29/19

Norwood, Sallie - Certification Engineer Date

Plex 10/29/19 7:54 AM vulc.sano Page 2 of 2

PORTLAND BOLT
PO 45740
INV 80296
50 1-1/4" X 144" B7 ATR, H.D.G. 2OF2
MAY 13, 2020

https://www.plexonline.com/8b3f6397-ab3b-40a7-8908-032dc75c84b8/Sales/Report_Job_Cert.asp?Mod... 10/30/2019

Figure B-4. 1¼-in. Dia. Anchor Rod, Test No. HMDBR-1 (Item No. b2), Page 2 of 2

Job Material Certification

Vulcan THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 578337 **Job Information** **Certified Date:** 5/15/18

Containers: S14030915

Customer: Conklin and Conklin **Ship To:** 34201 Seventh Street Union City, CA 94587

Vulcan Part No: BAR B7 .5626x144 SC

Customer Part No: BAR B7 .562x144

Customer PO No: 18796 **Shipped Qty:** 3039 lbs

Order No: 350846 **Line No:** 2

Note:

Applicable Specifications

Type	Specification	Rev	Amend	Option
-	ASTM F1554 Gd 105 S4	2015		
Heat Treat	ASME SA-193/SA-193M B7	2013		
	ASTM A193 B7	2016		
Quality	EN 10204 3.1	2004		

Test Results

See following pages for tests

Certified Chemical Analysis

Heat No: 10543730 Origin: USA

C	Mn	P	S	Si	Cr	Mo	Ni	V	Cu
0.410	0.89	0.008	0.023	0.27	0.93	0.21	0.06	0.003	0.14
Al	Nb	Sn	Ti	N	B	DI	RR	G.S.	Macro S
0.027	0.002	0.006	0.002	0.0060	0.0001	5.31	81:1	Fine	2
Macro R	Macro C	J1	J2	J3	J4	J5	J6	J7	J8
2	2	57	57	57	57	57	57	57	55
J9	J10	J12	J14	J16	J18	J20	J24	J28	J32
54	53	50	49	47	46	45	43	41	39

Notes

Material was manufactured, tested and inspected as required by the product standard and in accordance with Vulcan's ISO 9001:2015 Quality Management System registered June 30th, 2017. No weld repair performed on the material. No Mercury used in the production of this material. Document is in accordance with EN 10204 - 3.1B of 2004 (3.1).

Plex 5/15/18 9:42 AM vulc.mgri Page 1 of 2

PORTLAND BOLT
PO 46352
INV 80522
45 5/8" X 144" B7 ATR, H.D.G. 1OF2
JUNE 25, 2020

4635-4

JUL 17 2018

https://www.plexonline.com/a2a08224-b139-4fcf-b6fb-272d0eba1b07/Sales/Report_Job_Cert.asp?Mode=... 7/10/2018

Figure B-5. ⅝-in. Dia. Anchor Rod, Test No. HMDBR-1 (Item No. b3), Page 1 of 2

Job Material Certification

Vulcan THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 578337 **Job Information** **Certified Date:** 5/15/18

Containers: S14030915

Test Results

Part No: BAR B7 .5626x292 HT

Test No: 48511 **Test:** Quench & Temper Information (Lbs)

Description	Austenitizing Temp (F)	Tempering Temp (F)	Run Speed (Ft/min)	Quench Water Temp (F)	Note
Quench & Temper Information Results	1,652	1,328	37	89	

Test No: 48514 **Test:** Partial Decarb Test

Description	Surface Carb. (in.)	Surface Decarb. (in.)	Note
	0.000	0.003	

Test No: 48512 **Test:** A193 B7, F1554-105 Requirements

Description	Tensile (ksi)	Yield 0.2% Offset (ksi)	Elongation (%)	Elongation Gage Length	ROA (%)	Midradius Hardness	Surface Hardness	Center Hardness	Hardness Test Type	Note
	135	125	21	4D	63	30	28		HRC	
	136	125	22	4D	63	30	28		HRC	
	136	125	24	4D	60	31	28		HRC	
	136	125	23	4D	62	30	28		HRC	
	135	125	23	4D	64	30	27		HRC	
	134	124	23	4D	63	31	27		HRC	
	136	125	22	4D	62	31	29		HRC	

Test No: 48513 **Test:** F1554-15 gd105 S4 Charpy ft/lbs Requirements

Description	Container	Test Temp (F)	Test1 (ft/lbs)	Test2 (ft/lbs)	Test3 (ft/lbs)	Results Avg (ft/lbs)	Note
		-20	179	144	190	171	

Griffin, Mitchell - Certification Engineer 5/15/18 Date

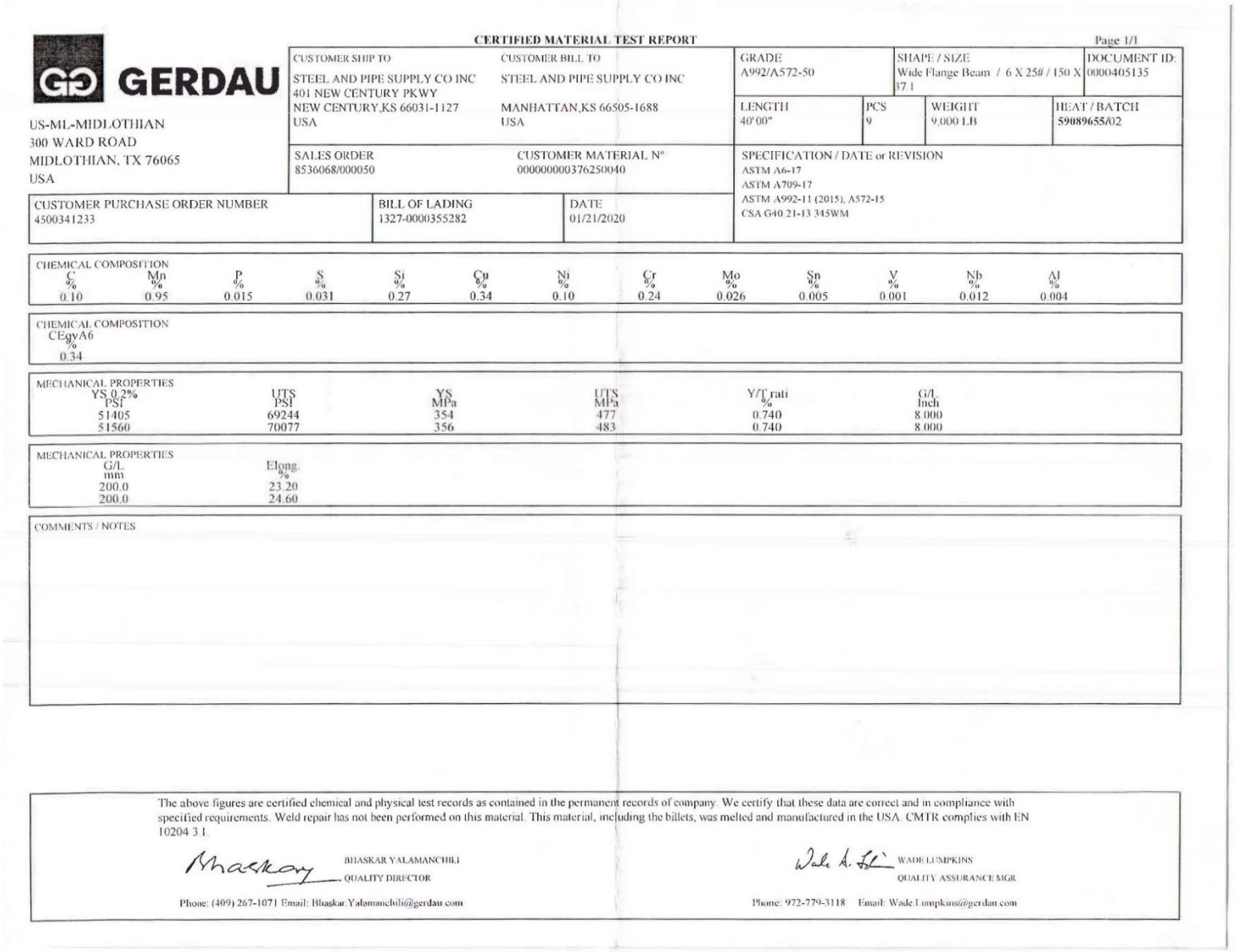
Plex 5/15/18 9:42 AM vulc.mgri Page 2 of 2

PORTLAND BOLT
PO 46352
INV 80522
45 5/8" X 144" B7 ATR, H.D.G. 2OF2
JUNE 25, 2020

JUL 17 2018

https://www.plexonline.com/a2a08224-b139-4fcf-b6fb-272d0eba1b07/Sales/Report_Job_Cert.asp?Mode=... 7/10/2018

Figure B-6. ⅝-in. Dia. Anchor Rod, Test No. HMDBR-1 (Item No. b3), Page 2 of 2



CERTIFIED MATERIAL TEST REPORT — Page 1/1

GERDAU

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 25# / 150 X 37.1	00000405135

LENGTH	PCS	WEIGHT	HEAT / BATCH
40' 00"	9	9,000 LB	59089655/02

SALES ORDER	CUSTOMER MATERIAL N°
8536068/000050	000000000376250040

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

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
4500341233	1327-0000355282	01/21/2020

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.10	0.95	0.015	0.031	0.27	0.34	0.10	0.24	0.026	0.005	0.001	0.012	0.004

CHEMICAL COMPOSITION

CEqvA6 %
0.34

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	Y/T rati %	G/L Inch
51405	69244	354	477	0.740	8.000
51560	70077	356	483	0.740	8.000

MECHANICAL PROPERTIES

G/L mm	Elong. %
200.0	23.20
200.0	24.60

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

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

Figure B-7. W6x25 Steel Post, Test No. HMDBR-1 (Item No. d9)

CMC STEEL TENNESSEE
1919 Tennessee Avenue
Knoxville TN 37921-2686

CERTIFIED MILL TEST REPORT
For additional copies call

We hereby certify that the test results presented here are accurate and conform to the reported grade specification

Jim Hall
Quality Assurance Manager

HEAT NO.:7006848 SECTION: REBAR 13MM (#4) 60'0" 420/60 GRADE: ROLL DATE: MELT DATE: 01/05/2020 Cert. No.: 82944733 / 006848L265	SOLD TO	ABC Coating Co - Tulsa 2236 S Yukon Ave Tulsa OK US 74107-2765 9185852587 9185858131	SHIP TO	CPU Chicago Depot 13535 S Torrence Ave Chicago IL US 60633-2164 7736466363	Delivery#: 82944733 BOL#: 1865847 CUST PO#: 010620-Minn CUST P/N: DLVRY LBS / HEAT: 26932.000 LB DLVRY PCS / HEAT: 672 EA

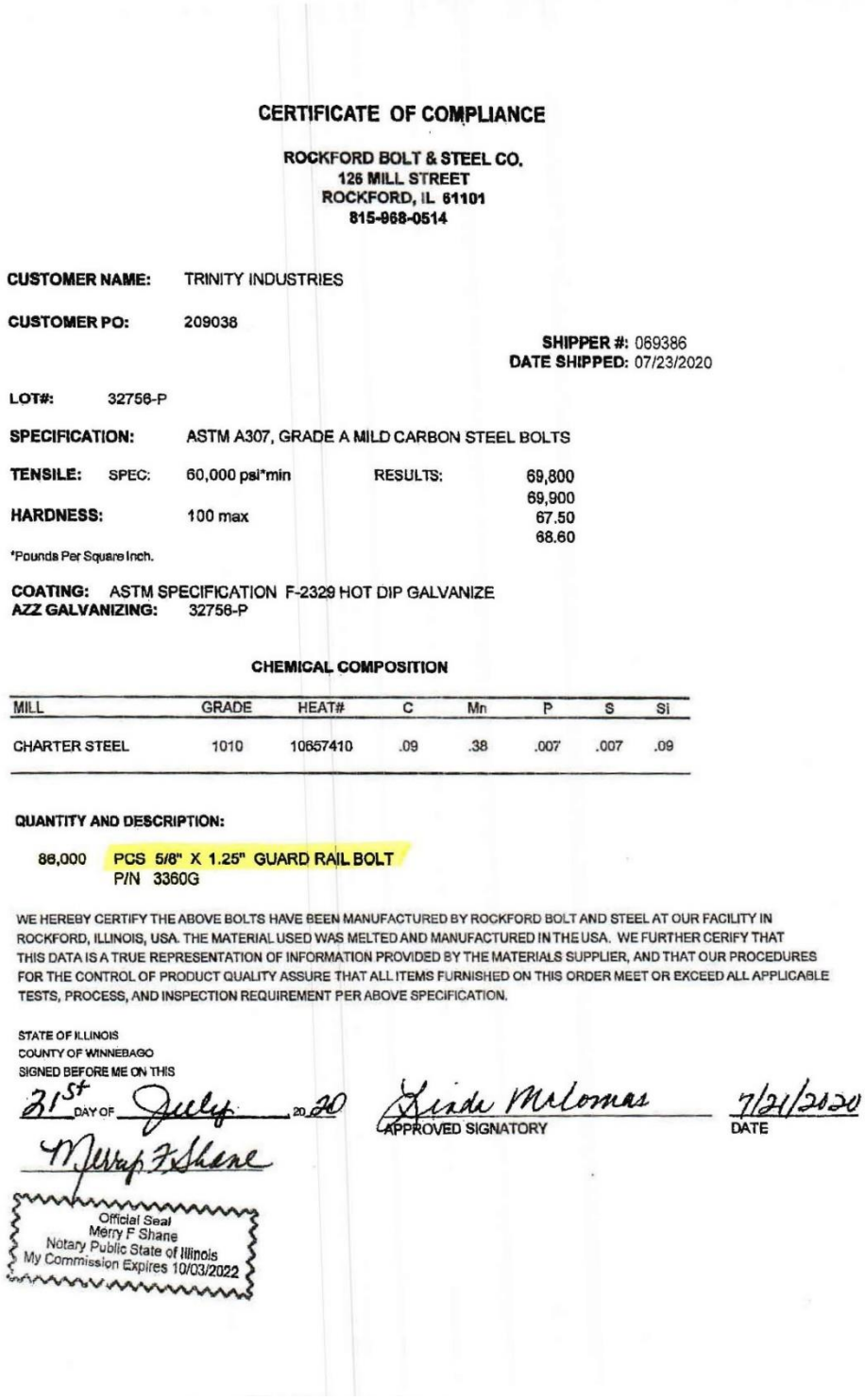
Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.27%	Rebar Deformation Avg. Spaci	0.329IN		
Mn	0.59%	Rebar Deformation Avg. Heigh	0.034IN		
P	0.008%	Rebar Deformation Max. Gap	0.106IN		
S	0.048%				
Si	0.20%				
Cu	0.33%				
Cr	0.17%				
Ni	0.11%				
Mo	0.014%				
V	0.002%				
Sn	0.007%				
Yield Strength test 1	85.9ksi				
Yield Strength test 1 (metri	592MPa				
Tensile Strength test 1	99.1ksi				
Tensile Strength 1 (metric)	684MPa				
Elongation test 1	13%				
Elongation Gage Lgth test 1	8IN				
Elongation Gage Lgth 1(metri	200mm				
Bend Test 1	Passed				

The Following is true of the material represented by this MTR:
*Material is fully killed
*100% melted and rolled in the USA
*EN10204:2004 3.1 compliant
*Contains no weld repair
*Contains no Mercury contamination
*Manufactured in accordance with the latest version of the plant quality manual
*Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661
*Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov

REMARKS :

Page 1 OF 1 01/21/2020 09:09:21

Figure B-8. #4 Rebar, Test No. HMDBR-1 (Item Nos. e1, e2, and e7)



CERTIFICATE OF COMPLIANCE

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

CUSTOMER NAME: TRINITY INDUSTRIES

CUSTOMER PO: 209038

SHIPPER #: 069386
DATE SHIPPED: 07/23/2020

LOT#: 32756-P

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE:	SPEC:	60,000 psi*min	RESULTS:	69,800 69,900
HARDNESS:		100 max		67.50 68.60

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
AZZ GALVANIZING: 32756-P

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
CHARTER STEEL	1010	10657410	.09	.38	.007	.007	.09

QUANTITY AND DESCRIPTION:

88,000 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
31st DAY OF July 2020

Linda Meloma
APPROVED SIGNATORY

7/21/2020
DATE

Merry F Shane

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

Figure B-9. ⅝ in. Dia. Guardrail Bolt, Test No. HMDBR-1 (Item No. f3)

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, 2017

Merry F. Shane

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

Linda McComas
APPROVED SIGNATORY

3/7/17
DATE

Figure B-10. ⅝-in. – 11 UNC, 2-in. Long Guardrail Bolt, Test No. HMDBR-1 (Item No. f7)

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#: 134913
Cust PO#: HMDT
Date: 9/16/2020
Shipped: 9/16/2020

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 8 GALV ASTM F3125 GRADE A325 HEAVY HEX BOLT

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

Source: COMMERCIAL METALS CO **Proof Load:** 40,428 LBF

C :	.400	**Mn:** .810	**P :** .016	**Hardness:**	269 HBN		
S :	.019	**Si:** .240	**Ni:** .190	**Tensile:**	58,440 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#19810

Coatings:
ITEMS HOT DIP GALVANIZED PER ASTM F2329/A153C

By: _____
Certification Department Quality Assurance
Dane McKinnon

Figure B-11. ⅞-in. Dia. Heavy Hex Head Bolt, Test No. HMDBR-1 (Item No. f8)

TEST REPORT

USS FLAT WASHER, HDG

CUSTOMER:

DATE: 30/12/2018

PO NUMBER: 180164126

MFG LOT NUMBER: M-SWE0412454-8

SIZE: 5/8

PART NO: 1133185

HEADMARKS:

QNTY: 6,000 PCS

DIMENSIONAL INSPECTIONS

SPECIFICATION: ASME B18.21.1(2009)

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F788-07	PASSED	100	0
OUTSIDE DIA	1.743-1.780	1.752-1.756	8	0
INSIDE DIA	0.681-0.718	0.700-0.707	8	0
THICKNESS	0.108-0.160	0.114-0.119	8	0
HOT DIP GALVANIZED	ASTM A153 class C. RoHS Compliant	Min 0.0017"	Min 0.0019 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.
MFG ISO 9001:2015 SGS Certificate # HK04/0105

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.

IFI & MORGAN LTD. 检验专用章

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

IFI & MORGAN LTD. *ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan, Zhejiang, China*

Figure B-12. ⅝-in. Dia. Plain USS Washer, Test No. HMDBR-1 (Item No. g1)

HEXICO ENTERPRISE CO., LTD.

NO.355-3,SEC. 3,CHUNG SHAN ROAD,KAU-JEN,TAINAN,TAIWAN,R.O.C.
TEL : 886 - 6 - 2390616 FAX : 886 - 6 - 2308947

INSPECTION CERTIFICATE

CUSTOMER	**FASTENAL COMPANY**	REPORT DATE	2019/10/22
PART NAME	Flat Washer , SAE , EcoGuard		
SIZE	5/8"	MAF. DATE	2019/6/17
PART NO.	W2A2C5003S2LK0	REPORT NO.	1081022-44
CUST. PART NO.	11241707	ORDER NO.	210189154
MATERIAL	10B21 / 19 mm	MAT. CER. NO.	10806002
HEAT(COIL) NO.	1P832	LOT NO.	872C5FNY5
LOT QTY	103,500 PCS	MAF. QTY	103,500 PCS

THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH REQUIREMENT OF THE ORDER.

THE REPORT IS ISSUED ACCORDING TO EN10204 3.1

SAMPLING PLAN STANDARD	ASME B18.18-2017 / ASTM F1470-2018
DIMENSION STANDARD	ASME B18.21.1 -2009
COATING STANDARD	FNL.C.1000.ECO.S REV-002
HARDNESS TEST METHOD	ASTM F606/F606M-2016
COATING TEST METHOD	
SALT SPRAY TEST METHOD	ASTM B117-2016

DIMENSIONS IN inch

	INSPECTION ITEM	SPECIFICATION	TEST QTY	INSPECTION RESULTS MIN.	INSPECTION RESULTS MAX.	INSPECTION EQUIPMENT
1	OUTSIDE DIAMETER	1.305 - 1.342	8	1.3202	1.3324	Caliper
2	INSIDE DIAMETER	0.649 - 0.686	8	0.6777	0.6807	Caliper
3	THICKNESS	0.074 - 0.121	8	0.1014	0.1037	Caliper
4	HARDNESS	HRC 38 - 45	5	41.2	42.3	Hardness tester
5	COATING	GEOMET 321+PLUSL	5	OK		
6	SALT SPRAY TEST	1000 Hrs No Red Rust	5	OK		S.S.T tester
7	APPEARANCE	VISUAL	100	OK		

INSPECTOR Yu Tain Lin QC CHIEF Jing Yeh Tsao

Figure B-13. ⅝-in. Dia. Hardened Washer, Test No. HMDBR-1 (Item No. g2)

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-14. ⅞-in. Dia. Plain Round Washer, Test No. HMDBR-1 (Item No. g3)

NUCOR
SHEET MILL GROUP

METALLURGICAL TESTING CERTIFICATION

D069507

Certificate Number: 788498
Date Issued: 09/02/2018

Page: 2 of 3

Nucor Steel-Crawfordsville
4537 South Nucor Road
Crawfordsville, IN 47933-0907

Order Number: 304155 - 0016 HOT ROLLED PICKLED & OILED
Order Dimensions: 0.1360 in X 48.0000 in
HRPO,MILL,1035

ASTM A568-17A
SAE J403-14 1035

Customer Name: WROUGHT WASHER MFG INC
Customer Address: 2100 S BAY ST

MILWAUKEE WI 53207

Release Order:
Cust PO Number: H3454

Coil Number 2316515.000 TAIL Rockwell B: 87

Part Number
842149-60 TONS
Weight: 41,920 LBS

CHEMICAL ANALYSIS

Heat	Slab	C	Mn	P	S	Si	Cu	Sn	Ni	Cr	Mo	Al	N	V	Nb	Ti	B	Sb
182540	04	0.33	0.850	0.010	0.002	0.250	0.135	0.003	0.069	0.063	0.023	0.028	0.007	0.002	<0.001	0.003	<0.0005	0.002

Coil Number 2316516.000 TAIL Rockwell B: 87

Part Number
842149-60 TONS
Weight: 41,920 LBS

CHEMICAL ANALYSIS

Heat	Slab	C	Mn	P	S	Si	Cu	Sn	Ni	Cr	Mo	Al	N	V	Nb	Ti	B	Sb
182540	05	0.33	0.850	0.010	0.002	0.250	0.135	0.003	0.069	0.063	0.023	0.028	0.007	0.002	<0.001	0.003	<0.0005	0.002

WE HEREBY CERTIFY THE ABOVE IS CORRECT AS CONTAINED IN THE RECORDS OF THE CORPORATION
MELTED AND ROLLED IN THE USA

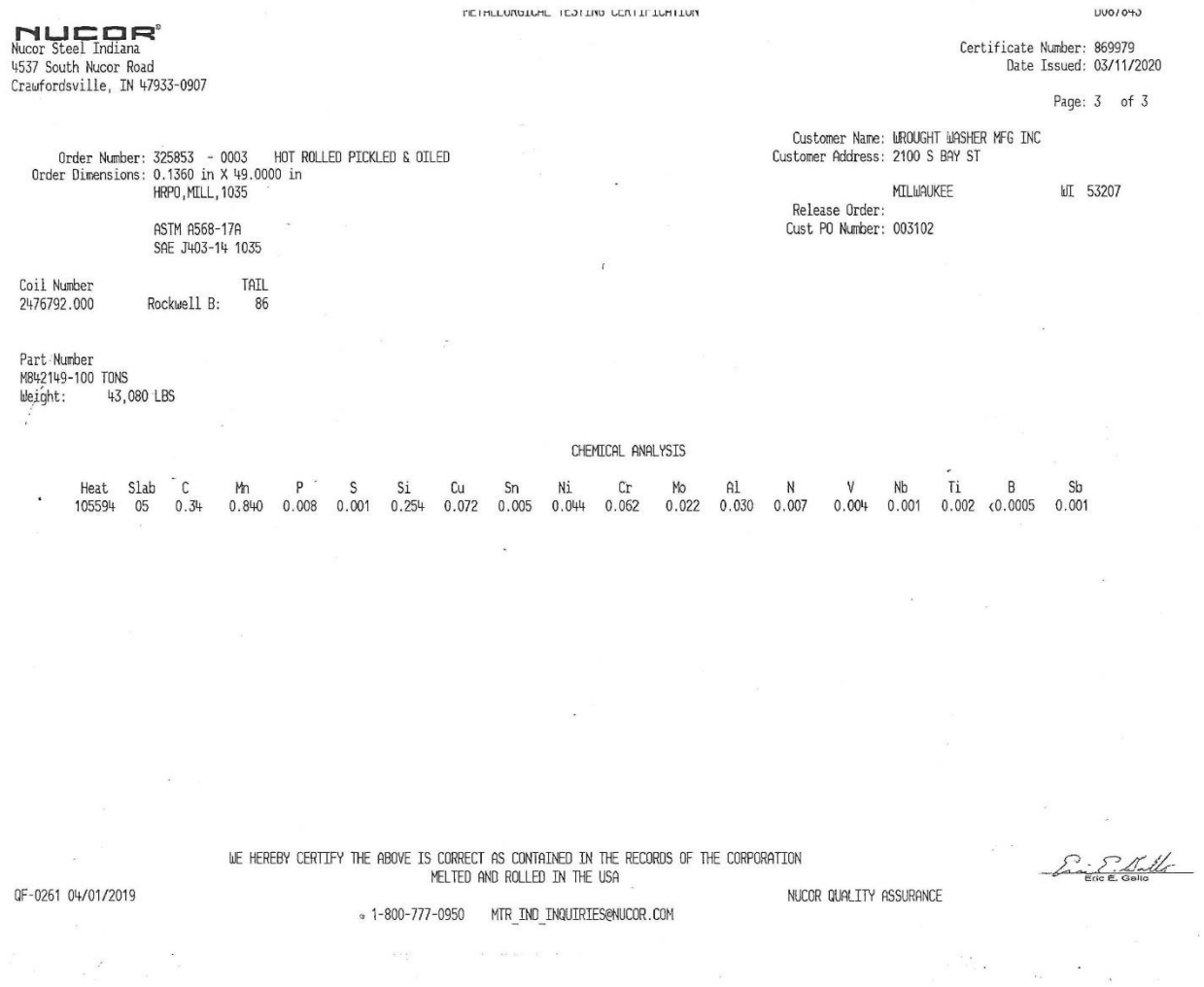
QF-0261 11/29/2012

1-800-777-0950 MTR_IND_INQUIRIES@NUCOR.COM

NUCOR QUALITY ASSURANCE

Eric E. Gallo

Figure B-15. 1¼-in. Dia. Hardened Washer, Test No. HMDBR-1 (Item No. g5)



METALLURGICAL TESTING CERTIFICATION

NUCOR®
Nucor Steel Indiana
4537 South Nucor Road
Crawfordsville, IN 47933-0907

Certificate Number: 869979
Date Issued: 03/11/2020

Page: 3 of 3

Customer Name: WROUGHT WASHER MFG INC
Customer Address: 2100 S BAY ST

MILWAUKEE WI 53207

Release Order:
Cust PO Number: 003102

Order Number: 325853 - 0003 HOT ROLLED PICKLED & OILED
Order Dimensions: 0.1360 in X 49.0000 in
HRPO,MILL,1035

ASTM A568-17A
SAE J403-14 1035

Coil Number TAIL
2476792.000 Rockwell B: 86

Part Number
M842149-100 TONS
Weight: 43,080 LBS

CHEMICAL ANALYSIS

Heat	Slab	C	Mn	P	S	Si	Cu	Sn	Ni	Cr	Mo	Al	N	V	Nb	Ti	B	Sb
105594	05	0.34	0.840	0.008	0.001	0.254	0.072	0.005	0.044	0.062	0.022	0.030	0.007	0.004	0.001	0.002	<0.0005	0.001

WE HEREBY CERTIFY THE ABOVE IS CORRECT AS CONTAINED IN THE RECORDS OF THE CORPORATION
MELTED AND ROLLED IN THE USA

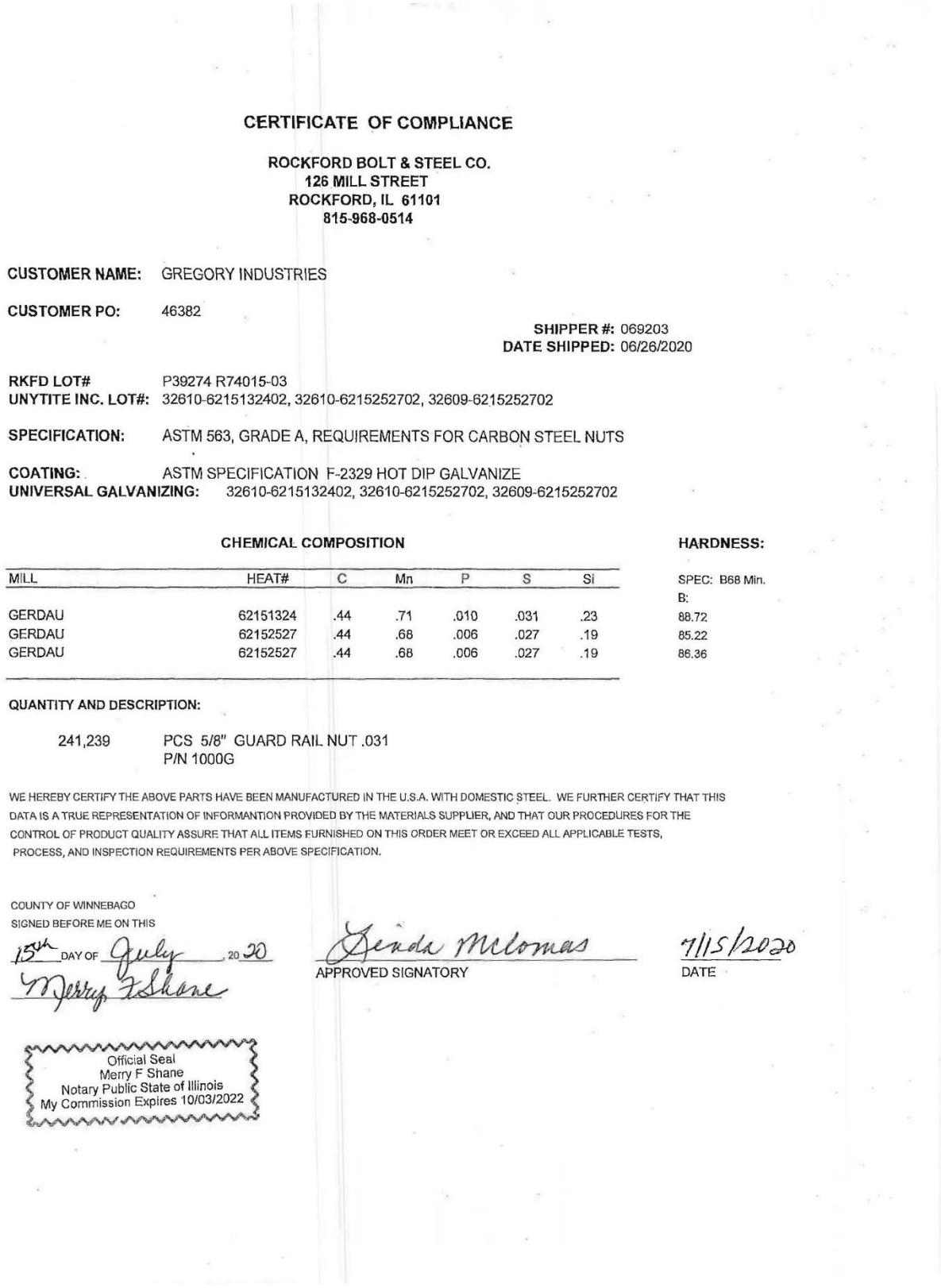
Eric E. Gallo

QF-0261 04/01/2019

NUCOR QUALITY ASSURANCE

1-800-777-0950 MTR_IND_INQUIRIES@NUCOR.COM

Figure B-16. 1-in. Dia. Hardened Flat Washer, Test No. HMDBR-1 (Item No. g6)



CERTIFICATE OF COMPLIANCE

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

CUSTOMER NAME: GREGORY INDUSTRIES

CUSTOMER PO: 46382

SHIPPER #: 069203
DATE SHIPPED: 06/26/2020

RKFD LOT# P39274 R74015-03
UNYTITE INC. LOT#: 32610-6215132402, 32610-6215252702, 32609-6215252702

SPECIFICATION: ASTM 563, GRADE A, REQUIREMENTS FOR CARBON STEEL NUTS

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
UNIVERSAL GALVANIZING: 32610-6215132402, 32610-6215252702, 32609-6215252702

CHEMICAL COMPOSITION

MILL	HEAT#	C	Mn	P	S	Si
GERDAU	62151324	.44	.71	.010	.031	.23
GERDAU	62152527	.44	.68	.006	.027	.19
GERDAU	62152527	.44	.68	.006	.027	.19

HARDNESS:

SPEC: B68 Min. B:
88.72
85.22
86.36

QUANTITY AND DESCRIPTION:

241,239 PCS 5/8" GUARD RAIL NUT .031
P/N 1000G

WE HEREBY CERTIFY THE ABOVE PARTS HAVE BEEN MANUFACTURED IN THE U.S.A. WITH DOMESTIC STEEL. WE FURTHER CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMANTION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENTS PER ABOVE SPECIFICATION.

COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS
15th DAY OF July 2020
Merry F Shane

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

Jenda Mclomas
APPROVED SIGNATORY

7/15/2020
DATE

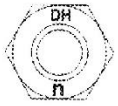
Figure B-17. ⅝-in. Dia. Heavy Hex Nut, Test No. HMDBR-1 (Item No. h1)

NUCOR
FASTENER DIVISION

LOT NO.
437306A

Post Office Box 6100
Saint Joe, Indiana 46785
Telephone 260/337-1600

CUSTOMER NO/NAME
7495 FASTENAL COMPANY-TX
TEST REPORT SERIAL# FB633133
TEST REPORT ISSUE DATE 6/05/20
DATE SHIPPED 8/25/20
NAME OF LAB SAMPLER: RYAN UNGER, LAB TECHNICIAN
NUCOR ORDER # 213442
CUST PART # 38207
CUSTOMER P.O. # 180203570



**********CERTIFIED MATERIAL TEST REPORT**********

NUCOR PART NO	QUANTITY	LOT NO.	DESCRIPTION
175747C	8500	437306A	5/8-11 GR DH HV H.D.G.
MANUFACTURE DATE 3/30/20			HEX NUT HOT DIP GAL.

--CHEMISTRY MATERIAL GRADE -1026L

MATERIAL NUMBER	HEAT NUMBER	**CHEMISTRY COMPOSITION (WT% HEAT ANALYSIS) BY MATERIAL SUPPLIER C	MN	P	S	SI	
RM032619	100890711	.24	.71	.005	.020	.22	NUCOR STEEL - NEBRASKA

--MECHANICAL PROPERTIES IN ACCORDANCE WITH ASTM A563-15

SURFACE HARDNESS (R30N)	CORE HARDNESS (RC)	PROOF LOAD 33900 LBS	TENSILE STRENGTH (LBS)	DEG-WEDGE STRESS (PSI)
N/A	31.9	PASS	N/A	N/A
N/A	31.9	PASS	N/A	N/A
N/A	33.3	PASS	N/A	N/A
N/A	32.4	PASS	N/A	N/A
N/A	31.3	PASS	N/A	N/A

AVERAGE VALUES FROM TESTS
32.2
PRODUCTION LOT SIZE 245000 PCS

--VISUAL INSPECTION IN ACCORDANCE WITH ASTM A563-15 160 PCS. SAMPLED LOT PASSED

--COATING - HOT DIP GALVANIZED TO ASTM F2329-15 - GALVANIZING PERFORMED IN THE U.S.A.

1.	0.00365	2.	0.00297	3.	0.00573	4.	0.00402	5.	0.00408	6.	0.00490	7.	0.00319
8.	0.00547	9.	0.00502	10.	0.00290	11.	0.00247	12.	0.00403	13.	0.00319	14.	0.00237
15.	0.00290												

AVERAGE THICKNESS FROM 15 TESTS .00379

--HEAT TREATMENT - AUSTENITIZED, OIL QUENCHED & TEMPERED (MIN 800 DEG F)

--DIMENSIONS PER ASME B18.2.6-2010

CHARACTERISTIC	#SAMPLES TESTED	MINIMUM	MAXIMUM
Width Across Corners	8	1.186	1.194
Thickness	32	0.596	0.602

ALL TESTS ARE IN ACCORDANCE WITH THE LATEST REVISIONS OF THE METHODS PRESCRIBED IN THE APPLICABLE SAE AND ASTM SPECIFICATIONS. THE SAMPLES TESTED CONFORM TO THE SPECIFICATIONS AS DESCRIBED/LISTED ABOVE AND WERE MANUFACTURED FREE OF MERCURY CONTAMINATION. NO INTENTIONAL ADDITIONS OF BISMUTH, SELENIUM, TELLURIUM, OR LEAD WERE USED IN THE STEEL USED TO PRODUCE THIS PRODUCT.
THE STEEL WAS MELTED AND MANUFACTURED IN THE U.S.A. AND THE PRODUCT WAS MANUFACTURED AND TESTED IN THE U.S.A.
PRODUCT COMPLIES WITH DFARS 252.225-7014. WE CERTIFY THAT THIS DATA IS A 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. CERTIFICATION FORMAT MEETS EN10204 3.1

A2LA ACCREDITED

MECHANICAL FASTENER
CERTIFICATE NO. A2LA 0139.01
EXPIRATION DATE 12/31/21

NUCOR FASTENER
A DIVISION OF NUCOR CORPORATION

BOB HAYWOOD
QUALITY ASSURANCE SUPERVISOR

Page 1 of 1

Figure B-18. ⅝-in. Dia. Heavy Hex Nut, Test No. HMDBR-1 (Item No. h2)

NINGBO DONGXIN HIGH-STRENGTH NUT CO.,LTD
TEST CERTIFICATE
(EN 10204.3.1)

Customer: FASTENAL COMPANY PURCHASING	**Production Lot No.:**	1910DX100-1339-1	**Issue Date:**	2020/4/22
	Add.of Customer:	4730 SERVICE DRIVEWINONA MN 55897	**Inv. No.:**	20167DX100-871
	Description:	ASTM A563 GR.DH HEAVY HEX NUT	**Manu. Date:**	2019/11/29
		HDG With Blue Wax	**Manu. Qty:**	1680
	PO No.:	210199067	**Shipped Qty:**	1620
	Manufacturer:	Ningbo Dongxin High-strength Nut	**Marking:**	DX,DH
	Address:	Xijingtang,Luotuo,Ningbo,China	**LOT No.:**	1217DX100-1339-1
	Tel./Fax:	0574-86533751/86531751	**Sample Plan:**	ASME B18.18-2017(Category.2)/ASTM F1470-2019
	Size:	1 1/4"-7	**Part No.:**	36767

Chemical Composition

Material type: 45# Φ34 Heat No.: F19080206

Chemical Analysis % (items)	**C**	**Mn**	**P**	**S**	**Si**	**Cr**	**Ni**	**Mo**	**Others**
	0.18-0.58	**MIN0.57**	**MAX0.048**	**MAX0.058**	**/**	**/**	**/**	**/**	**/**
Result	0.45	0.60	0.022	0.007	0.27	0.064	0.019	0.007	/
Cert #:	F9080265			Material supplier:			QUZhou YuanLi Metal		

Dimensions

DIM.SPEC: ASME B18.2.2-2015 INSPECTOR & SAMPER: Ms.Li DATE: 2020/4/22

Item	**Specified**	**Result**	**Sampling**	**Rej.**	**Remark**	**Specification**
Widthacrossflats(inch)	1.938 - 2.002	1.952 - 1.961	3	0	OK	------
Widthacrossangle(inch)	2.209 - 2.309	2.239 - 2.242	3	0	OK	------
Height(inch)	1.187 - 1.251	1.228 - 1.232	3	0	OK	------
Minor diameter(inch)	1.119 - 1.147	1.125 - 1.128	13	0	OK	------
Thread-2B	Thread GO gauge	OK	13	0	OK	ASME B1.1-03
	Thread NO GO gauge	OK	13	0	OK	
Appearance	OK	OK	18	0	OK	ASTM F812-17
FIM	MAX 0.03	0.005 - 0.009	3	0	OK	ASME B18.2.2-2015

Mechanical Properties

MEC,SPEC:ASTM A563-15 INSPECTOR & SAMPLER: Ms.Li DATE: 2020/4/22

ITEM	**Test Method**	**SPECIFIED**	**Sampling**	**Result**	**JUG**
CoreHardness HRC	ASTM F606/F606M-19	24 - 38	3	26 - 29	OK
Proof loading KSI	ASTM F606/F606M-19	175	2	179	OK

Plating

Plating Spec: ASTM F2329-15 Inspector & Sampler : Ms Li Date: 2020/4/22

ITEM	Test Method	SPECIFIED	Sampling	Result	JUG
HDG With Blue Wax	ASTM B487 -2017	50.8 um Average	13	57 - 96 um	OK

MACROETCH

Division	**Surface Condition**	**Random Condition**	**Center Segregation**	**Test method**
Spec.	S2	R2	C3	ASTM E381-2017
Results	S2	R2	C3	

REMARK:

***This inspection certificate is for responsibility under test sample only.**
***Quench at880℃ about 90 minutes,Tempering at550℃ about 120 minutes**
***This test report shall not be reproduced except in full without written approval of the LAB.**
***The samples tested CONFORM to the fastener specification & standards above.**
***Dimensional Testing is done at Ningbo Dongxin High-Strength Nut Co.,Ltd**
***The documentation for chemical analysis is provided by the suppliers.**
***Parts are manufactured and tested according to above specification and compliance with order, we certify that this is a true representation of information provided by manufacturer and laboratory.**
***The products supplied are in compliance with all the requirements of the order.**
***The MTR's are in compliance to DIN EN 10204 3.1.**

Yan Yingjun

QA: Yan Yingjun
Ningbo Dongxin High-Strength Nut Co.,Ltd

Figure B-19. 1¼-in. Dia. Heavy Hex Nut, Test No. HMDBR-1 (Item No. h4)

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: 33342 **Job Information** **Certified Date:** 10/21/20

Customer: **Ship To:**
Customer Part No:
Customer PO No: **Shipped Qty:**
Lot Number: 33342-6215253305

Part Information

Part No: A563 1-8 +0.024 DH HHN HDG BLUE DYE
Description: ASTM A563 Heavy Hex Nut, Grade DH, Hot Dipped Galv, Blue Dye
Manufactured Quantity: 54,373

Applicable Specifications

Specification	Amend	Specification	Amend
ASME B1.1	2003	ASME B18.2.2	2015
ASME B18.2.6	2019	ASME B18.2.6M	2012
ASTM A563	2015	ASTM F2329/F2329M	2015
ASTM F606/606M	2019	ASTM F812	2017

Test Results
Test No: 22915 **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	28.95	1,166	90,900	Pass	Pass	Pass

Certified Chemical Analysis

Heat No	Grade	Manufacturer	Origin	C	Mn	P	S	Si	Cr	Ni	Cu
6215253305	1045	Gerdau Ameristeel	USA	0.4400	0.7400	0.0090	0.0250	0.2200	0.1900	0.0800	0.3000

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

10/21/20
Thorsen, Chris - Supervisor, Quality Date

Plex 10/21/20 7:56 AM cthorsen Page 1

Figure B-20. 1-in. Dia. Heavy Hex Nut, Test No. HMDBR-1 (Item No. h5)

NUCOR
FASTENER DIVISION

LOT NO.
441261A

Post Office Box 6100
Saint Joe, Indiana 46785
Telephone 260/337-1600

CUSTOMER NO/NAME
7494 FASTENAL COMPANY-IN
TEST REPORT SERIAL# FB644981
TEST REPORT ISSUE DATE 8/25/20
DATE SHIPPED 9/23/20
NAME OF LAB SAMPLER: DEANN WATSON, LAB TECHNICIAN

NUCOR ORDER # 219514
CUST PART # 38209
CUSTOMER P.O. # 120418048

**********CERTIFIED MATERIAL TEST REPORT**********

NUCOR PART NO	QUANTITY	LOT NO.	DESCRIPTION
175667	4950	441261A	7/8-9 GR DH HV H.D.G. HEX NUT HDG/GREEN LUBE

MANUFACTURE DATE 6/22/20

--CHEMISTRY MATERIAL GRADE -1045L

MATERIAL NUMBER	HEAT NUMBER	**CHEMISTRY COMPOSITION (WT% HEAT ANALYSIS) BY MATERIAL SUPPLIER C	MN	P	S	SI	
RM033997	100203930	.44	.67	.009	.011	.18	NUCOR STEEL - NEBRASKA

--MECHANICAL PROPERTIES IN ACCORDANCE WITH ASTM A563-15

SURFACE HARDNESS (R30N)	CORE HARDNESS (RC)	PROOF LOAD 69300 LBS	TENSILE STRENGTH (LBS)	DEG-WEDGE STRESS (PSI)
N/A	29.6	PASS	N/A	N/A
N/A	31.9	PASS	N/A	N/A
N/A	29.5	PASS	N/A	N/A
N/A	29.7	PASS	N/A	N/A
N/A	30.6	PASS	N/A	N/A

AVERAGE VALUES FROM TESTS 30.3
PRODUCTION LOT SIZE 133000 PCS

--VISUAL INSPECTION IN ACCORDANCE WITH ASTM A563-15 80 PCS. SAMPLED LOT PASSED

--COATING - HOT DIP GALVANIZED TO ASTM F2329-15 - GALVANIZING PERFORMED IN THE U.S.A.

1.	0.00249	2.	0.00404	3.	0.00263	4.	0.00345	5.	0.00453	6.	0.00267	7.	0.00311
8.	0.00231	9.	0.00424	10.	0.00264	11.	0.00453	12.	0.00265	13.	0.00273	14.	0.00329
15.	0.00395												

AVERAGE THICKNESS FROM 15 TESTS .00328

--HEAT TREATMENT - AUSTENITIZED, OIL QUENCHED & TEMPERED (MIN 800 DEG F)

--DIMENSIONS PER ASME B18.2.6-2010

CHARACTERISTIC	#SAMPLES TESTED	MINIMUM	MAXIMUM
Width Across Corners	8	1.611	1.628
Thickness	32	0.846	0.866

ALL TESTS ARE IN ACCORDANCE WITH THE LATEST REVISIONS OF THE METHODS PRESCRIBED IN THE APPLICABLE SAE AND ASTM SPECIFICATIONS. THE SAMPLES TESTED CONFORM TO THE SPECIFICATIONS AS DESCRIBED/LISTED ABOVE AND WERE MANUFACTURED FREE OF MERCURY CONTAMINATION. NO INTENTIONAL ADDITIONS OF BISMUTH, SELENIUM, TELLURIUM, OR LEAD WERE USED IN THE STEEL USED TO PRODUCE THIS PRODUCT.
THE STEEL WAS MELTED AND MANUFACTURED IN THE U.S.A. AND THE PRODUCT WAS MANUFACTURED AND TESTED IN THE U.S.A.
PRODUCT COMPLIES WITH DFARS 252.225-7014. WE CERTIFY THAT THIS DATA IS A 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. CERTIFICATION FORMAT MEETS EN10204 3.1

ACCREDITED
MECHANICAL FASTENER
CERTIFICATE NO. A2LA 0139.01
EXPIRATION DATE 12/31/21

NUCOR FASTENER
A DIVISION OF NUCOR CORPORATION
BOB HAYWOOD
QUALITY ASSURANCE SUPERVISOR

Page 1 of 1

Figure B-21. ⅞-in. Dia. UNC Heavy Hex Nut, Test No. HMDBR-1 (Item No. h7)

Job Material Certification

Page 3 of 6

Vulcan
THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 671813 **Job Information** **Certified Date:** 5/6/20

Containers: S16960313 S16960316 S16960327

Customer: Conklin and Conklin

Ship To: 34201 Seventh Street
Union City, CA 94587

Vulcan Part No: BAR B7 .9144x144 SC

Customer Part No: RAWSTEEL-.910-B

Customer PO No: 19944

Shipped Qty: 8985 lbs

Order No: 399299

Line No: 1

Note:

Applicable Specifications

Type	Specification	Rev	Amend	Option
-	ASTM F1554 Gd 105 S4	2018		
Heat Treat	ASTM A193 B7	2019		

Test Results

See following pages for tests

Certified Chemical Analysis

Heat No: A201673 Lot .9688 Origin: USA

C	Mn	P	S	Si	Cr	Mo	Ni	V	Cu	Al
0.41	0.80	0.008	0.021	0.25	0.82	0.16	0.19	0.002	0.27	0.025
Sn	N	B	Ca	As	Sb	H, ppm	DI	RR	G.S.	Macro S
0.012	0.0077	0.0002	0.0007	0.004	0.003	0.6	4.51	196.9:1	8	1
Macro R	Macro C	J1	J2	J3	J4	J5	J6	J7	J8	J9
1	2	57	57	57	57	57	53	52	50	49
J10	J12	J14	J16	J18	J20	J24	J28	J32		
47	44	43	40	39	38	36	34	32		

Notes

Processed material is Tempered - Stress Free. No weld repair performed on the material. No Mercury used in the production of this material. Melted and Manufactured in the USA.
Grade - 4140
EAF Melted

Plex 5/6/20 3:44 PM vulc.sano Page 1 of 2

PORTLAND BOLT
PO 47853
INV 081156
100 1" x 144" B7 ATR HDG 1OF2
SEPT 29, 2020

https://www.plexonline.com/733d7d16-dbb6-4893-ac4f-979d7fd9f9b4/Sales/Report_Job_Cert.asp?Mode... 5/21/2020

Figure B-22. 1-in. Dia. Threaded Rod, Test No. HMDBR-1 (Item No. i1), Page 1 of 2

Job Material Certification

Vulcan
THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 671813 **Job Information** **Certified Date:** 5/6/20

Containers: S16960313 S16960316 S16960327

Test Results

Part No: BAR B7 .9144x290 HT

Test No: 60063 **Test:** Quench & Temper Information (Lbs)

Description	Austenitizing Temp (F)	Tempering Temp (F)	Run Speed (Ft/min)	Quench Water Temp (F)	Note
Quench & Temper Information Results	1,625	1,345	25	89	

Test No: 60064 **Test:** Partial Decarb Test

Description	Surface Carb.	Partial Surface Decarb.	Note
	Pass	Pass	

Test No: 60065 **Test:** F1554-105 FB Requirements

Description	Tensile (ksi) (ksi)	Yield 0.2% Offset (ksi) (ksi)	Elongation (%)	Elongation Gage Length (8in)	ROA (%)	Note
	136	126	16	8in	63	tested by external provider

Test No: 60066 **Test:** A193 B7, F1554-105 Requirements

Description	Tensile (ksi)	Yield 0.2% Offset (ksi)	Elongation (%)	Elongation Gage Length	ROA (%)	Midradius Hardness	Surface Hardness	Center Hardness	Hardness Test Type	Note
	143	127	19	4D	56	30	28	30	HRC	
	141	130	21	4D	61	28	30	27	HRC	
	142	129	22	4D	63	29	29	28	HRC	
	141	129	21	4D	64	28	29	27	HRC	
	141	129	22	4D	65	29	28	26	HRC	
	142	129	22	4D	65	28	28	26	HRC	
	141	129	22	4D	64	28	29	27	HRC	
	141	128	21	4D	63	30	29	28	HRC	
	142	130	20	4D	63	30	29	29	HRC	
	140	128	23	4D	63	29	30	29	HRC	
	141	129	22	4D	64	30	30	28	HRC	
	141	128	21	4D	61	30	30	29	HRC	
	141	129	21	4D	65	30	29	29	HRC	
	138	126	21	4D	66	29	29	28	HRC	

Test No: 60067 **Test:** F1554 Gd105 S4 Charpy ft/lbs Requirements

Description	Container	Test Temp (F)	Test1 (ft/lbs)	Test2 (ft/lbs)	Test3 (ft/lbs)	Results Avg (ft/lbs)	Note
		-20	106	116	108	110	
		-20	102	113	99	105	

The reported test results conform to the specifications listed above.
The reported test results are the actual values measured on the samples taken from the production lot.
Material was manufactured, tested, and inspected as required by the product standard and in accordance with Vulcan"s ISO 9001:2015 Quality Management System registered June 30th, 2017.
Vulcan Steel Products" lab is ISO 17025:2017 accredited for tensile, Brinell and Rockwell hardness, Charpy impact, and carb/decarb testing.
Material was tested in accordance with the current revision of ASTM A370, F606, and F2328 test methods.
This test report shall not be reproduced or distributed, except in full, without the written permission of Vulcan Steel Products.
Document is in accordance with EN 10204 - 3.1B of 2004 (3.1).

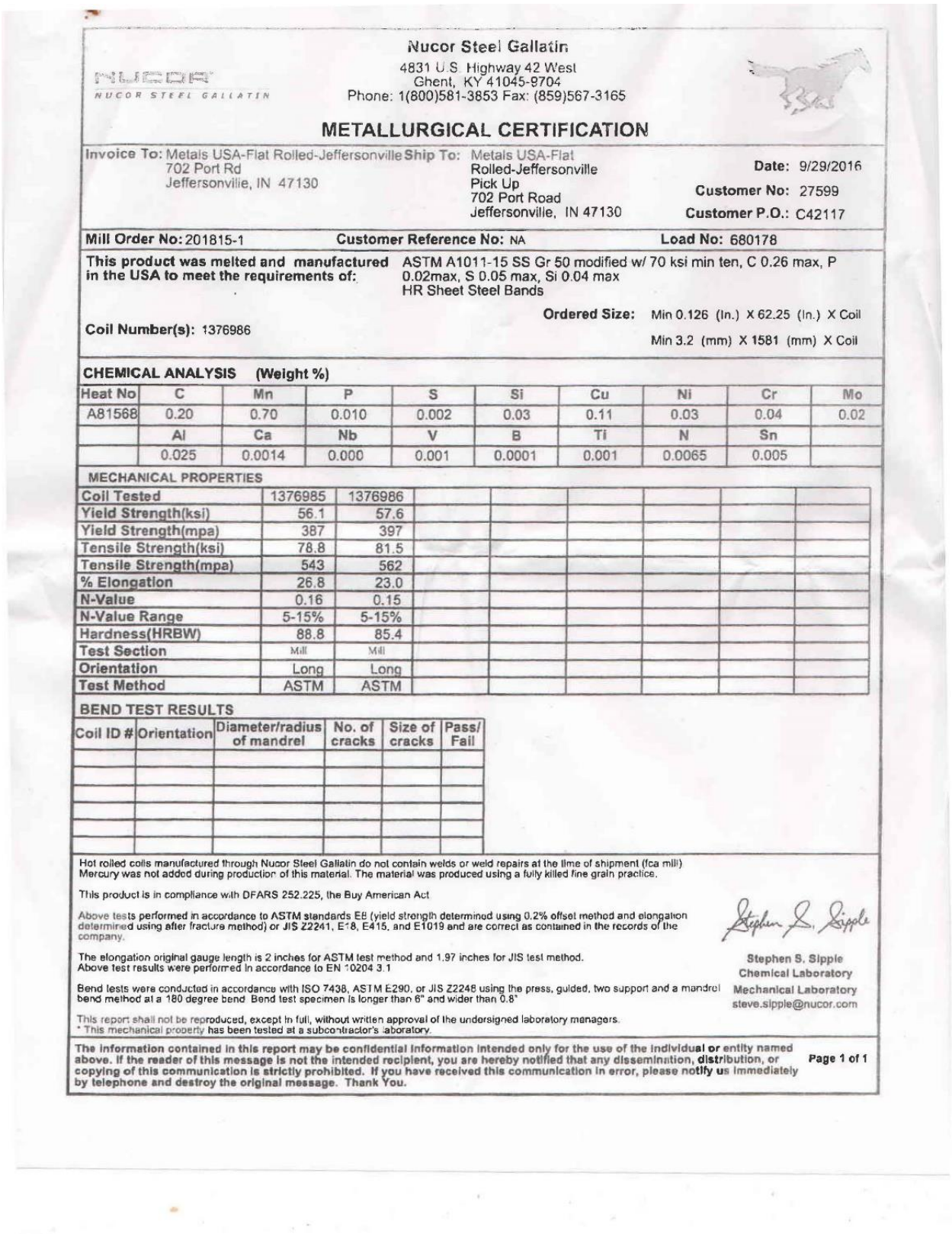
Sallie Norwood 5/6/20

Norwood, Sallie - Certification Engineer Date

Plex 5/6/20 3:44 PM vulc.sano Page 2 of 2

PORTLAND BOLT
PO 47853
INV 081156
100 1" x 144" B7 ATR HDG 2OF2
SEPT 29, 2020

Figure B-23. 1-in. Dia. Threaded Rod, Test No. HMDBR-1 (Item No. i1), Page 2 of 2



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

NUCOR
NUCOR STEEL GALLATIN

METALLURGICAL CERTIFICATION

Invoice To: Metals USA-Flat Rolled-Jeffersonville
702 Port Rd
Jeffersonville, IN 47130

Ship To: Metals USA-Flat
Rolled-Jeffersonville
Pick Up
702 Port Road
Jeffersonville, IN 47130

Date: 9/29/2016
Customer No: 27599
Customer P.O.: C42117

Mill Order No: 201815-1 **Customer Reference No:** NA **Load No:** 680178

This product was melted and manufactured in the USA to meet the requirements of: ASTM A1011-15 SS Gr 50 modified w/ 70 ksi min ten, C 0.26 max, P 0.02max, S 0.05 max, Si 0.04 max
HR Sheet Steel Bands

Ordered Size: Min 0.126 (In.) X 62.25 (In.) X Coil
Min 3.2 (mm) X 1581 (mm) X Coil

Coil Number(s): 1376986

CHEMICAL ANALYSIS (Weight %)

Heat No	C	Mn	P	S	Si	Cu	Ni	Cr	Mo
A81568	0.20	0.70	0.010	0.002	0.03	0.11	0.03	0.04	0.02
	Al	Ca	Nb	V	B	Ti	N	Sn	
	0.025	0.0014	0.000	0.001	0.0001	0.001	0.0065	0.005	

MECHANICAL PROPERTIES

Coil Tested	1376985	1376986						
Yield Strength(ksi)	56.1	57.6						
Yield Strength(mpa)	387	397						
Tensile Strength(ksi)	78.8	81.5						
Tensile Strength(mpa)	543	562						
% Elongation	26.8	23.0						
N-Value	0.16	0.15						
N-Value Range	5-15%	5-15%						
Hardness(HRBW)	88.8	85.4						
Test Section	Mill	Mill						
Orientation	Long	Long						
Test Method	ASTM	ASTM						

BEND TEST RESULTS

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

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

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

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

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

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

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

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

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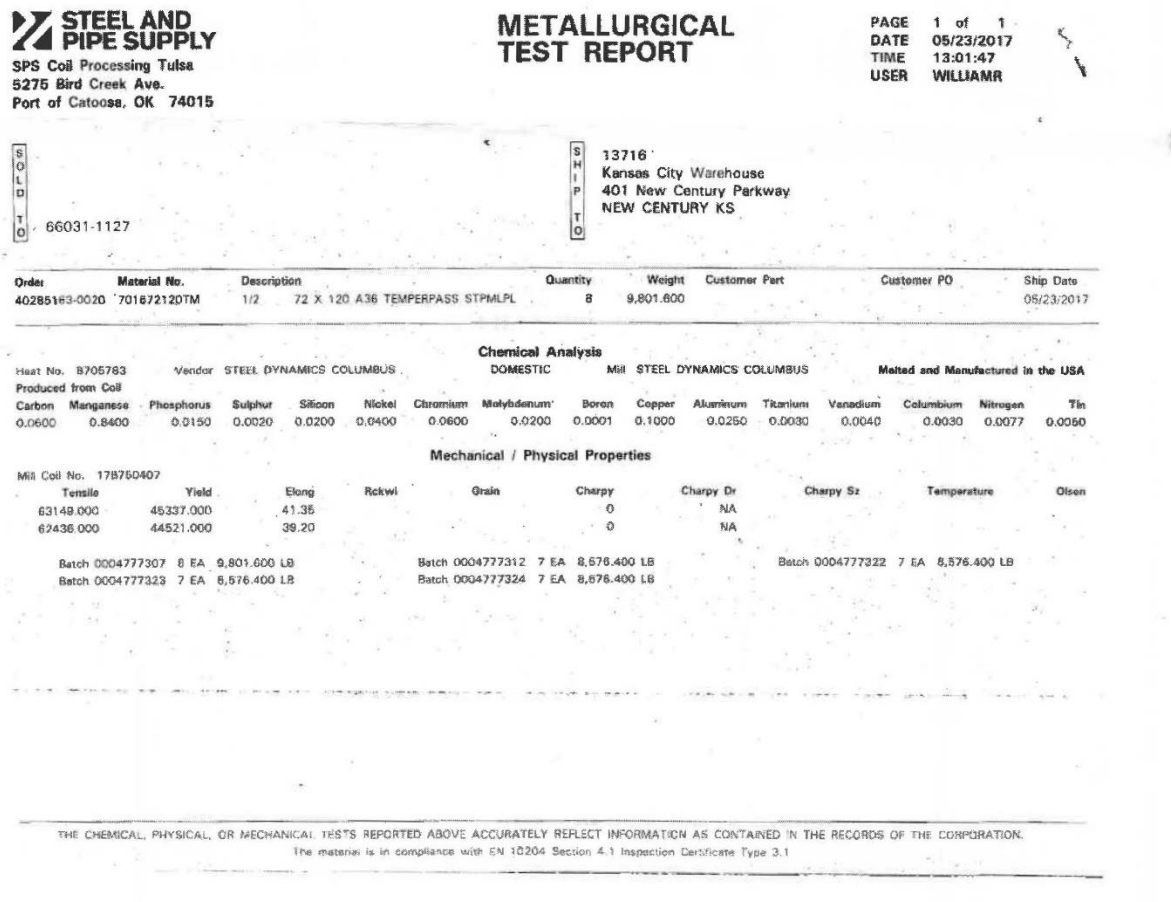
Page 1 of 1

Figure B-24. 10-gauge Thrie-Beam Terminal Connector, Test No. HMDBR-1 (Item No. i2)

R#17-708 NSRI PHASE III TEAM1-1
Steel Tube Frames
June 2017 SMT



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 05/23/2017
TIME 13:01:47
USER WILLIAMR

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
40285163-0020	701872120TM	1/2 72 X 120 A36 TEMPERPASS STPMLPL	8	9,801.600			05/23/2017

Chemical Analysis

Heat No. B705783 Vendor STEEL DYNAMICS COLUMBUS DOMESTIC Mill STEEL DYNAMICS COLUMBUS 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
0.0600	0.8400	0.0150	0.0020	0.0200	0.0400	0.0600	0.0200	0.0001	0.1000	0.0250	0.0030	0.0040	0.0030	0.0077	0.0050

Mechanical / Physical Properties

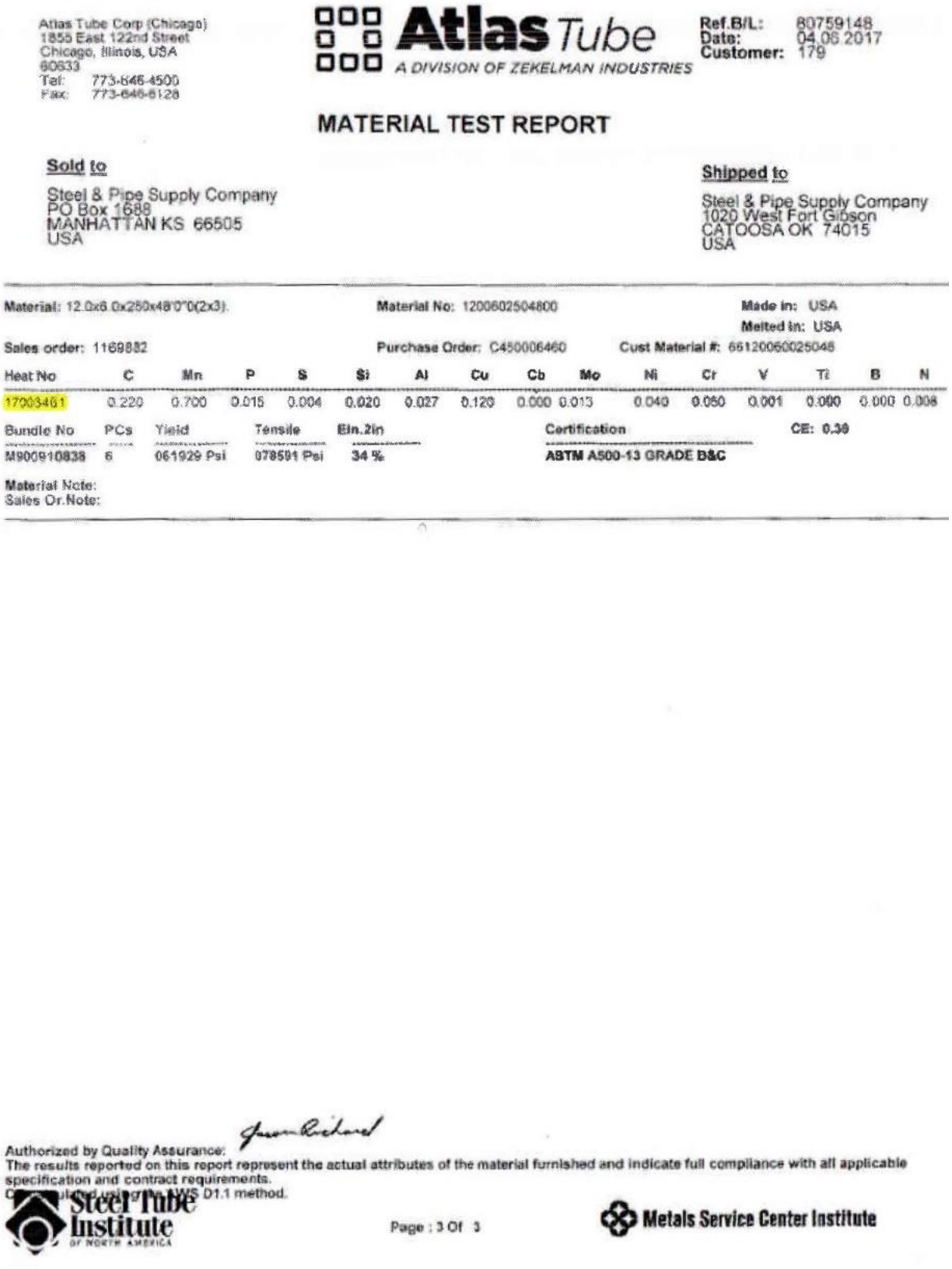
Mill Coil No. 178750407

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
63149.000	45337.000	41.35			0	NA			
62436.000	44521.000	39.20			0	NA			

Batch 0004777307 8 EA 9,801.600 LB
Batch 0004777323 7 EA 8,576.400 LB
Batch 0004777312 7 EA 8,576.400 LB
Batch 0004777324 7 EA 8,576.400 LB
Batch 0004777322 7 EA 8,576.400 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

Figure B-25. ½-in. Thick Steel Plate, Test No. HMDBR-1 (Item Nos. i3, i5, and i7)



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

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

Ref.B/L: 80759148
Date: 04.06.2017
Customer: 179

MATERIAL TEST REPORT

Sold to
Steel & Pipe Supply Company
PO Box 1688
MANHATTAN KS 66505
USA

Shipped to
Steel & Pipe Supply Company
1020 West Fort Gibson
CATOOSA OK 74015
USA

Material: 12.0x6.0x250x4810"0(2x3) Material No: 1200602504800 Made in: USA
Melted in: USA
Sales order: 1169882 Purchase Order: C450006460 Cust Material #: 66120060025048

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
17003401	0.220	0.700	0.015	0.004	0.020	0.027	0.120	0.000	0.013	0.040	0.050	0.001	0.000	0.000	0.008

Bundle No	PCs	Yield	Tensile	Elin.2in	Certification	CE: 0.30
M900910838	6	061929 Psi	078591 Psi	34 %	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

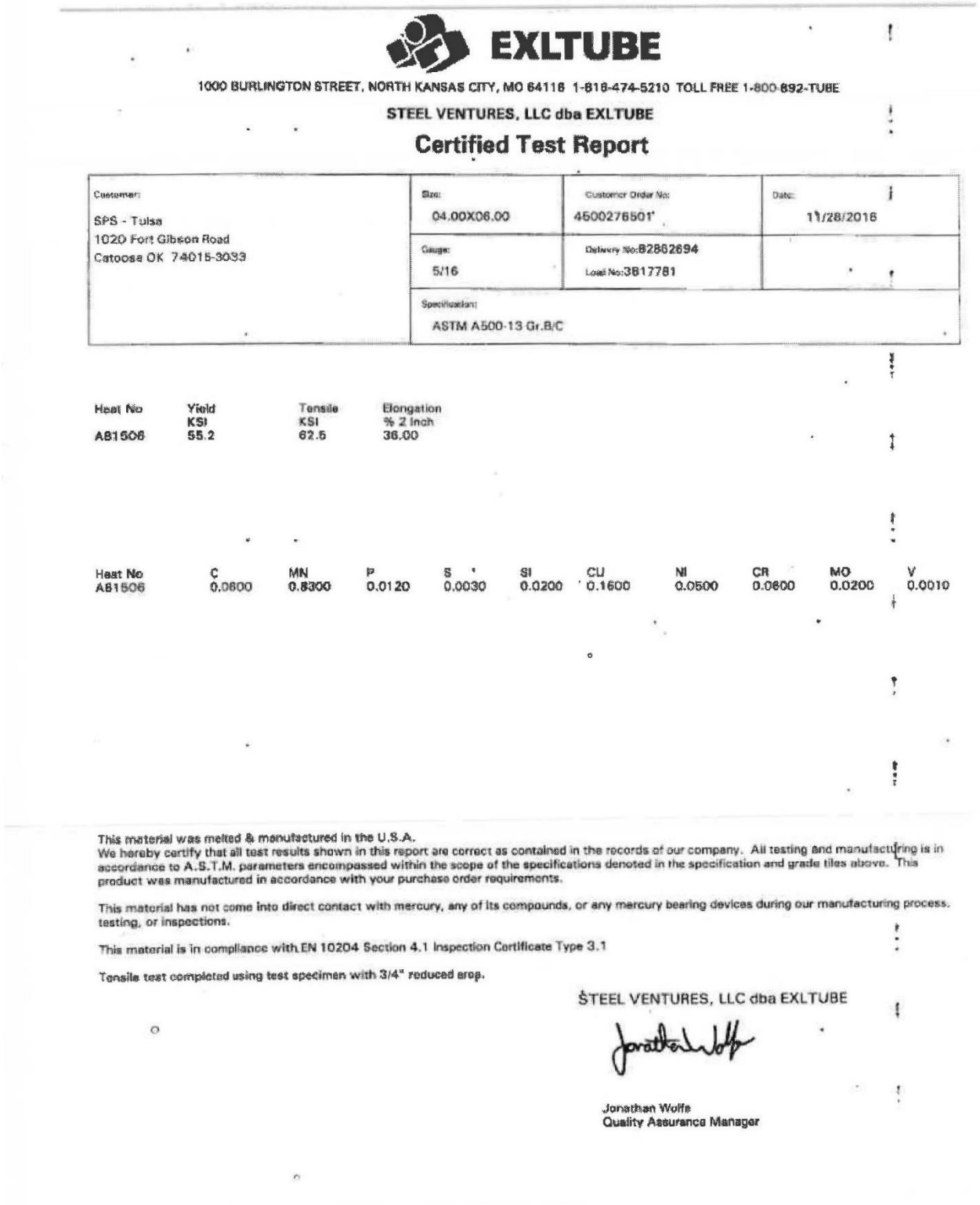
Authorized by Quality Assurance:
The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
[illegible] AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Page : 3 Of 3

Metals Service Center Institute

Figure B-26. 6-in. x 12-in. x ¼-in. HSS Tube, Test No. HMDBR-1 (Item No. i4)



EXLTUBE

1000 BURLINGTON STREET, NORTH KANSAS CITY, MO 64116 1-816-474-5210 TOLL FREE 1-800-892-TUBE

STEEL VENTURES, LLC dba EXLTUBE

Certified Test Report

Customer:	Size:	Customer Order No:	Date:
SPS - Tulsa 1020 Fort Gibson Road Catoosa OK 74015-3033	04.00X06.00	4500276501	11/28/2016
	Gauge: 5/16	Delivery No:82862694 Load No:3817781	
	Specification: ASTM A500-13 Gr.B/C		

Heat No	Yield KSI	Tensile KSI	Elongation % 2 Inch
A81506	55.2	62.5	36.00

Heat No	C	MN	P	S	SI	CU	NI	CR	MO	V
A81506	0.0600	0.8300	0.0120	0.0030	0.0200	0.1600	0.0500	0.0600	0.0200	0.0010

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

This material has not come into direct contact with mercury, any of its compounds, or any mercury bearing devices during our manufacturing process, testing, or inspections.

This material is in compliance with EN 10204 Section 4.1 Inspection Certificate Type 3.1

Tensile test completed using test specimen with 3/4" reduced area.

STEEL VENTURES, LLC dba EXLTUBE

Jonathan Wolfe
Quality Assurance Manager

Figure B-27. 6-in. x 4-in. x 5⁄16-in. HSS Tube, Test No. HMDBR-1 (Item No. i6)

benesch

Page 1 of 1

Concrete Sample Test Report
Cylinder Compressive Strength

Project Name:	Midwest Roadside Safety - Misc Testing
Project Number:	00110546.00
Client:	Midwest Roadside Safety Facility
Location:	MNPD
Sample:	007
Description:	HMDBR-1

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

		Property	Test Result
Supplier: Mix Name:		Slump (in):	
Ticket Number:		Air Content (%):	
Truck Number:		Unit Weight (lb/ft³):	
Load Volume (yd³):		Air Temp (°F):	
Mold Date:	10/20/2020	Mix Temp (°F):	
Molded By: Initial Cure Method:		Min Temp (°F): MaxTemp (°F):	

Laboratory Test Data (ASTM C39)

Sample Number:	007	007				
Set Number:	1	2				
Specimen Number:	1	1				
Age:	24	24				
Length (in):	12	12				
Diameter (in):	6	6.02				
Area (in²):	28.27	28.46				
Test Date:	11/13/2020	11/13/2020				
Break Type:	2	5				
Max Load (lbf):	138,392	128,341				
Strength (psi):	4,890	4,510				
Spec Strength (psi):						

Remarks:
Average 24-day Compressive Strength (psi): **4,700**

Date received: 11/13/2020
Curing: [x] Standard [ ] Field
ASTM C511
Submitted by: Matt Roeder

Distribution:

Report Date: 11/13/20

825 M Street Suite 100
Lincoln, NE 68508

Alfred Benesch & Company

Figure B-28. Concrete, Test No. HMDBR-1 (Item No. j1)

P.O. Box 21148
Tulsa, OK 74121
Phone (918) 252-6000
Fax No. (918) 252-6520

Date: 12/13/2016

Subject: Certificate of Conformance

Product: HIT RE-500 V3 Adhesive

To Whom it May Concern:

This is to certify that the HIT-RE 500 V3 is a high-strength, slow cure two-part epoxy adhesive contained in two cartridges separating the resin from the hardener.

Additionally, this certifies that the product has been seismically and cracked concrete qualified as represented in ICC-ES report ESR- 3814.

Sincerely,

Hilti, Inc.

5400 South 122 East Avenue

Tulsa, Oklahoma 74146

800-879-8000

800-879-7000 fax

US-Sales@hilti.com

Figure B-29. Epoxy Adhesive, Test No. HMDBR-1 (Item No. k1)

TECHNICAL DATA

SPECPOXY 500

GREENCONSCIOUS

ASTM 881 compliant hi-mod, ultra-low viscosity epoxy injection adhesive

DESCRIPTION

SPECPOXY 500 is a two component, very low viscosity, moisture insensitive, high modulus, structural epoxy bonding adhesive and crack injection resin. SPECPOXY 500 is 100% solids, solvent free, low odor, and high strength.

- Bonding concrete, steel and wood
- Gravity feed or pressure injection crack repairs
- Anchoring bolts, dowels and reinforcing bar

APPLICATION

Mixing Instructions: Air, material, and surface temperatures must be a minimum of 40°F prior to mixing or installation. To assist with mixing and dispensing, precondition material to 75°F. For bulk applications, mix two parts of component A and one part of component B by volume for three minutes with a low speed drill motor using a Jiffy mixer or paddle. Mix only as much material as can be used within the pot life. For cartridges, the resin and hardener are uniformly dispensed and mixed simultaneously through a mixing nozzle.

Surface Preparation: Surfaces to be bonded must be clean and structurally sound. Remove all oil, grease, dirt, laitance, curing compounds, and any other foreign matter by sandblasting, mechanical abrasion or oil free compressed air. For pressure injection, prepare the surface adjacent to the cracks to expose clean, sound concrete.

Crack Injection: Injection ports should be fastened to the surface of the concrete using SPECPOXY 3000 FS. The injection ports should be spaced approximately 6" to 24" apart depending upon the crack width and the thickness of the concrete. The surface of the crack should also be sealed using the SPECPOXY 3000 FS overlapping the crack approximately 1-1/2" on both sides. After the ports and crack surface have cured, inject SPECPOXY 500 with pressurized dispensing equipment or use cartridges.

Gravity Filling: Thoroughly remove any dust or contaminates from surface cracks with compressed air or wire brush. Pour or spread the properly mixed SpecPoxy 500 across the surface and reapply until rejection. Remove any excess epoxy from the surface or grind excess after cured.

Bonding: As a structural adhesive, apply the SPECPOXY

CLEANING

Tools and Equipment: Uncured material can be removed with SpecChem Orange Peel Citrus Cleaner or other approved solvent. Dispose of in accordance with local, state, and federal disposal regulations. Mechanical removal is necessary for cured material.

Revised 07/01/2018

PACKAGING

1 gallon units; 3 gallon units; 15 gallon units; 15 oz. dual cartridge

SHELF LIFE

Store SPECPOXY 500 in its original containers and keep tightly closed. Do not allow the accumulation of water, dirt, or other contaminants.

The shelf life of properly stored SPECPOXY 500 is two

STANDARDS

SPECPOXY 500 meets ASTM C-881, Type I, II, IV, and V Grade 1, Classes B & C.

TYPICAL PROPERTIES

Mix Ratio	2 to 1
Mixed Color:	Amber
Viscosity:	180 CPS
Gel time (ASTM 881):	25 minutes
Tack free time @ 70°F:	3.5 hours

TYPICAL CURED PROPERTIES

Initial Cure	24 hours
Final Cure	7 days
Compressive Strength (ASTM D-695)	12,175 psi
Compressive Modulus (ASTM D-695)	265,500 psi
Bond Strength at 2 days (ASTM 882)	2,275 psi
Bond Strength at 14 days (ASTM 882)	2,550 psi
Elongation (ASTM D-638)	2.4%
Tensile Strength (ASTM D-638)	7,050 psi
Water Absorption (ASTM D-570)	< 0.5%
Heat Deflection (ASTM D-648)	121°F

SPECCHEM
Solution to Service

1511 Baltimore Ave, Suite 600
Kansas City, MO 64108
www.specchemllc.com 866.791.8700

Figure B-30. Epoxy Post Cavity Filler, Test No. HMDBR-1 (Item No. k2)

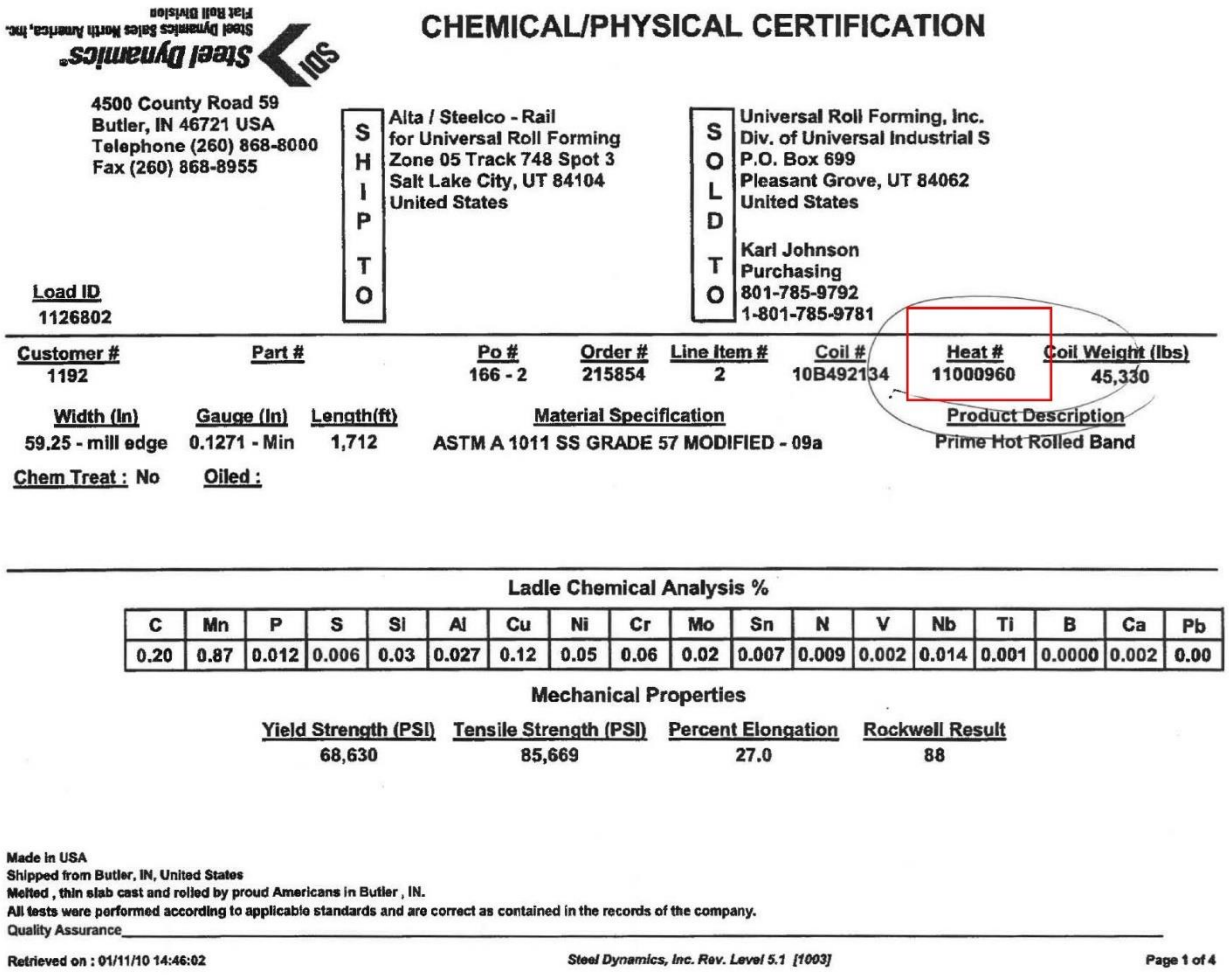
Appendix C. Material Specifications, Test Nos. HMDBR-2 and HMDBR-3

Table C-1. Bill of Materials, HMDBR-2 and HMDBR-3

Item No.	Description	Material Specification	Reference
a1	6'-3" 10-gauge Thrie Beam Section	AASHTO M180	H#11000960
a2	10-gauge Thrie Beam Terminal Connector	AASHTO M180 Min. yield strength = 50 ksi Min. tensile strength = 70 ksi	H#A90588
b1	16"x11"x1" Base Plate	ASTM A36	H#A0G801
b2	1 1/4" Dia., 14" Long Anchor Rod	ASTM F1554-15 Grade 105, Class 2A	H#A202999
b3	5/8" Dia., 8" Long Anchor Rod	ASTM F1554-15 Grade 105, Class 2A	H#10546920
b4	W6x25, 26 1/4" Long Steel Post	ASTM A992	H#59093087.02
c1	1" Dia. UNC, 11" Long Threaded Rod	ASTM A449 or A354 Gr. BC or A193 Gr. B7	H#A202719
c2	14"x14"x1/2" Steel Plate	ASTM A36 or A572 Gr. 50	H#B705783
c3	HSS 6"x12"x1/4" Tube, 38 1/2" Long	ASTM A500 Gr. B	H#17003401
c4	11 1/2"x5 1/2"x1/2" Steel Plate	ASTM A36 or A572 Gr. 50	H#B705783
c5	HSS 6"x4"x5/16" Tube, 46" Long	ASTM A500 Gr. B	H#A81506
c6	16"x12"x1/2" Steel Plate	ASTM A36 or A572 Gr. 50	H#B705783
d1	#4 Rebar, 30 3/4" Total Unbent Length	ASTM A615 Gr. 60	H#3600014740
d2	#4 Rebar, 97' 1" Total Length, 18" Min. Lap Length	ASTM A615 Gr. 60	H#62151622
d3	#4 Rebar, 32" Total Unbent Length	ASTM A615 Gr. 60	H#3600014740
e1	Concrete	Min. f'c = 4,000 psi NE Mix 47B1S384000HW or 47B1PF4000HW	Project#00110546.00
f1	5/8"-11 UNC, 2" Long Guardrail Bolt	ASTM A307 Gr. A	H#10621520
f2	5/8"-11 UNC, 1 1/4" Long Guardrail Bolt	ASTM A307 Gr. A	H#10653380 H#10647410
f3	7/8" Dia., 8" Long Heavy Hex Head Bolt	ASTM F3125 Gr. A325 Type 1	H#75068447
g1	5/8" Dia. Plain USS Washer	ASTM F844	L#20200831

Table C-2. Bill of Materials, HMDBR-2 and HMDBR-3, Cont.

Item No.	Description	Material Specification	Reference
g2	5/8" Dia. Hardened Washer	ASTM F436	H#193903
g3	7/8" Dia. Plain Round Washer	ASTM F844	L#1844804
g4	1 1/4" Dia. Hardened Washer	ASTM F436	H#209197
g5	1" Dia. Hardened Flat Washer	ASTM F436	H#105594
h1	5/8"-11 UNC Heavy Hex Nut	ASTM A563A or equivalent	H#10635460 H#62151324 H#62152527
h2	5/8"-11 UNC Heavy Hex Nut	ASTM A563-15 Grade DH	H#100890711
h3	1 1/4"-7 UNC Heavy Hex Nut	ASTM A563-15 Grade DH	H#F19080206
h4	1" Dia. Heavy Hex Nut	ASTM A563DH or A194 Gr. 2H	H#6215253305
h5	7/8" Dia. UNC Heavy Hex Nut	ASTM A563DH or ASTM A194 Gr. 2H	H#100894559
k1	Epoxy Adhesive	Hilti HIT RE-500 V3 Class C881	COC
k2	Epoxy Post Cavity Filler	ASTM C881 Type IV, Grade I, Class C	COC



Steel Dynamics Sales North America, Inc.
Flat Roll Division

CHEMICAL/PHYSICAL CERTIFICATION

4500 County Road 59
Butler, IN 46721 USA
Telephone (260) 868-8000
Fax (260) 868-8955

SHIP TO
Alta / Steelco - Rail
for Universal Roll Forming
Zone 05 Track 748 Spot 3
Salt Lake City, UT 84104
United States

SOLD TO
Universal Roll Forming, Inc.
Div. of Universal Industrial S
P.O. Box 699
Pleasant Grove, UT 84062
United States

Karl Johnson
Purchasing
801-785-9792
1-801-785-9781

Load ID
1126802

Customer #	Part #	Po #	Order #	Line Item #	Coil #	Heat #	Coil Weight (lbs)
1192		166 - 2	215854	2	10B492134	11000960	45,330

Width (in)	Gauge (in)	Length(ft)	Material Specification	Product Description
59.25 - mill edge	0.1271 - Min	1,712	ASTM A 1011 SS GRADE 57 MODIFIED - 09a	Prime Hot Rolled Band

Chem Treat : No Oiled :

Ladle Chemical Analysis %

C	Mn	P	S	Si	Al	Cu	Ni	Cr	Mo	Sn	N	V	Nb	Ti	B	Ca	Pb
0.20	0.87	0.012	0.006	0.03	0.027	0.12	0.05	0.06	0.02	0.007	0.009	0.002	0.014	0.001	0.0000	0.002	0.00

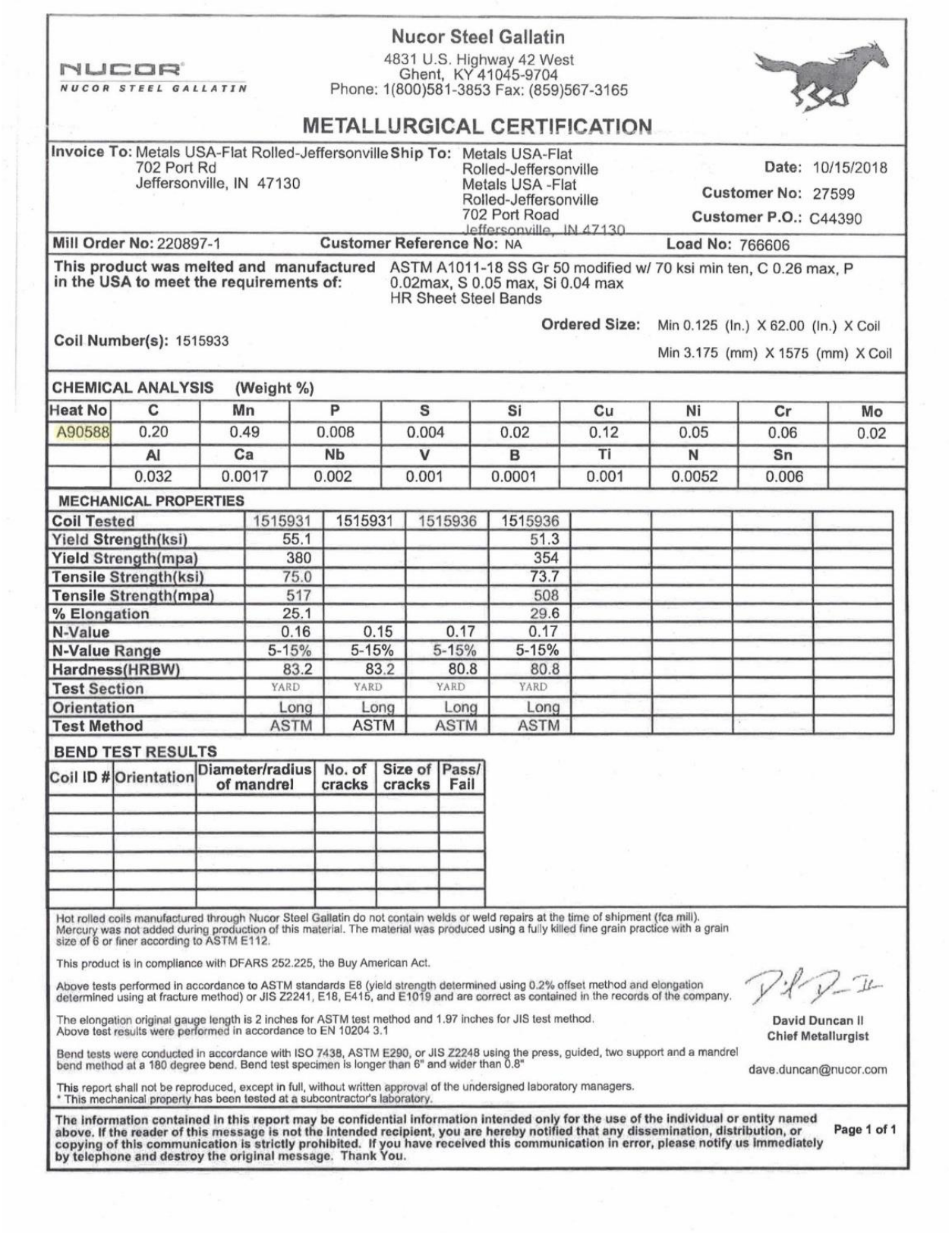
Mechanical Properties

Yield Strength (PSI)	Tensile Strength (PSI)	Percent Elongation	Rockwell Result
68,630	85,669	27.0	88

Made in USA
Shipped from Butler, IN, United States
Melted , thin slab cast and rolled by proud Americans in Butler , IN.
All tests were performed according to applicable standards and are correct as contained in the records of the company.
Quality Assurance

Retrieved on : 01/11/10 14:46:02 *Steel Dynamics, Inc. Rev. Level 5.1 [1003]* Page 1 of 4

Figure C-1. 10-gauge Thrie Beam Section, Test Nos. HMDBR-2 and HMDBR-3 (Item No. a1)



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

NUCOR
NUCOR STEEL GALLATIN

METALLURGICAL CERTIFICATION

Invoice To: Metals USA-Flat Rolled-Jeffersonville
702 Port Rd
Jeffersonville, IN 47130

Ship To: Metals USA-Flat Rolled-Jeffersonville
Metals USA -Flat Rolled-Jeffersonville
702 Port Road
Jeffersonville, IN 47130

Date: 10/15/2018
Customer No: 27599
Customer P.O.: C44390

Mill Order No: 220897-1 **Customer Reference No:** NA **Load No:** 766606

This product was melted and manufactured in the USA to meet the requirements of: ASTM A1011-18 SS Gr 50 modified w/ 70 ksi min ten, C 0.26 max, P 0.02max, S 0.05 max, Si 0.04 max
HR Sheet Steel Bands

Coil Number(s): 1515933

Ordered Size: Min 0.125 (In.) X 62.00 (In.) X Coil
Min 3.175 (mm) X 1575 (mm) X Coil

CHEMICAL ANALYSIS (Weight %)

Heat No	C	Mn	P	S	Si	Cu	Ni	Cr	Mo
A90588	0.20	0.49	0.008	0.004	0.02	0.12	0.05	0.06	0.02
	Al	Ca	Nb	V	B	Ti	N	Sn	
	0.032	0.0017	0.002	0.001	0.0001	0.001	0.0052	0.006	

MECHANICAL PROPERTIES

Coil Tested	1515931	1515931	1515936	1515936				
Yield Strength(ksi)	55.1			51.3				
Yield Strength(mpa)	380			354				
Tensile Strength(ksi)	75.0			73.7				
Tensile Strength(mpa)	517			508				
% Elongation	25.1			29.6				
N-Value	0.16	0.15	0.17	0.17				
N-Value Range	5-15%	5-15%	5-15%	5-15%				
Hardness(HRBW)	83.2	83.2	80.8	80.8				
Test Section	YARD	YARD	YARD	YARD				
Orientation	Long	Long	Long	Long				
Test Method	ASTM	ASTM	ASTM	ASTM				

BEND TEST RESULTS

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

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

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

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

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

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

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

David Duncan II
Chief Metallurgist
dave.duncan@nucor.com

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Page 1 of 1

Figure C-2. 10-gauge Thrie Beam Terminal Connector, Test Nos. HMDBR-2 and HMDBR-3 (Item No. a2)

H#A0G801 R#21-175 16"x11"x1" Base Plate

SSAB

1770 Bill Sharp Boulevard, Muscatine, IA 52761-9412, US

Test Certificate

WARNING: This product can expose you to chemicals including nickel and nickel compounds, which are known to the State of California to cause cancer. For more information go to www.P65Warnings.ca.gov.

Form TC1: Revision 4: Date 6 Feb 2019

Customer:
STEEL & PIPE SUPPLY
P.O. BOX 1688

MANHATTAN
KS 66502

Customer P.O.No.: 4500353259 | **Mill Order No.** 41-616884-02 | **Shipping Manifest:** MT414463

Product Description: ASTM A36(19)/A709(18)36/ASME SA36(19)
AASHTO M270(19)36

Ship Date: 17 Sep 20 | **Cert No:** 061855475
Cert Date: 17 Sep 20 | (Page 1 of 1)

Size: 1.000 X 72.00 X 120.0 (IN)

Tested Pieces:				Tensiles:						Charpy Impact Tests						
Heat Id	Piece Id	Tested Thickness	Tst Loc	YS (KSI)	UTS (KSI)	%RA	Elong % 2in 8in	Tst Dir	Hardness	Abs. Energy(FTLB) 1 2 3 Avg	% Shear 1 2 3 Avg	Tst Tmp	Tst Dir	Tst Siz (mm)	BDWTT Tmp %Shr
A0G801	A08	0.999 (DISCRT)	L	52	75		25	T							
A0I121	B03	0.998 (DISCRT)	L	49	72		26	T							
A0I807	C07	0.999 (DISCRT)	L	49	72		27	T							

Heat Id	Chemical Analysis C	Mn	P	S	Si	Tot Al	Cu	Ni	Cr	Mo	Cb	V	Ti	B	N	ORGN
A0G801	.20	.93	.018	.002	.18	.030	.28	.16	.15	.01	.001	.003	.017	.0003	.0071	USA
A0I121	.20	.83	.013	.001	.20	.032	.27	.25	.18	.04	.001	.005	.023	.0001	.0071	USA
A0I807	.19	.93	.011	.002	.18	.032	.28	.14	.17	.03	.002	.014	.018	.0002	.0084	USA

KILLED STEEL
MERCURY IS NOT A METALLURGICAL COMPONENT OF THE STEEL AND NO MERCURY WAS INTENTIONALLY ADDED DURING THE MANUFACTURE OF THIS PRODUCT.
MTR EN 10204:2004 INSPECTION CERTIFICATE 3.1 COMPLIANT
100% MELTED AND MANUFACTURED IN THE USA
PRODUCTS SHIPPED:

A0I121	B03	PCES:	5,	LBS:	12250	A0I807	C07	PCES:	3,	LBS:	7350
A0G801	A08	PCES:	2,	LBS:	4900						

(P) Cust Part #: 7210072120

WE HEREBY CERTIFY THAT THIS MATERIAL WAS TESTED IN ACCORDANCE WITH, AND MEETS THE REQUIREMENTS OF, THE APPROPRIATE SPECIFICATION

Brian Wales
SENIOR METALLURGIST - PRODUCT

Figure C-3. Base Plate, Test Nos. HMDBR-2 and HMDBR-3 (Item No. b1)

Job Material Certification H202999 R#21-166 1 1/4" Dia., 14" Long Anchor Rod Page 5 of 10

Vulcan
THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 688287 **Job Information** **Certified Date:** 9/17/20

Containers: S17482279

Customer: Portland Bolt & Mfg., Inc. **Ship To:** 3441 N W Guam Street Portland, OR 97210

Vulcan Part No: ATR B7 1-1/4x12

Customer Part No: ATR B7 1-1/4x12

Customer PO No: 47880 **Shipped Qty:** 70 pcs

Order No: 408834 **Line No:** 2

Note:

Applicable Specifications

Type	Specification	Rev	Amend	Option
-	ASTM F1554 Gd 105 S4	2018		
Heat Treat	ASME SA-193/SA-193M B7	2013		
	ASTM A193 B7	2019		

Test Results

See following pages for tests

Certified Chemical Analysis

Heat No: A202999 Lot 1.218 **Origin**: USA

C	Mn	P	S	Si	Cr	Mo	Ni	V	Cu	Al
0.40	0.80	0.010	0.019	0.24	0.86	0.16	0.16	0.003	0.29	0.027
Sn	**Ti**	**N**	**B**	**Ca**	**As**	**Sb**	**H, ppm**	**DI**	**RR**	**G.S.**
0.012	0.001	0.0093	0.0002	0.0006	0.004	0.004	1.4	4.61	124.6:1	8
Macro S	**Macro R**	**Macro C**	**J1**	**J2**	**J3**	**J4**	**J5**	**J6**	**J7**	**J8**
1	1	2	56	56	56	56	56	53	52	50
J9	**J10**	**J12**	**J14**	**J16**	**J18**	**J20**	**J24**	**J28**	**J32**	
49	48	45	43	40	39	38	37	34	33	

Notes

Processed material is Tempered - Stress Free. No weld repair performed on the material. No Mercury used in the production of this material. Melted and Manufactured in the USA.
Grade - 4140/42
EAF Melted

Plex 9/17/20 4:07 PM vulc.sano Page 1 of 2

Figure C-4. 1¼-in. Dia., 1-ft 2-in. Long Anchor Rod, Test Nos. HMDBR-2 and HMDBR-3 (Item No. b2)

Job Material Certification Page 3 of 12

Vulcan
THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 586779 **Job Information** **Certified Date:** 6/27/18

Containers: S14149795 S14150345

Customer: Conklin and Conklin

PORTLAND BOLT
PO 48127
INV 081495
50 5/8" x 144" B7 ATR H.D.G. 1OF2
NOV 12, 2020

Ship To: 34201 Seventh Street
Union City, CA 94587

Vulcan Part No: BAR B7 .5626x144 SC

Customer Part No: BAR B7 .562x144

Customer PO No: 18772

Shipped Qty: 6078 lbs

Order No: 349870

Line No: 2

Note:

Applicable Specifications

Type	Specification	Rev	Amend	Option
-	ASTM F1554 Gd 105 S4	2015		
Heat Treat	ASME SA-193/SA-193M B7	2013		
	ASTM A193 B7	2016		
Quality	EN 10204 3.1	2004		

Test Results

See following pages for tests

Certified Chemical Analysis

Heat No: 10546920 Origin: USA

C	Mn	P	S	Si	Cr	Mo	Ni	V	Cu
0.420	0.88	0.009	0.023	0.28	0.91	0.20	0.06	0.002	0.16
Al	**Nb**	**Sn**	**Ti**	**N**	**B**	**DI**	**RR**	**G.S.**	**Macro S**
0.028	0.001	0.007	0.002	0.0060	0.0001	5.37	99:1	Fine	2
Macro R	**Macro C**	**J1**	**J2**	**J3**	**J4**	**J5**	**J6**	**J7**	**J8**
2	2	57	57	57	57	57	57	57	55
J9	**J10**	**J12**	**J14**	**J16**	**J18**	**J20**	**J24**	**J28**	**J32**
54	53	50	48	46	45	45	43	40	38

Notes

Material was manufactured, tested and inspected as required by the product standard and in accordance with Vulcan's ISO 9001:2015 Quality Management System registered June 30th, 2017. No weld repair performed on the material. No Mercury used in the production of this material.
Document is in accordance with EN 10204 - 3.1B of 2004 (3.1).

Plex 6/27/18 9:22 AM vulc.mgri Page 1 of 2

Figure C-5. ⅝-in. Dia., 8-in. Long Anchor Rod, Test Nos. HMDBR-2 and HMDBR-3 (Item No. b3)

H#59093087.02 R#21-175 W6x25, 26 1/4" Long Steel Post

CERTIFIED MATERIAL TEST REPORT

Page 1 / 1

GERDAU

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 25# / 150 X 37.1	0000515762

LENGTH	PCS	WEIGHT	HEAT / BATCH
40' 00"	18	18,000 LB	**59093087**/02

SALES ORDER	CUSTOMER MATERIAL N°
9307972/000040	000000000376250040

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

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
4500353334	1327-0000388471	10/05/2020

CHEMICAL COMPOSITION

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cu (%)	Ni (%)	Cr (%)	Mo(%)	Sn (%)	V (%)	Nb (%)	Al (%)	CEqvA6 (%)
0.10	0.94	0.015	0.032	0.24	0.32	0.13	0.31	0.034	0.005	0.002	0.016	0.004	0.35

MECHANICAL PROPERTIES

YS 0.2% (PSI)	UTS (PSI)	YS (MPa)	UTS (MPa)	Y/T rati (%)	G/L (Inches)	G/L (mm)	Elong. (%)
52077	68094	359	470	0.760	8.000	200.0	23.30
53762	69642	371	480	0.770	8.000	200.0	22.20

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

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

Figure C-6. W6x25 Steel Post, Test Nos. HMDBR-2 and HMDBR-3 (Item No. b4)

Job Material Certification H#A202719 R#21-166 1" Dia. UNC, 11" Long Threaded Rod Page 7 of 10

Vulcan
THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 680891 **Job Information** **Certified Date:** 8/11/20

Containers: S17343380

Customer: Portland Bolt & Mfg., Inc. **Ship To:** 3441 N W Guam Street Portland, OR 97210

Vulcan Part No: ATR B7 1x12

Customer Part No: ATR B7 1x12

Customer PO No: 47376 **Shipped Qty:** 120 pcs

Order No: 406262 **Line No:** 1

Note:

Applicable Specifications

Type	Specification	Rev	Amend	Option
-	ASTM F1554 Gd 105 S4	2018		
Heat Treat	ASME SA-193/SA-193M B7	2013		
	ASTM A193 B7	2019		

Test Results

See following pages for tests

Certified Chemical Analysis

Heat No: A202719 Lot .9688 Origin: USA

C	Mn	P	S	Si	Cr	Mo	Ni	V	Cu	Al
0.41	0.79	0.008	0.021	0.28	0.85	0.16	0.24	0.002	0.25	0.024
Cb	**Sn**	**Ti**	**N**	**B**	**Ca**	**As**	**Sb**	**H, ppm**	**DI**	**RR**
0.001	0.011	0.001	0.0088	0.0003	0.0013	0.004	0.004	2.1	4.69	196.9:1
G.S.	**Macro S**	**Macro R**	**Macro C**	**J1**	**J2**	**J3**	**J4**	**J5**	**J6**	**J7**
7	1	1	1	57	57	57	57	57	55	53
J8	**J9**	**J10**	**J12**	**J14**	**J16**	**J18**	**J20**	**J24**	**J28**	**J32**
52	51	49	46	44	42	41	40	38	35	34

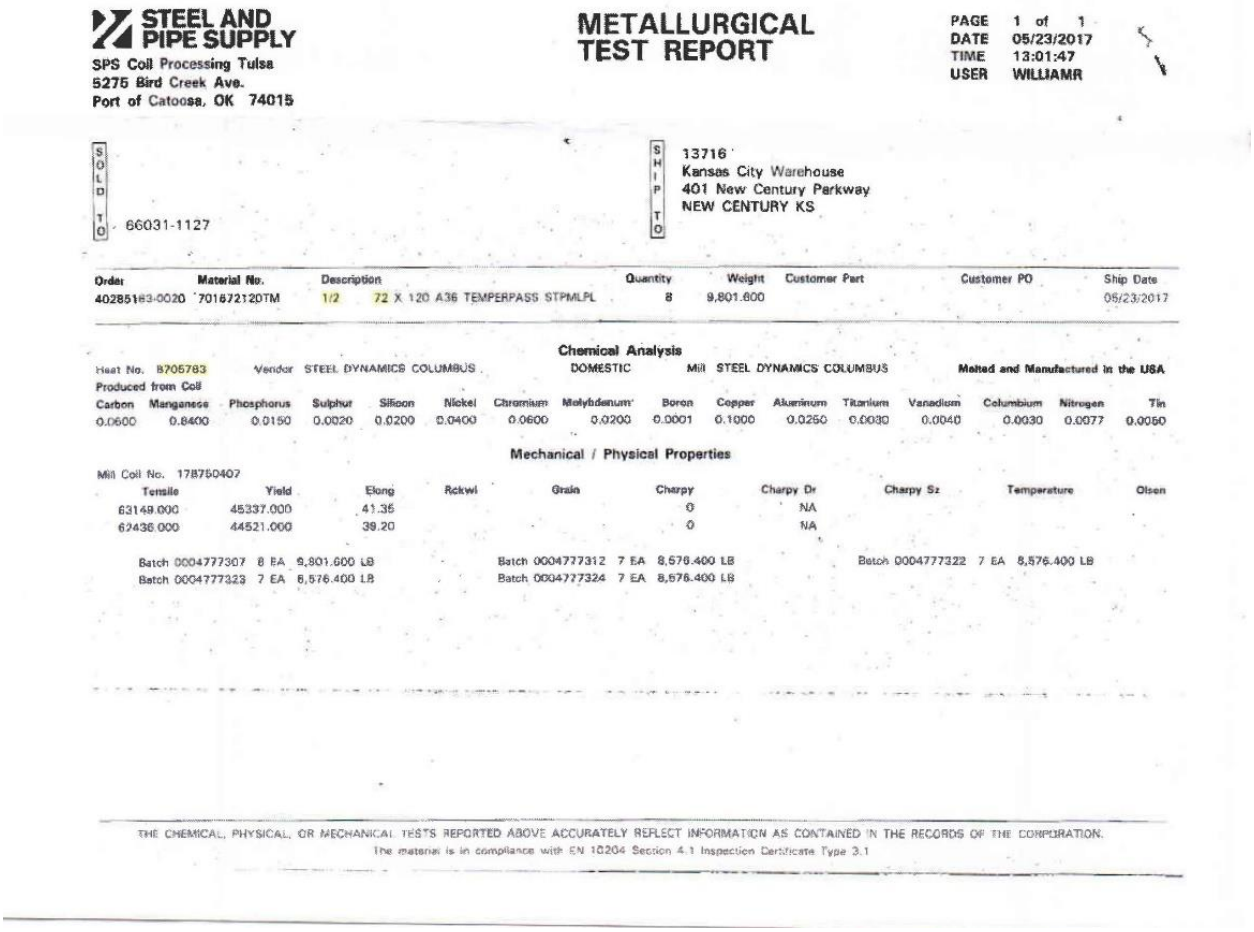
Notes

Processed material is Tempered - Stress Free. No weld repair performed on the material. No Mercury used in the production of this material. Melted and Manufactured in the USA.
Grade - 4140/42
EAF Melted

Plex 8/11/20 10:46 AM vulc.sano Page 1 of 2

Figure C-7. 1-in. Dia., UNC Threaded Rod, Test Nos. HMDBR-2 and HMDBR-3 (Item No. c1)

H#B705783 R#17-708 14"x14"x1/2" Steel Plate



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 05/23/2017
TIME 13:01:47
USER WILLIAMR

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
4028516 3-0020	701672120TM	1/2 72 X 120 A36 TEMPERPASS STPMLPL	8	9,801.600			05/23/2017

Chemical Analysis

Heat No. B705783 Vendor STEEL DYNAMICS COLUMBUS DOMESTIC Mill STEEL DYNAMICS COLUMBUS 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
0.0600	0.8400	0.0150	0.0020	0.0200	0.0400	0.0600	0.0200	0.0001	0.1000	0.0250	0.0030	0.0040	0.0030	0.0077	0.0050

Mechanical / Physical Properties

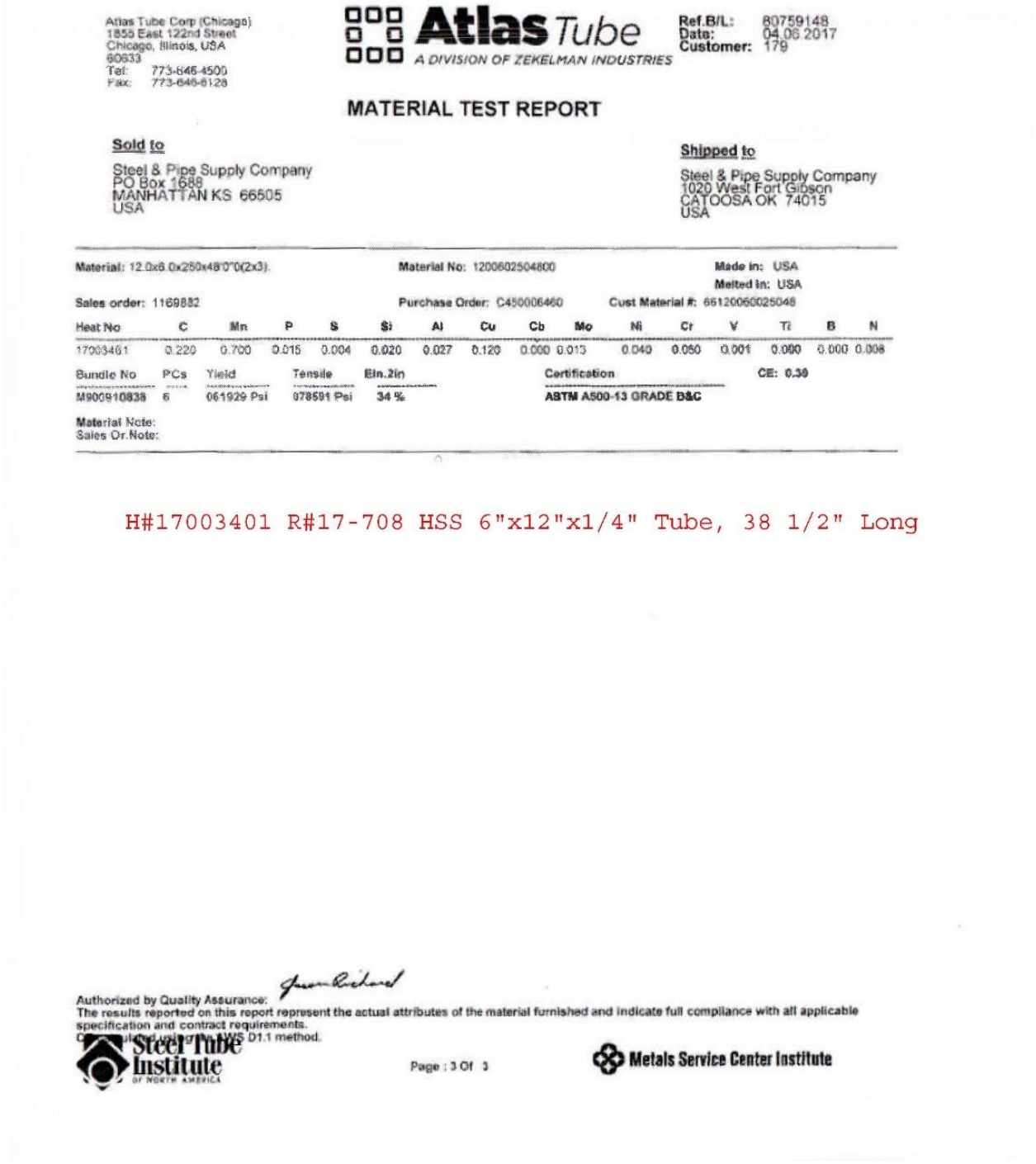
Mill Coil No. 178750407

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
63149.000	45337.000	41.35			0	NA			
62436.000	44521.000	39.20			0	NA			

Batch 0004777307 8 EA 9,801.600 LB
Batch 0004777323 7 EA 8,576.400 LB
Batch 0004777312 7 EA 8,576.400 LB
Batch 0004777324 7 EA 8,576.400 LB
Batch 0004777322 7 EA 8,576.400 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

Figure C-8. 1-ft 2-in. x 1-ft-2in. x ½-in. Steel Plate, Test Nos. HMDBR-2 and HMDBR-3 (Item No. c2)



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

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

Ref.B/L: 80759148
Date: 04.06.2017
Customer: 179

MATERIAL TEST REPORT

Sold to
Steel & Pipe Supply Company
PO Box 1688
MANHATTAN KS 66505
USA

Shipped to
Steel & Pipe Supply Company
1020 West Fort Gibson
CATOOSA OK 74015
USA

Material: 12.0x6.0x250x48'0"0(2x3). Material No: 1200602504800 Made in: USA
Melted in: USA
Sales order: 1169882 Purchase Order: C450006460 Cust Material #: 66120060025048

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
17003401	0.220	0.700	0.015	0.004	0.020	0.027	0.120	0.000	0.013	0.040	0.050	0.001	0.000	0.000	0.008

Bundle No	PCs	Yield	Tensile	Elin.2in	Certification	CE: 0.30
M900910838	6	061929 Psi	078591 Psi	34 %	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

H#17003401 R#17-708 HSS 6"x12"x1/4" Tube, 38 1/2" Long

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.
Certified welding per the AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Page : 3 Of 3

Metals Service Center Institute

Figure C-9. 6-in. x 1-ft x ¼ in. 3-ft 2½-in. Long HSS Tube, Test Nos. HMDBR-2 and HMDBR-3 (Item No. c3)

R#17-708 NSRI PHASE III TEAM1-1
Steel Tube Frames
June 2017 SMT

H#B705783 R#17-708 11 1/2"x5 1/2"x1/2" Steel Plate

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 05/23/2017
TIME 13:01:47
USER WILLIAMR

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
402851 83-0020	701672120TM	1/2 72 X 120 A36 TEMPERPASS STPMLPL	8	9,801.600			05/23/2017

Chemical Analysis

Heat No. B705783 Vendor STEEL DYNAMICS COLUMBUS DOMESTIC Mill STEEL DYNAMICS COLUMBUS **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
0.0600	0.8400	0.0150	0.0020	0.0200	0.0400	0.0600	0.0200	0.0001	0.1000	0.0250	0.0030	0.0040	0.0030	0.0077	0.0050

Mechanical / Physical Properties

Mill Coil No. 178750407

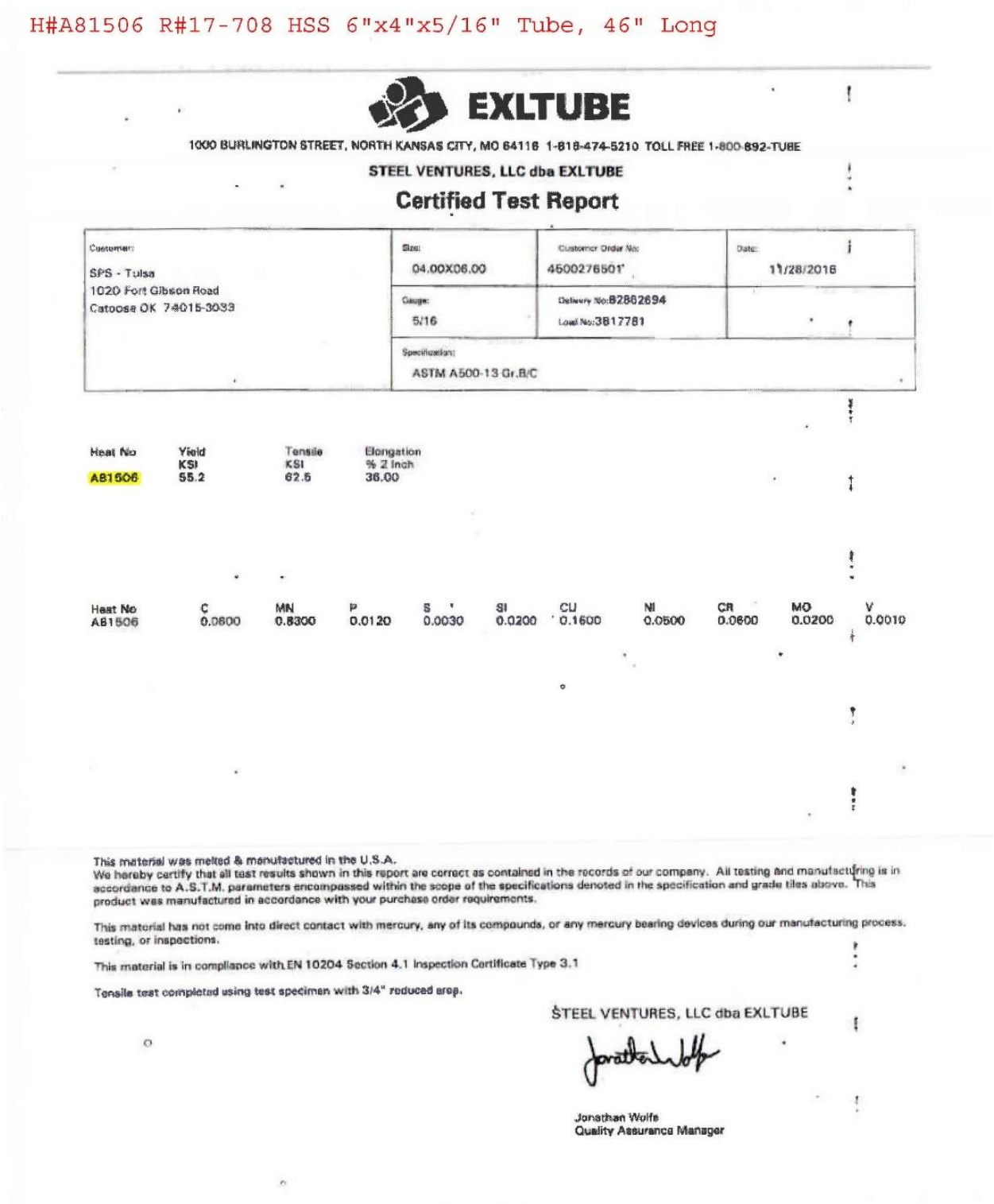
Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
63149.000	45337.000	41.35			0	NA			
62436.000	44521.000	39.20			0	NA			

Batch 0004777307 8 EA 9,801.600 LB
Batch 0004777323 7 EA 8,576.400 LB
Batch 0004777312 7 EA 8,576.400 LB
Batch 0004777324 7 EA 8,576.400 LB
Batch 0004777322 7 EA 8,576.400 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

Figure C-10. 11½-in. x 5½-in. x ½-in. Steel Plate, Test Nos. HMDBR-2 and HMDBR-3 (Item No. c4)

H#A81506 R#17-708 HSS 6"x4"x5/16" Tube, 46" Long



EXLTUBE

1000 BURLINGTON STREET, NORTH KANSAS CITY, MO 64116 1-816-474-5210 TOLL FREE 1-800-892-TUBE

STEEL VENTURES, LLC dba EXLTUBE

Certified Test Report

Customer:	Size:	Customer Order No:	Date:
SPS - Tulsa 1020 Fort Gibson Road Catoosa OK 74015-3033	04.00X06.00	4500276501	11/28/2016
	Gauge: 5/16	Delivery No: 82862694 Load No: 3817781	
	Specification: ASTM A500-13 Gr.B/C		

Heat No	Yield KSI	Tensile KSI	Elongation % 2 inch
A81506	55.2	62.5	36.00

Heat No	C	MN	P	S	SI	CU	NI	CR	MO	V
A81506	0.0600	0.8300	0.0120	0.0030	0.0200	0.1600	0.0500	0.0600	0.0200	0.0010

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

This material has not come into direct contact with mercury, any of its compounds, or any mercury bearing devices during our manufacturing process, testing, or inspections.

This material is in compliance with EN 10204 Section 4.1 Inspection Certificate Type 3.1

Tensile test completed using test specimen with 3/4" reduced area.

STEEL VENTURES, LLC dba EXLTUBE

Jonathan Wolfe
Quality Assurance Manager

Figure C-11. 6-in. x 4-in. x $^{5}/_{16}$-in., 3-ft 10-in. Long HSS Tube, Test Nos. HMDBR-2 and HMDBR-3 (Item No. c5)

H#B705783 R#17-708 16"x12"x1/2" Steel Plate

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 05/23/2017
TIME 13:01:47
USER WILLIAMR

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
402851 83-0020	701672120TM	1/2 72 X 120 A36 TEMPERPASS STPMLPL	8	9,801.600			05/23/2017

Chemical Analysis

Heat No. B705783 Vendor STEEL DYNAMICS COLUMBUS DOMESTIC Mill STEEL DYNAMICS COLUMBUS **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
0.0600	0.8400	0.0150	0.0020	0.0200	0.0400	0.0600	0.0200	0.0001	0.1000	0.0250	0.0030	0.0040	0.0030	0.0077	0.0050

Mechanical / Physical Properties

Mill Coil No. 178750407

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
63149.000	45337.000	41.35			0	NA			
62436.000	44521.000	39.20			0	NA			

Batch 0004777307 8 EA 9,801.600 LB
Batch 0004777323 7 EA 8,576.400 LB
Batch 0004777312 7 EA 8,576.400 LB
Batch 0004777324 7 EA 8,576.400 LB
Batch 0004777322 7 EA 8,576.400 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

Figure C-12. 1-ft 4-in. x 1-ft x ½-in. Steel Plate, Test Nos. HMDBR-2 and HMDBR-3 (Item No. c6)

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

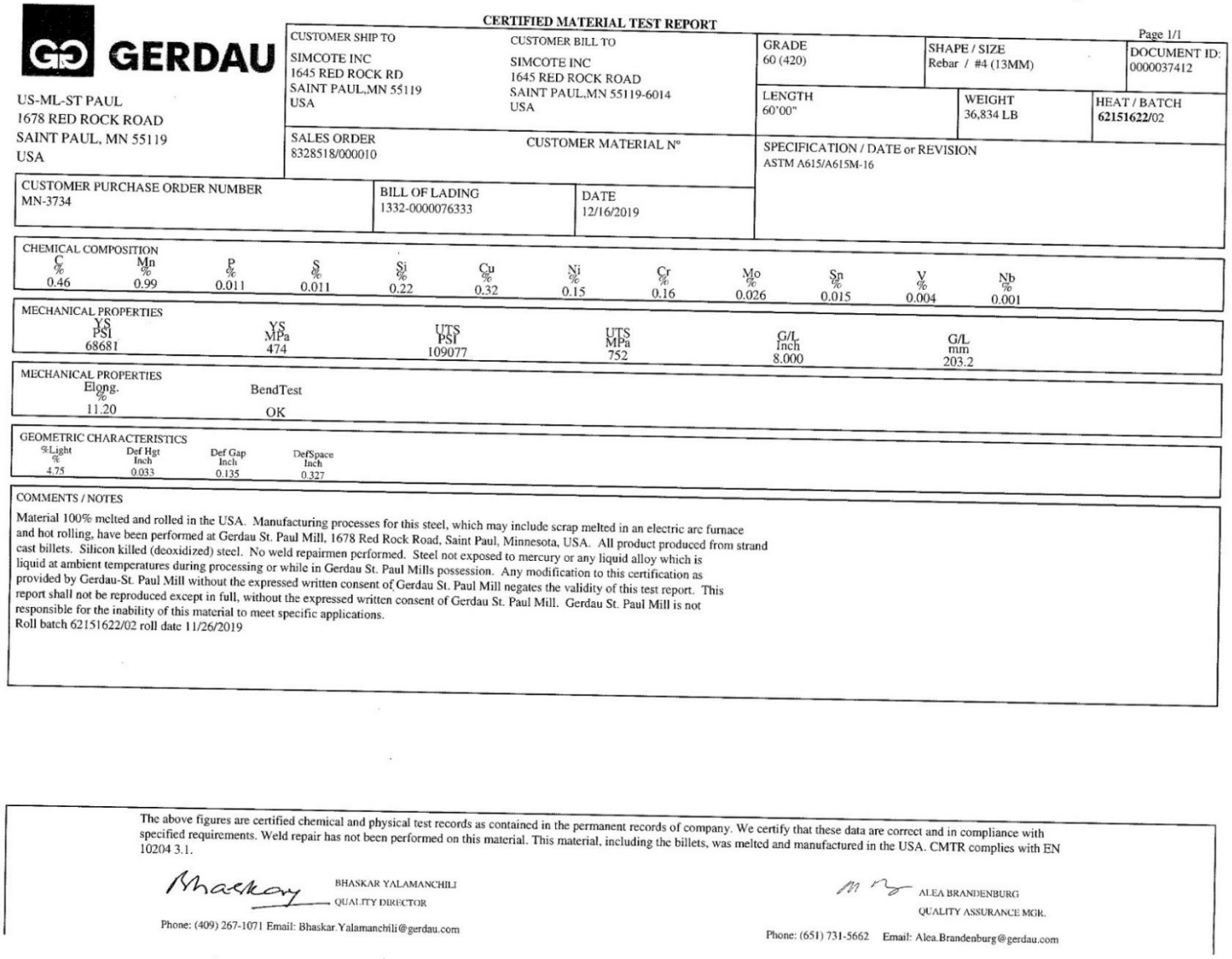
Comments:

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.

Zachary Sprintz, Chief Metallurgist

Page 1 of 1

Figure C-13. #4 Rebar, 2 ft – 6¾ in. Total Unbent Length, Test Nos. HMDBR-2 and HMDBR-3 (Item No. d1)



GERDAU

CERTIFIED MATERIAL TEST REPORT

Page 1/1

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

CUSTOMER SHIP TO	CUSTOMER BILL TO
SIMCOTE INC 1645 RED ROCK RD SAINT PAUL,MN 55119 USA	SIMCOTE INC 1645 RED ROCK ROAD SAINT PAUL,MN 55119-6014 USA

GRADE	SHAPE / SIZE	DOCUMENT ID:
60 (420)	Rebar / #4 (13MM)	0000037412

LENGTH	WEIGHT	HEAT / BATCH
60'00"	36,834 LB	**62151622**/02

SALES ORDER	CUSTOMER MATERIAL Nº
8328518/000010	

SPECIFICATION / DATE or REVISION
ASTM A615/A615M-16

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
MN-3734	1332-0000076333	12/16/2019

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %
0.46	0.99	0.011	0.011	0.22	0.32	0.15	0.16	0.026	0.015	0.004	0.001

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
68681	474	109077	752	8.000	203.2

MECHANICAL PROPERTIES

Elong. %	BendTest
11.20	OK

GEOMETRIC CHARACTERISTICS

%Light %	Def Hgt Inch	Def Gap Inch	DefSpace Inch
4.75	0.033	0.135	0.327

COMMENTS / NOTES

Material 100% melted and rolled in the USA. Manufacturing processes for this steel, which may include scrap melted in an electric arc furnace and hot rolling, have been performed at Gerdau St. Paul Mill, 1678 Red Rock Road, Saint Paul, Minnesota, USA. All product produced from strand cast billets. Silicon killed (deoxidized) steel. No weld repairmen performed. Steel not exposed to mercury or any liquid alloy which is liquid at ambient temperatures during processing or while in Gerdau St. Paul Mills possession. Any modification to this certification as provided by Gerdau-St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill negates the validity of this test report. This report shall not be reproduced except in full, without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill is not responsible for the inability of this material to meet specific applications.
Roll batch 62151622/02 roll date 11/26/2019

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

ALEA BRANDENBURG
QUALITY ASSURANCE MGR.
Phone: (651) 731-5662 Email: Alea.Brandenburg@gerdau.com

Figure C-14. #4 Rebar, 97 ft – 1 in. Total Length, 1 ft – 6 in. Minimum Lap Length, Test Nos. HMDBR-2 and HMDBR-3 (Item No. d2)

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.

Zachary Sprintz, Chief Metallurgist

Page 1 of 1

Figure C-15. #4 Rebar, 2 ft – 8 in. Total Unbent Length, Test Nos. HMDBR-2 and HMDBR-3 (Item No. d3)

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:	016
Description:	HMDBR2

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

Supplier: Mix Name:		Property Slump (in):	Test Result
Ticket Number:		Air Content (%):	
Truck Number:		Unit Weight (lb/ft³):	
Load Volume (yd³):		Air Temp (°F):	
Mold Date:	01/21/2021	Mix Temp (°F):	
Molded By: Initial Cure Method:		Min Temp (°F): MaxTemp (°F):	

Laboratory Test Data (ASTM C39)

Sample Number:	016	016				
Set Number:	001	002				
Specimen Number:	1	1				
Age:	8	8				
Length (in):	8	12				
Diameter (in):	4.01	5.98				
Area (in²):	12.63	28.09				
Test Date:	01/29/2021	01/29/2021				
Break Type:	5	6				
Max Load (lbf):	62,108	110,695				
Strength (psi):	4,920	3,940				
Spec Strength (psi):						

Remarks:
Average 8-day Compressive Strength (psi): **4,430**

Date received: 01/29/2021
Curing: [x] Standard [ ] Field
ASTM C511
Submitted by: Matt Roeuler

Distribution:

Report Date: 1/29/21

825 M Street Suite 100
Lincoln, NE 68508

Alfred Benesch & Company

Figure C-16. Reinforced Concrete, Test Nos. HMDBR-2 and HMDBR-3 (Item No. e1), Page 1 of 2

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:	017
Description:	HMDBR2

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

Supplier: Mix Name:		Property Slump (in):	Test Result
Ticket Number:		Air Content (%):	
Truck Number:		Unit Weight (lb/ft³):	
Load Volume (yd³):		Air Temp (°F):	
Mold Date:	01/21/2021	Mix Temp (°F):	
Molded By: Initial Cure Method:		Min Temp (°F): MaxTemp (°F):	

Laboratory Test Data (ASTM C39)

Sample Number:	017	017				
Set Number:	1	2				
Specimen Number:	1	1				
Age: Length (in):	14 12	14 12				
Diameter (in):	5.99	6				
Area (in²):	28.18	28.27				
Test Date:	02/04/2021	02/04/2021				
Break Type:	5	1				
Max Load (lbf):	116,988	122,711				
Strength (psi): Spec Strength (psi):	4,150	4,340				

Remarks:
Average 14-day Compressive Strength (psi): **4,250**

Date received: 02/04/2021
Curing: [x] Standard [ ] Field
ASTM C511
Submitted by: Matt Roesler

Distribution:

Report Date: 2/4/21

825 M Street Suite 100
Lincoln, NE 68508

Alfred Benesch & Company

Figure C-17. Reinforced Concrete Continued, Test Nos. HMDBR-2 and HMDBR-3 (Item No. e1), Page 2 of 2

AZZ GALVANIZING ROCKFORD

CERTIFICATE OF COMPLIANCE

FOR HOT DIP GALVANIZING

CUSTOMER: FASTENAL

DATE: October 4, 2019

PO#: 040044155

ORDER#: 480010485

This is to certify that the hot dip galvanizing of the following material conforms to specification ASTM A-153. The following sizes and lot numbers comply with the coating, workmanship, finish, and appearance requirements of ASTM F2329 specifications. The hot dip galvanizing is ROHS compliant. The galvanizing process was conducted in a temperature range of 830F to 855F.

HEAT#	PART#	DESCRIPTION	PIECES	LOT#	MIL
10621520	10393684	5/8-11 x 2 A307 Guard Rail Bolt	48,525	848773-13	5.81

This certification in no way implies anything other than the quality of our hot dip galvanizing as it pertains to your order.

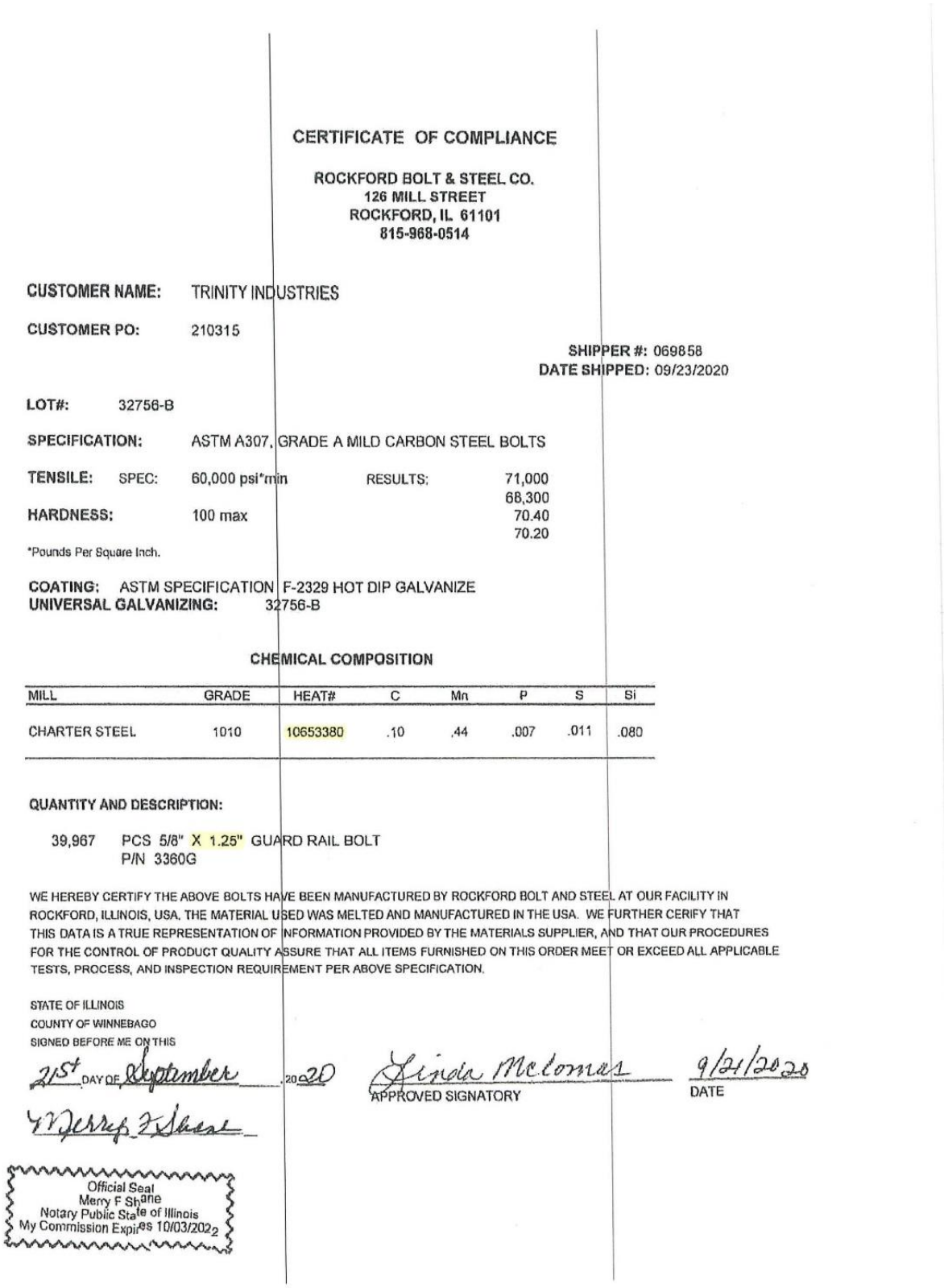
This product was galvanized in Rockford, IL USA

AZZ Galvanizing Rockford, IL

Peggy Doering
Office Manager

PD:mt

Figure C-18. ⅝-in. – 11 UNC, 2-in. Long Guardrail Bolt, Test Nos. HMDBR-2 and HMDBR-3 (Item No. f1)



CERTIFICATE OF COMPLIANCE

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

CUSTOMER NAME: TRINITY INDUSTRIES

CUSTOMER PO: 210315

SHIPPER #: 069858
DATE SHIPPED: 09/23/2020

LOT#: 32756-B

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE:	SPEC:	60,000 psi*min	RESULTS:	71,000 68,300
HARDNESS:		100 max		70.40 70.20

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
UNIVERSAL GALVANIZING: 32756-B

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
CHARTER STEEL	1010	10653380	.10	.44	.007	.011	.080

QUANTITY AND DESCRIPTION:

39,967 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
21st DAY OF September 2020

Linda McComas
APPROVED SIGNATORY

9/21/2020
DATE

Merry F Shane

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

Figure C-19. ⅝-in. – 11 UNC, 1¼-in. Long Guardrail Bolt, Test Nos. HMDBR-2 and HMDBR-3 (Item No. f2)

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#: 136936
Cust PO#: HMDBR-2/3
Date: 11/19/2020
Shipped: 11/23/2020

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 8 GALV ASTM F3125 GRADE A325 HEAVY HEX BOLT

Heat#: 75068447 **Base Steel:** 4140 **Diam:** 7/8

Source: KREHER STEEL CO LLC **Proof Load:** 39,300 LBF

C :	.410	**Mn:** .880	**P :** .011	**Hardness:**	262 HBN		
S :	.022	**Si:** .240	**Ni:** .080	**Tensile:**	57,660 LBF	**RA:**	.00%
Cr:	1.010	**Mo:** .170	**Cu:** .220	**Yield:**	0	**Elon:**	.00%
Pb:	.000	**V :** .002	**Cb:** .000	**Sample Length:**	0		
N :	.000		**CE:** .6635	**Charpy:**		**CVN Temp:**	

LOT#18734

Product:
ASTM F1554G105 ALL THRD ROD
ASTM A449 ALL THRD RODS

Nuts:
ASTM A563DH HVY HX

Coatings:
ITEMS HOT DIP GALVANIZED PER ASTM F2329/A153C

Other:
ALL ITEMS MELTED & MANUFACTURED IN THE USA

By: _____
Certification Department Quality Assurance
Dane McKinnon

Figure C-20. ⅞-in. Dia. UNC Heavy Hex Head Bolt, Test Nos. HMDBR-2 and HMDBR-3 (Item No. f3)

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

SSF INDUSTRIAL CO., LIMITED

MILL TEST CERTIFICATION

Certification Conforms to EN1024 3.1B

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

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

RAW MATERIAL scrap

Element	C	Si	Mn	S	P	Ni	Cr	Cu

SURFACE

Test Item	Spec.	Standard	Remark
Appearance	Flawless	/	OK

DIMENSION MEASUREMENT(UNI According to : USS

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

MACHANICAL PROPERTIES According to : ISO 6507

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

COATING According to : ISO 4042

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

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

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

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

Figure C-21. ⅝-in. Dia. Plain USS Washer, Test Nos. HMDBR-2 and HMDBR-3 (Item No. g1)

Wrought Washer Mfg., Inc
2100 South Bay Street
Milwaukee, WI 53207
Tel 414-744-0771

Material Certification

Customer: **Fastenal Company**
Ship To: **Fastenal - Edwardsville**
Customer PO No: **210233008**
Wrought Washer Mfg., Inc. Order No: **10347**
Order Line: **1**
Wrought Washer Mfg., Inc. Part No: **017285**
Customer Part No: **0156025**
Shipped Qty: **13,500**
Heat: **193903**
Heat Code: **193903**
Grade: **1035**
Note: **Melted and rolled in the USA**

Material Specification Type	Material Specification	Actual
Chemistry	C	0.34 %
	Mn	0.83 %
	P	0.011 %
	S	0.001 %
	Si	0.277 %
	Cu	0.101 %
	Ni	0.039 %
	Cr	0.062 %

We hereby certify that chemical analysis and/or physical characteristics shown are a true copy of original test reports on file with us from the producing source covering the heat or lot from which this material was taken.

Plex 11/3/2020 3:40 PM / AHess.ww *1 of 1*

Figure C-22. ⅝-in. Dia. Hardened Washer, Test Nos. HMDBR-2 and HMDBR-3 (Item No. g2)

P#33187 C#17089822 L#1844804 7/8" Dia. Plain Round Washer

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 C-23. ⅞-in. Dia. Plain Round Washer, Test Nos. HMDBR-2 and HMDBR-3 (Item No. g3)

FNL Part#0156040

Prestige Stamping, LLC

23513 Groesbeck Highway
Warren, Michigan 48089
(586)773-2700 * Fax (586)773-2298
www.PrestigeStamping.com

PRODUCT CERTIFICATION
CERTIFICATION NUMBER
217853

THIS IS TO CERTIFY THE PRODUCT STATED BELOW WAS FABRICATED AND PROCESSED TO THE ORDER AS INDICATED AND CONFORMS TO THE APPLICABLE SPECIFICATIONS AND STANDARDS.

Customer: FASTENAL/EDWARDSVILLE
9911 WOODEND ROAD
EDWARDSVILLE, KS 66111
USA

R#0156040 C#210227501 L#D9597 H#209197 R#21-176 1 1/4" Dia. Hardened Washer

Customer Part: 1-1/4" F436 HDG
Prestige Part: P2500HP300
Part Name: 1-1/4" F436 H/D GALV
Purchase Order: 210227501
Shipment BOL: B227760
Shipment ID: A0248543
Quantity: 1050
Manufacturers Marking: "P"

Steel Supplier: MARATHON METALS, LLC
Grade: CF436 GRADE STEEL
Lot: D9597
Heat: 209197
Carbon: .53
Manganese: .63
Phosphorous: .008
Sulfur: .002
Silicon: .236

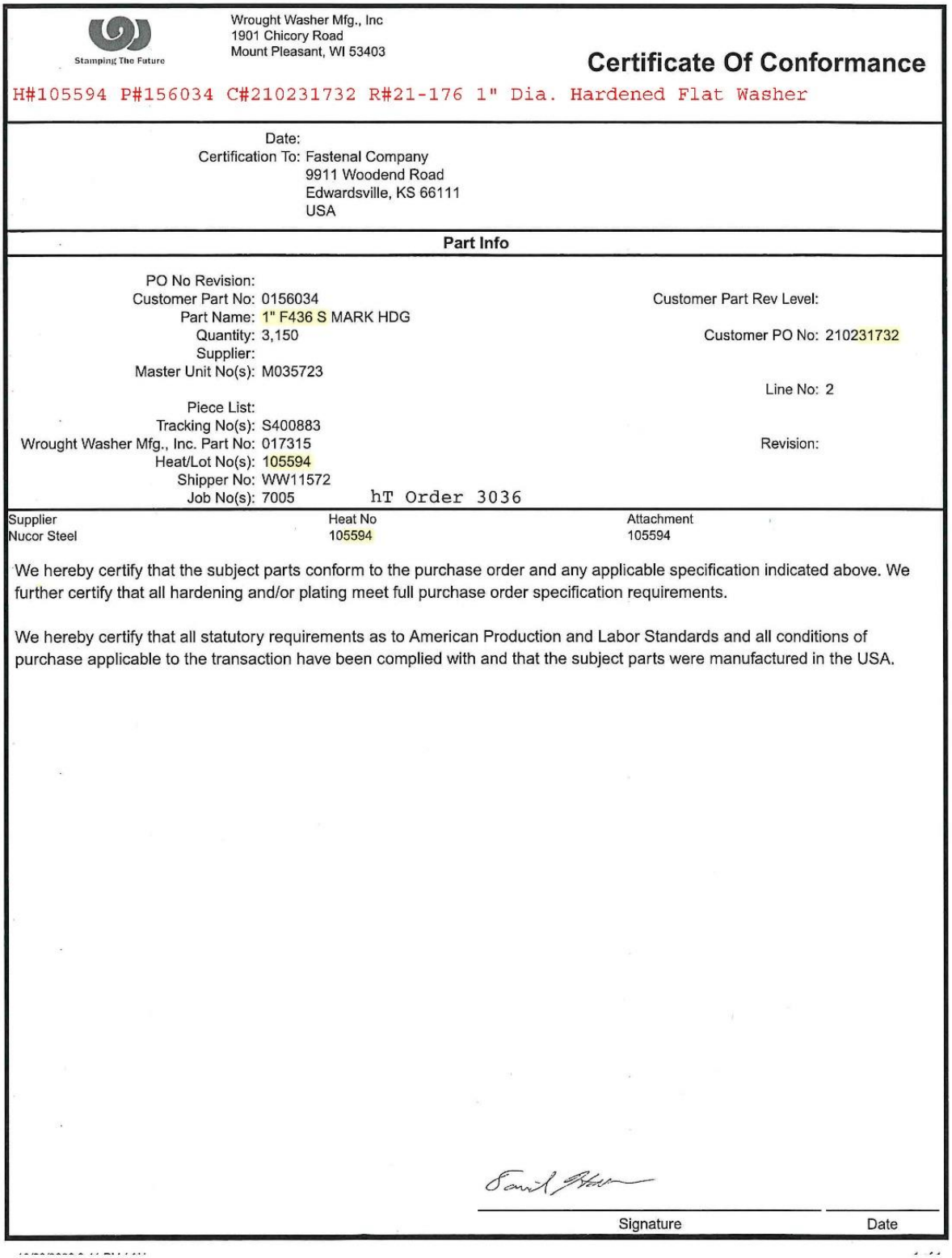
SPECIFICATIONS	TEST RESULTS
HARDNESS: TEST METHOD: ASTM E18 HRC 40 - 45 CHECKED TO ASTM F606 CHECKED AFTER GALVANIZING	HARDNESS: HRC 41 - 43
PLATING: TEST METHOD: ASTM B499 HOT DIP GALV TO ASTM F-2329 AND ASTM 153 CLASS C	PLATING: 0.0020" - 0.0022"

USS/SAE LC Washers are manufactured to the requirements of ASTM F844 specifications
Chemistry is as reported from raw material certification and does not fall under Prestige Stamping's accreditation.
This product was produced under an IATF 16949 Quality Assurance System.
IATF 16949 Certification No: 800334.
Material was melted and manufactured in the U.S.A.
This product was manufactured in Warren, Michigan U.S.A.
This product conforms to all requirements for washers as produced according to A.S.T.M. F-436-13.
Sampling Plan per P.S.I W.I. # 5.4.18.015.
The test results only apply to the items tested.
This test report must not be reproduced except in full without prior written approval.
Materials used to manufacture these products are mercury, asbestos and radio activity free.
Product is RoHS compliant.
No weld repairs made to material.
All certified product is AIS compliant.

FRANK SCHUBERT
Quality Assurance Manager

Econ Information System 09/03/20 08:26 RFOR PAGE 1 of 1

Figure C-24. 1¼-in. Dia. Hardened Washer, Test Nos. HMDBR-2 and HMDBR-3 (Item No. g4)



Wrought Washer Mfg., Inc
1901 Chicory Road
Mount Pleasant, WI 53403

Stamping The Future

Certificate Of Conformance

H#105594 P#156034 C#210231732 R#21-176 1" Dia. Hardened Flat Washer

Date:
Certification To: Fastenal Company
9911 Woodend Road
Edwardsville, KS 66111
USA

Part Info

PO No Revision:
Customer Part No: 0156034
Part Name: 1" F436 S MARK HDG
Quantity: 3,150
Supplier:
Master Unit No(s): M035723
Piece List:
Tracking No(s): S400883
Wrought Washer Mfg., Inc. Part No: 017315
Heat/Lot No(s): 105594
Shipper No: WW11572
Job No(s): 7005 hT Order 3036

Customer Part Rev Level:
Customer PO No: 210231732
Line No: 2
Revision:

Supplier	Heat No	Attachment
Nucor Steel	105594	105594

We hereby certify that the subject parts conform to the purchase order and any applicable specification indicated above. We further certify that all hardening and/or plating meet full purchase order specification requirements.

We hereby certify that all statutory requirements as to American Production and Labor Standards and all conditions of purchase applicable to the transaction have been complied with and that the subject parts were manufactured in the USA.

Signature Date

Figure C-25. 1-in. Dia. Hardened Round Washer, Test Nos. HMDBR-2 and HMDBR-3 (Item No. g5)

DECKER
SINCE 1927 www.deckernut.com

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

Printed: 10/6/2020 3:39:27 PM
October 6, 2020

TRINITY HWY PRODUCTS LLC 55
550 E ROBB AVENUE
LIMA, OH 45801

PRODUCT MATERIAL CERTIFICATION

CUSTOMER PART NUMBER : 003340G
CUSTOMER P.O. NUMBER : 207374 B2
INVOICE: 522623

LOT NUMBER: 20-35-006
DATE: Dec 11, 2019
HEAT NUMBER: 10635460
MATERIAL: STEEL - C1010
DESCRIPTION: 5/8 GRD RAIL NUT .031
QUANTITY: 27,000
MATERIAL SUPPLIER: CHARTER STEEL

We certify the product above was manufactured at DECKER MANUFACTURING CORPORATION from the specified raw material and that said product is certified to be manufactured, randomly sampled, tested and/or inspected and conforms to applicable specifications. We additionally certify that said raw material was domestically manufactured in the United States of America and that said raw material was manufactured free of mercury contamination.

The items were processed under the Decker Quality Manual. The current revision is dated January 12, 2005
No welding was performed.

This document accurately represents values and statements provided by our suppliers accredited testing facility. The original metallurgical test report shall be retained on file by DECKER MANUFACTURING CORPORATION for a period of not less than (10) years.

CHEMICAL ANALYSIS BY MATERIAL SUPPLIER

CARBON : 0.090
MANGANESE : 0.470
PHOSPHOROUS : 0.007
SULFUR : 0.009

DECKER MANUFACTURING CORPORATION

Russel L. Wilson
Quality Assurance Manager

The above results pertain only to the items tested. This report shall not be reproduced except in full without the approval of this testing facility.

Figure C-26. ⅝-in. Dia. Heavy Hex Nut, Test Nos. HMDBR-2 and HMDBR-3 (Item No. h1)

H#100890711 P#38207 C#180202299 R#21-181 5/8"-11 UNC Heavy Hex Nut

NUCOR
FASTENER DIVISION

LOT NO.
435042A

Post Office Box 6100
Saint Joe, Indiana 46785
Telephone 260/337-1600

CUSTOMER NO/NAME
7495 FASTENAL COMPANY-TX
TEST REPORT SERIAL# FB634592
TEST REPORT ISSUE DATE 5/19/20
DATE SHIPPED 7/29/20
NAME OF LAB SAMPLER: RYAN UNGER, LAB TECHNICIAN
NUCOR ORDER # 210522
CUST PART # 38207
CUSTOMER P.O. # 180202299

**********CERTIFIED MATERIAL TEST REPORT**********

NUCOR PART NO	QUANTITY	LOT NO.	DESCRIPTION
175747C	6800	435042A	5/8-11 GR DH HV H.D.G.

MANUFACTURE DATE 2/05/20 HEX NUT HOT DIP GAL.

--CHEMISTRY MATERIAL GRADE -1026L

MATERIAL NUMBER	HEAT NUMBER	**CHEMISTRY COMPOSITION (WT% HEAT ANALYSIS) BY MATERIAL SUPPLIER C	MN	P	S	SI	
RM032619	100890711	.24	.71	.005	.020	.22	NUCOR STEEL - NEBRASKA

--MECHANICAL PROPERTIES IN ACCORDANCE WITH ASTM A563-15

SURFACE HARDNESS (R30N)	CORE HARDNESS (RC)	PROOF LOAD 33900 LBS	TENSILE STRENGTH (LBS)	DEG-WEDGE STRESS (PSI)
N/A	30.4	PASS	N/A	N/A
N/A	28.1	PASS	N/A	N/A
N/A	30.3	PASS	N/A	N/A
N/A	26.4	PASS	N/A	N/A
N/A	28.9	PASS	N/A	N/A

AVERAGE VALUES FROM TESTS
28.8
PRODUCTION LOT SIZE 200000 PCS

--VISUAL INSPECTION IN ACCORDANCE WITH ASTM A563-15 160 PCS. SAMPLED LOT PASSED

--COATING - HOT DIP GALVANIZED TO ASTM F2329-15 - GALVANIZING PERFORMED IN THE U.S.A.

1.	0.00219	2.	0.00388	3.	0.00284	4.	0.00218	5.	0.00722	6.	0.00273	7.	0.00475
8.	0.00305	9.	0.00351	10.	0.00616	11.	0.00430	12.	0.00243	13.	0.00242	14.	0.00253
15.	0.00445												

AVERAGE THICKNESS FROM 15 TESTS .00364

--HEAT TREATMENT - AUSTENITIZED, OIL QUENCHED & TEMPERED (MIN 800 DEG F)

--DIMENSIONS PER ASME B18.2.6-2010

CHARACTERISTIC	#SAMPLES TESTED	MINIMUM	MAXIMUM
Width Across Corners	8	1.189	1.193
Thickness	32	0.602	0.607

ALL TESTS ARE IN ACCORDANCE WITH THE LATEST REVISIONS OF THE METHODS PRESCRIBED IN THE APPLICABLE SAE AND ASTM SPECIFICATIONS. THE SAMPLES TESTED CONFORM TO THE SPECIFICATIONS AS DESCRIBED/LISTED ABOVE AND WERE MANUFACTURED FREE OF MERCURY CONTAMINATION. NO INTENTIONAL ADDITIONS OF BISMUTH, SELENIUM, TELLURIUM, OR LEAD WERE USED IN THE STEEL USED TO PRODUCE THIS PRODUCT.
THE STEEL WAS MELTED AND MANUFACTURED IN THE U.S.A. AND THE PRODUCT WAS MANUFACTURED AND TESTED IN THE U.S.A.
PRODUCT COMPLIES WITH DFARS 252.225-7014. WE CERTIFY THAT THIS DATA IS A 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. CERTIFICATION FORMAT MEETS EN10204 3.1

A2LA ACCREDITED

MECHANICAL FASTENER
CERTIFICATE NO. A2LA 0139.01
EXPIRATION DATE 12/31/21

NUCOR FASTENER
A DIVISION OF NUCOR CORPORATION

BOB HAYWOOD
QUALITY ASSURANCE SUPERVISOR

Page 1 of 1

Figure C-27. ⅝-in. Dia. Heavy Hex Nut, Test Nos. HMDBR-2 and HMDBR-3 (Item No. h2)

H#F19080206 P#36767 C#210199067 R#21-176 1-1/4"-7 UNC Heavy Hex Nut

NINGBO DONGXIN HIGH-STRENGTH NUT CO.,LTD

TEST CERTIFICATE

(EN 10204.3.1)

Customer: FASTENAL COMPANY PURCHASING	Production Lot No.:	1910DX100-1339-1	**Issue Date:**	2020/4/22
	Add.of Customer:	4730 SERVICE DRIVEWINONA MN 55897	**Inv. No.:**	20167DX100-871
	Description:	ASTM A563 GR.DH HEAVY HEX NUT	**Manu. Date:**	2019/11/29
		HDG With Blue Wax	**Manu. Qty:**	1680
	PO No.:	210199067	**Shipped Qty:**	1620
	Manufacturer:	Ningbo Dongxin High-strength Nut	**Marking:**	DX,DH
	Address:	Xijingtang,Luotuo,Ningbo,China	**LOT No.:**	1217DX100-1339-1
	Tel./Fax:	0574-86533751/86531751	**Sample Plan:**	ASME B18.18-2017(Category.2)/ASTM F1470-2019
	Size:	1 1/4"-7	**Part No.:**	36767

Chemical Composition

Material type: 45# Φ34 Heat No.: F19080206

Chemical Analysis % (items)	**C**	**Mn**	**P**	**S**	**Si**	**Cr**	**Ni**	**Mo**	**Others**
	0.18-0.58	**MIN0.57**	**MAX0.048**	**MAX0.058**	**/**	**/**	**/**	**/**	**/**
Result	0.45	0.60	0.022	0.007	0.27	0.064	0.019	0.007	/
Cert #:	F9080265			Material supplier:			QUZhou YuanLi Metal		

Dimensions

DIM.SPEC: ASME B18.2.2-2015 INSPECTOR & SAMPER: Ms.Li DATE: 2020/4/22

Item	**Specified**	**Result**	**Sampling**	**Rej.**	**Remark**	**Specification**
Widthacrossflats(inch)	1.938 - 2.002	1.952 - 1.961	3	0	OK	------
Widthacrossangle(inch)	2.209 - 2.309	2.239 - 2.242	3	0	OK	------
Height(inch)	1.187 - 1.251	1.228 - 1.232	3	0	OK	------
Minor diameter(inch)	1.119 - 1.147	1.125 - 1.128	13	0	OK	------
Thread-2B	Thread GO gauge	OK	13	0	OK	ASME B1.1-03
	Thread NO GO gauge	OK	13	0	OK	
Appearance	OK	OK	18	0	OK	ASTM F812-17
FIM	MAX 0.03	0.005 - 0.009	3	0	OK	ASME B18.2.2-2015

Mechanical Properties

MEC,SPEC:ASTM A563-15 INSPECTOR & SAMPLER: Ms.Li DATE: 2020/4/22

ITEM	**Test Method**	**SPECIFIED**	**Sampling**	**Result**	**JUG**
CoreHardness HRC	ASTM F606/F606M-19	24 - 38	3	26 - 29	OK
Proof loading KSI	ASTM F606/F606M-19	175	2	179	OK

Plating

Plating Spec: ASTM F2329-15 Inspector & Sampler : Ms Li Date: 2020/4/22

ITEM	Test Method	SPECIFIED	Sampling	Result	JUG
HDG With Blue Wax	ASTM B487-2017	50.8 um Average	13	57 - 96 um	OK

MACROETCH

Division	**Surface Condition**	**Random Condition**	**Center Segregation**	**Test method**

Figure C-28. 1¼-in. Dia. Heavy Hex Nut, Test Nos. HMDBR-2 and HMDBR-3 (Item No. h3), Page 1 of 2

Spec.	S2	R2	C3	ASTM E381-2017
Results	S2	R2	C3	

REMARK:

***This inspection certificate is for responsibility under test sample only.**

***Quench at880℃ about 90 minutes,Tempering at550℃ about 120 minutes**

***This test report shall not be reproduced except in full without written approval of the LAB.**

***The samples tested CONFORM to the fastener specification & standards above.**

***Dimensional Testing is done at Ningbo Dongxin High-Strength Nut Co.,Ltd**

***The documentation for chemical analysis is provided by the suppliers.**

***Parts are manufactured and tested according to above specification and compliance with order, we certify that this is a true representation of information provided by manufacturer and laboratory.**

***The products supplied are in compliance with all the requirements of the order.**

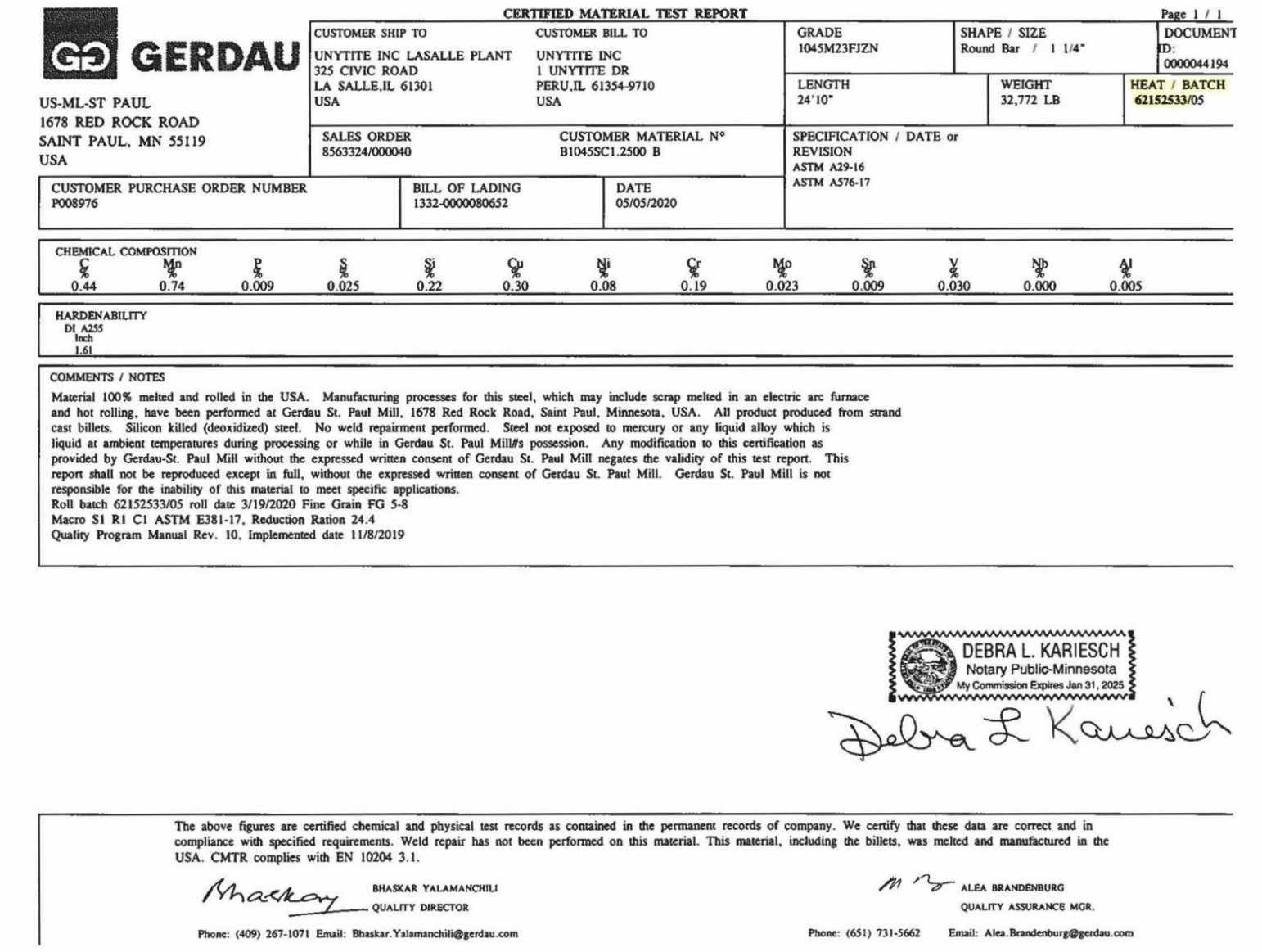
***The MTR's are in compliance to DIN EN 10204 3.1.**

Yan Yingjun

QA: Yan Yingjun

Ningbo Dongxin High-Strength Nut Co.,Ltd

Figure C-29. 1¼-in. Dia. Heavy Hex Nut, Test Nos. HMDBR-2 and HMDBR-3 (Item No. h3), Page 2 of 2



GERDAU

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

CERTIFIED MATERIAL TEST REPORT

Page 1 / 1

CUSTOMER SHIP TO	CUSTOMER BILL TO
UNYTITE INC LASALLE PLANT 325 CIVIC ROAD LA SALLE,IL 61301 USA	UNYTITE INC 1 UNYTITE DR PERU,IL 61354-9710 USA

GRADE	SHAPE / SIZE	DOCUMENT ID:
1045M23FJZN	Round Bar / 1 1/4"	0000044194

LENGTH	WEIGHT	HEAT / BATCH
24'10"	32,772 LB	62152533/05

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
8563324/000040	B1045SC1.2500 B	ASTM A29-16 ASTM A576-17

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
P008976	1332-0000080652	05/05/2020

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.44	0.74	0.009	0.025	0.22	0.30	0.08	0.19	0.023	0.009	0.030	0.000	0.005

HARDENABILITY
DI A255
Inch
1.61

COMMENTS / NOTES

Material 100% melted and rolled in the USA. Manufacturing processes for this steel, which may include scrap melted in an electric arc furnace and hot rolling, have been performed at Gerdau St. Paul Mill, 1678 Red Rock Road, Saint Paul, Minnesota, USA. All product produced from strand cast billets. Silicon killed (deoxidized) steel. No weld repairment performed. Steel not exposed to mercury or any liquid alloy which is liquid at ambient temperatures during processing or while in Gerdau St. Paul Mill#s possession. Any modification to this certification as provided by Gerdau-St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill negates the validity of this test report. This report shall not be reproduced except in full, without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill is not responsible for the inability of this material to meet specific applications.
Roll batch 62152533/05 roll date 3/19/2020 Fine Grain FG 5-8
Macro S1 R1 C1 ASTM E381-17, Reduction Ration 24.4
Quality Program Manual Rev. 10, Implemented date 11/8/2019

DEBRA L. KARIESCH
Notary Public-Minnesota
My Commission Expires Jan 31, 2025

Debra L Kariesch

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

ALEA BRANDENBURG
QUALITY ASSURANCE MGR.
Phone: (651) 731-5662 Email: Alea.Brandenburg@gerdau.com

Figure C-30. 1-in. Dia. Heavy Hex Nut, Test Nos. HMDBR-2 and HMDBR-3 (Item No. h4)

H#100894559 R#21-166 7/8" Dia. UNC Heavy Hex Nut

NUCOR
FASTENER DIVISION

LOT NO.
417521B

Post Office Box 6100
Saint Joe, Indiana 46785
Telephone 260/337-1600

CUSTOMER NO/NAME
1554 BRIGHTON-BEST/CA
TEST REPORT SERIAL# FB594019
TEST REPORT ISSUE DATE 3/04/19
DATE SHIPPED 12/08/19
NAME OF LAB SAMPLER: DEANN WATSON, LAB TECHNICIAN
NUCOR ORDER # 175251
CUST PART # 175092
CUSTOMER P.O. # U70154

**********CERTIFIED MATERIAL TEST REPORT**********

NUCOR PART NO	QUANTITY	LOT NO.	DESCRIPTION
175667	9900	417521B	7/8-9 GR DH HV H.D.G.

MANUFACTURE DATE 12/04/18
HEX NUT HDG/GREEN LUBE

--CHEMISTRY MATERIAL GRADE -1045L

MATERIAL NUMBER	HEAT NUMBER	**CHEMISTRY COMPOSITION (WT% HEAT ANALYSIS) BY MATERIAL SUPPLIER C	MN	P	S	SI	
RM032885	100894559	.44	.67	.007	.017	.18	NUCOR STEEL - NEBRASKA

--MECHANICAL PROPERTIES IN ACCORDANCE WITH ASTM A563-15

SURFACE HARDNESS (R30N)	CORE HARDNESS (RC)	PROOF LOAD 69300 LBS	TENSILE STRENGTH (LBS)	DEG-WEDGE STRESS (PSI)
N/A	30.3	PASS	N/A	N/A
N/A	31.7	PASS	N/A	N/A
N/A	31.9	PASS	N/A	N/A
N/A	29.4	PASS	N/A	N/A
N/A	29.6	PASS	N/A	N/A

AVERAGE VALUES FROM TESTS
30.6
PRODUCTION LOT SIZE 118000 PCS

--VISUAL INSPECTION IN ACCORDANCE WITH ASTM A563-15 80 PCS. SAMPLED LOT PASSED

--COATING - HOT DIP GALVANIZED TO ASTM F2329-15 - GALVANIZING PERFORMED IN THE U.S.A.

1.	0.00297	2.	0.00348	3.	0.00263	4.	0.00247	5.	0.00223	6.	0.00354	7.	0.00267
8.	0.00286	9.	0.00400	10.	0.00300	11.	0.00322	12.	0.00398	13.	0.00294	14.	0.00261
15.	0.00269												

AVERAGE THICKNESS FROM 15 TESTS .00302

--HEAT TREATMENT - AUSTENITIZED, OIL QUENCHED & TEMPERED (MIN 800 DEG F)

--DIMENSIONS PER ASME B18.2.6-2010

CHARACTERISTIC	#SAMPLES TESTED	MINIMUM	MAXIMUM
Width Across Corners	8	1.616	1.623
Thickness	32	0.858	0.879

ALL TESTS ARE IN ACCORDANCE WITH THE LATEST REVISIONS OF THE METHODS PRESCRIBED IN THE APPLICABLE SAE AND ASTM SPECIFICATIONS. THE SAMPLES TESTED CONFORM TO THE SPECIFICATIONS AS DESCRIBED/LISTED ABOVE AND WERE MANUFACTURED FREE OF MERCURY CONTAMINATION. NO INTENTIONAL ADDITIONS OF BISMUTH, SELENIUM, TELLURIUM, OR LEAD WERE USED IN THE STEEL USED TO PRODUCE THIS PRODUCT.
THE STEEL WAS MELTED AND MANUFACTURED IN THE U.S.A. AND THE PRODUCT WAS MANUFACTURED AND TESTED IN THE U.S.A.
PRODUCT COMPLIES WITH DFARS 252.225-7014. WE CERTIFY THAT THIS DATA IS A 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. CERTIFICATION FORMAT MEETS EN10204 3.1

A2LA
ACCREDITED

MECHANICAL FASTENER
CERTIFICATE NO. A2LA 0139.01
EXPIRATION DATE 12/31/19

NUCOR FASTENER
A DIVISION OF NUCOR CORPORATION

BOB HAYWOOD
QUALITY ASSURANCE SUPERVISOR

Page 1 of 1

Figure C-31. ⅞-in. Dia. Heavy Hex Nut, Test Nos. HMDBR-2 and HMDBR-3 (Item No. h5)

Appendix D. Vehicle Center of Gravity Determination

		Test Name:	**HMDBR-1**	**VIN:**	**1C6RRGT6ES314223**
Model Year:	**2014**	**Make:**	**Dodge**	**Model:**	**Ram**

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	5104	28.786056	146924.03
+	Hub	19	15	285
+	Brake activation cylinder & frame	7	29	203
+	Pneumatic tank (Nitrogen)	30	26	780
+	Strobe/Brake Battery	5	28	140
+	Brake Receiver/Wires	5	52.25	261.25
+	CG Plate including DAQ	30	31.375	941.25
-	Battery	-39	43	-1677
-	Oil	-12	20	-240
-	Interior	-105	42	-4410
-	Fuel	-166	18	-2988
-	Coolant	-16	30	-480
-	Washer fluid	-4	34	-136
+	Water Ballast (In Fuel Tank)	130	17	2210
+	Onboard Supplemental Battery	5	28	140
				0
				0
				141953.53

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

Estimated Total Weight (lb)	4993
Vertical CG Location (in.)	28.4305

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.25 in. Front Track Width: 67.875 in.
Rear Track Width: 67.625 in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb)	5000 ± 110	5001	1.0
Longitudinal CG (in.)	63 ± 4	59.986953	-3.01305
Lateral CG (in.)	NA	-0.196436	NA
Vertical CG (in.)	28 or greater	28.43	0.43051

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	1497	1435	
Rear	1085	1087	
FRONT	2932		lb
REAR	2172		lb
TOTAL	5104		lb

TEST INERTIAL WEIGHT (lb.)

	Left	Right	
Front	1456	1406	
Rear	1059	1080	
FRONT	2862		lb
REAR	2139		lb
TOTAL	5001		lb

Figure D-1. Vehicle Mass Distribution, Test No. HMDBR-1

		Test Name:	**HMDBR-2**	**VIN:**	**KMHCT4AE3GU979226**
Model Year:	**2016**	**Make:**	**Hyundai**	**Model:**	**Accent**

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)
+	Unballasted Car (Curb)	2497
+	Hub	19
+	Brake activation cylinder & frame	7
+	Pneumatic tank (Nitrogen)	30
+	Strobe/Brake Battery	5
+	Brake Receiver/Wires	5
+	CG Plate including DAQ	18
-	Battery	-36
-	Oil	-2
-	Interior	-66
-	Fuel	-8
-	Coolant	-6
-	Washer fluid	-4
+	Water Ballast (In Fuel Tank)	
+	Onboard Supplemental Battery	

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

Estimated Total Weight (lb): 2459

Vehicle Dimensions for C.G. Calculations

Wheel Base:	101.0	in.	Front Track Width:	59.0	in.
Roof Height:	56.375	in.	Rear Track Width:	59.5	in.

Center of Gravity	**1100C MASH Targets**	**Test Inertial**	**Difference**
Test Inertial Weight (lb)	2420 ± 55	2453	33.0
Longitudinal CG (in.)	39 ± 4	39.033	0.033
Lateral CG (in.)	NA	-0.954	NA
Vertical CG (in.)	NA	21.827	NA

Note: Long. CG is measured from front axle of test vehicle

Note: Lateral CG measured from centerline - positive to vehicle right (passenger) side

CURB WEIGHT (lb)

	Left	Right	
Front	763	781	
Rear	516	437	
FRONT	1544		lb
REAR	953		lb
TOTAL	2497		lb

TEST INERTIAL WEIGHT (lb)

	Left	Right	
Front	773	732	
Rear	493	455	
FRONT	1505		lb
REAR	948		lb
TOTAL	2453		lb

Figure D-2. Vehicle Mass Distribution, Test No. HMDBR-2

		Test Name:	**HMDBR-3**	**VIN:**	**1C6RR6KG2FS506038**
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)	4963	28.480128	141346.88
+	Hub	19	15	285
+	Brake activation cylinder & frame	7	28	196
+	Pneumatic tank (Nitrogen)	30	25 1/2	765
+	Strobe/Brake Battery	4	26	104
+	Brake Receiver/Wires	5	52 1/4	261.25
+	CG Plate including DAQ	50	29 5/8	1481.25
-	Battery	-46	43	-1978
-	Oil	-9	19	-171
-	Interior	-89	34	-3026
-	Fuel	-154	18	-2772
-	Coolant	-1	31	-31
-	Washer fluid	0	35	0
+	Water Ballast (In Fuel Tank)	218	18	3924
+	Onboard Supplemental Battery	4	26	104
				0
				0
				140489.38

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

Estimated Total Weight (lb)	5001
Vertical CG Location (in.)	28.0923

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.25 in. Front Track Width: 68 in.
Rear Track Width: 68 in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb)	5000 ± 110	5001	1.0
Longitudinal CG (in.)	63 ± 4	65.034943	2.03494
Lateral CG (in.)	NA	-0.564287	NA
Vertical CG (in.)	28 or greater	28.09	0.09226

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	1405	1299	
Rear	1116	1143	
FRONT	2704		lb
REAR	2259		lb
TOTAL	4963		lb

TEST INERTIAL WEIGHT (lb.)

	Left	Right	
Front	1403	1279	
Rear	1139	1180	
FRONT	2682		lb
REAR	2319		lb
TOTAL	5001		lb

Figure D-3. Vehicle Mass Distribution, Test No. HMDBR-3

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 documented herein. MASH 2016 defines intrusion as the occupant compartment being deformed and reduced in size with no penetration. Outward deformations, which are denoted as negative numbers within this Appendix, are not considered as crush toward the occupant, and are not subject to evaluation by MASH 2016 criteria. In test no. HMDBR-2, the reference points for Data Set 1 were compromised, therefore, only Data Set 2 is reported.

Model Year: 2014 Test Name: HMDBR-1 Make: Dodge VIN: 1C6RRGT6ES314223 Model: Ram

VEHICLE DEFORMATION
DRIVER 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	53.0291	-25.3022	-1.5337	47.8465	-19.9607	-4.3417	5.1826	5.3415	2.8080	7.9546	5.8944	X, Z
	2	54.1597	-22.0314	-0.6596	49.1658	-16.8396	-3.5364	4.9939	5.1918	2.8768	7.7569	5.7632	X, Z
	3	54.1800	-17.8279	-0.4255	52.0978	-16.3540	-0.4939	2.0822	1.4739	0.0684	2.5520	2.0833	X, Z
	4	53.6102	-13.7587	-0.1033	52.6650	-13.7435	0.6664	0.9452	0.0152	-0.7697	1.2190	0.9452	X
	5	52.8590	-9.5803	-0.9037	52.0602	-9.6804	-0.4456	0.7988	-0.1001	-0.4581	0.9263	0.7988	X
	6	50.0257	-25.8895	1.9094	43.8374	-19.8553	-2.0859	6.1883	6.0342	3.9953	9.5220	7.3660	X, Z
	7	50.5023	-20.6689	1.6253	47.2457	-16.5190	0.8373	3.2566	4.1499	0.7880	5.3337	3.3506	X, Z
	8	50.1797	-17.8856	1.7922	48.9220	-17.3889	2.4592	1.2577	0.4967	-0.6670	1.5078	1.2577	X
	9	50.1785	-14.3001	1.7882	49.5469	-14.1244	2.7454	0.6316	0.1757	-0.9572	1.1602	0.6316	X
	10	50.2136	-8.1151	1.7305	49.9940	-7.9556	2.4820	0.2196	0.1595	-0.7515	0.7990	0.2196	X
FLOOR PAN (Z)	11	46.3731	-26.7862	3.9706	42.2149	-22.9535	0.5195	4.1582	3.8327	3.4511	6.6250	3.4511	Z
	12	46.3869	-21.5636	3.8722	44.5974	-19.9557	3.8217	1.7895	1.6079	0.0505	2.4063	0.0505	Z
	13	46.5075	-17.7698	3.7895	46.1673	-17.3293	5.1339	0.3402	0.4405	-1.3444	1.4551	-1.3444	Z
	14	46.5966	-13.6154	3.7401	46.3492	-13.2395	4.9283	0.2474	0.3759	-1.1882	1.2706	-1.1882	Z
	15	46.4850	-7.7307	3.2036	46.1751	-7.4211	3.8473	0.3099	0.3096	-0.6437	0.7786	-0.6437	Z
	16	42.6016	-26.5119	4.5170	41.2186	-25.0206	3.6887	1.3830	1.4913	0.8283	2.1961	0.8283	Z
	17	42.5308	-22.0098	4.4352	42.2278	-21.4089	6.0958	0.3030	0.6009	-1.6606	1.7918	-1.6606	Z
	18	42.5098	-18.3515	4.4408	42.3514	-17.8678	6.3996	0.1584	0.4837	-1.9588	2.0238	-1.9588	Z
	19	42.5007	-14.2956	4.4487	42.2822	-13.8590	5.9222	0.2185	0.4366	-1.4735	1.5523	-1.4735	Z
	20	42.9118	-8.4392	4.2837	42.6261	-8.0576	4.8418	0.2857	0.3816	-0.5581	0.7340	-0.5581	Z
	21	37.0412	-26.7185	4.6805	36.8686	-26.2076	6.6095	0.1726	0.5109	-1.9290	2.0030	-1.9290	Z
	22	37.0659	-22.9679	4.5272	36.9293	-22.5820	6.4597	0.1366	0.3859	-1.9325	1.9754	-1.9325	Z
	23	36.9901	-18.5105	4.5297	36.7950	-18.1694	6.0791	0.1951	0.3411	-1.5494	1.5985	-1.5494	Z
	24	36.8314	-14.9140	4.5409	36.5716	-14.5384	5.6246	0.2598	0.3756	-1.0837	1.1760	-1.0837	Z
	25	37.0165	-9.1527	4.5574	36.7312	-8.8017	4.9557	0.2853	0.3510	-0.3983	0.6027	-0.3983	Z
	26	31.3433	-27.2233	4.6429	31.3035	-26.8892	5.8554	0.0398	0.3341	-1.2125	1.2583	-1.2125	Z
	27	31.2307	-23.1343	4.6326	31.1348	-22.8727	5.6113	0.0959	0.2616	-0.9787	1.0176	-0.9787	Z
	28	30.9909	-18.8114	4.5823	30.9075	-18.6232	5.3823	0.0834	0.1882	-0.8000	0.8261	-0.8000	Z
	29	30.9323	-15.4169	4.5742	30.7711	-15.1218	5.2141	0.1612	0.2951	-0.6399	0.7229	-0.6399	Z
	30	31.4084	-9.5828	4.6702	31.1688	-9.2825	4.9614	0.2396	0.3003	-0.2912	0.4821	-0.2912	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. HMDBR-1

Model Year: 2014 Test Name: HMDBR-1 Make: Dodge VIN: 1C6RRGT6ES314223 Model: Ram

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	53.7954	-10.8289	-5.5310	48.7799	-5.1959	-8.4177	5.0155	5.6330	2.8867	8.0758	5.7869	X, Z
	2	54.9718	-7.5714	-4.6678	50.0981	-2.1381	-7.6077	4.8737	5.4333	2.9399	7.8687	5.6917	X, Z
	3	55.0515	-3.3679	-4.4485	53.0443	-1.7072	-4.5204	2.0072	1.6607	0.0719	2.6061	2.0085	X, Z
	4	54.5393	0.7102	-4.1410	53.6634	0.8773	-3.3601	0.8759	-0.1671	-0.7809	1.1853	0.8759	X
	5	53.8479	4.8959	-4.9565	53.1147	5.0297	-4.4200	0.7332	-0.1338	-0.5365	0.9183	0.7332	X
	6	50.7821	-11.3615	-2.0876	44.7274	-5.0950	-6.1575	6.0547	6.2665	4.0699	9.6173	7.2954	X, Z
	7	51.3328	-6.1492	-2.3899	48.3523	-1.8457	-3.1347	2.9805	4.3035	0.7448	5.2876	3.0722	X, Z
	8	51.0496	-3.3609	-2.2329	49.8650	-2.7370	-1.5872	1.1846	0.6239	-0.6457	1.4864	1.1846	X
	9	51.0993	0.2241	-2.2496	50.5352	0.5402	-1.2795	0.5641	-0.3161	-0.9701	1.1659	0.5641	X
	10	51.2221	6.4078	-2.3291	51.0424	6.6785	-1.4626	0.1797	-0.2707	-0.8665	0.9254	0.1797	X
FLOOR PAN (Z)	11	47.1160	-12.1989	-0.0254	43.0756	-8.2103	-3.5343	4.0404	3.9886	3.5089	6.6743	3.5089	Z
	12	47.2038	-6.9774	-0.1422	45.4943	-5.2553	-0.2490	1.7095	1.7221	0.1068	2.4289	0.1068	Z
	13	47.3784	-3.1861	-0.2383	47.1054	-2.6443	1.0817	0.2730	0.5418	-1.3200	1.4527	-1.3200	Z
	14	47.5263	0.9665	-0.3022	47.3177	1.4479	0.9287	0.2086	-0.4814	-1.2309	1.3380	-1.2309	Z
	15	47.4985	6.8502	-0.8596	47.2239	7.2443	-0.0794	0.2746	-0.3941	-0.7802	0.9162	-0.7802	Z
	16	43.3484	-11.8692	0.5178	42.0669	-10.2519	-0.4394	1.2815	1.6173	0.9572	2.2747	0.9572	Z
	17	43.3416	-7.3669	0.4201	43.1136	-6.7251	1.9804	0.2280	0.6418	-1.5603	1.7025	-1.5603	Z
	18	43.3724	-3.7087	0.4127	43.2451	-3.2134	2.3508	0.1273	0.4953	-1.9381	2.0044	-1.9381	Z
	19	43.4208	0.3470	0.4063	43.2475	0.8573	1.9034	0.1733	-0.5103	-1.4971	1.5911	-1.4971	Z
	20	43.9150	6.1963	0.2209	43.6781	6.6326	0.8985	0.2369	-0.4363	-0.6776	0.8400	-0.6776	Z
	21	37.7855	-11.9964	0.6786	37.7215	-11.4893	2.4318	0.0640	0.5071	-1.7532	1.8262	-1.7532	Z
	22	37.8636	-8.2471	0.5122	37.8173	-7.8045	2.3491	0.0463	0.4426	-1.8369	1.8900	-1.8369	Z
	23	37.8510	-3.7891	0.4989	37.7077	-3.3757	2.0081	0.1433	0.4134	-1.5092	1.5713	-1.5092	Z
	24	37.7433	-0.1907	0.4973	37.5408	0.1979	1.5966	0.2025	0.3886	-1.0993	1.1834	-1.0993	Z
	25	38.0101	5.5674	0.4936	37.7774	6.0227	0.9689	0.2327	-0.4553	-0.4753	0.6981	-0.4753	Z
	26	32.0811	-12.4205	0.6395	32.1751	-12.0426	1.7075	-0.0940	0.3779	-1.0680	1.1368	-1.0680	Z
	27	32.0265	-8.3303	0.6148	31.9558	-8.0299	1.4721	0.0707	0.3004	-0.8573	0.9112	-0.8573	Z
	28	31.8481	-4.0047	0.5491	31.8275	-3.7123	1.2998	0.0206	0.2924	-0.7507	0.8059	-0.7507	Z
	29	31.8376	-0.6098	0.5289	31.7263	-0.2738	1.1655	0.1113	0.3360	-0.6366	0.7284	-0.6366	Z
	30	32.3964	5.2173	0.6046	32.1814	5.5544	0.9768	0.2150	-0.3371	-0.3722	0.5463	-0.3722	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-2. Floor Pan Deformation Data – Set 2, Test No. HMDBR-1

Model Year: 2014 Test Name: HMDBR-1 Make: Dodge VIN: 1C6RRGT6ES314223 Model: Ram

VEHICLE DEFORMATION
DRIVER 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	41.6368	-27.3340	-27.5105	42.0404	-27.2610	-28.6926	-0.4036	0.0730	-1.1821	1.2512	1.2512	X, Y, Z
	2	38.8347	-15.4127	-30.3566	39.5836	-15.2754	-31.2013	-0.7489	0.1373	-0.8447	1.1372	1.1372	X, Y, Z
	3	36.2064	1.3043	-27.4220	36.8263	1.4001	-27.6646	-0.6199	-0.0958	-0.2426	0.6725	0.6725	X, Y, Z
	4	36.8505	-27.9847	-16.4476	35.8030	-28.0327	-18.4041	1.0475	-0.0480	-1.9565	2.2198	2.2198	X, Y, Z
	5	34.9546	-16.4158	-15.5070	34.1296	-16.4017	-16.7625	0.8250	0.0141	-1.2555	1.5024	1.5024	X, Y, Z
	6	33.4644	1.7499	-16.7041	33.4521	1.6104	-17.1310	0.0123	0.1395	-0.4269	0.4493	0.4493	X, Y, Z
SIDE PANEL (Y)	7	46.5638	-29.6414	1.3471	42.0665	-25.7526	-0.4734	4.4973	3.8888	-1.8205	6.2179	3.8888	Y
	8	46.9699	-29.8352	-6.8677	44.2419	-28.4287	-7.8640	2.7280	1.4065	-0.9963	3.2269	1.4065	Y
	9	50.9162	-29.6199	-6.5630	47.3359	-26.8004	-7.6157	3.5803	2.8195	-1.0527	4.6772	2.8195	Y
IMPACT SIDE DOOR (Y)	10	14.7669	-32.6723	-18.1855	13.6837	-35.4985	-17.8388	1.0832	-2.8262	0.3467	3.0465	-2.8262	Y
	11	24.9769	-31.7763	-19.1681	23.8541	-35.2062	-19.1898	1.1228	-3.4299	-0.0217	3.6091	-3.4299	Y
	12	37.1178	-32.1020	-18.7550	36.0996	-35.0050	-19.1558	1.0182	-2.9030	-0.4008	3.1024	-2.9030	Y
	13	14.7079	-32.4045	-3.2096	13.9585	-33.8692	-3.1816	0.7494	-1.4647	0.0280	1.6455	-1.4647	Y
	14	26.3538	-33.0667	-3.8201	25.5955	-34.0551	-3.8863	0.7583	-0.9884	-0.0662	1.2475	-0.9884	Y
	15	30.6020	-33.0437	-4.0419	29.8202	-33.9705	-4.2124	0.7818	-0.9268	-0.1705	1.2244	-0.9268	Y
ROOF - (Z)	16	20.1995	-19.8424	-45.7670	21.1373	-19.9917	-45.8096	-0.9378	-0.1493	-0.0426	0.9506	-0.0426	Z
	17	20.6601	-15.9367	-46.0711	21.4977	-16.1005	-46.1227	-0.8376	-0.1638	-0.0516	0.8550	-0.0516	Z
	18	23.6691	-8.8362	-46.0462	24.5465	-9.0168	-46.0296	-0.8774	-0.1806	0.0166	0.8959	0.0166	Z
	19	24.8969	-1.6734	-46.0362	25.7458	-1.8790	-45.9635	-0.8489	-0.2056	0.0727	0.8765	0.0727	Z
	20	25.4420	3.9119	-45.9526	26.2156	3.7090	-45.8338	-0.7736	0.2029	0.1188	0.8085	0.1188	Z
	21	12.7886	-19.2076	-46.4421	13.6054	-19.4069	-46.3748	-0.8168	-0.1993	0.0673	0.8435	0.0673	Z
	22	13.9247	-13.9431	-46.6784	14.6839	-14.1723	-46.8238	-0.7592	-0.2292	-0.1454	0.8063	-0.1454	Z
	23	15.1819	-8.8004	-46.8556	16.0146	-8.9896	-46.9479	-0.8327	-0.1892	-0.0923	0.8589	-0.0923	Z
	24	16.7210	-2.8190	-47.0223	17.6119	-3.0461	-47.0400	-0.8909	-0.2271	-0.0177	0.9196	-0.0177	Z
	25	16.8257	2.5946	-47.0543	17.7194	2.4033	-47.0453	-0.8937	0.1913	0.0090	0.9140	0.0090	Z
	26	6.3026	-18.9659	-46.6713	7.1901	-19.1106	-46.4669	-0.8875	-0.1447	0.2044	0.9222	0.2044	Z
	27	6.4181	-14.2101	-46.9792	7.3672	-14.4168	-47.1638	-0.9491	-0.2067	-0.1846	0.9887	-0.1846	Z
	28	6.2288	-8.7087	-47.2343	7.1496	-8.8812	-47.4226	-0.9208	-0.1725	-0.1883	0.9556	-0.1883	Z
	29	6.4302	-4.2096	-47.3559	7.3734	-4.4312	-47.5054	-0.9432	-0.2216	-0.1495	0.9803	-0.1495	Z
	30	6.5424	0.0791	-47.4075	7.4555	-0.1350	-47.5215	-0.9131	0.2141	-0.1140	0.9448	-0.1140	Z
A-PILLAR Maximum (X, Y, Z)	31	42.0206	-27.7238	-31.8408	43.2454	-28.1392	-32.5119	-1.2248	-0.4154	-0.6711	1.4571	0.0000	NA
	32	38.2834	-26.1979	-33.9456	39.5046	-26.5805	-34.5176	-1.2212	-0.3826	-0.5720	1.4017	0.0000	NA
	33	36.4445	-26.6814	-36.3103	37.5544	-27.0471	-36.8564	-1.1099	-0.3657	-0.5461	1.2899	0.0000	NA
	34	34.1420	-26.1911	-37.7500	35.2084	-26.5300	-38.2339	-1.0664	-0.3389	-0.4839	1.2191	0.0000	NA
	35	31.7451	-25.7160	-39.2512	32.7257	-26.0051	-39.6547	-0.9806	-0.2891	-0.4035	1.0991	0.0000	NA
	36	27.0171	-24.3853	-41.0374	27.9911	-24.6507	-41.2607	-0.9740	-0.2654	-0.2233	1.0339	0.0000	NA
A-PILLAR Lateral (Y)	31	42.0206	-27.7238	-31.8408	43.2454	-28.1392	-32.5119	-1.2248	-0.4154	-0.6711	1.4571	-0.4154	Y
	32	38.2834	-26.1979	-33.9456	39.5046	-26.5805	-34.5176	-1.2212	-0.3826	-0.5720	1.4017	-0.3826	Y
	33	36.4445	-26.6814	-36.3103	37.5544	-27.0471	-36.8564	-1.1099	-0.3657	-0.5461	1.2899	-0.3657	Y
	34	34.1420	-26.1911	-37.7500	35.2084	-26.5300	-38.2339	-1.0664	-0.3389	-0.4839	1.2191	-0.3389	Y
	35	31.7451	-25.7160	-39.2512	32.7257	-26.0051	-39.6547	-0.9806	-0.2891	-0.4035	1.0991	-0.2891	Y
	36	27.0171	-24.3853	-41.0374	27.9911	-24.6507	-41.2607	-0.9740	-0.2654	-0.2233	1.0339	-0.2654	Y
B-PILLAR Maximum (X, Y, Z)	37	0.8425	-25.8461	-39.0938	1.6335	-25.9427	-38.9647	-0.7910	-0.0966	0.1291	0.8073	0.1291	Z
	38	4.0796	-27.6297	-34.3368	4.7937	-27.7050	-34.0819	-0.7141	-0.0753	0.2549	0.7620	0.2549	Z
	39	1.6740	-29.0467	-29.6529	2.3428	-29.0548	-29.4997	-0.6688	-0.0081	0.1532	0.6862	0.1532	Z
	40	5.1053	-29.6593	-24.1229	5.5815	-29.6128	-23.9132	-0.4762	0.0465	0.2097	0.5224	0.2148	Y, Z
B-PILLAR Lateral (Y)	37	0.8425	-25.8461	-39.0938	1.6335	-25.9427	-38.9647	-0.7910	-0.0966	0.1291	0.8073	-0.0966	Y
	38	4.0796	-27.6297	-34.3368	4.7937	-27.7050	-34.0819	-0.7141	-0.0753	0.2549	0.7620	-0.0753	Y
	39	1.6740	-29.0467	-29.6529	2.3428	-29.0548	-29.4997	-0.6688	-0.0081	0.1532	0.6862	-0.0081	Y
	40	5.1053	-29.6593	-24.1229	5.5815	-29.6128	-23.9132	-0.4762	0.0465	0.2097	0.5224	0.0465	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-3. Occupant Compartment Deformation Data – Set 1, Test No. HMDBR-1

Model Year: 2014 Test Name: HMDBR-1 Make: Dodge VIN: 1C6RRGT6ES314223 Model: Ram

VEHICLE DEFORMATION
DRIVER 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	42.4266	-12.8022	-31.4574	42.8335	-12.2151	-32.9018	-0.4069	0.5871	-1.4444	1.6114	1.6114	X, Y, Z
	2	39.8029	-0.8515	-34.3502	40.5268	-0.1763	-35.2958	-0.7239	0.6752	-0.9456	1.3690	1.3690	X, Y, Z
	3	37.4131	15.9122	-31.4789	37.9805	16.4983	-31.6000	-0.5674	-0.5861	-0.1211	0.8247	0.8247	X, Y, Z
	4	37.6128	-13.3441	-20.4006	36.5901	-13.0058	-22.6183	1.0227	0.3383	-2.2177	2.4655	2.4655	X, Y, Z
	5	35.8838	-1.7456	-19.5039	35.0636	-1.3708	-20.8659	0.8202	0.3748	-1.3620	1.6335	1.6335	X, Y, Z
	6	34.6601	16.4355	-20.7673	34.6126	16.6511	-21.0634	0.0475	-0.2156	-0.2961	0.3693	0.3693	X, Y, Z
SIDE PANEL (Y)	7	47.2712	-15.0788	-2.5835	42.8874	-10.9747	-4.6696	4.3838	4.1041	-2.0861	6.3571	4.1041	Y
	8	47.6881	-15.3076	-10.7969	45.0266	-13.6078	-12.0862	2.6615	1.6998	-1.2893	3.4110	1.6998	Y
	9	51.6367	-15.1487	-10.4861	48.1409	-12.0209	-11.8237	3.4958	3.1278	-1.3376	4.8778	3.1278	Y
IMPACT SIDE DOOR (Y)	10	15.4663	-17.7162	-22.1601	14.3788	-20.1980	-22.1142	1.0875	-2.4818	0.0459	2.7100	-2.4818	Y
	11	25.6899	-16.9722	-23.1282	24.5517	-20.0208	-23.4668	1.1382	-3.0486	-0.3386	3.2717	-3.0486	Y
	12	37.8241	-17.4730	-22.6930	36.7988	-19.9739	-23.4362	1.0253	-2.5009	-0.7432	2.8032	-2.5009	Y
	13	15.3861	-17.3946	-7.1854	14.6787	-18.7113	-7.4423	0.7074	-1.3167	-0.2569	1.5166	-1.3167	Y
	14	27.0222	-18.2282	-7.7735	26.3122	-19.0367	-8.1538	0.7100	-0.8085	-0.3803	1.1412	-0.8085	Y
	15	31.2706	-18.2678	-7.9880	30.5376	-19.0021	-8.4809	0.7330	-0.7343	-0.4929	1.1487	-0.7343	Y
ROOF - (Z)	16	21.1311	-5.0643	-49.7771	22.0180	-4.5217	-49.9401	-0.8869	0.5426	-0.1630	1.0524	-0.1630	Z
	17	21.6490	-1.1668	-50.0941	22.4273	-0.6325	-50.2165	-0.7783	0.5343	-0.1224	0.9520	-0.1224	Z
	18	24.7609	5.8893	-50.0890	25.5650	6.4111	-50.0576	-0.8041	-0.5218	0.0314	0.9591	0.0314	Z
	19	26.0928	13.0335	-50.1020	26.8538	13.5323	-49.9244	-0.7610	-0.4988	0.1776	0.9271	0.1776	Z
	20	26.7189	18.6105	-50.0370	27.3940	19.1125	-49.7420	-0.6751	-0.5020	0.2950	0.8915	0.2950	Z
	21	13.7314	-4.3241	-50.4672	14.4939	-3.8369	-50.4964	-0.7625	0.4872	-0.0292	0.9053	-0.0292	Z
	22	14.9444	0.9224	-50.7200	15.6380	1.3878	-50.8963	-0.6936	-0.4654	-0.1763	0.8537	-0.1763	Z
	23	16.2765	6.0456	-50.9131	17.0337	6.5543	-50.9719	-0.7572	-0.5087	-0.0588	0.9141	-0.0588	Z
	24	17.9027	12.0034	-51.0982	18.7056	12.4778	-51.0083	-0.8029	-0.4744	0.0899	0.9369	0.0899	Z
	25	18.0862	17.4147	-51.1490	18.8817	17.9252	-50.9620	-0.7955	-0.5105	0.1870	0.9635	0.1870	Z
	26	7.2499	-3.9890	-50.7084	8.0828	-3.4591	-50.5829	-0.8329	0.5299	0.1255	0.9951	0.1255	Z
	27	7.4352	0.7636	-51.0328	8.3187	1.2385	-51.2354	-0.8835	-0.4749	-0.2026	1.0233	-0.2026	Z
	28	7.3263	6.2662	-51.3076	8.1707	6.7786	-51.4416	-0.8444	-0.5124	-0.1340	0.9968	-0.1340	Z
	29	7.5934	10.7614	-51.4447	8.4504	11.2260	-51.4824	-0.8570	-0.4646	-0.0377	0.9756	-0.0377	Z
	30	7.7680	15.0478	-51.5111	8.5864	15.5208	-51.4578	-0.8184	-0.4730	0.0533	0.9468	0.0533	Z
A-PILLAR Maximum (X, Y, Z)	31	42.8119	-13.2128	-35.7857	44.0262	-13.0721	-36.7298	-1.2143	0.1407	-0.9441	1.5446	0.1407	Y
	32	39.1009	-11.6401	-37.9023	40.3046	-11.4476	-38.7190	-1.2037	0.1925	-0.8167	1.4673	0.1925	Y
	33	37.2591	-12.1053	-40.2685	38.3480	-11.8674	-41.0613	-1.0889	0.2379	-0.7928	1.3678	0.2379	Y
	34	34.9664	-11.5866	-41.7138	36.0082	-11.3079	-42.4327	-1.0418	0.2787	-0.7189	1.2961	0.2787	Y
	35	32.5791	-11.0820	-43.2208	33.5318	-10.7383	-43.8475	-0.9527	0.3437	-0.6267	1.1910	0.3437	Y
	36	27.8740	-9.6890	-45.0198	28.8141	-9.3094	-45.4385	-0.9401	0.3796	-0.4187	1.0969	0.3796	Y
A-PILLAR Lateral (Y)	31	42.8119	-13.2128	-35.7857	44.0262	-13.0721	-36.7298	-1.2143	0.1407	-0.9441	1.5446	0.1407	Y
	32	39.1009	-11.6401	-37.9023	40.3046	-11.4476	-38.7190	-1.2037	0.1925	-0.8167	1.4673	0.1925	Y
	33	37.2591	-12.1053	-40.2685	38.3480	-11.8674	-41.0613	-1.0889	0.2379	-0.7928	1.3678	0.2379	Y
	34	34.9664	-11.5866	-41.7138	36.0082	-11.3079	-42.4327	-1.0418	0.2787	-0.7189	1.2961	0.2787	Y
	35	32.5791	-11.0820	-43.2208	33.5318	-10.7383	-43.8475	-0.9527	0.3437	-0.6267	1.1910	0.3437	Y
	36	27.8740	-9.6890	-45.0198	28.8141	-9.3094	-45.4385	-0.9401	0.3796	-0.4187	1.0969	0.3796	Y
B-PILLAR Maximum (X, Y, Z)	37	1.6777	-10.7623	-43.1162	2.4431	-10.2916	-43.1433	-0.7654	0.4707	-0.0271	0.8990	0.4707	Y
	38	4.8805	-12.5758	-38.3475	5.5824	-12.1397	-38.2789	-0.7019	0.4361	0.0686	0.8292	0.4415	Y, Z
	39	2.4467	-13.9412	-33.6627	3.1162	-13.5020	-33.7086	-0.6695	0.4392	-0.0459	0.8020	0.4392	Y
	40	5.8595	-14.5841	-28.1247	6.3494	-14.1535	-28.1290	-0.4899	0.4306	-0.0043	0.6523	0.4306	Y
B-PILLAR Lateral (Y)	37	1.6777	-10.7623	-43.1162	2.4431	-10.2916	-43.1433	-0.7654	0.4707	-0.0271	0.8990	0.4707	Y
	38	4.8805	-12.5758	-38.3475	5.5824	-12.1397	-38.2789	-0.7019	0.4361	0.0686	0.8292	0.4361	Y
	39	2.4467	-13.9412	-33.6627	3.1162	-13.5020	-33.7086	-0.6695	0.4392	-0.0459	0.8020	0.4392	Y
	40	5.8595	-14.5841	-28.1247	6.3494	-14.1535	-28.1290	-0.4899	0.4306	-0.0043	0.6523	0.4306	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. HMDBR-1

Test Name: HMDBR-1 VIN: 1C6RRGT6ES314223

Model Year: 2014 Make: Dodge Model: Ram

Driver Side Maximum Deformation

Reference Set 1				Reference Set 2			
Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]	Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	0.2	≤ 4	Z	Roof	0.3	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.0	≤ 5	NA	A-Pillar Maximum	0.4	≤ 5	Y
A-Pillar Lateral	-0.4	≤ 3	Y	A-Pillar Lateral	0.4	≤ 3	Y
B-Pillar Maximum	0.3	≤ 5	Z	B-Pillar Maximum	0.5	≤ 5	Y
B-Pillar Lateral	-0.4	≤ 3	Y	B-Pillar Lateral	0.5	≤ 3	Y
Toe Pan - Wheel Well	7.4	≤ 9	X, Z	Toe Pan - Wheel Well	7.3	≤ 9	X, Z
Side Front Panel	3.9	≤ 12	Y	Side Front Panel	4.1	≤ 12	Y
Side Door (above seat)	-3.4	≤ 9	Y	Side Door (above seat)	-3.0	≤ 9	Y
Side Door (below seat)	-1.5	≤ 12	Y	Side Door (below seat)	-1.3	≤ 12	Y
Floor Pan	3.5	≤ 12	Z	Floor Pan	3.5	≤ 12	Z
Dash - no MASH requirement	2.2	NA	X, Y, Z	Dash - no MASH requirement	2.2	NA	X, Y, Z

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

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

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

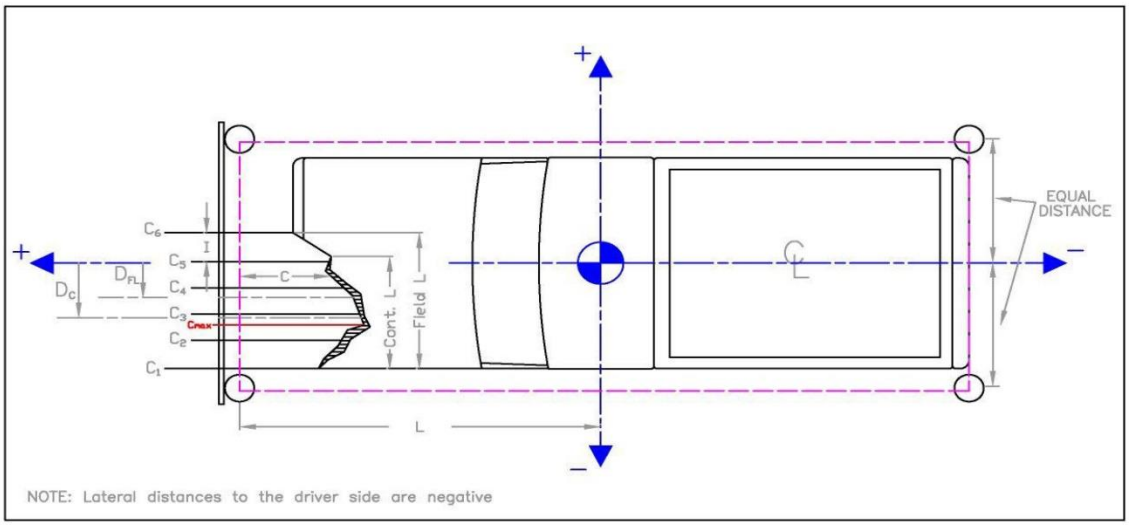
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

Notes on vehicle interior crush:

Point number 7 on the Floor Pan is an estimated location. The reference point was displaced during the impact.

Figure E-5. Maximum Occupant Compartment Deformations by Location, Test No. HMDBR-1

Date Measured:	12/23/2020	Test Name:	HMDBR-1	VIN:	1C6RRGT6ES314223
Model Year:	2014	Make:	Dodge	Model:	Ram



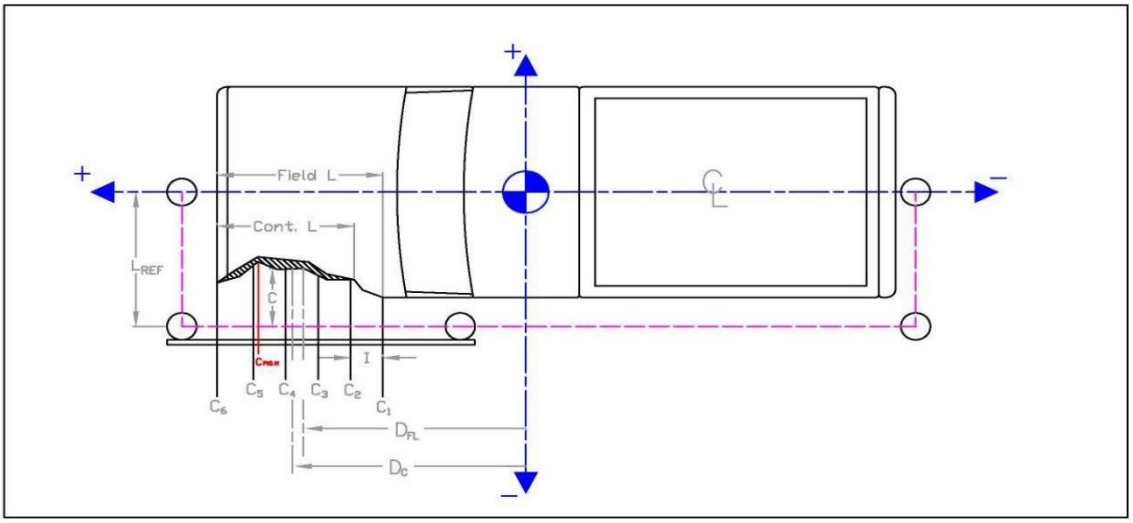
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	109	(2769)
Total Vehicle Width:	77 1/2	(1969)
Width of contact and induced crush - Field L:	77 1/2	(1969)
Crush measurement spacing interval (L/5) - I:	15 1/2	(394)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	77 1/2	(1969)
Distance from center of vehicle to center of contact damage - D_C:	0	()

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

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/a	N/A	-38 3/4	-(984)	22 1/2	(572)	4 3/4	(121)	N/A	N/A
C_2	41	(1041)	-23 1/4	-(591)	6 1/2	(165)			29 3/4	(756)
C_3	11 1/2	(292)	-7 3/4	-(197)	4 1/4	(108)			2 1/2	(64)
C_4	7 3/4	(197)	7 3/4	(197)	4 1/4	(108)			-1 1/4	-(32)
C_5	10 1/2	(267)	23 1/4	(591)	6 1/4	(159)			- 1/2	-(13)
C_6	N/a	N/A	38 3/4	(984)	20 1/2	(521)			N/A	N/A
C_{MAX}	41	(1041)	-23 1/2	-(597)	6 5/8	(168)			29 5/8	(752)

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

Date Measured:	12/23/2020	Test Name:	HMDBR-1	VIN:	1C6RRGT6ES314223
Model Year:	2014	Make:	Dodge	Model:	Ram



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	50	(1270)
Total Vehicle Length:	228 1/2	(5804)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-6	-(152)
Width of contact and induced crush - Field L:	228 1/2	(5804)
Crush measurement spacing interval (L/5) - I:	45 3/4	(1162)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-14 1/4	-(362)
Width of Contact Damage:	228 1/2	(5804)
Distance from vehicle c.g. to center of contact damage - D_C:	-14 1/4	-(362)

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	-128 1/2	-(3264)	33 1/2	(851)	6	(152)	N/A	N/A
C_2	n/a	N/A	-82 3/4	-(2102)	5 1/2	(140)			N/A	N/A
C_3	12	(305)	-37	-(940)	5 3/4	(146)			1/4	(6)
C_4	12	(305)	8 3/4	(222)	5	(127)			1	(25)
C_5	n/a	N/A	54 1/2	(1384)	5 3/4	(146)			N/A	N/A
C_6	44	(1118)	100 1/4	(2546)	10 1/8	(257)			27 7/8	(708)
C_{MAX}	37	(940)	88 1/2	(2248)	5 7/8	(149)			25 1/8	(638)

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

Test Name: HMDBR-2 VIN: KMHCT4AE3GU979226
Model Year: 2016 Make: Hyundai Model: Accent

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	49.2093	17.8370	-9.1453	49.2519	17.6864	-9.1204	-0.0426	0.1506	-0.0249	0.1585	0.0000	NA
	2	50.8272	22.0561	-7.2283	50.6707	21.8144	-7.5423	0.1565	0.2417	0.3140	0.4260	0.3508	X, Z
	3	51.6240	28.2497	-8.0600	50.8256	27.6889	-8.5893	0.7984	0.5608	0.5293	1.1100	0.9579	X, Z
	4	52.0245	33.1047	-8.7716	51.3282	32.4237	-9.3670	0.6963	0.6810	0.5954	1.1415	0.9162	X, Z
	5	49.7807	36.6535	-11.2587	48.1453	34.8487	-12.0944	1.6354	1.8048	0.8357	2.5749	1.8366	X, Z
	6	44.2409	17.6581	-7.6468	44.1902	17.4733	-7.8068	0.0507	0.1848	0.1600	0.2496	0.1678	X, Z
	7	43.9795	22.9274	-3.2138	43.7585	22.6331	-3.5256	0.2210	0.2943	0.3118	0.4824	0.3822	X, Z
	8	44.9319	28.8477	-4.1569	44.7171	28.3590	-4.2640	0.2148	0.4887	0.1071	0.5445	0.2400	X, Z
	9	45.5432	34.1087	-4.8524	45.3353	33.5700	-4.9485	0.2079	0.5387	0.0961	0.5854	0.2290	X, Z
	10	45.9627	39.0151	-5.3489	45.5998	37.9094	-5.6716	0.3629	1.1057	0.3227	1.2076	0.4856	X, Z
FLOOR PAN (Z)	11	39.9245	17.7657	-7.5884	39.9279	17.5813	-7.8126	-0.0034	0.1844	0.2242	0.2903	0.2242	Z
	12	39.3699	22.3303	-2.6141	39.3140	22.1927	-2.8505	0.0559	0.1376	0.2364	0.2792	0.2364	Z
	13	40.1530	28.2720	-2.8070	39.9342	27.8481	-2.8907	0.2188	0.4239	0.0837	0.4843	0.0837	Z
	14	40.5006	34.6429	-3.1995	40.2827	34.1891	-3.2908	0.2179	0.4538	0.0913	0.5116	0.0913	Z
	15	41.1388	39.0289	-3.6268	41.0223	38.4889	-4.0398	0.1165	0.5400	0.4130	0.6897	0.4130	Z
	16	36.3585	17.6022	-7.5183	36.3336	17.4031	-7.7670	0.0249	0.1991	0.2487	0.3196	0.2487	Z
	17	35.6708	23.0501	-2.5077	35.5422	22.8403	-2.7679	0.1286	0.2098	0.2602	0.3581	0.2602	Z
	18	35.4401	28.5286	-2.7875	35.1803	28.1816	-2.9172	0.2598	0.3470	0.1297	0.4525	0.1297	Z
	19	35.4126	34.8753	-3.4447	35.2709	34.4583	-3.5431	0.1417	0.4170	0.0984	0.4513	0.0984	Z
	20	36.6948	39.0843	-3.3952	36.4979	38.6146	-3.7129	0.1969	0.4697	0.3177	0.6003	0.3177	Z
	21	31.6202	17.6683	-7.3095	31.5831	17.4277	-7.6466	0.0371	0.2406	0.3371	0.4158	0.3371	Z
	22	31.7739	22.7923	-2.2144	31.7538	22.5390	-2.5358	0.0201	0.2533	0.3214	0.4097	0.3214	Z
	23	31.5349	28.3102	-2.6439	31.3741	27.9692	-2.6465	0.1608	0.3410	0.0026	0.3770	0.0026	Z
	24	31.3941	34.8541	-3.2949	31.3423	34.5856	-3.3829	0.0518	0.2685	0.0880	0.2873	0.0880	Z
	25	31.6604	39.0373	-3.2111	31.4944	38.7184	-3.4962	0.1660	0.3189	0.2851	0.4588	0.2851	Z
	26	26.3635	17.5760	-7.0990	26.3071	17.3369	-7.5569	0.0564	0.2391	0.4579	0.5196	0.4579	Z
	27	26.8658	22.3104	-2.0474	26.7362	22.1032	-2.4443	0.1296	0.2072	0.3969	0.4661	0.3969	Z
	28	26.6984	28.1750	-2.3361	26.5806	28.0131	-2.6510	0.1178	0.1619	0.3149	0.3732	0.3149	Z
	29	26.5170	34.5047	-2.6761	26.3372	34.1720	-2.7982	0.1798	0.3327	0.1221	0.3974	0.1221	Z
	30	26.6271	39.0942	-2.8951	26.4817	38.8707	-3.1178	0.1454	0.2235	0.2227	0.3474	0.2227	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-8. Floor Pan Deformation Data – Set 2, Test No. HMDBR-2

Test Name: HMDBR-2 VIN: KMHCT4AE3GU979226
Model Year: 2016 Make: Hyundai Model: Accent

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	40.3631	13.2657	-32.2900	40.2431	13.2983	-32.6650	0.1200	-0.0326	-0.3750	0.3951	0.3951	X, Y, Z
	2	42.8023	27.1993	-32.1517	42.3816	27.3254	-32.7891	0.4207	-0.1261	-0.6374	0.7741	0.7741	X, Y, Z
	3	41.9057	37.4401	-32.4744	41.2287	37.4281	-33.3802	0.6770	0.0120	-0.9058	1.1309	1.1309	X, Y, Z
	4	32.4014	13.6541	-24.7732	32.2639	13.7018	-25.0027	0.1375	-0.0477	-0.2295	0.2718	0.2718	X, Y, Z
	5	35.2926	27.4569	-26.8021	34.8535	27.5403	-27.4807	0.4391	-0.0834	-0.6786	0.8126	0.8126	X, Y, Z
	6	35.3703	35.7427	-27.8845	34.6129	35.6797	-28.7704	0.7574	0.0630	-0.8859	1.1672	1.1672	X, Y, Z
SIDE PANEL (Y)	7	42.2090	40.3922	-10.7566	41.5527	39.8996	-11.5641	0.6563	0.4926	-0.8075	1.1513	0.4926	Y
	8	42.8677	40.2360	-13.5673	41.9398	39.7788	-14.4013	0.9279	0.4572	-0.8340	1.3288	0.4572	Y
	9	47.6081	40.2360	-12.9355	46.0971	38.5663	-13.6659	1.5110	1.6697	-0.7304	2.3674	1.6697	Y
IMPACT SIDE DOOR (Y)	10	7.5210	41.3649	-27.3114	6.8092	43.3302	-27.7319	0.7118	-1.9653	-0.4205	2.1321	-1.9653	Y
	11	20.8744	41.4796	-27.6685	20.0217	43.7499	-28.1918	0.8527	-2.2703	-0.5233	2.4810	-2.2703	Y
	12	28.4718	40.8734	-27.3594	27.6445	43.3092	-28.0661	0.8273	-2.4358	-0.7067	2.6678	-2.4358	Y
	13	10.7022	41.9071	-14.0847	9.9732	42.4803	-13.7211	0.7290	-0.5732	0.3636	0.9961	-0.5732	Y
	14	20.9531	42.5992	-12.1914	20.5750	44.1220	-12.7790	0.3781	-1.5228	-0.5876	1.6755	-1.5228	Y
	15	28.5062	43.1138	-13.2811	27.9976	45.4112	-13.8406	0.5086	-2.2974	-0.5595	2.4186	-2.2974	Y
ROOF - (Z)	16	24.2333	12.0024	-45.5267	23.9586	12.2049	-45.8470	0.2747	-0.2025	-0.3203	0.4680	-0.3203	Z
	17	23.4844	21.9983	-46.0492	23.2364	22.2797	-46.4297	0.2480	-0.2814	-0.3805	0.5343	-0.3805	Z
	18	22.3395	30.9904	-46.1483	22.0033	31.1804	-46.6384	0.3362	-0.1900	-0.4901	0.6240	-0.4901	Z
	19	15.6433	11.7599	-48.6427	15.3175	11.9381	-48.9013	0.3258	-0.1782	-0.2586	0.4525	-0.2586	Z
	20	15.3230	21.4485	-49.0464	14.9432	21.5718	-49.3804	0.3798	-0.1233	-0.3340	0.5206	-0.3340	Z
	21	15.1922	29.5244	-49.0256	14.8511	29.7706	-49.3995	0.3411	-0.2462	-0.3739	0.5628	-0.3739	Z
	22	9.0787	12.7698	-49.3810	8.8472	12.9271	-49.6017	0.2315	-0.1573	-0.2207	0.3564	-0.2207	Z
	23	7.9225	21.4761	-49.7391	7.5493	21.6750	-50.0203	0.3732	-0.1989	-0.2812	0.5079	-0.2812	Z
	24	6.8766	28.1848	-49.7725	6.5866	28.3390	-49.8809	0.2900	-0.1542	-0.1084	0.3459	-0.1084	Z
	25	2.1674	13.5773	-49.6918	1.8697	13.7604	-49.8255	0.2977	-0.1831	-0.1337	0.3742	-0.1337	Z
	26	2.3467	21.2286	-49.9135	2.0194	21.3444	-50.1059	0.3273	-0.1158	-0.1924	0.3969	-0.1924	Z
	27	2.3528	28.0795	-49.8869	2.0572	28.2392	-50.0588	0.2956	-0.1597	-0.1719	0.3774	-0.1719	Z
	28	-6.9438	14.6172	-49.5197	-7.2685	14.6659	-49.6136	0.3247	-0.0487	-0.0939	0.3415	-0.0939	Z
	29	-8.2612	21.8228	-49.6197	-8.6106	21.9259	-49.7285	0.3494	-0.1031	-0.1088	0.3802	-0.1088	Z
	30	-8.5022	29.8080	-49.5082	-8.8664	29.8284	-49.6258	0.3642	-0.0204	-0.1176	0.3833	-0.1176	Z
A-PILLAR Maximum (X, Y, Z)	31	47.1436	38.7379	-34.4352	46.6597	39.2851	-35.0354	0.4839	-0.5472	-0.6002	0.9454	0.4839	X
	32	41.6571	37.6093	-37.7624	41.3560	37.9882	-38.6010	0.3011	-0.3789	-0.8386	0.9682	0.3011	X
	33	37.1067	36.6545	-39.9904	36.8403	37.0816	-40.9553	0.2664	-0.4271	-0.9649	1.0883	0.2664	X
	34	33.8628	35.9164	-41.2491	33.5939	36.3376	-42.0947	0.2689	-0.4212	-0.8456	0.9822	0.2689	X
	35	28.9964	34.8084	-43.5222	28.6697	35.1239	-44.2153	0.3267	-0.3155	-0.6931	0.8286	0.3267	X
	36	24.3387	33.9646	-45.5694	23.9343	34.2434	-46.2209	0.4044	-0.2788	-0.6515	0.8159	0.4044	X
A-PILLAR Lateral (Y)	31	47.1436	38.7379	-34.4352	46.6597	39.2851	-35.0354	0.4839	-0.5472	-0.6002	0.9454	-0.5472	Y
	32	41.6571	37.6093	-37.7624	41.3560	37.9882	-38.6010	0.3011	-0.3789	-0.8386	0.9682	-0.3789	Y
	33	37.1067	36.6545	-39.9904	36.8403	37.0816	-40.9553	0.2664	-0.4271	-0.9649	1.0883	-0.4271	Y
	34	33.8628	35.9164	-41.2491	33.5939	36.3376	-42.0947	0.2689	-0.4212	-0.8456	0.9822	-0.4212	Y
	35	28.9964	34.8084	-43.5222	28.6697	35.1239	-44.2153	0.3267	-0.3155	-0.6931	0.8286	-0.3155	Y
	36	24.3387	33.9646	-45.5694	23.9343	34.2434	-46.2209	0.4044	-0.2788	-0.6515	0.8159	-0.2788	Y
B-PILLAR Maximum (X, Y, Z)	37	1.9324	33.9797	-44.8914	1.4588	34.1653	-45.0698	0.4736	-0.1856	-0.1784	0.5390	0.4736	X
	38	-0.1929	36.0014	-40.7280	-0.6428	36.1096	-40.8801	0.4499	-0.1082	-0.1521	0.4871	0.4499	X
	39	3.7634	37.9485	-36.6482	3.3374	38.0757	-36.8076	0.4260	-0.1272	-0.1594	0.4723	0.4260	X
	40	0.4837	38.6894	-33.5162	0.1251	38.8096	-33.6376	0.3586	-0.1202	-0.1214	0.3972	0.3586	X
B-PILLAR Lateral (Y)	37	1.9324	33.9797	-44.8914	1.4588	34.1653	-45.0698	0.4736	-0.1856	-0.1784	0.5390	-0.1856	Y
	38	-0.1929	36.0014	-40.7280	-0.6428	36.1096	-40.8801	0.4499	-0.1082	-0.1521	0.4871	-0.1082	Y
	39	3.7634	37.9485	-36.6482	3.3374	38.0757	-36.8076	0.4260	-0.1272	-0.1594	0.4723	-0.1272	Y
	40	0.4837	38.6894	-33.5162	0.1251	38.8096	-33.6376	0.3586	-0.1202	-0.1214	0.3972	-0.1202	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-9. Occupant Compartment Deformation Data – Set 2, Test No. HMDBR-2

Test Name: HMDBR-2 VIN: KMHCT4AE3GU979226

Model Year: 2016 Make: Hyundai Model: Accent

Passenger Side Maximum Deformations

Reference Set 1				Reference Set 2			
Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]	Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	Reference Points Compromised	≤ 4	Z	Roof	-0.5	≤ 4	Z
Windshield[D]		≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum		≤ 5	NA	A-Pillar Maximum	0.5	≤ 5	X
A-Pillar Lateral		≤ 3	Y	A-Pillar Lateral	-0.5	≤ 3	Y
B-Pillar Maximum		≤ 5	NA	B-Pillar Maximum	0.5	≤ 5	X
B-Pillar Lateral		≤ 3	Y	B-Pillar Lateral	-0.2	≤ 3	Y
Toe Pan - Wheel Well		≤ 9	NA	Toe Pan - Wheel Well	1.8	≤ 9	X, Z
Side Front Panel		≤ 12	Y	Side Front Panel	1.7	≤ 12	Y
Side Door (above seat)		≤ 9	Y	Side Door (above seat)	-2.4	≤ 9	Y
Side Door (below seat)		≤ 12	Y	Side Door (below seat)	-2.3	≤ 12	Y
Floor Pan		≤ 12	Z	Floor Pan	0.5	≤ 12	Z
Dash - no MASH requirement		NA	X, Y, Z	Dash - no MASH requirement	1.2	NA	X, Y, Z

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

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

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

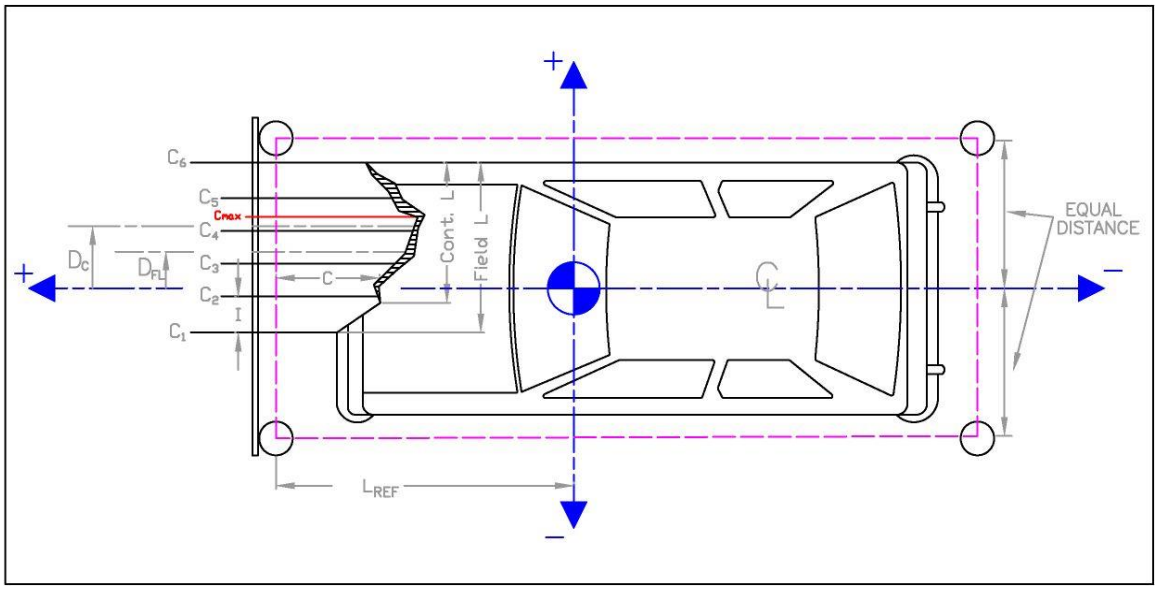
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

Notes on vehicle crush:

The reference points for Reference Set 1 were compromised, therefore, maximum deformations are only reported for Reference Set 2.

Figure E-10. Maximum Occupant Compartment Deformations by Location, Test No. HMDBR-2

Date Measured:	3/16/21		HMDBR-2	**VIN:**	KMHCT4AE3GU979226
Model Year:	2016	**Make:**	Hyundai	**Model:**	Accent



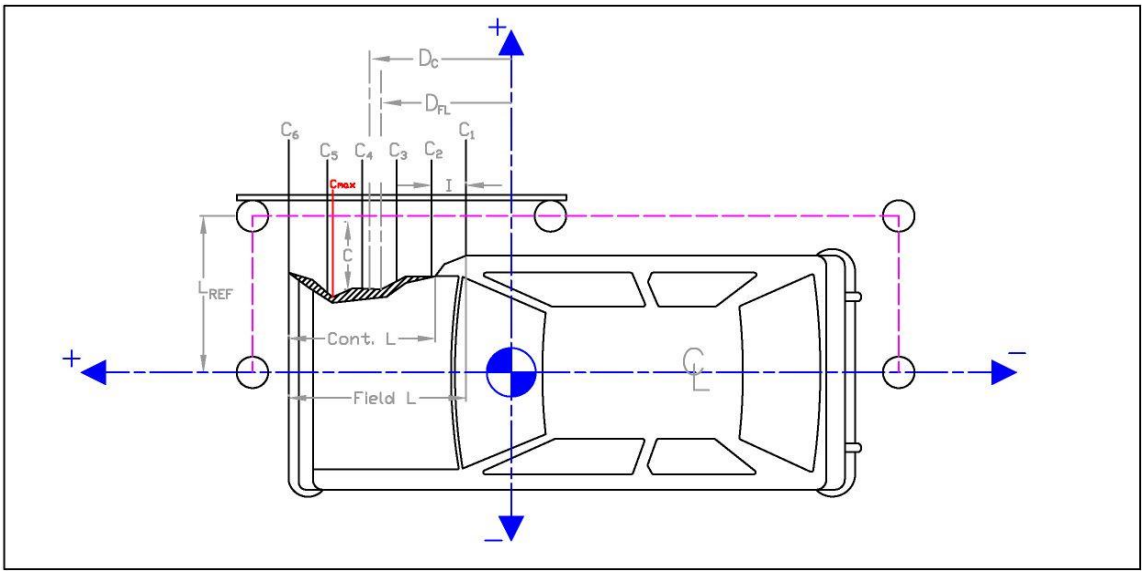
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	85	(2159)
Total Width of Vehicle:	66 1/4	(1683)
Width of contact and induced crush - Field L:	66 1/4	(1683)
Crush measurement spacing interval (L/5) - I:	13 1/4	(337)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	19 1/8	(486)
Distance from center of vehicle to center of contact damage - D_C:	22	(560)

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

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/a	NA	-33 1/8	-(841)	15 5/8	(397)	9 4/9	(240)	NA	NA
C_2	13	(330)	-19 7/8	-(505)	6 7/8	(175)			-3 1/3	-(84)
C_3	12 1/2	(318)	-6 5/8	-(168)	4 3/8	(111)			-1 1/3	-(33)
C_4	13 1/2	(343)	6 5/8	(168)	4 1/2	(114)			- 4/9	-(11)
C_5	16 3/8	(416)	19 7/8	(505)	6 3/4	(171)			1/5	(5)
C_6	n/a	NA	33 1/8	(841)	15 5/8	(397)			NA	NA
C_{MAX}	20 1/4	(514)	27	(686)	10 3/8	(264)			4/9	(11)

Figure E-11. Exterior Vehicle Crush (NASS) - Front, Test No. HMDBR-2

Date Measured:	3/16/21	**Test Name:**	HMDBR-2	**VIN:**	KMHCT4AE3GU979226
Model Year:	2016	**Make:**	Hyundai	**Model:**	Accent



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	36 3/4	(933)
Total Vehicle Length:	171 3/4	(4362)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-23	-(583)
Width of contact and induced crush - Field L:	171 3/4	(4362)
Crush measurement spacing interval (L/5) - I:	34 3/8	(873)
Distance from vehicle c.g. to center of Field L - D_{FL}:	23	(583)
Width of Contact Damage:	171 3/4	(4362)
Distance from vehicle c.g. to center of contact damage - D_C:	23	(584)

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	17 5/8	(448)	-63	-(1600)	7	(178)	-4 1/2	-(114)	15 1/8	(384)
C_2	N/a	NA	-28 5/8	-(727)	8 1/8	(206)			NA	NA
C_3	2 3/4	(70)	5 3/4	(146)	8 1/4	(210)			-1	-(25)
C_4	3 7/8	(98)	40 1/8	(1019)	7	(178)			1 3/8	(35)
C_5	4 3/8	(111)	74 1/2	(1892)	27 1/2	(699)			-18 5/8	-(473)
C_6	n/a	NA	108 7/8	(2765)	27 1/2	(699)			NA	NA
C_{MAX}	17 5/8	(448)	-63	-(1600)	7	(178)			15 1/8	(384)

Figure E-12. Exterior Vehicle Crush (NASS) - Side, Test No. HMDBR-2

Model Year: 2015 Test Name: HMDBR-3 Make: Dodge VIN: 1C6RR6KG2FS506038 Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	57.3105	13.8433	-4.2068	56.9649	14.4396	-4.5066	0.3456	-0.5963	0.2998	0.7516	0.4575	X, Z
	2	58.0099	17.6761	-2.2469	57.5141	18.1969	-2.5375	0.4958	-0.5208	0.2906	0.7756	0.5747	X, Z
	3	59.3170	21.1910	1.1835	58.8706	21.2402	1.0625	0.4464	-0.0492	0.1210	0.4651	0.4625	X, Z
	4	59.4654	26.8564	1.9199	55.5603	25.6874	-0.6639	3.9051	1.1690	2.5838	4.8262	4.6825	X, Z
	5	59.3435	32.0706	1.9544	55.3828	30.1428	-0.7281	3.9607	1.9278	2.6825	5.1575	4.7836	X, Z
	6	54.0518	11.5031	-3.3689	53.6681	12.0472	-3.9049	0.3837	-0.5441	0.5360	0.8547	0.6592	X, Z
	7	55.0913	17.7094	-0.1254	54.6642	17.9886	-0.3065	0.4271	-0.2792	0.1811	0.5414	0.4639	X, Z
	8	56.3886	21.3191	3.2555	56.0687	21.4777	3.2295	0.3199	-0.1586	0.0260	0.3580	0.3210	X, Z
	9	56.4475	27.4881	3.6233	54.1484	26.8798	2.3225	2.2991	0.6083	1.3008	2.7107	2.6416	X, Z
	10	56.1821	32.5321	3.7713	53.3712	30.3974	3.1300	2.8109	2.1347	0.6413	3.5874	2.8831	X, Z
FLOOR PAN (Z)	11	50.5508	11.4468	-1.9399	50.3761	11.7022	-2.2493	0.1747	-0.2554	0.3094	0.4376	0.3094	Z
	12	52.0437	17.0022	2.1320	51.7825	17.0772	1.9662	0.2612	-0.0750	0.1658	0.3183	0.1658	Z
	13	53.1358	21.4888	5.0909	52.8464	21.5240	5.1321	0.2894	-0.0352	-0.0412	0.2944	-0.0412	Z
	14	52.8219	28.2894	5.0708	52.1862	28.3424	5.5079	0.6357	-0.0530	-0.4371	0.7733	-0.4371	Z
	15	52.9130	32.4771	5.1704	51.8264	31.5367	4.6462	1.0866	0.9404	0.5242	1.5297	0.5242	Z
	16	46.9748	11.6722	-1.0568	46.8235	11.9287	-1.2010	0.1513	-0.2565	0.1442	0.3309	0.1442	Z
	17	48.9729	16.8556	5.0660	48.7509	17.0023	4.9666	0.2220	-0.1467	0.0994	0.2841	0.0994	Z
	18	49.2463	21.6683	5.0669	48.9633	21.7631	5.4448	0.2830	-0.0948	-0.3779	0.4815	-0.3779	Z
	19	49.2835	28.2155	5.0901	49.0167	28.2647	6.5528	0.2668	-0.0492	-1.4627	1.4876	-1.4627	Z
	20	49.0861	32.2905	5.1893	48.6716	31.8235	6.2682	0.4145	0.4670	-1.0789	1.2466	-1.0789	Z
	21	43.0170	11.7957	-0.6131	42.8426	12.2918	-0.8423	0.1744	-0.4961	0.2292	0.5736	0.2292	Z
	22	43.3798	16.8326	5.0612	43.1659	16.8638	5.0734	0.2139	-0.0312	-0.0122	0.2165	-0.0122	Z
	23	43.2675	21.5243	5.0577	43.0623	21.6234	5.5295	0.2052	-0.0991	-0.4718	0.5239	-0.4718	Z
	24	43.1110	27.5655	5.1016	42.9059	27.5849	6.5888	0.2051	-0.0194	-1.4872	1.5014	-1.4872	Z
	25	43.1877	32.6177	5.1965	42.9117	32.3837	6.7779	0.2760	0.2340	-1.5814	1.6223	-1.5814	Z
	26	37.9973	12.1796	0.2274	37.7760	12.6484	-0.1409	0.2213	-0.4688	0.3683	0.6359	0.3683	Z
	27	37.6426	14.8569	4.3570	37.4473	14.9707	4.2675	0.1953	-0.1138	0.0895	0.2431	0.0895	Z
	28	37.5738	21.5456	4.3731	37.4845	21.7090	4.5488	0.0893	-0.1634	-0.1757	0.2560	-0.1757	Z
	29	37.6940	28.2121	4.3946	37.6276	28.3166	4.9117	0.0664	-0.1045	-0.5171	0.5317	-0.5171	Z
	30	37.6004	32.4536	4.1818	37.6175	32.6016	5.0339	-0.0171	-0.1480	-0.8521	0.8650	-0.8521	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-13. Floor Pan Deformation Data – Set 1, Test No. HMDBR-3

Model Year: 2015 Test Name: HMDBR-3 Make: Dodge VIN: 1C6RR6KG2FS506038 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	60.5539	30.7806	-8.3108	60.2256	30.9841	-8.6789	0.3283	-0.2035	0.3681	0.5336	0.4932	X, Z
	2	61.2714	34.6077	-6.3462	60.7972	34.7445	-6.7222	0.4742	-0.1368	0.3760	0.6204	0.6052	X, Z
	3	62.5956	38.1122	-2.9117	62.1703	37.7914	-3.1316	0.4253	0.3208	0.2199	0.5763	0.4788	X, Z
	4	62.7703	43.7759	-2.1681	58.8895	42.2537	-4.8758	3.8808	1.5222	2.7077	4.9708	4.7320	X, Z
	5	62.6723	48.9906	-2.1270	58.7404	46.7099	-4.9553	3.9319	2.2807	2.8283	5.3536	4.8435	X, Z
	6	57.2847	28.4544	-7.4749	56.9133	28.6147	-8.0716	0.3714	-0.1603	0.5967	0.7209	0.7028	X, Z
	7	58.3537	34.6517	-4.2238	57.9444	34.5620	-4.4928	0.4093	0.0897	0.2690	0.4979	0.4898	X, Z
	8	59.6685	38.2511	-0.8387	59.3682	38.0542	-0.9676	0.3003	0.1969	0.1289	0.3815	0.3268	X, Z
	9	59.7557	44.4192	-0.4629	57.4830	43.4652	-1.8946	2.2727	0.9540	1.4317	2.8504	2.6861	X, Z
	10	59.5135	49.4642	-0.3085	56.7275	46.9903	-1.0997	2.7860	2.4739	0.7912	3.8089	2.8962	X, Z
FLOOR PAN (Z)	11	53.7840	28.4122	-6.0448	53.6180	28.2963	-6.4174	0.1660	0.1159	0.3726	0.4241	0.3726	Z
	12	55.3035	33.9556	-1.9663	55.0552	33.6766	-2.2192	0.2483	0.2790	0.2529	0.4511	0.2529	Z
	13	56.4170	38.4334	0.9979	56.1449	38.1274	0.9323	0.2721	0.3060	0.0656	0.4147	0.0656	Z
	14	56.1343	45.2353	0.9866	55.5278	44.9511	1.2843	0.6065	0.2842	-0.2977	0.7330	-0.2977	Z
	15	56.2447	49.4225	1.0915	55.1889	48.1446	0.4114	1.0558	1.2779	0.6801	1.7917	0.6801	Z
	16	50.2093	28.6529	-5.1604	50.0661	28.5489	-5.3726	0.1432	0.1040	0.2122	0.2763	0.2122	Z
	17	52.2330	33.8193	0.9684	52.0209	33.6312	0.7791	0.2121	0.1881	0.1893	0.3409	0.1893	Z
	18	52.5284	38.6307	0.9753	52.2632	38.3922	1.2411	0.2652	0.2385	-0.2658	0.4448	-0.2658	Z
	19	52.5956	45.1776	1.0069	52.3570	44.8971	2.3270	0.2386	0.2805	-1.3201	1.3705	-1.3201	Z
	20	52.4170	49.2534	1.1114	52.0347	48.4570	2.0300	0.3823	0.7964	-0.9186	1.2745	-0.9186	Z
	21	46.2522	28.7940	-4.7153	46.0873	28.9384	-5.0183	0.1649	-0.1444	0.3030	0.3740	0.3030	Z
	22	46.6398	33.8219	0.9653	46.4351	33.5285	0.8820	0.2047	0.2934	0.0833	0.3673	0.0833	Z
	23	46.5490	38.5142	0.9678	46.3613	38.2902	1.3218	0.1877	0.2240	-0.3540	0.4590	-0.3540	Z
	24	46.4202	44.5559	1.0195	46.2420	44.2561	2.3606	0.1782	0.2998	-1.3411	1.3857	-1.3411	Z
	25	46.5201	49.6076	1.1207	46.2781	49.0554	2.5333	0.2420	0.5522	-1.4126	1.5359	-1.4126	Z
	26	41.2346	29.1999	-3.8728	41.0225	29.3295	-4.3221	0.2121	-0.1296	0.4493	0.5135	0.4493	Z
	27	40.8934	31.8735	0.2603	40.7052	31.6690	0.0781	0.1882	0.2045	0.1822	0.3323	0.1822	Z
	28	40.8553	38.5625	0.2849	40.7849	38.4078	0.3364	0.0704	0.1547	-0.0515	0.1776	-0.0515	Z
	29	41.0061	45.2283	0.3149	40.9697	45.0156	0.6769	0.0364	0.2127	-0.3620	0.4214	-0.3620	Z
	30	40.9319	49.4705	0.1075	40.9867	49.3009	0.7845	-0.0548	0.1696	-0.6770	0.7001	-0.6770	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-14. Floor Pan Deformation Data – Set 2, Test No. HMDBR-3

Model Year: 2015 Test Name: HMDBR-3 Make: Dodge VIN: 1C6RR6KG2FS506038 Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	50.2885	33.4910	-26.8051	50.1938	33.5609	-27.6352	0.0947	-0.0699	-0.8301	0.8384	0.8384	X, Y, Z
	2	48.5865	20.8467	-26.5798	48.5683	21.0080	-27.2098	0.0182	-0.1613	-0.6300	0.6506	0.6506	X, Y, Z
	3	45.5103	3.5536	-26.9712	45.5559	3.6665	-27.4336	-0.0456	-0.1129	-0.4624	0.4782	0.4782	X, Y, Z
	4	45.5334	33.7702	-16.1500	45.1297	33.9371	-17.1729	0.4037	-0.1669	-1.0229	1.1123	1.1123	X, Y, Z
	5	44.6982	21.8751	-16.4243	44.5007	21.8508	-17.2414	0.1975	0.0243	-0.8171	0.8410	0.8410	X, Y, Z
	6	42.5432	3.5548	-16.2391	42.4517	3.7914	-16.7619	0.0915	-0.2366	-0.5228	0.5811	0.5811	X, Y, Z
SIDE PANEL (Y)	7	54.1707	35.9522	0.2846	53.1881	33.0441	-0.4640	0.9826	2.9081	-0.7486	3.1596	2.9081	Y
	8	54.1870	35.9772	-3.9390	53.1985	33.0077	-4.8539	0.9885	2.9695	-0.9149	3.2607	2.9695	Y
	9	56.5399	35.9418	-1.9546	55.2502	32.8044	-2.8688	1.2897	3.1374	-0.9142	3.5132	3.1374	Y
IMPACT SIDE DOOR (Y)	10	20.0210	38.1732	-14.7811	19.0865	40.0042	-14.8386	0.9345	-1.8310	-0.0575	2.0565	-1.8310	Y
	11	31.9128	38.5000	-14.5410	30.9696	41.0260	-14.7531	0.9432	-2.5260	-0.2121	2.7047	-2.5260	Y
	12	39.9725	38.3988	-15.2469	38.9566	40.1893	-15.6765	1.0159	-1.7905	-0.4296	2.1030	-1.7905	Y
	13	20.4184	38.0047	-4.1637	19.6779	39.0284	-4.2379	0.7405	-1.0237	-0.0742	1.2656	-1.0237	Y
	14	32.4586	38.4929	-4.2575	31.6756	39.5099	-4.5804	0.7830	-1.0170	-0.3229	1.3235	-1.0170	Y
	15	39.5210	39.1486	-3.7423	38.7312	39.4902	-4.2134	0.7898	-0.3416	-0.4711	0.9810	-0.3416	Y
ROOF - (Z)	16	37.9520	25.4149	-42.4147	37.9940	25.7139	-42.6234	-0.0420	-0.2990	-0.2087	0.3670	-0.2087	Z
	17	40.5612	15.4136	-42.6967	40.5805	15.7465	-42.8623	-0.0193	-0.3329	-0.1656	0.3723	-0.1656	Z
	18	41.3815	3.7331	-42.9799	41.4257	4.0321	-43.0998	-0.0442	-0.2990	-0.1199	0.3252	-0.1199	Z
	19	32.1534	24.7174	-45.0785	32.1798	24.9538	-45.2452	-0.0264	-0.2364	-0.1667	0.2905	-0.1667	Z
	20	34.3291	14.7688	-45.4633	34.3383	15.0467	-45.6077	-0.0092	-0.2779	-0.1444	0.3133	-0.1444	Z
	21	35.1584	3.5990	-45.6284	35.2075	3.8312	-45.7389	-0.0491	-0.2322	-0.1105	0.2618	-0.1105	Z
	22	26.6805	24.3288	-45.8471	26.5776	24.5846	-45.9967	0.1029	-0.2558	-0.1496	0.3137	-0.1496	Z
	23	27.2123	15.1662	-46.4065	27.2134	15.4288	-46.5539	-0.0011	-0.2626	-0.1474	0.3011	-0.1474	Z
	24	28.6240	4.5379	-46.6318	28.5672	4.8630	-46.7877	0.0568	-0.3251	-0.1559	0.3650	-0.1559	Z
	25	20.6025	24.5672	-46.2346	20.5310	24.7927	-46.3629	0.0715	-0.2255	-0.1283	0.2691	-0.1283	Z
	26	20.5966	15.5463	-46.7899	20.5589	15.8506	-46.9193	0.0377	-0.3043	-0.1294	0.3328	-0.1294	Z
	27	22.5699	4.6735	-47.0448	22.5562	4.9109	-47.1805	0.0137	-0.2374	-0.1357	0.2738	-0.1357	Z
	28	14.5799	24.5708	-46.5410	14.5357	24.7894	-46.6332	0.0442	-0.2186	-0.0922	0.2413	-0.0922	Z
	29	14.6810	15.2590	-47.0819	14.5901	15.5204	-47.1702	0.0909	-0.2614	-0.0883	0.2905	-0.0883	Z
	30	14.7000	4.8915	-47.3461	14.5791	5.1589	-47.4627	0.1209	-0.2674	-0.1166	0.3158	-0.1166	Z
A-PILLAR Maximum (X, Y, Z)	31	55.3424	35.0550	-27.7798	55.5147	35.4618	-28.2919	-0.1723	-0.4068	-0.5121	0.6763	0.0000	NA
	32	52.6262	34.4945	-30.1674	52.7678	34.7752	-30.8512	-0.1416	-0.2807	-0.6838	0.7526	0.0000	NA
	33	49.0104	33.7169	-33.0715	49.1291	34.0871	-33.6081	-0.1187	-0.3702	-0.5366	0.6626	0.0000	NA
	34	45.9189	33.0791	-35.5857	46.0660	33.4235	-35.9731	-0.1471	-0.3444	-0.3874	0.5388	0.0000	NA
	35	41.8440	32.1751	-38.2978	41.9672	32.4910	-38.6459	-0.1232	-0.3159	-0.3481	0.4859	0.0000	NA
	36	37.3616	31.1288	-40.7907	37.4554	31.4201	-40.9990	-0.0938	-0.2913	-0.2083	0.3702	0.0000	NA
A-PILLAR Lateral (Y)	31	55.3424	35.0550	-27.7798	55.5147	35.4618	-28.2919	-0.1723	-0.4068	-0.5121	0.6763	-0.4068	Y
	32	52.6262	34.4945	-30.1674	52.7678	34.7752	-30.8512	-0.1416	-0.2807	-0.6838	0.7526	-0.2807	Y
	33	49.0104	33.7169	-33.0715	49.1291	34.0871	-33.6081	-0.1187	-0.3702	-0.5366	0.6626	-0.3702	Y
	34	45.9189	33.0791	-35.5857	46.0660	33.4235	-35.9731	-0.1471	-0.3444	-0.3874	0.5388	-0.3444	Y
	35	41.8440	32.1751	-38.2978	41.9672	32.4910	-38.6459	-0.1232	-0.3159	-0.3481	0.4859	-0.3159	Y
	36	37.3616	31.1288	-40.7907	37.4554	31.4201	-40.9990	-0.0938	-0.2913	-0.2083	0.3702	-0.2913	Y
B-PILLAR Maximum (X, Y, Z)	37	13.3168	30.7494	-41.5801	13.3261	30.9695	-41.5231	-0.0093	-0.2201	0.0570	0.2276	0.0570	Z
	38	10.8163	34.3100	-31.6803	10.7732	34.4448	-31.6151	0.0431	-0.1348	0.0652	0.1558	0.0782	X, Z
	39	14.3221	35.0200	-28.3390	14.3032	35.1636	-28.3000	0.0189	-0.1436	0.0390	0.1500	0.0433	X, Z
	40	11.4383	35.4924	-24.0394	11.3918	35.5870	-23.9303	0.0465	-0.0946	0.1091	0.1517	0.1186	X, Z
B-PILLAR Lateral (Y)	37	13.3168	30.7494	-41.5801	13.3261	30.9695	-41.5231	-0.0093	-0.2201	0.0570	0.2276	-0.2201	Y
	38	10.8163	34.3100	-31.6803	10.7732	34.4448	-31.6151	0.0431	-0.1348	0.0652	0.1558	-0.1348	Y
	39	14.3221	35.0200	-28.3390	14.3032	35.1636	-28.3000	0.0189	-0.1436	0.0390	0.1500	-0.1436	Y
	40	11.4383	35.4924	-24.0394	11.3918	35.5870	-23.9303	0.0465	-0.0946	0.1091	0.1517	-0.0946	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-15. Occupant Compartment Deformation Data – Set 1, Test No. HMDBR-3

Model Year: 2015 Test Name: HMDBR-3 Make: Dodge VIN: 1C6RR6KG2FS506038 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	53.6219	50.2667	-30.8553	53.5904	50.0672	-31.8826	0.0315	0.1995	-1.0273	1.0470	1.0470	X, Y, Z
	2	51.8619	37.6300	-30.6522	51.8896	37.5260	-31.4082	-0.0277	0.1040	-0.7560	0.7636	0.7636	X, Y, Z
	3	48.7065	20.3519	-31.0737	48.7739	20.2020	-31.5650	-0.0674	0.1499	-0.4913	0.5181	0.5181	X, Y, Z
	4	48.8688	50.5490	-20.1993	48.5198	50.5156	-21.4263	0.3490	0.0334	-1.2270	1.2761	1.2761	X, Y, Z
	5	47.9790	38.6583	-20.4945	47.8187	38.4331	-21.4469	0.1603	0.2252	-0.9524	0.9917	0.9917	X, Y, Z
	6	45.7401	20.3478	-20.3414	45.6615	20.3883	-20.8966	0.0786	-0.0405	-0.5552	0.5622	0.5622	X, Y, Z
SIDE PANEL (Y)	7	57.5170	52.6624	-3.7616	56.5585	49.6418	-4.7070	0.9585	3.0206	-0.9454	3.3070	3.0206	Y
	8	57.5332	52.6948	-7.9851	56.5724	49.5876	-9.0968	0.9608	3.1072	-1.1117	3.4371	3.1072	Y
	9	59.8860	52.6452	-6.0009	58.6212	49.3801	-7.1090	1.2648	3.2651	-1.1081	3.6727	3.2651	Y
IMPACT SIDE DOOR (Y)	10	23.3768	55.0665	-18.8209	22.5112	56.7473	-19.1391	0.8656	-1.6808	-0.3182	1.9172	-1.6808	Y
	11	35.2701	55.3383	-18.5811	34.4001	57.6985	-19.0473	0.8700	-2.3602	-0.4662	2.5583	-2.3602	Y
	12	43.3291	55.2014	-19.2877	42.3828	56.8105	-19.9604	0.9463	-1.6091	-0.6727	1.9842	-1.6091	Y
	13	23.7742	54.8774	-8.2038	23.0878	55.8106	-8.5341	0.6864	-0.9332	-0.3303	1.2046	-0.9332	Y
	14	35.8165	55.3106	-8.2977	35.0885	56.2192	-8.8681	0.7280	-0.9086	-0.5704	1.2965	-0.9086	Y
	15	42.8818	55.9330	-7.7817	42.1435	56.1588	-8.4948	0.7383	-0.2258	-0.7131	1.0510	-0.2258	Y
ROOF - (Z)	16	41.2475	42.2747	-46.4782	41.3566	42.2329	-46.8499	-0.1091	0.0418	-0.3717	0.3896	-0.3717	Z
	17	43.8108	32.2622	-46.7780	43.8838	32.2493	-47.0464	-0.0730	0.0129	-0.2684	0.2784	-0.2684	Z
	18	44.5775	20.5785	-47.0818	44.6593	20.5292	-47.2362	-0.0818	0.0493	-0.1544	0.1816	-0.1544	Z
	19	35.4456	41.6085	-49.1428	35.5402	41.4969	-49.4737	-0.0946	0.1116	-0.3309	0.3618	-0.3309	Z
	20	37.5756	31.6507	-49.5453	37.6398	31.5758	-49.7944	-0.0642	0.0749	-0.2491	0.2679	-0.2491	Z
	21	38.3537	20.4776	-49.7301	38.4422	20.3548	-49.8798	-0.0885	0.1228	-0.1497	0.2129	-0.1497	Z
	22	29.9709	41.2464	-49.9117	29.9366	41.1581	-50.2286	0.0343	0.0883	-0.3169	0.3308	-0.3169	Z
	23	30.4606	32.0824	-50.4872	30.5182	31.9965	-50.7484	-0.0576	0.0859	-0.2612	0.2809	-0.2612	Z
	24	31.8237	21.4482	-50.7314	31.8091	21.4220	-50.9385	0.0146	0.0262	-0.2071	0.2093	-0.2071	Z
	25	23.8941	41.5133	-50.2983	23.8917	41.4009	-50.6008	0.0024	0.1124	-0.3025	0.3227	-0.3025	Z
	26	23.8467	32.4935	-50.8695	23.8666	32.4565	-51.1213	-0.0199	0.0370	-0.2518	0.2553	-0.2518	Z
	27	25.7702	21.6122	-51.1437	25.7988	21.5042	-51.3369	-0.0286	0.1080	-0.1932	0.2232	-0.1932	Z
	28	17.8715	41.5450	-50.6043	17.8966	41.4322	-50.8763	-0.0251	0.1128	-0.2720	0.2955	-0.2720	Z
	29	17.9299	32.2339	-51.1616	17.8962	32.1610	-51.3761	0.0337	0.0729	-0.2145	0.2290	-0.2145	Z
	30	17.9013	21.8668	-51.4440	17.8236	21.7987	-51.6270	0.0777	0.0681	-0.1830	0.2102	-0.1830	Z
A-PILLAR Maximum (X, Y, Z)	31	58.6828	51.8093	-31.8276	58.9231	51.9336	-32.5423	-0.2403	-0.1243	-0.7147	0.7642	0.0000	NA
	32	55.9639	51.2654	-34.2160	56.1743	51.2531	-35.1012	-0.2104	0.0123	-0.8852	0.9099	0.0123	Y
	33	52.3443	50.5095	-37.1212	52.5338	50.5757	-37.8585	-0.1895	-0.0662	-0.7373	0.7641	0.0000	NA
	34	49.2498	49.8904	-39.6363	49.4689	49.9208	-40.2235	-0.2191	-0.0304	-0.5872	0.6275	0.0000	NA
	35	45.1707	49.0098	-42.3497	45.3668	49.0021	-42.8962	-0.1961	0.0077	-0.5465	0.5807	0.0077	Y
	36	40.6834	47.9885	-44.8441	40.8507	47.9487	-45.2488	-0.1673	0.0398	-0.4047	0.4397	0.0398	Y
A-PILLAR Lateral (Y)	31	58.6828	51.8093	-31.8276	58.9231	51.9336	-32.5423	-0.2403	-0.1243	-0.7147	0.7642	-0.1243	Y
	32	55.9639	51.2654	-34.2160	56.1743	51.2531	-35.1012	-0.2104	0.0123	-0.8852	0.9099	0.0123	Y
	33	52.3443	50.5095	-37.1212	52.5338	50.5757	-37.8585	-0.1895	-0.0662	-0.7373	0.7641	-0.0662	Y
	34	49.2498	49.8904	-39.6363	49.4689	49.9208	-40.2235	-0.2191	-0.0304	-0.5872	0.6275	-0.0304	Y
	35	45.1707	49.0098	-42.3497	45.3668	49.0021	-42.8962	-0.1961	0.0077	-0.5465	0.5807	0.0077	Y
	36	40.6834	47.9885	-44.8441	40.8507	47.9487	-45.2488	-0.1673	0.0398	-0.4047	0.4397	0.0398	Y
B-PILLAR Maximum (X, Y, Z)	37	16.6370	47.7206	-45.6324	16.7197	47.6399	-45.7921	-0.0827	0.0807	-0.1597	0.1971	0.0807	Y
	38	14.1535	51.2752	-35.7262	14.1791	51.1702	-35.9004	-0.0256	0.1050	-0.1742	0.2050	0.1050	Y
	39	17.6627	51.9632	-32.3839	17.7105	51.8813	-32.5852	-0.0478	0.0819	-0.2013	0.2225	0.0819	Y
	40	14.7814	52.4413	-28.0833	14.7980	52.3396	-28.2197	-0.0166	0.1017	-0.1364	0.1709	0.1017	Y
B-PILLAR Lateral (Y)	37	16.6370	47.7206	-45.6324	16.7197	47.6399	-45.7921	-0.0827	0.0807	-0.1597	0.1971	0.0807	Y
	38	14.1535	51.2752	-35.7262	14.1791	51.1702	-35.9004	-0.0256	0.1050	-0.1742	0.2050	0.1050	Y
	39	17.6627	51.9632	-32.3839	17.7105	51.8813	-32.5852	-0.0478	0.0819	-0.2013	0.2225	0.0819	Y
	40	14.7814	52.4413	-28.0833	14.7980	52.3396	-28.2197	-0.0166	0.1017	-0.1364	0.1709	0.1017	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-16. Occupant Compartment Deformation Data – Set 2, Test No. HMDBR-3

Test Name: HMDBR-3 VIN: 1C6RR6KG2FS506038

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	-0.2	≤ 4	Z	Roof	-0.4	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.0	≤ 5	NA	A-Pillar Maximum	0.0	≤ 5	Y
A-Pillar Lateral	-0.4	≤ 3	Y	A-Pillar Lateral	0.0	≤ 3	Y
B-Pillar Maximum	0.1	≤ 5	X, Z	B-Pillar Maximum	0.1	≤ 5	Y
B-Pillar Lateral	-0.2	≤ 3	Y	B-Pillar Lateral	0.1	≤ 3	Y
Toe Pan - Wheel Well	4.8	≤ 9	X, Z	Toe Pan - Wheel Well	4.8	≤ 9	X, Z
Side Front Panel	3.1	≤ 12	Y	Side Front Panel	3.3	≤ 12	Y
Side Door (above seat)	-2.5	≤ 9	Y	Side Door (above seat)	-2.4	≤ 9	Y
Side Door (below seat)	-1.0	≤ 12	Y	Side Door (below seat)	-0.9	≤ 12	Y
Floor Pan	0.5	≤ 12	Z	Floor Pan	0.7	≤ 12	Z
Dash - no MASH requirement	1.1	NA	X, Y, Z	Dash - no MASH requirement	1.3	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.

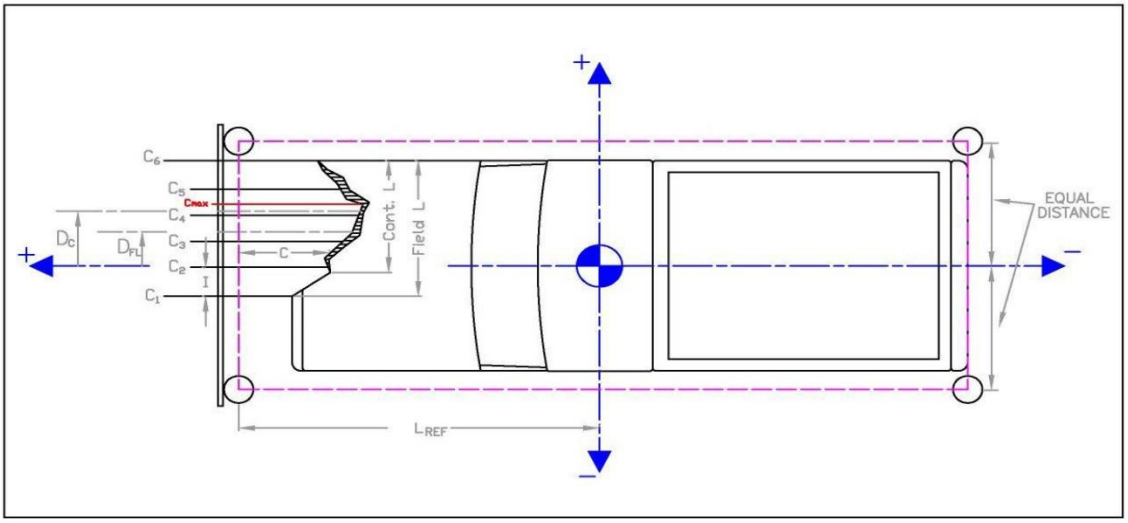
[C] For Toe Pan - Wheel Well the direction of defromation may include X and Z direction. For A-Pillar Maximum and B-Pillar Maximum the direction of deformation may include X, Y, and Z directions. The direction of deformation for Toe Pan -Wheel Well, A-Pillar Maximum, and B-Pillar Maximum only include 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-17. Maximum Occupant Compartment Deformations by Location, Test No. HMDBR-3

Date Measured:	4/9/2021	Test Name:	HMDBR-3	VIN:	1C6RR6KG2FS506038
Model Year:	2015	Make:	Dodge	Model:	Ram 1500



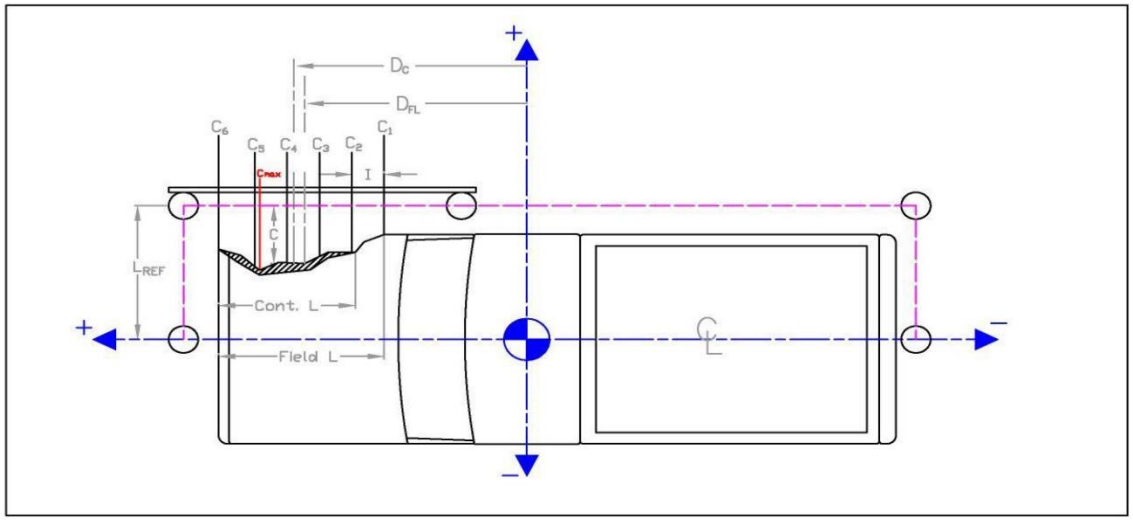
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	110	(2794)
Total Vehicle Width:	77 3/4	(1975)
Width of contact and induced crush - Field L:	77 3/4	(1975)
Crush measurement spacing interval (L/5) - I:	15 1/2	(394)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	54 3/8	(1381)
Distance from center of vehicle to center of contact damage - D_C:	12 1/2	(318)

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	14 3/4	(375)	-38 7/8	-(987)	22 1/2	(572)	2/3	(17)	-8 4/9	-(214)
C_2	9 3/8	(238)	-23 3/8	-(594)	6 5/8	(168)			2	(52)
C_3	13 5/8	(346)	-7 7/8	-(200)	4 1/4	(108)			8 2/3	(221)
C_4	18 3/8	(467)	7 5/8	(194)	4 1/4	(108)			13 4/9	(341)
C_5	28 5/8	(727)	23 1/8	(587)	6 1/8	(156)			21 4/5	(554)
C_6	N/A	N/A	38 5/8	(981)	20 1/2	(521)			N/A	N/A
C_{MAX}	34	(864)	28 5/8	(727)	8 3/8	(213)			25	(633)

Figure E-18. Exterior Vehicle Crush (NASS) - Front, Test No. HMDBR-3

Date Measured:	4/9/2021	Test Name:	HMDBR-3	VIN:	1C6RR6KG2FS506038
Model Year:	2015	Make:	Dodge	Model:	Ram 1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	50	(1270)
Total Vehicle Length:	229	(5817)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-2 1/5	-(56)
Width of contact and induced crush - Field L:	229	(5817)
Crush measurement spacing interval (L/5) - I:	45 3/4	(1162)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-8	-(202)
Width of Contact Damage:	229	(5817)
Distance from vehicle c.g. to center of contact damage - D_C:	-8	-(202)

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

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual	Crush
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/A	N/A	-122 1/2	-(3112)	33 1/2	(851)	6	(152)	N/A	N/A
C_2	N/A	N/A	-76 3/4	-(1949)	5 1/2	(140)			N/A	N/A
C_3	9	(229)	-31	-(787)	5 7/8	(149)			-2 7/8	-(73)
C_4	10	(254)	14 3/4	(375)	5	(127)			-1	-(25)
C_5	N/A	N/A	60 1/2	(1537)	5 7/8	(149)			N/A	N/A
C_6	N/A	N/A	106 1/4	(2699)	11 7/8	(302)			N/A	N/A
C_{MAX}	27	(686)	78	(1981)	5 7/8	(149)			15 1/8	(384)

Figure E-19. Exterior Vehicle Crush (NASS) - Side, Test No. HMDBR-3

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

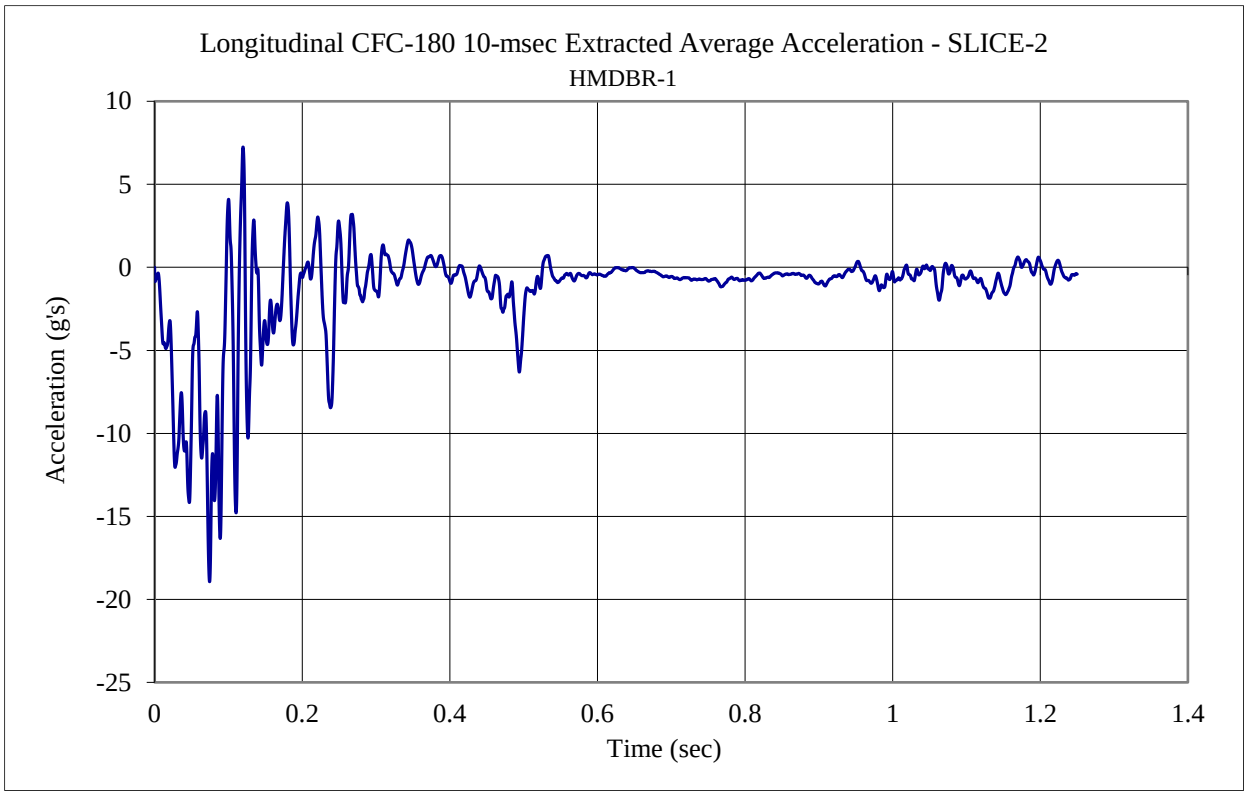


Figure F-1. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HMDBR-1

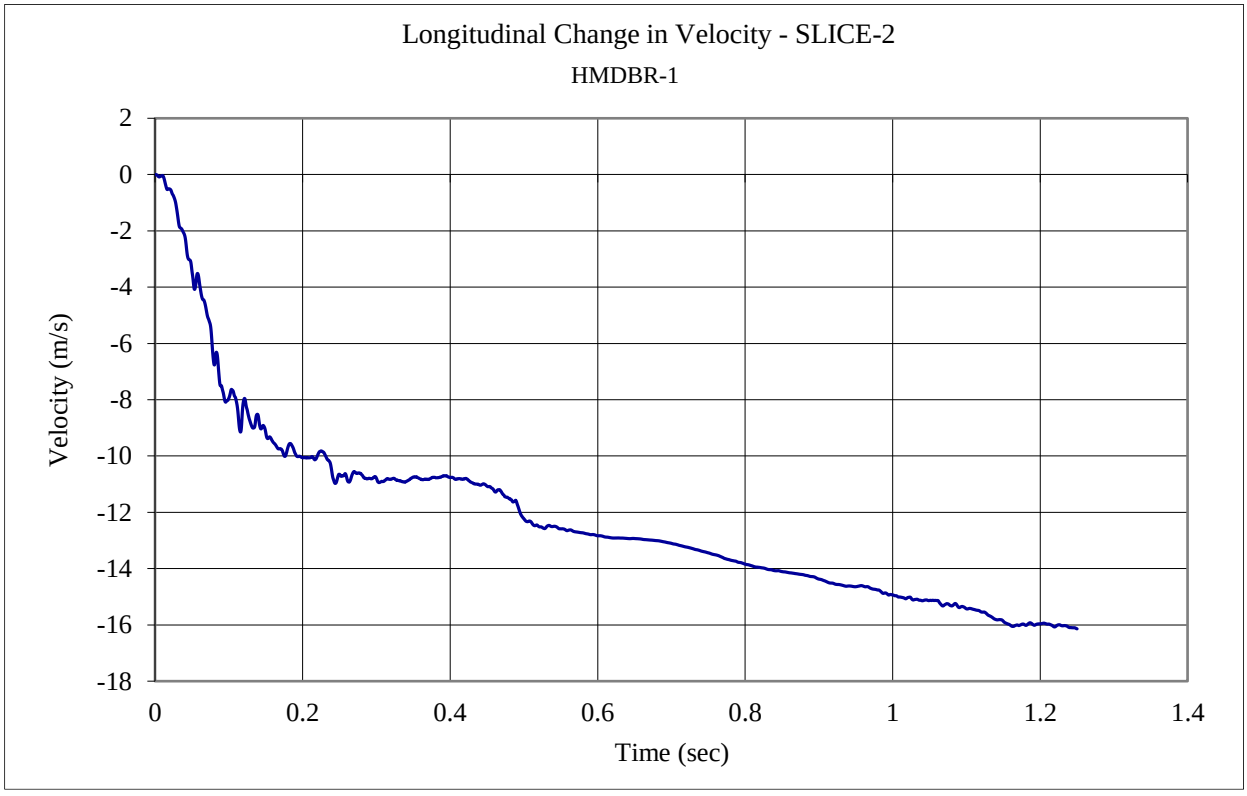


Figure F-2. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HMDBR-1

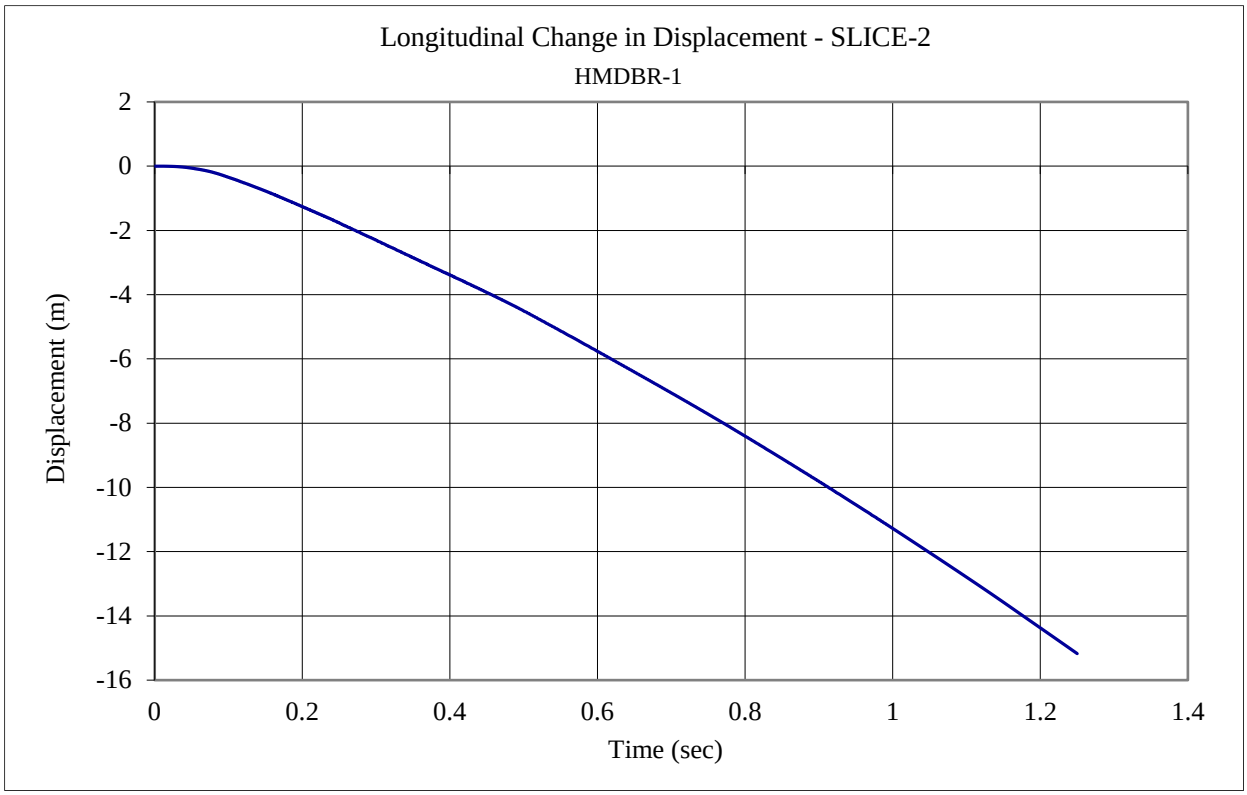


Figure F-3. Longitudinal Occupant Displacement (SLICE-2), Test No. HMDBR-1

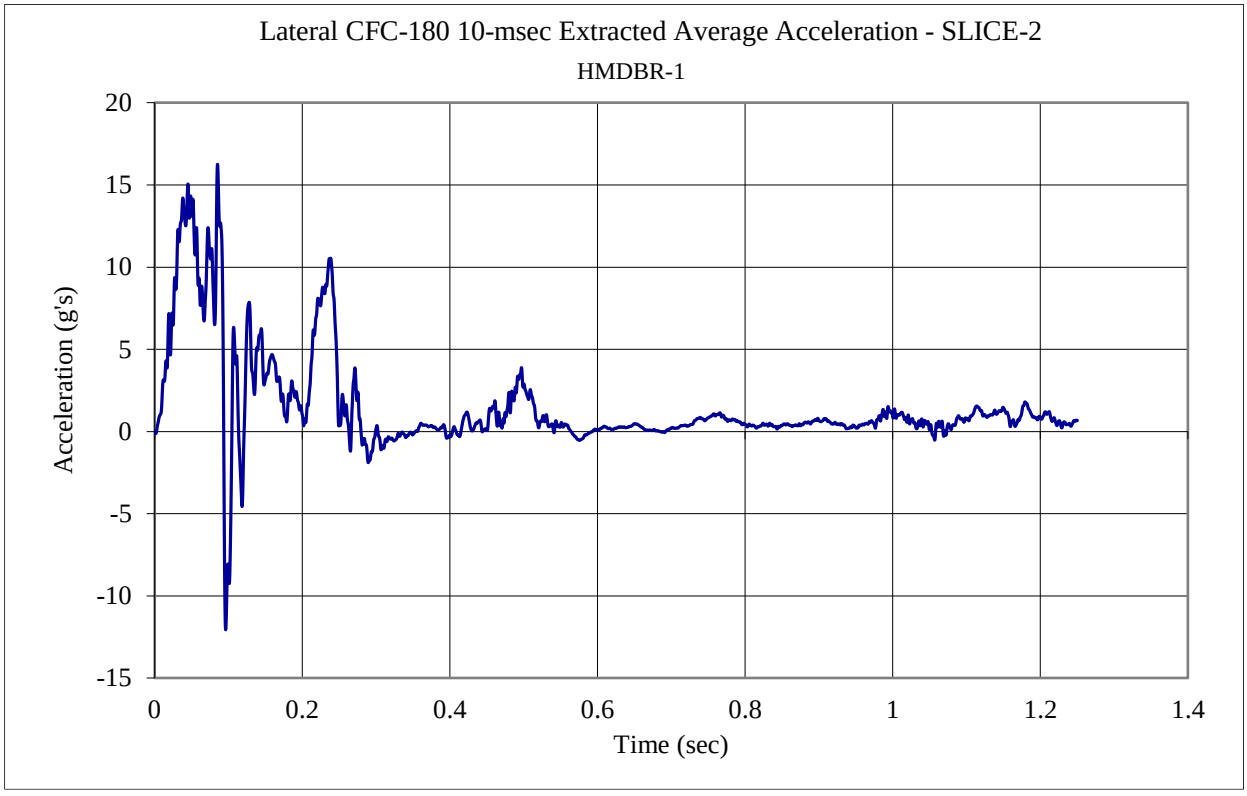


Figure F-4. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HMDBR-1

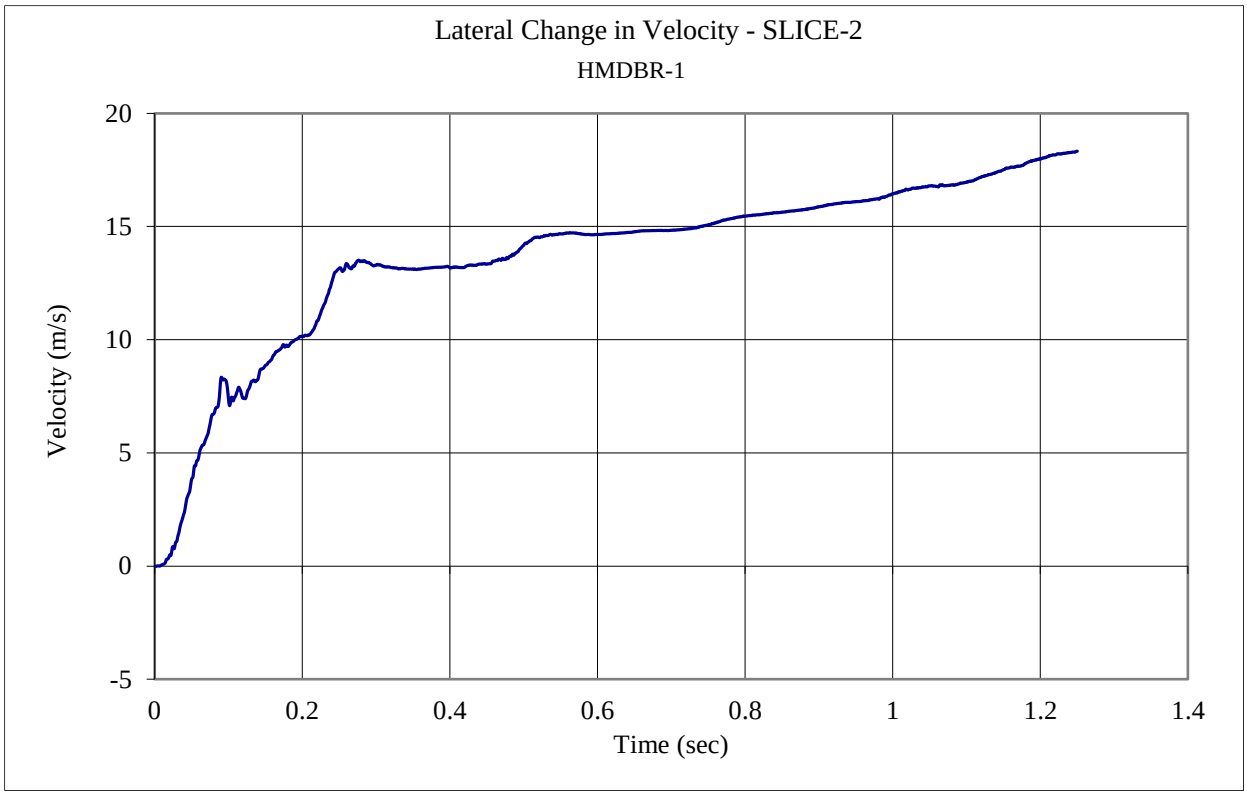


Figure F-5. Lateral Occupant Impact Velocity (SLICE-2), Test No. HMDBR-1

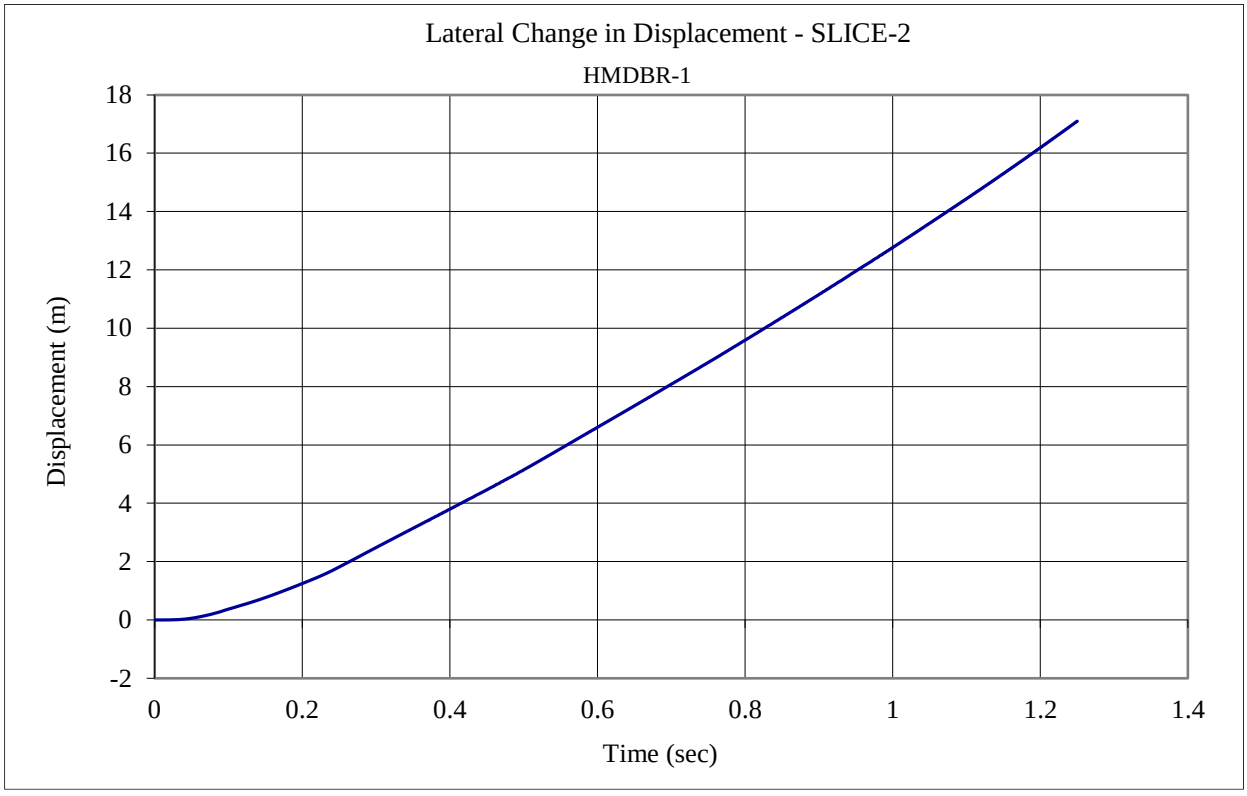


Figure F-6. Lateral Occupant Displacement (SLICE-2), Test No. HMDBR-1

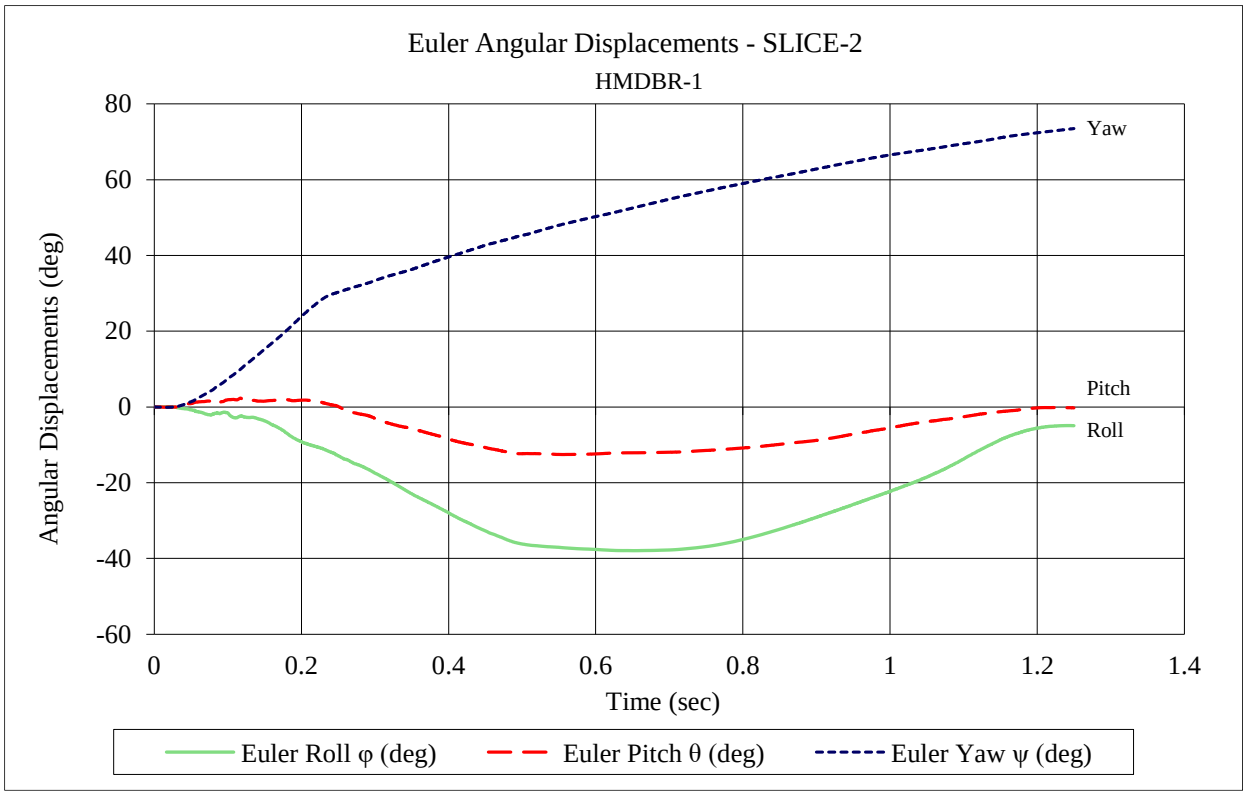


Figure F-7. Vehicle Angular Displacements (SLICE-2), Test No. HMDBR-1

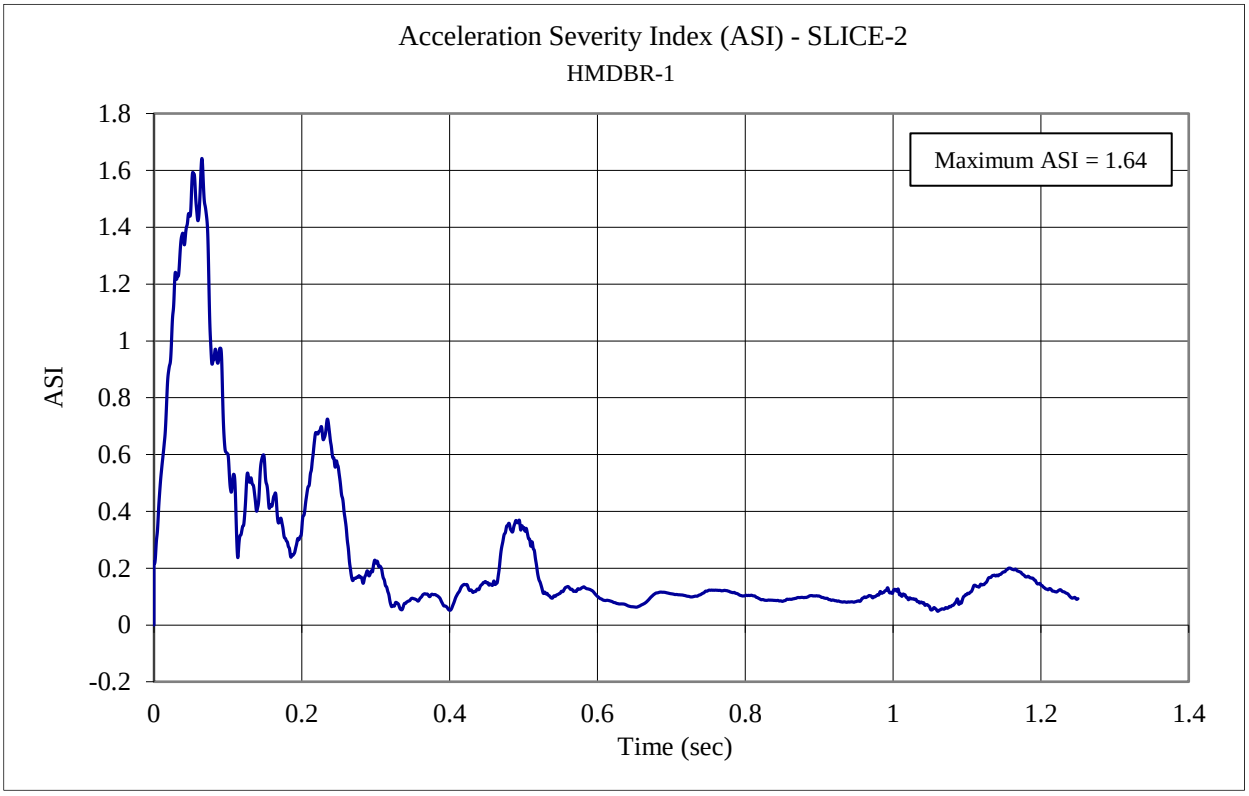


Figure F-8. Acceleration Severity Index (SLICE-2), Test No. HMDBR-1

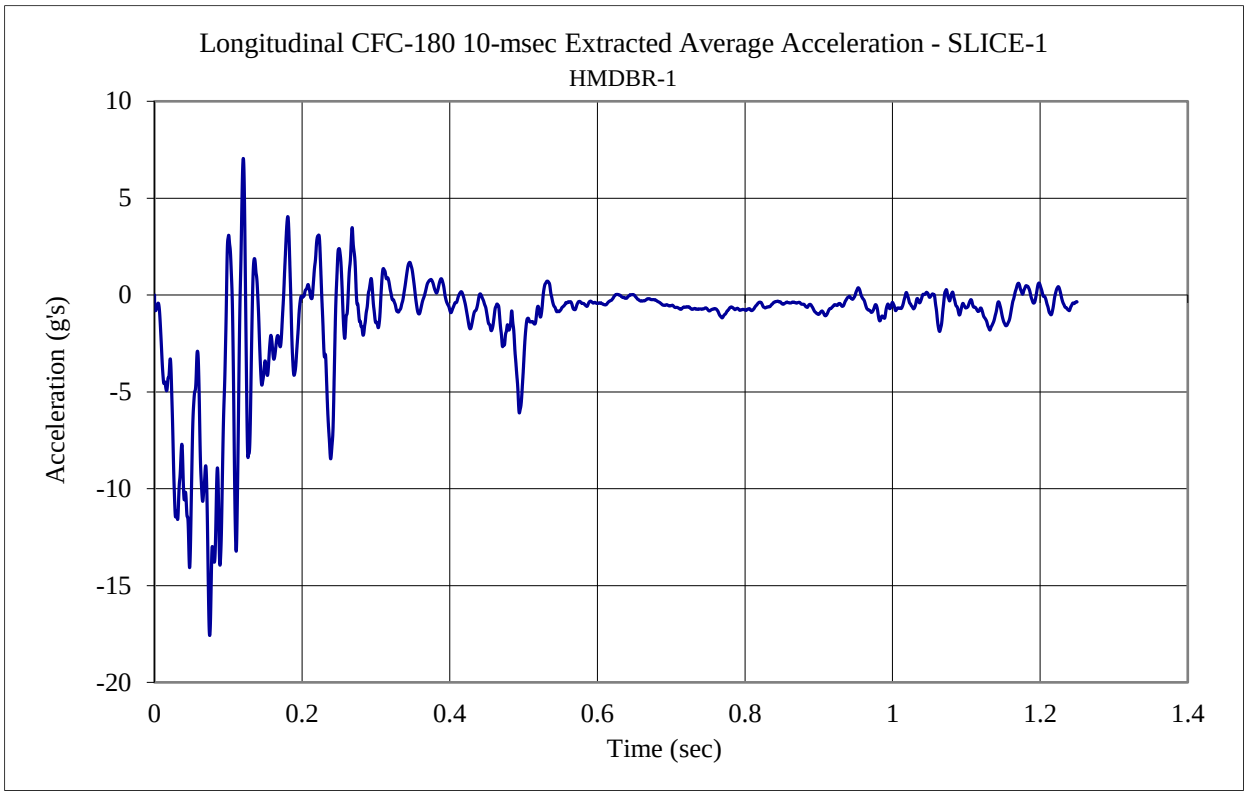


Figure F-9. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HMDBR-1

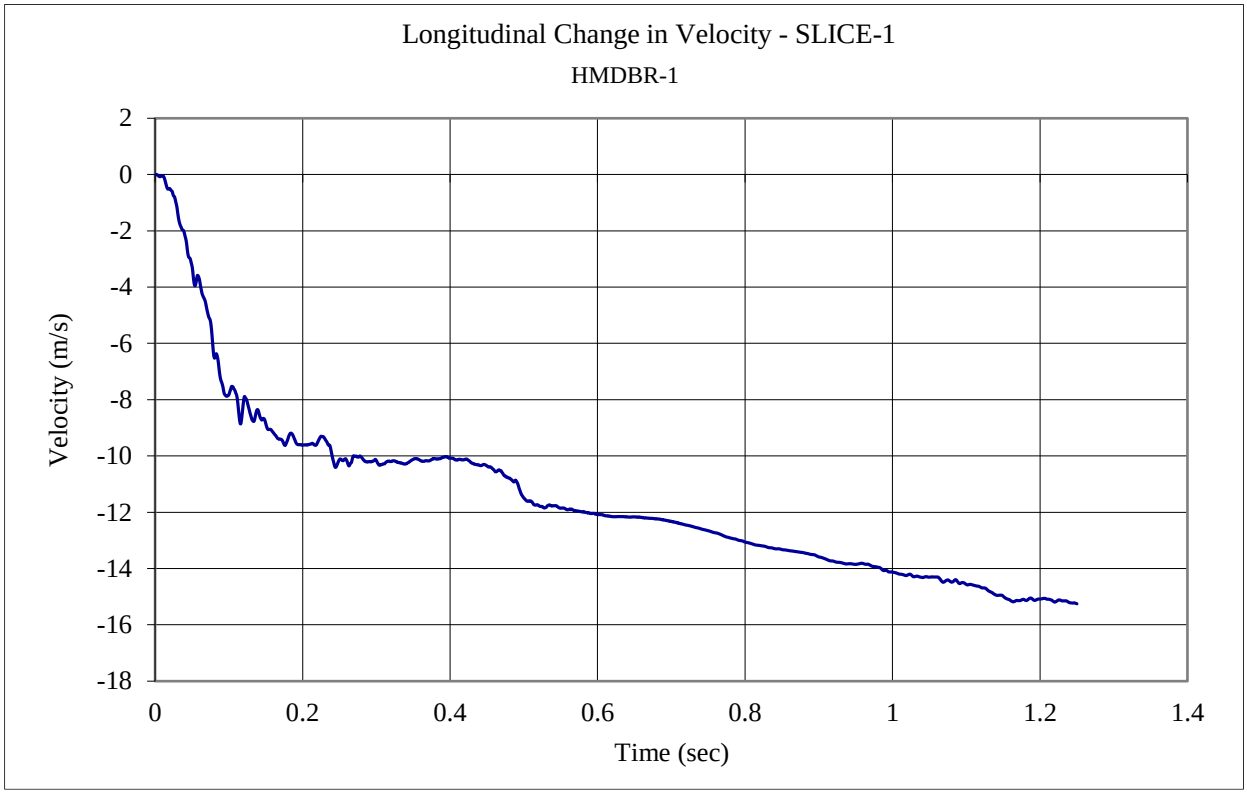


Figure F-10. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HMDBR-1

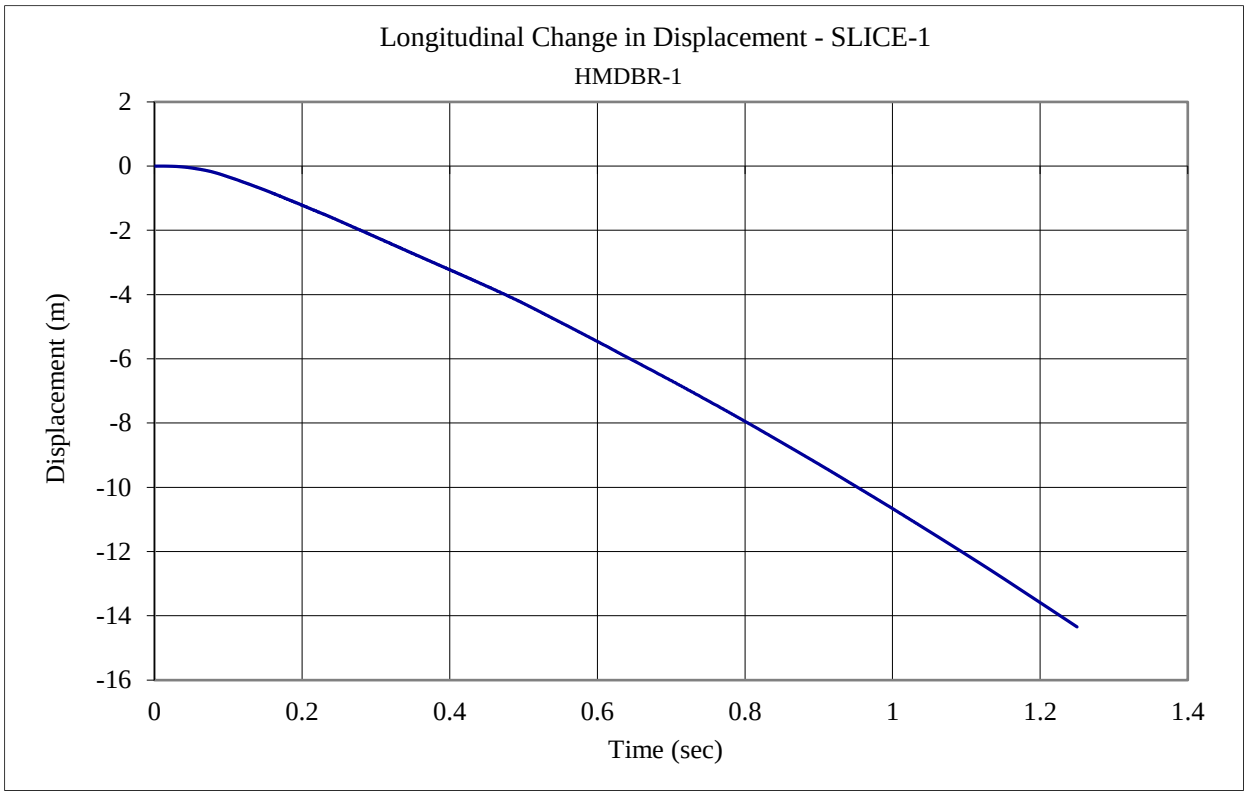


Figure F-11. Longitudinal Occupant Displacement (SLICE-1), Test No. HMDBR-1

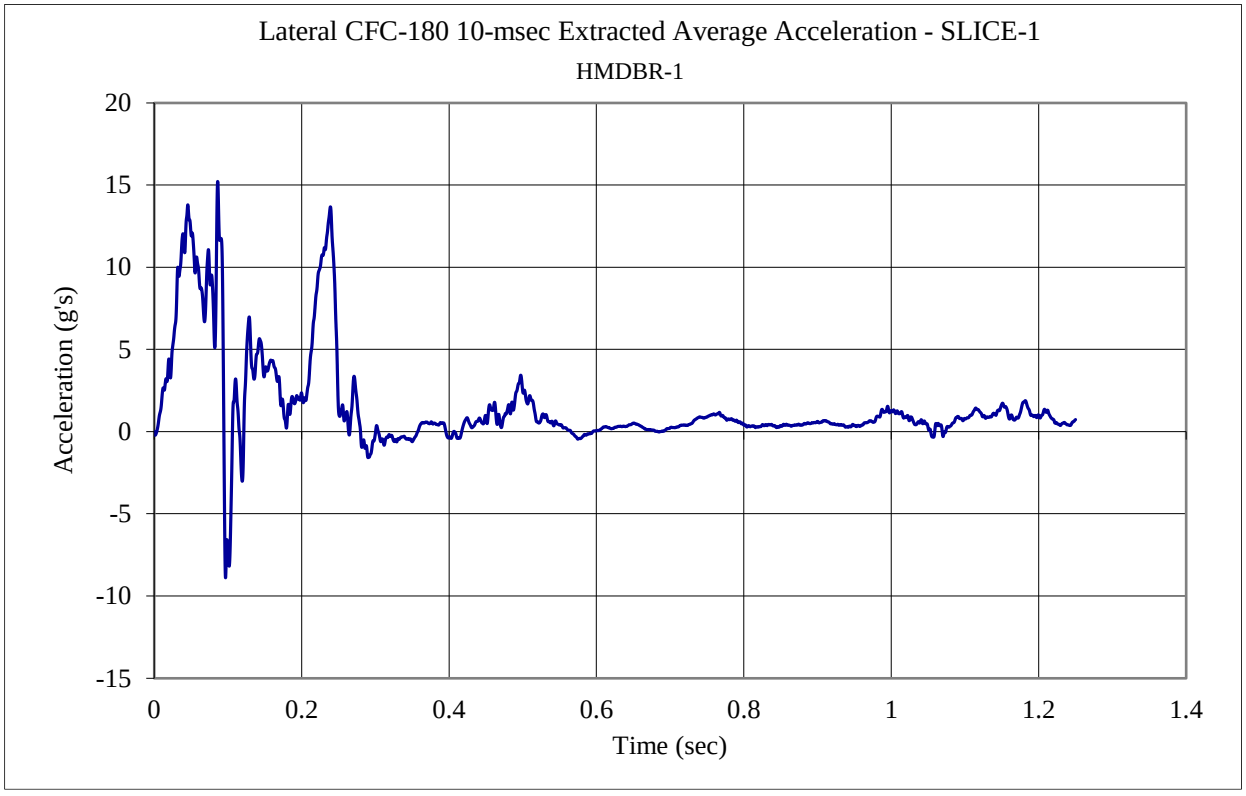


Figure F-12. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HMDBR-1

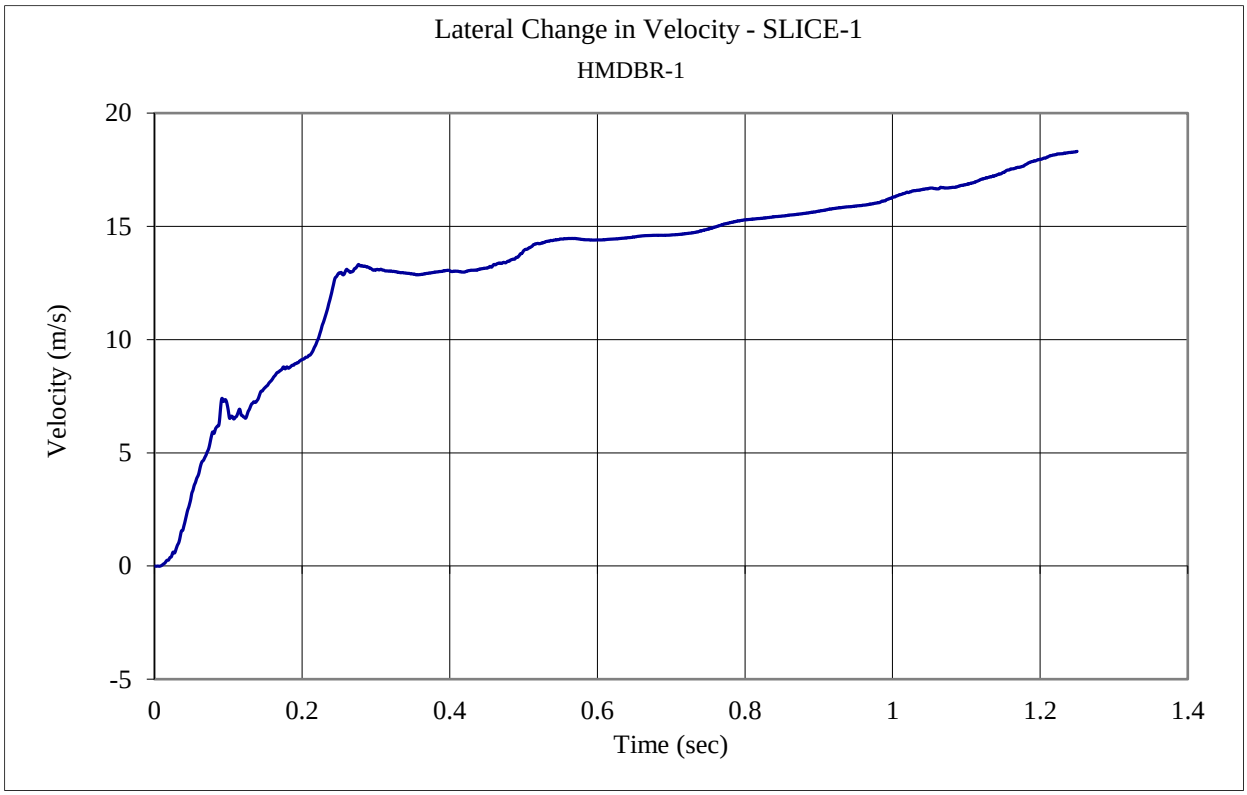


Figure F-13. Lateral Occupant Impact Velocity (SLICE-1), Test No. HMDBR-1

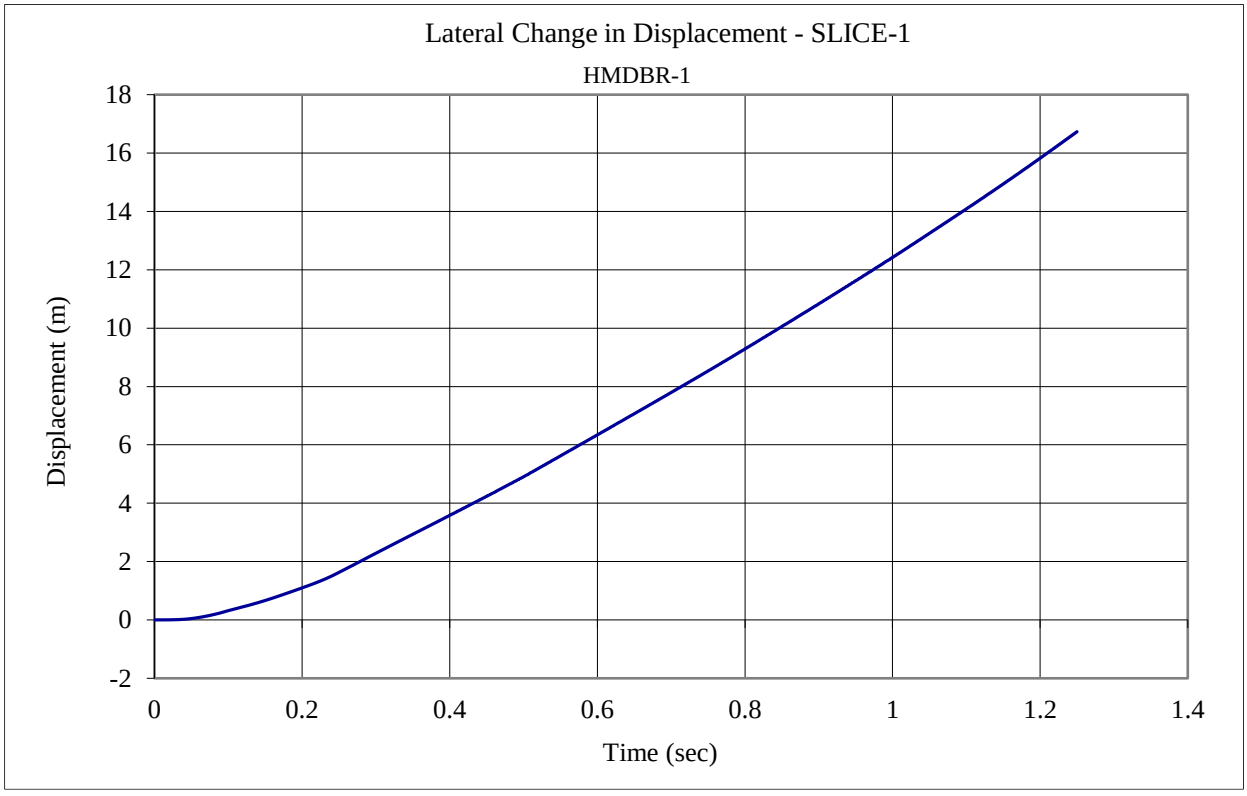


Figure F-14. Lateral Occupant Displacement (SLICE-1), Test No. HMDBR-1

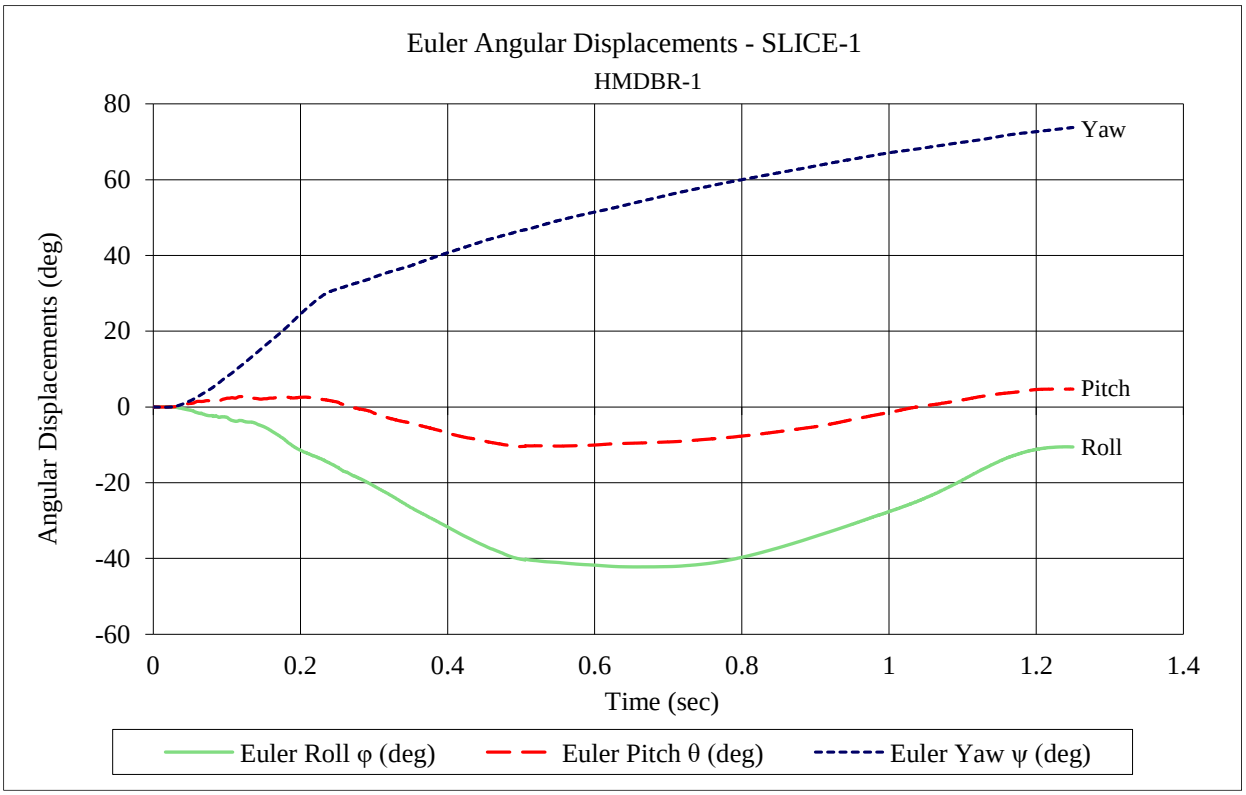


Figure F-15. Vehicle Angular Displacements (SLICE-1), Test No. HMDBR-1

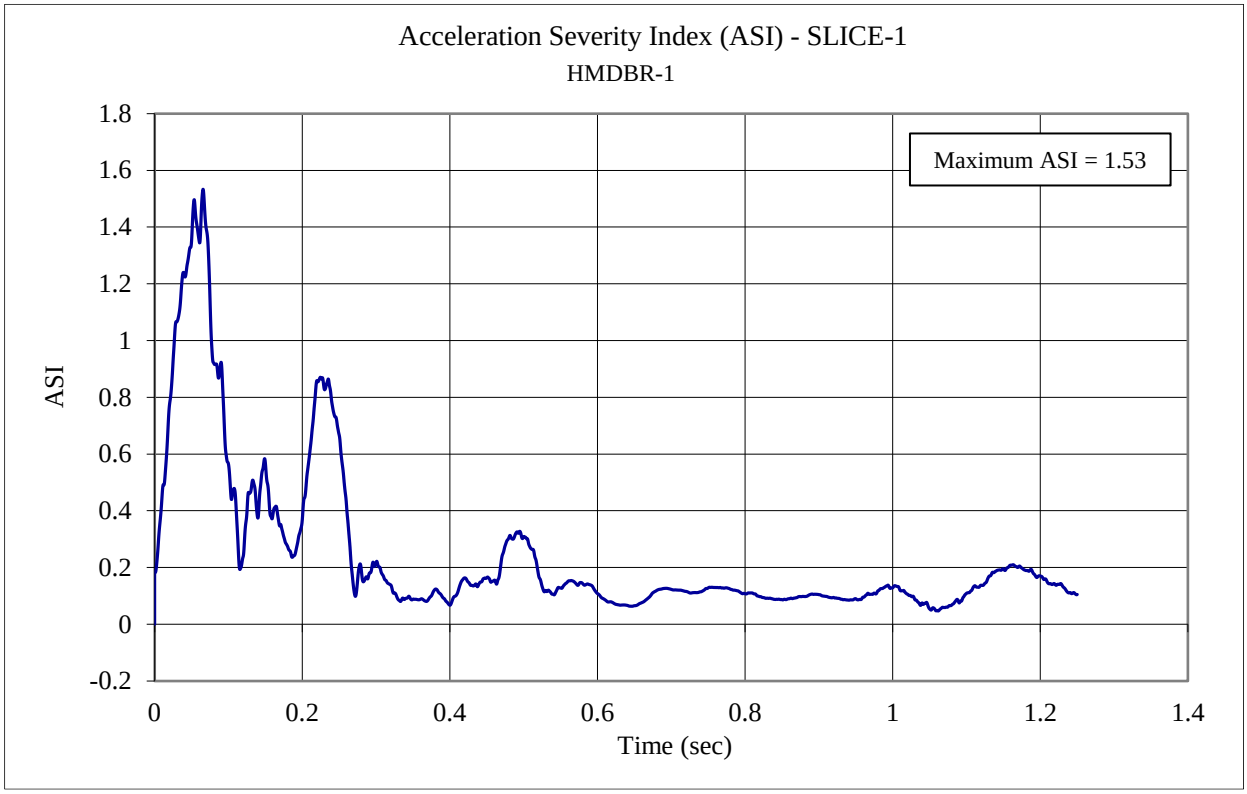


Figure F-16. Acceleration Severity Index (SLICE-1), Test No. HMDBR-1

Appendix G. Accelerometer and Rate Transducer Data Plots, Test No. HMDBR-2

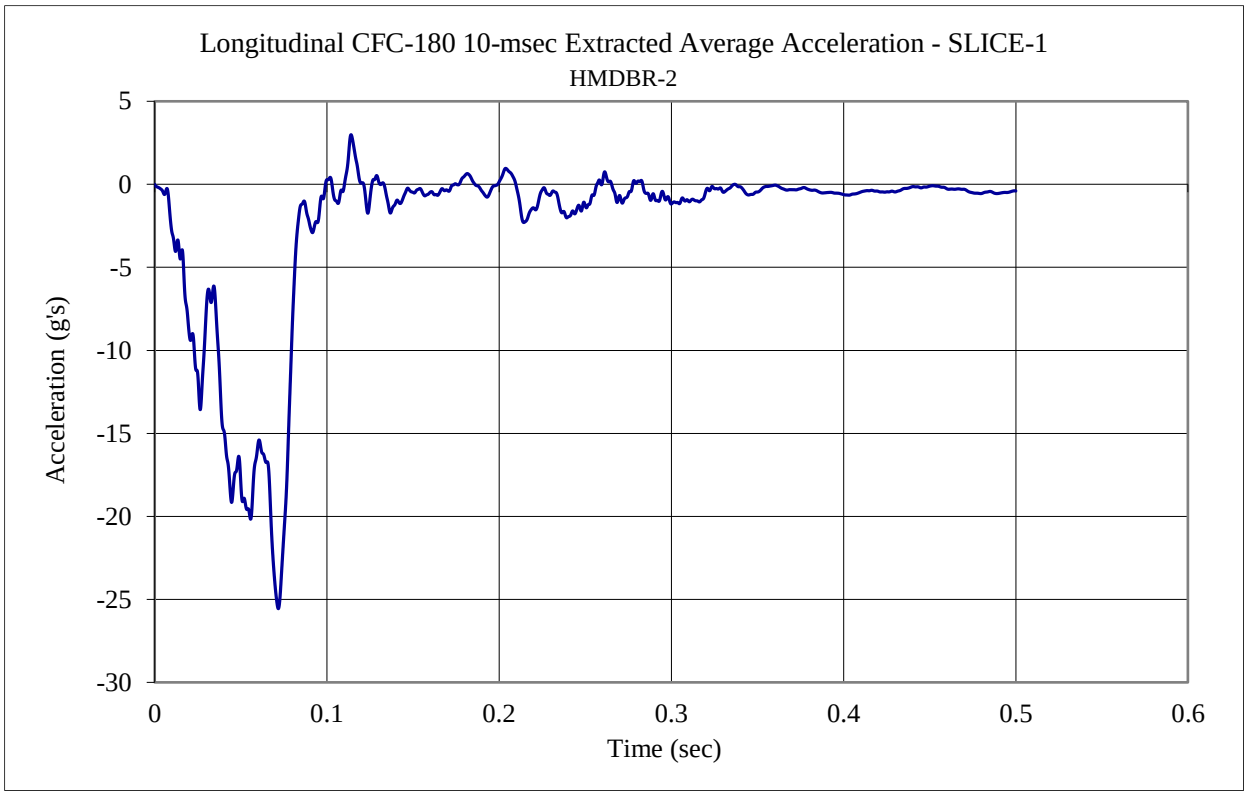


Figure G-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HMDBR-2

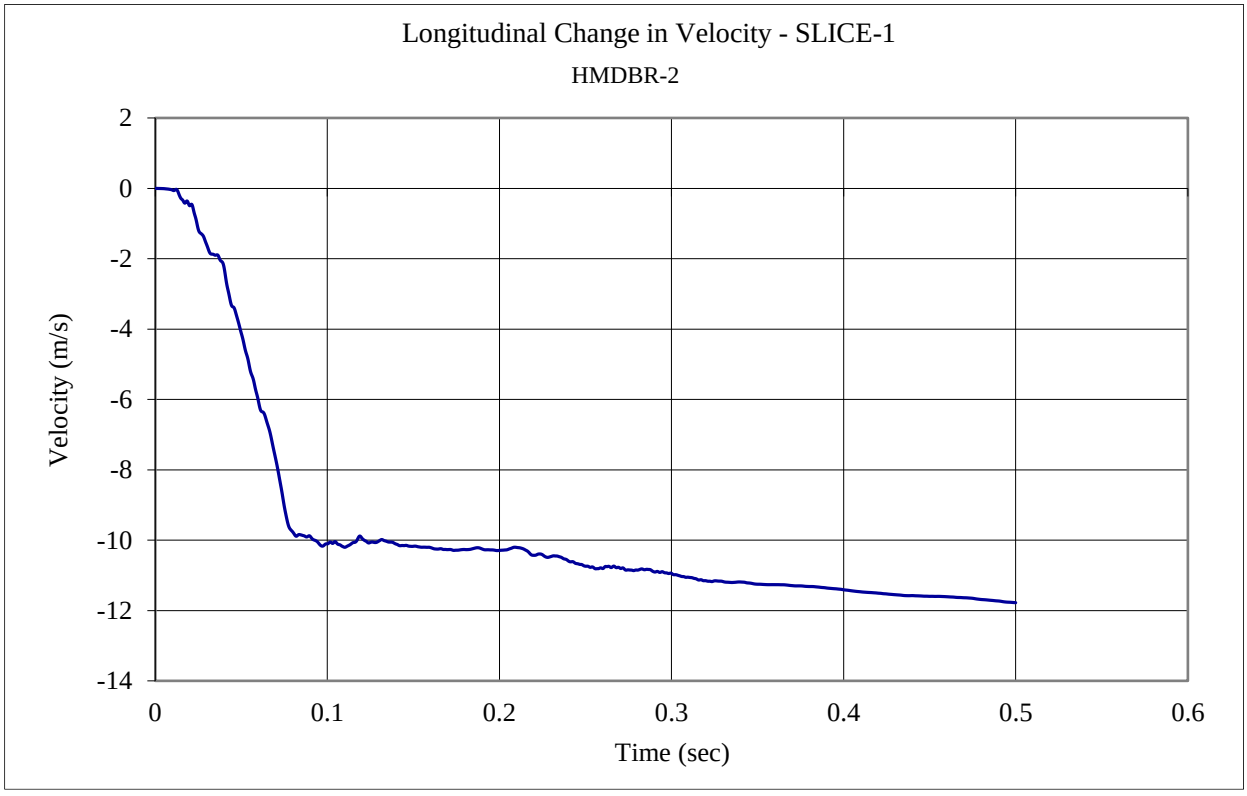


Figure G-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HMDBR-2

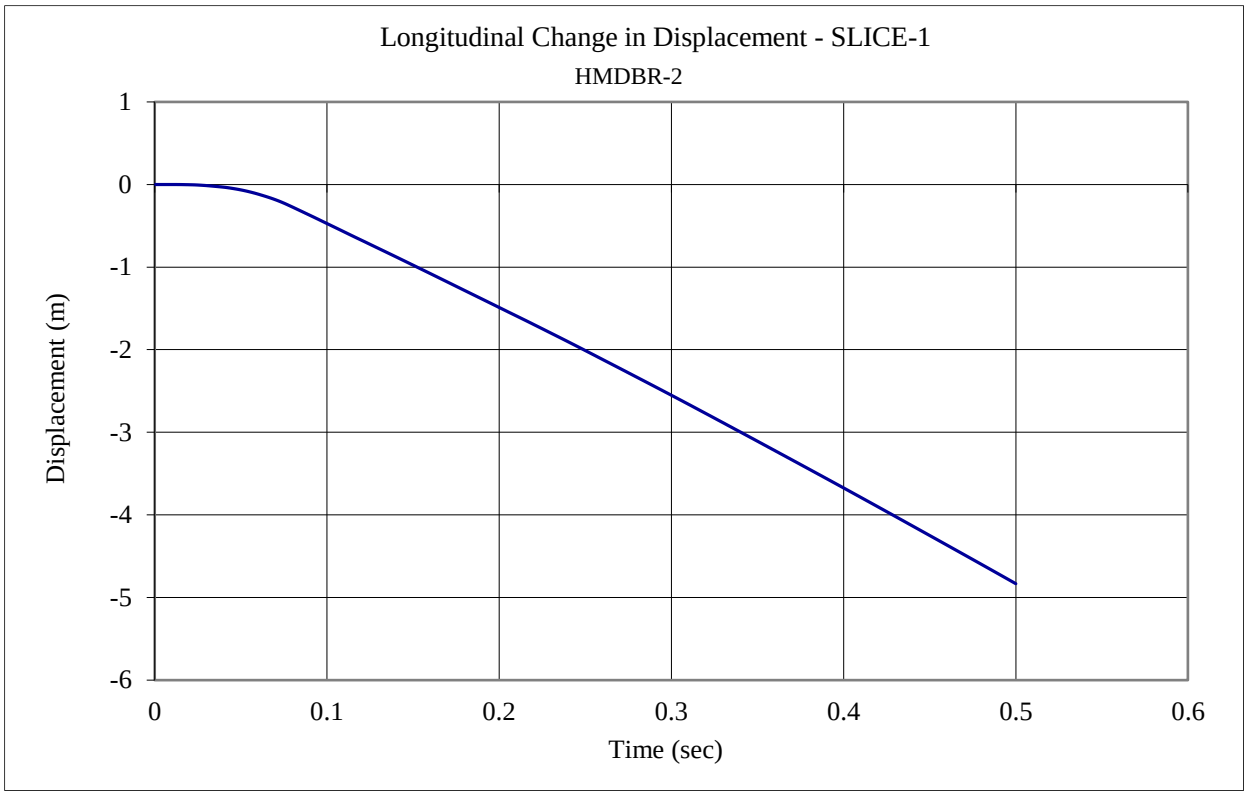


Figure G-3. Longitudinal Occupant Displacement (SLICE-1), Test No. HMDBR-2

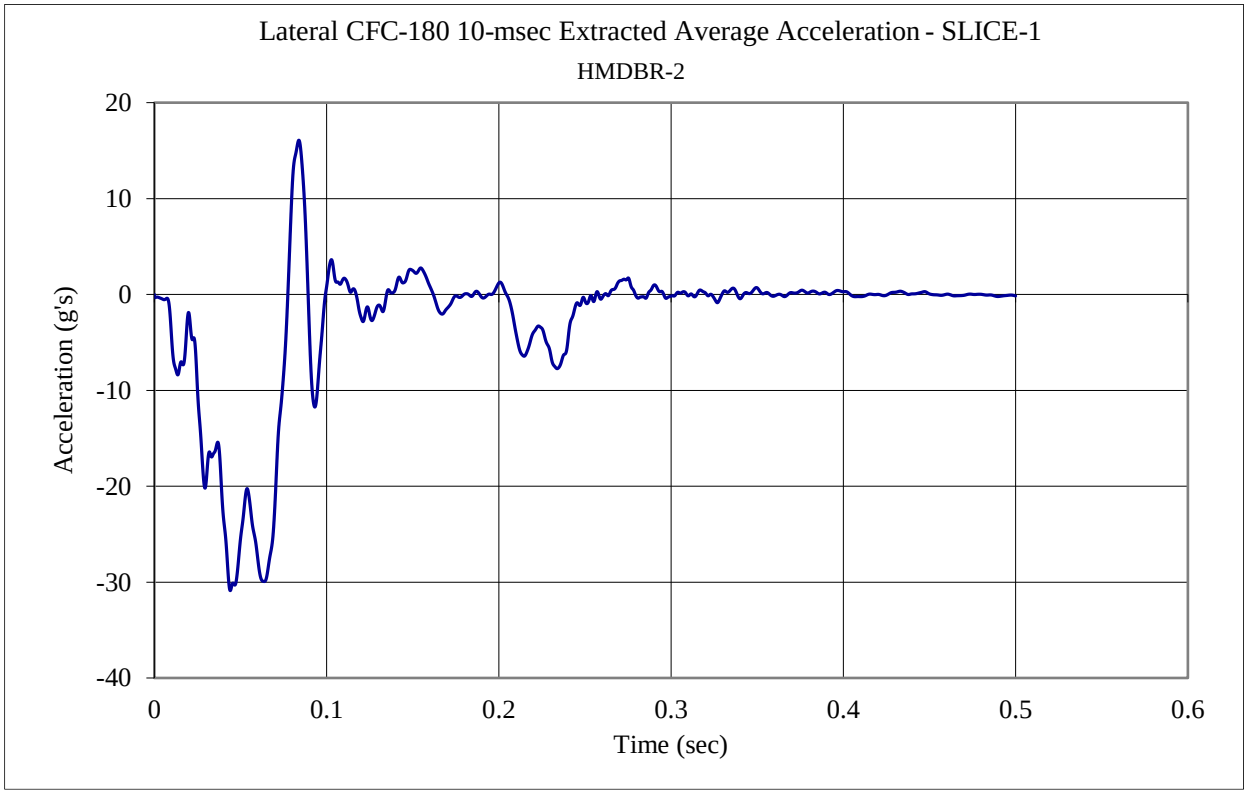


Figure G-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HMDBR-2

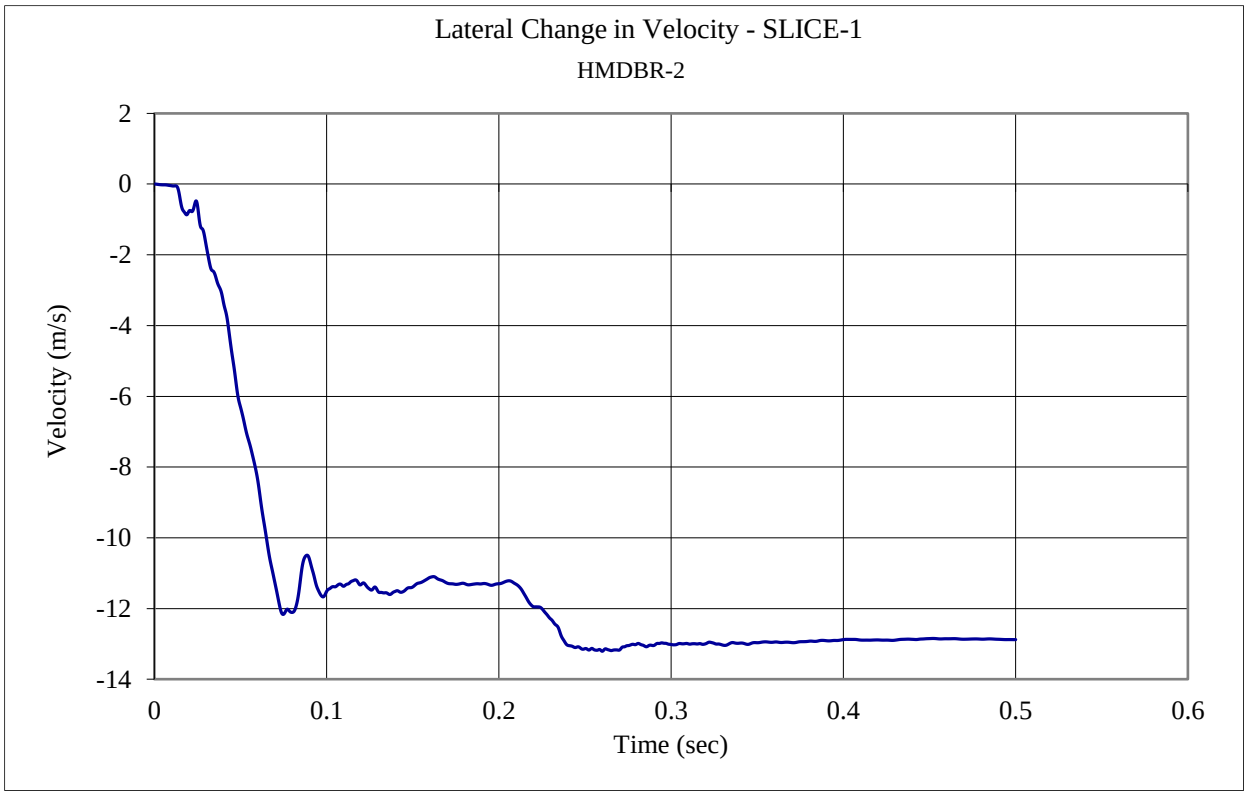


Figure G-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. HMDBR-2

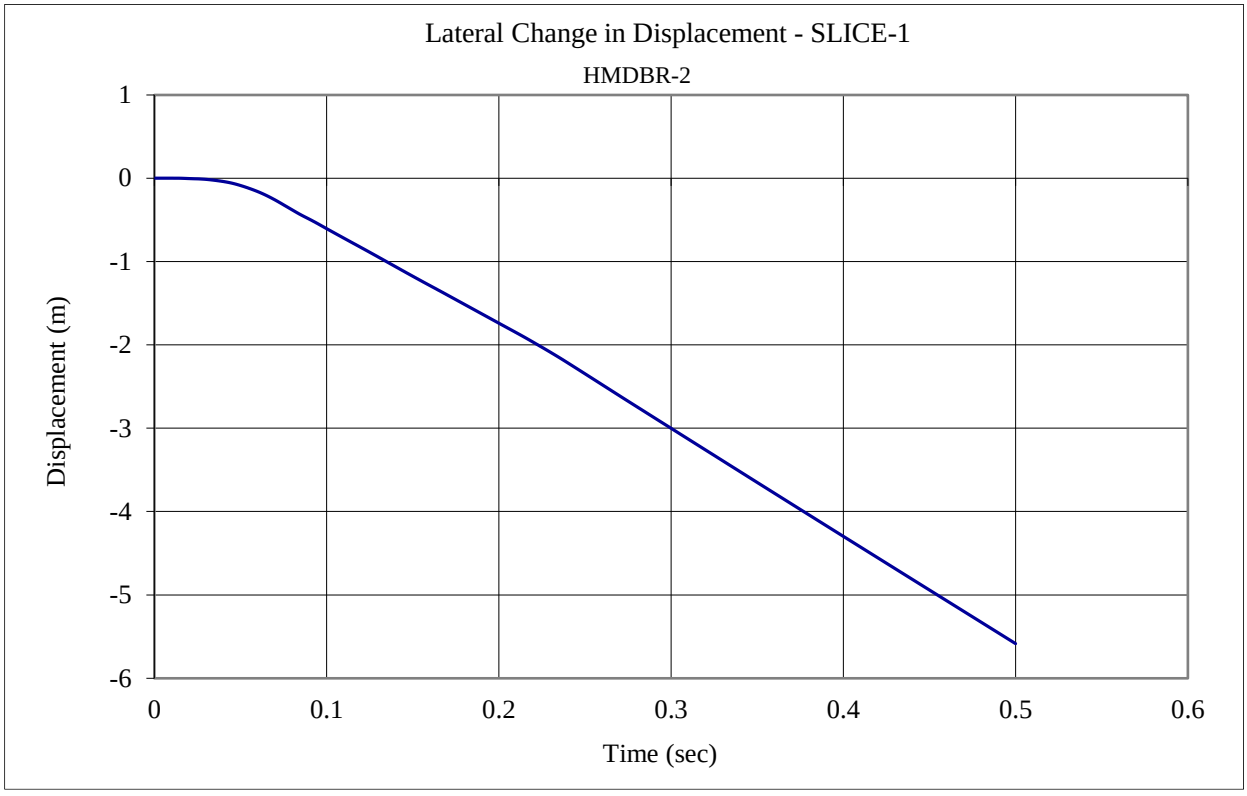


Figure G-6. Lateral Occupant Displacement (SLICE-1), Test No. HMDBR-2

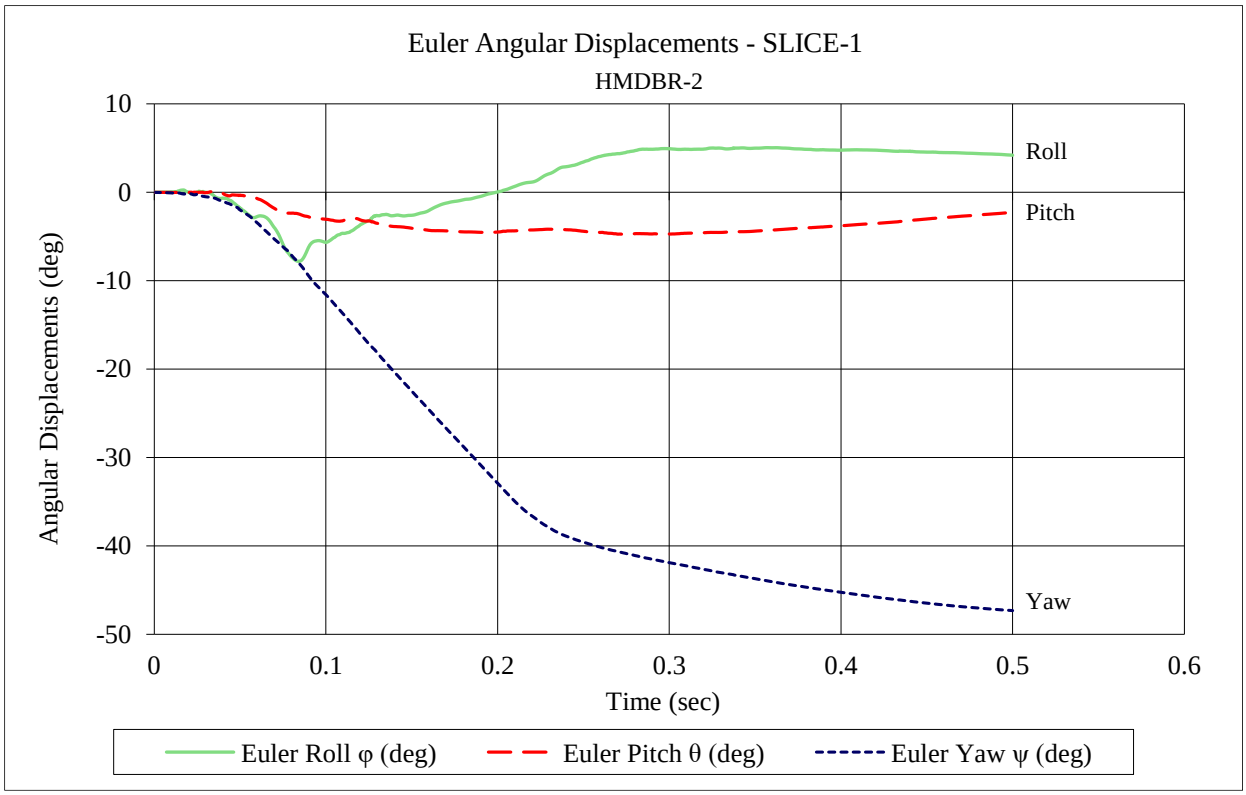


Figure G-7. Vehicle Angular Displacements (SLICE-1), Test No. HMDBR-2

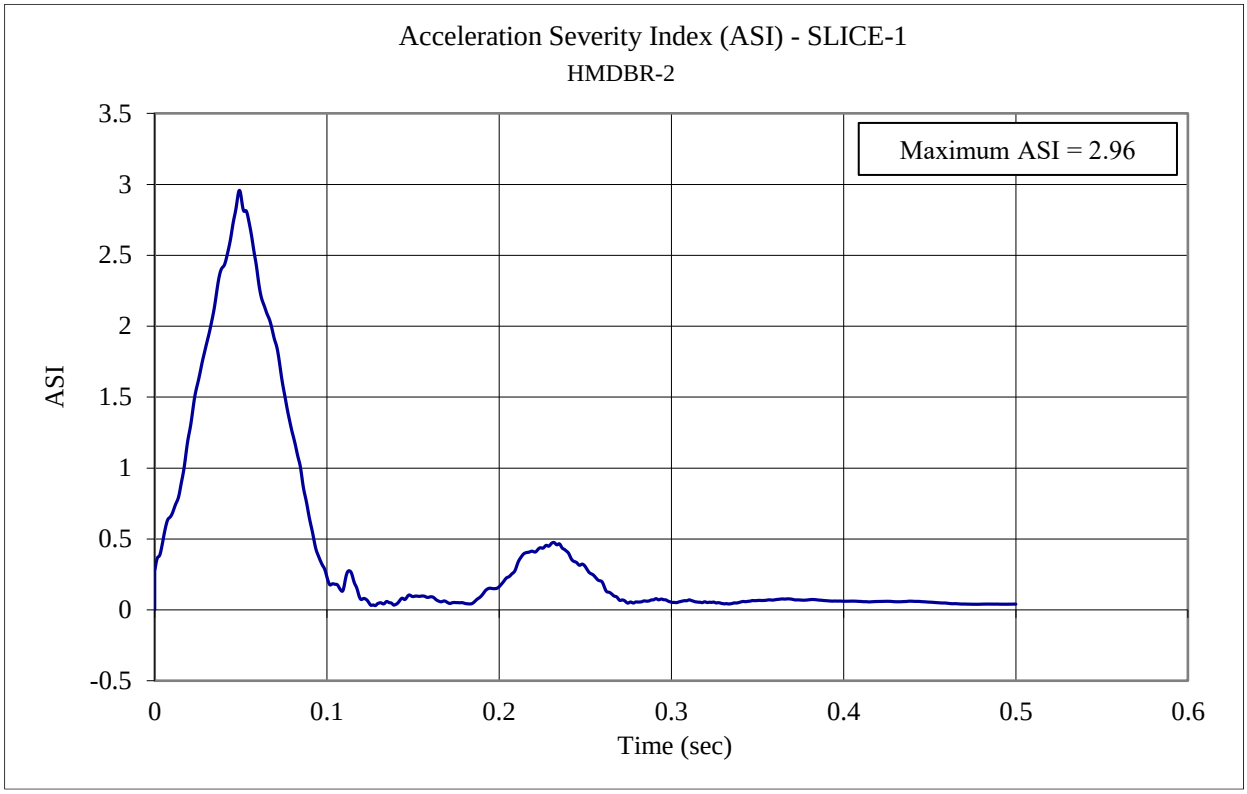


Figure G-8. Acceleration Severity Index (SLICE-1), Test No. HMDBR-2

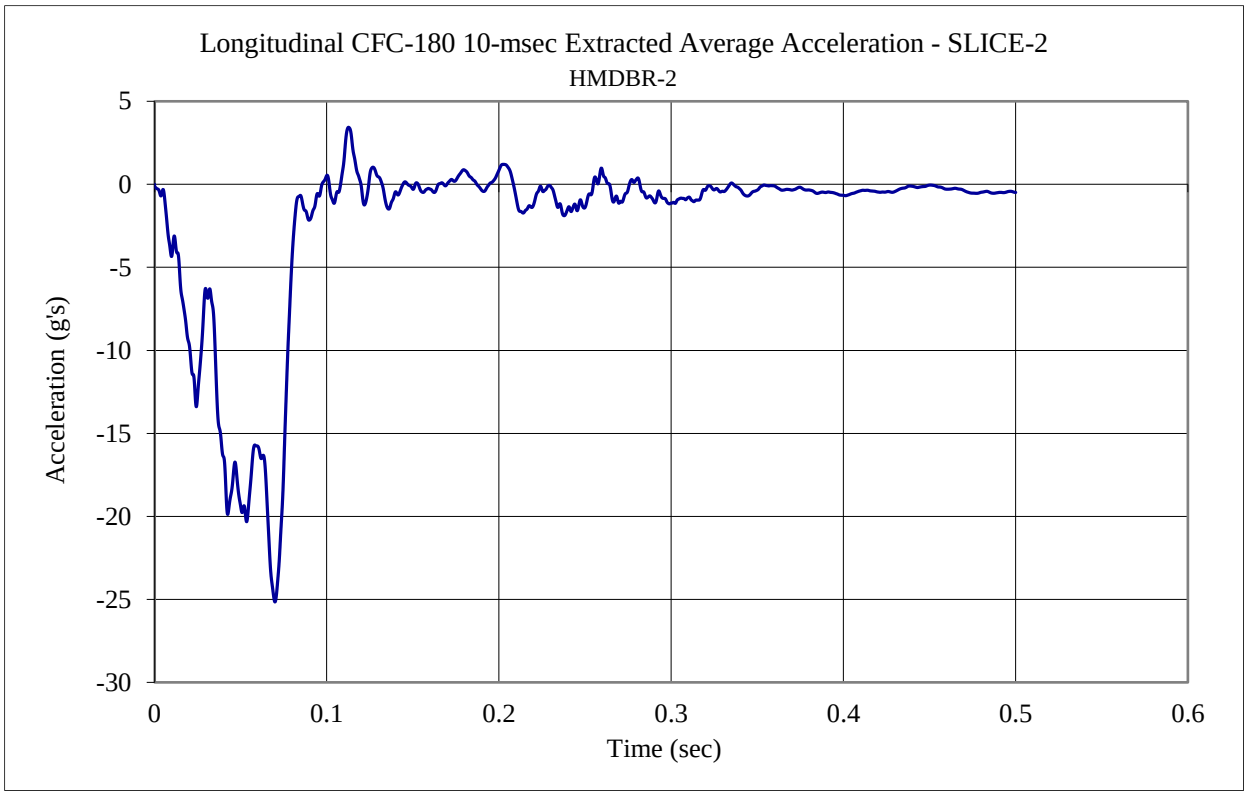


Figure G-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HMDBR-2

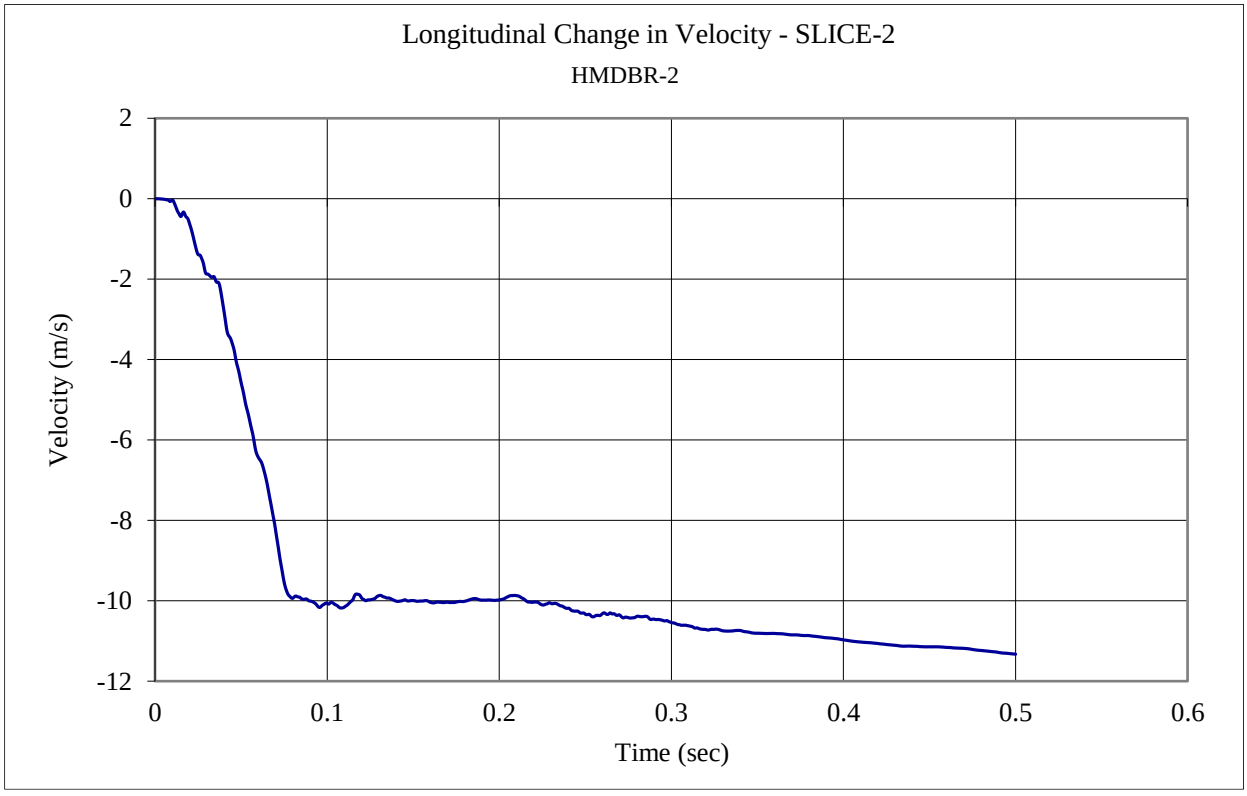


Figure G-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HMDBR-2

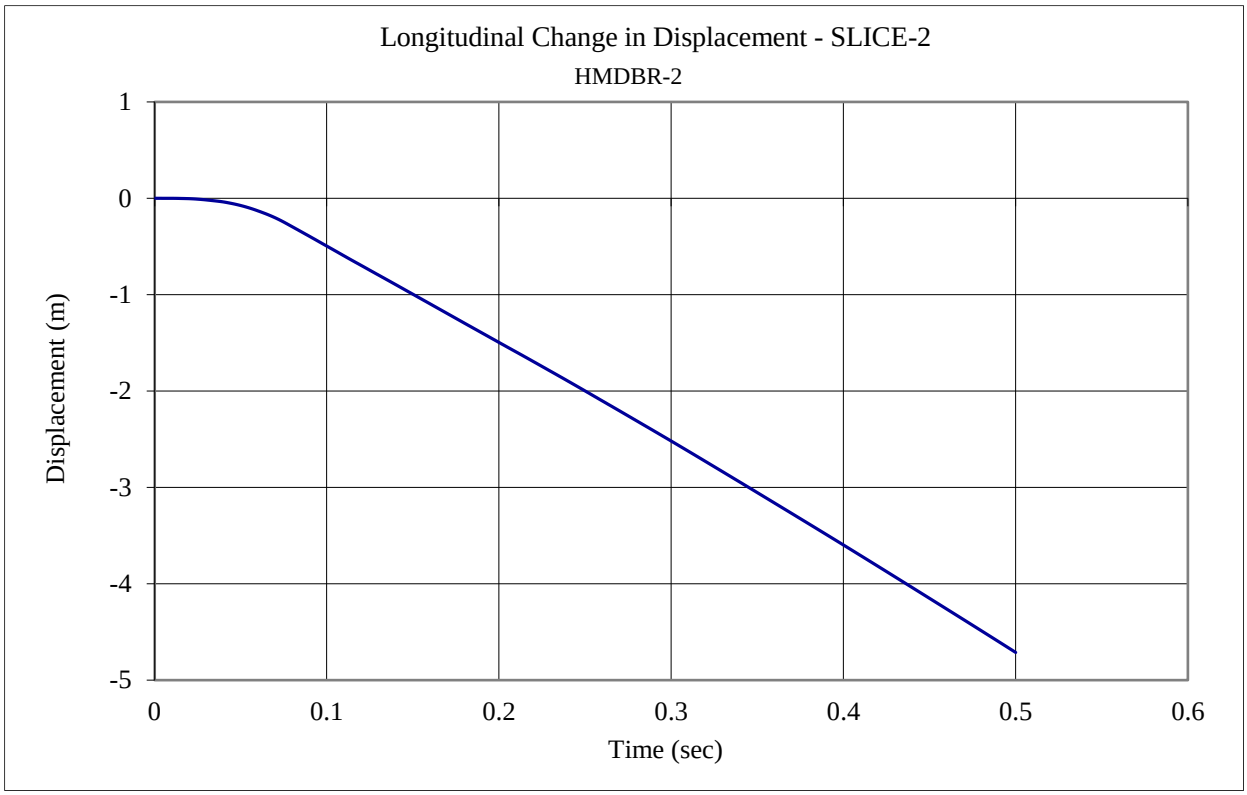


Figure G-11. Longitudinal Occupant Displacement (SLICE-2), Test No. HMDBR-2

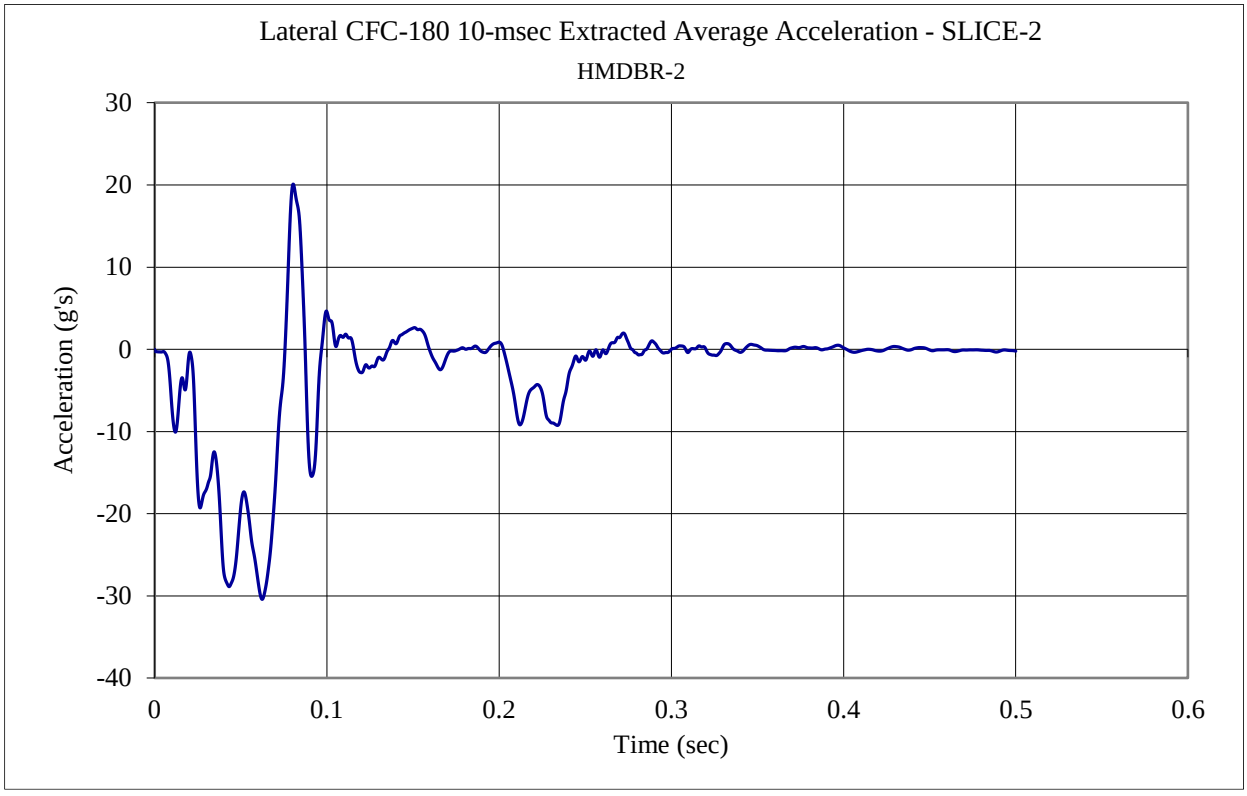


Figure G-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HMDBR-2

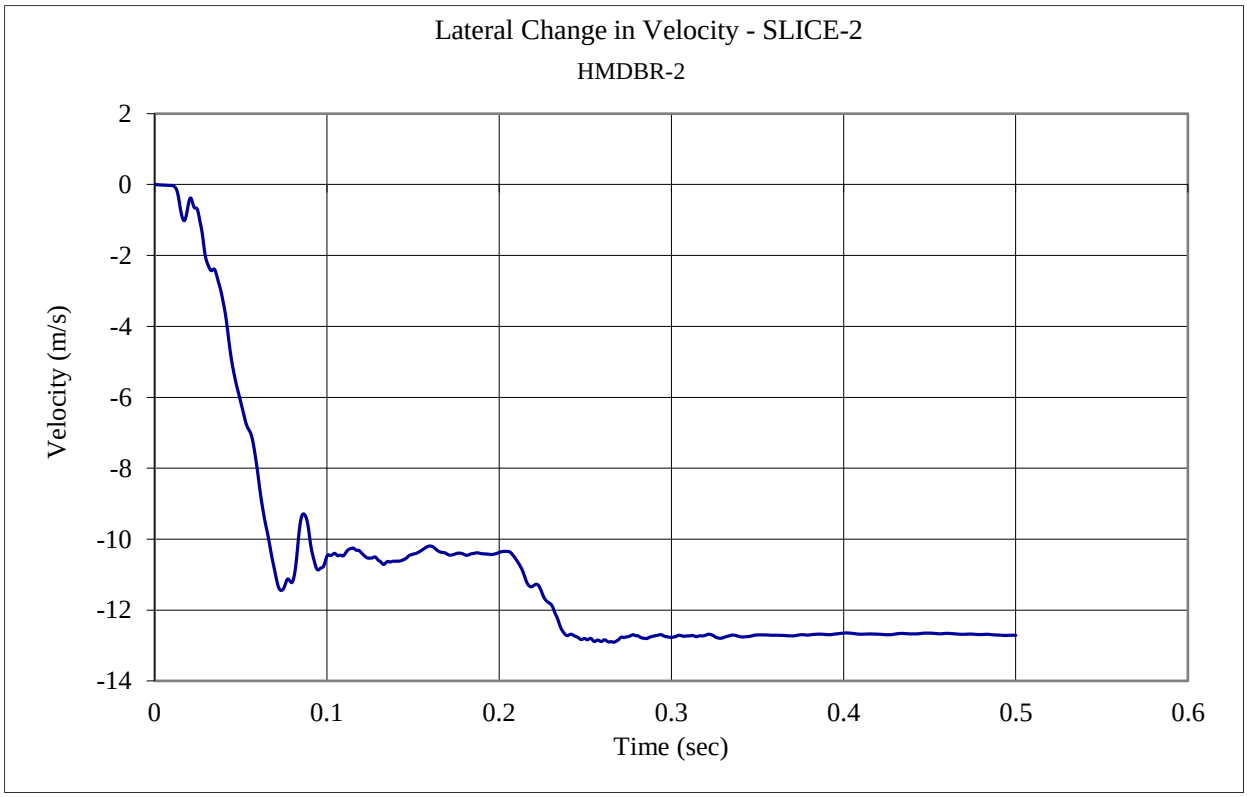


Figure G-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. HMDBR-2

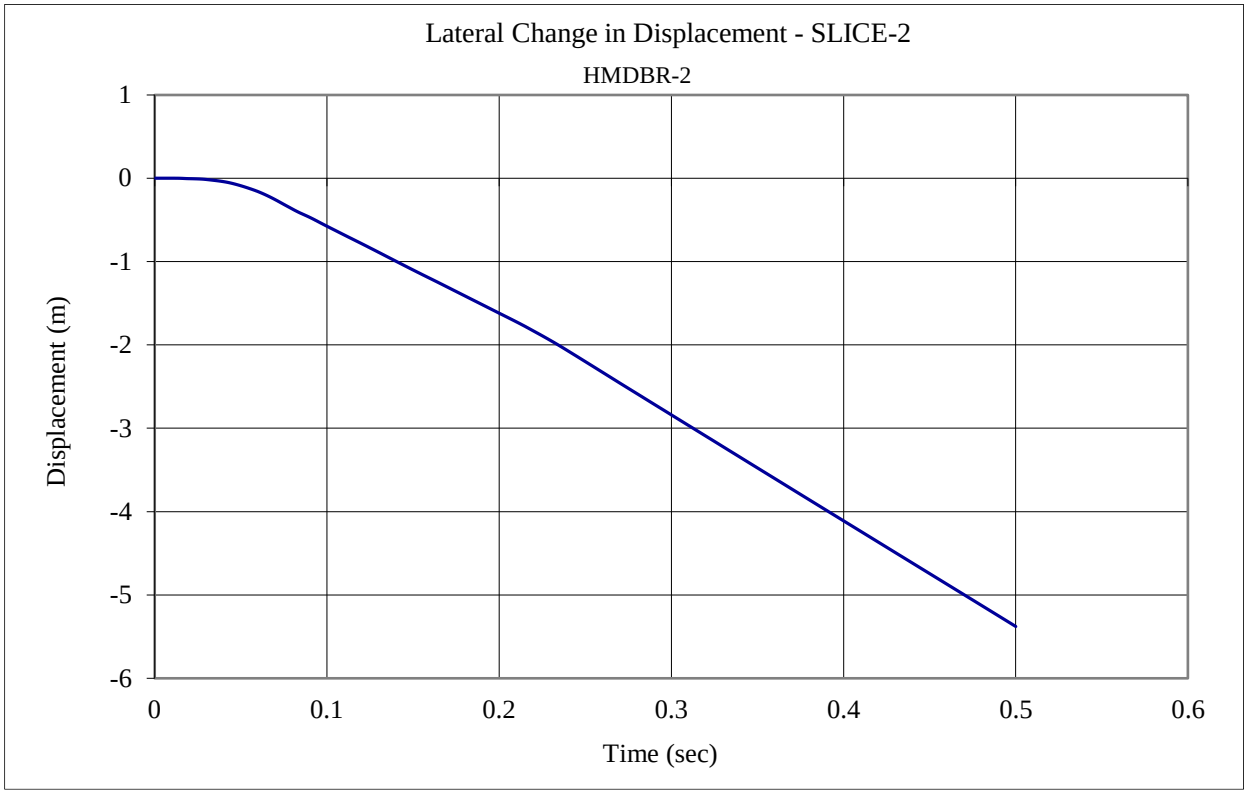


Figure G-14. Lateral Occupant Displacement (SLICE-2), Test No. HMDBR-2

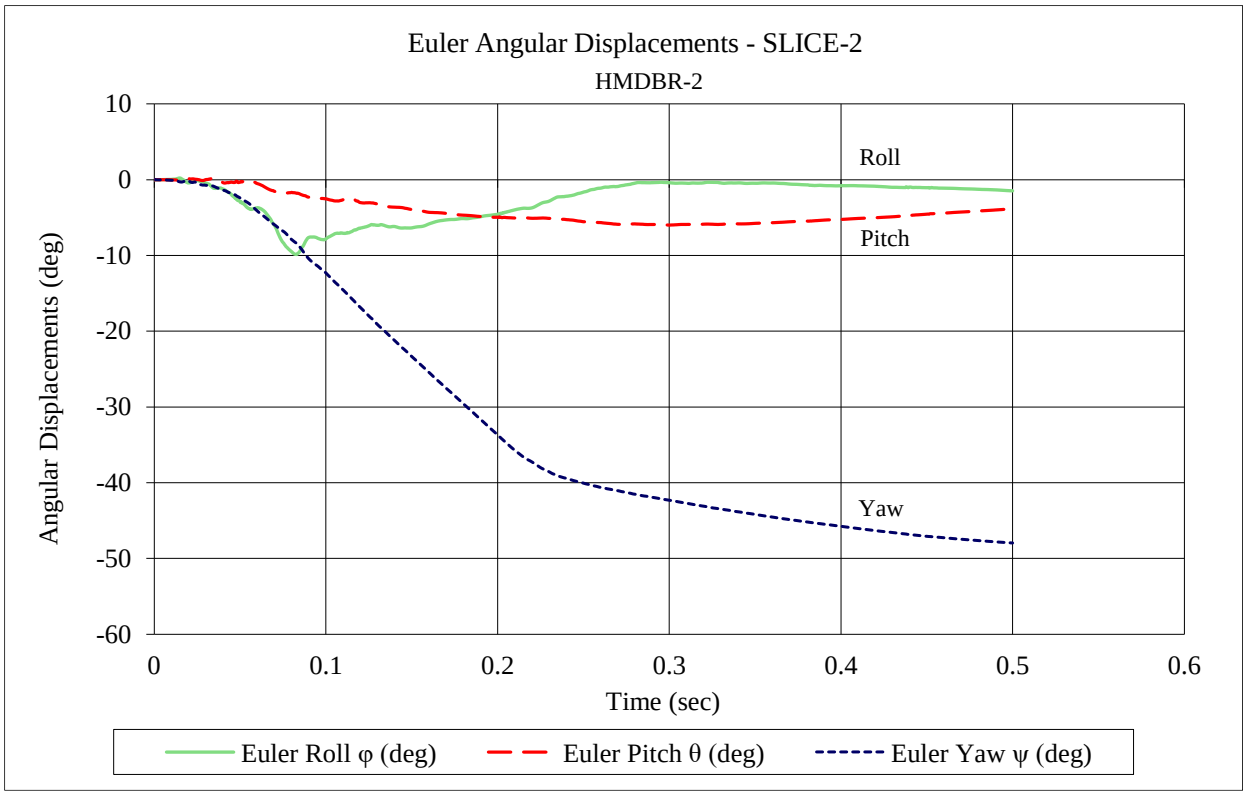


Figure G-15. Vehicle Angular Displacements (SLICE-2), Test No. HMDBR-2

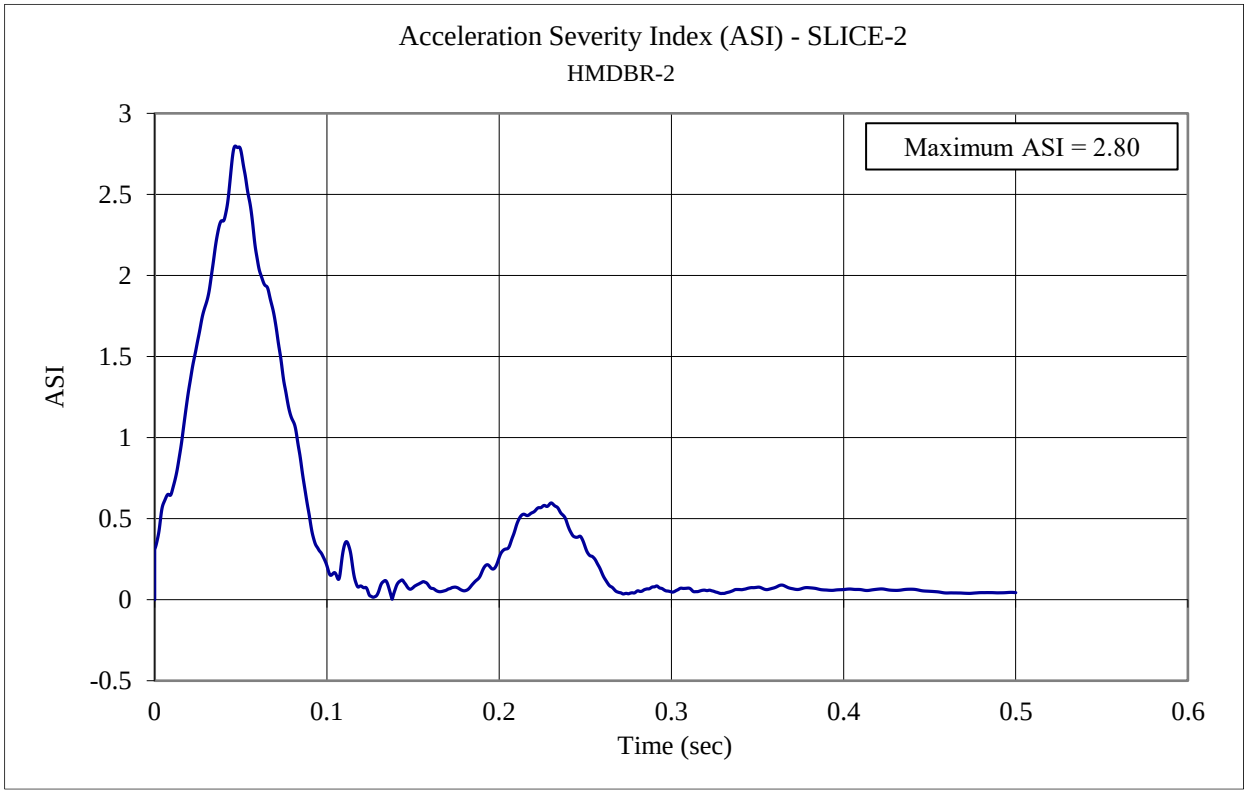


Figure G-16. Acceleration Severity Index (SLICE-2), Test No. HMDBR-2

Appendix H. Accelerometer and Rate Transducer Data Plots, Test No. HMDBR-3

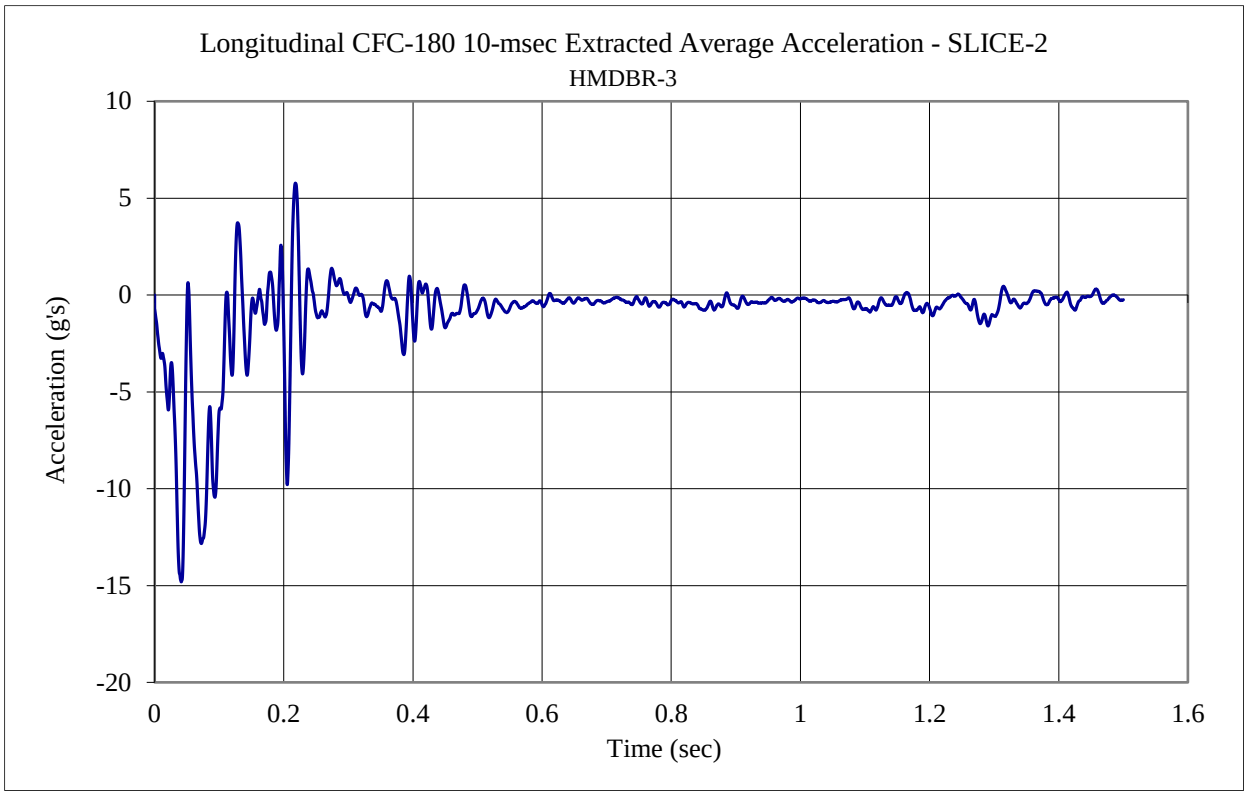


Figure H-1. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HMDBR-3

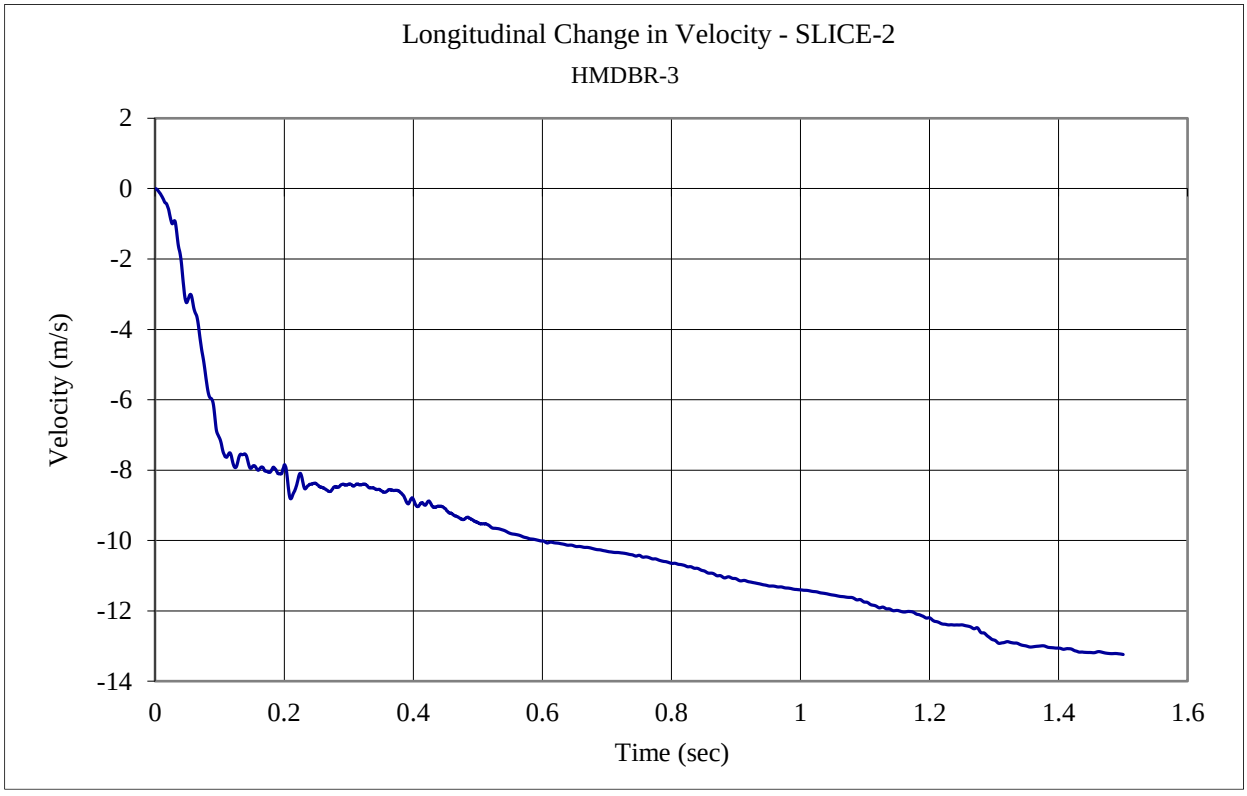


Figure H-2. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HMDBR-3

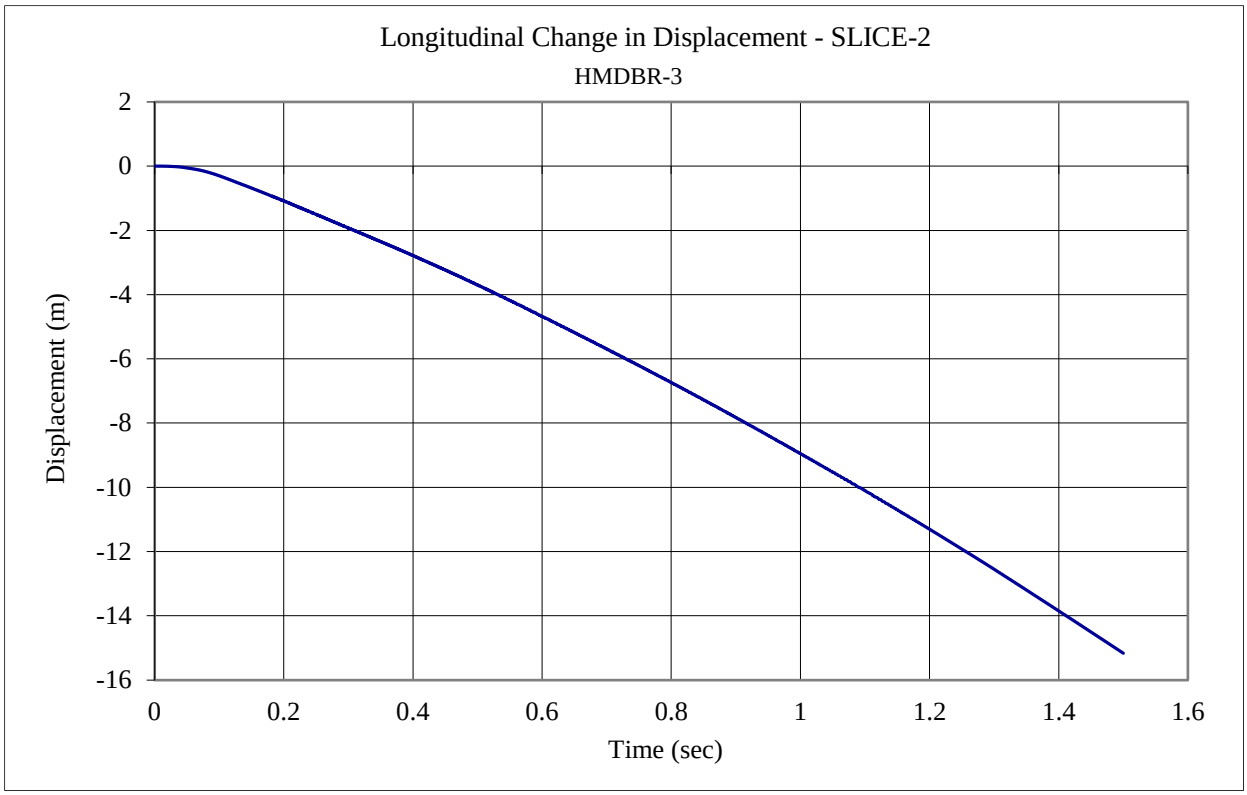


Figure H-3. Longitudinal Occupant Displacement (SLICE-2), Test No. HMDBR-3

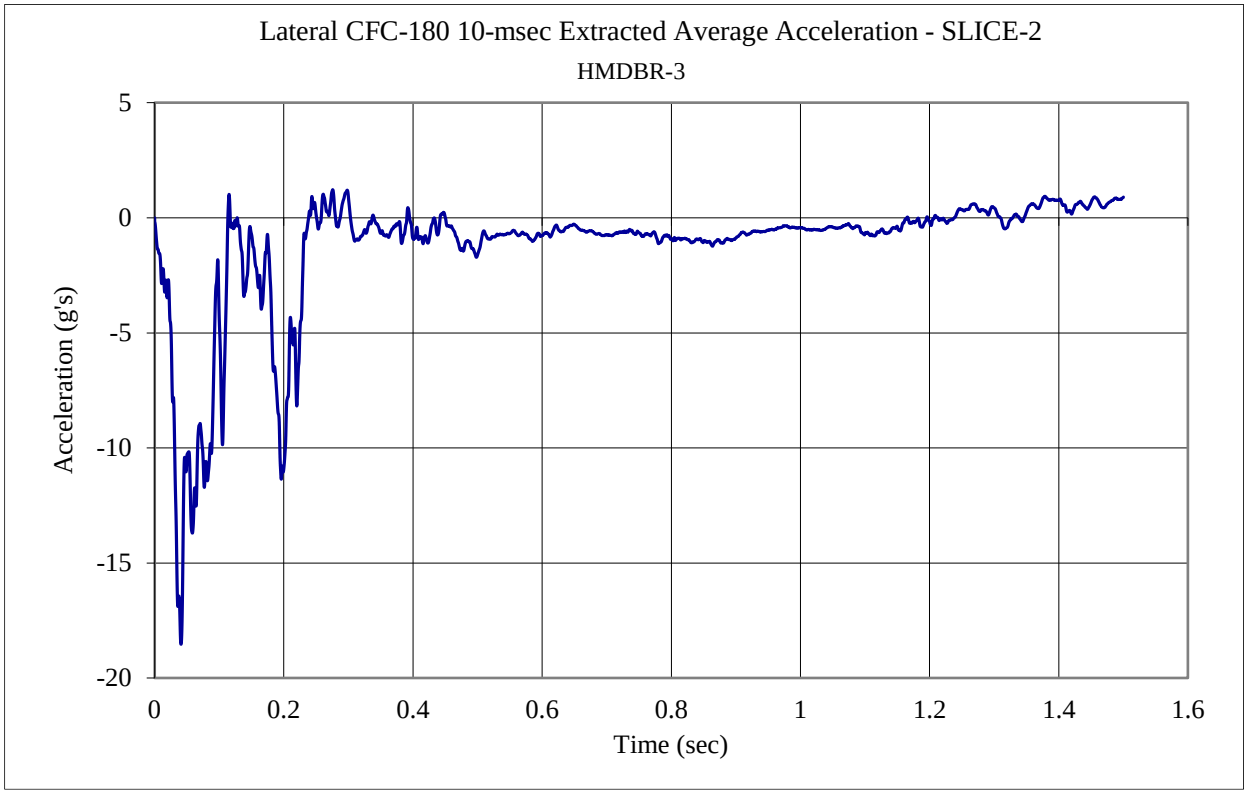


Figure H-4. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HMDBR-3

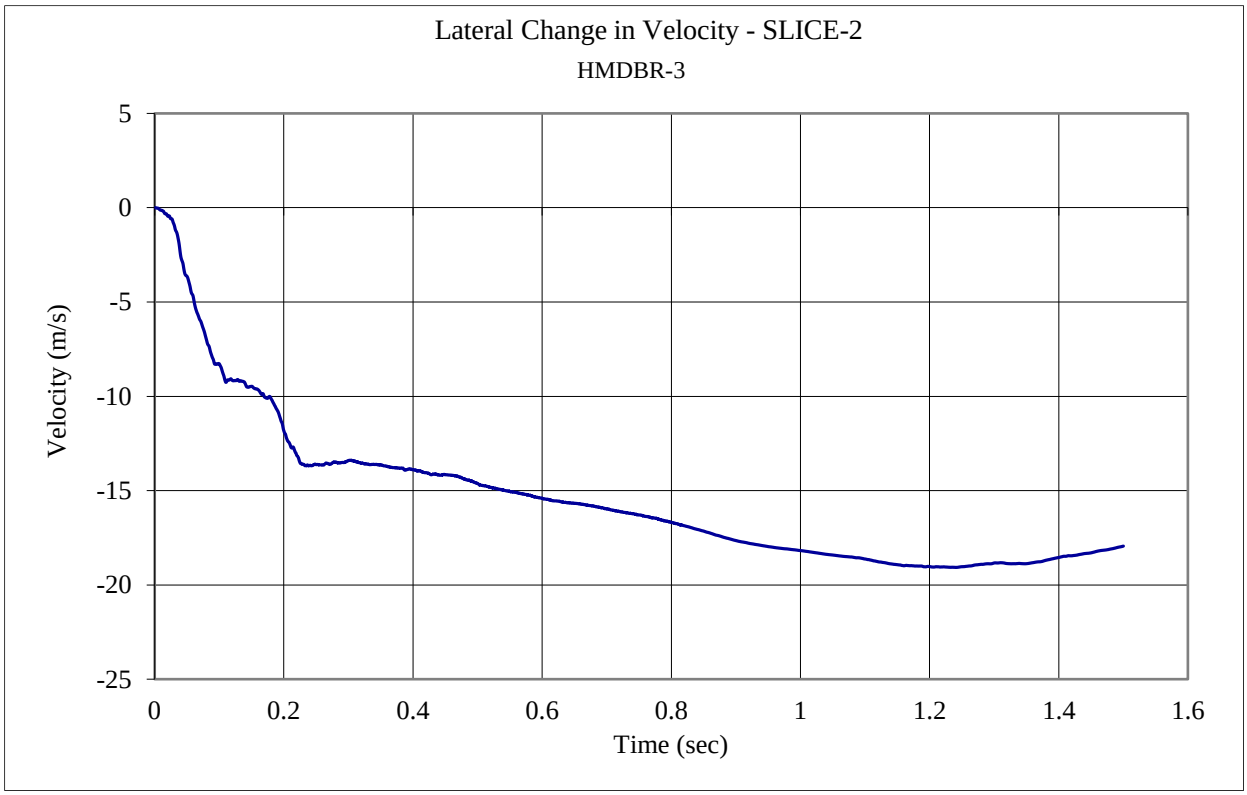


Figure H-5. Lateral Occupant Impact Velocity (SLICE-2), Test No. HMDBR-3

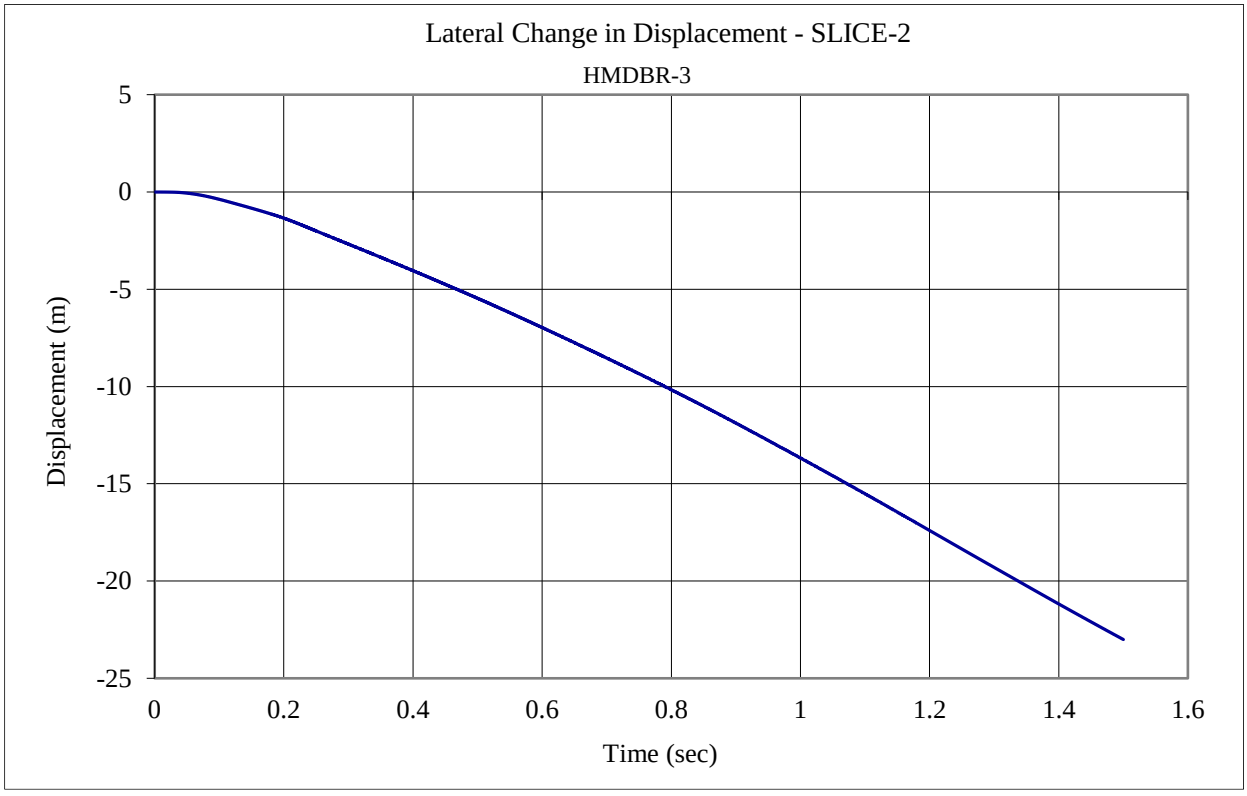


Figure H-6. Lateral Occupant Displacement (SLICE-2), Test No. HMDBR-3

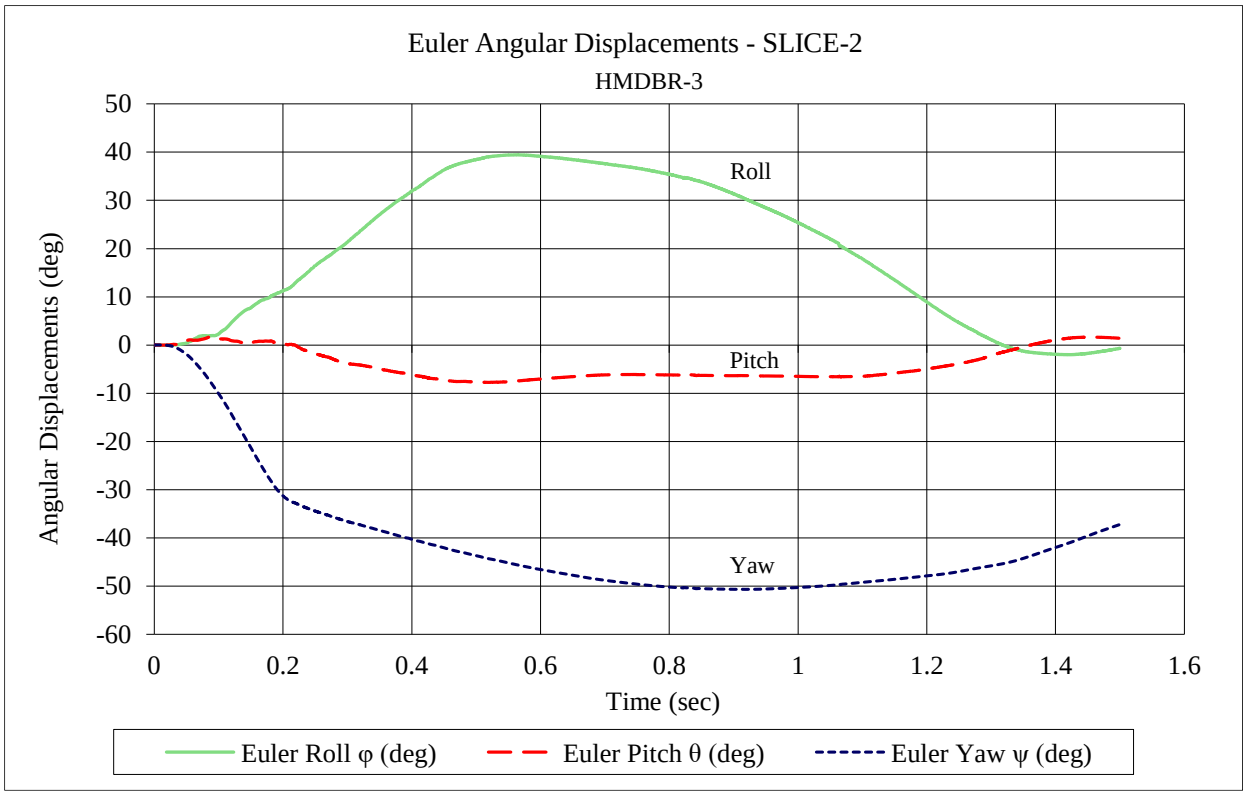


Figure H-7. Vehicle Angular Displacements (SLICE-2), Test No. HMDBR-3

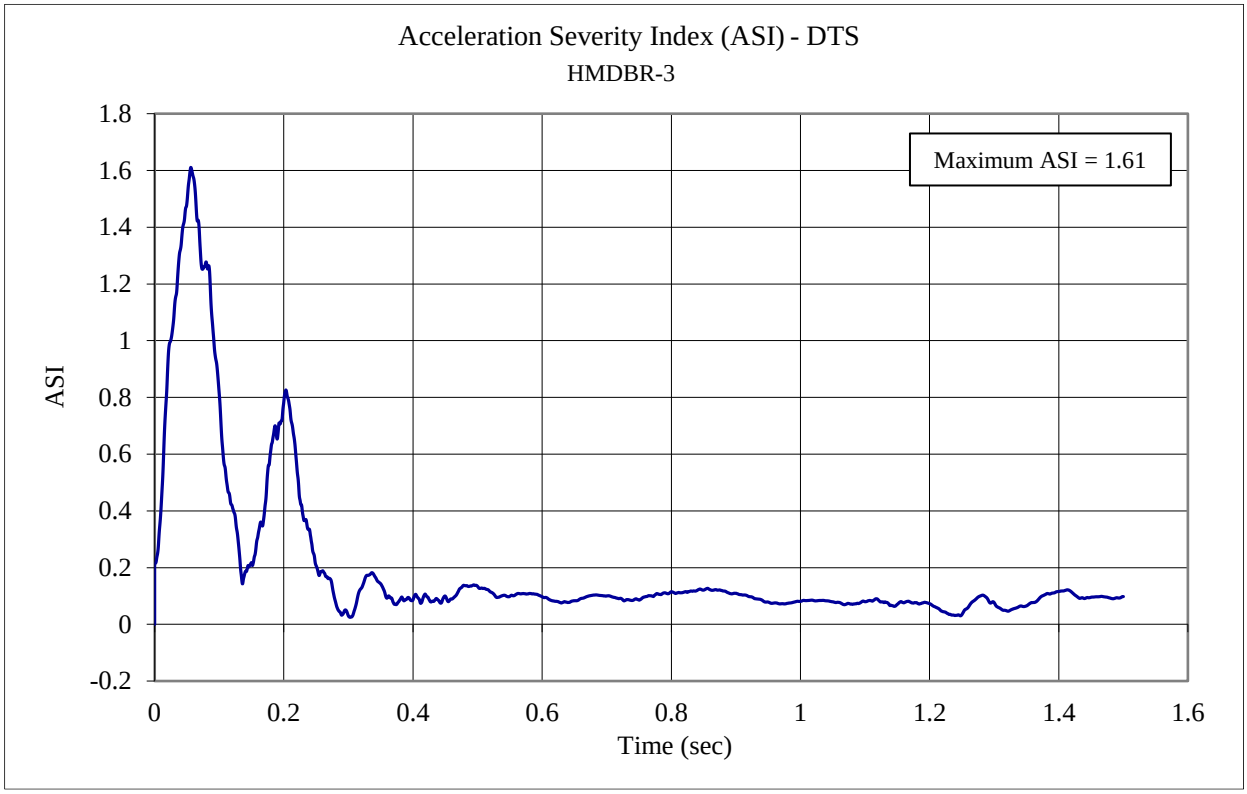


Figure H-8. Acceleration Severity Index (SLICE-2), Test No. HMDBR-3

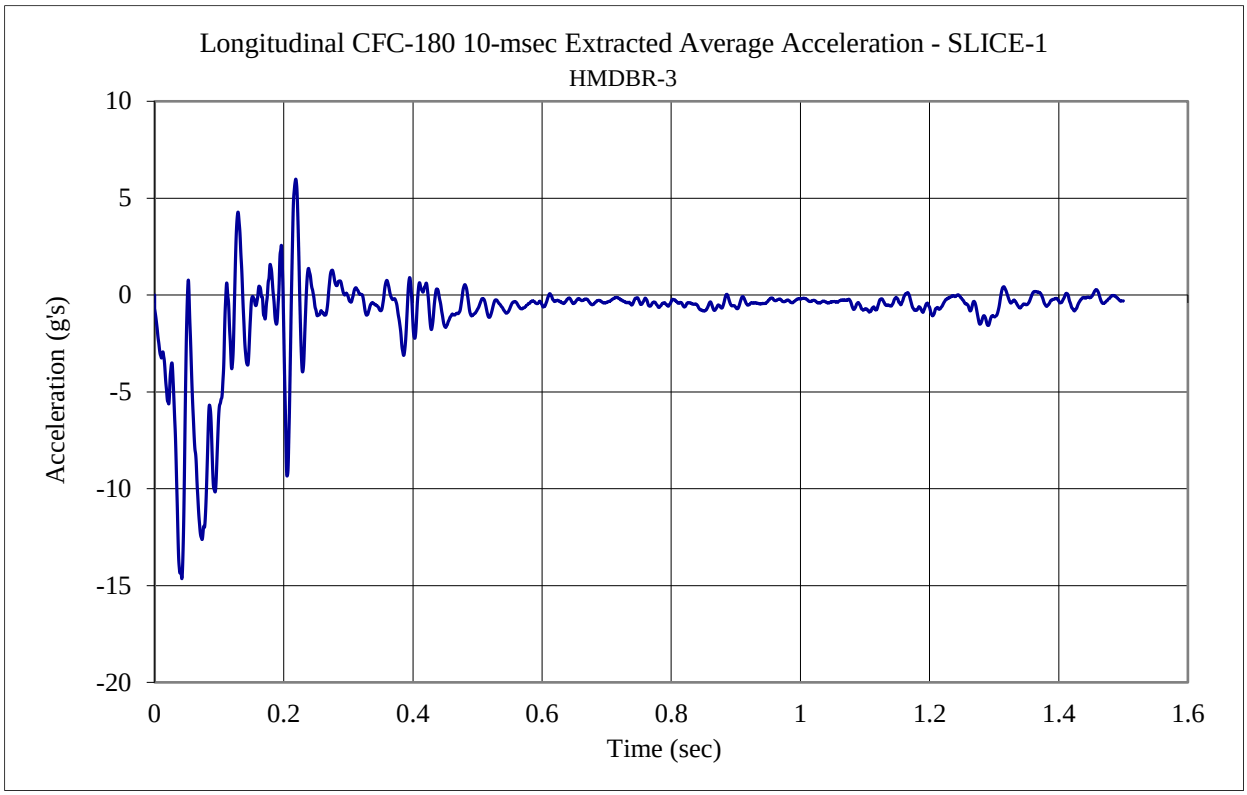


Figure H-9. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HMDBR-3

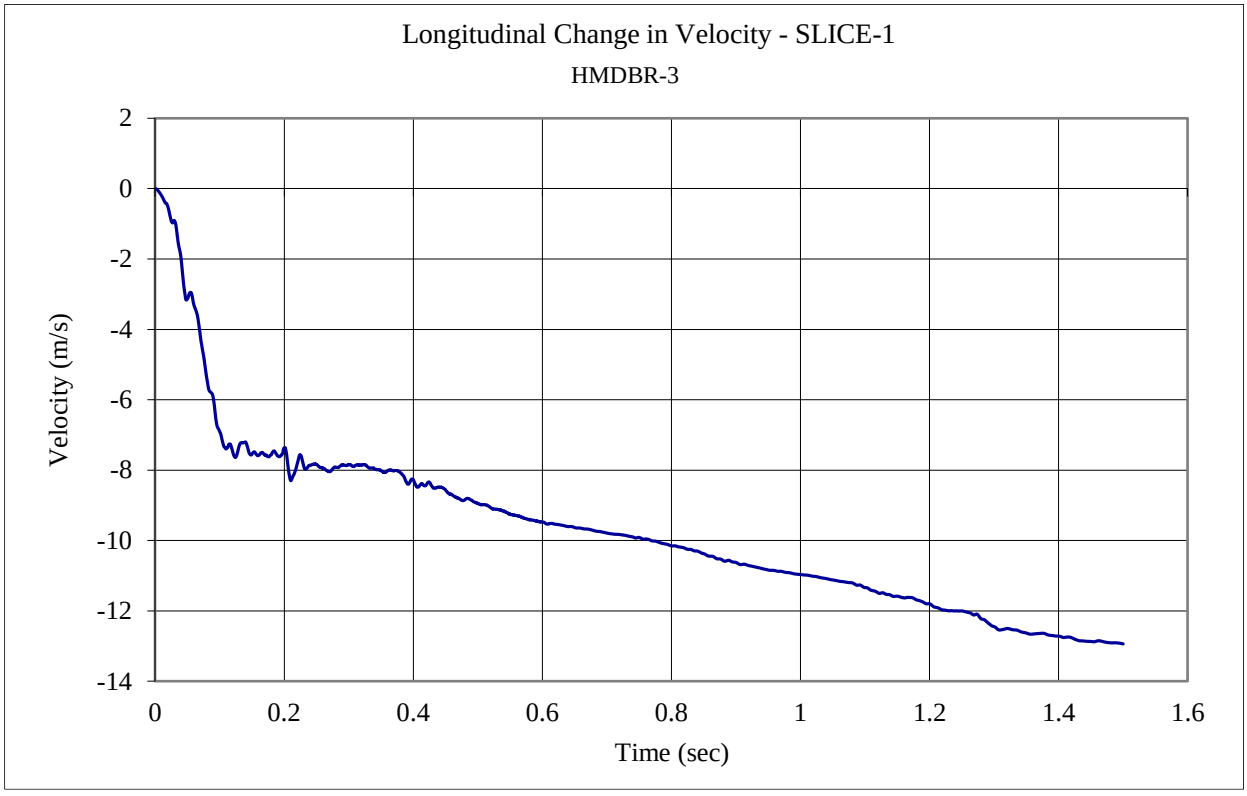


Figure H-10. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HMDBR-3

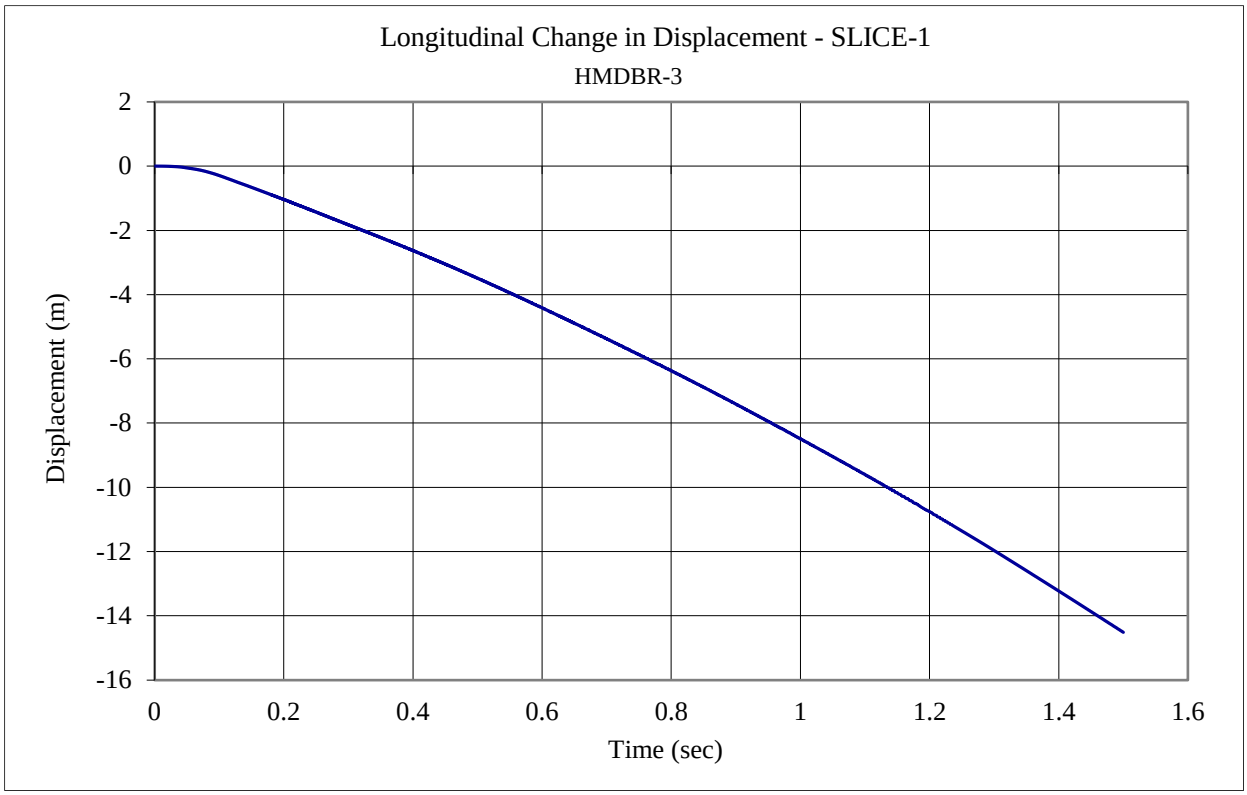


Figure H-11. Longitudinal Occupant Displacement (SLICE-1), Test No. HMDBR-3

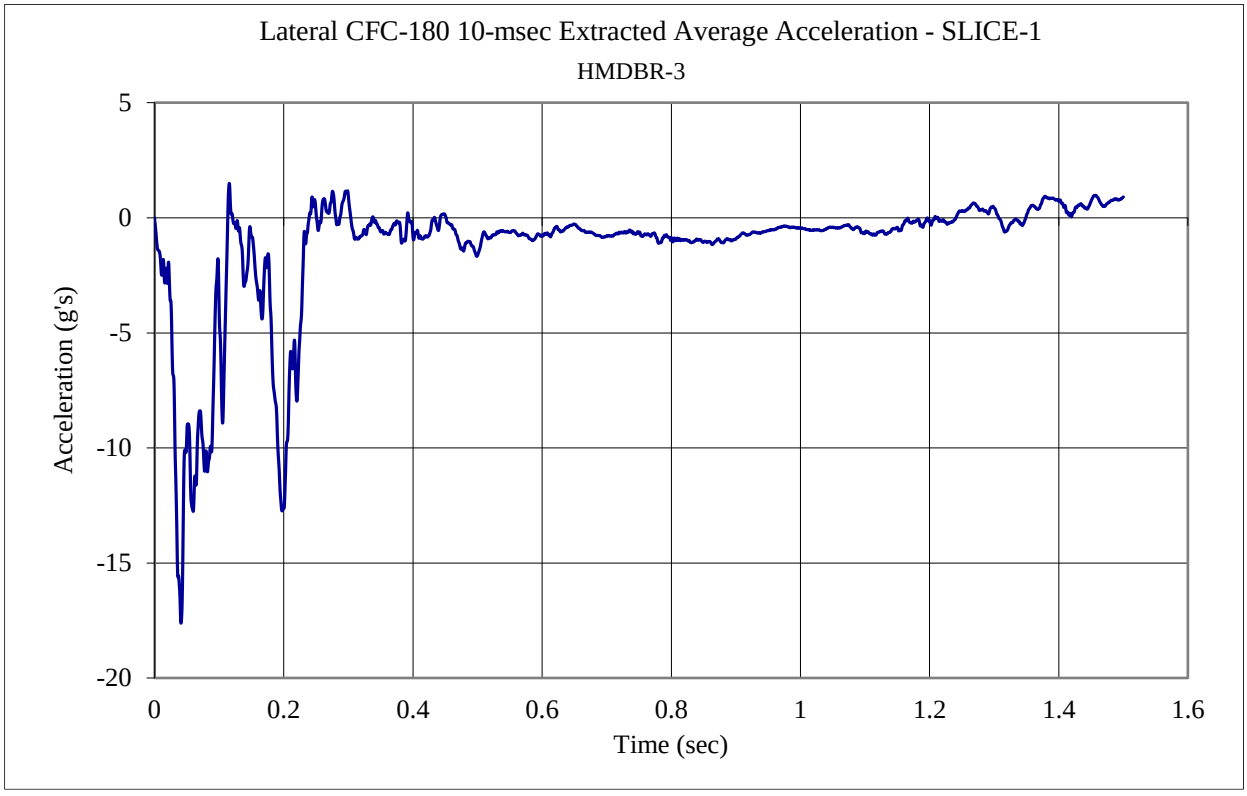


Figure H-12. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HMDBR-3

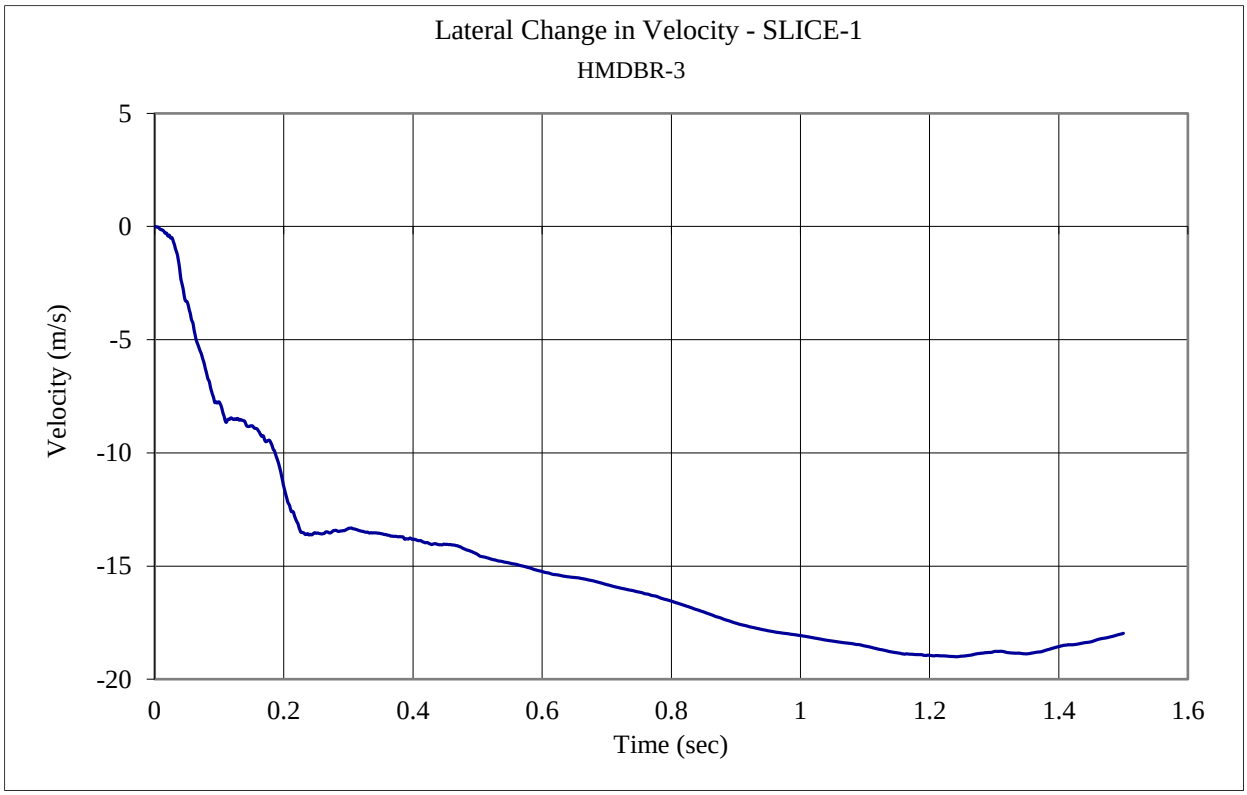


Figure H-13. Lateral Occupant Impact Velocity (SLICE-1), Test No. HMDBR-3

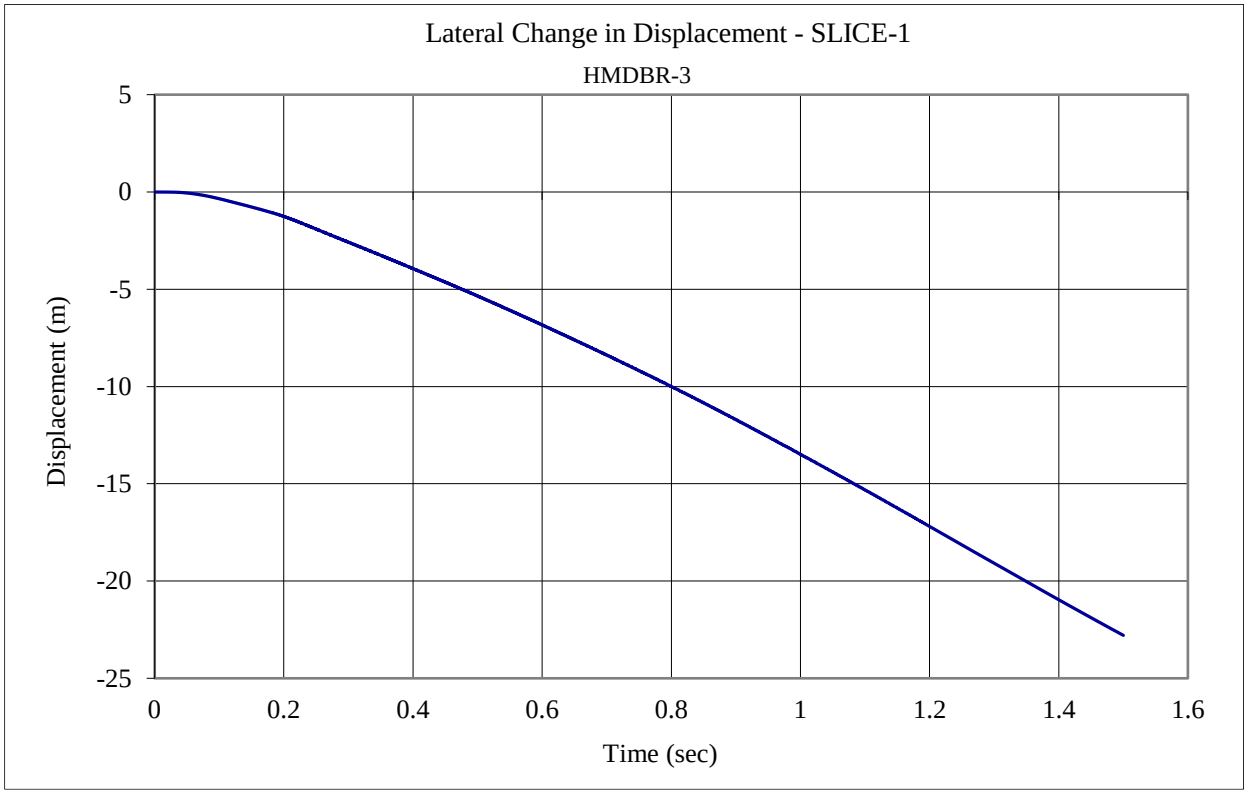


Figure H-14. Lateral Occupant Displacement (SLICE-1), Test No. HMDBR-3

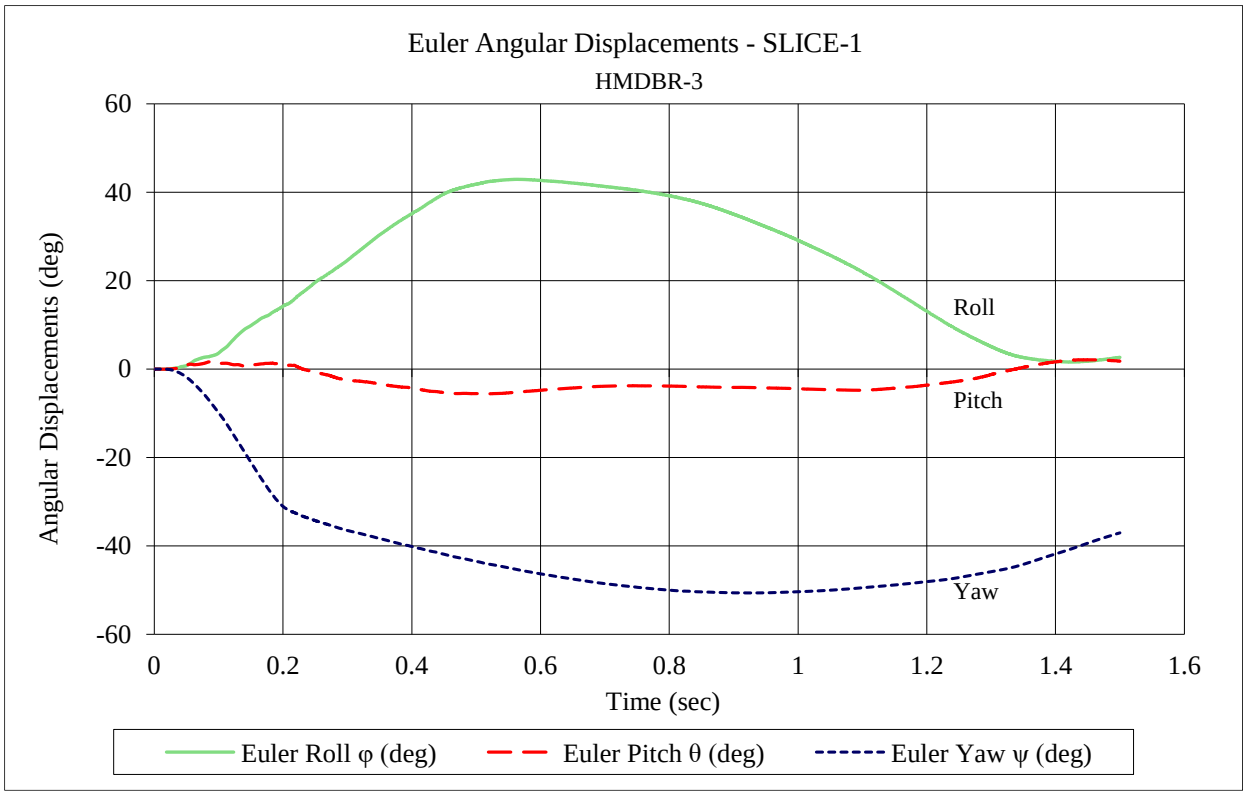


Figure H-15. Vehicle Angular Displacements (SLICE-1), Test No. HMDBR-3

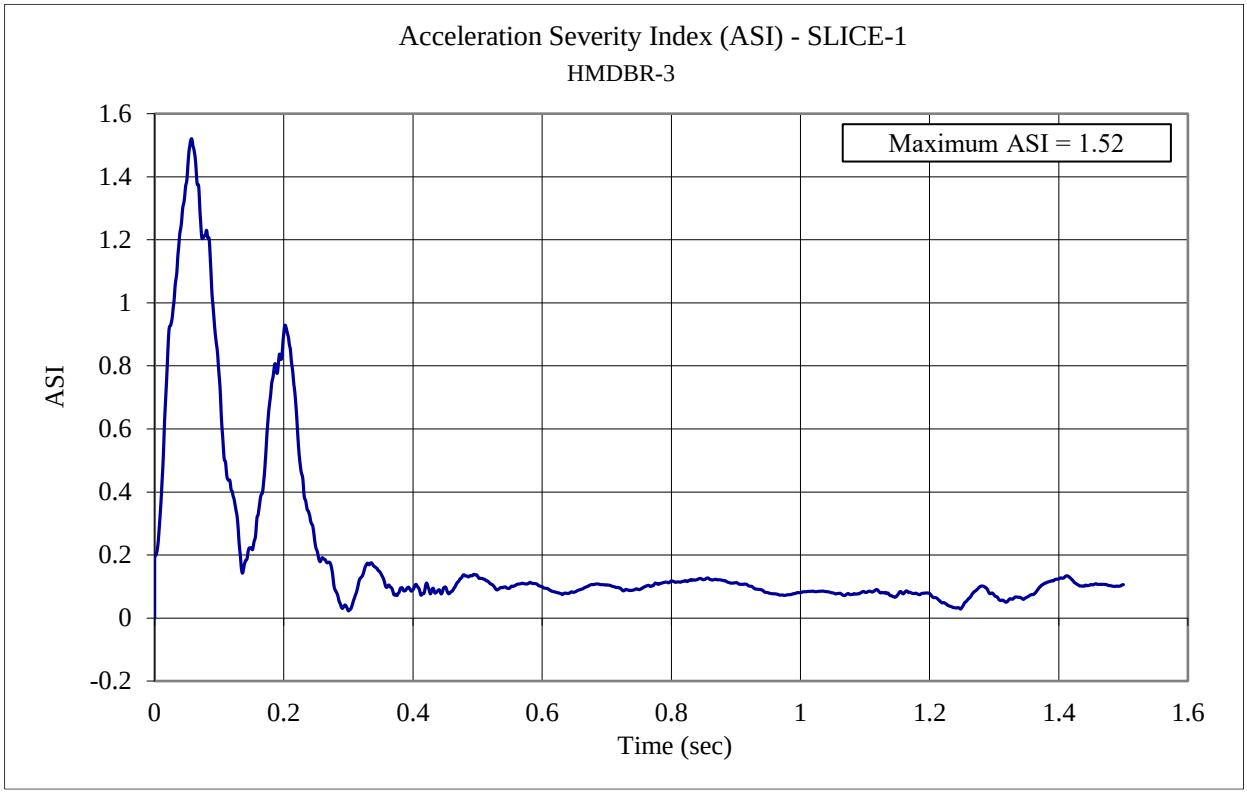


Figure H-16. Acceleration Severity Index (SLICE-1), Test No. HMDBR-3

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