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MASH TEST DESIGNATION NOS. 3-11 & 3-17 OF A NON-PROPRIETARY, HIGH-TENSION CABLE MEDIAN BARRIER WITH CLOSED-SECTION POSTS

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16. Abstract
This study is part of an ongoing effort undertaken by the Midwest Pooled Fund Program to develop a non-proprietary, high-tension cable median barrier for use in a 6H:1V median V-ditch. The system is composed of posts spaced at 8 to 16 ft (2.4 to 4.9 m) to which four cables are attached using clips and tabbed brackets. Previous iterations of the system have failed to meet the safety criteria of the *Manual for Assessing Safety Hardware, Second Edition* (MASH 2016), primarily due to floor pan tearing caused by the sharp edges of the open-section posts used in earlier designs. After a series of investigations to mitigate the obstacles encountered in previous tests, a cable median barrier system with closed-section posts was developed. The design featured HSS3x2x⅛ (76x51x3) posts with weakening holes drilled at the ground line to reduce bending strength and, in turn, the propensity for floor pan tearing. To assess the crashworthiness of the modified system design, two full-scale crash tests adhering to the criteria of MASH 2016 test designation nos. 3-11 and 3-17 were performed.

The system successfully contained the 2270P and 1500A test vehicles and satisfied the MASH 2016 safety criteria. In test no. MTP-1, the vehicle sustained no floor pan damage and in test no. MTP-2, the vehicle experience minor floor pan deformation that fell within the MASH 2016 criteria, demonstrating improved behavior of the closed-section post over previous open-section iterations. The dynamic deflection and working width of the system were measured via high-speed video analysis at 101.8 in. (2,586 mm) and 102.1 in. (2,593 mm) for test no. MTP-1 and 112.6 in. (2,860 mm) and 146.4 in. (3,719 mm) for test no. MTP-2, respectively. The performance of the modified system in these tests indicate a design that, with further crash testing, could provide the states with the opportunity to implement an effective cable median barrier on level terrain and in V-ditch medians along the nation's highways and roadways.

17. Key Words
Highway Safety, Crash Test, Roadside Appurtenances, Compliance Test, MASH 2016, Longitudinal Barrier, Cable Barrier, Median Barrier, High-Tension, V-Ditch

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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, Research Assistant Professor.

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1 INTRODUCTION

1.1 Background

In 2012, the Midwest Roadside Safety Facility (MwRSF) conducted an expansive research and development effort that led to a prototype, non-proprietary, four-cable, high-tension median barrier system [1-2]. The cable barrier system consisted of three unique hardware pieces: (1) a steel post fabricated from a bent plate, referred to as the Midwest Weak Post (MWP); (2) a steel cable-to-post attachment bracket used to fasten the lower three cables to the post; and (3) a V-notch and a brass rod cable attachment located on the top of the post. Previous full-scale crash tests on the cable median barrier demonstrated a propensity for the free edges of the MWP to penetrate the occupant compartment during vehicle override of the posts [1-2]. Research efforts were made to mitigate floor pan tearing and compartment penetration by using a two-part cap, which was fastened to the top of the MWP with a single ½-in. (13-mm) diameter retainer bolt in order to shield the free edges of the MWP during post-to-vehicle contact [3]. However, in the most recent full-scale crash test of the high-tension cable median barrier, test no. MWP-9, the top cables snagged on the cap retainer bolt and nut, inducing an increased downward and lateral force on the A-pillar [4]. This interlock between the top cables and the A-pillar resulted in excessive A-pillar crush. Consequently, test no. MWP-9 was determined to have failed the safety performance criteria of the *Manual for Assessing Safety Hardware, Second Edition* (MASH 2016) test designation no. 3-10 [5].

Following the full-scale crash tests of the MWP series, MwRSF reviewed the design of the high-tension cable median barrier and identified several areas of concern. First, the MWP had exposed free edges which had torn the vehicle floor pan in multiple full-scale crash tests. It was also noted that weakening of the MWP in the lateral direction could potentially reduce concerns for excessive A-pillar crush, and weakening the post strength in the longitudinal direction could reduce small car stability concerns. Further, it was observed that only a single cable was active in capturing vehicles in several of the full-scale crash tests of the system. Thus, it was inferred that increasing the number of cables and decreasing the vertical cable spacing could potentially result in improved vehicle containment.

To improve upon the previous cable barrier design, three possible design changes were identified: (1) using a closed-section post to mitigate vehicle occupant compartment penetration; (2) fastening brackets with rounded sleeve nuts to reduce the likelihood of cable snagging; and (3) increasing the number of cables to five or six cables to better capture the vehicle. A survey related to various high-tension cable barrier design options, including four-cable, five-cable, and six-cable systems, was sent to the Midwest Pooled Fund members to gauge their interest in the addition of more cables to the system. The majority of the states preferred a four-cable system over the five- and six-cable systems. Thus, per the states' preference, the number of cables in the system was left unchanged. Instead, the implementation of closed-section posts and rounded sleeve nuts was investigated.

A series of dynamic component tests were conducted on various closed-section posts to identify the sections that exhibited performance similar to or better than that of the MWP [6]. The results of the bogie testing series indicated that a 3-in. x 2-in. x ⅛-in. (76-mm x 51-mm x 3-mm) Hollow Structural Section (HSS) with two ¾-in. (19-mm) diameter holes at the ground line would provide the desired strong- and weak-axis bending strengths. Additionally, this section was found to be less prone to floor pan tearing, required less material than the MWP, and consisted of more readily available components than the MWP. Thus, the HSS3x2x⅛ (75x51x31) post was recommended for further evaluation and was implemented in the full-scale crash tests described herein.

Additionally, rounded sleeve nuts were investigated to ensure that their use as replacements for traditional nuts would not affect the bracket-to-post connection strength. In a series of quasi-static tensile tests, the sleeve nut implemented in this cable barrier design developed the full strength of the inserted bolt and thus was recognized as an acceptable alternative to the fastener used in earlier designs [7].

By incorporating these changes into the previous cable barrier design, researchers at MwRSF revised the previous design of the non-proprietary, four-cable, high-tension median barrier system to incorporate closed-section posts and cable-to-post brackets fastened with round sleeve nuts. The post, which is referred to as the Midwest Tube Post (MTP), has an HSS3x2x⅛ (76x51x3) profile with two ¾-in. (19-mm) diameter holes in the upstream and downstream walls at the ground line, to reduce weak-axis (longitudinal) bending strength. This reduction in weak-axis bending strength was anticipated to reduce the potential for floor pan tearing by reducing the elastic restoring force of the post and, in turn, the intensity with which an overridden post presses upward on the undercarriage of the vehicle.

1.2 Objective

The objective of this project report was to evaluate the safety performance of the modified high-tension cable median barrier with a weakened closed-section posts and cable-to-post brackets fastened with round sleeve nuts. The system was evaluated according to the Test Level 3 (TL-3) criteria of MASH 2016 [5].

1.3 Scope

The research objective was achieved through the completion of several tasks. Two full-scale crash tests were conducted on the modified cable median barrier according to MASH 2016 test designation nos. 3-11 and 3-17. Next, the full-scale vehicle crash test results were analyzed, evaluated, and documented. Conclusions and recommendations were then made pertaining to the safety performance of the modified cable median barrier.

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 2016. According to TL-3 of MASH 2016, a cable barrier system for use anywhere in a 6H:1V V-ditch must be subjected to eight full-scale vehicle crash tests, as shown in Table 1.

Cable systems with variable post spacing must be conducted with both the narrowest and widest post spacing to bracket the working widths of the barrier system, thereby increasing the required number of crash tests from eight to nine. Only two of the prescribed full-scale crash tests, test designation nos. 3-11 and 3-17, were 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 and the slope of the ditch.

Many cable barriers have variable post spacing, which allows 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. MASH 2016 has identified the critical post spacing, either the narrowest or the widest spacing, for each individual test within the testing matrix.

MASH 2016 test designation no. 3-11 must be conducted twice – once with the narrowest post spacing of 8 ft and once with the widest post spacing of 16 ft. The test conducted and reported herein featured the narrowest post spacing of 8 ft. In accordance with MASH 2016 requirements, the critical impact point for the 2270P vehicle was determined to be located 12 in. (305 mm) upstream from a post. In crash tests involving flexible cable barriers, this impact location aims to remove a post at impact, creating critical conditions for vehicle containment, vehicle stability, A-pillar integrity, and working width.

MASH 2016 test designation no. 3-17 was tested with the widest post spacing of 16 ft. In accordance with MASH 2016 requirements, the critical impact point for the 1500A vehicle was determined to be located 96 in. (2,438 mm) upstream from a post, which is also the mid-span between posts. In crash tests involving flexible cable barriers, this impact location aims to evaluate the potential for underride or penetration between cables, creating critical conditions for vehicle containment, vehicle stability, A-pillar integrity, and working width.

When non-symmetrical cable barriers are tested, it is important to test the orientation that produces the greatest risk of failure. To accomplish this, 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 2270P vehicle was determined to be the third cable from the bottom. Selecting this orientation allowed for the greatest risk of failure due to the post pushing the backside cables down and preventing vehicle capture. This would then allow the vehicle to overrun the barrier. The primary capture cable for the 1500A vehicle was determined to be the second cable from the bottom. Selecting this orientation allowed for the greatest risk of failure due to delaying vehicle interlock with the barrier and increasing the potential for the vehicle to penetrate the system.

Table 1. MASH 2016 TL-3 Test Matrix for Single Cable Median 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.	Barrier Location[1]	Post Spacing	
3-10	1100C	2,420 (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 (2.7 m) from Front Slope Break Point	Narrow	A,D,F,H,I
3-14	1100C	2,420 (1,100)	62 (100)	25	9 ft (2.7 m) from Front Slope Break Point	Narrow	A,D,F,H,I
3-15	1100C	2,420 (1,100)	62 (100)	25	4 ft (1.2 m) from Ditch Bottom	Wide	A,D,F,H,I
3-16	1100C	2,420 (1,100)	62 (100)	25	1 ft (0.3 m) from Back Slope Break Point	Narrow	A,D,F,H,I
3-17	1500A	3,300 (1,500)	62 (100)	25	Variable[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 from 0 to 4 ft on front slope of ditch in order to maximize propensity for front end of 1500A vehicle to penetrate between vertically adjacent cables. Critical factors may include vertical cable spacing, position of cables relative to front bumper, location and type of cable release mechanisms, trajectory of vehicle’s front bumper, etc.

2.2 Evaluation Criteria

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

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

Table 2. MASH 2016 Evaluation Criteria for Longitudinal Barrier

<table>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td></tr>
<tr><td rowspan="10">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s
(9.1 m/s)</td><td>40 ft/s
(12.2 m/s)</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
</table>

2.3 Soil Strength Requirements

In accordance with Chapter 3 and Appendix B of MASH 2016, foundation soil strength must be verified before any full-scale crash testing can occur. During the installation of a soil-dependent system, W6x16 (W152x23.8) posts are installed near the impact region utilizing the same installation procedures as the system itself. Prior to full-scale testing, a dynamic impact test must be conducted to verify a minimum dynamic soil resistance of 7.5 kips (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 ground line. If dynamic testing near the system is not desired, MASH 2016 permits a static test to be conducted instead and compared against the results of a previously established baseline test. In this situation, the soil must provide a resistance of at least 90 percent of the static baseline test at deflections of 5, 10, and 15 in. (127, 254, and 381 mm). Further details can be found in Appendix B of MASH 2016.

3 TEST CONDITIONS

3.1 Test Facility

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

3.2 Vehicle Tow and Guidance System

A reverse-cable tow system with a 1:2 mechanical advantage was used to propel the test vehicle. The 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 [8] 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.

3.3 Test Vehicle

For test no. MTP-1, a 2012 Dodge Ram 1500 quad cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,063 lb (2,297 kg), 4,986 lb (2,262 kg), and 5,148 lb (2,335 kg), respectively. The test vehicle is shown in Figures 1 and 2. Vehicle dimensions are shown in Figure 3. MASH recommends that passenger vehicles used for crash testing be no more than six years old on the day the test is conducted, though at the time of this project, it was also permissible to measure the six model years from the project award date. All dimensions and properties of the vehicle met the requirements as provided in MASH 2016 Sections 4.2.1 and A4.2.1 and Table 4-1. Thus, a test vehicle older than six years from the date of the test was utilized as allowed by FHWA and AASHTO in the MASH implementation guidance dated May of 2018 [9].

For test no. MTP-2, a 2013 Hyundai Sonata sedan was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 3,206 lb (1,454 kg), 3,301 lb (1,497 kg), and 3,471 lb (1,574 kg), respectively. The test vehicle is shown in Figures 4 and 5. Vehicle dimensions are shown in Figure 6.

Figure 1. Test Vehicle, Test No. MTP-1

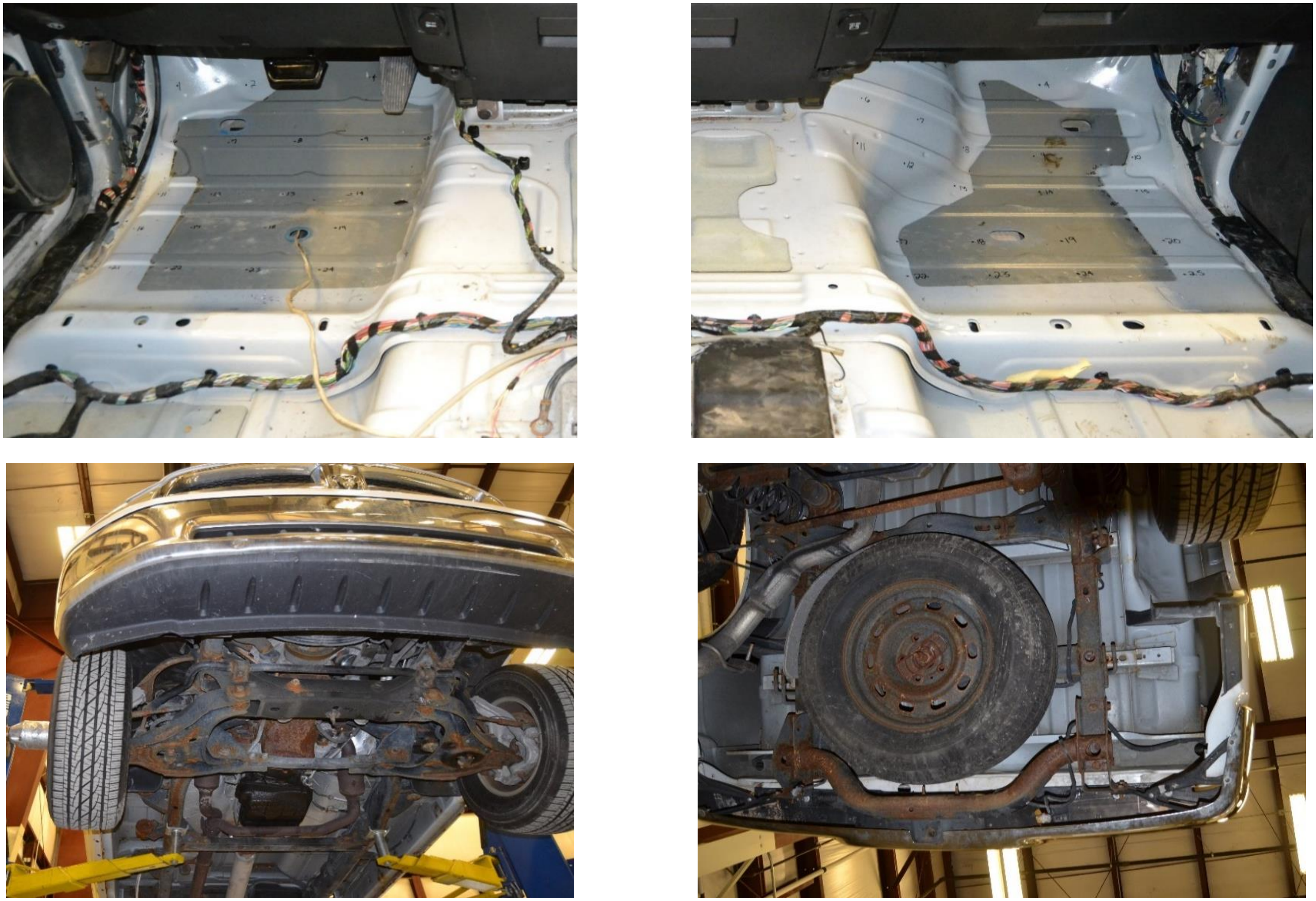
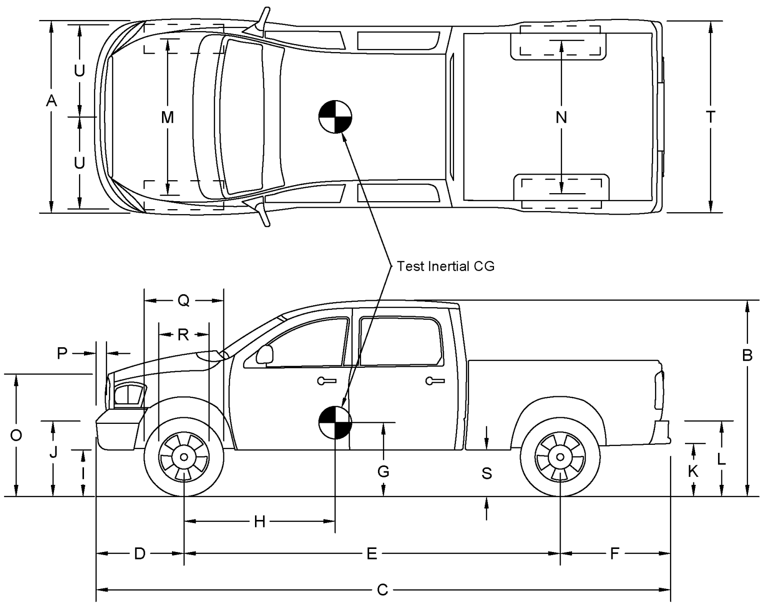


Figure 2. Test Vehicle's Interior Floorboards and Undercarriage, Test No. MTP-1

Date:	4/11/2019	**Test Name:**	MTP-1	**VIN No:**	1C6RD6GP3CS253410
Year:	2012	**Make:**	Dodge	**Model:**	Ram 1500
Tire Size:	P265/70R17	**Tire Inflation Pressure:**	40 psi	**Odometer:**	252174



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

A:	77 5/8 (1972) 78±2 (1950±50)	**B:**	74 (1880)
C:	229 (5817) 237±13 (6020±325)	**D:**	39 (991) 39±3 (1000±75)
E:	148 (3761) 148±12 (3760±300)	**F:**	42 (1067)
G:	28 7/16 (722) min: 28 (710)	**H:**	64 5/16 (1634) 63±4 (1575±100)
I:	12 1/4 (311)	**J:**	26 (660)
K:	19 3/8 (492)	**L:**	30 5/8 (778)
M:	67 3/4 (1721) 67±1.5 (1700±38)	**N:**	67 3/4 (1721) 67±1.5 (1700±38)
O:	44 1/8 (1121) 43±4 (1100±75)	**P:**	4 5/8 (117)
Q:	30 3/4 (781)	**R:**	18 5/8 (473)
S:	12 1/8 (308)	**T:**	79 1/4 (2013)
		U (impact width):	36 1/3 (922)

Mass Distribution - lb (kg)

Gross Static	**LF**	1506 (683)	**RF**	1412 (640)
	LR	1116 (506)	**RR**	1114 (505)

Weights lb (kg)	**Curb**	**Test Inertial**	**Gross Static**
W-front	2884 (1308)	2821 (1280)	2918 (1324)
W-rear	2179 (988)	2165 (982)	2230 (1012)
W-total	5063 (2297)	4986 (2262) 5000±110 (2270±50)	5148 (2335) 5165±110 (2343±50)

Wheel Center Height (Front):	15 (381)
Wheel Center Height (Rear):	15 1/4 (387)
Wheel Well Clearance (Front):	4 1/2 (114)
Wheel Well Clearance (Rear):	7 (178)
Bottom Frame Height (Front):	11 7/8 (302)
Bottom Frame Height (Rear):	12 7/8 (327)
Engine Type:	Gasoline
Engine Size:	4.7L V8
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Quad Cab
Bed Length:	76"

GVWR Ratings - lb

Front	3700
Rear	3900
Total	6700

Surrogate Occupant Data

Type:	Hybrid II
Mass:	162 lb
Seat Position:	Left/Driver

Note any damage prior to test: None

Figure 3. Vehicle Dimensions, Test No. MTP-1

Figure 4. Test Vehicle, Test No. MTP-2

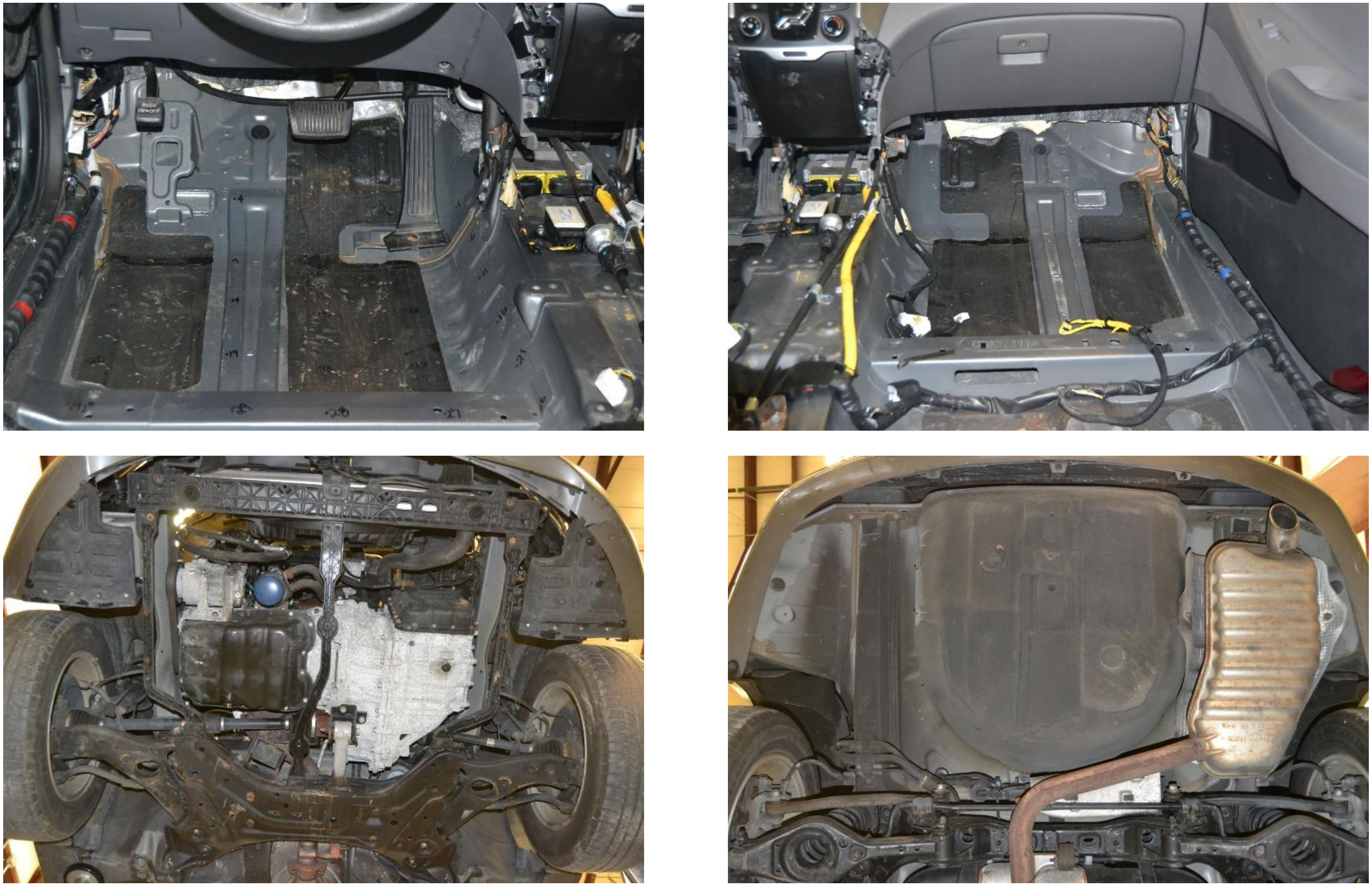
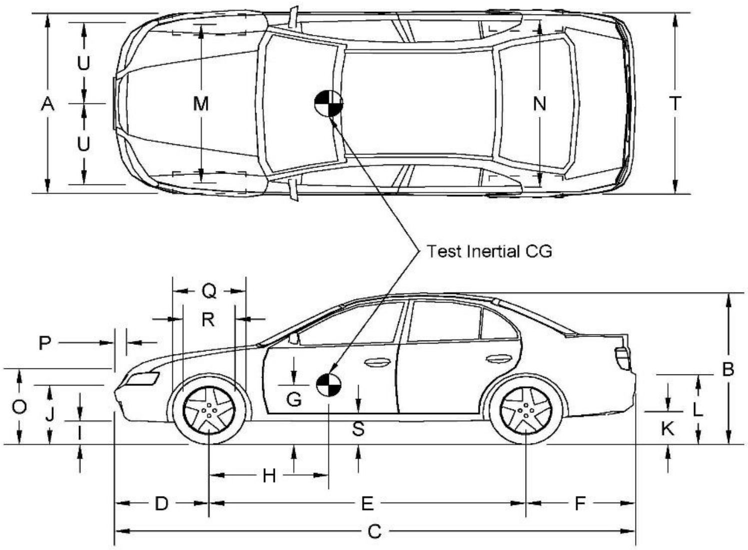


Figure 5. Test Vehicle's Interior Floorboards and Undercarriage, Test No. MTP-2

Date:	7/15/2019	Test Name:	MTP-2	VIN No:	5NPEB4ACXDH545633
Year:	2013	Make:	Hyundai	Model:	Sonata
Tire Size:	205/65 R16	Tire Inflation Pressure:	33 psi	Odometer:	213496



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

A:	71 1/2	(1816)	B:	57 5/8	(1464)
C:	189 3/4	(4820)	D:	37	(940)
E:	110 1/8	(2797)	F:	41 1/2	(1054)
G:	22 1/16	(560)	H:	46 7/16	(1180)
I:	15 3/4	(400)	J:	20 1/4	(514)
K:	16	(406)	L:	23	(584)
M:	63	(1600)	N:	63	(1600)
O:	28 1/2	(724)	P:	4 1/2	(114)
Q:	25 3/4	(654)	R:	17 1/4	(438)
S:	10 1/2	(267)	T:	70 3/4	(1797)

U (impact width):	63 3/4	(1619)
Top of radiator core support:	29 1/2	(749)
Wheel Center Height (Front):	12 1/4	(311)
Wheel Center Height (Rear):	12 5/8	(321)
Wheel Well Clearance (Front):	27 5/8	(702)
Wheel Well Clearance (Rear):	27 1/4	(692)
Bottom Frame Height (Front):	5 1/2	(140)
Bottom Frame Height (Rear):	7 1/4	(184)
Engine Type:	Gasoline	
Engine Size:	2.4L Gdi	
Transmission Type:	Automatic	
Drive Type:	FWD	

Mass Distribution - lb (kg)

Gross Static	LF	1028	(466)	RF	970	(440)
	LR	738	(335)	RR	735	(333)

Weights lb (kg)	Curb		Test Inertial		Gross Static	
W-front	1967	(892)	1909	(866)	1998	(906)
W-rear	1239	(562)	1392	(631)	1473	(668)
W-total	3206	(1454)	3301	(1497)	3471	(1574)
			3300±220 (1500±100)		3465±220 (1572±100)	

GVWR Ratings - lb

Front	2425
Rear	2116
Total	4299

Surrogate Occupant Data

Type:	Hybrid II
Mass:	161 lb
Seat Position:	Left/Driver

Note any damage prior to test: Dent front left quarter panel along top of wheel well.

Figure 6. Vehicle Dimensions, Test No. MTP-2

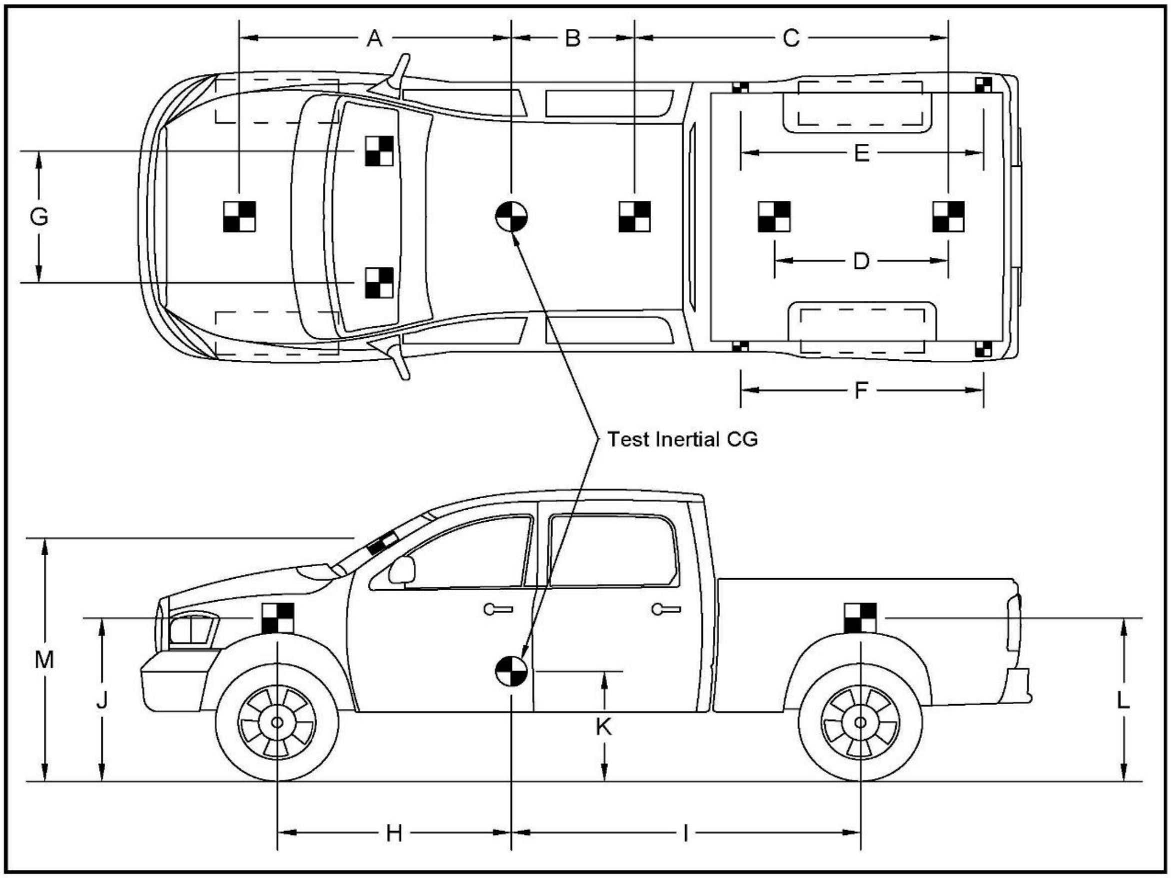
The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [10] was used to determine the vertical component of the c.g. for the 2270P vehicle. This method is based on the principle that the c.g. of any freely suspended body is in the vertical plane through the point of suspension. The vehicle was suspended successively in three positions, and the respective planes containing the c.g. were established. The intersection of these planes pinpointed the final c.g. location for the test inertial condition. The vertical component of the c.g. for the 1500A vehicle was determined utilizing a procedure published by the Society of Automotive Engineers (SAE) [11]. The final c.g. locations are shown in Figures 7 and 8. Ballast information and data used to calculate the c.g. locations are shown in Appendix A.

Square, black-and-white checkered targets were placed on the vehicles, as shown in Figures 7 and 8, to serve as a reference in the high-speed digital video and aid in the video analysis. Round, checkered targets were placed at the c.g. on the left-side door, the right-side door, and the roof of the vehicles.

The front wheels of the test vehicles were aligned to vehicle standards except the toe-in value was adjusted to zero such that the vehicles would track properly along the guide cable. For both tests nos. MTP-1 and MTP-2, a 5B flash bulb was mounted under the vehicle’s left-side windshield wiper and was fired by a pressure tape switch mounted at the impact corner of the bumper. The flash bulb was fired upon initial impact with the test article to create a visual indicator of the precise time of impact on the high-speed digital videos. A radio-controlled brake system was installed in the test vehicles so the vehicles could be brought safely to a stop after the tests.

Date: 4/22/2019 **Test Name:** MTP-1 **VIN:** 1C6RD6GP3CS253410

Year: 2012 **Make:** Dodge **Model:** Ram 1500

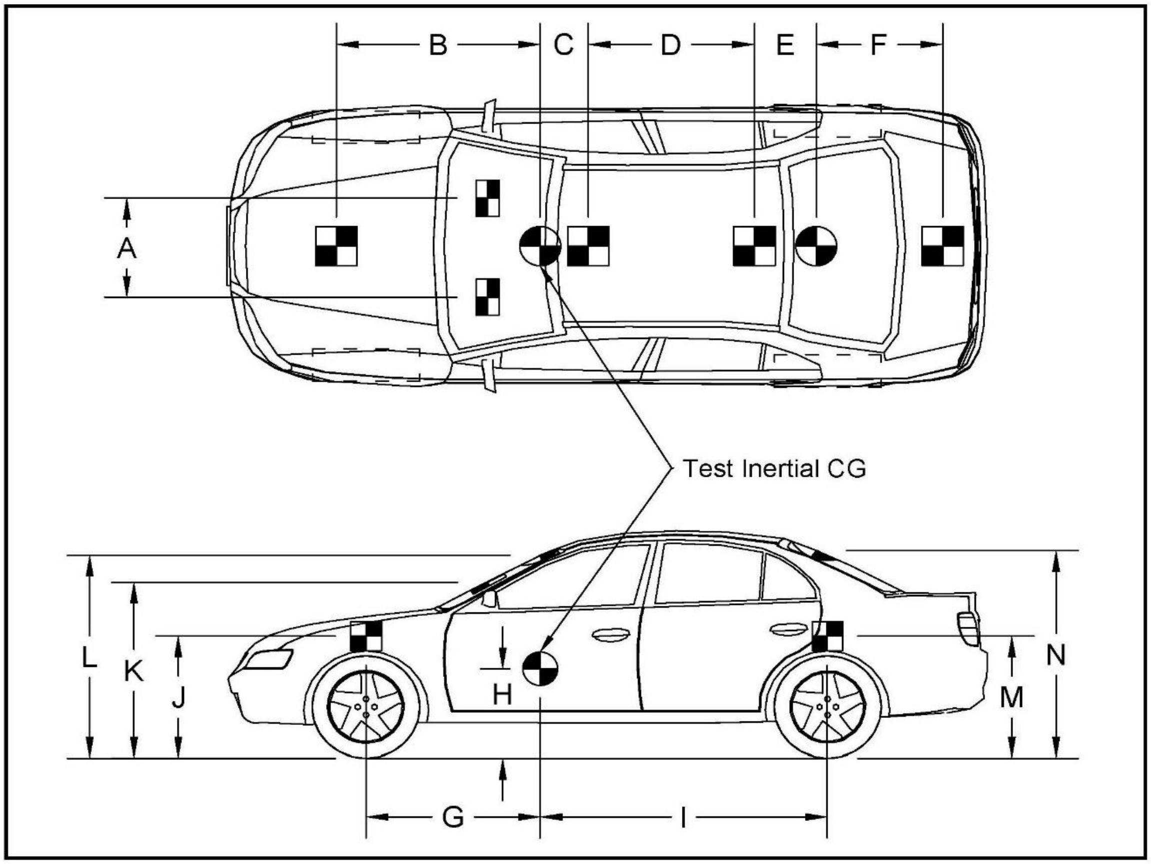


TARGET GEOMETRY-- in. (mm)

A:	79 1/4	(2013)	E:	66 5/8	(1692)	J:	38 15/16	(989)
B:	23 5/8	(600)	F:	66 3/4	(1695)	K:	28 7/16	(722)
C:	76 3/4	(1949)	G:	31 1/4	(794)	L:	41 1/2	(1054)
D:	41 5/16	(1049)	H:	64 3/8	(1635)	M:	63 1/3	(1609)
			I:	75 7/16	(1916)			

Figure 7. Target Geometry, Test No. MTP-1

Date:	**7/15/2019**	**Test Name:**	**MTP-2**	**VIN:**	**5NPEB4ACXDH545633**
Year:	**2013**	**Make:**	**Hyundai**	**Model:**	**Sonata**



TARGET GEOMETRY-- in. (mm)

A:	**26 (660)**	**F:**	**39 3/4 (1010)**	**K:**	**46 1/8 (1172)** Windshield Target
B:	**54 3/4 (1391)**	**G:**	**46 7/16 (1180)**	**L:**	**54 3/4 (1391)** Front round CG target
C:	**12 1/2 (318)**	**H:**	**22 (559)**	**M:**	**31 1/2 (800)**
D:	**33 (838)**	**I:**	**63 3/8 (1610)**	**N:**	**54 1/2 (1384)** Rear Round target
E:	**10 1/4 (260)**	**J:**	**31 7/8 (810)**		

Figure 8. Target Geometry, Test No. MTP-2

3.4 Simulated Occupant

For test nos. MTP-1 and MTP-2, a Hybrid II 50th-Percentile, Adult Male Dummy, equipped with clothing and footwear, was placed in the left-front seat of the test vehicles with the seat belt fastened. The simulated occupant had a final weight of 162 lb (73 kg) and 161 lb (73 kg) for test nos. MTP-1 and MTP-2, respectively. As recommended by MASH 2016, the simulated occupant was not included in calculating the c.g. location.

3.5 Data Acquisition Systems

3.5.1 Accelerometers

Two environmental shock and vibration sensor/recorder systems were used to measure the accelerations in the longitudinal, lateral, and vertical directions. Both accelerometer systems were mounted near the c.g. of the test vehicles. The SLICE-2 unit was designated as the primary system for test no. MTP-1, and the SLICE-1 unit was designated as the primary system for test no. MTP-2. 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 [12].

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 programs and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

3.5.2 Rate Transducers

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

3.5.3 Retroreflective Optic Speed Trap

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

3.5.4 Load Cells

Four load cells were installed upstream from impact for test nos. MTP-1 and MTP-2. The load cells were Transducer Techniques model no. TLL-50K with a load range up to 50 kips (222 kN). During testing, output voltage signals were sent from the load cells 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 load cells are shown in Figures 9 and 10.

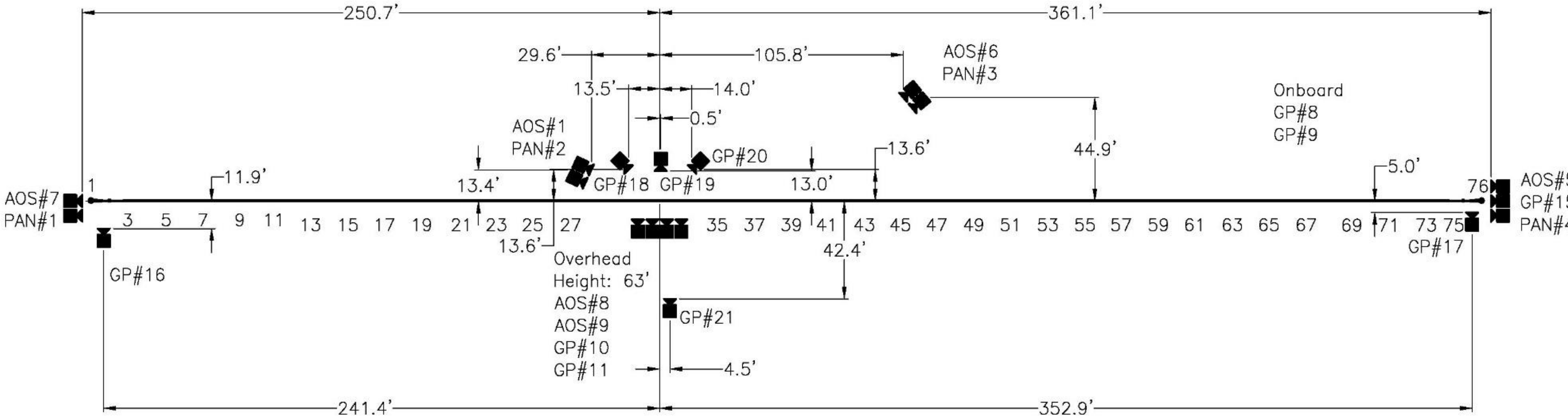
Figure 9. Location and Setup of Load Cells, Test No. MTP-1

Figure 10. Location and Setup of Load Cells, Test No. MTP-2

3.5.5 Digital Photography

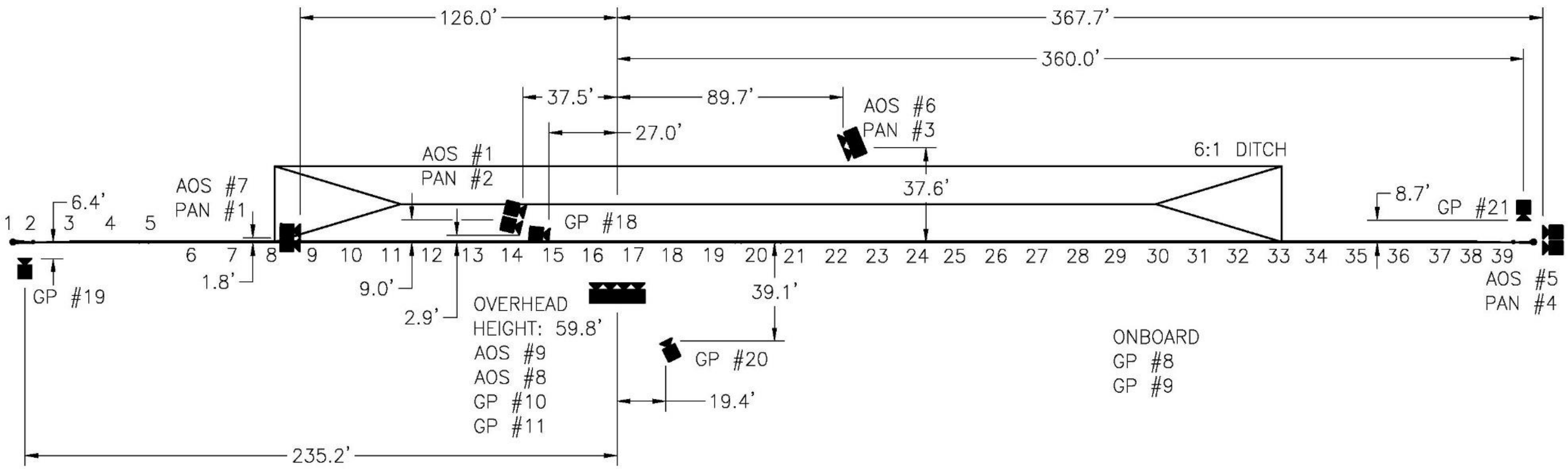
Six AOS high-speed digital video cameras, eleven GoPro digital video cameras, and four Panasonic video cameras were used to film test no. MTP-1. Six AOS high-speed digital video cameras, eight GoPro digital video cameras, and four Panasonic video cameras were used to film test no. MTP-2. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the systems for test nos. MTP-1 and MTP-2 are shown in Figures 11 and 12, respectively.

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



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-1	AOS Vitcam CTM	500	Sigma 28-70	28
AOS-5	AOS X-PRI	500	100mm fixed	-
AOS-6	AOS X-PRI	500	Fujinon 25mm fixed	-
AOS-7	AOS X-PRI	500	Fujinon 50mm fixed	-
AOS-8	AOS S-VIT 1531	500	Kowa 16mm fixed	-
AOS-9	AOS TRI-VIT 2236	500	Kowa 12mm fixed	-
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-10	GoPro Hero 4	120		
GP-11	GoPro Hero 4	240		
GP-15	GoPro Hero 4	240		
GP-16	GoPro Hero 4	240		
GP-17	GoPro Hero 4	120		
GP-18	GoPro Hero 6	240		
GP-19	GoPro Hero 6	240		
GP-20	GoPro Hero 6	240		
GP-21	GoPro Hero 6	240		
PAN-1	Panasonic HC-V770	120		
PAN-2	Panasonic HC-V770	120		
PAN-3	Panasonic HC-V770	120		
PAN-4	Panasonic HC-V770	120		

Figure 11. Camera Locations, Speeds, and Lens Settings, Test No. MTP-1



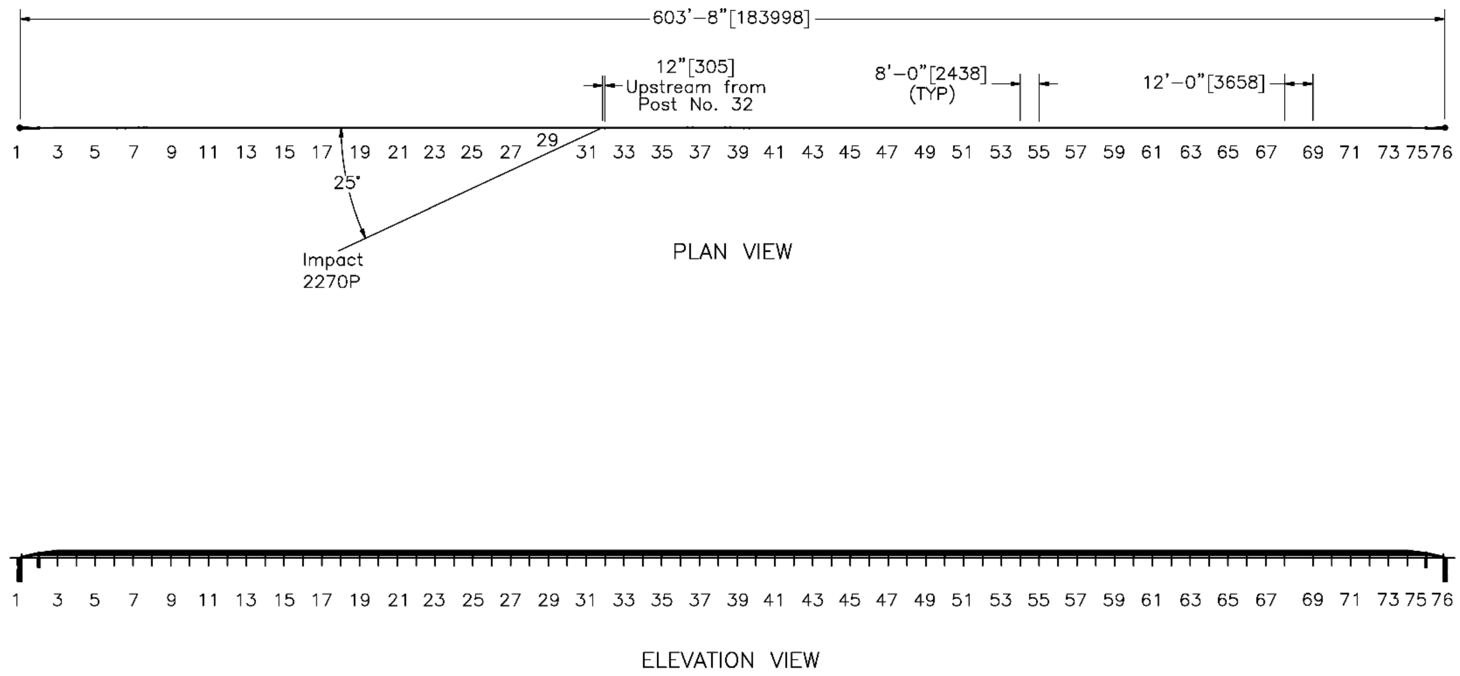
No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-1	AOS Vitcam CTM	500	Fujinon 25mm fixed	-
AOS-5	AOS X-PRI	500	100mm fixed	-
AOS-6	AOS X-PRI	500	Sigma 28-70 #1	28
AOS-7	AOS X-PRI	500	Sigma 28-70	28
AOS-8	AOS S-VIT 1531	500	Kowa 8mm fixed	-
AOS-9	AOS TRI-VIT 2236	500	Kowa 12mm fixed	-
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-10	GoPro Hero 4	120		
GP-11	GoPro Hero 4	240		
GP-18	GoPro Hero 6	240		
GP-19	GoPro Hero 6	240		
GP-20	GoPro Hero 6	240		
GP-21	GoPro Hero 6	240		
PAN-1	Panasonic HC-V770	120		
PAN-2	Panasonic HC-V770	120		
PAN-3	Panasonic HC-V770	120		
PAN-4	Panasonic HC-V770	120		

Figure 12. Camera Locations, Speeds, and Lens Settings, Test No. MTP-2

4 DESIGN DETAILS TEST NO. MTP-1

The test installation consisted of a 603-ft 8-in. (184.0-m) long, four-cable median barrier system, as shown in Figures 13 through 38. Photographs of the test installation are shown in Figures 39 through 42. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

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 IWRC IPS (pre-stretched) wire ropes were used 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 ground line. The cables were numbered 1 through 4, starting with the bottom cable and proceeding upward to the top cable. These cables were tensioned up to a nominal force of 2,500 lb (11.1 kN). The cables were supported by 78-in. (1,981-mm) long, HSS3x2x⅛ (75x51x31) steel posts with two ¾-in. (19-mm) holes in the upstream and downstream walls at the ground line, as shown in Figure 18. The posts were placed on level terrain and installed with a soil embedment depth of 38 ¾ in. (984 mm) in a compacted, coarse, crushed limestone material that met American Association of State Highway and Transportation Officials (AASHTO) standard soil designation M147 Grade B, alternatively classified as well-graded gravel by the Unified Soil Classification System. The posts were spaced 8 ft (2.4 m) on center, except post nos. 68 and 69 which were spaced at 12 ft (3.7 m) on center. Each cable-to-post attachment bracket was fastened to its respective post by a bolt and sleeve nut. The free end of each bracket was inserted into a notch cut into the MTP, as shown in Figure 18.



Notes: (1) Test shall be performed according to test designation no. 3-11 using MASH 2016 criteria.
(2) The impact location is 12" [305] upstream from post no. 32.
(3) At a minimum, critical post nos. 26-48 are placed in 18" [457] diameter hole backfilled and tamped in well compacted soil.
(4) Test cable tensions of 2500 ± 200 lb [11.1 ± 0.890 kN].
(5) Bottom cable attached to line posts on non-impact side.
(6) Span between posts 68 and 69 is 144" [3658].

MwRSF Midwest Roadside Safety Facility	Non-Proprietary Cable Median Barrier Test No. MTP-1 System Layout	SHEET: 1 of 26 DATE: 6/11/2019 DRAWN BY: MBD/MKB/JEK/DJW
	DWG. NAME. MTP-1_R5 SCALE: 1:750 UNITS: in.[mm]	REV. BY: KAL/JCH

Figure 13. System Layout, Test No. MTP-1

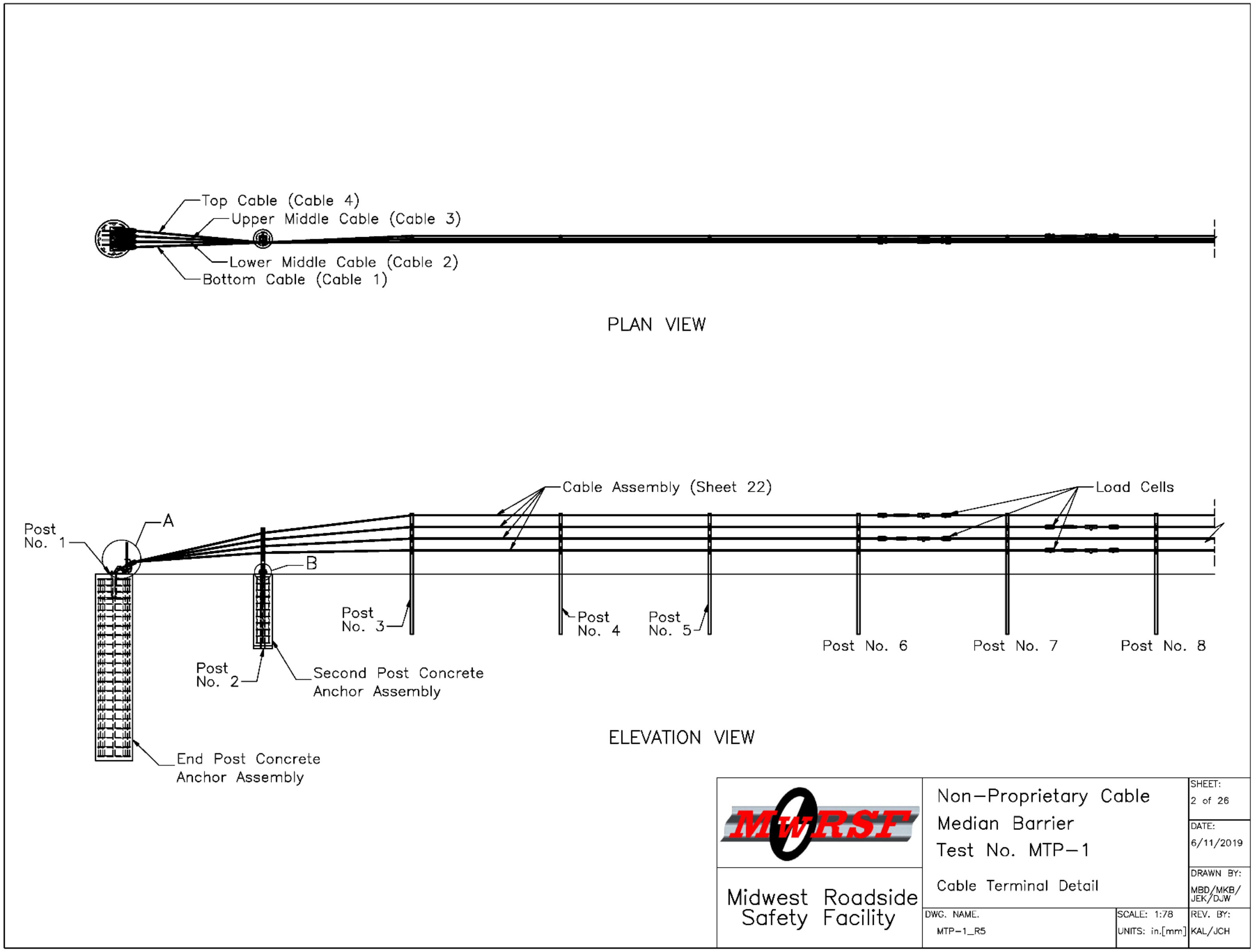


Figure 14. Cable Terminal Detail, Test No. MTP-1

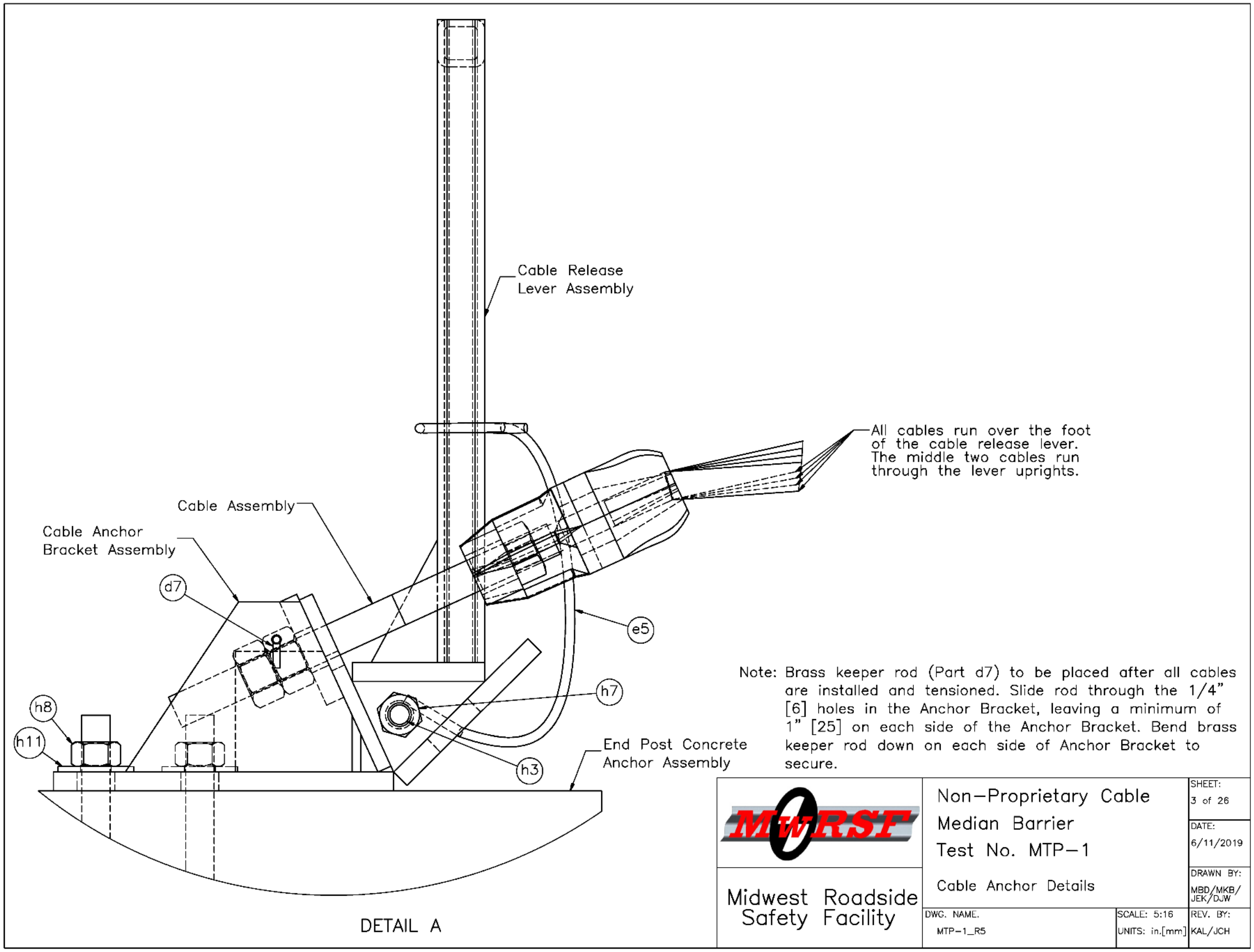


Figure 15. Cable Anchor Details, Test No. MTP-1

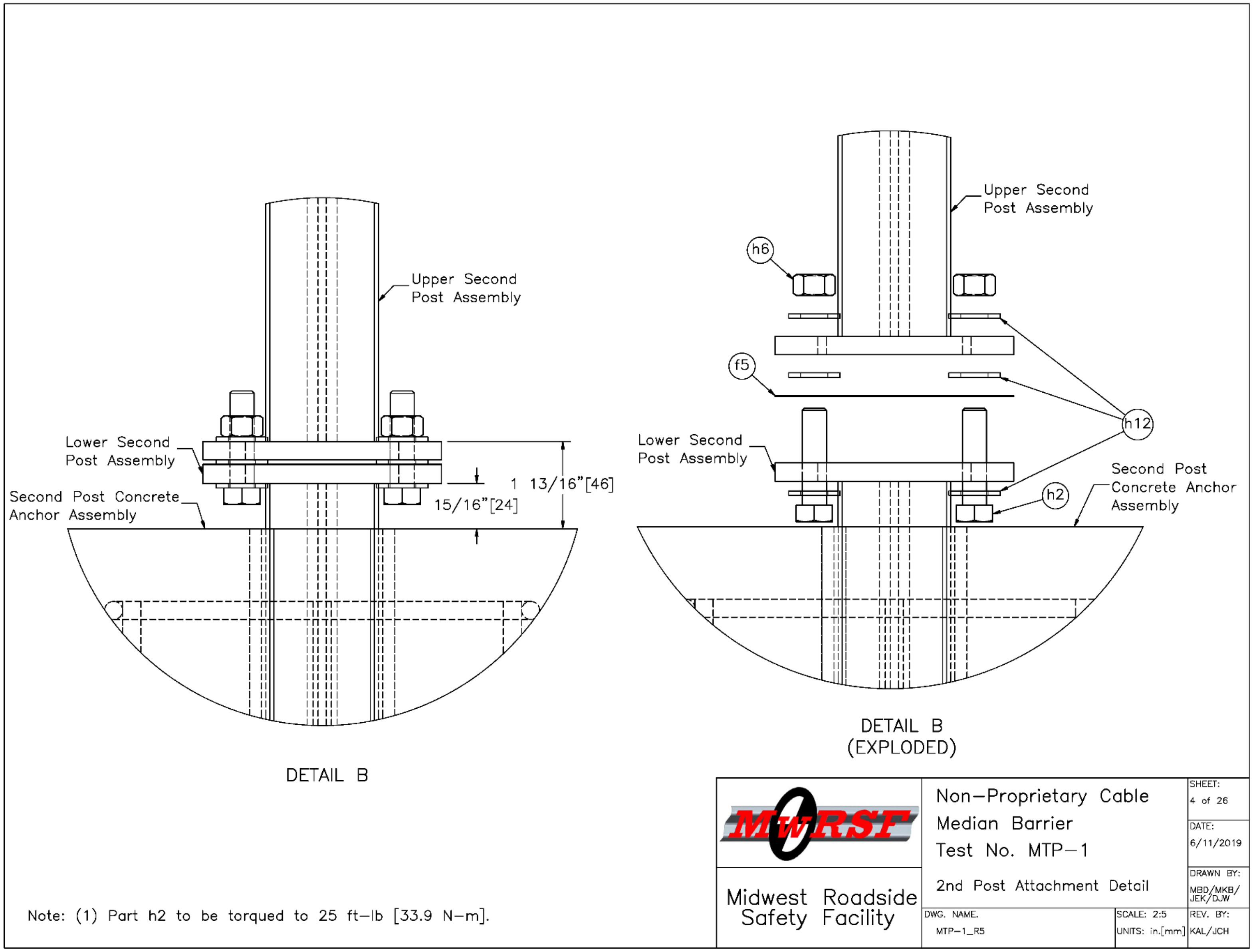


Figure 16. Second Post Attachment Detail, Test No. MTP-1

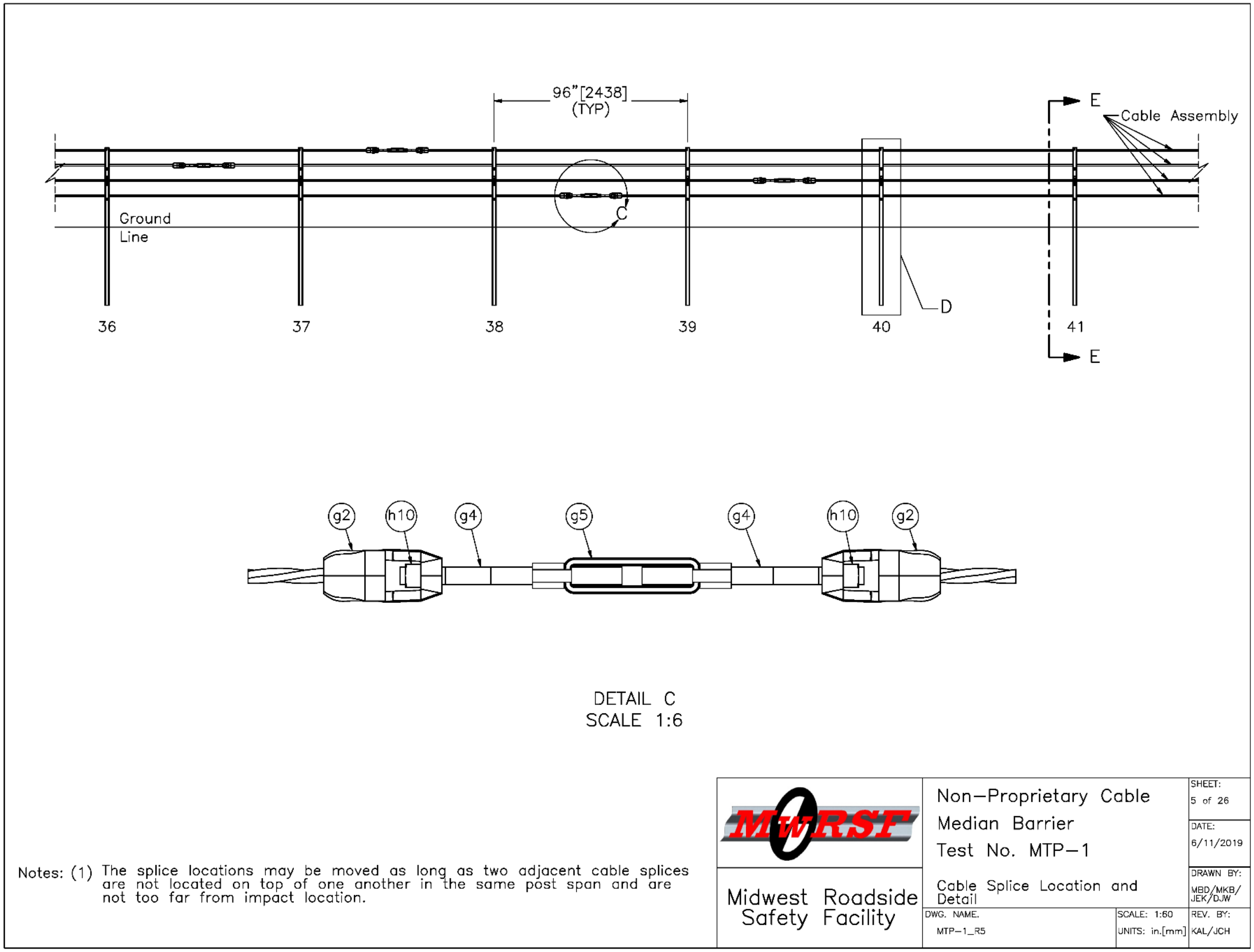


Figure 17. Cable Splice Location and Detail, Test No. MTP-1

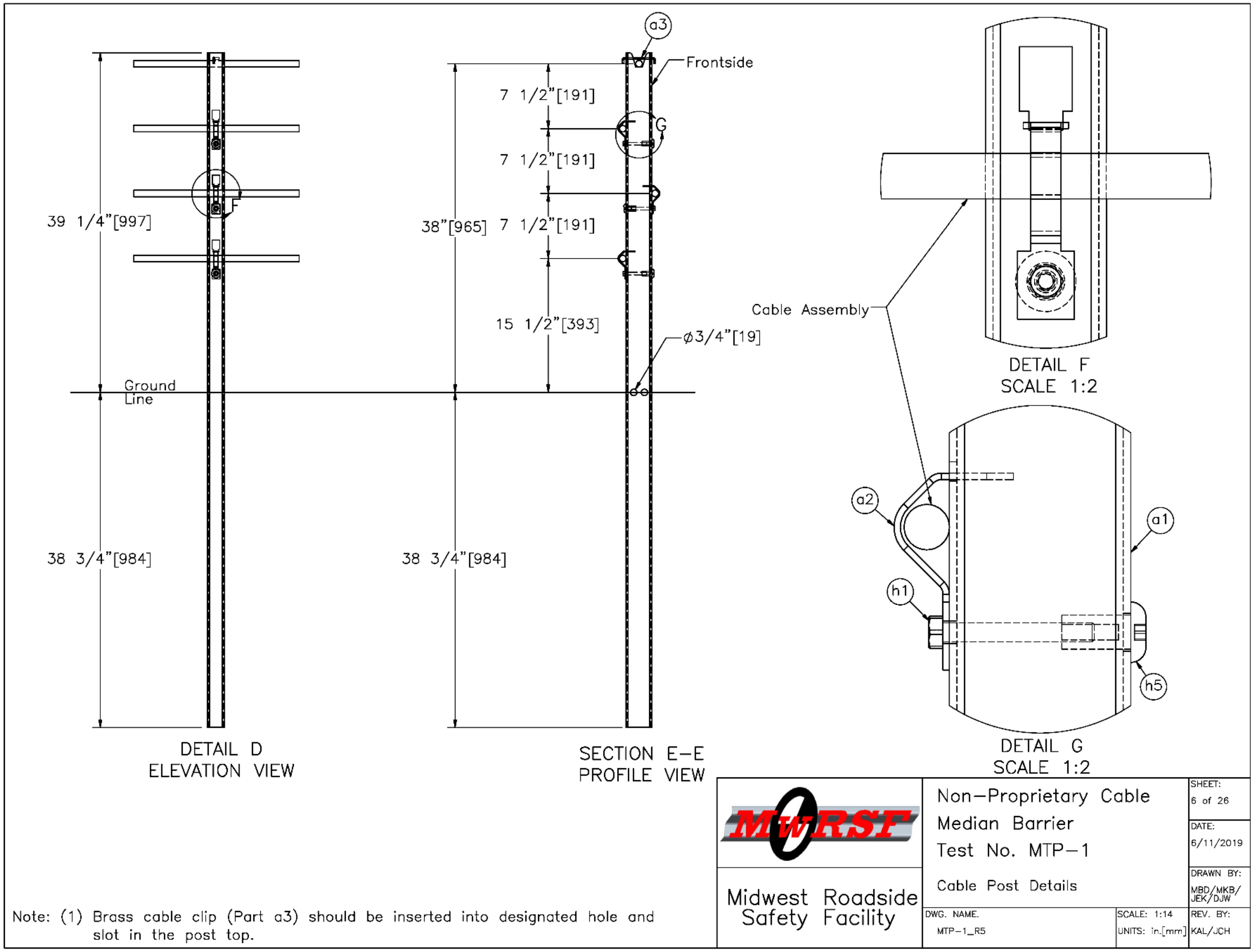


Figure 18. Cable Post Details, Test No. MTP-1

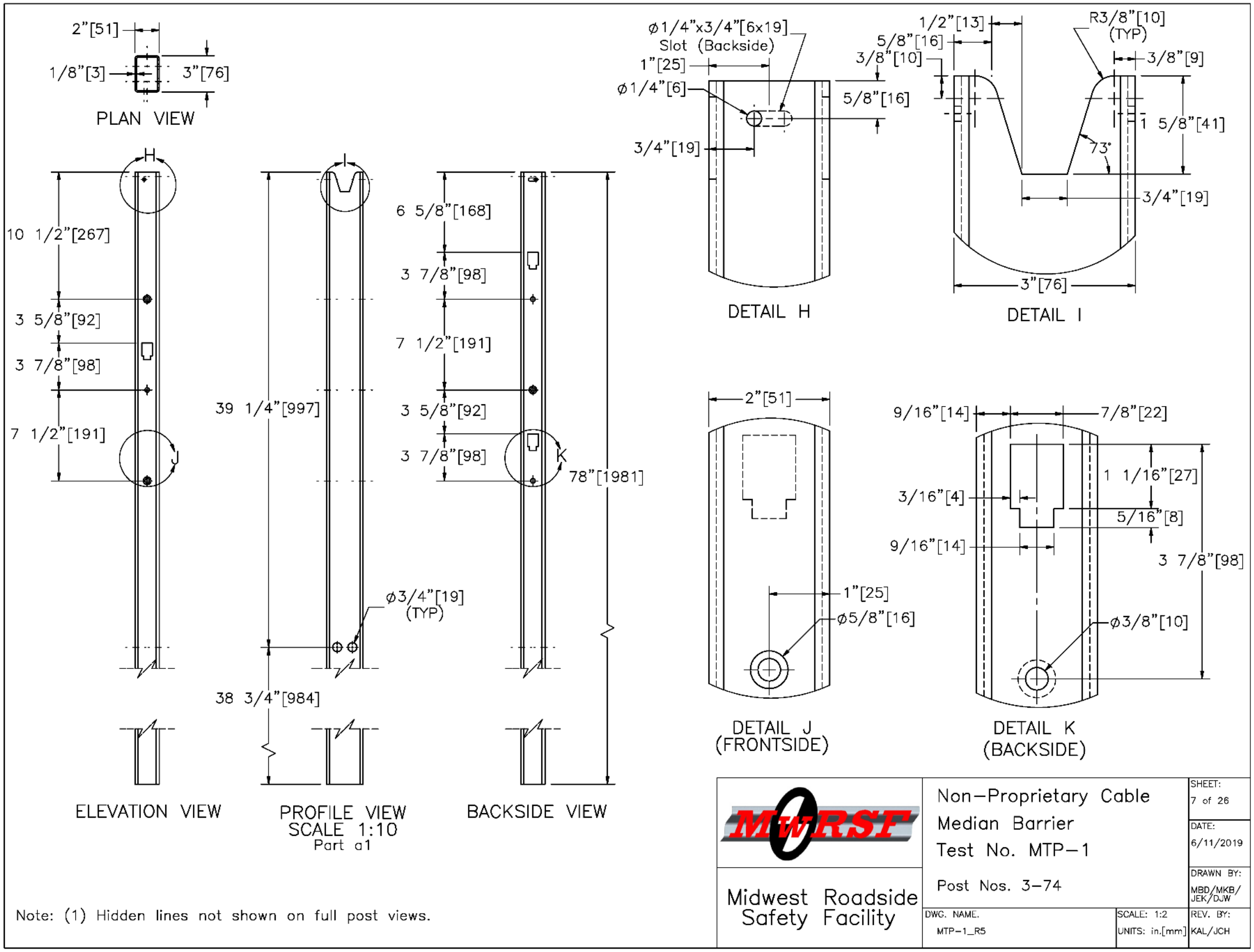


Figure 19. Post Nos. 3 through 74, Test No. MTP-1

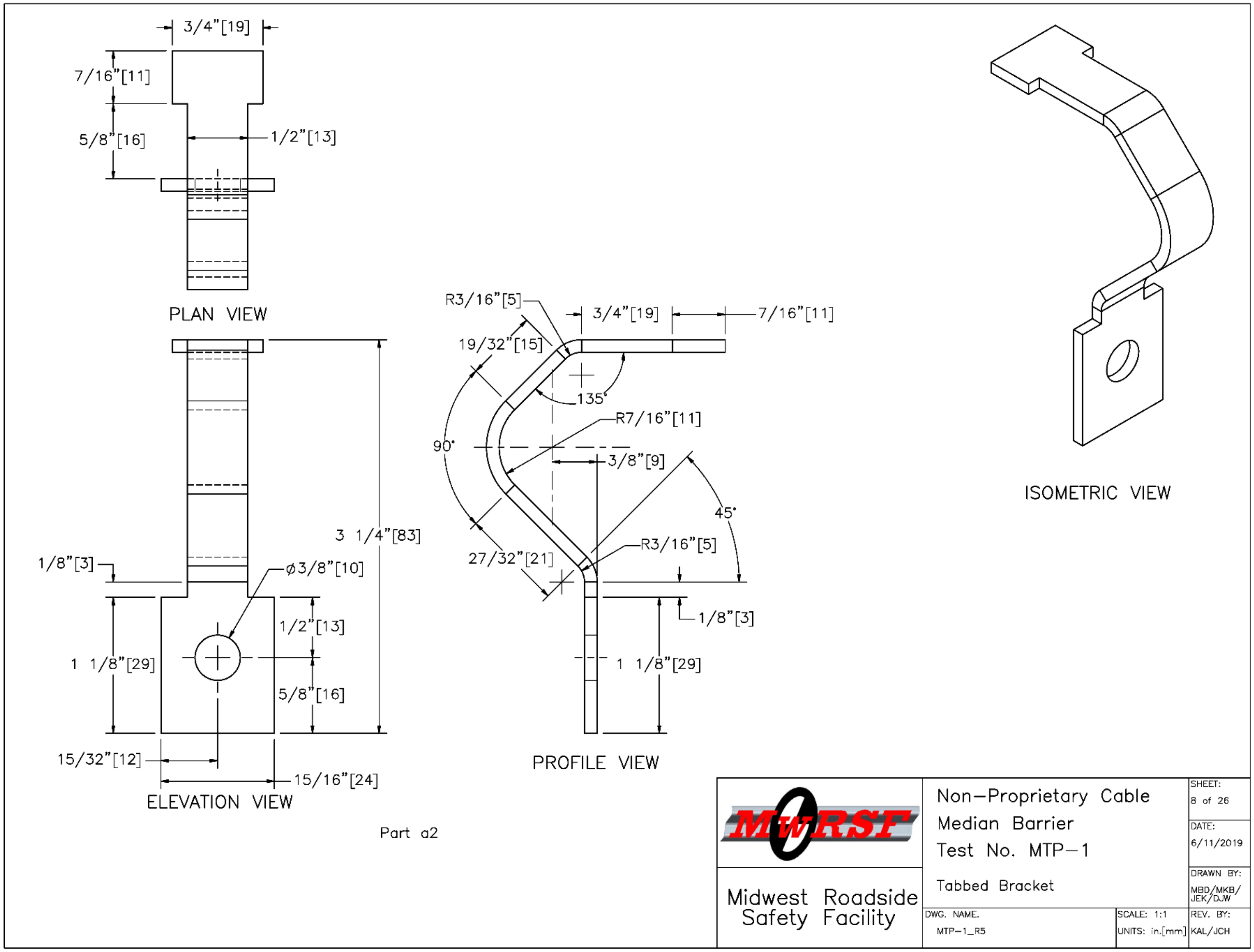


Figure 20. Tabbed Bracket, Test No. MTP-1

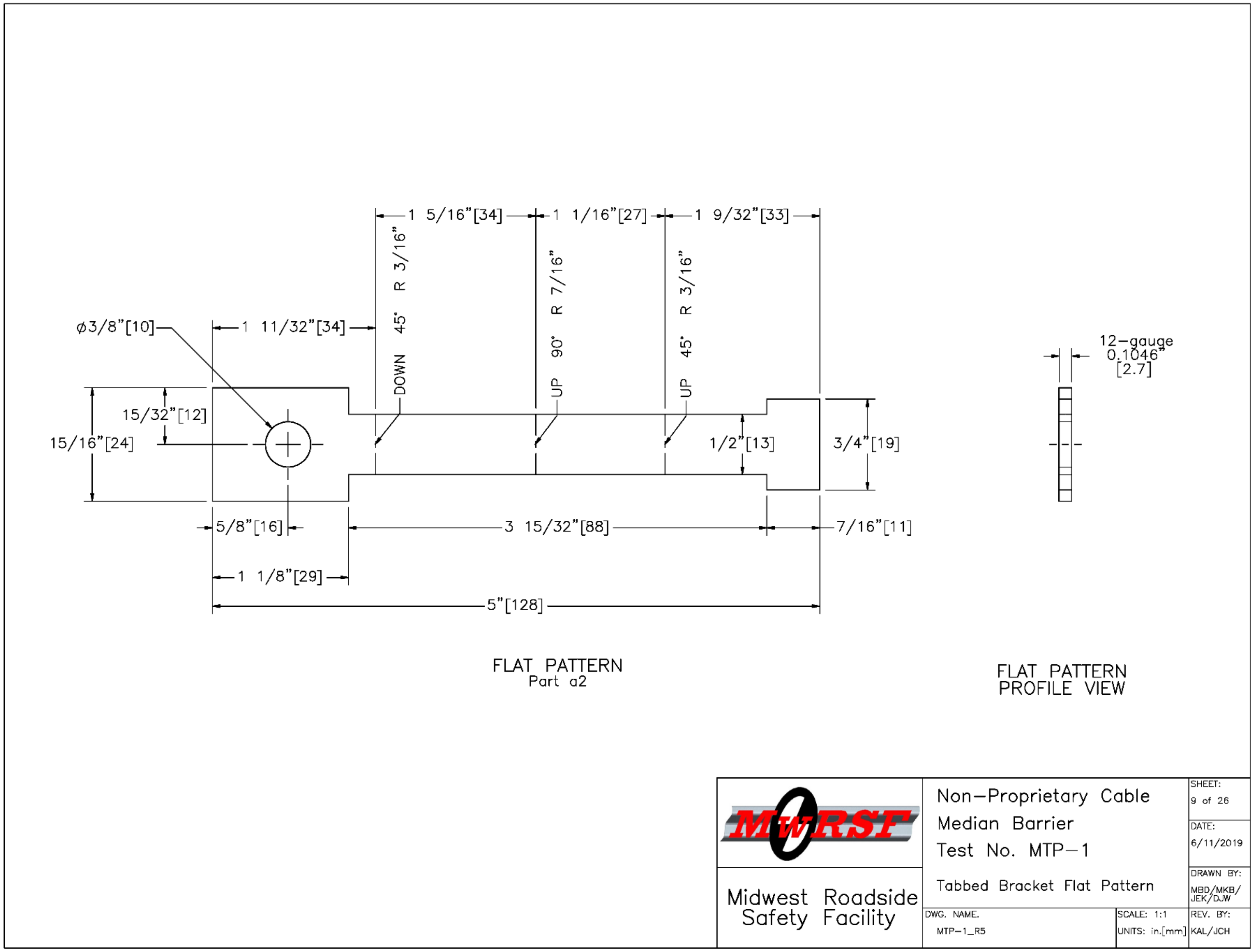
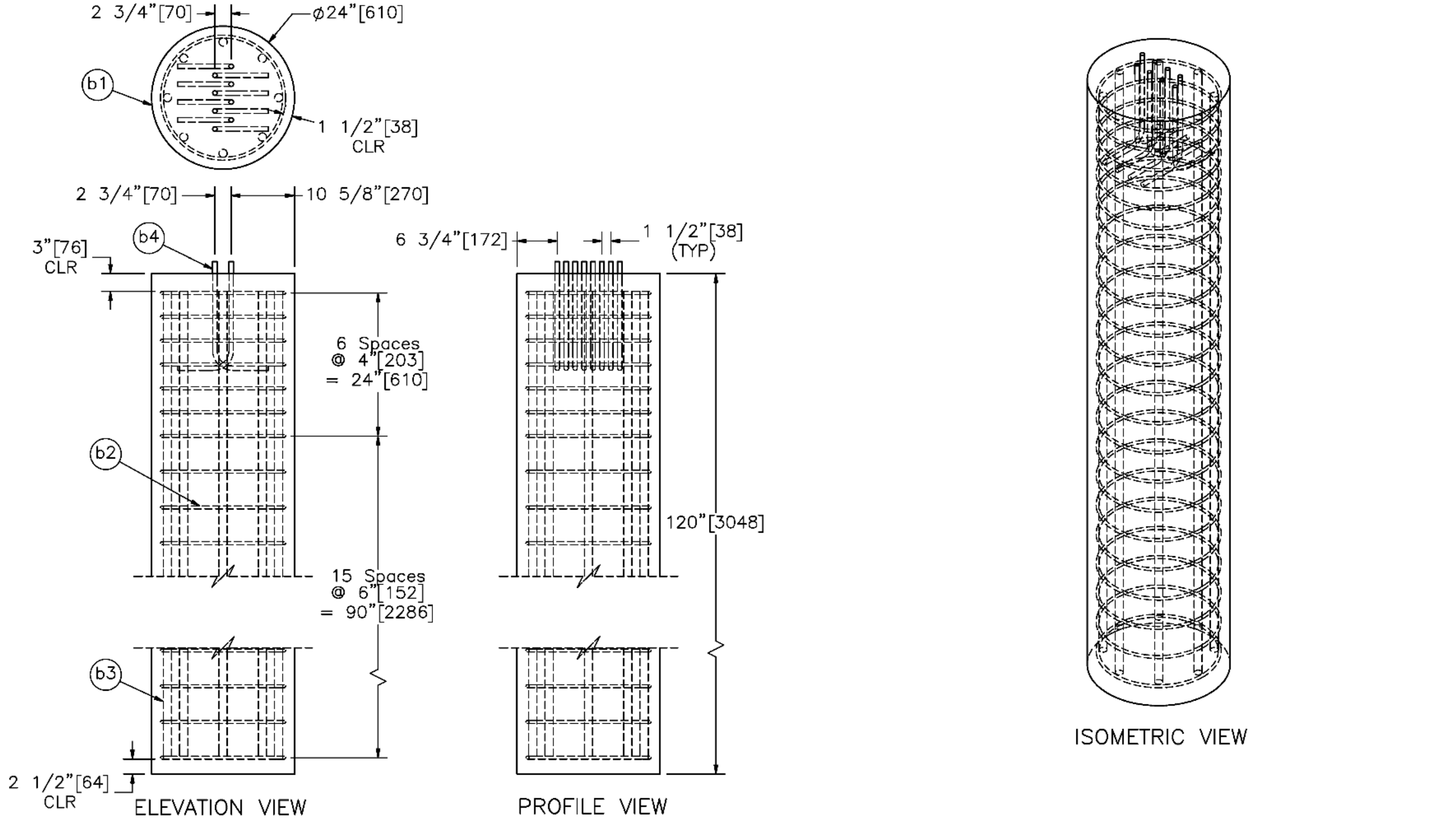


Figure 21. Tabbed Bracket Flat Pattern, Test No. MTP-1



Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	2	End Post Concrete Anchor Assembly	–	–	–
b1	1	24" [610] Dia. Concrete Anchor, 120" [3,048] Long	Min. f'c = 4,000 psi [27.6 MPa]	–	–
b2	22	#4 [13] Hoop Bar with 21" [533] Dia., 84" [2,134] Unbent Length	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
b3	8	#11 [35] Bar, 114" [2,896] Long	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
b4	8	3/4"-10 UNC [M20x2.5] J-Hook Anchor	ASTM A449	ASTM A153 or B695 Class 55 or F2329	FRJ16a

Note: (1) The two outer bent anchor studs may need to be turned inward so they do not stick out of concrete cover.

Midwest Roadside Safety Facility

Non-Proprietary Cable Median Barrier
Test No. MTP-1

End Post Concrete Anchor Assembly

SHEET: 10 of 26
DATE: 6/11/2019
DRAWN BY: MBD/MKB/JEK/DJW
DWG. NAME. MTP-1_R5
SCALE: 1:24
UNITS: in.[mm]
REV. BY: KAL/JCH

Figure 22. End Post Concrete Anchor Assembly, Test No. MTP-1

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	2	Second Post Concrete Anchor Assembly	–	–	–
c1	1	12" [305] Dia. 2nd Post Concrete Anchor, 46" [1,168] Long	Min. f'c = 4,000 psi [27.6 MPa]	–	–
c2	1	12" [305] Dia. 2nd Post Anchor Aggregate, 2" [51] Deep	Standard Strong Soil	–	–
c3	11	#3 [10] Hoop Bar with 9" [229] Dia., 37" [940] Unbent Length	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy–Coated (ASTM A775 or A934)	–
c4	4	#3 [10] Bar, 43" [1,092] Long	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy–Coated (ASTM A775 or A934)	–
c5	1	4"x3"x1/4" [102x76x6] Foundation Tube, 48" [1,219] Long	ASTM A500 Gr. B	ASTM A123	–
h4	1	3/4"–10 UNC [M20x2.5], 5 1/2" [140] Long Hex Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBX20a
h8	1	3/4"–10 UNC [M20x2.5] Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX20a
h11	2	3/4" [19] Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC20a

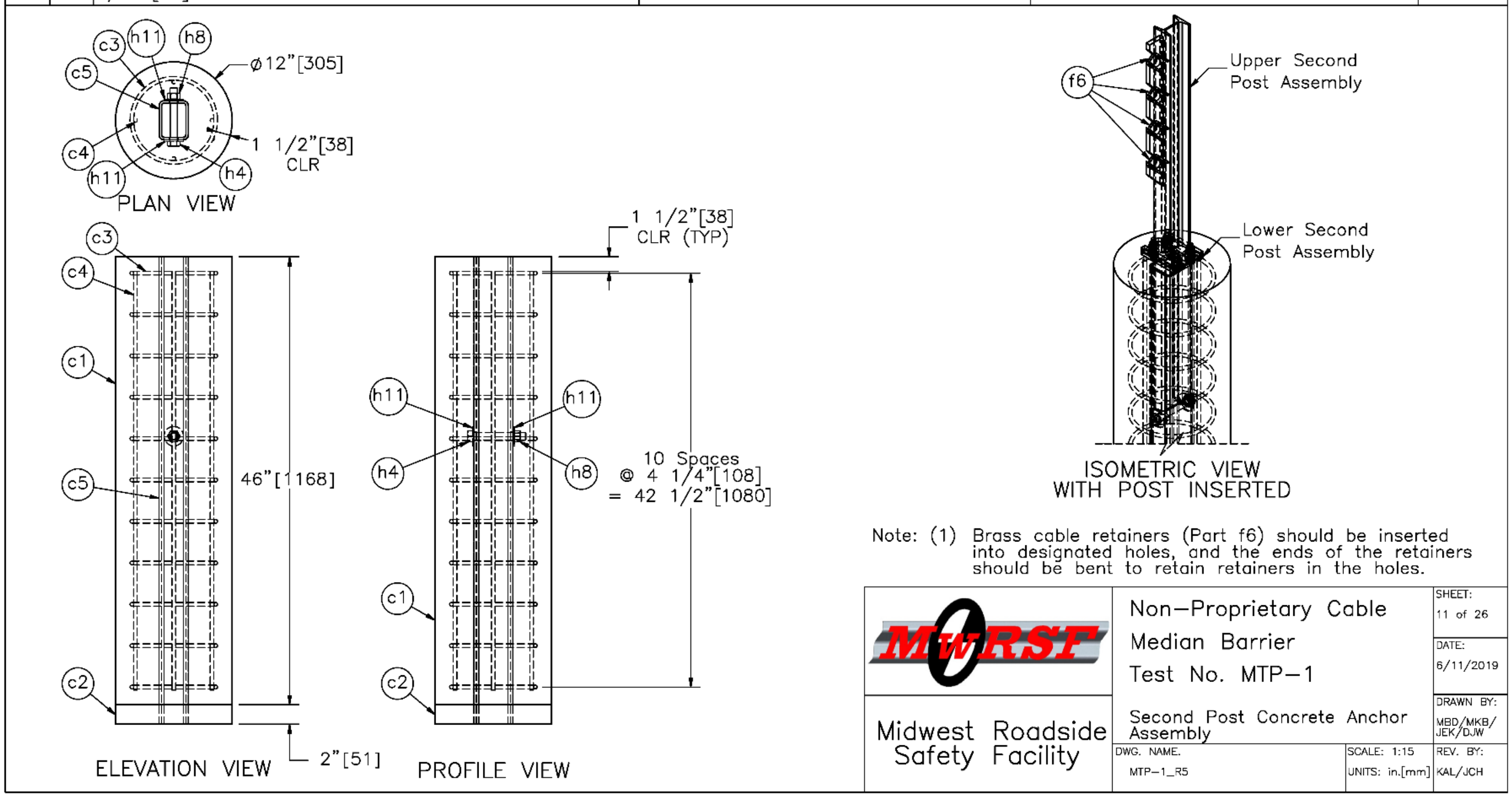
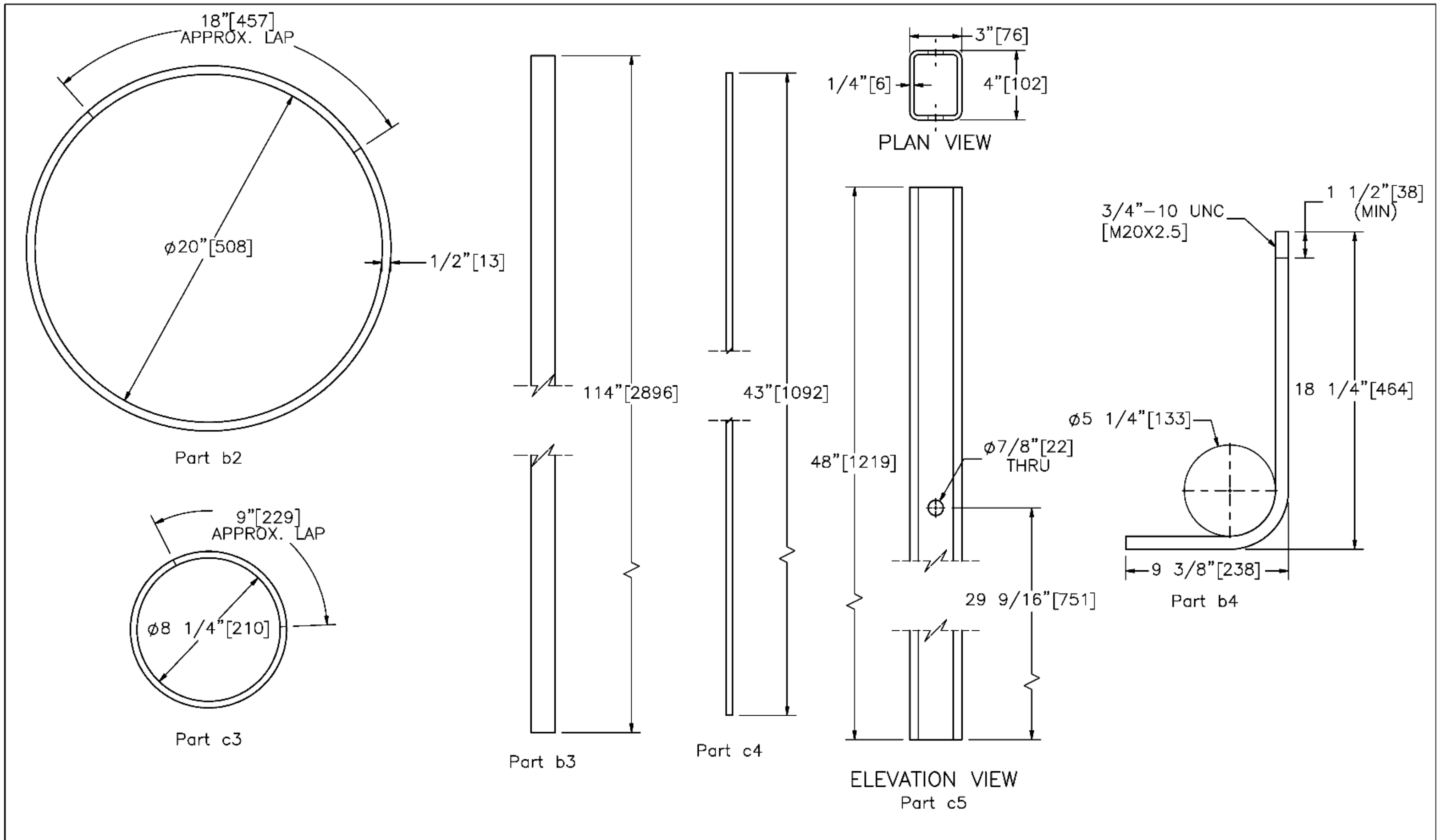


Figure 23. Second Post Concrete Anchor Assembly, Test No. MTP-1



Note: (1) Part b4 total unbent length is 25 9/16" [649].

Bill of Bars

Bar	QTY.	Size	Total Unbent Length	Material Specification	Treatment Specification
b2	44	#4	84" [2,134]	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy-Coated (ASTM A775 or A934)
b3	16	#11	114" [2,896]	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy-Coated (ASTM A775 or A934)
c3	22	#3	37" [940]	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy-Coated (ASTM A775 or A934)
c4	8	#3	43" [1,092]	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy-Coated (ASTM A775 or A934)

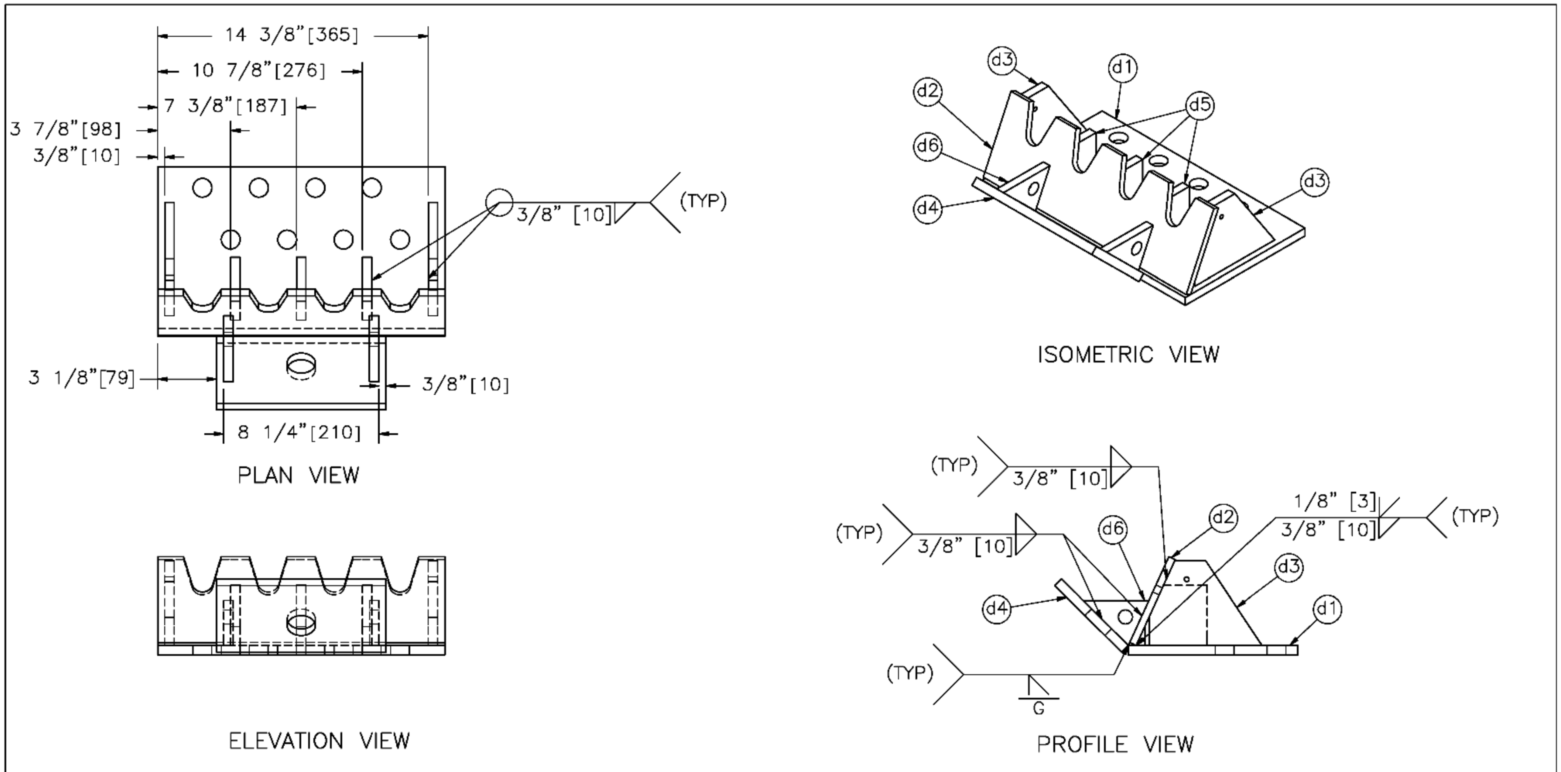
Midwest Roadside Safety Facility

Non-Proprietary Cable Median Barrier
Test No. MTP-1

Reinforcement Details

SHEET: 12 of 26
DATE: 6/11/2019
DRAWN BY: MBD/MKB/JEK/DJW
DWG. NAME. MTP-1_R5
SCALE: 1:8
UNITS: in.[mm]
REV. BY: KAL/JCH

Figure 24. Reinforcement Details, Test No. MTP-1



Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	2	Cable Anchor Bracket Assembly	–	ASTM A123	FPA02
d1	1	15 1/4"x9"x1/2" [387x229x13] Cable Anchor Base Plate	ASTM A36	See Assembly	–
d2	1	15 1/4"x5"x3/8" [387x127x10] Anchor Bracket Plate	ASTM A36	See Assembly	–
d3	2	6"x4 1/2"x1/2" [152x114x13] Exterior Cable Plate Gusset	ASTM A36	See Assembly	–
d4	1	9"x5"x1/2" [229x127x13] Release Lever Plate	ASTM A36	See Assembly	–
d5	3	3 5/16"x3 3/16"x1/2" [84x81x13] Interior Cable Plate Gusset	ASTM A36	See Assembly	–
d6	2	3 1/2"x2 3/8x1/2" [89x61x13] Release Gusset	ASTM A36	See Assembly	–

Midwest Roadside Safety Facility

Non–Proprietary Cable Median Barrier
Test No. MTP–1

Cable Anchor Bracket Assembly

SHEET: 13 of 26
DATE: 6/11/2019
DRAWN BY: MBD/MKB/JEK/DJW
DWG. NAME. MTP–1_R5
SCALE: 1:8
UNITS: in.[mm]
REV. BY: KAL/JCH

Figure 25. Cable Anchor Bracket Assembly, Test No. MTP-1

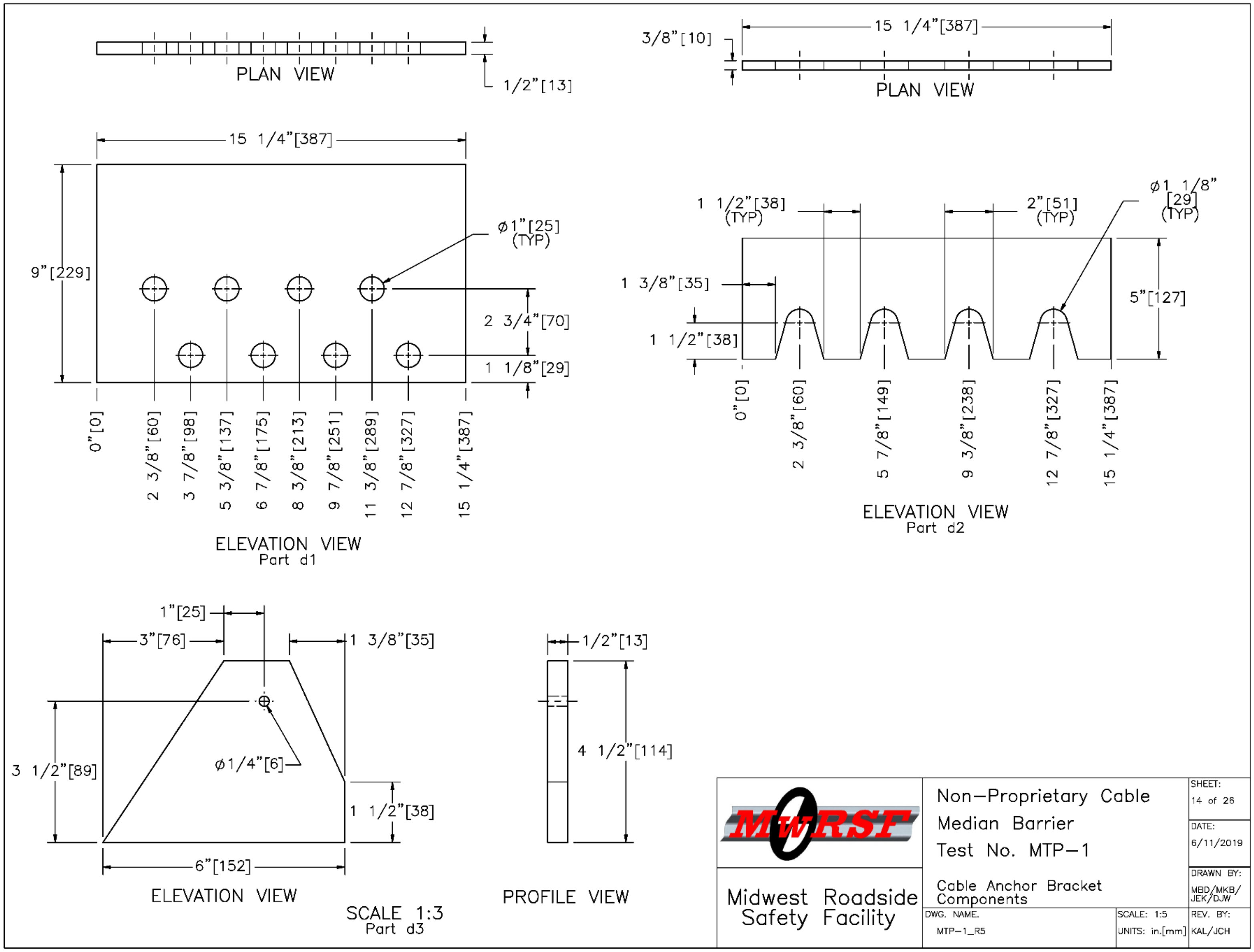


Figure 26. Cable Anchor Bracket Components, Test No. MTP-1

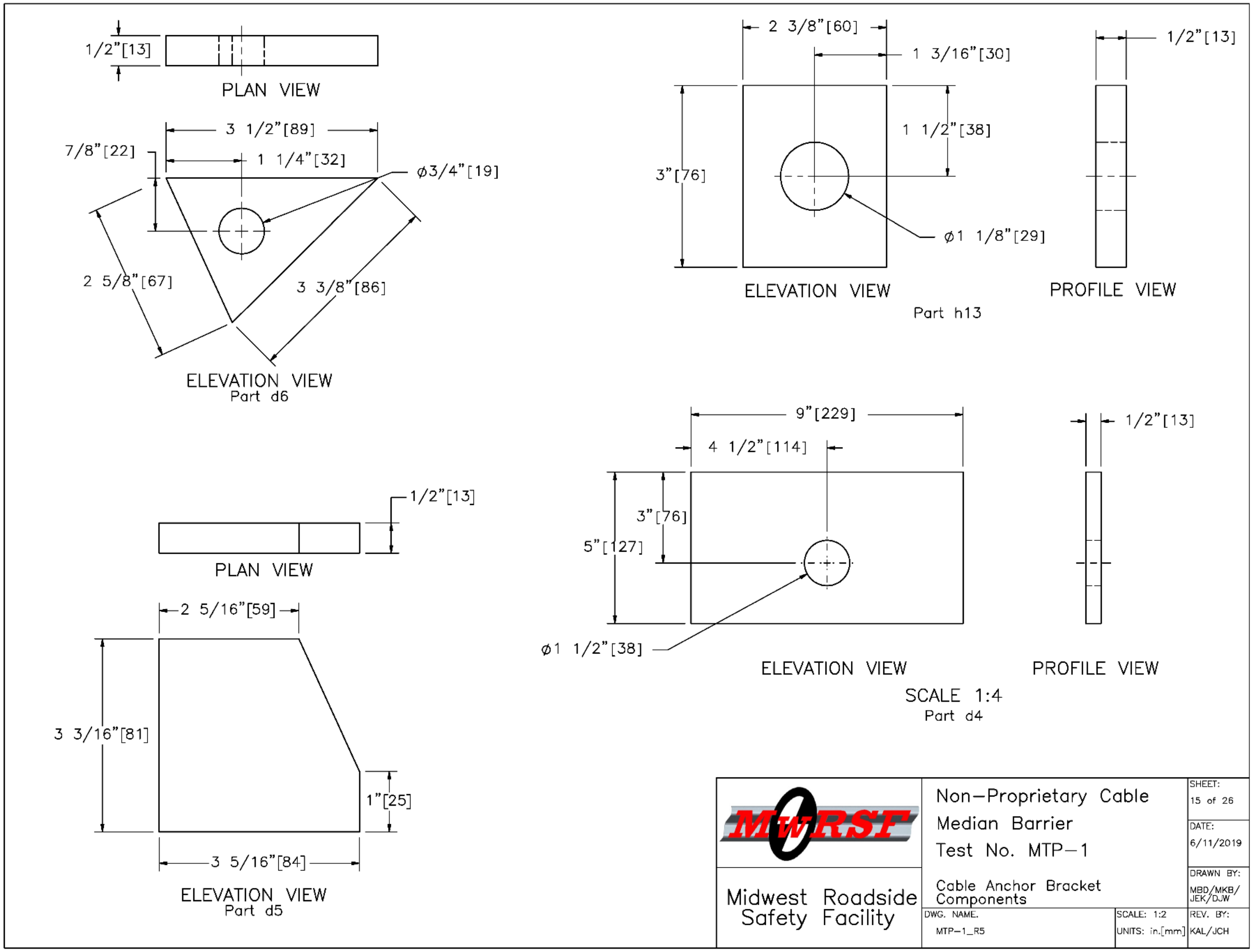
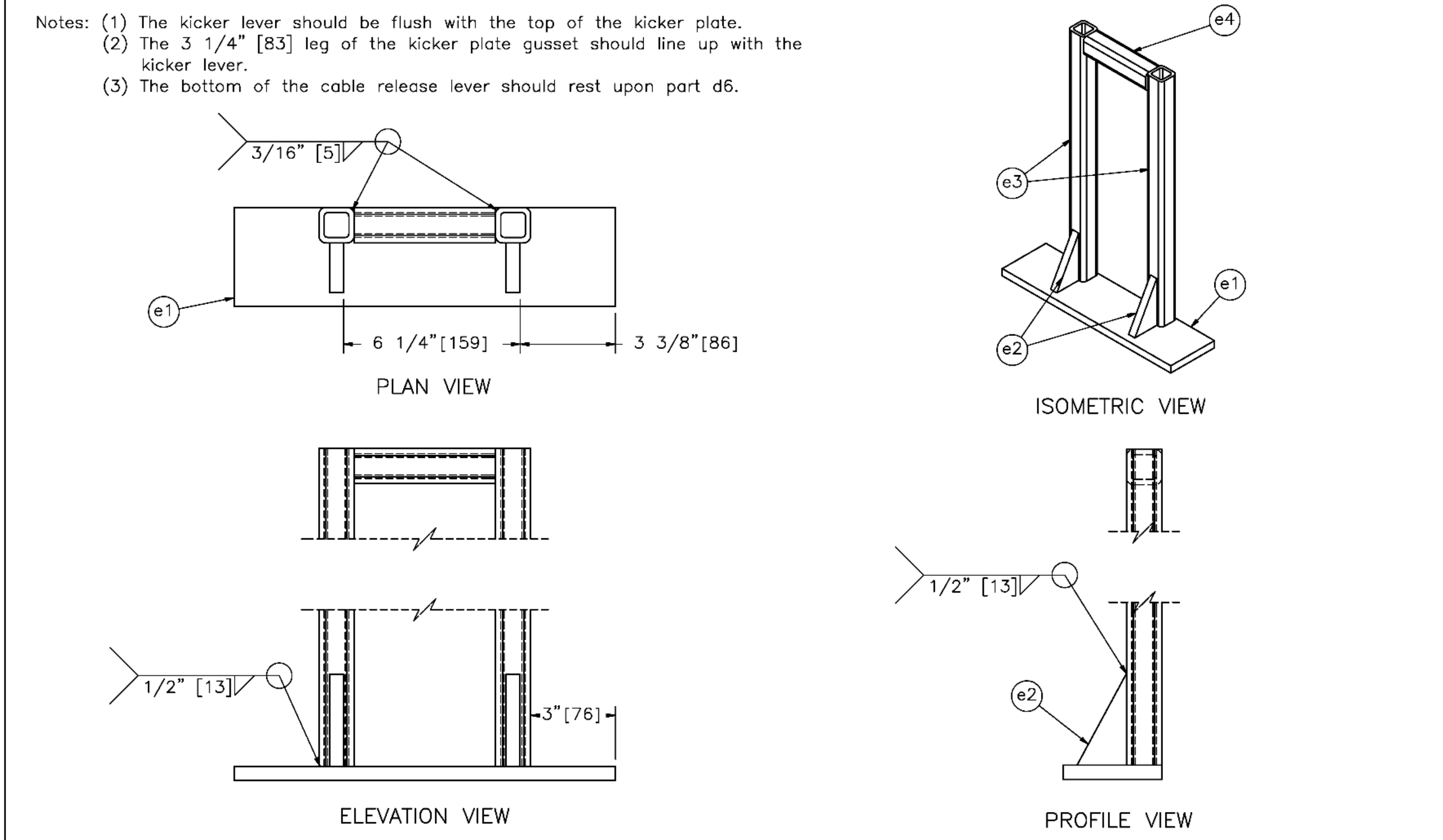


Figure 27. Cable Anchor Bracket Components, Test No. MTP-1



Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	2	Cable Release Lever Assembly	–	ASTM A123	–
e1	1	13 1/2"x3 1/2"x1/2" [343x89x13] Kicker Plate	ASTM A36	See Assembly	–
e2	2	3 1/4"x1 3/4"x1/2" [83x44x13] Kicker Gusset	ASTM A36	See Assembly	–
e3	2	1 1/4"x1 1/4"x3/16" [32x32x5], 17" [432] Long Square Tube	ASTM A500 Gr. B	See Assembly	–
e4	1	1 1/4"x1 1/4"x3/16" [32x32x5], 5" [127] Long Square Tube	ASTM A500 Gr. B	See Assembly	–

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Non–Proprietary Cable Median Barrier
Test No. MTP–1
Cable Release Lever Assembly

SHEET: 16 of 26
DATE: 6/11/2019
DRAWN BY: MBD/MKB/JEK/DJW
REV. BY: KAL/JCH
DWG. NAME. MTP–1_R5
SCALE: 1:5
UNITS: in.[mm]

Figure 28. Cable Release Lever Assembly, Test No. MTP-1

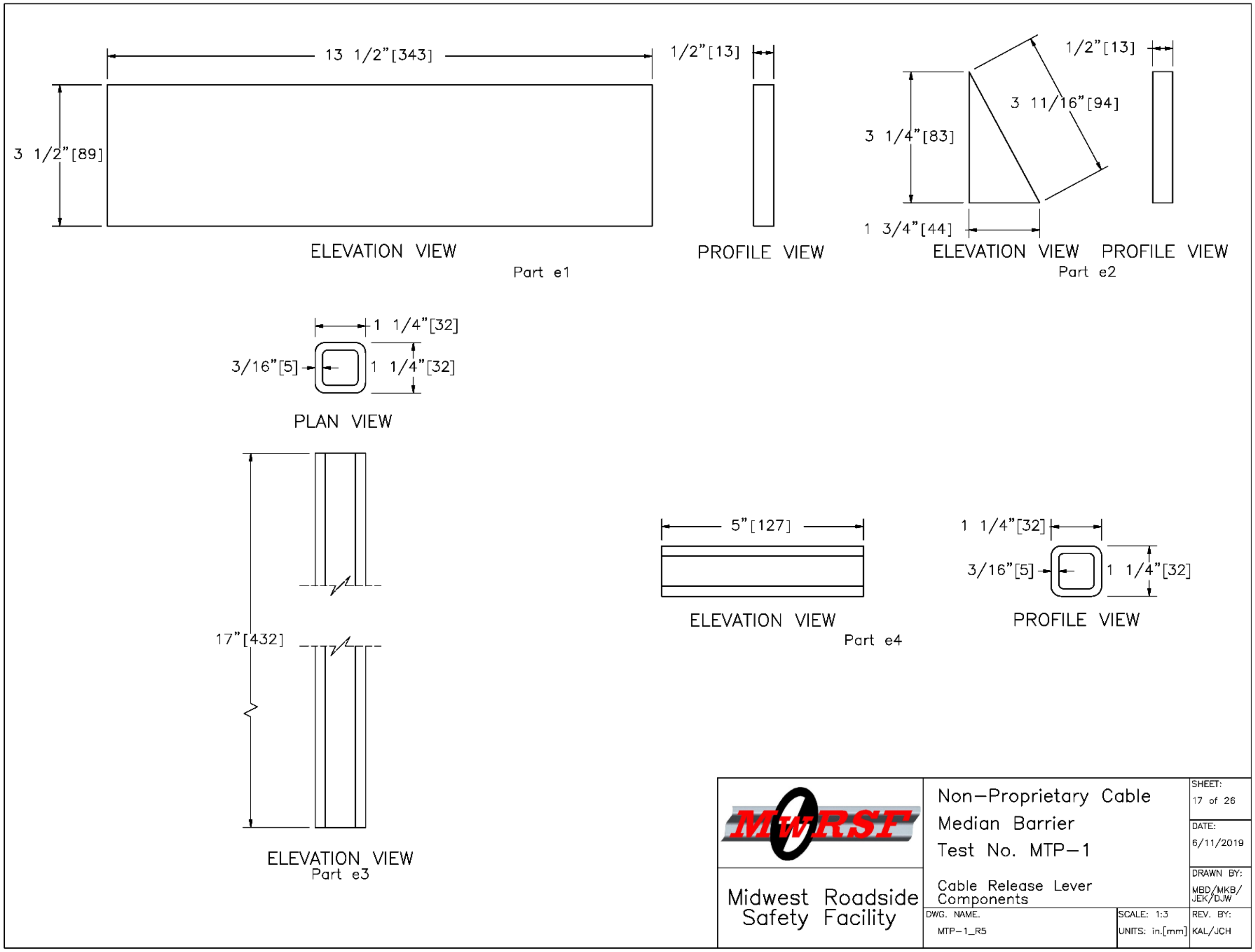
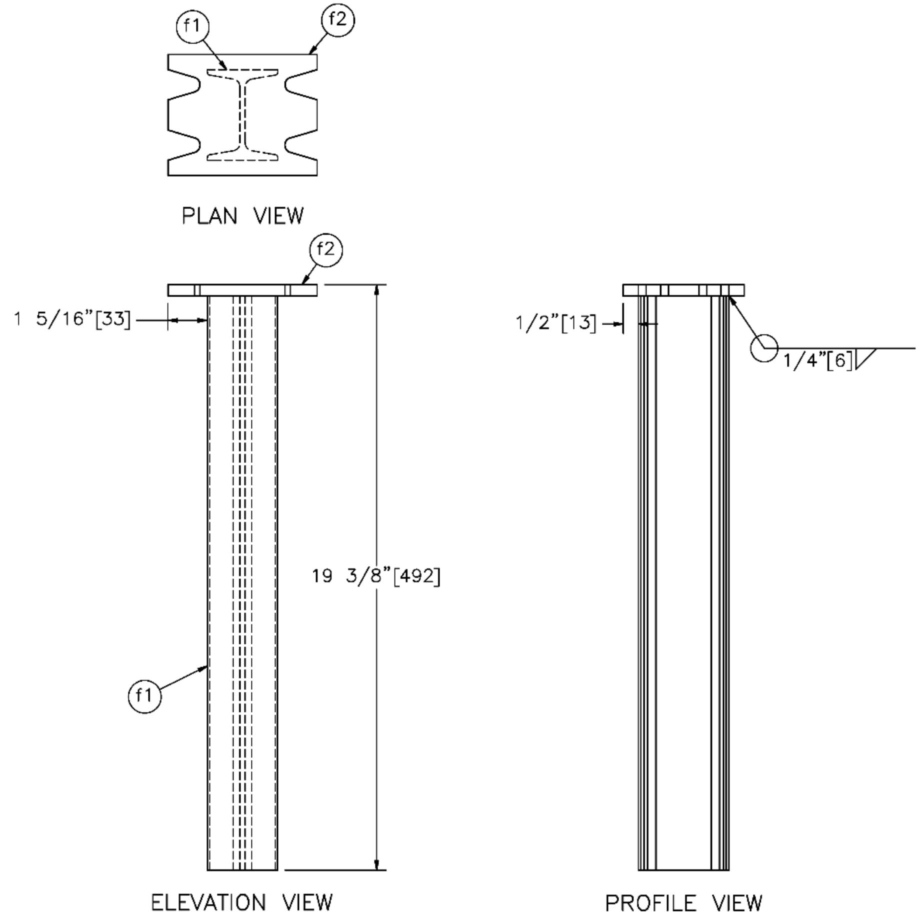


Figure 29. Cable Release Lever Components, Test No. MTP-1



Item No.	QTY.	Description	Material Specification	Treatment Specification
–	2	Lower Second Post Assembly	–	ASTM A123
f1	1	S3x5.7 [S75x8.5], 19" [483] Long Post	ASTM A36	See Assembly
f2	1	4 15/16"x4"x3/8" [125x102x10] Base Plate	ASTM A36	See Assembly

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Non-Proprietary Cable Median Barrier
Test No. MTP-1

Lower Second Post Assembly

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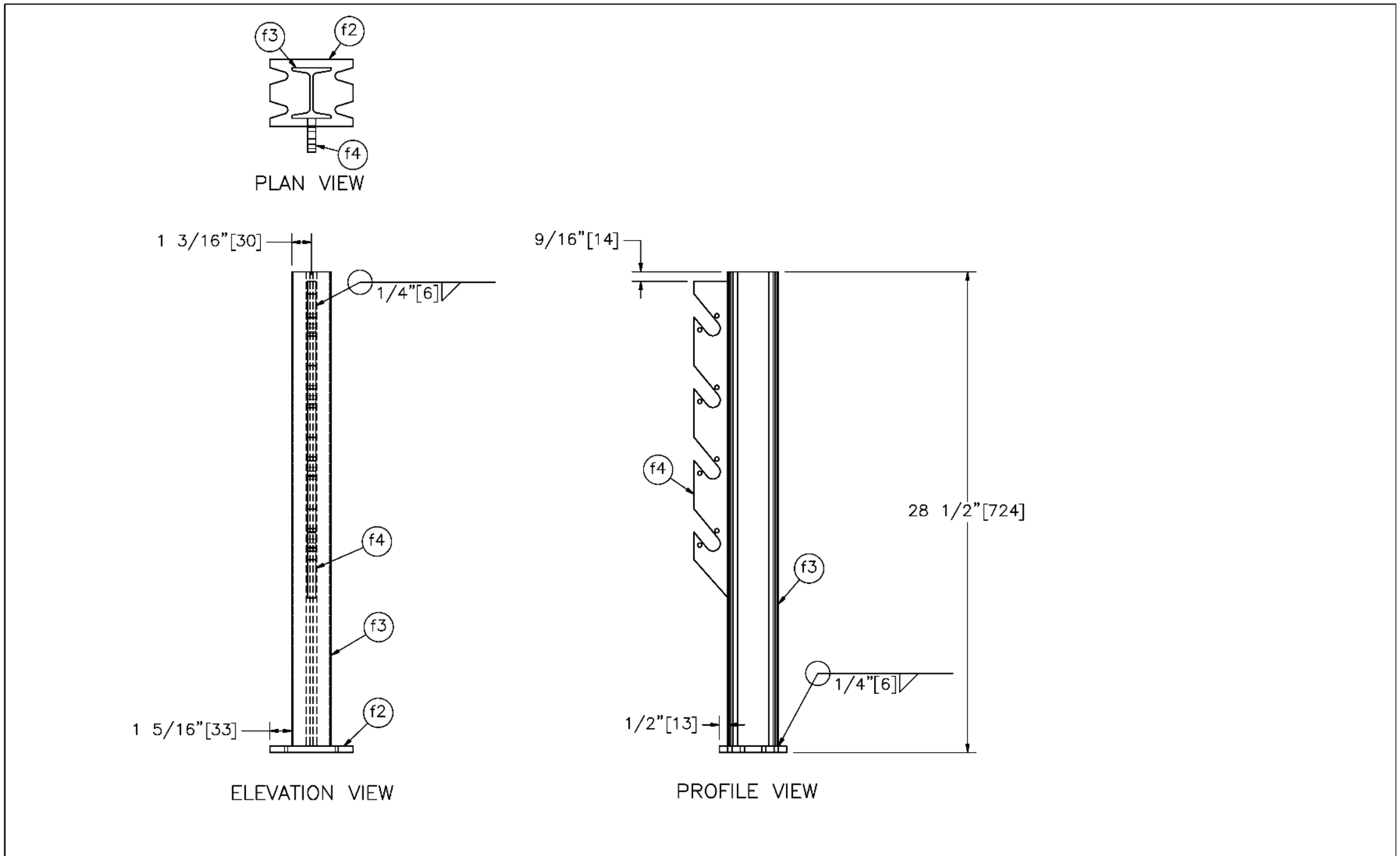
DATE: 6/11/2019
DRAWN BY: MBD/MKB/JEK/DJW
DWG. NAME. MTP-1_R5
SCALE: 1:5
UNITS: in.[mm]
REV. BY: KAL/JCH

Figure 30. Lower Second Post Assembly, Test No. MTP-1



Item No.	QTY.	Description	Material Specification	Treatment Specification
–	2	Upper Second Post Assembly	–	ASTM A123
f2	1	4 15/16"x4"x3/8" [125x102x10] Base Plate	ASTM A36	See Assembly
f3	1	S3x5.7 [S75x8.5], 28 1/8" [714] Long Post	ASTM A36	See Assembly
f4	1	18 3/4"x2"x1/2" [476x51x13] Cable Hanger	ASTM A36	See Assembly

Midwest Roadside Safety Facility	Non–Proprietary Cable Median Barrier Test No. MTP–1 Upper Second Post Assembly		SHEET: 19 of 26
			DATE: 6/11/2019
			DRAWN BY: MBD/MKB/JEK/DJW
	DWG. NAME. MTP–1_R5	SCALE: 1:8 UNITS: in.[mm]	REV. BY: KAL/JCH

Figure 31. Upper Second Post Assembly, Test No. MTP-1

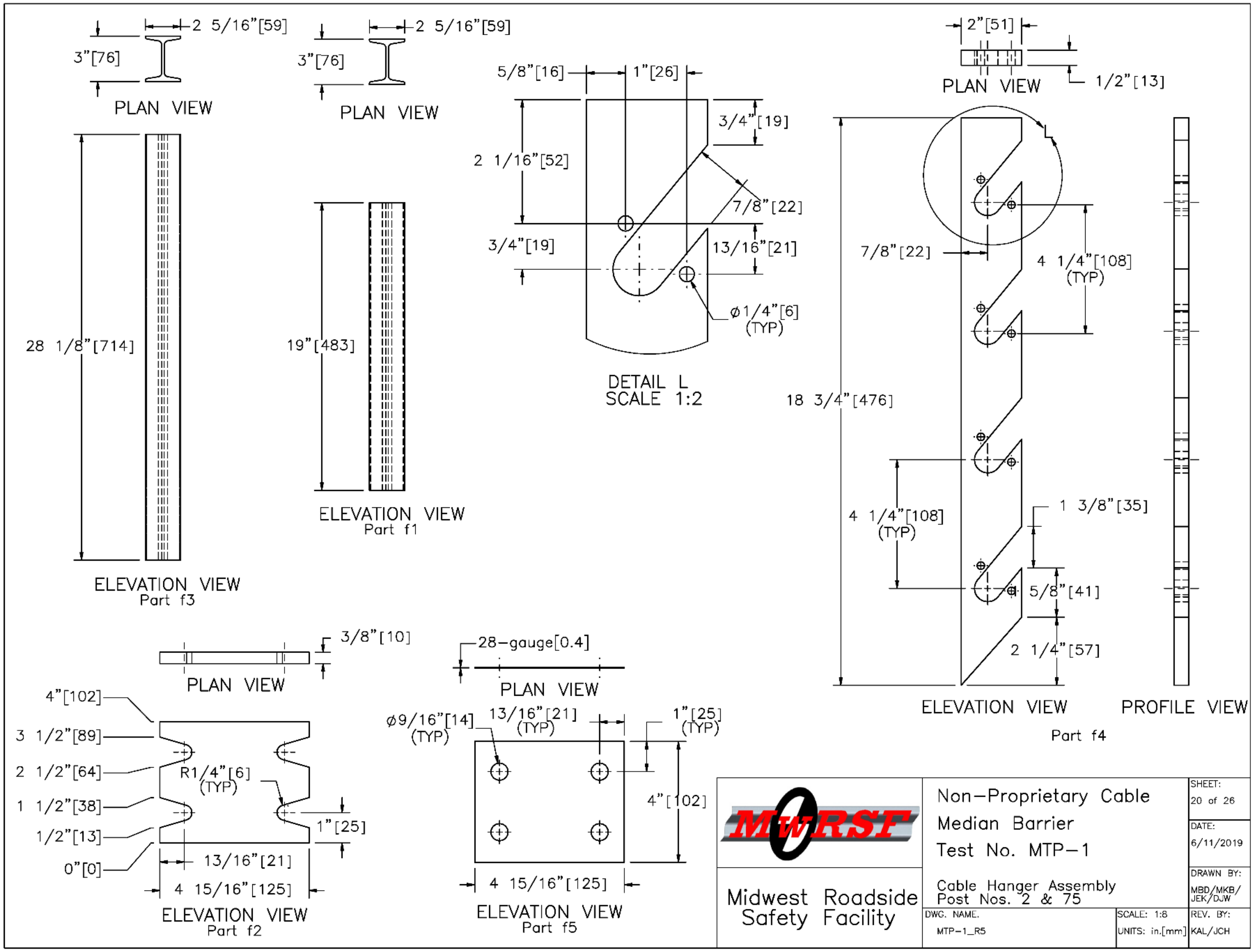
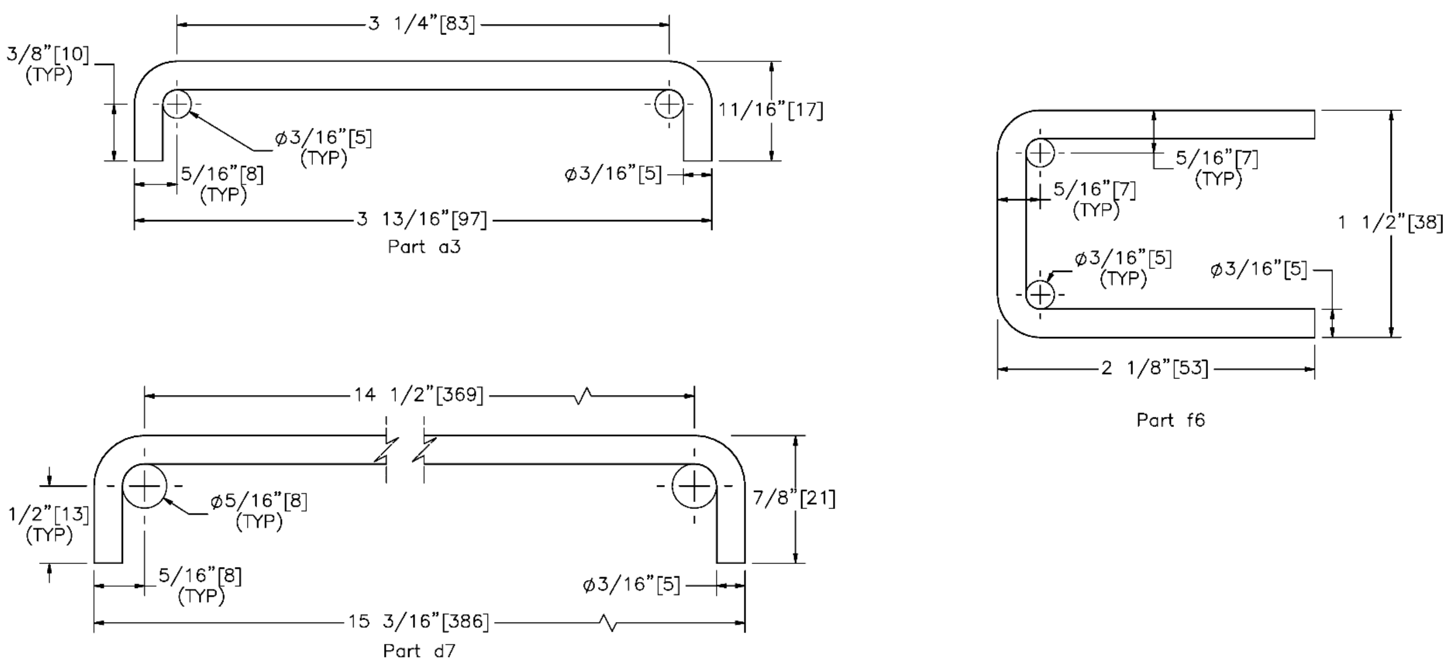


Figure 32. Cable Hanger Assembly, Post Nos. 2 and 75, Test No. MTP-1



Bar	Total Unbent Length
a3	4 9/16" [116]
d7	16 1/4" [413]
f6	5 1/8" [130]

Midwest Roadside Safety Facility

Non-Proprietary Cable Median Barrier
Test No. MTP-1

Brass Cable Clip Details

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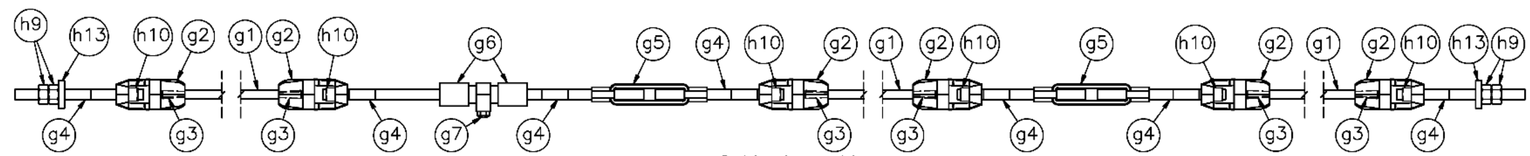
DWG. NAME. MTP-1_R5
SCALE: 1:1
UNITS: in.[mm]
REV. BY: KAL/JCH

Figure 33. Brass Cable Clip Details, Test No. MTP-1



Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	4	Cable Assembly	–	–	–
g1	3	3/4" [19] Dia. 3x7 IWRC IPS Wire Rope – Lengths as Needed	ASTM A741 Type 1	Class A Coating	RCM01
g2	6	Bennett Cable End Fitter – 7/8" [22] Dia.	ASTM A220 Gr. 50005	ASTM A153 or B695	RCE03
g3	6	Cable Wedge	ASTM A47 Gr. 32510 or A536 Gr. 65–45–12	–	FMM01
g4	7	7/8"–9 UNC [M22x2.5], 11" [279] Long Threaded Rod	ASTM A449 Type 1 or ASTM A193 Gr. B7	ASTM A153 or B695 Class 55 or F2329	RCE03
g5	2	Bennett Short 7/8"–9 UNC [M22x2.5] Threaded Turnbuckle	As Supplied	As Supplied	–
g6	2	Threaded Load Cell Coupler	–	–	–
g7	1	50,000–lb [222.4–kN] Load Cell	–	–	–
h9	4	7/8"–9 UNC [M22x2.5] Heavy Hex Nut	ASTM A563C or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX22b
h10	6	7/8"–9 UNC [M22x2.5] Heavy Square Nut	ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	–
h13	2	3"x2 3/8"x1/2" [76x60x13] Rectangular Washer Plate	ASTM A36	ASTM A123	–

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Non–Proprietary Cable Median Barrier
Test No. MTP–1

Cable Assembly

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DATE: 6/11/2019
DRAWN BY: MBD/MKB/JEK/DJW
DWG. NAME. MTP–1_R5
SCALE: 1:13
UNITS: in.[mm]
REV. BY: KAL/JCH

Figure 34. Cable Assembly, Test No. MTP-1

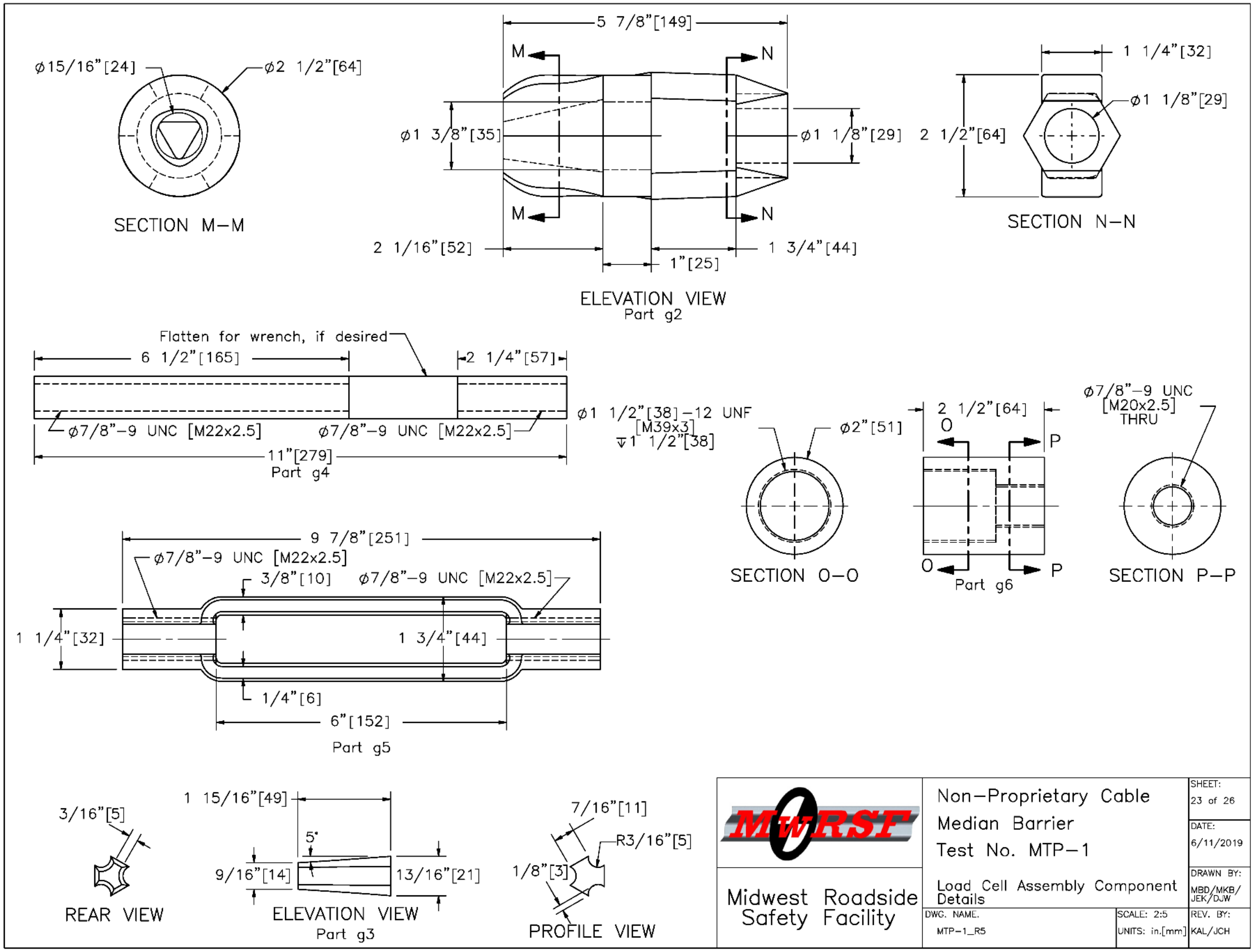

Figure 35. Load Cell Assembly Component Details, Test No. MTP-1

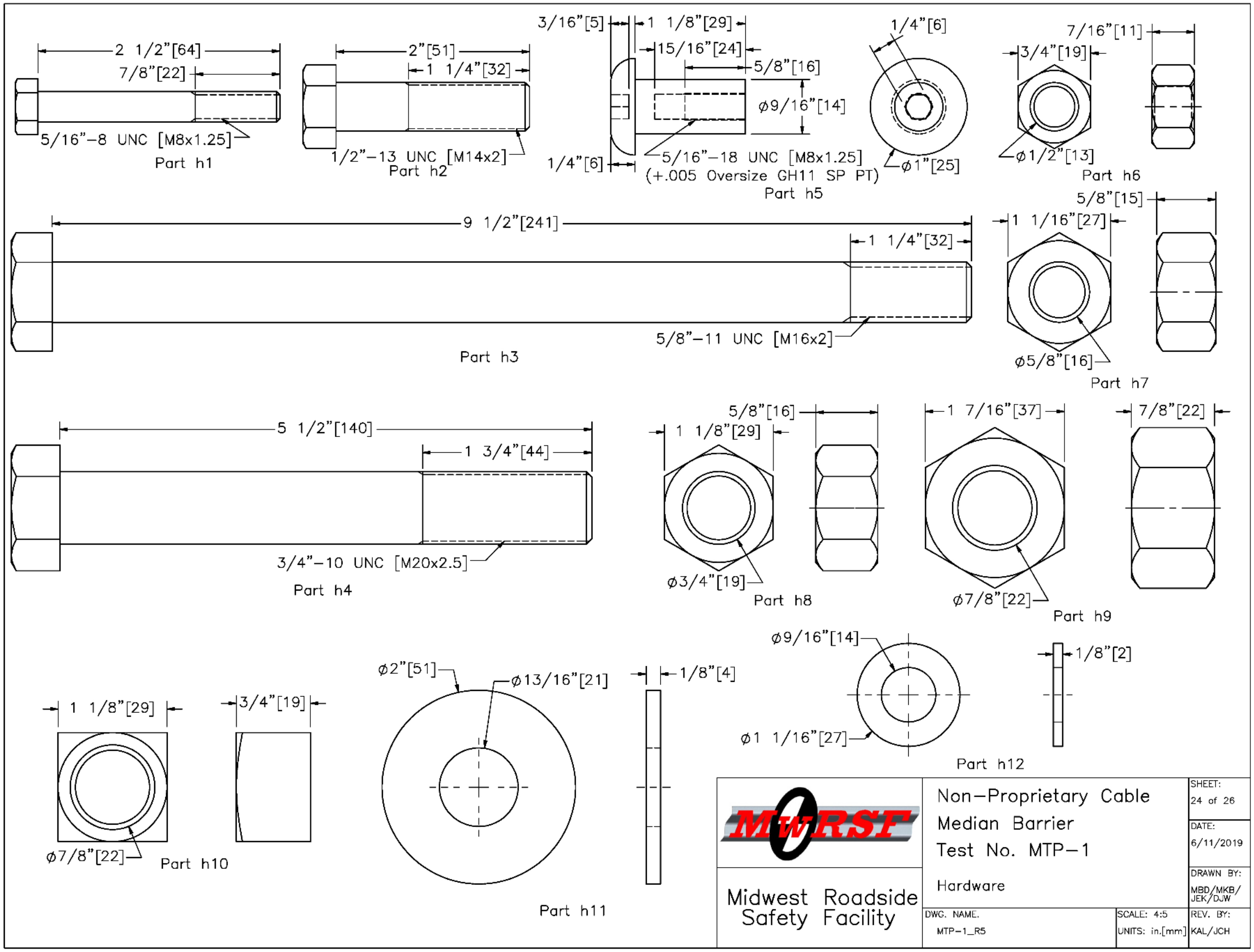

Figure 36. Hardware, Test No. MTP-1

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	72	HSS 3x2x1/8 [76x51x3], 78" [1,981] Long Steel Post with two 3/4" [19] holes	ASTM A500 Gr. C	ASTM A123	–
a2	216	5"x15/16"x12–Gauge [128x24x2.7] Tabbed Bracket	Hot–Rolled ASTM A1011 HSLA Gr. 50	ASTM A123	–
a3	72	3/16" [5] Dia. Brass Cable Clip, 4 9/16" [116] Long Unbent	ASTM B16–00	–	
b1	2	24" [610] Dia. Concrete Anchor, 120" [3,048] Long	Min. f'c = 4,000 psi [27.6 MPa]	–	–
b2	44	#4 [13] Hoop Bar with 21" [533] Dia., 84" [2,134] Unbent Length	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy–Coated (ASTM A775 or A934)	–
b3	16	#11 [35] Bar, 114" [2,896] Long	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy–Coated (ASTM A775 or A934)	–
b4	16	3/4"–10 UNC [M20x2.5] J–Hook Anchor	ASTM A449	ASTM A153 or B695 Class 55 or F2329	FRJ16a
c1	2	12" [305] Dia. 2nd Post Concrete Anchor, 46" [1,168] Long	Min. f'c = 4,000 psi [27.6 MPa]	–	–
c2	2	12" [305] Dia. 2nd Post Anchor Aggregate, 2" [51] Deep	Standard Strong Soil	–	–
c3	22	#3 [10] Hoop Bar with 9" [229] Dia., 37" [940] Unbent Length	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy–Coated (ASTM A775 or A934)	–
c4	8	#3 [10] Bar, 43" [1,092] Long	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy–Coated (ASTM A775 or A934)	–
c5	2	4"x3"x1/4" [102x76x6] Foundation Tube, 48" [1,219] Long	ASTM A500 Gr. B	ASTM A123	–
d1	2	15 1/4"x9"x1/2" [387x229x13] Cable Anchor Base Plate	ASTM A36	See Assembly	–
d2	2	15 1/4"x5"x3/8" [387x127x10] Anchor Bracket Plate	ASTM A36	See Assembly	–
d3	4	6"x4 1/2"x1/2" [152x114x13] Exterior Cable Plate Gusset	ASTM A36	See Assembly	–
d4	2	9"x5"x1/2" [229x127x13] Release Lever Plate	ASTM A36	See Assembly	–
d5	6	3 5/16"x3 3/16"x1/2" [84x81x13] Interior Cable Plate Gusset	ASTM A36	See Assembly	–
d6	4	3 1/2"x2 3/8x1/2" [89x61x13] Release Gusset	ASTM A36	See Assembly	–
d7	2	3/16" [5] Dia. Brass Keeper Rod, 16 1/4" [413] Long Unbent	ASTM B16–00	–	–
e1	2	13 1/2"x3 1/2"x1/2" [343x89x13] Kicker Plate	ASTM A36	See Assembly	–
e2	4	3 1/4"x1 3/4"x1/2" [83x44x13] Kicker Gusset	ASTM A36	See Assembly	–
e3	4	1 1/4"x1 1/4"x3/16" [32x32x5], 17" [432] Long Square Tube	ASTM A500 Gr. B	See Assembly	–
e4	2	1 1/4"x1 1/4"x3/16" [32x32x5], 5" [127] Long Square Tube	ASTM A500 Gr. B	See Assembly	–
e5	2	1/4" [6] Dia. 7x19 Aircraft Retaining Cable, 36" [914] Long	ASTM A1023	Hot–Dipped Galvanized	–

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Non–Proprietary Cable Median Barrier Test No. MTP–1

Bill of Materials

SHEET: 25 of 26
DATE: 6/11/2019
DRAWN BY: MBD/MKB/JEK/DJW
DWG. NAME. MTP–1_R5
SCALE: None
UNITS: in.[mm]
REV. BY: KAL/JCH

Figure 37. Bill of Materials, Test No. MTP-1

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
f1	2	S3x5.7 [S75x8.5], 19" [483] Long Post	ASTM A36	See Assembly	–
f2	4	4 15/16"x4"x3/8" [125x102x10] Base Plate	ASTM A36	See Assembly	–
f3	2	S3x5.7 [S75x8.5], 28 1/8" [714] Long Post	ASTM A36	See Assembly	–
f4	2	18 3/4"x2"x1/2" [476x51x13] Cable Hanger	ASTM A36	See Assembly	–
f5	2	4 15/16"x4"x28–Guage [125x102x0.4] Keeper Plate	ASTM A36	–	–
f6	8	3/16" [5] Dia., 5 1/8" [130] Long Unbent Brass Rod	ASTM B16–00	–	–
g1	12	3/4" [19] Dia. 3x7 IWRC IPS Wire Rope – Lengths as Needed	ASTM A741 Type 1	Class A Coating	RCM01
g2	24	Bennett Cable End Fitter – 7/8" [22] Dia.	ASTM A220 Gr. 50005	ASTM A153 or B695	RCE03
g3	24	Cable Wedge	ASTM A47 Gr. 32510 or A536 Gr. 65–45–12	–	FMM01
g4	28	7/8"–9 UNC [M22x2.5], 11" [279] Long Threaded Rod	ASTM A449 Type 1 or ASTM A193 Gr. B7	ASTM A153 or B695 Class 55 or F2329	RCE03
g5	8	Bennett Short 7/8"–9 UNC [M22x2.5] Threaded Turnbuckle	As Supplied	As Supplied	–
g6	8	Threaded Load Cell Coupler	–	–	–
g7	4	50,000–lb [222.4–kN] Load Cell	–	–	–
h1	216	5/16"–18 UNC [M8x1.25], 2 1/2" [64] Long Heavy Hex Bolt	SAE J429 Gr. 5	ASTM A153 or B695 Class 55 or F2329	FBX08b
h2	8	1/2"–13 UNC [M14x2], 2" [51] Long Hex Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBX14a
h3	2	5/8"–11 UNC [M16x2], 9 1/2" [241] Long Heavy Hex Bolt	ASTM A449 or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16b
h4	2	3/4"–10 UNC [M20x2.5], 5 1/2" [140] Long Hex Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBX20a
h5	216	5/16"–18 UNC [M8x1.25] Sleeve Nut	ASTM A311 Gr. 1144 Class B	ASTM A123 or A153	–
h6	8	1/2"–13 UNC [M14x2] Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX14a
h7	2	5/8"–11 UNC [16x2] Heavy Hex Nut	ASTM A563C or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX16b
h8	18	3/4"–10 UNC [M20x2.5] Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX20a
h9	16	7/8"–9 UNC [M22x2.5] Heavy Hex Nut	ASTM A563C or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX22b
h10	24	7/8"–9 UNC [M22x2.5] Heavy Square Nut	ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	–
h11	20	3/4" [19] Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC20a
h12	24	1/2" [13] Dia. Plain SAE Washer	ASTM F844	ASTM A123 or A153 or F2329	–
h13	8	3"x2 3/8"x1/2" [76x60x13] Rectangular Washer Plate	ASTM A36	ASTM A123	–

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Non–Proprietary Cable Median Barrier Test No. MTP–1

Bill of Materials

SHEET: 26 of 26
DATE: 6/11/2019
DRAWN BY: MBD/MKB/JEK/DJW
REV. BY: KAL/JCH
DWG. NAME. MTP–1_R5
SCALE: None
UNITS: in.[mm]

Figure 38. Bill of Materials, Test No. MTP-1

Figure 39. System Installation, Test No. MTP-1

Figure 40. System Installation, Test No. MTP-1

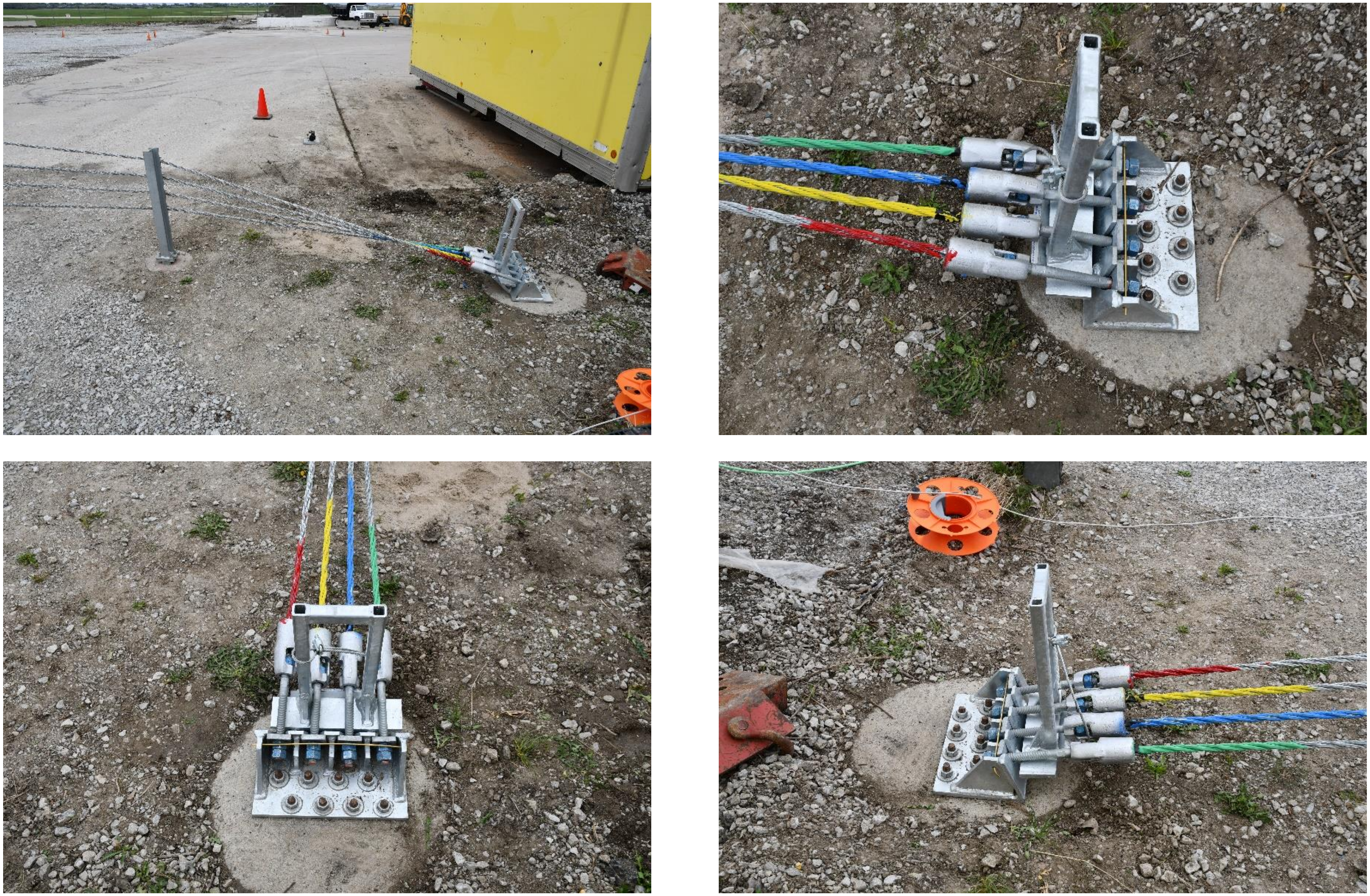


Figure 41. System Installation – Upstream Anchorage, Test No. MTP-1

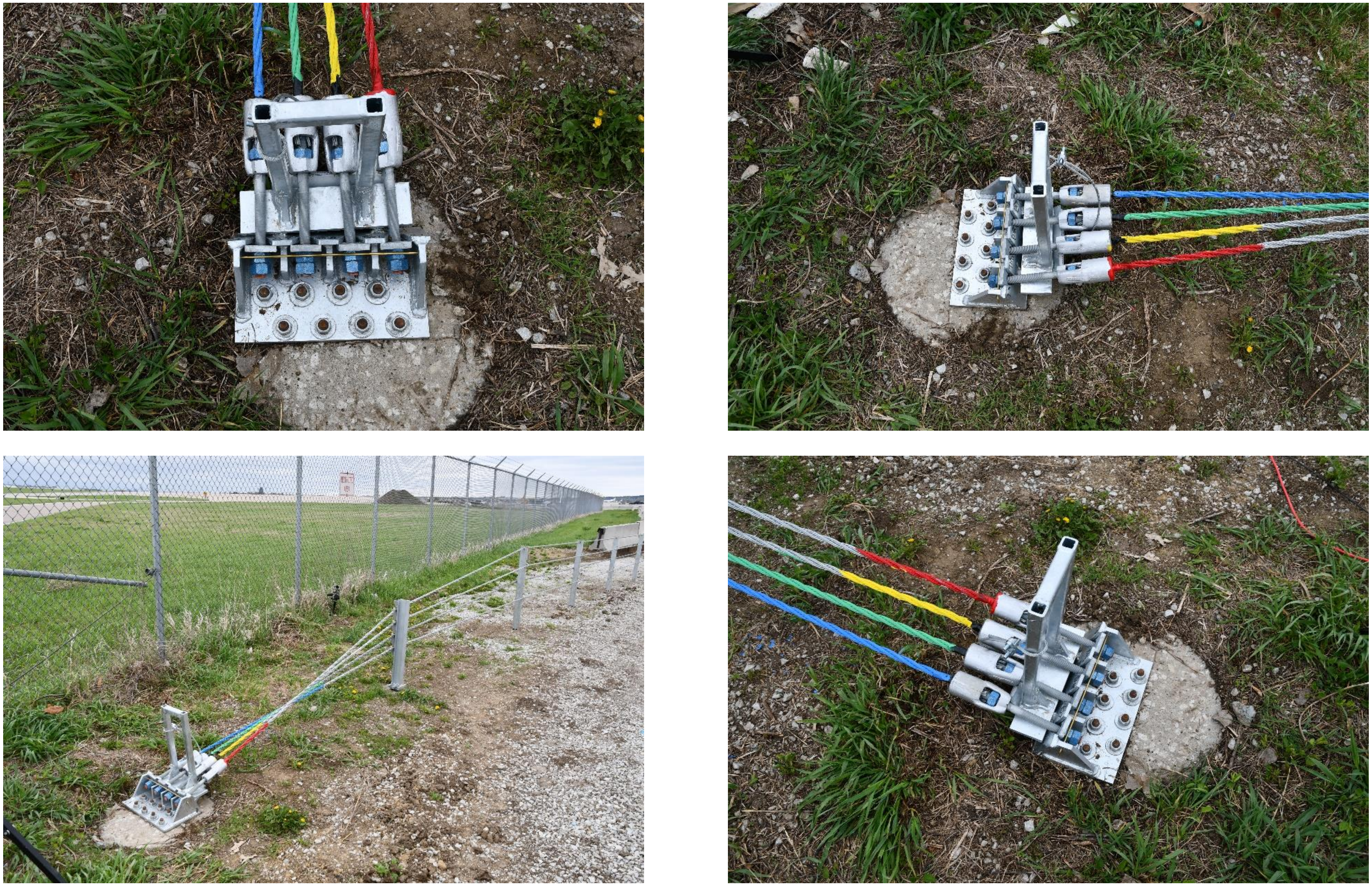


Figure 42. System Installation – Downstream Anchorage, Test No. MTP-1

5 FULL-SCALE CRASH TEST NO. MTP-1

5.1 Static Soil Test

Before full-scale crash test no. MTP-1 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. 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. MTP-1 was conducted on April 22, 2019 at approximately 3:00 p.m. The weather conditions as reported by the National Oceanic and Atmospheric Administration (station 14939/KLNK) are shown in Table 3.

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

Temperature	57°F (13.9°C)
Humidity	69%
Wind Speed	18 mph (29.0 km/h)
Wind Direction	340° from True North
Sky Conditions	Cloudy
Visibility	10 Statute Miles (16.1 km)
Pavement Surface	Dry
Previous 3-Day Precipitation	0.16 in. (4 mm)
Previous 7-Day Precipitation	0.16 in. (4 mm)

5.3 Test Description

Initial vehicle impact was to occur 12 in. (305 mm) upstream from post no. 32, as shown in Figure 43, which was selected in accordance with MASH test designation no. 3-11 requirements. The 4,986-lb (2,262-kg) quad cab pickup truck impacted the cable barrier system at a speed of 61.3 mph (98.7 km/h) and at an angle of 25.0 degrees, for an impact severity of 111.4 kip-ft (151.0 kJ). The actual point of impact was 8 in. (203 mm) upstream from post no. 32. The vehicle came to rest 210 ft (64.0 m) downstream from the impact point after brakes were applied. In its final position, the vehicle was roughly parallel to and still in contact with the system.

A detailed description of the sequential impact events is contained in Tables 4 through 6. Sequential photographs are shown in Figures 44 through 45. Documentary photographs of the crash test are shown in Figures 46 through 48. The vehicle trajectory and final position are shown in Figure 49.

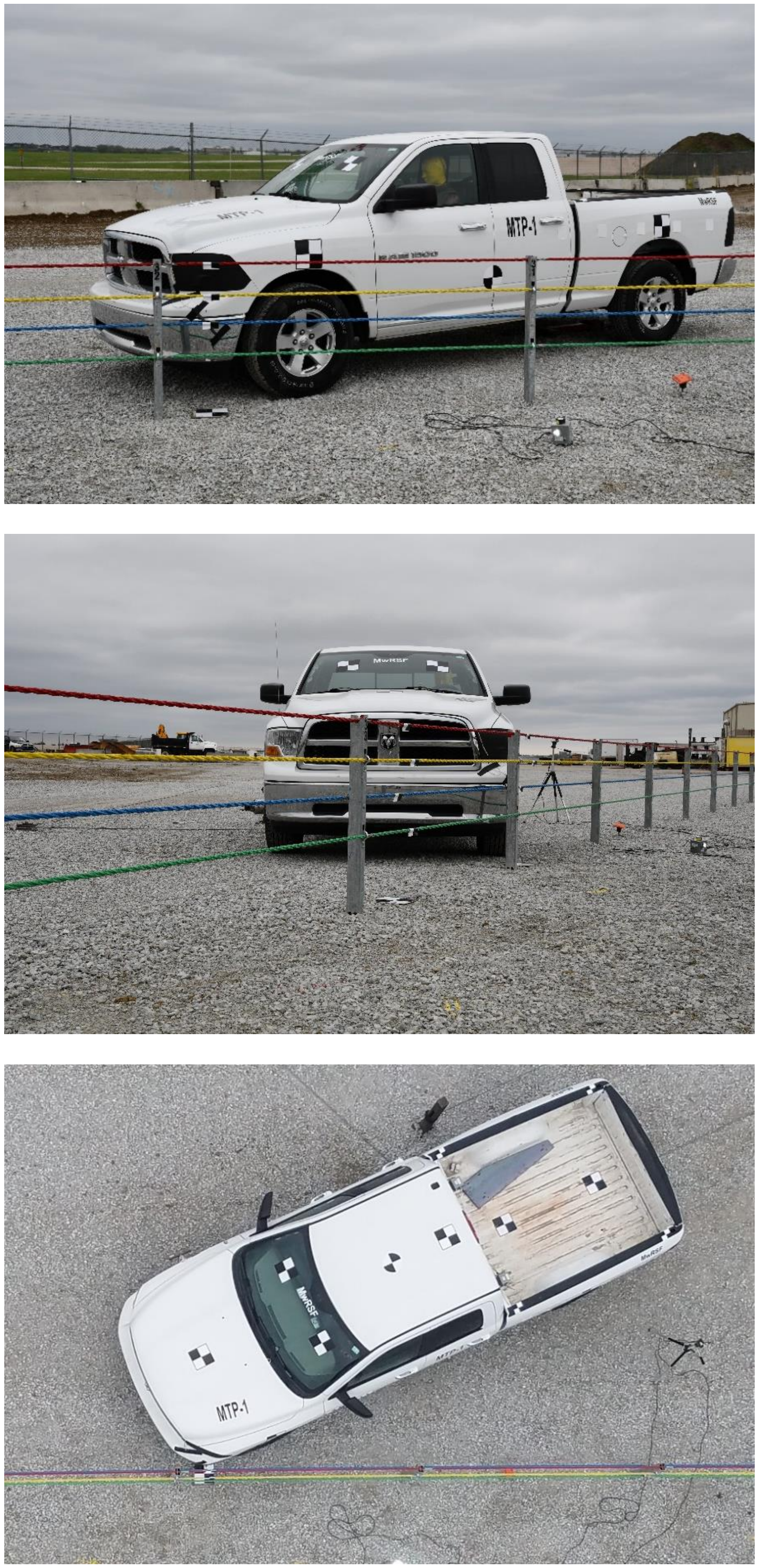


Figure 43. Impact Location, Test No. MTP-1

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

Time (sec)	Event
0.000	Vehicle's front bumper contacted cable no. 2 between post nos. 31 and 32 and deformed.
0.004	Vehicle's front bumper contacted post no. 32 and post no. 32 rotated downstream.
0.010	Vehicle's left headlight contacted cable no. 4, post no. 32, and deformed.
0.020	Vehicle's left fender contacted cable no. 4, post no. 32 and deformed, vehicle's left-front tire contacted cable no. 2, and vehicle's front bumper contacted cable no. 1.
0.024	Vehicle's left-front tire contacted post no. 32 and cable no. 1. Post no. 32 bent downstream and cable no. 4 disengaged from post no. 32.
0.030	Post no. 32 twisted counterclockwise, post no. 33 deflected backward, and vehicle's front bumper cover became disengaged.
0.032	Post no. 31 deflected backward and post no. 32 fractured.
0.038	Cable nos. 1, 2, and 3 disengaged from post no. 32.
0.050	Post no. 34 deflected backward. Vehicle's front bumper contacted cable no. 3.
0.062	Cable no. 2 disengaged from post no. 33 and vehicle's left-front tire contacted cable no. 3.
0.072	Left-front tire overrode post no. 32.
0.078	Cable no. 4 disengaged from post no. 33.
0.084	Cable no. 3 disengaged from post no. 33, cable no. 2 disengaged from post no. 34, vehicle's front bumper contacted post no. 33, and post no. 33 bent downstream.
0.092	Cable no. 3 disengaged from post no. 31. Post no. 33 fractured.
0.100	Post no. 34 bent backward and post no. 35 deflected backward.
0.110	Cable no. 4 disengaged from post no. 34 and cable no. 1 contacted vehicle's undercarriage. Cable no. 3 disengaged from post no. 30 and front bumper overrode post no. 33.
0.120	Post no. 32 contacted vehicle's undercarriage and vehicle yawed away from system.
0.124	Cable no. 3 disengaged from post no. 34 and 29.
0.128	Post no. 31 bent backward and post no. 36 deflected backward.
0.140	Cable no. 2 disengaged from post no. 35 and vehicle rolled away from system. Vehicle's left fender contacted cable no. 2.
0.144	Cable no. 4 disengaged from post no. 35.
0.154	Post no. 36 bent backward and vehicle's left fender contacted cable no. 3. Post no. 33 contacted vehicle's undercarriage. Cable no. 3 disengaged from post no. 35.
0.168	Cable no. 2 disengaged from post no. 31, and post no. 36, cable no. 4 disengaged from post no. 36, and the vehicle pitched upward. Post no. 37 deflected backward.
0.176	Cable no. 2 disengaged from post no. 37 and vehicle's front bumper contacted post no. 34. Post no. 34 bent downstream.
0.184	Post no. 36 fractured and the vehicle's right-front tire contacted cable no. 1.
0.190	Post no. 37 bent backward and post no. 34 fractured. Cable no. 2 disengaged from post no. 38. Post no. 30 deflected backward and cable no. 4 disengaged from post no. 31.
0.198	Post no. 38 deflected backward and cable no. 3 disengaged from post no. 36. Vehicle's left-front door deformed.

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

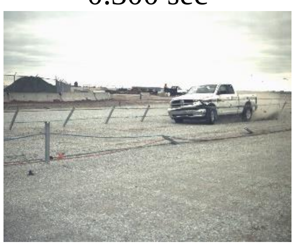
Time (sec)	Event
0.200	Cable no. 4 disengaged from post no. 37 and cable no. 2 disengaged from post no. 39.
0.218	Post no. 32 deflected upstream, post no. 39 deflected backward, and post no. 37 fractured.
0.224	Cable no. 3 disengaged from post no. 37. Cable no. 2 disengaged from post no. 40. Cable no. 4 disengaged from post no. 38.
0.234	Cable no. 2 disengaged from post no. 41. Post no. 38 bent backward.
0.240	Vehicle’s right-front tire overrode post no. 34.
0.248	Cable no. 3 disengaged from post no. 38.
0.252	Post no. 40 deflected backward and cable no. 4 disengaged from post no. 30. Vehicle's left-front door contacted cable no. 2.
0.258	Cable no. 4 disengaged from post no. 39 and contacted vehicle's left-front door.
0.260	Post no. 39 bent backward.
0.266	Post no. 29 deflected backward.
0.272	Post no. 40 bent backward. Cable no. 2 disengaged from post no. 30.
0.280	Cable no. 3 disengaged from post no. 39.
0.284	Post no. 41 deflected backward and vehicle's front bumper contacted post no. 35.
0.286	Post no. 39 fractured.
0.288	Post no. 35 bent downstream.
0.290	Vehicle's left-front tire became airborne.
0.292	Post no. 35 fractured.
0.296	Cable no. 4 disengaged from post no. 40.
0.300	Post no. 41 bent backward. Vehicle's left-front door contacted cable no. 3.
0.306	Post no. 40 fractured.
0.308	Cable no. 3 disengaged from post no. 40.
0.316	Cable no. 4 disengaged from post no. 41.
0.326	Vehicle's left-rear door contacted cable nos. 2 and 3.
0.334	Cable no. 3 disengaged from post no. 41 and vehicle's left quarter panel contacted cable no. 2. Vehicle's left quarter panel deformed and cable no. 4 contacted vehicle's left-rear door.
0.344	Post no. 30 bent backward. Vehicle's left quarter panel contacted cable no. 3. Cable no. 4 contacted vehicle's left quarter panel.
0.364	Vehicle's rear bumper contacted cable no. 3.
0.370	Vehicle's left taillight contacted cable no. 4 and deformed.
0.380	Vehicle pitched downward.
0.394	Vehicle overrode cable no. 1.
0.410	Vehicle's left taillight cracked. Cable no. 4 disengaged from post no. 29.
0.434	Post no. 29 bent backward. Cable no. 2 disengaged from post no. 29.
0.460	Vehicle's left-front tire regained contact with ground.
0.476	Vehicle was parallel to the system at a speed of 51.2 mph (82.4 km/h)

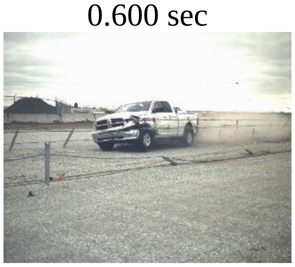
Table 6. Sequential Description of Impact Events, Test No. MTP-1, Cont.

Time (sec)	Event
0.520	Vehicle rolled away from system.
0.540	Vehicle's left fender snagged on cable no. 4 splice.
0.560	Vehicle yawed toward system.
0.588	Vehicle's left-front door snagged on cable no. 4 splice.
0.650	Vehicle pitched upward.
0.708	Vehicle's left-front tire became airborne.
0.764	Vehicle's left headlight became disengaged.
0.820	Vehicle rolled toward system.
0.844	Vehicle's left-front door snagged on cable no. 2 splice.
0.850	Vehicle's left-front door flexed away from frame.
0.950	Vehicle yawed away from system.
0.972	Vehicle's left-rear door deformed.
1.048	Vehicle's left-front tire regained contact with ground.
1.092	Vehicle's right quarter panel contacted post no. 40 and deformed.
1.116	Vehicle rolled away from system.
1.192	Vehicle's right fender deformed.
1.256	Vehicle's right headlight contacted a post and shattered.
1.278	Vehicle's left-front tire became airborne.
1.426	Vehicle rolled toward system.
1.558	Vehicle's left-front tire regained contact with ground.
1.686	Vehicle rolled away from system.
1.696	Vehicle yawed toward system.
1.976	Vehicle rolled toward system.
2.230	Vehicle yawed away from system.
2.266	Vehicle rolled away from system.
2.520	Vehicle rolled toward system.
5.008	Vehicle came to rest without brakes applied.


0.000 sec


0.300 sec


0.600 sec


0.850 sec


1.100 sec


1.300 sec


0.000 sec


0.800 sec


1.400 sec


2.000 sec


2.450 sec


2.950 sec

Figure 44. Sequential Photographs, Test No. MTP-1

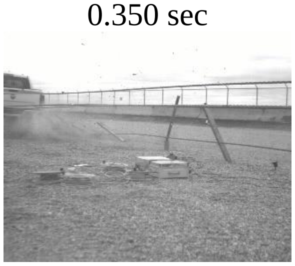
0.000 sec

0.100 sec

0.200 sec

0.250 sec

0.350 sec



0.500 sec

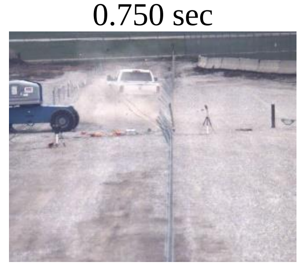
0.000 sec

0.150 sec

0.450 sec

0.600 sec

0.750 sec



1.000 sec

Figure 45. Sequential Photographs, Test No. MTP-1

Figure 46. Documentary Photographs, Test No. MTP-1

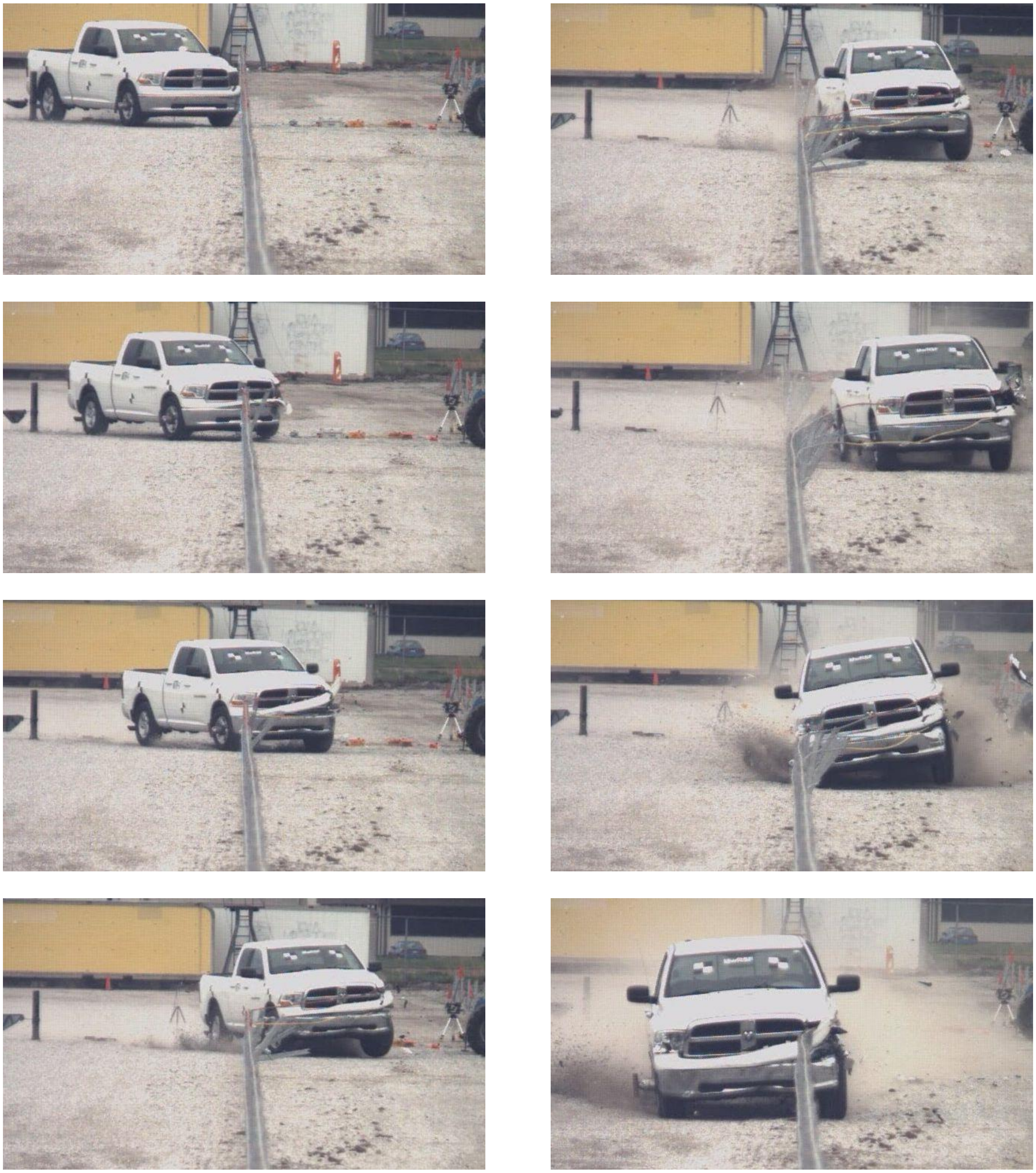


Figure 47. Documentary Photographs, Test No. MTP-1

Figure 48. Documentary Photographs, Test No. MTP-1

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

5.4 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 50 through 73. Barrier damage consisted of fractured posts, deformed posts and brackets, and detached cables. The length of vehicle contact along the barrier was approximately 210 ft (64.0 m), spanning from post nos. 32 to 59. Damage was sustained from post nos. 18 through 65, with the most severe damage localized to the area between post nos. 32 and 58.

Damage consisted primarily of bracket and brass rod deformation, cable release, soil gap formation, and minor post rotation between post nos. 18 and 25. Significant ground line post bending began at post no. 26, which bent backward. Combined backward bending and non-impact side wall buckling behavior occurred at post nos. 27 and 29 through 31. Partial section fracture occurred at post no. 28, with the upstream, downstream, and impact side walls of the post separating entirely from the post base along a plane through the two ground line holes. The non-impact side wall of post no. 28 remained intact. Post no. 32 twisted significantly but a small section of material remained between the two ground line holes on the downstream side wall. Post nos. 33 through 37 and 39 bent backward and downstream and experienced partial section fracture. Post no. 38 did not fracture, but bent backward and downstream. Complete section fracture through the ground line holes occurred at post no. 40. Post nos. 41 through 45 and 48 through 58 sustained a combination of partial section fracture and downstream bending. Post nos. 46 and 47 fractured completely. Only minor damage including bracket deformation, minor soil gap formation, and brass rod damage occurred between post no. 59 and 76. A summary of disengaged cables, bracket damage, and brass rod damage is shown in Table 7.

Table 7. Bracket Damage and Disengaged Cables, Test No. MTP-1

Post No.	Cable 1	Cable 2	Cable 3	Cable 4
1-17	0	0	0	0
18	0	1	0	0
19	0	1	0	0
20	0	1	0	0
21	0	1	0	0
22	0	1	0	7
23	0	1	0	0
24	0	1	0	7
25	0	1	0	6
26	0	1	1	6
27	0	1	1	6
28	0	1	1	6
29	0	1	1	6
30	0	1	1	6
31	1	1	1	6
32	1	1	1	6
33	1	1	1	6
34	1	1	1	6
35	1	1	1	6
36	0	1	1	7
37	0	1	1	6
38	0	1	1	6
39	0	1	1	6
40	1	1	1	6
41	1	1	1	6
42	1	1	1	6
43	1	1	1	6
44	1	1	1	6
45	1	1	1	6
46	1	1	1	6
47	1	1	1	6
48	1	1	1	6
49	1	1	1	6
50	1	1	1	6
51	1	1	1	6
52	1	1	1	6
53	1	1	1	6
54	1	1	1	6
55	1	1	1	6
56	1	1	1	6
57	1	1	1	6
58	1	1	1	6
59-62	0	0	0	0
63	0	1	1	7
64	1	1	1	6
65	1	1	1	0
66-76	0	0	0	0

0 = No Damage/Disengagement
1= Deformed in Place
2 = Released Entirely
3 = Fractured at Tab
4 = Fractured at Neck
5 = Fractured through Bolt Hole
6 = Brass Rod Fractured
7 = Brass Rod Bent in Place
*Note numbers 1 through 7 also means cable disengaged

Figure 50. Overall System Damage, Test No. MTP-1

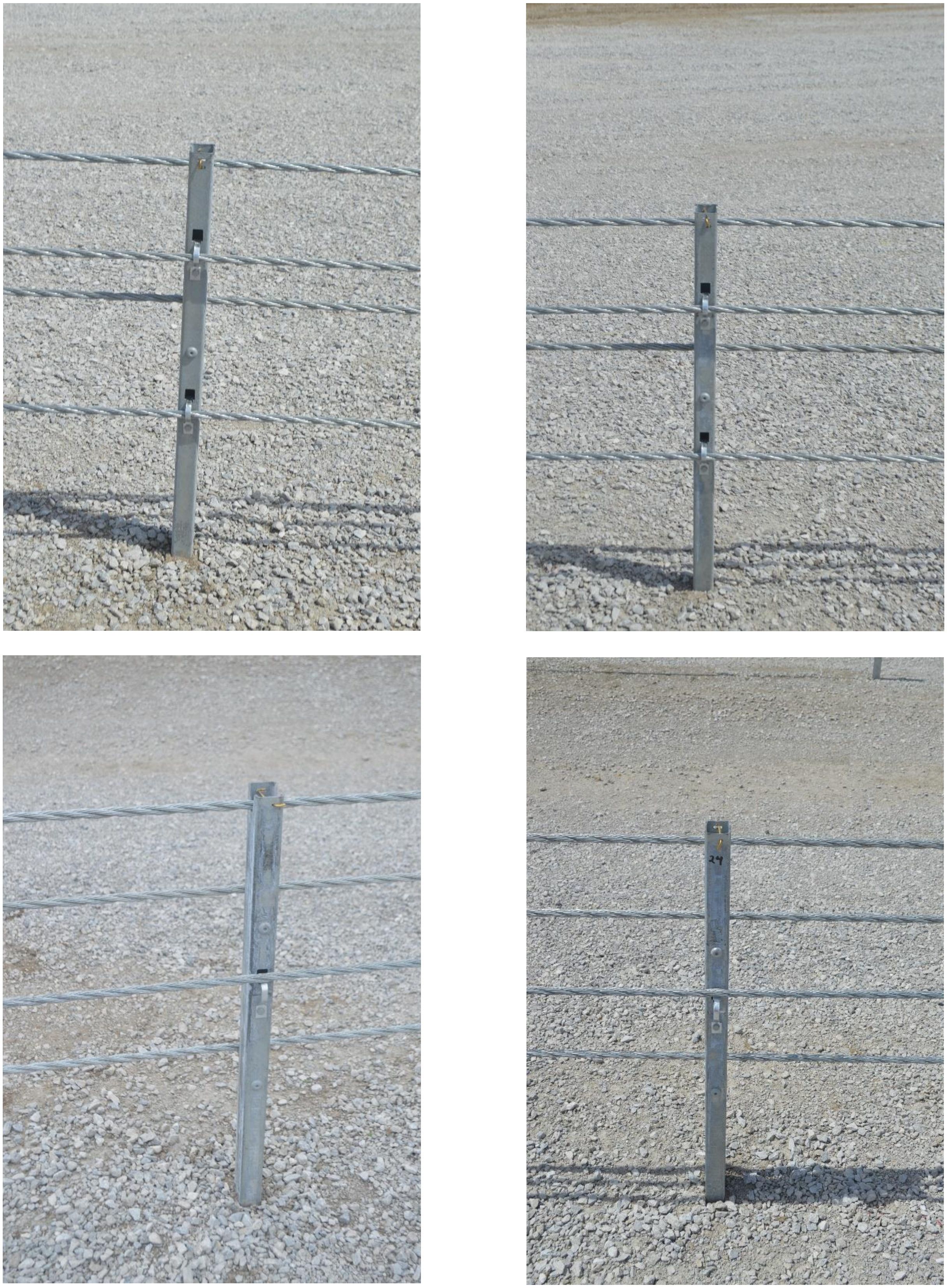


Figure 51. Post Nos. 23 (Left) and 24 (Right) Damage, Test No. MTP-1

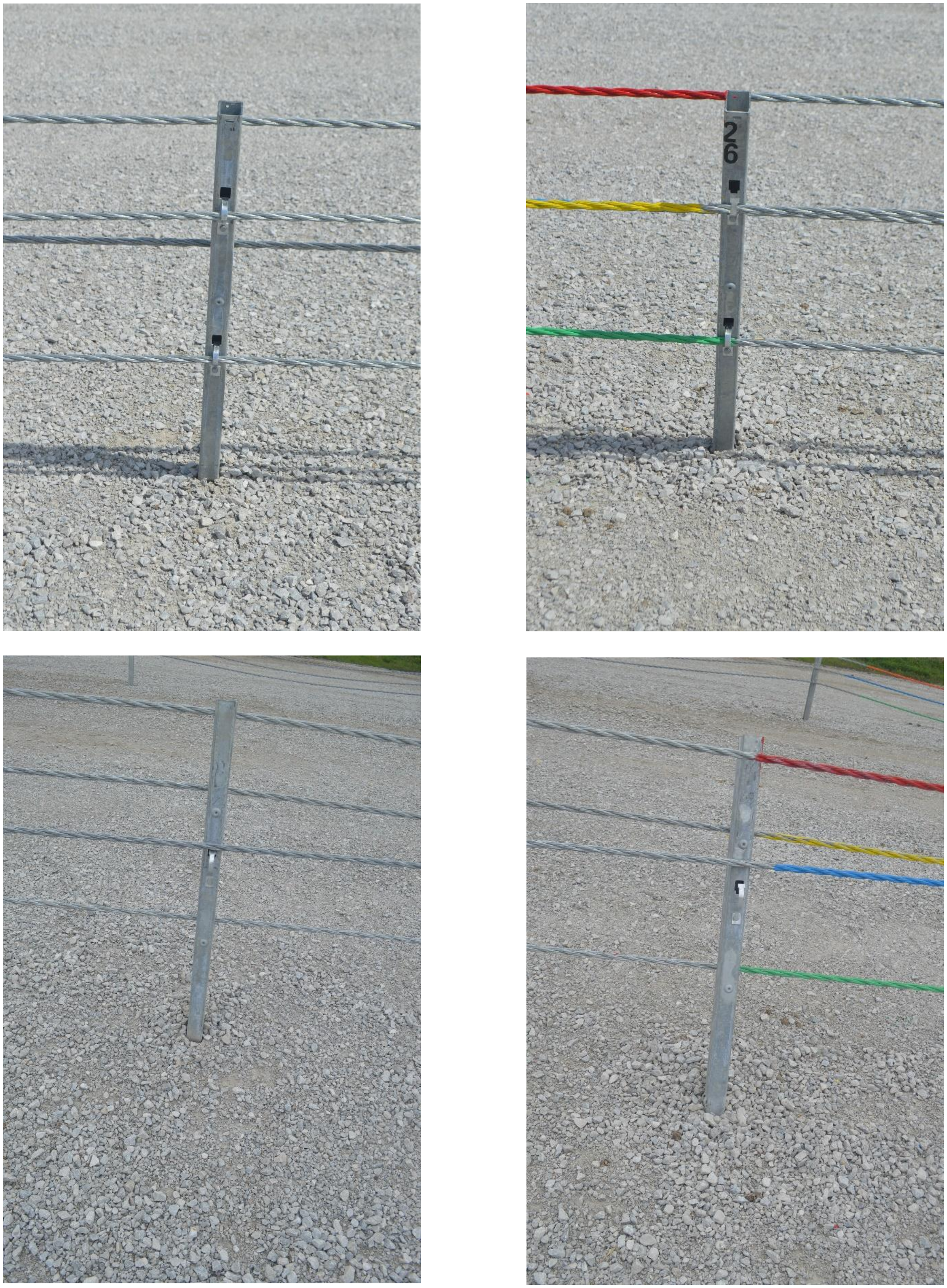


Figure 52. Post Nos. 25 (Left) and 26 (Right) Damage, Test No. MTP-1

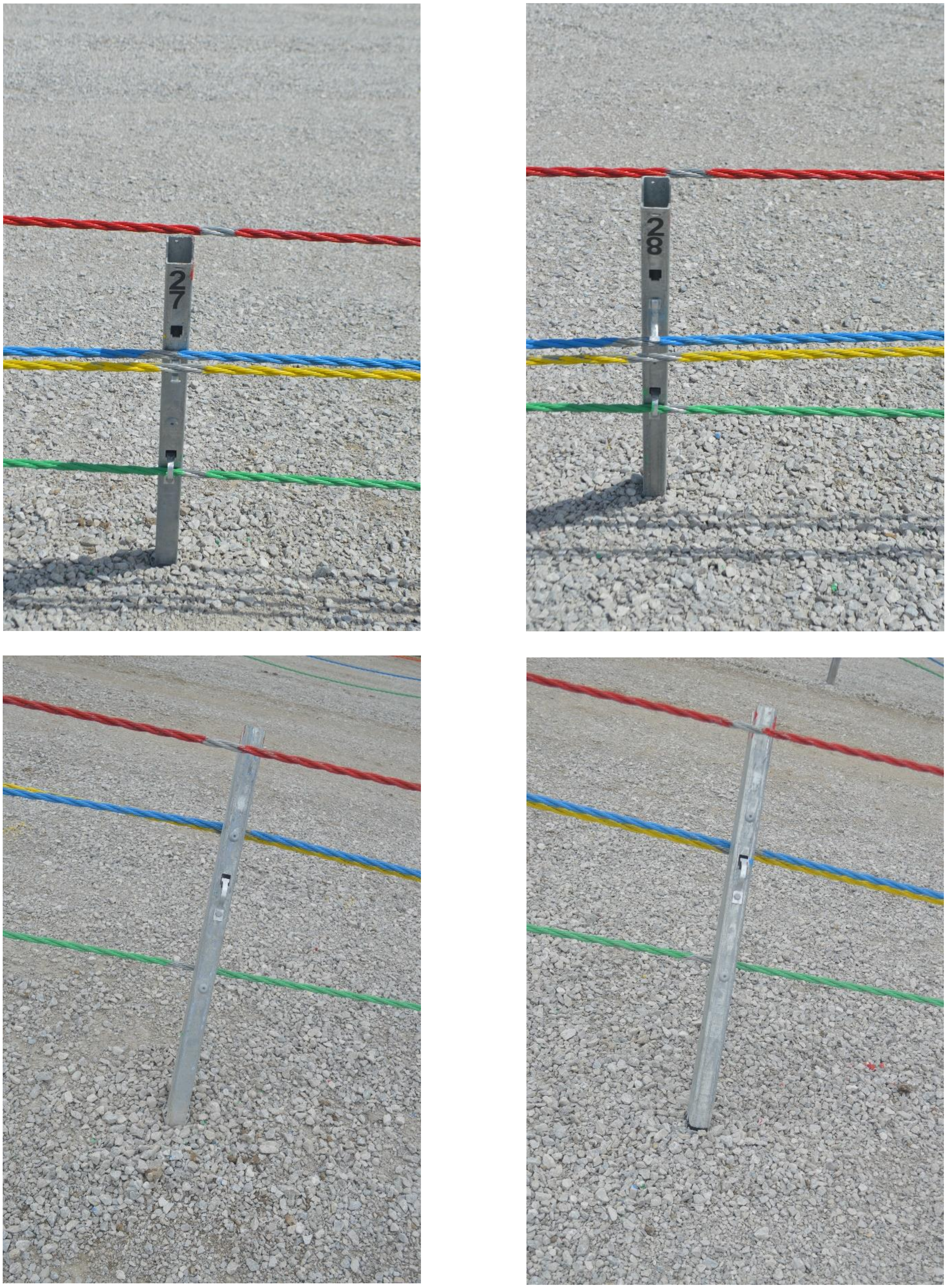


Figure 53. Post Nos. 27 (Left) and 28 (Right) Damage, Test No. MTP-1

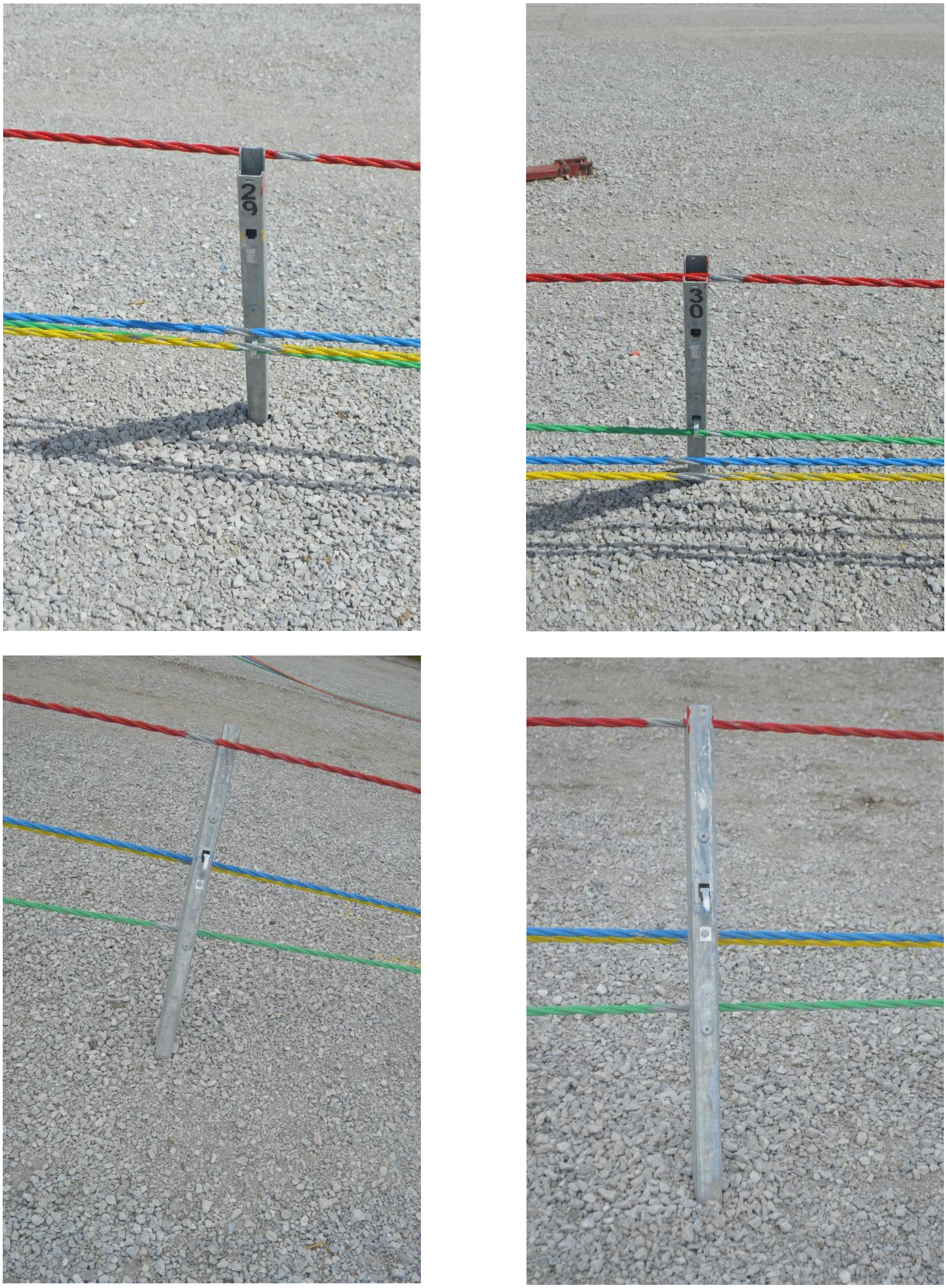


Figure 54. Post Nos. 29 (Left) and 30 (Right) Damage, Test No. MTP-1

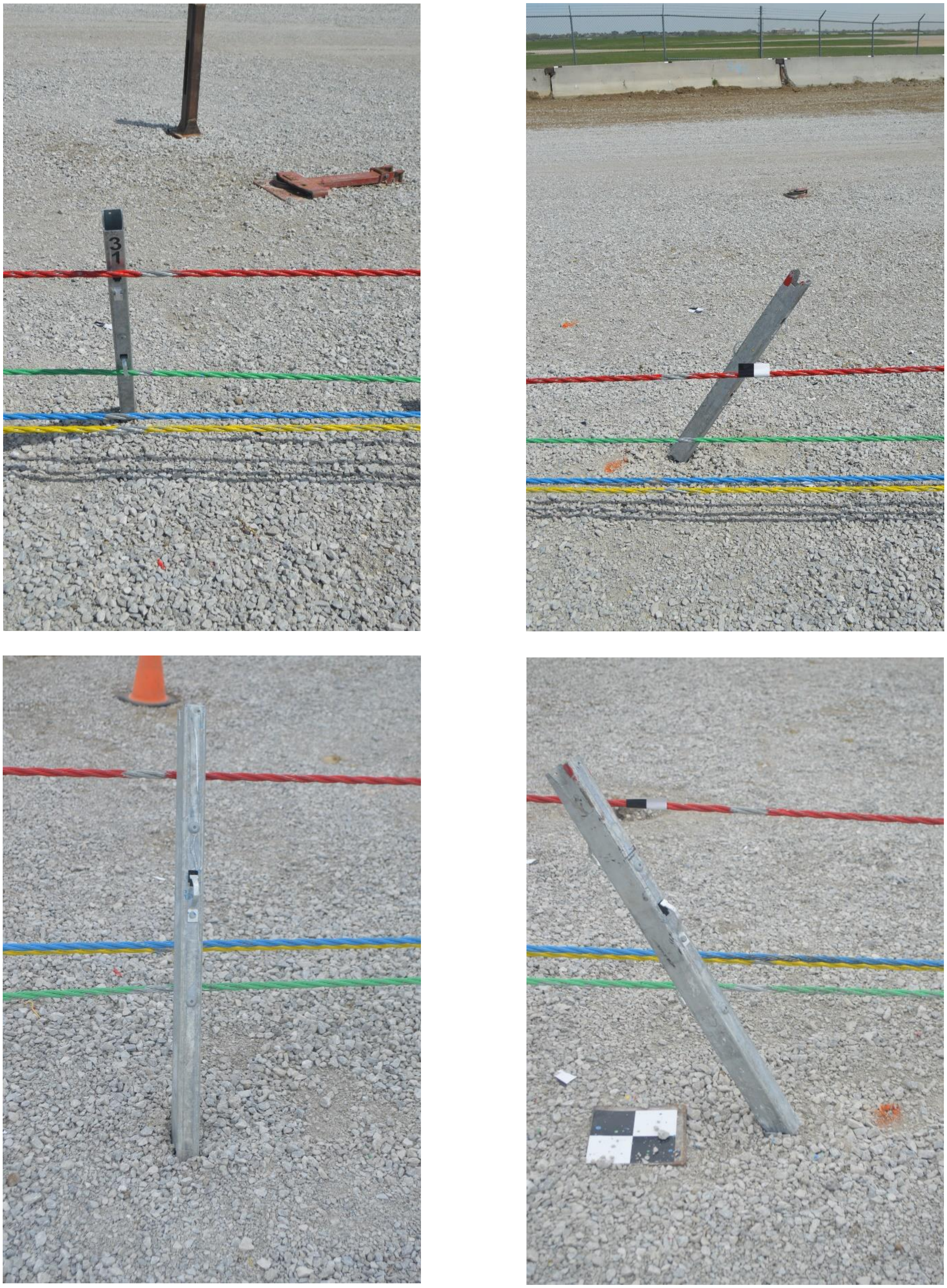


Figure 55. Post Nos. 31 (Left) and 32 (Right) Damage, Test No. MTP-1

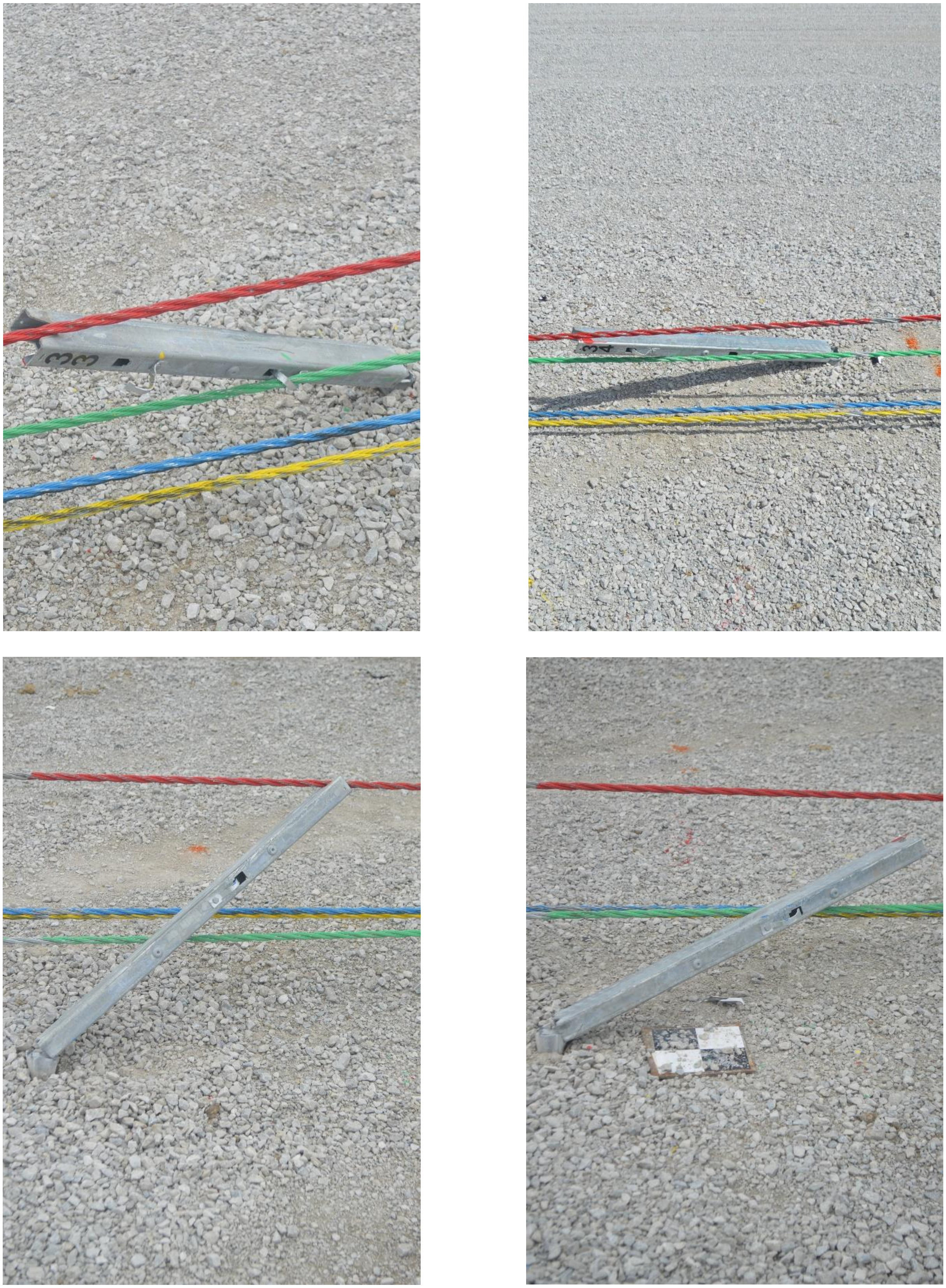


Figure 56. Post Nos. 33 (Left) and 34 (Right) Damage, Test No. MTP-1

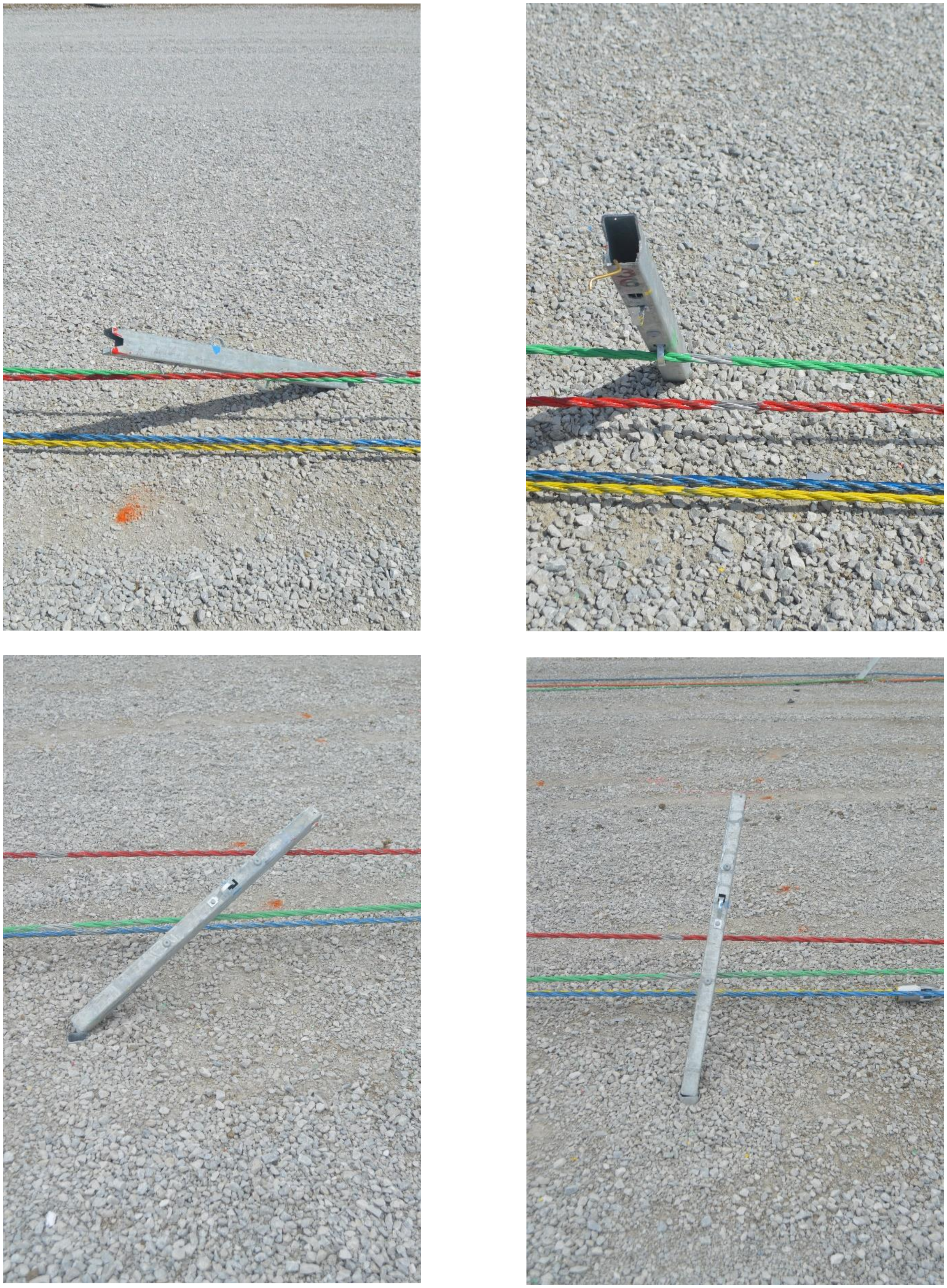


Figure 57. Post Nos. 35 (Left) and 36 (Right) Damage, Test No. MTP-1

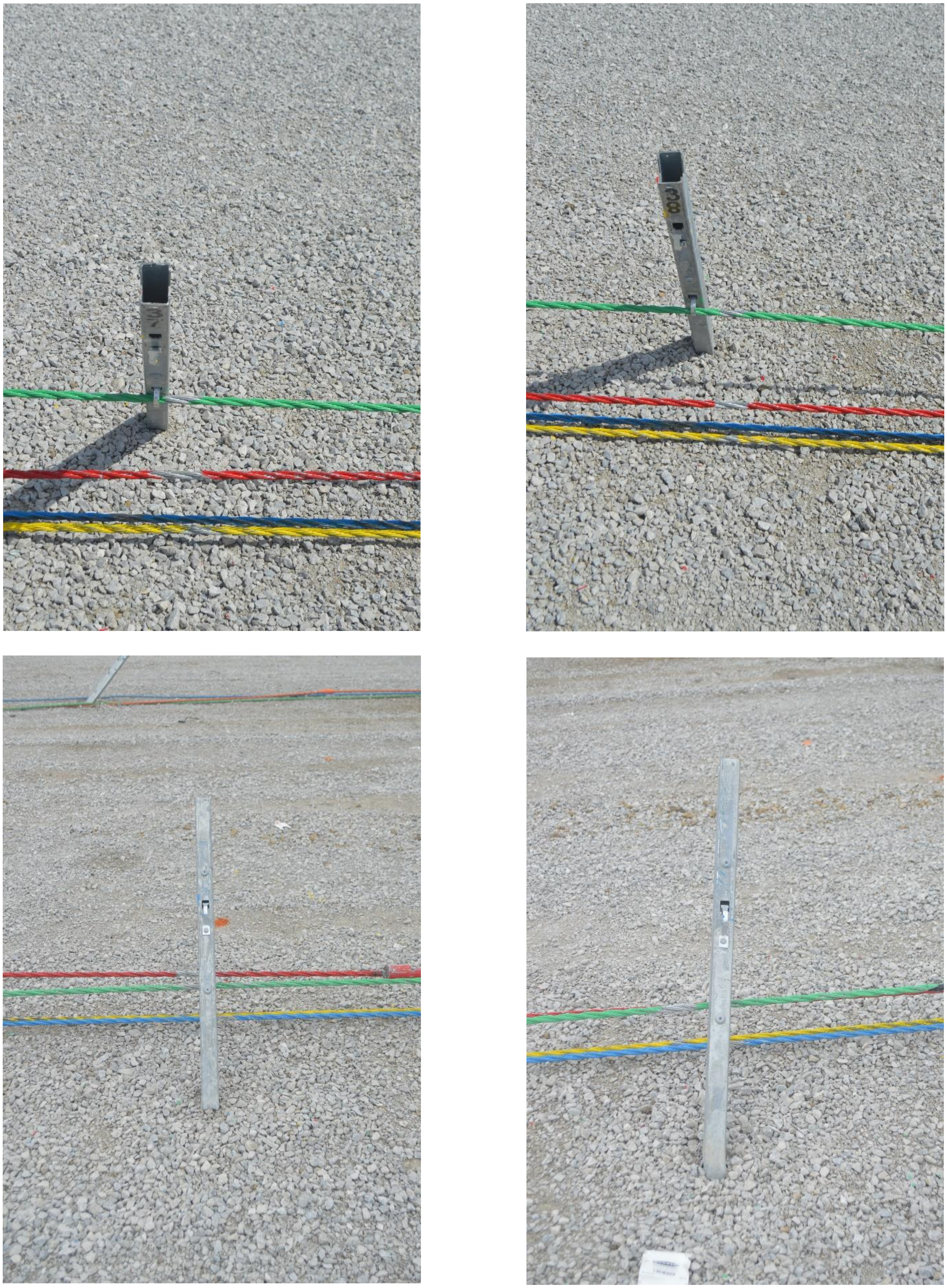


Figure 58. Post Nos. 37 (Left) and 38 (Right) Damage, Test No. MTP-1

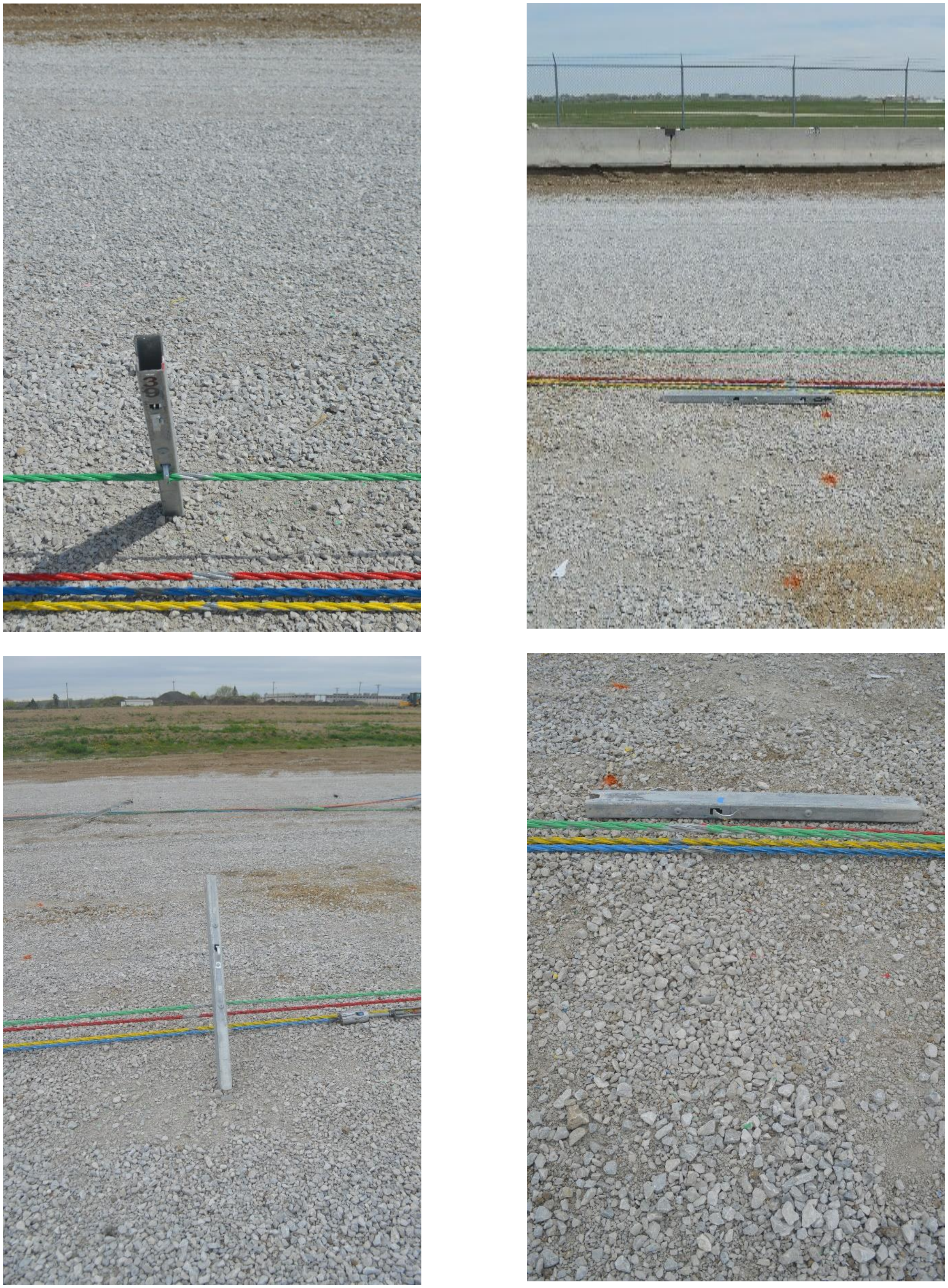


Figure 59. Post Nos. 39 (Left) and 40 (Right) Damage, Test No. MTP-1

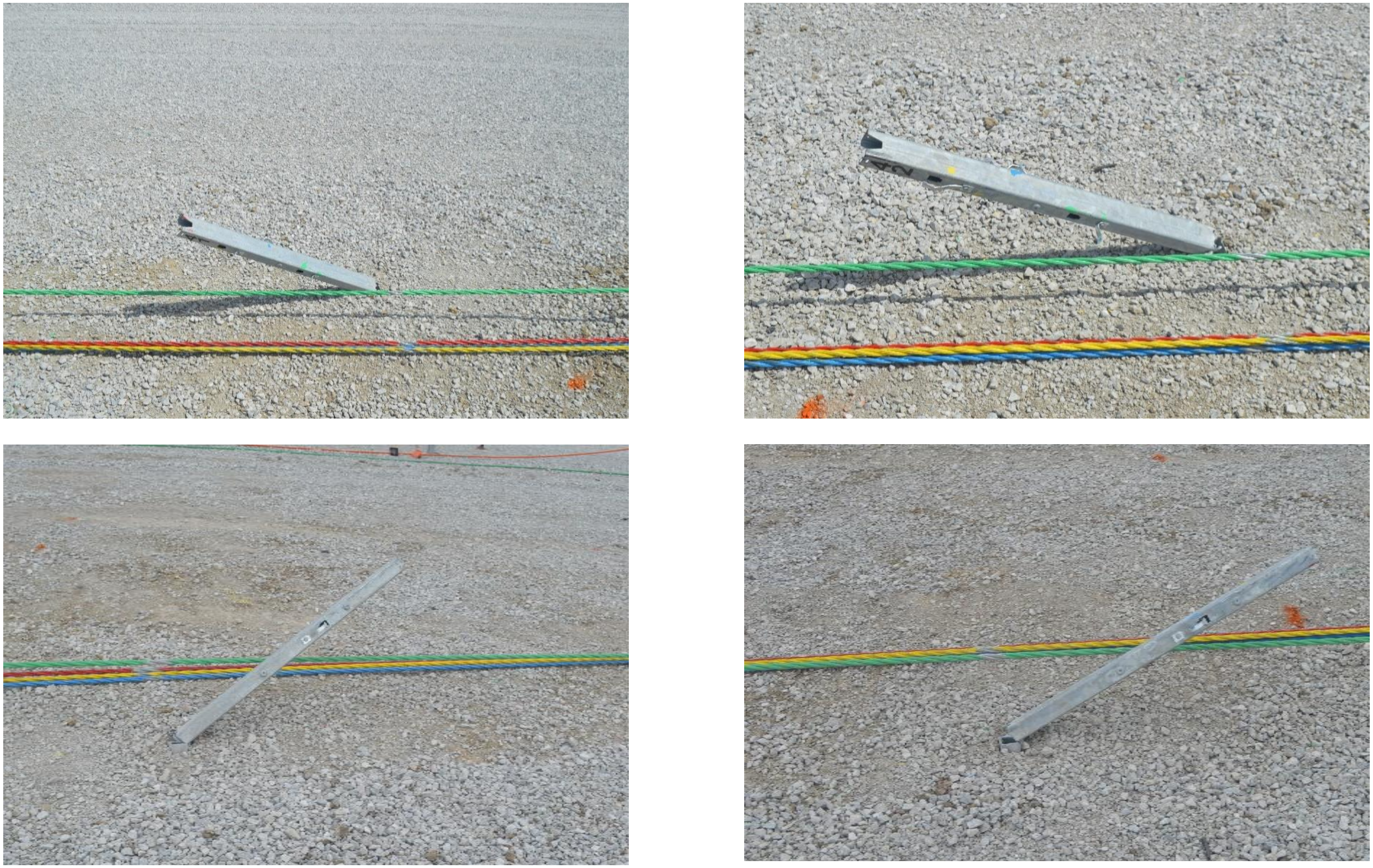


Figure 60. Post Nos. 41 (Left) and 42 (Right) Damage, Test No. MTP-1

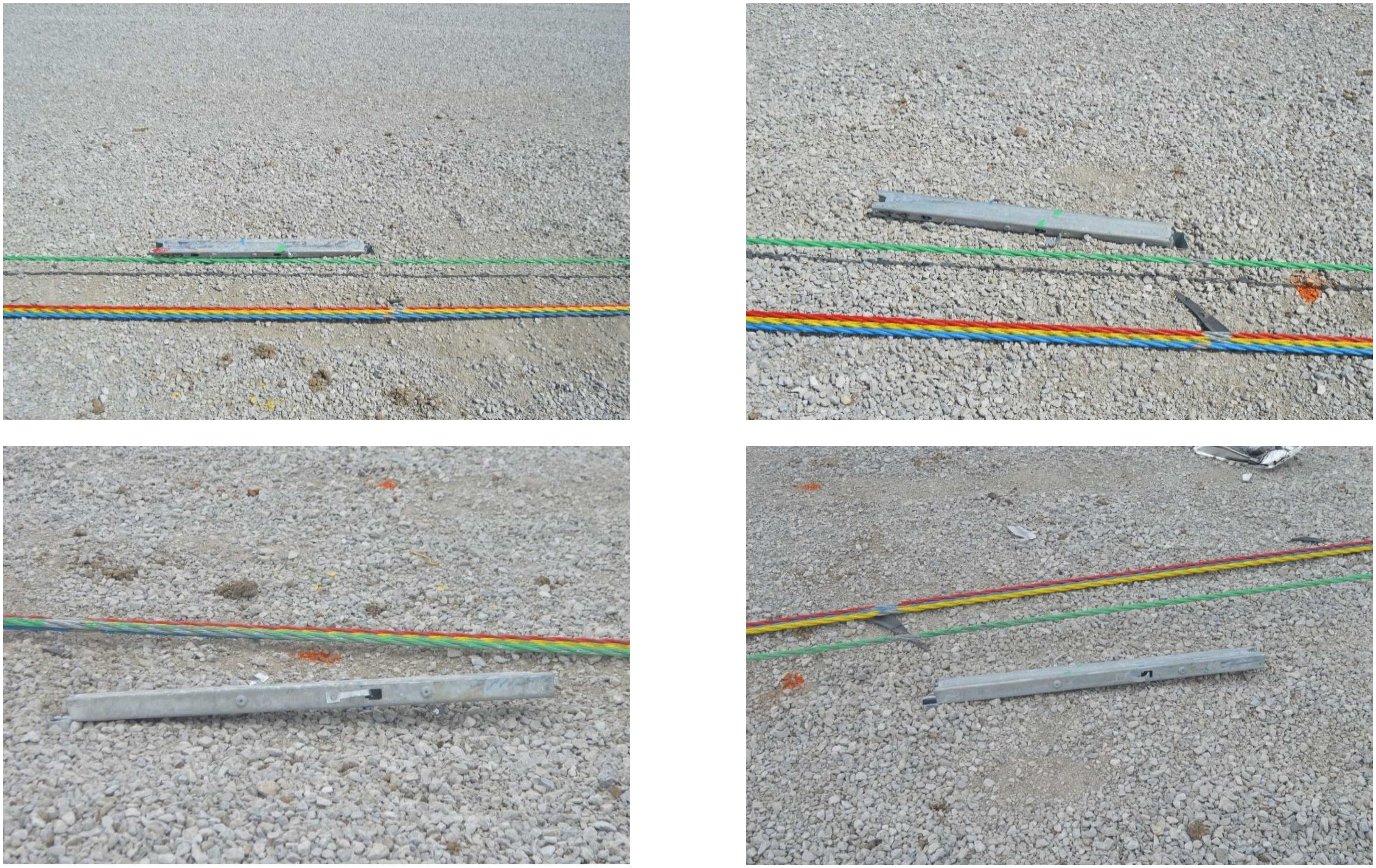


Figure 61. Post Nos. 43 (Left) and 44 (Right) Damage, Test No. MTP-1

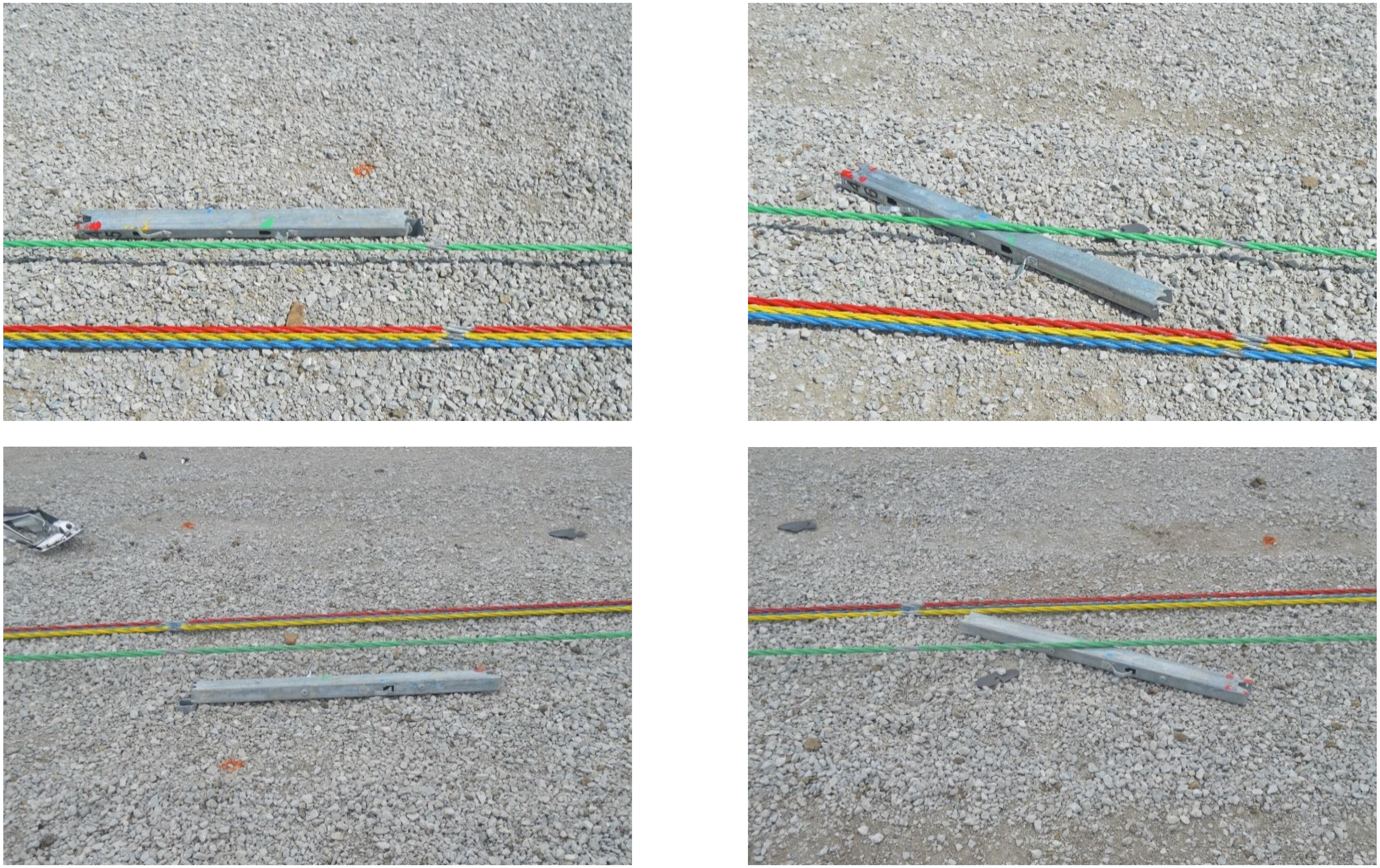


Figure 62. Post Nos. 45 (Left) and 46 (Right) Damage, Test No. MTP-1

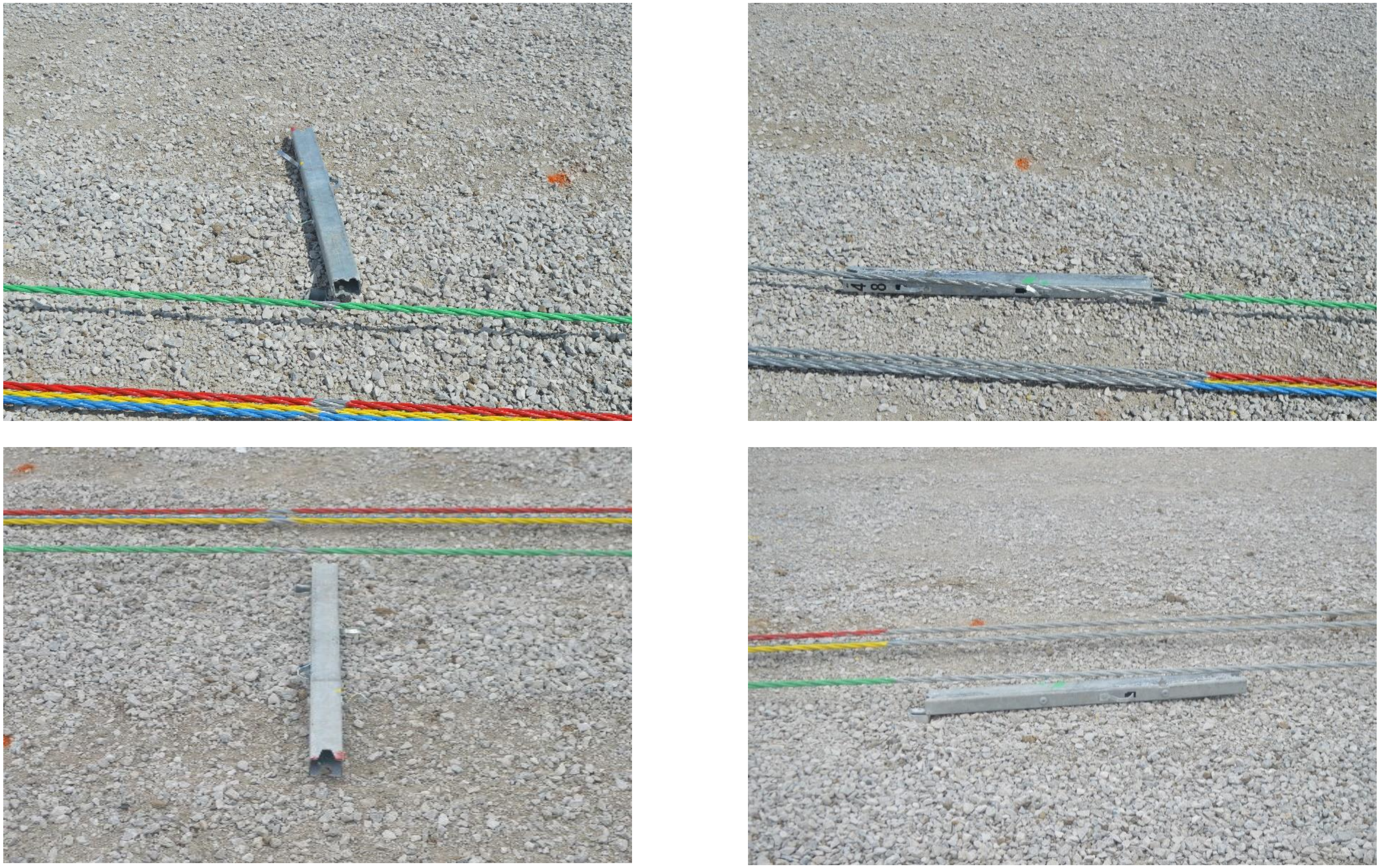


Figure 63. Post Nos. 47 (Left) and 48 (Right) Damage, Test No. MTP-1

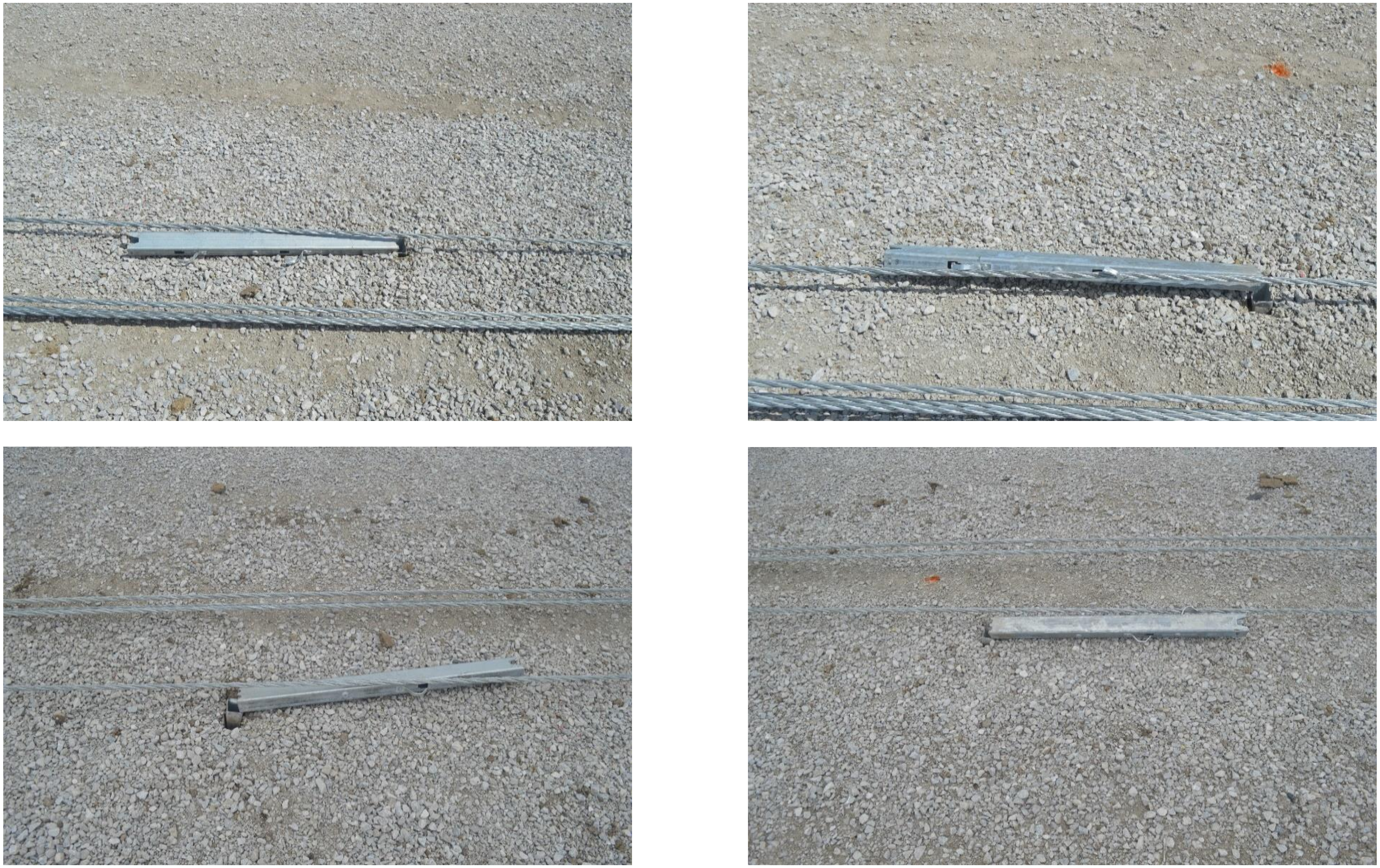


Figure 64. Post Nos. 49 (Left) and 50 (Right) Damage, Test No. MTP-1

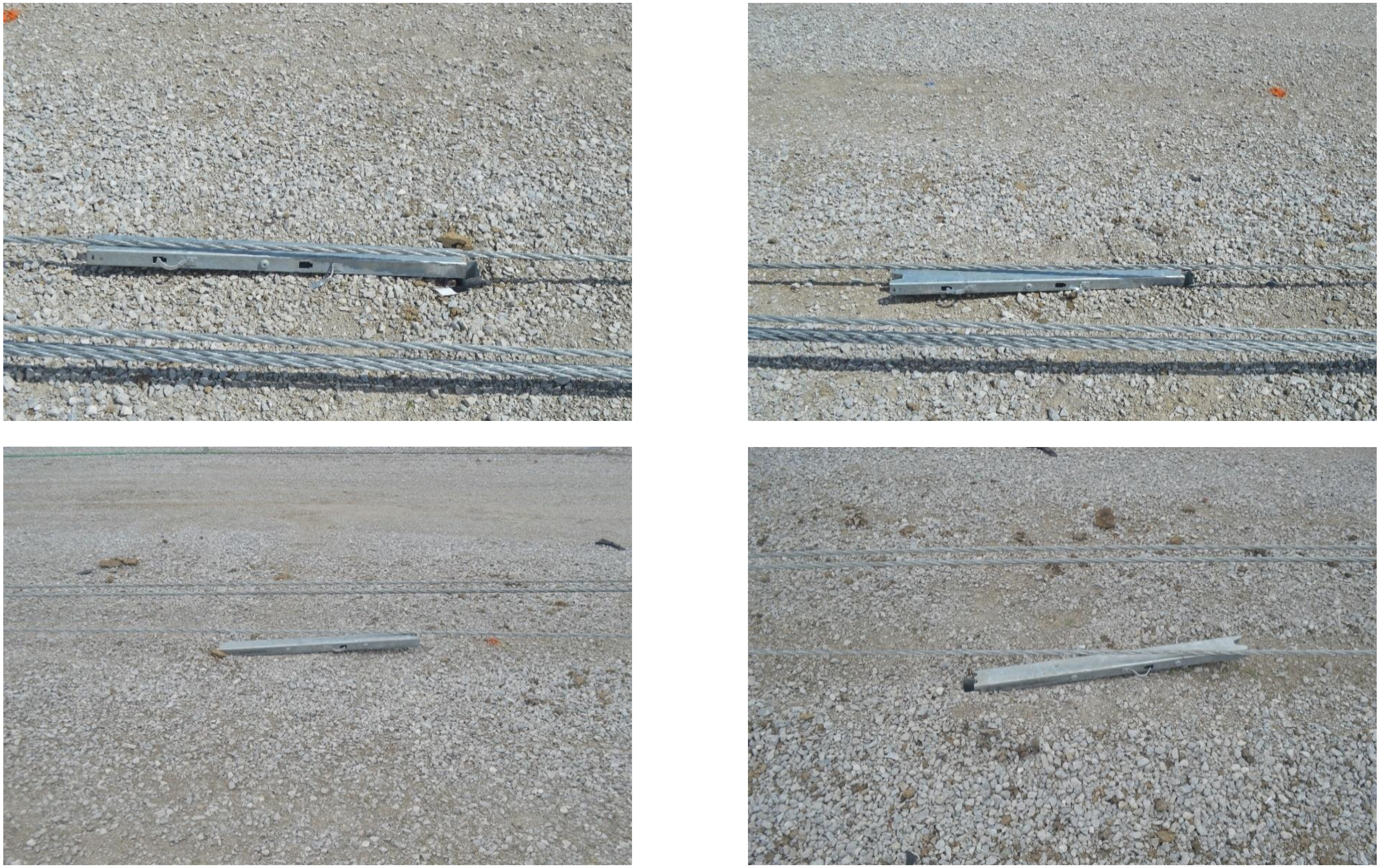


Figure 65. Post Nos. 51 (Left) and 52 (Right) Damage, Test No. MTP-1

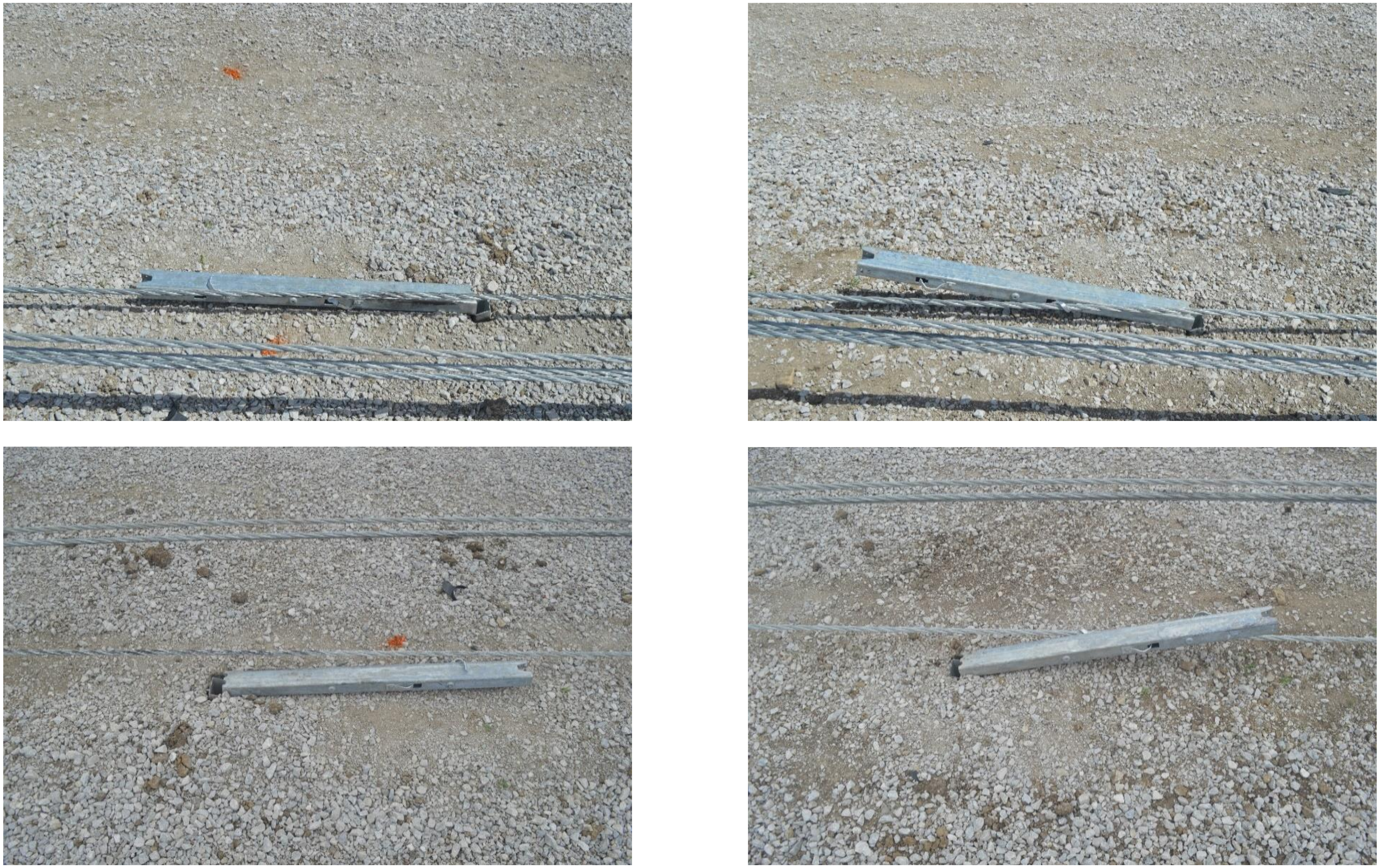


Figure 66. Post Nos. 53 (Left) and 54 (Right) Damage, Test No. MTP-1

Figure 67. Post Nos. 55 (Left) and 56 (Right) Damage, Test No. MTP-1

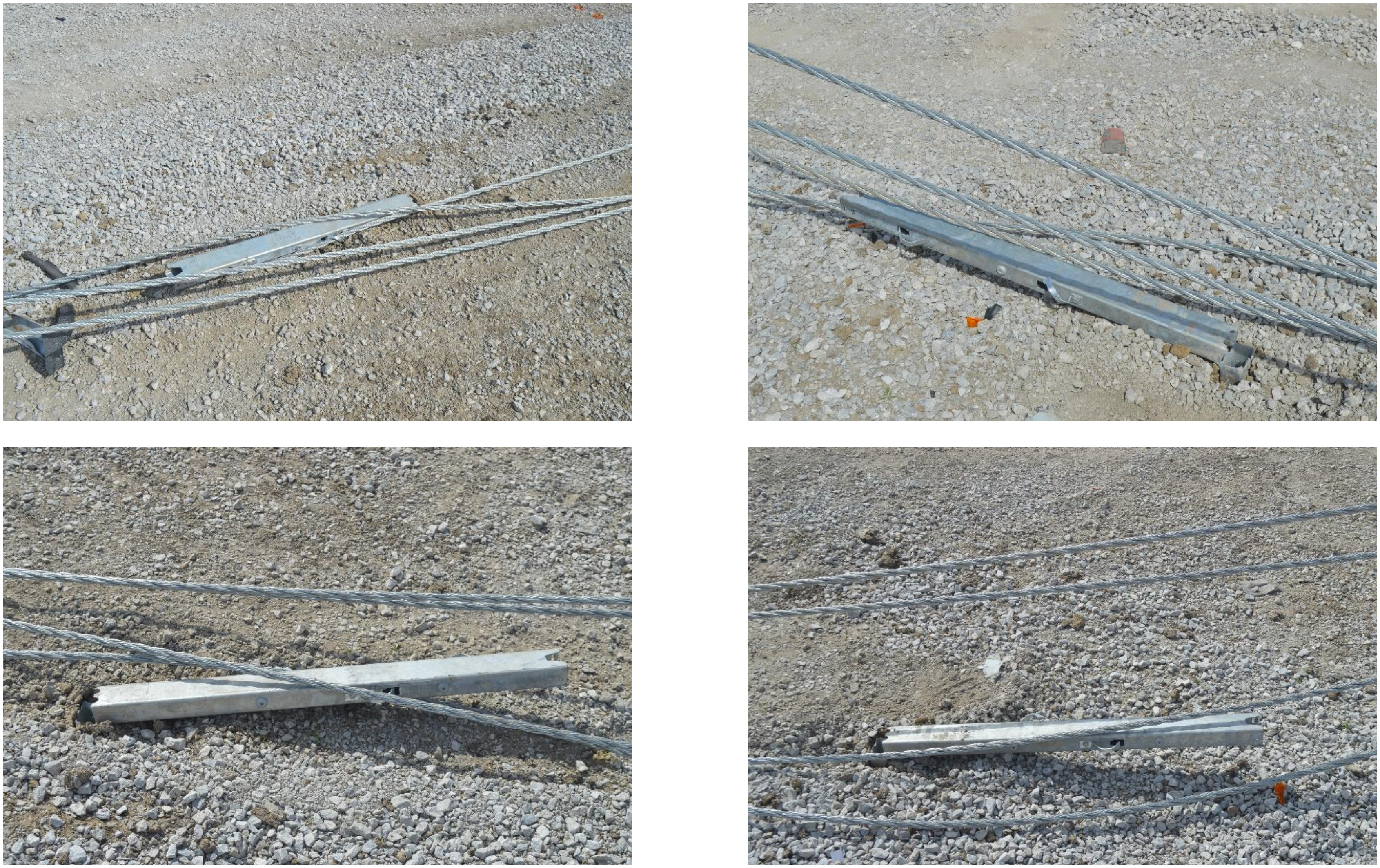


Figure 68. Post Nos. 57 (Left) and 58 (Right) Damage, Test No. MTP-1

Figure 69. Post Nos. 57 and 58 with Vehicle, Test No. MTP-1

Figure 70. Post Nos. 59 (Left) and 60 (Right) Damage, Test No. MTP-1

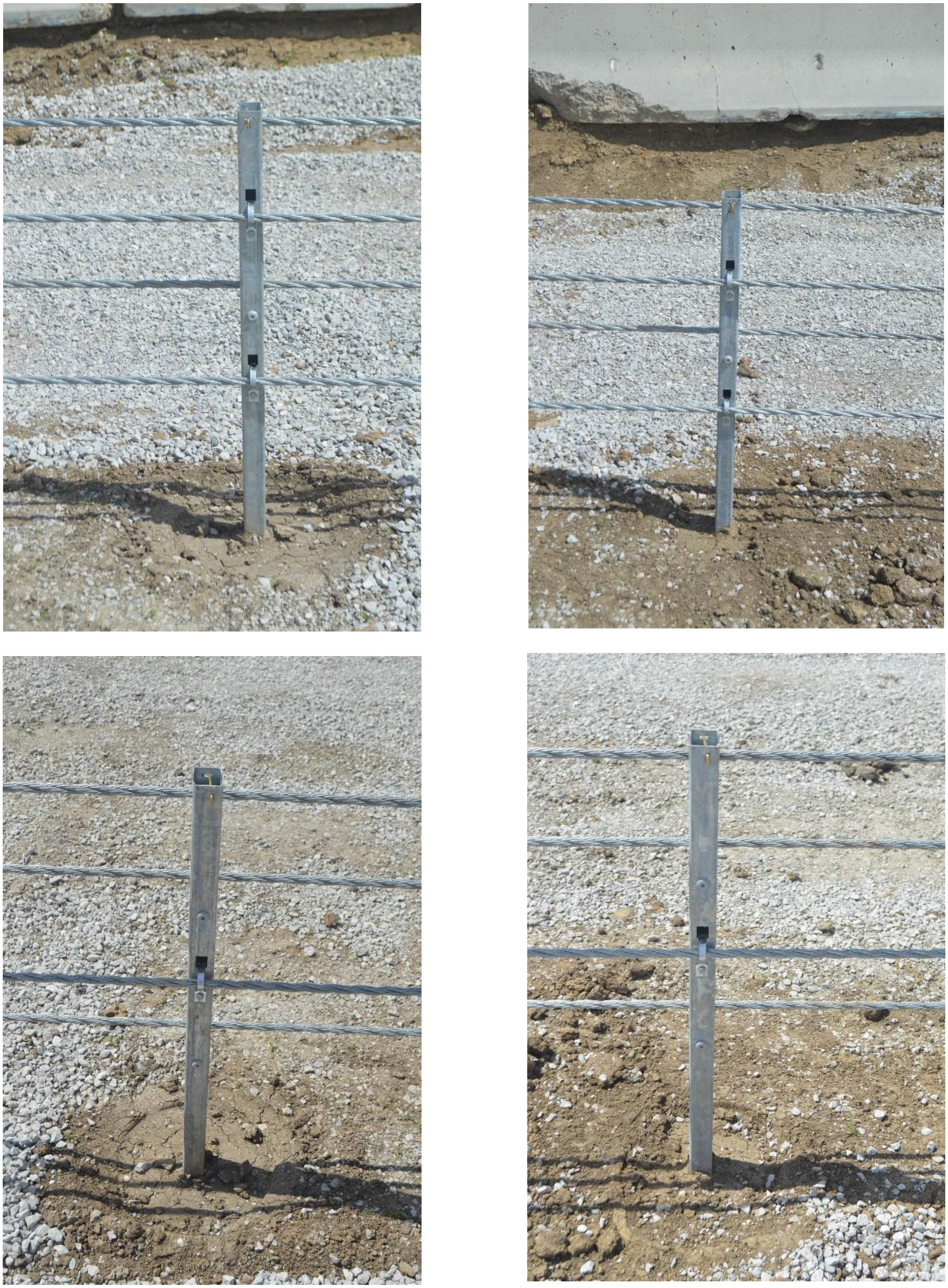


Figure 71. Post Nos. 61 (Left) and 62 (Right) Damage, Test No. MTP-1

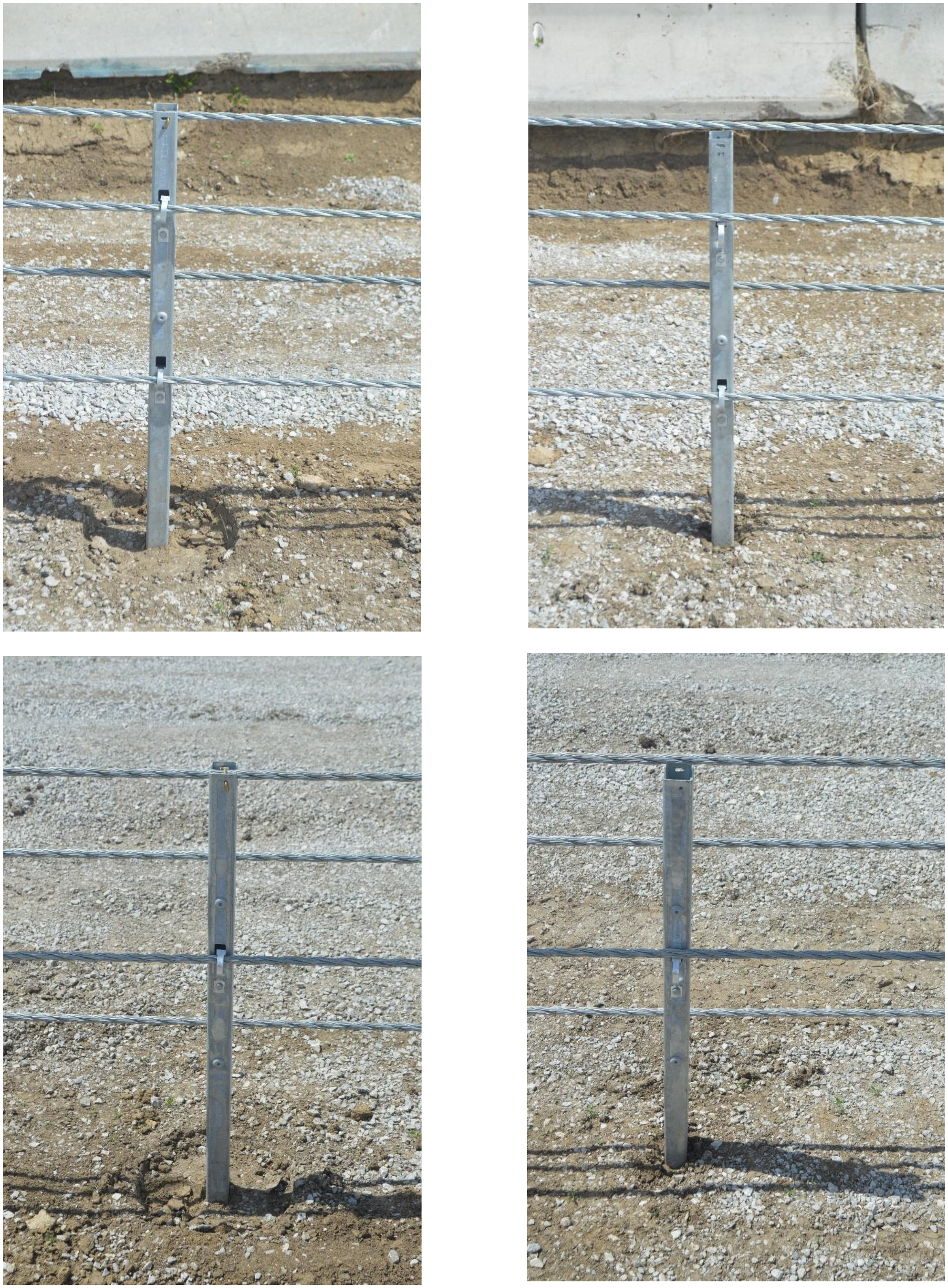


Figure 72. Post Nos. 63 (Left) and 64 (Right) Damage, Test No. MTP-1

Figure 73. Post Nos. 65 (Left) and 66 (Right) Damage, Test No. MTP-1

Figure 74. Post-Test Downstream Anchorage, Test No. MTP-1

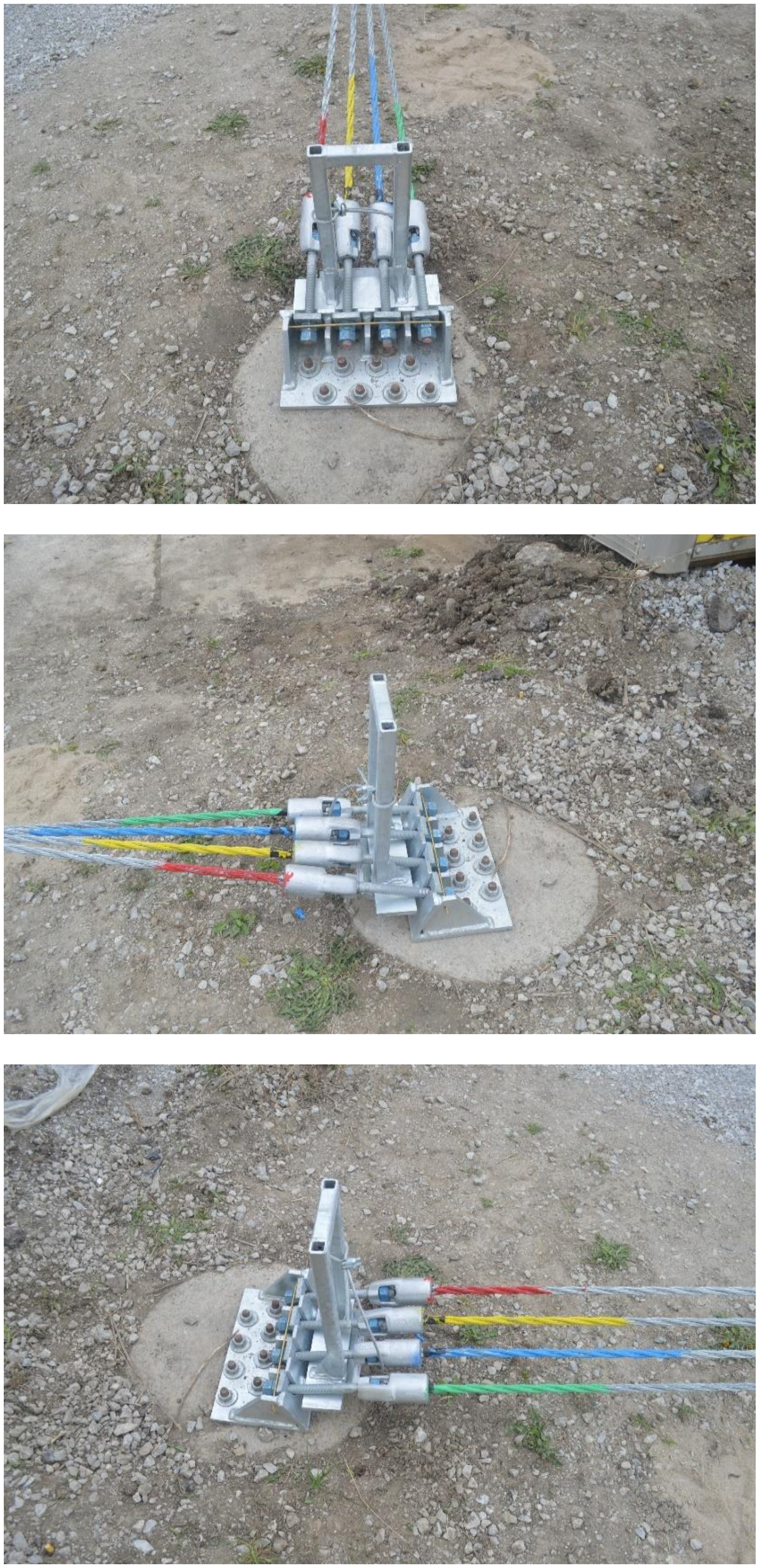


Figure 75. Post-Test Upstream Anchorage, Test No. MTP-1

The maximum lateral permanent set of the posts in the system was 28.1 in. (714 mm), which occurred at post no. 39, as measured via GPS in the field. The maximum lateral dynamic barrier deflection was 101.8 in. (2,586 mm), as determined from high-speed digital video analysis. The working width of the system was found to be 102.1 in. (2,593 mm), which was also determined from high-speed digital video analysis. The working width and dynamic deflection were determined to be the point reached by the test vehicle's left-rear bumper between post nos. 35 and 36 and the cable in contact with the bumper at that same location, respectively. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 76.

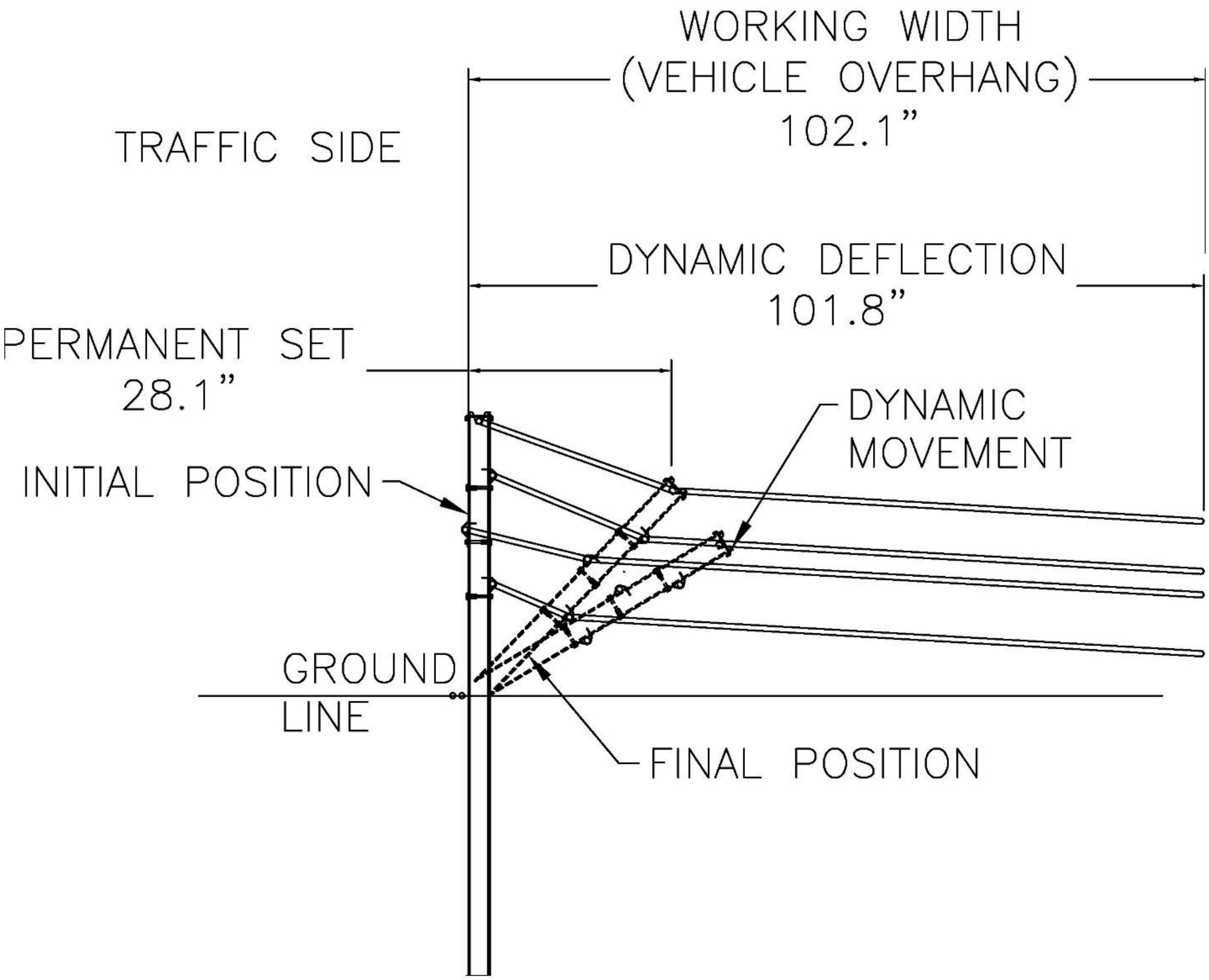


Figure 76. Permanent Set, Dynamic Deflection, and Working Width, Test No. MTP-1

5.5 Vehicle Damage

The damage to the vehicle was minor, as shown in Figures 77 through 80. The maximum occupant compartment intrusions are listed in Table 8 along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. Complete occupant compartment and vehicle deformations as well as the corresponding locations are provided in Appendix D. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. There were no penetrations into the occupant compartment, and none of the established MASH 2016 deformation limits were violated. Outward deformations, which are denoted as negative numbers in Appendix D, are not considered crush toward the occupant, and are not evaluated by MASH 2016 criteria.

Majority of the vehicle damage was concentrated on the left-front corner, where primary impact occurred. Significant damage was sustained in this region. The cable bearing force on the left fender produced deep gouging, resulted in pronounced striations, and caused the fender to crease along the contact line. The left-front door was deformed, experiencing creasing and striations similar to those on the left fender. The front edge of the door was crushed, primarily near the bottom corner where the deformation exposed the a portion of the interior cab. Additionally, the left-front headlight disengaged from the vehicle, and the front bumper cover detached almost completely, remaining fastened to the vehicle only at the rightmost connection.

Deformation and contact marks continued along the left side of the vehicle, decreasing in severity with distance from the impact point. The left-rear door and left quarter panel experienced only minor deformation and contact marks along the cable bearing paths. The right side of the vehicle encountered only small gouges caused by the top edge of post no. 35 as the vehicle passed the post on the non-impact side during redirection.

The vehicle undercarriage sustained only minor damage. Scrapes were found on the left steering knuckle, the lower-left control arm, and both transmission cross members. Additionally, the frame horn on the left side was bent slightly to the right. No other undercarriage damage occurred; specifically the floor pan remained undamaged.

Figure 77. Vehicle Damage, Test No. MTP-1

Figure 78. Vehicle Damage, Test No. MTP-1

Figure 79. Occupant Compartment Damage, Test No. MTP-1

Figure 80. Vehicle Undercarriage Damage, Test No. MTP-1

Table 8. Maximum Occupant Compartment Intrusion by Location, Test No. MTP-1

LOCATION	Maximum Intrusion in. (mm)	MASH 2016 Allowable Intrusion in. (mm)
Wheel Well & Toe Pan	0.0 (0)	≤ 9 (229)
Floor Pan & Transmission Tunnel	0.0 (0)*	≤ 12 (305)
A-Pillar	0.5 (13)	≤ 5 (127)
A-Pillar (Lateral)	0.5 (13)	≤ 3 (76)
B-Pillar	0.3 (8)	≤ 5 (127)
B-Pillar (Lateral)	0.5 (13)	≤ 3 (76)
Side Front Panel (in Front of A-Pillar)	0.8 (20)	≤ 12 (305)
Side Door (Above Seat)	0.6 (15)	≤ 9 (229)
Side Door (Below Seat)	0.7 (18)	≤ 12 (305)
Roof	0.0 (0)	≤ 4 (102)
Windshield	0.0 (0)	≤ 3 (76)
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	0.6 (15)	N/A

N/A – No MASH 2016 criteria exist for this location.
*Negative value reported as 0.0. See Appendix D for further information.

5.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from accelerometer data, are shown in Table 9. The OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 9. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix E.

Table 9. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. MTP-1

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-2 (Primary)	SLICE-1	
OIV ft/s (m/s)	Longitudinal	-10.13 (-3.09)	-10.27 (-3.13)	±40 (12.2)
	Lateral	8.65 (2.64)	8.40 (2.56)	±40 (12.2)
ORA g's	Longitudinal	-8.48	-8.12	±20.49
	Lateral	3.51	3.93	±20.49
Maximum Angular Displacement degrees	Roll	11.2	8.1	±75
	Pitch	2.3	2.4	±75
	Yaw	26.9	27.2	not required
THIV ft/s (m/s)		13.09 (3.99)	12.61 (3.84)	not required
PHD g's		8.49	8.13	not required
ASI		0.29	0.33	not required

5.7 Load Cells

The pertinent data from the load cells was extracted from the bulk signal and analyzed using the transducer's calibration factor. 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 a measurable signal increase in the data. Thus, the extracted data curves should not be taken as precise time after impact, but rather a general timeline between events within the data curve itself. Maximum cable tension loads recorded by each load cell and the times after impact at which they occurred are shown in Table 10, and all recorded cable loads are plotted in Figure 81.

Table 10. Maximum Cable Loads, Test No. MTP-1

Cable Location	Sensor Location	Maximum Cable Load kips (kN)	Time sec
Combined Cable Load	Upstream of Impact	41.4 (184.2)	0.525
Cable No. 4	Upstream of Impact between Post Nos. 6 and 7	13.7 (60.9)	0.602
Cable No. 3	Upstream of Impact between Post Nos. 7 and 8	13.0 (58.0)	0.468
Cable No. 2	Upstream of Impact between Post Nos. 6 and 7	16.8 (74.8)	0.857
Cable No. 1	Upstream of Impact between Post Nos. 7 and 8	7.0 (31.1)	0.055

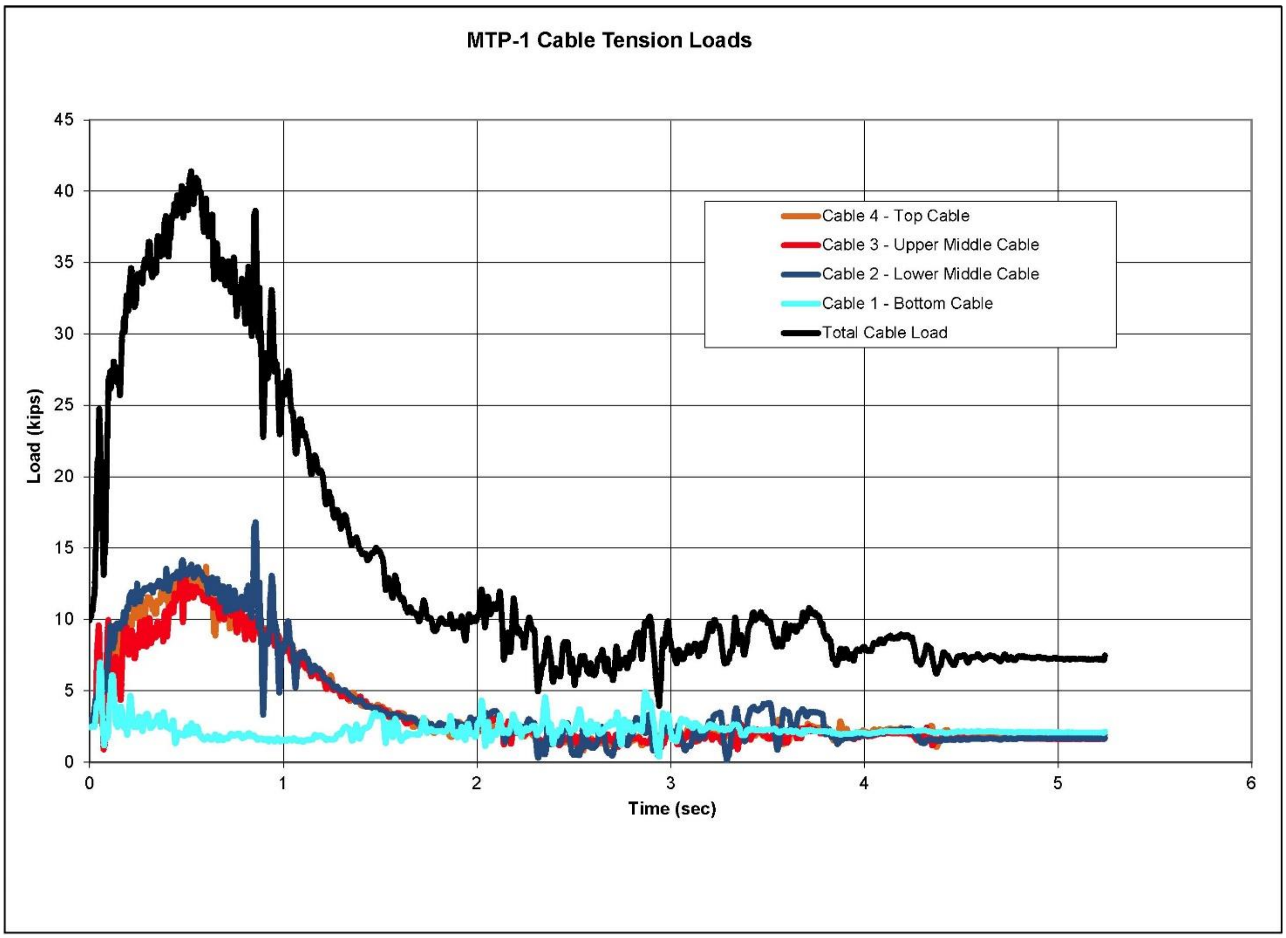
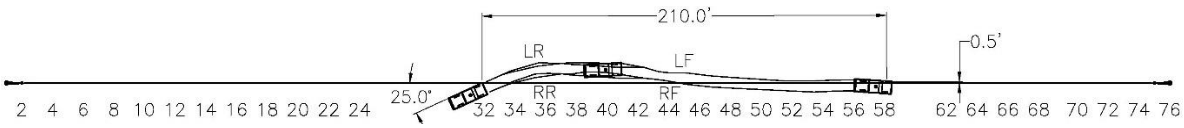


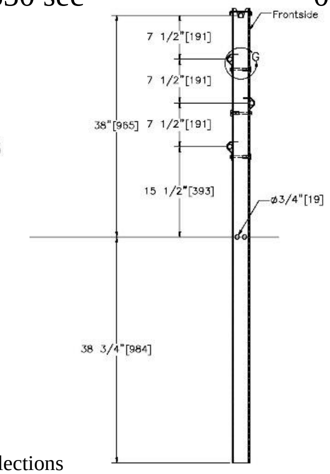
Figure 81. Cable Tension Loads, Test No. MTP-1

5.8 Discussion

The analysis of the test results for test no. MTP-1 showed that the system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown in Figure 82. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix E, were deemed acceptable because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle did not exit the system, but was instead brought to a halt while still in contact with the system. Therefore, test no. MTP-1 was determined to be successful according to the MASH 2016 safety performance criteria for test designation no. 3-11.

0.000 sec | 0.250 sec | 0.450 sec | 0.650 sec | 0.850 sec





- Test Agency .... MwRSF
- Test Number MTP-1
- Date 4/22/2019
- MASH 2016 Test Designation No. 3-11
- Test Article .... Four-Cable Median Barrier
- Total Length .... 603 ft – 8 in. (184.0 m)
- Key Component - Cable
  - Size .... ¾-in. (19-mm) dia. 3x7 IWRC IPS
  - Cable Heights .... 15½, 23, 30½, 38 in. (394, 584, 775, 965 mm)
- Key Component - MTP
  - Section .... HSS 3x2x⅛ (76x51x3)
  - Length .... 78 in. (1,981 mm)
  - Spacing .... 96 in. (2,438 mm)
- Soil Type .... Compacted, coarse, crushed limestone (well-graded gravel)
- Vehicle Make /Model .... 2012 Dodge Ram 1500 Quad Cab
  - Curb .... 5,063 lb (2,297 kg)
  - Test Inertial .... 4,986 lb (2,262 kg) (MASH 2016 limit 5000 ± 110 lb)
  - Gross Static .... 5,148 lb (2,335 kg)
- Impact Conditions
  - Speed .... 61.3 mph (98.7 km/h) (MASH 2016 limit 62 ± 2.5 mph)
  - Angle .... 25.0 deg. (MASH 2016 limit 25 ± 1.5 deg.)
  - Impact Location .... 8 in. (203 mm) upstream from Post No. 32
- Impact Severity .... 111.4 kip-ft (151.0 kJ) > 106 kip-ft (144 kJ) limit from MASH 2016
- Exit Conditions
  - Speed .... N/A
  - Angle .... N/A
  - Exit Box Criterion .... Vehicle did not exit system
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 210 ft (64.0 m) downstream
- Vehicle Damage .... Minor
  - VDS [13] 11-LFQ-2
  - CDC [14] 11-FLES 1
  - Maximum Interior Deformation ..0.8 in. (20 mm) < 12 in. (305 mm) MASH 2016 limit
- Test Article Damage .... Moderate
- Maximum Test Article Deflections
  - Permanent Set .... 28.1 in. (714 mm)
  - Dynamic .... 101.8 in. (2,586 mm)
  - Working Width .... 102.1 in. (2,593 mm)
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1	SLICE-2 (Primary)	
OIV ft/s (m/s)	Longitudinal	-10.27 (-3.13)	-10.13 (-3.09)	±40 (12.2)
	Lateral	8.40 (2.56)	8.65 (2.64)	±40 (12.2)
ORA g's	Longitudinal	-8.12	-8.48	±20.49
	Lateral	3.93	3.51	±20.49
Maximum Angular Displacement degrees	Roll	8.1	11.2	±75
	Pitch	2.4	2.3	±75
	Yaw	27.2	26.9	not required
THIV – ft/s (m/s)		12.61 (3.84)	13.09 (3.99)	not required
PHD – g's		8.13	8.49	not required
ASI		0.33	0.29	not required

Figure 82. Summary of Test Results and Sequential Photographs, Test No. MTP-1

6 DESIGN DETAILS TEST NO. MTP-2

The cable median barrier system used for test MTP-2 was nearly identical to that used in test no. MTP-1, but the installation was placed at the front slope break point of the 6H:1V V-ditch in accordance with MASH test designation no. 3-17, as shown in Figures 83 through 108. For MASH 2016 test designation no. 3-17, testing laboratories are to determine critical barrier position from 0 to 4 ft (0 to 1.22 m) on the front slope of a ditch in order to maximize the propensity for the front end of 1500A vehicle to penetrate between vertically adjacent cables. Utilizing the individual cable heights and vertical cable spacing of the system and the front-end geometry of the test vehicle, it was determined that the front bumper of the 1500A vehicle was located directly between cable nos. 1 and 2 when placed on level terrain. Therefore, the four-cable median barrier system was placed at the front slope break point of the 6H:1V V-ditch.

A 400-ft (121.9-m) long V-ditch was constructed using an overall width of 30 ft (9.1 m) in combination with 6H:1V side slopes. The V-ditch was located between post nos. 8 and 33. Additionally, the system was mirrored so that cable no. 2 was on the non-impact side of the barrier, and cable nos. 1 and 3 were on the impact side. The post spacing was increased to 16 ft (4.9 m). Photographs of the test installation are shown in Figures 109 through 113. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

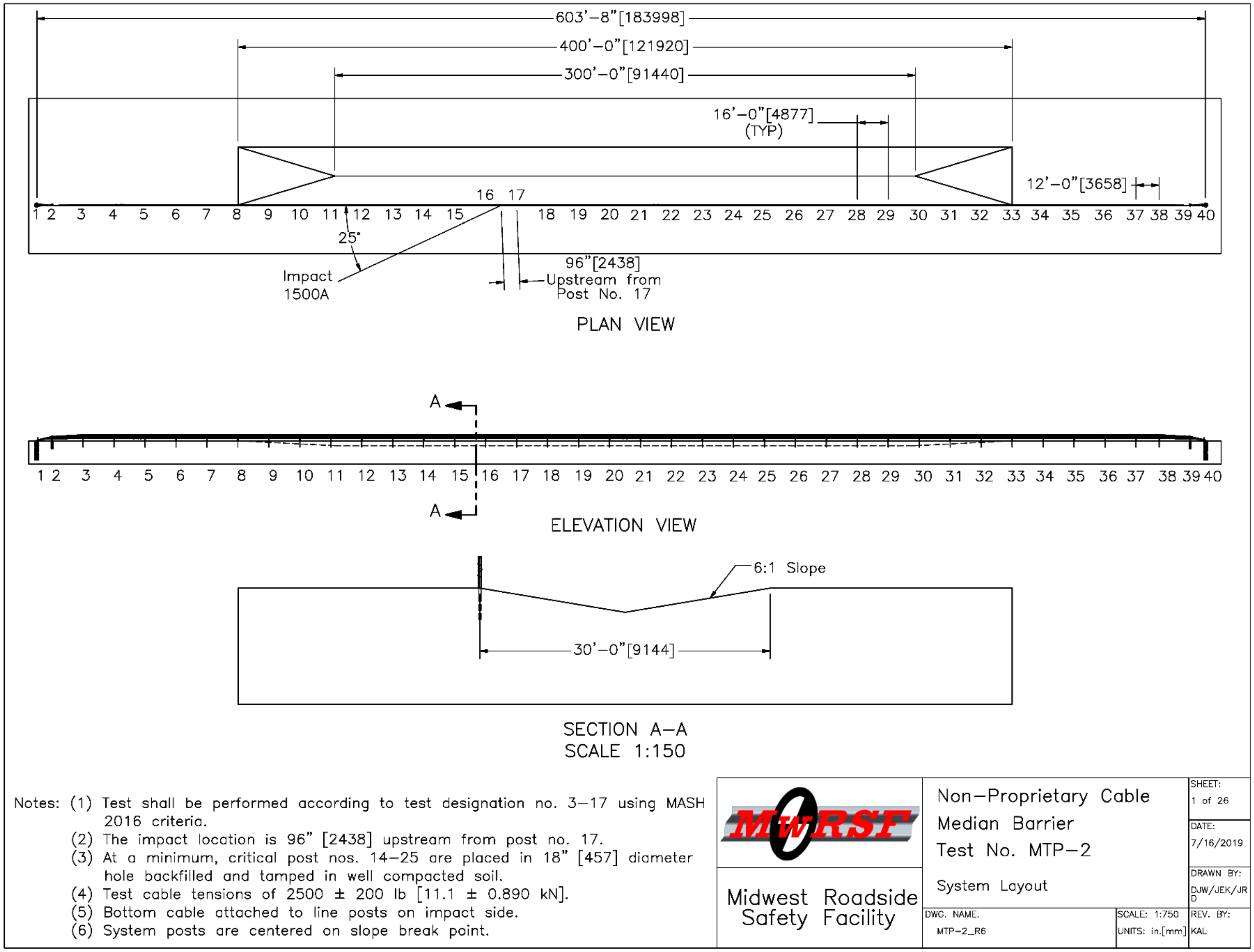


Figure 83. System Layout, Test No. MTP-2

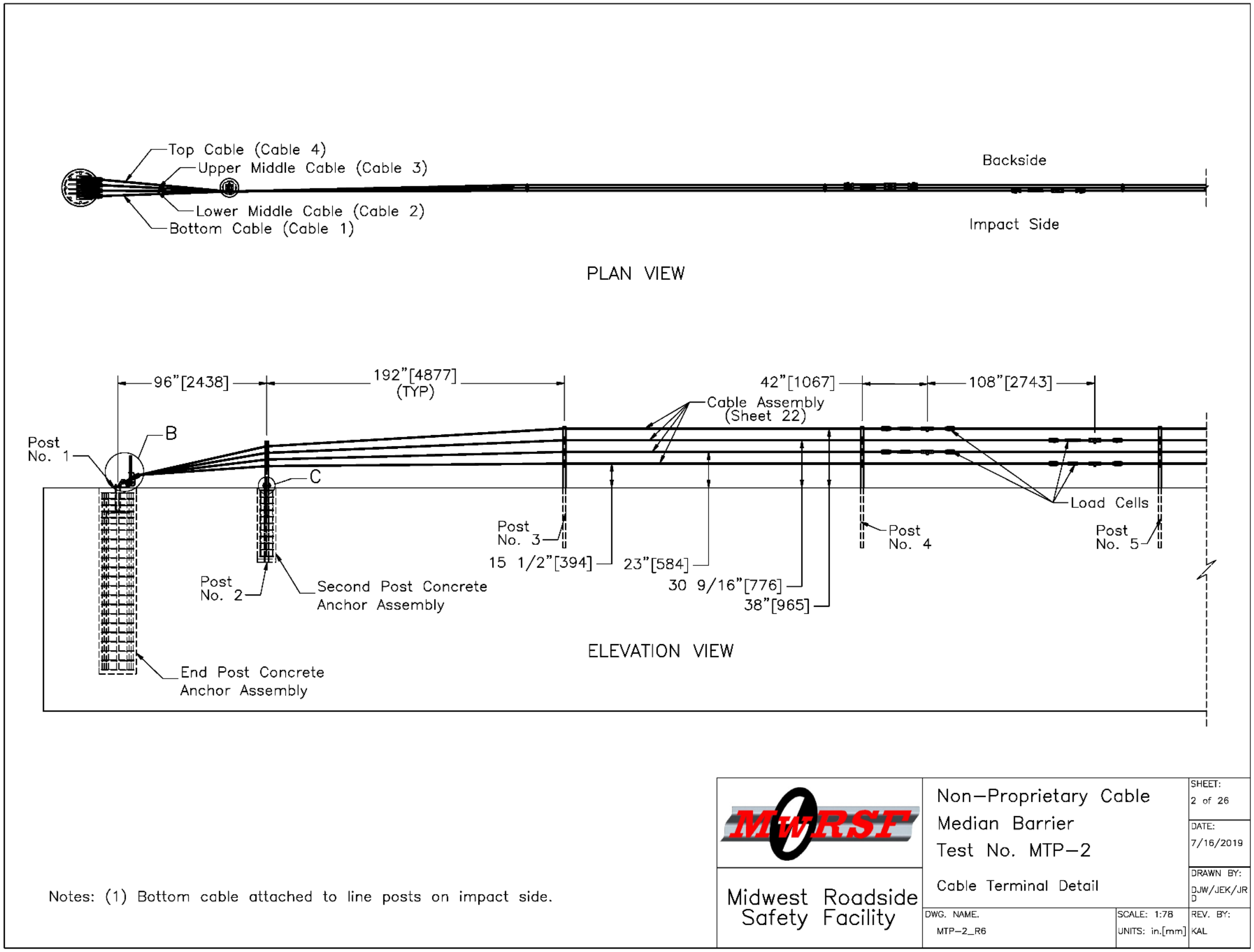


Figure 84. Cable Terminal Detail, Test No. MTP-2

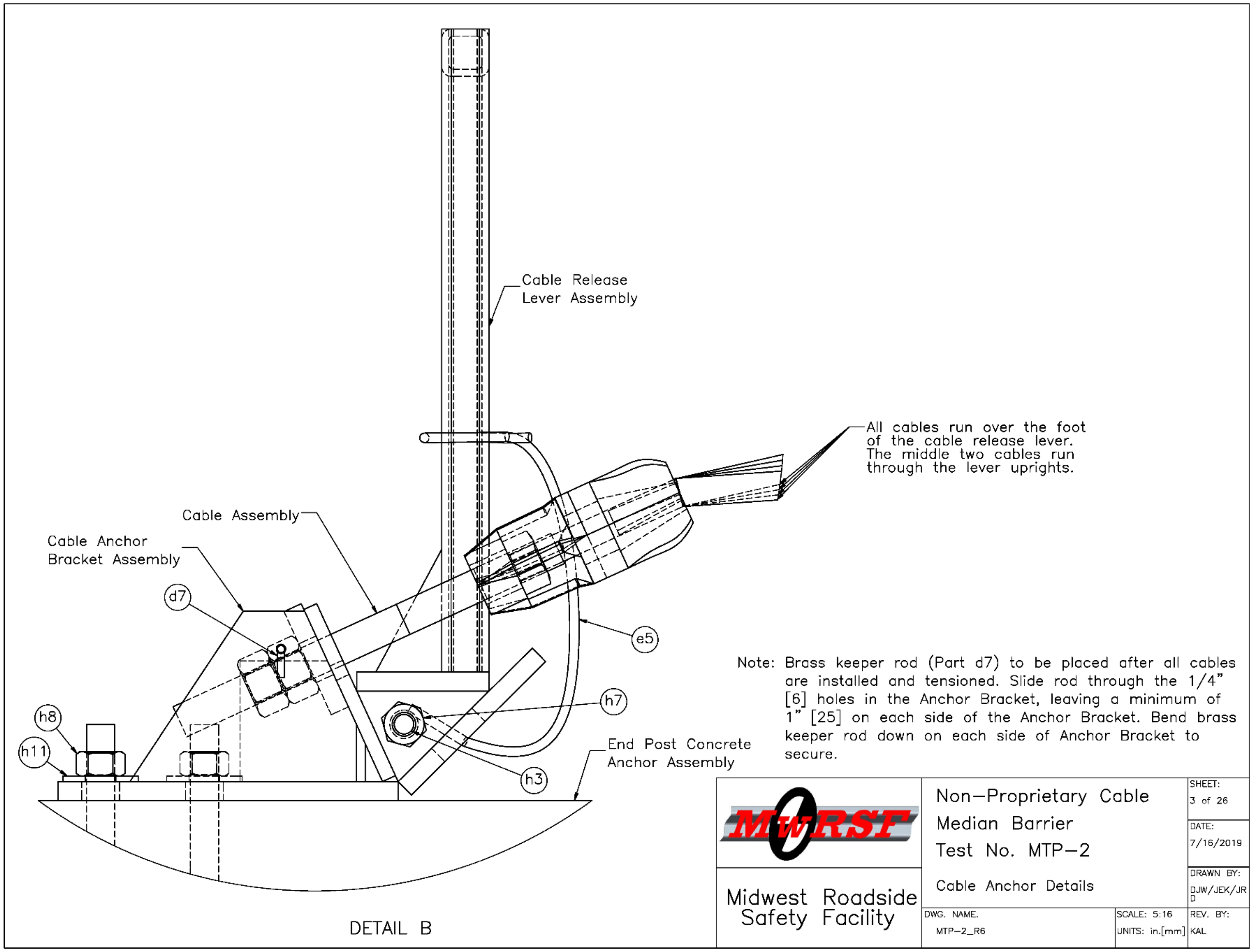


Figure 85. Cable Anchor Details, Test No. MTP-2

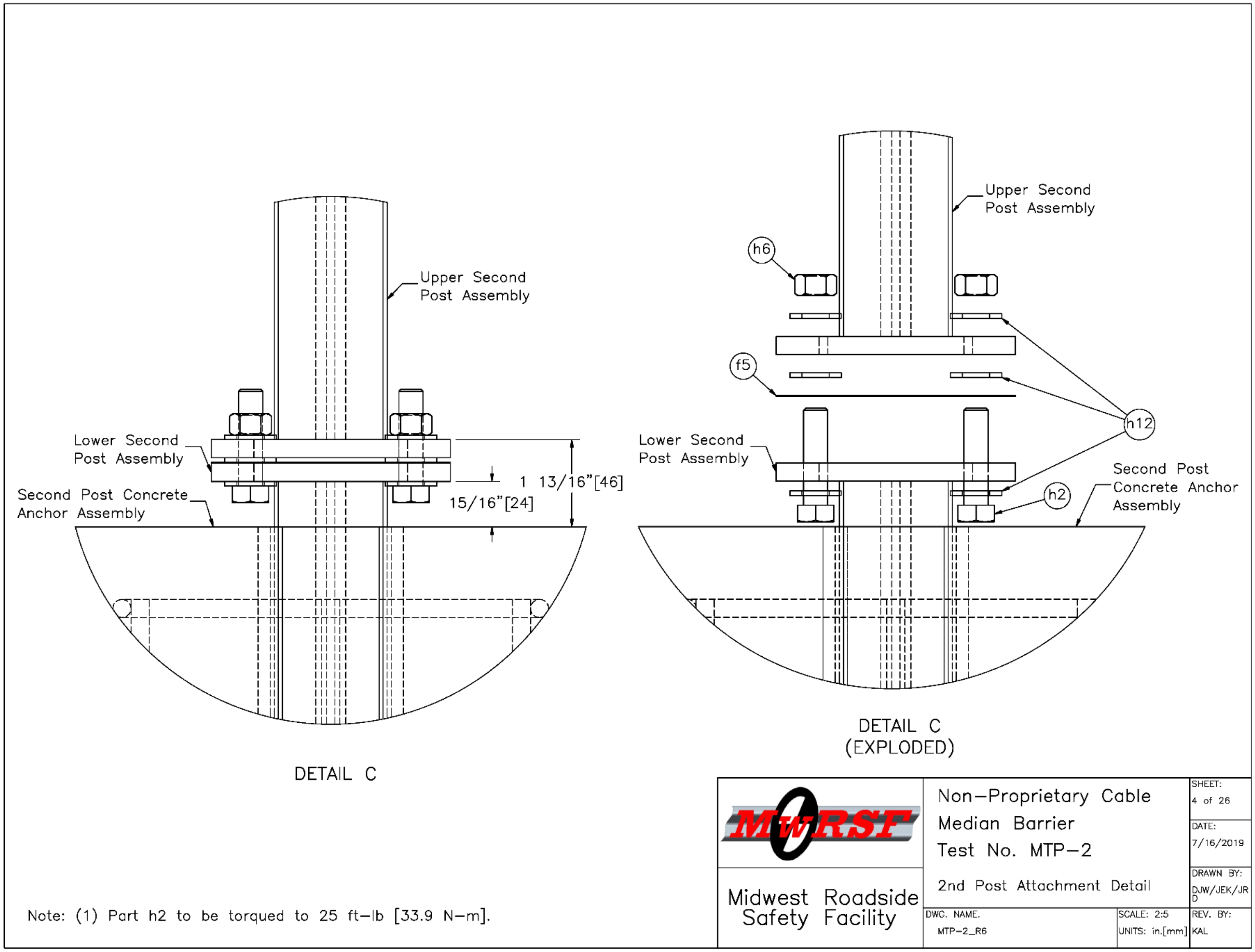


Figure 86. Second Post Attachment Detail, Test No. MTP-2

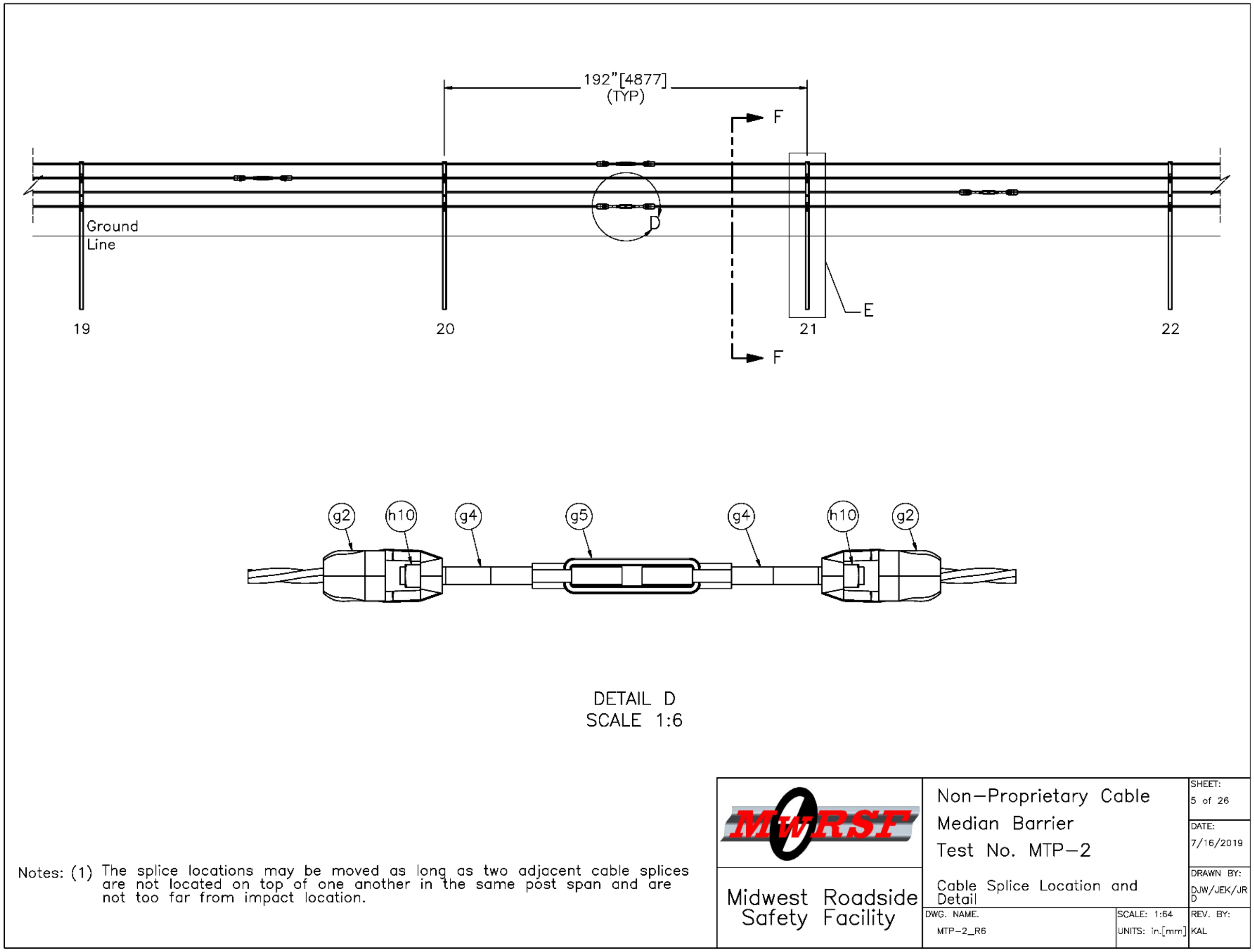


Figure 87. Cable Splice Location and Detail, Test No. MTP-2

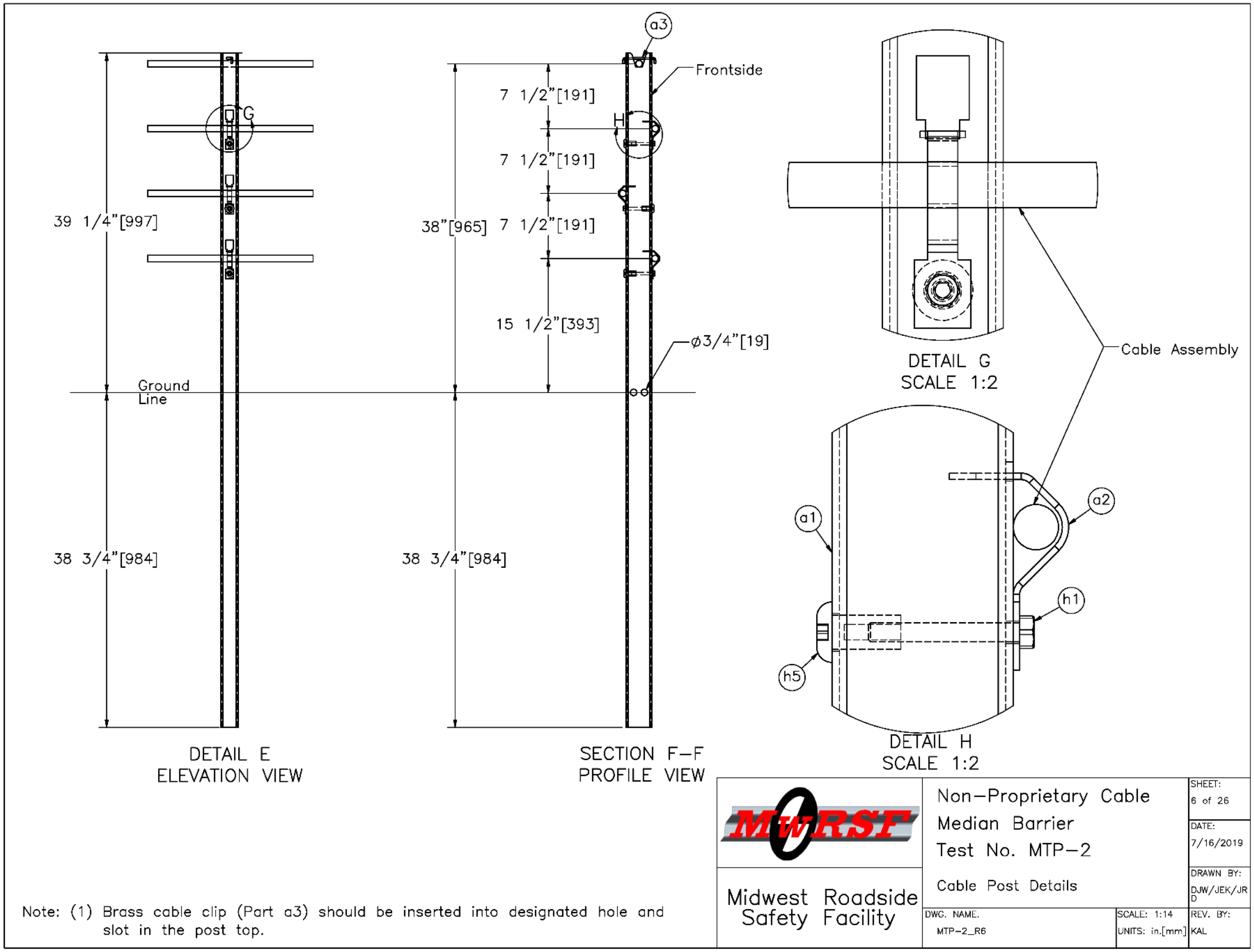


Figure 88. Cable Post Details, Test No. MTP-2

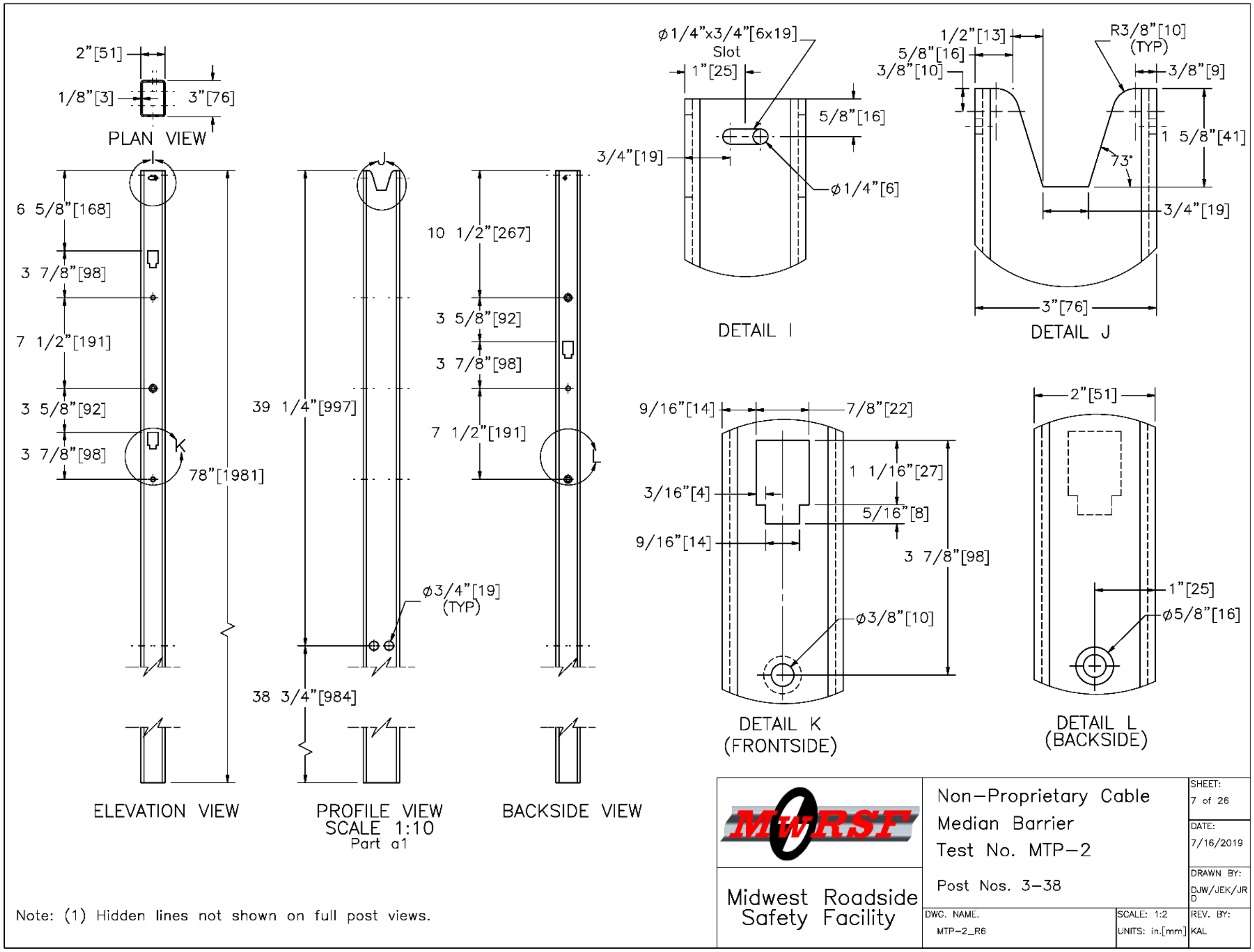


Figure 89. Post Nos. 3 through 38, Test No. MTP-2

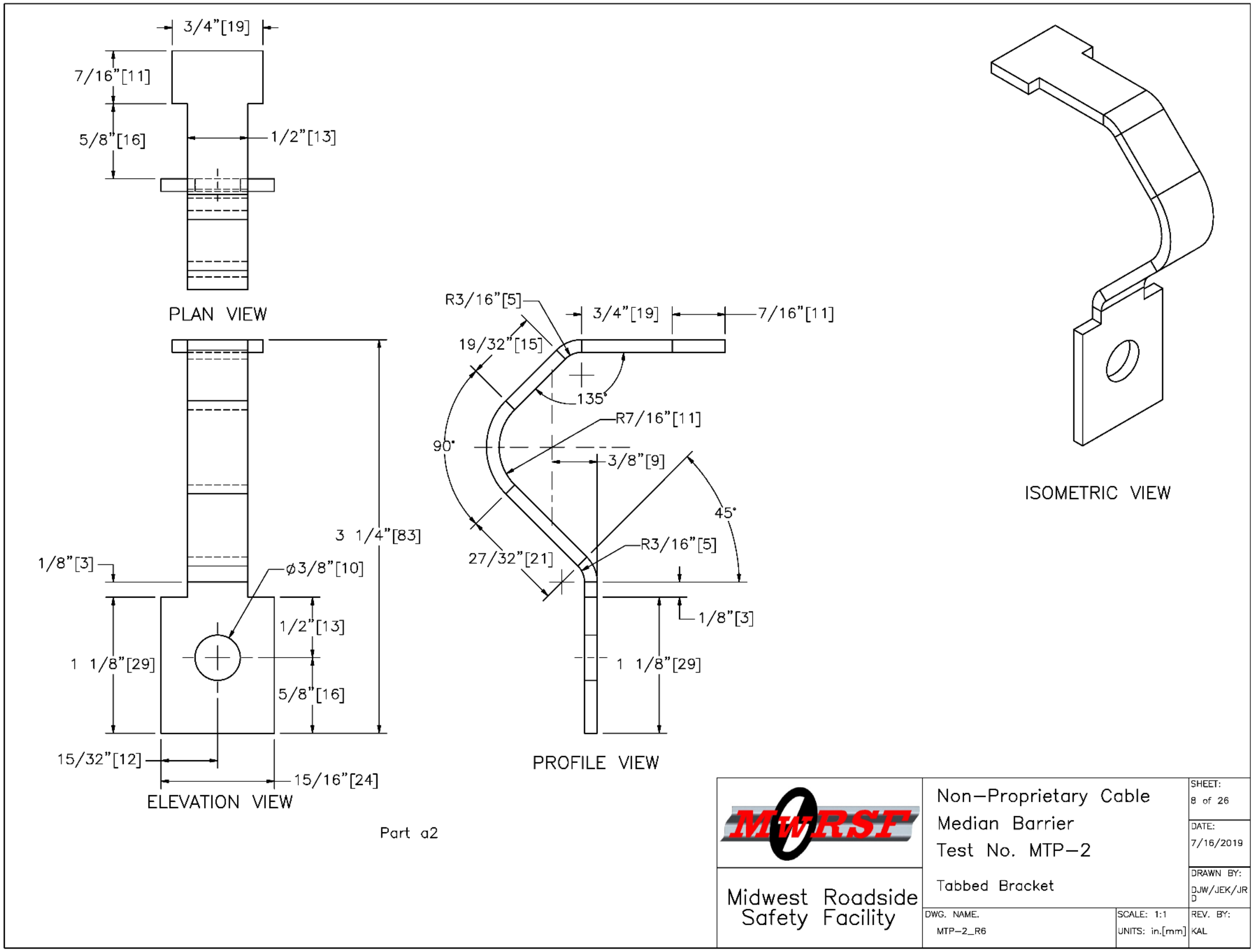


Figure 90. Tabbed Bracket, Test No. MTP-2

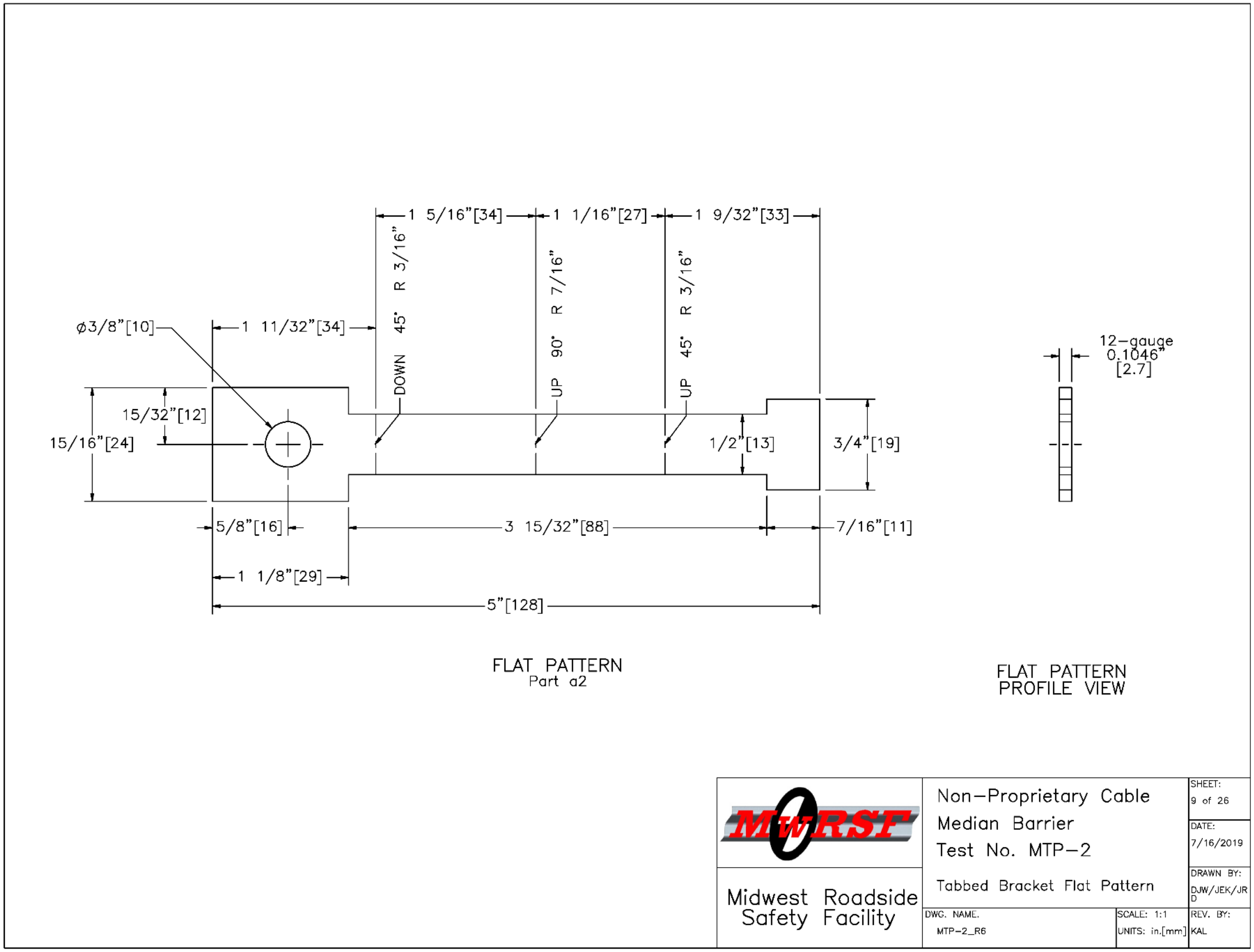
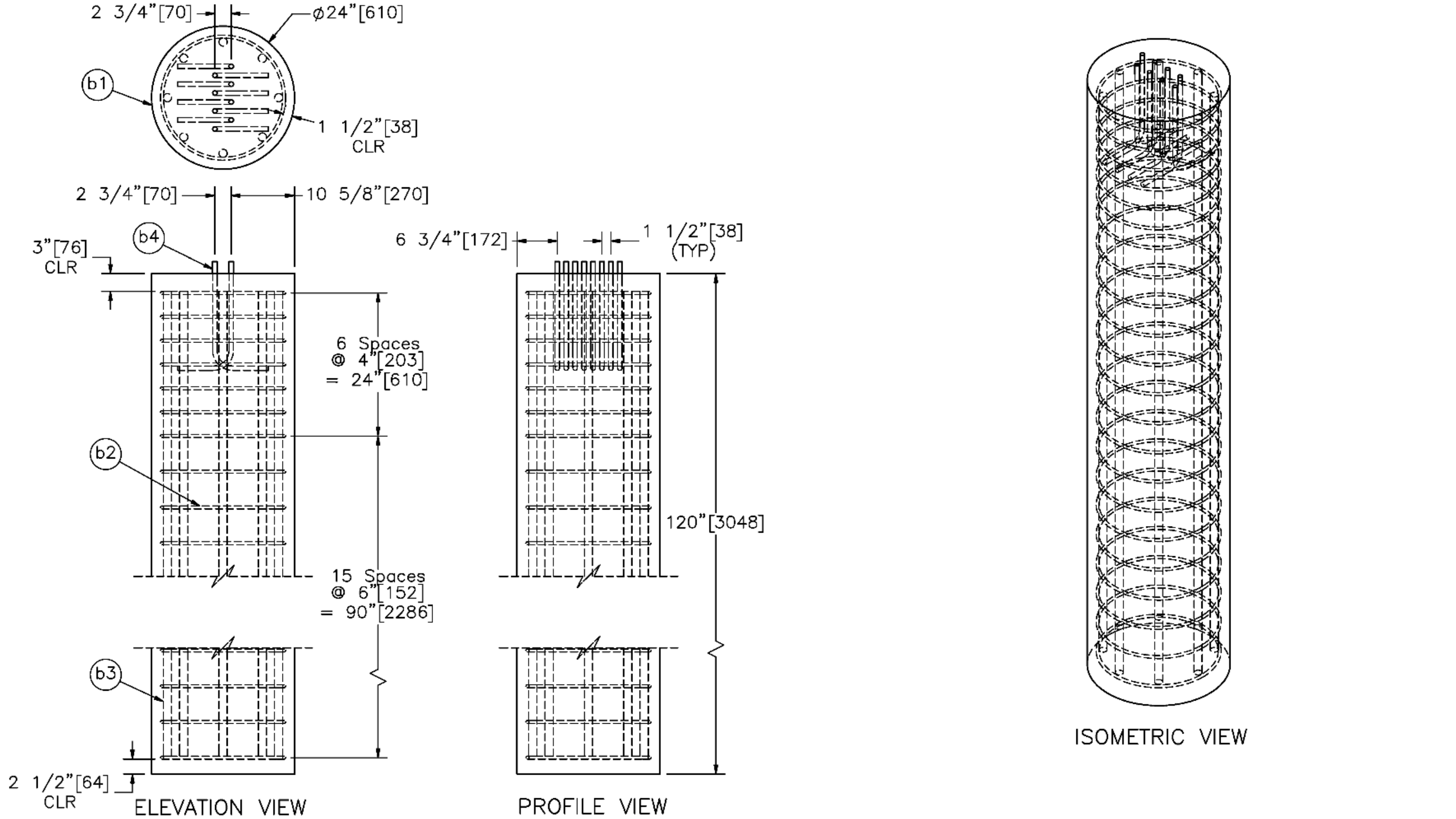


Figure 91. Tabbed Bracket Flat Pattern, Test No. MTP-2



Note: (1) The two outer bent anchor studs may need to be turned inward so they do not stick out of concrete cover.

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	2	End Post Concrete Anchor Assembly	–	–	–
b1	1	24" [610] Dia. Concrete Anchor, 120" [3,048] Long	Min. f'c = 4,000 psi [27.6 MPa]	–	–
b2	22	#4 [13] Hoop Bar with 21" [533] Dia., 84" [2,134] Unbent Length	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
b3	8	#11 [35] Bar, 114" [2,896] Long	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
b4	8	3/4"-10 UNC [M20x2.5] J-Hook Anchor	ASTM A449	ASTM A153 or B695 Class 55 or F2329	FRJ16a

MwRSF Midwest Roadside Safety Facility	Non-Proprietary Cable Median Barrier Test No. MTP-2	SHEET: 10 of 26
		DATE: 7/16/2019
	End Post Concrete Anchor Assembly	DRAWN BY: DJW/JEK/JRD
	DWG. NAME. MTP-2_R6 / SCALE: 1:24 / UNITS: in.[mm]	REV. BY: KAL

Figure 92. End Post Concrete Anchor Assembly, Test No. MTP-2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	2	Second Post Concrete Anchor Assembly	–	–	–
c1	1	12" [305] Dia. 2nd Post Concrete Anchor, 46" [1,168] Long	Min. f'c = 4,000 psi [27.6 MPa]	–	–
c2	1	12" [305] Dia. 2nd Post Anchor Aggregate, 2" [51] Deep	Standard Strong Soil	–	–
c3	11	#3 [10] Hoop Bar with 9" [229] Dia., 37" [940] Unbent Length	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
c4	4	#3 [10] Bar, 43" [1,092] Long	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
c5	1	4"x3"x1/4" [102x76x6] Foundation Tube, 48" [1,219] Long	ASTM A500 Gr. B	ASTM A123	–
h4	1	3/4"-10 UNC [M20x2.5], 5 1/2" [140] Long Hex Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBX20a
h8	1	3/4"-10 UNC [M20x2.5] Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX20a
h11	2	3/4" [19] Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC20a

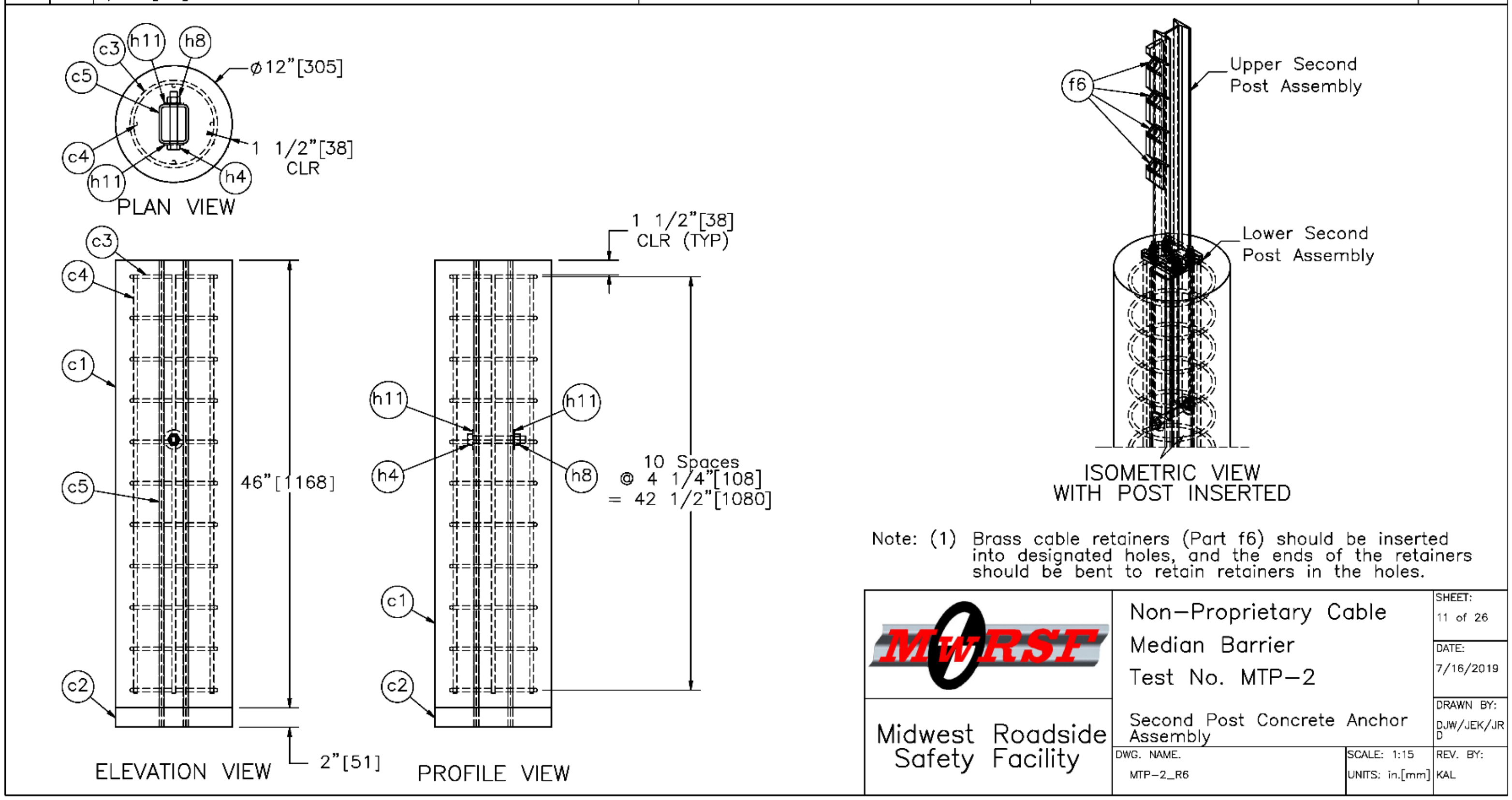
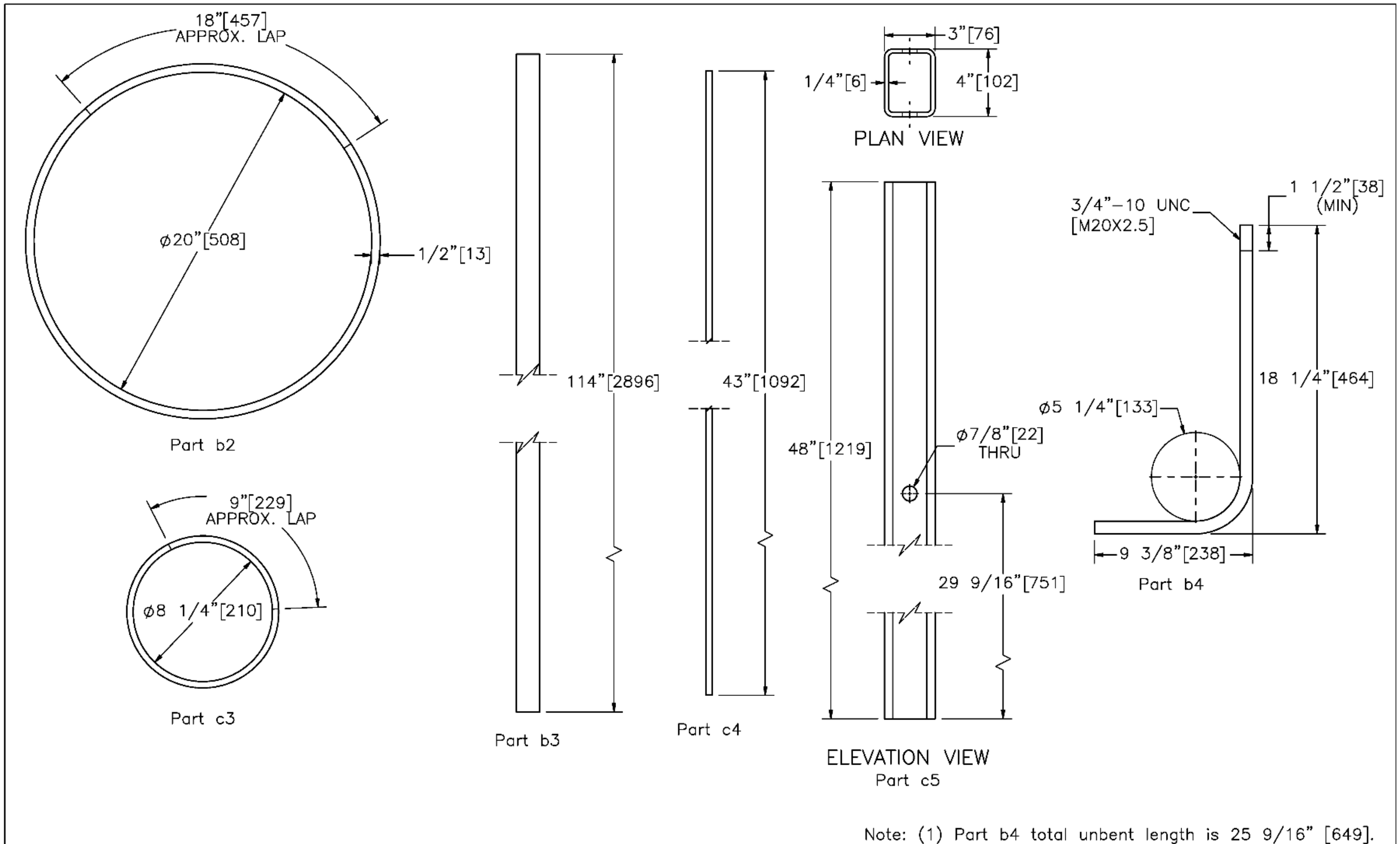


Figure 93. Second Post Concrete Anchor Assembly, Test No. MTP-2



Bill of Bars

Bar	QTY.	Size	Total Unbent Length	Material Specification	Treatment Specification
b2	44	#4	84" [2,134]	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy−Coated (ASTM A775 or A934)
b3	16	#11	114" [2,896]	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy−Coated (ASTM A775 or A934)
c3	22	#3	37" [940]	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy−Coated (ASTM A775 or A934)
c4	8	#3	43" [1,092]	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy−Coated (ASTM A775 or A934)

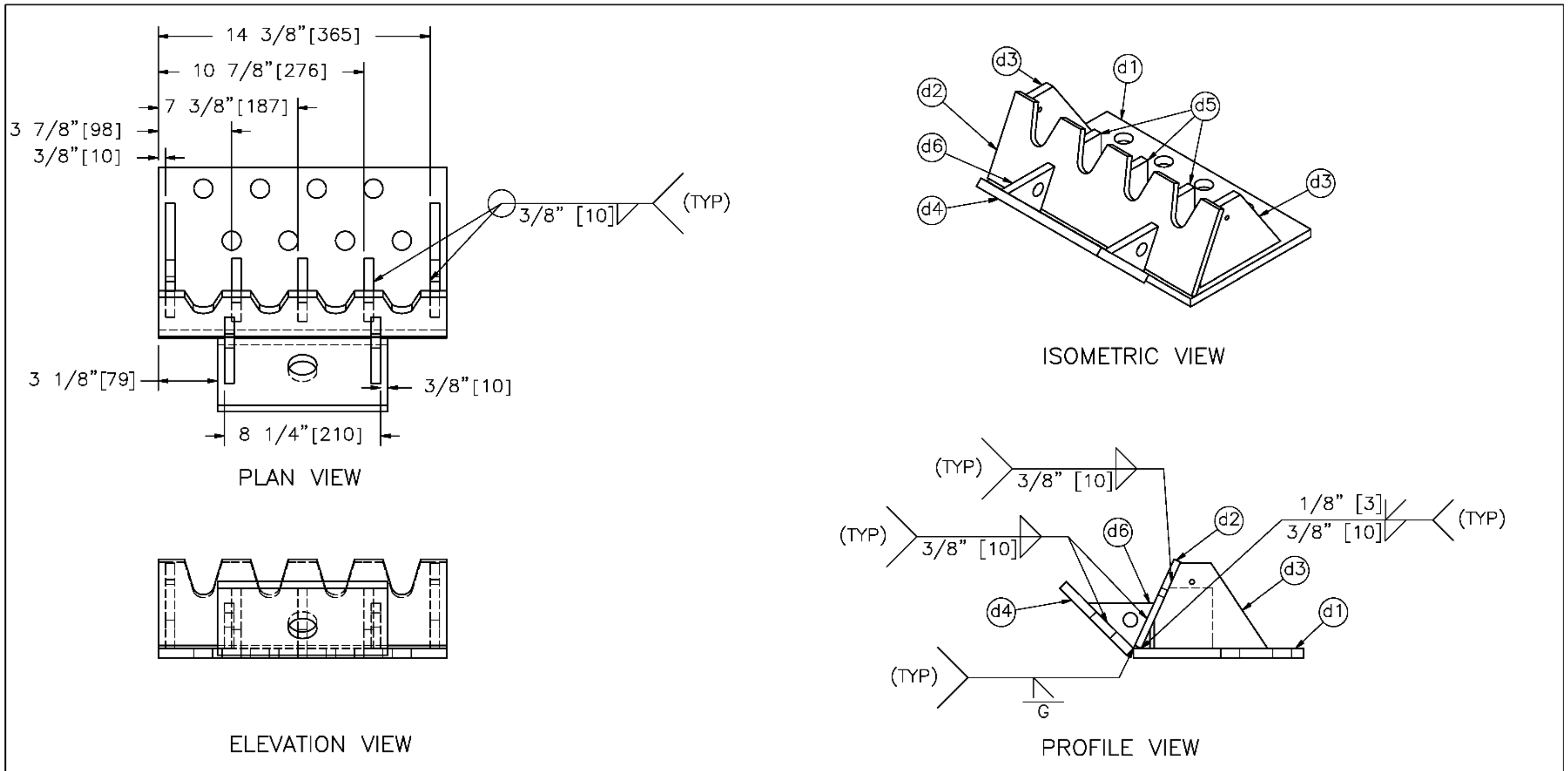
Midwest Roadside Safety Facility

Non−Proprietary Cable Median Barrier
Test No. MTP−2

Reinforcement Details

SHEET: 12 of 26
DATE: 7/16/2019
DRAWN BY: DJW/JEK/JRD
DWG. NAME. MTP−2_R6
SCALE: 1:8
UNITS: in.[mm]
REV. BY: KAL

Figure 94. Reinforcement Details, Test No. MTP-2



Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	2	Cable Anchor Bracket Assembly	–	ASTM A123	FPA02
d1	1	15 1/4"x9"x1/2" [387x229x13] Cable Anchor Base Plate	ASTM A36	See Assembly	–
d2	1	15 1/4"x5"x3/8" [387x127x10] Anchor Bracket Plate	ASTM A36	See Assembly	–
d3	2	6"x4 1/2"x1/2" [152x114x13] Exterior Cable Plate Gusset	ASTM A36	See Assembly	–
d4	1	9"x5"x1/2" [229x127x13] Release Lever Plate	ASTM A36	See Assembly	–
d5	3	3 5/16"x3 3/16"x1/2" [84x81x13] Interior Cable Plate Gusset	ASTM A36	See Assembly	–
d6	2	3 1/2"x2 3/8x1/2" [89x61x13] Release Gusset	ASTM A36	See Assembly	–

Midwest Roadside Safety Facility

Non–Proprietary Cable Median Barrier Test No. MTP–2

Cable Anchor Bracket Assembly

SHEET: 13 of 26
DATE: 7/16/2019
DRAWN BY: DJW/JEK/JRD
DWG. NAME. MTP–2_R6
SCALE: 1:8
UNITS: in.[mm]
REV. BY: KAL

Figure 95. Cable Anchor Bracket Assembly, Test No. MTP-2

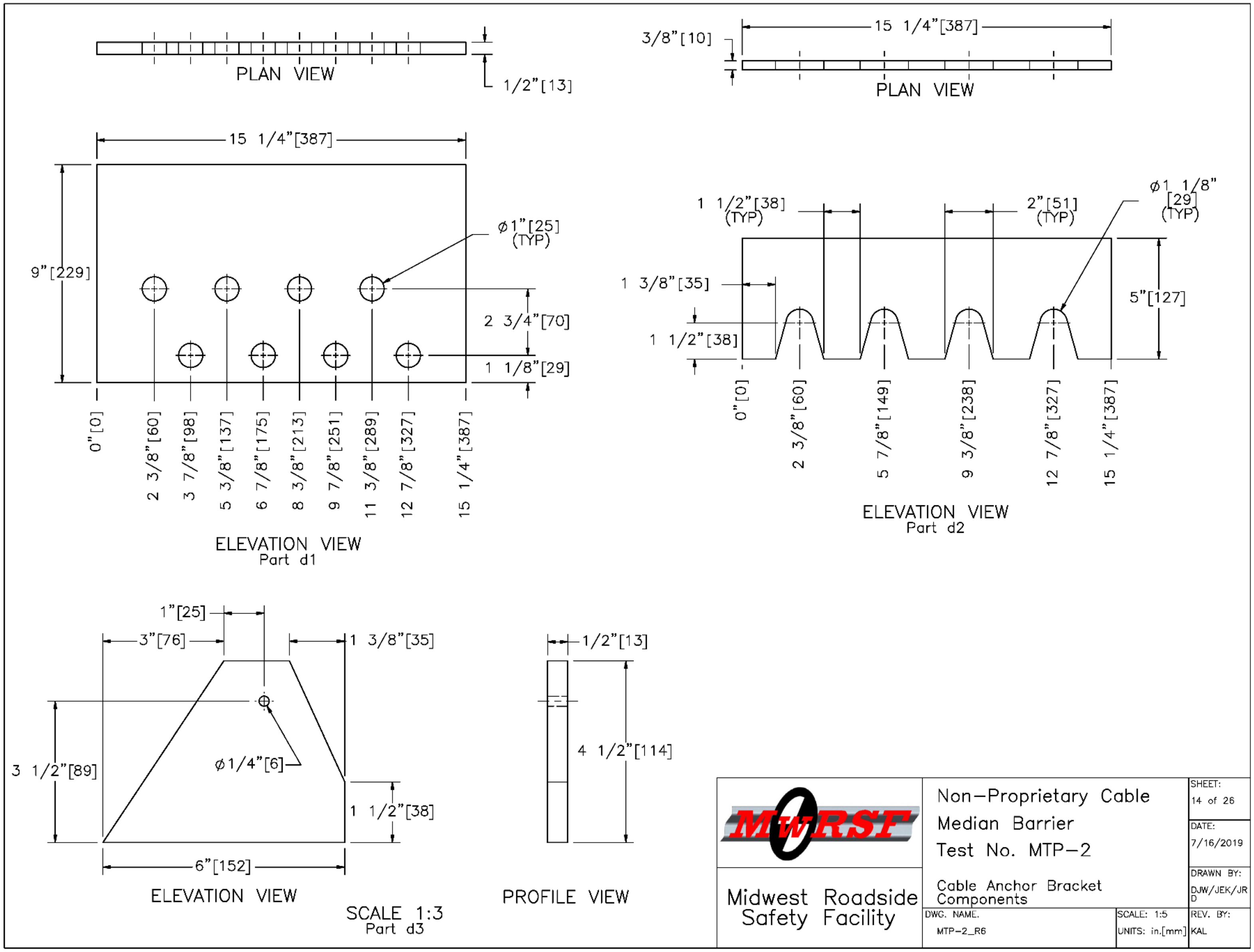


Figure 96. Cable Anchor Bracket Components, Test No. MTP-2

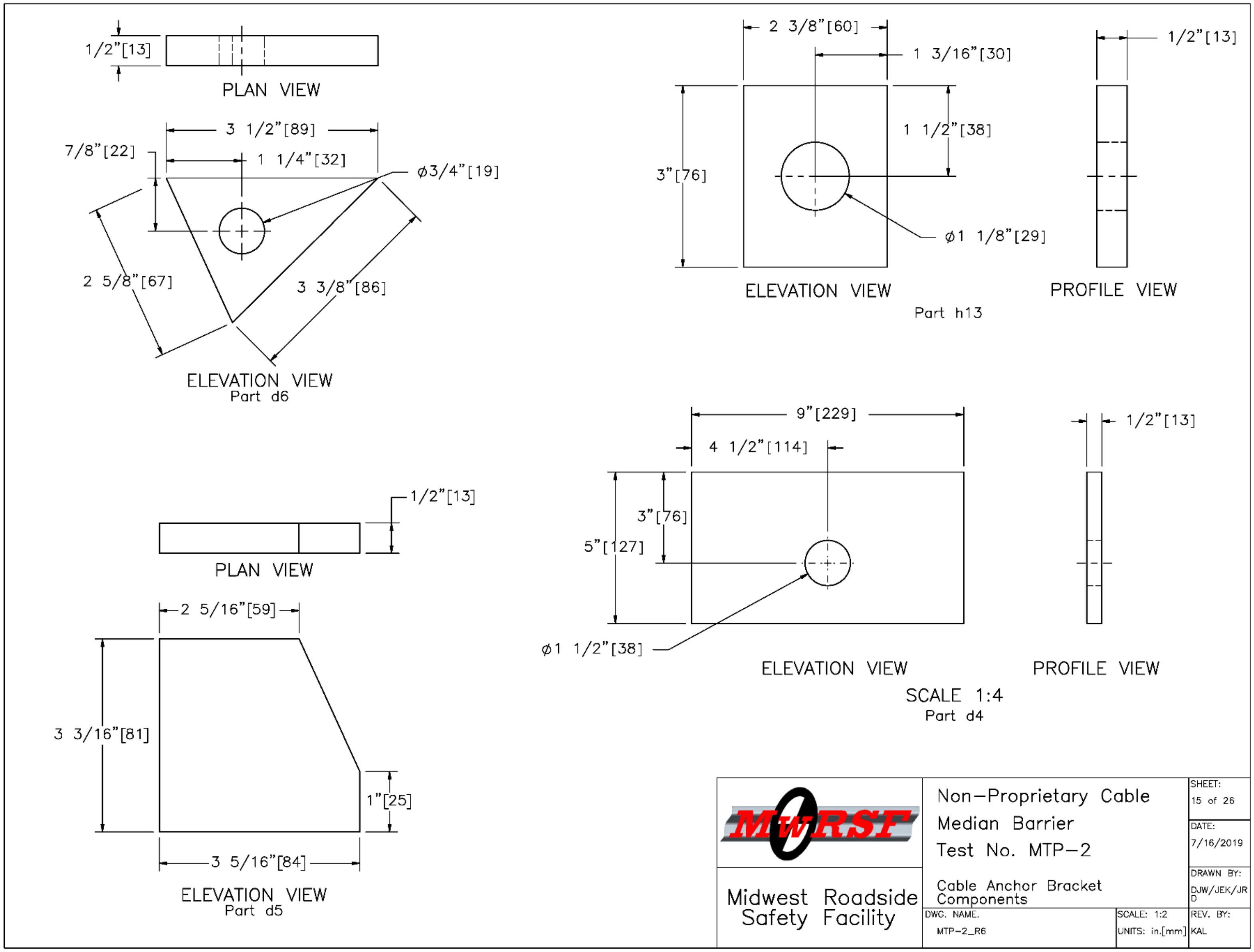
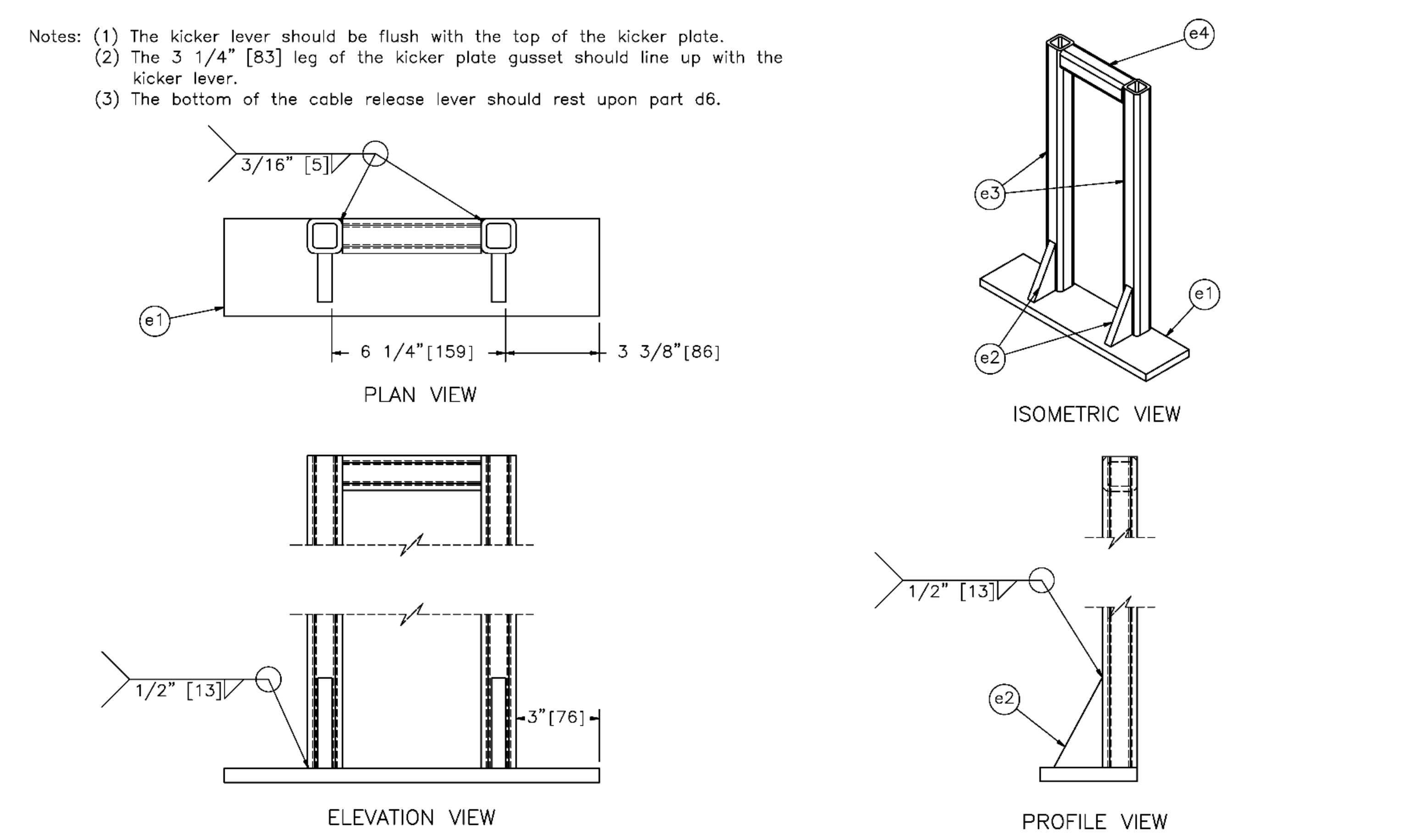


Figure 97. Cable Anchor Bracket Components, Test No. MTP-2



Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	2	Cable Release Lever Assembly	–	ASTM A123	–
e1	1	13 1/2"x3 1/2"x1/2" [343x89x13] Kicker Plate	ASTM A36	See Assembly	–
e2	2	3 1/4"x1 3/4"x1/2" [83x44x13] Kicker Gusset	ASTM A36	See Assembly	–
e3	2	1 1/4"x1 1/4"x3/16" [32x32x5], 17" [432] Long Square Tube	ASTM A500 Gr. B	See Assembly	–
e4	1	1 1/4"x1 1/4"x3/16" [32x32x5], 5" [127] Long Square Tube	ASTM A500 Gr. B	See Assembly	–

Midwest Roadside Safety Facility

Non-Proprietary Cable Median Barrier
Test No. MTP-2

Cable Release Lever Assembly

SHEET: 16 of 26
DATE: 7/16/2019
DRAWN BY: DJW/JEK/JRD
DWG. NAME. MTP-2_R6
SCALE: 1:5
UNITS: in.[mm]
REV. BY: KAL

Figure 98. Cable Release Lever Assembly, Test No. MTP-2

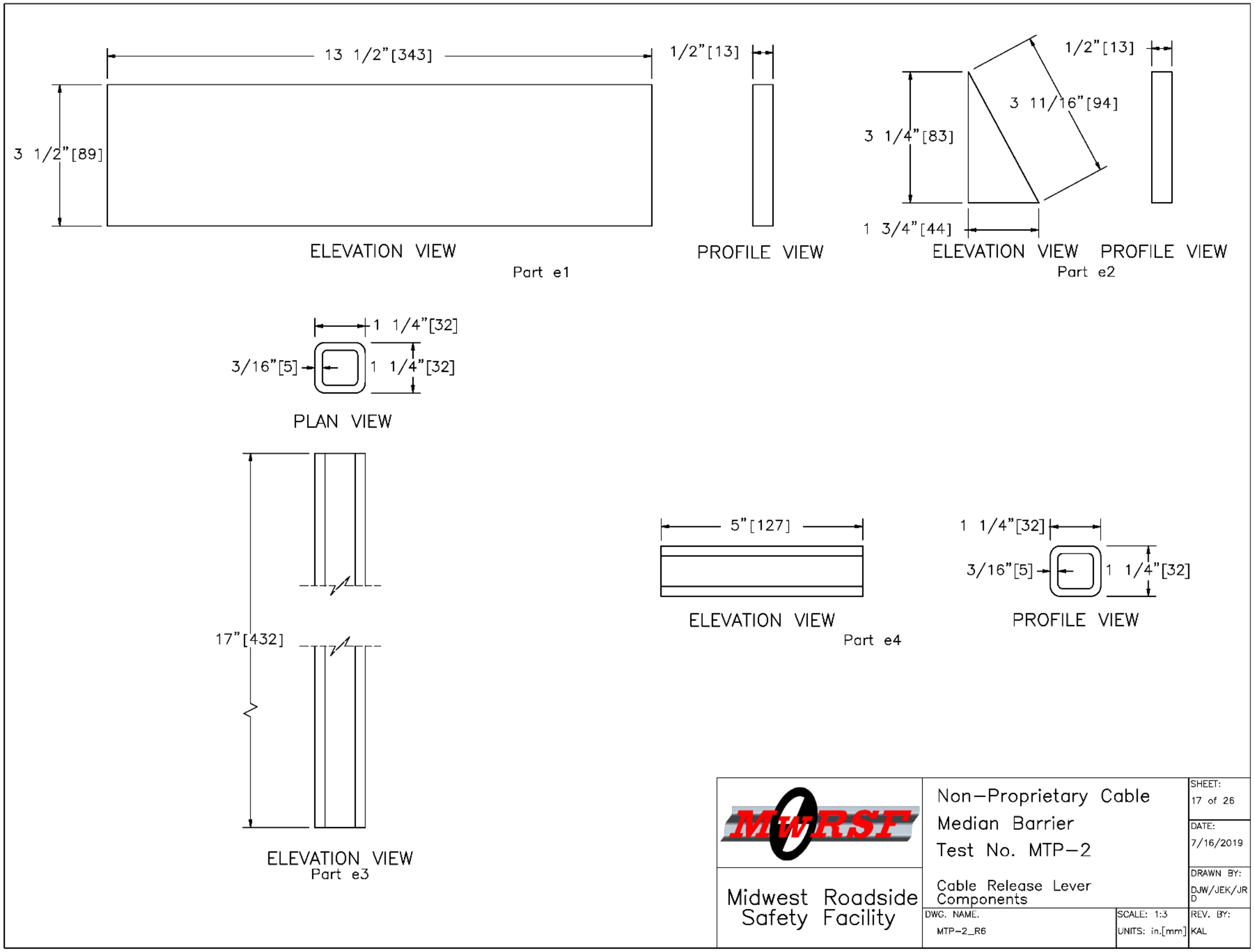
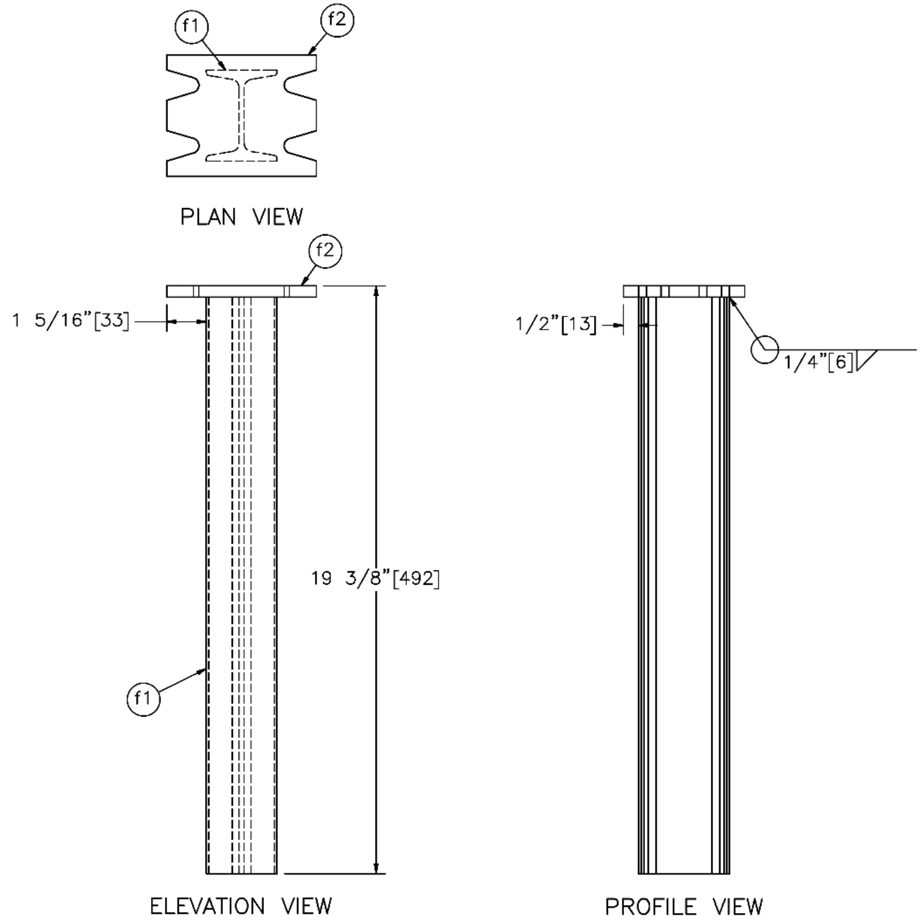


Figure 99. Cable Release Lever Components, Test No. MTP-2



Item No.	QTY.	Description	Material Specification	Treatment Specification
–	2	Lower Second Post Assembly	–	ASTM A123
f1	1	S3x5.7 [S75x8.5], 19" [483] Long Post	ASTM A36	See Assembly
f2	1	4 15/16"x4"x3/8" [125x102x10] Base Plate	ASTM A36	See Assembly

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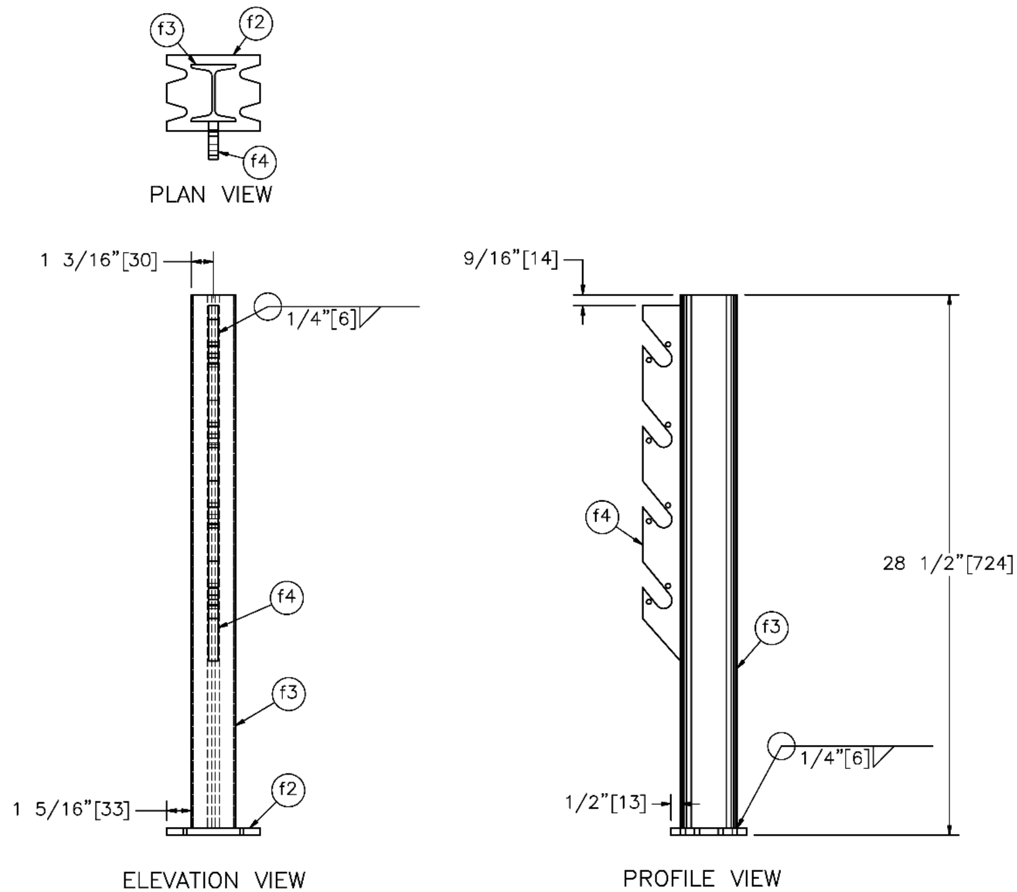
Non–Proprietary Cable Median Barrier Test No. MTP–2

Lower Second Post Assembly

SHEET: 18 of 26
DATE: 7/16/2019
DRAWN BY: DJW/JEK/JRD
DWG. NAME. MTP–2_R6
SCALE: 1:5 UNITS: in.[mm]
REV. BY: KAL

Figure 100. Lower Second Post Assembly, Test No. MTP-2



Item No.	QTY.	Description	Material Specification	Treatment Specification
–	2	Upper Second Post Assembly	–	ASTM A123
f2	1	4 15/16"x4"x3/8" [125x102x10] Base Plate	ASTM A36	See Assembly
f3	1	S3x5.7 [S75x8.5], 28 1/8" [714] Long Post	ASTM A36	See Assembly
f4	1	18 3/4"x2"x1/2" [476x51x13] Cable Hanger	ASTM A36	See Assembly

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Non-Proprietary Cable Median Barrier
Test No. MTP-2

Upper Second Post Assembly

SHEET: 19 of 26
DATE: 7/16/2019
DRAWN BY: DJW/JEK/JRD
DWG. NAME. MTP-2_R6
SCALE: 1:8
UNITS: in.[mm]
REV. BY: KAL

Figure 101. Upper Second Post Assembly, Test No. MTP-2

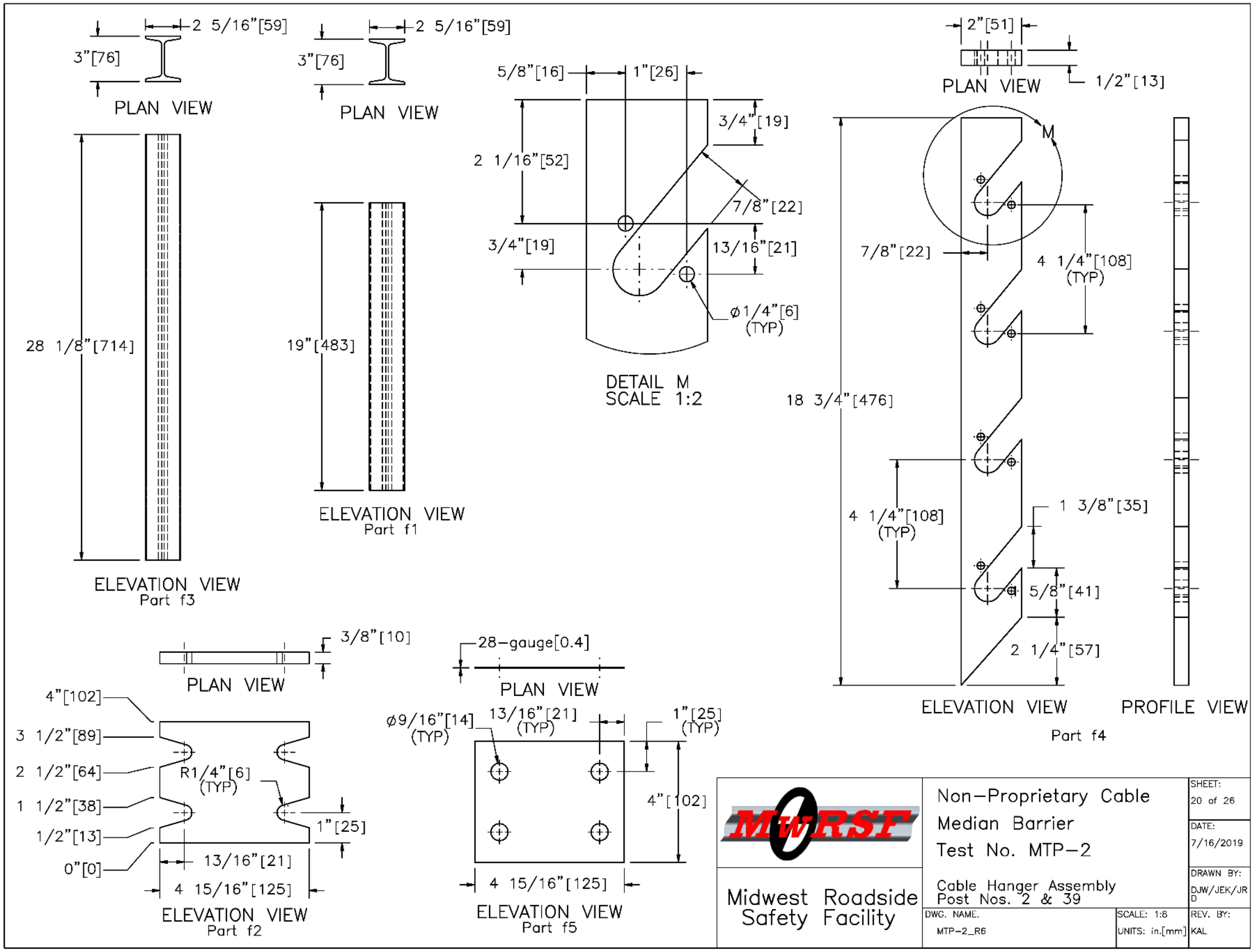
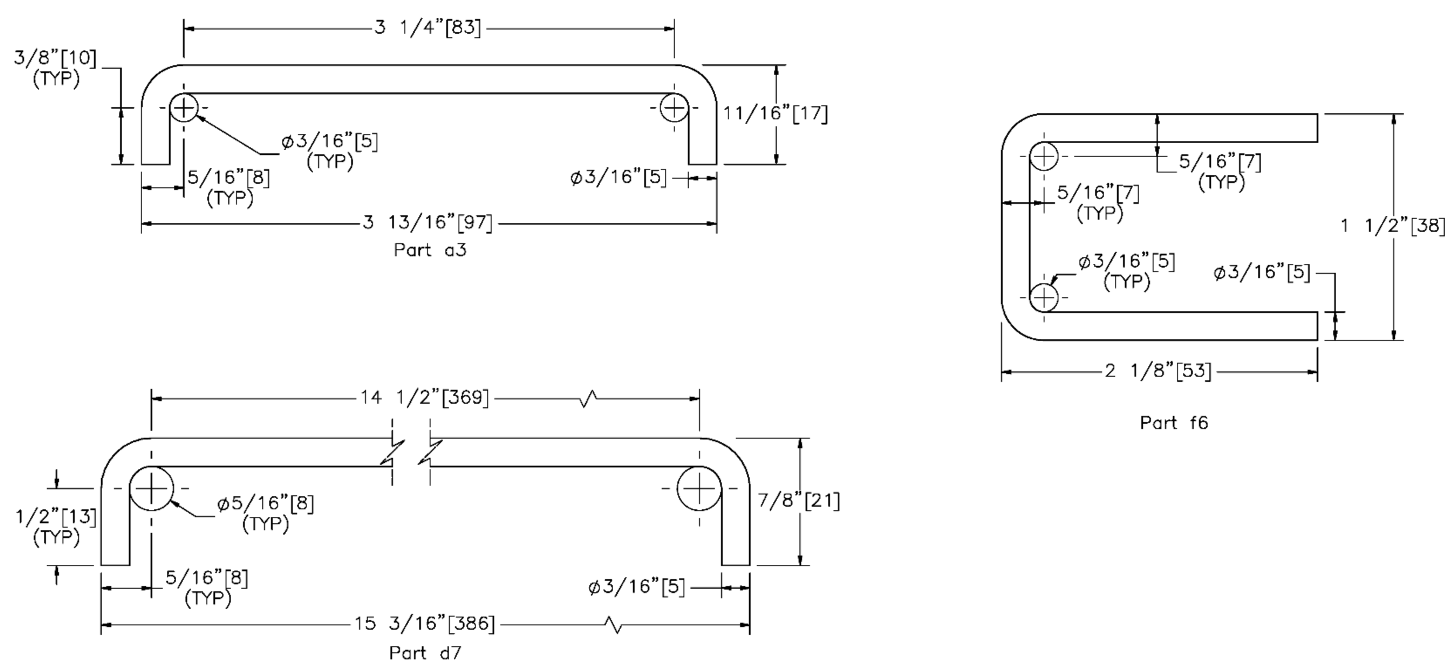


Figure 102. Cable Hanger Assembly Post Nos. 2 and 39, Test No. MTP-2



Bar	Total Unbent Length
a3	4 9/16" [116]
d7	16 1/4" [413]
f6	5 1/8" [130]

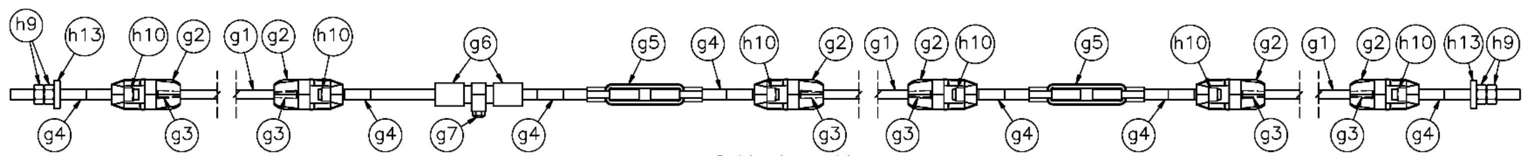
Midwest Roadside Safety Facility

Non-Proprietary Cable Median Barrier
Test No. MTP-2

Brass Cable Clip Details

SHEET: 21 of 26
DATE: 7/16/2019
DRAWN BY: DJW/JEK/JRD
DWG. NAME. MTP-2_R6
SCALE: 1:1
UNITS: in.[mm]
REV. BY: KAL

Figure 103. Brass Cable Clip Details, Test No. MTP-2



Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	4	Cable Assembly	–	–	–
g1	3	3/4" [19] Dia. 3x7 IWRC IPS Wire Rope – Lengths as Needed	ASTM A741 Type 1	Class A Coating	RCM01
g2	6	Bennett Cable End Fitter – 7/8" [22] Dia.	ASTM A220 Gr. 50005	ASTM A153 or B695	RCE03
g3	6	Cable Wedge	ASTM A47 Gr. 32510 or A536 Gr. 65–45–12	–	FMM01
g4	7	7/8"–9 UNC [M22x2.5], 11" [279] Long Threaded Rod	ASTM A449 Type 1 or ASTM A193 Gr. B7	ASTM A153 or B695 Class 55 or F2329	RCE03
g5	2	Bennett Short 7/8"–9 UNC [M22x2.5] Threaded Turnbuckle	As Supplied	As Supplied	–
g6	2	Threaded Load Cell Coupler	–	–	–
g7	1	50,000–lb [222.4–kN] Load Cell	–	–	–
h9	4	7/8"–9 UNC [M22x2.5] Heavy Hex Nut	ASTM A563C or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX22b
h10	6	7/8"–9 UNC [M22x2.5] Heavy Square Nut	ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	–
h13	2	3"x2 3/8"x1/2" [76x60x13] Rectangular Washer Plate	ASTM A36	ASTM A123	–

Midwest Roadside Safety Facility

Non–Proprietary Cable Median Barrier
Test No. MTP–2

Cable Assembly

SHEET:	DATE:	DRAWN BY:	DWG. NAME.	SCALE:	UNITS:	REV. BY:
22 of 26	7/16/2019	DJW/JEK/JRD	MTP–2_R6	1:13	in.[mm]	KAL

Figure 104. Cable Assembly, Test No. MTP-2

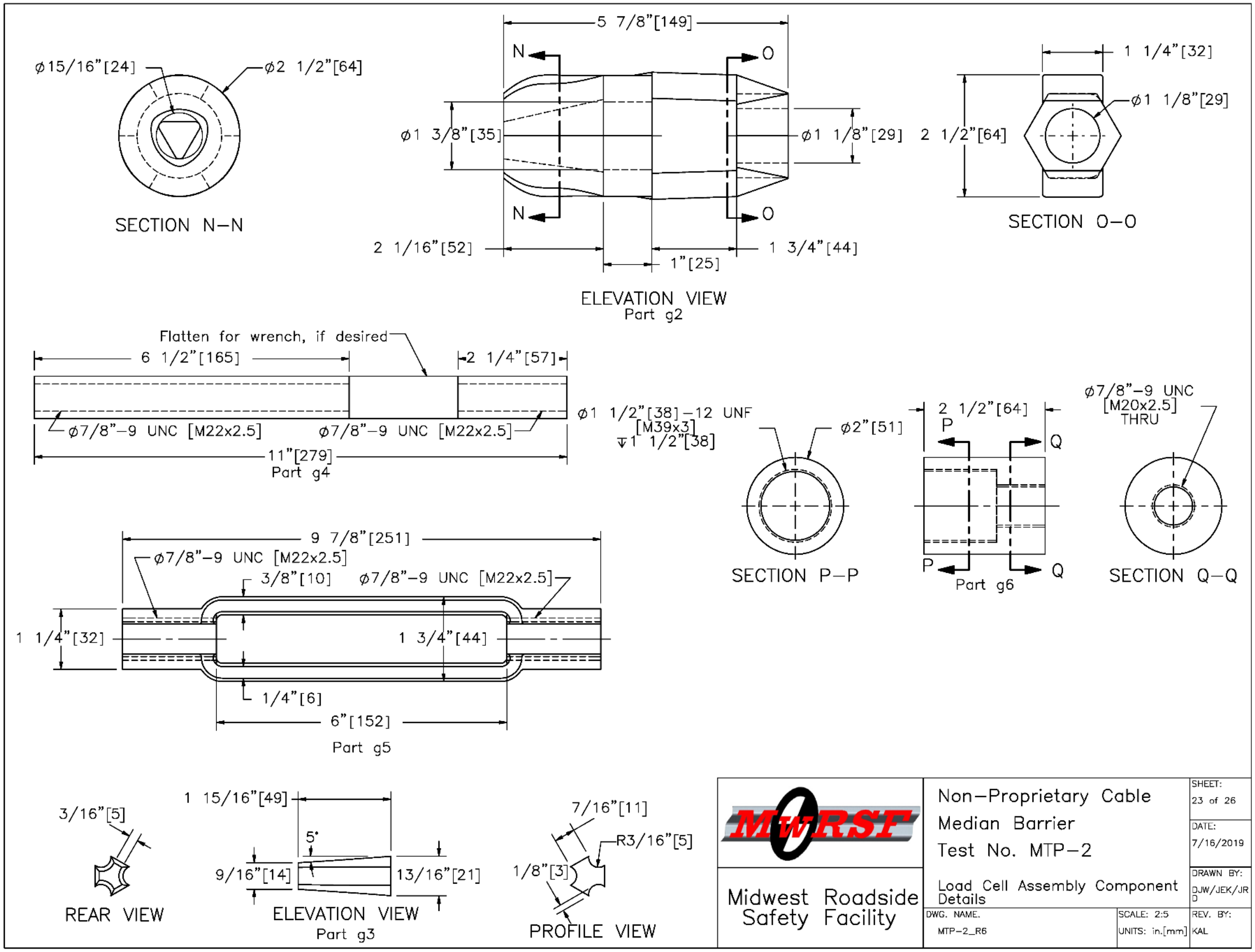


Figure 105. Load Cell Assembly Component Details, Test No. MTP-2

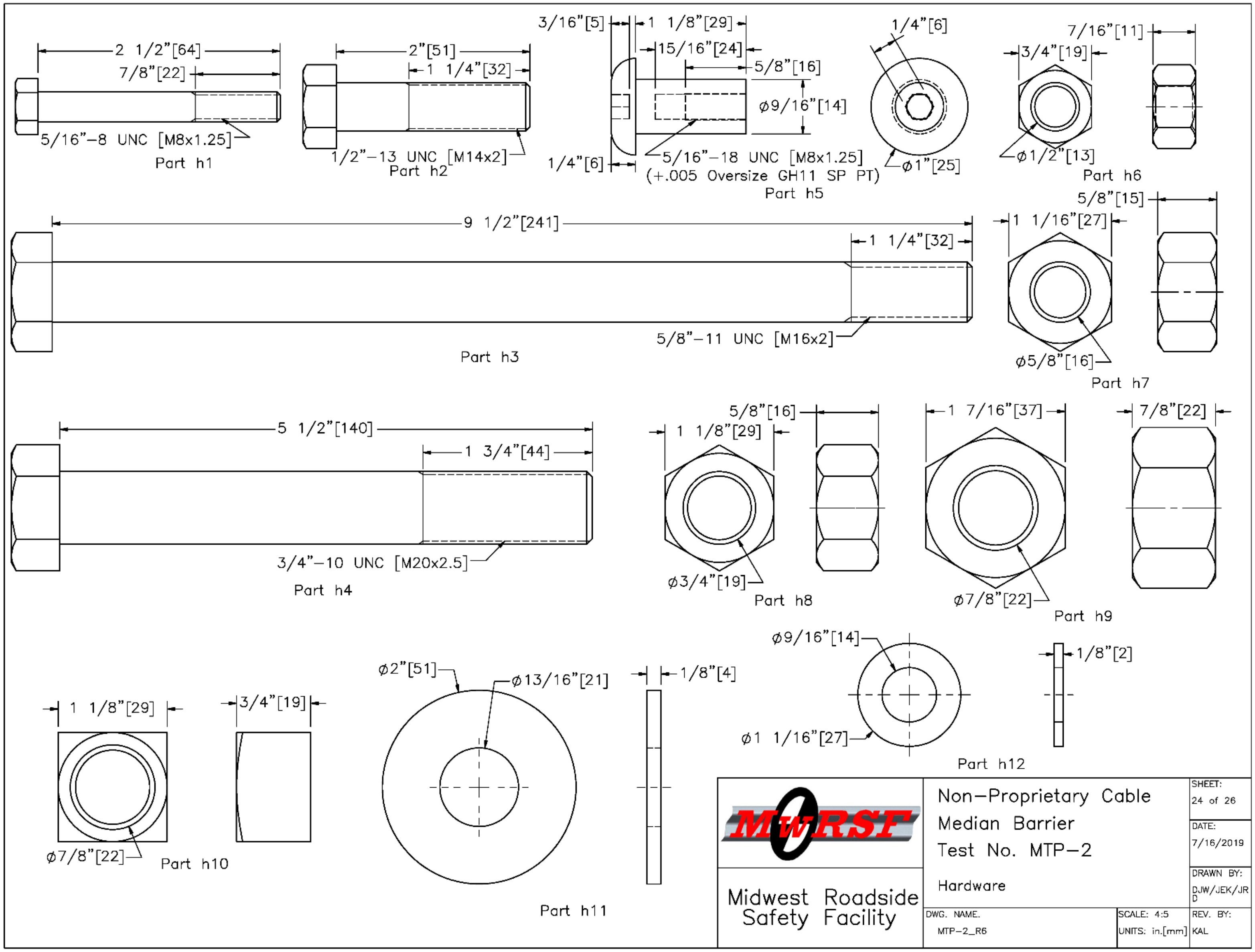


Figure 106. Hardware, Test No. MTP-2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	36	HSS 3x2x1/8 [76x51x3], 78" [1,981] Long Steel Post with two 3/4" [19] holes	ASTM A500 Gr. C	ASTM A123	–
a2	108	5"x15/16"x12-Gauge [128x24x2.7] Tabbed Bracket	Hot-Rolled ASTM A1011 HSLA Gr. 50	ASTM A123	–
a3	36	3/16" [5] Dia. Brass Cable Clip, 4 9/16" [116] Long Unbent	ASTM B16-00	–	
b1	2	24" [610] Dia. Concrete Anchor, 120" [3,048] Long	Min. f'c = 4,000 psi [27.6 MPa]	–	–
b2	44	#4 [13] Hoop Bar with 21" [533] Dia., 84" [2,134] Unbent Length	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
b3	16	#11 [35] Bar, 114" [2,896] Long	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
b4	16	3/4"-10 UNC [M20x2.5] J-Hook Anchor	ASTM A449	ASTM A153 or B695 Class 55 or F2329	FRJ16a
c1	2	12" [305] Dia. 2nd Post Concrete Anchor, 46" [1,168] Long	Min. f'c = 4,000 psi [27.6 MPa]	–	–
c2	2	12" [305] Dia. 2nd Post Anchor Aggregate, 2" [51] Deep	Standard Strong Soil	–	–
c3	22	#3 [10] Hoop Bar with 9" [229] Dia., 37" [940] Unbent Length	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
c4	8	#3 [10] Bar, 43" [1,092] Long	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
c5	2	4"x3"x1/4" [102x76x6] Foundation Tube, 48" [1,219] Long	ASTM A500 Gr. B	ASTM A123	–
d1	2	15 1/4"x9"x1/2" [387x229x13] Cable Anchor Base Plate	ASTM A36	See Assembly	–
d2	2	15 1/4"x5"x3/8" [387x127x10] Anchor Bracket Plate	ASTM A36	See Assembly	–
d3	4	6"x4 1/2"x1/2" [152x114x13] Exterior Cable Plate Gusset	ASTM A36	See Assembly	–
d4	2	9"x5"x1/2" [229x127x13] Release Lever Plate	ASTM A36	See Assembly	–
d5	6	3 5/16"x3 3/16"x1/2" [84x81x13] Interior Cable Plate Gusset	ASTM A36	See Assembly	–
d6	4	3 1/2"x2 3/8x1/2" [89x61x13] Release Gusset	ASTM A36	See Assembly	–
d7	2	3/16" [5] Dia. Brass Keeper Rod, 16 1/4" [413] Long Unbent	ASTM B16-00	–	–
e1	2	13 1/2"x3 1/2"x1/2" [343x89x13] Kicker Plate	ASTM A36	See Assembly	–
e2	4	3 1/4"x1 3/4"x1/2" [83x44x13] Kicker Gusset	ASTM A36	See Assembly	–
e3	4	1 1/4"x1 1/4"x3/16" [32x32x5], 17" [432] Long Square Tube	ASTM A500 Gr. B	See Assembly	–
e4	2	1 1/4"x1 1/4"x3/16" [32x32x5], 5" [127] Long Square Tube	ASTM A500 Gr. B	See Assembly	–
e5	2	1/4" [6] Dia. 7x19 Aircraft Retaining Cable, 36" [914] Long	ASTM A1023	Hot-Dipped Galvanized	–

Midwest Roadside Safety Facility

Non-Proprietary Cable Median Barrier
Test No. MTP-2

Bill of Materials

SHEET: 25 of 26
DATE: 7/16/2019
DRAWN BY: DJW/JEK/JRD
DWG. NAME. MTP-2_R6
SCALE: None
UNITS: in.[mm]
REV. BY: KAL

Figure 107. Bill of Materials, Test No. MTP-2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
f1	2	S3x5.7 [S75x8.5], 19" [483] Long Post	ASTM A36	See Assembly	–
f2	4	4 15/16"x4"x3/8" [125x102x10] Base Plate	ASTM A36	See Assembly	–
f3	2	S3x5.7 [S75x8.5], 28 1/8" [714] Long Post	ASTM A36	See Assembly	–
f4	2	18 3/4"x2"x1/2" [476x51x13] Cable Hanger	ASTM A36	See Assembly	–
f5	2	4 15/16"x4"x28–Guage [125x102x0.4] Keeper Plate	ASTM A36	–	–
f6	8	3/16" [5] Dia., 5 1/8" [130] Long Unbent Brass Rod	ASTM B16–00	–	–
g1	12	3/4" [19] Dia. 3x7 IWRC IPS Wire Rope – Lengths as Needed	ASTM A741 Type 1	Class A Coating	RCM01
g2	24	Bennett Cable End Fitter – 7/8" [22] Dia.	ASTM A220 Gr. 50005	ASTM A153 or B695	RCE03
g3	24	Cable Wedge	ASTM A47 Gr. 32510 or A536 Gr. 65–45–12	–	FMM01
g4	28	7/8"–9 UNC [M22x2.5], 11" [279] Long Threaded Rod	ASTM A449 Type 1 or ASTM A193 Gr. B7	ASTM A153 or B695 Class 55 or F2329	RCE03
g5	8	Bennett Short 7/8"–9 UNC [M22x2.5] Threaded Turnbuckle	As Supplied	As Supplied	–
g6	8	Threaded Load Cell Coupler	–	–	–
g7	4	50,000–lb [222.4–kN] Load Cell	–	–	–
h1	108	5/16"–18 UNC [M8x1.25], 2 1/2" [64] Long Heavy Hex Bolt	SAE J429 Gr. 5	ASTM A153 or B695 Class 55 or F2329	FBX08b
h2	8	1/2"–13 UNC [M14x2], 2" [51] Long Hex Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBX14a
h3	2	5/8"–11 UNC [M16x2], 9 1/2" [241] Long Heavy Hex Bolt	ASTM A449 or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16b
h4	2	3/4"–10 UNC [M20x2.5], 5 1/2" [140] Long Hex Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBX20a
h5	108	5/16"–18 UNC [M8x1.25] Sleeve Nut	ASTM A311 Gr. 1144 Class B	ASTM A123 or A153	–
h6	8	1/2"–13 UNC [M14x2] Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX14a
h7	2	5/8"–11 UNC [16x2] Heavy Hex Nut	ASTM A563C or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX16b
h8	18	3/4"–10 UNC [M20x2.5] Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX20a
h9	16	7/8"–9 UNC [M22x2.5] Heavy Hex Nut	ASTM A563C or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX22b
h10	24	7/8"–9 UNC [M22x2.5] Heavy Square Nut	ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	–
h11	20	3/4" [19] Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC20a
h12	24	1/2" [13] Dia. Plain SAE Washer	ASTM F844	ASTM A123 or A153 or F2329	–
h13	8	3"x2 3/8"x1/2" [76x60x13] Rectangular Washer Plate	ASTM A36	ASTM A123	–

Midwest Roadside Safety Facility

Non–Proprietary Cable Median Barrier
Test No. MTP–2

Bill of Materials

SHEET: 26 of 26
DATE: 7/16/2019
DRAWN BY: DJW/JEK/JRD
DWG. NAME. MTP–2_R6
SCALE: None
UNITS: in.[mm]
REV. BY: KAL

Figure 108. Bill of Materials, Test No. MTP-2

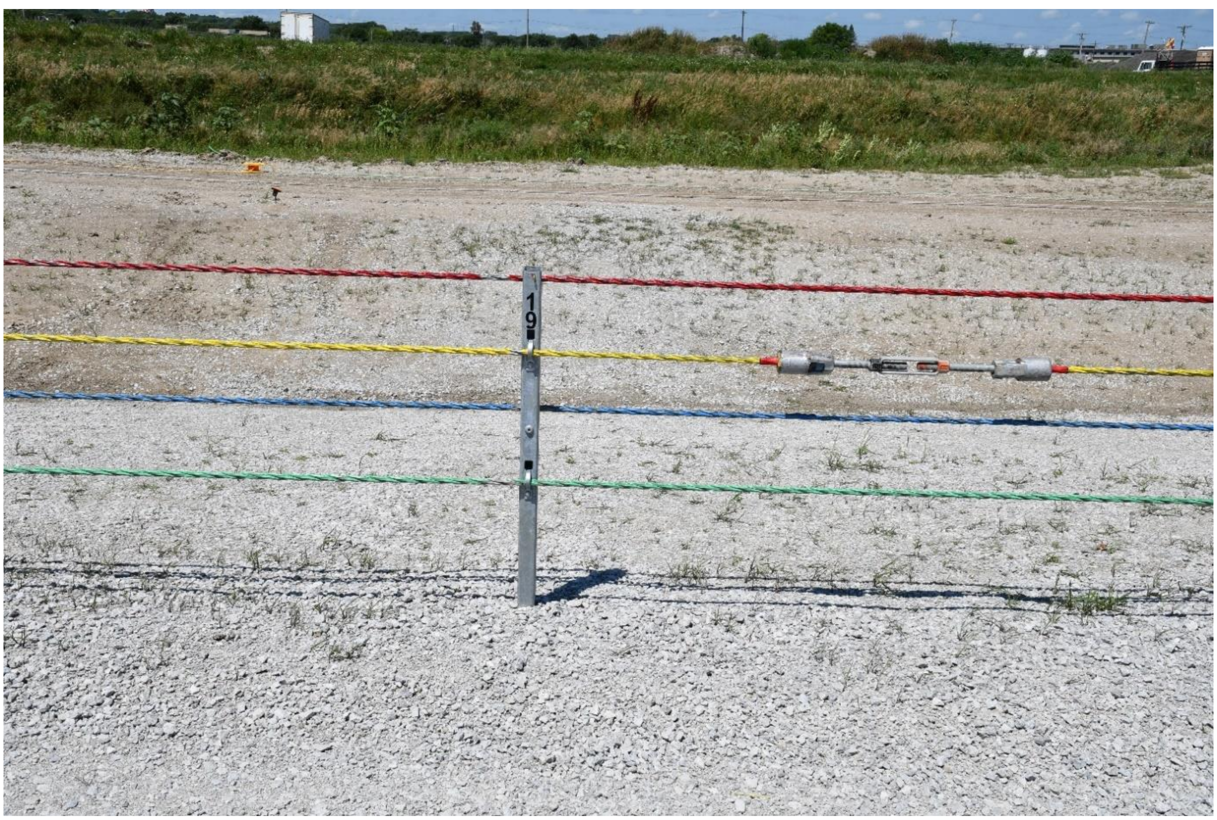


Figure 109. System Installation, Test No. MTP-2

Figure 110. System Installation, Test No. MTP-2

Figure 111. System Installation – Upstream Anchorage, Test No. MTP-2

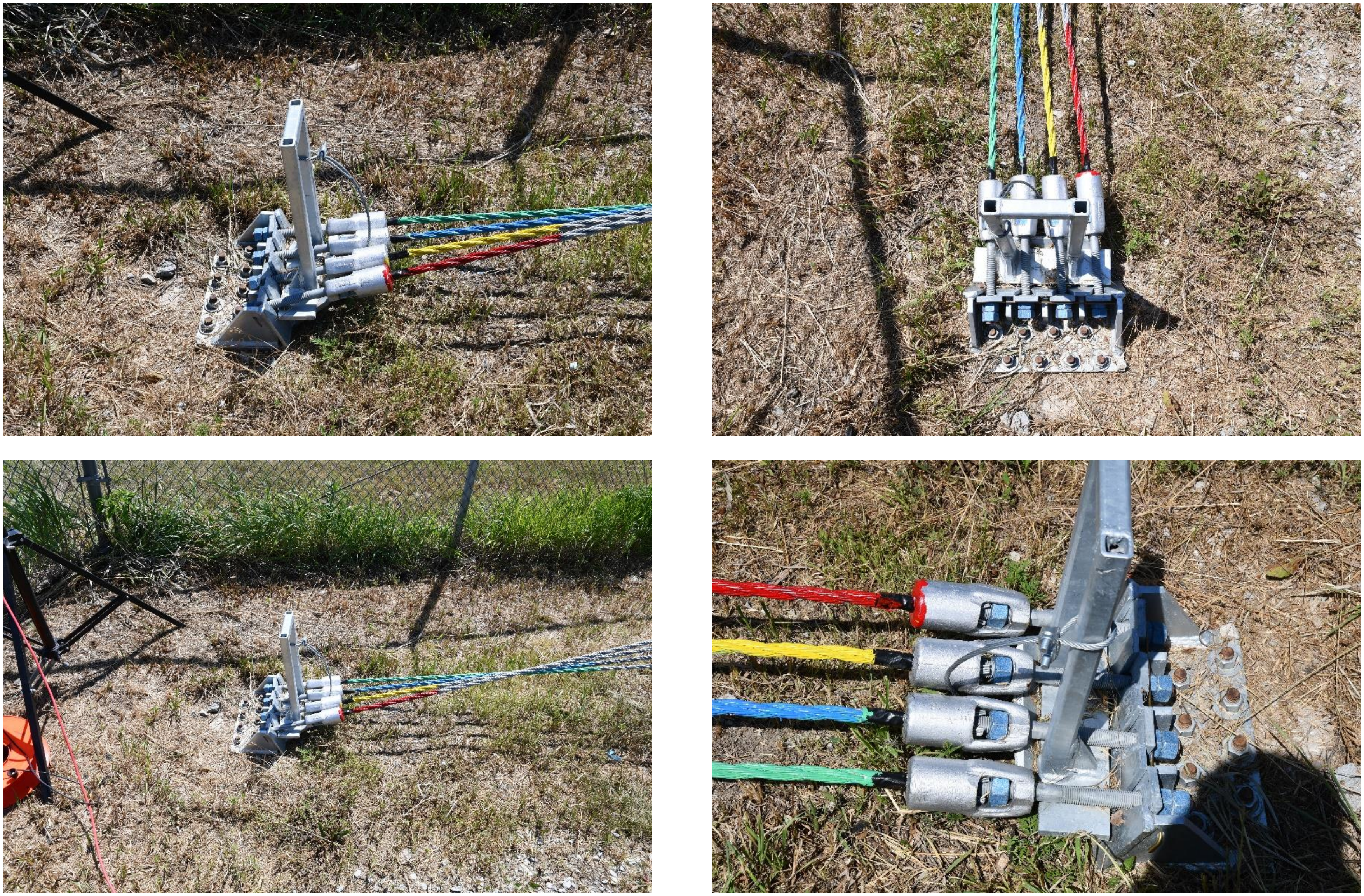


Figure 112. System Installation – Downstream Anchorage, Test No. MTP-2

Figure 113. System Installation, Test No. MTP-2

7 FULL-SCALE CRASH TEST NO. MTP-2

7.1 Static Soil Test

Before full-scale crash test no. MTP-2 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. 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.

7.2 Weather Conditions

Test no. MTP-2 was conducted on July 15, 2019, at approximately 1:45 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/KLNK) were reported and are shown in Table 11.

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

Temperature	91°F (32.8°C)
Humidity	52%
Wind Speed	14 mph (22.5 km/h)
Wind Direction	190° from True North
Sky Conditions	Clear
Visibility	10 Statute Miles (16.1 km)
Pavement Surface	Dry
Previous 3-Day Precipitation	0.02 in. (0.5 mm)
Previous 7-Day Precipitation	0.33 in. (8.4 mm)

7.3 Test Description

Initial vehicle impact was to occur 96 in. (2,438 mm) upstream from the centerline of post no. 17, as shown in Figure 114, which was selected using Table 2-2D of MASH 2016. The 3,301-lb (1,497-kg) sedan impacted the cable barrier system at a speed of 61.6 mph (99.1 km/h) and at an angle of 25.0 degrees for an impact severity of 74.8 kip-ft (101.4 kJ). The actual point of impact was at the target impact location. The vehicle came to rest 266 ft – 10 in. (81.3 m) downstream and 8.3 ft (2.5 m) behind the system and in contact with the system after brakes were applied.

A detailed description of the sequential impact events is contained in Tables 12 through 16. Sequential photographs are shown in Figures 115 and 116. Documentary photographs of the crash test are shown in Figures 118 and **Error! Reference source not found.**. The vehicle trajectory and final position are shown in Figure 120.

Figure 114. Impact Location, Test No. MTP-2

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

Time (sec)	Event
0.000	Vehicle's front bumper contacted cable no. 1 and deformed.
0.008	Vehicle's left headlight contacted cable no. 3 between post nos. 16 and 17.
0.014	Vehicle's front bumper contacted cable no. 2 between post nos. 16 and 17.
0.018	Vehicle's left-front tire contacted cable no. 1.
0.028	Vehicle's hood contacted cable no. 3 and post no. 17 deflected backward.
0.032	Vehicle's front bumper contacted post no. 17, post no. 16 rotated backward, and cable no. 3 disengaged from post no. 17. Vehicle's hood contacted cable no. 4 between post nos. 16 and 17.
0.044	Vehicle's left mirror contacted cable no. 4.
0.048	Vehicle's left-front tire contacted cable no. 2.
0.056	Post no. 17 bent backward and post no. 15 deflected backward.
0.068	Cable no. 3 disengaged from post no. 16.
0.072	Post no. 17 bent downstream and vehicle's left-front tire became airborne.
0.076	Post no. 18 rotated backward. Vehicle's left-front bumper cover mounts disengaged.
0.082	Cable no. 4 disengaged from post no. 17.
0.092	Vehicle's right-front bumper cover mounts disengaged.Cable no. 3 disengaged from post nos. 15 and 18.
0.100	Cable no. 2 disengaged from post no. 17.
0.106	Post no. 18 bent backward. Cable nos. 3 and 4 contacted vehicle's left A-pillar which deformed.
0.114	Vehicle's left mirror disengaged.
0.122	Vehicle yawed away from system.
0.128	Vehicle's left-rear tire contacted cable no. 2.
0.136	Post no. 19 deflected backward and cable no. 4 disengaged from post no. 16.
0.142	Cable no. 3 disengaged from post no. 19, cable no. 2 contacted vehicle's left fender which deformed, and cables contacted vehicle's left-front door.
0.148	Vehicle rolled toward system and vehicle's left-front door deformed.
0.164	Cable no. 4 disengaged from post no. 18.
0.176	Vehicle's windshield cracked. Cable no. 2 disengaged from post no. 18.
0.190	Cable nos. 3 and 4 contacted vehicle’s roof. Vehicle overrode cable no. 1. Cable no. 3 disengaged from post no. 20.
0.202	Post no. 19 bent backward. Vehicle's roof deformed and cable no. 1 contacted vehicle's undercarriage.
0.212	Cable nos. 2 and 4 disengaged from post no. 19.
0.226	Cable no. 4 disengaged from post no. 15.
0.232	Cable no. 1 disengaged from post no. 16 and vehicle under rode cable no. 3.
0.236	Vehicle under rode cable no. 4. Cable no. 2 disengaged from post no. 20.
0.242	Cable no. 2 contacted vehicle's left-rear door.
0.258	Cable no. 1 disengaged from post no. 15.
0.272	Post no. 16 bent backward.

Table 13. Sequential Description of Impact Events, Test No. MTP-2, Cont.

Time (sec)	Event
0.280	Cable no. 4 disengaged from post no. 20. Cable no. 2 contacted vehicle's left quarter panel.
0.298	Cable no. 2 contacted vehicle's rear bumper.
0.326	Cable no. 3 disengaged from post no. 14.
0.342	Vehicle's right-rear tire became airborne. Cable no. 1 disengaged from post no. 14.
0.350	Vehicle's left quarter panel deformed.
0.364	Vehicle's left-front tire regained contact with ground. Post no. 20 deflected backward.
0.368	Vehicle pitched downward and cable no. 3 disengaged from post no. 13.
0.376	Cable no. 2 disengaged from post no. 16.
0.392	Cable no. 1 disengaged from post no. 13 and post no. 15 bent backward. Post no. 14 deflected backward.
0.398	Post no. 15 fractured.
0.408	Vehicle's right-front tire became airborne and cable no. 2 disengaged from post no. 21.
0.434	Cable no. 2 disengaged from post no. 22.
0.436	Vehicle was parallel to the system at a speed of 52.7 mph (84.8 km/h).
0.442	Cable no. 2 disengaged from post no. 15.
0.458	Post no. 14 bent backward.
0.492	Post no. 13 deflected backward.
0.536	Vehicle rolled away from system. Vehicle's left-front tire ruptured.
0.550	Cable no. 2 disengaged from post no. 23. Vehicle yawed toward system.
0.560	Vehicle pitched upward.
0.576	Cable no. 2 disengaged from post no. 24.
0.636	Vehicle's right-front tire regained contact with ground.
0.642	Vehicle's right-rear tire regained contact with ground.
0.682	Vehicle's left-front tire became airborne.
0.736	Vehicle's left-rear tire became airborne.
0.850	Vehicle's front bumper grille contacted cable no. 2 splice.
0.856	Vehicle's left headlight contacted cable no. 2 splice.
0.862	Vehicle's front grille cracked.
0.878	Vehicle's left fender deformed.
0.902	Vehicle rolled toward system.
0.916	Vehicle's left headlight became disengaged, vehicle's left fender snagged on cable no. 2 splice, and vehicle pitched downward.
0.924	Vehicle's left-front door contacted and snagged on cable no. 2 splice.
1.052	Vehicle's left-front tire regained contact with ground.
1.082	Vehicle's left-rear tire regained contact with ground.
1.172	Vehicle rolled away from system.
6.876	Vehicle came to a rest behind and in contact with the system after brakes were applied.


0.000 sec


0.200 sec


0.400 sec


0.600 sec


0.800 sec

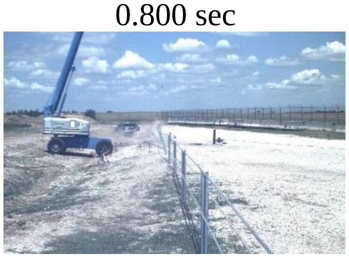

1.000 sec


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Figure 115. Sequential Photographs, Test No. MTP-2


0.000 sec


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0.150 sec


0.150 sec


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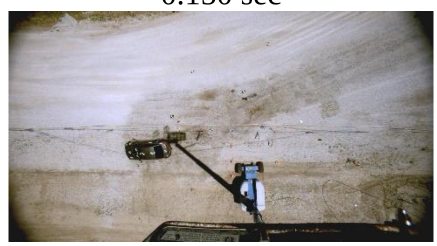
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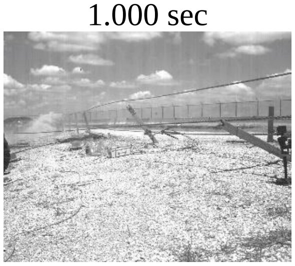
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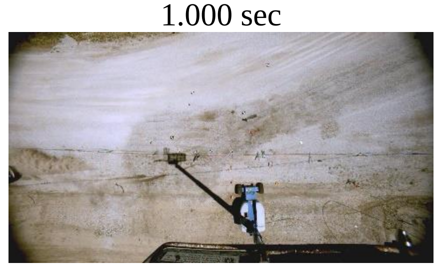
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Figure 116. Sequential Photographs, Test No. MTP-2

0.000 sec

0.150 sec

0.400 sec

0.750 sec

1.000 sec

1.250 sec

Figure 117. Sequential Photographs, Test No. MTP-2

Figure 118. Documentary Photographs, Test No. MTP-2

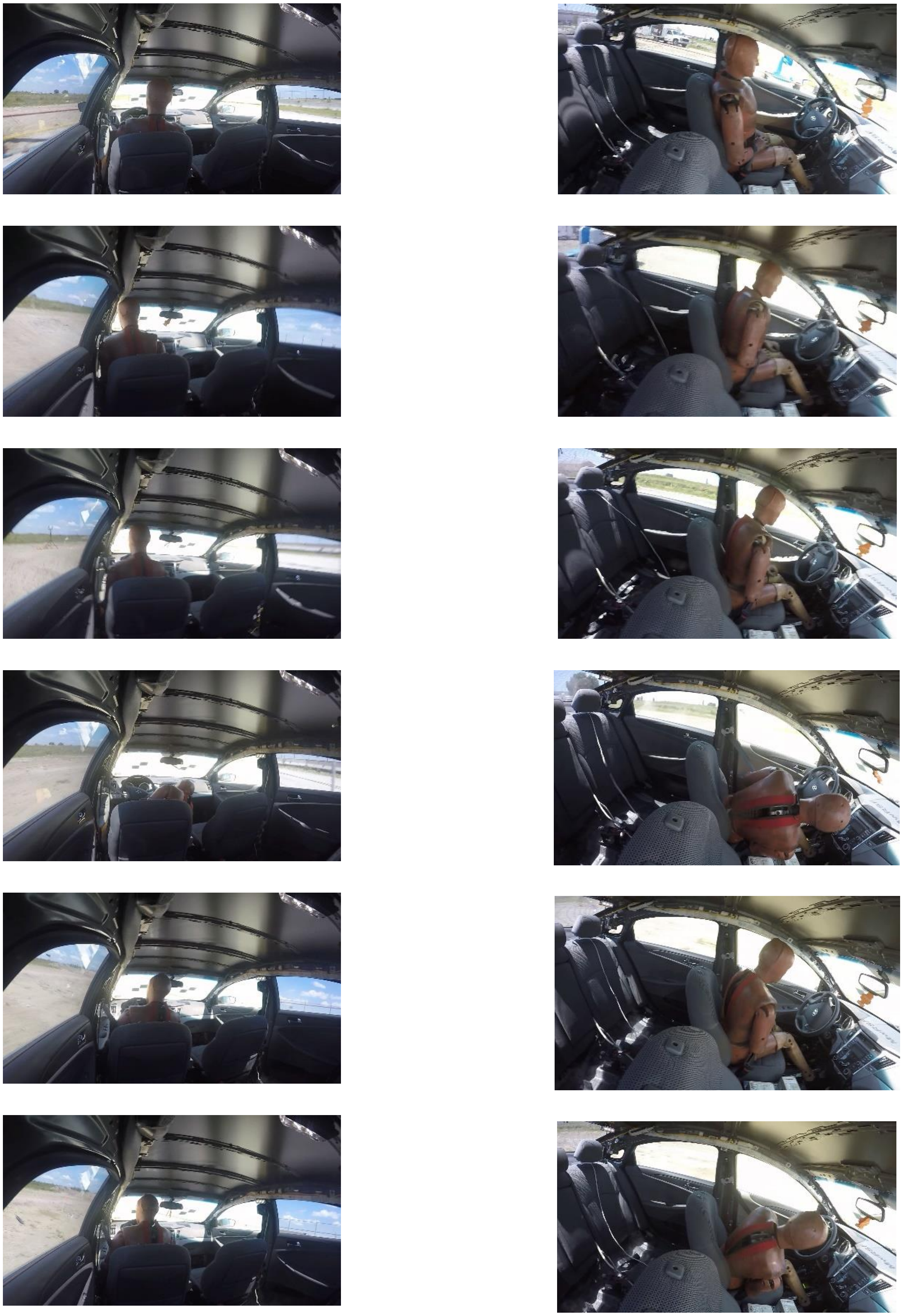


Figure 119. Documentary Photographs, Test No. MTP-2

Figure 120. Vehicle Final Position and Trajectory Marks, Test No. MTP-2

7.4 Barrier Damage

Damage to the system was moderate, as shown in Figures 121 through 137. Barrier damage consisted of fractured posts, deformed posts and brackets, and detached cables. The length of vehicle contact along the barrier was approximately 267 ft – 7 in. (82 m) which spanned from 97 in. (2,464 mm) downstream from the center line of post no. 16 to 44 in. (1,118 mm) downstream from the center line of post no. 33.

Post no. 13 rotated backward, while post no. 14 bent and rotated backward. Post no. 15 rotated backward and bent backward and upstream in addition to fracturing on the front face, upstream, and downstream sides through the weakening holes. Post no. 16 rotated backward and upstream and bent backward. Post no. 17 was twisted counterclockwise and bent backward and downstream. The bend in post no. 17 was located 46 in. (1,168 mm) from the top of the post. Post no. 18 bent and rotated backward and clockwise. Post no. 19 bent backward and rotated backward and upstream. Post no. 20 rotated clockwise and downstream. Post nos. 21 and 26 rotated backward and downstream. Post nos. 22, 24, 27, and 35 rotated backward. Post nos. 16, 23, 36, and 37 rotated backward and upstream. Cable bracket deformation, bracket fracture through the bolt hole, and brass rod deformation and fracture are specified for each cable and post in Table 14.

Table 14. Bracket Damage and Disengaged Cables, Test No. MTP-2

Post No.	Cable 1	Cable 2	Cable 3	Cable 4
1	0	0	0	0
2	1	0	0	0
3-9	0	0	0	0
10	0	1	0	0
11	0	0	1	0
12	1	1	1	0
13	1	1	1	0
14	1	1	1	7
15	1	1	1	6
16	1	1	1	6
17	1	1	1	6
18	0	1	1	6
19	0	1	1	6
20	0	1	1	6
21	0	5	1	6
22	0	1	1	7
23	0	1	1	0
24	0	1	1	0
25	0	1	1	0
26	0	1	1	7
27	0	1	0	0
28	0	1	0	0
29	0	1	0	0
30	0	1	0	0
31	0	1	0	0
32	0	1	0	0
33	0	1	0	0
34	0	1	0	0
35	0	1	0	0
36	0	1	0	0
37-39	0	0	0	0
40	6	0	0	0

0 = No Damage/Disengagement
1= Deformed in Place
2 = Released Entirely
3 = Fractured at Tab
4 = Fractured at Neck
5 = Fractured through Bolt Hole
6 = Brass Rod Fractured
7 = Brass Rod Bent in Place
*Note numbers 1 through 7 also means cable disengaged

Figure 121. Overall System Damage, Test No. MTP-2

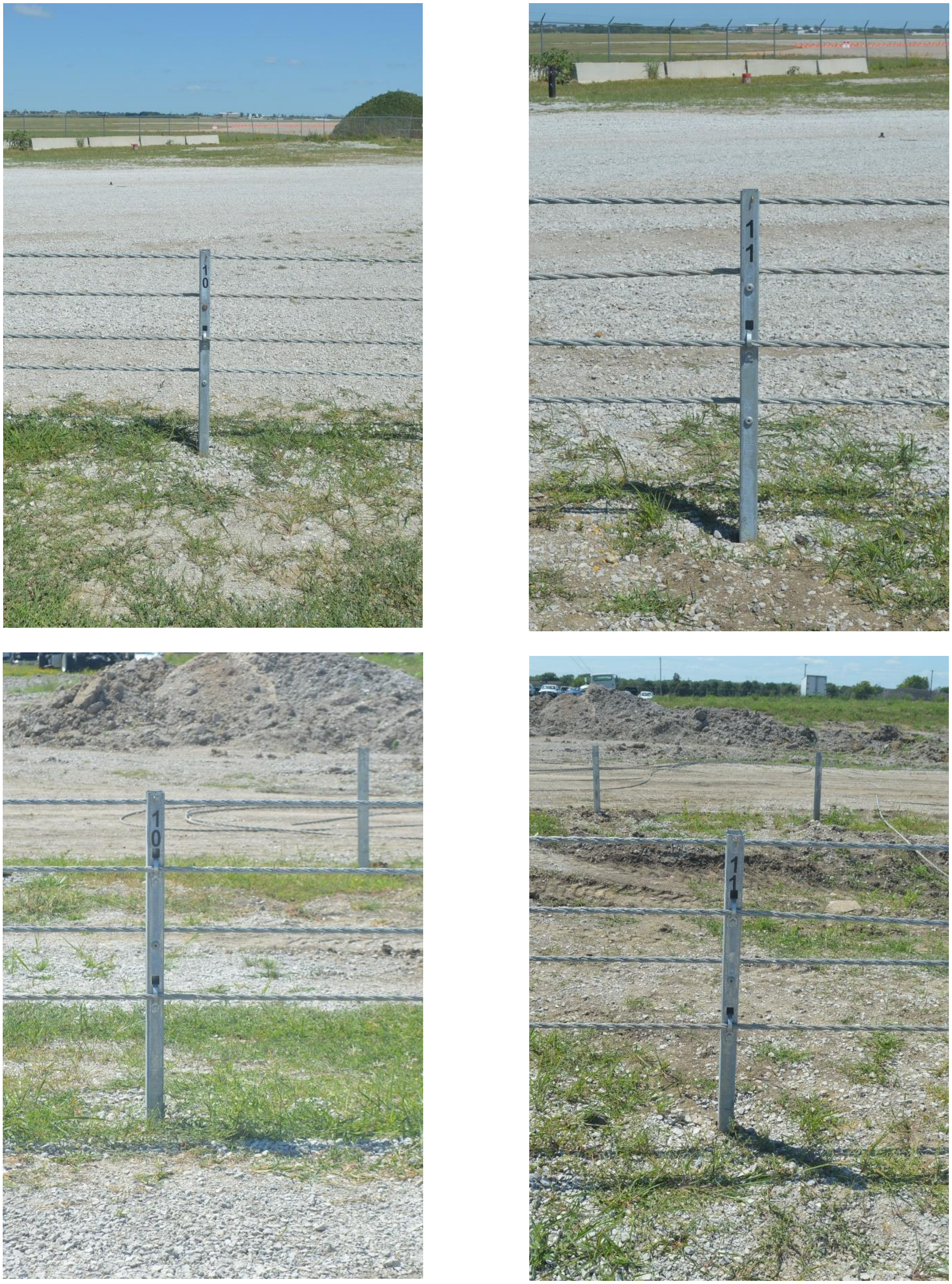


Figure 122. Post Nos. 10 (Left) and 11 (Right) Damage, Test No. MTP-2

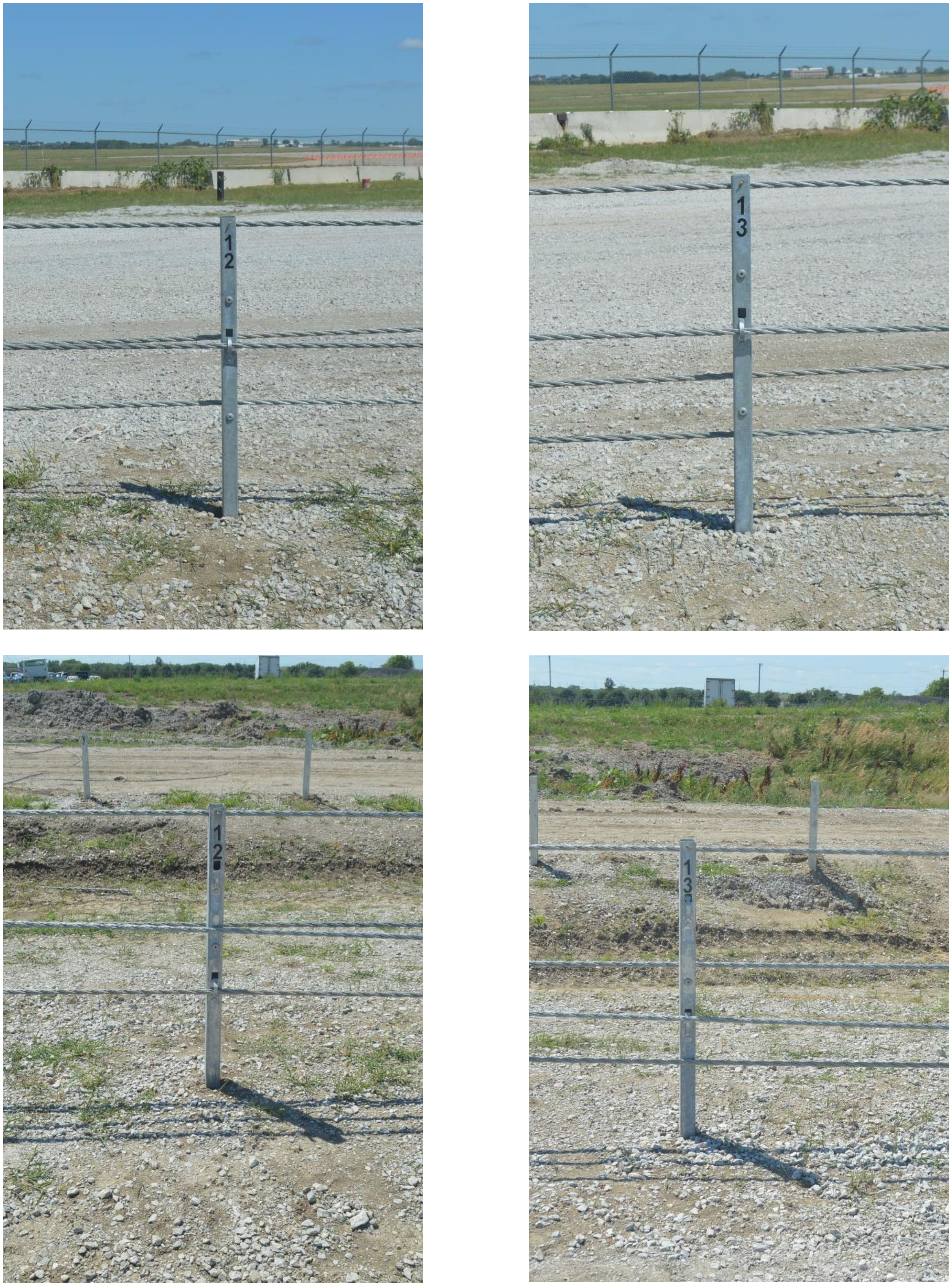


Figure 123. Post Nos. 12 (Left) and 13 (Right) Damage, Test No. MTP-2

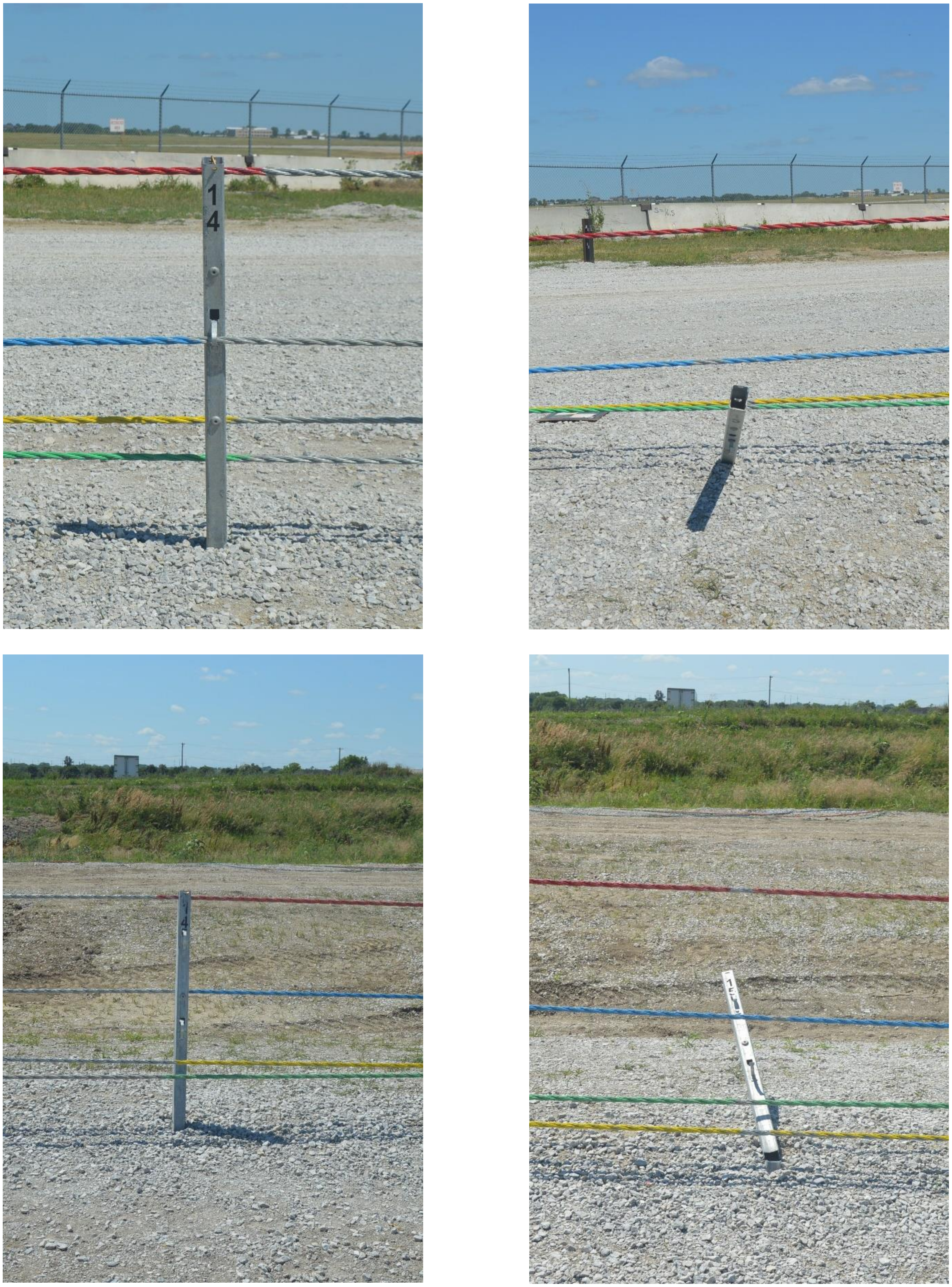


Figure 124. Post Nos. 14 (Left) and 15 (Right) Damage, Test No. MTP-2

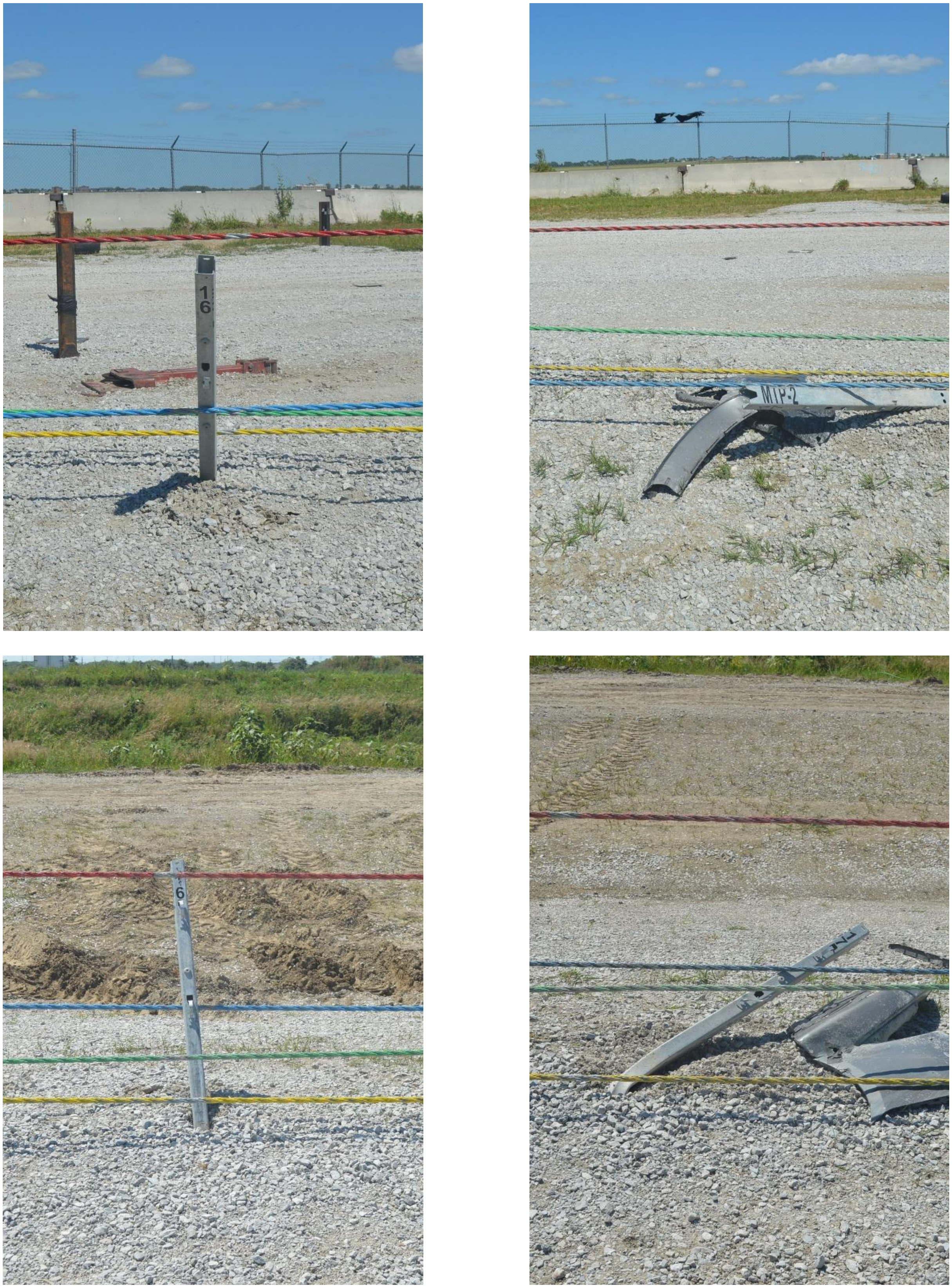


Figure 125. Post Nos. 16 (Left) and 17 (Right) Damage, Test No. MTP-2

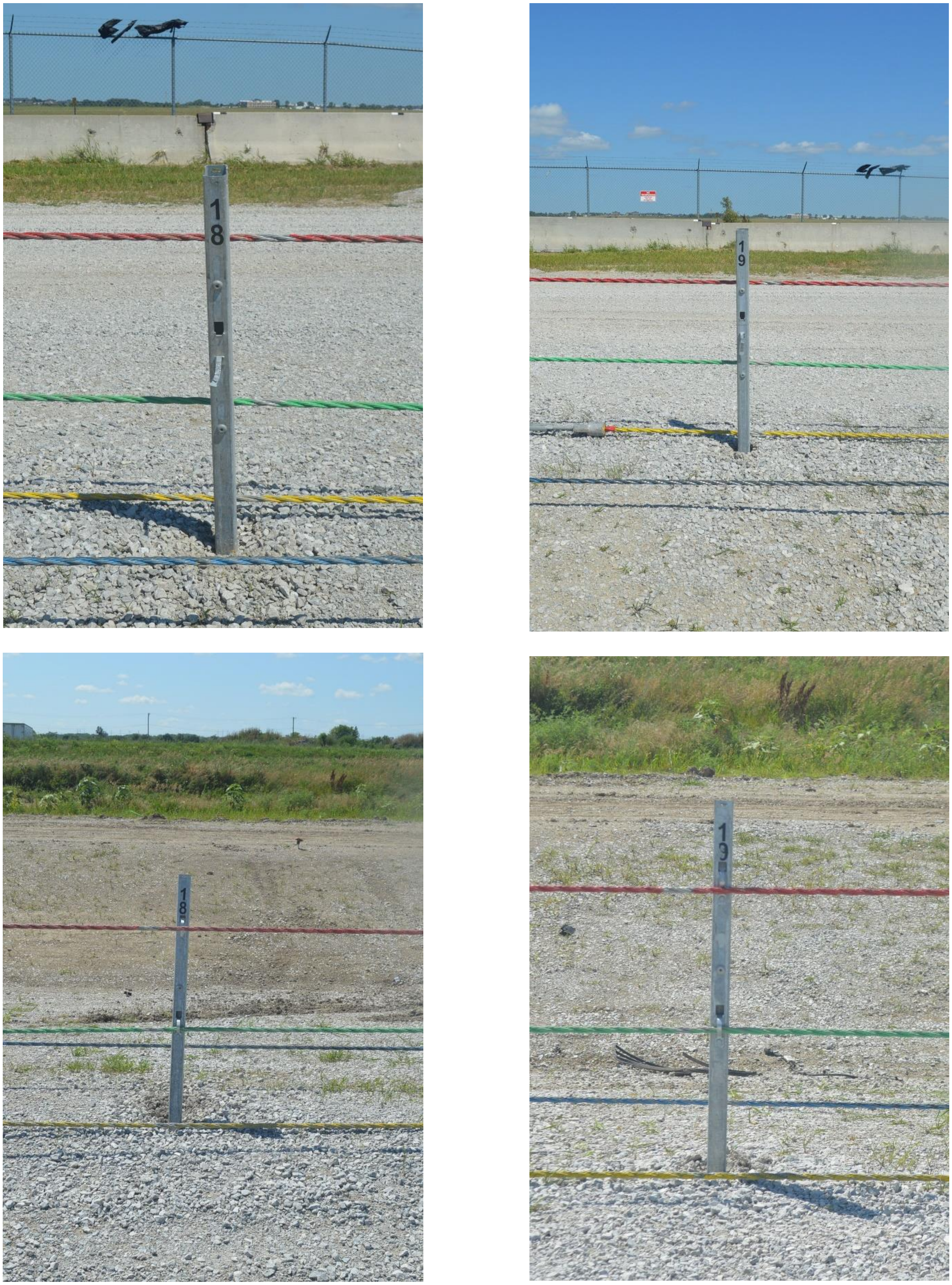


Figure 126. Post Nos. 18 (Left) and 19 (Right) Damage, Test No. MTP-2

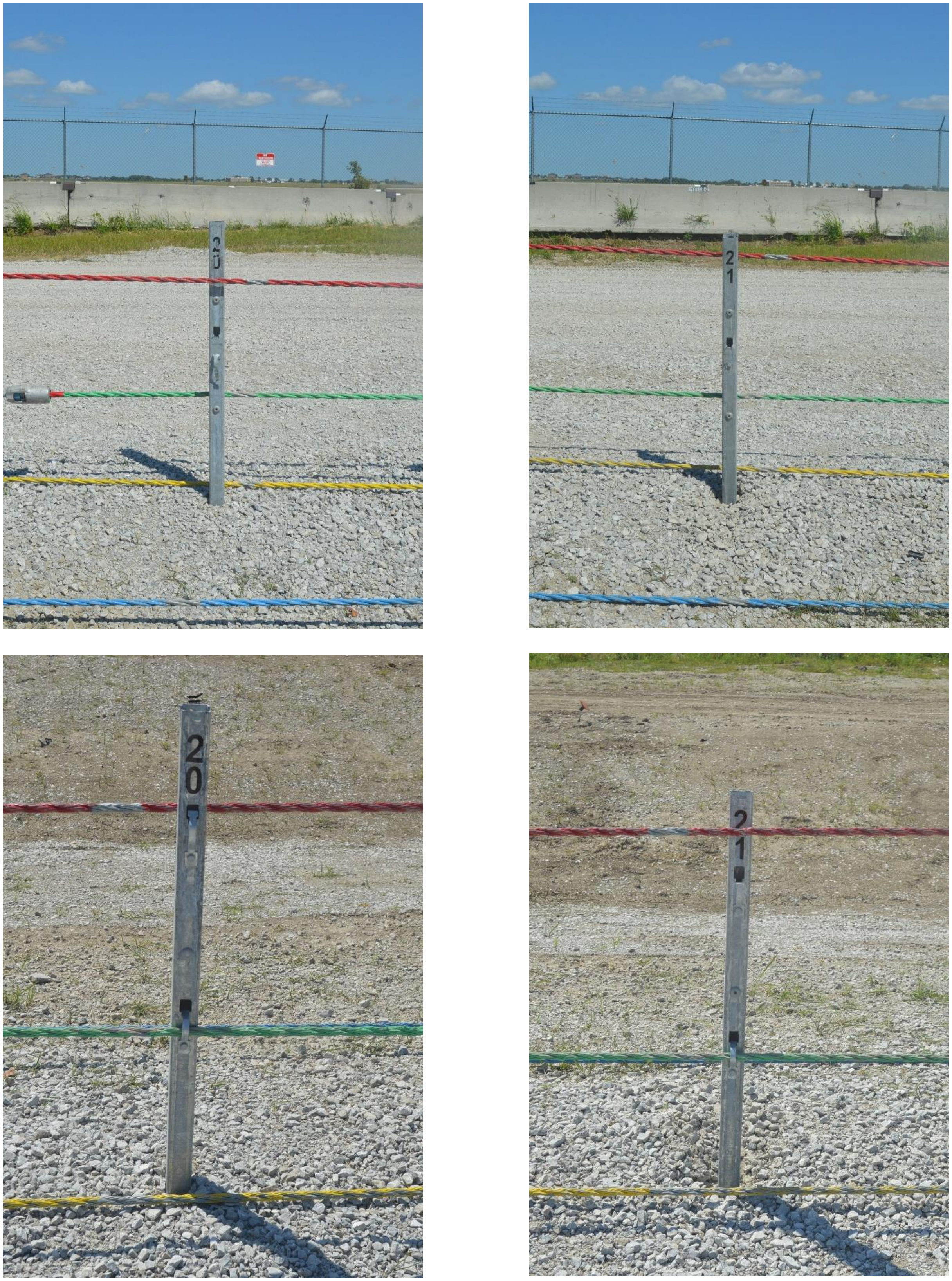


Figure 127. Post Nos. 20 (Left) and 21 (Right) Damage, Test No. MTP-2

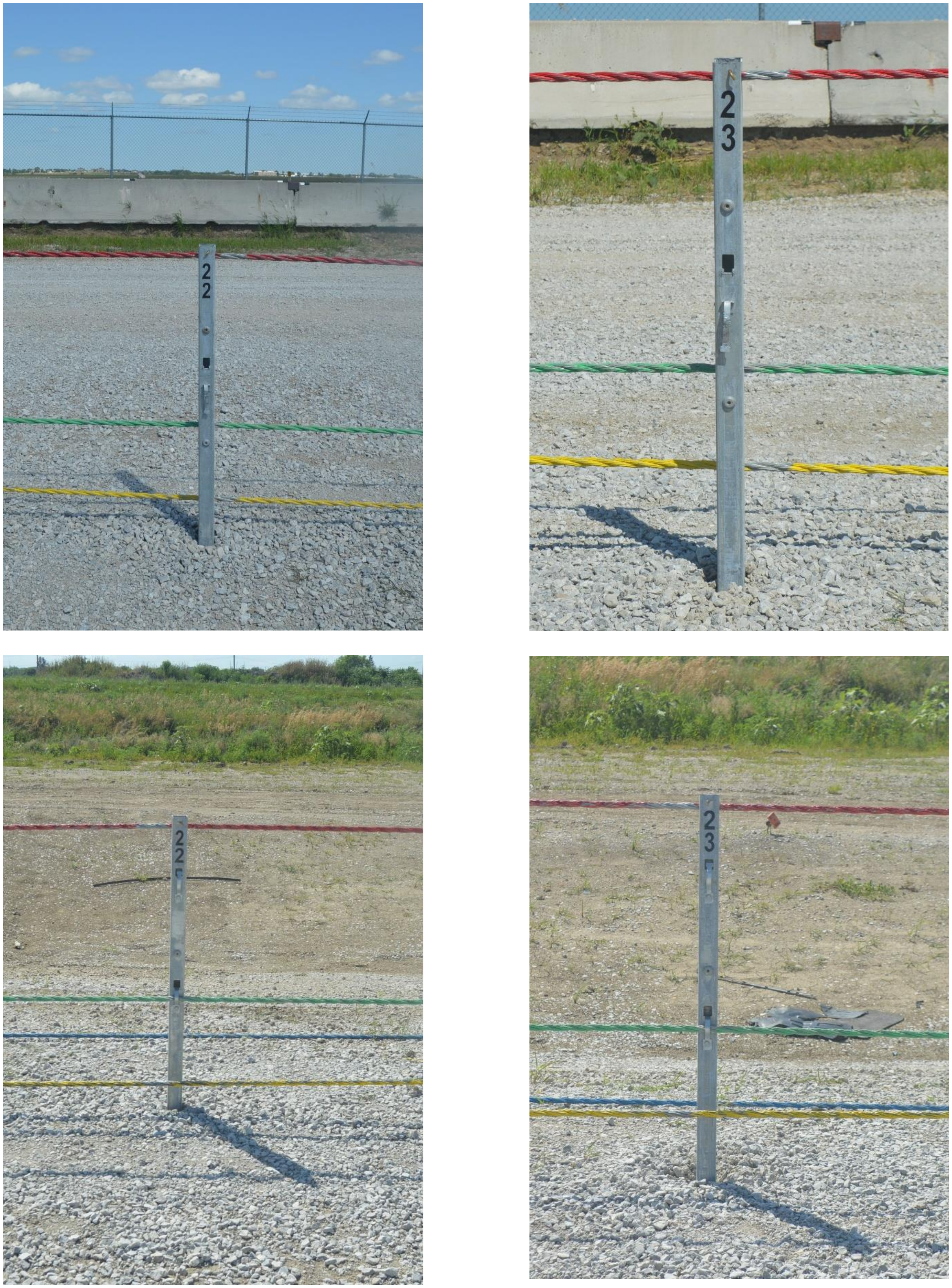


Figure 128. Post Nos. 22 (Left) and 23 (Right) Damage, Test No. MTP-2

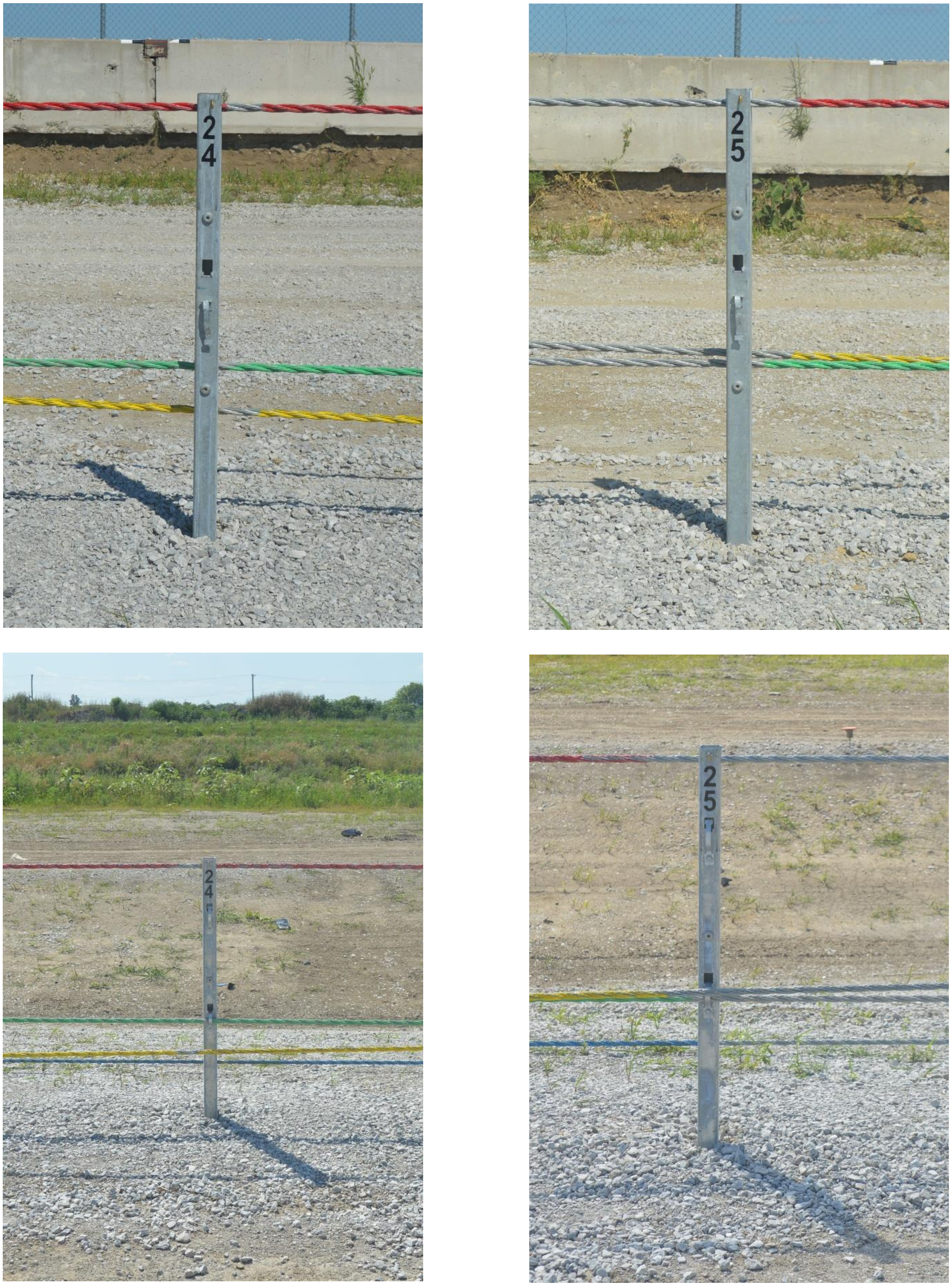


Figure 129. Post Nos. 24 (Left) and 25 (Right) Damage, Test No. MTP-2

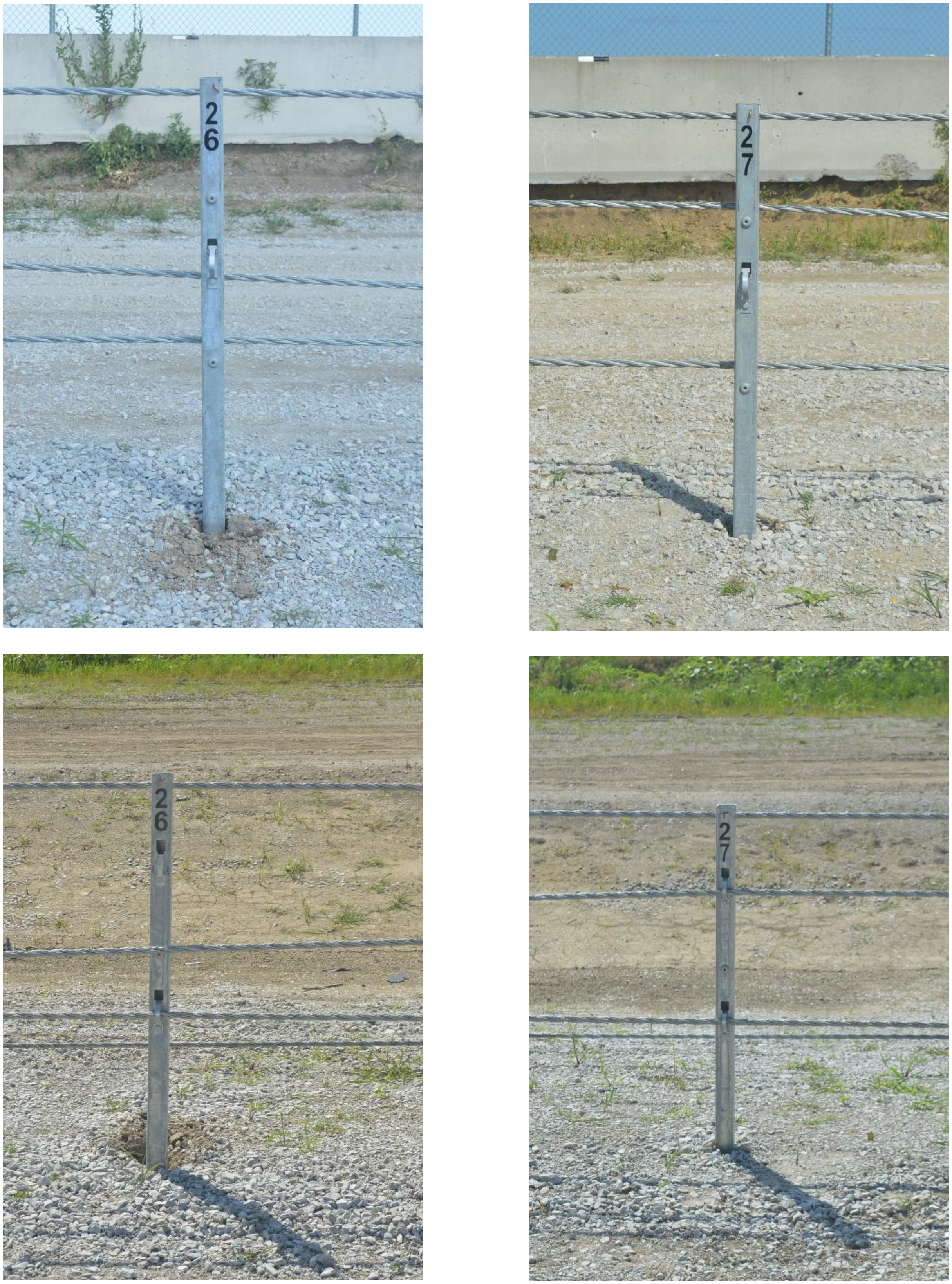


Figure 130. Post Nos. 26 (Left) and 27 (Right) Damage, Test No. MTP-2

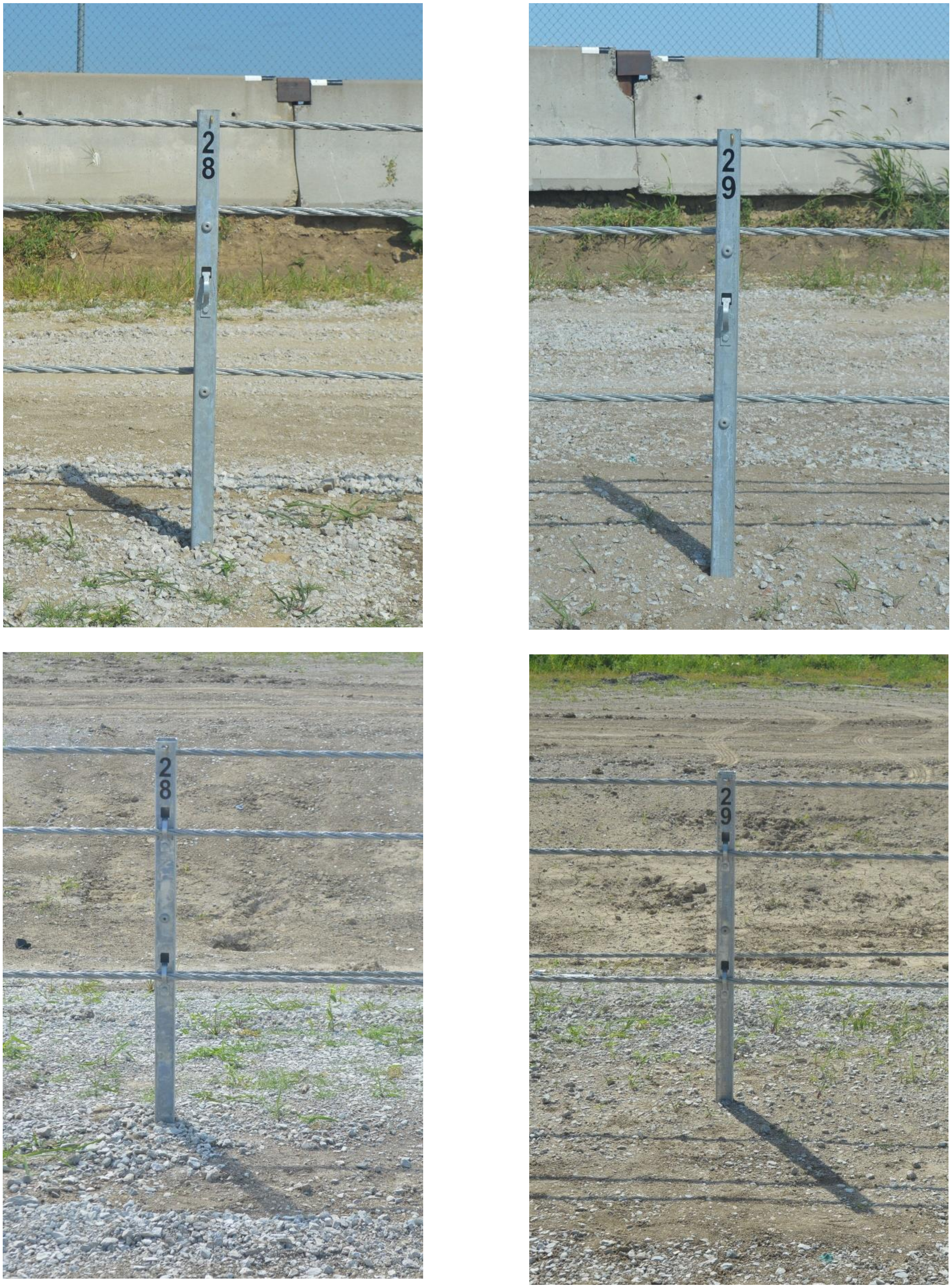


Figure 131. Post Nos. 28 (Left) and 29 (Right) Damage, Test No. MTP-2

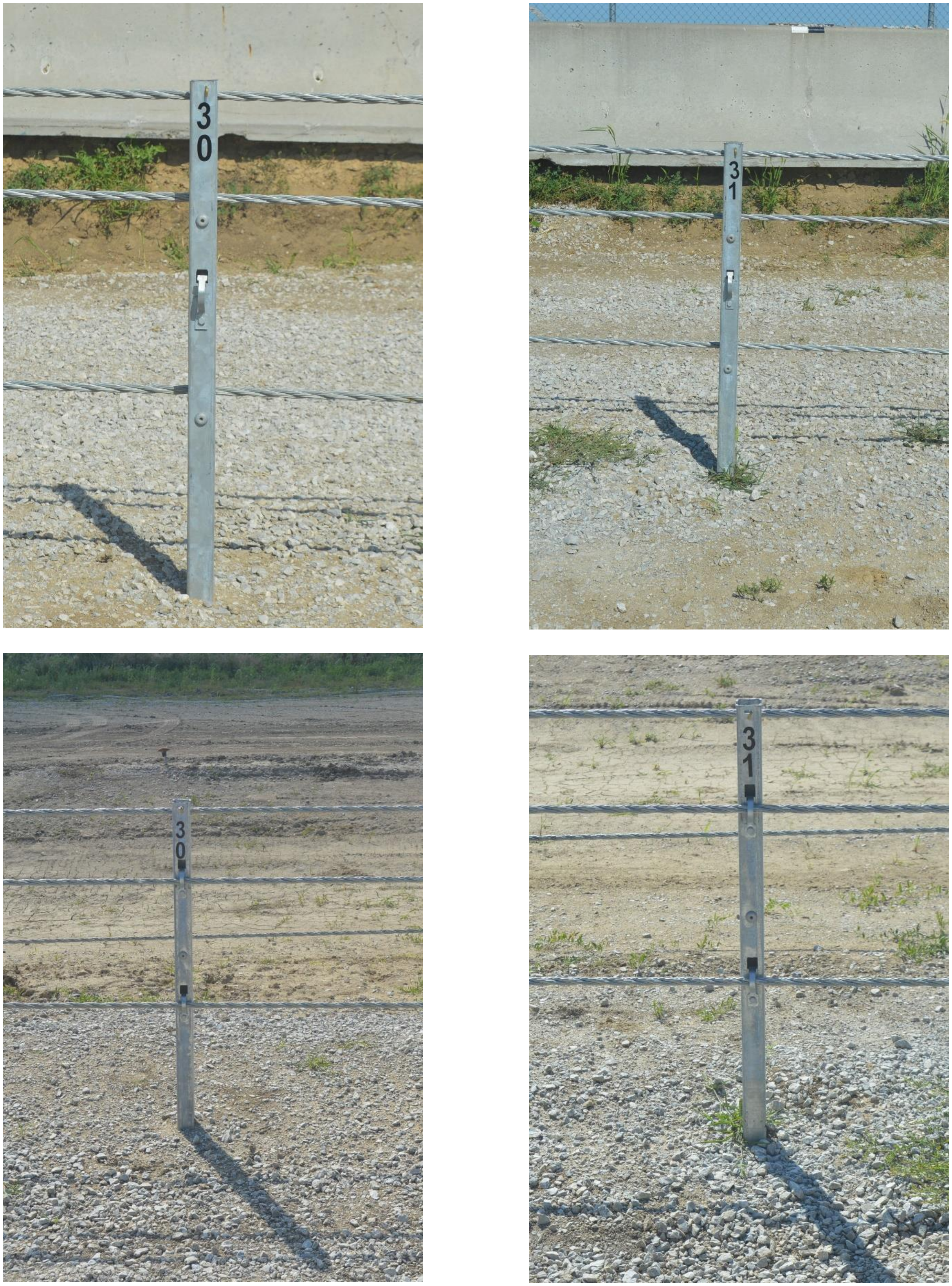


Figure 132. Post Nos. 30 (Left) and 31 (Right) Damage, Test No. MTP-2

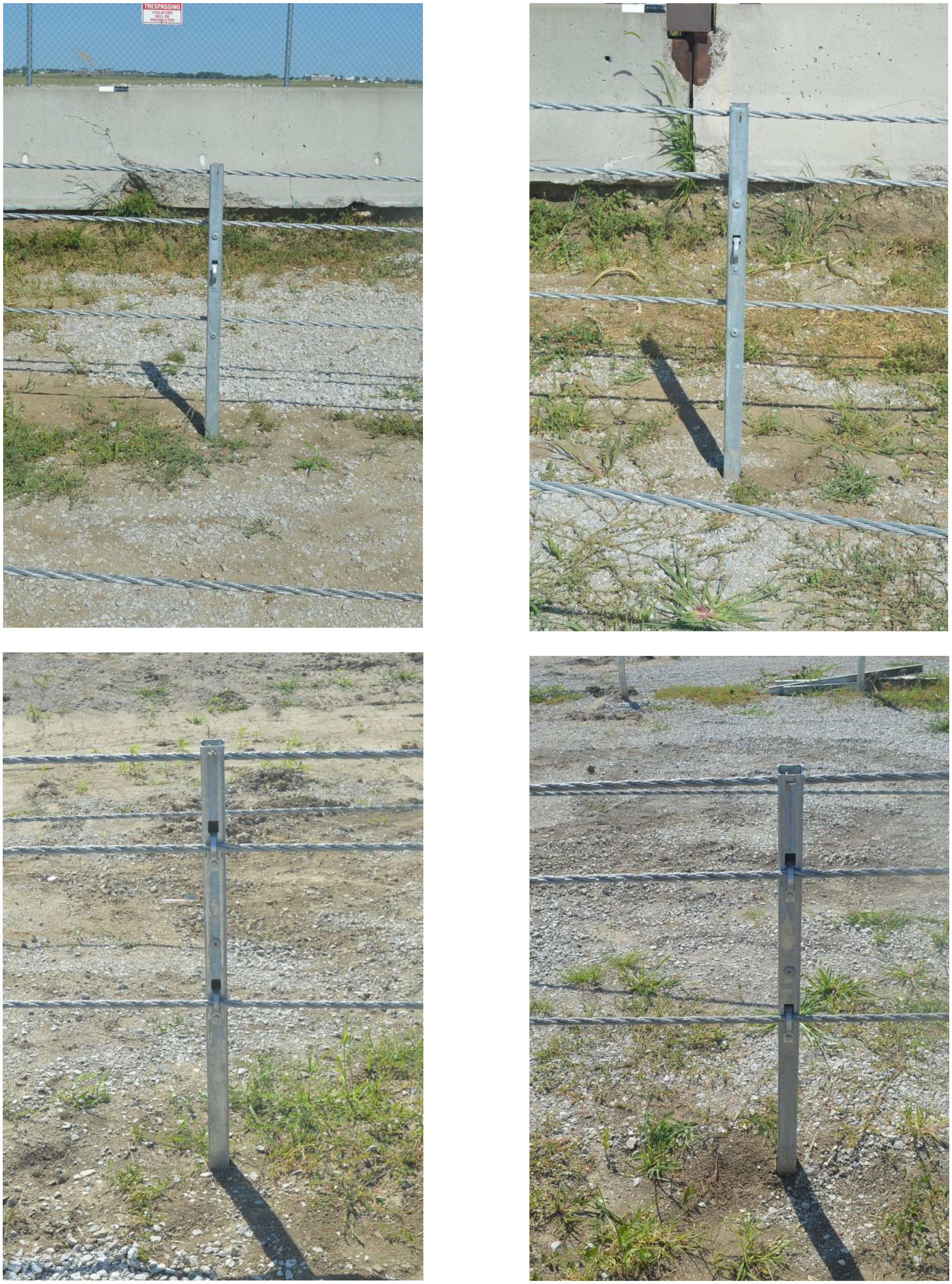


Figure 133. Post Nos. 32 (Left) and 34 (Right) Damage, Test No. MTP-2

Figure 134. Post No. 33 Damage with Vehicle, Test No. MTP-2

Figure 135. Post Nos. 35 (Left) and 36 (Right) Damage, Test No. MTP-2

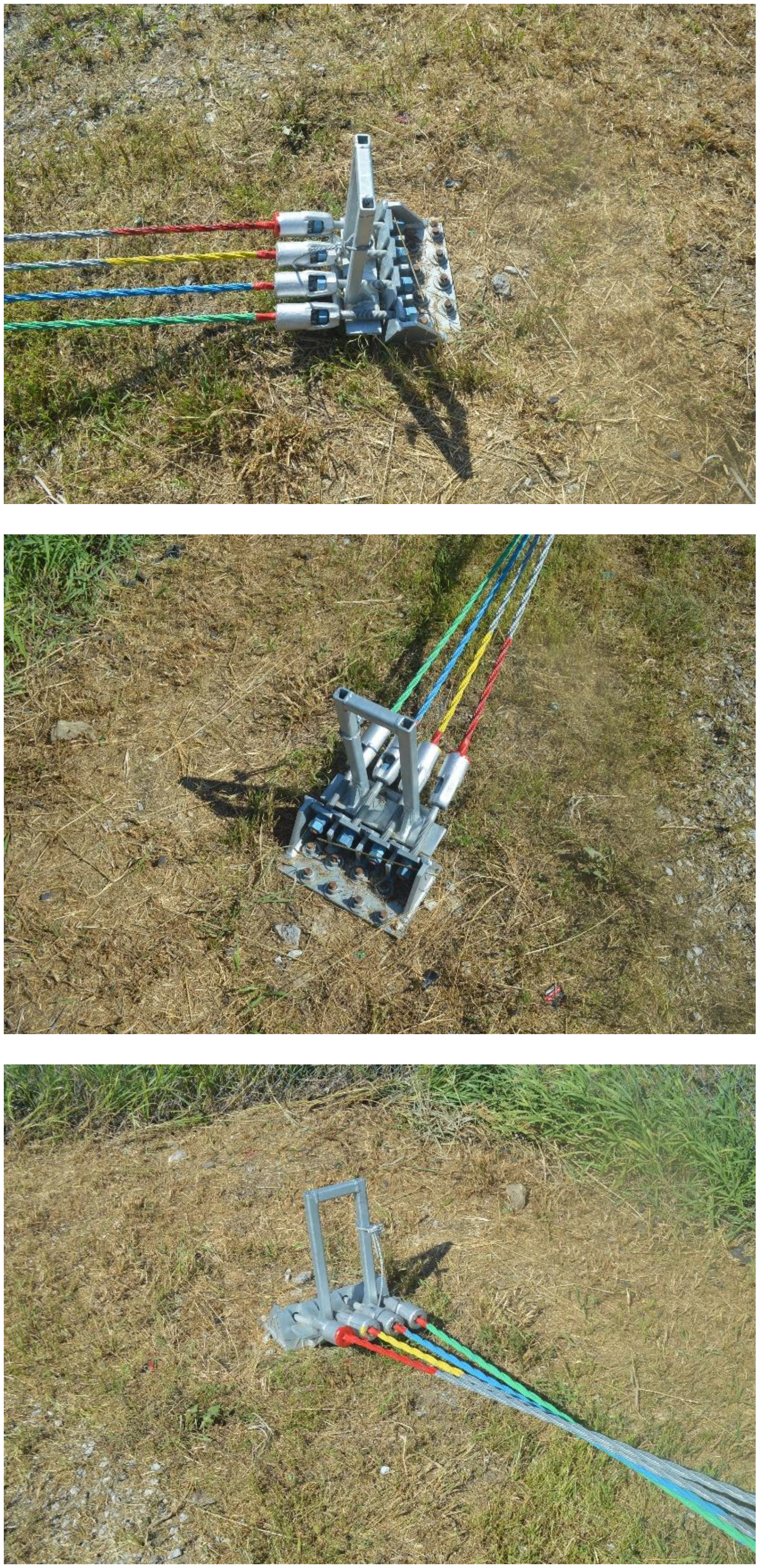


Figure 136. Post-Test Downstream Anchor, Test No. MTP-2

Figure 137. Post-Test Upstream Anchor, Test No. MTP-2

The maximum lateral permanent set of the posts in the system was 36.8 in. (935 mm), which occurred at post no. 15, as measured via GPS in the field. The maximum lateral dynamic barrier deflection was 199.9 in. (5,077 mm), as determined from high-speed digital video analysis and the GPS trajectory data in the field. The working width of the system was found to be 200.6 in. (5,095 mm) determined from the GPS trajectory data in the field. The working width and dynamic deflection were determined to be the point reached by the test vehicle's left-front corner between post nos. 24 and 25 and the cable's position on the vehicle at that time, respectively. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 138.

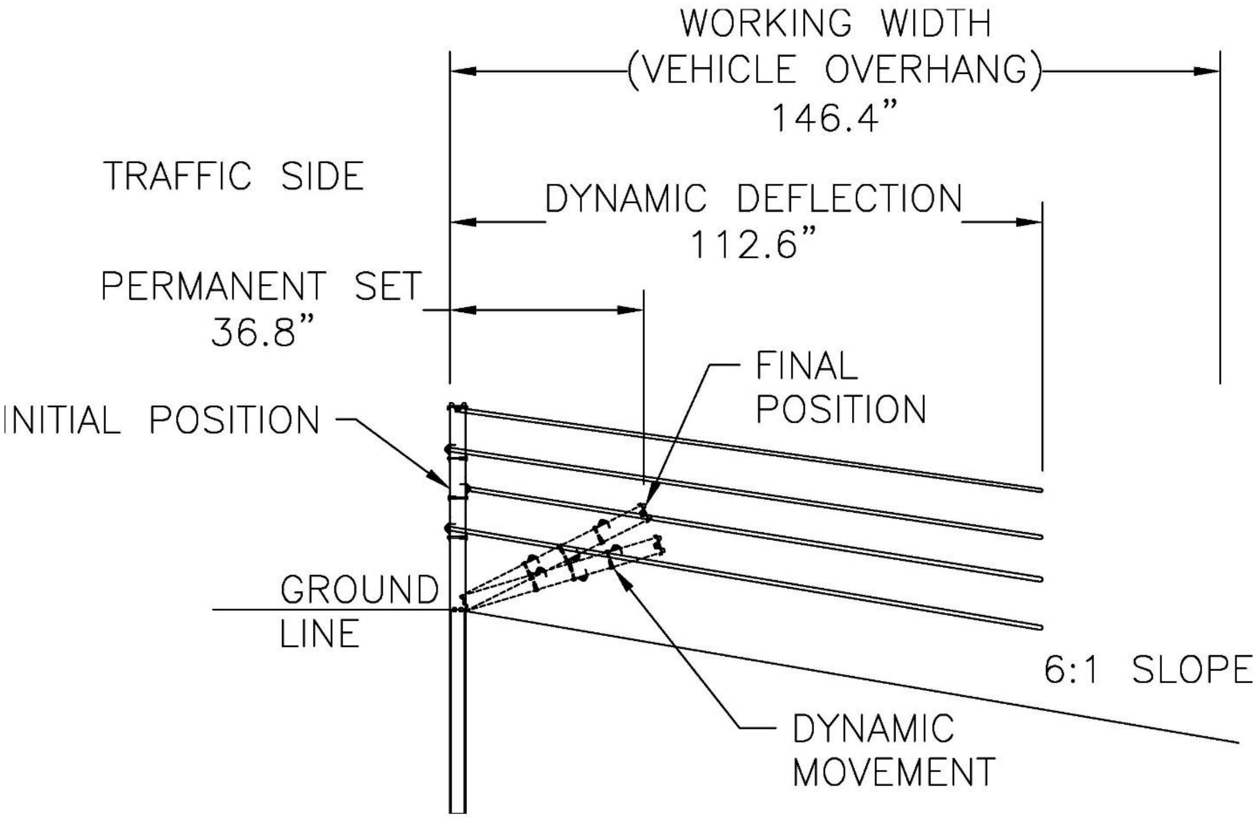


Figure 138. Permanent Set, Dynamic Deflection, and Working Width, Test No. MTP-2

7.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 139 through 143. The maximum occupant compartment intrusions are listed in Table 15 along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. There were no penetrations into the occupant compartment and none of the established MASH 2016 deformation limits were violated. Outward deformations, which are denoted as negative numbers in Appendix D, are not considered crush toward the occupant, and are not evaluated by MASH 2016 criteria.

The majority of the damage was found on the vehicle's left-front side, where the impact occurred. The grille cracked and the left side was partially disengaged. The left corner of the front bumper cover disengaged from the vehicle and the right-front corner was partially disengaged. The left-front fender was pushed inward toward the rear of the vehicle. The fender was also torn starting at the rear edge of the left-front wheel well to the left-front door. The left side mirror disengaged from the vehicle. The left A-pillar was dented along its length from cable contact. The left-front door skin was torn and scraped. The left rear door was scraped along the entire length of the door. The left-rear fender was dented in front of the wheel well. The left corner of the rear bumper cover and the roof were scraped. The windshield sustained numerous minor cracks throughout. The side windows remained undamaged.

The bottom of the steering control arm gear box, transmission tunnel, and transmission mount were scraped. The oil pan was scraped and dented. The left-side frame horn was bent toward the rear of the vehicle. The left skid plate mounting member disengaged and the middle mounting member disengaged from the front mount. The floor pan, gas tank, and trunk pan remained undamaged.

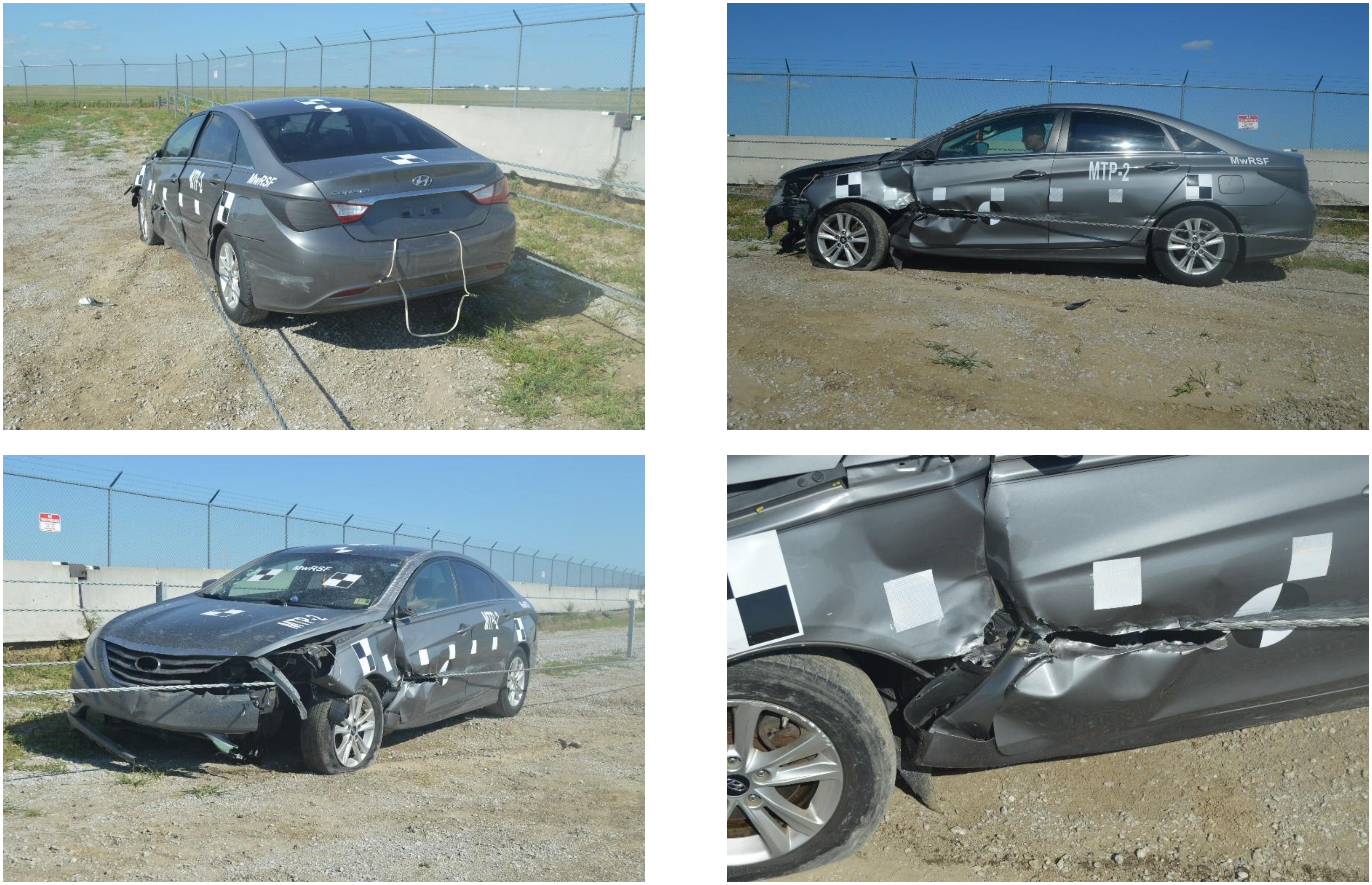


Figure 139. Vehicle Damage, Test No. MTP-2

Figure 140. Additional Vehicle Damage, Test No. MTP-2

Figure 141. Vehicle Interior Damage, Test No. MTP-2

Figure 142. Vehicle Undercarriage Damage, Test No. MTP-2

Figure 143. Vehicle Windshield Damage, Test No. MTP-2

Table 15. Maximum Occupant Compartment Intrusion by Location, Test No. MTP-2

LOCATION	Maximum Intrusion in. (mm)	MASH 2016 Allowable Intrusion in. (mm)
Wheel Well & Toe Pan	2.7 (69)	≤ 9 (229)
Floor Pan & Transmission Tunnel	0.1 (3)	≤ 12 (305)
A-Pillar	0.2 (5)	≤ 5 (127)
A-Pillar (Lateral)	0.2 (5)	≤ 3 (76)
B-Pillar	0.5 (13)	≤ 5 (127)
B-Pillar (Lateral)	0.2 (5)	≤ 3 (76)
Side Front Panel (in Front of A-Pillar)	0.1 (3)	≤ 12 (305)
Side Door (Above Seat)	0.0 (0)*	≤ 9 (229)
Side Door (Below Seat)	0.2 (5)	≤ 12 (305)
Roof	0.4 (10)	≤ 4 (102)
Windshield	0.0 (0)	≤ 3 (76)
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	0.2 (5)	N/A

N/A – No MASH 2016 criteria exist for this location.
*Negative value reported as 0.0. See Appendix D for further information.

7.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ride down accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 16. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 16. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix G.

Table 16. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. MTP-2

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (primary)	SLICE-2	
OIV ft/s (m/s)	Longitudinal	-8.27 (-2.52)	-8.24 (-2.51)	±40 (12.2)
	Lateral	9.62 (2.93)	8.90 (2.71)	±40 (12.2)
ORA g's	Longitudinal	-5.14	-5.28	±20.49
	Lateral	5.17	5.07	±20.49
Maximum Angular Displacement degrees	Roll	-23.0	-20.6	±75
	Pitch	-5.8	-5.6	±75
	Yaw	28.9	28.6	not required
THIV ft/s (m/s)		11.82 (3.60)	10.62 (3.24)	not required
PHD g's		5.50	5.85	not required
ASI		0.29	0.31	not required

7.7 Load Cells

The pertinent data from the load cells was extracted from the bulk signal and analyzed using the transducer's calibration factor. The recorded data and analyzed results are detailed in Appendix H. The maximum cable loads are shown in Table 20, and all the cable loads are graphed in Figure 144. The exact moment of impact could not be determined from the transducer data as impact may have occurred a few milliseconds prior to a measurable signal increase in the data. Thus, the extracted data curves should not be taken as precise time after impact, but rather a general timeline between events within the data curve itself.

Table 17. Maximum Cable Loads, Test No. MTP-2

Cable Location	Sensor Location	Maximum Cable Load kips (kN)	Time sec
Combined Cable Load	Upstream from Impact	30.4 (135.2)	0.489
Cable No. 4	Upstream from Impact between Post Nos. 4 and 5	6.6 (29.1)	0.148
Cable No. 3	Upstream from Impact between Post Nos. 4 and 5	6.0 (26.7)	0.194
Cable No. 2	Upstream from Impact between Post Nos. 4 and 5	20.3 (90.4)	1.185
Cable No. 1	Upstream from Impact between Post Nos. 4 and 5	10.6 (47.3)	0.075

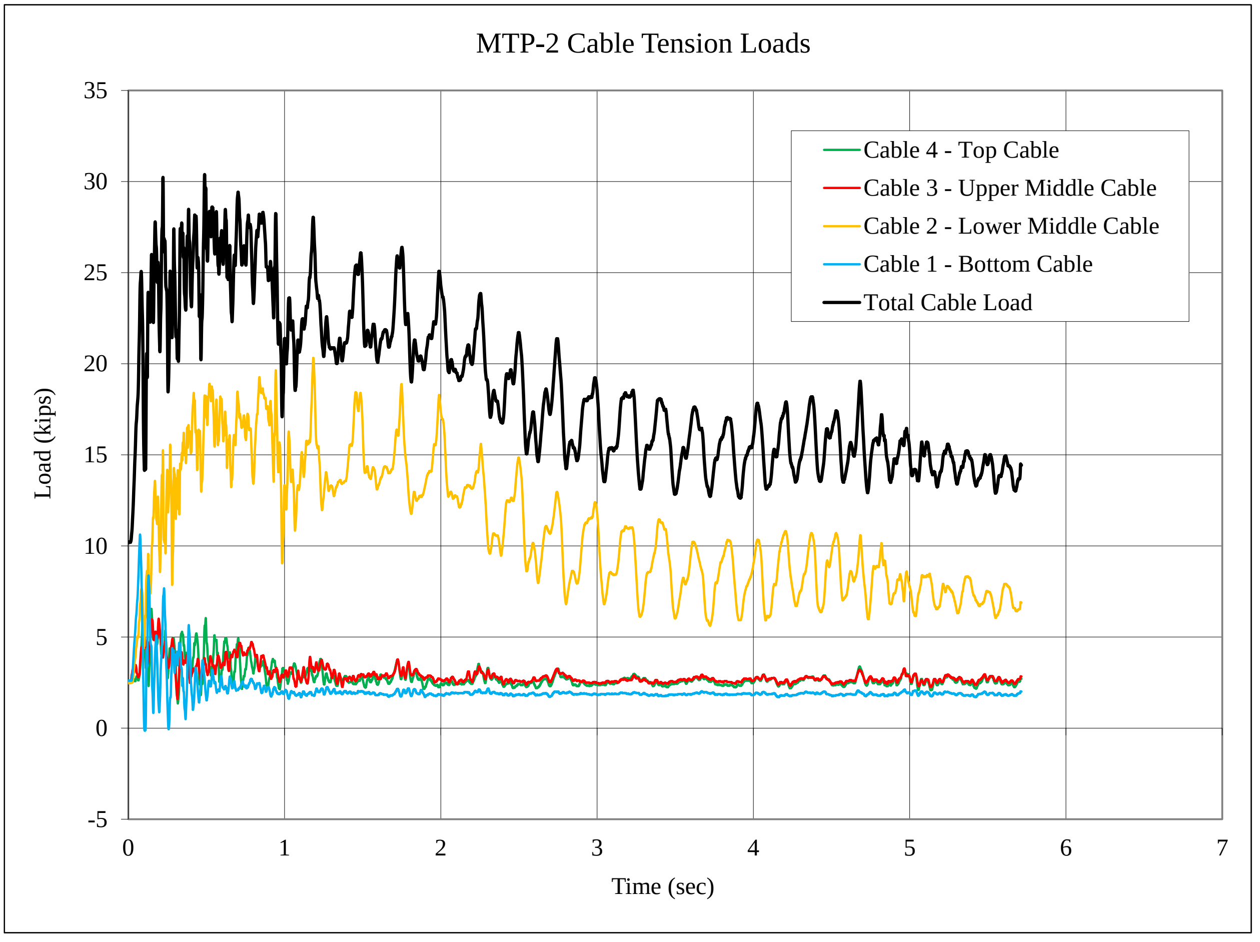
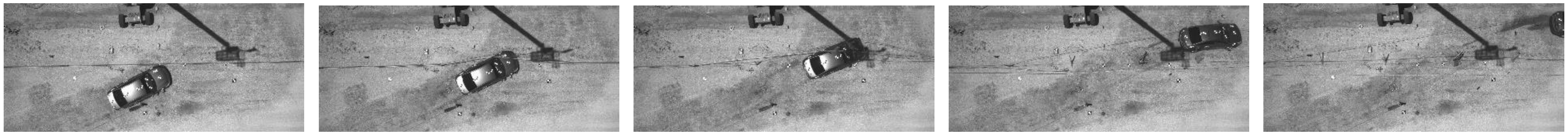


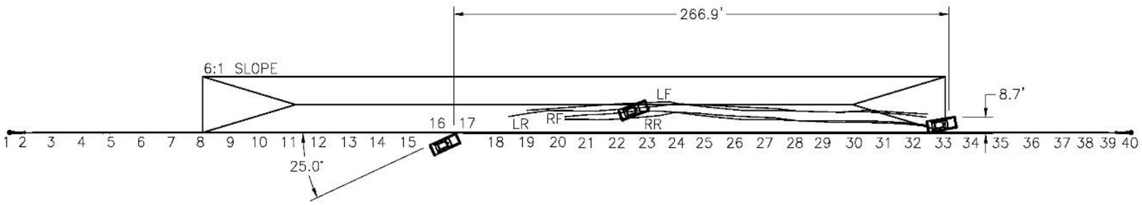
Figure 144. Cable Tension Loads, Test No. MTP-2

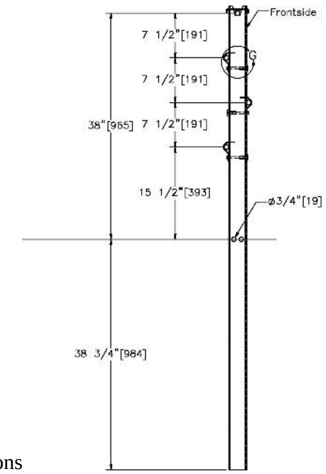
7.8 Discussion

The analysis of the test results for test no. MTP-2 showed that the system adequately contained and redirected the 1500A vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown in Figure 145. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix G, were deemed acceptable because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle did not exit the system, instead it remained in contact with the system. Therefore, test no. MTP-2 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-17.



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





- Test Agency .... MwRSF
- Test Number MTP-2
- Date 7/15/2019
- MASH 2016 Test Designation No. 3-17
- Test Article .... Four-Cable Median Barrier
- Total Length .... 603 ft – 8 in. (184 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 - MTP
  - Length .... 78 in. (1,981 mm)
  - Width .... HSS 3x2x⅛ (76x51x3),
  - Spacing .... 192 in. (4,877 mm)
- Soil Type .... Compacted, coarse, crushed limestone (well-graded gravel)
- Vehicle Make /Model .... 2013 Hyundai Sonata
  - Curb .... 3,206 lb (1,454 kg)
  - Test Inertial .... 3,301 lb (1,497 kg) (MASH 2016 limit 3300 ± 220 lb)
  - Gross Static .... 3,471 lb (1,574 kg)
- Impact Conditions
  - Speed .... 61.6 mph (99.2 km/h) (MASH 2016 limit 62 ± 2.5 mph)
  - Angle .... 25.0 deg. (MASH 2016 limit 25 ± 1.5 deg.)
  - Impact Location .... 96 in. (2,438 mm) upstream from post no. 17
- Impact Severity .... 74.8 kip-ft (101.4 kJ) > 70 kip-ft (95.1 kJ) limit from MASH 2016
- Exit Conditions
  - Speed .... N/A
  - Angle .... N/A
- Exit Box Criterion .... N/A (Did not exit system)
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 266 ft – 10 in. (81.3 m) downstream within system
- Vehicle Damage .... Moderate
  - VDS (13) 11-LFQ-3
  - CDC (14) 11-FLEK-1
  - Maximum Interior Deformation .... 2.7 in. (69 mm) < 9 in. MASH 2016 limit
- Test Article Damage .... Moderate
- Maximum Test Article Deflections
  - Permanent Set .... 36.8 in. (935 mm)
  - Dynamic .... 199.9 in. (5,076 mm)
  - Working Width .... 200.6 in. (5,095 mm)
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (primary)	SLICE-2	
OIV ft/s (m/s)	Longitudinal	-8.27 (-2.52)	-8.24 (-2.51)	±40 (12.2)
	Lateral	9.62 (2.93)	8.90 (2.71)	±40 (12.2)
ORA g's	Longitudinal	-5.14	-5.28	±20.49
	Lateral	5.17	5.07	±20.49
Maximum Angular Displacement degrees	Roll	-23.0	-20.6	±75
	Pitch	-5.8	-5.6	±75
	Yaw	28.9	28.6	not required
THIV – ft/s (m/s)		11.82 (3.60)	10.62 (3.24)	not required
PHD – g's		5.50	5.85	not required
ASI		0.29	0.31	not required

Figure 145. Summary of Test Results and Sequential Photographs, Test No. MTP-2

8 SUMMARY AND CONCLUSIONS

The objective of this study was to evaluate the modified high-tension four-cable median barrier that was configured with closed-section posts, cable-to-post bracket, and round sleeve nuts. The high-tension, four-cable median barrier system was to be evaluated according to the MASH 2016 TL-3 safety performance criteria using the updated test matrix for cable barrier systems installed anywhere within 6H:1V median V-ditches. Two full-scale tests were conducted on the system and were reported herein. A summary of the test evaluation is shown in Table 11.

Test no. MTP-1 was conducted in accordance with MASH 2016 test designation no. 3-11 on the four-cable median barrier system with post spacing of 8 ft (2.4 m) placed on level terrain. A 4,986-lb (2,262-kg) pickup truck impacted the cable barrier system at a speed of 61.3 mph (98.7 km/h), an angle of 25.0 degrees, and at a location 8 in. (203 mm) upstream from post no. 32, thus resulting in an impact severity of 111.4 kip-ft (151.0 kJ). The vehicle did not exit the system, but it was successfully contained and brought safely to a stop. Exterior vehicle damage was moderate, and the interior occupant compartment deformations were minimal, with a maximum of 0.8 in. (20 mm), consequently not violating the limits established in MASH 2016. Damage to the barrier was moderate, consisting of fractured posts, deformed posts and brackets, and detached cables. The maximum lateral dynamic barrier deflection was 101.8 in. (2,586 mm). The working width of the system was 102.1 in. (2,593 mm). All occupant risk measures were below the recommended values established in MASH 2016. The test vehicle showed no tendency to rollover and did not penetrate or ride over the barrier. Therefore, test no. MTP-1 was deemed successful according to the safety criteria of MASH 2016 test designation no. 3-11 for the post spacing of 8 ft on level terrain.

Test no. MTP-2 was conducted in accordance with MASH 2016 test designation no. 3-17 on the four-cable median barrier system with the post spacing of 16 ft (4.8 m) placed on the 6H:1V median V-ditch. A 3,301-lb (1,497-kg) sedan impacted the cable barrier system at a speed of 61.6 mph (99.1 km/h), an angle of 25.0 degrees, and at a location 96 in. (2,438 mm) upstream from post no. 17, thus resulting in an impact severity of 74.8 kip-ft (101.4 kJ). The vehicle did not exit the system, but it was successfully contained and brought safely to a stop. Exterior vehicle damage was moderate, and the interior occupant compartment deformations were minimal, with a maximum of 2.7 in. (68.6 mm), consequently not violating the limits established in MASH 2016. Damage to the barrier was moderate, consisting of fractured posts, deformed posts and brackets, and detached cables. The maximum lateral dynamic barrier deflection was 199.9 in. (5,076 mm). The working width of the system was 200.6 in. (5,095 mm). All occupant risk measures were below the recommended values established in MASH 2016. The test vehicle showed no tendency to rollover and did not penetrate or ride over the barrier. Therefore, test no. MTP-2 was deemed successful according to the safety criteria of MASH 2016 test designation no. 3-17 for the post spacing of 16 ft placed on a 6H:1V V-ditch.

Post behavior demonstrated significant improvement over previous design iterations. Previous tests had been deemed unsuccessful due to floor pan tearing caused by the sharp corners of the open-section posts used in earlier versions of the cable median barrier system [4]. During test nos. MTP-1 and MTP-2, minimal undercarriage damage was observed, as shown in Figures 80 and 142. The weakening holes drilled in the posts at the ground line produced favorable post behavior. Many posts bent at the ground line to the point of lying flat on the ground, thus avoiding contact with the vehicle’s undercarriage while remaining embedded in the ground. Therefore, test nos. MTP-1 and MTP-2 demonstrated that the MTP reduced the propensity for floor pan contact and tearing, consequently avoiding the need for the post caps implemented in test no. MWP-9.

Previous tests were also unsuccessful due to cable snag on the bolt head used to fasten the post cap to the post as seen in test no. MWP-9, in which the 1100C test vehicle's A-pillar deformed excessively [4]. In test nos. MTP-1 and MTP-2, rounded sleeve nuts were used in lieu of traditional nuts to fasten the cable-to-post brackets to the posts. This design alternative mitigated cable snag on the nut. However, cable snag occurred on the impact-side fender and front door, causing damage to the vehicle, but the deformation was within the MASH 2016 limits.

The modified cable median barrier system showed improvement over previous system designs by alleviating the complications of its predecessors. The modified system utilized more readily available components and less material than previous iterations. The modified cable barrier system satisfied the safety performance requirements of MASH 2016 test designation nos. 3-11 and 3-17, as shown in Table 21. However, the system must be subjected to the remaining tests in the required test matrix for cable barriers placed anywhere within 6H:1V or flatter median V-ditches. These remaining tests include test designation nos. 3-10, 3-13, 3-14, 3-16 at a post spacing of 8 ft and 3-11, 3-15, and 3-18 at a post spacing of 16 ft.

Table 18. Summary of Safety Performance Evaluation

<table>
<tr><th>Evaluation Factors</th><th colspan="4">Evaluation Criteria</th><th>Test No. MTP-1</th><th>Test No. MTP-2</th></tr>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td><td>S</td><td>S</td></tr>
<tr><td rowspan="12">Occupant Risk</td><td rowspan="2">D.</td><td colspan="3">1. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.</td><td>S</td><td>S</td></tr>
<tr><td colspan="3">2. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.</td><td>S</td><td>S</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td><td>S</td><td>S</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td><td rowspan="4">S</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s (9.1 m/s)</td><td>40 ft/s (12.2 m/s)</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ride down Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td><td rowspan="4">S</td></tr>
<tr><td colspan="3">Occupant Ride down Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
<tr><td colspan="5">MASH 2016 Test Designation No.</td><td>3-11</td><td>3-17</td></tr>
<tr><td colspan="5">Final Evaluation (Pass or Fail)</td><td>Pass</td><td>Pass</td></tr>
</table>

S – Satisfactory U – Unsatisfactory NA – Not Applicable

9 REFERENCES

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

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10 APPENDICES

Appendix A. Vehicle Center of Gravity Determination

Date:	4/11/2019	Test Name:	MTP-1	VIN:	1C6RD6GP3CS253410
Year:	2012	Make:	Dodge	Model:	Ram 1500

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	5063	28.505975	144325.75
+	Hub	19	15	285
+	Brake activation cylinder & frame	7	28 7/8	202.125
+	Pneumatic tank (Nitrogen)	22	27 1/2	605
+	Strobe/Brake Battery	5	27	135
+	Brake Receiver/Wires	6	52 3/4	316.5
+	CG Plate including DAQ	27	31 1/8	840.375
-	Battery	-44	39	-1716
-	Oil	-6	17 3/8	-104.25
-	Interior	-96	32 1/4	-3096
-	Fuel	-148	17 1/8	-2534.5
-	Coolant	-10	36 5/8	-366.25
-	Washer fluid	-7	37 1/2	-262.5
+	Water Ballast (In Fuel Tank)	86	15 3/4	1354.5
+	Onboard Supplemental Battery	13	26	338
	TDAS	17	26 3/5	452.2
				0
				140774.95

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

Estimated Total Weight (lb)	4954
Vertical CG Location (in.)	28.4164

Vehicle Dimensions for C.G. Calculations

Wheel Base: 148.0625 in.
Front Track Width: 67.75 in.
Rear Track Width: 67.75 in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb)	5000 ± 110	4986	-14.0
Longitudinal CG (in.)	63 ± 4	64.291078	1.29108
Lateral CG (in.)	NA	0	NA
Vertical CG (in.)	28 or greater	28.42	0.41642

Note: Long. CG is measured from front axle of test vehicle

Note: Lateral CG measured from centerline - positive to vehicle right (passenger) side

CURB WEIGHT (lb)

	Left	Right
Front	1473	1411
Rear	1083	1096

FRONT	2884	lb
REAR	2179	lb
TOTAL	5063	lb

TEST INERTIAL WEIGHT (lb)

	Left	Right
Front	1421	1400
Rear	1072	1093

FRONT	2821	lb
REAR	2165	lb
TOTAL	4986	lb

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

Date:	7/15/2019	Test Name:	MTP-2	VIN:	5NPEB4ACXDH545633
Year:	2013	Make:	Hyundai	Model:	Sonata

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)
+	Unballasted Car (Curb)	3206
+	Hub	19
+	Brake activation cylinder & frame	7
+	Pneumatic tank (Nitrogen)	30
+	Strobe/Brake Battery	5
+	Brake Receiver/Wires	6
+	CG Plate including DAQ	21
-	Battery	-39
-	Oil	-20
-	Interior	-87
-	Fuel	-33
-	Coolant	-2
-	Washer fluid	-8
+	Water Ballast (In Fuel Tank)	181
+	Onboard Supplemental Battery	13
+	Lead Block	18

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

Estimated Total Weight (lb) 3317

Vehicle Dimensions for C.G. Calculations

Wheel Base:	110.125	in.	Front Track Width:	63.0	in.
Roof Height:	57.625	in.	Rear Track Width:	63.0	in.

Center of Gravity	1500A MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb)	3300 ± 220	3301	1
Longitudinal CG (in.)	NA	46.439	NA
Lateral CG (in.)	NA	0.162	NA
Vertical CG (in.)	NA	22.079	NA

Note: Long. CG is measured from front axle of test vehicle

Note: Lateral CG measured from centerline - positive to vehicle right (passenger) side

CURB WEIGHT (lb)

	Left	Right
Front	1008	959
Rear	609	630

FRONT	1967	lb
REAR	1239	lb
TOTAL	3206	lb

TEST INERTIAL WEIGHT (lb)

	Left	Right
Front	957	952
Rear	685	707

FRONT	1909	lb
REAR	1392	lb
TOTAL	3301	lb

Figure A-2. Vehicle Mass Disribution, Test No. MTP-2.

Appendix B. Material Specifications

Table B-1. Bill of Materials, Test Nos. MTP-1 and MTP-2

Item No.	Description	Material Specification	Reference
a1	HSS3x2x⅛ (76x51x3), 78" (1,981) Long Steel Post with two ¾" (19) holes	ASTM A500 Gr. C	H#1285260
a2	5"x15/16"x12-Gauge (128x24x2.7) Tabbed Bracket	Hot-Rolled ASTM A1011 HSLA Gr. 50	H#8196D4
a3	3/16" (5) Dia. Brass Cable Clip, 4 9/16" (116) Long Unbent	ASTM B16-00	H#14311-1
b1	24" (610) Dia. Concrete Anchor, 120" (3,048) Long	Min. f'c = 4,000 psi (27.6 MPa)	R#14-0353 T#4156617
b2	#4 (13) Hoop Bar with 21" (533) Dia., 84" (2,134) Unbent Length	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	H#111485
b3	#11 (35) Bar, 114" (2,896) Long	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	H#5819611302
b4	¾"-10 UNC (M20x2.5) J-Hook Anchor	ASTM A449	H#11618020
c1	12" (305) Dia. 2nd Post Concrete Anchor, 46" (1,168) Long	Min. f'c = 4,000 psi (27.6 MPa)	R#14-0353 T#4156617
c2	12" (305) Dia. 2nd Post Anchor Aggregate, 2" (51) Deep	Standard Strong Soil	N/A
c3	#3 (10) Hoop Bar with 9" (229) Dia., 37" (940) Unbent Length	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	H#537484
c4	#3 (10) Bar, 43" (1,092) Long	ASTM A615 Gr. 60 or ASTM A706 Gr. 60	H#JW12105480
c5	4"x3"x¼" (102x76x6) Foundation Tube, 48" (1,219) Long	ASTM A500 Gr. B	H#B200931
d1	15 ¼"x9"x½" (387x229x13) Cable Anchor Base Plate	ASTM A36	H#18120021
d2	15 ¼"x5"x⅜" (387x127x10) Anchor Bracket Plate	ASTM A36	H#18048521
d3	6"x4 ½"x½" (152x114x13) Exterior Cable Plate Gusset	ASTM A36	H#18120021
d4	9"x5"x½" (229x127x13) Release Lever Plate	ASTM A36	H#18120021
d5	3 5/16"x3 3/16"x½" (84x81x13) Interior Cable Plate Gusset	ASTM A36	H#18120021
d6	3 ½"x2 ⅜x½" (89x61x13) Release Gusset	ASTM A36	H#18120021
d7	3/16" (5) Dia. Brass Keeper Rod, 16 ¼" (413) Long Unbent	ASTM B16-00	H#14311-1
e1	13 ½"x3 ½"x½" (343x89x13) Kicker Plate	ASTM A36	H#18120021
e2	3 ¼"x1 ¾"x½" (83x44x13) Kicker Gusset	ASTM A36	H#18120021
e3	1 ¼"x1 ¼"x3/16" (32x32x5), 17" (432) Long Square Tube	ASTM A500 Gr. B	H#NG0971
e4	1 ¼"x1 ¼"x3/16" (32x32x5), 5" (127) Long Square Tube	ASTM A500 Gr. B	H#NG0971

Table B-2. Bill of Materials, Test Nos. MTP-1 and MTP-2, Cont.

Item No.	Description	Material Specification	Reference
e5	¼" (6) Dia. 7x19 Aircraft Retaining Cable, 36" (914) Long	ASTM A1023	Cert#18Eagle061 P#45506 PO#210163546
f1	S3x5.7 (S75x8.5), 19" (483) Long Post	ASTM A36	H#59074590/02
f2	4 15/16"x4"x⅜" (125x102x10) Base Plate	ASTM A572 GR50	H#A7K273
f3	S3x5.7 (S75x8.5), 28 ⅛" (714) Long Post	ASTM A36	H#59074590/02
f4	18 ¾"x2"x½" (476x51x13) Cable Hanger	ASTM A572-50/M345(18)/A709-50/M345(17)	H#A8G844 H#A8G080
f5	4 15/16"x4"x28-Guage (125x102x0.4) Keeper Plate	ASTM A36 Zinc-Galvanized Low-Carbon Steel Sheet	Certificate of Compliance for PO E000575588
f6	3/16" (5) Dia., 5 ⅛" (130) Long Unbent Brass Rod	ASTM B16-00	H#14311-1
g1	¾" (19) Dia. 3x7 IWRC IPS Wire Rope - Lengths as Needed	ASTM A741 Type 1	H#53143418/06 H#53143984/06
g2	Bennett Cable End Fitter - ⅞" (22) Dia.	ASTM A220 Gr. 50005	H#OP5 H#9Q4
g3	Cable Wedge	ASTM A47 Gr. 32510 or A536 Gr. 65-45-12	H#GQ2
g4	⅞"-9 UNC (M22x2.5), 11" (279) Long Threaded Rod	ASTM A449 Type 1 or ASTM A193 Gr. B7	H#121424
g5	Bennett Short ⅞"-9 UNC (M22x2.5) Threaded Turnbuckle	As Supplied	COC PO#6017836
g6	Threaded Load Cell Coupler	-	N/A
g7	50,000-lb (222.4-kN) Load Cell	-	N/A
h1	5/16"-18 UNC (M8x1.25), 2 ½" (64) Long Heavy Hex Bolt	ASTM A449 or equivalent	H#341408026
h2	½"-13 UNC (M14x2), 2" (51) Long Hex Bolt	ASTM A307 Gr. A	H#G1808306003
h3	⅝"-11 UNC (M16x2), 9 ½" (241) Long Heavy Hex Bolt	ASTM A449 or equivalent	H#14206525-4
h4	¾"-10 UNC (M20x2.5), 5 ½" (140) Long Hex Bolt	ASTM A307 Gr. A	R# 14-0343 Structural Bolt Co. Affidavit
h5	5/16"-18 UNC (M8x1.25) Sleeve Nut	ASTM A311 Gr. 1144 Class B	H#892027
h6	½"-13 UNC (M14x2) Hex Nut	ASTM A563A or equivalent	H#17312243-3
h7	⅝"-11 UNC (16x2) Heavy Hex Nut	ASTM A563C or equivalent	H#366128
h8	¾"-10 UNC (M20x2.5) Hex Nut	ASTM A563A or equivalent	R# 14-0343 Structural Bolt Co. Affidavit applicable to the cast in nuts; P#1136715 L#GL18218-3

Table B-3. Bill of Materials, Test Nos. MTP-1 and MTP-2, Cont.

Item No.	Description	Material Specification	Reference
h9	⅞"-9 UNC (M22x2.5) Heavy Hex Nut	ASTM A563C or equivalent	H#6214510204
h10	⅞"-9 UNC (M22x2.5) Heavy Square Nut	ASTM A563DH or equivalent	H#6214510204
h11	¾" (19) Dia. Plain USS Washer	ASTM F844	L#M-SWE0412350-7 P#1133186 C#210161958
h12	½" (13) Dia. Plain SAE Washer	ASTM F844	L#M-SWE0412094-1 P#0136086 C#110246244
h13	3"x2 ⅜"x½" (76x60x13) Rectangular Washer Plate	ASTM A36	H#18120021

04Oct18 19:31 T E S T C E R T I F I C A T E No: MAR 880752

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

P/O No 01026889
Rel
S/O No MAR 358837-022
B/L No MAR 209835-002 Shp 04Oct18
Inv No Inv

Sold To: (1403)
NORFOLK IRON & METAL
P.O. BOX 1129
NORFOLK, NE 68701

Ship To: (1)
NORFOLK IRON & METAL
3001 NORTH VICTORY RD
NORFOLK, NE 68702

Tel: 402-371-1810 Fax: 402 379-5409

CERTIFICATE of ANALYSIS and TESTS Cert. No: MAR 880752
01Oct18

Part No 00949
TUBING A500 GRADE B(C)
3" X 2" X 1/8" X 20'

		Pcs	Wgt
		250	19,500

Heat Number	Tag No	Pcs	Wgt
1285260	250174 YLD=59320/TEN=67290/ELG=25.2	25	1,950
1285260	250175	25	1,950
1285260	250176	25	1,950
1285260	250177	25	1,950
1285260	250178	25	1,950
1285260	250179	25	1,950
1285260	250180	25	1,950
1285260	250181	25	1,950
1285260	250182	25	1,950
1285260	250183	25	1,950

Heat Number *** Chemical Analysis ***
1285260 C=0.0600 Mn=0.4900 P=0.0080 S=0.0004 Si=0.0300 Al=0.0300
Cu=0.0700 Cr=0.0400 Mo=0.0100 V=0.0030 Ni=0.0300 Nb=0.0020
Cb=0.0020 Sn=0.0020 N=0.0080 B=0.0000 Ti=0.0020 Sb=0.0000
Ca=0.0030
MELTED AND MANUFACTURED IN THE USA

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

CURRENT STANDARDS:
A252-10
A500/A500M-18
A513/A513M-15
ASTM A53/A53M-12 | ASME SA-53/SA-53M-13
A847/A847M-14
A1085/A1085M-15

Page: 1 ....Continued

Figure B-1. HSS3x2x⅛ Steel Post, Test Nos. MTP-1 and MTP-2 (Item No. a1)

040ct18 19:31 T E S T C E R T I F I C A T E No: MAR 880752

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

P/O No 01026889
Rel
S/O No MAR 358837-022
B/L No MAR 209835-002 Shp 04Oct18
Inv No Inv

Sold To: (1403)
NORFOLK IRON & METAL
P.O. BOX 1129
NORFOLK, NE 68701

Ship To: (1)
NORFOLK IRON & METAL
3001 NORTH VICTORY RD
NORFOLK, NE 68702

Tel: 402-371-1810 Fax: 402 379-5409

CERTIFICATE of ANALYSIS and TESTS Cert. No: MAR 880752
01Oct18

Page: 2 .... Last

Figure B-2. HSS3x2x⅛ Steel Post, Test Nos. MTP-1 and MTP-2 (Item No. a1)

ESSAR STEEL

ESSAR STEEL ALGOMA INC.,105 West Street, Sault Ste. Marie,Ontario, Canada P6A 7B4

SO No.,Item & Date.:	8062235 000010 2018/04/06	Shipment No.& Date.:	1000279857 2018/04/09	TC No., Date & Time:	ESA-474806 2018/04/13 - 09:48:13
Sold to Customer Name and Address:		Ship to Customer Name and Address:		Customer PO NO./Item:	P80212BL911 / 1
STATE STEEL SUPPLY CO.		STATE STEEL OF OMAHA		BOL NO.:	1000279857
COURT STREET 214		CENTECH ROAD 13433		Cust.Part No.:	
SIOUX CITY,Iowa,USA		OMAHA,Nebraska,USA		Carrier:	CN (USD FUNDS) - FURX 382810
51102		68138			

Customer Specification: HR STEEL SHEET HSLA DQ / DS ASTM A1011 HSLAS-F GR 50 (2017) MOD CU .10 MAX, SI .050 MAX Top Semi Critical Surface Standard Shape Gauge type MIN - 0/+ 0.0067 "

Supplementary Instructions: Test Cert 1:tpx@StateSteel.com

Insp T/R: Test Report As Per Spec

Cust Use: VETTED RESALE

ESSAR STEEL ALGOMA INC. HEREBY CERTIFIES THAT THE MATERIAL HEREIN DESCRIBED WAS MADE AND TESTED IN ACCORDANCE WITH THE RULES OF THE SPECIFICATION SHOWN. ALL RESULTS ARE RETAINED IN ACCORDANCE WITH THE COMPANY'S STANDARD RECORD KEEPING PRACTICES.
THIS MILL TEST REPORT MAY NOT BE REPRODUCED EXCEPT IN FULL WITHOUT WRITTEN APPROVAL OF ESSAR STEEL ALGOMA INC. IF YOU RECEIVE THIS DOCUMENT AND ARE NOT THE INTENDED RECEIVER, PLEASE CALL (705)945-4095 FOR INSTRUCTIONS ON METHOD OF DISPOSAL OF DOCUMENT. THIS TEST REPORT HAS BEEN GENERATED BY A COMPUTERIZED SYSTEM AND IS VALID WITHOUT A PHYSICAL SIGNATURE.

MEETS EN 10204 3.1
ISO QUALITY AND ENVIRONMENTAL CERTIFICATES AVAILABLE AT WWW.ALGOMA.COM

ALL HEATS FULLY KILLED.
HEATS INDICATED WITH (*) FINE GRAINED.
HEATS INDICATED WITH (+) Made in Canada for NAFTA duty preference and NAFTA marking purposes

Dimensions (T x W x L)	Batch No.	Heat No-MS	Quantity	Pcs
0.0970 " x 48.000 "	TBW3054	8196D4-02	42,590 LB	1

CHEMICAL PROPERTIES

Heat No. (wt%)	C	Mn	P	S	Si	Cr	Ni	Cu	Mo	Al	Nb	V	Ti	N	Ca
+ 8196D4*	0.06	0.45	0.008	0.002	0.018	0.03	0.03	0.04	0.00	0.026	0.005	0.036	0.000	0.0110	0.00380

MECHANICAL PROPERTIES

Tensile Tests

Heat No.	Batch No.	SRCE	LAB	GAUGE	COND	METH	DIR	LOC	YIELD(KSI)	TENSILE(KSI)	EL SCALE	ELONG(%)
8196D4		DSPC	ALG	0.0970	AR	2	L	F	59.0	70.0	2"	29

KASHIF REHMAN
MANAGER METALLURGICAL SERVICES

WARNING THE TEST RESULTS AND VALUES REPORTED HEREIN INDICATE ONLY THAT (1) THE PARTICULAR STEEL FOR WHICH THIS CERTIFICATE IS ISSUED MEETS THE MINIMUM SPECIFIED YIELD STRENGTH AND (2) THE ANALYSIS AND PHYSICAL PROPERTIES OF SUCH STEEL ARE IN CONFORMANCE WITH THE REQUIREMENTS OF THE SPECIFICATION INDICATED. THE RESULTS OR VALUES REPORTED HEREIN CAN NOT BE USED TO QUALIFY THE STEEL FOR ANY SPECIFICATION OTHER THAN THE ONE INDICATED AND CAN NOT BE RELIED UPON FOR ANY PURPOSE (INCLUDING DESIGN OR CALCULATIONS) AS REPRESENTING THE ACTUAL STRENGTH OF SUCH STEEL.

Date:2018/04/13 Time:10:35:31 Page no:1 of 1

P80212BL91115

8196D4

Figure B-3. Tabbed Bracket, Test Nos. MTP-1 and MTP-2 (Item No. a2)

Customer Name	Customer PO#	Shipper No	Heat Number
UNL-MwRSF	Paid by visa	1336131	14311-1

CERTIFICATE OF TEST

Customer COPPER AND BRASS SALES INC.
Invoice No 130701K18
P.O. No 5400402982
Mill & Country Melting DAECHANG, KOREA

No 2018-06-26-044-6
Date 06/26/18
Commodity FREE CUTTING BRASS C36000 H02 (HALF HARD), 12 FT
Spec PER ASTM B 16/16M REV 2010, ROHS COMPLIANT

Job No.	18-04-	Size			Quantity		Temper	Remarks	B/D No.	Mat No.	Inspection Result	
Item No.	Lot No.					Wt., Lbs	-	-	-	-	Dimension	Surface
0010	14473-1	7/16"(+/-0.003) DPS, HEXAGON, S.C., STRES				1,949	H02	S/RELIEF	-	CUHEX00097	GOOD	GOOD
0020	14325-1	3/4"(+/-0.004) DPS, HEXAGON, S.C., STRESS				4,042	H02	S/RELIEF	-	CUHEX00033	GOOD	GOOD
0030	14331-1	7/8"(+/-0.004) DPS, HEXAGON, S.C., STRESS				5,034	H02	S/RELIEF	-	CUHEX00057	GOOD	GOOD
0040	15249-1	1-5/16"(+/-0.005) DPS, HEXAGON, S.C., STRE				2,104	H02	S/RELIEF	-	CUHEX00045	GOOD	GOOD
0050	14311-1	3/16"(+/-0.0015) DIA, ROUND, W/PKG				507	H02	-	-	CURD00477	GOOD	GOOD
0060	14316-1	1/4"(+/-0.0015) DIA, ROUND, W/PKG				1,993	H02	-	-	CURD00527	GOOD	GOOD
0070	15069-1	5/16"(+/-0.0015) DIA, ROUND, W/PKG				2,010	H02	-	-	CURD00289	GOOD	GOOD
0080	14727-1	3/8"(+/-0.0015) DIA, ROUND				1,920	H02	-	-	CURD00231	GOOD	GOOD
0090	15089-1	1/2"(+/-0.0015) DIA, ROUND				2,899	H02	-	-	CURD00895	GOOD	GOOD
Chemical/Physical	Element	Cu	Pb	Fe	-	-	Zn	Ammonia	T.S., Ksi	Y.S., Ksi	E/L (%)	HRB
Composition, %	Spec	60 - 63	2.5 - 3.0	0.35 max	-	-	Rem.	Vapor	-	-	-	-
0010	14473-1	60.4722	2.7158	0.1157	-	-	Rem.	GOOD	60	46	21.2	72.7
0020	14325-1	60.2720	2.7848	0.1390	-	-	Rem.	GOOD	58	41	35.7	69.9
0030	14331-1	60.2471	2.7326	0.1396	-	-	Rem.	GOOD	58	35	37.4	59.9
0040	15249-1	60.0822	2.8023	0.1401	-	-	Rem.	GOOD	53	28	44.3	53.4
0050	14311-1	60.4047	2.7215	0.1374	-	-	Rem.	GOOD	72	68	7.8	83.4
0060	14316-1	60.5118	2.6278	0.1572	-	-	Rem.	GOOD	70	60	14.6	78.4
0070	15069-1	60.4049	2.6061	0.1323	-	-	Rem.	GOOD	65	60	17.2	75.1
0080	14727-1	60.6078	2.6899	0.1231	-	-	Rem.	GOOD	60	53	10.4	75.6
0090	15089-1	60.5141	2.7013	0.1112	-	-	Rem.	GOOD	63	50	18.9	74.2

MERCURY FREE

WE CERTIFY THAT ABOVE INFORMATION IS TRUE AND OUR MATERIAL MEETS THE ABOVE ASTM SPECIFICATIONS.

SIGNED FOR DAE CHANG IND.

Lloyds Pacific International, Inc.

```
From: ThyssenKrupp Materials NA
Cust. ONLINE METALS - TX          Del.: 2406163743
CstAr 4345                CstOr 101990
Wgt.: 36.563 LB           Date  08/14/2018
```

Figure B-4. $^{3}/_{16}$-in. Dia. Brass Cable Clip, Brass Keeper Rod, 2nd Brass Rod, Test Nos. MTP-1 and MTP-2 (Item Nos. a3, d7, and f6)

benesch
engineers · scientists · planners

LINCOLN OFFICE
825 "J" Street
Lincoln, NE 68508
Phone: (402) 479-2200
Fax: (402) 479-2276

COMPRESSION TEST OF CYLINDRICAL CONCRETE SPECIMENS - 6x12

ASTM Designation: C 39

Client Name: Midwest Roadside Safety Facility
Date 19-Mar-14
Project Name: Midwest 4 - Cable Barrier System
Placement Location: Cast 3-12-2014, A, B.

Mix Designation:
Required Strength: 4000

Laboratory Test Data

Laboratory Identification	Field Identification	Date Cast	Date Received	Date Tested	Days Cured in Field	Days Cured in Laboratory	Age of Test, Days	Length of Specimen, in.	Diameter of Specimen, in.	Cross-Sectional Area, sq.in.	Maximum Load, lbf	Compressive Strength, psi.	Required Strength, psi.	Type of Fracture	ASTM Practice for Capping Specimen
CBS- 1	A	3/12/2014	3/19/2014	3/19/2014	7	0	7	12	5.99	28.18	126,980	4,510		5	C 1231
CBS- 2	B	3/12/2014	3/19/2014	3/19/2014	7	0	7	12	5.99	28.18	136,850	4,860		5	C 1231

1 cc: Midwest Roadside Safety Facility

MWP-1 Concrete Anchors
R# 14-0353

Remarks:

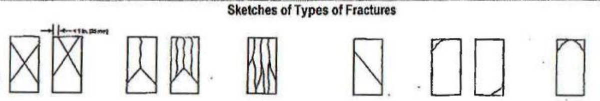
All concrete test data in this report was produced by Benesch personnel using ASTM Standard Methods and Practices unless otherwise noted.

Test results presented relate only to the concrete sampled by Benesch personnel as referenced above.

This report shall not be reproduced except in full, without the written approval of Alfred Benesch & Company.

Report Number 2147365937
Page 1

Sketches of Types of Fractures



Type 1: Reasonably well-formed cones on both ends, less than 1 in. [25 mm] of cracking through caps
Type 2: Well-formed cone on one end, vertical cracks running through caps, no well-defined cone on other end
Type 3: Columnar vertical cracking through both ends, no well-formed cones
Type 4: Diagonal fracture with no cracking through ends; tap with hammer to distinguish from Type 1
Type 5: Side fractures at top or bottom (occur commonly with unbonded caps)
Type 6: Similar to Type 5 but end of cylinder is pointed

ALFRED BENESCH & COMPANY
CONSTRUCTION MATERIALS LABORATORY

By__________
Brant Wells, Coordinator

Figure B-5. Concrete Anchors, Test Nos. MTP-1 and MTP-2 (Item Nos. b1 and c1)

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

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

PLANT	MIX CODE	YARDS	TRUCK	DRIVER	DESTINATION	CLASS	TIME	DATE	TICKET
04	25513000	3.00	0135	056			10:23AM	03/12/14	4156617

CUSTOMER	JOB	CUSTOMER NAME	TAX CODE	PARTIAL	NIGHT R.	LOADS
00003		CIA---MIDWEST ROADSIDE SAFTEY				1

DELIVERY ADDRESS	SPECIAL INSTRUCTIONS	P.O. NUMBER
4800 NW. 35TH	N OF N GOODYEAR HANGER	402-450-6250

LOAD QUANTITY	CUMULATIVE QUANTITY	ORDERED QUANTITY	PRODUCT CODE	PRODUCT DESCRIPTION		UNIT PRICE	AMOUNT
3.00	3.00	3.00	25513000	L5500 (HE) .40	4.00	104.91	314.73
				MINIMUM HAUL			40.00
				WINTER SERVICE			12.00
							366.73

TER ADDED ON JOB AT CUSTOMER'S REQUEST ____ GAL   RECEIVED BY ____

SUBTOTAL 366.73
TAX
TOTAL 366.73

TRUCK	USER LOGIN	DISP TICKET NUM	TICKET NUM	TICKET ID	TIME	DATE
0135	USER	4156617	176440	191052	10:23	03/12/2014

LOAD SIZE	MIX CODE	SEQ	LOAD ID
3.00 yd	25513000	W	19304I

MATERIAL	SOURCE	DESIGN QTY	REQUIRED	BATCHED	VAR	% VAR	%MOISTURE	ACTUAL WAT
S47B	47B GRAVEL	1915.0 lb	5825.4 lb	5800.0	-25.4	-.44%	1.40 M	9.60 gl
L47B	47B ROCK	833.0 lb	2509.0 lb	2500.0	-9.0	-.36%	0.40 M	1.19 gl
CEM1	CEMENT TYP	752.0 lb	2256.0 lb	2245.0	-11.0	-.49%		
LRWR	POZZ 322N	23.0 oz	69.0 oz	69.0	0.0	0.00%		
AIR	MB-AE 90 A	3.0 oz	9.0 oz	9.0	0.0	0.00%		
WATER	WATER	34.0 gl	94.2 gl	94.9	0.7	0.74%		94.91 gl
WATER2	RECYCLE WA	0.0 gl *	0.0 gl	0.0	0.0	0.00%		

NON-SIMULATED NUM BATCHES: 1
LOAD TOTAL: 11342 lb DESIGN W/C: 0.377 WATER/CEMENT: 0.393A DESIGN WATER: 102.0 gl ACTUAL WATER: 105.7 gl
SLUMP: 4.00 "0 WATER IN TRUCK: 0.0 gl

ORIGINAL

Figure B-6. Concrete Anchors, Test Nos. MTP-1 and MTP-2 (Item Nos. b1 and c1)

EVRAZ | ROCKY MOUNTAIN STEEL
A DIVISION OF EVRAZ INC. NA

P.O. Box 316
Pueblo, CO 81002 USA

MATERIAL TEST REPORT

Date Printed: 21-MAR-12

Date Shipped: 21-MAR-12 **Product:** DEF 13mm **Specification:** ASTM-A-615M09b GR 420/ASTM-A-706M09b
FWIP: 52815348 **Customer:** CONCRETE INDUSTRIES INC **Cust. PO:** 93051

CHEMICAL ANALYSIS (Heat chemistry entered 03/05/12)

Heat Number	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al	V	B	Cb	Sn	N	Ti
111485	0.27	1.23	0.012	0.024	0.24	0.31	0.13	0.10	0.044		0.046	0.0003		0.014	0.0108	0.001

Carbon Equivalent = 0.494

MECHANICAL PROPERTIES

Heat Number	Sample No.		Yield (Psi)	Ultimate (Psi)	Elongation (%)	Reduction (%)	Bend	Wt/ft
111485	01		74160	103330	14.4		ok	0.664
		(MPa)	511.3	712.4				
111485	02		74037	102730	15.6		ok	0.663
		(MPa)	510.5	708.3				

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 B-7. #4 Hoop Bar, Test Nos. MTP-1 and MTP-2 (Item No. b2)

GERDAU

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

CERTIFIED MATERIAL TEST REPORT

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE
NEBCO INC STEEL DIVISION HAVELOCK,NE 68529 USA	CONCRETE INDUSTRIES INC LINCOLN,NE 68529-0529 USA	60/420	REBAR ROUND / #11 (36MM)

LENGTH	WEIGHT	HEAT / BATCH
60'00"	33,790 LB	5819611302

SALES ORDER	SPECIFICATION / DATE or REVISION
126287/000020	ASTM A615/A615M-09B

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
95510	1327-0000015536	08/01/2012

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.44	0.87	0.012	0.022	0.23	0.24	0.07	0.09	0.027	0.007	0.025	0.021	0.002

CHEMICAL COMPOSITION

CEA706 %
0.60

MECHANICAL PROPERTIES

YS KSI	YS MPa	UTS MPa	G/L Inch	G/L mm	Elong. %
73.4	506	730	8.000	200.0	12.90

MECHANICAL PROPERTIES

Bend tes
OK

COMMENTS / NOTES

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. We certify that these data are correct and in compliance with specified requirements. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

TOM HARRINGTON
QUALITY ASSURANCE MGR.

Figure B-8. #11 Bar, Test Nos. MTP-1 and MTP-2 (Item No. b3)

'2012/THU 02:08 PM TSA MANUFACTURING FAX No. 4028953297 P. 0

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 B-9. J-Hook Anchor, Test Nos. MTP-1 and MTP-2 (Item No. b4)

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.

Mark F Espamer

Quality Assurance Department

Figure B-10. #3 Hoop Bar, Test Nos. MTP-1 and MTP-2 (Item No. c3)

SOLD TO: ADELPHIA METALS I LLC
411 MAIN ST E
NEW PRAGUE, MN 56071-

SHIP TO: ADELPHIA METALS-CUST PU
N/A
JEWETT, TX 75846-

NUCOR
NUCOR CORPORATION
NUCOR STEEL TEXAS

CERTIFIED MILL TEST REPORT

Page: 1

Ship from:
Nucor Steel - Texas
8812 Hwy 79 W
JEWETT, TX 75846
800-527-6445

Date: 25-Jul-2012
B.L. Number: 611543
Load Number: 217850

Material Safety Data Sheets are available at www.nucorbar.com or by contacting your inside sales representative.

NBMG-08 January 1, 2012

LOT # / HEAT #	DESCRIPTION	PHYSICAL TESTS					CHEMICAL TESTS						
		YIELD P.S.I.	TENSILE P.S.I.	ELONG % IN 8"	BEND	WT% / DEF	C / Ni	Mn / Cr	P / Mo	S / V	Si / Cb	Cu / Sn	C.E.
PO# =>	804132												
JW1210548001	Nucor Steel - Texas	77,800	111,200	12.0%			.38	.86	.012	.026	.14	.38	.56
JW12105480	10/#3 Rebar	536MPa	767MPa				.17	.18	.045	.015	.002		
	40' A615M GR 420 (Gr60)												
	ASTM A615/A615M-12 GR 60[420]												
	AASHTO M31-07												

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.
1.) Weld repair was not performed on this material.
2.) Melted and Manufactured in the United States.
3.) Mercury, Radium, or Alpha source materials in any form have not been used in the production of this material.

QUALITY ASSURANCE: Nathan Stewart

Figure B-11. #3 Bar, Test Nos. MTP-1 and MTP-2 (Item No. c4)

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 YLD=69070/TEN=81790/ELG=23.9	20	8,408

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 B-12. Foundation Tube, Test Nos. MTP-1 and MTP-2 (Item No. c5)

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 10/08/2018
TIME 05:54:34
USER WF-BATCH

SOLD TO
66031-1127

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

Order	Material No.	Description	Quantity	Weight	Customer Part	Customer PO	Ship Date
40316704-0010	701672120TM	1/2 72 X 120 A36 TEMPERPASS STPMLPL	4	4,900.800			10/05/2018

Chemical Analysis

Heat No. 18120021 Vendor BIG RIVER STEEL LLC DOMESTIC Mill BIG RIVER STEEL LLC **Melted and Manufactured in the USA**
Produced from Coil

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.2100	0.8400	0.0090	0.0020	0.0200	0.0400	0.0500	0.0120	0.0001	0.1000	0.0280	0.0010	0.0030	0.0010	0.0075	0.0045

Mechanical / Physical Properties

Mill Coil No. 18120021-05

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
73100.000	48200.000	34.80			0	NA			
68400.000	42800.000	33.80			0	NA			

Batch 0005501662 4 EA 4,900.800 LB

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

Figure B-13. ½-in. (13-mm) Plate, Test Nos. MTP-1 and MTP-2 (Item Nos. d1, d3, d4, d5, d6, e1, e2, and h13)

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

METALLURGICAL TEST REPORT

PAGE	1 of 1
DATE	05/18/2018
TIME	20:21:00
USER	WF-BATCH

SOLD TO

SHIP TO
13713
Warehouse 0020
1050 Fort Gibson Rd
CATOOSA OK 74015-3033

Order	Material No.	Description	Quantity	Weight	Customer Part	Customer PO	Ship Date
40308637-0040	701272120TM	3/8 72 X 120 A36 TEMPERPASS STPMLPL	6	5,515.200			05/17/2018

Chemical Analysis

Heat No. 18048521 Vendor BIG RIVER STEEL LLC DOMESTIC Mill BIG RIVER STEEL LLC **Melted and Manufactured in the USA**
Produced from Coil

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.2200	0.8500	0.0160	0.0040	0.0200	0.0400	0.0600	0.0110	0.0001	0.1100	0.0260	0.0010	0.0040	0.0020	0.0067	0.0037

Mechanical / Physical Properties

Mill Coil No. 18048521-02

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
70500.000	44400.000	36.00			0	NA			
68800.000	43800.000	33.60			0	NA			
67600.000	42700.000	35.60			0	NA			
71800.000	48000.000	35.80			0	NA			

Batch 0005300162 6 EA 5,515.200 LB
Batch 0005300158 11 EA 10,111.200 LB
Batch 0005300146 11 EA 10,111.200 LB
Batch 0005300160 11 EA 10,111.200 LB
Batch 0005300147 11 EA 10,111.200 LB

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

Figure B-14. Anchor Bracket Plate, Test Nos. MTP-1 and MTP-2 (Item No. d2)

SOUTHLAND TUBE INCORPORATED
a NUCOR company

3525 Richard Arrington, Jr., Blvd. N.
Birmingham, Alabama 35234
Phone: (205) 251-1884
Lab Fax (205) 421-4561
Lab@SouthlandTube.com

TEST REPORT

Customer Name: STEEL & PIPE SUPPLY

Customer PO No.: 4500284274

Spec/Grade:	A500-13 Grade B/C	Heat No.:	NG0971
Description:	CARBON STEEL TUBING	Print Date:	3/27/2017
Size/Length:	1-1/4" X 1-1/4" X 3/16" 24'	Nominal Thickness:	0.188

Carbon (C):	**0.0600**	Tin (Sn):	**0.0060**	Vanadium (V):	**0.0020**
Manganese (Mn):	**0.3900**	Nickel (Ni):	**0.0300**	Columbium (Cb):	**0.0030**
Phosphorus (P):	**0.0090**	Chromium (Cr):	**0.0400**	Titanium (Ti):	**0.0010**
Sulphur (S):	**0.0040**	Molybdenum (Mo):	**0.0100**	Boron (B):	**0.0001**
Silicon (Si):	**0.0200**	Aluminum (Al):	**0.0260**	Calcium (Ca):	**0.0031**
Copper (Cu):	**0.0900**	Nitrogen (N):	**0.0055**	Carbon Equiv. (CE):	0.1434

Sample Number	**Sample Date**	**Tensile (psi)**	**Yield (psi)**	**Elongation (%)**
SLF55910	2/27/2017	80,300	74,700	23.90

We hereby certify that the above figures are correct as contained in the records of this company. Testing, where it is performed, is performed according to applicable standards (Yield Strength determined using 0.2% offset method and Elongation is measured over a 2" gauge length). Finished goods that require destructive testing by either flattening or flaring to meet the requirements of the standard to which they are certified have been destructively tested in accordance with the pertinent standard. Further, this certification is compliant with the EN10204:2004 Standard for Type 3.1 Inspection Documents.

Ron Lowery

Laboratory Manager
Southland Tube Incorporated

Melted & Manufactured in the U.S.A.

STI Pickup No.: 03MJ009 STI Order No.: 00428923 STI Item No.: 1.25S724

Figure B-15. 1¼-in. x 1¼-in. x $^3/_{16}$-in. (32-mm x 32-mm x 5-mm), Square Tube, Test Nos. MTP-1 and MTP-2 (Item Nos. e3 and e4)

PO# 210163546
Part# 45506

JIANGYIN EAGLE BRAND STEEL WIRE ROPES CO., LTD

MILL TEST CERTIFICATE

We hereby guarantee that the laboratory tests and inspection results of steel wire rope meets dimension and strength requirements of the specification as per contract:

Customer INDUSCO GROUP　　**Date** 4-30-2018
Reel No. 01-120　　**N.weight** 2850.20KGS

TYPE& GRADE

Diameter	1/4"	**Construction**	7*19
Grade	C1070	**Order No.**	P266304
Finish	HOT GALV	**Lay**	RRL
Length	500FT/REEL	Certificate No.	18Eagle061
Lubrication:	DRY	**Specification:**	RR-W-410/ASTM-A-1023

TEST RESULT

A. Rope

Nominal Diameter of Rope :	0.2500 INCH
Actual Diameter of Rope :	0.2532 INCH
Actual Lay Length of Rope :	1.6142 INCH
Spec Breacking Load :	7000.0 LBS
Actual Breaking Load :	7200.0 LBS
Preforming Test :	GOOD

B. Wires

Tensile Strength Test :	SATISFACTORY
Torsion :	SATISFACTORY
Actual Zinc Coating :	38.0g/m2
Wrapping & Unwrapping Test :	SATISFACTORY
Uniformity of Coating :	SATISFACTORY

CHEMICAL ANALYSIS OF WIRE ROD

Charge No	C.(%)	Si(%)	Mn(%)	P(%)	S(%)
	0.59-0.62	0.19-0.22	0.55-0.57	<0. 012	<0. 005

RoHS compliant, mercury fre

Remarks: ______

Figure B-16. ¼-in. (6-mm) Dia. 7x19 Aircraft Retaining Cable, Test Nos. MTP-1 and MTP-2 (Item No. e5)

GERDAU

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

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
STEEL & PIPE SUPPLY CO INC 401 NEW CENTURY PKWY NEW CENTURY,KS 66031-1127 USA	STEEL & PIPE SUPPLY CO INC MANHATTAN,KS 66505-1688 USA	A36/A572-50	Standard I-Beam / 3 X 5.7# / 75 X 8.5	0000112317

LENGTH	WEIGHT	HEAT / BATCH
40'00"	8,208 LB	59074590/02

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
5055450/000030	000000000035357040	ASME SA36 ASTM A572-15 ASTM A6-14, A36-14 ASTM A709-15

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
4500286888	1327-0000234797	05/04/2017

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.09	0.88	0.017	0.023	0.21	0.34	0.09	0.19	0.011	0.007	0.002	0.014	0.006

CHEMICAL COMPOSITION

CEqyA6 %
0.31

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	G/L Inch	G/L mm
58629	71644	404	494	8.000	200.0
60289	69610	416	480	8.000	200.0

MECHANICAL PROPERTIES

Elong. %
23.80
23.50

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 769-1014 Email: Bhaskar.Yalamanchili@gerdau.com

TOM HARRINGTON
QUALITY ASSURANCE MGR.
Phone: 972-779-1872 Email: Tommy.Harrington@gerdau.com

Figure B-17. S3x5.7 Post, Test Nos. MTP-1 and MTP-2 (Item Nos. f1 and f3)

SSAB

Test Certificate

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

Form TC1: Revision 2: Date 23 Apr 2014

Customer: OLYMPIC STEEL - IOWA 6425 STATE STREET BETTENDORF IA 52722	**Customer P.O.No.:** 320525 **Product Description:** ASTM A572-50/M345(15)/A709-50/M345(17) **Size:** 0.375 X 96.00 X 240.0 (IN)	**Mill Order No.** 41-522290-01 **Ship Date:** 05 Dec 17 **Cert Date:** 05 Dec17	**Shipping Manifest:** MT332155 **Cert No:** 061679283 (Page 1 of 1)

Heat Id	Piece Id	Piece Dimensions	Tst Loc	YS (KSI)	UTS (KSI)	%RA	Elong % 2in 8in	Tst Dir	Hardness	Abs. Energy(FTLB) 1 2 3 Avg	% Shear 1 2 3 Avg	Tst Tmp	Tst Dir	Tst Siz (mm)	BDWTT Tmp %Shr
A7K273	D48	0.371 (DISCRT)	L	62	81		27	T							

Chemical Analysis

Heat Id	C	Mn	P	S	Si	Tot Al	Cu	Ni	Cr	Mo	Cb	V	Ti	ORGN
A7K273	.17	1.09	.007	.001	.05	.029	.28	.14	.10	.04	.001	.034	.006	USA

KILLED STEEL
MERCURY IS NOT A METALLURGICAL COMPONENT OF THE STEEL AND NO MERCURY WAS INTENTIONALLY ADDED DURING THE MANUFACTURE OF THIS PRODUCT.
MTR EN 10204:2004 INSPECTION CERTIFICATE 3.1 COMPLIANT
100% MELTED AND MANUFACTURED IN THE USA.
PRODUCTS SHIPPED:
A7K273 D48 PCES: 19, LBS: 46550

(P) Cust Part #: 106004-17

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

Brian Wales
SENIOR METALLURGIST - PRODUCT

Figure B-18. Base Plate, Test Nos. MTP-1 and MTP-2 (Item No. f2)

SSAB

Preliminary Test Certificate

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

Form TC1: Revision 3: Date 7 Feb 2018

Customer: STEEL & PIPE SUPPLY P.O. BOX 1688 MANHATTAN KS 66502	Customer P.O. No.: 4500311075	Mill Order No.: 41-545121-04	Shipping Manifest : MT351864
	Product Description: ASTM A572-50/M345(18)/A709-50/M345(17)	Ship Date: 18 Jul 18 Cert Date: 18 Jul 18	Cert No: 061721304 (Page 1 of 1)
	Size: 0.500 X 96.00 X 240.0 (IN)		

Tested Pieces				Tensiles							Charpy Impact Tests					
Heat Id	Piece Id	Tested Thickness	Tst Loc	YS (KSI)	UTS (KSI)	%RA	Elong % 2in	Elong % 8in	Tst Dir	Hardness	Abs. Energy(FTLB) 1 2 3 Avg	% Shear 1 2 3 Avg	Tst Tmp	Tst Dir	Tst Siz (mm)	BDWTT Tmp %Shr
A8G080	A02	0.499 (DISCRT)	L	53	67		37		T							
A8G844	D13	0.498 (DISCRT)	L	64	74			35	T							

Chemical Analysis

Heat Id	C	Mn	P	S	Si	Tot Al	Cu	Ni	Cr	Mo	Cb	V	Ti	ORGN
A8G080	.05	1.20	.017	.002	.16	.027	.29	.10	.14	.03	.001	.054	.001	USA
A8G844	.05	1.28	.013	.003	.14	.028	.33	.12	.10	.03	.016	.042	.001	USA

KILLED STEEL
MERCURY IS NOT A METALLURGICAL COMPONENT OF THE STEEL AND NO MERCURY WAS INTENTIONALLY ADDED DURING THE MANUFACTURE OF THIS PRODUCT.
MTR EN 10204:2004 INSPECTION CERTIFICATE 3.1 COMPLIANT
100% MELTED AND MANUFACTURED IN THE USA.
PRODUCTS SHIPPED:
A8G844 D13 PCES: 8, LBS: 26136 A8G080 A02 PCES: 6, LBS: 19602

(II) Cust Part # : 721696240A2

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

SENIOR METALLURGIST - PRODUCT

Figure B-19. Cable Hanger, Test Nos. MTP-1 and MTP-2 (Item No. f4)

McMASTER-CARR®

Certificate of Compliance

600 N County Line Rd
Elmhurst IL 60126-2081
630-600-3600
chi.sales@mcmaster.com

University of Nebraska
Midwest Roadside Safety Facility
M W R S F
4630 Nw 36TH St
Lincoln NE 68524-1802
Attention: Shaun M Tighe
Midwest Roadside Safety Facility

Purchase Order
E000575588

Order Placed By
Shaun M Tighe

McMaster-Carr Number
3074230-01

Page 1 of 1

Line		Product	Ordered	Shipped
1	**8943K23**	Zinc-Galvanized Low-Carbon Steel Sheet, 48" x 48" x 0.0150"	**1 Each**	**1**

Certificate of compliance

This is to certify that the above items were supplied in accordance with the description and as illustrated in the catalog. Your order is subject only to our terms and conditions, available at www.mcmaster.com or from our Sales Department.

Sarah Weinberg
Compliance Manager

Figure B-20. Keeper Plate, Test Nos. MTP-1 and MTP-2 (Item No. f5)

GERDAU

CERTIFIED MATERIAL TEST REPORT

Page 1/1

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

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
BEKAERT CORPORATION 2020 RIVERFRONT RD VAN BUREN,AR 72956-6319 USA	BEKAERT CORPORATION 1395 S MARIETTA PKWY BLDG 500 MARIETTA,GA 30067-4440 USA	BVB-GR	Wire Rod / 7/32"	0000000000

LENGTH	WEIGHT	HEAT / BATCH
	17,156 LB	53143418/06

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
5056501/000050	1101120	

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
2010603051-Z1	1320-0000062018	05/19/2017

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	N %
0.6020	0.79	0.014	0.008	0.20	0.08	0.04	0.08	0.012	0.004	0.004	0.0072

MECHANICAL PROPERTIES

Std.Dev. PSI	R/A Avg %	UTS PSI	UTS MPa
0	46.5	155500	1072

COMMENTS / NOTES

NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.

BEKAERT SAP NO. 1025346

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 769-1014 Email: Bhaskar.Yalamanchili@gerdau.com

LEONARDO RADICCHI
QUALITY ASSURANCE MGR.
Phone: 409-769-1086 Email: Leonardo.Cunha@gerdau.com

Figure B-21. ¾-in. (19-mm) Dia. 3x7 IWRC IPS Wire Rope, Test Nos. MTP-1 and MTP-2 (Item No. g1)

CERTIFIED MATERIAL TEST REPORT

Page 1/1

GERDAU

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

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
BEKAERT CORPORATION 2020 RIVERFRONT RD VAN BUREN,AR 72956-6319 USA	BEKAERT CORPORATION 1395 S MARIETTA PKWY BLDG 500 MARIETTA,GA 30067-4440 USA	BVB-GR	Wire Rod / 7/32"	0000000000

LENGTH	WEIGHT	HEAT / BATCH
	42,974 LB	53143984/06

SALES ORDER	CUSTOMER MATERIAL Nº	SPECIFICATION / DATE or REVISION
4986227/000030	1101120	

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
2010600627-A	1320-0000063639	06/26/2017

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	N %
0.6600	0.81	0.019	0.007	0.18	0.13	0.01	0.10	0.018	0.006	0.005	0.0062

MECHANICAL PROPERTIES

Std.Dev. PSI	R/A Avg %	UTS PSI	UTS MPa
1961	51.6	159616	1101

COMMENTS / NOTES

NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.

BEKAERT SAP NO. 1025346

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 769-1014 Email: Bhaskar.Yalamanchili@gerdau.com

LEONARDO RADICCHI
QUALITY ASSURANCE MGR.
Phone: 409-769-1086 Email: Leonardo.Cunha@gerdau.com

Figure B-22. ¾-in. (19-mm) Dia. 3x7 IWRC IPS Wire Rope, Test Nos. MTP-1 and MTP-2 (Item No. g1)

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
Yield Str. PSI	45032	Silicon	2.86
Elongation	22	Manganese	.34
		Sulfur	.016
		Phosphorus	.030
		Chrome	.025
		Magnesium	.019
		Copper	.052

PHYSICAL PROPERTIES

Brinell Hardness 163

PCS SHIPPED 20

1 of 1

DATE SHIPPED 8-30-07

Quality Assurance Representative

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

Figure B-23. Bennett Cable End Fitter, Test Nos. MTP-1 and MTP-2 (Item No. g2)

09/27/2007 10:02 3156893999 BENNETT BOLT WORKS PAGE 05
SEP-26-2007 10:13AM FROM-Buck Co. HR 717-284-4321 T-131 P.003/004 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 11/14/06 Form Number CERT-7C REV. A

CUSTOMER: Bennett Bolt Works

ORDER NUMBER 75410

PATTERN NUMBER CGBBHT 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. Melted & Manufactured in the USA.

Type Material: Malleable Iron

Specifications: ASTM-A47

Grade or Class: 32510

Heat Number: OP5

MECHANICAL PROPERTIES		CHEMICAL ANALYSIS	
Tensile Str. PSI	57,112	Total Carbon	2.53
Yield Str. PSI	35,584	Silicon	1.57
Elongation	15	Manganese	.33
		Sulfur	.130
		Phosphorus	.015
		Chrome	.0310
		Magnesium	.001
		Copper	.115

PHYSICAL PROPERTIES

Brinell Hardness 121

PCS SHIPPED 105

DATE SHIPPED 11/14/06

1 of 1

Quality Assurance Representative

Quality Castings
ISO 9002 CERTIFIED

Ferritic and Pearlitic Malleable Iron, Gray and Ductile Iron - Brass - Aluminum

Figure B-24. Bennett Cable End Fitter, Test Nos. MTP-1 and MTP-2 (Item No. g2)

Buck Company, Inc.
897 Lancaster Pike
Quarryville, PA 17566

1/8/2018 12:50:53PM

717-284-4114 Phone
717-284-3737 Fax

Certification

Product: 1986-5-0004

Customer Part: CGW1

Customer: 1986
Bennett Bolt Works, Inc
Att: Accounts Payable
PO Box 922
Jordan, NY 13080
USA

Shipto: 1986-2
Bennett Bolt Works, Inc.
12 Elbridge Street
Jordan, NY 13080
USA

Melted and Manufactured in the USA

	Quantity	Date	Heat Treat	Lot Number
GQ2 32510	9,000	12/6/2017		

Shop Order/Item: 118152 - 1 Customer Order/Item: 52207 - 1 S

Specification: ASTM A47, SAE J158
Material Type: M1B32510
Customer PO: 6016655

CHEMICALS

Al: 0.00100	B: 0.01000	C: 2.61000
Cr: 0.05800	Fe: 94.80000	Mn: 0.36500
P: 0.01300	S: 0.11800	Si: 1.52000
Ti: 0.00100		

PHYSICALS

Brinnell:	126	Elongation:	18
Tensile:	56300	Yield:	34200

Date: 1/8/2018 Signature: Lolita Lopez

Page: 1

Figure B-25. Cable Wedge, Test Nos. MTP-1 and MTP-2 (Item No. g3)

01Oct13 8:44 TEST CERTIFICATE No: 1 109934

KREHER STEEL COMPANY, LLC.
1550 NORTH 25TH AVENUE
MELROSE PARK, IL 60160
Tel: 708-345-8180 Fax: 708-345-8293

P/O No SO-15838
Rel
S/O No 1 253491-001
B/L No Shp
Inv No Inv

Sold To: (8669)
THE STEEL SUPPLY COMPANY, INC.
35 PINE DRIVE
COLD SPRING HARBOR NY 11724

Ship To: (1)
THE STEEL SUPPLY COMPANY, INC.
88 EAST INDUSTRY COURT
DEER PARK, NY 11729

Tel: 631-385-7273 Fax: 631-385-7274

CERTIFICATE of ANALYSIS and TESTS Cert. No: 1 109934
01Oct13

Part No
HOT ROLLED ROUNDS 1045QT A449
.8750 X 24' 0

MELTED IN U.S.A
QUENCH, TEMPERED AND STRAIGHTENED
ASTM A449
LOT NO. 82569

TENSILE	132000	
YIELD	116000	
ELONGATION	19 %	
REDUCTION OF AREA	55 %	
SURFACE HARDNESS	269-302	BHN

Heat Number *** Chemical Analysis ***
121424 C=0.4400 Mn=0.7500 P=0.0080 S=0.0340 Cu=0.2100 Ni=0.0850
Cr=0.1130 Mo=0.0290 Sn=<.011> Al=<.001> V=<.003> B=<.0003>
Ti=<.0007> N=<.0105> Ca=<.0001>

I hereby certify that this data is correct as contained in the records of this company.
I hereby certify that no mercury came in contact with or no weld repair was done to this product while in our possession.

BPapp

Page: 1 .... Last

10-205

Figure B-26. ⅞-in. (22-mm) Dia. Threaded Rod, Test Nos. MTP-1 and MTP-2 (Item No. g4)

CHICAGO HARDWARE & FIXTURE COMPANY
www.chicagohardware.com

American Owned
American Made
American Quality

9100 Parklane Avenue
Franklin Park, Illinois 60131
Phone: 847.455.6609
Fax: 847.455.0012

C & F FORGE COMPANY
Plant: 1243 North Kirk Road
Batavia, Illinois 60510
Phone: 773. 625.0930
Fax: 847.455.0012

October 31, 2018

Bennett Bolt Works
12 Elbridge Street
Jordan, NY 13080

CERTIFICATION OF CONFORMANCE

This is to certify that the following Chicago Hardware & Fixture Company's products listed below are furnished on Bennett Bolt Works' Purchase Order No. 6017836. The turnbuckle bodies are made in the United States of America by Chicago Hardware & Fixture Company from Domestic C-1035 Hot Rolled Steel, forged at our Batavia, IL forge facility and machined at our Franklin Park, IL machinery facility. Additionally, they are Hot Dip Galvanized to ASTM A153 Specifications and meet the performance requirements of ASTM F1145, Type 1, Grade 1 and Class 2 Component.

Part No. 040129 / Quantity 16 Pieces
7/8" x 6" Drop Forged, Galvanized Turnbuckle Bodies Only

Chicago Hardware & Fixture
Darlene Slowik
Darlene Slowik
Quality Representative

Figure B-27. Bennett Short Threaded Turnbuckle, Test Nos. MTP-1 and MTP-2 (Item No. g5)

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 :	2015-01-16
Product:	HEX CAP SCREWS	Contract No:	14JDF599T
Class:	5	Invoice No:	00331096-5
Size:	5/16-18X2-1/2	Lot No:	3321720016
Marking:	JDF three radius	Order No.	120209249
Quantity:	7.700 mpcs	Part No.	11241184
		Production Date	2014-10-16
Dimensions Of SPEC:		Certificate No.:	20141024431

Inspection Items		Standard	Result	Sample	Pass
Visual Appearance		-------------	OK	22	22
Body Diameter		0.313-0.307	0.307-0.307	4	4
Thread	Go	3A	OK	15	15
	No Go	2A	OK	15	15
Width Across Flats		0.500-0.489	0.493-0.495	4	4
Width Across Corners		0.577-0.557	0.571-0.567	4	4
Major Diameter		0.311-0.303	0.308-0.309	15	15
Head Height		0.211-0.195	0.199-0.203	4	4
Total Length		2.500-2.461	2.480-2.472	15	15
Thread Length		min 0.875	0.876-0.878	15	15
Key Engagement		/	/		
Head Diameter		/	/		
Mechanical Properties					
CharacTeristics		Standard	Result		
Surface Hardness	[30N]	MAX 54	43-48	15	15
Core Hardness	[HRC]	25-34	27-30	15	15
Wedge Strength	[psi]	min 119880	125104-130474	4	4
Yield Strength	[psi]	min 91869	101303-111026	4	4
Elongation	[%]	min 14	15.6-17.8	4	4
Reduction Of area	[%]	min 35	40.7-51.1	4	4
Proof Load	[Ib]	4450	4450	4	4
Impact test -20℃	[Akv/J]	/	/		
Decarburization		N≥1/2H1 HV0.3	296.09 296.09 311.91	4	4
HV2>=HV1-30, HV3<=HV1+30		G 0.0006max			
CHEMICAL COMPOSITION(%)					

Heat No		C	Si	Mn	P	S	Cr	Ni	Cu	Mo	B
35#	341408026	0.36	0.15	0.70	0.012	0.003	0.03	0.01	0.01		
Thickness	[UM]										
Surface Coating:		GEOMET									

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

尹巍

Figure B-28. 5/16-in. (8-mm) Dia. Heavy Hex Bolt, Test Nos. MTP-1 and MTP-2 (Item No. h1)

IATF 16949:2016 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

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

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2019/01/31

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 110272390
COMMODITY : HEX MACHINE BOLT GR-A
SIZE : 1/2-13X2 NC
LOT NO : 1B1891449
SHIP QUANTITY : 6,000 PCS
LOT QUANTITY 118,101 PCS
HEADMARKS : CYI & 307A

PACKING NO : GEM181018025
INVOICE NO : GEM/FNL-181101WI-3
PART NO : 1191887
SAMPLING PLAN : ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : G1808306003
MATERIAL : ML08
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

MANUFACTURE DATE : 2018/10/09
COUNTRY OF ORIGIN : CHINA

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A307-2014

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0.3300	1.2500	0.0410		
Test Value	0.0380	0.0600	0.3800	0.0140	0.0060	0.0400

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.1-2012

SAMPLED BY : LXQING

INSPECTIONS ITEM	SAMPLE	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
THREAD LENGTH	15PCS	1.2500 inch	1.3560-1.3620 inch	15	0
MAJOR DIAMETER	15PCS	0.4870-0.4980 inch	0.4910-0.4930 inch	15	0
BODY DIAMETER	5PCS	0.4820-0.5150 inch	0.5000-0.5020 inch	5	0
WIDTH ACROSS CORNERS	5PCS	0.8260-0.8660 inch	0.8540-0.8600 inch	5	0
HEIGHT	5PCS	0.3020-0.3640 inch	0.3420-0.3430 inch	5	0
NOMINAL LENGTH	15PCS	1.9400-2.0400 inch	1.9950-2.0020 inch	15	0
WIDTH ACROSS FLATS	5PCS	0.7360-0.7500 inch	0.7400-0.7430 inch	5	0
SURFACE DISCONTINUITIES	29PCS	ASTM F788-2013	PASSED	29	0
AND IS MATCHED WITH THE REAMING NUT AFTER PLATING	29PCS	nut	PASSED	29	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A 307-2014

SAMPLED BY : ZLINGLING

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15PCS	ASTM F606-2016		Max. 100 HRB	82-86 HRB	15	0
TENSILE STRENGTH	4PCS	ASTM F606-2016		Min. 60 KSI	76-81 KSI	4	0
PLATING THICKNESS(μm)	5PCS	ASTM B568-1998		>=53	70.19-71.08	5	0

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER
WE CERTIFY THAT ALL PRODUCTS WE SUPPLIED ARE IN COMPLIANCE WITH DIN EN 10204 3.1 CONTENT

page 1 of 2

Figure B-29. ½-in. (14-mm) Dia Hex Bolt, Test Nos. MTP-1 and MTP-2 (Item No. h2)

IATF 16949:2016 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

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

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2019/01/31

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 110272390
COMMODITY : HEX MACHINE BOLT GR-A
SIZE : 1/2-13X2 NC
LOT NO : 1B1891449
SHIP QUANTITY : 6, 000 PCS
LOT QUANTITY 118, 101 PCS
HEADMARKS : CYI & 307A
MANUFACTURE DATE : 2018/10/09
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM181018025
INVOICE NO : GEM/FNL-181101WI-3
PART NO : 1191887
SAMPLING PLAN : ASME B18. 18-2011(Category. 2)/ASTM F1470-2012
HEAT NO : G1808306003
MATERIAL : ML08
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

Quality Supervisor:

page 2 of 2

Figure B-30. ½-in. (14-mm) Dia. Hex Bolt, Test Nos. MTP-1 and MTP-2 (Item No. h2)

ISO/TS 16949
BUREAU VERITAS
Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

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

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2014/12/22

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 120213956
COMMODITY : HEX CAP SCREW GR-5
SIZE : 5/8-11X9-1/2 NC
LOT NO : 1B14A1530
SHIP QUANTITY : 765 PCS
HEADMARKS : CYI & 3 RADIAL LINES
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM141128032
INVOICE NO : GEM/FNL-141224IN-4
PART NO : 12332
SAMPLING PLAN : ASME B18.18/ASTM F1470
HEAT NO : 14206525-4
MATERIAL : X40ACR
FINISH : H.T. PLAIN

PERCENTAGE COMPOSITION OF CHEMISTRY :

Chemistry	Al%	C%	Cr%	Mn%	P%	S%	Si%
Spec. : MIN.	0.0200	0.4000	0.2000	0.7000			
MAX.		0.4300	0.4000	0.9000	0.0250	0.0150	0.1000
Test Value	0.0330	0.4100	0.2740	0.7800	0.0140	0.0020	0.0500

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME/ANSI B18.2.1
TEST DATE : 2014/11/10 SAMPLED BY : FCHUN SAMPLING DATE : 2014/11/10

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
THREAD LENGTH	11 PCS	MIL-STD-120	44.45		45.990-46.070 MM	11	0
MAJOR DIAMETER	3 PCS	MIL-STD-120		15.530-15.830 MM	15.670-15.690 MM	3	0
BODY DIAMETER	3 PCS	MIL-STD-120		15.680-15.870 MM	15.760-15.780 MM	3	0
WIDTH ACROSS CORNERS	3 PCS	MIL-STD-120		26.700-27.500 MM	26.940-26.950 MM	3	0
HEIGHT	3 PCS	MIL-STD-120		9.610-10.230 MM	9.860-9.900 MM	3	0
NOMINAL LENGTH	11 PCS	MIL-STD-120		236.730-241.300 MM	238.600-238.650 MM	11	0
WIDTH ACROSS FLATS	3 PCS	MIL-STD-120		23.420-23.820 MM	23.690-23.740 MM	3	0
SURFACE DISCONTINUITIES	15 PCS	ASTM F788/F788M			PASSED	15	0
THREAD	3 PCS	MIL-STD-120		2A	PASSED	3	0

MECHANICAL PROPERTIES : ACCORDING TO SAE J 429-2013
TEST DATE : 2014/11/12 SAMPLED BY : JWEN SAMPLING DATE : 2014/11/12

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	11 PCS	ASTM F606/F606M		25-34 HRC	28-31 HRC	11	0
SURFACE HARDNESS	11 PCS	ASTM E18		Max. 54 HR30N	44-47 HR30N	11	0
TENSILE STRENGTH	3 PCS	ASTM F606/F606M		Min. 120 KSI	134-140 KSI	3	0

ALL TESTS ARE IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM/SAE/ASME/MIL-STD-120 SPECIFICATION. WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.

WE CERTIFY THE PARTS ARE ROHS COMPLIANT.

SIGNATURE : Jerry

page 1 of 1

Figure B-31. ⅝-in. (16-mm) Dia. Heavy Hex Bolt, Test Nos. MTP-1 and MTP-2 (Item No. h3)

R#14-0343

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	Description	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 Burris* Date: 2/18/2014
Title: General Manager

Figure B-32. ¾-in. (20-mm) Dia. Hex Bolt, Test Nos. MTP-1 and MTP-2 (Item No. h4)

Material Sold to Central Steel & Wire: Heat: 892027 IAC: 59681 PO: CHI56767

CENTRAL STEEL & WIRE CO - CHICAGO
ATTENTION: SEND WITH TRUCK

CHICAGO, IL 60680

Nucor Cold Finish EN 10204 / 3.1
Division of Nucor Corporation
P.O. Box 94 • Norfolk, Nebraska 68702-0094 • Telephone (402) 644-8600 800-228-8107

Date: 10/16/18 16:22:02
B/L #: 227137
Load #: 77463

Heat Number	Size	Grade	C	Mn	P	S	Si	Pb	Yield PSI	Tensile PSI	EL% In 2	RA% Inch	Hardness BHN
892027	1.1250	1144	.430	1.390	.010	.266	.210		115,500	134,700	9.4	25.8	241.8

(Chemical Analysis: C, Mn, P, S, Si, Pb; Physical Properties: Yield, Tensile, EL%, RA%, Hardness)

CC#: IAC59681 PO#: CHI56767
C.D. RD NU-STANDARD S/R A 4819
--Certifies to ASTM A311-10 B & Cust Spec F-28, 12/20/13 & SAE J403 ASTM A311-B

Cu= .200 Cr= .080 Ni= .080 Mo= .020 Sn= .012
V = .004 Cb= .004 Al= .000

Reduction ratio = 37.6:1
Meets minimum reduction ratio of 5.0:1
Material is strand cast
Made to a coarse grain practice
Material is mercury free
Manufactured in the USA
Rounds have passed eddy current inspection
Material has not been magnetized
Material source: NUCOR STEEL - NEBRASKA NE
Country of origin (melt): United States
Country of origin (rolling): United States

** Material Certifies to ASTM A108-13 unless otherwise noted

Matt Hicks - Metallurgist Approved By ncf5007

Figure B-33. 5/16-in. (8-mm) Dia. Sleeve Nut, Test Nos. MTP-1 and MTP-2 (Item No. h5)

IATF 16949:2016 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

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

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2019/01/31

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 180148596
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 1/2-13 NC O/T 0.46MM
LOT NO : 1N17C0245
SHIP QUANTITY : 28,125 PCS
LOT QUANTITY 286,640 PCS
HEADMARKS :

PACKING NO : GEM180228004
INVOICE NO : GEM/FNL-180314DE-2
PART NO : 1136709
SAMPLING PLAN : ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : 17312243-3
MATERIAL : X1008A
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

MANUFACTURE DATE : 2018/01/20
COUNTRY OF ORIGIN : CHINA

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2015

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0.5800		0.1300	0.2300	
Test Value	0.0400	0.0600	0.2800	0.0100	0.0090	0.0200

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2015

SAMPLED BY : HXNAN

INSPECTIONS ITEM	SAMPLE	SPECIFIED		ACTUAL RESULT	ACC.	REJ.
WIDTH ACROSS CORNERS	6PCS		0.8400-0.8660 inch	0.8490-0.8520 inch	6	0
FIM	15PCS	ASME B18.2.2-2015	Max. 0.0110 inch		0	0
THICKNESS	6PCS		0.4270-0.4480 inch	0.4340-0.4380 inch	6	0
WIDTH ACROSS FLATS	6PCS		0.7360-0.7500 inch	0.7430-0.7440 inch	6	0
SURFACE DISCONTINUITIES	29PCS		ASTM F812-2012	PASSED	29	0
THREAD	15PCS		GAGING SYSTEM 21	PASSED	15	0

MECHANICAL PROPERTIES :

SAMPLED BY : LUYI

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15 PCS	ASTM F606-2014		68-107 HRB	83-86 HRB	15	0
PROOF LOAD	4 PCS	ASTM F606-2014		Min. 90 LBF	OK	4	0
PLATING THICKNESS(μm)	5 PCS	ASTM B568-1998		>=53	77.73-92.41	5	0

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER
WE CERTIFY THAT ALL PRODUCTS WE SUPPLIED ARE IN COMPLIANCE WITH DIN EN 10204 3.1 CONTENT

Quality Supervisor: Erin

page 1 of 1

Figure B-34. ½-in. (14-mm) Dia. Hex Nut, Test Nos. MTP-1 and MTP-2 (Item No. h6)

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. #： S66180305 ISSUED DATE： 2018/3/20 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 #：210151213
PART # 36313 QTY SHIPPED：46,800 PCS

COMMODITY：GRADE 5 FIN HEX NUT FINISH： PLN
SIZE： 5/8-11 LOT#： S66180305 SAMPLING PLAN：ASME B18.18-17 / ASTM F1470-12
QTY： 300000 PCS MATERIAL： 1010AM HEAT NO.： 366128
MANUFACTURER：SUPER CHENG IND. CO., LTD. MANU. DATE： 2018/3/13

DIMENSIONAL INSPECTION SPEC.：ASME B18.2.2-15 SAMPLED BY： CHUN CHUN XU

ITEM	SAMPLE SIZE	SPECIFIED	ACTUAL RESULT	JUDGMENT
APPEARANCE	29	ASTM F812-12	GOOD	OK
THREAD	15	ASME B1.1-03	PASS	OK
W.A.F.	6	0.938 ~ 0.922 in	0.930 ~ 0.928 in.	OK
W.A.C.	6	1.083 ~ 1.051 in	1.063 ~ 1.061 in.	OK
THICKNESS	6	0.559 ~ 0.535 in	0.547 ~ 0.546 in.	OK

MECHANICAL PROPERTIES SPEC.：SAE J995-17 SAMPLED BY： CHUN CHUN XU

ITEM	SAMPLE SIZE	TEST METHOD	SPECIFIED	ACTUAL RESULT	JUDGMENT
HARDNESS	6	ASTM F606/F606M-16	MAX HRC32	96 ~ 93 HRBW	PASS
PROOF LOAD	4	ASTM F606/F606M-16	MIN 27100 LB	27247 ~ 27247 LB	PASS

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

世鎧工業產業股份有限公司 測試實驗室專用章 SUPER CHENG INDUSTRIAL CO., LTD.

LAB. DIRECTOR(SIGNATORY)：

表單編號：LQC 10E Rev.0

Figure B-35. ⅝-in. (16-mm) Dia. Heavy Hex Nut, Test Nos. MTP-1 and MTP-2 (Item No. h7)

R#14-0343

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	Description	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 Burris* Date: 2/18/2014
Title: General Manager

Figure B-36. ¾-in. (20-mm) Dia. Hex Nut, Test Nos. MTP-1 and MTP-2 (Item No. h8)

UNYTITE INC.
INNOVATIVE FASTENING SYSTEMS

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

INSPECTION CERTIFICATE

Job No: 27656 **Job Information** **Certified Date:** 3/7/18

Customer: FASTENAL COMPANY
Customer Part No: 38209
Customer PO No: 120326625
Lot Number: 27656-6214510204

Ship To: FASTENAL
Shipped Qty: 5,850

Part Information

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

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

Manufactured Quantity: 92,087

Applicable Specifications

Specification	Amend	Specification	Amend
ASME B1.1	2003	ASME B18.2.2	2015
ASME B18.2.6	2010	ASTM A563	2015
ASTM F2329	2013	ASTM F606/606M	2014
ASTM F812/F812M	2012		

Test Results
Test No: 16962 **Test**: A563 DH Mechanical Properties

Description	Hardness (HRC)	Tempering Temp (800 degree F Min)	Proof Load (Pass/Fail) (ASTM Min)	Shape & Dimension ASME B18.2.2	Thread Precision ASME B18.1.1	Visual ASTM F812
Sample Inspection	28.3	1,157	69,300	Pass	Pass	Pass

Certified Chemical Analysis

Heat No	Grade	Manufacturer	Origin	C	Mn	P	S	Si	Cr	Ni	Cu
6214510204	1045	Gerdau Ameristeel	USA	0.4400	0.7500	0.009	0.0230	0.2000	0.1800	0.0900	0.2500

Notes

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

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

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

OFFICIAL SEAL
JEAN E MARGHERIO
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES:09/18/21

Savage, Dan - Supervisor, Quality 3/7/18
Date

Plex 3/7/18 11:01 AM dsavage Page 1

Figure B-37. ⅞-in. (22-mm) Dia. Heavy Hex Nut and Heavy Square Nut, Test Nos. MTP-1 and MTP-2 (Item Nos. h9 and h10)

TEST REPORT

USS FLAT WASHER, HDG

CUSTOMER:

DATE: **2018-08-25**

PO NUMBER: **210161958**

MFG LOT NUMBER: **M-SWE0412350-7**

SIZE: **3/4**

PART NO: **1133186**

HEADMARKS:

QNTY: **7,500 PCS**

DIMENSIONAL INSPECTIONS — SPECIFICATION: **ASME B18.21.1(2009)**

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
**********************	*************************************	*******************	********	********
APPEARANCE	**ASTM F788-07**	**PASSED**	**100**	**0**
OUTSIDE DIA	**1.993-2.030**	**1.999-2.004**	**8**	**0**
INSIDE DIA	**0.805-0.842**	**0.831-0.833**	**8**	**0**
THICKNESS	**0.122-0.177**	**0.126-0.131**	**8**	**0**

HOT DIP GALVANIZED	**ASTM A153 class C. RoHS Compliant**	**Min 0.0017"**	**Min 0.0018In**	**8**	**0**

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

We hereby certify that above products supplied are in compliance with all the requirements of the order.
We here by certify that this MTR is in compliance to DIN EN 10204 3.1 content.

MORGAN 检验专用章 QUANLITY CONTROL

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

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

Figure B-38. ¾-in. (19-mm) Dia. Plain USS Washer, Test Nos. MTP-1 and MTP-2 (Item No. h11)

TEST REPORT

SAE FLAT WASHER, HDG

CUSTOMER:		DATE:	2017-12-03
PO NUMBER:	110246244	MFG LOT NUMBER:	M-SWE0412094-1
SIZE:	1/2	PART NO:	0136086
HEADMARKS:		QNTY:	150,000 PCS

DIMENSIONAL INSPECTIONS — SPECIFICATION: **ASME B18.21.1(2009)**

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
**********************	************************************	*******************	********	********
APPEARANCE	ASTM F788-07	PASSED	100	0
OUTSIDE DIA	1.055-1.092	1.063-1.067	8	0
INSIDE DIA	0.526-0.546	0.536-0.540	8	0
THICKNESS	0.071-0.121	0.074-0.079	8	0

HOT DIP GALVANIZED	ASTM A153 class C. RoHS Compliant	Min 0.0017"	Min 0.0018 In	8	0

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

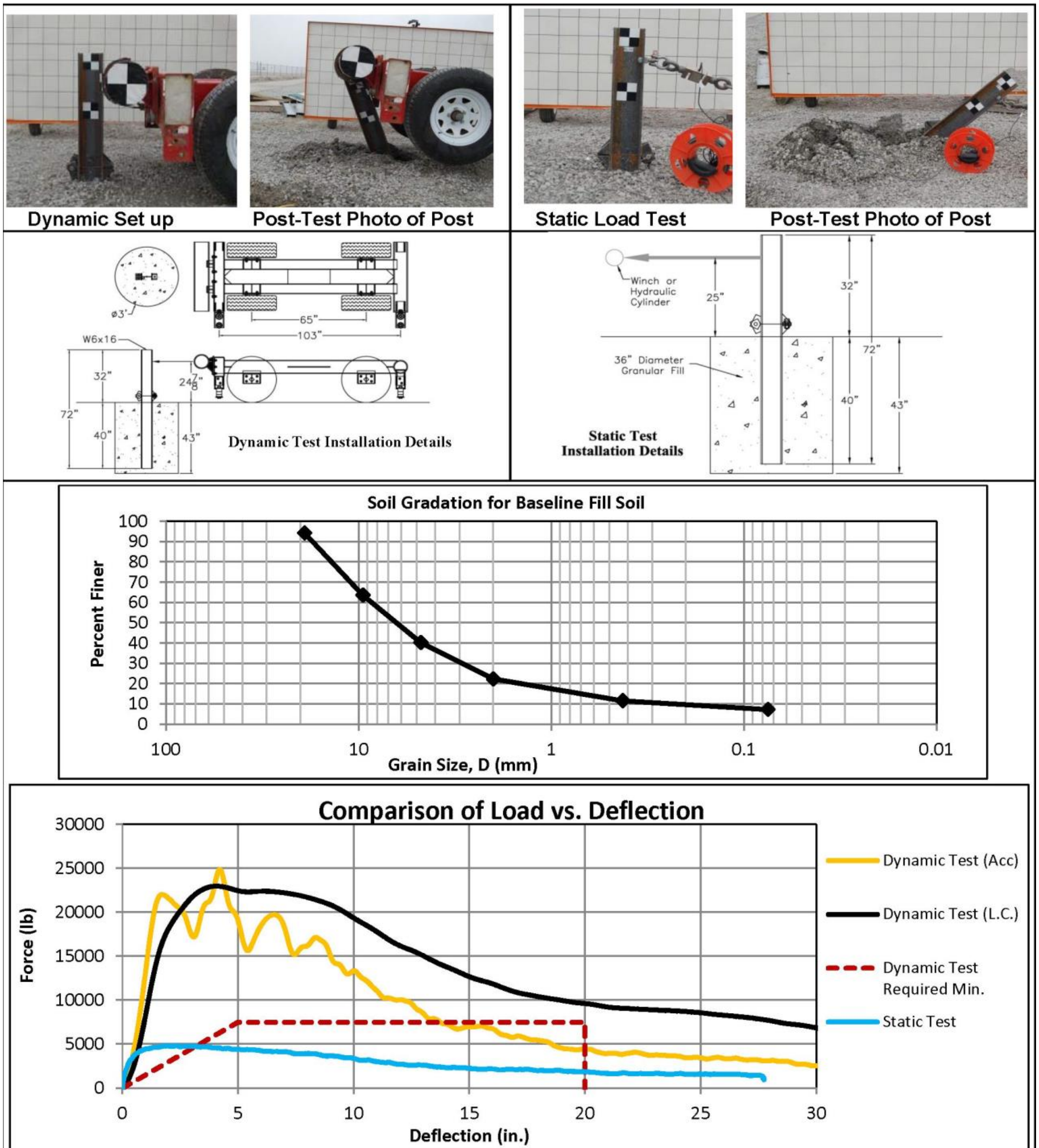
IFI & MORGAN LTD. 检验专用章 QUANLITY CONTROL

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

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

Figure B-39. ½-in. (13-mm) Dia. Plain SAE Washer, Test Nos. MTP-1 and MTP-2 (Item No. h12)

Appendix C. Static Soil Tests

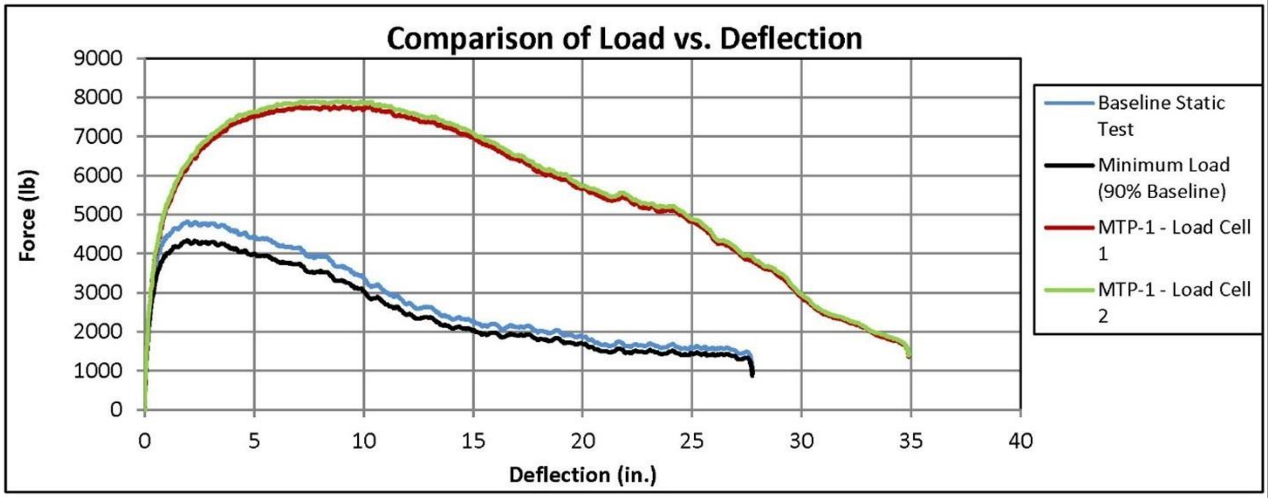


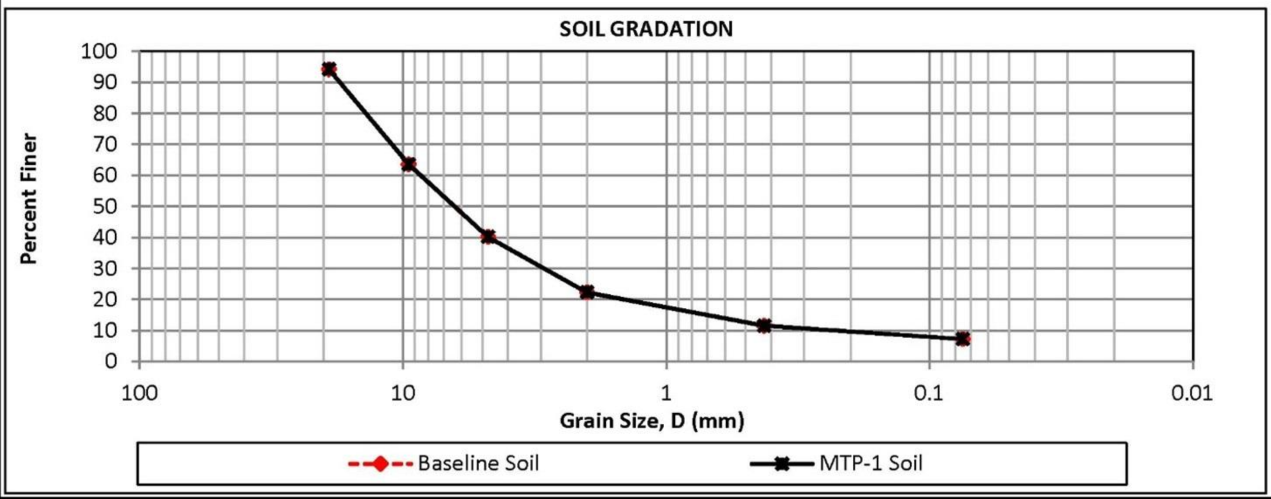
Date......	2/16/2018
Test Facility & Site Location......	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)......	Well-Graded Gravel (GW)
Fill material description (ASTM D2487)......	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure......	H.E.-8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

Figure C-1. Soil Strength, Initial Calibration Tests, Test Nos. MTP-1 and MTP-2

Static Load Test Setup

Post-Test Photo of Post

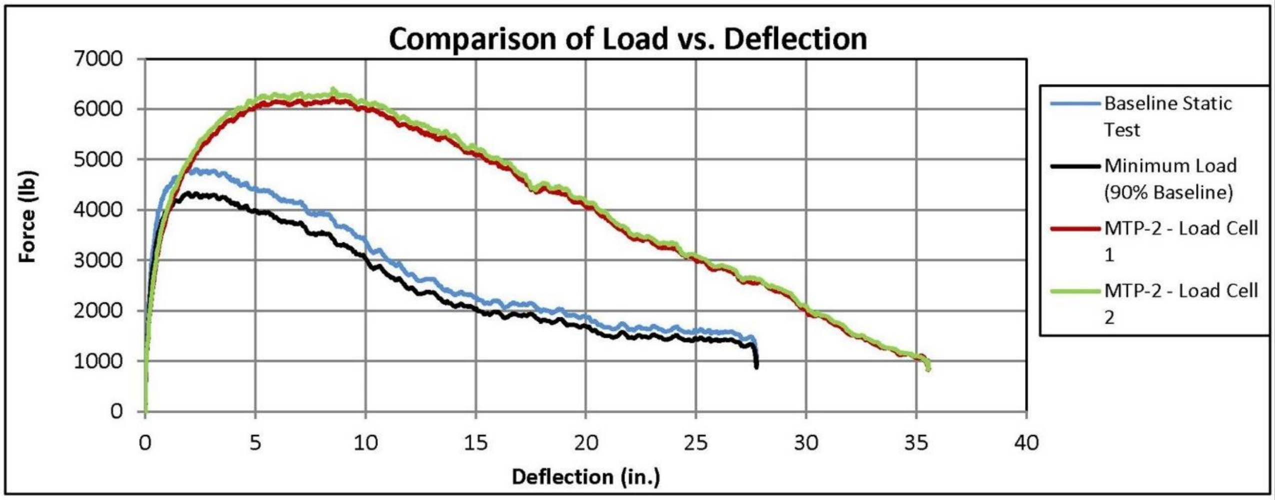


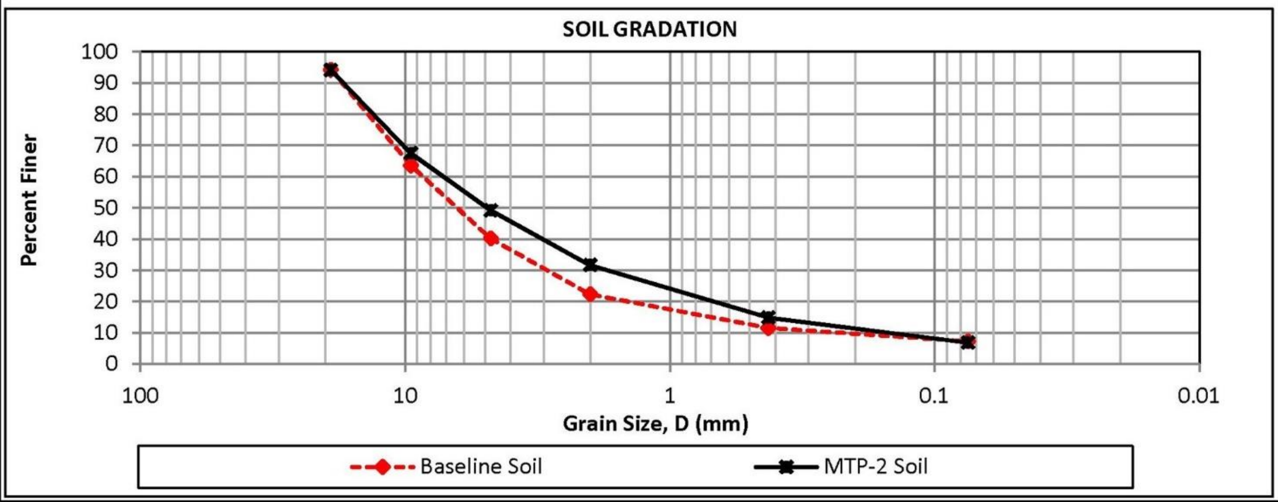


Date...	4/22/2019
Test Facility & Site Location.......................	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)...........	Well-Graded Gravel (GW)
Fill material description (ASTM D2487).........	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure........	8-inch lifts tamped with a pneumatic compactor

Figure C-2. Static Soil Test, Test No. MTP-1

Static Load Test Setup	Post-Test Photo of Post
	





Date..	7/15/2019
Test Facility & Site Location.......................	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)...........	Well-Graded Gravel (GW)
Fill material description (ASTM D2487).........	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure........	8-inch lifts tamped with a pneumatic compactor

Figure C-3. Static Soil Test, Test No. MTP-2

Appendix D. Vehicle Deformation Records

The following figures and tables describe all occupant compartment measurements taken on the test vehicles used in full-scale crash testing herein. MASH 2016 defines intrusion as the occupant compartment being deformed and reduced in size with no penetration. Outward deformations, which are denoted as negative numbers within this Appendix, are not considered to be crush toward the occupant, and are not subject to evaluation by MASH 2016 criteria.

Note that for test no. MTP-2, no pre-test exterior profile was populated so no post-test crush profile is available.

Date: 4/11/2019 Test Name: MTP-1 VIN: 1C6RD6GP3CS253410
Year: 2012 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	54.8413	-25.2259	-0.7071	54.8690	-24.9416	-0.6640	-0.0277	0.2843	-0.0431	0.2889	0.0000	NA
	2	56.3679	-20.5280	-0.0408	56.3813	-20.2952	0.0562	-0.0134	0.2328	-0.0970	0.2526	0.0000	NA
	3	56.7400	-15.7451	-0.2068	56.7602	-15.4583	-0.1124	-0.0202	0.2868	-0.0944	0.3026	0.0000	NA
	4	57.0184	-11.2010	-0.4075	57.0651	-10.9437	-0.3228	-0.0467	0.2573	-0.0847	0.2749	0.0000	NA
	5	56.3697	-7.4140	-2.0211	56.4058	-7.1604	-2.0012	-0.0361	0.2536	-0.0199	0.2569	0.0000	NA
	6	51.3445	-25.1871	2.5457	51.3518	-24.8898	2.6585	-0.0073	0.2973	-0.1128	0.3181	0.0000	NA
	7	51.1884	-20.8333	2.5983	51.1843	-20.5539	2.7107	0.0041	0.2794	-0.1124	0.3012	0.0041	X
	8	51.2272	-15.9284	2.5768	51.2232	-15.7113	2.6804	0.0040	0.2171	-0.1036	0.2406	0.0040	X
	9	51.3729	-11.0793	2.5208	51.3928	-10.8077	2.6031	-0.0199	0.2716	-0.0823	0.2845	0.0000	NA
	10	51.3345	-6.5785	2.4512	51.3596	-6.3052	2.5271	-0.0251	0.2733	-0.0759	0.2848	0.0000	NA
FLOOR PAN (Z)	11	46.5322	-24.8133	4.5677	46.5796	-24.5950	4.6899	-0.0474	0.2183	-0.1222	0.2546	-0.1222	Z
	12	46.5044	-20.9925	4.5533	46.5369	-20.7163	4.6678	-0.0325	0.2762	-0.1145	0.3008	-0.1145	Z
	13	46.5344	-15.9366	4.5815	46.5555	-15.6831	4.6875	-0.0211	0.2535	-0.1060	0.2756	-0.1060	Z
	14	46.5657	-11.1486	4.5737	46.5599	-10.8928	4.6691	0.0058	0.2558	-0.0954	0.2731	-0.0954	Z
	15	46.5081	-6.1596	3.8114	46.5383	-5.8757	3.8856	-0.0302	0.2839	-0.0742	0.2950	-0.0742	Z
	16	42.0694	-24.7753	4.6574	42.0720	-24.6094	4.7690	-0.0026	0.1659	-0.1116	0.2000	-0.1116	Z
	17	42.2265	-20.8744	4.6420	42.2212	-20.6241	4.7359	0.0053	0.2503	-0.0939	0.2674	-0.0939	Z
	18	42.2222	-15.9213	4.6575	42.1982	-15.6909	4.7458	0.0240	0.2304	-0.0883	0.2479	-0.0883	Z
	19	42.2385	-11.2830	4.6633	42.1947	-11.0227	4.7426	0.0438	0.2603	-0.0793	0.2756	-0.0793	Z
	20	42.1694	-6.0009	3.5816	42.1341	-5.7236	3.6383	0.0353	0.2773	-0.0567	0.2852	-0.0567	Z
	21	37.5868	-24.5103	4.7284	37.5376	-24.2535	4.8160	0.0492	0.2568	-0.0876	0.2758	-0.0876	Z
	22	37.4859	-20.8523	4.7113	37.4680	-20.5867	4.8018	0.0179	0.2656	-0.0905	0.2812	-0.0905	Z
	23	37.3879	-15.7905	4.7281	37.3645	-15.4833	4.8122	0.0234	0.3072	-0.0841	0.3194	-0.0841	Z
	24	37.4934	-11.2836	4.7509	37.4430	-10.9976	4.8268	0.0504	0.2860	-0.0759	0.3002	-0.0759	Z
	25	37.2547	-6.0278	3.6414	37.2753	-5.7728	3.7217	-0.0206	0.2550	-0.0803	0.2681	-0.0803	Z
	26	33.0610	-24.6253	4.3888	33.1206	-24.3835	4.5028	-0.0596	0.2418	-0.1140	0.2739	-0.1140	Z
	27	33.0677	-20.7996	4.4037	33.1035	-20.6303	4.4961	-0.0358	0.1693	-0.0924	0.1962	-0.0924	Z
	28	33.0836	-15.6203	4.4240	33.0760	-15.3958	4.4883	0.0076	0.2245	-0.0643	0.2337	-0.0643	Z
	29	32.8684	-11.2869	4.2970	32.8937	-11.0571	4.3802	-0.0253	0.2298	-0.0832	0.2457	-0.0832	Z
	30	33.0148	-6.1263	3.4450	33.0171	-5.8771	3.5203	-0.0023	0.2492	-0.0753	0.2603	-0.0753	Z

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

Pretest Floor Pan

Posttest Floor Pan

Figure D-1. Floor Pan Deformation Data – Set 1, Test No. MTP-1

Date:	4/11/2019	Test Name:	MTP-1	VIN:	1C6RD6GP3CS253410
Year:	2012	Make:	Dodge	Model:	Ram 1500

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 2

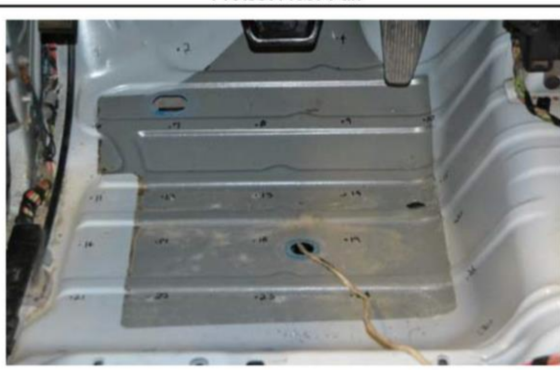
	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	54.0729	-45.2052	-4.2617	54.0707	-45.4319	-4.1971	0.0022	-0.2267	-0.0646	0.2357	0.0022	X
	2	55.6603	-40.5289	-3.5857	55.6446	-40.8099	-3.4525	0.0157	-0.2810	-0.1332	0.3114	0.0157	X
	3	56.1025	-35.7520	-3.7531	56.0988	-35.9791	-3.6100	0.0037	-0.2271	-0.1431	0.2685	0.0037	X
	4	56.4480	-31.2126	-3.9559	56.4747	-31.4694	-3.8106	-0.0267	-0.2568	-0.1453	0.2963	0.0000	NA
	5	55.8691	-27.4186	-5.5797	55.8931	-27.6745	-5.4916	-0.0240	-0.2559	-0.0881	0.2717	0.0000	NA
	6	50.5460	-45.1125	-1.0427	50.5150	-45.3306	-0.9169	0.0310	-0.2181	-0.1258	0.2537	0.0310	X
	7	50.4520	-40.7568	-0.9962	50.4128	-40.9927	-0.8608	0.0392	-0.2359	-0.1354	0.2748	0.0392	X
	8	50.5613	-35.8530	-1.0223	50.5255	-36.1512	-0.8841	0.0358	-0.2982	-0.1382	0.3306	0.0358	X
	9	50.7770	-31.0066	-1.0820	50.7704	-31.2506	-0.9526	0.0066	-0.2440	-0.1294	0.2763	0.0066	X
	10	50.8038	-26.5057	-1.1568	50.8065	-26.7481	-1.0229	-0.0027	-0.2424	-0.1339	0.2769	0.0000	NA
FLOOR PAN (Z)	11	45.7204	-44.6673	0.9327	45.7238	-44.9657	1.0575	-0.0034	-0.2984	-0.1248	0.3235	-0.1248	Z
	12	45.7476	-40.8465	0.9140	45.7403	-41.0868	1.0402	0.0073	-0.2403	-0.1262	0.2715	-0.1262	Z
	13	45.8498	-35.7915	0.9372	45.8350	-36.0545	1.0670	0.0148	-0.2630	-0.1298	0.2937	-0.1298	Z
	14	45.9499	-31.0046	0.9246	45.9123	-31.2648	1.0552	0.0376	-0.2602	-0.1306	0.2936	-0.1306	Z
	15	45.9711	-26.0161	0.1566	45.9763	-26.2470	0.2784	-0.0052	-0.2309	-0.1218	0.2611	-0.1218	Z
	16	41.2580	-44.5653	0.9795	41.2160	-44.9117	1.0826	0.0420	-0.3464	-0.1031	0.3638	-0.1031	Z
	17	41.4712	-40.6671	0.9615	41.4260	-40.9291	1.0567	0.0452	-0.2620	-0.0952	0.2824	-0.0952	Z
	18	41.5377	-35.7144	0.9717	41.4778	-35.9962	1.0731	0.0599	-0.2818	-0.1014	0.3054	-0.1014	Z
	19	41.6205	-31.0768	0.9729	41.5451	-31.3285	1.0762	0.0754	-0.2517	-0.1033	0.2823	-0.1033	Z
	20	41.6375	-25.7955	-0.1150	41.5782	-26.0277	-0.0215	0.0593	-0.2322	-0.0935	0.2572	-0.0935	Z
	21	36.7792	-44.2360	1.0072	36.6872	-44.4871	1.0758	0.0920	-0.2511	-0.0686	0.2761	-0.0686	Z
	22	36.7310	-40.5769	0.9852	36.6735	-40.8196	1.0658	0.0575	-0.2427	-0.0806	0.2621	-0.0806	Z
	23	36.7054	-35.5142	0.9959	36.6472	-35.7152	1.0819	0.0582	-0.2010	-0.0860	0.2262	-0.0860	Z
	24	36.8753	-31.0093	1.0149	36.7937	-31.2313	1.1036	0.0816	-0.2220	-0.0887	0.2526	-0.0887	Z
	25	36.7227	-25.7520	-0.1024	36.7185	-26.0033	0.0036	0.0042	-0.2513	-0.1060	0.2728	-0.1060	Z
	26	32.2557	-44.2865	0.6243	32.2728	-44.5496	0.7095	-0.0171	-0.2631	-0.0852	0.2771	-0.0852	Z
	27	32.3171	-40.4613	0.6352	32.3127	-40.7966	0.7077	0.0044	-0.3353	-0.0725	0.3431	-0.0725	Z
	28	32.4070	-35.2827	0.6503	32.3648	-35.5623	0.7067	0.0422	-0.2796	-0.0564	0.2883	-0.0564	Z
	29	32.2552	-30.9468	0.5166	32.2496	-31.2211	0.6024	0.0056	-0.2743	-0.0858	0.2875	-0.0858	Z
	30	32.4838	-25.7899	-0.3394	32.4620	-26.0426	-0.2489	0.0218	-0.2527	-0.0905	0.2693	-0.0905	Z

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

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

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

Pretest Floor Pan



Posttest Floor Pan

Figure D-2. Floor Pan Deformation Data – Set 2, Test No. MTP-1

Date: 4/11/2019 Test Name: MTP-1 VIN: 1C6RD6GP3CS253410
Year: 2012 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
DRIVER SIDE INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	42.9265	-0.0774	-28.5131	42.7468	0.4914	-28.4946	0.1797	0.5688	0.0185	0.5968	0.5968	X, Y, Z
	2	40.8942	-12.4348	-30.1638	40.8093	-11.9072	-30.2043	0.0849	0.5276	-0.0405	0.5359	0.5359	X, Y, Z
	3	43.6237	-22.0012	-27.5334	43.6065	-21.4814	-27.5156	0.0172	0.5198	0.0178	0.5204	0.5204	X, Y, Z
	4	36.3324	-0.2498	-16.4115	36.1983	0.2483	-16.4555	0.1341	0.4981	-0.0440	0.5177	0.5177	X, Y, Z
	5	37.4899	-13.4256	-15.5847	37.4150	-12.8438	-15.5410	0.0749	0.5818	0.0437	0.5882	0.5882	X, Y, Z
	6	39.1085	-22.6909	-16.6298	39.1135	-22.1198	-16.6079	-0.0050	0.5711	0.0219	0.5715	0.5715	X, Y, Z
SIDE PANEL (Y)	7	48.5594	-27.7540	-5.2062	48.6501	-26.9960	-5.1333	-0.0907	0.7580	0.0729	0.7669	0.7580	Y
	8	52.0108	-27.8238	-5.3473	52.1022	-27.0340	-5.2793	-0.0914	0.7898	0.0680	0.7980	0.7898	Y
	9	48.7118	-27.7405	-2.0263	48.7972	-27.0622	-1.9551	-0.0854	0.6783	0.0712	0.6874	0.6783	Y
IMPACT SIDE DOOR (Y)	10	14.9606	-30.3310	-19.6492	14.7776	-30.0082	-19.6071	0.1830	0.3228	0.0421	0.3734	0.3228	Y
	11	27.4131	-29.8081	-19.7146	27.1875	-29.2757	-19.6436	0.2256	0.5324	0.0710	0.5826	0.5324	Y
	12	39.5079	-29.7867	-20.3540	39.4021	-29.1416	-20.3873	0.1058	0.6451	-0.0333	0.6546	0.6451	Y
	13	15.5387	-30.4787	-0.9327	15.4400	-30.2558	-0.9267	0.0987	0.2229	0.0060	0.2438	0.2229	Y
	14	27.0622	-30.6060	-0.7703	26.9825	-30.1935	-0.8038	0.0797	0.4125	-0.0335	0.4215	0.4125	Y
	15	35.4002	-30.8286	-0.8862	35.2954	-30.1268	-0.9211	0.1048	0.7018	-0.0349	0.7104	0.7018	Y
ROOF - (Z)	16	31.6281	0.0590	-43.5408	31.6212	0.3392	-43.5676	0.0069	-0.2802	-0.0268	0.2816	-0.0268	Z
	17	31.3059	-4.8914	-43.3760	31.2497	-4.6483	-43.3969	0.0562	0.2431	-0.0209	0.2504	-0.0209	Z
	18	31.0247	-9.5963	-43.3218	30.9761	-9.3079	-43.3285	0.0486	0.2884	-0.0067	0.2925	-0.0067	Z
	19	29.8595	-14.2304	-43.0730	29.9452	-13.9930	-43.0769	-0.0857	0.2374	-0.0039	0.2524	-0.0039	Z
	20	28.7691	-18.7852	-42.6758	28.7895	-18.5214	-42.6918	-0.0204	0.2638	-0.0160	0.2651	-0.0160	Z
	21	27.5082	0.4749	-45.9196	27.5321	0.7305	-45.9404	-0.0239	-0.2556	-0.0208	0.2576	-0.0208	Z
	22	27.1263	-4.5742	-45.8505	27.1099	-4.3142	-45.8777	0.0164	0.2600	-0.0272	0.2619	-0.0272	Z
	23	26.5365	-8.8614	-45.7440	26.5258	-8.6297	-45.7675	0.0107	0.2317	-0.0235	0.2331	-0.0235	Z
	24	25.7547	-13.5858	-45.5380	25.8676	-13.3699	-45.5309	-0.1129	0.2159	0.0071	0.2437	0.0071	Z
	25	24.7905	-18.1227	-45.2511	24.8430	-17.9536	-45.2476	-0.0525	0.1691	0.0035	0.1771	0.0035	Z
	26	23.6858	0.8756	-46.5053	23.7392	1.1350	-46.5290	-0.0534	-0.2594	-0.0237	0.2659	-0.0237	Z
	27	23.1237	-4.1310	-46.4519	23.2246	-3.9089	-46.4646	-0.1009	0.2221	-0.0127	0.2443	-0.0127	Z
	28	22.6732	-8.3548	-46.3349	22.7180	-8.1719	-46.3448	-0.0448	0.1829	-0.0099	0.1886	-0.0099	Z
	29	22.1655	-13.0636	-46.0975	22.1668	-12.8752	-46.1090	-0.0013	0.1884	-0.0115	0.1888	-0.0115	Z
	30	21.4381	-17.6606	-45.7783	21.5038	-17.4832	-45.7751	-0.0657	0.1774	0.0032	0.1892	0.0032	Z
A-PILLAR Maximum (X, Y, Z)	31	46.4254	-26.4017	-28.9984	46.4065	-26.0233	-28.9888	0.0189	0.3784	0.0096	0.3790	0.3790	X, Y, Z
	32	43.4736	-25.5178	-31.7550	43.4863	-25.1802	-31.6799	-0.0127	0.3376	0.0751	0.3461	0.3459	Y, Z
	33	39.9936	-24.5554	-34.4630	40.0197	-24.1896	-34.4568	-0.0261	0.3658	0.0062	0.3668	0.3659	Y, Z
	34	37.2416	-23.6522	-36.3677	37.3100	-23.3214	-36.3653	-0.0684	0.3308	0.0024	0.3378	0.3308	Y, Z
	35	34.2599	-23.0658	-38.2148	34.2873	-22.7360	-38.2384	-0.0274	0.3298	-0.0236	0.3318	0.3298	Y
	36	30.8337	-23.1915	-40.5527	30.8181	-22.6590	-40.5656	0.0156	0.5325	-0.0129	0.5329	0.5327	X, Y
A-PILLAR Lateral (Y)	31	46.4254	-26.4017	-28.9984	46.4065	-26.0233	-28.9888	0.0189	0.3784	0.0096	0.3790	0.3784	Y
	32	43.4736	-25.5178	-31.7550	43.4863	-25.1802	-31.6799	-0.0127	0.3376	0.0751	0.3461	0.3376	Y
	33	39.9936	-24.5554	-34.4630	40.0197	-24.1896	-34.4568	-0.0261	0.3658	0.0062	0.3668	0.3658	Y
	34	37.2416	-23.6522	-36.3677	37.3100	-23.3214	-36.3653	-0.0684	0.3308	0.0024	0.3378	0.3308	Y
	35	34.2599	-23.0658	-38.2148	34.2873	-22.7360	-38.2384	-0.0274	0.3298	-0.0236	0.3318	0.3298	Y
	36	30.8337	-23.1915	-40.5527	30.8181	-22.6590	-40.5656	0.0156	0.5325	-0.0129	0.5329	0.5325	Y
B-PILLAR Maximum (X, Y, Z)	37	3.3845	-23.6741	-39.2988	3.4038	-23.4420	-39.2666	-0.0193	0.2321	0.0322	0.2351	0.2343	Y, Z
	38	6.4947	-25.1165	-35.5182	6.7495	-24.8392	-35.5309	-0.2548	0.2773	-0.0127	0.3768	0.2773	Y
	39	3.9497	-26.5000	-31.6243	4.1110	-26.2643	-31.5839	-0.1613	0.2357	0.0404	0.2885	0.2391	Y, Z
	40	7.4631	-27.1773	-28.6071	7.7024	-26.8936	-28.6337	-0.2393	0.2837	-0.0266	0.3721	0.2837	Y
B-PILLAR Lateral (Y)	37	3.3845	-23.6741	-39.2988	3.4038	-23.4420	-39.2666	-0.0193	0.2321	0.0322	0.2351	0.2321	Y
	38	6.4947	-25.1165	-35.5182	6.7495	-24.8392	-35.5309	-0.2548	0.2773	-0.0127	0.3768	0.2773	Y
	39	3.9497	-26.5000	-31.6243	4.1110	-26.2643	-31.5839	-0.1613	0.2357	0.0404	0.2885	0.2357	Y
	40	7.4631	-27.1773	-28.6071	7.7024	-26.8936	-28.6337	-0.2393	0.2837	-0.0266	0.3721	0.2837	Y

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

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

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

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

Date: 4/11/2019 Test Name: MTP-1 VIN: 1C6RD6GP3CS253410
Year: 2012 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
DRIVER SIDE INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	42.8471	-20.1501	-32.2549	42.8247	-20.0977	-32.1343	0.0224	0.0524	0.1206	0.1334	0.1334	X, Y, Z
	2	40.5689	-32.4629	-33.9175	40.6118	-32.4443	-33.8863	-0.0429	0.0186	0.0312	0.0562	0.0562	X, Y, Z
	3	43.0739	-42.0832	-31.2602	43.1457	-42.0861	-31.1782	-0.0718	-0.0029	0.0820	0.1090	0.1090	X, Y, Z
	4	36.1491	-20.1764	-20.2093	36.1256	-20.1985	-20.1764	0.0235	-0.0221	0.0329	0.0461	0.0461	X, Y, Z
	5	37.0217	-33.3732	-19.3673	37.0170	-33.3171	-19.2669	0.0047	0.0561	0.1004	0.1151	0.1151	X, Y, Z
	6	38.4534	-42.6711	-20.3948	38.5057	-42.6299	-20.3270	-0.0523	0.0412	0.0678	0.0950	0.0950	X, Y, Z
SIDE PANEL (Y)	7	47.6990	-47.9254	-8.8897	47.7817	-47.7473	-8.7444	-0.0827	0.1781	0.1453	0.2443	0.1781	Y
	8	51.1492	-48.0680	-9.0016	51.2334	-47.8679	-8.8483	-0.0842	0.2001	0.1533	0.2658	0.2001	Y
	9	47.8248	-47.9133	-5.7086	47.8883	-47.8209	-5.5647	-0.0635	0.0924	0.1439	0.1824	0.0924	Y
IMPACT SIDE DOOR (Y)	10	14.1763	-49.8027	-23.6148	14.0263	-49.9288	-23.6347	0.1500	-0.1261	-0.0199	0.1970	-0.1261	Y
	11	26.6371	-49.5422	-23.5752	26.4497	-49.4941	-23.5188	0.1874	0.0481	0.0564	0.2015	0.0481	Y
	12	38.7346	-49.7760	-24.1126	38.6722	-49.6520	-24.1133	0.0624	0.1240	-0.0007	0.1388	0.1240	Y
	13	14.5933	-49.9514	-4.8940	14.4541	-50.2151	-4.9480	0.1392	-0.2637	-0.0540	0.3030	-0.2637	Y
	14	26.1098	-50.3213	-4.6343	25.9924	-50.4297	-4.6843	0.1174	-0.1084	-0.0500	0.1674	-0.1084	Y
	15	34.4419	-50.7196	-4.6797	34.3054	-50.5622	-4.7001	0.1365	0.1574	-0.0204	0.2093	0.1574	Y
ROOF - (Z)	16	31.6811	-19.7847	-47.3775	31.8838	-19.9648	-47.3421	-0.2027	-0.1801	0.0354	0.2735	0.0354	Z
	17	31.2534	-24.7271	-47.2133	31.3909	-24.9422	-47.1834	-0.1375	-0.2151	0.0299	0.2570	0.0299	Z
	18	30.8727	-29.4250	-47.1595	31.0049	-29.5939	-47.1255	-0.1322	-0.1689	0.0340	0.2172	0.0340	Z
	19	29.6080	-34.0334	-46.9187	29.8590	-34.2533	-46.8935	-0.2510	-0.2199	0.0252	0.3347	0.0252	Z
	20	28.4186	-38.5640	-46.5288	28.5905	-38.7532	-46.5294	-0.1719	-0.1892	-0.0006	0.2556	-0.0006	Z
	21	27.5912	-19.2835	-49.7911	27.8345	-19.4726	-49.7640	-0.2433	-0.1891	0.0271	0.3093	0.0271	Z
	22	27.1024	-24.3234	-49.7232	27.2908	-24.5058	-49.7140	-0.1884	-0.1824	0.0092	0.2624	0.0092	Z
	23	26.4216	-28.5971	-49.6198	26.6022	-28.8063	-49.6175	-0.1806	-0.2092	0.0023	0.2764	0.0023	Z
	24	25.5386	-33.3039	-49.4185	25.8278	-33.5296	-49.3961	-0.2892	-0.2257	0.0224	0.3675	0.0224	Z
	25	24.4767	-37.8194	-49.1379	24.6903	-38.0878	-49.1323	-0.2136	-0.2684	0.0056	0.3431	0.0056	Z
	26	23.7832	-18.8028	-50.4092	24.0598	-18.9767	-50.3982	-0.2766	-0.1739	0.0110	0.3269	0.0110	Z
	27	23.1152	-23.7964	-50.3585	23.4238	-24.0068	-50.3476	-0.3086	-0.2104	0.0109	0.3737	0.0109	Z
	28	22.5749	-28.0096	-50.2435	22.8138	-28.2566	-50.2404	-0.2389	-0.2470	0.0031	0.3436	0.0031	Z
	29	21.9661	-32.7066	-50.0085	22.1473	-32.9456	-50.0186	-0.1812	-0.2390	-0.0101	0.3001	-0.0101	Z
	30	21.1394	-37.2871	-49.6935	21.3700	-37.5368	-49.6997	-0.2306	-0.2497	-0.0062	0.3399	-0.0062	Z
A-PILLAR Maximum (X, Y, Z)	31	45.7946	-46.5425	-32.6996	45.8539	-46.6920	-32.6240	-0.0593	-0.1495	0.0756	0.1777	0.0756	Z
	32	42.8854	-45.5983	-35.4814	42.9879	-45.7759	-35.3493	-0.1025	-0.1776	0.1321	0.2439	0.1321	Z
	33	39.4494	-44.5645	-38.2191	39.5802	-44.6990	-38.1667	-0.1308	-0.1345	0.0524	0.1948	0.0524	Z
	34	36.7332	-43.6046	-40.1473	36.9156	-43.7638	-40.1068	-0.1824	-0.1592	0.0405	0.2455	0.0405	Z
	35	33.7802	-42.9566	-42.0198	33.9308	-43.1038	-42.0157	-0.1506	-0.1472	0.0041	0.2106	0.0041	Z
	36	30.3719	-43.0115	-44.3865	30.4933	-42.9408	-44.3849	-0.1214	0.0707	0.0016	0.1405	0.0707	Y, Z
A-PILLAR Lateral (Y)	31	45.7946	-46.5425	-32.6996	45.8539	-46.6920	-32.6240	-0.0593	-0.1495	0.0756	0.1777	-0.1495	Y
	32	42.8854	-45.5983	-35.4814	42.9879	-45.7759	-35.3493	-0.1025	-0.1776	0.1321	0.2439	-0.1776	Y
	33	39.4494	-44.5645	-38.2191	39.5802	-44.6990	-38.1667	-0.1308	-0.1345	0.0524	0.1948	-0.1345	Y
	34	36.7332	-43.6046	-40.1473	36.9156	-43.7638	-40.1068	-0.1824	-0.1592	0.0405	0.2455	-0.1592	Y
	35	33.7802	-42.9566	-42.0198	33.9308	-43.1038	-42.0157	-0.1506	-0.1472	0.0041	0.2106	-0.1472	Y
	36	30.3719	-43.0115	-44.3865	30.4933	-42.9408	-44.3849	-0.1214	0.0707	0.0016	0.1405	0.0707	Y
B-PILLAR Maximum (X, Y, Z)	37	2.9091	-42.9151	-43.3641	3.0543	-43.0679	-43.4214	-0.1452	-0.1528	-0.0573	0.2184	0.0000	NA
	38	5.9562	-44.4204	-39.5568	6.3196	-44.5495	-39.6473	-0.3634	-0.1291	-0.0905	0.3961	0.0000	NA
	39	3.3499	-45.7477	-35.6839	3.5996	-45.9157	-35.7350	-0.2497	-0.1680	-0.0511	0.3053	0.0000	NA
	40	6.8227	-46.4970	-32.6370	7.1386	-46.6345	-32.7422	-0.3159	-0.1375	-0.1052	0.3602	0.0000	NA
B-PILLAR Lateral (Y)	37	2.9091	-42.9151	-43.3641	3.0543	-43.0679	-43.4214	-0.1452	-0.1528	-0.0573	0.2184	-0.1528	Y
	38	5.9562	-44.4204	-39.5568	6.3196	-44.5495	-39.6473	-0.3634	-0.1291	-0.0905	0.3961	-0.1291	Y
	39	3.3499	-45.7477	-35.6839	3.5996	-45.9157	-35.7350	-0.2497	-0.1680	-0.0511	0.3053	-0.1680	Y
	40	6.8227	-46.4970	-32.6370	7.1386	-46.6345	-32.7422	-0.3159	-0.1375	-0.1052	0.3602	-0.1375	Y

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

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

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

Figure D-4. Occupant Compartment Deformation Data – Set 2, Test No. MTP-1

Date: 4/22/2019 Test Name: MTP-1 VIN: 1C6RD6GP3CS253410
Year: 2012 Make: Dodge Model: Ram 1500

Driver Side Maximum Deformation

Reference Set 1				Reference Set 2			
Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]	Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	0.0	≤ 4	Z	Roof	0.0	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.5	≤ 5	X, Y	A-Pillar Maximum	0.1	≤ 5	Z
A-Pillar Lateral	0.5	≤ 3	Y	A-Pillar Lateral	0.1	≤ 3	Y
B-Pillar Maximum	0.3	≤ 5	Y	B-Pillar Maximum	0.0	≤ 5	NA
B-Pillar Lateral	0.5	≤ 3	Y	B-Pillar Lateral	-0.2	≤ 3	Y
Toe Pan - Wheel Well	0.0	≤ 9	X	Toe Pan - Wheel Well	0.0	≤ 9	X
Side Front Panel	0.8	≤ 12	Y	Side Front Panel	0.2	≤ 12	Y
Side Door (above seat)	0.6	≤ 9	Y	Side Door (above seat)	0.1	≤ 9	Y
Side Door (below seat)	0.7	≤ 12	Y	Side Door (below seat)	0.2	≤ 12	Y
Floor Pan	-0.1	≤ 12	Z	Floor Pan	-0.1	≤ 12	Z
Dash - no MASH requirement	0.6	NA	X, Y, Z	Dash - no MASH requirement	0.6	NA	X, Y, Z

[A] Items highlighted in red do not meet MASH allowable deformations.

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

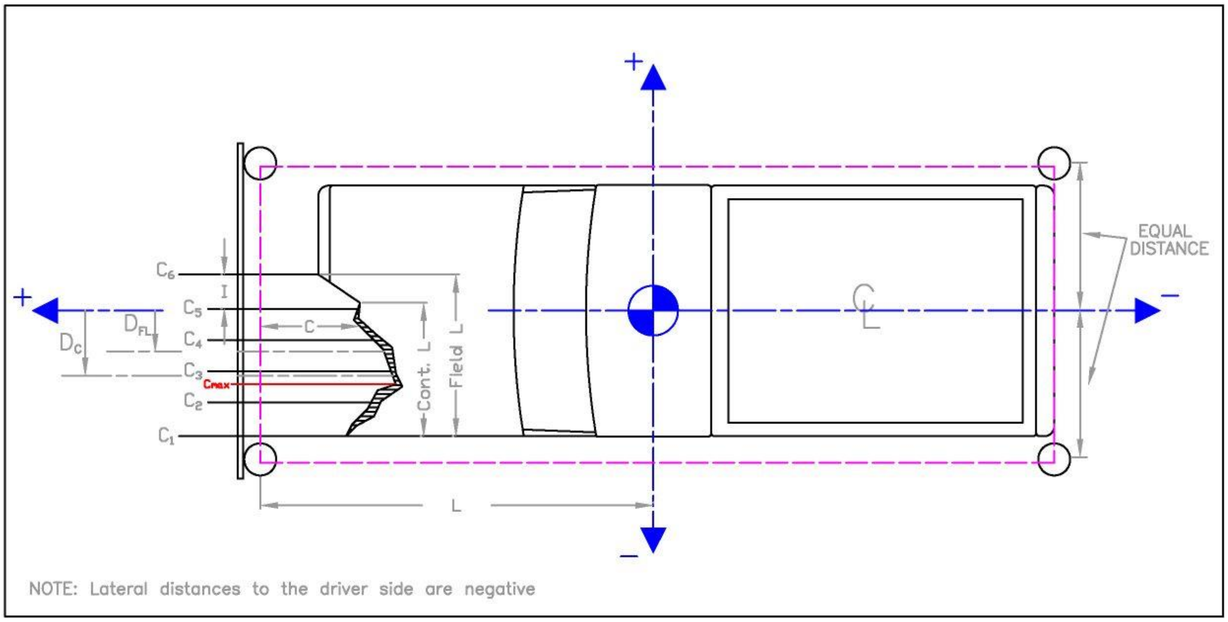
[C] For Toe Pan - Wheel Well the direction of defromation may include X and Z direction. For A-Pillar Maximum and B-Pillar Maximum the direction of deformation may include X, Y, and Z directions. The direction of deformation for Toe Pan -Wheel Well, A-Pillar Maximum, and B-Pillar Maximum only include components where the deformation is positive and intruding into the occupant compartment. If direction of deformation is "NA" then no intrusion is recorded and deformation will be 0.

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

Notes on vehicle interior crush:

Figure D-5. Maximum Occupant Compartment Deformation Data, Test No. MTP-1

Date:	**4/25/2019**	**Test Name:**	**MTP-1**	**VIN:**	**1C6RD6GP3CS253410**
Year:	**2012**	**Make:**	**Dodge**	**Model:**	**Ram 1500**



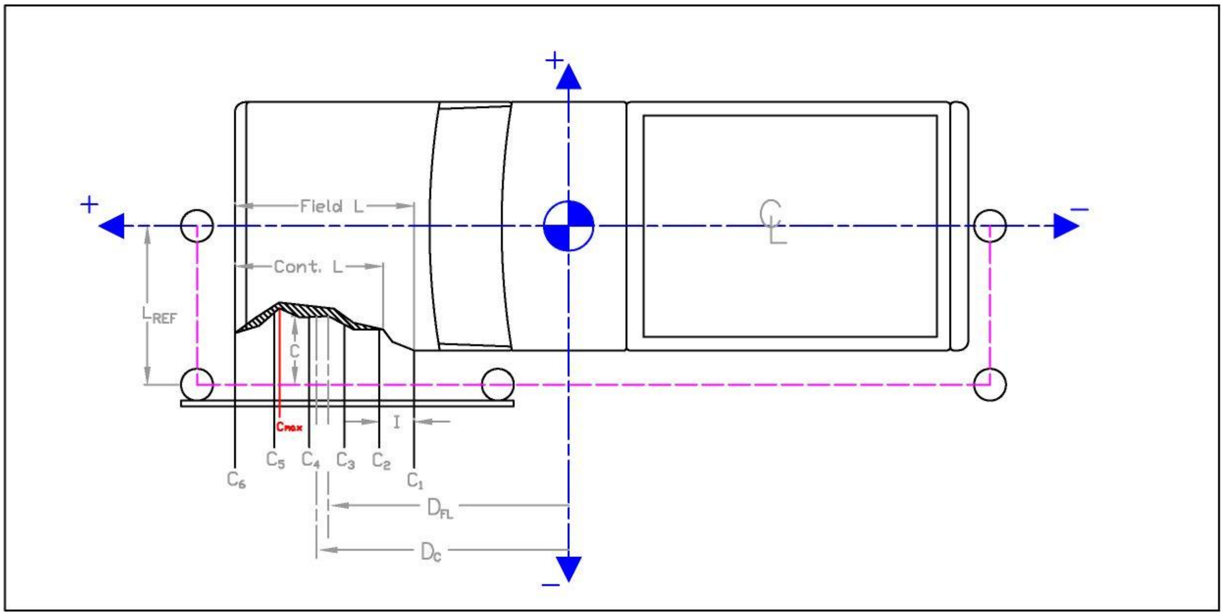
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	**119**	**(3023)**
Total Vehicle Width:	**77 5/8**	**(1972)**
Width of contact and induced crush - Field L:	**77 5/8**	**(1972)**
Crush measurement spacing interval (L/5) - I:	**15 1/2**	**(394)**
Distance from center of vehicle to center of Field L - D_{FL}:	**0**	**()**
Width of Contact Damage:	**77 5/8**	**(1972)**
Distance from center of vehicle to center of contact damage - D_C:	**0**	**()**

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

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/A	N/A	-38 7/8	-(987)	22 1/2	(572)	18 1/4	(464)	N/A	N/A
C_2	22 5/8	(575)	-23 3/8	-(594)	6 5/8	(168)			-2 1/4	-(57)
C_3	19 5/8	(498)	-7 7/8	-(200)	4 1/4	(108)			-2 7/8	-(73)
C_4	20 1/4	(514)	7 5/8	(194)	4 1/4	(108)			-2 1/4	-(57)
C_5	21 5/8	(549)	23 1/8	(587)	6 1/8	(156)			-2 3/4	-(70)
C_6	N/A	N/A	38 5/8	(981)	20 1/2	(521)			N/A	N/A
C_{MAX}	21 5/8	(549)	23 1/8	(587)	6 1/8	(156)			-2 3/4	-(70)

Figure D-6. Exterior Vehicle Crush (NASS) - Front, Test No. MTP-1

Date:	**4/25/2019**	**Test Name:**	**MTP-1**	**VIN:**	**1C6RD6GP3CS253410**
Year:	**2012**	**Make:**	**Dodge**	**Model:**	**Ram 1500**



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	**49**	**(1245)**
Total Vehicle Length:	**229**	**(5817)**
Distance from vehicle c.g. to 1/2 of Vehicle total length:	**-8 1/5**	**-(208)**
Width of contact and induced crush - Field L:	**229**	**(5817)**
Crush measurement spacing interval (L/5) - I:	**45 3/4**	**(1162)**
Distance from vehicle c.g. to center of Field L - D_{FL}:	**-8**	**-(203)**
Width of Contact Damage:	**229**	**(5817)**
Distance from vehicle c.g. to center of contact damage - D_C:	**-8**	**-(203)**

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)

NOTE: All values must be filled out above before crush measurements are filled out.

Crush Measurement			Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual	Crush
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/A	N/A	-122 1/2	-(3112)	33 1/2	(851)	5	(127)	N/A	N/A
C_2	N/A	N/A	-76 3/4	-(1949)	5 1/4	(133)			N/A	N/A
C_3	10 1/4	(260)	-31	-(787)	5 1/2	(140)			- 1/4	-(6)
C_4	10 1/2	(267)	14 3/4	(375)	5 1/8	(130)			3/8	(10)
C_5	N/A	N/A	60 1/2	(1537)	5	(127)			N/A	N/A
C_6	N/A	N/A	106 1/4	(2699)	30	(762)			N/A	N/A
C_{MAX}	15	(381)	38 1/2	(978)	5 1/8	(130)			4 7/8	(124)

Figure D-7. Exterior Vehicle Crush (NASS) - Side, Test No. MTP-1

Date: 7/15/2019 Test Name: MTP-2 VIN: 5NPEB4ACXDH545633
Year: 2013 Make: Hyundai Model: Sonata

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	56.0637	8.3213	-3.3045	54.5264	13.8413	-4.2299	1.5373	-5.5200	0.9254	5.8043	1.7943	X, Z
	2	56.4863	3.8749	-3.4470	56.0397	8.8158	-3.3937	0.4466	-4.9409	-0.0533	4.9613	0.4466	X
	3	56.4666	-0.8753	-3.7265	56.3987	4.2791	-3.4807	0.0679	5.1544	-0.2458	5.1607	0.0679	X
	4	56.5083	-8.0373	-3.1743	56.3539	-0.4205	-3.7302	0.1544	7.6168	0.5559	7.6386	0.5769	X, Z
	5	49.7719	13.3776	-3.9330	56.4079	-7.6045	-3.1652	-6.6360	20.9821	-0.7678	22.0199	0.0000	NA
	6	50.8445	9.4522	-1.5955	49.6794	13.7985	-4.0345	1.1651	-4.3463	2.4390	5.1183	2.7030	X, Z
	7	50.9182	4.1310	-1.1884	50.8195	9.9367	-1.6485	0.0987	-5.8057	0.4601	5.8247	0.4706	X, Z
	8	50.9739	-0.7920	-1.8280	50.8135	4.5711	-1.2144	0.1604	5.3631	-0.6136	5.4005	0.1604	X
	9	50.6267	-8.0713	-1.1132	50.9000	-0.3741	-1.8453	-0.2733	7.6972	0.7321	7.7368	0.7321	Z
	10	45.2662	13.2544	-3.8421	50.5485	-7.6661	-1.1283	-5.2823	20.9205	-2.7138	21.7471	0.0000	NA
FLOOR PAN (Z)	11	45.2529	13.2431	-3.8195	45.1523	13.6247	-3.8710	0.1006	-0.3816	0.0515	0.3980	0.0515	Z
	12	45.9612	9.3833	-1.3503	45.8996	9.7723	-1.3868	0.0616	-0.3890	0.0365	0.3955	0.0365	Z
	13	46.0977	4.0679	-0.9517	46.0501	4.4790	-0.9695	0.0476	-0.4111	0.0178	0.4142	0.0178	Z
	14	46.2022	-0.7859	-1.6240	46.2145	-0.3906	-1.6418	-0.0123	0.3953	0.0178	0.3959	0.0178	Z
	15	46.4285	-7.8706	-1.0040	46.3760	-7.4892	-1.0259	0.0525	0.3814	0.0219	0.3856	0.0219	Z
	16	39.9701	13.1897	-3.8964	39.9006	13.5613	-3.9479	0.0695	-0.3716	0.0515	0.3815	0.0515	Z
	17	40.3163	9.0397	-1.0437	40.2722	9.4144	-1.0831	0.0441	-0.3747	0.0394	0.3793	0.0394	Z
	18	40.5204	4.2417	-0.6960	40.5251	4.5730	-0.7346	-0.0047	-0.3313	0.0386	0.3336	0.0386	Z
	19	40.5583	-0.7834	-1.4081	40.5369	-0.4355	-1.4195	0.0214	0.3479	0.0114	0.3487	0.0114	Z
	20	40.5760	-8.1397	-0.8662	40.4382	-7.7627	-0.8715	0.1378	0.3770	0.0053	0.4014	0.0053	Z
	21	35.3995	13.2240	-4.1075	35.3032	13.5217	-4.0432	0.0963	-0.2977	-0.0643	0.3194	-0.0643	Z
	22	35.1408	8.9252	-0.9297	35.0897	9.3218	-0.9948	0.0511	-0.3966	0.0651	0.4051	0.0651	Z
	23	35.1905	4.1528	-0.5806	35.2010	4.5081	-0.5634	-0.0105	-0.3553	-0.0172	0.3559	-0.0172	Z
	24	35.0066	-0.8051	-1.2449	34.9681	-0.4465	-1.2177	0.0385	0.3586	-0.0272	0.3617	-0.0272	Z
	25	35.4297	-8.3181	-0.7339	35.3825	-7.9612	-0.6955	0.0472	0.3569	-0.0384	0.3620	-0.0384	Z
	26	31.0571	13.2662	-4.2918	30.9503	13.5255	-4.3119	0.1068	-0.2593	0.0201	0.2812	0.0201	Z
	27	31.1973	9.1418	-4.2008	31.1070	9.4865	-4.2195	0.0903	-0.3447	0.0187	0.3568	0.0187	Z
	28	31.3621	3.9522	-4.0970	31.1901	4.2553	-4.0982	0.1720	-0.3031	0.0012	0.3485	0.0012	Z
	29	31.5516	-0.2242	-3.9948	31.3852	0.0999	-3.9896	0.1664	0.3241	-0.0052	0.3644	-0.0052	Z
	30	31.7880	-7.3315	-3.8776	31.7236	-6.9718	-3.8675	0.0644	0.3597	-0.0101	0.3656	-0.0101	Z

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

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

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

Pretest Floor Pan

Posttest Floor Pan

Figure D-8. Floor Pan Deformation Data – Set 1, Test No. MTP-2

Date: 7/15/2019 Test Name: MTP-2 VIN: 5NPEB4ACXDH545633
Year: 2013 Make: Hyundai Model: Sonata

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	55.8891	-9.2372	-0.1753	54.7960	-3.7359	-1.0344	1.0931	5.5013	0.8591	5.6743	1.3903	X, Z
	2	56.0499	-13.6972	-0.4052	55.9877	-8.8617	-0.2923	0.0622	4.8355	-0.1129	4.8372	0.0622	X
	3	55.7528	-18.4312	-0.7837	56.0682	-13.4091	-0.4744	-0.3154	5.0221	-0.3093	5.0415	0.0000	NA
	4	55.3635	-25.5927	-0.3804	55.7376	-18.0907	-0.8268	-0.3741	7.5020	0.4464	7.5246	0.4464	Z
	5	49.9164	-3.8044	-0.7739	55.3433	-25.2747	-0.4181	-5.4269	-21.4703	-0.3558	22.1484	0.0000	NA
	6	50.7238	-7.8328	1.4941	49.9537	-3.4837	-0.8908	0.7701	4.3491	2.3849	5.0195	2.5062	X, Z
	7	50.4773	-13.1560	1.7911	50.8261	-7.4581	1.4223	-0.3488	5.6979	0.3688	5.7205	0.3688	Z
	8	50.2500	-18.0598	1.0498	50.4852	-12.8210	1.7391	-0.2352	5.2388	-0.6893	5.2892	0.0000	NA
	9	49.4634	-25.3185	1.6088	50.2751	-17.7477	1.0015	-0.8117	7.5708	0.6073	7.6384	0.6073	Z
	10	45.4105	-3.6615	-0.7398	49.4677	-25.0176	1.5555	-4.0572	-21.3561	-2.2953	21.8589	0.0000	NA
FLOOR PAN (Z)	11	45.3962	-3.6724	-0.7176	45.4229	-3.3813	-0.7785	-0.0267	0.2911	0.0609	0.2986	0.0609	Z
	12	45.8422	-7.6163	1.6790	45.9026	-7.3241	1.6288	-0.0604	0.2922	0.0502	0.3026	0.0502	Z
	13	45.6587	-12.9373	1.9685	45.7226	-12.6242	1.9321	-0.0639	0.3131	0.0364	0.3216	0.0364	Z
	14	45.4848	-17.7743	1.1966	45.5953	-17.4794	1.1555	-0.1105	0.2949	0.0411	0.3176	0.0411	Z
	15	45.2834	-24.8709	1.6716	45.3130	-24.5858	1.6181	-0.0296	0.2851	0.0535	0.2916	0.0535	Z
	16	40.1211	-3.4103	-0.8591	40.1784	-3.1190	-0.9118	-0.0573	0.2913	0.0527	0.3015	0.0527	Z
	17	40.1833	-7.6300	1.9105	40.2607	-7.3405	1.8657	-0.0774	0.2895	0.0448	0.3030	0.0448	Z
	18	40.0986	-12.4376	2.1606	40.2114	-12.1945	2.1112	-0.1128	0.2431	0.0494	0.2725	0.0494	Z
	19	39.8486	-17.4408	1.3446	39.9235	-17.1786	1.3173	-0.0749	0.2622	0.0273	0.2741	0.0273	Z
	20	39.4239	-24.7945	1.7334	39.3682	-24.4957	1.7043	0.0557	0.2988	0.0291	0.3053	0.0291	Z
	21	35.5636	-3.1002	-1.1244	35.5887	-2.8727	-1.0560	-0.0251	0.2275	-0.0684	0.2389	-0.0684	Z
	22	35.0091	-7.4390	1.9599	35.0816	-7.1150	1.8977	-0.0725	0.3240	0.0622	0.3378	0.0622	Z
	23	34.7717	-12.2120	2.2100	34.8917	-11.9344	2.2252	-0.1200	0.2776	-0.0152	0.3028	-0.0152	Z
	24	34.3036	-17.1358	1.4406	34.3626	-16.8503	1.4606	-0.0590	0.2855	-0.0200	0.2922	-0.0200	Z
	25	34.2747	-24.6694	1.8001	34.3082	-24.3856	1.8230	-0.0335	0.2838	-0.0229	0.2867	-0.0229	Z
	26	31.2342	-2.7964	-1.3600	31.2477	-2.5947	-1.3701	-0.0135	0.2017	0.0101	0.2024	0.0101	Z
	27	31.1289	-6.9228	-1.3532	31.1548	-6.6368	-1.3641	-0.0259	0.2860	0.0109	0.2874	0.0109	Z
	28	30.9850	-12.1141	-1.3555	30.9148	-11.8645	-1.3561	0.0702	0.2496	0.0006	0.2593	0.0006	Z
	29	30.9257	-16.2956	-1.3380	30.8529	-16.0254	-1.3361	0.0728	0.2702	-0.0019	0.2798	-0.0019	Z
	30	30.7397	-23.4053	-1.3660	30.7546	-23.1055	-1.3648	-0.0149	0.2998	-0.0012	0.3002	-0.0012	Z

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

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

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

Pretest Floor Pan	Posttest Floor Pan
	

Figure D-9. Floor Pan Deformation Data – Set 2, Test No. MTP-2

Date: 7/15/2019 | Test Name: MTP-2 | VIN: 5NPEB4ACXDH545633

Year: 2013 | Make: Hyundai | Model: Sonata

VEHICLE DEFORMATION
DRIVER SIDE INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	43.9452	16.3436	-31.5270	43.8319	16.4565	-31.5147	0.1133	-0.1129	0.0123	0.1604	0.1604	X, Y, Z
	2	44.1384	3.8356	-33.4845	43.9974	3.8491	-33.5920	0.1410	-0.0135	-0.1075	0.1778	0.1778	X, Y, Z
	3	47.8666	-9.7550	-29.8800	47.8463	-9.5191	-29.8317	0.0203	0.2359	0.0483	0.2416	0.2416	X, Y, Z
	4	38.3428	17.0238	-19.5289	38.2776	17.1660	-19.4625	0.0652	-0.1422	0.0664	0.1699	0.1699	X, Y, Z
	5	44.5447	2.9722	-17.9602	44.3868	3.0423	-17.9955	0.1579	-0.0701	-0.0353	0.1763	0.1763	X, Y, Z
	6	45.6494	-8.7525	-18.9262	45.4436	-8.6392	-18.9323	0.2058	0.1133	-0.0061	0.2350	0.2350	X, Y, Z
SIDE PANEL (Y)	7	52.2638	-9.7126	-12.9661	52.0260	-9.6085	-12.9203	0.2378	0.1041	0.0458	0.2636	0.1041	Y
	8	51.6563	-10.4519	-7.6617	51.4339	-10.3670	-7.6288	0.2224	0.0849	0.0329	0.2403	0.0849	Y
	9	53.9041	-10.5535	-6.9384	53.7314	-10.5013	-6.9248	0.1727	0.0522	0.0136	0.1809	0.0522	Y
IMPACT SIDE DOOR (Y)	10	16.1207	-12.9802	-29.2420	15.9080	-13.3004	-29.2404	0.2127	-0.3202	0.0016	0.3844	-0.3202	Y
	11	30.6709	-12.9126	-28.9037	30.4446	-13.1601	-28.7449	0.2263	-0.2475	0.1588	0.3711	-0.2475	Y
	12	43.8955	-12.2581	-28.4370	43.7378	-12.3600	-28.2387	0.1577	-0.1019	0.1983	0.2731	-0.1019	Y
	13	18.9044	-12.8664	-11.9128	18.5883	-12.9717	-11.9176	0.3161	-0.1053	-0.0048	0.3332	-0.1053	Y
	14	31.1031	-12.9186	-11.3096	30.7735	-12.9540	-11.1217	0.3296	-0.0354	0.1879	0.3810	-0.0354	Y
	15	41.1089	-12.7493	-11.3099	40.7157	-12.5843	-11.2279	0.3932	0.1650	0.0820	0.4342	0.1650	Y
ROOF - (Z)	16	30.7141	15.6596	-45.5841	30.7416	15.8910	-45.5767	-0.0275	-0.2314	0.0074	0.2331	0.0074	Z
	17	31.1996	10.8502	-45.2835	31.2798	11.1126	-45.2456	-0.0802	-0.2624	0.0379	0.2770	0.0379	Z
	18	30.8230	6.4513	-44.9272	30.9165	6.7201	-44.8958	-0.0935	-0.2688	0.0314	0.2863	0.0314	Z
	19	30.5613	1.3983	-44.4706	30.6088	1.7250	-44.4654	-0.0475	-0.3267	0.0052	0.3302	0.0052	Z
	20	29.8518	-4.6928	-43.9751	29.8892	-4.4823	-43.9543	-0.0374	0.2105	0.0208	0.2148	0.0208	Z
	21	23.9897	15.4591	-48.3913	24.0135	15.7156	-48.3719	-0.0238	-0.2565	0.0194	0.2583	0.0194	Z
	22	23.9002	11.3249	-48.2490	23.9763	11.5990	-48.2247	-0.0761	-0.2741	0.0243	0.2855	0.0243	Z
	23	23.5371	6.5343	-47.9984	23.6700	6.7872	-47.9725	-0.1329	-0.2529	0.0259	0.2869	0.0259	Z
	24	23.0411	2.3584	-47.7331	23.0708	2.5584	-47.7028	-0.0297	-0.2000	0.0303	0.2045	0.0303	Z
	25	22.5335	-3.6213	-47.0557	22.4808	-3.4069	-46.6944	0.0527	0.2144	0.3613	0.4234	0.3613	Z
	26	16.2589	15.2957	-49.4088	16.2847	15.4927	-49.3485	-0.0258	-0.1970	0.0603	0.2076	0.0603	Z
	27	16.3912	10.9131	-49.2162	16.4124	11.1180	-49.1657	-0.0212	-0.2049	0.0505	0.2121	0.0505	Z
	28	16.2902	5.7230	-48.8690	16.2605	5.9119	-48.8186	0.0297	-0.1889	0.0504	0.1978	0.0504	Z
	29	16.3655	0.9479	-48.3854	16.2925	1.1596	-48.3197	0.0730	-0.2117	0.0657	0.2334	0.0657	Z
	30	16.4433	-4.0133	-47.7063	16.3128	-3.8142	-47.6865	0.1305	0.1991	0.0198	0.2389	0.0198	Z
A-PILLAR Maximum (X, Y, Z)	31	49.8635	-9.9355	-32.0565	49.9146	-9.7541	-32.0007	-0.0511	0.1814	0.0558	0.1965	0.1898	Y, Z
	32	48.7232	-9.6107	-33.9773	48.7764	-9.4196	-33.9996	-0.0532	0.1911	-0.0223	0.1996	0.1911	Y
	33	45.7349	-9.2031	-36.2041	45.6262	-9.0048	-36.2447	0.1087	0.1983	-0.0406	0.2298	0.2261	X, Y
	34	42.8132	-8.8347	-37.3124	42.7901	-8.6518	-37.2680	0.0231	0.1829	0.0444	0.1896	0.1896	X, Y, Z
	35	38.1099	-8.0031	-40.1414	38.0959	-7.7975	-40.0352	0.0140	0.2056	0.1062	0.2318	0.2318	X, Y, Z
	36	33.3584	-7.2651	-42.0505	33.3157	-7.0617	-42.0032	0.0427	0.2034	0.0473	0.2131	0.2131	X, Y, Z
A-PILLAR Lateral (Y)	31	49.8635	-9.9355	-32.0565	49.9146	-9.7541	-32.0007	-0.0511	0.1814	0.0558	0.1965	0.1814	Y
	32	48.7232	-9.6107	-33.9773	48.7764	-9.4196	-33.9996	-0.0532	0.1911	-0.0223	0.1996	0.1911	Y
	33	45.7349	-9.2031	-36.2041	45.6262	-9.0048	-36.2447	0.1087	0.1983	-0.0406	0.2298	0.1983	Y
	34	42.8132	-8.8347	-37.3124	42.7901	-8.6518	-37.2680	0.0231	0.1829	0.0444	0.1896	0.1829	Y
	35	38.1099	-8.0031	-40.1414	38.0959	-7.7975	-40.0352	0.0140	0.2056	0.1062	0.2318	0.2056	Y
	36	33.3584	-7.2651	-42.0505	33.3157	-7.0617	-42.0032	0.0427	0.2034	0.0473	0.2131	0.2034	Y
B-PILLAR Maximum (X, Y, Z)	37	8.2549	-7.3781	-42.0845	7.8748	-7.1821	-42.0672	0.3801	0.1960	0.0173	0.4280	0.4280	X, Y, Z
	38	6.1124	-8.9250	-39.2442	5.7092	-8.6937	-39.2543	0.4032	0.2313	-0.0101	0.4649	0.4648	X, Y
	39	9.8386	-9.6796	-37.0984	9.5333	-9.5119	-37.0332	0.3053	0.1677	0.0652	0.3544	0.3544	X, Y, Z
	40	6.9880	-10.9624	-32.6472	6.6500	-10.7341	-32.6653	0.3380	0.2283	-0.0181	0.4083	0.4079	X, Y
B-PILLAR Lateral (Y)	37	8.2549	-7.3781	-42.0845	7.8748	-7.1821	-42.0672	0.3801	0.1960	0.0173	0.4280	0.1960	Y
	38	6.1124	-8.9250	-39.2442	5.7092	-8.6937	-39.2543	0.4032	0.2313	-0.0101	0.4649	0.2313	Y
	39	9.8386	-9.6796	-37.0984	9.5333	-9.5119	-37.0332	0.3053	0.1677	0.0652	0.3544	0.1677	Y
	40	6.9880	-10.9624	-32.6472	6.6500	-10.7341	-32.6653	0.3380	0.2283	-0.0181	0.4083	0.2283	Y

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

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

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

Figure D-10. Occupant Compartment Deformation Data – Set 1, Test No. MTP-2

Date: 7/15/2019 Test Name: MTP-2 VIN: 5NPEB4ACXDH545633
Year: 2013 Make: Hyundai Model: Sonata

VEHICLE DEFORMATION
DRIVER SIDE INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	44.7355	-0.0705	-28.3190	44.6179	0.1003	-28.3466	0.1176	0.1708	-0.0276	0.2092	0.2092	X, Y, Z
	2	44.1537	-12.5184	-30.5622	44.0262	-12.4450	-30.7037	0.1275	0.0734	-0.1415	0.2041	0.2041	X, Y, Z
	3	46.9576	-26.3974	-27.2294	46.9912	-26.1054	-27.2018	-0.0336	0.2920	0.0276	0.2952	0.2952	X, Y, Z
	4	39.0326	0.7007	-16.3739	38.9700	0.8931	-16.3432	0.0626	-0.1924	0.0307	0.2046	0.2046	X, Y, Z
	5	44.3019	-13.7518	-15.0582	44.1723	-13.6123	-15.1259	0.1296	0.1395	-0.0677	0.2021	0.2021	X, Y, Z
	6	44.6668	-25.4988	-16.2817	44.5134	-25.3138	-16.3125	0.1534	0.1850	-0.0308	0.2423	0.2423	X, Y, Z
SIDE PANEL (Y)	7	51.1281	-27.0145	-10.2693	50.9483	-26.8216	-10.2519	0.1798	0.1929	0.0174	0.2643	0.1929	Y
	8	50.4057	-27.8312	-4.9908	50.2450	-27.6562	-4.9855	0.1607	0.1750	0.0053	0.2377	0.1750	Y
	9	52.6327	-28.0931	-4.2441	52.5209	-27.9486	-4.2594	0.1118	0.1445	-0.0153	0.1833	0.1445	Y
IMPACT SIDE DOOR (Y)	10	15.0648	-27.5896	-27.0327	14.8749	-27.9008	-27.0458	0.1899	-0.3112	-0.0131	0.3648	-0.3112	Y
	11	29.5839	-28.4646	-26.5248	29.3850	-28.6775	-26.3878	0.1989	-0.2129	0.1370	0.3220	-0.2129	Y
	12	42.8161	-28.6717	-25.8905	42.6950	-28.7186	-25.7181	0.1211	-0.0469	0.1724	0.2158	-0.0469	Y
	13	17.6244	-28.0411	-9.6745	17.3565	-28.1152	-9.6916	0.2679	-0.0741	-0.0171	0.2785	-0.0741	Y
	14	29.7860	-28.8904	-8.9318	29.5086	-28.8743	-8.7619	0.2774	0.0161	0.1699	0.3257	0.0161	Y
	15	39.7812	-29.3644	-8.8126	39.4551	-29.1227	-8.7506	0.3261	0.2417	0.0620	0.4106	0.2417	Y
ROOF - (Z)	16	31.6718	0.4104	-42.5400	31.6923	0.6566	-42.5605	-0.0205	-0.2462	-0.0205	0.2479	-0.0205	Z
	17	31.8446	-4.4257	-42.3448	31.9287	-4.1522	-42.3306	-0.0841	0.2735	0.0142	0.2865	0.0142	Z
	18	31.1828	-8.7982	-42.0945	31.2893	-8.5201	-42.0833	-0.1065	0.2781	0.0112	0.2980	0.0112	Z
	19	30.5925	-13.8328	-41.7576	30.6668	-13.4944	-41.7682	-0.0743	0.3384	-0.0106	0.3466	-0.0106	Z
	20	29.4884	-19.8753	-41.4110	29.5571	-19.6544	-41.4043	-0.0687	0.2209	0.0067	0.2314	0.0067	Z
	21	24.9854	0.7050	-45.4285	25.0013	0.9614	-45.4325	-0.0159	-0.2564	-0.0040	0.2569	-0.0040	Z
	22	24.6297	-3.4171	-45.3827	24.7068	-3.1471	-45.3780	-0.0771	0.2700	0.0047	0.2808	0.0047	Z
	23	23.9577	-8.1788	-45.2469	24.0994	-7.9348	-45.2370	-0.1417	0.2440	0.0099	0.2823	0.0099	Z
	24	23.1922	-12.3191	-45.0838	23.2356	-12.1228	-45.0687	-0.0434	0.1963	0.0151	0.2016	0.0151	Z
	25	22.2943	-18.2675	-44.5505	22.2641	-18.0602	-44.2007	0.0302	0.2073	0.3498	0.4077	0.3498	Z
	26	17.2738	1.0613	-46.5387	17.2862	1.2419	-46.4987	-0.0124	-0.1806	0.0400	0.1854	0.0400	Z
	27	17.1231	-3.3239	-46.4459	17.1399	-3.1352	-46.4124	-0.0168	0.1887	0.0335	0.1924	0.0335	Z
	28	16.6857	-8.5032	-46.2196	16.6608	-8.3280	-46.1837	0.0249	0.1752	0.0359	0.1806	0.0359	Z
	29	16.4491	-13.2829	-45.8455	16.3917	-13.0829	-45.7911	0.0574	0.2000	0.0544	0.2151	0.0544	Z
	30	16.2005	-18.2528	-45.2802	16.0954	-18.0608	-45.2692	0.1051	0.1920	0.0110	0.2192	0.0110	Z
A-PILLAR Maximum (X, Y, Z)	31	48.9670	-26.6572	-29.3863	49.0676	-26.4218	-29.3527	-0.1006	0.2354	0.0336	0.2582	0.2378	Y, Z
	32	47.8749	-26.2172	-31.3121	47.9771	-25.9738	-31.3560	-0.1022	0.2434	-0.0439	0.2676	0.2434	Y
	33	44.9480	-25.5689	-33.5632	44.8866	-25.3149	-33.6257	0.0614	0.2540	-0.0625	0.2687	0.2613	X, Y
	34	42.0706	-24.9889	-34.6964	42.0908	-24.7637	-34.6719	-0.0202	0.2252	0.0245	0.2274	0.2265	Y, Z
	35	37.4672	-23.7940	-37.5596	37.4931	-23.5588	-37.4706	-0.0259	0.2352	0.0890	0.2528	0.2515	Y, Z
	36	32.7980	-22.7099	-39.5059	32.7925	-22.4840	-39.4739	0.0055	0.2259	0.0320	0.2282	0.2282	X, Y, Z
A-PILLAR Lateral (Y)	31	48.9670	-26.6572	-29.3863	49.0676	-26.4218	-29.3527	-0.1006	0.2354	0.0336	0.2582	0.2354	Y
	32	47.8749	-26.2172	-31.3121	47.9771	-25.9738	-31.3560	-0.1022	0.2434	-0.0439	0.2676	0.2434	Y
	33	44.9480	-25.5689	-33.5632	44.8866	-25.3149	-33.6257	0.0614	0.2540	-0.0625	0.2687	0.2540	Y
	34	42.0706	-24.9889	-34.6964	42.0908	-24.7637	-34.6719	-0.0202	0.2252	0.0245	0.2274	0.2252	Y
	35	37.4672	-23.7940	-37.5596	37.4931	-23.5588	-37.4706	-0.0259	0.2352	0.0890	0.2528	0.2352	Y
	36	32.7980	-22.7099	-39.5059	32.7925	-22.4840	-39.4739	0.0055	0.2259	0.0320	0.2282	0.2259	Y
B-PILLAR Maximum (X, Y, Z)	37	7.7412	-21.2089	-39.8325	7.3960	-21.0172	-39.8197	0.3452	0.1917	0.0128	0.3951	0.3951	X, Y, Z
	38	5.4673	-22.6778	-37.0536	5.1062	-22.4515	-37.0652	0.3611	0.2263	-0.0116	0.4263	0.4262	X, Y
	39	9.1094	-23.7180	-34.8829	8.8444	-23.5544	-34.8212	0.2650	0.1636	0.0617	0.3175	0.3175	X, Y, Z
	40	6.1249	-24.9138	-30.4957	5.8371	-24.6888	-30.5137	0.2878	0.2250	-0.0180	0.3658	0.3653	X, Y
B-PILLAR Lateral (Y)	37	7.7412	-21.2089	-39.8325	7.3960	-21.0172	-39.8197	0.3452	0.1917	0.0128	0.3951	0.1917	Y
	38	5.4673	-22.6778	-37.0536	5.1062	-22.4515	-37.0652	0.3611	0.2263	-0.0116	0.4263	0.2263	Y
	39	9.1094	-23.7180	-34.8829	8.8444	-23.5544	-34.8212	0.2650	0.1636	0.0617	0.3175	0.1636	Y
	40	6.1249	-24.9138	-30.4957	5.8371	-24.6888	-30.5137	0.2878	0.2250	-0.0180	0.3658	0.2250	Y

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

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

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

Figure D-11. Occupant Compartment Deformation Data – Set 2, Test No. MTP-2

Date: 7/15/2019 Test Name: MTP-2 VIN: 5NPEB4ACXDH545633
Year: 2013 Make: Hyundai Model: Sonata

Driver Side Maximum Deformation

Reference Set 1				Reference Set 2			
Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]	Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	0.4	≤ 4	Z	Roof	0.3	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.2	≤ 5	X, Y, Z	A-Pillar Maximum	0.3	≤ 5	X, Y
A-Pillar Lateral	0.2	≤ 3	Y	A-Pillar Lateral	0.3	≤ 3	Y
B-Pillar Maximum	0.5	≤ 5	X, Y	B-Pillar Maximum	0.4	≤ 5	X, Y
B-Pillar Lateral	0.2	≤ 3	Y	B-Pillar Lateral	0.2	≤ 3	Y
Toe Pan - Wheel Well	2.7	≤ 9	X, Z	Toe Pan - Wheel Well	2.5	≤ 9	X, Z
Side Front Panel	0.1	≤ 12	Y	Side Front Panel	0.2	≤ 12	Y
Side Door (above seat)	-0.3	≤ 9	Y	Side Door (above seat)	-0.3	≤ 9	Y
Side Door (below seat)	0.2	≤ 12	Y	Side Door (below seat)	0.2	≤ 12	Y
Floor Pan	0.1	≤ 12	Z	Floor Pan	0.1	≤ 12	Z
Dash - no MASH requirement	0.2	NA	X, Y, Z	Dash - no MASH requirement	0.3	NA	X, Y, Z

[A] Items highlighted in red do not meet MASH allowable deformations.

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

[C] For Toe Pan - Wheel Well the direction of defromation may include X and Z direction. For A-Pillar Maximum and B-Pillar Maximum the direction of deformation may include X, Y, and Z directions. The direction of deformation for Toe Pan -Wheel Well, A-Pillar Maximum, and B-Pillar Maximum only include components where the deformation is positive and intruding into the occupant compartment. If direction of deformation is "NA" then no intrusion is recorded and deformation will be 0.

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

Notes on vehicle interior crush:

Figure D-12. Max Occupant Compartment Deformation Data, Test No. MTP-2

Appendix E. Accelerometer and Rate Transducer Data Plots, Test No. MTP-1

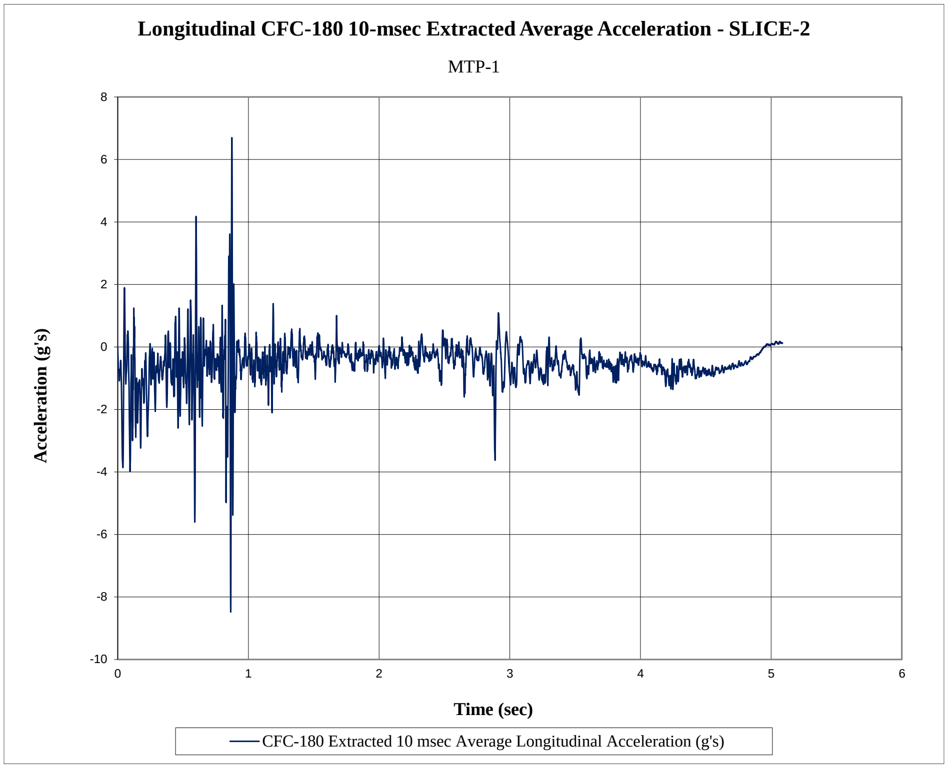


Figure E-1. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. MTP-1

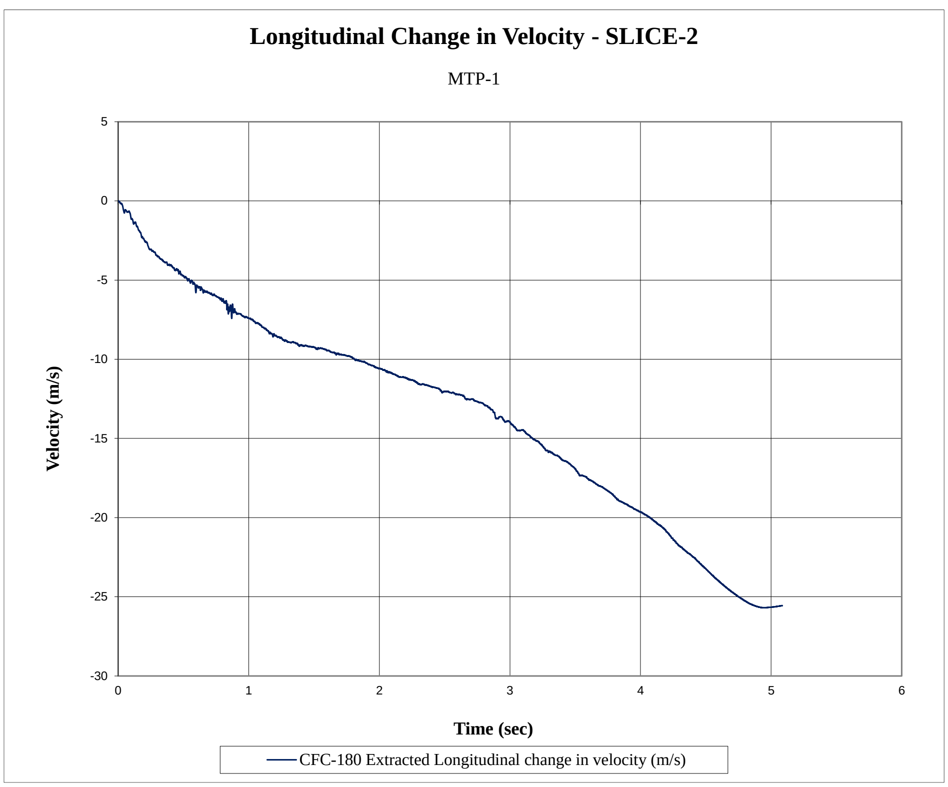


Figure E-2. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. MTP-1

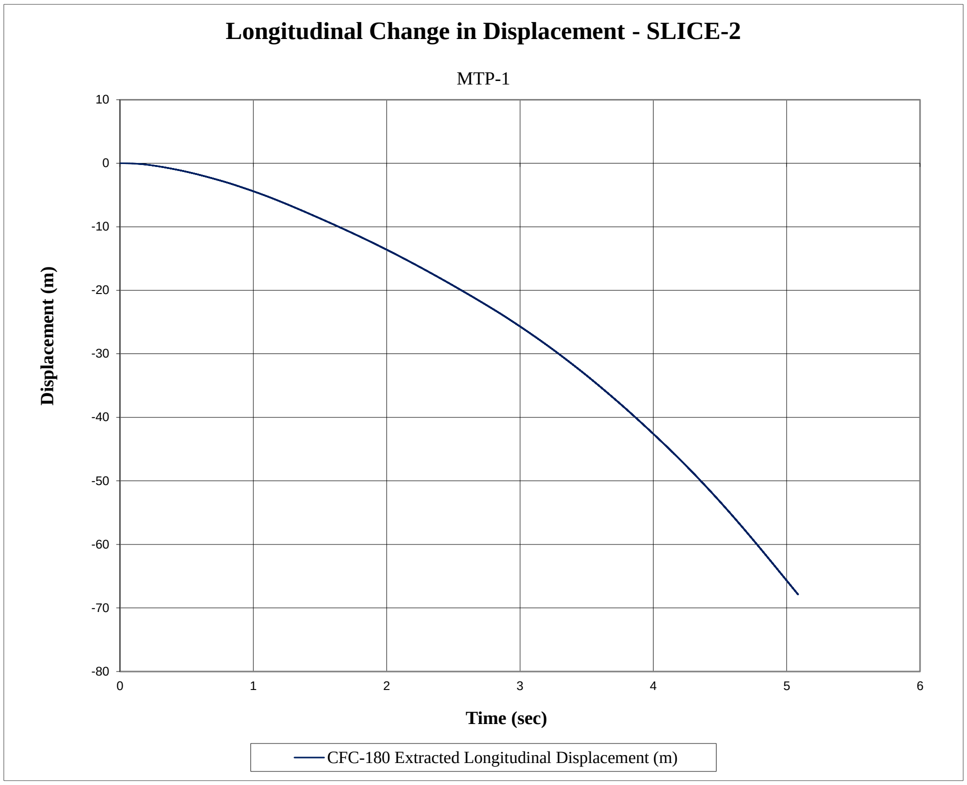


Figure E-3. Longitudinal Occupant Displacement (SLICE-2), Test No. MTP-1

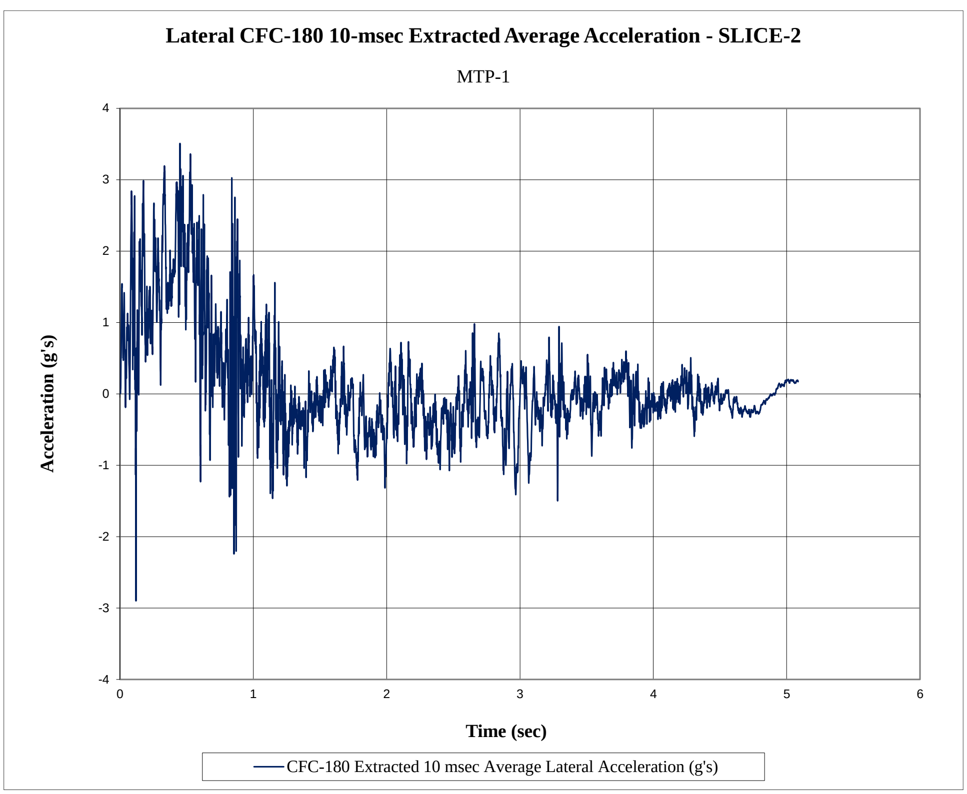


Figure E-4. 10-ms Average Lateral Deceleration (SLICE-2), Test No. MTP-1

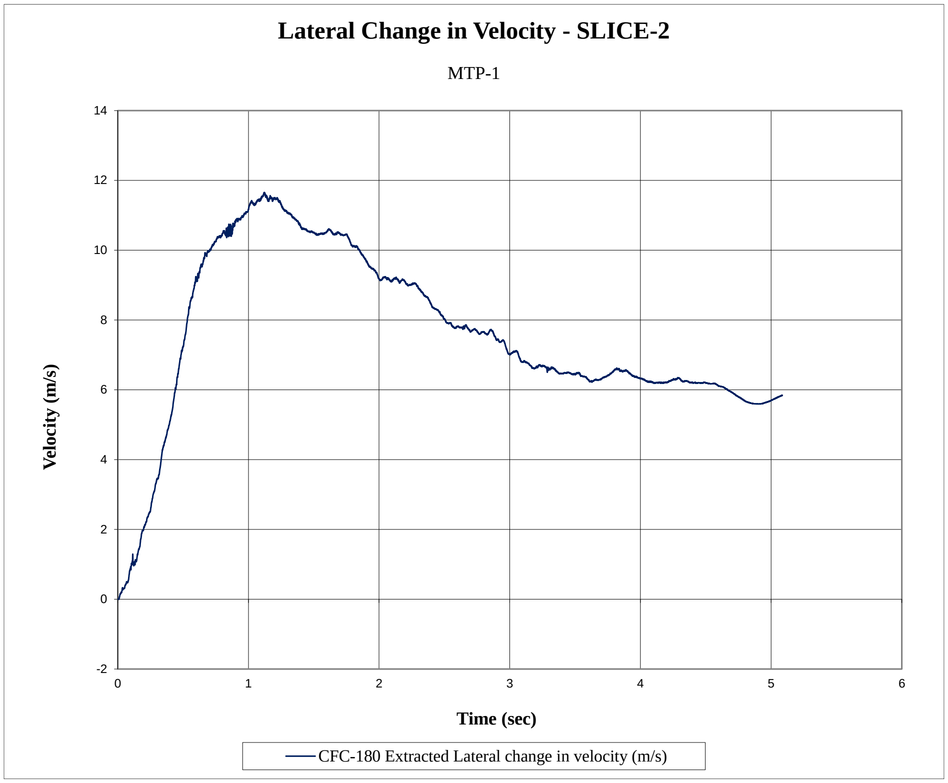


Figure E-5. Lateral Occupant Impact Velocity (SLICE-2), Test No. MTP-1

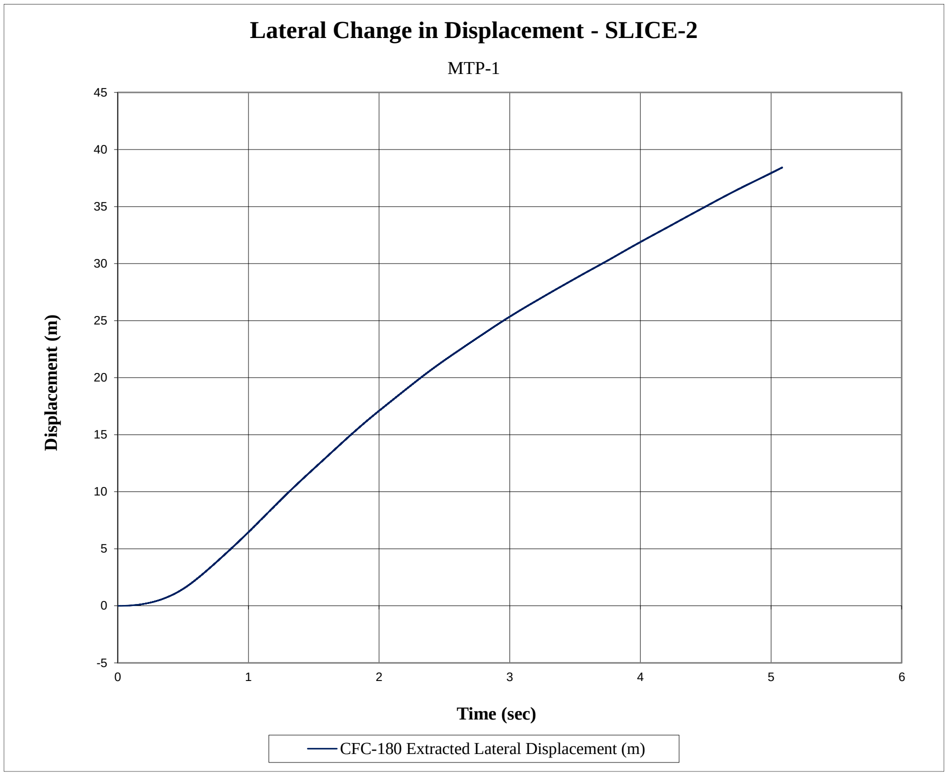


Figure E-6. Lateral Occupant Displacement (SLICE-2), Test No. MTP-1

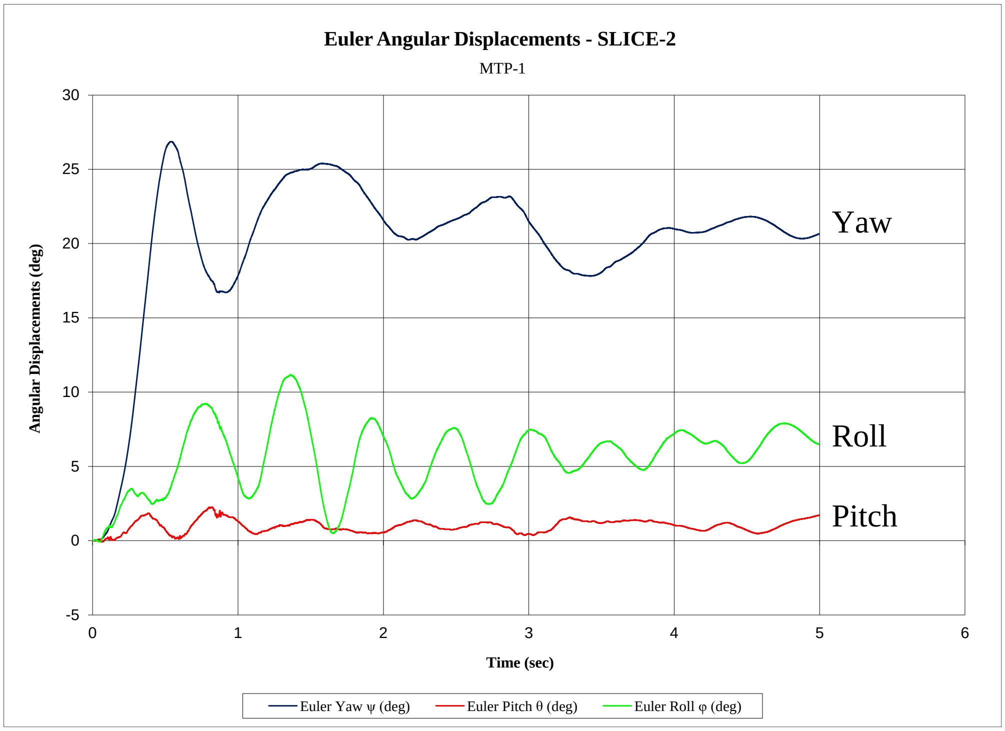


Figure E-7. Vehicle Angular Displacements (SLICE-2), Test No. MTP-1

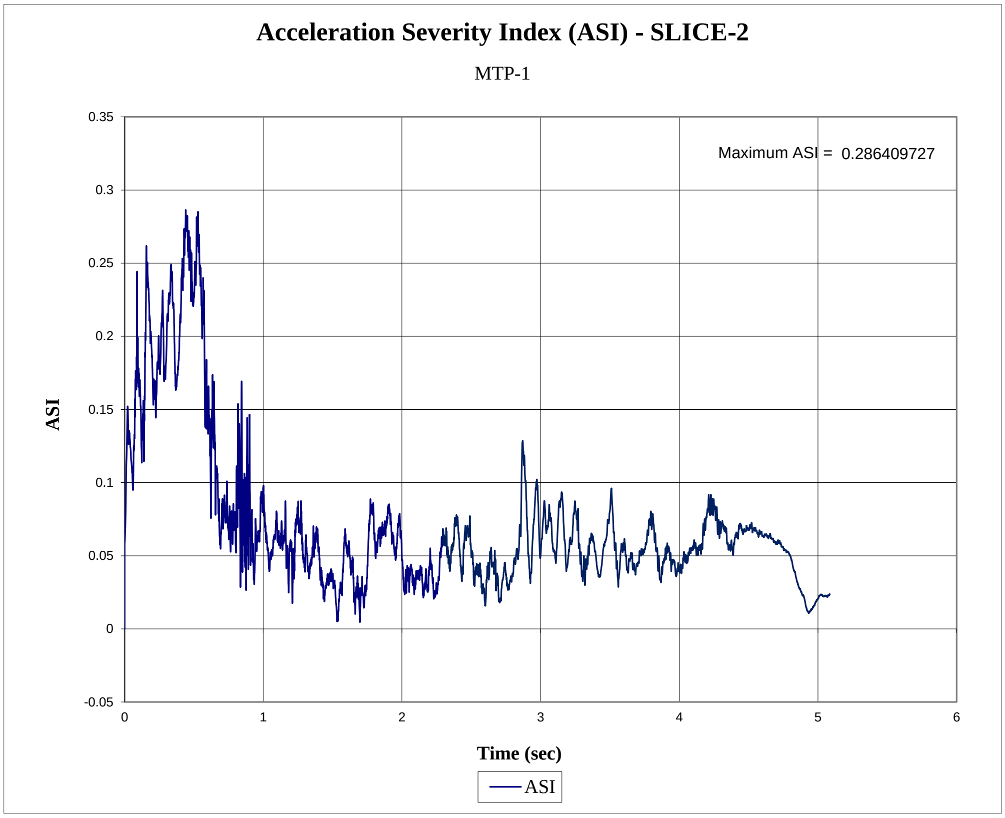


Figure E-8. Acceleration Severity Index (SLICE-2), Test No. MTP-1

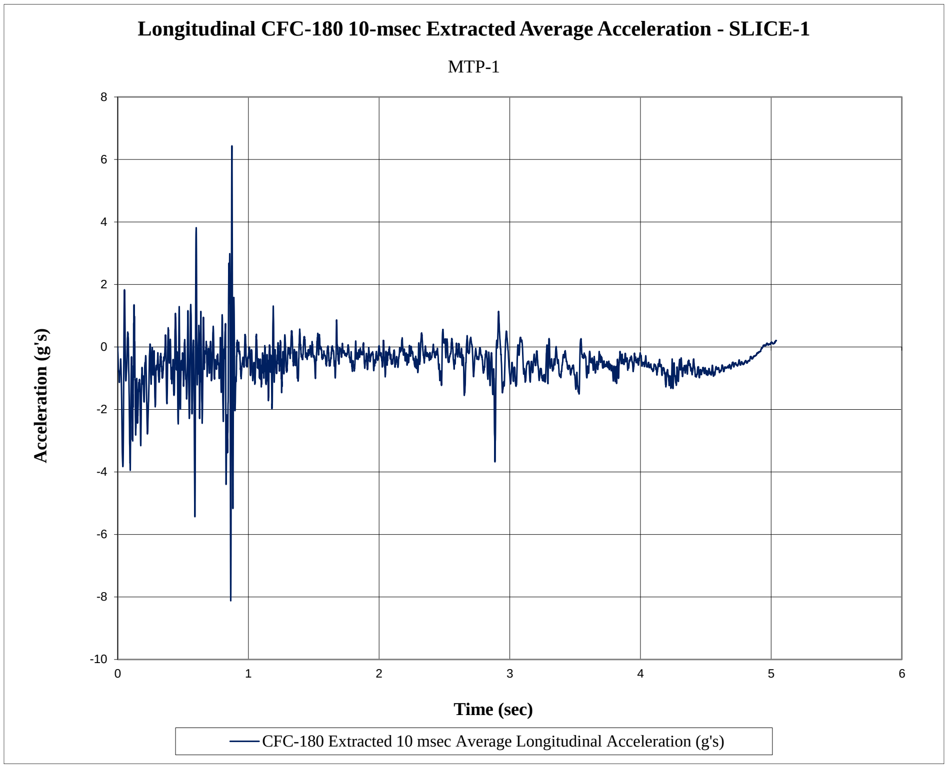


Figure E-9. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. MTP-1

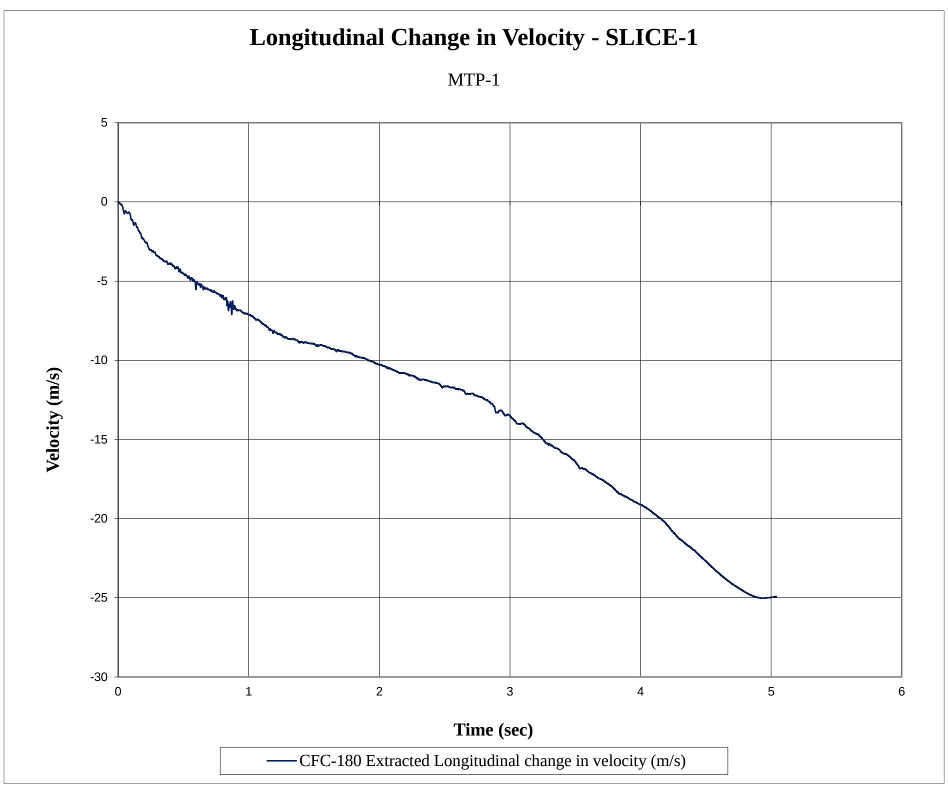


Figure E-10. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. MTP-1

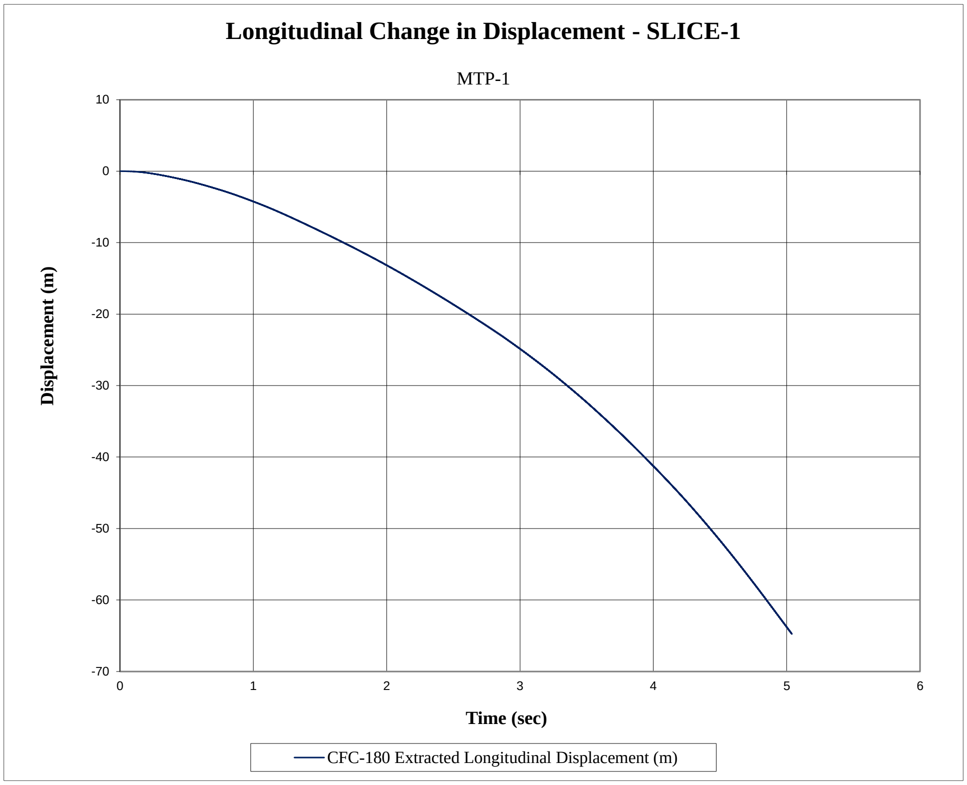


Figure E-11. Longitudinal Occupant Displacement (SLICE-1), Test No. MTP-1

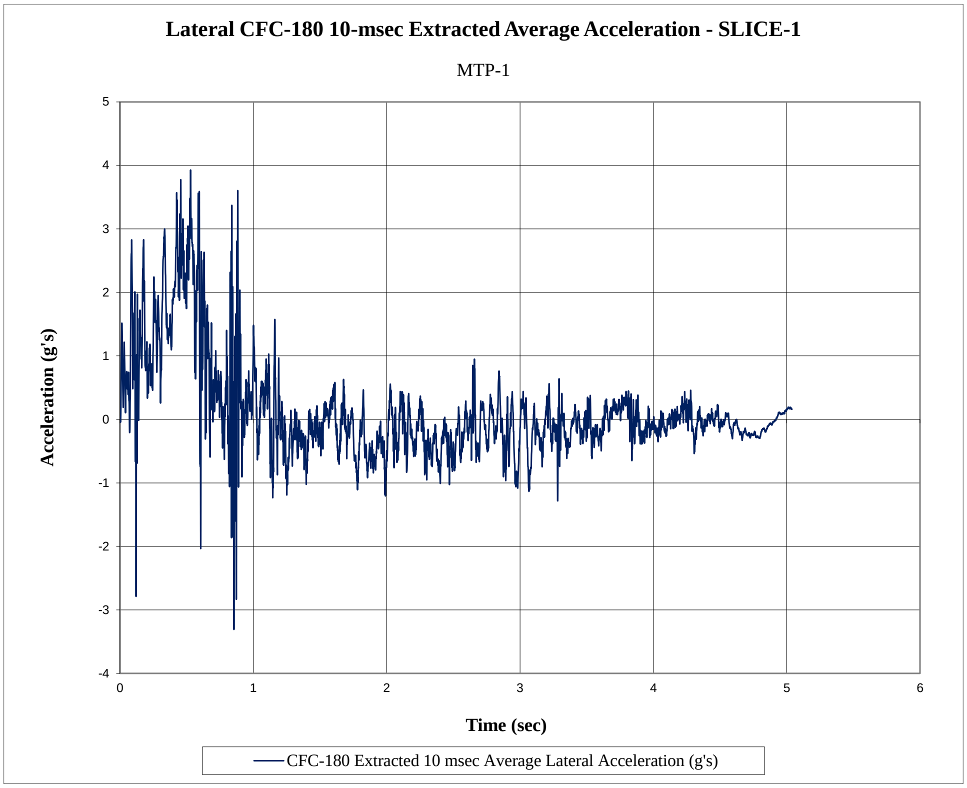


Figure E-12. 10-ms Average Lateral Deceleration (SLICE-1), Test No. MTP-1

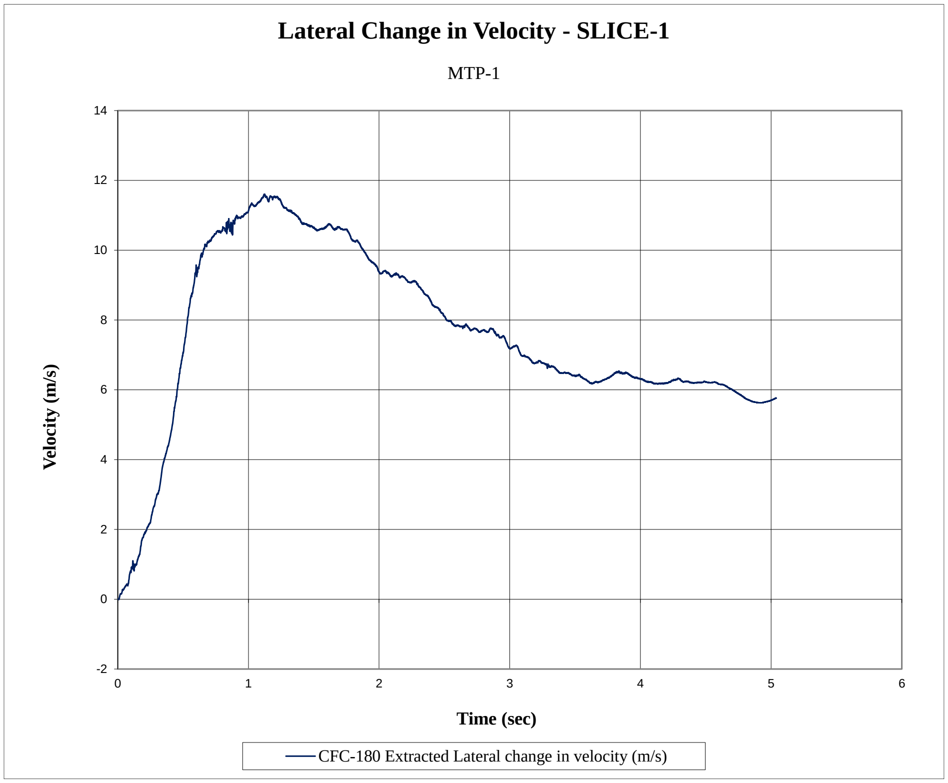


Figure E-13. Lateral Occupant Impact Velocity (SLICE-1), Test No. MTP-1

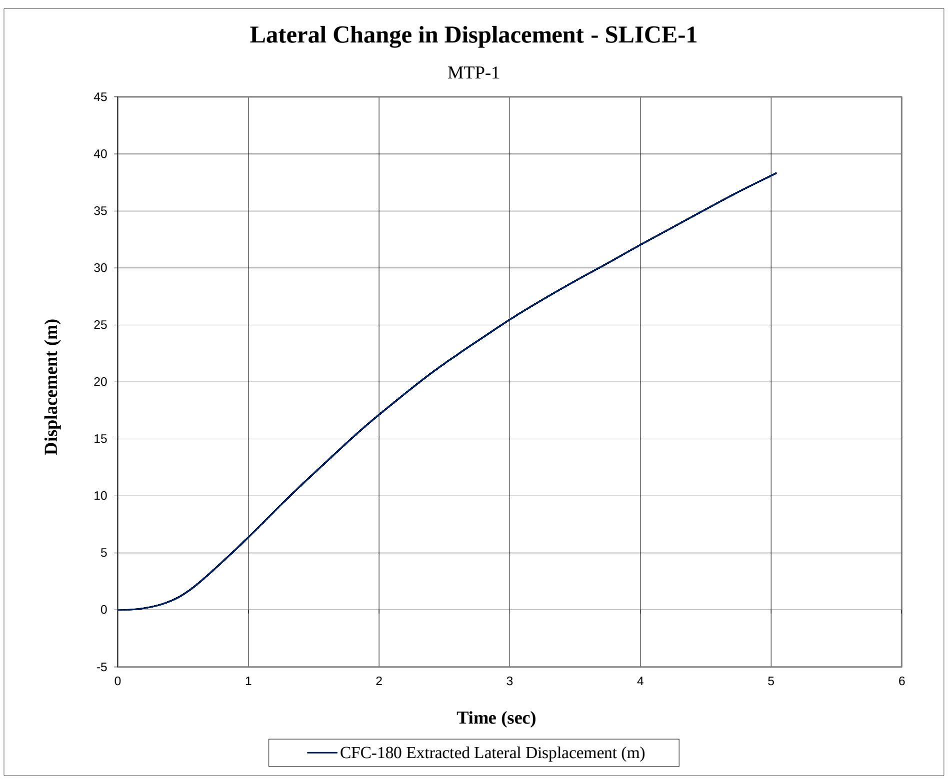


Figure E-14. Lateral Occupant Displacement (SLICE-1), Test No. MTP-1

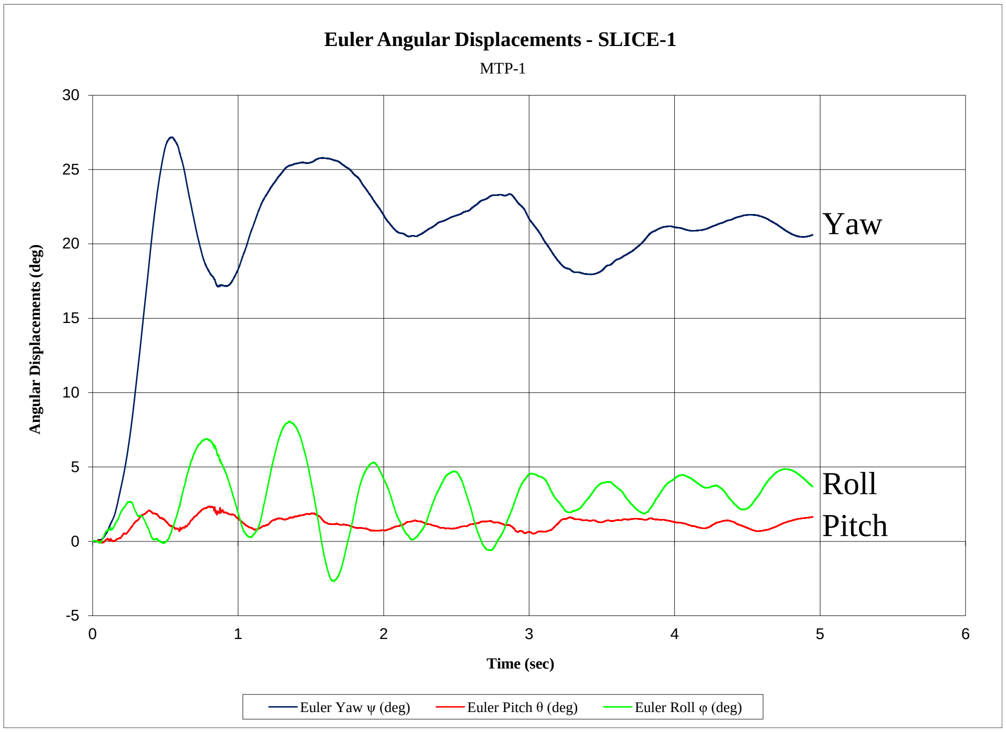


Figure E-15. Vehicle Angular Displacements (SLICE-1), Test No. MTP-1

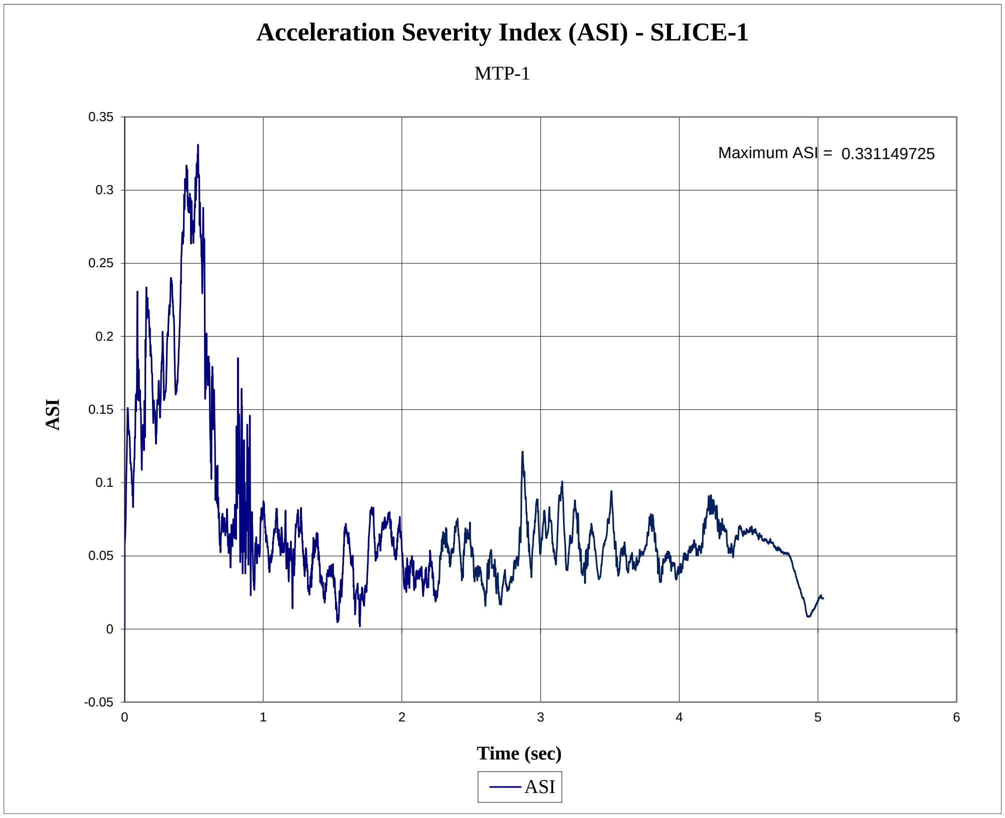


Figure E-16. Acceleration Severity Index (SLICE-1), Test No. MTP-1

Appendix F. Load Cell Data, Test No. MTP-1

MIDWEST ROADSIDE SAFETY FACILITY

Load Cell Summary

Test Information:

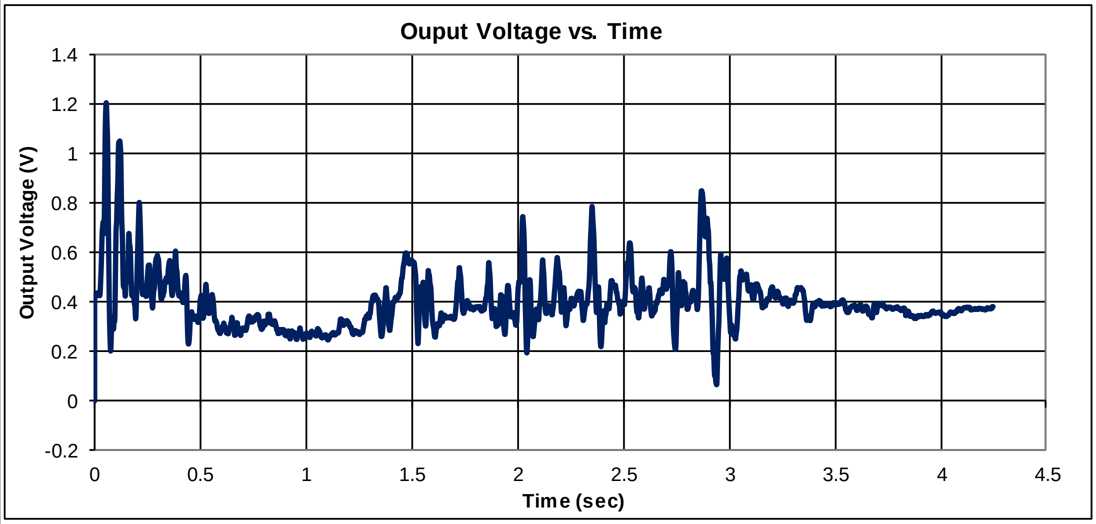
Test No:	MTP-1
Date:	4/22/2019
System / Test Article:	Midwest Cable Median Barrier
LC Location / Component:	Cable 1 - Bottom Cable
Additional Notes:	

Load Cell Information:

Load Cell No.:	143432
Calibration Factor:	2.156969 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:	7.00 kips
Time of Max. Load:	0.0547 sec
Event Duration:	5.2421 sec
Final Load:	2.14 kips



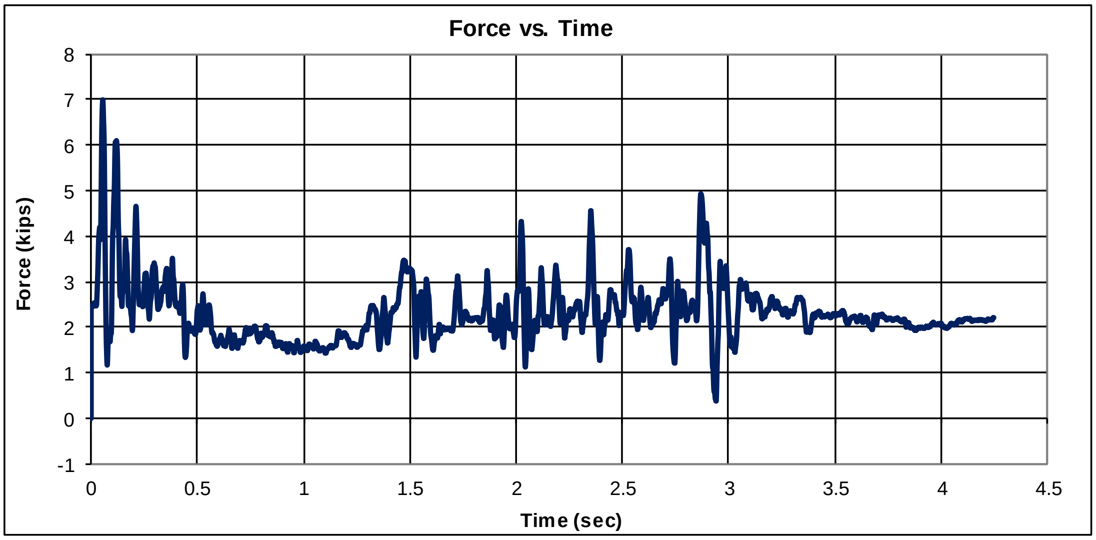


Figure F-1. Load Cell Data, Cable 1 (Bottom), Test No. MTP-1

MIDWEST ROADSIDE SAFETY FACILITY

Load Cell Summary

Test Information:

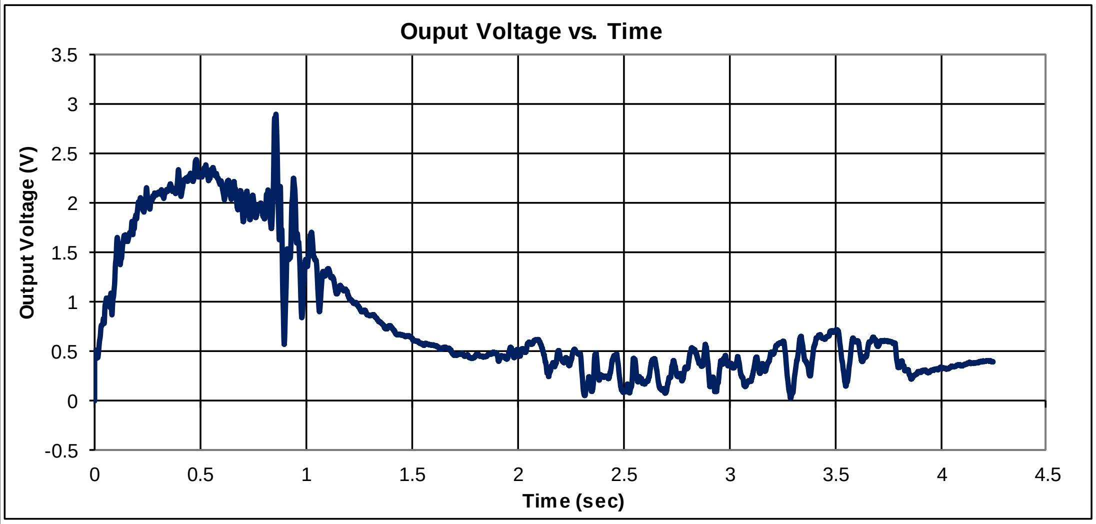
Test No:	MTP-1
Date:	4/22/2019
System / Test Article:	Midwest Cable Median Barrier
LC Location / Component:	Cable 2 - Lower Middle
Additional Notes:	

Load Cell Information:

Load Cell No.:	143436
Calibration Factor:	2.15037 mv/V
Input Voltage (excitation):	10.01 Volts
Gain:	400
Full Scale Load:	50 kips
Sample Rate:	10000 Hz
Cutoff Frequency:	100 Hz

Results:

Preload:	0 kips
Max. Load:	16.82 kips
Time of Max. Load:	0.8572 sec
Event Duration:	5.2421 sec
Final Load:	1.71 kips



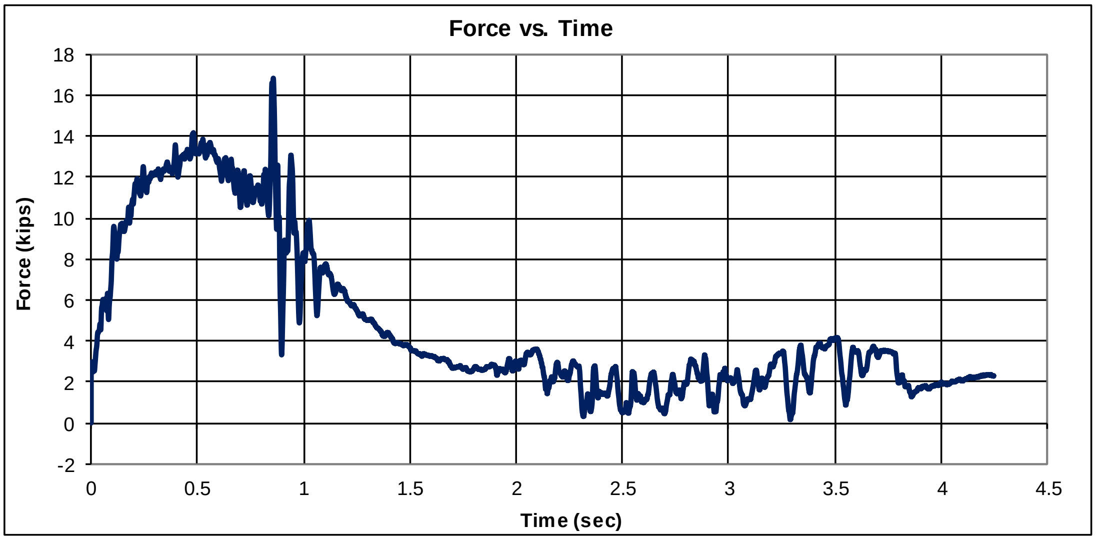


Figure F-2. Load Cell Data, Cable 2, Test No. MTP-1

MIDWEST ROADSIDE SAFETY FACILITY

Load Cell Summary

Test Information:

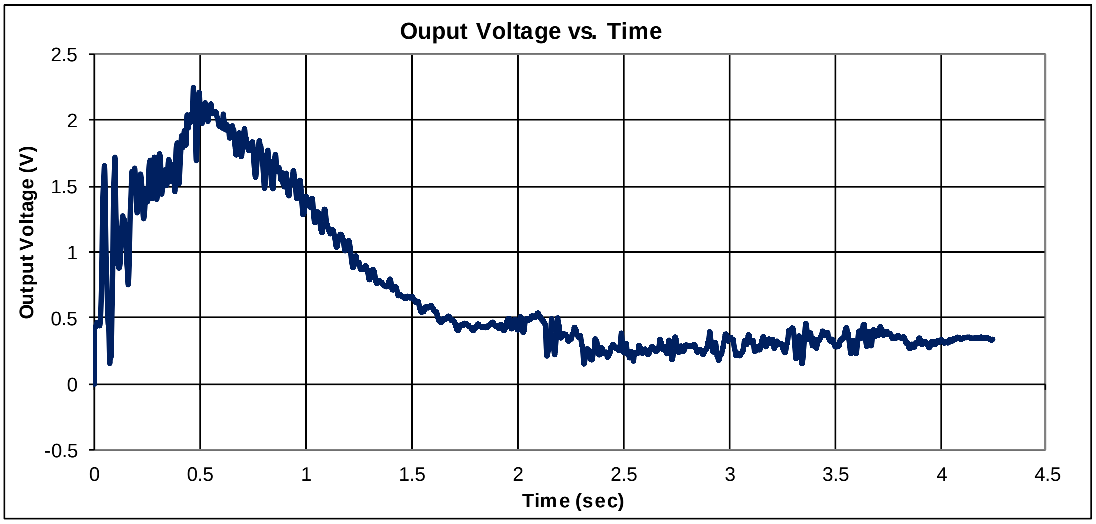
Test No:	MTP-1
Date:	4/22/2019
System / Test Article:	Midwest Cable Median Barrier
LC Location / Component:	Cable 3 - Upper Middle
Additional Notes:	

Load Cell Information:

Load Cell No.:	241593
Calibration Factor:	2.153969 mv/V
Input Voltage (excitation):	10.01 Volts
Gain:	400
Full Scale Load:	50 kips
Sample Rate:	10000 Hz
Cutoff Frequency:	100 Hz

Results:

Preload:	0 kips
Max. Load:	13.04 kips
Time of Max. Load:	0.4682 sec
Event Duration:	5.2421 sec
Final Load:	1.68 kips



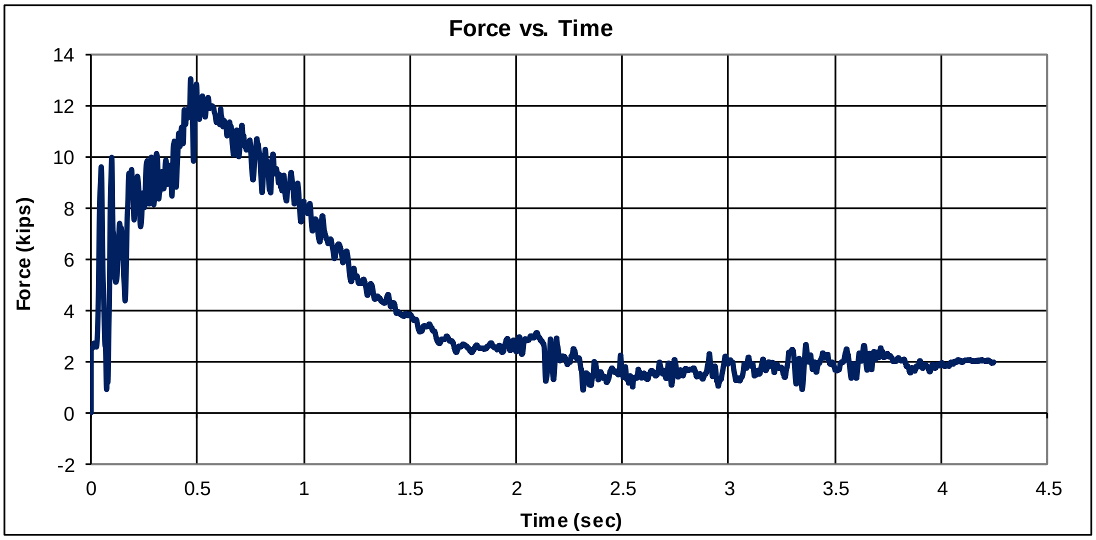


Figure F-3. Load Cell Data, Cable 3, Test No. MTP-1

MIDWEST ROADSIDE SAFETY FACILITY

Load Cell Summary

Test Information:

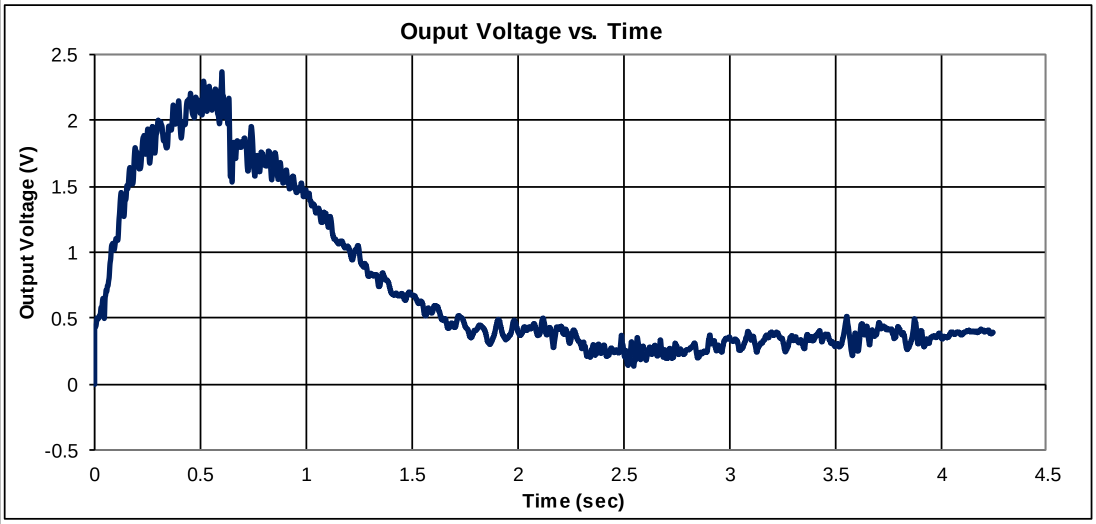
Test No:	MTP-1
Date:	4/22/2019
System / Test Article:	Midwest Cable Median Barrier
LC Location / Component:	Cable 4 - Top Cable
Additional Notes:	

Load Cell Information:

Load Cell No.:	143433
Calibration Factor:	2.15737 mv/V
Input Voltage (excitation):	10.01 Volts
Gain:	400
Full Scale Load:	50 kips
Sample Rate:	10000 Hz
Cutoff Frequency:	100 Hz

Results:

Preload:	0 kips
Max. Load:	13.71 kips
Time of Max. Load:	0.6017 sec
Event Duration:	5.2421 sec
Final Load:	1.92 kips



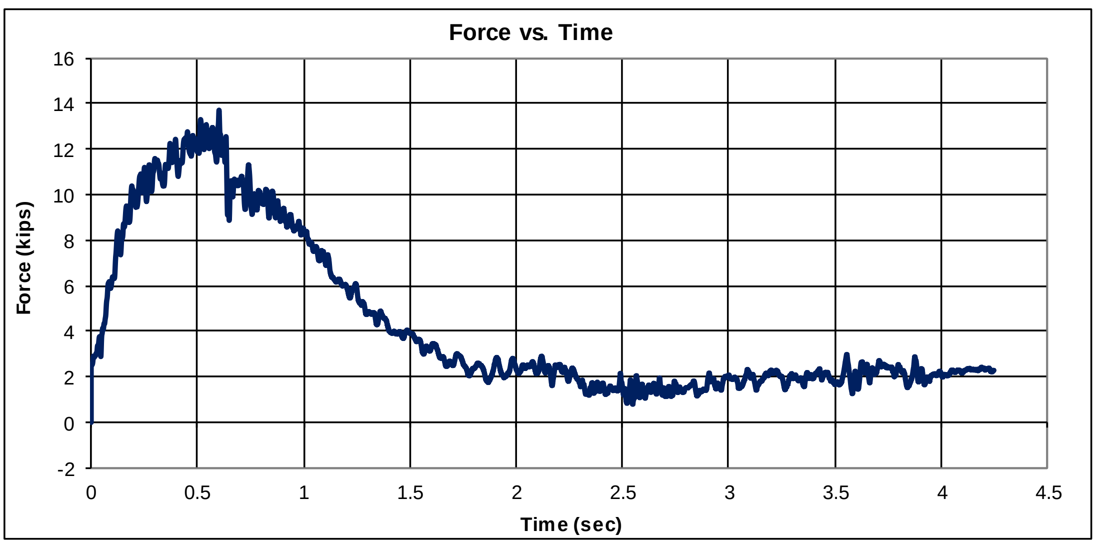


Figure F-4. Load Cell Data, Cable 4 (Top), Test No. MTP-1

Appendix G. Accelerometer and Rate Transducer Data Plots, Test No. MTP-2

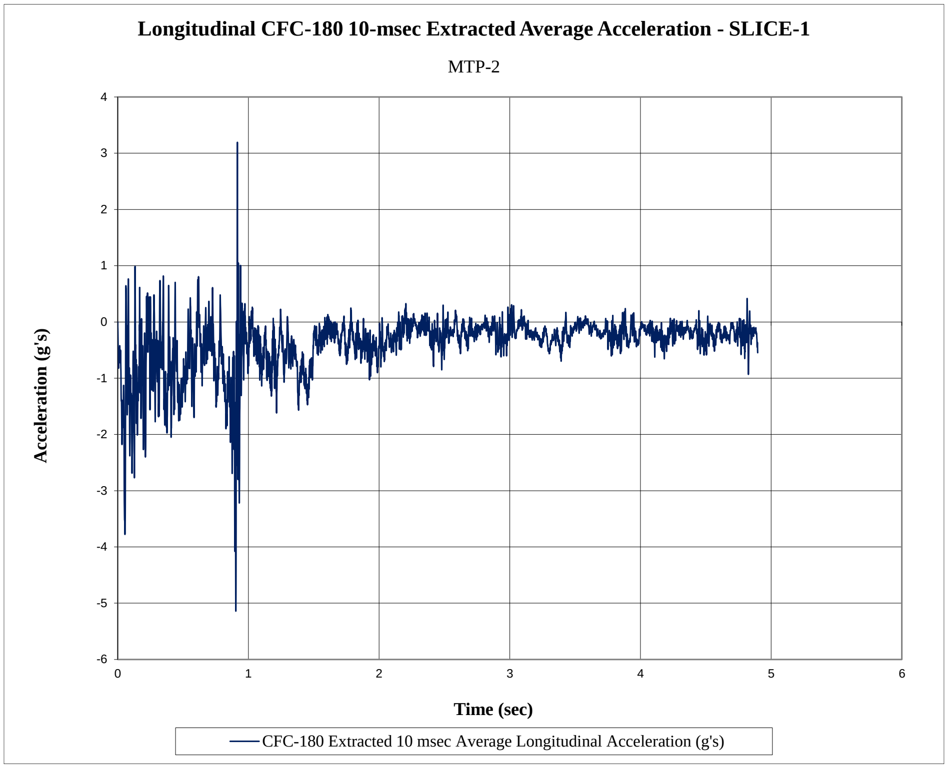


Figure G-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. MTP-2

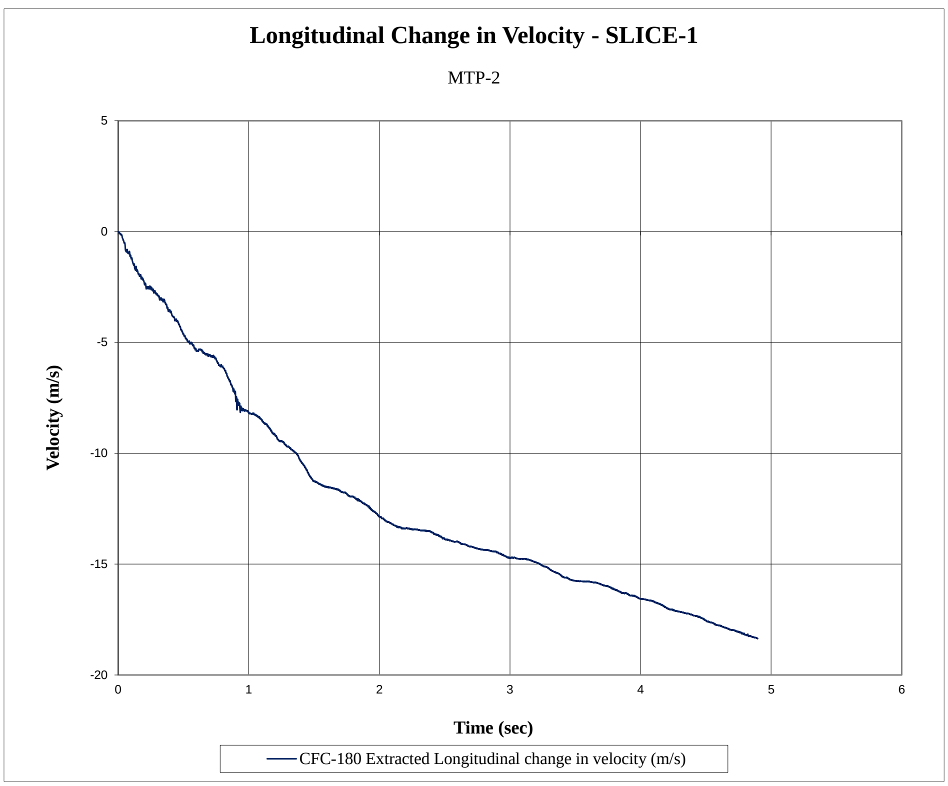


Figure G-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. MTP-2

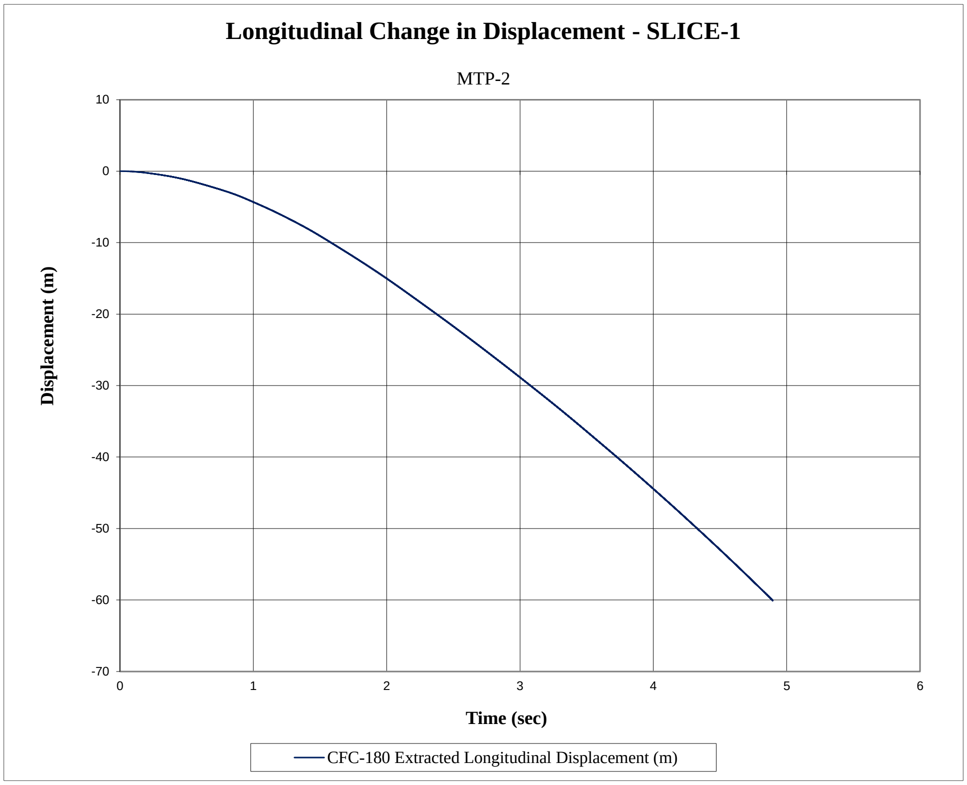


Figure G-3. Longitudinal Occupant Displacement (SLICE-1), Test No. MTP-2

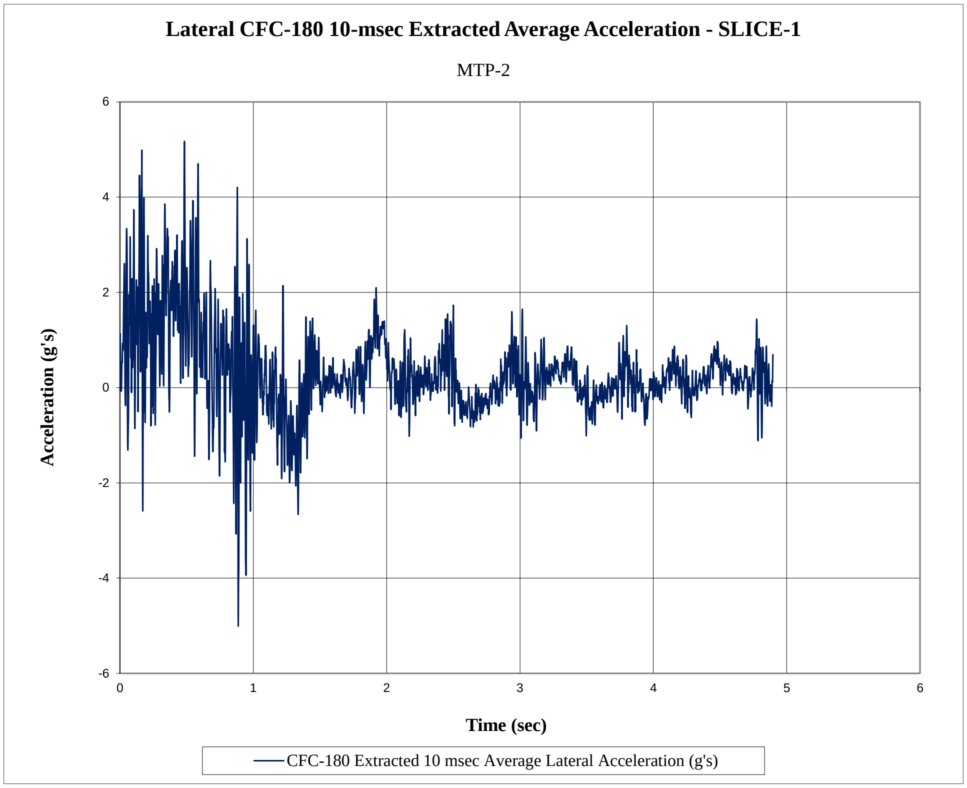


Figure G-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. MTP-2

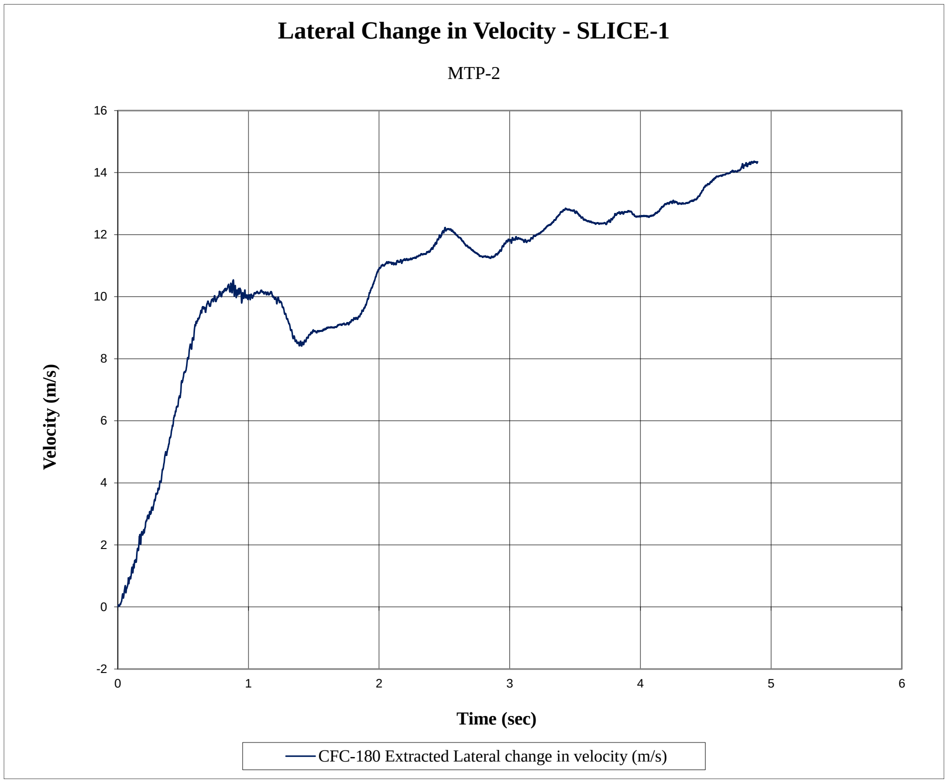


Figure G-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. MTP-2

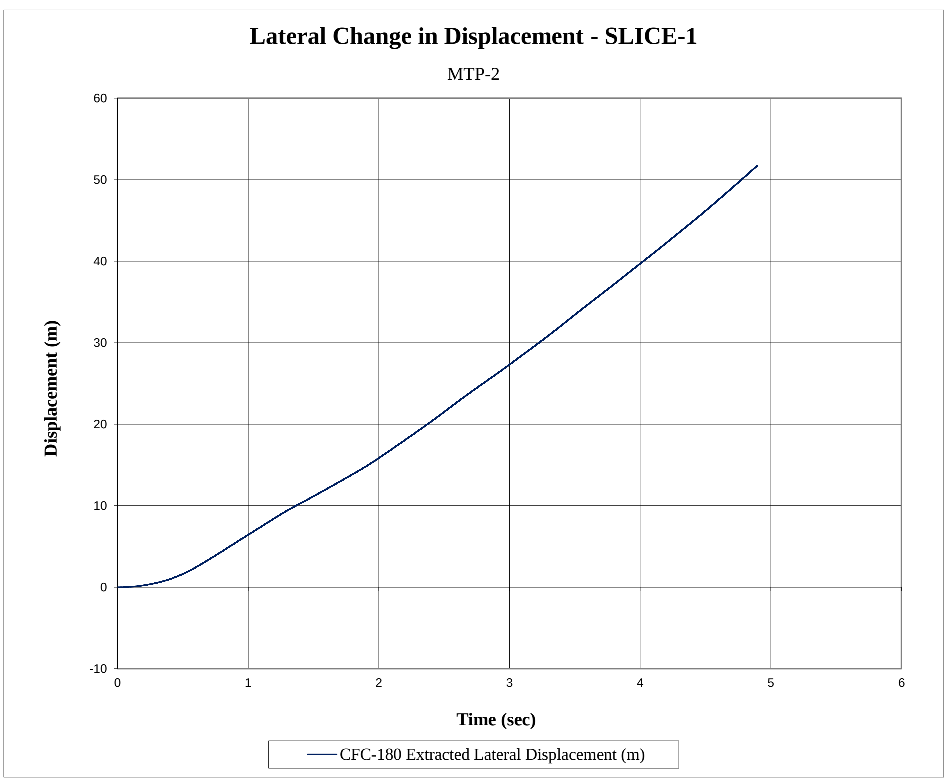


Figure G-6. Lateral Occupant Displacement (SLICE-1), Test No. MTP-2

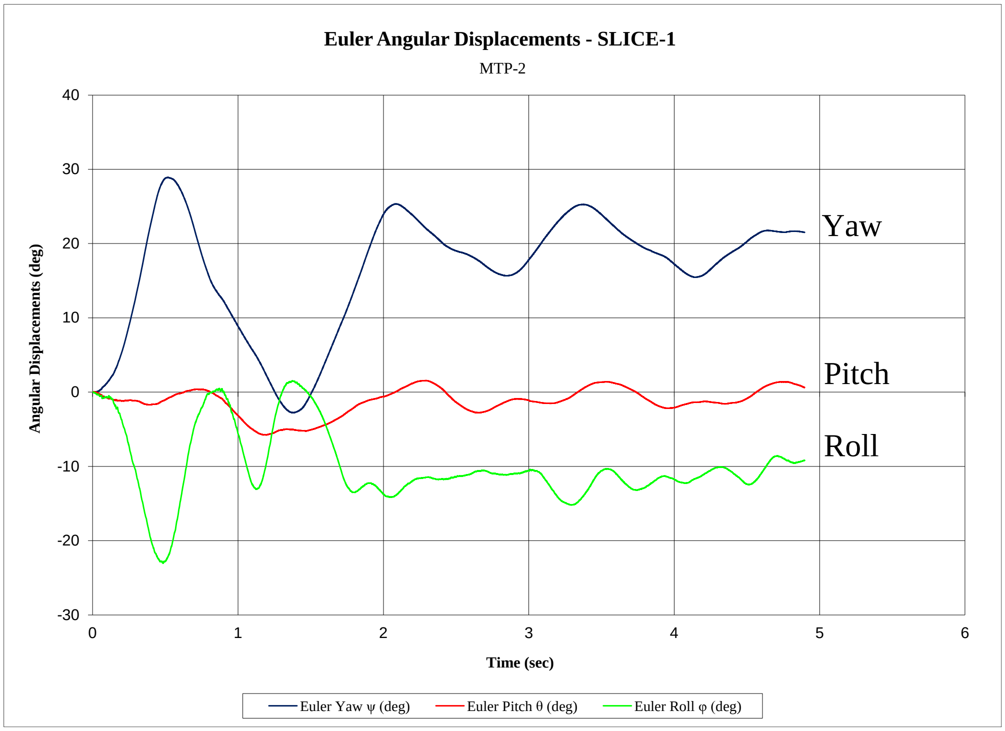


Figure G-7. Vehicle Angular Displacements (SLICE-1), Test No. MTP-2

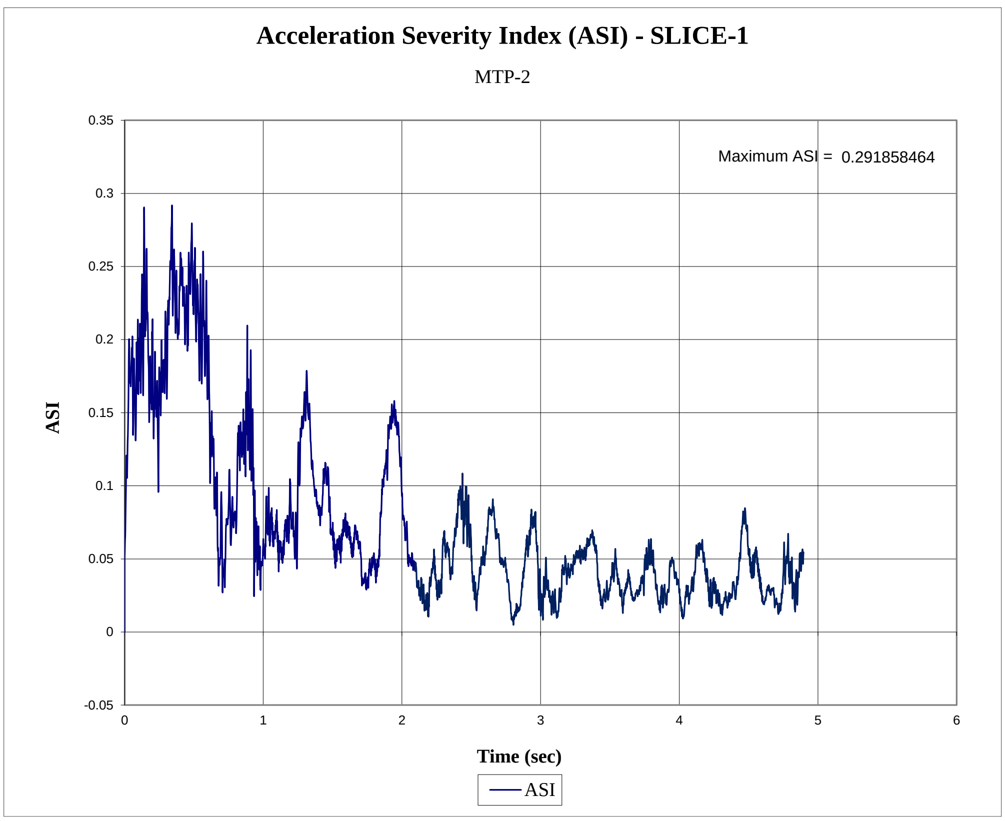


Figure G-8. Acceleration Severity Index (SLICE-1), Test No. MTP-2

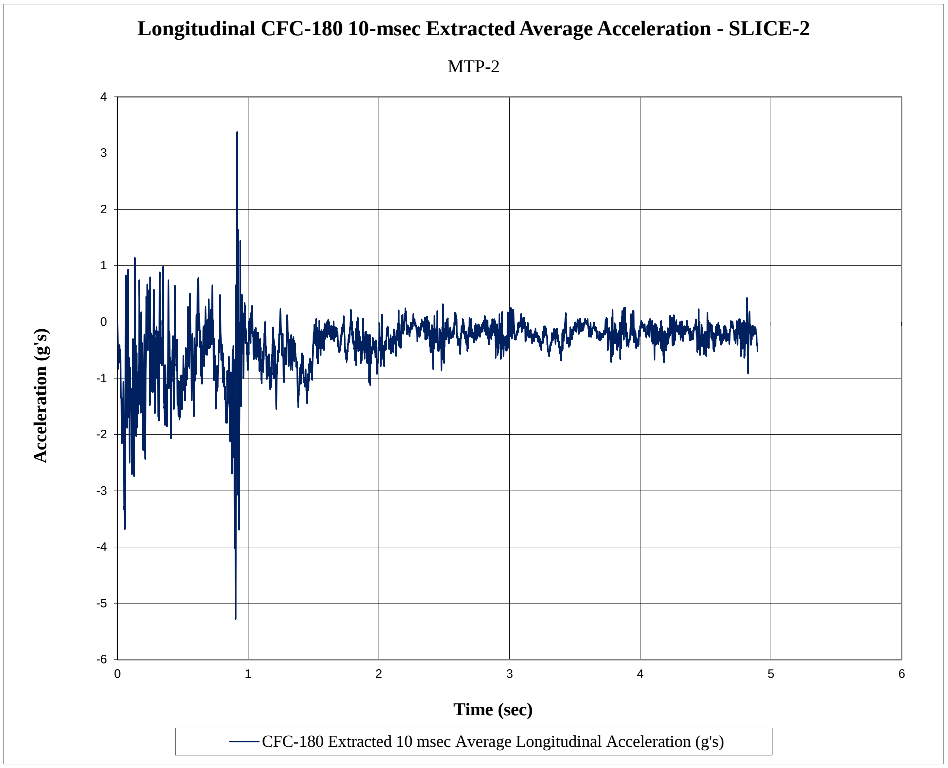


Figure G-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. MTP-2

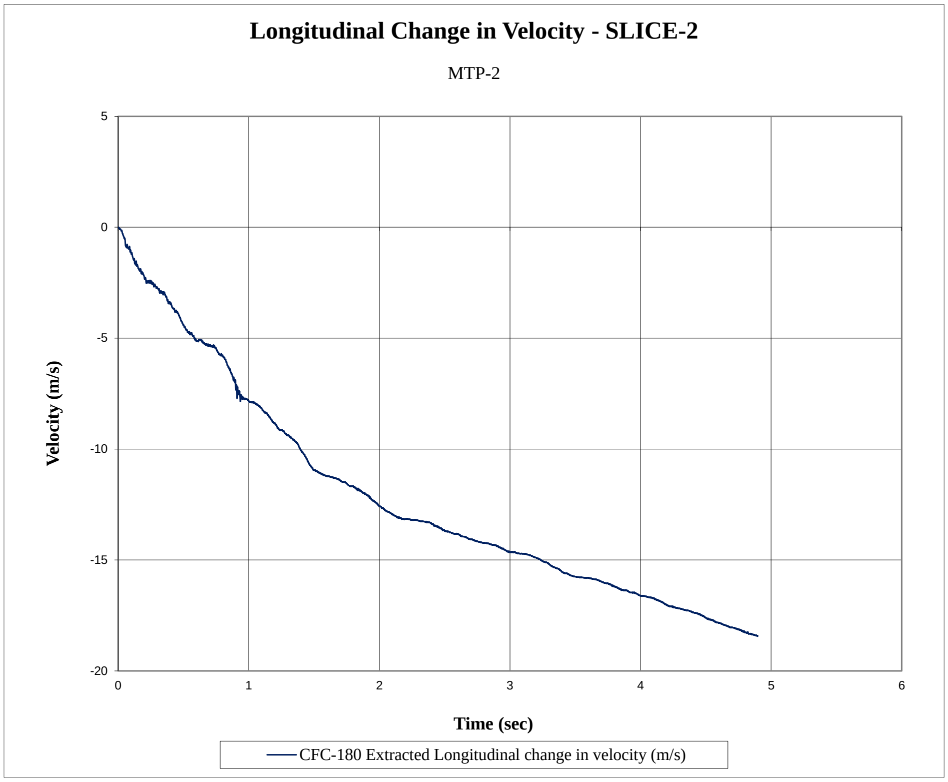


Figure G-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. MTP-2

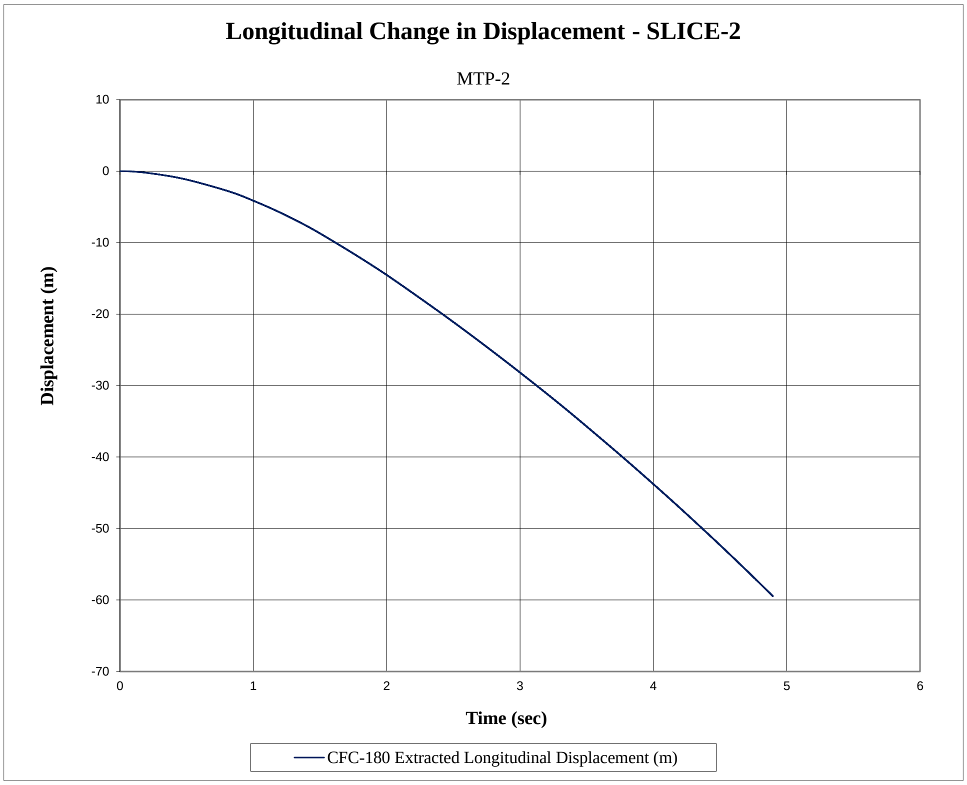


Figure G-11. Longitudinal Occupant Displacement (SLICE-2), Test No. MTP-2

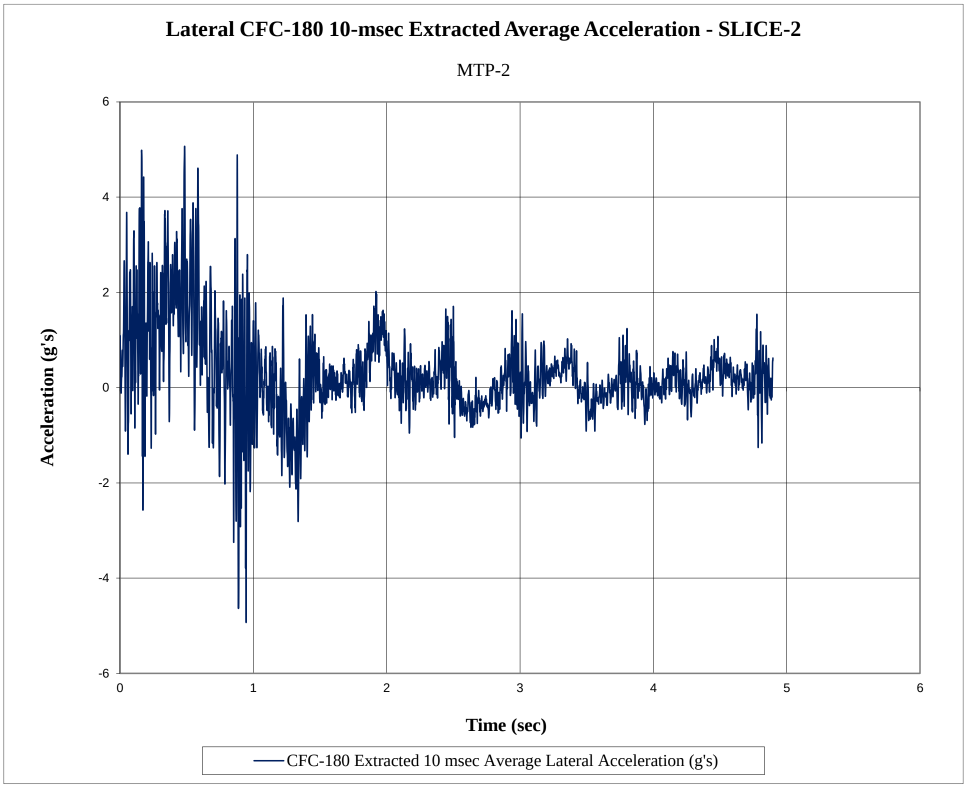


Figure G-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. MTP-2

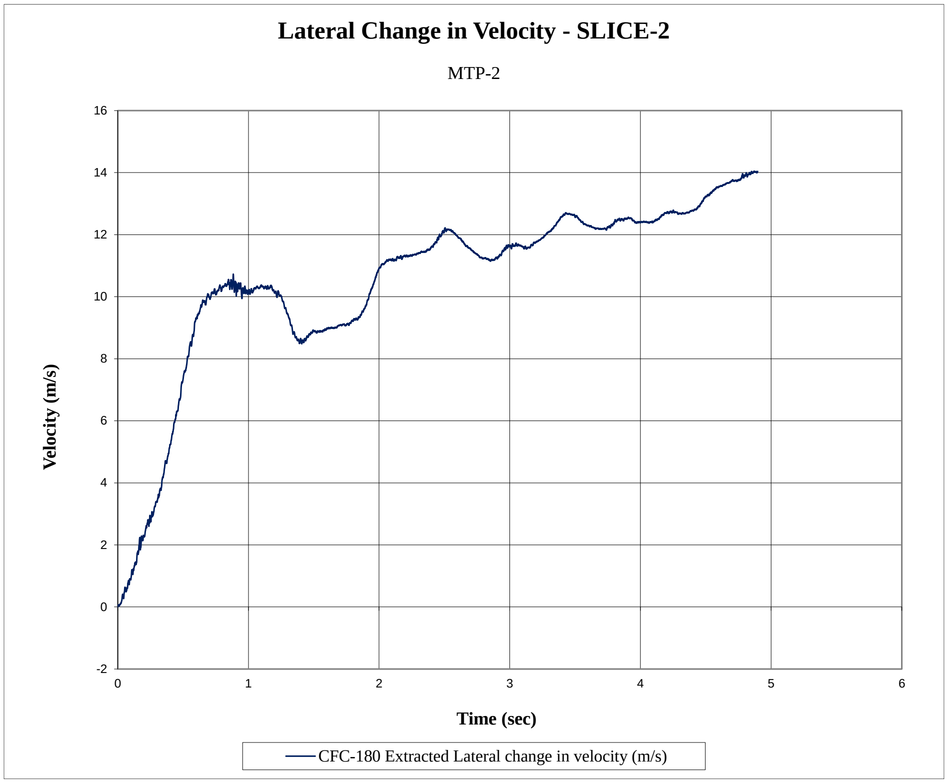


Figure G-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. MTP-2

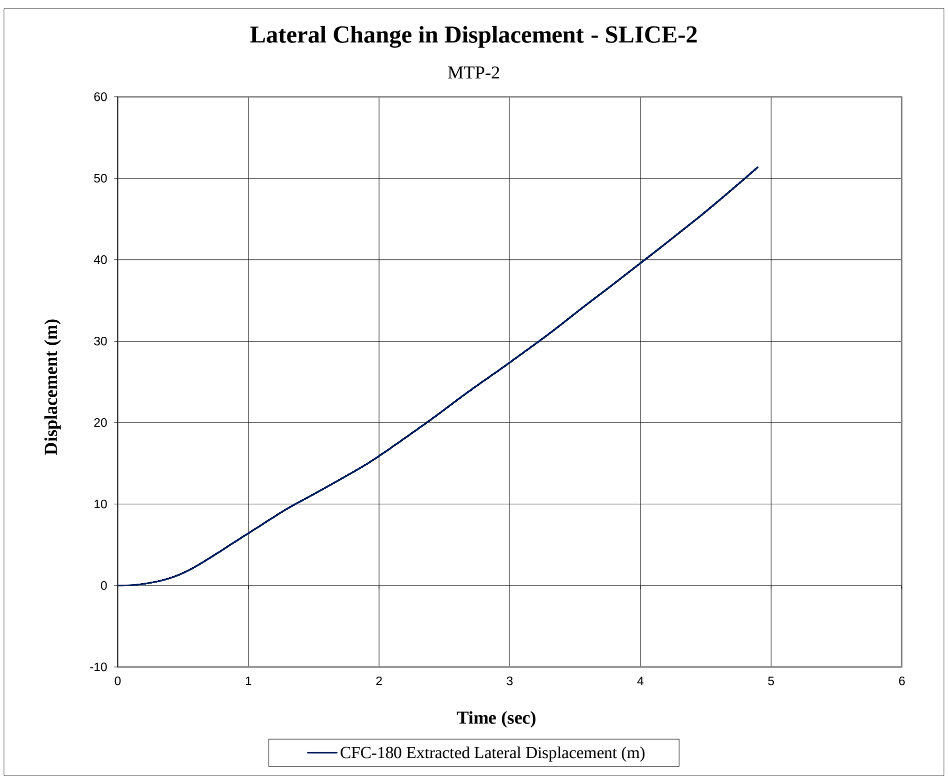


Figure G-14. Lateral Occupant Displacement (SLICE-2), Test No. MTP-2

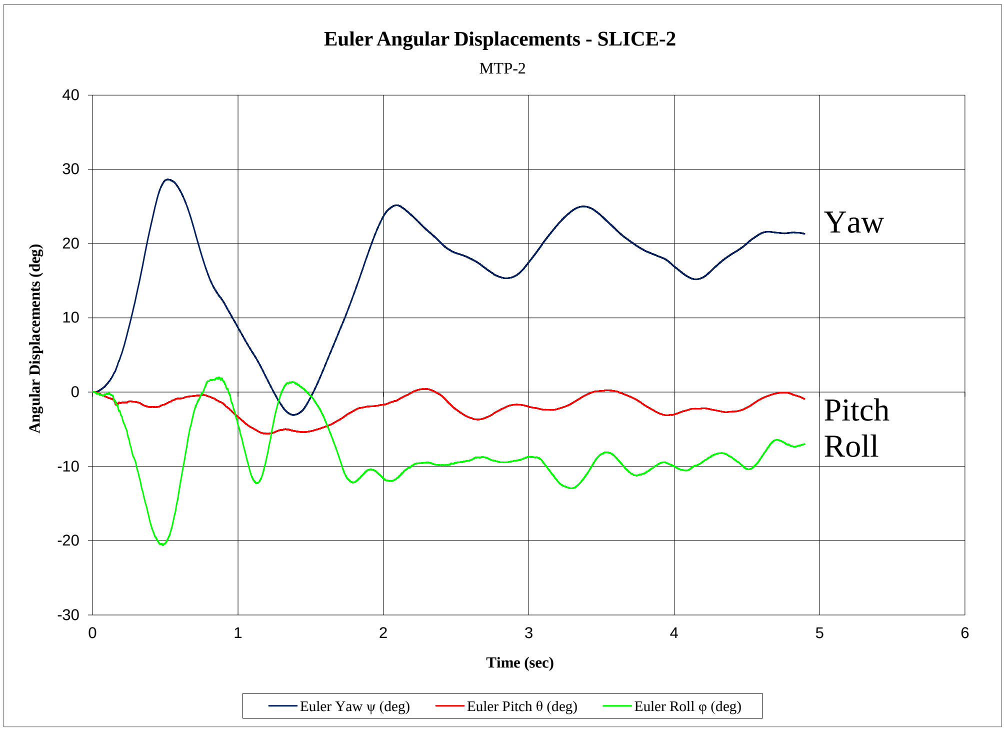


Figure G-15. Vehicle Angular Displacements (SLICE-2), Test No. MTP-2

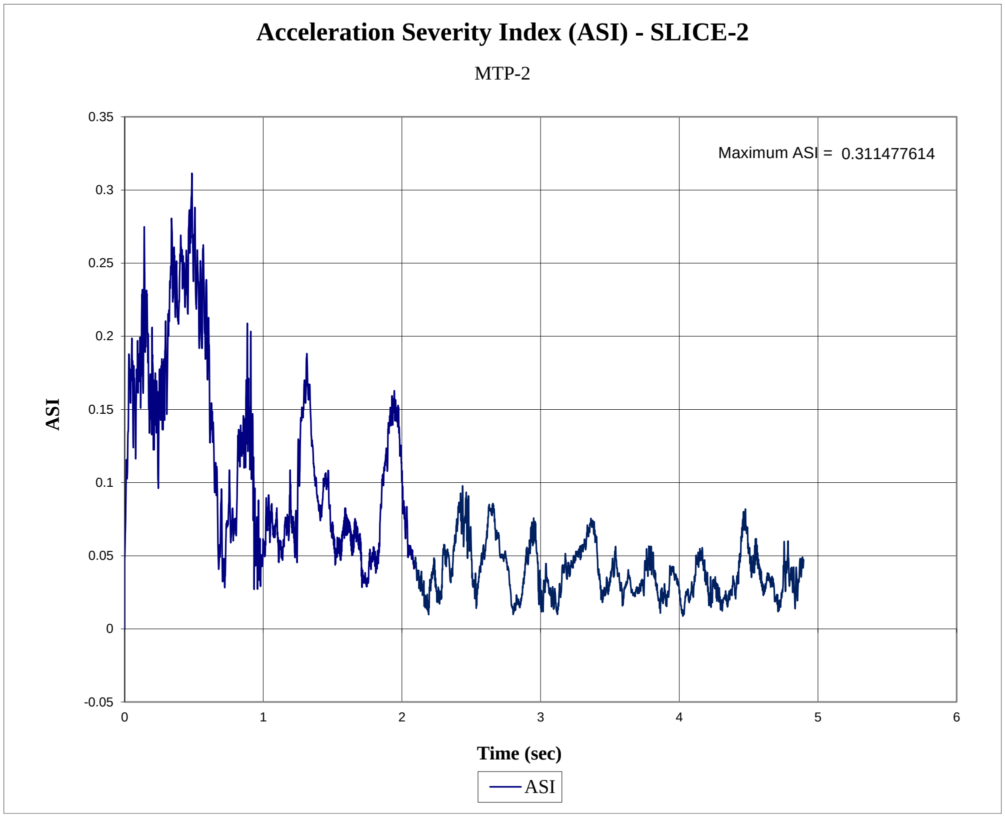


Figure G-16. Vehicle Angular Displacements (SLICE-2), Test No. MTP-2

Appendix H. Load Cell Data, Test No. MTP-2

MIDWEST ROADSIDE SAFETY FACILITY

Load Cell Summary

Test Information:

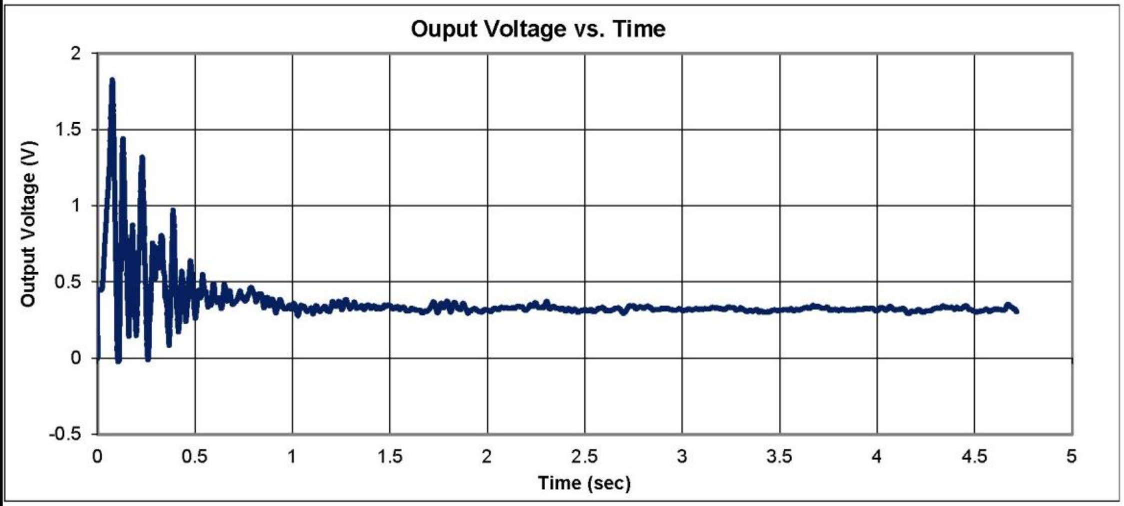
Test No:	MTP-2
Date:	7/15/2019
System / Test Article:	Pool Fund Generic 4-Cable Median Barrier
LC Location / Component:	Cable 1 Bottom
Additional Notes:	

Load Cell Information:

Load Cell No.:	143432
Calibration Factor:	2.156969 mv/V
Input Voltage (excitation):	9.97 Volts
Gain:	400
Full Scale Load:	50 kips
Sample Rate:	10000 Hz
Cutoff Frequency:	100 Hz

Results:

Preload:	0 kips
Max. Load:	10.63 kips
Time of Max. Load:	0.0753 sec
Event Duration:	5.7105 sec
Final Load:	2.00 kips



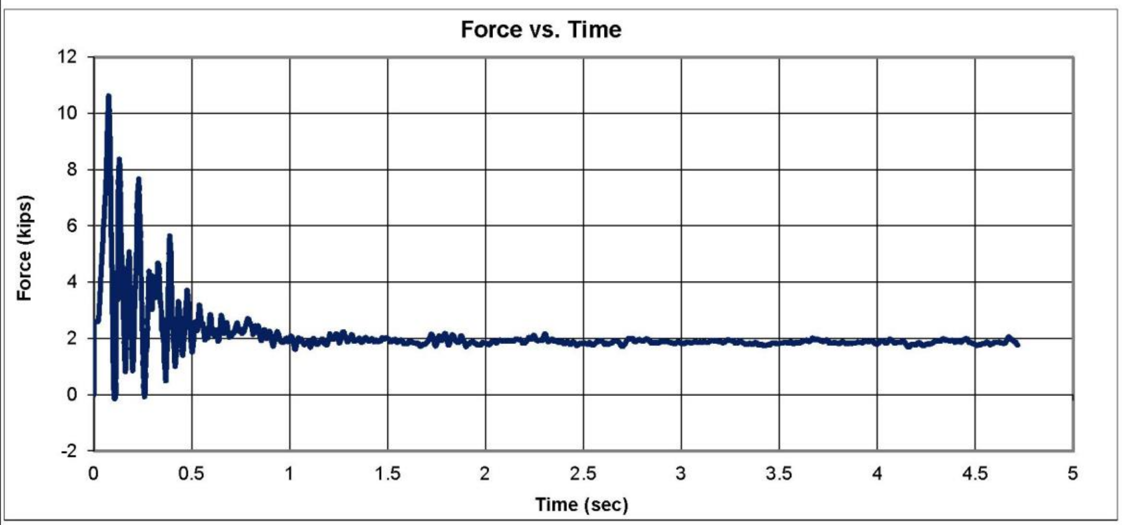


Figure H-1. Load Cell Data, Cable 1 (Bottom), Test No. MTP-2

MIDWEST ROADSIDE SAFETY FACILITY

Load Cell Summary

Test Information:

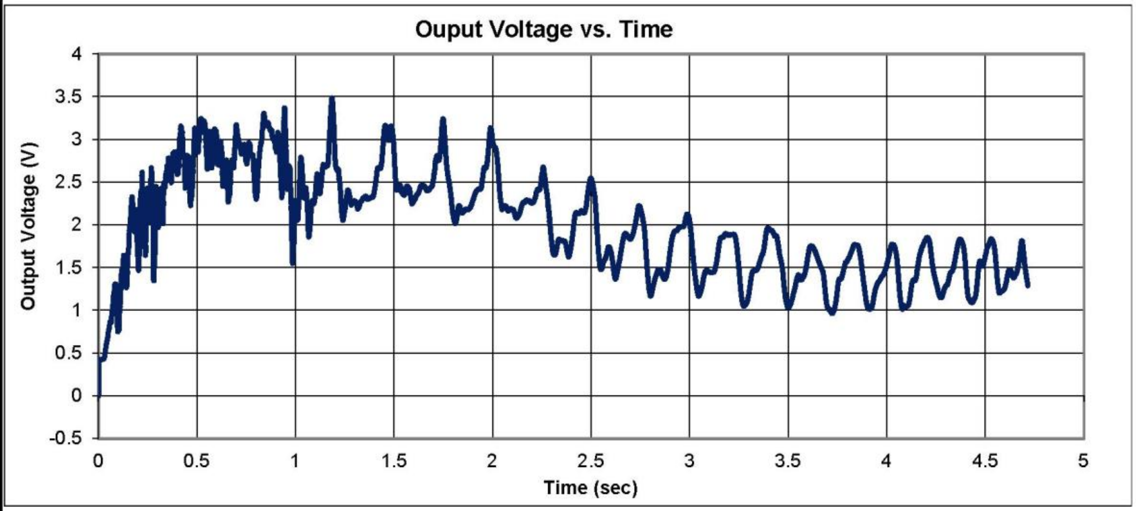
Test No:	MTP-2
Date:	7/15/2019
System / Test Article:	Pool Fund Generic 4-Cable Median Barrier
LC Location / Component:	Cable 2 Bottom Middle
Additional Notes:	

Load Cell Information:

Load Cell No.:	143436
Calibration Factor:	2.15037 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:	20.32 kips
Time of Max. Load:	1.1845 sec
Event Duration:	5.7105 sec
Final Load:	6.89 kips



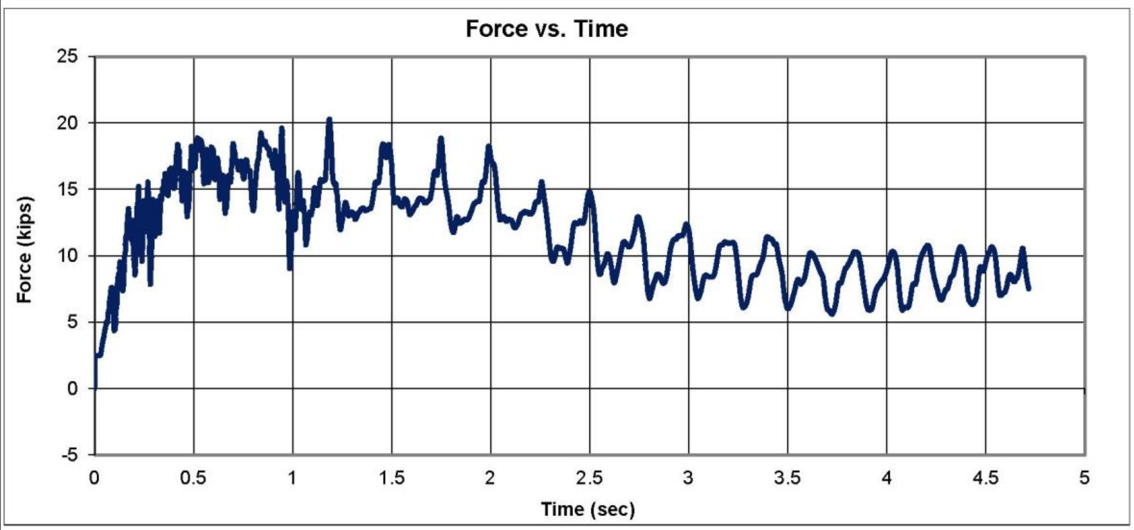


Figure H-2. Load Cell Data, Cable 2, Test No. MTP-2

MIDWEST ROADSIDE SAFETY FACILITY

Load Cell Summary

Test Information:

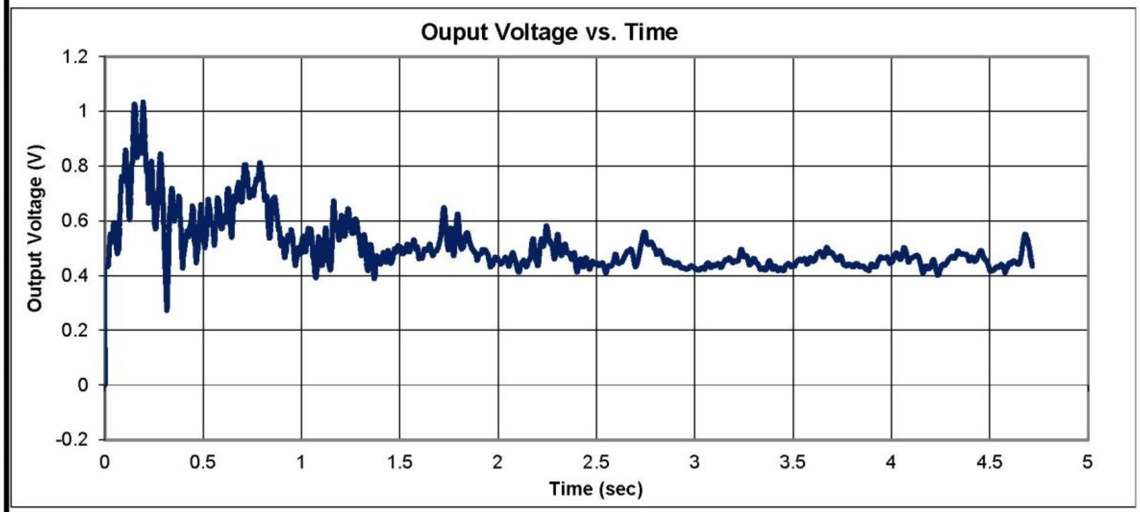
Test No:	MTP-2
Date:	7/15/2019
System / Test Article:	Pool Fund Generic 4-Cable Median Barrier
LC Location / Component:	Cable 3 Top Middle
Additional Notes:	

Load Cell Information:

Load Cell No.:	241593
Calibration Factor:	2.153969 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:	6.01 kips
Time of Max. Load:	0.1944 sec
Event Duration:	5.7105 sec
Final Load:	2.83 kips



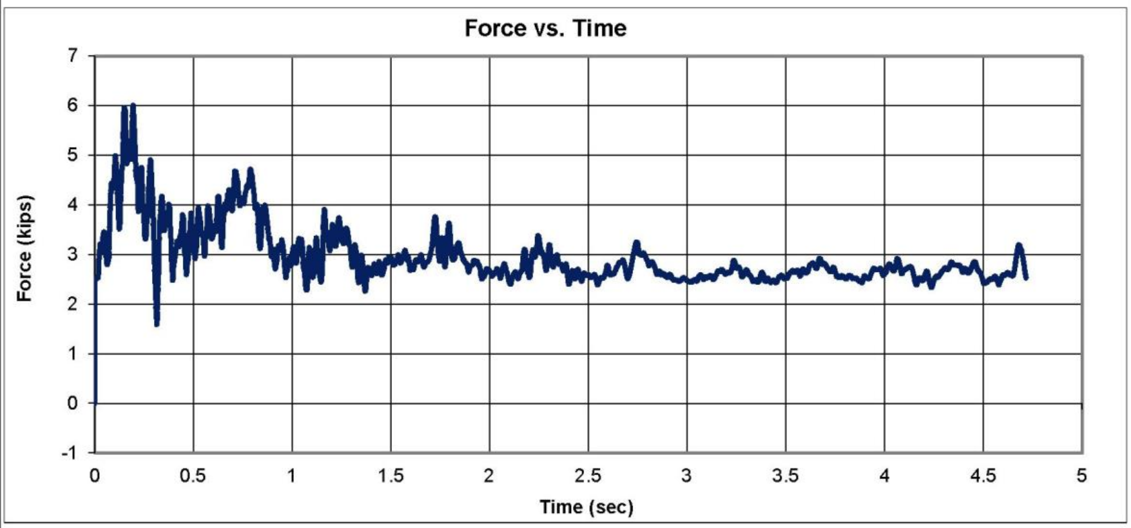


Figure H-3. Load Cell Data, Cable 3, Test No. MTP-2

MIDWEST ROADSIDE SAFETY FACILITY

Load Cell Summary

Test Information:

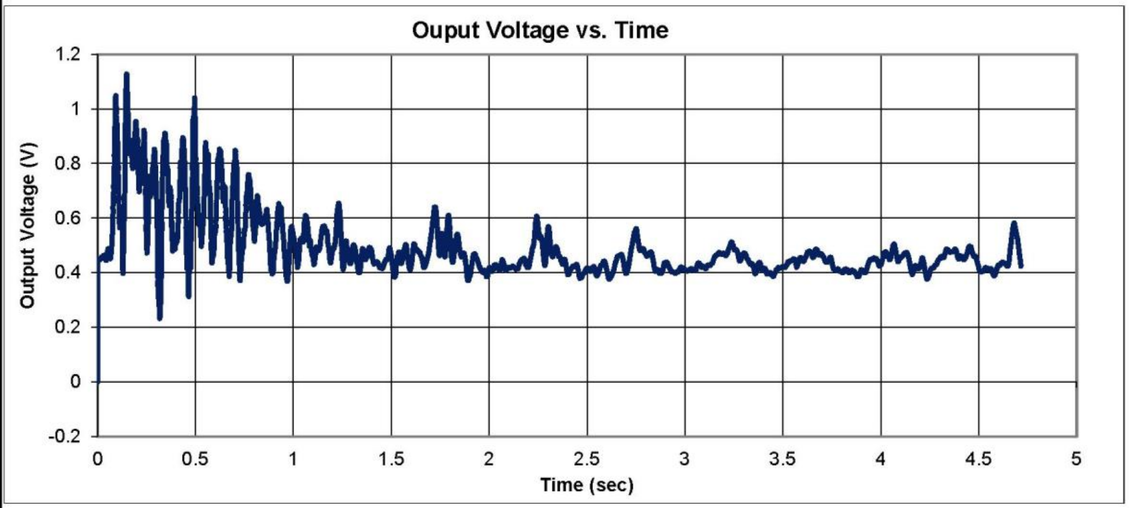
Test No:	MTP-2
Date:	7/15/2019
System / Test Article:	Pool Fund Generic 4-Cable Median Barrier
LC Location / Component:	Cable 4 Top
Additional Notes:	

Load Cell Information:

Load Cell No.:	143433
Calibration Factor:	2.157369 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:	6.55 kips
Time of Max. Load:	0.148 sec
Event Duration:	5.7105 sec
Final Load:	2.71 kips



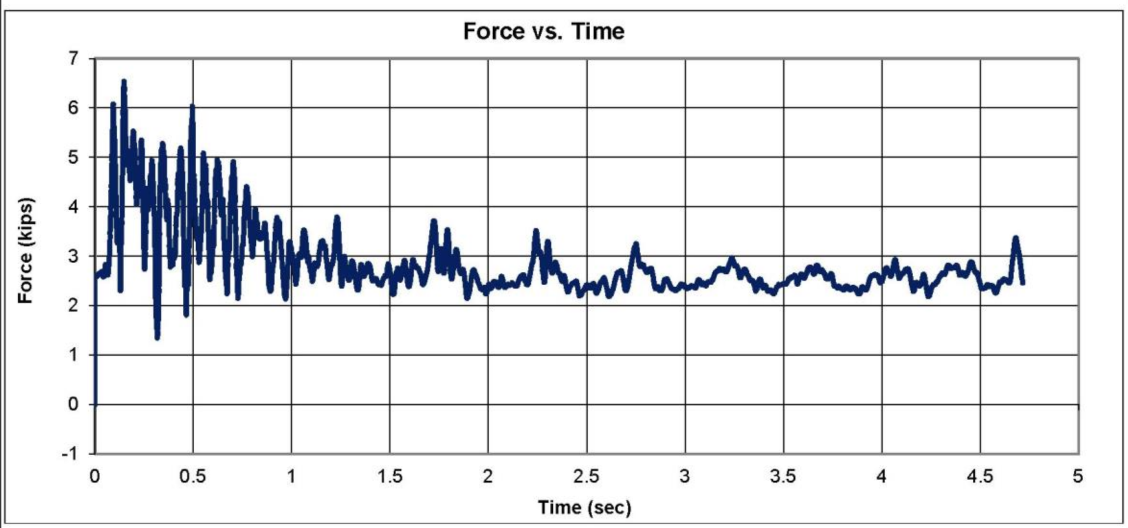


Figure H-4. Load Cell Data, Cable 4 (Top), Test No. MTP-2

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