Midwest States Pooled Fund Research Program
Fiscal Years 2014-2015 (Years 24 and 25)
Research Project Number TPF-5(193) Supplement #64 and #79
NDOR Sponsoring Agency Code RPFP-14-CABLE-1 and RPFP-15-CABLE-1

MASH TEST NO. 3-10 OF A NON-PROPRIETARY, HIGH-TENSION CABLE MEDIAN BARRIER FOR USE IN 6H:1V V-DITCH (TEST NO. MWP-8)

Submitted by

Dylan T. Meyer
Undergraduate Research Assistant

Karla A. Lechtenberg, M.S.M.E., E.I.T.
Research Associate Engineer

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

Robert W. Bielenberg, M.S.M.E., E.I.T.
Research Associate Engineer

Scott K. Rosenbaugh, M.S.C.E., E.I.T.
Research Associate Engineer

John D. Reid, Ph.D.
Professor

MIDWEST ROADSIDE SAFETY FACILITY
Nebraska Transportation Center
University of Nebraska-Lincoln
130 Whittier Research Center
2200 Vine Street
Lincoln, Nebraska 68583-0853
(402) 472-0965

Submitted to

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

MwRSF Research Report No. TRP-03-331-17

May 10, 2017

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. TRP-03-331-17	2.	3. Recipient's Accession No.
4. Title and Subtitle MASH Test No. 3-10 of a Non-Proprietary, High-Tension, Cable Median Barrier for Use in 6H:1V V-Ditch (Test No. MWP-8)		5. Report Date May 10, 2017 6.
7. Author(s) Meyer, D.T., Lechtenberg, K.A., Faller, R.K., Bielenberg, R.W., Rosenbaugh, S.K., and Reid, J.D.		8. Performing Organization Report No. TRP-03-331-17
9. Performing Organization Name and Address Midwest Roadside Safety Facility (MwRSF) Nebraska Transportation Center University of Nebraska-Lincoln 130 Whittier Research Center 2200 Vine Street Lincoln, Nebraska 68583-0853		10. Project/Task/Work Unit No. 11. Contract © or Grant (G) No. TPF-5(193) Supplement #64 and #79
12. Sponsoring Organization Name and Address Midwest States Pooled Fund Program Nebraska Department of Roads 1500 Nebraska Highway 2 Lincoln, Nebraska 68502		13. Type of Report and Period Covered Final Report: 2015 - 2017 14. Sponsoring Agency Code RPFP–14-CABLE-1 RPFP–15-CABLE-1

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

16. Abstract
The Midwest States Pooled Fund Program has been developing a prototype design for a non-proprietary, high-tension cable median barrier for use in a 6H:1V V-ditch. This system incorporates four evenly spaced cables, Midwest Weak Posts (MWP) spaced at 8 to 16 ft (2.4-4.9 m) intervals, and a bolted, tabbed bracket to attach three or four cables to the sides of each post. According to the *Manual for Assessing Safety Hardware* (MASH) testing matrix for cable barriers installed within a 6H:1V median V-ditch, a series of eight full-scale tests are required to evaluate the safety performance of a system. A ninth test is required to establish the working width for the systems with variable post spacing.

Several previous tests have failed due to posts penetrating the occupant compartment. In order to mitigate this behavior, a modified MWP was designed. Test no. MWP-8 was conducted on the modified barrier system, consisting of MWPs with rounded top edges and a ¾-in. (19-mm) diameter weakening hole at the groundline. This test was conducted according to MASH test designation no. 3-10 and utilized an 1100C passenger car impacting the barrier on a level terrain. The vehicle was contained by the system. Through the initial two vehicle crossover events across the barrier and posts, no floorpan tearing was observed. During the third impact series with the posts, post penetration into the occupant compartment and floorpan tearing was observed. Therefore, test no. MWP-8 was deemed unacceptable.

17. Document Analysis/Descriptors Highway Safety, Crash Test, MASH, Compliance Test, Longitudinal Barrier, Cable Barrier, Median Barrier, High-Tension, and 6H:1V Median V-Ditch		18. Availability Statement No restrictions. Document available from: National Technical Information Services, Springfield, Virginia 22161	
19. Security Class (this report) Unclassified	20. Security Class (this page) Unclassified	21. No. of Pages 173	22. Price

DISCLAIMER STATEMENT

This report was completed with funding from the Federal Highway Administration, U.S. Department of Transportation and the Midwest States Pooled Fund Program. 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 state highway departments participating in the Midwest States Pooled Fund Program nor the Federal Highway Administration, U.S. Department of Transportation. This report does not constitute a standard, specification, regulation, product endorsement, or an endorsement of 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 Dr. Cody Stolle, E.I.T., Research Assistant Professor.

ACKNOWLEDGEMENTS

The authors wish to acknowledge several sources that made a contribution to this project: (1) the Midwest States Pooled Fund Program funded by the Illinois Department of Transportation, Indiana Department of Transportation, Iowa Department of Transportation, Kansas Department of Transportation, Minnesota Department of Transportation, Missouri Department of Transportation, Nebraska Department of Roads, New Jersey Department of Transportation, Ohio Department of Transportation, South Dakota Department of Transportation, Wisconsin Department of Transportation, and Wyoming Department of Transportation for sponsoring this project and (2) MwRSF personnel for constructing the barrier and conducting the crash test.

Acknowledgement is also given to the following individuals who made a contribution to the completion of this research project.

Midwest Roadside Safety Facility

J.C. Holloway, M.S.C.E., E.I.T., Test Site Manager
J.D. Schmidt, Ph.D., P.E., Research Assistant Professor
C.S. Stolle, Ph.D., Research Assistant Professor
A.T. Russell, B.S.B.A., Shop Manager
S.M. Tighe, Laboratory Mechanic
D.S. Charroin, Laboratory Mechanic
M.A. Rasmussen, Laboratory Mechanic
E.W. Krier, Laboratory Mechanic
Undergraduate and Graduate Research Assistants

Illinois Department of Transportation

Priscilla A. Tobias, P.E., State Safety Engineer/Bureau Chief
Tim Sheehan, P.E., Safety Design Engineer
Paul L. Lorton, P.E., Safety Programs Unit Chief

Indiana Department of Transportation

Todd Shields, P.E., Maintenance Field Support Manager

Iowa Department of Transportation

Chris Poole, P.E., Roadside Safety Engineer
Brian Smith, P.E., Methods Engineer
Khyle Clute, P.E., Methods Transportation Engineer

Kansas Department of Transportation

Ron Seitz, P.E., Bureau Chief
Scott King, P.E., Road Design Bureau Chief

Kelly Keele, P.E., Road Design Leader
Thomas Rhoads, P.E., Engineering Associate III, Bureau of Road Design

Minnesota Department of Transportation

Michael Elle, P.E., Design Standards Engineer
Michelle Moser, Assistant Design Standards Engineer

Missouri Department of Transportation

Ronald Effland, P.E., ACTAR, LCI, Non-Motorized Transportation Engineer
Joseph G. Jones, P.E., former Engineering Policy Administrator

Nebraska Department of Roads

Phil TenHulzen, P.E., Design Standards Engineer
Jim Knott, P.E., State Roadway Design Engineer
Jodi Gibson, Research Coordinator

New Jersey Department of Transportation

Dave Bizuga, Senior Executive Manager, Roadway Design Group 1

Ohio Department of Transportation

Don Fisher, P.E., Roadway Standards Engineer
Maria E. Ruppe, P.E., former Roadway Standards Engineer

South Dakota Department of Transportation

David Huft, P.E., Research Engineer
Bernie Clocksin, P.E., Lead Project Engineer

Wisconsin Department of Transportation

Jerry Zogg, P.E., Chief Roadway Standards Engineer
Erik Emerson, P.E., Standards Development Engineer
Rodney Taylor, P.E., Roadway Design Standards Unit Supervisor

Wyoming Department of Transportation

William Wilson, P.E., Architectural and Highway Standards Engineer

Federal Highway Administration

John Perry, P.E., Nebraska Division Office
Danny Briggs, Nebraska Division Office

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Background

In recent years, the Midwest States Pooled Fund Program has been developing a non-proprietary, high-tension cable median barrier in conjunction with the Midwest Roadside Safety Facility (MwRSF) [1]. This cable barrier system was intended for use anywhere within a 6H:1V median V-ditch and consisted of four cables supported by Midwest Weak Posts (MWPs) spaced at intervals ranging between 8 ft and 16 ft (2.4 m and 4.9 m). A bolted, tabbed bracket was utilized to attach the lower three cables to alternating sides of the MWPs, while a brass keeper rod was utilized to contain the top cable within a V-notch cut into the top of the posts.

Previously, this cable barrier system was subjected to six full-scale crash tests in accordance with the *Manual for Assessing Safety Hardware (MASH)* [2]. Test no. MWP-1, in accordance with MASH test designation no. 3-17, was conducted with a 1500A vehicle impacting the system placed on the slope break point of a 6H:1V median V-ditch. During the test, the sedan was successfully captured and redirected by cable no. 2, having overridden cable no. 1 and underridden cable nos. 3 and 4 [1].

For test no. MWP-2, the barrier was placed on level terrain, and the system cables were mirrored so that cable no. 2 was on the impact side of the posts and cable nos. 1 and 3 were on the non-impact side. A 16-ft (4.9-m) post spacing was utilized to evaluate the system's maximum deflection and working width. During the test, the front tires of the 2270P pickup overrode cable nos. 1 and 3. However, cable nos. 2 and 4 successfully captured and contained the vehicle [1].

For test no. MWP-3, the post spacing was changed to 8 ft (2.4 m) to evaluate system deflections and working width with the tighter post spacing. During the test, the 2270P pickup was initially captured by cable nos. 2 and 3 after overriding cable no. 1 and underriding cable no. 4. However, the capture cables were eventually pushed downward and overridden by the left-front tire of the pickup. After containment of the vehicle was lost, the cables wrapped around the left-rear tire and yawed the pickup rapidly toward the barrier. The pickup ultimately rolled over as the right-side tires dug into the ground [1].

Modifications were made to improve system performance, which required further full-scale crash testing to evaluate the crashworthiness of the system according to the MASH Test Level 3 (TL-3) criteria [2]. Test no. MWP-4 was conducted in accordance with MASH test no. 3-11. The barrier was placed on level terrain and utilized a 10-ft (3.0-m) post spacing to establish the working width associated with a reduced post spacing. During the test, the 2270P pickup truck was initially captured and redirected by cable nos. 2 and 4. However, the vehicle eventually overrode cable no. 2 after the vehicle was parallel with the system [3].

Test no. MWP-6, conducted in accordance with MASH test no. 3-10, involved a 1100C small car impacting the four-cable median barrier system with 8-ft (2.4-m) post spacing on level terrain. During the test, the small car was captured and redirected by cable no. 2. The A-pillar received only 0.12 in. (3 mm) of deformation, as the vehicle underrode cable nos. 3 and 4. The occupant compartment was penetrated when the top of posts were overridden, causing tears in the floorpan in two locations. Thus, test no. MWP-6 was determined to have failed the safety performance criteria corresponding to MASH test designation no. 3-10 [3].

To reduce the likelihood of occupant compartment penetration, the top corners of the MWP post were rounded. The outer corners were radiused ⅝ in. (16 mm), and the inner bent corners were filleted ¼ in. (6 mm). Test no. MWP-7 was a repeat of MWP-6, but with the modified MWP post. During the test, the small car was captured and redirected by cable no. 2. However, the floorpan was again torn due to contact with the tops of the MWP posts as the vehicle overrode them. Four separate tears occurred. Thus, test no. MWP-7 was determined to have failed the safety performance criteria corresponding to MASH test designation no. 3-10 [3]. These performance issues highlighted the need to develop new barrier components or modify the existing barrier components to improve the safety performance of the cable median barrier.

Twenty-one bogie tests were conducted to evaluate several post modifications [4]. From the bogie test results, the MWP was modified to include rounded top edges of the post and a ¾-in. (19-mm) diameter weakening hole at the groundline. The rounded edge removed sharp corners at the top of the post and the weakening holes reduced the weak-axis capacity of the post to lower the forces exerted by the post on the floorpan. This report highlights one of the full-scale tests conducted on the redesigned, non-proprietary, four-cable median barrier system according to the MASH Test Level 3 (TL-3) criteria [2].

1.2 Research Objective

The objective of this research study was to evaluate the safety performance of the high-tension, cable median barrier in a V-ditch. The system was evaluated according to the TL-3 criteria of the *Manual for Assessing Safety Hardware (MASH)* [2]. This report documents the evaluation of the cable system to MASH test designation no. 3-10.

1.3 Research Scope

One full-scale crash test was conducted according to MASH test designation no. 3-10 on a non-proprietary, high-tension, cable median barrier system. The crash test utilized a small car weighing approximately 2,425 lb (1,100 kg). The target impact conditions for the test were a speed of 62 mph (100 km/h) and an angle of 25 degrees. The crash test was conducted to evaluate the system after modifications were made to the posts that removed sharp corners at the top of the post and reduced the weak-axis capacity of the post to lower the force exerted by the post on the floorpan. Data obtained from this crash test was analyzed, and the results were utilized to formulate conclusions and recommendations.

2 TEST REQUIREMENTS AND EVALUATION CRITERIA

2.1 Test Requirements

Longitudinal barriers, such as cable median barriers must satisfy impact safety standards in order to be declared eligible for federal reimbursement by the Federal Highway Administration (FHWA) for use on the National Highway System (NHS). For new hardware, these safety standards consist of the guidelines and procedures published in MASH [2]. According to TL-3 of MASH, a cable barrier for use anywhere in a 6H:1V V-ditch must be subjected to eight full-scale vehicle crash tests, as summarized in Table 1. However, systems with variable post spacings must be subjected to MASH test designation no. 3-11 with both the narrowest and widest post spacings to establish the working width bounds of the barrier system, thereby increasing the required number of crash tests from eight to nine. Although all nine tests are needed to complete the system evaluation, only one of the prescribed full-scale crash tests, test designation no. 3-10, was conducted and reported herein. Although the impact speed and angle are consistent for all nine tests, the critical location of the barrier system within the median ditch is dependent upon the specific crash test.

Many cable barriers have variable post spacings, which allow roadside designers to select the optimal configuration for a specific installation. When evaluating these variable post spacing systems, the critical post spacing should be utilized during crash testing. The 2016 edition of MASH has identified the critical post spacing, either the narrowest or the widest spacing, for each individual test within the testing matrix. MASH test designation 3-10 must be conducted with the narrowest post spacing to establish the working width bounds of the barrier system.

In accordance with MASH requirements, the critical impact point for the 1100C vehicle was determined to be located at the midspan between posts. This impact location was determined to maximize the potential for vehicle penetration by allowing the vehicle to penetrate between cables.

When non-symmetrical cable barriers are tested, it is important to test the orientation that produces the greatest risk of failure. To accomplish this critical evaluation, the orientation of the cables was selected such that primary capture cable would be located on the non-impact side of the post. The primary capture cable for the 1100C vehicle was determined to be the second cable from the ground (bottom-middle). Selecting this orientation allowed for the greatest risk of failure by delaying vehicle interlock with the barrier and increasing the potential for the vehicle to penetrate through the system.

Table 1. MASH TL-3 Test Matrix for Barrier Placement Anywhere Within a 6H:1V V-Ditch

Test No.	Test Vehicle	Vehicle Weight, lb (kg)	Impact Conditions		System Configuration		Evaluation Criteria[2]
			Speed, mph (km/h)	Angle, deg	System Location[1]	Post Spacing	
3-10	1100C	2,425 (1,100)	62 (100)	25	Level Terrain	Narrow	A,D,F,H,I
3-11	2270P	5,000 (2,270)	62 (100)	25	Level Terrain	Both	A,D,F,H,I
3-13	2270P	5,000 (2,270)	62 (100)	25	9 ft Down Front Slope	Narrow	A,D,F,H,I
3-14	1100C	2,425 (1,100)	62 (100)	25	9 ft Down Front Slope	Narrow	A,D,F,H,I
3-15	1100C	2,425 (1,100)	62 (100)	25	4 ft Up Back Slope	Wide	A,D,F,H,I
3-16	1100C	2,425 (1,100)	62 (100)	25	1 ft Down Back Slope	Narrow	A,D,F,H,I
3-17	1500A	3,300 (1,500)	62 (100)	25	See Note[3]	Wide	A,D,F,H,I
3-18	2270P	5,000 (2,270)	62 (100)	25	At Back Slope Break Point	Wide	A,D,F,H,I

[1] Test nos. 3-13 through 3-18 shall be conducted within a 30-ft (9.1-m) wide, 6H:1V V-ditch
[2] Evaluation criteria explained in Table 2.
[3] Testing laboratory to determine critical barrier position on front slope of ditch to maximize propensity for front end of 1500A vehicle to penetrate between vertically adjacent cables.

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 cable median barrier to contain and redirect impacting vehicles. In addition, controlled lateral deflection of the test article is acceptable. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Post-impact vehicle trajectory is a measure of the potential of the vehicle to result in a secondary collision with other vehicles and/or fixed objects, thereby increasing the risk of injury to the occupants of the impacting vehicle and/or other vehicles. These evaluation criteria are summarized in Table 2 and defined in greater detail in MASH. The full-scale vehicle crash test documented herein was conducted and reported in accordance with the procedures provided in MASH.

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

Table 2. MASH Evaluation Criteria for Longitudinal Barrier

<table>
<tr><td>Structural Adequacy</td><td>A.</td><td>Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td></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><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>
</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><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
</table></td></tr>
</table>

2.3 Soil Strength Requirements

In accordance with Chapter 3 and Appendix B of MASH, foundation soil strength must be verified before any full-scale crash testing can occur. During the installation of a soil dependent system, additional W6x16 (W152x23.8) posts were installed near the impact region utilizing the same installation procedures as the system itself. Prior to full-scale testing, dynamic impact testing was 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) above the groundline. If dynamic testing near the system is not desired, MASH permits a static test to be conducted instead and compared against the results of a previously established baseline test. In this situation, the soil must provide a resistance of at least 90 percent of the static baseline test at deflections of 5, 10, and 15 in. (127, 254, and 381 mm). Further details can be found in Appendix B of MASH.

3 DESIGN DETAILS

The test installation was comprised of a four-cable median barrier system as shown in Figures 1 through 24. Photographs of the test installation are shown in Figures 27 through 31. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix A.

The cable barrier system consisted of several distinct components: (1) high-tension cables or wire ropes; (2) cable splices; (3) steel support posts; (4) cable-to-post attachment brackets; (5) breakaway end terminals; and (6) reinforced concrete foundations. Four ¾-in. (19-mm) diameter, Class A galvanized 3x7 (pre-stretched) wire ropes were utilized for the longitudinal cables. The cables were placed at heights of 15½ in. (394 mm), 23 in. (584 mm), 30½ in. (775 mm), and 38 in. (965 mm) above the groundline. The cables were numbered 1 through 4, starting with the bottom cable and proceeding upward to the top cable. These cables were supported by modified MWPs measuring 83 in. (2,108 mm) in length. The MWP is fabricated from bent 7-gauge (4.6-mm) sheet steel to a 3-in. x 1¾-in. (76-mm x 44-mm) cross section. The modifications to the MWP included rounded top edges of the post and a ¾-in. (19-mm) diameter weakening hole at the groundline. The spacing between the posts was 8 ft (2.4 m). The overall length of the system was 604 ft (184 m).

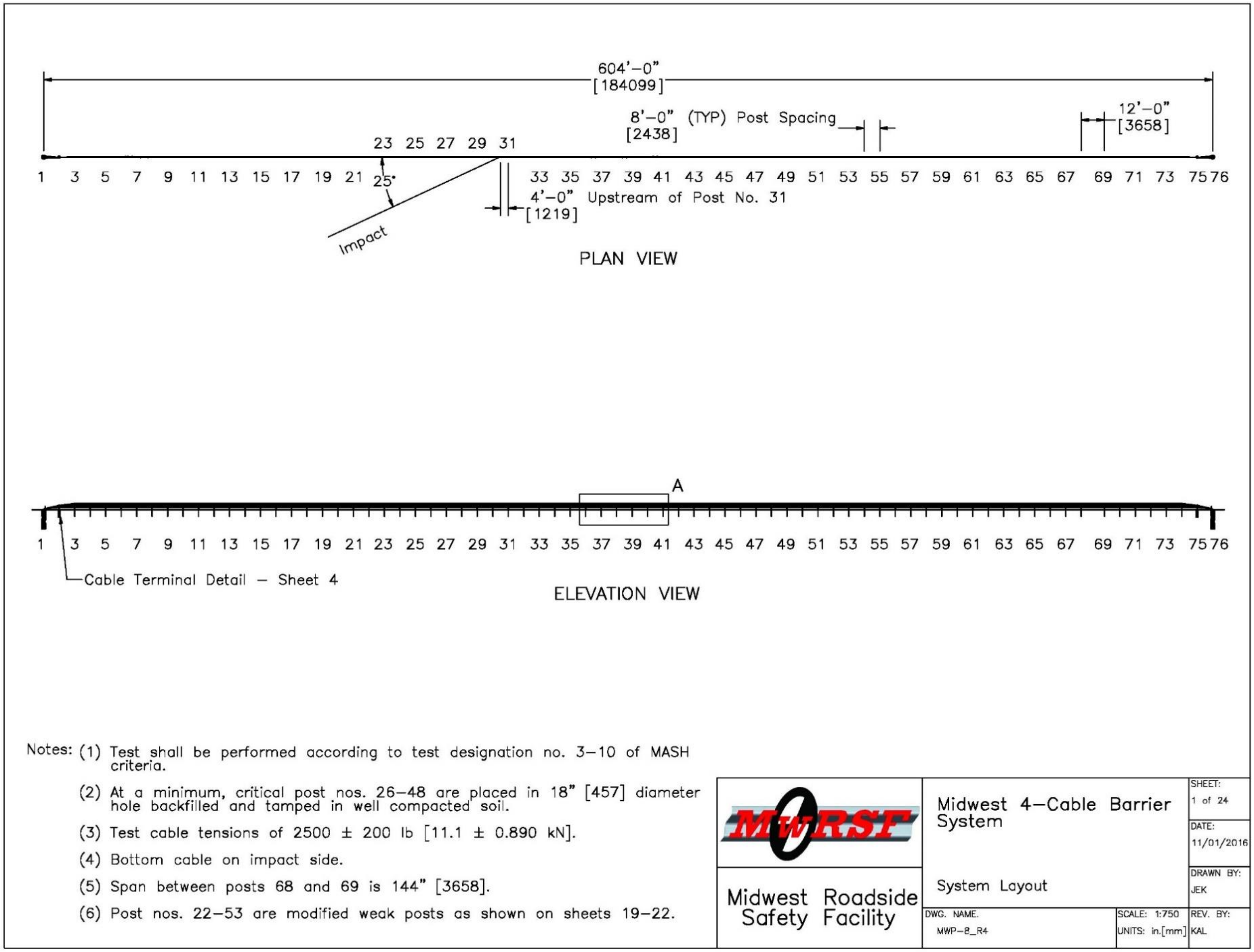


Figure 1. System Layout, Test No. MWP-8

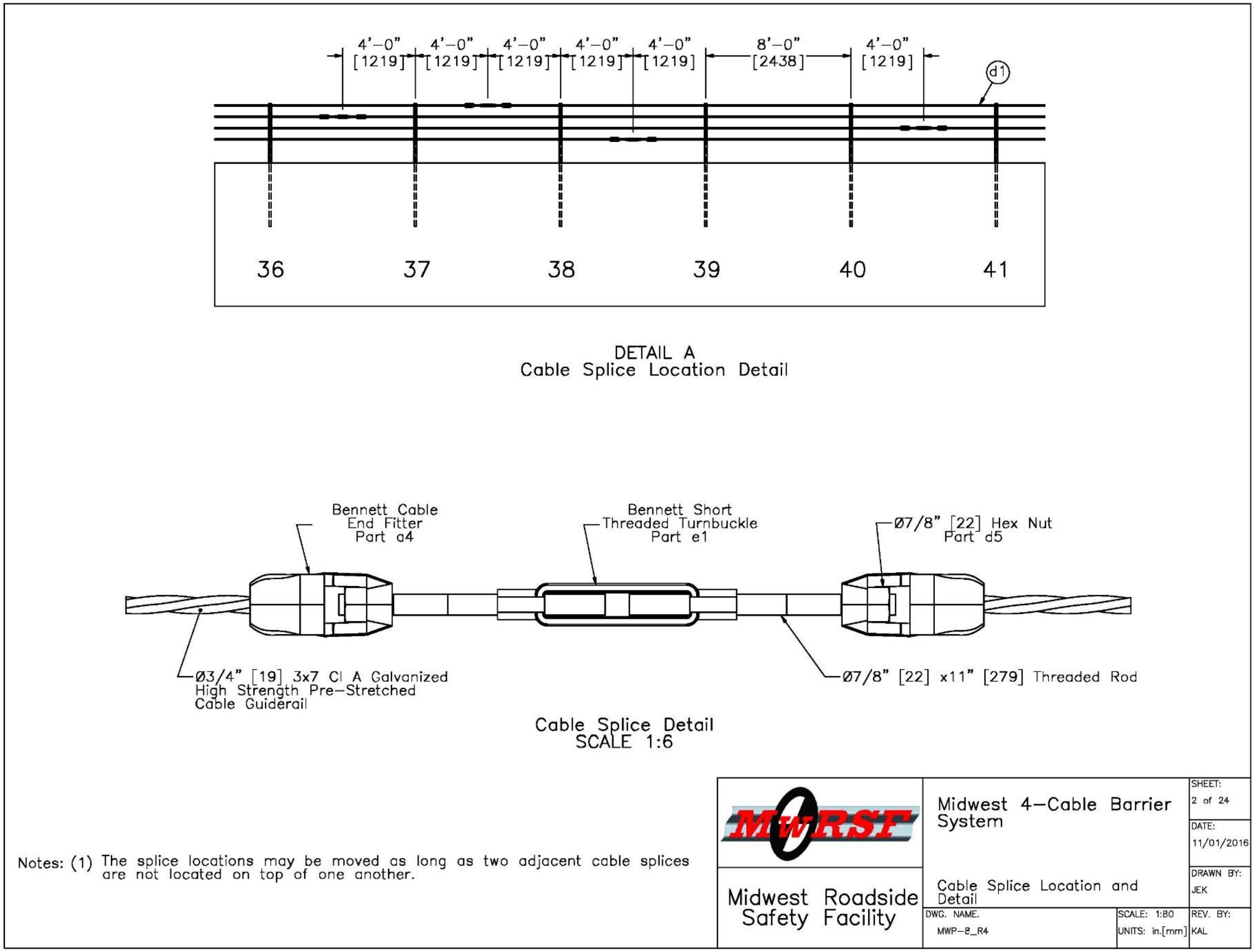


Figure 2. Cable Splice Location and Detail, Test No. MWP-8

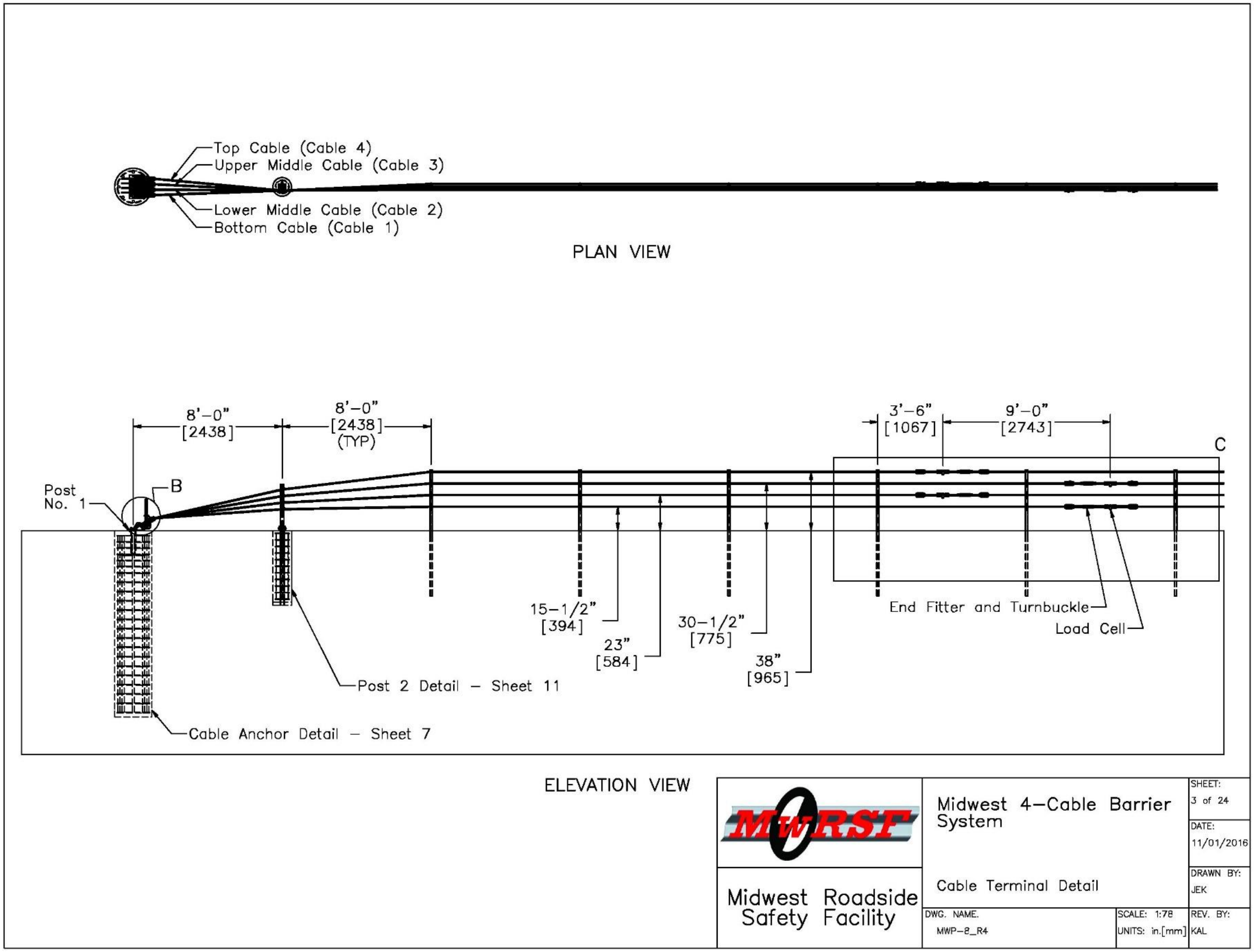


Figure 3. Cable Terminal Detail, Test No. MWP-8

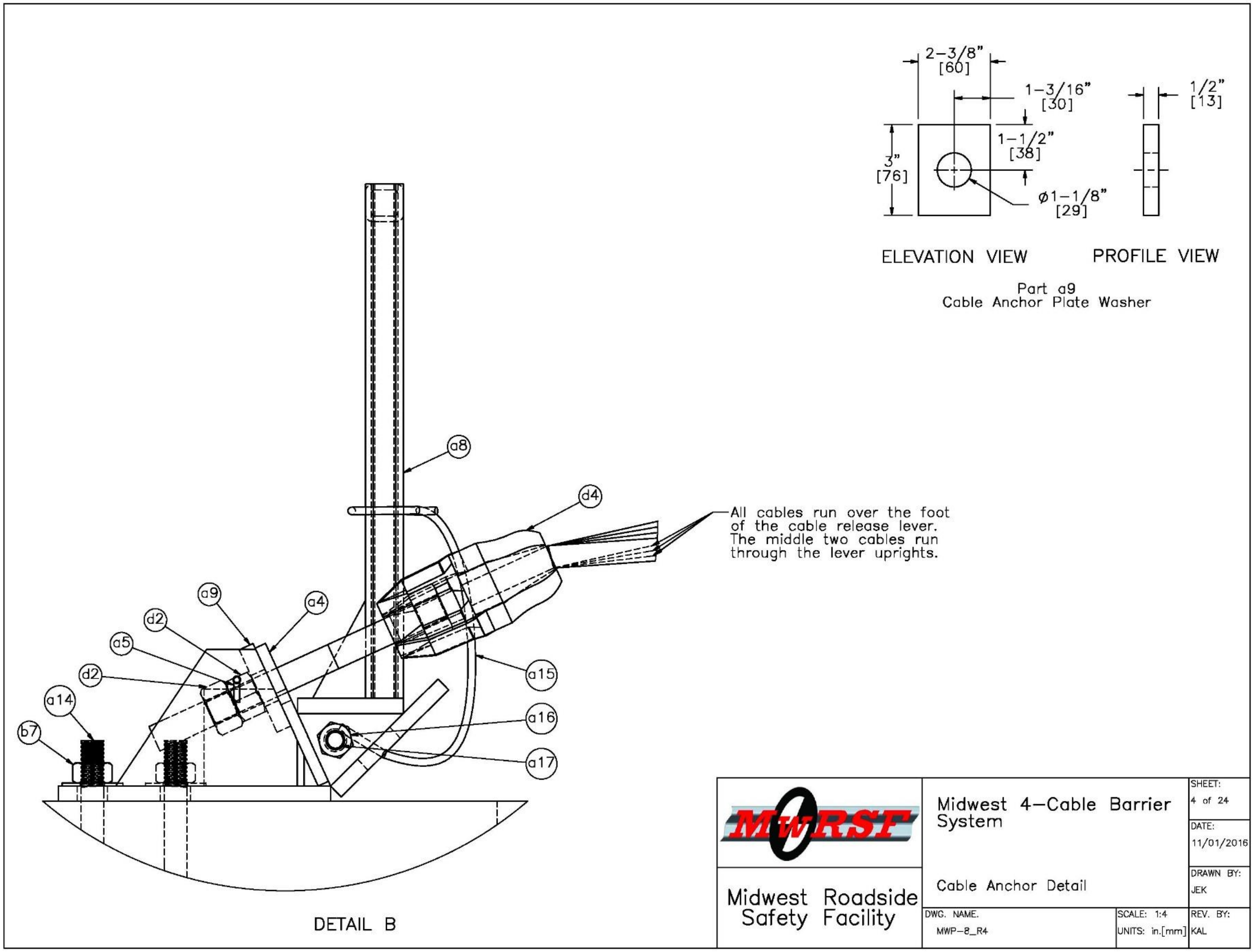


Figure 4. Cable Anchor Detail, Test No. MWP-8

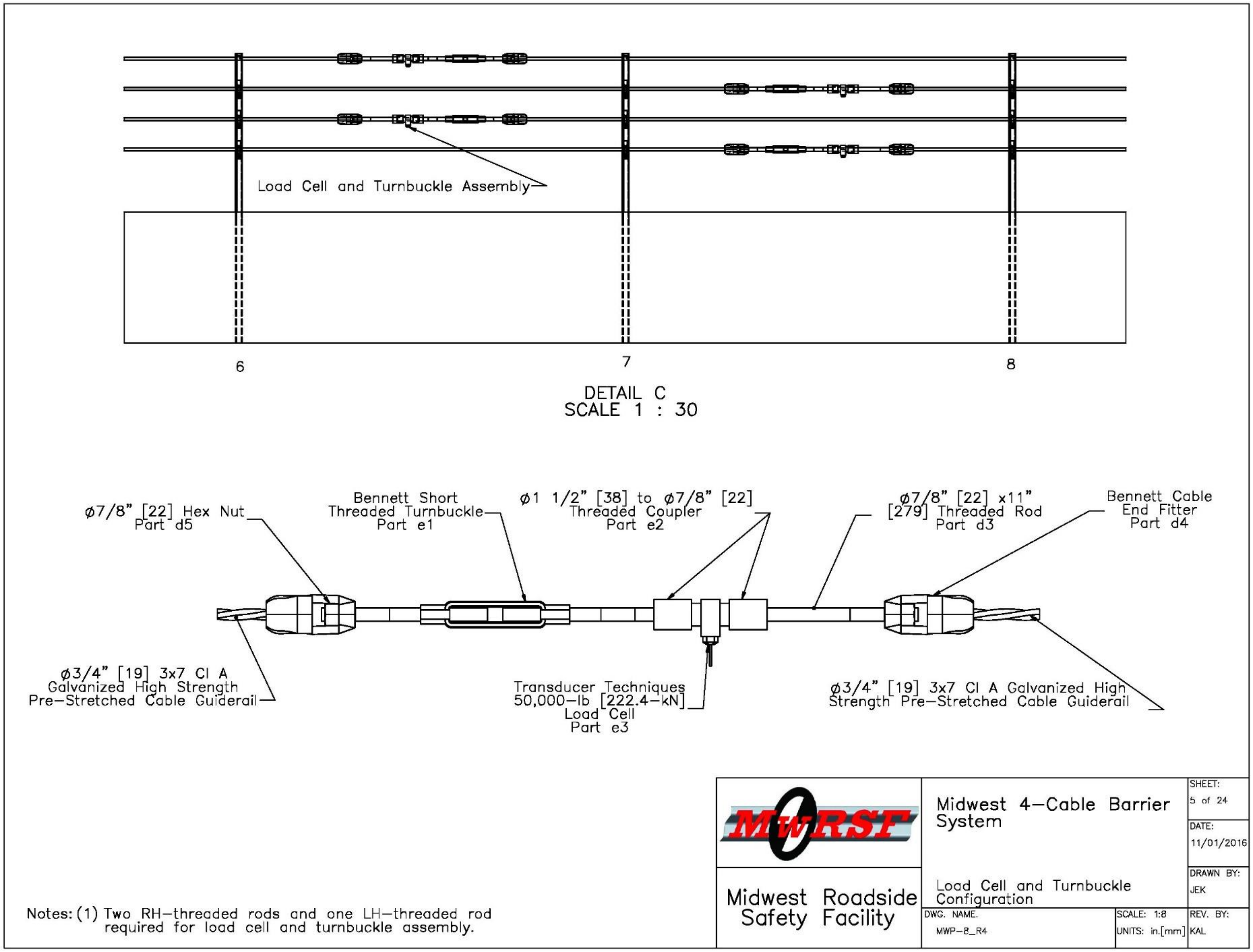


Figure 5. Load Cell and Turnbuckle Configuration, Test No. MWP-8

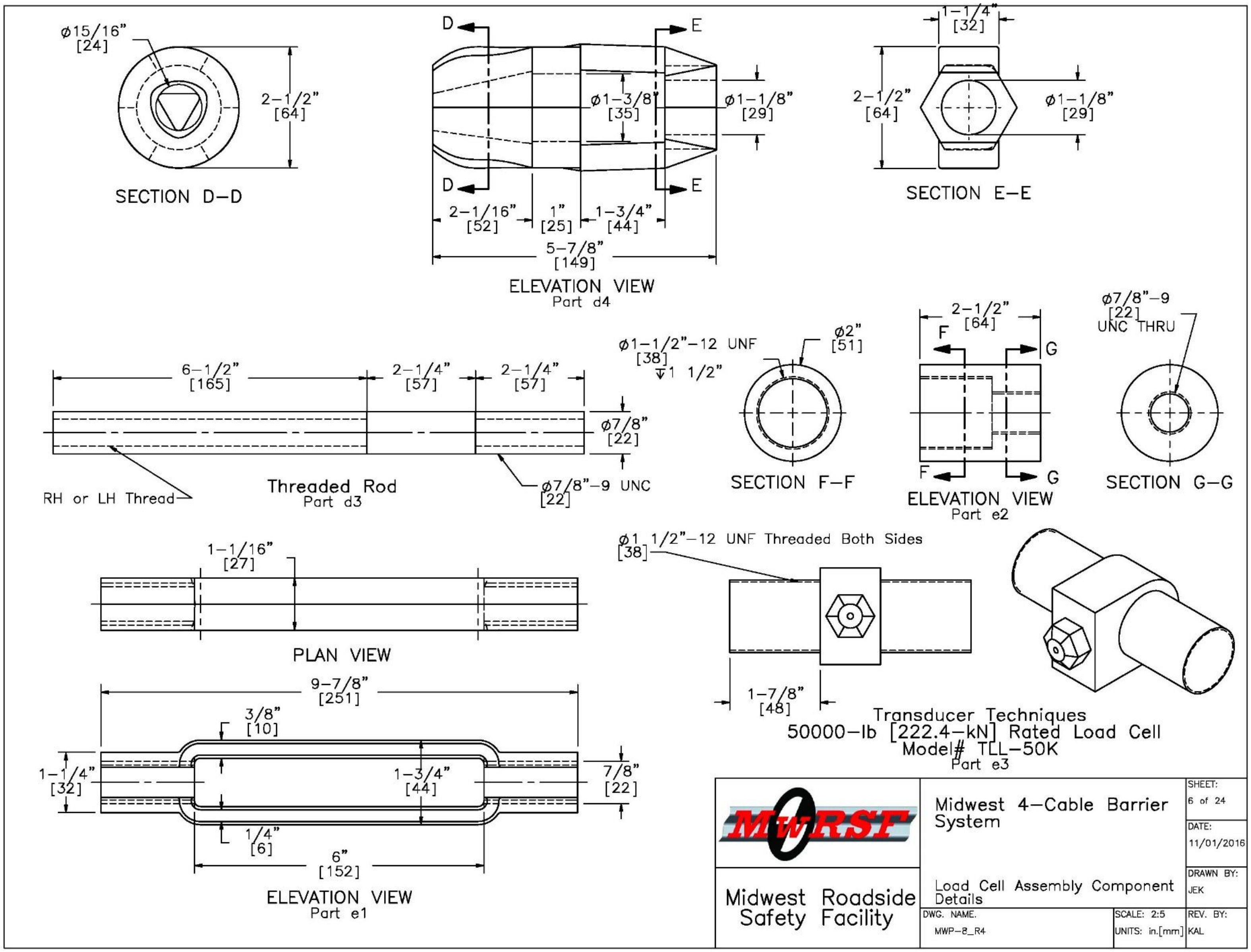


Figure 6. Load Cell Assembly Component Details, Test No. MWP-8

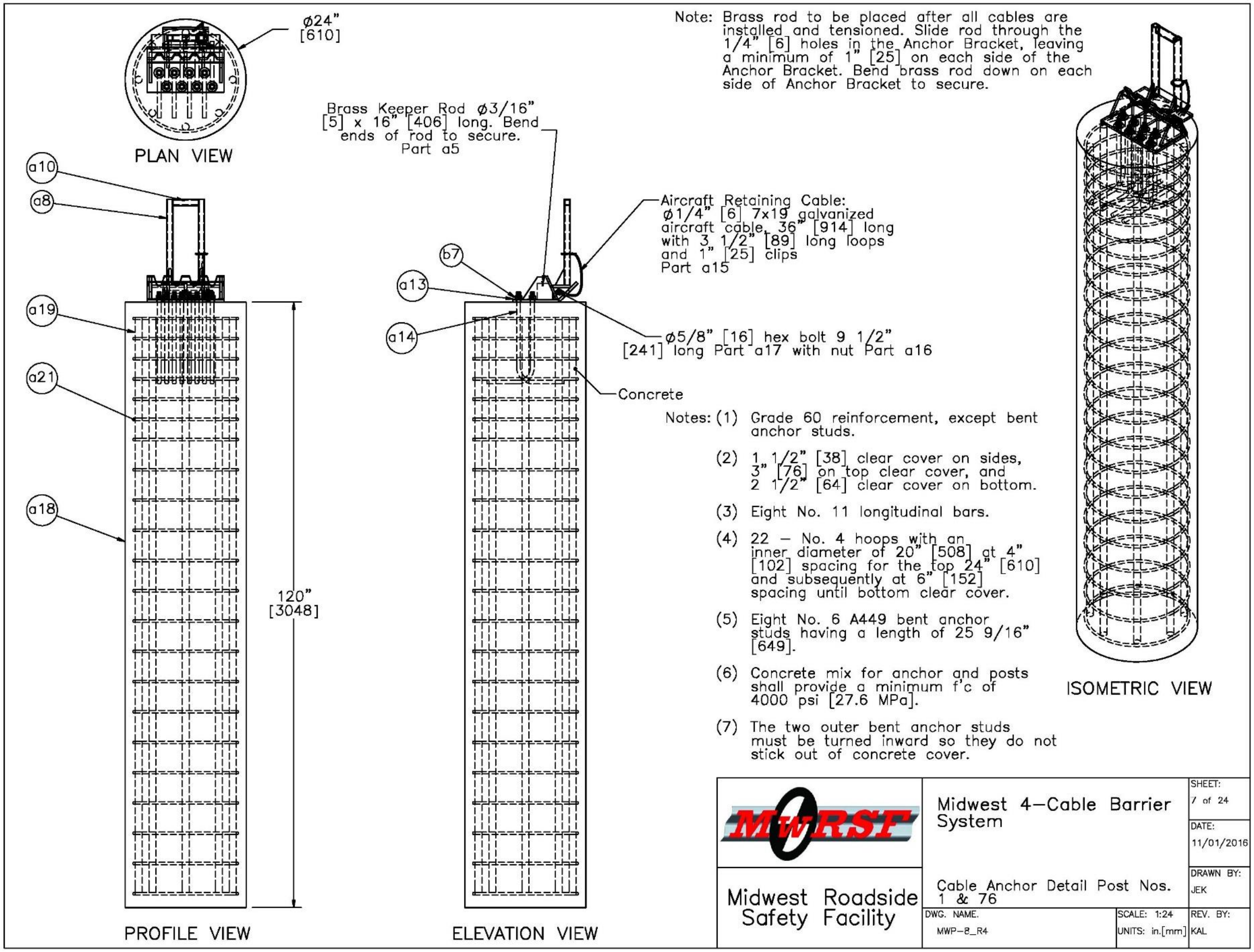


Figure 7. Cable Anchor Detail, Post Nos. 1 and 76, Test No. MWP-8

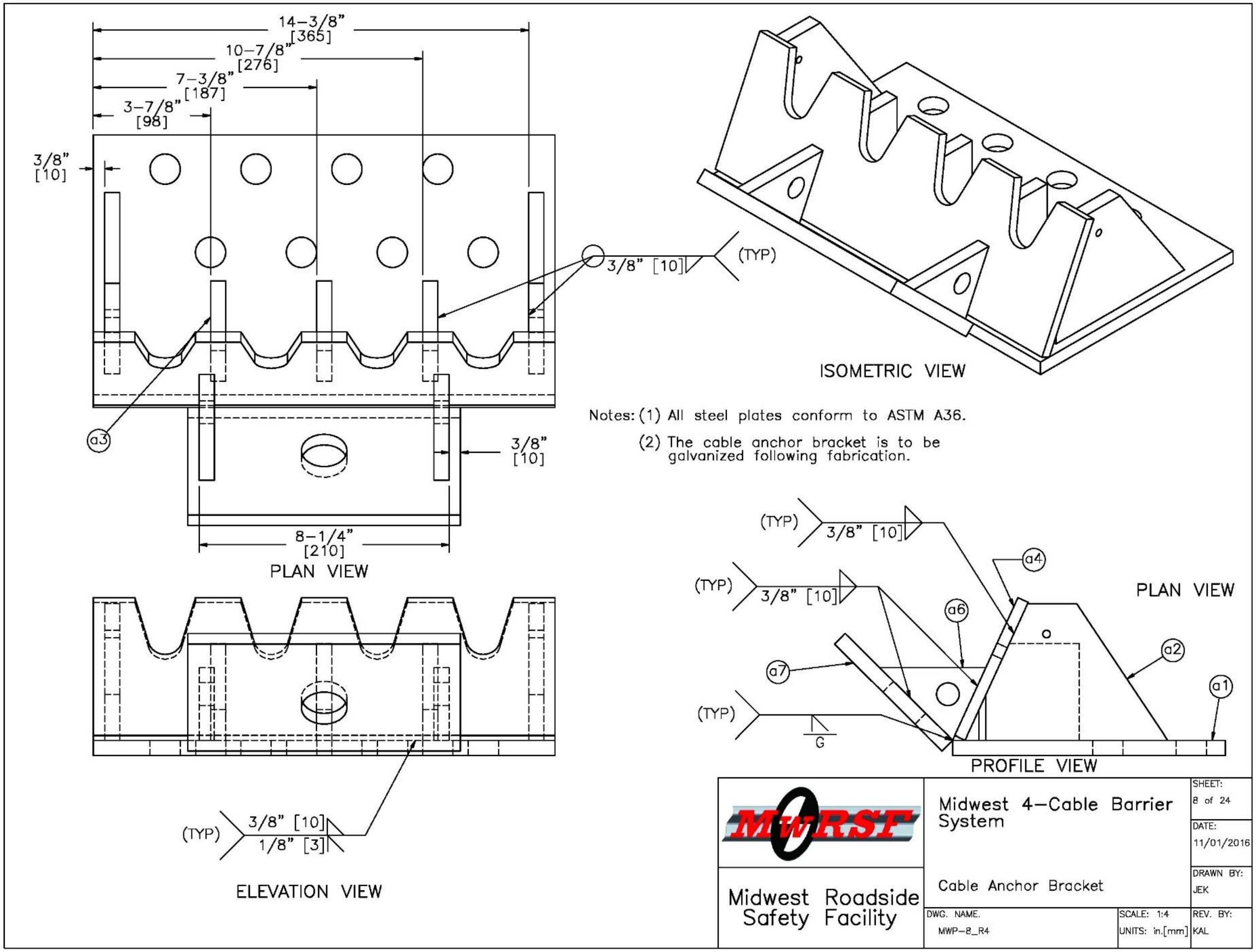


Figure 8. Cable Anchor Bracket, Test No. MWP-8

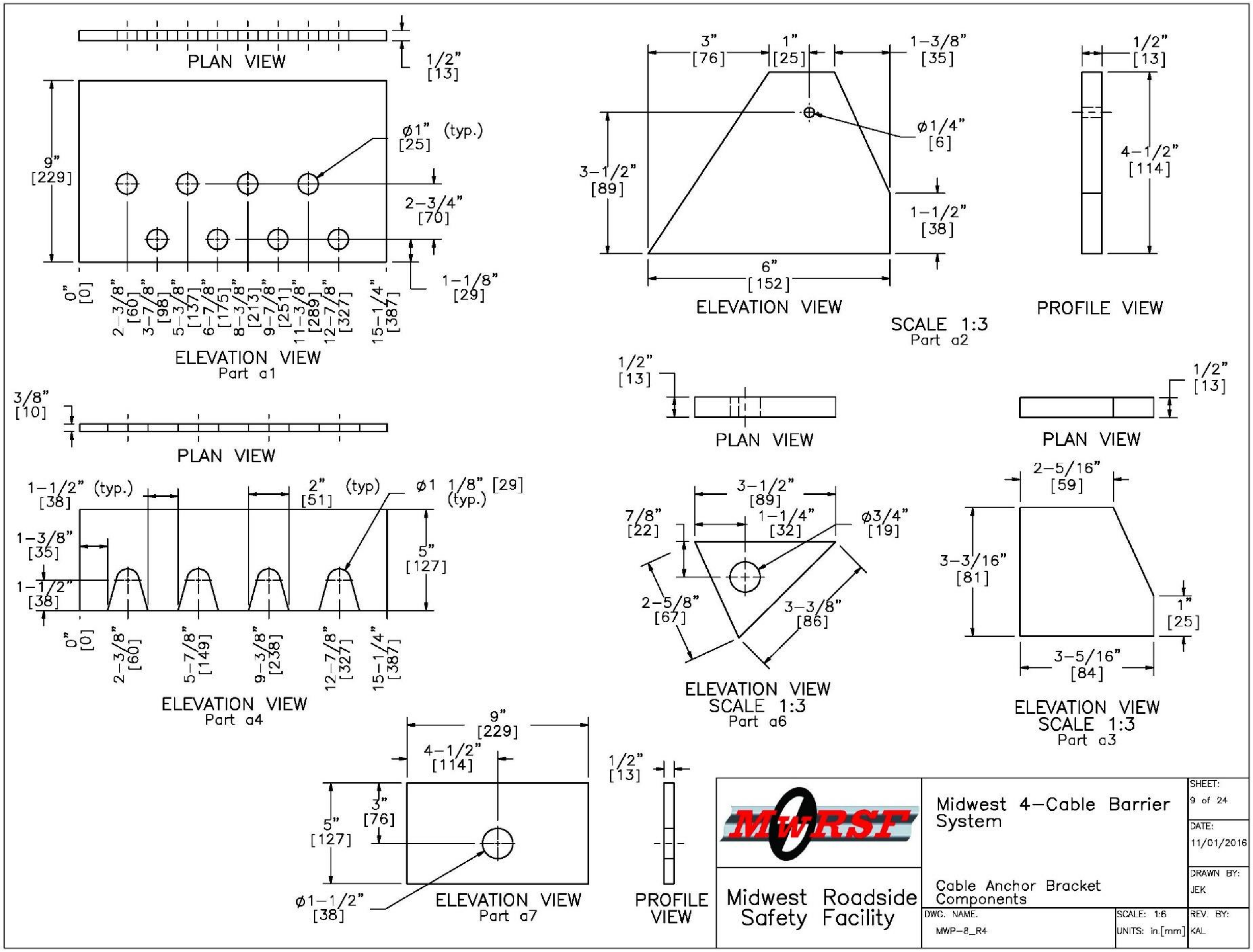


Figure 9. Cable Anchor Bracket Components, Test No. MWP-8

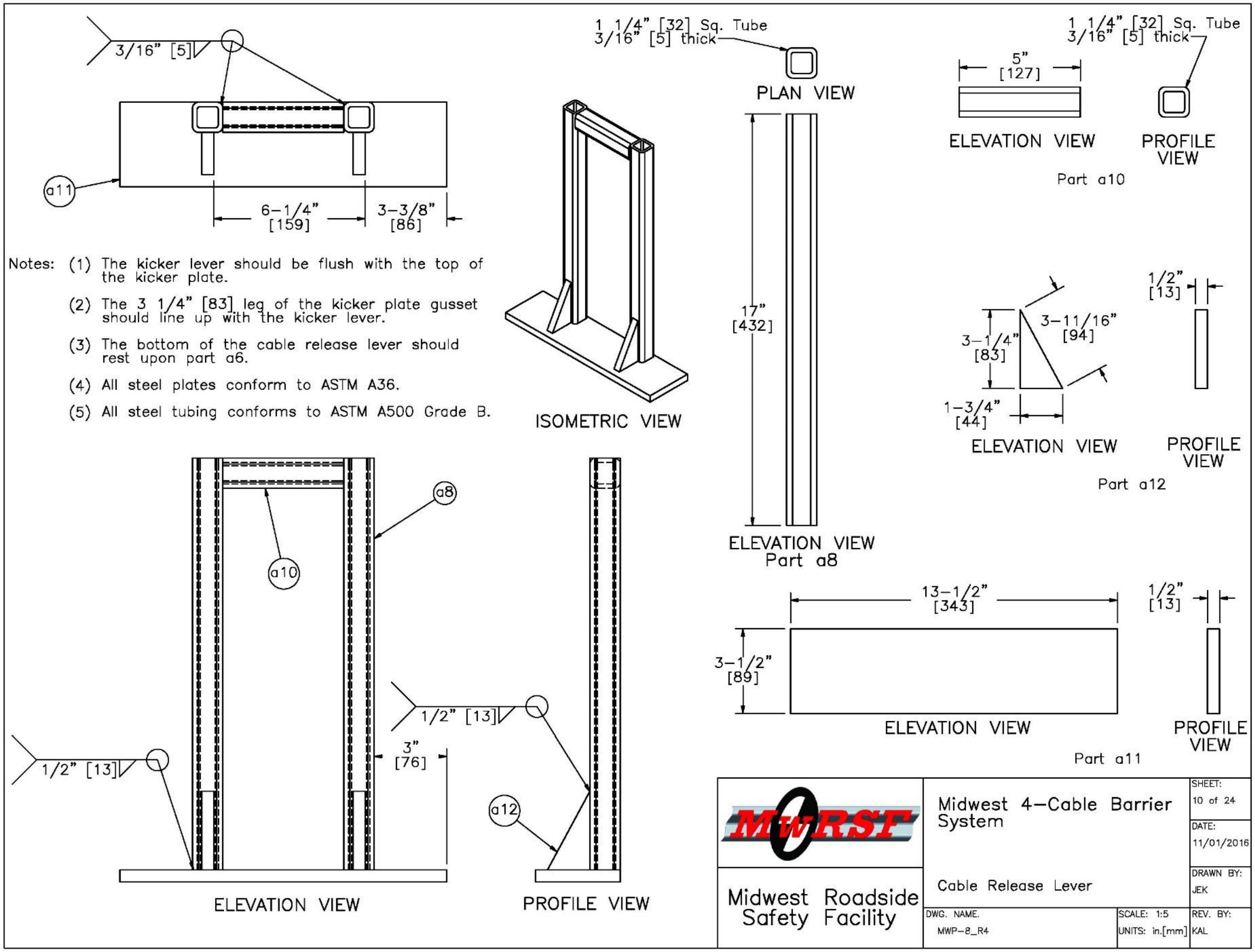


Figure 10. Cable Release Lever, Test No. MWP-8

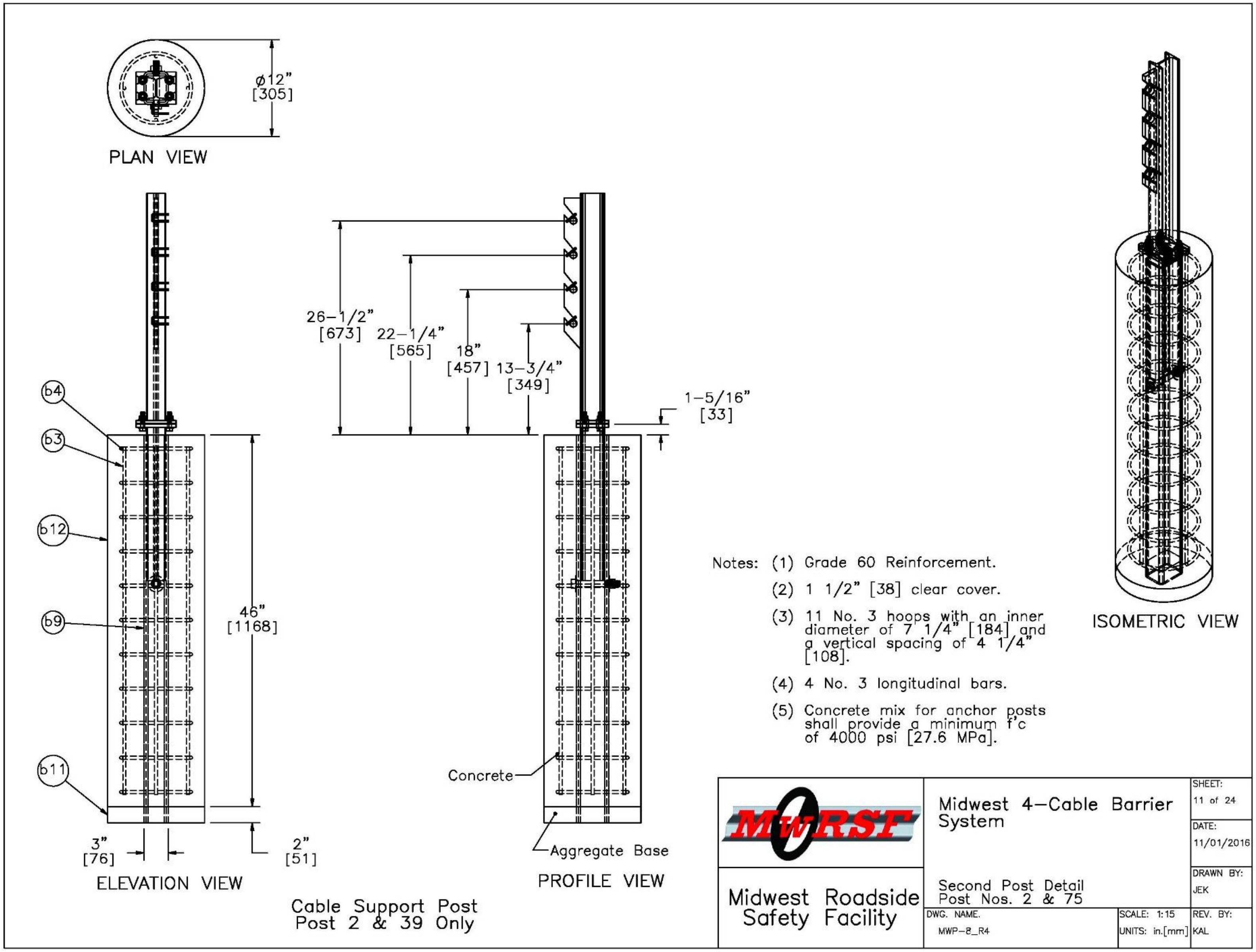


Figure 11. Second Post Detail, Post Nos. 2 and 75, Test No. MWP-8

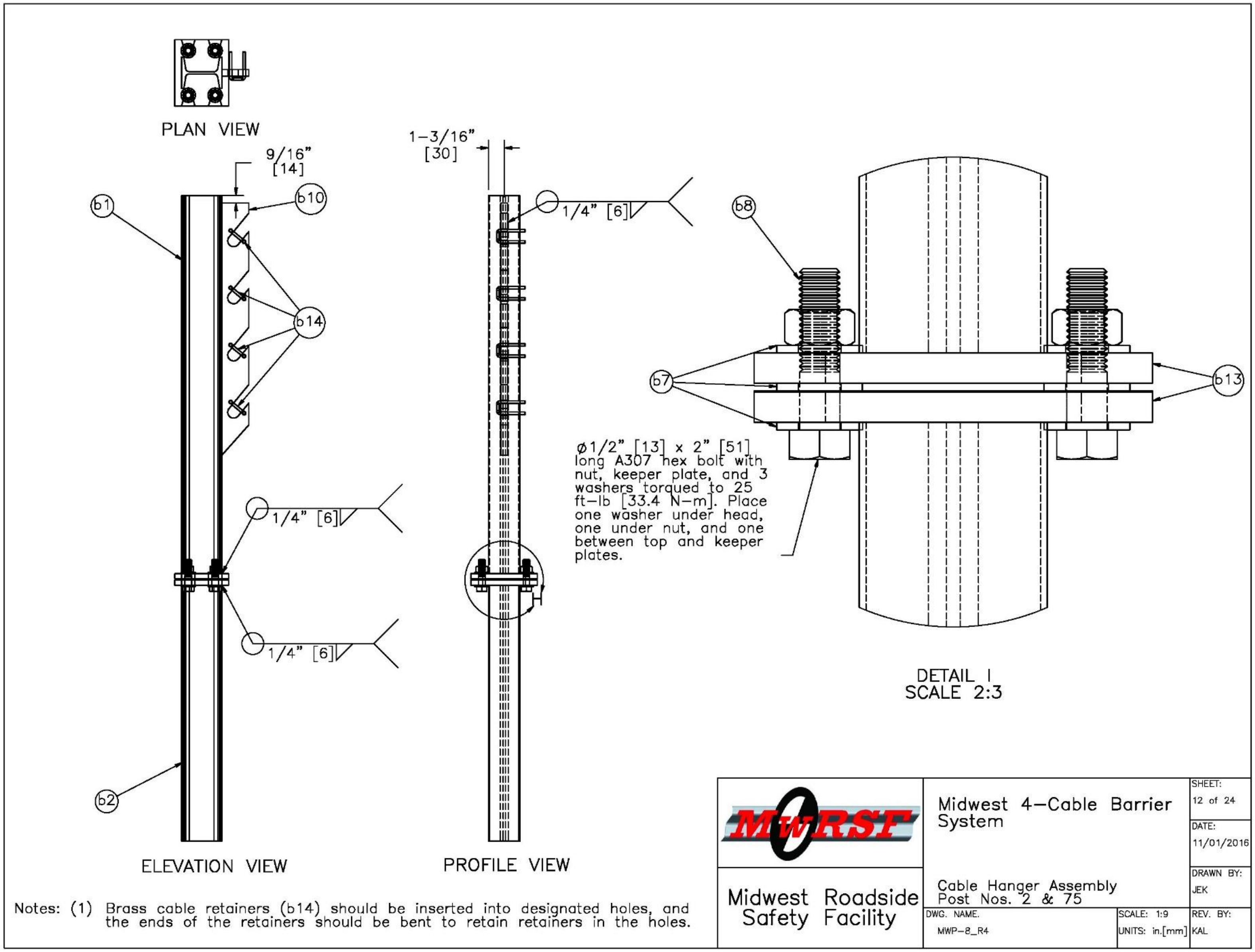


Figure 12. Cable Hanger Assembly, Post Nos. 2 and 75, Test No. MWP-8

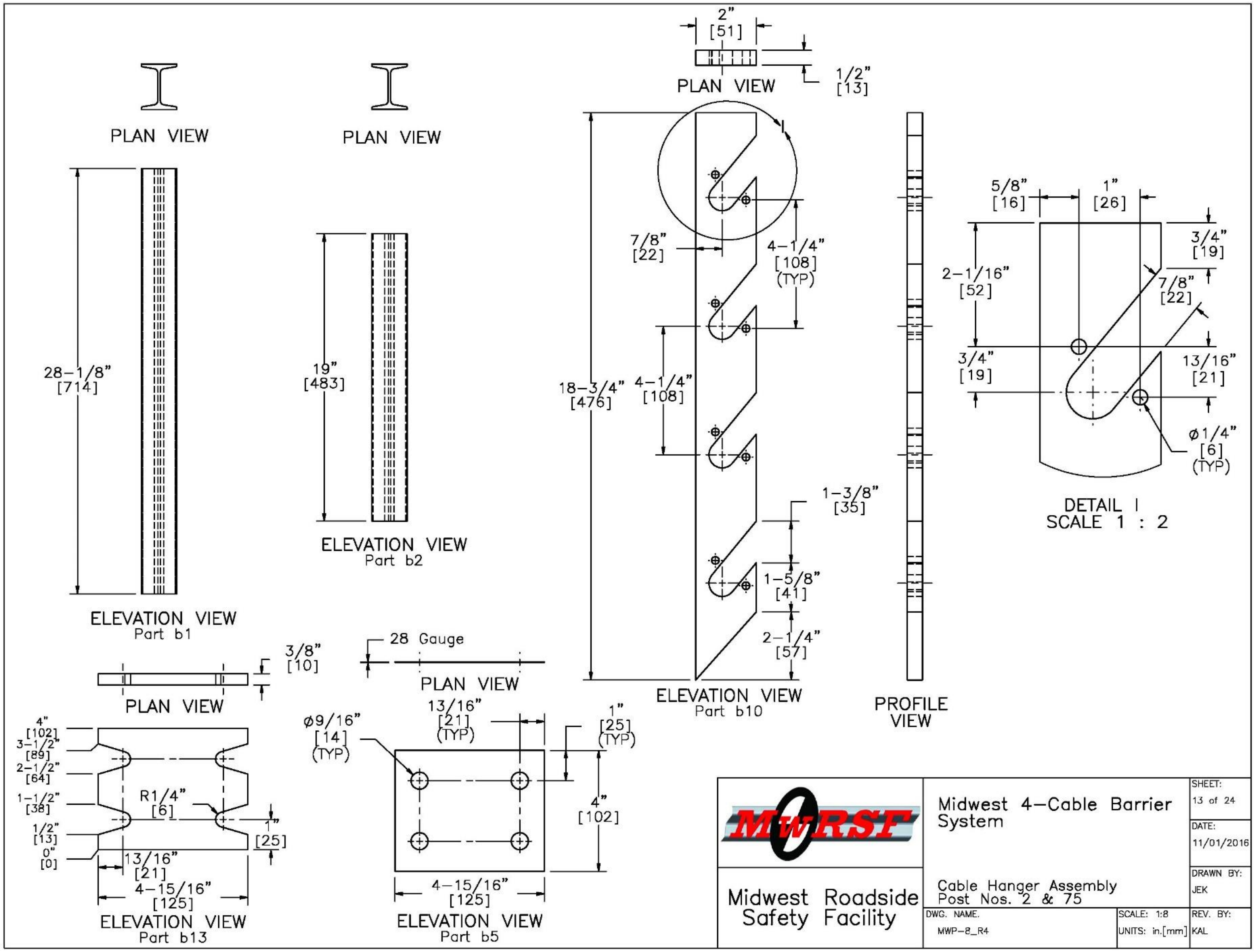


Figure 13. Cable Hanger Assembly, Post Nos. 2 and 75, Test No. MWP-8

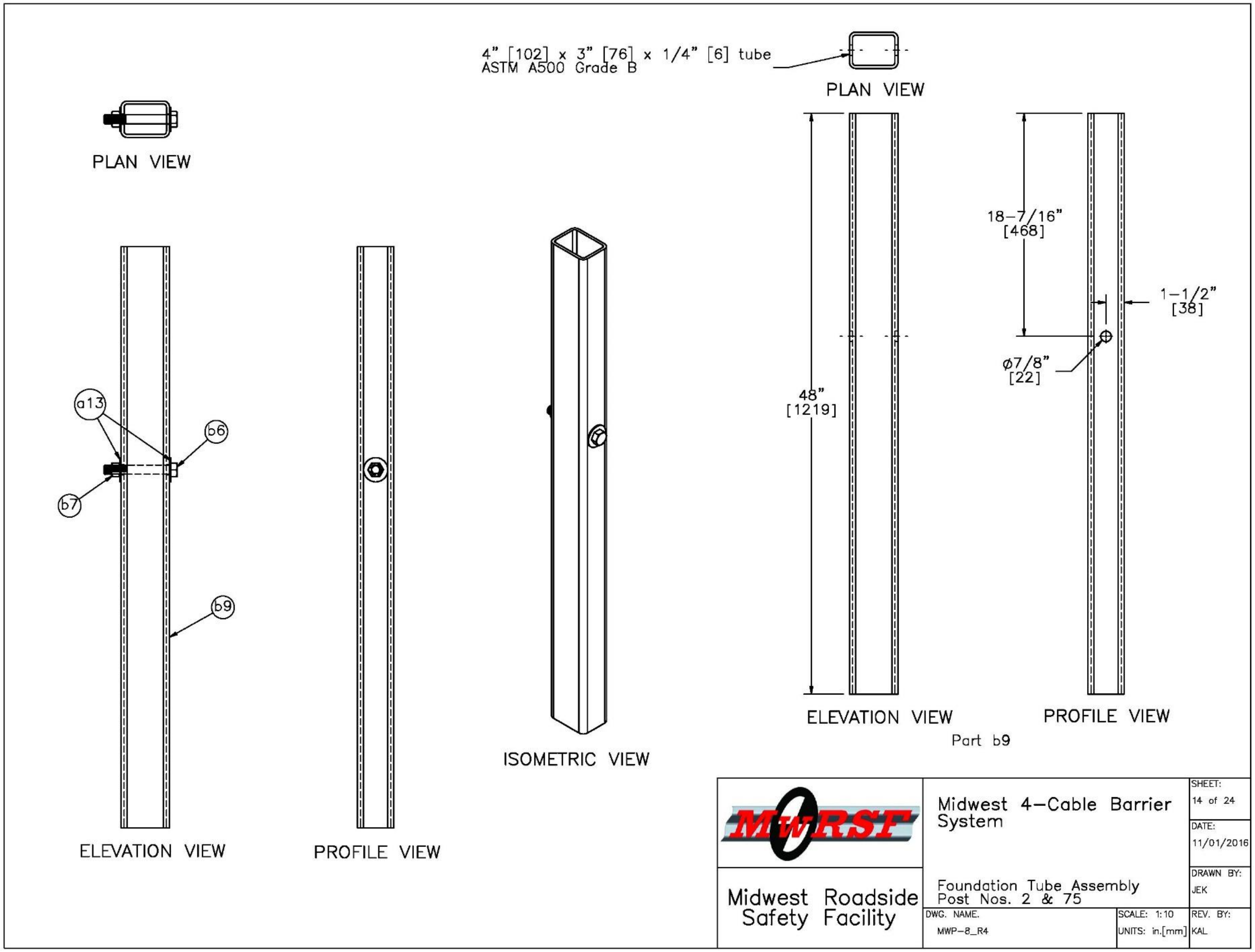


Figure 14. Foundation Tube Assembly, Post Nos. 2 and 75, Test No. MWP-8

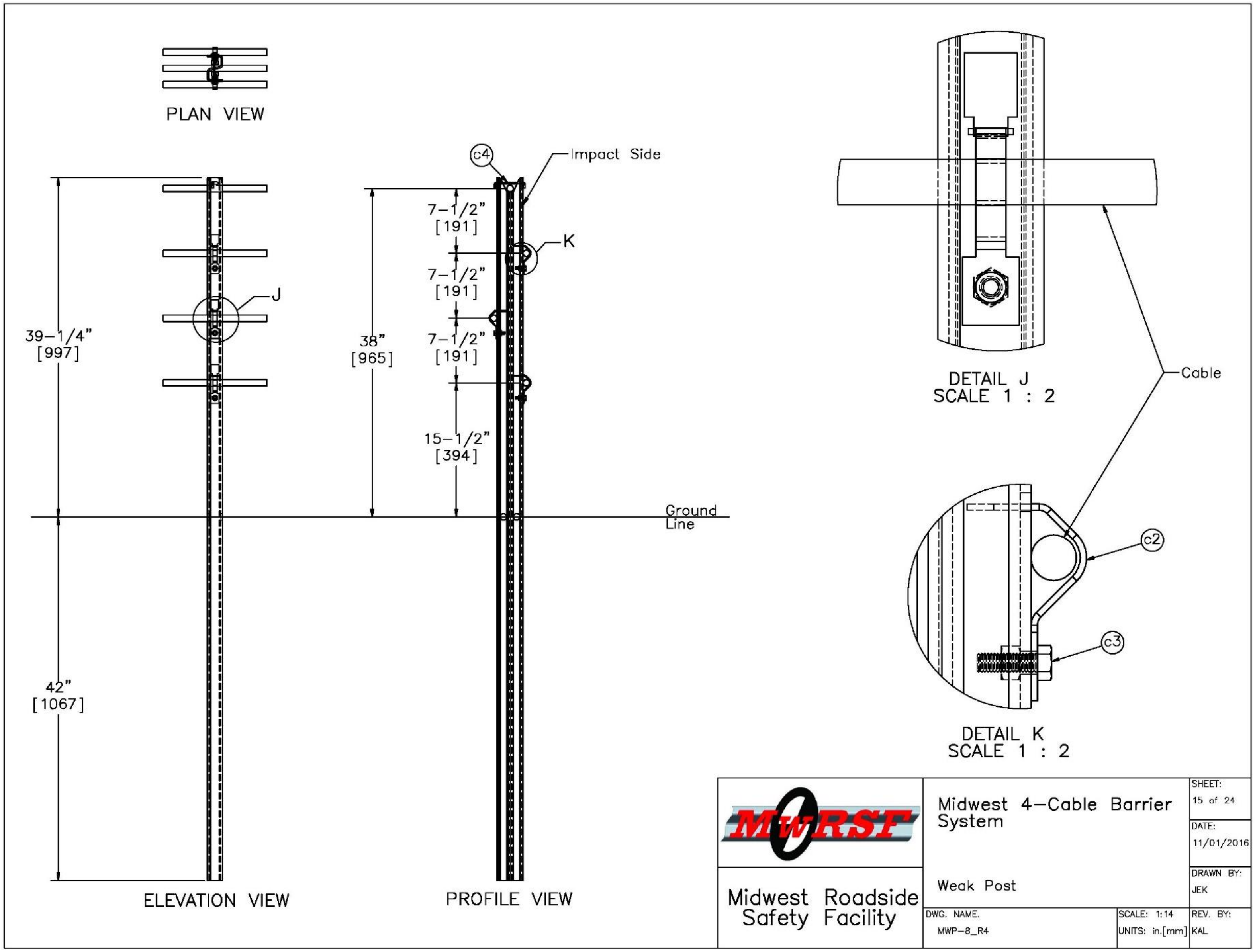


Figure 15. Midwest Weak Post Details, Test No. MWP-8

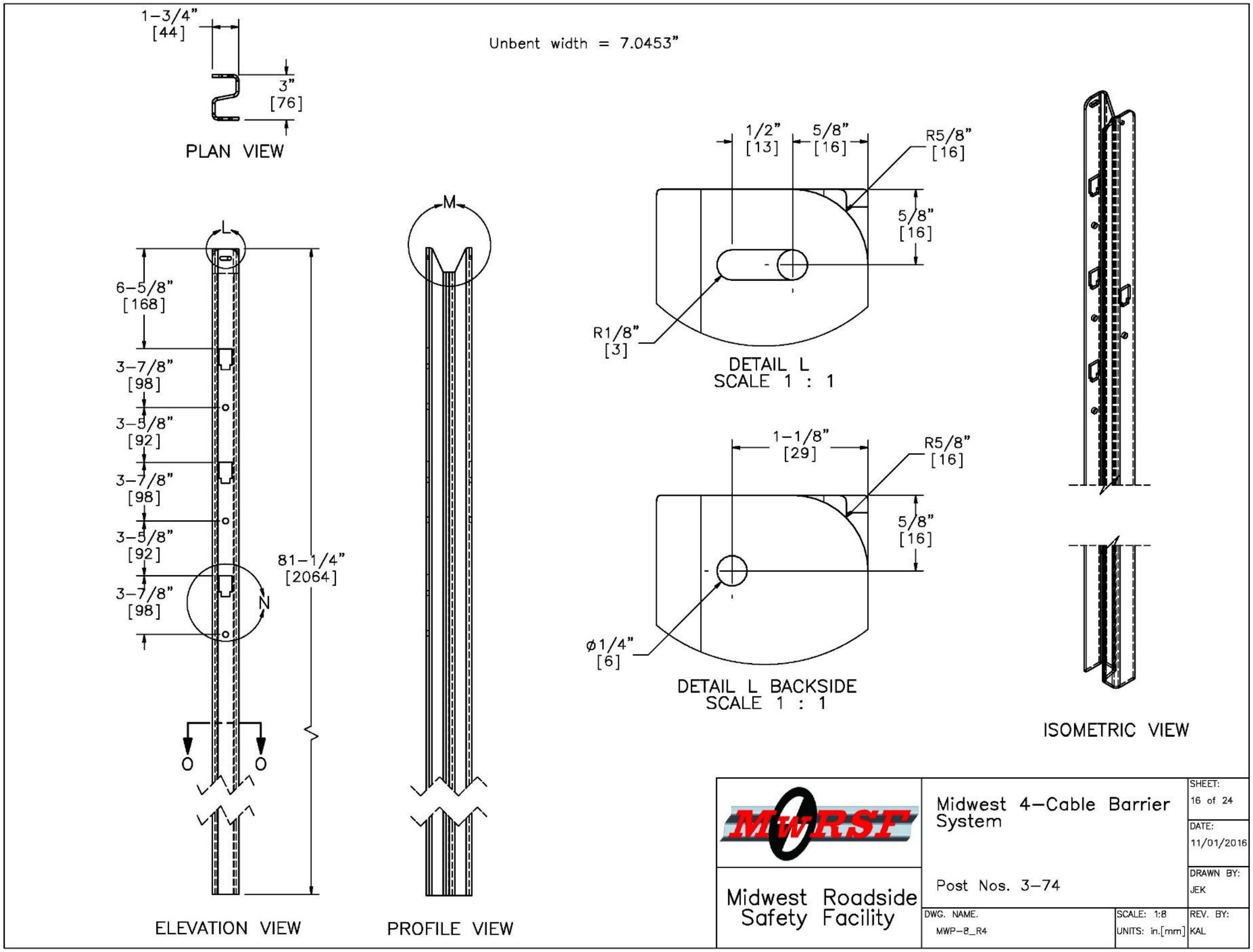


Figure 16. Midwest Weak Post Details, Test No. MWP-8

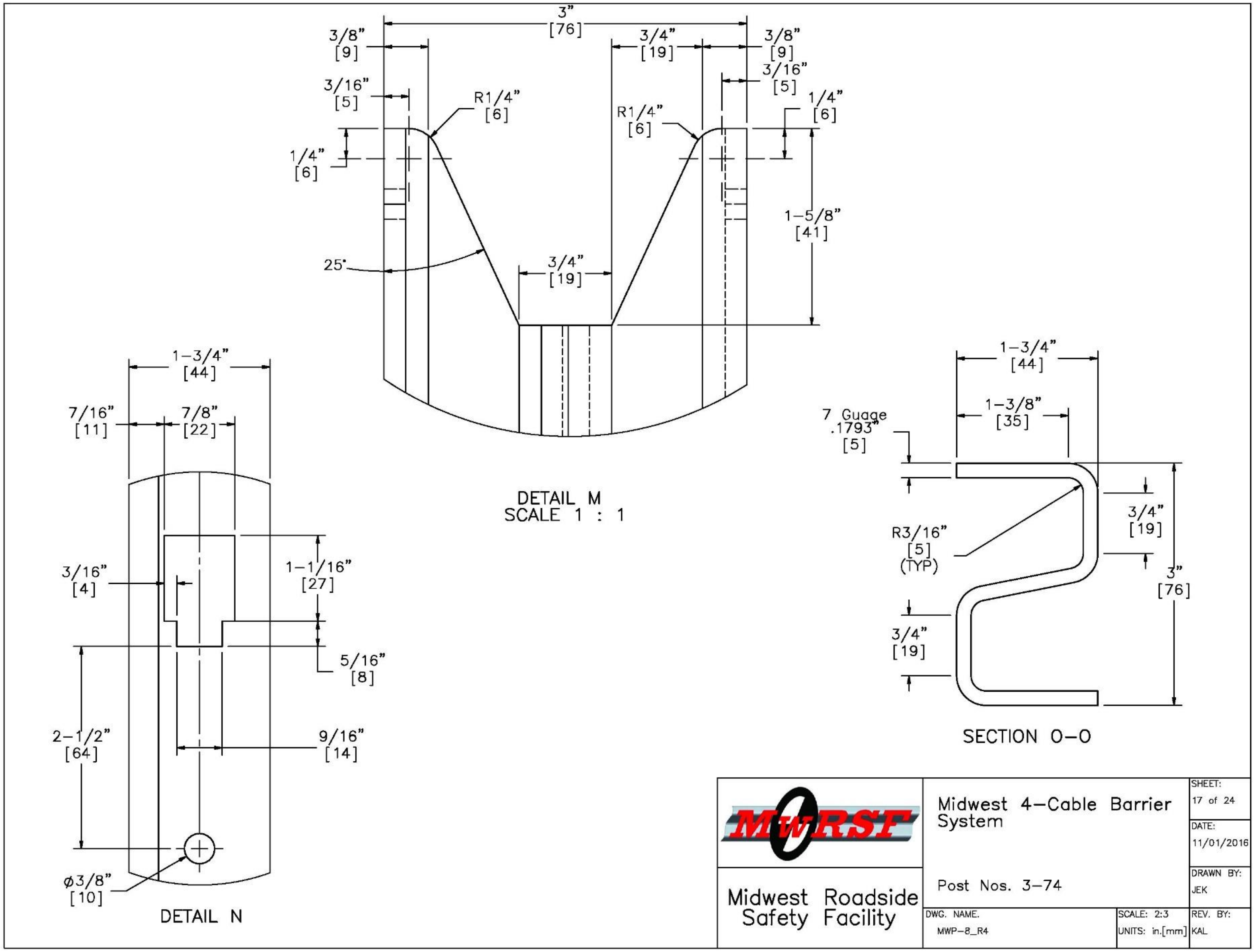


Figure 17. Midwest Weak Post Details, Test No. MWP-8

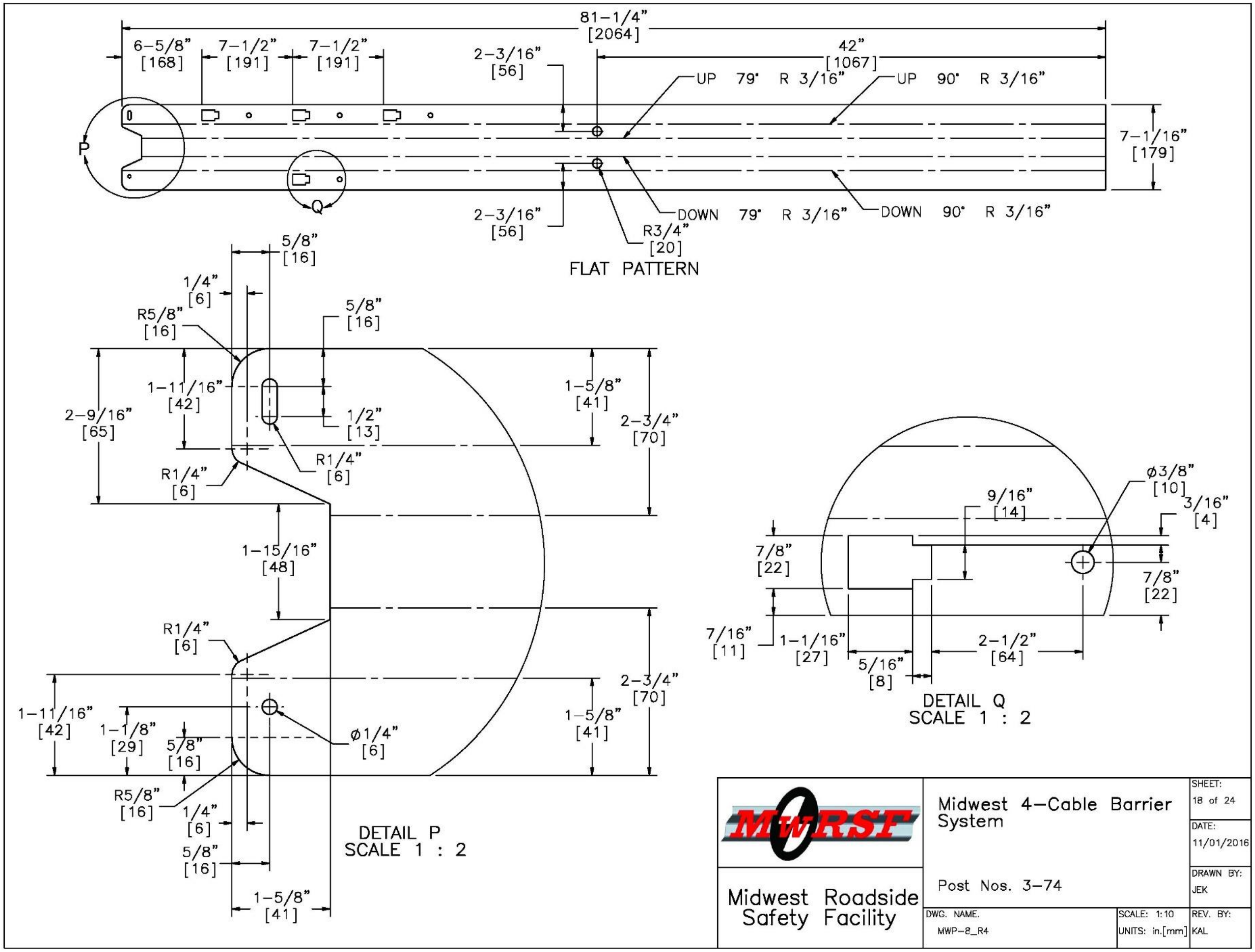


Figure 18. Post Nos. 3 through 74 Details, Test No. MWP-8

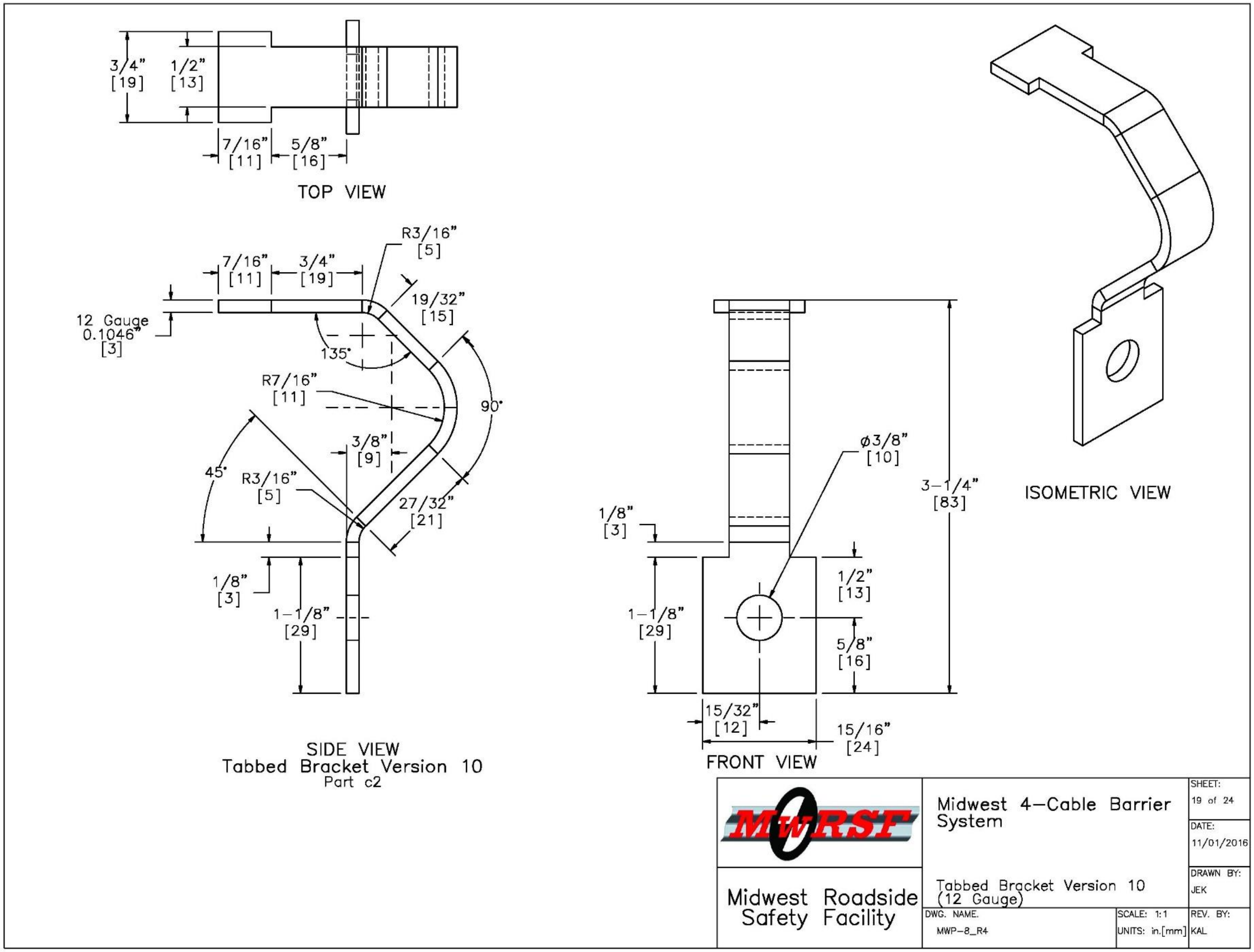


Figure 19. Tabbed Bracket Version 10 (12 Gauge), Test No. MWP-8

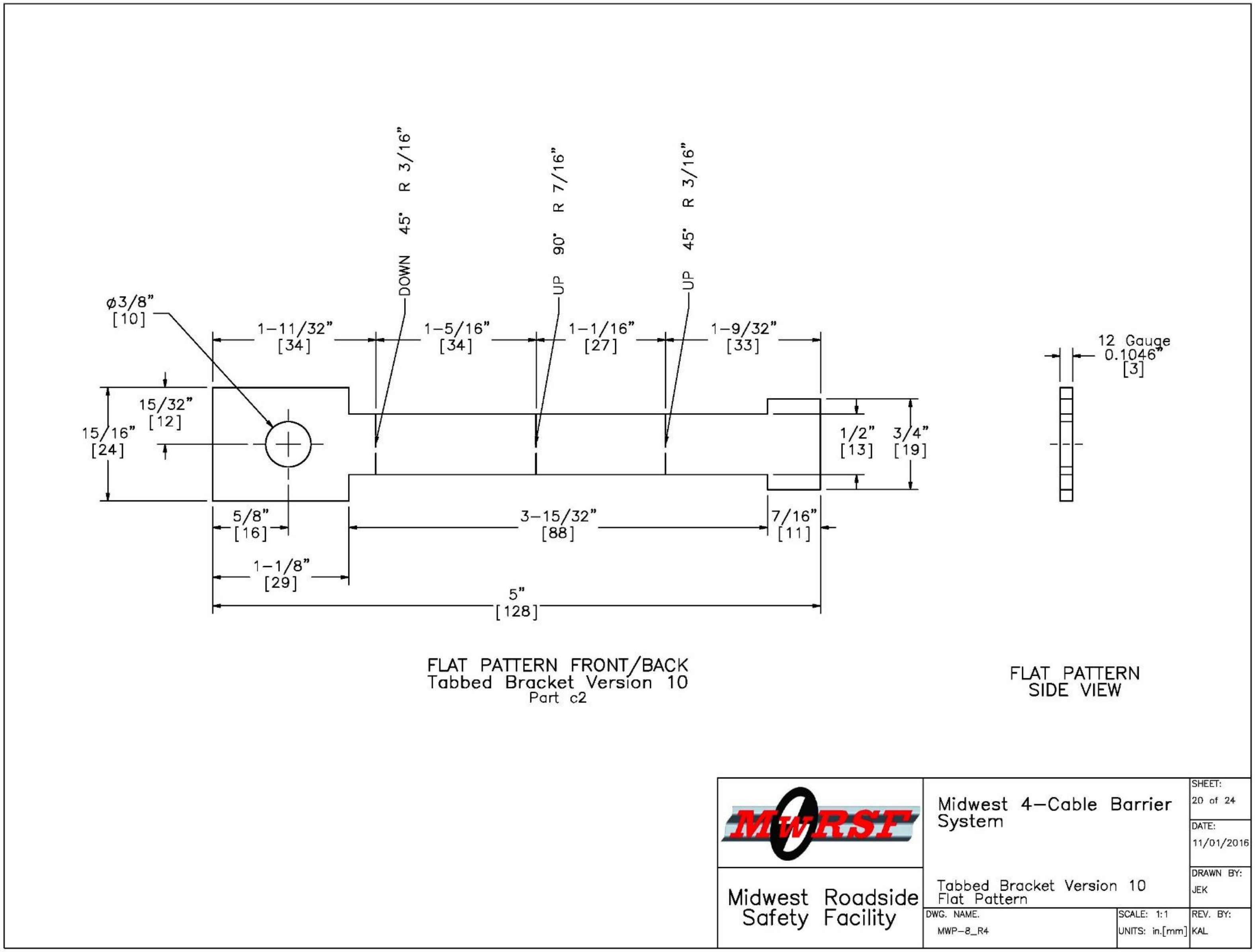


Figure 20. Tabbed Bracket Version 10 Flat Pattern, Test No. MWP-8

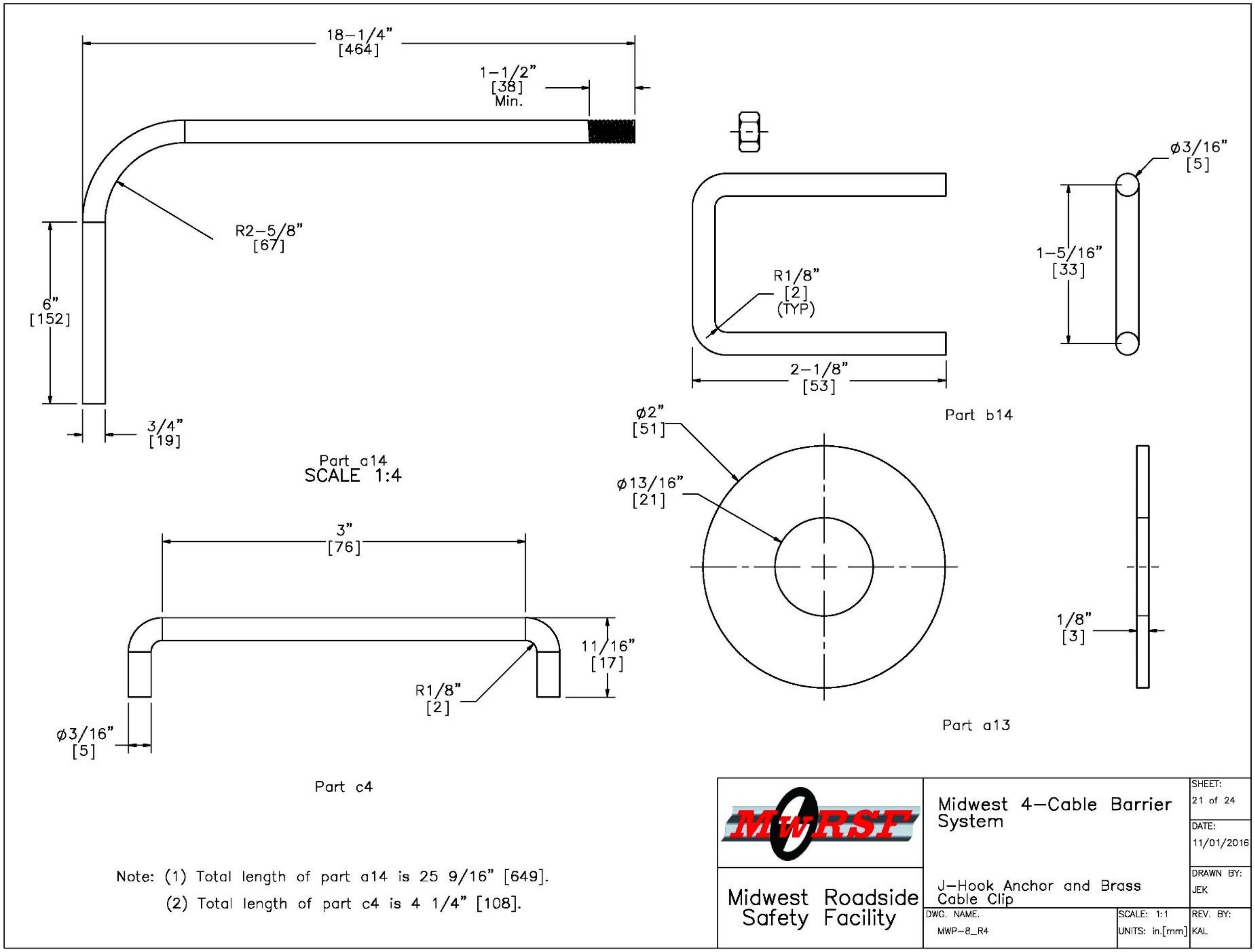


Figure 21. J-Hook Anchor and Brass Cable Clip, Test No. MWP-8

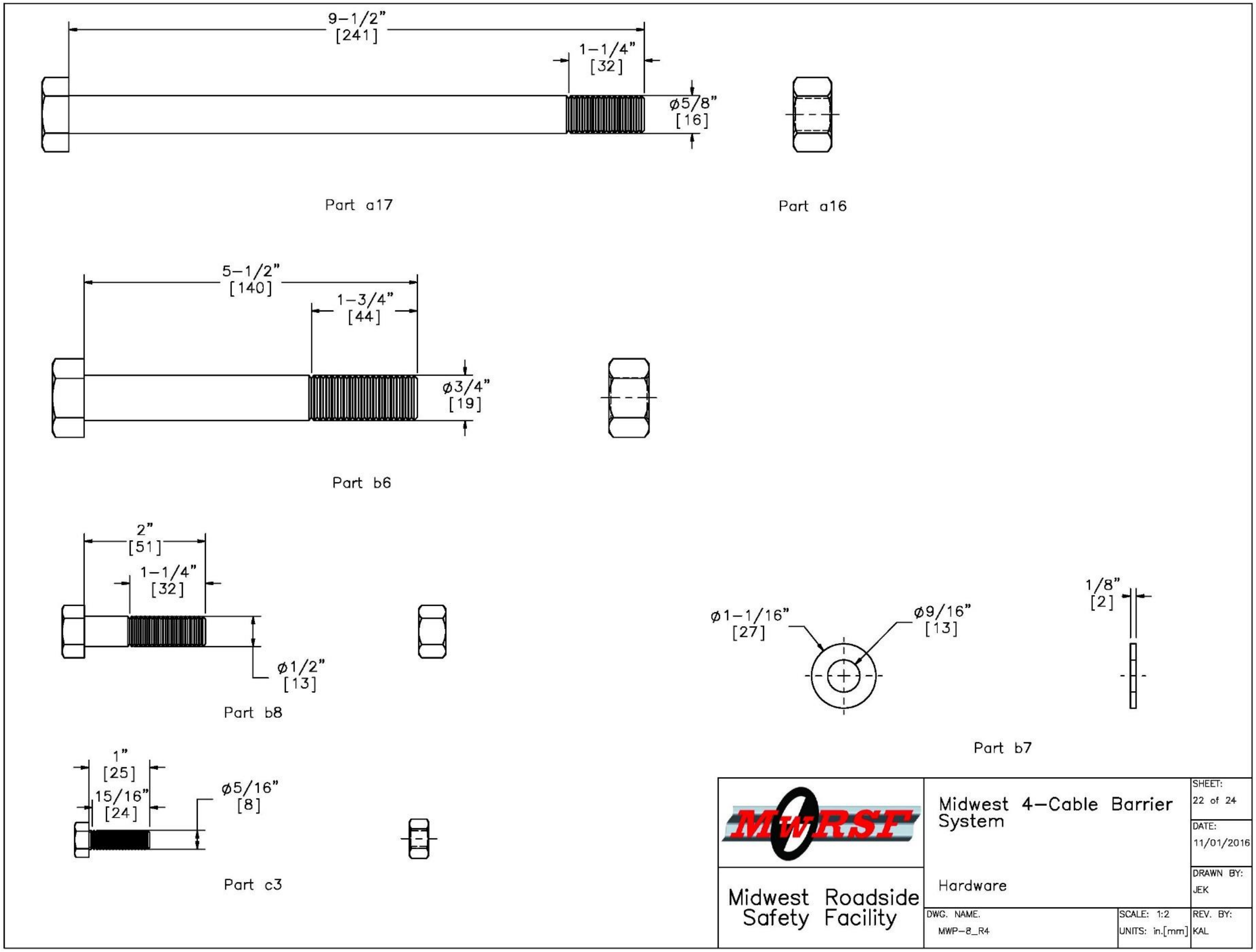


Figure 22. Hardware Details, Test No. MWP-8

Item No.	QTY.	Description	Material Specification
a1	2	Cable Anchor Base Plate	ASTM A36
a2	4	Exterior Cable Plate Gusset	ASTM A36
a3	6	Interior Cable Plate Gusset	ASTM A36
a4	2	Anchor Bracket Plate	ASTM A36
a5	2	3/16" [5] Dia. Brass Keeper Rod, 14" [356] long	Brass
a6	4	Release Gusset	A36 Steel
a7	2	Release Lever Plate	A36 Steel
a8	4	1.25x1.25x0.1875" [32x32x5] TS CT Kicker Lever Tube	ASTM A500 Gr. B
a9	8	CMB High Tension Anchor Plate Washer	ASTM A36
a10	2	1.25x1.25x0.1875" [32x32x5] TS CT Kicker Lever Connecting Tube	ASTM A 500 Gr. B
a11	2	3x10x0.5" [76x254x13] Kicker Plate	ASTM A36
a12	4	CT kicker – gusset	ASTM A36
a13	20	3/4" [19] Dia. Flat Washer	ASTM F844
a14	16	3/4" [19] Dia. UNC J–Hook Anchor and Hex Nut	J–Hook ASTM A449/Nut ASTM A563 DH
a15	2	1/4" [6] Dia. Aircraft Retaining Cable, 36" [914] long	7x19 Galv.
a16	2	5/8" [16] Dia. Heavy Hex Nut	ASTM A563C
a17	2	5/8" [16] Dia. UNC, 9 1/2" [241] Long Hex Bolt	ASTM A449 or SAE J429 Gr. 5
a18	2	24" [610] Dia. Concrete Anchor, 120" [3048] long	4,000 psi f'c
a19	16	#11 Straight Rebar, 114" [2896] long	Grade 60
a20	44	#4 Anchor Hoop Rebar with 21" [533] Dia.	Grade 60
b1	2	S3x5.7 [S76x8.5] Post by 28 1/8" [714]	ASTM A572 GR50–07, ASTM A709 GR50–09A, ASTM A992–06A
b2	2	S3x5.7 [S76x8.5] Post by 19" [483]	ASTM A572 GR50–07, ASTM A709 GR50–09A, ASTM A992–06A
b3	8	#3 Straight Rebar, 43" [1092] long	Grade 60
b4	22	7 1/4" [184] Dia. No. 3 Hoop Reinforcement	Grade 60
b5	2	2nd Post Keeper Plate, 28 Gauge	ASTM A36
b6	2	3/4" [19] Dia. UNC, 5 1/2" [140] Long Hex Bolt and Nut	Bolt ASTM A307 Gr. A/Nut ASTM A563A
b7	24	1/2" [13] Dia. Washer with 1 1/16" [27] OD	ASTM F844
b8	8	1/2" [13] Dia. UNC, 2" [51] long Hex Bolt and Nut	Bolt ASTM A307 Gr. A/Nut ASTM A563A
b9	2	4x3x1/4" [102x76x6] Foundation Tube, 48" [1168] long	ASTM A500 Grade B
b10	2	2nd Post Cable Hanger	ASTM A36
b11	2	2nd Post Anchor Aggregate 12 in, Depth	–
b12	2	12" Dia. 2nd Post Concrete Anchor, 46" long	4,000 psi f'c
b13	4	2nd Post Base Plate	ASTM A36
b14	8	3/16" [5] Dia. 5 1/4" [133] Long Brass Rod	ASTM B16–00

Midwest Roadside Safety Facility

Midwest 4–Cable Barrier System

Bill of Materials

SHEET: 23 of 24

DATE: 11/01/2016

DRAWN BY: JEK

DWG. NAME. MWP–8_R4

SCALE: NONE

UNITS: in.[mm]

REV. BY: KAL

Figure 23. Bill of Materials, Test No. MWP-8

Item No.	QTY.	Description	Material Spec
c1	72	3"x1-3/4"x7 Gauge [76x44x4.6], 81 1/4" [2064] Long Midwest Weak Post w/Holes	Hot-Rolled ASTM A1011 HSLA Gr. 50
c2	216	12 Gauge Tabbed Bracket - Version 10	Hot-Rolled ASTM A1011 HSLA Grade 50
c3	216	5/16" [8] Dia. UNC, 1" [25] Long Hex Cap Screw and Nut	Bolt SAE J429 Gr. 5 or ASTM A449/Nut ASTM A563 DH
c4	72	Straight Rod - ϕ3/16" [5] Cable Clip	ASTM B16 Brass C36000 Half Hard (HO2), ROUND. TS >= 68.0 ksi, YS >= 52.0 ksi
d1	1	3/4" [19] Dia. 3x7 Cable Guiderail	AASHTO M30-92(2000)/ASTM A741-98 Type 1 Class A coating except with Type 1 minimum breaking strength = 39 kips [173.5 kN]
d2	16	7/8" [22] Dia. Hex Nut	ASTM A563C
d3	28	Cable End Threaded Rod	ASTM A449
d4	24	Bennett Cable End Fitter	ASTM A47
d5	24	7/8" [22] Dia. Hex Nut	SAE J429 Gr. 5
e1	8	Bennett Short Threaded Turnbuckle	Not Specified
e2	8	Threaded Load Cell Coupler	N/A
e3	4	50,000-lb [222.4-kN] Load Cell	N/A

Midwest Roadside Safety Facility

Midwest 4-Cable Barrier System

Bill of Materials

SHEET: 24 of 24
DATE: 11/01/2016
DRAWN BY: JEK
DWG. NAME. MWP-8_R4
SCALE: NONE
UNITS: in.[mm]
REV. BY: KAL

Figure 24. Bill of Materials, Test No. MWP-8

Figure 25. System Photographs, Test No. MWP-8

Figure 26. Test Installation Photographs, Test No. MWP-8

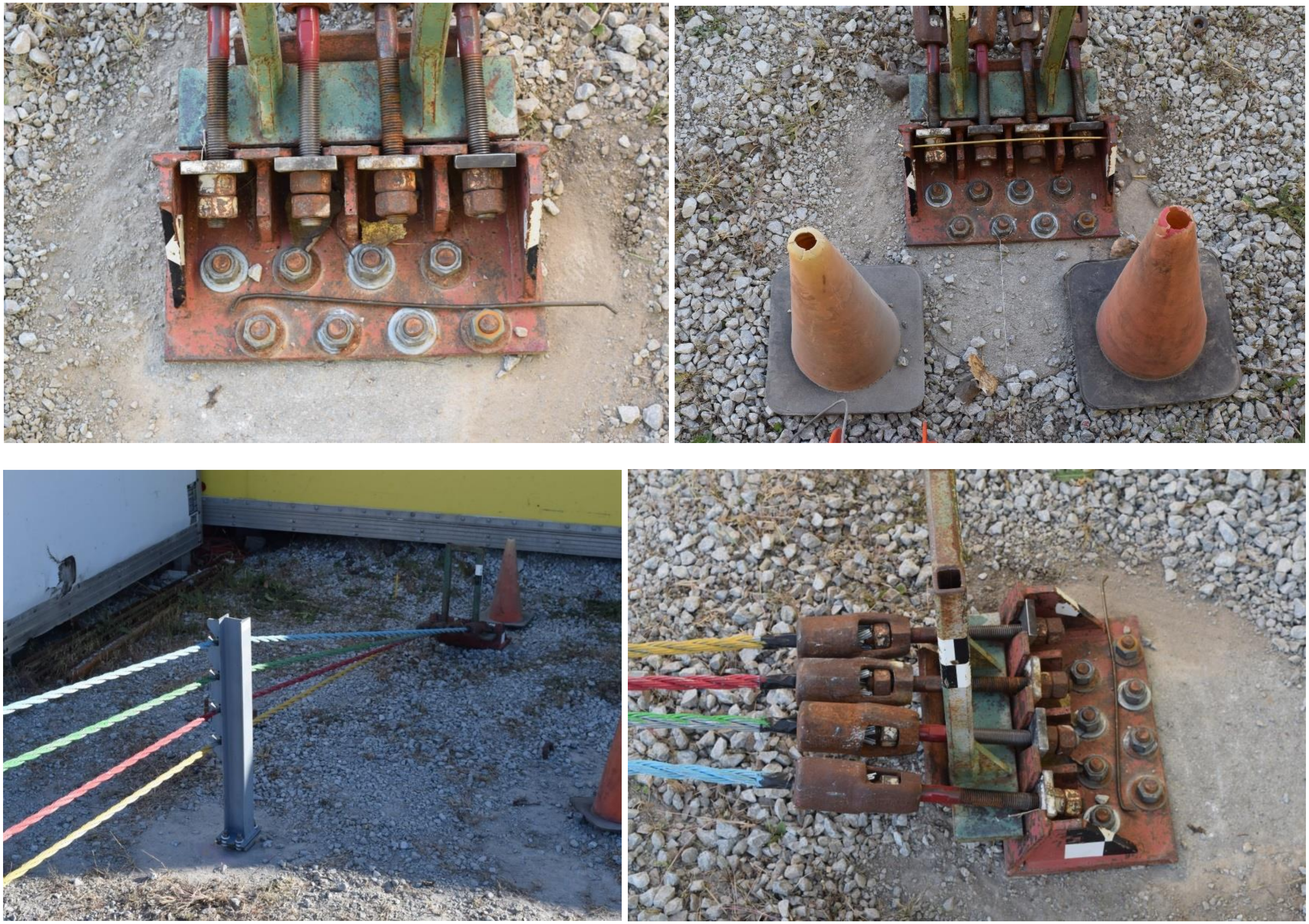


Figure 27. Upstream Anchorage, Test No. MWP-8

Figure 28. Downstream Anchorage, Test No. MWP-8

Figure 29. Post Details, Test No. MWP-8

Figure 30. Bracket Details, Test No. MWP-8

Figure 31. Downstream Cable Splices, Test No. MWP-8

Figure 32. Upstream Cable Splices, Test No. MWP-8

4 TEST CONDITIONS

4.1 Test Facility

The testing facility 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.

4.2 Vehicle Tow and Guidance System

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

A vehicle guidance system developed by Hinch [5] was used to steer the test vehicle. A guide flag, attached to the right-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 as the vehicle was towed down the line, the guide flag struck and knocked each stanchion to the ground.

4.3 Test Vehicles

For test no. MWP-8, a 2008 Kia Rio was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,398 lb (1,088 kg), 2,419 lb (1,097 kg), and 2,583 lb (1,172 kg), respectively. The test vehicle is shown in Figure 33, and vehicle dimensions are shown in Figure 34.

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The vertical component of the c.g. for the 1100C vehicle was determined utilizing a procedure published by SAE [6]. The location of the final c.g. is shown in Figures 34 and 35. Data used to calculate the location of the c.g. and ballast information is shown in Appendix B.

Square, black- and white-checkered targets were placed on the vehicle for reference to be viewed from the high-speed digital video cameras and aid in the video analysis, as shown in Figure 35. Round, checkered targets were placed on the center of gravity on the left-side door, the right-side door, and the roof of the vehicle.

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

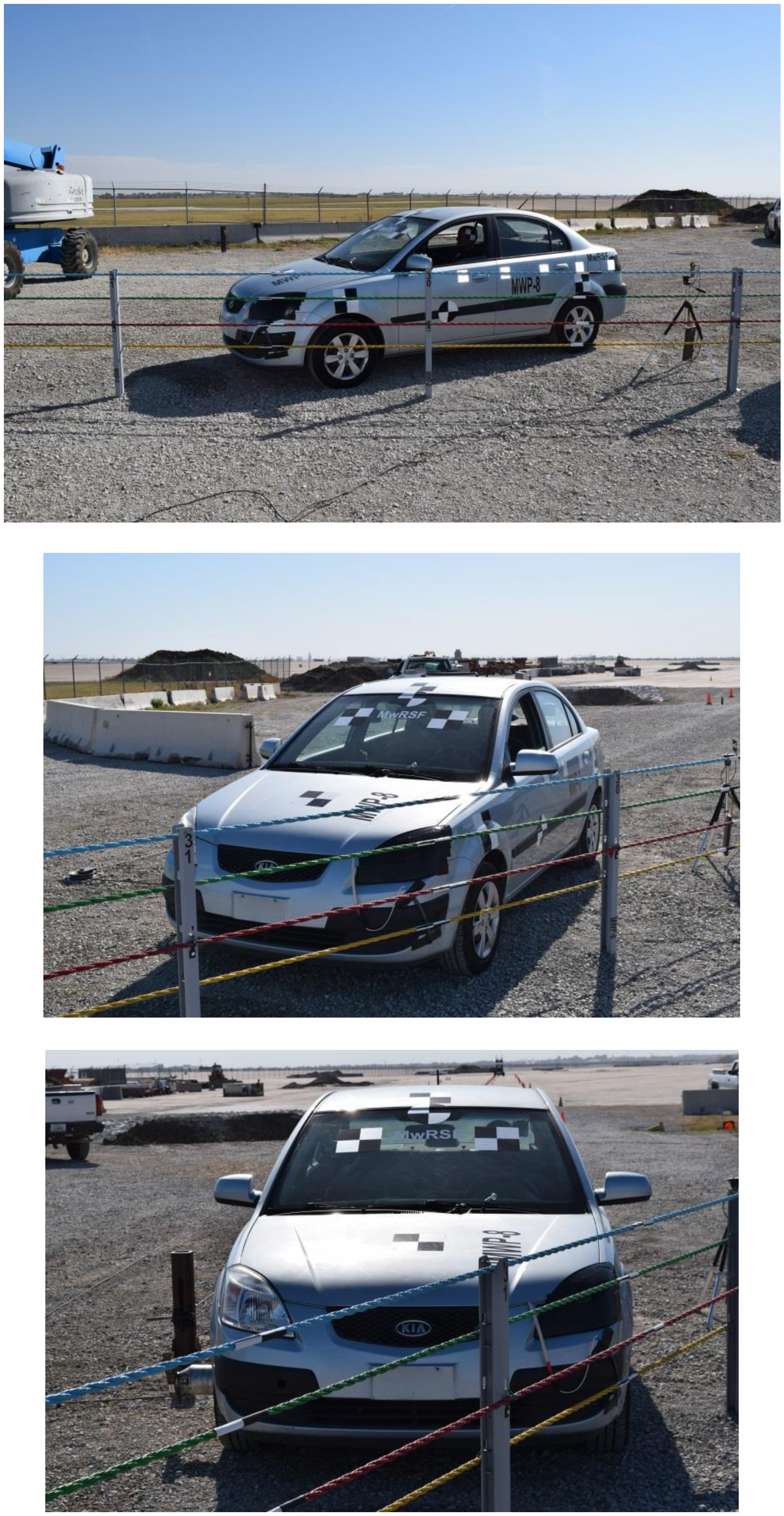


Figure 33. Test Vehicle, Test No. MWP-8

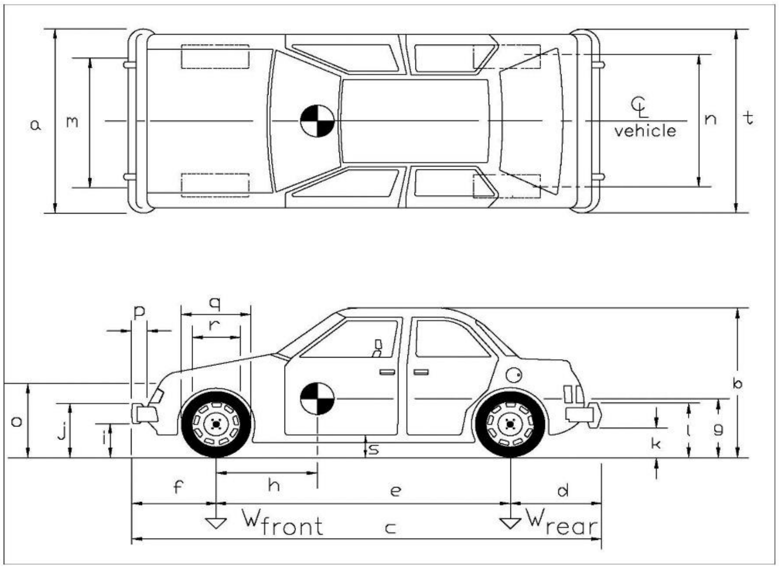
Date: 10/19/205 **Test Number:** MWP-8 **Model:** Rio

Make: Kia **Vehicle I.D.#:** knade123286393392

Tire Size: 185/65R14 **Year:** 2008 **Odometer:** 82180

Tire Inflation Pressure: 32

*(All Measurements Refer to Impacting Side)



Vehicle Geometry -- in. (mm)

a	61 3/4	(1568)	b	57 1/2	(1461)
c	167 1/4	(4248)	d	36	(914)
e	98 1/2	(2502)	f	32 3/4	(832)
g	22 1/2	(571)	h	37 3/8	(949)
i	9 1/8	(232)	j	21 1/4	(540)
k	12	(305)	l	23 5/8	(600)
m	57 3/8	(1457)	n	58	(1473)
o	30 1/4	(768)	p	1 3/4	(44)
q	23 1/4	(591)	r	15 3/8	(391)
s	11 3/4	(298)	t	63 7/8	(1622)

Wheel Center Height Front	10 3/4	(273)
Wheel Center Height Rear	11 1/4	(286)
Wheel Well Clearance (F)	25 1/8	(638)
Wheel Well Clearance (R)	24 7/8	(632)
Frame Height (F)	16 3/8	(416)
Frame Height (R)	15 5/8	(397)
Engine Type	4 cyl. Gas	
Engine Size	1.6L	
Transmission Type:	Manual	
Drive Axle:	Front	

Mass Distribution lb. (kg)

Gross Static	LF	785 (356)	RF	798 (362)
	LR	544 (247)	RR	456 (207)

Weights lb. (kg)	Curb	Test Inertial	Gross Static
W-front	1528 (693)	1501 (681)	1583 (718)
W-rear	870 (395)	918 (416)	1000 (454)
W-total	2398 (1088)	2419 (1097)	2583 (1172)

GVWR Ratings

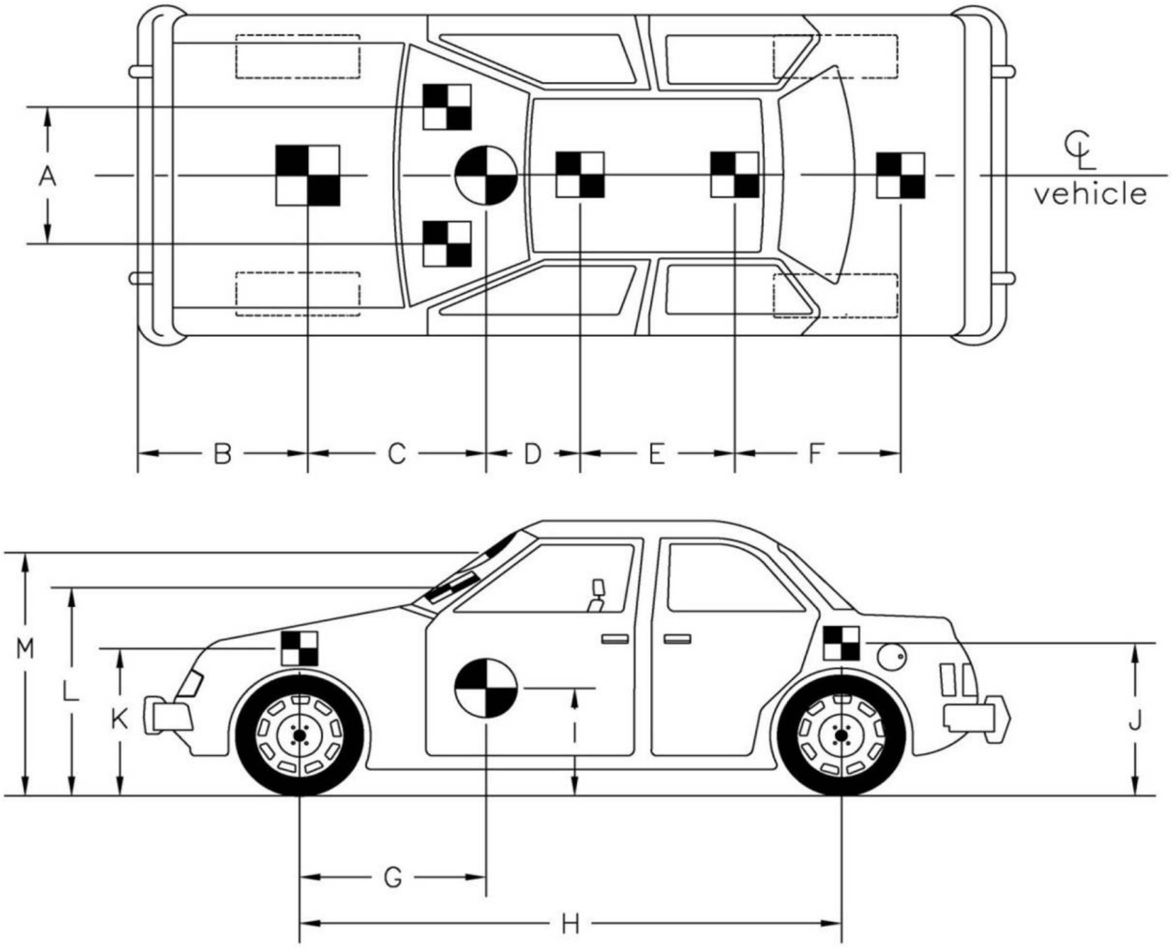
Front	1918 lbs.
Rear	1874 lbs.
Total	3638 lbs.

Dummy Data

Type:	Hybrid II
Mass:	170 lbs.
Seat Position:	Driver

Note any damage prior to test: Minor hail dents all over.

Figure 34. Vehicle Dimensions, Test No. MWP-8



TEST #: MWP-8 Vehicle: Kia Rio

TARGET GEOMETRY-- in. (mm)

A	**24 1/2**	**(622)**	**E**	**41 5/8**	**(1057)**	**I**	**22 1/2**	**(572)**
B	**21 1/8**	**(537)**	**F**	**35 1/2**	**(902)**	**J**	**28 3/4**	**(730)**
C	**48 3/8**	**(1229)**	**G**	**37 3/8**	**(949)**	**K**	**29 1/8**	**(740)**
D	**7 7/8**	**(200)**	**H**	**98 1/2**	**(2502)**	**L**	**48 3/4**	**(1238)**
						M	**53 3/8**	**(1356)**

Figure 35. Target Geometry, Test No. MWP-8

4.4 Simulated Occupant

For test no MWP-8, a Hybrid II 50th-Percentile, Adult Male Dummy, equipped with clothing and footwear, was placed in the left-front seat of the test vehicle with the seat belt fastened. The dummy, which had a final weight of 170 lb (77 kg), was represented by model no. 572, serial no. 451, and was manufactured by Android Systems of Carson, California. As recommended by MASH, the dummy was not included in calculating the c.g. location.

4.5 Data Acquisition Systems

4.5.1 Accelerometers

Two environmental shock and vibration sensor/recorder systems were used to measure the accelerations in the longitudinal, lateral, and vertical directions. Both of the accelerometers were mounted near the center of gravity of the test vehicle. The electronic accelerometer data obtained in dynamic testing was filtered using the SAE Class 60 and the SAE Class 180 Butterworth filter conforming to the SAE J211/1 specifications [7].

The two accelerometer 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 acceleration sensors were mounted inside the bodies of custom built SLICE 6DX event data recorders and recorded data at 10,000 Hz to the onboard microprocessor. Each SLICE 6DX was configured with 7 GB of non-volatile flash memory, a range of ±500 g's, a sample rate of 10,000 Hz, and a 1,650 Hz (CFC 1000) anti-aliasing filter. The "SLICEWare" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

4.5.2 Rate Transducers

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

4.5.3 Retroreflective Optic Speed Trap

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

4.5.4 Load Cells and String Potentiometers

Four load cells were installed upstream of the impact for test no. MWP-8. The load cells were Transducer Techniques model no. TLL-50K with a load range up to 50 kips (222 kN). A string potentiometer was also attached to the system on the upstream anchor. The string potentiometer was Unimeasure model no. PA-50-70124 with a displacement range up to 50 in. (127 cm). 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. The positioning and set up of the transducers are shown in Figure 36.

4.5.5 Digital Photography

Six AOS high-speed digital video cameras, eight GoPro digital video cameras, and four JVC digital video cameras were utilized to video test no. MWP-8. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 37.

The high-speed digital videos were analyzed using ImageExpress MotionPlus and RedLake MotionScope software programs. Actual camera speed and camera divergence factors were considered in the analysis of the high-speed videos. A Nikon D3200 digital still camera was also used to document pre- and post-test conditions for all tests.

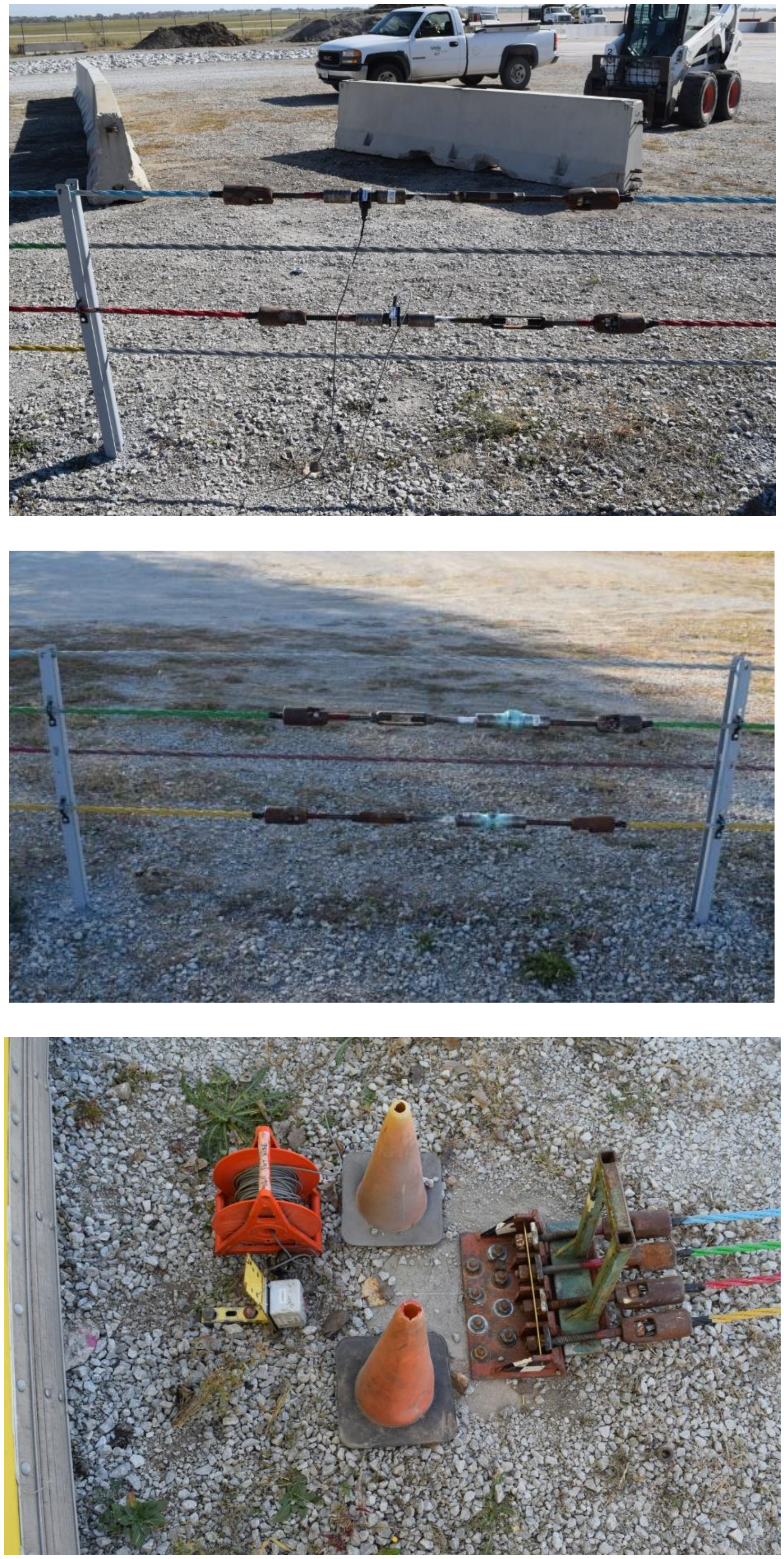
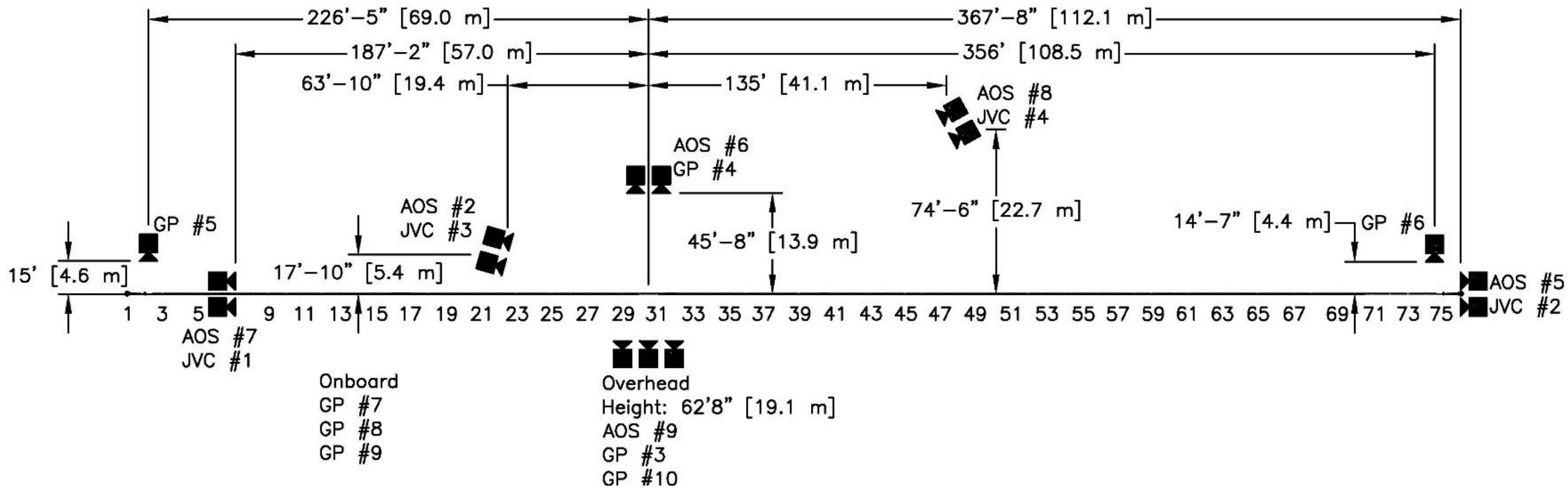


Figure 36. Location of Load Cells and String Potentiometers, Test No. MWP-8



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-2	AOS Vitcam CTM	500	Cosmicar 50mm Fixed	
AOS-5	AOS X-PRI Gigabit	500	Vivitar 135mm Fixed	
AOS-6	AOS X-PRI Gigabit	500	Cosmicar 12.5mm Fixed	
AOS-7	AOS X-PRI Gigabit	500	Fujinon 50mm Fixed	
AOS-8	AOS S-VIT 1531	500	Nikkor 20mm Fixed	
AOS-9	AOS TRI-VIT	500	Kowa 12mm Fixed	
GP-3	GoPro Hero 3+	120		
GP-4	GoPro Hero 3+	120		
GP-5	GoPro Hero 3+	120		
GP-6	GoPro Hero 3+ (Did not fire)	120		
GP-7	GoPro Hero 4	120		
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	240		
GP-10	GoPro Hero 4	240		
JVC-1	JVC – GZ-MC500 (Everio)	29.97		
JVC-2	JVC – GZ-MG27u (Everio)	29.97		
JVC-3	JVC – GZ-MG27u (Everio)	29.97		
JVC-4	JVC – GZ-MG27u (Everio)	29.97		

Figure 37. Camera Locations, Speeds, and Lens Settings, Test No. MWP-8

5 FULL-SCALE CRASH TEST NO. MWP-8

5.1 Static Soil Test

Before full-scale crash test no. MWP-8 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH. The static test results, as shown in Appendix C, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and full-scale crash testing could be conducted on the barrier system.

5.2 Weather Conditions

Test no. MWP-8 was conducted on October 19, 2015 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 3.

Table 3. Weather Conditions, Test No. MWP-8

Temperature	81° F
Humidity	29%
Wind Speed	20 mph
Wind Direction	210° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.00 in.

5.3 Test Description

The 2,583-lb (1,172-kg) car impacted the cable barrier system at a speed of 63.0 mph (101.4 km/h) and at an angle of 25.7 degrees. A summary of the test results and sequential photographs are shown in Figure 38. Additional sequential photographs are shown in Figures 39 through 41. Documentary photographs of the crash test are shown in Figure 42.

Initial vehicle impact was to occur at a midspan location, or 4 ft (1.2 m) upstream of post no. 31, as shown in Figure 43, which was selected using Table 2-2D of MASH. The actual point of impact was 3 ft – 4½ in. (1.0 m) upstream of post no. 31. A sequential description of the impact events is contained in Table 4. The vehicle came to rest approximately 154 ft (46.9 m) downstream from the point of impact, or between post nos. 52 and 53 and in contact with the cables. The right side of the vehicle was held in the air by cable nos. 2 and 3, which were underneath the vehicle. Cable nos. 1 and 4 were located on the non-impact side of the vehicle. The vehicle trajectory and final position are shown in Figures 38 and 44.

After the initial impact occurred, cable no. 2 captured the vehicle until it reached a maximum dynamic deflection of 93.3 in. (2,370 mm) and began to redirect the vehicle. During initial redirection, the vehicle became parallel with the system at 0.398 seconds after initial impact at a speed of 52.9 mph (85.1 km/h). As the vehicle was being redirected, cable no. 4

passed over the top of the vehicle and as the vehicle was exiting the system, cable no. 4 impacted the right side of the vehicle and caused it to be redirected back toward the barrier system. The vehicle then impacted the system at post no. 45 and overrode post nos. 45 through 53. The vehicle did not exit the system and rested on top of post nos. 52 and 53 at the conclusion of the test.

Table 4. Sequential Description of Impact Events, Test No. MWP-8

TIME (sec)	EVENT
0.000	Left-front bumper contacted cable no. 1.
0.002	Left-front bumper contacted cable no. 2.
0.008	Left-front bumper contacted cable no. 3.
0.010	Post no. 31 bent backward, vehicle’s front bumper deformed.
0.022	Post no. 30 bent backward, cable no. 3 detached from post no. 31.
0.026	Vehicle contacted post no. 31.
0.028	Cable no. 2 detached from post no. 31.
0.030	Cable no. 3 detached from post no. 30.
0.036	Cable nos. 1 and 4 detached from post no. 31, post no. 32 deflected backward.
0.044	Post no. 29 deflected downstream.
0.046	Cable no. 3 contacted vehicle’s left-side A-pillar, post no. 32 deflected downstream.
0.048	Cable no. 2 detached from post no. 32.
0.050	Cable no. 3 detached from post no. 32.
0.056	Vehicle overrode post no. 31.
0.060	Post no. 33 deflected backward.
0.066	Cable nos. 3 and 4 contacted vehicle’s left-side A-pillar, and post no. 29 deflected backward.
0.070	Cable no. 3 detached from post no. 33, vehicle’s hood deformed.
0.074	Left-side mirror detached from vehicle.
0.076	Vehicle’s left-front tire overrode cable no. 1.
0.082	Cable no. 4 detached from post no. 32, post no. 34 deflected backward.
0.090	Cable no. 3 detached from post no. 34.
0.096	Post no. 33 bent downstream.
0.098	Post no. 35 deflected backward, vehicle rolled away from barrier.
0.102	Cable no. 4 detached from post no. 32.
0.108	Cable no. 3 detached from post no. 35.
0.110	Vehicle contacted post no. 32.
0.120	Post no. 35 deflected forward, post no. 36 deflect backward.

0.126	Cable nos. 2 and 4 detached from post no. 33.
0.130	Vehicle overrode post no. 32. Cable no. 3 detached from post no. 36.
0.138	Post no. 34 bent downstream, post no. 37 deflected backward.
0.150	Cable no. 3 detached from post no. 37, cable no. 4 detached from post no. 34.
0.154	Cable no. 4 detached from post no. 30, post no. 38 deflected backward.
0.158	Post no. 35 deflected backward.
0.164	Cable no. 3 detached from post no. 38.
0.172	Post no. 39 deflected backward, cable no. 4 detached from post nos. 29 and 35.
0.176	Vehicle’s left-front fender detached from vehicle.
0.182	Cable no. 3 detached from post no. 39.
0.196	Vehicle underrode cable nos. 3 and 4.
0.200	Cable no. 2 detached from post no. 34.
0.204	Post no. 35 bent backward.
0.208	Cable no. 4 detached from post no. 36.
0.212	Vehicle roof deformed due to contact with cable no. 4.
0.220	Cable no. 4 detached from post no. 37.
0.228	Vehicle’s right-front fender contacted post no. 33.
0.256	Cable no. 2 detached from post no. 35.
0.295	Cable no. 2 detached from post no. 36.
0.326	Post no. 37 bent backward.
0.352	Cable no. 2 detached from post no. 37.
0.376	Cable no. 2 detached from post no. 30.
0.384	Post no. 29 bent backward.
0.388	Vehicle was parallel to barrier at a speed of 52.9 mph.
0.500	Cable no. 2 detached from post no. 29.
0.682	Vehicle’s right-rear quarter panel contacted post no. 36.
0.716	Vehicle overrode post no. 37.
1.018	Vehicle’s front bumper detached from vehicle.
1.320	Vehicle’s right mirror detached from vehicle.
1.914	Vehicle’s left headlight detached from vehicle.
3.159	Vehicle floorpan impacted post no. 50.
3.573	Vehicle floorpan impacted post no. 51.
4.000	Vehicle floorpan impacted post no. 52.
5.344	Vehicle came to rest in system.

5.4 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 45 through 73. Barrier damage consisted of bent posts, disengaged cables, and deformed brackets. At its final resting position, the vehicle was still in contact with the cables. Cable nos. 2 and 3 were underneath the vehicle while cable nos. 1 and 4 were on the non-impact side of the vehicle. The length of vehicle contact along the barrier was approximately 181 ft (55.2 m), which spanned from 3 ft – 4½ in. (1 m) upstream of post no. 31 to post no 53. Table 5 summarizes the release mechanisms of each cable from the posts.

Post nos. 29 through 53 had varying degrees of plastic deformation in the form of bending and twisting. Typically, the posts were bent laterally backward and longitudinally downstream. In addition to this, post nos. 31, 32, 36 through 40, and 45 through 53 encountered contact marks and grinding marks on the edges due to vehicle override. These same posts experienced the greatest deflections, except for post nos. 52 and 53, which remained in contact with the vehicle at its final position.

The working width of the system was found to be 94.7 in. (2,405 mm), as determined from high-speed digital video analysis. The maximum lateral dynamic barrier deflection was 93.3 in (2,370 mm) as determined from high-speed digital video analysis. The permanent set of the barrier was measured to be 39¾ in. (1,010 mm) as measured in the field. The upstream anchor had a maximum dynamic displacement of 0.16 in. (4 mm) downstream, as determined from the string potentiometer.

Table 5. Disengaged Cables and Release Mechanisms, Test No. MWP-8

Post No.	**Cable No.**			
	1	**2**	**3**	**4**
5	-	-	-	5
11	-	-	-	5
23	-	-	1	-
24	-	-	1	-
25	-	-	1	-
26	-	-	1	5
27	-	-	1	5
28	-	-	1	6
29	-	1	1	6
30	-	1	1	6
31	1	1	1	6
32	1	1	1	6
33	-	1	1	6
34	-	1	1	6
35	-	1	1	6
36	-	1	1	6
37	1	1	1	6
38	2	3	1	6
39	-	3	1	6
40	-	1	1	6
41	-	1	1	6
42	-	1	1	6
43	-	-	1	6
44	1	-	1	6
45	1	1	1	6
46	1	1	2	6
47	1	1	4	6
48	-	1	4	6
49	-	1	4	6
50	-	1	2	6
51	-	1	-	6
52	-	1	-	6
53	-	1	-	6
54	-	1	-	6
55	-	1	-	5
56	-	1	-	-
57	-	1	-	-

1-Bracket released entirely
2-Bracket fractured at neck
3-Bracket fractured at tab
4-Bracket fractured through bolt hole
5-Brass rod bent in place
6-Brass rod disengaged completely

5.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 74 through 76. The maximum occupant compartment deformations are listed in Table 6 along with the deformation limits established in MASH for various areas of the occupant compartment. Note that none of the MASH established deformation limits were violated. Complete occupant compartment and vehicle deformations as well as the corresponding locations are provided in Appendix D.

The majority of the vehicle damage was concentrated on the left-front corner, where primary impact occurred, and on the right-front corner, where it redirected back into the system. The cables caused striation marks, scrapes, and denting along the left- and right-front fenders and up the entire length of the A-pillar on both sides of the vehicle. Striation marks were also found on the roof, which were caused by the vehicle underriding cable nos. 3 and 4. The largest dent, which was 7 in. (178 mm) long and 4 in. (102 mm) wide, occurred at the rear of the left-front wheel well, and was caused by cable no. 2. The entire front bumper and fascia, left-side headlight, both side mirrors, and windshield fluid reservoir disengaged from the vehicle. The right-side headlight and right-side window were shattered. The left-front rim had gouges, and the tire was deflated. The right-rear rim was also gouged and the left-rear tire was scraped.

Two tears were found in the floorpan of the vehicle. One was a 3-in. (76-mm) long tear in the right-front floorpan and the other was a 7-in. (178-mm) long tear underneath the right-front seat, as shown in Figures 76 and 77. Although the occupant compartment deformations are within the bounds set by MASH, the occupant compartment penetration was unacceptable. The floorpan tearing was caused by the free edge of a post as the vehicle overrode the post.

Table 6. Maximum Occupant Compartment Deformations by Location

LOCATION	MAXIMUM DEFORMATION in. (mm)	MASH ALLOWABLE DEFORMATION in. (mm)
Wheel Well & Toe Pan	¼ (6)	≤ 9 (229)
Floorpan & Transmission Tunnel	½ (13)	≤ 12 (305)
Side Front Panel (in Front of A-Pillar)	0 (0)	≤ 12 (305)
Side Door (Above Seat)	¼ (6)	≤ 9 (229)
Side Door (Below Seat)	0 (0)	≤ 12 (305)
Roof	¼ (6)	≤ 4 (102)
Windshield	¼ (6)	≤ 3 (76)

5.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 7. Note that the OIVs and ORAs were within the suggested limits provided in MASH. As the vehicle was initially redirected by the barrier system, but then was redirected back into the system due to the contact with cable no. 4 after it had passed over the vehicle, two values for the ORAs for each accelerometer are reported in Table 7. The calculated THIV, PHD, and ASI values are also shown in Table 7. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 38. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix E.

Table 7. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. MWP-8

Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (Primary)	SLICE-2	
OIV ft/s (m/s)	Longitudinal	-13.35 (-4.07)	-14.44 (-4.40)	±40 (12.2)
	Lateral	11.91 (3.63)	11.52 (3.51)	±40 (12.2)
ORA g's	Longitudinal	-6.54	-5.63	±20.49
	Lateral (See Note 1)	5.47/-5.64	5.94/-5.46	±20.49
MAX ANGULAR DISPLACEMENT deg.	Roll	-55.13	-51.48	±75
	Pitch	-12.21	-11.54	±75
	Yaw	38.62	35.61	not required
THIV ft/s (m/s)		18.04 (5.50)	18.60 (5.67)	not required
PHD g's		6.54	6.53	not required
ASI		0.44	0.43	not required

1- Positive value corresponds to initial redirection and negative value corresponds to the second redirection of vehicle back into system

5.7 Load Cells and String Potentiometer

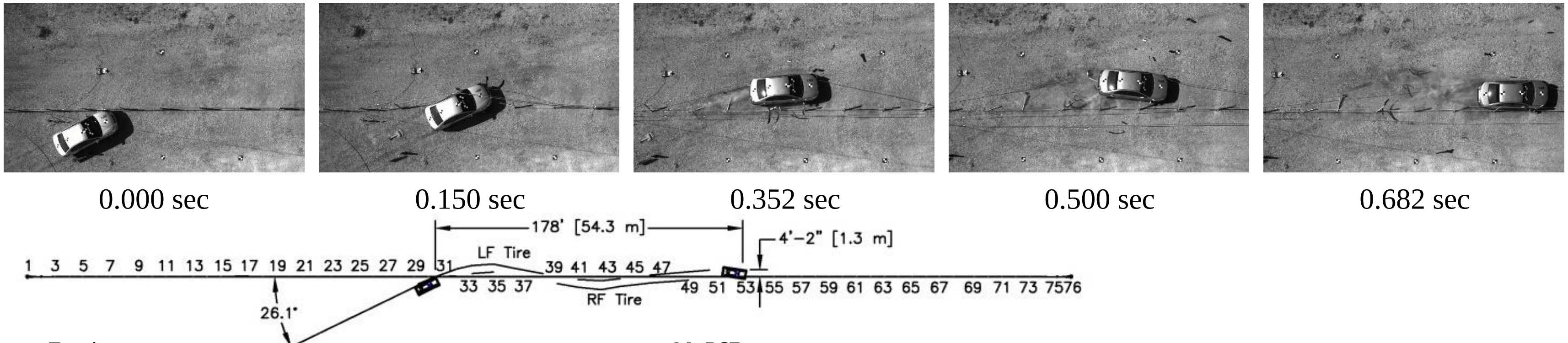
The pertinent data from the load cells and string potentiometer was extracted from the bulk signal and analyzed using the transducers' calibration factors. The maximum displacement of the upstream anchor was recorded as 0.16 in. (4 mm). A summary of the maximum cable loads can be found Table 8. The recorded data and analyzed results are 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 in the electronic data. Thus, the extracted data curves should not be taken as a precise time after impact, but rather a general timeline between events within the data curve itself.

Table 8. Maximum Cable Loads, Test No. MWP-8

Cable Location	Sensor Location	Maximum Cable Load kips (kN)	Time (sec)
Combined Cable Load	Upstream of Impact	33.28 (148.04)	0.1909
Cable No. 4	Upstream of Impact	11.79 (52.44)	1.3203
Cable No. 3	Upstream of Impact	9.43 (41.95)	2.3909
Cable No. 2	Upstream of Impact	16.53 (73.53)	0.2734
Cable No. 1	Upstream of Impact	9.86 (43.86)	0.1096

5.8 Discussion

The analysis of the test results for test no. MWP-8 showed that the high-tension, four-cable median barrier adequately contained and redirected the 1100C vehicle with controlled lateral displacements of the barrier. The test vehicle did not penetrate or 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 safety criteria nor cause rollover. After impact, the vehicle was captured and retained within the system, so there was no exit information. As the vehicle overrode the system posts, the posts tore the floorpan in two locations. The tears indicated that the free end of a post penetrated into the occupant compartment. Additional analysis and discussion of the floorpan tearing will be provided in the following chapter. Therefore, test no. MWP-8, conducted on the four-cable median barrier, was determined to be unacceptable according to the MASH safety performance criteria for test designation no. 3-10.



- Test Agency .... MwRSF
- Test Number MWP-8
- Date 10/19/2015
- MASH Test Designation 3-10
- Test Article .... Four-Cable Median Barrier
- Total Length .... 604 ft (184.1 m)
- Key Component – Cable
  - Size .... 3x7, ¾-in. (19-mm) diameter
  - Cable Heights .... 15½, 23, 30½, 38 in. (394, 584, 775, 965 mm)
- Key Component – MWP
  - Dimensions .... 3 x 1¾ x 81¼ in. (76 x 44 x 2,064 mm)
  - Spacing .... 12 ft (3.66 m)
- Soil Type .... Compacted, coarse, crushed limestone
- Vehicle Make /Model .... 2008 Kia Rio
  - Curb .... 2,398 lb (1,088 kg)
  - Test Inertial .... 2,419 lb (1,097 kg)
  - Gross Static .... 2,583 lb (1,172 kg)
- Impact Conditions
  - Speed .... 63.0 mph (101.4 km/h)
  - Angle .... 25.7 deg
  - Impact Location .... 3 ft – 4½ in. (1.0 m) upstream of Post No. 31
- Impact Severity (IS) .... 64.5 kip-ft (87.4 kJ) > 51 kip-ft (69.1 kJ)
- Exit Conditions
  - Speed .... NA
  - Angle .... NA
- Exit Box Criterion .... NA (Did not exit system)
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 178 ft (54.3 m)
- Vehicle Damage .... Moderate
  - VDS [8] 11-LFQ-5
  - CDC [9] 11-LYAK-9
  - Maximum Interior Deformation .... 1/2 in. (13 mm)
- Test Article Damage .... Moderate
- Maximum Test Article Deflections
  - Permanent Set .... 39¾ in. (1,010 mm)
  - Dynamic .... 93.3 in. (2,370 mm)
  - Working Width .... 94.7 in. (2,405 mm)
- Transducer Data

Evaluation Criteria		Transducer		MASH Limit
		SLICE-1 (primary)	SLICE-2	
OIV ft/s (m/s)	Longitudinal	-13.35 (-4.07)	-14.44 (-4.40)	±40 (12.2)
	Lateral	11.91 (3.63)	11.52 (3.51)	±40 (12.2)
ORA g's	Longitudinal	-6.54	-5.63	±20.49
	Lateral	5.47/-5.64	5.94/-5.46	±20.49
MAX ANGULAR DISPLACEMENT deg.	Roll	-55.13	-51.48	±75
	Pitch	-12.21	-11.54	±75
	Yaw	38.62	35.61	not required
THIV – ft/s (m/s)		18.04 (5.50)	18.60 (5.67)	not required
PHD – g's		6.54	6.53	not required
ASI		0.44	0.43	not required

Figure 38. Summary of Test Results and Sequential Photographs, Test No. MWP-8

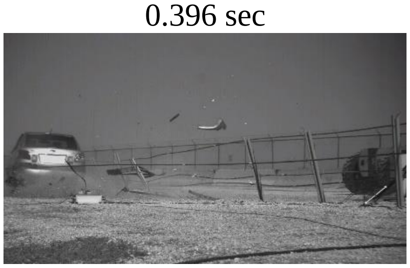

0.000 sec


0.074 sec


0.182 sec


0.296 sec

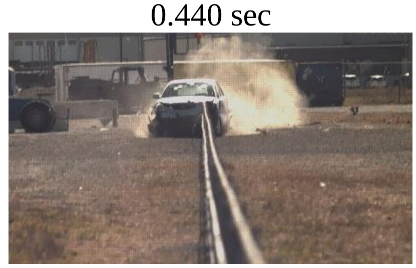

0.396 sec


0.596 sec


0.000 sec


0.160 sec

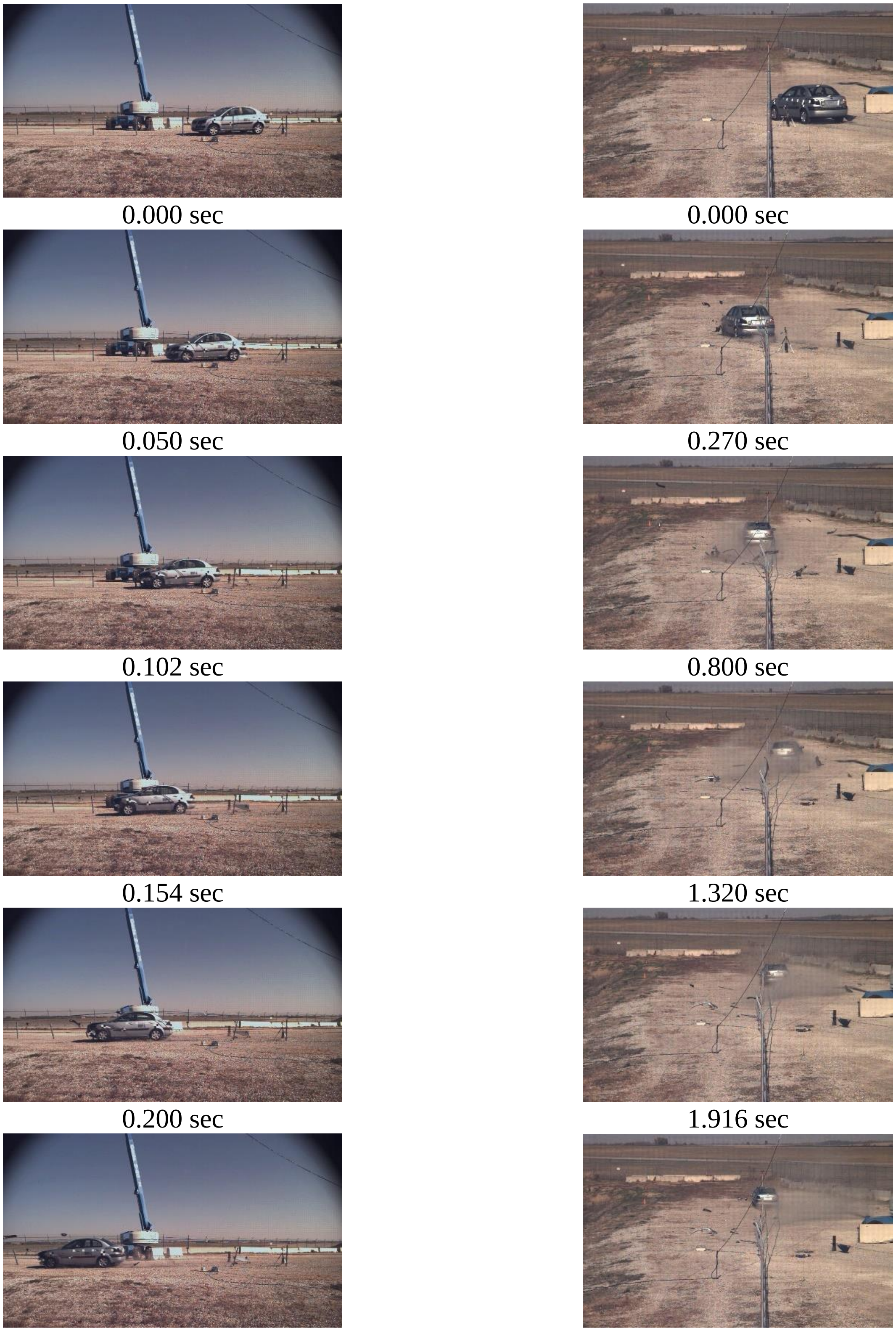

0.440 sec


1.018 sec


1.320 sec


2.560 sec

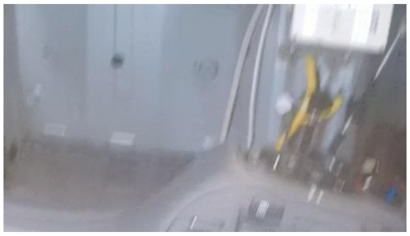
Figure 39. Additional Sequential Photographs, Test No. MWP-8



0.000 sec | 0.000 sec
0.050 sec | 0.270 sec
0.102 sec | 0.800 sec
0.154 sec | 1.320 sec
0.200 sec | 1.916 sec
0.300 sec | 2.478 sec

Figure 40. Additional Sequential Photographs, Test No. MWP-8

0.000 sec



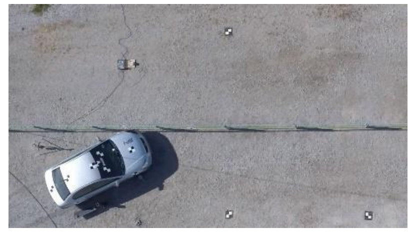
0.788 sec

1.838 sec

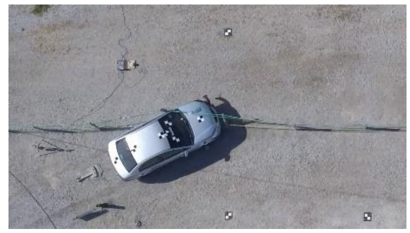
3.179 sec

3.583 sec

4.117 sec



0.000 sec

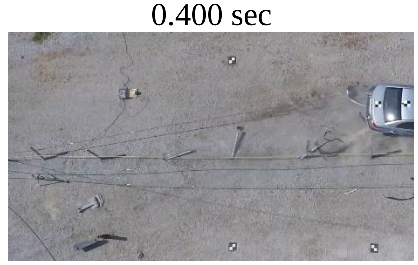


0.100 sec

0.200 sec

0.300 sec

0.400 sec



0.500 sec

Figure 41. Additional Sequential Photographs, Test No. MWP-8

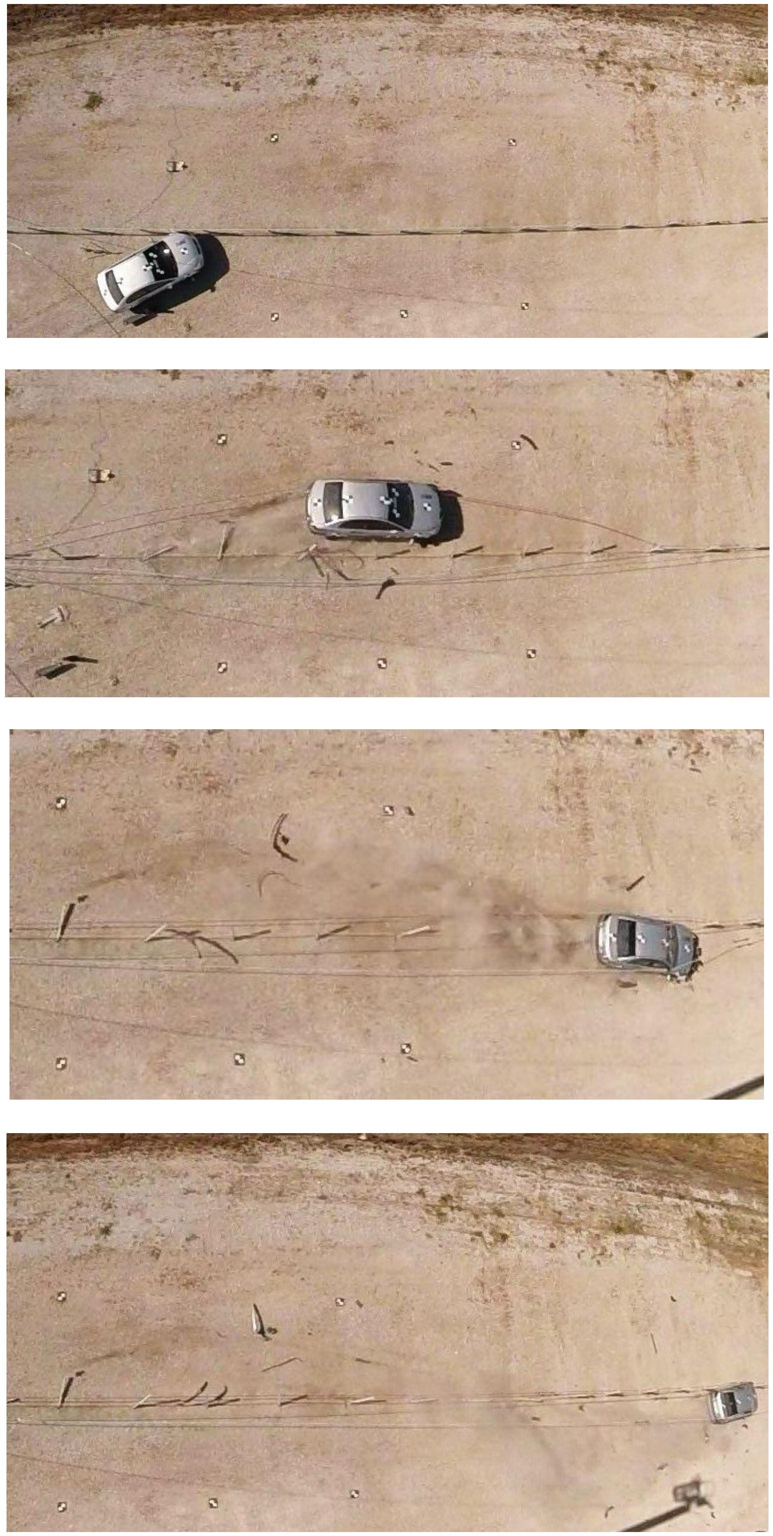


Figure 42. Documentary Photographs, Test No. MWP-8

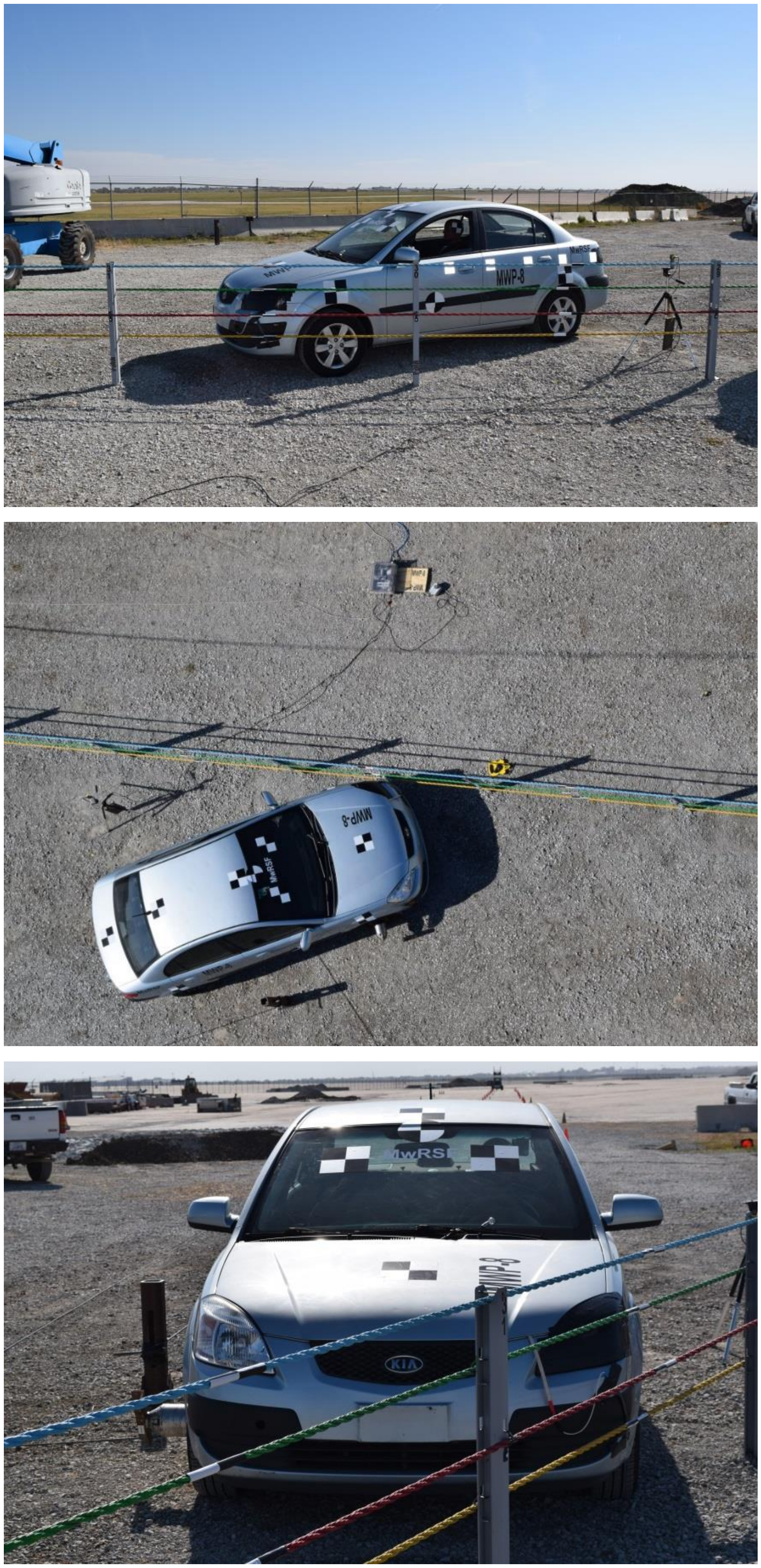
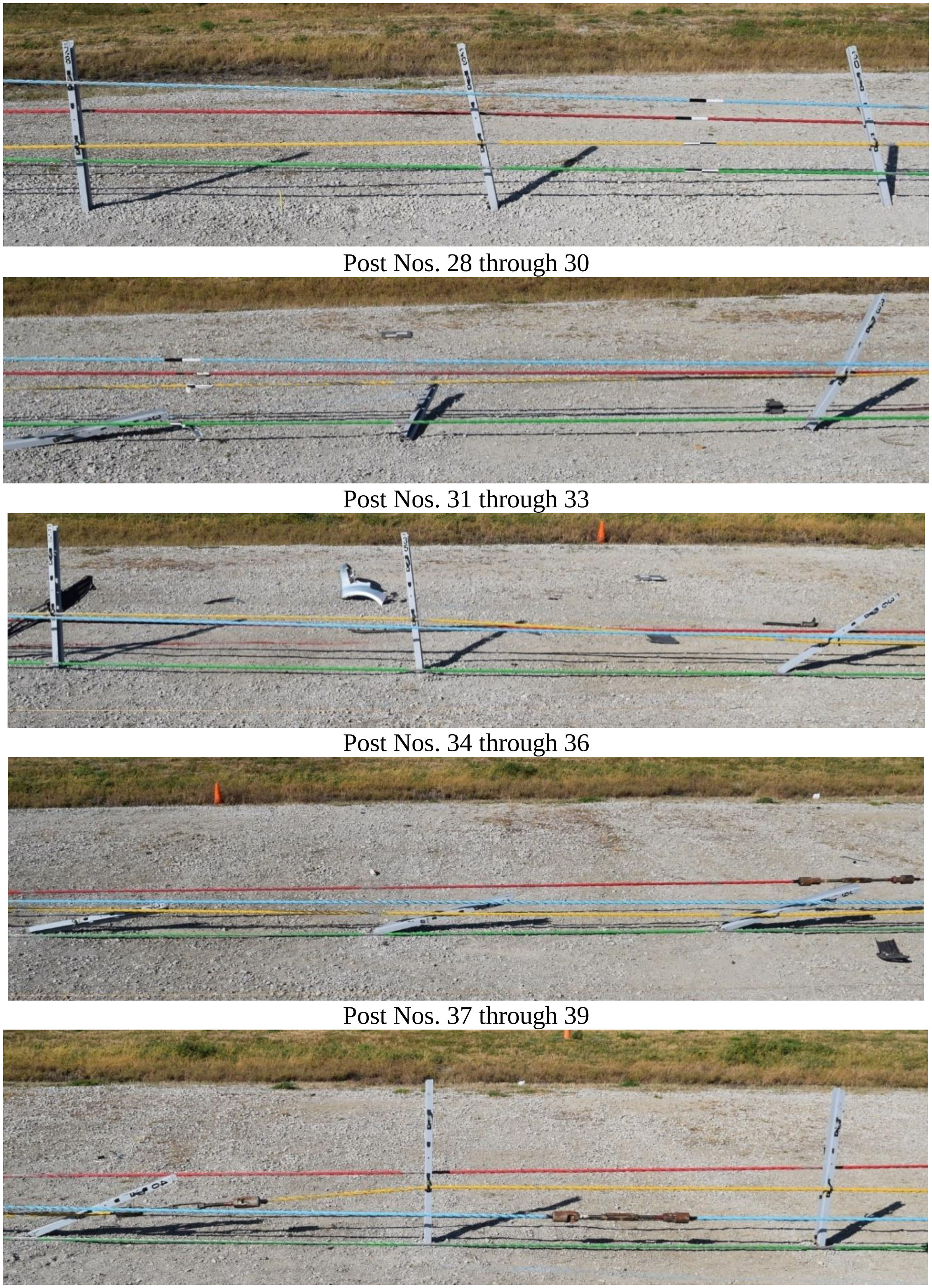


Figure 43. Impact Location, Test No. MWP-8

Figure 44. Vehicle Final Position and Trajectory Marks, Test No. MWP-8

Figure 45. System Damage, Test No. MWP-8



Post Nos. 28 through 30

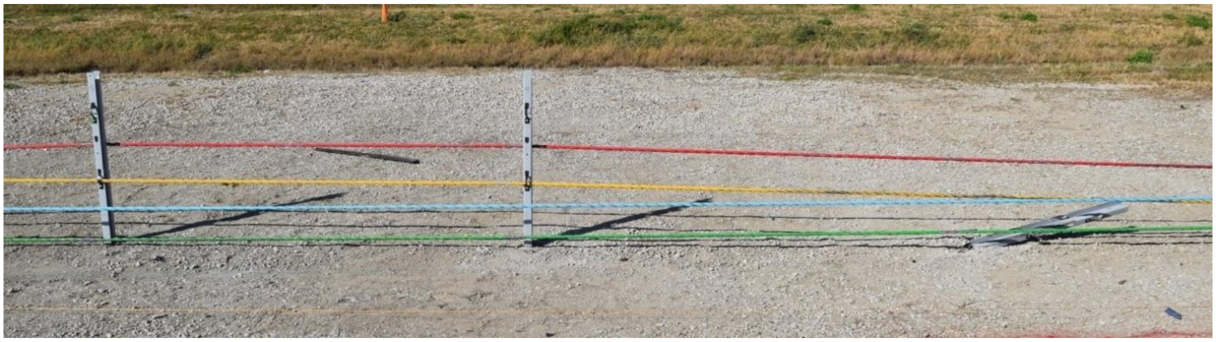
Post Nos. 31 through 33

Post Nos. 34 through 36

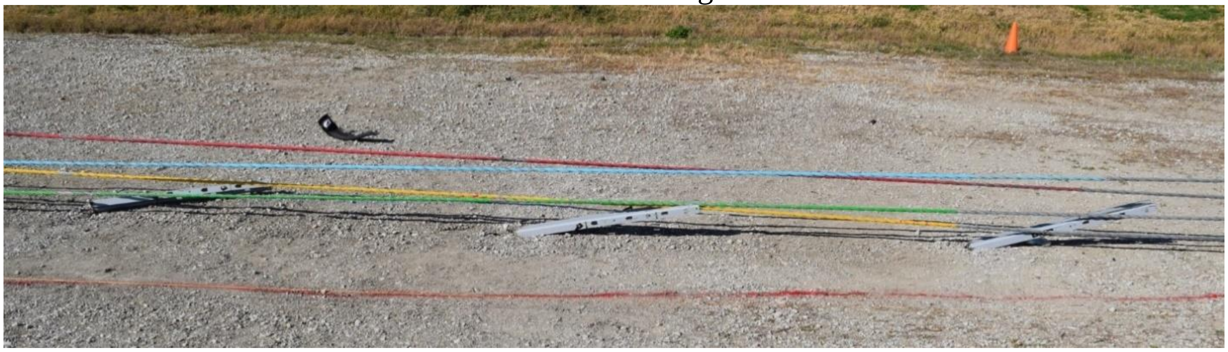
Post Nos. 37 through 39

Post Nos. 40 through 42

Figure 46. Post Damage, Test No. MWP-8



Post Nos. 43 through 45



Post Nos. 46 through 48

Post Nos. 49 through 51

Post Nos. 51 through 53

Figure 47. Post Damage Continued, Test No. MWP-8

Figure 48. Post No. 29 Damage, Test No. MWP-8

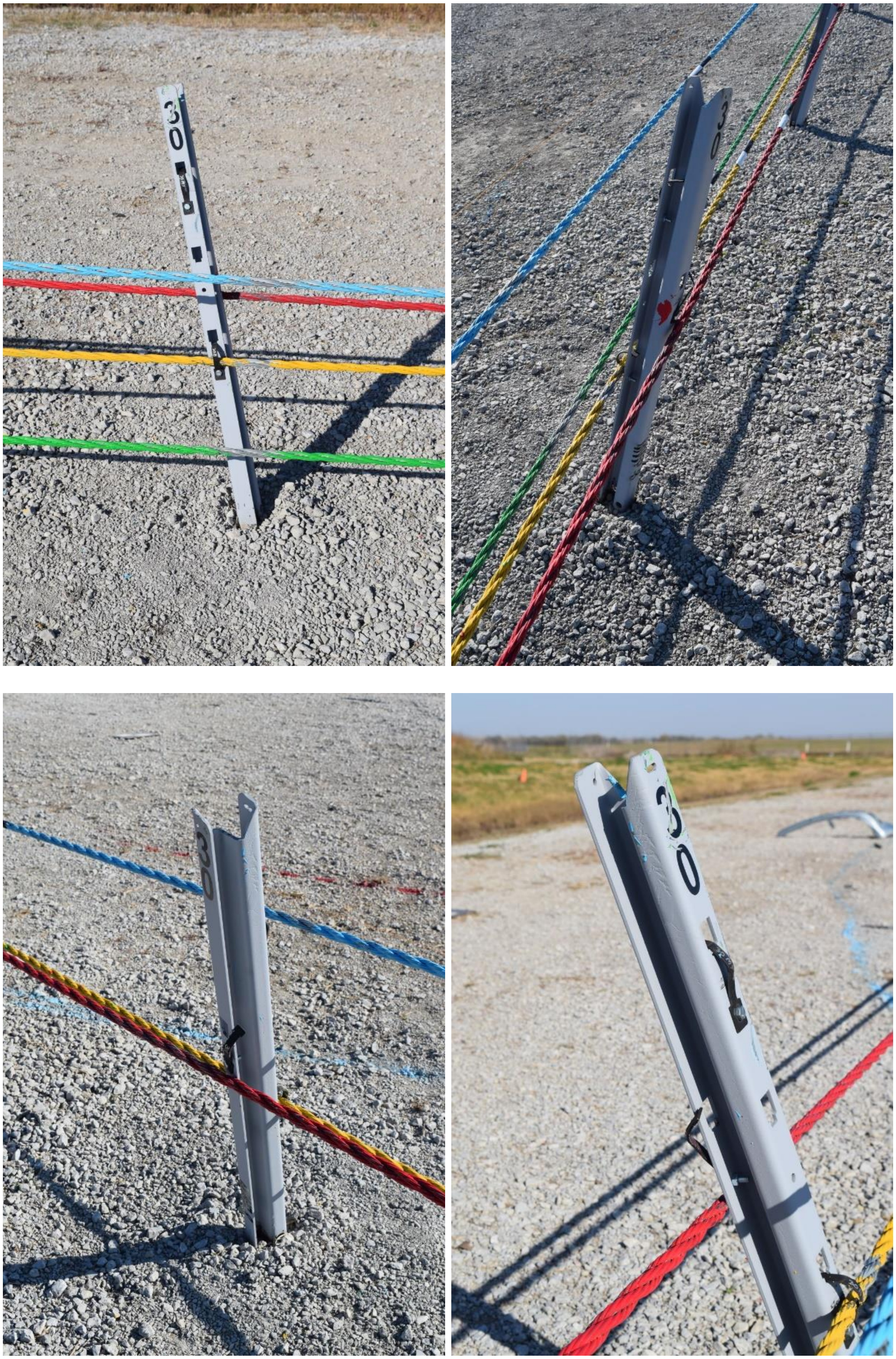


Figure 49. Post No. 30 Damage, Test No. MWP-8

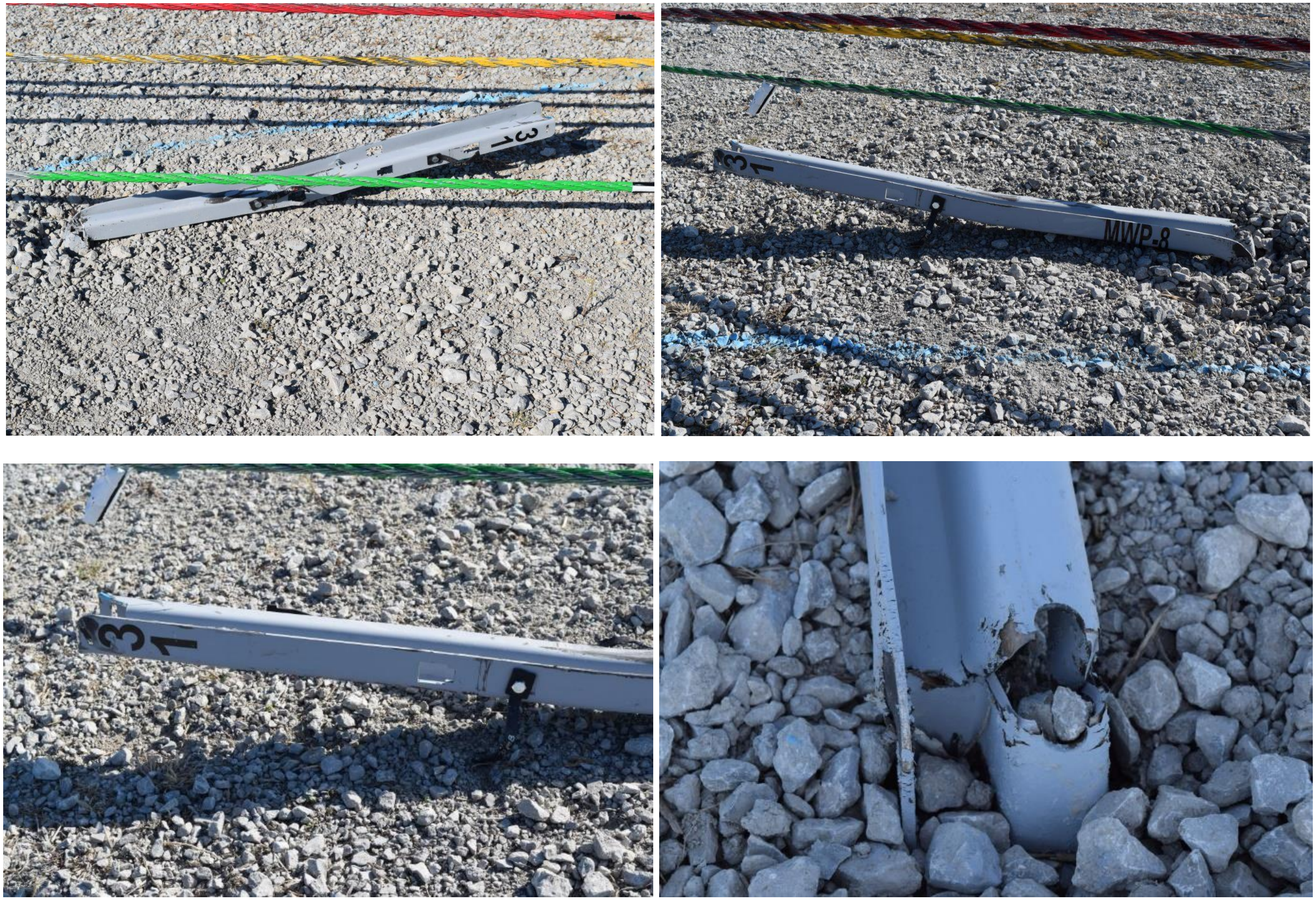


Figure 50. Post No. 31 Damage, Test No. MWP-8

Figure 51. Post No. 32 Damage, Test No. MWP-8

Figure 52. Post No. 33 Damage, Test No. MWP-8

Figure 53. Post No. 34 Damage, Test No. MWP-8

Figure 54. Post No. 35 Damage, Test No. MWP-8

Figure 55. Post No. 36 Damage, Test No. MWP-8

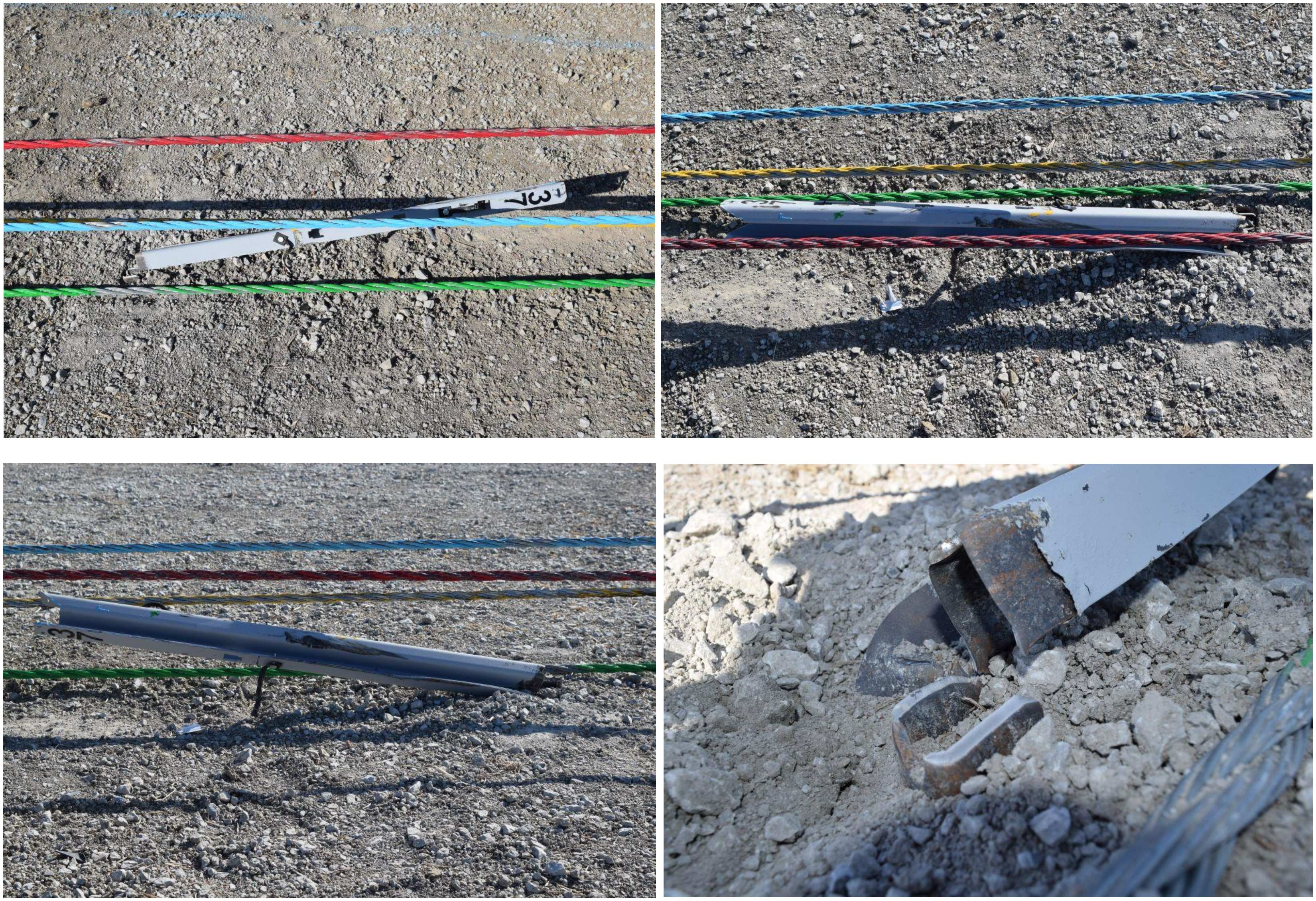


Figure 56. Post No. 37 Damage, Test No. MWP-8

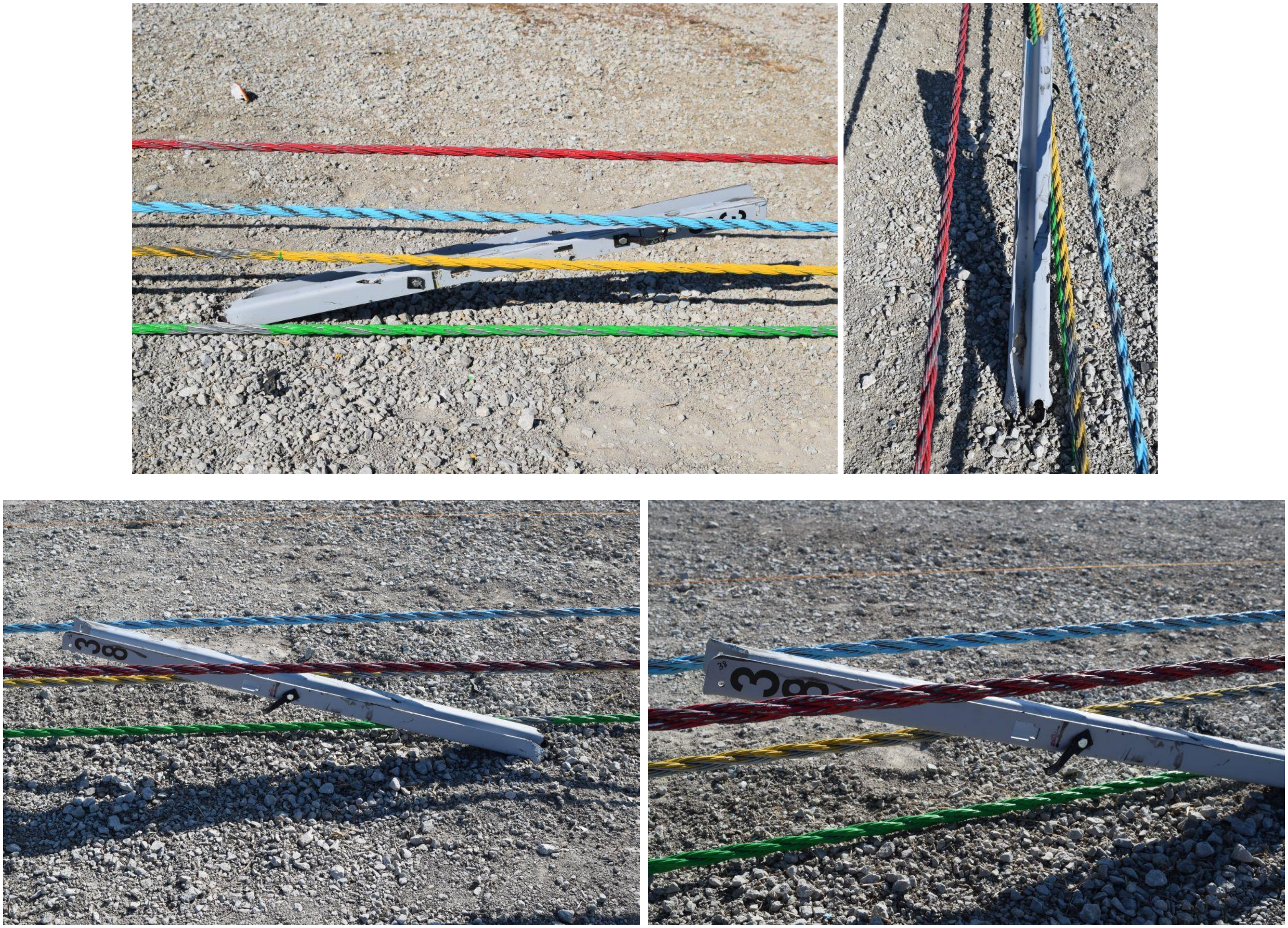


Figure 57. Post No. 38 Damage, Test No. MWP-8

Figure 58. Post No. 39 Damage, Test No. MWP-8

Figure 59. Post No. 40 Damage, Test No. MWP-8

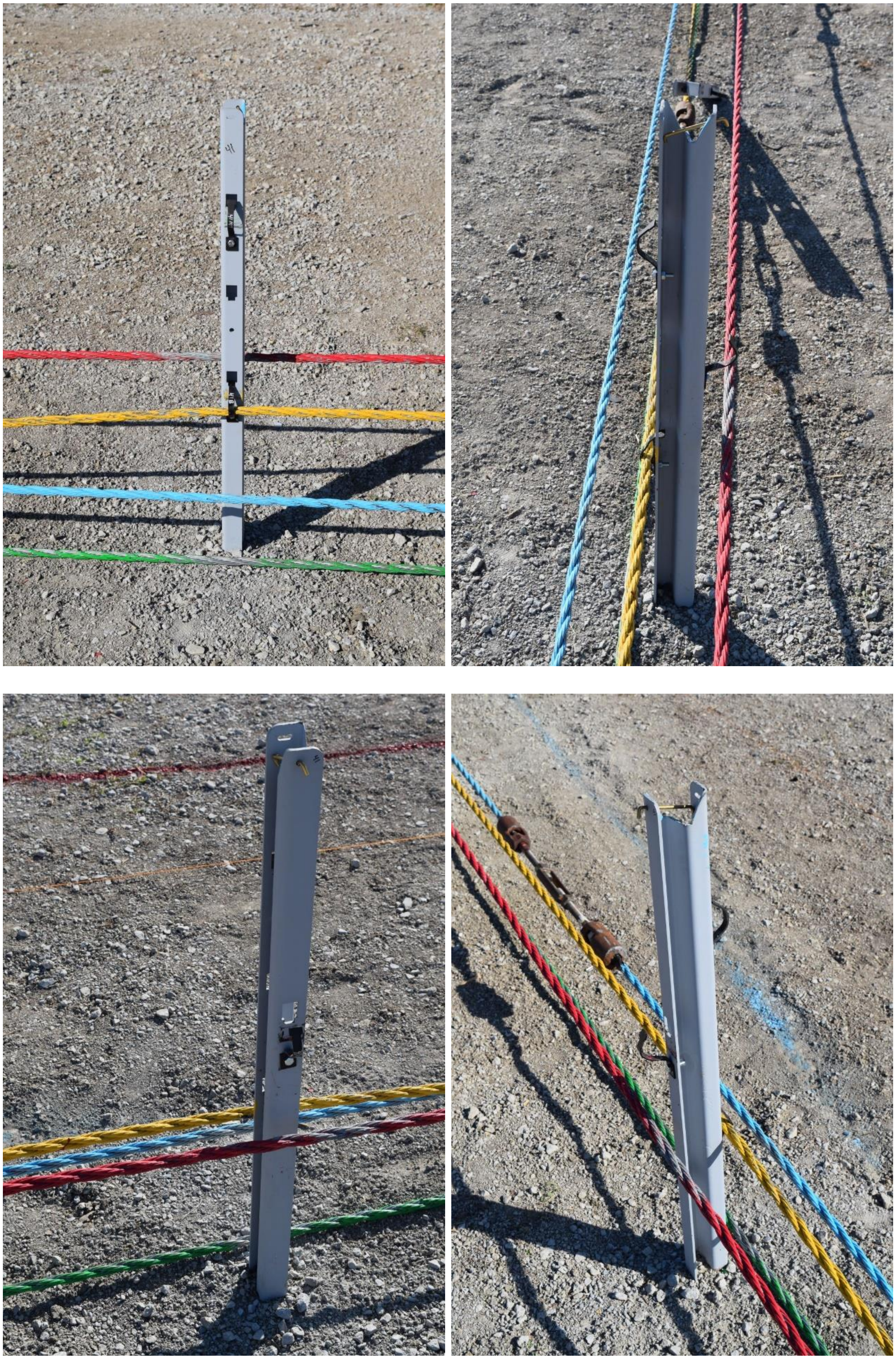


Figure 60. Post No. 41 Damage, Test No. MWP-8

Figure 61. Post No. 42 Damage, Test No. MWP-8

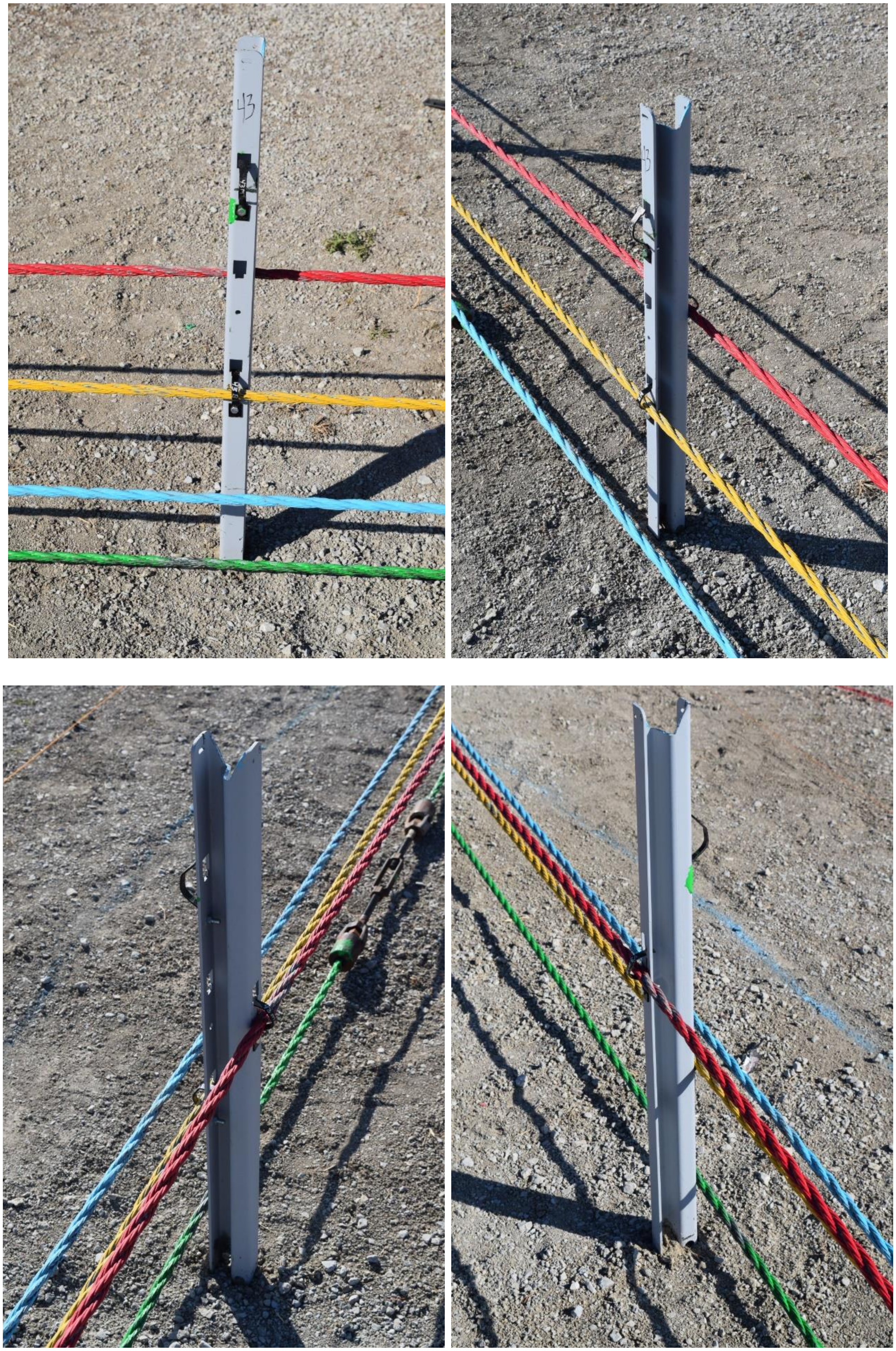


Figure 62. Post No. 43 Damage, Test No. MWP-8

Figure 63. Post No. 44 Damage, Test No. MWP-8

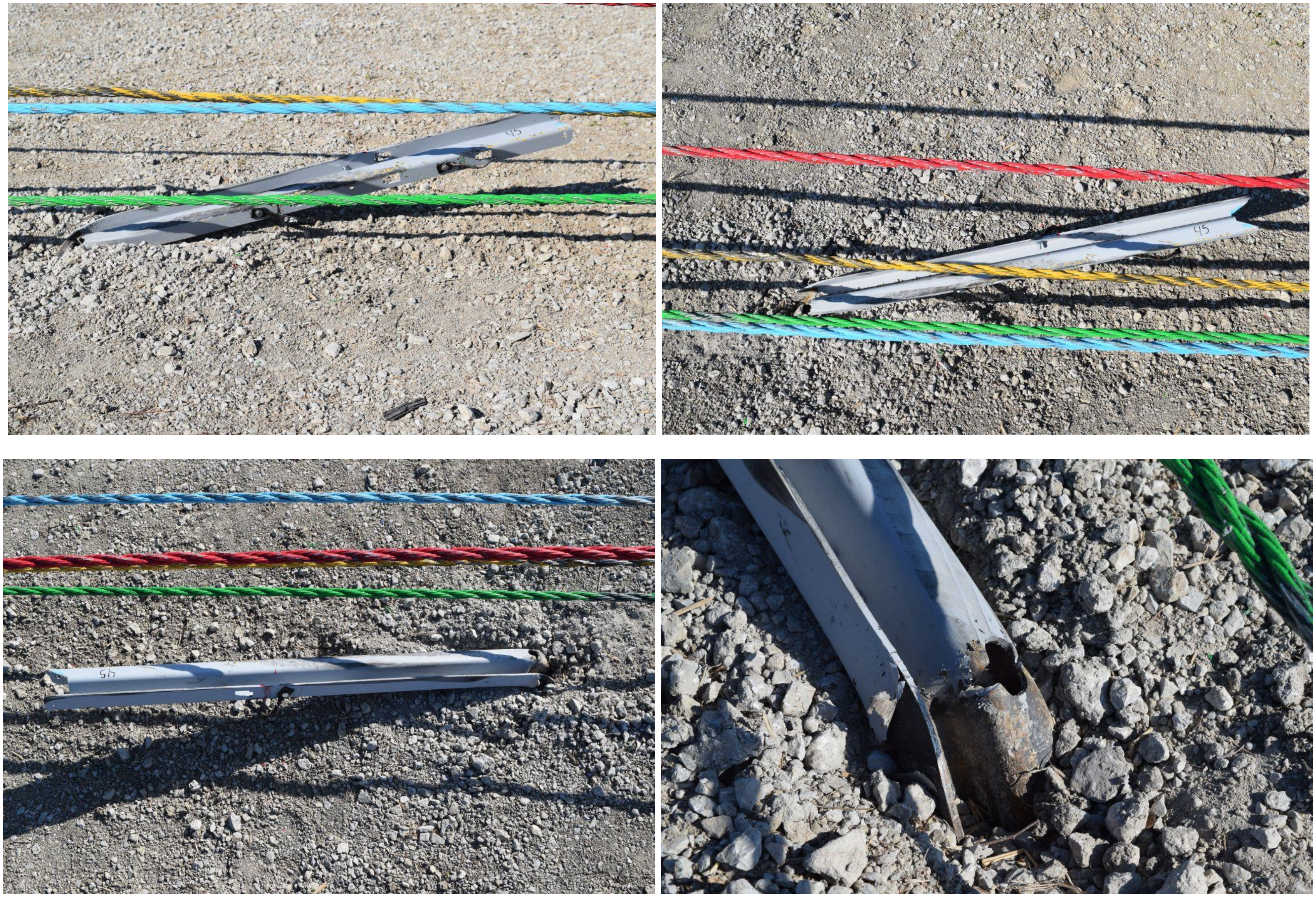


Figure 64. Post No. 45 Damage, Test No. MWP-8

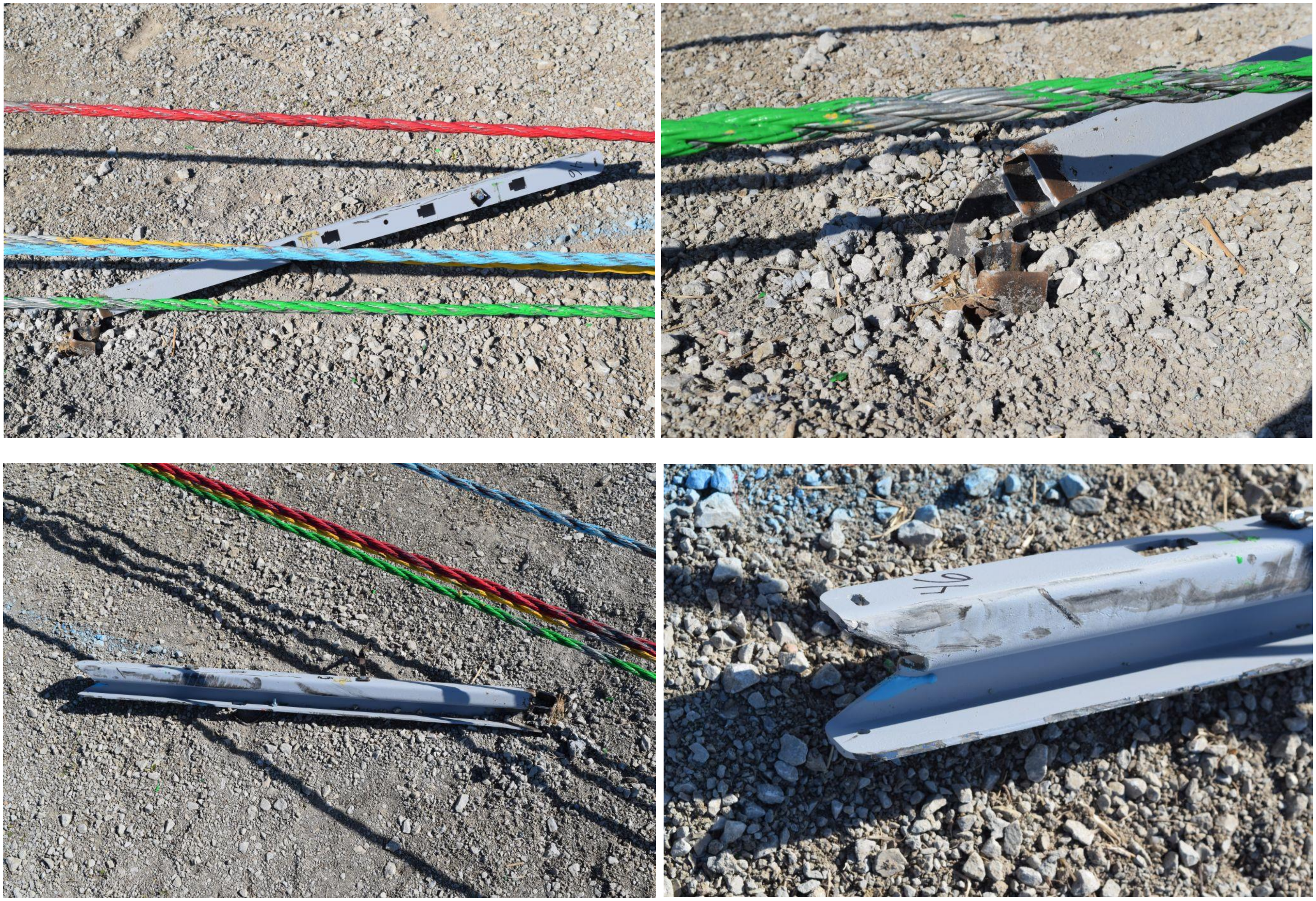


Figure 65. Post No. 46 Damage, Test No. MWP-8

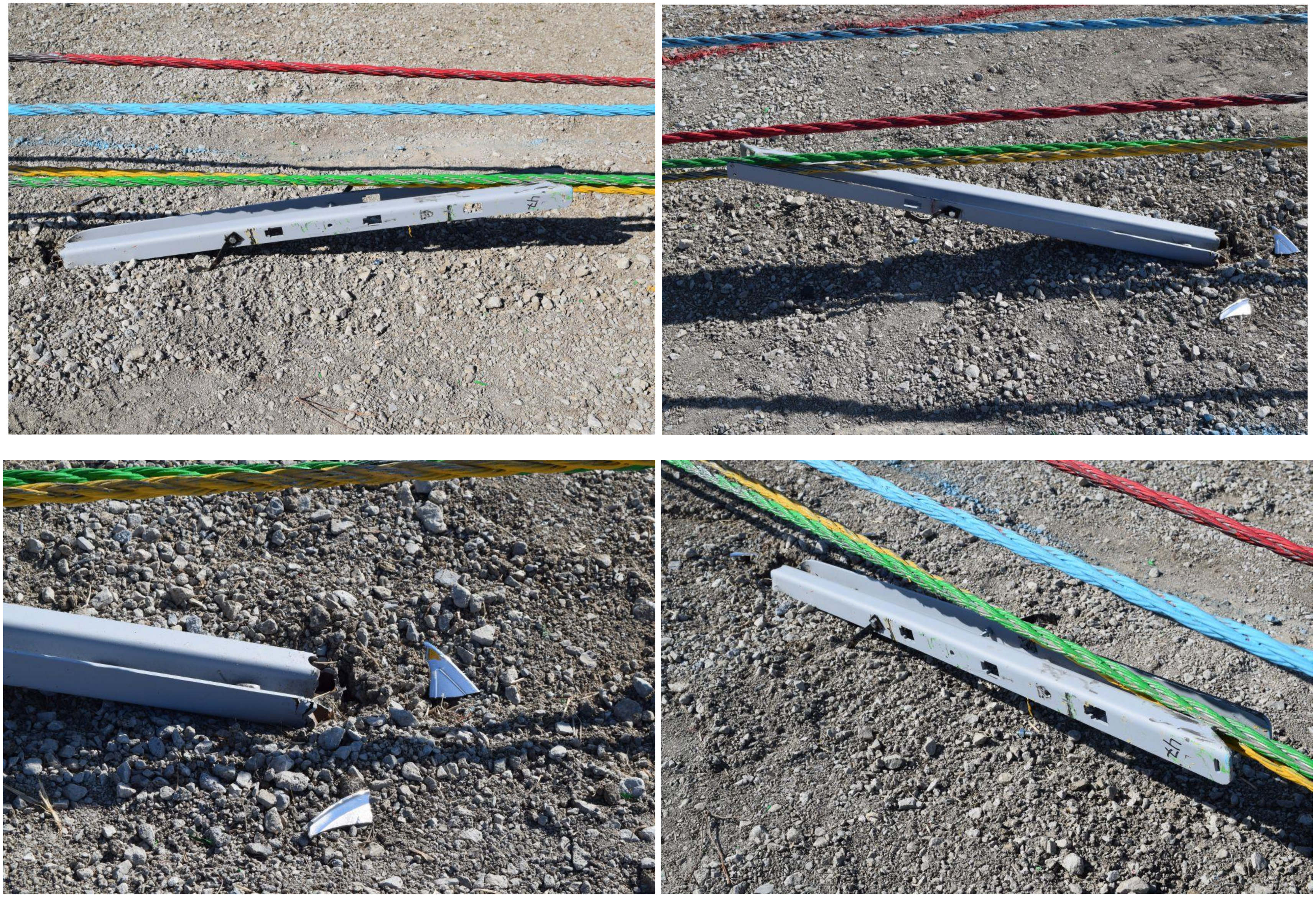


Figure 66. Post No. 47 Damage, Test No. MWP-8

Figure 67. Post No. 48 Damage, Test No. MWP-8

Figure 68. Post No. 49 Damage, Test No. MWP-8

Figure 69. Post No. 50 Damage, Test No. MWP-8

Figure 70. Post No. 51 Damage, Test No. MWP-8

Figure 71. Post No. 52 Damage, Test No. MWP-8

Figure 72. Post No. 53 Damage, Test No. MWP-8

Upstream Anchorage

Downstream Anchorage

Figure 73. Anchorage Damage, Test No. MWP-8

Figure 74. Vehicle Damage, Test No. MWP-8

Figure 75. Vehicle Damage, Test No. MWP-8

Figure 76. Floorpan Damage, Test No. MWP-8

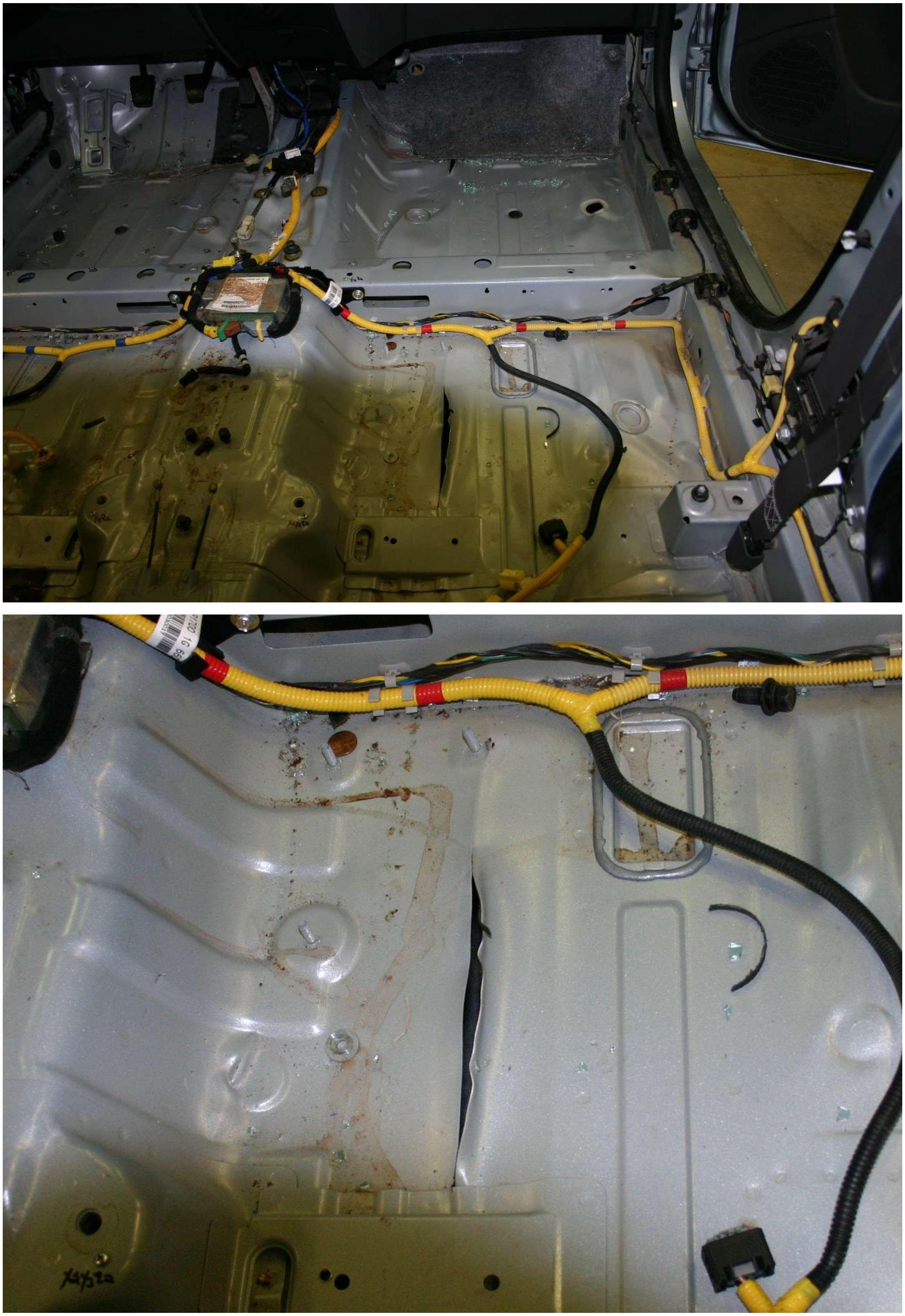


Figure 77. Floorpan Tearing, Test No. MWP-8

6 ANALYSIS OF FLOORPAN TEARING IN TEST NO. MWP-8

As mentioned previously, floorpan tearing occurred on the right side of the floorpan of the vehicle utilized in test no. MWP-8. Photographs of the floorpan damage can be seen in Figures 76 and 77. Although the occupant compartment deformations were within the bounds established in MASH, the occupant compartment penetration was unacceptable. Therefore, an investigation was conducted to determine which post(s) caused the penetration as well as the causes of the penetration.

To determine which post(s) caused the floorpan tearing, two analysis methods were used, the first of which relied on video analysis to determine the times at which the posts came into contact with the floorpan of the vehicle. By utilizing an onboard GoPro camera focused on the floorpan of the vehicle, it was observed that the floorpan tearing occurred near the end of the impact event, at approximately 3.2 seconds after impact. Additionally, floorpan deformations could be seen corresponding to individual posts contacting the undercarriage of the vehicle. These results were then compared to the other camera views of the test to determine which posts were impacted at those respective times. The times in which post impacted the floorpan are shown in Table 9. From this analysis, it was determined that post no. 50 caused the floorpan tearing, and contact with post nos. 51 and 52 resulted in significant floorpan deformations.

Table 9. Post and Floorpan Impact Events, Test No. MWP-8

Time (s)	Event
3.2	Impact with post #50, tearing occurred
3.6	Impact with post #51
4.0	Impact with post #52

In addition, contact marks and damage on post nos. 47 through 52 were reviewed. During this review, heavy damage was found on the upper free edge of post no. 50, as shown in Figure 78. This further reinforced the conclusions of the original investigation that the floorpan tears were caused by post no. 50.

A second analysis method was utilized to ensure the validity of the floorpan tearing findings. To accomplish this, the 10-ms average longitudinal deceleration data from the SLICE-1 and SLICE-2 accelerometers were analyzed to determine the times when acceleration spikes occurred, as these would indicate an impact with a post. These times were then compared with the events occurring in the high-speed test videos to determine the post impacts that corresponded with the acceleration changes. The results of this analysis are shown in Table 10. Note, limited camera views were available in which the vehicle could be observed so late in the impact event. Thus, only a few of the impacts to individual posts could be determined from video analysis.

Figure 78. Post No. 50 Damage, Test No. MWP-8

Table 10. Time of Impact with Post, Test No. MWP-8

Impacted Post No.	Impact Time from High-Speed Video	Impact Time from Accelerometer
Post no. 45	1.86	1.84
Post no. 46	2.00	1.98
Post no. 47	-	2.17
Post no. 48	2.42	2.41
Post no. 49	-	2.66
Post no. 50	-	2.93
Post no. 51	-	3.26
Post no. 52	-	3.59
Post no. 53	-	4.07

The results of both analysis methods correlated reasonably well with one another. As expected, the accelerometer data recorded post impacts prior to the video showing posts contacting the floorpan. The acceleration spikes were associated with the front of the vehicle impacting the posts, while the floorpan deformations and/or tearing occurred after the vehicle overrode the post.

Combining the video and accelerometer analyses allowed for the floorpan damage from each individual post to be identified. Deformations to the floorpan caused by post nos. 45 through 49 was minimal. However, significant localized deformations occurred as the vehicle overrode post nos. 50 through 52, and the top of post no. 50 tore the floorpan in two locations. The difference in the behavior of these two sets of posts as the vehicle overrode them can be explained by the extent in which the posts were bent over. Post nos. 45 through 49 were bent to a nearly 90 degree angle and resulted in the top of the post being close to the ground. Post nos. 50 through 52 were not bent as severely and the tops of these posts were higher above the ground, as shown in Figure 79.

Partial tearing was observed at groundline on each of the posts in this region of the barrier system. The weakening holes had performed correctly and initiated tearing in the upstream webs of each post. Thus, the resistance to bending deformations observed in post nos. 50 through 52 could not be explained by differing post strengths or inconsistent activation of the weakening mechanism in the posts.

The difference in behavior between these groups of posts was determined to be linked to the cable release, or lack thereof, of the cable-to-post attachment brackets on cable no. 3. The upper tabs of the brackets on post nos. 47 through 49 were pulled out of the keyways in the posts and allowed cable no. 3 to disengage from the post. However, the brackets attaching cable no. 3 to post nos. 50 through 52 did not release as intended. The brackets remained attached to the post and held cable no. 3 in place. Cable no. 3 then applied a vertical force to each of these three posts that prevented them from completely bending over and resulted in excessive contact between the top of the posts and the vehicle floorpan.

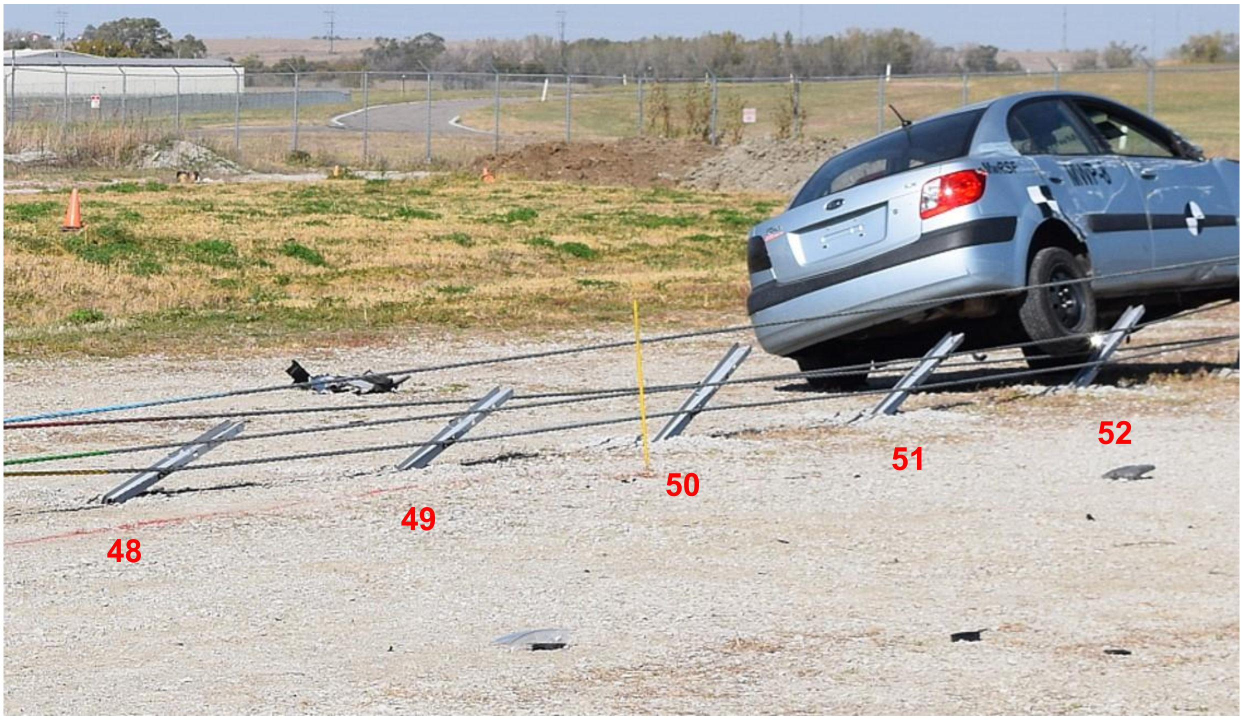


Figure 79. Post Deformation Difference – Post Nos. 48 Through 52, Test No. MWP-8

At the time of impact with post nos. 50 through 52, the vehicle was traveling very near to parallel with the system. Thus, the posts were pushed almost directly downstream as they were pushed and bent over. This motion cause the bracket to twist within the keyway as the cable resisted the displacement. The edges of the bracket tabs were then jammed against the side of the keyway and prevented the bracket from releasing the cable. This behavior is shown in Figure 80. Note, after the test, cable no. 3 was found disengaged from post no. 50. However, the bracket had fractured through its neck instead of releasing through the keyway as the cable brackets had on post nos. 47 through 49. This outcome indicated that the bracket had not released as intended, but it was instead twisted on the post and only fractured after high loading was applied through the cable to the bracket.

This bracket twisting was also observed in the brackets attaching cable no. 1 to nearly all of the posts between post nos. 47 and 52. However, since cable no. 1 is the bottom cable on the system and is so low to the ground, minimal vertical forces would be applied through cable no. 1 if it remains engaged with the post. Therefore, the failure of the brackets to release cable no. 3 were thought to provide a much greater vertical force to the posts which resisted post deformations.

Figure 80. Cable Mounting Bracket Twisting – Post Nos. 51 and 52, Test No. MWP-8

7 SUMMARY AND CONCLUSIONS

The objective of this study was to continue to test and evaluate the prototype high-tension, four-cable, median barrier system according to the MASH 2016 TL-3 safety criteria using the testing matrix for cable barrier systems installed within 6H:1V median V-ditches. One full-scale test was conducted on the system and is reported herein.

Test no. MWP-8, conducted in accordance with MASH test no. 3-10, involved a 1100C small car impacting the four-cable median barrier system with 8-ft (2.4-m) post spacing on level terrain. Test no. MWP-8 utilized modified MWP posts with rounded top edges and ¾-in. (19-mm) diameter weakening holes at the groundline. The rounded edge removed sharp corners at the top of the post and the weakening holes reduced the weak-axis capacity of the post to lower the forces exerted by the post on the floorpan and reduce the likelihood of occupant compartment penetration. During test no. MWP-8, the 2,419-lb (1,097-kg) car impacted the four-cable median barrier at a speed of 63.0 mph (101.4 km/h) and at an angle of 25.7 degrees, which resulted in an impact severity of 64.5 kip-ft (87.4 kJ).

Analysis of the test results showed that the system adequately contained and redirected the 1100C vehicle with controlled lateral displacements of the barrier. There were no detached elements or fragments that neither showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. 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 safety criteria nor cause rollover. However, the floorpan was torn in two locations resulting from contact with the top edge of post no. 50. Therefore, test no. MWP-8 was determined to be unacceptable according to the MASH safety performance criteria for test designation no. 3-10. A summary of the test results is shown in Table 11.

As a result of the unsuccessful 1100C crash test, the prototype high-tension, four-cable, median barrier system will need to be further redesigned to prevent penetration of the occupant compartment observed in test no. MWP-8. Possible design changes may include, but are not limited to, alternative post spacings, reduction of weak-axis post strength at the ground line, further treatment of the post edges, redesign of the cable-to-post attachment bracket, and changes to post geometry. After the cable barrier system has been redesigned, it will need to be re-evaluated according to MASH test designation no. 3-10 criteria before proceeding with remaining tests listed within the recommended testing matrix for cable barriers installed within median V-ditches. Depending on the nature of the design changes, it may be necessary to evaluate whether prior successful crash tests need to be rerun.

Table 11. Summary of Safety Performance Evaluation, Test No. MWP-8

<table>
<tr><th>Evaluation Factors</th><th colspan="4">Evaluation Criteria</th><th>Test No. MWP-8</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></tr>
<tr><td rowspan="12">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.</td><td>U</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></tr>
<tr><td rowspan="5">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.3 of MASH for calculation procedure) should satisfy the following limits:</td><td rowspan="5">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 colspan="3"></td></tr>
<tr><td rowspan="5">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.3 of MASH for calculation procedure) should satisfy the following limits:</td><td rowspan="5">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="3"></td></tr>
<tr><td colspan="5">MASH Test Designation</td><td>3-10</td></tr>
<tr><td colspan="5">Final Evaluation (Pass or Fail)</td><td>Fail</td></tr>
</table>

S – Satisfactory U – Unsatisfactory NA - Not Applicable

8 REFERENCES

1. Bielenberg, R.W., Rosenbaugh, S.K., Faller, R.K., Humphrey, B.M., Schmidt, T.L., Lechtenberg, K.A., and Reid, J.D., *MASH Test Nos. 3-17 and 3-11 on a Non-Proprietary Cable Median Barrier*, Final Report to the Midwest States Pooled Fund Program, Transportation Research Report No. TRP-03-303-15, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, November 3, 2015.

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

3. Kohtz, J.E., Bielenberg, R.W., Rosenbaugh, S.K., Faller, R.K., Lechtenberg, K.A., and Reid, J.D., *MASH Test Nos. 3-11 and 3-10 on a Non-Proprietary Cable Median Barrier*, Report to the Midwest States Regional Pooled Fund Program, Transportation Research Report No. TRP-03-327-16, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, January 21, 2016.

4. Rosenbaugh, S.K., Hartwell, J.H., Bielenberg, R.W., Faller, R.K., Holloway, J.C., and Lechtenberg, K.A., *Evaluation of Floor Pan Tearing and Cable Splices for Cable Barrier Systems*, Draft Report to the Midwest States Pooled Fund Program, Transportation Research Report No. TRP-03-324-16, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, April 4, 2016.

5. Hinch, J., Yang, T.L., and Owings, R., *Guidance Systems for Vehicle Testing*, ENSCO, Inc., Springfield, Virginia, 1986.

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

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

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

9. *Collision Deformation Classification – Recommended Practice J224 March 1980*, Handbook Volume 4, Society of Automotive Engineers (SAE), Warrendale, Pennsylvania, 1985.

9 APPENDICES

Appendix A. Material Specifications

Table A-1. Bill of Materials, Test No. MWP-8

Item No.	Description	Material Specification	References
a1	Cable Anchor Base Plate	ASTM A36	N/A
a2	Exterior Cable Plate Gusset	ASTM A36	N/A
a3	Interior Cable Plate Gusset	ASTM A36	N/A
a4	Anchor Bracket Plate	ASTM A36	N/A
a5	3/16" [5] Dia. Brass Keeper Rod, 14" [356] long	Brass	H#05543-1
a6	Release Gusset	A36 Steel	N/A
a7	Release Lever Plate	A36 Steel	N/A
a8	1.25x1.25x0.1875" [32x32x5] TS CT Kicker Lever Tube	ASTM A500 Gr. B	N/A
a9	CMB High Tension Anchor Plate Washer	ASTM A36	H#64047117
a10	1.25x1.25x0.1875" [32x32x5] TS CT Kicker Lever Connecting Tube	ASTM A 500 Gr. B	N/A
a11	3x10x0.5" [76x254x13] Kicker Plate	ASTM A36	N/A
a12	CT kicker - gusset	ASTM A36	N/A
a13	3/4" [19] Dia. Flat Washer	ASTM F844	PFC COC R#14-0082
a14	3/4" [19] Dia. UNC J-Hook Anchor and Heavy Hex Nut	J-Hook ASTM A449/Nut ASTM A563 DH	BOLT:H#11618020 NUT:Item#DHHNO75CG Lot#170277 H#1F543
a15	1/4" [6] Dia. Aircraft Retaining Cable, 36" [914] long	7x19 Galv.	N/A
a16	5/8" [16] Dia. Heavy Hex Nut	ASTM A563C	R#14-0343 COC
a17	5/8" [16] Dia. UNC, 9 1/2" [241] Long Hex Bolt	ASTM A449 or SAE J429 Gr. 5	Lot No. 490-454-94
a18	24" [610] Dia. Concrete Anchor,	4,000 psi f'c	R#14-0353 T#4156617

	120" [3048] long		
a19	#11 Straight Rebar, 114" [2896] long	Grade 60	H#M652732
a20	#4 Anchor Hoop Rebar with 21" [533] Dia.	Grade 60	H#534073
b1	S3x5.7 [S76x8.5] Post by 28 1/8" [714]	ASTM A572 GR50-07, ASTM A709 GR50-09A, ASTM A992-06A	R#15-0500 H#59058160
b2	S3x5.7 [S76x8.5] Post by 19" [483]	ASTM A572 GR50-07, ASTM A709 GR50-09A, ASTM A992-06A	R#15-0500 H#59058160
b3	#3 Straight Rebar, 43" [1092] long	Grade 60	H#22526780
b4	#3 Hoop Rebar, 7 1/4" [184]	Grade 60	H#537484
b5	2nd Post Keeper Plate, 28 Gauge	ASTM A36	N/A
b6	3/4" [19] Dia. UNC, 5 1/2" [140] Long Hex Bolt and Nut	Bolt ASTM A307 Gr. A/Nut ASTM A563A	Structural Bolt Distributor's Affidavit R#14-0343
b7	1/2" [13] Dia. Washer with 1 1/16" [27] OD	ASTM F844	R#14-0106 H#A32336 BL#195624
b8	1/2" [13] Dia. UNC, 2" [51] long Hex Bolt and Nut	Bolt ASTM A307 Gr. A/Nut ASTM A563A	Structural Bolt Distributor's Affidavit R#14-0343
b9	4x3x1/4" [102x76x6] Foundation Tube, 48" [1168] long	ASTM A500 Grade B	H#B200931 R#13-0175
b10	2nd Post Cable Hanger (1/2") [13]	ASTM A36	R#15-0500 H#A413247
b11	2nd Post Anchor Aggregate 12 in. Depth	-	N/A
b12	12" Dia. 2nd Post Concrete Anchor, 46" long	4,000 psi f'c	R#14-0353 T#4156617
b13	2nd Post Base Plate (3/8") [10]	ASTM A36	R#15-0500 H# A410722
b14	3/16" [5] Dia. 5 1/4" [133] Long Brass Rod	ASTM B16-00	H#05543-2
c1	3"x1-3/4"x7 Gauge [76x44x4.6], 81 1/4" [2064] Long Midwest Weak Post w/Holes	Hot-Rolled ASTM A1011 HSLA Gr. 50	H#667827 Coil#1131814950 R#14-0491

c2	12 Gauge Tabbed Bracket - Version 10	Hot-Rolled ASTM A1011 HSLA Grade 50	H#832D32560
c3	5/16" [8] Dia. UNC, 1" [25] Long Hex Cap Screw	Bolt SAE J429 Gr. 5 or ASTM A449	R#16-0105 P#13055 L#3324910004 H#4208029BA
c3	5/16" [8] Nut	Nut ASTM A563 DH	R#16-0105 P#36304 L#S77-1411-02 H#2QG45
c4	Straight Rod - 3/16" [5] Cable Clip	ASTM B16 Brass C36000 Half Hard (HO2), Round. TS >= 68.0 ksi, YS >= 52.0 ksi	H#05543-2
d1	3/4" [19] Dia. 3x7 Cable Guiderail	AASHTO M30-92 (2000)/ASTM A741-98 Type 1 Class A coating except with Type 1 min. breaking strength=39 kips [173.5 kN]	H#131499, H#59586/7
d2	7/8" [22] Dia. Hex Nut	ASTM A563C	R#14-0325 H#M643354
d3	Cable End Threaded Rod	ASTM A449	R#14-0325 H#133079
d4	Bennet Cable End Fitter	ASTM A47	H#9Q4 and OP5
	Cable Wedges		R#14-0455 H#BR1 and R#15-0635 H#DA8
d5	7/8" [22] Dia. Hex Nut	SAE J429 Gr. 5	N/A
e1	Bennet Short Threaded Turnbuckle	Not Specified	R#14-0325, COC
e2	Threaded Load Cell Coupler	N/A	N/A
e3	50,000-lb [222.4-kN] Load Cell	N/A	N/A

3/16" Brass Rod

MWP supply July 2014 SMT

Certificate of Test

Customer COPPER AND BRASS SALES INC.
Invoice No 51 ~ 520413K14
P.O. No SEE BELOW
Mill & Country Melting DAECHANG, KOREA

No 2014-04-07-080-1
Date 04/07/14
Commodity FREE CUTTING BRASS C36000 H02 (HALF HARD) , 12 FT
Spec PER ASTM B 16 & 249, REV. 2010, AMS 4610, ROHS COMPLIANT

Job No.	14-04-	Size			Quantity		Temper	Remarks	B/D No.	Mat No.	Inspection Result	
P.O. No.					Pieces	Wt., Lbs	-	-	-	-	Dimension	Surface
5400216061	08966-1	1-1/2"(+/-0.005) DPS, HEXAGON, S.C., STRES				858	H02	S/RELIEF	30	CUHEX00237	GOOD	GOOD
5400216061	13-04-35817-2	1-1/2"(+/-0.005) DPS, HEXAGON, S.C., STRES				260	H02	S/RELIEF	31	CUHEX00237	GOOD	GOOD
5400216061	13-04-32169-1	1/2"(+/-0.003) DPS, HEXAGON, R.C., STRESS				981	H02	S/RELIEF		CUHEX00063	GOOD	GOOD
5400216061	08978-1	5/8"(+/-0.004) DPS, HEXAGON, R.C., STRESS				917	H02	S/RELIEF		CUHEX00016	GOOD	GOOD
5400216061	08979-1	13/16"(+/-0.004) DPS, HEXAGON, R.C., STRE				2,555	H02	S/RELIEF		CUHEX00218	GOOD	GOOD
5400216061	08980-1	7/8"(+/-0.004) DPS, HEXAGON, R.C., STRESS				1,845	H02	S/RELIEF		CUHEX00075	GOOD	GOOD
5400216061	10033-1	1"(+/-0.004) DPS, HEXAGON, R.C., STRESS R				915	H02	S/RELIEF		CUHEX00048	GOOD	GOOD
5400216061	05540-1	1/8"(+/-0.0013) DIA, ROUND, W/PACKING				988	H02			CURD00223	GOOD	GOOD
5400216061	13-04-42374-1	9/64"(+/-0.0013) DIA, ROUND, W/PACKING				1,001	H02			CURD01358	GOOD	GOOD
5400216061	05543-1	3/16"(+/-0.0015) DIA, ROUND, W/PACKING				1,019	H02			CURD00477	GOOD	GOOD
5400216061	08262-1	1/4"(+/-0.0015) DIA, ROUND, W/PACKING				4,006	H02			CURD00527	GOOD	GOOD
5400216061	08967-1	3/8"(+/-0.0015) DIA, ROUND				3,010	H02			CURD00231	GOOD	GOOD
5400216061	08968-1	1/2"(+/-0.0015) DIA, ROUND				1,980	H02			CURD00895	GOOD	GOOD
5400216062	08969-1	9/16"(+/-0.002) DIA, ROUND				959	H02			CURD00116	GOOD	GOOD
5400216062	13-04-32223-1	5/8"(+/-0.002) DIA, ROUND				990	H02			CURD00462	GOOD	GOOD

Chemical/Physical	Element	Cu	Pb	Fe	-	-	Zn	S/C	T.S., Ksi	Y.S., Ksi	EL, %	HRB
Composition, %	Spec	60 - 63	2.5 - 3.0	0.35 max	-	-	Rem.	Ammonia Vapor				
5400216061	08966-1	60.4255	2.8174	0.1807	-	-	Rem.	GOOD	54	34	42.1	57.7
5400216061	13-04-35817-2	60.5177	2.6157	0.1823	-	-	Rem.	GOOD	53	31	37.3	59.5
5400216061	13-04-32169-1	60.2242	2.6270	0.1363	-	-	Rem.	GOOD	63	53	21.5	76.0
5400216061	08978-1	60.1911	2.8223	0.1398	-	-	Rem.	GOOD	61	46	23.0	72.4
5400216061	08979-1	60.9497	2.6670	0.1594	-	-	Rem.	GOOD	58	38	32.2	66.8
5400216061	08980-1	60.9497	2.6670	0.1594	-	-	Rem.	GOOD	58	40	34.0	67.6
5400216061	10033-1	60.2031	2.7522	0.1549	-	-	Rem.	GOOD	55	34	35.8	61.3
5400216061	05540-1	60.3935	2.8639	0.1057	-	-	Rem.	GOOD	73	69	9.6	86.0
5400216061	13-04-42374-1	60.5364	2.7259	0.1902	-	-	Rem.	GOOD	74	68	7.4	86.1
5400216061	05543-1	60.5388	2.7248	0.1118	-	-	Rem.	GOOD	76	64	8.9	88.6
5400216061	08262-1	60.5598	2.6363	0.1245	-	-	Rem.	GOOD	75	57	8.3	77.9
5400216061	08967-1	60.8321	2.6453	0.1590	-	-	Rem.	GOOD	64	54	13.9	75.3
5400216061	08968-1	60.2564	2.7579	0.1531	-	-	Rem.	GOOD	59	45	18.6	77.4
5400216062	08969-1	60.9497	2.6670	0.1594	-	-	Rem.	GOOD	62	43	23.0	72.9
5400216062	13-04-32223-1	60.3676	2.7201	0.1832	-	-	Rem.	GOOD	61	50	27.6	73.3

SIGNED FOR DAE CHANG IND.

Lloyds Pacific International, Inc.

page 3 of 4

From: ThyssenKrupp Materials NA
Cust. ONLINE METALS
CstAr 4345 CstOr 26402
Wgt.: 37 LB Date 05/21/2014
Del.: 2403167021

Figure A-1. $^{3}/_{16}$-in. (5-mm) Brass Rod, Test No. MWP-8

GERDAU

US-ML-WILTON
1500-2500 WEST 3RD STREET
WILTON, IA 52778
USA

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	
STATE STEEL SUPPLY CO INC 13433 CENTECH RD OMAHA,NE 68138-3492 USA	STATE STEEL SUPPLY CO INC SIOUX CITY,IA 51102-3224 USA	A36	Flat / 1/2 X 3	
		LENGTH	WEIGHT	HEAT / BATCH
		20'00"	34,272 LB	64047117/02

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
639595/000050		1-ASTM A6/A6M-11 2-A36/A36M-08 3-A709-11 4-AASHTO M270-11

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
P31101SW251	1334-0000007548	11/05/2013

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	V %	Nb %	Al %	Pb %
0.18	0.56	0.007	0.036	0.18	0.27	0.08	0.11	0.023	0.000	0.001	0.000	0.0003

CHEMICAL COMPOSITION

Sn %
0.010

MECHANICAL PROPERTIES

Elong. %	G/L Inch	UTS PSI	UTS MPa	YS PSI	YS MPa
26.30	8.000	66800	461	43700	301
30.00	8.000	67600	466	44100	304

GEOMETRIC CHARACTERISTICS

R:R
20.52

COMMENTS / NOTES

4CMB Cable Anchor Plate Washer

P31101SW25105

64047117

The above figures are certified chemical and physical test records as contained in the permanent records of company. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

BRETT KRAUSE
QUALITY ASSURANCE MGR.

Figure A-2. CMB High Tension Anchor Plate Washer, Test No. MWP-8

Low Deflection Washers R#14-0082
3/4" AND 1" Washers

Porteous Fastener Company
BOLTS NUTS SCREWS WASHERS

FIRST CLASS SERVICE

CORPORATE OFFICE
1040 Watson Center Road, Carson, CA 90745
(310) 549-9180 Fax (310) 835-0415
www.porteousfastener.com

February 7, 2013

Attn: Chris

The Structural Bolt
Dear: Chris,

You contacted our Denver office and requested that I write to you concerning specifications under which we purchase our USS Flat Washers

Firstly, our products are purchased to specifications where applicable. Our Purchase Orders clearly state that each product supplied to Porteous Fastener Company is to meet the proper specification as referenced in the Industrial Fastener Institute manual for that product when such specifications exist.

(ANSI B18.22.1 and ASTM F844. All HDG plating shall be done per ASTM A153)

Secondly, we require certifications from our suppliers of all products Grade 5 or better: A325 Structural Bolts, Grade 5 Hex Cap Screws, Grade 8 Hex Cap Screws, ASTM A194 2H Hvy. Hex Nuts, F436 Structural Washers, Grade 8 Finished Hex Nuts, ASTM A193 Grade B7 Threaded Rod, SAE Hi Nuts and Grade C Hex Locknuts. These certifications are on file at Porteous corporate office and copies of same are available to our customers.

We trust that you can be confident, as we are, that the product furnished to you meets specifications.

Please let me know if we can be of further service.

Sincerely,
Herbert Recinos
Inventory Control
Cc: Mike Hall -- Denver

Figure A-3. ¾-in (19-mm) Dia. Flat Washer, Test No. MWP-8

AUG/23/2012/THU 02:08 PM TSA MANUFACTURING FAX No. 4028953297 P. 001/001

P.O. # 145117

PO# 30078 SO# 89068

Item: 3/4-10 X 18 1/4	J HOOK ANCHOR		
Material Specification:	ASTM A449		
LOT#:	11618020		
Heat Number:	11618020		
Tensile Strength PSI:	131800 PSI	Yield Strength PSI:	121800 PSI
Elongation:	20	Reduction of Area:	58
Hardness:	27 HRC	Proof Load:	NA
Macro Etch:	NA	Tempering Temp.:	1340 F

Carbon (C):	0.44	Chromium (CR):	NA
Manganese (MN):	0.71	Molybdenum (MO):	NA
Phosphorus (P):	0.013	Copper (CU):	NA
Sulfur (S):	0.034	Nitrogen (N):	NA
Silicon (SI):	0.19	Nickel (NI):	NA
Cobalt (CO):	NA	Aluminum (AL):	NA
Vanadium (V):	NA	Tin (SN):	NA
Tungsten (W):	NA	Titanium (TI):	NA
Columbium/Niobium (NB/CB):	NA	Boron (B):	NA
Calcium (CA):	NA		

We hereby certify that the material was manufactured, sampled, tested and inspected per the most recent revision of the or material specification. The foregoing data was furnished to us by our supplier or resulting from a test performed in a recognized laboratory and is on file in the records of the corporation.
Name: Kayla Patterson Date:08.13.12

Figure A-4. J-Hook Anchor Bolts, Test No. MWP-8

NOV-08-2005 TUE 05:33 PM FAX NO. P. 05

TEST CERTIFICATE

Purchaser :[illegible]工廠股份有限公司	
Order NO : PO# P170277	Inspection date:9/08/2005
S/C NO : PI# 050594-T37	Issue date:09/20/2005
LOT NO :8VQ	
Size: ¾-10 ASTM A563 Grade DH Heavy Hex Nuts - Hot Dip Galvanized O/S: 0.50MM Marked "DH" + Makers Sign + "01GO"	
Quantity :54,000PCS 180CTNS	
Vessel Name: APL THAILANO / 089E	

Material : C-CH40ACR

Heat NO.	Size Diameter	C 100%	Mn 100%	P 1000%	S 1000%	Si 100%
1F543	28.00mm	43	81	20	10	5

Dimensional Inspections Specification: ANSI B18.2.2-1987

UNIT:inch

Characteristic	Specification	Actual Result	Ac.	Re.
Visual appearance	ASTM F812-2002	OK	32	0
Width across flats	1.250~1.212	1.233~1.224	32	0
Width across corners	1.443~1.382	1.405~1.395	32	0
Nuts thickness	0.758~0.710	0.736~0.721	32	0
Hole diameter	0.683~0.662	0.679~0.670	32	0
Thread	ASME B1.1-2002	OK	32	0

Mechanical Properties Specification: ASTM A563-04a

Characteristic	Requirement	Result	Ac.	Re.
Hardness	HRC 24~38	HRC30.9~33.0	8	0
Proof Load	Min 50100Lbf	58960Lbf	8	0

Signatory: Y.M. Wang
Y.M. WANG/Q.C.MANAGER

Figure A-5. ¾-in. (19-mm) Dia. Heavy Hex Nut, Test No. MWP-8

PFC
FIRST CLASS SERVICE

Porteous Fastener Company
BOLTS NUTS SCREWS WASHERS

CORPORATE OFFICE
1040 Watson Center Road, Carson, CA 90745
(310) 549-9180 Fax (310) 835-0415
www.porteousfastener.com

May 30, 2013

Attn: Chris Burris

Structural Bolt
2140 Cornhusker Hwy
Lincoln NE 68521
Fax: 402-435-3135

Dear: Chris,

You contacted our Denver office concerning specifications under which we purchase our N.C. Gr. 5 Hex Cap Screws.

Firstly, our products are purchased to specification where applicable. Our Purchase Orders clearly state that each product supplied to Porteous Fastener Company is to meet the proper specification as referenced in the Industrial Fastener Institute manual for that product when such specifications exist.

(ASME / ANSI B18.2.1 and SAE J429, GRADE 5.)

Secondly, we require certifications from our suppliers of all products Grade 5 or better: A325 Structural Bolts, Grade 5 Hex Cap Screws, Grade 8 Hex Cap Screws, ASTM A194 2H Hvy, Hex Nuts, F436 Structural Washers, Grade 8 Finished Hex Nuts, ASTM A193 Grade B7 Threaded Rod, SAE Hi Nuts and Grade C Hex Locknuts. These certifications are on file at Porteous corporate office and copies of same are available to our customers.

We trust that you can be confident, as we are, that the product furnished to you meets specifications.

Please let me know if we can be of further service.

Sincerely,

Herbert Recinos
Inventory Control

Cc: Carrie- Denver

Figure A-6. $^5/_8$-in. (16-mm) Dia. Heavy Hex Nut, Test No. MWP-8

Certificate of Conformance Page 1 of 1

Shipment Date: 04/18/2012

KANEBRIDGE CORPORATION

CERTIFICATE OF CONFORMANCE

Company:
HODELL-NATCO IND.
11688 FAIRGROVE IND. BLVD.
MARYLAND HEIGHTS, MO 63043
Attn: ONL/DANIEL

P.O. #: 4137087

Sales Order #: 4678123

Shipment #: 3243260

Item Number	Description	Lot No	Cert Ref
62152CH5O	5/8-11X9 1/2 COAR HEX CAP SCR GR5 ZINC	490-454-94	1
	Origin: CANADA	**Mfr:** 1110615263157G	

CertRef Certification Description

1 WE CERTIFY THAT THIS ITEM WAS MANUFACTURED TO SAE J429 SPECIFICATIONS. THE MANUFACTURER'S CHEMICAL AND PHYSICAL TEST REPORTS CERTIFYING THIS PART TO SAE J429 ARE ON FILE AND AVAILABLE AT ANY TIME UPON REQUEST. ADDITIONALLY, THEY HAVE NOT COME INTO CONTACT WITH MERCURY WHILE IN OUR POSSESSION.

Signed: RICK SAUL
Title: Certification Department

Claims against Kanebridge Corporation shall be limited to a refund or credit for the price billed or paid for improper merchandise. Seller shall not be responsible for buyer's manufacturing costs, labor, alternate purchases, extra freight, replating, plating, lost profit, good will, recall costs, or other incidental or consequential damages.

http://www.kanebridge.com/kanecofc.asp?InvoiceNo=3243260&PassAllLotInd=Y 2/21/2014

Figure A-7. $^5/_8$-in. (16-mm) Dia. UNC, 9½-in. (241-mm) Long Hex Bolt, Test No. MWP-8

CAUTION
FRESH CONCRETE

Body and or eye contact with fresh (moist) concrete should be avoided because it contains alkali and is caustic.

Ready Mixed Concrete Company
6200 Cornhusker Highway, P.O. Box 29288
Lincoln, Nebraska 68529
Telephone 402-434-1844

PLANT	MIX CODE	YARDS	TRUCK	DRIVER	DESTINATION	CLASS	TIME	DATE	TICKET
01	24033000	3.00	0120		NTE		12:25PM	03/21/13	1161319

CUSTOMER	JOB	CUSTOMER NAME	TAX CODE	PARTIAL	NIGHT R.	LOADS
00003		CIA---UNLMRS				1

DELIVERY ADDRESS	SPECIAL INSTRUCTIONS	P.O. NUMBER
4800 NW 35TH	NORTH OF GOODYEAR HANGER	4506250

LOAD QUANTITY	CUMULATIVE QUANTITY	ORDERED QUANTITY	PRODUCT CODE	PRODUCT DESCRIPTION		UNIT PRICE	AMOUNT
3.00	3.00	3.00	24033000	L4000 TYPE 3	4.00	102.39	307.17
				MINIMUM HAUL			40.00

SUBTOTAL	347.17
TAX	347.17
TOTAL	347.17

WATER ADDED ON JOB AT CUSTOMER'S REQUEST 2 GAL RECEIVED BY

TRUCK	USER LOGIN	DISP TICKET NUM	TICKET NUM	TICKET ID	TIME	DATE
0120	USER	1161319	182693	33630	12:25	03/21/2013

LOAD SIZE	MIX CODE	SEQ	LOAD ID
3.00 yd	24033000	W	33698

MATERIAL	DESIGN QTY	REQUIRED	BATCHED	VAR	% VAR	%MOISTURE	ACTUAL WAT
G47B	2090 lb	6383 lb	6360	-23	-.36%	1.80 M	13.48 gl
L47B	909 lb	2732 lb	2720	-12	-.44%	0.20 M	0.65 gl
CEM3	611 lb	1833 lb	1910 >	77	4.20%		
PROT	1.20 oz	3.60 oz	4.00	0.40	11.11%		
WATER	34.0 GL	90.8 GL	90.1	-0.7	-.77%		90.11 gl
WATER2	0.0 gl #	0.0 gl	0.0	0.0	0.00%		

NON-SIMULATED NUM BATCHES: 1
LOAD TOTAL: 11742 lb DESIGN W/C: 0.464 WATER/CEMENT: 0.455A DESIGN WATER: 102.0 gl ACTUAL WATER: 104.2 gl TO ADD: 0.0 gl
SLUMP: 4.00 "# WATER IN TRUCK: 0.0 gl ADJUST WATER: 0.0 gl /load TRIM WATER: 0.0 gl /yd

MWP-2 (Level Terrain)

Concrete Anchors

SMT

3/21/13 HOAB Concrete Anchor

ORIGINAL

Figure A-8. Concrete Anchor, Test No. MWP-8

CONCRETE INDUSTRIES, INC.

6300 Cornhusker Highway, Lincoln, NE 68529-0529
402-434-1800 Fax: 402-434-1899
www.ConcreteIndustries.com

Customer Receipt

Driver:
Truck #:
Ordered By: CALL

Bill To:
91123 UNIVERSITY OF NEBRASKA
MIDWEST RDSIDE SAFETY FACILITY
W328.1 NEBRASKA HALL
PO BOX 880529
LINCOLN NE 68588-0529

ATTN: KEN KRENK

Ship To:
UNIVERSITY OF NEBRASKA
MIDWEST RDSIDE SAFETY FACILITY
W328.1 NEBRASKA HALL
PO BOX 880529
LINCOLN NE 68588-0529

Ship From:
CONCRETE INDUSTRIES
6300 CORNHUSKER HWY
LINCOLN NE 68507

Delivery Directions:

09:01 Order Number: SP 1195733 0 Delivery Date: 05/11/10 Customer PO Number:

Line	Item Description	Picked	Ordered	Back Order	Units	Unit Price	Discount	Extension
1	#11 STOCK REBAR GRADE 60 R1160		1,700.00		LB	GERDAU	M652	732
2	#11 REBAR FABRICATED / CUT 11FAB 32 PCS #11 X 10-0 STR		1,700.00		LB			
3	#3 STOCK REBAR GRADE 60 R360		104.00		LB	GERDAU	22526	78C
4	#3 REBAR FABRICATED / CUT 3FAB 16 PCS #3 X 4-0 STR		104.00		LB			
5	#4 STOCK REBAR GRADE 60 R460		104.00		LB	EVRAZ	5340	73
6	#4 REBAR FABRICATED / CUT 4FAB		104.00		LB			
7	LIGHT BENDING CHARGE LBCHG 24 PCS #4 X 6-6 BENT		104.00		LB			
8	24" FORM TUBE 67508 1 PCS 24" DIAMETER X 4'-0" FORM TUBE		4.00		FT			
9	12" FORM TUBE 67503 1 PCS 12" DIAMETER X 4'-0" FORM TUBE		4.00		FT			
10	#4 STOCK REBAR GRADE 60 20'-0" R46020		35.00		EA	GERDAU	1186	1680

Received by________________ **Print Name/Company**________________

Returns: No returns w/o invoice. No returns on unusable material, seconds, architectural, decorative, all special order materials, and fractional units. All returnable materials subject to 50% restocking charge. No returns accepted after 30 days from date of purchase.

Terms: All invoices must be paid within 30 days of invoice. Past due accounts will be charged an interest rate of 1.33% per month which is 16% per year.

Tax Code:
Total Weight: 2,404.80
Total Cubic:

Sub Total:
Sales Tax:
Total Amount:
Down Payment:
Balance Due:

Document: 0 0 Print Date: 05/10/10 Print Time: 11:45 Page: 1 kathys

Figure A-9. Rebar for Anchorage, Test No. MWP-8

GERDAU AMERISTEEL

ST PAUL STEEL MILL
1678 RED ROCK ROAD
ST PAUL MN 55119 USA
(651) 731-5600

Chemical and Physical Test Report
MADE IN UNITED STATES

M-075139

SHIP TO	INVOICE TO	SHIP DATE
NEBCO, INC. STEEL DIVISION HAVELOCK, NE 68521	CONCRETE INDUSTRIES INC ACCOUNTS PAYABLE PO BOX 29529 LINCOLN, NE 68529-0529	10/09/09 **CUST. ACCOUNT NO** 60052172

PRODUCED IN: ST PAUL

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
X36MM REBAR (#11)	420 (60)	A615/A615M-09 GR 60/420 A6/A6M-08a	9193731-01	79682-01

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Sn
M652732	.44	1.22	.013	.029	.22	.26	.11	.14	.034	.004	.014

Mechanical Test: Yield 64400 PSI, 444.02 MPA,Load 100 KIPS Tensile: 110300 PSI, 760.49 MPA %El: 15.6/8in, 15.6/203.2mm Bend: OK
Customer Requirements SOURCE: GA-STP CASTING: STRAND CAST

This material, including the billets, was produced and manufactured in the United States of America

THE ABOVE FIGURES ARE CERTIFIED EXTRACTS FROM THE ORIGINAL CHEMICAL AND PHYSICAL TEST RECORDS AS CONTAINED IN THE PERMANENT RECORDS OF COMPANY.

Bhaskar Yalamanchili
Quality Director
Gerdau Ameristeel

Metallurgical Services Manager
ST PAUL STEEL MILL

Seller warrants that all material furnished shall comply with specifications subject to standard published manufacturing variations. NO OTHER WARRANTIES, EXPRESSED OR IMPLIED, ARE MADE BY THE SELLER, AND SPECIFICALLY EXCLUDED ARE WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.
In no event shall seller be liable for indirect, consequential or punitive damages arising out of or related to the materials furnished by seller.
Any claim for damages for materials that do not conform to specifications must be made from buyer to seller immediately after delivery of same in order to allow the seller the opportunity to inspect the material in question.

Figure A-10. #11 Rebar for Anchorage, Test No. MWP-8

EVRAZ ROCKY MOUNTAIN STEEL
A DIVISION OF EVRAZ INC. NA

P.O. Box 316
Pueblo, CO 81002 USA

MATERIAL TEST REPORT

Date Printed: 07–MAY–10

Date Shipped: 07–MAY–10 **Product:** DEF 13mm #4 **Specification:** ASTM–A–615M08b GR 420/ASTM–A–706M08a

FWIP: 52815348 **Customer:** CONCRETE INDUSTRIES INC **Cust. PO:** 82444

CHEMICAL ANALYSIS (Heat cast 05/01/10)

Heat Number	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al	V	B	Cb	Sn	N	Ti
534073	0.27	1.26	0.013	0.009	0.24	0.27	0.08	0.13	0.019	0.003	0.038	0.0005	0.000	0.013	0.0083	0.002

Carbon Equivalent = 0.500

MECHANICAL PROPERTIES

Heat Number	Sample No.		Yield (Psi)	Ultimate (Psi)	Elongation (%)	Reduction (%)	Bend	Wt/ft
534073	01		67005	98190	15.4		ok	0.663
		(MPa)	462.0	677.0				
534073	02		67313	96890	16.1		ok	0.665
		(MPa)	464.1	668.0				

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

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

Mark Espanoza

Quality Assurance Department

Figure A-11. #4 Rebar for Anchorage, Test No. MWP-8

GERDAU

CERTIFIED MATERIAL TEST REPORT

Page 1/1

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

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE
STEEL & PIPE SUPPLY CO INC 1003 FORT GIBSON RD CATOOSA,OK 74015-3033 USA	STEEL & PIPE SUPPLY CO INC MANHATTAN,KS 66505-1688 USA	A36/A57250	Standard I-Beam / 3 X 5.7# / 75 X 8.5

LENGTH	WEIGHT	HEAT / BATCH
40'00"	8,208 LB	59058160/03

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
812105/000020	000000000035357040	A36/A36M-08 A572/A572M-07 ASTM A6/A6M-11

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
4500221191	1327-0000099969	04/02/2014

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.09	0.79	0.014	0.026	0.20	0.36	0.11	0.06	0.027	0.009	0.001	0.011	0.003

CHEMICAL COMPOSITION

CEqyA6 %
0.3

MECHANICAL PROPERTIES

YS KSI	UTS KSI	YS MPa	UTS MPa	G/L Inch	G/L mm
53.4	69.5	382	468	8.000	200.0
55.3	67.9	368	479	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	Y/T rati %
23.20	0.786
23.60	0.796

COMMENTS / NOTES

4 Cable MWP 6-2part Posts
R#15-0500
April 2015 SMT

The above figures are certified chemical and physical test records as contained in the permanent records of company. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

TOM HARRINGTON
QUALITY ASSURANCE MGR.

Figure A-12. S3x5.7-in. (S76x8.5-mm) Post by 28⅛ in. (714 mm) and S3x5.7-in. (S76x8.5-mm) Post by 19 in. (483 mm), Test No. MWP-8

Bill To:
CONCRETE INDUSTRIES, INC.
P.O. BOX 29529
LINCOLN NE
68529 US

Ship To: 1
CONCRETE INDUSTRIES, INC.
6300 CORNHUSKER HIGHWAY
LINCOLN NE
US

Order Date:02/19/2010
PO No:81224
Mill Order No:3703679
Load No:1293276
Manifest No:1993673

CERTIFIED MATERIAL TEST REPORT
GERDAU AMERISTEEL
Midlothian Mill
300 Ward Road
Midlothian, TX 76065
(972)775-8241

SPECIFICATIONS
ASTM A615/A615M-09

SIZE	GRADE	LENGTH	PRODUCT
# 3 REBAR/10 MM / 10 MM	60/420	40 FT / 12.192 M	REBAR

HEAT NO: 22526780

CHEMICAL ANALYSIS

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	V	Al	Nb
.46	.86	.016	.038	.25	.34	.11	.14	.028	.014	.002	.004	.005

PHYSICAL PROPERTIES

Yield Strength		Tensile Strength		Specimen Area		Elongation	Gage Length		Bend Test		ROA
KSI	MPa	KSI	MPa	Sq In	Sq cm	%			Dia.	Result	%
67.0	461.9	106.3	732.9	0.110	0.71	15.3	8 In	200 mm	3.5	PASS	

All manufacturing processes of this product, including electric arc MELTING and continuous CASTING, occurred in the U.S.A.
CMTR complies with EN 10204 3.1

"I hereby certify that the contents of this report are correct and accurate. All tests and operations performed by this material manufacturer or its sub-contractors, when applicable, are in compliance with the requirements of the material specifications and applicable purchaser designated requirements."

Signed: [signature] Date:Mar. 01, 2010 Signed: ________________ Date: ________
Tom L. Harrington: Quality Assurance Manager Notary Public (If applicable)

Page: 1 of 1

Figure A-13. #3 Rebar for Anchorage, Test No. MWP-8

EVRAZ ROCKY MOUNTAIN STEEL
A DIVISION OF EVRAZ INC. NA

P.O. Box 316
Pueblo, CO 81002 USA

MATERIAL TEST REPORT

Date Printed: 16–DEC–10

Date Shipped: 16–DEC–10	Product: DEF 10mm	Specification: ASTM–A–615M09b GR 420/ ASTM–A–706M09l
FWIP: 52815347	Customer: CONCRETE INDUSTRIES INC	Cust. PO: 86205

CHEMICAL ANALYSIS (Heat cast 09/27/10)

Heat Number	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al	V	B	Cb	Sn	N	Ti
537484	0.26	1.24	0.015	0.007	0.24	0.25	0.08	0.14	0.013	0.004	0.037	0.0006	0.000	0.013	0.0081	0.002

Carbon Equivalent = 0.487

MECHANICAL PROPERTIES

Heat Number	Sample No.		Yield (Psi)	Ultimate (Psi)	Elongation (%)	Reduction (%)	Bend	Wt/ft
537484	01		68260	98900	17.3		OK	0.372
		(MPa)	470.6	681.9				
537484	02		66012	96040	16.5		OK	0.372
		(MPa)	455.1	662.2				

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

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

Quality Assurance Department

Figure A-14. #3 Hoop Rebar, 7¼ in. (184 mm), Test No. MWP-8

SUPERIOR WASHER AND GASKET CORP. 170 Adams Avenue Hauppauge, New York 11788 Phone: (631) 273-8282 Fax: (631) 273-8088 E-Mail: swg@superiorwasher.com Web: superiorwasher.com **(In the East)**	SUPERIOR WASHER AND GASKET CORP. 662 Bryant Blvd. Rock Hill, South Carolina 29732 Phone: (803) 366-3250 Fax: (803) 366-3511 E-Mail: swg@superiorwasher.com Web: superiorwasher.com **(In the South)**

ACCURATE MANUFACTURE GROUP
P.O. BOX 7232 - DEPT. 168

INDIANAPOLIS , IN 46206

Customer Purchase Order Number		Superior Order Number	Superior Lot Number	Tracer No.	
9454		504612-1	504612 - 1	SC31483 -3 /21153114	
Date	Production Card	Part Number			Quantity
04-02-13	175383	WASB12NZ			15,000
Drawing		Dual Cert No.			
P/N S-1/2TYBNZ A					

We hereby certify that all materials and processes conform to the required drawing specifications and that the parts have been manufactured in the U.S.A.
All parts are manufactured in a Mercury-free environment

Material

1008 LOW CARBON STEEL No. 5

ZINC TRIVALENT CHROMIUM

Chemical Analysis

C	CARBON	.0700
Mn	MANGANESE	.3300
P	PHOSPHORUS	.0080
S	SULPHUR	.0070
Si	SILICON	.0100
Cr	CHROMIUM	.0200
Ni	NICKEL	.0100
Mo	MOLYBDENUM	.0100
Cu	COPPER	.0200
Fe	IRON	
Ti	TITANIUM	
Co	COBALT	
N	NITROGEN	
Cb	COLUMBIUM	
Al	ALUMINUM	.0430
Sn	TIN	
Mg	MAGNESIUM	
Zn	ZINC	
Pb	LEAD	
Va	VANADIUM	

Mechanical Properties

Yield	
Tensile	
Elongation	
Hardness	B 49.0
Heat	4179170
Magnetic Permeability	
Bend Test	

SUPERIOR WASHER & GASKET CORP.

By Richard Anderson, Jr.

Richard Anderson, Jr.
Quality Control Manager

Figure A-15. ½-in. (13-mm) Washers, Test No. MWP-8

THE STRUCTURAL BOLT COMPANY

DISTRIBUTOR'S AFFIDAVIT

DISTRIBUTOR:
THE STRUCTURAL BOLT CO
2140 CORNHUSKER HWY
LINCOLN, NE 68521

REFERENCE PO# 4CMB

The Strcutrual Bolt Co, hereby certifies that the items below meets or exceeds requirements per your purchase order

Quantity	Size	Descripition	Spec	Finish
20	3/4 x 5-1/2	HEX BOLT	A307	PL
20	3/4-10 NUT	HEX NUT	A307	PL
100	1/2 WASHER	FLAT WASHER	A307	PL
50	1/2-13 X 2	HEX BOLT	A307	PL
50	1/2-13 NUT	HEX NUT	A307	PL

Order# 4CMB
TSBC Inv# 108423

Distributor's Signature Chris Barris Date: 2/18/2014
Title: General Manager

Figure A-16. ½-in. (13-mm) Dia. UNC 2-in. (51-mm) Long Hex Bolt and Nut and ¾-in. (19-mm) Dia. UNC 5½-in. (140-mm) Long Hex Bolt and Nut, Test No. MWP-8

26Apr12 9:26 TEST CERTIFICATE No: MAR 877775

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

P/O No 4500179833
Rel
S/O No MAR 212696-001
B/L No MAR 123862-004 Shp 23Apr12
Inv No Inv

Sold To: (5017)
STEEL & PIPE SUPPLY
401 NEW CENTURY PARKWAY
KANSAS CITY WHSE.
NEW CENTURY, KS 66031

Ship To: (1)
STEEL & PIPE SUPPLY
401 NEW CENTURY PKWY
NEW CENTURY, KS 66031

Tel: 913-768-4333 Fax: 913 768-6683

CERTIFICATE of ANALYSIS and TESTS Cert. No: MAR 877775
19Apr12

Part No		Pcs	Wgt
TUBING A500 GRADE B(C) 4" X 3" X 1/4" X 40'		20	8,408

Heat Number	Tag No	Pcs	Wgt
B200931	621072	20	8,408

YLD=69070/TEN=81790/ELG=23.9

Heat Number *** Chemical Analysis ***
B200931 C=0.2000 Mn=0.4500 P=0.0120 S=0.0020 Si=0.0300 Al=0.0330
Cu=0.1200 Cr=0.0400 Mo=0.0100 V=0.0010 Ni=0.0400

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-10a
................................A513-07
................................A252-98 (2002)

Page: 1 .... Last

Figure A-17. Foundation Tubes, Test No. MWP-8

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

METALLURGICAL TEST REPORT

PAGE 1 of 1
DATE 02/05/2015
TIME 16:05:32
USER MEHEULAL

SOLD TO

SHIP TO
13713
Warehouse 0020
1050 Fort Gibson Rd
CATOOSA OK 74015

Order	Material No.	Description	Quantity	Weight	Customer Part	Customer PO	Ship Date
40237114-0040	701672120TM	1/2 72 X 120 A36 TEMPERPASS STPMLPL	8	9,801.600			02/05/2015

Chemical Analysis

Heat No. A413247 Vendor STEEL DYNAMICS COLUMBUS DOMESTIC Mill STEEL DYNAMICS COLUMBUS Melted and Manufactured in the USA
Batch 0003769220 8 EA 9,801.600 LB Produced from Coil

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.2000	0.8000	0.0110	0.0020	0.0300	0.0400	0.0700	0.0100	0.0001	0.0900	0.0300	0.0010	0.0030	0.0010	0.0068	0.0070

Mechanical/ Physical Properties

Mill Coil No. A413247-01

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
74800.000	49800.000	32.10			0	NA			
73300.000	47900.000	32.70			0	NA			

Chemical Analysis

Heat No. A413247 Vendor STEEL DYNAMICS COLUMBUS DOMESTIC Mill STEEL DYNAMICS COLUMBUS Melted and Manufactured in the USA
Batch 0003769231 7 EA 8,576.400 LB Produced from Coil

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.2000	0.8000	0.0110	0.0020	0.0300	0.0400	0.0700	0.0100	0.0001	0.0900	0.0300	0.0010	0.0030	0.0010	0.0068	0.0070

Mechanical/ Physical Properties

Mill Coil No. A413247-01

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
74800.000	49800.000	32.10			0	NA			
73300.000	47900.000	32.70			0	NA			

THE CHEMICAL, PHYSICAL, OR MECHANICAL TESTS REPORTED ABOVE ACCURATELY REFLECT INFORMATION AS CONTAINED

Figure A-18. 2nd Post Cable Hanger, ½ in. (13 mm), Test No. MWP-8

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 01/23/2015
TIME 11:13:42
USER WILLIAMR

SOLD TO

SHIP TO
13713
Warehouse 0020
1050 Fort Gibson Rd
CATOOSA OK 74015

Order	Material No.	Description	Quantity	Weight	Customer Part	Customer PO	Ship Date
40235941-0020	701272120TM	3/8 72 X 120 A36 TEMPERPASS STPMLPL	5	4,596			01/23/2015

Chemical Analysis

Heat No. A410722 Vendor STEEL DYNAMICS COLUMBUS DOMESTIC Mill SEVERSTAL COLUMBUS Melted and Manufactured in the USA
Batch 0003748836 5 EA 4,596 LB Produced from Coil

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.2000	0.8800	0.0160	0.0010	0.0200	0.0500	0.0700	0.0100	0.0001	0.0900	0.0280	0.0020	0.0030	0.0020	0.0073	0.0040

Mechanical/ Physical Properties

Mill Coil No. A410722-04

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
73700.000	50200.000	32.00			0	NA			
70900.000	47900.000	32.80			0	NA			
72100.000	48800.000	33.30			0	NA			
70200.000	47100.000	31.20			0	NA			

Chemical Analysis

Heat No. A410722 Vendor STEEL DYNAMICS COLUMBUS DOMESTIC Mill SEVERSTAL COLUMBUS Melted and Manufactured in the USA
Batch 0003748828 10 EA 9,192 LB Produced from Coil

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.2000	0.8800	0.0160	0.0010	0.0200	0.0500	0.0700	0.0100	0.0001	0.0900	0.0280	0.0020	0.0030	0.0020	0.0073	0.0040

Mechanical/ Physical Properties

Mill Coil No. A410722-04

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
73700.000	50200.000	32.00			0	NA			
70900.000	47900.000	32.80			0	NA			
72100.000	48800.000	33.30			0	NA			
70200.000	47100.000	31.20			0	NA			

THE CHEMICAL. PHYSICAL. OR MECHANICAL TESTS REPORTED ABOVE ACCURATELY REFLECT INFORMATION AS CONTAINED IN THE RECORDS OF THE [illegible]

Figure A-19. 2nd Post Base Plate, ⅜ in. (10 mm), Test No. MWP-8

ThyssenKrupp Steel USA
1 ThyssenKrupp Drive
Calvert, Al. 36513

Mill Certificate

ThyssenKrupp

CUSTOMER ORIGINAL

Order - Item	Certificate Number	Delivery No	Ship Date	Page
42820-70	1131814950	80554939-10	02/27/2014	1 of 1

Customer No: 10779 | Cust PO: 01013159

Customer Part No: 26576

Customer Sold to:	Customer Ship to:	Contact - Customer Service
Norfolk Iron & Metal Company 3001 North Victory Rd. NORFOLK NE 68702 USA	Norfolk Iron & Metal Company 3001 North Victory Rd. NORFOLK NE 68702 USA	Company ThyssenKrupp Steel USA P.O. Box 456 CALVERT AL 36513 USA Email: CS.Calvert@Thyssenkrupp.com Ph : 1-251-289-3000

Steel Grade / Customer Specification
Hot Roll Black Coil HSLAS-F GRADE 50 [340] / 0.1750 " X 60.0000 " ACCORDING TO A1011 {Light < 0.230"(6.0 mm)}

Type of Product/Surface
Hot Roll Black Coil Semi exposed

TEST METHOD
ASTM

MATERIAL DESCRIPTION

	ORDERED	Heat No.	Coil No.	Weight Net LB	Weight Gross LB
(mm)	4.445	667827	1131814950	47,818	47,818
(in)	0.1750				

CHEMICAL COMPOSITION OF THE LADLE *

Heat No.	C	Si	Mn	P	S	Al	Cr	Cu	Mo	N
667827	0.0550	0.02	0.42	0.013	0.004	0.049	0.01	0.01	0.00	0.0058

Ni	Nb	Ti	B	V	Ca
0.011	0.018	0.000	0.0001	0.001	0.0032

TENSILE TEST

Test Direction	Yield Strength	Tensile Strength	% Total Elong.
L	60.7 ksi	67.1 ksi	33.0

ThyssenKrupp Steel USA, LLC certify that the material herein described has been manufactured, sampled, tested and inspected in accordance with the contract requirements and is fully in compliance.

Bertram Ehrhardt
Bertram Ehrhardt
Director, Quality Assurance and Development

Rev.

Figure A-20. 3x1¾x7-gauge. (76x44x4.6 mm), 81¼-in. (2,064 mm) Long Midwest Weak Post with Holes, Test No. MWP-8

Quality Assurance Department

REPORT OF TEST AND ANALYSES

1

VENDOR	SOLD TO	SHIP TO
ARCELORMITTAL BURNS HARBOR LLC 250 WEST US HIGHWAY 12 BURNS HARBOR, IN 46304-9745	STATE STEEL SUPPLY CO PO BOX 3224 208 COURT ST SIOUX CITY IA 51102	STATE STEEL SUPPLY CO 208 COURT ST SIOUX CITY IA 51102

SHIPMENT NO.	DATE SHIPPED	MILL ORDER NO.	CAR OR VEHICLE NO.	PURCHASE ORDER NO.
86B-47178	11/12/13	ISG-YH 874-52010-A	TRLR 013	P30913BN017

MATERIAL DESCRIPTION

GAUGE	WIDTH	LENGTH	CUSTOMER APPLICATION:	SPECIFICATION:
.0970 M IN	48 IN	COIL IN	PAINTED PARTS	HOT ROLL PICKLE OUTSIDE PI & OIL & TEMPER ROLL HSLAS OIL/MEDIUM /MILL EDGE---ASTM A1011 LATEST REVIS SLAS-F GR 50 MOD 203 (SI=.050X)

ITEM — TEST RESULTS

COIL NUMBER	NO. PCS.	WEIGHT	HEAT NUMBER	TEST LOC.	YLD PT LONG.	TENSILE KSI-L	ELONG-L IN--PCT
271370 7499613	1	46240	832D32560	L F	60.1	68.3	2 29

12gauge 50ksi ASTM A1011
Midwest Posts Clips and Clip Testing
May 2014 SMT

CHEMICAL ANALYSIS — MELTED AND MANUFACTURED IN THE U.S.A.

HEAT NUMBER	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Ti	Al	Cb	N	B	SN
832D32560	.06	.42	.015	.008	.015	.029	.02	.04	.015	.001	.002	.035	.019	.005	.0002	.004
	CO .003	PB	AS	ZR	W	MG	CA .0002									

I certify that the above results are a true and correct copy of records prepared and maintained by ArcelorMittal Burns Harbor in compliance with the requirements of the specification cited above.

Not to be reproduced except for in full. Crosshead Speed Control Method Used for all Tensile Tests

Test certificates are prepared in accordance with procedures outlined in DIN EN 10204:2005 Type 3.1

DIVISION MANAGER
QUALITY ASSURANCE

D.J. FARRELL

BHTSTRPT.TIF

Page 2 of 2

Figure A-21. 12-Guage Tabbed Bracket, Version 10, Test No. MWP-8

MWP Hardware
R#16-0105
P#13055
Sept2015 SMT

QUALITY CERTIFICATE

NINGBO JINDING FASTENING PIECE CO., LTD

XIJINGTANG JIULONGHU NINGBO CHINA TEL:+86-574-86530122 FAX: +86-574-86530858

Customer:	FASTENAL COMPANY PURCHASING--IMPORT	Date :	2015-01-09
Product:	HEX CAP SCREWS	Contract No:	14JDF643T
Class:	5	Invoice No:	00331052-1
Size:	5/16-18X1	Lot No:	3324910004
Marking:	JDF three radius	Order No.	100045659
Quantity:	53.200 mpcs	Part No.	13055
		Production Date	2014-11-05
Dimensions Of SPEC:		Certificate No.:	20141024022

Inspection Items		Standard	Result	Sample	Pass
Visual Appearance		-------------	OK	29	29
Body Diameter		/	/	5	5
Thread	Go	3A	OK	15	15
	No Go	2A	OK	15	15
Width Across Flats		0.500-0.489	0.490-0.494	5	5
Width Across Corners		0.577-0.557	0.571-0.567	5	5
Major Diameter		0.311-0.303	0.309-0.310	15	15
Head Height		0.211-0.195	0.201-0.207	5	5
Total Length		0.970-1.000	0.984-0.976	15	15
Thread Length		min 0.861	0.886-0.925	15	15
Key Engagement		/	/		
Head Diameter		/	/		
Mechanical Properties					
CharacTeristics		Standard	Result		
Surface Hardness	[30N]	MAX 54	43-46	15	15
Core Hardness	[HRC]	25-34	27-29	15	15
Wedge Strength	[psi]	min 119880	140779-143536	5	5
Yield Strength	[psi]	min 91869	108995-110446	5	5
Elongation	[%]	min 14	17.4-17.7	5	5
Reduction Of area	[%]	min 35	48.9-50.5	5	5
Proof Load	[Ib]	4450	4450	5	5
Impact test -20℃	[Akv/J]	/	/		
Decarburization		N≥1/2H1 HV0.3	299.54 299.54 308.46	5	5
HV2>=HV1-30, HV3<=HV1+30		G 0.0006max			
CHEMICAL COMPOSITION(%)					

Heat No		C	Si	Mn	P	S	Cr	Ni	Cu	Mo	B
35#	4208029BA	0.36	0.18	0.67	0.018	0.009					
Thickness	[UM]		min 5				10.2-7.73			29	29

Surface Coating: ZPCr3+(coating test method: X ray according to ASTM B568M 2007 standard test

Thread Specification: ASME B1.1 2008, UNIFIED INCH SCREW THREADS(UN AND UNR THREAD FORM)

Sampling Dimension Specification: ASME B18.18.2 2011 inspection and quality assurance for high-volume machine assembly

Dimension Specification: ASME B18.2.1 2012, HEX CAP SCREWS

Sampling mechanical properties specification: ASTM F1470 2012 Standard Guide for Fastener Sampling for Specified Mechanical

Mechanical Properties: SAE J429 2013, MECHANICAL AND MATERIAL REQUIREMENTS FOR EXTERNALLY THREADED FASTENERS

Surface Defect: ASTM F788/F788M, SURFACE DISCONTINUITIES OF BOLTS, SCREWS, AND STUDS

Plating Specification: ASTM 1941 2010, Electrodeposited Coatings On Threaded Fasteners

Quality Control Supervisor | Quality Control Manager

Figure A-22. $^{5}/_{16}$-in. (8-mm) Dia. UNC, 1-in. (25-mm) Long Hex Cap Screw, Test No. MWP-8

SUPER CHENG INDUSTRIAL CO.,LTD.

NO. 18 BEN-GONG 2nd ROAD., BEN CHOU INDUSTRIAL PARK, KAOHSIUNG COUNTY 820, TAIWAN R.O.C.
TEL：886-7-6225326-30(5 LINES) FAX：886-7-6215377/6212335/6235829

CERTIFICATE OF INSPECTION

CERT. #： S77-1411-02T ISSUED DATE： 2014/12/13 PAGE 1 OF 1

CLIENT：SUPER CHENG INDUSTRIAL CO., LTD.
ADDRESS：NO. 18 BEN-GONG 2nd ROAD., BEN CHOU INDUSTRIAL PARK, KAOHSIUNG COUNTY 820, TAIWAN R.O.C.

PURCHASER： FASTENAL COMPANY PURCHASING PO #：210085084
PART #36304 QTY SHIPPED：162,000 PCS

COMMODITY：GRADE 5 FIN HEX NUT FINISH： TRIVALENT ZINC
SIZE： 5/16-18 LOT#： S77-1411-02 SAMPLING PLAN：ANSI/ASME B18.18.2M-93
QTY： 820000 PCS MATERIAL： SAE1010 HEAT NO.： 2QG45
MANUFACTURER：SUPER CHENG IND. CO., LTD. MANU. DATE： 2014/11/15

DIMENSIONAL INSPECTION SPEC.：ANSI/ASME B18.2.2-10 SAMPLED BY： FENG TE SU

ITEM	SAMPLE SIZE	SPECIFIED	ACTUAL RESULT	JUDGMENT
APPEARANCE	100	ASTM F812-12	GOOD	OK
W.A.F.	32	0.500 ~ 0.489 in.	0.494 ~ 0.494 in.	OK
W.A.C.	8	0.577 ~ 0.557 in.	0.562 ~ 0.559 in.	OK
THICKNESS	8	0.273 ~ 0.258 in.	0.268 ~ 0.264 in.	OK
THREAD	32	ANSI/ASME B1.1	PASS	OK

MECHANICAL PROPERTIES SPEC.：SAE J995-12 SAMPLED BY： FENG TE SU

ITEM	SAMPLE SIZE	TEST METHOD	SPECIFIED	ACTUAL RESULT	JUDGMENT
HARDNESS	8	ASTM F606-13	MAX HRC32	12.0 ~ 9.0 HRC	PASS
PROOF LOAD	4	ASTM F606-13	MIN 6300LB	6493 ~ 6486 LB	PASS
PLATING THICKNESS	4	ASTM B568-98	MIN 0.0001 in	0.00023 ~ 0.00016 in	PASS

MWP Hardware
R#16-0105
Sept2015 SMT

REMARK：1、THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL WITHOUT WRITTEN APPROVAL OF THE LAB.
2、THIS INSPECTION CERTIFICATE IS FOR RESPONSIBILITY UNDER SAMPLE ONLY
3、ABOVE SAMPLES TESTED CONFORM TO THE FASTENER SPECIFICATION OR STANDARDS

LAB. DIRECTOR(SIGNATORY)：

表單編號：LQC 10E Rev.0

Figure A-23. $^{5}/_{16}$-in. (8-mm) Nut, Test No. MWP-8

GERDAU

US-ML-BEAUMONT
100 OLD HIGHWAY 90 WEST
VIDOR, TX 77662
USA

CERTIFIED MATERIAL TEST REPORT Page 1/1

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	
BEKAERT CORPORATION 2020 RIVERFRONT RD VAN BUREN,AR 72956-6319 USA		1074M9	Wire Rod / 7/32"	
		LENGTH	WEIGHT	HEAT / BATCH
			0	53131499/02
SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION		
		1-WNA-1074 2-K02C/073		

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	N %
0.7353	0.54	0.008	0.016	0.23	0.11	0.06	0.03	0.016	0.006	0.0063

MECHANICAL PROPERTIES

Std.Dev. PSI	R/A Avg %	UTS PSI	UTS MPa
927	45.9	158598	1093

COMMENTS / NOTES

NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.

BEKAERT SAP NO. 1016904

The above figures are certified chemical and physical test records as contained in the permanent records of company. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

THAD BOUDREAUX
QUALITY ASSURANCE MGR.

Figure A-24. ¾-in. (19-mm) Diameter 3x7 Cable Guiderail, Test No. MWP-8

4CMwP 7/8" Nuts
R# 14-0325 White Paint
Feb 2014 SMT

INSPECTION CERTIFICATE

UNYTITE,INC.
One Unytite Drive
Peru, Illinois 61354
815-224-2221 — FAX# 815-224-3434

Customer	Specification	Size	Lot No.	Date
BENNETT BOLT WORKS 12 ELBRIDGE STREET JORDAN, N.Y. 13080	ASTM A-563 GRADE DH HEAVY HEX NUT	7/8- 9 UNC	MW471	Aug. 19,'08

Mechanical properties tested in accordance to ASTM F606/F606M, ASTM A370, ASTM E18

Chemical Composition (%)

Mill Maker	Material Size	Heat No. \ Spec.	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	
GERDAU AMER	CARBON		0.20 0.55	-	MIN. 0.60	MAX. 0.040	MAX. 0.050	-	-	-	-	-
ISTEEL(NO	STEEL	M643354	0.45	0.20	0.70	0.009	0.029	0.24	0.12	0.07	0.03	-

Shape & Dimension Inspection	ANSI B18.2.2 GOOD
Thread Precision Inspection	ANSI B1.1 CLASS 2B GOOD
Appearance Inspection	GOOD

Mechanical Property Inspection

Item	Proof Load	Cone Stripping	Hardness	Hardness	Absorbed Energy	Heat Treatment
Spec.	80,850 lbf	- kN • kgf • lbf	24-38 HRC	HRB • HB	J • kgfm • ftlbf	T:MIN.800 F
Results	n 5 Results GOOD	n - Results -	27.1 27.2 27.1 27.5 27.6 27.3	Hardness Treatment After 24 Hr.X °F (°C)	at °F (°C)	Q:FORGING Q (W.Q.) T:1149 F/45M. (W.C. Q : Quenching T : Tempering ST : Solution Treatment

Remarks:

"DH U"

Production Quantity 71,940 pcs.

OFFICIAL SEAL
JEAN MARGHERIO
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES:10/18/09
08-26-08

Material used for the nut was melted and manufactured in the USA. The nut was manufactured in the USA to the above specification.

We hereby certify that the material described has been manufactured and inspected satisfactorily with the requirement of the above specification.

Chief of Quality Assurance Section

Figure A-25. ⅞-in. (22-mm) Hex Nut, Test No. MWP-8

TC Industries Test Center
3703 South Route 31
Crystal Lake, IL 60012-1412
Telephone (815) 459-2400 Fax (815) 459-3419

TEST REPORT
REPORT NO: 168646
DATE: JULY 30, 2013
PAGE 1 OF 1

BILL TO: AMERICAN EAGLE STEEL
317 EAST 11TH STREET
CHICAGO HEIGHTS, IL 60411

SHIP TO: AMERICAN EAGLE STEEL
317 EAST 11TH STREET
CHICAGO HEIGHTS, IL 60411

DESC: 362 PCS .875"RD X 24' HEAT: 133079 GRADE: 1045 WT: 17740
PO: 1563-TC MO: 60190 CO: 1563 LOT: 88006

SPEC: QUENCH,TEMPER,STRAIGHTEN PINK ENDS ASTM A449-10

PROCESS: FURN TEMP: 1600 FURN TIME hh.mm: 1.00 QUENCH: WATER
TEMPER TEMP: 1125 TEMPER TIME hh.mm: 1.00
STRESS TEMP: STRESS TIME hh.mm:

PARAMETER	UNITS	LIMITS		TEST RESULTS (See sampling plan on back)					
TENSILE	KSI	120.0	N/A	143.0					
YIELD .2%	KSI	92.0	N/A	130.0					
ELONG 2"	%	14.0	N/A	17.0					
RED AREA	%	35.0	N/A	48.0					
SURF HB	HBW	255	321	282	285	285	293	285	285
				285	285				

4CMwP
Cable End Threaded Rod A449/1045
White Paint for Left
Red Paint for Right
Bennett Bolt Lot# 83219(left)83218(right)
Feb 2014 R#14-0325 SMT

ACCREDITED
Testing Cert #1281-01

TC INDUSTRIES and SUBCONTRACTED LABS (A2LA ACCREDITED)

Tensile, Standard TC	Rockwell	Micro Analysis
Tensile, Full Size	Brinell TC	Decarb Measure
Charpy V Notch	Ultra Sonic*	Chemistry*
Microhardness,Knoop*	Bend Test*	

TC: TC Test Center	BE: Berg Eng.	EX: Exova	MSI: Metallurgical Ser.
Cert #1281.01	Cert #L1157-1	Cert #104.02	Cert #0510.01
2/28/15	2/4/14	6/30/14	12/31/14

Time 17:39 DATE IN: 7/20/13 *not included in our scope of accreditation FC 4.12.16F 7/15/10
NOTES:

Ken Rueff
Ken Rueff
Test Center Supervisor

There are no deviations from test methods unless noted. It should not be assumed that mechanical properties of raw material heat treated to a fastener standard will have the same properties of a finished fastener whose original material characteristics may have been significantly altered.
No mercury was used/added and no welding/weld repair was performed on this material while in the possession of TC Industries, Inc.
This test report relates only to the items tested and shall not be reproduced, except in full, without the written permission of TC Industries Test Center.

Figure A-26. Cable End Threaded Rod, Test No. MWP-8

09/27/2007 10:02 3156893999 BENNETT BOLT WORKS PAGE 04
SEP-26-2007 10:13AM FROM-Buck Co. HR 717-284-4321 T-131 P.004/004 F-840

BUCK COMPANY, INC.

897 Lancaster Pike, Quarryville, PA 17566-9738
Phone (717) 284-4114 Fax (717) 284-4321
www.buckcompany.com greatcastings@buckcompany.com

MATERIAL CERTIFICATION

Date 8-30-07 Form# CERT-7A Rev C 4-21-06

CUSTOMER Bennett Bolt, Inc

ORDER NUMBER 75590

PATTERN NUMBER CGBBWTH REV. —

This is to certify that the castings listed conform to the following specifications and comply in all respects with the drawing or ordered requirements. All Quality Assurance provisions and / or Quality Assurance requirements and / or supplementary Quality Assurance provisions have been completed and accepted. SPC data is on file and available upon request.

Type Material: Malleable Iron

Specifications: ASTM-A47

Grade or Class: 32510

Heat Number: 924

MECHANICAL PROPERTIES		CHEMICAL ANALYSIS	
Tensile Str. PSI	24562	Total Carbon	3.70
		Silicon	2.86
Yield Str. PSI	45032	Manganese	.34
		Sulfur	.016
Elongation	22	Phosphorus	.020
		Chrome	.045
PHYSICAL PROPERTIES		Magnesium	.049
		Copper	.052
Brinell Hardness	163		
PCS SHIPPED	20	DATE SHIPPED	8-30-07

1 of 1

Quality Assurance Representative

Quality Castings
ISO 9001, 2000 CERTIFIED
Ferritic and Pearlitic Malleable Iron, Gray and Ductile Iron, Brass, Aluminum

Figure A-27. Bennett Cable End Fitter, Test No. MWP-8

Phone (717) 284-4114 Fax (717) 284-4321
www.buckcompany.com greatcastings@buckcompany.com

MWP Cable Wedges R#14-0455 July 2014 SMT

MATERIAL CERTIFICATION

Date 12/4/12 Form# CERT-7A Rev C 4-21-06

CUSTOMER Bennett Bolt

ORDER NUMBER 6010328

PATTERN NUMBER W1 Wedge REV. Orig

This is to certify that the castings listed conform to the following specifications and comply in all respects with the drawing or ordered requirements. All Quality Assurance provisions and / or Quality Assurance requirements and / or supplementary Quality Assurance provisions have been completed and accepted. SPC data is on file and available upon request.

Type Material: Malleable Iron

Specifications: ASTM - A47

Grade or Class: 32510

Heat Number: BR1

MECHANICAL PROPERTIES		CHEMICAL ANALYSIS	
Tensile Str. PSI	51,300	Total Carbon	2.62
		Silicon	1.69
Yield Str. PSI	35,200	Manganese	.34
		Sulfur	.125
Elongation	11	Phosphorus	.019
		Chrome	.038
PHYSICAL PROPERTIES		Magnesium	.001
		Copper	.483
Brinell Hardness	126		

PCS SHIPPED 5,123 DATE SHIPPED 12/3/12

1 of 1

Lolita Lopez
Quality Assurance Representative

Quality Castings
ISO 9001: 2008 CERTIFIED
Ferritic and Pearlitic Malleable Iron, Gray and Ductile Iron, Brass, Aluminum

Figure A-28. Cable Wedges, Test No. MWP-8

10/05/99 15:05 ☎14409920360 KEN FORGING 002/002

KEN FORGING
KEN FORGING, INC.

OCTOBER 5, 1999

BENNETT BOLT WORKS, INC.
12 ELBRIDGE STREET
JORDAN, NY 13080

4CMwP Turnbuckles
R# 14-0325 White Paint
Bennett Bolt Lot# 21331/18305
COC Feb 2014 SMT

CERIFICATION OF CONFORMANCE

THIS LETTER IS TO ADVISE THE TURNBUCKLES NOTED BELOW ARE MANUFACTURED IN THE UNITED STATES OF AMERICA BY KEN FORGING, INC,

THESE TURNBUCKLES ARE MANUFACTURED IN COMPLIANCE WITH FEDERAL SPECIFICATION FF-T-791 1b TYPE 1

PURCHASED ORDER NO. 7158

PART NUMBER : TB109-G TB110-G

QUANTITY SHIPPED: 8PCS. 100PCS

DATE SHIPPED: 9/8/99

KEN FORGING, INC.

1049 Griggs Road • Post Office Box 277 • Jefferson, OH 44047
(440) 993-8091 • Fax: (440) 992-0360

Figure A-29. Bennet Short Threaded Turnbuckle, Test No. MWP-8

Certificate of Quality

BEKAERT CORPORATION Van Buren,Arkansas

1881 BEKAERT DRIVE
VAN BUREN, AR 72956
TEL(479)474-5211 FAX(479)474-9075
TELEX 537439

DATE: 06/03/2010

Customer Midwest Roadside Safety Facili
Our Order No 4060145416 0010
Product 3/4" 3X7 CL A GALV GUIDERAIL SHORTS
Customer Part No
MFG SMP No AST3043SE10S

Customer Order No sample
Qty 3 Carriers
Customer Spec No ASTM A 741

nished g#	Diameter in	Lay Length (in.)	Breaking Load lbf	Adherence Appearance of Wires	Steel Ductility
609409	0.79	6	46525	Pass	Pass
609459	0.75	7	46548	Pass	Pass
609513	0.75	7.3	49219	Pass	Pass

terial was melted and made in the U.S.A.
e undersigned certifies that the results are actual results and conform to the specification indicated
contained in the records of this Corporation.

ocess Control Manager

Notary Public Commission Expires

Figure A-30. Bekaert Wire Rope, Test No. MWP-8

Appendix B. Vehicle Center of Gravity Determination

Test: MWP-8 Vehicle: Kia Rio

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb.)
+	Non-ballasted Car (curb)	2398
+	Brake receivers/wires	5
+	Brake Actuator and Frame	7
+	Nitrogen Cylinder	22
+	Strobe/Brake Battery	5
+	Hub	19
+	Data Acquisition Tray	13
-	Battery	-31
-	Oil	-5
-	Interior	-49
-	Fuel	0
-	Coolant	-9
-	Washer fluid	-5
	Water Ballast	32
	Misc.	
	Misc.	
	Estimated Total Weight (lb.)	2402

Roof Height (in.) 57 1/2
Wheel base (in.) 98 1/2

Center of Gravity	1100C MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb.)	2420 (+/-)55	2419	-1.0
Longitudinal CG (in.)	39 (+/-)4	37.38	-1.61968
Lateral CG (in.)	NA	0	NA
Vertical CG (in.)	NA	#REF!	NA

Note: Long. CG is measured from front axle of test vehicle
Note: Lateral CG measured from centerline - positive to vehicle right (passenger) side
Note: Cells Highlighted in Red do not meet target requirements

CURB WEIGHT (lb.)

	Left	Right
Front	788	740
Rear	423	447

FRONT 1528 lb.
REAR 870 lb.
TOTAL 2398 lb.

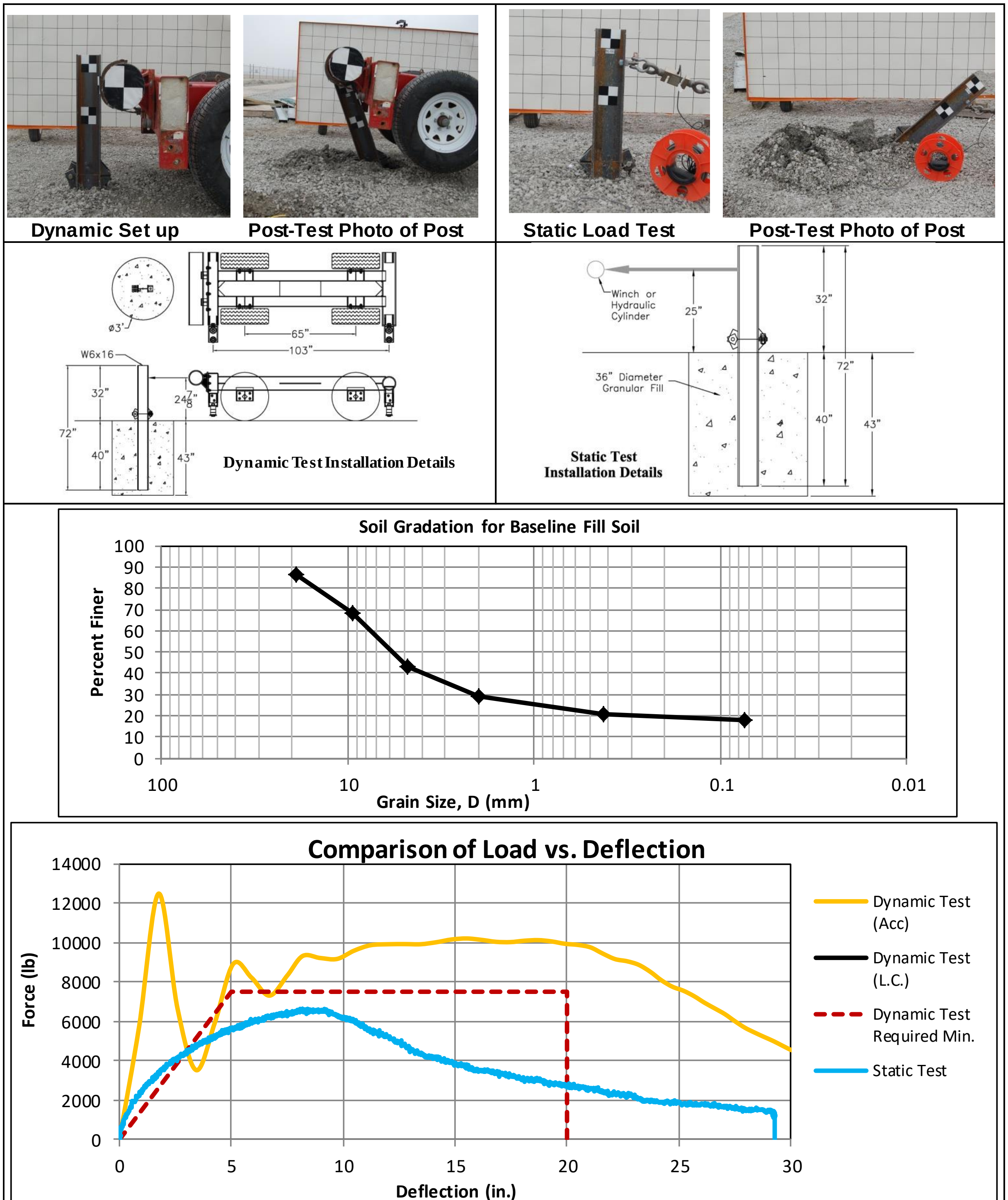
TEST INERTIAL WEIGHT (lb.)
(from scales)

	Left	Right
Front	736	765
Rear	472	446

FRONT 1501 lb.
REAR 918 lb.
TOTAL 2419 lb.

Figure B-1. Vehicle Mass Distribution, Test No. MWP-8

Appendix C. Static Soil Tests

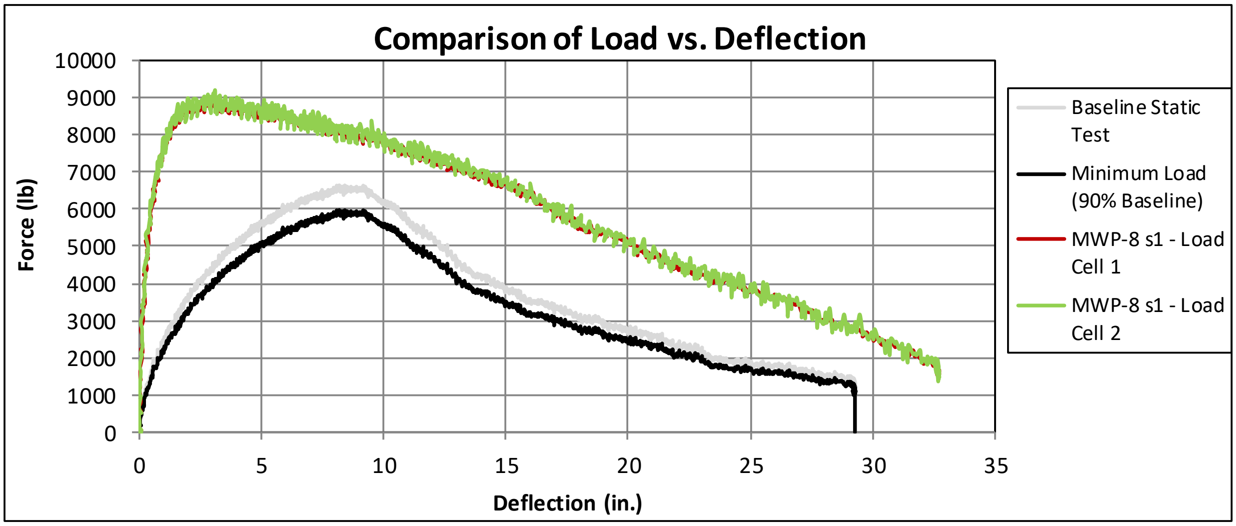


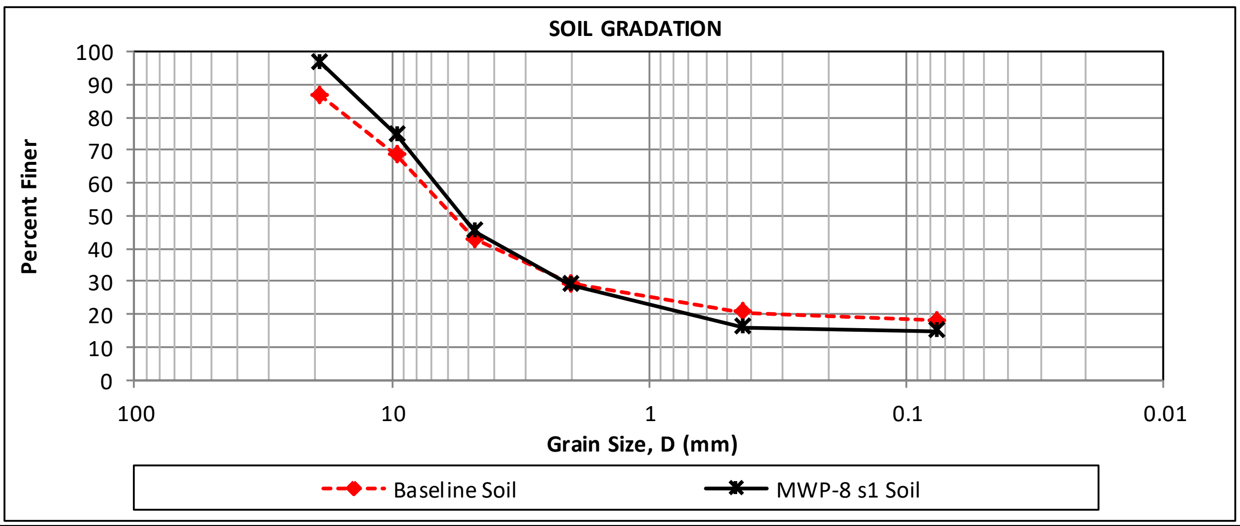
Date	4/4/2012
Test Facility & Site Location	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)	Well-Graded Gravel (GW)
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure	3 Pass, 8" Lift
Bogie Weight	1844 lb — 836 kg
Impact Velocity	20.1 mph — 32.3 km/h

Figure C-1. Soil Strength, Initial Calibration Tests, Test No. MWP-8

Static Load Test Setup

Post-Test Photo of Post





Date..	10/16/2015
Test Facility & Site Location.....................	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487).........	Low Plasticity Silt (ML)
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. MWP-8

Appendix D. Vehicle Deformation Records

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 1

TEST: MWP-8
VEHICLE: Kia Rio

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
1	28.566	-21.592	4.639	28.551	-21.558	4.826	-0.015	0.034	0.187
2	30.610	-17.401	3.058	30.578	-17.400	3.301	-0.032	0.001	0.243
3	33.174	-12.259	0.515	33.169	-12.223	0.736	-0.006	0.037	0.222
4	31.191	-5.192	-1.687	31.159	-5.152	-1.474	-0.032	0.040	0.213
5	28.367	-18.087	-1.238	28.356	-18.063	-0.975	-0.010	0.024	0.263
6	30.755	-14.519	-1.218	30.730	-14.521	-0.995	-0.025	-0.002	0.223
7	30.702	-10.518	-1.811	30.714	-10.542	-1.568	0.012	-0.025	0.243
8	30.029	-3.894	-2.543	30.025	-3.870	-2.322	-0.003	0.024	0.220
9	25.000	-18.487	-4.249	25.000	-18.422	-4.032	0.000	0.065	0.217
10	24.833	-14.478	-4.233	24.843	-14.511	-3.986	0.010	-0.033	0.247
11	25.017	-10.302	-4.698	25.009	-10.342	-4.471	-0.008	-0.040	0.228
12	24.668	-3.845	-5.095	24.706	-3.859	-4.869	0.038	-0.014	0.226
13	21.765	-18.596	-5.046	21.805	-18.563	-4.832	0.040	0.033	0.214
14	21.522	-13.949	-5.089	21.488	-13.915	-4.869	-0.033	0.033	0.220
15	21.205	-9.621	-5.563	21.259	-9.587	-5.285	0.053	0.034	0.277
16	20.160	-4.636	-5.680	20.169	-4.652	-5.255	0.010	-0.016	0.425
17	16.140	-22.412	-4.809	16.131	-22.382	-4.611	-0.010	0.030	0.198
18	15.653	-15.842	-4.910	15.665	-15.838	-4.699	0.012	0.004	0.212
19	16.159	-11.295	-5.251	16.178	-11.280	-5.037	0.019	0.015	0.214
20	15.649	-4.635	-5.878	15.658	-4.689	-5.398	0.008	-0.054	0.480
21	9.800	-22.546	-4.442	9.833	-22.541	-4.226	0.034	0.004	0.216
22	9.087	-16.417	-4.476	9.100	-16.377	-4.269	0.013	0.040	0.207
23	8.983	-10.324	-4.830	9.008	-10.327	-4.483	0.025	-0.004	0.347
24	8.671	-5.048	-5.608	8.693	-5.045	-5.222	0.021	0.003	0.386
25	2.488	-21.638	-0.443	2.484	-21.571	-0.229	-0.004	0.068	0.214
26	1.988	-16.547	-0.484	1.986	-16.549	-0.272	-0.002	-0.002	0.212
27	1.979	-11.016	-0.818	1.945	-11.046	-0.603	-0.034	-0.029	0.214
28	2.440	-4.492	-1.557	2.395	-4.410	-1.338	-0.045	0.082	0.220

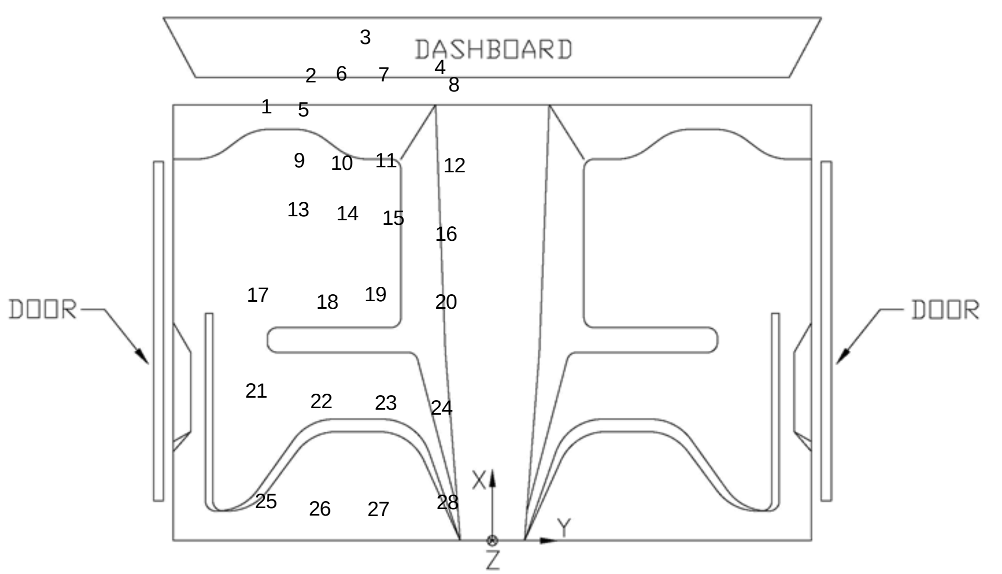


Figure D-1. Floorpan Deformation Data – Set 1, Test No. MWP-8

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 2

TEST: MWP-8
VEHICLE: Kia Rio

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
1	45.408	-28.419	4.420	45.181	-28.359	4.410	-0.227	0.060	-0.010
2	47.400	-24.184	3.153	47.143	-24.161	3.151	-0.257	0.023	-0.002
3	49.942	-18.787	0.899	49.702	-18.744	0.921	-0.240	0.043	0.022
4	47.861	-11.654	-0.860	47.713	-11.776	-0.850	-0.148	-0.121	0.010
5	45.151	-24.588	-1.199	44.894	-24.513	-1.229	-0.257	0.074	-0.030
6	47.484	-20.984	-0.981	47.276	-20.972	-0.971	-0.208	0.012	0.010
7	47.439	-17.026	-1.303	47.188	-16.971	-1.317	-0.251	0.055	-0.014
8	46.700	-10.331	-1.626	46.462	-10.311	-1.644	-0.238	0.020	-0.018
9	41.745	-24.799	-4.213	41.540	-24.762	-4.222	-0.205	0.037	-0.009
10	41.584	-20.846	-3.937	41.375	-20.853	-3.918	-0.209	-0.007	0.019
11	41.688	-16.632	-4.166	41.503	-16.596	-4.146	-0.184	0.036	0.020
12	41.384	-10.148	-4.116	41.141	-10.144	-4.134	-0.243	0.004	-0.018
13	38.577	-24.855	-4.984	38.354	-24.828	-5.007	-0.224	0.027	-0.023
14	38.209	-20.229	-4.741	37.975	-20.183	-4.756	-0.234	0.046	-0.015
15	37.948	-15.843	-4.940	37.737	-15.887	-4.895	-0.211	-0.043	0.045
16	36.848	-10.960	-4.738	36.620	-10.967	-4.556	-0.228	-0.007	0.182
17	32.946	-28.729	-4.948	32.672	-28.718	-4.992	-0.274	0.011	-0.043
18	32.472	-22.207	-4.640	32.187	-22.228	-4.667	-0.286	-0.021	-0.027
19	32.896	-17.662	-4.703	32.648	-17.629	-4.721	-0.249	0.032	-0.018
20	32.325	-10.937	-4.898	32.091	-10.981	-4.678	-0.234	-0.044	0.219
21	26.578	-28.969	-4.561	26.397	-28.935	-4.590	-0.181	0.035	-0.029
22	25.886	-22.825	-4.214	25.639	-22.820	-4.247	-0.248	0.005	-0.033
23	25.667	-16.719	-4.187	25.465	-16.696	-4.093	-0.202	0.022	0.095
24	25.308	-11.470	-4.636	25.140	-11.447	-4.505	-0.169	0.023	0.131
25	19.312	-28.283	-0.473	19.092	-28.297	-0.504	-0.221	-0.014	-0.031
26	18.744	-23.292	-0.195	18.568	-23.302	-0.229	-0.176	-0.010	-0.035
27	18.691	-17.749	-0.183	18.487	-17.766	-0.217	-0.204	-0.017	-0.034
28	19.133	-11.092	-0.520	18.878	-11.187	-0.545	-0.255	-0.094	-0.025

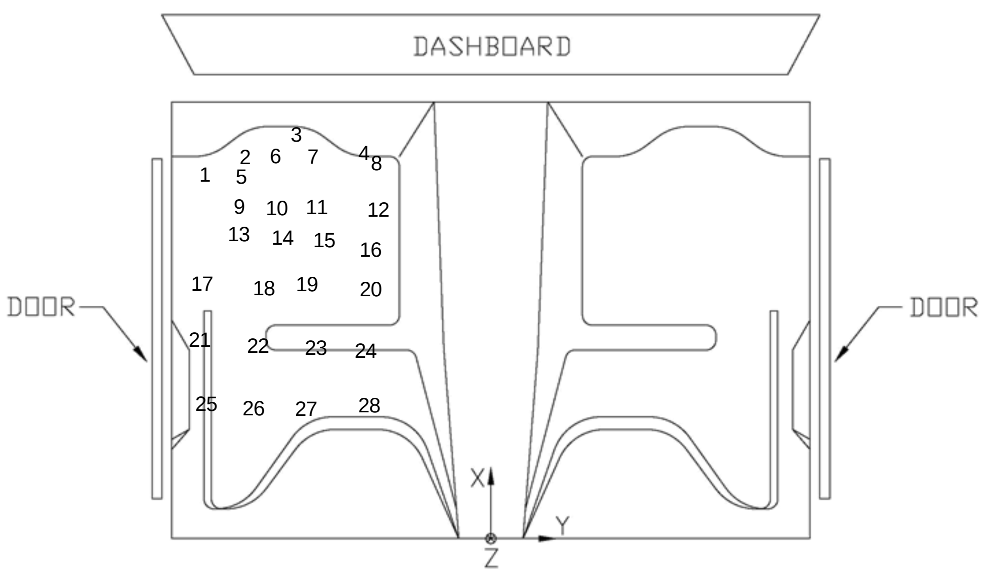


Figure D-2. Floorpan Deformation Data – Set 2, Test No. MWP-8

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1

TEST: MWP-8
VEHICLE: Kia Rio

	POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
DASH	1	16.158	-21.841	23.014	16.208	-21.841	23.194	0.051	0.001	0.180
	2	13.422	-9.954	26.183	13.496	-9.926	26.399	0.074	0.028	0.216
	3	15.596	4.805	22.465	15.584	4.897	22.680	-0.012	0.092	0.215
	4	13.500	-21.954	15.332	13.538	-21.969	15.522	0.038	-0.015	0.189
	5	13.368	-3.902	15.315	13.369	-3.840	15.569	0.001	0.062	0.255
	6	10.683	3.406	15.485	10.733	3.429	15.719	0.050	0.023	0.234
SIDE PANEL	7	19.921	-24.417	4.525	19.884	-24.369	4.751	-0.038	0.048	0.227
	8	19.224	-24.636	1.687	19.169	-24.597	1.897	-0.055	0.039	0.210
	9	24.869	-24.290	6.362	24.897	-24.250	6.551	0.028	0.041	0.189
IMPACT SIDE DOOR	10	-10.519	-24.119	25.463	-10.381	-24.336	25.717	0.137	-0.217	0.254
	11	2.376	-24.161	23.862	2.446	-24.321	24.228	0.071	-0.160	0.366
	12	13.690	-24.258	22.538	13.733	-24.369	22.732	0.044	-0.111	0.193
	13	-7.505	-25.887	4.505	-7.478	-25.899	4.761	0.028	-0.012	0.256
	14	1.246	-26.095	4.427	1.253	-26.152	4.681	0.007	-0.057	0.255
	15	9.233	-26.171	2.682	9.206	-26.264	2.833	-0.027	-0.093	0.151
ROOF	1	19.980	-21.638	26.981	20.057	-21.523	27.122	0.077	0.115	0.142
	2	13.679	-19.991	31.585	13.784	-19.828	31.656	0.105	0.162	0.071
	3	7.385	-18.357	35.468	7.580	-18.237	35.595	0.195	0.119	0.127
	4	3.186	-16.242	39.149	3.270	-16.259	39.339	0.084	-0.017	0.190
	5	4.177	-9.080	39.177	4.205	-9.024	39.413	0.028	0.056	0.236
	6	4.673	-2.364	38.969	4.777	-2.338	39.161	0.105	0.026	0.191
	7	4.763	4.376	38.637	4.828	4.339	38.854	0.065	-0.037	0.217
	8	-2.045	-14.804	41.827	-1.879	-14.824	42.001	0.165	-0.020	0.173
	9	-1.587	-8.619	41.934	-1.486	-8.619	42.137	0.100	-0.001	0.203
	10	-0.797	-1.796	41.656	-0.737	-1.756	41.875	0.061	0.040	0.219
	11	-0.868	4.451	41.389	-0.788	4.487	41.601	0.080	0.036	0.212
	12	-9.615	-11.991	43.628	-9.515	-12.002	43.826	0.100	-0.011	0.199
	13	-9.617	-6.979	43.694	-9.575	-7.018	43.910	0.041	-0.039	0.216
	14	-9.686	-0.862	43.592	-9.569	-0.862	43.799	0.117	-0.001	0.207
	15	-9.673	5.571	43.259	-9.493	5.591	43.453	0.181	0.019	0.194

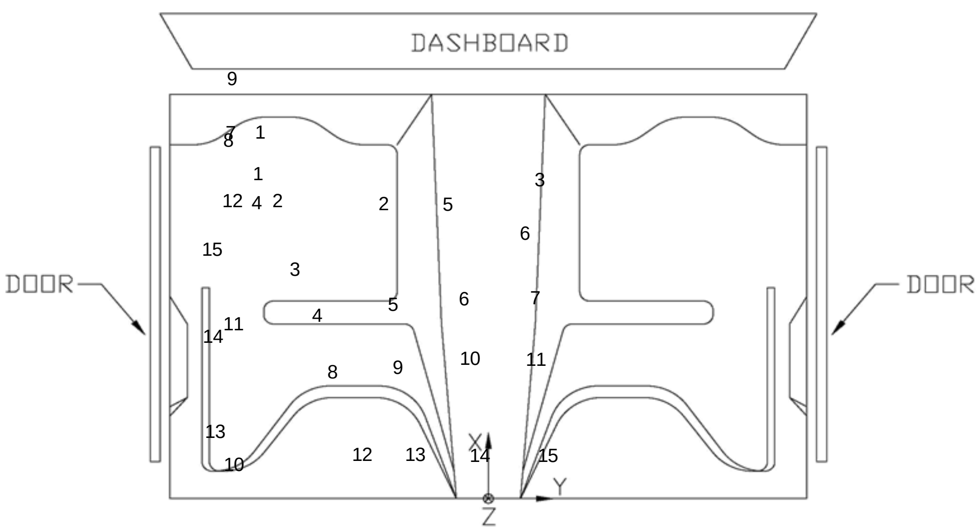


Figure D-3. Occupant Compartment Deformation Data – Set 1, Test No. MWP-8

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2

TEST: MWP-8
VEHICLE: Kia Rio

	POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
DASH	1	33.178	-29.942	22.894	32.939	-29.935	22.850	-0.239	0.007	-0.044
	2	30.313	-18.328	26.783	30.102	-18.284	26.731	-0.212	0.044	-0.052
	3	32.313	-3.257	23.950	32.122	-3.229	23.907	-0.191	0.028	-0.043
	4	30.421	-29.642	15.201	30.211	-29.572	15.179	-0.210	0.070	-0.022
	5	30.148	-11.621	16.283	29.937	-11.504	16.236	-0.211	0.117	-0.047
	6	27.421	-4.364	16.953	27.212	-4.294	16.908	-0.209	0.070	-0.045
SIDE PANEL	7	36.746	-31.319	4.274	36.566	-31.271	4.209	-0.180	0.048	-0.065
	8	36.095	-31.365	1.393	35.790	-31.330	1.343	-0.304	0.035	-0.049
	9	41.749	-31.266	6.008	41.509	-31.227	5.982	-0.240	0.039	-0.026
IMPACT SIDE DOOR	10	6.406	-32.570	25.279	6.294	-32.769	25.318	-0.112	-0.199	0.039
	11	19.337	-32.407	23.663	19.196	-32.564	23.643	-0.141	-0.157	-0.019
	12	30.646	-32.315	22.222	30.451	-32.437	22.203	-0.195	-0.122	-0.020
	13	9.413	-32.991	4.218	9.178	-33.009	4.258	-0.235	-0.018	0.040
	14	18.159	-33.124	4.150	17.904	-33.182	4.092	-0.254	-0.058	-0.058
	15	26.064	-33.035	2.281	25.846	-33.131	2.359	-0.218	-0.097	0.078
ROOF	1	37.008	-29.927	26.812	36.774	-29.811	26.743	-0.234	0.116	-0.069
	2	30.736	-28.620	31.511	30.537	-28.452	31.385	-0.199	0.168	-0.125
	3	24.519	-27.277	35.501	24.331	-27.161	35.433	-0.188	0.116	-0.068
	4	20.243	-25.447	39.353	20.033	-25.451	39.333	-0.210	-0.004	-0.020
	5	21.174	-18.244	39.827	20.974	-18.261	39.815	-0.201	-0.018	-0.013
	6	21.674	-11.533	40.006	21.490	-11.434	39.979	-0.184	0.099	-0.027
	7	21.711	-4.830	40.098	21.507	-4.793	40.079	-0.204	0.037	-0.019
	8	14.972	-24.230	42.159	14.806	-24.189	42.124	-0.166	0.042	-0.035
	9	15.437	-18.049	42.636	15.282	-18.045	42.604	-0.156	0.003	-0.031
	10	16.091	-11.169	42.805	15.978	-11.173	42.766	-0.113	-0.004	-0.039
	11	15.998	-4.962	42.917	15.842	-4.977	42.891	-0.156	-0.015	-0.026
	12	7.357	-21.538	44.179	7.200	-21.556	44.145	-0.157	-0.018	-0.033
	13	7.350	-16.554	44.550	7.206	-16.619	44.519	-0.145	-0.065	-0.031
	14	7.243	-10.428	44.829	7.066	-10.491	44.810	-0.176	-0.062	-0.019
	15	7.284	-3.988	44.878	7.129	-3.967	44.858	-0.155	0.021	-0.019

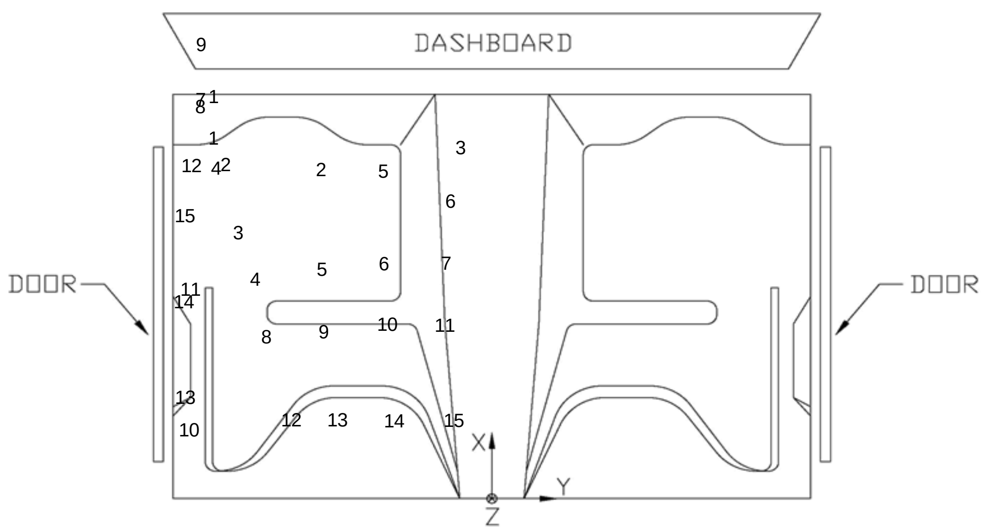
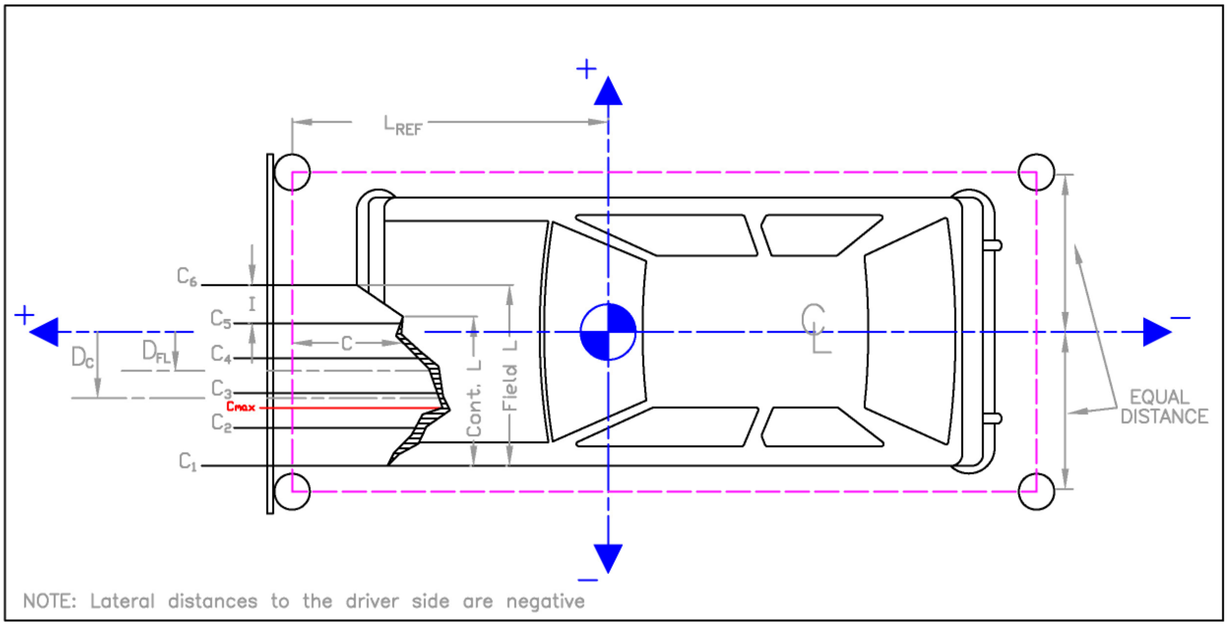


Figure D-4. Occupant Compartment Deformation Data – Set 2, Test No. MWP-8

Date: 10/21/2015 **Test Number:** MWP-8

Make: Kia **Model:** Rio **Year:** 2008



Blue Cells to be filled out Before Test
Orange Cells to Be filled out After Test

	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	71	(1803)
Total Width of Vehicle:	61 3/4	(1568)
Width of contact and induced crush - Field L:	61 3/4	(1568)
Crush measurement spacing interval (L/5) - I:	12 1/3	(314)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	61 3/4	(1568)
Distance from center of vehicle to center of contact damage - D_C:	0	()

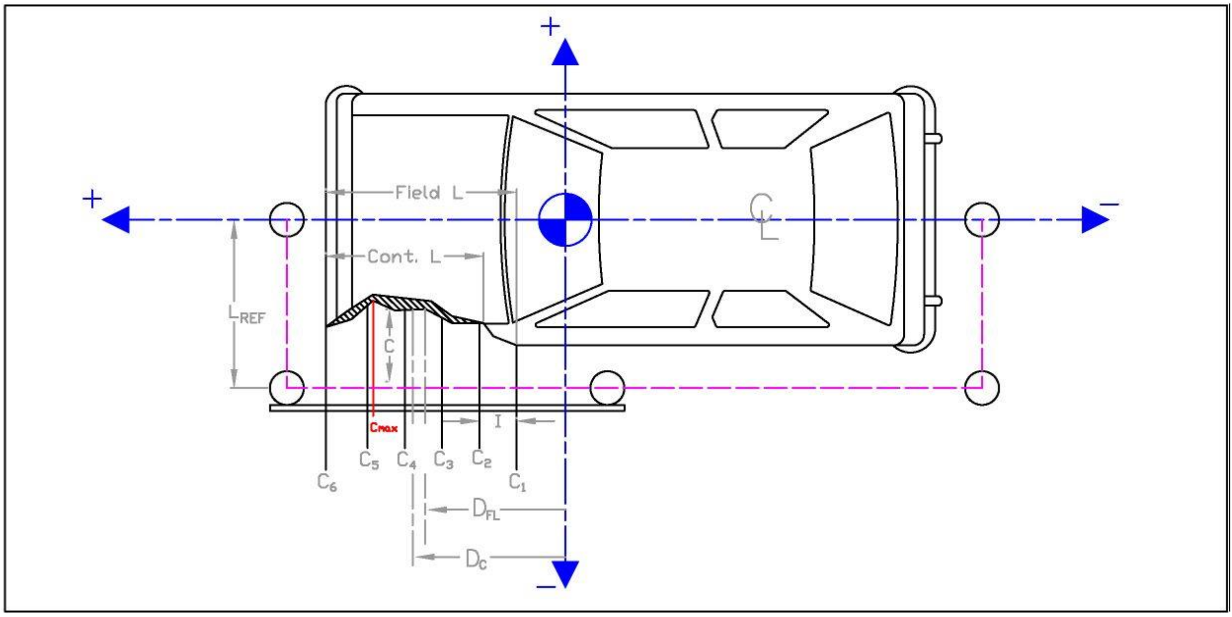
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement in.	(mm)	Lateral Location in.	(mm)	Original Profile Measurement in.	(mm)	Dist. Between Ref. Lines in.	(mm)	Actual Crush in.	(mm)
C_1	NA	NA	-30 7/8	-(784)	19 7/8	(505)	-5 3/8	-(137)	NA	NA
C_2	5 1/2	(140)	-18 1/2	-(471)	8 1/4	(210)			2 3/5	(66)
C_3	3 3/8	(86)	-6 1/6	-(157)	6 1/7	(156)			2 3/5	(66)
C_4	3 1/8	(79)	6 1/6	(157)	6 1/8	(156)			2 3/8	(60)
C_5	4 1/4	(108)	18 1/2	(471)	8 2/9	(209)			1 2/5	(36)
C_6	NA	NA	30 7/8	(784)	18 5/6	(479)			NA	NA
C_{MAX}	5 1/2	(140)	18	(457)	8 1/8	(206)			2 3/4	(70)

Figure D-5. Exterior Vehicle Crush (NASS) - Front, Test No. MWP-8

Date: 42298 **Test Number:** MWP-8

Make: Kia **Model:** Rio **Year:** 2008



Blue Cells to be filled out Before Test
Orange Cells to Be filled out After Test

	in.	(mm)
Distance from centerline to reference line - L_{REF}:	37.5	(953)
Total Vehicle Length:	167.25	(4248)
Width of contact and induced crush - Field L:	167.25	(4248)
Crush measurement spacing interval (L/5) - I:	33.45	(850)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-13 1/2	-(343)
Width of Contact Damage:	167.25	(4248)
Distance from vehicle c.g. to center of contact damage - D_C:	-13 1/2	-(343)

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

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual	Crush
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	NA	NA	-97.12	-(2467)	26.00	(660)	1.5	(38)	NA	NA
C_2	5.25	(133)	-63.67	-(1617)	4.00	(102)			-0.3	-(6)
C_3	4.625	(117)	-30.22	-(768)	3.63	(92)			-0.5	-(13)
C_4	4.875	(124)	3.2303	(82)	3.75	(95)			-0.4	-(10)
C_5	5	(127)	36.68	(932)	3.25	(83)			0.3	(6)
C_6	NA	NA	70.13	(1781)	21.75	(552)			NA	NA
C_{MAX}	10	(254)	54	(1372)	4.56	(116)			3.9	(100)

Figure D-6. Exterior Vehicle Crush (NASS) - Side, Test No. MWP-8

Appendix E. Accelerometer and Rate Transducer Data Plots, Test No. MWP-8

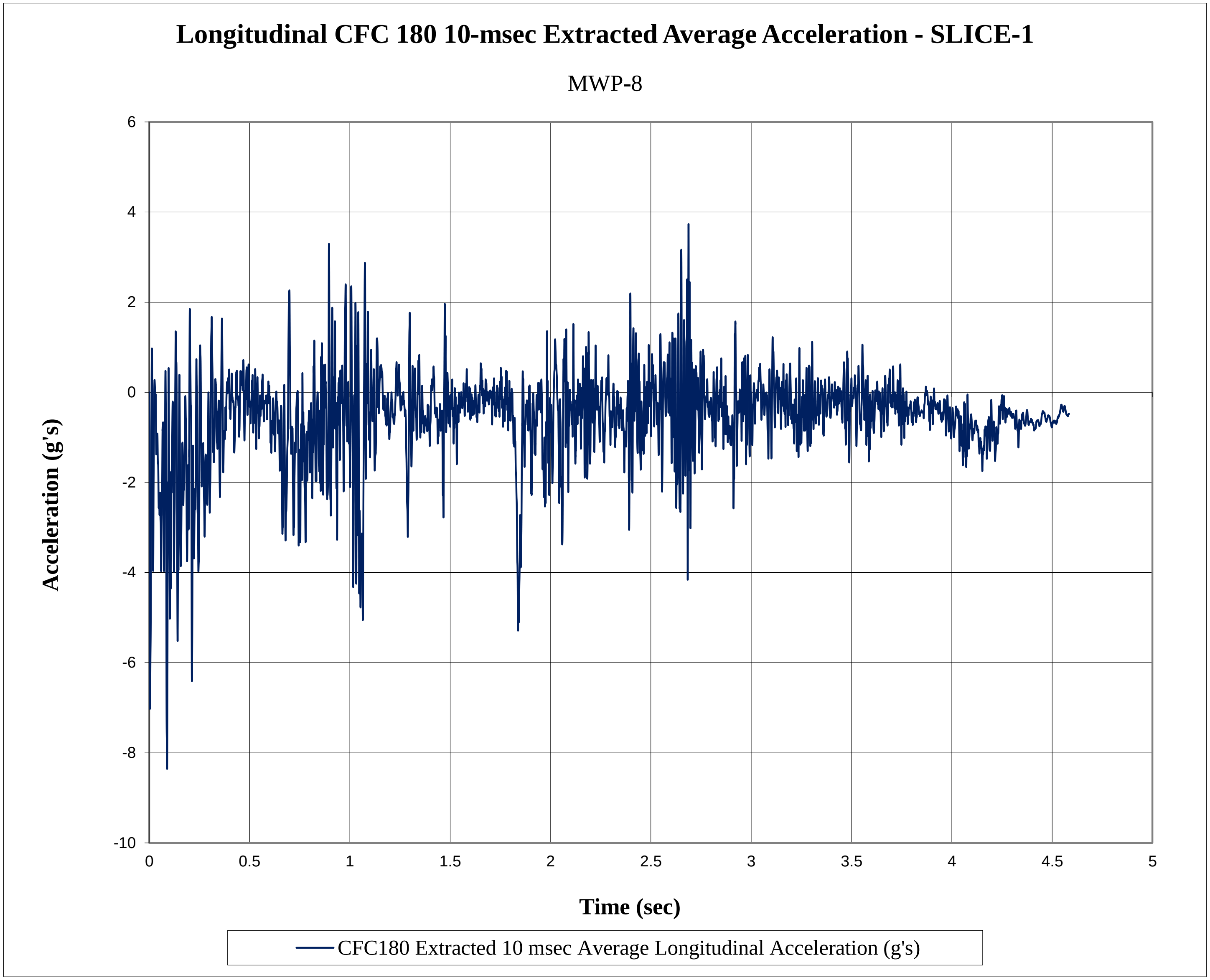


Figure E-1. 10-ms Average Longitudinal Acceleration (SLICE-1), Test No. MWP-8

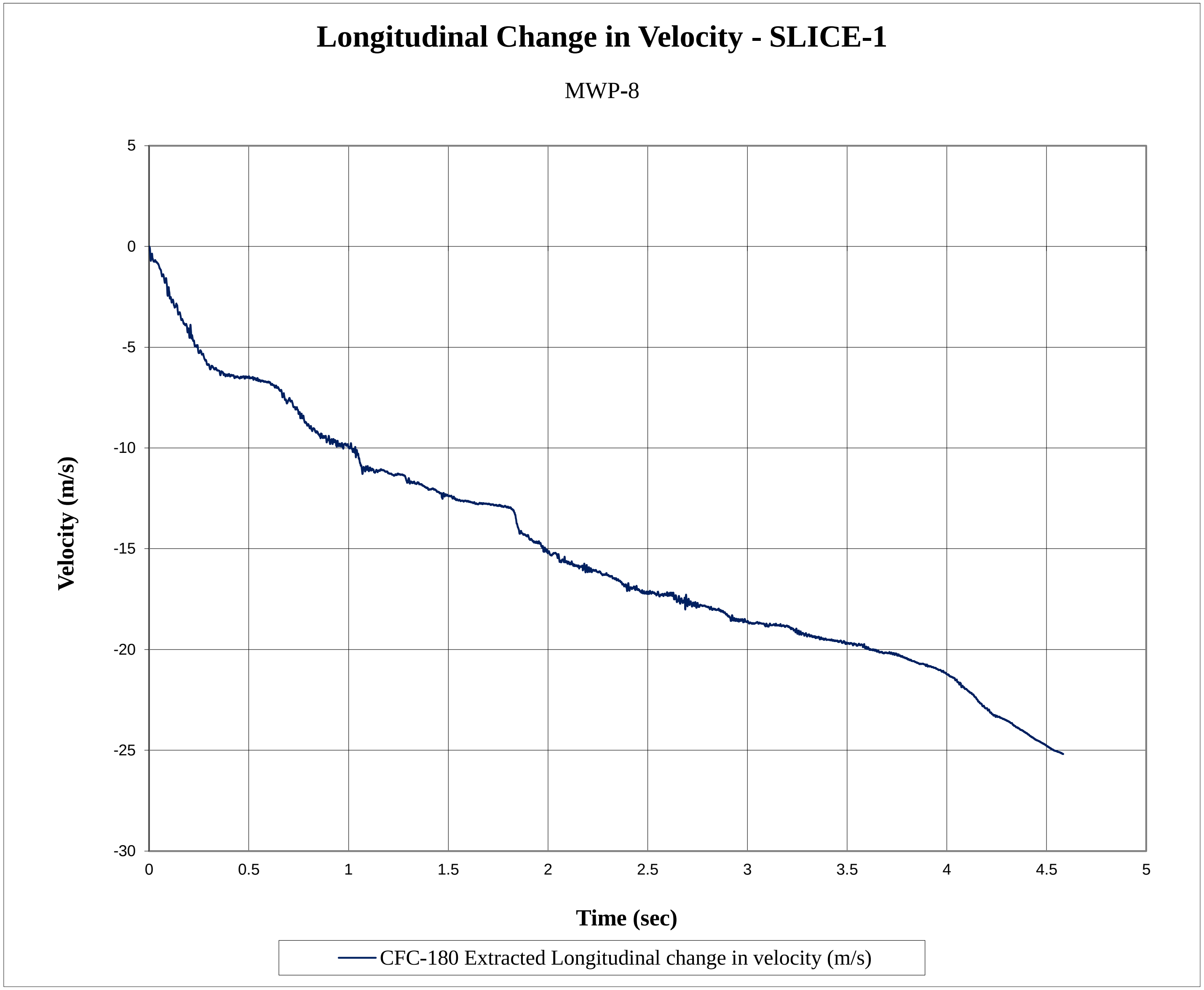


Figure E-2. Longitudinal Change in Velocity (SLICE-1), Test No. MWP-8

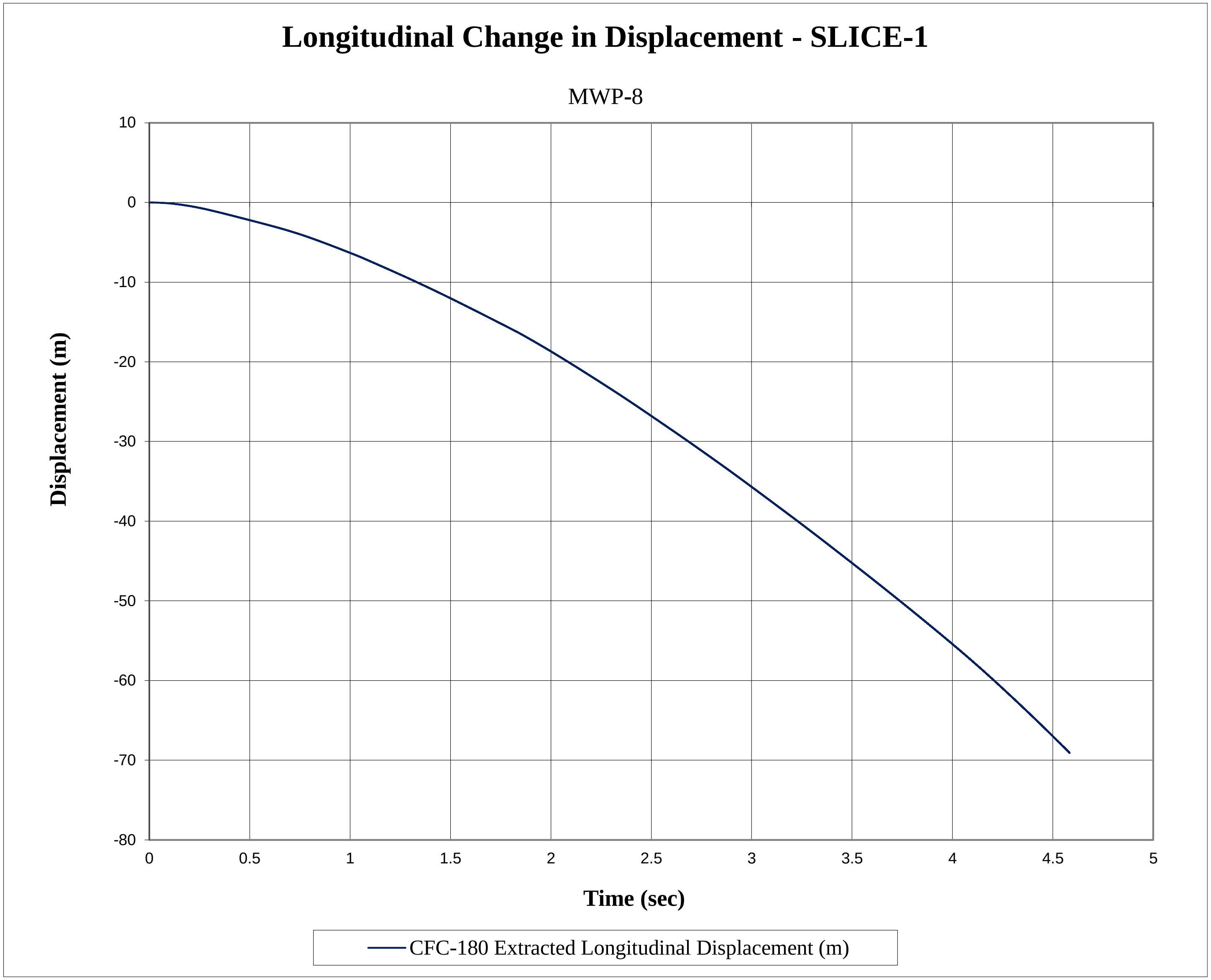


Figure E-3. Longitudinal Occupant Displacement (SLICE-1), Test No. MWP-8

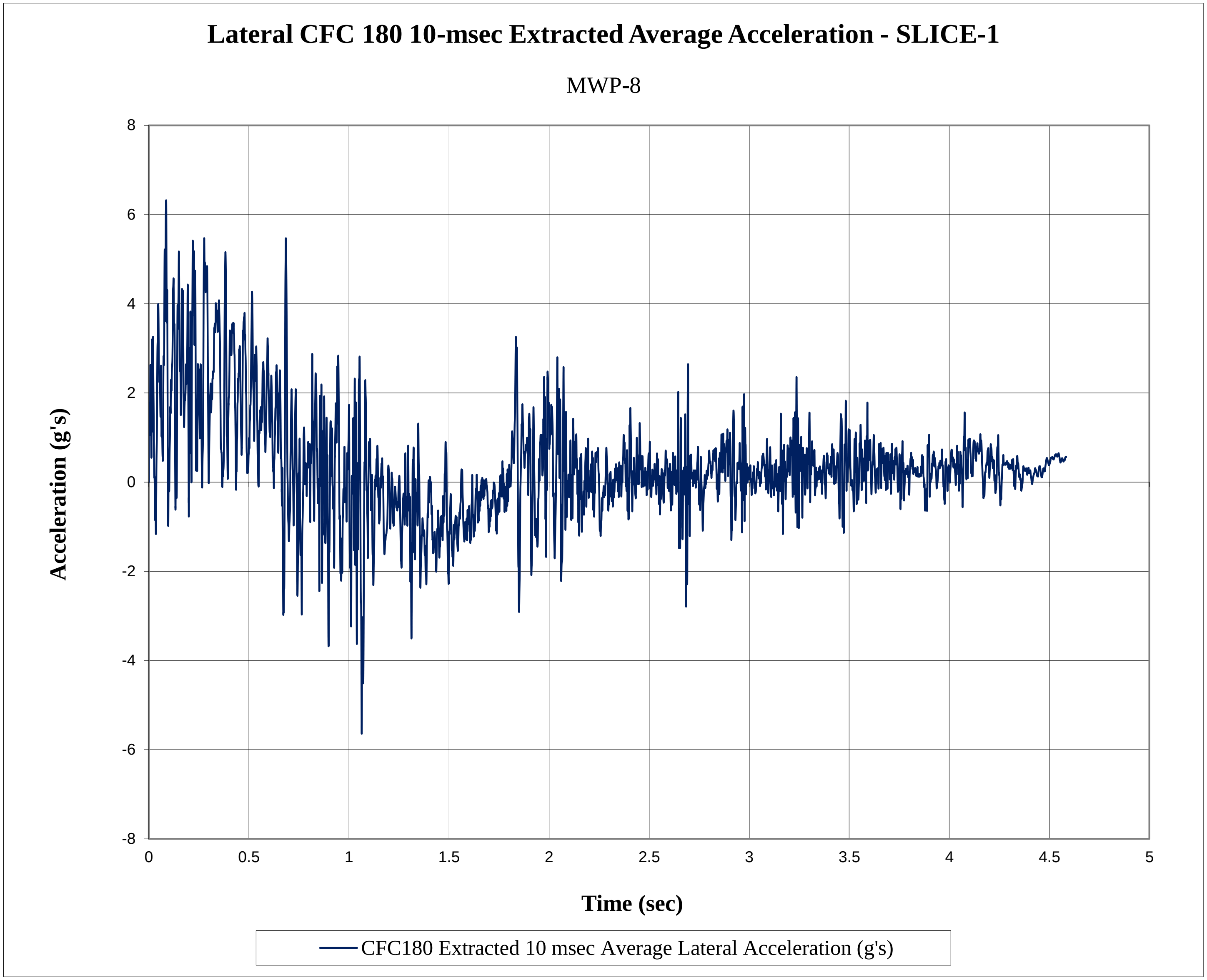


Figure E-4. 10-ms Average Lateral Acceleration (SLICE-1), Test No. MWP-8

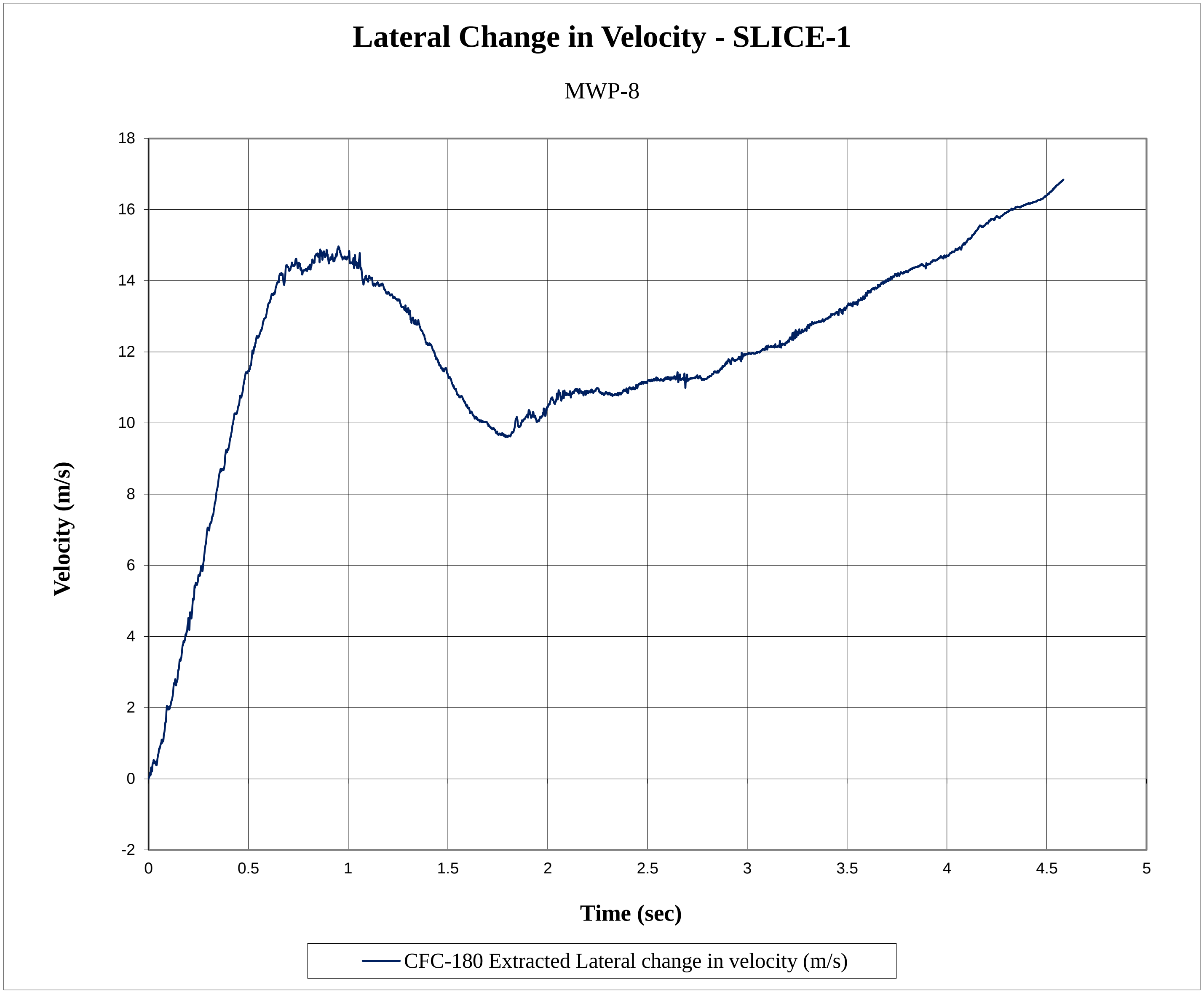


Figure E-5. Lateral Change in Velocity (SLICE-1), Test No. MWP-8

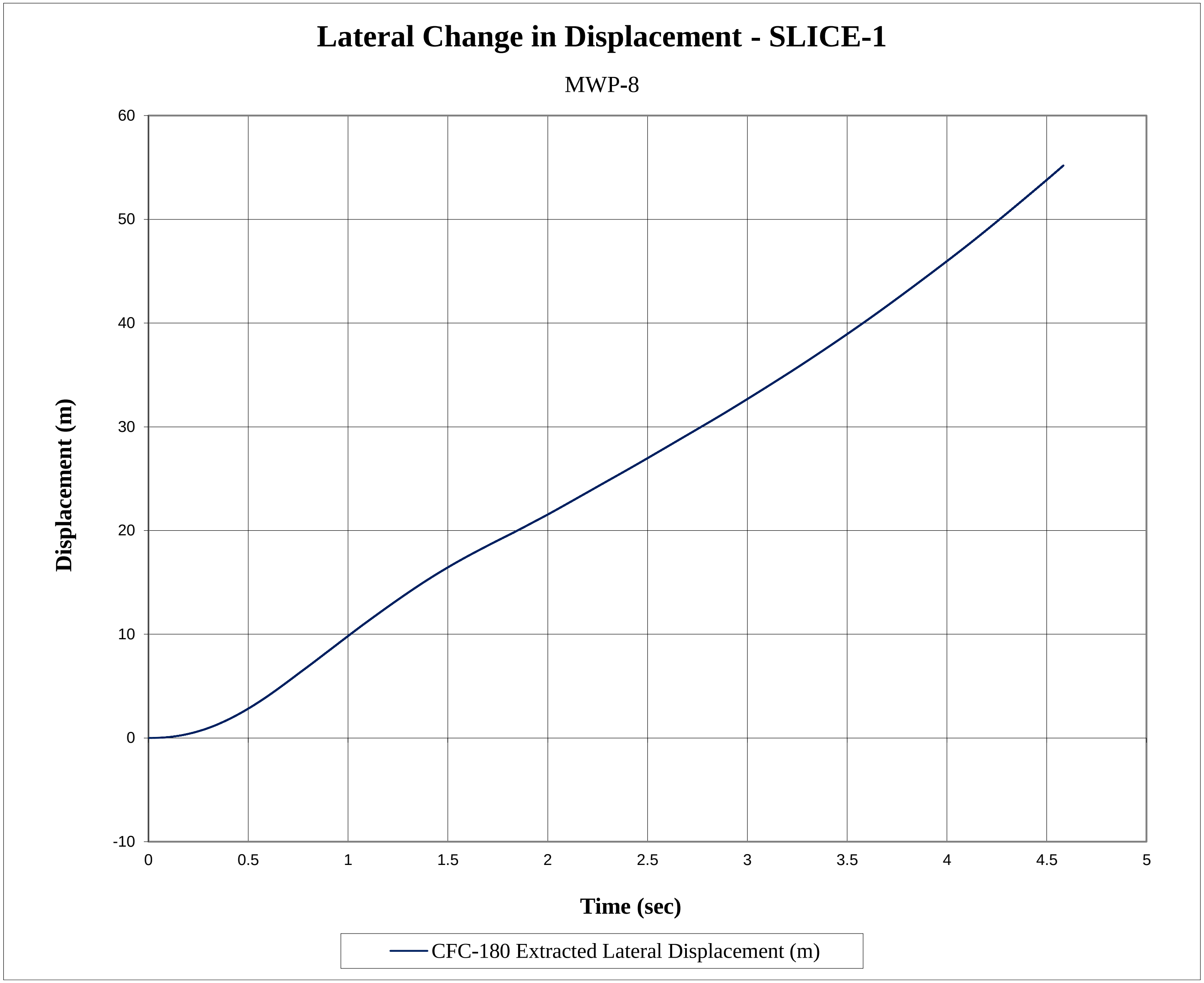


Figure E-6. Lateral Occupant Displacement (SLICE-1), Test No. MWP-8

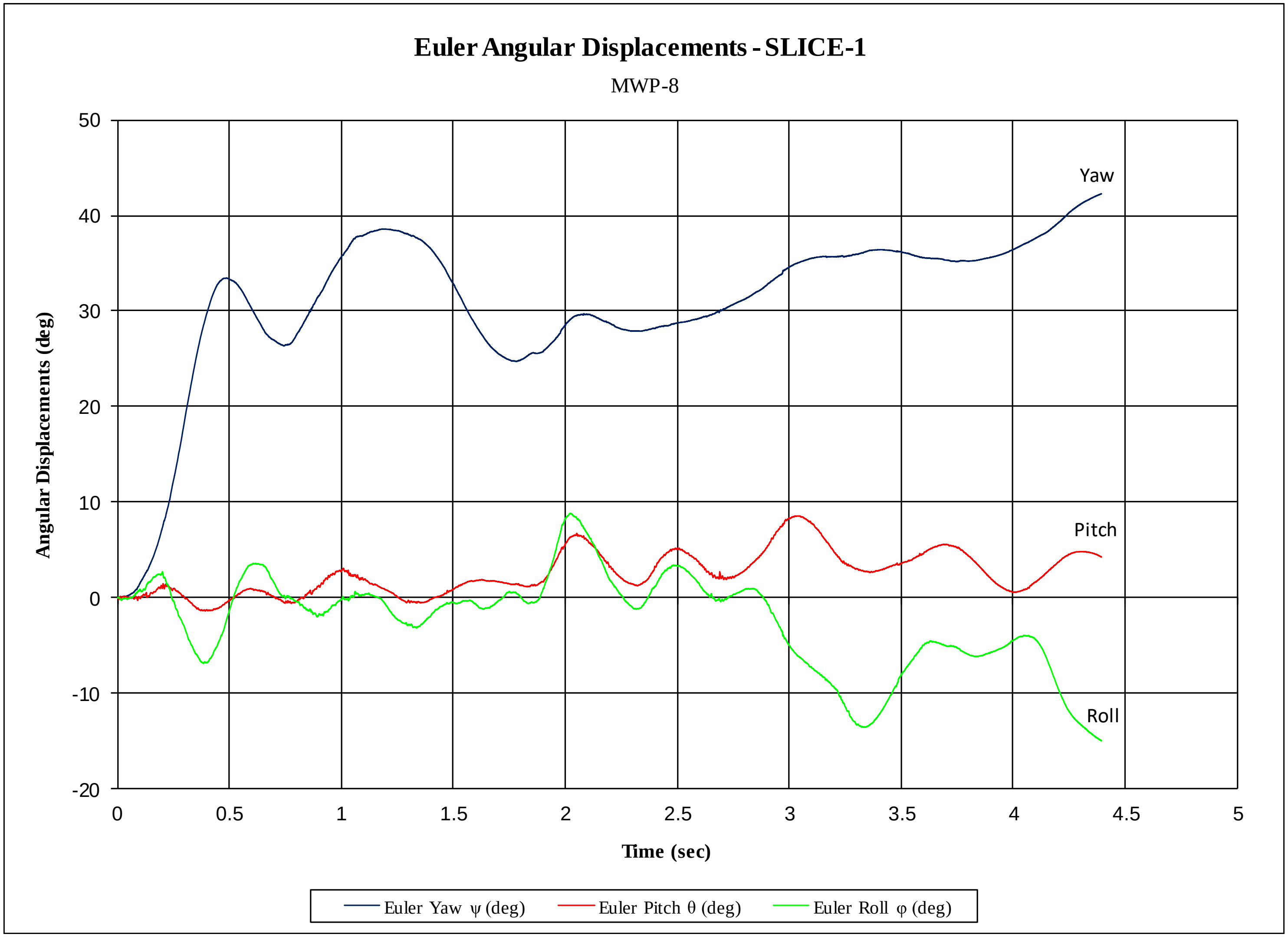


Figure E-7. Vehicle Angular Displacements (SLICE-1), Test No. MWP-8

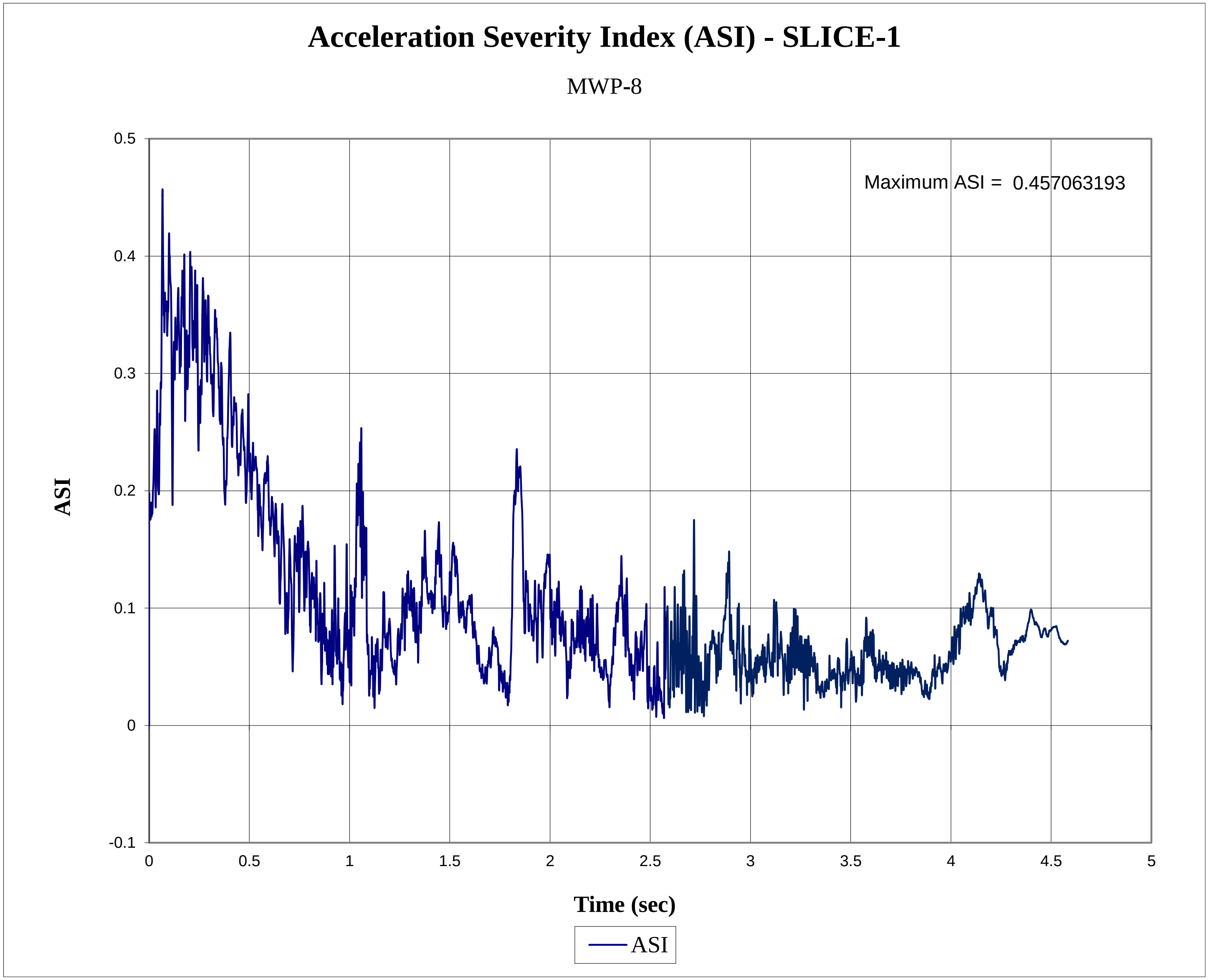


Figure E-8. Acceleration Severity Index (SLICE-1), Test No. MWP-8

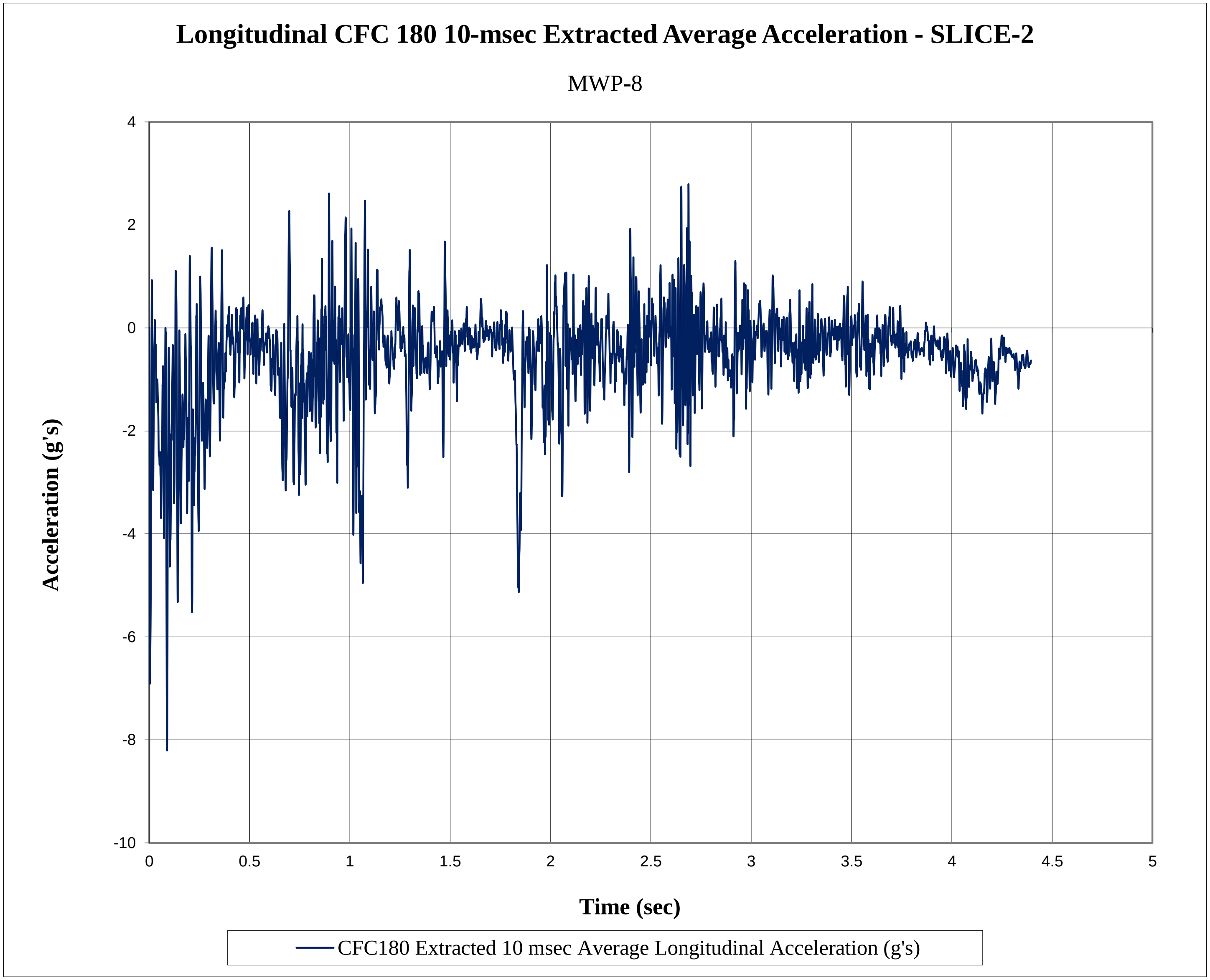


Figure E-9. 10-ms Average Longitudinal Acceleration (SLICE-2), Test No. MWP-8

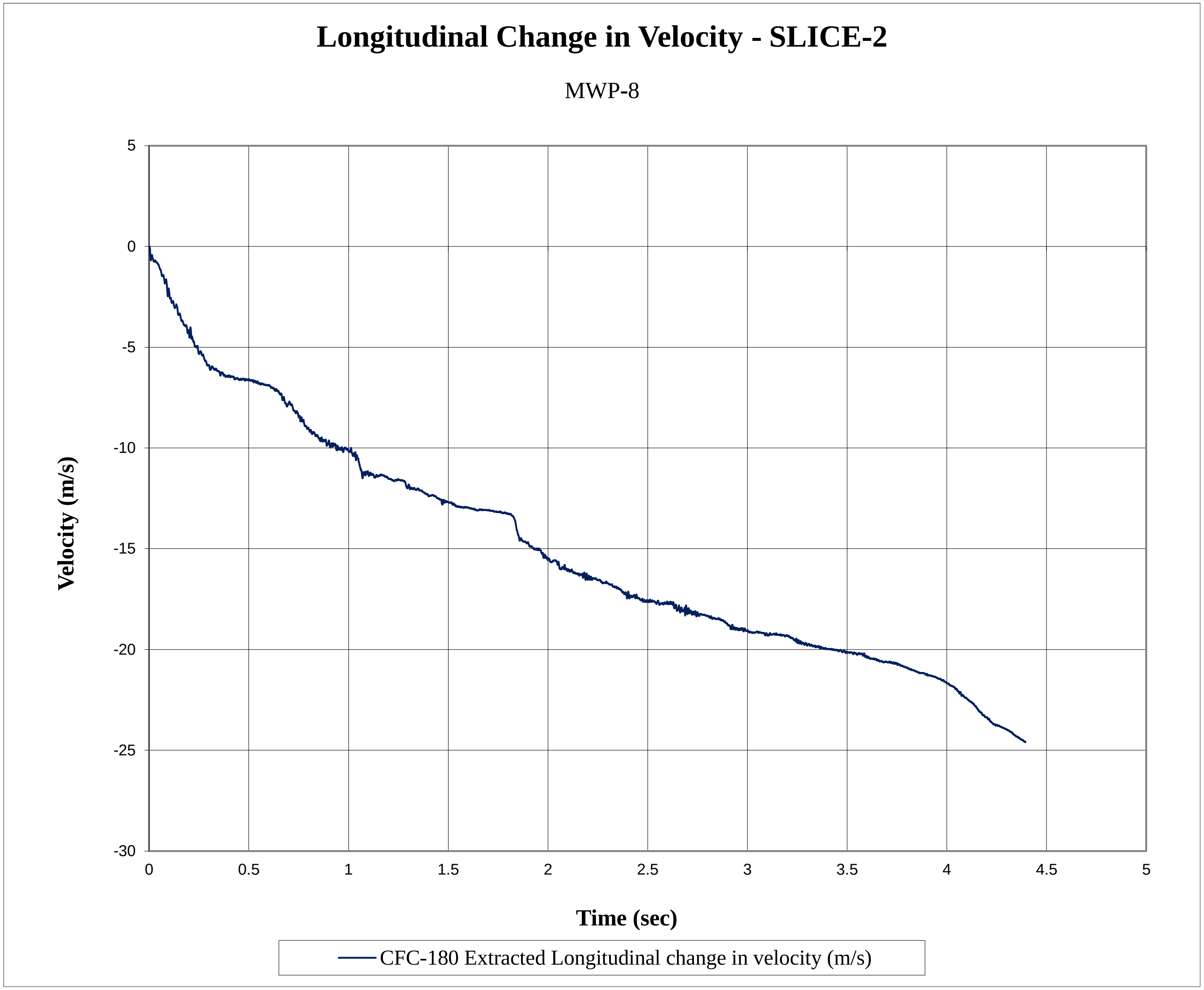


Figure E-10. Longitudinal Change in Velocity (SLICE-2), Test No. MWP-8

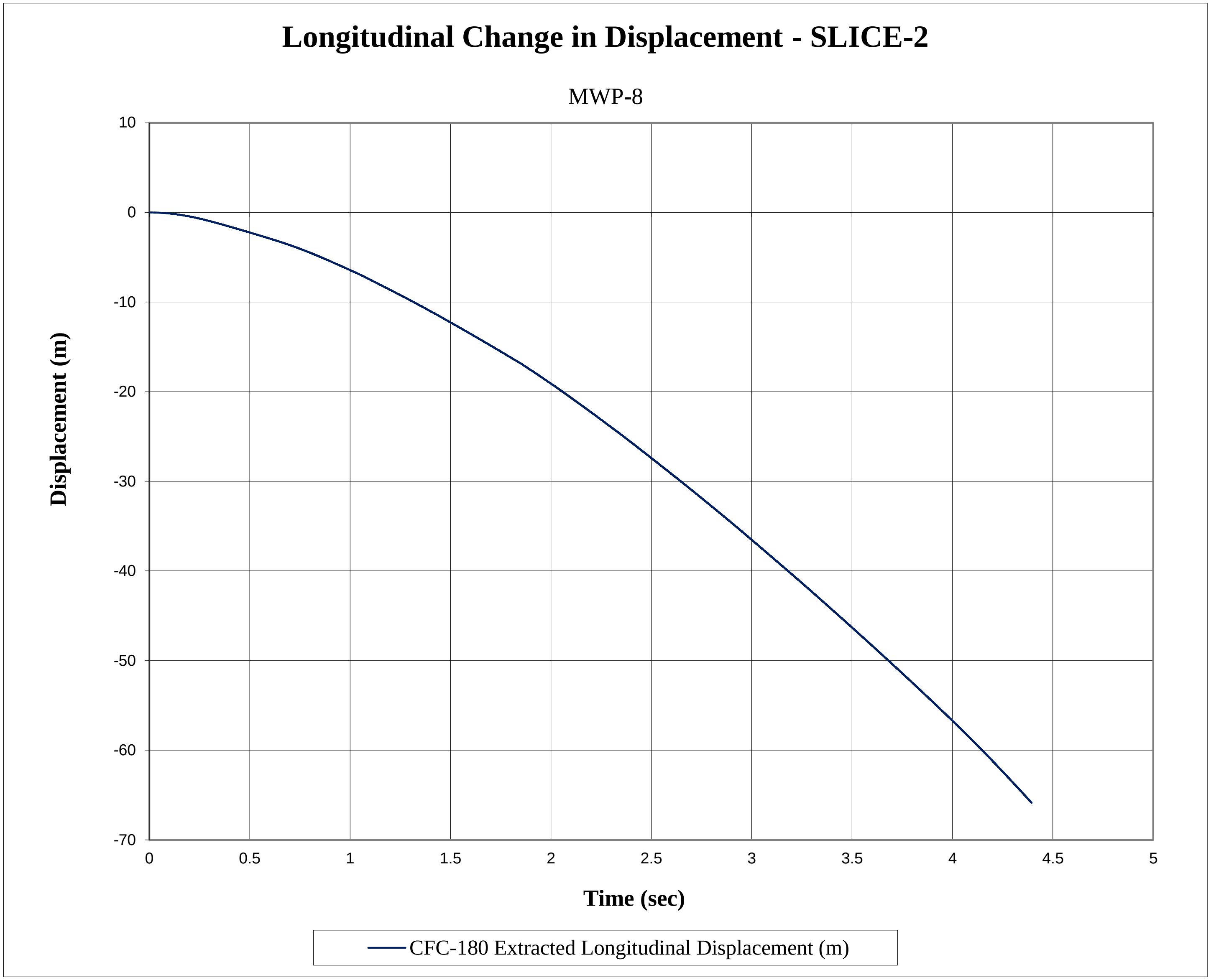


Figure E-11. Longitudinal Occupant Displacement (SLICE-2), Test No. MWP-8

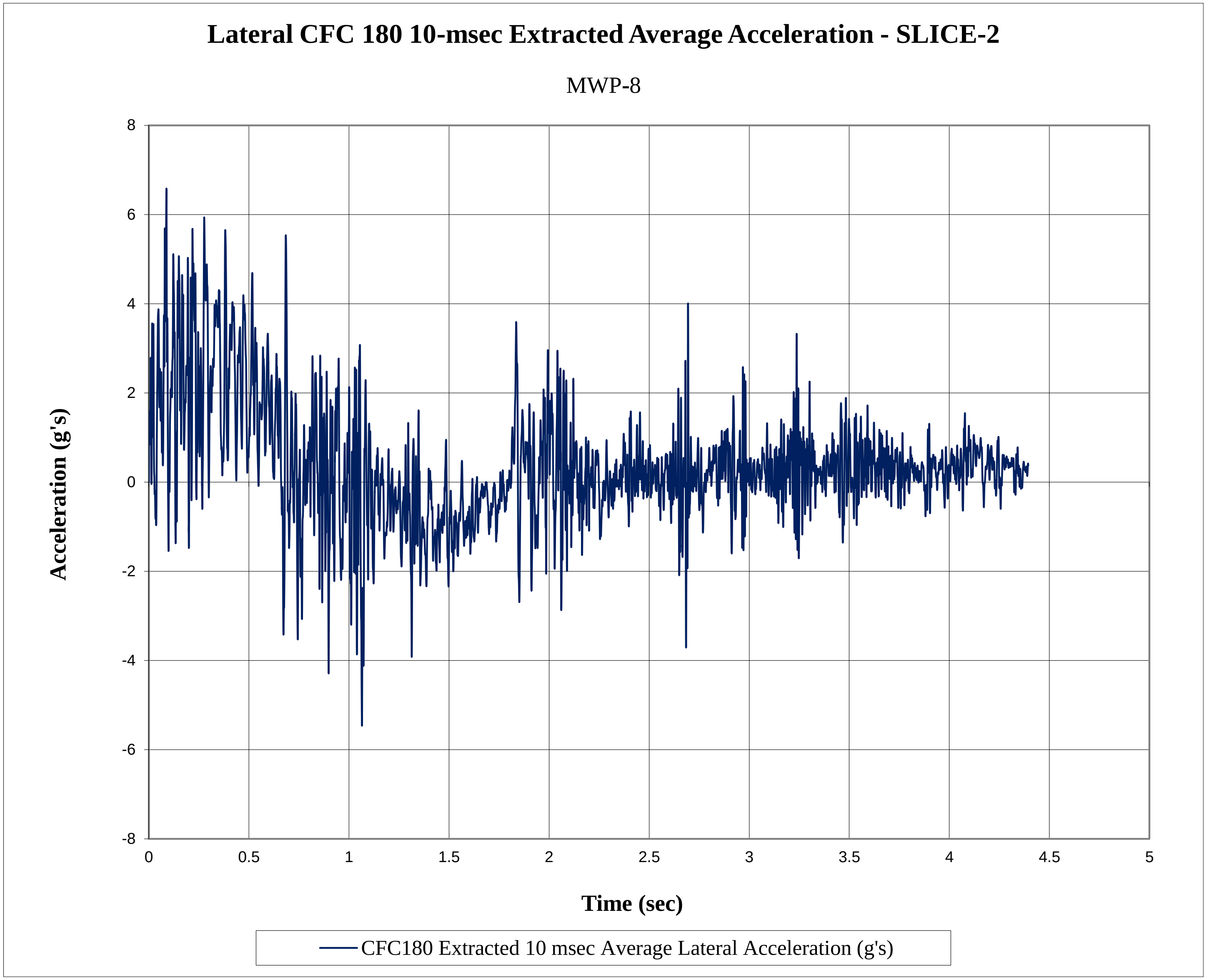


Figure E-12. 10-ms Average Lateral Acceleration (SLICE-2), Test No. MWP-8

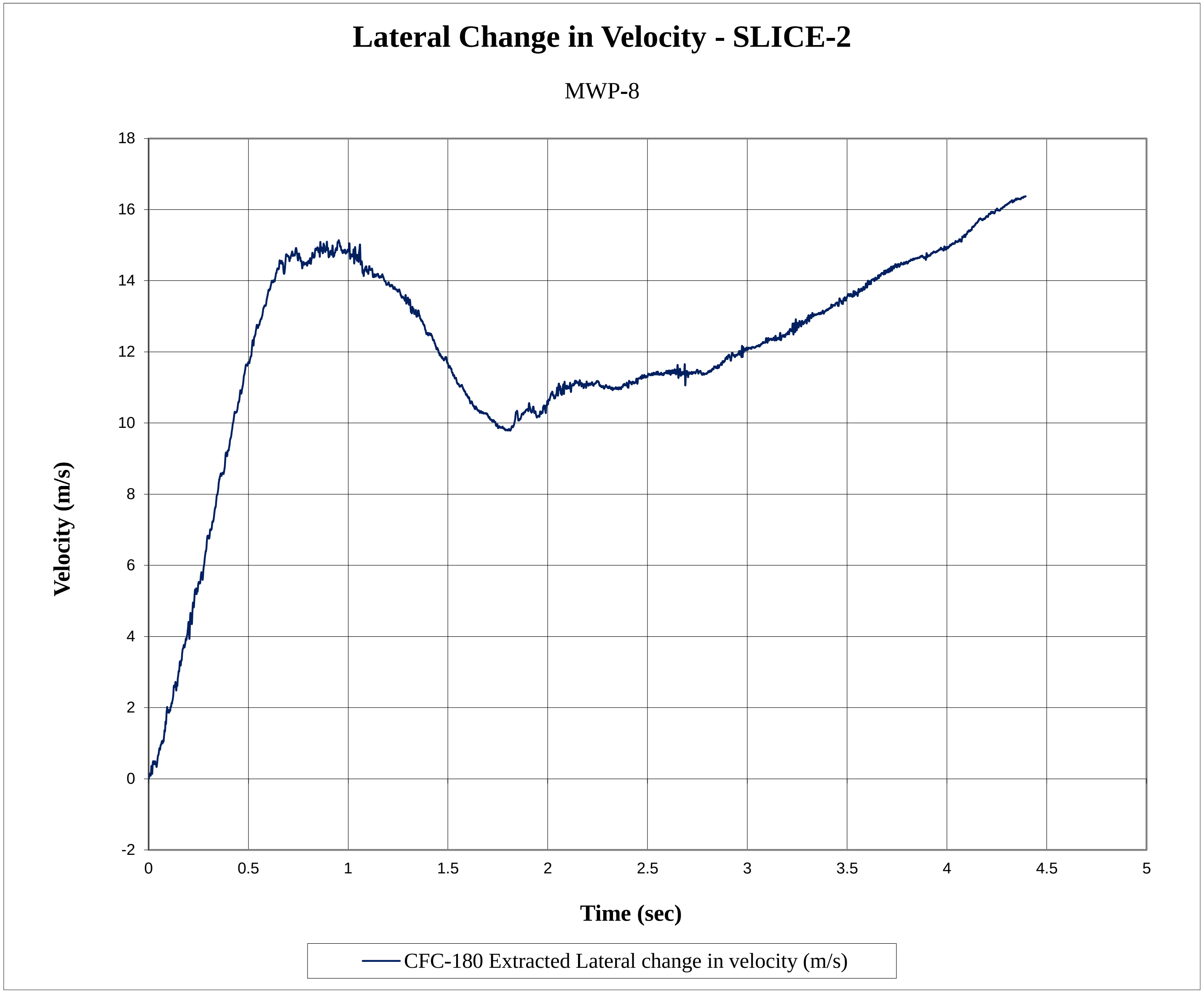


Figure E-13. Lateral Change in Velocity (SLICE-2), Test No. MWP-8

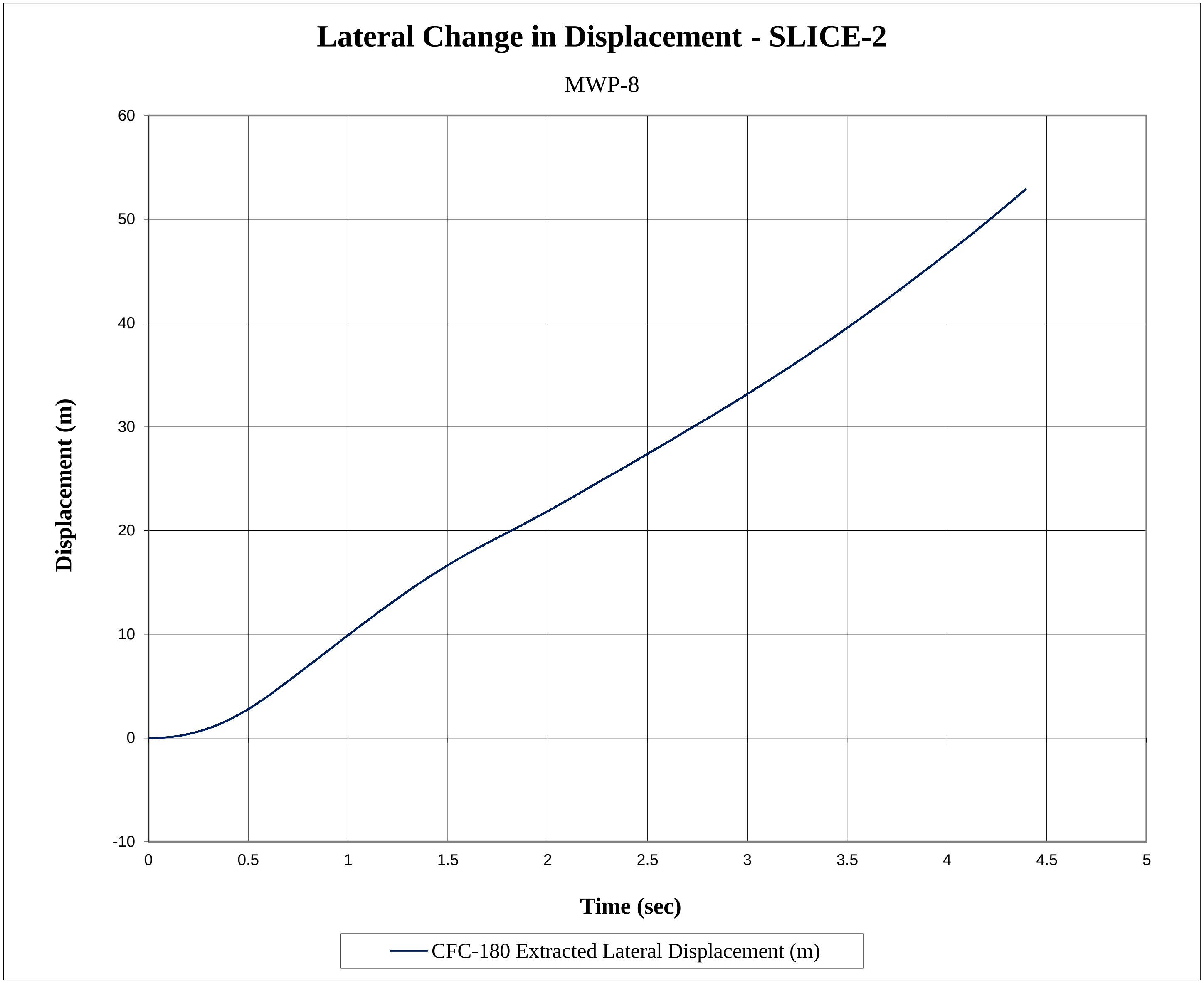


Figure E-14. Lateral Occupant Displacement (SLICE-2), Test No. MWP-8

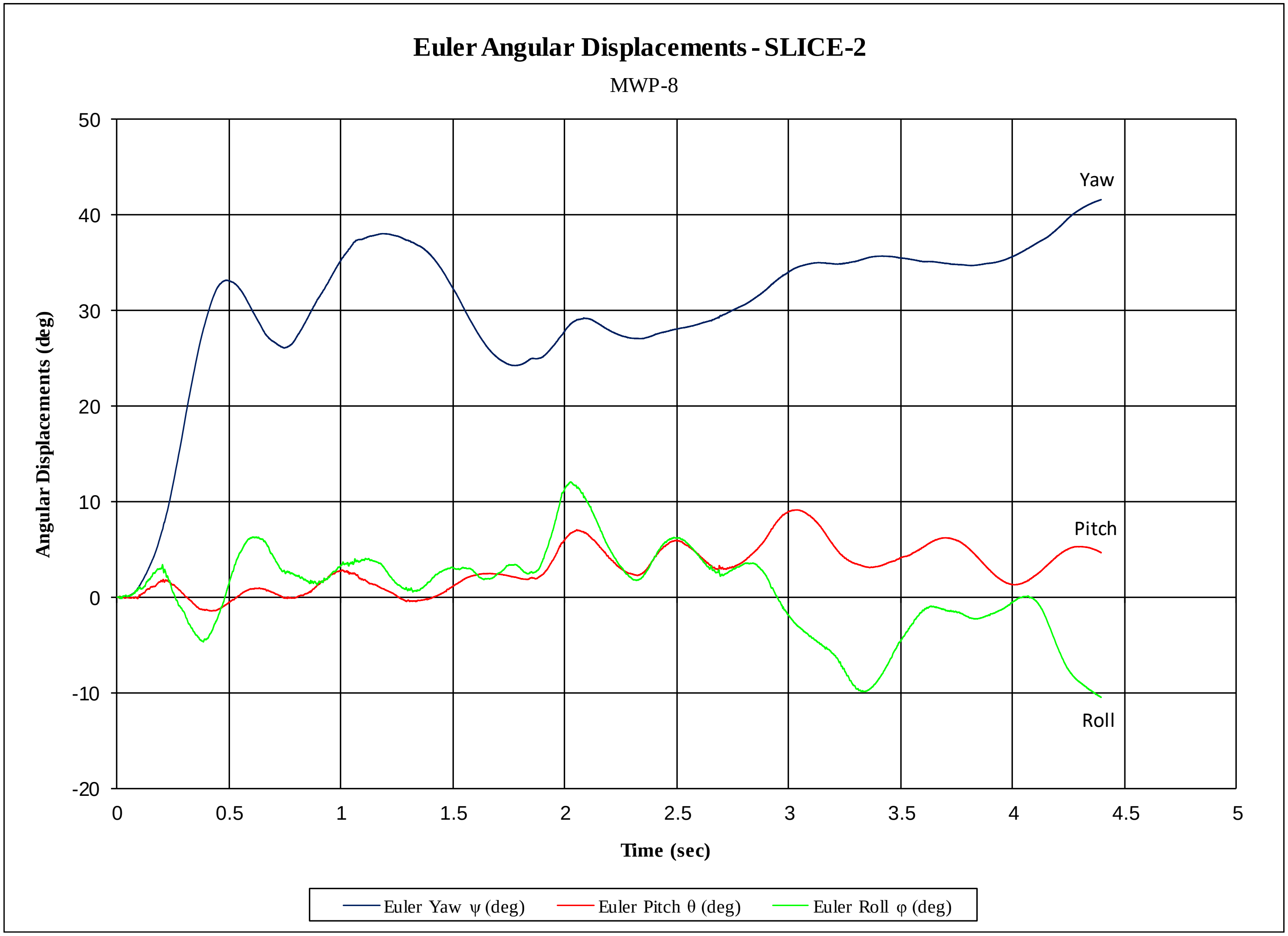


Figure E-15. Vehicle Angular Displacements (SLICE-2), Test No. MWP-8

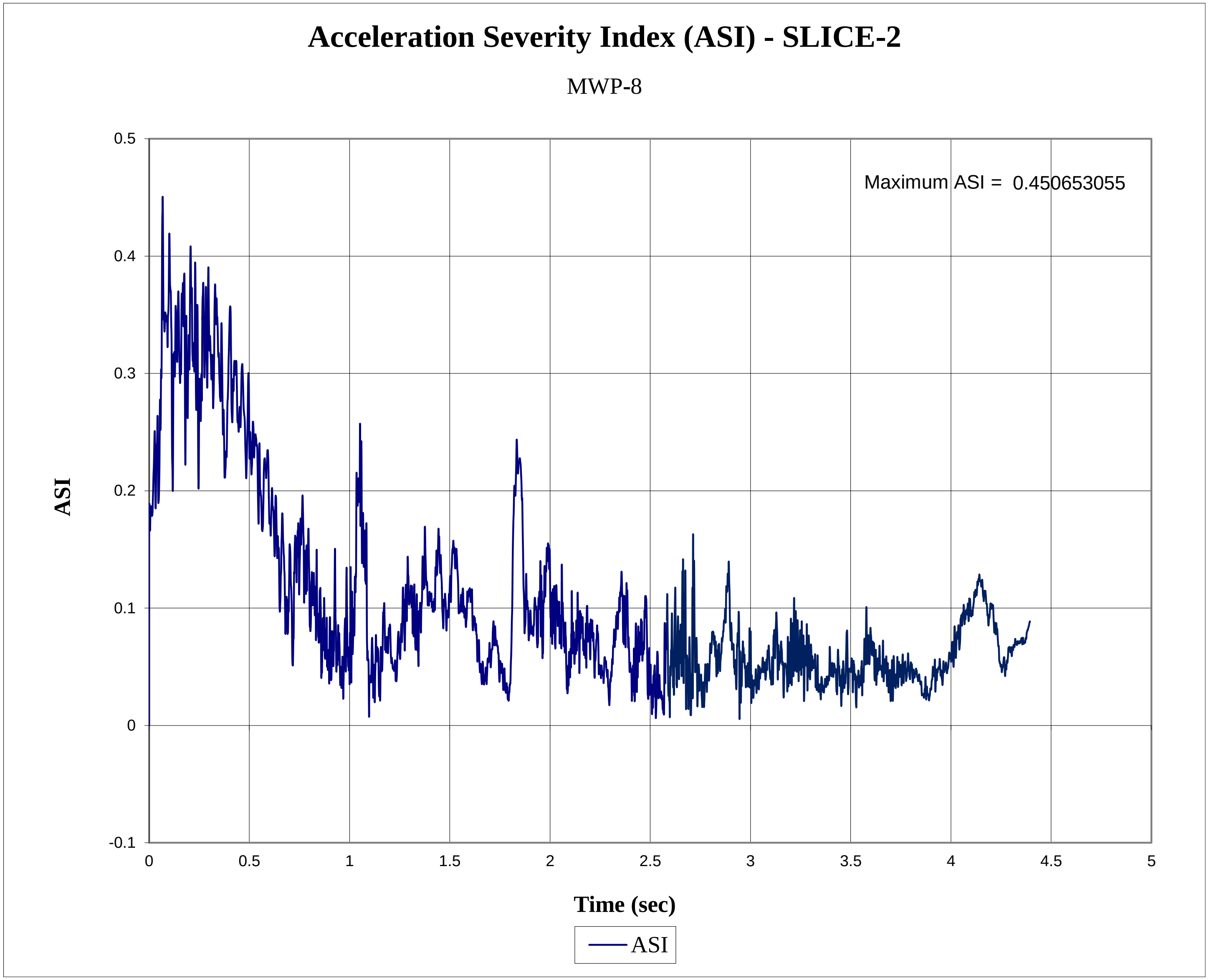


Figure E-16. Acceleration Severity Index (SLICE-2), Test No. MWP-8

Appendix F. Load Cell and String Potentiometer Data

MIDWEST ROADSIDE SAFETY FACILITY

Load Cell Summary

Test Information:

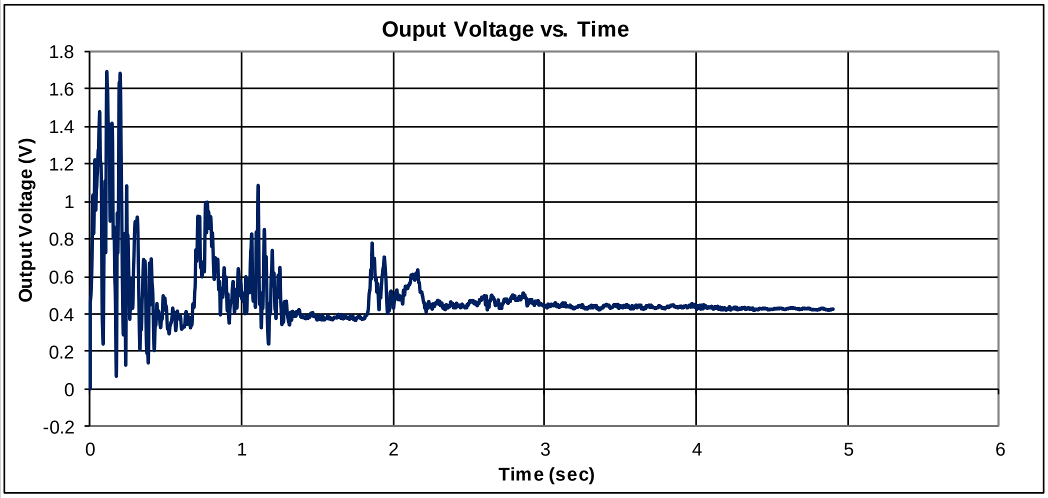
Test No:	MWP-8
Date:	10/19/2015
System / Test Article:	4-Cable Median Barrier
LC Location / Component:	Bottom Cable-US of Impact
Additional Notes:	

Load Cell Information:

Load Cell No.:	241593
Calibration Factor:	2.14857 mv/V
Input Voltage (excitation):	9.99 Volts
Gain:	400
Full Scale Load:	50 kips
Sample Rate:	10000 Hz
Cutoff Frequency:	100 Hz

Results:

Preload:	0 kips
Max. Load:	9.86 kips
Time of Max. Load:	0.1096 sec
Event Duration:	5.5 sec
Final Load:	2.44 kips



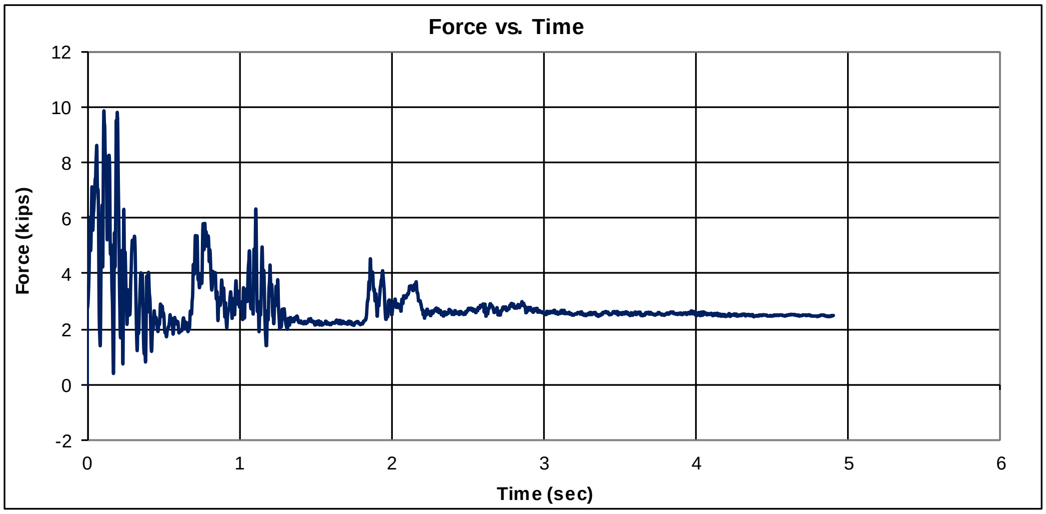


Figure F-1. Load Cell Data, Cable No. 1, Test No. MWP-8

MIDWEST ROADSIDE SAFETY FACILITY

Load Cell Summary

Test Information:

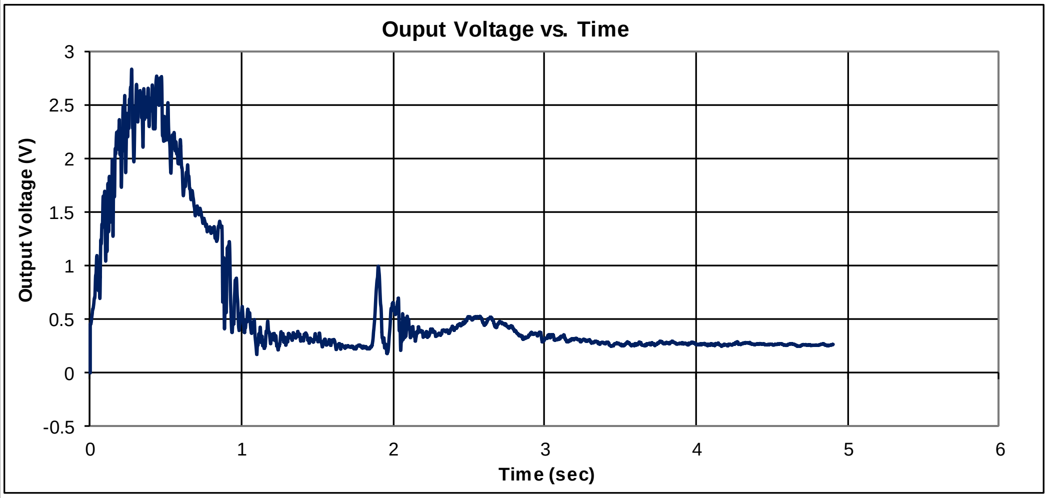
Test No:	MWP-8
Date:	10/19/2015
System / Test Article:	4-Cable Median Barrier
LC Location / Component:	Bottom Middle Cable-US of Impact
Additional Notes:	

Load Cell Information:

Load Cell No.:	143436
Calibration Factor:	2.14575 mv/V
Input Voltage (excitation):	9.99 Volts
Gain:	400
Full Scale Load:	50 kips
Sample Rate:	10000 Hz
Cutoff Frequency:	100 Hz

Results:

Preload:	0 kips
Max. Load:	16.53 kips
Time of Max. Load:	0.2734 sec
Event Duration:	5.5 sec
Final Load:	1.52 kips



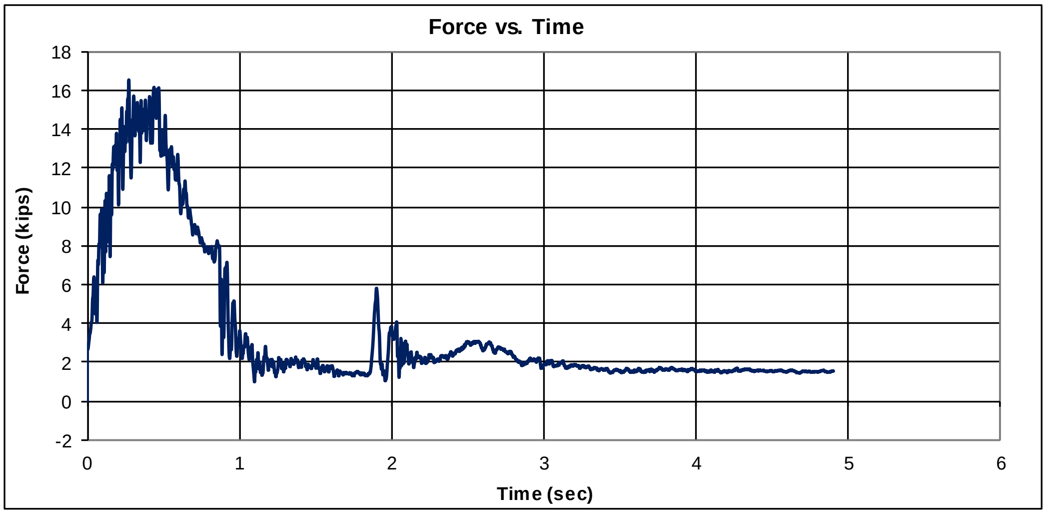


Figure F-2. Load Cell Data, Cable No. 2, Test No. MWP-8

MIDWEST ROADSIDE SAFETY FACILITY

Load Cell Summary

Test Information:

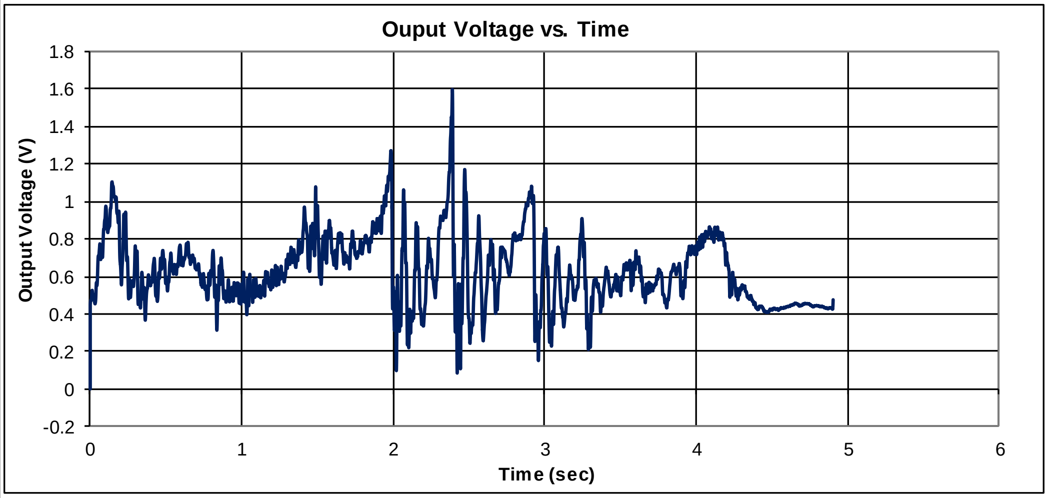
Test No:	MWP-8
Date:	10/19/2015
System / Test Article:	4-Cable Median Barrier
LC Location / Component:	Top Middle Cable -US of Impact
Additional Notes:	

Load Cell Information:

Load Cell No.:	120642
Calibration Factor:	2.11878 mv/V
Input Voltage (excitation):	9.99 Volts
Gain:	400
Full Scale Load:	50 kips
Sample Rate:	10000 Hz
Cutoff Frequency:	100 Hz

Results:

Preload:	0 kips
Max. Load:	9.43 kips
Time of Max. Load:	2.3909 sec
Event Duration:	5.5 sec
Final Load:	3.17 kips



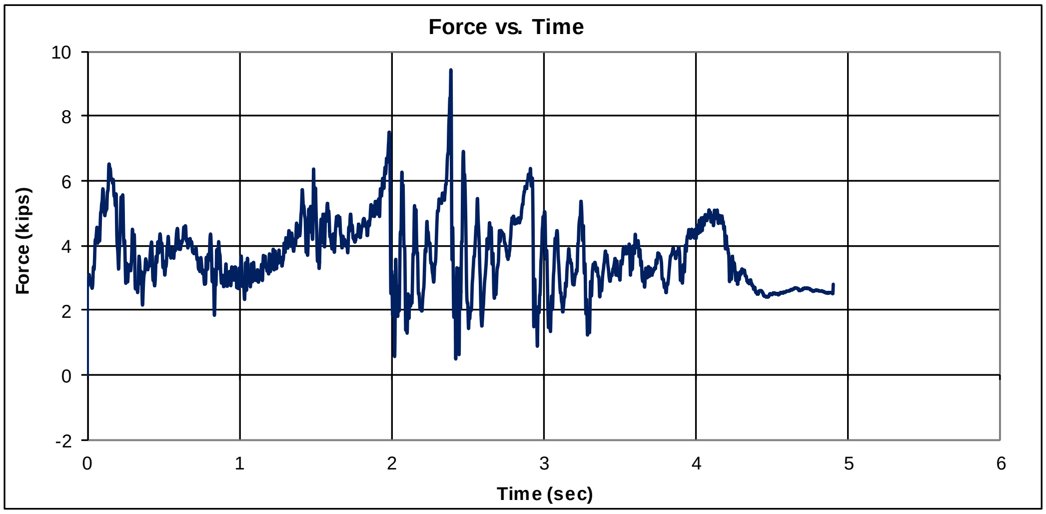


Figure F-3. Load Cell Data, Cable No. 3, Test No. MWP-8

MIDWEST ROADSIDE SAFETY FACILITY

Load Cell Summary

Test Information:

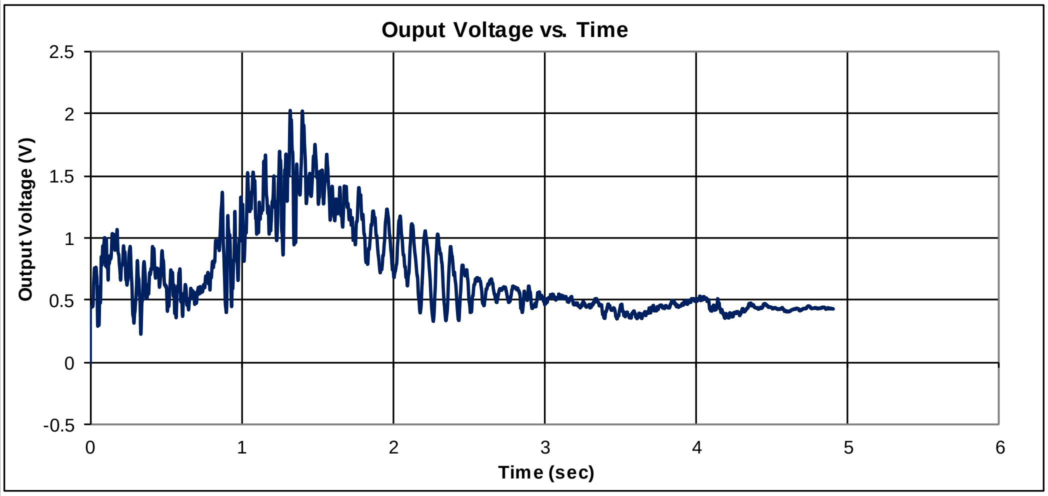
Test No:	MWP-8
Date:	10/19/2015
System / Test Article:	4-Cable Median Barrier
LC Location / Component:	Top Cable - US of Impact
Additional Notes:	

Load Cell Information:

Load Cell No.:	143435
Calibration Factor:	2.1539 mv/V
Input Voltage (excitation):	9.98 Volts
Gain:	400
Full Scale Load:	50 kips
Sample Rate:	10000 Hz
Cutoff Frequency:	100 Hz

Results:

Preload:	0 kips
Max. Load:	11.79 kips
Time of Max. Load:	1.3203 sec
Event Duration:	5.5 sec
Final Load:	2.58 kips



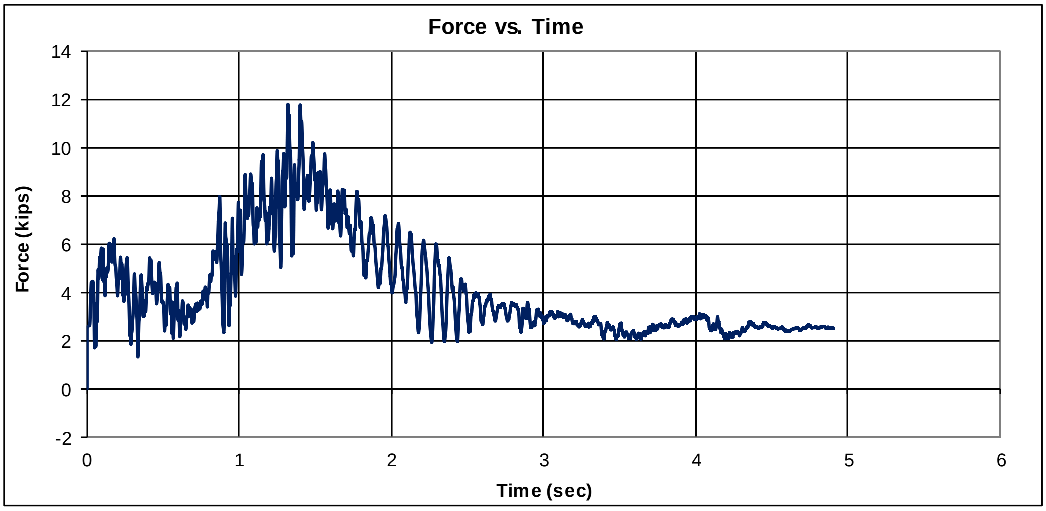


Figure F-4. Load Cell Data, Cable No. 4, Test No. MWP-8

MIDWEST ROADSIDE SAFETY FACILITY

String Potentiometer Summary

Test Information:

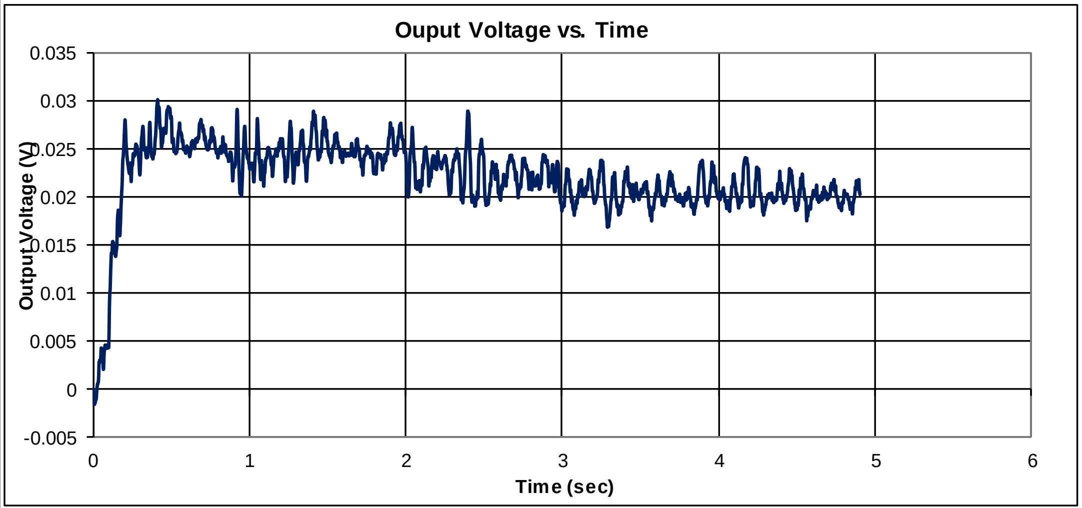
Test No:	MWP-8
Date:	10/19/2015
System / Test Article:	4-Cable Median Barrier
SP Location / Component:	Upstream Anchor
Additional Notes:	

String Potentiometer Information:

String Pot No.:	27039202	
Calibration Factor:	19.4483	mV/V/in.
Input Voltage (excitation):	9.99	Volts
Gain:	1	
Full Scale Load:	1	
Sample Rate:	10000	Hz
Cutoff Frequency:	100	Hz

Results:

Max. Displacement:	0.16	in.
Time of Max. Displacement:	0.4125	sec
Event Duration:	5.5	sec
Final Displacement:	0.10	in.



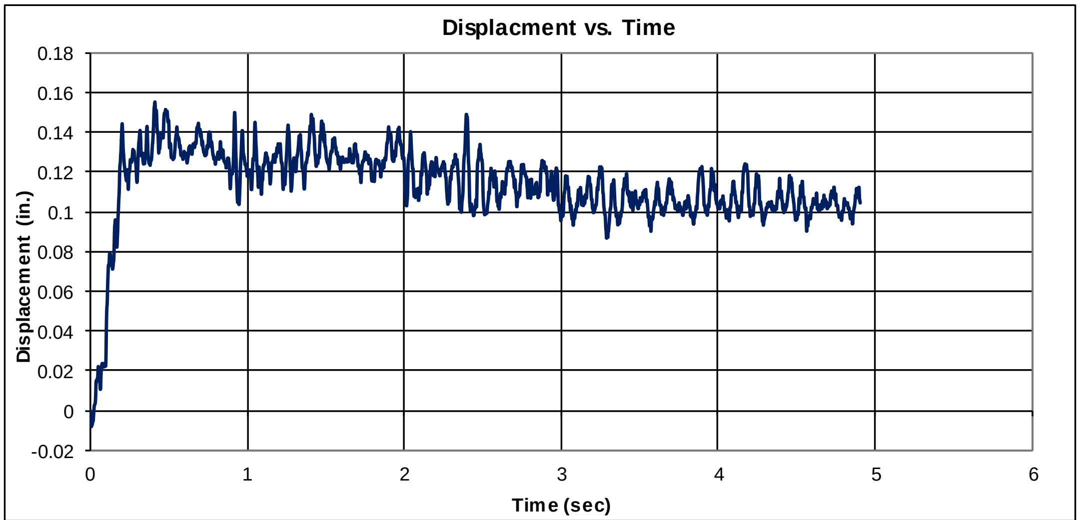


Figure F-5. String Potentiometer Data, Upstream Anchor, Test No. MWP-8

END OF DOCUMENT