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EVALUATION OF THE NEW YORK LOW-TENSION THREE-CABLE BARRIER ON CURVED ALIGNMENT

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16. Abstract (Limit: 200 words)

Three full-scale crash tests were performed on the New York Department of Transportation's (NYSDOT's) curved, low-tension, three-cable barrier systems utilizing the MASH Test Level 3 safety performance criteria. The cable barrier system for test no. NYCC-1 was 399.1 ft (121.6 m) long and used a radius of 360 ft (110 m). For test nos. NYCC-2 and NYCC-3, the cable barrier systems were 396.5 ft (120.9 m) long and used radii of 440 ft (134 m). In test nos. NYCC-1 and NYCC-2, the three cables were positioned at heights of 1 ft 3 in. (0.38 m), 1 ft 9 in. (0.53 m), and 2 ft 3 in. (0.69 m). In each of the tests, a 2270P vehicle was used. The first test redirected the pickup truck with all safety performance criteria being satisfied. During the second test, the pickup truck overrode the cable barrier and came to rest behind the system, thus resulting in unacceptable barrier performance. The barrier system was modified using a 2 in. (51 mm) height increase and retested with cables centered at 1 ft 5 in. (0.41 m), 1 ft 11 in.(0.58 m) and 2 ft 5 in. (0.74 m). In the third test, the pickup truck was redirected, and all safety performance criteria were satisfied.

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This report was completed with funding from the New York State Department of Transportation. The contents of this report reflect the views and opinions of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the New York State Department of Transportation nor the Federal Highway Administration, U.S. Department of Transportation. This report does not constitute a standard, specification, regulation, product endorsement, or an endorsement of manufacturers.

UNCERTAINTY OF MEASUREMENT STATEMENT

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

INDEPENDENT APPROVING AUTHORITY

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

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1 INTRODUCTION

1.1 Background

For several decades, the New York State Department of Transportation (NYSDOT) has installed its generic cable barrier systems in various configurations, including placement around curves. The active tensioning required for these installations have occasionally resulted in the posts being pulled to the inside of the curve. As a result, limitations were placed on the amount of curvature that could be used for a given post spacing, thus raising questions of whether there exists a minimum limit of curvature for a given roadway.

NYSDOT currently restricts cable barrier installations to roads with curves having radii greater than or equal to 440 ft (139 m). However, the post spacing is reduced from 16 ft (4.9 m) to 12 ft (3.7 m) or less on curves ranging between 440 ft (139 m) and 715 ft (218 m). Post spacing is believed to be directly related to system deflection, such that reduced post spacing will decrease the system deflection during an impact event. Currently, the safety performance and dynamic barrier deflections of low-tension, three-cable barriers placed around curves is unknown. Unfortunately, no prior research studies have involved the full-scale crash testing of low-tension, three-cable barrier systems with curved alignment. The NYSDOT personnel have desired that the low tension, three-cable barrier system be available for use on roads with radii of 360 ft and 440 ft (110 m and 139 m) but using an 8-ft (2.4-m) post spacing. Therefore, full-scale crash testing was deemed necessary on these smaller radii systems according to the Test Level 3 (TL-3) impact safety standards published in the American Association of State Highway and Transportation Officials (ASSHTO) *Manual for Assessing Safety Hardware* [1].

1.2 Objective

The purpose of this study was to determine dynamic deflections for a cable barrier system placed around a curve for a known impact condition and post spacing as well as to determine the energy absorbed when an impacting vehicle strikes a typical weak post, rubs on the cable rail, and skids on the ground/pavement surface. During this research project, evaluations were made on the performance of the systems using different radii and according to the TL-3 criteria designated in MASH.

However, per the request from the NYSDOT, the full-scale crash test program was to be performed using a speed of 62 mph (98 km/h) and an angle of 20 degrees to the tangent segment. It was assumed by NYSDOT that roads with sharp curves would be mostly two-way secondary highways which would limit the offset distance from which the guide rail could be approached. Based on an assumption of steep curves and normal pavement friction limitations, a NYSDOT analysis indicated that only a 20-degree maximum impact angle was possible for a vehicle traveling at 62 mph (100 km/h) and crossing 25 ft (7.6 m) of travel lanes and shoulder prior to contacting a barrier on a roadway with a 360-ft (110-m) radius. Thus, a 20-degree target impact angle was recommended for the full-scale crash testing program.

1.3 Scope

The research study was accomplished by completing a series of tasks. First, a curved, low-tension, three-cable barrier system with an interior radius of 360 ft (110 m) and a post spacing of 8 ft (2.4 m) was constructed. Next, a full-scale crash test was performed with a pickup truck weighing approximately 5,000 lb (2,268 kg) and impacting the system at a speed of 62 mph (100 km/h) and at an angle of 20 degrees relative to the tangent (modified test designation no. 3-11). Next, the cable barrier system was reconstructed with an interior radius of 440 ft (134 m) and a post spacing of 8 ft (2.4 m). The second full-scale crash test was performed with a pickup truck weighing approximately 5,000 lb (2,268 kg) and striking the system at a speed of 62 mph (100 km/h) and at an angle of 20 degrees relative to the tangent (modified test designation no. 3-11). Following the unsatisfactory test, the 440 ft (134 m) radius cable system with 8-ft (2.4-m) post spacing was reconstructed, but the entire system was raised 2 in. (51 mm) to where the top cable was located 29 in. (734 mm) from the ground. The third full-scale crash test was performed with a pickup truck weighing approximately 5,000 lb (2,268 kg) and striking the system at a speed of 62 mph (100 km/h) and at an angle of 20 degrees relative to the tangent (modified test designation no. 3-11). Finally, the test results were analyzed, evaluated, and documented as they pertain to the safety performance of the cable barrier systems. The additional crash investigation and analysis was performed to investigate the impacting vehicle's energy dissipation as a function of time and various events and will be included in Volume II.

2 TEST REQUIREMENTS AND EVALUATION CRITERIA

2.1 Test Requirements

Historically, longitudinal barriers, such as cable guardrails, have been required to satisfy safety performance criteria in order to be accepted by the Federal Highway Administration (FHWA) for use on the National Highway System (NHS). Currently, these safety standards consist of the guidelines and procedures published in MASH [1]. According to TL-3 testing conditions identified in MASH, longitudinal barrier systems must be subjected to two full-scale vehicle crash tests. The two full-scale crash tests are noted below:

1. Test Designation No. 3-10 consists of a 2,425-lb (1,100-kg) passenger car impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 25 degrees, respectively.

2. Test Designation No. 3-11 consists of a 5,000-lb (2,268-kg) pickup truck impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 25 degrees, respectively.

The test conditions of TL-3 longitudinal barriers are summarized in Table 1.

Table 1. MASH TL-3 Crash Test Conditions

Test Article	Test Designation No.	Test Vehicle	Impact Conditions			Evaluation Criteria [1]
			Speed		Angle (deg)	
			mph	km/h		
Longitudinal Barrier	3-10	1100C	62	100	25	A,D,F,H,I
	3-11	2270P	62	100	25	A,D,F,H,I

[1] Evaluation criteria explained in Table 2.

According to the request of NYSDOT personnel, a curved run of generic, low-tension, three-cable barrier was crash tested according to modified test designation no. 3-11 for test nos. NYCC-1, NYCC-2, and NYCC-3. According to MASH, the critical impact point for cable barrier systems is 1 ft (0.3 m) upstream from a given post. However, NYSDOT personnel requested that an impact angle of 20 degrees be used in combination with an impact location of 70 ft (21.3 m) downstream from the tangent along the arc or 24 in. (610 mm) upstream of post no. 17. The impact angle was to be measured relative to the curve's tangent line at the impact point.

2.2 Evaluation Criteria

Evaluation criteria for full-scale vehicle crash testing are based on three appraisal areas: (1) structural adequacy; (2) occupant risk; and (3) vehicle trajectory after collision. Criteria for structural adequacy are intended to evaluate the ability of the cable guardrails 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 be involved in a secondary collision with other vehicles and/or fixed objects, thereby increasing the risk of injury to the occupants of the impacting vehicle. These evaluation criteria are summarized in Table 2 and defined in greater detail in MASH. The full-scale vehicle crash tests were conducted and reported in accordance with the procedures provided in MASH with the exceptions of impact angle and system length, as requested by NYSDOT.

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

2.3 Soil Strength Requirements

In order to limit the variation of soil strength among testing agencies, foundation soil must satisfy the recommended performance characteristics set forth in Chapter 3 and Appendix B of MASH. Testing facilities must first subject the designated soil to a dynamic post test to demonstrate a minimum dynamic load of 7.5 kips (33.4 kN) at deflections between 5 and 20 in. (127 and 508 mm). If satisfactory results are observed, a static test is conducted using an identical test installation. The results from this static test become the baseline requirement for soil strength in future full-scale crash testing in which the designated soil is used. An additional post installed near the impact point was to be statically tested on the day of full-scale crash test in the same manner as used in the baseline static test. The full-scale crash test could be conducted only if the static test results showed a soil resistance equal to or greater than 90 percent of the baseline test at deflections of 5, 10, and 15 in. (127, 254, and 381 mm). Otherwise, the crash test was to be postponed until the soil demonstrated adequate post-soil strength.

Table 2. MASH Evaluation Criteria for Longitudinal Barrier

<table>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td></tr>
<tr><td rowspan="11">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.</td></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 A5.3 of MASH for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s
(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 A5.3 of MASH for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
</table>

3 TEST CONDITIONS

3.1 Test Facility

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

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 [2] was used to steer the test vehicle. A guide flag, attached to the left-front wheel and the guide cable, was sheared off before impact with the barrier system. The ⅜-in. (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 Vehicles

For test no. NYCC-1, a 2005 Dodge Ram was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,094 lb (2,311 kg), 5,020 lb (2,277 kg), and 5,190 lb (2,354 kg), respectively. The test vehicle is shown in Figure 1, and vehicle dimensions are shown in Figure 2.

For test no. NYCC-2, a 2005 Dodge Ram was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,001 lb (2,268 kg), 4,998 lb (2,267 kg), and 5,168 lb (2,344 kg), respectively. The test vehicle is shown in Figure 3, and vehicle dimensions are shown in Figure 4.

For test no NYCC-3, a 2005 Dodge Ram was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,134 lb (2,329 kg), 4,994 lb (2,265 kg), and 5,166 lb (2,343 kg), respectively. The test vehicle is shown in Figure 5, and vehicle dimensions are shown in Figure 6.

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [3] was used to determine the vertical component of the c.g. for the pickup truck. This method is based on the principle that the c.g. of any freely suspended body is in the vertical plane through the point of suspension. The vehicle was suspended successively in three positions, and the respective planes containing the c.g. were established. The intersection of these planes pinpointed the final c.g. location for the test inertial condition. The locations of the final centers of gravity are shown in Figures 1 through 6. Data used to calculate the location of the c.g. and ballast information are shown in Appendix A.

Square, black- and white-checkered targets were placed on the vehicle for reference to be viewed from the high-speed digital video cameras and aid in the video analysis, as shown in Figures 7 through 9. Round, checkered targets were placed on the center of gravity on the left-side door, the right-side door, and the roof of the vehicle.

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

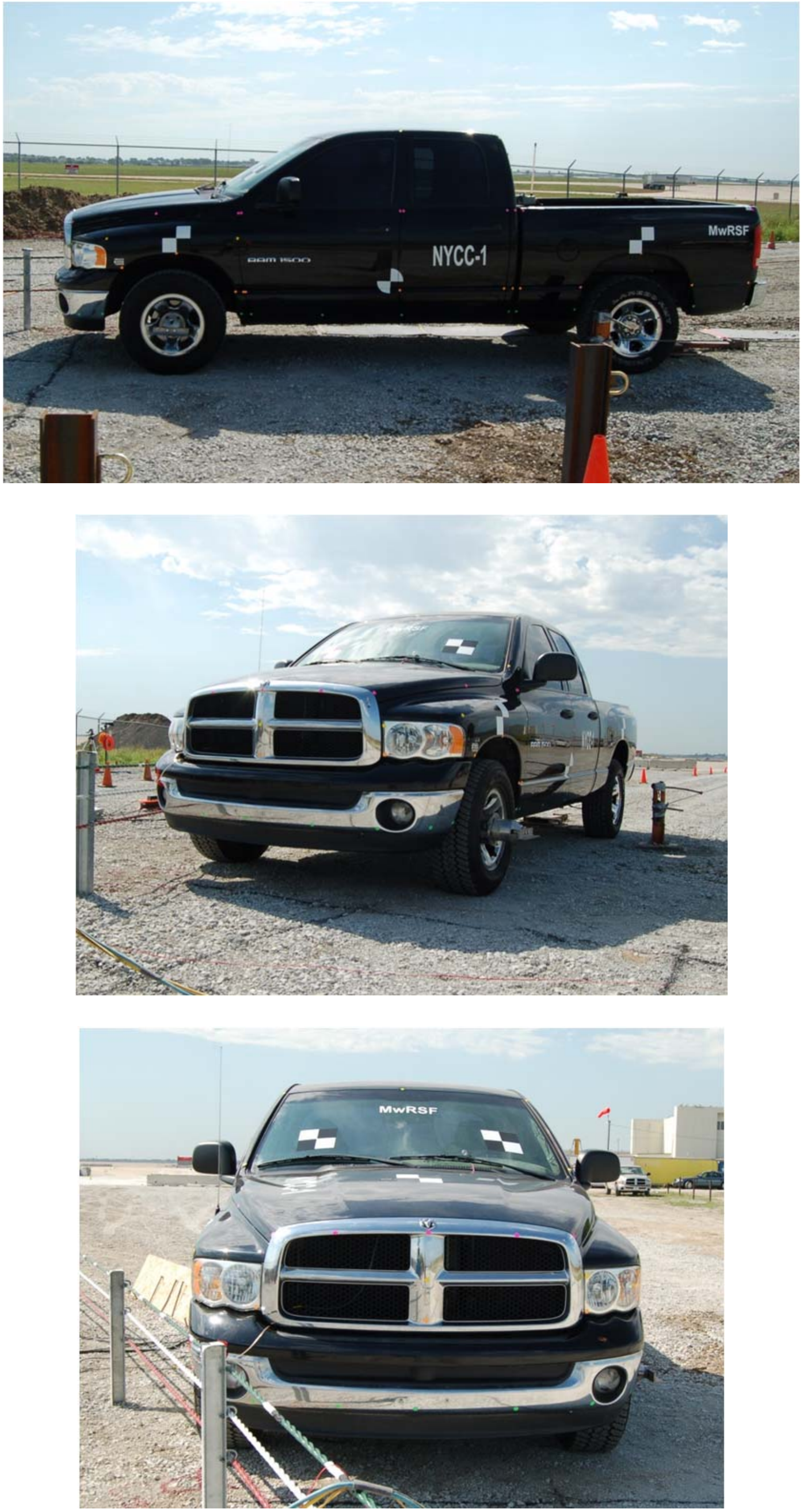
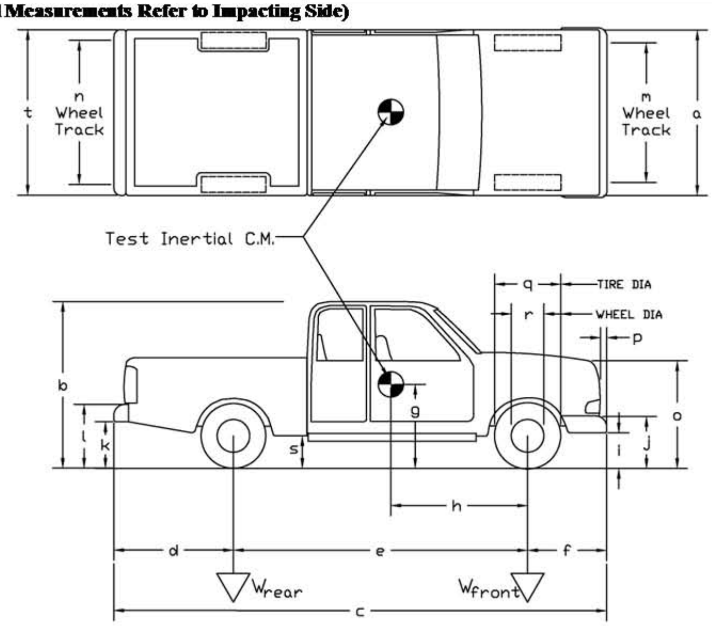


Figure 1. Test Vehicle, Test No. NYCC-1

Date:	8/2/2011	**Test Number:**	NYCC-1	**Model:**	2270P/Ram
Make:	Dodge	**Vehicle I.D.#:**	1D7HA18N05J560193		
Tire Size:	LT265/70 R17	**Year:**	2005	**Odometer:**	147869

Tire Inflation Pressure: 35psi

***(All Measurements Refer to Impacting Side)**



Vehicle Geometry – in. (mm)

a	78	(1981)	b	74	(1880)
c	227 3/4	(5785)	d	47	(1194)
e	140 1/4	(3562)	f	40 1/2	(1029)
g	28 7/8	(733)	h	63	(1602)
i	15	(381)	j	27	(686)
k	21	(533)	l	29 1/4	(743)
m	68 1/8	(1730)	n	67 1/2	(1715)
o	45 1/2	(1156)	p	3	(76)
q	31 1/2	(800)	r	18 1/4	(464)
s	15 1/2	(394)	t	75 1/2	(1918)

Wheel Center Height Front	15	(381)
Wheel Center Height Rear	15 1/4	(387)
Wheel Well Clearance (F)	35	(889)
Wheel Well Clearance (R)	37 1/2	(953)
Frame Height (F)	17 3/4	(451)
Frame Height (R)	24 3/4	(629)
Engine Type	8cyl GAS	
Engine Size	4.7L	

Transmition Type: Automatic (circled) Manual

FWD RWD (circled) 4WD

Mass Distribution lb (kg)

Gross Static	LF	1494 (678)	RF	1380 (626)
	LR	1107 (502)	RR	1209 (548)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2819 (1279)	2769 (1256)	2874 (1304)
W-rear	2275 (1032)	2251 (1021)	2316 (1051)
W-total	5094 (2311)	5020 (2277)	5190 (2354)

GVWR Ratings

Front	3650
Rear	3900
Total	6650

Dummy Data

Type:	Hybrid II
Mass:	170 lbs
Seat Position:	Passenger

Note any damage prior to test: None

Figure 2. Vehicle Dimensions, Test No. NYCC-1

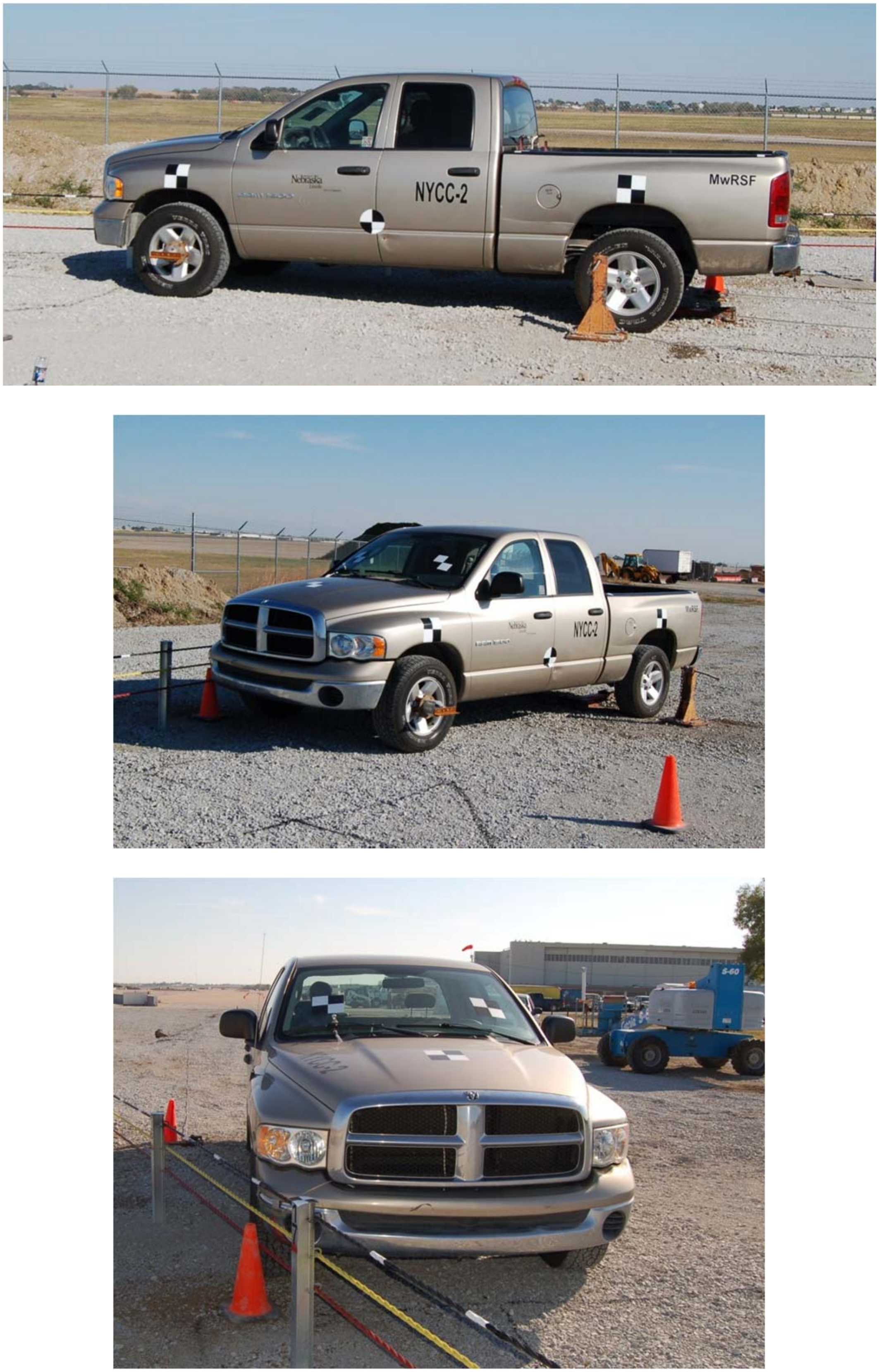


Figure 3. Test Vehicle, Test No. NYCC-2

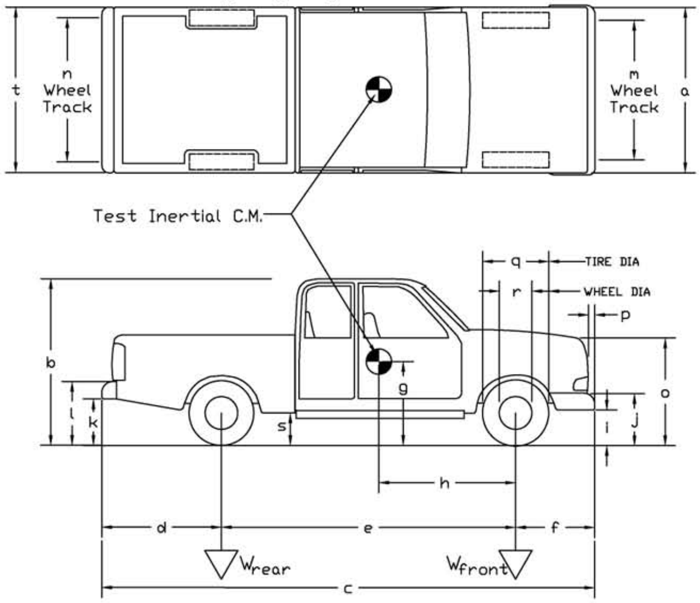
Date: 11/1/2011 **Test Number:** NYCC-2 **Model:** 2270P

Make: Dodge Ram **Vehicle I.D.#:** 1D7HA18N95J610492

Tire Size: 265/70 R17 **Year:** 2005 **Odometer:** 84180

Tire Inflation Pressure: 35

***(All Measurements Refer to Impacting Side)**



Vehicle Geometry – in. (mm)

a	77 3/4 (1975)	b	73 1/8 (1857)
c	227 7/8 (5788)	d	48 (1219)
e	140 1/4 (3562)	f	39 5/8 (1006)
g	28 (711)	h	63 8/9 (1623)
i	15 (381)	j	25 1/2 (648)
k	20 1/2 (521)	l	28 1/2 (724)
m	67 7/8 (1724)	n	67 3/8 (1711)
o	43 (1092)	p	2 3/4 (70)
q	30 3/4 (781)	r	18 1/2 (470)
s	14 1/2 (368)	t	75 (1905)

Wheel Center Height Front	14 1/2 (368)
Wheel Center Height Rear	14 3/4 (375)
Wheel Well Clearance (F)	35 (889)
Wheel Well Clearance (R)	37 3/8 (949)
Frame Height (F)	17 1/8 (435)
Frame Height (R)	24 1/2 (622)
Engine Type	8cyl Gas
Engine Size	4.7L

Mass Distribution lb (kg)

Gross Static	LF	1442 (654)	RF	1386 (629)
	LR	1172 (532)	RR	1168 (530)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2774 (1258)	2721 (1234)	2828 (1283)
W-rear	2227 (1010)	2277 (1033)	2340 (1061)
W-total	5001 (2268)	4998 (2267)	5168 (2344)

Transmition Type: Automatic (circled) Manual

FWD RWD (circled) 4WD

GVWR Ratings

Front	3700
Rear	3900
Total	6650

Dummy Data

Type: Hybrid II

Mass: 170 lbs

Seat Position: Passenger

Note any damage prior to test: Small door dent left rear door.

Figure 4. Vehicle Dimensions, Test No. NYCC-2

Figure 5. Test Vehicle, Test No. NYCC-3

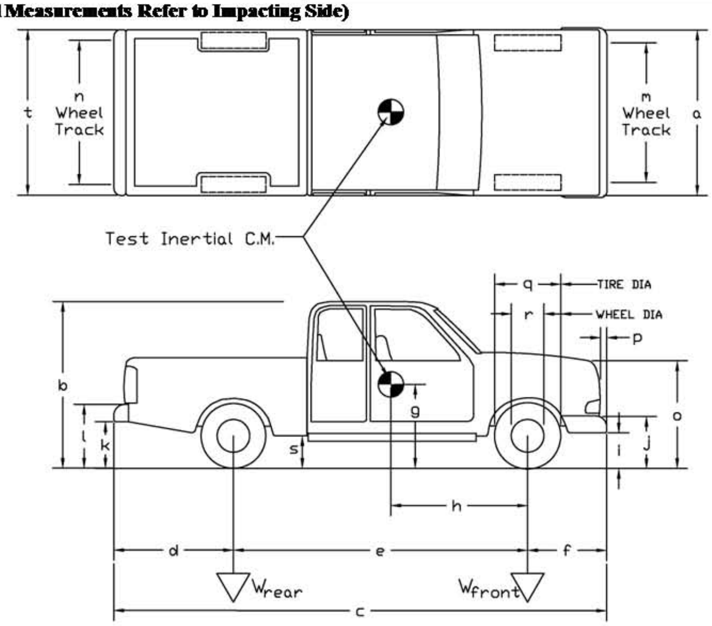
Date: 4/26/2012 **Test Number:** NYCC-3 **Model:** 2270P

Make: Dodge Ram **Vehicle I.D.#:** 1D7HA18D45S262716

Tire Size: 265/70 R17 **Year:** 2005 **Odometer:** 89914

Tire Inflation Pressure: 35 Psi

***(All Measurements Refer to Impacting Side)**



Vehicle Geometry – in. (mm)

a	78 1/4	(1988)	b	75 1/4	(1911)
c	228 1/2	(5804)	d	47 1/4	(1200)
e	140 1/2	(3569)	f	40 3/4	(1035)
g	29	(737)	h	62	(1574)
i	15 1/4	(387)	j	27	(686)
k	21 1/4	(540)	l	29 3/4	(756)
m	68 1/8	(1730)	n	67 1/2	(1715)
o	46	(1168)	p	3 1/2	(89)
q	31 3/4	(806)	r	18 1/2	(470)
s	16	(406)	t	75 1/2	(1918)

Wheel Center Height Front	14 7/8	(378)
Wheel Center Height Rear	15 1/8	(384)
Wheel Well Clearance (F)	36	(914)
Wheel Well Clearance (R)	38 1/2	(978)
Frame Height (F)	18 1/4	(464)
Frame Height (R)	25 1/4	(641)
Engine Type	8cyl Gas	
Engine Size	5.7L	

Transmition Type: Automatic (circled) Manual

FWD RWD (circled) 4WD

Mass Distribution lb (kg)

Gross Static	LF	1410 (640)	RF	1484 (673)
	LR	1123 (509)	RR	1149 (521)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2884 (1308)	2792 (1266)	2894 (1313)
W-rear	2250 (1021)	2202 (999)	2272 (1031)
W-total	5134 (2329)	4994 (2265)	5166 (2343)

GVWR Ratings

Front	3700
Rear	3900
Total	6650

Dummy Data

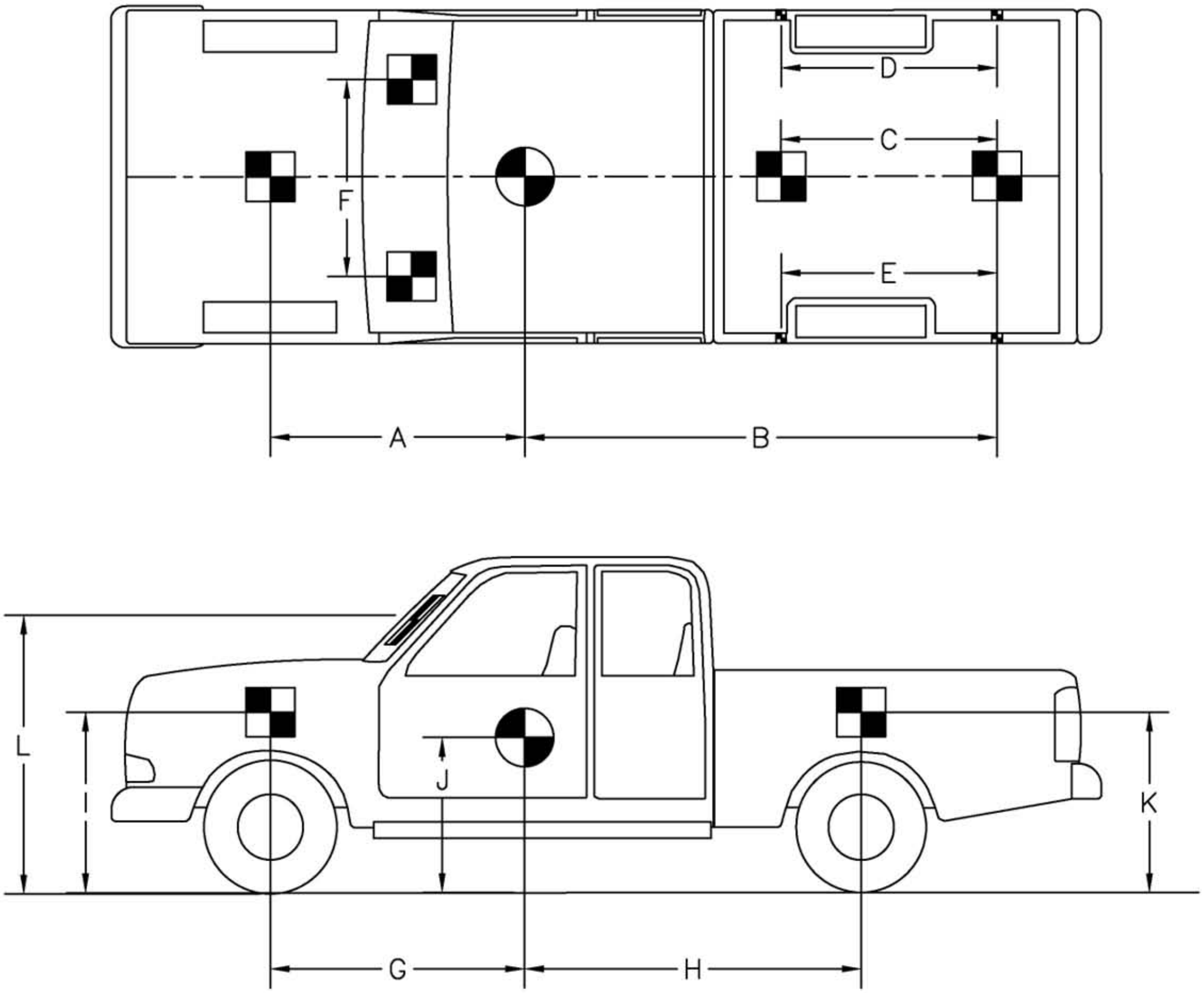
Type: Hybrid II

Mass: 170 lbs

Seat Position: Passenger

Note any damage prior to test: None

Figure 6. Vehicle Dimensions, Test No. NYCC-3

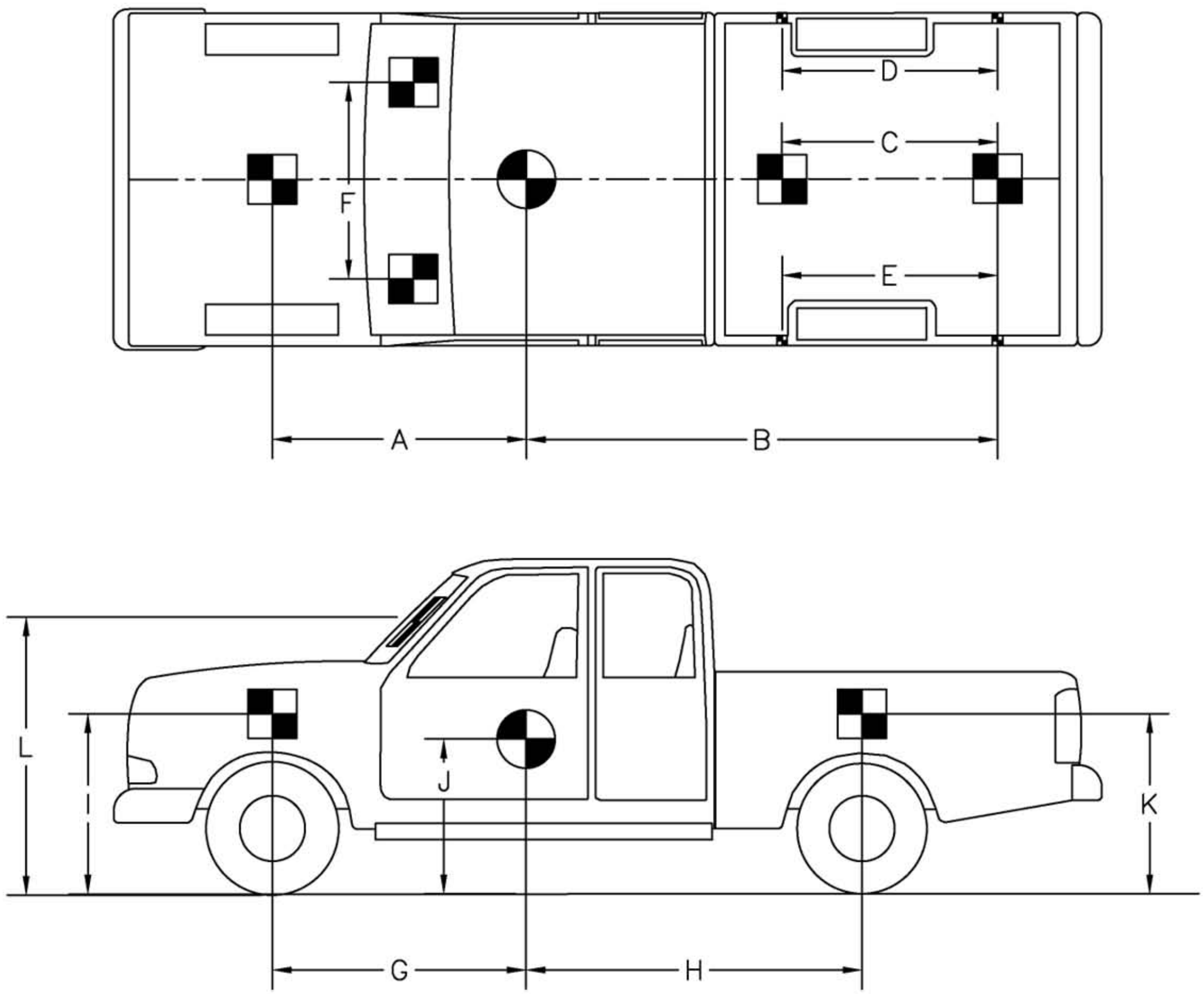


TEST #: NYCC-1

TARGET GEOMETRY– in. (mm)

A	**73**	**(1854)**	**E**	**69 1/2**	**(1765)**	**I**	**39 3/4**	**(1010)**
B	**100 1/4**	**(2546)**	**F**	**39**	**(991)**	**J**	**28 7/8**	**(733)**
C	**48**	**(1219)**	**G**	**63**	**(1600)**	**K**	**42 1/2**	**(1080)**
D	**69 1/2**	**(1765)**	**H**	**77 1/4**	**(1962)**	**L**	**58 1/2**	**(1486)**

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

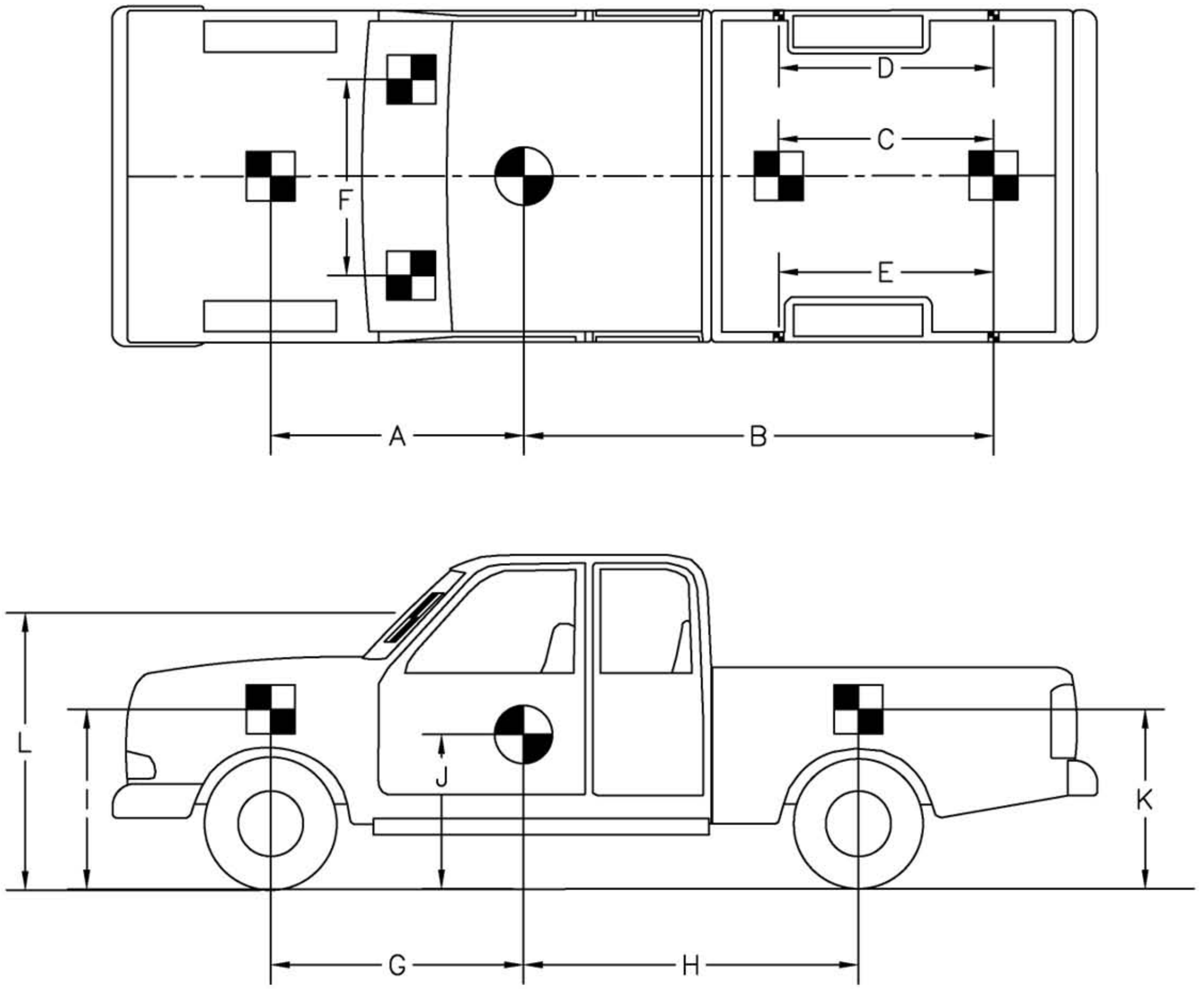


TEST #: NYCC-2

TARGET GEOMETRY– in. (mm)

A	**78 3/4**	**(2000)**	**E**	**68 3/4**	**(1746)**	**I**	**39**	**(991)**
B	**103 3/4**	**(2635)**	**F**	**41**	**(1041)**	**J**	**28**	**(711)**
C	**48**	**(1219)**	**G**	**63 7/8**	**(1622)**	**K**	**41 1/2**	**(1054)**
D	**65 1/4**	**(1657)**	**H**	**76 3/8**	**(1940)**	**L**	**59**	**(1499)**

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



TEST #: NYCC-3

TARGET GEOMETRY-- in. (mm)

A	79 3/4	(2026)	E	64	(1626)	I	40	(1016)
B	97 1/4	(2470)	F	40	(1016)	J	29	(737)
C	33 1/8	(841)	G	62	(1575)	K	42 3/4	(1086)
D	64	(1626)	H	78 1/2	(1994)	L	61	(1549)

Figure 9. Target Geometry, Test No. NYCC-3

videos. A remote controlled brake system was installed in the test vehicle so the vehicle could be brought safely to a stop after the test.

3.4 Simulated Occupant

For test nos. NYCC-1, NYCC-2, and NYCC-3, a Hybrid II 50th-Percentile, Adult Male Dummy, equipped with clothing and footwear, was placed in the right-front seat of the test vehicle with the seat belt fastened. The dummy, which had a final weight of 170 lb (77 kg), was represented by model no. 572, serial no. 451, and was manufactured by Android Systems of Carson, California. As recommended by MASH, the dummy was not included in calculating the c.g location.

3.5 Data Acquisition Systems

3.5.1 Accelerometers

Three environmental shock and vibration sensor/recorder systems were used to measure the accelerations in the longitudinal, lateral, and vertical directions. All of the accelerometers were mounted near the center of gravity of the test vehicles. The electronic accelerometer data obtained in dynamic testing was filtered using the SAE Class 60 and the SAE Class 180 Butterworth filter conforming to the SAE J211/1 specifications [4].

The first accelerometer system was a two-arm piezoresistive accelerometer system manufactured by Endevco of San Juan Capistrano, California. The three accelerometers were used to measure each of the longitudinal, lateral, and vertical accelerations independently at a sample rate of 10,000 Hz. The accelerometers were configured with a range of ±500 g's and controlled using a DTS Sensor Input Module (SIM), Model TDAS3-SIM-16M manufactured by Diversified Technical Systems, Inc. (DTS) of Seal Beach, California. The SIM was configured with 16 MB SRAM and 8 sensor input channels with 250 kB SRAM/channel. The SIM was mounted on a TDAS3-R4 module rack which was configured with isolated power/event/communications, 10BaseT Ethernet and RS232 communication, and an internal backup battery. The "DTS TDAS Control" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

The second system, SLICE 6DX, was a modular data acquisition system manufactured by DTS of Seal Beach, California. The acceleration sensors were mounted inside the body of the custom built SLICE 6DX event data recorder and recorded data at 10,000 Hz to the onboard microprocessor. The 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.

The third system, Model EDR-3, was a triaxial piezoresistive accelerometer system manufactured by IST of Okemos, Michigan. The EDR-3 was configured with 256 kB of RAM, a range of ±200 g's, a sample rate of 3,200 Hz, and a 1,120 Hz low-pass filter. The "DynaMax 1 (DM-1)" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

The DTS and EDR-3 units were utilized on test nos. NYCC-1 through NYCC-3. The DTS-SLICE unit was only utilized during test no. NYCC-3.

3.5.2 Rate Transducers

An angle rate sensor, the ARS-1500, with a range of 1,500 degrees/sec in each of the three directions (roll, pitch, and yaw) was used to measure the rates of rotation of the test vehicles. The angular rate sensors were mounted on an aluminum block inside the test vehicle near the center of gravity and recorded data at 10,000 Hz to the SIM. The raw data measurements were then downloaded, converted to the proper Euler angles for analysis, and plotted. The "DTS TDAS Control" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the angular rate sensor data.

A second angle rate sensor system, the SLICE MICRO Triax ARS, with a range of 1,500 degrees/sec in each of the three directions (roll, pitch, and yaw) was used to measure the rates of rotation of the test vehicles. The angular rate sensors were mounted inside the body of the custom built SLICE 6DX event data recorder and recorded data at 10,000 Hz to the onboard microprocessor. 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.

A third system, an Analog Systems 3-axis rate transducer with a range of 1,200 degrees/sec in each of the three directions (roll, pitch, and yaw), was used to measure the rates of motion of the test vehicles. The rate transducer was mounted inside the body of the EDR-4 6DOF-500/1200 and recorded data at 10,000 Hz to a second data acquisition board inside the EDR-4 6DOF-500/1200 housing. The raw data measurements were then downloaded, converted to the appropriate Euler angles for analysis, and plotted. The "EDR4COM" and "DynaMax Suite" computer software programs and a customized Microsoft Excel worksheet were used to analyze and plot the angular rate transducer data.

The rate gyro within the DTS unit was utilized in test nos. NYCC-1 through NYCC-3. The EDR-4 unit was only utilized during test no. NYCC-1. The DTS-SLICE unit was only utilized during test no. NYCC-3.

3.5.3 Pressure Tape Switches

For test nos. NYCC-1, NYCC-2, and NYCC-3, five pressure-activated tape switches, spaced at approximately 6.56-ft (2-m) intervals, were used to determine the speed of the vehicle before impact. Each tape switch fired a strobe light which sent an electronic timing signal to the data acquisition system as the right-front tire of the test vehicle passed over it. Test vehicle speeds were determined from electronic timing mark data recorded using TestPoint and LabVIEW computer software programs. Strobe lights and high-speed video analysis are used only as a backup in the event that vehicle speed cannot be determined from the electronic data.

3.5.4 Digital Photography

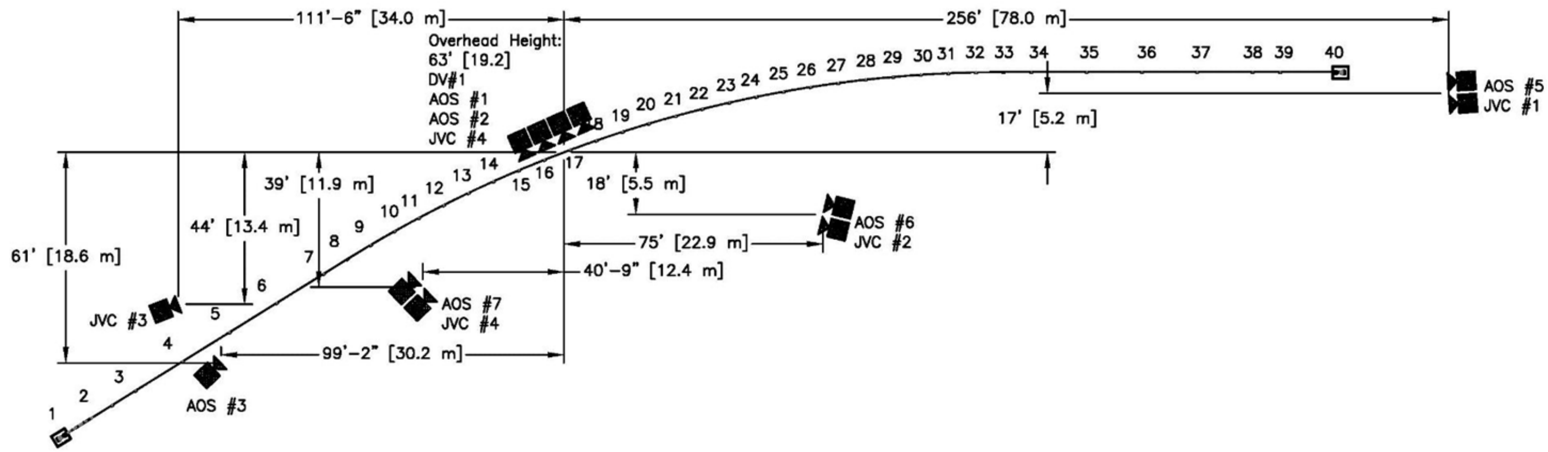
Three AOS VITcam high-speed digital video cameras, three AOS X-PRI high-speed digital video cameras, four JVC digital video cameras, and one Canon digital video camera were utilized to film test nos. NYCC-1, NYCC-2, and NYCC-3. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figures 10 through 12.

The high-speed videos were analyzed using ImageExpress MotionPlus and RedLake MotionScope software programs. Actual camera speed and camera divergence factors were considered in the analysis of the high-speed videos. A Nikon D50 digital still camera was also used to document pre- and post-test conditions for all tests.

3.5.5 Load Cell

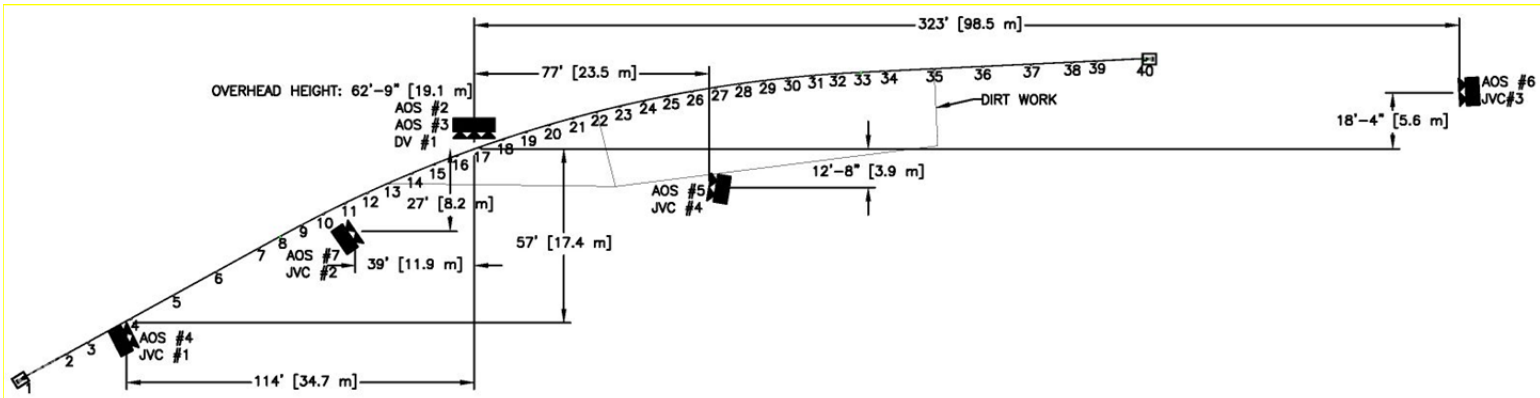
Each of the three cables in the barrier system had a load cell installed along it. Each load cell was positioned in line with the cable on the upstream end. The load cells were placed between post nos. 1 and 2, as shown in Figure 13.

The load cells were manufactured by Transducer Techniques and conformed to 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 Keithly Metrabyte DAS-1802HC data acquisition board, acquired with Test Point software, and stored permanently on a personal computer. The data collection rate for the load cells was 10,000 samples per second (10,000 Hz).



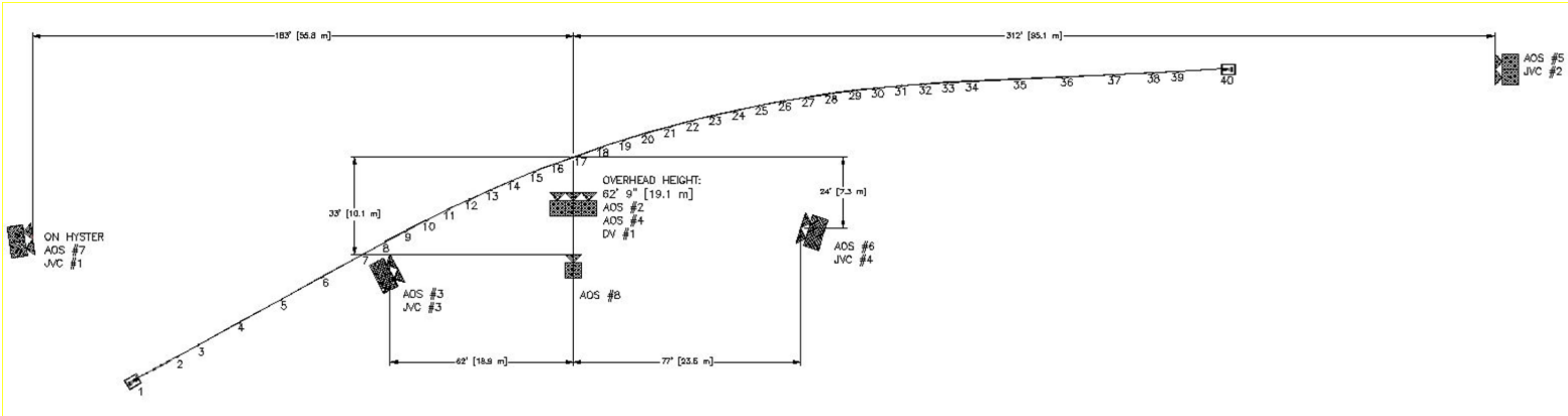
	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	1	AOS Vitcam CTM	500	Cosmicar 12.5 mm Fixed	--
	2	AOS Vitcam CTM	500	Kowa 8 mm Fixed	--
	3	AOS Vitcam CTM	500	Sigma 50 mm Fixed	--
	5	AOS X-PRI Gigabit	500	Canon 17-102 mm	100 mm
	6	AOS X-PRI Gigabit	500	Fuji 50 mm	--
	7	AOS X-PRI Gigabit	500	Computar 12.5 mm Fixed	--
Digital Video	1	JVC – GZ-MC500 (Everio)	29.97		
	2	JVC – GZ-MG27u (Everio)	29.97		
	3	JVC – GZ-MG27u (Everio)	29.97		
	4	JVC – GZ-MG27u (Everio)	29.97		
	1	Canon ZR90	29.97		
	2	Canon ZR10	29.97		

Figure 10. Camera Locations, Speeds, and Lens Settings, Test No. NYCC-1



	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	2	AOS Vitcam CTM	500	Cosmicar 12.5 mm Fixed	--
	3	AOS Vitcam CTM	500	Kowa 8 mm Fixed	--
	4	AOS Vitcam CTM	500	Fuji 50 mm Fixed	--
	5	AOS X-PRI Gigabit	500	Computar 12.5 mm Fixed	--
	6	AOS X-PRI Gigabit	500	TV Zoom 17-102 mm	50 mm
	7	AOS X-PRI Gigabit	500	Sigma 50 mm Fixed	--
Digital Video	1	JVC – GZ-MC500 (Everio)	29.97		
	2	JVC – GZ-MG27u (Everio)	29.97		
	3	JVC – GZ-MG27u (Everio)	29.97		
	4	JVC – GZ-MG27u (Everio)	29.97		
	1	Canon ZR90	29.97		
	2	Canon ZR10	29.97		

Figure 11. Camera Locations, Speeds, and Lens Settings, Test No. NYCC-2



	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	2	AOS Vitcam CTM	500	Cosmicar 12.5 mm Fixed	--
	3	AOS Vitcam CTM	500	Sigma 24-135	35 mm
	4	AOS Vitcam CTM	500	Kowa 8 mm Fixed	--
	5	AOS X-PRI Gigabit	500	Canon 17-102	50 mm
	6	AOS X-PRI Gigabit	500	Sigma 50 mm Fixed	
	7	AOS X-PRI Gigabit	500	Fujinon 50 mm Fixed	--
	8	AOS S-VIT 153A	500	OSAWA 28-80	28 mm
Digital Video	1	JVC – GZ-MC500 (Everio)	29.97		
	2	JVC – GZ-MG27u (Everio)	29.97		
	3	JVC – GZ-MG27u (Everio)	29.97		
	4	JVC – GZ-MG27u (Everio)	29.97		
	1	Canon ZR90	29.97		
	2	Canon ZR10	29.97		

Figure 12. Camera Locations, Speeds, and Lens Settings, Test No. NYCC-3

Figure 13. Typical Load Cell Locations

4 DESIGN DETAILS - TEST NO. NYCC-1

Test no. NYCC-1 utilized a generic low-tension 3-cable barrier system, as shown in Figures 14 through 27. Photographs of the test installation are shown in Figures 28 through 31. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

The cable barrier system had a total length of 399.1 ft (121.6 m). The cable barrier layout consisted of a 96-ft (29.3-m) long straight section spanning between post nos. 1 and 8, a 200-ft (61-m) long curved section with a 360-ft (110-m) radius spanning an angle of 32 degrees between post nos. 8 and 33, and another 96-ft (29.3-m) long straight section spanning between post nos. 33 and 40. The test installation was comprised of several distinct components, systems, and features: (1) wire ropes or cables; (2) steel support posts; (3) cable-to-post attachments; (4) cable compensating hardware; (5) cable anchorage plates; and (6) reinforced concrete anchor foundations.

Three ¾-in. (19-mm) diameter 3x7, Class A galvanized wire ropes were utilized for the cable elements. For the standard line posts, the three cables were attached to the posts and placed at 15 in. (381 mm), 21 in. (533 mm), and 27 in. (686 mm) above the ground surface. Each cable was attached to the impact side of the post utilizing a $^{5}/_{16}$-in. (8-mm) steel J-bolt, as shown in Figures 14 and 26. Each of the three wire ropes was spliced to a cable tension compensating assembly between post nos. 1 and 2, as shown in Figures 21 and 25. The cables were tensioned according to NYSDOT standards, as shown in Figure 27.

The cables were supported by 40 posts and anchored at the upstream and downstream ends, as shown in Figure 14. Post nos. 2 through 39 consisted of S3x5.7 (S76x8.5) standard steel line posts measuring 63 in. (1,600 mm) long, and a 24x8x¼ in. (610x203x6 mm) soil plate was welded to the back side of each post. The spacing between posts on the curved portion of the system plus the first adjacent span, post nos. 8 through 33, was 8 ft (2.4 m). The two straight segments of the system utilized a 16 ft (4.9 m) post spacing with the exceptions of 8 ft (2.4 m) spans between post nos. 2 and 3 and between post nos. 38 and 39. These two spans are set by the end terminal design of the system.

Each anchorage system consisted of a reinforced concrete foundation, a welded plate anchor angle, and an end post. The concrete foundation was 4 ft - 9 in. (1.4-m) long, 3 ft - 9 in. (1.1 m) wide, and 3 ft - 3 in. (1 m) deep. Both the welded plate anchor angle and the end post were attached to the foundation with ¾-in. (19-mm) diameter, hooked anchor studs. The welded anchor angle was assembled from ½-in. (13-mm) steel plates and used to restrain the ends of the cables, as shown in Figures 18 through 20. The end post was an S3x5.7 (S76x8.5) bolted to the slipbase assembly anchored to the foundation, as shown in Figures 21 and 22.

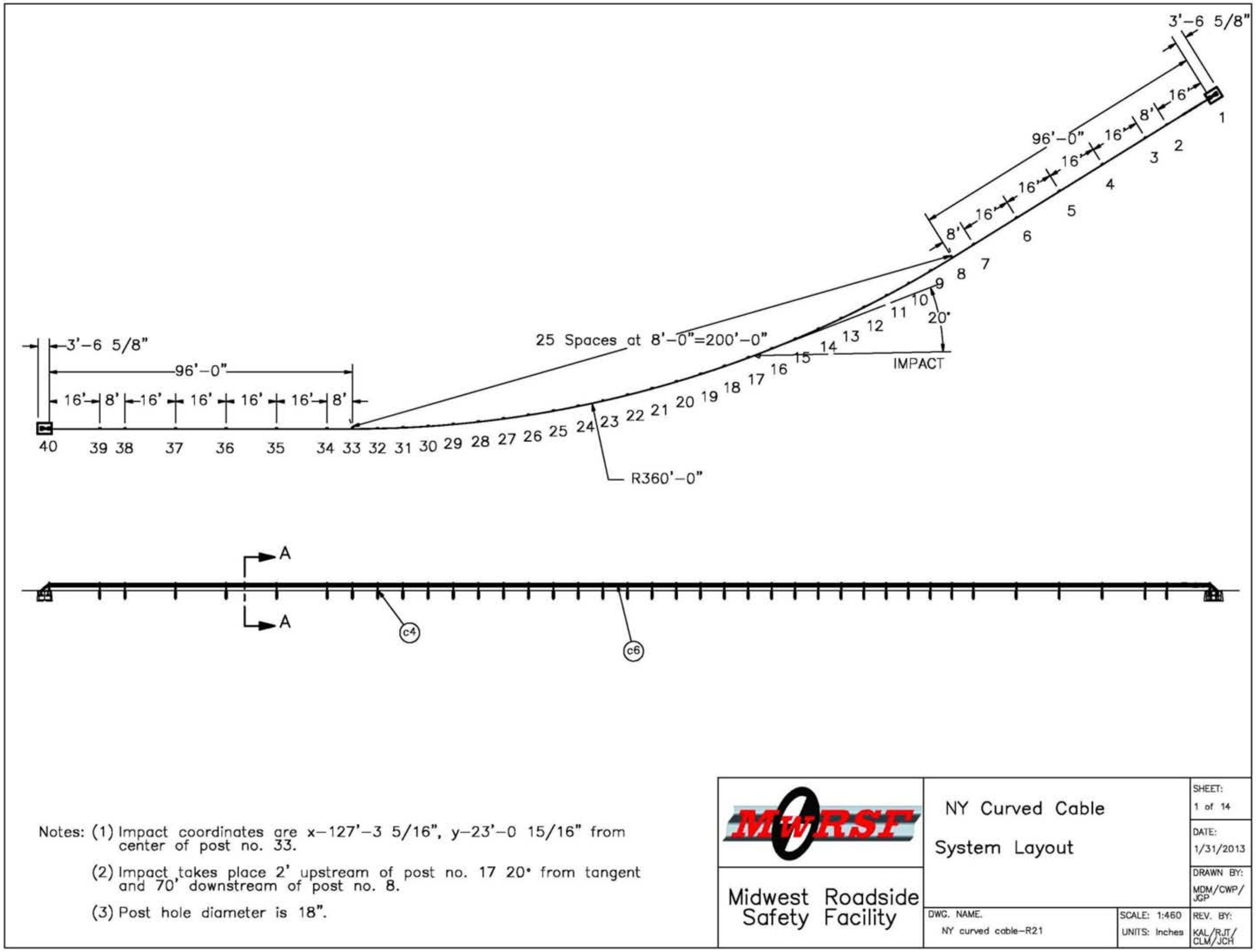


Figure 14. Test Installation Layout, Test No. NYCC-1

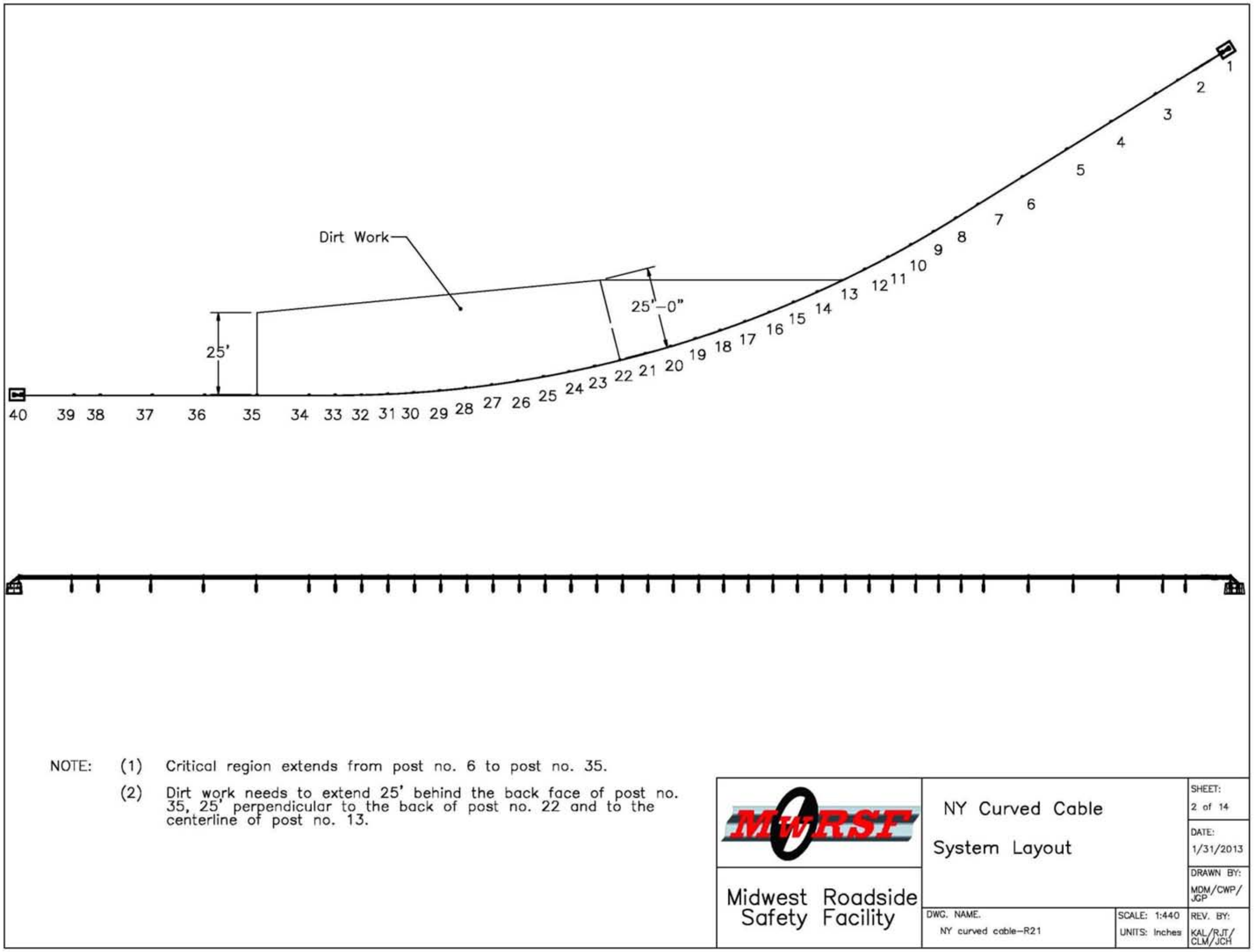


Figure 15. Critical Region, Test No. NYCC-1

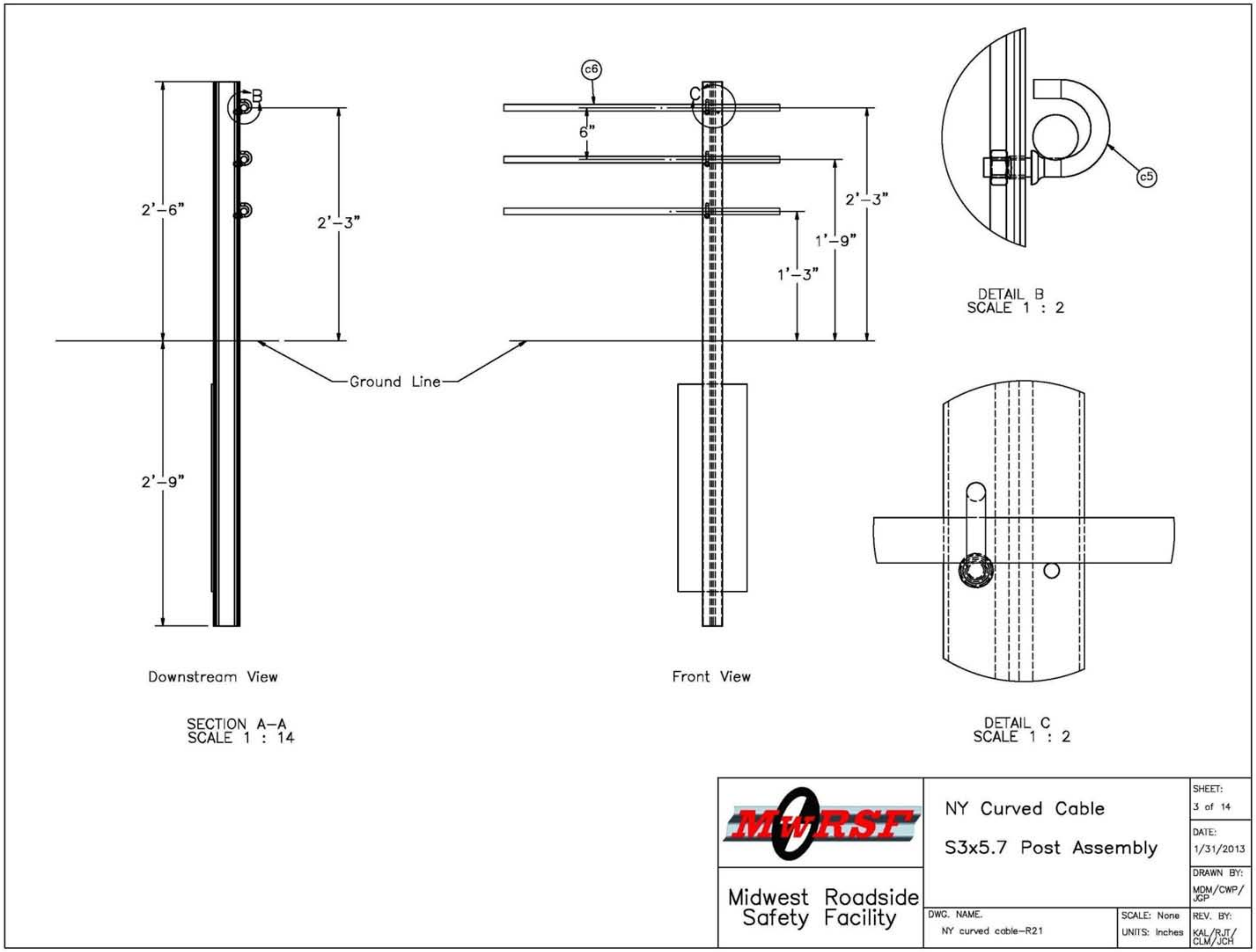


Figure 16. Line Post Assembly Details, Test No. NYCC-1

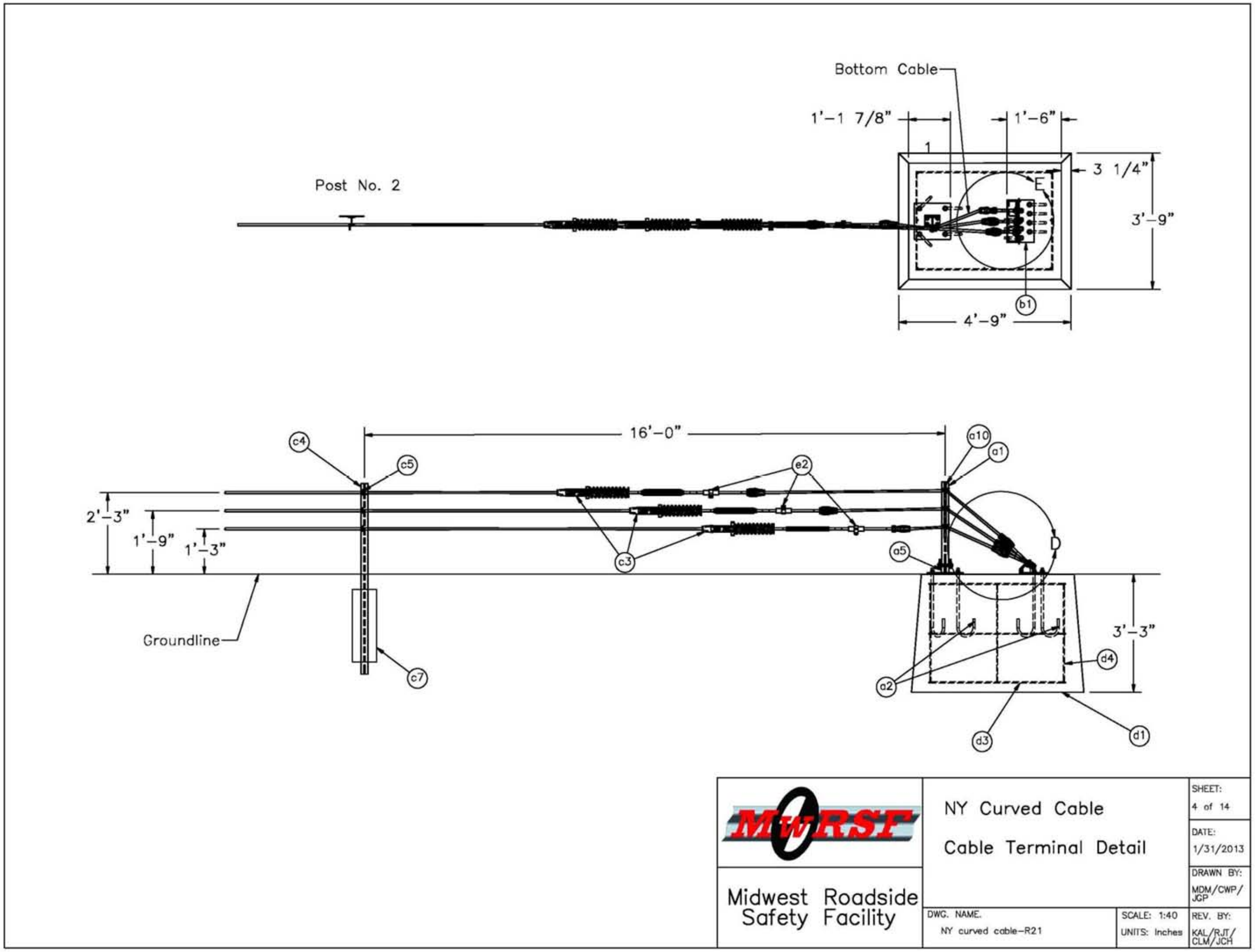


Figure 17. Terminal Details, Test No. NYCC-1

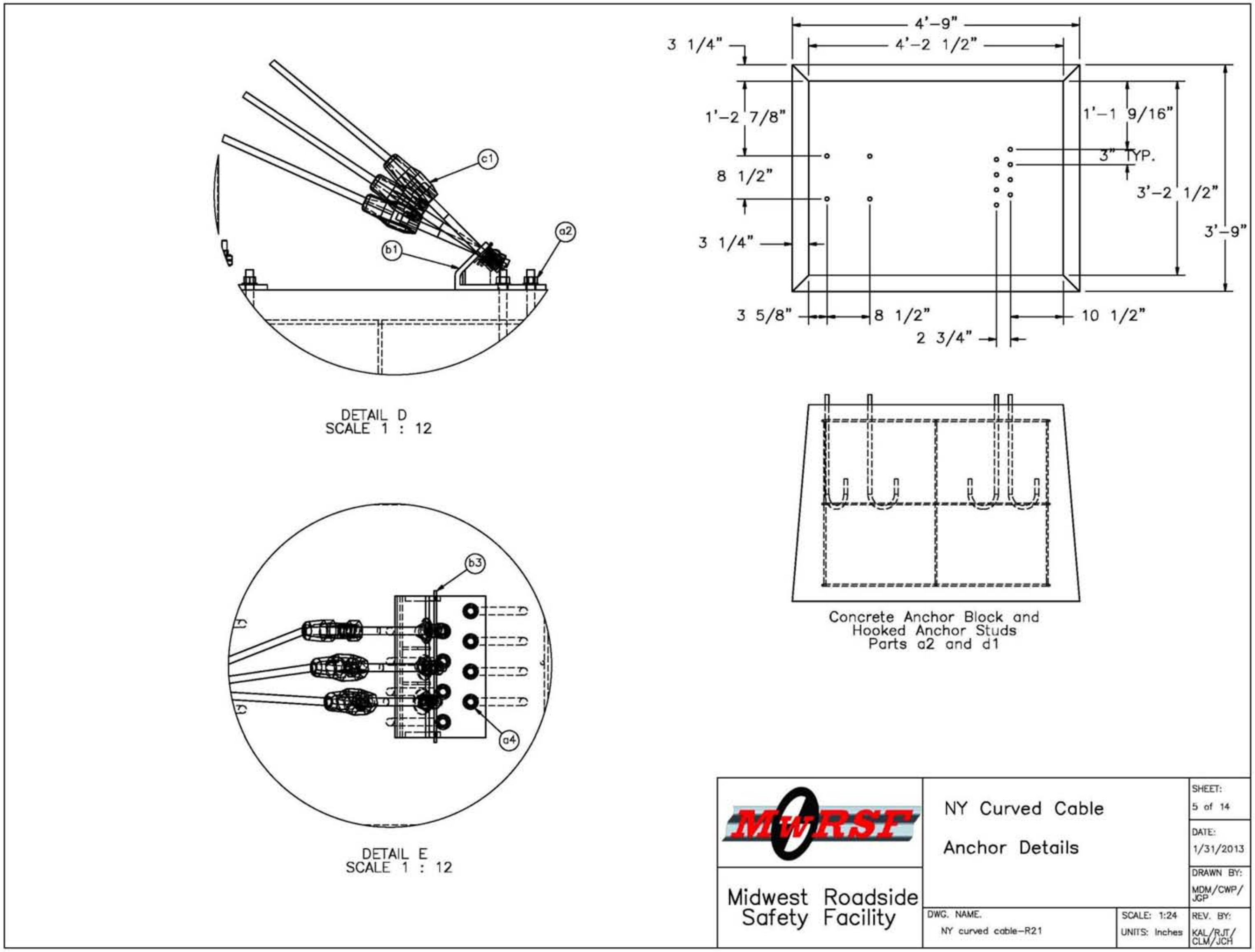


Figure 18. Anchor Details, Test No. NYCC-1

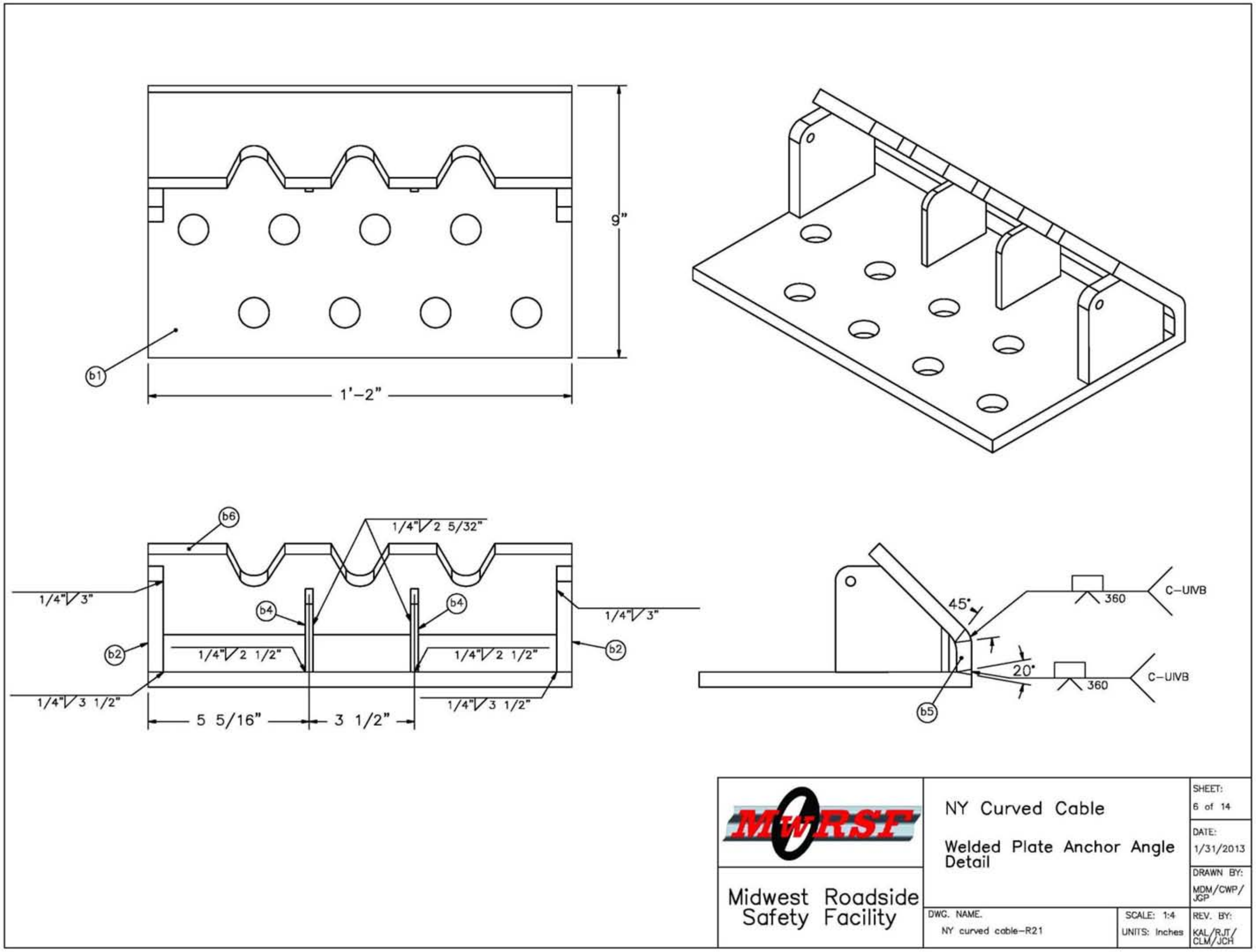


Figure 19. Cable Anchor Bracket Details, Test No. NYCC-1

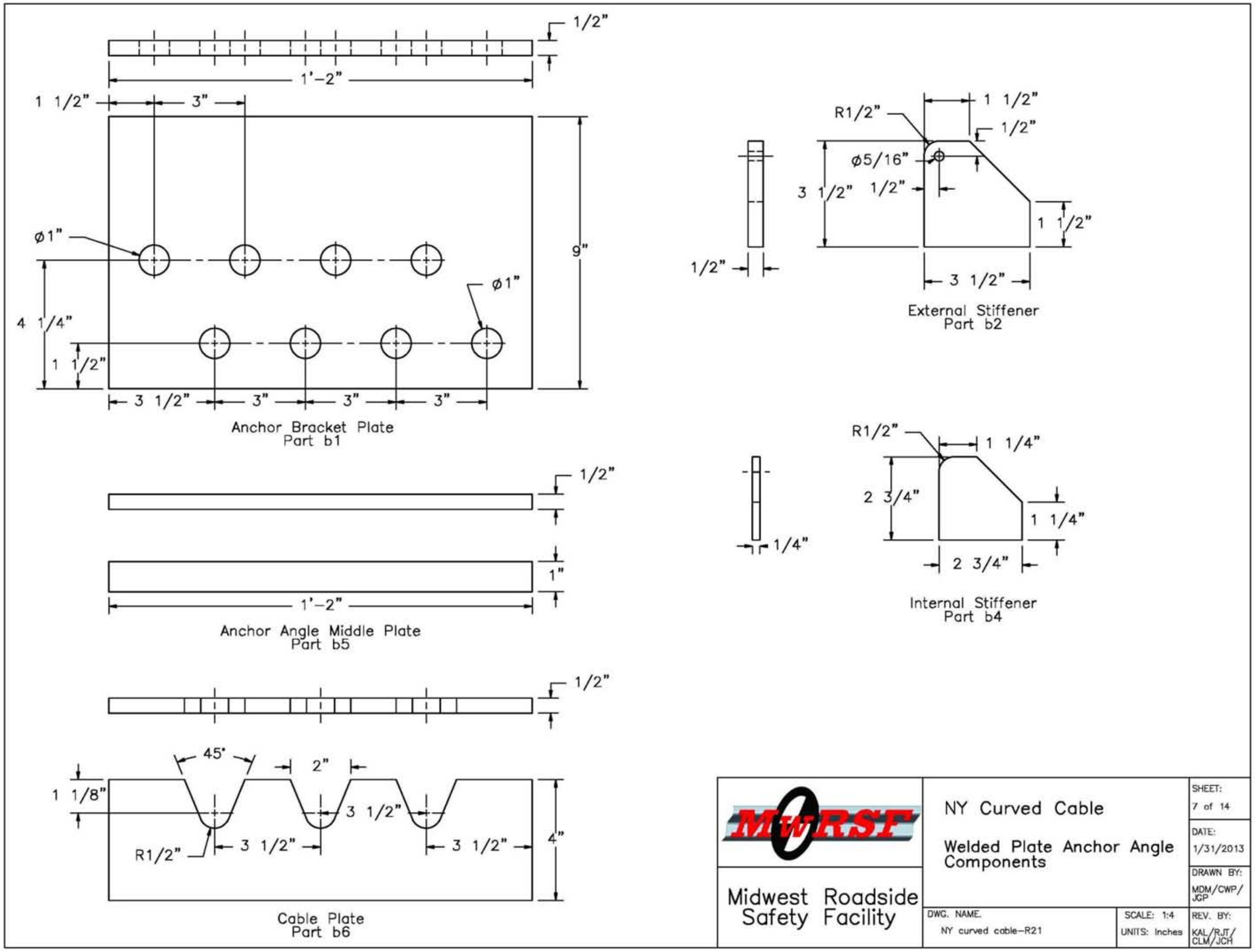


Figure 20. Cable Anchor Bracket Component Details, Test No. NYCC-1

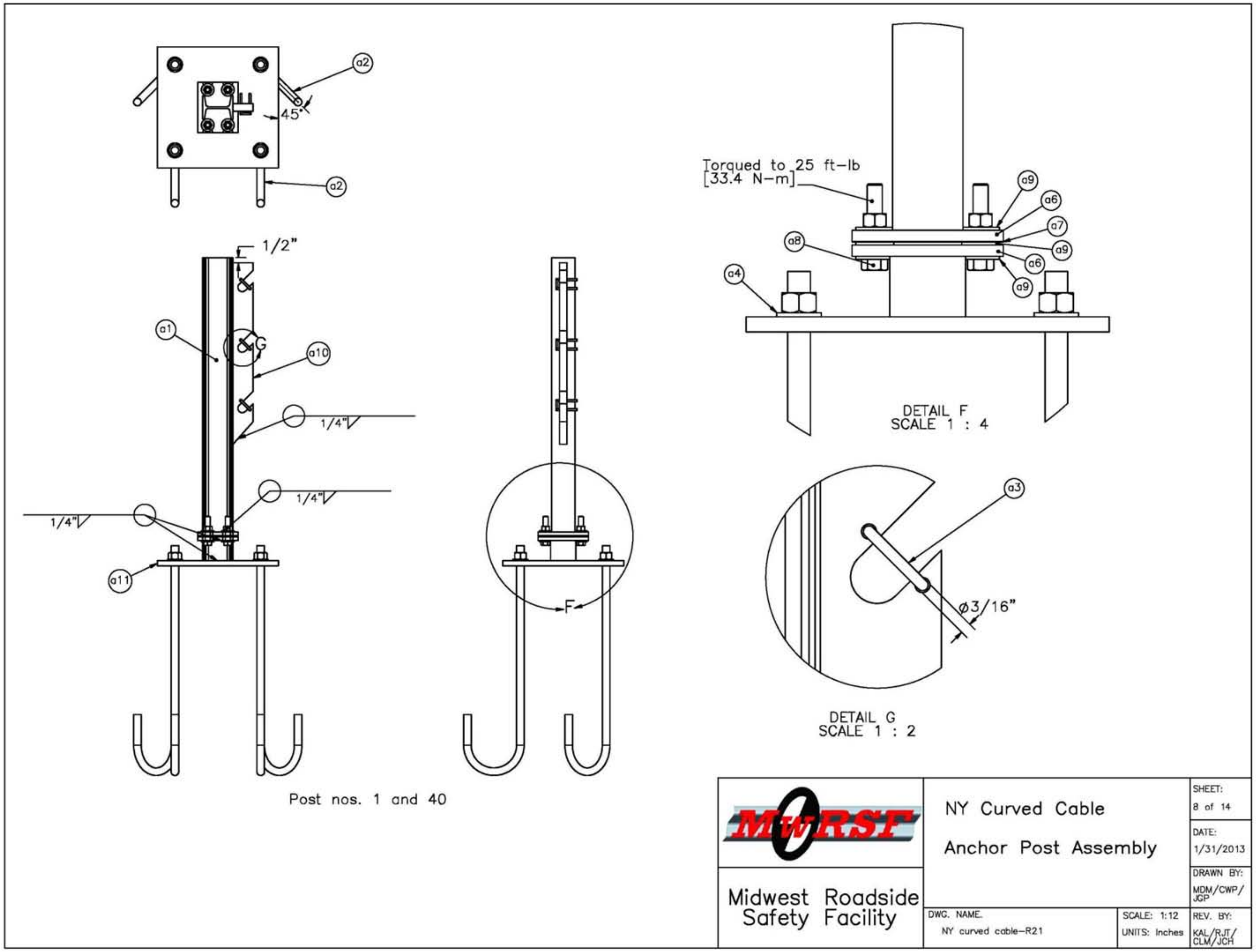


Figure 21. Anchor Post Assembly Details, Test No. NYCC-1

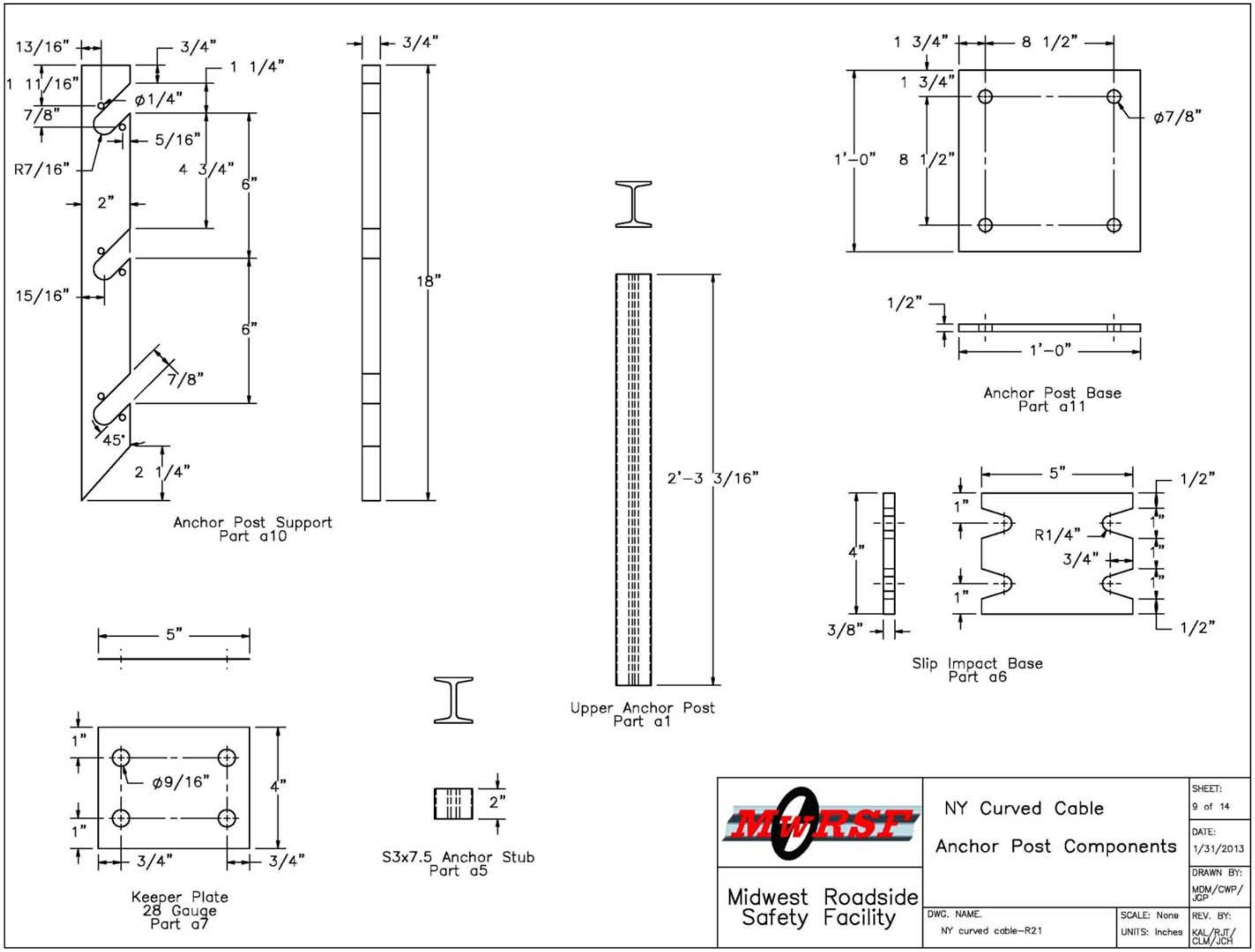


Figure 22. Anchor Post Component Details, Test No. NYCC-1

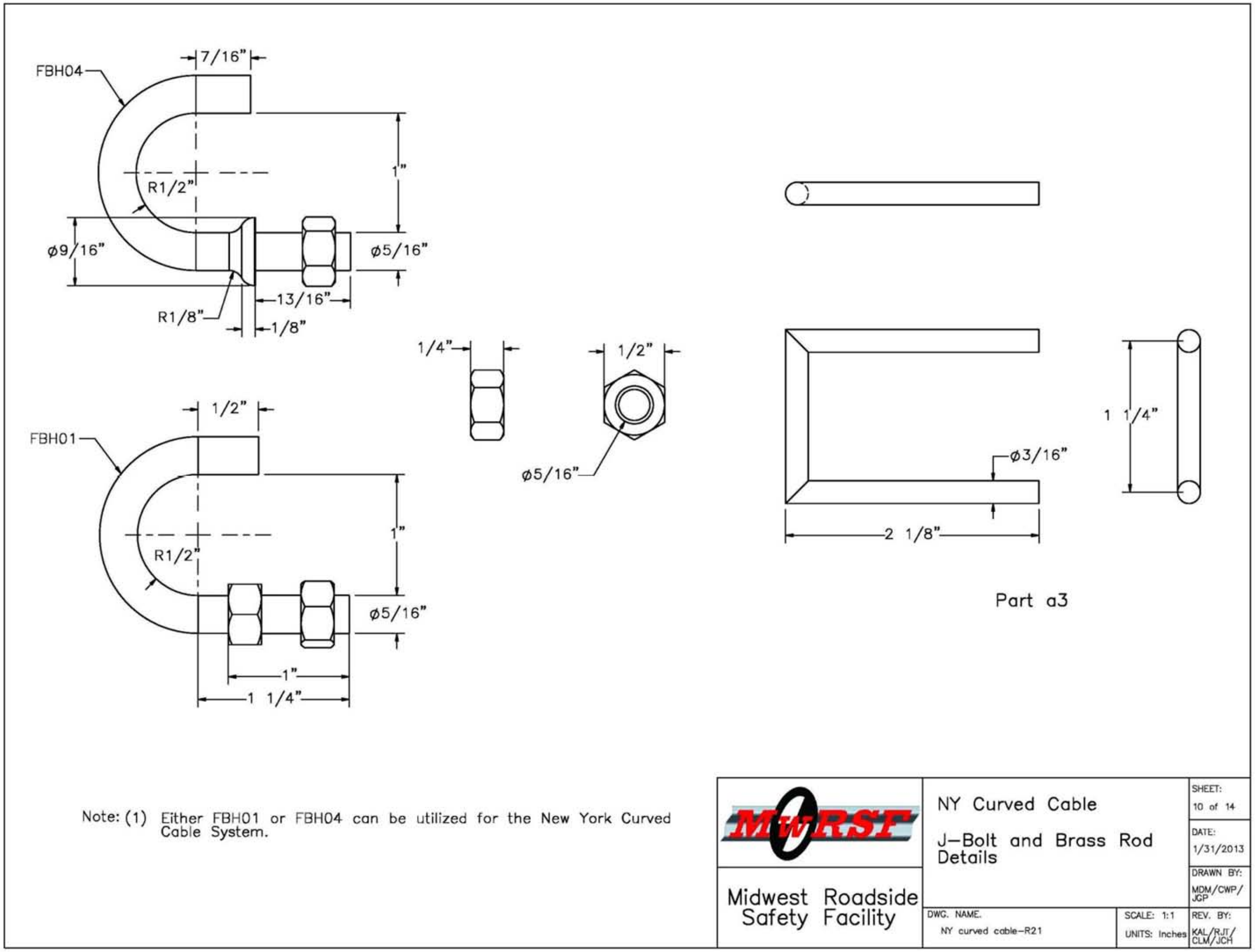


Figure 23. Cable Clip Details, Test No. NYCC-1

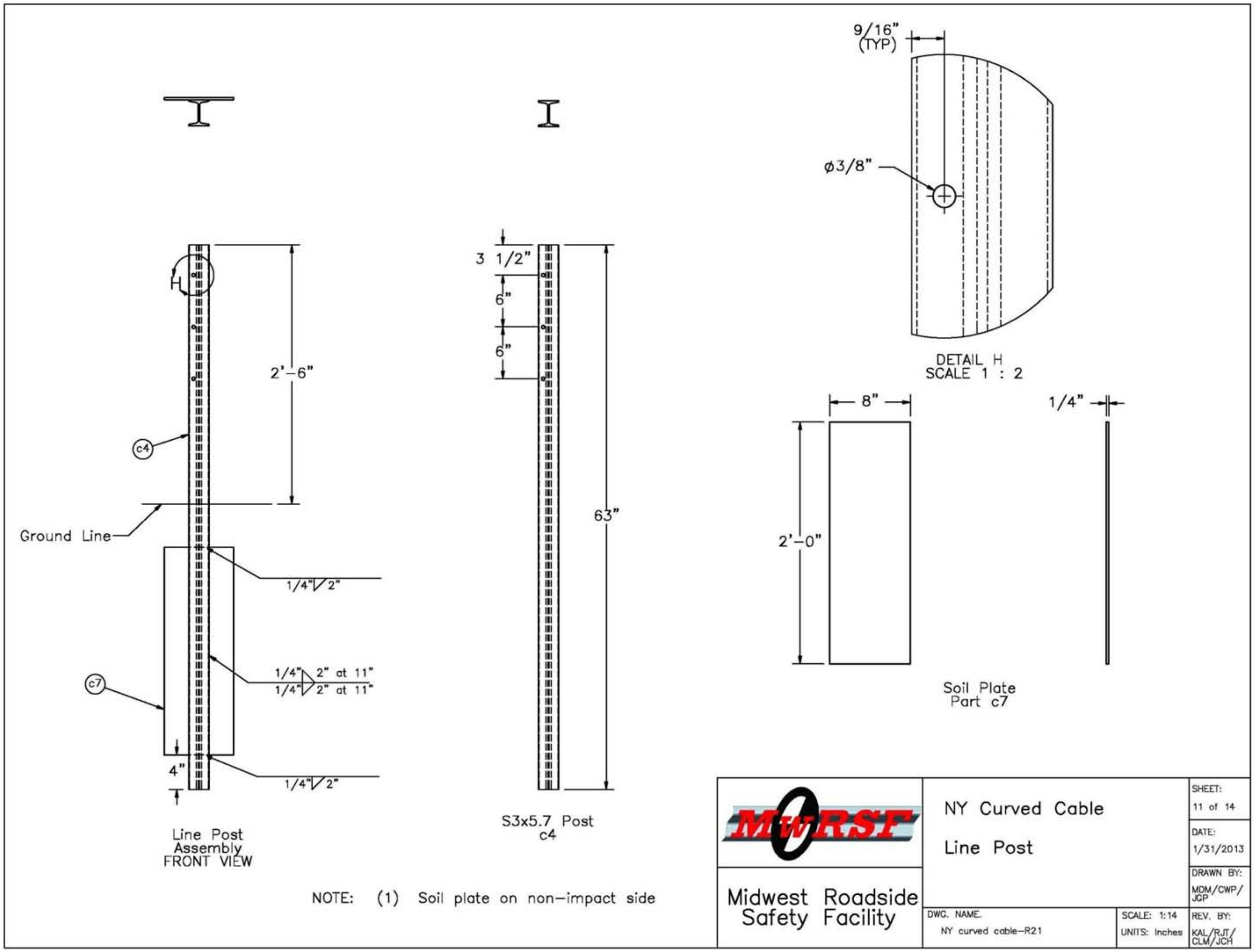


Figure 24. Line Post Details, Test No. NYCC-1

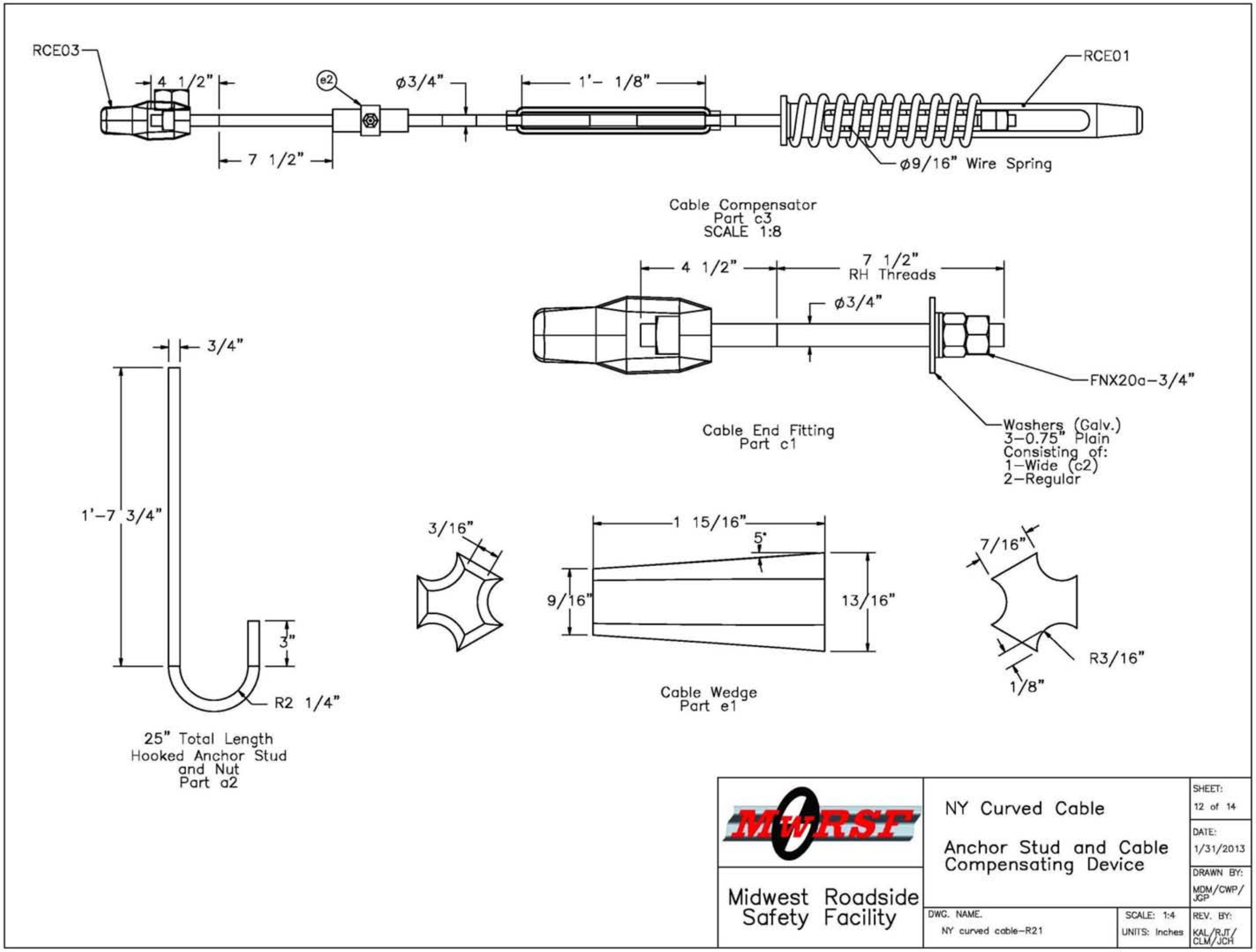


Figure 25. Cable Compensator Component Details, Test No. NYCC-1

New York Curved Cable System				
Item No.	QTY.	Description	Material Spec	Hardware Guide
a1	2	S3x5.7 27 3/16" long Anchor Post	ASTM A36 Galvanized	–
a2	24	Hooked Anchor Stud and Nut	ASTM A36 and ASTM A563 DH Galvanized	FRH20a
a3	6	ϕ3/16" 5 1/4" Long Brass Rod	Brass	–
a4	36	ϕ3/4" Plain Round Washer–OD 1.5"	Grade 2	FWC20a
a5	2	S3x7.5 Anchor Post Stub	ASTM A36 Galvanized	–
a6	4	Slip Impact Base	ASTM A36 Galvanized	–
a7	2	4"x5" 28 Gauge Keeper Plate	ASTM A36 Galvanized	–
a8	8	ϕ1/2" x2 1/2" Long Bolt and Nut	Grade 2 Galvanized	FBX14a
a9	24	ϕ1/2" Narrow Washer–OD 1"	Grade 2 Galvanized	FWC12a
a10	2	3/4" Anchor Post Support Plate	ASTM A707 Grade 36 Galvanized	–
a11	2	Anchor Post Base	ASTM A709 Grade 36 Galvanized	–
b1	2	Anchor Bracket Plate	ASTM A709 Grade 36 Galvanized	–
b2	4	1/2" Thick External Stiffener	ASTM A709 Grade 36 Galvanized	–
b3	2	ϕ1/4"x15" Brass Rod	Brass	–
b4	4	1/4" Thick Internal Stiffener	ASTM A709 Grade 36 Galvanized	–
b5	2	Anchor Angle Middle Plate	ASTM A709 Grade 36 Galvanized	–
b6	2	Cable Plate	ASTM A709 Grade 36 Galvanized	–
c1	6	Cable End Fitting	ASTM A27 Galvanized	RCE03
c2	6	ϕ3/4" Plain Round Washer–OD 2"	Grade 2 Galvanized	FWC20a
c3	3	Compensating Cable End Assembly	ASTM A27 Galvanized	RCE01
c4	38	S3x5.7 63 in. long Line Post	ASTM A36 Galvanized	–
c5	114	Cable Hook Bolt	ASTM F568 Class 4.6 and ASTM A563 Galvanized	FBH04
c6	3	ϕ3/4" Cable Approx. 392'	AASHTO M30 Type 1 Class A Galvanized	RCM01
c7	38	2'x8"x0.25" Soil Plate	ASTM A36 Galvanized	–
d1	2	Concrete Anchor Block	3000 psi Compressive Strength	–
d2	12	#3 Rebar 32.5" long	Grade 60	–
d3	12	#3 Rebar 44.5" long	Grade 60	–
d4	16	#3 Rebar 33" long	Grade 60	–
e1	12	Cable Wedge	ASTM A47 Grade 32510	FMM01
e2	3	50,000–lb Load Cell	N/A	–

Midwest Roadside Safety Facility

NY Curved Cable
Bill of Materials

SHEET: 13 of 14
DATE: 1/31/2013
DRAWN BY: MDM/CWP/JGP
DWG. NAME. NY curved cable–R21
SCALE: None
UNITS: Inches
REV. BY: KAL/RJT/CLM/JCH

Figure 26. Bill of Materials, Test No. NYCC-1

(1) All posts shall be s3x5.7 rolled steel section. The anchor post stub shall be s3x7.5. Where the rail is parallel to the edge of the pavement, every sixth post starting with the first shall be reflectorized. Do not reflectorize posts in the intermediate anchorage section, typical approach and terminal section, or when used as a median barrier.

(2) Reflectors shall be aluminum alloy 1/16" thick with reflective sheeting. The reflective sheeting shall be white when installed on the right side of traffic and fluorescent yellow when on the left.

(3) 3/4" round wire cable shall consist of three strands (7 wires per strand) and have a minimum tensile strength of 25,000 lbf.

(4) Cable ends shall be fabricated from malleable iron or cast steel. The cable splice and wedge shall be fabricated from malleable iron or ASTM A536 ductile.

(5) All cable ends and splices shall be designed to use the wedge shown on sheet 12 and shall develop the full strength of the 3/4" round cable (25000 lbs.). The cables, ends, and splices shall be hot dipped galvanized as indicated in material specification for cable guide rail. The wedge shall not be galvanized.

(6) Stagger cable splices, provide a minimum of 20' between any pair. Provide a minimum of 100' between cable splices on the same cable.

(7) Alternate designs for the steel turnbuckle cable end assembly or spring cable end assembly shall be submitted for approval.

(8) For arrangement of spring cable end assemblies (compensating device) and turnbuckle cable end assemblies, the following criteria shall apply:
-Length of cable runs up to 1000'-use compensating device (RCE01) on one end, and turnbuckle on the other end of each individual cable.
-Length of cable runs 1000' to 2000'-use compensating device (RCE01) on the ends of each individual cable.
-Length of cable runs over 2000'-start a new stretch by interlacing at last parallel post (see typical intermediate anchorage details).

Prior to final acceptance by the state, the following values shall be used to tighten the turnbuckles, depending on the temperature at the time of adjustment.

Temperature (degrees Farenheit)													
120 to 110	109 to 100	99 to 90	89 to 80	79 to 70	69 to 60	59 to 50	49 to 40	39 to 30	29 to 20	19 to 10	9 to 0	-1 to -19	-20 to -29
Spring Compression from Unloaded Position in Each Spring-Measured in Inches													
1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4	4 1/2

(9) The concrete anchor shall be set into the excavation as detailed. The bottom of the anchor shall have a full and even bearing on the surface under it. The top shall be back filled in accordance with the requirements of 203-3.15 "fill and back fill at structures, culverts, pipes, conduits, and direct burial cables."

(10) Do not install cable guide railing on curves with a centerline radius of less than 440'.

(11) Curbs greater than 3" high are not to be retained or placed if design, posted, or operating speed exceeds 35 mph. Rail mounting height is to be measured from pavement if offset between pavement and curb is less than or equal to 9" and from ground beneath rail if offset > 9".

(12) Lifting devices, if embedded in concrete, shall be rated by their manufacturer as having a "safe working load" of four tons for the one piece anchor and two tons for each of the halves of the two piece anchor unit.

(13) At all locations where the cable is connected to a cable socket with a wedge type connection, one wire of the wire rope shall be crimped over the base of the wedge to hold it firmly in place.

Midwest Roadside Safety Facility

NY Curved Cable

Notes

SHEET: 14 of 14

DATE: 1/31/2013

DRAWN BY: MDM/CWP/JGP

DWG. NAME. NY curved cable-R21

SCALE: None
UNITS: Inches

REV. BY: KAL/RJT/CLM/JCH

Figure 27. System Notes, Test No. NYCC-1

Figure 28. Test Installation Photographs, Test No. NYCC-1

Figure 29. Post Photographs, Test No. NYCC-1

Figure 30. End Anchorage Photographs, Test No. NYCC-1

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Figure 31. Cable Splices and Load Cells, Test No. NYCC-1

5 FULL-SCALE CRASH TEST NO. NYCC-1

5.1 Static Soil Test

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

5.2 Test No. NYCC-1

The 5,020-lb (2,277-kg) pickup truck impacted the curved, three-cable barrier system at a speed of 61.6 mph (99.1 km/h) and at an angle of 19.9 degrees. A summary of the test results and sequential photographs are shown in Figure 32. Additional sequential photographs are shown in Figures 33 through 37. Documentary photographs are shown in Figure 38.

5.3 Weather Conditions

Test no. NYCC-1 was conducted on August 2, 2011 at approximately 12:00 P.M. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were recorded and are shown in Table 3.

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

Temperature	91° F
Humidity	56%
Wind Speed	11 mph
Wind Direction	340° from True North
Sky Conditions	Sunny / Overcast
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0 in.
Previous 7-Day Precipitation	0.1 in.

5.4 Test Description

Initial vehicle impact occurred at the targeted impact point 70 ft (21.3 m) downstream of post no. 8, or 2 ft (0.6 m) upstream of post no. 17, as shown in Figure 39, which was selected by NYSDOT personnel. A sequential description of the impact events is contained in Table 4. The vehicle came to rest 220 ft - 10 in. (67.3 m) downstream of impact and adjacent to the downstream anchorage. The vehicle trajectory and final position are shown in Figures 32 and 40.

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

TIME (sec)	EVENT
0.000	The right-front bumper impacted middle cable.
0.006	The right-front bumper contacted post no. 17, which bent backward and downstream.
0.012	Post no. 16 rotated backward.
0.030	All the cables had released from post no. 17.
0.038	The right-front tire contacted post no. 17.
0.052	The right-front tire overrode bottom cable, and post 18 deflected backward and downstream.
0.086	The right-front tire overrode middle cable.
0.096	The bumper contacted post no. 18.
0.100	All the cables had released from post no. 18.
0.114	Post no. 19 bent backward.
0.136	Vehicle yawed away from system.
0.162	The top cable released from post no. 19.
0.174	Post no. 20 deflected backward and downstream.
0.190	Post no. 21 deflected backward and downstream.
0.194	The bumper and left-front tire contacted post no. 19.
0.200	The top cable released from post no. 20.
0.214	The right-rear tire overrode bottom cable.
0.230	The right-rear tire overrode middle cable.
0.234	The middle cable released from post no. 19.
0.238	Vehicle rolled toward the system.
0.270	The left-front tire overrode bottom cable.
0.282	The top cable released from post no. 21.
0.296	The middle cable released from post no. 20.
0.302	Post no. 22 deflected backward and downstream.
0.310	The left-front tire overrode middle cable.
0.366	The top cable released from post no. 22.
0.386	Post no. 23 deflected backward and downstream.
0.406	The top cable released from post no. 23.

0.432	Post no. 24 deflected backward.
0.482	Vehicle rolled away from system.
0.486	The thread rod anchoring the top cable to the anchor plate fractured and the cable was pulled down stream.
0.628	Vehicle was parallel with system.
0.718	The top cable released from post no. 24.
0.862	Post no. 25 deflected downstream.
0.912	The top cable released from post no. 25.
1.002	Post no. 26 deflected downstream.
1.126	The top cable released from post no. 26.
1.200	The top cable released from post no. 8.
1.270	Post no. 27 deflected downstream.
1.282	Vehicle contacted the backside of the system.
1.286	The middle cable released from post no. 30, and the top cable released from post 7.
1.340	The top cable released from post no. 27.
1.344	The vehicle bumper contacted post no. 30, causing it to bend downstream.
1.366	Vehicle pitched upward.
1.420	The middle cable released from post no. 31.
1.450	The vehicle was overriding the top and bottom cables. The middle cable was interlocked with the vehicle's left-front bumper corner.
1.454	The middle cable released from post no. 32.
1.458	Vehicle contacted post no. 31, causing it to bend downstream.
1.470	The middle cable released from post no. 33.
1.554	The top cable released from post no. 9.
1.578	Vehicle contacted post no. 32, causing it to bend downstream.
1.610	The middle cable released from post no. 34.
1.630	The top cable released from post no. 10.
1.660	Right-rear tire leaves ground.
1.704	The middle cable released from post no. 35.
1.722	The top cable released from post no. 11.
1.730	Right-front tire struck post no. 31.
1.756	The middle cable released from post no. 36, and top cable released from post no. 31.
1.778	The top cable released from post no. 32.
1.808	The middle cable released from post no. 37.
1.818	The top cable released from post no. 14.
1.850	The middle cable released from post no. 38.
1.874	The middle cable released from post no. 39.
1.882	The top cable released from post no. 12.
1.928	Right-rear contacted ground.
2.200	The vehicle yawed toward the system due to interacting with middle cable.
2.032	The top cable released from post no. 13.
2.062	The top cable released from post no. 15.
2.362	The top cable released from post no. 16.
2.650	The weld connecting the lower base plate to the post stub on post no. 40 failed due to tension loading from the middle cable.

2.725	The threaded rod anchoring the middle cable to the anchor plate fractured, and the cable was pulled upstream
4.000	The vehicle had exited the system by rolling over the detached downstream end of the middle cable.
5.500	The vehicle came to a stop parallel to the system and adjacent to the downstream anchorage.

5.5 Barrier Damage

Damage to the barrier was extensive, as shown in Figures 41 through 55. Barrier damage consisted of bent posts, disengaged cables, weld failures, and anchor rod fractures. The length of vehicle contact along the barrier was approximately 130 ft (39.6 m), which spanned from 2 ft (0.6 m) upstream from post no. 17 through post no. 33.

The upstream anchorage was moderately and unexpectedly damaged. The weld between post no. 1 and the slip base plate failed, as shown in Figure 42. Both the post and the plate were found adjacent to the slip base stub. All of the cables were disengaged from post no. 1. The top cable anchor rod fractured and the middle cable anchor rod bent, as shown in Figure 43. The upstream end of the top cable came to rest about 10 ft (3 m) in front of post no. 15. The brass keeper rod on the angled anchor plate was also bent.

The downstream anchorage experienced similar damage. The weld between the bottom slip base plate and the post stub failed, as shown in Figure 44. The post came to rest adjacent to the stub with the slip base completely intact. All three cables were disengaged from the post. The middle cable anchor rod fractured, as shown in Figure 45, due to the cable being snagged on the vehicle. The downstream end of the middle cable came to rest behind the vehicle, about 6 ft (2 m) in front of post no. 38.

The top cable disengaged from post nos. 2 through 39. The middle cable disengaged from post nos. 17, 19 through 21, and 28 through 39. The bottom cable disengaged from post nos. 17

through 19, 30, and 33. The middle cable between post nos. 17 and 18 frayed. The fray consisted of two broken wire strands, as shown in Figure 46.

Post no. 16 had rotated backward and post no. 17 was bent and rotated downstream and rotated slightly backward. Post nos. 18 through 33 were bent and rotated downstream. Post nos. 21, 22, and 29 had also twisted downstream. The top J-bolt cable attachments on post nos. 2 through 39 were bent downward. Similarly, the middle cable J-bolts were bent downward on post nos. 17 through 22, 28, 29, and 31 through 39. The bottom cable J-bolts were twisted downward on post nos. 17 through 19, 21, 29, 30, and 33. Additionally, the top J-bolts were twisted downstream on post nos. 4 through 16, 18, 20, 29, 30, and 32 through 34, while the middle J-bolts were twisted downstream on post nos. 18 and 33.

The maximum lateral dynamic barrier deflection before the cable release at the end anchorage was 8.5 ft (2.6 m) located 2 ft (0.6 m) upstream from post no. 21, as determined from high-speed digital video analysis. The working width of the system was determined to be 12 ft – 8 in. (3.9 m), as shown in Figure 56. The maximum lateral dynamic barrier deflection after the cable released from the end anchorage was 12 ft – 7 in. (3.8 m), which was calculated at the same location and time as the working width. The working width of the system was determined to be larger than expected due to the fracture of the top cable's upstream end anchor rod.

5.6 Vehicle Damage

The damage to the vehicle was minimal, as shown in Figures 57 and 58. The maximum occupant compartment deformations are listed in Table 5 along with the deformation limits established in MASH for various areas of the occupant compartment. Note that none of the MASH established deformation limits were violated. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D.

Table 5. Maximum Occupant Compartment Deformations by Location, Test No. NYCC-1

LOCATION	MAXIMUM DEFORMATION in. (mm)	MASH ALLOWABLE DEFORMATION in. (mm)
Wheel Well & Toe Pan	¾ (19)	≤ 9 (229)
Floor Pan & Transmission Tunnel	¾ (19)	≤ 12 (305)
Side Front Panel (in Front of A-Pillar)	¼ (6)	≤ 12 (305)
Side Door (Above Seat)	¼ (6)	≤ 9 (229)
Side Door (Below Seat)	0 (0)	≤ 12 (305)
Roof	0 (0)	≤ 4 (102)
Windshield	0 (0)	≤ 3 (76)

The majority of the damage was concentrated on the right-front corner and right side of the vehicle where the impact occurred. The lower front bumper trim was disengaged, and the front bumper was dented and bent inward near the vehicle centerline due to contact with posts. The right side of the front bumper had contact marks from the cables as well as denting and kinking due to contact with posts. The left side of the front bumper had dents and contact marks from the cables and posts. The right-front door experienced some gouging and denting. The right-rear door was dented and had a tear and fold at the front edge of the door, caused by the top cable contact. The right-rear quarter panel experienced gouging. The left-front wheel experienced gouging along the edge of the rim. The left-rear door was gouged along the bottom. The left-rear quarter panel had a small dent near the cab. Contact marks from the cables extended along the entire right side of the vehicle.

5.7 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 6. Note that the OIVs and ORAs were within the suggested limits provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 6. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 32. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix E. Due to technical difficulties, DTS unit did not collect valid rate gyro data.

Table 6. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NYCC-1

Evaluation Criteria		**Transducer**		**MASH Limits (Absolute Value)**
		EDR-3	**DTS**	
OIV ft/s (m/s)	Longitudinal	-6.60 (-2.01)	-7.73 (-2.36)	≤ 40 (12.2)
	Lateral	-7.34 (-2.24)	-6.52 (-1.99)	≤ 40 (12.2)
ORA g's	Longitudinal	-4.25	-4.42	≤ 20.49
	Lateral	-2.71	-3.35	≤ 20.49
THIV ft/s (m/s)		NA	9.25 (2.82)	not required
PHD g's		NA	4.86	not required
ASI		0.22	0.20	not required

5.8 Load Cell Results

As previously discussed, tension load cells were installed in line with the cables at the upstream end of the barrier system in order to monitor the total load transferred to the end anchor system with respect to time. The load cell results are summarized in Table 7. The individual cable loads and the total combined cable load imparted to the upstream end anchor are shown graphically in Figures 59 and 60, respectively. The pre-tension for each cable was 800 lb (3.56 kN), as measured by displacements in the spring compensators near the upstream anchorage. During the test, the top cable anchor rod fractured, and the cable was pulled upstream. Subsequently, the load cell wire severed, and data was no longer recorded for the top cable. Also, near the end of the test, the downstream end anchor rod on the middle cable fractured. Thus, the tension in the middle cable dropped to nearly zero for the remainder of the test. At the end of the test, the tension in the middle and bottom cables were 29.5 lb (0.13 kN) and 277 lb (1.23 kN), respectively.

Table 7. Summary of Load Cell Results, Test No. NYCC-1

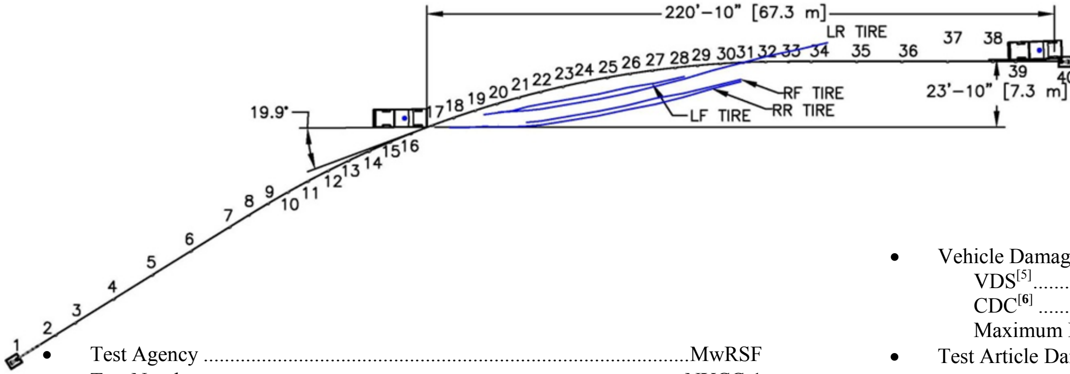
Cable Location	Sensor Location	Maximum Cable Load		Time* (sec)
		kips	kN	
Combined Cables	Upstream End	14.67	65.26	0.271
Top Cable	Upstream End	12.25**	54.51	0.271
Middle Cable	Upstream End	12.38	55.07	2.223
Bottom Cable	Upstream End	2.67	11.88	0.073

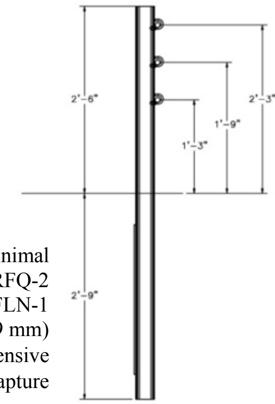
* - Time determined from initial vehicle impact with the barrier system.
** - Cable fracture, so data stopped recording at 0.3067 seconds

5.9 Discussion

The analysis of the test results for test no. NYCC-1 showed that the generic, three-cable barrier with a 360 ft (109.7 m) curved radius and a 27 in. (686 mm) top mounting height adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. There were no detached elements nor fragments which showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. 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 safety criteria nor cause rollover. Therefore, test no. NYCC-1 was determined to be acceptable according to the MASH safety performance criteria for modified test designation no. 3-11.

0.000 sec | 0.114 sec | 0.302 sec | 0.458 sec | 0.580 sec

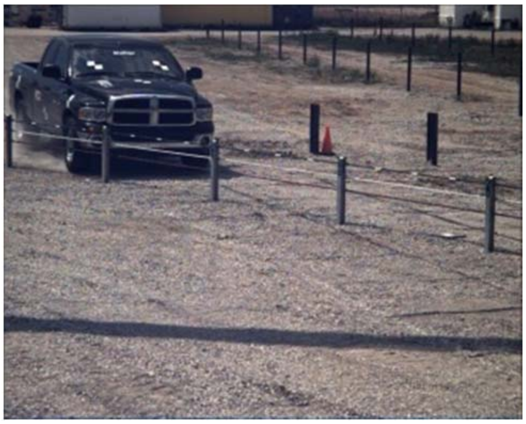




- Test Agency .... MwRSF
- Test Number NYCC-1
- Date 8/2/11
- MASH Test Designation .... Modified 3-11
- Test Article .... 360 ft (109.7 m) radius curved three cable barrier
- Total Length .... 400 ft (122 m)
- Key Component – Wire Rope
  - Diameter .... ¾ in. (19 mm)
  - Size 3x7
  - Top Cable Height .... 27 in. (686 mm)
  - Middle Cable Height .... 21 in. (533 mm)
  - Bottom Cable Height .... 15 in. (381 mm)
- Key Component - Post
  - Length .... 63 in. (1,600 mm)
  - Shape S3x5.7 (S76x8.5)
  - Spacing - Curved Section .... 8 ft (2.4 m)
  - Spacing - Tangent End Segments .... 16 ft (4.9 m)
- Soil Type .... Grade B of AASHTO M147-65 (1990)
- Vehicle Make /Model .... 2005 Dodge Ram 1500 Quad Cab
  - Curb .... 5,094 lb (2,311 kg)
  - Test Inertial .... 5,020 lb (2,277 kg)
  - Gross Static .... 5,190 lb (2,354 kg)
- Impact Conditions
  - Speed .... 61.6 mph (99.1 km/h)
  - Angle .... 19.9 deg
  - Impact Location .... 2 ft (0.6 m) upstream of post 17
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 220 ft – 10 in. (67.3 m)
  Adjacent to downstream anchorage
- Vehicle Damage .... Minimal
  - VDS[5] 01-RFQ-2
  - CDC[6] 01-RFLN-1
  - Maximum Interior Deformation .... ¾ in. (19 mm)
- Test Article Damage .... Extensive
- Exit Conditions .... NA due to vehicle capture
- Maximum Test Article Deflections
  - Dynamic Before Release .... 8 ft - 6 in. (2.6 m)
  - Dynamic After Release .... 12 ft - 7 in. (3.8 m)
  - Working Width .... 12 ft - 8 in. (3.9 m)
- Maximum Angular Displacements
  - Roll .... -6.1° < 75°
  - Pitch .... -3.0° < 75°
  - Yaw .... -21.7°
- Impact Severity (IS) .... 76.2 kip-ft (103.3 kJ)
- Transducer Data

Evaluation Criteria		Transducer		MASH Limit (Absolute Value)
		EDR-3	DTS	
OIV ft/s (m/s)	Longitudinal	-6.60 (-2.01)	-7.73 (-2.36)	≤ 40 (12.2)
	Lateral	-7.34 (-2.24)	-6.52 (-1.99)	≤ 40 (12.2)
ORA g's	Longitudinal	-4.25	-4.42	≤ 20.49
	Lateral	-2.71	-3.35	≤ 20.49
THIV – ft/s (m/s)		NA	9.25 (2.82)	Not required
PHD – g's		NA	4.86	Not required
ASI		0.22	0.20	Not required

Figure 32. Summary of Test Results and Sequential Photographs, Test No. NYCC-1



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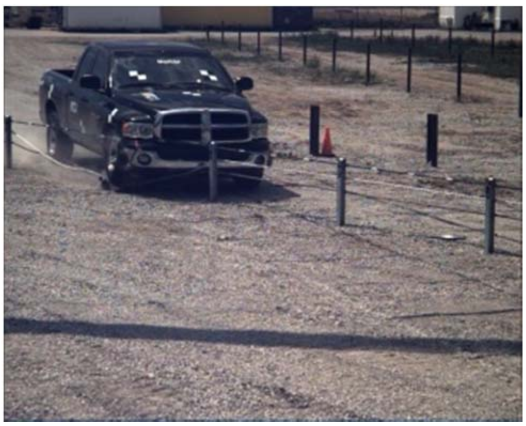

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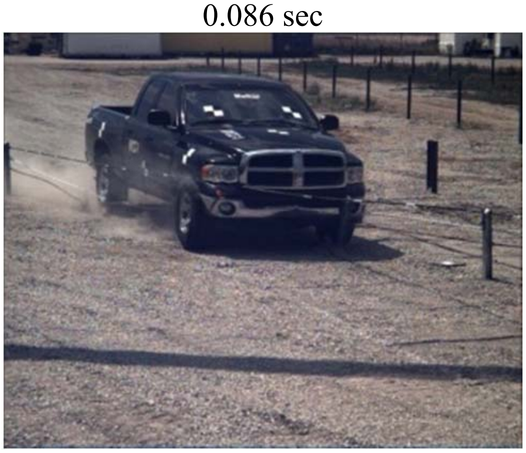

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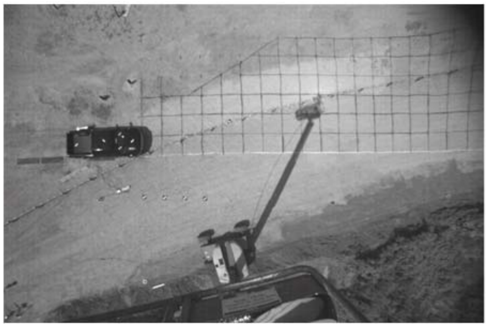
0.296 sec

0.412 sec

0.512 sec

Figure 33. Additional Sequential Photographs, Test No. NYCC-1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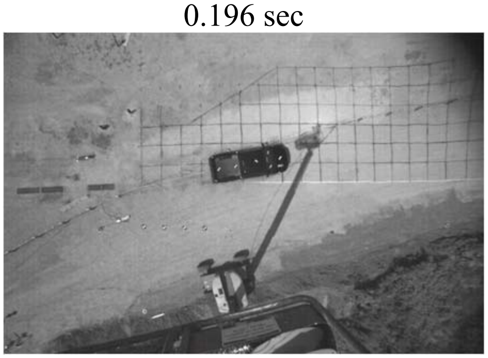
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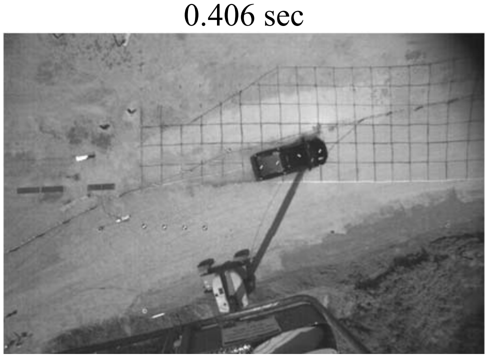
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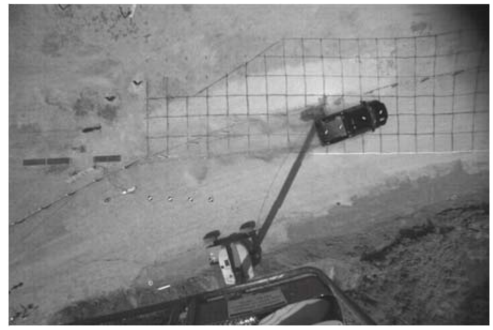
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0.862 sec


1.002 sec

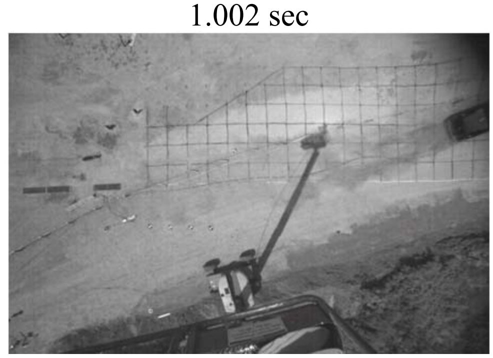
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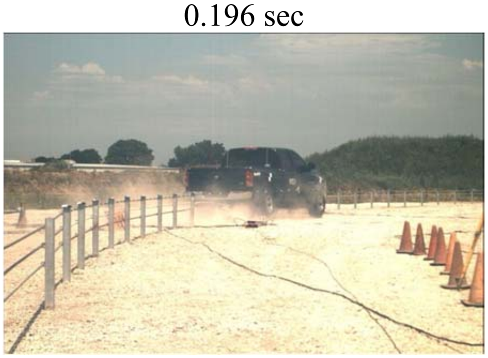
Figure 34. Additional Sequential Photographs, Test No. NYCC-1

0.000 sec

0.196 sec



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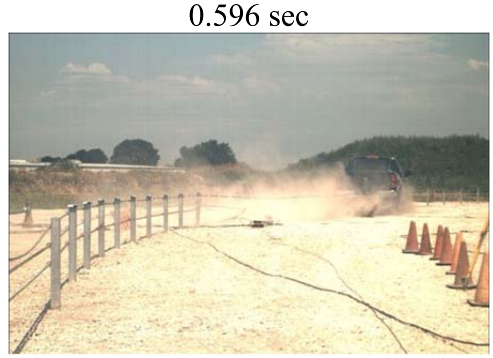
0.596 sec



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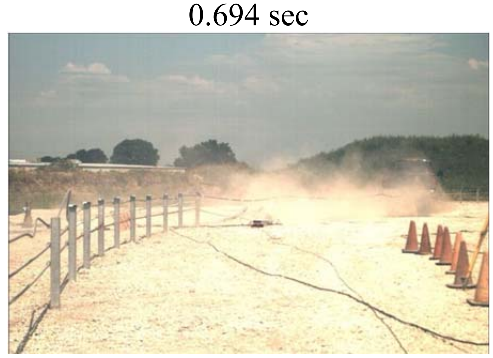


0.988 sec

Figure 35. Additional Sequential Photographs, Test No. NYCC-1

Figure 36. Additional Sequential Photographs, Test No. NYCC-1


0.000 sec


0.108 sec


0.206 sec


0.304 sec


0.402 sec


0.504 sec


0.702 sec


0.900 sec


1.196 sec


1.492 sec

Figure 37. Additional Sequential Photographs, Test No. NYCC-1

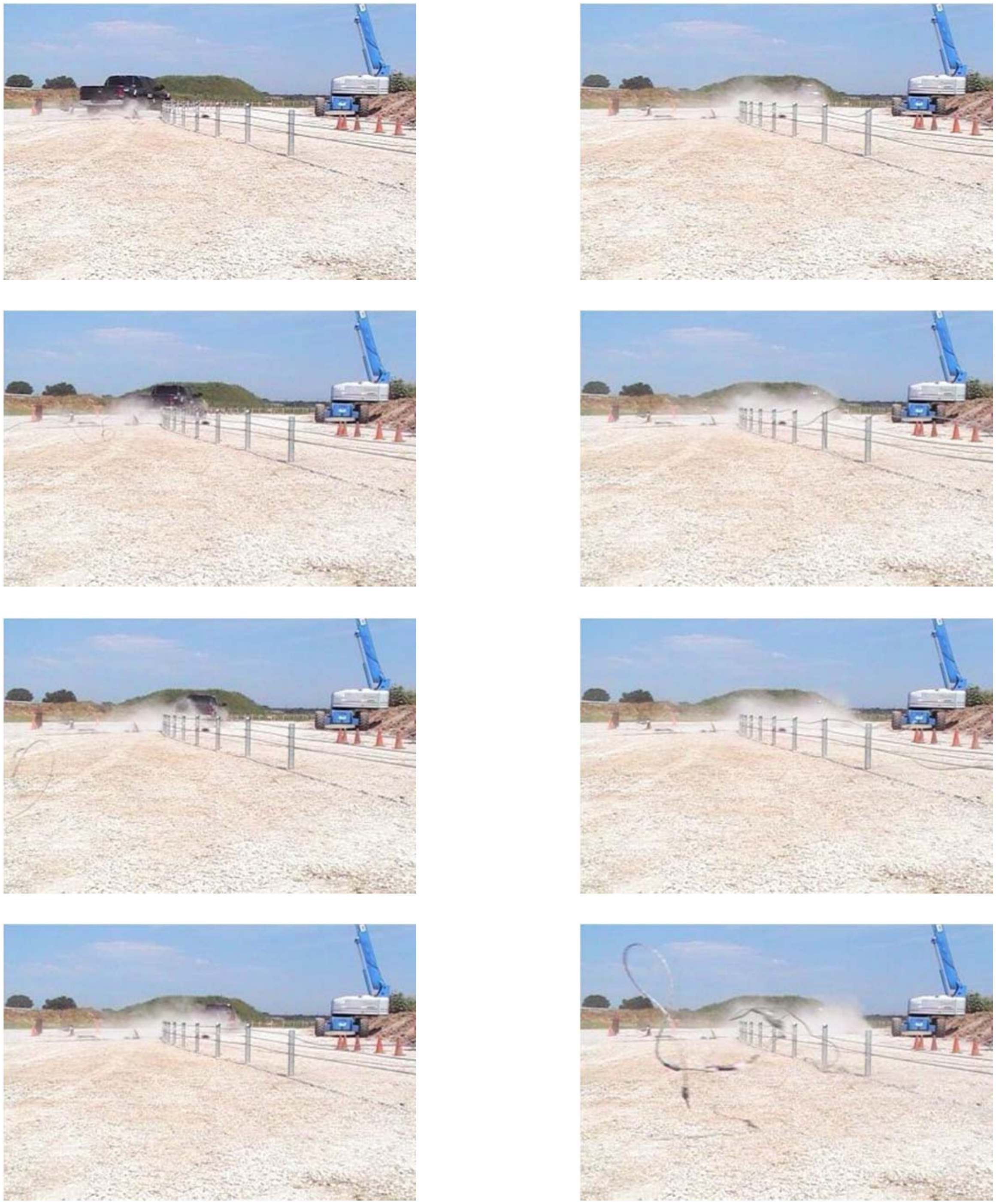


Figure 38. Documentary Photographs, Test No. NYCC-1

Figure 39. Impact Location, Test No. NYCC-1

Figure 40. Vehicle Final Position and Trajectory Marks, Test No. NYCC-1

Figure 41. System Damage, Test No. NYCC-1

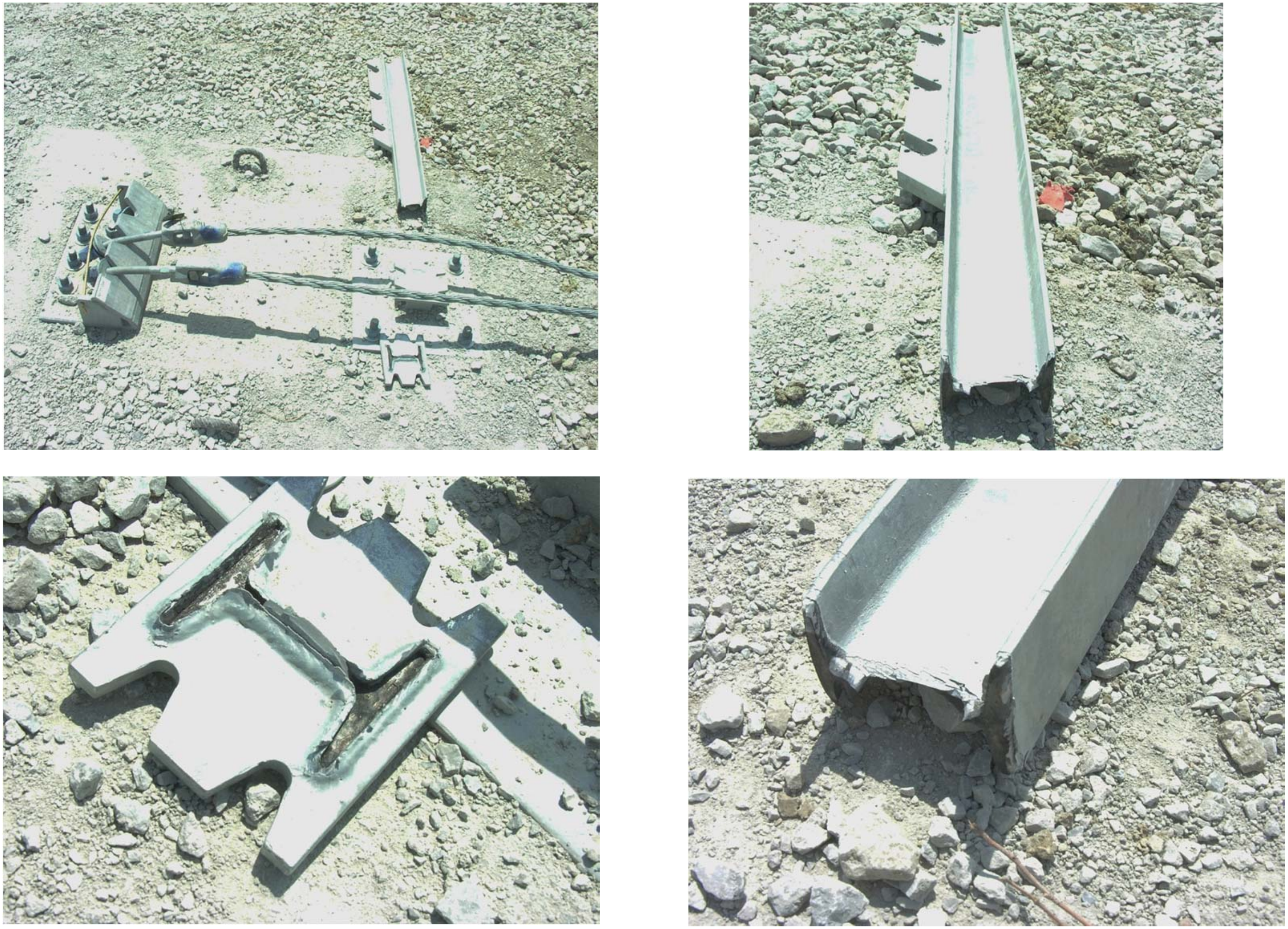


Figure 42. System Damage: Upstream Anchor and Post No. 1, Test No. NYCC-1

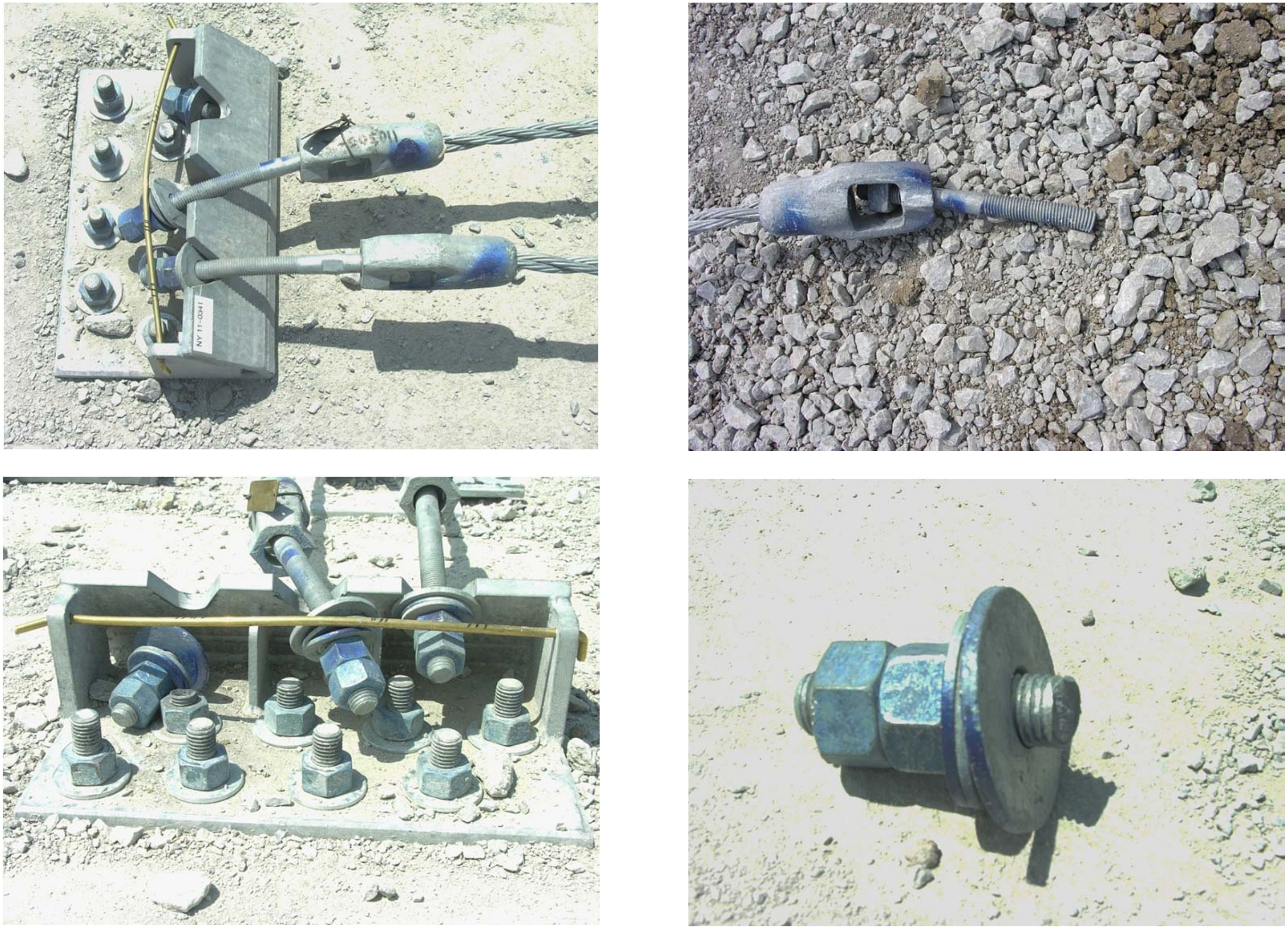
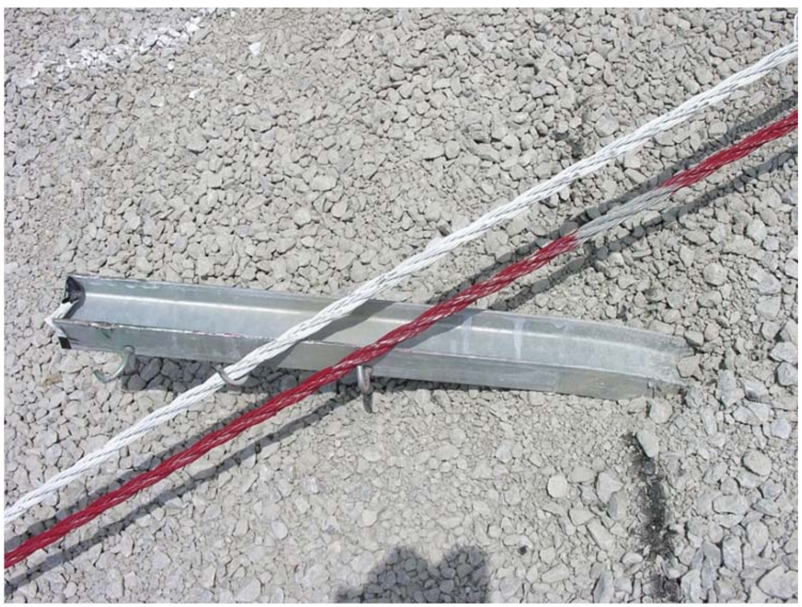


Figure 43. System Damage: Upstream Angle Plate and Top Cable, Test No. NYCC-1

Figure 44. System Damage: Downstream Anchor and Post No. 40, Test No. NYCC-1

Figure 45. System Damage: Downstream Angle Plate and Middle Cable, Test No. NYCC-1

Figure 46. System Damage: Middle Cable between Post Nos. 17 and 18, Test No. NYCC-1



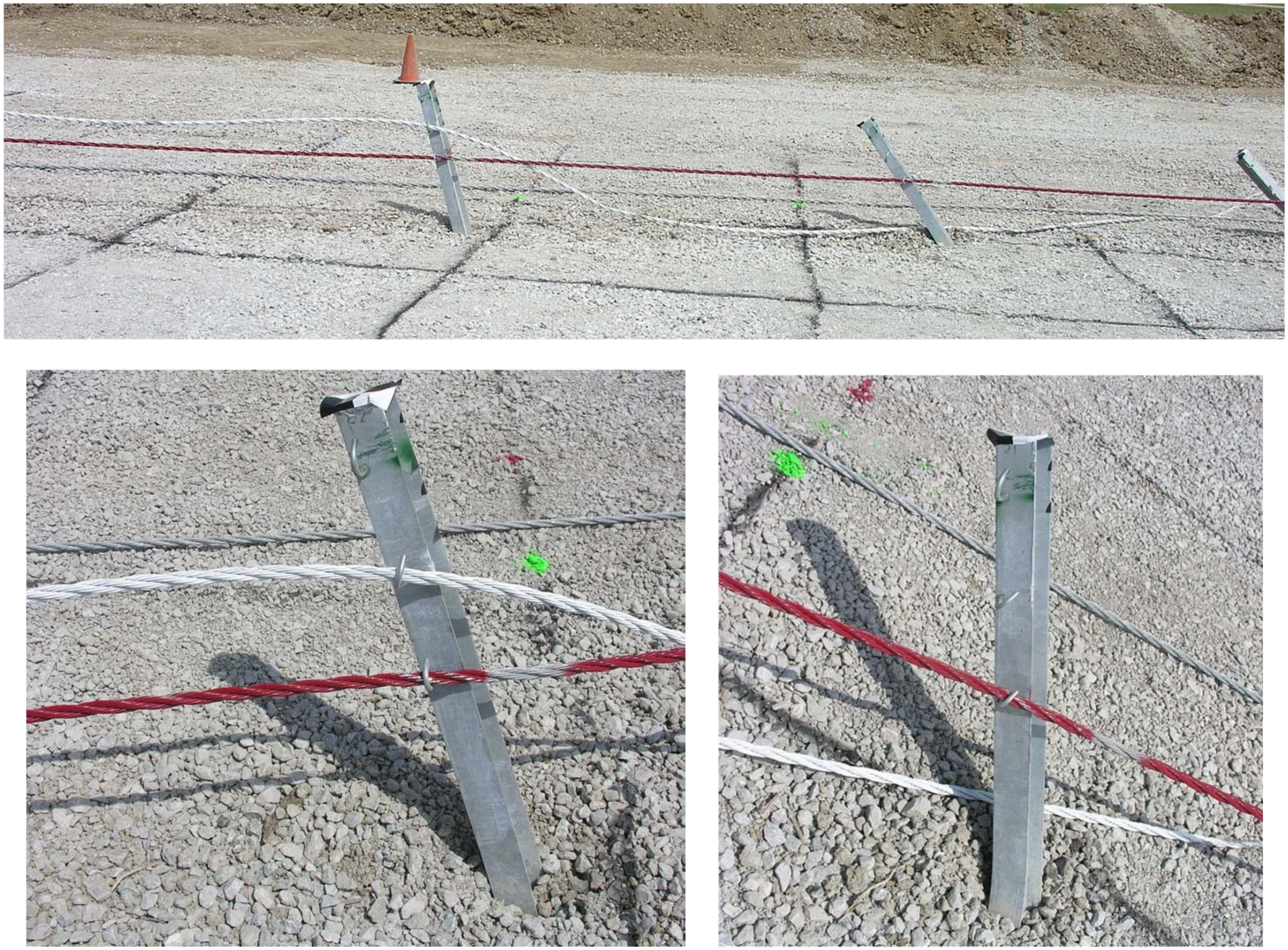
Post No. 18

Post No. 17

Figure 47. System Damage: Post Nos. 17 and 18, Test No. NYCC-1

Post No. 20 Post No. 19

Figure 48. System Damage: Post Nos. 19 and 20, Test No. NYCC-1

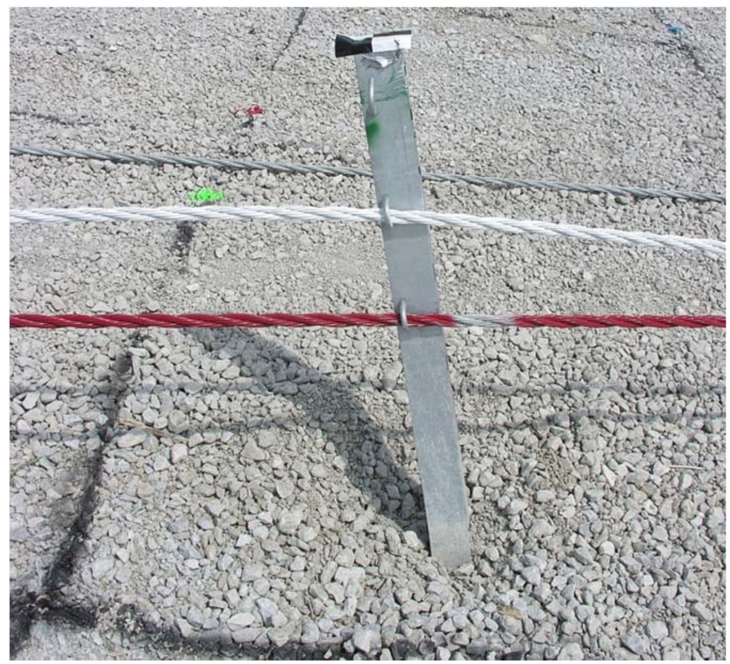


Post No. 22

Post No. 21

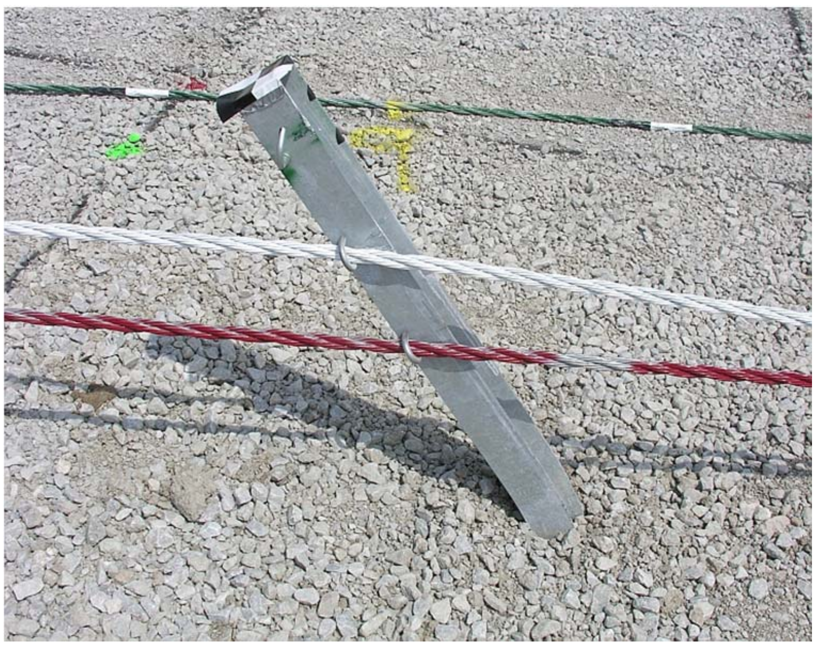
Figure 49. System Damage: Post Nos. 21 and 22, Test No. NYCC-1

Post No. 24

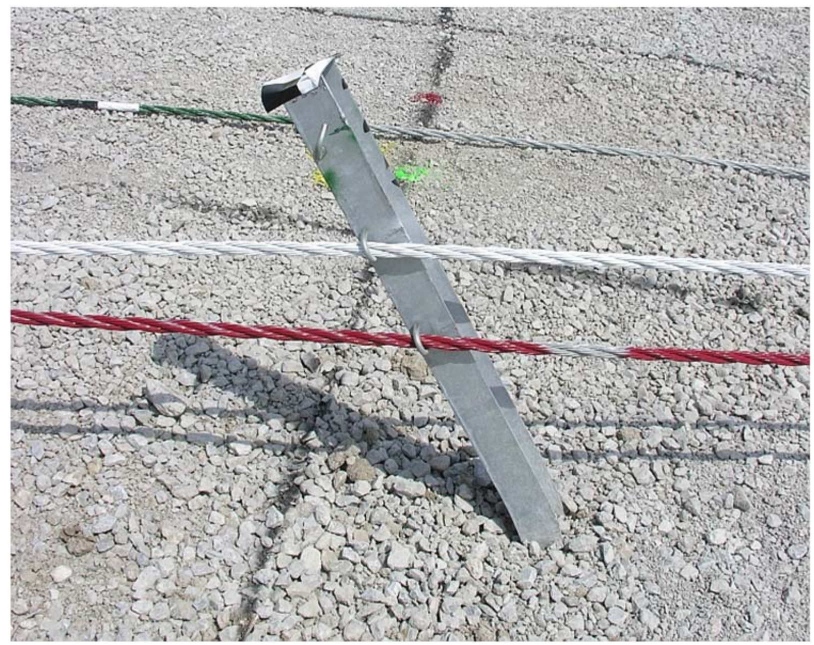


Post No. 23

Figure 50. System Damage: Post Nos. 23 and 24, Test No. NYCC-1

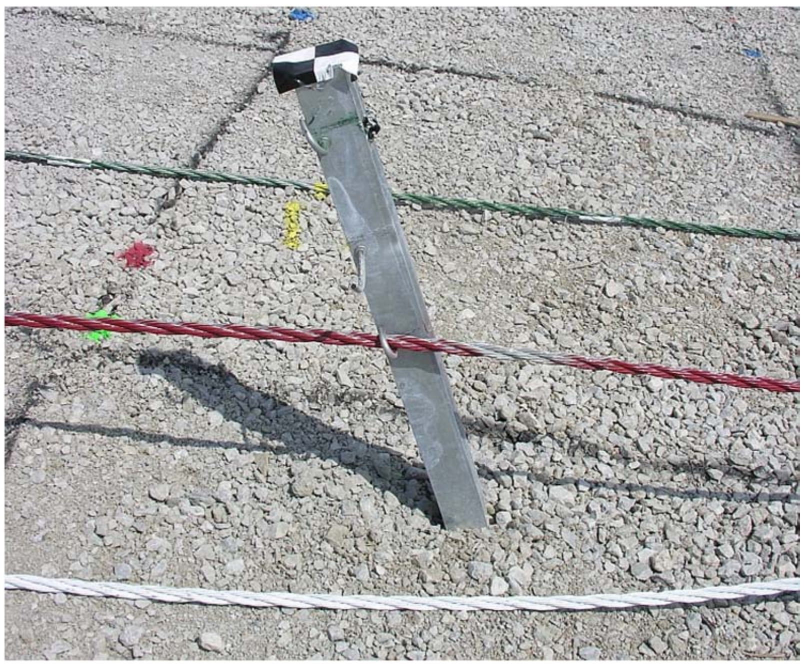


Post No. 26

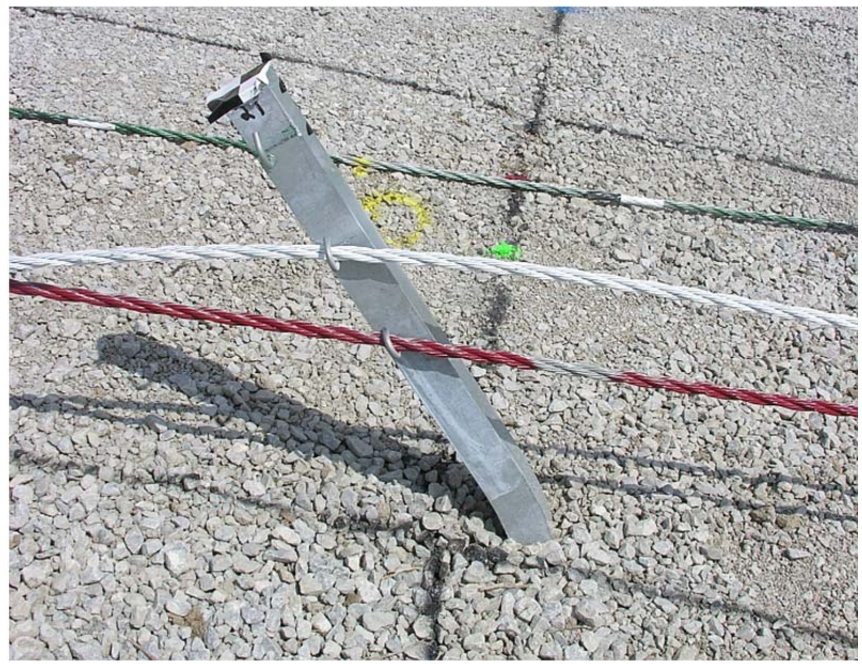


Post No. 25

Figure 51. System Damage: Post Nos. 25 and 26, Test No. NYCC-1

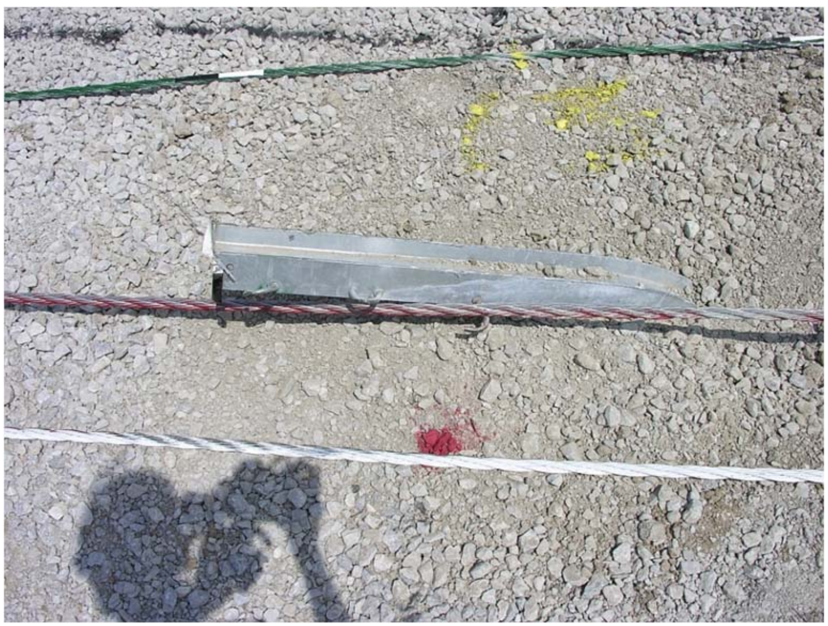


Post No. 28



Post No. 27

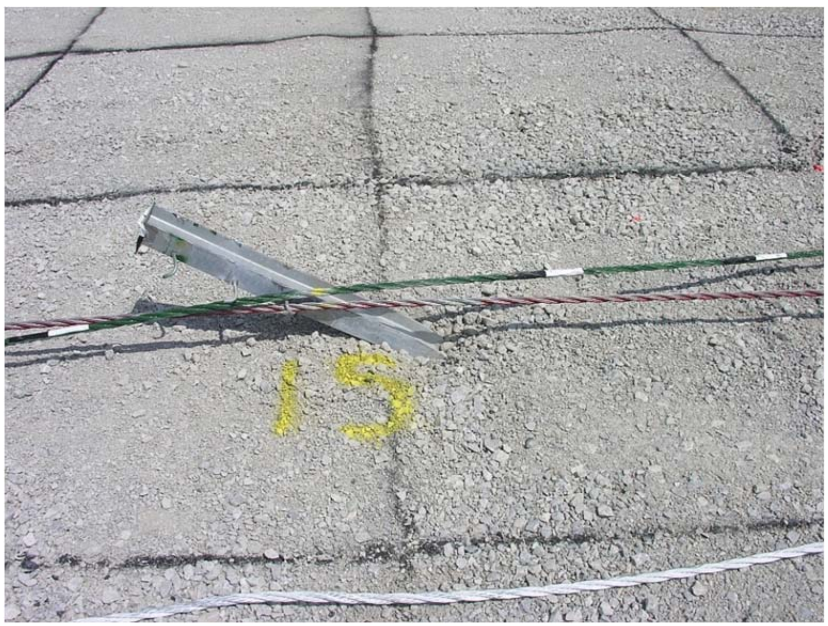
Figure 52. System Damage: Post Nos. 27 and 28, Test No. NYCC-1



Post No. 30

Post No. 29

Figure 53. System Damage: Post Nos. 29 and 30, Test No. NYCC-1



Post No. 32

Post No. 31

Figure 54. System Damage: Post Nos. 31 and 32, Test No. NYCC-1

Post No. 34

Post No. 33

Figure 55. System Damage: Post Nos. 33 and 34, Test No. NYCC-1

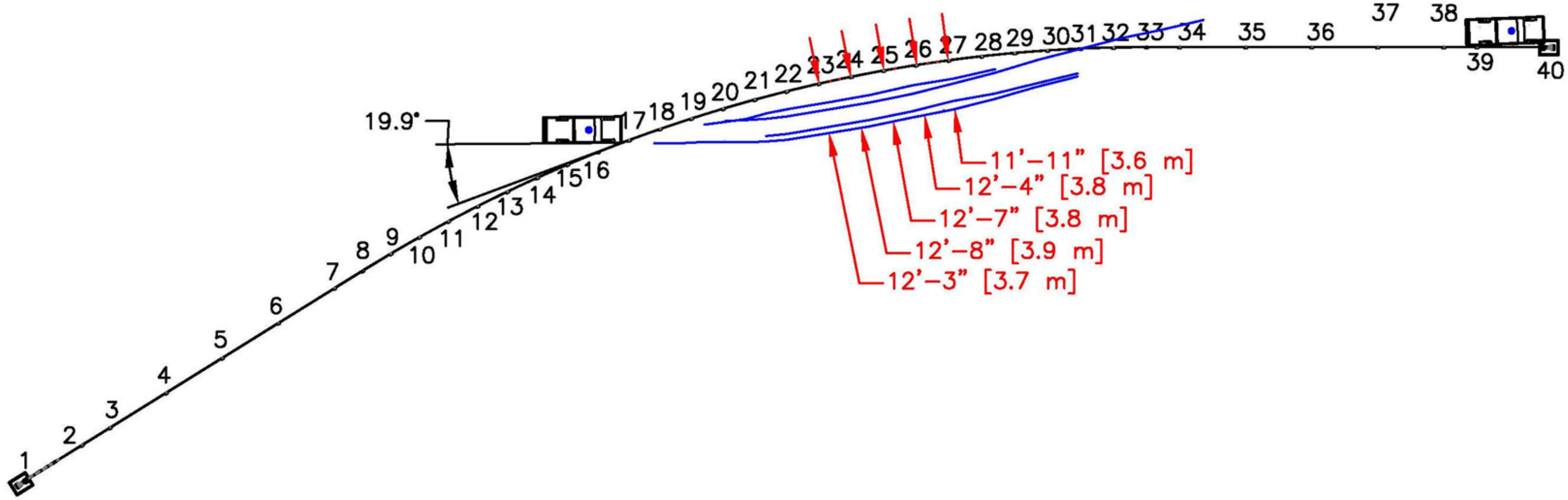


Figure 56. Working Width, Test No. NYCC-1

Figure 57. Vehicle Damage: Right Side, Test No. NYCC-1

Figure 58. Vehicle Damage: Front and Left Side, Test No. NYCC-1

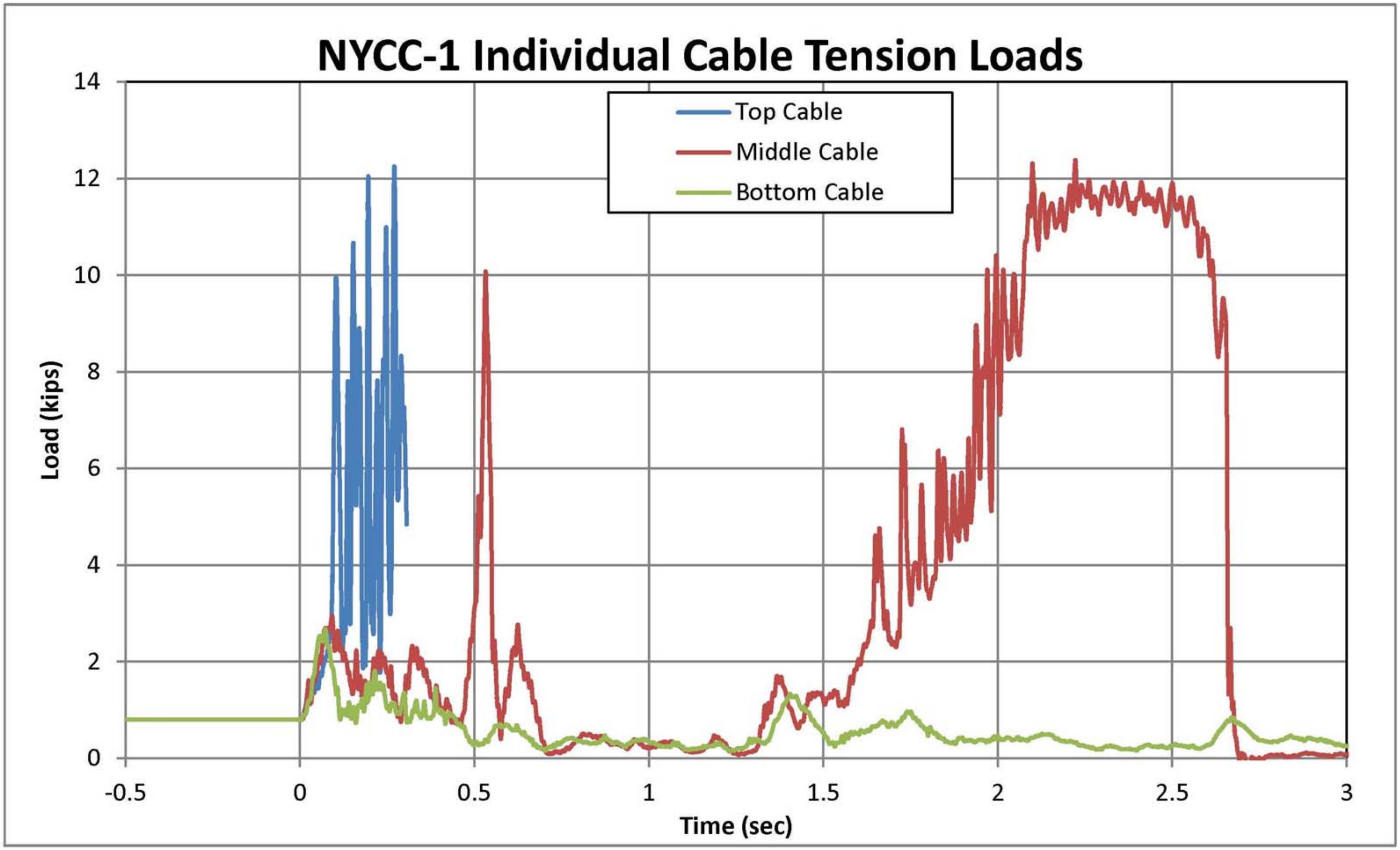


Figure 59. Individual Cable Tension vs. Time, Test No. NYCC-1

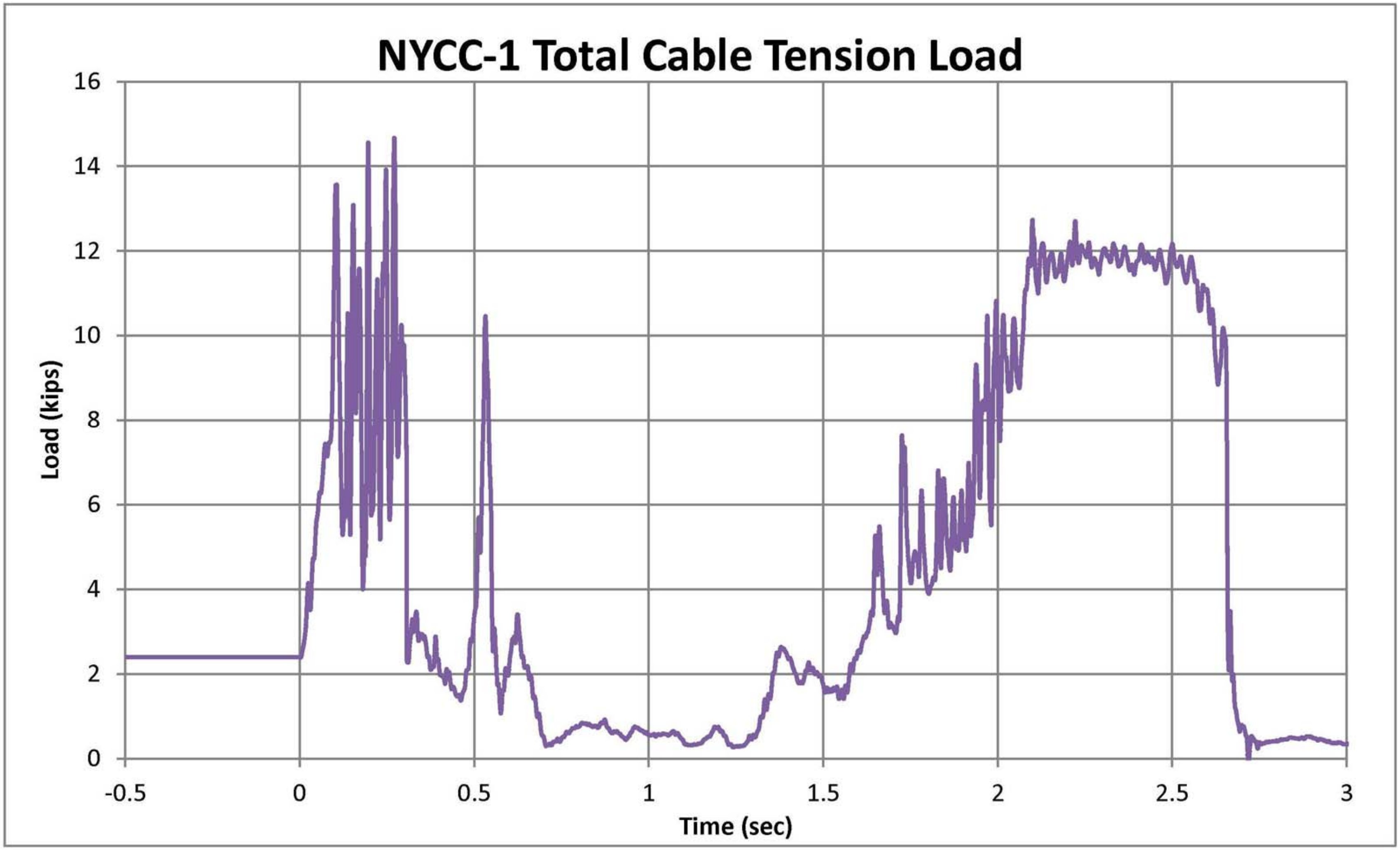


Figure 60. Total Cable Tension vs. Time, Test No. NYCC-1

6 DESIGN DETAILS - TEST NO. NYCC-2

The generic, low-tension, three-cable barrier system for test no. NYCC-2 was nearly identical to the system used for test no. NYCC-1 except for the radius of the curve. The radius of the system in test no. NYCC-2 was 440 ft (134 m) spanning an angle of 26 degrees between post nos. 8 and 33, as shown in Figure 61. Due to the radius change, and utilizing the same anchor locations, the cable barrier system had a total length of 396.5 ft (120.9 m). The impact angle and location remained the same - 20 degrees and 2 ft (0.6 m) upstream of post no. 17 or 70 ft (21.3 m) downstream of post no. 8, respectively. Photographs of the test installation are shown in Figures 62 through 65. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

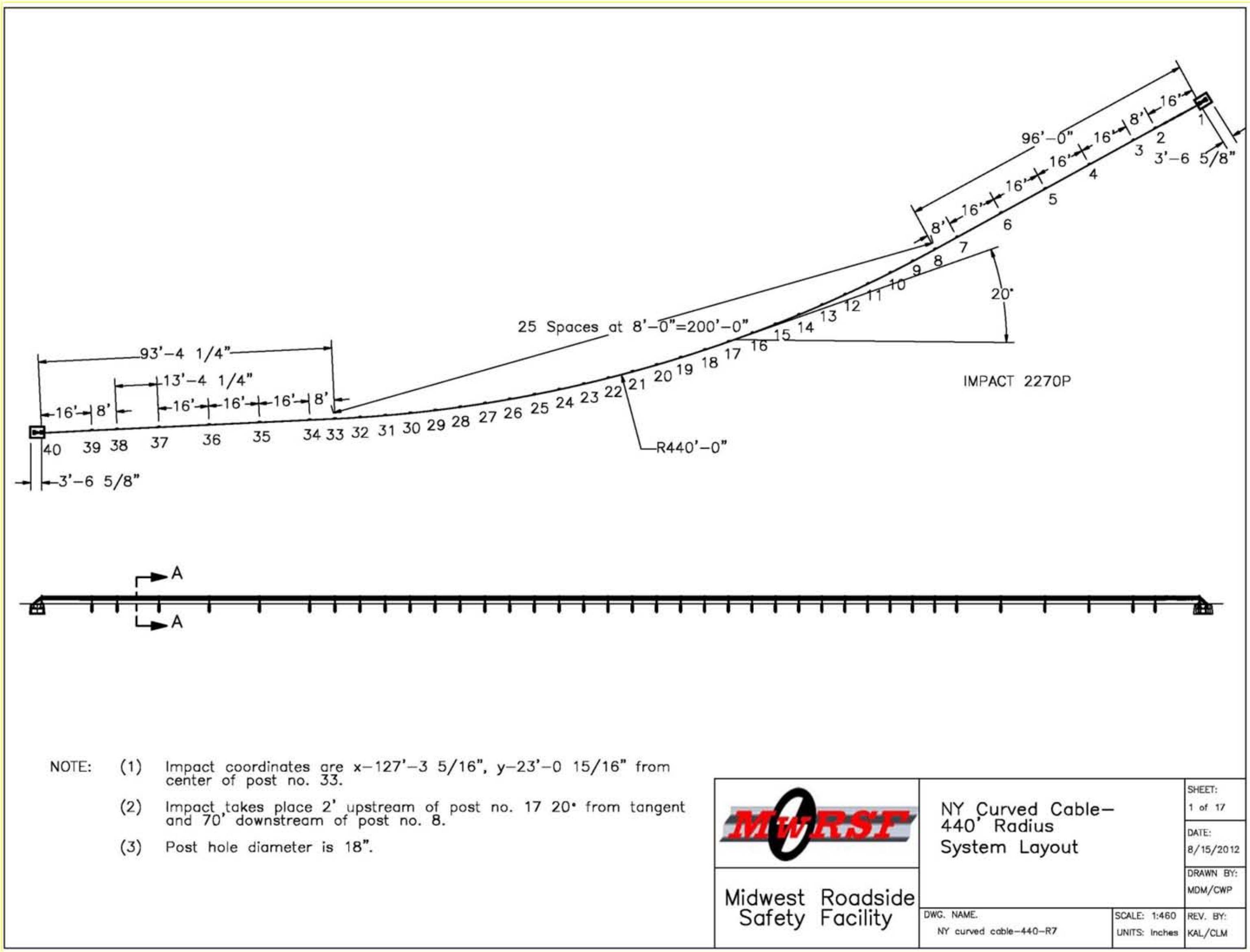


Figure 61. Test Installation Layout, Test No. NYCC-2

Figure 62. Test Installation Photographs, Test No. NYCC-2

Figure 63. Post Photographs, Test No. NYCC-2

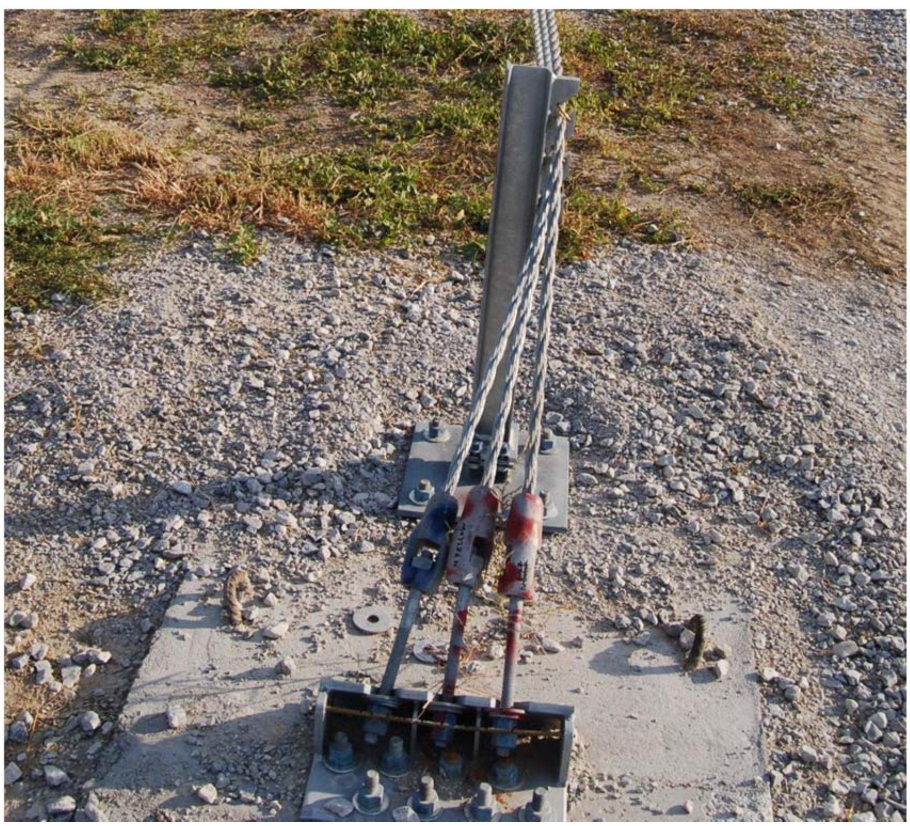


Figure 64. End Anchorage Photographs, Test No. NYCC-2

Figure 65. Cable Splices and Load Cells, Test No. NYCC-2

7 FULL-SCALE CRASH TEST NO. NYCC-2

7.1 Static Soil Test

Before full-scale crash test no. NYCC-2 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH. The static test results, as shown in Appendix 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 Test No. NYCC-2

The 4,998-lb (2,267-kg) pickup truck impacted the curved, three-cable barrier system at a speed of 61.7 mph (99.3 km/h) and at an angle of 22.1 degrees. A summary of the test results and sequential photographs are shown in Figure 66. Additional sequential photographs are shown in Figures 67 through 69.

7.3 Weather Conditions

Test no. NYCC-2 was conducted on November 1, 2011 at approximately 2:45 pm. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were recorded and are shown in Table 8.

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

Temperature	77° F
Humidity	36%
Wind Speed	8 mph
Wind Direction	350° from True North
Sky Conditions	Sunny / Clear
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0 in.
Previous 7-Day Precipitation	0 in.

7.4 Test Description

Initial vehicle impact occurred at the targeted impact point 2 ft (0.6 m) upstream of post no. 17, or 70 ft (21.3 m) downstream of post no. 8, as shown in Figure 70, which was selected by NYSDOT personnel. A sequential description of the impact events is contained in Table 9. The vehicle came to rest on its side behind the barrier at a location of 282 ft (86.0 m) downstream of impact and 7 ft (2.1 m) laterally behind a line parallel to the impact point, as shown in Figures 66 and 71.

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

TIME (sec)	EVENT
0.000	The right-front bumper impacted top cable.
0.006	The right-front bumper contacted post no. 17.
0.030	The right-front tire contacted post no. 17.
0.038	Post no. 17 was bending backward and down with all cables still attached.
0.044	The right-front tire overrode post no. 17.
0.046	The top cable disengaged from post no. 17.
0.056	The middle cable disengaged from post no. 17.
0.058	The right-front tire rose off the ground.
0.064	The right-front tire overrode the bottom and middle cables.
0.086	The front bumper contacted post no. 18 and deflected it downstream.
0.090	The right-front tire overrode the top cable.
0.102	Vehicle began to override post no. 18.
0.108	Vehicle pitched upward.
0.176	The left-front bumper deflected post no. 19 downstream.
0.198	The left-front tire contacted post no. 19.
0.202	The left-front tire deflected post no. 19, and the vehicle began to pitch upward
0.214	Post no. 20 deflected backwards and downstream.
0.230	Vehicle began to roll away from backside of barrier.
0.236	Left-front tire became airborne as it overrode post no. 19 and all 3 cables.
0.340	Vehicle began to pitch downward.
0.356	The right front tire contacted the ground.
0.400	Post no. 20 stopped deflecting.
0.440	Vehicle completely overrode system and was no longer in contact with system.
0.600	Vehicle was free-wheeling behind barrier in a stable manor.
1.206	Vehicle contacted and began to climb embankment and rolled toward barrier.
1.480	Right-front tire was airborne.
1.532	Left-front tire became airborne.
1.708	Left-rear tire became airborne

2.242	The left side of the vehicle contacted the ground.
13.000	Vehicle came to a stop on its right side after rolling over twice.

7.5 Barrier Damage

Damage to the barrier was minimal, as shown in Figures 71 through 74. Barrier damage consisted of bent posts and disengaged cables. The length of vehicle contact along the barrier was approximately 24 ft (7.32 m), which spanned from 2 ft (0.6 m) upstream from post 17 through 2 ft (0.6 m) upstream from post 20.

The upstream cable anchor assembly experienced minor damage. The top and middle cables had disengaged from both the angled anchor bracket and post no. 1. Post no. 1 was slightly bent downstream. Post nos. 17 through 19 were all bent backward and downstream.

The top, middle, and bottom cables disengaged from post nos. 17 through 19. All cable-to-post J-bolt attachments on post nos. 17 and 18 were bent. Additionally, the top and middle J-bolts on post nos. 17 and 18 were rotated upstream. The top and middle J-bolts on post no. 19 were fractured and the bottom J-bolt was bent and rotated upstream.

The maximum lateral dynamic barrier deflection was 30.0 in. (762 mm) at post no. 17, as determined from high-speed digital video analysis. The working width of the system was not calculated since the vehicle overrode the system.

7.6 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 75 through 78. However, only minor vehicle damage resulted from the interaction with the barrier. The damage due to rollover was not attributable to the curved-cable system as the vehicle was stable and tracking before climbing the embankment. The maximum occupant compartment deformations are listed in Table 10 along with the deformation limits established in MASH for various areas of the occupant compartment. Note that the maximum permissible roof crush limits described in

MASH were exceeded. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D.

Table 10. Maximum Occupant Compartment Deformations by Location, Test No. NYCC-2

LOCATION	MAXIMUM DEFORMATION in. (mm)	MASH ALLOWABLE DEFORMATION in. (mm)
Wheel Well & Toe Pan	$^3/_8$ (10)	≤ 9 (229)
Floor Pan & Transmission Tunnel	3½ (89)	≤ 12 (305)
Side Front Panel (in Front of A-Pillar)	¼ (6)	≤ 12 (305)
Side Door (Above Seat)	½ (13)	≤ 9 (229)
Side Door (Below Seat)	¼ (6)	≤ 12 (305)
Roof	8 (203)	≤ 4 (102)
Windshield	0 (0)	≤ 3 (76)

The entire cab of the vehicle was dented due to rollover. The left-front bumper was crushed inward, and the hood was bent inward. A large indentation was present on the left side. The windshield experienced spider-web cracking, concentrated in the top right corner. The rear windshield was shattered. The roof of the cab was crushed downward about 8.5 in. (216 mm). Both of the rear tail lights were disengaged as well as the right side of the tailgate. The left-front wheel was disengaged, and the ball joint support was fractured. The left-front brake line was cut. The driveshaft was disengaged from the transmission. Cable contact marks were found on the underside of the gas tank. The passenger and driver side windows were fractured.

7.7 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 11. Note that the OIVs and ORAs were within the suggested limits provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 11. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 66. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix F.

Table 11. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NYCC-2

Evaluation Criteria		Transducers		MASH Limits (Absolute Value)
		EDR-3	DTS	
OIV ft/s (m/s)	Longitudinal	-4.66 (-1.42)	-5.58 (-1.70)	≤ 40 (12.2)
	Lateral	-3.02 (-0.92)	-1.97 (-0.60)	≤ 40 (12.2)
ORA g's	Longitudinal	1.04	1.01	≤ 20.49
	Lateral	1.14	1.34	≤ 20.49
THIV ft/s (m/s)		NA	5.92 (1.80)	not required
PHD g's		NA	1.60	not required
ASI		0.18	0.21	not required

7.8 Load Cell Results

As previously discussed, tension load cells were installed in line with the cables at the upstream end of the barrier system in order to monitor the total load transferred to the end anchor system with respect to time. The load cell results are summarized in Table 12. The individual cable loads and the total combined cable load imparted to the upstream end anchor are shown graphically in Figures 79 and 80. The pre-tension in each cable was 914 lb (4.07 kN), as measured by the displacement in the spring compensators near the upstream anchorage. After the crash test, tension in the top, middle, and bottom cables was 1,398 lb (6.22 kN), 905 lb (4.03 kN), and 756 lb (3.36 kN), respectively.

Table 12. Summary of Load Cell Results, Test No. NYCC-2

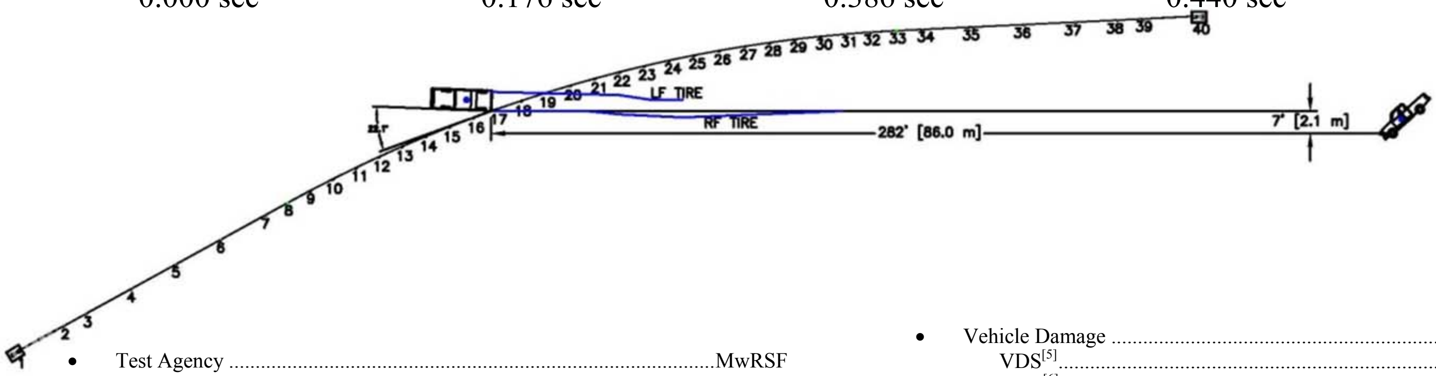
Cable Location	Sensor Location	Maximum Cable Load		Time* (sec)
		kips	kN	
Combined Cables	Upstream End	16.97	75.52	0.089
Top Cable	Upstream End	13.27	59.03	0.089
Middle Cable	Upstream End	3.58	15.92	0.239
Bottom Cable	Upstream End	2.85	12.68	0.061

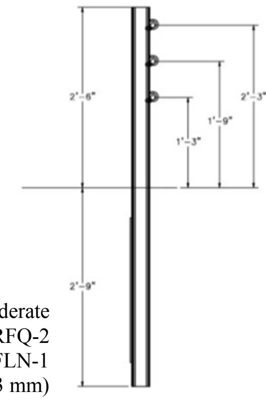
* - Time determined from initial vehicle impact with the barrier system.

7.9 Discussion

The analysis of the test results for test no. NYCC-2 showed that the generic, three-cable barrier with a 440 ft (134.1 m) curved radius and a 27 in. (686 mm) top mounting height did not adequately contain or redirect the 2270P vehicle since the vehicle overrode the barrier. The vehicle did not remain upright after the collision; however, it is believed that the rollover was caused by contact with an embankment behind the system. Thus, the rollover was not directly caused by the system containment failure. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix F, were deemed acceptable prior to the vehicle rolling over the embankment. There were no detached elements or fragments which showed potential for penetrating the occupant compartment, nor did any detached elements present undue hazard to other traffic. However, excessive occupant compartment deformations were imparted to the roof of the vehicle due to the eventual vehicle rollover. Therefore, test no. NYCC-2 was determined to be unacceptable according to the MASH safety performance criteria for modified test designation no. 3-11.

0.000 sec 0.176 sec 0.386 sec 0.440 sec 0.640 sec





- Test Agency .... MwRSF
- Test Number NYCC-2
- Date 11/1/11
- MASH Test Designation .... Modified 3-11
- Test Article .... 440 ft (134 m) radius curved three cable barrier
- Total Length .... 389 ft - 4 in. (118.7 m)
- Key Component – Wire Rope
  - Diameter .... ¾ in. (19 mm)
  - Size 3x7
  - Top Cable Height .... 27 in. (686 mm)
  - Middle Cable Height .... 21 in. (533 mm)
  - Bottom Cable Height .... 15 in. (381 mm)
- Key Component - Post
  - Length .... 63 in. (1,600 mm)
  - Shape S3x5.7 (S76x8.5)
  - Spacing - Curved Section .... 8 ft (2.4 m
  - Spacing - Tangent End Segments .... 16 ft (4.9 m)
- Soil Type .... Grade B of AASHTO M147-65 (1990)
- Vehicle Make /Model .... 2005 Dodge Ram 1500 Quad Cab
  - Curb .... 5,001 lb (2,268 kg)
  - Test Inertial .... 4,998 lb (2,267 kg)
  - Gross Static .... 5,168 lb (2,344 kg)
- Impact Conditions
  - Speed .... 61.7 mph (99.3 km/h)
  - Angle .... 22.1 deg.
  - Impact Location .... 2 ft (0.6 m) upstream of post 17
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 282 ft (86.0 m) downstream
  7 ft (2.1 m) laterally behind
- Vehicle Damage .... Moderate
  - VDS[5] 01–RFQ-2
  - CDC[6] 01-RFLN-1
  - Maximum Interior Deformation .... 8 in. (203 mm)
- Test Article Damage .... Minimal
- Exit Conditions .... NA due to vehicle override
- Maximum Test Article Deflections
  - Permanent Set .... NA
  - Dynamic .... 30 in. (762 mm)
  - Working Width .... NA
- Maximum Angular Displacements (Prior to Secondary Impact With Embankment)
  - Roll .... 5.6° < 75°
  - Pitch .... -3.4° < 75°
  - Yaw .... -3.8°
- Impact Severity (IS) .... 93.1 kip-ft (126.2 kJ)
- Transducer Data

Evaluation Criteria		Transducers		MASH Limit (Absolute Value)
		EDR-3	DTS	
OIV ft/s (m/s)	Longitudinal	-4.66 (-1.42)	-5.58 (-1.70)	≤ 40 (12.2)
	Lateral	-3.02 (-0.92)	-1.97 (-0.60)	≤ 40 (12.2)
ORA g's	Longitudinal	1.04	1.01	≤ 20.49
	Lateral	1.14	1.34	≤ 20.49
THIV – ft/s (m/s)		NA	5.92 (1.80)	Not required
PHD – g's		NA	1.60	Not required
ASI		0.18	0.21	Not required

Figure 66. Summary of Test Results and Sequential Photographs, Test No. NYCC-2

0.000 sec

0.640 sec

0.120 sec

0.840 sec

0.284 sec

1.232 sec

Figure 67. Additional Sequential Photographs, Test No. NYCC-2

Figure 68. Additional Sequential Photographs, Test No. NYCC-2


0.000 sec


0.182 sec


0.486 sec

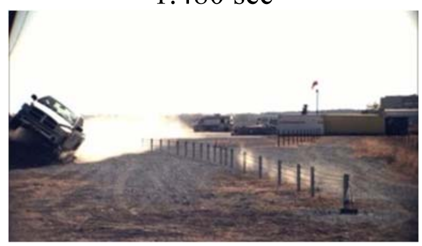

0.660 sec


0.870 sec


1.076 sec


1.206 sec


1.480 sec


1.612 sec


1.708 sec


2.158 sec


2.316 sec

Figure 69. Additional Sequential Photographs, Test No. NYCC-2

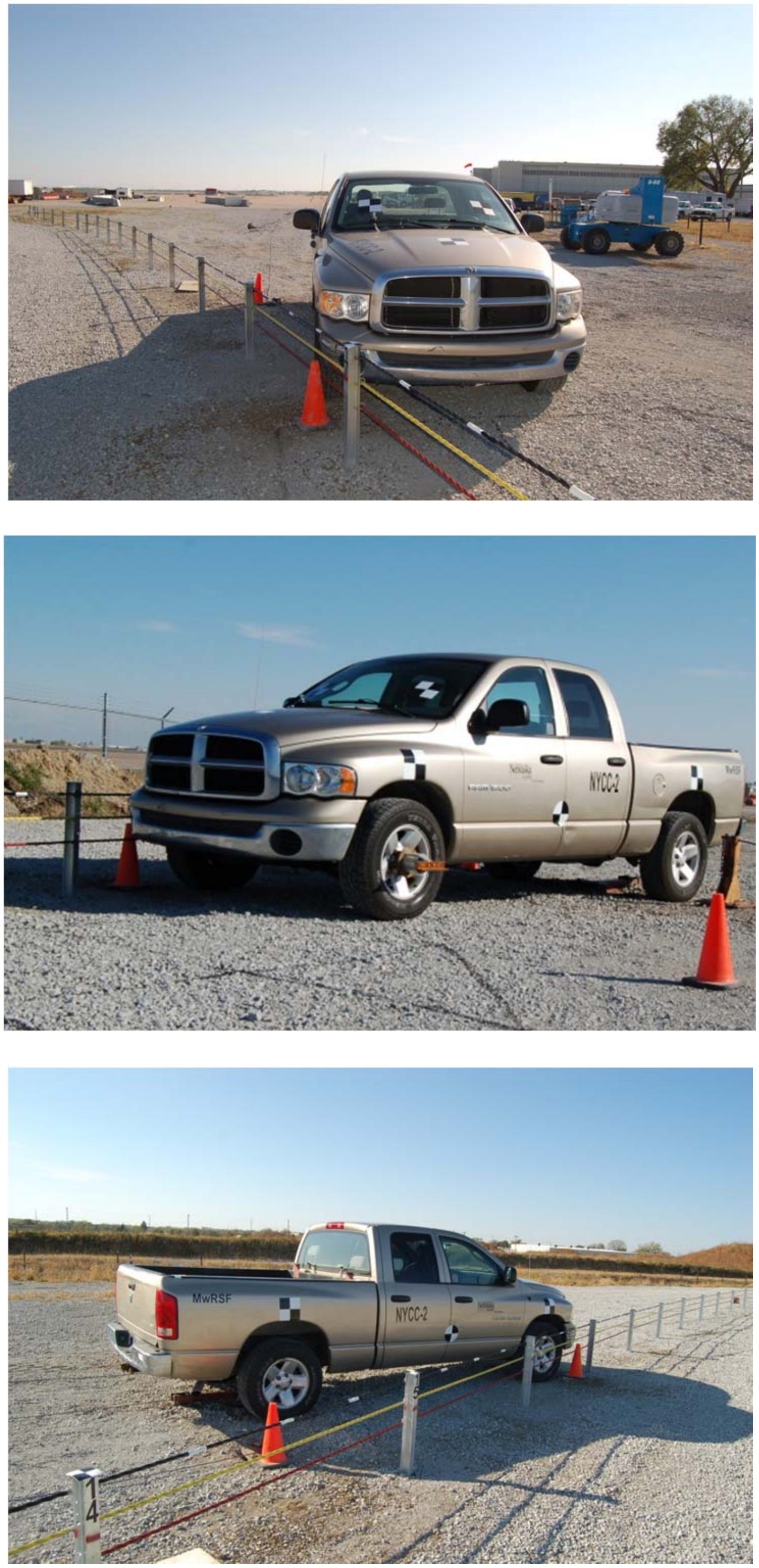


Figure 70. Impact Location, Test No. NYCC-2

Figure 71. Vehicle Final Position and Trajectory Marks, Test No. NYCC-2

Figure 72. System Damage: Upstream Anchorage, Test No. NYCC-2

Figure 73. System Damage, Test No. NYCC-2

Post No. 19

Post No. 18

Post No. 17

Figure 74. System Damage: Post Nos. 17 through 19, Test No. NYCC-2

Figure 75. Vehicle Damage, Test No. NYCC-2

Figure 76. Vehicle Damage, Test No. NYCC-2

Figure 77. Vehicle Damage, Test No. NYCC-2

Figure 78. Vehicle Damage, Test No. NYCC-2

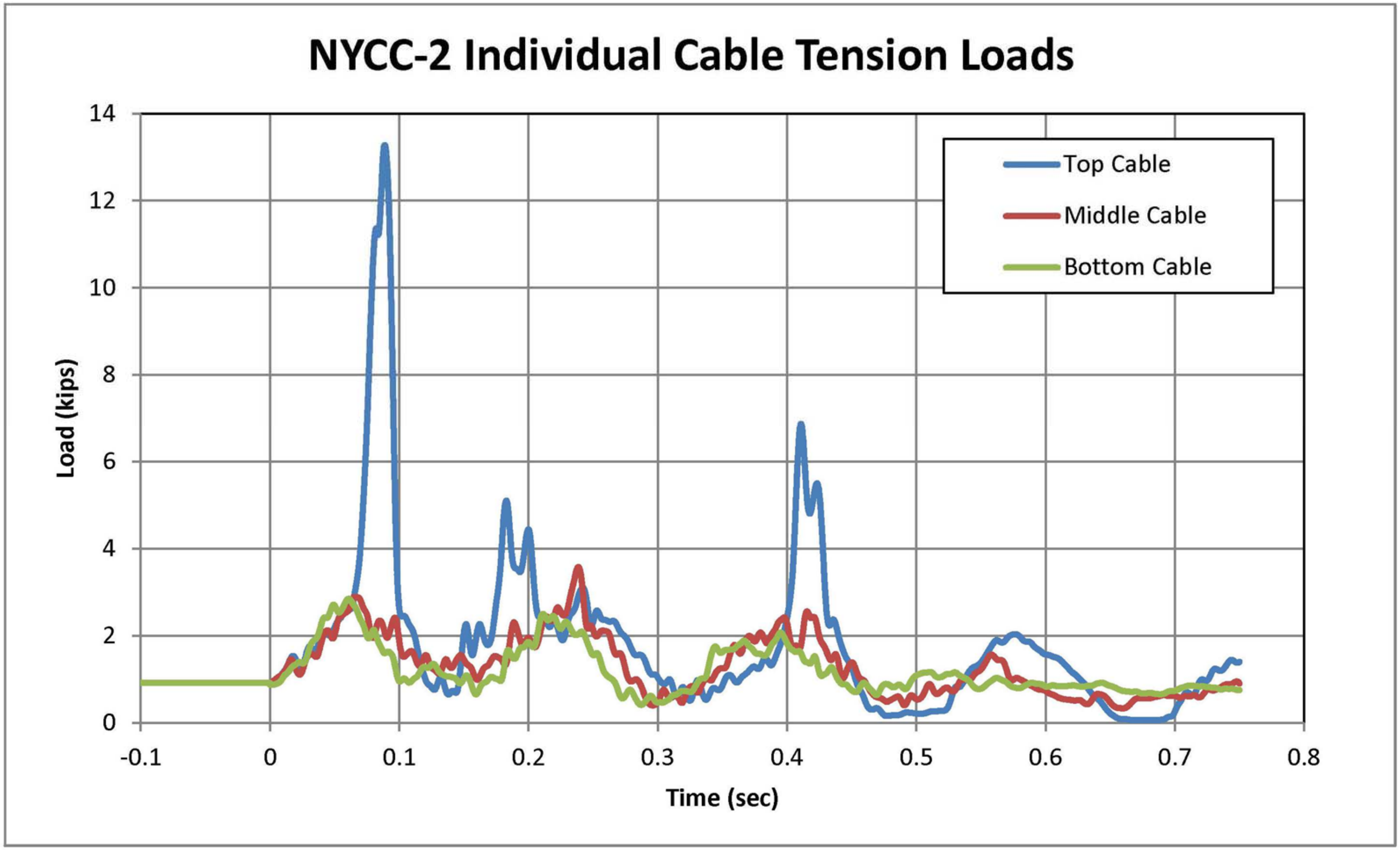


Figure 79. Individual Cable Tension vs. Time, Test No. NYCC-2

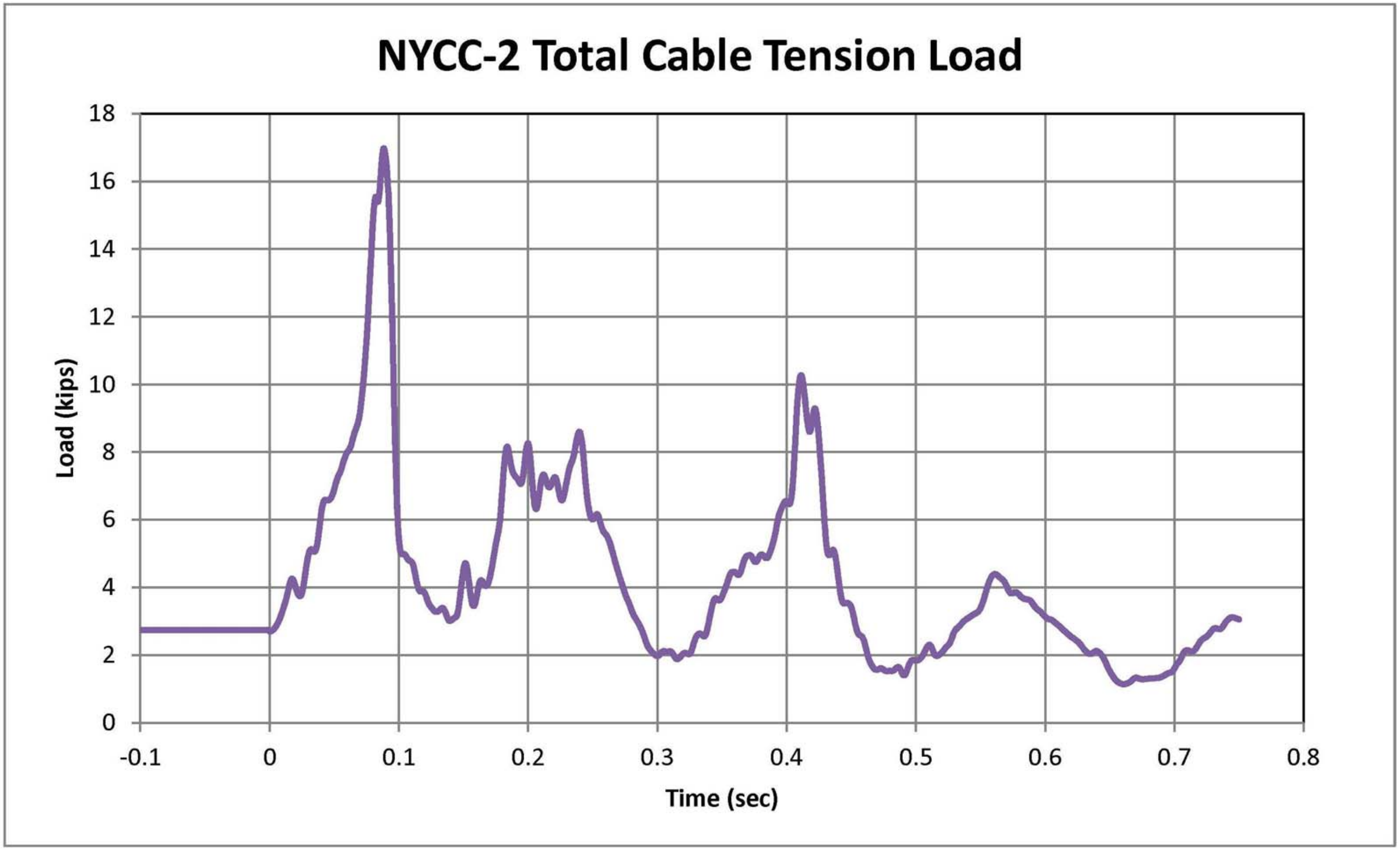


Figure 80. Total Cable Tension vs. Time, Test No. NYCC-2

8 DESIGN DETAILS - TEST NO. NYCC-3

Due to the unsuccessful performance of the curved cable barrier in test no. NYCC-2, the system was examined to identify what features, if any, could improve barrier performance and its ability to contain and redirect high center-of-mass passenger vehicles. It was observed that the top bumper height of the test vehicle in test no. NYCC-2 was 25½ in. (648 mm). However, the bumper cover was higher around the left-front and right-front corners adjacent to the headlights. This vertical extension was approximately 2½ in. (64 mm) tall. To ensure adequate capture of the vehicle with at least one cable, the system would need to be at least 28 in. (711 mm) tall. In order to account for construction tolerances and variations in vehicle fleet, the cable barrier system was raised by 2 in. (51 mm), thus resulting in a reduced post embedment depth of 2 in. (51mm). The new cable mounting heights utilized in test no. NYCC-3 were 29 in., 23 in., and 17 in. (740 mm, 584 mm, and 432 mm).

The cable barrier system for test no. NYCC-3 was identical to the system used in test no. NYCC-2, with the exception that the cables were raised by 2 in. (51 mm), as shown in Figures 81 through 94. Photographs of the test installation are shown in Figures 95 through 98. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

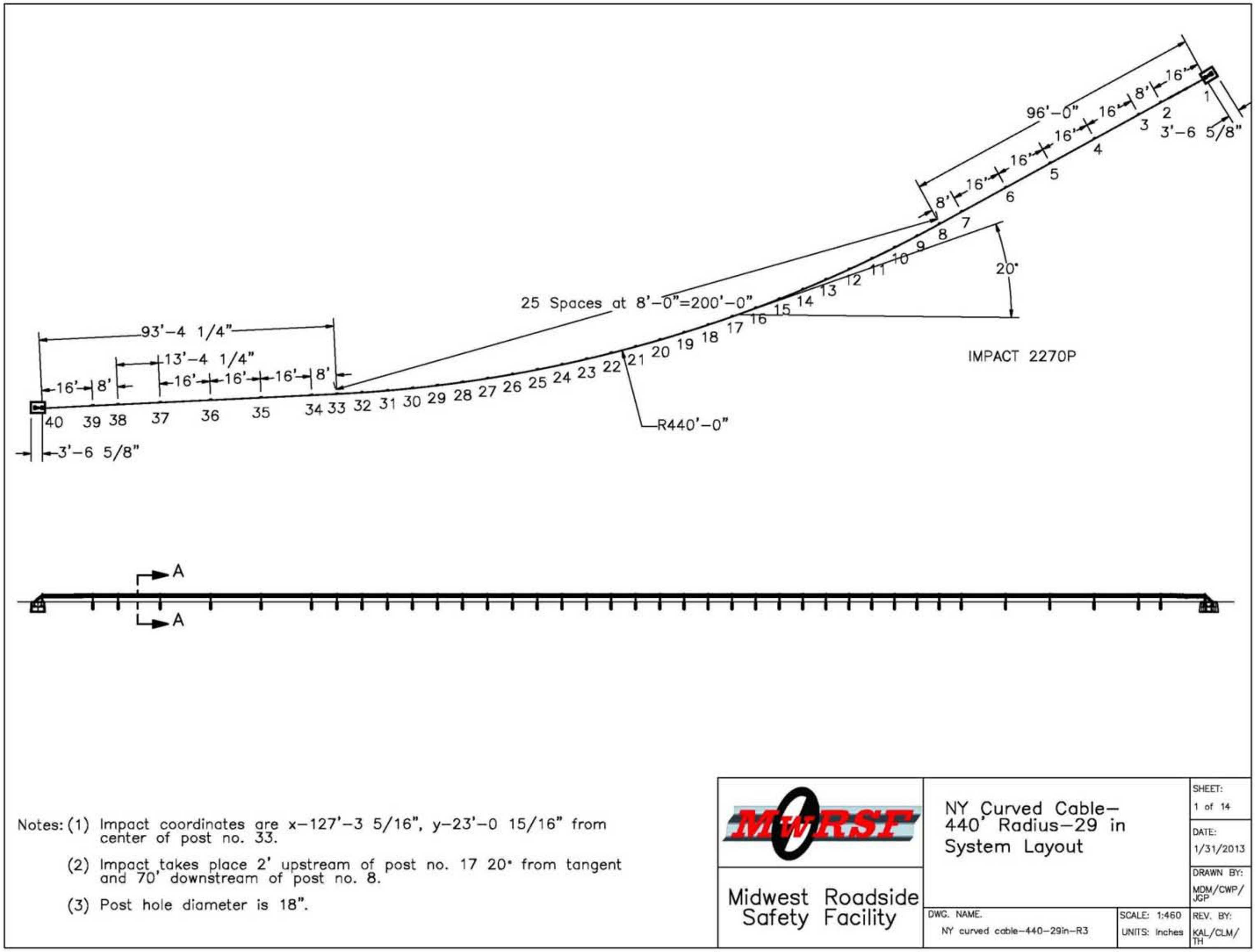


Figure 81. Test Installation Layout, Test No. NYCC-3

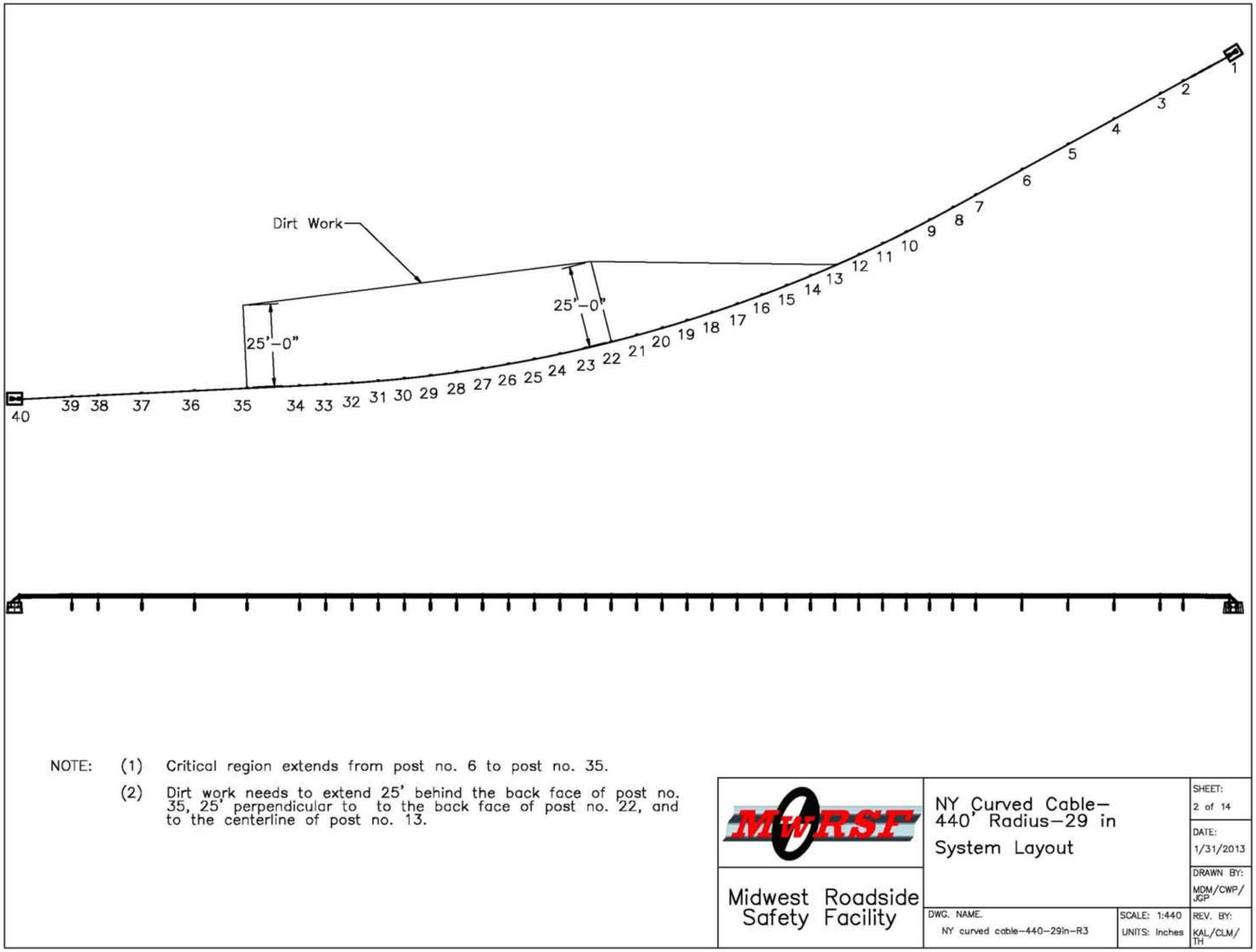


Figure 82. Critical Region, Test No. NYCC-3

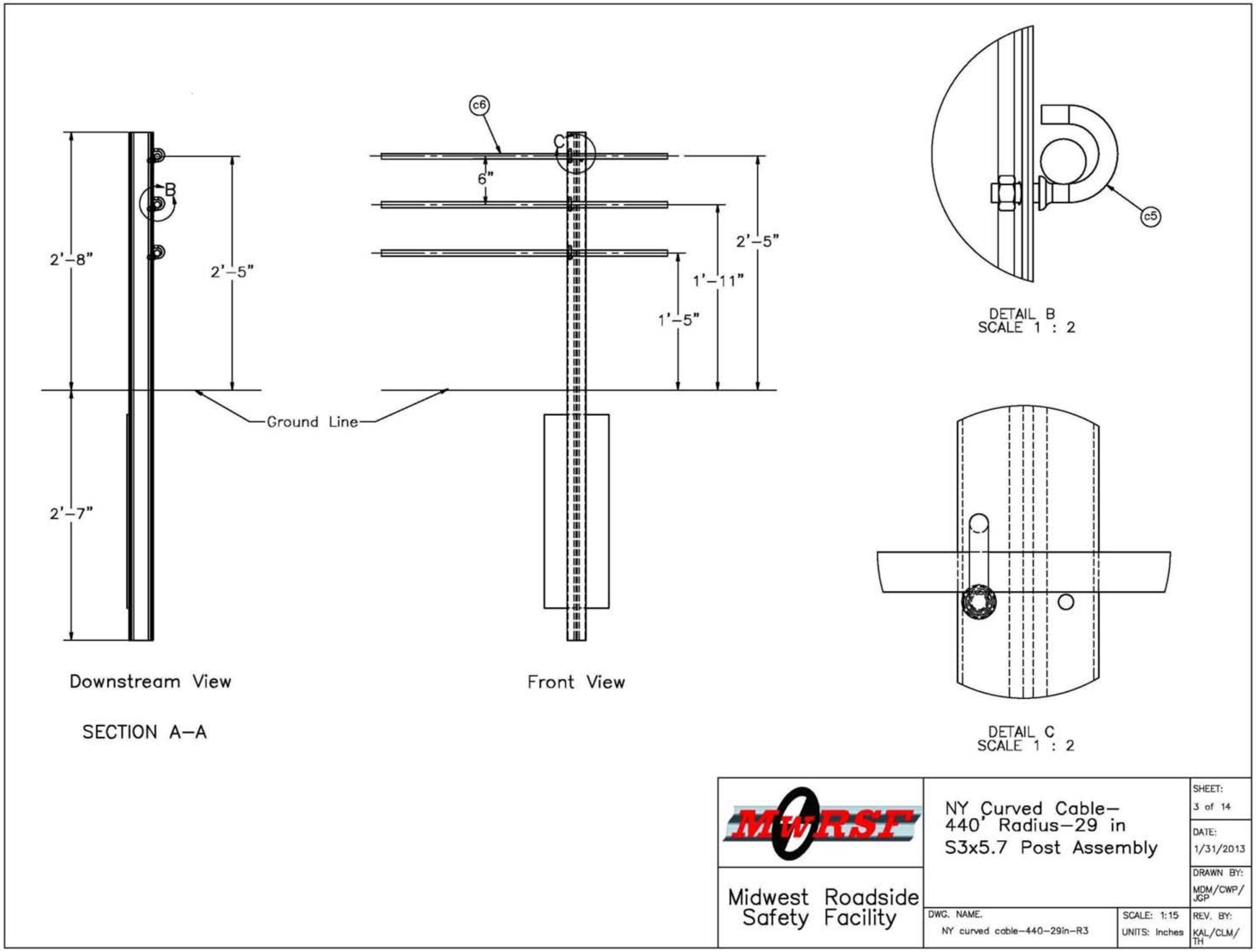


Figure 83. Line Post Assembly Details, Test No. NYCC-3

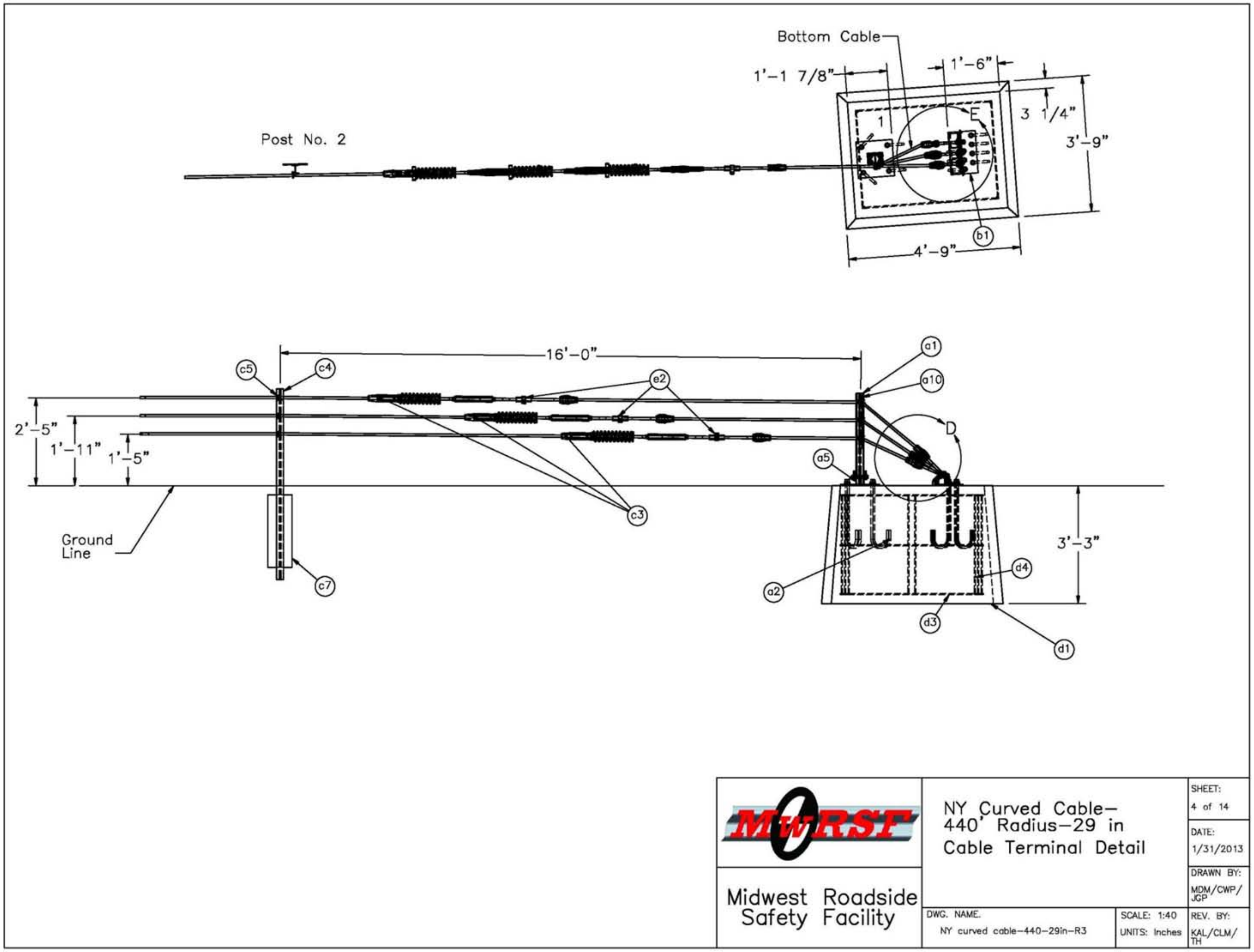


Figure 84. Terminal Details, Test No. NYCC-3

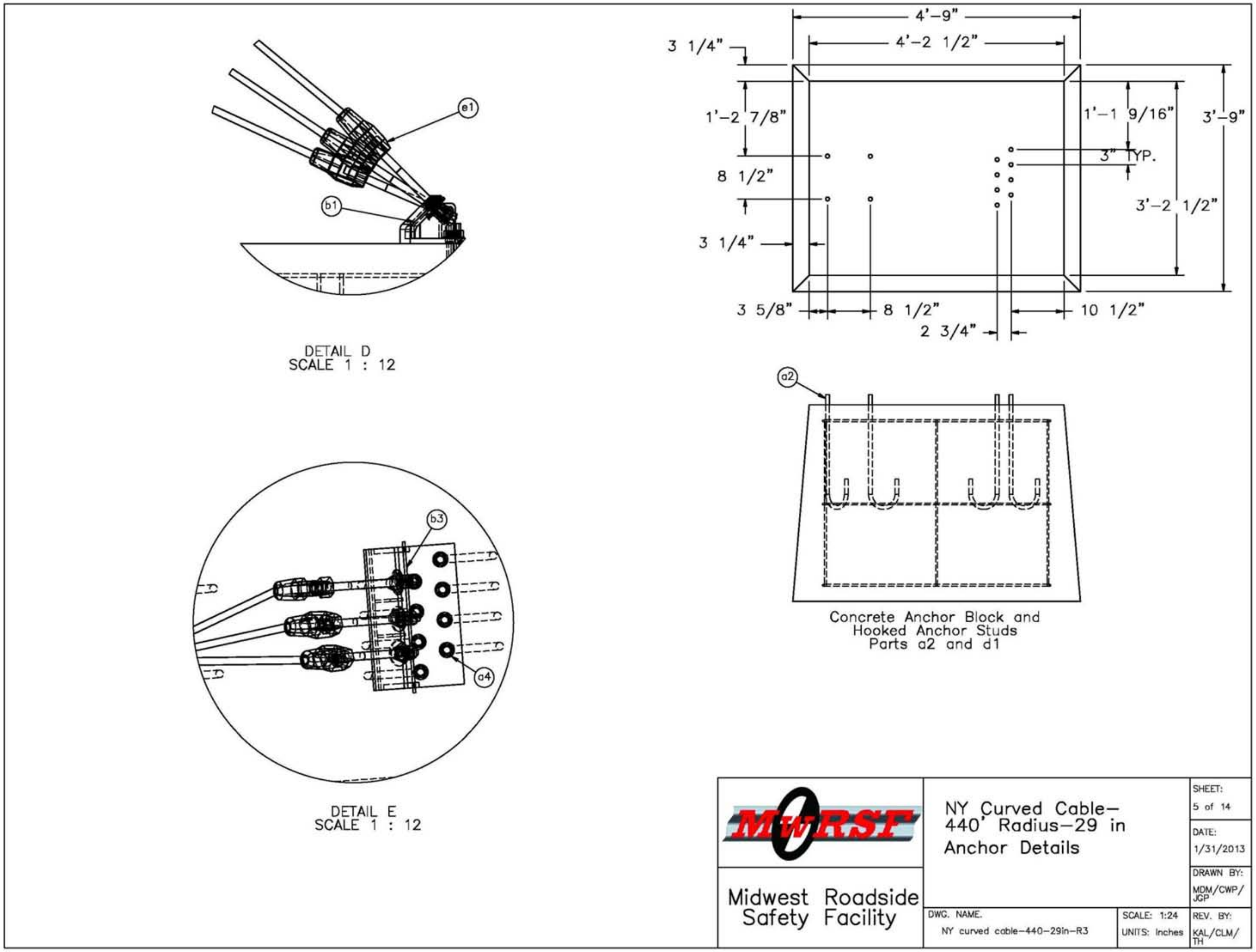


Figure 85. Anchor Details, Test No. NYCC-3

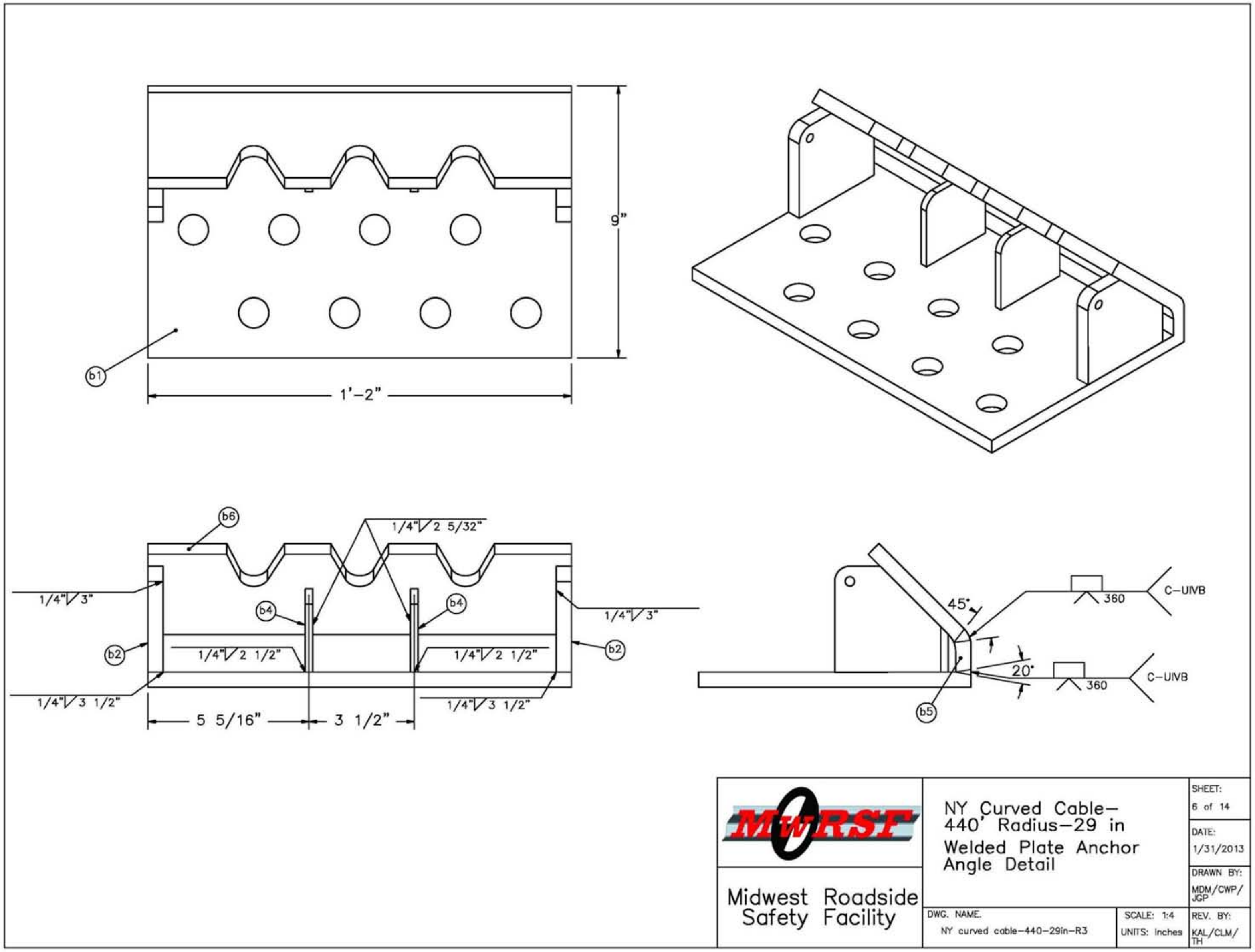


Figure 86. Cable Anchor Bracket Details, Test No. NYCC-3

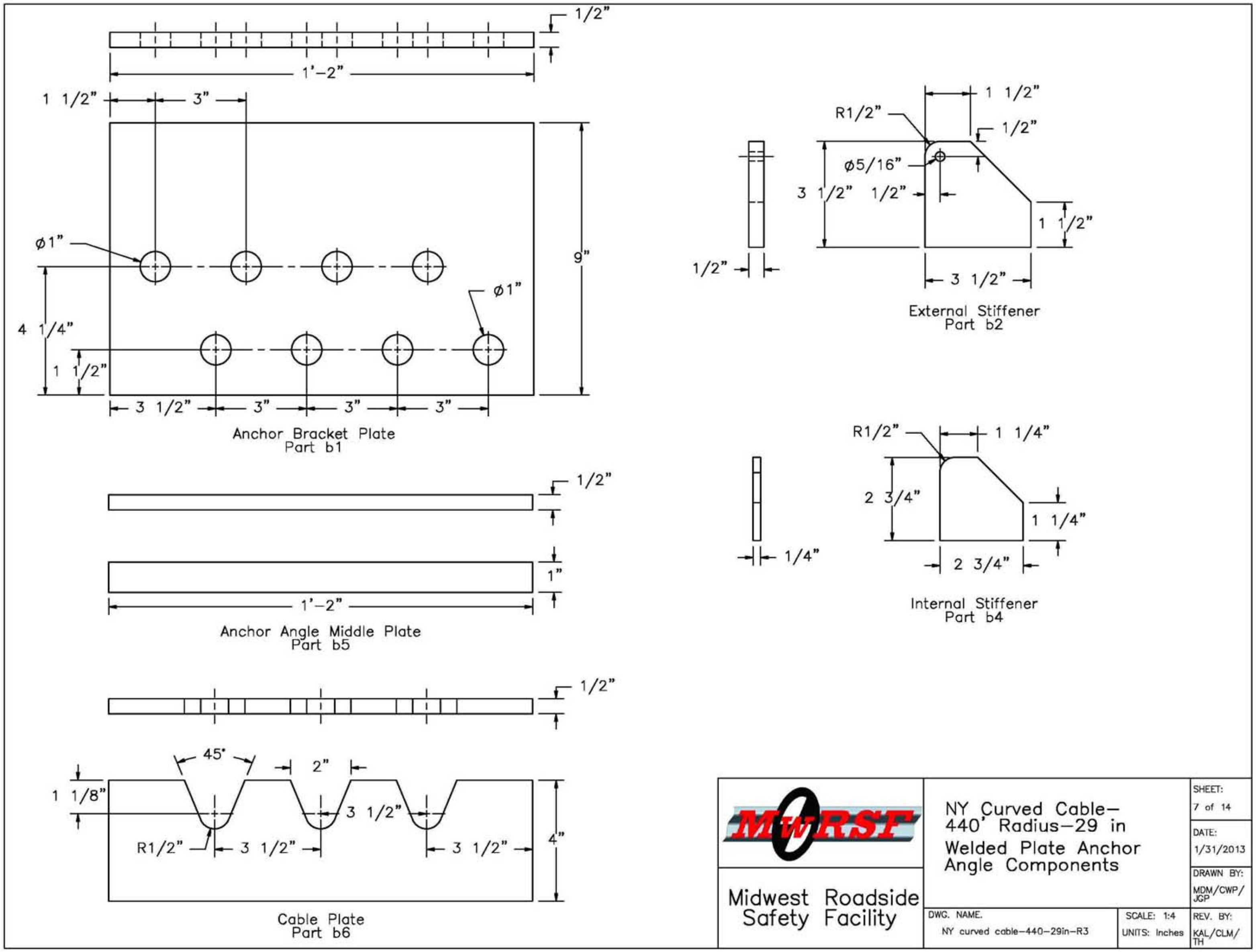


Figure 87. Cable Anchor Bracket Component Details, Test No. NYCC-3

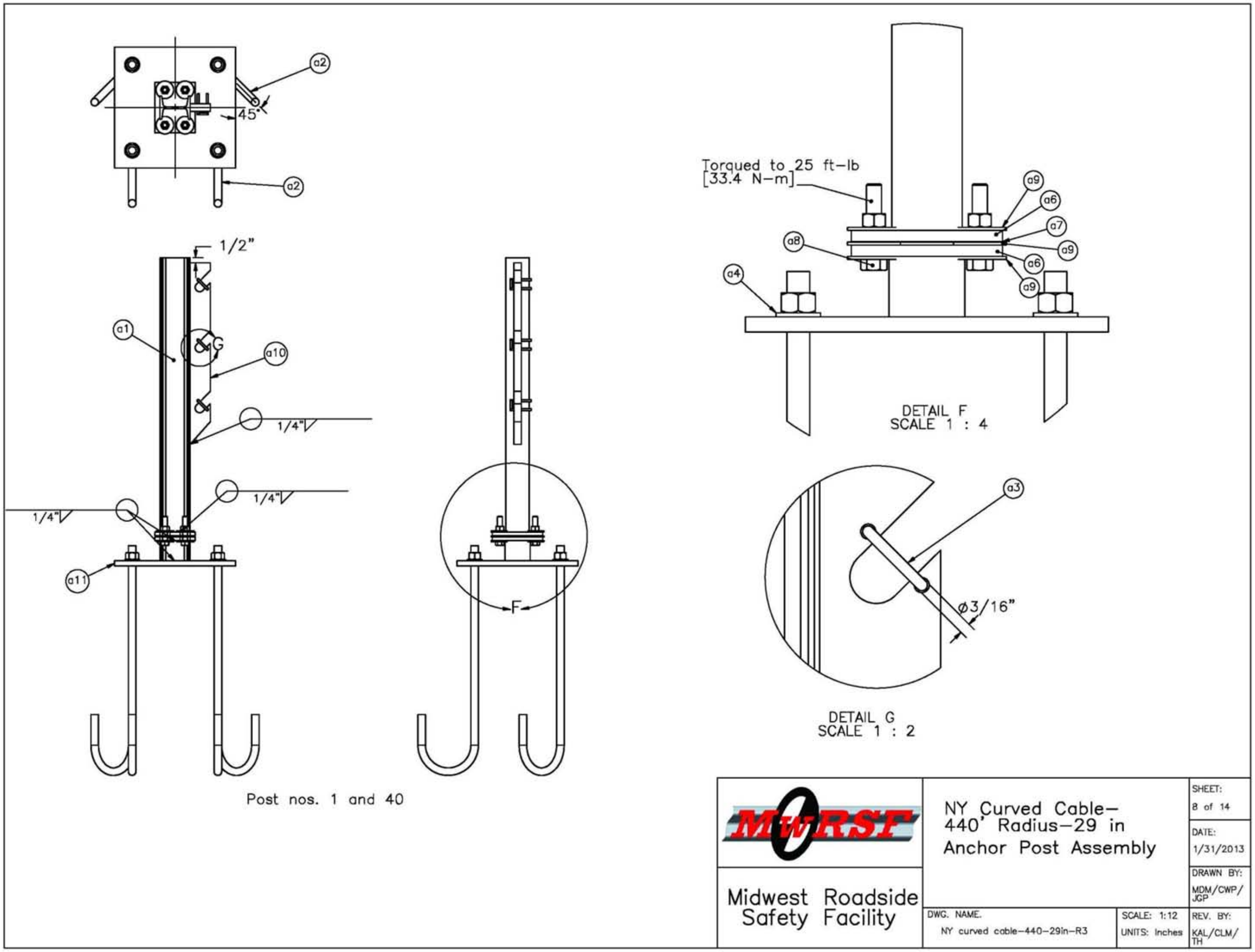


Figure 88. Anchor Post Assembly Details, Test No. NYCC-3

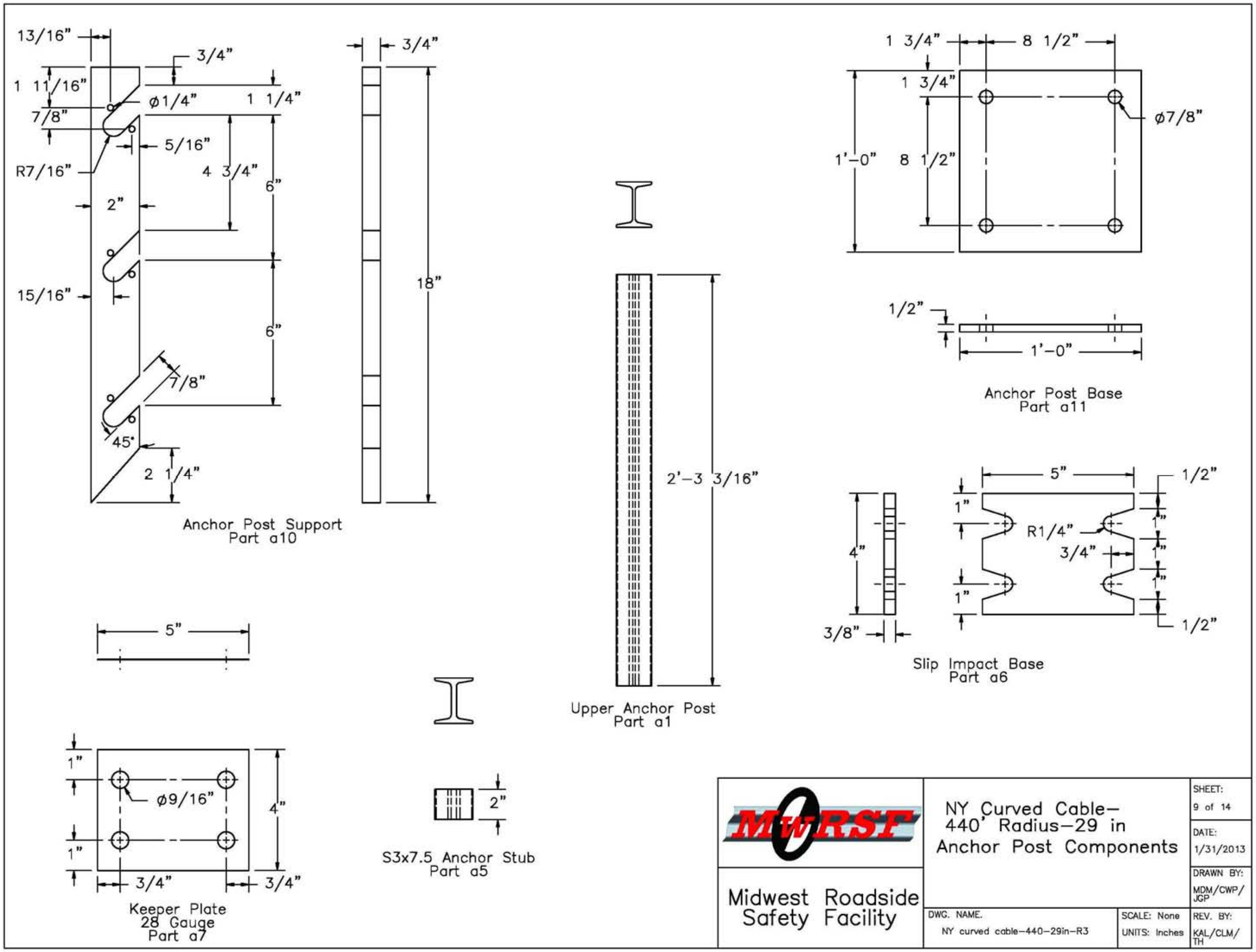


Figure 89. Anchor Post Component Details, Test No. NYCC-3

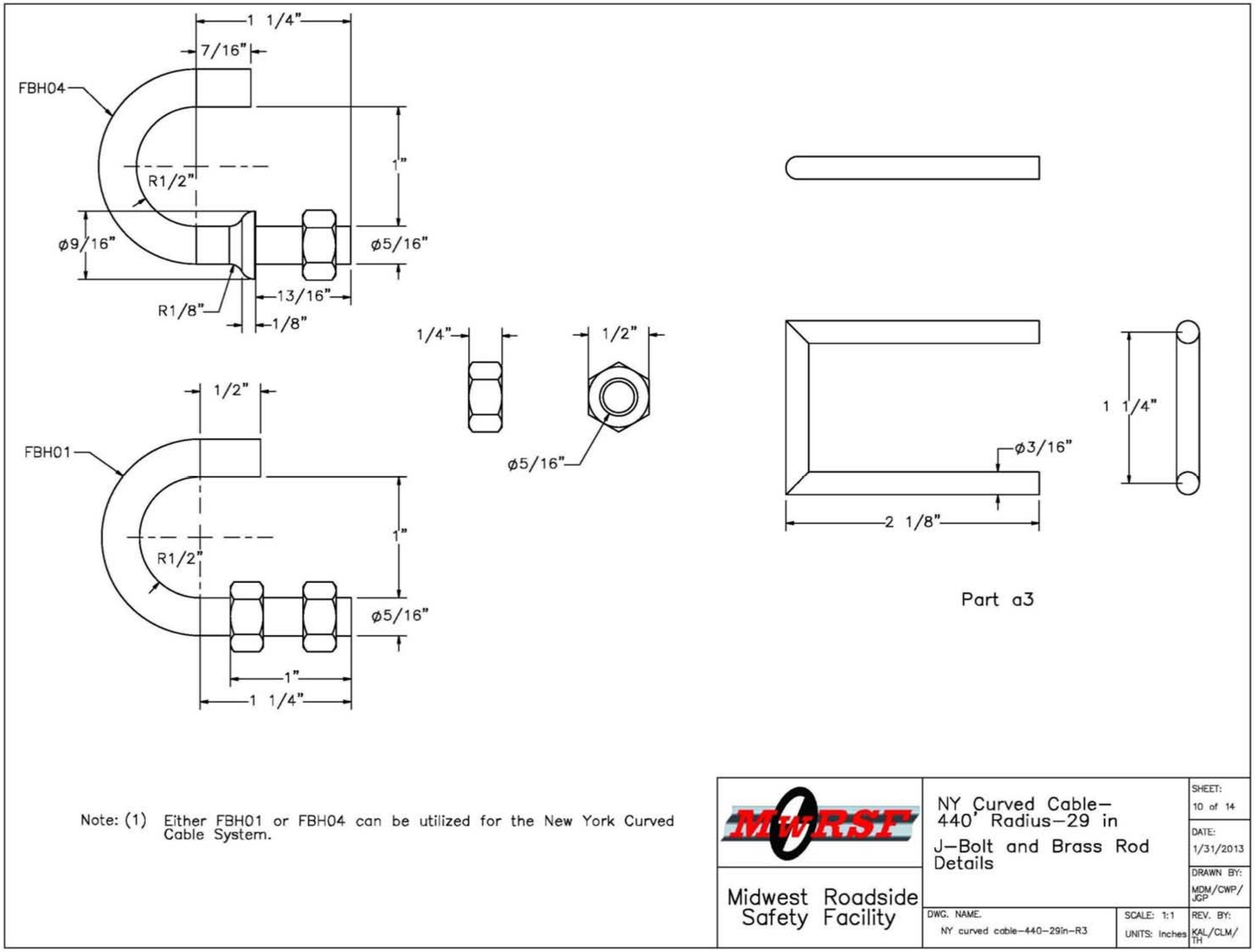


Figure 90. Cable Clip Details, Test No. NYCC-3

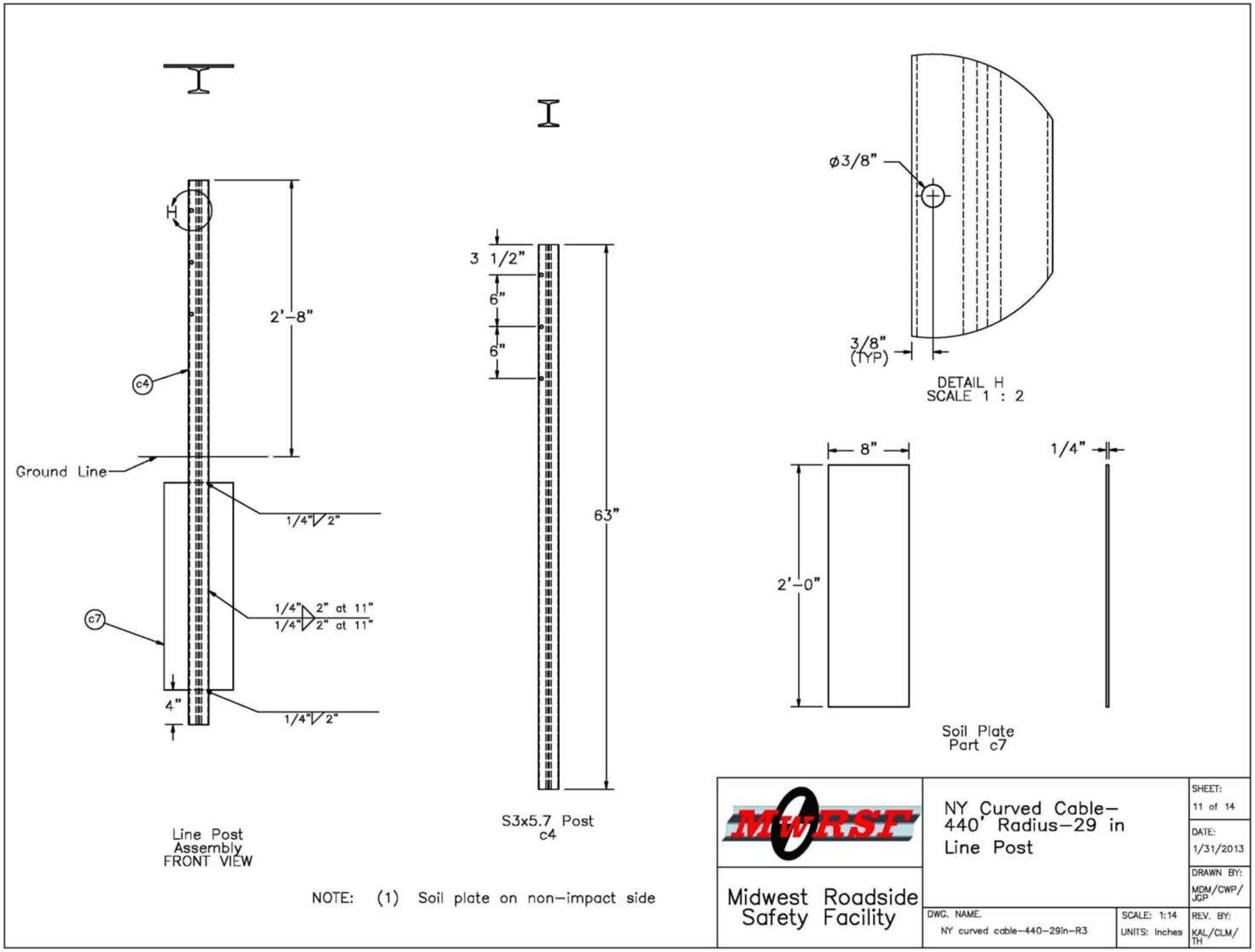
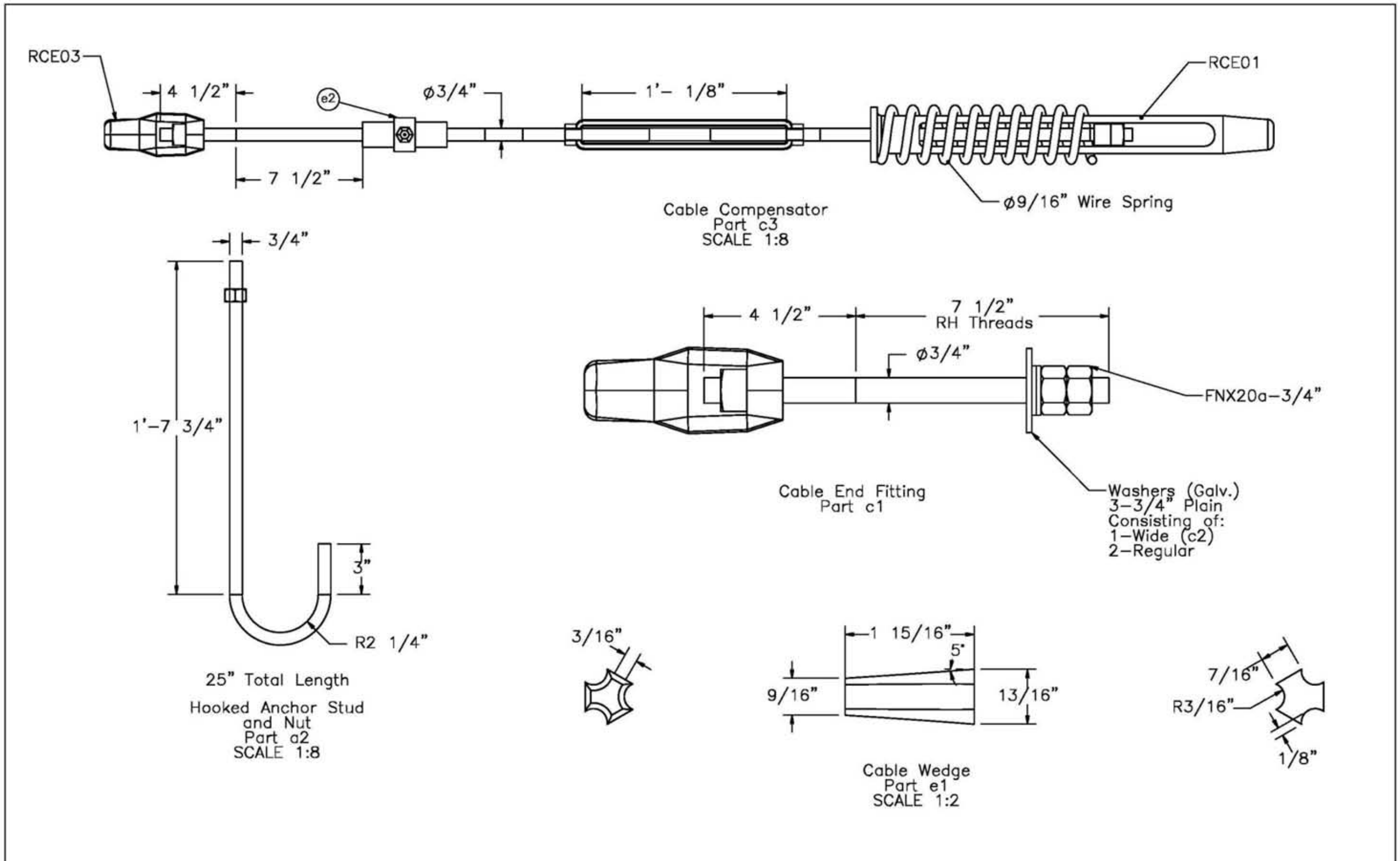


Figure 91. Line Post Details, Test No. NYCC-3



Washer	Washer Series	Inside Diameter "A" Basic	Inside Diameter "A" Tolerance Plus	Inside Diameter "A" Tolerance Minus	Outside Diameter "B" Basic	Outside Diameter "B" Tolerance Plus	Outside Diameter "B" Tolerance Minus	Thickness "C" Basic	Thickness "C" Max.	Thickness "C" Min.
3/4"	Regular	0.812	0.03	0.007	1.469	0.03	0.007	0.134	0.16	0.108
	Wide	0.812	0.03	0.007	2	0.03	0.007	0.165	0.192	0.136
1/2"	Narrow	0.531	0.015	0.005	1.062	0.03	0.007	0.095	0.121	0.074

Midwest Roadside Safety Facility

NY Curved Cable-440' Radius-29 in Anchor Stud and Cable Compensating Device

SHEET: 12 of 14
DATE: 1/31/2013
DRAWN BY: MDM/CWP/JGP
DWG. NAME. NY curved cable-440-29in-R3
SCALE: 1:4
UNITS: Inches
REV. BY: KAL/CLM/TH

Figure 92. Cable Compensator Component Details, Test No. NYCC-3

New York Curved Cable System				
Item No.	QTY.	Description	Material Spec	Hardware Guide
a1	2	S3x5.7 27 3/16" long Anchor Post	ASTM A36 Galvanized	–
a2	24	Hooked Anchor J–Bolt and Nut	ASTM A36 and ASTM A–563 DH Galvanized	FRH20a
a3	6	ϕ3/16" 5 1/4" Long Brass Rod	Brass	–
a4	36	ϕ3/4" Plain Round Washer–OD 1.5"	Grade 2 Galvanized	FWC20a
a5	2	S3x7.5 Anchor Post Stub	ASTM A36 Galvanized	–
a6	4	Slip Impact Base	ASTM A36 Galvanized	–
a7	2	4"x5" 28 Gauge Keeper Plate	ASTM A36 Galvanized	–
a8	8	ϕ1/2" x2 1/2" Long Bolt and Nut	Grade 2 Galvanized	FBX14a
a9	24	ϕ1/2" Narrow Washer–OD 1"	Grade 2 Galvanized	FWC12a
a10	2	3/4" Anchor Post Support Plate	A707 Grade 36 Galvanized	–
a11	2	Anchor Post Base	A709 Grade 36 Galvanized	–
b1	2	Anchor Bracket Plate	ASTM A709 Grade 36 Galvanized	–
b2	4	1/2" Thick External Stiffener	ASTM A709 Grade 36 Galvanized	–
b3	2	ϕ1/4"x15" Brass Rod	Brass	–
b4	4	1/4" Thick Internal Stiffener	ASTM A709 Grade 36 Galvanized	–
b5	2	Anchor Angle Middle Plate	ASTM A709 Grade 36 Galvanized	–
b6	2	Cable Plate	ASTM A709 Grade 36 Galvanized	–
c2	6	ϕ3/4" Plain Round Washer–OD 2"	Grade 2 Galvanized	FWC20a
c3	3	Compensating Cable End Assembly	ASTM A27 Galvanized	RCE01 & RCE03
c4	38	S3x5.7 63 in. long Line Post	ASTM A36 Galvanized	–
c5	114	Cable Hook Bolt and Nuts	ASTM F568 Class 4.6 and Grade A307 Galvanized	FBH04
c6	1	ϕ3/4" Cable Approx. 392'	AASHTO M30 Type 1 Class A Galvanized	RCM01
c7	38	2'x8"x0.25" Soil Plate	ASTM A36 Galvanized	–
d1	2	Concrete Anchor Block	3000 psi Compressive Strength	–
d2	12	#3 Rebar 32.5" long	Grade 60	–
d3	12	#3 Rebar 44.5" long	Grade 60	–
d4	16	#3 Rebar 33" long	Grade 60	–
e1	12	Cable Wedge	ASTM A47 Grade 32510	FMM01
e2	3	50,000–lb Load Cell	N/A	–

Midwest Roadside Safety Facility

NY Curved Cable–
440' Radius–29 in
Bill of Materials

SHEET: 13 of 14
DATE: 1/31/2013
DRAWN BY: MDM/CWP/JGP
DWG. NAME. NY curved cable–440–29in–R3
SCALE: None
UNITS: Inches
REV. BY: KAL/CLM/TH

Figure 93. Bill of Materials, Test No. NYCC-3

(1) All posts shall be s3x5.7 rolled steel section. The anchor post stub shall be s3x7.5. Where the rail is parallel to the edge of the pavement, every sixth post starting with the first shall be reflectorized. Do not reflectorize posts in the intermediate anchorage section, typical approach and terminal section, or when used as a median barrier.

(2) Reflectors shall be aluminum alloy 1/16" thick with reflective sheeting. The reflective sheeting shall be white when installed on the right side of traffic and fluorescent yellow when on the left.

(3) 3/4" round wire cable shall consist of three strands (7 wires per strand) and have a minimum tensile strength of 25,000 lbf.

(4) Cable ends shall be fabricated from malleable iron or cast steel. The cable splice and wedge shall be fabricated from malleable iron or ASTM A536 ductile.

(5) All cable ends and splices shall be designed to use the wedge shown on sheet 15 and shall develop the full strength of the 3/4" round cable (25000 lbs.). The cables, ends, and splices shall be hot dipped galvanized as indicated in material specification for cable guide rail. The wedge shall not be galvanized.

(6) Stagger cable splices, provide a minimum of 20' between any pair. Provide a minimum of 100' between cable splices on the same cable.

(7) Alternate designs for the steel turnbuckle cable end assembly or spring cable end assembly shall be submitted for approval.

(8) For arrangement of spring cable end assemblies (compensating device) and turnbuckle cable end assemblies, the following criteria shall apply:
- –Length of cable runs up to 1000'–use compensating device (RCE01) on one end, and turnbuckle (RCE03) on the other end of each individual cable.
- –Length of cable runs 1000' to 2000'–use compensating device (RCE01) on the ends of each individual cable.
- –Length of cable runs over 2000'–start a new stretch by interlacing at last parallel post (see typical intermediate anchorage details).

Prior to final acceptance by the state, the following values shall be used to tighten the turnbuckles, depending on the temperature at the time of adjustment.

Temperature (degrees Farenheit)													
120 to 110	109 to 100	99 to 90	89 to 80	79 to 70	69 to 60	59 to 50	49 to 40	39 to 30	29 to 20	19 to 10	9 to 0	-1 to -19	-20 to -29
Spring Compression from Unloaded Position in Each Spring-Measured in Inches													
1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4	4 1/2

(9) The concrete anchor shall be set into the excavation as detailed. The bottom of the anchor shall have a full and even bearing on the surface under it. The top shall be back filled in accordance with the requirements of 203–3.15 "fill and back fill at structures, culverts, pipes, conduits, and direct burial cables."

(10) Do not install cable guide railing on curves with a centerline radius of less than 440'.

(11) Curbs greater than 3" high are not to be retained or placed if design, posted, or operating speed exceeds 35 mph. Rail mounting height is to be measured from pavement if offset between pavement and curb is less than or equal to 9" and from ground beneath rail if offset > 9".

(12) Lifting devices, if embedded in concrete, shall be rated by their manufacturer as having a "safe working load" of four tons for the one piece anchor and two tons for each of the halves of the two piece anchor unit.

(13) At all locations where the cable is connected to a cable socket with a wedge type connection, one wire of the wire rope shall be crimped over the base of the wedge to hold it firmly in place.

Midwest Roadside Safety Facility	NY Curved Cable– 440' Radius–29 in Notes	SHEET: 14 of 14
		DATE: 1/31/2013
		DRAWN BY: MDM/CWP/JGP
DWG. NAME. NY curved cable–440–29in–R3	SCALE: None UNITS: Inches	REV. BY: KAL/CLM/TH

Figure 94. System Notes, Test No. NYCC-3

Figure 95. Test Installation Photographs, Test No. NYCC-3

Figure 96. Post Photographs, Test No. NYCC-3

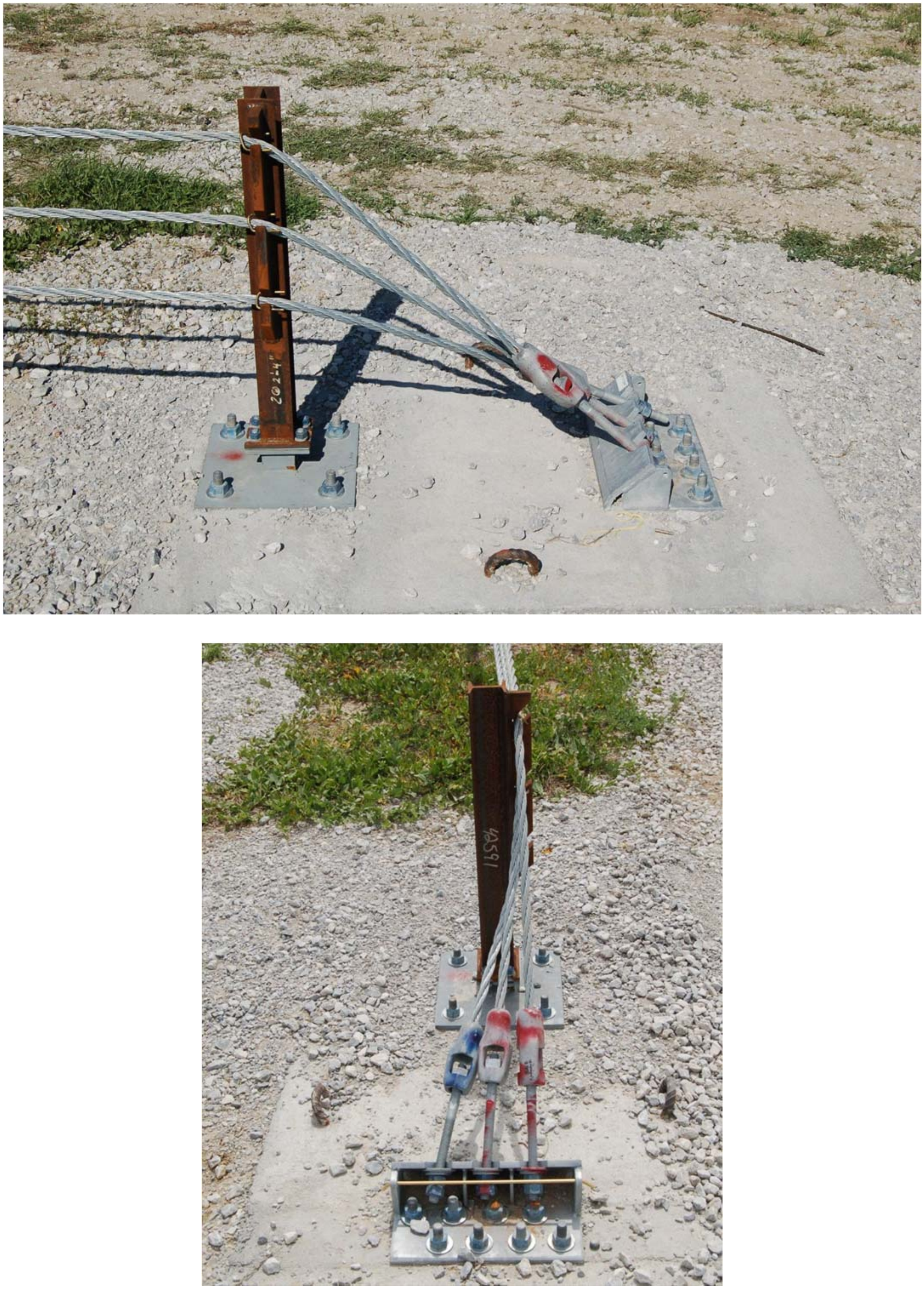


Figure 97. End Anchorage Photographs, Test No. NYCC-3

129

Figure 98. Cable Splices and Load Cells, Test No. NYCC-3

9 FULL-SCALE CRASH TEST NO. NYCC-3

9.1 Dynamic Soil Test

Before full-scale crash test no. NYCC-3 was conducted, the strength of the foundation soil was evaluated with a dynamic test, as described in MASH. The dynamic test results demonstrated a soil resistance above the minimum force limits described in MASH, as shown in Appendix C. Thus, the soil provided adequate strength, and full-scale crash testing could be conducted on the barrier system.

9.2 Test No. NYCC-3

The 4,998-lb (2,267-kg) pickup truck impacted the curved, three-cable barrier system at a speed of 63.1 mph (101.6 km/h), and at an angle of 21.6 degrees. A summary of the test results and sequential photographs are shown in Figure 99. Additional sequential photographs are shown in Figures 100 through 104.

9.3 Weather Conditions

Test no. NYCC-3 was conducted on April 26, 2012 at approximately 1:50 pm. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were recorded and are shown in Table 13.

Table 13. Weather Conditions, Test No. NYCC-3

Temperature	75° F
Humidity	34%
Wind Speed	11 mph
Wind Direction	70° from True North
Sky Conditions	Clear
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0 in.
Previous 7-Day Precipitation	0.1 in.

9.4 Test Description

Initial vehicle impact occurred at the targeted impact point 2 ft (0.6 m) upstream of post no. 17, as shown in Figure 105, which was selected by NYSDOT personnel. A sequential description of the impact events is contained in Table 14. The vehicle came to rest 310 ft – 7 in. (94.7 m) downstream of impact and 78 ft – 11 in. (24.0 m) laterally from the original impact point. The vehicle trajectory and final position are shown in Figures 99 and 106.

Table 14. Sequential Description of Impact Events, Test No. NYCC-3

TIME (sec)	EVENT
0.000	Vehicle impacted the system.
0.002	Top cable between post nos. 16 and 17 began to deflect downstream.
0.006	Right-front bumper contacted post no. 17.
0.008	Post no. 17 deflected backward.
0.010	Post no. 17 bent downstream.
0.022	Post no. 16 deflected backward and downstream.
0.030	Top cable released from post no. 17.
0.036	Vehicle right-front tire contacted post no. 17.
0.040	Post no. 18 deflected downstream.
0.052	Post no. 18 deflected backward.
0.056	Middle cable released from post no. 17.
0.062	Vehicle right-front tire rose off of the ground.
0.064	Posts between post nos. 17 and 37 began to deflect upstream.
0.080	Front-right tire overrode post no. 17 as well as bottom and middle cables.
0.082	Front bumper contacted post no. 18 and pushed it back and downstream.
0.102	Top cable released from post no. 18.
0.114	Vehicle bumper overrode post no. 18.
0.136	Post no. 20 deflected upstream.
0.146	Post no. 39 deflected upstream.
0.152	Top cable released from post no. 19.
0.170	Right-rear tire overrode post no.17.
0.172	Post no. 20 deflected backward.
0.178	Vehicle contacted post no. 19, bending it downstream.
0.186	Post nos. 21 deflected upstream.
0.188	Top cable released from post no. 20.
0.192	Left-front tire overrode bottom cable.
0.206	Vehicle bumper overrode post no. 19.
0.208	Right-rear tire lifted off ground.
0.246	Top cable released from post no. 21.

0.278	Left-front tired overrode bottom cable.
0.290	Right-front tire lifted off ground.
0.302	Left-front tire overrode middle cable.
0.304	Guidance hub on left-front tire contacted post no. 20. Post no. 24 deflected upstream.
0.316	Top cable released from post no. 22.
0.386	Top cable released from post no. 23.
0.398	Right-front tire contacted ground.
0.412	Post no. 24 deflected backward.
0.482	Top cable released from post no. 24.
0.500	Post no. 25 deflected backward.
0.518	Top cable released from post no. 25.
0.536	Post no. 26 deflected backward.
0.660	Top cable released from post no. 26.
0.666	Post no. 27 deflected backward.
0.810	Top cable released from post no. 27.
0.928	Vehicle contacted post no. 26, and it deflected downstream.
0.980	Post no. 28 deflected backward.
1.004	Vehicle contacted post no. 27, and it deflected downstream.
1.044	Vehicle contacted post no. 28, and it deflected downstream.
1.052	Top cable released from post no. 28.
1.074	Post no. 30 deflected upstream.
1.220	Top cable released from post no. 29.
1.212	Vehicle contacted post no. 29, and it deflected downstream.
1.258	Post no. 31 deflected upstream.
1.310	Vehicle contacted post no. 30, and it deflected downstream.
1.442	Post no. 32 deflected upstream.
1.538	Vehicle exited system.

9.5 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 107 through 116. Barrier damage consisted of bent posts and disengaged cables. The length of vehicle contact along the barrier was approximately 130 ft (39.6 m), which spanned from 2 ft (0.6 m) upstream from post no. 17 through post no. 31.

Post no. 1 was bent downstream at the slip base. All cables remained engaged with the upstream end anchorage as shown in Figure 108. No damage occurred to the system between post nos. 2 and 15.

The top cable disengaged from post nos. 16 through 30. The middle cable disengaged from post nos. 16 through 20 and 27 through 31. The bottom cable disengaged from post nos. 17 through 20 and 27 through 31. The cable-to-post attachment J-bolts were bent at varying magnitudes and directions between post nos. 16 and 32. Additionally, the middle cable J-bolt on post no. 27 was fractured.

Post no. 16 was bent and rotated downstream. Post nos. 17 through 20 were severely bent backward and twisted downstream with contact marks observed on the front flanges. Post nos. 21 through 25 were bent and rotated backward and downstream. Post nos. 26 through 30 were bent and twisted downstream with contact marks on the upstream edges of the flanges. Additionally, post no. 30 had gouges in the front and back flanges. The brass keeper rod for the bottom cable on post no. 40 was disengaged and the post was bent upstream with weld failure under the slip base as shown in Figure 116.

The permanent set of the system was 24 in. (610 mm) which occurred at post no. 17, as measured in the field. The maximum lateral dynamic barrier deflection was 14 ft - 4 in. (3,564 mm) which occurred near post no. 22, as determined from high-speed digital video analysis. The working width of the system was found to be 14 ft – 5 in. (4.4 m) and is shown in Figure 117.

9.6 Vehicle Damage

The damage to the vehicle was minimal, as shown in Figures 118 and 119. The maximum occupant compartment deformations are listed in Table 15 along with the deformation limits established in MASH for various areas of the occupant compartment. Note that none of the MASH established deformation limits were exceeded. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D.

Table 15. Maximum Occupant Compartment Deformations by Location, Test No. NYCC-3

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

The majority of the damage was concentrated on the right-front corner and right side of the vehicle where the impact occurred. Cable contact marks were found along the entire right side of the vehicle as well as on both right-side tires and on the right-rear rim. All tires remained inflated. Contact marks were located on the right-front bumper that resulted in buckling. The right headlight was partially disengaged. The right side of the grill was cracked. The left side of the vehicle and all window glass remained undamaged.

9.7 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 16. Note that the OIVs and ORAs were within the suggested limits provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 16. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 99. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix E.

Table 16. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NYCC-3

Evaluation Criteria		Transducer			MASH Limits (Absolute Value)
		EDR-3	DTS SLICE	DTS	
OIV ft/s (m/s)	Longitudinal	-10.20 (-3.11)	-8.36 (-2.55)	-8.49 (-2.59)	≤ 40 (12.2)
	Lateral	-7.55 (-2.30)	-7.04 (-2.14)	-6.88 (-2.10)	≤40 (12.2)
ORA g’s	Longitudinal	-4.26	-2.24	-2.74	≤ 20.49
	Lateral	-2.71	-3.69	-3.03	≤ 20.49
THIV ft/s (m/s)		NA	10.27 (3.13)	10.89 (3.32)	not required
PHD g’s		NA	3.72	3.08	not required
ASI		0.25	0.23	0.23	not required

9.8 Load Cell Results

As previously discussed, tension load cells were installed in line with the cables at the upstream end of the barrier system in order to monitor the total load transferred to the end anchor system with respect to time. The load cell results are summarized in Table 17. The individual cable loads and the total combined cable load imparted to the upstream end anchor are shown graphically in Figures 120 and 121, respectively. The pre-tension in each cable was 914 lb (4.07 kN) as measured from the displacement in the spring compensators near the upstream anchorage. After the crash test, the tension in the top, middle, and bottom cables was 99.8 lb (0.44 kN), 378 lb (1.68 kN), and 883 lb (3.93 kN), respectively.

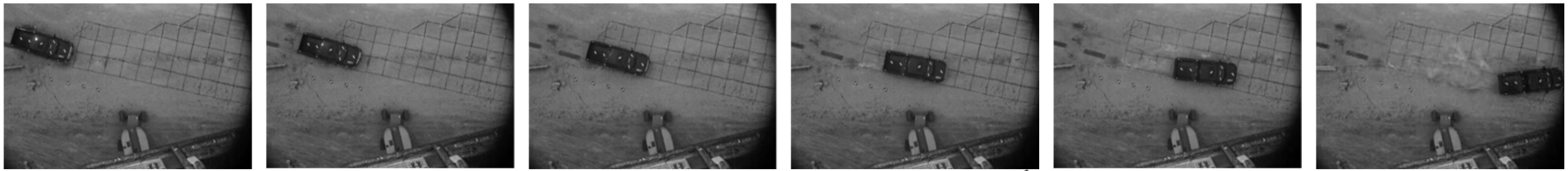
Table 17. Summary of Load Cell Results, Test No. NYCC-3

Cable Location	Sensor Location	Maximum Cable Load		Time* (sec)
		kips	kN	
Combined Cables	Upstream End	17.34	77.13	0.308
Top Cable	Upstream End	14.73	65.55	0.241
Middle Cable	Upstream End	8.37	37.23	0.293
Bottom Cable	Upstream End	2.54	11.30	0.063

* - Time determined from initial vehicle impact with the barrier system.

9.9 Discussion

The analysis of the test results for test no. NYCC-3 showed that the generic, three-cable barrier with a 440 ft (134.1 m) curved radius and a 29 in. (734 mm) top mounting height adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. There were no detached elements nor fragments which showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. 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 safety criteria nor cause rollover. Therefore, test no. NYCC-3 was determined to be acceptable according to the MASH safety performance criteria for modified test designation no. 3-11.



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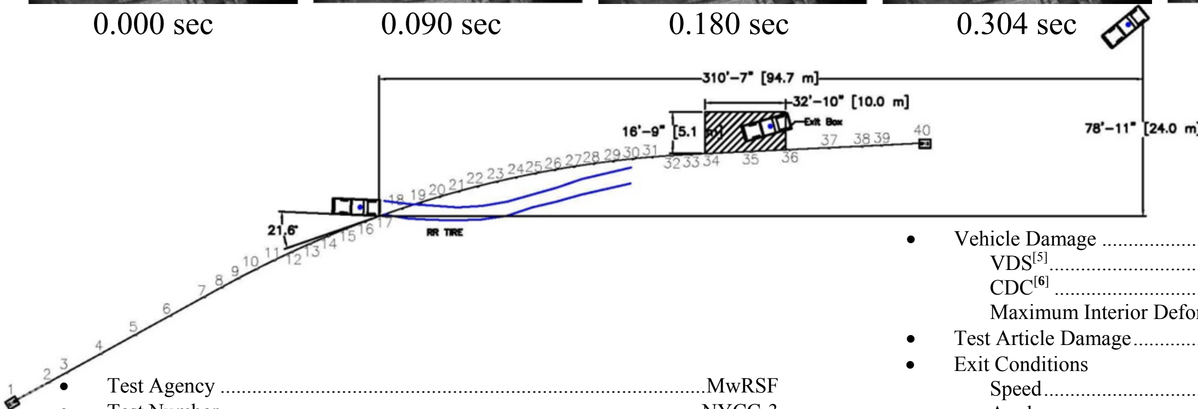

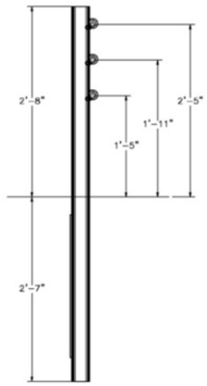

- Test Agency .... MwRSF
- Test Number NYCC-3
- Date 4/26/12
- MASH Test Designation .... Modified 3-11
- Test Article .... 440 ft (134.1 m) radius curved three cable barrier
- Total Length .... 389 ft 4 in. (118.7 m)
- Key Component - Rail
  - Diameter .... ¾ in. (19 mm)
  - Size S3x7
  - Top Cable Height .... 29 in. (737 mm)
  - Middle Cable Height .... 23 in. (584 mm)
  - Bottom Cable Height .... 17 in. (432 mm)
- Key Component - Post
  - Length .... 63 in. (1,600 mm)
  - Shape S3x5.7 (S76x8.5)
  - Spacing - Curved Section .... 8 ft (2.4 m)
  - Spacing - Tangent End Sections .... 16 ft (4.9 m)
- Soil Type .... Grade B of AASHTO M147-65 (1990)
- Vehicle Make /Model .... 2005 Dodge Ram 1500 Quad Cab
  - Curb .... 5,134 lb (2,329 kg)
  - Test Inertial .... 4,994 lb (2,265 kg)
  - Gross Static .... 5,166 lb (2,343 kg)
- Impact Conditions
  - Speed .... 63.1 mph (101.6 km/h)
  - Angle .... 21.6 deg.
  - Impact Location .... 2 ft (0.6 m) upstream of post 17
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 310 ft – 7 in. (94.7 m) downstream
- 78 ft – 11 in. (24.0 m) laterally
- Vehicle Damage .... Minimal
  - VDS[5] 01-RFQ-3
  - CDC[6] 01-RYEE-1
  - Maximum Interior Deformation .... ½ in. (13 mm)
- Test Article Damage .... Moderate
- Exit Conditions
  - Speed .... 50 mph (80.5 km/h)
  - Angle .... 18 deg.
- Maximum Test Article Deflections
  - Permanent Set .... 2 ft (0.6 m)
  - Dynamic .... 14 ft - 4 in. (4.37 m)
  - Working Width .... 14 ft – 5 in. (4.39 m)
- Maximum Angular Displacements
  - Roll .... -5.6° < 75°
  - Pitch .... -4.1° < 75°
  - Yaw .... -24.4°
- Impact Severity (IS) .... 83.5 kip-ft (113.2 kJ)
- Transducer Data

Evaluation Criteria		Transducer			MASH Limit (Absolute Value)
		EDR-3	DTS SLICE	DTS	
OIV ft/s (m/s)	Longitudinal	-10.20 (-3.11)	-8.36 (-2.55)	-8.49 (-2.59)	≤ 40 (12.2)
	Lateral	-7.55 (-2.30)	-7.04 (-2.14)	-6.88 (-2.10)	≤ 40 (12.2)
ORA g's	Longitudinal	-4.26	-2.24	-2.74	≤ 20.49
	Lateral	-2.71	-3.69	-3.03	≤ 20.49
THIV – ft/s (m/s)		NA	10.27 (3.13)	10.89 (3.32)	Not required
PHD – g's		NA	3.72	3.08	Not required
ASI		0.25	0.23	0.23	Not required

Figure 99. Summary of Test Results and Sequential Photographs, Test No. NYCC-3


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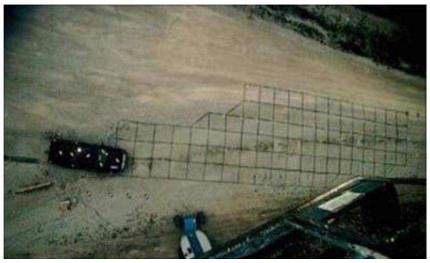
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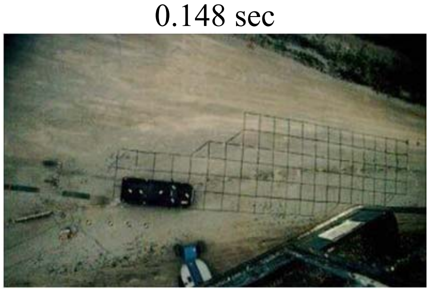
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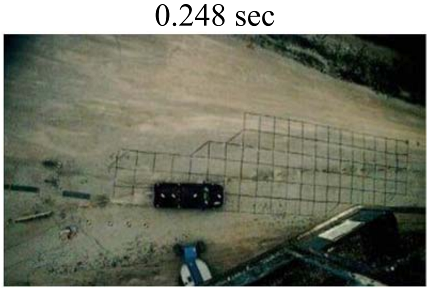
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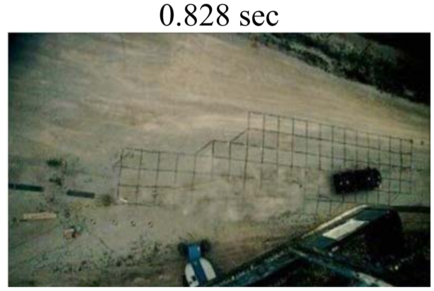
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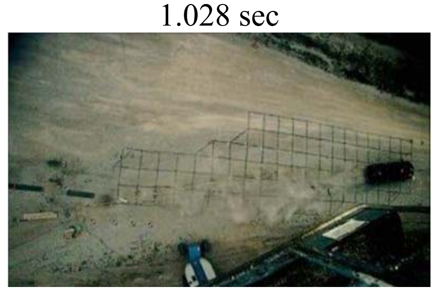
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Figure 100. Additional Sequential Photographs, Test No. NYCC-3

0.000 sec

0.046 sec

0.100 sec

0.430 sec

0.590 sec

0.690 sec

0.000 sec

0.038 sec

0.062 sec

0.088 sec

0.118 sec

0.208 sec

Figure 101. Additional Sequential Photographs, Test No. NYCC-3


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0.114 sec


0.160 sec


0.192 sec


0.228 sec

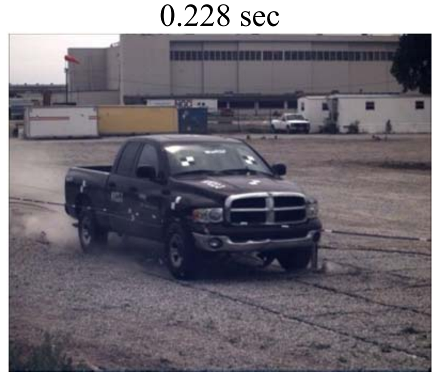
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Figure 102. Additional Sequential Photographs, Test No. NYCC-3

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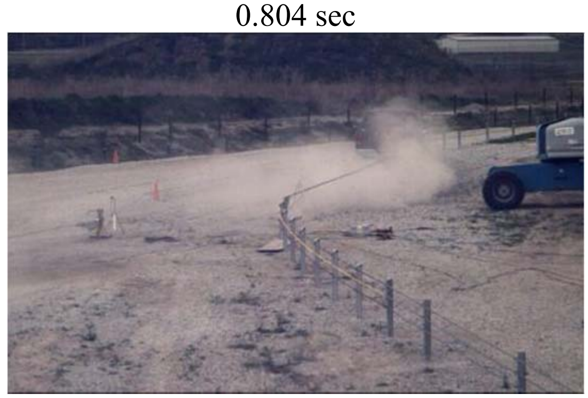
0.064 sec

0.206 sec

0.304 sec

0.504 sec

0.804 sec



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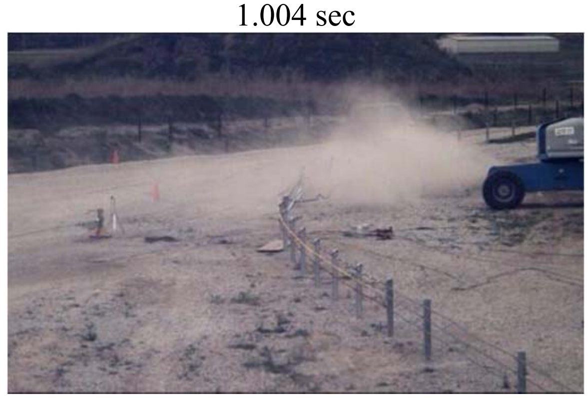

1.398 sec

Figure 103. Additional Sequential Photographs, Test No. NYCC-3

0.000 sec

0.108 sec

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0.304 sec

0.404 sec

0.512 sec

0.672 sec

0.900 sec

1.004 sec

1.258 sec

1.442 sec

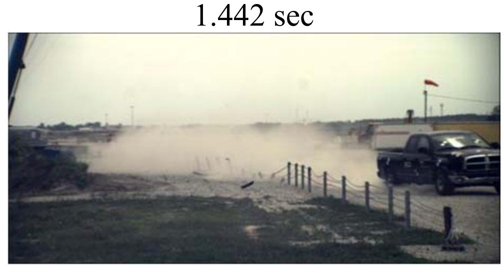

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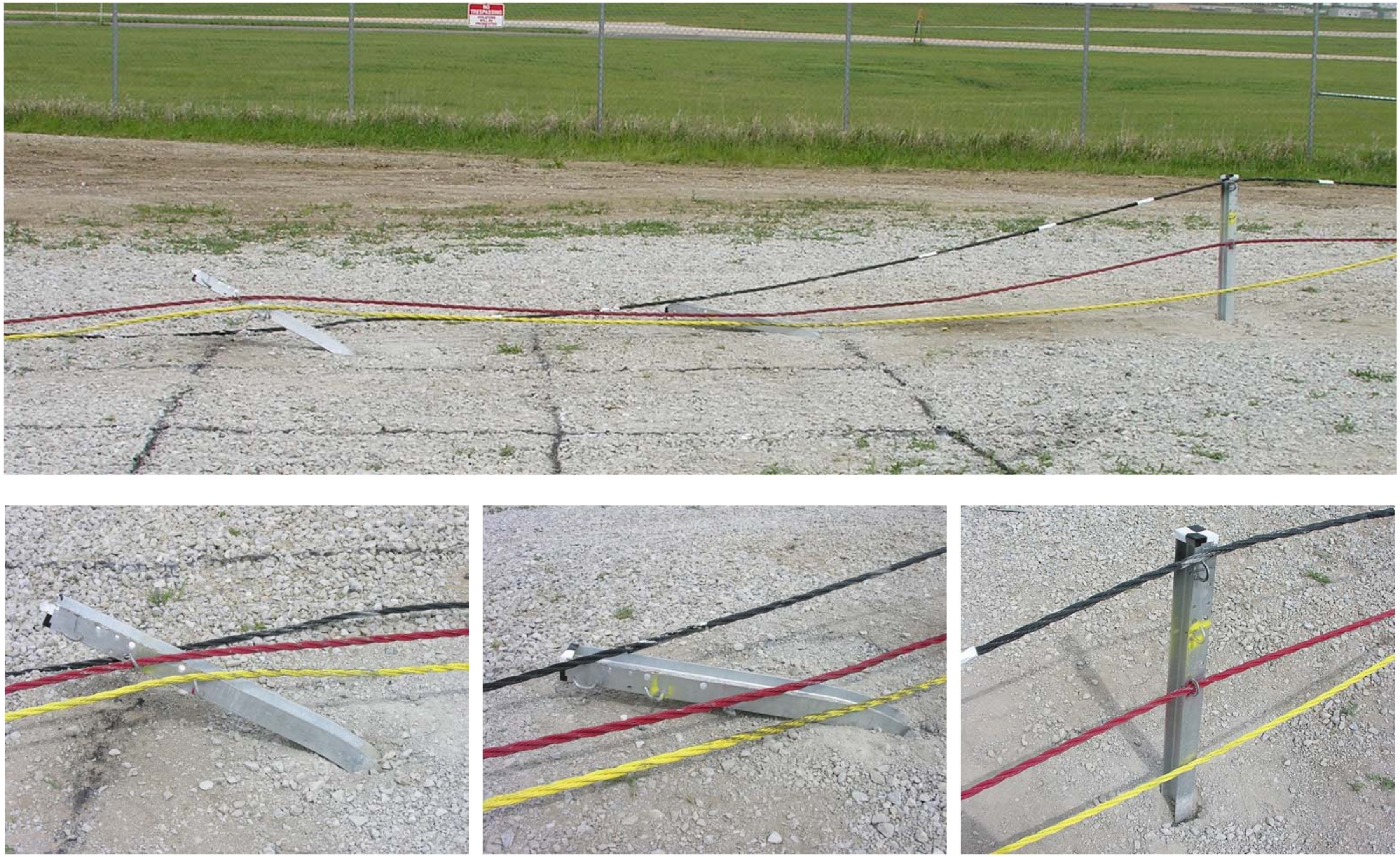
Figure 104. Additional Sequential Photographs, Test No. NYCC-3

Figure 105. Impact Location, Test No. NYCC-3

Figure 106. Vehicle Final Position and Trajectory Marks, Test No. NYCC-3

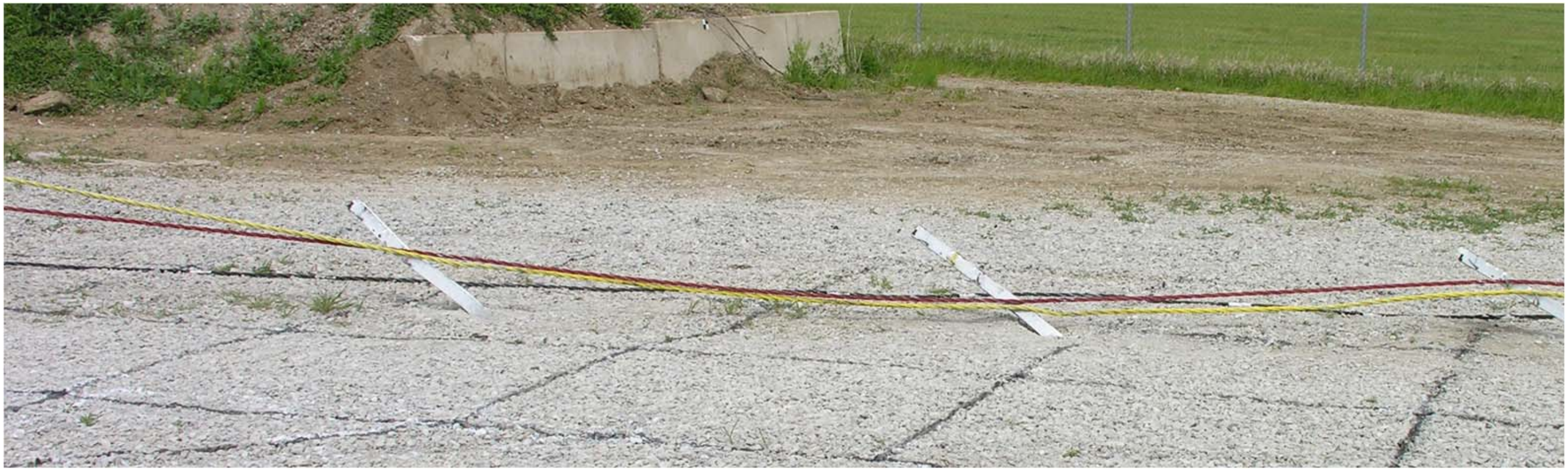
Figure 107. System Damage, Test No. NYCC-3

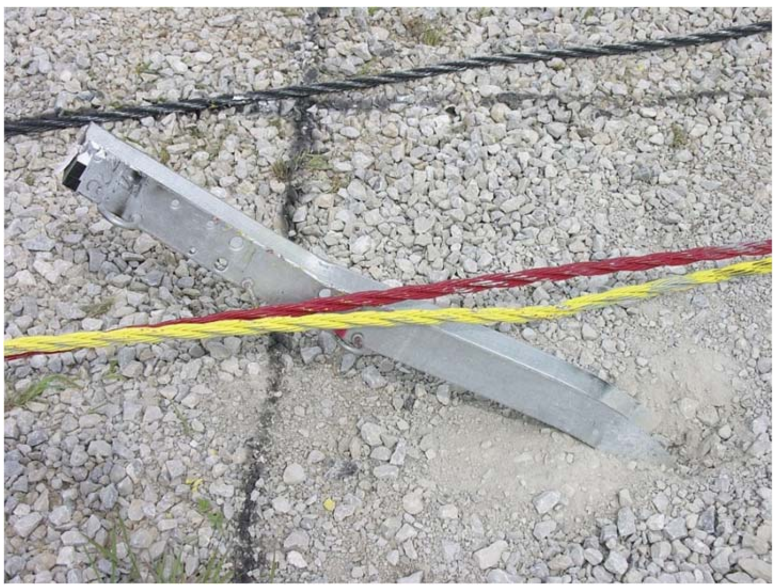
Figure 108. System Damage: Post No. 1, Test No. NYCC-3



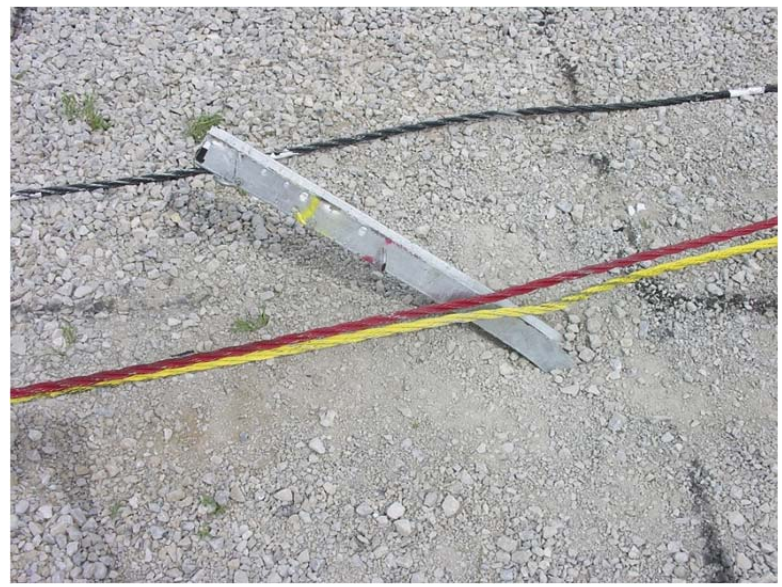
Post No. 18 Post No. 17 Post No. 16

Figure 109. System Damage: Post Nos. 16 through 18, Test No. NYCC-3





Post No. 20



Post No. 19

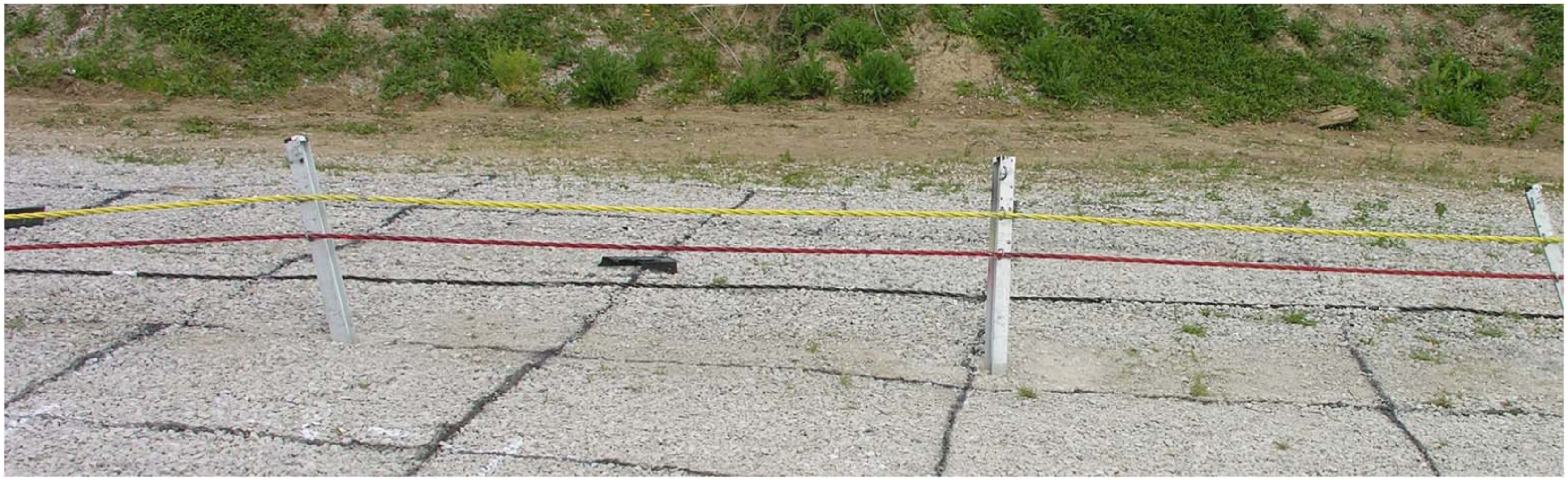
Figure 110. System Damage: Post Nos. 19 and 20, Test No. NYCC-3

Post No. 23

Post No. 22

Post No. 21

Figure 111. System Damage: Post Nos. 21 through 23, Test No. NYCC-3

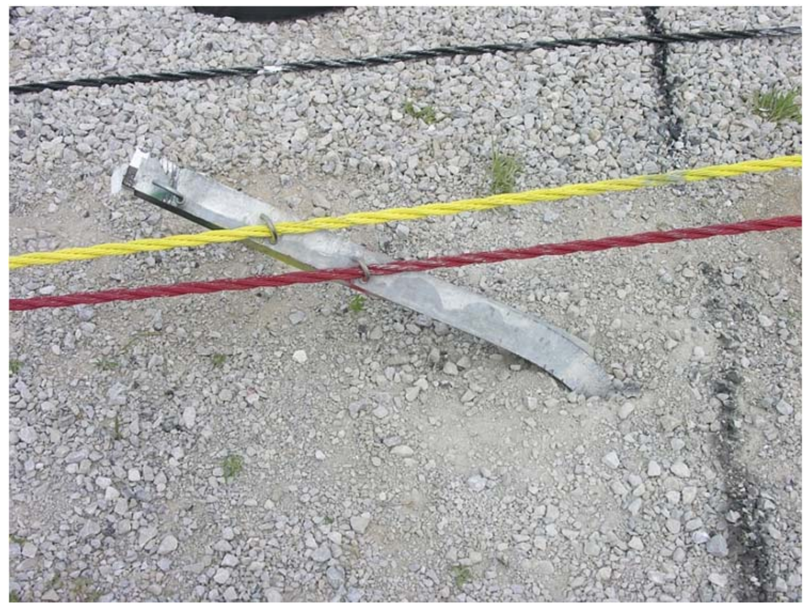


Post No. 25

Post No. 24

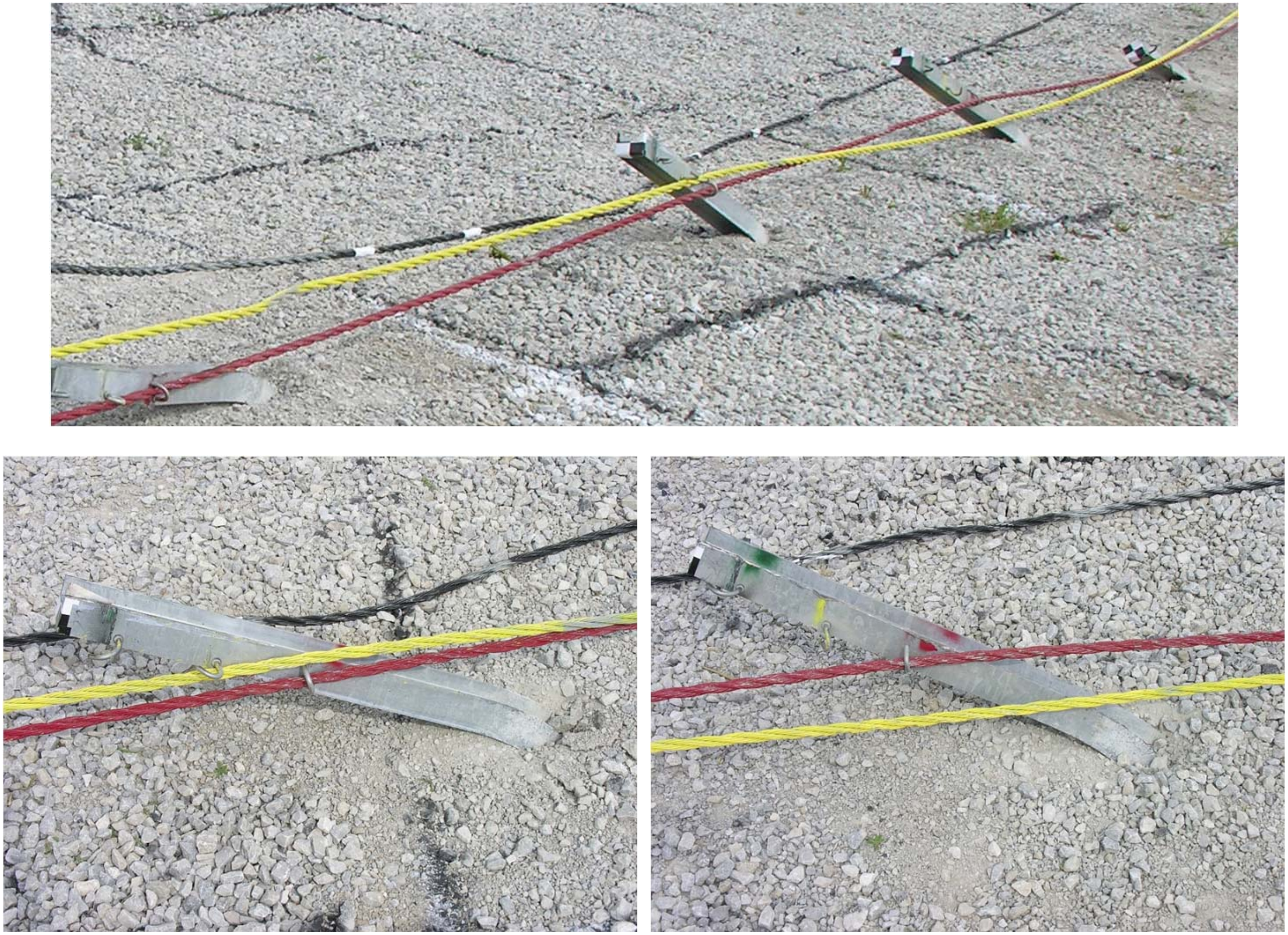
Figure 112. System Damage: Post Nos. 24 and 25, Test No. NYCC-3

Post No. 27



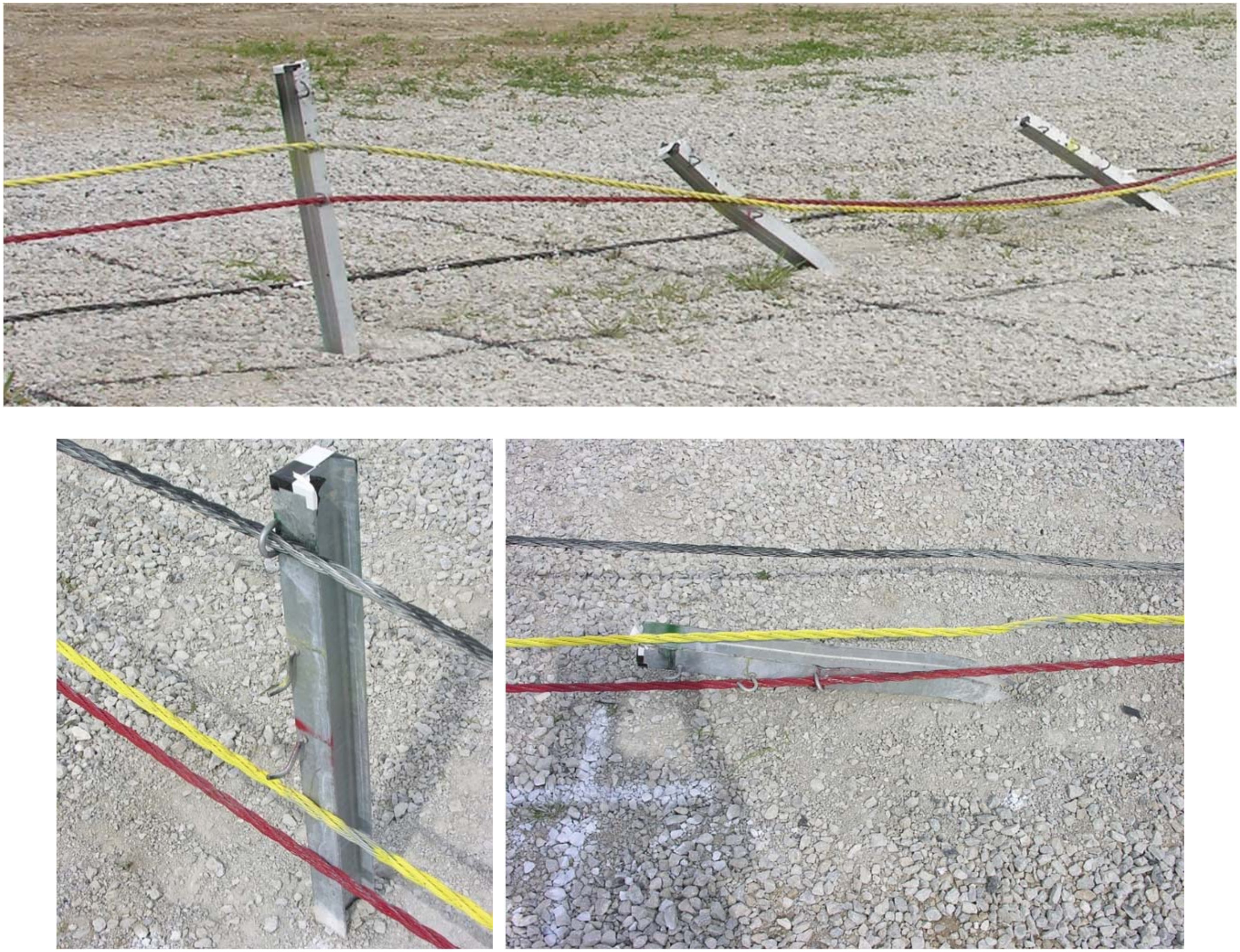
Post No. 26

Figure 113. System Damage: Post Nos. 26 and 27, Test No. NYCC-3



Post No. 29 Post No. 28

Figure 114. System Damage: Post Nos. 28 and 29, Test No. NYCC-3



Post No. 31

Post No. 30

Figure 115. System Damage: Post Nos. 30 and 31, Test No. NYCC-3

Figure 116. System Damage: Post No. 40, Test No. NYCC-3

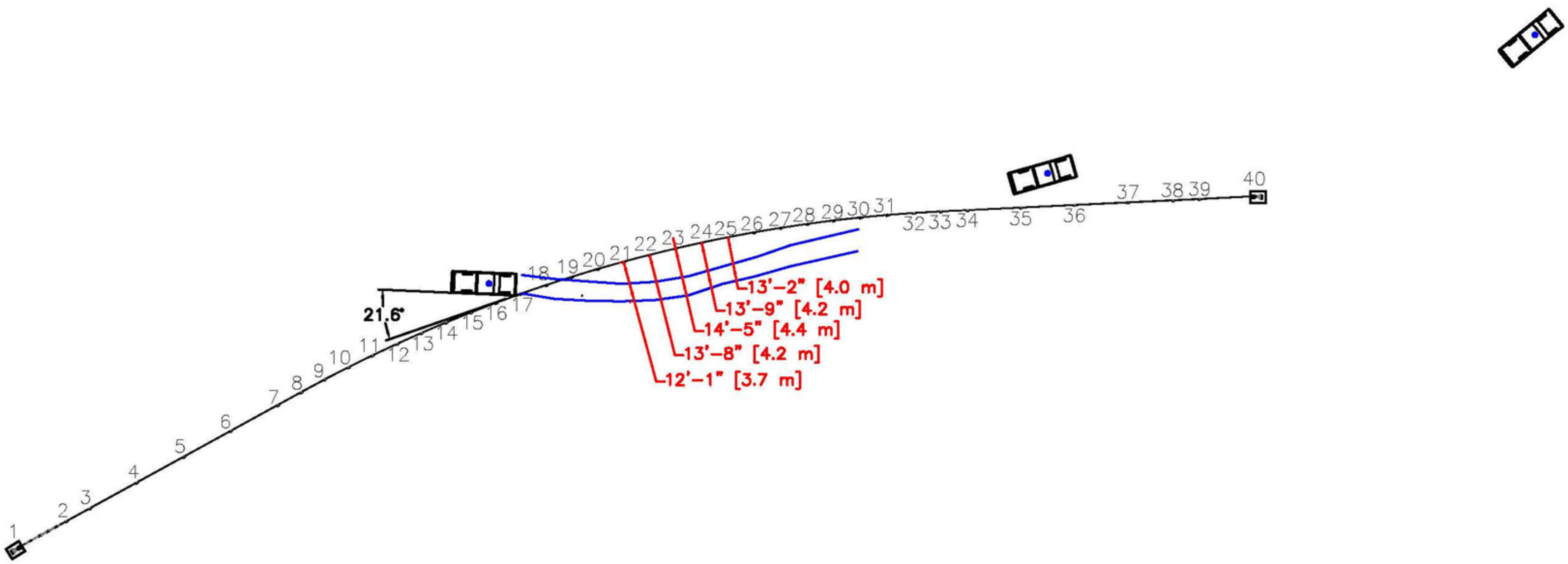
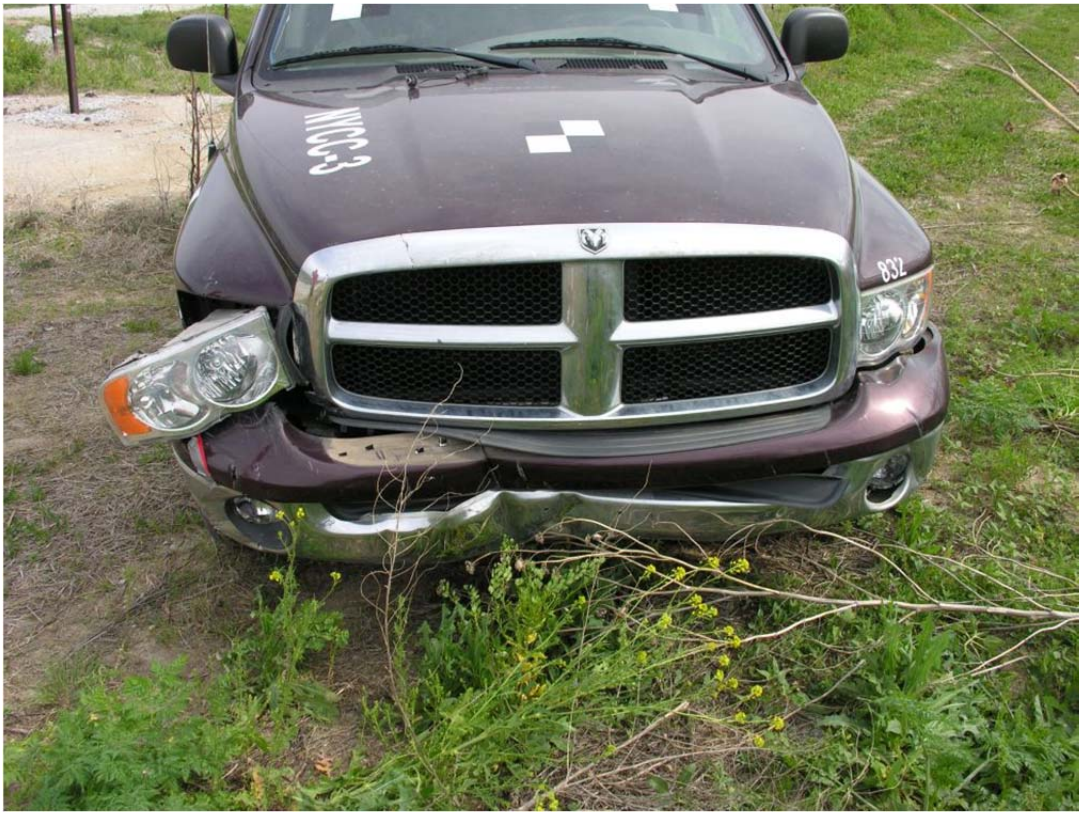


Figure 117. Working Width, Test No. NYCC-3

Figure 118. Vehicle Damage, Test No. NYCC-3



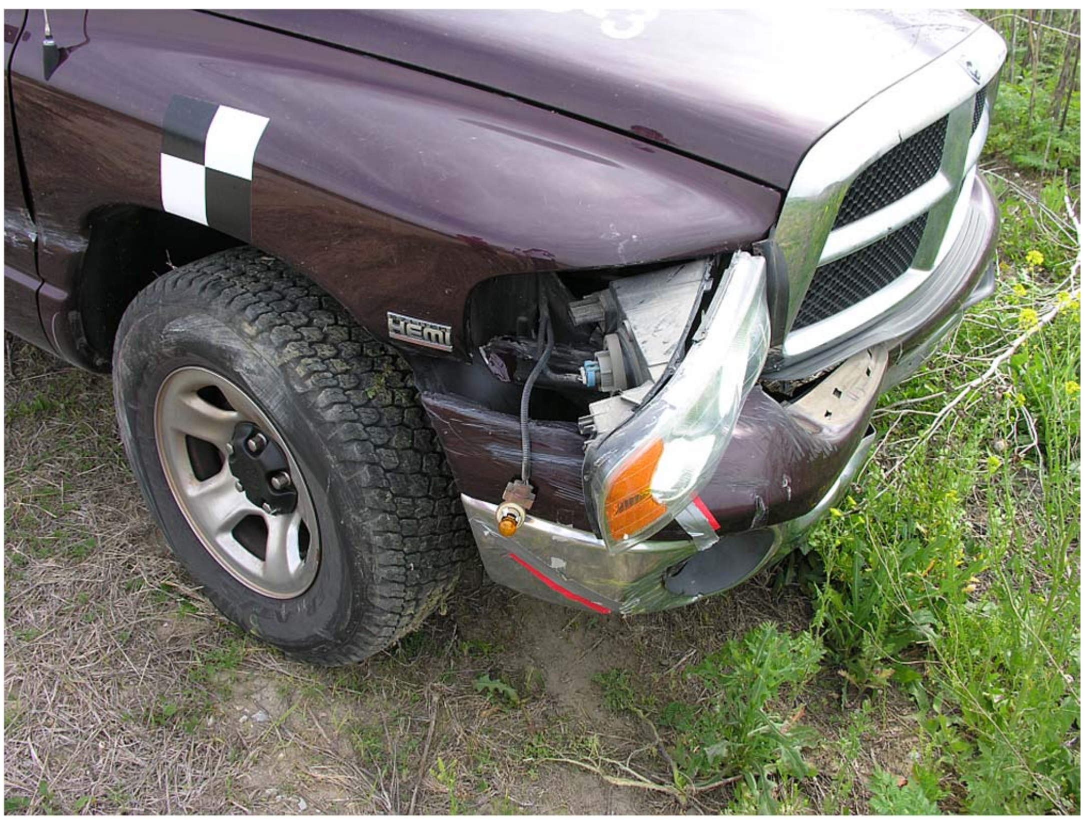


Figure 119. Vehicle Damage, Test No. NYCC-3

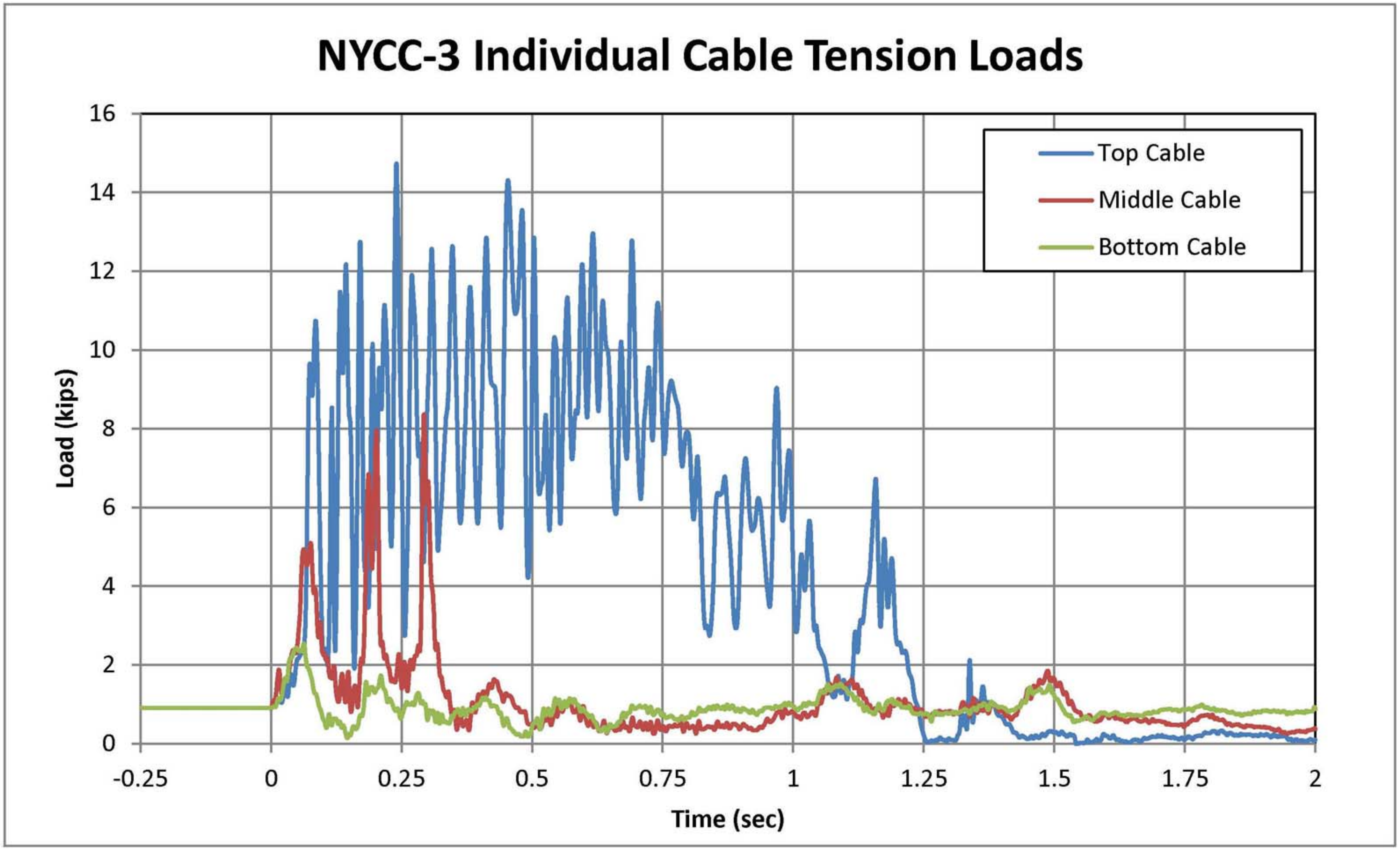


Figure 120. Individual Cable Tension vs. Time, Test No. NYCC-3

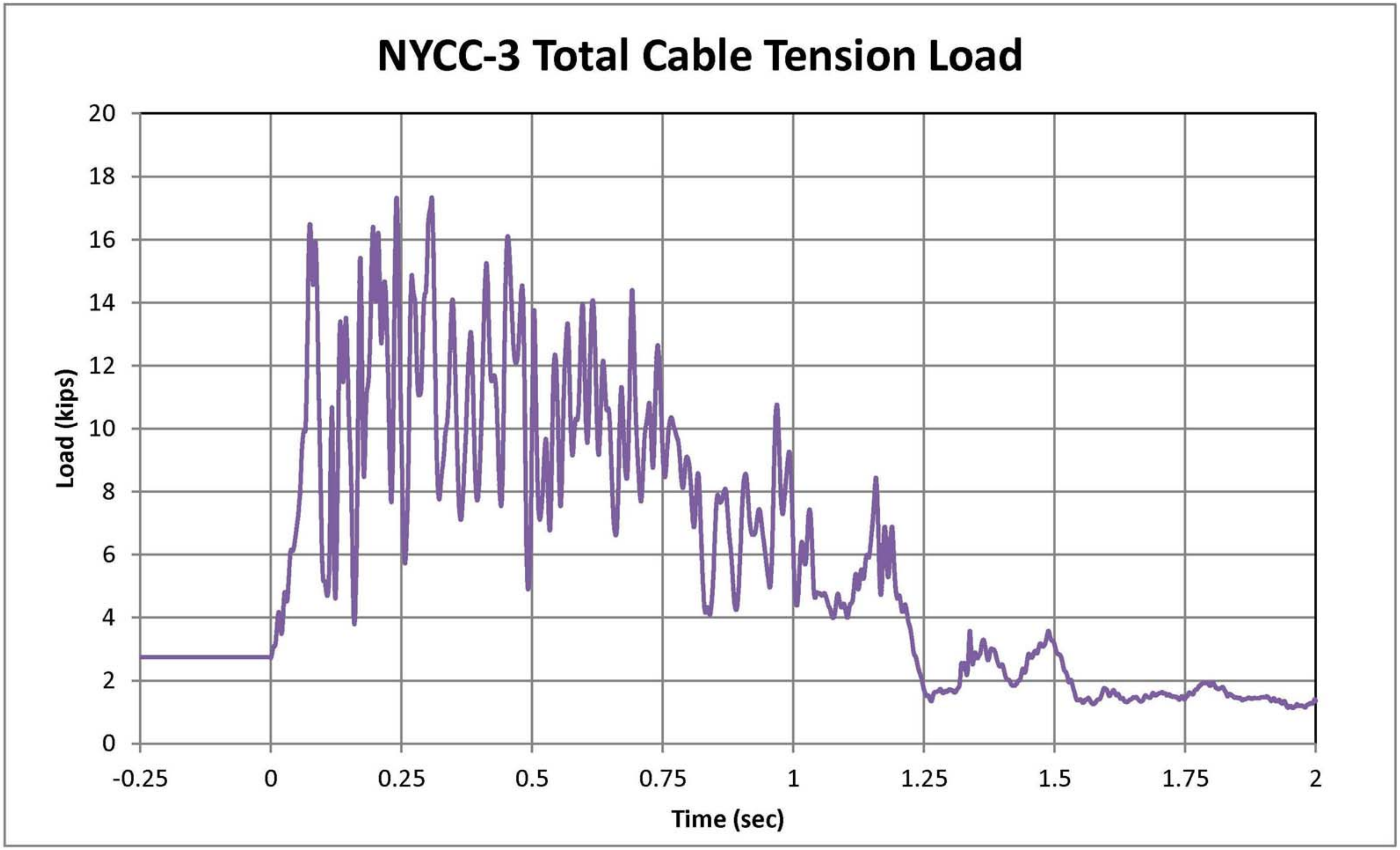


Figure 121. Total Cable Tension vs. Time, Test No. NYCC-3

10 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The goal of this study was to evaluate the safety performance and dynamic barrier deflections of the New York State DOT generic, low-tension, three-cable barrier system when installed in curved configurations. During the evaluation process, the cable barrier was subjected to three full-scale crash tests and evaluated according to the TL-3 impact safety standards provided in MASH using a modified test designation no. 3-11. The deviations from a standard MASH test designation no. 3-11 were: (1) the impact angle was 20 degrees instead of 25 degrees and (2) the impact point was targeted as 70 ft (21.3 m) downstream from the end tangent segment or 2 ft (0.6 m) upstream from a post, as specified by NYSDOT personnel.

The system installation for test no. NYCC-1 consisted of a top cable height of 27 in. (686 mm) and a curve radius of 360 ft (110 m). In test no. NYCC-1, the 2270P vehicle impacted the system at an angle of 19.9 degrees relative to the tangent of the curve and at a speed of 61.6 mph (99.1 km/h). The vehicle was satisfactorily contained and redirected. No excessive deformations or penetrations to the occupant compartment occurred, and the recorded vehicle accelerations did not violate the OIV or ORA limits established in MASH. Therefore, test no. NYCC-1 was deemed a successful test according to the modified MASH test designation no. 3-11 safety evaluation criteria.

The radius of the barrier system for test no. NYCC-2 was increased to 440 ft (134 m), but all other components and dimensions remained the same. In test no. NYCC-2, the 2270P vehicle impacted the system at an angle of 22.1 degrees relative to the tangent of the curve and at a speed of 61.7 mph (99.3 km/h). The vehicle overrode the barrier system as the top cable did not release quick enough to capture the bumper of the vehicle. The vehicle was free-wheeling behind the system for approximately 150 ft (45 m) before striking an embankment, which caused it to roll over. Thus, the rollover was not considered a result of the vehicle to barrier interaction.

However, test no. NYCC-2 was deemed unsuccessful according to the modified MASH test designation no. 3-11 safety evaluation criteria because the vehicle was not contained by the barrier.

Following the results of test no. NYCC-2, it was thought that the barrier mounting height was too low to capture taller vehicles (e.g., 2270P vehicle). Thus, it was decided to raise the entire system 2 in. (51 mm) to achieve a top cable height of 29 in. (737 mm). In test no. NYCC-3, the 2270P vehicle impacted the system at an angle of 21.6 degrees relative to the tangent of the curve and at a speed of 63.1 mph (101.6 km/h). The vehicle was satisfactorily contained and redirected. No excessive deformations or penetrations to the occupant compartment occurred, and the recorded vehicle accelerations did not violate the OIV or ORA limits established in MASH. Therefore, test no. NYCC-1 was deemed a successful test according to the modified MASH test designation no. 3-11 safety evaluation criteria. Summaries of the safety performance evaluations conducted for all three tests are shown in Table 18.

Based on the results of these tests, the standard top cable height of 27 in. (686 mm) for New York State DOT cable barrier was deemed acceptable for use on curves with radius of 360 ft (110 m). Unfortunately, a similar test with a larger radius of 440 ft (134 m) resulted in barrier override. Following the crash test failure of a barrier with a 27-in. (686-mm) top cable height in combination with a 440 ft (134 m) curve, a 29-in. (737-mm) top cable height was crash tested and provided acceptable results. Of course, it would seem reasonable to consider using a consistent top mounting height for all curved cable guardrail installations regardless of radii.

Table 18. Summary of Safety Performance Evaluation Results

<table>
<tr><th>Evaluation Factors</th><th colspan="4">Evaluation Criteria</th><th>Test No. NYCC-1</th><th>Test No. NYCC-2</th><th>Test No. NYCC-3</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>U</td><td>S</td></tr>
<tr><td rowspan="11">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.</td><td>S</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><td>S</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.3 of MASH for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td><td rowspan="4">S</td><td rowspan="4">S</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s (9.1 m/s)</td><td>40 ft/s (12.2 m/s)</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.3 of MASH for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td><td rowspan="4">S</td><td rowspan="4">S</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g's</td><td>20.49 g's</td></tr>
<tr><td colspan="5">MASH Test Designation No.</td><td>Modified 3-11</td><td>Modified 3-11</td><td>Modified 3-11</td></tr>
<tr><td colspan="5">Pass/Fail</td><td>Pass</td><td>Fail</td><td>Pass</td></tr>
</table>

S – Satisfactory U – Unsatisfactory NA - Not Applicable

REFERENCES

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

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

3. *Center of Gravity Test Code - SAE J874 March 1981,* SAE Handbook Vol. 4, Society of Automotive Engineers, Inc., Warrendale, Pennsylvania, 1986.

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

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

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

11 APPENDICES

Appendix A. Vehicle Center of Gravity Determination

Test: NYCC-1 Vehicle: 2270P

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb)	Vert CG (in.)	Vert M (lb-in.)
+	Unbalasted Truck (Curb)	5094	28.87094	147068.6
+	Brake receivers/wires	6	52	312
+	Brake Frame	5	25	125
+	Brake Cylinder (Nitrogen)	27	27	729
+	Strobe/Brake Battery	6	31	186
+	Hub	26	14.875	386.75
+	CG Plate (EDRs)	7.5	32	240
-	Battery	-42	40	-1680
-	Oil	-7	18	-126
-	Interior	-62	23	-1426
-	Fuel	-161	21	-3381
-	Coolant	-13	37	-481
-	Washer fluid	0	0	0
BALLAST	Water	120	21	2520
	DTS	17	30	510
	Misc.			0
				144983.3

Estimated Total Weight (lb)	5023.5
Vertical CG Location (in.)	28.86102

wheel base (in.) 140.25

MASH Targets	Targets	Test Inertial	Difference
Test Inertial Weight (lb)	5000 ± 110	5023.5	23.5
Long CG (in.)	63 ± 4	63.06	0.06249
Lat CG (in.)	NA	0.102232	NA
Vert CG (in.)	≥ 28	28.86	0.86102

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	1433	1386
Rear	1133	1142

FRONT	2819 lb
REAR	2275 lb
TOTAL	5094 lb

TEST INERTIAL WEIGHT (lb)

(from scales)

	Left	Right
Front	1481	1288
Rear	1085	1166

FRONT	2769 lb
REAR	2251 lb
TOTAL	5020 lb

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

Test: NYCC-2 Vehicle: 2270P

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb)	Vert CG (in.)	Vert M (lb-in.)
+	Unbalasted Truck (Curb)	5001	28.17057	140881
+	Brake receivers/wires	5	52.5	262.5
+	Brake Frame	5	26	130
+	Brake Cylinder (Nitrogen)	22	28	616
+	Strobe/Brake Battery	6	31	186
+	Hub	26	14.6875	381.875
+	CG Plate (EDRs)	7.5	31.5	236.25
-	Battery	-36	40	-1440
-	Oil	-8	19	-152
-	Interior	-60	23	-1380
-	Fuel	-149	19	-2831
-	Coolant	-20	35	-700
-	Washer fluid	-4	40.5	-162
BALLAST	Water	180	19	3420
	DTS	17	29.5	501.5
	Misc.			0
				139950.2

Estimated Total Weight (lb)	4992.5
Vertical CG Location (in.)	28.03208

wheel base (in.) 140.25

MASH Targets		Targets	Test Inertial	Difference
Test Inertial Weight (lb)		5000 ± 110	4998	-2.0
Long CG (in.)		63 ± 4	63.90	0.89541
Lat CG (in.)		NA	-1.01478	NA
Vert CG (in.)	≥	28	28.03	0.03208

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	1407	1367
Rear	1154	1073
FRONT	2774 lb	
REAR	2227 lb	
TOTAL	5001 lb	

TEST INERTIAL WEIGHT (lb)
(from scales)

	Left	Right
Front	1423	1298
Rear	1151	1126
FRONT	2721 lb	
REAR	2277 lb	
TOTAL	4998 lb	

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

Test: NYCC-3 Vehicle: 2270P

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb)	Vert CG (in.)	Vert M (lb-in.)
+	Unbalasted Truck (Curb)	5134	28.90134	148379.5
+	Brake receivers/wires	6	52.5	315
+	Brake Frame	6	26	156
+	Brake Cylinder (Nitrogen)	22	30	660
+	Strobe/Brake Battery	6	32	192
+	Hub	27	14.875	401.625
+	CG Plate (EDRs)	8	32.5	260
-	Battery	-46	39	-1794
-	Oil	-11	16.5	-181.5
-	Interior	-78	24	-1872
-	Fuel	-154	17.5	-2695
-	Coolant	-16	36	-576
-	Washer fluid	-7	38	-266
BALLAST	Water	86	15.5	1333
	DTS	17	30	510
	Misc.			0
				144822.6

Estimated Total Weight (lb)	5000
Vertical CG Location (in.)	28.96453

wheel base (in.) 140.5

MASH Targets	Targets	Test Inertial	Difference
Test Inertial Weight (lb)	5000 ± 110	4994	-6.0
Long CG (in.)	63 ± 4	61.95	-1.04946
Lat CG (in.)	NA	-0.04074	NA
Vert CG (in.)	≥ 28	28.96	0.96452

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	1454	1430
Rear	1129	1121

FRONT	2884 lb
REAR	2250 lb
TOTAL	5134 lb

TEST INERTIAL WEIGHT (lb)

(from scales)

	Left	Right
Front	1397	1395
Rear	1103	1099

FRONT	2792 lb
REAR	2202 lb
TOTAL	4994 lb

Figure A-3. Vehicle Mass Distribution, Test No. NYCC-3

Appendix B. Material Specifications

New York Curved Cable System, Test No. NYCC-1				
Item No.	QTY.	Description	Material Spec	Reference
a1	2	S3x5.7 27 3/16" long Anchor Post	A36 Galvanized Steel	11-0341
a2	24	Hooked Anchor Stud and Nut	AASHTO M314	110305-3
a3	6	ø 3/16" 5 1/4" Long Brass Rod	Brass	N/A
a4	36	ø 3/4" Plain Round Washer-OD 1.5"	Grade 2 Steel	10-0259-2
a5	2	S3x7.5 Anchor Post Stub	A36 Galvanized Steel	N/A
a6	4	Slip Impact Base	ASTM A36 Steel	11-0341
a7	2	4"x5" 28 Gauge Keeper Plate	Galvanized ASTM A36 Steel	11-0341
a8	8	ø 1/2" x2 1/2" Long Bolt and Nut	AASHTO M291	(00026-2824-401)
a9	24	ø 1/2" Narrow Washer-OD 1"	ASTM A153	H01476653
a10	2	3/4" Anchor Post Support Plate	-	11-0341
a11	2	Anchor Post Base	-	11-0341
b1	2	Anchor Bracket Plate	ASTM A709M Grade 250	11-0341
b2	4	1/2" Thick External Stiffener	ASTM A709M Grade 250	11-0341
b3	2	ø 1/4"x15" Brass Rod	Brass	N/A
b4	4	1/4" Thick Internal Stiffener	ASTM A709M Grade 250	11-0341
b5	2	Anchor Angle Middle Plate	ASTM A709M Grade 250	11-0341
b6	2	Cable Plate	ASTM A709M Grade 250	11-0341
c1	6	Cable End Fitting	ASTM A27	110305-2
c2	6	ø 3/4" Plain Round Washer-OD 2"	Grade 2	110305-3
c3	3	Compensating Cable End Assembly	ASTM A27	110305-1
c4	38	S3x5.7 63 in. long Line Post	A36 Galvanized Steel	Blue Paint
c5	114	Cable Hook Bolt	Grade A307	Black Paint
c6	3	ø 3/4" Cable Approx. 392'	AASHTO M30 Type 1 Class A	C4
c7	38	2'x8"x0.25" Soil Plate	A36 Galvanized Steel	11-0314
d1	2	Concrete Anchor Block	3000 psi Compressive Strength	NYCC-1_anchor
d2	12	#3 Rebar 32.5" long	Grade 60	10-0151-4
d3	12	#3 Rebar 44.5" long	Grade 60	10-0151-4
d4	16	#3 Rebar 33" long	Grade 60	10-0151-4

Figure B-1. Bill of Materials, Test No. NYCC-1

New York Curved Cable System, Test No. NYCC-2

Item	QTY.	Description	Material Spec	Reference
a1	2	S3x5.7 27 3/16" long	ASTM A36 Galvanized	12-0036(RED)
a2	24	Hooked Anchor J-Bolt and	ASTM A36 and ASTM A-563 DH	110305-3 (BLUE PAINT)
a3	6	ø 3/16" 5 1/4" Long	Brass	12-0036 (RED SHARPIE)
a4	36	ø 3/4" Plain Round Washer-OD 1.5"	Grade 2 Galvanized	110305-2(NO PAINT, BLUE)/ 12-0034(RED)
a5	2	S3x7.5 Anchor Post Stub	ASTM A36 Galvanized	12-0038
a6	4	Slip Impact Base	ASTM A36 Galvanized	12-0036/12-0038
a7	2	4"x5" 28 Gauge Keeper	ASTM A36 Galvanized	12-0036
a8	8	ø 1/2" x2 1/2" Long Bolt	Grade 2 Galvanized	12-0036
a9	24	ø 1/2" Narrow Washer-OD	Grade 2 Galvanized	12-0036
a10	2	3/4" Anchor Post Support Plate	A707 Grade 36 Galvanized	12-0038
a11	2	Anchor Post Base	A709 Grade 36 Galvanized	12-0038
b1	2	Anchor Bracket Plate	ASTM A709 Grade 36 Galvanized	11-0341
b2	4	1/2" Thick External Stiffener	ASTM A709 Grade 36 Galvanized	11-0341
b3	2	ø 1/4"x15" Brass Rod	Brass	BLACK SHARPIE
b4	4	1/4" Thick Internal Stiffener	ASTM A709 Grade 36 Galvanized	11-0341
b5	2	Anchor Angle Middle Plate	ASTM A709 Grade 36 Galvanized	11-0341
b6	2	Cable Plate	ASTM A709 Grade 36 Galvanized	11-0341
c1	6	Cable End Fitting	ASTM A27 Galvanized	11-0305(BLUE)/12-0034 (RED)
c2	6	ø 3/4" Plain Round	Grade 2 Galvanized	11-0305(BLUE)/12-0034 (RED)
c3	3	Compensating Cable End Assembly	ASTM A27 Galvanized	11-0305(BLUE)/12-0034 (RED)
c4	38	S3x5.7 63 in. long Line	ASTM A36 Galvanized	11-0341(BLUE)/12-0036 (RED)
c5	114	Cable Hook Bolt and Nuts	ASTM F568 Class 4.6 and Grade A307 Galvanized	BLACK PAINT
c6	1	ø 3/4" Cable Approx. 392'	AASHTO M30 Type 1 Class A Galvanized	C4-RED/ C5-YELLOW, BLACK
c7	38	2'x8"x0.25" Soil Plate	ASTM A36 Galvanized	11-0341(BLUE)/12-0036 (RED)
d1	2	Concrete Anchor Block	3000 psi Compressive Strength	N/A
d2	12	#3 Rebar 32.5" long	Grade 60	N/A
d3	12	#3 Rebar 44.5" long	Grade 60	N/A
d4	16	#3 Rebar 33" long	Grade 60	N/A
e1	12	Cable Wedge	ASTM A47 Grade 32510	12-0034
e2	3	50,000-lb Load Cell	N/A	
–	1	SOIL	350	6222011

Figure B-2. Bill of Materials, Test No. NYCC-2

New York Curved Cable System, Test No. NYCC-3

Item	QTY.	Description	Material Spec	Reference
a1	2	S3x5.7 27 3/16" long	ASTM A36 Galvanized	12-0240 (sticker labeled)
a2	24	Hooked Anchor J-Bolt	ASTM A36 and ASTM A-563 DH	BLUE PAINT
a3	6	Ø 3/16" 5 1/4" Long	Brass	RED SHARPIE
a4	36	Ø 3/4" Plain Round Washer-OD 1.5"	Grade 2 Galvanized	H#8270027(NO PAINT, BLUE)/12-0034(RED)
a5	2	S3x7.5 Anchor Post Stub	ASTM A36 Galvanized	12-0038
a6	4	Slip Impact Base	ASTM A36 Galvanized	12-0240/12-0038
a7	2	4"x5" 28 Gauge Keeper	ASTM A36 Galvanized	12-0036
a8	8	Ø 1/2" x2 1/2" Long	Grade 2 Galvanized	12-0036
a9	24	Ø 1/2" Narrow Washer-	Grade 2 Galvanized	12-0036
a10	2	3/4" Anchor Post Support Plate	A707 Grade 36 Galvanized	12-0240
a11	2	Anchor Post Base	A709 Grade 36 Galvanized	12-0038
b1	2	Anchor Bracket Plate	ASTM A709 Grade 36 Galvanized	11-0341
b2	4	1/2" Thick External Stiffener	ASTM A709 Grade 36 Galvanized	11-0341
b3	2	Ø 1/4"x15" Brass Rod	Brass	BLACK SHARPIE
b4	4	1/4" Thick Internal Stiffener	ASTM A709 Grade 36 Galvanized	11-0341
b5	2	Anchor Angle Middle Plate	ASTM A709 Grade 36 Galvanized	11-0341
b6	2	Cable Plate	ASTM A709 Grade 36 Galvanized	11-0341
c1	6	Cable End Fitting	ASTM A27 Galvanized	11-0305(BLUE)/12-0034 (RED)
c2	6	Ø 3/4" Plain Round	Grade 2 Galvanized	11-0305(BLUE)/12-0034 (RED)
c3	3	Compensating Cable End Assembly	ASTM A27 Galvanized	11-0305(BLUE)/12-0034 (RED)
c4	38	S3x5.7 63 in. long Line	ASTM A36 Galvanized	11-0341(BLUE)/12-0036 (RED)
c5	114	Cable Hook Bolt and Nuts	ASTM F568 Class 4.6 and Grade A307 Galvanized	BLACK PAINT
c6	1	Ø 3/4" Cable Approx. 392'	AASHTO M30 Type 1 Class A Galvanized	C4-RED/ C5-YELLOW, BLACK
c7	38	2'x8"x0.25" Soil Plate	ASTM A36 Galvanized	11-0341(BLUE)/12-0036 (RED)
d1	2	Concrete Anchor Block	3000 psi Compressive Strength	N/A
d2	12	#3 Rebar 32.5" long	Grade 60	N/A
d3	12	#3 Rebar 44.5" long	Grade 60	N/A
d4	16	#3 Rebar 33" long	Grade 60	N/A
e1	12	Cable Wedge	ASTM A47 Grade 32510	12-0034
e2	3	50,000-lb Load Cell	N/A	N/A
–	1	SOIL	350	6222011

Figure B-3. Bill of Materials, Test No. NYCC-3

Certificate of Quality

BEKAERT CORPORATION Van Buren,Arkansas

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

DATE: 06/01/2011

Customer Midwest Machinery & Supply Com
Our Order No 4060170474 0010
Product 3/4" 3X7 GUIDERAIL 2,000'RLS
Customer Part No
MFG SMP No AST3043SE10S02000

Customer Order No 11-0519-3
Qty 16 Carriers
Customer Spec No ASTM A-741 - 98

Finished Tag#	Breaking Strength (lbs.)	Lay Length (in.)	Adherence Appearance of Wires	Steel Ductility
95814119	44495	7.2	Pass	Pass
95814180	44495	7.2	Pass	Pass
95814191	44528	6.3	Pass	Pass
95814208	44528	6.3	Pass	Pass
95814225	44528	6.3	Pass	Pass
95814277	44545	5.94	Pass	Pass
95814285	44545	5.94	Pass	Pass
95814330	44545	5.94	Pass	Pass
95814602	44490	6.2	Pass	Pass
95814605	44490	6.2	Pass	Pass
95814606	44490	6.2	Pass	Pass
95814637	44352	6.2	Pass	Pass
95814896	44352	6.2	Pass	Pass
95814897	44318	6.74	Pass	Pass
95814901	44318	6.74	Pass	Pass
95814913	44318	6.74	Pass	Pass

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

Matthew Philpott

Quality Engineer | Notary Public | Commission Expires

Figure B-4. Cable, Test Nos. NYCC-1 through NYCC-3

Certificate of Quality

BEKAERT CORPORATION Van Buren,Arkansas

1881 BEKAERT DRIVE
ᐟAN BUREN, AR 72956
.EL(479)474-5211 FAX(479)474-9075
TELEX 537439

DATE: 06/01/2011

Customer Midwest Machinery & Supply Com
Our Order No 4060170474 0010
Product 3/4" 3X7 GUIDERAIL 2,000'RLS
Customer Part No
MFG SMP No AST3043SE10S02000

Customer Order No 11-0519-3
Qty 16 Carriers
Customer Spec No ASTM A-741 - 98

Finished Tag#	Breaking Strength (lbs.)	Lay Length (in.)	Adherence Appearance of Wires	Steel Ductility
95814119	44495	7.2	Pass	Pass
95814180	44495	7.2	Pass	Pass
95814191	44528	6.3	Pass	Pass
95814208	44528	6.3	Pass	Pass
95814225	44528	6.3	Pass	Pass
95814277	44545	5.94	Pass	Pass
95814285	44545	5.94	Pass	Pass
95814330	44545	5.94	Pass	Pass
95814602	44490	6.2	Pass	Pass
95814605	44490	6.2	Pass	Pass
95. .606	44490	6.2	Pass	Pass
95814637	44352	6.2	Pass	Pass
95814896	44352	6.2	Pass	Pass
95814897	44318	6.74	Pass	Pass
95814901	44318	6.74	Pass	Pass
95814913	44318	6.74	Pass	Pass

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

Matthew Philpott

Qua..ity Engineer

Notary Public Commission Expires

Figure B-5. Cable, Test Nos. NYCC-2 and NYCC-3

10-05-10;02:23PM;Bennett-Bolt-Works Midwest Machinery ;3156893999 # 2/ 6

BENNETT BOLT WORKS, INC.

12 Elbridge Street
P.O. Box 922
Jordan, New York 13080

PH 315-689-3981
FX 315-689-3999

CERTIFICATION OF COMPLIANCE

Customer: MIDWEST MACHINERY & SUPPLY
PO BOX 703
MILFORD, NE 68405

We certify that our system and procedures for the control of quality assures that all items furnished on the order will meet applicable tests, process requirements, and inspection requirements as required by the purchase order and applicable specifications.

Customer PO No.: · 2376

Date Shipped: · 10/4/10

Invoice No.: · 5019565

Purchase Date: . 9/23/10

QUANTITY DESCRIPTION

1800 - 5/16 X 2 HOOK BOLT W/ HVY HEX NUT MG (MFG- RIVES MFG #1001360/10043190, GALV.- MECH GALV PLATING, TELEFAST IND #O19317-1-76883, GALV.- MECH GALV PLATING)
84 - CG184N-H (SEE ATTACHED)
39 - CG197-H (SEE ATTACHED)
45 - CG177N-H (SEE ATTACHED)
14 - CG1241-H (SEE ATTACHED)

All products were melted and manufactured in the U.S.A. This material is in compliance with domesticity requirements, and conforms to ASTM & AASHTO specifications for standardized highway barrier rail and hardware.

James [signature]
SUPERVISOR QUALITY ASSURANCE
DATE: 10/5/10

Figure B-6. Compensating Cable Assembly, Test Nos. NYCC-1 through NYCC-3

10-05-10;02:23PM;Bennett-Bolt-Works Midwest Machinery ;3156893999 # 3/ 6

BENNETT BOLT WORKS, INC.

12 Elbridge Street
P.O. Box 922
Jordan, New York 13080

PH 315-689-3981
FX 315-689-3999

CG184N-H NEW CABLE END ASSEMBLY W/ 11'" STUD
MEETS 25,000# TEST

1 EA	3/4"OD X 11" FLATTENED STUD HDG A153 CLASS C THD 2 1/4"RH X 6 1/2"RH - MATERIAL - AISI 1045 MADE BY NUCOR STEEL #AU0810878A GALVANIZED BY UNIVERSAL GALV.
1 EA	3/4 X 5 3/4 CASTING PART # BBW-T HDG A153 CLASS A MATERIAL - ASTM A220 GRADE 500005 MALLEABLE IRON MADE BY BUCK CO. #8X1 GALVANIZED BY V & S GALV.
1 EA	7/8 X 1 7/8 X 9/32 WEDGE PART # W 1 MATERIAL - ASTM A47 GRADE 32510 MALLEABLE IRON MADE BY BUCK CO #5W6
1 EA	3/4-10 A563 GR DH HVY HEX NUT HDG A153 CLASS C MADE BY UNYTITE #NT421 GALVANIZED BY ROGERS BROTHERS GALV.
1 EA	3/4 X 2 1/2 X 3/16 ROUND WASHER HDG A153 CLASS C MATERIAL - ASTM A36 MADE BY ALLOWAY STAMPING #64474 GALVANIZED BY V & S GALV.
2 EA	3/4 F844 USS FW HDG A153 CLASS C MADE BY PRESTIGE STAMPING #C1952 GALVANIZED BY ROGERS BROTHERS GALV.

ALL PRODUCTS WERE MELTED AND MANUFACTURED IN THE U.S.A.

James [signature]
MANAGER QUALITY ASSURANCE

Figure B-7. Compensating Cable Assembly Cont., Test Nos. NYCC-1 through NYCC-3

10-05-10;02:23PM;Bennett-Bolt-Works Midwest Machinery ;3156893999 # 4/ 6

BENNETT BOLT WORKS, INC.

12 Elbridge Street
P.O. Box 922
Jordan, New York 13080

PH 315-689-3981
FX 315-689-3999

CG197-H ASSEMBLY BRIDGE ANCHOR
MEETS - 25,000# TEST

1 EA	3/4"OD X 18" FLATTENED STUD HDG A153 CLASS C THD 7 1/2"RH X 7"RH - MATERIAL - AISI 1045 MADE BY NUCOR STEEL #AU08108178A GALVANIZED BY UNIVERSAL GALV.
1 EA	3/4"OD X 11" FLATTENED STUD HDG A153 CLASS C THD 2 1/4"RH X 6 1/2"LH - MATERIAL - AISI 1045 MADE BY NUCOR STEEL #AU08108178A GALVANIZED BY UNIVERSAL GALV. & V & S GALV.
1 EA	7/8 X 1 7/8 X 9/32 WEDGE PART # W 1 MATERIAL - ASTM A47 GRADE 32510 MALLEABLE IRON MADE BY BUCK CO #5W6
2 EA	3/4-10 A563 GR DH HVY HEX NUT HDG A153 CLASS C MADE BY UNYTITE # NT421 GALVANIZED BY ROGERS BROTHERS GALV.
1 EA	3/4-10 X 12 TURNBUCKLE BODY ONLY - HDG A153 CLASS C MATERIAL - ASTM F1145/AASHTO M269-96(2000) FF-T 79 LBS MADE BY EDWARD DANIELS #907863 GALVANIZED BY ART GALV.

ALL PRODUCTS WERE MELTED AND MANUFACTURED IN THE U.S.A.

James Simebeaux
MANAGER QUALITY ASSURANCE

Figure B-8. Compensating Cable Assembly Cont., Test Nos. NYCC-1 through NYCC-3

10-05-10;02:23PM;Bennett-Bolt-Works Midwest Machinery ;3156893999 # 5/ 6

BENNETT BOLT WORKS, INC.

12 Elbridge Street
P.O. Box 922
Jordan, New York 13080

PH 315-689-3981
FX 315-689-3999

CG177N-H NEW SPRING COMPENSATOR W/ 11" STUD
MEETS 25,000# TEST

1 EA	3/4"OD X 11" FLATTENED STUD HDG A153 CLASS C THD 2 1/4"RH X 6 1/2"RH - MATERIAL -AISI 1045 MADE BY NUCOR STEEL #AU08108178A GALVANIZED BY V & S GALV.
1 EA	3/4"OD X 25" FLATTENED STUD HDG A153 CLASS C THD 2 1/4"RH X 6 1/2"LH - MATERIAL AISI 1045 MADE BY NUCOR STEEL #AU08108178A GALVANIZED BY V & S GALV.
2 EA	7/8 X 1 7/8 X 9/32 WEDGE PART # W 1 MATERIAL - ASTM A47 GRADE 32510 MALLEABLE IRON MADE BY BUCK CO. #5W6
1 EA	2 5/16 X 23 3/4 CASTING PART # BBW-9 HDG A153 CLASS A MATERIAL - ASTHA47 GRADE 32510 MALLEABLE IRON MADE BY BUCK CO #9X1/9X2 GALVANIZED BY V & S GALV.
1 EA	3/4-10 X 12 TURNBUCKLE BODY ONLY HDG A153 CLASS C MATERIAL - ASTM F1144/AASHTO -M269-96(2000) FF-T 79 LBS MADE BY EDWARD DANIELS #907683 GALVANIZED BY ART GALV.
1 EA	1 X 1 1/4 X 4 1/2 SPRING BLOCK FOR CABLE END HDG A153 CLASS C MATERIAL - ASTM A36 / MADE BY RYERSON STEEL #5020523 GALVANIZED BY V & S GALV.
1 EA	2 5/16 X 14 SPRING FOR CABLE END HDG A153 CLASS C MATERIAL - ASTM A304-02/ASTM A689-97 MADE BY DUER CAROLINA COIL #AU0910008201 GALVANIZED BY V & S GALV.
1 EA	3/4 F844 USS FW HDG A153 CLASS C MADE BY PRESTIGE STAMPING #C1952 GALVANIZED BY ROGERS BROTHERS GALV.
1 EA	3/4 X 5 3/4 CASTING PART #BBW-T HDG A153 CLASS A MATERIAL - ASTM A220 GRADE 5000005 MALLEABLE IRON MADE BY BUCK CO #8X1 / GALVANIZED BY V & S GALV.

ALL PRODUCTS WERE MELTED AND MANUFACTURED IN THE U.S.A.

James Gimenbeaux
MANAGER QUALITY ASSURANCE

Figure B-9. Compensating Cable Assembly Cont., Test Nos. NYCC-1 through NYCC-3

Chemical and Physical Test Report
Made and Melted In USA

G-160885

SHIP TO	INVOICE TO	SHIP DATE
SIOUX CITY FOUNDRY INC 801 DIVISION STREET 800-831-0874 SIOUX CITY, IA 51102	SIOUX CITY FOUNDRY INC ACCTS PAYABLE PO BOX 3067 SIOUX CITY, IA 51102	09/16/10 **CUST. ACCOUNT NO** 60044062

PRODUCED IN: CARTERSVILLE

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
W3 X 5.7# S-BEAM	A57250/992	ASTM A572 GR50-07, ASTM A992 -06A, ASTM A709 GR50-09A	0096209-01	127098W-01

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	N	Sn	Al	Ti	Ca	Zn	C Eqv
G104601	.15	.92	.012	.020	20	.30	.09	.03	.022	.016	.002	.0002	.0088	.011	.001	.00100	.00070	.00630	.38

Mechanical Test: Yield 53100 PSI, 366.11 MPA Tensile: 73200 PSI, 504.7 MPA %El: 21.1/8in, 21.1/200MM
Customer Requirements CASTING: STRAND CAST
Comment NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.
Mechanical Test: Yield 53700 PSI, 370.25 MPA Tensile: 72400 PSI, 499.18 MPA %El: 19.9/8in, 19.9/200MM
Customer Requirements CASTING: STRAND CAST
Comment NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.

PRODUCED IN: CARTERSVILLE

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
W10 X 19#	A57250/992	ASTM A572 GR50-07, ASTM A992 -06A, ASTM A709 GR50-09A	0096209-08	127098W-08

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	N	Sn	Al	Ti	Ca	Zn	C Eqv
G105180	.08	1.10	.014	.021	.27	.29	.10	.05	.021	.026	.002	.0003	.0100	.009	.001	.00200	.00140	.00480	.355

Mechanical Test: Yield 57900 PSI, 399.21 MPA Tensile: 70500 PSI, 486.08 MPA %El: 21.0/8in, 21.0/200MM
Customer Requirements CASTING: STRAND CAST
Comment NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.
Mechanical Test: Yield 57400 PSI, 395.76 MPA Tensile: 71900 PSI, 495.73 MPA %El: 25.2/8in, 25.2/200MM
Customer Requirements CASTING: STRAND CAST
Comment NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.

Customer Notes
NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.

All manufacturing processes including melt and cast, occurred in USA. MTR complies with EN10204 3.1B

Bhaskar Yalamanchili
Quality Director
Gerdau Ameristeel

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

Metallurgical Services Manager
CARTERSVILLE STEEL MILL

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

Figure B-10. Line Post, Test Nos. NYCC-1 through NYCC-3

valmont
COATINGS

April 7, 2011

Midwest Roadside Safe / UNL
4800 NW 35th St
Lincoln, NE 68524

Re: Galvanized Structural Steel Mil Certification

The following information is the criteria for determining the mil certification in accordance with ASTM 123-89a. Reference tables 1 and 2.

Steel Category:	Structural
Size:	¼" or over
Thickness Grade:	100
Mils Required:	3.9

PO – Load 4-4-11

<u>Mil Readings</u>

End	4.2
Middle	4.4
End	4.7
AVERAGE	4.4

Should you have questions concerning the mil certifications or other matters please contact me at 1-800-345-6825, ext. 6885.

Sincerely,

Adam M. Brovont

Adam Brovont
Operations Manager

Coatings Division Valmont Industries, Inc.
7002 North 288th Street P.O. Box 358 Valley, Nebraska 68064-0358 USA
402-359-2201 www.valmont.com

Figure B-11. Line Post Galvanization, Test No. NYCC-1

Chemical and Physical Test Report
Made and Melted In USA

G-167153

SHIP TO	INVOICE TO	SHIP DATE
SIOUX CITY FOUNDRY INC 801 DIVISION STREET 800-831-0874 SIOUX CITY, IA 51102	SIOUX CITY FOUNDRY INC ACCTS PAYABLE PO BOX 3067 SIOUX CITY, IA 51102	01/08/11 **CUST. ACCOUNT NO** 60044062

PRODUCED IN: CARTERSVILLE

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
F1/2 X 8	A36	ASTM A36-08, ASTM A529 GR50-05, SA-36 08,ASTM A709 GR36-09A	1088504-03	130767W-03

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	N	Sn	Al	Ti	Ca	Zn	C Eqv
G107094	.16	.88	.014	.027	.19	.28	.10	.06	.024	.016	.001	.0003	.0090	.011	.000	.00100	.00020	.00320	.38

Mechanical Test: Yield 52200 PSI, 359.91 MPA Tensile: 73400 PSI, 506.08 MPA %El: 22.5/8in, 22.5/200MM
Customer Requirements CASTING: STRAND CAST
Comment NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.
Mechanical Test: Yield 51000 PSI, 351.63 MPA Tensile: 71900 PSI, 495.73 MPA %El: 22.0/8in, 22.0/200MM
Customer Requirements CASTING: STRAND CAST
Comment NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.

PRODUCED IN: CARTERSVILLE

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
F1/4 X 8	A36	ASTM A36-08, ASTM A529 GR50-05, SA-36 08,ASTM A709 GR36-09A	1088504-01	130767W-01

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	N	Sn	Al	Ti	Ca	Zn	C Eqv
G107118	.14	.95	.014	.030	.23	.33	.09	.07	.030	.016	< .008	.0002	.0119	.012	.001	.00100	.00070	.00360	.38

Mechanical Test: Yield 54800 PSI, 377.83 MPA Tensile: 74900 PSI, 516.42 MPA %El: 22.4/8in, 22.4/200MM
Customer Requirements CASTING: STRAND CAST
Comment NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.
Mechanical Test: Yield 54500 PSI, 375.76 MPA Tensile: 75300 PSI, 519.18 MPA %El: 21.6/8in, 21.6/200MM
Customer Requirements CASTING: STRAND CAST
Comment NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.

Customer Notes
NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.

All manufacturing processes including melt and cast, occurred in USA. MTR complies with EN10204 3.1B

Bhaskar Yalamanchili
Quality Director
Gerdau Ameristeel

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

Metallurgical Services Manager
CARTERSVILLE STEEL MILL

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

Figure B-12. Line Post Soil Plate, Test Nos. NYCC-1 through NYCC-3

06-13-11;02:42PM;Bennett-Bolt-Works Midwest Machinery ;3156893999 # 13/ 28

Rives Manufacturing, Inc.

4000 Rives Eaton Road • P.O. Box 98 • Rives Junction, MI 49277-0098
Telephone (517)569-3380 • Facsimile (517)569-2103

Hot Upset and Cold Headed Wire Parts

NYCC System
12-0019
7/22/11
MARKED w/BLACK SPRAY

3/10/10

To whom it may concern;

Please consider this letter verification that production for Bennett Bolt #15250 (RMI #050250), produced for Bennett Bolt PO #6006477, has been manufactured in the United States at all levels of the manufacturing process.

If you have any questions, please feel free to contact me at 517-569-3380 ext 215 or via email at quality@rivesmfg.com.

Respectfully,

Richard Stahl
President-RMI

ISO 9001

Figure B-13. Cable Hook Bolt, Test Nos. NYCC-1 through NYCC-3

5-13-11;02:42PM;Bennett-Bolt-Works Midwest Machinery ;3156893999 # 14/ 28

Production Part Approval - Dimensional Results

CUSTOMER	CUSTOMER PART NUMBER	RM NUMBER
BENNETT BOLT WORKS, INC.	15250	#050250
NAME OF SUPPLIER/INSPECTION FACILITY: RIVES MANUFACTURING, INC.	PART NAME: HOOK BOLT	

ITEM	DIMENSION/SPECIFICATION	SUPPLIER MEASUREMENT RESULTS	OK	NOT OK
1.	500 Lb. Min. Pull Test	1) 725 2) 705	☑	☐
	MATERIAL PO No.: #19726 - #20110 - #20121			
	MATERIAL HEAT No.: 10001360 & 10043190			

NOTES

QUANTITY: 461,731
DATE SHIPPED: 3/5/2010
TEST DATE: 3/5/2010

SIGNATURE: [signature] TITLE: QA Mgr. DATE: 3/5/10

QF-023 PAPP Dimensional Results; Rev A ; 01/01/02

Figure B-14. Cable Hook Bolt Cont., Test Nos. NYCC-1 through NYCC-3

Chemical and Physical Test Report
Made and Melted in USA

G-163740

SHIP TO	INVOICE TO	SHIP DATE
SIOUX CITY FOUNDRY INC 801 DIVISION STREET 800-831-0874 SIOUX CITY, IA 51102	SIOUX CITY FOUNDRY INC ACCTS PAYABLE PO BOX 3067 SIOUX CITY, IA 51102	11/08/10 **CUST. ACCOUNT NO** 60044062

PRODUCED IN: CARTERSVILLE

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
W3 X 5.7# S-BEAM	A57250/992	ASTM A572 GR50-07, ASTM A992 -06A, ASTM A709 GR50-09A	0123380-05	129309W-05

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	N	Sn	Al	Ti	Ca	Zn	C Eqv
G104598	14	91	.012	.020	.22	.30	.09	.05	.022	.016	.002	.0003	.0100	.010	.002	.00100	.00030	.00710	.374

Mechanical Test: Yield 53300 PSI, 367.49 MPA Tensile: 74200 PSI, 511.59 MPA %El: 19.2/8in, 19.2/200MM
Customer Requirements CASTING: STRAND CAST
Comment NO WELD REPAIRMENT PERFORMED STEEL NOT EXPOSED TO MERCURY.
Mechanical Test: Yield 53900 PSI, 371.63 MPA Tensile: 73300 PSI, 505.39 MPA %El: 20.0/8in, 20.0/200MM
Customer Requirements CASTING: STRAND CAST
Comment NO WELD REPAIRMENT PERFORMED STEEL NOT EXPOSED TO MERCURY.

PRODUCED IN: CARTERSVILLE

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
W3 X 5.7# S-BEAM	A57250/992	ASTM A572 GR50-07, ASTM A992 -06A, ASTM A709 GR50-09A	0123380-05	129309W-05

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	N	Sn	Al	Ti	Ca	Zn	C Eqv
G104599	14	92	.014	.023	.22	28	.09	.05	.025	.016	.002	.0003	.0095	.010	.002	.00100	.00050	.00740	.373

Mechanical Test: Yield 54800 PSI, 377.83 MPA Tensile: 74700 PSI, 515.04 MPA %El: 19.5/8in, 19.5/200MM
Customer Requirements CASTING: STRAND CAST
Comment NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.
Mechanical Test: Yield 53800 PSI, 370.94 MPA Tensile: 73700 PSI, 508.14 MPA %El: 21.3/8in, 21.3/200MM
Customer Requirements CASTING: STRAND CAST
Comment NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.

Customer Notes

NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.

All manufacturing processes including melt and cast, occurred in USA. MTR complies with EN10204 3.1B

Bhaskar Yalamanchili
Quality Director
Gerdau Ameristeel

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

Metallurgical Services Manager
CARTERSVILLE STEEL MILL

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

Figure B-15. Cable Anchor Assembly, Test Nos. NYCC-1 through NYCC-3

Chemical and Physical Test Report
MADE IN UNITED STATES

V-688543

SHIP TO	INVOICE TO	SHIP DATE
SIOUX CITY FOUNDRY INC 801 DIVISION STREET 800-831-0874 SIOUX CITY, IA 51102	SIOUX CITY FOUNDRY INC ACCTS PAYABLE PO BOX 3067 SIOUX CITY, IA 51102	01/19/11 **CUST. ACCOUNT NO** 60044062

PRODUCED IN: JACKSON TN

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
A2 X 2 X 3/16	A36	ASTM A36-08; ASME SA-36-08, ASTM A709-36-08	0127748-01	129665W-01

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	N	Sn	Al	Ti	Zr	Ca	C Eqv
V910076	.14	.60	.022	.034	.19	.35	.12	.18	.034	.005	.001	.0006	.0098	.011	.002	.00100	.000	.00000	.342

Mechanical Test: Yield 50870 PSI, 350.74 MPA Tensile: 70460 PSI, 485.8 MPA %El: 32.0/8in, 32.0/200MM Def HT 0, 0MM %/h 0L Red R 37.75
Mechanical Test: Yield 49500 PSI, 341.29 MPA Tensile: 69550 PSI, 479.53 MPA %El: 34.5/8in, 34.5/200MM Def HT: 0, 0MM %/h 0L Red R 37.75

PRODUCED IN: JACKSON TN

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
F3/8 X 2	A36	ASTM A36-08; ASME SA-36-08; ASTM A709-36-08; C.S.A. G40.21-98 44W	1003457-01	130970W-01

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	N	Sn	Al	Ti	Zr	Ca	C Eqv
V910160	.13	.73	.016	.033	.25	.31	.12	.10	.031	.004	.002	.0006	.0112	.011	.001	.00100	.000	.00000	.347

Mechanical Test: Yield 48670 PSI, 335.57 MPA Tensile: 67370 PSI, 464.5 MPA %El: 28.0/8in, 28.0/200MM Def HT: 0, 0MM %/h 0L Red R 36.24
Mechanical Test: Yield 46850 PSI, 323.02 MPA Tensile: 67810 PSI, 467.53 MPA %El: 29.0/8in, 29.0/200MM Def HT: 0, 0MM %/h 0L Red R 36.24

PRODUCED IN: JACKSON TN

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
F1/2 X 3	A36	ASTM A36-08; ASME SA-36-08; ASTM A709-36-08; C.S.A. G40.21-98 44W	1003457-02	130970W-02

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	N	Sn	Al	Ti	Zr	Ca	C Eqv
V910229	.13	.71	.017	.031	.23	.33	.10	.11	.032	.019	.001	.0006	.0095	.012	.001	.00100	.000	.00000	.349

Mechanical Test: Yield 51370 PSI, 354.18 MPA Tensile: 71440 PSI, 492.56 MPA %El: 27.5/8in, 27.5/200MM Def HT: 0, 0MM %/h 0L Red R 18.12
Mechanical Test: Yield 50180 PSI, 345.98 MPA Tensile: 70090 PSI, 483.25 MPA %El: 26.5/8in, 26.5/200MM Def HT: 0, 0MM %/h 0L Red R 18.12

Customer Notes

NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.

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

Bhaskar Yalamanchili
Quality Director
Gerdau Ameristeel

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

Metallurgical Services Manager
JACKSON STEEL MILL

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

Figure B-16. Cable Anchor Assembly, Test Nos. NYCC-1 through NYCC-3

[redacted]

Page 6 of 7

Chemical and Physical Test Report
MADE IN UNITED STATES

I-265598

SHIP TO	**INVOICE TO**	**SHIP DATE**
SIOUX CITY FOUNDRY INC	SIOUX CITY FOUNDRY INC	07/22/10
801 DIVISION STREET	ACCTS PAYABLE	
800-831-0874	PO BOX 3067	**CUST. ACCOUNT NO**
SIOUX CITY, IA 51102	SIOUX CITY, IA 51102	60044062

PRODUCED IN: WILTON

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
F3/8 X 5	A36	ASTM A36-08, ASME SA36, ASTM A709 GR 36-08	0092822-04	126826W-04

X

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	Sn	Al	Ti	C Eqv
W36609	.19	.60	.012	.036	.18	.29	.12	.12	.029	.001	.001	.0003	.014	.000	.00038	.376

Mechanical Test: Yield 46100 PSI, 317.85 MPA Tensile: 70800 PSI, 488.15 MPA %El: 31.3/8in, 31.3/203.2mm Red R 16 Std Dev:0 Idl Diam: .548
Customer Requirements SOURCE: IOWA BILLETS CASTING: STRAND CAST
Mechanical Test: Yield 47900 PSI, 330.26 MPA Tensile: 71400 PSI, 492.29 MPA %El: 31.3/8in, 31.3/203.2mm Red R 16 Std Dev:0 Idl Diam: .548
Customer Requirements SOURCE: IOWA BILLETS CASTING: STRAND CAST

PRODUCED IN: WILTON

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
A3 X 3 X 3/8	A36	ASTM A36-08, ASME SA36, ASTM A709 GR 36-08	0092822-07	126826W-07

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	Sn	Al	Ti	C Eqv
W36623	.18	.60	.009	.037	.17	.22	.08	.10	.021	.001	.013	.0002	.011	.000	.00029	.351

Mechanical Test: Yield 51700 PSI, 356.46 MPA Tensile: 72000 PSI, 496.42 MPA %El: 23.8/8in, 23.8/203.2mm Red R 14 Std Dev:0
Customer Requirements SOURCE: IOWA BILLETS CASTING: STRAND CAST
Mechanical Test: Yield 51500 PSI, 355.08 MPA Tensile: 72200 PSI, 497.8 MPA %El: 23.8/8in, 23.8/203.2mm Red R 14 Std Dev:0
Customer Requirements SOURCE: IOWA BILLETS CASTING: STRAND CAST

Customer Notes

NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.
This material, including the billets, was melted and manufactured in the United States of America

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

Bhaskar Yalamanchili
Quality Director
Gerdau Ameristeel

Metallurgical Services Manager
WILTON STEEL MILL

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

Figure B-17. Cable Anchor Assembly, Test Nos. NYCC-1 through NYCC-3

MATERIAL CERTIFICATION REPORT

SIOUX CITY FOUNDRY

51102-3067 Sioux City

SIOUX CITY FOUNDRY
SIOUX CITY, IA
801 DIVISION STREET
51105 Sioux City

Tested in Accordance With: ASTM A6

Invoice NO.		Date	12/07/2010
Product	Flat bars	Cust	40006577
Heat NO.	L74445	Grade	A3644W
Length	20' 00"	Size	3" X3/8" X3.830

PO: 129661W
Ref. 80258523
Pieces 65

CHEMICAL ANALYSIS	
C	0.13
Mn	0.89
P	0.017
S	0.037
Si	0.19
Cu	0.26
Ni	0.15
Cr	0.16
Mo	0.032
Cb	0.000
V	0.000
B	
Al	
Sn	0.012
N	
Ti	
Ci	5.5
CE	0.34

MECHANICAL PROPERTIES	TEST 1		TEST 2		TEST 3	
	IMPERIAL	METRIC	IMPERIAL	METRIC	IMPERIAL	METRIC
YIELD STRENGTH	46,200 PSI	319 MPa	49,800 PSI	343 MPa		
TENSILE STRENGTH	69,400 PSI	478 MPa	69,400 PSI	478 MPa		
ELONGATION	32 %	32 %	31 %	31 %		
GAUGE LENGTH	8 IN	203 mm	8 IN	203 mm		
BEND TEST DIAMETER						
BEND TEST RESULTS						
SPECIMEN AREA						
REDUCTION OF AREA						
IMPACT STRENGTH						

IMPACT STRENGTH	IMPERIAL	METRIC	INTERNAL CLEANLINESS			
AVERAGE			SEVERITY		GRAIN SIZE	
TEST TEMP			FREQUENCY		HARDNESS	
ORIENTATION			RATING		GRAIN PRACTICE	
					REDUCTION RATIO	

A36-08,44W

I hereby certify that the material test results presented here are from the reported heat and are correct. All tests were performed in accordance to the specification reported above. All steel is electric furnace melted, manufactured, processed, and tested in the U.S.A with satisfactory results, and is free of Mercury contamination in the process.

Notarized upon request:
Sworn to and subscribed before me on 7th day of December, 2010
In Roane County, Tennessee by ____________________

Signed Robert L. Mowan
ROBERT L. MOWAN, QUALITY ASSURANCE MANAGER

Direct any questions or necessary clarifications concerning this report to the Sales Department.
1-800-[illegible] (USA)

Figure B-18. Cable Anchor Assembly, Test Nos. NYCC-1 through NYCC-3

MATERIAL CERTIFICATION REPORT

SIOUX CITY FOUNDRY

^102-3067 Sioux City

SIOUX CITY FOUNDRY
SIOUX CITY, IA
801 DIVISION STREET
51105 Sioux City

Tested in Accordance
With: ASTM A6

Invoice NO.		Date	12/07/2010
Product	Flat bars	Cust	40006577
Heat NO.	L74464	Grade	A3644W
Length	20' 00"	Size	2" X3/4" X5.106

PO: 129661W
Ref. 80258523
Pieces 48

CHEMICAL ANALYSIS	
C	0.14
Mn	0.87
P	0.017
S	0.033
Si	0.17
Cu	0.28
Ni	0.15
Cr	0.14
Mo	0.029
Cb	0.000
V	0.000
B	
Al	
Sn	0.009
N	
Ti	

Ci	5.6
CE	0.35

MECHANICAL PROPERTIES	TEST 1		TEST 2		TEST 3	
	IMPERIAL	METRIC	IMPERIAL	METRIC	IMPERIAL	METRIC
YIELD STRENGTH	45,400 PSI	313 MPa	44,000 PSI	303 MPa		
TENSILE STRENGTH	66,700 PSI	460 MPa	66,700 PSI	460 MPa		
ELONGATION	29 %	29 %	30 %	30 %		
GAUGE LENGTH	8 IN	203 mm	8 IN	203 mm		
BEND TEST DIAMETER						
BEND TEST RESULTS						
SPECIMEN AREA						
REDUCTION OF AREA						
IMPACT STRENGTH						

IMPACT STRENGTH	IMPERIAL	METRIC	INTERNAL CLEANLINESS		GRAIN SIZE	
AVERAGE			SEVERITY		HARDNESS	
TEST TEMP			FREQUENCY		GRAIN PRACTICE	
ORIENTATION			RATING		REDUCTION RATIO	

A36-08,44W

I hereby certify that the material test results presented here are from the reported heat and are correct. All tests were performed in accordance to the specification reported above. All steel is electric furnace melted, manufactured, processed, and tested in the U.S.A with satisfactory results, and is free of Mercury contamination in the process.

Notarized upon request:
Sworn to and subscribed before me on 7th day of December, 2010
In Roane County, Tennessee by ____________________

Signed Robert L. Mowan
ROBERT L. MOWAN, QUALITY ASSURANCE MANAGER

Direct any questions or necessary clarifications concerning this report to the Sales Department.
1-800-535-7692 (USA)

Figure B-19. Cable Anchor Assembly, Test Nos. NYCC-1 through NYCC-3

MATERIAL CERTIFICATION REPORT

SIOUX CITY FOUNDRY

02-3067 Sioux City

SIOUX CITY FOUNDRY
SIOUX CITY, IA
801 DIVISION STREET
51105 Sioux City

Tested in Accordance With: ASTM A6

Invoice NO.
Product Flat bars
Heat NO. L75613
Length 20'00"

Date 12/07/2010
Cust 40006577
Grade A3652950
Size 6" X1/4" X5.106

PO: 129661W
Ref. 80258523
Pieces 48

CHEMICAL ANALYSIS		MECHANICAL PROPERTIES	TEST 1 IMPERIAL	TEST 1 METRIC	TEST 2 IMPERIAL	TEST 2 METRIC	TEST 3 IMPERIAL	TEST 3 METRIC
C	0.14	YIELD STRENGTH	54,700 PSI	377 MPa	54,200 PSI	374 MPa		
Mn	0.92	TENSILE STRENGTH	76,200 PSI	525 MPa	78,200 PSI	539 MPa		
P	0.015	ELONGATION	34 %	34 %	34 %	34 %		
S	0.038	GAUGE LENGTH	8 IN	203 mm	8 IN	203 mm		
Si	0.22	BEND TEST DIAMETER						
Cu	0.23	BEND TEST RESULTS						
Ni	0.19	SPECIMEN AREA						
Cr	0.17	REDUCTION OF AREA						
Mo	0.054	IMPACT STRENGTH						
Cb	0.015							
V	0.000							
B								
Al								
Sn	0.005							
N								
Ti								
CI	5.3							
CE	0.37							

IMPACT STRENGTH	IMPERIAL	METRIC	INTERNAL CLEANLINESS		GRAIN SIZE	
AVERAGE			SEVERITY		HARDNESS	
TEST TEMP			FREQUENCY		GRAIN PRACTICE	
ORIENTATION			RATING		REDUCTION RATIO	

A36-08,A52950-05,CSA50W,44W,A70936-09a

I hereby certify that the material test results presented here are from the reported heat and are correct. All tests were performed in accordance to the specification reported above. All steel is electric furnace melted, manufactured, processed, and tested in the U.S.A with satisfactory results, and is free of Mercury contamination in the process.

Notarized upon request:
Sworn to and subscribed before me in and for ST. John Parish on this 7th day of December, 2010

Michael E. Soileau, #81887, Notary Public

Signed [signature]
MARK EDWARDS, QUALITY ASSURANCE SUPERVISOR

Direct any questions or necessary clarifications concerning this report to the Sales Department 1-800-535-7692(USA)

Figure B-20. Cable Anchor Assembly, Test Nos. NYCC-1 through NYCC-3

INSPECTION CERTIFICATE

Customer	Specification	Size	Lot No.	Date
	ASTM A-563 GRADE DH HEAVY HEX NUT	H.D.G. 3/4-10 UNC 0.020" BLUE DYE	SC842	Oct.28,'10

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

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

Chemical Composition (%)

Mill Maker	Material Size	Heat No.	Spec.	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	
MCSTEEL	CARBON			0.20 0.55	-	MIN. 0.60	MAX. 0.040	MAX. 0.050	-	-	-	-	-
	STEEL	M37945		0.44	0.25	0.80	0.017	0.031	0.31	0.09	0.16	0.03	-

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

Mechanical Property Inspection

Item	Proof Load	Cone stripping	Hardness	After Heat Treatment Hardness	Absorbed Energy	Heat Treatment
Spec.	50,100 lbf	- kN·kgf·lbf	24-38 HrC	HrB·HB	J·kgfm·ftlbf	T:MIN.800 F
Results	n 5 Results GOOD	n - Results -	28.5 28.5 28.8 29.0 28.7 28.7	5 Piece Average After Heat Treament Hardness Treatment After 24 Hr.X °F(°C)	at °F(°C)	Q:FORGING Q (W.Q.) T:1211 F/45M. (W.C.) Q: Quenching T: Tempering ST: Solution Treatment

Remarks:

" DH U"

Production Quantity 74,545 pcs.

OFFICIAL SEAL
JEAN MARGHERIO
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES:10/18/13

10-29-10

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

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

Chief of Quality Assurance Section

Figure B-21. Anchor Rods, Test No. NYCC-1

CAUTION FRESH CONCRETE

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

Ready Mixed Concrete Company

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

PLANT	MIX CODE	YARDS	TRUCK	DRIVER	DESTINATION	CLASS	TIME	DATE	TICKET
01	23033000	5.00	0107		NTE		09:38A	06/30/11	1140435

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

DELIVERY ADDRESS	SPECIAL INSTRUCTIONS	P.O. NUMBER
4800 NW 35TH	NORTH OF GOODYEAR HANGERS	402-770-9121 KE

LOAD QUANTITY	CUMULATIVE QUANTITY	ORDERED QUANTITY	PRODUCT CODE	PRODUCT DESCRIPTION	UNIT PRICE	AMOUNT
5.00	5.00	5.00	23033000	L-3000 TYPE 3 4.00	93.21	466.05
				MINIMUM HAUL		20.00
					SUBTOTAL	486.05
					TAX	486.05
					TOTAL	486.05

WATER ADDED ON JOB AT CUSTOMER'S REQUEST 0 GAL   RECEIVED BY [signature]

TRUCK	USER LOGIN	DISP TICKET NUM	TICKET NUM	TICKET ID	TIME	DATE
0107	USER	1140435	161944	12695	09:38	06/30/2011

LOAD SIZE	MIX CODE	SEQ	LOAD ID
5.00 yd	23033000	W	12712

MATERIAL	DESIGN QTY	REQUIRED	BATCHED	VAR	% VAR	%MOISTURE	ACTUAL WAT
G47B	2173 lb	11062 lb	11060	-2	-.02%	1.81 A	23.57 gl
L47B	931 lb	4678 lb	4660	-18	-.38%	0.50 M	2.78 gl
CEM3	517 lb	2585 lb	2595	10	0.39%		
PROT	4.00 oz	20.00 oz	20.00	0.00	0.00%		
WATER	32.8 GL	142.6 GL	141.9	-0.7	-.49%		141.88 gl
WATER2	0.0 gl #	0.0 gl	0.0	0.0	0.00%		

NON-SIMULATED NUM BATCHES: 1
LOAD TOTAL: 19500 lb DESIGN W/C: 0.529 WATER/CEMENT: 0.541A DESIGN WATER: 164.0 gl ACTUAL WATER: 168.2 gl TO ADD: 0.0 gl
SLUMP: 4.00 "# WATER IN TRUCK: 0.0 gl ADJUST WATER: 0.0 gl /load TRIM WATER: 0.0 gl /yd

NP Curved Cable End Blocks

ORIGINAL

Figure B-22. Concrete Anchor, Test No. NYCC-1

Figure B-23. Post Nos. 1 and 40 Bolt Assembly, Test Nos. NYCC-1 through NYCC-3

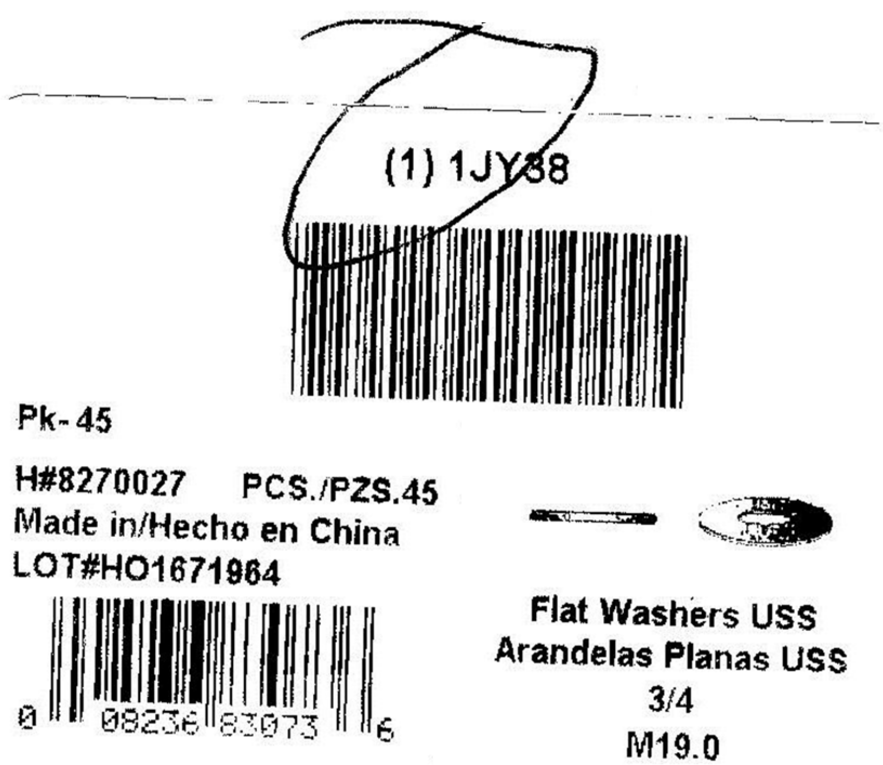


Figure B-24. Cable End Washer, Test Nos. NYCC-1 through NYCC-3

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

CERTIFIED MILL TEST REPORT

4/07/08 17:36:09
100% MELTED AND MANUFACTURED IN THE USA
All beams produced by Nucor-Berkeley are cast and rolled to a fully killed and fine grain practice.

Sold To: STEEL & PIPE SUPPLY CO., INC.
PO BOX 1688

MANHATTAN, KS 66505

Ship To: STEEL & PIPE SUPPLY CO., INC.
310 SOUTH SMITH RD

JONESBURG, MO 63351

Customer #.: 472 - 3
Customer PO: 4500104078
B.O.L. #...: 683949

SPECIFICATIONS: Tested in accordance with ASTM specification A6/A6M and A370.
AASHTO : M270-36-05/M270-50-05
ASME : SA-36 07a
ASTM : A992-06a://A36-05/A572-06-50/A709-06a36/A709-07 50/A709-345M
CSA : CSA-44W/G40.21-50W

	Heat#	Yield/	Yield	Tensile		C	Mn	P	S	Si	Cu	Ni	CE1
	Grade(s)	Tensile	(PSI)	(PSI)	Elong	Cr	Mo	Sn	Al	V	Nb	******	CE2
Description	Test	Ratio	(MPa)	(MPa)	%	Pb	Ti	Ca	B	N	Zr	CI	Pcm
S3X7.5	2710536	.81	56700	70000	25.89	.0590	.7900	.0066	.0243	.2020	.1100	.0450	.2106
040' 00.00"	A992-06a		391	483		.0270	.0180	.0067	.0017	.0031	.0266		.2496
S75X11.2		.81	56900	70100	24.68	.0013	.0013	.0000	.0009	.0058	.0000	3.0403	.1187
012.1920m			392	483		35 Piece(s)						Inv#:	0
S8X18.4	2804528	.84	56800	68000	29.36	.0660	.8250	.0083	.0276	.2000	.1380	.0430	.2272
040' 00.00"	A992-06a		392	469		.0360	.0190	.0063	.0017	.0032	.0264		.2658
S200X27.4		.83	56500	67800	28.71	.0018	.0018	.0000	.0016	.0054	.0000	3.5585	.1328
012.1920m			390	467		8 Piece(s)						Inv#:	0
S8X18.4	2804637	.83	56100	68000	24.91	.0650	.8530	.0080	.0278	.2070	.0880	.0340	.2279
050' 00.00"	A992-06a		387	469		.0440	.0160	.0067	.0015	.0031	.0254		.2675
S200X27.4		.83	56200	67800	27.66	.0017	.0016	.0003	.0014	.0052	.0000	2.6374	.1300
015.2400m			387	467		8 Piece(s)						Inv#:	0
S8X23	1804632	.78	52800	67400	24.55	.0670	.8060	.0111	.0285	.2210	.0870	.0310	.2209
040' 00.00"	A992-06a		364	465		.0340	.0210	.0081	.0032	.0033	.0256		.2628
S200X34		.79	53300	67100	21.51	.0064	.0020	.0005	.0000	.0058	.0000	2.6695	.1229
012.1920m			368	463		8 Piece(s)						Inv#:	0
W10x19	1800626	.82	55900	67800	27.74	.0670	.8470	.0099	.0232	.2250	.1210	.0390	.2291
040' 00.00"	A992-06a		385	467		.0290	.0190	.0059	.0021	.0032	.0252		.2716
W250X28.4		.82	55200	67400	28.24	.0025	.0018	.0000	.0024	.0048	.0000	3.3129	.1385
012.1920m			381	465		8 Piece(s)						Inv#:	0

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

Hg free and no contact with Hg during manufacture.
CE1= C+(Mn/6)+((Cr+Mo+V)/5)+((Ni+Cu)/15)
CE2 = C+((Mn+Si)/6)+((Cr+Mo+V+Cb)/5)+((Ni+Cu)/15)

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

Bruce A. Work
Metallurgist

(State of South Carolina
(County of Berkeley
Sworn and subscribed before me

_______ day of _______________

Figure B-25. Concrete Anchor Post, Test Nos. NYCC-2 and NYCC-3

SPS Coil Processing Tulsa
5275 Bird Creek Ave.
Port of Catoosa, OK 74015

STEEL & PIPE SUPPLY COMPANY INC.

METALLURGICAL TEST REPORT

PAGE 1 of 1
DATE 06/13/2011
TIME 10:53:30
USER WILLIAMR

SOLD TO

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

Order	Material No.	Description	Quantity	Weight	Customer Part	Customer PO	Ship Date
40163208-0010	721696240A2	1/2 96 X 240 A572GR50 MILL PLATE	2	6,534.400			06/13/2011

Chemical Analysis

Heat No. B1R6591 Vendor NUCOR STEEL TUSCALOOSA INC DOMESTIC Mill NUCOR STEEL TUSCALOOSA INC Melted and Manufactured in the USA
Batch 0001046810 2 EA 6,534.400 LB

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.0600	1.2800	0.0060	0.0050	0.0300	0.0800	0.0600	0.0260	0.0001	0.2100	0.0290	0.0010	0.0020	0.0280	0.0080	0.0080

Mechanical/ Physical Properties

Mill Coil No. 1E0804

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Olsen
69300.000	61300.000	35.00	0	0.000	0	NA		
69500.000	61800.000	32.50	0	0.000	0	NA		

Chemical Analysis

Heat No. B1R6591 Vendor NUCOR STEEL TUSCALOOSA INC DOMESTIC Mill NUCOR STEEL TUSCALOOSA INC Melted and Manufactured in the USA
Batch 0001046836 2 EA 6,534.400 LB

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.0600	1.2800	0.0060	0.0050	0.0300	0.0800	0.0600	0.0260	0.0001	0.2100	0.0290	0.0010	0.0020	0.0280	0.0080	0.0080

Mechanical/ Physical Properties

Mill Coil No. 1E0804

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Olsen
69300.000	61300.000	35.00	0	0.000	0	NA		
69500.000	61800.000	32.50	0	0.000	0	NA		

THE CHEMICAL, PHYSICAL, OR MECHANICAL TESTS REPORTED ABOVE ACCURATELY REFLECT INFORMATION AS CONTAINED IN THE RECORDS OF THE CORPORATION.

Figure B-26. Concrete Anchor Cont., Test No. NYCC-2

CHAPEL STEEL CO. Certificate of Mill Test Results PHL-000000-000 Pg 1/1
Attn: PO/Rel PART NO.

NUCOR PLATE MILL P.O.Box 279 Winton, NC 27986 (252) 356-3700

Mill Test Report
Page 1

NUCOR It's our Nature.

Issuing Date : 08/26/2010 B/L No. : 270857 Load No. : 272633 Our Order No. : 84477/2 Cust. Order No. : PHL-8513

Vehicle No: ALY 91745

Specification : 0.7500" x 96.000" x 240.000"
ASTM A36-08/ASTM A709 Grade 36-09a/AASHTO M270Grade 36/ASME
SA36-03a 2009 Addenda Al Killed

Sold To : CHAPEL STEEL CO
P O Box 1000
FAX# 215-793-9416
SPRINGHOUSE,PA 19477

Ship To : CHAPEL STEEL POTTSTOWN -
INDUSTRIAL COMPLEX - ZTS# 819
(RAIL)
MAIN TRACKS 201 & 202
CONRAIL ZONE 45 PAGE 4
HARRISBURG DIVISION
POTTSTOWN,PA 19464

Marking :

Heat No	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al(tot)	V	Nb	Ti	N	Ca	B	Sn	CEQ	PCM
0506014 ✓	0.21	0.85	0.007	0.002	0.17	0.28	0.09	0.06	0.02	0.026	0.004	0.001	0.002		0.0017	0.0002	0.012	0.39	0.28

Tensile Test								Charpy Impacts											
Plate Serial No	Pieces	Tons	Dir.	(psi) Yield	(psi) Tensile	Elongation % in 2"	Elongation % in 8"	Dir.	1	(%) shear	2	(%) shear	3	(%) shear	Ave.	(%) shear	Size	Temp	Min Ave.
0506014-01	9	22.05	T	45,300	74,500		22.1												
			T	44,700	72,500		22.0												
0506014-02	9	22.05	T	45,300	74,500		22.1												
			T	44,700	72,500		22.0												
0506014-03	9	22.05	T	45,300	74,500		22.1												
			T	44,700	72,500		22.0												
0506014-04	3	7.35	T	45,300	74,500		22.1												
			T	44,700	72,500		22.0												

Manufactured to fully killed fine grain practice by Electric Arc Furnace. Welding or weld repair was not performed on this material. Mercury has not been used in the direct manufacturing of this material. Produced as continuous cast discrete plate as-rolled, unless otherwise noted in Specification.
Yield by 0.5EUL method unless otherwise specified. Ceq = C+(Mn/6)+((Cr+Mo+V)/5)+((Cu+Ni)/15)
Pcm = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B
✓Melted and manufactured in the USA. ISO 9001-2000 certified (8006461) by SRI Quality System Registrar (80985-09). PED 97/23/EC 7/2 Annex 1, Para. 4.3 Compliant. DIN 50049 3.1.B/EN 10204 3.1B(2004), DIN EN 10204 3.1(2005) compliant. For ABS grades only, Quality Assurance certificate 06-MMPOA-383

We hereby certify that the contents of this report are accurate and correct. All test results and operations performed by the material manufacturer are in compliance with the applicable specifications, including customer specifications.

T. A. Depretis

T. A. Depretis, Metallurgist 08/26/2010 8:17:14 AM

Figure B-27. Concrete Anchor Cont., Test Nos. NYCC-2 and NYCC-3

From: Steve Fisher 3046988230 To: Elderlee Date: 6/17/2011 Time: 9:52:08 Page 1 of 1

STEEL OF WEST VIRGINIA
HUNTINGTON, WEST VIRGINIA 25726-2547

DATE: June 17, 2011

SOLD TO: Elderlee Inc.
729 Cross Road
Oaks Corner, NY 14518

SHIP TO:
Same

CUSTOMER ORDER: P003617 SWV ORDER: 50104

MATERIAL SPECIFICATION
3" X 5.7 lb/ft I-Beam. SWV Section 2658.
LENGTH: 42'. GRADE: ASTM A36-08.
All manufacturing processes for these materials occurred in the U.S.A.

Heat	Yield psi	Tensile psi	Elon % 8"	C	Mn	P	S	Si	Cu	Cr	Ni	Mo	V	Cb
18064	46000	67000	22.7	.12	0.67	.016	.028	.24	.24	.13	.08	.03	.001	.001
18064	46000	67000	22.9	.12	0.67	.016	.028	.24	.24	.13	.08	.03	.001	.001
18674	45000	65000	23.4	.12	0.59	.015	.034	.21	.30	.10	.09	.02	.001	.001
18674	45000	65000	24.4	.12	0.59	.015	.034	.21	.30	.10	.09	.02	.001	.001
20853	44000	67000	22.8	.12	0.60	.012	.026	.21	.26	.10	.09	.02	.004	.001
20853	44000	67000	23.9	.12	0.60	.012	.026	.21	.26	.10	.09	.02	.004	.001
57034	43000	64000	23.6	.13	0.59	.009	.027	.23	.23	.06	.08	.02	.003	.001
57034	42000	63000	23.0	.13	0.59	.009	.027	.23	.23	.06	.08	.02	.003	.001
57036	44000	62000	25.2	.12	0.58	.010	.023	.18	.23	.06	.09	.02	.002	.001
57036	44000	64000	24.7	.12	0.58	.010	.023	.18	.23	.06	.09	.02	.002	.001

This is to certify that the above is a true and correct report as contained in the records of this company.

Steve Fisher
Metallurgist
304-696-8200

ELDERLEE, INC.
CERT RECEIVED: 6/17/11
PURCHASE ORDER # P3617
SALES ORDER # 50104
SHIPPED FROM: SWVA

Figure B-28. Galvanized Wire, Test No. NYCC-2 m: Stevo Fichor 3046068230 To: DI Dato: 5/11/2011 Timo: 12:37:16 Pago 1 of 1

STEEL OF WEST VIRGINIA
HUNTINGTON, WEST VIRGINIA 25726-2547

DATE: May 11, 2011

SOLD TO: D I Hwy Sign Corp
P.O. Box 123
New York Mills, NY 13417

SHIP TO: DI-Highway Sign Corp.
40 Greenman Ave.
New York Mills, NY

CUSTOMER ORDER: 26867 SWV ORDER: 31188

MATERIAL SPECIFICATION
3" X 5.7 lb/ft I-Beam. SWV Section 2658.
LENGTH: 63" & 42'. GRADE: ASTM A36-08.
All manufacturing processes for these materials occurred in the U.S.A.

Heat	Yield psi	Tensile psi	Elon % 8"	C	Mn	P	S	Si	Cu	Cr	Ni	Mo	V	Cb
16444	46000	65000	25.4	.12	0.56	.018	.025	.20	.23	.12	.08	.02	.005	.001
16444	46000	65000	24.9	.12	0.56	.018	.025	.20	.23	.12	.08	.02	.005	.001
17611	48000	69000	22.8	.13	0.61	.018	.044	.23	.37	.18	.10	.02	.001	.001
17611	47000	69000	23.5	.13	0.61	.018	.044	.23	.37	.18	.10	.02	.001	.001
20246	45000	67000	24.2	.11	0.61	.018	.030	.23	.30	.14	.10	.03	.001	.001
20246	45000	66000	24.3	.11	0.61	.018	.030	.23	.30	.14	.10	.03	.001	.001

This is to certify that the above is
a true and correct report as contained
in the records of this company.

Steve Fisher
Metallurgist
304-696-8200

Figure B-29. Galvanized Wire Cont., Test No. NYCC-2

STEEL OF WEST VIRGINIA
HUNTINGTON, WEST VIRGINIA 25726-2547

DATE: October 9, 2007

SOLD TO: D I Hwy Sign Corp
P.O. Box 123
New York Mills, NY 13417

SHIP TO: DI-Highway Sign Corp.
40 Greenman Ave.
New York Mills, NY

CUSTOMER ORDER: 24159 **SWV ORDER:** 82951

MATERIAL SPECIFICATION
3″ X 7.5 lb/ft I-Beam. SWV Section 2663.
LENGTH: 41′6″. GRADE: ASTM A36-05.
All manufacturing processes for these materials occurred in the U.S.A.

Heat	Yield psi	Tensile psi	Elon % 8″	C	Mn	P	S	Si	Cu	Cr	Ni	Mo	V	Cb
12237	48000	78000	20.6	.19	0.78	.025	.029	.27	.28	.17	.09	.02	.011	.001
12237	48000	78000	21.6	.19	0.78	.025	.029	.27	.28	.17	.09	.02	.011	.001

This is to certify that the above is
a true and correct report as contained
in the records of this company.

Steve Fisher
Metallurgist

Figure B-30. Galvanized Wire Cont., Test No. NYCC-2

BENNETT BOLT WORKS, INC.

12 Elbridge Street
P.O. Box 922
Jordan, New York 13080

PH 315-689-3981
FX 315-689-3999

CG 1241 -H CABLE SPLICE - MEETS 25,000# TEST

3 PIECE CASTING #1W482/1W483/1W484 HDG A153 CLASS A
MATERIAL - ASTM A536-72 DUCTILE IRON #64-45-12
MADE BY VICTAULIC CO OF AMERICA #963352-001
GALVANIZED BY KORNS GALV.

2 WEDGES PART # W 1
MATERIAL - ASTM A47 GRADE 32510 MALLEABLE IRON
MADE BY BUCK CO. # 1S7

ALL PRODUCTS WERE MELTED AND MANUFACTURED IN THE U.S.A.

MANAGER QUALITY ASSURANCE

Figure B-31. Cable Wedge, Test No. NYCC-2

INSPECTION CERTIFICATE

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

Customer	Specification	Size	Lot No.	Date
	ASTM A-563 GRADE DH HEAVY HEX NUT	H.D.G. 3/4-10 UNC 0.020" BLUE DYE	SC842	Oct.28,'10

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

Chemical Composition (%)

Mill Maker	Material Size	Heat No.	Spec.	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	
MCSTEEL	CARBON			0.20 0.55	-	MIN. 0.60	MAX. 0.040	MAX. 0.050	-	-	-	-	-
	STEEL	M37945		0.44	0.25	0.80	0.017	0.031	0.31	0.09	0.16	0.03	-

Mechanical Property Inspection

Item	Proof Load	Cone stripping	Hardness	After Heat Treatment Hardness	Absorbed Energy	Heat Treatment
Spec.	50,100 lbf	- kN·kgf·lbf	24-38 HrC	HrB·HB	J·kgfm·ftlbf	T: MIN. 800 °F
Results	n 5 Results GOOD	n - Results -	28.5 28.5 28.8 29.0 28.7 28.7	5 Piece Average After Heat Treament; Hardness Treatment After 24 Hr.X °F(°C)	at °F(°C)	Q: FORGING Q (W.Q.) T: 1211 °F/45M. (W.C.)

Q: Quenching
T: Tempering
ST: Solution Treatment

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

Remarks:

" DH U"

Production Quantity 74,545 pcs.

OFFICIAL SEAL
JEAN MARGHERIO
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES:10/18/13
10-29-10

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

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

Chief of Quality Assurance Section

Figure B-32. Cable Hook Nuts, Test Nos. NYCC-2 and NYCC-3

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

CERTIFIED MILL TEST REPORT

4/07/08 17:36:09
100% MELTED AND MANUFACTURED IN THE USA
All beams produced by Nucor-Berkeley are cast and rolled to a fully killed and fine grain practice.

Sold To: STEEL & PIPE SUPPLY CO., INC.
PO BOX 1688

MANHATTAN, KS 66505

Ship To: STEEL & PIPE SUPPLY CO., INC.
310 SOUTH SMITH RD

JONESBURG, MO 63351

Customer #.: 472 - 3
Customer PO: 4500104078
B.O.L. #...: 683949

SPECIFICATIONS: Tested in accordance with ASTM specification A6/A6M and A370.
AASHTO : M270-36-05/M270-50-05
ASME : SA-36 07a
ASTM : A992-06a://A36-05/A572-06-50/A709-06a36/A709-07 50/A709-345M
CSA : CSA-44W/G40.21-50W

Description	Heat# Grade(s) Test	Yield/ Tensile Ratio	Yield (PSI) (MPa)	Tensile (PSI) (MPa)	Elong %	C Cr Pb	Mn Mo Ti	P Sn Ca	S Al B	Si V N	Cu Nb Zr	Ni ****** CI	CE1 CE2 Pcm
S3X7.5	2710536	.81	56700	70000	25.89	.0590	.7900	.0066	.0243	.2020	.1100	.0450	.2106
040' 00.00"	A992-06a		391	483		.0270	.0180	.0067	.0017	.0031	.0266		.2496
S75X11.2		.81	56900	70100	24.68	.0013	.0013	.0000	.0009	.0058	.0000	3.0403	.1187
012.1920m			392	483		35 Piece(s)						Inv#:	0
S8X18.4	2804528	.84	56800	68000	29.36	.0660	.8250	.0083	.0276	.2000	.1380	.0430	.2272
040' 00.00"	A992-06a		392	469		.0360	.0190	.0063	.0017	.0032	.0264		.2658
S200X27.4		.83	56500	67800	28.71	.0018	.0018	.0000	.0016	.0054	.0000	3.5585	.1328
012.1920m			390	467		8 Piece(s)						Inv#:	0
S8X18.4	2804637	.83	56100	68000	24.91	.0650	.8530	.0080	.0278	.2070	.0880	.0340	.2279
050' 00.00"	A992-06a		387	469		.0440	.0160	.0067	.0015	.0031	.0254		.2675
S200X27.4		.83	56200	67800	27.66	.0017	.0016	.0003	.0014	.0052	.0000	2.6374	.1300
015.2400m			387	467		8 Piece(s)						Inv#:	0
S8X23	1804632	.78	52800	67400	24.55	.0670	.8060	.0111	.0285	.2210	.0870	.0310	.2209
040' 00.00"	A992-06a		364	465		.0340	.0210	.0081	.0032	.0033	.0256		.2628
S200X34		.79	53300	67100	21.51	.0064	.0020	.0005	.0000	.0058	.0000	2.6695	.1229
012.1920m			368	463		8 Piece(s)						Inv#:	0
W10x19	1800626	.82	55900	67800	27.74	.0670	.8470	.0099	.0232	.2250	.1210	.0390	.2291
040' 00.00"	A992-06a		385	467		.0290	.0190	.0059	.0021	.0032	.0252		.2716
W250X28.4		.82	55200	67400	28.24	.0025	.0018	.0000	.0024	.0048	.0000	3.3129	.1385
012.1920m			381	465		8 Piece(s)						Inv#:	0

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

Hg free and no contact with Hg during manufacture.
CE1= C+(Mn/6)+((Cr+Mo+V)/5)+((Ni+Cu)/15)
CE2 = C+((Mn+Si)/6)+((Cr+Mo+V+Cb)/5)+((Ni+Cu)/15)

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

Bruce A. Work
Metallurgist

(State of South Carolina
(County of Berkeley
Sworn and subscribed before me

______ day of ______________

Figure B-33. Anchor Post Assembly, Test No. NYCC-3

GERDAU AMERISTEEL

JACKSON STEEL MILL
801 AMERISTEEL ROAD
JACKSON TN 38305 USA
(731) 424-5600

Chemical and Physical Test Report
MADE IN UNITED STATES

V-691084

SHIP TO	INVOICE TO	SHIP DATE
STEEL AND PIPE SUPPLY CO. INC. 4750 WEST MARSHALL AVENUE 785-587-5119 LONGVIEW, TX 75604	STEEL AND PIPE SUPPLY CO. INC. PO BOX 1688 MANHATTAN, KS 66505-1688	02/26/11 **CUST. ACCOUNT NO** 40130833

PRODUCED IN: JACKSON TN

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
F1/2 X 5 1/2	A36	ASTM A36-08; ASME SA-36-08; ASTM A709-36-08; C.S.A. G40.21-98 44W	1013165-01	4500154891-01

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	N	Sn	Al	Ti	Zr	Ca	C Eqv
V909279	.16	.78	.013	.033	20	35	.09	.11	.026	.020	.001	.0005	.0120	.012	.001	.00100	.000	.00000	38

Mechanical Test: Yield 57420 PSI, 395.9 MPA Tensile: 76200 PSI, 525.38 MPA %El: 28.0/8in, 28.0/200MM Def HT: 0, 0MM %I/h 0L Red R 12.73
Comment ASTM A36-05 & ASTM A709 GR36
Mechanical Test: Yield 56500 PSI, 389.55 MPA Tensile: 76120 PSI, 524.83 MPA %El: 27.0/8in, 27.0/200MM Def HT: 0, 0MM %I/h 0L Red R 12.73
Comment ASTM A36-05 & ASTM A709 GR36

PRODUCED IN: JACKSON TN

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
F3/4 X 2	A36	ASTM A36-08; ASME SA-36-08; ASTM A709-36-08; C.S.A. G40.21-98 44W	1012737-01	4500154814-01

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	N	Sn	Al	Ti	Zr	Ca	C Eqv
V910172	.15	.70	.011	.030	22	.36	.10	.06	.027	.003	.001	.0005	.0090	.012	.001	.00100	.000	.00000	.353

Mechanical Test: Yield 47060 PSI, 324.47 MPA Tensile: 71570 PSI, 493.46 MPA %El: 29.5/8in, 29.5/200MM Def HT: 0, 0MM %I/h 0L Red R 18.12
Comment ASTM A36-05 & ASTM A709 GR36
Mechanical Test: Yield 45743 PSI, 315.39 MPA Tensile: 70480 PSI, 485.94 MPA %El: 28.5/8in, 28.5/200MM Def HT: 0, 0MM %I/h 0L Red R 18.12
Comment ASTM A36-05 & ASTM A709 GR36

Customer Notes

NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.

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

Bhaskar Yalamanchili
Quality Director
Gerdau Ameristeel

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

Metallurgical Services Manager
JACKSON STEEL MILL

Figure B-34. Anchor Post Assembly Cont., Test No. NYCC-3

GERDAU
JACKSON STEEL MILL
801 AMERISTEEL ROAD
JACKSON TN 38305 USA
(731) 424-5600

Chemical and Physical Test Report
MADE IN UNITED STATES

V-704512

SHIP TO	INVOICE TO	SHIP DATE
STEEL AND PIPE SUPPY CO INC 401 NEW CENTURY PARKWAY 785-587-5185 NEW CENTURY, KS 66031	STEEL AND PIPE SUPPLY CO. INC. PO BOX 1688 MANHATTAN, KS 66505-1688	10/13/11 **CUST. ACCOUNT NO** 40130833

PRODUCED IN: JACKSON TN

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
F5/16 X 3	A36	ASTM A36-08, A709-10-36,ASME SA-36;CSA G40.21-44W-04,	1076250-01	4500166902-01

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	Sn	Al	Ti	Zr	Ca	C Eqv
V912683	.12	.75	.017	.028	.24	.25	.09	.12	.028	.018	.001	.0004	.010	.001	.00100	.000	.00000	.343

Mechanical Test: Yield 51670 PSI, 356.25 MPA Tensile: 73050 PSI, 503.66 MPA %El: 26.0/8in, 26.0/200MM
Customer Requirements CASTING: STRAND CAST
Mechanical Test: Yield 52760 PSI, 363.77 MPA Tensile: 70730 PSI, 487.67 MPA %El: 27.0/8in, 27.0/200MM
Customer Requirements CASTING: STRAND CAST

PRODUCED IN: JACKSON TN

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
F3/8 X 4	A36	ASTM A36-08, A709-10-36,ASME SA-36;CSA G40.21-44W-04,	2639163-24	G450007728

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	Sn	Al	Ti	C Eqv
V913909	.15	.76	.014	.024	.24	.30	.09	.11	.030	.015	.001	.0004	.010	.001	.00100	.377

Mechanical Test: Yield 51173 PSI, 352.83 MPA Tensile: 73130 PSI, 504.21 MPA %El: 28.0/8in, 28.0/200MM Red R 23.18
Customer Requirements CASTING: STRAND CAST
Mechanical Test: Yield 53951 PSI, 371.98 MPA Tensile: 74200 PSI, 511.59 MPA %El: 28.0/8in, 28.0/200MM Red R 23.18
Customer Requirements CASTING: STRAND CAST
CUST ITEM NUMBER: 000000000101240020

Customer Notes

NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.

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

Bhaskar Yalamanchili
Quality Director
Gerdau

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

Metallurgical Services Manager
JACKSON STEEL MILL

Figure B-35. Anchor Post Assembly Cont., Test No. NYCC-3

125002
Page 3 of 3

GERDAU AMERISTEEL

CALVERT CITY STEEL MILL
1035 SHAR-CAL ROAD
CALVERT CITY KY 42029 USA
(270) 395-3100

Chemical and Physical Test Report
MADE IN UNITED STATES

Y-057407

SHIP TO	INVOICE TO	SHIP DATE
STEEL AND PIPE SUPPY CO INC 401 NEW CENTURY PARKWAY 785-587-5185 NEW CENTURY, KS 66031	STEEL AND PIPE SUPPLY CO. INC. PO BOX 1688 MANHATTAN, KS 66505-1688	01/08/10 CUST. ACCOUNT NO 40130833

PRODUCED IN: CALVERT CITY

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
F3/8 X 8	A36	ASTM A36-08, ASTM A709 GR36	9177198-03	4500125002-03

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	N	Sn	Ti	C Eqv
Y013646	.15	.67	.011	.016	.25	.29	.08	.04	.022	<.008	<.008	.0002	.0093	.009	.00100	.34

Mechanical Test: Yield 52000 PSI, 358.53 MPA Tensile: 71000 PSI, 489.53 MPA %El: 24.0/8in, 24.0/203.2mm Corrosion Index: 5.48
Customer Requirements CASTING: STRAND CAST
Comment: ASTM A36-05 & ASTM A709 GR36
Mechanical Test: Yield 51000 PSI, 351.63 MPA Tensile: 71000 PSI, 489.53 MPA %El: 24.0/8in, 24.0/203.2mm Corrosion Index: 5.48
Customer Requirements CASTING: STRAND CAST
Comment: ASTM A36-05 & ASTM A709 GR36

PRODUCED IN: CALVERT CITY

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
F1/2 X 12	A36	ASTM A36-08, A709 GR36, ASME SA36	9177198-17	4500125002-17

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	N	Sn	Ti	C Eqv
Y013672	.15	.70	.010	.027	.22	.28	.08	.04	.023	.001	<.008	.0002	.0073	.010	.00100	.34

Mechanical Test: Yield 49000 PSI, 337.84 MPA Tensile: 69000 PSI, 475.74 MPA %El: 24.0/8in, 24.0/203.2mm Corrosion Index: 5.35
Customer Requirements CASTING: STRAND CAST
Comment: ASTM A36-05 & ASTM A709 GR36
Mechanical Test: Yield 49000 PSI, 337.84 MPA Tensile: 70000 PSI, 482.63 MPA %El: 24.0/8in, 24.0/203.2mm Corrosion Index: 5.35
Customer Requirements CASTING: STRAND CAST
Comment: ASTM A36-05 & ASTM A709 GR36

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

Bhaskar Yalamanchili
Quality Director
Gerdau Ameristeel

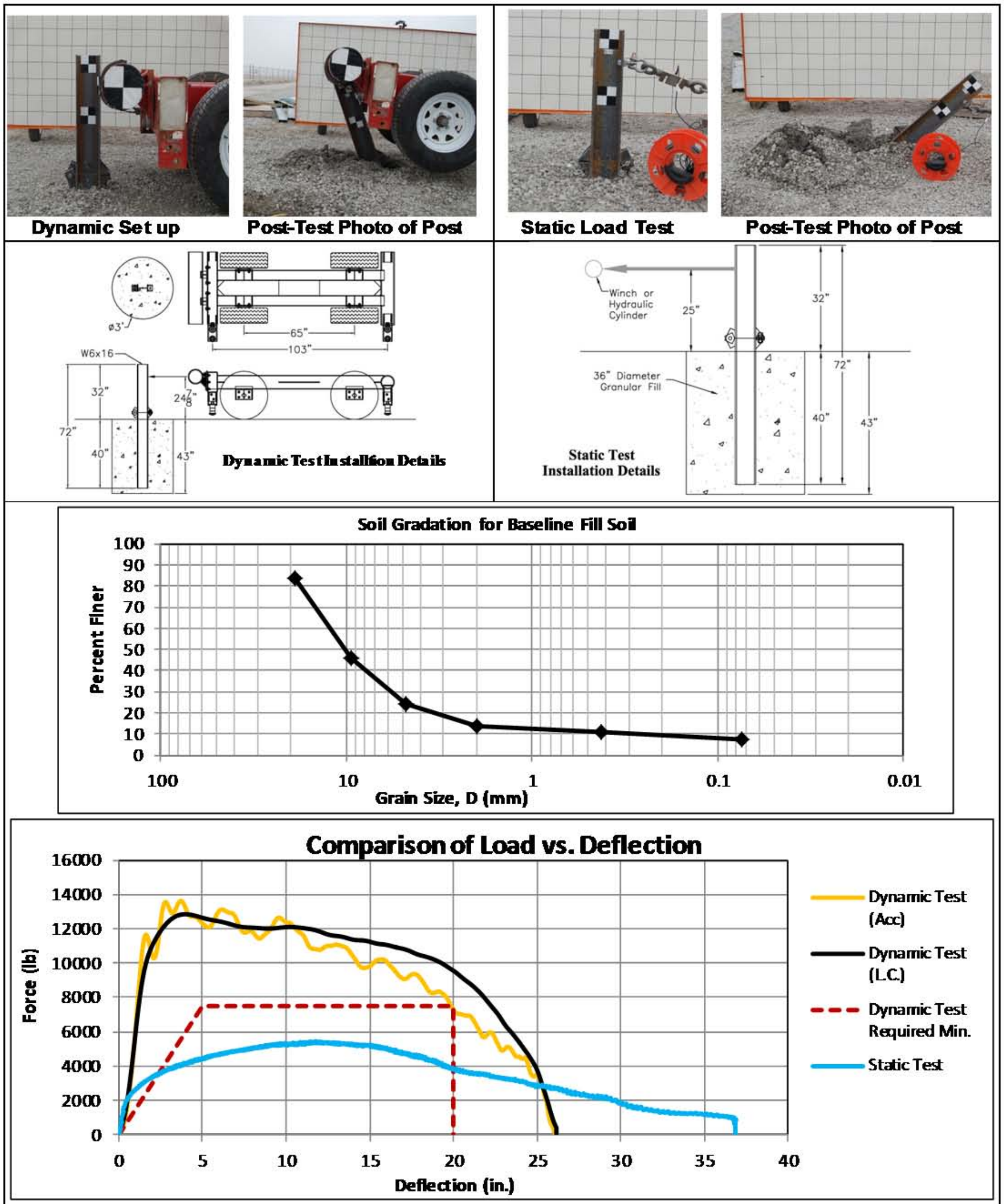
THE ABOVE FIGURES ARE CERTIFIED EXTRACTS FROM THE ORIGINAL CHEMICAL AND PHYSICAL TEST RECORDS AS CONTAINED IN THE PERMANENT RECORDS OF COMPANY.

Metallurgical Services Manager
CALVERT CITY STEEL MILL

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

Figure B-36. Galvanized Wire, Test No. NYCC-3

Appendix C. Soil and Calibration Tests

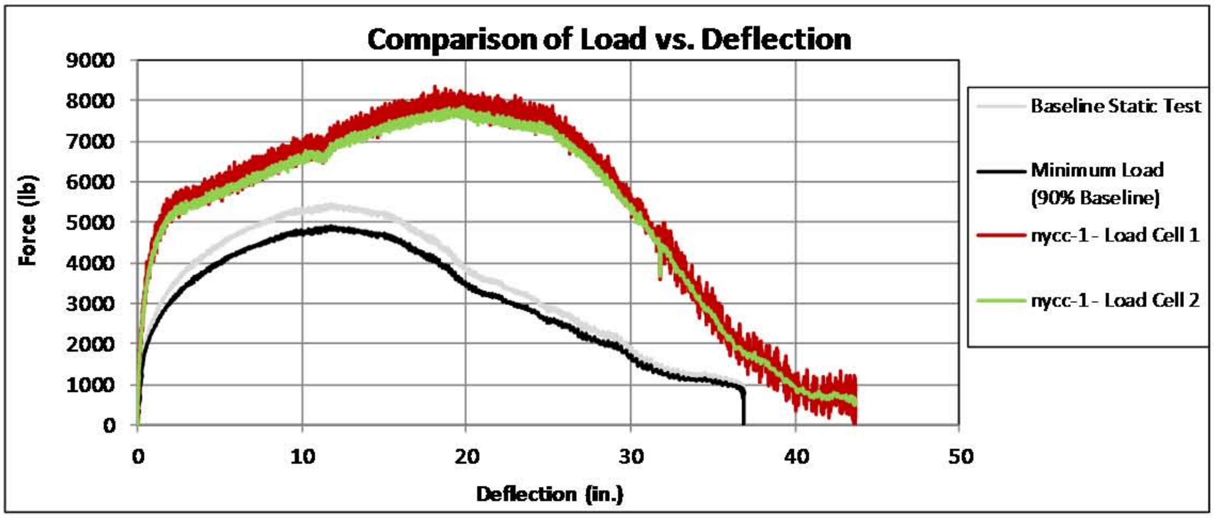


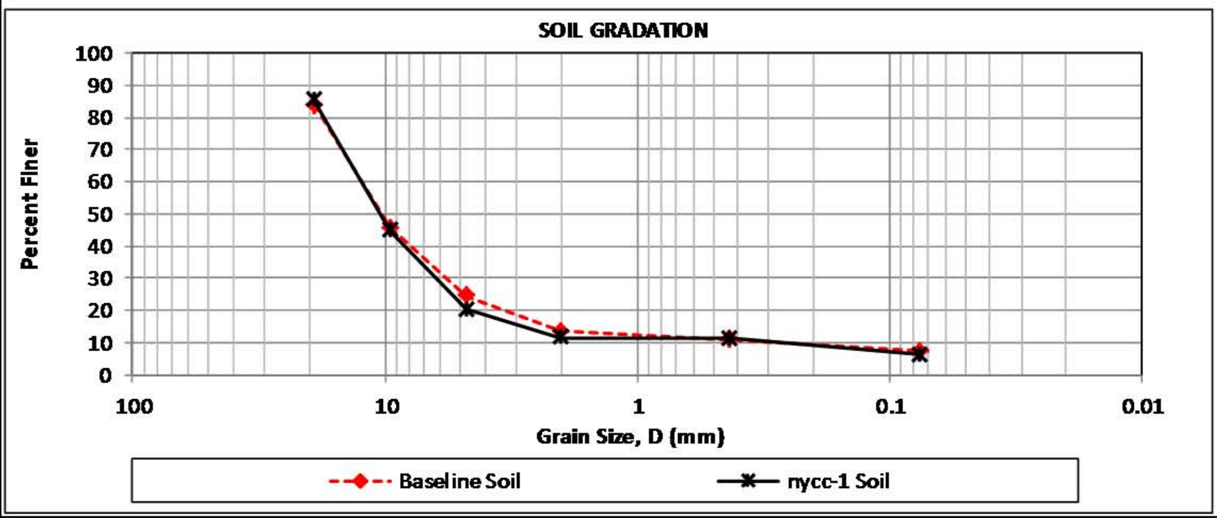
Date	3/28/2011
Test Facility & Site Location	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)	Well Graded Gravel (GW)
Fill material description (ASTM D2487)	Well Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure	8-in. Lifts, High Compaction, Pnuematic Tamper
Bogie Weight	1,727 lb
Impact Velocity	18.81 mph

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

Static Load Test Setup

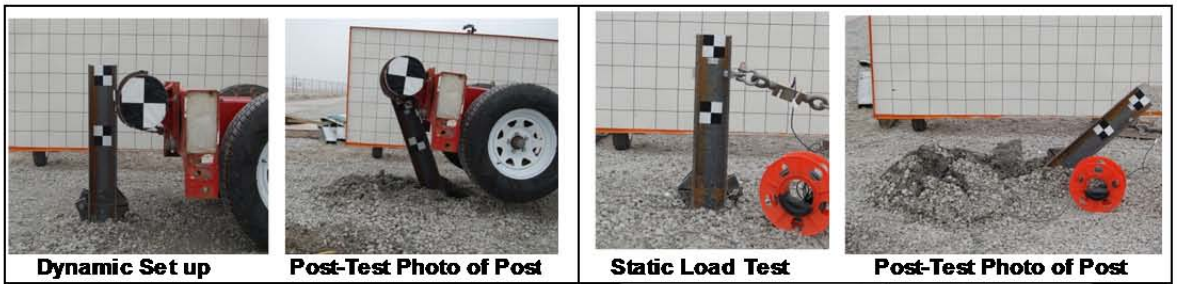
Post-Test Photo of Post

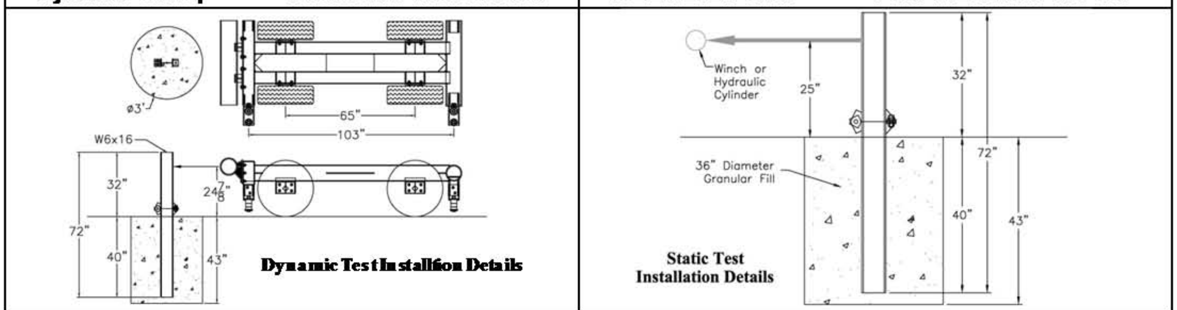


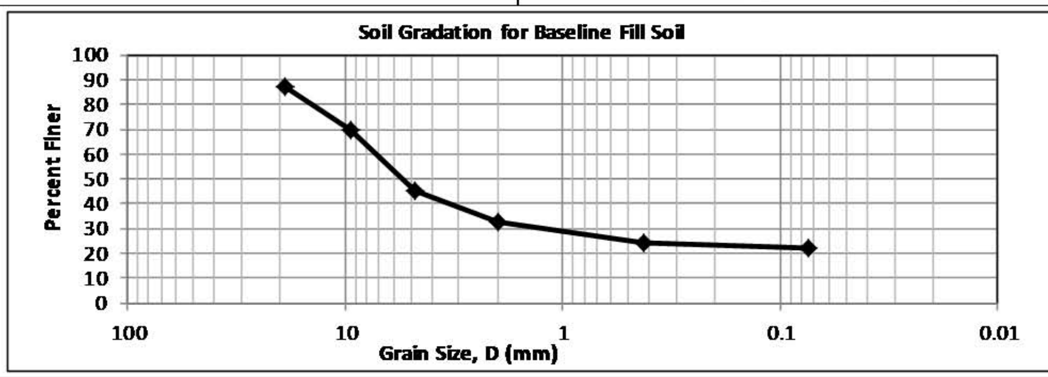


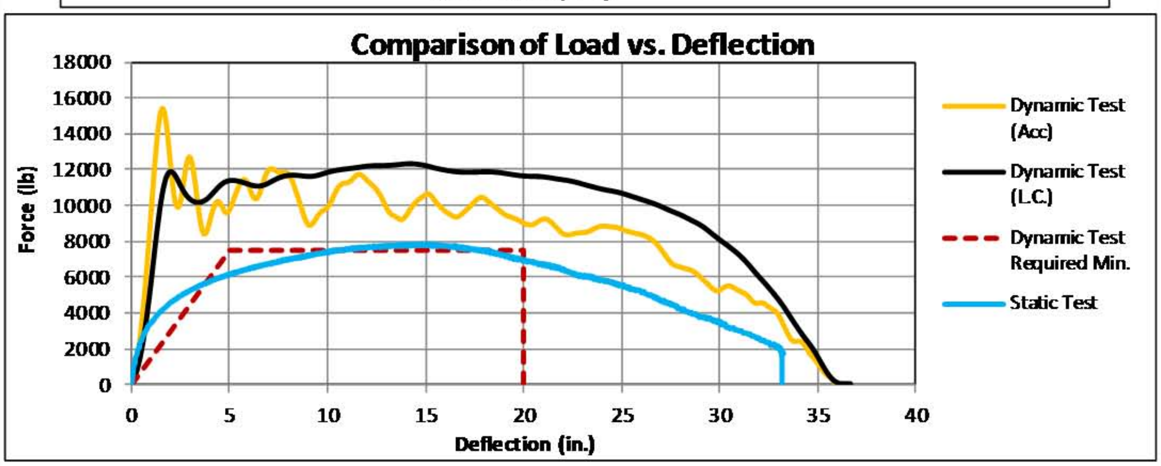
Date	8/2/2011
Test Facility & Site Location	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)	Well Graded Gravel (GW)
Fill material description (ASTM D2487)	Well Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure	8-inch lifts tamped with a pneumatic compactor

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







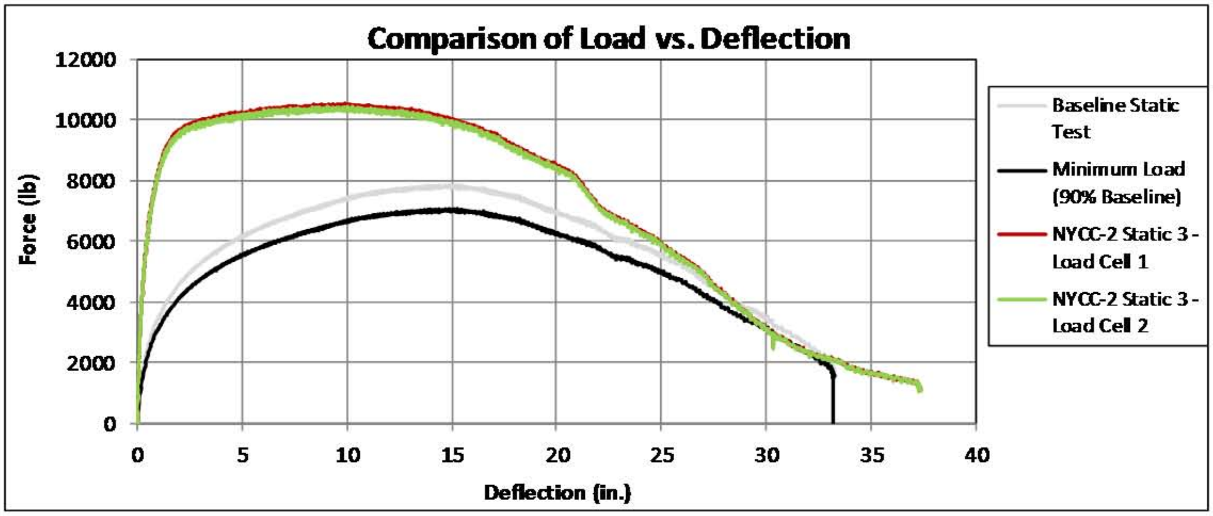


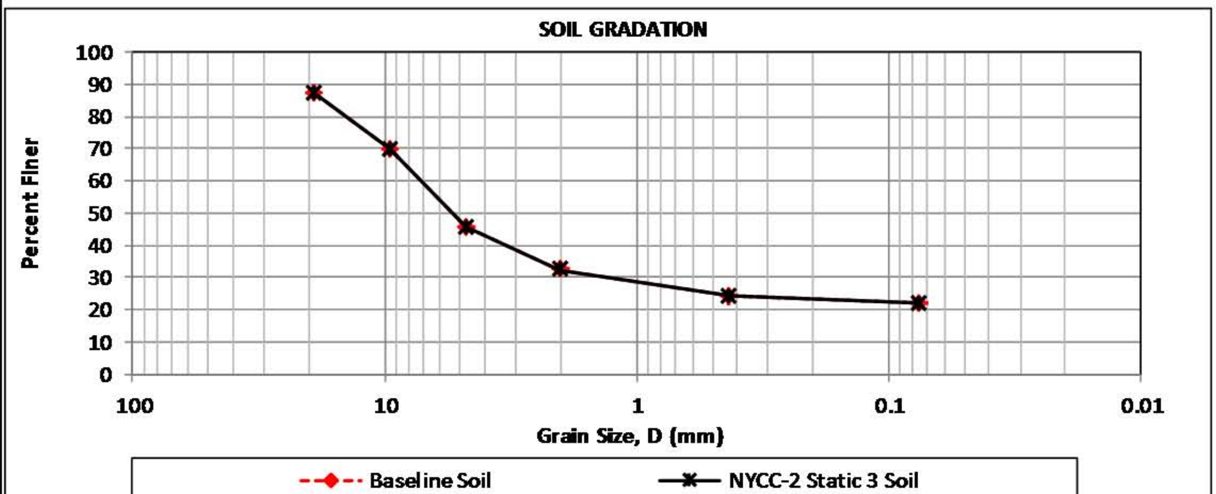
Date	7/8/2011
Test Facility & Site Location	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)	Well Graded Gravel (GW)
Fill material description (ASTM D2487)	Well Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure	H.E. - 8
Bogie Weight	1,726 lb
Impact Velocity	22.03 mph

Figure C-3. Soil Strength, Initial Calibration Tests, Test No. NYCC-2

Static Load Test Setup

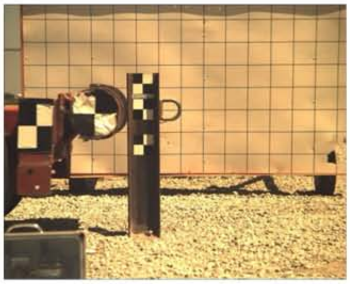
Post-Test Photo of Post



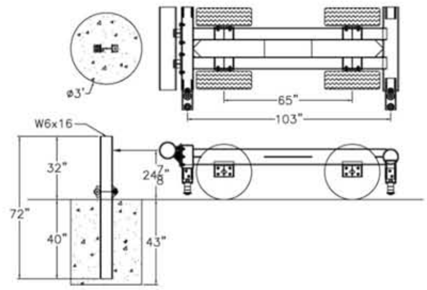


Date	**11/1/2011**
Test Facility & Site Location	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)	Well Graded Gravel (GW)
Fill material description (ASTM D2487)	Well Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure	8-inch lifts tamped with a pneumatic compactor

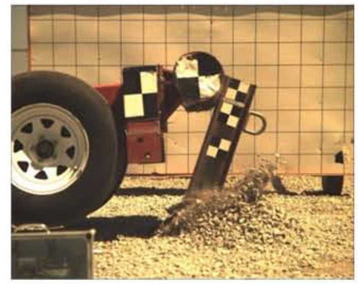
Figure C-4. Static Soil Test, Test No. NYCC-2



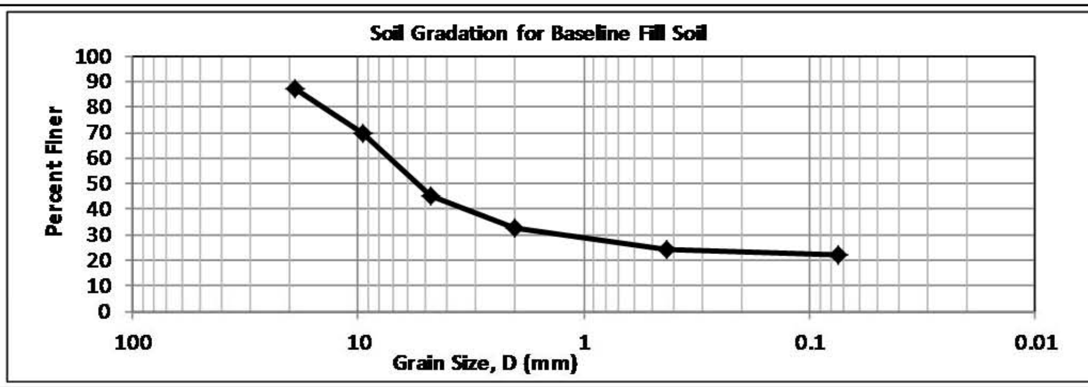
Dynamic Set up

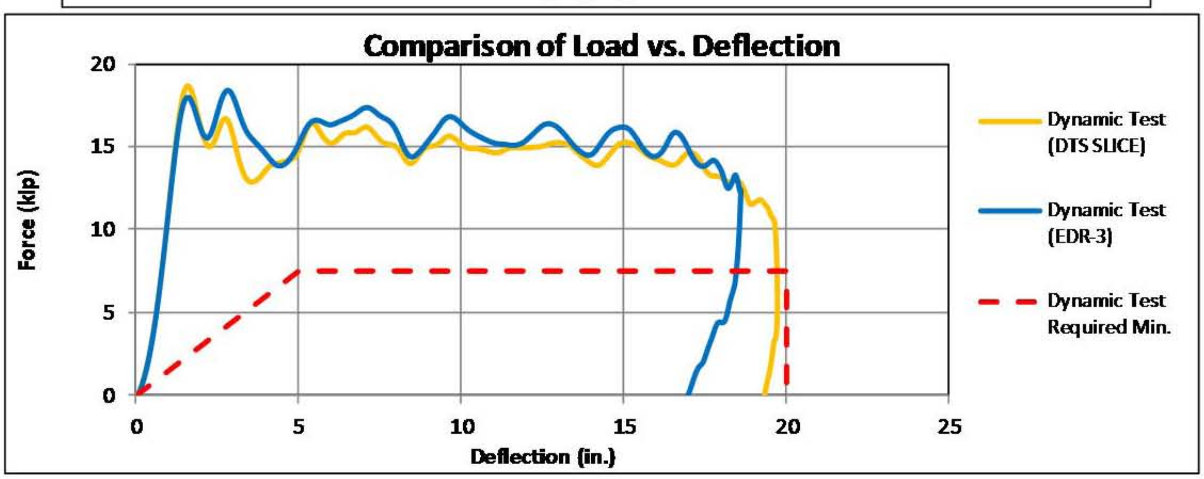


Dynamic Test Installtion Details



Post-Test Photo of Post





Date	4/25/2012
Test Facility & Site Location	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)	Well Graded Gravel (GW)
Fill material description (ASTM D2487)	Well Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure	H.E. - 8
Bogie Weight	1,726 lb
Impact Velocity	22.03 mph

Figure C-5. Dynamic Soil Strength Test, Test No. NYCC-3

Appendix D. Vehicle Deformation Records

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 1

TEST: NYCC-1
VEHICLE: 2270P/Ram

Note: If impact is on driver side need to enter negative number for Y

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
1	25	12 3/4	- 1/4	25	12 3/4	- 1/4	0	0	0
2	29 1/4	19 1/4	-4 1/4	29 1/4	19 1/4	-4	0	0	1/4
3	29	24 3/4	-4	29	25 1/2	-4	0	3/4	0
4	27 3/4	29 1/4	-2 3/4	27 3/4	29 3/4	-2 3/4	0	1/2	0
5	21	10	-1 1/4	21	10 1/4	-1 1/4	0	1/4	0
6	22	15 1/4	-4	22	15 1/4	-4	0	0	0
7	23 1/4	20 3/4	-7	23 1/4	21	-7	0	1/4	0
8	23	29 1/4	-7	23 1/4	29 3/4	-7 1/4	1/4	1/2	- 1/4
9	12	4	-2 1/4	12	4	-2 1/4	0	0	0
10	15 1/2	7	-1 3/4	15 1/2	7	-1 3/4	0	0	0
11	19	13 3/4	-5 1/2	19	14	-5 1/2	0	1/4	0
12	20 1/2	18 1/4	-8 3/4	20 1/2	18 1/2	-8 3/4	0	1/4	0
13	20 1/2	24 1/4	-8 3/4	20 1/2	24 1/2	-8 3/4	0	1/4	0
14	20 1/2	28 1/2	-8 3/4	20 1/2	28 3/4	-8 3/4	0	1/4	0
15	10 1/4	4 3/4	-2 1/2	10	4 1/2	-2 1/2	- 1/4	- 1/4	0
16	17	14 3/4	-8 3/4	17	14 3/4	-8 3/4	0	0	0
17	17	21 3/4	-8 3/4	17	21 1/2	-8 3/4	0	- 1/4	0
18	17	29	-8 3/4	17	28 3/4	-9	0	- 1/4	- 1/4
19	8 1/4	2 1/4	-2 3/4	8 1/2	2	-2 3/4	1/4	- 1/4	0
20	11	12 1/4	-8 3/4	11	12 1/4	-8 3/4	0	0	0
21	11 1/4	18	-8 3/4	11 1/4	18	-8 3/4	0	0	0
22	11 1/4	24 1/4	-8 3/4	11 1/4	24	-8 3/4	0	- 1/4	0
23	11	29 1/4	-8 3/4	11	29 1/4	-8 3/4	0	0	0
24	6 1/4	14 1/2	-9	6 1/4	14 1/2	-9	0	0	0
25	6 1/2	25	-9	6 1/2	25	-9	0	0	0
26	1 1/2	7	-2 1/4	1 1/2	7	-2 1/2	0	0	- 1/4
27	1	18 1/2	-5	1	18 1/2	-5	0	0	0
28	3/4	27 1/4	-5	3/4	27	-5	0	- 1/4	0
29							0	0	0
30							0	0	0
31							0	0	0

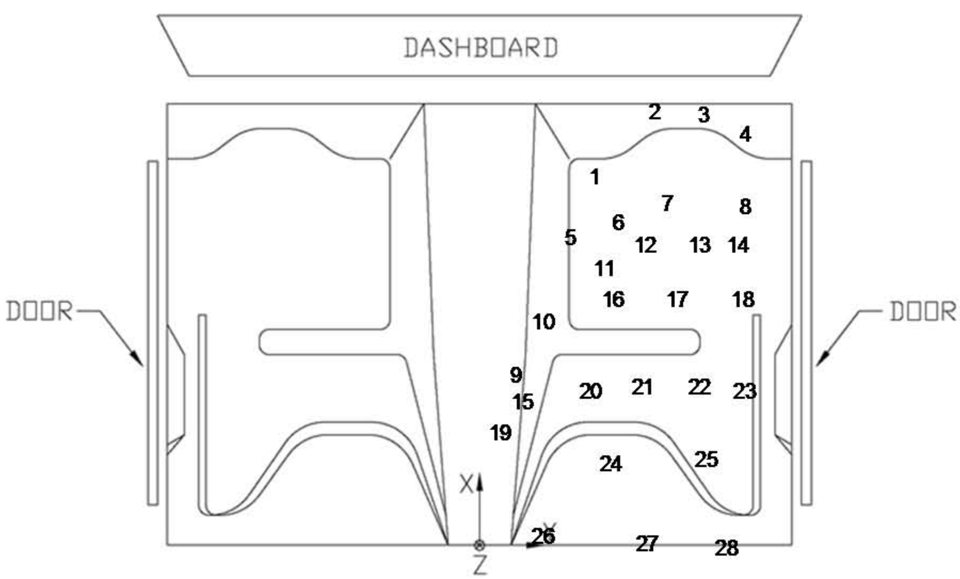


Figure D-1. Floor Pan Deformation Data – Set 1, Test No. NYCC-1

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 2

TEST: NYCC-1
VEHICLE: 2270P/Ram

Note: If impact is on driver side need to enter negative number for Y

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
1	40 3/4	19	0	40 3/4	19	0	0	0	0
2	45 1/2	25 1/4	-4	45 3/4	25 1/2	-4	1/4	1/4	0
3	45 1/2	31 1/4	-4	45 1/4	31 1/2	-4	- 1/4	1/4	0
4	44 1/4	35 1/2	-2 1/2	44	35 3/4	-2 3/4	- 1/4	1/4	- 1/4
5	37 1/4	16 3/4	- 3/4	37 1/4	16 1/2	-1	0	- 1/4	- 1/4
6	38 1/4	22	-3 3/4	38 1/4	21 1/2	-3 3/4	0	- 1/2	0
7	40	27 1/4	-7	39 3/4	27 1/2	-7	- 1/4	1/4	0
8	39 3/4	35 3/4	-7	39 3/4	35 1/2	-7	0	- 1/4	0
9	28 1/4	10 1/2	-1 3/4	28 1/4	10 1/2	-1 3/4	0	0	0
10	31 3/4	13 1/2	-1 1/2	31 3/4	13 1/2	-1 1/2	0	0	0
11	35 1/2	20 1/2	-5 1/4	35 1/4	20 1/2	-5	- 1/4	0	1/4
12	37	24 3/4	-8 1/2	37	25 1/2	-8 1/2	0	3/4	0
13	37 1/4	30 1/2	-8 1/2	37 1/4	31	-8 1/2	0	1/2	0
14	37 1/4	35	-8 1/2	37 1/4	35 1/2	-8 1/2	0	1/2	0
15	26 1/4	11 1/4	-2 1/4	26 1/4	11 1/4	-2 1/4	0	0	0
16	33 1/2	21 1/4	-8 1/2	33 1/4	21 1/4	-8 1/2	- 1/4	0	0
17	33 1/2	28 1/4	-8 1/2	33 1/2	28 1/4	-8 1/2	0	0	0
18	33 1/2	34 3/4	-8 3/4	33 3/4	35 1/2	-8 3/4	1/4	3/4	0
19	24 1/2	8 3/4	-2 1/4	24 1/2	8 3/4	-2 1/4	0	0	0
20	27 3/4	19	-8 1/2	27 1/2	18 3/4	-8 1/2	- 1/4	- 1/4	0
21	27 3/4	24 3/4	-8 1/2	27 1/2	25	-8 1/2	- 1/4	1/4	0
22	27 3/4	30 3/4	-8 1/2	27 3/4	31	-8 1/2	0	1/4	0
23	27 3/4	36	-8 1/2	27 1/2	36 1/2	-8 1/2	- 1/4	1/2	0
24	23	21	-8 1/2	23	21 1/2	-8 1/2	0	1/2	0
25	23 1/4	31 1/4	-8 3/4	23 1/4	31 3/4	-8 3/4	0	1/2	0
26	17 1/2	13 3/4	-2	17 3/4	13 3/4	-2	1/4	0	0
27	17 1/4	24 3/4	-4 1/2	17 1/2	24 1/4	-4 1/2	1/4	- 1/2	0
28	17 1/2	33 3/4	-4 1/2	17 1/4	33 3/4	-4 1/2	- 1/4	0	0
29							0	0	0
30							0	0	0
31							0	0	0

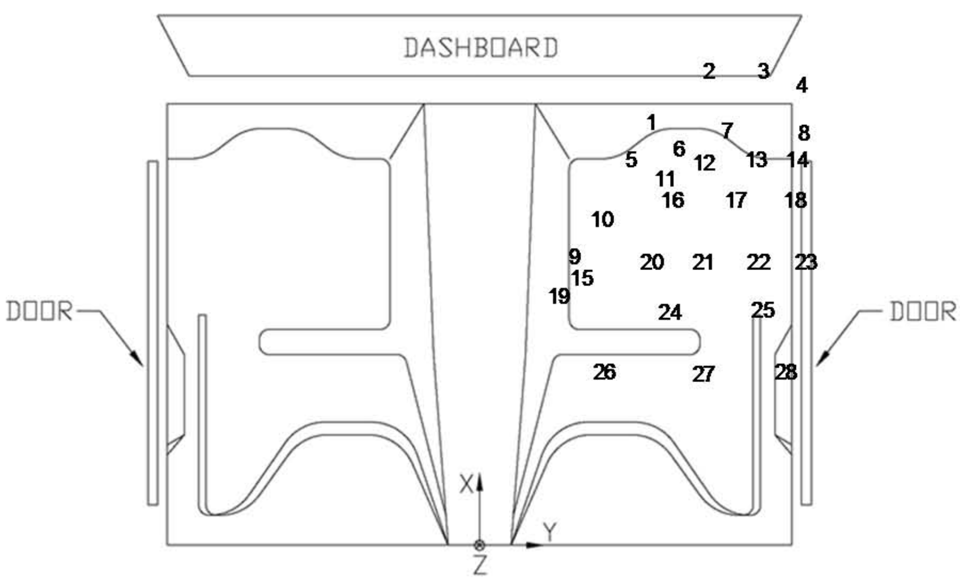


Figure D-2. Floor Pan Deformation Data – Set 2, Test No. NYCC-1

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1

TEST: NYCC-1
VEHICLE: 2270P/Ram

Note: If impact is on driver side need to enter negative number for Y

	POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
DASH	A1	39 3/4	41	22	39 3/4	41	22 1/4	0	0	1/4
	A2	39 1/2	48 3/4	22	39 1/2	48 3/4	22	0	0	0
	A3	39	58 1/4	21 1/2	39	58 1/4	21 1/4	0	0	- 1/4
	A4	34 1/4	42 1/2	15 1/2	34 1/4	42 1/2	15 1/2	0	0	0
	A5	34 1/4	50	15 1/2	34	50	15 1/2	- 1/4	0	0
	A6	34 1/4	59 1/4	15 1/2	34 1/4	59 1/4	15 1/2	0	0	0
SIDE PANEL	B1	23 1/4	27 1/2	-1 3/4	23 1/2	27 1/2	-1 1/2	1/4	0	1/4
	B2	21	27 1/4	0	21	27 1/2	0	0	1/4	0
	B3	20 3/4	27 3/4	-4 1/4	21	28	-4 1/4	1/4	1/4	0
IMPACT SIDE DOOR	C1	27	40 1/4	18	26 3/4	40 1/4	18	- 1/4	0	0
	C2	17	39 3/4	18 1/2	17	40	18 1/4	0	1/4	- 1/4
	C3	5 1/2	40 1/4	17 1/4	5 3/4	40 1/2	17 1/2	1/4	1/4	1/4
	C4	23 3/4	34	- 3/4	23 3/4	34	- 3/4	0	0	0
	C5	18 1/2	33 1/4	-2 3/4	18 1/2	33 1/4	-2 3/4	0	0	0
	C6	4 1/2	34 1/2	-1	4 1/2	34 1/2	-1	0	0	0
ROOF	D1							0	0	0
	D2							0	0	0
	D3							0	0	0
	D4							0	0	0
	D5							0	0	0
	D6							0	0	0
	D7							0	0	0
	D8							0	0	0
	D9							0	0	0
	D10							0	0	0
	D11							0	0	0
	D12							0	0	0
	D13							0	0	0
	D14							0	0	0
	D15							0	0	0

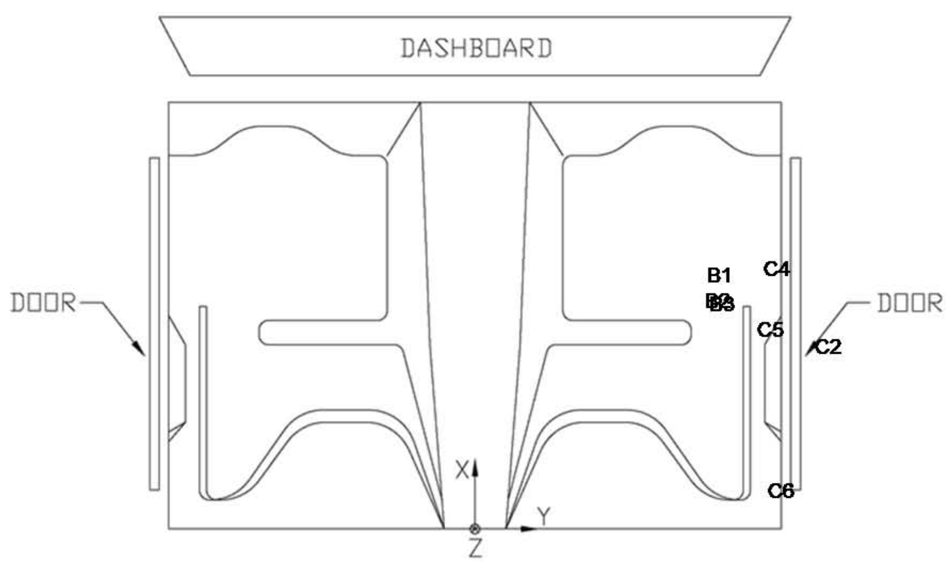


Figure D-3. Occupant Compartment Deformation Data – Set 1, Test No. NYCC-1

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2

TEST: NY CC-1
VEHICLE: 2270P/Ram

Note: If impact is on driver side need to enter negative number for Y

	POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
DASH	A1	53	41 1/4	22 1/4	53	41	22 1/2	0	- 1/4	1/4
	A2	53	48 3/4	22	53	49	22	0	1/4	0
	A3	55 1/2	58 1/4	21 1/2	55 1/2	58 1/2	21 1/2	0	1/4	0
	A4	48 1/2	43	15 3/4	48 1/2	43	15 3/4	0	0	0
	A5	48 1/2	50 1/4	15 3/4	48 1/2	50 1/2	15 1/2	0	1/4	- 1/4
	A6	51 3/4	59 1/4	15 3/4	51 3/4	59 1/2	15 3/4	0	1/4	0
SIDE PANEL	B1	39 1/2	30	-1 3/4	39 1/2	30	-1 1/2	0	0	1/4
	B2	36 3/4	29 1/4	0	36 3/4	29 1/4	0	0	0	0
	B3	37	29 1/2	-4 1/4	37	29 1/2	-4	0	0	1/4
IMPACT SIDE DOOR	C1	30 1/4	45 3/4	18 1/4	30 1/4	45 3/4	18 1/2	0	0	1/4
	C2	20 1/4	46	18 3/4	20 1/2	46 1/4	18 1/2	1/4	1/4	- 1/4
	C3	9 1/4	46	17 3/4	9 1/4	46 1/4	17 3/4	0	1/4	0
	C4	29 1/4	41	- 1/2	29 1/4	40 3/4	- 1/2	0	- 1/4	0
	C5	24	40 3/4	-2 1/2	24	40 3/4	-2 1/2	0	0	0
	C6	9 3/4	41 1/4	- 1/2	9 3/4	41 1/4	- 1/2	0	0	0
ROOF	D1							0	0	0
	D2							0	0	0
	D3							0	0	0
	D4							0	0	0
	D5							0	0	0
	D6							0	0	0
	D7							0	0	0
	D8							0	0	0
	D9							0	0	0
	D10							0	0	0
	D11							0	0	0
	D12							0	0	0
	D13							0	0	0
	D14							0	0	0
	D15							0	0	0

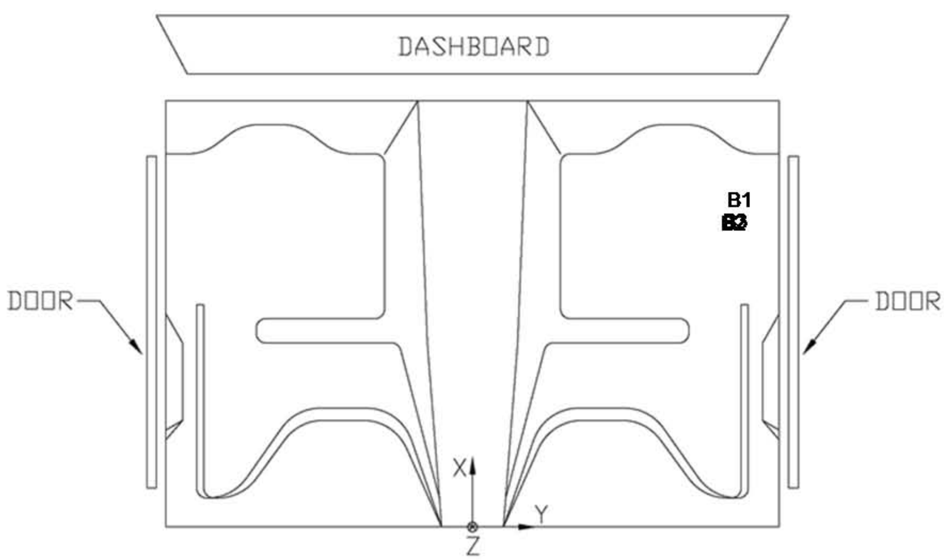
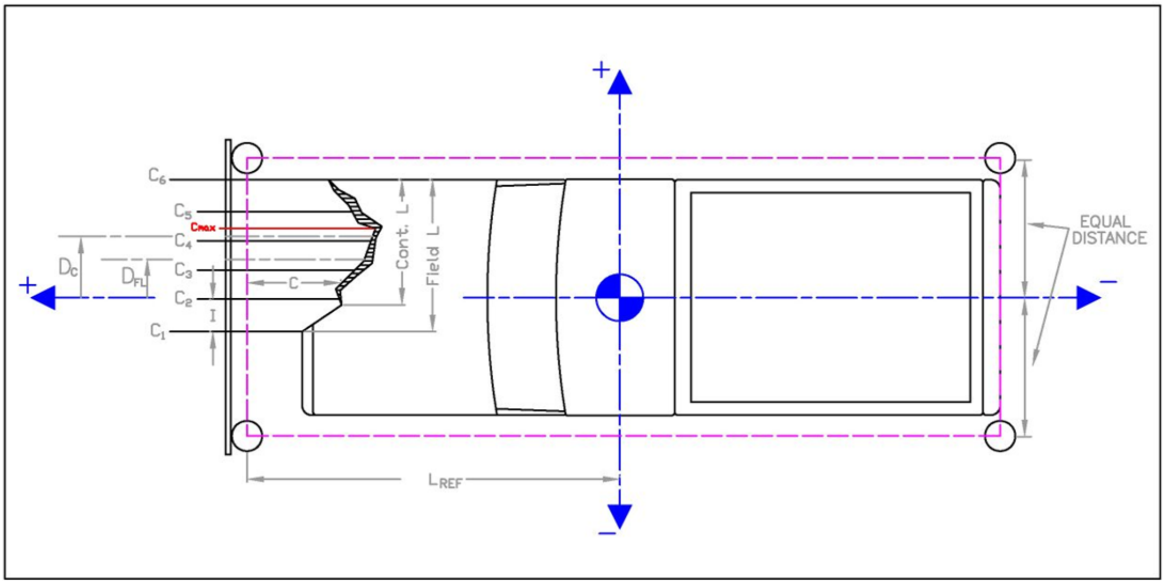


Figure D-4. Occupant Compartment Deformation Data – Set 2, Test No. NYCC-1

Date: 3/12/2012 Test Number: NYCC-1

Make: Dodge Model: 2270P/Ram Year: 2005



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	105.25	(2673)
Width of contact and induced crush - Field L:	78	(1981)
Crush measurement spacing interval (L/5) - I:	15.6	(396)
Distance from center of vehicle to center of Field L - D_{FL}:	0	0
Width of Contact Damage:	78	(1981)
Distance from center of vehicle to center of contact damage - D_C:	0	0

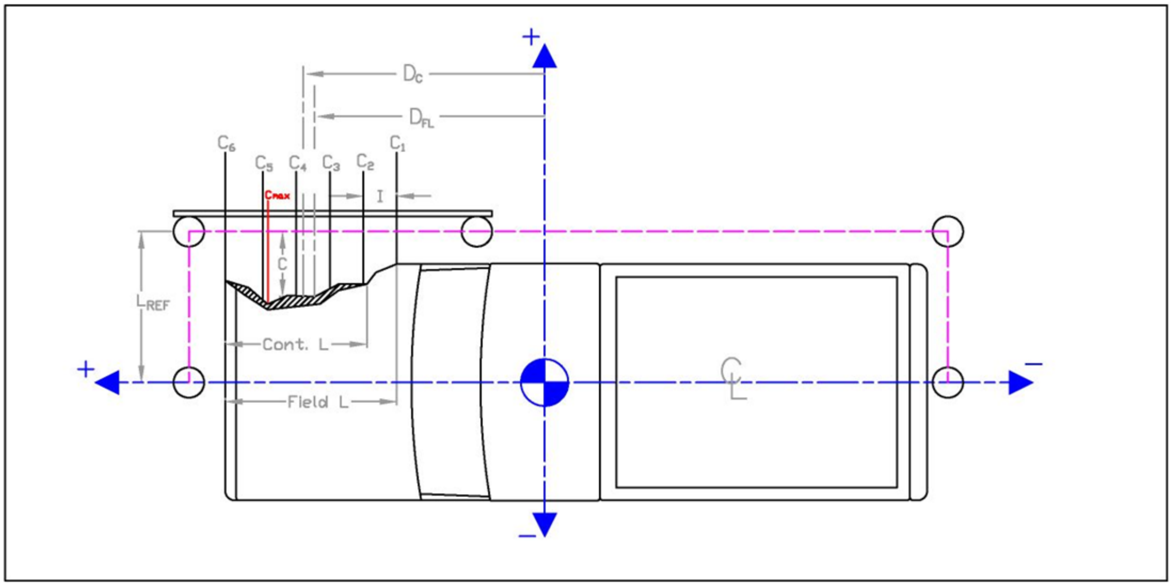
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)

	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	na	NA	-39	-(991)	29.00	(737)	-7.56	-(192)	NA	NA
C_2	6.5	(165)	-23.4	-(594)	13.47	(342)			0.6	(15)
C_3	4	(102)	-7.8	-(198)	10.50	(267)			1.1	(27)
C_4	4	(102)	7.8	(198)	10.48	(266)			1.1	(27)
C_5	6.75	(171)	23.4	(594)	13.39	(340)			0.9	(23)
C_6	na	NA	39	(991)	29.00	(737)			NA	NA
C_{MAX}	15	(381)	37	(940)	25.50	(648)			-2.9	-(75)

Figure D-5. Exterior Vehicle Crush (NASS) - Front, Test No. NYCC-1

Date: 3/12/2012 **Test Number:** NYCC-1

Make: Dodge **Model:** 2270P/Ram **Year:** 2005



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	45.25	(1149)
Width of contact and induced crush - Field L:	227.75	(5785)
Crush measurement spacing interval (L/5) - I:	45.55	(1157)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-9.875	-(251)
Width of Contact Damage:	227.75	(5785)
Distance from vehicle c.g. to center of contact damage - D_C:	10.375	(264)

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 remeoved)

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	na	NA	-123.8	-(3143)	15.38	(391)	-4.75	-(121)	NA	NA
C_2	8.5	(216)	-78.2	-(1986)	10.50	(267)			2.8	(70)
C_3	8	(203)	-32.65	-(829)	11.56	(294)			1.2	(30)
C_4	7.75	(197)	12.9	(328)	11.25	(286)			1.3	(32)
C_5	8.75	(222)	58.45	(1485)	10.50	(267)			3.0	(76)
C_6	na	NA	104	(2642)	37.00	(940)			NA	NA
C_{MAX}	8.75	(222)	58.45	(1485)	10.50	(267)			3.0	(76)

Figure D-6. Exterior Vehicle Crush (NASS) - Side, Test No. NYCC-1

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 1

TEST: NYCC-2
VEHICLE: 2270P

Note: If impact is on driver side need to enter negative number for Y

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
1	24 1/2	12 1/2	0	24 1/4	13 1/2	0	- 1/4	1	0
2	26 1/2	18 1/2	-5	26 1/2	19 1/4	-4 3/4	0	3/4	1/4
3	26 1/2	24	-5 1/4	26 1/4	24 1/2	-5 1/4	- 1/4	1/2	0
4	25 3/4	29 1/2	-6	25 3/4	29 3/4	-6	0	1/4	0
5	18	9 1/2	-1 3/4	18	10	-2	0	1/2	- 1/4
6	19 1/4	14 1/2	-5 1/4	19 1/4	15 1/4	-5 1/2	0	3/4	- 1/4
7	20 1/2	21 3/4	-8 1/2	20 1/2	22 1/2	-8 1/2	0	3/4	0
8	20 1/4	28 3/4	-9	20 1/4	29 3/4	-8 3/4	0	1	1/4
9	13 1/4	4 1/4	-1 1/4	13 1/4	4 1/4	-1 1/4	0	0	0
10	15	10	-3 3/4	15	10	-4	0	0	- 1/4
11	16 3/4	14	-8	16 3/4	14 3/4	-8 1/4	0	3/4	- 1/4
12	16 3/4	20 1/4	-8 1/2	16 3/4	20 1/2	-8 3/4	0	1/4	- 1/4
13	16 3/4	25 1/4	-8 3/4	16 3/4	25 1/2	-9	0	1/4	- 1/4
14	16 1/2	29 1/2	-9 1/4	16 1/2	29 3/4	-9 1/4	0	1/4	0
15	8 1/2	7	-1 3/4	8 1/2	7	-2	0	0	- 1/4
16	11	11 1/2	-8	11 1/4	12	-8 1/4	1/4	1/2	- 1/4
17	11	17 1/4	-8 1/4	11 1/4	17 1/2	-8 1/2	1/4	1/4	- 1/4
18	11	23 1/4	-8 1/2	11 1/4	23 1/4	-8 3/4	1/4	0	- 1/4
19	11	29 1/2	-9	11	29 3/4	-9	0	1/4	0
20	5	3	1 3/4	5	2 3/4	-1 3/4	0	- 1/4	-3 1/2
21	5 3/4	7 3/4	-2 1/2	5 3/4	8	-2 1/2	0	1/4	0
22	6 1/4	15	-8 1/2	6 1/4	15 3/4	-8 1/2	0	3/4	0
23	6 1/2	20 3/4	-8 3/4	6 1/2	21	-8 3/4	0	1/4	0
24	6 1/2	28	-9	6 1/2	28 1/4	-9	0	1/4	0
25	1 1/2	6 1/4	-1 1/2	1 1/2	6 1/4	-1 1/2	0	0	0
26	3/4	13 1/4	-4 1/4	3/4	13 1/4	-4 1/2	0	0	- 1/4
27	1/2	21	-4 1/2	3/4	21	-4 3/4	1/4	0	- 1/4
28	1/2	27 1/2	-4 3/4	1/2	27 1/4	-5	0	- 1/4	- 1/4
29							0	0	0
30							0	0	0
31							0	0	0

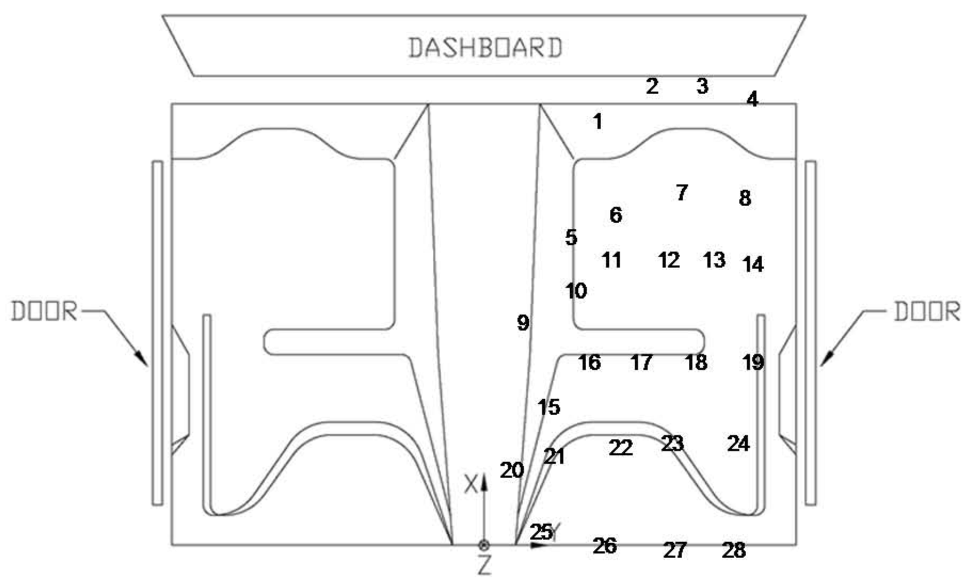


Figure D-7. Floor Pan Deformation Data – Set 1, Test No. NYCC-2

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 2

TEST: NYCC-2
VEHICLE: 2270P

Note: If impact is on driver side need to enter negative number for Y

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
1	40 1/2	18 3/4	- 1/4	40 1/4	19	- 1/4	- 1/4	1/4	0
2	42 3/4	25	-5	42 3/4	25 1/4	-5 1/4	0	1/4	- 1/4
3	42 3/4	30 1/2	-5 1/4	42 3/4	30 1/4	-5 1/2	0	- 1/4	- 1/4
4	42 1/4	35 3/4	-6	42 1/4	35 3/4	-6	0	0	0
5	34 1/4	15 3/4	-2	34	16 3/4	-2 1/4	- 1/4	1	- 1/4
6	35 3/4	20 3/4	-5 1/2	35 1/2	21 1/2	-5 3/4	- 1/4	3/4	- 1/4
7	37	27 3/4	-8 1/2	37	28 1/4	-8 3/4	0	1/2	- 1/4
8	37 1/4	35 3/4	-8 3/4	37	35 1/2	-9	- 1/4	- 1/4	- 1/4
9	29 1/2	10 1/2	-1 1/4	29 1/4	10 1/2	-1 1/2	- 1/4	0	- 1/4
10	31 1/4	16	-4	31 1/4	16 1/2	-4 1/4	0	1/2	- 1/4
11	33 1/4	20	-8	33	21	-8 1/4	- 1/4	1	- 1/4
12	33 1/4	26 1/4	-8 1/2	33 1/4	26 3/4	-8 3/4	0	1/2	- 1/4
13	33 1/2	31 1/4	-8 3/4	33 1/2	31 3/4	-9	0	1/2	- 1/4
14	33 1/2	35 3/4	-9	33 1/2	36 1/4	-9 1/4	0	1/2	- 1/4
15	24 1/2	13 1/2	-2	24 1/2	13 3/4	-2 1/4	0	1/4	- 1/4
16	27 1/2	17 1/4	-8	27 1/2	18 3/4	-8 1/4	0	1 1/2	- 1/4
17	27 3/4	23	-8 1/4	27 1/2	24	-8 1/2	- 1/4	1	- 1/4
18	27 3/4	29	-8 1/2	27 3/4	30	-8 3/4	0	1	- 1/4
19	27 3/4	35 1/2	-8 3/4	27 1/2	36 1/4	-9	- 1/4	3/4	- 1/4
20	21	9	-2	21	9 1/2	-2	0	1/2	0
21	21 3/4	14 1/4	-2 1/2	22	14 3/4	-2 3/4	1/4	1/2	- 1/4
22	23	21 1/4	-8 1/2	22 3/4	22 1/2	-8 3/4	- 1/4	1 1/4	- 1/4
23	23 1/2	26 3/4	-8 3/4	23	27 3/4	-8 3/4	- 1/2	1	0
24	23 1/2	34	-9	23 1/4	35	-9	- 1/4	1	0
25	17 1/2	12 1/2	-1 1/2	17 1/2	13	-1 3/4	0	1/2	- 1/4
26	17 1/4	19 1/2	-4 1/4	17	19 3/4	-4 1/2	- 1/4	1/4	- 1/4
27	17	27 1/4	-4 1/2	17	27 1/2	-4 3/4	0	1/4	- 1/4
28	17	33 3/4	-4 3/4	17 1/4	34	-5	1/4	1/4	- 1/4
29							0	0	0
30							0	0	0
31							0	0	0

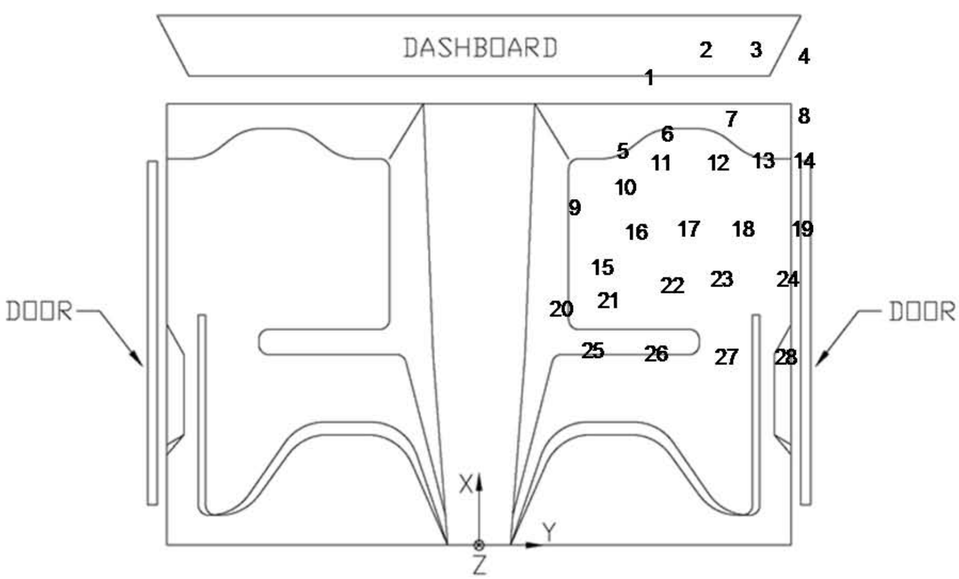


Figure D-8. Floor Pan Deformation Data – Set 2, Test No. NYCC-2

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1

TEST: NYCC-2
VEHICLE: 2270P

Note: If impact is on driver side need to enter negative number for Y

	POINT	X (in.)	Y (in.)	Z (in.)	X (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
DASH	A1	39 1/2	41	22 3/4	39 1/2	41 1/4	23	0	1/4	1/4
	A2	39 1/4	48 1/2	22	39 1/2	48 3/4	22 1/4	1/4	1/4	1/4
	A3	38 3/4	58 1/2	21	39	58 1/2	21 3/4	1/4	0	3/4
	A4	34	42 3/4	16	34 1/4	43	16 1/4	1/4	1/4	1/4
	A5	34	50 1/4	15 1/2	34	50 1/4	15 3/4	0	0	1/4
	A6	34	60 1/2	15 1/4	34	60 1/2	15 1/2	0	0	1/4
SIDE PANEL	B1	20 3/4	27 1/4	- 1/2	20 1/2	27 1/4	- 1/2	- 1/4	0	0
	B2	22	27 1/2	-1 1/2	22 1/4	27 3/4	-1 1/2	1/4	1/4	0
	B3	19 1/2	27 1/2	-4 1/2	19 1/2	27 3/4	-4 1/2	0	1/4	0
IMPACT SIDE DOOR	C1	26 1/2	37 1/4	17 3/4	26 1/2	36 3/4	18	0	- 1/2	1/4
	C2	17 1/2	37	18	17 1/2	36 1/2	18	0	- 1/2	0
	C3	2 3/4	37 1/2	18 3/4	2 1/2	37 3/4	18 3/4	- 1/4	1/4	0
	C4	23	30 3/4	2	22 3/4	30 3/4	2	- 1/4	0	0
	C5	18 1/2	30	1/2	18 1/2	30 1/4	1/2	0	1/4	0
	C6	3 1/2	30	-1 1/4	3 1/2	30	-1 1/4	0	0	0
ROOF	D1							0	0	0
	D2							0	0	0
	D3							0	0	0
	D4							0	0	0
	D5							0	0	0
	D6							0	0	0
	D7							0	0	0
	D8							0	0	0
	D9							0	0	0
	D10							0	0	0
	D11							0	0	0
	D12							0	0	0
	D13							0	0	0
	D14							0	0	0
	D15							0	0	0

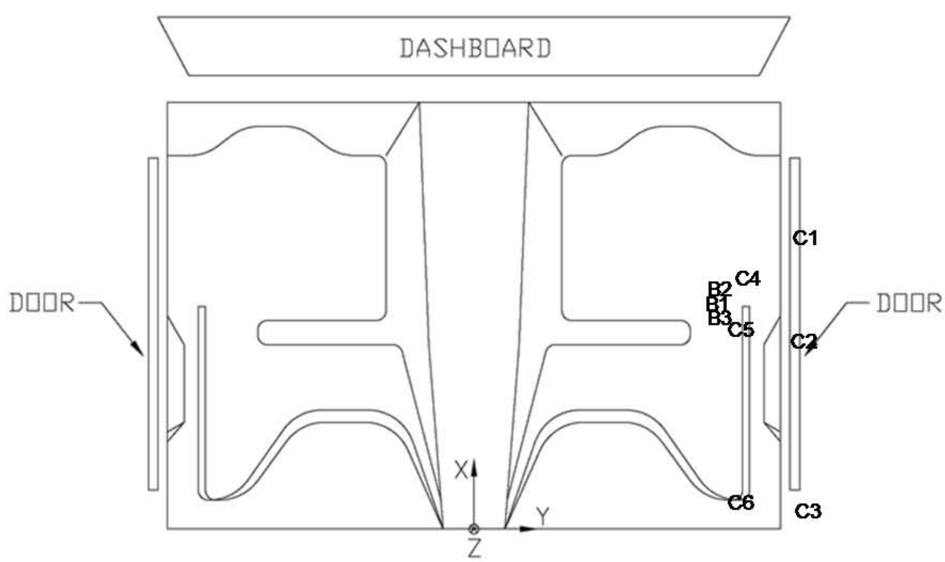


Figure D-9. Occupant Compartment Deformation Data – Set 1, Test No. NYCC-2

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2

TEST: NYCC-2
VEHICLE: 2270P

Note: If impact is on driver side need to enter negative number for Y

	POINT	X (in.)	Y (in.)	Z (in.)	X (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
DASH	A1	52 3/4	41 1/2	22 3/4	53	42	23	1/4	1/2	1/4
	A2	53	48 3/4	22 1/4	53 1/4	49 1/4	22 1/4	1/4	1/2	0
	A3	56 1/2	58 1/2	21	56 1/2	58 3/4	21 1/2	0	1/4	1/2
	A4	48 1/2	43 1/2	16	48 1/2	44	16	0	1/2	0
	A5	48 3/4	50 3/4	15 3/4	48 3/4	51	15 3/4	0	1/4	0
	A6	52 3/4	60 1/2	15 1/2	52 3/4	60 3/4	15 1/2	0	1/4	0
SIDE PANEL	B1	37	26 1/2	- 1/2	36 3/4	26 1/2	- 1/2	- 1/4	0	0
	B2	38 3/4	27	-1 1/4	38 3/4	27	-1 1/2	0	0	- 1/4
	B3	36 1/2	26 1/2	-4 1/4	36 3/4	26 1/2	-4 1/2	1/4	0	- 1/4
IMPACT SIDE DOOR	C1	29 3/4	45 1/4	18 1/4	29 3/4	44 3/4	17 3/4	0	- 1/2	- 1/2
	C2	20 3/4	45 3/4	18 1/4	20 3/4	45 1/2	18	0	- 1/4	- 1/4
	C3	5 3/4	46 1/2	19 1/4	5 3/4	46 3/4	18 3/4	0	1/4	- 1/2
	C4	27 1/4	40 3/4	2 1/2	27 1/4	40 1/2	2	0	- 1/4	- 1/2
	C5	23 1/4	40 1/2	1	23 1/4	40 3/4	1/2	0	1/4	- 1/2
	C6	8 1/2	41	-1	9	41 1/4	-1 1/4	1/2	1/4	- 1/4
ROOF	D1							0	0	0
	D2							0	0	0
	D3							0	0	0
	D4	*	*	10 3/4	*	*	18 3/4	0	0	8
	D5							0	0	0
	D6							0	0	0
	D7							0	0	0
	D8							0	0	0
	D9							0	0	0
	D10	Maximum crush was taken only.						0	0	0
	D11							0	0	0
	D12							0	0	0
	D13							0	0	0
	D14							0	0	0
	D15							0	0	0

* the vertical measurements obtained were from a similar reference vehicle in order to obtain the maximum roof deformation

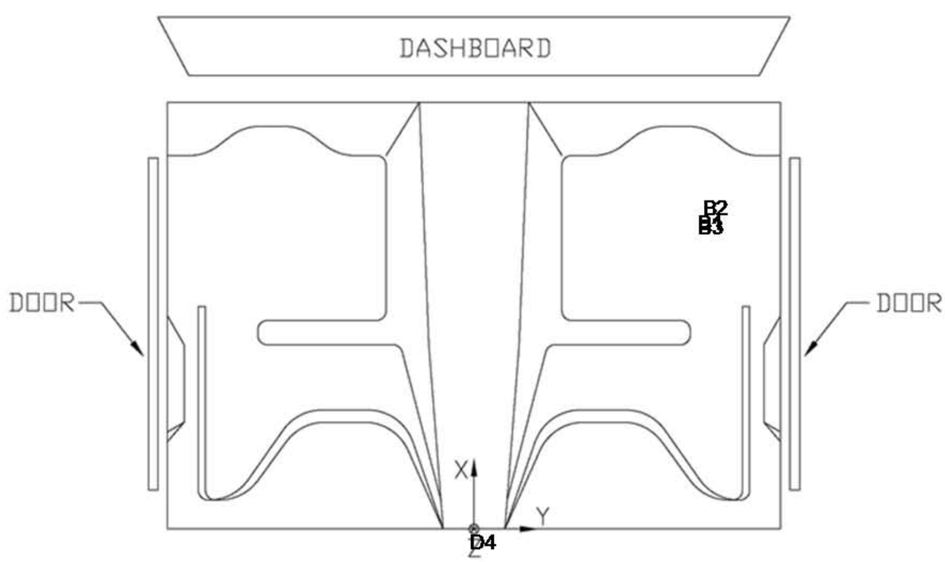
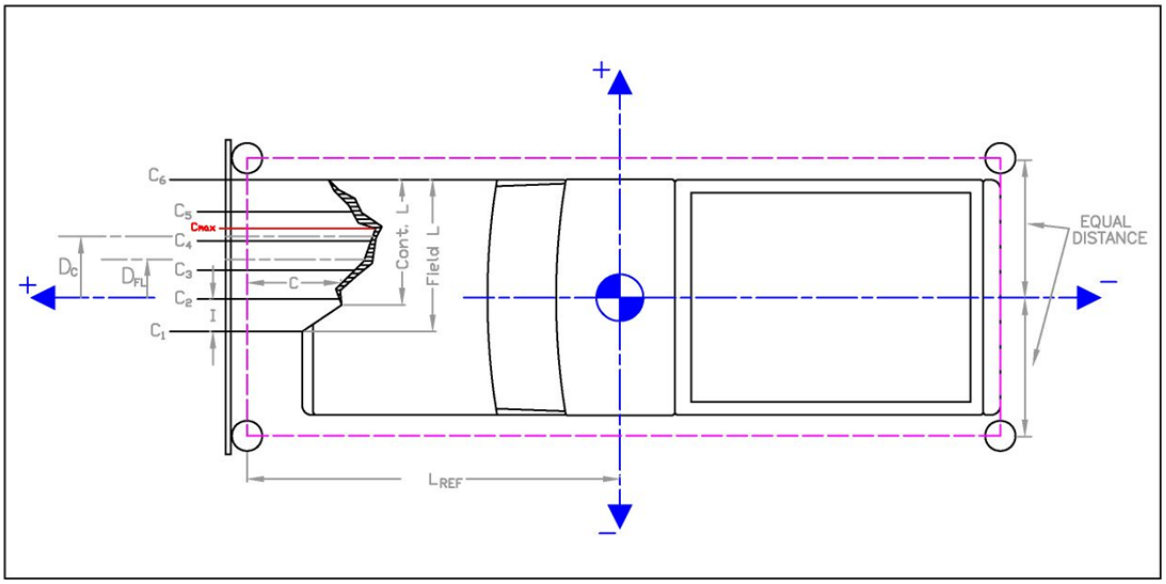


Figure D-10. Occupant Compartment Deformation Data – Set 2, Test No. NYCC-2

Date: 6/7/2012 **Test Number:** NYCC-2

Make: Dodge Ram **Model:** 2270P **Year:** 2005



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	106 1/2	(2705)
Width of contact and induced crush - Field L:	77 3/4	(1975)
Crush measurement spacing interval (L/5) - I:	15.55	(395)
Distance from center of vehicle to center of Field L - D_{FL}:	0	0
Width of Contact Damage:	77 3/4	(1975)
Distance from center of vehicle to center of contact damage - D_C:	0	0

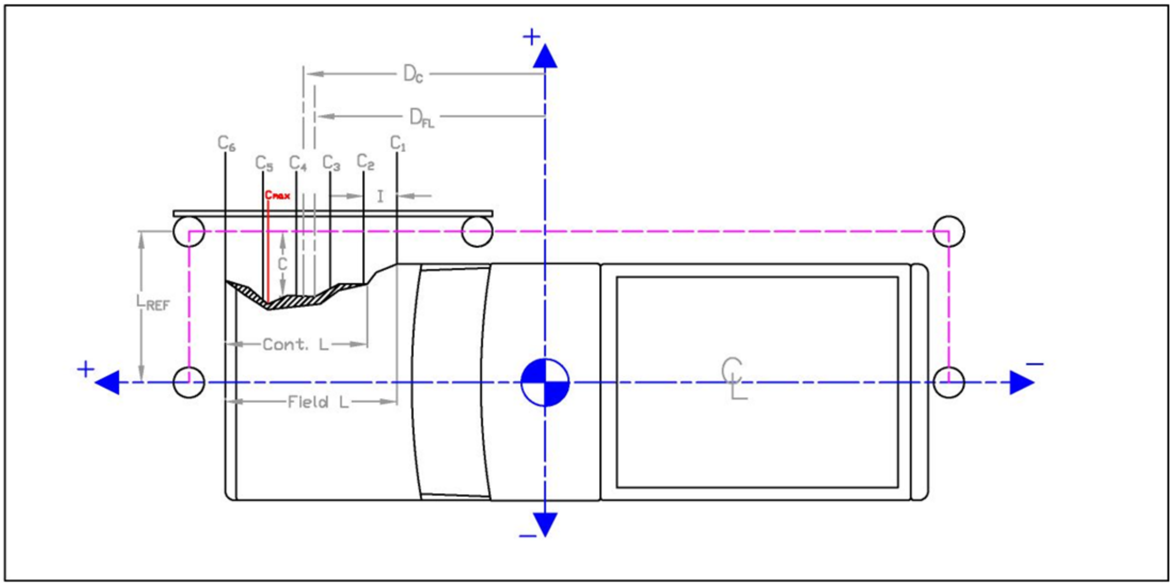
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)

	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	NA	NA	-38 7/8	-(987)	29	(737)	-7 1/7	-(181)	NA	NA
C_2	16 1/2	(419)	-23 1/3	-(592)	13 1/2	(342)			10 1/6	(258)
C_3	14	(356)	-7 7/9	-(197)	10 1/2	(267)			10 2/3	(270)
C_4	7 1/2	(191)	7 7/9	(197)	10 1/2	(266)			4 1/6	(106)
C_5	4 1/2	(114)	23 1/3	(592)	13 2/5	(340)			-1 3/4	-(44)
C_6	NA	NA	38 7/8	(987)	29	(737)			NA	NA
C_{MAX}	14	(356)	-7 7/9	-(198)	10 1/2	(267)			10 2/3	(270)

Figure D-11. Exterior Vehicle Crush (NASS) - Front, Test No. NYCC-2

Date: 6/7/2012 **Test Number:** NYCC-2

Make: Dodge Ram **Model:** 2270P **Year:** 2005



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	50 1/2	(1283)
Width of contact and induced crush - Field L:	227 7/8	(5788)
Crush measurement spacing interval (L/5) - I:	45.575	(1158)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-10.4375	-(265)
Width of Contact Damage:	227 7/8	(5788)
Distance from vehicle c.g. to center of contact damage - D_C:	10 4/9	(265)

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)

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	NA	NA	-124 3/8	-(3159)	16	(406)	1/2	(13)	NA	NA
C_2	13 1/4	(337)	-78 4/5	-(2002)	10 1/2	(267)			2 1/4	(57)
C_3	12 1/2	(318)	-33 2/9	-(844)	11 5/8	(295)			3/8	(10)
C_4	11 1/2	(292)	12 1/3	(314)	11 1/4	(286)			- 1/4	-(6)
C_5	10 1/4	(260)	58	(1471)	10 1/2	(267)			- 3/4	-(19)
C_6	NA	NA	103 1/2	(2629)	35 1/4	(895)			NA	NA
C_{MAX}	13 1/4	(337)	-78 4/5	-(2002)	10 1/2	(267)			2 1/4	(57)

Figure D-12. Exterior Vehicle Crush (NASS) - Side, Test No. NYCC-2

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 1

TEST: NYCC-3
VEHICLE: 2270P

Note: If impact is on driver side need to enter negative number for Y

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
1	24 3/4	11	0	24 1/2	10 3/4	0	- 1/4	- 1/4	0
2	25 3/4	15 3/4	-2 3/4	25 3/4	15 3/4	-2 3/4	0	0	0
3	29 3/4	21 1/2	-4 1/2	29 1/2	21	-5	- 1/4	- 1/2	- 1/2
4	29	26 1/2	-3 1/2	29	27	-3 3/4	0	1/2	- 1/4
5	28	26 3/4	-3	28	26 1/2	-3 1/4	0	- 1/4	- 1/4
6	21 1/4	9 3/4	-1 1/4	21 1/2	10	-1 1/4	1/4	1/4	0
7	22 1/4	15 1/4	-4 1/4	22 1/4	15 3/4	-4 1/2	0	1/2	- 1/4
8	23 1/2	22	-7 1/2	23 1/2	21 1/4	-7 1/2	0	- 3/4	0
9	23 1/2	26	-7 1/2	23 1/4	26	-7 3/4	- 1/4	0	- 1/4
10	23 3/4	29 3/4	-7 1/2	23 1/2	29 3/4	-7 1/2	- 1/4	0	0
11	18	9 1/2	-3	18	10	-3	0	1/2	0
12	19 1/4	14 3/4	-6 1/2	19 1/4	15 1/2	-6 3/4	0	3/4	- 1/4
13	20 1/2	22	-9	20 1/4	22 1/4	-9	- 1/4	1/4	0
14	20 1/2	26 1/4	-9	20 1/2	26 3/4	-9	0	1/2	0
15	21 1/2	30	-9	21 1/4	30 1/4	-9 1/4	- 1/4	1/4	- 1/4
16	12 3/4	3 3/4	-2	12 3/4	3 3/4	-2 1/4	0	0	- 1/4
17	14	9 3/4	-6	13 3/4	9 1/4	-6	- 1/4	- 1/2	0
18	14 3/4	15 3/4	-9	14 1/2	15	-9 1/4	- 1/4	- 3/4	- 1/4
19	15	21 3/4	-9	14 3/4	21	-9 1/4	- 1/4	- 3/4	- 1/4
20	15	27 3/4	-9 1/4	15	27 1/2	-9 1/4	0	- 1/4	0
21	8 1/4	7	-2 1/2	8 1/4	7	-2 3/4	0	0	- 1/4
22	10	11 1/4	-8 1/2	10 1/4	11 1/4	-8 1/2	1/4	0	0
23	10 1/2	15 3/4	-8 3/4	10 3/4	16	-8 3/4	1/4	1/4	0
24	10 1/2	22	-8 3/4	10 3/4	22 1/4	-8 3/4	1/4	1/4	0
25	10 1/2	28	-8 3/4	10 3/4	28	-9	1/4	0	- 1/4
26	1	12 1/4	-4 1/2	1	12	-4 1/2	0	- 1/4	0
27	1 1/4	19 1/2	-4 3/4	1 1/4	19 1/2	-4 3/4	0	0	0
28	1 1/4	26 1/2	-4 1/2	1 1/4	26 1/2	-4 3/4	0	0	- 1/4
29							0	0	0
30							0	0	0
31							0	0	0

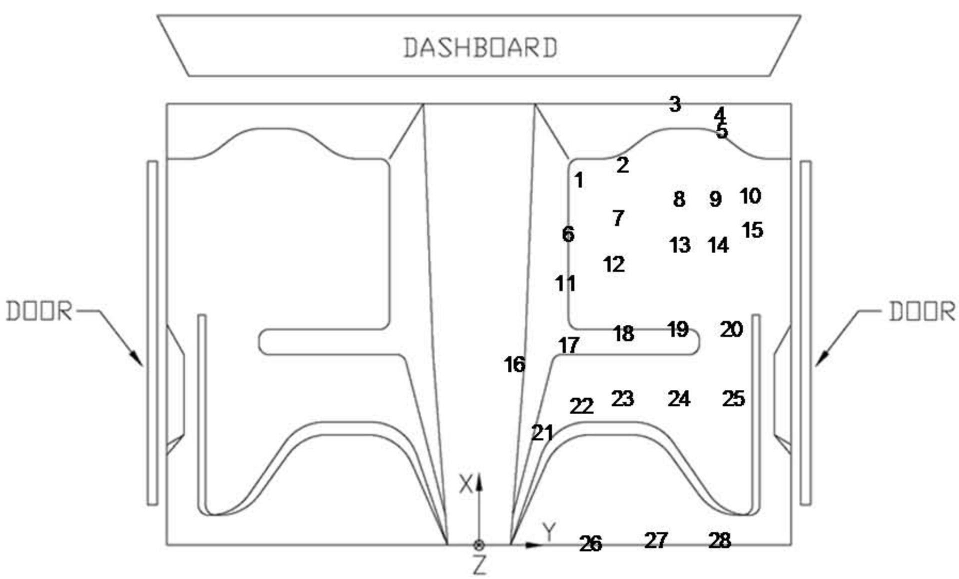


Figure D-13. Floor Pan Deformation Data – Set 1, Test No. NYCC-3

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 2

TEST: NYCC-3
VEHICLE: 2270P

Note: If impact is on driver side need to enter negative number for Y

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
1	40	17 1/4	0	40	17	0	0	- 1/4	0
2	41 1/2	22 3/4	-2 3/4	41 1/2	22 3/4	-2 1/2	0	0	1/4
3	45 1/2	28	-5	45 1/2	28 3/4	-4 3/4	0	3/4	1/4
4	44 3/4	33 1/4	-4	44 1/2	33 1/4	-4	- 1/4	0	0
5	44	36	-3 1/2	43 3/4	36	-3 1/2	- 1/4	0	0
6	37	16 1/4	-1 1/4	37	16	-1	0	- 1/4	1/4
7	38	22	-4 1/2	38	22 1/4	-4 1/4	0	1/4	1/4
8	39 1/2	28 3/4	-7 3/4	39 1/4	28 3/4	-7 1/2	- 1/4	0	1/4
9	39 1/2	32 3/4	-8	39 1/4	33	-7 3/4	- 1/4	1/4	1/4
10	39 1/2	36 1/4	-8	39 1/2	36 1/2	-7 3/4	0	1/4	1/4
11	33 3/4	16 1/4	-3	33 3/4	16 1/2	-3	0	1/4	0
12	35 1/4	21 1/2	-6 3/4	35	22 1/4	-6 3/4	- 1/4	3/4	0
13	36 1/2	28 1/2	-9 1/2	36 1/2	28 3/4	-9 1/4	0	1/4	1/4
14	36 1/2	33 1/4	-9 1/2	36 1/2	33 1/2	-9 1/2	0	1/4	0
15	37 1/4	36 1/2	-9 1/2	37 1/4	36 1/2	-9 1/2	0	0	0
16	28 1/2	10 1/2	-2	28 1/2	10 1/2	-2	0	0	0
17	29 3/4	16 1/2	-6	29 3/4	16 1/2	-6	0	0	0
18	30 1/2	22 1/2	-9 1/2	30 1/2	22 1/2	-9 1/4	0	0	1/4
19	30 3/4	28 1/2	-9 1/2	30 3/4	28 3/4	-9 1/2	0	1/4	0
20	31	34 1/2	-9 3/4	31	34 1/2	-9 3/4	0	0	0
21	24	14	-2 3/4	24	14 1/2	-2 3/4	0	1/2	0
22	26 1/4	18 1/4	-8 3/4	26	18	-8 3/4	- 1/4	- 1/4	0
23	26 1/2	22 3/4	-9	26 1/2	22	-9	0	- 3/4	0
24	26 1/2	29	-9 1/4	26 1/2	28 3/4	-9 1/4	0	- 1/4	0
25	26 1/2	34 3/4	-9 1/4	26 3/4	34 3/4	-9 1/4	1/4	0	0
26	17	19	-5	17	18 3/4	-5	0	- 1/4	0
27	17 1/4	26 1/4	-5 1/4	17	26 1/2	-5 1/4	- 1/4	1/4	0
28	17 1/4	33 1/4	-5 1/4	17	33 1/4	-5 1/4	- 1/4	0	0
29							0	0	0
30							0	0	0
31							0	0	0

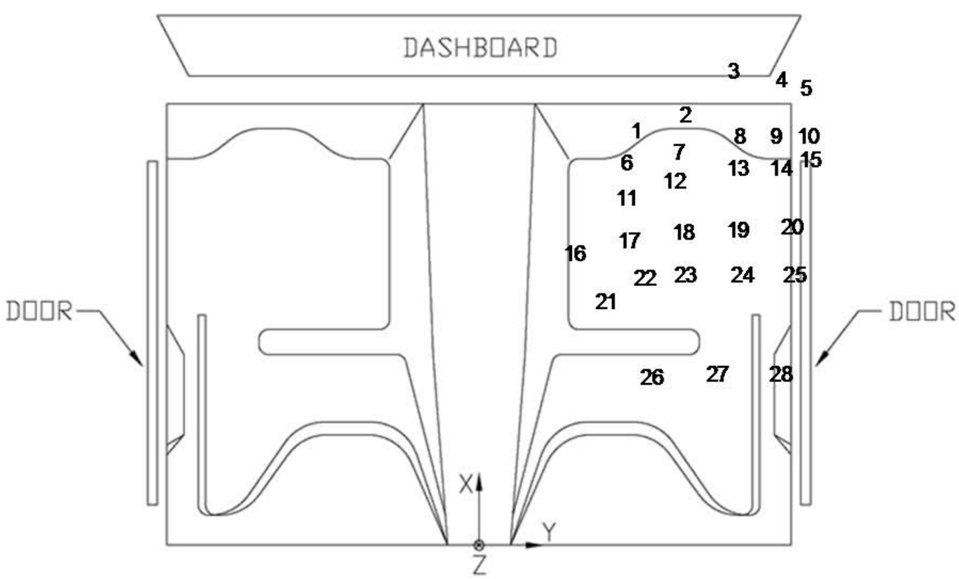


Figure D-14. Floor Pan Deformation Data – Set 2, Test No. NYCC-3

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1

TEST: NYCC-3
VEHICLE: 2270P

Note: If impact is on driver side need to enter negative number for Y

	POINT	X (in.)	Y (in.)	Z (in.)	X (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
DASH	A1	40 1/4	36 3/4	23 1/4	40 1/4	36 3/4	23 1/4	0	0	0
	A2	39 3/4	48	22 1/4	40	48	22	1/4	0	- 1/4
	A3	39 1/4	57	21 1/2	39 1/2	57	21 1/2	1/4	0	0
	A4	33 3/4	38	16	33 3/4	38	16	0	0	0
	A5	34 1/2	50	16	34 1/2	50	16	0	0	0
	A6	34 1/2	58 1/4	15 3/4	34 1/2	58 1/4	15 1/2	0	0	- 1/4
SIDE PANEL	B1	23 1/2	29 1/2	-1 1/2	23 1/2	29 1/2	-1 1/2	0	0	0
	B2	20 3/4	29 1/4	-5 1/4	20 3/4	29 1/4	-5 1/4	0	0	0
	B3	22	29 1/4	1/2	22	29 1/4	1/2	0	0	0
IMPACT SIDE DOOR	C1	24	38	17	24	38	17	0	0	0
	C2	14 1/4	36 1/4	17 1/2	14 1/4	36 1/4	17 1/2	0	0	0
	C3	6	37	17 3/4	6	37	17 3/4	0	0	0
	C4	23 1/2	32 1/4	1 3/4	23 1/2	32	1 3/4	0	- 1/4	0
	C5	17 1/2	30 3/4	4 1/4	17 1/2	30 3/4	4	0	0	- 1/4
	C6	7 3/4	31 1/4	3 1/2	8	31 1/4	3 1/2	1/4	0	0
ROOF	D1							0	0	0
	D2							0	0	0
	D3							0	0	0
	D4							0	0	0
	D5							0	0	0
	D6							0	0	0
	D7							0	0	0
	D8							0	0	0
	D9							0	0	0
	D10							0	0	0
	D11							0	0	0
	D12							0	0	0
	D13							0	0	0
	D14							0	0	0
	D15							0	0	0

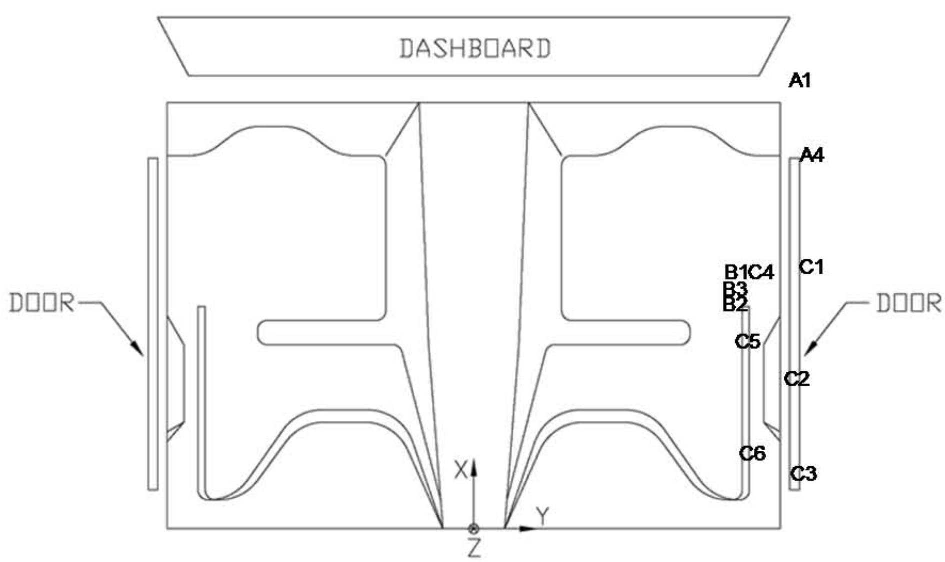


Figure D-15. Occupant Compartment Deformation Data – Set 1, Test No. NYCC-3

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2

TEST: NYCC-3
VEHICLE: 2270P

Note: If impact is on driver side need to enter negative number for Y

	POINT	X (in.)	Y (in.)	Z (in.)	X (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
DASH	A1	52 3/4	36	23 1/4	52 1/2	36	23 1/4	- 1/4	0	0
	A2	53 1/4	47 3/4	21 3/4	53	47 1/2	22	- 1/4	- 1/4	1/4
	A3	55	56 3/4	21	54 1/2	56 3/4	21	- 1/2	0	0
	A4	47 1/2	37	16	47 1/4	37	16	- 1/4	0	0
	A5	48 3/4	49 1/4	15 3/4	48 3/4	49 1/4	15 1/2	0	0	- 1/4
	A6	50 3/4	58	15 1/4	50 3/4	58	15 1/4	0	0	0
SIDE PANEL	B1	39	27 1/4	-2	39 1/4	27 1/4	-2	1/4	0	0
	B2	36 1/2	27	-5 3/4	36 3/4	27	-5 3/4	1/4	0	0
	B3	37 1/4	27	0	37 1/2	27	0	1/4	0	0
IMPACT SIDE DOOR	C1	27 3/4	45 1/4	16 1/4	27 1/2	45 1/2	16 1/4	- 1/4	1/4	0
	C2	17 1/4	45 1/2	16 3/4	17 1/4	45 3/4	16 3/4	0	1/4	0
	C3	9	45 3/4	17 1/4	9 1/4	46	17 1/4	1/4	1/4	0
	C4	28 1/4	41	1	28 1/2	41	1	1/4	0	0
	C5	22 1/4	41 1/2	3 1/2	22	41 1/2	3 1/2	- 1/4	0	0
	C6	12 1/2	41 1/2	3	12 1/2	41 1/2	3	0	0	0
ROOF	D1							0	0	0
	D2							0	0	0
	D3							0	0	0
	D4							0	0	0
	D5							0	0	0
	D6							0	0	0
	D7							0	0	0
	D8							0	0	0
	D9							0	0	0
	D10							0	0	0
	D11							0	0	0
	D12							0	0	0
	D13							0	0	0
	D14							0	0	0
	D15							0	0	0

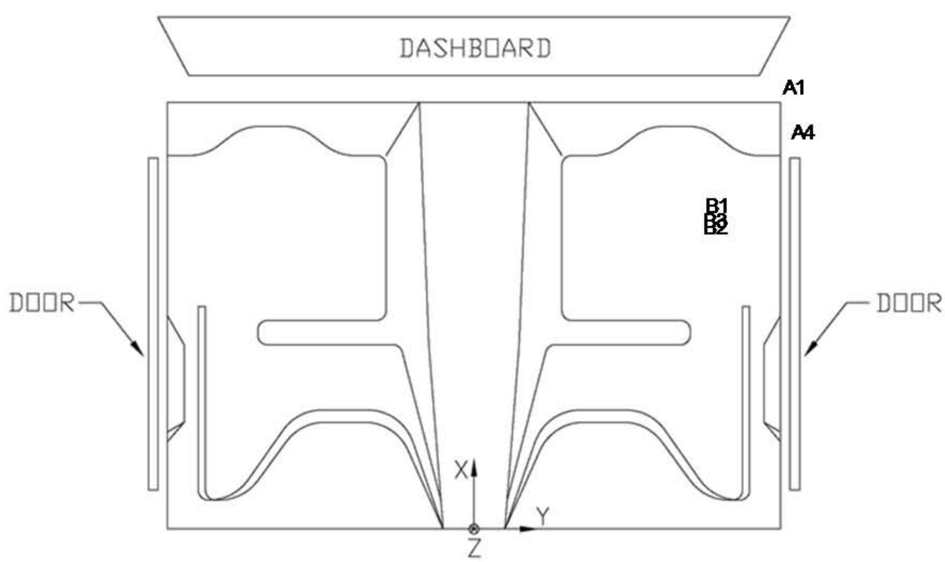
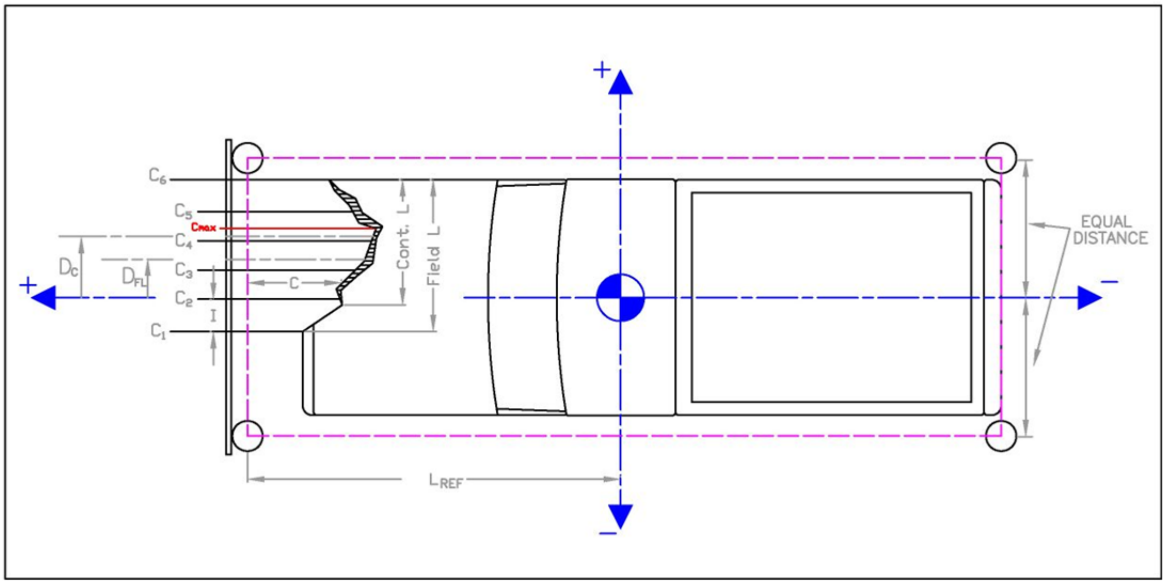


Figure D-16. Occupant Compartment Deformation Data – Set 2, Test No. NYCC-3

Date: 6/5/2012 **Test Number:** NYCC-3

Make: 105.5 **Model:** 2270P **Year:** 2005



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	105 1/2	(2680)
Width of contact and induced crush - Field L:	78 1/4	(1988)
Crush measurement spacing interval (L/5) - I:	15.65	(398)
Distance from center of vehicle to center of Field L - D_{FL}:	0	0
Width of Contact Damage:	78 1/4	(1988)
Distance from center of vehicle to center of contact damage - D_C:	0	0

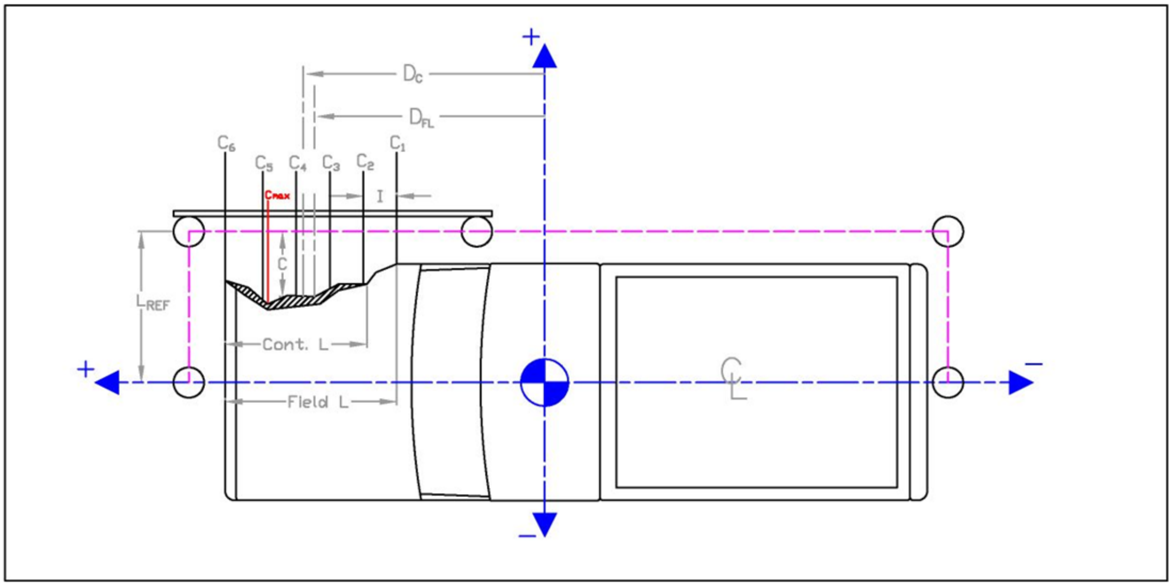
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)

	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	na	NA	-39 1/8	-(994)	29	(737)	-6	-(151)	NA	NA
C_2	6 3/4	(171)	-23 1/2	-(596)	13 1/2	(342)			- 3/4	-(20)
C_3	7	(178)	-7 5/6	-(199)	10 1/2	(267)			2 4/9	(62)
C_4	8 3/4	(222)	7 5/6	(199)	10 1/2	(266)			4 2/9	(107)
C_5	7 1/2	(191)	23 1/2	(596)	13 2/5	(340)			0	(2)
C_6	na	NA	39 1/8	(994)	29	(737)			NA	NA
C_{MAX}	10	(254)	2	(51)	10 1/4	(260)			5 5/7	(145)

Figure D-17. Exterior Vehicle Crush (NASS) - Front, Test No. NYCC-3

Date: 6/5/2012 **Test Number:** NYCC-3

Make: Dodge Ram **Model:** 2270P **Year:** 2005



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	49 3/4	(1264)
Width of contact and induced crush - Field L:	228 1/2	(5804)
Crush measurement spacing interval (L/5) - I:	45.7	(1161)
Distance from vehicle c.g. to center of Field L - D_{FL}:	11.5	(292)
Width of Contact Damage:	228 1/2	(5804)
Distance from vehicle c.g. to center of contact damage - D_C:	11 1/2	(292)

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 remeoved)

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual	Crush
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	na	NA	-102 3/4	-(2610)	12 1/5	(310)	- 1/4	-(6)	NA	NA
C_2	12	(305)	-57	-(1449)	12	(305)			1/4	(6)
C_3	11 3/4	(298)	-11 1/3	-(288)	11 1/4	(286)			3/4	(19)
C_4	12	(305)	34 1/3	(872)	11 1/4	(286)			1	(25)
C_5	na	NA	80	(2033)	11 1/4	(286)			NA	NA
C_6	na	NA	125 3/4	(3194)	37	(940)			NA	NA
C_{MAX}	12	(305)	34 1/3	(872)	11 1/4	(286)			1	(25)

Figure D-18. Exterior Vehicle Crush (NASS) - Side, Test No. NYCC-3

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

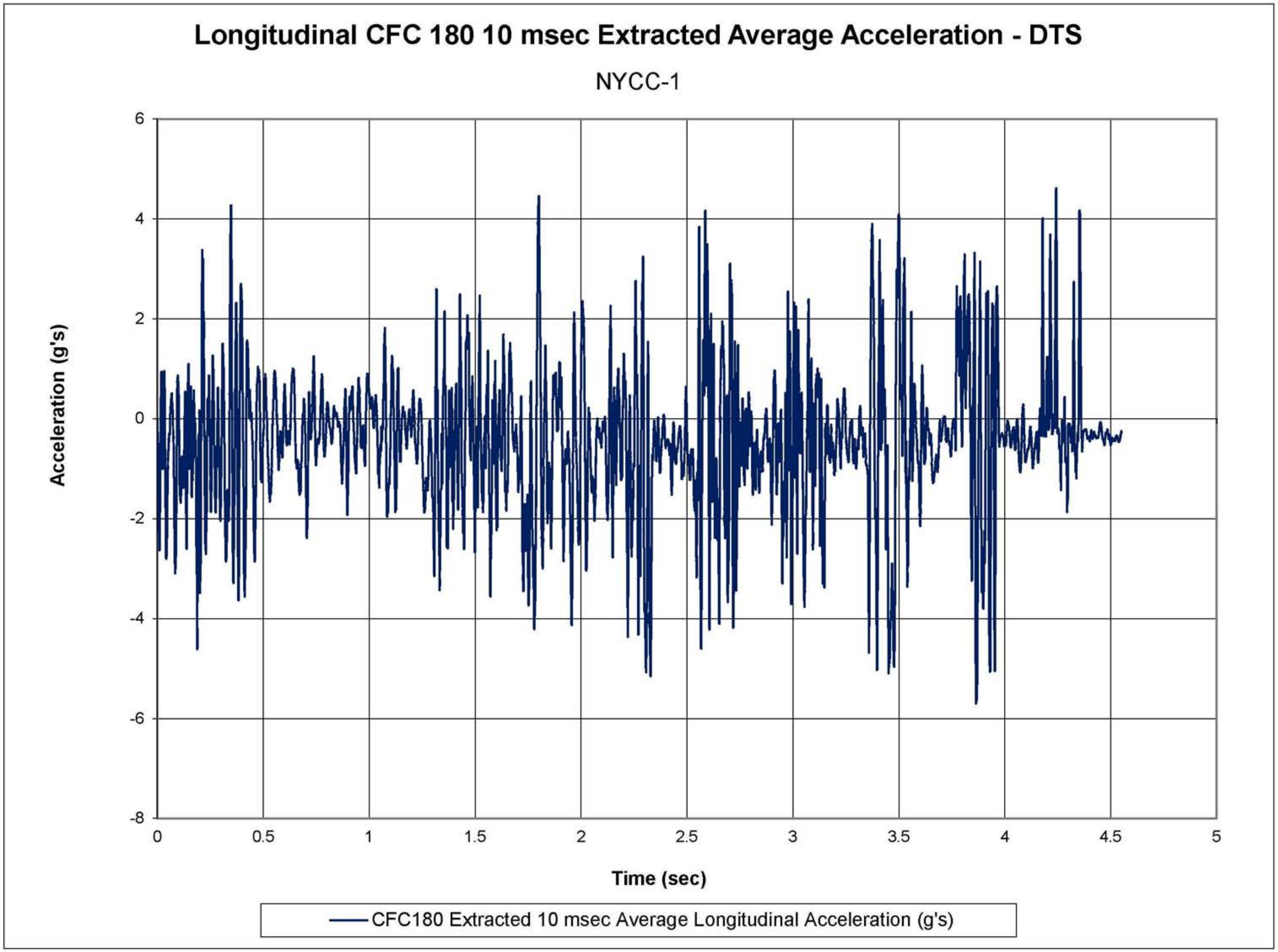


Figure E-1. 10-ms Average Longitudinal Deceleration (DTS), Test No. NYCC-1

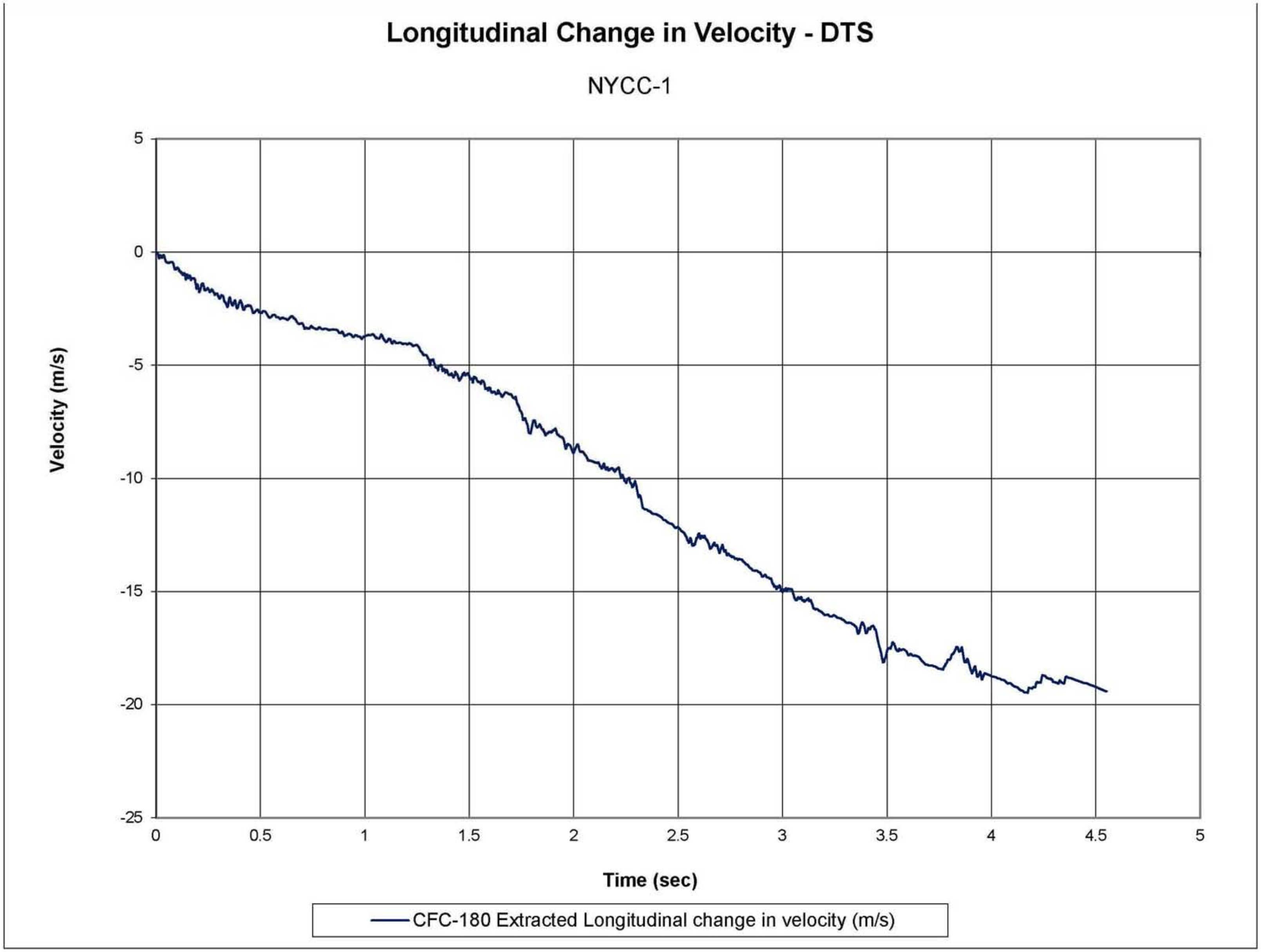


Figure E-2. Longitudinal Occupant Impact Velocity (DTS), Test No. NYCC-1

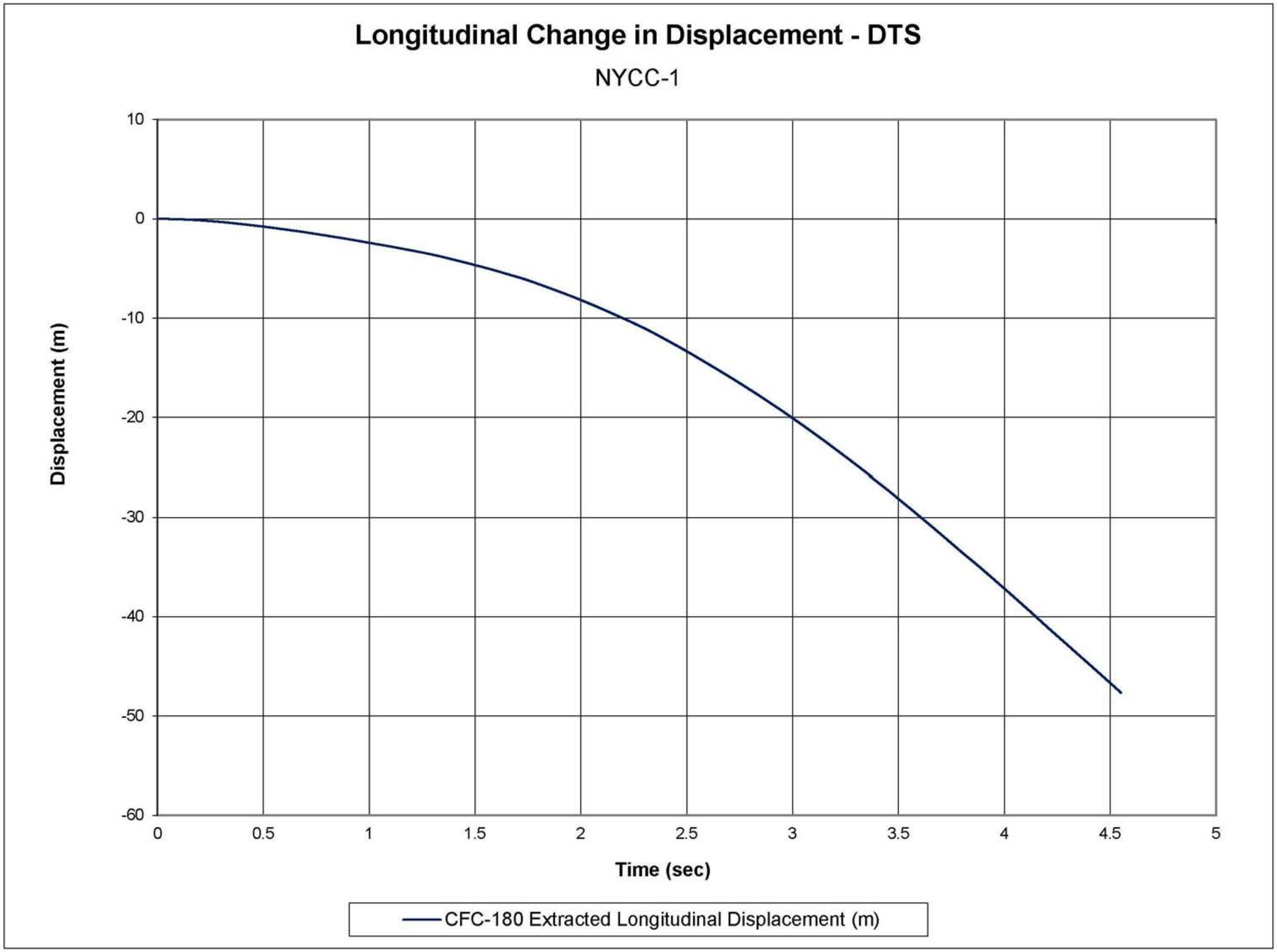


Figure E-3. Longitudinal Occupant Displacement (DTS), Test No. NYCC-1

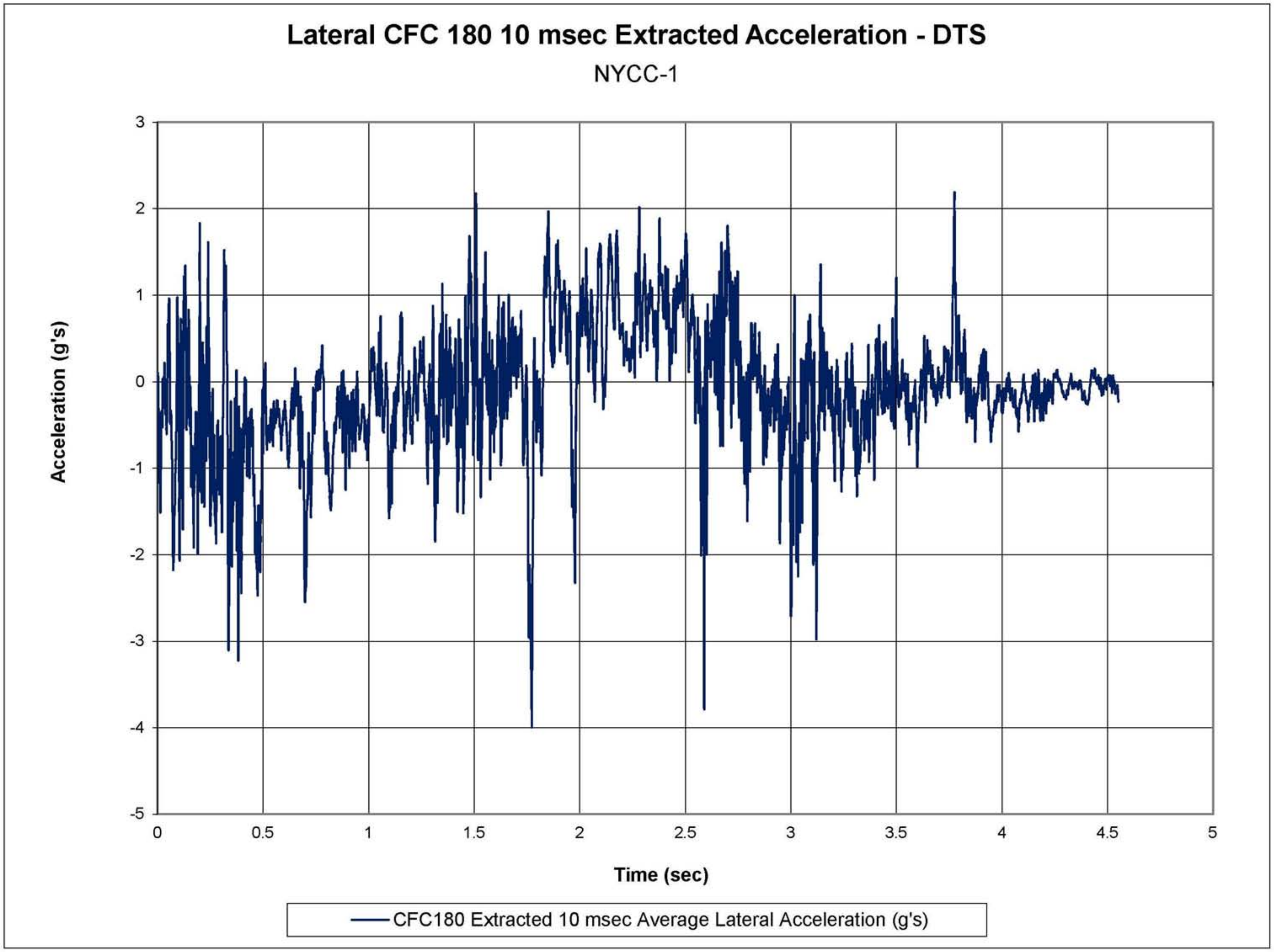


Figure E-4. 10-ms Average Lateral Deceleration (DTS), Test No. NYCC-1

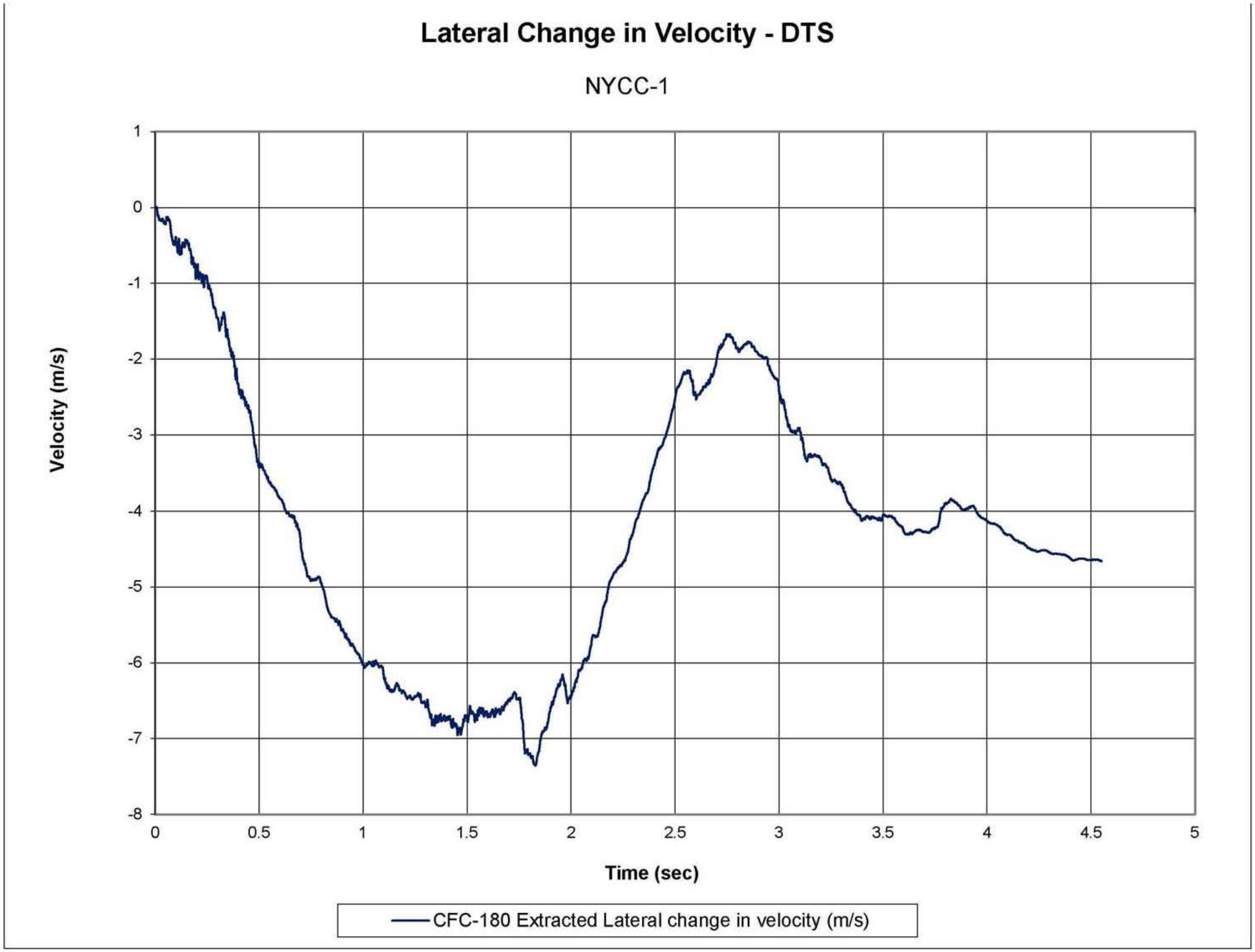


Figure E-5. Lateral Occupant Impact Velocity (DTS), Test No. NYCC-1

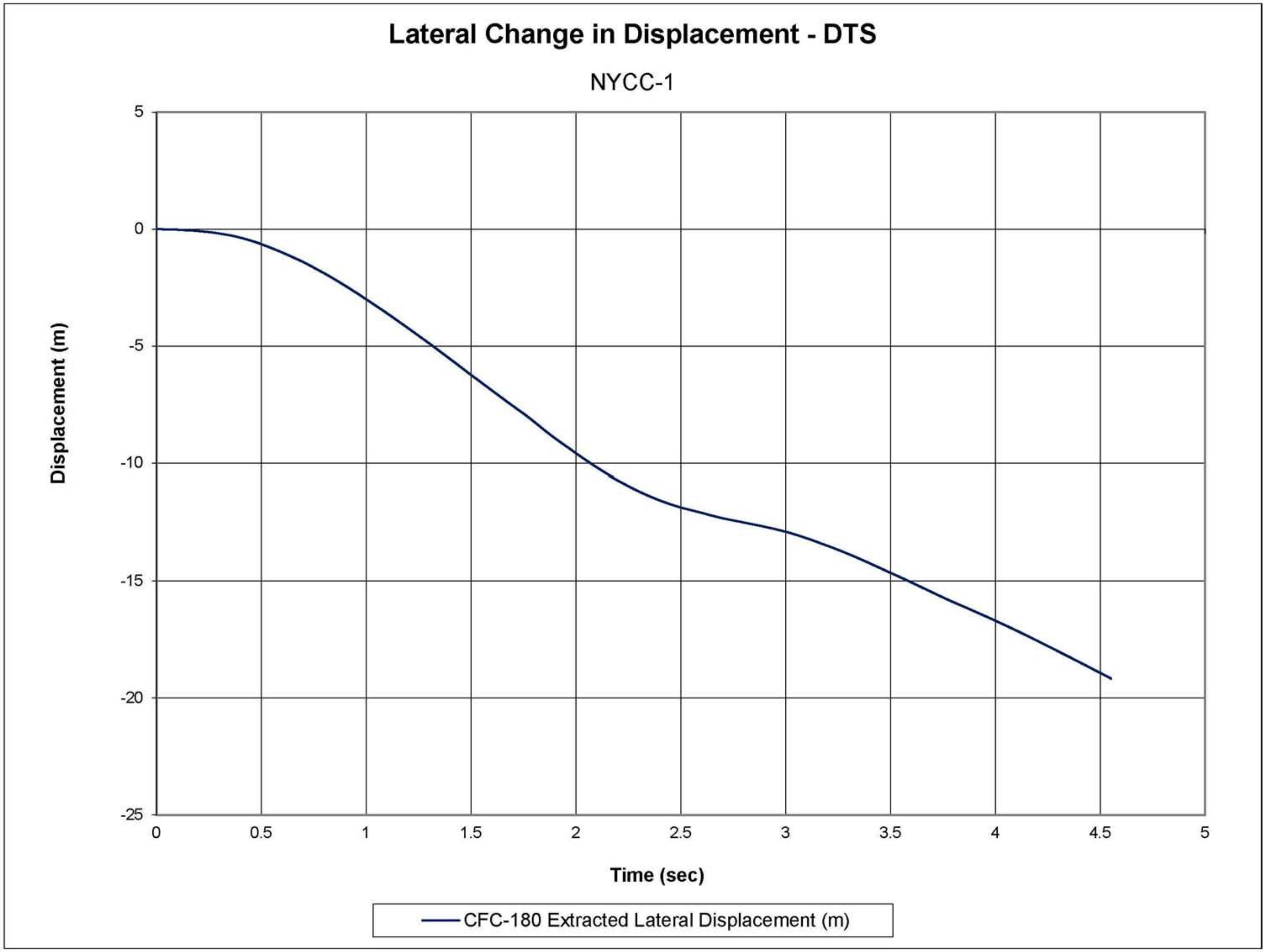


Figure E-6. Lateral Occupant Displacement (DTS), Test No. NYCC-1

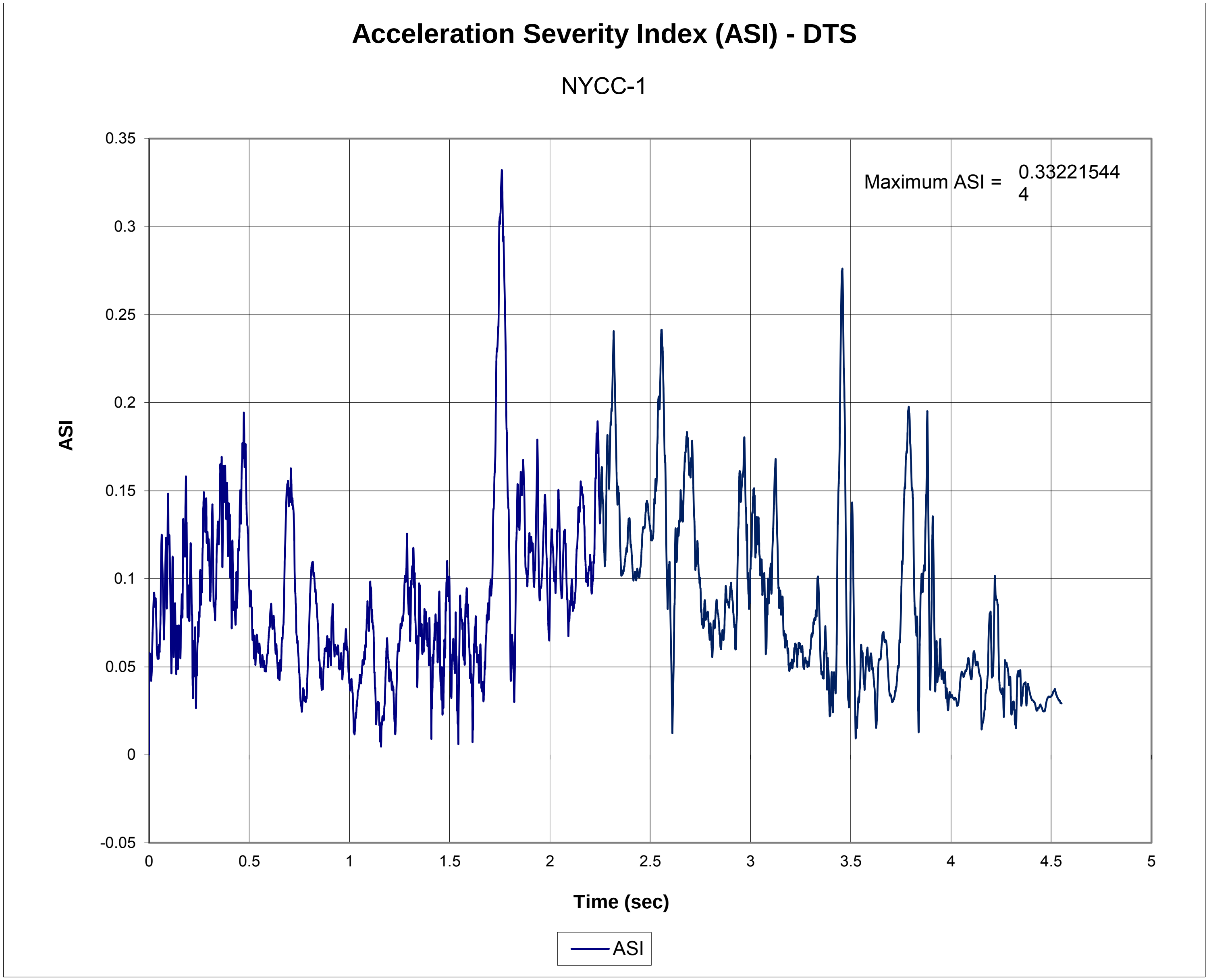


Figure E-7. Acceleration Severity Index (DTS), Test No. NYCC-1

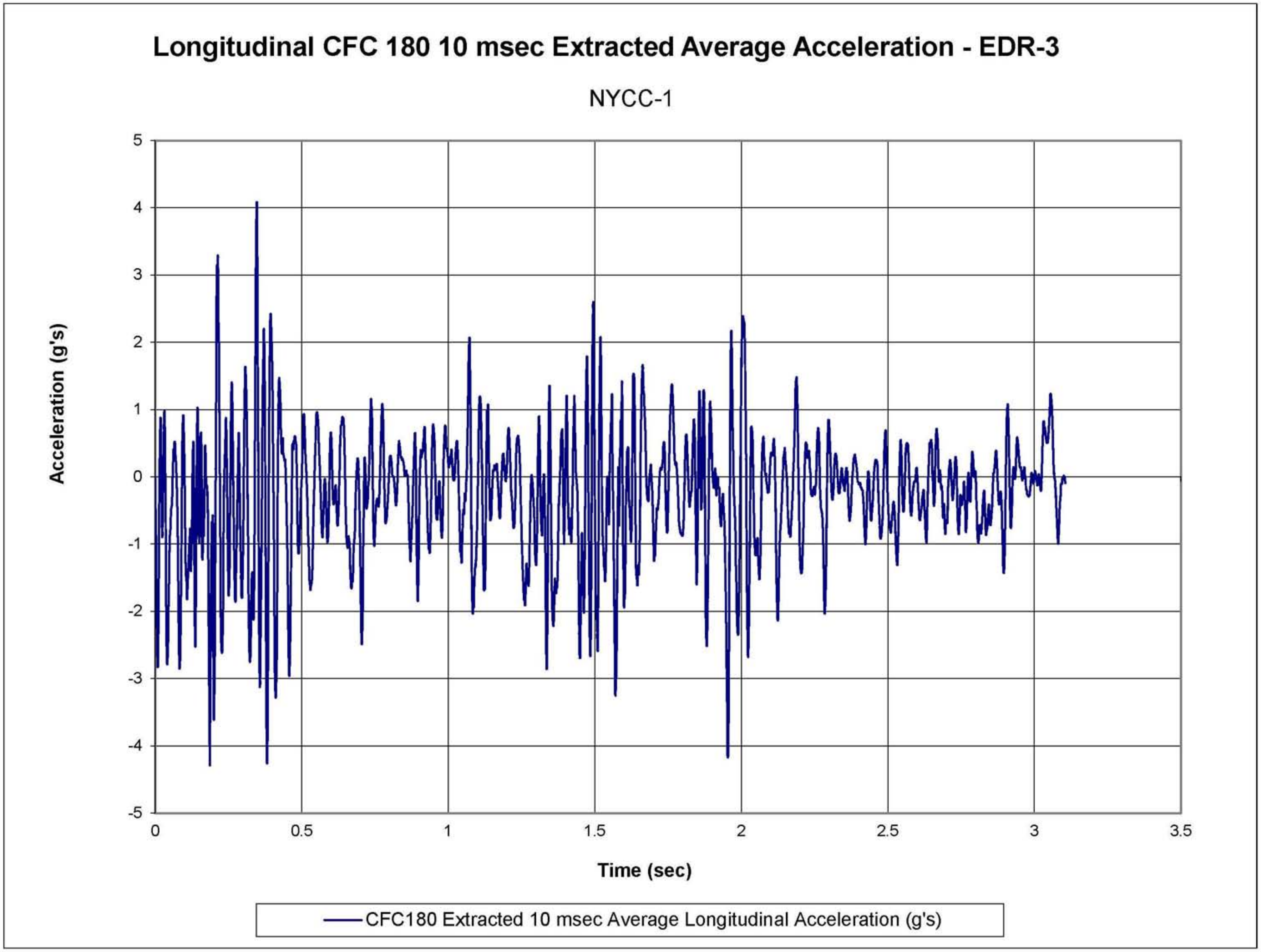


Figure E-8. 10-ms Average Longitudinal Deceleration (EDR-3), Test No. NYCC-1

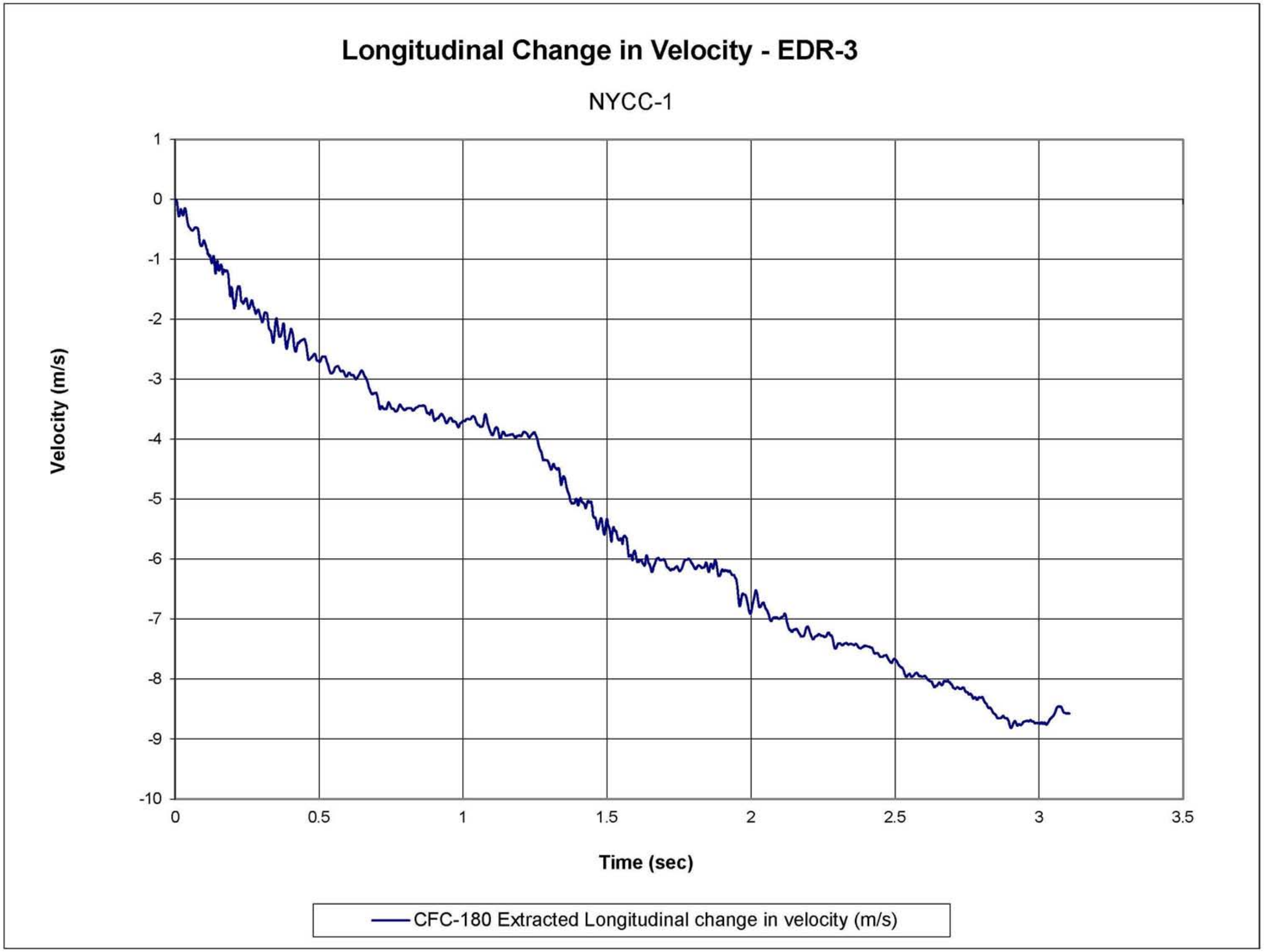


Figure E-9. Longitudinal Occupant Impact Velocity (EDR-3), Test No. NYCC-1

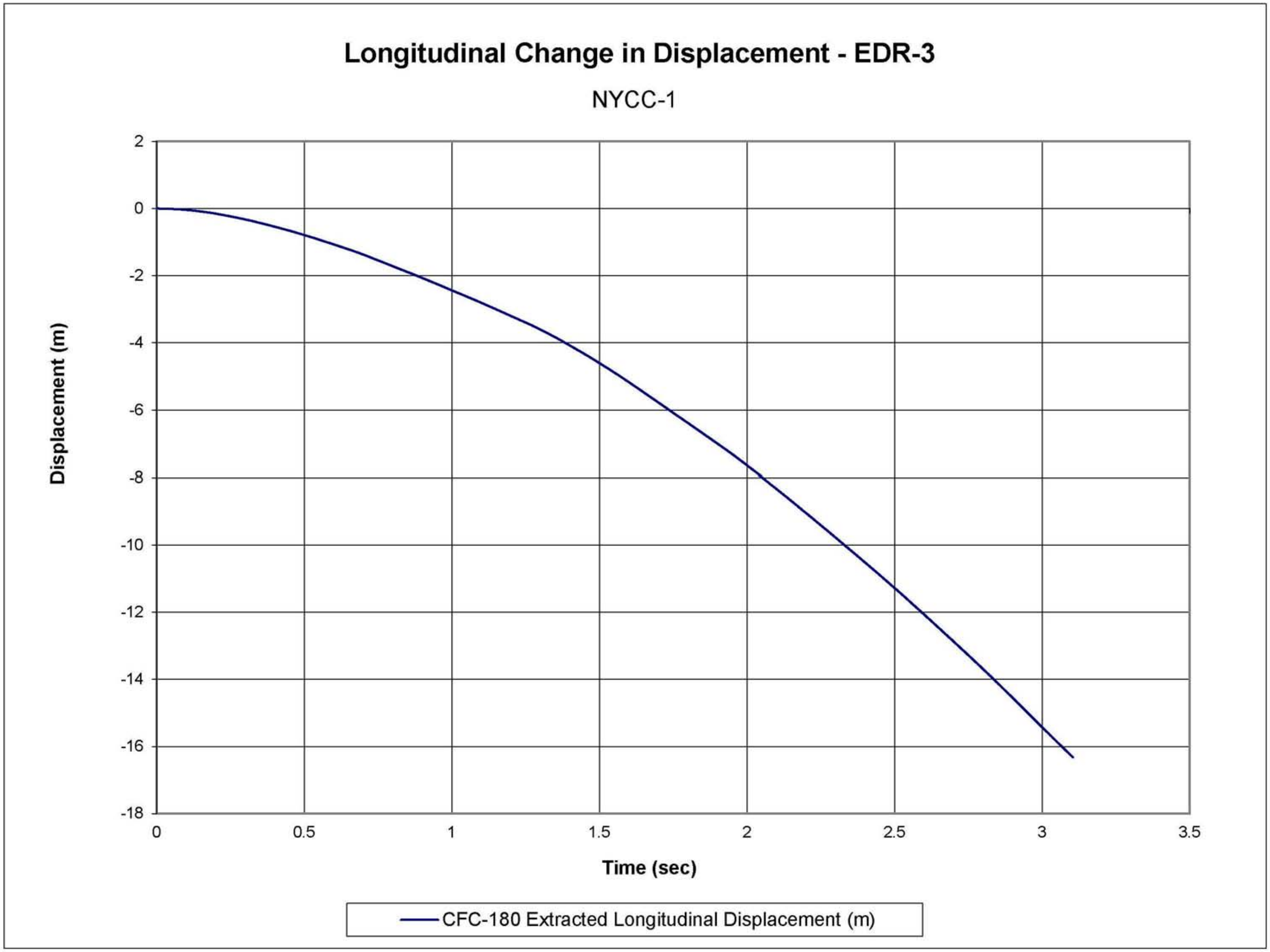


Figure E-10. Longitudinal Occupant Displacement (EDR-3), Test No. NYCC-1

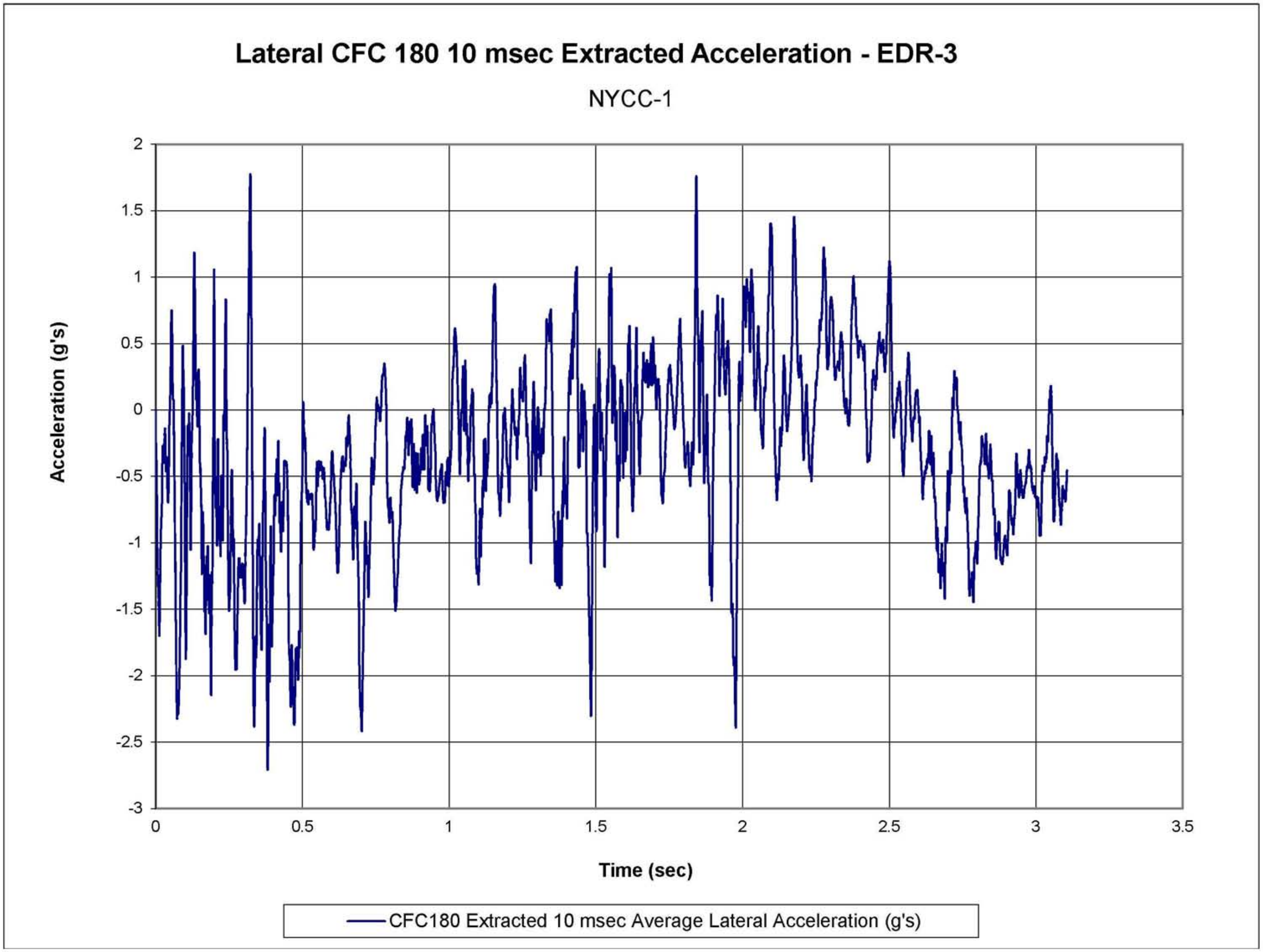


Figure E-11. 10-ms Average Lateral Deceleration (EDR-3), Test No. NYCC-1

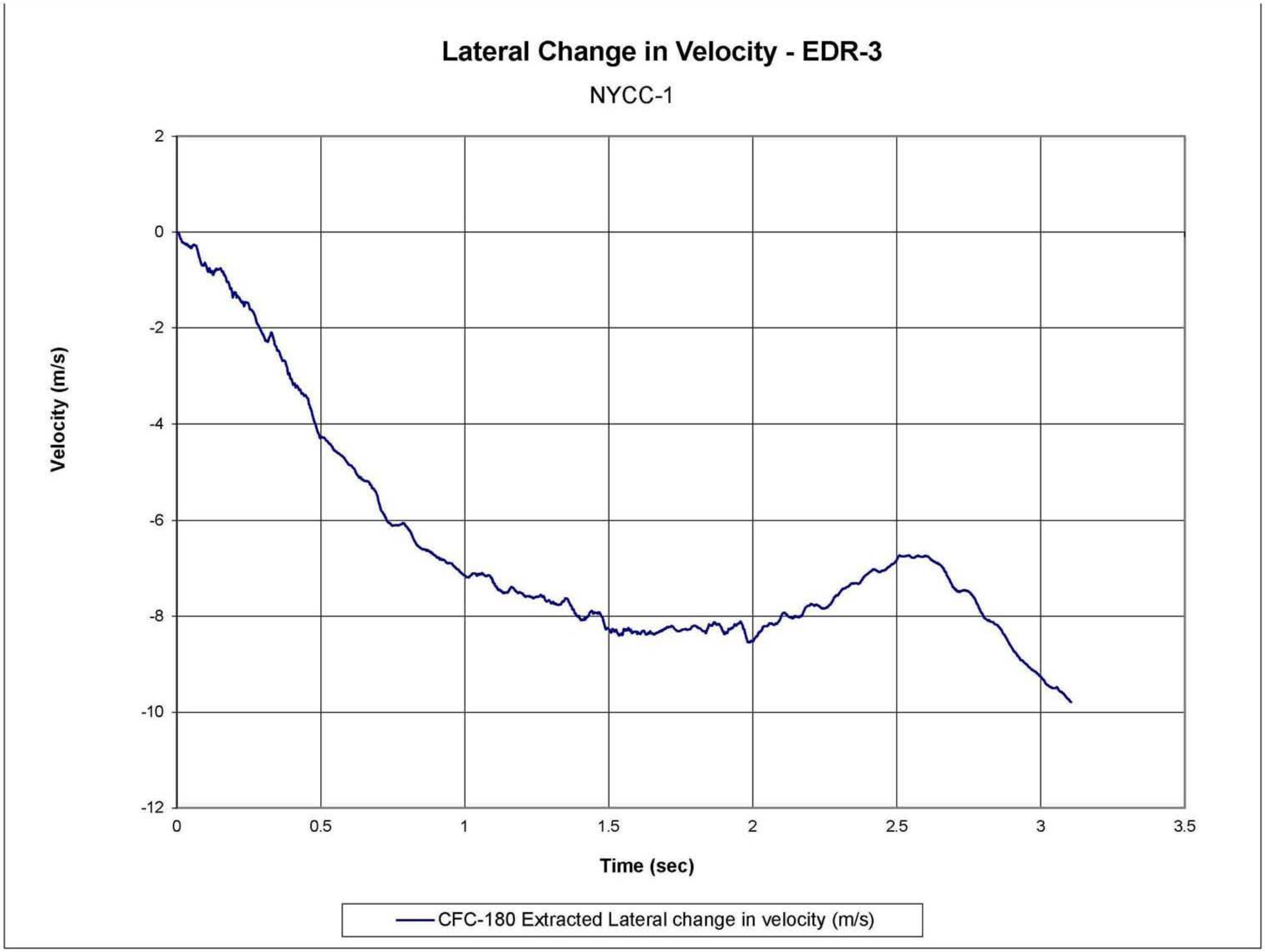


Figure E-12. Lateral Occupant Impact Velocity (EDR-3), Test No. NYCC-1

Figure E-13. Lateral Occupant Displacement (EDR-3), Test No. NYCC-1

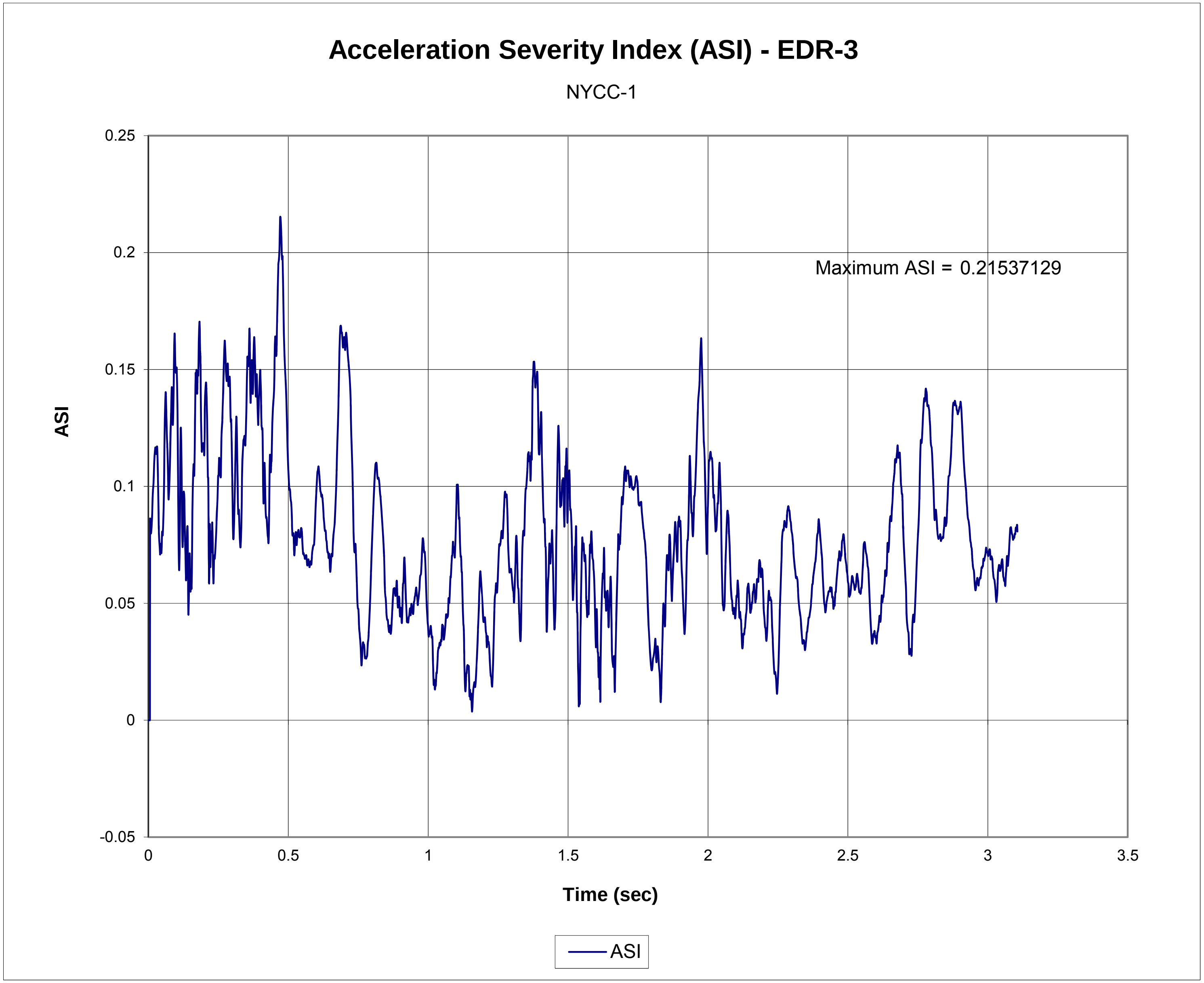


Figure E-14. Acceleration Severity Index (EDR-3), Test No. NYCC-1

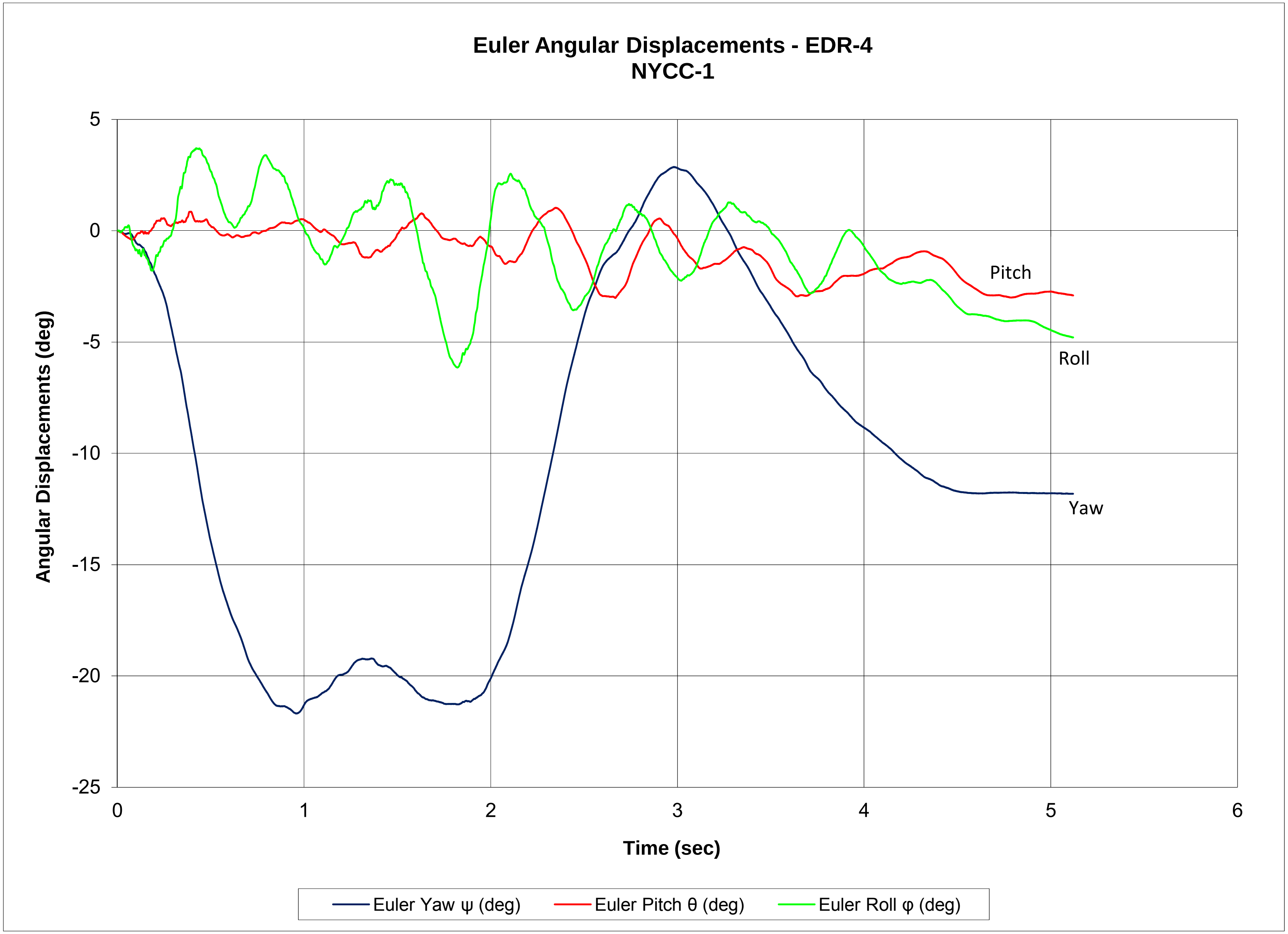


Figure E-15. Vehicle Angular Displacements (EDR-4), Test No. NYCC-1

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

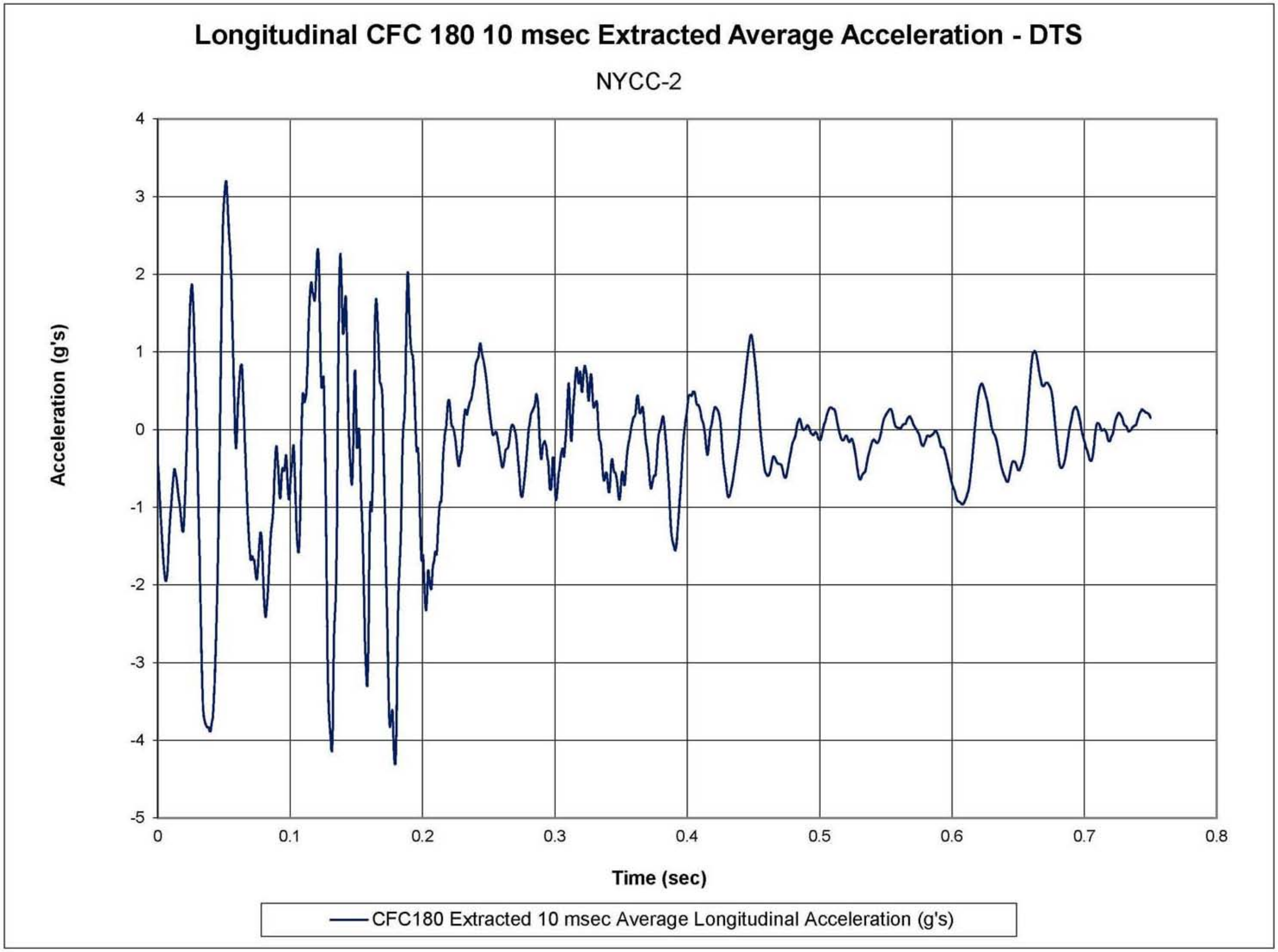


Figure F-1. 10-ms Average Longitudinal Deceleration (DTS), Test No. NYCC-2

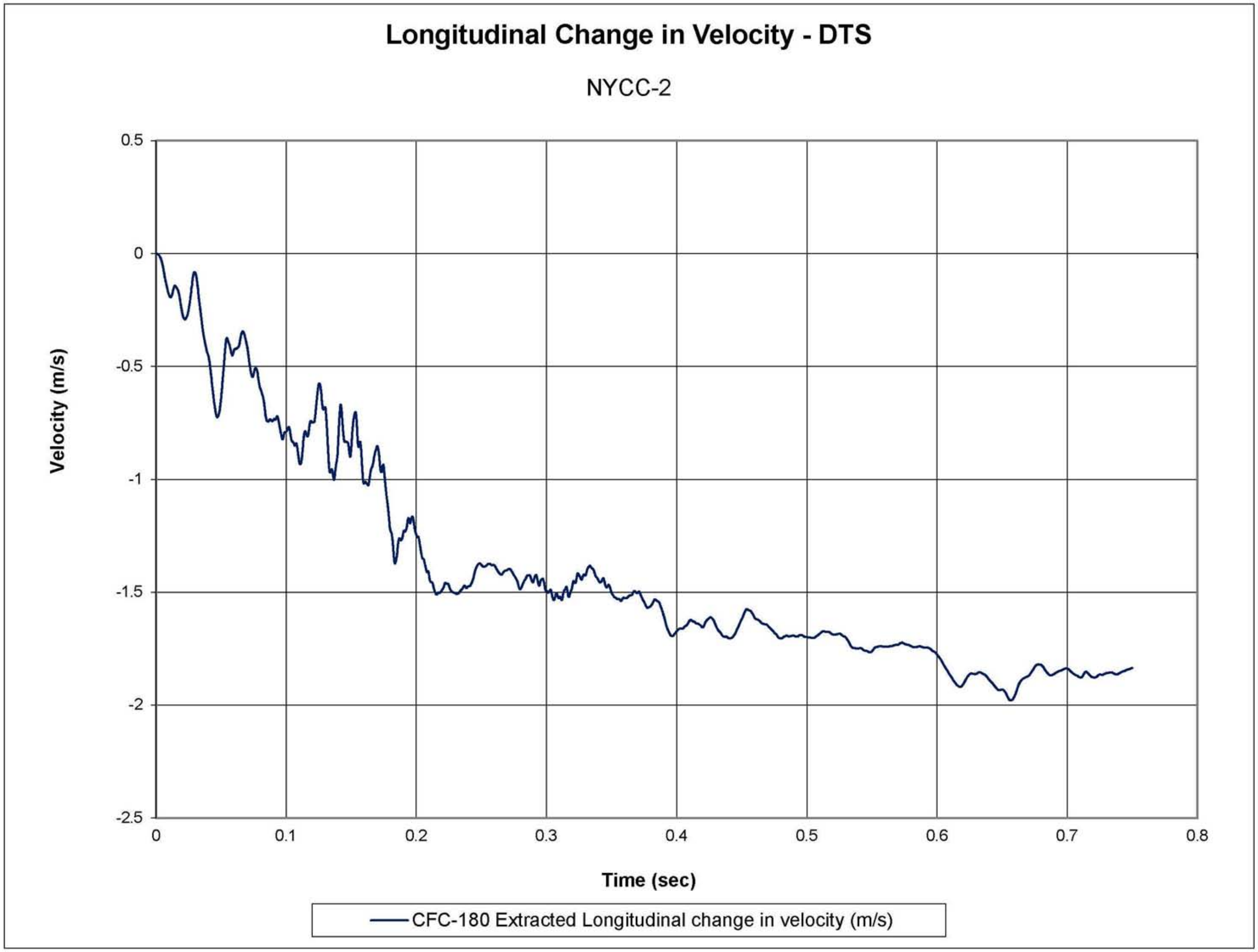


Figure F-2. Longitudinal Occupant Impact Velocity (DTS), Test No. NYCC-2

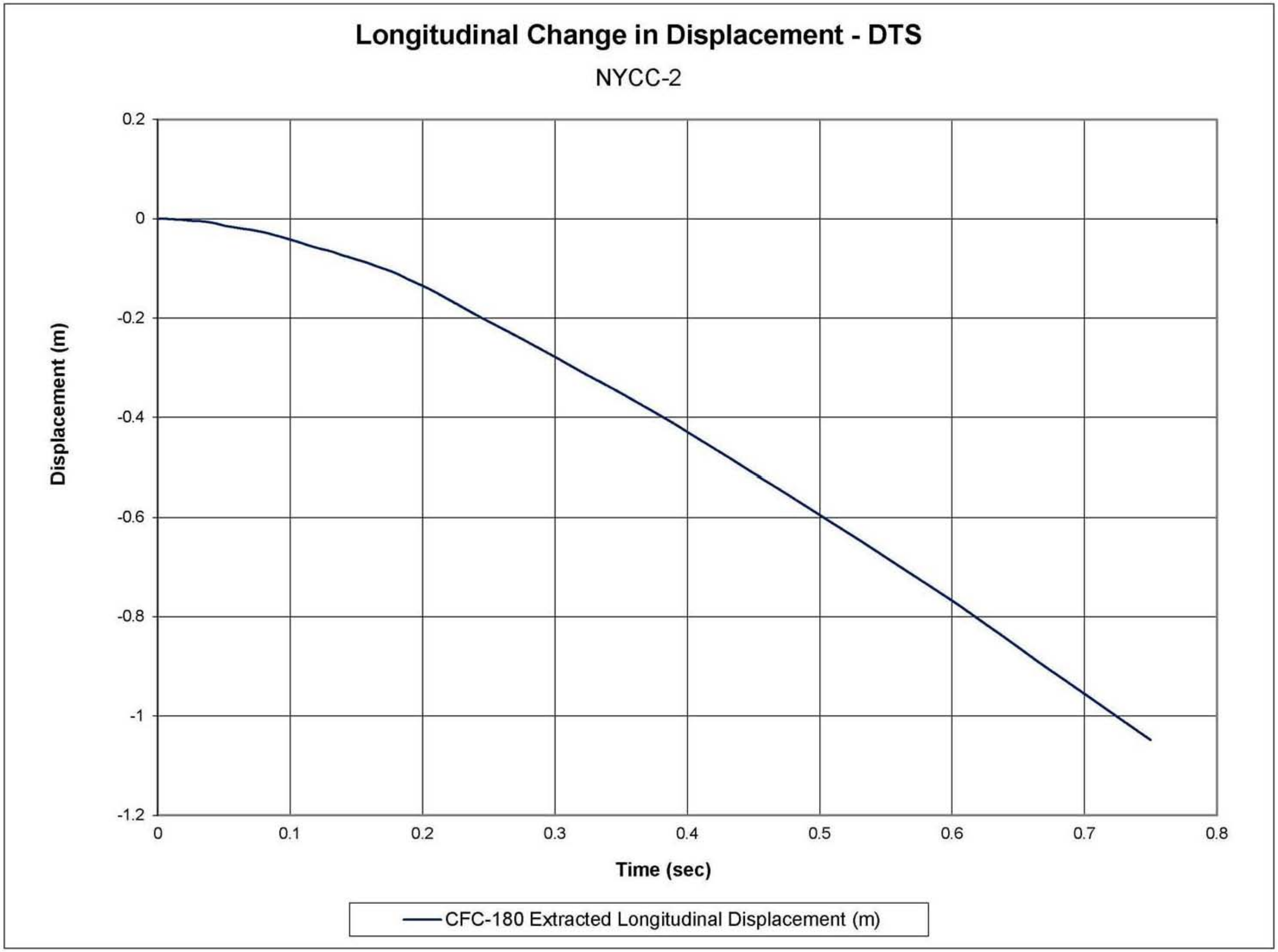


Figure F-3. Longitudinal Occupant Displacement (DTS), Test No. NYCC-2

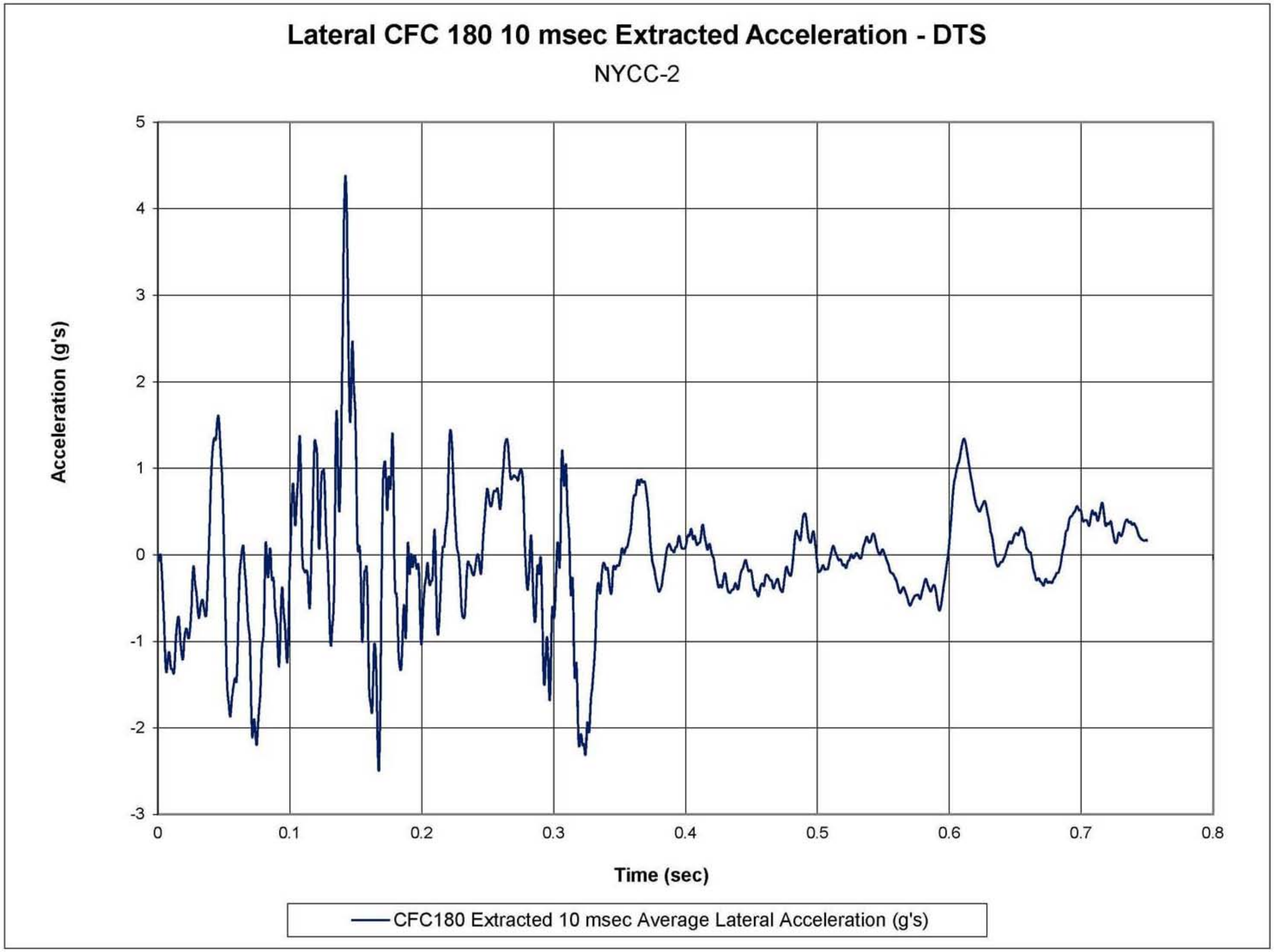


Figure F-4. 10-ms Average Lateral Deceleration (DTS), Test No. NYCC-2

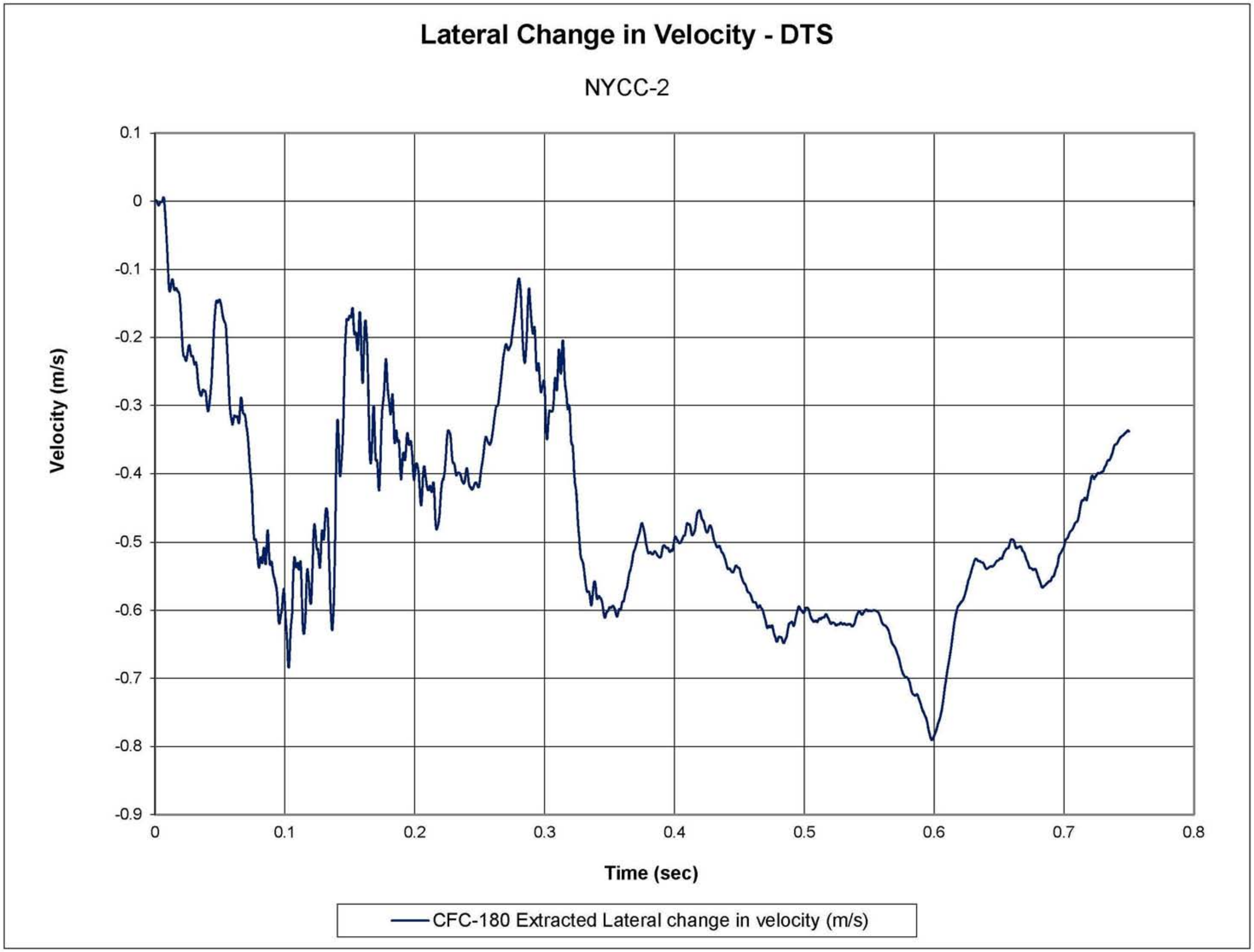


Figure F-5. Lateral Occupant Impact Velocity (DTS), Test No. NYCC-2

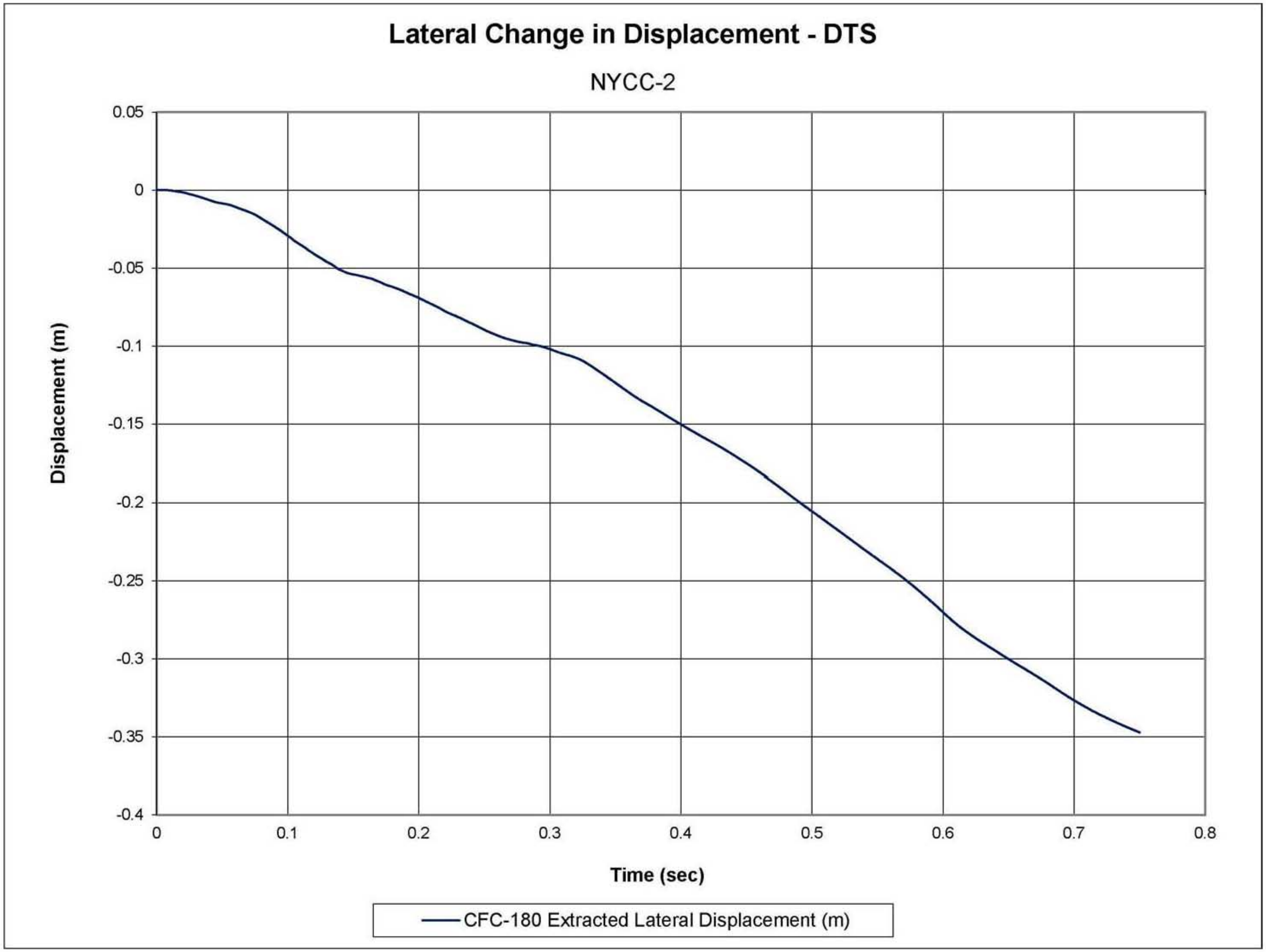


Figure F-6. Lateral Occupant Displacement (DTS), Test No. NYCC-2

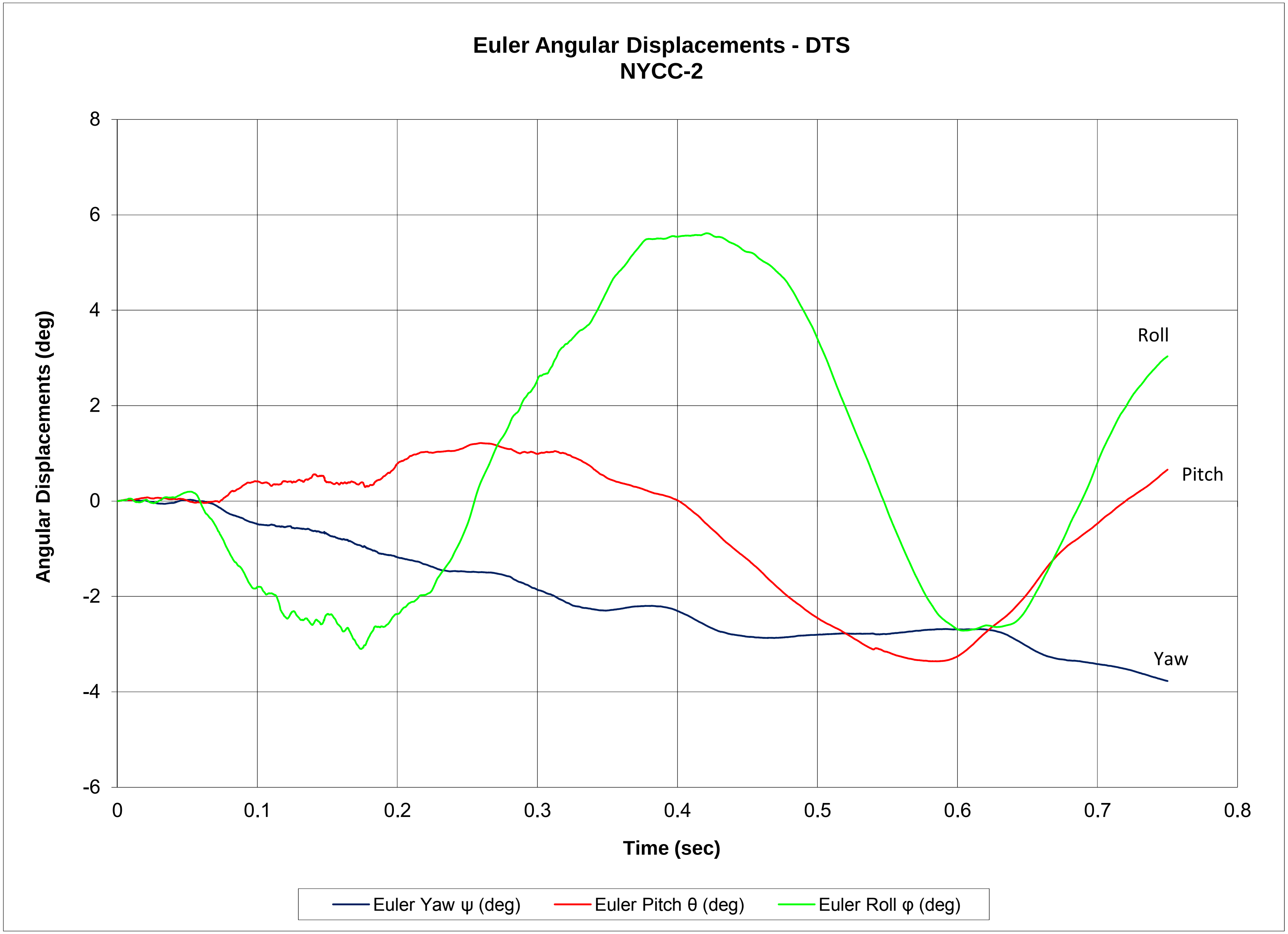


Figure F-7. Vehicle Angular Displacements (DTS), Test No. NYCC-2

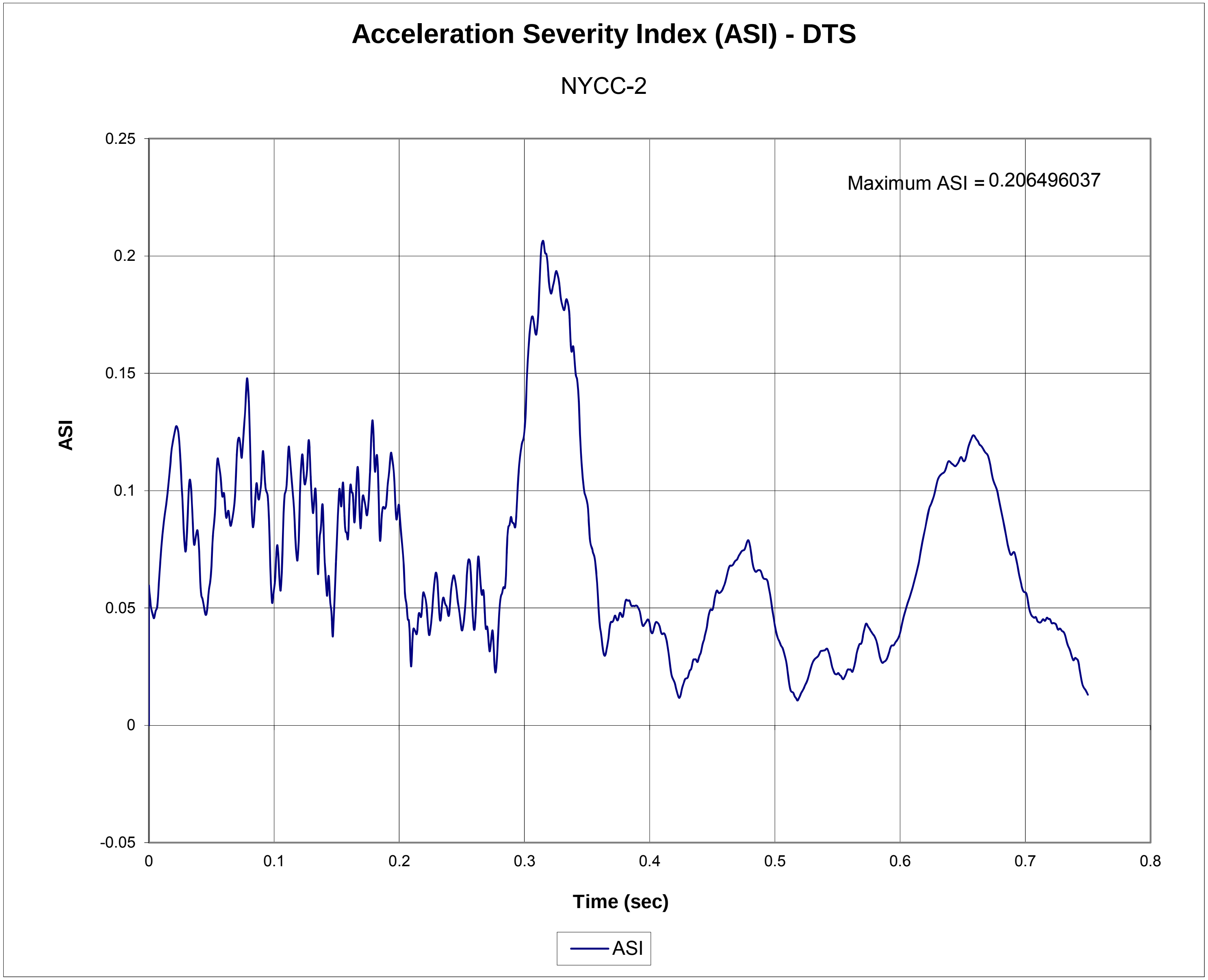


Figure F-8. Acceleration Severity Index (DTS), Test No. NYCC-2

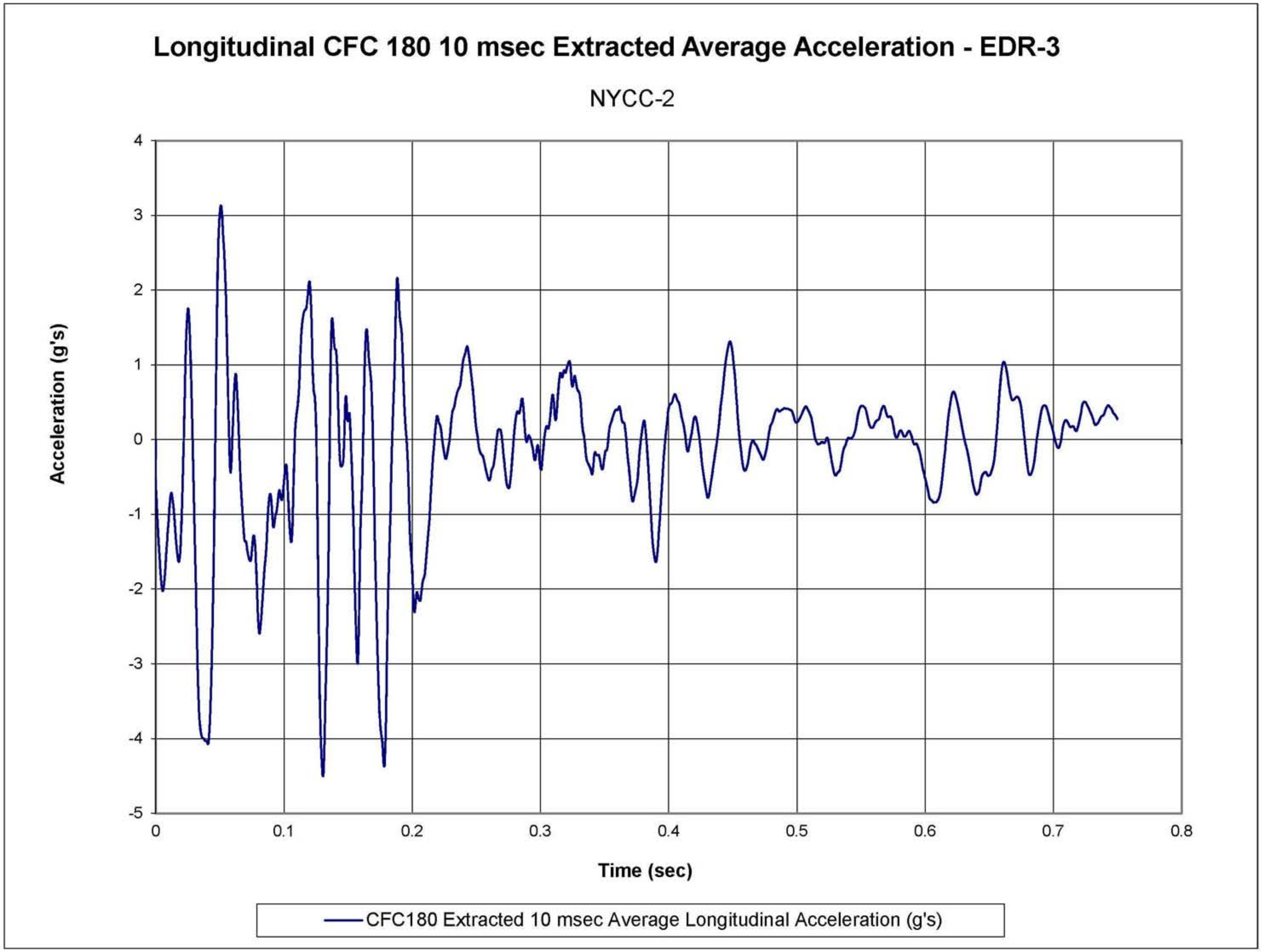


Figure F-9. 10-ms Average Lateral Deceleration (EDR-3), Test No. NYCC-2

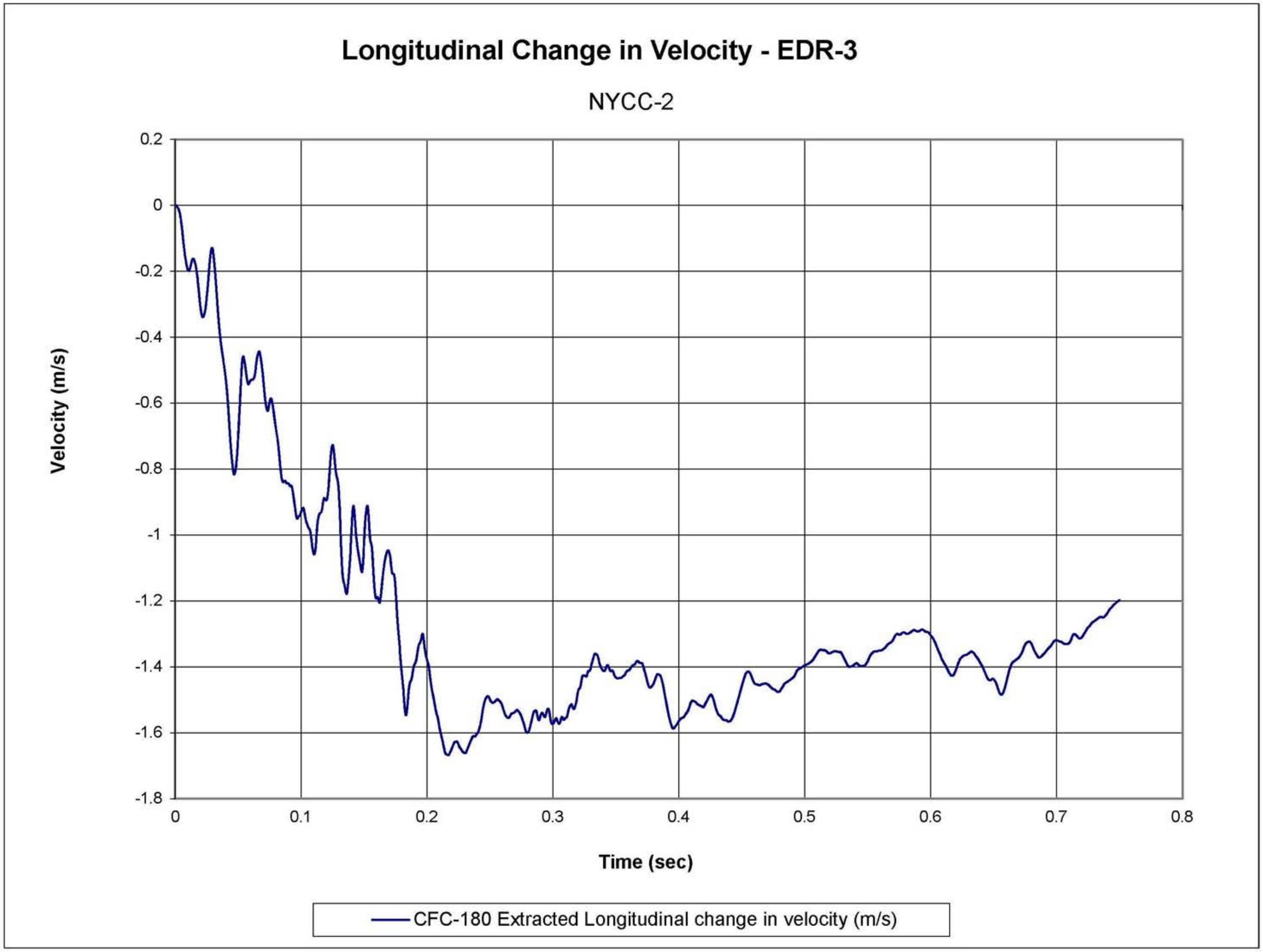


Figure F-10. Longitudinal Occupant Impact Velocity (EDR-3), Test No. NYCC-2

Figure F-11. Longitudinal Occupant Displacement (EDR-3), Test No. NYCC-2

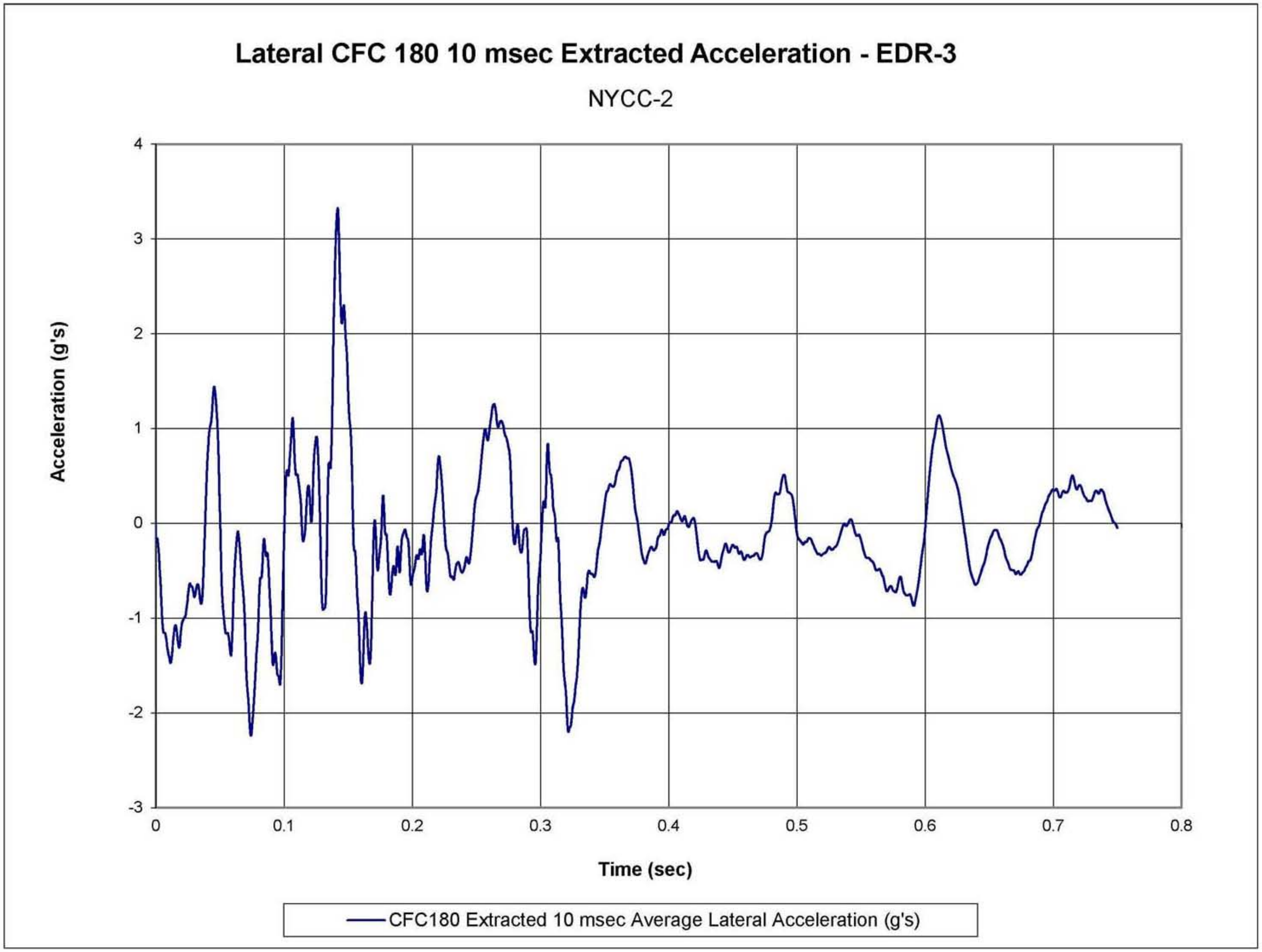


Figure F-12. 10-ms Average Lateral Deceleration (EDR-3), Test No. NYCC-2

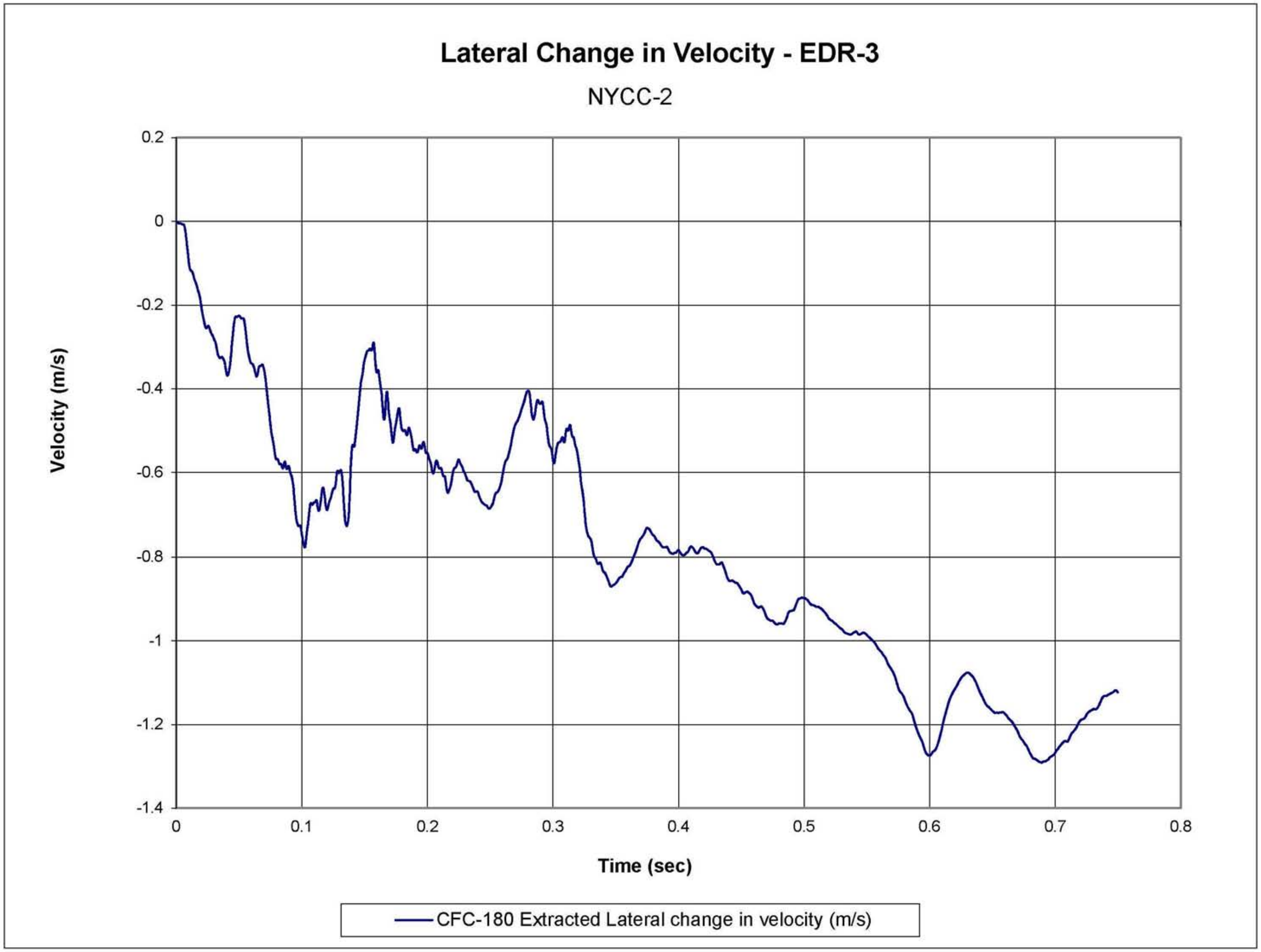


Figure F-13. Lateral Occupant Impact Velocity (EDR-3), Test No. NYCC-2

Figure F-14. Lateral Occupant Displacement (EDR-3), Test No. NYCC-2

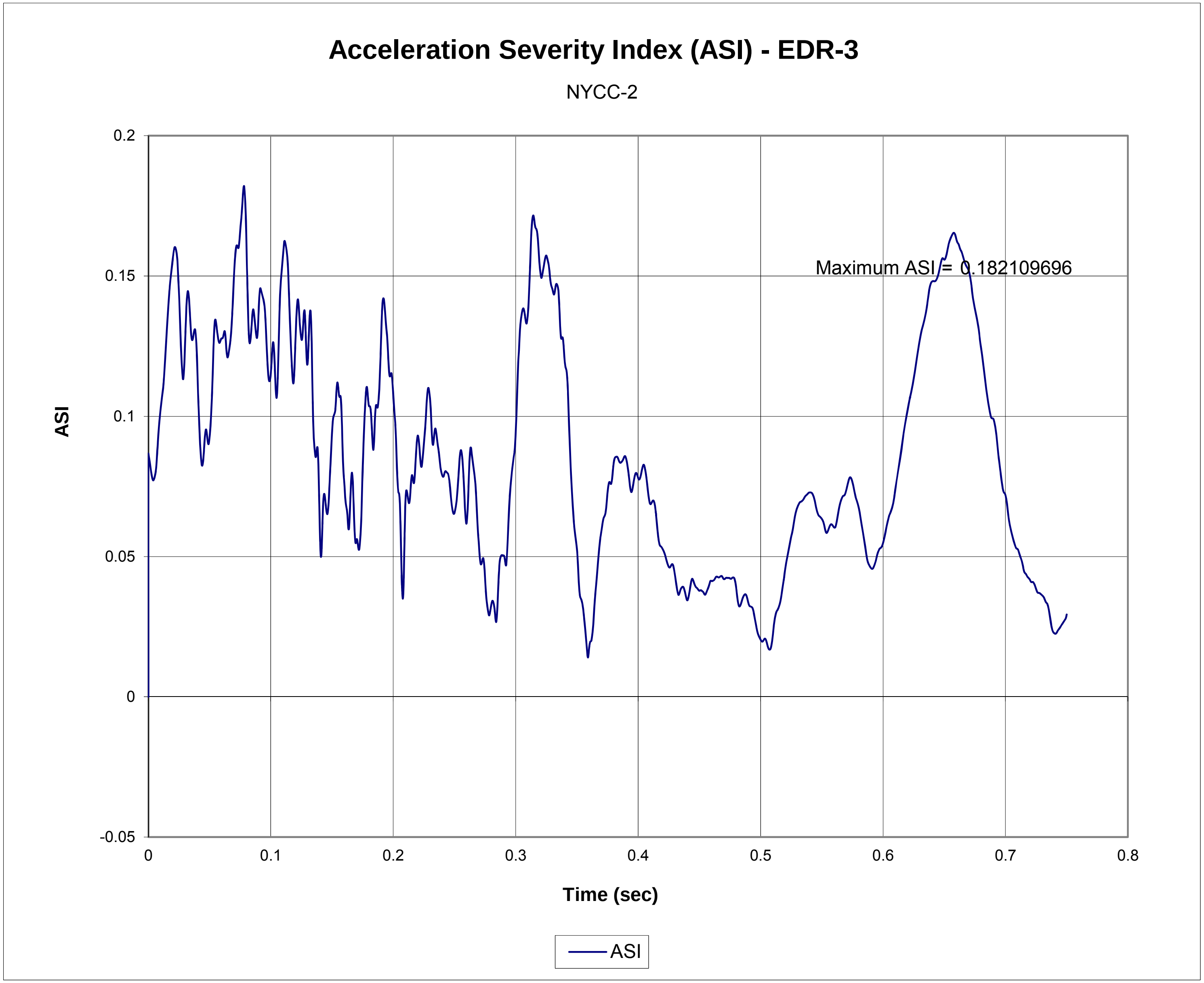


Figure F-15. Acceleration Severity Index (EDR-3), Test No. NYCC-2

Appendix G. Accelerometer and Rate Transducer Data Plots, Test No. NYCC-3

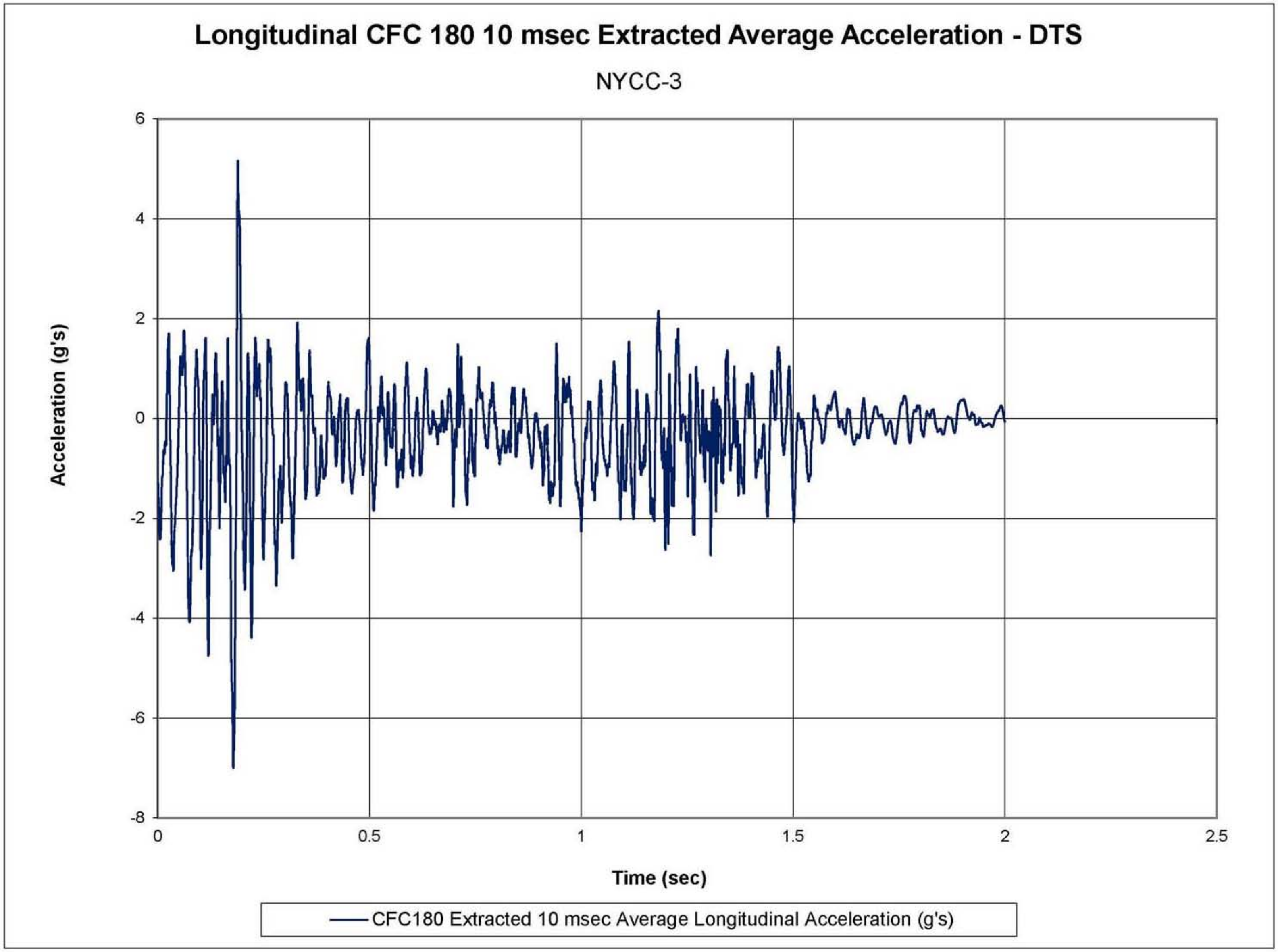


Figure G-1. 10-ms Average Longitudinal Deceleration (DTS), Test No. NYCC-3

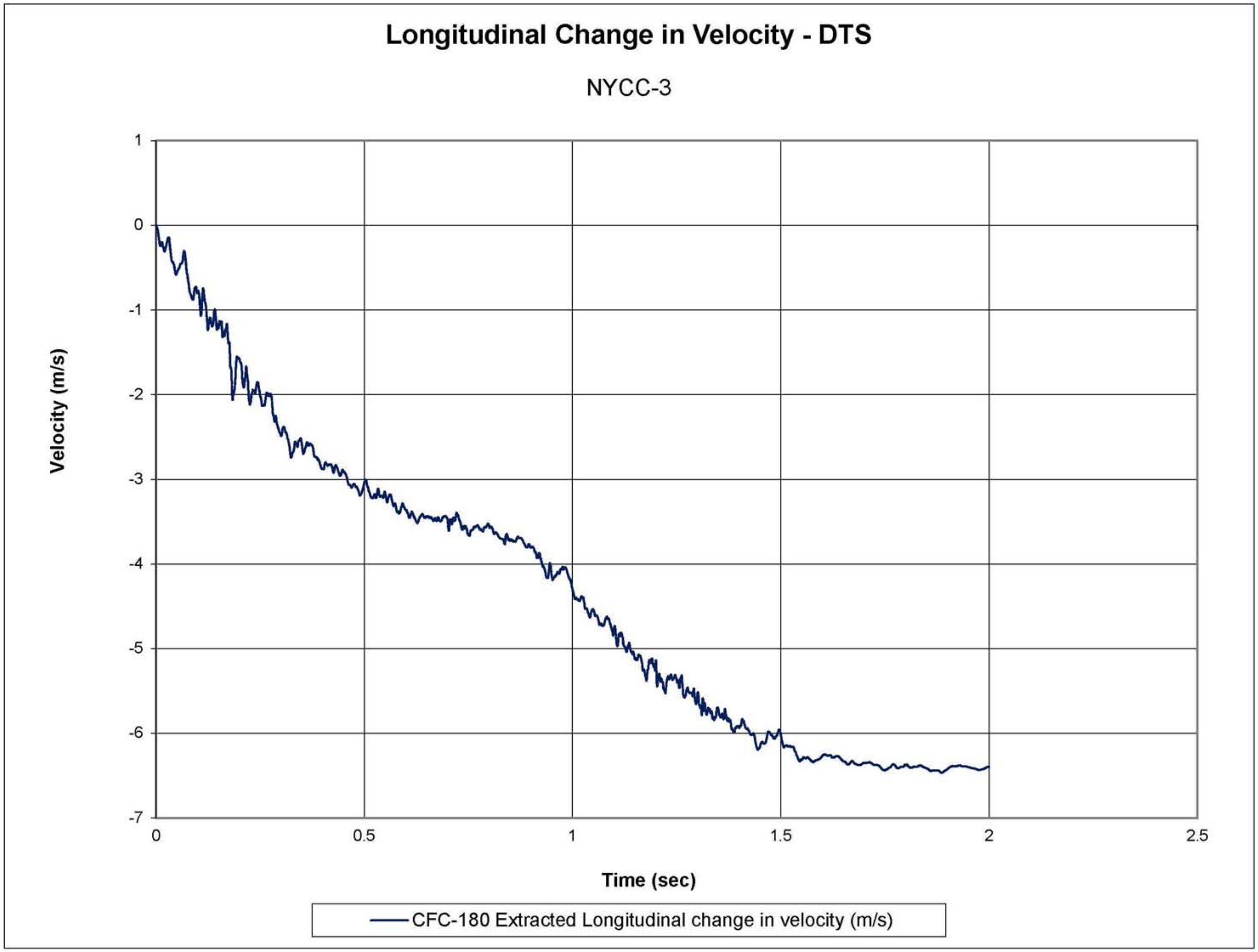


Figure G-2. Longitudinal Occupant Impact Velocity (DTS), Test No. NYCC-3

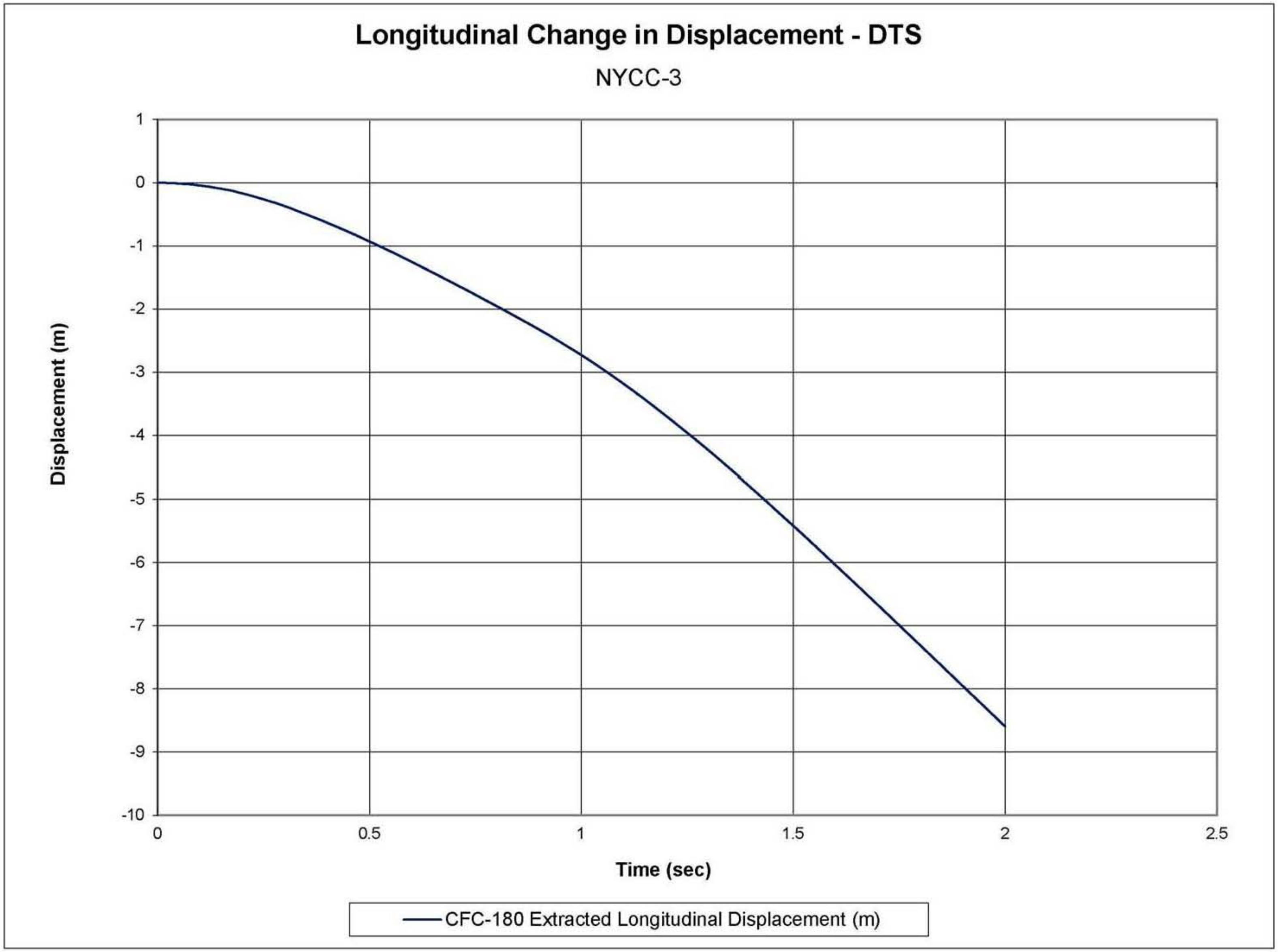


Figure G-3. Longitudinal Occupant Displacement (DTS), Test No. NYCC-3

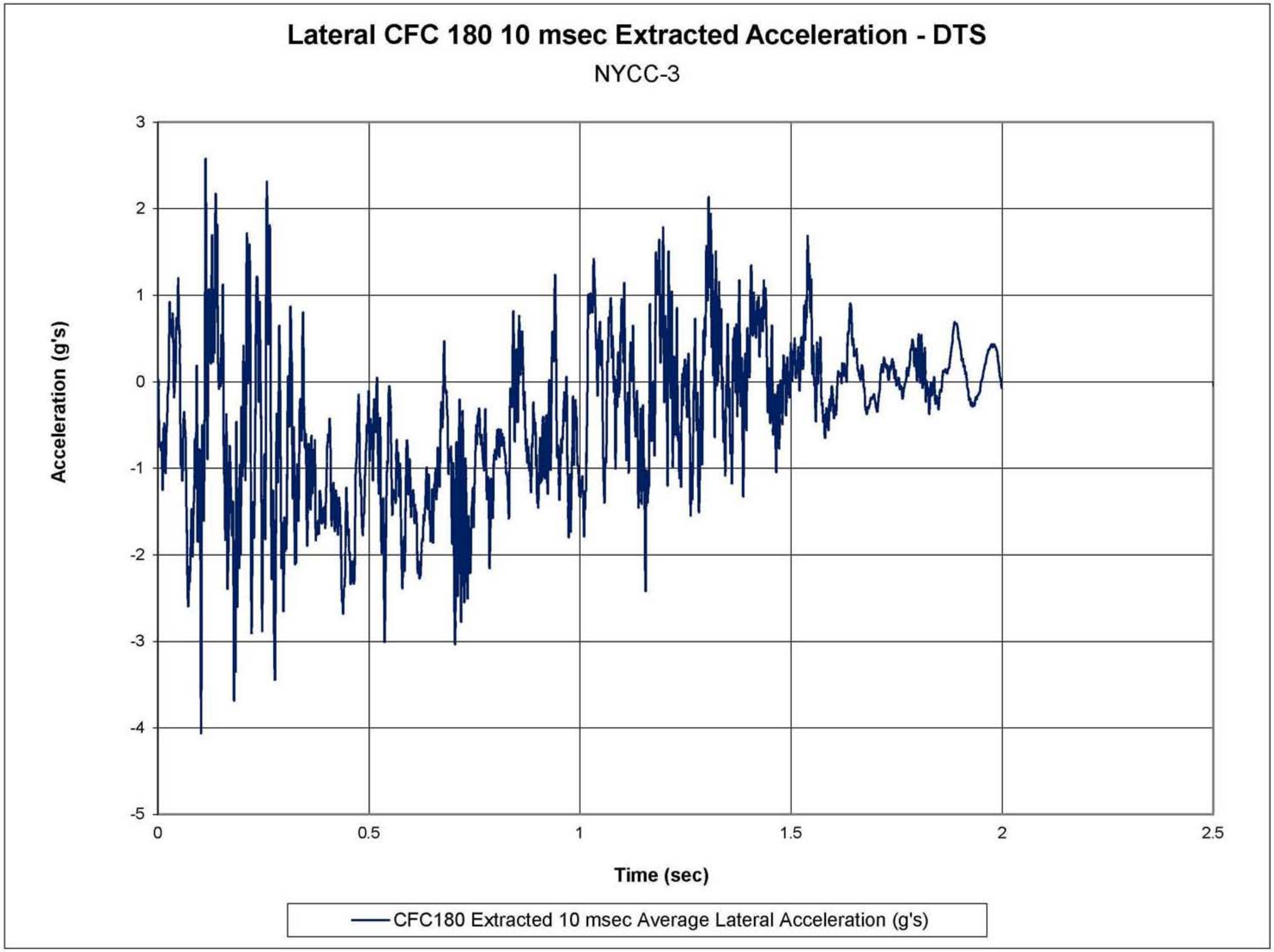


Figure G-4. 10-ms Average Lateral Deceleration (DTS), Test No. NYCC-3

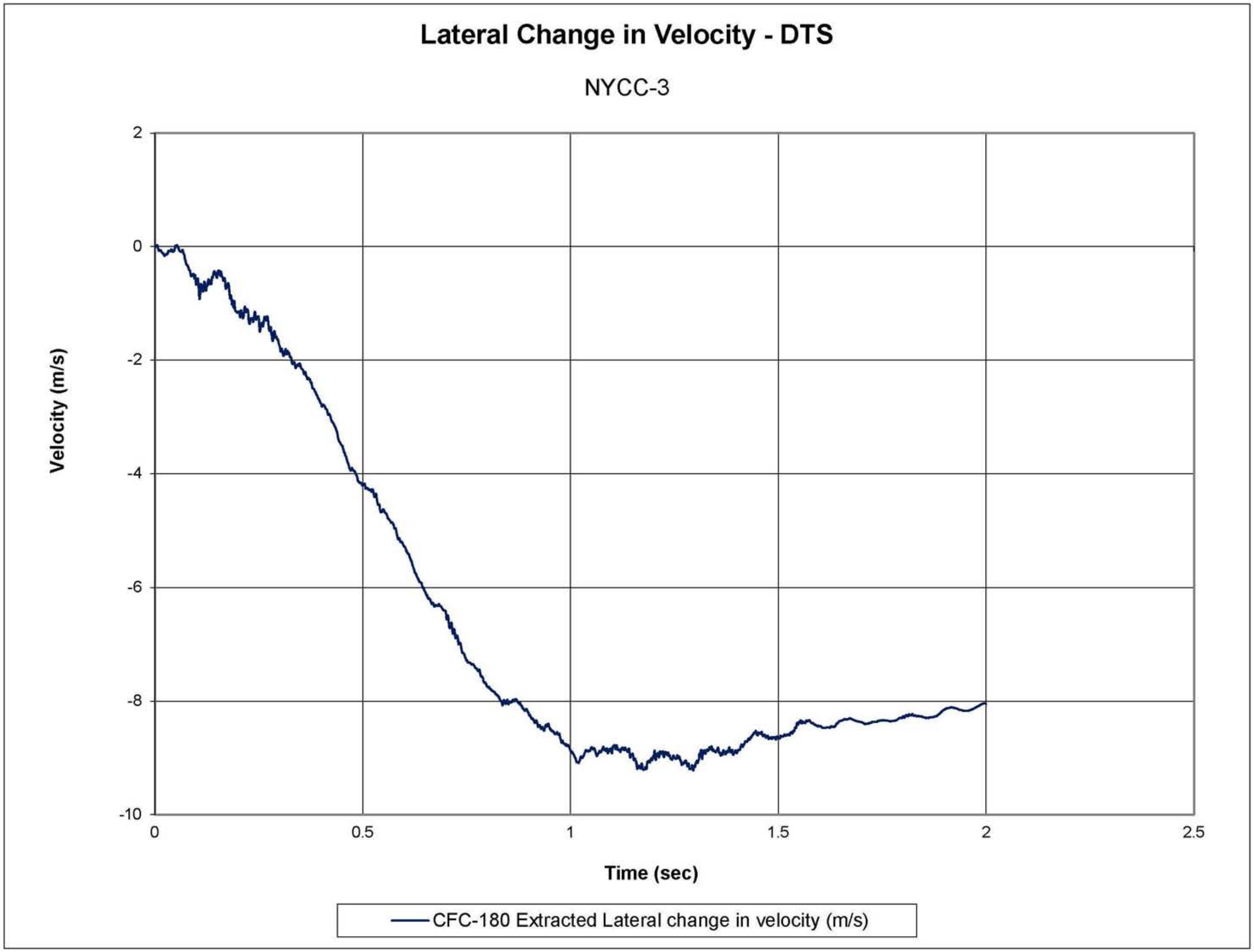


Figure G-5. Lateral Occupant Impact Velocity (DTS), Test No. NYCC-3

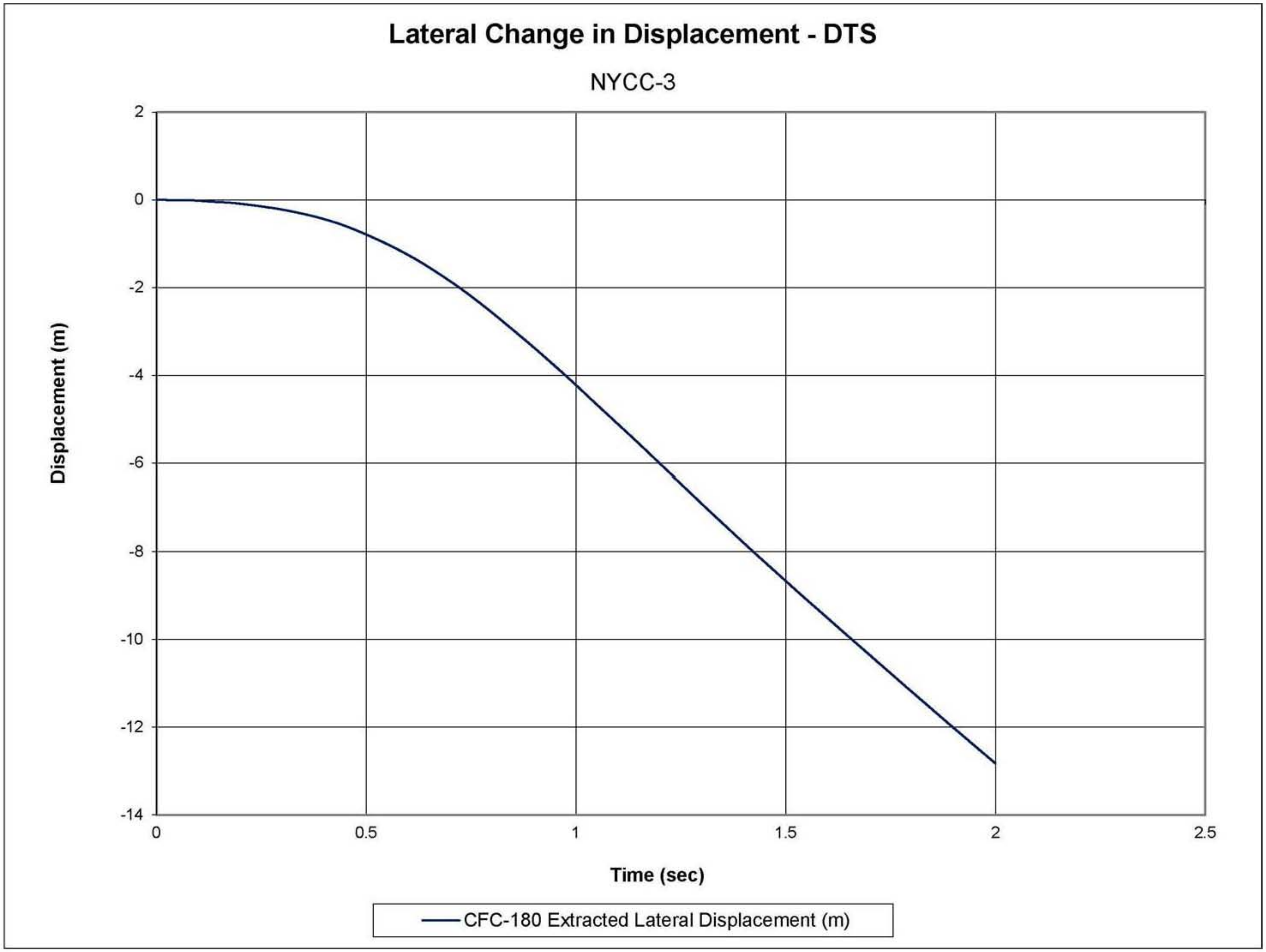


Figure G-6. Lateral Occupant Displacement (DTS), Test No. NYCC-3

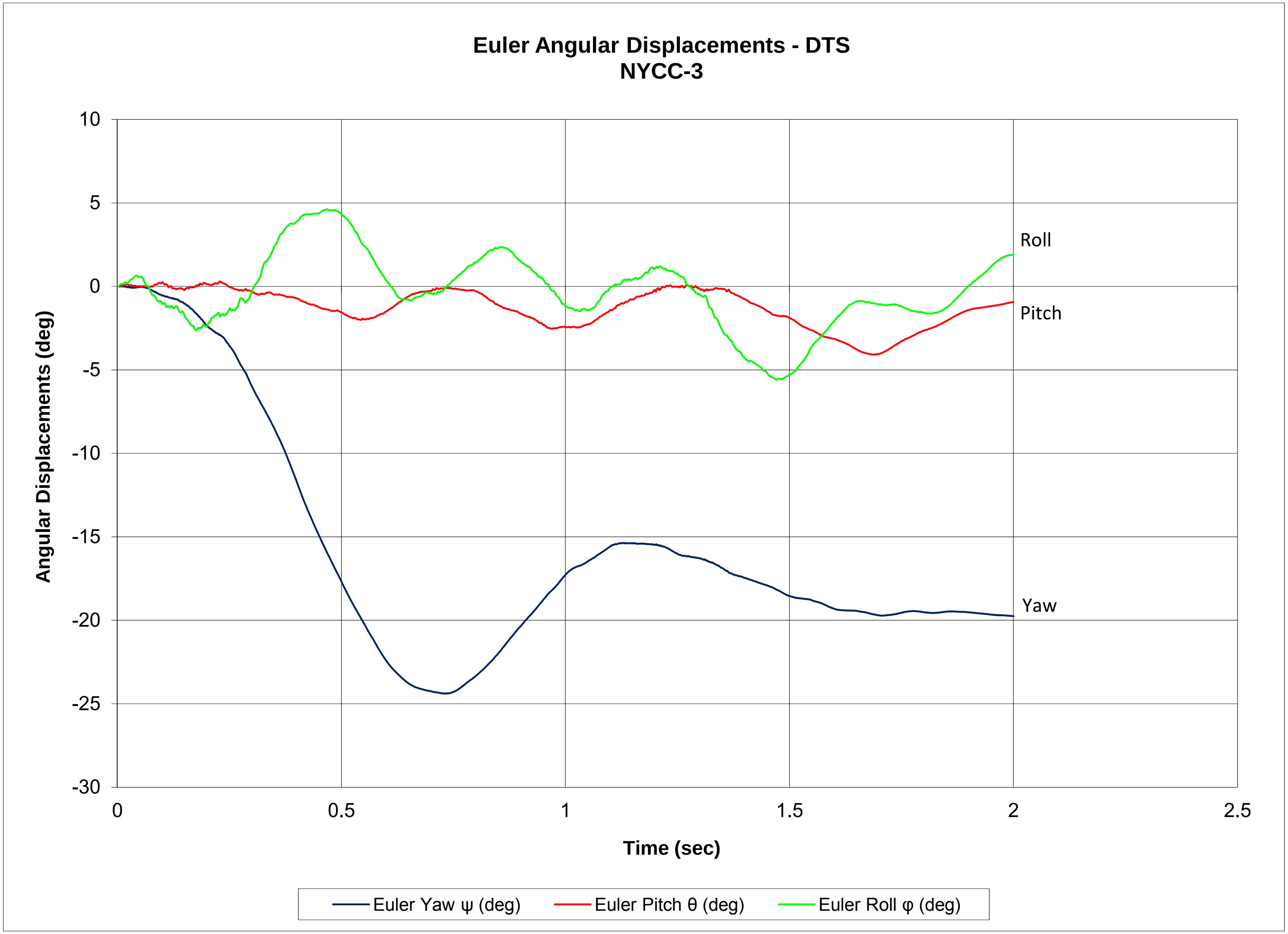


Figure G-7. Vehicle Angular Displacements (DTS), Test No. NYCC-3

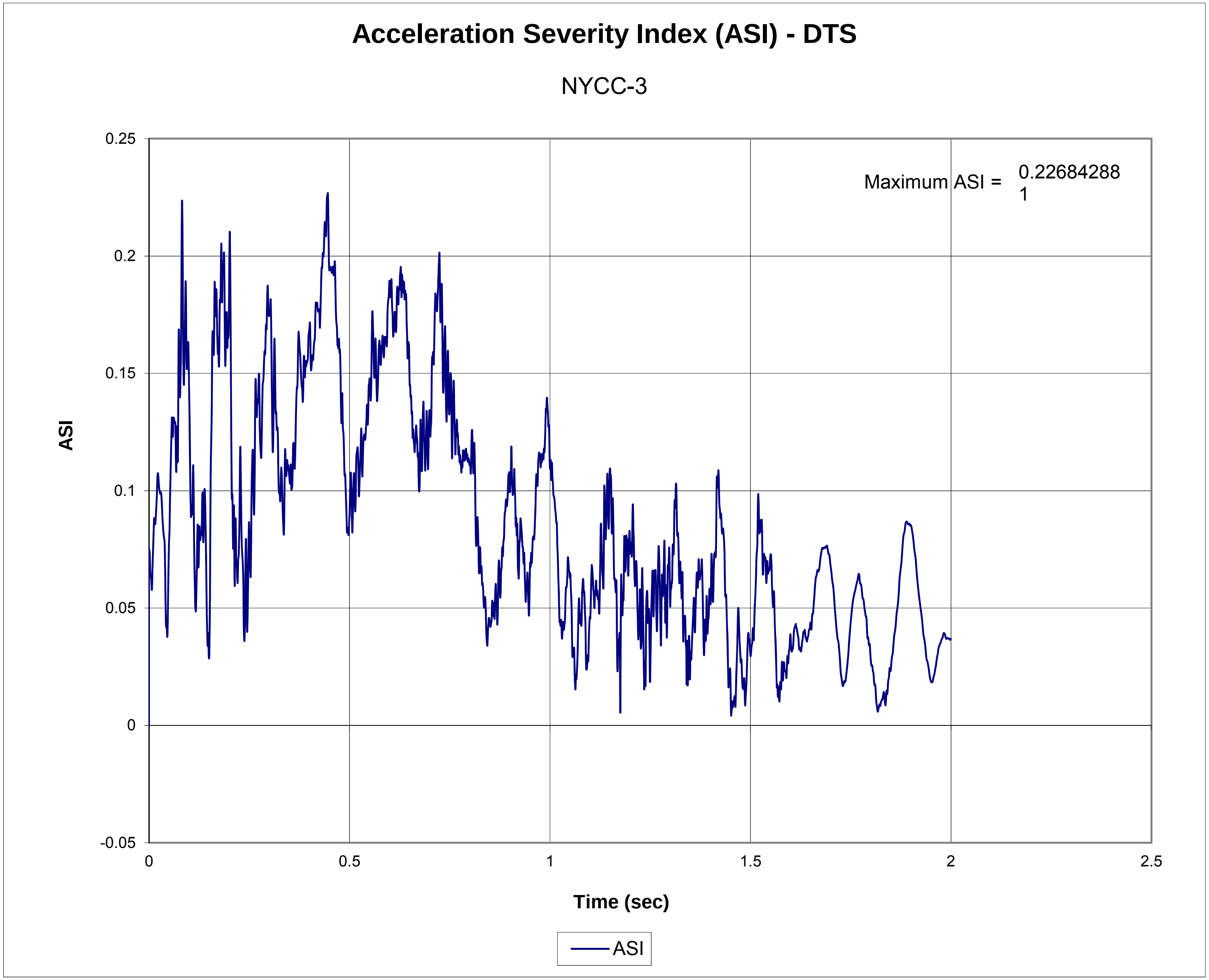


Figure G-8. Acceleration Severity Index (DTS), Test No. NYCC-3

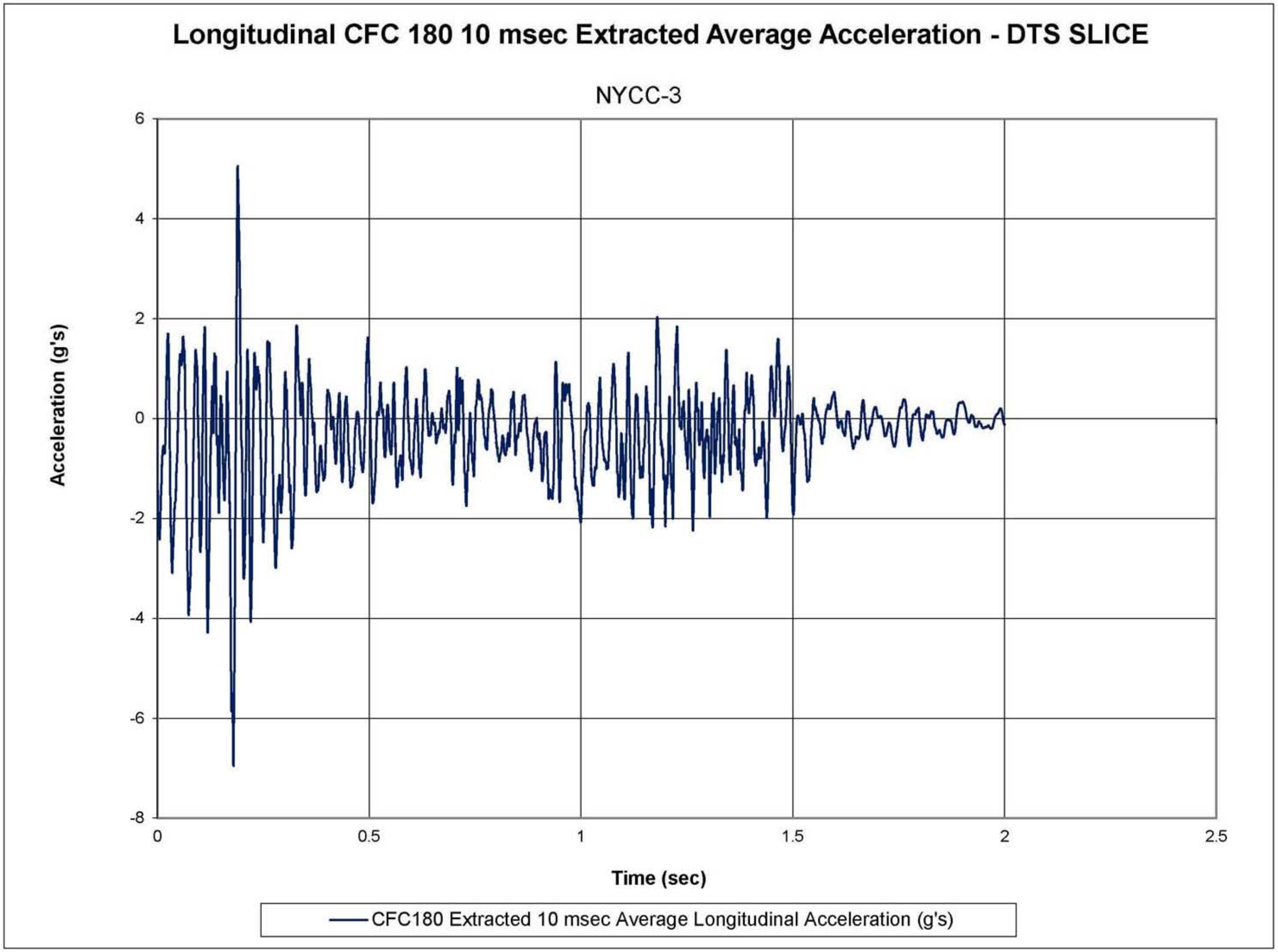


Figure G-9. 10-ms Average Longitudinal Deceleration (DTS SLICE), Test No. NYCC-3

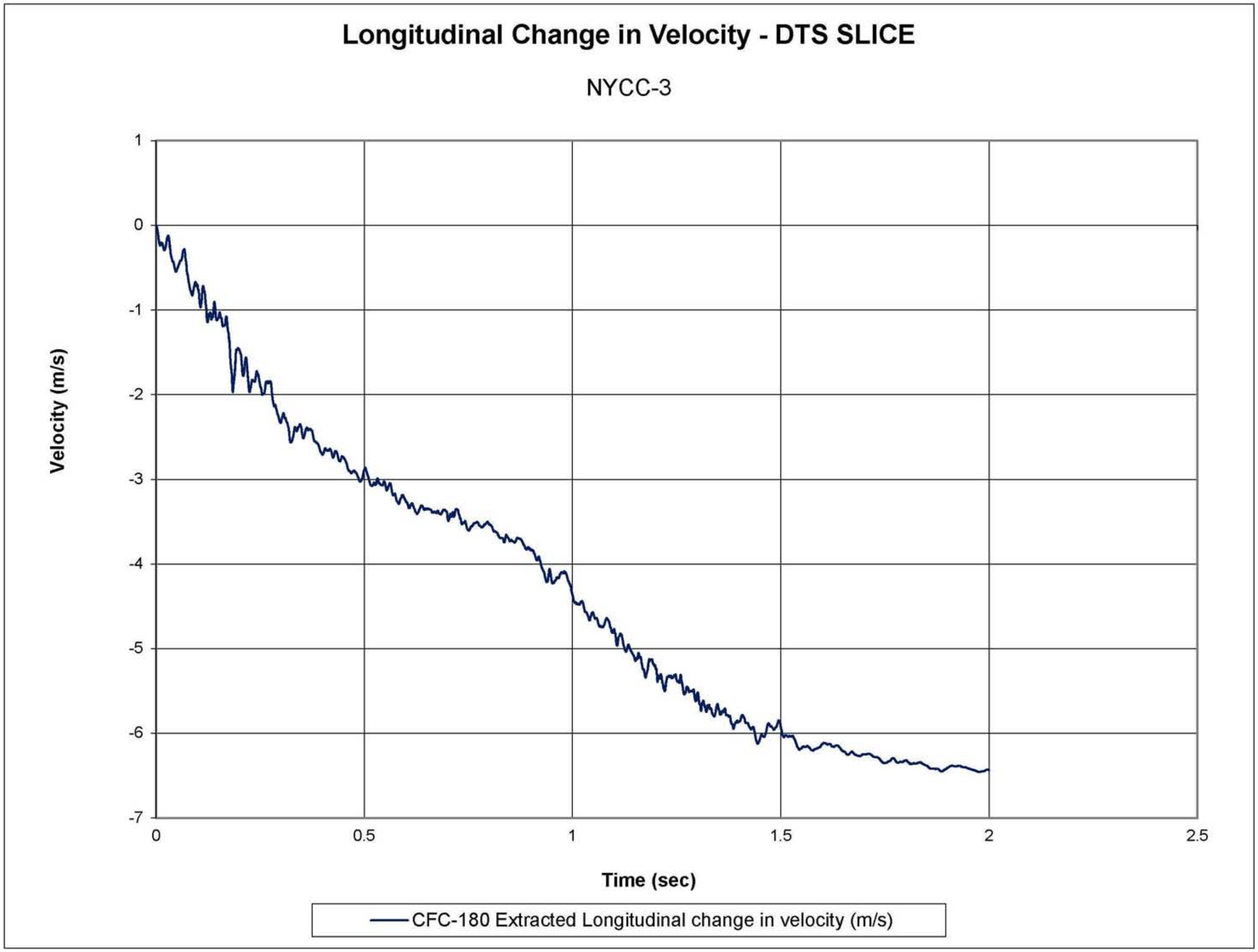


Figure G-10. Longitudinal Occupant Impact Velocity (DTS SLICE), Test No. NYCC-3

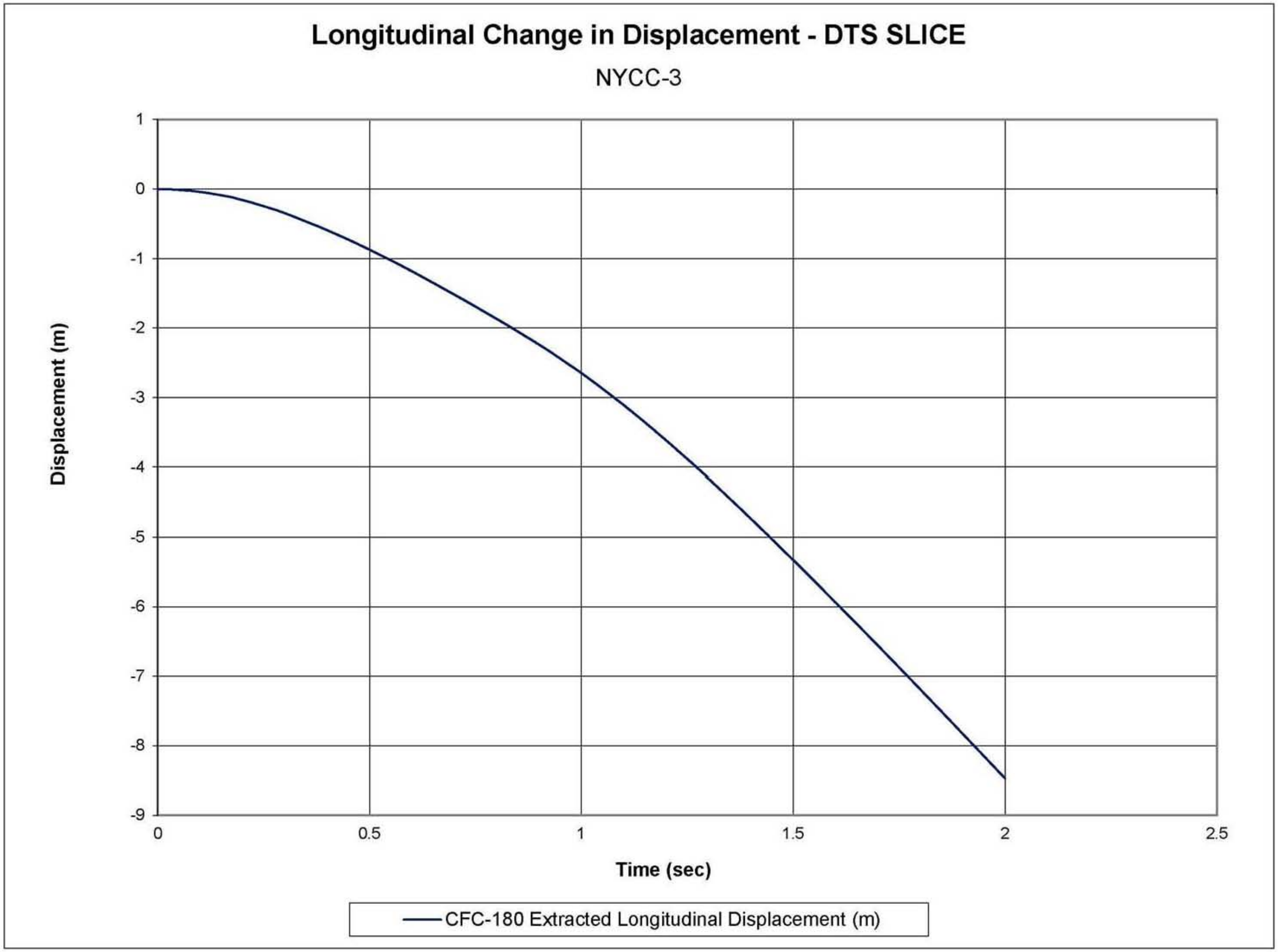


Figure G-11. Longitudinal Occupant Displacement (DTS SLICE), Test No. NYCC-3

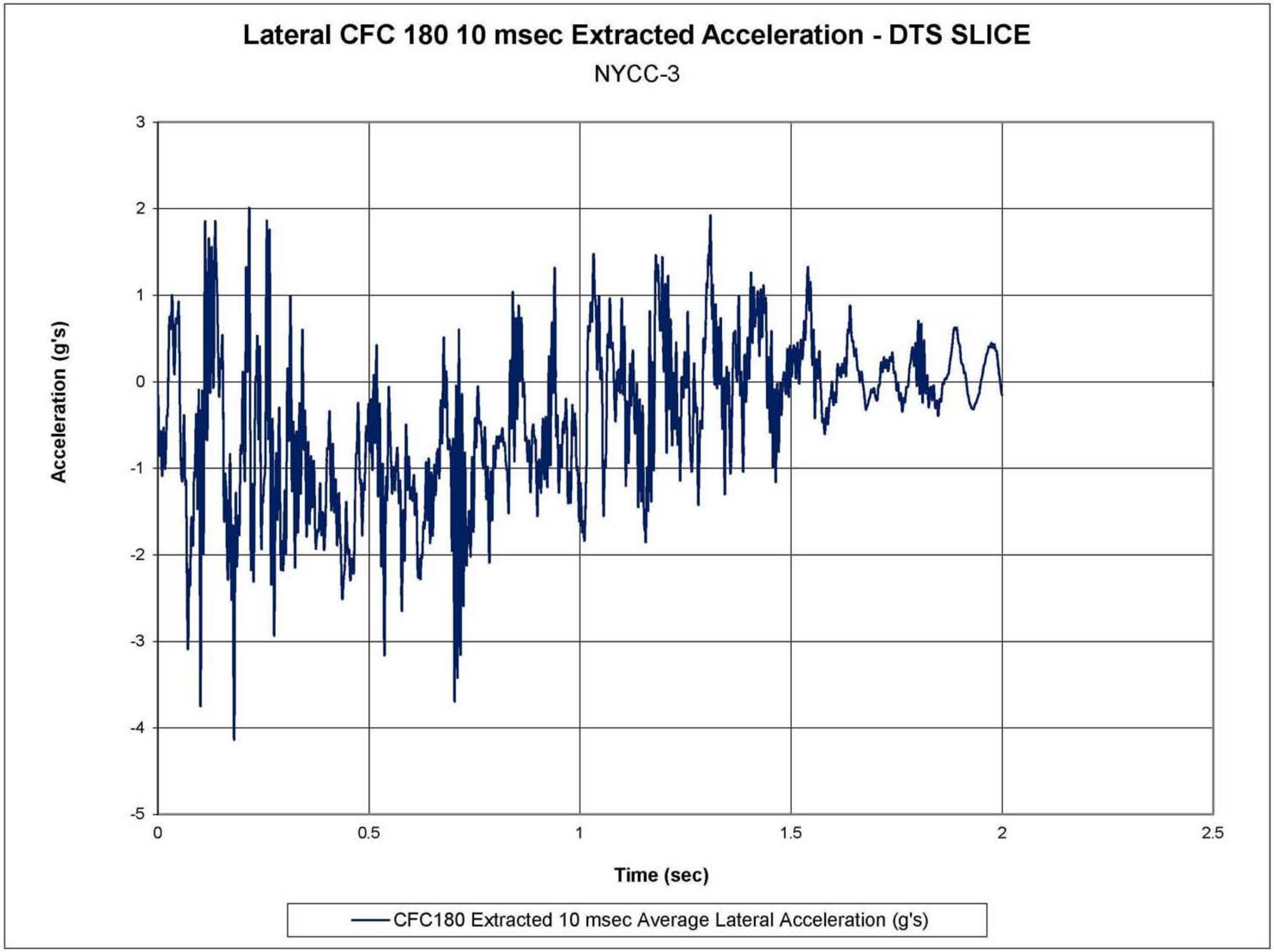


Figure G-12. 10-ms Average Lateral Deceleration (DTS SLICE), Test No. NYCC-3

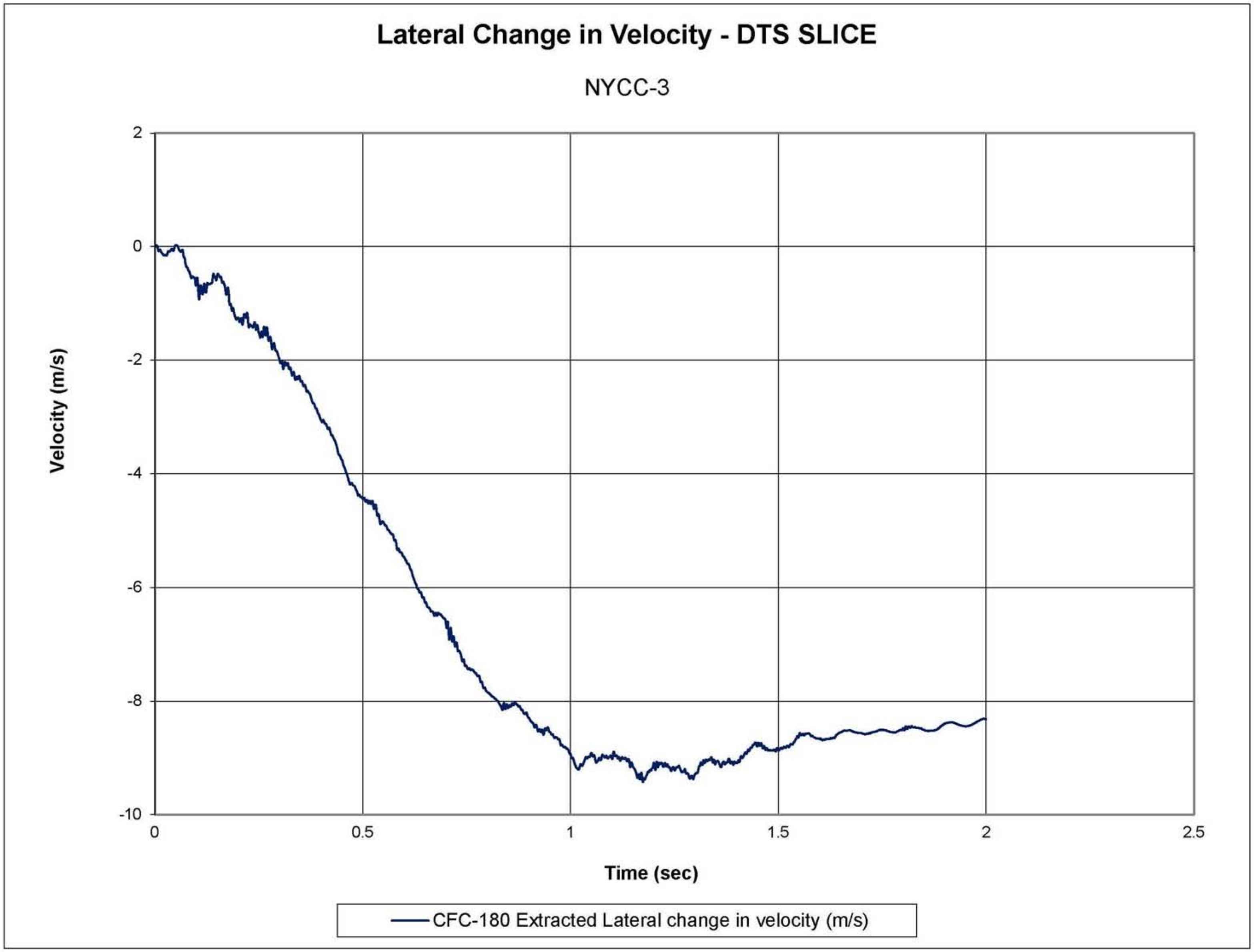


Figure G-13. Lateral Occupant Impact Velocity (DTS SLICE), Test No. NYCC-3

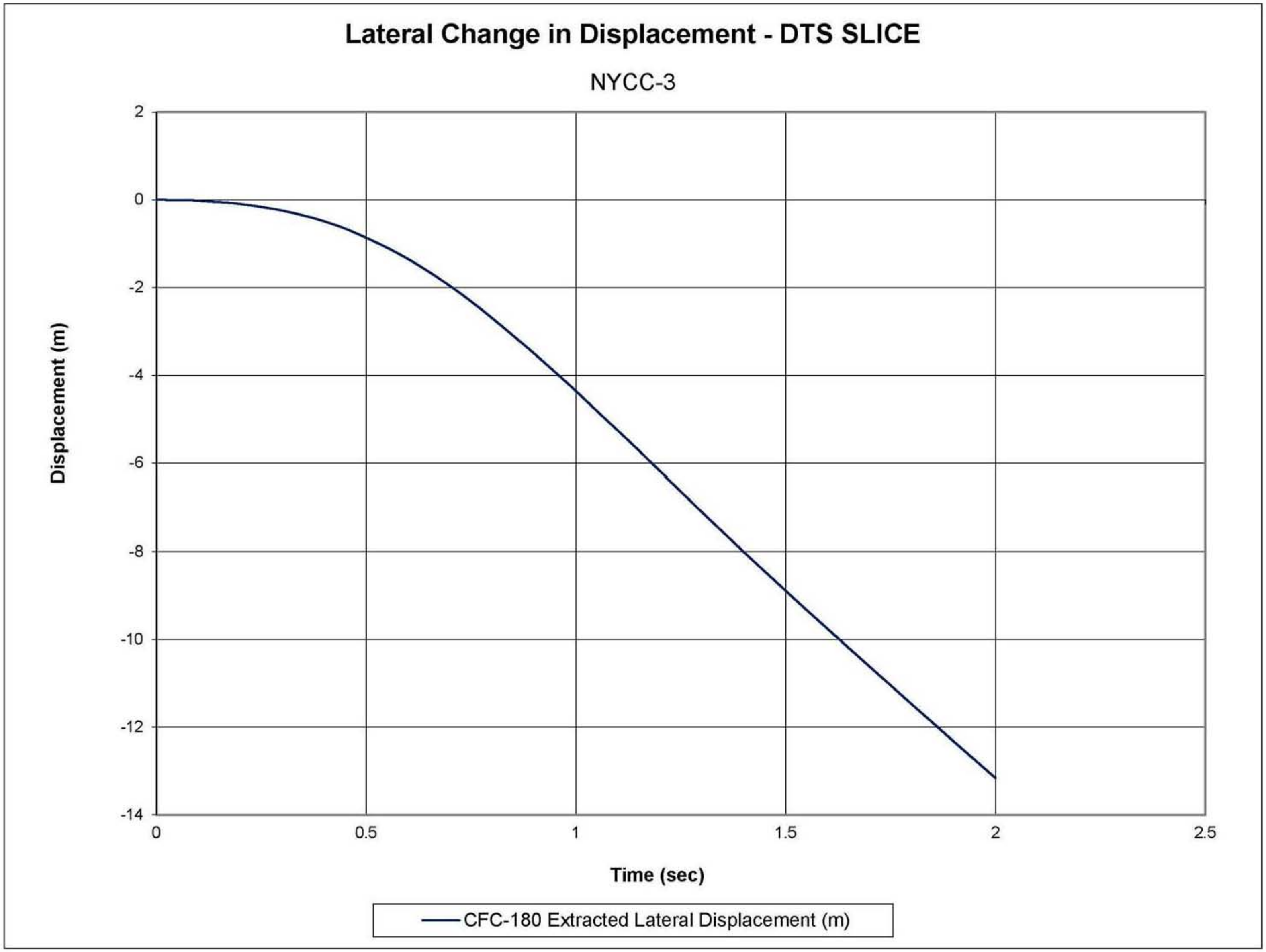


Figure G-14. Lateral Occupant Displacement (DTS SLICE), Test No. NYCC-3

Figure G-15. Vehicle Angular Displacements (DTS SLICE), Test No. NYCC-3

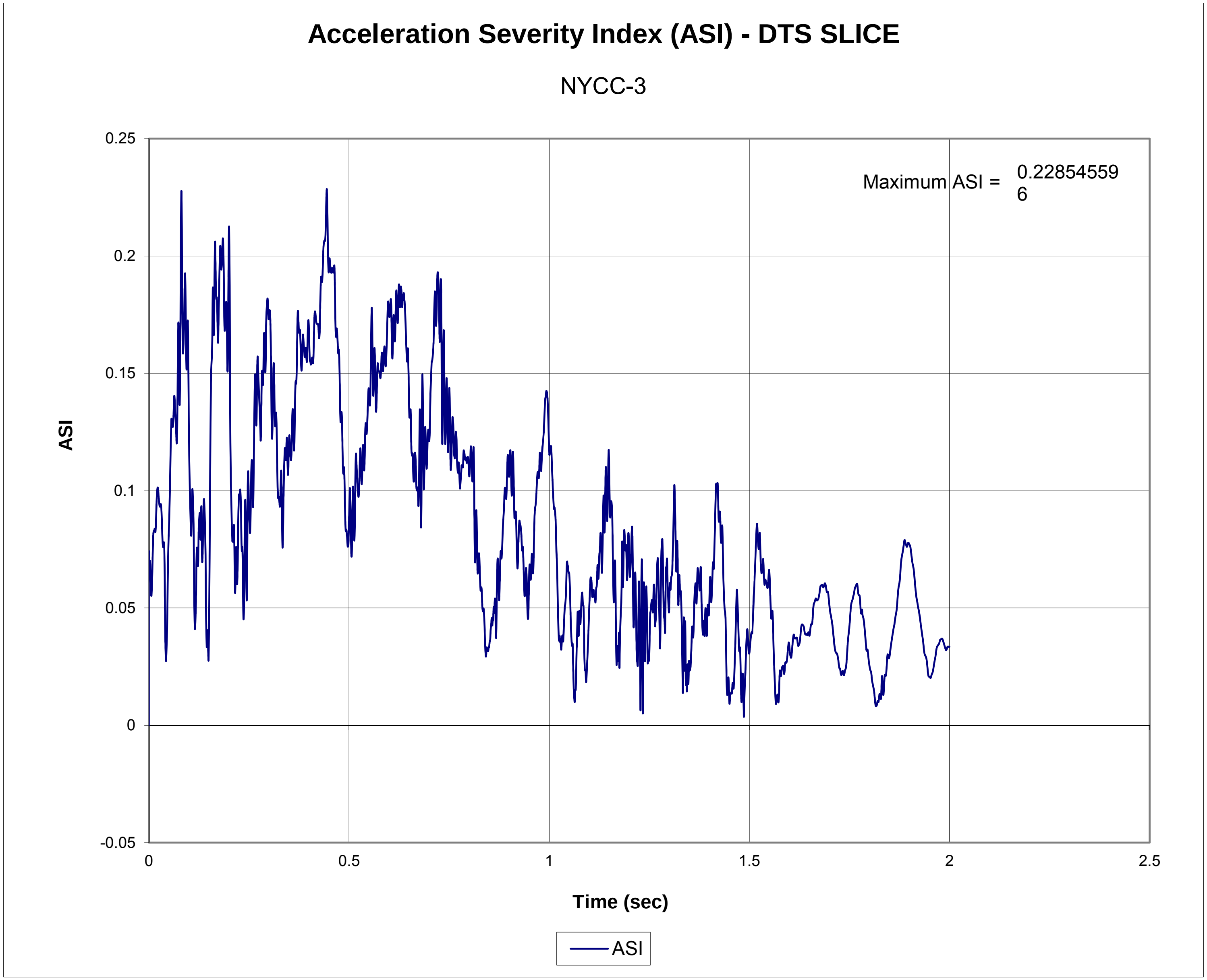


Figure G-16. Acceleration Severity Index (DTS SLICE), Test No. NYCC-3

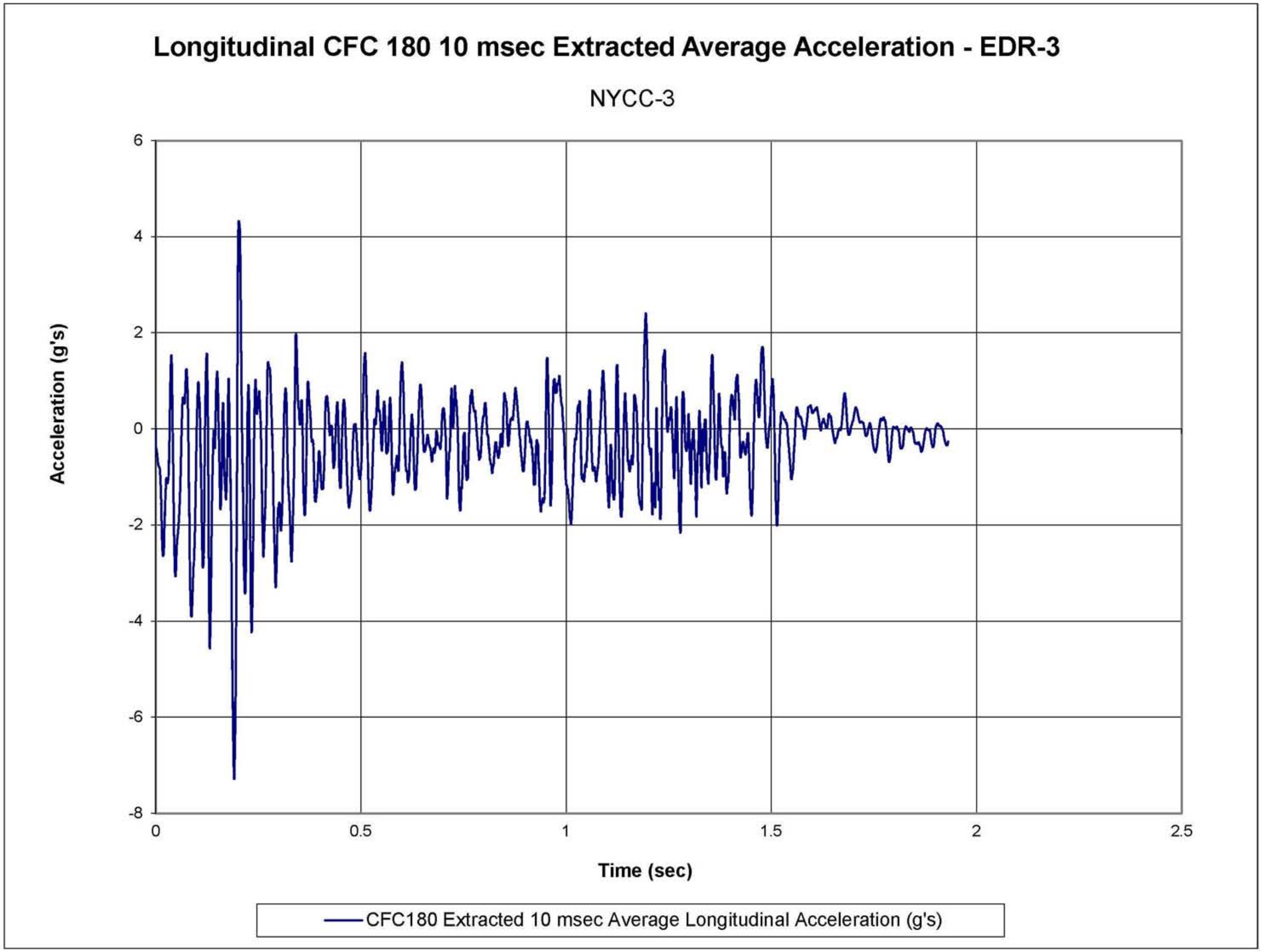


Figure G-17. 10-ms Average Longitudinal Deceleration (EDR-3), Test No. NYCC-3

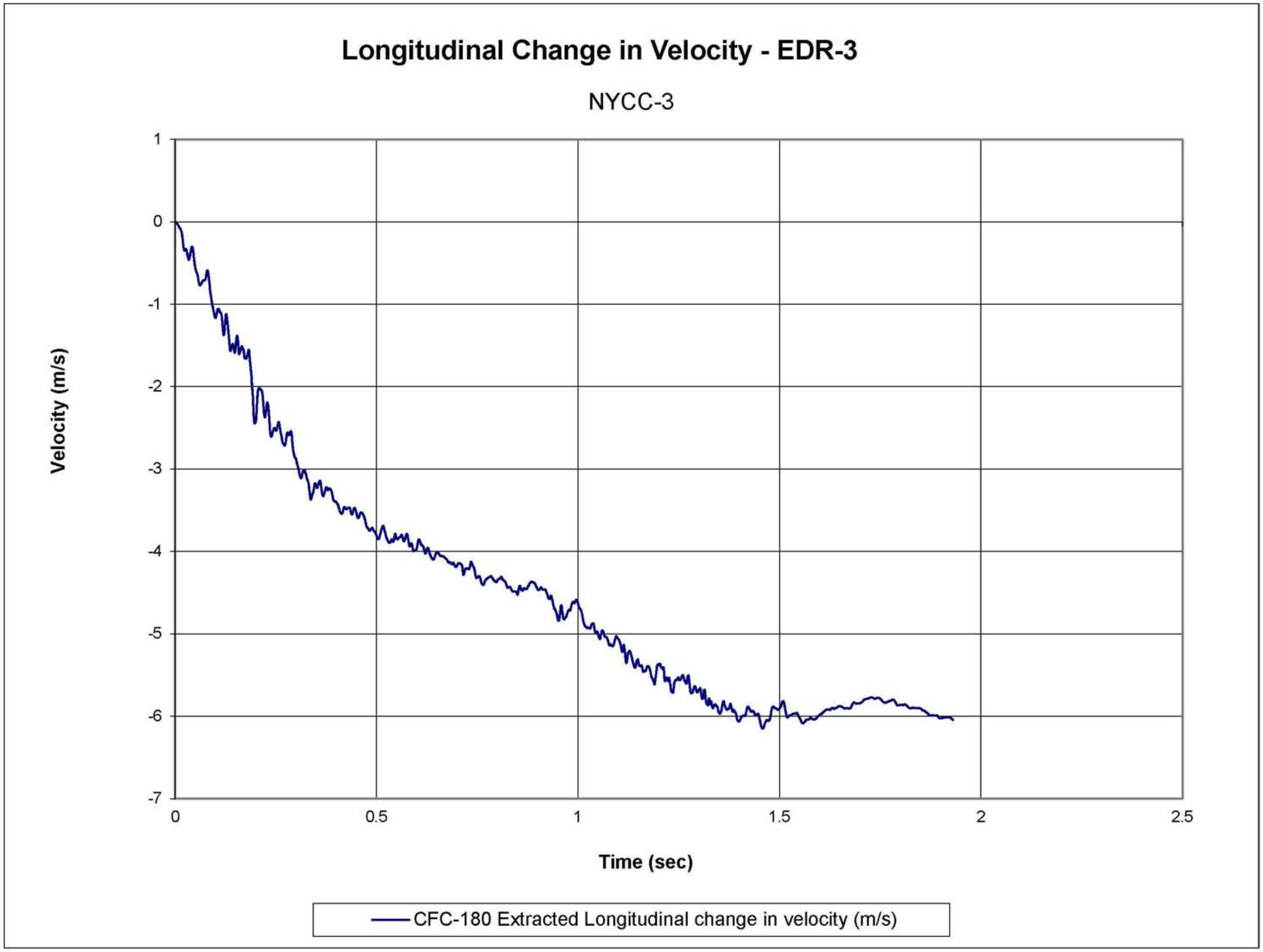


Figure G-18. Longitudinal Occupant Impact Velocity (EDR-3), Test No. NYCC-3

Figure G-19. Longitudinal Occupant Displacement (EDR-3), Test No. NYCC-3

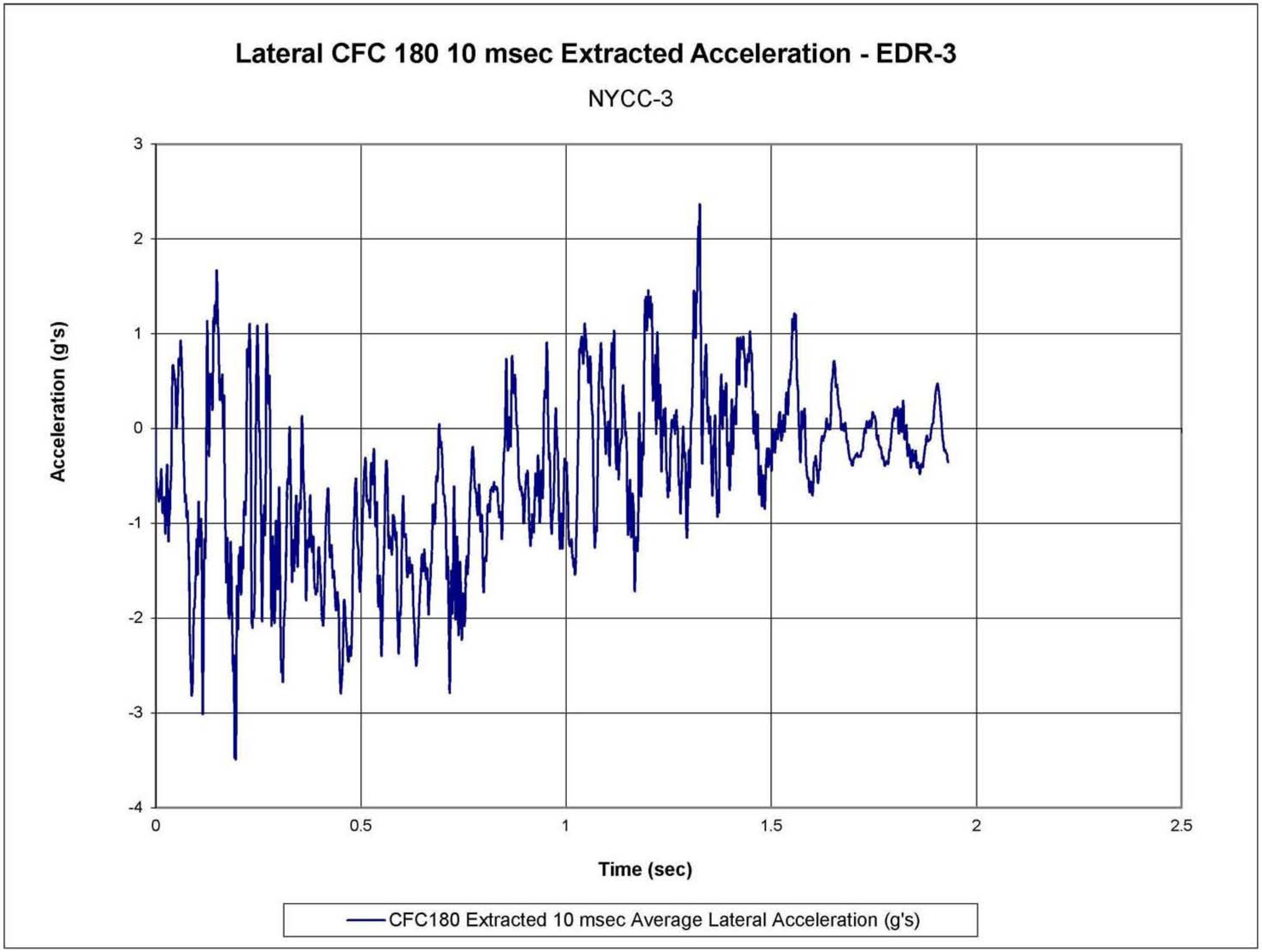


Figure G-20. 10-ms Average Lateral Deceleration (EDR-3), Test No. NYCC-3

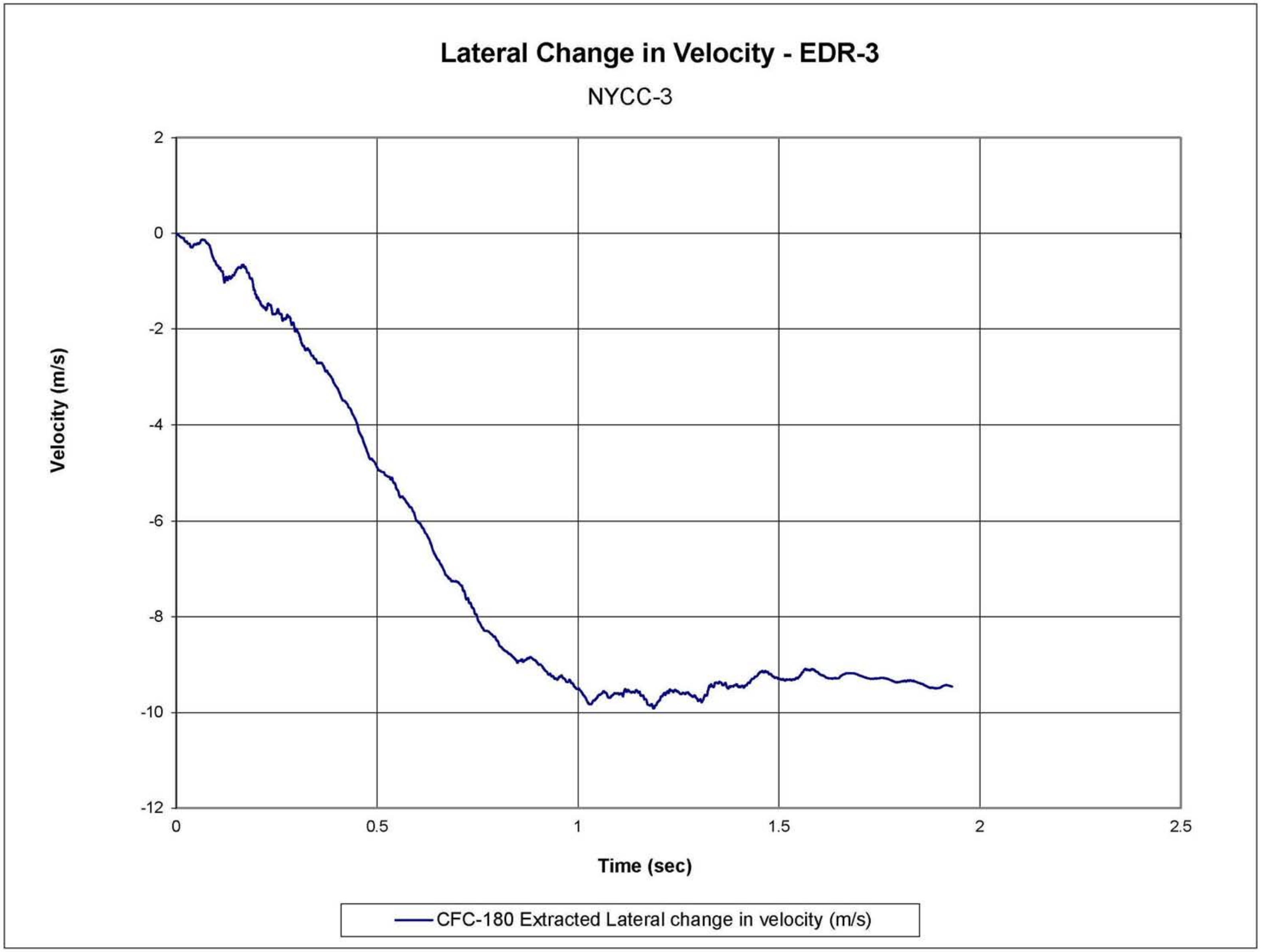


Figure G-21. Lateral Occupant Impact Velocity (EDR-3), Test No. NYCC-3

Figure G-22. Lateral Occupant Displacement (EDR-3), Test No. NYCC-3

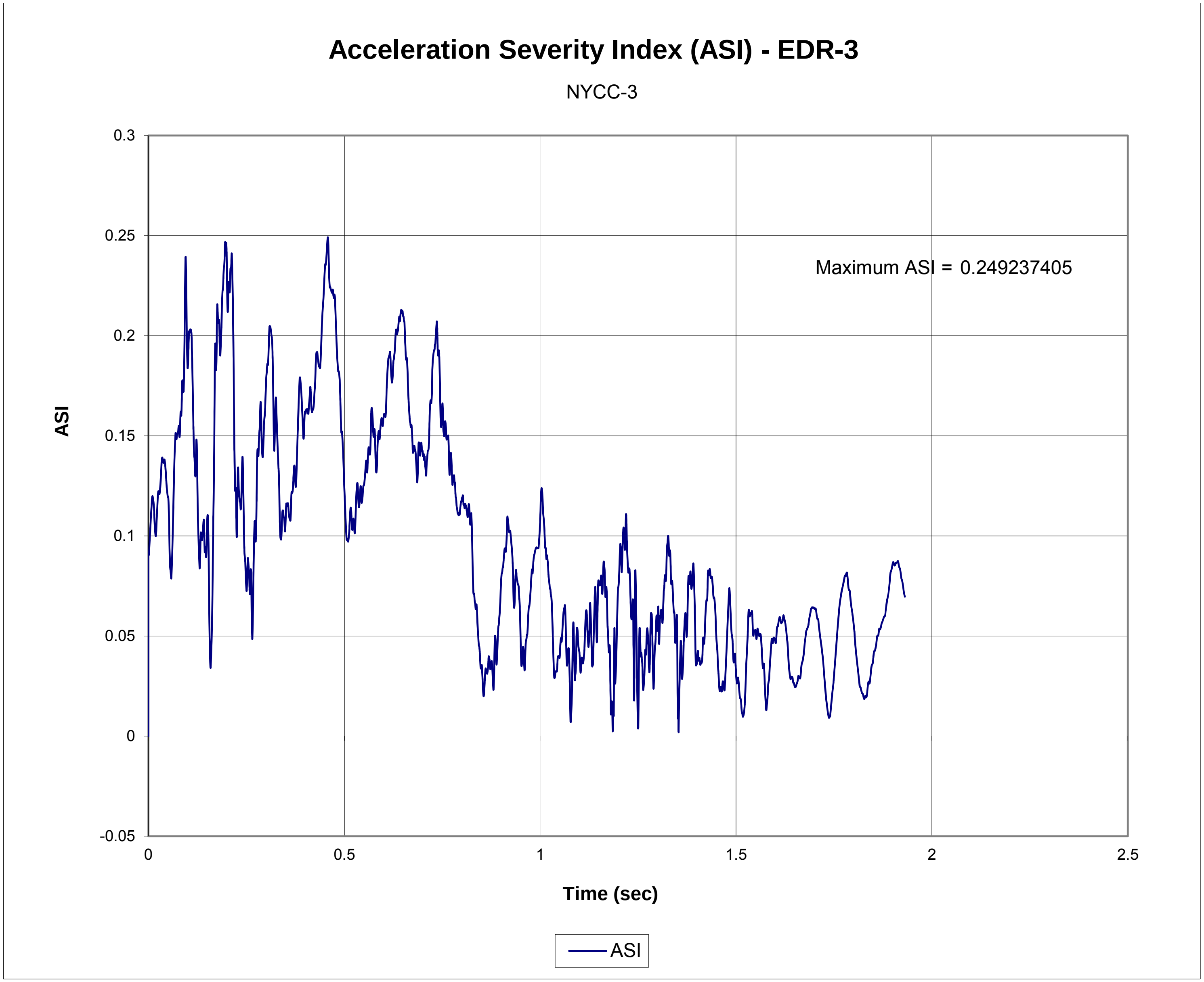


Figure G-23. Acceleration Severity Index (EDR-3), Test No. NYCC-3

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