Midwest Pooled Fund Research Program
Fiscal Years 2017-2020 (Years 28 through 31)
Research Project Number TPF-5(193) Supplement #120
NDOT Sponsoring Agency Code RPFP-18-MGS-1

MASH EVALUATION OF THE STEEL-POST, TRAILING-END ANCHORAGE SYSTEM

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Nebraska Department of Transportation
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MwRSF Research Report No. TRP-03-370b-20

December 17, 2020

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
TRP-03-370b-20		

4. Title and Subtitle
MASH Evaluation of the Steel-Post, Trailing-End Anchorage System

5. Report Date
December 17, 2020

6.

7. Author(s)
Lechtenberg, K.A., Asadollahi Pajouh, M., Faller, R.K., Lingenfelter, J.L., Noll, P., and Holloway, J.C.

8. Performing Organization Report No.
TRP-03-370b-20

9. Performing Organization Name and Address
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10. Work Unit No.

11. Contract
TPF-5(193) Supplement #120

12. Sponsoring Agency Name and Address
Midwest Pooled Fund Program
Nebraska Department of Transportation
1500 Nebraska Highway 2
Lincoln, Nebraska 68502

13. Type of Report and Period Covered
Final Report: 2016 – 2020

14. Sponsoring Agency Code
RPFP-18-MGS-1

15. Supplementary Notes
Prepared in cooperation with U.S. Department of Transportation, Federal Highway Administration.

16. Abstract

A research study was conducted to develop and evaluate a steel-post, trailing-end, anchorage system for the Midwest Guardrail System (MGS) as an alternative to the existing wood-post, trailing-end anchorage system with BCT posts. Following the design and development of the steel-post, trailing-end anchorage system for the MGS, two full-scale crash tests, test nos. SPTA-1 and SPTA-2, were performed according to the American Association of State Highway and Transportation Officials' (AASHTO) *Manual for Assessing Safety Hardware, Second Edition* (MASH 2016) test designation nos. 3-37a and 3-37b, respectively. The steel-post, trailing-end anchorage system included the following components: two breakaway steel posts, two steel foundation tubes, a steel compression ground line strut, one steel anchor cable, and a T-shaped, breaker bar attached to the end anchor post. In test no. SPTA-1, the 5,074-lb (2,302-kg) pickup truck impacted the MGS at a speed of 62.1 mph (99.9 km/h) and an angle of 25.0 degrees and was captured and redirected. The vehicle remained upright and stable throughout the test, and all vehicle decelerations and occupant compartment deformations were within the allowable MASH 2016 limits. In test no. SPTA-2, the 2,429-lb (1,102-kg) small car impacted the system at a speed of 63.3 mph (101.9 km/h) and an angle of 25.2 degrees near the anchorage system. The vehicle gated through the system but remained upright and stable throughout the test, and all vehicle decelerations and occupant compartment deformations were within the allowable MASH 2016 limits. The MGS with the steel-post, trailing-end anchorage system performed adequately. Therefore, test nos. SPTA-1 and SPTA-2 were determined to satisfy the safety performance criteria for MASH 2016 test designation nos. 3-37a and 3-37b, respectively. Recommendations were provided for the installation of steel-post, trailing-end anchorage system when used in combination with the MGS.

17. Key Words
Highway Safety, Crash Test, Roadside Appurtenances, Compliance Test, MASH 2016, Trailing-End Anchorage System, Guardrail, Midwest Guardrail System (MGS), Guardrail End Terminal, and Trailing-End Terminal

18. Distribution Statement
No restrictions. Document available from: National Technical Information Services, Springfield, Virginia 22161

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	302	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

DISCLAIMER STATEMENT

This material is based upon work supported by the Federal Highway Administration, U.S. Department of Transportation and the Midwest Pooled Fund Program under TPF-5(193) Supplement #120. The contents of this report reflect the views and opinions of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the University of Nebraska-Lincoln, state highway departments participating in the Midwest Pooled Fund Program, nor the Federal Highway Administration, U.S. Department of Transportation. This report does not constitute a standard, specification, or regulation. Trade or manufacturers' names, which may appear in this report, are cited only because they are considered essential to the objectives of the report. The United States (U.S.) government and the State of Nebraska do not endorse products or manufacturers.

UNCERTAINTY OF MEASUREMENT STATEMENT

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

INDEPENDENT APPROVING AUTHORITY

The Independent Approving Authority (IAA) for the data contained herein was Scott Rosenbaugh, Research Engineer

ACKNOWLEDGEMENTS

The authors wish to acknowledge several sources that made a contribution to this project: (1) the Midwest Pooled Fund Program funded by the California Department of Transportation, Florida Department of Transportation, Georgia Department of Transportation, Hawaii Department of Transportation, Illinois Department of Transportation, Indiana Department of Transportation, Iowa Department of Transportation, Kansas Department of Transportation, Kentucky Department of Transportation, Minnesota Department of Transportation, Missouri Department of Transportation, Nebraska Department of Transportation, New Jersey Department of Transportation, North Carolina Department of Transportation, Ohio Department of Transportation, South Carolina Department of Transportation, South Dakota Department of Transportation, Utah Department of Transportation, Virginia Department of Transportation, Wisconsin Department of Transportation, and Wyoming Department of Transportation for sponsoring this project; and (2) MwRSF personnel for constructing the barriers and conducting the crash tests.

Acknowledgement is also given to the following individuals who contributed to the completion of this research project.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Background

1.1.1 Wood-Post, Trailing-End Anchorage System

Most state departments of transportation use adaptations of crashworthy guardrail end terminals as trailing-end anchorage systems, which typically include breakaway posts and an anchor cable. Breakaway Cable Terminal (BCT) anchorage systems and their derivatives have often been used as an economical means of providing tensile anchorage to a W-beam guardrail system. In 2013, a non-proprietary, trailing-end anchorage system with BCT wood posts was developed by the Midwest Roadside Safety Facility (MwRSF) for use with the Midwest Guardrail System (MGS) [1-3]. This trailing-end anchorage system has been successfully crash tested and adequately met the TL-3 safety requirements set forth in the *Manual for Assessing Safety Hardware* (MASH) [4-5]. This system consisted of the following components: (1) two breakaway wood posts (BCT posts); (2) two steel foundation tubes with an attached steel soil plate; (3) a steel compression ground line strut between the two steel foundation tubes; and (4) one steel anchor cable connecting the W-beam rail to the base of the end post, as shown in Figure 1.

The two steel foundation tubes within the trailing-end anchorage system enhance the post-soil resistance by distributing the tensile load from the rail in a more homogenous manner, while allowing for easier wood post replacement if fractured. The soil resistance can be further increased by attaching vertical steel bearing plates (soil plates) to the foundation tubes, which increases the area of the tube that is exposed to the soil. A compression ground line strut between the two foundation tubes is used to maximize the soil resistance by coupling the two foundation tubes [6]. For common crashworthy guardrail end terminals, steel anchor cables have been used to develop the tensile strength of the rail for impacts occurring beyond the length-of-need (LON) of the barrier. For the downstream end of longitudinal guardrail systems, the end of the LON has been previously defined as a downstream critical impact point (CIP) at which the end anchorage system would no longer redirect an errant vehicle but instead gate and permit the vehicle to encroach behind the system [1-3]. In crashworthy guardrail end terminals, one end of the cable is anchored to the base of the upstream end post and foundation tube near the ground line. The other end of the cable is connected to the back of the rail near the second post using a steel mounting bracket and is designed to quickly release away from the rail during end-on impact events.

A second trailing-end anchorage system was developed for the Texas Department of Transportation (TxDOT) [7]. The TxDOT end anchorage system also utilized two BCT wood posts embedded into steel foundation tubes along with a cable anchor and two C3x5 channel sections that connect the two foundation tubes to one another, as shown in Figure 2. The W-beam rail was supported at the downstream end post with a steel, shelf-angle bracket. Texas A&M Transportation Institute researchers conducted one full-scale, reverse-direction, crash test using an 1100C small car to evaluate the safety performance of the trailing-end anchorage system. This end anchorage system was successfully crash tested in combination with a 31-in. (787-mm) tall, 8-in. (203-mm) blocked MGS under MASH 2009 [4] modified test designation no. 3-37 conditions, later defined as test designation no. 3-37b conditions in MASH 2016 [5].

Figure 1. MGS Trailing-End Anchorage System [1-3]

Figure 2. TxDOT Trailing-End Anchorage System [7]

In both the MwRSF and TTI wood-post, trailing-end anchorage systems, the two BCT wood posts were designed to break away in a controlled manner, allowing an impacting vehicle to pass through the barrier without a sudden deceleration or rapid change in trajectory. This release behavior minimized the risk of vehicle rollover and/or snag on the cable anchorage system during near-end impact events.

Wood has historically been selected for use in breakaway posts due to it being readily available, relatively low cost, its brittle fracture behavior, and its ability to control load duration and fracture energy with holes drilled through the post at the ground level. However, wood posts also have notable drawbacks. First, the structural properties and performance of graded wood posts can still vary due to the presence of small knots, checks, and splits, thus often requiring enhanced grading and inspection. Second, the breakaway holes drilled near the ground line of BCT posts expose the interior of the wood post to the environment, which may accelerate deterioration. Further, the chemical preservatives used to treat the breakaway wood posts have been deemed harmful to the environment by some government agencies. Thus, treated wood posts may require special disposal considerations.

Due to these concerns, a critical need existed for a non-wood, trailing-end anchorage for W-beam guardrail systems, and this motivated the development of a new, steel-post, trailing-end anchorage system for use with the MGS.

1.1.2 Universal Steel Breakaway Post Development

In 2010, MwRSF developed the UBSP with fracturing bolts as a replacement for timber controlled-release terminal (CRT) posts used in the thrie beam bullnose system [8]. The UBSP was designed to break away under lateral load when applied bending moment at the base plate connection causes tensile fracture of the four vertical bolts. The UBSP consisted of an ASTM A36 W6x8.5 top section, and a 6-in. x 8-in. x $^{3}/_{16}$-in. (152-mm x 203-mm x 4.8-mm) ASTM A500 Grade B steel tube bottom section, as shown in Figure 3. The two post sections were welded to the base plates and connected by four $^{7}/_{16}$-in. (11-mm) diameter, ASTM A325 hex-head bolts. Different strong- and weak-axis capacities were generated by altering the spacing of the base plate connection bolts. During the development of the UBSP, three successful full-scale crash tests were performed on the thrie beam bullnose barrier with UBSPs according to the TL-3 criteria provided in NCHRP Report No. 350 [8-9]. The satisfactory crash performance of UBSPs demonstrated that the UBSP was a suitable alternative for the wood CRT posts used in the original thrie beam bullnose system.

In another research study involving component testing of UBSPs, the average strong- and weak-axis peak forces for the UBSP were found to be 14.6 kips and 7.9 kips (64.9 kN and 35.1 kN), respectively, comparable to the performance of the CRT posts [10]. Thus, it was concluded that the use of the modified UBSP could be expanded to other systems with CRT posts. Although the UBSP was designed to replace CRT posts, BCT posts have an identical material, similar cross section, and weakening holes placed at and/or near the ground line. Thus, it was believed that the UBSP could be adapted for use in BCT post applications and offer similar performance.

Figure 3. UBSP Utilized in Thrie Beam Bullnose System [8]

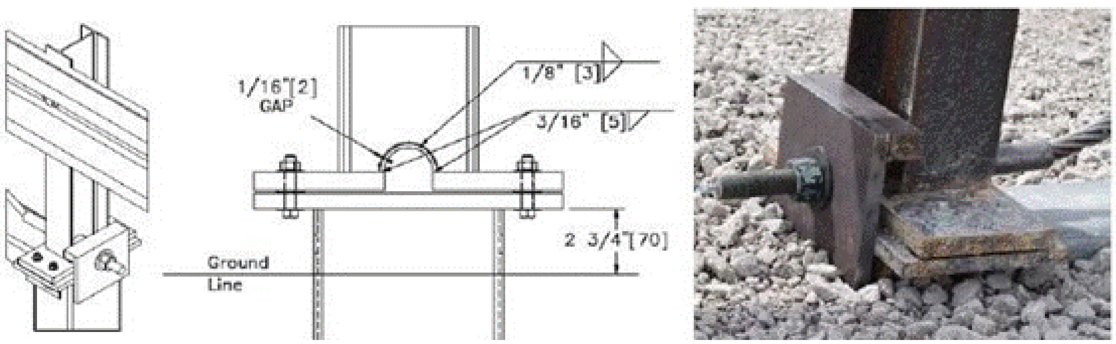
1.1.3 Steel-Post, Trailing-End Anchorage Concept Design Development

In 2016, an MwRSF research project was initiated by the Midwest Pooled Fund Program to develop a prototype for a non-proprietary, steel-post, trailing-end anchorage system [11]. This project consisted of a literature review of current end anchorage systems and a review of patents associated with end terminal posts and guardrail anchorages. The literature review and initial engineering analysis revealed that a modification of the Universal Breakaway Steel Post (UBSP) [8] could be a viable option to replicate the breakaway performance of the BCT wood posts.

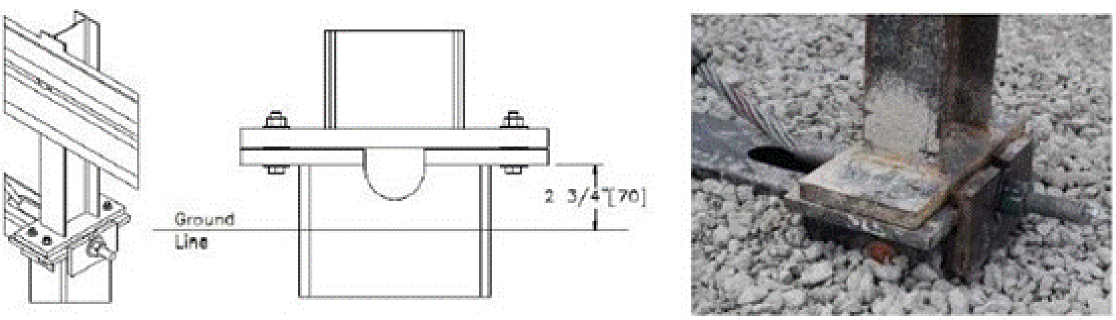
Three design concepts were developed for the steel-post, trailing-end anchorage system [11], all of which incorporated a modified UBSP and used the same cable anchorage and ground line strut hardware as the existing, trailing-end anchorage system, as shown in Figure 4.

Figure 4. Steel-Post, Trailing-End Anchorage System Prototype

The three design concepts differed primarily in how the anchorage cable was secured to the end post. Concept no. 1 passed the cable through the bottom of the top W6x8.5 steel post, concept no. 2 passed the cable through the top of the foundation tube, and concept no. 3 passed the cable through an angled plate welded to the foundation tube, as shown in Figure 5. Several dynamic bogie pull tests were conducted to evaluate the impact performance of the steel-post anchorage system concepts. Based on results from the initial bogie testing, concept nos. 1 and 3 were modified for improved anchorage capacity. Concept no. 4 was based on concept no. 1 with a raised bearing plate height. Concept no. 5 was based on concept no. 3 with a modified bearing plate angle and the introduction of a brass keeper rod. The results from the dynamic component testing program demonstrated that concept nos. 2, 4, and 5 developed sufficient tensile strength, and would perform adequately for impacts at the guardrail system's LON while providing the desired breakaway performance.



(a)



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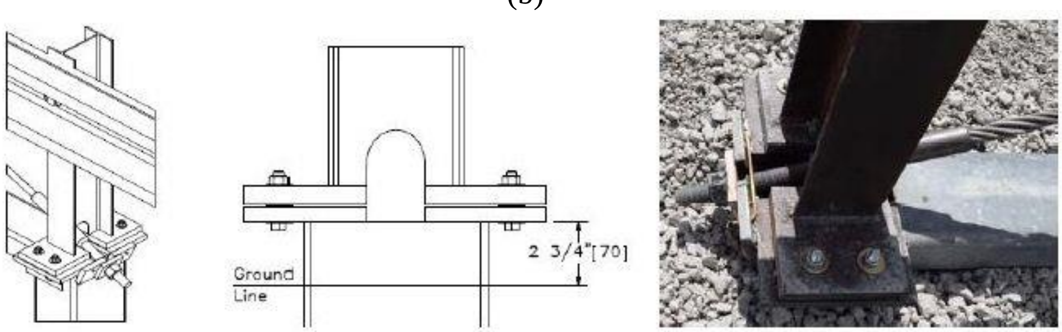


(c)

Figure 5. Candidate Design Concepts: (a) Concept Nos. 1&4 – Cable Through Upper Post, (b) Concept No. 2 – Cable Through Foundation Tube, and (c) Concept Nos. 3&5 – Anchor Cable Through Foundation Tube with Angled Bearing Plate

Design concept nos. 1 and 4 pass the cable through a welded base plate and a vertical slot at the bottom of the steel W6x8.5 post, as shown in Figure 5a, allowing the cable to release when the post disengages from the foundation tube. Design concept no. 2 included a slot in the foundation tube that forms the lower post and an opening in the bottom plate to facilitate the cable release, as shown in Figure 5b. Design concept nos. 3 and 5 were similar to design concept no. 2, but used an angled bearing plate welded to the foundation tube to restrain the cable, as shown in Figure 5c. Design concept no. 5 added a brass keeper rod to better anchor the bearing plate. The peak tensile force, energy, and overall behavior of breakaway post concept nos. 2, 4, and 5, as documented in the component tests, were compared with the component test results from the wood-post, trailing-end anchorage system, as presented in Table 1. Design concept no. 2 generated 25% more peak force and design concept nos. 4 and 5 developed 40% more peak force as compared to the wood-post trailing-end anchorage system. All of the steel-post anchor design concepts showed the ability to cleanly breakaway and release the cable during the component testing.

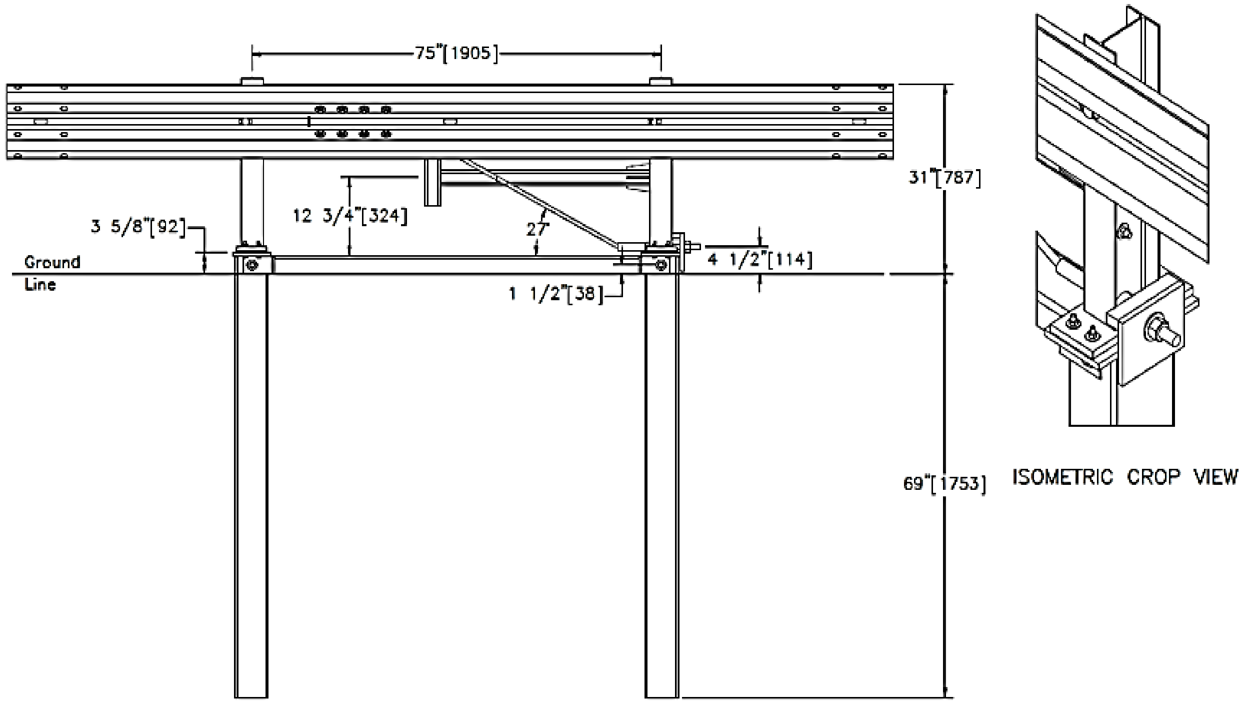
Table 1. Performance Comparison of Steel-Post, Trailing-End Design Concepts and Wood-Post Trailing-End Anchorage System [11]

Performance Criteria	**Steel-Post Design Concepts**			**Wood Post Trailing-End Anchorage**
	No. 2	**No. 4**	**No. 5**	
Peak Tensile Force, kips (kN)	44.0 (195.7)	49.5 (220.2)	49.4 (219.7)	35.0 (155.7)
Energy Dissipated at Peak Force kip-in. (kN-m)	49.6 (5.6)	50.6 (5.7)	81.2 (9.2)	16.8 (1.9)
Breakaway Behavior	Yes	Yes	N/A*	Yes
Anchor Cable Release	Yes	Yes	N/A*	Yes

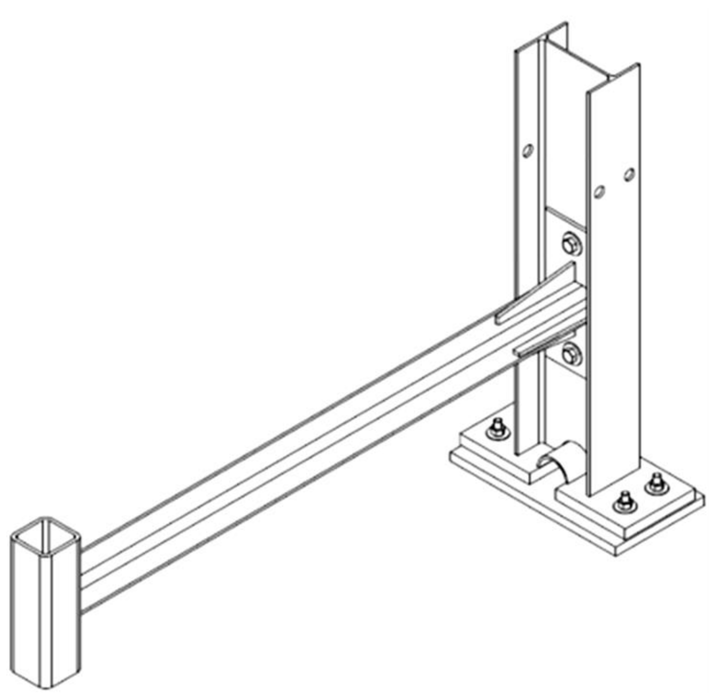
* Anchor cable broke at load exceeding tensile strength

1.1.4 Steel-Post, Trailing-End Anchorage Final Design Development

The design and performance details of concept nos. 2, 4, and 5 were presented to the Midwest Pooled Fund Program member states. Member states gave input on a preferred final concept for full scale crash testing. Based on this input, a modified version of concept no. 4, as shown in Figure 6, was selected as the final design for use in full-scale vehicle crash testing. Modifications to the system included the addition of a T-shaped, breaker bar assembly attached to the end anchor post to facilitate the release and rotation of the end post as well as the subsequent release of the cable anchor for impacts occurring upstream from the anchor post. The T-shaped, breaker bar assembly was bolted to the web of the upper end post stub to ensure a controlled release of the anchor as well as reduce the potential for vehicle instability and/or unacceptable ridedown decelerations.



(a)



(b)

Figure 6. Final Design Concept for Steel-Post, MGS Trailing-End Anchorage System (a) Design Concept No. 4 and (b) T-Shaped Breaker Bar Design

Another modification involved reconfiguring the ground line strut that connected the two foundation tubes. For field installations of the MGS wood-post, trailing-end anchorage system, the ground line strut can be installed before or after the installation of the two breakaway wood posts. For the current prototypes of the steel-post, trailing-end anchorage system, the steel base plates are welded to the top and bottom ends of the adjoining sections, making installation of the ground line strut difficult. Therefore, modifications were necessary to facilitate the ground line strut installation procedure. A total of four ground line strut design concepts were developed, as shown in Figure 7, including:

(1) Bolted yoke placed outside strut, in which two 17-in. x 3-in. x ¼-in. (432-mm x 76-mm x 6-mm) ASTM A36, bent steel plates were placed outside of a 66½-in. x 11¾-in. x 10-gauge (1,689-mm x 298-mm x 3.4-mm) ASTM A36 steel C-channel (C6x8.2) and bolted to the strut using one 7/8-in. diameter, 8½-in. long hex-head bolt at each end, as shown in Figure 7a. At the location of the anchor and second posts, a 17-in. x 2¾-in. x ½-in. (432-mm x 76- mm x 6-mm) steel bent plate was placed outside of the strut and bolted to the strut using one 7/8-in. diameter, 8½-in. long hex head bolt. The steel bent plate was bolted to the ½-in. thick, 7-in. x 2¾-in. steel plate and the foundation tube using two ½-in. diameter, 2-in. long hex-head bolts. To secure the connection between the steel plate and foundation tube, the heads of the bolts were designed to be welded inside the foundation tube using a $^{3}/_{16}$-in. (5-mm) weld.

(2) Bolted yoke placed inside strut, which was similar to the ground line strut design concept no. 1, except the two $15^{3}/_{8}$-in. x 3-in. x ¼-in (391-mm x 76-mm x 6-mm) steel bent plates were placed inside the C-channel ground line strut, as shown in Figure 7b.

(3) Welded yoke placed outside strut, in which two 17-in. x 3-in. x ¼-in. (432-mm x 76-mm x 6-mm) steel bent plates placed outside the C-channel strut and bolted to the strut using one 7/8-in. diameter, 8½-in. long hex-head bolt at each end. Two 7-in. x 2¾-in. x ½-in. (178-mm x 70-mm x 13-mm) steel plates welded to the steel bent plate and the foundation tube with a 3/16-in. (5-mm) weld at the location of the anchor and second posts, as shown in Figure 7c.

(4) Welded yoke placed inside strut, which was similar to the ground line strut design concept no. 3 except the two $15^{3}/_{8}$-in. x 3-in. x ¼-in. (391-mm x 76-mm x 6-mm) steel bent plates placed inside the C-channel strut and bolted to the strut using one 7/8-in. diameter, 8½-in. long hex-head bolt at each end, as shown in Figure 7d. Two 7-in. x 2¾-in. x ½-in. (178-mm x 70-mm x 13-mm) steel plates welded to the steel bent plate and the foundation tube with a $^{3}/_{16}$-in. (5-mm) weld at the location of the anchor and second posts.

The ground line strut design concepts were discussed with the Midwest Pooled Fund Program member states. Using a survey, a majority of the member states desired ground line strut concept no. 1, where the bolted yoke was placed outside the ground line strut, as shown in Figure 7a, due to its increased ease of installation over the other concepts.

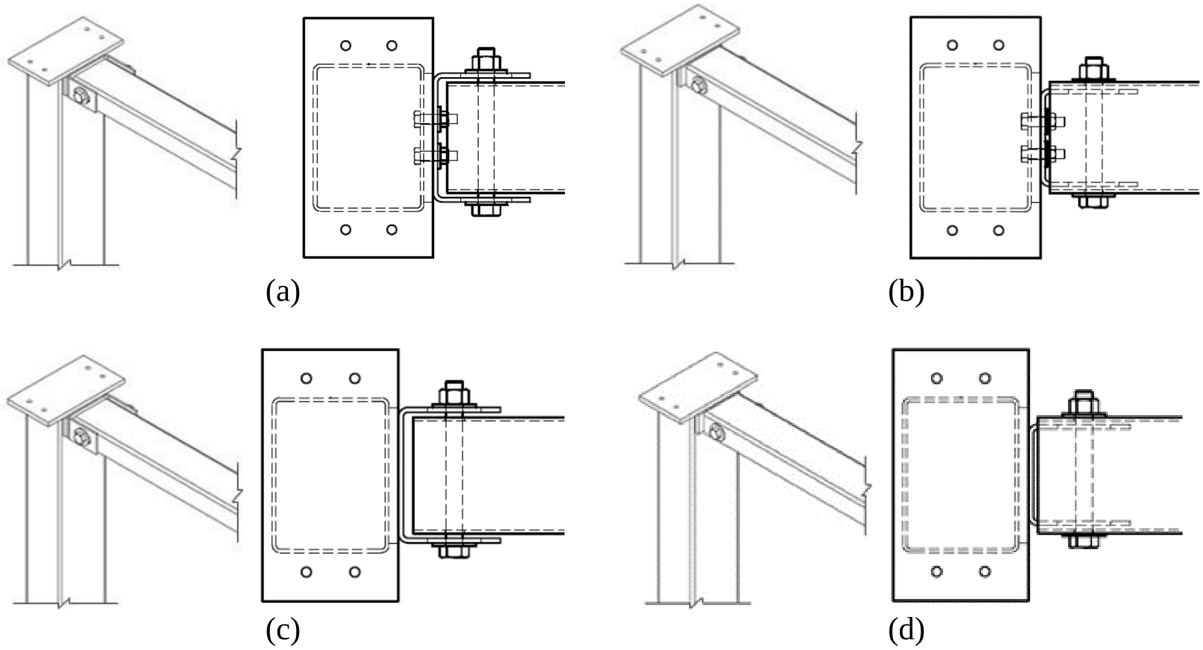


Figure 7. Ground Line Strut Design Concepts: (a) No. 1 – Bolted Yoke Outside Strut, (b) No. 2 – Bolted Yoke Inside Strut, (c) No. 3 – Welded Yoke Outside Strut, and (d) No. 4 – Welded Yoke Inside Strut

1.2 Objective

The objective of this research study was to evaluate the crashworthiness of the steel-post, trailing-end anchorage system developed during the research and development effort. This system was to be evaluated according to the MASH 2016 TL-3 safety performance criteria.

1.3 Scope

Earlier research developed concepts, conducted dynamic component testing, and made recommendations for a future full-scale vehicle crash testing program. A final design concept was selected based on the results from the dynamic component testing program and the input from the Midwest Pooled Fund Program member states. In the current research, that final anchorage configuration was evaluated through full-scale vehicle crash testing under the TL-3 safety performance criteria outlined in MASH 2016.

MwRSF constructed the new steel-post, trailing-end anchorage system at MwRSF's Outdoor Testing Facility. Two full-scale crash tests were conducted, documented, and evaluated by MwRSF personnel in accordance with MASH 2016 TL-3 guidelines. Following the full-scale crash testing program, a summary report was compiled, which detailed the new steel-post, trailing-end anchorage system, the full-scale crash tests, and recommendations for the implementation of the new trailing-end anchorage system.

2 TEST REQUIREMENTS AND EVALUATION CRITERIA

2.1 Test Requirements

Guardrail end terminals, such as trailing-end anchorage systems, must satisfy impact safety standards to be declared eligible for federal reimbursement by the Federal Highway Administration for use on the National Highway System. For new hardware, these safety standards consist of the guidelines and procedures published in MASH 2016. According to TL-3 of MASH 2016, W-beam guardrail terminals must be subjected to up to ten full-scale vehicle crash tests, as summarized in Table 2.

Table 2. MASH 2016 TL-3 Crash Test Conditions for Gating End Terminals

Test Article	Test Designation No.	Test Vehicle	Vehicle Weight lb (kg)	Impact Conditions		Evaluation Criteria [1]
				Speed Mph (km/h)	Angle deg.	
Gating End Terminal	3-30	1100C	2,420 (1,100)	62 (100)	0	C,D,F,H,I,N
	3-31	2270P	5,000 (2,270)	62 (100)	0	C,D,F,H,I,N
	3-32	1100C	2,420 (1,100)	62 (100)	5-15	C,D,F,H,I,N
	3-33	2270P	5,000 (2,270)	62 (100)	5-15	C,D,F,H,I,N
	3-34	1100C	2,420 (1,100)	62 (100)	15	C,D,F,H,I,N
	3-35	2270P	5,000 (2,270)	62 (100)	25	A,D,F,H,I
	3-36	2270P	5,000 (2,270)	62 (100)	25	A,D,F,H,I
	3-37a	2270P	5,000 (2,270)	62 (100)	25	C,D,F,H,I,N
	3-37b	1100C	2,420 (1,100)	62 (100)	25	C,D,F,H,I,N
	3-38	1500A	3,300 (1,500)	62 (100)	0	C,D,F,H,I,N

[1] Evaluation criteria explained in Table 4.

The steel-post trailing-end anchorage system is to be used only in locations where vehicles impacting the anchorage head on are not a concern (e.g., one-way roadways or outside the clear zone of opposing traffic headed toward the middle of the MGS). As such, the trailing-end anchorage system would only be impacted by vehicles exiting the guardrail installation, which are traditionally described as reverse direction impacts. Within the gaiting end terminal test matrix end terminals, only MASH test designation nos. 3-37a and 3-37b involve reverse-direction impacts, and would be necessary in evaluating the trailing-end anchorage system. All of the other tests within the matrix involve head-on or normal direction impacts, and therefore, were not applicable in the evaluation of the trailing-end anchorage system. The reduced test matrix selected for the evaluation of the trailing-end anchorage system is shown in Table 3.

MASH 2016 test designation no. 3-37a with a 2270P vehicle is normally required to evaluate vehicle snag on crash cushions. However, in this research, this test was conducted to evaluate the downstream LON with the steel-post, trailing-end anchorage system connected to the MGS. MASH 2016 test designation no. 3-37b with an 1100C vehicle was required to evaluate vehicle snag, vehicle instabilities, and occupant risk criteria resulting from the interaction with the trailing-end anchorage.

Table 3. MASH 2016 TL-3 Crash Tests for Trailing-End Anchorage Systems

Test Article	Test Designation No.	Test Vehicle	Vehicle Weight, lb (kg)	Impact Conditions		Evaluation Criteria [1]
				Speed mph (km/h)	Angle degrees	
Gating End Terminal	3-37a	2270P	5,000 (2,270)	62 (100)	25	C,D,F,H,I,N
	3-37b	1100C	2,420 (1,100)	62 (100)	25	C,D,F,H,I,N

[1] Evaluation criteria explained in Table 4.

The research team discussed whether full-scale crash testing was required to evaluate the tensile load capacity of the steel-post, trailing-end anchorage system during redirective impacts on the MGS (i.e., conducting a MASH 3-11 test on the MGS with the new steel-post anchorage system at both ends of the installation). The steel-post, trailing-end anchorage system was derived from the BCT end anchorage that has been used in a wide variety of full-scale crash testing programs for decades. As such, the steel-post, trailing-end anchorage system would be expected to possess a similar load bearing capacity in such crash testing programs. Additionally, dynamic component testing of the steel-post design concepts indicated greater tensile load capacity as compared to the wood-post, trailing-end anchorage system [11]. Thus, it was not believed that a separate anchor capacity crash test would be required for the steel-post, trailing-end anchorage system.

The steel-post, trailing-end anchorage system was developed to mimic the capacity and performance of the original BCT, wood-post, trailing-end anchorage system [1-3]. Thus, the CIPs for each full-scale crash test were selected to be the same as those used during the MASH TL-3 evaluation of the BCT, trailing-end anchorage system [1]. For test no. SPTA-1 (test designation no. 3-37a), the CIP was determined to be at the center of post no. 24, or the sixth post upstream from the downstream end of the barrier. For test no. SPTA-2 (test designation no. 3-37b), the CIP was determined to be the midspan between post nos. 27 and 28, or midspan between the second and third posts upstream from the downstream end of the barrier.

It should be noted that any tests deemed non-critical for evaluation may eventually need to be evaluated based on additional knowledge gained over time or additional FHWA eligibility letter requirements.

2.2 Evaluation Criteria

Evaluation criteria for full-scale vehicle crash testing are based on three appraisal areas: (1) structural adequacy; (2) occupant risk; and (3) vehicle trajectory after collision. Criteria for structural adequacy are intended to evaluate the ability of the end anchorage to contain and redirect impacting vehicles. In addition, controlled lateral deflection of the test article is acceptable. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Post-impact vehicle trajectory is a measure of the potential of the vehicle to result in a secondary collision with other vehicles and/or fixed objects, thereby increasing the risk of injury to the occupants of the impacting vehicle and/or other vehicles. These evaluation criteria are summarized in Table 4 and defined in greater detail in MASH 2016.

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

Table 4. MASH 2016 Evaluation Criteria for Gating End Terminals

<table>
<tr><td>Structural Adequacy</td><td>C.</td><td>Acceptable test article performance may be redirection, controlled penetration, or controlled stopping of the vehicle.</td></tr>
<tr><td rowspan="4">Occupant Risk</td><td>D.</td><td>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 5.3 and Appendix E of MASH.</td></tr>
<tr><td>F.</td><td>The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td></tr>
<tr><td>H.</td><td>Occupant Impact Velocity (OIV) (see Appendix A, Section A5.3 of MASH for calculation procedure) should satisfy the following limits:
<table>
<tr><th colspan="3">Occupant Impact Velocity Limits</th></tr>
<tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s
(9.1 m/s)</td><td>40 ft/s
(12.2 m/s)</td></tr>
</table></td></tr>
<tr><td>I.</td><td>The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.3 of MASH for calculation procedure) should satisfy the following limits:
<table>
<tr><th colspan="3">Occupant Ridedown Acceleration Limits</th></tr>
<tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
</table></td></tr>
<tr><td>Vehicle Trajectory</td><td>N.</td><td>Vehicle trajectory behind the test article is acceptable.</td></tr>
</table>

2.3 Soil Strength Requirements

In accordance with Chapter 3 and Appendix B of MASH 2016, foundation soil strength must be verified before any full-scale crash testing can occur. During the installation of a soil dependent system, W6x16 posts are installed near the impact region utilizing the same installation procedures as the full-scale system. Prior to full-scale testing, a dynamic impact test must be conducted to verify a minimum dynamic soil resistance of 7.5 kips (33.4 kN) at post deflections between 5 and 20 in. (127 and 508 mm) measured at a height of 25 in. (635 mm). If dynamic testing near the system is not desired, MASH 2016 permits a static test to be conducted instead and compared against the results of a previously established baseline test. In this situation, the soil must provide a resistance of at least 90 percent of the static baseline test at deflections of 5, 10, and 15 in. (127, 254, and 381 mm). Further details can be found in Appendix B of MASH 2016.

3 TEST CONDITIONS

3.1 Test Facility

The Outdoor Test Site is located at the Lincoln Air Park on the northwest side of the Lincoln Municipal Airport and is approximately 5 miles (8.0 km) northwest of the University of Nebraska-Lincoln.

3.2 Vehicle Tow and Guidance System

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

A vehicle guidance system developed by Hinch [12] was used to steer the test vehicles. A guide flag that was attached to the left-front wheel, and the guide cable was sheared off before impact with the barrier system. The ⅜-in. (9.5-mm) diameter guide cable was tensioned to approximately 3,500 lb (15.6 kN) and supported both laterally and vertically every 100 ft (30.5 m) by hinged stanchions. The hinged stanchions stood upright while holding up the guide cable, but the guide flag struck and knocked each stanchion to the ground as the vehicles were towed down the line.

3.3 Test Vehicles

For test no. SPTA-1, a 2011 Dodge Ram 1500 crew cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,121 lb (2,323 kg), 5,074 lb (2,302 kg), and 5,236 lb (2,375 kg), respectively. The 2270P test vehicle is shown in Figures 8 and 9, and vehicle dimensions are shown in Figure 10.

For test no. SPTA-2, a 2011 Hyundai Accent was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,505 lb (1,136 kg), 2,429 lb (1,102 kg), and 2,590 lb (1,175 kg), respectively. The 1100C test vehicle is shown in Figures 11 and 12, and vehicle dimensions are shown in Figure 13. Note that both test vehicles were within six model years of the 2017 research project contract date.

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [13] was used to determine the vertical component of the c.g. for the pickup truck. This method is based on the principle that the c.g. of any freely suspended body is in the vertical plane through the point of suspension. The vehicle was suspended successively in three positions, and the respective planes containing the c.g. were established. The intersection of these planes pinpointed the final c.g. location for the test inertial condition. The vertical component of the c.g. for the 1100C vehicle was determined utilizing a procedure published by SAE [14]. The location of the final c.g. is shown in Figures 10 and 14 for test no. SPTA-1 and Figures 13 and 15 for test no. SPTA-2. Data used to calculate the location of the c.g. and ballast information are shown in Appendix A.

Square, black- and white-checkered targets were placed on the vehicles for reference to be viewed from the high-speed digital video cameras and aid in the video analysis, as shown in Figures 14 and 15. 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 value was adjusted to zero such that the vehicles would track properly along the guide cable. A 5B flash bulb was mounted on the vehicles' right-side windshield wipers and was signaled 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 tests.

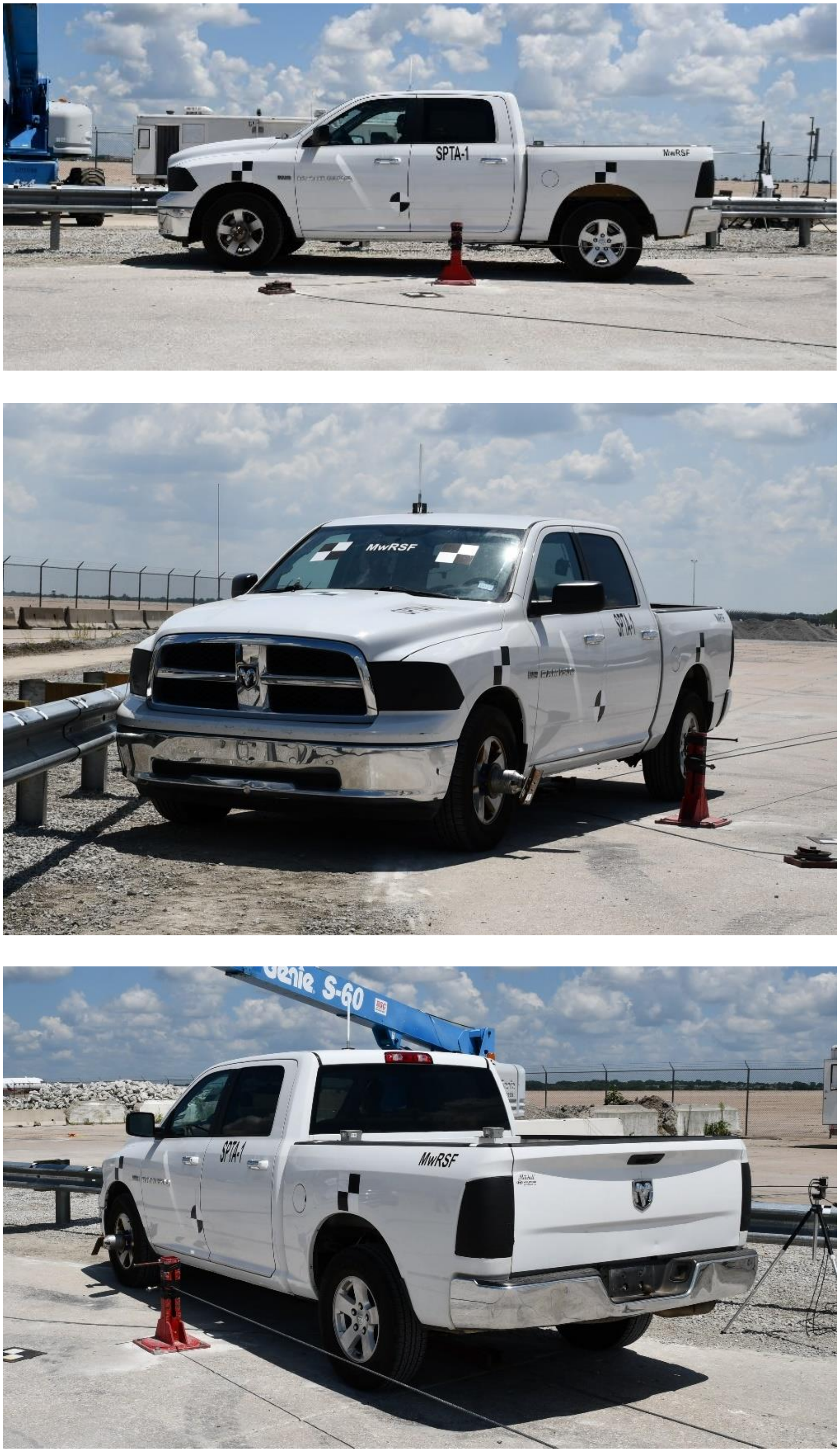
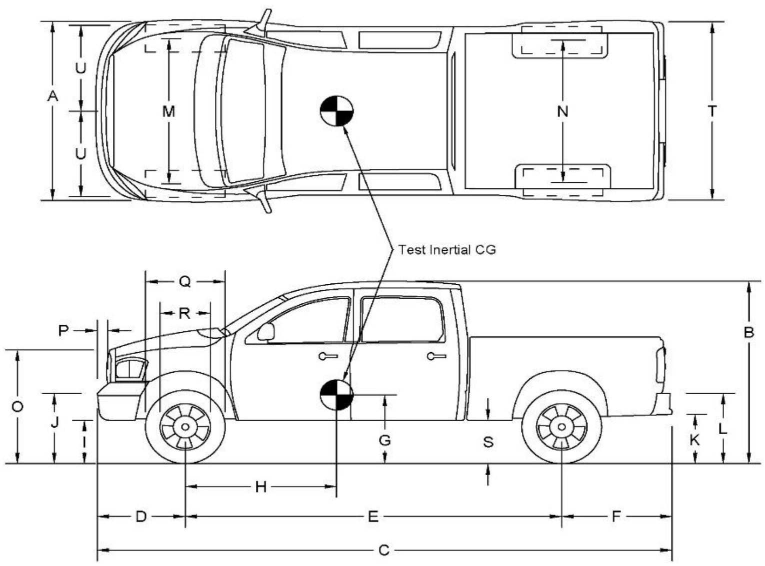


Figure 8. Test Vehicle, Test No. SPTA-1

Figure 9. Test Vehicle’s Interior Floorboards and Undercarriage, Test No. SPTA-1

Date:	7/31/2018	Test Name:	SPTA-1	VIN No:	1D7RB1CT2BS582287
Year:	2011	Make:	Dodge	Model:	Ram 1500
Tire Size:	265/70 R17	Tire Inflation Pressure:	40 Psi	Odometer:	152215



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

A:	76 1/2 (1943) 78±2 (1950±50)	B:	74 (1880)		
C:	229 1/8 (5820) 237±13 (6020±325)	D:	37 1/2 (953) 39±3 (1000±75)		
E:	140 3/8 (3566) 148±12 (3760±300)	F:	46 7/8 (1191)		
G:	28 1/2 (724) min: 28 (710)	H:	61 3/4 (1568) 63±4 (1575±100)		
I:	11 1/2 (292)	J:	24 3/4 (629)		
K:	20 1/2 (521)	L:	29 1/4 (743)		
M:	67 1/2 (1715) 67±1.5 (1700±38)	N:	67 1/2 (1715) 67±1.5 (1700±38)		
O:	44 (1118) 43±4 (1100±75)	P:	5 (127)		
Q:	31 (787)	R:	18 1/2 (470)		
S:	15 (381)	T:	76 (1930)		

U (impact width): 77 7/8 (1978)

Mass Distribution lb (kg)

Gross Static	LF	1440 (653)	RF	1494 (678)
	LR	1146 (520)	RR	1156 (524)

Wheel Center Height (Front):	14 3/4 (375)
Wheel Center Height (Rear):	15 (381)
Wheel Well Clearance (Front):	34 1/2 (876)
Wheel Well Clearance (Rear):	37 3/4 (959)
Bottom Frame Height (Front):	9 3/4 (248)
Bottom Frame Height (Rear):	20 (508)
Engine Type:	Gasoline
Engine Size:	5.7L V8
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Crew Cab
Bed Length:	67"

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2898 (1315)	2842 (1289)	2934 (1331)
W-rear	2223 (1008)	2232 (1012)	2302 (1044)
W-total	5121 (2323)	5074 (2302) 5000±110 (2270±50)	5236 (2375) 5165±110 (2343±50)

GVWR Ratings lb

Front	3700
Rear	3900
Total	6700

Surrogate Occupant Data

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

Note any damage prior to test: right rear fender is scraped and dented behind rear tire.

Figure 10. Vehicle Dimensions, Test No. SPTA-1

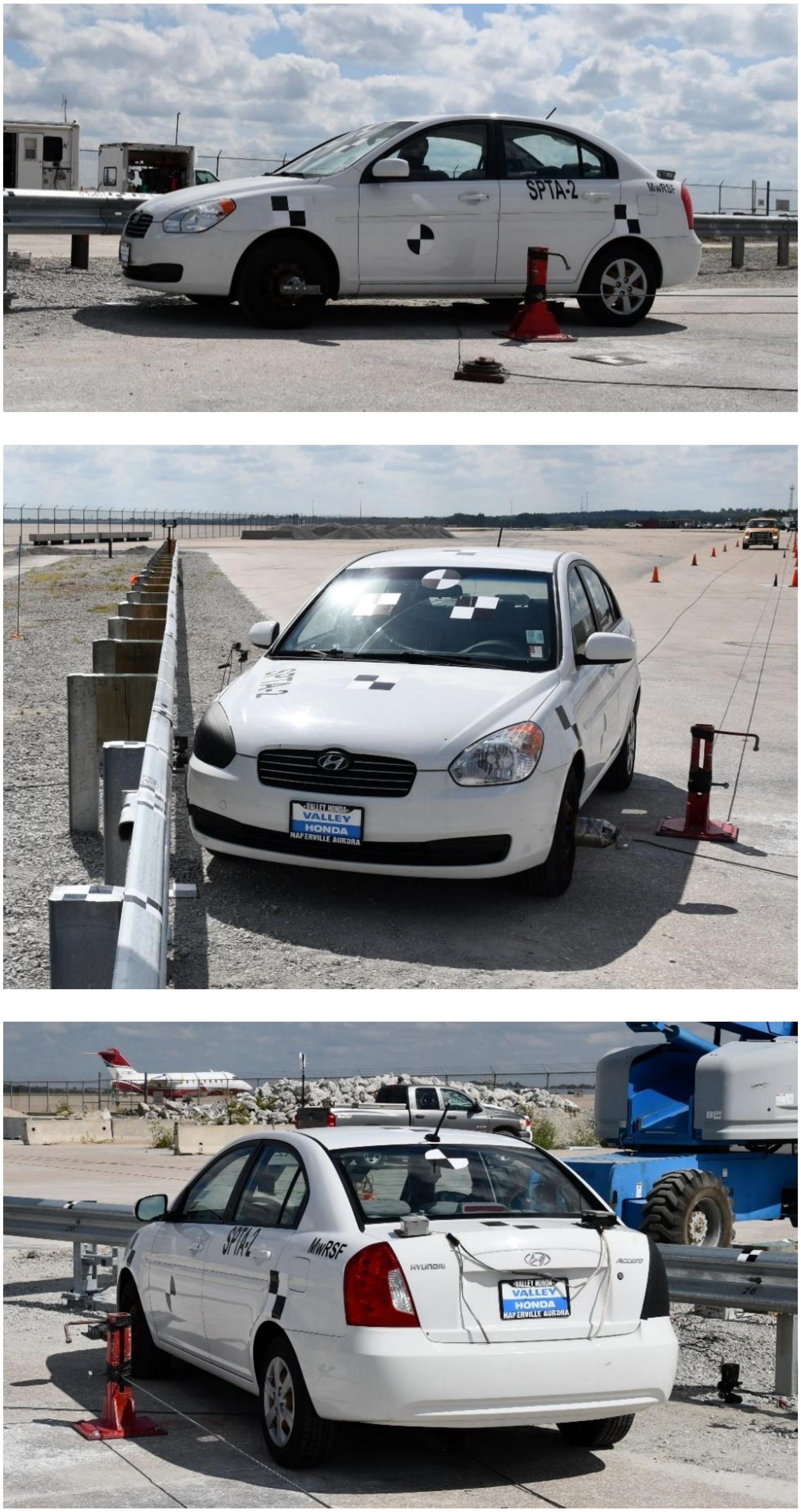


Figure 11. Test Vehicle, Test No. SPTA-2

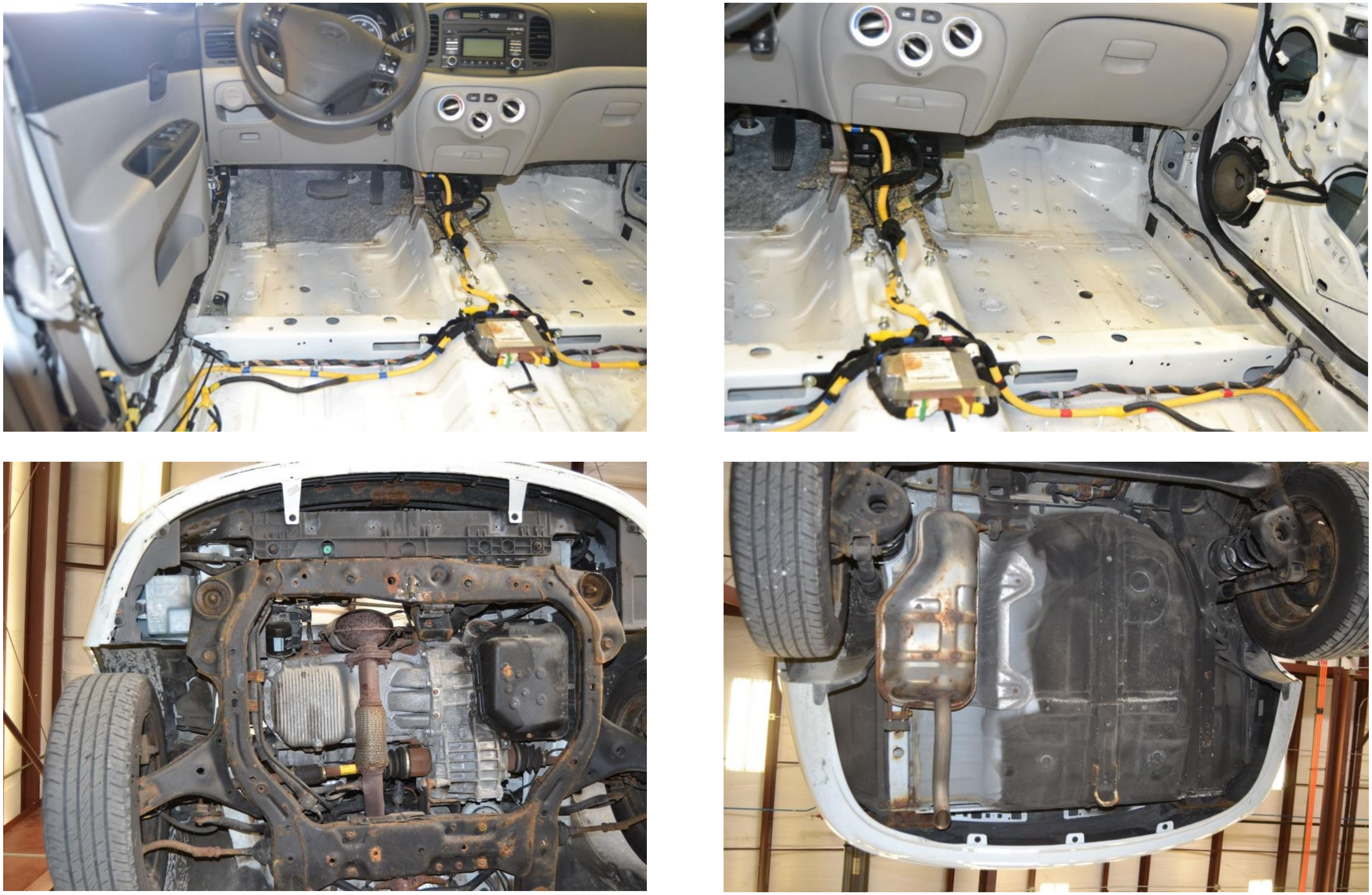
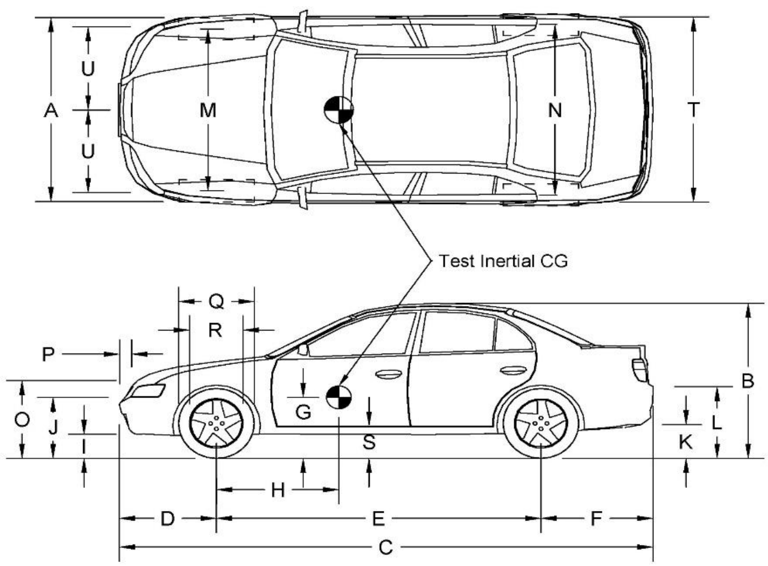


Figure 12. Test Vehicle's Interior Floorboards and Undercarriage, Test No. SPTA-2

Date:	9/12/2018	**Test Name:**	SPTA-2	**VIN No:**	kmhcn4ac2bu618362
Year:	2011	**Make:**	Hyundai	**Model:**	Accent
Tire Size:	185/65p14	**Tire Inflation Pressure:**	32 Psi	**Odometer:**	157090



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

A: 65 5/8 (1667) 65±3 (1650±75)	B: 57 1/2 (1461)
C: 168 1/2 (4280) 169±8 (4300±200)	D: 33 1/2 (851) 35±4 (900±100)
E: 98 (2489) 98±5 (2500±125)	F: 36 (914)
G: 22 11/16 (576)	H: 35 5/16 (897) 39±4 (990±100)
I: 7 7/8 (200)	J: 23 1/2 (597)
K: 11 1/2 (292)	L: 25 5/8 (651)
M: 57 3/4 (1467) 56±2 (1425±50)	N: 57 3/4 (1467) 56±2 (1425±50)
O: 27 1/4 (692) 24±4 (600±100)	P: 1 (25)
Q: 22 3/4 (578)	R: 15 1/2 (394)
S: 11 3/8 (289)	T: 63 3/8 (1610)

U (impact width):	28 5/8 (727)
Top of radiator core support:	28 (711)
Wheel Center Height (Front):	10 5/8 (270)
Wheel Center Height (Rear):	10 7/8 (276)
Wheel Well Clearance (Front):	26 (660)
Wheel Well Clearance (Rear):	26 1/2 (673)
Bottom Frame Height (Front):	5 7/8 (149)
Bottom Frame Height (Rear):	7 3/8 (187)
Engine Type:	Gasoline
Engine Size:	1.4L 4 cyl
Transmission Type:	Automatic
Drive Type:	FWD

Mass Distribution lb (kg)

Gross Static	LF	827 (375)	RF	810 (367)
	LR	454 (206)	RR	499 (226)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	1597 (724)	1554 (705)	1637 (743)
W-rear	908 (412)	875 (397)	953 (432)
W-total	2505 (1136)	2429 (1102) 2420±55 (1100±25)	2590 (1175) 2585±55 (1175±50)

GVWR Ratings lb

Front	1918
Rear	1874
Total	3638

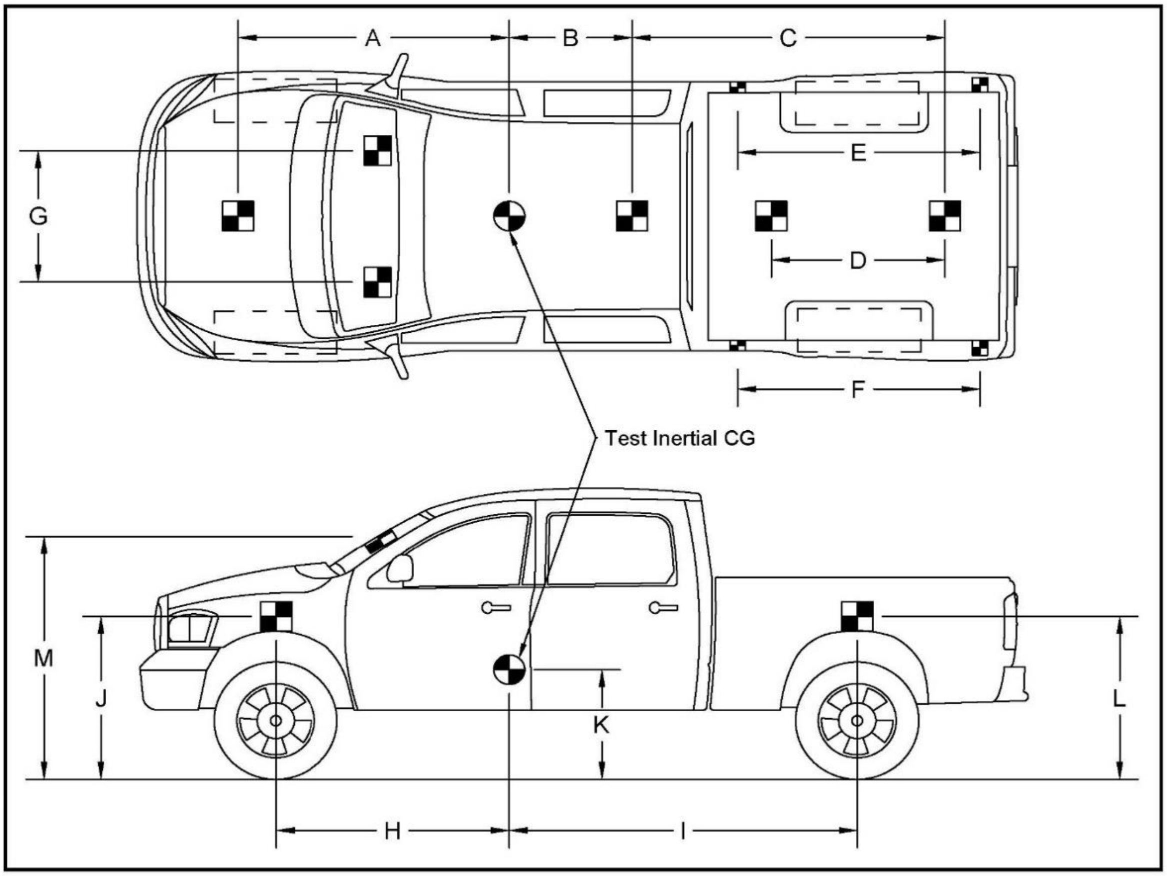
Surrogate Occupant Data

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

Note any damage prior to test:

Figure 13. Vehicle Dimensions, Test No. SPTA-2

Date: 7/31/2018	Test Name: SPTA-1	VIN: 1D7RB1CT2BS582287
Year: 2011	Make: Dodge	Model: Ram 1500

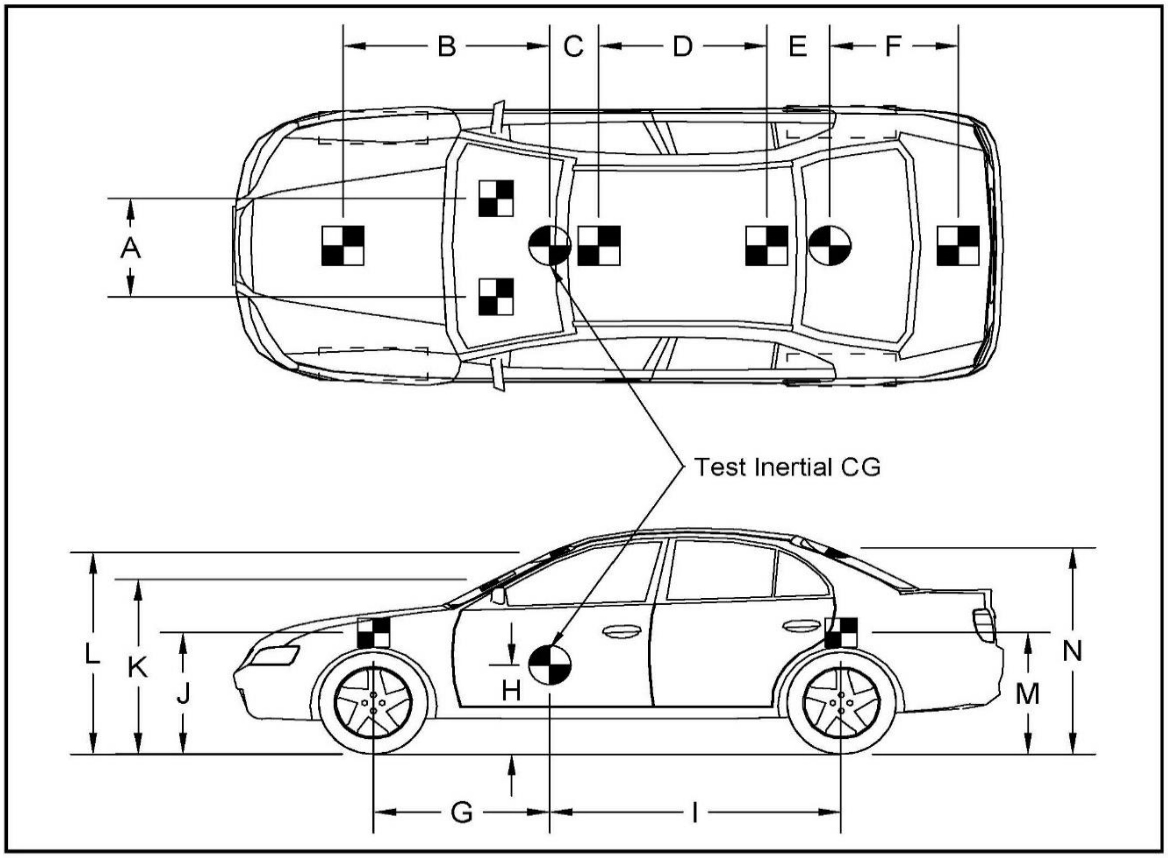


TARGET GEOMETRY-- in. (mm)

A:	67 1/8	(1705)	E:	54 5/8	(1387)	J:	38 1/4	(972)
B:	37 1/8	(943)	F:	54 5/8	(1387)	K:	28 1/2	(724)
C:	67	(1702)	G:	32 1/8	(816)	L:	42 1/8	(1070)
D:	43 5/8	(1108)	H:	61 7/8	(1572)	M:	52 1/2	(1334)
			I:	79	(2007)			

Figure 14. Target Geometry, Test No. SPTA-1

Date:	9/12/2018	Test Name:	SPTA-2	VIN:	kmhcn4ac2bu618362
Year:	2011	Make:	Hyundai	Model:	Accent



TARGET GEOMETRY-- in. (mm)

A:	19 1/2	(495)	F:	22 5/8	(575)	K:	46 3/4	(1187)
						Windshield Target		
B:	42	(1067)	G:	35 1/8	(892)	L:	51 1/4	(1302)
						Front round CG target		
C:	17	(432)	H:	22 3/4	(578)	M:	29	(737)
D:	28 1/8	(714)	I:	62 7/8	(1597)	N:	52 1/8	(1324)
						Rear Round target		
E:	19 3/4	(502)	J:	28 3/4	(730)			

Figure 15. Target Geometry, Test No. SPTA-2

3.4 Simulated Occupant

For test nos. SPTA-1 and SPTA-2, a Hybrid II 50th-Percentile, Adult Male Dummy that was equipped with footwear, was placed in the right-front seat of each test vehicle with the seat belt fastened. The simulated occupant had a final weight of 162 lb (73.5 kg) and 161 lb (73.0 kg) for test nos. SPTA-1 and SPTA-2, respectively. As recommended by MASH 2016, the simulated occupant was not included in calculating the c.g. locations.

3.5 Data Acquisition Systems

3.5.1 Accelerometers

Two environmental shock and vibration sensor/recorder systems were used to measure the accelerations in the longitudinal, lateral, and vertical directions. Both accelerometer systems were mounted near the c.g. of the test vehicles. 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 [15].

The two systems, the SLICE-1 and SLICE-2 units, were modular data acquisition systems manufactured by Diversified Technical Systems, Inc. (DTS) of Seal Beach, California. The SLICE-2 unit was designated as the primary system for test no. SPTA-1, and the SLICE-1 unit was designated as the primary system for test no. SPTA-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 programs and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

3.5.2 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.

3.5.3 Retroreflective Optic Speed Trap

The retroreflective optic speed trap was used to determine the speed of the test vehicles before impact. Five retroreflective targets, spaced at approximately 18-in. (457-mm) intervals, were applied to the sides of the vehicles. When the emitted beam of light was reflected by the targets and returned to the Emitter/Receiver, a signal was sent to the data acquisition computer, recording at 10,000 Hz, as well as the external LED box activating the LED flashes. The speed was then calculated using the spacing between the retroreflective targets and the time between the signals. LED lights and high-speed digital video analysis are only used as a backup in the event that vehicle speeds cannot be determined from the electronic data.

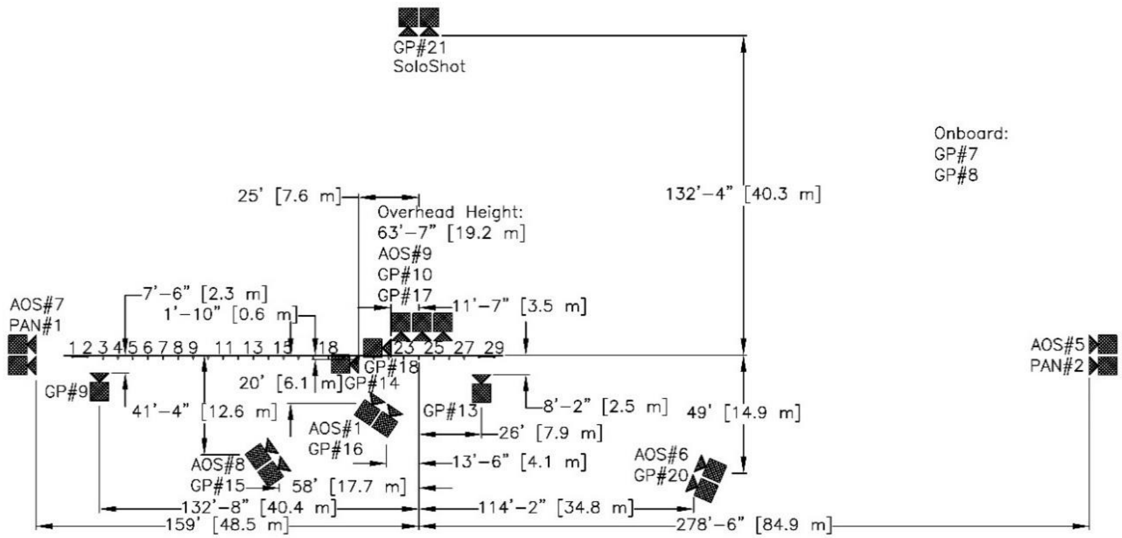
3.5.4 Load Cells

A load cell was installed on the upstream anchorage cable for test no. SPTA-1 to obtain peak tensile forces during a dynamic impact. Data from the full-scale crash test was compared to data from previous component tests [11] and wood post tests [1-3]. The load cell was Transducer Techniques model no. TLL-50K with a load range up to 50 kips (222 kN). During testing, output voltage signals were sent from the transducers to a National Instruments PCI-6071E data acquisition board, acquired with LabView software, and stored on a personal computer at a sample rate of 10,000 Hz.

3.5.5 Digital Photography

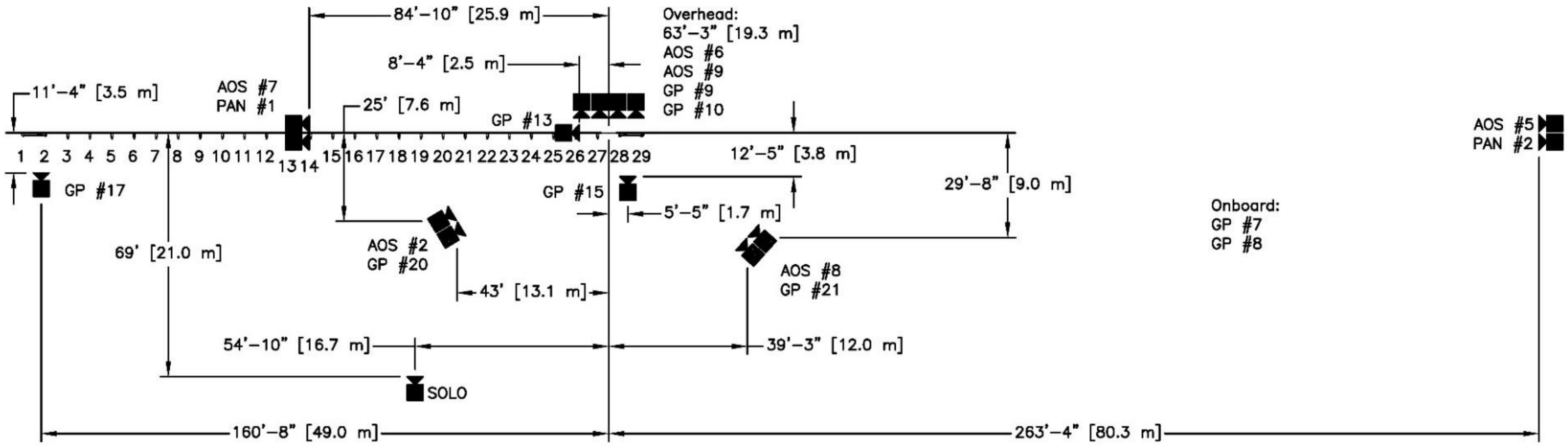
Six AOS high-speed digital video cameras, 12 GoPro digital video cameras, two Panasonic digital video cameras, and one Soloshot digital video camera were utilized to film test no. SPTA-1. Note that GoPro no. 7 experienced technical difficulties. Six AOS high-speed digital video cameras, nine GoPro digital video cameras, two Panasonic digital video cameras, and one Soloshot digital video camera were utilized to film test no. SPTA-2. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system for test nos. SPTA-1 and SPTA-2 are shown in Figures 16 and 17, respectively.

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



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-1	AOS Vitcam	500	Sigma 28-70 #1	70
AOS-5	AOS X-PRI	500	100mm Fixed	-
AOS-6	AOS X-PRI	500	Cosmicar 50mm Fixed	-
AOS-7	AOS X-PRI	500	Fujinon 75mm Fixed	-
AOS-8	AOS S-VIT 1531	500	Fujinon 50mm Fixed	-
AOS-9	AOS TRI-VIT 2236	1000	KOWA 12mm Fixed	-
GP-7	GoPro Hero 4	30		
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-10	GoPro Hero 4	120		
GP-13	GoPro Hero 4	120		
GP-14	GoPro Hero 4	240		
GP-15	GoPro Hero 4	240		
GP-16	GoPro Hero 4	240		
GP-17	GoPro Hero 4	120		
GP-18	GoPro Hero 6	120		
GP-20	GoPro Hero 6	240		
GP-21	GoPro Hero 6	120		
PAN-1	Panasonic	60		
PAN-2	Panasonic	60		
SoloShot	SoloShot	120		

Figure 16. Camera Locations, Speeds, and Lens Settings, Test No. SPTA-1



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-2	AOS Vitcam	500	Sigma 28-70 #2	70
AOS-5	AOS X-PRI Gigabit	500	100mm Fixed	-
AOS-6	AOS X-PRI Gigabit	500	KOWA 16mm	-
AOS-7	AOS X-PRI Gigabit	500	Fujinon 50mm	-
AOS-8	AOS S-VIT 1531	500	Sigma 28-70 #1	50
AOS-9	AOS TRI-VIT	1000	KOWA 12mm	-
GP-7	GoPro Hero 4	120		
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	240		
GP-10	GoPro Hero 4	240		
GP-13	GoPro Hero 4	240		
GP-15	GoPro Hero 4	240		
GP-17	GoPro Hero 4	240		
GP-20	GoPro Hero 6	120		
GP-21	GoPro Hero 6	120		
PAN-1	Panasonic HC-V770	60		
PAN-2	Panasonic HC-V770	60		
SoloShot	SoloShot	120		

Figure 17. Camera Locations, Speeds, and Lens Settings, Test No. SPTA-2

4 DESIGN DETAILS – TEST NO. SPTA-1

In test no. SPTA-1, the test installation consisted of 12-gauge AASHTO M180 standard W-beam guardrail, W6x8.5 steel posts with timber blockouts, a tangent non-proprietary, wood-post, trailing-end anchorage system at the upstream end, and a steel-post, trailing-end anchorage system at the downstream end, as shown in Figures 18 through 47. The total system length was 182 ft – 3½ in. (55.6 m). Photographs of the test installation are shown in Figures 48 through 51. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

Post nos. 3 through 27 were standard 72-in. (1,829-mm) long, W6x8.5 ASTM A992 steel posts, embedded to a depth of 40 inches (1,016 mm). Post nos. 1 and 2 were wood BCT posts inserted into steel foundation tubes embedded to a depth of 70 in. (1,778 mm), while post nos. 28 and 29, comprising the steel-post, trailing-end anchorage system, were embedded to a depth of 69 in. (1,753 mm). All posts were embedded in coarse, crushed limestone, alternatively classified as well-graded gravel according to the Unified Soil Classification System, and spaced 75 in. (1,905 mm) on center. Timber blockouts, measuring 6 in. x 12 in. x 14¼ in. (152 mm x 305 mm x 362 mm), were used to block the rail away from the front face of each steel line post. The W-beam guardrail was mounted with a top rail height of 31 in. (787 mm), as measured from the surface of the roadway. Splice joints located between posts were oriented with the leading edge of the downstream W-beam rail covered by the trailing edge of the upstream rail to provide a proper overlap for normal-direction traffic and reduce vehicle snag concerns.

The downstream end of the guardrail installation was configured with the non-proprietary, steel-post, trailing-end anchorage system that was designed in the Phase I research project [11]. The end anchor posts (post nos. 28 and 29) were two-part breakaway steel posts. The top portion of the post consisted of a 27½ in. (699 mm) long, W6x8.5 ASTM A992 steel post welded to a 5½-in. x 5½-in. x ¾-in. (140-mm- x 140-mm x 19-mm), ASTM 36 steel base plate. The bottom portion of the post was a HSS 6-in. x 8-in. x $^{3}/_{16}$ -in. (152-mm x 203-mm x 5-mm) ASTM A500 Grade B steel tube welded to a 13-in. x 7-in. x ⅝-in. (330-mm- x 178-mm x 16-mm), ASTM 36 steel base plate. The top and bottom base plates were connected using four $^{7}/_{16}$-in. (11-mm) diameter, ASTM A325 bolts.

The two foundation tubes were connected with a 66½-in. (1,689-mm) long, modified ground line strut, (i.e., bolted yoke placed outside strut), as shown in Figures 33 through 35. At the location of the anchor and second posts, two 17-in. x 2¾-in. x ½-in. (432-mm x 70-mm x 13-mm) bent steel plates were placed outside of the strut and bolted to the strut using one ⅞-in. (22-mm) diameter, 8½-in. (216-mm) long hex-head ASTM A307 bolt. The steel bent plate was bolted to the ½-in. (13-mm) thick, 7-in. x 2¾-in. (178-mm x 70-mm) steel plate and the foundation tubes using two ½-in. ½-in. (13-mm) diameter, 2-in. (51-mm) long hex-head ASTM A307 bolts. To secure the connection between the steel plate and foundation tube, the heads of the bolts were designed to be welded inside the foundation tube using a $^{3}/_{16}$-in. (5-mm) weld.

The anchor cable assembly consisted of an anchor bearing plate, an anchor bracket mounted on the rail, an end plate, and a steel cable which was secured against the end anchor post on one end. The other end of the cable was connected to the back of the rail through a steel mounting bracket, which would quickly release away from the rail during end-on impact event. More details on the system design are provided in reference 11. The bearing plate assembly consisted of a vertical, 8-in. x 6¼-in. x ⅝-in. (203-mm x 159-mm x 16-mm) steel bearing plate was welded to an 8-in. x 1½-in. x 1-in. (203-mm x 38-mm x 25-mm) compression block. The bearing plate assembly was secured against the end anchor post through anchor cable, as shown in Figure 23.

The upstream end of the guardrail installation was configured with a non-proprietary, tensile end anchorage system utilizing BCT posts and hardware [1-3]. The upstream guardrail anchorage system consisted of two BCT timber posts, foundation tubes, an anchor cable and connection hardware, a bearing plate, a rail bracket, and a channel strut.

A T-shaped, breaker bar was attached to the end anchor post (i.e., post no. 29) with a mounting height of 15¾ in. (400 mm). The T-shaped, breaker bar consisted of a horizontal 40-in. (1,016-mm) long, 2½-in. x 2½-in x ¼-in. (64-mm x 64-mm x 6-mm) ASTM A500 Grade B steel square tube welded to a vertical 9-in. (229-mm) long, 3-in. x 3-in. x ¼-in. (76-mm x 76-mm x 6-mm) steel square tube. The attachment to post no. 29, as shown in Figure 50, consisted of a 10-in. x 4½-in. x ¼-in. (254-mm x 114-mm x 6-mm) ASTM A36 steel plate along with two 6-in. x ¾-in. x ¼-in. (152-mm x 19-mm x 6-mm) and two 6-in. x 1¼-in. x ¼-in. ASTM (152-mm x 32-mm x 6-mm) A36 steel gusset plates to facilitate cable anchor disengagement and mitigate vehicle snag under the anchor cable.

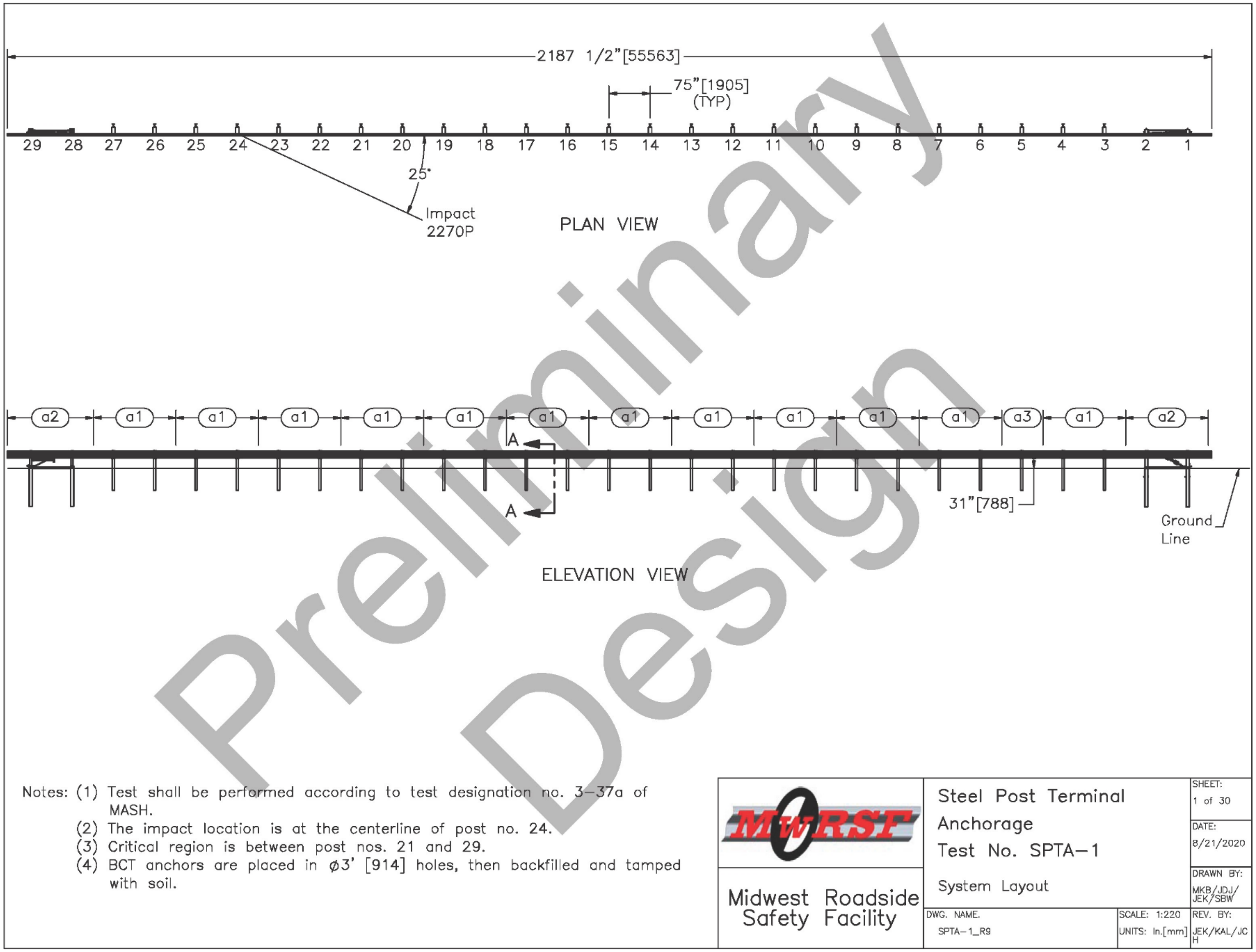


Figure 18. Test Installation Layout, Test No. SPTA-1

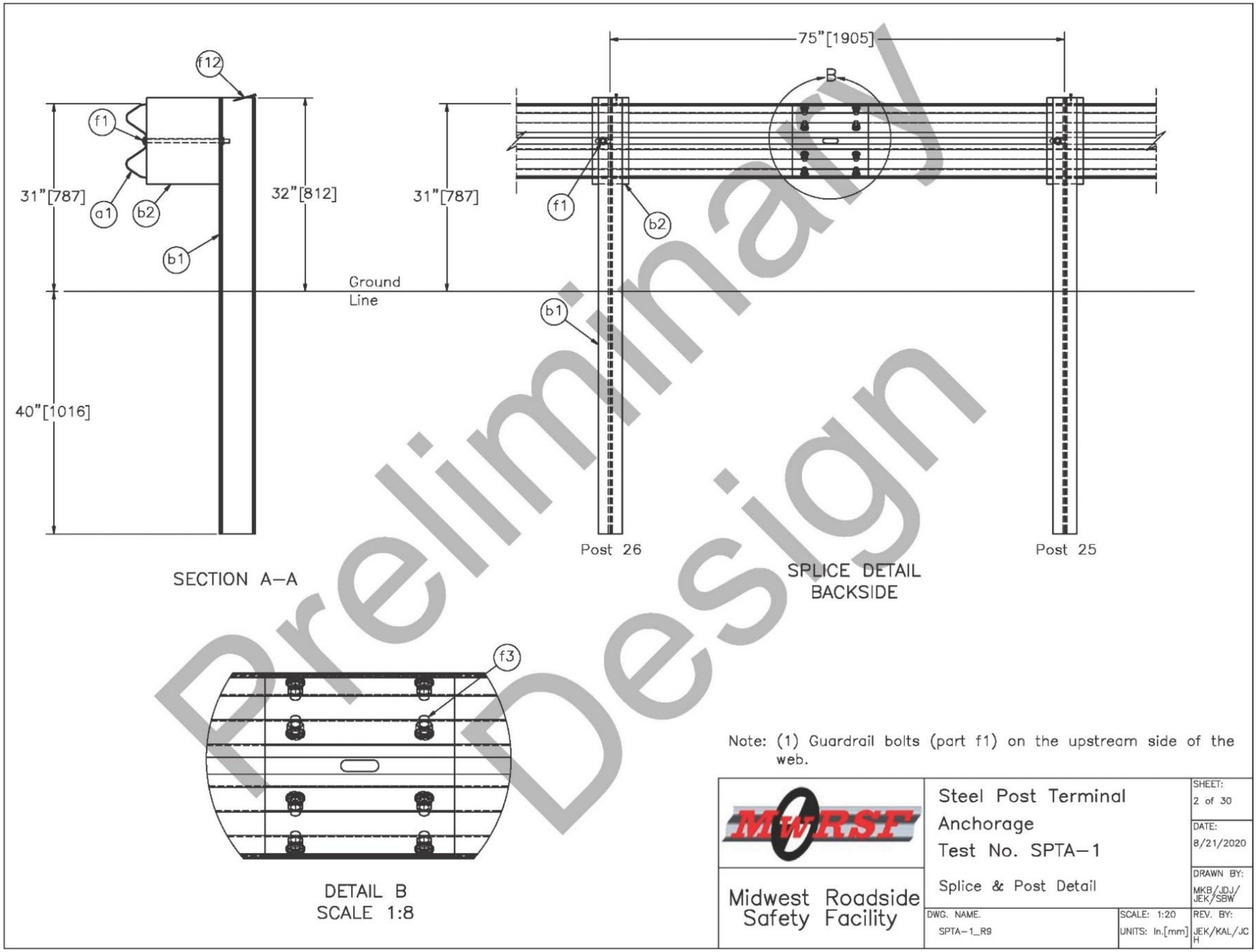


Figure 19. Splice and Post Detail, Test No. SPTA-1

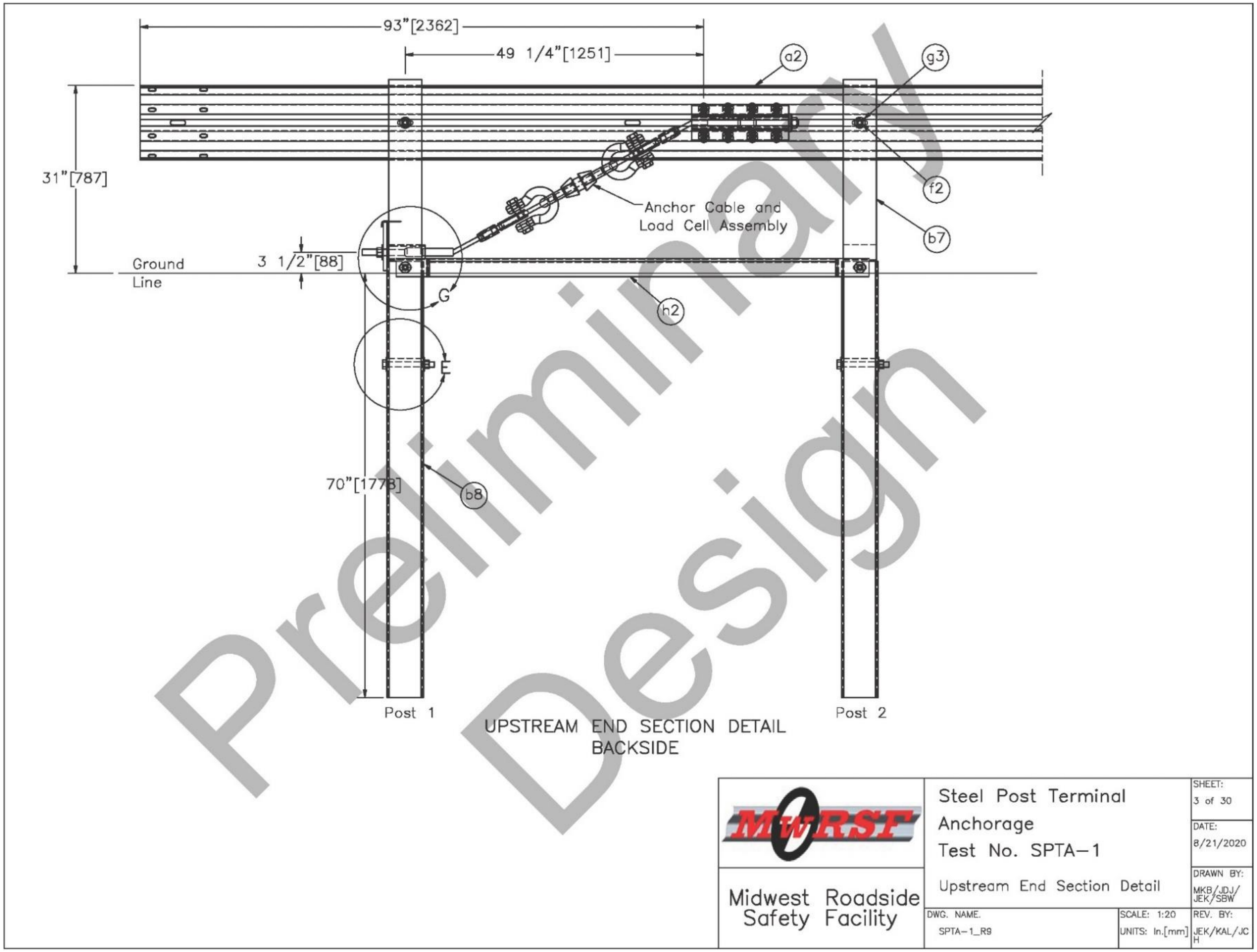


Figure 20. Upstream End Section Detail, Test No. SPTA-1

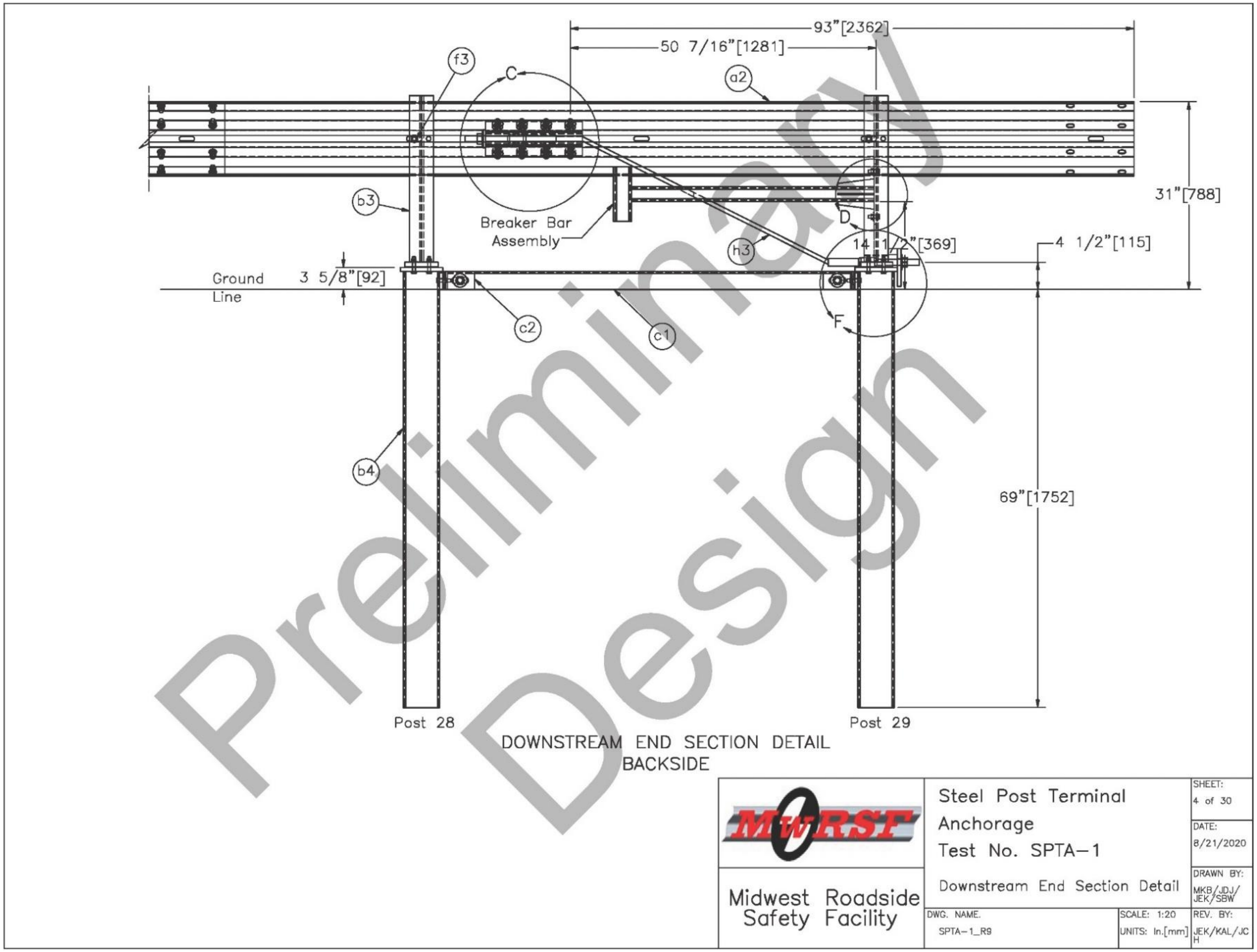


Figure 21. Downstream End Section Detail, Test No. SPTA-1

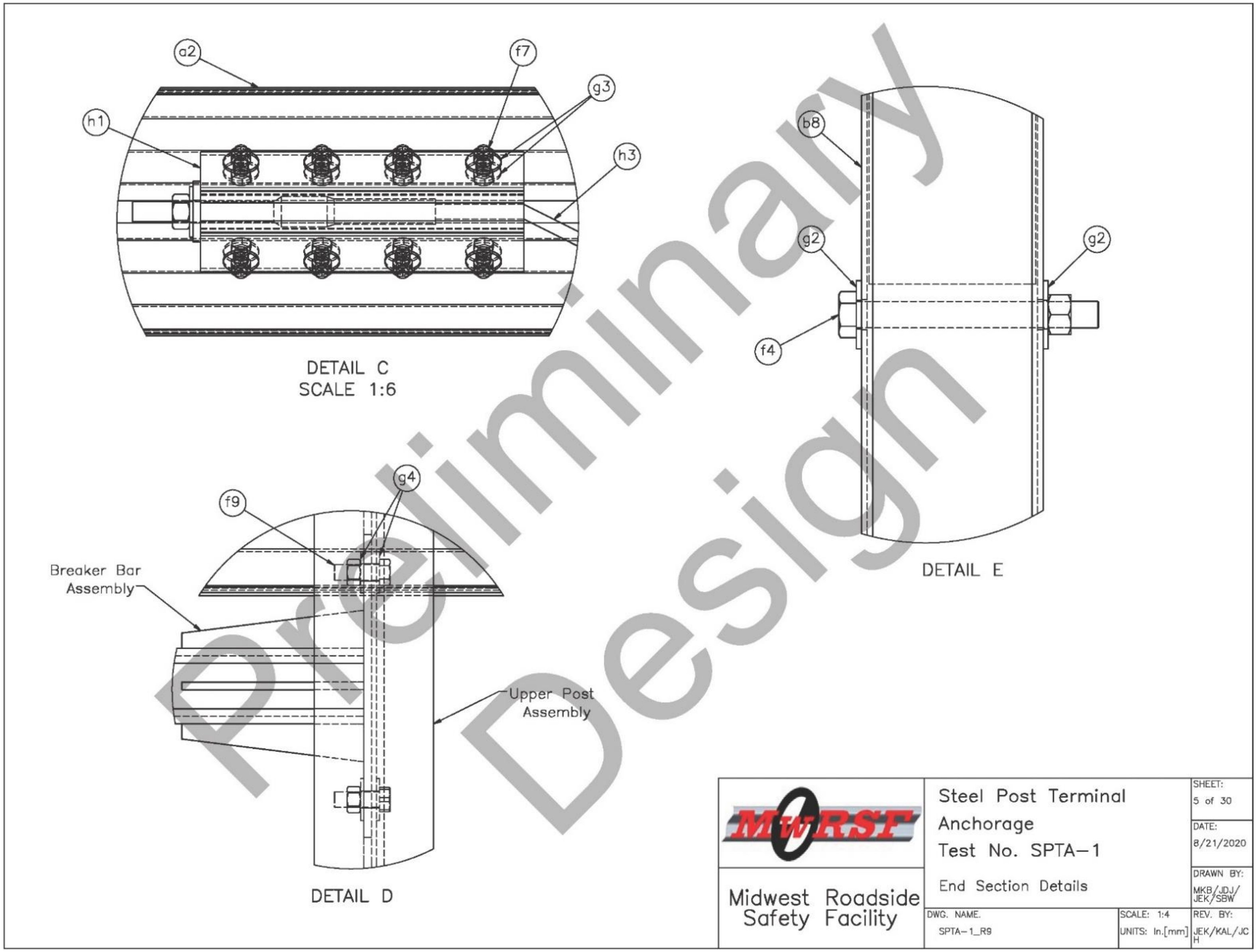


Figure 22. End Section Details, Test No. SPTA-1

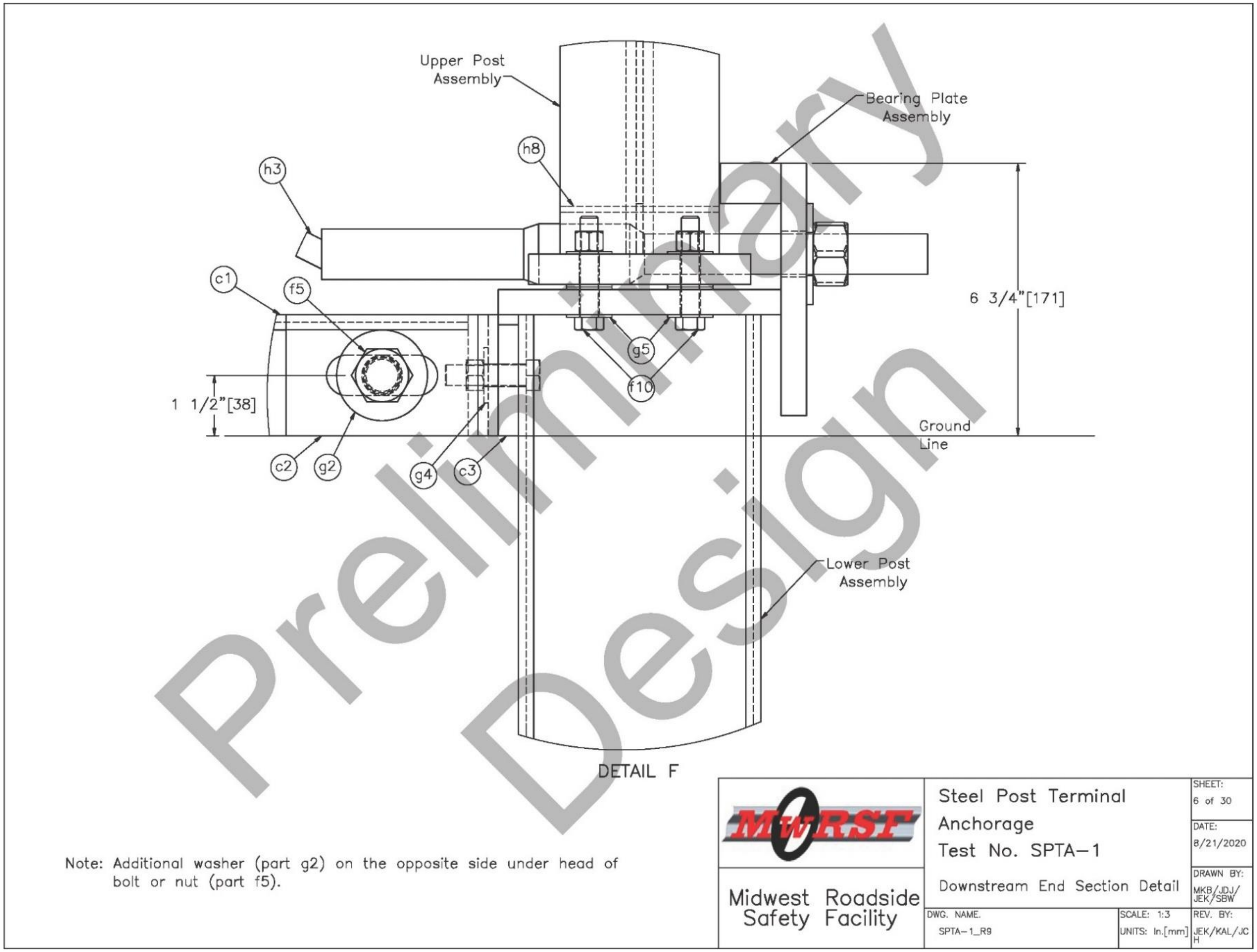


Figure 23. Downstream End Section Detail, Test No. SPTA-1

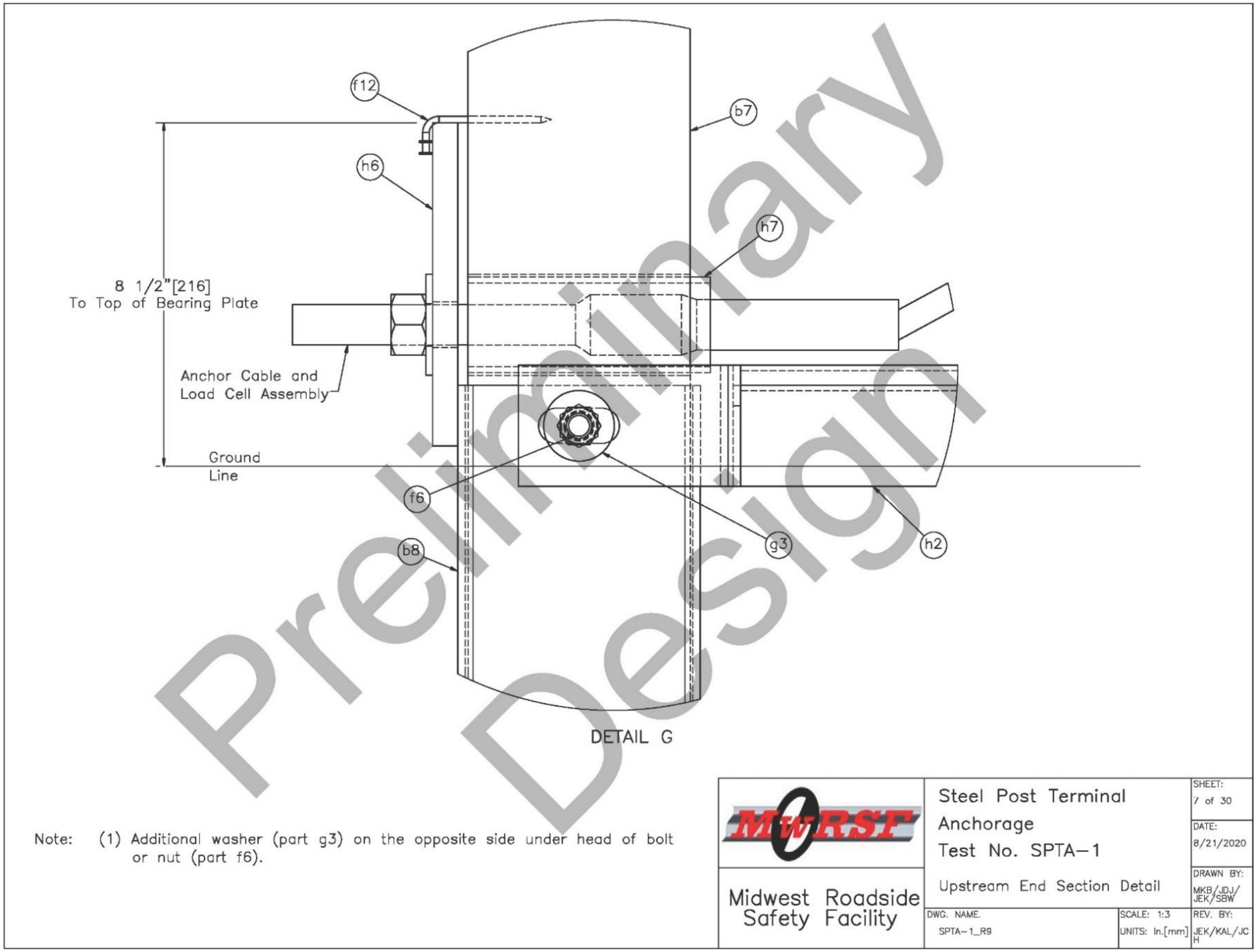


Figure 24. Upstream End Section Detail, Test No. SPTA-1

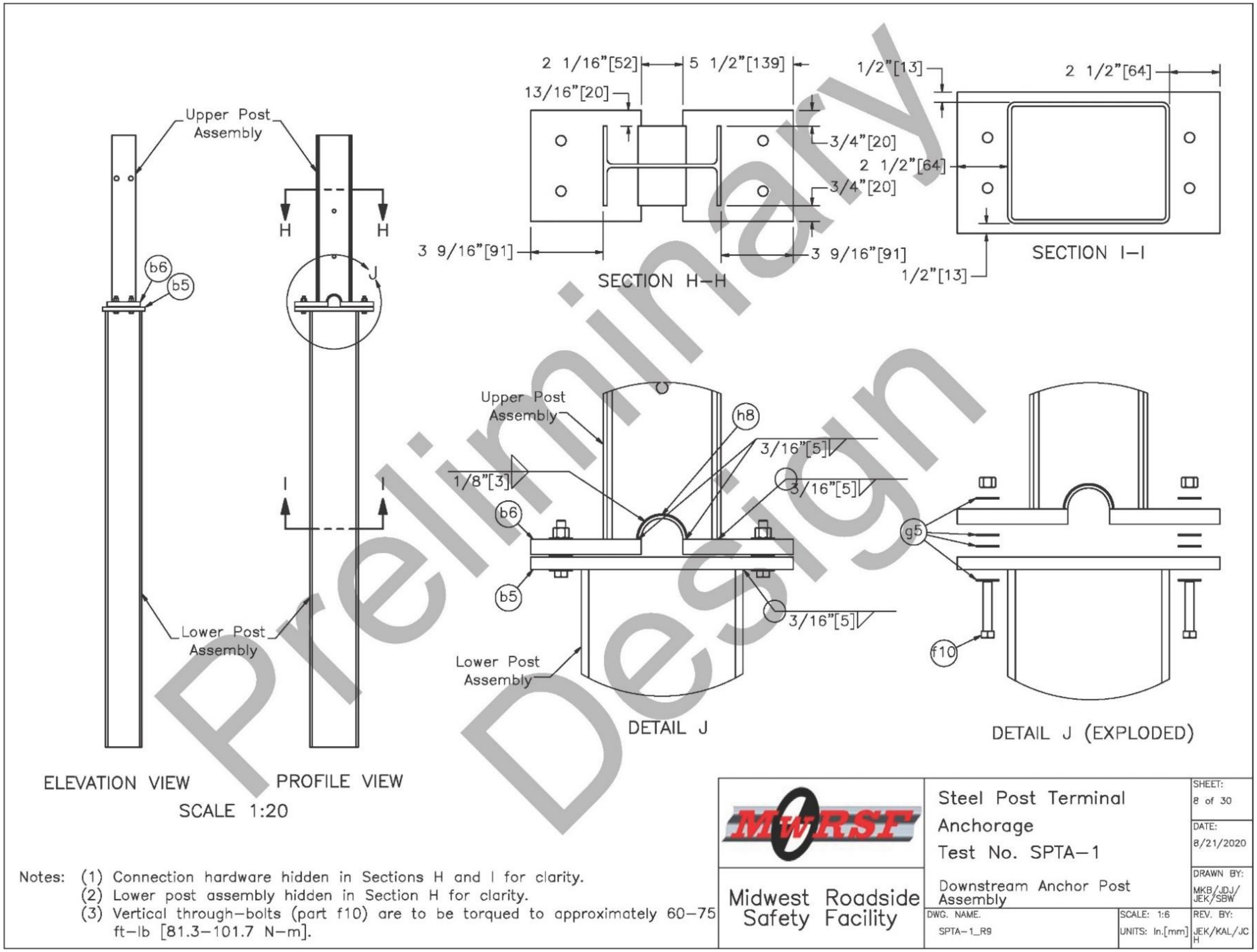
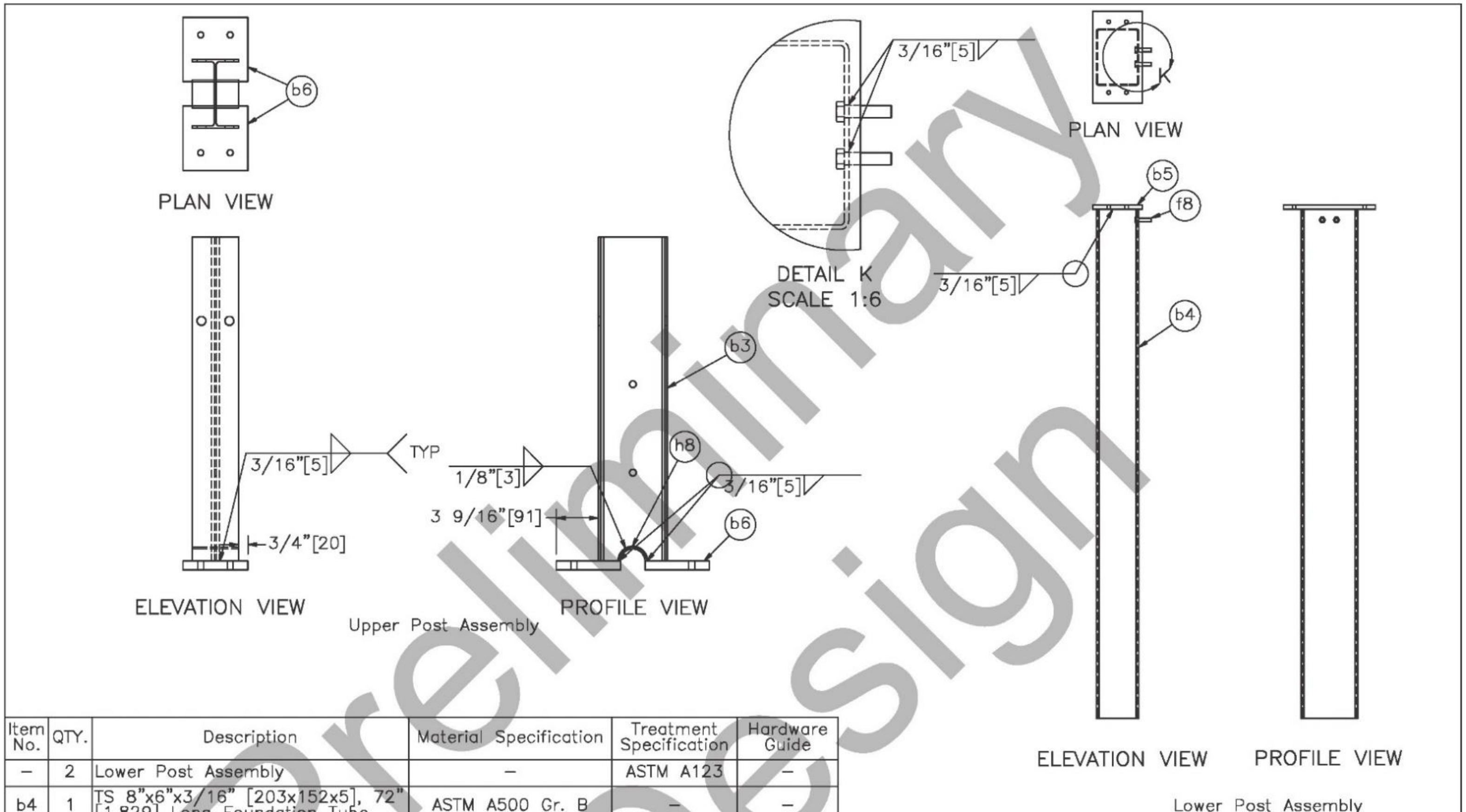


Figure 25. Downstream Anchor Post Assembly, Test No. SPTA-1



Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	2	Lower Post Assembly	–	ASTM A123	–
b4	1	TS 8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	–	–
b5	1	13"x7"x5/8" [330x178x16] Steel Plate	ASTM A36	–	–
f8	2	1/2"-13 UNC [M14x2], 2" [51] Long Hex Bolt and Nut	Bolt ASTM A307 Gr. A or equivalent Nut – ASTM A563A or equivalent	–	FBX14a
–	2	Upper Post Assembly	–	ASTM A123	–
b3	1	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 27 1/2" [699] Long Steel Post	ASTM A992	–	–
b6	2	5 1/2"x5 1/2"x3/4" [140x140x19] Steel Plate	ASTM A36	–	–
h8	1	2 3/8" [60] O.D. x 3 15/16" [100] Long Post Sleeve	ASTM A53 Gr. B Schedule 40	–	FMM02

MwRSF
Midwest Roadside Safety Facility

Steel Post Terminal Anchorage
Test No. SPTA-1

Downstream Anchor Post Assembly Details

SHEET: 9 of 30
DATE: 8/21/2020
DRAWN BY: MKB/JDJ/JEK/SBW
DWG. NAME. SPTA-1_R9
SCALE: 1:12
UNITS: in.[mm]
REV. BY: JEK/KAL/JCH

Figure 26. Downstream Anchor Post Assembly Details, Test No. SPTA-1

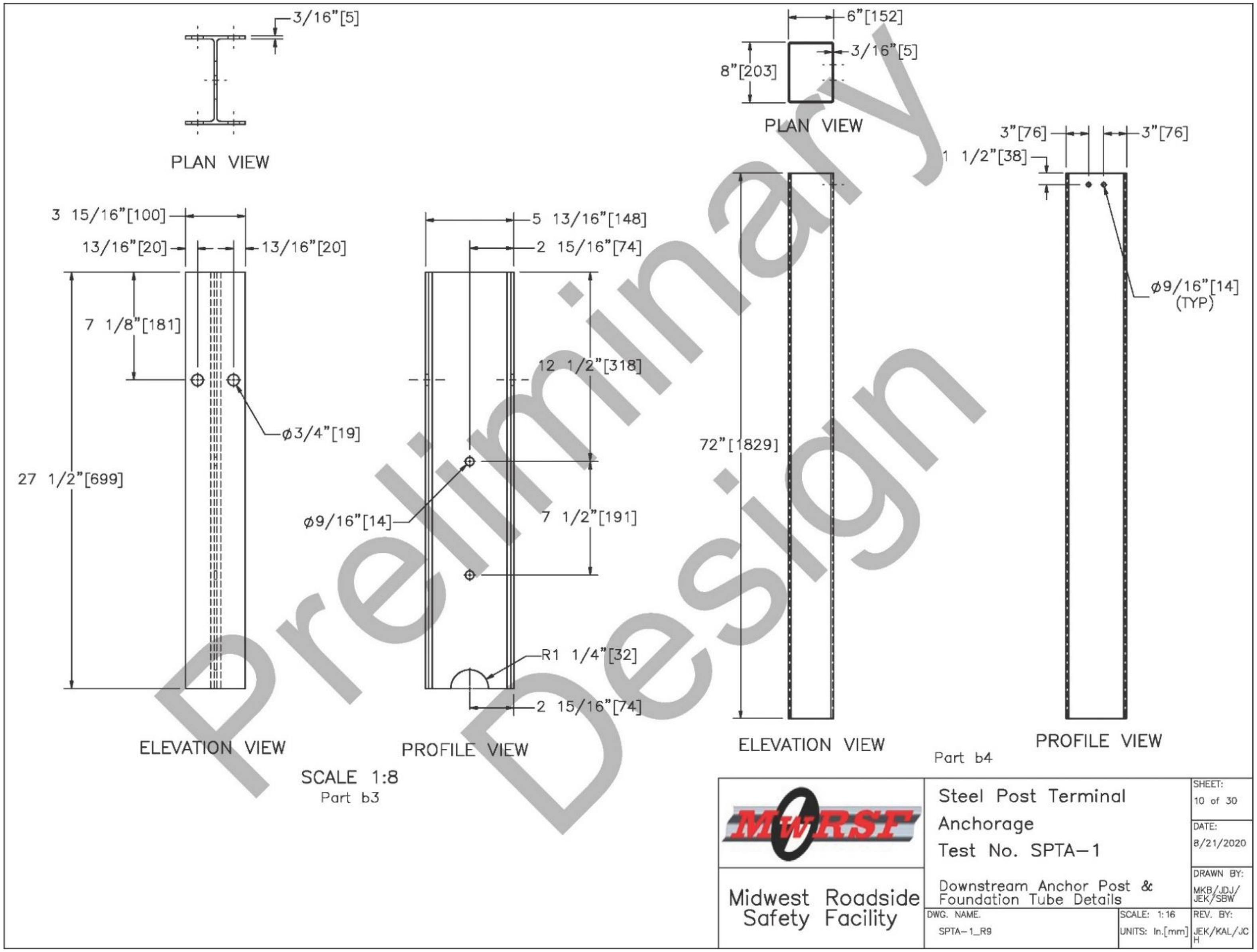


Figure 27. Downstream Anchor Post and Foundation Tube Details, Test No. SPTA-1

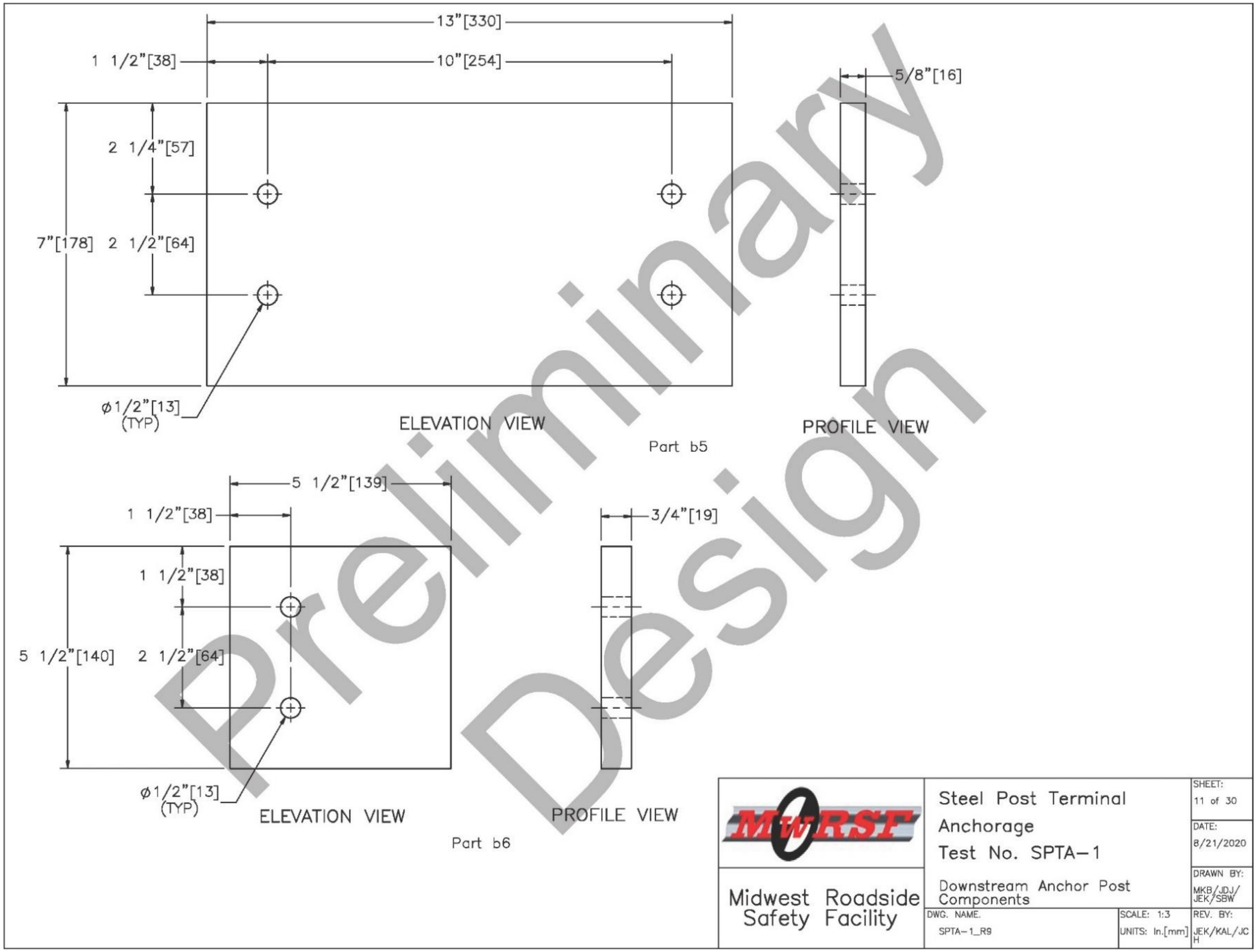


Figure 28. Downstream Anchor Post Components, Test No. SPTA-1

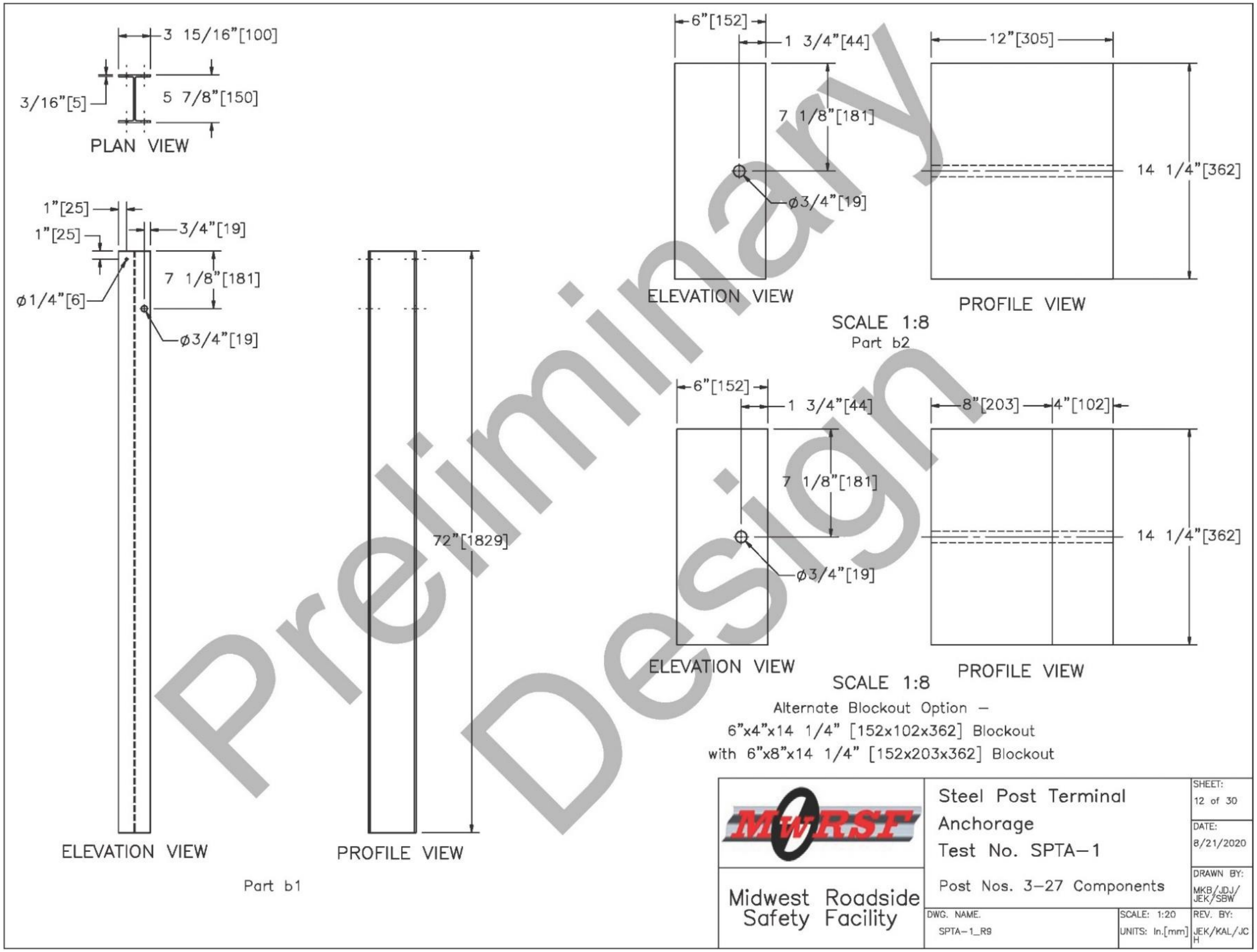


Figure 29. Post Nos. 3 through 27 Components, Test No. SPTA-1

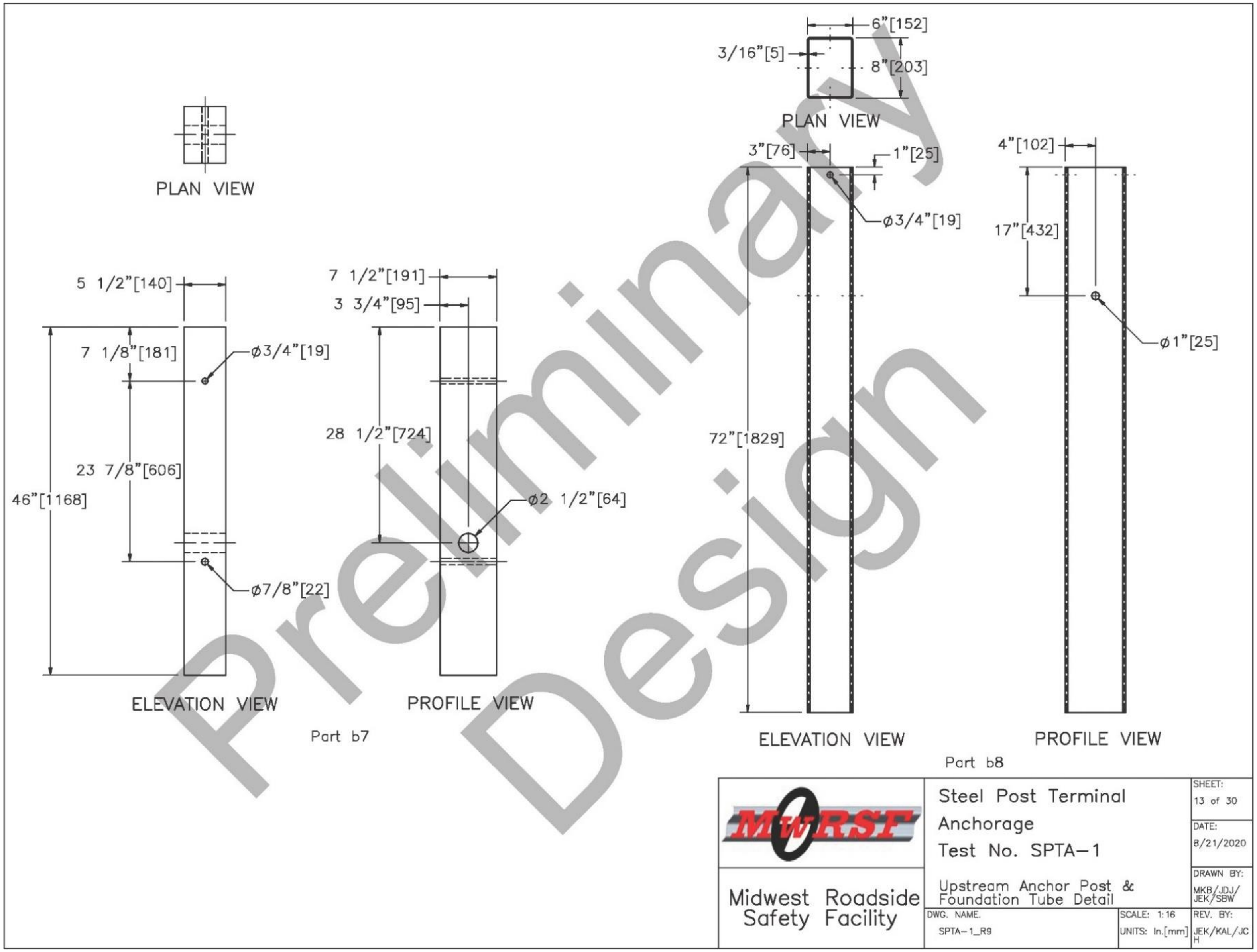


Figure 30. Upstream Anchor Post and Foundation Tube Detail, Test No. SPTA-1

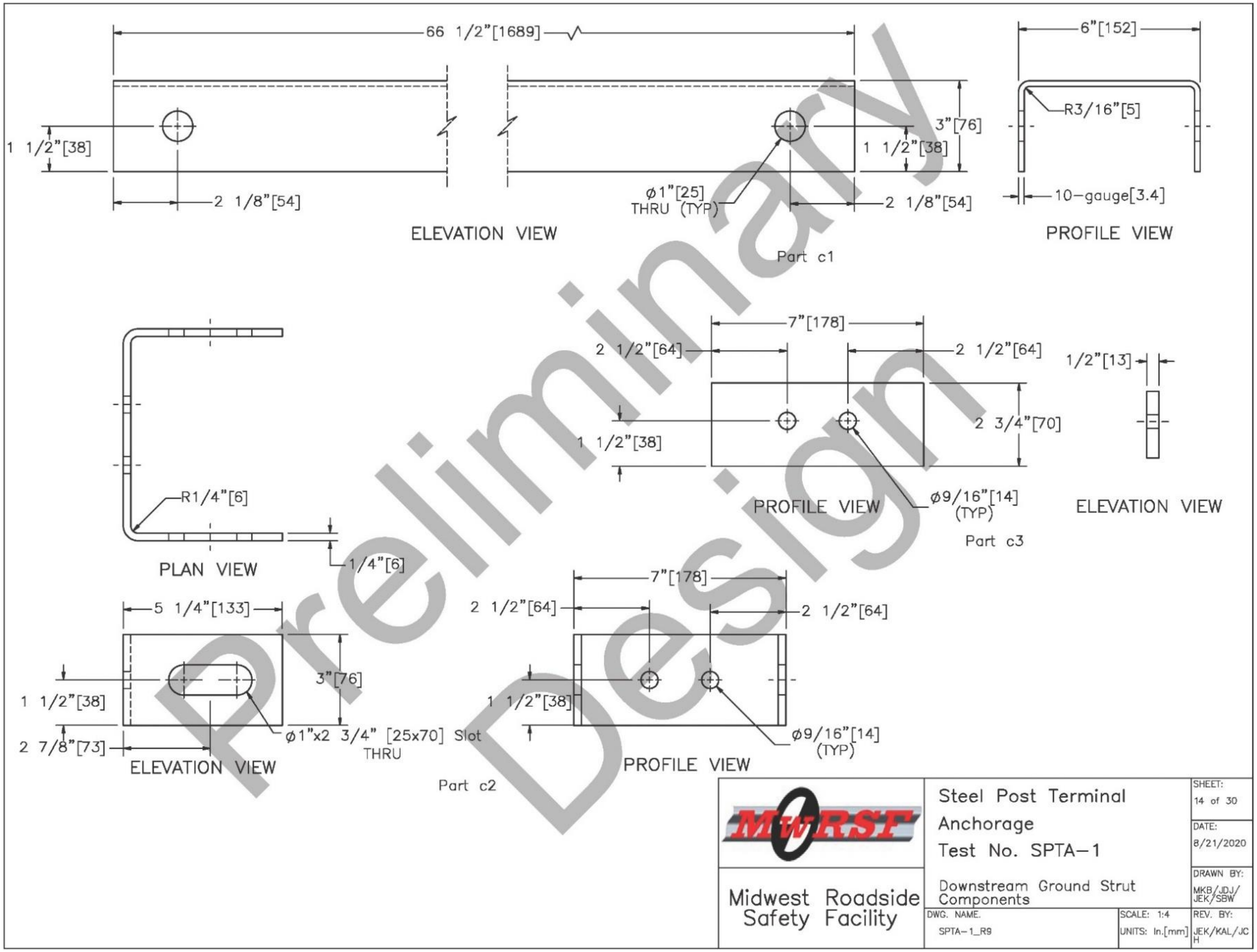


Figure 31. Downstream Ground Strut Components, Test No. SPTA-1

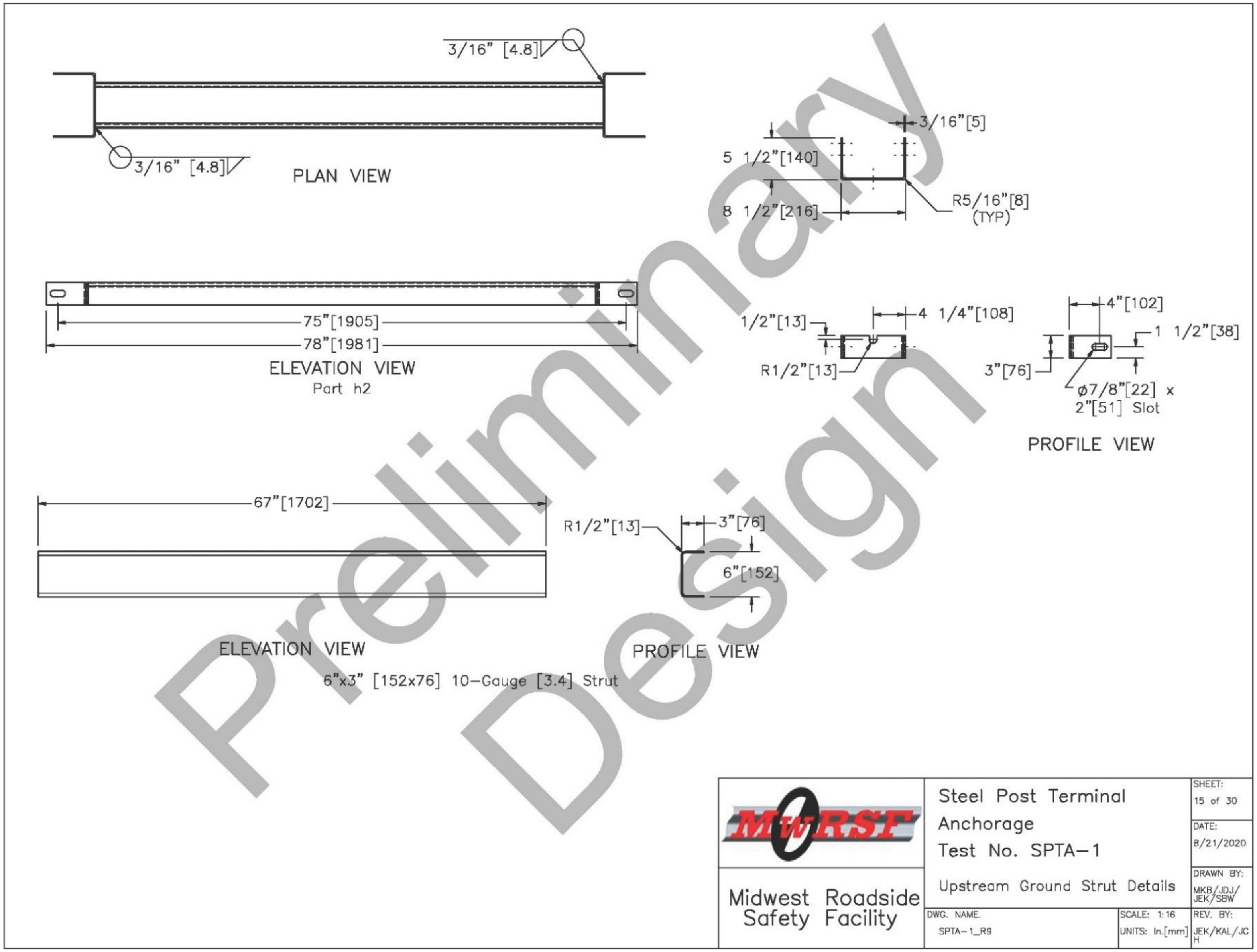
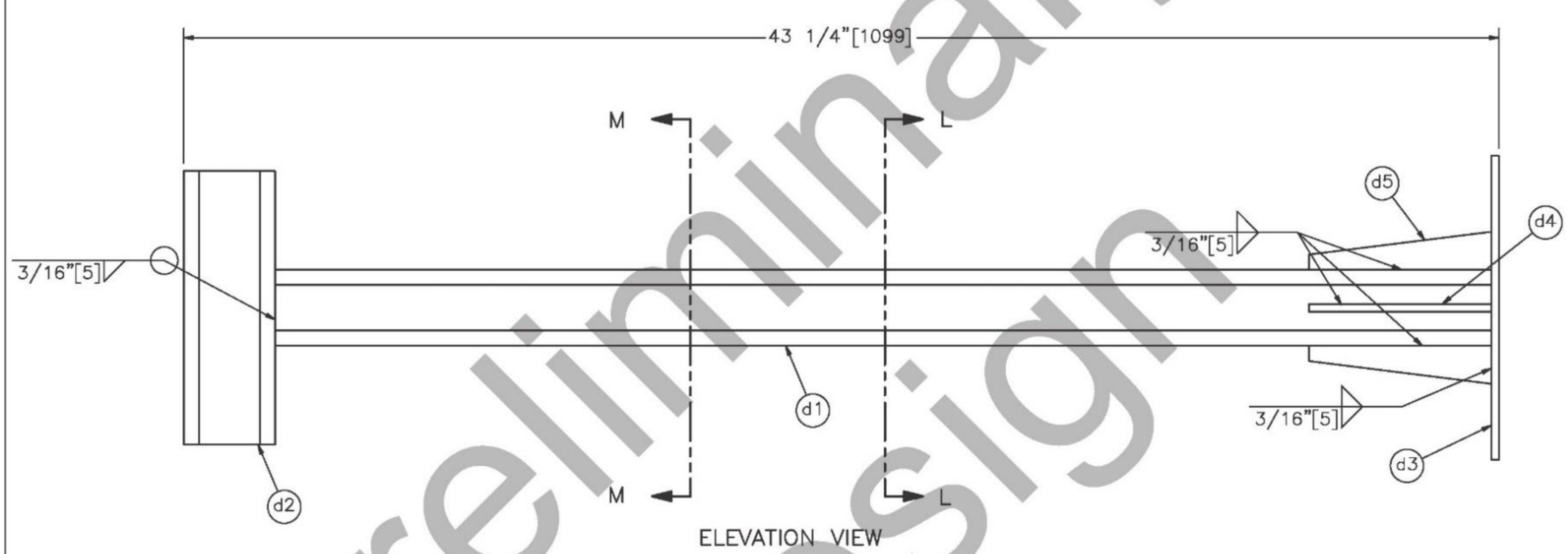


Figure 32. Upstream Ground Strut Details, Test No. SPTA-1



Item No.	QTY.	Description	Material Specification	Treatment Specification
–	1	Breaker Arm Assembly	–	ASTM A123
d1	1	HSS 2 1/2"x2 1/2"x1/4" [64x64x6], 40" [1,016] Long Square Tube	ASTM A500 Gr. B	–
d2	1	HSS 3"x3"x1/4" [76x76x6], 9" [229] Long Square Tube	ASTM A500 Gr. B	–
d3	1	10"x4 1/2"x1/4" [254x114x6] Plate	ASTM A36	–
d4	2	6"x3/4"x1/4" [152x19x6] Gusset	ASTM A36	–
d5	2	6"x1 1/4"x1/4" [152x32x6] Gusset	ASTM A36	–

Midwest Roadside Safety Facility

Steel Post Terminal Anchorage
Test No. SPTA-1

Breaker Arm Assembly

SHEET: 16 of 30
DATE: 8/21/2020
DRAWN BY: MKB/JDJ/JEK/SBW
DWG. NAME. SPTA-1_R9
SCALE: 1:5
UNITS: In.[mm]
REV. BY: JEK/KAL/JCH

Figure 33. Breaker Arm Assembly, Test No. SPTA-1

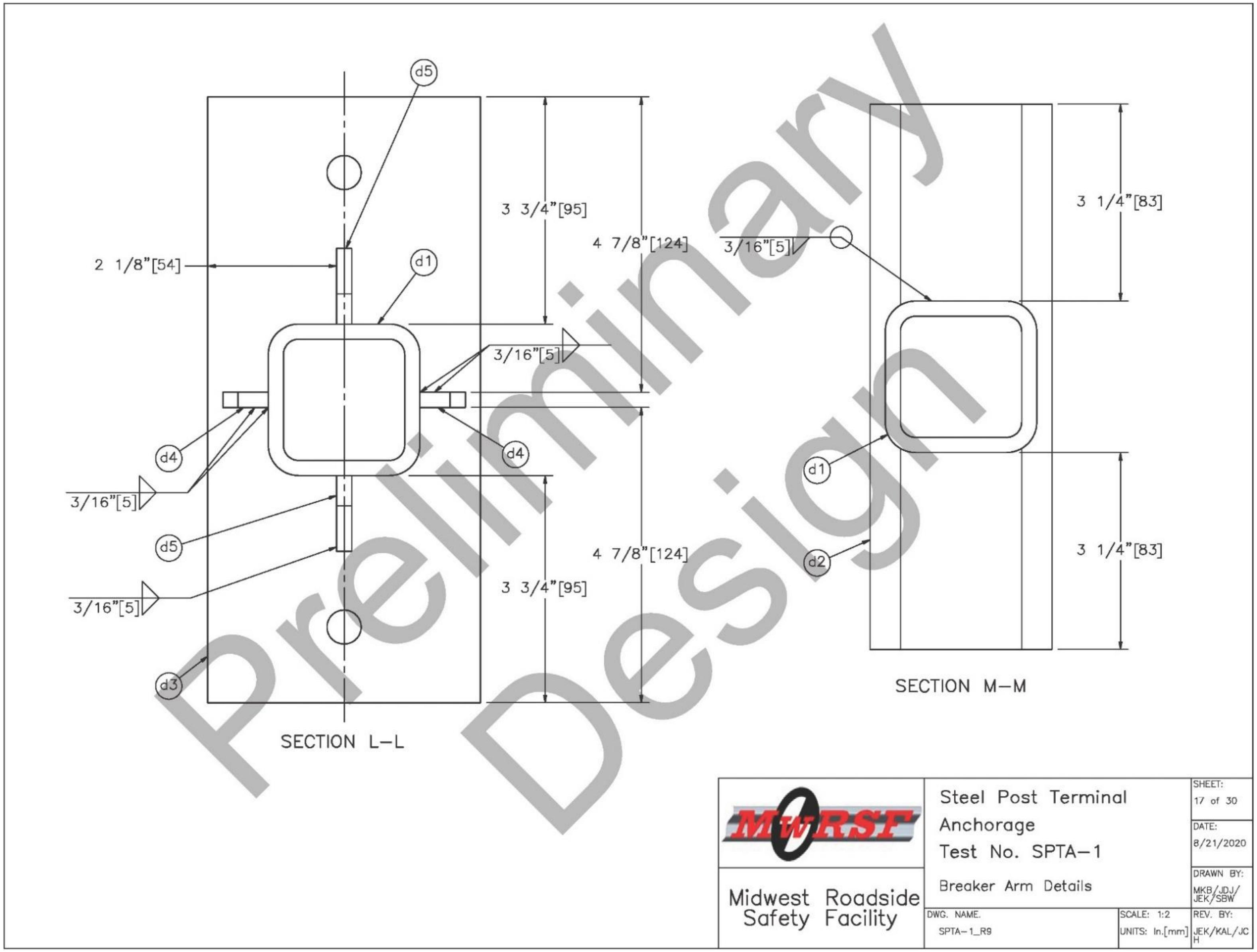


Figure 34. Breaker Arm Details, Test No. SPTA-1

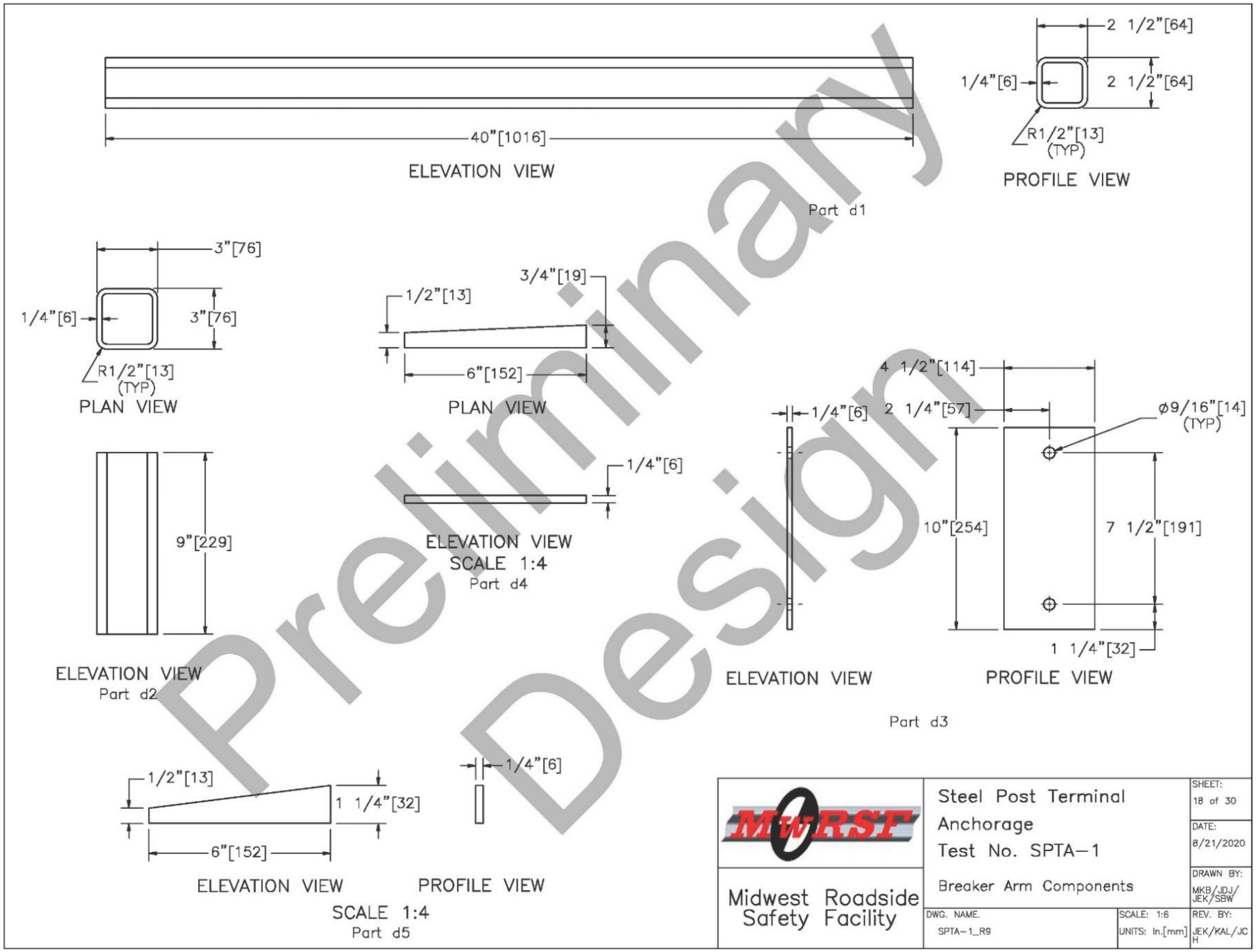


Figure 35. Breaker Arm Components, Test No. SPTA-1

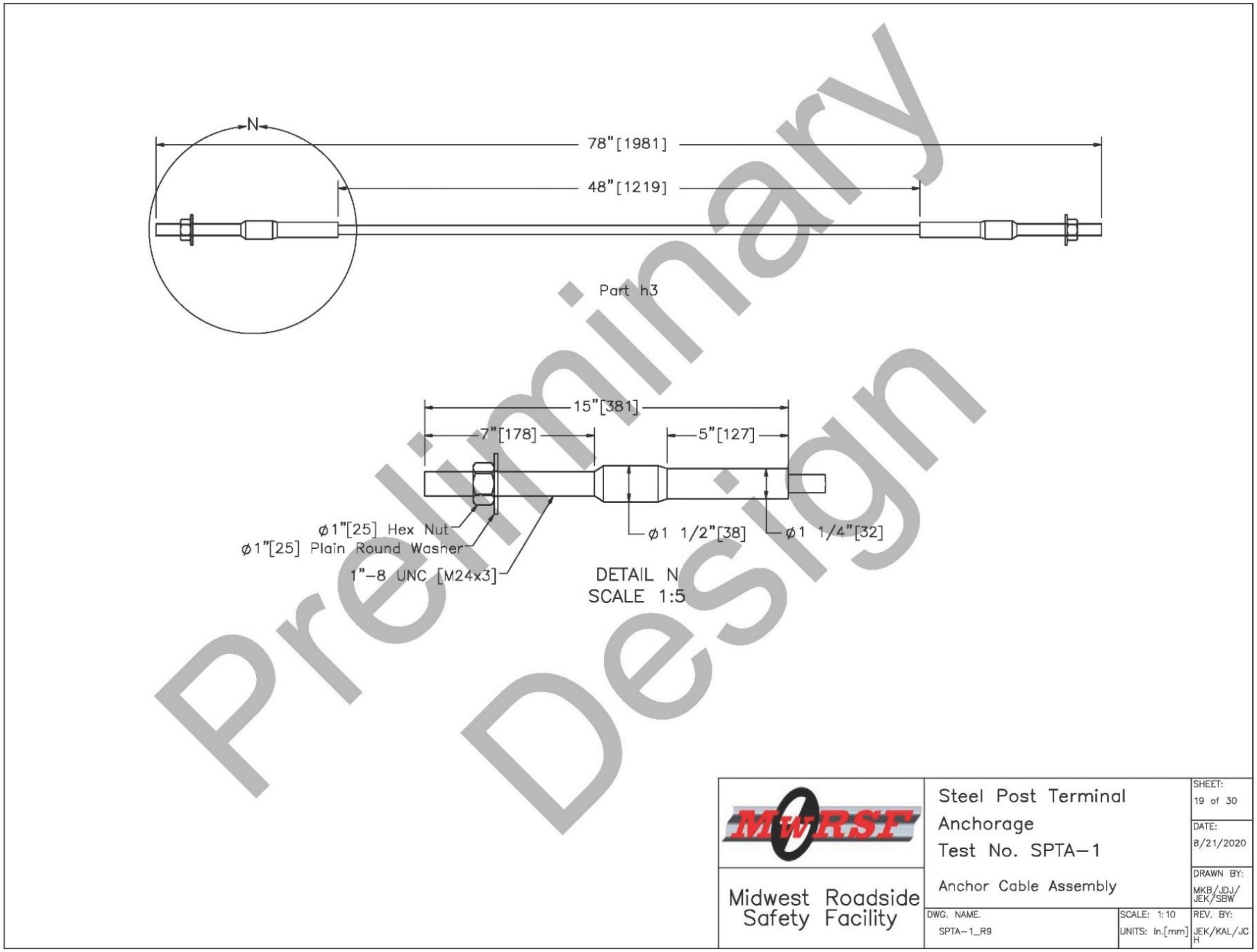
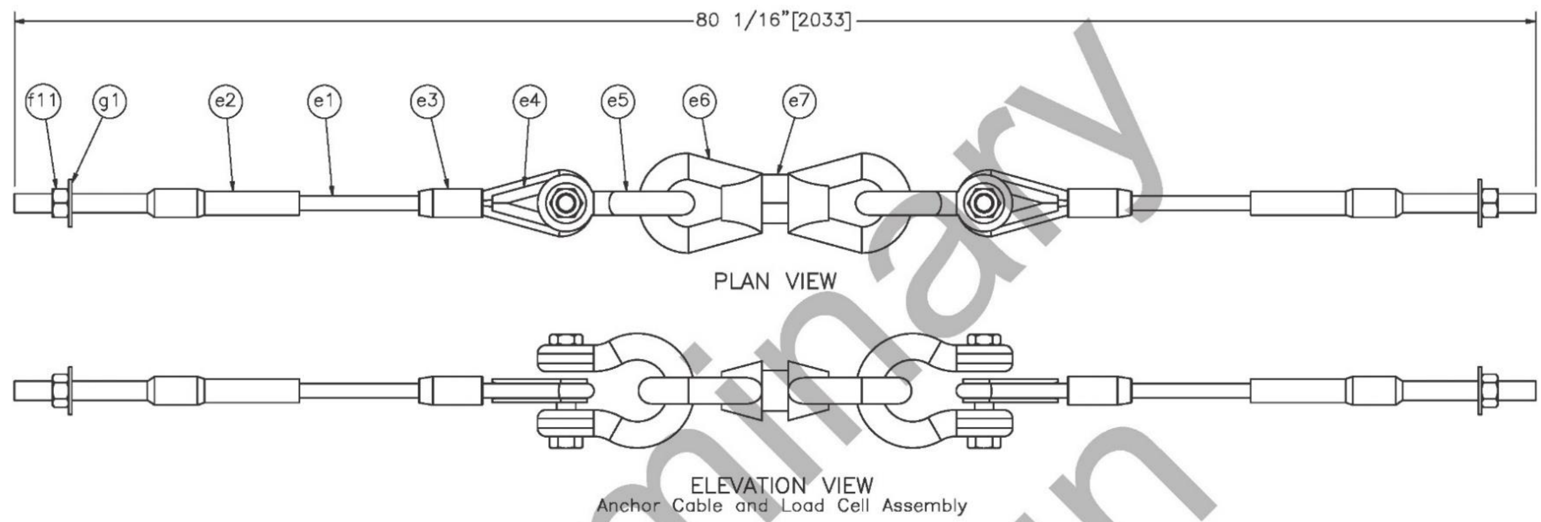


Figure 36. Anchor Cable Assembly, Test No. SPTA-1



Item No.	QTY.	Description	Material Specification	Treatment Specification
–	1	Anchor Cable and Load Cell Assembly	–	–
e1	2	3/4" 6x19, 20" [508] Long IWRC IPS Wire Rope	IPS	ASTM A741 Type II Class A
e2	2	Anchor Cable End Swaged Fitting	Fitting – ASTM A576 Gr. 1035 Stud – ASTM F568 Class C	Fitting – ASTM A153 Stud – ASTM A153 or B695
e3	2	115-HT Mechanical Splice – 3/4" [19] Dia.	As Supplied	–
e4	2	Crosby Heavy Duty HT – 3/4" [19] Dia. Cable Thimble	Stock No. 1037773	As Supplied
e5	2	Crosby G2130 or S2130 Bolt Type Shackle – 1 1/4" [32] Dia. with thin head bolt, nut, and cotter pin, Grade A, Class 3	Stock Nos. 1019597 and 1019604 – As Supplied	–
e6	2	Chicago Hardware Drop Forged Heavy Duty Eye Nut – Drilled and Tapped 1 1/2" [38] Dia. – UNC 6 [M36x4]	Stock No. 107 – As Supplied	–
e7	1	TLL-50K-PTB Load Cell	–	–
f11	2	1"-8 UNC [M24x3] Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329
g1	2	1" [25] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329

Midwest Roadside Safety Facility

Steel Post Terminal Anchorage Test No. SPTA-1
Anchor Cable & Load Cell Assembly

SHEET: 20 of 30
DATE: 8/21/2020
DRAWN BY: MKB/JDJ/JEK/SBW
DWG. NAME. SPTA-1_R9
SCALE: 1:8
UNITS: In.[mm]
REV. BY: JEK/KAL/JCH

Figure 37. Anchor Cable and Load Cell Assembly, Test No. SPTA-1

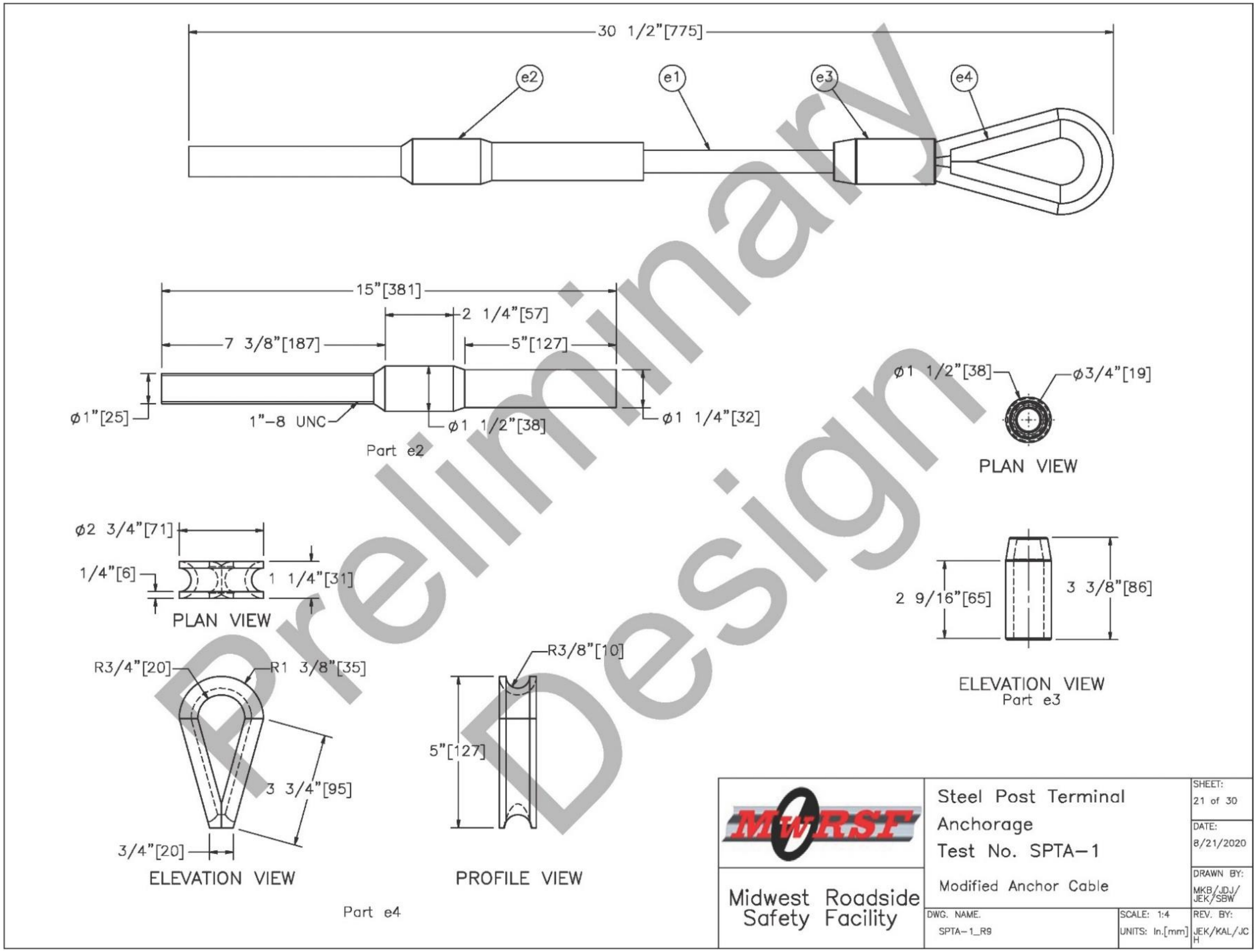


Figure 38. Modified Anchor Cable, Test No. SPTA-1

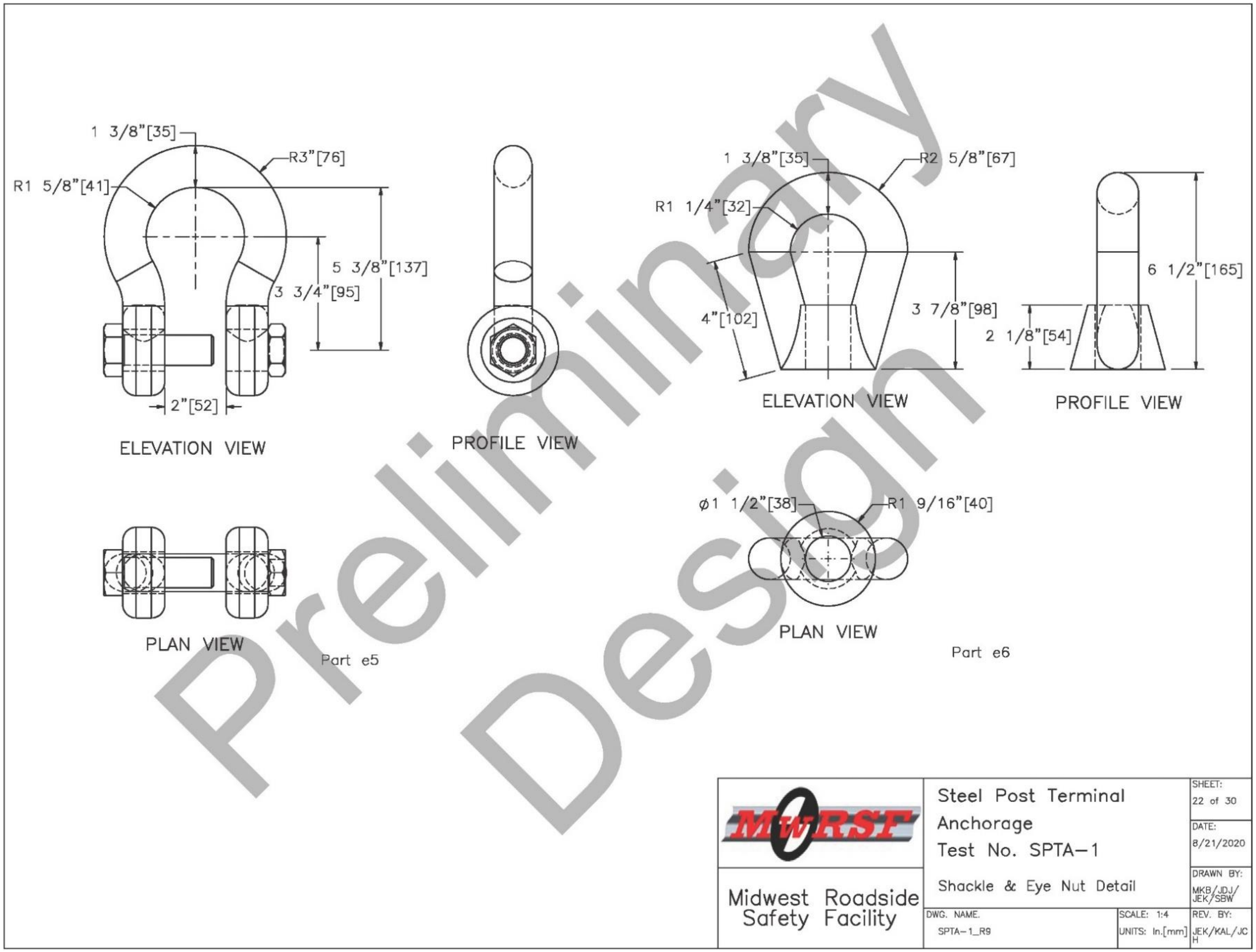


Figure 39. Shackle and Eye Nut Detail, Test No. SPTA-1

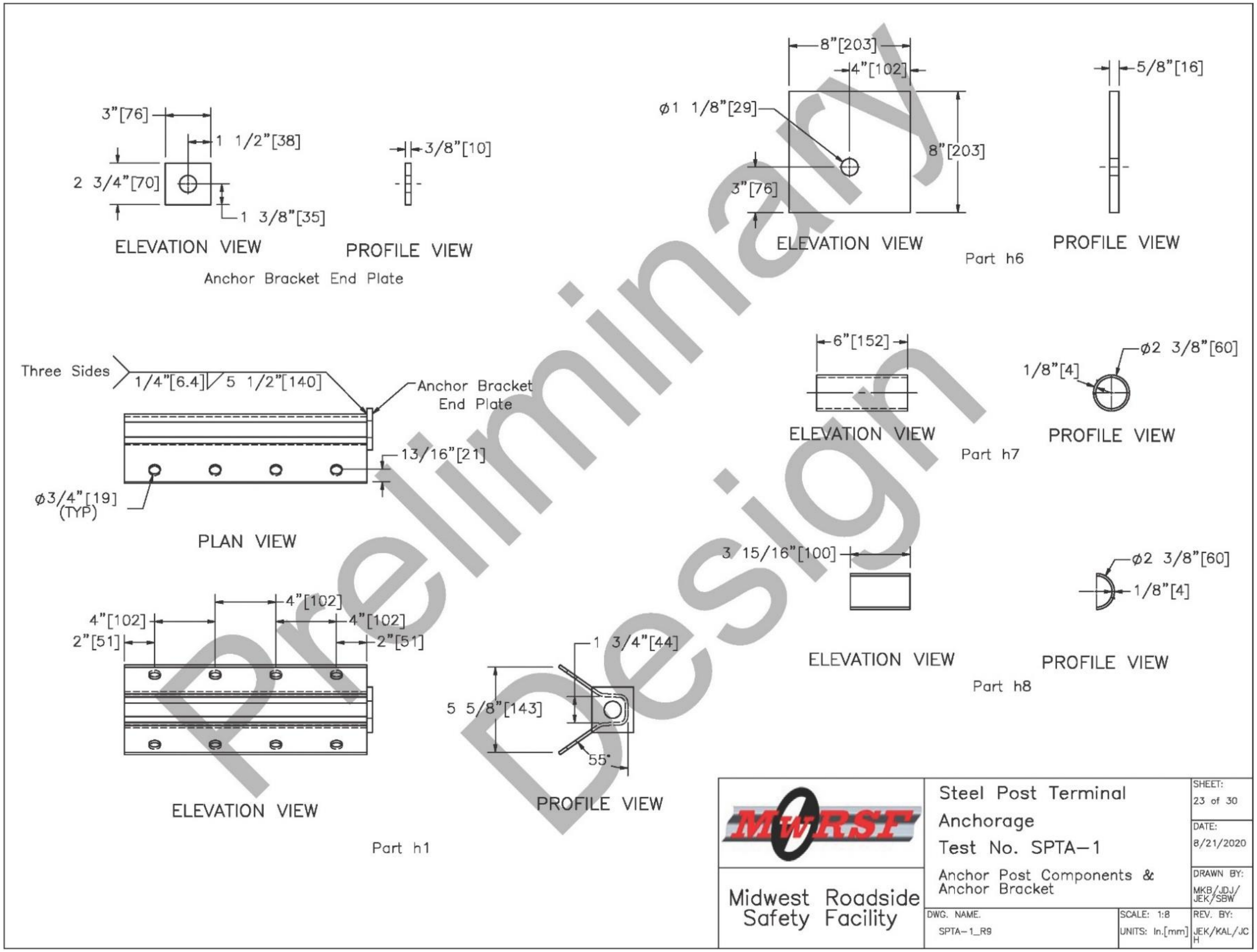
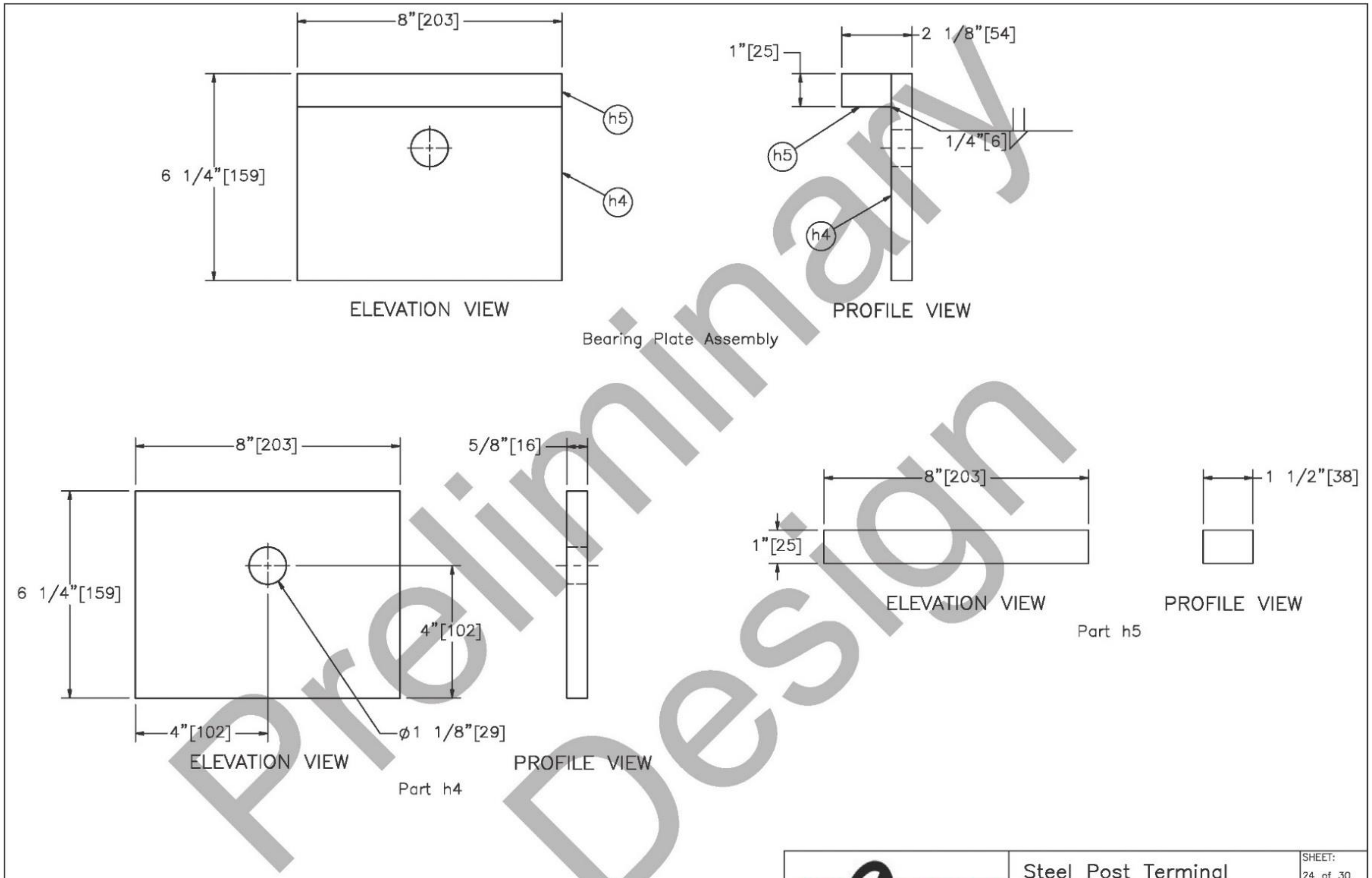


Figure 40. Anchor Post Components and Anchor Bracket, Test No. SPTA-1



Item No.	QTY.	Description	Material Specification	Treatment Specification
–	1	Bearing Plate Assembly	–	ASTM A123
h4	1	8"x6 1/4"x5/8" [203x159x16] Bearing Plate Base	ASTM A36	–
h5	1	8"x1 1/2"x1" [203x38x25] Bearing Plate Flange	ASTM A36	–

MwRSF Midwest Roadside Safety Facility	Steel Post Terminal Anchorage Test No. SPTA-1		SHEET: 24 of 30
			DATE: 8/21/2020
	Bearing Plate Assembly & Components		DRAWN BY: MKB/JDJ/JEK/SBW
	DWG. NAME. SPTA-1_R9	SCALE: 1:4 UNITS: In.[mm]	REV. BY: JEK/KAL/JCH

Figure 41. Bearing Plate Assembly and Components, Test No. SPTA-1

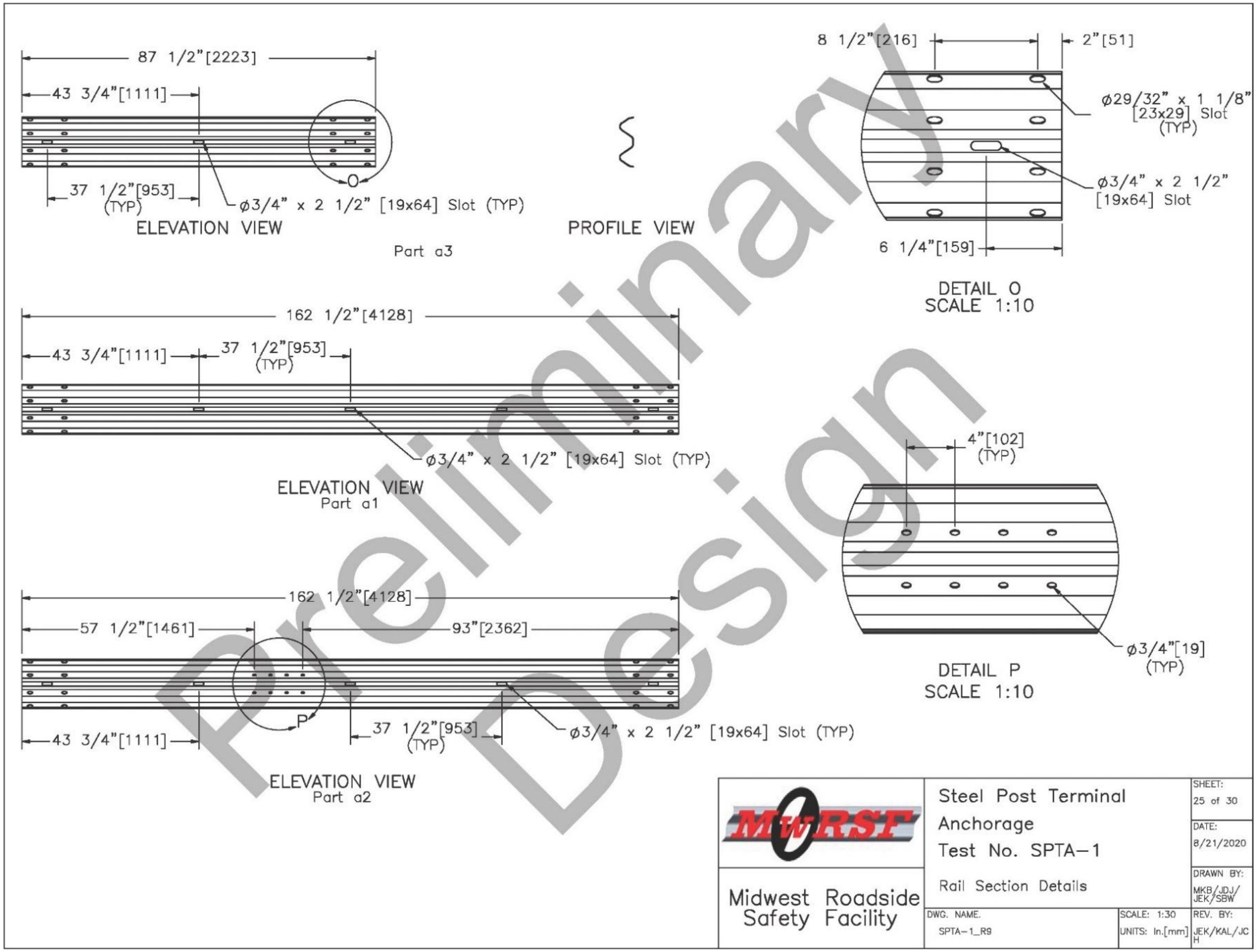


Figure 42. Rail Section Details, Test No. SPTA-1

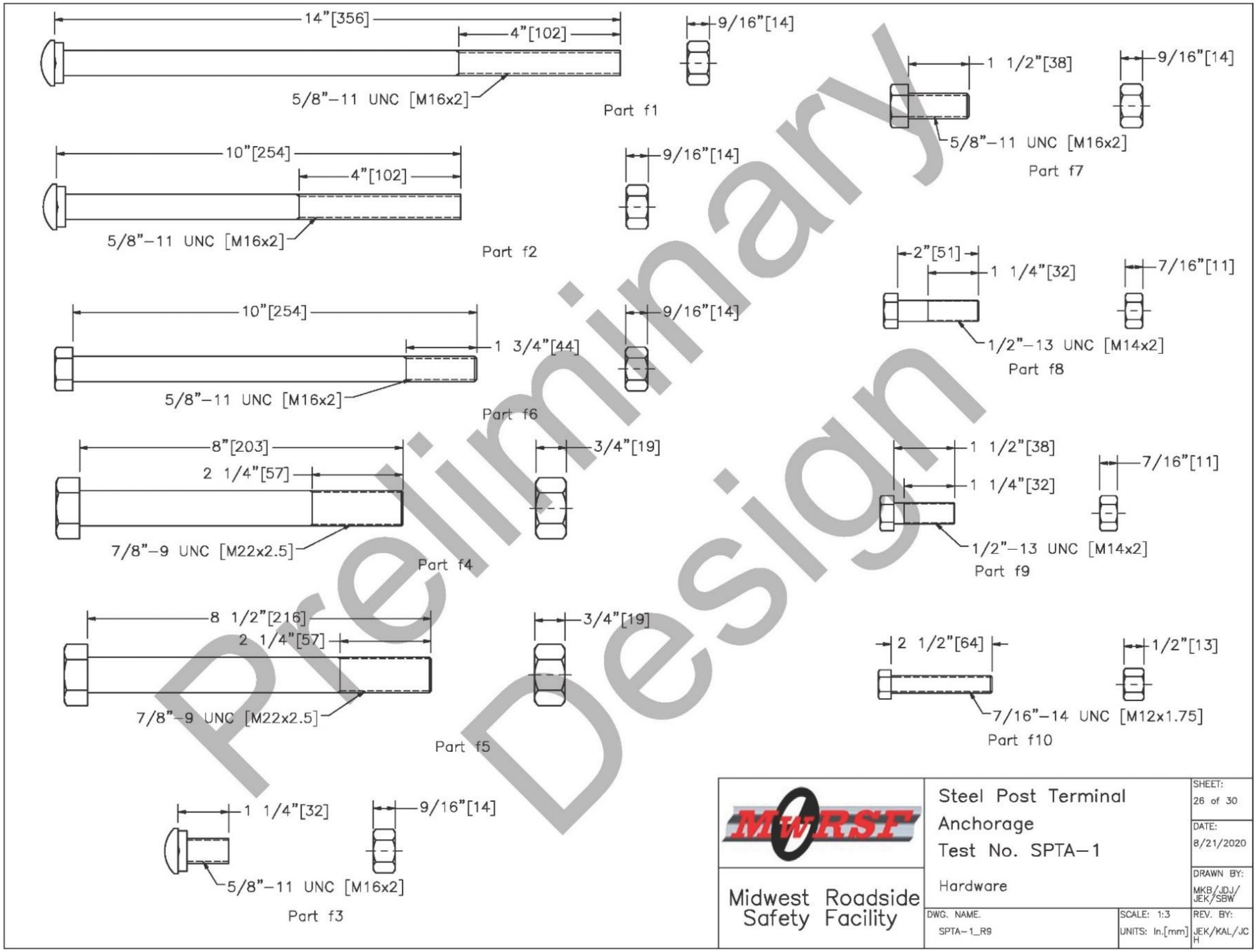


Figure 43. Hardware, Test No. SPTA-1

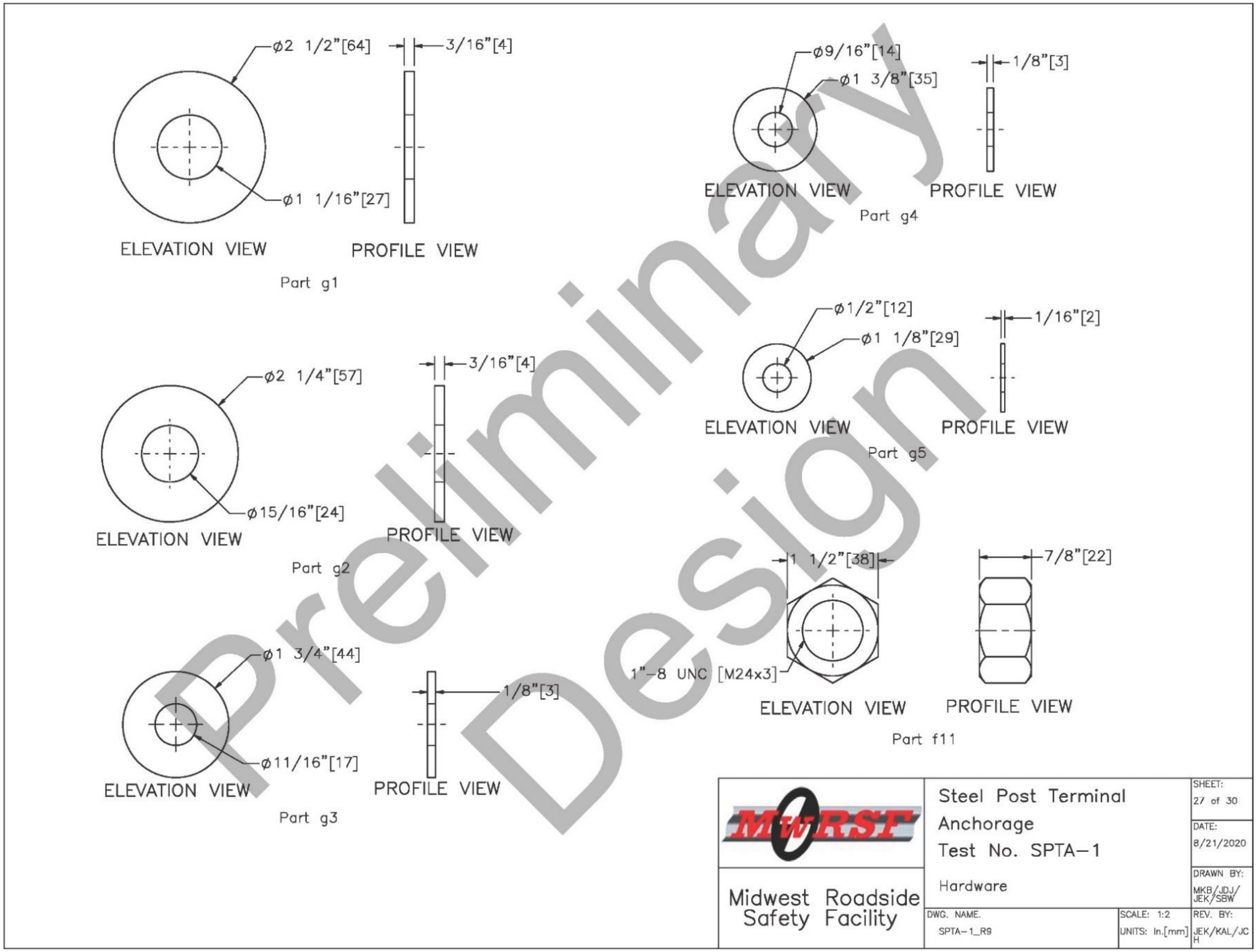


Figure 44. Hardware, Test No. SPTA-1

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	12	12'–6" [3,810] 12–gauge [2.7] W–Beam MGS Section	AASHTO M180	ASTM A123 or A653	RWM04a
a2	2	12'–6" [3,810] 12–gauge [2.7] W–Beam MGS End Section	AASHTO M180	ASTM A123 or A653	–
a3	1	6'–3" [1,905] 12–gauge [2.7] W–Beam MGS Section	AASHTO M180	ASTM A123 or A653	–
b1	25	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 72" Long [1,829] Steel Post	ASTM A992	ASTM A123	PWE06
b2	25	6"x12"x14 1/4" [152x305x368] Timber Blockout	SYP Grade No.1 or better	–	PDB10a
b3	2	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 27 1/2" [699] Long Steel Post	ASTM A992	–	–
b4	2	TS 8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	–	–
b5	2	13"x7"x5/8" [330x178x16] Steel Plate	ASTM A36	–	–
b6	4	5 1/2"x5 1/2"x3/4" [140x140x19] Steel Plate	ASTM A36	–	–
b7	2	BCT Timber Post – MGS Height	SYP Grade No. 1 or better (No knots 18" [457] above or below ground tension face)	–	PDF01
b8	2	TS 8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	ASTM A123	PTE06
c1	1	66 1/2"x11 3/4"x10–gauge [1,689x298x3.4] Bent Steel Channel Strut	ASTM A36	ASTM A123	–
c2	2	17"x3"x1/4" [432x76x6] Bent Steel Plate	ASTM A36	ASTM A123	–
c3	2	7"x2 3/4"x1/2" [178x70x13] Steel Plate	ASTM A36	ASTM A123	–
d1	1	HSS 2 1/2"x2 1/2"x1/4" [64x64x6], 40" [1,016] Long Square Tube	ASTM A500 Gr. B	–	–
d2	1	HSS 3"x3"x1/4" [76x76x6], 9" [229] Long Square Tube	ASTM A500 Gr. B	–	–
d3	1	10"x4 1/2"x1/4" [254x114x6] Plate	ASTM A36	–	–
d4	2	6"x3/4"x1/4" [152x19x6] Gusset	ASTM A36	–	–
d5	2	6"x1 1/4"x1/4" [152x32x6] Gusset	ASTM A36	–	–

Midwest Roadside Safety Facility

Steel Post Terminal Anchorage
Test No. SPTA–1

Bill of Materials

SHEET:	28 of 30
DATE:	8/21/2020
DRAWN BY:	MKB/JDJ/JEK/SBW
REV. BY:	JEK/KAL/JCH
DWG. NAME.	SPTA–1_R9
SCALE:	None
UNITS:	In.[mm]

Figure 45. Bill of Materials, Test No. SPTA-1

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
e1	2	3/4" 6x19, 20" [508] Long IWRC IPS Wire Rope	IPS	ASTM A741 Type II Class A	–
e2	2	Anchor Cable End Swaged Fitting	Fitting – ASTM A576 Gr. 1035 Stud – ASTM F568 Class C	Fitting – ASTM A153 Stud – ASTM A153 or B695	–
e3	2	115–HT Mechanical Splice – 3/4" [19] Dia.	As Supplied	–	–
e4	2	Crosby Heavy Duty HT – 3/4" [19] Dia. Cable Thimble	Stock No. 1037773	As Supplied	–
e5	2	Crosby G2130 or S2130 Bolt Type Shackle – 1 1/4" [32] Dia. with thin head bolt, nut, and cotter pin, Grade A, Class 3	Stock Nos. 1019597 and 1019604 – As Supplied	–	–
e6	2	Chicago Hardware Drop Forged Heavy Duty Eye Nut – Drilled and Tapped 1 1/2" [38] Dia. – UNC 6 [M36x4]	Stock No. 107 – As Supplied	–	–
e7	1	TLL–50K–PTB Load Cell	–	–	–
f1	25	5/8"–11 UNC [M16x2], 14" [356] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB06
f2	2	5/8"–11 UNC [M16x2], 10" [254] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB03
f3	114	5/8"–11 UNC [M16x2], 1 1/4" [32] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB01
f4	2	7/8"–9 UNC [M22x2.5], 8" [203] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A or equivalent Nut – ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	–
f5	2	7/8"–9 UNC [M22x2.5], 8 1/2" [216] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A or equivalent Nut – ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	–
f6	2	5/8"–11 UNC [M16x2], 10" [254] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A or equivalent Nut – ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f7	16	5/8"–11 UNC [M16x2], 1 1/2" [38] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A or equivalent Nut – ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f8	4	1/2"–13 UNC [M14x2], 2" [51] Long Hex Bolt and Nut	Bolt ASTM A307 Gr. A or equivalent Nut – ASTM A563A or equivalent	–	FBX14a
f9	2	1/2"–13 UNC [M14x2], 1 1/2" [38] Long Hex Bolt and Nut	Bolt ASTM A307 Gr.A or equivalent Nut – ASTM A563A or equivalent	ASTM A153 OR B695 Class 55 or F2329	FBX14a
f10	8	7/16"–14 UNC [M12x1.75], 2 1/2" [64] Long Fully Threaded Hex Tap Bolt and Nut	Bolt – ASTM A449 or equivalent Nut – ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX12b
f11	2	1"–8 UNC [M24x3] Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX24a
f12	26	16D Double Head Nail	–	–	–

Note: (1) 6x25 IWRC IPS cables meet the minimum breaking strength of 42.7 kips [190 kN] and may be substituted for the 6x19 IWRC IPS cables.

MwRSF
Midwest Roadside Safety Facility

Steel Post Terminal Anchorage
Test No. SPTA–1

Bill of Materials

SHEET: 29 of 30
DATE: 8/21/2020
DRAWN BY: MKB/JDJ/JEK/SBW
REV. BY: JEK/KAL/JCH
DWG. NAME. SPTA–1_R9
SCALE: None
UNITS: In.[mm]

Figure 46. Bill of Materials, Test No. SPTA-1

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
g1	2	1" [25] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC24a
g2	8	7/8" [22] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	–
g3	38	5/8" [16] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC16a
g4	8	1/2" [13] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC14a
g5	32	7/16" [11] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC12a
h1	2	Anchor Bracket Assembly	ASTM A36	ASTM A123	FPA01
h2	1	Upstream Ground Strut	ASTM A36	ASTM A123	–
h3	1	Anchor Cable Assembly	–	–	FCA01
h4	1	8"x6 1/4"x5/8" [203x159x16] Bearing Plate Base	ASTM A36	–	–
h5	1	8"x1 1/2"x1" [203x38x25] Bearing Plate Flange	ASTM A36	–	–
h6	1	8"x8"x5/8" [203x203x16] Anchor Bearing Plate	ASTM A36	ASTM A123	FPB01
h7	1	2 3/8" [60] O.D. x 6" [152] Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	ASTM A123	FMM02
h8	1	2 3/8" [60] O.D. x 3 15/16" [100] Long Post Sleeve	ASTM A53 Gr. B Schedule 40	ASTM A123	–

Midwest Roadside Safety Facility

Steel Post Terminal Anchorage
Test No. SPTA-1

Bill of Materials

SHEET: 30 of 30
DATE: 8/21/2020
DRAWN BY: MKB/JDJ/JEK/SBW
DWG. NAME. SPTA-1_R9
SCALE: None
UNITS: In.[mm]
REV. BY: JEK/KAL/JCH

Figure 47. Bill of Materials, Test No. SPTA-1

Figure 48. Test Installation Photographs – Trailing-End Anchorage System, Test No. SPTA-1

Figure 49. Test Installation Photographs, Test No. SPTA-1

Figure 50. Test Installation Photographs, Test No. SPTA-1

Figure 51. Test Installation Photographs – Test No. SPTA-1

5 FULL-SCALE CRASH TEST NO. SPTA-1

5.1 Static Soil Test

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

5.2 Weather Conditions

Test no. SPTA-1 was conducted on July 31, 2018 at approximately 2:00 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 5.

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

Temperature	84°F
Humidity	40%
Wind Speed	6 mph
Wind Direction	0° True North
Sky Conditions	Clear
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.11 in.
Previous 7-Day Precipitation	0.41 in.

5.3 Test Description

Initial vehicle impact was to occur at the center of post no. 24, as shown in Figure 52, which matched the impact point used in the evaluation of the wood-post trailing anchorage system and was selected to evaluate the downstream length-of-need point on the installation. The 5,074-lb (2,302-kg) vehicle impacted the guardrail installation at a speed of 62.1 mph (99.9 km/h) and at an angle of 25.0 degrees. The actual point of impact was 3.9 in. (99 mm) downstream from post no. 24. During the impact event, the vehicle was captured and redirected by the guardrail system. As the vehicle approach the downstream end of the installation, a guardrail pocket formed just upstream of post no 28, or the interior breakaway steel anchor post. The lateral load in the rail caused post no. 28 to cleanly break away from its foundation tube base. At about the same time, the rail released from the attachment bolt at post no. 29, though the cable anchorage remained intact. Subsequently, the guardrail dropped vertically and translated laterally toward the back side of the installation. The lateral motion of the rail caused the anchor cable to contact the T-shaped breaker bar and push the bar backward. The dropping W-beam covered the face of the T-shaped breaker bar, and prevented the vehicle from impacting the upstream face of the breaker bar, as intended. Eventually, the vehicle’s right tire overrode the guardrail as the vehicle’s bumper impacted post no. 29, or the downstream most anchor post. The front two attachment bolts on post no. 29 fractured, but the back two bolt remained intact. The vehicle overrode post no. 29 and bent the post downstream. The vehicle remained stable throughout the impact event and came to rest 201 ft – 6 in. (61.4 m) downstream from the point of impact after brakes were applied.A detailed description of the sequential impact events is contained in Table 6. Sequential photographs are shown in Figures 53 and 54. Documentary photographs of the crash test are shown in Figures 55 and 56. The vehicle trajectory and final position are shown in Figure 57.

Figure 52. Impact Location, Test No. SPTA-1

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

TIME (sec)	EVENT
0.000	Vehicle’s front bumper contacted rail 3.9 in. (99 mm) downstream from post no. 24.
0.004	Post no. 24 deflected backward, vehicle's front bumper deformed, and vehicle’s right fender contacted rail.
0.006	Vehicle’s right fender deformed.
0.010	Vehicle’s right headlight contacted rail.
0.012	Post no. 25 deflected backward and vehicle's right headlight deformed.
0.020	Vehicle’s grille contacted rail.
0.022	Post no. 24 rotated backward, and vehicle's grille deformed.
0.026	Vehicle yawed away from system.
0.027	Post no. 24 twisted clockwise.
0.028	Post no. 23 rotated clockwise.
0.032	Post no. 22 rotated clockwise.
0.034	Post nos. 6 through 21 rotated clockwise due to rail movement.
0.040	Post no. 25 rotated backward.
0.042	Post no. 28 deflected upstream, and vehicle's right-front tire contacted rail.
0.044	Post no. 29 deflected upstream.
0.048	Vehicle’s right-front rim contacted rail.
0.054	Post no. 26 deflected backward.
0.056	Post no. 25 twisted counterclockwise.
0.068	Post no. 26 twisted counterclockwise.
0.070	Vehicle’s right headlight contacted blockout at post no. 25 and shattered.
0.072	Rail disengaged from bolt at post no. 25.
0.077	Post no. 27 rotated counterclockwise.
0.078	Post no. 25 bent backward.
0.086	Post no. 26 rotated backward.
0.090	Vehicle’s right-front tire contacted post no. 25.
0.096	Post no. 28 twisted counterclockwise.
0.098	Vehicle’s right-front door contacted rail.
0.104	Post no. 27 twisted counterclockwise.
0.106	Rail disengaged from bolt at post no. 26.
0.108	Post no. 27 deflected backward.
0.116	Post no. 26 rotated downstream.
0.120	Post no. 27 rotated backward.
0.130	Post no. 28 deflected downstream.
0.138	Post no. 28 deflected backward.
0.142	Vehicle rolled toward system.

Table 7. Sequential Description of Impact Events, Test No. SPTA-1, Cont.

TIME (sec)	EVENT
0.148	Blockout disengaged from post no. 26.
0.150	Post no. 27 rotated downstream.
0.152	Post no. 26 bent backward, and post no. 29 twisted counterclockwise.
0.156	Vehicle’s front bumper contacted post no. 26.
0.176	Post no. 27 bent backward.
0.178	Rail disengaged from bolt at post no. 27.
0.186	Vehicle’s right-front quarter panel contacted rail and deformed.
0.194	Vehicle’s rear bumper contacted rail.
0.197	Post no. 23 deflected backward.
0.212	Vehicle’s rear bumper deformed.
0.224	Vehicle’s front bumper contacted post no. 27, and post nos. 6 through 21 rotated counterclockwise due to rail movement.
0.230	Post no. 27 bent downstream.
0.240	Post no. 28 rotated backward, rail disengaged from bolt at post no. 29, and top of post no. 28 detached from base.
0.260	Vehicle pitched downward.
0.274	Post no. 29 deflected backward.
0.276	Blockout disengaged from post no. 27.
0.282	Rail disengaged from bolt at post no. 28.
0.306	Vehicle was parallel to system at a speed of 43.6 mph (70.2 km/h).
0.332	Vehicle pitched upward.
0.364	Vehicle rolled away from system.
0.388	Post no. 29 deflected downstream.
0.390	Vehicle’s front bumper contacted post no. 29, and right-front wheel overrode rail.
0.392	Post no. 29 twisted clockwise.
0.400	Vehicle’s left-front tire became airborne.
0.402	Post no. 29 bent downstream.
0.464	Vehicle’s right-front tire contacted post no. 29.
0.466	Vehicle’s right-front tire became airborne.
0.498	Vehicle’s right-rear tire contacted rail.
0.502	Vehicle yawed toward system.
0.616	Vehicle pitched downward.
0.620	Vehicle’s right-rear tire became airborne, and right-rear wheel overrode rail. Vehicle exited system at a speed of 37.0 mph (59.6 km/h) and an angle of 10.6 degrees.
0.826	Vehicle’s left-front tire regained contact with ground.
0.924	Vehicle yawed away from system.

Table 8. Sequential Description of Impact Events, Test No. SPTA-1, Cont.

TIME (sec)	EVENT
0.928	Vehicle rolled toward system.
1.072	Vehicle pitched upward.
1.100	Vehicle’s right-front tire regained contact with ground.
1.124	Vehicle’s right-rear tire regained contact with ground.
1.202	Vehicle’s left-front tire became airborne.
1.258	Vehicle rolled away from system.
1.336	Vehicle’s left-front tire regained contact with ground.
1.382	Vehicle pitched downward.
1.522	Vehicle pitched upward.
1.524	Vehicle rolled toward system.
1.554	System came to rest.
1.620	Vehicle’s right-front tire deflated.
1.832	Vehicle rolled away from system.
1.848	Vehicle pitched downward.
1.894	Vehicle yawed toward system.

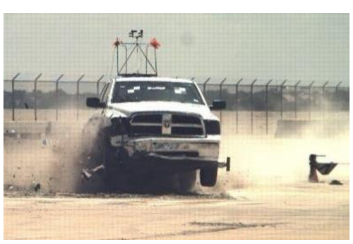
0.000 sec

0.100 sec

0.200 sec

0.306 sec

0.400 sec



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0.100 sec

0.200 sec

0.306 sec

0.400 sec

0.500 sec

Figure 53. Sequential Photographs, Test No. SPTA-1

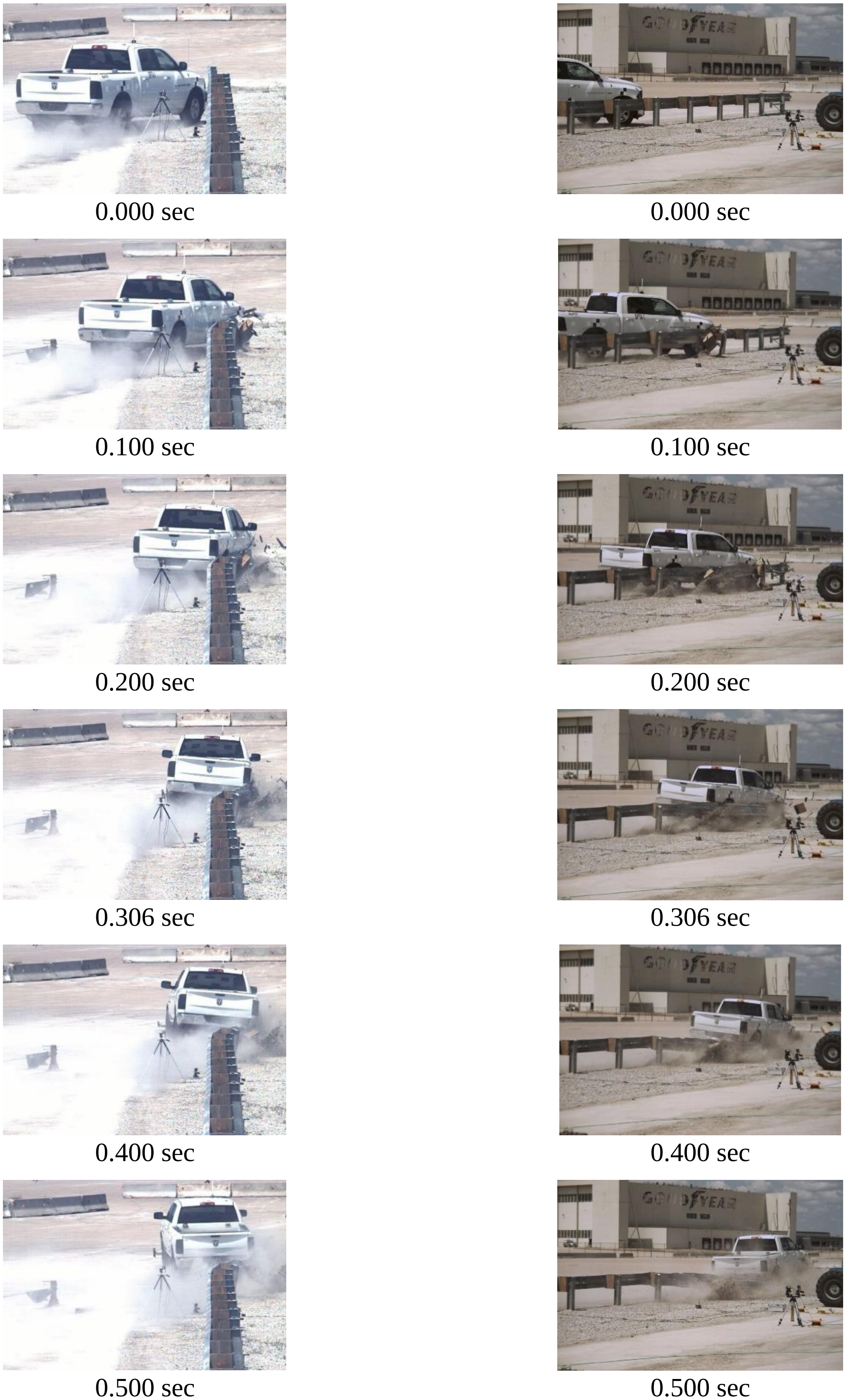


Figure 54. Additional Sequential Photographs, Test No. SPTA-1

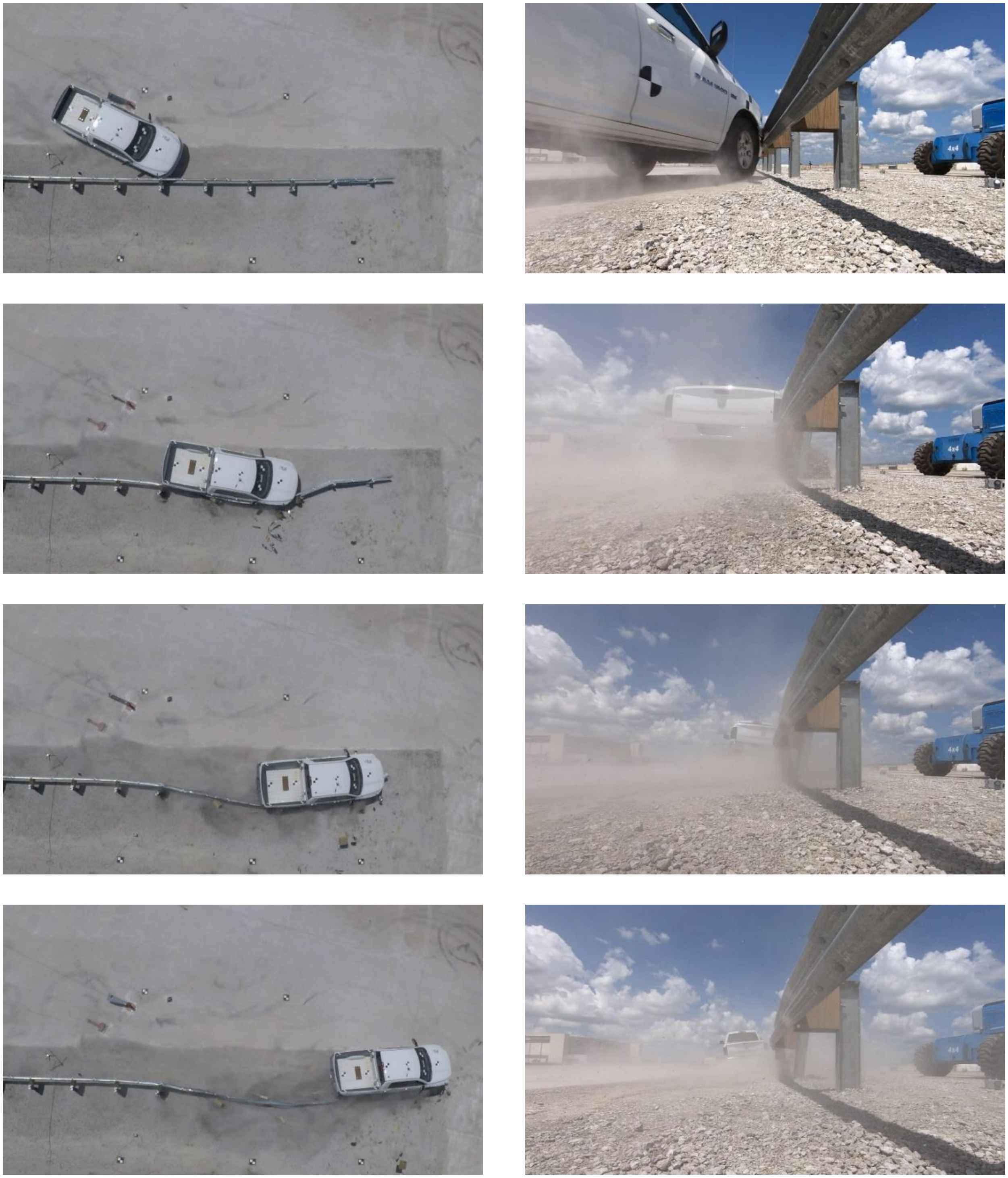


Figure 55. Documentary Photographs, Test No. SPTA-1

Figure 56. Documentary Photographs, Test No. SPTA-1

Figure 57. Vehicle Final Position and Trajectory Marks, Test No. SPTA-1

5.4 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 58 through 64. Barrier damage consisted of deformation and twisting of the rail; deflection, twisting, and rotation of posts; disengagement of rail and wood blockouts from the posts; fracture of the breakaway bolts in the steel anchor posts; and deformation and flange tearing at the base of post no. 29. The length of vehicle contact along the barrier was approximately 35 ft – 1 in. (10.7 m), which spanned from 2 in. (51 mm) upstream from post no. 24 to the downstream end of the rail.

The guardrail experienced bending, flattening, denting, kinking, and scraping beginning just upstream from post no. 24 and extending to the end of the system. The guardrail bolts pulled out of the rail at post nos. 25 through 29, and the rail disengaged at these posts. The rail buckled 2 in. (51 mm) upstream from post no. 24 through the entire cross section of guardrail.

Post nos. 10, 11, and 13 through 23 were rotated slightly downstream from their original orientations. The blockout at post no. 20 fractured along the front top edge. Post no. 24 twisted to face downstream. Post nos. 25 through 29 sustained local bending, scraping, and gouging on their traffic-side flanges. Post no. 25 bent backward and downstream approximately 39½ in. (1,003 mm) from its original position and twisted to face upstream. The blockout at post no. 25 was fractured on the back downstream corner, and the bolt connecting it to the post was deformed but still in place. Post no. 26 bent backward 10⅞ in. (276 mm), bent downstream, and twisted to face upward and upstream. The blockout at post no. 26 completely detached from the post, and the bolt pulled out of the post. Post no. 27 twisted upstream and bent backward 6.5 in. (165 mm) and downstream approximately 40 in. (1,016 mm) from its original position. The blockout at post no. 27 completely detached from the post, and the bolted connection at the post failed by shear rupture of the post flange.

All four bolts fractured at the breakaway connection in post no. 28 as the upper portion of the post disengeaged from its foundation, as intended. The post-to-rail bolt remained in post no. 28. In post no. 29, the two traffic-side bolts fractured, but the other two non-traffic-side bolts remained intact. The base of post no. 29 was bent and twisted, and the post leaned downstream. The upstream side of the back flange in post no. 29 was torn, and the web of the post was twisted.The post-to-rail bolt remained in the post. The weld between the T-shaped, breaker bar baseplate and the top gusset plate ruptured, the top bolt fastening the baseplate to post no. 29 fractured, and the baseplate was bent. The T-shaped, breaker bar was rotated back away from the impact. The cable anchor remained intact, and the bearing plate maintained its position adjacent to the downstream face of the foundation tube.

Figure 58. System Damage, Test No. SPTA-1

Figure 59. System Damage, Test No. SPTA-1

Figure 60. System Damage, Test No. SPTA-1

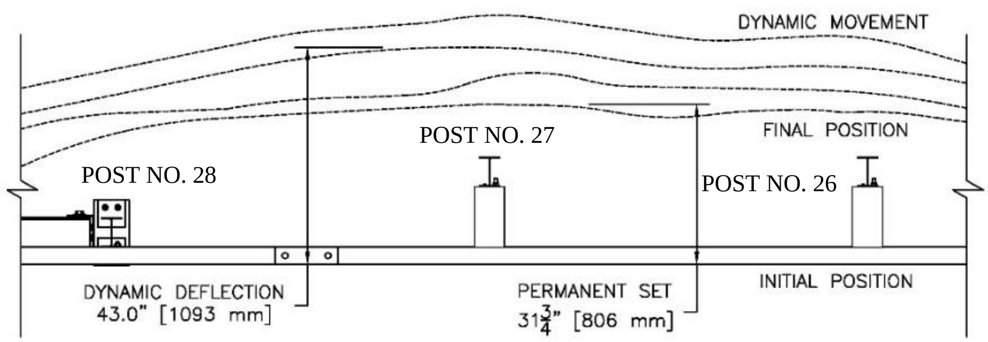
Figure 61. System Damage, Test No. SPTA-1

Figure 62. System Damage, Post Nos. 24, 25, 26, and 27, Test No. SPTA-1

Figure 63. System Damage, Post Nos. 28 and 29, Test No. SPTA-1

Figure 64. System Damage – Upstream End Anchorage System, Test No. SPTA-1

The maximum lateral permanent set of the rail was 31¾ in. (806 mm) and occurred downstream from post no. 27. The maximum lateral permanent set of the posts was 23⅝ in. (600 mm) at post no. 25. Permanent sets were determined from field measurements. The maximum dynamic rail deflection was 43.0 in. (1,093 mm) at the rail at the center of post no. 27, and the maximum post dynamic deflection was 32.7 in. (831 mm) at the centerline of post no. 28. The rail and post dynamic deflections were determined from high-speed, digital video analysis. The working width of the system was found to be 50.8 in. (1,289 mm), also determined from high-speed, digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 65.



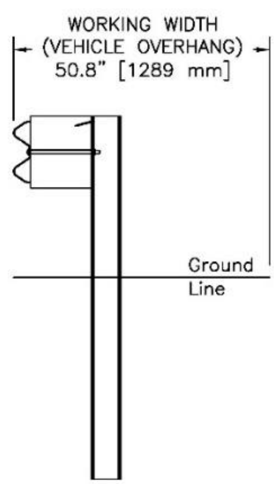


Figure 65. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. SPTA-1

5.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 66 through 68. The maximum occupant compartment intrusions are listed in Table 9 along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in

Appendix D. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. Interior occupant compartment deformations were minimal with a maximum of 0.2 in., which did not violate the limits established in MASH 2016. Outward deformations, which are denoted as negative numbers in Appendix D, are not considered crush toward the occupant and are not evaluated by MASH 2016 criteria.

Most of the damage was concentrated on the right-front corner and right side of the vehicle where impact occurred. The right headlight disengaged from the vehicle. The right-front bumper was crushed and bent toward the engine housing, and the right-front tire was punctured. The right fender was crushed from approximately the center of the wheel to the door. Scraping and denting continued along the right-front door, right-rear door, and right quarter panel. The right corner of the rear bumper was crushed inward. The anti-roll bar shifted to the right side of the vehicle. The right-front upper and lower control arms and right-front joints shifted backward. The floor pan sustained minor scraping. The roof, left-side panels, windshield, and window glass remained undamaged.

Figure 66. Vehicle Damage, Test No. SPTA-1

Figure 67. Vehicle Damage, Test No. SPTA-1

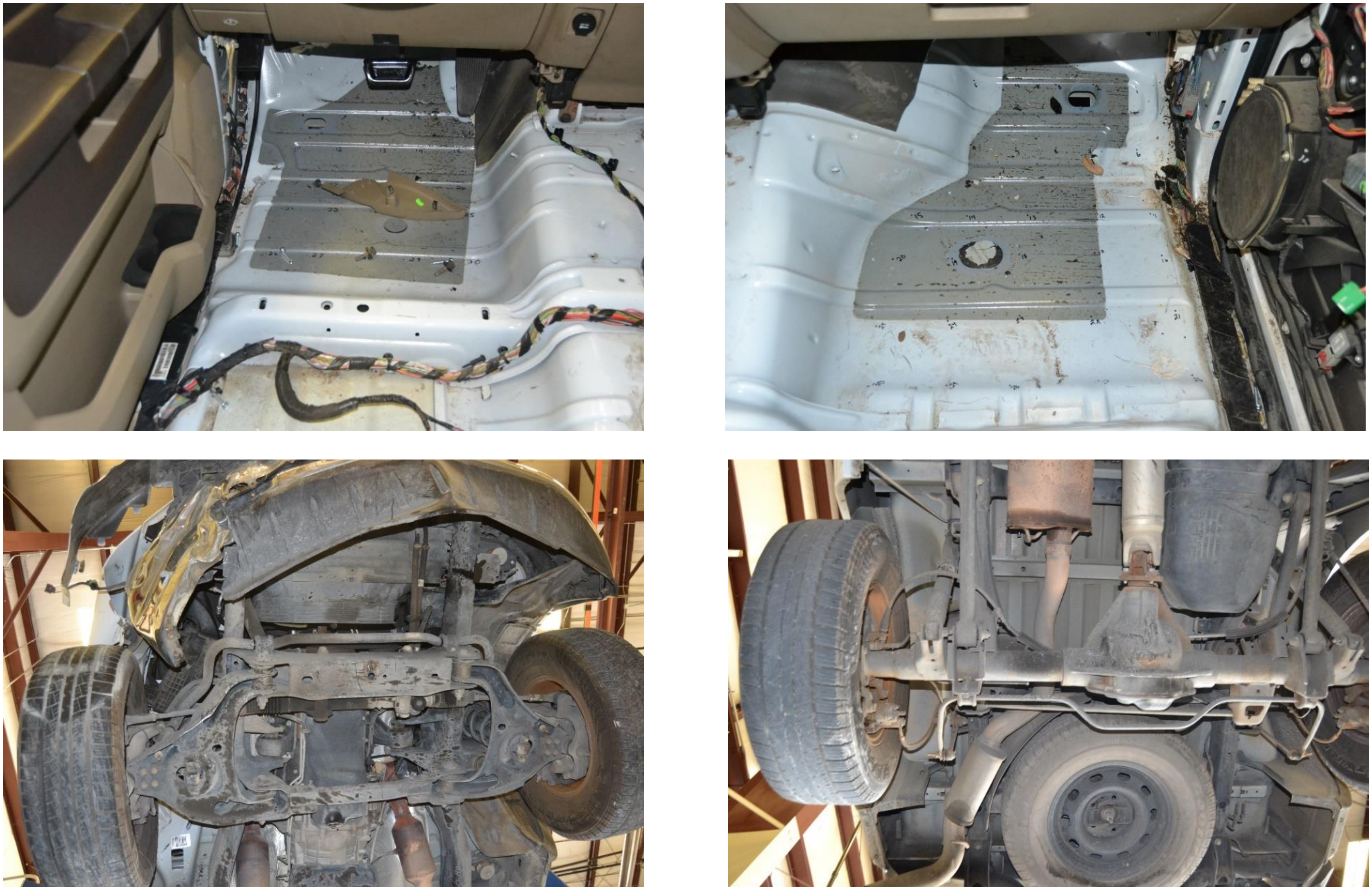


Figure 68. Occupant Compartment and Undercarriage Damage, Test No. SPTA-1

Table 9. Maximum Occupant Compartment Intrusion by Location, Test No. SPTA-1

LOCATION	MAXIMUM INTRUSION in. (mm)	MASH 2016 ALLOWABLE INTRUSION in. (mm)
Wheel Well & Toe Pan	0.1 (3)	≤ 9 (229)
Floor Pan & Transmission Tunnel	0.1 (3)	≤ 12 (305)
A-Pillar	0.2 (5)	≤ 5 (127)
B-Pillar	0.1 (3)	≤ 5 (127)
A-Pillar (Lateral)	0.1 (3)	≤ 3 (76)
B-Pillar (Lateral)	0.1 (3)	≤ 3 (76)
Side Front Panel (in Front of A-Pillar)	0.1 (3)	≤ 12 (305)
Side Door (Above Seat)	0.1 (3)	≤ 9 (229)
Side Door (Below Seat)	0.2 (5)	≤ 12 (305)
Roof	0.2 (5)	≤ 4 (102)
Windshield	0.0 (0)	≤ 3 (76)
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	0.1 (3)	N/A

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

5.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ride down accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 10. 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 10. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix E.

Table 10. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. SPTA-1

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1	SLICE-2 (primary)	
OIV ft/s (m/s)	Longitudinal	-15.40 (-4.69)	-14.31 (-4.36)	±40 (12.2)
	Lateral	-13.75 (-4.19)	-14.49 (-4.42)	±40 (12.2)
ORA g's	Longitudinal	-5.88	-6.02	±20.49
	Lateral	-8.13	-7.78	±20.49
MAXIMUM ANGULAR DISPLACEMENT degrees	Roll	-20.2	-22.6	±75
	Pitch	6.3	6.8	±75
	Yaw	-30.4	-30.8	not required
THIV ft/s (m/s)		19.68 (6.00)	19.50 (5.94)	not required
PHD g's		9.73	9.58	not required
ASI		0.66	0.63	not required

5.7 End Anchor Loads

The pertinent data from the load cell at the upstream anchorage system was extracted from the bulk signal and analyzed using the transducer's calibration factor. The recorded data and analyzed results are shown in Figure 69 and detailed in Appendix F. The exact moment of impact could not be determined from the transducer data as impact may have occurred a few milliseconds prior to observing a measurable signal increase in the data. Thus, the extracted data curves should not be taken as precise time after impact, but rather a general timeline between events within the data curve itself.

The peak tensile force of 16.7 kip (74.3 kN) was measured in the upstream cable anchor, as shown in Figure 69. Note, in test no. WIDA-1, which involved a pickup vehicle impacting the wood-post, trailing-end anchorage system under MASH test designation no. 3-37a, a peak load of 18.5 kip (82.3 kN) was measured in the upstream cable anchor [1].

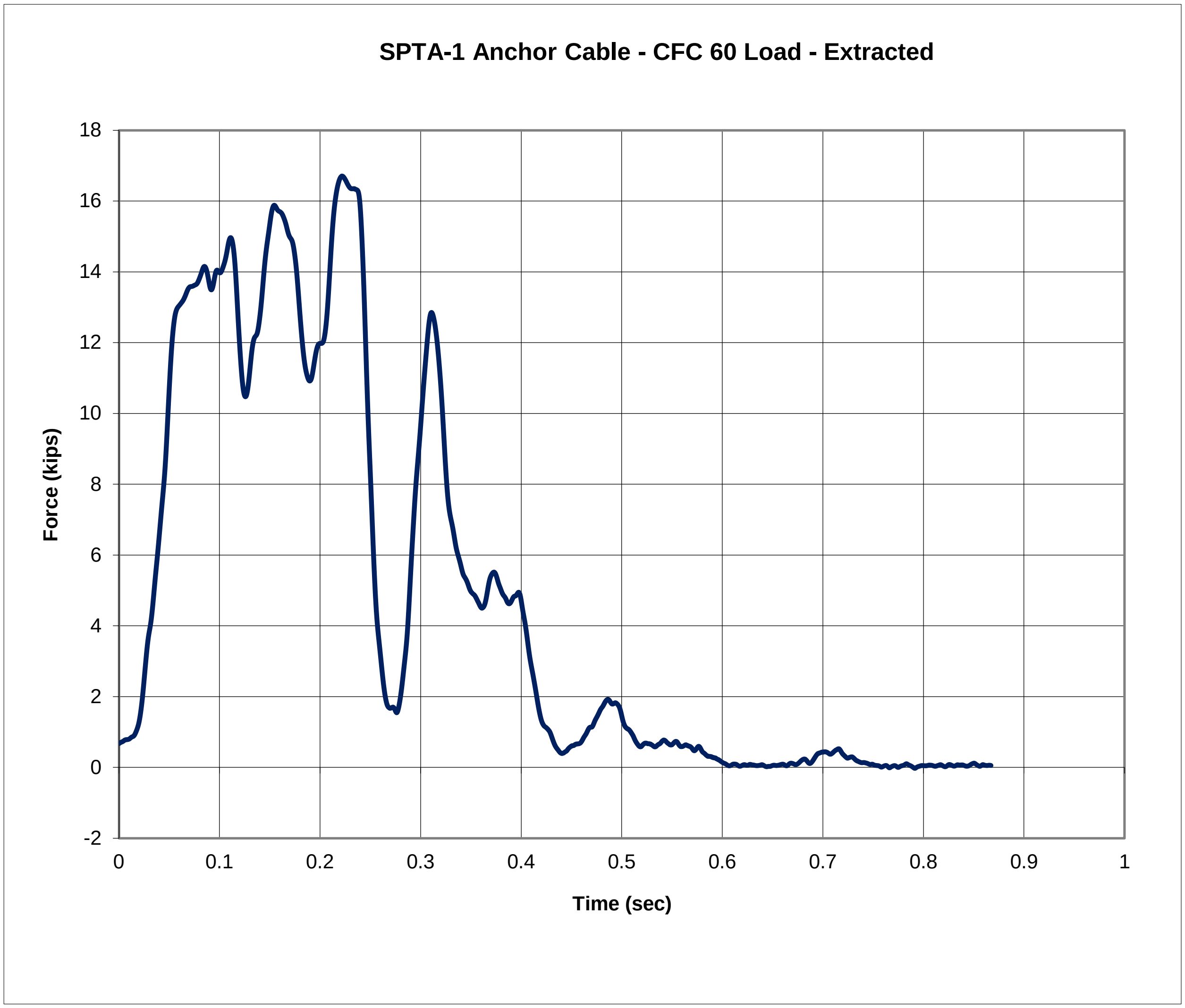


Figure 69. Upstream Anchor Cable Load, Test No. SPTA-1

5.8 Discussion

The analysis of the test results for test no. SPTA-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 70. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix E, were deemed acceptable, because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the barrier at an angle of 10.6 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. SPTA-1 satisfied all of the safety performance criteria of MASH 2016 test designation no. 3-37a.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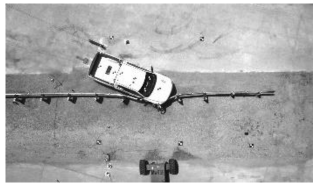
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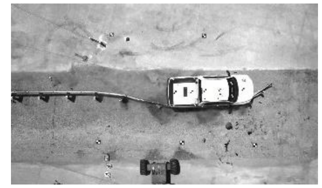
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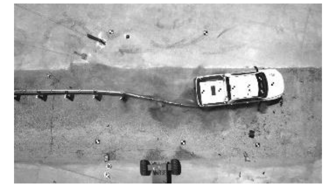
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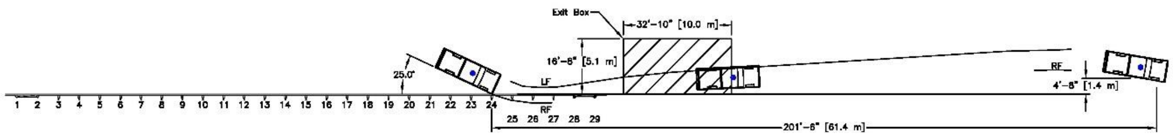
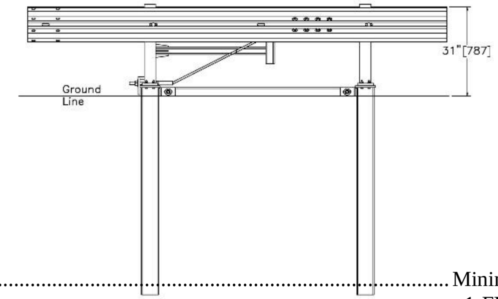




- Test Agency .... MwRSF
- Test Number SPTA-1
- Date 07/31/2018
- MASH 2016 Test Designation No. 3-37a
- Test Article .... MGS with steel-post, trailing-end anchorage system
- Total Length .... 182 ft – 3½ in. (55.6 m)
- Key Component – W-Beam Rail
  - Thickness .... 12 gauge (2.66 mm)
  - Top Mounting Height .... 31 in. (787 mm)
- Key Component – Line Posts (Nos. 3-27)
  - Type W6x8.5
  - Length .... 72 in. (1,829 mm)
  - Spacing .... 75 in. (1,905 mm) on-center
- Key Component – Steel-Post, Trailing-End Anchorage
  - Steel Post .... 27½-in. (699-mm) long, W6x8.5
  - Foundation Tube Section ..... 8-in. x 6-in. x 3/16-in. (203-mm x 152-mm x 5-mm) Tube
  - Foundation Tube Length .... 72 in. (1829 mm)
  - Ground Line Strut .... 66½ in. (1689 mm) long, C-channel (C6x8.2)
- Soil Type .... Coarse, crushed limestone (well-graded gravel)
- Vehicle Make /Model .... 2011 Dodge Ram 1500 Crew Cab
  - Curb .... 5,121 lb (2,323 kg)
  - Test Inertial .... 5,074 lb (2,302 kg)
  - Gross Static .... 5,236 lb (2,375kg)
- Impact Conditions
  - Speed .... 62.1 mph (99.9 km/h), MASH 2016 limit: 62 ±2.5 mph (100 ±4.0 km/h)
  - Angle .... 25.0 degrees, MASH 2016 limit: 25 ±1.5 degrees
  - Impact Location .... 3.9 in. (99 mm) downstream from post no. 24
- Impact Severity .... 116.6 kip-ft (158.0 kJ) > 106 kip-ft (144 kJ) limit from MASH 2016
- Exit Conditions
  - Speed .... 37.0 mph (59.6 km/h)
  - Angle .... 10.6 degrees
- Exit Box Criterion .... Pass
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 201 ft – 6 in. (61.4 m) downstream
  4 ft – 8 in. (1.4 m) laterally in front
- Vehicle Damage .... Minimal
  - VDS [16] 1-FR-3
  - CDC [17] 01-RFEW-3
  - Maximum Interior Deformation .... 0.2 in. (5 mm)
- Test Article Damage .... Moderate
- Maximum Test Article Deflections
  - Permanent Set .... 31¾ in. (806 mm)
  - Dynamic .... 43.0 in. (1,093 mm)
  - Working Width .... 50.8 in. (1,289 mm)
- Transducer Data

Evaluation Criteria		Transducer SLICE-1	Transducer SLICE-2 (primary)	MASH 2016 Limit
OIV ft/s (m/s)	Longitudinal	-15.40 (-4.69)	-14.31 (-4.36)	±40 (12.2)
	Lateral	-13.75 (-4.19)	-14.49 (-4.42)	±40 (12.2)
ORA g's	Longitudinal	-5.88	-6.02	±20.49
	Lateral	-8.13	-7.78	±20.49
MAXIMUM ANGULAR DISPLACEMENT degrees	Roll	-20.2	-22.6	±75
	Pitch	6.3	6.8	±75
	Yaw	-30.4	-30.8	not required
THIV – ft/s (m/s)		19.68 (6.00)	19.50 (5.94)	not required
PHD – g's		9.73	9.58	not required
ASI		0.66	0.63	not required

Figure 70. Summary of Test Results and Sequential Photographs, Test No. SPTA-1

6 DESIGN DETAILS – TEST NO. SPTA-2

The test installation in test no. SPTA-2, as shown in Figures 71 through 96, was identical to the installation used for test no. SPTA-1 with a few exceptions. First, the system was raised 1 in. from its nominal 31-in. (787-mm) rail height to evaluate the potential for the small car to extend under the W-beam rail within standard construction tolerances. Thus, post nos. 3 through 27 were embedded to a depth of 39 in. (991 mm), and the W-beam guardrail was mounted with a top rail height of 32 in. (813 mm).

Modifications were also made to the T-shaped breaker bar. In test no. SPTA-1, the T-shaped, breaker bar was ineffective to facilitate the end anchor post breaking away from its foundation. First, as the guardrail deformed laterally backwards, the anchor cable pressed against the breaker bar and rotated it away from the vehicle's path. Second, the long length of the breaker bar accentuated the lateral displacement of its upstream end as the breaker bar rotated. Thus, in test no. SPTA-2, the T-shaped, breaker bar was modified to use a shorter tube, and the breaker bar was mounted at a slightly lower height to avoid contact with the anchor cable and backside of the guardrail. For test no. SPTA-2, the T-shaped, breaker bar was a 15-in. (381-mm) long, 2½-in. x 2½-in. x ¼-in. (64-mm x 64-mm x 6-mm) horizontal steel tube, as shown in Figure 100. Additionally, a 2½-in. x 2½-in. x ¼-in. (64-mm x 64-mm x 6-mm) by 4-in. (102-mm) long steel tube was welded to the traffic-side face of the vertically-oriented, steel tube. The T-shaped, breaker bar was attached to the end anchor post at a height of 15 in. (381 mm).

Further, weld failures and bolt rupture was observed at the attachment of the T-shaped, breaker bar and the downstream anchor post during test no. SPTA-1. The premature failure of this connection made it easier for the bar breaker to deflect away from the impacting vehicle. Therefore, for test SPTA-2, the strength of the joint between the breaker bar and the downstream anchor post was increased by using a thicker, 3/8-in. (10-mm) steel attachment plate. The same gusset plates were used.

Finally, in test no. SPTA-1, the downstream anchor post was bent over instead of breaking away when the vehicle impacted the post. To prevent plastic deformations and tearing in the post, ¼-in. (6-mm) thick steel plates were welded between the flanges on both the upstream and downstream sides of the anchor posts. Slots similar to those cut in the web of the post were cut into the bottom of these steel plate stiffeners to fit over the cable anchor. Note, the additional plates were placed on both breakaway posts in the trailing end anchorage system for simplicity.

These modifications were not expected to affect the performance of the steel-post, trailing-end anchorage system relative to the previous successful MASH 2016 crash test (i.e., test no. SPTA-1 under test designation no. 3-37a). It was determined that the previous test would not need to be rerun if the proposed modifications were successful. Photographs of the test installation are shown in Figures 97 through 101. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

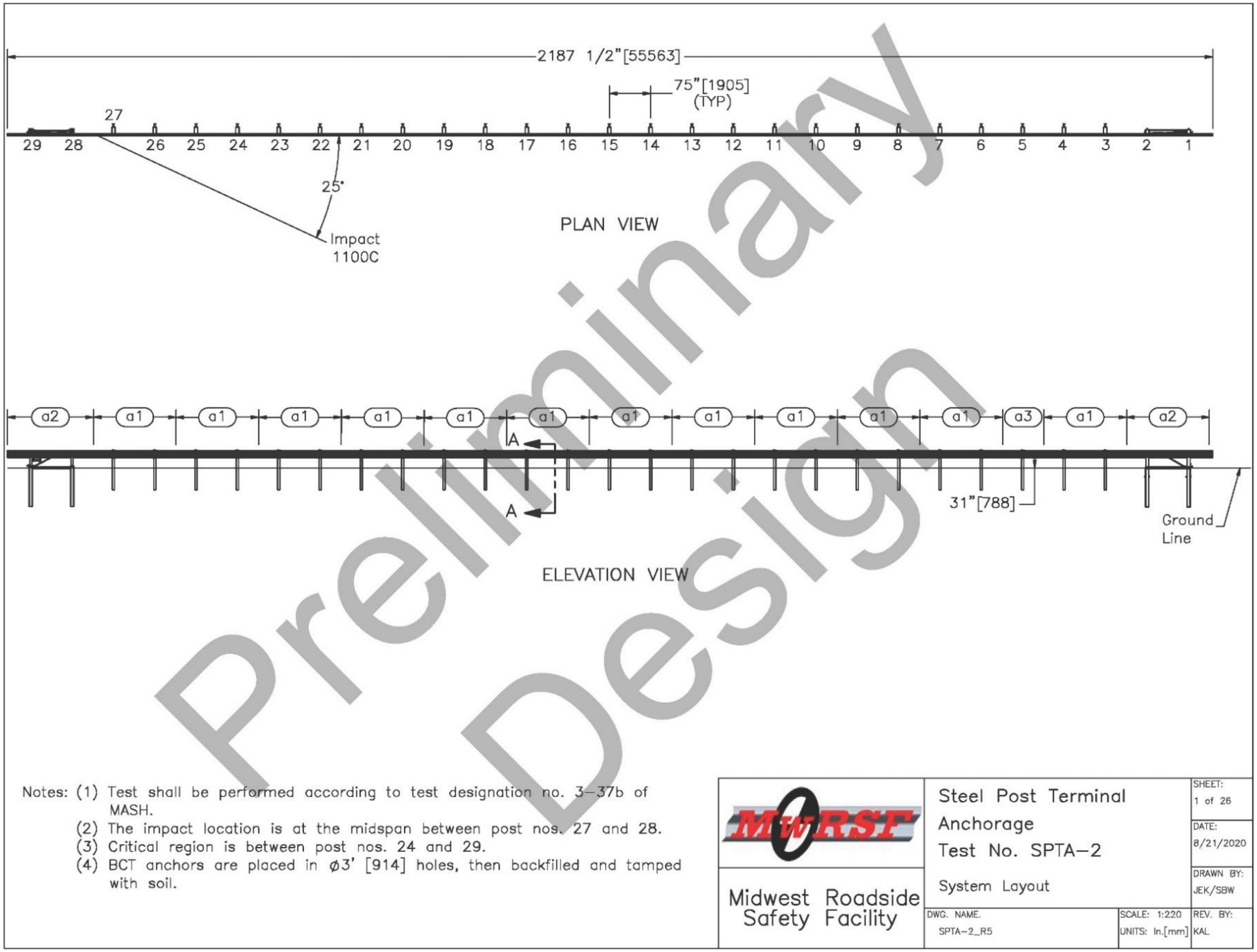


Figure 71. Test Installation Layout, Test No. SPTA-2

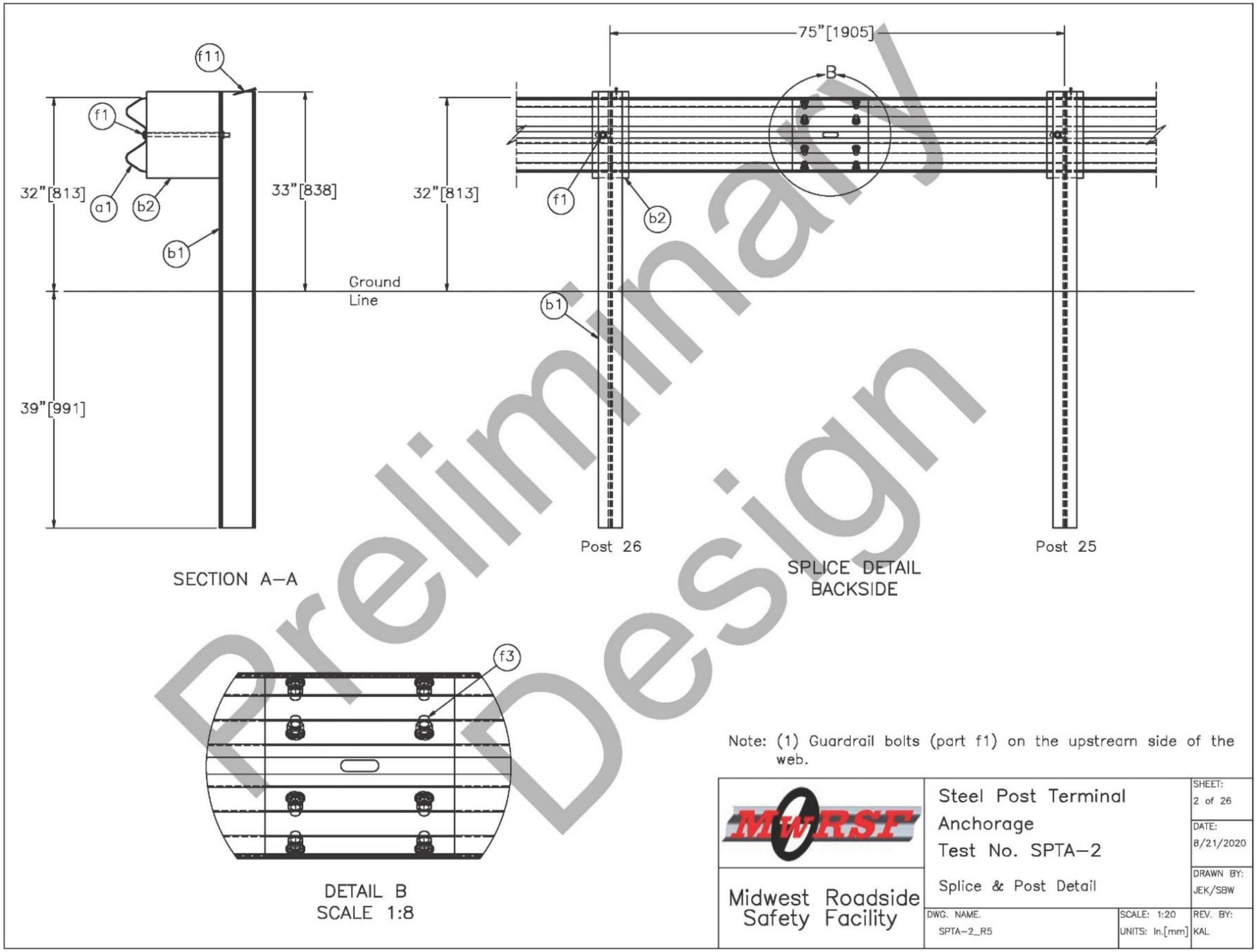


Figure 72. Splice and Post Detail, Test No. SPTA-2

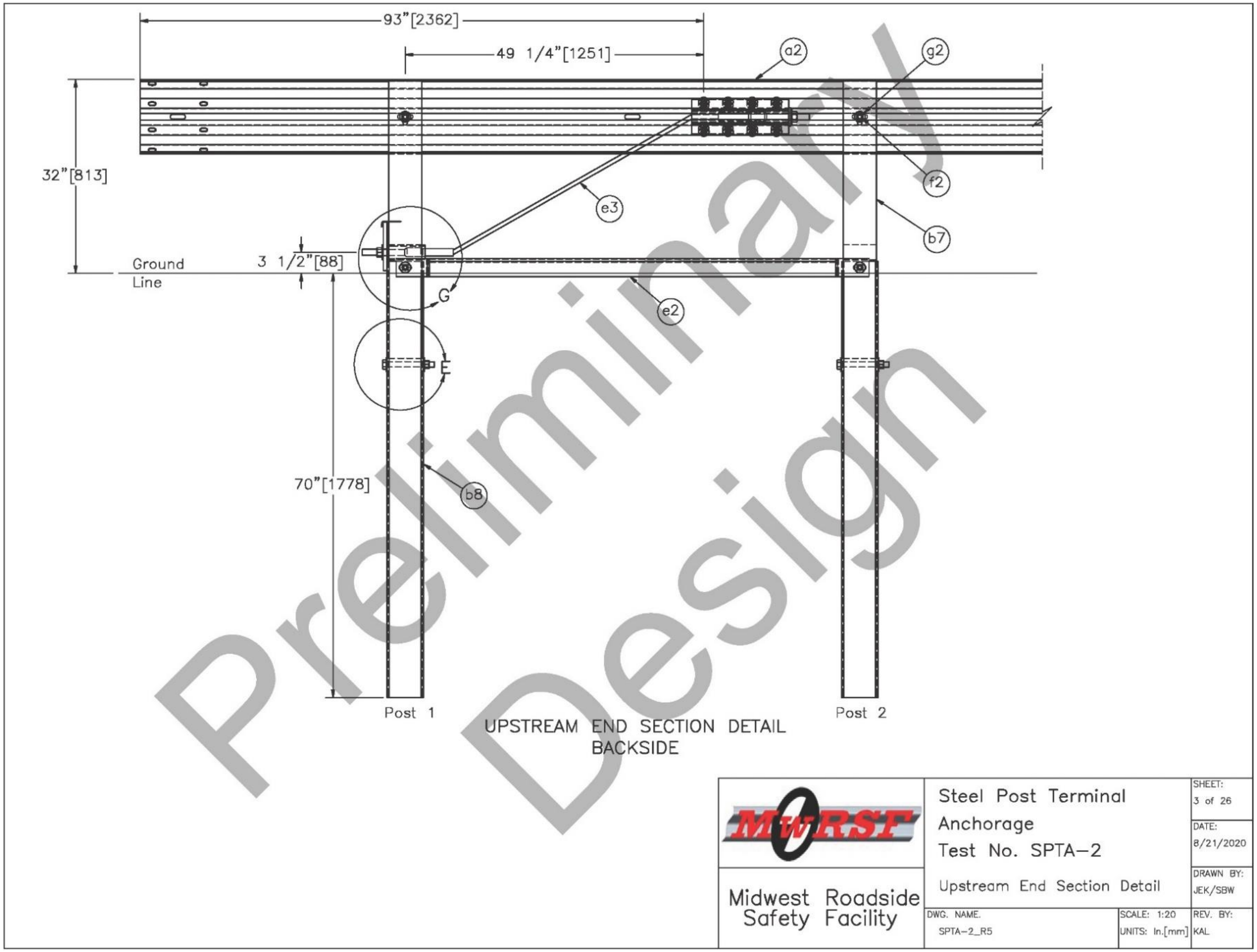


Figure 73. Upstream End Section Detail, Test No. SPTA-2

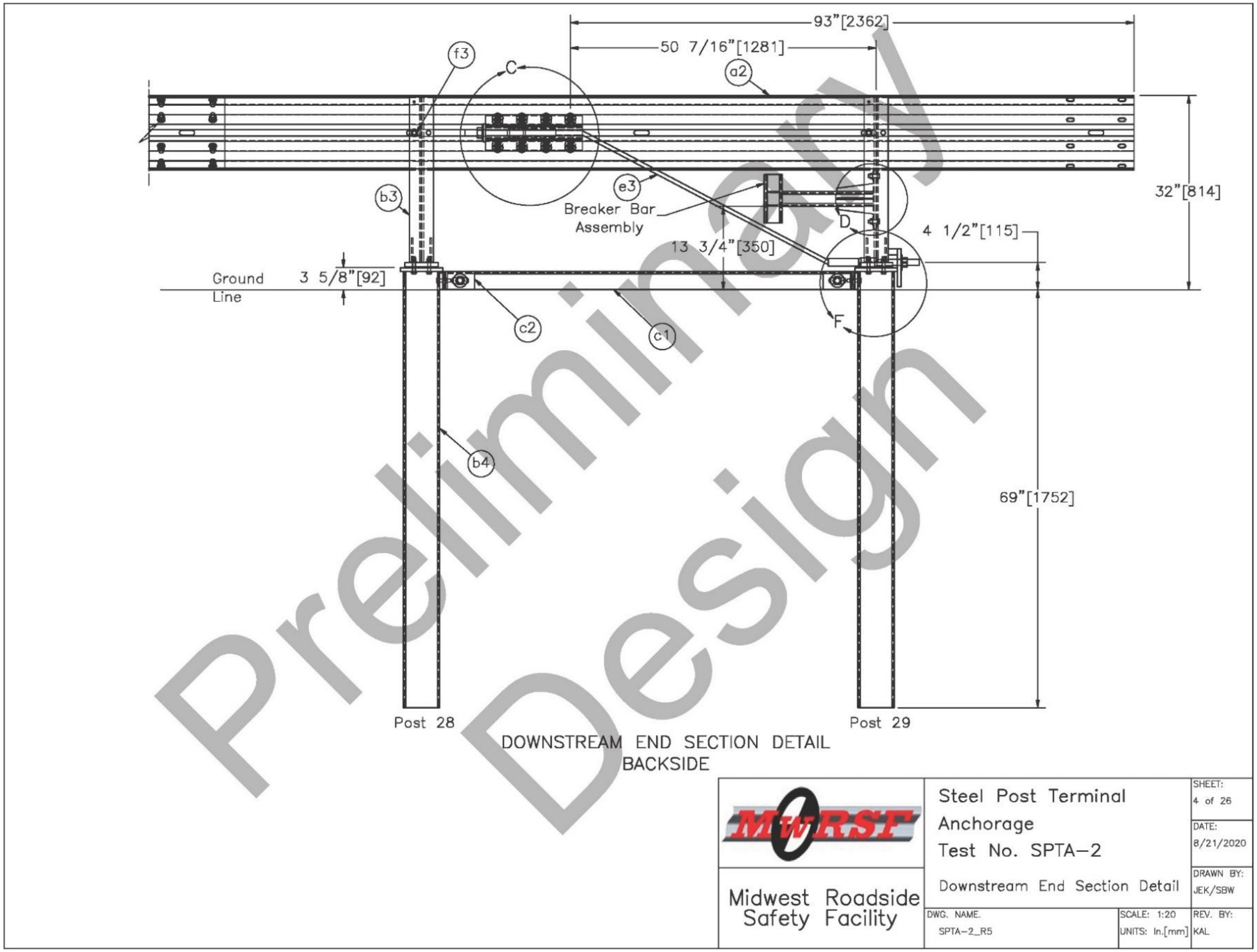


Figure 74. Downstream End Section Detail, Test No. SPTA-2

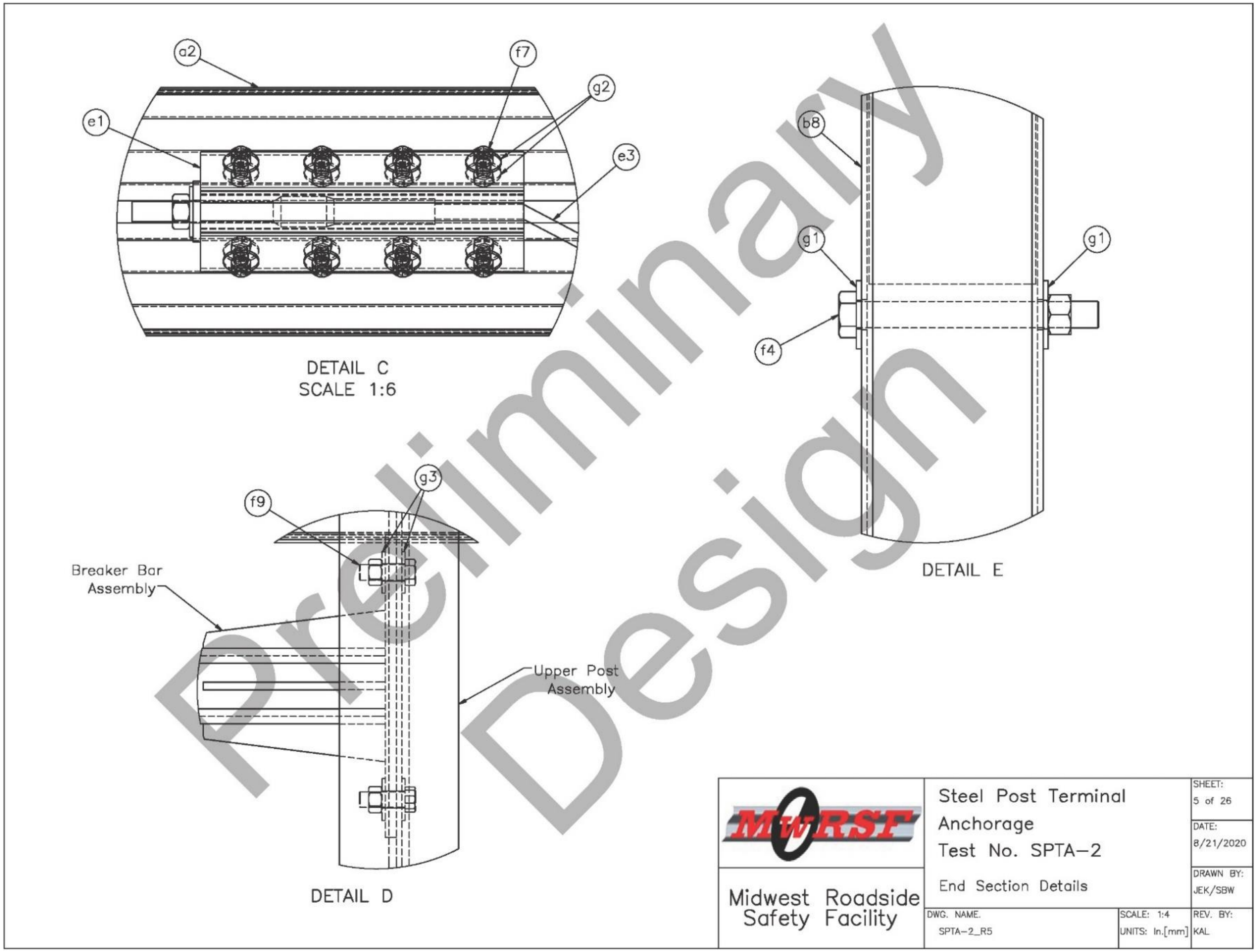


Figure 75. End Section Details, Test No. SPTA-2

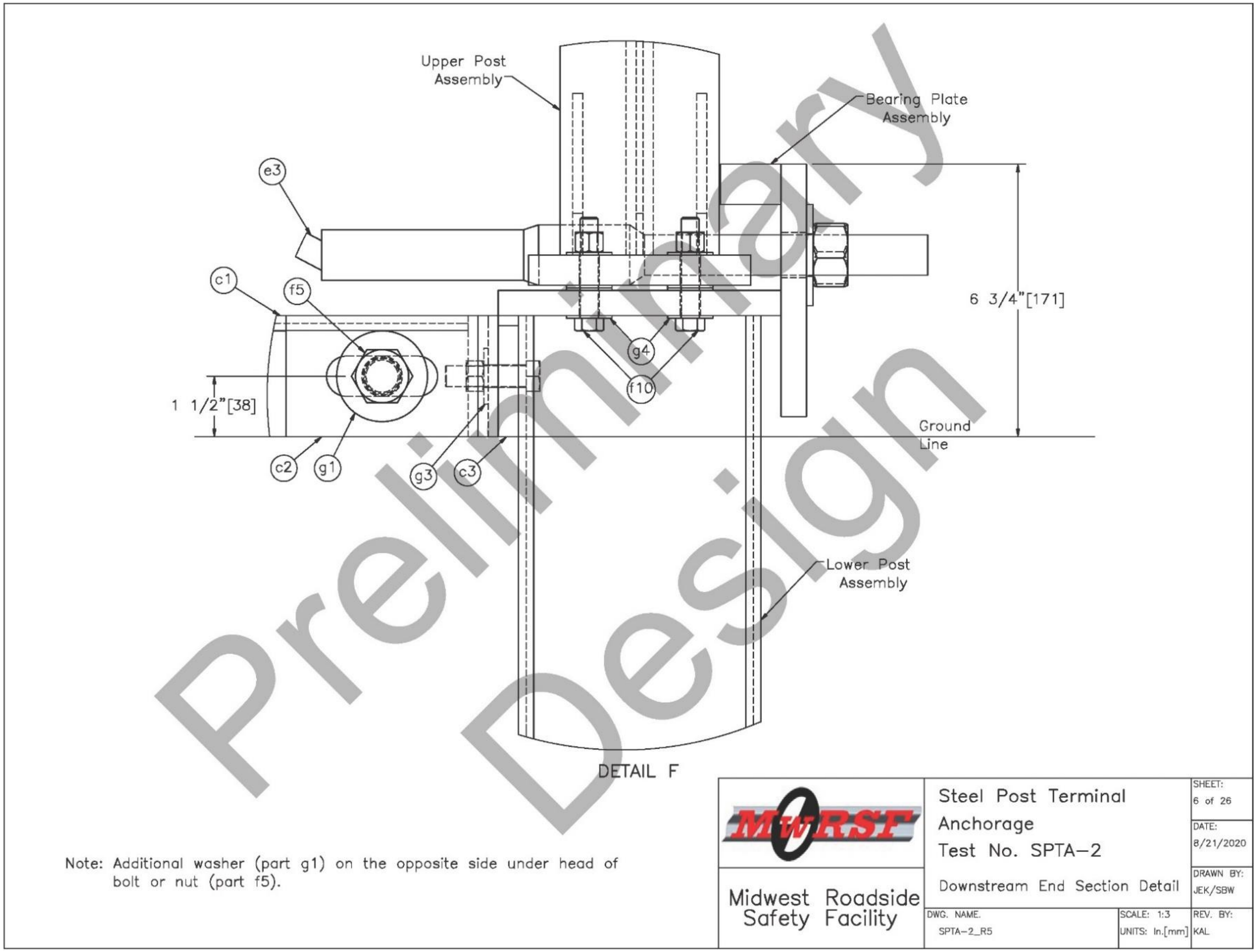


Figure 76. Downstream End Section Detail, Test No. SPTA-2

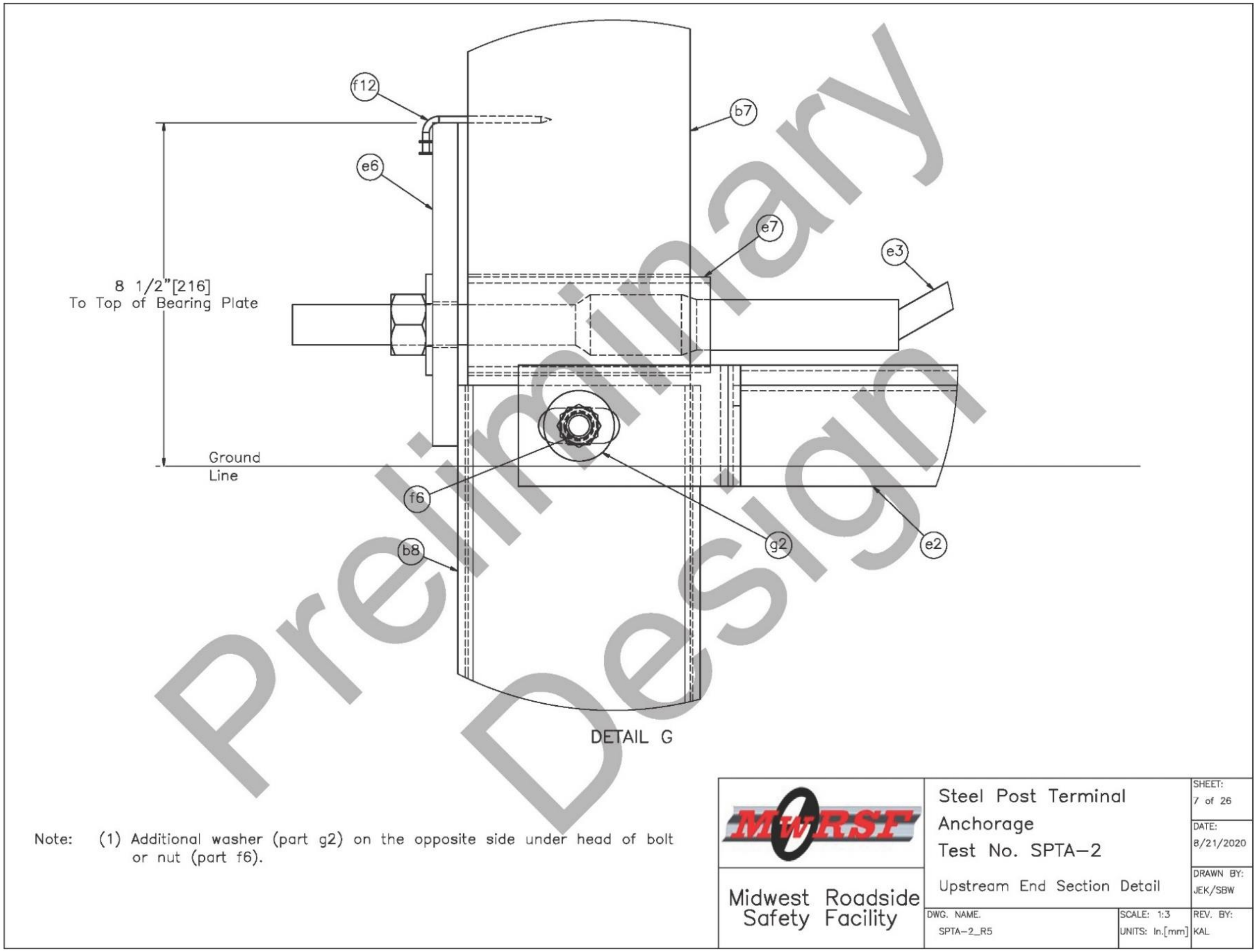


Figure 77. Upstream End Section Detail, Test No. SPTA-2

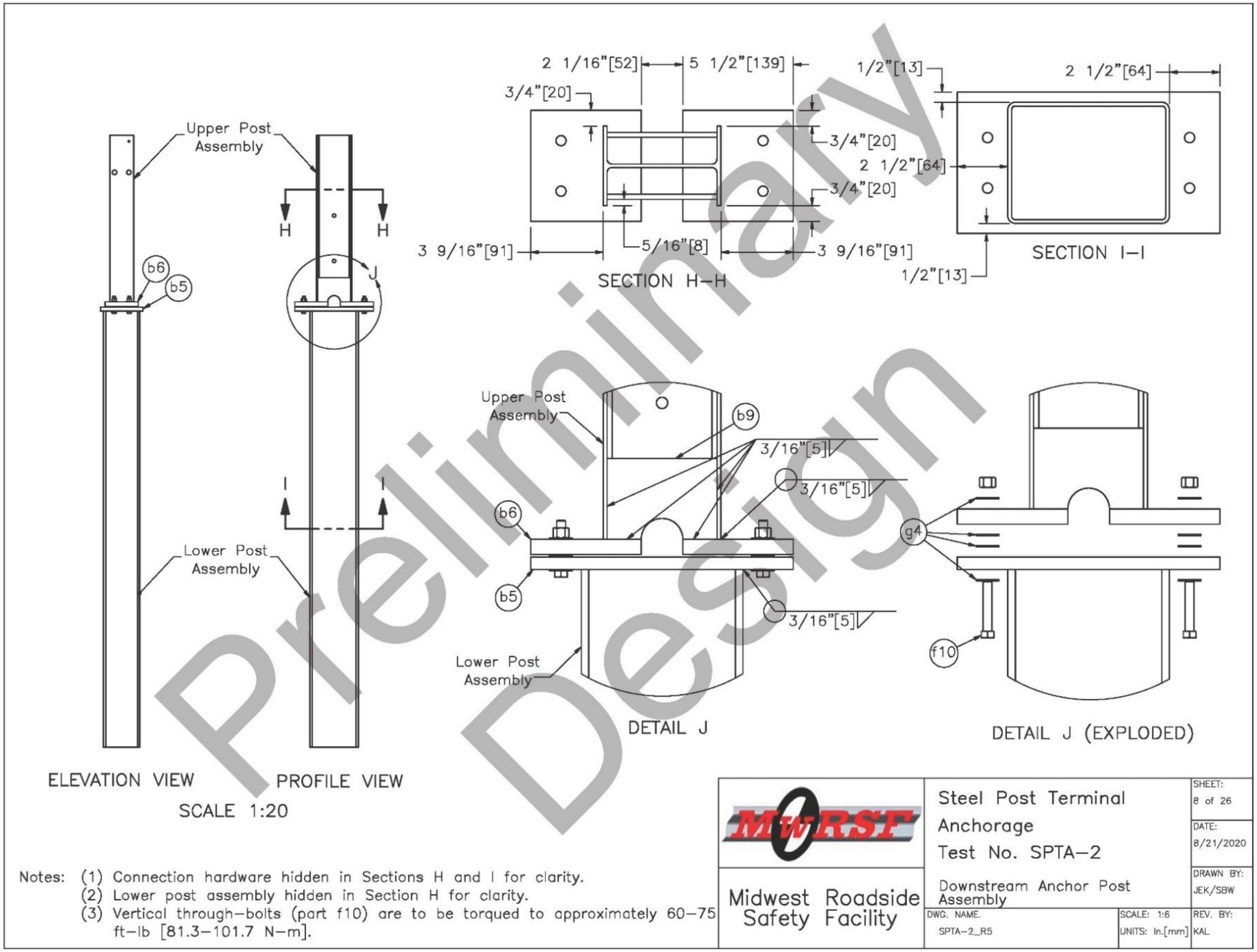
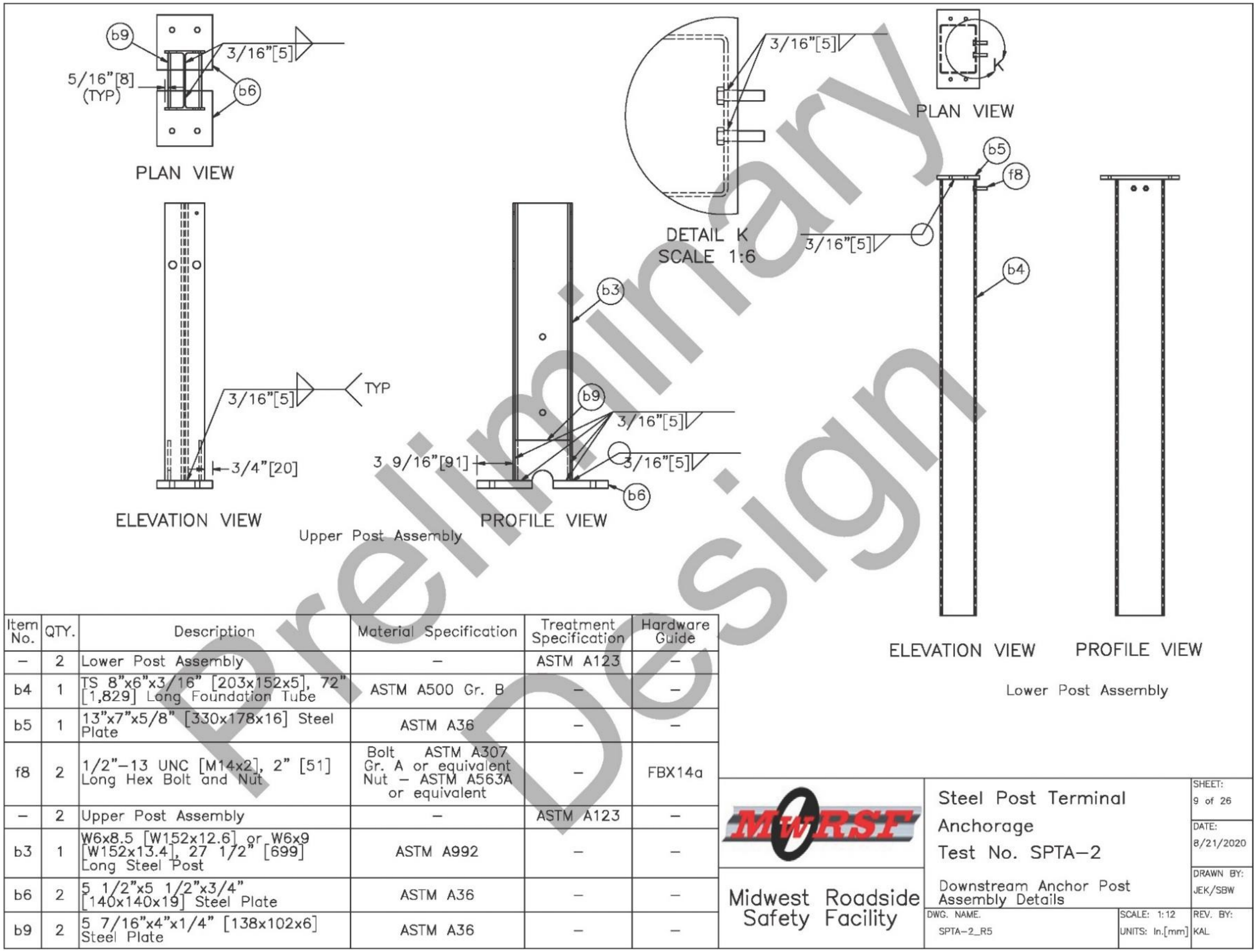


Figure 78. Downstream Anchor Post Assembly, Test No. SPTA-2



Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	2	Lower Post Assembly	–	ASTM A123	–
b4	1	TS 8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	–	–
b5	1	13"x7"x5/8" [330x178x16] Steel Plate	ASTM A36	–	–
f8	2	1/2"-13 UNC [M14x2], 2" [51] Long Hex Bolt and Nut	Bolt ASTM A307 Gr. A or equivalent Nut – ASTM A563A or equivalent	–	FBX14a
–	2	Upper Post Assembly	–	ASTM A123	–
b3	1	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 27 1/2" [699] Long Steel Post	ASTM A992	–	–
b6	2	5 1/2"x5 1/2"x3/4" [140x140x19] Steel Plate	ASTM A36	–	–
b9	2	5 7/16"x4"x1/4" [138x102x6] Steel Plate	ASTM A36	–	–

Figure 79. Downstream Anchor Post Assembly Details, Test No. SPTA-2

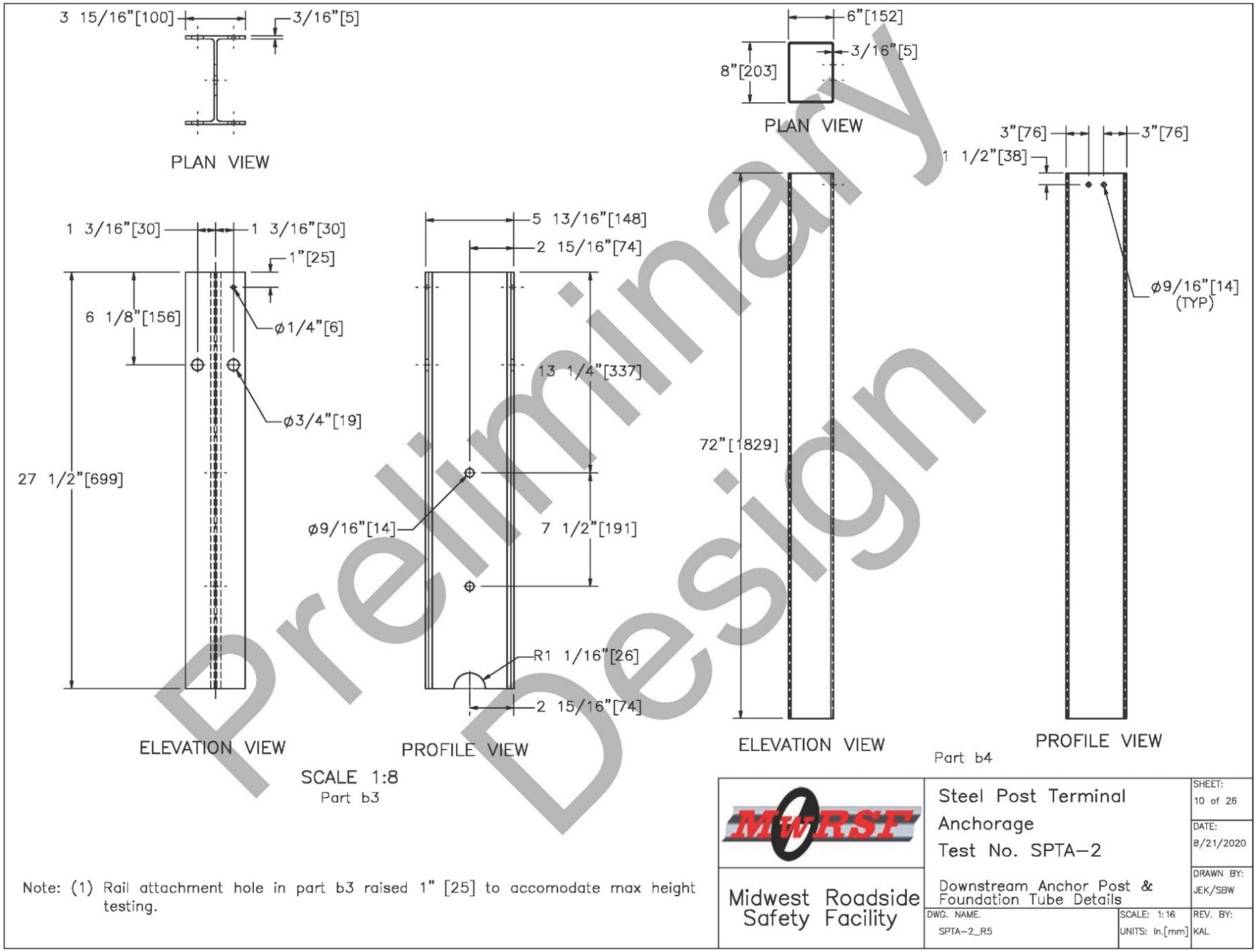


Figure 80. Downstream Anchor Post and Foundation Tube Details, Test No. SPTA-2

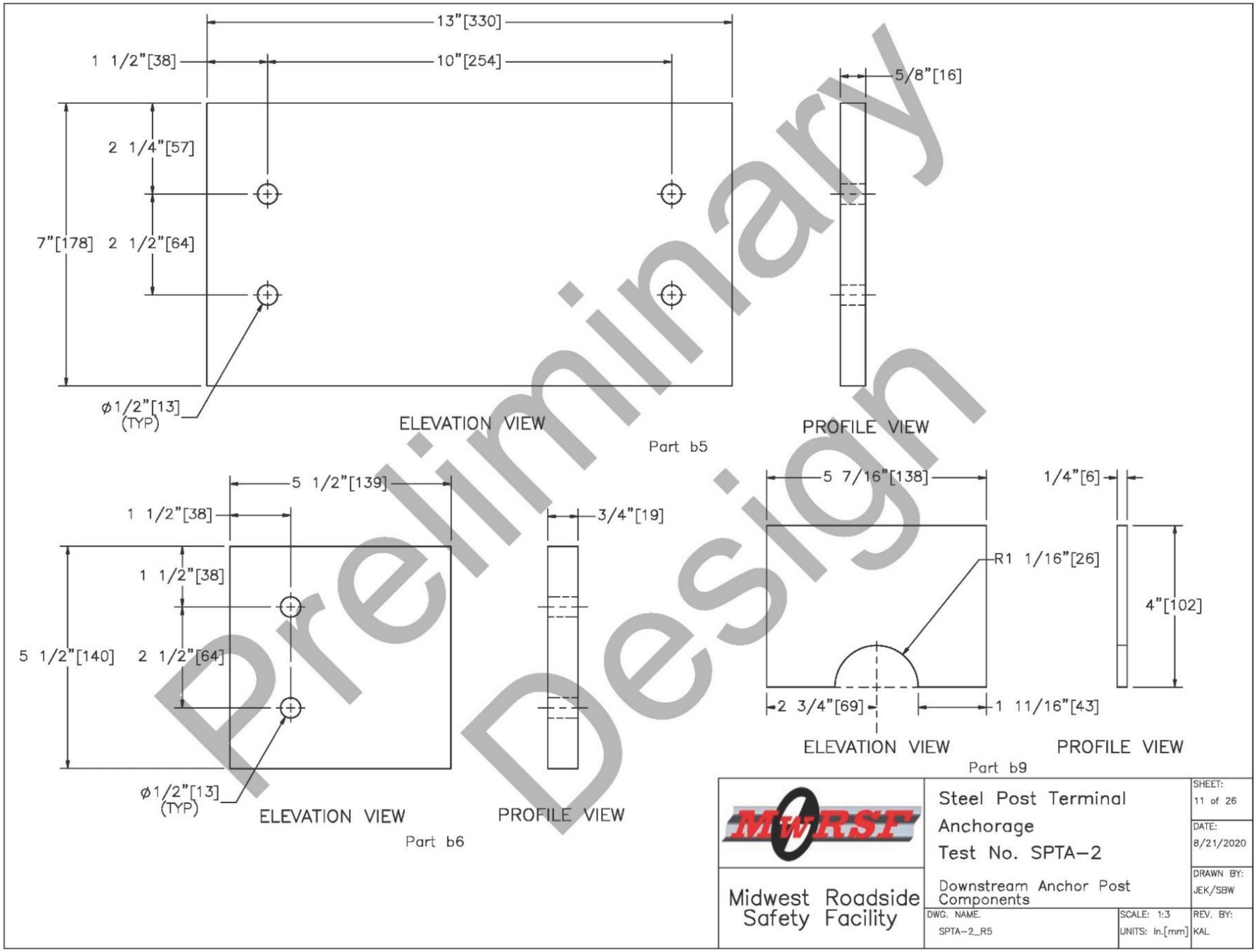


Figure 81. Downstream Anchor Post Components, Test No. SPTA-2

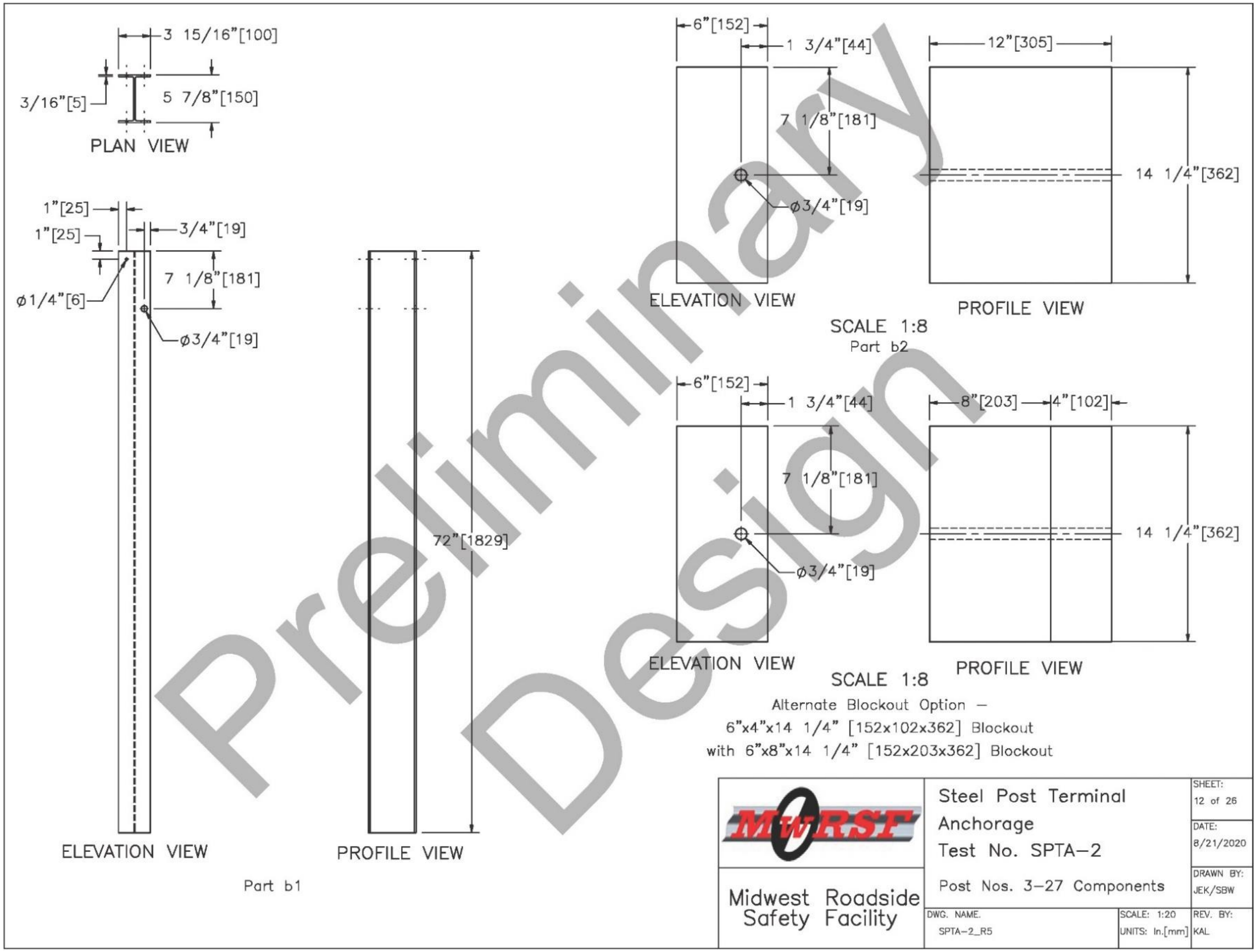


Figure 82. Post Nos. 3 through 27 Components, Test No. SPTA-2

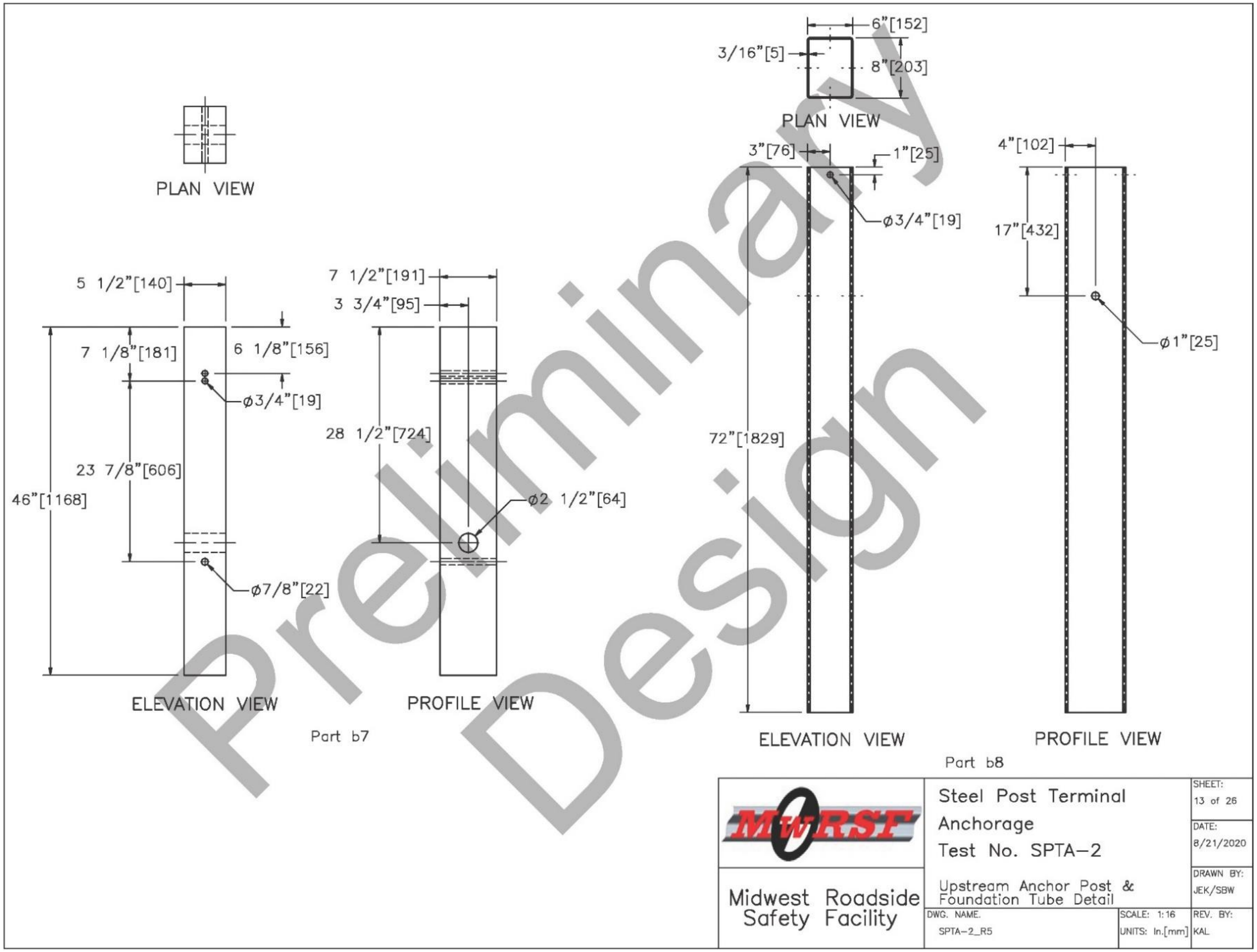


Figure 83. Upstream Anchor Post and Foundation Tube Detail, Test No SPTA-2

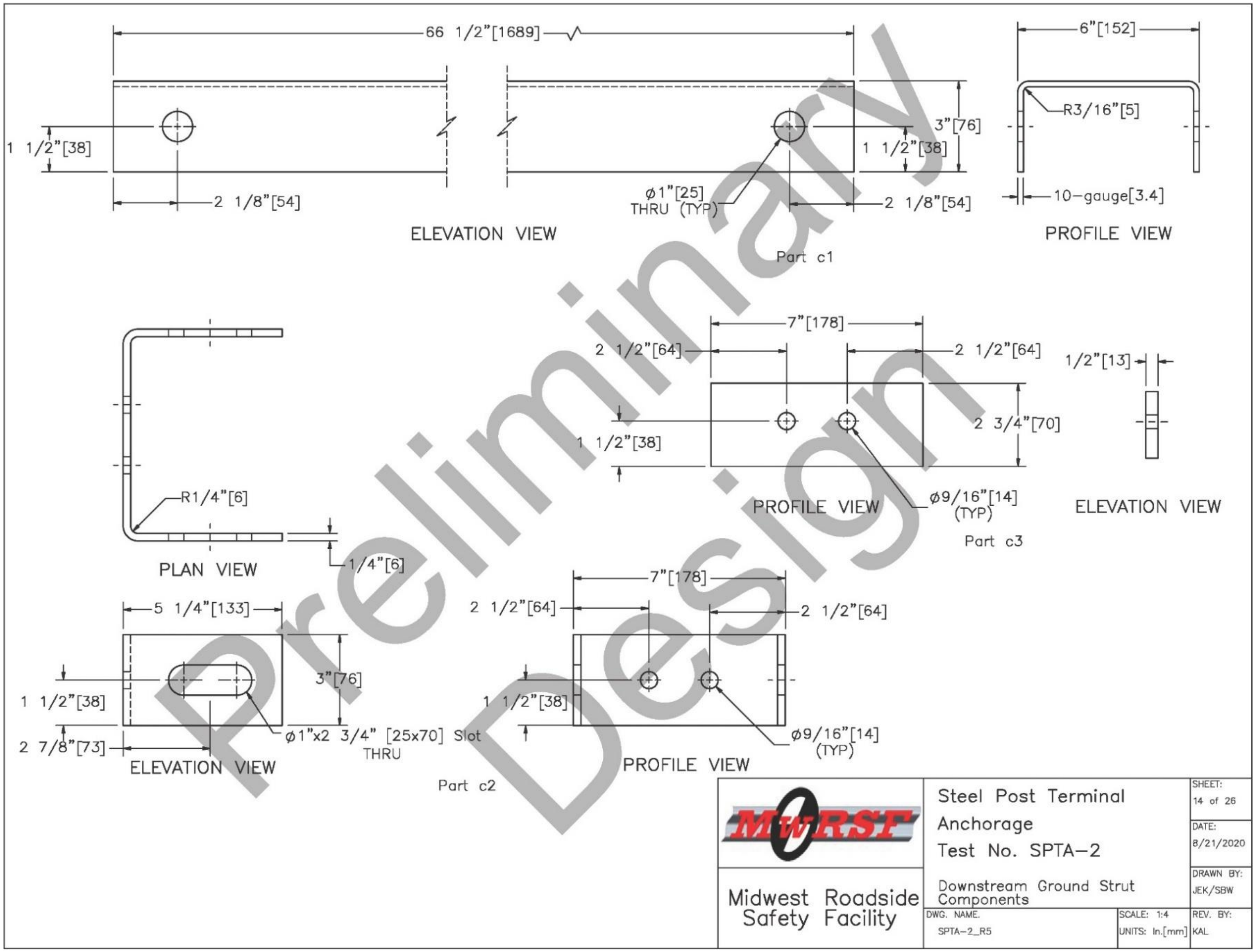


Figure 84. Downstream Ground Strut Components, Test No. SPTA-2

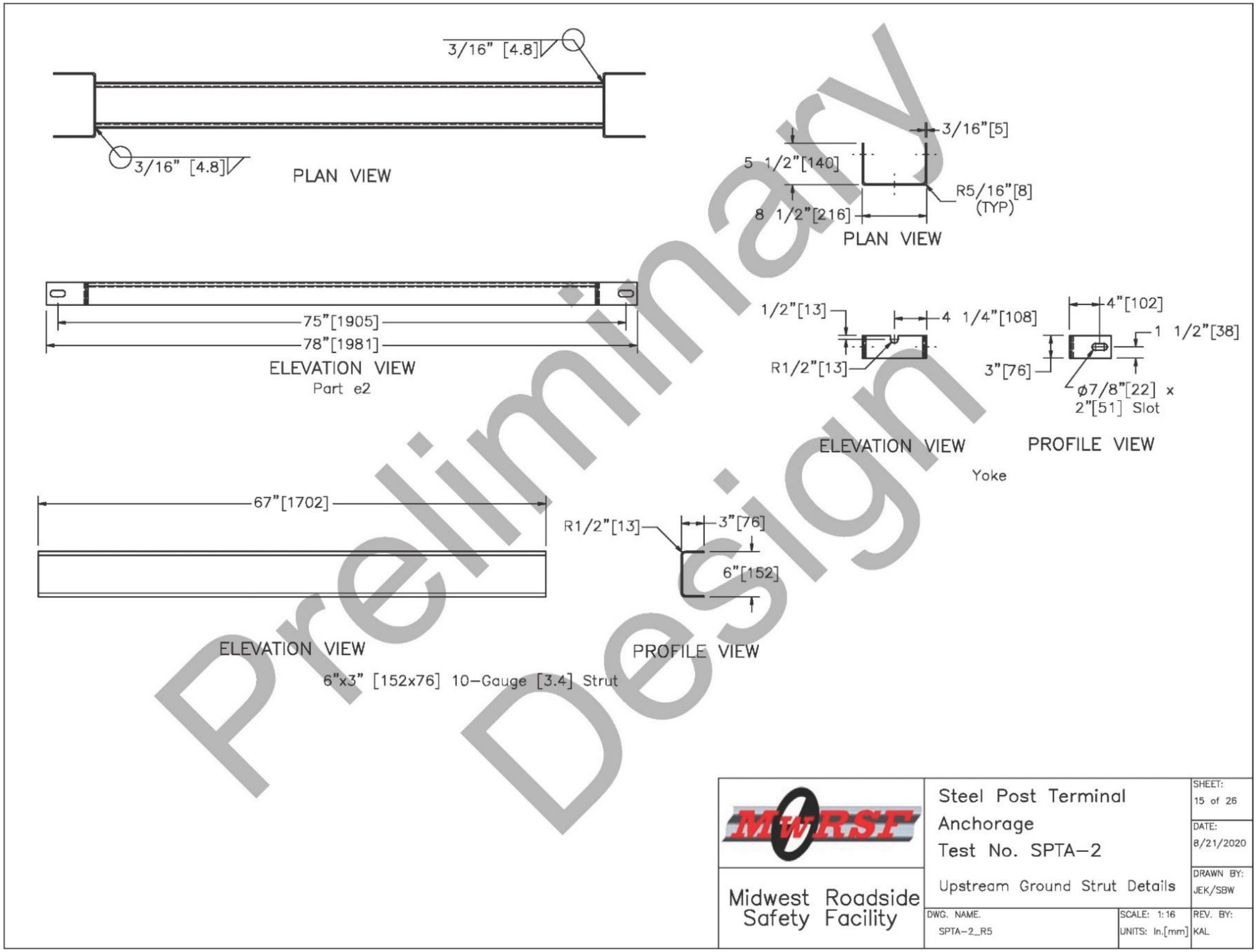
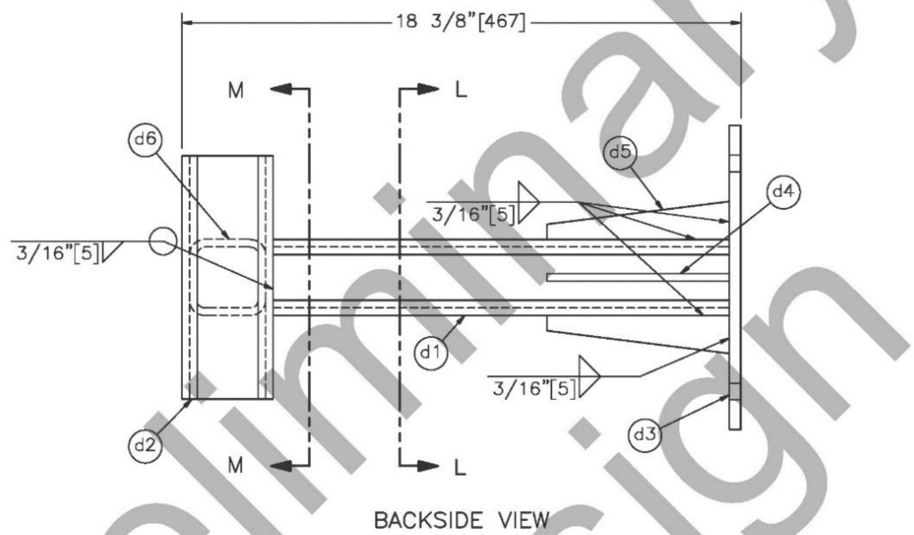


Figure 85. Upstream Ground Strut Details, Test No. SPTA-2



Item No.	QTY.	Description	Material Specification	Treatment Specification
–	1	Breaker Arm Assembly	–	ASTM A123
d1	1	HSS 2 1/2"x2 1/2"x1/4" [64x64x6], 15" [381] Long Square Tube	ASTM A500 Gr. B	–
d2	1	HSS 3"x3"x1/4" [76x76x6], 8" [203] Long Square Tube	ASTM A500 Gr. B	–
d3	1	10"x4 1/2"x3/8" [254x114x10] Plate	ASTM A36	–
d4	2	6"x3/4"x1/4" [152x19x6] Gusset	ASTM A36	–
d5	2	6"x1 1/4"x1/4" [152x32x6] Gusset	ASTM A36	–
d6	1	HSS 2 1/2"x2 1/2"x1/4" [64x64x6], 4" [102] Long Square Tube	ASTM A500 Gr. B	–

MwRSF Midwest Roadside Safety Facility	Steel Post Terminal Anchorage Test No. SPTA-2 Breaker Arm Assembly		SHEET: 16 of 26 DATE: 8/21/2020 DRAWN BY: JEK/SBW
	DWG. NAME. SPTA-2_R5	SCALE: 1:5 UNITS: In.[mm]	REV. BY: KAL

Figure 86. Breaker Arm Assembly, Test No. SPTA-2

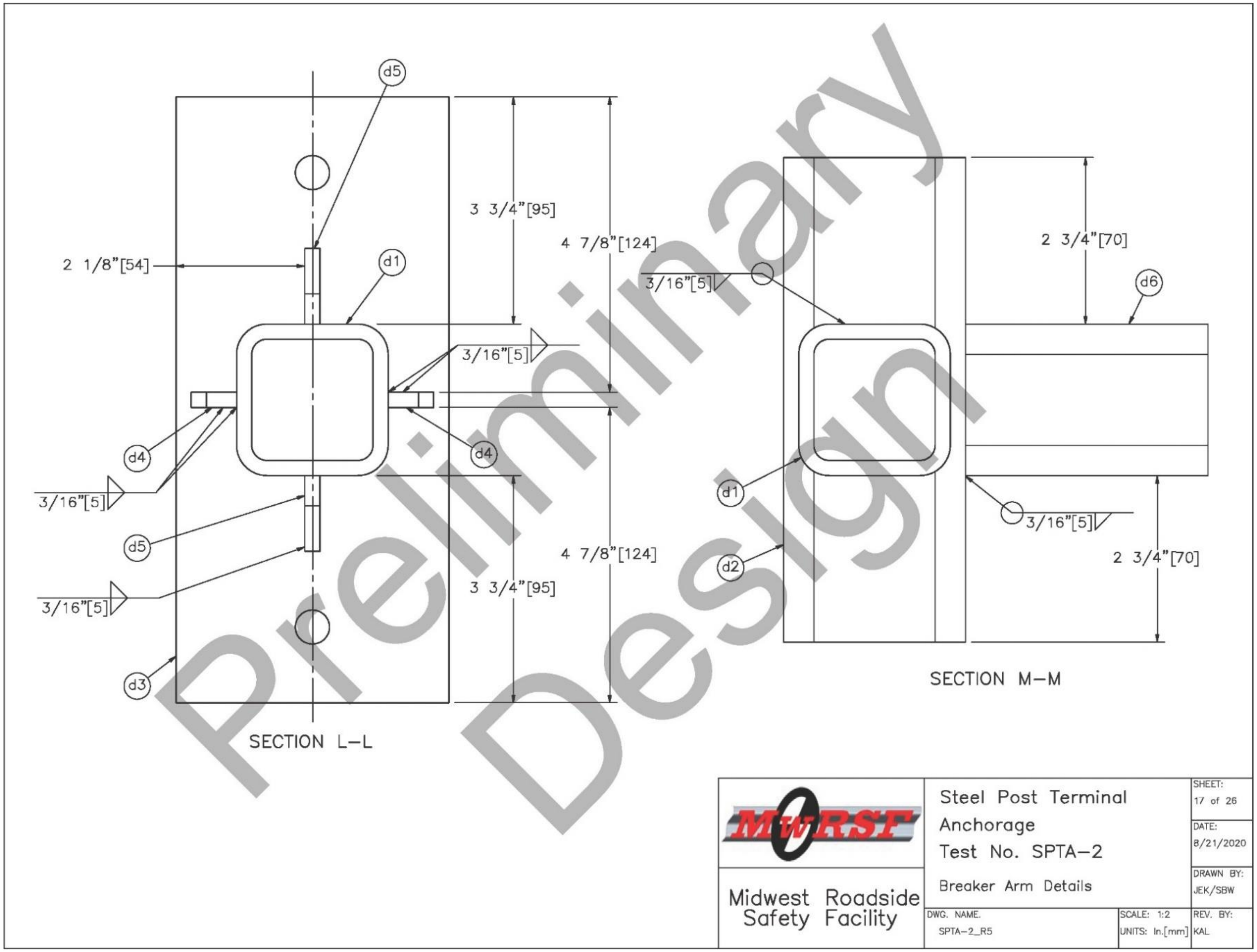


Figure 87. Breaker Arm Details, Test No. SPTA-2

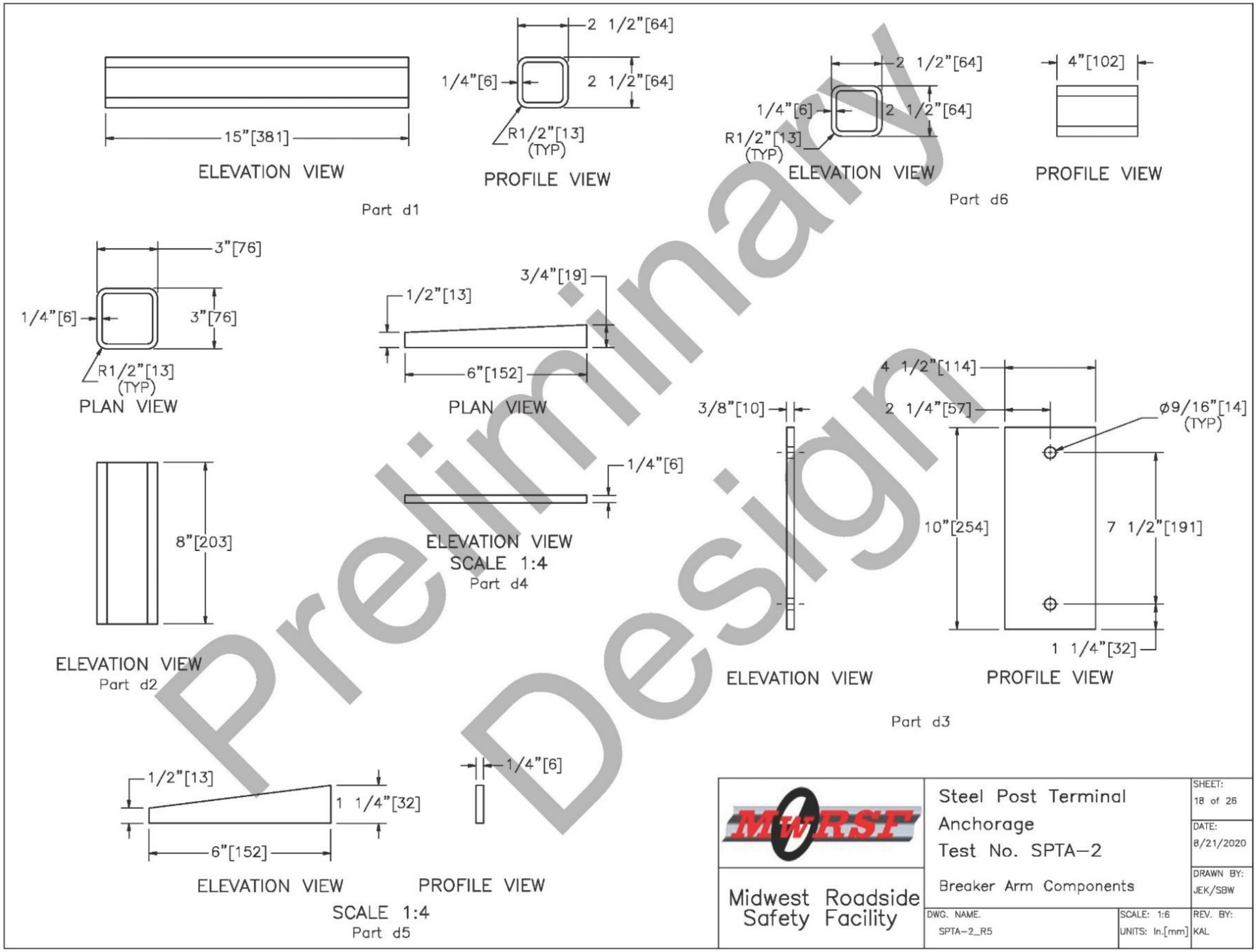


Figure 88. Breaker Arm Components, Test No. SPTA-2

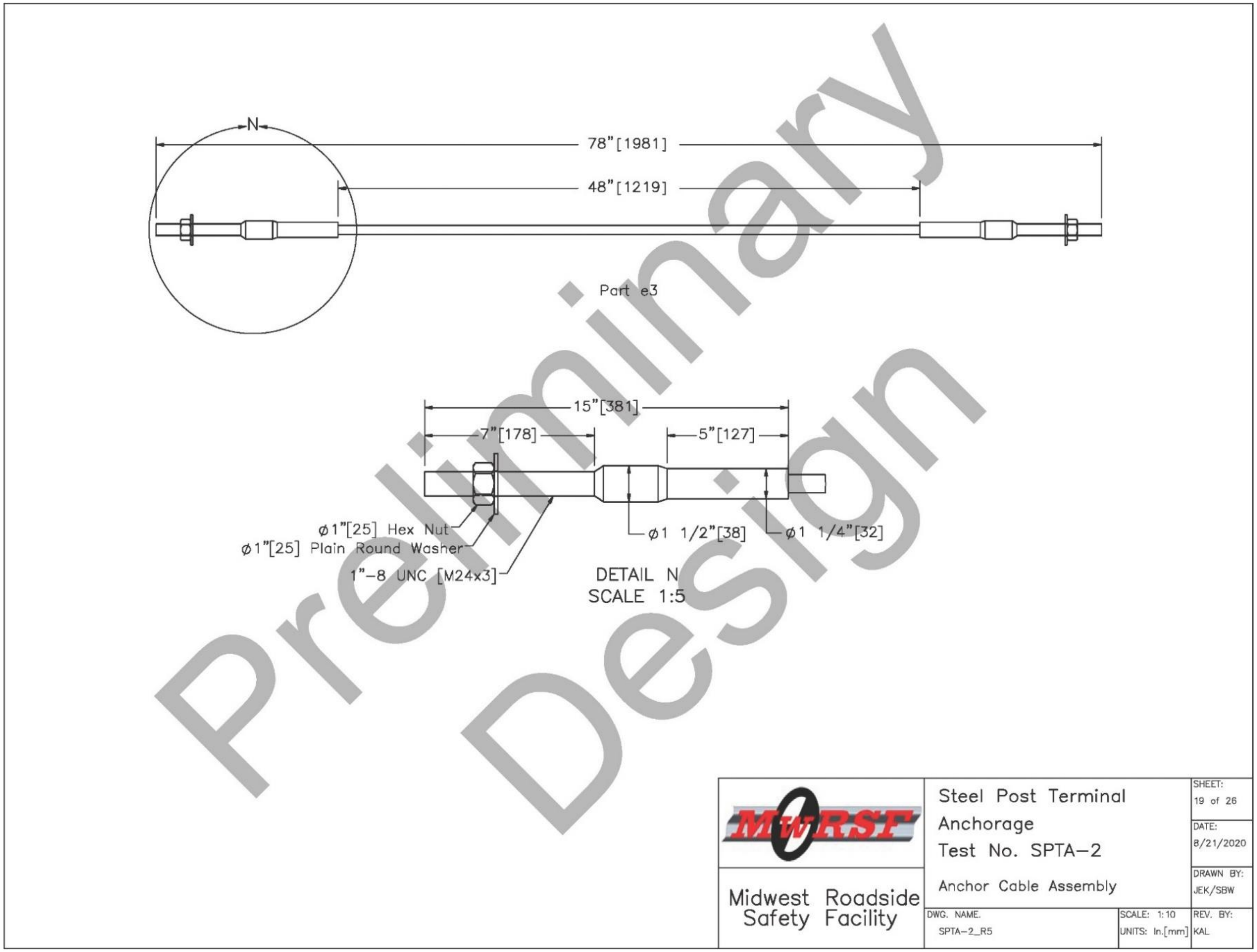


Figure 89. Anchor Cable Assembly, Test No. SPTA-2

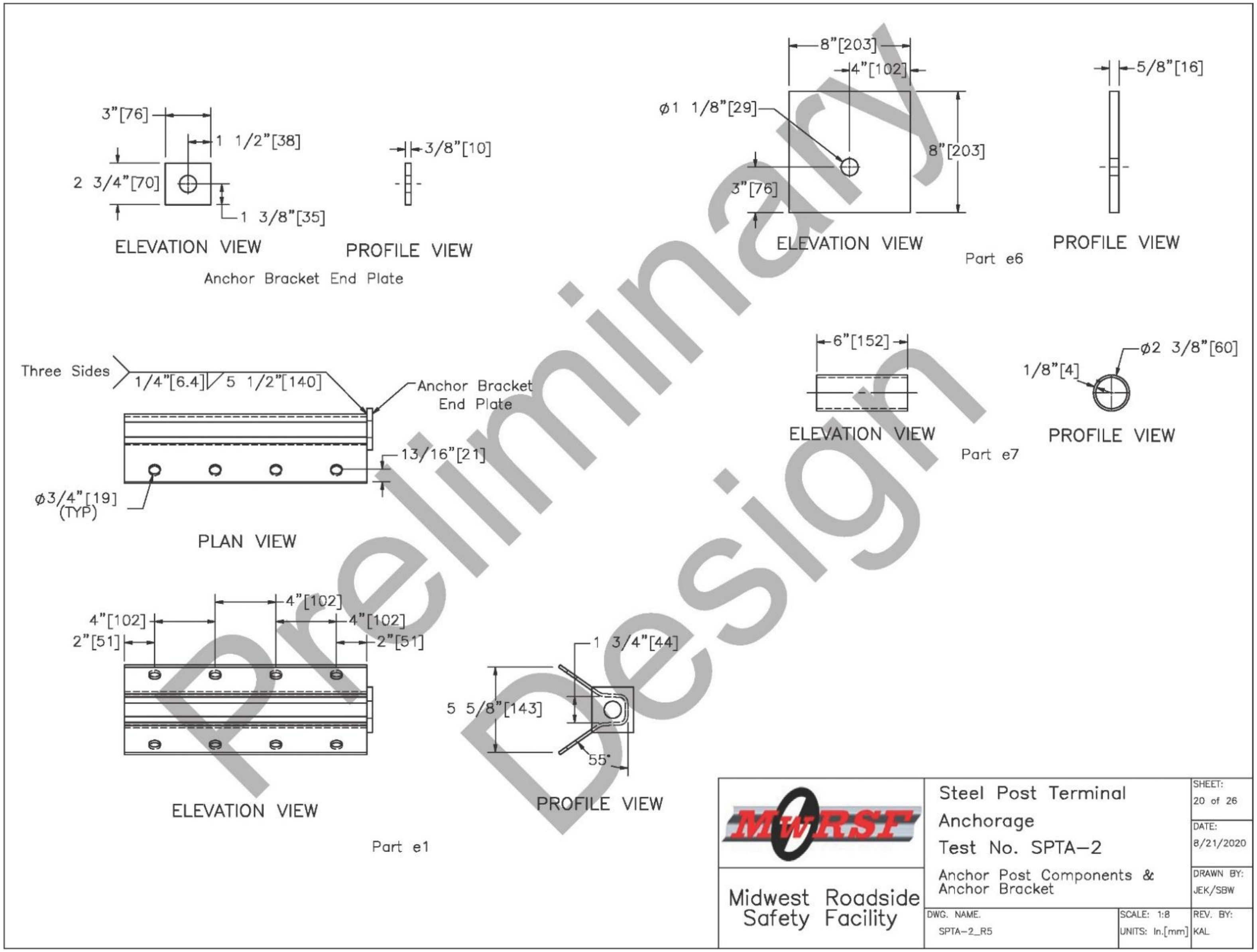


Figure 90. Anchor Post Components and Anchor Bracket, Test No. SPTA-2

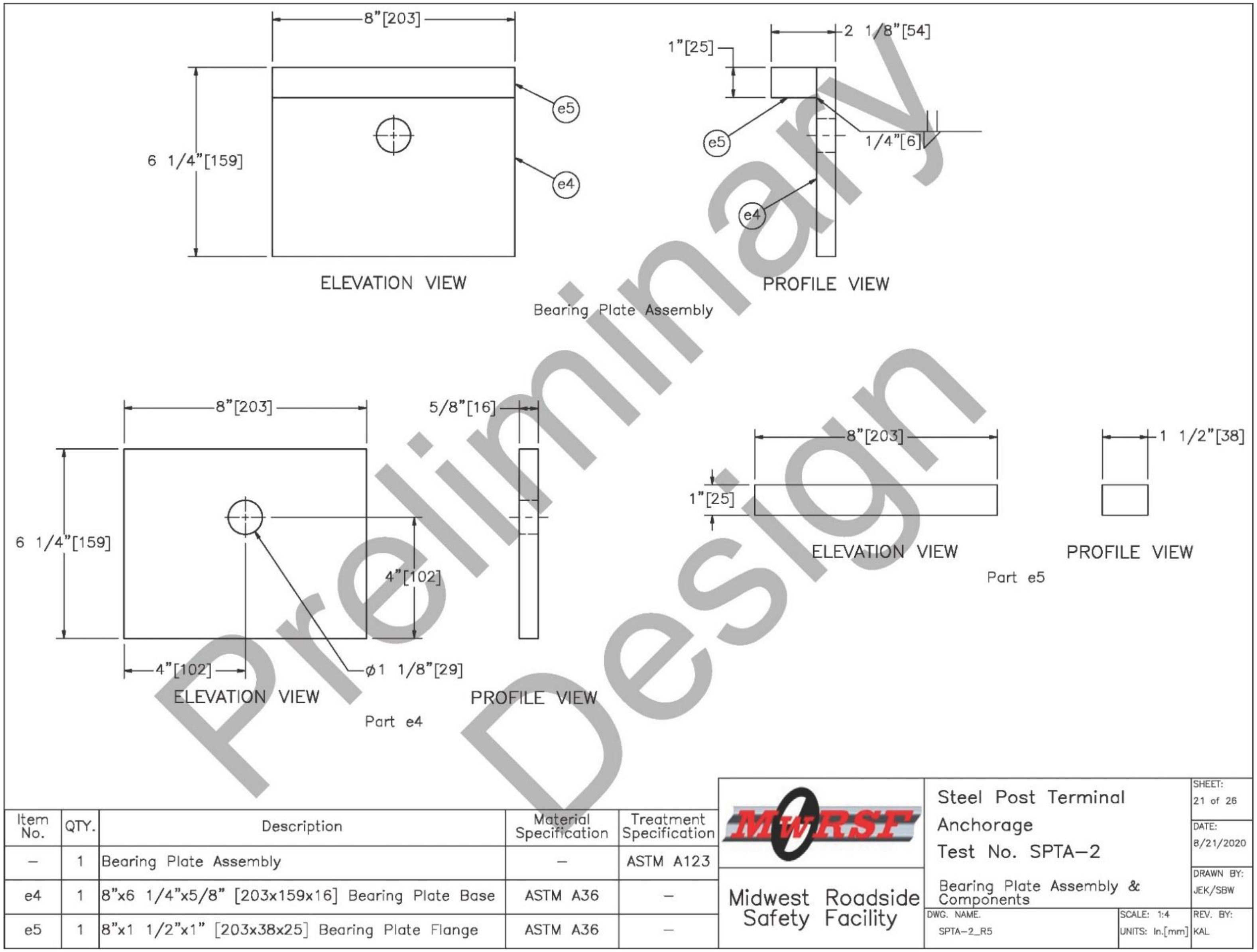


Figure 91. Bearing Plate Assembly and Components, Test No. SPTA-2

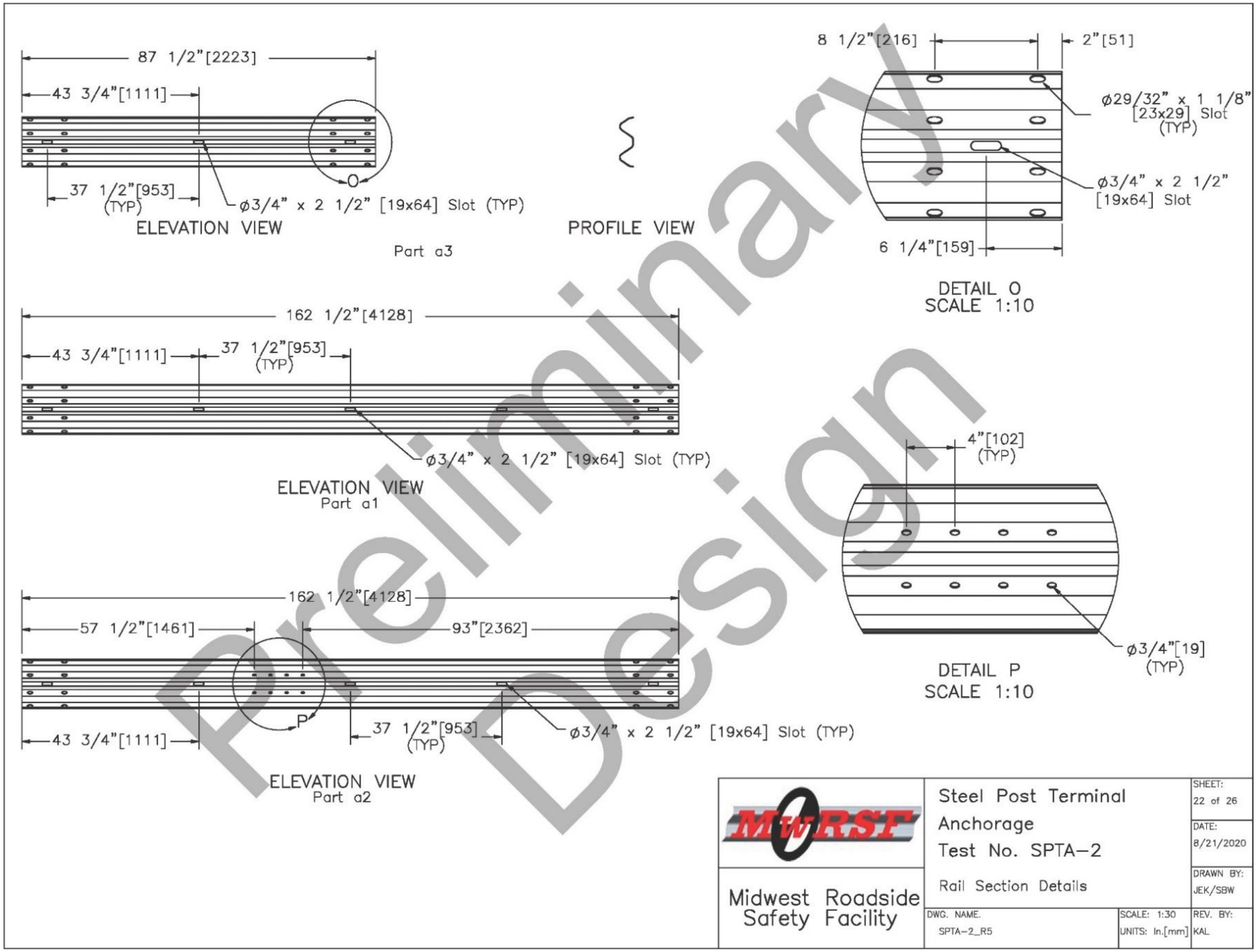


Figure 92. Rail Section Details, Test No. SPTA-2

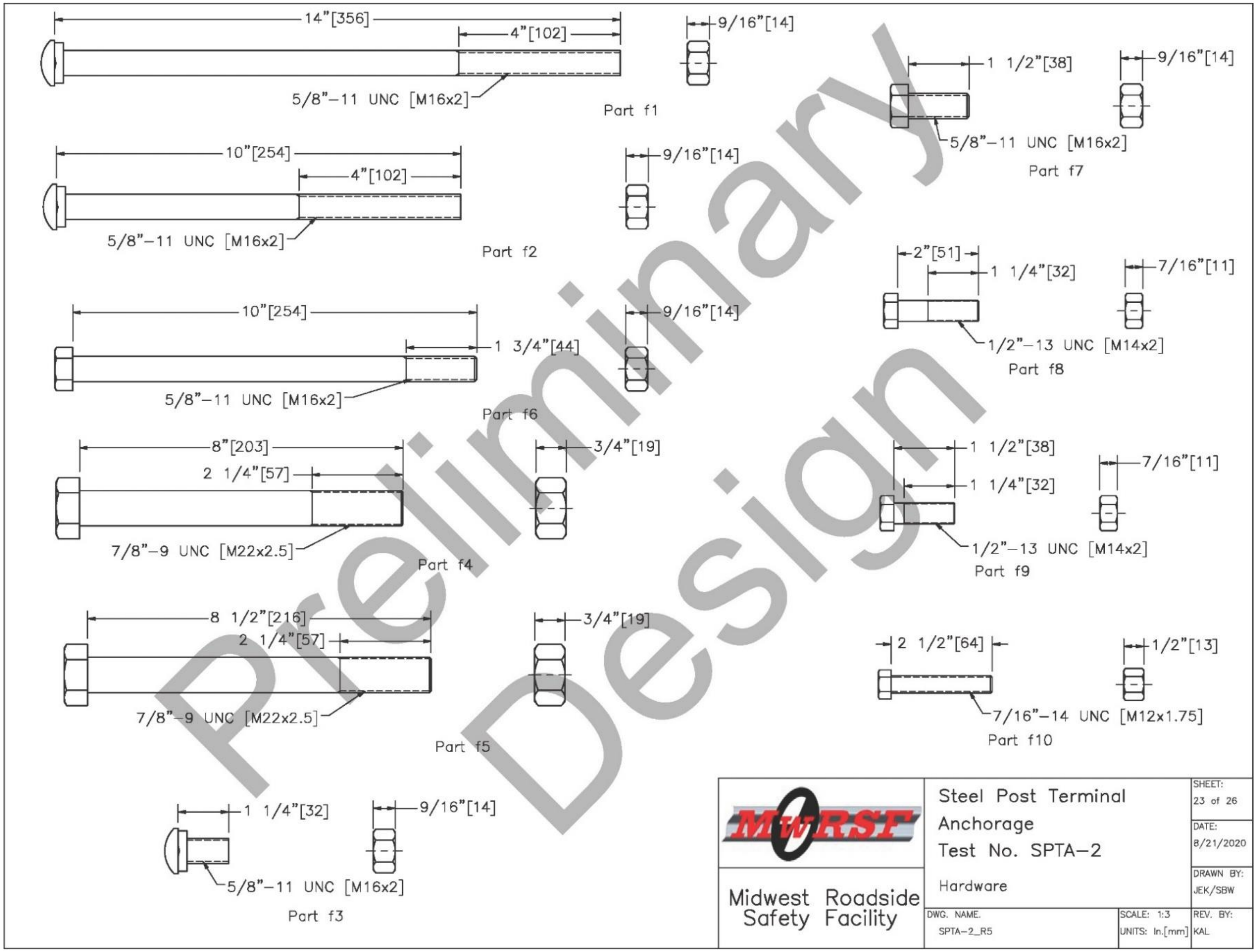


Figure 93. Hardware, Test No. SPTA-2

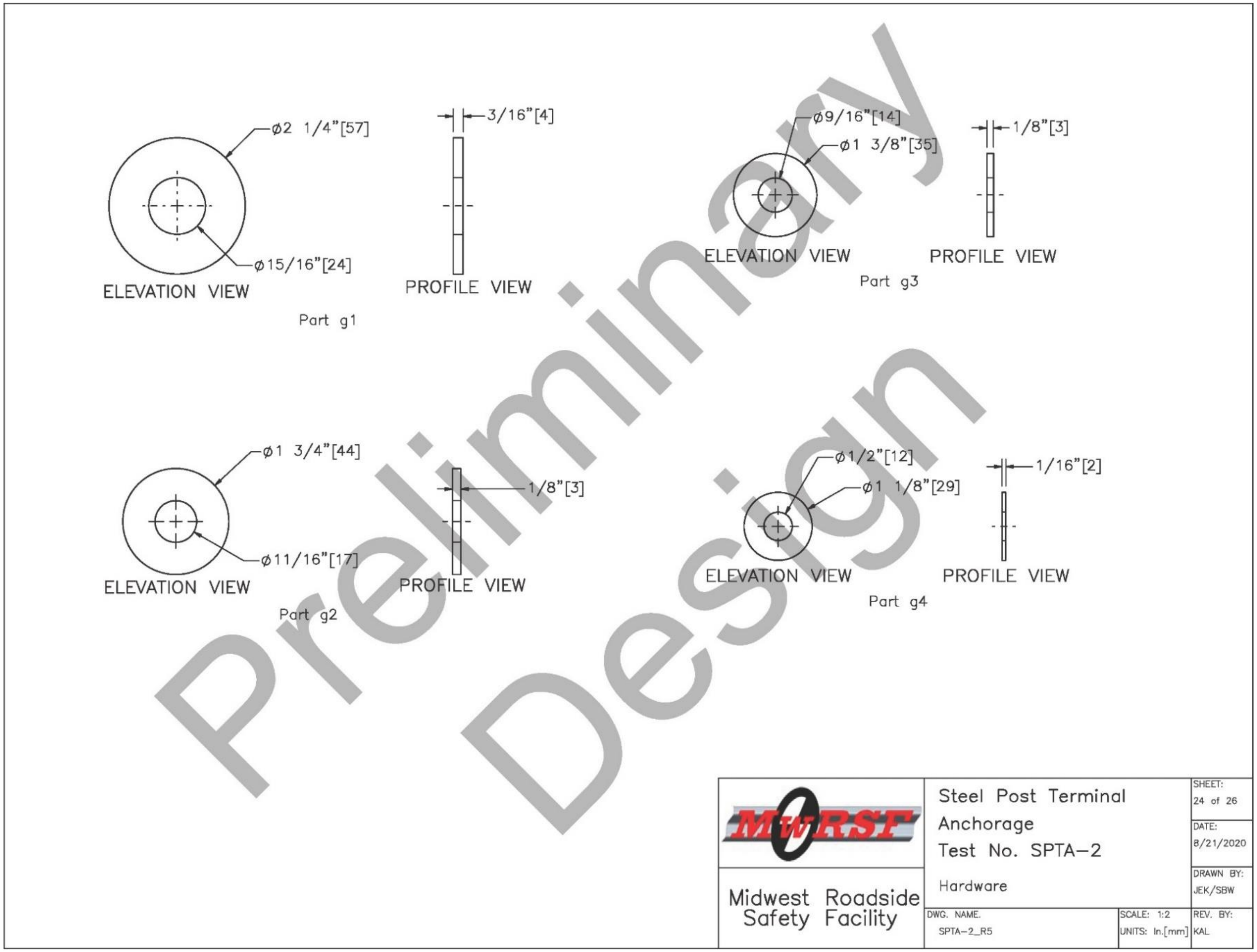


Figure 94. Hardware, Test No. SPTA-2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	12	12'–6" [3,810] 12–gauge [2.7] W–Beam MGS Section	AASHTO M180	ASTM A123 or A653	RWM04a
a2	2	12'–6" [3,810] 12–gauge [2.7] W–Beam MGS End Section	AASHTO M180	ASTM A123 or A653	–
a3	1	6'–3" [1,905] 12–gauge [2.7] W–Beam MGS Section	AASHTO M180	ASTM A123 or A653	–
b1	25	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 72" Long [1,829] Steel Post	ASTM A992	ASTM A123	PWE06
b2	25	6"x12"x14 1/4" [152x305x368] Timber Blockout	SYP Grade No.1 or better	–	PDB10a
b3	2	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 27 1/2" [699] Long Steel Post	ASTM A992	–	–
b4	2	TS 8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	–	–
b5	2	13"x7"x5/8" [330x178x16] Steel Plate	ASTM A36	–	–
b6	4	5 1/2"x5 1/2"x3/4" [140x140x19] Steel Plate	ASTM A36	–	–
b7	2	BCT Timber Post – MGS Height	SYP Grade No. 1 or better (No knots 18" [457] above or below ground tension face)	–	PDF01
b8	2	TS 8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	ASTM A123	PTE06
b9	4	5 7/16"x4"x1/4" [138x102x6] Steel Plate	ASTM A36	–	–
c1	1	66 1/2"x11 3/4"x10–gauge [1,689x298x3.4] Bent Steel Channel Strut	ASTM A36	ASTM A123	–
c2	2	17"x3"x1/4" [432x76x6] Bent Steel Plate	ASTM A36	ASTM A123	–
c3	2	7"x2 3/4"x1/2" [178x70x13] Steel Plate	ASTM A36	ASTM A123	–
d1	1	HSS 2 1/2"x2 1/2"x1/4" [64x64x6], 15" [381] Long Square Tube	ASTM A500 Gr. B	–	–
d2	1	HSS 3"x3"x1/4" [76x76x6], 8" [203] Long Square Tube	ASTM A500 Gr. B	–	–
d3	1	10"x4 1/2"x3/8" [254x114x10] Plate	ASTM A36	–	–
d4	2	6"x3/4"x1/4" [152x19x6] Gusset	ASTM A36	–	–
d5	2	6"x1 1/4"x1/4" [152x32x6] Gusset	ASTM A36	–	–
d6	1	HSS 2 1/2"x2 1/2"x1/4" [64x64x6], 4" [102] Long Square Tube	ASTM A500 Gr. B	–	–

Midwest Roadside Safety Facility

Steel Post Terminal Anchorage
Test No. SPTA–2

Bill of Materials

SHEET: 25 of 26
DATE: 8/21/2020
DRAWN BY: JEK/SBW
DWG. NAME. SPTA–2_R5
SCALE: None
UNITS: In.[mm]
REV. BY: KAL

Figure 95. Bill of Materials, Test No. SPTA-2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
e1	2	Anchor Bracket Assembly	ASTM A36	ASTM A123	FPA01
e2	1	Upstream Ground Strut	ASTM A36	ASTM A123	PFP02
e3	2	Anchor Cable Assembly	–	–	FCA01
e4	1	8"x6 1/4"x5/8" [203x159x16] Bearing Plate Base	ASTM A36	–	FPB01
e5	1	8"x1 1/2"x1" [203x38x25] Bearing Plate Flange	ASTM A36	–	–
e6	1	8"x8"x5/8" [203x203x16] Anchor Bearing Plate	ASTM A36	ASTM A123	FPB01
e7	1	2 3/8" [60] O.D. x 6" [152] Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	ASTM A123	FMM02
f1	25	5/8"-11 UNC [M16x2], 14" [356] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB06
f2	2	5/8"-11 UNC [M16x2], 10" [254] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB03
f3	114	5/8"-11 UNC [M16x2], 1 1/4" [32] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB01
f4	2	7/8"-9 UNC [M22x2.5], 8" [203] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A or equivalent Nut – ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	–
f5	2	7/8"-9 UNC [M22x2.5], 8 1/2" [216] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A or equivalent Nut – ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	–
f6	2	5/8"-11 UNC [M16x2], 10" [254] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A or equivalent Nut – ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f7	16	5/8"-11 UNC [M16x2], 1 1/2" [38] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A or equivalent Nut – ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f8	4	1/2"-13 UNC [M14x2], 2" [51] Long Hex Bolt and Nut	Bolt ASTM A307 Gr. A or equivalent Nut – ASTM A563A or equivalent	–	FBX14a
f9	2	1/2"-13 UNC [M14x2], 1 1/2" [38] Long Hex Bolt and Nut	Bolt ASTM A307 Gr.A or equivalent Nut – ASTM A563A or equivalent	ASTM A153 OR B695 Class 55 or F2329	FBX14a
f10	8	7/16"-14 UNC [M12x1.75], 2 1/2" [64] Long Fully Threaded Hex Tap Bolt and Nut	Bolt – ASTM A449 or equivalent Nut – ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX12b
f11	26	16D Double Head Nail	–	–	–
g1	8	7/8" [22] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	–
g2	38	5/8" [16] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC16a
g3	8	1/2" [13] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC14a
g4	32	7/16" [11] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC12a

MwRSF Midwest Roadside Safety Facility	Steel Post Terminal Anchorage Test No. SPTA-2		SHEET: 26 of 26
			DATE: 8/21/2020
	Bill of Materials		DRAWN BY: JEK/SBW
	DWG. NAME. SPTA-2_R5	SCALE: None UNITS: In.[mm]	REV. BY: KAL

Figure 96. Bill of Materials, Test No. SPTA-2

Figure 97. Test Installation Photographs – Trailing-End Anchorage System, Test No. SPTA-2

Figure 98. Test Installation Photographs – Trailing-End Anchorage System, Test No. SPTA-2

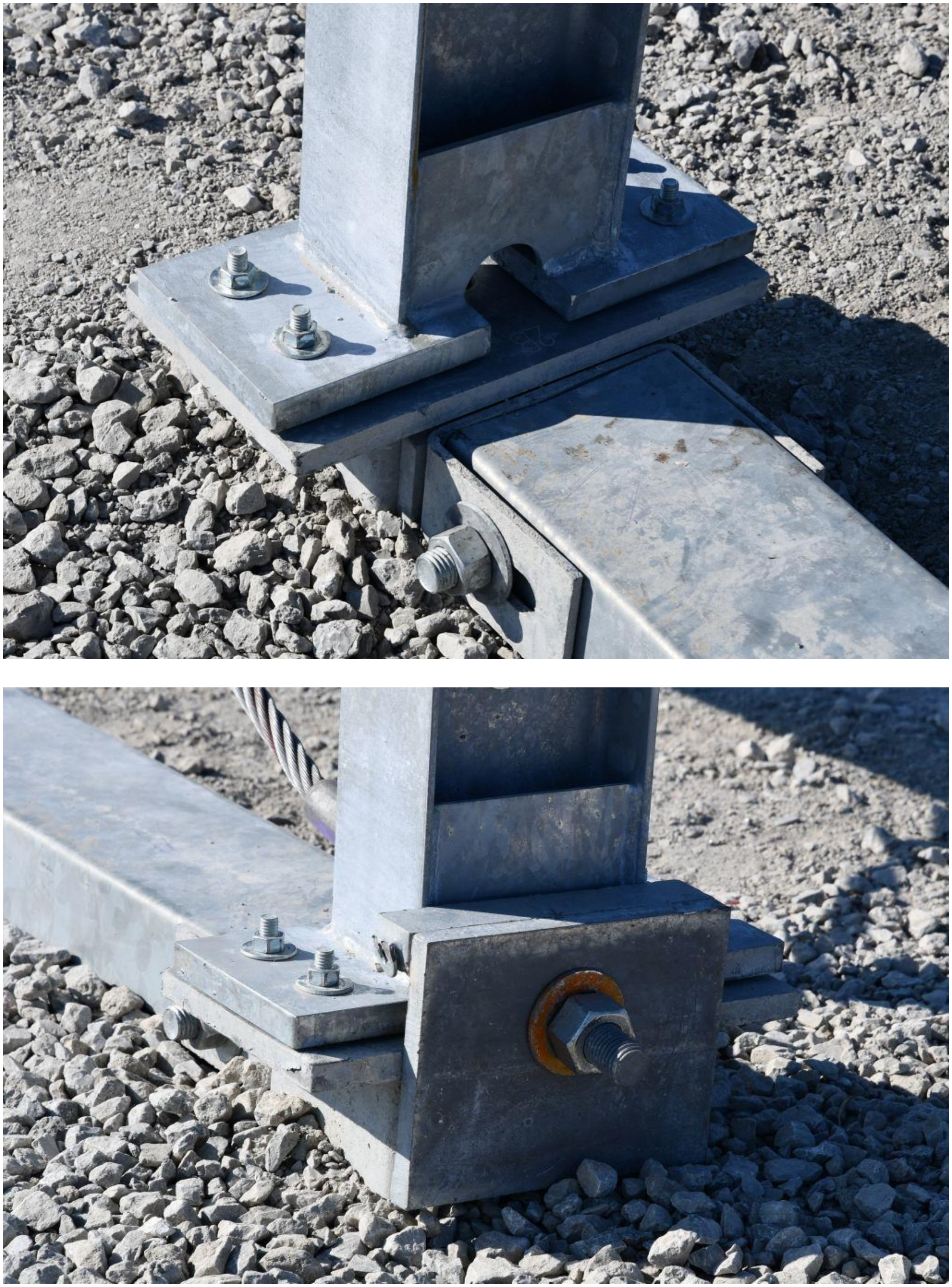


Figure 99. Test Installation Photographs – Trailing-End Anchorage System, Test No. SPTA-2

Figure 100. Test Installation Photographs – Trailing-End Anchorage System, Test No. SPTA-2

Figure 101. Test Installation Photographs – Upstream End Anchorage System, Test No. SPTA-2

7 FULL-SCALE CRASH TEST NO. SPTA-2

7.1 Static Soil Test

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

7.2 Weather Conditions

Test no. SPTA-2 was conducted on September 12, 2018 at approximately 1:30 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 11.

Table 11. Weather Conditions, Test No. SPTA-2

Temperature	82° F
Humidity	51%
Wind Speed	18 mph
Wind Direction	180° from True North
Sky Conditions	Partly Cloudy
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.10 in.

7.3 Test Description

Initial vehicle impact was to occur at the midspan between post nos. 27 and 28, or 37.5 in. (953 mm) upstream of the steel-post trailing end anchorage system, as shown in Figure 102. This impact point matched that used during the evaluation of the wood-post trailing end anchorage system and was selected to maximize vehicle snag on the cable anchorage. The actual point of impact was 1.3 in. (34 mm) upstream from the targeted impact point. The 2,429-lb (1,102-kg) small car impacted the guardrail system at a speed of 63.3 mph (101.9 km/h) and at an angle of 25.2 degrees. During the impact event, the vehicle gated through the system and remained upright and stable. Both of the breakaway anchor posts cleanly fractured away from their foundation tubes. The vehicle directly impacted post no. 28 and caused it to break away. The breaker bar remained in place as the guardrail and anchor cable deflected backward. The vehicle impacted the upstream end of the breaker bar and caused post no. 29 (the downstream anchor post) to breakaway. Subsequently, the anchor cable was released, the downstream end of the W-beam guardrail swung back and away from the vehicle, and the vehicle rolled over the remaining anchorage hardware consisting of post stubs and the ground line strut. The vehicle eventually came to rest 171 ft – 3 in. (52.2 m) downstream from the point of impact and 74 ft (22.6 m) laterally behind the system after brakes were applied.

A detailed description of the sequential impact events is contained in Table 12. Sequential photographs are shown in Figures 103 and 104. Documentary photographs of the crash test are shown in Figures 105 and 106. The vehicle trajectory and final position are shown in Figure 107.

Figure 102. Impact Location, Test No. SPTA-2

Table 12. Sequential Description of Impact Events, Test No. SPTA-2

TIME (sec)	EVENT
0.000	Vehicle’s front bumper contacted rail 1.3 in. (34 mm) upstream from the midspan between post nos. 27 and 28.
0.004	Vehicle’s right headlight contacted rail.
0.006	Vehicle’s right fender contacted rail.
0.008	Vehicle’s right fender deformed.
0.010	Post nos. 27 and 28 deflected backward, and vehicle’s right headlight deformed.
0.012	Vehicle’s hood contacted rail.
0.014	Vehicle’s hood deformed.
0.020	Vehicle’s right headlight shattered.
0.022	Vehicle’s front bumper contacted post no. 28.
0.028	Post no. 27 rotated clockwise, post no. 28 bent backward, and vehicle’s grille and right-front door contacted rail.
0.030	Post no. 28 bent downstream, and rail disengaged from bolt at post no. 28.
0.036	Right portion of vehicle's front bumper tore and disengaged.
0.038	Post no. 29 deflected backward.
0.040	Post no. 28 disengaged from base.
0.044	Post no. 29 rotated counterclockwise.
0.046	Post no. 26 rotated clockwise.
0.056	Vehicle yawed away from barrier.
0.061	Vehicle's hood buckled.
0.078	Vehicle’s front bumper contacted post no. 29.
0.080	Post no. 29 bent downstream.
0.086	Rail disengaged from bolt at post no. 29.
0.090	Vehicle’s left headlight contacted rail.
0.096	Vehicle pitched downward.
0.098	Post no. 29 disengaged from base.
0.102	Vehicle left headlight shattered.
0.120	Vehicle's right-front tire deflated.
0.150	Vehicle exited system at a speed of 44.9 mph (72.3 km/h) and an angle of 20.1 degrees.
0.176	Vehicle’s right-rear tire became airborne.
0.200	Post no. 27 rotated counterclockwise.
0.222	Vehicle’s left-rear tire became airborne.
0.224	Vehicle’s right-rear tire regained contact with ground.
0.228	Vehicle’s grille disengaged.
0.242	Remainder of vehicle's front bumper disengaged.
0.304	Vehicle pitched upward.
0.366	Vehicle’s left-rear tire regained contact with ground.

0.000 sec

0.050 sec

0.100 sec

0.150 sec

0.200 sec

0.250 sec

0.000 sec

0.050 sec

0.100 sec

0.150 sec

0.200 sec

0.250 sec

Figure 103. Sequential Photographs, Test No. SPTA-2

0.000 sec

0.050 sec

0.100 sec

0.150 sec

0.200 sec

0.250 sec

0.000 sec

0.050 sec

0.100 sec

0.150 sec

0.200 sec

0.250 sec

Figure 104. Additional Sequential Photographs, Test No. SPTA-2

Figure 105. Documentary Photographs, Test No. SPTA-2

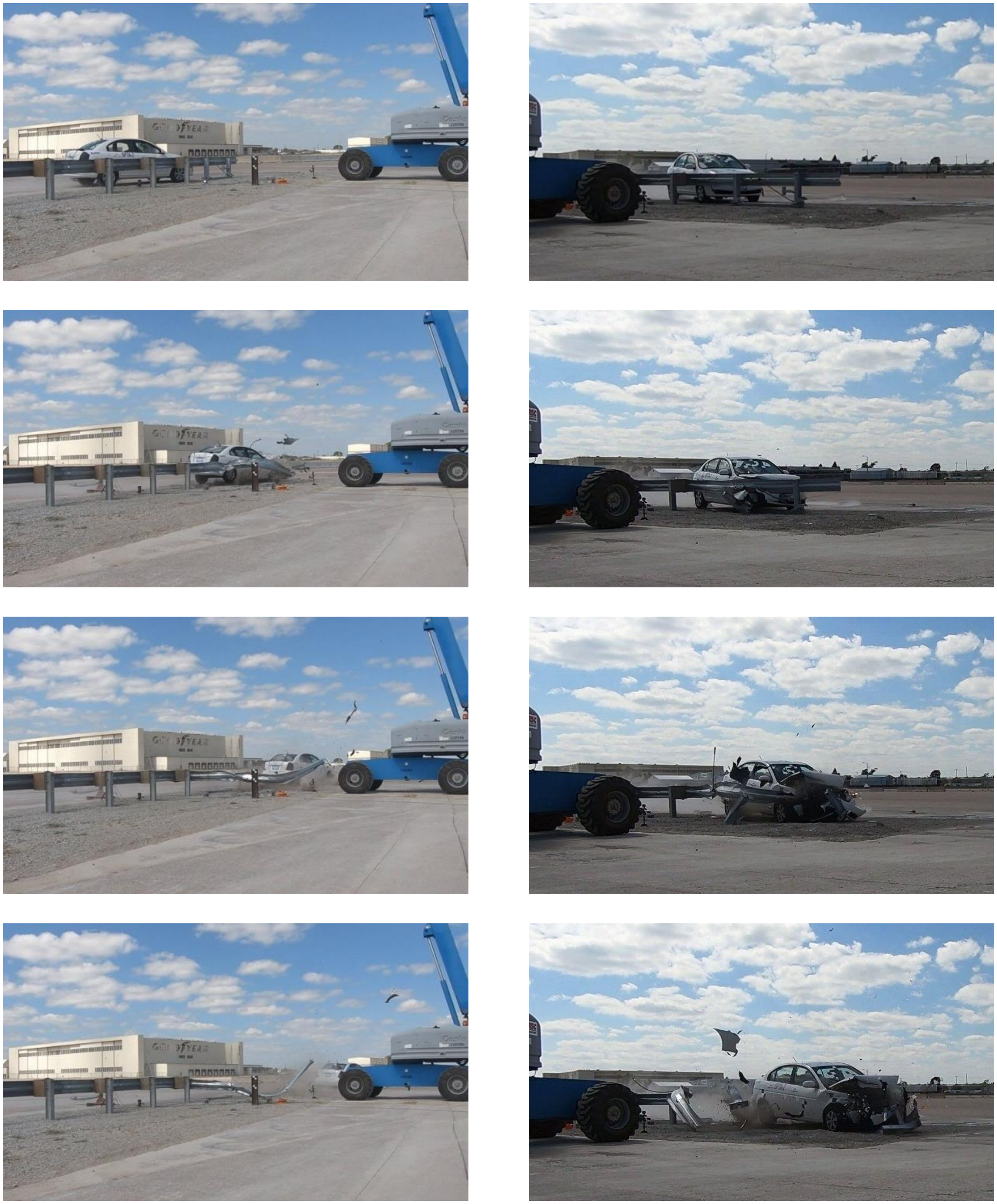


Figure 106. Documentary Photographs, Test No. SPTA-2

Figure 107. Vehicle Final Position and Trajectory Marks, Test No. SPTA-2

7.4 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 108 through 111. Barrier damage consisted of deformation and twisting of the rail assembly; deflection, twisting, and rotation of posts; and lease of both trailing-end anchorage breakaway steel posts. The length of vehicle contact along the barrier was approximately 13 ft – 7 in. (4.1 m), which spanned from 44 in. (1,118 mm) upstream from post no. 28 to the downstream end of the system.

The guardrail experienced various degrees of bending, flattening, denting, kinking, and scraping extending from 44 in. (1,118 mm) upstream from post no. 28 to the downstream end of the system. The post-to-rail bolts pulled through the rail at post nos. 27, 28, and 29, and the rail disengaged from these posts. The W-beam was bent backward at a 90-degree angle around post no. 27. Flattening of the top W-beam corrugation began 38 in. (965 mm) downstream from post no. 28 and ended 3 in. (76 mm) downstream from post no. 29. Flattening of the bottom W-beam corrugation began 6 in. (152 mm) downstream from post no. 28 and ended 18 in. (457 mm) upstream from post no. 29. Additional flattening of the bottom W-beam edge began 16 in. (406 mm) upstream from the end of rail and extended through the end of the system. Additional buckles and kinks were found on the W-beam throughout the impact region.

Post no. 27 twisted counterclockwise to face upstream and the post-to-rail bolt remained in the post. All bolts in the base of post nos. 28 and 29 fractured and the top portions of the posts were disengaged from their base plates. The post-to-rail bolts remained in both breakaway anchor posts. Post no. 28 was twisted counterclockwise and the traffic-side flange had a 12-in. (305-mm) long by 2-in. (51-mm) deep dent. Post no. 29 twisted counterclockwise and had multiple kinks in the upstream front and back flanges. Contact marks were present on the foundation base plates of post nos. 28 and 29. The T-shaped, breaker bar assembly remained attached to post no. 29 with both bolts intact. The corners of the breaker bar attachment plate were bent. The cable anchor was released from post no. 29 but remained attached to the guardrail.

The maximum lateral permanent set of the rail was 142¼ in. (3,613 mm) at the downstream end of the rail as determined from field measurements. The maximum dynamic rail deflection was 183.0 in. (4,648 mm) at the end of the rail, as determined from high-speed, digital video analysis. The working width of the system coincided with the dynamic deflection, which was 183.0 in. (4,648 mm). Note, working width measurements did not include vehicle position since the terminal gated and the vehicle was not redirected. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 112.

Figure 108. System Damage, Test No. SPTA-2

Figure 109. System Damage, Test No. SPTA-2

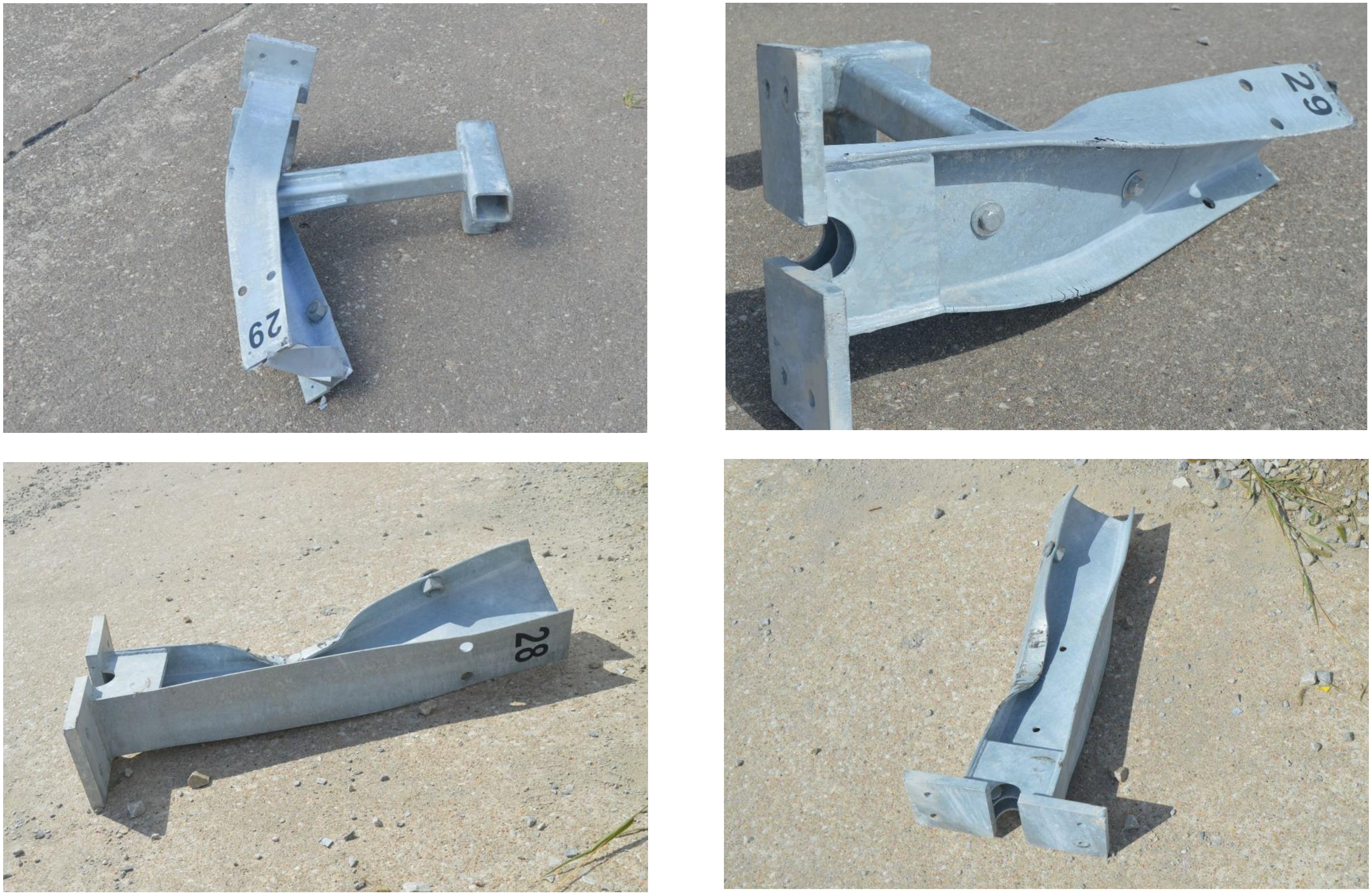


Figure 110. System Damage – Post Nos. 28 and 29, Test No. SPTA-2

Figure 111. System Damage – Upstream End Anchorage System, Test No. SPTA-2

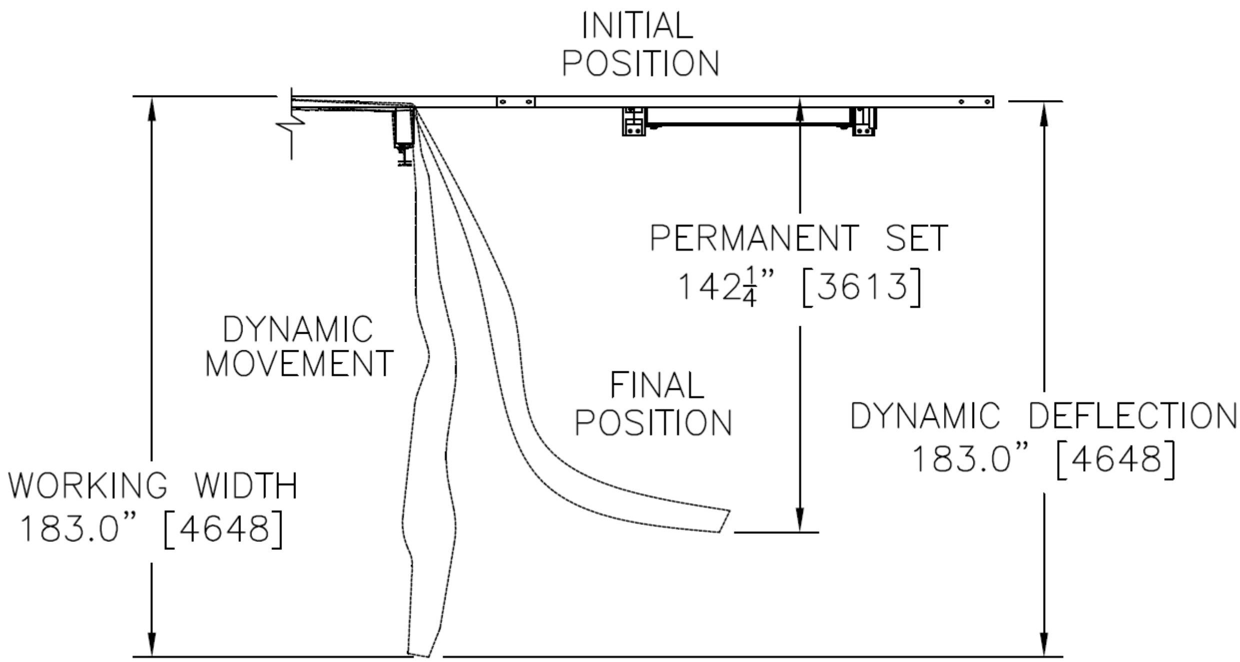


Figure 112. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. SPTA-2

7.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 113 through 116. The maximum occupant compartment deformations are listed in Table 13 along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. Interior occupant compartment deformations were minimal with a maximum of 0.3 in., which did not violate the limits established in MASH 2016. Outward deformations, which are denoted as negative numbers in Appendix D, are not considered crush toward the occupant and are not evaluated by MASH 2016 criteria.

Most of the damage was concentrated on the right-front corner of the vehicle where impact occurred. The front bumper cover was disengaged from the vehicle. The middle of the front bumper was crushed inward into the radiator. The hood, left headlight, right-front fender, and right wheel well crushed inward. The hood buckled upward. The right headlight disengaged from the vehicle.

Damage to the vehicle undercarriage was moderate. Most significantly, the steering gear box disengaged from its mounts. The transmission oil pan was punctured. The front engine and transmission mounts were fractured, and the cross members were bent. The left-side frame fractured, and the frame horn was bent up and backward into the engine compartment. The underside floor pan was scraped in multiple locations. The exhaust bracket fractured. The roof, windshield, and window glass remained undamaged.

Figure 113. Vehicle Damage, Test No. SPTA-2

Figure 114. Vehicle Damage, Test No. SPTA-2

Figure 115. Occupant Compartment Damage, Test No. SPTA-2

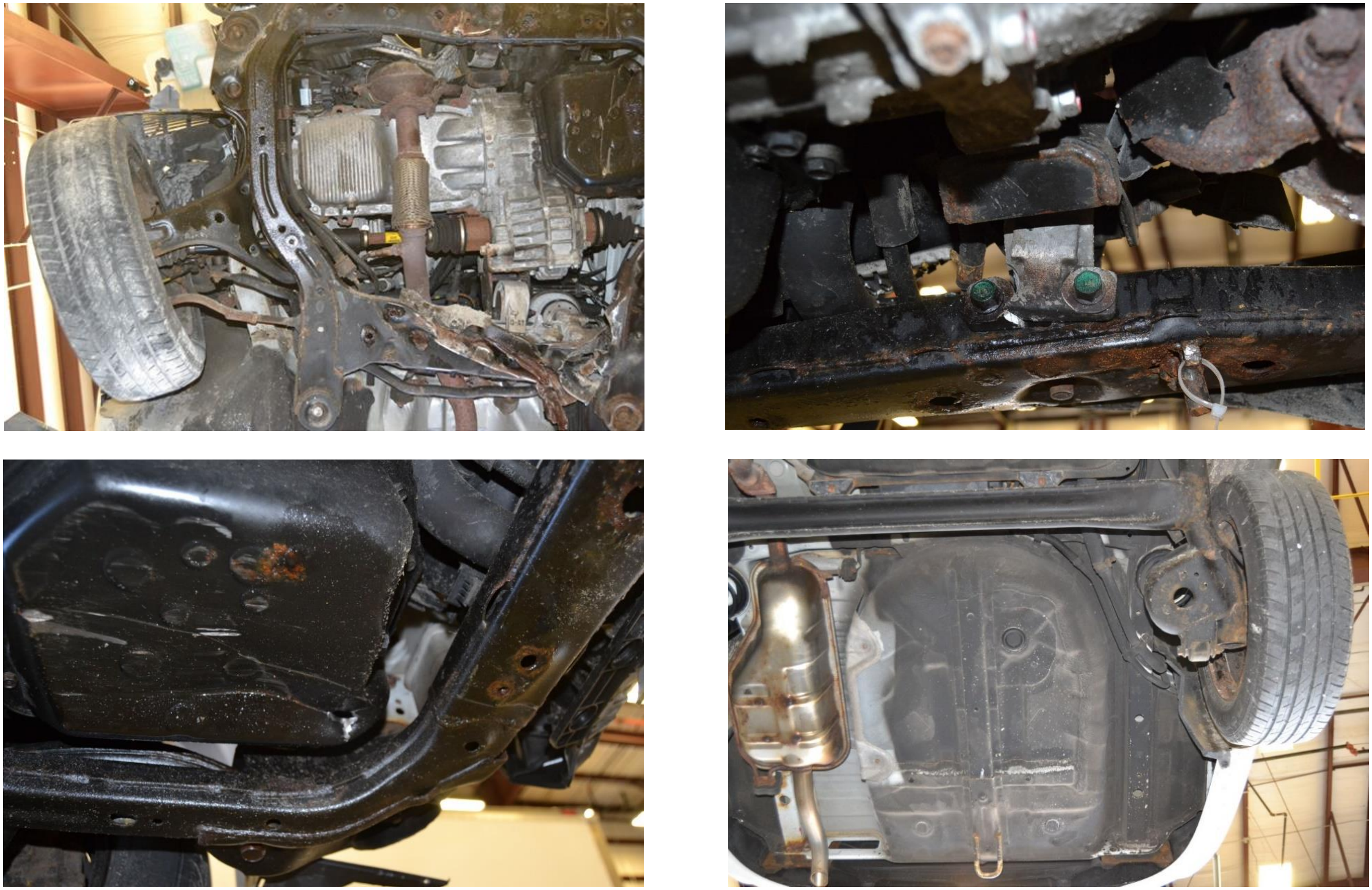


Figure 116. Undercarriage Damage, Test No. SPTA-2

Table 13. Maximum Occupant Compartment Intrusion by Location, Test No. SPTA-2

LOCATION	MAXIMUM INTRUSION in. (mm)	MASH 2016 ALLOWABLE INTRUSION in. (mm)
Wheel Well & Toe Pan	0.2 (5)	≤ 9 (229)
Floor Pan & Transmission Tunnel	0.0 (0)	≤ 12 (305)
A-Pillar Maximum	0.3 (8)	≤ 5 (127)
A-Pillar (Lateral)	0.1 (3)	≤ 3 (76)
B-Pillar Maximum	0.2 (5)	≤ 5 (127)
B-Pillar (Lateral)	0.1 (3)	≤ 3 (76)
Side Front Panel (in Front of A-Pillar)	0.1 (3)	≤ 12 (305)
Side Door (Above Seat)	0.1 (3)	≤ 9 (229)
Side Door (Below Seat)	0.1 (3)	≤ 12 (305)
Roof	0.2 (5)	≤ 4 (102)
Windshield	0.0 (0)	≤ 3 (76)
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	0.4 (10)	N/A

N/A – No MASH 2016 criteria exists for this location

7.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ride down accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 14. 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 14. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix G.

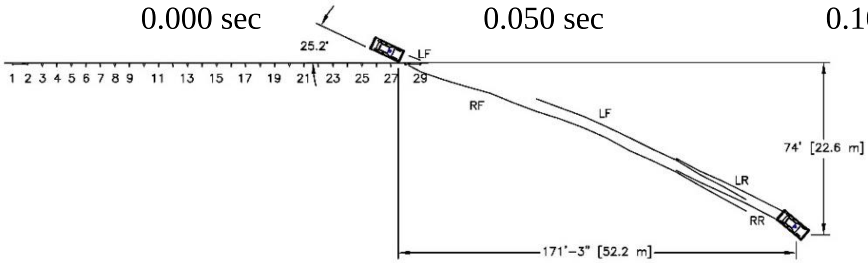
Table 14. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. SPTA-2

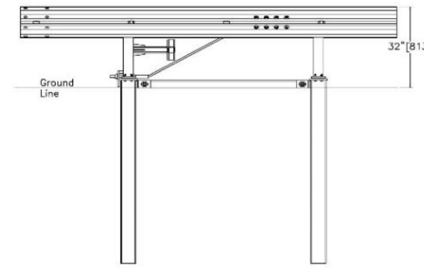
Evaluation Criteria		**Transducer**		**MASH 2016 Limits**
		SLICE-1 (primary)	**SLICE-2**	
OIV ft/s (m/s)	Longitudinal	-24.76 (-7.55)	-24.38 (-7.43)	±40 (12.2)
	Lateral	-7.66 (-2.33)	-7.65 (-2.33)	±40 (12.2)
ORA g's	Longitudinal	4.56	3.53	±20.49
	Lateral	-3.72	-3.69	±20.49
MAXIMUM ANGULAR DISPLACEMENT degrees	Roll	4.0	4.1	±75
	Pitch	-3.6	-3.2	±75
	Yaw	-7.6	-7.9	not required
THIV ft/s (m/s)		25.32 (7.72)	25.33 (7.72)	not required
PHD g's		5.75	5.09	not required
ASI		0.89	0.87	not required

7.7 Discussion

The analysis of the test results for test no. SPTA-2 showed that the system performed adequately and allowed the 1100C vehicle to safely gate through the system. The test results and sequential photographs are summarized in Figure 117. 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 gated through 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. As such, the gating action was safe and controlled and did not pose a risk to occupants. Gating through the system, the vehicle continued traveling downstream at an angle of 20.1 degrees relative to the barrier's original position. Therefore, test no. SPTA-2 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-37b.

0.000 sec 0.050 sec 0.100 sec 0.150 sec 0.200 sec





- Test Agency .... MwRSF
- Test Number SPTA-2
- Date 09/12/2018
- MASH 2016 Test Designation No. 3-37b
- Test Article .... MGS with steel-post, trailing-end anchorage system
- Total Length .... 182 ft – 3½ in. (55.6 m)
- Key Component – W-Beam Rail
  - Thickness .... 12 gauge (2.66 mm)
  - Top Mounting Height .... 32 in. (813 mm)
- Key Component – Line Posts (Nos. 3-27)
  - Type .... 72 in. (1,829 mm) long W6x8.5
  - Spacing .... 75 in. (1,905 mm) on-center
- Key Component – Steel-Post, Trailing-End Anchorage
  - Steel Post .... 27½-in. (699-mm) long, W6x8.5
  - Foundation Tube Section ...... 8-in. x 6-in. x 3/16-in. (203-mm x 152-mm x 5-mm) tube
  - Foundation Tube Length .... 72 in. (1829 mm)
- Ground Line Strut .... 66½ in. (1689 mm) long, C-channel (C6x8.2)
- Soil Type .... coarse, crushed limestone (well-graded gravel)
- Vehicle Make /Model .... 2011 Hyundai Accent
  - Curb .... 2,505 lb (1,136 kg)
  - Test Inertial .... 2,429 lb (1,102 kg)
  - Gross Static .... 2,590 lb (1,175 kg)
- Impact Conditions
  - Speed .... 63.3 mph (101.9 km/h), MASH 2016 limit: 62 ±2.5 mph (100 ±4.0 km/h)
  - Angle .... 25.2 degrees, MASH 2016 limit: 25 ±1.5 degrees
  - Impact Location .... 1.3 in. (34 mm) upstream from midspan of post nos. 27-28
- Impact Severity .... 59.2 kip-ft (80.3 kJ) > 51 kip-ft (69.7 kJ) limit from MASH 2016
- Exit Conditions
  - Speed .... 44.9 mph (72.3 km/h)
  - Angle .... 20.1 degrees
- Exit Box Criterion .... N/A
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 171 ft – 3 in. (52.2 m) downstream from impact
- Vehicle Damage .... Moderate
  - VDS [16] 1-FR-4
  - CDC [17] 01-FDEW-5
  - Maximum Interior Deformation .... 0.3 in. (8 mm)
- Test Article Damage .... Moderate
- Maximum Test Article Deflections
  - Permanent Set .... 142¼ in. (3,613 mm)
  - Dynamic .... 183.0 in. (4,648 mm)
  - Working Width .... 183.0 in. (4,648 mm)*
  - * Vehicle position not included in working width measurements – gating system
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limit
		SLICE-1 (primary)	SLICE-2	
OIV ft/s (m/s)	Longitudinal	-24.76 (-7.55)	-24.38 (-7.43)	±40 (12.2)
	Lateral	-7.66 (-2.33)	-7.65 (-2.33)	±40 (12.2)
ORA g's	Longitudinal	4.56	3.53	±20.49
	Lateral	-3.72	-3.69	±20.49
MAXIMUM ANGULAR DISPLACEMENT degrees	Roll	4.0	4.1	±75
	Pitch	-3.6	-3.2	±75
	Yaw	-7.6	-7.9	Not required
THIV – ft/s (m/s)		25.32 (7.72)	25.33 (7.72)	Not required
PHD – g's		5.75	5.09	Not required
ASI		0.89	0.87	Not required

Figure 117. Summary of Test Results and Sequential Photographs, Test No. SPTA-2

8 FINAL DESIGN FOR STEEL-POST, TRAILING-END ANCHORAGE SYSTEM

The final design for the non-proprietary, steel-post, trailing-end anchorage system was nearly identical to that of the as-tested system evaluated in test no. SPTA-2. However, test no. SPTA-2 was conducted with a 32-in. (813-mm) rail height to maximize the risk of vehicle snag on the anchor cable below the rail. Thus, the final recommended design lowered the bolt holes in the anchor posts to allow for the nominal 31-in. (787-mm) rail mounting height of the MGS. No other design changes were made.

The final recommended design includes: (1) two breakaway steel posts; (2) two steel foundation tubes; (3) a steel compression ground line strut between the two steel foundation tubes; (4) one steel anchor cable connecting the W-beam rail to the base of the end post; and (5) a T-shaped, breaker bar attached to the end anchor post to initiate fracture of the end post and release of the anchor cable. Details for the final steel-post, trailing end MGS anchorage system are shown in Figures 118 through 133. Note, the details herein include a shortened section of W-beam located at the downstream end of the installation such that the guardrail ends at the end post. However, longer guardrail segments extending past the end post (similar to the as-tested installations) or the use of curved guardrail end segments downstream of the end post should also be considered crashworthy.

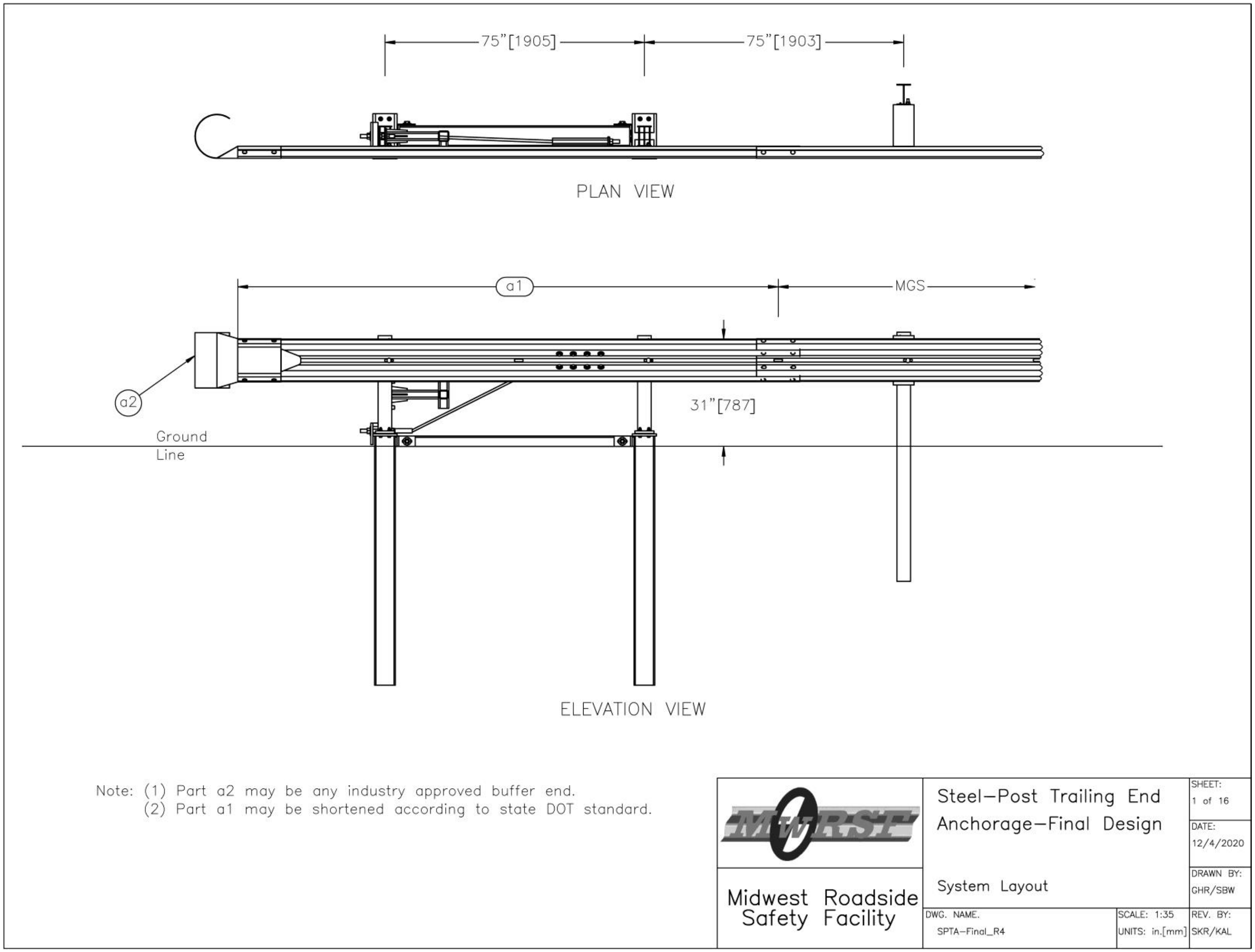


Figure 118. Steel-Post Trailing End Anchorage, System Layout

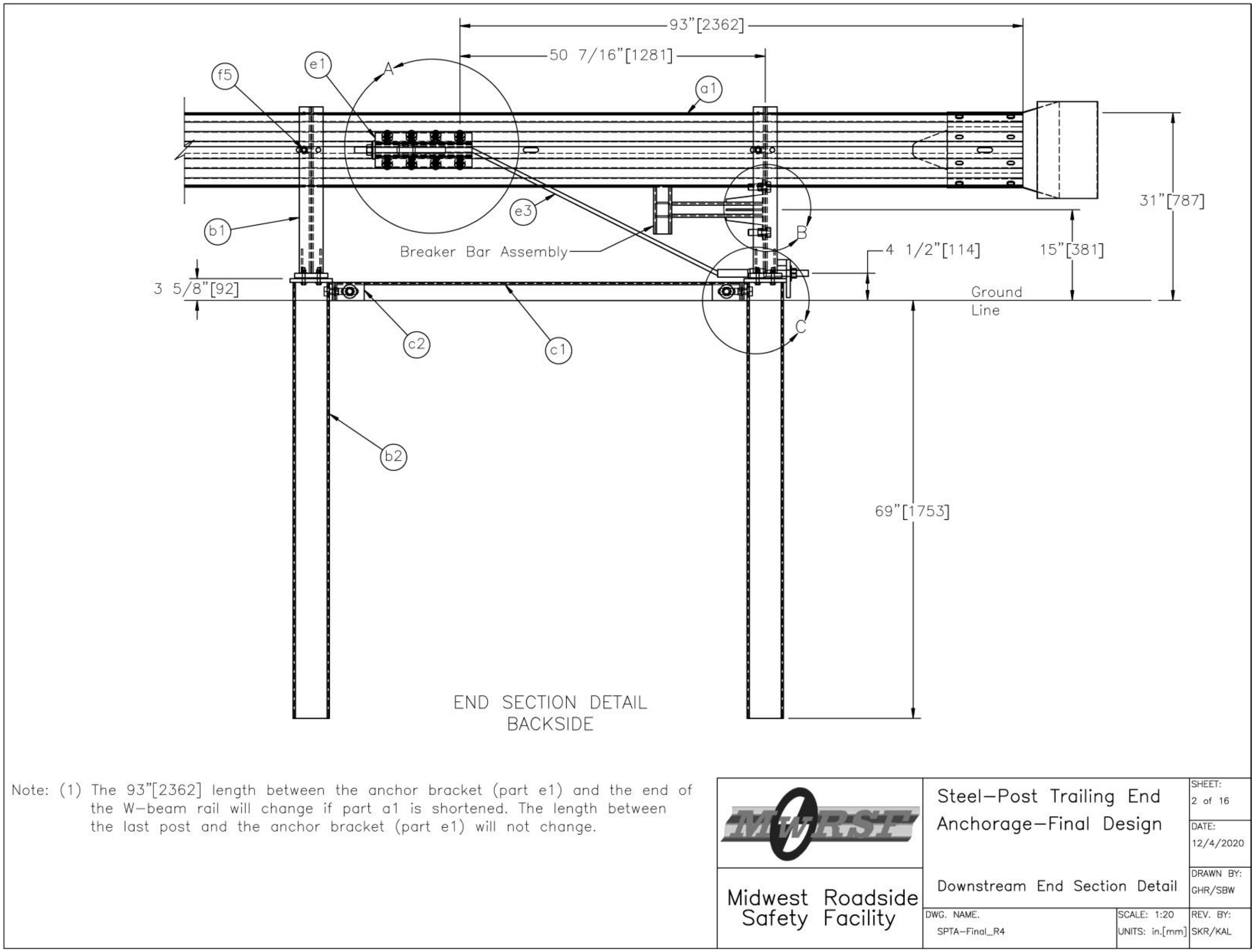


Figure 119. Steel-Post Trailing End Anchorage, Downstream End Section Detail

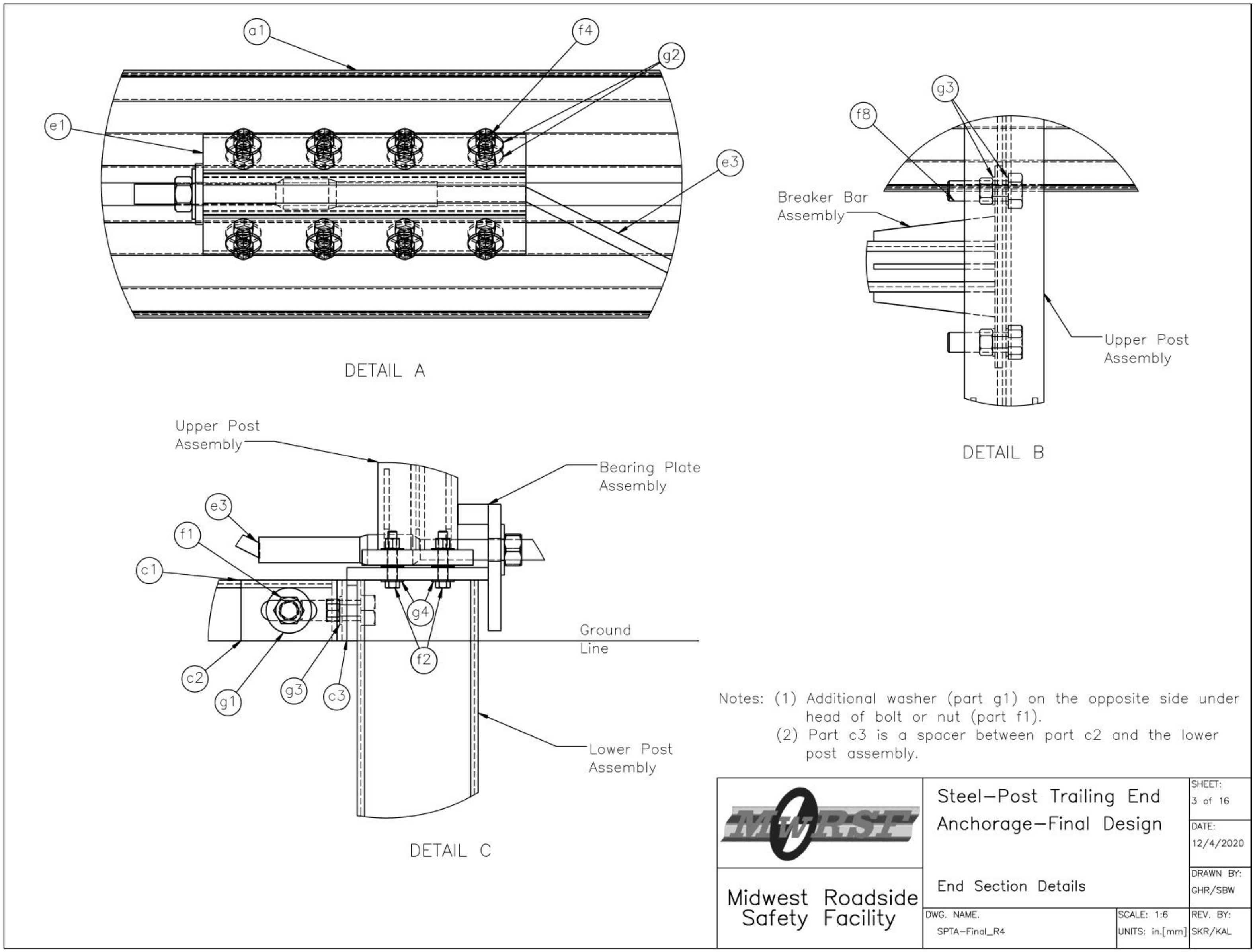


Figure 120. Steel-Post Trailing End Anchorage, End Section Details

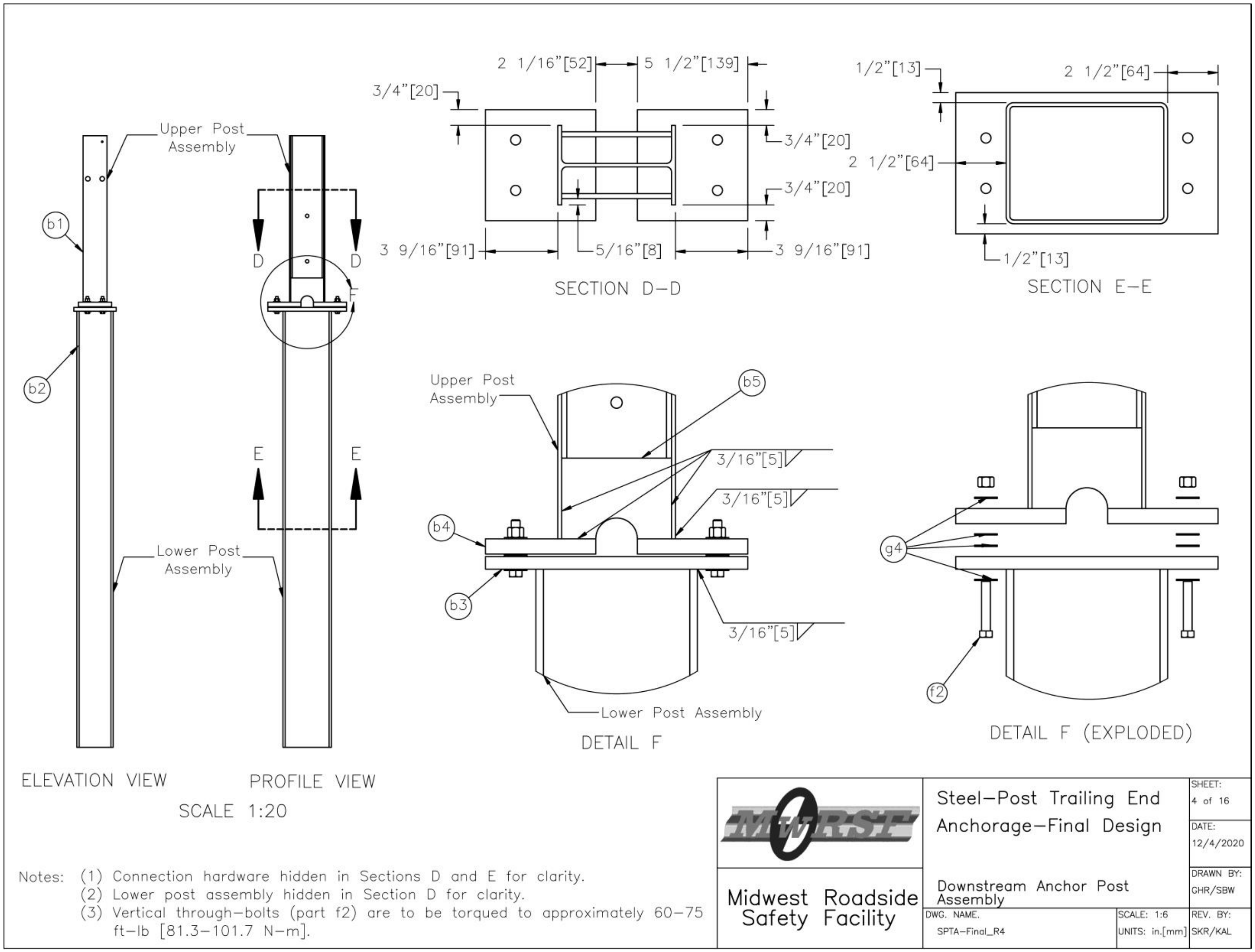
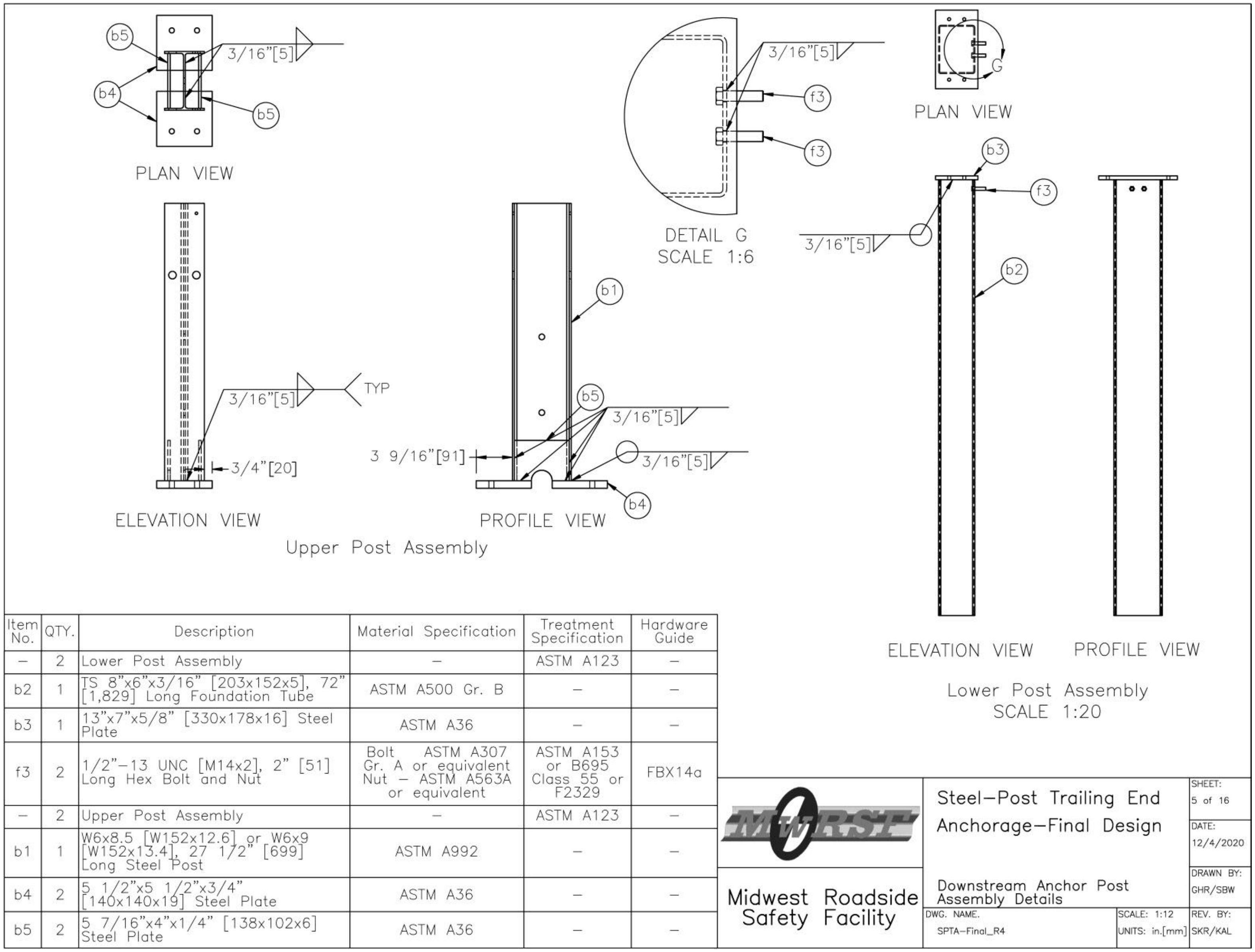


Figure 121. Steel-Post Trailing End Anchorage, Downstream Anchor Post Assembly



Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	2	Lower Post Assembly	–	ASTM A123	–
b2	1	TS 8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	–	–
b3	1	13"x7"x5/8" [330x178x16] Steel Plate	ASTM A36	–	–
f3	2	1/2"-13 UNC [M14x2], 2" [51] Long Hex Bolt and Nut	Bolt ASTM A307 Gr. A or equivalent Nut – ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX14a
–	2	Upper Post Assembly	–	ASTM A123	–
b1	1	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 27 1/2" [699] Long Steel Post	ASTM A992	–	–
b4	2	5 1/2"x5 1/2"x3/4" [140x140x19] Steel Plate	ASTM A36	–	–
b5	2	5 7/16"x4"x1/4" [138x102x6] Steel Plate	ASTM A36	–	–

Figure 122. Steel-Post Trailing End Anchorage, Downstream Anchor Post Assembly Details

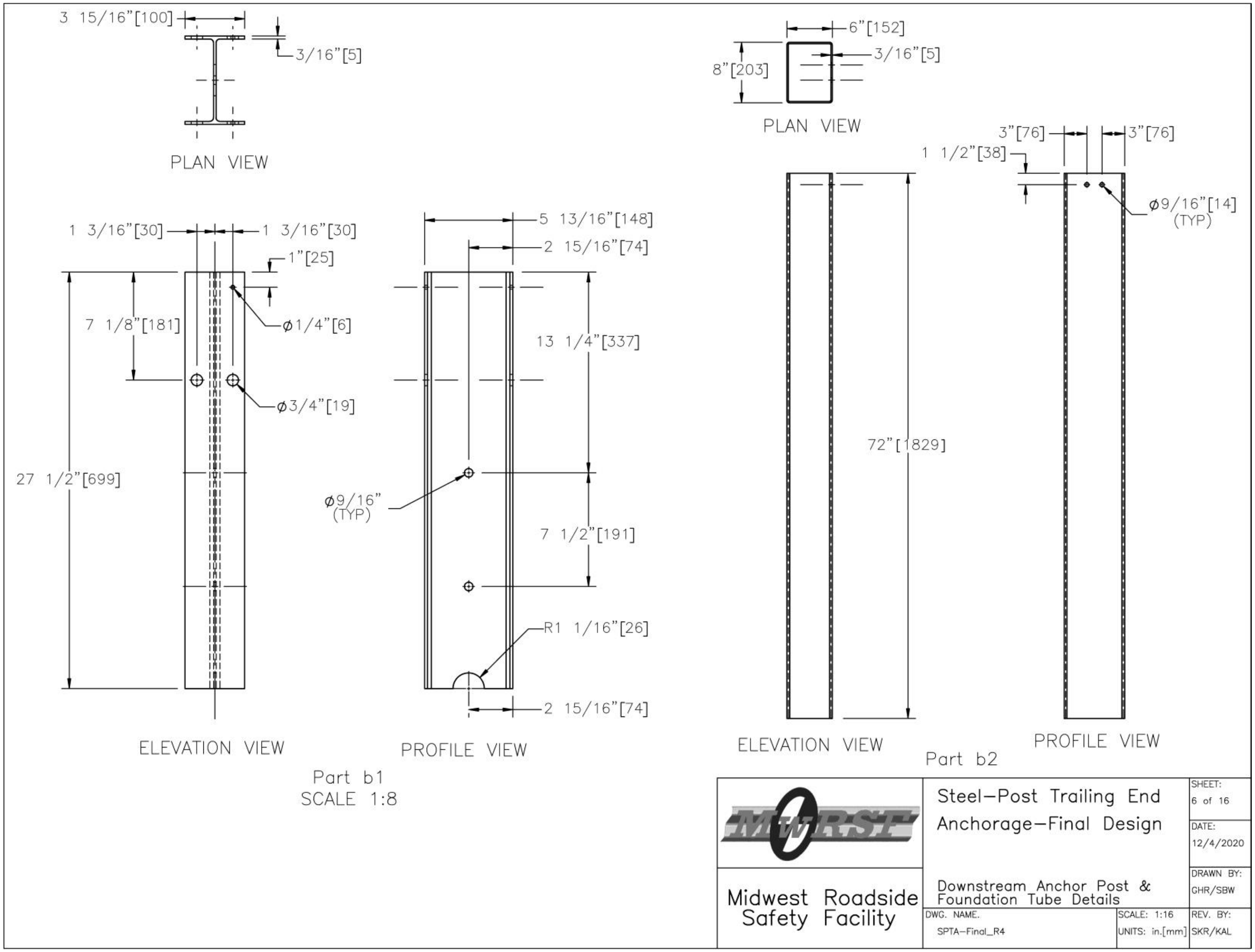


Figure 123. Steel-Post Trailing End Anchorage, Downstream Anchor Post and Foundation Tube Details

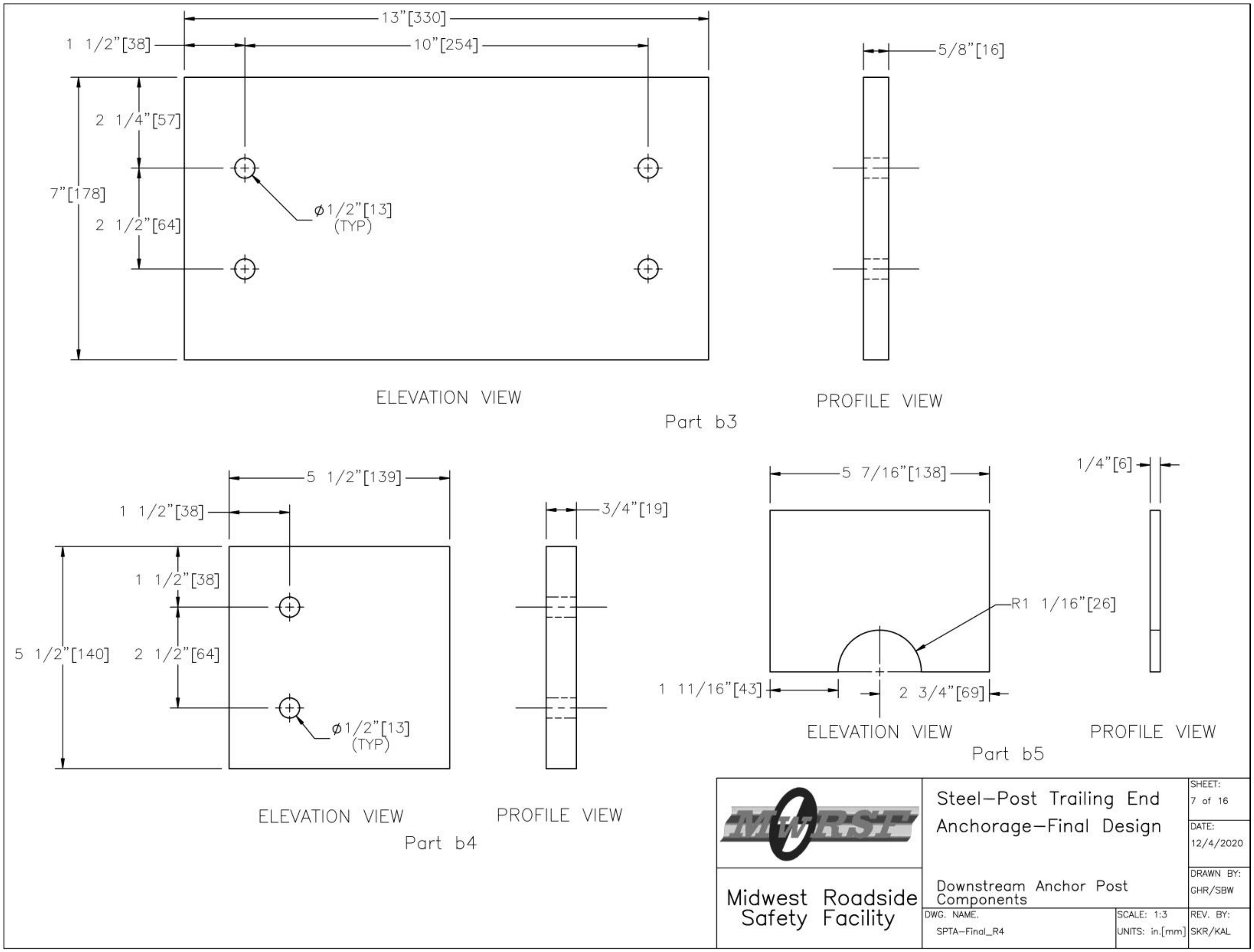


Figure 124. Steel-Post Trailing End Anchorage, Downstream Anchor Post Components

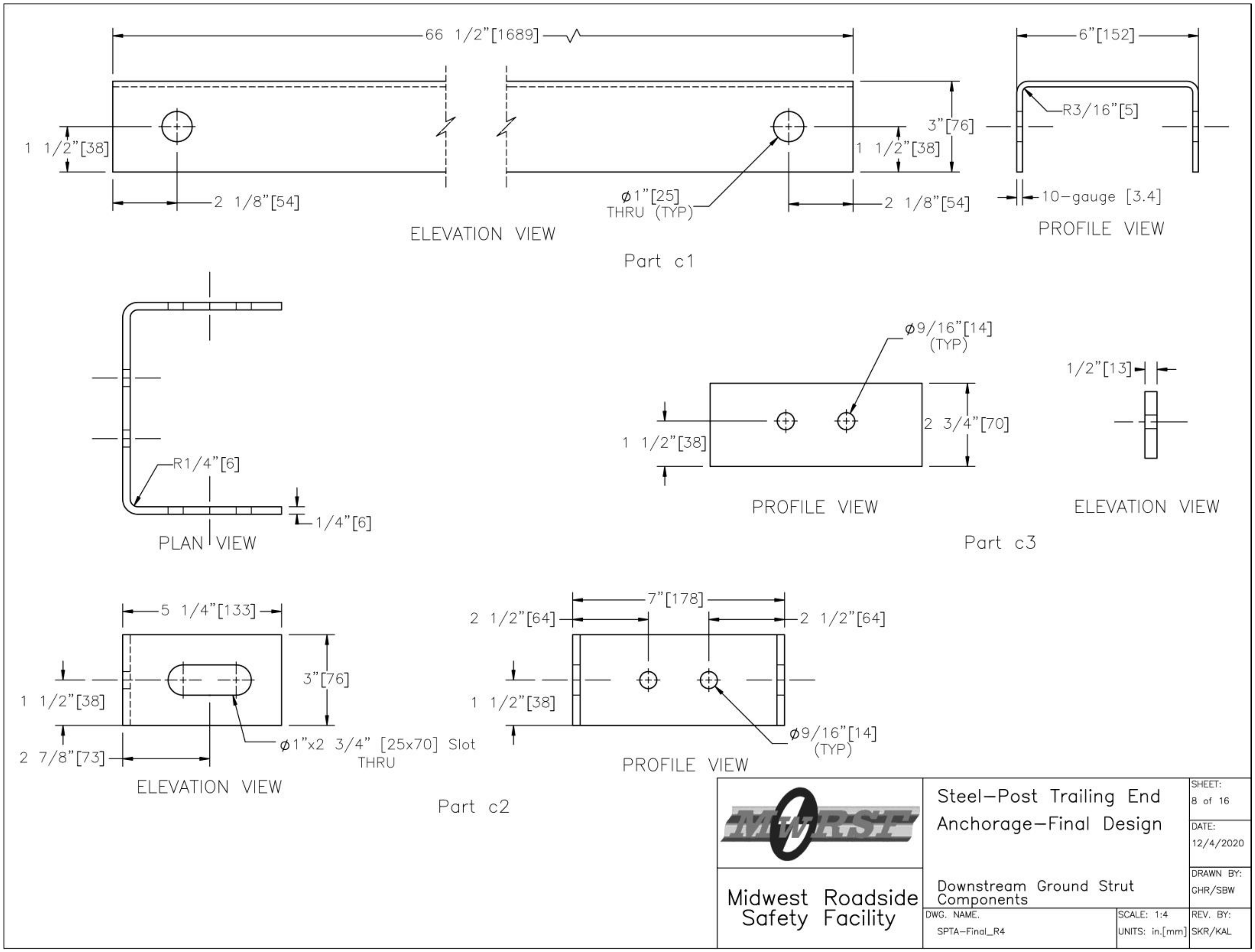
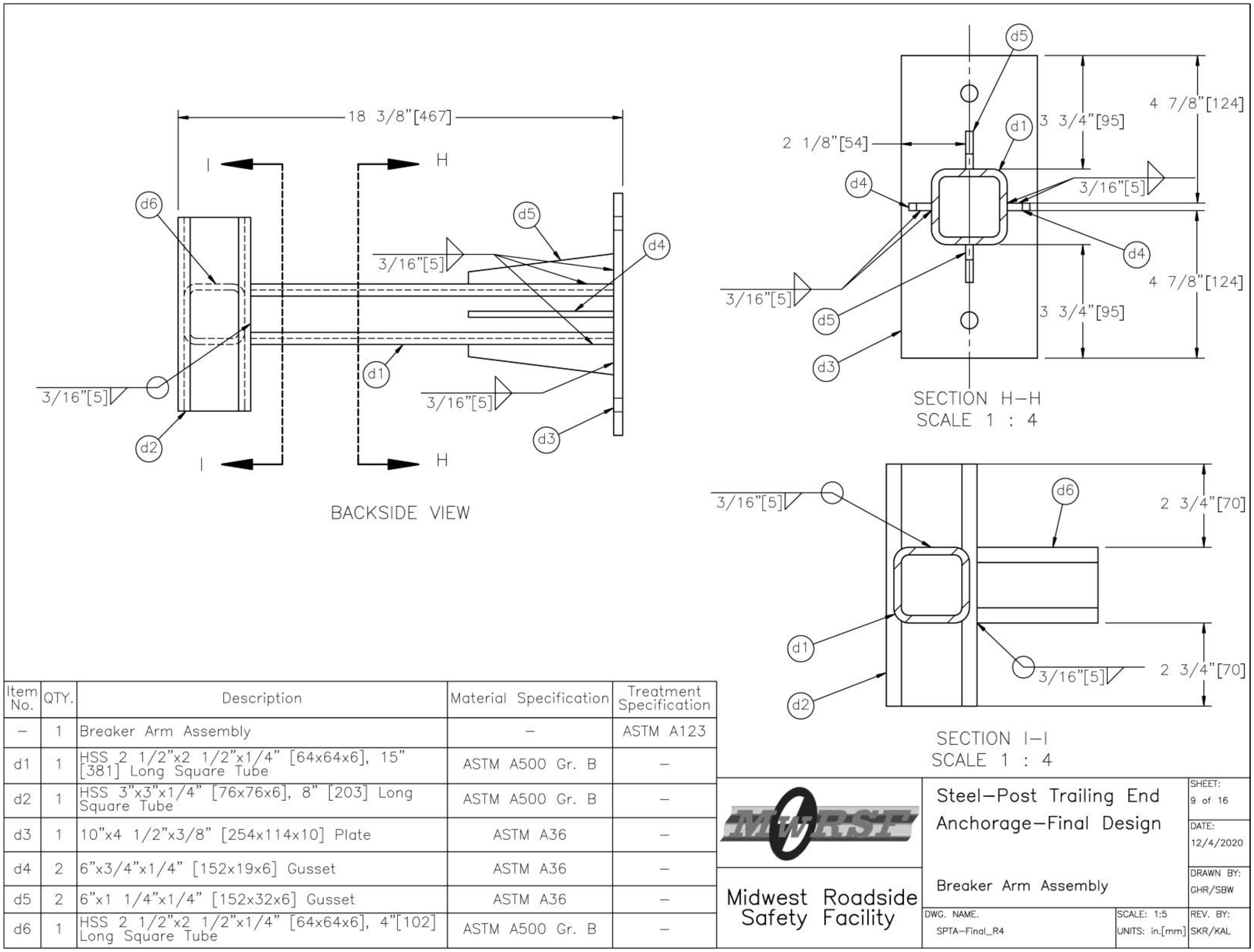


Figure 125. Steel-Post Trailing End Anchorage, Downstream Ground Strut Components



Item No.	QTY.	Description	Material Specification	Treatment Specification
–	1	Breaker Arm Assembly	–	ASTM A123
d1	1	HSS 2 1/2"x2 1/2"x1/4" [64x64x6], 15" [381] Long Square Tube	ASTM A500 Gr. B	–
d2	1	HSS 3"x3"x1/4" [76x76x6], 8" [203] Long Square Tube	ASTM A500 Gr. B	–
d3	1	10"x4 1/2"x3/8" [254x114x10] Plate	ASTM A36	–
d4	2	6"x3/4"x1/4" [152x19x6] Gusset	ASTM A36	–
d5	2	6"x1 1/4"x1/4" [152x32x6] Gusset	ASTM A36	–
d6	1	HSS 2 1/2"x2 1/2"x1/4" [64x64x6], 4"[102] Long Square Tube	ASTM A500 Gr. B	–

Figure 126. Steel-Post Trailing End Anchorage, Breaker Arm Assembly

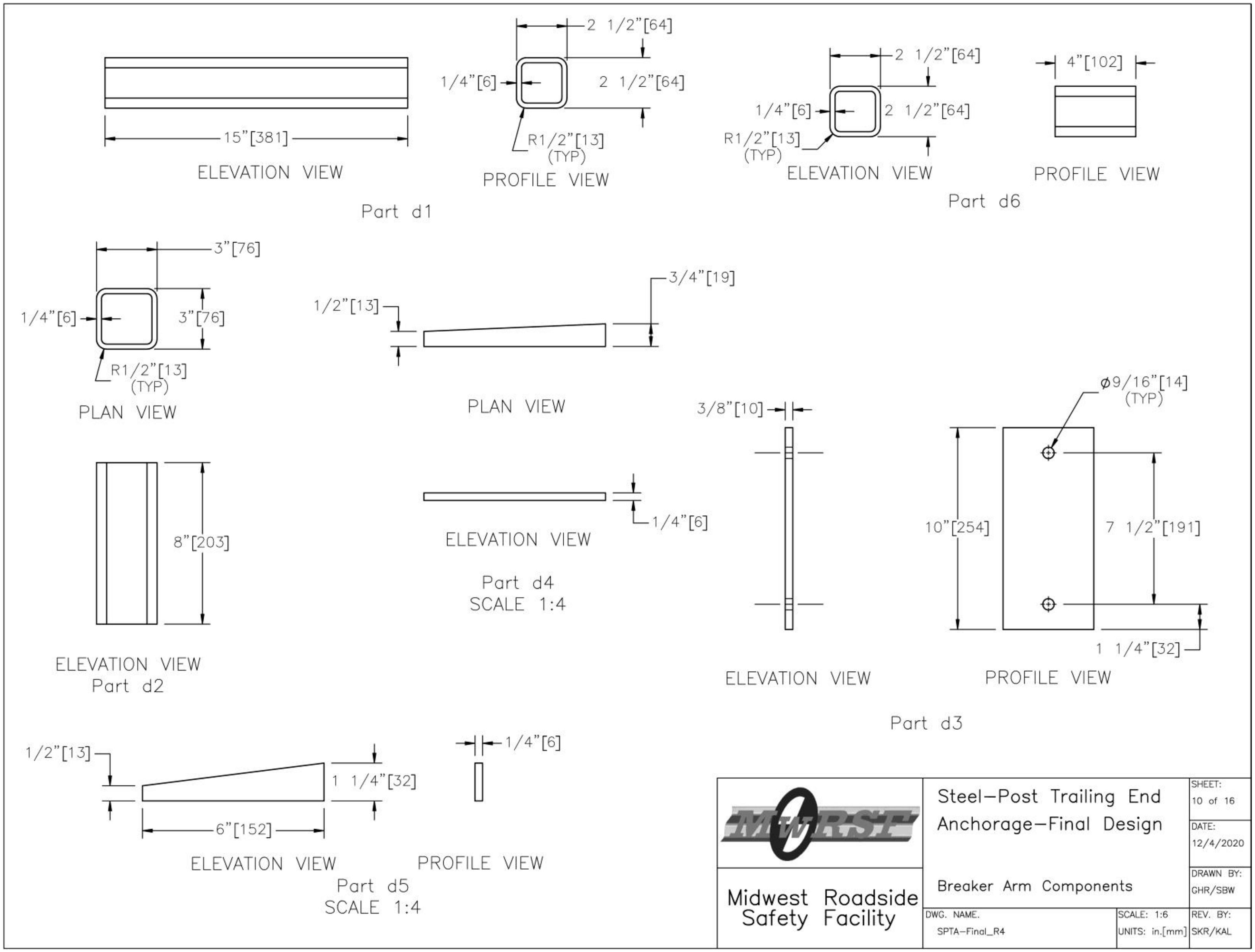


Figure 127. Steel-Post Trailing End Anchorage, Breaker Arm Components

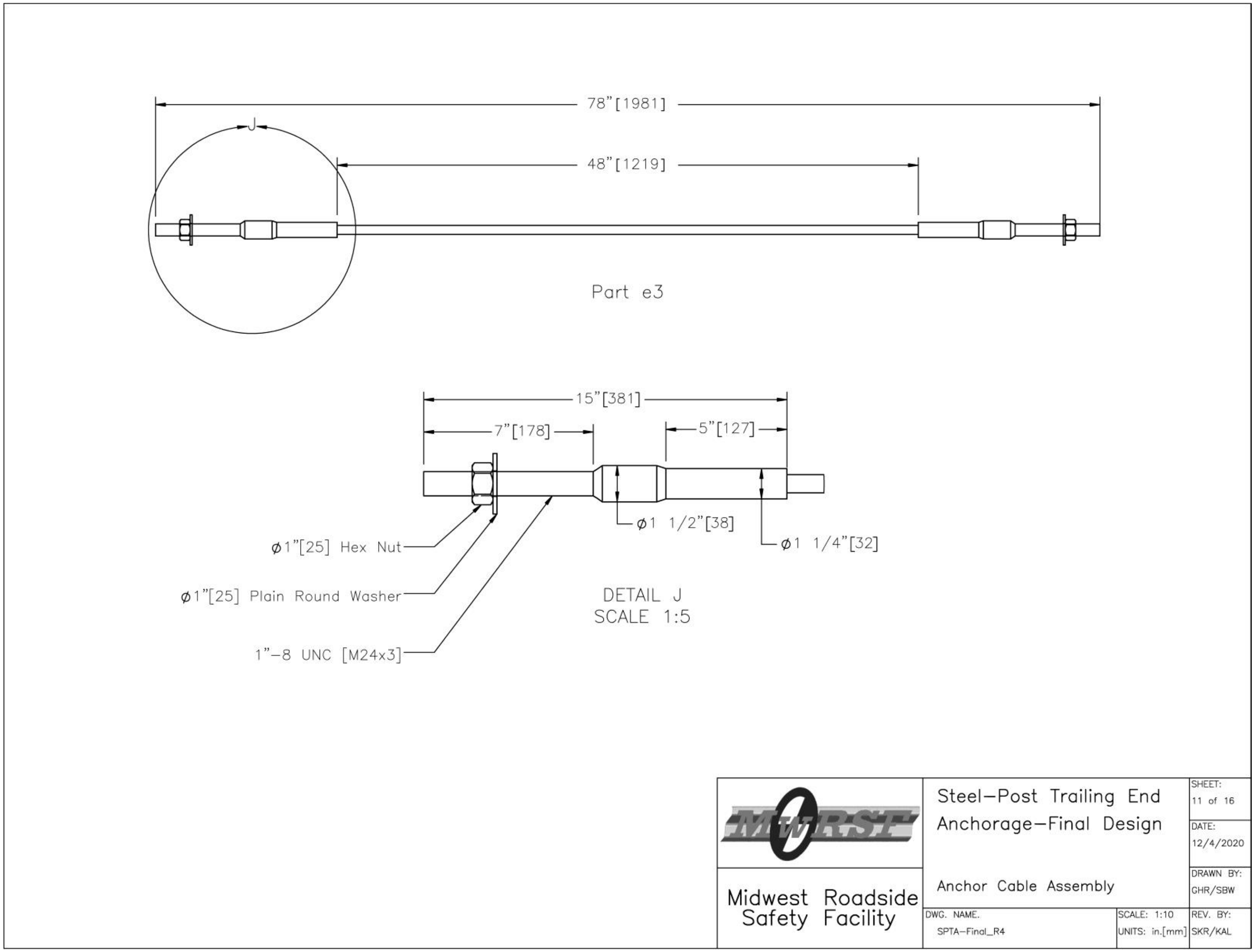


Figure 128. Steel-Post Trailing End Anchorage, Anchor Cable Assembly

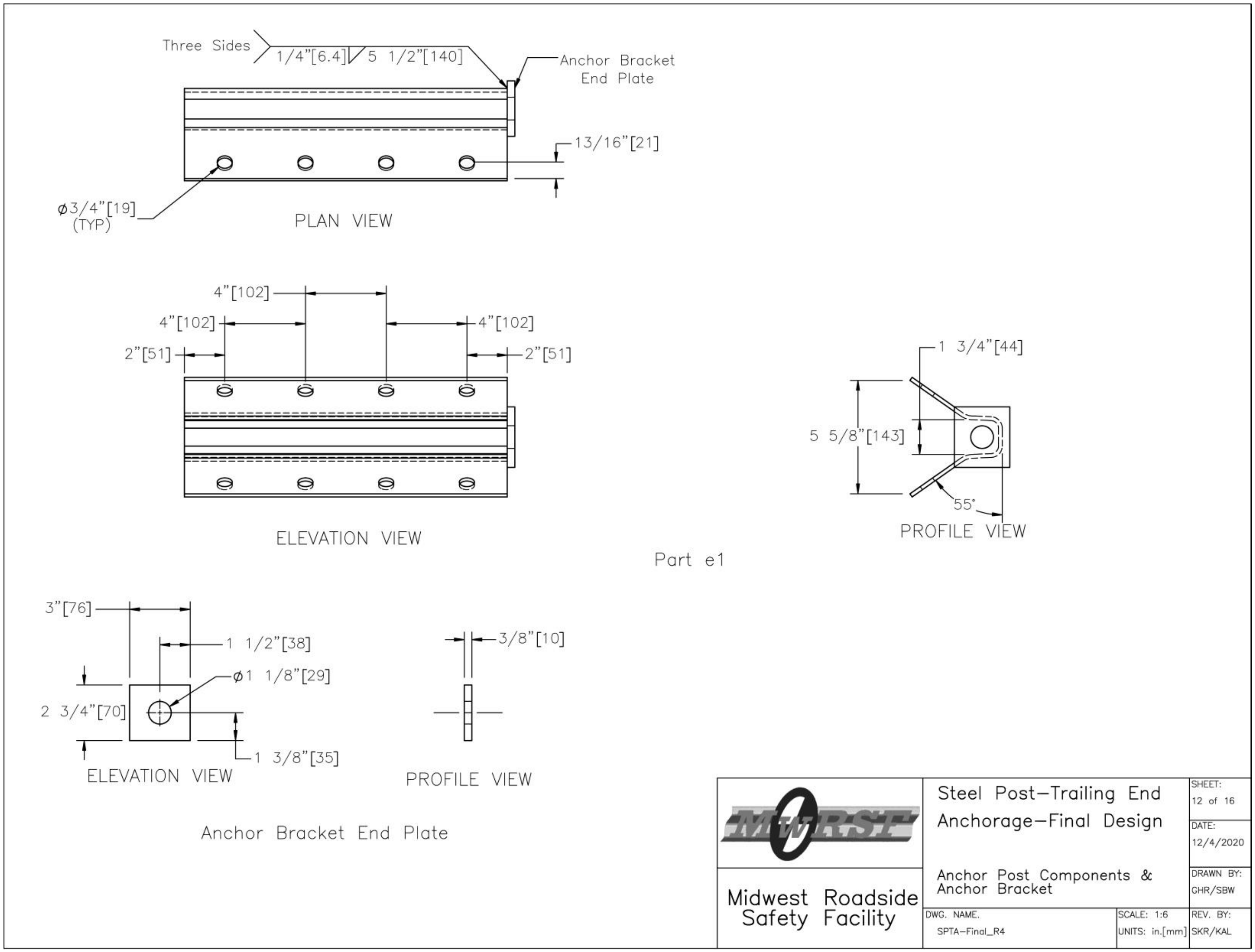
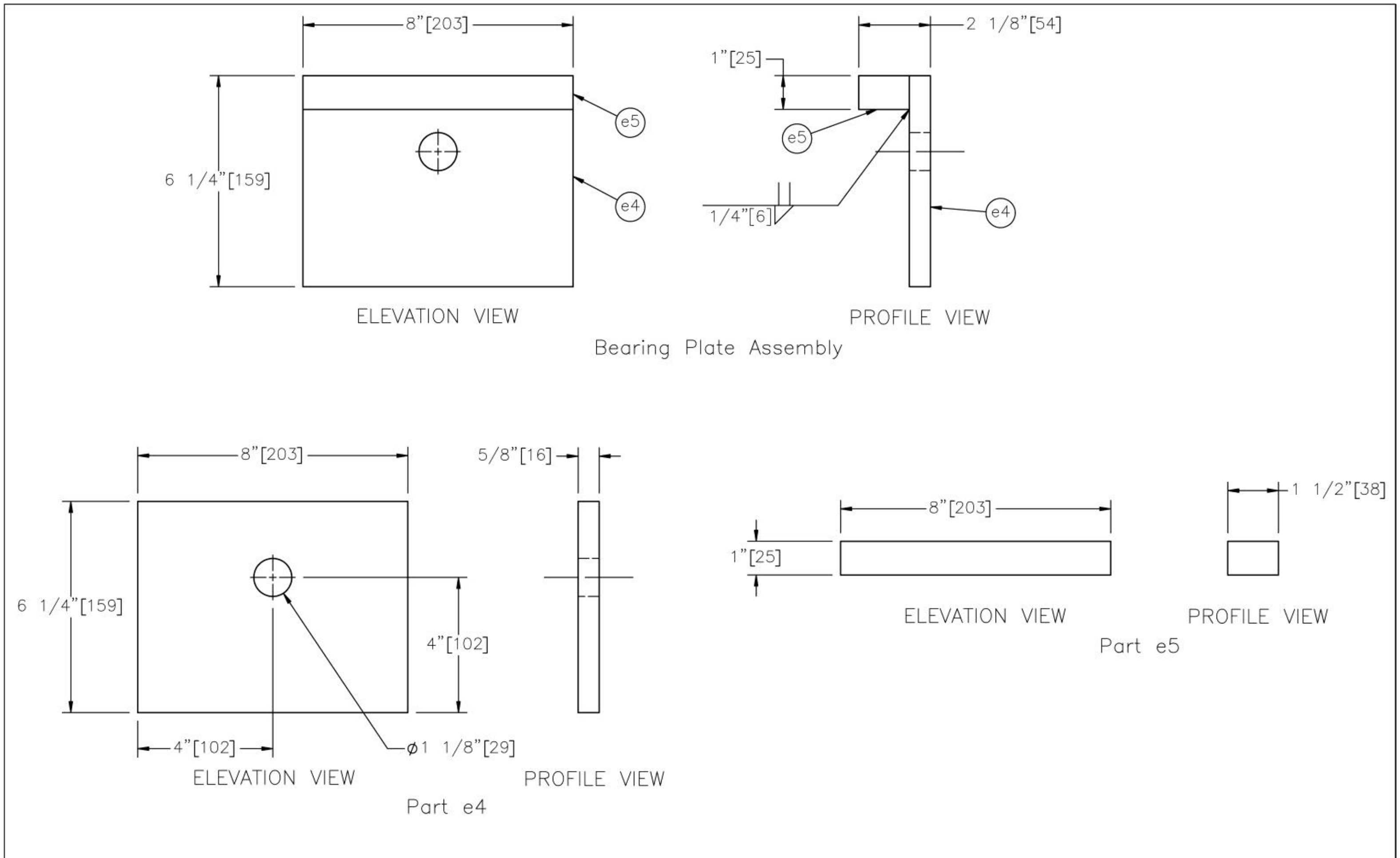


Figure 129. Steel-Post Trailing End Anchorage, Anchor Post Components and Anchor Bracket



Item No.	QTY.	Description	Material Specification	Treatment Specification
–	1	Bearing Plate Assembly	–	ASTM A123
e4	1	8"x6 1/4"x5/8" [203x159x16] Bearing Plate Base	ASTM A36	–
e5	1	8"x1 1/2"x1" [203x38x25] Bearing Plate Flange	ASTM A36	–

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Steel–Post Trailing End Anchorage–Final Design

Bearing Plate Assembly & Components

SHEET:	DATE:	DRAWN BY:	DWG. NAME.	SCALE:	UNITS:	REV. BY:
13 of 16	12/4/2020	GHR/SBW	SPTA–Final_R4	1:4	in.[mm]	SKR/KAL

Figure 130. Steel-Post Trailing End Anchorage, Bearing Plate Assembly and Components

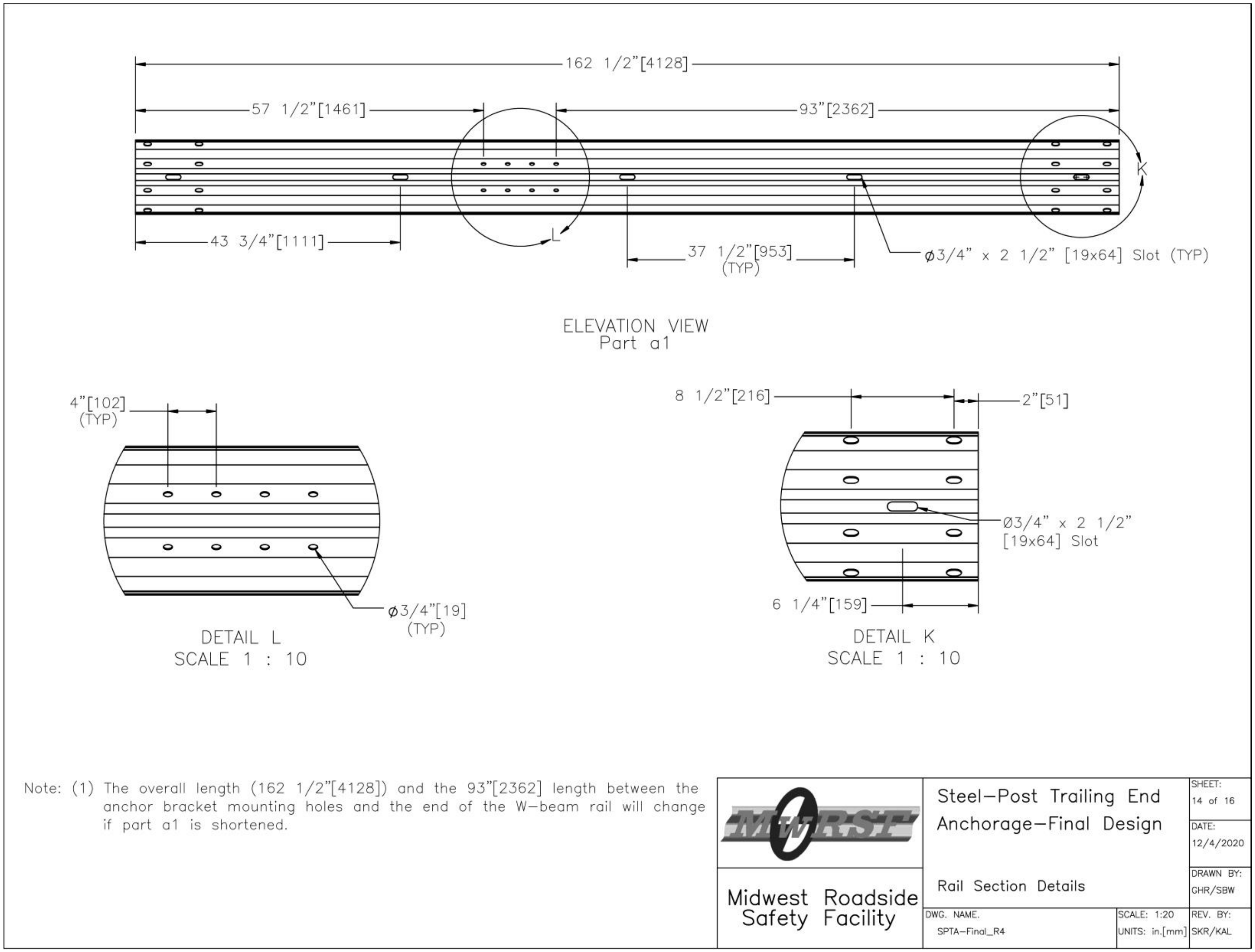

Figure 131. Steel-Post Trailing End Anchorage, Rail Section Details

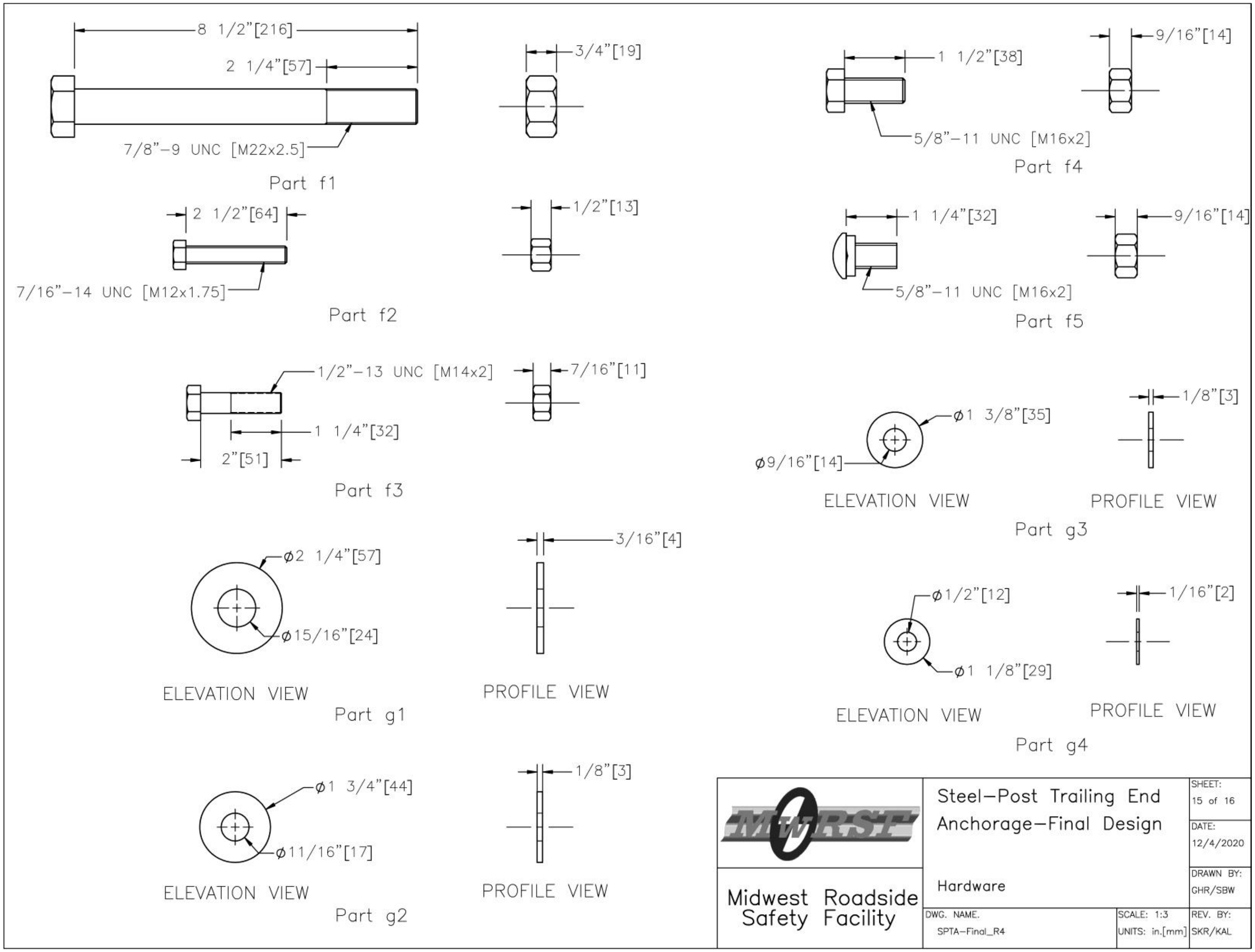

Figure 132. Steel-Post Trailing End Anchorage, Hardware

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	1	12'–6" [3,810] 12–gauge [2.7] W–Beam MGS End Section	AASHTO M180	ASTM A123 or A653	–
a2	1	W–Beam Rounded End Section 12–gauge [2.7]	12 gauge [2.7] AASHTO M180		RWE03a
b1	2	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 27 1/2" [699] Long Steel Post	ASTM A992	–	–
b2	2	TS 8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	–	–
b3	2	13"x7"x5/8" [330x178x16] Steel Plate	ASTM A36	–	–
b4	4	5 1/2"x5 1/2"x3/4" [140x140x19] Steel Plate	ASTM A36	–	–
b5	4	5 7/16"x4"x1/4" [138x102x6] Steel Plate	ASTM A36	–	–
c1	1	66 1/2"x11 3/4"x10–gauge [1,689x298x3.4] Bent Steel Channel Strut	ASTM A36	ASTM A123	–
c2	2	17"x3"x1/4" [432x76x6] Bent Steel Plate	ASTM A36	ASTM A123	–
c3	2	7"x2 3/4"x1/2" [178x70x13] Steel Plate	ASTM A36	ASTM A123	–
d1	1	HSS 2 1/2"x2 1/2"x1/4" [64x64x6], 15" [381] Long Square Tube	ASTM A500 Gr. B	–	–
d2	1	HSS 3"x3"x1/4" [76x76x6], 8" [203] Long Square Tube	ASTM A500 Gr. B	–	–
d3	1	10"x4 1/2"x3/8" [254x114x10] Plate	ASTM A36	–	–
d4	2	6"x3/4"x1/4" [152x19x6] Gusset	ASTM A36	–	–
d5	2	6"x1 1/4"x1/4" [152x32x6] Gusset	ASTM A36	–	–
d6	1	HSS 2 1/2"x2 1/2"x1/4" [64x64x6], 4"[102] Long Square Tube	ASTM A500 Gr. B	–	–
e1	1	Anchor Bracket Assembly	ASTM A36	ASTM A123	FPA01
e2	2	Anchor Cable End Swaged Fitting	Fitting – ASTM A576 Gr. 1035 Stud – ASTM F568 Class C	Fitting – ASTM A153 Stud – ASTM A153 or B695	–
e3	1	Anchor Cable Assembly	–	–	FCA01
e4	1	8"x6 1/4"x5/8" [203x159x16] Bearing Plate Base	ASTM A36	–	FPB01
e5	1	8"x1 1/2"x1" [203x38x25] Bearing Plate Flange	ASTM A36	–	–
f1	2	7/8"–9 UNC [M22x2.5], 8 1/2" [216] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A or equivalent Nut – ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	–
f2	8	7/16"–14 UNC [M12x1.75], 2 1/2" [64] Long Fully Threaded Hex Tap Bolt and Nut	Bolt – ASTM A449 or equivalent Nut – ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX12b
f3	6	1/2"–13 UNC [M16x2], 2" [51] Long Hex Bolt and Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX24a
f4	8	5/8"–11 UNC [M16x2], 1 1/2" [38] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A or equivalent Nut – ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f5	2	5/8"–11 UNC [M16x2], 1 1/4" [32] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB01
g1	2	1" [25] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC24a
g1	4	7/8" [22] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	–
g2	16	5/8" [16] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC16a
g3	8	1/2" [13] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC14a
g4	32	7/16" [11] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC12a

Midwest Roadside Safety Facility

Steel–Post Trailing End Anchorage–Final Design

Bill of Materials

SHEET: 16 of 16

DATE: 12/4/2020

DRAWN BY: GHR/SBW

REV. BY: SKR/KAL

DWG. NAME. SPTA–Final_R4

SCALE: None

UNITS: in.[mm]

Figure 133. Steel-Post Trailing End Anchorage, Bill of Materials

9 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The project objective was to develop and evaluate a MASH 2016 TL-3 crashworthy, steel-post, trailing-end anchorage system for use with the MGS. Following the prototype design of the steel-post, trailing-end anchorage system, five candidate design concepts were subjected to dynamic component testing, and three of these designs proved to be viable options. Based on the component testing results and consideration for ease of fabrication and installation of the design concepts, a singular design configuration was selected for full-scale vehicle crash testing. The selected design concept utilized breakaway anchor posts consisting of a W6x8.5 top portion and a 6-in. x 8-in. x $^{3}/_{16}$-in. (76-mm x 203-mm x 5-mm) steel foundation tube. The top portion of the post incorporated a slot through the base plate and the web so that the anchor cable could pass through the post and be supported by the downstream face of the post and foundation tube. A T-shaped, breaker bar assembly was attached to the end anchor post and configured to initiate fracture of the post attachment bolts and release of the anchor cable, thus reducing the potential for vehicle snag on the anchor. Finally, a new ground line strut and yolk design was developed for the new anchorage system to avoid conflicts with the breakaway hardware in the posts.

Two full-scale crash tests, test nos. SPTA-1 and SPTA-2, were performed according to the MASH 2016 test designation nos. 3-37a and 3-37b, respectively. In test no. SPTA-1, the 5,074-lb (2,302-kg) pickup truck impacted the system 31.25 ft (9.5 m) from the end post (6th post from the end) at a speed of 62.1 mph (99.9 km/h) and an angle of 25.0 degrees. The 2270P was safely contained and redirected, and all vehicle decelerations and occupant compartment deformations were within the allowable MASH 2016 limits. Thus, test no. SPTA-1 satisfied the MASH 2016 safety requirements for test designation no. 3-37a.

However, during test no. SPTA-1, the lateral displacement of the guardrail and anchor cable pushed the T-shaped breaker bar backward and away from impact. Subsequently, the vehicle did not contact the breaker bar as intended and instead directly impacted the end post. Additionally, the end post did not break away and the anchor cable was not released. Although these behaviors did not result in a test failure, the breaker bar was modified to avoid contact with the anchor cable and promote a clean breakaway of the end post. As such, in test no. SPTA-2, the T-shaped, breaker bar was modified to incorporate a shorter length tube, a lower mounting height on the end anchor post, and a thicker steel attachment plate at the bolted connection to the end post. Additionally, stiffening plates were welded between the flanges on both the upstream and downstream sides of the anchor posts to prevent bending prior to bolt fracture.

In test no. SPTA-2, the 2,429-lb (1,102-kg) small car impacted the system at the midspan between the 2nd and 3rd post from the end of the system at a speed of 63.3 mph (101.9 km/h) and an angle of 25.2 degrees. The small car impacted the upstream end of the breaker bar causing the end post to break cleanly away and the anchor cable to be released. The vehicle gated through the system and remained upright and stable throughout the test. All vehicle decelerations and occupant compartment deformations were within the allowable MASH 2016 limits. Thus, test no. SPTA-2 satisfied all MASH 2016 safety requirements for test designation no. 3-37b. A summary of both test evaluations is shown in Table 15.

As demonstrated in test no. SPTA-2, the modifications to breaker bar resulted in the vehicle impacting the upstream end of the breaker bar and causing a clean release of the end post and anchor cable. The additional stiffening plates at the base of the W6x8.5 breakaway post also prevented bending of the posts prior to breaking away. If the modified breaker bar and posts had been used during test no. SPTA-1, similar behavior is likely to have occurred with the pickup truck impacting the breaker bar and causing the end post and anchor cable to be cleanly released. Subsequently, the pickup would have not impacted and bent over the end post, and decelerations to the pickup would have been reduced. The pickup truck was already being redirected out of the system by the time it reached the location of the breaker bar, so the modified design would not have affected the containment or redirection of the vehicle. Therefore, the modified breaker bar and post stiffening plates would only improve the performance of the steel-post, trailing end anchorage system, and rerunning MASH 2016 test designation 3-37a was unnecessary. With the successful completion of test nos. SPTA-1 and SPTA-2 and the improved performance of the modified breaker bar, the final design for the steel-post trailing end anchorage system was deemed crashworthy to MASH 2016 TL-3 criteria.

Similar to the previous wood-post trailing end system, the steel-post trailing end anchorage system was not designed for and would not likely be crashworthy when impacted head-on. It is to be installed only in locations where it will only be impacted by vehicles exiting the MGS installation in traditional reverse-direction impacts. Typical trailing-end anchorage installations would include one-way roadways or at locations were they are outside of the clear zone for traffic headed in the opposite direction.

Since the full-scale crash testing program was successful according to the MASH 2016 TL-3 criteria and two other trailing-end anchorage concepts (concept no. 2 - cable passing through foundation tube, and concept no. 5 – cable passing through foundation tube with angled bearing plate) were similar in design and met the desired tensile capacity, it is possible that all three steel-post design concepts are crashworthy. However, the two alternative designs were investigated only through tensile component testing and their breakaway post and cable release behavior remain unknown in actual crash tests. Further analysis and/or evaluation is necessary prior to either of the two alternative steel-post, trailing-end guardrail anchorage concepts being deemed crashworthy.

Due to conflicts between typical ground strut attachment hardware and the breakaway hardware of the steel anchor posts, four alternative strut and yolk designs were presented in Section 1.1.4 herein. All four designs utilized the same basic concept and similarly-sized components. The differences between the design alternatives was only in the yolk fitting inside or outside of the strut and whether the yolk was welded or bolted to the lower foundation tubes of the anchor posts. The welded and bolted connections were designed to have similar strengths. Thus, it is believed that all four of the ground strut and yolk alternatives could be used within the crashworthy, steel-post, trailing-end anchorage developed herein.

Finally, results from steel-post, trailing-end anchorage were compared to the results from the evaluation of the previous wood-post trailing-end system. The steel-post system showed increased strength and reduced dynamic deflections and working widths as compared to the wood-post system. Thus, the previously-recommended acceptable hazard zone envelope for the wood-post system represented conservative and safe guidelines for the steel-post, trailing-end anchorage system in combination with the MGS.

Table 15. Summary of Safety Performance Evaluation, Test Nos. SPTA-1 and SPTA-2

<table>
<tr><th>Evaluation Factors</th><th colspan="4">Evaluation Criteria</th><th>Test No. SPTA-1</th><th>Test No. SPTA-2</th></tr>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td><td>S</td><td>S</td></tr>
<tr><td rowspan="11">Occupant Risk</td><td rowspan="2">D.</td><td colspan="3">1. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.</td><td>S</td><td>S</td></tr>
<tr><td colspan="3">2. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.</td><td>S</td><td>S</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td><td>S</td><td>S</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td><td rowspan="4">S</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s
(9.1 m/s)</td><td>40 ft/s
(12.2 m/s)</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td><td rowspan="4">S</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
<tr><td colspan="5">MASH 2016 Test Designation No.</td><td>3-37a</td><td>3-37b</td></tr>
<tr><td colspan="5">Final Evaluation (Pass or Fail)</td><td>Pass</td><td>Pass</td></tr>
</table>

S – Satisfactory U – Unsatisfactory NA – Not Applicable

10 IMPLEMENTATION GUIDELINES

10.1 Guideline for Shielding Hazards Near Steel-Post, Trailing-End Anchorage System

In a previous MwRSF study [1-3], the combination of full-scale crash testing and computer simulations were conducted on the trailing-end anchorage system with BCT wood posts to determine the downstream end of the guardrail system's LON and investigate the path of the 2270P vehicle during impacts near the downstream end of the system. A shielding window for hazards placed behind the MGS in close proximity to the wood-post, trailing-end anchorage system was proposed, as shown in Figure 134. These guidelines were based on MASH TL-3 impacts at each post location along the MGS through the trailing-end anchorage system. Simulations with impact points at the ninth, eighth, and seventh posts predicted a complete redirection with maximum vehicle working widths typical of the MGS at about 60 in. (1,524 mm. Therefore, a conservative safe distance of 60 in. (1,524 mm) was proposed for locations upstream from the fifth post. For impacts at the sixth post and further downstream, the vehicle working widths increased and terminal began to gate.

The results from the new LON test with the pickup truck on the steel-post, trailing-end anchorage system, test no. SPTA-1, were added to the envelope to determine if any adjustments were necessary. The vehicle working width from test no. SPTA-1 revealed a lower lateral vehicle trajectory as compared to test no. WIDA-1 and the previous simulations, as shown in Figure 134. This reduction in vehicle working width is likely due to the increased tensile capacity of the steel-post, trailing-end anchorage system. Because the steel-post system reduced deflections and working widths, the previously-recommended acceptable hazard zone envelope for the wood-post, trailing-end anchorage system can be conservatively and safely utilized for the steel-post, trailing-end anchorage system. The acceptable hazard zone envelope could be modified to reflect the reduced deflections observed with the steel-post system. However, further analysis would be needed to define this modified envelope.

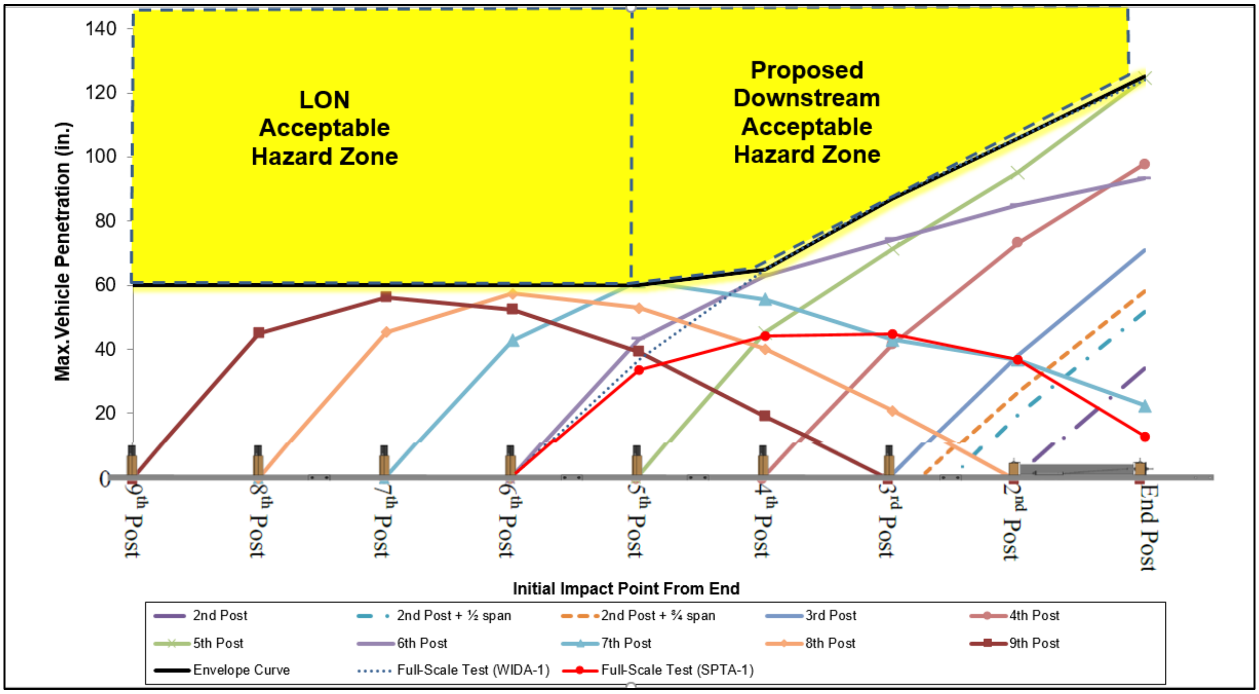

Figure 134. Proposed MGS Placement Guideline for Shielding Hazards Near Trailing-End Anchorage System – Wood-Post and Steel-Post Systems

10.2 MGS Height Tolerances

The breakaway steel posts used in the trailing-end anchorage system are detailed with specific heights and guardrail bolt hole locations, so the only height variance related to construction tolerances should be related to the embedment of the lower foundation tubes. Test no. SPTA-2 was conducted with the rail artificially raised 1 in (25-mm) to demonstrate crashworthiness with a practical worst-case upper installation tolerance resulting in a rail height of 32 in. (813 mm). Rail heights significantly lower than the nominal 31 in. (787 mm) would be difficult to achieve as the strut and yolk would be below the ground line – an unlikely installation. As such, it is anticipated that installations of the steel-post, trailing-end anchorage system developed herein would have rail mounting heights at or near the nominal 31-in. (787-mm) height. If other rail mounting heights were desired, further analysis would be necessary to evaluate the modified system.

10.3 MGS Configurations and Special Applications

The research and testing detailed herein demonstrated that the steel-post, trailing-end anchorage system was crashworthy according to the TL-3 safety standards of MASH 2016 in combination with the standard MGS. However, variations of the MGS developed for special applications may raise concern if installed along with the steel-post, end-trailing anchorage system. The following sections provide implementation guidance and recommendations regarding various MGS configurations installed in combination with the steel-post, trailing-end anchorage system.

10.3.1 MGS in Combination with Curbs

To date, no guardrail anchorage system has been evaluated to MASH criteria when placed adjacent to curbs. As such, the system performance of the steel-post, trailing-end anchorage system in combination with curbs is unknown, and therefore it is not recommended for use until further evaluation has been conducted. Further, the only successfully MASH TL-3 tested configuration of the MGS in combination with curbs was with the MGS when placed 6 in. (152 mm) behind a 6-in. (152-mm) tall AASHTO Type B curb [18]. However, this configuration utilized soil backfill, which would prevent proper installation of the breakaway steel posts in the trailing-end anchorage as the strut, yolk, and post-to-foundation tube attachment bolts would be located below ground line. Therefore, use of the steel-post, trailing-end anchorage system would require either the development of a modified system with a shorter rail height relative to the ground line or the successful evaluation of the MGS positioned farther behind the curb and with a 31-in. (787-mm) rail height relative to the ground.

10.3.2 MGS with an Omitted Post

Omitting a post near guardrail anchorages may degrade system performance by leading to increased deflections, increased rail loads, and increased pocketing. In the previous evaluation of the wood-post, trailing-end anchorage system, simulation results indicated that impacts farther than 43.75 ft (13.3 m) upstream from the downstream end post resulted in consistent redirection and working widths [1-3]. Within the evaluation of MGS with an omitted post, it was conservatively recommended that an omitted post not fall within this 43.75 ft (13.3 m) or the adjacent 12.5 ft (3.8 m) of MGS [19]. Since the steel-post, trailing-end anchorage system was shown to perform similarly to the wood-post system, the same recommendations can be applied to the steel-post system. Thus, it is recommended that the location of the first allowable omitted post be 62.5 ft (19.1 m) from the downstream anchorage post, or the 11th post of the installation, as shown in Figure 135.

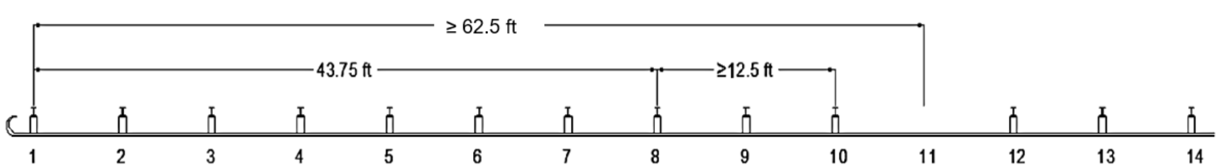

Figure 135. Recommended Distance between Omitted Posts and Steel-Post Trailing-End Anchorage System

10.3.3 MGS Adjacent to Slopes

Multiple versions of the MGS have been successfully evaluated to MASH TL-3 when placed adjacent to steep roadside slopes [20-25]. However, the guardrail trailing-end system developed and evaluated herein is a gating system, so traversable terrain must be located directly behind and downstream from the anchorage system. Further, placement of guardrail anchorages adjacent to slopes may reduce the soil resistance forces and negatively affect the tensile capacity and movement of the anchors. Until further research and evaluation is conducted, we recommended following the guidelines presented in the AASHTO *Roadside Design Guide* [26] regarding grading surrounding end terminals based on previous Federal Highway Administration (FHWA) memos [27, 28].

10.3.4 MGS with 8-in. Deep Blockouts

Although a reduction in blockout depth has been associated with increased snag potential, the performance of 8-in. and 12-in. blockouts have been shown to be similar for installations on level terrain [29], so the performance of either blockout type should also be similar when placed adjacent to the trailing-end anchorage system. Thus, it is recommended to utilize the same implementation guidance and restrictions presented herein for the steel-post, trailing-end anchorage system placed adjacent to MGS installations incorporating 8-in. (203-mm) blockouts.

10.3.5 MGS without Blockouts

Previously, full-scale crash testing was successfully performed on the MGS without blockouts. The installation utilized standard steel guardrail posts and 12-in. (305-mm) long backup plates to prevent contact between the rail and the posts and reduce the probability of rail tearing. The system was successfully crash tested to MASH TL-3 [30]. However, the omission of blockouts in guardrail systems has been shown to increase vehicle snag on the system posts. Although the steel-post, trailing-end system limited vehicle snag on the anchor cable and breakaway posts and proved crashworthy to MASH TL-3, the combined effects of vehicle snag on the anchorage system and increased vehicle snag on the posts just upstream of the anchorage is unknown. There are concerns that increased snag on the upstream posts may alter t* times and the resulting OIV and ORAs calculated as part of the flail space model occupant risk evaluation required by MASH 2016. As such, it is not recommended to install the steel-post, trailing-end anchorage system adjacent to non-blocked MGS installations until further evaluation is conducted.

If there is a desire to install a steel-post, trailing-end anchorage system on a non-blocked MGS installation, the four posts adjacent to the anchorage system (i.e., 3rd through 6th posts upstream from end anchor post, as shown in Figure 134) should incorporate standard blockouts. Note, the 6th post upstream from the end post represented the transition point between standard redirection and gating behavior of the end terminal.

11 MASH EVALUATION

The steel-post, trailing-end anchorage system was developed as a crashworthy downstream anchorage system for use with the MGS. The system consists of two breakaway steel anchorage posts bolted to embedded steel foundation tubes. The foundation tubes are connected through a modified yolk and strut design that avoids conflicts with the breakaway hardware while still transferring load between the two foundation tubes. A standard guardrail anchor cable is attached to the rail between the anchor posts, passed through a slot cut into the bottom of the breakaway steel post, and attached to a bearing plate that rest against the downstream face of the end post and foundation tube. An 18⅜-in. (467-mm) T-shaped breaker bar is bolted to the upstream side of the web of the end anchor post. The system was designed such that a vehicle would impact the breaker bar, causing the end post to breakaway and the anchor cable to release prior to the vehicle snagging on these components.

The steel-post, trailing-end anchorage system was designed for use only in locations where vehicles impacting the anchorage head-on are not a concern (e.g., one-way roadways or outside the clear zone of opposing traffic headed toward the middle of the MGS installation). As such, the trailing-end anchorage system would only be impacted by vehicles exiting the guardrail installation, which are traditionally described as reverse direction impacts. Within the gaiting end terminal test matrix end terminals, only MASH test designation nos. 3-37a and 3-37b involve reverse-direction impacts, and they would be necessary in evaluating the trailing-end anchorage system. All of the other tests within the matrix involve head-on or normal direction impacts and were therefore not applicable in the evaluation of the trailing-end anchorage system.

MASH 2016 test designation no. 3-37a with a 2270P vehicle is normally required to evaluate vehicle snag on crash cushions. However, in this research, this test was conducted to evaluate the downstream LON with the steel-post, trailing-end anchorage system connected to the MGS. MASH 2016 test designation no. 3-37b with an 1100C vehicle was required to evaluate vehicle snag, vehicle instabilities, and occupant risk criteria resulting from the interaction with the trailing-end anchorage.

The research team discussed whether full-scale crash testing was required to evaluate the tensile load capacity of the steel-post, trailing-end anchorage system during redirective impacts on the MGS (i.e., conducting a MASH 3-11 test on the MGS with the new steel-post anchorage system at both ends of the installation). The steel-post, trailing-end anchorage system was derived from the BCT end anchorage that has been used in a wide variety of full-scale crash testing programs for decades. As such, the steel-post, trailing-end anchorage system would be expected to possess a similar load bearing capacity in such crash testing programs. Additionally, dynamic component testing of the steel-post design indicated greater tensile load capacity as compared to the wood-post, trailing-end anchorage system. Thus, it was not believed that a separate anchor capacity crash test would be required for the steel-post, trailing-end anchorage system.

The steel-post, trailing-end anchorage system was developed to mimic the capacity and performance of the original BCT, wood-post, trailing-end anchorage system. Thus, the CIPs for each full-scale crash test were selected to be the same as those used during the MASH TL-3 evaluation of the BCT, trailing-end anchorage system. For test no. SPTA-1 (test designation no. 3-37a), the CIP was determined to be at the center of the sixth post upstream from the downstream end of the barrier. For test no. SPTA-2 (test designation no. 3-37b), the CIP was determined to be the midspan between the 2nd and 3rd posts upstream from the downstream end of the barrier.

In test no. SPTA-1, the 2270P pickup truck was successfully contained and smoothly redirected. The vehicle remained upright and stable through the test, and all vehicle decelerations and occupant compartment deformations were within the allowable MASH 2016 limits. Test no. SPTA-1 satisfied all the safety performance requirements for MASH 2016 test designation no. 3-37a.

However, during test no. SPTA-1, the lateral displacement of the guardrail and anchor cable pushed the T-shaped breaker bar backward and away from impact. Subsequently, the vehicle did not contact the breaker bar as intended and instead directly impacted the end post. Additionally, the end post bent over and twisted upon impact with the vehicle and the anchor cable was not released. Although these behaviors did not result in a test failure, the breaker bar was modified to avoid contact with the anchor cable and promote a clean breakaway of the end post. As such, prior to test no. SPTA-2, the T-shaped, breaker bar was modified to incorporate a shorter length tube, a lower mounting height on the end anchor post, and a thicker steel attachment plate at the bolted connection to the end post. Additionally, stiffening plates were welded between the flanges on both the upstream and downstream sides of the anchor posts to prevent bending prior to bolt fracture. Slots similar to those cut in the web of the post were cut into the bottom of these steel plate stiffeners to fit over the cable anchor. Note, the additional plates were placed on both breakaway posts in the trailing end anchorage system for simplicity.

In test no. SPTA-2, the 1100C small car impacted the upstream end of the breaker bar, which caused the end post to break cleanly away and the anchor cable to be released. The vehicle gated through the system and remained upright and stable throughout the test. All vehicle decelerations and occupant compartment deformations were within the allowable MASH 2016 limits. Thus, test no. SPTA-2 satisfied all MASH 2016 safety requirements for test designation no. 3-37b.

As demonstrated in test no. SPTA-2, the modifications to breaker bar resulted in the vehicle impacting the upstream end of the breaker bar and causing early release of the end post and anchor cable. The additional stiffening plates at the base of the W6x8.5 breakaway post also prevented bending of the posts prior to it breaking away. If the modified breaker bar and posts had been used during test no. SPTA-1, similar behavior is likely to have occurred. Thus, the pickup truck would not have impacted and bent over the end post, and decelerations to the pickup would have been reduced. The pickup truck was already being redirected out of the system by the time it reached the location of the breaker bar, so the modified design would not have affected the containment or redirection of the vehicle. Therefore, the modified breaker bar and post stiffening plates would only improve the performance of the steel-post, trailing-end anchorage system and rerunning MASH 2016 test designation 3-37a was unnecessary. With the successful completion of test nos. SPTA-1 and SPTA-2 and the improved performance of the modified breaker bar, the final design for the steel-post, trailing-end anchorage system was deemed crashworthy to MASH 2016 TL-3 criteria.

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13 APPENDICES

Appendix A. Vehicle Center of Gravity Determination

Date:	7/31/2018	Test Name:	SPTA-1	VIN:	1D7RB1CT2BS582287
Year:	2011	Make:	Dodge	Model:	Ram 1500

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb.)	Vertical CG (in.)	Vertical M (lb.-in.)
+	Unballasted Truck (Curb)	5121	28.225884	144544.75
+	Hub	19	14.75	280.25
+	Brake activation cylinder & frame	8	26 3/4	214
+	Pneumatic tank (Nitrogen)	22	27 1/2	605
+	Strobe/Brake Battery	5	26 1/2	132.5
+	Brake Receiver/Wires	5	52 1/8	260.625
+	CG Plate including DAS	50	31 1/2	1575
-	Battery	-47	39 1/4	-1844.75
-	Oil	-7	15 3/4	-110.25
-	Interior	-98	36	-3528
-	Fuel	-194	17 1/2	-3395
-	Coolant	-12	37 1/4	-447
-	Washer fluid	-8	38 1/2	-308
+	Water Ballast (In Fuel Tank)	0	0	0
+	Onboard Supplemental Battery	12	27 3/4	333
	Smart Barrier	9	24 1/2	220.5
	Ballast Plate	101	33 7/8	3421.375
				141954

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

Estimated Total Weight (lb.)	4986
Vertical CG Location (in.)	28.4705

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.375 in.
Front Track Width: 67.5 in.
Rear Track Width: 67.5 in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb.)	5000 ± 110	5074	74.0
Longitudinal CG (in.)	63 ± 4	61.749507	-1.25049
Lateral CG (in.)	NA	-0.226153	NA
Vertical CG (in.)	28 or greater	28.47	0.47052

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	1459	1439
Rear	1116	1107

FRONT	2898	lb.
REAR	2223	lb.
TOTAL	5121	lb.

TEST INERTIAL WEIGHT (lb.)

	Left	Right
Front	1430	1412
Rear	1124	1108

FRONT	2842	lb.
REAR	2232	lb.
TOTAL	5074	lb.

Figure A-1. Vehicle Mass Distribution, Test No. SPTA-1

Date:	9/12/2018	Test Name:	SPTA-2	VIN:	kmhcn4ac2bu618362
Year:	2011	Make:	Hyundai	Model:	Accent

Vehicle CG Determination

	Vehicle Equipment	Weight (lb.)
+	Unballasted Car (Curb)	2505
+	Hub	19
+	Brake activation cylinder & frame	8
+	Pneumatic tank (Nitrogen)	22
+	Strobe/Brake Battery	5
+	Brake Receiver/Wires	6
+	CG Plate including DAS	13
-	Battery	-31
-	Oil	-7
-	Interior	-62
-	Fuel	-23
-	Coolant	-5
-	Washer fluid	-5
+	Water Ballast (In Fuel Tank)	
+	Onboard Supplemental Battery	
+	Smart Barrier	9
	Spare tire+Jack	-28

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

Estimated Total Weight (lb.) 2426

Vehicle Dimensions for C.G. Calculations

Wheel Base:	98.0	in.	Front Track Width:	57.75	in.
Roof Height:	57.5	in.	Rear Track Width:	57.75	in.

Center of Gravity	1100C MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb.)	2420 ± 55	2429	9.0
Longitudinal CG (in.)	39 ± 4	35.303	-3.697
Lateral CG (in.)	NA	-0.63	NA
Vertical CG (in.)	NA	22.701	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	819	778
Rear	451	457

FRONT	1597	lb.
REAR	908	lb.
TOTAL	2505	lb.

TEST INERTIAL WEIGHT (lb.)

	Left	Right
Front	812	742
Rear	429	446

FRONT	1554	lb.
REAR	875	lb.
TOTAL	2429	lb.

Figure A-2. Vehicle Mass Distribution, Test No. SPTA-2

Appendix B. Material Specifications

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

Item No.	Description	Material Specification	Reference No.
a1	12'-6" [3,810] 12-gauge [2.7] W-Beam MGS Section	AASHTO M180	HT#1207 H#C85187
a2	12'-6" [3,810] 12-gauge [2.7] W-Beam MGS End Section	AASHTO M180	HT#8534 H#9411949
a3	6'-3" [1,905] 12-gauge [2.7] W-Beam MGS Section	AASHTO M180	HT#9830 H#9513565
b1	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 72" Long [1,829] Steel Post	ASTM A992	H#55044251 H#1702406
b2	6"x12"x14¼" [152x305x368] Timber Blockout	SYP Grade No.1 or better	Ch#18379
b3	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 27½" [699] Long Steel Post	ASTM A992	H#A134873
b4	TS 8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	H#M24919
b5	13"x7"x⅝" [330x178x16] Steel Plate	ASTM A36	H#A8C352
b6	5½"x5½"x¾" [140x140x19] Steel Plate	ASTM A36	H#B8E678
b7	BCT Timber Post - MGS Height	SYP Grade No. 1 or better (No knots 18" [457] above or below ground tension face)	Ch#24233
b8	TS 8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	R#15-0157 Green Paint
c1	66½"x11¾"x10-gauge [1,689x298x3.4] Bent Steel Channel Strut	ASTM A36	H#17044641
c2	17"x3"x¼" [432x76x6] Bent Steel Plate	ASTM A36	H#18040241
c3	7"x2¾"x½" [178x70x13] Steel Plate	ASTM A36	H#A8C269
d1	HSS 2½"x2½"x¼" [64x64x6], 40" [1,016] Long Square Tube	ASTM A500 Gr. B	H#A710851
d2	HSS 3"x3"x¼" [76x76x6], 9" [229] Long Square Tube	ASTM A500 Gr. B	H#A804182
d3	10"x4½"x¼" [254x114x6] Plate	ASTM A36	H#18040241
d4	6"x¾"x¼" [152x19x6] Gusset	ASTM A36	H#18040241

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

Item No.	Description	Material Specification	Reference No.
d5	6"x1¼"x¼" [152x32x6] Gusset	ASTM A36	H#18040241
e1	¾" 6x19, 20" [508] Long IWRC IPS Wire Rope	IPS	R#17-700
e2	Anchor Cable End Swaged Fitting	Fitting - ASTM A576 Gr. 1035 Stud - ASTM F568 Class C	R#17-700
e3	115-HT Mechanical Splice - ¾" [19] Dia.	As Supplied	n/a
e4	Crosby Heavy Duty HT - ¾" [19] Dia. Cable Thimble	Stock No. 1037773	n/a
e5	Crosby G2130 or S2130 Bolt Type Shackle - 1¼" [32] Dia. with thin head bolt, nut, and cotter pin, Grade A, Class 3	Stock Nos. 1019597 and 1019604 - As Supplied	n/a
e6	Chicago Hardware Drop Forged Heavy Duty Eye Nut - Drilled and Tapped 1½" [38] Dia. - UNC 6 [M36x4]	Stock No. 107 - As Supplied	n/a
e7	TLL-50K-PTB Load Cell	-	n/a
f1	⅝"-11 UNC [M16x2], 14" [356] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolts: H#DL17100590 Nuts: H#10508780
f2	⅝"-11 UNC [M16x2], 10" [254] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolts: H#20351510 Nuts: H#10508780
f3	⅝"-11 UNC [M16x2], 1¼" [32] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolt: H#10435580 Nut: H#10508780
f4	⅞"-9 UNC [M22x2.5], 8" [203] Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A or equivalent Nut - ASTM A563A or equivalent	Bolt: H#2038622 Nut: H#NF12101054
f5	⅞"-9 UNC [M22x2.5], 8½" [216] Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A or equivalent Nut - ASTM A563A or equivalent	Bolts: H#NF16102579 Nuts: H#75062745
f6	⅝"-11 UNC [M16x2], 10" [254] Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A or equivalent Nut - ASTM A563A or equivalent	Bolts: DL15107048 Nuts: C#210101523 COC
f7	⅝"-11 UNC [M16x2], 1½" [38] Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A or equivalent Nut - ASTM A563A or equivalent	Bolts: H#816070039 Nuts: C#210101523 COC
f8	½"-13 UNC [M14x2], 2" [51] Long Hex Bolt and Nut	Bolt – ASTM A307 Gr. A or equivalent Nut - ASTM A563A or equivalent	Bolt and Nut: Midwest Steel COC

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

Item No.	Description	Material Specification	Reference No.
f9	½"-13 UNC [M14x2], 1½" [38] Long Hex Bolt and Nut	Bolt – ASTM A307 Gr.A or equivalent Nut - ASTM A563A or equivalent	Bolts: L#XY3005140047 Nuts: H#180036
f10	$^{7}/_{16}$"-14 UNC [M12x1.75], 2½" [64] Long Fully Threaded Hex Tap Bolt and Nut	Bolt - ASTM A449 or equivalent Nut - ASTM A563DH or equivalent	Bolts: H#1708007009 Nuts: H#17101400-3
f11	1"-8 UNC [M24x3] Hex Nut	ASTM A563A or equivalent	H#DL15105591
f12	16D Double Head Nail	-	McMaster Carr PO#E000548963
g1	1" [25] Dia. Plain Round Washer	ASTM F844	L#16H-168236-30
g2	⅞" [22] Dia. Plain Round Washer	ASTM F844	n/a
g3	⅝" [16] Dia. Plain Round Washer	ASTM F844	n/a
g4	½" [13] Dia. Plain Round Washer	ASTM F844	L#542160900006
g5	$^{7}/_{16}$" [11] Dia. Plain Round Washer	ASTM F844	P#M-SWE041885-18 L#33183 PO#220024002
h1	Anchor Bracket Assembly	ASTM A36	North: H#4153095 South: H#JK16101488
h2	Upstream Ground Strut	ASTM A36	H#195070 H#A82292 H#645887 H#15056184
h3	Anchor Cable Assembly	-	CGLP#256284
h4	8"x6¼"x⅝" [203x159x16] Bearing Plate Base	ASTM A36	H#A8C352
h5	8"x1½"x1" [203x38x25] Bearing Plate Flange	ASTM A36	H#B8B522
h6	8"x8"x⅝" [203x203x16] Anchor Bearing Plate	ASTM A36	H#DL15103543
h7	2⅜" [60] O.D. x 6" [152] Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	H#E86298
h8	2⅜" [60] O.D. x 3$^{15}/_{16}$" [100] Long Post Sleeve	ASTM A53 Gr. B Schedule 40	H#B712810

Table B-4. Bill of Materials, Test No. SPTA-2

Item No.	Description	Material Specification	Reference No.
a1	12'-6" [3,810] 12-gauge [2.7] W-Beam MGS Section	AASHTO M180	HT#1207 H#C85187
a2	12'-6" [3,810] 12-gauge [2.7] W-Beam MGS End Section	AASHTO M180	HT#8534 H#9411949
a3	6'-3" [1,905] 12-gauge [2.7] W-Beam MGS Section	AASHTO M180	HT#9830 H#9513565
b1	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 72" Long [1,829] Steel Post	ASTM A992	H#55044251 H#1702406
b2	6"x12"x14¼" [152x305x368] Timber Blockout	SYP Grade No.1 or better	Ch#18379 Ch#23888
b3	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 27½" [699] Long Steel Post	ASTM A992	H#A134873 H#59077955/03
b4	TS 8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	H#M24919
b5	13"x7"x⅝" [330x178x16] Steel Plate	ASTM A36	H#A8C352
b6	5½"x5½"x¾" [140x140x19] Steel Plate	ASTM A36	H#A8D843
b7	BCT Timber Post - MGS Height	SYP Grade No. 1 or better (No knots 18" [457] above or below ground tension face)	Ch#25033
b8	TS 8"x6"x3/16" [203x152x5], 72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	R#15-0157 Green Paint
b9	5 7/16"x4"x¼" [138x102x6] Steel Plate	ASTM A36	H#18040241
c1	66½"x11¾"x10-gauge [1,689x298x3.4] Bent Steel Channel Strut	ASTM A36	H#17044641
c2	17"x3"x¼" [432x76x6] Bent Steel Plate	ASTM A36	H#18040241
c3	7"x2¾"x½" [178x70x13] Steel Plate	ASTM A36	H#A8C269
d1	HSS 2½"x2½"x¼" [64x64x6], 15" [381] Long Square Tube	ASTM A500 Gr. B	H#A710851
d2	HSS 3"x3"x¼" [76x76x6], 8" [203] Long Square Tube	ASTM A500 Gr. B	H#V3726

Table B-5. Bill of Materials, Test No. SPTA-2, Cont.

Item No.	Description	Material Specification	Reference No.
d3	10"x4½"x⅜" [254x114x10] Plate	ASTM A36	H#18072721
d4	6"x¾"x¼" [152x19x6] Gusset	ASTM A36	H#B809345
d5	6"x1¼"x¼" [152x32x6] Gusset	ASTM A36	H#B809345
d6	HSS 2½"x2½"x¼" [64x64x6], 4" [102] Long Square Tube	ASTM A500 Gr. B	H#A710851
e1	Anchor Bracket Assembly	ASTM A123	H#JK16101488
e2	Upstream Ground Strut	ASTM A123	H#195070 H#A82292 H#645887 H#15056184
e3	Anchor Cable Assembly	-	CGLP#256284
e4	8"x6¼"x⅝" [203x159x16] Bearing Plate Base	-	H#A8C352
e5	8"x1½"x1" [203x38x25] Bearing Plate Flange	-	H#B8B522
e6	8"x8"x⅝" [203x203x16] Anchor Bearing Plate	ASTM A123	H#DL15103543
e7	2⅜" [60] O.D. x 6" [152] Long BCT Post Sleeve"	ASTM A123	R#15-0626 H#E86298
f1	⅝"-11 UNC [M16x2], 14" [356] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolts: H#DL17100590 Nuts: H#10508780
f2	⅝"-11 UNC [M16x2], 10" [254] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolts: H#20351510 Nuts: H#10508780
f3	⅝"-11 UNC [M16x2], 1¼" [32] Long Guardrail Bolt and Nut	Bolt - ASTM A307 Gr. A Nut - ASTM A563A	Bolt: H#10435580 Nut: H#10508780
f4	⅞"-9 UNC [M22x2.5], 8" [203] Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A or equivalent Nut - ASTM A563A or equivalent	Bolt: H#2038622 Nut: H#NF12101054
f5	⅞"-9 UNC [M22x2.5], 8½" [216] Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A or equivalent Nut - ASTM A563A or equivalent	Bolts: C#120139589 H#331200696 Nuts: H#G16-7344
f6	⅝"-11 UNC [M16x2], 10" [254] Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A or equivalent Nut - ASTM A563A or equivalent	Bolts: DL15107048 Nuts: C#210101523 COC
f7	⅝"-11 UNC [M16x2], 1½" [38] Long Hex Head Bolt and Nut	Bolt - ASTM A307 Gr. A or equivalent Nut - ASTM A563A or equivalent	Bolts: H#816070039 Nuts: C#210101523 COC
f8	½"-13 UNC [M14x2], 2" [51] Long Hex Bolt and Nut	Bolt – ASTM A307 Gr. A or equivalent Nut - ASTM A563A or equivalent	Bolt: H#18200477-3 Nut: C#210165954 COC

Table B-6. Bill of Materials, Test No. SPTA-2, Cont.

Item No.	Description	Material Specification	Reference No.
f9	½"-13 UNC [M14x2], 1½" [38] Long Hex Bolt and Nut	Bolt – ASTM A307 Gr.A or equivalent Nut - ASTM A563A or equivalent	Bolts: H#Q195/180196 Nuts: C#210165954 COC
f10	7/16"-14 UNC [M12x1.75], 2½" [64] Long Fully Threaded Hex Tap Bolt and Nut	Bolt - ASTM A449 or equivalent Nut - ASTM A563DH or equivalent	Bolts: H#1708007009 Nuts: H#17101400-3
f11	16D Double Head Nail	-	McMaster Carr PO#E000548963
g1	⅞" [22] Dia. Plain Round Washer	ASTM F844	P#33187 L#M-SWE0410533-5
g2	⅝" [16] Dia. Plain Round Washer	ASTM F844	n/a
g3	½" [13] Dia. Plain Round Washer	ASTM F844	P#33184 PO#170081147 COC
g4	7/16" [11] Dia. Plain Round Washer	ASTM F844	P#M-SWE041885-18 L#33183 PO#220024002

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

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

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

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

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

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

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

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

Notary Public, State of Ohio

Figure B-1. 12-ft 6-in. (3.8-m) W-Beam MGS Section, Test Nos. SPTA-1 and SPTA-2

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

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

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

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

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

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

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

NOTARIAL SEAL
STATE OF OHIO

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

Figure B-2. 12-ft 6-in. (3.8-m) W-Beam MGS Section and End Section, Test Nos. SPTA-1 and SPTA-2

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

Customer: MIDWEST MACHINERY & SUPPLY CO.
P. O. BOX 703
MILFORD,NE,68405

Test Report
Ship Date: 11/15/2016
Customer P O 3356
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project INVENTORY
GHP Order No.: 202136

HT # code	Heat #	C.	MN.	P.	S.	Si.	Tensile	Yield	Elong.	Quanity	Class	Type	Description
9830	9513565	0.21	0.3	0.01	0.008	0.01	76639	56644	25.65	80	A	1	12GA 12FT6IN/3FT1 1/2IN WB T1
9827	9513566	0.22	0.76	0.011	0.008	0.01	79453	59412	28.02	3	A	2	12GA 12FT6IN/3FT1 1/2IN WB T2
9818	31639313	0.19	0.82	0.01	0.005	0.03	77300	56000	27	3	A	2	12 GA 12FT6IN WB T2 FLEAT-SKT COMBO PAN
9828	9513569	0.23	0.78	0.009	0.008	0.01	78281	58917	24.96	170	A	1	12GA 25FT0IN 3FT1 1/2IN WB T1
9818	31639313	0.19	0.82	0.01	0.005	0.03	77300	56000	27	3	A	2	12GA 9FT4 1/2IN 3FT1 1/2IN WB T2
9830	9513565	0.21	0.3	0.01	0.008	0.01	76639	56644	25.65	40	A	1	12GA 6FT 3IN WB T1 HS@ 3FT 1.5IN

R#17-410 HT Code#9830 H#9513565
6'3" W-Beam Yellow Paint Feb 2017 SMT

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

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

NOTARIAL SEAL — STATE OF OHIO

KARA J CARPENTER
Notary Public
In and for the State of Ohio
My Commission Expires
February 16, 2021

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by Andrew Artar this 16 day of November, 2016
[signature]
Notary Public, State of Ohio

Figure B-3. 6-ft 3-in. (1.9-m) W-Beam MGS Section, Test Nos. SPTA-1 and SPTA-2

GERDAU

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

CERTIFIED MATERIAL TEST REPORT — Page 1/1

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
HIGHWAY SAFETY CORP 473 W FAIRGROUND ST MARION,OH 43302-1701 USA	HIGHWAY SAFETY CORP GLASTONBURY,CT 06033-0358 USA	A992/A709-36	Wide Flange Beam / 6 X 8.5# / 150 X 13.0	0000006197
		LENGTH: 42'00"	WEIGHT: 44,982 LB	HEAT / BATCH: 55044251/02

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
3399484/000010	IB-B0600800	ASTM A6-14 ASTM A709-13A ASTM A992-11 CSA G40.21-13 345WM

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
000167 PO#1677003	1323-0000066391	03/16/2016

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %
0.14	0.90	0.014	0.019	0.19	0.28	0.08	0.09	0.023	0.012	0.017	0.000

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	G/L Inch	Elong. %
56700	77700	391	536	8.000	21.30
54800	75700	378	522	8.000	22.60

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. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

YAN WANG
QUALITY ASSURANCE MGR.

Figure B-4. W6x8.5 Steel Post, Test Nos. SPTA-1 and SPTA-2

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

H#1702406

CERTIFIED MILL TEST REPORT

3/09/17 16:15:20
100% EAF MELTED AND MANUFACTURED IN THE USA
All beams produced by Nucor-Berkeley are cast and rolled to a fully killed and fine grain practice.
Mercury has not been used in the direct manufacturing of this material.

Sold To: HIGHWAY SAFETY CORP Stamped "A"
PO BOX 358
GLASTONBURY, CT 06033

Ship To: HIGHWAY SAFETY CORP
473 WEST FAIRGROUND STREET
MARION, OH 43301

Customer #.: 352 - 3
Customer PO: 1722007
B.O.L. #...: 1255973
MOS: T

SPECIFICATIONS: Tested in accordance with ASTM specification A6/A6M-16a and A370. Quality Manual Rev H10 (12-13-16).
AASHTO : m270-345M270-50-10
ASME : SA-36 13
ASTM : A992-11(15:/A36-14/A529-14-50/A572 5015/A709-5016a
CSA : G40.21-50w/G40.2150WM/G402150WMT

IB-B0600800

Description Part #	Heat# Grade(s) Test/Heat JW	Yield/ Tensile Ratio	Yield (PSI) (MPa)	Tensile (PSI) (MPa)	Elong %	C Cr XXXXXX	Mn Mo Ti	P Sn XXXXXX	S B XXXXXX	Si V N	Cu Nb XXXXXX	Ni XXXXXX CI	CE1 CE2 Pcm
W6X8.5 042' 00.00' W150X12.6 012.8016m	1702434 A992 11(15 ANS	.82 .83	60300 416 59900 413	73200 505 72300	27.74 27.83 84 Pc(s)	.07 .05 29,988 lbs	.86 .01 .001	.007 .0086	.015 .0002	.19 .003 .0042	.14 .016	.05 3.66 Inv#:	.24 .2701 .1288 0
W6X8.5 042' 00.00' W150X12.6 012.8016m	*1702406 A992-11(15 ANS	.83 .83	59000 407 58900 406	71200 491 71100 490	28.19 28.26 42 Pc(s)	.07 .04 14,994 lbs	.86 .01 .001	.006 .0056	.022 .0002	.20 .003 .0056	.11 .015	.03 3.07 Inv#:	.23 .2652 .1260 0

2 Heat(s) for this MTR.

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

CE1 = C+(Mn/6)+((Cr+Mo+V)/5)+((Ni+Cu)/15)
CE2 = C+((Mn+Si)/6)+((Cr+Mo+V+Cb)/5)+((Ni+Cu)/15)

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

Bruce A. Work
Metallurgist

Figure B-5. W6x8.5 Steel Post, Test Nos. SPTA-1 and SPTA-2

CENTRAL NEBRASKA WOOD PRESERVERS, INC.

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

CWNP Invoice 10048570
Shipped To MIDWEST-MILFORD
Customer PO 2892

Central Nebraska Wood Preservers, Inc.
Certification of Inspection

Date: 4/23/14

Specifications: Highway Construction Use

Preservative: CCA – C 0.60 pcf

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

Number of pieces rejected and reason for rejection:
None

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

Kurt Andres, General Manager

4/23/14
Date

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

Figure B-6. 6-in. x 12-in. x 14¼-in. Timber Blockout, Test Nos. SPTA-1 and SPTA-2

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

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

CERTIFICATE OF COMPLIANCE

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

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

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

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

Nick Sowl, General Counsel

1/11/2018
Date

Figure B-7. 6-in. x 12-in. x 14¼-in. Timber Blockout, Test No. SPTA-2

Steel Dynamics, Inc.
Long Products Group

(260) 625-8100 (260) 625-8950 FAX
Quality Steel 100% EAF Melted and Manufactured in the USA
Recycled content: PC = 79.6%, PI = 18.0%
ISO 9001:2008 and ABS Certified

CERTIFIED MILL TEST REPORT

Printed: **05 / 18 / 2017**
Produced: **04 / 30 / 2017**

Customer # 000058

Ship to:
Steel & Pipe Supply
401 New Century Parkway
New Century KS, 66031 US
Attn: Receiving

Bill to:
Steel & Pipe Supply - Kansas
555 Poyntz Avenue
PO Box 1688
Manhattan KS, 66505 US
Attn: David Chizek

GENERAL INFORMATION

Product	Wide Flange Beam
Size	W6X9
	W150X13.5
Heat Number	A134873
Condition(s)	As-Rolled
	Fine Grained
	Fully Killed
	No Weld Repair

SPECIFICATIONS

Standards	Grades
ASTM A6/A6M - 16a	
» ASTM A992/A992M - 11	A992 / A992M
ASTM A709/A709M - 16a	A709 gr50/gr345
ASTM A572/A572M - 15	A572 gr50/gr345
AASHTO M270M/M270 - 12	M270 gr345/gr50
CSA G40.21-13	50WM/345WM
ASTM A36/A36M - 14	A36 / A36M

SHIPMENT DETAILS

BOL # 0000454311 - 8640.00 lbs

Bundle / ASN #	Length	pcs	Cust PO | Recv PO | Job
060771395	60' 0"	16	4500287578

CHEMICAL ANALYSIS (weight percent)

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	V	Nb/Cb	Al	N	B	*C1	*C2	*C3	*PC	*I	Analysis Type
.06	.95	.016	.011	.23	.37	.12	.13	.051	.012	.021	<.001	.001	.0121	.0002	.29	.33	.27	.15	5.93	Heat

MECHANICAL TESTING

Test	Yield (fy) Strength ksi / MPa	Tensile (fu) Strength ksi / MPa	fy / fu ratio	% Elong. {8" gage}
1	56 / 386	70 / 483	.80	28
2	57 / 393	71 / 490	.80	28
3				
4				

CHARPY IMPACT TESTS (available only when specified at time of order)

Test	Temp F / C	Absorbed Energy ft-lbf / J Specimen 1	Specimen 2	Specimen 3	Average	Minimum
1						
2						
3						
4						
5						
6						
7						

Notes: *Calculated Chemistry Values: Carbon Equivalents (C1, C2, C3, PC), Corrosion Index (I) I (ASTM G101)= 26.01(Cu)+3.88(Ni)+1.20(Cr)+1.49(Si)+17.29(P)-7.29(Cu)(Ni)-9.10(Ni)(P)-33.39(Cu²)
CE1 (IIW)=C+Mn/6+(Cr+Mo+V)/5+(Ni+Cu)/15 **CE2** (AWS)=C+(Mn+Si)/6+(Cr+Mo+V)/5+(Ni+Cu)/15 **CE3** (CET) = C + (Mn/6) + (Si/24) + (Cr/5) + (Ni/40) +(Mo/4) + (V/14) **Pcm**(AWS) = C+Si/30+Mn/20+Cu/20+Ni/60+Cr/20+mo/15+V/10+5B

I hereby certify that the material described herein has been made to the applicable specification by the electric arc furnace/continuous cast process and tested in accordance with the requirements of American Bureau of Shipping Rules with satisfactory results.

Signed:

ABS CERTIFICATION

I hereby certify that the content of this report are accurate and correct. All tests and operations performed by this material manufacturer are in compliance with the requirements of the material specifications and applicable purchaser designated requirements

Signed: **Todd Bashford**
Quality Manager

Form F-6100-002-054 rev 8

State of Indiana, County of Whitley Sworn to and subscribed before me

this _________ day of ____________________

Signed: ______________________ My commission expires:__________
Notary Public

ASTM A6 - 14.6: A signature is not required on the test report, however, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report

Page 3 of 4

Figure B-8. W6x9 Steel Post, Test Nos. SPTA-1 and SPTA-2

GERDAU

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

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
STEEL & PIPE SUPPLY CO INC 401 NEW CENTURY PKWY NEW CENTURY,KS 66031-1127 USA	STEEL & PIPE SUPPLY CO INC MANHATTAN,KS 66505-1688 USA	A992/A572-50	Wide Flange Beam / 6 X 9# / 150 X 13.5	0000201334

LENGTH	PCS	WEIGHT	HEAT / BATCH
20'00"	48	8,640 LB	59077955/03

SALES ORDER	CUSTOMER MATERIAL Nº	SPECIFICATION / DATE or REVISION
6208992/000010	000000000037690020	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
4500304572	1327-0000270972	03/14/2018

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.09	0.92	0.016	0.038	0.24	0.34	0.10	0.18	0.022	0.007	0.002	0.013	0.003

CHEMICAL COMPOSITION

CEqyA6 %
0.31

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	Y/T ratio %	G/L Inch
60845	75978	420	524	0.800	8.000
61138	76788	422	529	0.800	8.000

MECHANICAL PROPERTIES

G/L mm	Elong. %
200.0	24.00
200.0	24.90

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. 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) 769-1014 Email: Bhaskar.Yalamanchili@gerdau.com

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

Figure B-9. W6x9 Steel Post, Test No. SPTA-2

10Aug16 11:15 T E S T C E R T I F I C A T E No: MAR 464882

INDEPENDENCE TUBE CORPORATION
6226 W. 74TH STREET
CHICAGO, IL 60638
Tel: 708-496-0380 Fax: 708-563-1950

P/O No 4500271090
Rel
S/O No MAR 312450-001
B/L No MAR 181804-001 Shp 11Aug16
Inv No Inv

Sold To: (5015)
STEEL & PIPE SUPPLY
SOUTH SMITH ROAD
JONESBURG, MO 63351

Ship To: (1)
STEEL & PIPE SUPPLY
310 SMITH ROAD
JONESBURG, MO 63351

Tel: 636-488-5999 Fax: 314 488-5960

CERTIFICATE of ANALYSIS and TESTS Cert. No: MAR 464882
09Aug16

Part No		Pcs	Wgt
TUBING A500 GRADE B(C) 8" X 6" X 3/16" X 48'		18	14,757

Heat Number	Tag No	Pcs	Wgt
M24919	44516 YLD=59270/TEN=71290/ELG=31.9	6	4,919
M24919	44517	6	4,919
M24919	44523	6	4,919

Heat Number *** Chemical Analysis ***
M24919 C=0.2200 Mn=0.8300 P=0.0160 S=0.0100 Si=0.0140 Al=0.0490
Cu=0.0200 Cr=0.0400 Mo=0.0040 V=0.0010 Ni=0.0100 Nb=0.0010
Cb=0.0010 Sn=0.0020 N=0.0030 B=0.0001 Ti=0.0010
MELTED AND MANUFACTURED IN THE USA

WE PROUDLY MANUFACTURE ALL OUR PRODUCT IN THE USA.
INDEPENDENCE TUBE PRODUCT IS MANUFACTURED, TESTED,
AND INSPECTED IN ACCORDANCE WITH ASTM STANDARDS.
MATERIAL IDENTIFIED AS A500 GRADE B(C) MEETS BOTH
ASTM A500 GRADE B AND A500 GRADE C SPECIFICATIONS.

CURRENT STANDARDS:
A252-10
A500/A500M-13
A513-13
ASTM A53/A53M-12 | ASME SA-53/SA-53M-13
A847/A847M-14
A1085/A1085M-15

Page: 1 .... Last

Figure B-10. TS8x6x$^{3}/_{16}$ Foundation Tube, Test Nos. SPTA-1 and SPTA-2

SSAB

Preliminary Test Certificate

Form TC1: Revision 3: Date 7 Feb 2018

1770 Bill Sharp Boulevard, Muscatine, IA 52761-9412, US **Official copy to follow**

Customer: STEEL & PIPE SUPPLY P.O. BOX 1688 MANHATTAN KS 66502	Customer P.O. No.: 4500301987 Product Description: ASTM A36(14)/A709(17)36/ASME SA36(17) AASHTO M270(15)36 Size: 0.625 X 72.00 X 240.0 (IN)	Mill Order No.: 41-530763-01 Ship Date: 04 Apr 18 Cert Date: 04 Apr 18	Shipping Manifest: MT342897 Cert No: 061701178 (Page 1 of 1)

Tested Pieces				Tensiles							Charpy Impact Tests													
Heat Id	Piece Id	Tested Thickness	Tst Loc	YS (KSI)	UTS (KSI)	%RA	Elong % 2in	Elong % 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
A8C352	C22	0.623 (DISCRT)	L	46	70		33		T														
A8C352	C26	0.747 (DISCRT)	L	47	70		29		T														

Chemical Analysis

Heat Id	C	Mn	P	S	Si	Tot Al	Cu	Ni	Cr	Mo	Cb	V	Ti	B	N	ORGN
A8C352	.20	.53	.009	.002	.05	.032	.31	.17	.20	.05	.001	.004	.006	.0001	.0086	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:
A8C352 C23 PCES: 14, LBS: 42882

(H) Cust Part # : 722072240

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

SENIOR METALLURGIST - PRODUCT

Figure B-11. ⅝-in. (16-mm) Steel Plate, Test Nos. SPTA-1 and SPTA-2

SSAB

Preliminary Test Certificate

1770 Bill Sharp Boulevard, Muscatine, IA 52761-9412, US **Official copy to follow**

Form TC1: Revision 3: Date 7 Feb 2018

Customer: STEEL & PIPE SUPPLY P.O. BOX 1688 MANHATTAN KS 66502	Customer P.O. No.: 4500306433	Mill Order No.: 41-537680-01	Shipping Manifest : MT347708
	Product Description: ASTM A36(14)/A709(17)36/ASME SA36(17) AASHTO M270(15)36	Ship Date: 29 May 18 Cert Date: 29 May 18	Cert No: 061711969 (Page 1 of 1)
	Size: 0.750 X 72.00 X 240.0 (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
B8E678	A40	0.748 (DISCRT)	L	53	75		34	T							
B8E678	A41	0.748 (DISCRT)	L	54	77		33	T							

Chemical Analysis

Heat Id	C	Mn	P	S	Si	Tot Al	Cu	Ni	Cr	Mo	Cb	V	Ti	B	N	ORGN
B8E678	.18	1.14	.018	.003	.07	.030	.32	.17	.21	.04	.002	.004	.023	.0002	.0085	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:

B8E678	A41	PCES: 2, LBS: 7350	B8E678	A42	PCES: 10, LBS: 36750

Cust Part # : 722472240

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

SENIOR METALLURGIST - PRODUCT

Figure B-12. ¾-in. (19-mm) Steel Plate, Test No. SPTA-1

SSAB

Preliminary Test Certificate

1770 Bill Sharp Boulevard, Muscatine, IA 52761-9412, US **Official copy to follow**

Form TC1: Revision 3: Date 7 Feb 2018

Customer: STEEL & PIPE SUPPLY P.O. BOX 1688 MANHATTAN KS 66502	Customer P.O. No.: 4500308540	Mill Order No.: 41-540918-01	Shipping Manifest : MT349854
	Product Description: ASTM A36(14)/A709(17)36/ASME SA36(17) AASHTO M270(15)36	Ship Date: 22 Jun 18 Cert Date: 22 Jun 18	Cert No: 061716530 (Page 1 of 1)
	Size: 0.750 X 72.00 X 240.0 (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
A8D843	D30	0.751 (DISCRT)	L	54	67		40	T							

Chemical Analysis

Heat Id	C	Mn	P	S	Si	Tot Al	Cu	Ni	Cr	Mo	Cb	V	Ti	B	N	ORGN
A8D843	.05	1.18	.011	.003	.05	.024	.32	.11	.10	.03	.019	.021	.006	.0003	.0091	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:
A8D843 D30 PCES: 5, LBS: 18375

(B) Cust Part # : 722472240

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

SENIOR METALLURGIST - PRODUCT

Figure B-13. ¾-in. (19-mm) Steel Plate, Test No. SPTA-2

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

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

CERTIFICATE OF COMPLIANCE

Shipped To: Midwest Machinery and Supply
BOL# 10057594
Customer PO# 3475
Preservative: CCA – C 0.60D pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
GR6806PST	6x8-6′ Thrie Beam Post	70	24232	.636
GS6846PST	5.5x7.5-46′ BCT	42	24233	.627
GR61219BLK	6x12-19″ Thrie OCD Block	168	24230	.638
GR61222BLK	6x12-22″ Thrie OCD Block	56	24089	.673
GR6814BLK	6x8-14″ OCD Block	126	24195	.648

marked orange Tab

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

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

Nicholas Sowl, General Counsel

8/25/2017
Date

Figure B-14. BCT Timber Post, Test No. SPTA-1

CNWP

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

CERTIFICATE OF COMPLIANCE

Shipped To: Midwest Machinery and Supply
BOL# N02529
Customer PO# 3560
Preservative: CCA – C 0.60D pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
GR6806.5 CRT	6x8-6.5 CRT	70	25008	.740
GS6846 PST	5.5x7.5-46" BCT	84	25033	.864
GR6814 BLKTAP	6x8-14" Tapered Block	90	25041	.892
GR668 3HB	6x6-8" 3 Hole Block	56	25033	.864
GR6819 BLK	6x8-19" OCD Block	168	25024	.941
GR61219 BLK	6x12-19" Thrie Block	168	25033	.864
GR61219 BLK	6x12-19" Trans Block	56	25042	.733
GR61222 BLK	6x12-22" Block	112	25042	.733

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

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

Nick Sowl, General Counsel

4/18/18
Date

Figure B-15. BCT Timber Post, Test No. SPTA-2

Certified Analysis

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

MILFORD, NE 68405
Project: STOCK

Order Number: 1215324   Prod Ln Grp: 9-End Terminals (Dom)
Customer PO: 2884   As of: 4/14/14
BOL Number: 80821   Ship Date:
Document #: 1
Shipped To: NE
Use State: KS

Foundation Tubes Green Paint
R#15-0157 September 2014 SMT

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
10	701A	.25X11.75X16 CAB ANC	A-36			A3V3361	48,600	69,000	29.1	0.180	0.410	0.010	0.005	0.040	0.270	0.000	0.070	0.001	4
	701A		A-36			JJ4744	50,500	71,900	30.0	0.150	1.060	0.010	0.035	0.240	0.270	0.002	0.090	0.021	4
12	729G	TS 8X6X3/16X8'-0" SLEEVE	A-500			0173175	55,871	74,495	31.0	0.160	0.610	0.012	0.009	0.010	0.030	0.000	0.030	0.000	4
15	736G	5'/TUBE SL/.188"X6"X8"FLA	A-500			0173175	55,871	74,495	31.0	0.160	0.610	0.012	0.009	0.010	0.030	0.000	0.030	0.000	4
12	749G	TS 8X6X3/16X6'-0" SLEEVE	A-500			0173175	55,871	74,495	31.0	0.160	0.610	0.012	0.009	0.010	0.030	0.000	0.030	0.000	4
5	783A	5/8X8X8 BEAR PL 3/16 STP	A-36			10903960	56,000	79,500	28.0	0.180	0.810	0.009	0.005	0.020	0.100	0.012	0.030	0.000	4
	783A		A-36			DL13106973	57,000	72,000	22.0	0.160	0.720	0.012	0.022	0.190	0.360	0.002	0.120	0.050	4
20	3000G	CBL 3/4X6'6/DBL	HW			99692													
25	4063B	WD 6'0 POST 6X8 CRT	HW			43360													
15	4147B	WD 3'9 POST 5.5"X7.5"	HW			2401													
20	15000G	6'0 SYT PST/8.5/31" GR HT	A-36			34940	46,000	66,000	25.3	0.130	0.640	0.012	0.043	0.220	0.310	0.001	0.100	0.002	4
10	19948G	.135(10Ga)X1.75X1.75	HW			P34744													
2	33795G	SYT-3"AN STRT 3-HL 6'6	A-36			JJ6421	53,600	73,400	31.3	0.140	1.050	0.009	0.028	0.210	0.280	0.000	0.100	0.022	4
4	34053A	SRT-31 TRM UP PST 2'6.625	A-36			JJ5463	56,300	77,700	31.3	0.170	1.070	0.009	0.016	0.240	0.220	0.002	0.080	0.020	4

1 of 3

Figure B-16. TS8x6x$^{3}/_{16}$ Foundation Tube, Test Nos. SPTA-1 and SPTA-2

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 06/05/2018
TIME 06:40:36
USER WF-BATCH

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
40309309-0010	70872120TM	1/4 72 X 120 A36 TEMPERPASS STPMLPL	16	9,801.600			06/04/2018

Chemical Analysis

Heat No. 18040241 Vendor BIG RIVER STEEL LLC DOMESTIC Mill BIG RIVER STEEL LLC **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
0.2200	0.8400	0.0080	0.0030	0.0400	0.0500	0.0500	0.0130	0.0001	0.1100	0.0320	0.0010	0.0040	0.0010	0.0067	0.0049

Mechanical / Physical Properties

Mill Coil No. 18040241-06

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
71900.000	46400.000	32.00			0	NA			
68700.000	42800.000	35.80			0	NA			
68200.000	43400.000	30.00			0	NA			
73400.000	48200.000	33.00			0	NA			

Batch 0005324466 16 EA 9,801.600 LB

Batch 0005325167 12 EA 7,351.200 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-17. ¼-in. (6-mm) Steel Plate and Bent Steel Plate (Test Nos. SPTA-1 and SPTA-2) and Gusset (Test No. SPTA-1)

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

METALLURGICAL TEST REPORT

PAGE 2 of 2
DATE 06/23/2017
TIME 13:52:25
USER GIANGRER

SOLD TO

SHIP TO
13716
Kansas City Warehouse
401 New Century Parkway
NEW CENTURY KS 66031-1127

Order	Material No.	Description	Quantity	Weight	Customer Part	Customer PO	Ship Date
40287943-0020	801060120TM	10GA 60 X 120 A1011-CS-TYB TEMP HS	35	9,843.750			06/23/2017

Chemical Analysis

Heat No. 17044641 Vendor BIG RIVER STEEL LLC DOMESTIC Mill BIG RIVER STEEL LLC **Melted and Manufactured in the USA**

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.0800	0.3700	0.0070	0.0010	0.0500	0.0400	0.0400	0.0120	0.0001	0.1200	0.0300	0.0000	0.0020	0.0010	0.0085	0.0064

Mechanical / Physical Properties

Mill Coil No. 17044641-05

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen

Batch 0004821914 35 EA 9,843.750 LB Batch 0004821915 35 EA 9,843.750 LB Batch 0004821927 35 EA 9,843.750 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-18. 10-gauge (3.4-mm) Bent Steel Channel Strut, Test Nos. SPTA-1 and SPTA-2

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 06/18/2018
TIME 08:43:38
USER WF-BATCH

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
40308865-0010	701672240TM	1/2 72 X 240 A36 TEMPERPASS STPMLPL	2	4,900.800			06/15/2018

Chemical Analysis

Heat No. A8C269 Vendor SSAB - MONTPELIER WORKS DOMESTIC Mill SSAB - MONTPELIER WORKS **Melted and Manufactured in the USA**
Produced from Coil

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.1600	0.8400	0.0080	0.0040	0.0300	0.1200	0.1000	0.0300	0.0001	0.2900	0.0370	0.0060	0.0030	0.0010	0.0087	0.0000

Mechanical / Physical Properties

Mill Coil No. A8C2690693

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
76700.000	59300.000	24.20			0	NA			
73200.000	55400.000	26.20			0	NA			
70900.000	50500.000	33.90			0	NA			
71600.000	51400.000	31.60			0	NA			

Batch 0005342674 2 EA 4,900.800 LB Batch 0005342658 4 EA 9,801.600 LB Batch 0005342672 4 EA 9,801.600 LB

THE CHEMICAL, PHYSICAL, OR MECHANICAL TESTS REPORTED ABOVE ACCURATELY REFLECT INFORMATION AS CONTAINED IN THE RECORDS OF THE CORPORATION.
The material is in compliance with EN 10204 Section 4.1 Inspection Certificate Type 3.1

Figure B-19. ½-in. (13-mm) Steel Plate, Test Nos. SPTA-1 and SPTA-2

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 - New Century 401 New Century Parkway NEW CENTURY KS 66031-1127	02.50X02.50	4500298385	01/04/2018
	Gauge: 1/4	Delivery No:83076040 Load No:3963994	
	Specification: ASTM A500-13 Gr.B/C		

Heat No	Yield KSI	Tensile KSI	Elongation % 2 Inch
A710851	57.5	65.8	30.00

Heat No	C	MN	P	S	SI	CU	NI	CR	MO	V
A710851	0.0600	0.7200	0.0130	0.0040	0.0200	0.0900	0.0400	0.0600	0.0200	0.0040

This material was melted & manufactured in the U.S.A.
Coil Producing Mill: STEEL DYNAMICS COLUMBUS, COLUMBUS, MS

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

Jonathan Wolfe
Quality Assurance Manager

Figure B-20. HSS2½x2½x¼ Square Tube, Test Nos. SPTA-1 and SPTA-2

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

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

Ref.B/L: 80819500
Date: 05.11.2018
Customer: 179

MATERIAL TEST REPORT

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

Shipped to
Steel & Pipe Supply Company
401 New Century Parkway
NEW CENTURY KS 66031
USA

Material: 2.0x1.0x083x24'0"0(5x10).A513 | Material No: 0200100832400-B | Made in: USA | Melted in: USA

Sales order: 1278654 | Purchase Order: 4500307729 | Cust Material #: 662001008324

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	CA
B804732	0.050	0.320	0.009	0.004	0.020	0.029	0.090	0.002	0.020	0.030	0.050	0.000	0.001	0.0000	0.0060	0.0020

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.13
MC00025933	50	000000 Psi	Psi	%	ASTM A513, TYPE 1	

Material Note:
Sales Or.Note:

Material: 3.0x3.0x250x48'0"0(4x4). | Material No: 0300302504800-B | Made in: USA | Melted in: USA

Sales order: 1279621 | Purchase Order: 4500307900 | Cust Material #: 6530025048

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	CA
A804182	0.210	0.470	0.008	0.002	0.020	0.026	0.100	0.000	0.010	0.030	0.060	0.001	0.001	0.0000	0.0070	0.0020

Bundle No	PCs	Yield	Tensile	Eln.2in	Rb	Certification	CE: 0.31
MA00016461	16	054240 Psi	069516 Psi	26 %	93	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

Material: 3.0x3.0x250x48'0"0(4x4). | Material No: 0300302504800-B | Made in: USA | Melted in: USA

Sales order: 1279621 | Purchase Order: 4500307900 | Cust Material #: 6530025048

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	CA
A804182	0.210	0.470	0.008	0.002	0.020	0.026	0.100	0.000	0.010	0.030	0.060	0.001	0.001	0.0000	0.0070	0.0020

Bundle No	PCs	Yield	Tensile	Eln.2in	Rb	Certification	CE: 0.31
MA00016462	16	054240 Psi	069516 Psi	26 %	93	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

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

Steel Tube Institute OF NORTH AMERICA

Page : 3 Of 5

Metals Service Center Institute

Figure B-21. HSS3x3x¼ Square Tube, Test No. SPTA-1

Atlas Tube Corporation
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: 80807322
Date: 02.20.2018
Customer: 179

MATERIAL TEST REPORT

Sold to

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

Shipped to

Steel & Pipe Supply Company
310 Smith Road
JONESBURG MO 63351
USA

Material: 3.0x3.0x250x40'0"0(6x3). **Material No:** 300302504000 **Made in:** USA **Melted in:** USA

Sales order: 1256602 **Purchase Order:** 4500302878 **Cust Material #:** 6530025040

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
V3726	0.040	0.760	0.011	0.007	0.020	0.030	0.170	0.023	0.020	0.070	0.090	0.003	0.002	0.000	0.008

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800750088	18	076262 Psi	082496 Psi	24 %	ASTM A500-13 GRADE B&C	0.21

Material Note:
Sales Or.Note:

Material: 3.0x3.0x250x40'0"0(6x3). **Material No:** 300302504000 **Made in:** USA **Melted in:** USA

Sales order: 1256602 **Purchase Order:** 4500302878 **Cust Material #:** 6530025040

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
V3726	0.040	0.760	0.011	0.007	0.020	0.030	0.170	0.023	0.020	0.070	0.090	0.003	0.002	0.000	0.008

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800750087	18	076262 Psi	082496 Psi	24 %	ASTM A500-13 GRADE B&C	0.21

Material Note:
Sales Or.Note:

Material: 3.0x3.0x250x40'0"0(6x3). **Material No:** 300302504000 **Made in:** USA **Melted in:** USA

Sales order: 1256602 **Purchase Order:** 4500302878 **Cust Material #:** 6530025040

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
V3726	0.040	0.760	0.011	0.007	0.020	0.030	0.170	0.023	0.020	0.070	0.090	0.003	0.002	0.000	0.008

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800750090	18	076262 Psi	082496 Psi	24 %	ASTM A500-13 GRADE B&C	0.21

Material Note:
Sales Or.Note:

Jason Richard

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

Steel Tube Institute OF NORTH AMERICA

Page : 1 Of 3

Metals Service Center Institute

Figure B-22. HSS3x3x¼ Square Tube, Test No. SPTA-2

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 08/07/2018
TIME 15:51:50
USER T.HIPP

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
40311347-0010	70127212OTM	3/8 72 X 120 A36 TEMPERPASS STPMLPL	6	5,515.200			08/07/2018

Chemical Analysis

Heat No. 18072721 Vendor BIG RIVER STEEL LLC DOMESTIC Mill BIG RIVER STEEL LLC

Melted and Manufactured in the USA
Produced from Coil
Country of Origin: USA

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.2000	0.8400	0.0080	0.0040	0.0200	0.0500	0.0400	0.0150	0.0001	0.1100	0.0300	0.0010	0.0030	0.0010	0.0076	0.0053

Mechanical / Physical Properties

Mill Coil No. 18072721-01

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
72500.000	50500.000	33.80			0	NA			
68400.000	45700.000	34.00			0	NA			

Batch 0005416524 6 EA 5,515.200 LB Batch 0005416521 10 EA 9,192 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-23. ⅜-in. (10-mm) Plate, Test No. SPTA-2

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	**08/07/2018**
TIME	**07:06:16**
USER	**WF-BATCH**

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
40313432-0010	70872120TM	1/4 72 X 120 A36 TEMPERPASS STPMLPL	9	5,513.400			08/06/2018

Chemical Analysis

Heat No. B809345 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	0.8100	0.0110	0.0040	0.0200	0.0300	0.0500	0.0100	0.0001	0.1000	0.0310	0.0010	0.0020	0.0020	0.0078	0.0060

Mechanical / Physical Properties

Mill Coil No. 18B502017

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
61000.000	43800.000	32.50			0	NA			
60700.000	43100.000	33.20			0	NA			

Batch 0005411781 9 EA 5,513.400 LB Batch 0005411778 16 EA 9,801.600 LB Batch 0005411779 16 EA 9,801.600 LB

THE CHEMICAL, PHYSICAL, OR MECHANICAL TESTS REPORTED ABOVE ACCURATELY REFLECT INFORMATION AS CONTAINED IN THE RECORDS OF THE CORPORATION.
The material is in compliance with EN 10204 Section 4.1 Inspection Certificate Type 3.1

Figure B-24. Gusset, Test No. SPTA-2

COMMERCIAL GROUP LIFTING PRODUCTS

Feb 15th 2017

SOLD TO:
GREGORY INDUSTRIES, INC.
4100 13TH ST. SW
CANTON, OH. 44710

SHIP TO:
HIGHWAY – FINISHED GOODS
GREGORY INDUSTRIES, INC.
ATTN: STEVE PENNINGTON
CANTON, OH 44710

R#17-700
BCT Cables Yellow Paint

CERTIFICATON

CGLP ORDER# 256284
GREGORY PO# 36454

THIS LETTER AND THE ENCLOSED ATTACHMENTS ARE TO CERTIFY THAT THE FOLLOWING ITEMS WERE 100% MANUFACTURED IN THE UNITED STATES OF AMERICA.

1,330 PCS, PART# 3012G, 3/4IN X 6FT 6IN DOUBLE SWAGE GUARD RAIL ASSEMBLYS.

THEY SHOW THE DOMESTICITY OF ALL MATERIAL USED, 100% MELTED & MANUFACTURED IN THE USA. THESE ITEMS ARE HOT DIPPED GALVANIZED TO ASTM-153 SPECIFICATIONS AND STANDARDS, GALV PROCESS ALSO TOOK PLACE IN THE U.S.A.

ATTACHMENTS:
(WIRE ROPE) WIRECO WORLD GROUP REEL# 428-671806-1; HEAT# .15R582807; 16R584001; 72987C; 16R586548; 73253F; 16R588160; 16R584967; 16R585464; 16R586547; 14R574048; 14R571682; 16R586549; 16R586401; (ROCKY MOUNTAIN STEEL / EVRAZ)

(END FITTINGS) REMLINGER MFG: HEAT#S 75063022; 75062074; 765063075 (GERDAU NORTH AMERICA)

VERY TRULY YOURS

BILL KOTARSKI
GEN MGR CLEV OFFICE

HEADQUARTERS	FLINT BRANCH	CLEVELAND BRANCH
12801 UNIVERSAL DRIVE	G2427 E. JUDD ROAD	5213 GRANT AVE
TAYLOR, MI 48180	BURTON, MI 48529	CLEVELAND, OH 44105
NEW PH# (734) 947-4000	PH# (810) 744-4540	PH# (216) 641-4100
NEW FAX# (734) 947-4004	FAX# (810) 744-1588	FAX# (216) 641-1814

Figure B-25. ¾-in. (19-mm) Wire Rope and Anchor Cable Swaged Fitting, Test No. SPTA-1

Certified Analysis

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

MILFORD, NE 68405
Project: RESALE

Order Number: 1269489
Customer PO: 3346
BOL Number: 97457
Document #: 1
Shipped To: NE
Use State: NE

Prod Ln Grp: 3-Guardrail (Dom)
Ship Date:

As of: 11/7/16

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

3 of 5

Figure B-26. Anchor Bracket Assembly and Anchor Bearing Plate, Test Nos. SPTA-1 and SPTA-2

Certified Analysis

Trinity Highway Products , LLC
2548 N.E. 28th St.
Ft Worth, TX
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097
Project: RESALE

Order Number: 1095199
Customer PO: 2341
BOL Number: 24481
Document #: 1
Shipped To: NE
Use State: KS

As of: 6/20/08

Qty	Part#	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
25	6G	12/6'3/S	M-180	A		84964	64,230	81,300	25.4	0.180	0.720	0.012	0.001	0.040	0.080	0.000	0.060	0.000	4
20	701A	.25X11.75X16 CAB ANC	A-36			4153095	44,900	60,800	36.0	0.240	0.750	0.012	0.003	0.020	0.020	0.000	0.040	0.002	4
10	742G	6'0 TUBE SL/.188X8X6	A-500			A8P1160	74,000	87,000	25.2	0.050	0.670	0.013	0.005	0.030	0.220	0.000	0.060	0.021	4
20	782G	5/8"X8"X8" BEAR PL/OF	A-36			6106195	46,700	69,900	23.5	0.180	0.830	0.010	0.005	0.020	0.230	0.000	0.070	0.006	4
40	907G	12/BUFFER/ROLLED	M-180	A		L0049	54,200	73,500	25.0	0.160	0.700	0.011	0.008	0.020	0.200	0.000	0.100	0.000	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL OTHER GALVANIZED MATERIAL CONFORMS WITH ASTM-123.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH -- 49100 LB

State of Texas, County of Tarrant. Sworn and subscribed before me this 20th day of June, 2008

Notary Public:
Commission Expires

RACHEL R. MEDINA
Notary Public
State of Texas
My Commission Expires

Trinity Highway Products , LLC
Certified By: Stefanie Oneal

Figure B-27. Anchor Bracket Assembly, Test No. SPTA-1

Certified Analysis

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

MILFORD, NE 68405
Project: RESALE

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

As of: 3/22/17

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

2 of 4

Figure B-28. Upstream Ground Line Strut, Page 1, Test Nos. SPTA-1 and SPTA-2

Certified _nalysis

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

MILFORD, NE 68405
Project: RESALE

Order Number: 1275956 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3415
BOL Number: 99204 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 3/22/17

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
			M-180	A	2	208318	64,140	81,540	24.5	0.190	0.720	0.011	0.003	0.020	0.110	0.000	0.060	0.000	4
			M-180	A	2	208674	63,250	82,410	22.7	0.190	0.730	0.011	0.003	0.020	0.100	0.000	0.060	0.002	4
			M-180	A	2	208675	62,100	81,170	22.7	0.190	0.730	0.012	0.004	0.020	0.090	0.000	0.050	0.001	4
			M-180	A	2	208676	62,920	82,040	25.4	0.190	0.720	0.012	0.004	0.010	0.100	0.000	0.060	0.002	4
	12365G				2	L35216													
			M-180	A	2	209331	62,090	81,500	28.1	0.190	0.720	0.013	0.002	0.020	0.110	0.000	0.070	0.002	4
			M-180	A	2	209332	61,400	81,290	25.3	0.190	0.730	0.014	0.003	0.020	0.120	0.000	0.060	0.001	4
			M-180	A	2	209333	61,200	80,050	25.8	0.200	0.740	0.016	0.005	0.010	0.120	0.000	0.070	0.002	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT , 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.

ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED

BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 46000 LB

2 of 3

Figure B-29. Upstream Ground Line Strut, Page 2, Test No. SPTA-2

COMMERCIAL GROUP LIFTING PRODUCTS

Feb 15th 2017

SOLD TO:
GREGORY INDUSTRIES, INC.
4100 13TH ST. SW
CANTON, OH. 44710

SHIP TO:
HIGHWAY – FINISHED GOODS
GREGORY INDUSTRIES, INC.
ATTN: STEVE PENNINGTON
CANTON, OH 44710

CERTIFICATON

CGLP ORDER# 256284
GREGORY PO# 36454

THIS LETTER AND THE ENCLOSED ATTACHMENTS ARE TO CERTIFY THAT THE FOLLOWING ITEMS WERE 100% MANUFACTURED IN THE UNITED STATES OF AMERICA.

1,330 PCS, PART# 3012G, 3/4IN X 6FT 6IN DOUBLE SWAGE GUARD RAIL ASSEMBLYS.

THEY SHOW THE DOMESTICITY OF ALL MATERIAL USED, 100% MELTED & MANUFACTURED IN THE USA. THESE ITEMS ARE HOT DIPPED GALVANIZED TO ASTM-153 SPECIFICATIONS AND STANDARDS, GALV PROCESS ALSO TOOK PLACE IN THE U.S.A.

ATTACHMENTS:
(WIRE ROPE) WIRECO WORLD GROUP REEL# 428-671806-1; HEAT# .15R582807; 16R584001; 72987C; 16R586548; 73253F; 16R588160; 16R584967; 16R585464; 16R586547; 14R574048; 14R571682; 16R586549; 16R586401; (ROCKY MOUNTAIN STEEL / EVRAZ)

(END FITTINGS) REMLINGER MFG: HEAT#S 75063022; 75062074; 765063075 (GERDAU NORTH AMERICA)

VERY TRULY YOURS

BILL KOTARSKI
GEN MGR CLEV OFFICE

HEADQUARTERS	FLINT BRANCH	CLEVELAND BRANCH
12801 UNIVERSAL DRIVE TAYLOR, MI 48180 *NEW PH# (734) 947-4000* *NEW FAX# (734) 947-4004*	G2427 E. JUDD ROAD BURTON, MI 48529 PH# (810) 744-4540 FAX# (810) 744-1588	5213 GRANT AVE CLEVELAND, OH 44105 PH# (216) 641-4100 FAX# (216) 641-1814

Figure B-30. Anchor Cable Assembly, Test No. SPTA-2

SSAB

Preliminary Test Certificate

Form TC1: Revision 3: Date 7 Feb 2018

1770 Bill Sharp Boulevard, Muscatine, IA 52761-9412, US **Official copy to follow**

Customer: STEEL & PIPE SUPPLY, P.O. BOX 1688, MANHATTAN KS 66502	Customer P.O. No.: 4500301987	Mill Order No.: 41-530763-01	Shipping Manifest : MT342897
	Product Description: ASTM A36(14)/A709(17)36/ASME SA36(17) AASHTO M270(15)36	Ship Date: 04 Apr 18 Cert Date: 04 Apr 18	Cert No: 061701178 (Page 1 of 1)
	Size: 0.625 X 72.00 X 240.0 (IN)		

Tested Pieces				Tensiles							Charpy Impact Tests												BDWTT	
Heat Id	Piece Id	Tested Thickness	Tst Loc	YS (KSI)	UTS (KSI)	%RA	Elong % 2in	Elong % 8in	Tst Dir	Hardness	Abs. Energy(FTLB) 1	2	3	Avg	% Shear 1	2	3	Avg	Tst Tmp	Tst Dir	Tst Siz (mm)		Tmp	%Shr
A8C352	C22	0.623 (DISCRT)	L	46	70		33		T															
A8C352	C26	0.747 (DISCRT)	L	47	70		29		T															

Chemical Analysis

Heat Id	C	Mn	P	S	Si	Tot Al	Cu	Ni	Cr	Mo	Cb	V	Ti	B	N	ORGN
A8C352	.20	.53	.009	.002	.05	.032	.31	.17	.20	.05	.001	.004	.006	.0001	.0086	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:
A8C352 C23 PCES: 14, LBS: 42882

(B) Cust Part # : 722072240

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

SENIOR METALLURGIST - PRODUCT

Figure B-31. Bearing Plate Base, Test Nos. SPTA-1 and SPTA-2

SSAB

Preliminary Test Certificate

1770 Bill Sharp Boulevard, Muscatine, IA 52761-9412, US **Official copy to follow**

Form TC1: Revision 2: Date 23 Apr 2014

Customer: STEEL & PIPE SUPPLY P.O. BOX 1688 MANHATTAN KS 66502	Customer P.O. No.: 4500301092	Mill Order No.: 41-528480-02	Shipping Manifest: MT340015
	Product Description: ASTM A36(14)/A709(17)36/ASME SA36(17) AASHTO M270(15)36	Ship Date: 05 Mar 18 Cert Date: 05 Mar 18	Cert No: 061695070 (Page 1 of 1)
	Size: 1.000 X 72.00 X 240.0 (IN)		

Heat Id	Piece Id	Tested Thickness	Tst Loc	YS (KSI)	UTS (KSI)	%RA	Elong % 2in	Elong % 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
B8B522	B45	1.000 (DISCRT)	L	42	66			25	T														
B8B522	B47	1.123 (DISCRT)	L	42	65			25	T														
B8B648	E36	1.001 (DISCRT)	L	54	76			18	T														

Chemical Analysis

Heat Id	C	Mn	P	S	Si	Tot Al	Cu	Ni	Cr	Mo	Cb	V	Ti	B	N	ORGN
B8B522	.15	.84	.013	.006	.04	.025	.25	.12	.19	.04	.002	.003	.006	.0001	.0082	USA
B8B648	.17	1.10	.013	.004	.03	.029	.30	.10	.15	.03	.001	.034	.006	.0001	.0088	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:
B8B648 E36 PCES: 2, LBS: 9802 B8B522 B46 PCES: 7, LBS: 34307

Cust Part # : 7210072240

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

SENIOR METALLURGIST - PRODUCT

Figure B-32. Bearing Plate Flange, Test Nos. SPTA-1 and SPTA-2

09Mar15 13:22 TEST CERTIFICATE No: MAR 268339

INDEPENDENCE TUBE CORPORATION
6226 W. 74TH STREET
CHICAGO, IL 60638
Tel: 708-496-0380 Fax: 708-563-1950

P/O No 4500240795
Rel
S/O No MAR 280576-001
B/L No MAR 163860-003 Shp 09Mar15
Inv No Inv

Sold To: (5016)
STEEL & PIPE SUPPLY
1003 FORT GIBSON ROAD
CATOOSA, OK 74015

Ship To: (1)
STEEL & PIPE SUPPLY
1003 FORT GIBSON ROAD
CATOOSA, OK 74015

Tel: 918-266-6325 Fax: 918 266-4652

CERTIFICATE of ANALYSIS and TESTS Cert. No: MAR 268339
05Mar15

Part No 0010
ROUND A500 GRADE B(C)
2.375"OD (2"NPS) X SCH40 X 21'

		Pcs	Wgt
		111	8,508

Heat Number	Tag No	Pcs	Wgt
E86298	927111	37	2,836
	YLD=69600/TEN=79070/ELG=24.2		
E86298	927113	37	2,836
E86298	927114	37	2,836

Heat Number *** Chemical Analysis ***
E86298 C=0.1700 Mn=0.5100 P=0.0100 S=0.0110 Si=0.0190 Al=0.0450
Cu=0.0300 Cr=0.0300 Mo=0.0030 V=0.0010 Ni=0.0100 Cb=0.0010
MELTED AND MANUFACTURED IN THE USA

R#15-0626 H#E86298
BCT Pipe Sleeves
June 2015 SMT

WE PROUDLY MANUFACTURE ALL OF OUR HSS IN THE USA.
INDEPENDENCE TUBE PRODUCT IS MANUFACTURED, TESTED,
AND INSPECTED IN ACCORDANCE WITH ASTM STANDARDS.

CURRENT STANDARDS:
.................................A500/A500M-13
.................................A513-12
.................................A252-10
.................................A847/A847M-12

MATERIAL IDENTIFIED AS A500 GRADE B(C) MEETS BOTH
ASTM A500 GRADE B AND A500 GRADE C SPECIFICATIONS.

Page: 1 .... Last

Figure B-33. BCT Post Sleeve, Test No. SPTA-2

CERTIFICATE OF COMPLIANCE

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

CUSTOMER NAME: TRINITY INDUSTRIES

CUSTOMER PO: 187087

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

LOT#: 30361-P

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

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

*Pounds Per Square Inch.

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

CHEMICAL COMPOSITION

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

QUANTITY AND DESCRIPTION:

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

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

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS

6th DAY OF November, 20 17 — Linda McComas — 11/6/17
APPROVED SIGNATORY — DATE

Merry F. Shane

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

Figure B-34. 14-in. (356-mm) Long Guardrail Bolt, Test Nos. SPTA-1 and SPTA-2

CHARTER STEEL
A Division of Charter Manufacturing Company, Inc.

Melted in USA Manufactured in USA

EMAIL

CHARTER STEEL TEST REPORT

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

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

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

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

Test results of Heat Lot # 10508780

Lab Code: 7388

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

Test results of Rolling Lot # 1221251

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

REDUCTION RATIO=30:1

Specifications: Manufactured per Charter Steel Quality Manual Rev Date 05/12/17
Charter Steel certifies this product is indistinguishable from background radiation levels by having process radiation detectors in place to measure for the presence of radiation within our process & products.
Meets customer specifications with any applicable Charter Steel exceptions for the following customer documents:
Customer Document = ASTM A29/A29M Revision = 16 Dated = 01-DEC-16

Additional Comments:

Melt Source:
Charter Steel
Saukville, WI, USA

Trip: 1166878

ACCREDITED
Testing Laboratory

Page 1 of 2

This MTR supersedes all previously dated MTRs for this order
Janice Barnard Division Mgr. of Quality Assurance
barnardJ@chartersteel.com
Printed Date : 08/27/2017

Figure B-35. ⅝-in. (16-mm) Diameter Nut, Test Nos. SPTA-1 and SPTA-2

R#16-692 5/8"x10" GR Bolt
Orange Paint H#20351510 L#150424L

3500G

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

MATERIAL CERTIFICATION

Customer: Stock
Date: December 16, 2015
Invoice Number:
Lot Number: 150424L
Part Number: 3500G
Quantity: 16,702 Pcs.
Description: 5/8" x 10" G.R. Bolt
Heat Numbers: 20351510 16,702

Specification: ASTM A307-A / A153 / F2329

MATERIAL CHEMISTRY

Heat	C	MN	P	S	SI	NI	CR	MO	CU	SN	V	AL	N	B	TI	NB
20351510	.09	.33	.007	.002	.06	.04	.05	.01	.06	.004	.001	.028	.007	.0001	.001	.001

PLATING OR PROTECTIVE COATING

HOT DIP GALVANIZED (Lot Ave.Thickness / Mils) 2.52 (2.0 Mils Minimum)

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

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

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

TRINITY HIGHWAY PRODUCTS LLC

STATE OF OHIO, COUNTY OF ALLEN
SWORN AND SUBSCRIBED BEFORE ME THIS 12-17-15

NOTARY PUBLIC

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

NOTARIAL SEAL STATE OF OHIO

MONIQUE HOLMES
Notary Public, State of Ohio
My Commission Expires
July 5, 2020

Figure B-36. 10-in. (254-mm) Long Guardrail Bolt, Test Nos. SPTA-1 and SPTA-2

33606

AZZ GALVANIZING-HAMILTON
7825 S. HOMESTEAD DRIVE
HAMILTON, IN 46742
TEL: (260) 488-4477
FAX: (260) 488-4499

ELGIN FASTENER GROUP
1415 S BENHAM RD
VERSAILLES IN 47042

8/17/16

MATERIAL CERTIFICATION

DESCRIPTION Misc. Fabricated Steel

P. O./ JOB# 114381/0053014/AAJ

GALVANIZED WEIGHT# 43,369

AZZ JOB #: 43534234

HEAT # 10435580

CERTIFICATION: AZZ GALVANIZING-HAMILTON CERTIFIES THAT THE ABOVE REFERENCED MATERIALS HAVE BEEN GALVANIZIED IN ACCORDANCE WITH THE ASTM-123 AND OR ASTM-153 SPECIFICATION STANDARD AND MEET THE CRITERIA THEREIN. THIS PRODUCT HAS BEEN GALVANIZED IN THE USA.

AVERAGE MIL THICKNESS: 2.94

Beverly Laney
Quality

Figure B-37. 1¼-in. (32-mm) Long Guardrail Bolt

From: FAXmaker To: 1-815-877-0734 Page: 1/1 Date: 5/14/2015 4:00:16 PM

Heat Number	Shipper No	Invoice No	Customer PO#	Customer Name
2038622	680907	701917	5-7-2015 MIKE	GAFFNEY BOLT CO.

CMC

1SERIES-BPS ®

CMC STEEL SOUTH CAROLINA
310 New State Road
Cayce SC 29033-3704

CERTIFIED MILL TEST REPORT
For additional copies call
800-637-3227

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

Richard S. Ray
Richard S. Ray - CMC Steel SC
Quality Assurance Manager

	SOLD TO	SHIP TO	
HEAT NO.:2038622 SECTION: ROUND 7/8 x 40'0" A36/52950 GRADE: ASTM A36-12/A529-05 Gr 50 ROLL DATE: 09/09/2014 MELT DATE: 09/08/2014	Infra-Metals - Mars 1601 Broadway St Marseilles IL US 61341-9326 8009875283	Infra-Metals - Mars 1601 Broadway St Marseilles IL US 61341-9326 8009875283	Delivery#: 81471569 BOL#: 70533247 CUST PO#: CE-485729 CUST P/N: DLVRY LBS / HEAT: 9075.000 LB DLVRY PCS / HEAT: 111 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.16%	Elongation Gage Lgth test 1	8IN		
Mn	0.73%	Reduction of Area test 1	58%		
P	0.013%	Yield to tensile ratio test1	0.75		
S	0.021%	Yield Strength test 2	56.9ksi		
Si	0.22%	Tensile Strength test 2	76.5ksi		
Cu	0.32%	Elongation test 2	25%		
Cr	0.13%	Elongation Gage Lgth test 2	8IN		
Ni	0.10%	Reduction of Area test 2	57%		
Mo	0.027%	Yield to tensile ratio test2	0.74		
V	0.000%	C+(Mn/6)	0.28%		
Cb	0.026%				
Sn	0.010%				
Al	0.000%				
Ti	0.001%				
N	0.0084%				
Carbon Eq A529	0.38%				
Yield Strength test 1	57.1ksi				
Tensile Strength test 1	76.3ksi				
Elongation test 1	23%				

THIS MATERIAL IS FULLY KILLED, 100% MELTED AND MANUFACTURED IN THE USA, WITH NO WELD REPAIR OR MERCURY CONTAMINATION IN THE PROCESS.

REMARKS :

ALSO MEETS ASTM GRADE A36 REV-03A, A529 GR.50, A572-2013A GR.50, A709 GR.36, A709 GR.50, A992, AASHTO GRADE M270 GR.36, M270 GR.50, CSA G40.21-04 GRADE 44W, 50WASME SA-36 2008A ADDEND A.

03/18/2015 14:05:35
Page 1 OF 1

Figure B-38. 8-in. (203-mm) Long Guardrail Bolt, Test Nos. SPTA-1 and SPTA-2

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: CASH SALE
PB Invoice#: 96359
Cust PO#: MIDWEST ROADSIDE
Date: 2/08/2017
Shipped: 2/10/2017

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 8-1/2 GALV ASTM F3125 GRADE A325 HEAVY HEX BOLT

Heat#: NF16102579 **Base Steel:** 4140 **Diam:** 7/8

Source: KREHER STEEL CO LLC **Proof Load:** 39,250 LBF

C :	.420	**Mn:**	.930	**P :**	.013	**Hardness:**	269 HBN				
S :	.025	**Si:**	.250	**Ni:**	.080	**Tensile:**	57,700 LBF	**RA:**	.00%		
Cr:	.910	**Mo:**	.180	**Cu:**	.190	**Yield:**	0	**Elon:**	.00%		
Pb:	.000	**V :**	.009	**Cb:**	.000	**Sample Length:**	0				
N :	.000			**CE:**	.6702	**Charpy:**		**CVN Temp:**			

LOT#18344

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

R#17-414 NY DOT BOX BEAM
7/8" BOLTS AND NUTS

Figure B-39. 8½-in. (216-mm) Long Bolt, Test No. SPTA-1

GERDAU

GERDAU SPECIAL STEEL NORTH AMERICA
5591 MORRILL ROAD
JACKSON, MICHIGAN 49201

CERTIFIED MATERIAL TEST REPORT

CUSTOMER ORDER NUMBER	CUSTOMER PART NUMBER	HEAT NUMBER	WORK ORDER NUMBER	DATE
P005973-2	B1045SC1.1250	75062745 210mm Billet	301868 101	5/23/16

REPORT TO

UNYTITE INC
ONE UNYTITE DRIVE

PERU , IL 61354-9710

SHIP TO

UNYTITE, INC
LASALLE PLANT

325 CIVIC RD
LASALLE , IL 61301

ORDERED

GRADE	SIZE	LENGTH
1045	1 1/8" RND	24' 10 1/2"

CUSTOMER SPECIFICATIONS

SAE 1045; ASTM E381-01; RMS 021 DATED 9/28/06

CHEMICAL ANALYSIS

C	Mn	P	S	Si	Ni	Cr	Mo	Cu	Sn	Al
0.44	0.73	0.012	0.028	0.25	0.11	0.16	0.04	0.18	0.001	0.003

V	Nb
0.055	0.001

GRAIN SIZE SPECIFICATION ASTM E112 FINE GRAIN 5-8

MICROCLEANLINESS SPECIFICATION ASTM E45 METH A

	A		B		C		D	
	T	H	T	H	T	H	T	H
AVERAGE	1.7	0.5	1.3	0.0	0.8	0.1	0.8	0.2

MACROSTRUCTURAL TEST PER - ASTM E381

	PLATE I S	PLATE I R	PLATE I C	PLATE II
FRONT	1	1	1	NONE
MIDDLE	1	1	1	NONE

PAGE 1

We certify that these data are correct and in compliance with specified requirements.

Gerdau Monroe
3000 East Front Street
Monroe, MI 48161

Gabriela Felipe
Quality Assurance Representative

CONTINUED ON PAGE 2

Figure B-40. ⅞-in. (22-mm) Hex Nut, Test No. SPTA-1

NUCOR
NUCOR CORPORATION
NUCOR STEEL NEBRASKA

Mill Certification
4/5/2012

2911 East Nucor Road
NORFOLK, NE 68701
(402) 644-0200
Fax: (402) 644-0329

Sold To: SHINSHO AMERICAN CORP
26200 TOWN CENTER DR
NOVI, MI 48375
(860) 793-1232
Fax: (248) 675-5575

Ship To: UNYTITE, INC
ONE UNYTITE DRIVE
PERU, IL 61354
(815) 224-2221

Customer P.O.	SA7599	Sales Order	121270.1
Product Group	Special Bar Quality	Part Number	30001000300XHL0
Grade	1045MLAT Magnetic Flux Leakage Test	Lot #	NF1210105451
Size	1" (1.0000) Round	Heat #	NF12101054
Product	1" (1.0000) Round 25 0" 1045MLAT	B.L. Number	N1-224254
Description	1045MLAT	Load Number	N1-171354
Customer Spec		Customer Part #	

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.

* - Test outside scope of L-A-B accreditation

C	Mn	V	Si	S	P	Cu	Cr	Ni	Mo	Al	Cb
0.43%	0.87%	0.000%	0.24%	0.020%	0.015%	0.09%	0.08%	0.04%	0.00%	0.021%	0.000%
Pb	**Sn**	**Ca**	**As**	**N**	***NICR**						
0.000%	0.003%	0.0008%	0.0000%	66 ppm	0.12						

*NICR: Ni+Cr

*Yield 1: 63674psi (439MPa) | *Tensile 1: 102223psi (705MPa) | *Elongation 20% in 8"(% in 203.3mm)

*Decarb depth 0.0017in | *MAGNETIC FLUX LEAKAGE OK | *Machined Straightened OK

*Austenitic Grain Size: 8.000 per ASTM E112-9 | 6"Reduction Ratio 56 :1

ASTM E381
*Surface: 1 *Mid Radius: 1 *Center: 2

ASTM E45 Method A (Worst)
Sulfides: T: 1.5 H: 1.0 Alumina: T: 0.5 H: 0.0 Silicates: T: 0.0 H: 0.0 Globular: T: 0.5 H: 0.0

1. All manufacturing processes of the steel materials in this product, including melting, have been performed in the United States.
2. All products produced are weld free.
3. Mercury, in any form, has not been used in the production or testing of this material.
4. L.A.B Accredited, Chemical: ASTM E415, E1019; Mechanical: A370, E10, E18, Inclusion:E45 Cert.#L2232 exp. 12/16/2013
5. Test conform to ASTM A29-11a, ASTM E415 and ASTM E1019-resulphurized grades or applicable customer requirements.
6. All material melted at Nucor Steel Nebraska is produced in an Electric Arc Furnace
7. Strand Cast

LABORATORY ACCREDITATION BUREAU
ACCREDITED ISO/IEC 17025
Cert# L-2232 Testing - Chemical

Jim Hill
Division Metallurgist

NBMG-10 January 1, 2012

Page 1 of 1

Figure B-41. ⅞-in. (22-mm) Hex Nut, Test Nos. SPTA-1 and SPTA-2

JINAN STAR FASTENER CO., LTD

NO.75 CUIPING STREET PINGYIN JINAN CHINA
TEL: 0086 531 87896380 FAX: 0086 531 87871032
E-mail: zhangyuhua@star-fastener.com

CERTIFICATE OF INSPECTION

Manufacturering Date:2012-7-1 **DATE: 2012-7-12**

Customer Part Number客户产品代号	92006
Customer Control (PO) Number客户订单号	120139589
Product Description产品描述	7/8-9x8-1/2 A307 G
Surface Condition表面处理	HDG
Head Marking头部标记	307A and 01RL
Lot Size (QTY Shipped):装运数量	700pcs
Lot Number订单号	FAS1251
Mechanical properties机械性能要求	SAE J429-2011 307A

Material type:	24mm LY		Heat Number		331200696			
Chemical composition:	C%	Mn%	Si%	S%	P%	Ni%	Cr%	Cu%
	0.05	0.40	0.14	0.016	0.023			

Sampling Plan Used 使用的抽样方案	ISO 3269-2000 Dimensional & Appearance AQL=0.65 AC=1 / Mechanical AQL= 0.65 AC=0

Specification技术要求:	Test method 檢測标准	Standard 标准	单位	Test value 实测值	Sampling Plan 抽样方案	ACC 合格	REJ 不合格
Width across Flat对边尺寸	ASME B18.2.1-2010	1.269-1.312	in	1.295-1.299	50/1	50	0
Width across Corners对角尺寸	ASME B18.2.1-2010	1.447-1.516	in	1.484-1.489	50/1	50	0
Height高度	ASME B18.2.1-2010	0.531-0.604	in	0.543-0.549	50/1	50	0
Body Dia杆径	ASME B18.2.1-2010	0.852-0.895	in	0.864-0.866	50/1	50	0
Thread length螺纹长度	ASME B18.2.1-2010	min:2.25	in	2.32-2.34	50/1	50	0
Length总长度	ASME B18.2.1-2010	8.3-8.66	in	8.48-8.52	50/1	50	0
Major 大径	ASME B18.2.1-2010	0.859-0.873	in	0.8625-0.866	50/1	50	0
Thread 螺纹	ANSI B1.1-2003	GO		GO	50/1	50	0
	ANSI B1.1-2003	NO GO		NO.GO	50/1	50	0
Surface hardness表面硬度	ASTM F606-2011		30N		5/0	5	0
Core Hardness芯部硬度	ASTM F606-2011	69-100	HRB	91-96.7	5/0	5	0
Tensile Strength抗拉强度	ASTM F606-2011	60	KSI	92.4-93.9	5/0	5	0
Proof Load保证载荷	ASTM F606-2011		KSI		1/0	1	0
Decarburized脱碳	ASTM F606-2011		in		1/0	1	0
Appearance外观	ASTM F788-2008	Visual		OK	50/1	50	0

Signature: Fu Yan Jun

Figure B-42. 8½-in. (216-mm) Long Bolt, Test No. SPTA-2

CERTIFIED MATERIAL TEST REPORT
FOR ASTM A563, GRADE A FIN HEX NUTS

FACTORY: JIAXIN GUANGMING HARDWARE CO.,LTD.. DATE:2017.8.15
ADDRESS DALIU INDUSTRY ZONE,WUYUAN TOWN,HAIYAN,ZHEJIANG,CHINA.
MFG LOT NUMBER D705JS111
CUSTOMI INFASCO DISTRIBUTION
PO NUMBER: PO#229695

SAMPLE SIZE : ACC. TO ASME B18. 18-2011 PART NO NFJ1U-56000G01V
SIZE: 7/8-9 HDG T/O.022" QNTY: 4800 PCS MANU.DATE:2017.5.15

STEEL PROPERTIES
STEEL GRADE: C1008 HEAT NUMBER: G16-7344

CHEMISTRY SPEC:	C %*100 0.55max	Mn%*100 min	P %*1000 0.12max	S %*1000 0.15max
TEST:	0.06	0.28	0.028	0.013

DIMENSIONAL INSPECTIONS SPECIFICATION: ASME/ANSI B18.2.2-2010

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F812-07		PASSED	100	0
THREAD	ASME B1.3		PASSED	32	0
ACROSS FLATS		1.269-1.312	1.289-1.301	32	0
WIDTH A/C		1.447-1.516	1.451-1.502	8	0
HEIGHT		0.724-0.776	0.731-0.769	8	0
MINOR DIA.					
MARK	NO MARKING		PASSED	100	0

MECHANICAL PROPERTIES: 1/4"thru1" SPECIFICATION: ASTM A563-07a GR-A

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
HARDNESS :	ASTM F606-10a	B 68-32 HRC	HRC21-HRC23	8	0
PROOF LOAD:	ASTM F606-10a	MIN 68000 PSI	68020PSI	4	0

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
HOT DIP GALVANI	ASTM F 2329-05	MIN 0.0017"	0.0019 IN"	5	0

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM OR SAE SPECIFICATION. WE CERTIFY THATTHIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER 嘉兴光明五金制品有限公司 TESTING LABORATORY. All parts meet the requirements of FQA and records of compli JIAXING GUANGMING HARDWARE CO.,LTD.
Maker's ISO#626012Q11102ROS

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

Figure B-43. ⅞-in. (22-mm) Hex Nut, Test No. SPTA-2

Certificate of Compliance

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

Customer Midwest Machinery **Date Shipped** 06/16/2016

Customer Order Number 3275 **BFM Order Number** 1338859

Item Description

Description 5/8"-11 x 10" Hex Bolt **Qty** 157

Lot # 208977 **Specification** ASTM A307-14 Gr A **Finish** ASTM F2329

Raw Material Analysis

Heat# DL15107048

Chemical Composition (wt% Heat Analysis) By Material Supplier

C	Mn	P	S	Si	Cu	Ni	Cr	Mo
0.22	0.82	0.007	0.010	0.27	0.20	0.06	0.10	0.015

Mechanical Properties

Sample #	Hardness	Tensile Strength (lbs)	Tensile Strength (psi)
1	91 HRBW	21,700	97,660
2			
3			
4			
5			

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

Authorized Signature: ____________ **Date:** 6/16/2016

Brian Hughes
Quality Assurance

Figure B-44. 10-in. (254-mm) Long Bolts, Test Nos. SPTA-1 and SPTA-2

R#16-0217
BCT Hex Nuts
December 2015 SMT
Fastenal part#36713
Control# 210101523

STELFAST® INC.

22979 Stelfast Parkway
Strongsville, Ohio 44149

CERTIFICATE OF CONFORMANCE

DESCRIPTION OF MATERIAL AND SPECIFICATIONS

- Sales Order #: 129980
- Part No: AFH2G0625C
- Cust Part No: 36713
- Quantity (PCS): 1200
- Description: 5/8-11 Fin Hx Nut Gr2 HDG/TOS 0.020
- Specification: SAE J995(99) - GRADE 2 / ANSI B18.2.2
- Stelfast I.D. NO: 595689-O201087
- Customer PO: 210101523
- Warehouse: DAL

The data in this report is a true representation of the information provided by the material supplier certifying that the product meets the mechanical and material requirements of the listed specification. This certificate applies to the product shown on this document, as supplied by STELFAST INC. Alterations to the product by our customer or a third party shall render this certificate void.

This document may only be reproduced unaltered and only for certifying the same or lesser quantity of the product specified herein. Reproduction or alteration of this document for any other purpose is prohibited.

Stelfast certifies parts to the above description. The customer part number is only for reference purposes.

David Biss
Quality Manager

December 07, 2015

Page 1 of 1

Figure B-45. ⅝-in. (16-mm) Diameter Nuts, Test Nos. SPTA-1 and SPTA-2

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

FACTORY: NINGBO ECONOMIC & TECHNICAL DEVELOPMENT ZONE YONGGANG FASTENERS CO., LTD.
REPORT DATE:2016/12/29
R#17-507 H#816070039
ADDRESS: FuShan South Road No.17,BeiLun NingBo China
BCT Cable Bracket Bolts
MANUFACTURE DATE:2016/12/2
TEL#(852)25423366
CUSTOMER: FASTENAL
MFG LOT NUMBER:M-2016HT927-9
SAMPE SIZE: ACC.TO Dimension:ASME B18.18-11;Mechanical Properties:ASTM F1470-12
MANU QTY: 4800PCS
SHIPPED QTY: 4800PCS
SIZE: 5/8-11X1 1/2 HDG
HEADMARKS: 307A PLUS NY
PO NUMBER:220023115
PART NO:1191919

STEEL PROPERTIES:
MATERIAL TYPE:Q195
HEAT NUMBER: 816070039

CHEMISTRY SPEC:	C %*100	Mn%*100	P %*1000	S %*1000
Grade A ASTM A307-12	0.29max	1.20 max	0.04max	0.15max
TEST:	0.07	0.28	0.016	0.003

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

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
**********************	**********************************	******************	********	********
VISUAL	ASTM F788-2013	PASSED	22	0
THREAD	ASME B1.1-2003,3A GO,2A NOGO	PASSED	15	0
WIDTH FLATS	0.906-0.938	0.915-0.928	4	0
WIDTH A/C	1.033-1.083	1.048-1.057	4	0
HEAD HEIGHT	0.378-0.444	0.394-0.424	4	0
THREAD LENGTH	1.420-1.560	1.435-1.541	15	0
LENGTH	1.420-1.560	1.435-1.541	15	0

MECHANICAL PROPERTIES: SPECIFICATION: ASTM A307-2012 GR-A

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
********************	*****************	*****************	*****************	********	********
CORE HARDNESS :	ASTM F606-2014	69-100 HRB	76-79 HRB	4	0
WEDGE TENSILE:	ASTM F606-2014	Min 60 KSI	65-69 KSI	4	0

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
COATINGS OF ZINC:	SPECIFIATION:ASTM F2329-2013				
HOT DIP GALVANIZED	ASTM B568-98(2104)	Min 0.0017"	0.0017" -0.0018"	4	0

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.

Maker's ISO# 00109Q16722R3M/3302

NINGBO ECONOMIC & TECHNICAL DEVELOPMENT ZONE YONGGANG FASTENERS CO., LTD

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

Figure B-46. 1½-in. (38-mm) Long Bolt, Test Nos. SPTA-1 and SPTA-2

Certificate of Compliance

Sold To: **Midwest Steel** **Purchase Order: 8894**

Part# 307-050200 (1/2 x 2 A307 HHC PLAIN) **Invoice: 583078**

Qty: 62 **Invoice Date: 07/14/18**

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

ASTM A307 - 14

Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60000 PSI Tensile Strength

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

Nuts & Bolts Representative

Boyd Rydel

Printed Name

08/16/18

Figure B-47. 2-in. (51-mm) Long Bolt, Test No. SPTA-1

ISO/TS 16949 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

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

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2018/08/23

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 210154443
COMMODITY : HEX MACHINE BOLT GR-A
SIZE : 1/2-13X2 NC
LOT NO : 1B1832558
SHIP QUANTITY : 8, 400 PCS
LOT QUANTITY 21, 199 PCS
HEADMARKS : CYI & 307A
MANUFACTURE DATE : 2018/05/09
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM180524005
INVOICE NO : GEM/FNL-180606ED
PART NO : 91887
SAMPLING PLAN : ASME B18. 18-2011(Category. 2)/ASTM F1470-2012
HEAT NO : 18200477-3
MATERIAL : X1008A
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A307-2014

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0. 3300	1. 2500	0. 0410		
Test Value	0. 0300	0. 0600	0. 2800	0. 0100	0. 0090	0. 0200

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

SAMPLED BY : FCHUN

INSPECTIONS ITEM	SAMPLE	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
THREAD LENGTH	15 PCS	1. 2500 inch	1. 2500-1. 2540 inch	15	0
MAJOR DIAMETER	15 PCS	0. 4870-0. 4980 inch	0. 4910-0. 4930 inch	15	0
BODY DIAMETER	4 PCS	0. 4820-0. 5150 inch	0. 4910-0. 4910 inch	4	0
WIDTH ACROSS CORNERS	4 PCS	0. 8260-0. 8660 inch	0. 8380-0. 8410 inch	4	0
HEIGHT	4 PCS	0. 3020-0. 3640 inch	0. 3250-0. 3270 inch	4	0
NOMINAL LENGTH	15 PCS	1. 9400-2. 0400 inch	1. 9750-1. 9780 inch	15	0
WIDTH ACROSS FLATS	4 PCS	0. 7360-0. 7500 inch	0. 7400-0. 7420 inch	4	0
SURFACE DISCONTINUITIES	29 PCS	ASTM F788-2013	PASSED	29	0
AND IS MATCHED WITH THE REAMING NUT AFTER PLATING	29 PCS	nut	PASSED	29	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A 307-2014

SAMPLED BY : GDAN LIAN

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15 PCS	ASTM F606-2016		Max. 100 HRB	82-83 HRB	15	0
TENSILE STRENGTH	4 PCS	ASTM F606-2016		Min. 60 KSI	76-79 KSI	4	0
PLATING THICKNESS(μ m)	5 PCS	ASTM B568-1998		>=53	80. 36-87. 57	5	0

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

page 1 of 2

Figure B-48. 2-in. (51-mm) Long Bolt, Test No. SPTA-2

STELFAST® INC.

22979 Stelfast Parkway
Strongsville, Ohio 44149

CERTIFICATE OF CONFORMANCE

DESCRIPTION OF MATERIAL AND SPECIFICATIONS

- Sales Order #: 173821
- Part No: AFH2G0500C
- Cust Part No: 36709
- Quantity (PCS): 16800
- Description: 1/2-13 Fin Hx Nut Gr2 HDG/TOS 0.018
- Specification: SAE J995(99) - GRADE 2 / ANSI B18.2.2
- Stelfast I.D. NO: 676197-O202987
- Customer PO: 210165954
- Warehouse: DAL

The data in this report is a true representation of the information provided by the material supplier certifying that the product meets the mechanical and material requirements of the listed specification. This certificate applies to the product shown on this document, as supplied by STELFAST INC. Alterations to the product by our customer or a third party shall render this certificate void.

This document may only be reproduced unaltered and only for certifying the same or lesser quantity of the product specified herein. Reproduction or alteration of this document for any other purpose is prohibited.

Stelfast certifies parts to the above description. The customer part number is only for reference purposes.

David Biss
Quality Manager

August 13, 2018

Page 1 of 1

Figure B-49. ½-in. (13-mm) Diameter Nuts, Test No. SPTA-2

连 云 港 兴 怡 紧 固 件 有 限 公 司
LIANYUNGANG XINGYI FASTENERS CO.,LTD.
ADDRESS: Industrial Assembly Zone,Haizhon Bay,Haitou Town,Ganyu County, Lianyungang City
Tel:0574-86505922
Fax:0574-86505904

检测报告
TEST REPORT

DATE（日期):MAR.2014

PURCHASER(客户): BRIGHTON-BEST INTERNATIONAL(TAIWAN)INC.	ISO NO .(ISO号码):0104Q17660R1M/3302
CONTRACT NO.(合同号):U15838LA PART NO.:495053	SIZE(规格):1/2-13*1-1/2
MANUFACTURING DATE(生产日期):2014-01-20	QUANTITIES(数量):64800PCS
COMMODITY(品名):A307A HEX BOLTS	FINISH(色别):HDG
MATERIAL(材料):A3	LOT NO.(批号):XY3005140047

DIMENSIONAL INSPECTION ACCORDING TO ASME B18.2.1-2010 SAMPLING ACCORDING TO ASME B18.2.1-2010
SAMPLING DATE(抽检日期):2014-01-20 SAMPLED BY :WANGJUAN SAMPLES(抽样数): 20件

INSPECTION ITEM (检测项目)	STANDARD (标准值)	ACTUAL RESULT (实测值)	RESULT
APPEARANCE外观	OK	OK	OK
HEAD MARK 标记	XYLX &307A	OK	OK
MAJOR DIA牙大径	0.4891-0.5	0.491-0.493	OK
WIDTH ACROSS FLATS 对边	0.725-0.75	0.741-0.746	OK
WIDTH ACROSS CORNERS 对角	0.826-0.866	0.845-0.855	OK
HEAD HEIGHT 头部厚度	0.302-0.364	0.315-0.342	OK
BODY DIAMETER 杆径	F/T	F/T	OK
LENGTH 长度	1.44-1.54	1.45-1.52	OK
THREAD LENGTH 螺纹长度	F/T	F/T	OK
GO-GAGE 通规	GO	GO	OK
NO-GO-GAGE止规	NO-GO	NO-GO	OK
ZINC THICKNESS锌层厚度(ASTMF-2329)	0.0017MIN	0.002	OK

CHEMICAL COMPOSITION ACCORDING TO ASTM A307 2010
SAMPLING DATE(抽检日期):2014-01-15 SAMPLED BY :LIUYONGJIAN HEAT NO .炉号:180135

CHEMICAL 化学元素(%)	C 碳	Mn 锰	P 磷	S 硫	Si 硅						
TEST RESULT 实测值	0.06	0.38	0.016	0.033	0.12						

MECHANICAL PROPERTIES ACCORDING TO ASTM A307 2010 SAMPLING ACCORDING TO ASTM A307 2010
SAMPLING DATE(抽检日期):2014-01-20 SAMPLED BY :CHENWENTAO SAMPLES(抽样数): 3件

TEST ITEM 检测项目		STANDARD (标准值)	ACTUAL RESULT (实测值)	RESULT
HARDNESS 硬度(HRB)	SURFACE 表面	100MAX		
	CORE 芯部		80-89	OK
TENSILE STRENGTH 抗拉强度(Psi)		60MIN	81-84	OK

ADDRESS: Industrial Assembly Zone,Haizhon Bay,Haitou Town,Ganyu County, Lianyungang City
FROM:Sunny wang
TEL:0574-86508138

连云港兴怡紧固件有限公司 LIANYUNGANG XINGYI FASTENERS CO.,LTD. 质量部 INSPECTION DEPARTMENT

(SIGNATURE)

Figure B-50. 1½-in. (38-mm) Long Bolts, Test No. SPTA-1

HAIYAN YUXING NUTS CO.,LTD.

CHANGQIAN TOWN,HAIYAN COUNTY ZHEJIANG ,314304 CHINA

QUALITY CERTIFICATE COUNTRY OF ORIGIN-CHINA

CUSTOMER:BRIGHTON-BEST INTERNATIONAL,INC. SIZE:1/2-13
GOODS: GRADE 2 FINISHED HEX NUT (INCH) HOT DIP GALVANIZED ASTM F2329
ORDERNO.:U29216 DATE:AUG.15,2015
PART NO.:323200 INV NO.:00607179
LOT NO.: HY1534005G LOT SIZE:43.20MPCS
MATERIAL TYPE: Q195 HEAT NO.:180036

CHARACTERISTIC	SEPCIFICAT	STANDARD (MM)	RESULT	ACCEPT
WIDTH ACROSS FLATS SAMPLE SIZE N=32	ASME/ANSI B18.2.2-10	MAX-MIN 19.05-18.69	MAX-MIN 19.03-18.72	OK
WIDTH ACROSS CORNER SAMPLE SIZE N=32		MAX-MIN 22.00-21.34	MAX-MIN 21.97-21.37	OK
HEIGHT SAMPLE SIZE N=32		MAX-MIN 11.38-10.85	MAX-MIN 11.35-10.89	OK
THREAD 'GO"SAMPLE SIZE N=32	ASMEB1.1-03	2B +0.018	OK	OK
THREAD "NO GO" SAMPLE SIZE N=32		2B +0.018	OK	OK
PROOF LOAD SAMPLE SIZE N=4	ASTM A563-2007a	MIN 56934N	56934N	OK
HARDENESS SAMPLE SIZE N=8		HRC MAX. 32	16-17	OK
PLATING THICKNESS SAMPLE SIZE N=8	ASTM F2329	MIN 3MY	3MY	OK

	C	Mn	Si	P	S
CHEMICAL ANALYSIS	0.08	0.37	0.10	0.020	0.033

THIS CERTIFICATE CONFIRMING QUALIFICATION TO ASME B18.2.2-2010 / ASTM A563-2007a
FACTORY INSPECTOR: 黄伟明 DIRECTOR: 沈家华

海盐宇星螺帽有限责任公司
HAIYAN YUXING NUTS CO., LTD.
沈家华

8

Figure B-51. ½-in. (14-mm) Dia. Nuts, Test No. SPTA-1

FNL PART#91885
FNL PO#110272208

ZHEJIANG LAIBAO PRECISION TECHNOLOGY CO.,LTD
NO.668 DONGHAI ROAD,XITANGQIAO TOWN,HAIYAN,ZHEJIANG,CHINA
TEL: +86-573-86813788 FAX:+86-573-86811201

QUALITY CERTIFICATE

Customer Name :	BRIGHTON - BEST INTERNATIONAL (TAIWAN), INC.	**Country of origin:**	China
INV.NO.:	BBT1983	**QUANTITY:**	5.400 MPcs
P.O.NO.:	U53338	**TEST DATE:**	05.10,2018
S/C NO.:	BBI18146	**ON BOARD:**	05.12,2018
PART NO.:	495053	**SIZE:**	1/2-13×1-1/2
LOT NO.:	1803107601	**DESCRIPTION:**	A307 GRADE A HEX BOLT H.D.G
PRODUCTION DATE:	03.14,2018		

Size: ASME B18.2.1 2012
Material and Mechanical properties: ASTM A307-2014 GR.A
Zinc Coatings: ASTM F2329-13

1.Chemical Composition Of Material （％）

STEEL GRADE /HEAT NO:	DIA. （mm）	C	Si	Mn	P	S	Cr	B	Ni	Al	Mo
Q195/180196	14	0.07	0.1	0.32	0.015	0.024					

2.Dimension

INSPECTION ITEM	SPECIFICATION	RESULT	SAMPLE SIZE
Head Marking	LB307A	LB307A	1
Width A/F (inch)	0.725-0.750	0.730-0.735	9
Width A/C (inch)	0.826-0.866	0.832-0.844	9
Head Height (inch)	0.302-0.364	0.305-0.316	9
Body Dia (inch)	0.482-0.515	0.486-0.490	3
Total Length (inch)	1.440-1.540	1.485-1.503	9
Thread Length (inch)	NOM 1.25	1.266-1.275	9
Major Dia (inch)	0.4891-0.5000	0.492-0.495	3
GO Ring Gauge	THE NUT OF UNC 1/2-13$^{+0.40}$ 2B	OK	3
NO GO Ring Gauge	UNC 1/2-13 2A	OK	3
Tensile Strength (Psi)	MIN 60000	77821-81230	2
Hardness (HRB)	MAX 100	80-82	4
Visual	OK	OK	25
Salt Spray Test	/	/	/
Zinc Thickness (μm)	MIN 53	57.9-59.1	9

We hereby certify that the material described herein has been manufactured and tested with satisfactory results in accordance with the requirement of the above material/dimensional specifications.

QIN YUE ZHU
Q.C Supervisor

Figure B-52. 1½-in. (38-mm) Long Bolts, Test No. SPTA-2

CERTIFIED MATERIAL TEST REPORT
FOR SAE J429 GRADE 5 HEX TAP BOLTS

SUPPLIER'S NAME:ZHEJIANG HEITER MFG & TRADE CO.LTD — REPORT DATE: 2018-1-18
ADDRESS: XITANGQIAO HAIYAN ZHEJIANG CHINA — MANUFACTURE COMPLETE DATE: 2017-12-25
CONTACT INFORMATION: JACK /(86)-0573-86862565
CUSTOMER: FASTENAL COMPANY PURCHASING--IMPORT TRAFFIC
MFG LOT NUMBER: 171223SM01
SAMPLING PLAN PER ASME B18.18-2011 Categories 2;ASTM F1470- — PO NUMBER: 220026125
DESCRIPTION: HEX TAP BOLTS GRADE 5 ZINC PLATED
SIZE: 7/16-14X2-1/2" QTY: 16450 PCS — PART NO: 0144506
HEADMARKS: NDF+THREE RADIAL LINE

STEEL PROPERTIES:
STEEL GRADE:1035 — HEAT NUMBER: H1708007009

CHEMISTRY SPEC:	C %	Mn%	P %	S %
	0.25~0.55	min	0.025max	0.025max
TEST:	0.33	0.78	0.025	0.01

DIMENSIONAL INSPECTIONS — SPECIFICATION: ASME B18.2.1-2012

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F788/F788M-13	PASSED	100	0
THREAD	ASME B1.1-08 2A	PASSED	32	0
WIDTH FLATS	0.625 " - 0.603 "	0.615 " - 0.621 "	8	0
WIDTH A/C	0.722 " - 0.687 "	0.699 " - 0.715 "	8	0
HEAD HEIGHT	0.316 " - 0.272 "	0.279 " - 0.303 "	8	0
MAJOR DIA	0.436 " - 0.426 "	0.433 " - 0.435 "	8	0
LENGTH	2.54 " - 2.44 "	2.48 " - 2.51 "	8	0

MECHANICAL PROPERTIES: 1/4"thru1" — SPECIFICATION: SAE J429-2014 GR-5

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS:	ASTM F606-14	25-34 HRC	28 - 31 HRC	8	0
SURFACE HARDNESS :	ASTM F606-14	30N54 MAX	48 - 50	8	0
WEDGE TENSILE:	ASTM F606-14	MIN 120000 PSI	132563 - 133441 PSI	4	0
PROOF LOAD	ASTM F606-14	MIN 85000 PSI	PASS	1	0
DECARBURIZATION	ASTM F2328-14		PASSED	1	0

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
ZINC PLATED	ASTM F1941-15	Clear Zinc FE/Zn 3AN			
Thickness	ASTM B568-98	Min3 μm	4.8-5.5 μm	8	0
Salt Spray Corrosion	ASTM B117-11	6 hours NO White Corrosion 12 hours NO Red Rust	PASS	8	0

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE SAE SPECIFICATION. WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.
All parts meet the requirements of FQA and records of compliance are on file.
Maker's ISO#CN11/20818

(SIGNATURE OF Q.A. LAB MGR.)
(ZHEJIANG GOLDEN AUTOMOTIVE FASTENER CO.LTD)

Figure B-53. 2½-in. (64-mm) Long Bolts, Test Nos. SPTA-1 and SPTA-2

ISO/TS 16949 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

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

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2017/08/15

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 210135286
COMMODITY : FINISHED HEX NUT GR-5
SIZE : 7/16-14 NC
LOT NO : 1N1760174
SHIP QUANTITY : 22, 500 PCS
LOT QUANTITY 152, 179 PCS
HEADMARKS : GENIUS SYMBOL & 2 ARC LINES(120 DEGREE)
MANUFACTURE DATE : 2017/07/25
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM170731007
INVOICE NO : GEM/FNL-170816ED-1
PART NO : 1136308
SAMPLING PLAN : ASME B18. 18-2011(Category. 2)/ASTM F1470-2012
HEAT NO : 17101400-3
MATERIAL : X1015A
FINISH : Fe/Zn 3AN ASTM F1941/F1941M-2016

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO SAE J995-2012

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.			0. 3000			
MAX.		0. 5500		0. 0500	0. 1500	
Test Value	0. 0300	0. 1400	0. 3700	0. 0120	0. 0060	0. 0400

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18. 2. 2-2015

SAMPLED BY : HXNAN

INSPECTIONS ITEM	SAMPLE	SPECIFIED		ACTUAL RESULT	ACC.	REJ.
WIDTH ACROSS CORNERS	6 PCS		0. 7680-0. 7940 inch	0. 7730-0. 7760 inch	6	0
FIM	15 PCS	ASME B18. 2. 2-2015	Max. 0. 0180 inch	0. 0160-0. 0180 inch	15	0
THICKNESS	6 PCS		0. 3650-0. 3850 inch	0. 3750-0. 3760 inch	6	0
WIDTH ACROSS FLATS	6 PCS		0. 6750-0. 6880 inch	0. 6790-0. 6800 inch	6	0
SURFACE DISCONTINUITIES	29 PCS		ASTM F812-2012	PASSED	29	0
THREAD	15 PCS		GAGING SYSTEM 21	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO SAE J 995-2012

SAMPLED BY : TANGHAO

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15 PCS	ASTM F606-2014		Max. 32 HRC	28-29 HRC	15	0
PROOF LOAD	6 PCS	ASTM F606-2014		Min. 120, 000 PSI	OK	6	0
PLATING THICKNESS(μ m)	29 PCS	ASTM B568-1998		>=3	3. 2-4. 77	29	0
SALT SPRAY TEST	15 PCS	ASTM B117-16		6 HOURS NO WHITE RUST, 12 HOURS NO RED RUST	OK	15	0

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

Quality Supervisor: Erin

page 1 of 1

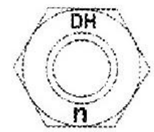
Figure B-54. 7/16-in. (11-mm) Diameter Nuts, Test Nos. SPTA-1 and SPTA-2

NUCOR
FASTENER DIVISION

LOT NO.
371123B

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

CUSTOMER NO/NAME
8001 FASTENAL COMPANY-KS   NUCOR ORDER # 978943
TEST REPORT SERIAL# FB488556   CUST PART # 38210
TEST REPORT ISSUE DATE 3/04/16
DATE SHIPPED 8/17/16   CUSTOMER P.O. # 210117217
NAME OF LAB SAMPLER: SANDRA NEUMANN-PLUMMER, LAB TECHNICIAN



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

NUCOR PART NO	QUANTITY	LOT NO.	DESCRIPTION
175647	3600	371123B	1-8 GR DH HV H.D.G.

MANUFACTURE DATE 1/07/16   HEX NUT H.D.G./GREEN LUBE

--CHEMISTRY   MATERIAL GRADE -1045L

**CHEMISTRY COMPOSITION (WT% HEAT ANALYSIS) BY MATERIAL SUPPLIER   NUCOR STEEL - SOUTH CAROL

MATERIAL NUMBER	HEAT NUMBER	C	MN	P	S	SI
RM030412	DL15105591	.44	.64	.005	.020	.20

--MECHANICAL PROPERTIES IN ACCORDANCE WITH ASTM A563-07a

SURFACE HARDNESS (R30N)	CORE HARDNESS (RC)	PROOF LOAD 90900 LBS	TENSILE STRENGTH DEG-WEDGE (LBS)	STRESS (PSI)
N/A	26.6	PASS	N/A	N/A
N/A	27.0	PASS	N/A	N/A
N/A	27.6	PASS	N/A	N/A
N/A	28.9	PASS	N/A	N/A
N/A	26.7	PASS	N/A	N/A
AVERAGE VALUES FROM TESTS	27.4			

PRODUCTION LOT SIZE 90800 PCS

--VISUAL INSPECTION IN ACCORDANCE WITH ASTM A563-07a   80 PCS. SAMPLED   LOT PASSED

--COATING - HOT DIP GALVANIZED TO ASTM F2329-13 - GALVANIZING PERFORMED IN THE U.S.A.

1. 0.00294	2. 0.00311	3. 0.00346	4. 0.00235	5. 0.00218	6. 0.00270	7. 0.00353
8. 0.00322	9. 0.00406	10. 0.00269	11. 0.00275	12. 0.00315	13. 0.00487	14. 0.00253
15. 0.00416						

AVERAGE THICKNESS FROM 15 TESTS .00318
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	1.824	1.844
Thickness	32	0.980	1.001

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.

ACCREDITED

MECHANICAL FASTENER
CERTIFICATE NO. A2LA 0139.01
EXPIRATION DATE 12/31/17

NUCOR FASTENER
A DIVISION OF NUCOR CORPORATION

John W. Ferguson

JOHN W. FERGUSON
QUALITY ASSURANCE SUPERVISOR

Page 1 of 1

Figure B-55. 1-in. (25-mm) Diameter Nuts, Test No. SPTA-2

McMASTER-CARR

Certificate of Compliance

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

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

Purchase Order
E000548963

Order Placed By
Shaun M Tighe

McMaster-Carr Number
7204107-01

Page 1 of 1

08/02/2018

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

Certificate of compliance

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

Sarah Weinberg
Compliance Manager

Figure B-56. 16D Double Head Nail, Test Nos. SPTA-1 and SPTA-2

Certified Material Test Report to BS EN ISO 10204-2004 3.1

FOR USS FLAT WASHER HDG

COUNTRY OF ORIGIN: CHINA
CUSTOMER: FASTENAL
FACTORY NAME: IFI & MORGAN LTD.
FACTORY ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan, Zhejiang, China

DESCRIPTION: 1
INVOICE NBR: TD16680155
PART NBR.: 33188
LOT NO.: 16H-168236-30

DATE: 2016-10-08
ORDER NBR. 210114135
QUANTITY:3240PCS

DIMENSIONS (UNIT:INCH)

	STANDARD	RESULT				
		1	2	3	4	5
INSIDE DIA	1.055-1.092	1.068	1.068	1.067	1.069	1.068
OUTSIDE DIA	2.493-2.530	2.514	2.513	2.514	2.514	2.511
THICKNESS	0.136-0.192	0.146	0.149	0.152	0.152	0.147

WE HEREBY CERTIFY THAT THIS WAS PRODUCED AS PER CUSTOMER'S REQUIREMENT.

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
HOT DIP GALVANIZED ASTM F2329				
	Min 43 um	48-64um	8	0

NOTE

1. QUANTITY OF SAMPLES: 5 PCS

2. JUDGEMENT: GOOD

3. CHIEF INSPECTOR:

IFI & MORGAN LTD.
检验专用章
QUANLITY CONTROL

Figure B-57. 1-in. (25-mm) Diameter Round Washer, Test No. SPTA-1

TEST REPORT

USS FLAT WASHER, HDG

CUSTOMER:	DATE: **2013-04-05**
PO NUMBER: **110129471**	MFG LOT NUMBER: **M-SWE0410533-5**
SIZE: **7/8**	PART NO: **33187**
HEADMARKS:	QNTY: **10,800 PCS**

DIMENSIONAL INSPECTIONS SPECIFICATION: **ASME B18.21.1(2009)**

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
**********************	*************************************	*******************	********	********
APPEARANCE	**ASTM F788-07**	**PASSED**	**100**	**0**
OUTSIDE DIA	**2.243-2.280**	**2.253-2.255**	**8**	**0**
INSIDE DIA	**0.931-0.968**	**0.957-0.959**	**8**	**0**
THICKNESS	**0.136-0.192**	**0.141-0.149**	**8**	**0**

HOT DIP GALVANIZED	**ASTM A153 class C. RoHS Compliant**	**Min 0.0017"**	**Min 0.0018 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 QUANLITY CONTROL

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

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

Figure B-58. ⅞-in. (22-mm) Diameter Round Washer, Test No. SPTA-2

CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS HDG

FACTORY: IFI & Morgan Ltd — REPORT DATE: 26/4/2018
ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan,Zhejiang, China

SAMPLING PLAN PER ASME B18.18-11 — PO NUMBER: 170081147
SIZE: USS 1/2 HDG — QNTY(Lot size): 64800PCS
HEADMARKS: NO MARK — PART NO: 33184

DIMENSIONAL INSPECTIONS — SPECIFICATION: ASTM B18.21.1-2011

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F844	PASSED	100	0
OUTSIDE DIA	1.368-1.405	1.370-1.378	10	0
INSIDE DIA	0.557-0.577	0.567-0.575	10	0
THICKNESS	0.086-0.132	0.086-0.102	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-59. ½-in. (13-mm) Diameter Round Washer, Test No. SPTA-2

Certificate of Compliance

BRIGHTON-BEST INTERNATIONAL, INC.
9700 E 56TH AVE
DENVER CO 80238
303-576-0530

ND7000
THE STRUCTURAL BOLT CO., LLC
2140 CORNHUSKER HWY
LINCOLN NE 68521

Date : 7/27/2018

This is to certify that the LOW CARBON FLAT WASHERS (LBS) stated below conforms to the requirements and specifications per

ASME B18.21.1, Type-A, ASTM F2329 H.D.G.

or the revision in effect at the time of manufacture.

Item code	Size	Description	Lot#	Country Of Origin
345005	1/2"	LOW CARBON FLAT WASHERS (LBS)	54216090006	CHINA

Stephen McFalls
Quality Control Manager

Figure B-60. ½-in. (13-mm) Diameter Round Washer, Test No. SPTA-1

TEST REPORT

USS FLAT WASHER, HDG

CUSTOMER:		DATE:	**2017-04-05**
PO NUMBER:	**220024002**	MFG LOT NUMBER:	**33183**
SIZE:	**7/16**	PART NO:	**M-SWE0411885-18**
HEADMARKS:		QNTY:	**24,600 PCS**

DIMENSIONAL INSPECTIONS — SPECIFICATION: **ASME B18.21.1(2009)**

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
**********************	************************************	*******************	********	********
APPEARANCE	**ASTM F788-07**	**PASSED**	**100**	**0**
OUTSIDE DIA	**1.243-1.280**	**1.249-1.252**	**8**	**0**
INSIDE DIA	**0.495-0.515**	**0.506-0.508**	**8**	**0**
THICKNESS	**0.064-0.104**	**0.068-0.072**	**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

IFI & MORGAN LTD. 检验专用章 QUANLITY CONTROL

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

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

Figure B-61. $^{7}/_{16}$-in. (11-mm) Diameter Round Washer, Test Nos. SPTA-1 and SPTA-2

Certified Analysis

Trinity Highway Products , LLC
2548 N.E. 28th St.
Ft Worth, TX
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097
Project: RESALE

Order Number: 1095199
Customer PO: 2841
BOL Number: 24481
Document #: 1
Shipped To: NE
Use State: KS

As of: 6/20/08

Qty	Part#	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
25	6G	12/6'3/S	M-180	A		84964	64,230	81,300	25.4	0.180	0.720	0.012	0.001	0.040	0.080	0.000	0.060	0.000	4
20	701A	.25X11.75X16 CAB ANC	A-36			4153095	44,900	60,800	36.0	0.240	0.750	0.012	0.003	0.020	0.020	0.000	0.040	0.002	4
10	742G	6'0 TUBE SL/.188X8X6	A-500			A8P1160	74,000	87,000	25.2	0.050	0.670	0.013	0.005	0.030	0.220	0.000	0.060	0.021	4
20	782G	5/8"X8"X8" BEAR PL/OF	A-36			6106195	46,700	69,900	23.5	0.180	0.830	0.010	0.005	0.020	0.230	0.000	0.070	0.006	4
40	907G	12/BUFFER/ROLLED	M-180	A		L0049	54,200	73,500	25.0	0.160	0.700	0.011	0.008	0.020	0.200	0.000	0.100	0.000	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL OTHER GALVANIZED MATERIAL CONFORMS WITH ASTM-123.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH -- 49100 LB

State of Texas, County of Tarrant. Sworn and subscribed before me this 20th day of June, 2008

Notary Public:
Commission Expires

RACHEL R. MEDINA
Notary Public
State of Texas
My Commission Expires

Trinity Highway Products , LLC
Certified By:

Stefanie Oneal

Figure B-62. Anchor Bracket Assembly, Test No. SPTA-1

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

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

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

MATERIAL TEST REPORT

Sold to

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

Shipped to

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

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

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

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

Material Note:
Sales Or.Note:

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

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

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

Material Note:
Sales Or.Note:

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

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

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

Material Note:
Sales Or.Note:

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

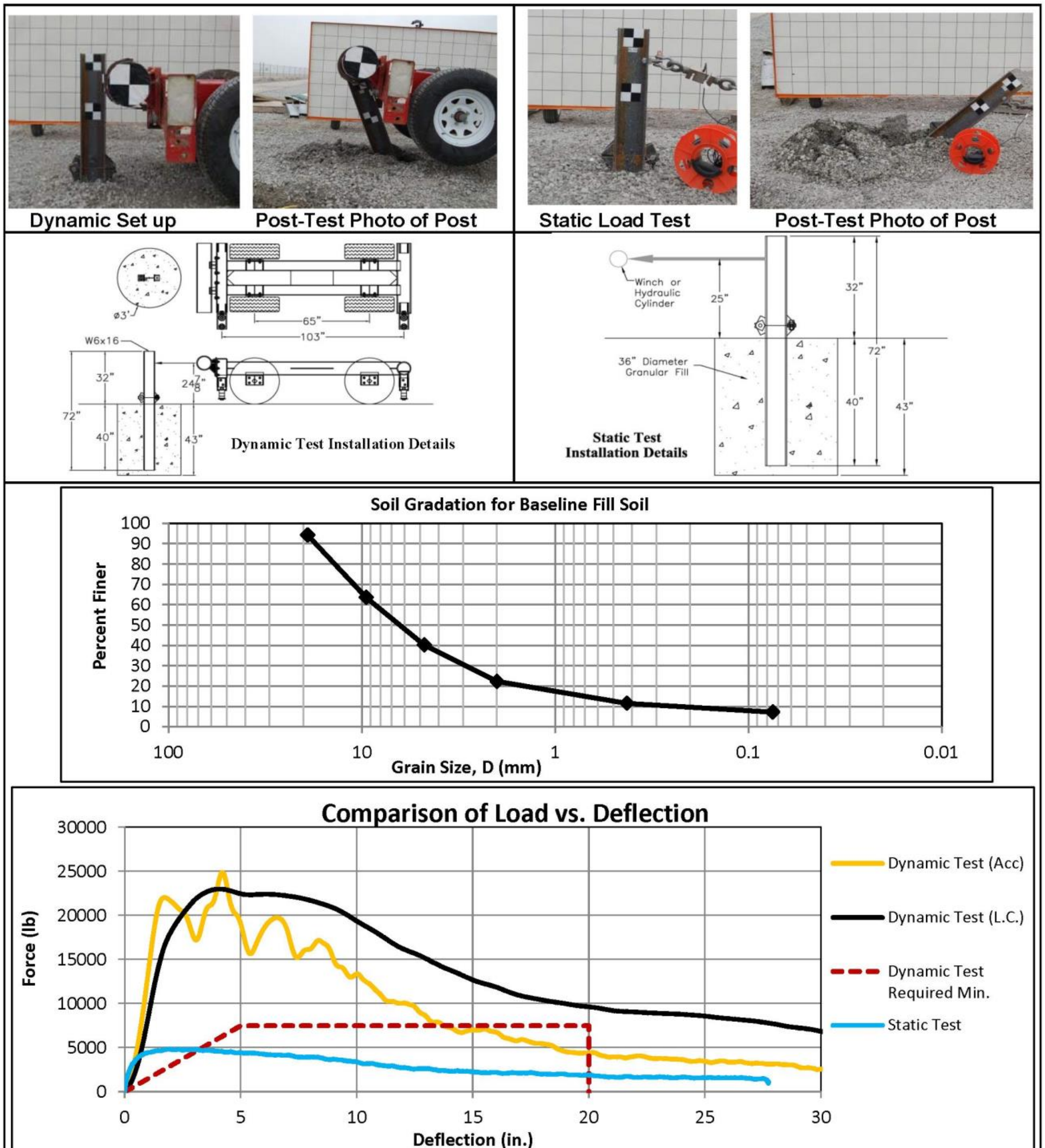
Steel Tube Institute OF NORTH AMERICA

Page : 3 Of 4

Metals Service Center Institute

Figure B-63. Post Sleeve, Test No. SPTA-1

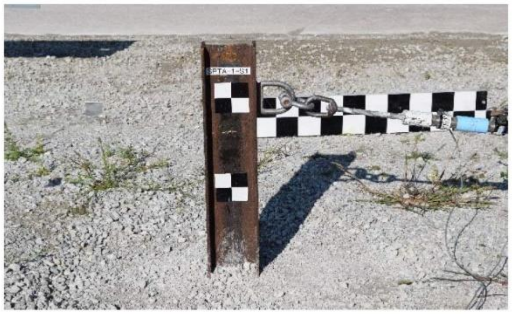
Appendix C. Static Soil Tests



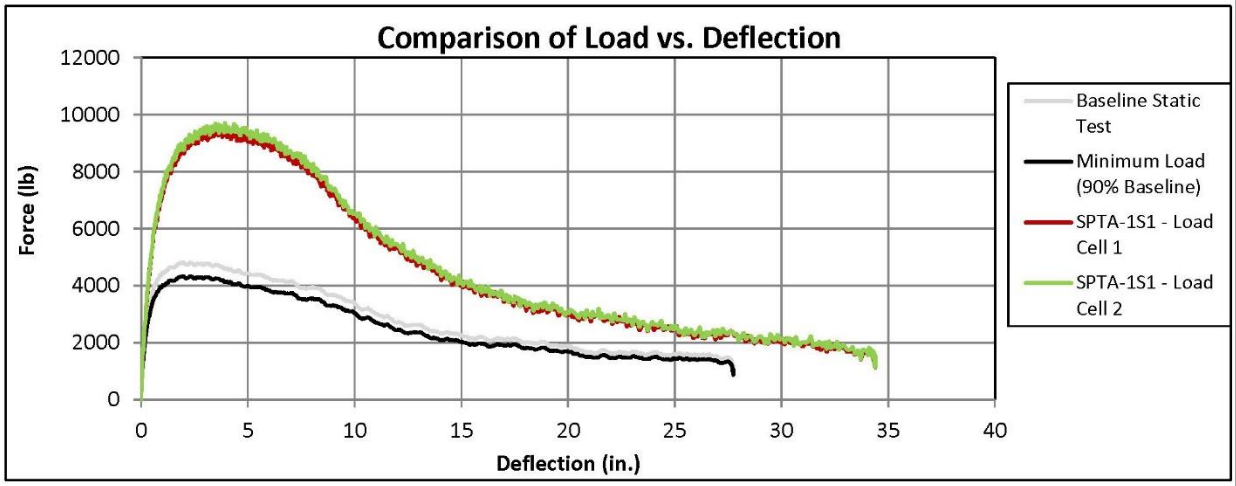
Date	2/16/2018		
Test Facility & Site Location	Midwest Roadside Safety Facility		
In situ soil description (ASTM D2487)	Well-Graded Gravel (GW)		
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)		
Description of fill placement procedure	H.E.-8		
Bogie Weight	1786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

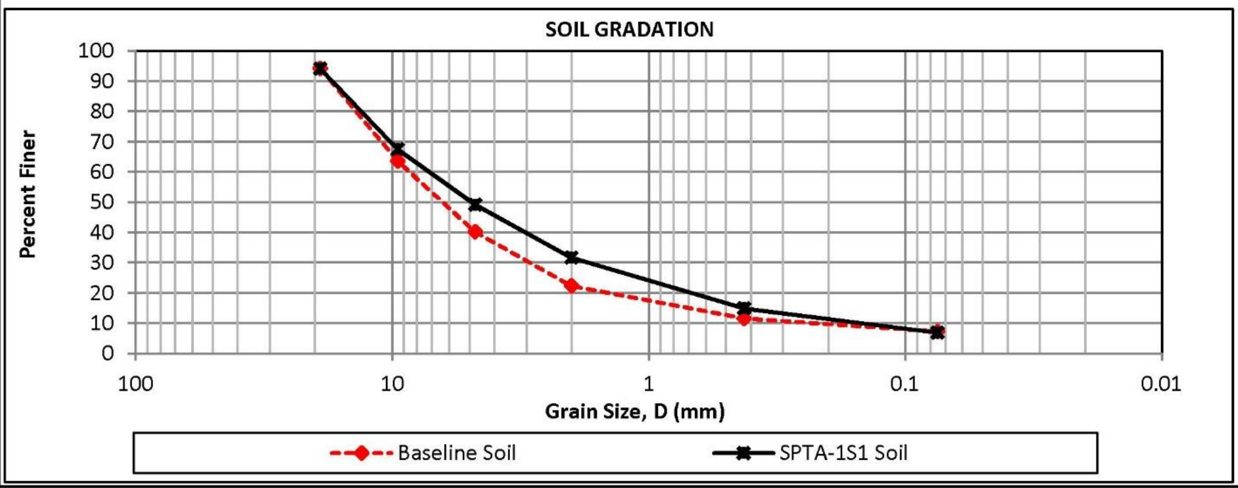
Figure C-1. Soil Strength, Initial Calibration Test, Test Nos. SPTA-1 and SPTA-2

Static Load Test Setup



Post-Test Photo of Post



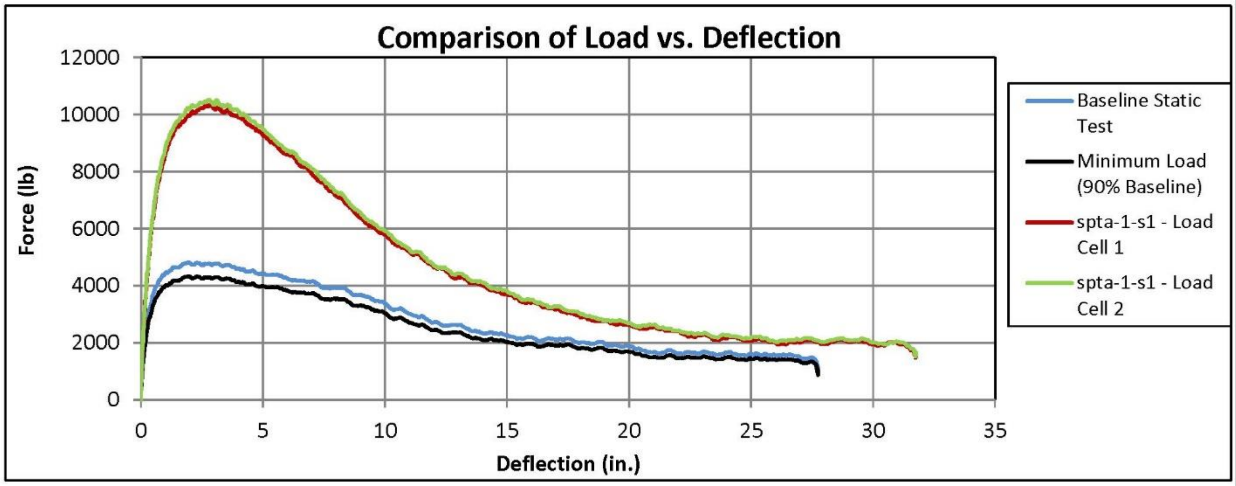


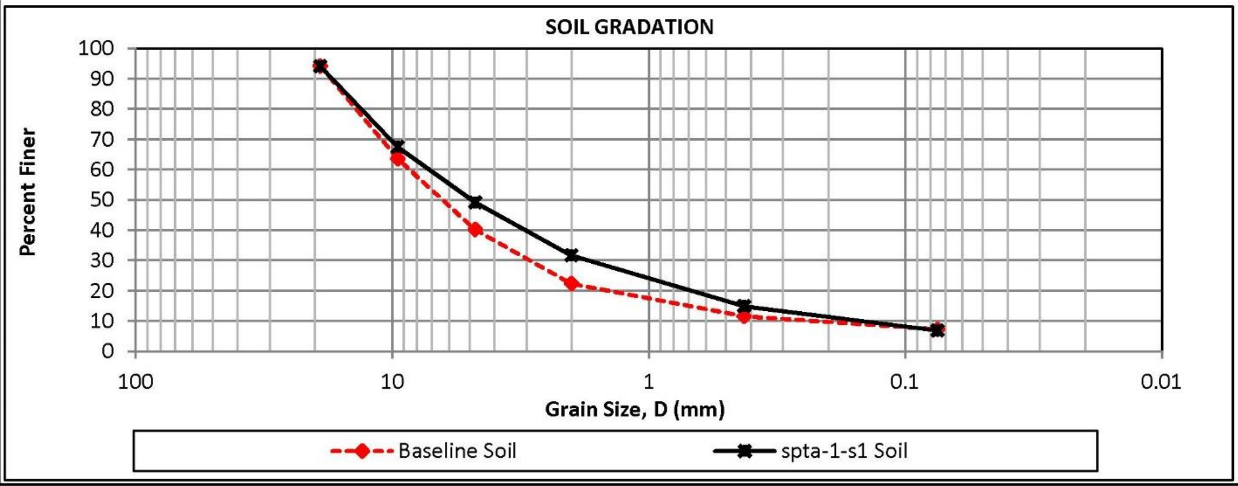
Date..	7/31/2018
Test Facility & Site Location.......................	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)...........	Well-Graded Gravel (GW)
Fill material description (ASTM D2487).........	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure........	8-inch lifts tamped with a pneumatic compactor

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

Static Load Test Setup

Post-Test Photo of Post





Date..	9/12/2018
Test Facility & Site Location.......................	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)...........	Well-Graded Gravel (GW)
Fill material description (ASTM D2487).........	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure........	8-inch lifts tamped with a pneumatic compactor

Figure C-3. Static Soil Test, Test No. SPTA-2

Appendix D. Vehicle Deformation Records

Date: 7/31/2018 Test Name: SPTA-1 VIN: 1D7RB1CT2BS582287
Year: 2011 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
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	58.8522	32.9904	2.3025	59.1705	32.8977	2.2427	-0.3183	0.0927	0.0598	0.3369	0.0598	Z
	2	59.0225	29.9464	2.2410	59.3289	29.9849	2.1635	-0.3064	-0.0385	0.0775	0.3184	0.0775	Z
	3	59.0012	27.3135	2.2478	59.2882	27.3036	2.1914	-0.2870	0.0099	0.0564	0.2927	0.0564	Z
	4	59.0601	24.2675	2.1978	59.3383	24.1989	2.1639	-0.2782	0.0686	0.0339	0.2885	0.0339	Z
	5	58.6132	21.6686	1.6529	58.9233	21.6406	1.6131	-0.3101	0.0280	0.0398	0.3139	0.0398	Z
	6	54.9137	32.8702	4.5516	55.2436	32.8392	4.4658	-0.3299	0.0310	0.0858	0.3423	0.0858	Z
	7	54.9409	29.6206	4.5298	55.2458	29.5574	4.4503	-0.3049	0.0632	0.0795	0.3214	0.0795	Z
	8	54.9692	27.1991	4.5109	55.2894	27.1626	4.4315	-0.3202	0.0365	0.0794	0.3319	0.0794	Z
	9	55.0045	24.4471	4.4855	55.3127	24.3841	4.4192	-0.3082	0.0630	0.0663	0.3215	0.0663	Z
	10	54.7796	21.4167	4.0378	55.0703	21.4012	4.0160	-0.2907	0.0155	0.0218	0.2919	0.0218	Z
FLOOR PAN (Z)	11	49.7178	33.0608	5.1498	50.0173	33.0570	5.0854	-0.2995	0.0038	0.0644	0.3064	0.0644	Z
	12	49.7371	29.5441	5.1476	50.0314	29.5633	5.0830	-0.2943	-0.0192	0.0646	0.3019	0.0646	Z
	13	49.6421	25.0800	5.1413	49.9542	25.0163	5.0833	-0.3121	0.0637	0.0580	0.3238	0.0580	Z
	14	49.6242	21.1651	5.1480	49.9522	21.1455	5.0991	-0.3280	0.0196	0.0489	0.3322	0.0489	Z
	15	49.4412	17.6977	4.8238	49.7992	17.8068	4.8045	-0.3580	-0.1091	0.0193	0.3748	0.0193	Z
	16	46.5911	33.3234	5.3824	46.8900	33.3201	5.3210	-0.2989	0.0033	0.0614	0.3052	0.0614	Z
	17	46.8512	29.1120	5.3817	47.1434	29.0602	5.3194	-0.2922	0.0518	0.0623	0.3032	0.0623	Z
	18	46.8013	24.4199	5.3852	47.0933	24.3783	5.3317	-0.2920	0.0416	0.0535	0.2998	0.0535	Z
	19	46.5442	20.3092	5.3834	46.7770	20.3439	5.3373	-0.2328	-0.0347	0.0461	0.2398	0.0461	Z
	20	46.5347	16.7482	5.3912	46.8442	16.7266	5.3573	-0.3095	0.0216	0.0339	0.3121	0.0339	Z
	21	42.6669	33.4437	5.3729	42.9524	33.4148	5.3134	-0.2855	0.0289	0.0595	0.2931	0.0595	Z
	22	42.3334	28.4088	5.3542	42.6787	28.4037	5.2964	-0.3453	0.0051	0.0578	0.3501	0.0578	Z
	23	42.4749	24.3271	5.3532	42.8156	24.2905	5.3006	-0.3407	0.0366	0.0526	0.3467	0.0526	Z
	24	42.2632	20.2332	5.3715	42.5153	20.2927	5.3234	-0.2521	-0.0595	0.0481	0.2635	0.0481	Z
	25	41.9553	16.2270	5.3908	42.3149	16.2348	5.3551	-0.3596	-0.0078	0.0357	0.3615	0.0357	Z
	26	38.4843	33.4949	5.0605	38.7879	33.5124	5.0046	-0.3036	-0.0175	0.0559	0.3092	0.0559	Z
	27	38.3179	28.3155	4.9514	38.6303	28.3702	4.9111	-0.3124	-0.0547	0.0403	0.3197	0.0403	Z
	28	38.1568	23.6420	4.8433	38.4428	23.6375	4.7966	-0.2860	0.0045	0.0467	0.2898	0.0467	Z
	29	38.2916	20.3479	4.9586	38.5561	20.3383	4.9051	-0.2645	0.0096	0.0535	0.2700	0.0535	Z
	30	38.3290	16.2530	5.0052	38.6469	16.2679	4.9941	-0.3179	-0.0149	0.0111	0.3184	0.0111	Z

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

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

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

Pretest Floor Pan

Posttest Floor Pan

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

Date: 7/31/2018
Year: 2011

Test Name: SPTA-1
Make: Dodge

VIN: 1D7RB1CT2BS582287
Model: Ram 1500

VEHICLE DEFORMATION
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	62.1057	14.2585	-2.0396	62.1452	14.4018	-1.8066	-0.0395	-0.1433	-0.2330	0.2764	0.0000	NA
	2	62.3020	11.2160	-2.0978	62.3447	11.4915	-1.8870	-0.0427	-0.2755	-0.2108	0.3495	0.0000	NA
	3	62.3036	8.5830	-2.0875	62.3418	8.8099	-1.8603	-0.0382	-0.2269	-0.2272	0.3234	0.0000	NA
	4	62.3887	5.5376	-2.1337	62.4356	5.7062	-1.8892	-0.0469	-0.1686	-0.2445	0.3007	0.0000	NA
	5	61.9626	2.9342	-2.6740	62.0571	3.1426	-2.4415	-0.0945	-0.2084	-0.2325	0.3262	0.0000	NA
	6	58.1749	14.1072	0.2212	58.2180	14.2869	0.4137	-0.0431	-0.1797	-0.1925	0.2668	0.0000	NA
	7	58.2301	10.8579	0.2034	58.2664	11.0055	0.3967	-0.0363	-0.1476	-0.1933	0.2459	0.0000	NA
	8	58.2793	8.4367	0.1876	58.3437	8.6116	0.3768	-0.0644	-0.1749	-0.1892	0.2656	0.0000	NA
	9	58.3383	5.6851	0.1655	58.4062	5.8337	0.3632	-0.0679	-0.1486	-0.1977	0.2565	0.0000	NA
	10	58.1384	2.6523	-0.2777	58.2061	2.8479	-0.0415	-0.0677	-0.1956	-0.2362	0.3141	0.0000	NA
FLOOR PAN (Z)	11	52.9793	14.2537	0.8344	52.9886	14.4308	1.0296	-0.0093	-0.1771	-0.1952	0.2637	-0.1952	Z
	12	53.0290	10.7373	0.8365	53.0520	10.9377	1.0256	-0.0230	-0.2004	-0.1891	0.2765	-0.1891	Z
	13	52.9726	6.2726	0.8362	53.0389	6.3900	1.0238	-0.0663	-0.1174	-0.1876	0.2310	-0.1876	Z
	14	52.9885	2.3576	0.8480	53.0914	2.5196	1.0377	-0.1029	-0.1620	-0.1897	0.2698	-0.1897	Z
	15	52.8347	-1.1117	0.5288	52.9856	-0.8209	0.7415	-0.1509	0.2908	-0.2127	0.3906	-0.2127	Z
	16	49.8512	14.4896	1.0758	49.8578	14.6497	1.2630	-0.0066	-0.1601	-0.1872	0.2464	-0.1872	Z
	17	50.1476	10.2806	1.0797	50.1712	10.3938	1.2596	-0.0236	-0.1132	-0.1799	0.2139	-0.1799	Z
	18	50.1383	5.5882	1.0893	50.1871	5.7117	1.2698	-0.0488	-0.1235	-0.1805	0.2241	-0.1805	Z
	19	49.9168	1.4754	1.0935	49.9276	1.6732	1.2732	-0.0108	-0.1978	-0.1797	0.2675	-0.1797	Z
	20	49.9381	-2.0855	1.1059	50.0457	-1.9428	1.2916	-0.1076	0.1427	-0.1857	0.2577	-0.1857	Z
	21	45.9260	14.5759	1.0776	45.9193	14.6889	1.2526	0.0067	-0.1130	-0.1750	0.2084	-0.1750	Z
	22	45.6361	9.5383	1.0663	45.7162	9.6745	1.2331	-0.0801	-0.1362	-0.1668	0.2298	-0.1668	Z
	23	45.8128	5.4580	1.0701	45.9110	5.5636	1.2356	-0.0982	-0.1056	-0.1655	0.2195	-0.1655	Z
	24	45.6366	1.3624	1.0942	45.6670	1.5620	1.2563	-0.0304	-0.1996	-0.1621	0.2589	-0.1621	Z
	25	45.3634	-2.6462	1.1195	45.5237	-2.4983	1.2859	-0.1603	0.1479	-0.1664	0.2743	-0.1664	Z
	26	41.7422	14.5905	0.7774	41.7541	14.7280	0.9408	-0.0119	-0.1375	-0.1634	0.2139	-0.1634	Z
	27	41.6204	9.4097	0.6754	41.6690	9.5842	0.8448	-0.0486	-0.1745	-0.1694	0.2480	-0.1694	Z
	28	41.4993	4.7349	0.5737	41.5482	4.8494	0.7280	-0.0489	-0.1145	-0.1543	0.1983	-0.1543	Z
	29	41.6630	1.4422	0.6928	41.7079	1.5521	0.8351	-0.0449	-0.1099	-0.1423	0.1853	-0.1423	Z
	30	41.7359	-2.6521	0.7446	41.8559	-2.5167	0.9223	-0.1200	0.1354	-0.1777	0.2536	-0.1777	Z

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

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

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

Pretest Floor Pan

Posttest Floor Pan

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

Date: 7/31/2018 Test Name: SPTA-1 VIN: 1D7RB1CT2BS582287
Year: 2011 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
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	49.5197	29.7915	-26.3396	49.5615	29.8428	-26.3878	-0.0418	-0.0513	-0.0482	0.0819	0.0819	X, Y, Z
	2	48.1720	18.0587	-26.4800	48.1794	18.0851	-26.4990	-0.0074	-0.0264	-0.0190	0.0334	0.0334	X, Y, Z
	3	44.9042	4.3652	-26.5438	44.9291	4.3843	-26.5468	-0.0249	-0.0191	-0.0030	0.0315	0.0315	X, Y, Z
	4	45.3473	34.9112	-15.8473	45.3439	34.9426	-15.8823	0.0034	-0.0314	-0.0350	0.0471	0.0471	X, Y, Z
	5	44.2308	19.2507	-15.9431	44.2559	19.2553	-15.8630	-0.0251	-0.0046	0.0801	0.0841	0.0841	X, Y, Z
	6	42.1546	4.1412	-17.0413	42.1753	4.1316	-17.0065	-0.0207	0.0096	0.0348	0.0416	0.0416	X, Y, Z
SIDE PANEL (Y)	7	54.2835	36.4501	-4.3289	54.2646	36.4095	-4.2751	0.0189	0.0406	0.0538	0.0700	0.0406	Y
	8	54.2596	36.4431	0.0115	54.2237	36.4242	0.0467	0.0359	0.0189	0.0352	0.0537	0.0189	Y
	9	57.2717	36.3428	-1.3113	57.2932	36.3421	-1.2558	-0.0215	0.0007	0.0555	0.0595	0.0007	Y
IMPACT SIDE DOOR (Y)	10	43.2937	38.8675	-15.9379	43.2105	38.7815	-15.9263	0.0832	0.0860	0.0116	0.1202	0.0860	Y
	11	32.3703	39.1289	-16.0208	32.3065	39.1280	-16.0354	0.0638	0.0009	-0.0146	0.0655	0.0009	Y
	12	22.2156	39.4283	-15.9699	22.1901	39.4805	-15.9450	0.0255	-0.0522	0.0249	0.0632	-0.0522	Y
	13	44.0978	37.3540	-6.5529	44.0277	37.1837	-6.5413	0.0701	0.1703	0.0116	0.1845	0.1703	Y
	14	34.4939	39.7634	-3.5420	34.4561	39.6850	-3.5551	0.0378	0.0784	-0.0131	0.0880	0.0784	Y
	15	24.0323	39.0440	-2.7107	24.0009	39.0260	-2.6889	0.0314	0.0180	0.0218	0.0423	0.0180	Y
ROOF - (Z)	16	32.8491	24.7275	-44.4477	32.8153	24.6427	-44.4560	0.0338	0.0848	-0.0083	0.0917	-0.0083	Z
	17	34.0092	20.1779	-44.6440	34.0584	20.0953	-44.6247	-0.0492	0.0826	0.0193	0.0981	0.0193	Z
	18	34.7593	16.2162	-44.7503	34.7276	16.2040	-44.7447	0.0317	0.0122	0.0056	0.0344	0.0056	Z
	19	35.3865	11.6075	-44.8210	35.4186	11.6156	-44.7915	-0.0321	-0.0081	0.0295	0.0443	0.0295	Z
	20	35.6674	6.2449	-44.8941	35.7144	6.2147	-44.8586	-0.0470	0.0302	0.0355	0.0662	0.0355	Z
	21	23.2898	26.1893	-45.8672	23.2597	26.1486	-45.8385	0.0301	0.0407	0.0287	0.0582	0.0287	Z
	22	23.4528	20.2282	-46.2454	23.4468	20.1808	-46.2078	0.0060	0.0474	0.0376	0.0608	0.0376	Z
	23	23.6508	14.6562	-46.4953	23.6519	14.6139	-46.4581	-0.0011	0.0423	0.0372	0.0563	0.0372	Z
	24	23.8258	9.9253	-46.6970	23.8264	9.8892	-46.6729	-0.0006	0.0361	0.0241	0.0434	0.0241	Z
	25	23.8837	6.2544	-46.7514	23.8916	6.2515	-46.7158	-0.0079	0.0029	0.0356	0.0366	0.0356	Z
	26	15.1733	25.4055	-46.2981	15.1590	25.3577	-46.2691	0.0143	0.0478	0.0290	0.0577	0.0290	Z
	27	15.7238	19.8483	-46.6792	15.7129	19.7849	-46.6461	0.0109	0.0634	0.0331	0.0723	0.0331	Z
	28	16.1873	15.1756	-46.8885	16.2256	15.2463	-46.8430	-0.0383	-0.0707	0.0455	0.0924	0.0455	Z
	29	16.6753	10.2051	-47.0213	16.5886	10.2439	-46.9834	0.0867	-0.0388	0.0379	0.1023	0.0379	Z
	30	16.7147	6.5949	-47.0826	16.7518	6.6204	-47.0315	-0.0371	-0.0255	0.0511	0.0681	0.0511	Z
A-PILLAR Maximum (X, Y, Z)	31	54.2331	35.2977	-28.7962	54.2416	35.3028	-28.8191	-0.0085	-0.0051	-0.0229	0.0250	0.0000	NA
	32	51.2769	34.6561	-31.0780	51.3487	34.6668	-31.0583	-0.0718	-0.0107	0.0197	0.0752	0.0197	Z
	33	48.7424	34.1098	-33.0512	48.7592	34.0997	-33.0516	-0.0168	0.0101	-0.0004	0.0196	0.0101	Y
	34	45.7071	33.4339	-35.1289	45.7752	33.4378	-35.1482	-0.0681	-0.0039	-0.0193	0.0709	0.0000	NA
	35	42.8496	32.8524	-37.2897	42.8417	32.8356	-37.3347	0.0079	0.0168	-0.0450	0.0487	0.0186	X, Y
	36	38.9203	32.0087	-39.5726	38.9000	31.9758	-39.5910	0.0203	0.0329	-0.0184	0.0428	0.0387	X, Y
A-PILLAR Lateral (Y)	31	54.2331	35.2977	-28.7962	54.2416	35.3028	-28.8191	-0.0085	-0.0051	-0.0229	0.0250	-0.0051	Y
	32	51.2769	34.6561	-31.0780	51.3487	34.6668	-31.0583	-0.0718	-0.0107	0.0197	0.0752	-0.0107	Y
	33	48.7424	34.1098	-33.0512	48.7592	34.0997	-33.0516	-0.0168	0.0101	-0.0004	0.0196	0.0101	Y
	34	45.7071	33.4339	-35.1289	45.7752	33.4378	-35.1482	-0.0681	-0.0039	-0.0193	0.0709	-0.0039	Y
	35	42.8496	32.8524	-37.2897	42.8417	32.8356	-37.3347	0.0079	0.0168	-0.0450	0.0487	0.0168	Y
	36	38.9203	32.0087	-39.5726	38.9000	31.9758	-39.5910	0.0203	0.0329	-0.0184	0.0428	0.0329	Y
B-PILLAR Maximum (X, Y, Z)	37	12.5919	32.0019	-39.7501	12.5472	31.9360	-39.7943	0.0447	0.0659	-0.0442	0.0911	0.0796	X, Y
	38	10.4274	34.4835	-33.2969	10.4799	34.4304	-33.3123	-0.0525	0.0531	-0.0154	0.0762	0.0531	Y
	39	14.0331	35.7187	-28.4049	13.9094	35.6784	-28.4566	0.1237	0.0403	-0.0517	0.1400	0.1301	X, Y
	40	10.8423	36.2470	-23.9958	10.8003	36.2236	-23.9891	0.0420	0.0234	0.0067	0.0485	0.0485	X, Y, Z
B-PILLAR Lateral (Y)	37	12.5919	32.0019	-39.7501	12.5472	31.9360	-39.7943	0.0447	0.0659	-0.0442	0.0911	0.0659	Y
	38	10.4274	34.4835	-33.2969	10.4799	34.4304	-33.3123	-0.0525	0.0531	-0.0154	0.0762	0.0531	Y
	39	14.0331	35.7187	-28.4049	13.9094	35.6784	-28.4566	0.1237	0.0403	-0.0517	0.1400	0.0403	Y
	40	10.8423	36.2470	-23.9958	10.8003	36.2236	-23.9891	0.0420	0.0234	0.0067	0.0485	0.0234	Y

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

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

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

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

Date: 7/31/2018 Test Name: SPTA-1 VIN: 1D7RB1CT2BS582287
Year: 2011 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
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	52.4930	10.7120	-30.6233	52.9003	10.7390	-30.4859	-0.4073	-0.0270	0.1374	0.4307	0.4307	X, Y, Z
	2	51.2422	-1.0316	-30.7530	51.6111	-1.0294	-30.5877	-0.3689	0.0022	0.1653	0.4042	0.4042	X, Y, Z
	3	48.0879	-14.7518	-30.7996	48.4691	-14.7555	-30.6267	-0.3812	-0.0037	0.1729	0.4186	0.4186	X, Y, Z
	4	48.3074	15.8035	-20.1225	48.6298	15.8151	-19.9903	-0.3224	-0.0116	0.1322	0.3486	0.3486	X, Y, Z
	5	47.3205	0.1342	-20.2059	47.6656	0.1197	-19.9576	-0.3451	0.0145	0.2483	0.4254	0.4254	X, Y, Z
	6	45.3665	-14.9927	-21.2893	45.7058	-15.0210	-21.0895	-0.3393	-0.0283	0.1998	0.3948	0.3948	X, Y, Z
SIDE PANEL (Y)	7	57.2626	17.4235	-8.6299	57.5246	17.3631	-8.3737	-0.2620	0.0604	0.2562	0.3714	0.0604	Y
	8	57.2507	17.4190	-4.2895	57.4784	17.3814	-4.0520	-0.2277	0.0376	0.2375	0.3312	0.0376	Y
	9	60.2599	17.3428	-5.6206	60.5499	17.3223	-5.3507	-0.2900	0.0205	0.2699	0.3967	0.0205	Y
IMPACT SIDE DOOR (Y)	10	46.2209	19.7426	-20.2098	46.4663	19.6369	-20.0405	-0.2454	0.1057	0.1693	0.3163	0.1057	Y
	11	35.2956	19.9134	-20.2625	35.5600	19.8973	-20.1631	-0.2644	0.0161	0.0994	0.2829	0.0161	Y
	12	25.1389	20.1287	-20.1835	25.4411	20.1701	-20.0852	-0.3022	-0.0414	0.0983	0.3205	-0.0414	Y
	13	47.0635	18.2416	-10.8262	47.2846	18.0543	-10.6530	-0.2211	0.1873	0.1732	0.3376	0.1873	Y
	14	37.4484	20.5732	-7.7900	37.6900	20.4829	-7.6807	-0.2416	0.0903	0.1093	0.2801	0.0903	Y
	15	26.9955	19.7677	-6.9292	27.2393	19.7421	-6.8265	-0.2438	0.0256	0.1027	0.2658	0.0256	Y
ROOF - (Z)	16	35.8148	5.4988	-48.6820	36.2176	5.3901	-48.5694	-0.4028	0.1087	0.1126	0.4321	0.1126	Z
	17	37.0121	0.9589	-48.8789	37.4968	0.8525	-48.7324	-0.4847	0.1064	0.1465	0.5174	0.1465	Z
	18	37.7947	-2.9965	-48.9848	38.1968	-3.0335	-48.8479	-0.4021	-0.0370	0.1369	0.4264	0.1369	Z
	19	38.4598	-7.5999	-49.0545	38.9241	-7.6164	-48.8896	-0.4643	-0.0165	0.1649	0.4930	0.1649	Z
	20	38.7849	-12.9600	-49.1253	39.2625	-13.0148	-48.9513	-0.4776	-0.0548	0.1740	0.5113	0.1740	Z
	21	26.2398	6.8806	-50.0758	26.6521	6.8193	-49.9649	-0.4123	0.0613	0.1109	0.4313	0.1109	Z
	22	26.4512	0.9208	-50.4509	26.8867	0.8528	-50.3284	-0.4355	0.0680	0.1225	0.4575	0.1225	Z
	23	26.6947	-4.6495	-50.6980	27.1360	-4.7126	-50.5732	-0.4413	-0.0631	0.1248	0.4629	0.1248	Z
	24	26.9083	-9.3789	-50.8974	27.3480	-9.4359	-50.7834	-0.4397	-0.0570	0.1140	0.4578	0.1140	Z
	25	26.9965	-13.0493	-50.9497	27.4420	-13.0730	-50.8228	-0.4455	-0.0237	0.1269	0.4638	0.1269	Z
	26	18.1289	6.0293	-50.4838	18.5584	5.9641	-50.4045	-0.4295	0.0652	0.0793	0.4416	0.0793	Z
	27	18.7245	0.4766	-50.8630	19.1567	0.3955	-50.7756	-0.4322	0.0811	0.0874	0.4483	0.0874	Z
	28	19.2261	-4.1922	-51.0709	19.7054	-4.1392	-50.9676	-0.4793	0.0530	0.1033	0.4932	0.1033	Z
	29	19.7549	-9.1586	-51.2020	20.1081	-9.1387	-51.1029	-0.3532	0.0199	0.0991	0.3674	0.0991	Z
	30	19.8240	-12.7684	-51.2613	20.2999	-12.7607	-51.1474	-0.4759	0.0077	0.1139	0.4894	0.1139	Z
A-PILLAR Maximum (X, Y, Z)	31	57.1538	16.2556	-33.0962	57.5401	16.2335	-32.9166	-0.3863	0.0221	0.1796	0.4266	0.1810	Y, Z
	32	54.1968	15.5881	-35.3695	54.6551	15.5726	-35.1587	-0.4583	0.0155	0.2108	0.5047	0.2114	Y, Z
	33	51.6614	15.0195	-37.3353	52.0725	14.9832	-37.1546	-0.4111	0.0363	0.1807	0.4505	0.1843	Y, Z
	34	48.6260	14.3173	-39.4042	49.0963	14.2958	-39.2542	-0.4703	0.0215	0.1500	0.4941	0.1515	Y, Z
	35	45.7675	13.7108	-41.5566	46.1704	13.6684	-41.4437	-0.4029	0.0424	0.1129	0.4206	0.1206	Y, Z
	36	41.8390	12.8331	-43.8281	42.2383	12.7755	-43.7040	-0.3993	0.0576	0.1241	0.4221	0.1368	Y, Z
A-PILLAR Lateral (Y)	31	57.1538	16.2556	-33.0962	57.5401	16.2335	-32.9166	-0.3863	0.0221	0.1796	0.4266	0.0221	Y
	32	54.1968	15.5881	-35.3695	54.6551	15.5726	-35.1587	-0.4583	0.0155	0.2108	0.5047	0.0155	Y
	33	51.6614	15.0195	-37.3353	52.0725	14.9832	-37.1546	-0.4111	0.0363	0.1807	0.4505	0.0363	Y
	34	48.6260	14.3173	-39.4042	49.0963	14.2958	-39.2542	-0.4703	0.0215	0.1500	0.4941	0.0215	Y
	35	45.7675	13.7108	-41.5566	46.1704	13.6684	-41.4437	-0.4029	0.0424	0.1129	0.4206	0.0424	Y
	36	41.8390	12.8331	-43.8281	42.2383	12.7755	-43.7040	-0.3993	0.0576	0.1241	0.4221	0.0576	Y
B-PILLAR Maximum (X, Y, Z)	37	15.5112	12.6082	-43.9325	15.8870	12.5275	-43.9390	-0.3758	0.0807	-0.0065	0.3844	0.0807	Y
	38	13.3441	15.0757	-37.4748	13.7922	15.0116	-37.4618	-0.4481	0.0641	0.0130	0.4528	0.0654	Y, Z
	39	16.9530	16.3438	-32.5936	17.2058	16.2911	-32.6032	-0.2528	0.0527	-0.0096	0.2584	0.0527	Y
	40	13.7701	16.8483	-28.1759	14.0871	16.8159	-28.1399	-0.3170	0.0324	0.0360	0.3207	0.0484	Y, Z
B-PILLAR Lateral (Y)	37	15.5112	12.6082	-43.9325	15.8870	12.5275	-43.9390	-0.3758	0.0807	-0.0065	0.3844	0.0807	Y
	38	13.3441	15.0757	-37.4748	13.7922	15.0116	-37.4618	-0.4481	0.0641	0.0130	0.4528	0.0641	Y
	39	16.9530	16.3438	-32.5936	17.2058	16.2911	-32.6032	-0.2528	0.0527	-0.0096	0.2584	0.0527	Y
	40	13.7701	16.8483	-28.1759	14.0871	16.8159	-28.1399	-0.3170	0.0324	0.0360	0.3207	0.0324	Y

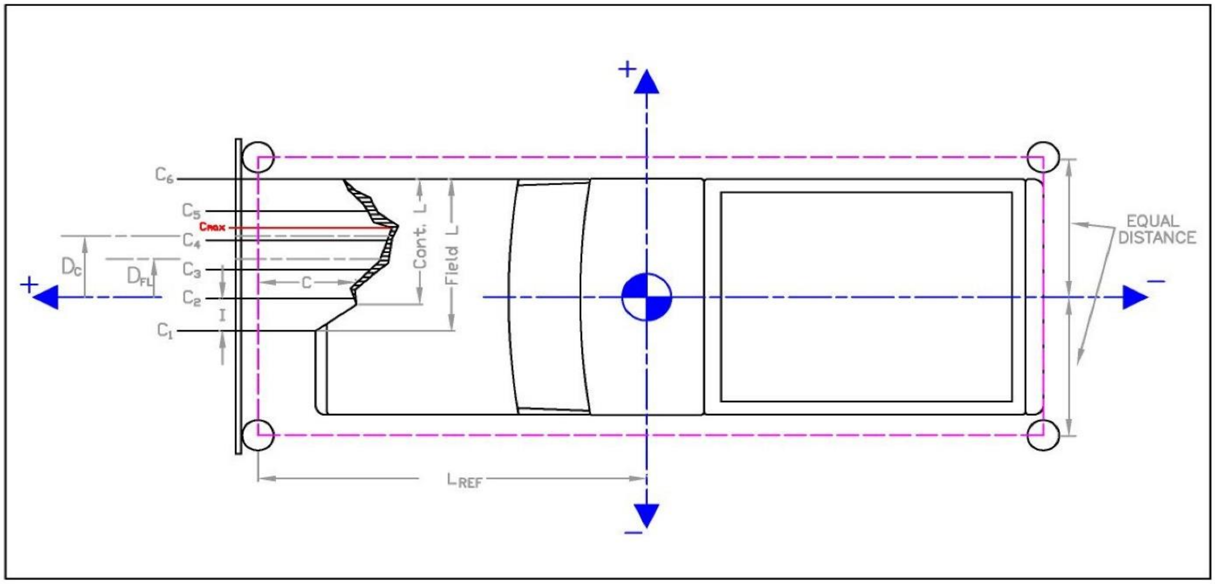
[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

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

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

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

Date:	8/1/2018	Test Name:	SPTA-1	VIN:	1D7RB1CT2BS582287
Year:	2011	Make:	Dodge	Model:	Ram 1500



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	115 1/2	(2934)
Total Vehicle Width:	76 1/2	(1943)
Width of contact and induced crush - Field L:	55	(1397)
Crush measurement spacing interval (L/5) - I:	11	(279)
Distance from center of vehicle to center of Field L - D_{FL}:	10 1/2	(267)
Width of Contact Damage:	32	(813)
Distance from center of vehicle to center of contact damage - D_C:	26	(660)

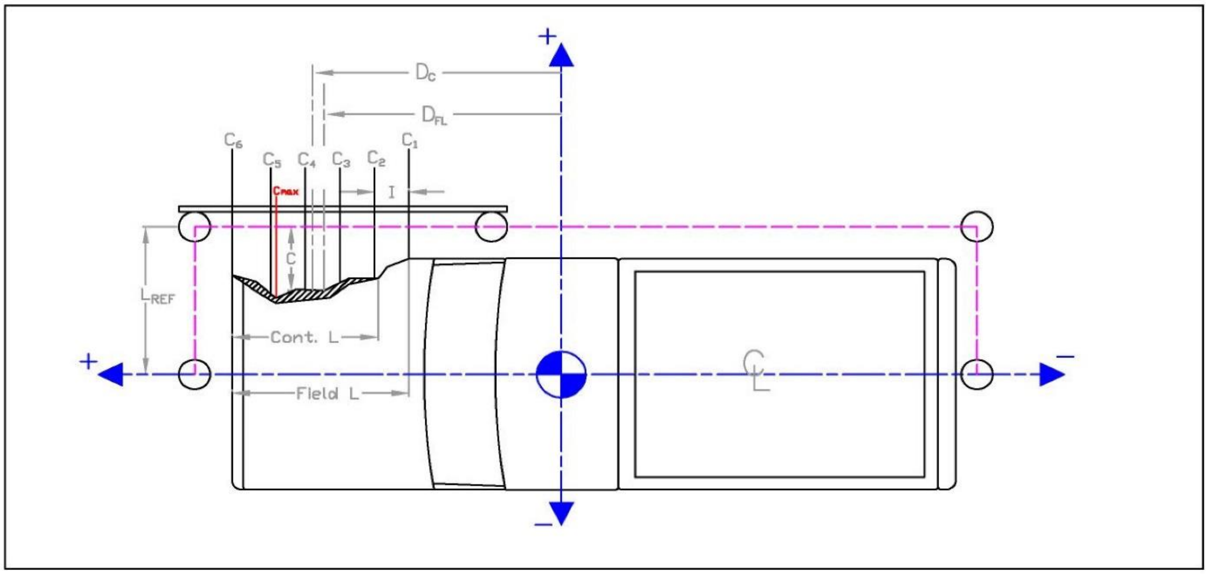
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)

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	15	(381)	-17	-(432)	5 1/8	(130)	9 5/8	(244)	1/4	(6)
C_2	14 1/2	(368)	-6	-(152)	4 1/8	(105)			3/4	(19)
C_3	14 3/8	(365)	5	(127)	4 1/8	(105)			5/8	(16)
C_4	18 1/8	(460)	16	(406)	5	(127)			3 1/2	(89)
C_5	31	(787)	27	(686)	7 1/2	(191)			13 7/8	(352)
C_6	N/A	N/A	38	(965)	20 1/2	(521)			N/A	N/A
C_{MAX}	37	(940)	29 5/8	(752)	9	(229)			18 3/8	(467)

Figure D-5. Exterior Vehicle Crush (NASS) - Front, Test No. SPTA-1

Date:	8/1/2018	Test Name:	SPTA-1	VIN:	1D7RB1CT2BS582287
Year:	2011	Make:	Dodge	Model:	Ram 1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	48 1/2	(1232)
Total Vehicle Length:	229 1/8	(5820)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-6	-(151)
Width of contact and induced crush - Field L:	229 1/8	(5820)
Crush measurement spacing interval (L/5) - I:	45 7/8	(1165)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-15 1/3	-(389)
Width of Contact Damage:	229 1/8	(5820)
Distance from vehicle c.g. to center of contact damage - D_C:	-15 1/3	-(389)

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	-129 7/8	-(3299)	33 1/2	(851)	4 1/2	(114)	N/A	N/A
C_2	N/A	N/A	-84	-(2134)	5 1/2	(140)			N/A	N/A
C_3	10	(254)	-38 1/8	-(968)	5 3/4	(146)			- 1/4	-(6)
C_4	10	(254)	7 3/4	(197)	5	(127)			1/2	(13)
C_5	N/A	N/A	53 5/8	(1362)	5 5/8	(143)			N/A	N/A
C_6	38	(965)	99 1/2	(2527)	8 7/8	(225)			24 5/8	(625)
C_{MAX}	38	(965)	99 1/2	(2527)	8 7/8	(225)			24 5/8	(625)

Figure D-6. Exterior Vehicle Crush (NASS) - Side, Test No. SPTA-1

Date:	7/31/2018	Test Name:	SPTA-1	VIN:	1D7RB1CT2BS582287
Year:	2011	Make:	Dodge	Model:	Ram 1500

Reference Set 1

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

Reference Set 2

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

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

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

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

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

Notes on vehicle interior crush:

Figure D-7. Maximum Occupant Compartment Deformation, Test No. SPTA-1

Date: 9/12/2018 Test Name: SPTA-2 VIN: kmhcn4ac2bu618362
Year: 2011 Make: Hyundai Model: Accent

VEHICLE DEFORMATION
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	60.0115	38.9026	2.8526	59.7735	38.8028	3.2019	0.2380	0.0998	-0.3493	0.4343	0.2380	X
	2	61.1422	36.1405	4.2877	60.9434	36.1692	4.5914	0.1988	-0.0287	-0.3037	0.3641	0.1988	X
	3	60.9368	32.5848	4.4677	60.8214	32.5007	4.7220	0.1154	0.0841	-0.2543	0.2916	0.1154	X
	4	61.1490	29.1709	4.6719	60.9109	29.0978	4.9608	0.2381	0.0731	-0.2889	0.3814	0.2381	X
	5	61.2756	25.0985	4.6986	61.1620	25.0153	5.0279	0.1136	0.0832	-0.3293	0.3581	0.1136	X
	6	58.0519	39.8720	5.9874	57.8480	39.7967	6.3320	0.2039	0.0753	-0.3446	0.4074	0.2039	X
	7	57.7947	36.4047	6.3458	57.6113	36.2386	6.6676	0.1834	0.1661	-0.3218	0.4059	0.1834	X
	8	57.7272	32.7870	6.2617	57.5546	32.6043	6.5701	0.1726	0.1827	-0.3084	0.3978	0.1726	X
	9	58.0283	29.1097	6.5839	57.9428	29.1163	6.8481	0.0855	-0.0066	-0.2642	0.2778	0.0855	X
	10	58.1498	26.0574	6.5599	57.9846	25.9450	6.8832	0.1652	0.1124	-0.3233	0.3801	0.1652	X
FLOOR PAN (Z)	11	52.6403	40.9697	7.5224	52.4782	40.9579	7.8456	0.1621	0.0118	-0.3232	0.3618	-0.3232	Z
	12	52.5261	36.5399	7.5811	52.4125	36.4740	7.8813	0.1136	0.0659	-0.3002	0.3277	-0.3002	Z
	13	52.2332	32.5854	7.4276	52.1048	32.5086	7.7331	0.1284	0.0768	-0.3055	0.3402	-0.3055	Z
	14	52.1146	28.2274	7.7402	51.9804	28.1789	7.8297	0.1342	0.0485	-0.0895	0.1684	-0.0895	Z
	15	52.2757	24.2810	7.7423	52.1335	24.1816	8.0174	0.1422	0.0994	-0.2751	0.3252	-0.2751	Z
	16	47.6965	41.2375	7.8308	47.5458	41.1541	8.1496	0.1507	0.0834	-0.3188	0.3624	-0.3188	Z
	17	47.3524	36.5085	8.0535	47.1987	36.3713	8.3373	0.1537	0.1372	-0.2838	0.3507	-0.2838	Z
	18	47.2680	32.2112	7.6085	47.0768	32.1652	7.9270	0.1912	0.0460	-0.3185	0.3743	-0.3185	Z
	19	47.3707	28.6821	7.8196	47.1706	28.5574	8.0029	0.2001	0.1247	-0.1833	0.2986	-0.1833	Z
	20	47.7993	24.3660	8.3566	47.6305	24.2855	8.6328	0.1688	0.0805	-0.2762	0.3336	-0.2762	Z
	21	42.1883	40.9582	7.9732	42.0410	40.8251	8.2342	0.1473	0.1331	-0.2610	0.3279	-0.2610	Z
	22	41.7448	36.0777	8.1303	41.5245	35.9429	8.4167	0.2203	0.1348	-0.2864	0.3857	-0.2864	Z
	23	41.3895	32.4147	7.8436	41.2117	32.2596	8.1027	0.1778	0.1551	-0.2591	0.3504	-0.2591	Z
	24	41.7121	28.2630	7.9050	41.5313	28.1417	8.1605	0.1808	0.1213	-0.2555	0.3357	-0.2555	Z
	25	41.5722	24.4431	8.3728	41.3967	24.3261	8.6271	0.1755	0.1170	-0.2543	0.3304	-0.2543	Z
	26	37.2061	40.6335	7.9269	37.0313	40.4174	8.1551	0.1748	0.2161	-0.2282	0.3596	-0.2282	Z
	27	37.2623	35.5387	7.8991	37.0930	35.3962	8.1653	0.1693	0.1425	-0.2662	0.3462	-0.2662	Z
	28	37.6604	31.9294	7.9370	37.4780	31.8343	8.1842	0.1824	0.0951	-0.2472	0.3216	-0.2472	Z
	29	38.1841	28.0841	7.9050	38.0359	27.9574	8.2151	0.1482	0.1267	-0.3101	0.3663	-0.3101	Z
	30	38.5403	24.0742	7.7557	38.4710	23.9299	8.0077	0.0693	0.1443	-0.2520	0.2985	-0.2520	Z

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

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

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

Pretest Floor Pan	Posttest Floor Pan
	

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

Date: 9/12/2018 Test Name: SPTA-2 VIN: kmhcn4ac2bu618362
Year: 2011 Make: Hyundai Model: Accent

VEHICLE DEFORMATION
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	53.2031	37.2400	-5.2116	53.2070	37.1471	-4.9596	-0.0039	0.0929	-0.2520	0.2686	0.0000	NA
	2	54.0792	34.4262	-3.7011	54.1283	34.4410	-3.5230	-0.0491	-0.0148	-0.1781	0.1853	0.0000	NA
	3	53.6095	30.8979	-3.4825	53.7173	30.7942	-3.3767	-0.1078	0.1037	-0.1058	0.1832	0.0000	NA
	4	53.5656	27.4812	-3.2264	53.5347	27.3966	-3.1175	0.0309	0.0846	-0.1089	0.1413	0.0309	X
	5	53.3946	23.4112	-3.1423	53.4651	23.3075	-3.0217	-0.0705	0.1037	-0.1206	0.1740	0.0000	NA
	6	51.2112	38.3971	-2.1619	51.2765	38.3110	-1.8919	-0.0653	0.0861	-0.2700	0.2908	0.0000	NA
	7	50.6901	34.9635	-1.7680	50.7539	34.7847	-1.5447	-0.0638	0.1788	-0.2233	0.2931	0.0000	NA
	8	50.3626	31.3593	-1.8074	50.4172	31.1651	-1.6246	-0.0546	0.1942	-0.1828	0.2722	0.0000	NA
	9	50.3840	27.6753	-1.4269	50.5244	27.6598	-1.3172	-0.1404	0.0155	-0.1097	0.1788	0.0000	NA
	10	50.2839	24.6221	-1.4069	50.3182	24.4951	-1.2641	-0.0343	0.1270	-0.1428	0.1942	0.0000	NA
FLOOR PAN (Z)	11	45.8436	39.9067	-0.8364	45.9726	39.8973	-0.5406	-0.1290	0.0094	-0.2958	0.3228	-0.2958	Z
	12	45.4055	35.4981	-0.7243	45.5569	35.4324	-0.4833	-0.1514	0.0657	-0.2410	0.2921	-0.2410	Z
	13	44.8313	31.5732	-0.8367	44.9456	31.5019	-0.6195	-0.1143	0.0713	-0.2172	0.2556	-0.2172	Z
	14	44.3851	27.2405	-0.4720	44.4816	27.1958	-0.5038	-0.0965	0.0447	0.0318	0.1110	0.0318	Z
	15	44.2586	23.2934	-0.4129	44.3176	23.2002	-0.2906	-0.0590	0.0932	-0.1223	0.1647	-0.1223	Z
	16	40.9246	40.5357	-0.7090	41.0637	40.4784	-0.3807	-0.1391	0.0573	-0.3283	0.3611	-0.3283	Z
	17	40.2300	35.8479	-0.4373	40.3400	35.7386	-0.1780	-0.1100	0.1093	-0.2593	0.3021	-0.2593	Z
	18	39.8487	31.5615	-0.8292	39.9026	31.5517	-0.5695	-0.0539	0.0098	-0.2597	0.2654	-0.2597	Z
	19	39.6870	28.0379	-0.5687	39.7130	27.9482	-0.4719	-0.0260	0.0897	-0.0968	0.1345	-0.0968	Z
	20	39.7815	23.7111	0.0393	39.8207	23.6583	0.1936	-0.0392	0.0528	-0.1543	0.1677	-0.1543	Z
	21	35.4092	40.6573	-0.7605	35.5499	40.5787	-0.4538	-0.1407	0.0786	-0.3067	0.3465	-0.3067	Z
	22	34.6066	35.8246	-0.5560	34.6497	35.7530	-0.2607	-0.0431	0.0716	-0.2953	0.3069	-0.2953	Z
	23	33.9959	32.1928	-0.8077	34.0601	32.1028	-0.5642	-0.0642	0.0900	-0.2435	0.2674	-0.2435	Z
	24	34.0134	28.0302	-0.6808	34.0562	27.9731	-0.4755	-0.0428	0.0571	-0.2053	0.2173	-0.2053	Z
	25	33.5797	24.2380	-0.1687	33.6116	24.1831	0.0071	-0.0319	0.0549	-0.1758	0.1869	-0.1758	Z
	26	30.4211	40.6926	-0.9813	30.5279	40.5609	-0.6759	-0.1068	0.1317	-0.3054	0.3493	-0.3054	Z
	27	30.1075	35.6073	-0.9409	30.1980	35.5503	-0.6375	-0.0905	0.0570	-0.3034	0.3217	-0.3034	Z
	28	30.2405	31.9797	-0.8418	30.3038	31.9695	-0.5887	-0.0633	0.0102	-0.2531	0.2611	-0.2531	Z
	29	30.4838	28.1066	-0.8050	30.5570	28.0613	-0.5212	-0.0732	0.0453	-0.2838	0.2966	-0.2838	Z
	30	30.5524	24.0796	-0.8894	30.6828	24.0108	-0.6947	-0.1304	0.0688	-0.1947	0.2442	-0.1947	Z

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

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

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

Pretest Floor Pan	Posttest Floor Pan
	

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

Date: 9/12/2018 Test Name: SPTA-2 VIN: kmhcn4ac2bu618362
Year: 2011 Make: Hyundai Model: Accent

VEHICLE DEFORMATION
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[D] (X, Y, Z)	1	[redacted]											X, Y, Z
	2	48.3445	28.3969	-20.5979	48.0209	28.5643	-20.8591	0.3236	-0.1674	-0.2612	0.4483	0.4483	X, Y, Z
	3	49.1121	19.0603	-21.3512	48.8812	19.2638	-21.6400	0.2309	-0.2035	-0.2888	0.4221	0.4221	X, Y, Z
	4	45.7575	41.0807	-9.3760	45.6325	41.3390	-9.5680	0.1250	-0.2583	-0.1920	0.3453	0.3453	X, Y, Z
	5	45.0626	23.5706	-8.3315	44.8918	23.7717	-8.5982	0.1708	-0.2011	-0.2667	0.3752	0.3752	X, Y, Z
	6	43.1688	16.4213	-9.4013	43.0365	16.6300	-9.5857	0.1323	-0.2087	-0.1844	0.3083	0.3083	X, Y, Z
SIDE PANEL (Y)	7	51.7272	43.5475	1.5015	51.6347	43.8439	1.1779	0.0925	-0.2964	-0.3236	0.4485	-0.2964	Y
	8	51.6732	43.5400	-1.0722	51.6068	43.8226	-1.4497	0.0664	-0.2826	-0.3775	0.4762	-0.2826	Y
	9	56.6415	43.8880	1.3440	56.5120	44.1915	1.1258	0.1295	-0.3035	-0.2182	0.3956	-0.3035	Y
IMPACT SIDE DOOR (Y)	10	42.8782	44.5200	-16.1782	42.6553	44.7155	-16.4929	0.2229	-0.1955	-0.3147	0.4324	-0.1955	Y
	11	30.2461	43.7776	-16.1325	30.0785	43.9639	-16.3156	0.1676	-0.1863	-0.1831	0.3104	-0.1863	Y
	12	19.7240	42.8584	-17.2330	19.4980	43.0152	-17.4249	0.2260	-0.1568	-0.1919	0.3354	-0.1568	Y
	13	42.4583	44.4022	-4.5691	42.3391	44.6806	-4.8960	0.1192	-0.2784	-0.3269	0.4456	-0.2784	Y
	14	33.8499	44.4944	-1.6087	33.7663	44.7702	-1.8571	0.0836	-0.2758	-0.2484	0.3805	-0.2758	Y
	15	24.4264	43.3711	-1.0565	24.3274	43.6183	-1.2657	0.0990	-0.2472	-0.2092	0.3386	-0.2472	Y
ROOF - (Z)	16	26.5478	32.3433	-37.7370	26.3123	32.4263	-37.8468	0.2355	-0.0830	-0.1098	0.2728	-0.1098	Z
	17	27.2943	26.8387	-38.1468	27.0022	26.9430	-38.2629	0.2921	-0.1043	-0.1161	0.3312	-0.1161	Z
	18	27.6958	23.5121	-38.2990	27.4029	23.6171	-38.4115	0.2929	-0.1050	-0.1125	0.3309	-0.1125	Z
	19	28.1402	19.6829	-38.3969	27.8405	19.8207	-38.5085	0.2997	-0.1378	-0.1116	0.3482	-0.1116	Z
	20	28.3909	15.1942	-38.4457	28.1644	15.3306	-38.5413	0.2265	-0.1364	-0.0956	0.2812	-0.0956	Z
	21	23.3448	31.5328	-38.2731	23.0821	31.6381	-38.3740	0.2627	-0.1053	-0.1009	0.3005	-0.1009	Z
	22	23.6225	27.8834	-38.5812	23.5510	28.0074	-38.6526	0.0715	-0.1240	-0.0714	0.1600	-0.0714	Z
	23	24.5124	24.1015	-38.7387	24.4561	24.2817	-38.8005	0.0563	-0.1802	-0.0618	0.1986	-0.0618	Z
	24	25.0686	20.0079	-38.8584	25.0360	20.2481	-38.9124	0.0326	-0.2402	-0.0540	0.2483	-0.0540	Z
	25	25.6254	15.5605	-38.8811	25.5554	15.7640	-38.9399	0.0700	-0.2035	-0.0588	0.2231	-0.0588	Z
	26	20.4064	31.1662	-38.5963	20.2936	31.2733	-38.6701	0.1128	-0.1071	-0.0738	0.1722	-0.0738	Z
	27	21.0004	27.6635	-38.8641	20.9682	27.7636	-38.9308	0.0322	-0.1001	-0.0667	0.1245	-0.0667	Z
	28	21.5910	23.9941	-39.0592	21.5035	24.1521	-39.1246	0.0875	-0.1580	-0.0654	0.1921	-0.0654	Z
	29	22.3720	20.0242	-39.1671	22.3160	20.1547	-39.2274	0.0560	-0.1305	-0.0603	0.1543	-0.0603	Z
	30	22.6291	15.7704	-39.2298	22.6160	15.9635	-39.2888	0.0131	-0.1931	-0.0590	0.2023	-0.0590	Z
A-PILLAR Maximum (X, Y, Z)	31	50.3539	42.2377	-23.7994	50.3105	42.3759	-23.9635	0.0434	-0.1382	-0.1641	0.2189	0.0434	X
	32	46.6222	41.2213	-26.1572	46.5634	41.3552	-26.2787	0.0588	-0.1339	-0.1215	0.1901	0.0588	X
	33	43.9813	40.4733	-27.6970	43.9214	40.5880	-27.8726	0.0599	-0.1147	-0.1756	0.2181	0.0599	X
	34	40.7327	39.5475	-29.6504	40.6887	39.6617	-29.8268	0.0440	-0.1142	-0.1764	0.2147	0.0440	X
	35	38.4832	38.8993	-30.8484	38.3334	38.9964	-30.9916	0.1498	-0.0971	-0.1432	0.2289	0.1498	X
	36	36.2753	38.2746	-31.9151	36.1852	38.3794	-32.0692	0.0901	-0.1048	-0.1541	0.2070	0.0901	X
A-PILLAR Lateral (Y)	31	50.3539	42.2377	-23.7994	50.3105	42.3759	-23.9635	0.0434	-0.1382	-0.1641	0.2189	-0.1382	Y
	32	46.6222	41.2213	-26.1572	46.5634	41.3552	-26.2787	0.0588	-0.1339	-0.1215	0.1901	-0.1339	Y
	33	43.9813	40.4733	-27.6970	43.9214	40.5880	-27.8726	0.0599	-0.1147	-0.1756	0.2181	-0.1147	Y
	34	40.7327	39.5475	-29.6504	40.6887	39.6617	-29.8268	0.0440	-0.1142	-0.1764	0.2147	-0.1142	Y
	35	38.4832	38.8993	-30.8484	38.3334	38.9964	-30.9916	0.1498	-0.0971	-0.1432	0.2289	-0.0971	Y
	36	36.2753	38.2746	-31.9151	36.1852	38.3794	-32.0692	0.0901	-0.1048	-0.1541	0.2070	-0.1048	Y
B-PILLAR Maximum (X, Y, Z)	37	12.6630	35.9238	-33.3123	12.6151	36.0501	-33.4214	0.0479	-0.1263	-0.1091	0.1736	0.0479	X
	38	10.8313	39.6701	-23.4231	10.7730	39.8375	-23.5233	0.0583	-0.1674	-0.1002	0.2036	0.0583	X
	39	15.6227	40.7215	-18.1912	15.5833	40.9099	-18.2557	0.0394	-0.1884	-0.0645	0.2030	0.0394	X
	40	12.0366	40.6231	-14.6114	12.0054	40.8110	-14.7085	0.0312	-0.1879	-0.0971	0.2138	0.0312	X
B-PILLAR Lateral (Y)	37	12.6630	35.9238	-33.3123	12.6151	36.0501	-33.4214	0.0479	-0.1263	-0.1091	0.1736	-0.1263	Y
	38	10.8313	39.6701	-23.4231	10.7730	39.8375	-23.5233	0.0583	-0.1674	-0.1002	0.2036	-0.1674	Y
	39	15.6227	40.7215	-18.1912	15.5833	40.9099	-18.2557	0.0394	-0.1884	-0.0645	0.2030	-0.1884	Y
	40	12.0366	40.6231	-14.6114	12.0054	40.8110	-14.7085	0.0312	-0.1879	-0.0971	0.2138	-0.1879	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.

[D] Dash point 1 - post test data was in error showing a deformation of >28". Post-test photos show virtually 0 deformation. Data point has been omitted.

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

Date:	9/12/2018	Test Name:	SPTA-2	VIN:	kmhcn4ac2bu618362
Year:	2011	Make:	Hyundai	Model:	Accent

VEHICLE DEFORMATION
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[D] (X, Y, Z)	1	[redacted]											X, Y, Z
	2	41.5917	27.4591	-29.0474	41.5770	27.3875	-28.9977	0.0147	0.0716	0.0497	0.0884	0.0884	X, Y, Z
	3	41.6927	18.0814	-29.6628	41.7883	18.0428	-29.6921	-0.0956	0.0386	-0.0293	0.1072	0.1072	X, Y, Z
	4	39.5957	40.4586	-18.0688	39.7234	40.3969	-17.8755	-0.1277	0.0617	0.1933	0.2397	0.2397	X, Y, Z
	5	37.5804	23.0633	-16.8362	37.6783	22.9378	-16.8285	-0.0979	0.1255	0.0077	0.1594	0.1594	X, Y, Z
	6	35.1996	16.0573	-17.8802	35.3465	15.9405	-17.8394	-0.1469	0.1168	0.0408	0.1921	0.1921	X, Y, Z
SIDE PANEL (Y)	7	45.3871	42.6379	-7.0346	45.5083	42.5534	-6.9365	-0.1212	0.0845	0.0981	0.1774	0.0845	Y
	8	45.4134	42.5973	-9.6085	45.5717	42.5118	-9.5633	-0.1583	0.0855	0.0452	0.1855	0.0855	Y
	9	50.3157	42.6152	-7.0373	50.3968	42.5476	-6.8160	-0.0811	0.0676	0.2213	0.2452	0.0676	Y
IMPACT SIDE DOOR (Y)	10	37.1923	44.0012	-25.0015	37.2449	43.9205	-24.9224	-0.0526	0.0807	0.0791	0.1246	0.0807	Y
	11	24.5445	44.1868	-25.3550	24.6482	44.0802	-25.1912	-0.1037	0.1066	0.1638	0.2212	0.1066	Y
	12	14.0231	44.0250	-26.7839	14.0725	43.8883	-26.6730	-0.0494	0.1367	0.1109	0.1828	0.1367	Y
	13	36.4012	44.0817	-13.4115	36.5179	44.0072	-13.3443	-0.1167	0.0745	0.0672	0.1539	0.0745	Y
	14	27.7344	44.8469	-10.7321	27.8723	44.7412	-10.6149	-0.1379	0.1057	0.1172	0.2096	0.1057	Y
	15	18.2411	44.4249	-10.4712	18.3597	44.2787	-10.3551	-0.1186	0.1462	0.1161	0.2212	0.1462	Y
ROOF - (Z)	16	20.6929	32.7441	-46.9283	20.8182	32.6617	-46.7745	-0.1253	0.0824	0.1538	0.2148	0.1538	Z
	17	21.0443	27.1942	-47.2473	21.1234	27.1396	-47.1331	-0.0791	0.0546	0.1142	0.1493	0.1142	Z
	18	21.2042	23.8453	-47.3463	21.2870	23.7922	-47.2475	-0.0828	0.0531	0.0988	0.1394	0.0988	Z
	19	21.3682	19.9928	-47.3835	21.4516	19.9735	-47.3063	-0.0834	0.0193	0.0772	0.1153	0.0772	Z
	20	21.2889	15.4976	-47.3701	21.4504	15.4716	-47.3008	-0.1615	0.0260	0.0693	0.1777	0.0693	Z
	21	17.4572	32.1627	-47.5578	17.5600	32.1043	-47.4124	-0.1028	0.0584	0.1454	0.1874	0.1454	Z
	22	17.4748	28.4987	-47.8126	17.7743	28.4470	-47.6525	-0.2995	0.0517	0.1601	0.3435	0.1601	Z
	23	18.0882	24.6599	-47.8957	18.4117	24.6645	-47.7458	-0.3235	-0.0046	0.1499	0.3566	0.1499	Z
	24	18.3448	20.5353	-47.9480	18.7015	20.5988	-47.8129	-0.3567	-0.0635	0.1351	0.3867	0.1351	Z
	25	18.5729	16.0592	-47.8991	18.8954	16.0888	-47.7951	-0.3225	-0.0296	0.1040	0.3401	0.1040	Z
	26	14.5114	32.0077	-47.9713	14.7646	31.9392	-47.8060	-0.2532	0.0685	0.1653	0.3100	0.1653	Z
	27	14.8538	28.4674	-48.1775	15.1920	28.3879	-48.0216	-0.3382	0.0795	0.1559	0.3808	0.1559	Z
	28	15.1783	24.7622	-48.3091	15.4707	24.7456	-48.1746	-0.2924	0.0166	0.1345	0.3223	0.1345	Z
	29	15.6677	20.7446	-48.3439	15.9947	20.6993	-48.2246	-0.3270	0.0453	0.1193	0.3510	0.1193	Z
	30	15.6126	16.4830	-48.3469	15.9923	16.4970	-48.2502	-0.3797	-0.0140	0.0967	0.3921	0.0967	Z
A-PILLAR Maximum (X, Y, Z)	31	44.7146	41.0679	-32.3491	44.9692	40.9709	-32.1001	-0.2546	0.0970	0.2490	0.3691	0.2672	Y, Z
	32	40.9939	40.2937	-34.8138	41.2421	40.2037	-34.5419	-0.2482	0.0900	0.2719	0.3790	0.2864	Y, Z
	33	38.3547	39.7191	-36.4289	38.6093	39.6157	-36.2248	-0.2546	0.1034	0.2041	0.3423	0.2288	Y, Z
	34	35.1095	39.0057	-38.4750	35.3891	38.9085	-38.2879	-0.2796	0.0972	0.1871	0.3502	0.2108	Y, Z
	35	32.8571	38.5068	-39.7372	33.0342	38.4051	-39.5324	-0.1771	0.1017	0.2048	0.2892	0.2287	Y, Z
	36	30.6436	38.0302	-40.8670	30.8864	37.9356	-40.6825	-0.2428	0.0946	0.1845	0.3193	0.2073	Y, Z
A-PILLAR Lateral (Y)	31	44.7146	41.0679	-32.3491	44.9692	40.9709	-32.1001	-0.2546	0.0970	0.2490	0.3691	0.0970	Y
	32	40.9939	40.2937	-34.8138	41.2421	40.2037	-34.5419	-0.2482	0.0900	0.2719	0.3790	0.0900	Y
	33	38.3547	39.7191	-36.4289	38.6093	39.6157	-36.2248	-0.2546	0.1034	0.2041	0.3423	0.1034	Y
	34	35.1095	39.0057	-38.4750	35.3891	38.9085	-38.2879	-0.2796	0.0972	0.1871	0.3502	0.0972	Y
	35	32.8571	38.5068	-39.7372	33.0342	38.4051	-39.5324	-0.1771	0.1017	0.2048	0.2892	0.1017	Y
	36	30.6436	38.0302	-40.8670	30.8864	37.9356	-40.6825	-0.2428	0.0946	0.1845	0.3193	0.0946	Y
B-PILLAR Maximum (X, Y, Z)	37	6.9778	37.3953	-42.9980	7.2720	37.3023	-42.8641	-0.2942	0.0930	0.1339	0.3364	0.1630	Y, Z
	38	5.1180	41.4078	-33.2191	5.3609	41.2969	-33.0610	-0.2429	0.1109	0.1581	0.3103	0.1931	Y, Z
	39	9.8075	42.1807	-27.8482	10.0474	42.0640	-27.6309	-0.2399	0.1167	0.2173	0.3441	0.2467	Y, Z
	40	6.1134	42.3968	-24.3853	6.3488	42.2539	-24.2136	-0.2354	0.1429	0.1717	0.3245	0.2234	Y, Z
B-PILLAR Lateral (Y)	37	6.9778	37.3953	-42.9980	7.2720	37.3023	-42.8641	-0.2942	0.0930	0.1339	0.3364	0.0930	Y
	38	5.1180	41.4078	-33.2191	5.3609	41.2969	-33.0610	-0.2429	0.1109	0.1581	0.3103	0.1109	Y
	39	9.8075	42.1807	-27.8482	10.0474	42.0640	-27.6309	-0.2399	0.1167	0.2173	0.3441	0.1167	Y
	40	6.1134	42.3968	-24.3853	6.3488	42.2539	-24.2136	-0.2354	0.1429	0.1717	0.3245	0.1429	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.

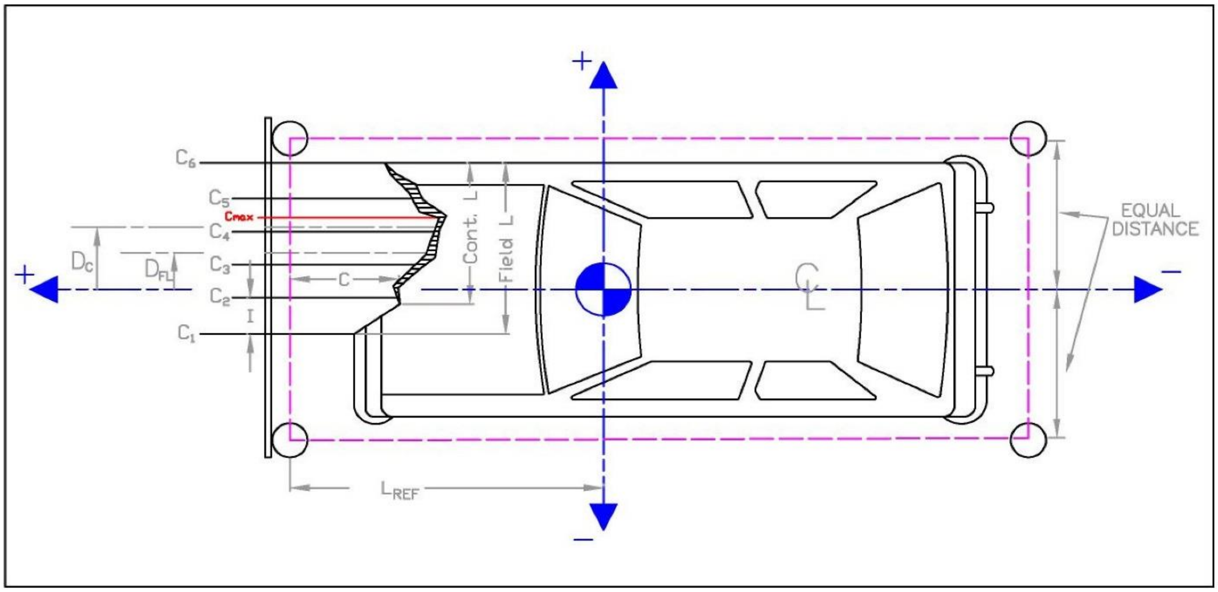
[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

[D] Dash point 1 - post test data was in error showing a deformation of >28". Post-test photos show virtually 0 deformation. Data point has been omitted.

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

Date: 9/14/2018 **Test Name:** SPTA-2 **VIN:** kmhcn4ac2bu618362

Year: 2011 **Make:** Hyundai **Model:** Accent



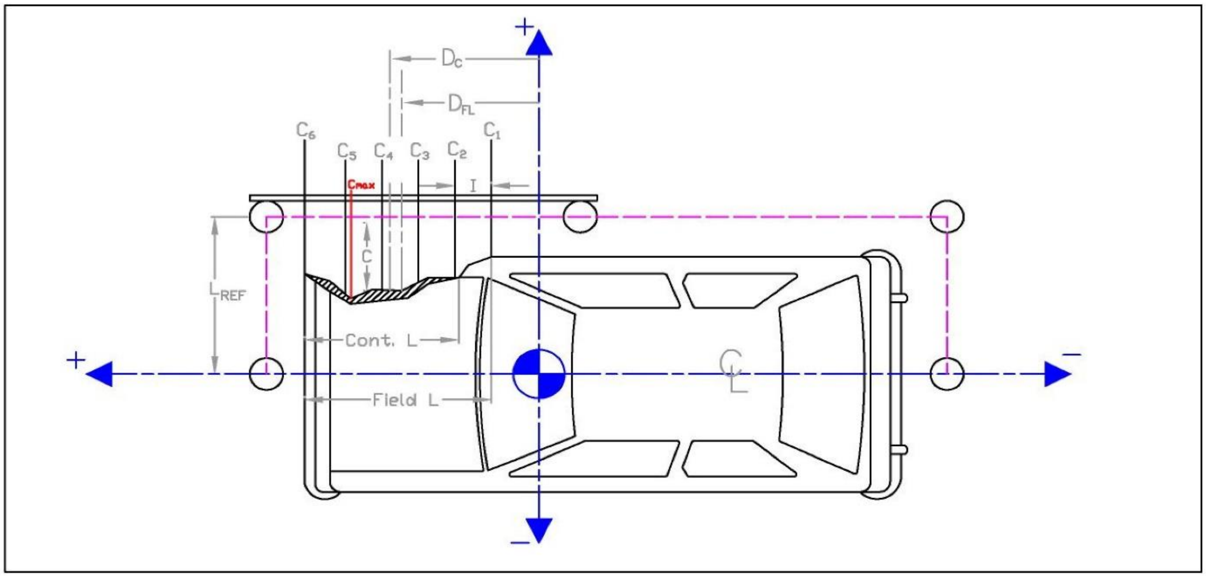
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	77 3/4	(1975)
Total Width of Vehicle:	65 5/8	(1667)
Width of contact and induced crush - Field L:	65 5/8	(1667)
Crush measurement spacing interval (L/5) - I:	13 1/8	(333)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	65 5/8	(1667)
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	29 1/2	(749)	-32 7/8	-(835)	20 1/4	(514)	6 2/3	(170)	2 4/7	(65)
C_2	16 1/4	(413)	-19 3/4	-(502)	4 3/4	(121)			4 4/5	(122)
C_3	18 3/8	(467)	-6 5/8	-(168)	2 3/8	(60)			9 1/3	(237)
C_4	21	(533)	6 1/2	(165)	2 3/8	(60)			12	(303)
C_5	16	(406)	19 5/8	(498)	4 3/4	(121)			4 4/7	(116)
C_6	N/A	N/A	32 3/4	(832)	19 7/8	(505)			N/A	N/A
C_{MAX}	21	(533)	6 1/2	(165)	2 3/8	(60)			12	(303)

Figure D-12. Exterior Vehicle Crush (NASS) – Front, Test No. SPTA-2

Date:	9/14/2018	Test Name:	SPTA-2	VIN:	kmhcn4ac2bu618362
Year:	2011	Make:	Hyundai	Model:	Accent



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	44	(1118)
Total Vehicle Length:	168 1/2	(4280)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-13	-(329)
Width of contact and induced crush - Field L:	49	(1245)
Crush measurement spacing interval (L/5) - I:	9 3/4	(248)
Distance from vehicle c.g. to center of Field L - D_{FL}:	42	(1067)
Width of Contact Damage:	49	(1245)
Distance from vehicle c.g. to center of contact damage - D_C:	42	(1067)

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	6 3/4	(171)	17 1/2	(445)	3 1/4	(83)	8	(203)	-4 1/2	-(114)
C_2	N/A	N/A	27 1/4	(692)	4	(102)			N/A	N/A
C_3	N/A	N/A	37	(940)	3 1/2	(89)			N/A	#VALUE!
C_4	12 1/2	(318)	46 3/4	(1187)	4	(102)			1/2	(13)
C_5	19	(483)	56 1/2	(1435)	6 1/8	(156)			4 7/8	(124)
C_6	N/A	N/A	66 1/4	(1683)	16 5/8	(422)			N/A	N/A
C_{MAX}	19	(483)	56 1/2	(1435)	6 1/8	(156)			4 7/8	(124)

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

Date: 9/12/2018 Test Name: SPTA-2 VIN: kmhcn4ac2bu618362
Year: 2011 Make: Hyundai Model: Accent

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

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

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

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

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

Notes on vehicle interior crush:

Figure D-14. Maximum Occupant Compartment Deformation, Test No. SPTA-2

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

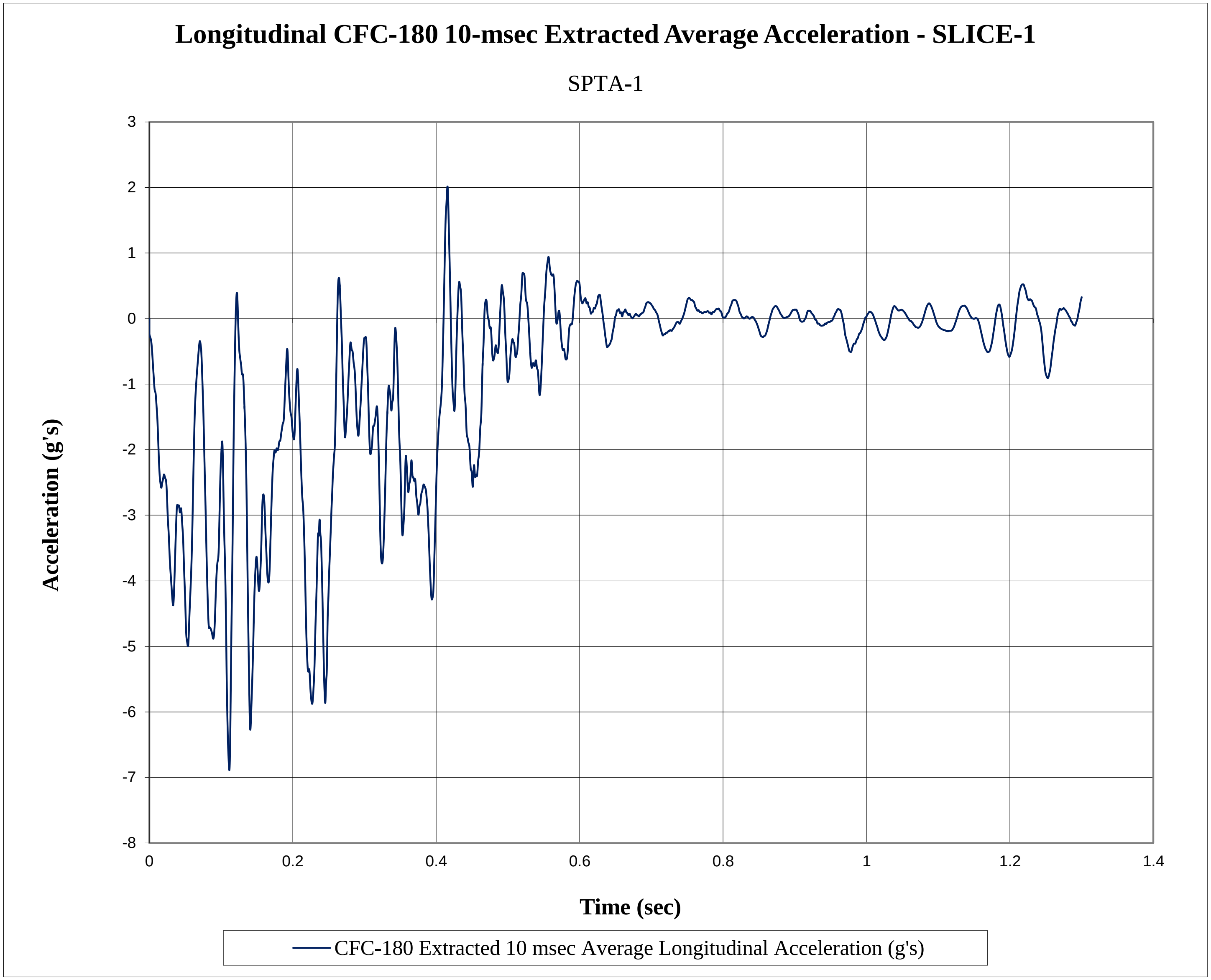


Figure E-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. SPTA-1

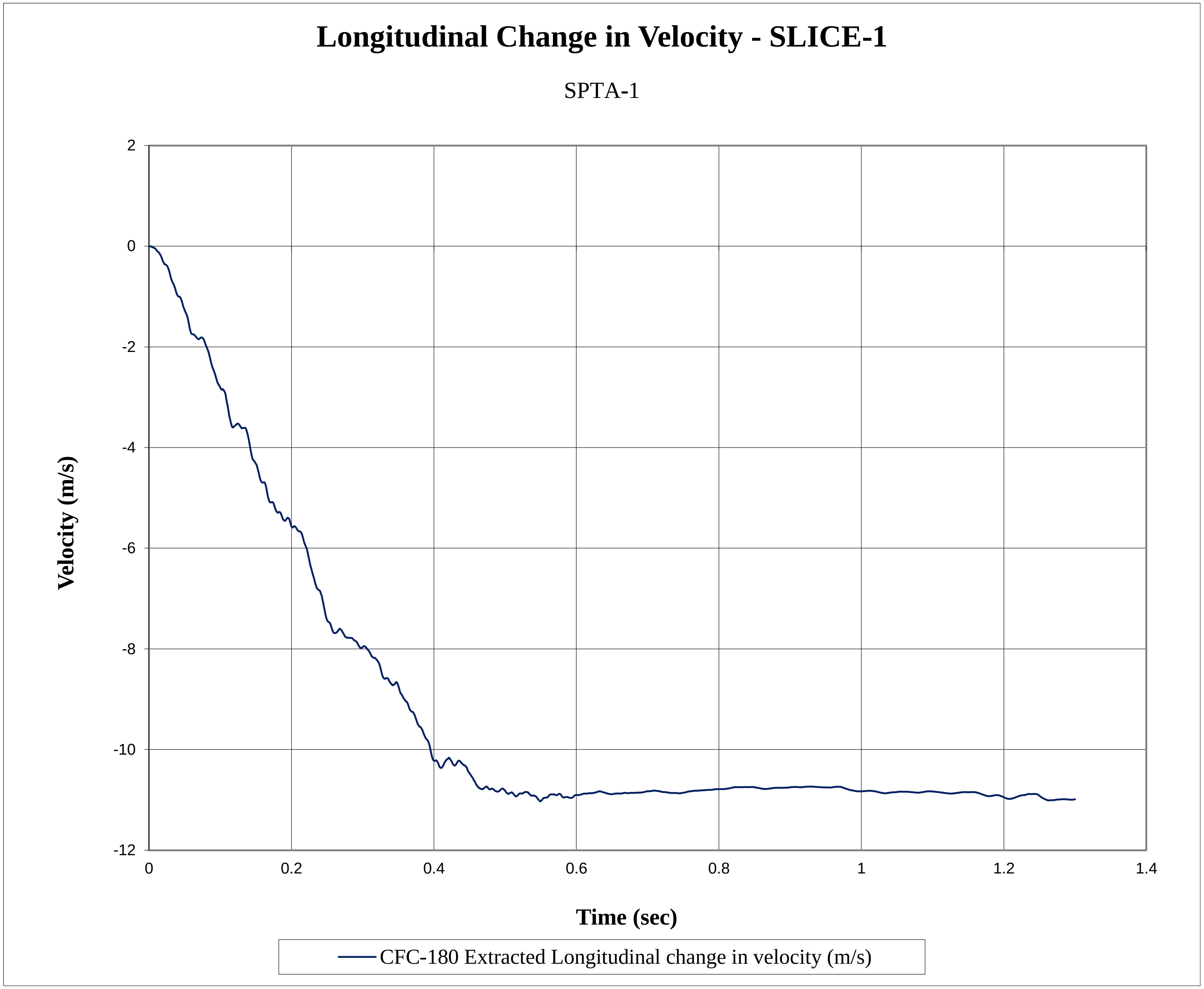


Figure E-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. SPTA-1

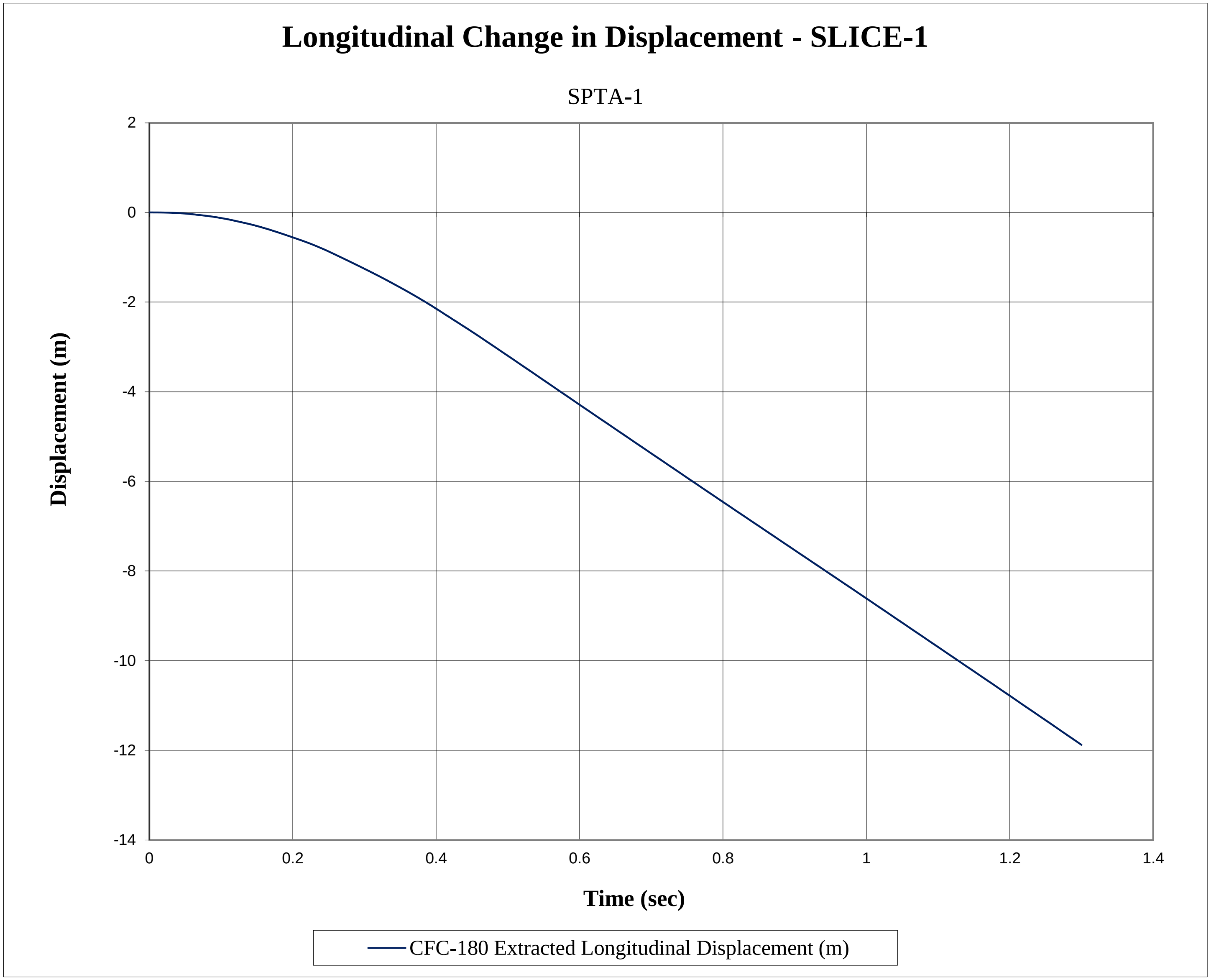


Figure E-3. Longitudinal Occupant Displacement (SLICE-1), Test No. SPTA-1

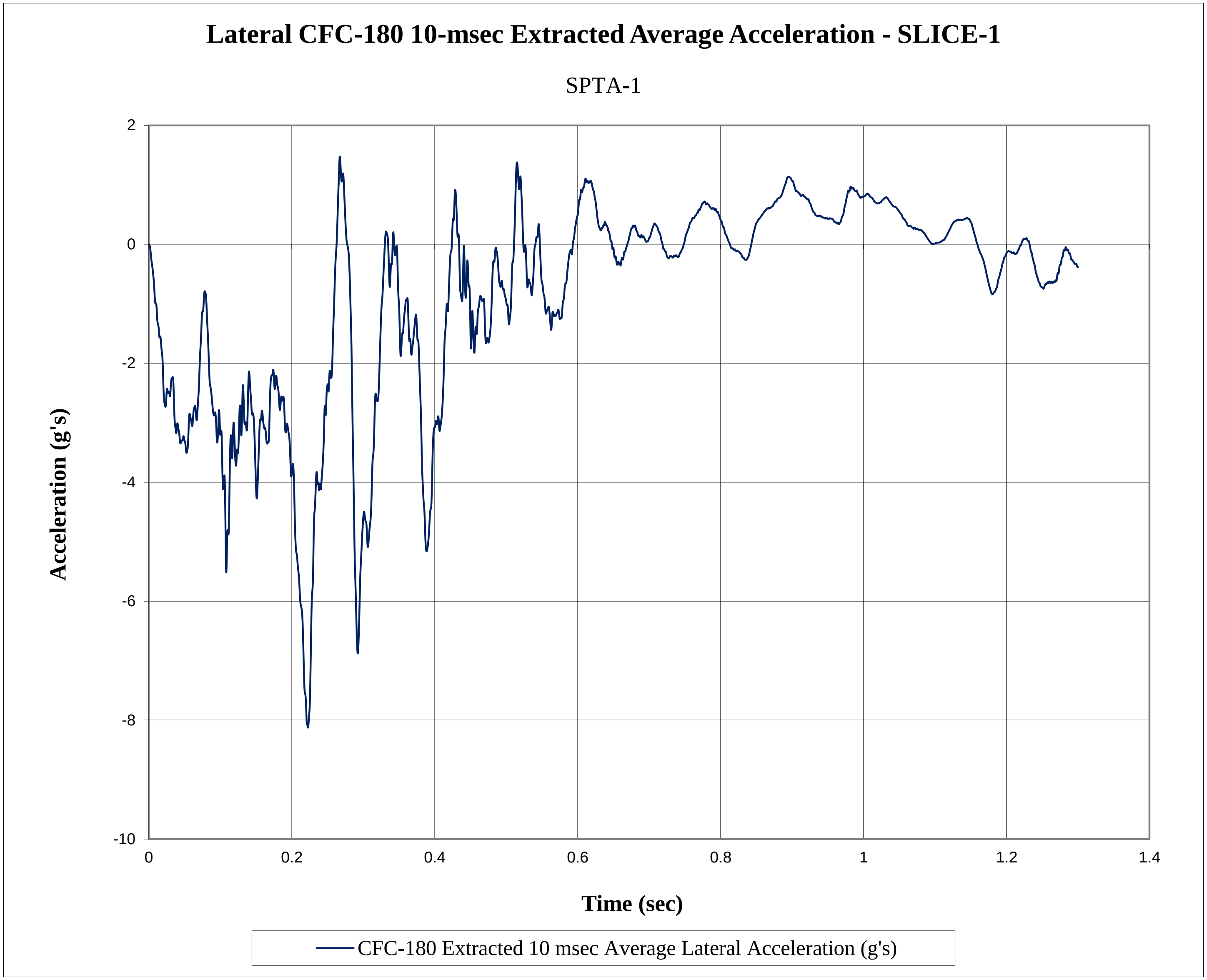


Figure E-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. SPTA-1

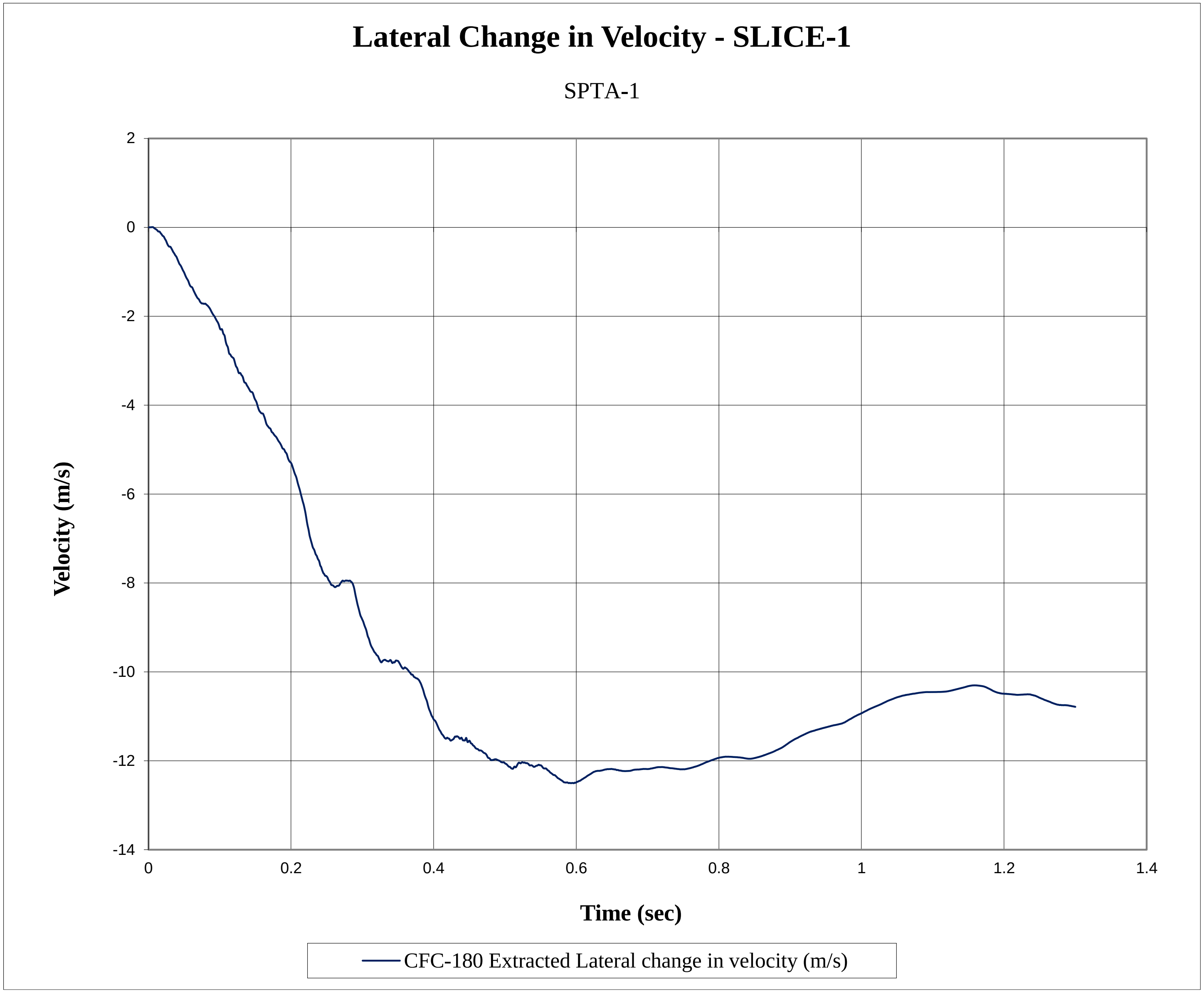


Figure E-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. SPTA-1

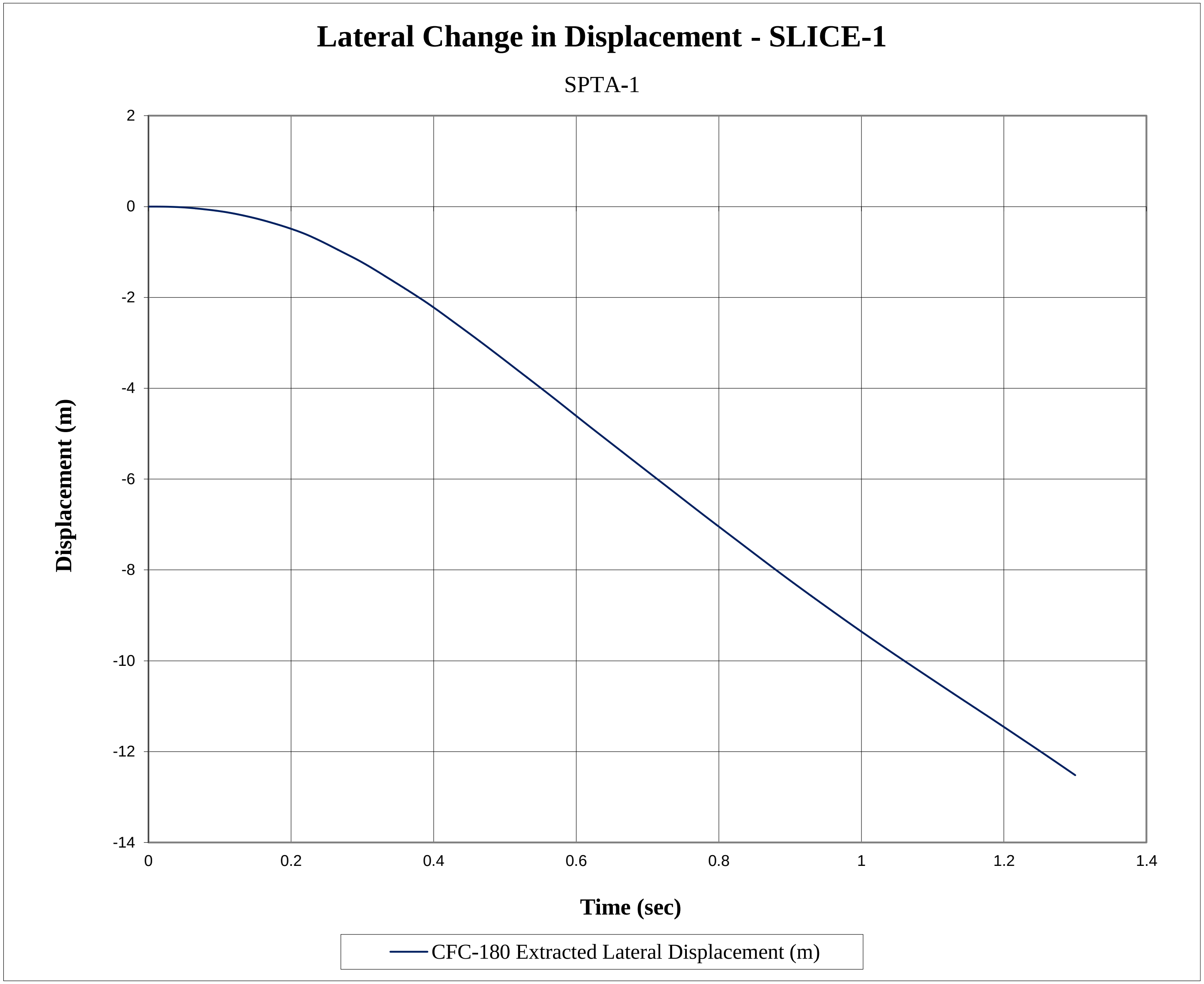


Figure E-6. Lateral Occupant Displacement (SLICE-1), Test No. SPTA-1

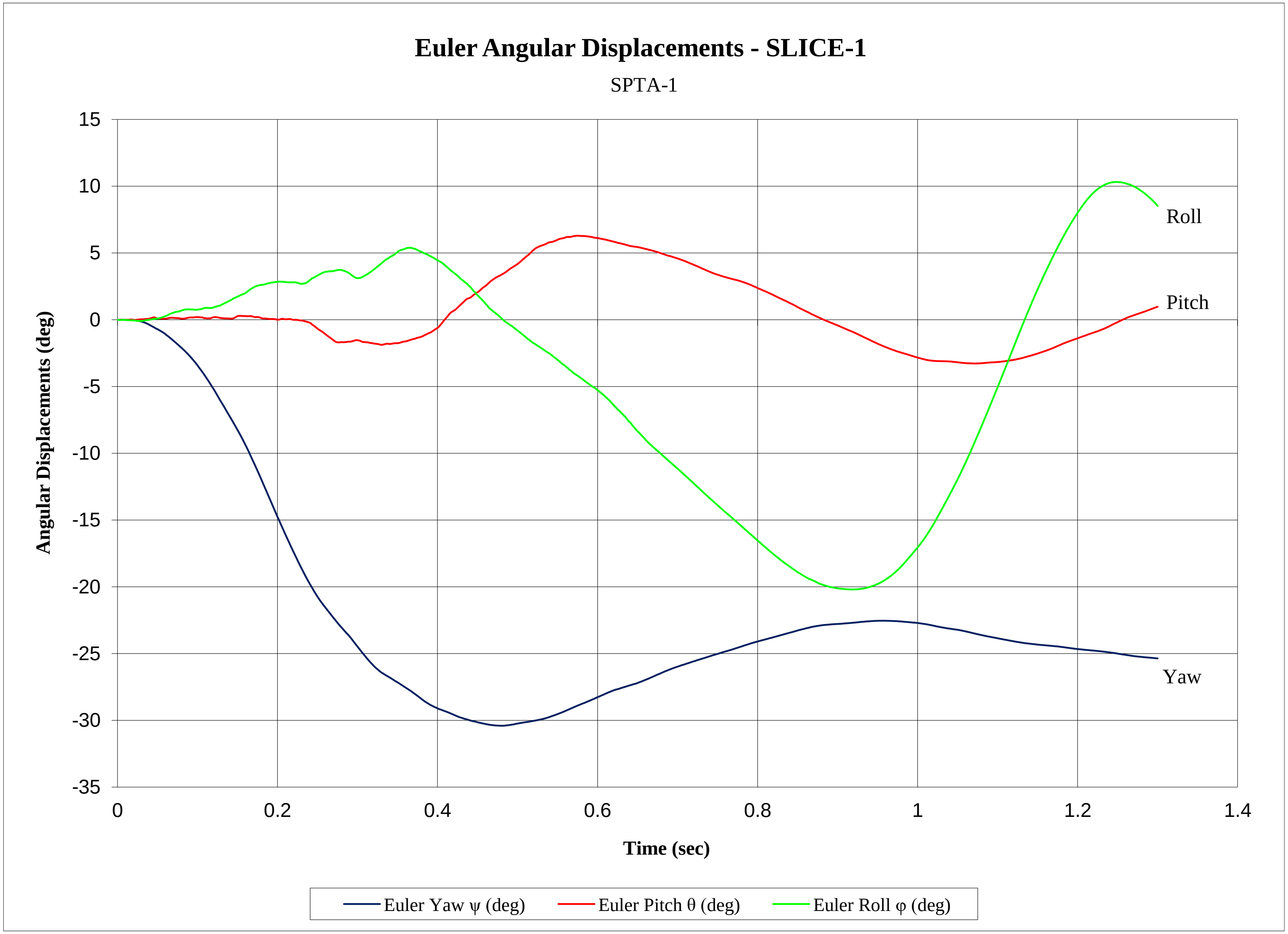


Figure E-7. Vehicle Angular Displacements (SLICE-1), Test No. SPTA-1

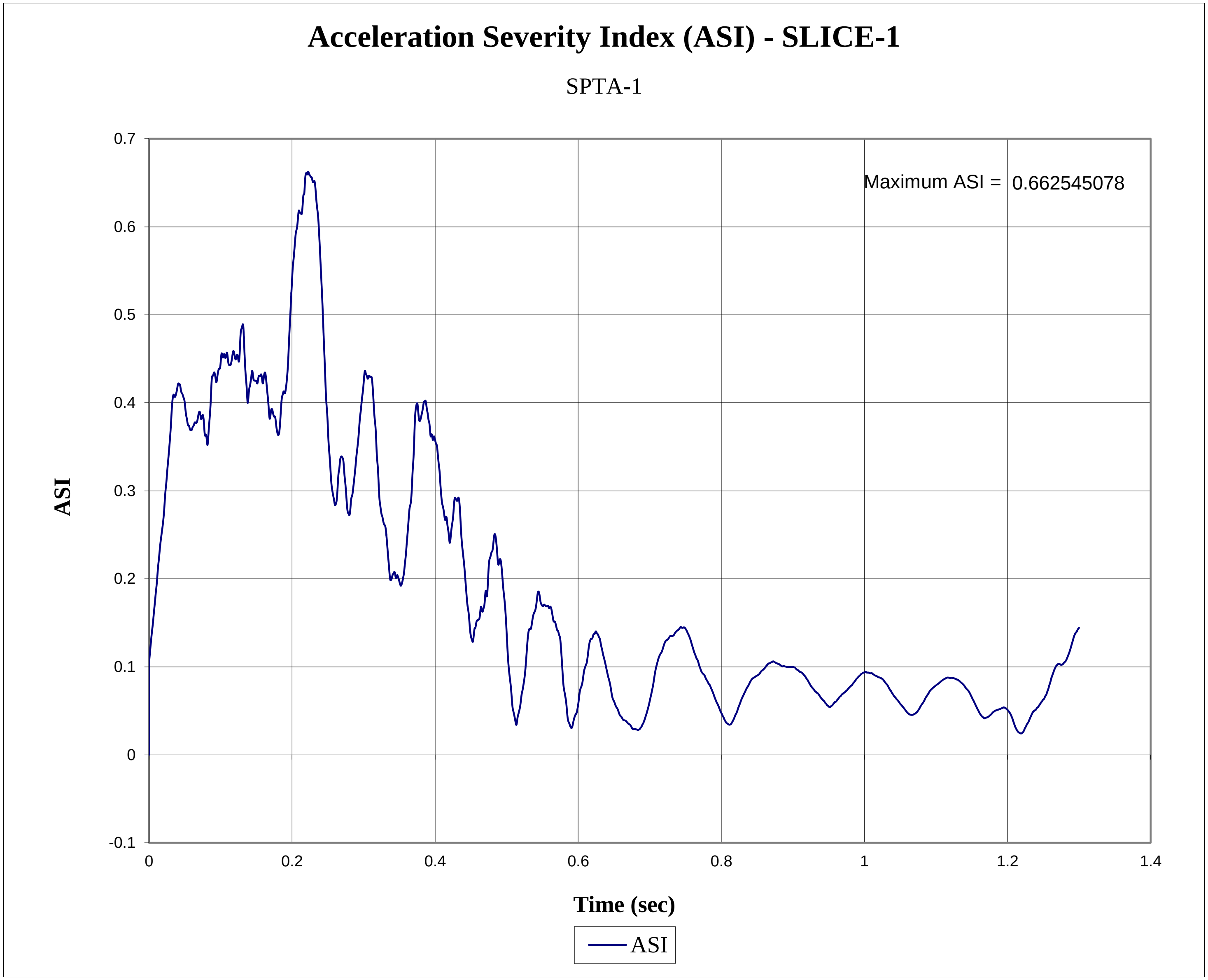


Figure E-8. Acceleration Severity Index (SLICE-1), Test No. SPTA-1

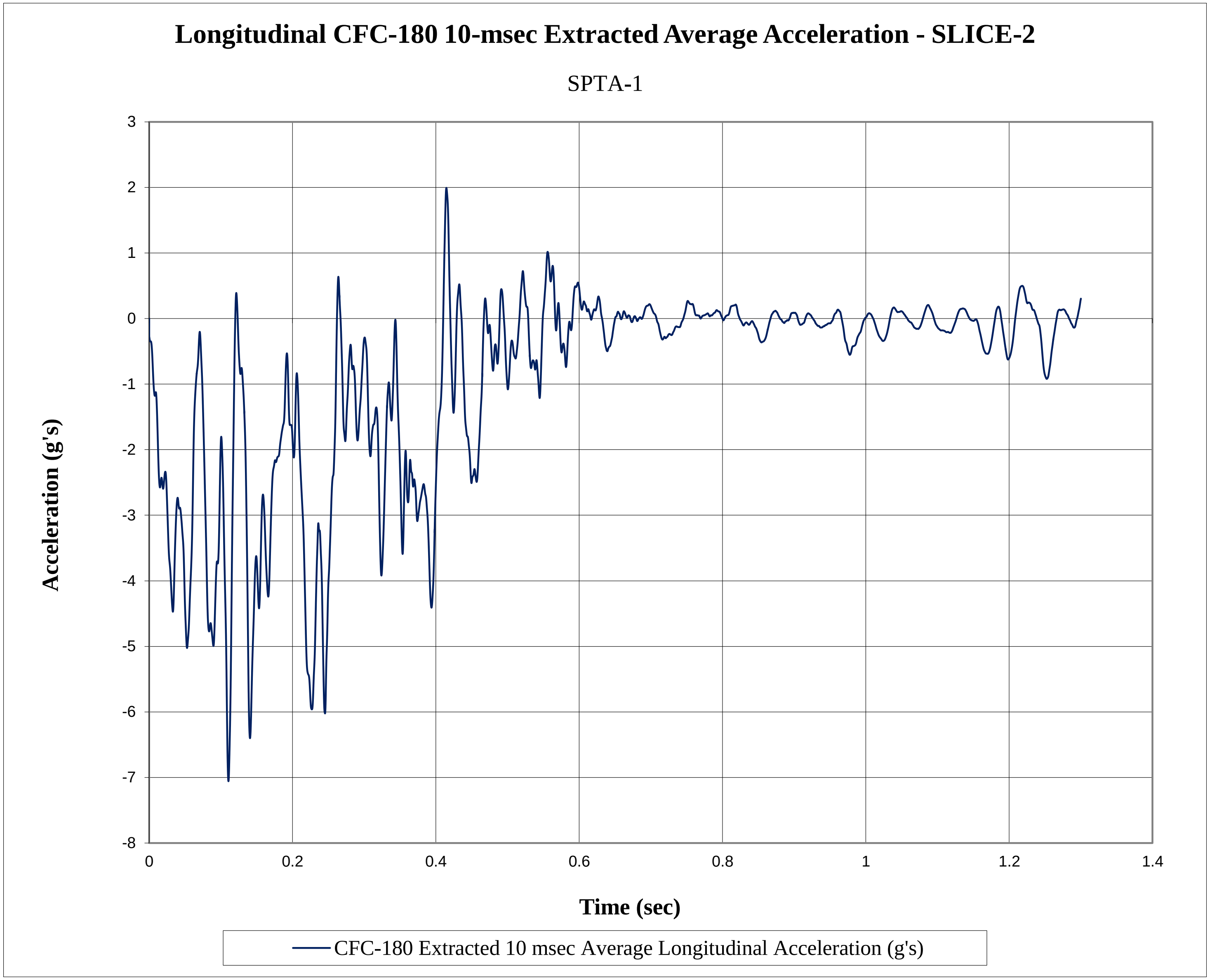


Figure E-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. SPTA-1

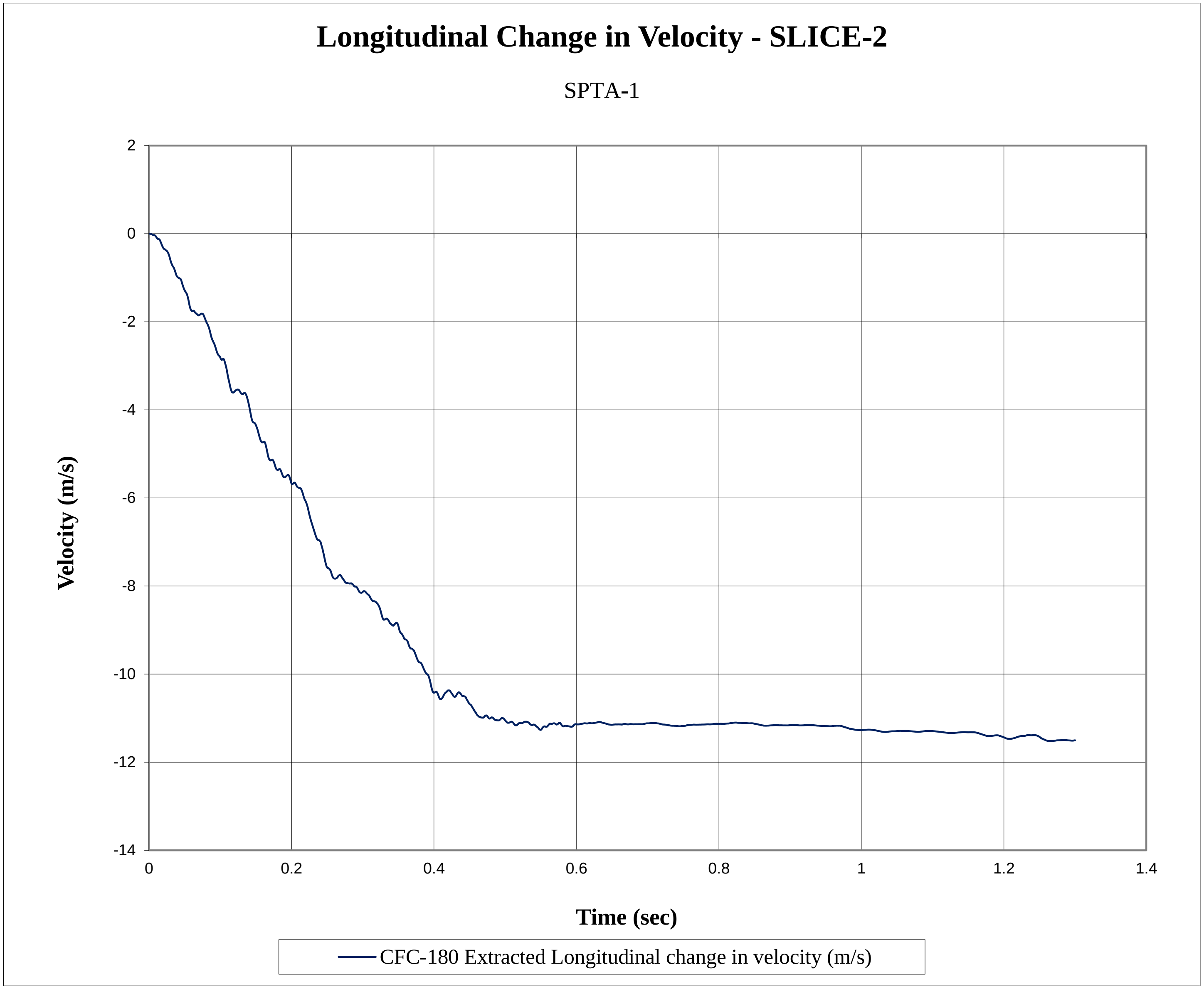


Figure E-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. SPTA-1

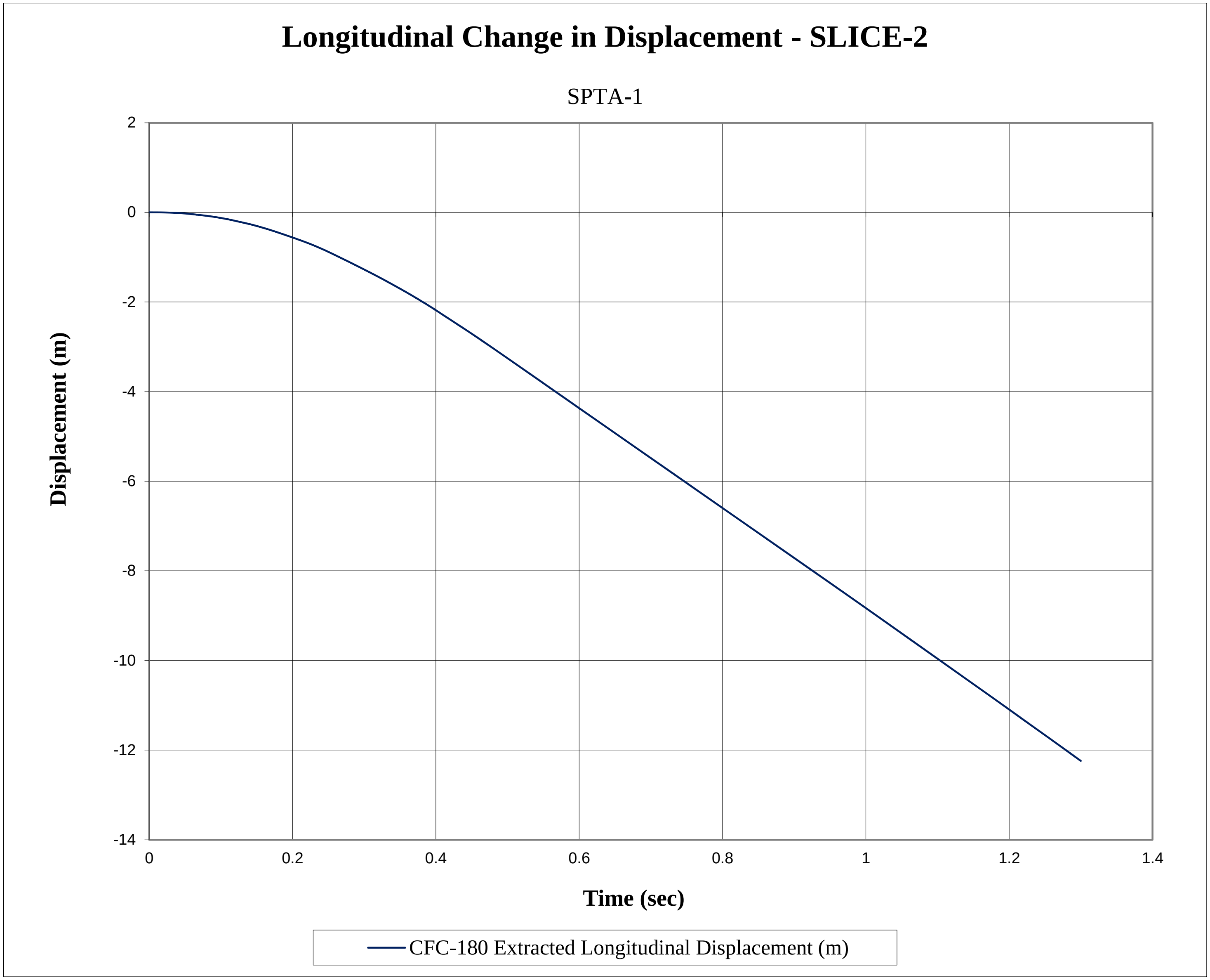


Figure E-11. Longitudinal Occupant Displacement (SLICE-2), Test No. SPTA-1

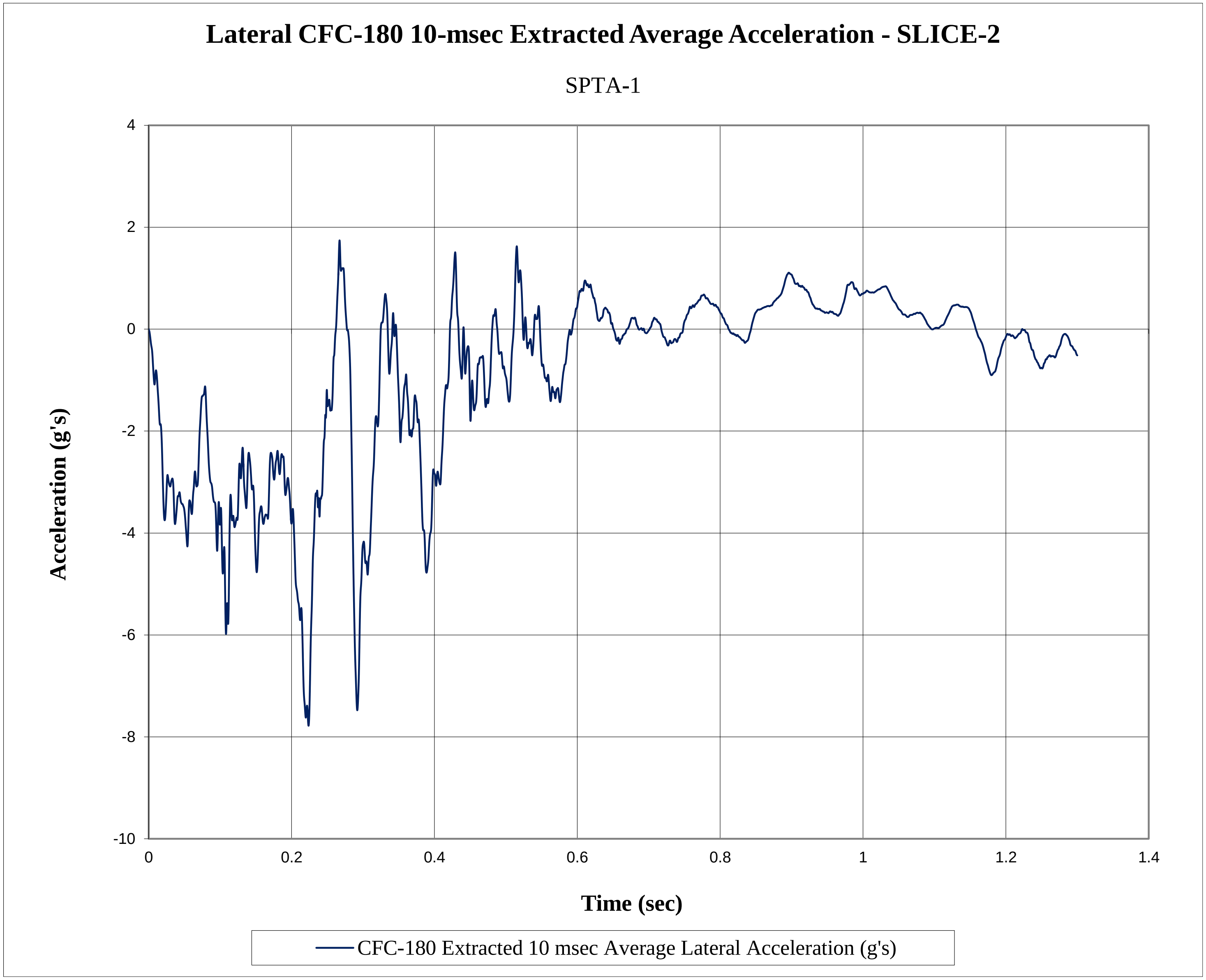


Figure E-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. SPTA-1

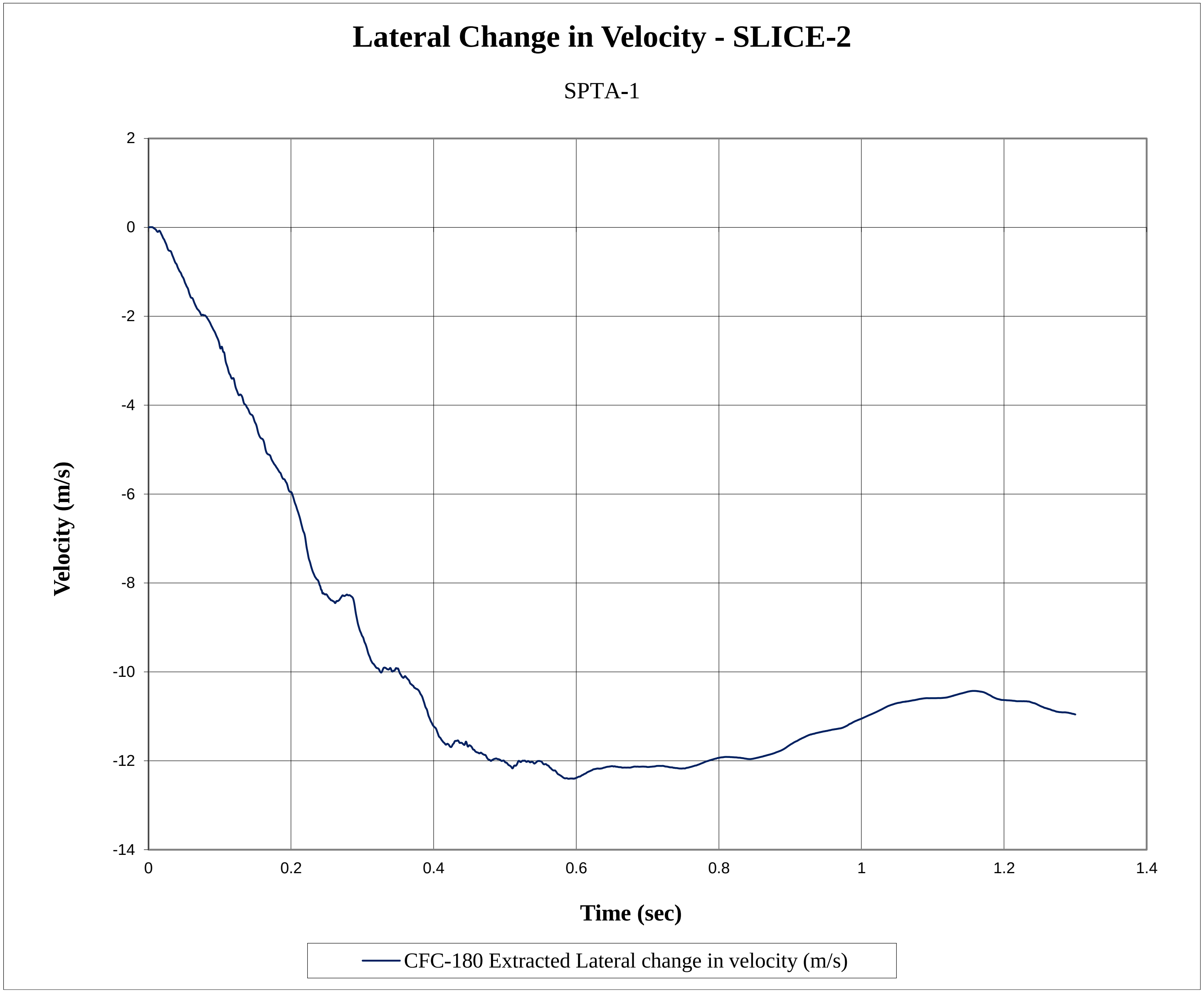


Figure E-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. SPTA-1

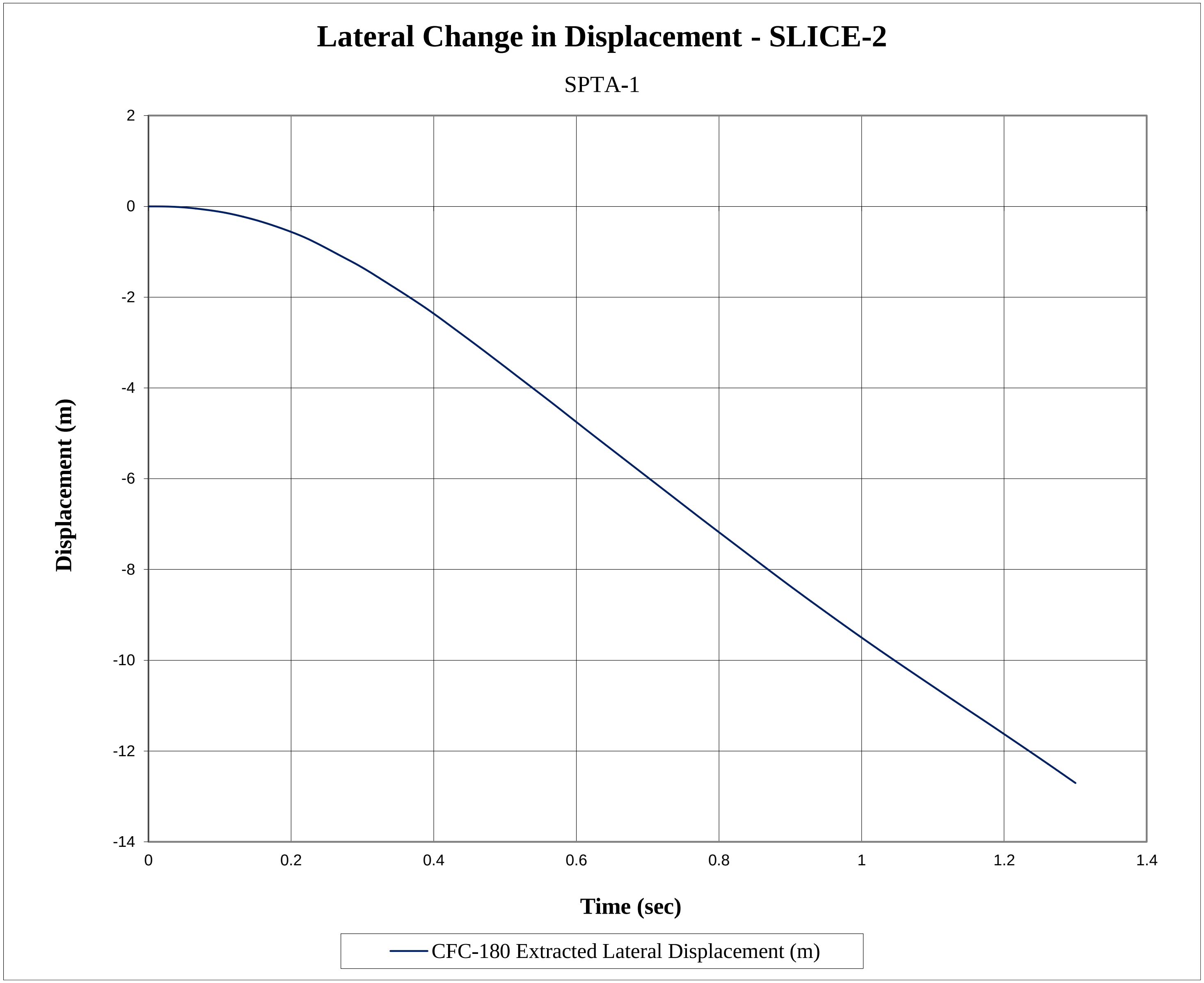


Figure E-14. Lateral Occupant Displacement (SLICE-2), Test No. SPTA-1

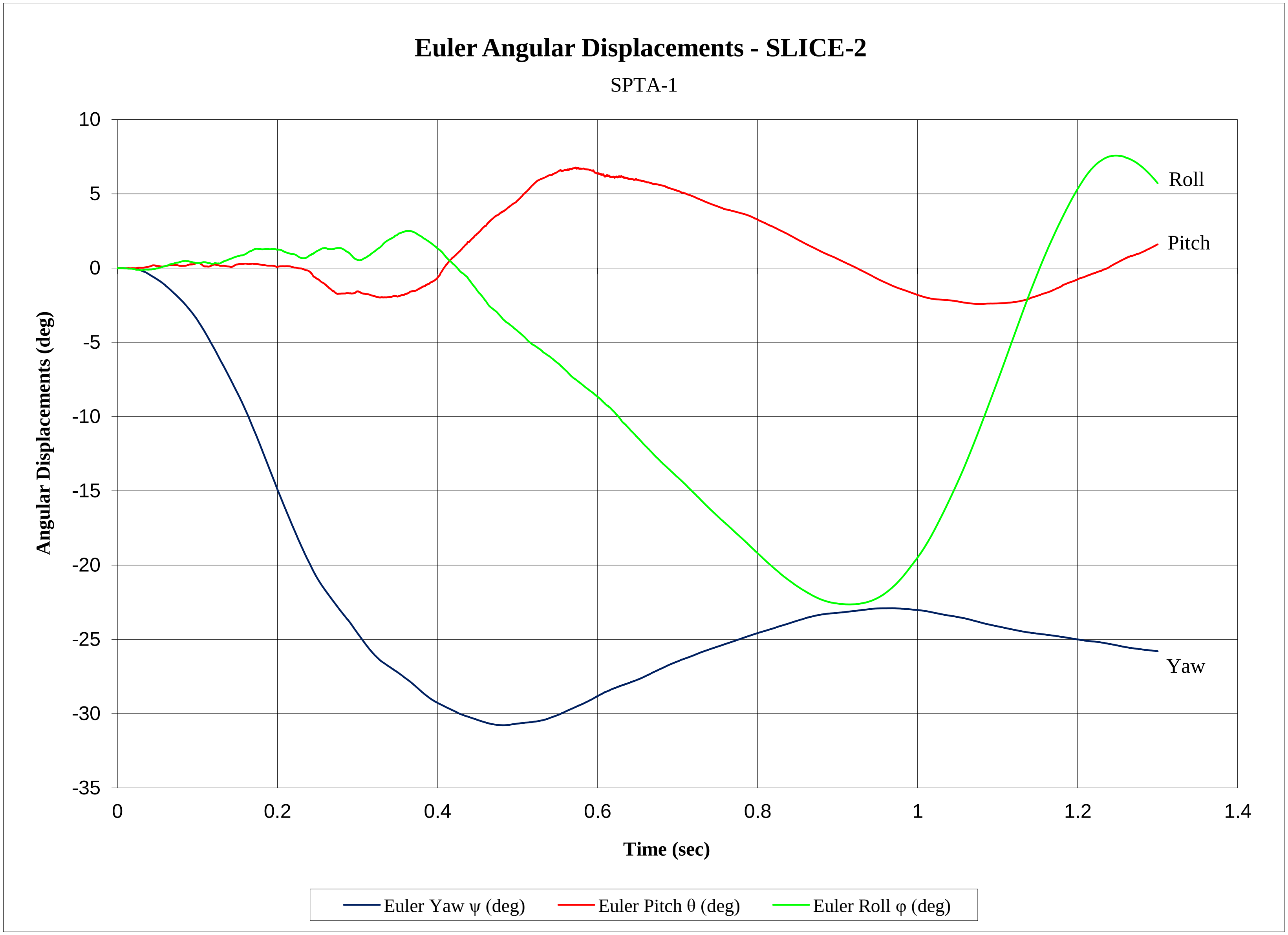


Figure E-15. Vehicle Angular Displacements (SLICE-2), Test No. SPTA-1

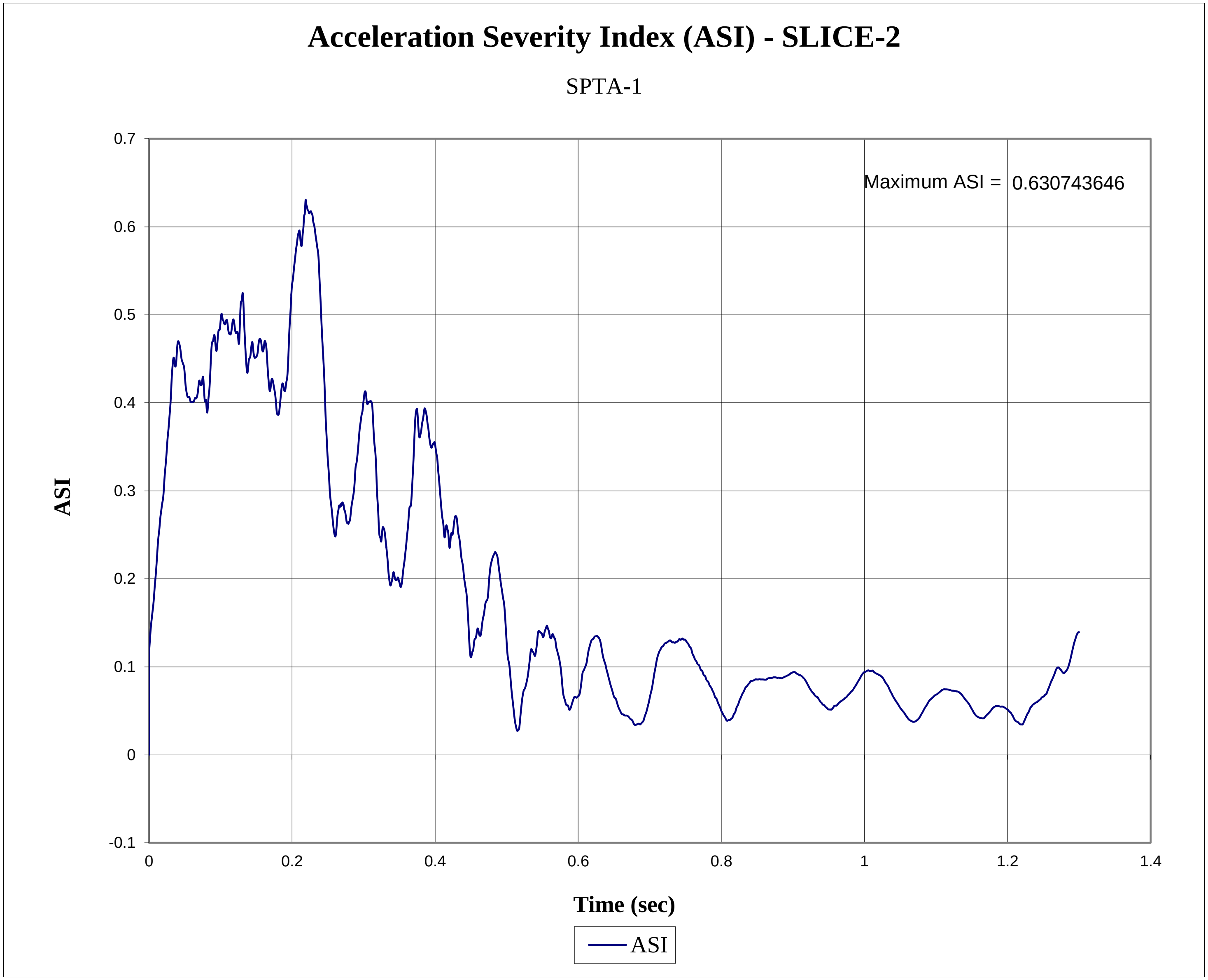


Figure E-16. Acceleration Severity Index (SLICE-2), Test No. SPTA-1

Appendix F. Load Cell Data, Test No. SPTA-1

MIDWEST ROADSIDE SAFETY FACILITY

Load Cell Summary

Test Information:

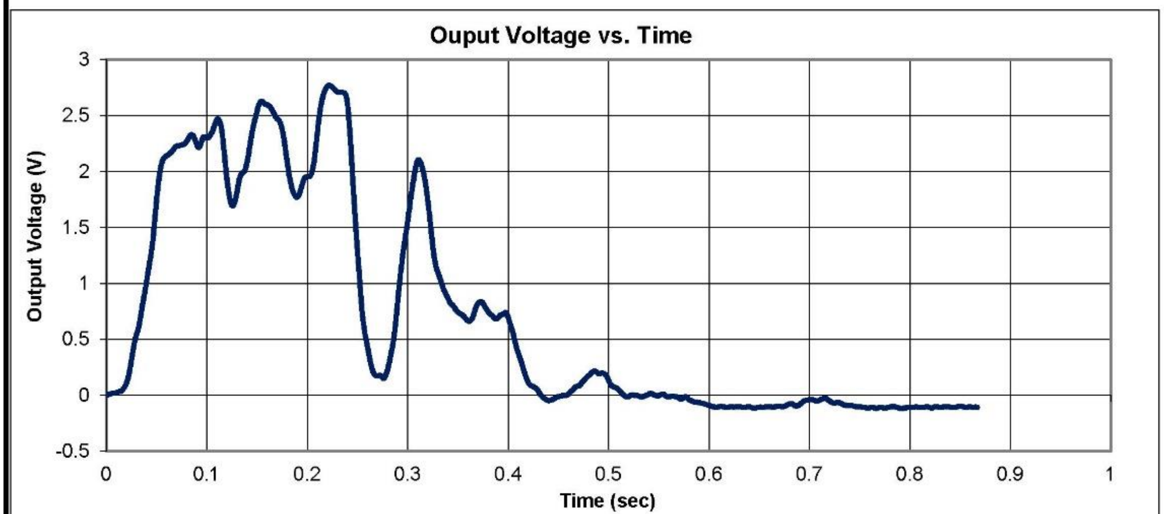
Test No:	spta-1
Date:	7/31/2018
System / Test Article:	Steep Post Terminal Achorage
LC Location / Component:	Upstream Anchor Cable
Additional Notes:	

Load Cell Information:

Load Cell No.:	433
Calibration Factor:	2.15809 mv/V
Input Voltage (excitation):	10.01 Volts
Gain:	400
Full Scale Load:	50 kips
Sample Rate:	10000 Hz
Cutoff Frequency:	100 Hz

Results:

Preload:	0.671 kips
Max. Load:	16.70 kips
Time of Max. Load:	0.222 sec
Event Duration:	0.8672 sec
Final Load:	0.05 kips



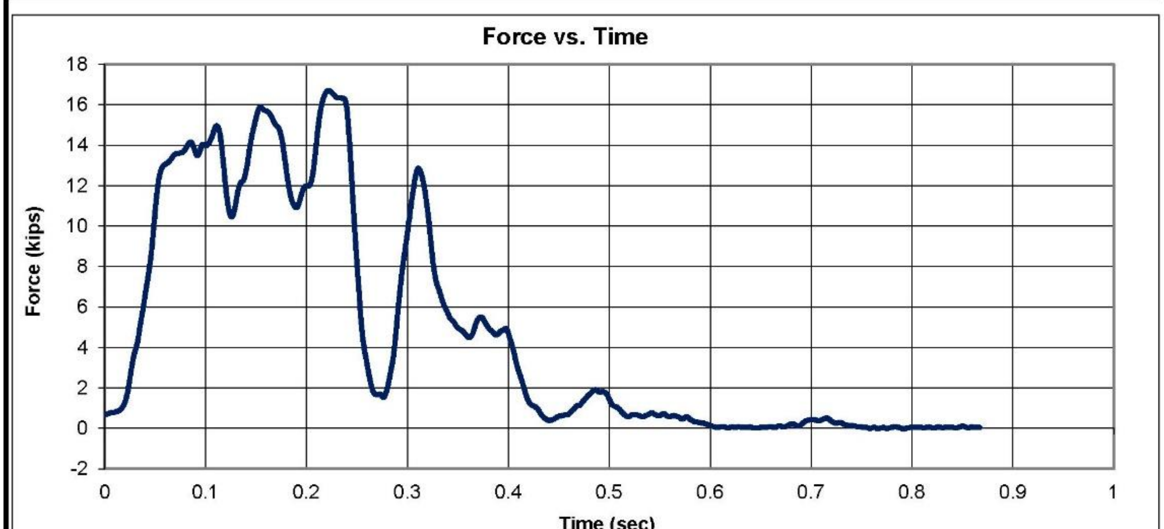


Figure F-1. Load Cell Data from Upstream Cable Anchor, Test No. SPTA-1

Appendix G. Accelerometer and Rate Transducer Data Plots, Test No. SPTA-2

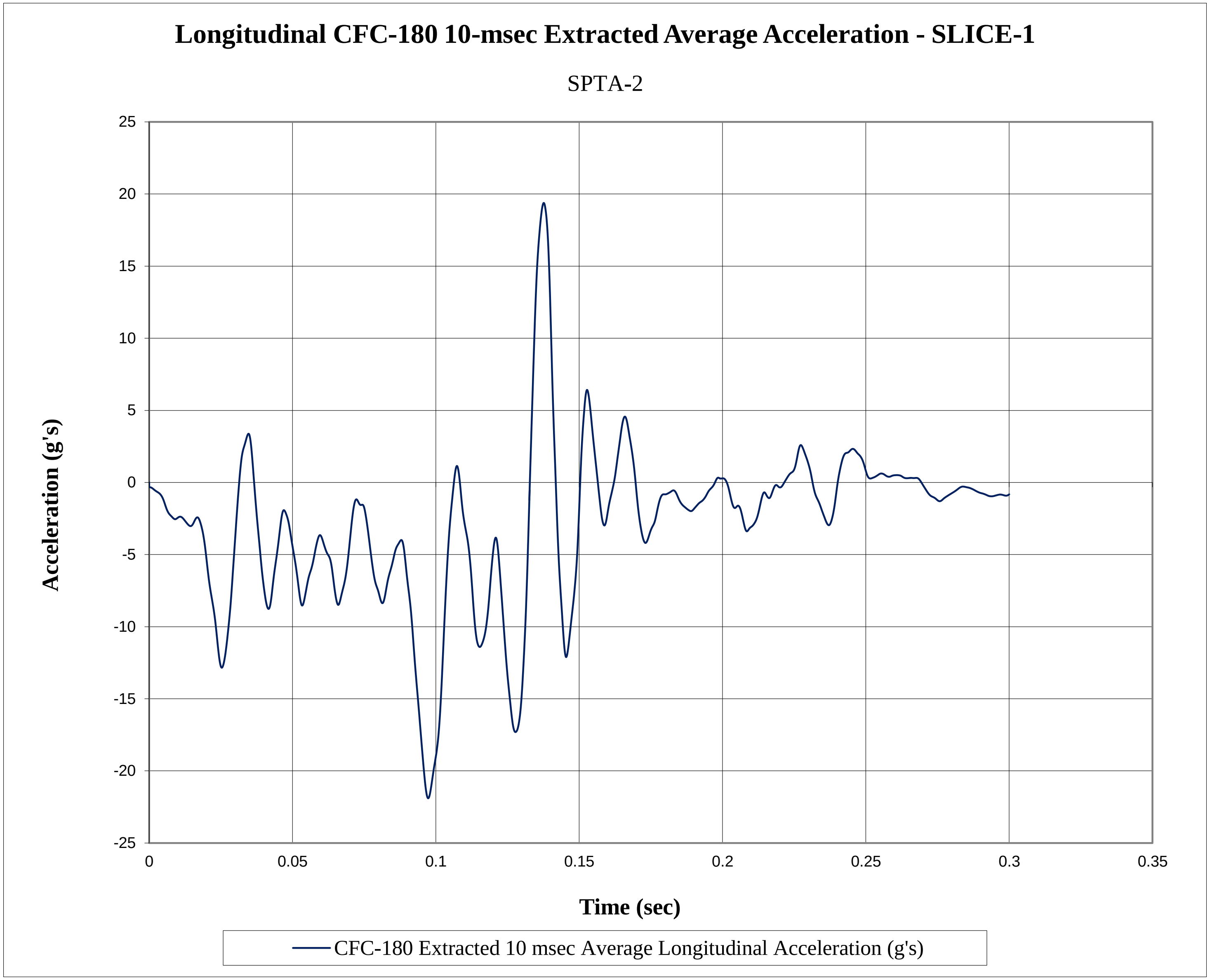


Figure G-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. SPTA-2

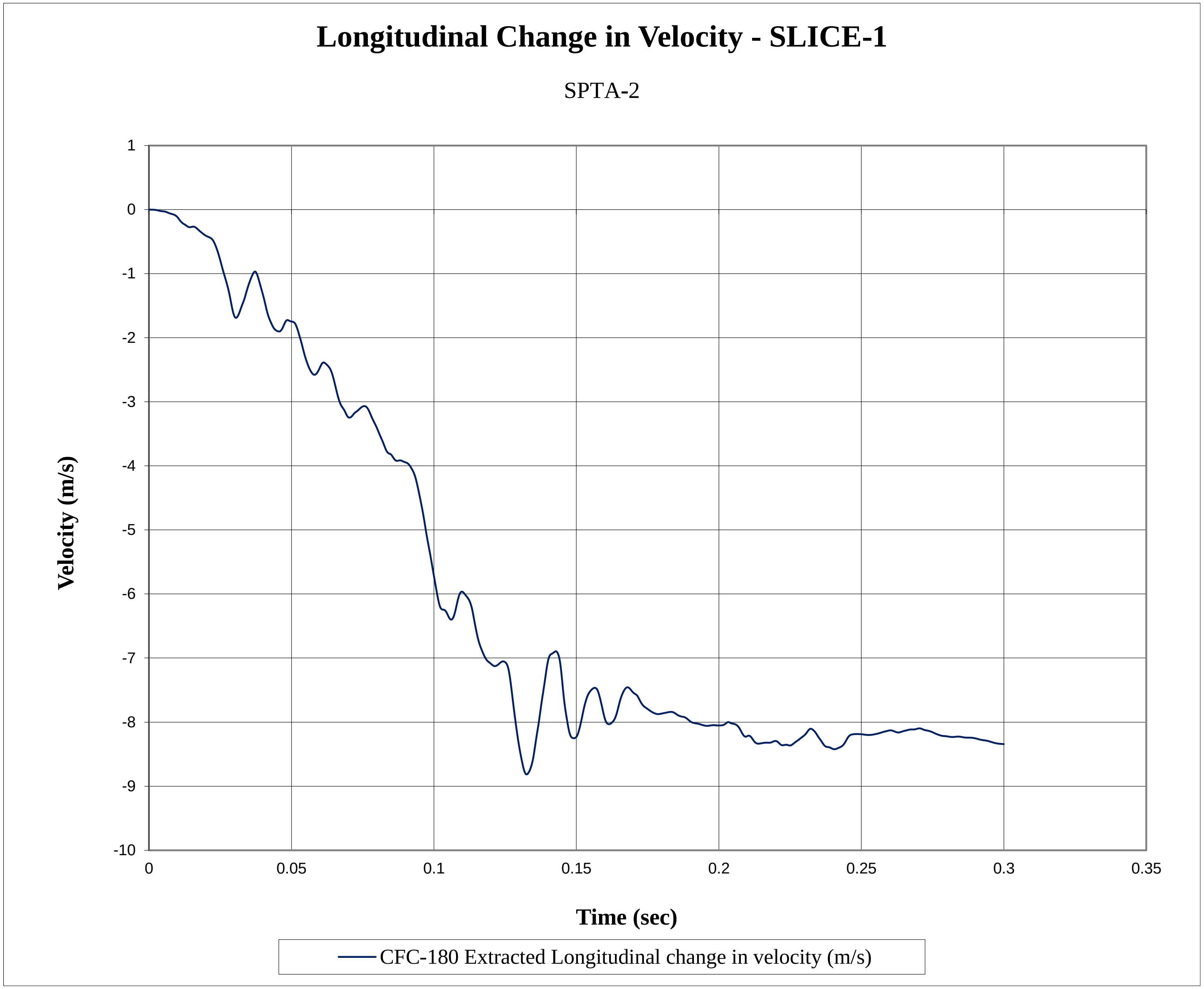


Figure G-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. SPTA-2

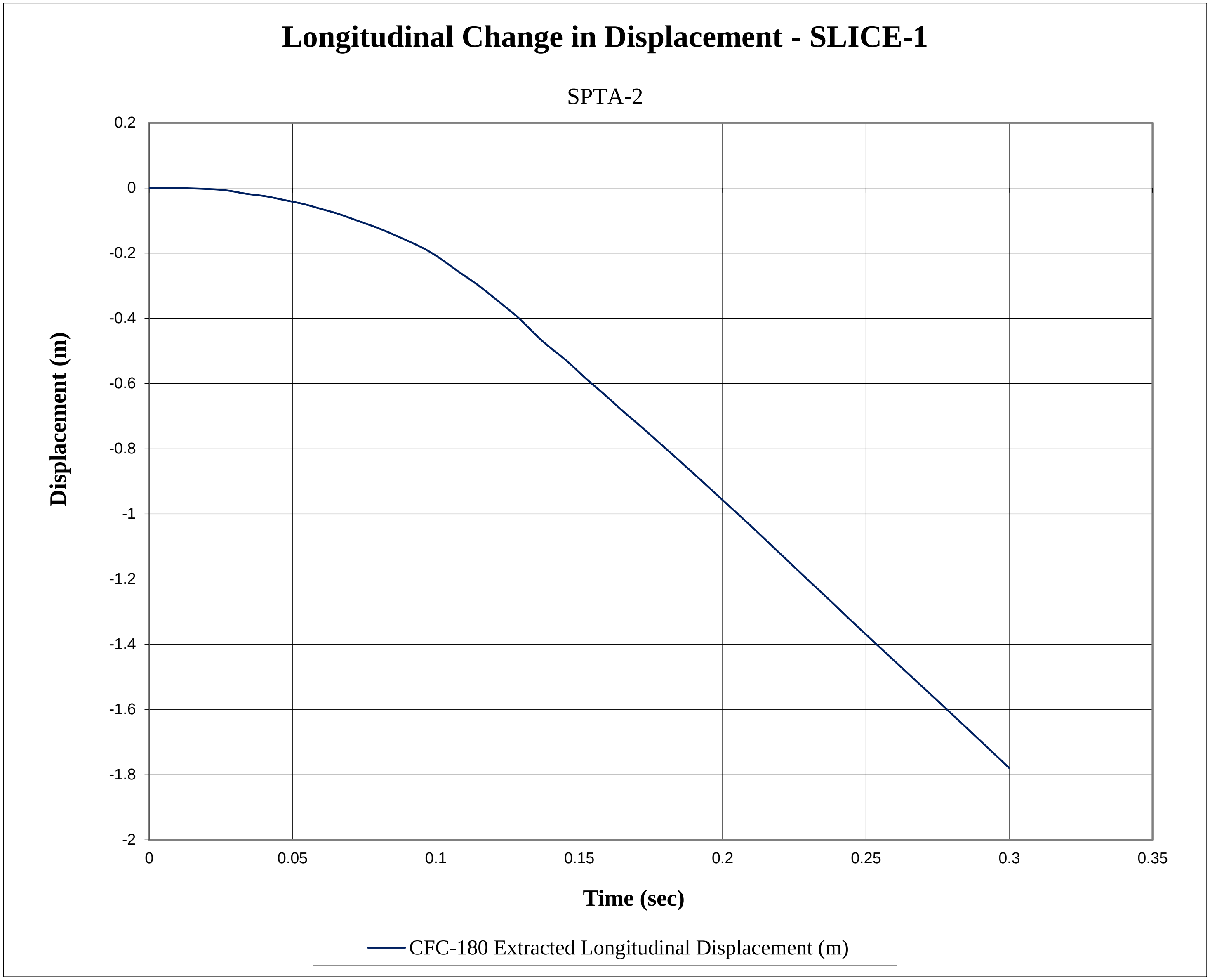


Figure G-3. Longitudinal Occupant Displacement (SLICE-1), Test No. SPTA-2

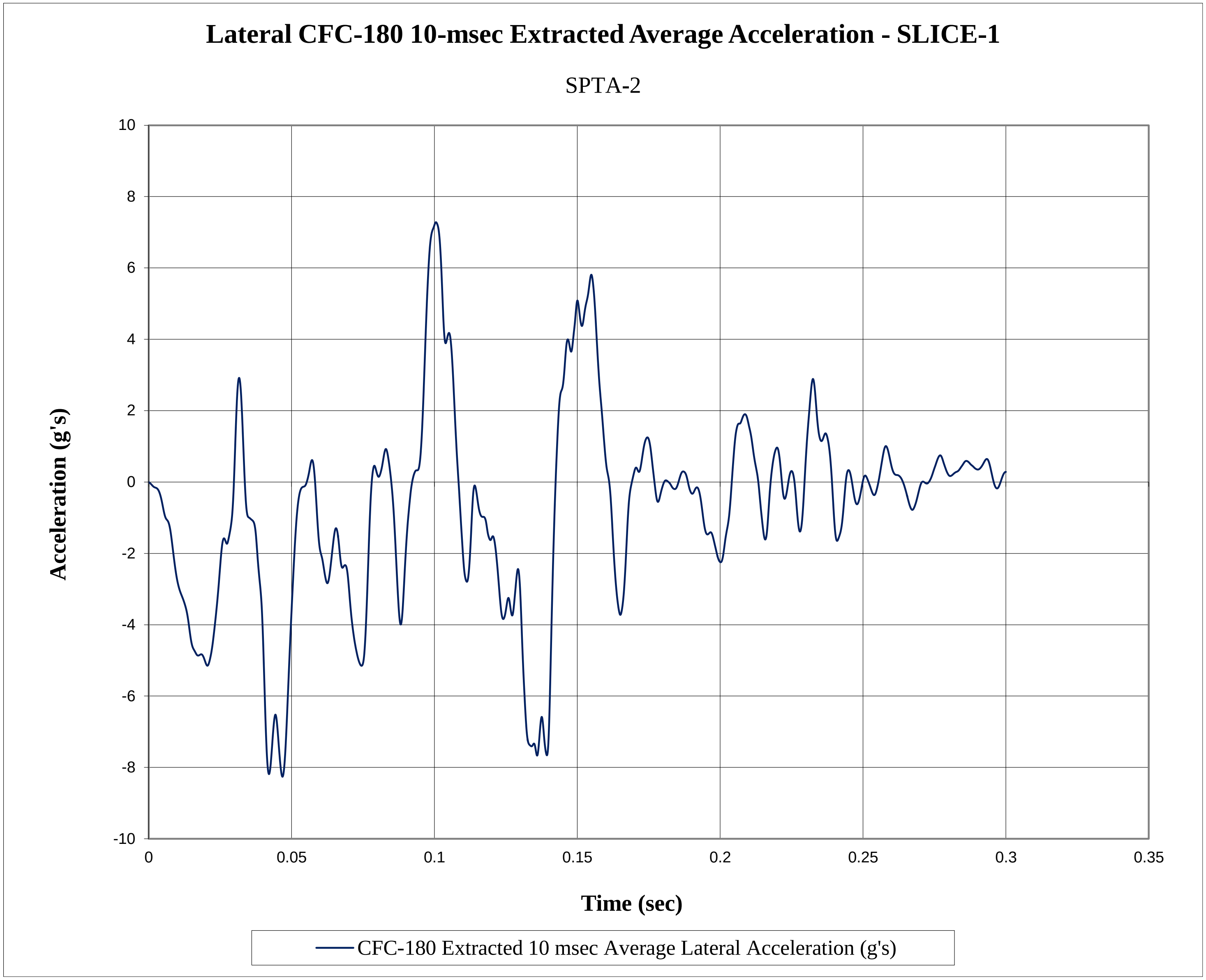


Figure G-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. SPTA-2

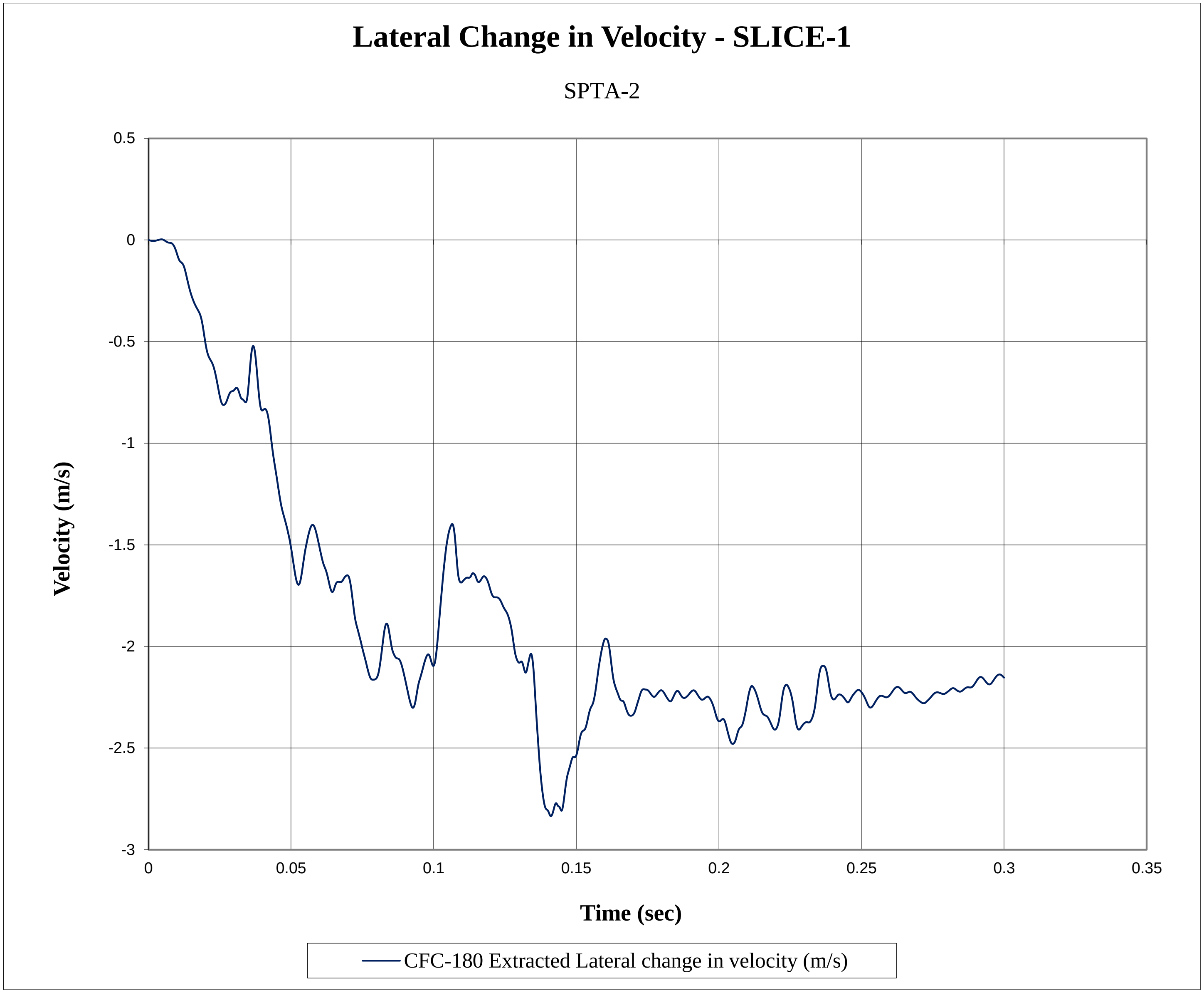


Figure G-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. SPTA-2

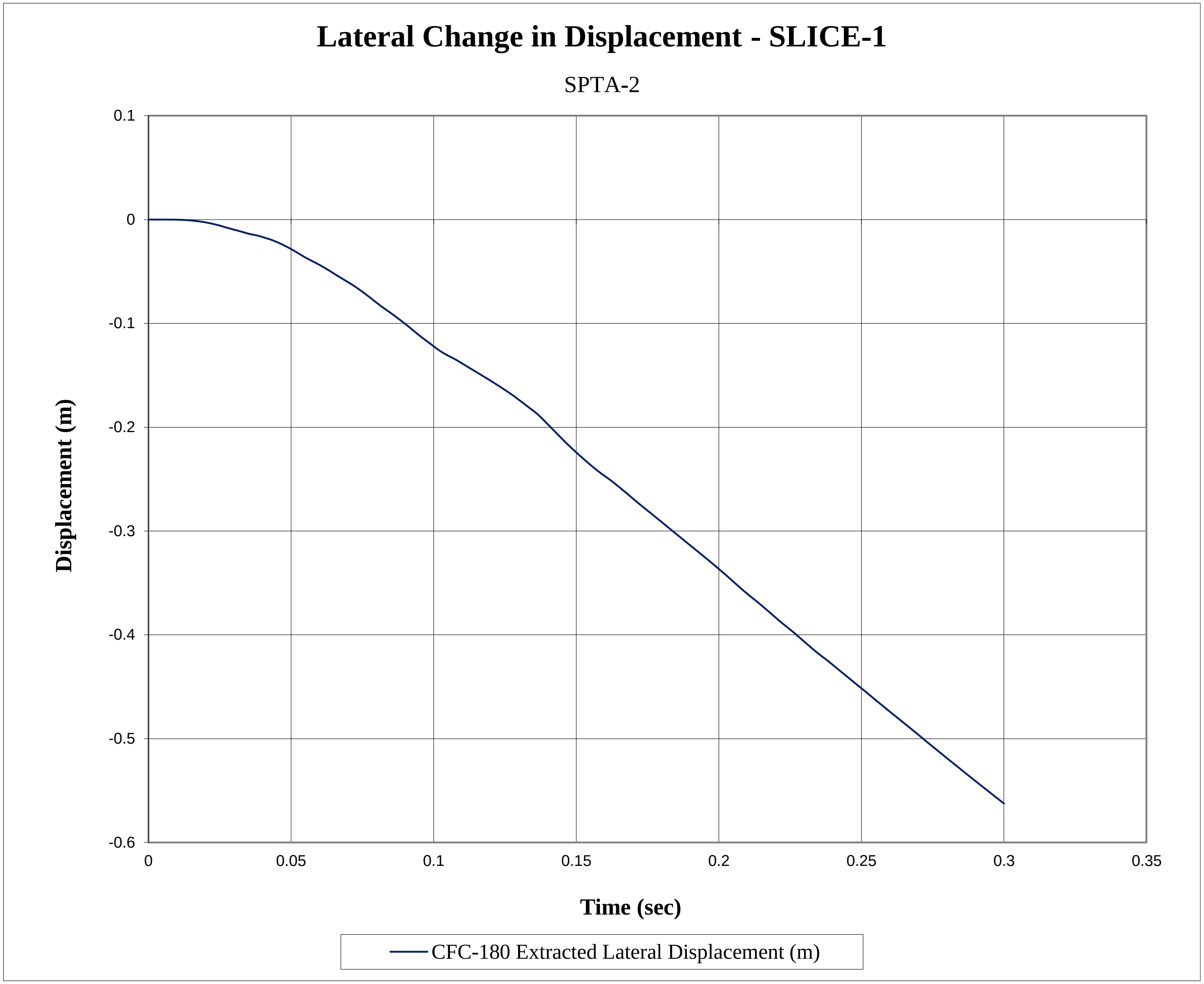


Figure G-6. Lateral Occupant Displacement (SLICE-1), Test No. SPTA-2

Figure G-7. Vehicle Angular Displacements (SLICE-1), Test No. SPTA-2

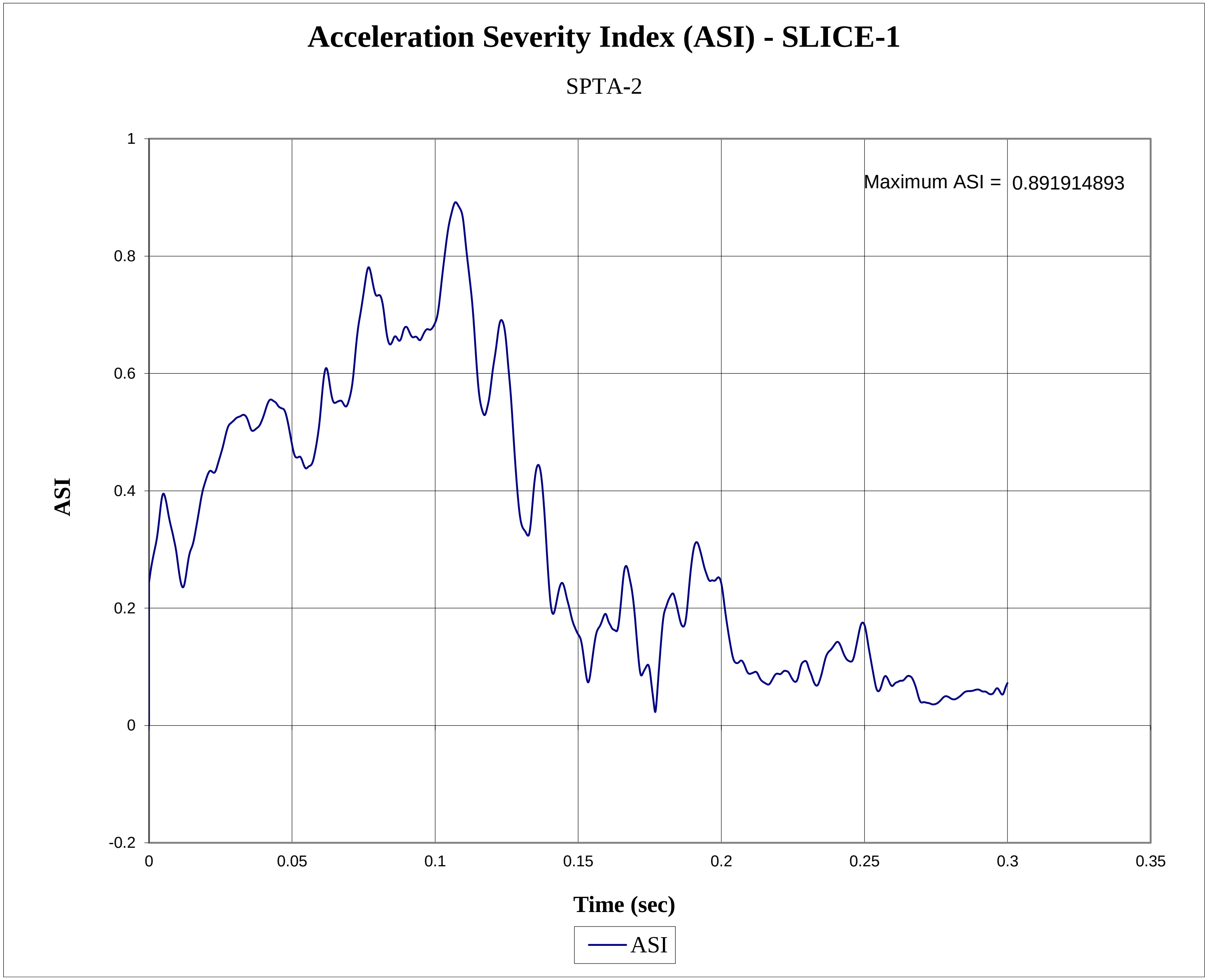


Figure G-8. Acceleration Severity Index (SLICE-1), Test No. SPTA-2

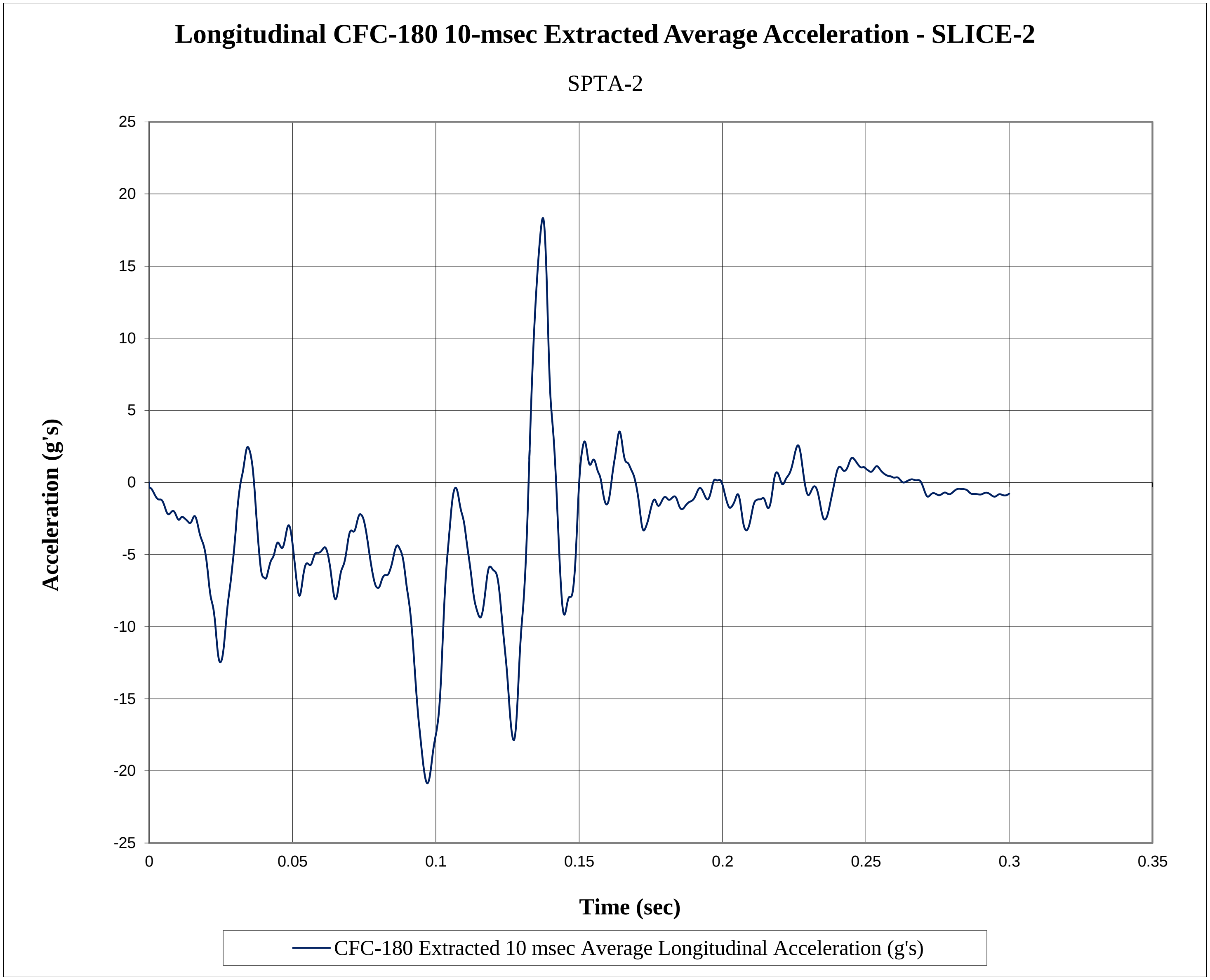


Figure G-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. SPTA-2

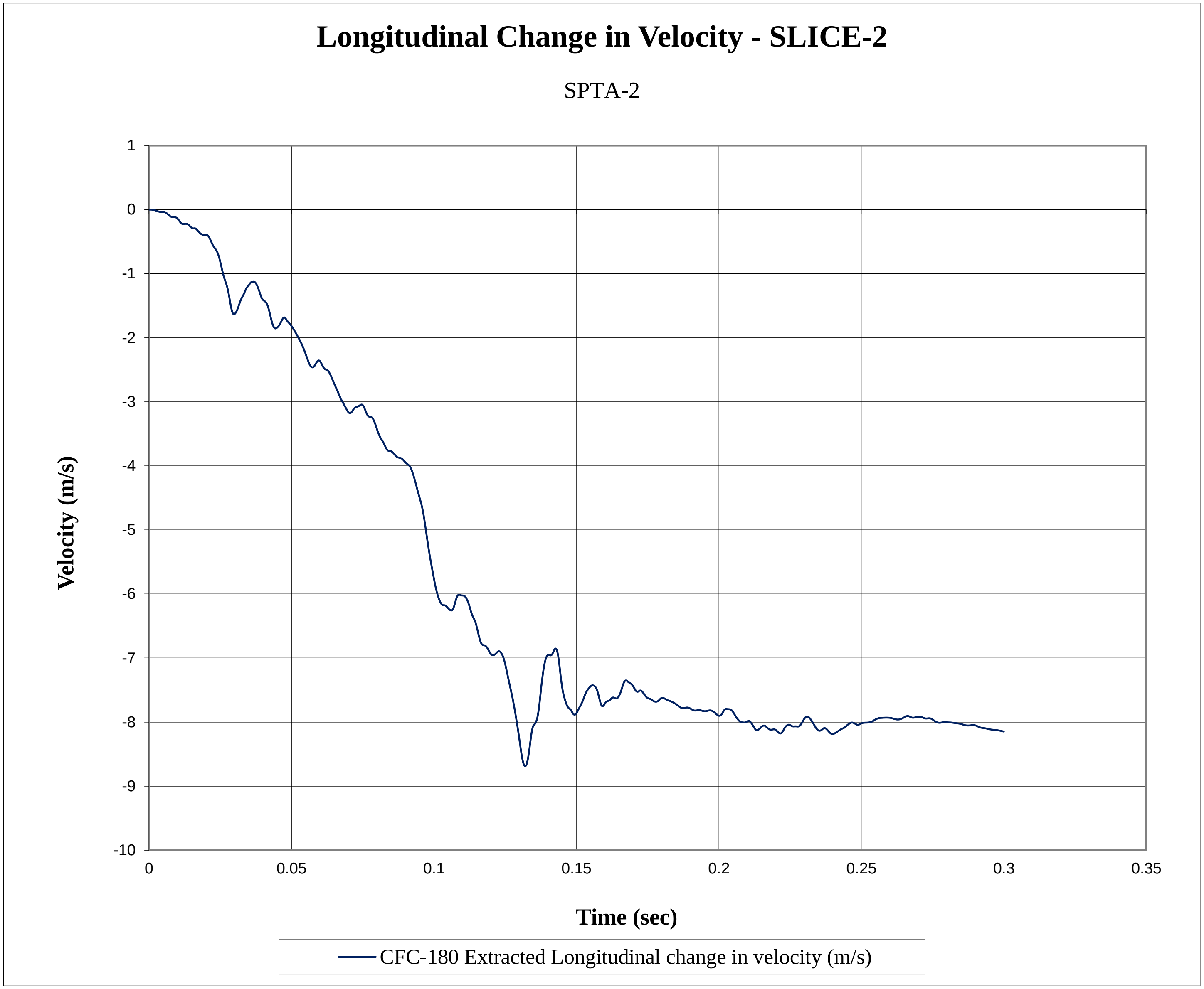


Figure G-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. SPTA-2

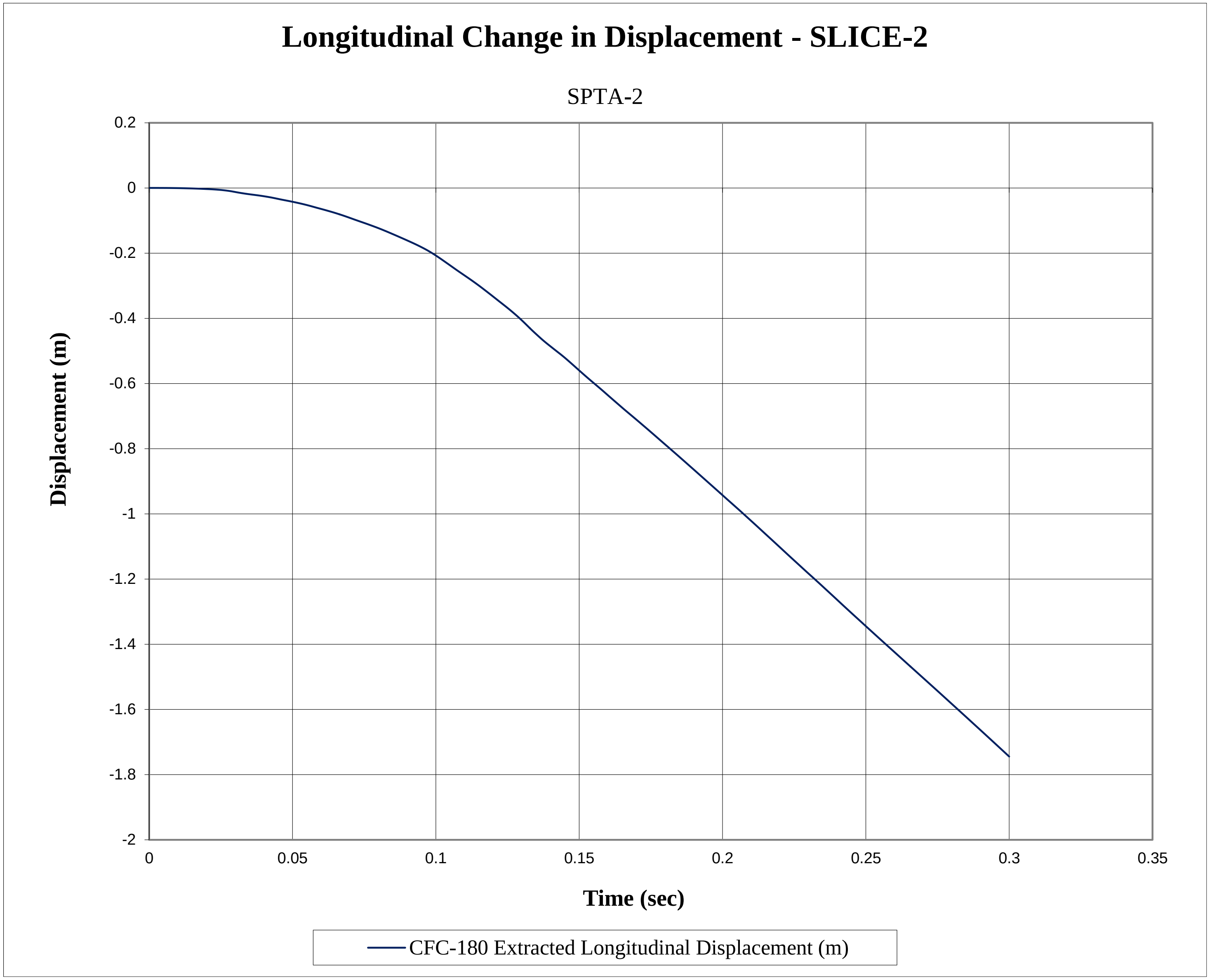


Figure G-11. Longitudinal Occupant Displacement (SLICE-2), Test No. SPTA-2

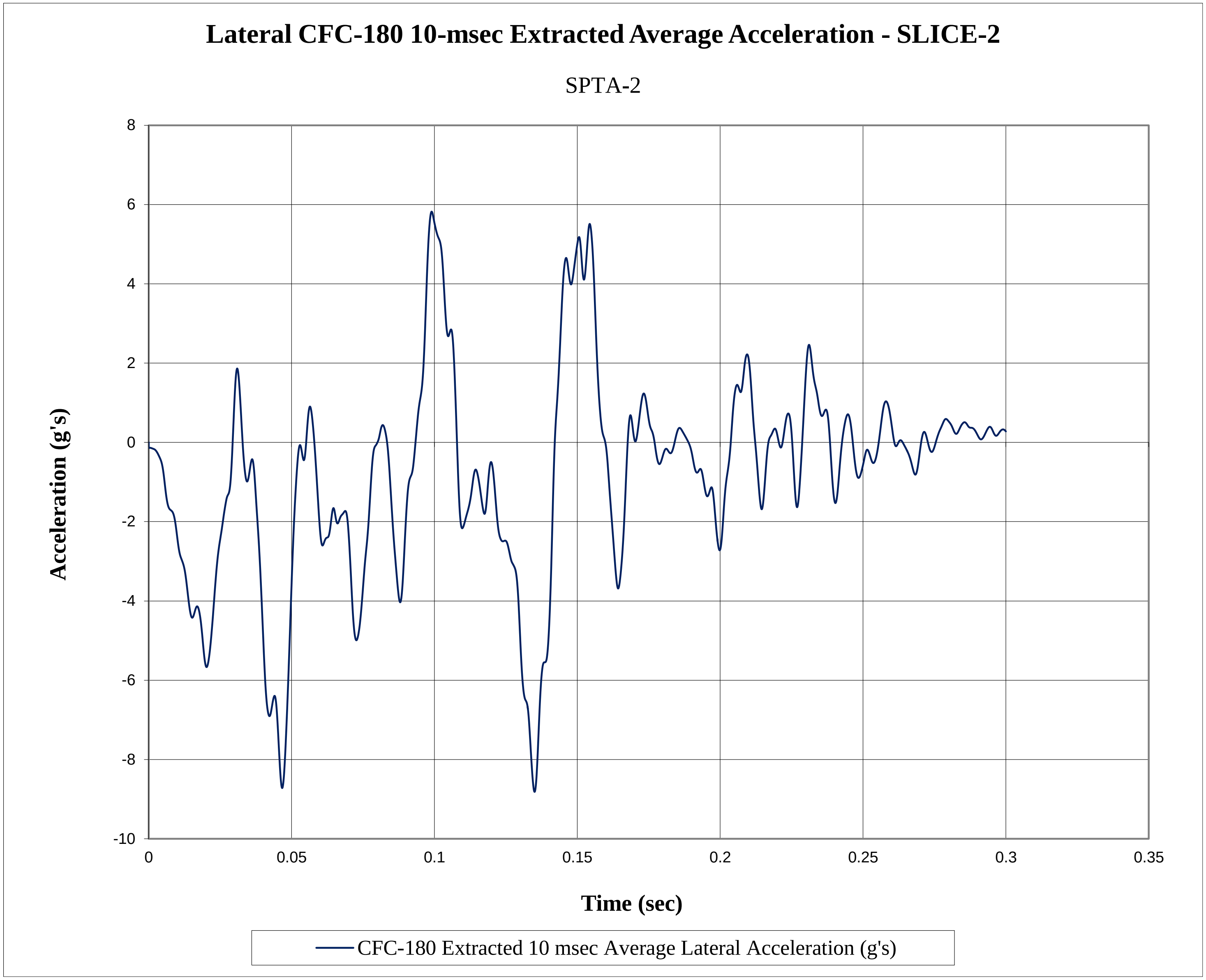


Figure G-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. SPTA-2

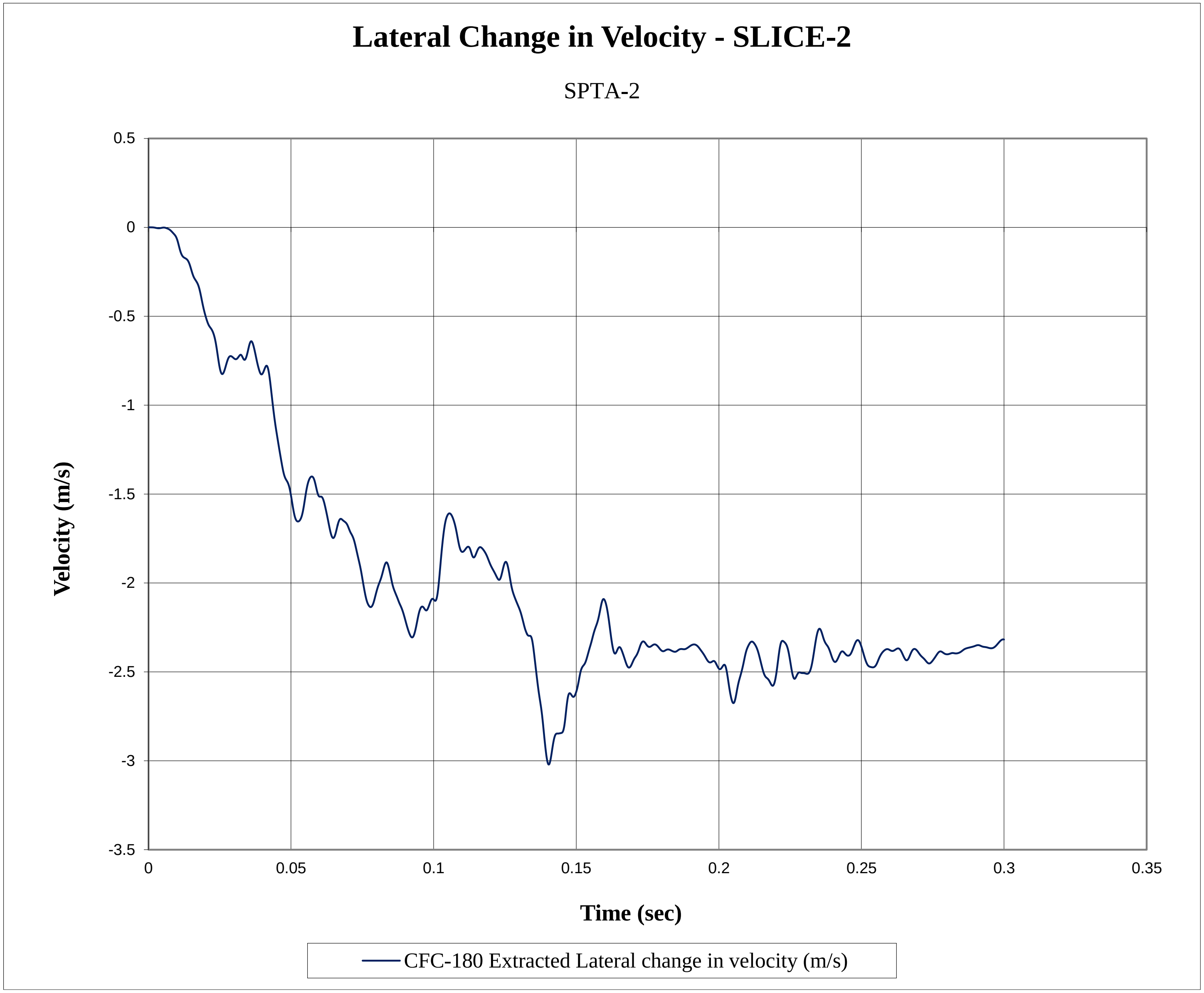


Figure G-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. SPTA-2

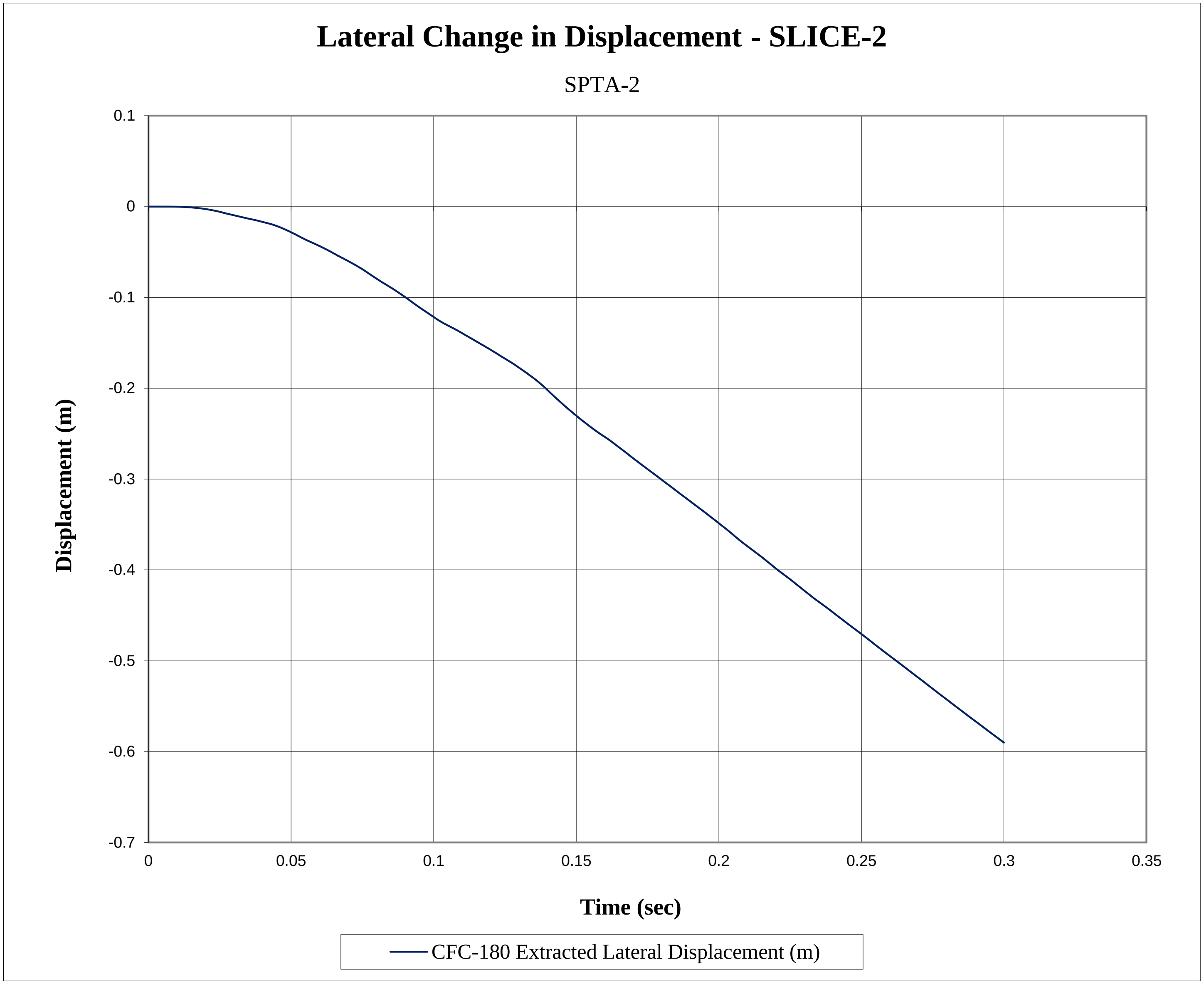


Figure G-14. Lateral Occupant Displacement (SLICE-2), Test No. SPTA-2

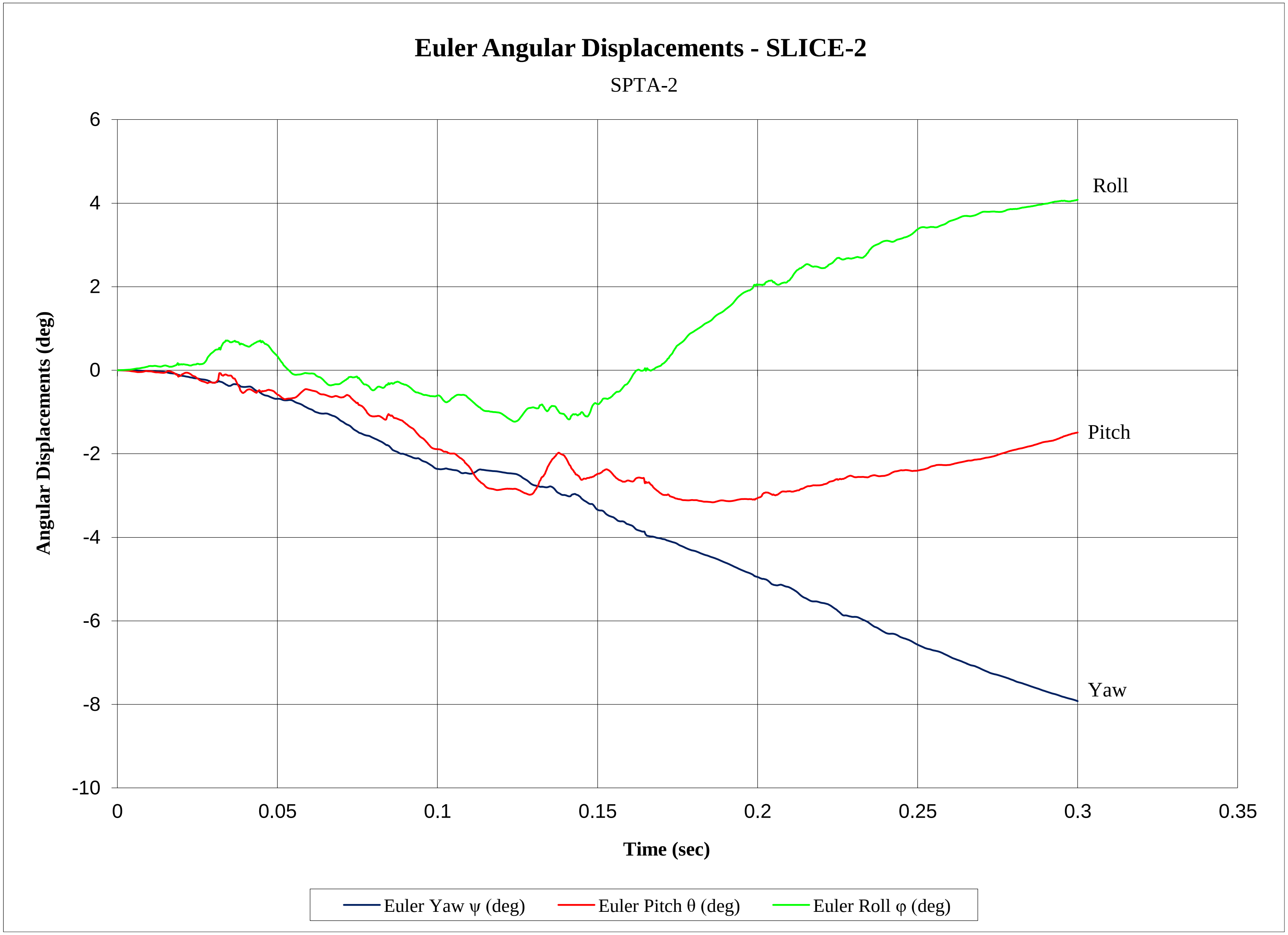


Figure G-15. Vehicle Angular Displacements (SLICE-2), Test No. SPTA-2

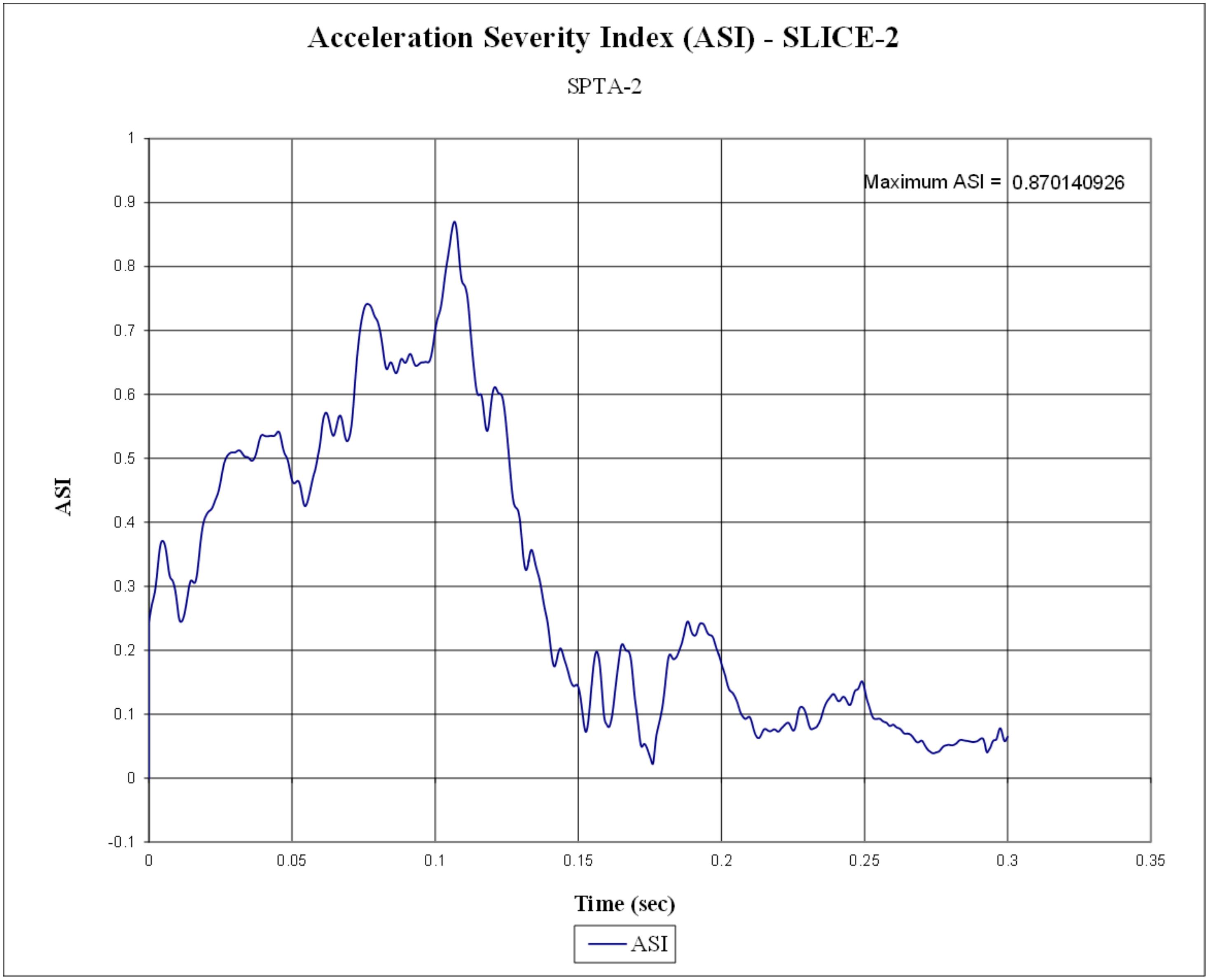


Figure G-16. Acceleration Severity Index (SLICE-2), Test No. SPTA-2

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