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CABLE GUARDRAIL WITH STRONG J-BOLTS

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16. Abstract (Limit: 200 words)

The New York State Department of Transportation (NYSDOT) evaluated a 3-cable, low-tension, cable barrier system that eliminated cable compensators and increased the size of cable-to-post attachments from $^{5}/_{16}$ in. (8 mm) to ½ in. (13 mm) diameter. Additionally, a new hanger end post was evaluated. These modifications were implemented to investigate dynamic deflections as well as tendencies for underride, override, penetration, and cable release.

For this study, three Test Level 3 (TL-3) full-scale crash tests were performed on the low-tension, three-cable roadside barrier with strong J-bolts according to the *Manual For Assessing Safety Hardware* (MASH). The cable barrier system was configured with center cable heights of 17 $^{1}/_{8}$ in. (435 mm), 23 $^{1}/_{8}$ in. (587 mm), and 29 $^{1}/_{8}$ in. (740 mm) above the ground surface. Braking tests were conducted to determine the maximum pitch of the 1500A vehicle that would perpetuate the vehicle to underride the barrier. The modified barrier system was tested using a 1500A full-sized passenger sedan for test nos. NYJ-1 and NYJ-2. During test no. NYJ-1, the vehicle ruptured the barrier, and therefore it did not meet the MASH impact safety standards. After considering the causes of test failure, a retest was performed, test no. NYJ-2. During this test, cable slap contributed to excessive windshield deformations, and therefore it did not meet the MASH impact safety standards. Test no. NYJ-3 utilized a 2270P vehicle, which also ruptured the barrier, and therefore it did not meet the MASH impact safety standards.

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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. Test nos. VBT1 – VBT13 were non-certified investigative tests conducted for research and development purposes only and are outside the scope of the MwRSF's A2LA Accreditation.

INDEPENDENT APPROVING AUTHORITY

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

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Background

Cable barriers are one of the most flexible barrier types used to shield roadside hazards. Large dynamic deflections and low occupant risk values have been observed in full-scale crash testing and have been correlated with low average crash severities [1]. Cable barriers are also the only barrier type approved for use with approach slopes and have captured or redirected semi tractor-trailers [2].

The New York State Department of Transportation (NYSDOT) commonly utilizes three-cable, low-tension guardrail to shield roadside and median hazards. However, recent testing of low-tension cable barriers under the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (MASH) impact safety standards [3] raised concerns regarding barrier override or underride depending on the cable heights [4]. Underride or override penetration crashes have been observed with cable barriers, particularly cable median barriers [5]. As such, the NYSDOT deemed it important to explore and investigate dynamic deflections as well as tendencies for underride, override, penetration, and cable release. The NYSDOT modified the design of a low-tension cable barrier by increasing the diameter of the J-bolts used for cable-to-post attachment from $^{5}/_{16}$ in. (8 mm) to ½ in. (13 mm). Other modifications included the elimination of spring compensators and the use of a new hanger end post. Because the purpose of the compensators is to maintain tension during changes in temperature (and thus changes in total cable length), they are more compliant than the cables in general. Thus, shortly after impact, small increases in cable tension contribute to undesirable cable compliance until the compensators bottom out. It was hoped that, by eliminating this source of longitudinal compliance, the deflections could be reduced.

The NYSDOT also expressed concern that typically, full-scale crash-tested vehicles are free-wheeling prior to impact. Piloted vehicles in real-world crashes typically undergo braking before impact, resulting in some front-end reduction in top bumper height. The magnitude of the bumper height drop could contribute to some underrides which would otherwise not occur during full-scale crash testing. Unfortunately, there is little contemporary research indicating what effect vehicle braking has on front-end pitch, particularly for vehicles with older shocks and struts which may amplify displacement due to braking pitch. Thus, the NYSDOT sponsored an effort to quantify bumper drop during vehicle braking when located on concrete tarmac or soil.

1.2 Research Objectives

The objectives of the research project were to: (1) determine whether the use of stronger J-bolts can reduce dynamic deflections for NYSDOT's standard three-strand cable guide rail system; (2) determine whether the use of stronger J-bolts can increase the likelihood of capturing small car passenger vehicles with low-profile, aerodynamic front ends, particularly those that are braking; (3) determine whether the use of stronger J-bolts can reduce the propensity of barrier override for light truck passenger vehicles and/or increase vehicle decelerations with cables more firmly attached to the support posts; (4) verify that the proposed revisions to the cable barrier system do not result in any MASH TL-3 crash criteria failures or maintenance problems; (5) determine the maximum dynamic barrier deflection for the baseline three-strand cable barrier system with an overall system length in excess of 600 ft (183 m); (6) develop a stiffened stub design for the end posts that will limit damage to acceptable amounts; and (7) estimate the amount of bumper drop due to vehicular braking prior to impact.

1.3 Scope

The research objective was achieved through the completion of several tasks. First, thirteen investigative tests were conducted to identify vehicular pitch in relation to braking. A cable guardrail system utilizing ½-in. (13-mm) diameter J-bolts was constructed. This system evaluated a new end post and eliminated cable compensators, which are common in low-tension cable systems. Two full-scale vehicle crash tests were performed according to modified 3-10 test conditions as described in MASH. The modified design was selected for crash testing using a 3,307-lb (1,500-kg) passenger car with the brakes applied at impact to maximize front-end dive into the system. The heavier car was determined to be more critical than the 2,420-lb (1,100-kg) passenger car. A third full-scale crash test was conducted according to test designation no. 3-11, as described in MASH. The target impact conditions for these tests were an impact speed and impact angle of 62 mph (100 km/h) and 25 degrees, respectively. The results of these tests were analyzed, evaluated, and documented. Conclusions and recommendations were made that pertain to the safety performance of the low-tension, three-cable guardrail with ½-in. (13-mm) diameter J-bolts.

2 VEHICLE BRAKING TESTS

2.1 Purpose

The NYSDOT wanted to investigate the effect of vehicle braking on front-end dive (i.e., forward pitch). Vehicles with worn shocks not designed with anti-dive suspension geometries may experience significant downward front-end pitch during hard braking or sliding. This front-end dive behavior could result in significant changes to the interaction of the front bumper with the cable barrier system.

Test vehicle accelerations were recorded in each test, and quasi-steady-state braking and rolling friction values were estimated. All dynamic tests were conducted at the MwRSF Proving Grounds in Lincoln, Nebraska.

2.2 Equipment and Instrumentation

Equipment and instrumentation utilized to collect and record data during the vehicle braking tests included a test vehicle, an accelerometer, retroreflective speed traps, high-speed and standard-speed digital video, and still cameras.

2.2.1 Test Vehicle

To evaluate the effectiveness of reducing vehicle penetration through the cable barrier system, a 3,313-lb (1,503-kg), 2006 Ford Taurus mid-size vehicle was selected in lieu of an 1100C small car for use in a modified test designation no. 3-10. The Ford Taurus was consistent with the optional MASH 1500A mid-size vehicle. The researchers believed that this vehicle would represent a practical worst-case impact condition for accentuating barrier underride or penetration through cable elements. In addition, Ford Taurus vehicles with model years between 1996 and 2007 had a higher percentage of crashes resulting in penetration than most other mid-size passenger cars [5], and thus presented a practical worst-case vehicle for use in full-scale crash testing. The test vehicle is shown in Figure 1.

Figure 1. Test Vehicle for Test Nos. VBT-1 through VBT-13

2.2.2 Accelerometers

The vehicle was instrumented with a two-arm piezoresistive accelerometer system manufactured by Endevco of San Juan Capistrano, California. 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 and controlled using a system developed and manufactured by Diversified Technical Systems, Inc. (DTS) of Seal Beach, California. More specifically, data was collected using a DTS Sensor Input Module (SIM), Model TDAS3-SIM-16M. The SIM was configured with 16 MB SRAM and eight sensor input channels with 250 kB SRAM/channel. The SIM was mounted on a TDAS3-R4 module rack. The module rack was configured with isolated power/event/communications, 10BaseT Ethernet and RS232 communication, and an internal backup battery. Both the SIM and module rack were crashworthy. The “DTS TDAS Control” computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

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 sensor was 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.

2.2.3 Retroreflective Speed Trap

Two optical speed sensor arrays were utilized to measure the vehicle's speed. One sensor was located prior to the onset of braking, and one sensor was utilized after the brakes were applied. The spacing of the optical targets on the test vehicle was 18 in. (457 mm).

2.2.4 Digital Photography

One AOS X-PRI high-speed digital video camera and one JVC digital video camera were used to document each test. The AOS high-speed camera had a frame rate of 500 frames per second and the JVC digital video camera had a frame rate of 29.97 frames per second. A Nikon D50 digital still camera was also used to document pre- and post-test conditions for all tests.

2.3 Test Procedure

For each test, a live driver accelerated the vehicle up to the target speed, a constant test speed was maintained as the vehicle entered the testing area, and the brakes were applied. Each test was characterized by a combination of four conditions:

1. Braking: mechanical (actuated) or human-powered
2. Initial speed: 30 or 60 mph (48 or 97 km/h)
3. Surface: soil or concrete tarmac
4. Brake power assist and ABS: activated or deactivated

Mechanical braking was activated using a hydraulically-actuated, remotely-controlled piston to depress the brake pedal. Human-activated and mechanically-activated brake tests were used to compare realistic run-off-road conditions with suddenly-applied brakes to typical test conditions.

2.4 Test Results

A total of 13 brake tests were conducted and are summarized in Table 1. Nine tests were conducted on concrete, and four were conducted on soil. The driver activated the brakes for five tests on concrete, and all other tests were mechanically actuated. Six tests on concrete and two tests on soil utilized brake power assist and ABS. Three tests on concrete tarmac and two tests on soil did not utilize either ABS or brake power assist. Nine tests were conducted at 30 mph (48 km/h), and four tests were conducted at 60 mph (97 km/h). Test results are summarized and shown in Appendix A.

Table 1. Summary of Braking Tests

Test No.	Target Speed mph (km/h)	Actual Speed mph (km/h)	Ground Surface	ABS & Power-Assisted Brakes?	Driver/Mech Braking	Rolling Resistance Coefficient	Avg ABS Braking Coefficient	Avg Non-ABS Braking Coefficient
VBT1	30 (48)	25.9 (41.7)	Concrete	Yes	Driver	0.005	0.734	-
VBT2	30 (48)	27.8 (44.8)	Concrete	Yes	Driver	0.031	0.962	-
VBT3	30 (48)	28.2 (45.4)	Concrete	Yes	Driver	0.013	0.809	-
VBT4	60 (97)	55.7 (89.6)	Concrete	Yes	Driver	0.035	0.929	-
VBT5	60 (97)	54.5 (87.7)	Concrete	Yes	Driver	0.065	0.784	-
VBT6	60 (97)	57.5 (92.6)	Concrete	Yes	Mechanical	0.047	0.928	-
VBT7	60 (97)	56.2 (90.4)	Concrete	No	Mechanical	0.078	-	0.710
VBT8	30 (48)	27.3 (43.9)	Concrete	No	Mechanical	0.014	-	0.650
VBT9	30 (48)	27.1 (43.5)	Concrete	No	Mechanical	0.037	-	0.672
VBT10	30 (48)	27.5 (44.3)	Soil	Yes	Mechanical	0.035	0.443	-
VBT11	30 (48)	27.8 (44.7)	Soil	Yes	Mechanical	0.055	0.439	-
VBT12	30 (48)	27.0 (43.5)	Soil	No	Mechanical	0.040	-	0.674
VBT13	30 (48)	27.4 (44.1)	Soil	No	Mechanical	0.050	-	0.638

The average effective coefficient of braking friction of the vehicle was nearly independent of speed for both soil and concrete tests. The average effective braking coefficient on concrete was measured with power-assisted braking and ABS, and was determined to be

0.858. Non-power-assisted and non-ABS braking on concrete had an average effective coefficient of 0.677. Analysis of the high-speed video indicated that hydraulically-actuated, non-power-assisted and non-ABS braking did not cause wheel rotation to stop until the vehicle had come to a complete stop. It was believed that the hydraulically-actuated brake piston had either a limiting pressure that could be applied to the brake pedals or a limiting brake pedal displacement, which prevented the wheels from skidding and reduced the non-powered braking coefficient. This friction coefficient was associated with a brake force of approximately 2,450 lb (10.9 kN).

The braking coefficient of friction on soil was 0.441 with power-assisted brakes and ABS and 0.656 without power-assisted brakes or ABS. For tests with ABS activated, when the piston depressed the brakes, the wheels continued to rotate with only brief periods in which rotation was arrested. When the ABS was deactivated and the brakes were hydraulically-actuated, the wheels completely stopped rotating, and the vehicle skidded to a stop.

2.5 Vehicle Pitch

Angular rotations were recorded using the rate transducer and high-speed video analysis. Images of maximum pitch and the resting orientation of the vehicle, recorded during one test with high-speed digital video, are shown in Figure 2. The maximum and minimum pitch values were 2.4 and 1.5 degrees, respectively, as shown in Figures 3 through 5. Pitch angles were higher on concrete than soil. Tests without ABS experienced relatively constant pitch during braking, but tests with ABS enabled experienced more oscillations in pitch angle.

(a) 0.7 sec, at max. front-end dive

(b) 3.0 sec, at rest

Figure 2. Sequential Images of Test No. VBT-1

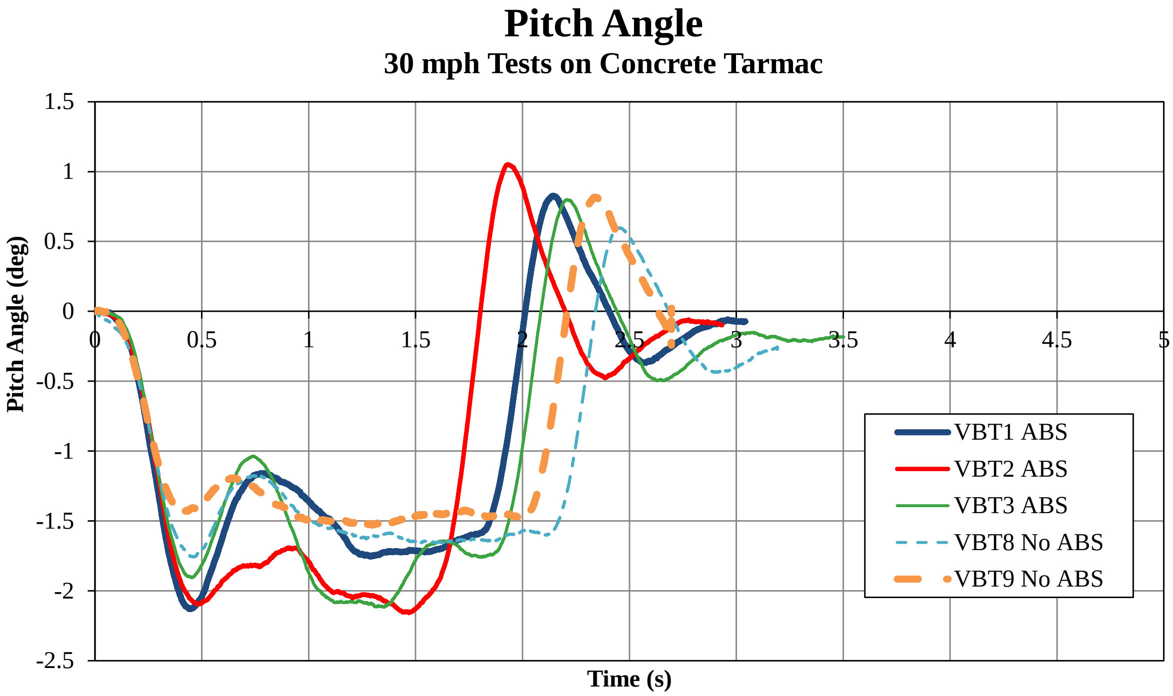


Figure 3. Pitch Angle, 30-mph (48-km/h) Braking Tests on Concrete Tarmac

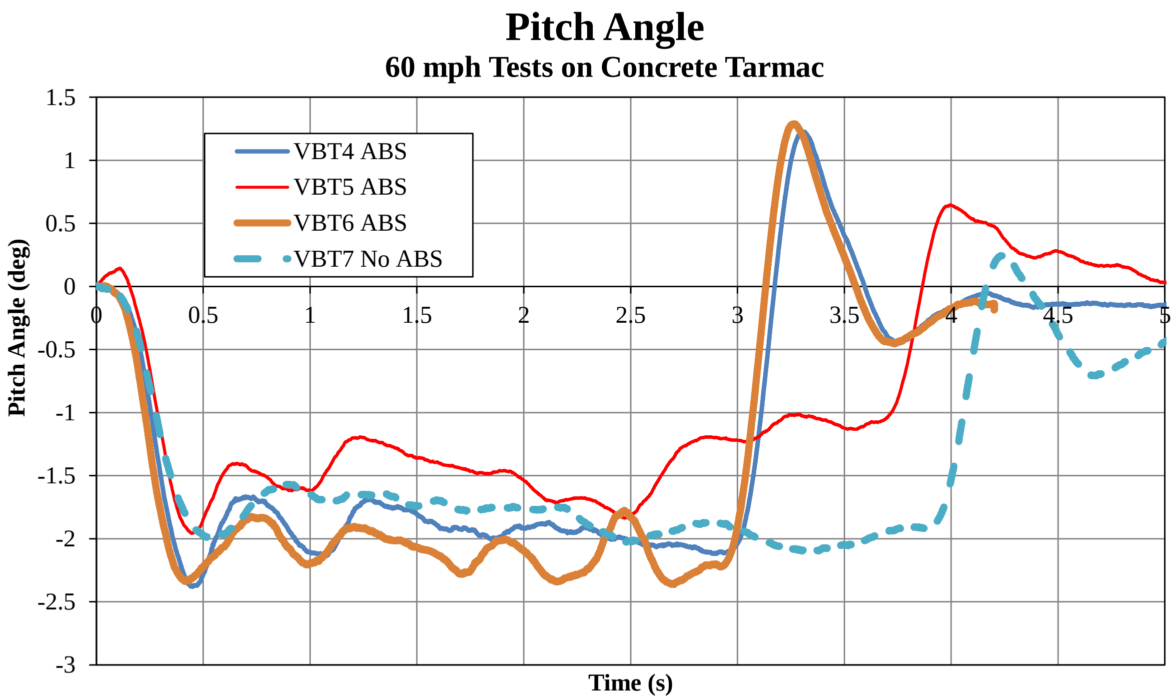


Figure 4. Pitch Angle, 60-mph (97-km/h) Braking Tests on Concrete Tarmac

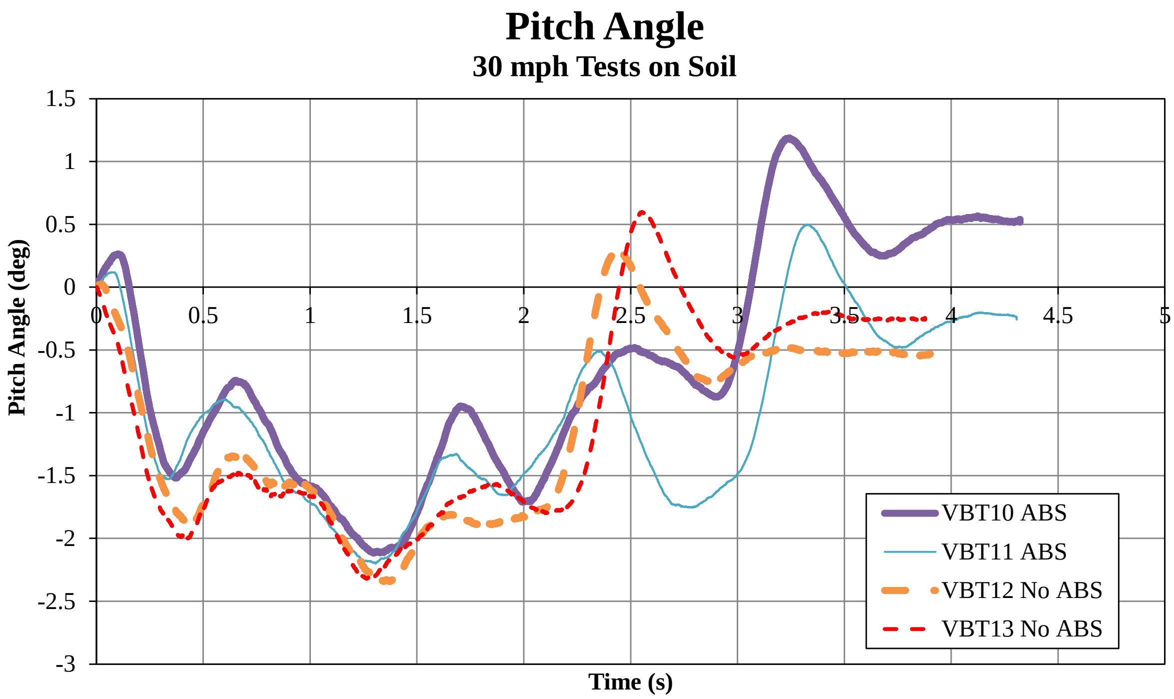


Figure 5. Pitch Angle, 30-mph (48-km/h) Braking Tests on Soil

For tests on concrete, pitch angles were higher for tests with ABS and power-assisted braking. The opposite was true for tests on soil, in which large oscillations in pitch angle were associated with similar large oscillations in accelerations. Non-vegetative soil is a particulate material and yields in shear during braking. Since ABS utilizes a feedback loop to reduce tire slip, the average friction force developed during ABS braking on soil was less than the force developed when the ABS was disabled.

Pitch angles increased to a local maximum between 0.35 sec and 0.49 sec after the brakes were applied. The average location of the first peak was at 0.38 sec after braking on soil without power-assist or ABS and 0.45 sec after braking on concrete tarmac regardless of power-assisted or ABS brakes. The pitch angle oscillated for power-assisted, ABS-enabled braking tests on soil, but the initial peak occurred at approximately 0.32 sec after braking. High-speed digital video analysis and vehicle geometry were used to determine front-end drop. The total bumper drop due to braking was estimated to be between 1.7 to 2.0 in. (43 to 51 mm).

The time required to depress the brake pedal was approximately 0.25 sec for both the driver and mechanically-actuated hydraulic piston. Brake timing was identified by evaluating the acceleration traces, identifying the start of the event, and observing the time at which brake force became relatively constant. In each non-ABS, non-power-assisted braking test, brake force was notably constant. Oscillations about a constant brake force were observed for power-assisted, ABS-activated brake systems. No differences were observed between human-powered and piston-powered braking onset timing. The mechanical brake activation was therefore considered representative of a human driver suddenly applying full braking force during a run-off-road excursion.

2.6 Identification of Braking Conditions

To maximize front-end dive prior to impact with the barrier, brake activation timing, distance to impact, and pitch angles were analyzed. The maximum brake force was obtained approximately 0.25 sec after brakes were activated in each test. For tests in which the ABS and power-assisted braking were disabled, brake forces were relatively constant after the initial impulse. Therefore, vehicle kinetics analysis used a bilinear brake force curve, ramping the coefficient of braking friction from 0 to 0.6435 over 0.25 sec and then retaining a constant brake force thereafter, and incorporated uncertainties in initial speed and angle with the barrier.

For most MASH tests conducted at MwRSF, vehicle engines are turned off, and the transmission is set to neutral prior to conducting the full-scale crash test. As a result, the non-power-assisted, disabled-ABS tests on soil were the most pertinent to determining the appropriate braking conditions. The maximum pitch during 30-mph (48-km/h) tests on soil occurred at approximately 0.38 sec after the brakes were applied. Therefore, impact was targeted to occur 0.38 sec with a +/-10 percent error window (0.34 to 0.42 sec) after the onset of full braking.

Using the bilinear brake force curve, a nominal impact speed of 62 mph (100 km/h), and a 25-degree impact, the speed drop during the initial 0.38-sec of braking was approximately 3.6 mph (5.8 km/h). Therefore the targeted initial speed was 65.7 mph (105.8 km/h), and the braking distance was 35 ft – 6 in. (10.8 m) prior to impact. Tolerances for initial speed and pre-impact braking distance were calculated to ensure that impact occurred 0.35-0.40 sec after the onset of braking (i.e., maximum pitch). Acceptable variations in speed and braking distance were +3%/-2% and +/-1 ft (0.3 m), respectively.

It should be noted that although test conditions were identified to maximize test vehicle front-end bumper dive due to braking, the magnitude of the brake force, the pitch related to braking, and actual front-end bumper displacement may be different for different vehicle makes, models, and service levels. Older vehicles with worn shocks and struts may experience significantly more braking-related front-end dive, contributing to a higher probability of penetration. Further research may be necessary to quantify the magnitude of front-end dive for vehicles with older struts and shocks.

3 TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 Test Requirements

Longitudinal barriers, such as cable guardrails, must satisfy impact safety standards in order to be accepted by the Federal Highway Administration (FHWA) for use on the National Highway System (NHS). For new hardware, these safety standards consist of the guidelines and procedures published in MASH. According to TL-3 of 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 2.

Table 2. 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 3.

For the first two full-scale crash tests, a modified version of test designation no. 3-10 was considered. A modified test no. 3-10 was selected using a 3,307-lb (1,500-kg) passenger car, designated 1500A, instead of a 1100C passenger car, because the heavier vehicle was determined to be more critical for resulting in cable underride and/or penetration. The NYSDOT desired to reduce the dynamic deflection and the propensity for passenger car underride and penetration for low-tension, 3-cable roadside barriers while still satisfying the MASH crash test criteria. Recent research has indicated that small cars are less susceptible to underride than larger, heavier passenger cars [5]. Ford Taurus cars with model years between 1996 and 2007 experienced vehicular penetration under or through cable barriers in 18 percent of crashes. The Ford Taurus had a sloped front-end profile, aerodynamic styling, and low hood, cowl, and roof heights relative to other mid-size cars.

3.2 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 guardrail system to contain and redirect impacting vehicles. In addition, controlled lateral deflection of the test article is acceptable. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Post-impact vehicle trajectory is a measure of the potential of the vehicle to result in a secondary collision with other vehicles and/or fixed objects, thereby increasing the risk of injury to the occupants of the impacting vehicle and/or other vehicles. These evaluation criteria are summarized in Table 3 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.

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.

3.3 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 4 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 is 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 can be conducted only if the static test results show 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 must be postponed until the soil demonstrates adequate post-soil strength.

Table 3. 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="10">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 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>

4 TEST CONDITIONS

4.1 Test Facility

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

4.2 Vehicle Tow and Guidance System

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

A vehicle guidance system developed by Hinch [7] was used to steer the test vehicle. A guide flag, attached to the right-front wheel and the guide cable, was sheared off before impact with the barrier system. The ⅜-in. (9.5-mm) diameter guide cable was tensioned to approximately 3,500 lb (15.6 kN) and supported both laterally and vertically every 100 ft (30.5 m) by hinged stanchions. The hinged stanchions stood upright while holding up the guide cable, but as the vehicle was towed down the line, the guide flag struck and knocked each stanchion to the ground.

4.3 Test Vehicles

For test no. NYJ-1, a 2006 Ford Taurus was the test vehicle. This was chosen specifically because it has a high propensity for penetrating cable median barriers, based on accident data [5]. The curb, test inertial, and gross static vehicle weights were 3,179 lb (1,442 kg), 3,294 lb (1,494 kg), and 3,460 lb (1,569 kg), respectively. The test vehicle is shown in Figure 6, and vehicle dimensions are shown in Figure 7.

For test no. NYJ-2, a 2006 Ford Taurus was the test vehicle. The curb, test inertial, and gross static vehicle weights were 3,189 lb (1,447 kg), 3,254 lb (1,476 kg), and 3,419 lb (1,551 kg), respectively. The test vehicle is show in Figure 8, and vehicle dimensions are shown in Figure 9.

For test no. NYJ-3, a 2007 Dodge Ram 1500 was the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,016 lb (2,275 kg), 5,006 lb (2,271 kg), and 5,173 lb (2,346 kg), respectively. The test vehicle is shown in Figure 10, and vehicle dimensions are shown in Figure 11.

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [8] was used to determine the vertical component of the c.g. for the pickup truck. This method is based on the principle that the c.g. of any freely suspended body is in the vertical plane through the point of suspension. The vehicle was suspended successively in three positions, and the respective planes containing the c.g. were established. The intersection of these planes pinpointed the final c.g. location for the test inertial condition. The vertical component of the c.g. for the 1500A vehicle was estimated based on historical c.g. height measurements. The location of the final c.g. is shown in Figures 7 and 12 for test no. NYJ-1, Figures 9 and 13 for test no. NYJ-2, and Figures 11 and 14 for test no. NYJ-3. Data used to calculate the location of the c.g. and ballast information are shown in Appendix A.

Square, black-and white-checkered targets were placed on the vehicles for reference to be viewed from the high-speed digital video cameras and aid in the video analysis, as shown in Figures 12, 13, and 14, respectively for test nos. NYJ-1, NYJ-2, and NYJ-3. Round, checkered targets were placed on the center of gravity on the left-side door, the right-side door, and the roof of the vehicles.

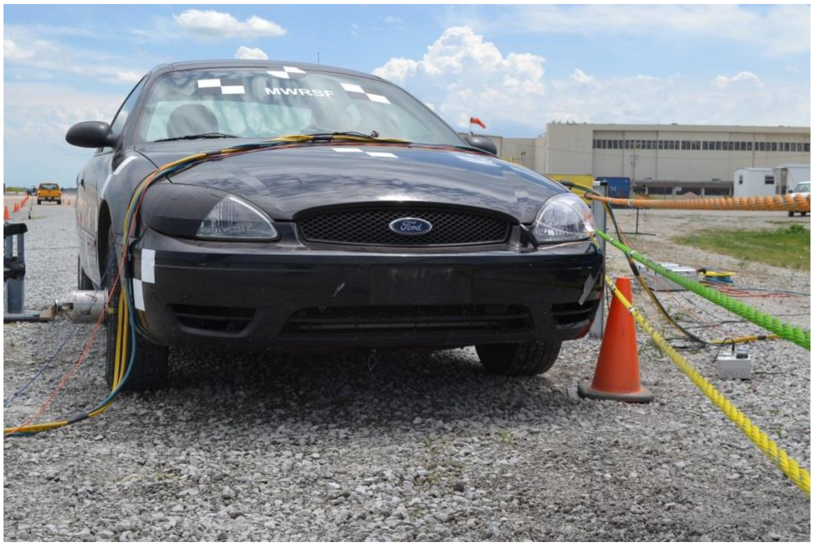


Figure 6. Test Vehicle, Test No. NYJ-1

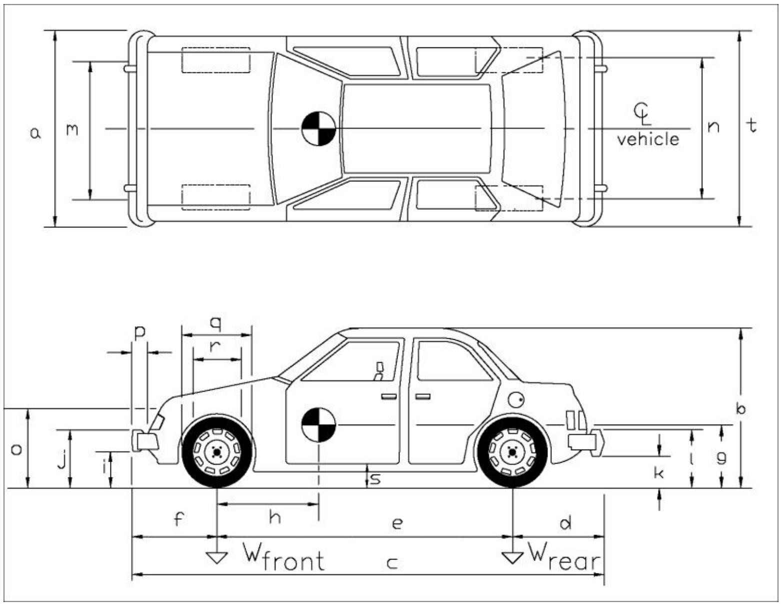
Date: 6/18/2013 **Test Number:** NYJ-1 **Model:** 1500A

Make: Ford Taurus **Vehicle I.D.#:** 1FAFP53U66A147062

Tire Size: 216/60 R16 **Year:** 2006 **Odometer:** 77020

Tire Inflation Pressure: 30 psi

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



Vehicle Geometry -- in. (mm)

a	67 1/4	(1708)	b	57	(1448)
c	197 1/2	(5017)	d	47 3/4	(1213)
e	108 1/2	(2756)	f	41 1/4	(1048)
g	39 3/4	(1010)	h	40 1/8	(1019)
i	10	(254)	j	22	(559)
k	13	(330)	l	25 1/2	(648)
m	61	(1549)	n	62	(1575)
o	28	(711)	p	4 1/2	(114)
q	25 3/4	(654)	r	17 1/4	(438)
s	10 1/2	(267)	t	68 3/4	(1746)

Wheel Center Height Front	12	(305)
Wheel Center Height Rear	12 1/4	(311)
Wheel Well Clearance (F)	28	(711)
Wheel Well Clearance (R)	26 1/2	(673)
Frame Height (F)	6 1/4	(159)
Frame Height (R)	16	(406)
Engine Type	6cyl Gas	
Engine Size	3.0L	

Transmition Type:

[✓ Automatic] Manual

[✓ FWD] RWD 4WD

Mass Distribution lb (kg)

Gross Static	LF	1107 (502)	RF	1071 (486)
	LR	638 (289)	RR	644 (292)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2104 (954)	2076 (942)	2178 (988)
W-rear	1075 (488)	1218 (552)	1282 (582)
W-total	3179 (1442)	3294 (1494)	3460 (1569)

GVWR Ratings

Front	2552
Rear	2132
Total	4684

Dummy Data

Type: Hybrid II

Mass: 166lbs

Seat Position: Driver

Note any damage prior to test: none

Figure 7. Vehicle Dimensions, Test No. NYJ-1

Figure 8. Test Vehicle, Test No. NYJ-2

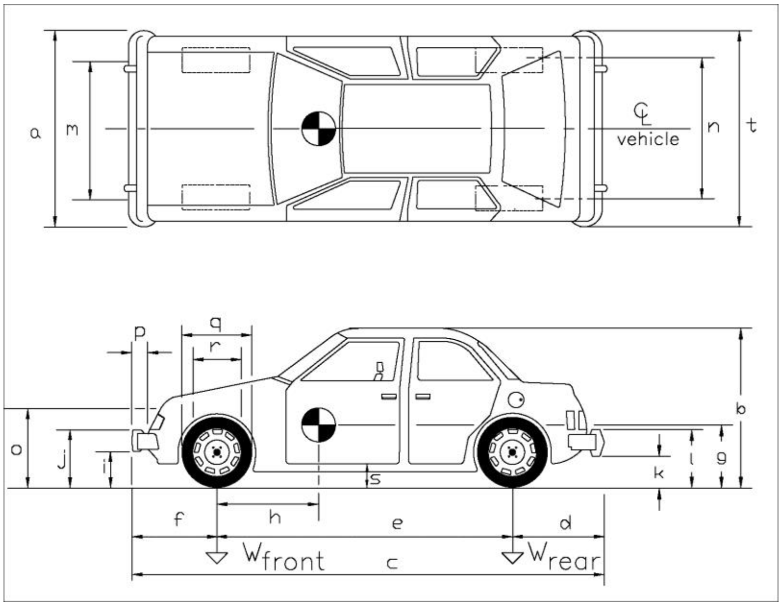
Date: 7/26/2013 **Test Number:** NYJ-2 **Model:** Taurus

Make: Ford **Vehicle I.D.#:** 1fafp53u86a147063

Tire Size: P215/60R16 **Year:** 2006 **Odometer:** 77612

Tire Inflation Pressure: 30 psi

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



Vehicle Geometry -- in. (mm)

a	69	(1753)	b	57	(1448)
c	198	(5029)	d	48	(1219)
e	108 1/4	(2750)	f	41 3/4	(1060)
g	20	(508)	h	39 7/9	(1010)
i	11	(279)	j	22	(559)
k	13	(330)	l	24	(610)
m	60 1/4	(1530)	n	61 3/4	(1568)
o	29 1/4	(743)	p	4 1/2	(114)
q	25	(635)	r	16	(406)
s	10 1/2	(267)	t	69	(1753)

Wheel Center Height Front	12	(305)
Wheel Center Height Rear	12 1/2	(318)
Wheel Well Clearance (F)	28	(711)
Wheel Well Clearance (R)	26 3/4	(679)
Frame Height (F)	6 3/4	(171)
Frame Height (R)	16	(406)
Engine Type	6cyl. Gas	
Engine Size	3.0L	

Transmition Type:

[✓ Automatic] Manual

[✓ FWD] RWD 4WD

Mass Distribution lb (kg)

Gross Static	LF	1094 (496)	RF	1058 (480)
	LR	631 (286)	RR	636 (288)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2098 (952)	2064 (936)	2152 (976)
W-rear	1091 (495)	1190 (540)	1267 (575)
W-total	3189 (1447)	3254 (1476)	3419 (1551)

GVWR Ratings

Front 2552
Rear 2132
Total 4684

Dummy Data

Type: Hybrid II
Mass: 162 lbs
Seat Position: Driver

Note any damage prior to test: None

Figure 9. Vehicle Dimensions, Test No. NYJ-2

Figure 10. Test Vehicle, Test No. NYJ-3

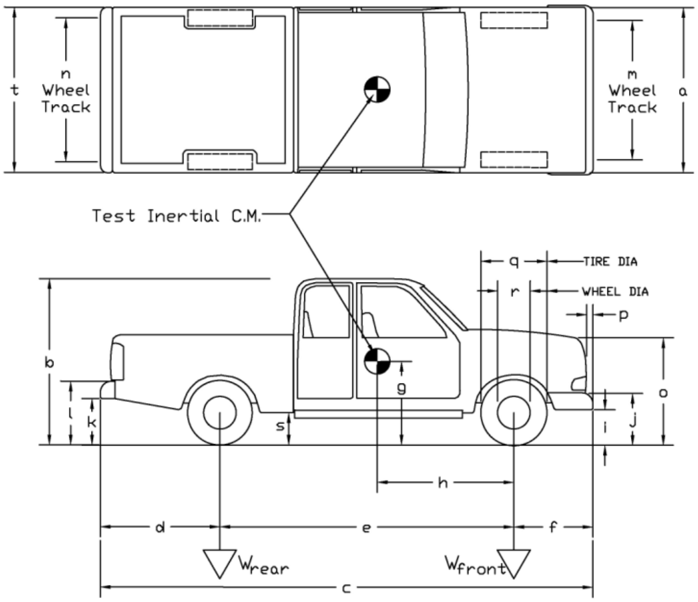
Date: 9/25/2013 **Test Number:** NYJ-3 **Model:** Ram 1500

Make: Dodge **Vehicle I.D.#:** 17J601990

Tire Size: 265/70 R17 **Year:** 2007 **Odometer:** 207534

Tire Inflation Pressure: 35 psi.

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



Vehicle Geometry -- in. (mm)

a	78	(1981)	**b**	75	(1905)
c	228	(5791)	**d**	47 1/2	(1207)
e	140 1/2	(3569)	**f**	40	(1016)
g	28 1/7	(715)	**h**	64 2/3	(1642)
i	16	(406)	**j**	29	(737)
k	21	(533)	**l**	28	(711)
m	67 3/8	(1711)	**n**	67 5/8	(1718)
o	46 1/2	(1181)	**p**	3	(76)
q	30 3/4	(781)	**r**	18 1/2	(470)
s	15 1/4	(387)	**t**	75	(1905)

Wheel Center Height Front 14 5/8 (371)

Wheel Center Height Rear 14 7/8 (378)

Wheel Well Clearance (F) 35 3/4 (908)

Wheel Well Clearance (R) 37 1/2 (953)

Frame Height (F) 18 7/8 (479)

Frame Height (R) 24 1/4 (616)

Engine Type 6cyl Gas

Engine Size 3.7L

Transmition Type:

[✓ Automatic] Manual

FWD [✓ RWD] 4WD

Mass Distribution lb (kg)

Gross Static	**LF**	1449 (657)	**RF**	1354 (614)
	LR	1181 (536)	**RR**	1189 (539)

Weights lb (kg)	**Curb**	**Test Inertial**	**Gross Static**
W-front	2753 (1249)	2703 (1226)	2803 (1271)
W-rear	2263 (1026)	2303 (1045)	2370 (1075)
W-total	5016 (2275)	5006 (2271)	5173 (2346)

GVWR Ratings

Front 3700

Rear 3900

Total 6700

Dummy Data

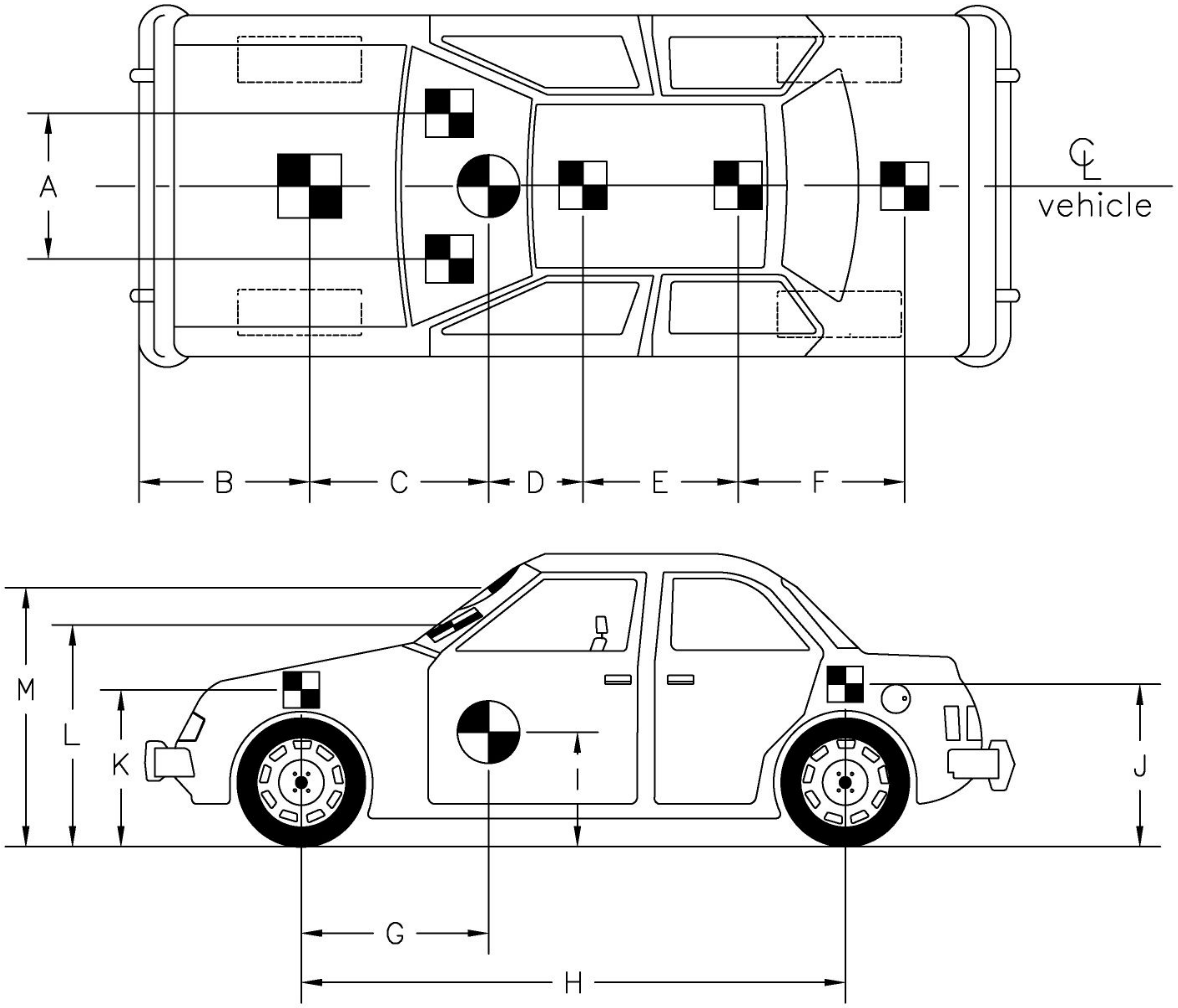
Type: Hybrid II

Mass: 170 lbs

Seat Position: Driver

Note any damage prior to test: minor scrapes and dents (Previously used for test and repaired)

Figure 11. Vehicle Dimensions, Test No. NYJ-3

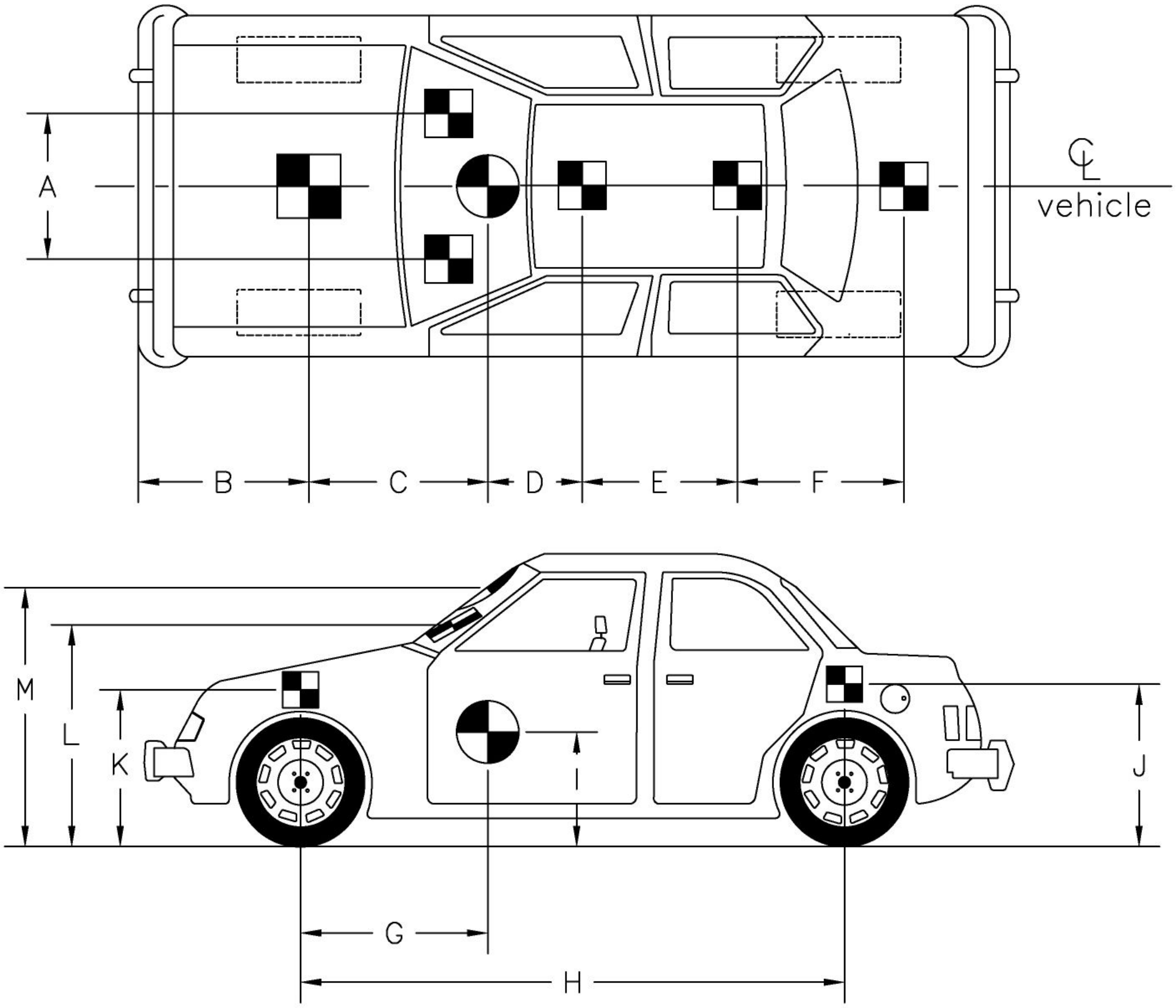


TEST #: NYJ-1

TARGET GEOMETRY-- in. (mm)

A	**27**	**(686)**	**E**	**33 3/4**	**(857)**	**I**	**18**	**(457)**
B	**25 1/2**	**(648)**	**F**	**47 1/4**	**(1200)**	**J**	**30 1/4**	**(768)**
C	**54**	**(1372)**	**G**	**39 3/4**	**(1010)**	**K**	**31 3/4**	**(806)**
D	**19**	**(483)**	**H**	**108 1/2**	**(2756)**	**L**	**48 1/4**	**(1226)**
						M	**52**	**(1321)**

Figure 12. Target Geometry, Test No. NYJ-1

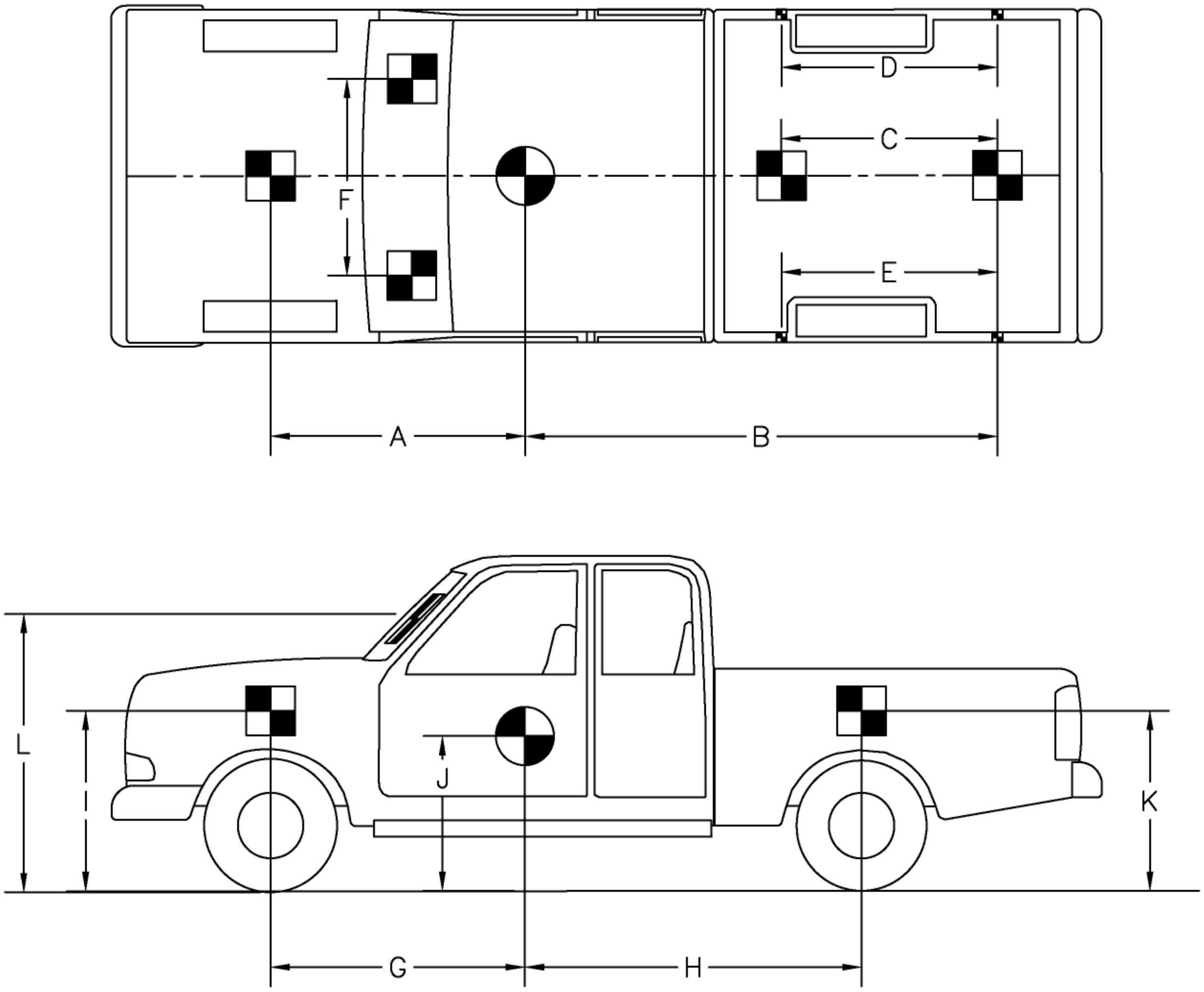


TEST #: NYJ-2

TARGET GEOMETRY-- in. (mm)

A	**23 3/4**	**(603)**	**E**	**24**	**(610)**	**I**	**20**	**(508)**
B	**25**	**(635)**	**F**	**53 1/4**	**(1353)**	**J**	**30 3/4**	**(781)**
C	**54 1/4**	**(1378)**	**G**	**39 3/4**	**(1010)**	**K**	**32 1/4**	**(819)**
D	**24 3/4**	**(629)**	**H**	**108 1/4**	**(2750)**	**L**	**42 1/4**	**(1073)**
						M	**52 1/4**	**(1327)**

Figure 13. Target Geometry, Test No. NYJ-2



TEST #: NYJ-3

TARGET GEOMETRY-- in. (mm)

A	**81**	**(2057)**	**E**	**64**	**(1626)**	**I**	**39 7/8**	**(1013)**
B	**99**	**(2515)**	**F**	**41 1/2**	**(1054)**	**J**	**28 1/8**	**(714)**
C	**48**	**(1219)**	**G**	**64 5/8**	**(1641)**	**K**	**41 3/4**	**(1060)**
D	**64**	**(1626)**	**H**	**75 7/8**	**(1927)**	**L**	**62 1/4**	**(1581)**

Figure 14. Target Geometry, Test No. NYJ-3

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 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.

4.4 Simulated Occupant

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

4.5 Data Acquisition Systems

4.5.1 Accelerometers

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 [9].

The first accelerometer system was a two-arm piezoresistive accelerometer system manufactured by Endevco of San Juan Capistrano, California. 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 and controlled using a system developed and manufactured by Diversified Technical Systems, Inc. (DTS) of Seal Beach, California. More specifically, data was collected using a DTS Sensor Input Module (SIM), Model TDAS3-SIM-16M. The SIM was configured with 16 MB SRAM and eight sensor input channels with 250 kB SRAM/channel. The SIM was mounted on a TDAS3-R4 module rack. The module rack was configured with isolated power/event/communications, 10BaseT Ethernet and RS232 communication, and an internal backup battery. Both the SIM and module rack were crashworthy. The “DTS TDAS Control” computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

The second accelerometer system, SLICE 6DX, was a modular data acquisition system manufactured by Diversified Technical Systems, Inc. (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.

4.5.2 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 sensor was 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.

4.5.3 Load Cells

For test no. NYJ-1, six load cells were installed in-line within the system, one on each cable near the upstream end of the three-cable barrier system and one on each cable near the downstream end. The positioning and setup of the load cells are shown in Figure 15. For test nos. NYJ-2 and NYJ-3, three load cells were installed in-line within the system, one on each cable near the upstream end of the barrier system. The load cells were manufactured by Transducer Techniques and conformed to model no. TLL-50K with a load range up to 50,000 lb (222.4 kN). During testing, output voltage signals were sent from the load cells to a Keithly Metrabyte DAS-

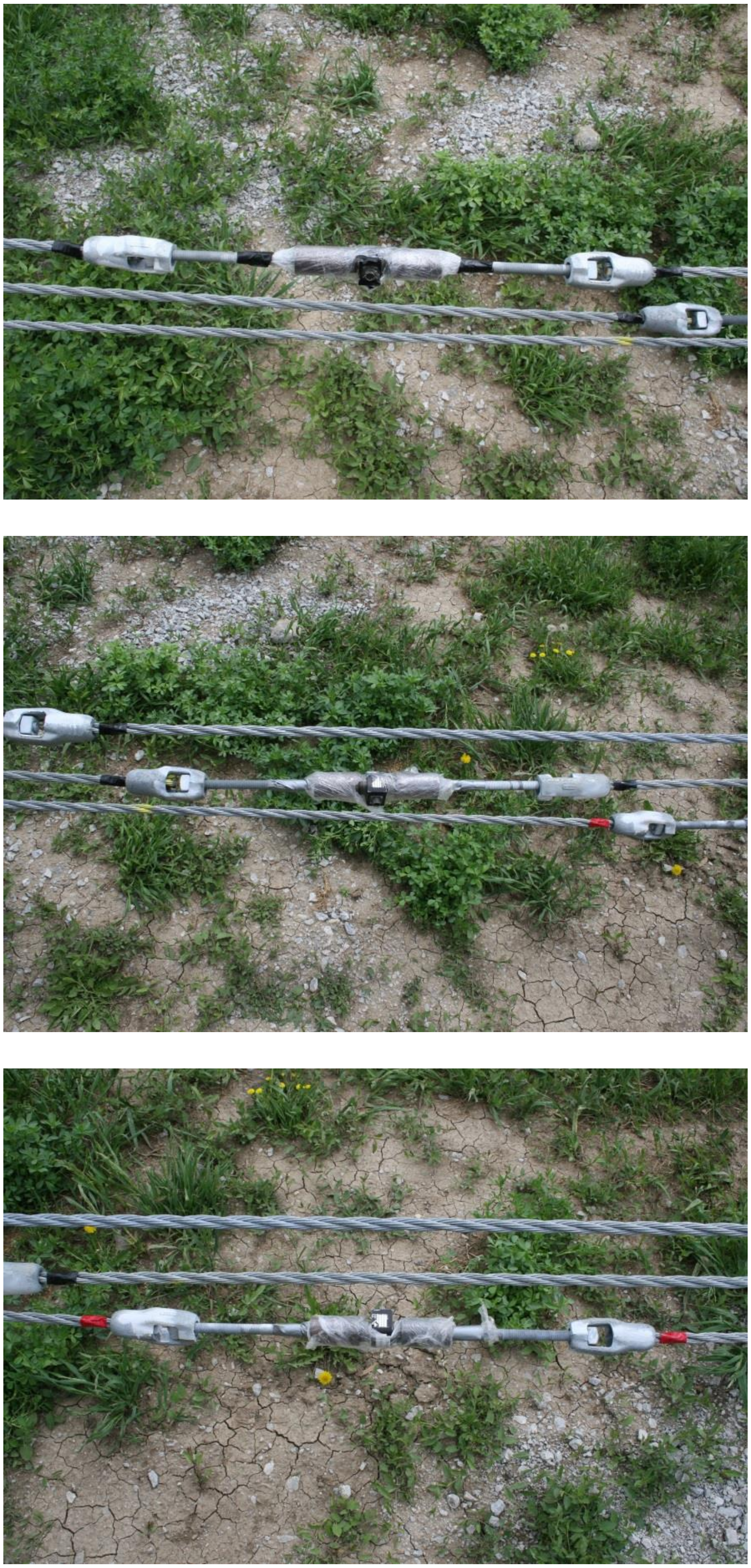


Figure 15. Load Cell Setup, Test No. NYJ-1

1802HC data acquisition board, and acquired with TestPoint software. The data collection rate for the load cells was 10,000 samples per second (10,000 Hz).

4.5.4 String Potentiometers

For test no. NYJ-1, one linear displacement transducer, or string potentiometer, was installed at each of the upstream and downstream anchors and were used to monitor longitudinal anchor displacement. The positioning and setup of the string potentiometers are shown in Figure 16. For test nos. NYJ-2 and NYJ-3, one string potentiometer was installed at the upstream anchor only. The string potentiometers used were UniMeasure PA-50 with a range of 50 in. (1,270 mm). A Measurements Group Vishay Model 2310 signal conditioning amplifier was used to condition and amplify the low-level signals to high-level outputs for multichannel, simultaneous dynamic recording in the “LabView” software. The sample rate of the string potentiometer was 1,000 Hz.

4.5.5 Retroreflective Optic Speed Trap

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

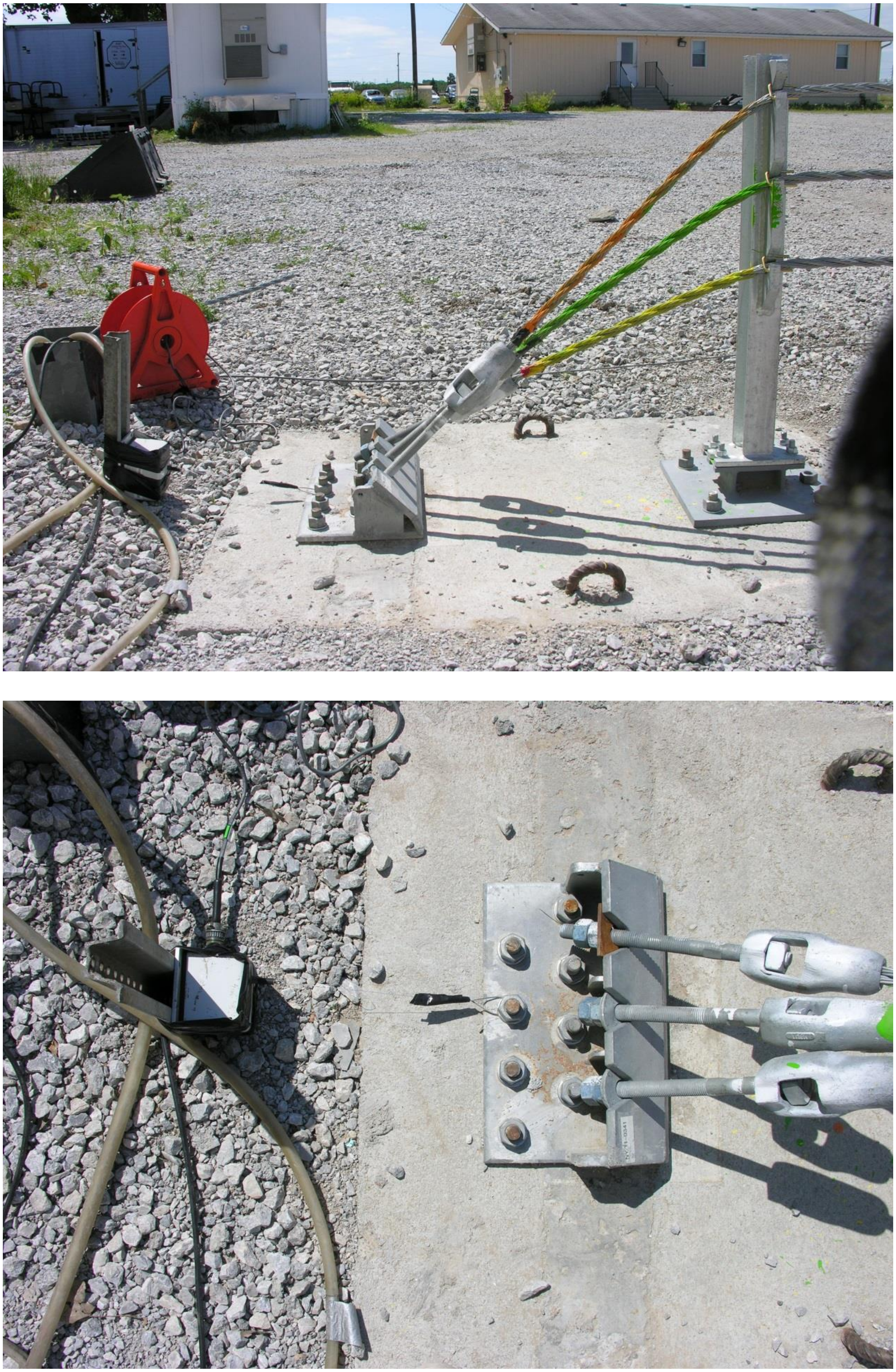


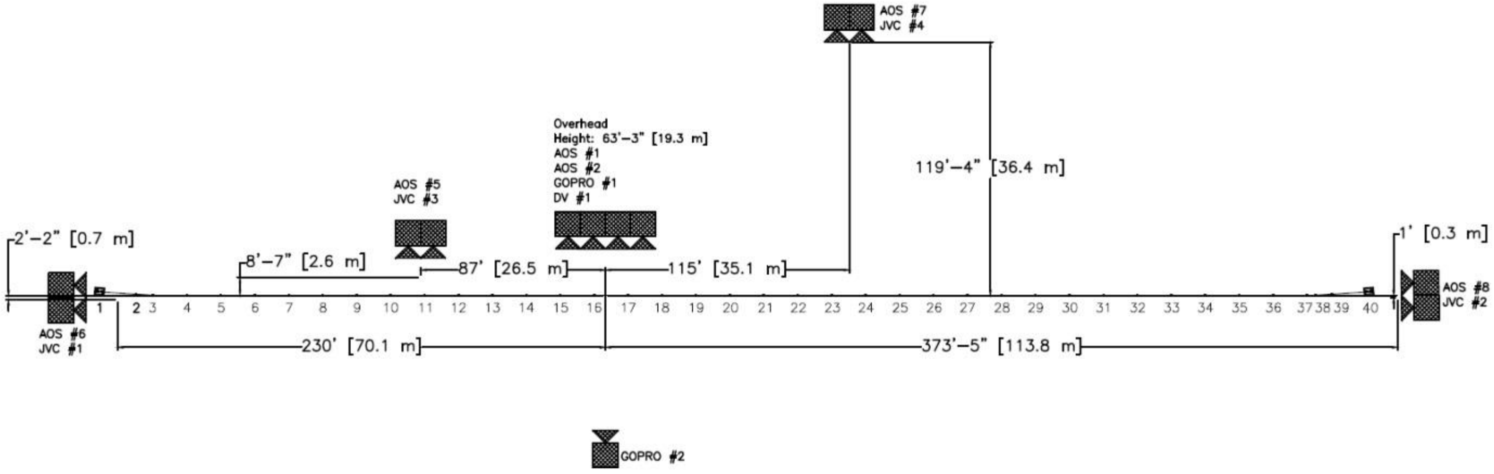
Figure 16. String Potentiometer Setup, Test No. NYJ-1

4.5.6 Digital Photography

Two AOS VITcam high-speed digital video cameras, three AOS X-PRI high-speed digital video cameras, one AOS S-VIT high-speed digital video camera, four JVC digital video cameras, one Canon digital video camera, and two GoPro Hero 3 digital video cameras were utilized to film test nos. NYJ-1 and NYJ-3. However, in test no. NYJ-3, video could not be obtained from the Canon digital video camera due to technical difficulties. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figures 17 and 19.

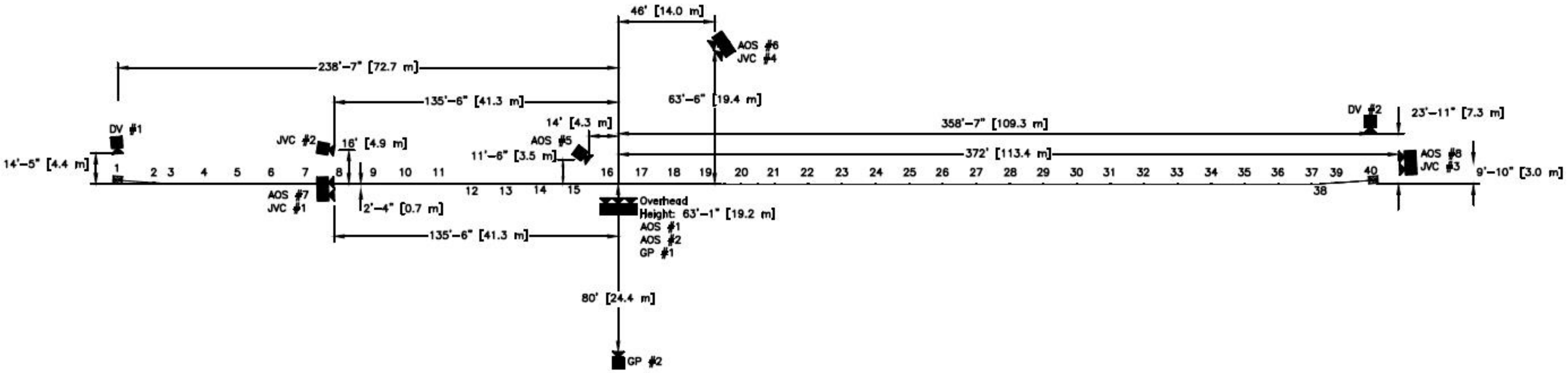
Two AOS VITcam high-speed digital video cameras, three AOS X-PRI high-speed digital video cameras, one AOS S-VIT high-speed digital video camera, four JVC digital video cameras, two Canon digital video cameras, and two GoPro Hero 3 digital video cameras were utilized to film test no. NYJ-2. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 18.

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.



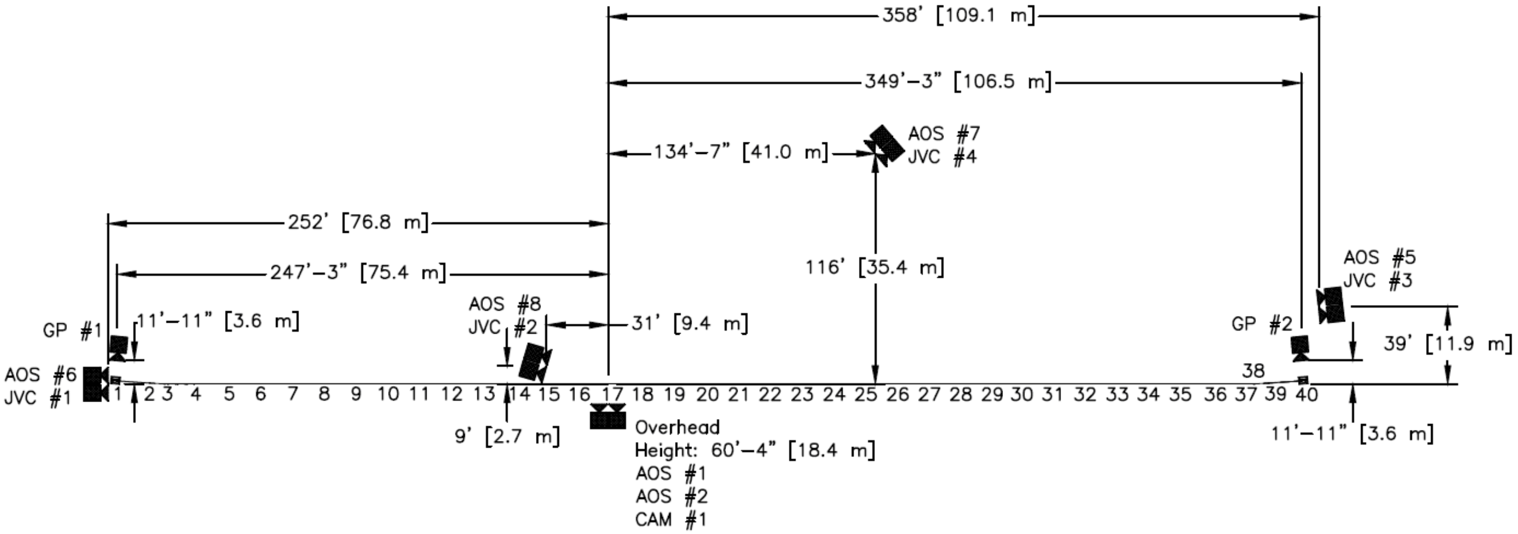
	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	1	AOS Vitcam CTM	500	Kowa 8 mm	Fixed
	2	AOS Vitcam CTM	500	Cosmicar 12.5 mm	Fixed
	5	AOS X-PRI Gigabit	500	Fujinon 50 mm	Fixed
	6	AOS X-PRI Gigabit	500	Canon 17-102	50
	7	AOS X-PRI Gigabit	500	Nikon Sigma 50 mm	Fixed
	8	AOS S-VIT 1531	500	Vivitar 75-205 mm	135
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		
	1	GoPro Hero 3	120		
	2	GoPro Hero 3	120		

Figure 17. Camera Locations, Speeds, and Lens Settings, Test No. NYJ-1



	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	1	AOS Vitcam CTM	500	Kowa 8 mm	Fixed
	2	AOS Vitcam CTM	500	Cosmicar 12.5 mm	Fixed
	5	AOS X-PRI Gigabit	500	Nikon Nikkor 20 mm	Fixed
	6	AOS X-PRI Gigabit	500	Nikon Nikkor 28 mm	Fixed
	7	AOS X-PRI Gigabit	500	TV Zoom 17-102	50
	8	AOS S-VIT 1531	500	Telesar 135 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		
	1	GoPro Hero 3	120		
	2	GoPro Hero 3	120		

Figure 18. Camera Locations, Speeds, and Lens Settings, Test No. NYJ-2



	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	1	AOS Vitcam CTM	500	Kowa 8 mm	Fixed
	2	AOS Vitcam CTM	500	Cosmicar 12.5 mm	Fixed
	5	AOS X-PRI Gigabit	500	Telesar 135 mm	Fixed
	6	AOS X-PRI Gigabit	500	Vivitar 75-205	135
	7	AOS X-PRI Gigabit	500	Nikkor 28 mm	Fixed
	8	AOS S-VIT 1531	500	Nikkor 20 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		
	1	GoPro Hero 3	120		
	2	GoPro Hero 3	120		

Figure 19. Camera Locations, Speeds, and Lens Settings, Test No. NYJ-3

5 PRELIMINARY DESIGN DETAILS

5.1 System Description

The cable guardrail system was constructed according to a modified standard provided by NYSDOT [6]. Design details are shown in Figures 20 through 35. Photographs of the test installation are shown in Figures 36 through 41. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix C.

The total length of the cable barrier system was 602.7 ft (183.7 m). The test installation consisted of several distinct components: (1) wire ropes or cables; (2) steel support posts; (3) ½-in. (13-mm) diameter J-bolts; (4) cable splice hardware; (5) breakaway anchor post hardware; and (6) cable end fittings.

Three ¾-in. (19-mm) diameter, Class A galvanized 3x7 (pre-stretched) wire ropes were utilized for the cable rail elements. The cables were supported by 40 posts and anchored at the upstream and downstream ends, as shown in Figure 20. Post nos. 1 and 40 were configured to serve as the upstream and downstream end anchors, respectively. These locations included a cable anchor bracket and a slipbase S3x5.7 (S76x8.5) steel post embedded in a concrete foundation. Post nos. 2 through 39 were 65-in. (1,651-mm) long, S3x5.7 (S76x8.5) standard steel line posts embedded 33 in. (838 mm) in the soil, with soil plates. The spacing between post nos. 2 and 3 as well as post nos. 38 and 39 was 8 ft (2.4 m), and the spacing between post nos. 37 and 38 was 4 ft (1.2 m). The spacing for the remainder of the posts was 16 ft (4.9 m). For the standard line posts, the three cables were attached to the posts with ½-in. (13-mm) diameter J-bolts and centered at 17 $^1/_8$ in. (435 mm), 23 $^1/_8$ in. (587 mm), and 29 $^1/_8$ in. (740 mm) above the ground line. All three cables were attached to the impact side of each post, as shown in Figure 26. Details for the J-bolt, mounting hardware, and locations are shown in Figures 26 and 32.

Cable splices were utilized between post nos. 18 through 21 according to MASH guidelines, as shown in Figure 21. At the ends of the cable barrier system, each cable was sloped down to the ground and anchored to the end terminal system, as shown in Figures 22 through 25 and Figures 28 and 29. Load cells were placed between posts nos. 3 and 4 on the upstream end of the system and between post nos. 36 and 37 on the downstream end of the system.

5.2 Cable Tension

Per the request of the New York State Department of Transportation, cable tension was varied between 100 and 900 lb (0.4 and 4.0 kN) to identify the relationship between cable sag and tension. Results indicated that cable sag followed an approximately linear relationship with tension between 100 and 700 lb (0.4 and 3.1 kN), such that the total sag was 1 in. (25 mm) at 138 lb (0.61 kN) tension, and 0.25 in. (6 mm) at 700 lb (3.1 kN)., as shown in Table 4.

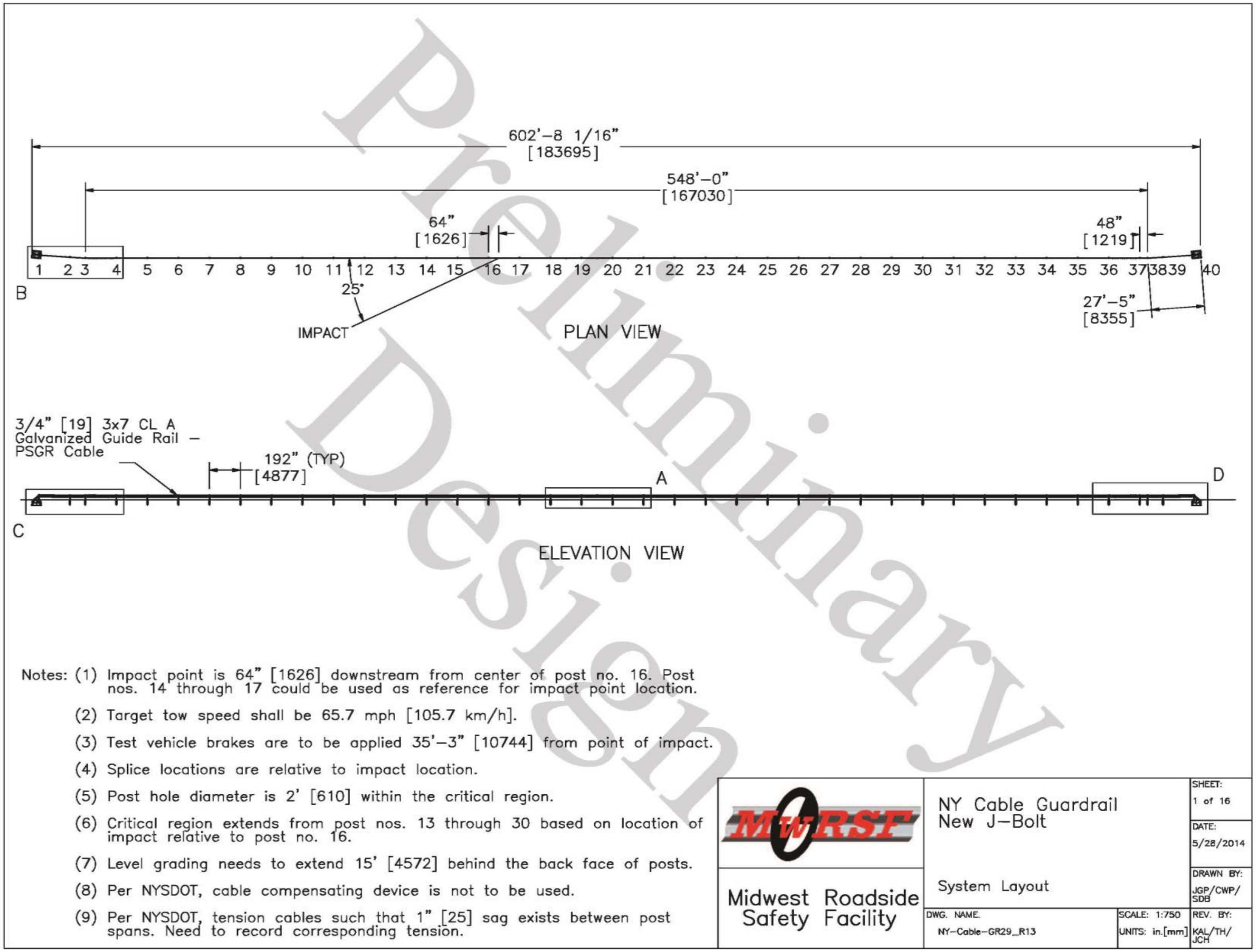
Table 4. Estimated Cable Sag for Various Cable Tensions, 16-ft (4.9-m) Post Spacing

Tension	Cable Droop at Midspan
100 lb (445 N)	1 in. (25 mm)
300 lb (1,334 N)	3/4 in. (19 mm)
500 lb (2,224 N)	1/2 in. (13 mm)
700 lb (3,114 N)	1/4 in. (6 mm)
900 lb (4,003 N)	< 1/4 in. (6 mm)

Actual low-tension, cable barrier systems installed in the field may have sag between posts that exceeds 1 in. (25 mm). The tension in these systems may be less than 95 lb (0.4 kN) or 10 percent of the nominal tension at 70 deg F (21 deg C), which is approximately 950 lb (4.2 kN). It was determined that visible sag in cable barrier systems likely corresponds to little or no sustained cable tension.

In addition, cable friction and tension loss due to cable-to-post attachment friction were investigated. Load cells were spliced in-line for all three cables, with one load cell at the upstream end of the system and one load cell at the downstream end of the system. The cables were tensioned on the upstream end of the system, and the downstream load cells did not record an increase in tension until the upstream had reached 200 lb (0.89 kN) of tension. By subsequently increasing tension on the upstream end to 1,000 lb (4.4 kN), a constant tension difference between upstream and downstream ends was determined to be approximately 200 lb (0.89 kN).

Per MASH requirements, the tension in the cables at the time of the test should correspond to the design tension at 100 deg F (38 deg C). Typically, cable tension is specified in terms of spring deflection of spring compensators for low-tension systems. Although spring compensators were not intended for use in the modified New York DOT low-tension, 3-cable barrier system, the nominal tension was selected to be identical to the tension of similar systems which utilize cable compensators. Using a spring compensation rate of 450 lb/in. (79 N/mm) and a nominal deflection of 2 in. (51 mm) between 70 and 79 deg F (21 and 26 deg C) and 1.0 in. (25 mm) between 120 and 110 deg F (49 and 43 deg C), the test tension corresponding to 100 deg F (38 deg C) was determined to be approximately 500 lb (2.2 kN), which was selected for the nominal test conditions.



Notes: (1) Impact point is 64" [1626] downstream from center of post no. 16. Post nos. 14 through 17 could be used as reference for impact point location.

(2) Target tow speed shall be 65.7 mph [105.7 km/h].

(3) Test vehicle brakes are to be applied 35'–3" [10744] from point of impact.

(4) Splice locations are relative to impact location.

(5) Post hole diameter is 2' [610] within the critical region.

(6) Critical region extends from post nos. 13 through 30 based on location of impact relative to post no. 16.

(7) Level grading needs to extend 15' [4572] behind the back face of posts.

(8) Per NYSDOT, cable compensating device is not to be used.

(9) Per NYSDOT, tension cables such that 1" [25] sag exists between post spans. Need to record corresponding tension.

Figure 20. Test Installation Layout, Test No. NYJ-1

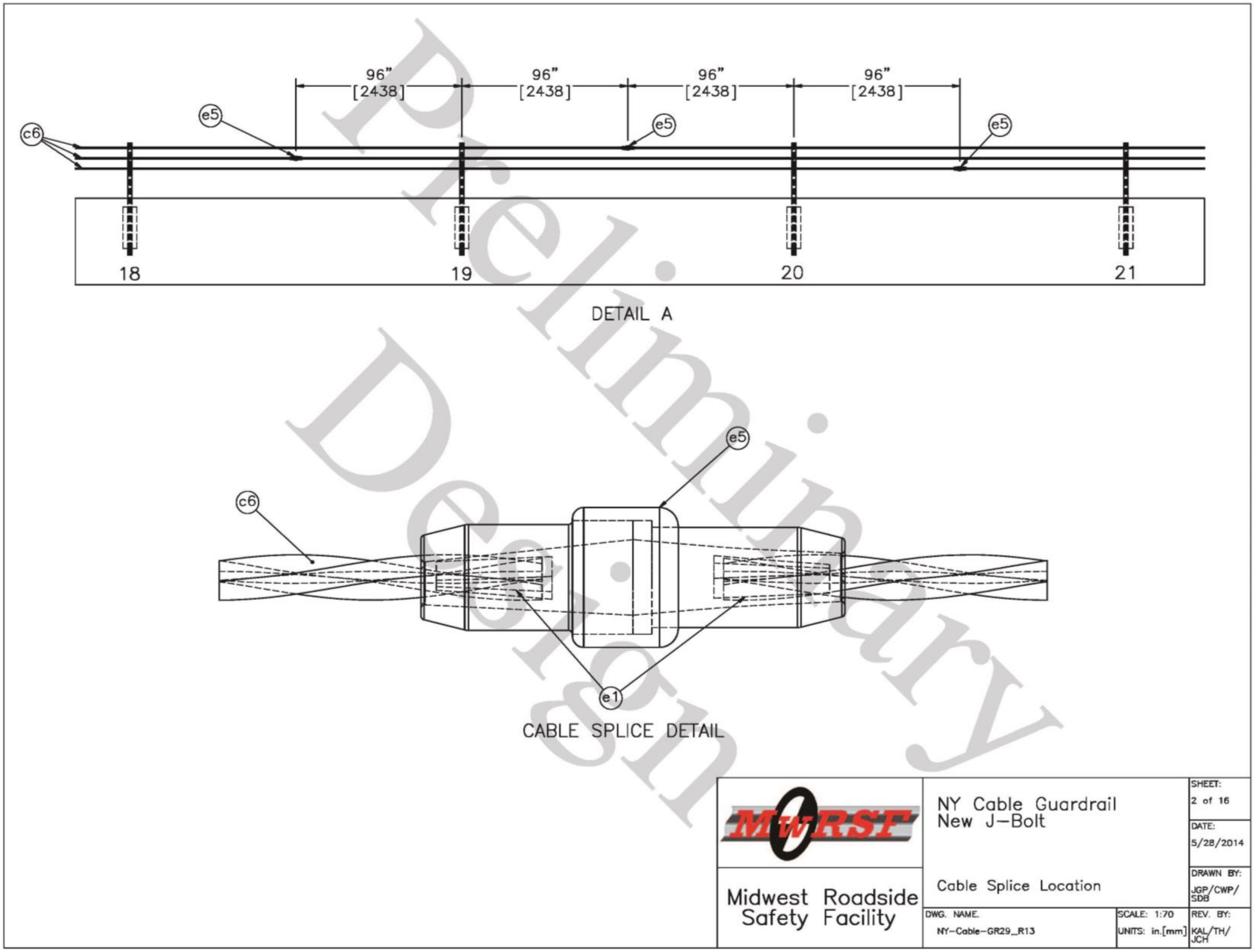


Figure 21. Cable Splice Location, Test No. NYJ-1

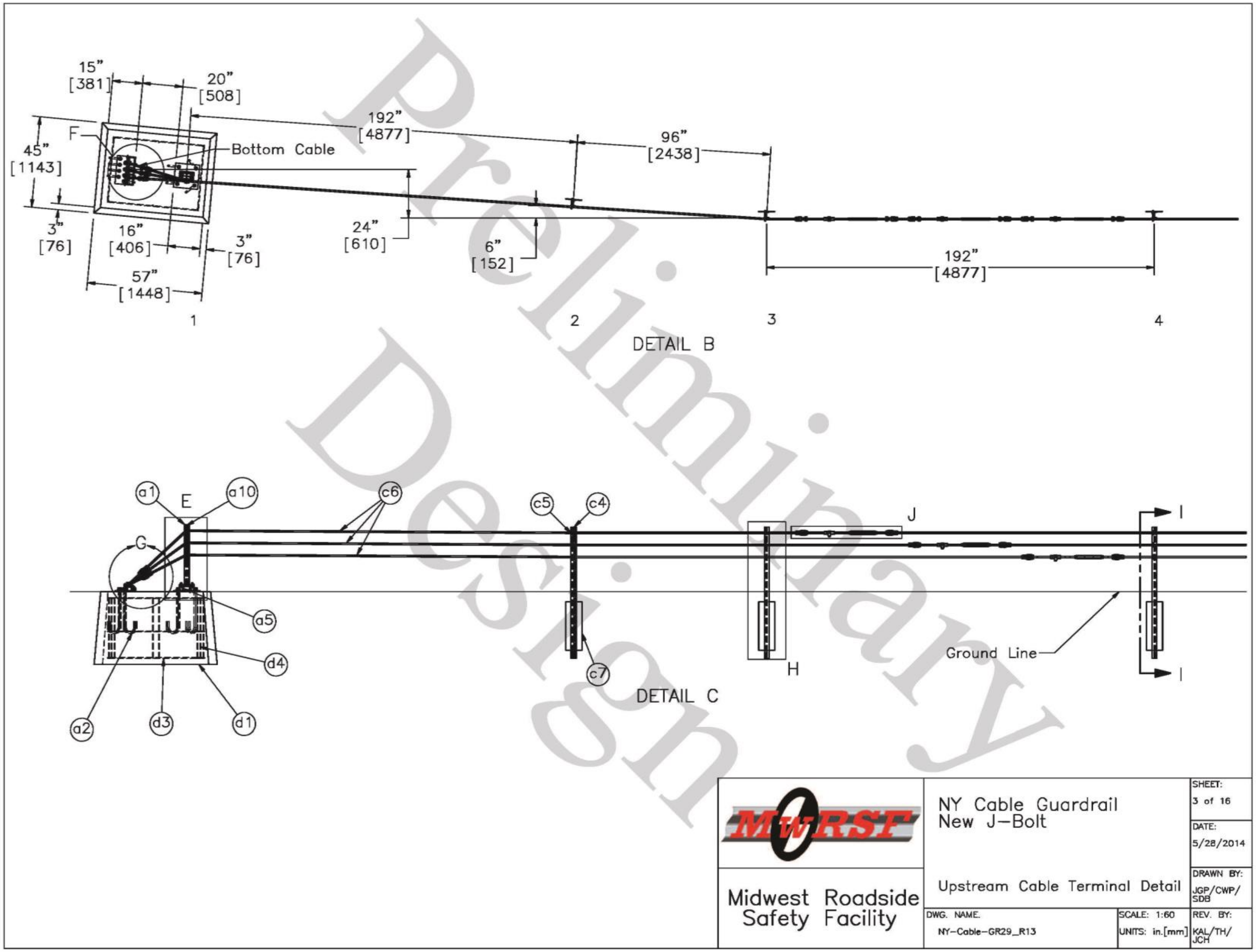


Figure 22. Upstream Cable Terminal Detail, Test No. NYJ-1

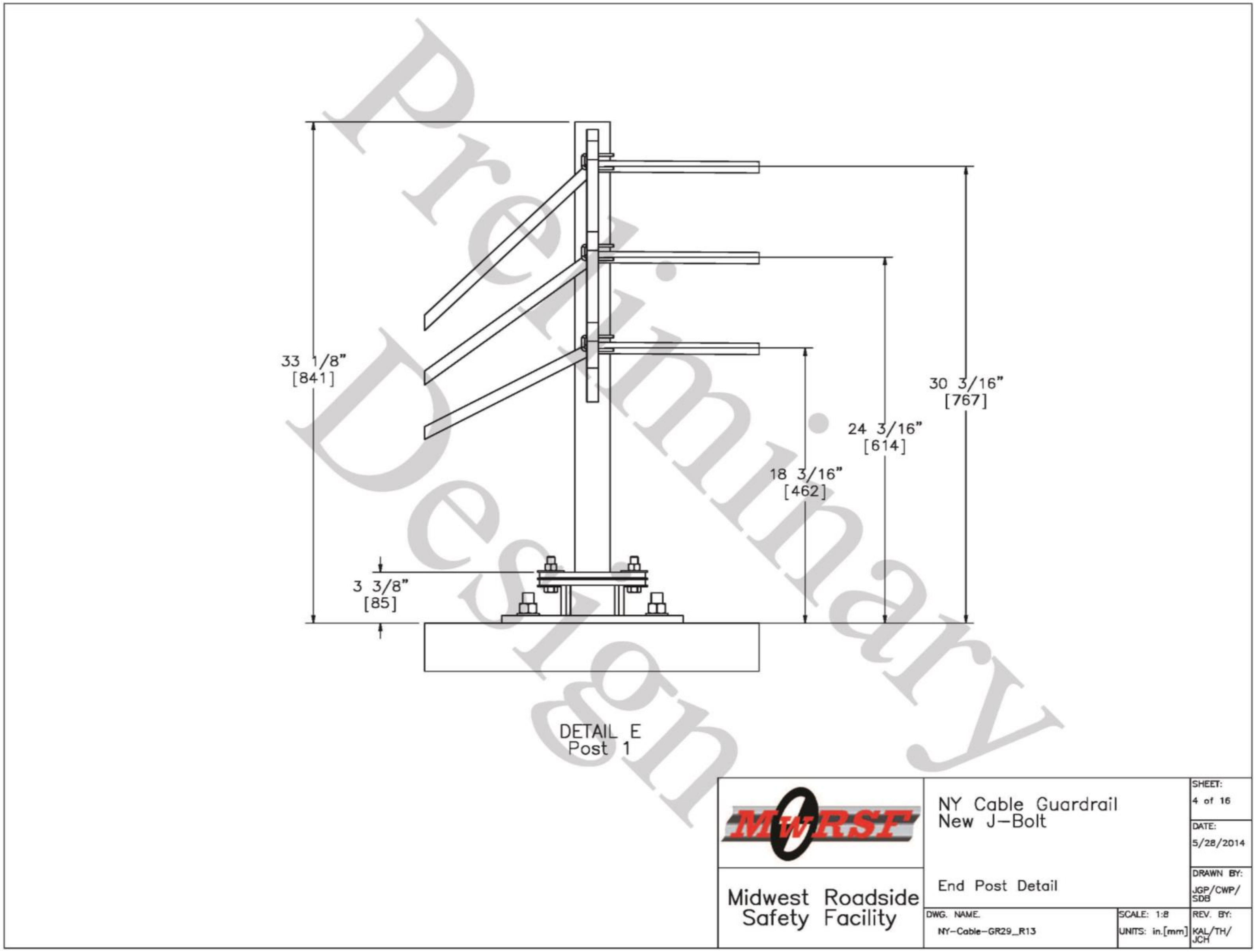


Figure 23. End Post Detail, Test No. NYJ-1

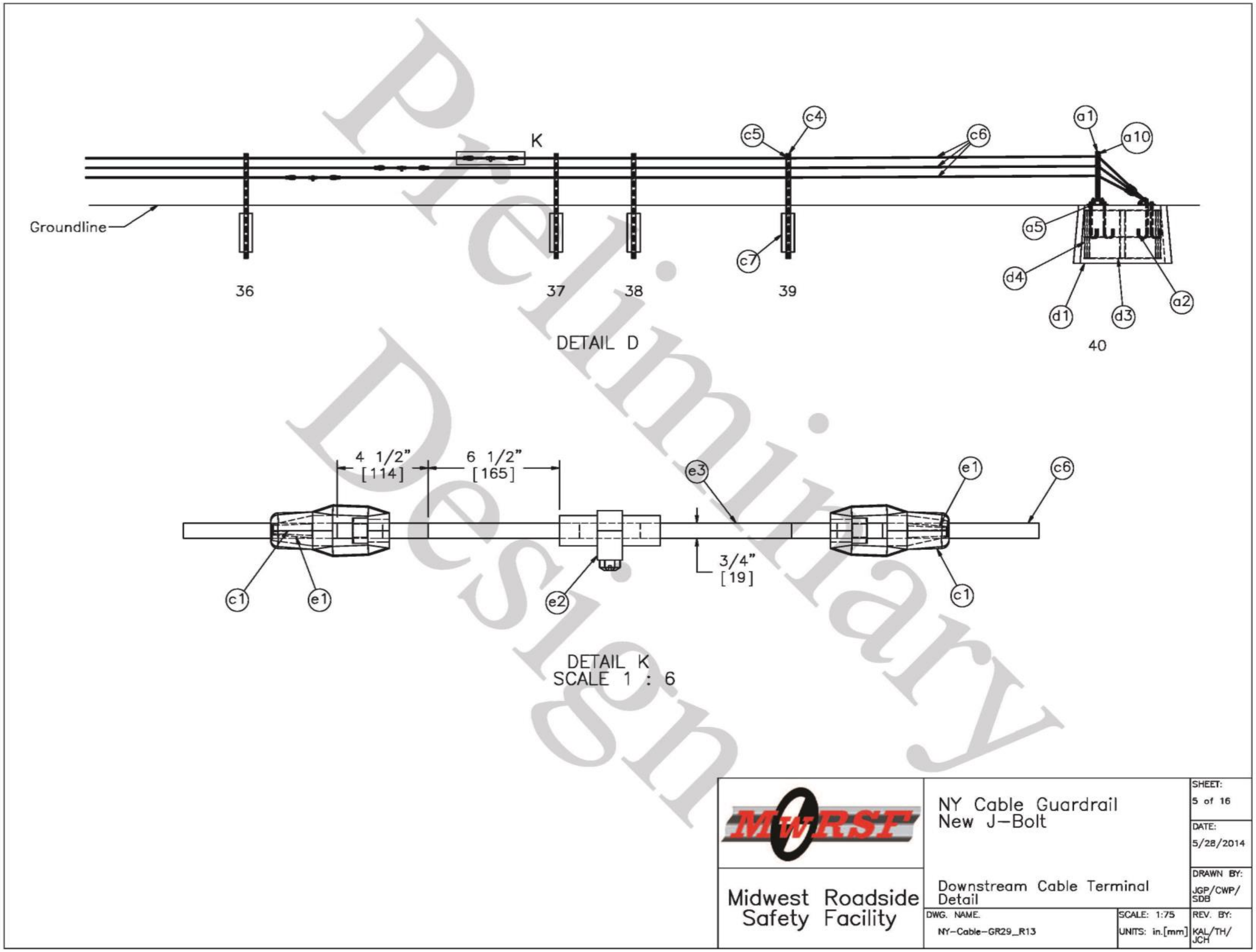
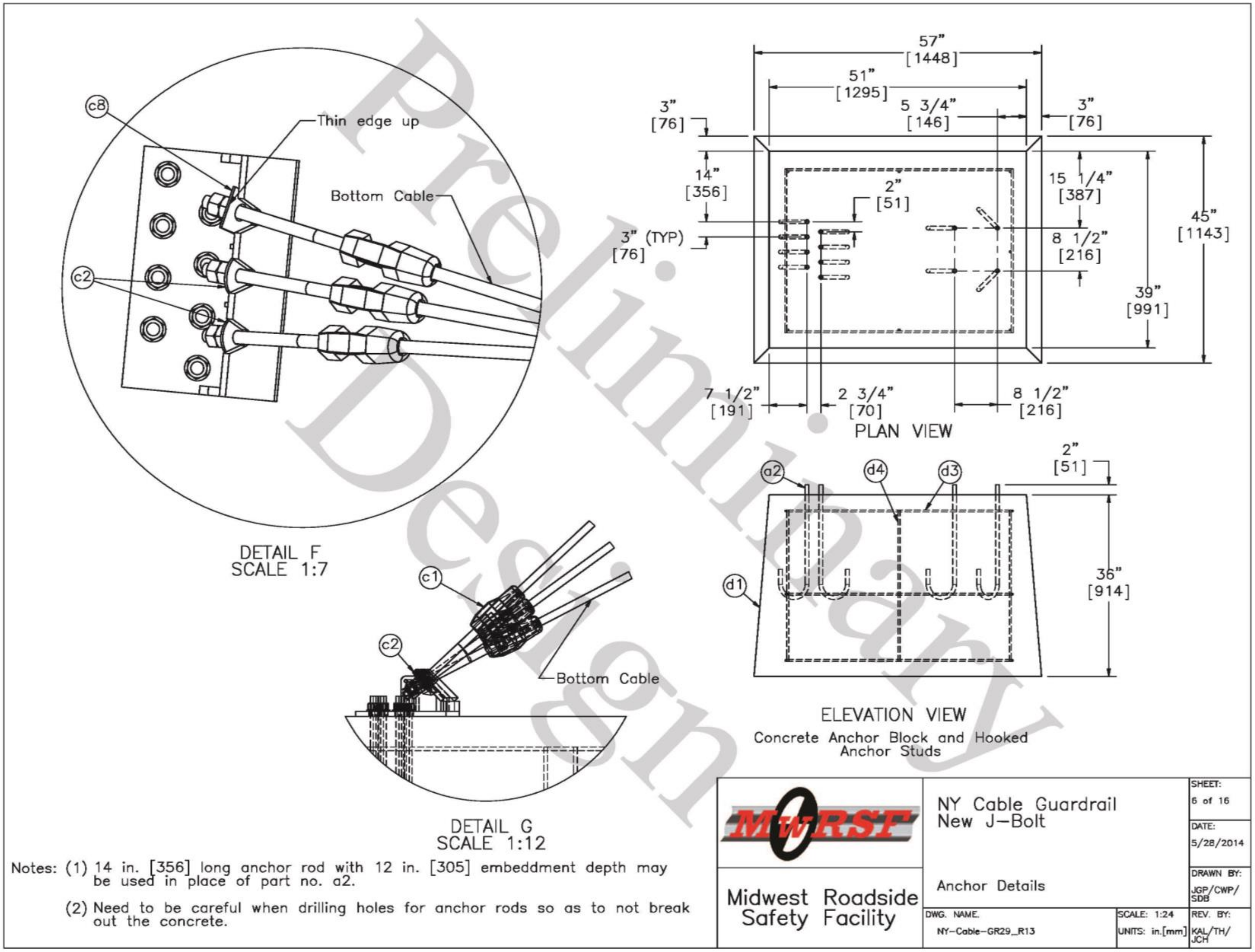


Figure 24. Downstream Cable Terminal Detail, Test No. NYJ-1



Notes: (1) 14 in. [356] long anchor rod with 12 in. [305] embeddment depth may be used in place of part no. a2.

(2) Need to be careful when drilling holes for anchor rods so as to not break out the concrete.

Figure 25. Anchor Details, Test No. NYJ-1

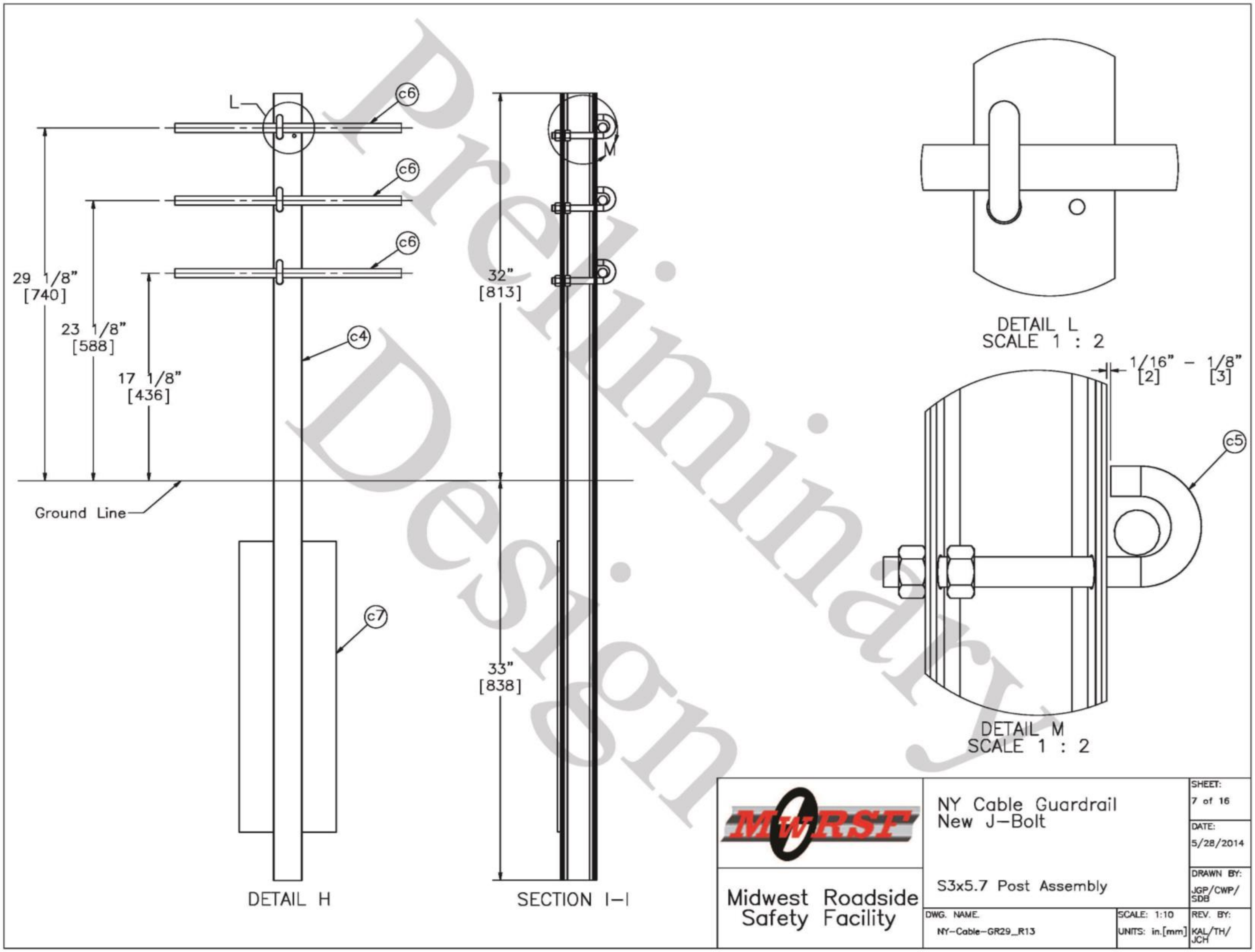
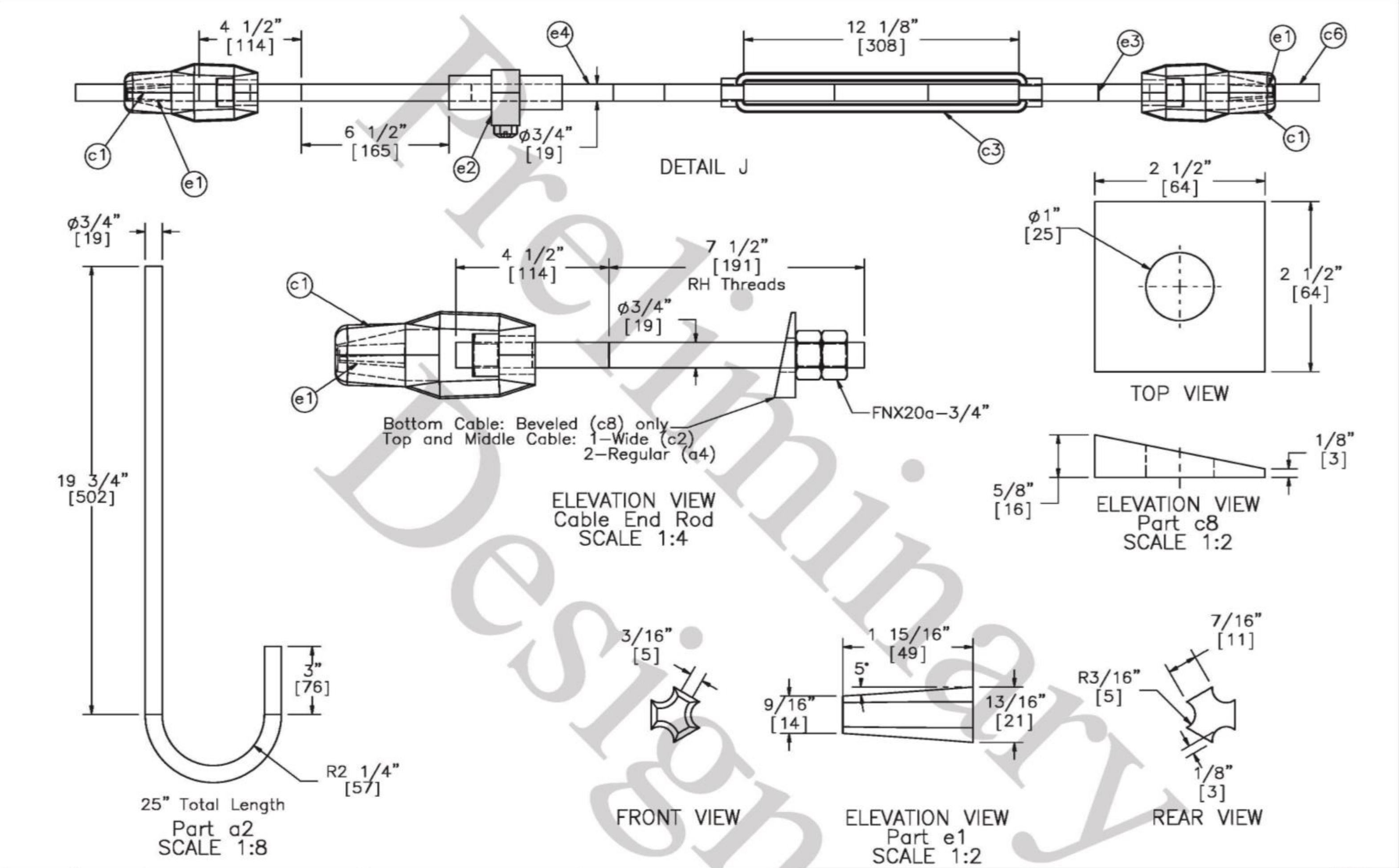


Figure 26. S3x5.7 Post Assembly, Test No. NYJ-1



		Inside Diameter "A"			Outside Diameter "B"			Thickness "C"		
	Washer		Tolerance			Tolerance				
Washer	Series	Basic	Plus	Minus	Basic	Plus	Minus	Basic	Max.	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

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NY Cable Guardrail
New J-Bolt

Anchor Stud and Cable
Turnbuckle

SHEET:
8 of 16

DATE:
5/28/2014

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NY-Cable-GR29_R13

SCALE: 1:6
UNITS: in.[mm]

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Figure 27. Anchor Stud and Cable Turnbuckle, Test No. NYJ-1

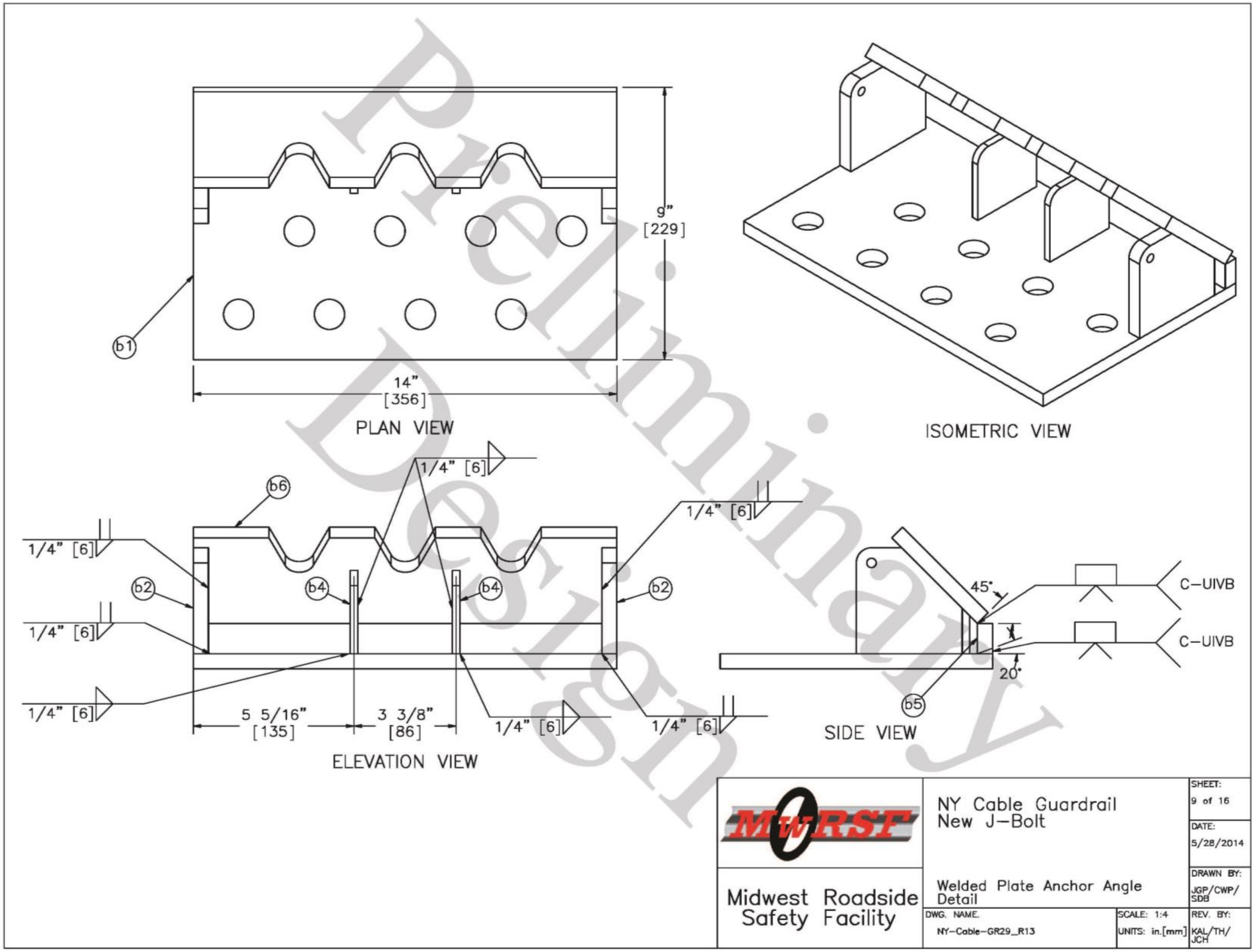


Figure 28. Welded Plate Anchor Angle Detail, Test No. NYJ-1

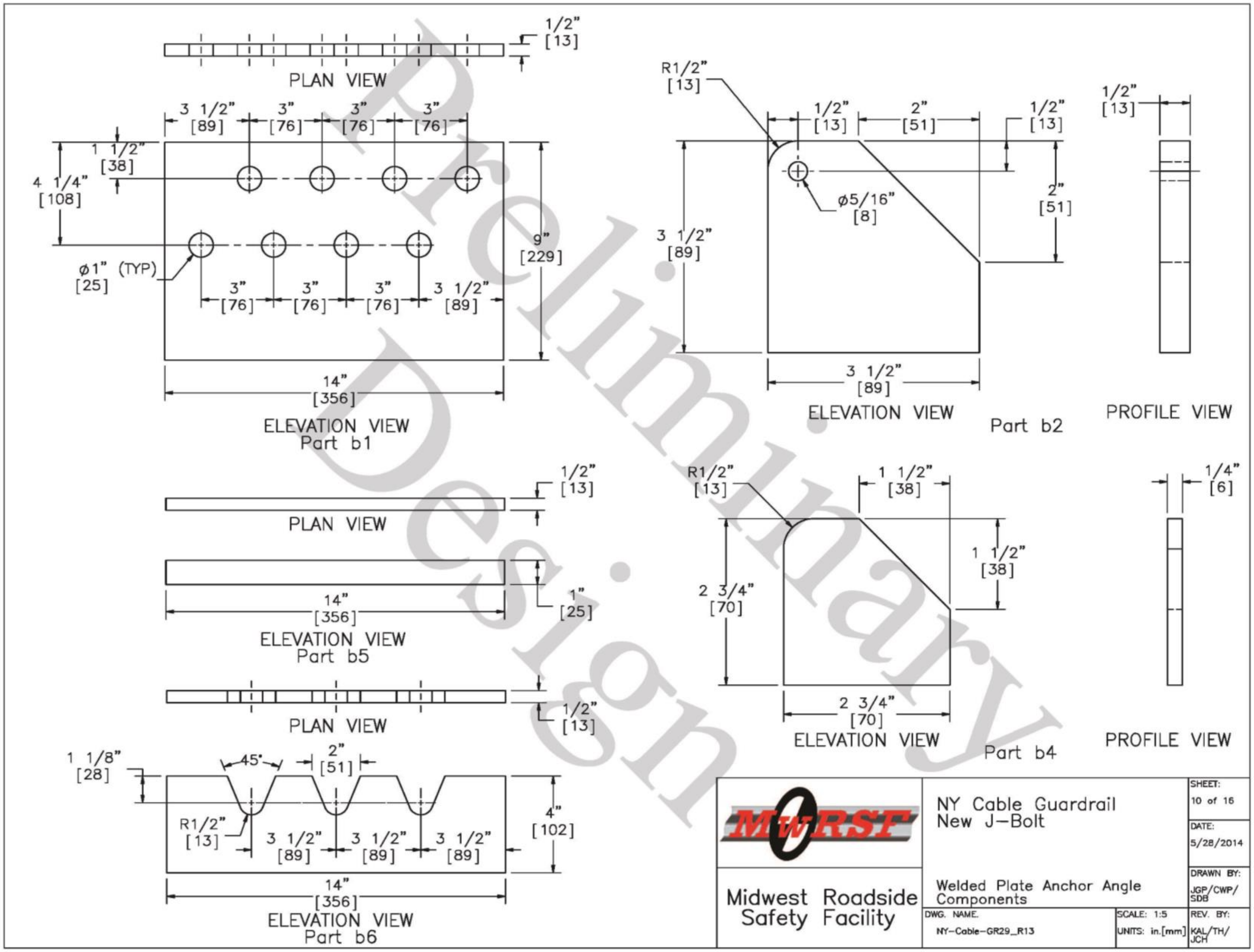


Figure 29. Welded Plate Anchor Angle Components, Test No. NYJ-1

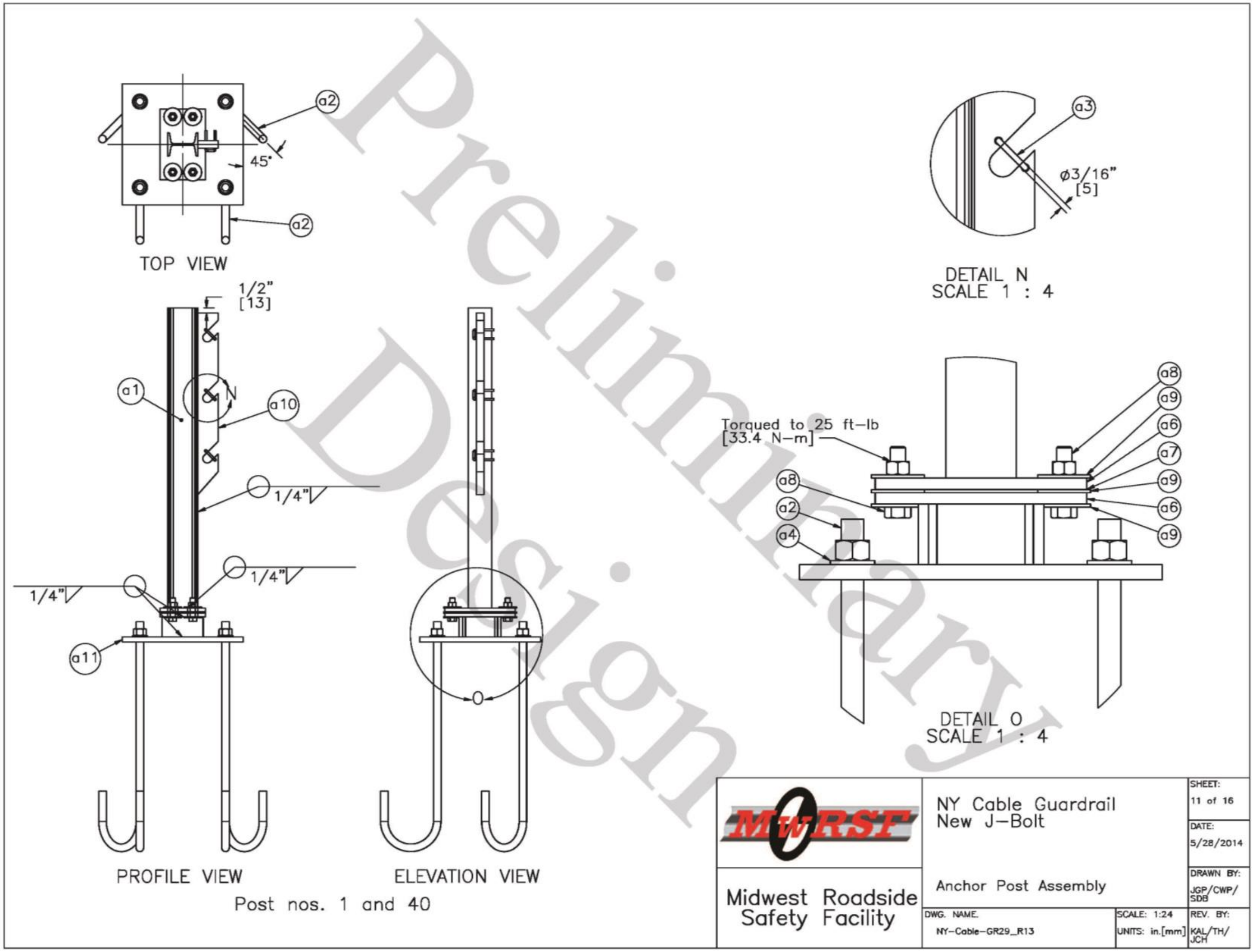


Figure 30. Anchor Post Assembly, Test No. NYJ-1

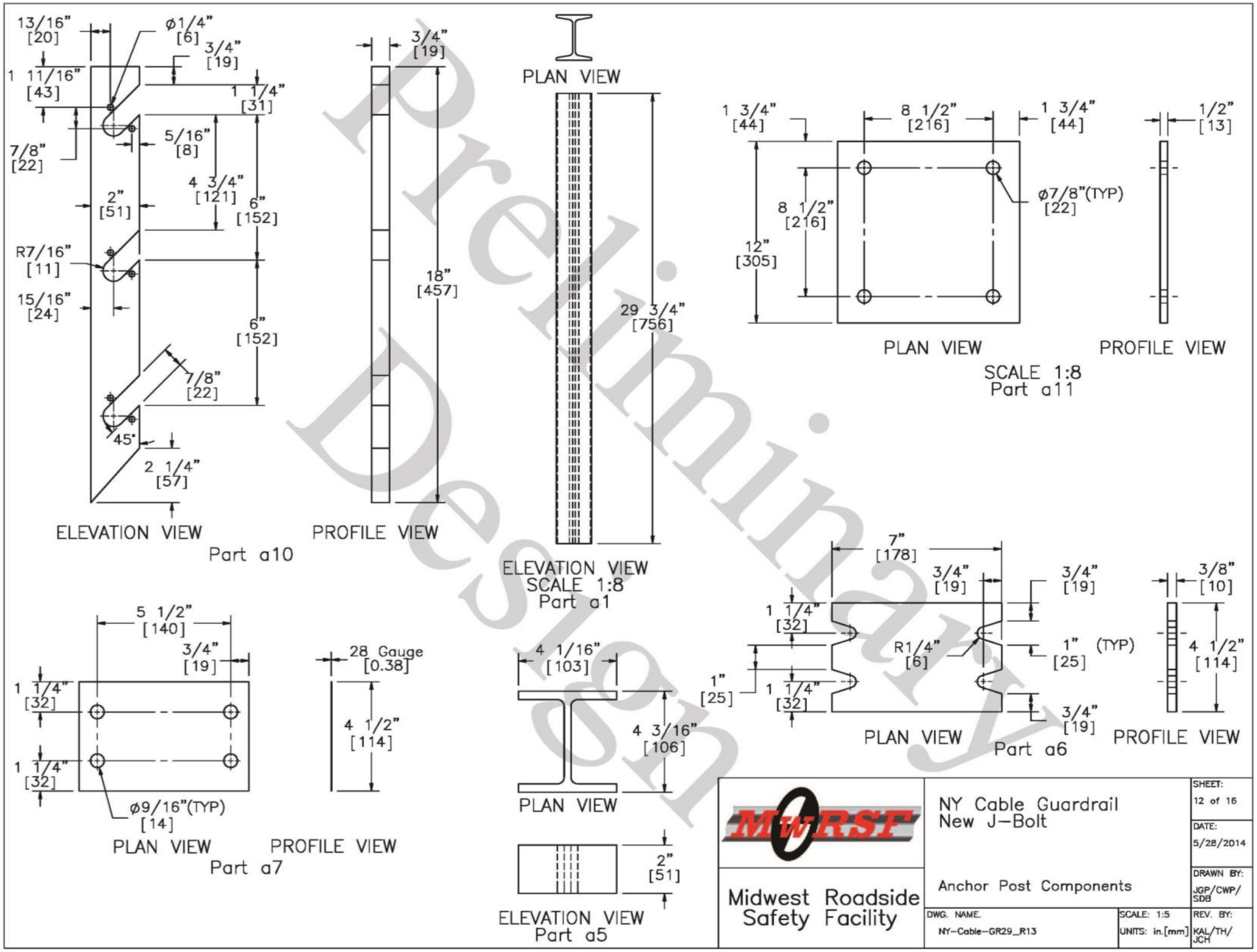
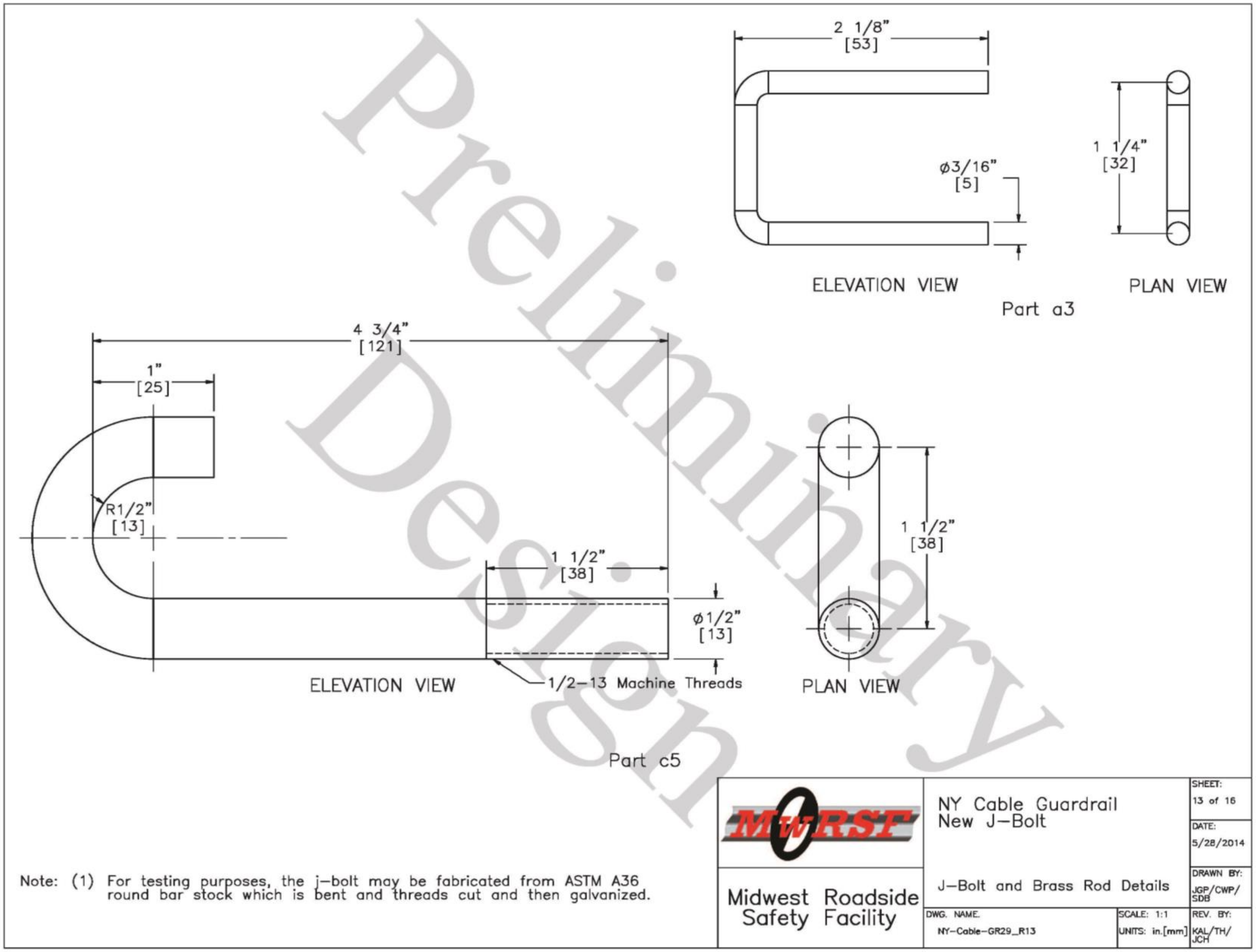


Figure 31. Anchor Post Components, Test No. NYJ-1



Note: (1) For testing purposes, the j–bolt may be fabricated from ASTM A36 round bar stock which is bent and threads cut and then galvanized.

Figure 32. J-Bolt and Brass Rod Details, Test No. NYJ-1

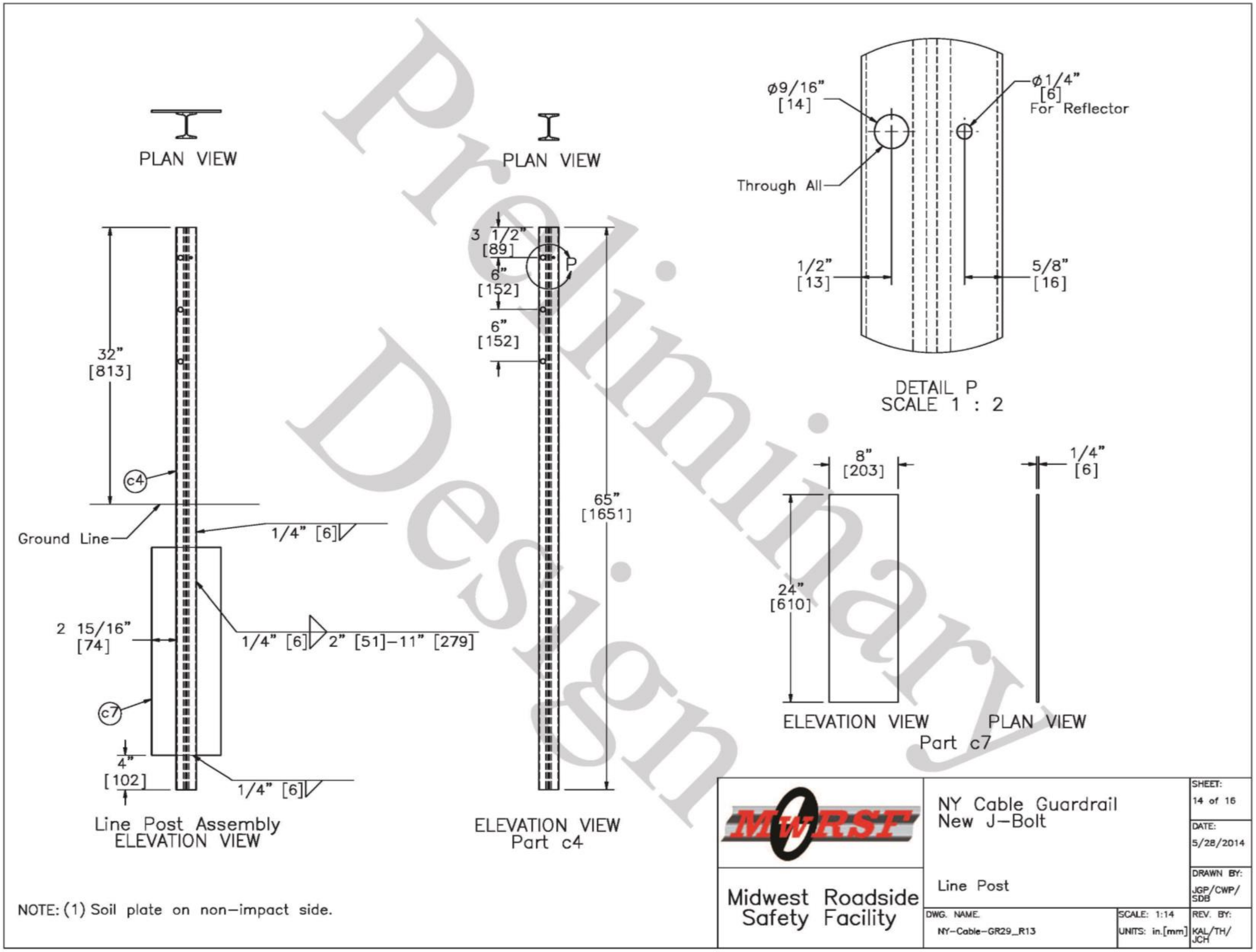


Figure 33. Line Post, Test No. NYJ-1

Item No.	QTY.	Description	Material Specification	Hardware Guide
a1	2	S3x5.7 [S76x8.5] 29 3/4" [756] Long Anchor Post	ASTM A36 Galv.	–
a2	24	3/4" [19] Dia. UNC, Hooked Anchor J–Bolt and Nut	ASTM A307 Gr. C and ASTM A563 DH Galv.	FRH20a
a3	6	3/16" [5] Dia. 5 1/4" [133] Long Brass Rod	ASTM B16–00	–
a4	32	ø3/4" Plain Round Washer–OD 1.5"	Grade 2 Galvanized	FWC20a
a5	2	W4x13 [W102x19.3] Anchor Post Stub	ASTM A36 Galv.	–
a6	4	7"x4 1/2"x3/8" [178x114x10] Slip Impact Base	ASTM A36 Galv.	–
a7	2	7"x4 1/2"x28 Gauge [178x144x0.38] Keeper Plate	ASTM A36 Galv.	–
a8	8	1/2" [13] Dia. UNC, 2" [51] Long Bolt and Nut	ASTM A307 Gr. A/ASTM F1554 Gr. 36/SAE Gr. 2 and ASTM A563 Gr. A	FBX14a
a9	24	1/2" [13] Dia. Narrow Washer (OD 1" [25])	ASTM 844/SAE Gr. 2	FWC12a
a10	2	18"x2"x3/4" [457x51x19] Anchor Post Cable Hanger	ASTM A707 Gr. 36 Galv.	–
a11	2	12"x12"x1/2" [305x305x13] Anchor Post Base	ASTM A709 Gr. 36 Galv.	–
b1	2	14"x9"x1/2" [356x229x13] Cable Anchor Base Plate	ASTM A709 Gr. 36 Galv.	–
b2	4	3 1/2"x3 1/2"x1/2" [89x89x13] Cable Anchor External Gusset	ASTM A709 Gr. 36 Galv.	–
b3	2	1/4" [6] Dia. 15" [381] Long Brass Rod	ASTM B16–00	–
b4	4	2 3/4"x2 3/4"x1/4" [70x70x6] Cable Anchor Internal Gusset	ASTM A709 Gr. 36 Galv.	–
b5	2	14"x1"x1/2" [356x25x13] Cable Anchor Front Plate	ASTM A709 Gr. 36 Galv.	–
b6	2	14"x4"x1/2" [356x102x13] Cable Anchor Top Plate	ASTM A709 Gr. 36 Galv.	–
c1	18	Cable End Fitting	ASTM A27 Galv.	RCE03
c2	4	3/4" [19] Plain Round Washer (OD 2" [51])	ASTM F844/SAE Gr. 2 Galv.	FWC20a
c3	3	Cable Turnbuckle	AASHTO M269/ASTM F1145	–
c4	38	S3x5.7 [S76x8.5] 65" [1651] Long Line Post	ASTM A36	–
c5	114	1/2" [13] J–Bolt and Nut	Bolt ASTM A36 and Nut ASTM A563DH Galv.	–
c6	3	3/4" [19] Dia. Cable Approx. 600' [183 m]	AASHTO M30 Type 1 Class A Galv.	RCM01
c7	38	2'x8"x0.25" Soil Plate	ASTM A36 Galv.	–
c8	2	1" [25] Dia. Beveled Washer	ASTM A36	–
d1	2	Concrete Anchor Block	3000 psi [20.68 MPa] Compressive Strength	–
d2	12	32 1/2" [826] Long #3 [#10] Rebar	ASTM A36	–
d3	12	44 1/2" [1130] Long #3 [#10] Rebar	ASTM A36	–
d4	16	30" [762] Long #3 [#10] Rebar	ASTM A36	–
e1	24	Cable Wedge	ASTM A47 Gr. 32510	–
e2	6	50,000–lb Load Cell	N/A	–
e3	18	3/4" [19] Dia. UNC Threaded Rod	ASTM A449	–
e4	3	3/4" [19] Dia. UNC Left–Handed Threaded Rod	ASTM A449	–
e5	3	3/4" [19] Cable Splice	ASTM A536	–

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NY Cable Guardrail
New J–Bolt

Bill of Materials

SHEET: 15 of 16
DATE: 5/28/2014
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DWG. NAME. NY–Cable–GR29_R13
SCALE: NONE
UNITS: in.[mm]
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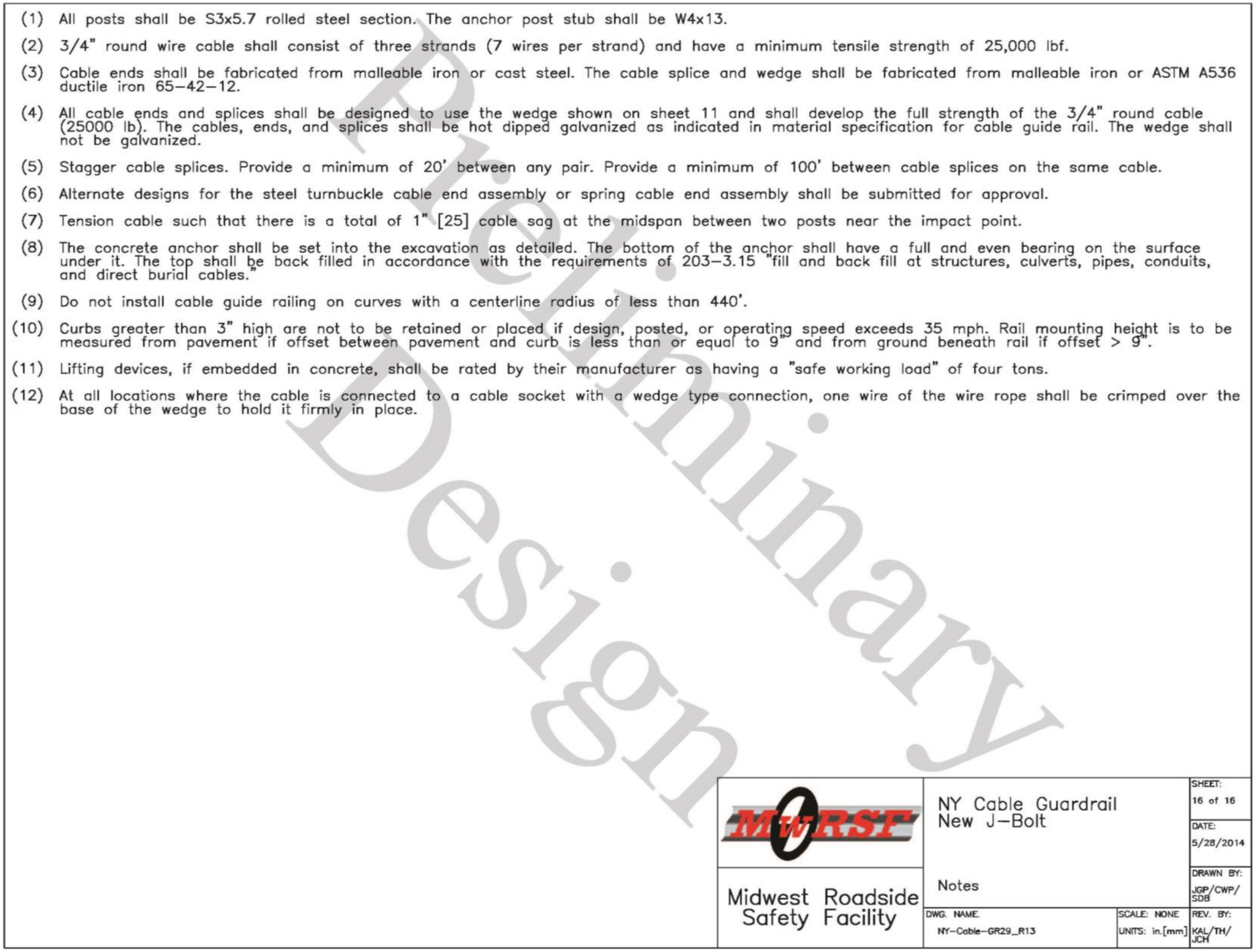
Figure 34. Bill of Materials, Test No. NYJ-1



(1) All posts shall be S3x5.7 rolled steel section. The anchor post stub shall be W4x13.

(2) 3/4" round wire cable shall consist of three strands (7 wires per strand) and have a minimum tensile strength of 25,000 lbf.

(3) 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 iron 65–42–12.

(4) All cable ends and splices shall be designed to use the wedge shown on sheet 11 and shall develop the full strength of the 3/4" round cable (25000 lb). 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.

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

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

(7) Tension cable such that there is a total of 1" [25] cable sag at the midspan between two posts near the impact point.

(8) 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."

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

(10) 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".

(11) Lifting devices, if embedded in concrete, shall be rated by their manufacturer as having a "safe working load" of four tons.

(12) 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.

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NY Cable Guardrail
New J–Bolt

Notes

SHEET: 16 of 16
DATE: 5/28/2014
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Figure 35. Additional Notes, Test No. NYJ-1

Figure 36. System Photographs, Test No. NYJ-1

Figure 37. Additional System Photographs, Test No. NYJ-1

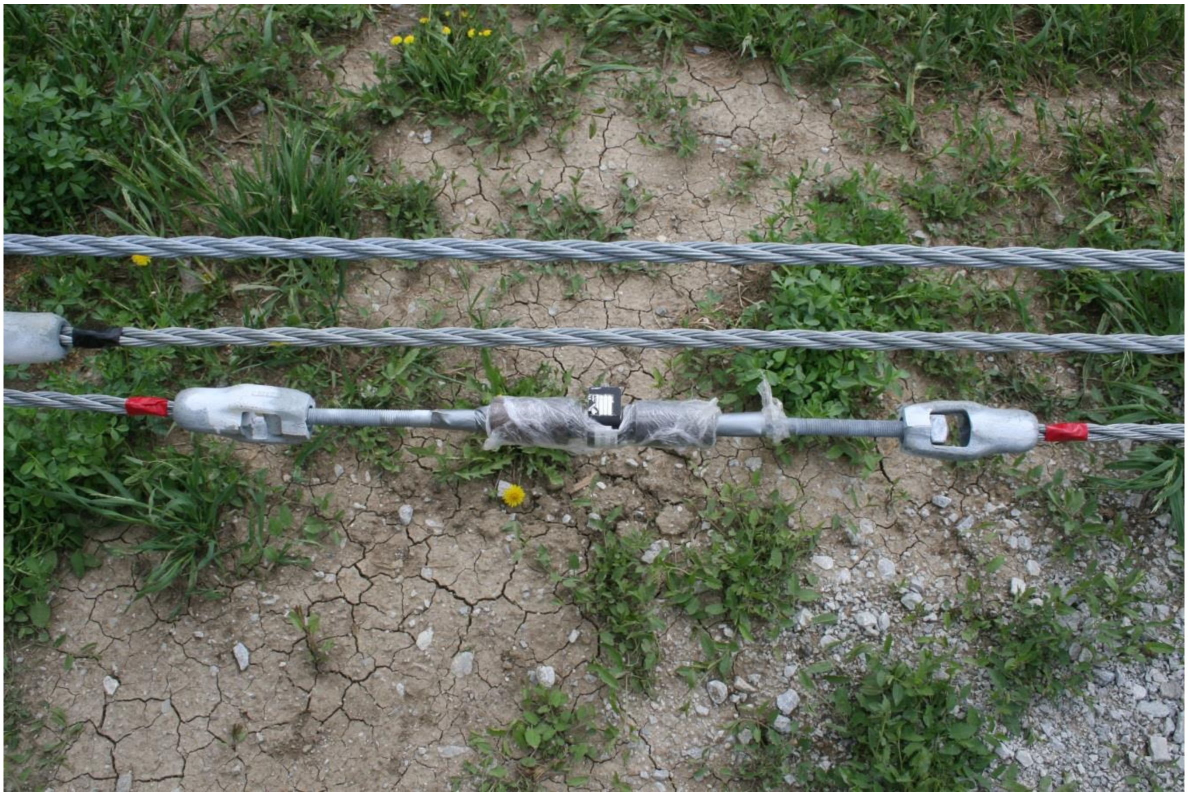


Figure 38. Load Cell Photographs, Test No. NYJ-1

Figure 39. Upstream Cable Terminal Photographs, Test No. NYJ-1

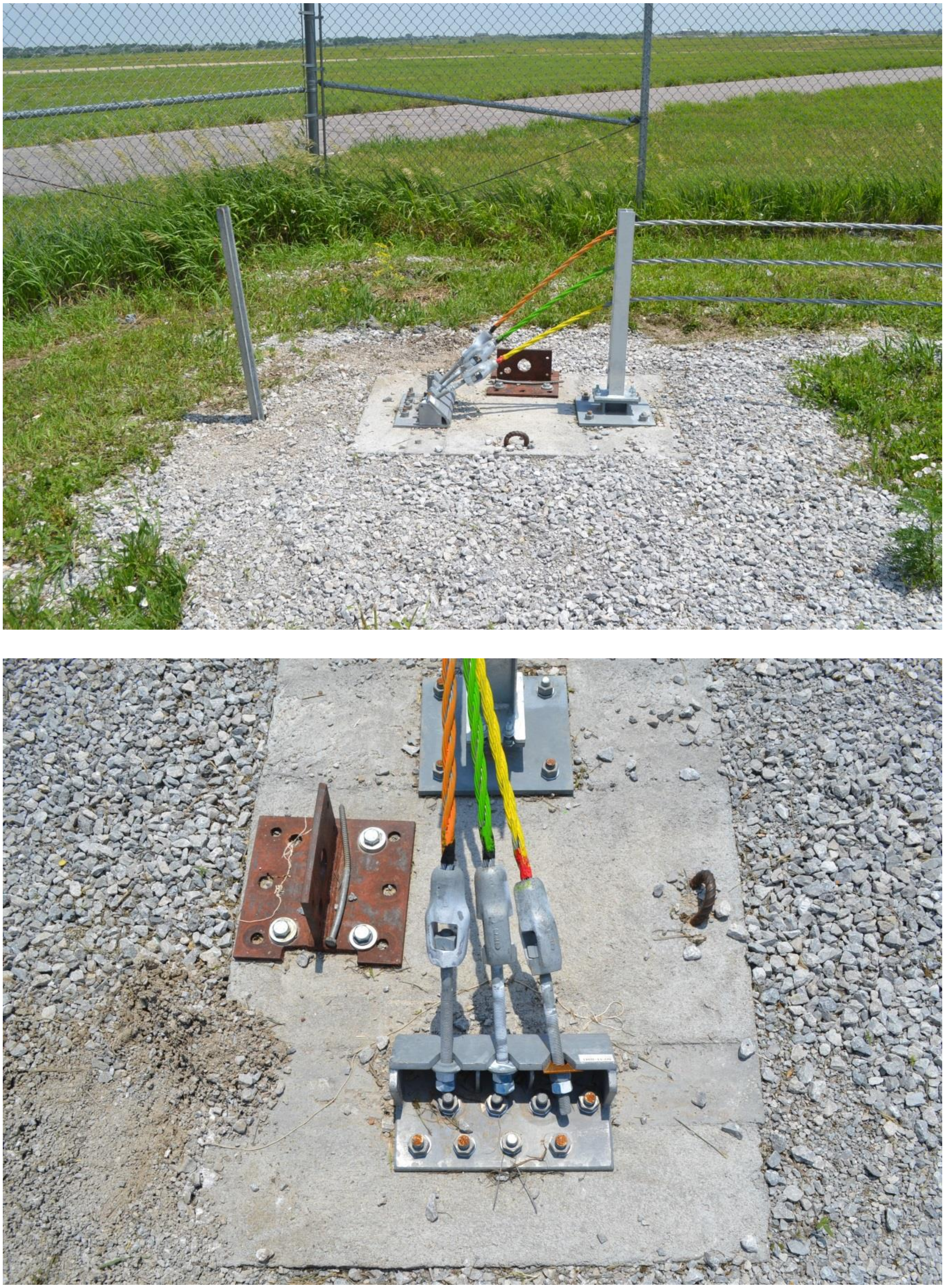


Figure 40. Downstream Cable Terminal Photographs, Test No. NYJ-1

Figure 41. Post Photographs, Test No. NYJ-1

6 FULL-SCALE CRASH TEST NO. NYJ-1

6.1 Static Soil Test

Before full-scale crash test no. NYJ-1 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 D, 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.

6.2 Test No. NYJ-1

The 3,294-lb (1,494-kg) passenger car impacted the cable guardrail system at a speed of 62.7 mph (100.9 km/h) and at an angle of 25.5 degrees. A summary of the test results and sequential photographs are shown in Figure 42. Additional sequential photographs are shown in Figures 43 and 44.

Prior to impact with the system in test no. NYJ-1, the vehicle’s initial pitch was estimated to be approximately 2.2 degrees. The tested pitch angle was slightly higher than what was observed during braking tests on concrete tarmac and in the soil pit. In addition, the pitch was maximized at approximately 0.33 sec, but the maximum pitch was sustained up to impact. The pre-impact coefficient of friction was not calculated in test no. NYJ-1.

6.3 Weather Conditions

Test no. NYJ-1 was conducted on June 18, 2013 at approximately 4:00 pm. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 5.

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

Temperature	82°F
Humidity	41%
Wind Speed	6.9 mph
Wind Direction	Variable
Sky Conditions	Partly Cloudy
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.01 in.
Previous 7-Day Precipitation	0.04 in.

6.4 Test Description

Initial vehicle impact was to occur 64 in. (1,625 mm) downstream from post no. 16, as shown in Figure 45, which was selected based on previous testing [10]. The actual point of impact was 65 in. (1,651 mm) downstream from post no. 16. A sequential description of the impact events is contained in Table 6. The vehicle came to rest 100 ft (30.5 m) downstream from impact and 30 ft – 8 in. (9.4 m) laterally behind the system. The vehicle trajectory and final position are shown in Figures 42 and 46.

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

TIME (sec)	EVENT
0.000	The vehicle impacted system.
0.002	The vehicle’s left-front bumper contacted bottom cable and began to deform.
0.010	The vehicle’s left-front fender contacted middle cable.
0.028	The vehicle began to underride middle cable between post nos. 16 and 17.
0.034	Post no. 17 began to deflect backward.
0.058	The vehicle’s left-side mirror contacted top cable between post nos. 16 and 17.
0.074	The vehicle’s left-side mirror began to detach away from A-pillar.
0.086	Post no. 15 began to deflect backward.
0.090	The vehicle began to override post no. 17.
0.104	The middle cable disengaged from post no. 17.

TIME (sec)	EVENT
0.114	The bottom cable disengaged from post no. 17.
0.118	The bottom cable failed at the upstream end.
0.116	The top cable disengaged from post no. 17.
0.124	Post no. 18 began to deflect backward and downstream.
0.138	The middle cable failed at the upstream end.
0.164	The top cable failed at the upstream end.
0.180	The top cable began to slide up the A-pillar.
0.182	The vehicle’s left-side mirror became disengaged.
0.204	The vehicle began to yaw away from barrier.
0.220	The vehicle’s windshield began to crush due to contact with top cable.
0.292	The top cable became disengaged from vehicle, and middle cable began to slide over vehicle’s roof.
0.328	The bottom cable made contact with left-rear wheel.
0.430	The middle cable disengaged away from vehicle.
0.500	The bottom cable contacted rear bumper.
0.536	The vehicle was parallel with the system and began to yaw.
1.224	The vehicle rotated such that the front was perpendicular with the system.
2.690	The vehicle came to rest, facing upstream and parallel with the system.

6.5 Barrier Damage

Damage to the barrier was severe, as shown in Figures 47 through 52. Barrier damage consisted of fractured J-bolts, deformed posts, and disengaged cables. The permanent set, dynamic deflection, and working width were not recorded due to release of the cables from end fittings on the upstream and downstream ends. The permanent displacements of the upstream and downstream anchors were 0.17 in. (4 mm) and 0.29 in. (7 mm), respectively.

The bottom cable disengaged from the cable end fitting at the upstream anchor. At the downstream end of the upstream load cell, the bottom cable threaded rod fractured and the bottom cable disengaged from the downstream end of the cable end fitting. At the downstream end of the upstream load cell, the middle cable disengaged from the downstream end of the cable end fitting. The top cable disengaged from the cable end fitting at the downstream anchor.

Post no. 1 deflected slightly downstream and the front flange cracked at the weld. Post nos. 3, 7, and 8 through 10 rotated downstream, and post nos. 4 through 6 bent and twisted downstream. Post no. 16 deflected backward, while post nos. 17 and 18 bent backward and downstream. Post nos. 19 and 38 rotated backward, post no. 36 rotated upstream, and post no. 40 bent upstream.

The top cable disengaged from post nos. 4, 17, 18, 19, and 40. The middle cable disengaged from post nos. 2, 4, 5, and 17. The bottom cable disengaged from post nos. 1 through 10 and post no. 18. The bottom J-bolt at post no. 4 fractured and localized gouging occurred at the location of the bottom J-bolt on the front, upstream flange of post nos. 7 and 8. On the front, upstream edge of the flange of post nos. 17 and 18, denting and gouging from the cable were observed. Contact marks were observed on the top of post no. 18. The bottom J-bolt of post no. 18 fractured.

6.6 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 53 and 54. The maximum occupant compartment deformations are listed in Table 7 along with the deformation limits established in MASH for various areas of the occupant compartment. Note that the maximum deformation on the windshield location exceeded MASH established deformation limits. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix E.

Table 7. Maximum Occupant Compartment Deformations by Location

LOCATION	MAXIMUM DEFORMATION in. (mm)	MASH ALLOWABLE DEFORMATION in. (mm)
Wheel Well & Toe Pan	⅜ (10)	≤ 9 (229)
Floor Pan & Transmission Tunnel	¼ (6)	≤ 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	0	≤ 4 (102)
Windshield	6¼ (159)	≤ 3 (76)

The majority of the damage was concentrated on the left-front corner and left side of the vehicle where the impact occurred. Gouging occurred along the top length of the left-front fender, and a 1-in. (25-mm) wide gap was found between the left-front fender and the hood. A 4-in. (102-mm) long dent occurred in the top of the left-front fender, and a 7-in. (178-mm) long gouge occurred on the left A-pillar. The left-side mirror was disengaged, and the antenna on the left-rear corner of the vehicle was bent.

A 22-in. (559-mm) long tear was found in the left-front bumper, approximately 21 in. (533 mm) above ground line due to the bottom cable. The entire length of the front bumper was gouged, also due to contact with the bottom cable. A 1-in. (25-mm) diameter hole was present on the left side of the bumper. Windshield penetration occurred in two areas: a 1¼-in. (32-mm) diameter hole in the lower-left corner and a 5-in. (127 mm) diameter hole in the upper-middle of the windshield. The windshield crush was 43 in. (1,092 mm) long, from the lower-right corner to the upper-middle of the windshield. A ¾-in. (19-mm) wide gap occurred between the right-front fender and the hood.

Cable contact marks were observed on the roof, left headlight, left-front and left-rear wheel hub cap, and along the entire length of the left-side doors. A 52-in. (1,321-mm) long dent occurred from the middle of the front of the hood to the left-rear of the hood with cable contact marks on the top of the left-front fender. There was significant deformation in both the front and rear windshields. The left-front A-pillar and fender were deformed.

6.7 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 8. 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 8. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 42. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix F.

Table 8. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NYJ-1

Evaluation Criteria		**Transducer**			**MASH Limits**
		DTS	**SLICE**	**EDR-3**	
OIV ft/s (m/s)	Longitudinal	-16.67 (-5.08)	-16.40 (-5.00)	-16.86 (-5.14)	≤ 40 (12.2)
	Lateral	7.15 (2.18)	7.12 (2.17)	6.63 (2.02)	≤40 (12.2)
ORA g’s	Longitudinal	-3.13	-3.19	-2.75	≤ 20.49
	Lateral	3.22	4.07	1.86	≤ 20.49
THIV ft/s (m/s)		18.37 (5.60)	17.72 (5.40)	NA	not required
PHD g’s		3.43	3.32	NA	not required
ASI		0.34	0.34	0.34	not required

6.8 Load Cell and String Potentiometer Results

Data was acquired by load cells near the upstream (US) and downstream (DS) anchors and later analyzed. The maximum loads measured by the transducers are summarized in Table 9. The individual cable loads were determined and are shown graphically in Figure 55.

Anchor displacement was also of primary concern in the evaluation of the three-cable guardrail system. The displacement-time histories of the downstream and upstream anchors are shown in Figure 56. The anchor on the downstream end of the barrier had a maximum displacement of 0.29 in. (7 mm). The anchor on the upstream end had a maximum displacement of 0.17 in. (4 mm).

Table 9. Load Cell Results, Test No. NYJ-1

Cable Location	Sensor Location	Maximum Cable Load		Time After Impact (sec)
		kips	kN	
Combined Cables	Upstream Anchor	19.54	86.92	0.144
Top Cable	Upstream End	5.82	25.89	0.116
Middle Cable	Upstream End	2.90	12.90	0.099
Bottom Cable	Upstream End	16.59	73.80	0.144
Combined Cables	Downstream Anchor	14.58	64.86	0.146
Top Cable	Downstream End	3.98	17.70	0.119
Middle Cable	Downstream End	2.42	10.76	0.139
Bottom Cable	Downstream End	12.35	54.94	0.146

6.9 Discussion

The analysis of the test results for test no. NYJ-1 showed that the cable guardrail with ½-in. (13-mm) diameter J-bolts and redesigned anchor post stub did not adequately contain the 1500A vehicle. The cable rail elements disengaged from the cable end fittings in multiple locations, leading to complete loss of rail tension and cable disengagement from the vehicle and extensive test article damage. In addition, cables caused significant windshield crush and penetration, which exceeded allowable deformation specified in MASH. Therefore, test no. NYJ-1 was determined to be unacceptable according to the MASH safety performance criteria for the modified test designation no. 3-10.

6.10 Analysis of Test No. NYJ-1 and Modifications for Retest

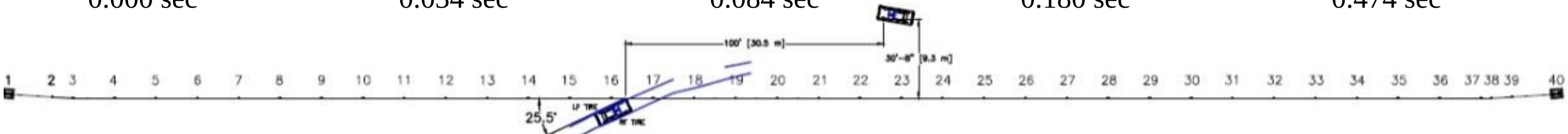
High-speed digital video, transducer data, and test installation procedures used in test no. NYJ-1 were analyzed to determine what modifications, if any, would contribute to a successful retest of the modified three-cable guardrail system with ½-in. (13-mm) diameter, cable-to-post attachments. Several potential causes were identified, but three were believed to be more significant and are discussed below.

1. Cable end fittings are commonly used in combination with low-tension, cable barrier systems. Cable end fittings consist of a malleable cast iron, tapered and grooved wedge that is swaged between the cable strands due to a combination of cable tension, pressure against the end fitting bucket, and friction. One wire is often bent over the wedge to retain it and guard against long-term thermal and impact load cycling, which could cause the wedge to become disengaged. For testing purposes, bending one wire over the wedge has never previously been required; because, the system was not subjected to long-term thermal cycling, and the systems were inspected before and after each crash test for possible end termination wedge slip. Therefore, one wire was not bent over the wedges at cable end fittings per normal operating procedures for test no. NYJ-1.
2. The detailed cable tension investigation involved extensive load cycling with maximum loads not exceeding 1,000 lb (4.4 kN). Dynamic, low-load cycle tests included staff abruptly loading cable wire rope multiple times and in multiple

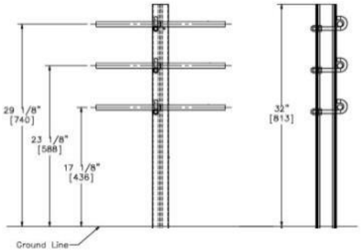
locations, as well as quasi-static tensioning of turnbuckles near the upstream end of the system. The load cycling may have contributed to partial loosening and/or disengagement of the wedges away from the cable ends and minor wedge slip. Although pre-test inspection did observe some wedge slip, it was not considered sufficient to cause cable release.

3. Cable-to-post attachments (i.e., J-bolts) were increased from $^{5}/_{16}$-in. (8-mm) to ½-in. (13-mm) diameter to potentially improve vehicle-to-barrier interaction. Cables are predominantly tension members, which transmit impact forces to posts and cable-to-post attachments via lateral and vertical displacements of the cable. The force transmitted to the attachments and posts is dependent on the deflection angle of the cable and cable tension. By increasing the size and strength of the cable-to-post attachment, the cable deflection required to disengage a cable away from a post or cable-to-post attachment increased significantly, and large-amplitude, high-frequency waves were propagated away from impact.

0.000 sec 0.034 sec 0.084 sec 0.180 sec 0.474 sec



- Test Agency.......................MwRSF
- Test Number.......................NYJ-1
- Date 6/18/2013
- MASH Test Designation.......................Modified 3-10
- Test Article ....Cable Guardrail with ½-in. (13-mm) diameter J-Bolts
- Total Length ....602.7 ft (183.7 m)
- Key Component – Cable
    - Size ....3x7, ¾-in. (19-mm) diameter
    - Top Cable Height.......................29⅛ in. (740 mm)
    - Bottom Cable Height ....17⅛ in. (435 mm)
    - Incremental Cable Spacing....................... 6 in. (152 mm)
    - Number of Cables 3
- Key Component - Post
    - Length.......................65 in. (1,651 mm)
    - Shape ....S3x5.7 (S76x8.5) with soil plate
    - Spacing .... 16 ft (4.9 m)
    - Embedment Depth ....33 in. (838 mm)
- Soil Type ....Grading B – AASHTO 147-65
- Vehicle Make/Model ....2006 Ford Taurus
    - Curb ....3,179 lb (1,442 kg)
    - Test Inertial.......................3,294 lb (1,494 kg)
    - Gross Static.......................3,426 lb (1,554 kg)
- Impact Conditions
    - Speed ....62.7 mph (100.9 km/h)
    - Angle .... 25.5 deg
    - Impact Severity (IS).......................80.2 kip-ft (108.7 kJ)
    - Impact Location ....65 in. (1,651 mm) downstream of post no. 16
- Exit Box Criterion .... NA
- Vehicle Stability.......................Satisfactory
- Vehicle Stopping Distance.................... 100 ft (30.5 m) downstream of impact
  30.7 ft (9.4 m) laterally behind system
- Vehicle Damage ....Moderate
    - VDS[11]....................... 11-FD-1
    - CDC[12].......................51-TYYW-3
- Test Article Damage .... Severe



- Maximum Test Article Deflections
    - Permanent Set.......................NA
    - Dynamic ....NA
    - Working Width.......................NA
- Maximum Windshield Deformation ....6¼ in. (159 mm)
- Maximum Angular Displacements
    - Roll .... 10.0° < 75°
    - Pitch....................... 7.3° < 75°
    - Yaw ....216.9°
- Transducer Data

Evaluation Criteria		Transducer			MASH Limit
		DTS	SLICE	EDR-3	
OIV ft/s (m/s)	Longitudinal	-16.67 (5.08)	-16.40 (-5.00)	-16.86 (-5.14)	≤ 40 (12.2)
	Lateral	7.15 (2.18)	7.12 (2.17)	6.63 (2.02)	≤ 40 (12.2)
ORA g's	Longitudinal	-3.13	-3.19	-2.75	≤ 20.49
	Lateral	3.22	4.07	1.86	≤ 20.49
THIV – ft/s (m/s)		18.37 (5.60)	17.72 (5.40)	NA	not required
PHD – g's		3.43	3.32	NA	not required
ASI		0.34	0.34	0.34	not required

Figure 42. Summary of Test Results and Sequential Photographs, Test No. NYJ-1

0.000 sec

0.022 sec

0.070 sec

0.124 sec

0.290 sec

0.430 sec

0.000 sec

0.010 sec

0.034

0.086 sec

0.182 sec

0.340 sec

Figure 43. Sequential Photographs, Test No. NYJ-1


0.000 sec


0.038 sec


0.114 sec


0.224 sec


0.420 sec


0.946 sec


0.000 sec


0.058 sec


0.106 sec


0.220 sec


0.412 sec


0.668 sec

Figure 44. Additional Sequential Photographs, Test No. NYJ-1

Figure 45. Impact Location, Test No. NYJ-1

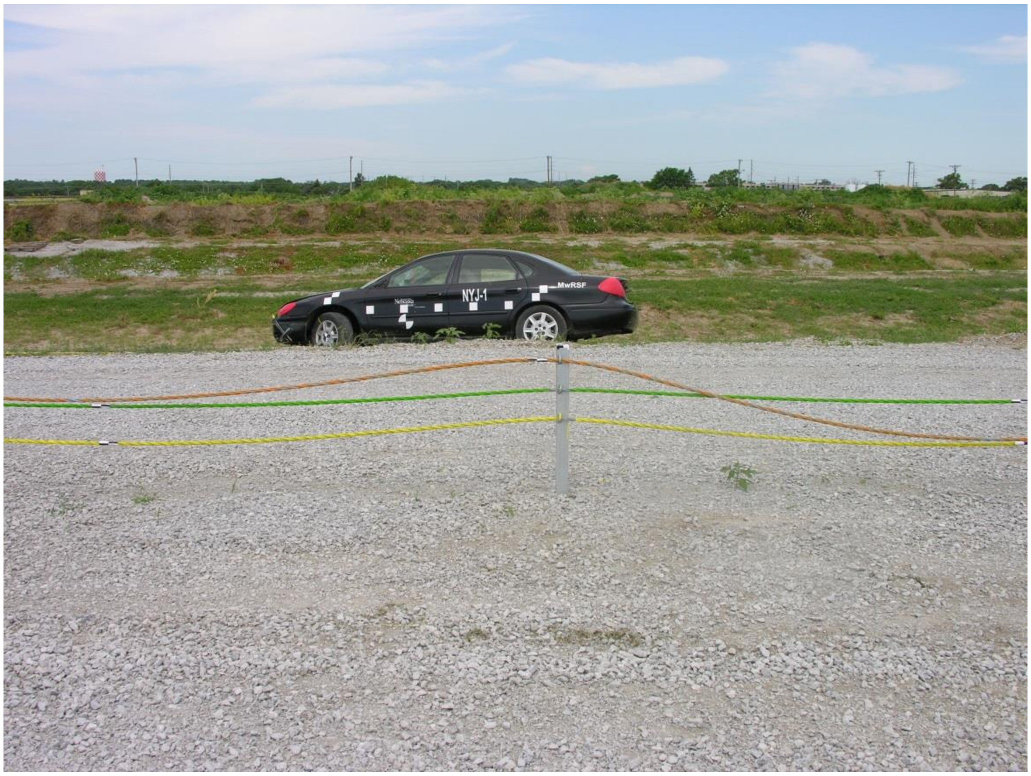


Figure 46. Vehicle Final Position, Test No. NYJ-1

Figure 47. Post Damage in Impact Region, Test No. NYJ-1

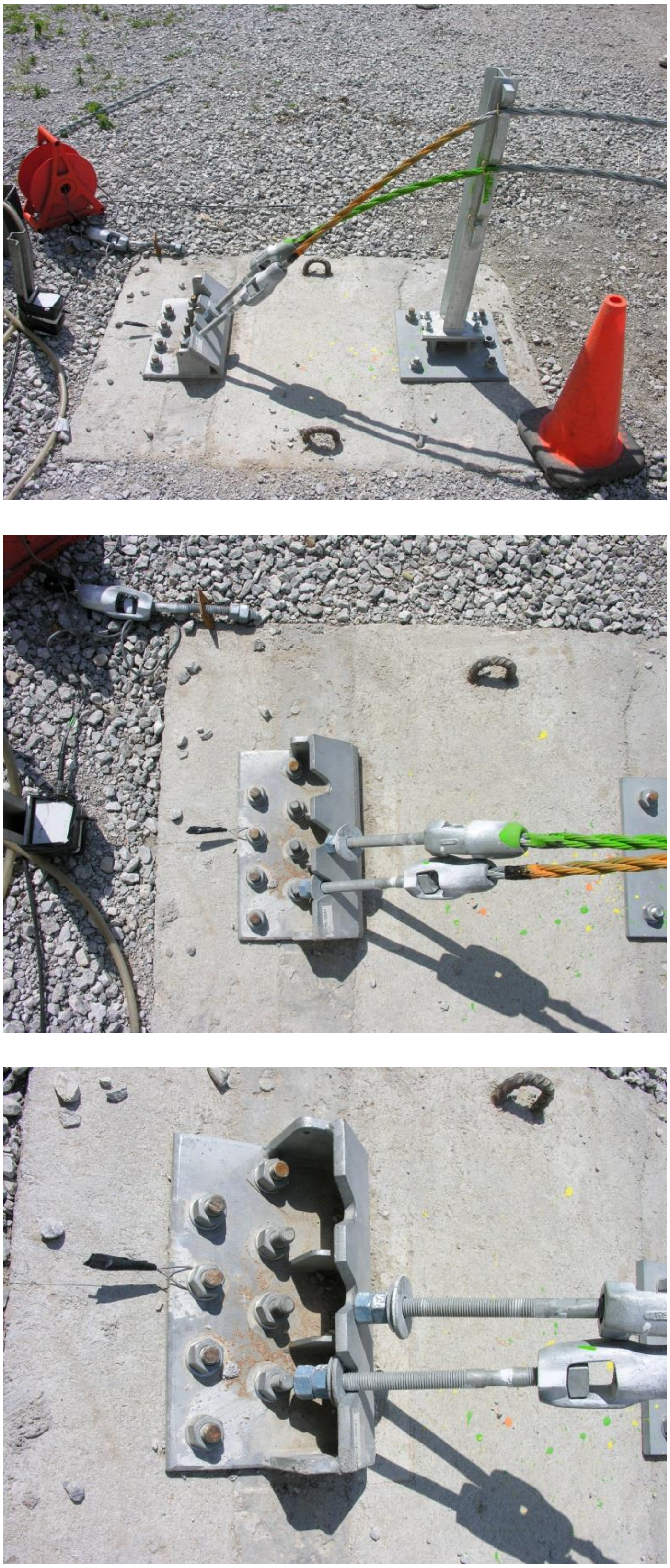


Figure 48. Upstream Anchor Damage, Test No. NYJ-1

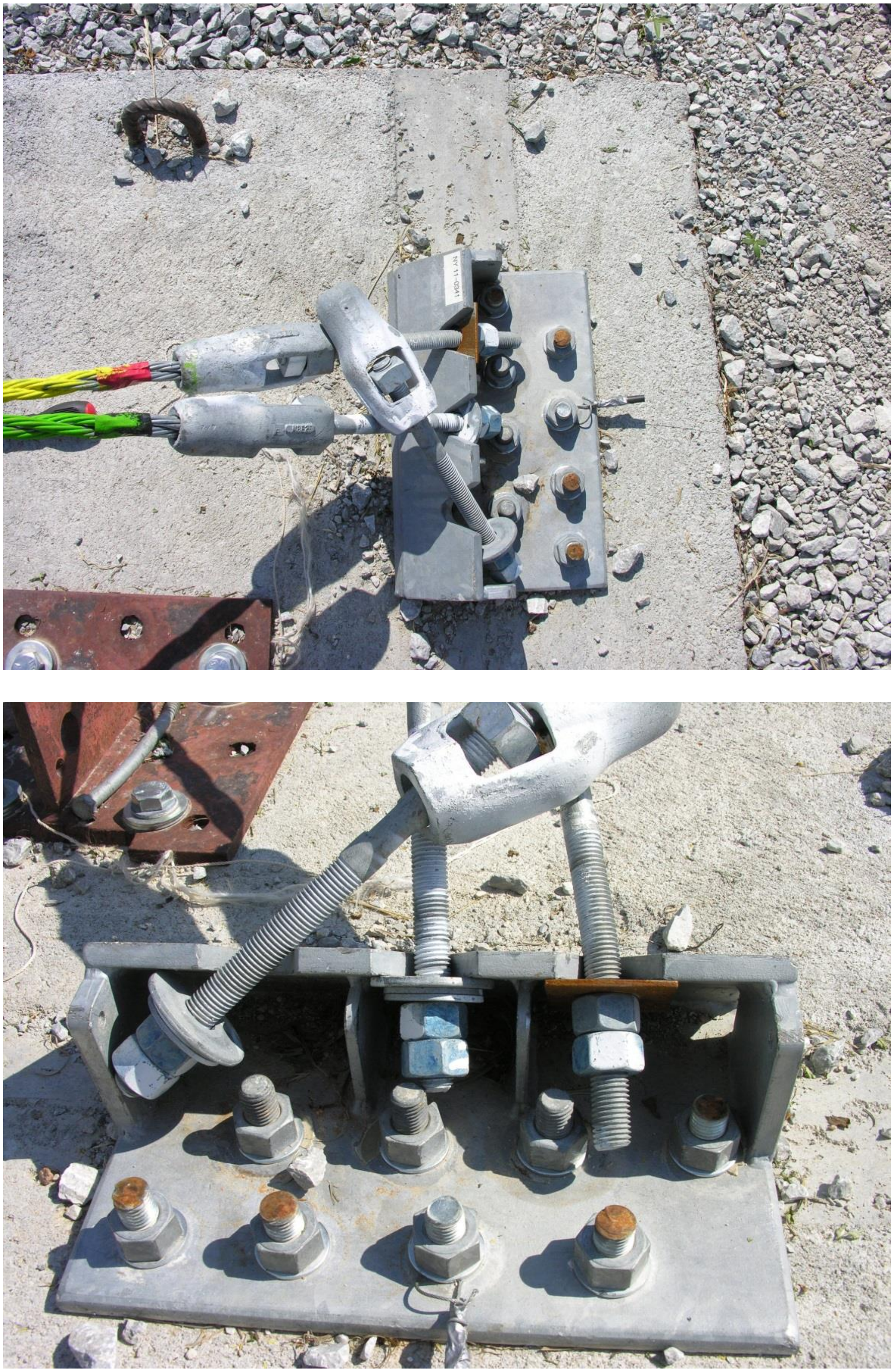


Figure 49. Downstream Anchor Damage, Test No. NYJ-1

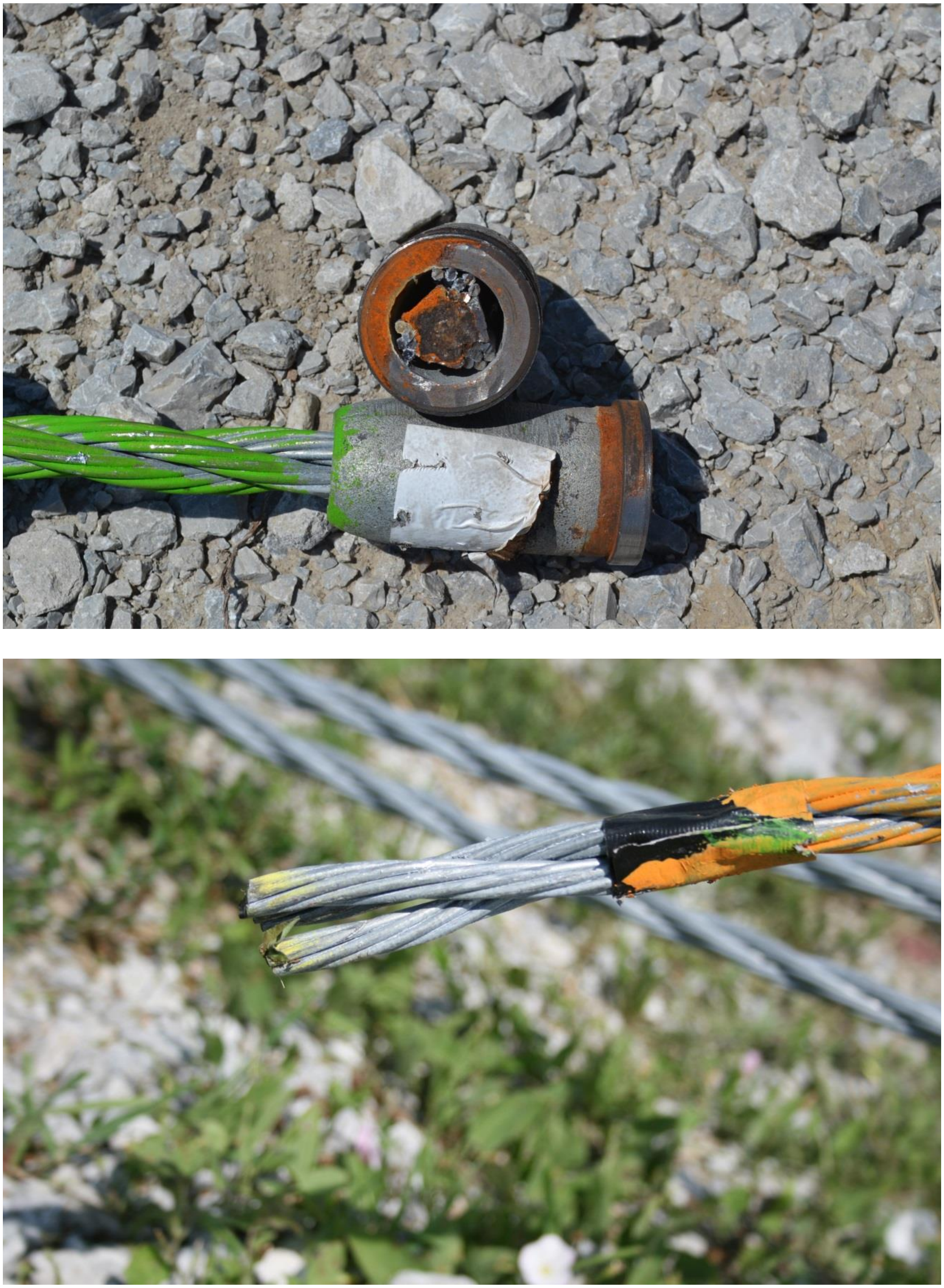


Figure 50. Hardware Fractures and Frayed Cable, Test No. NYJ-1

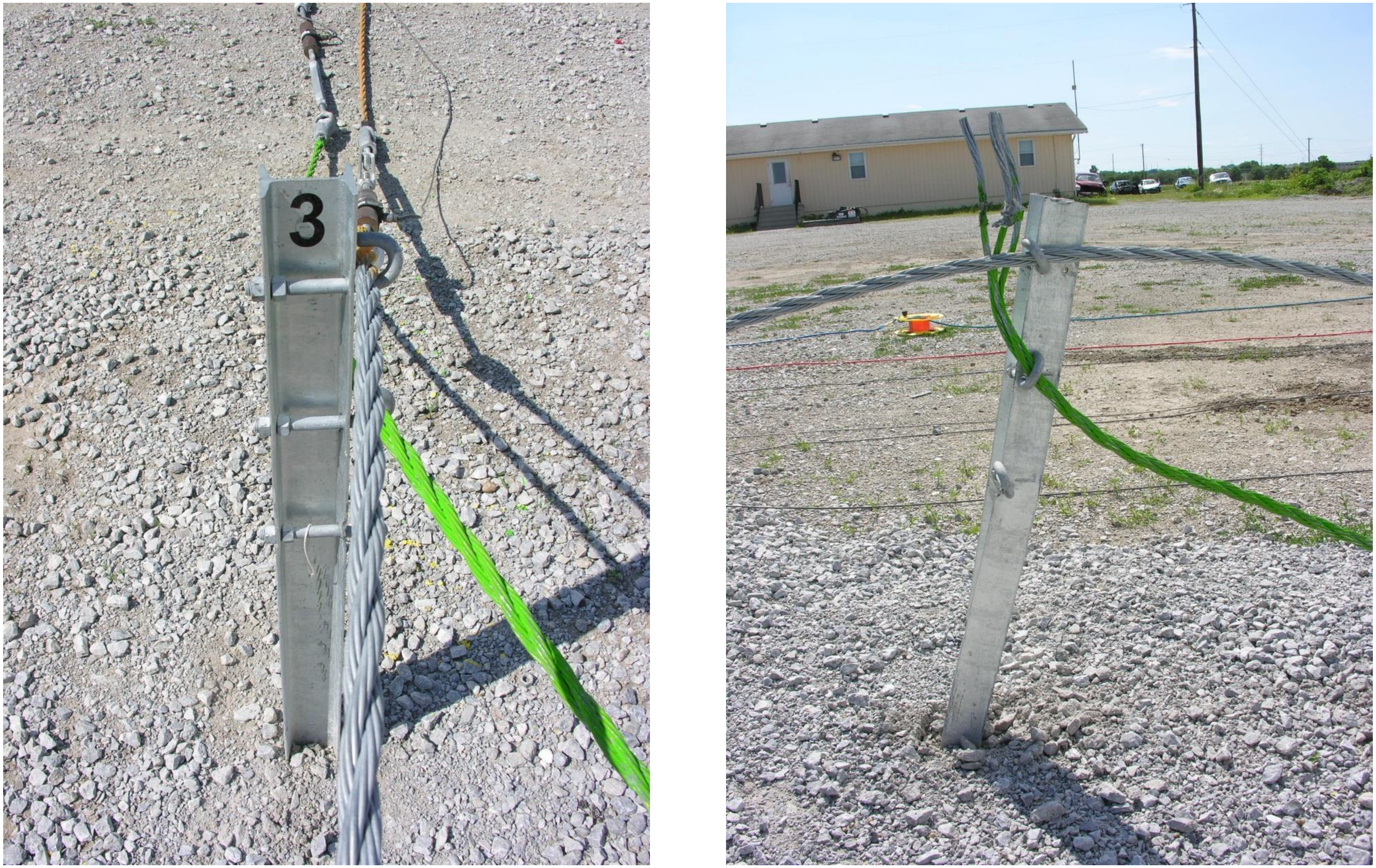


Figure 51. Cable Damage, Test No. NYJ-1

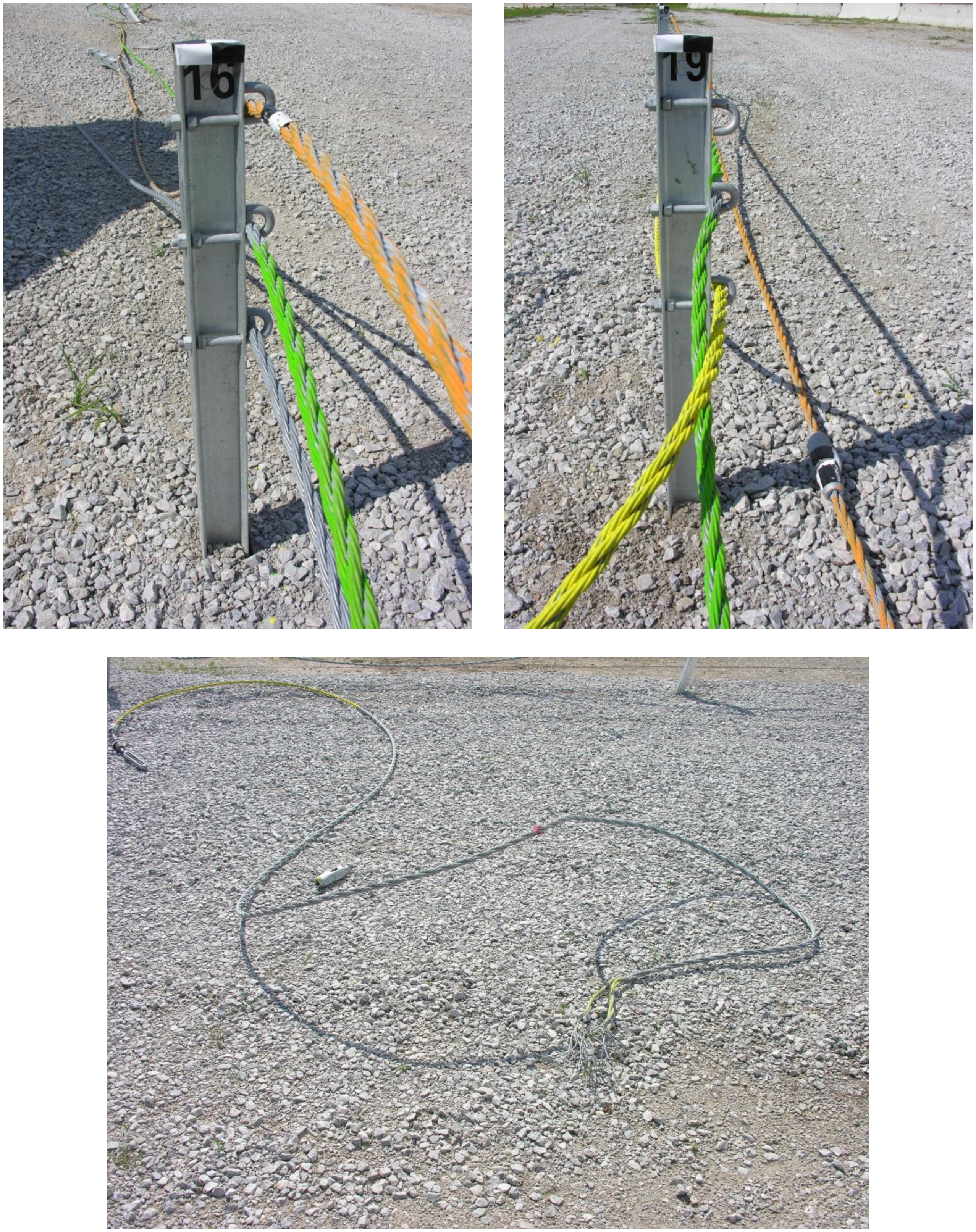


Figure 52. Additional Cable Damage, Test No. NYJ-1

Figure 53. Vehicle Damage, Test No. NYJ-1

Figure 54. Vehicle Damage, Test No. NYJ-1

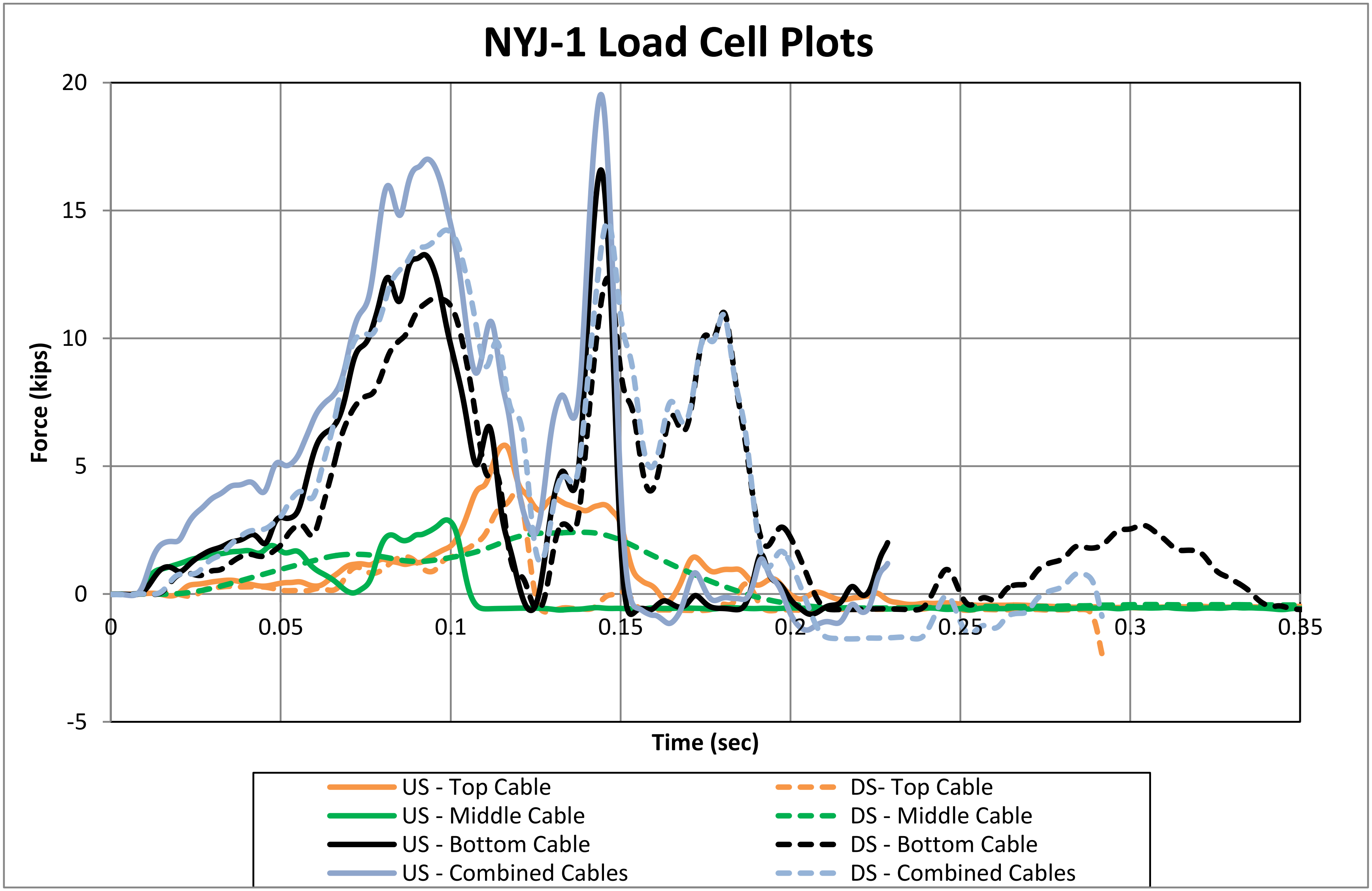


Figure 55. Cable Tension vs. Time, Test No. NYJ-1

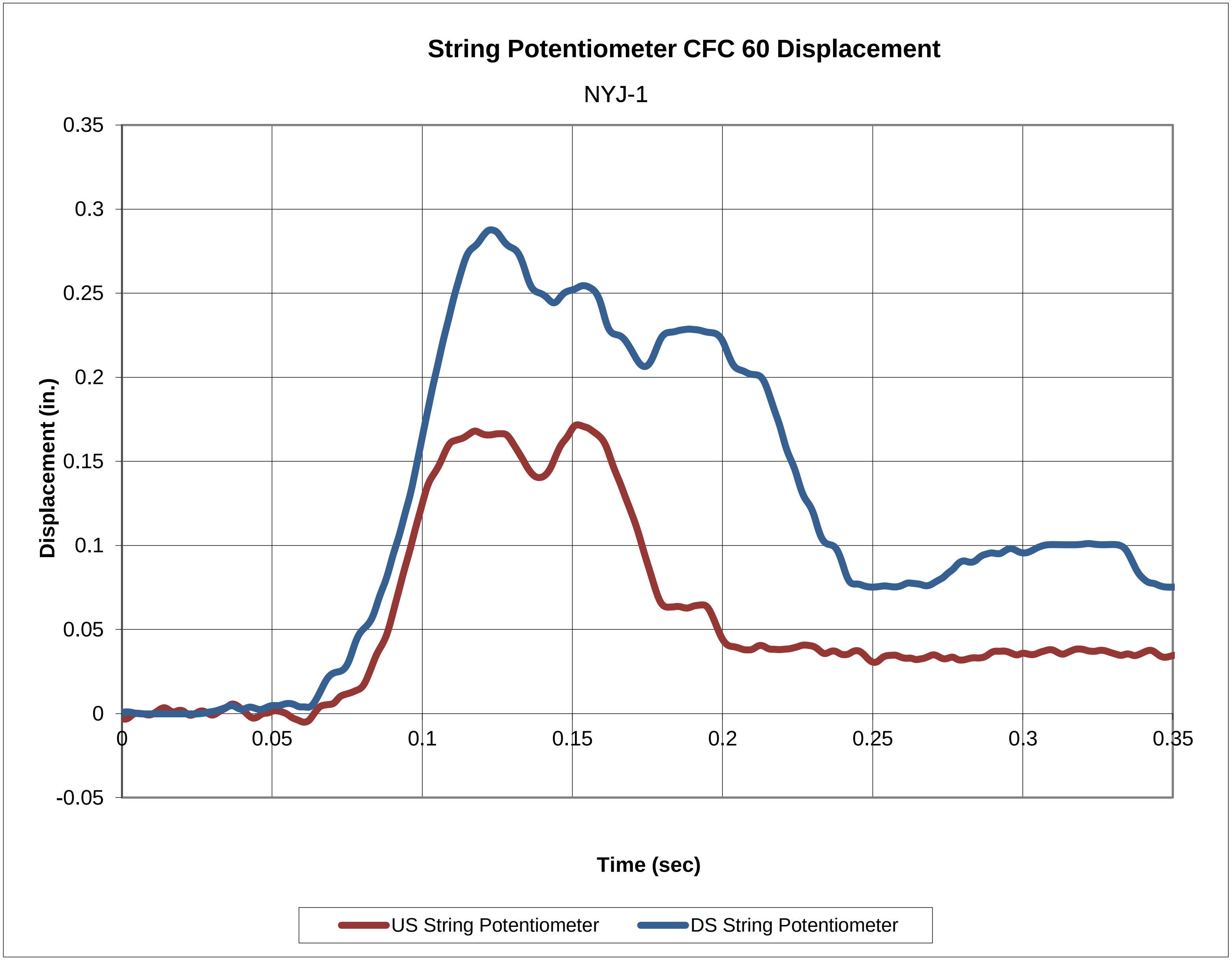
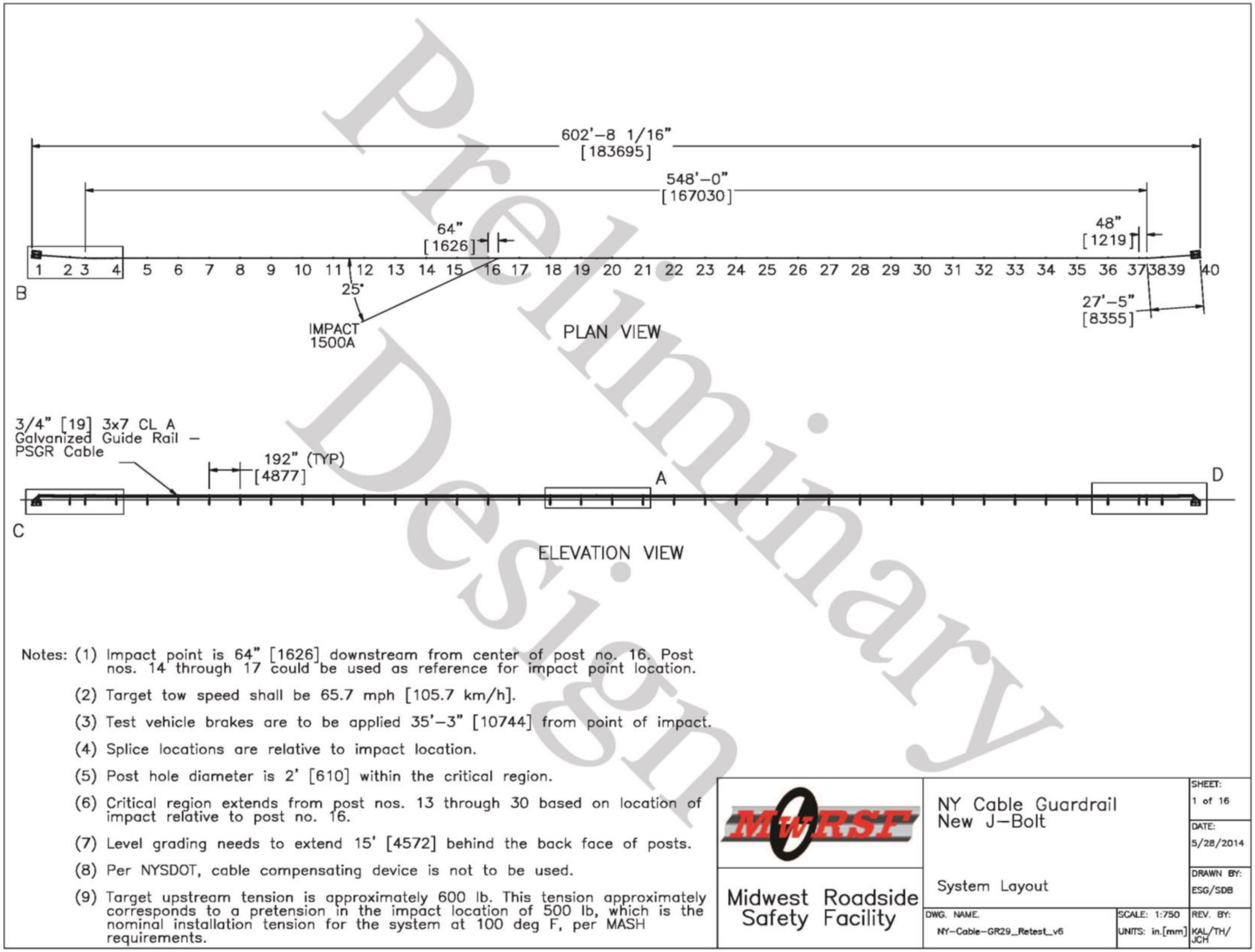


Figure 56. Displacement-Time History Plot for Anchors, Test No. NYJ-1

7 DESIGN DETAILS

Since several causes could have contributed to the unsuccessful test no. NYJ-1, the system was retested with the same configuration as used in test no. NYJ-1 for test no. NYJ-2. However, prior to test no. NYJ-2, a chisel and sledge hammer were used to pound wedges into end fittings, and a wire was bent over each wedge. Cyclic loading of the cables prior to testing did not occur, and tensioning only occurred on test day. The downstream load cells were not installed to eliminate six downstream cable end fittings. These modifications were believed to minimize the risk associated with non-test factors and to evaluate the adequacy of the increased cable-to-post attachment strengths. Design details for test nos. NYJ-2 and NYJ-3 are shown in Figures 57 through 73.



Notes: (1) Impact point is 64" [1626] downstream from center of post no. 16. Post nos. 14 through 17 could be used as reference for impact point location.

(2) Target tow speed shall be 65.7 mph [105.7 km/h].

(3) Test vehicle brakes are to be applied 35'-3" [10744] from point of impact.

(4) Splice locations are relative to impact location.

(5) Post hole diameter is 2' [610] within the critical region.

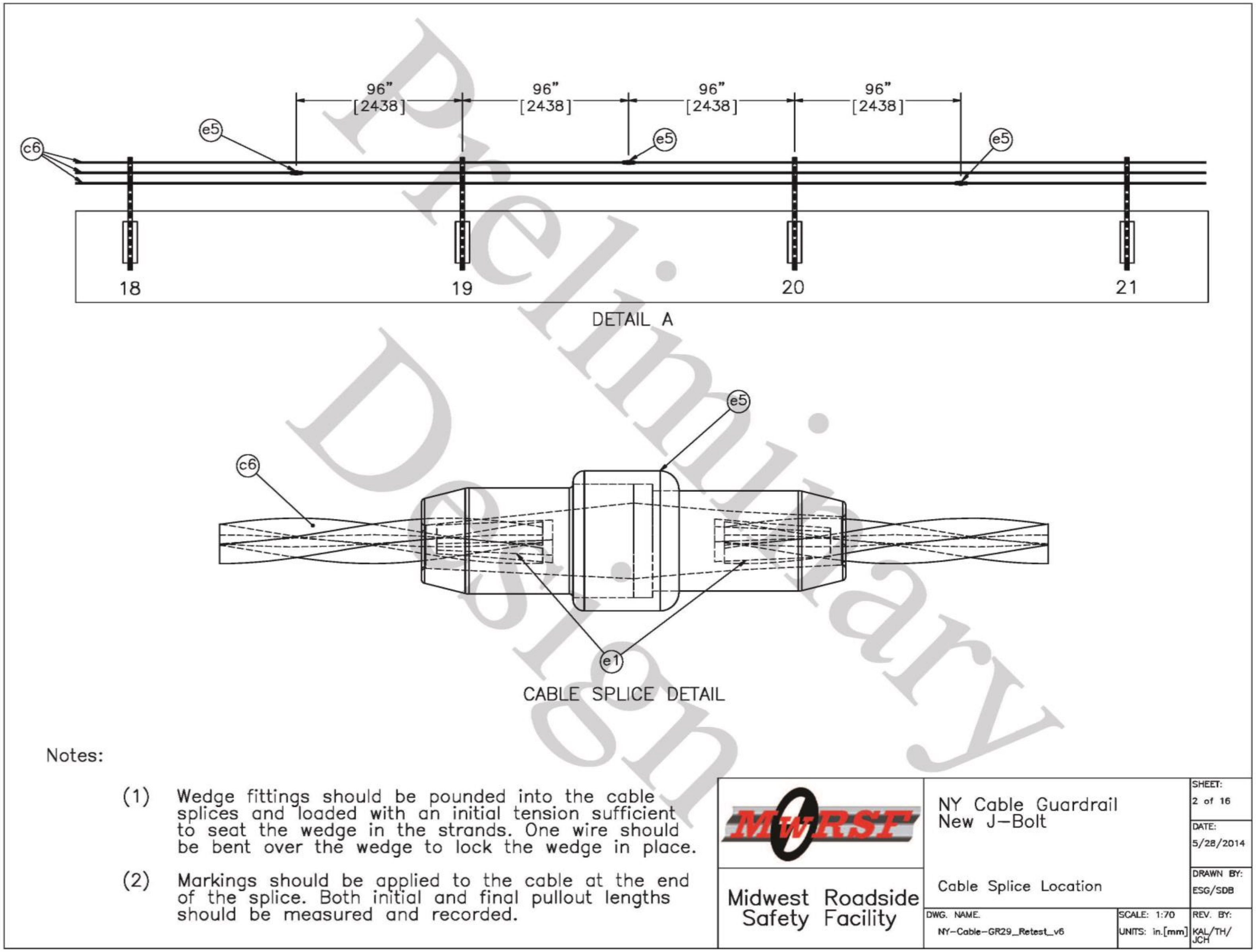
(6) Critical region extends from post nos. 13 through 30 based on location of impact relative to post no. 16.

(7) Level grading needs to extend 15' [4572] behind the back face of posts.

(8) Per NYSDOT, cable compensating device is not to be used.

(9) Target upstream tension is approximately 600 lb. This tension approximately corresponds to a pretension in the impact location of 500 lb, which is the nominal installation tension for the system at 100 deg F, per MASH requirements.

Figure 57. Test Installation Layout, Test No. NYJ-2

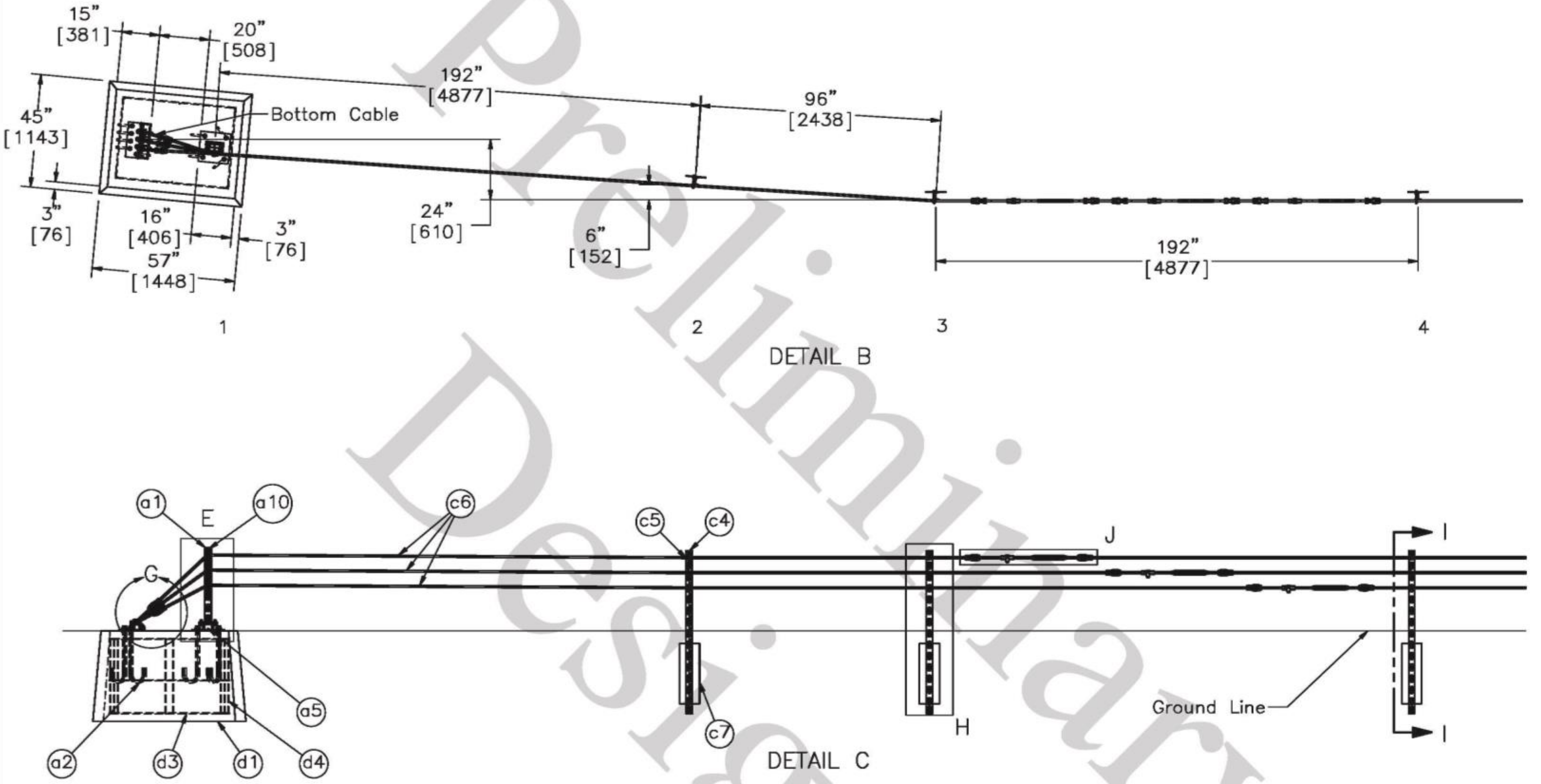


Notes:

(1) Wedge fittings should be pounded into the cable splices and loaded with an initial tension sufficient to seat the wedge in the strands. One wire should be bent over the wedge to lock the wedge in place.

(2) Markings should be applied to the cable at the end of the splice. Both initial and final pullout lengths should be measured and recorded.

Figure 58. Cable Splice Location, Test No. NYJ-2



Notes:

(1) Wedge fittings should be pounded into the cable end fittings and loaded with an initial tension sufficient to seat the wedge in the strands. One wire should be bent over the wedge to lock the wedge in place.

(2) Markings should be applied to the cable at the end of the fitting. Both initial and final pullout lengths should be measured and recorded.

(3) The threaded rods should be inserted such that the end of the threaded rod is within 1/4" of the wedge before the cable is tensioned.

MwRSF
Midwest Roadside Safety Facility

NY Cable Guardrail
New J–Bolt

Upstream Cable Terminal Detail

SHEET: 3 of 16
DATE: 5/28/2014
DRAWN BY: ESG/SDB
DWG. NAME. NY–Cable–GR29_Retest_v6
SCALE: 1:60
UNITS: in.[mm]
REV. BY: KAL/TH/JCH

Figure 59. Upstream Cable Terminal Detail, Test No. NYJ-2

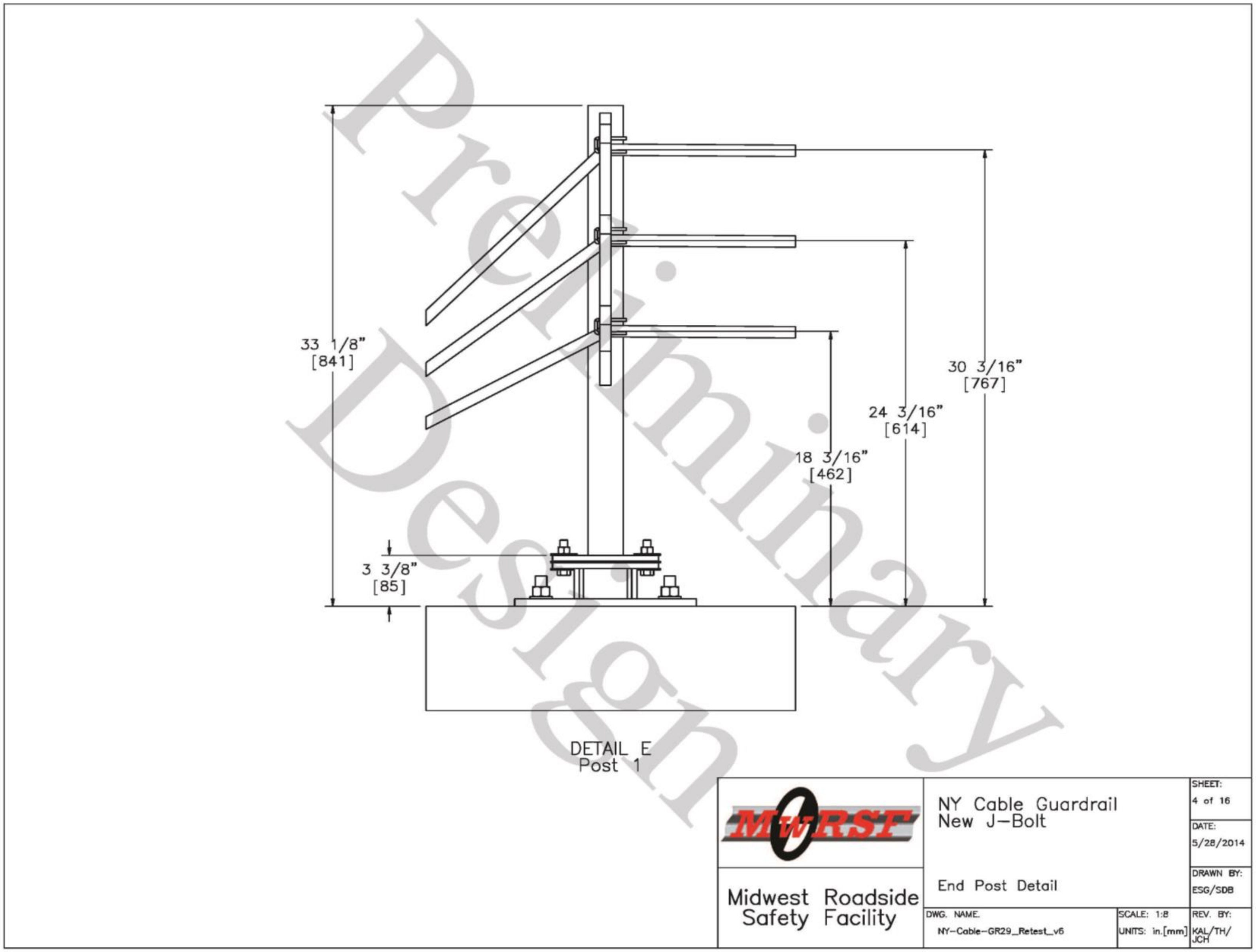
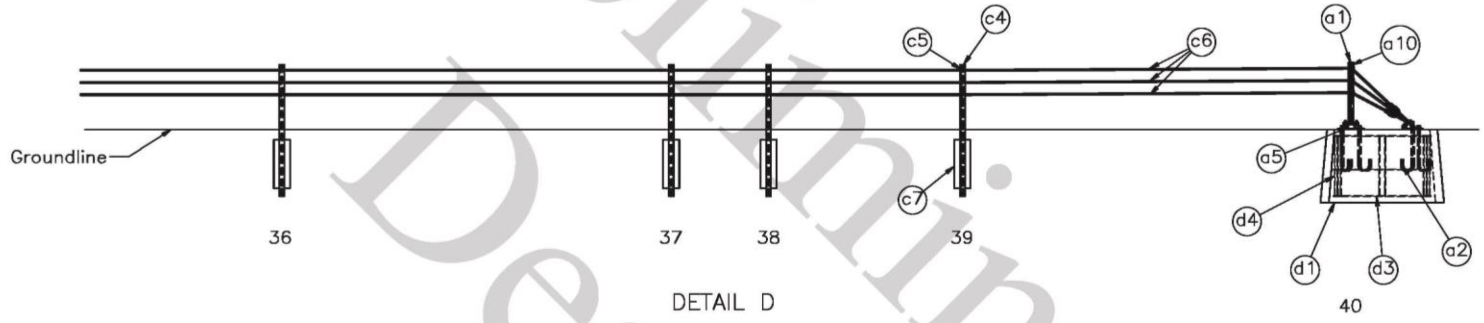


Figure 60. End Post Detail, Test No. NYJ-2



Notes:
(1) Wedge fittings should be pounded into the cable end fittings and loaded with an initial tension sufficient to seat the wedge in the strands. One wire should be bent over the wedge to lock the wedge in place.

(2) Markings should be applied to the cable at the end of the fitting. Both initial and final pullout lengths should be measured and recorded.

(3) The threaded rods should be inserted such that the end of the threaded rod is within 1/4" of the wedge before the cable is tensioned.

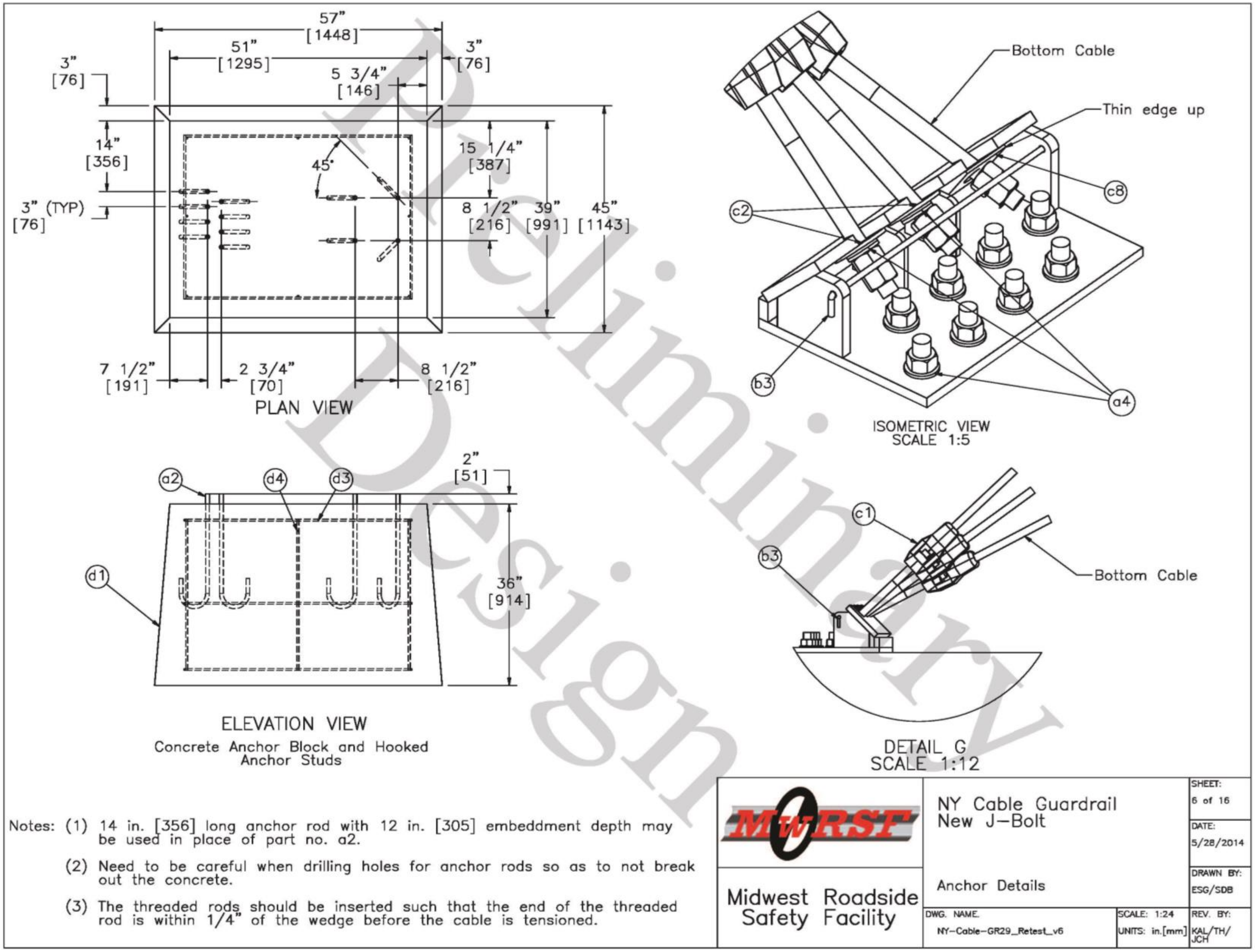
MwRSF
Midwest Roadside Safety Facility

NY Cable Guardrail
New J–Bolt

Downstream Cable Terminal Detail

SHEET: 5 of 16
DATE: 5/28/2014
DRAWN BY: ESG/SDB
DWG. NAME. NY–Cable–GR29_Retest_v6
SCALE: 1:75
UNITS: in.[mm]
REV. BY: KAL/TH/JCH

Figure 61. Downstream Cable Terminal Detail, Test No. NYJ-2



Notes: (1) 14 in. [356] long anchor rod with 12 in. [305] embeddment depth may be used in place of part no. a2.

(2) Need to be careful when drilling holes for anchor rods so as to not break out the concrete.

(3) The threaded rods should be inserted such that the end of the threaded rod is within 1/4" of the wedge before the cable is tensioned.

Figure 62. Anchor Details, Test No. NYJ-2

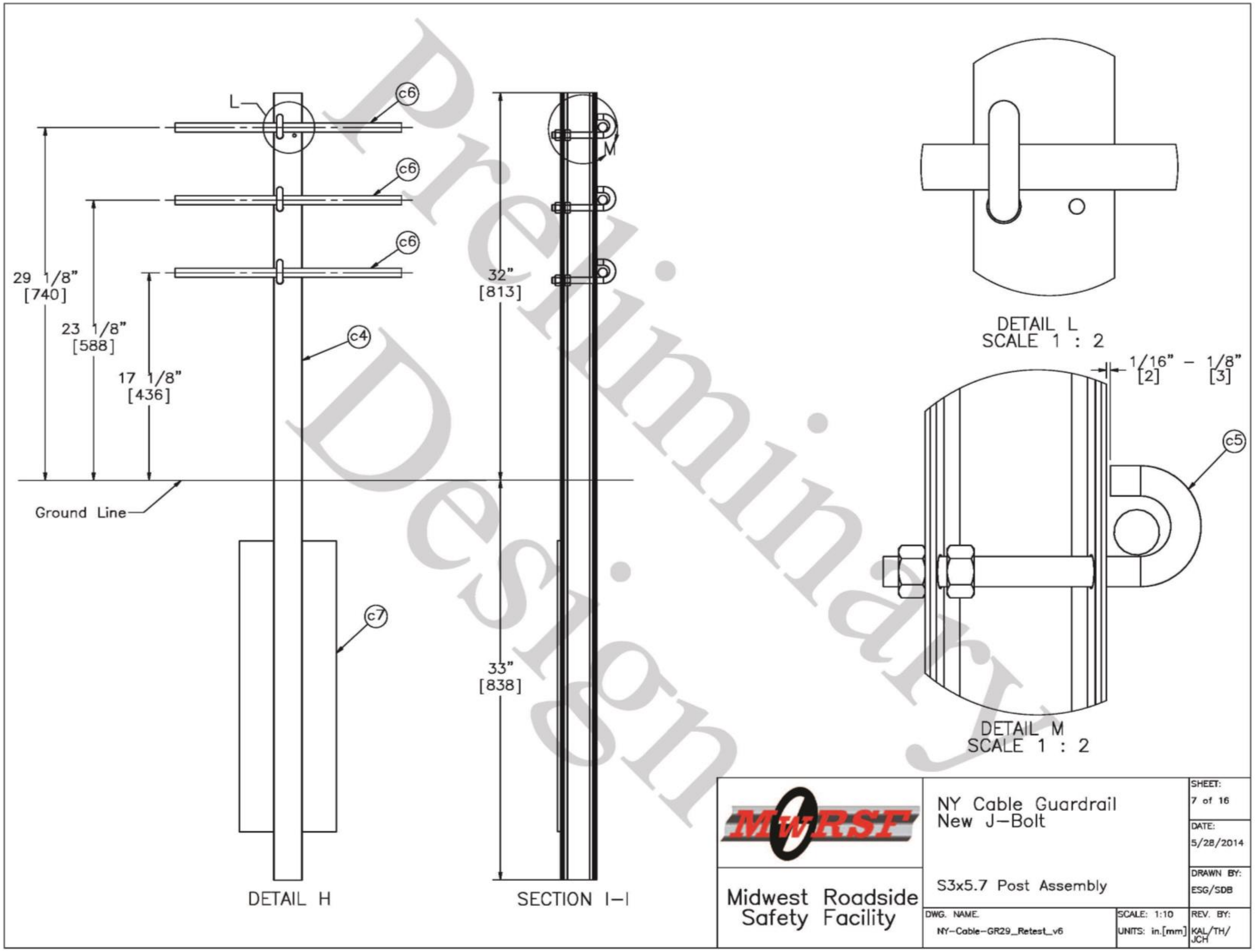
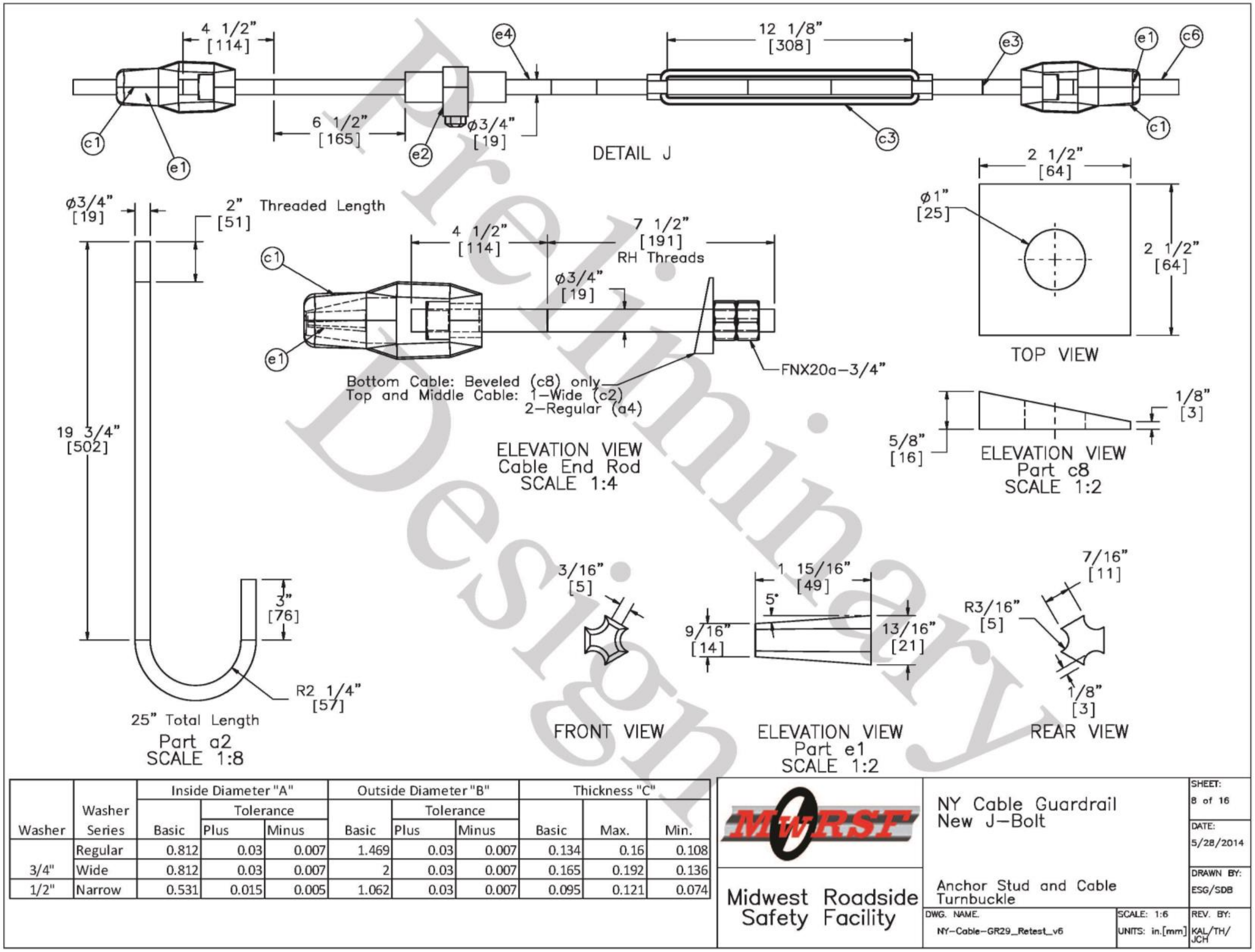


Figure 63. S3x5.7 Post Assembly, Test No. NYJ-2



		Inside Diameter "A"			Outside Diameter "B"			Thickness "C"		
			Tolerance			Tolerance				
Washer	Washer Series	Basic	Plus	Minus	Basic	Plus	Minus	Basic	Max.	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

Figure 64. Anchor Stud and Cable Turnbuckle, Test No. NYJ-2

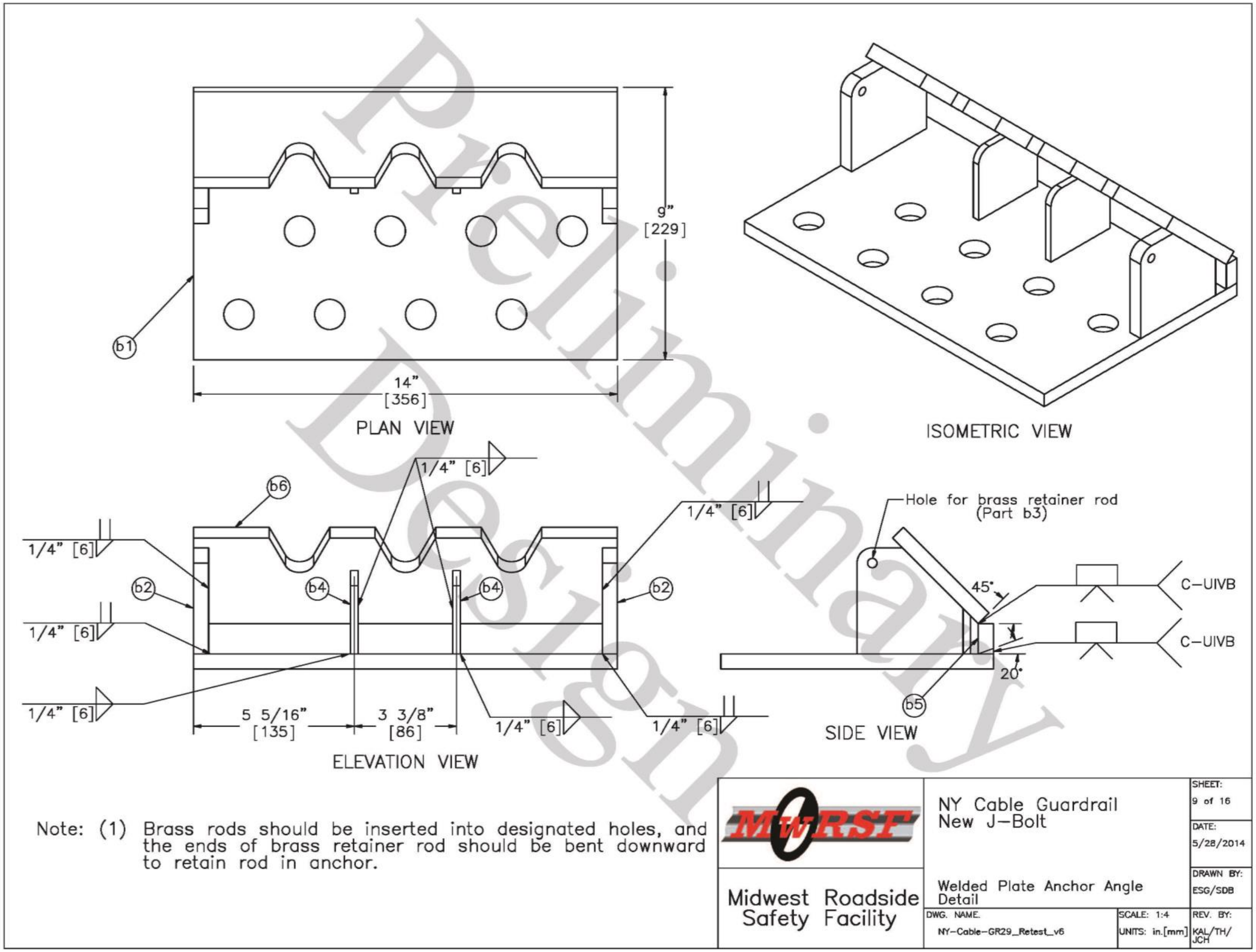


Figure 65. Welded Plate Anchor Angle Detail, Test No. NYJ-2

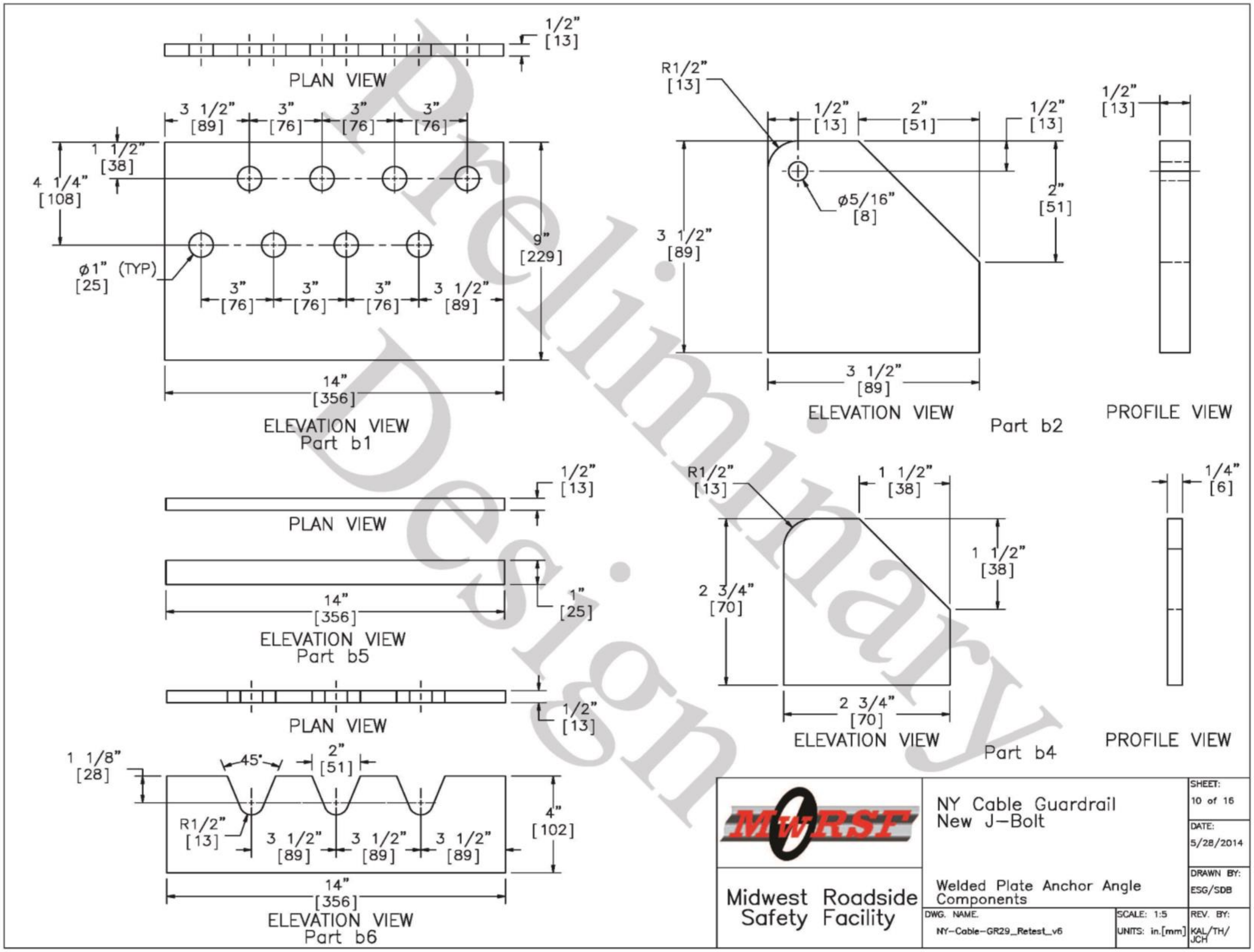


Figure 66. Welded Plate Anchor Angle Components, Test No. NYJ-2

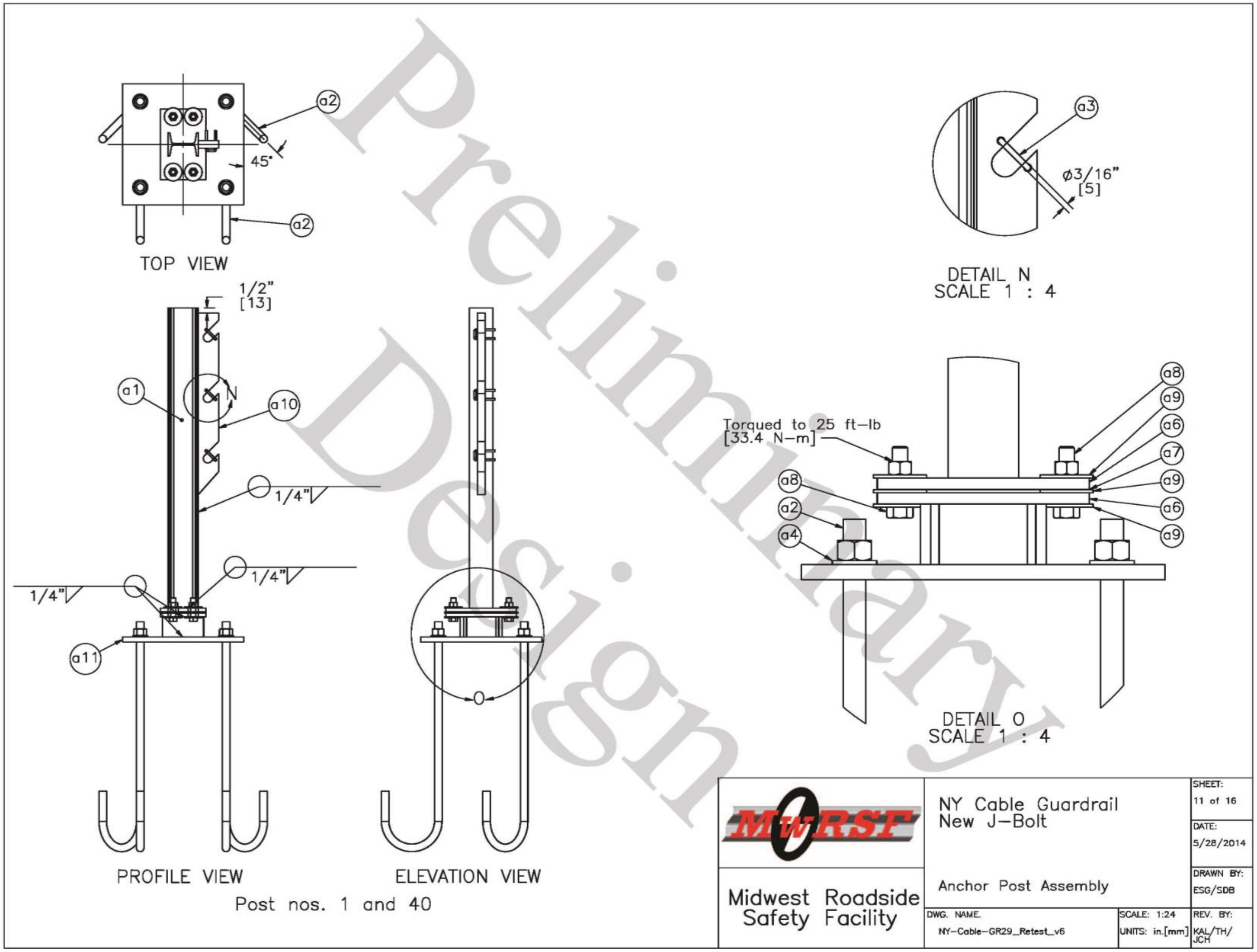


Figure 67. Anchor Post Assembly, Test No. NYJ-2

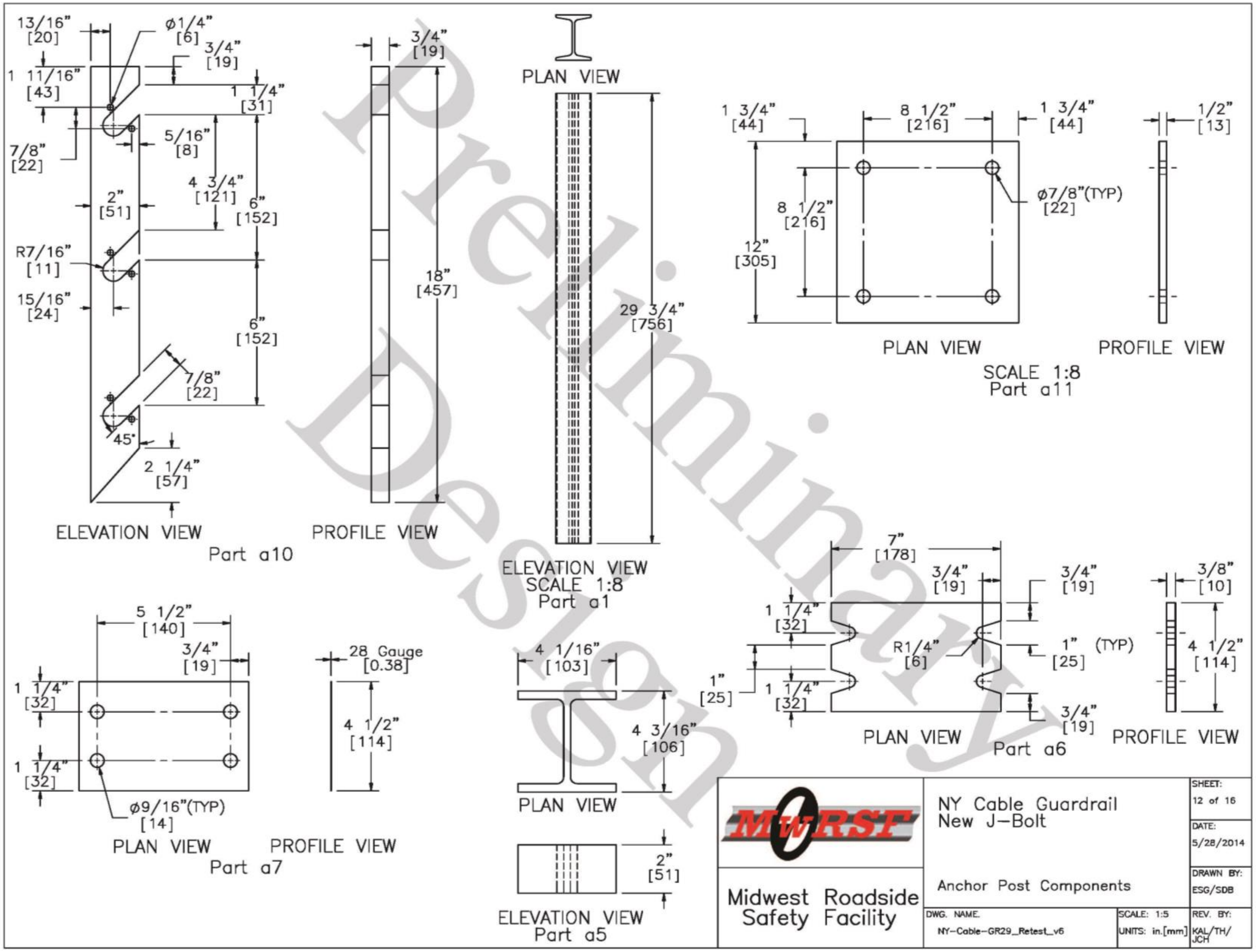


Figure 68. Anchor Post Components, Test No. NYJ-2

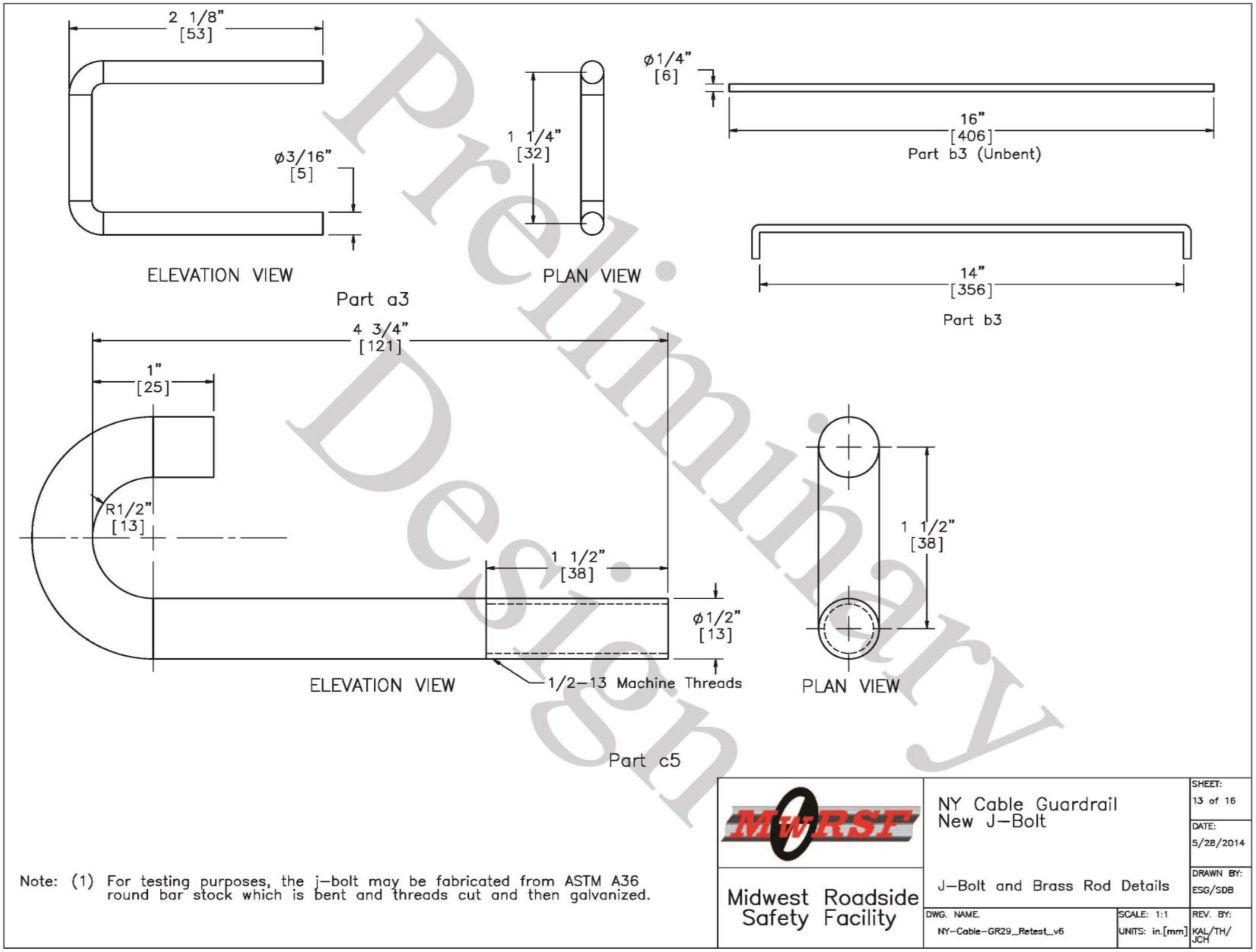


Figure 69. J-Bolt and Brass Rod Details, Test No. NYJ-2

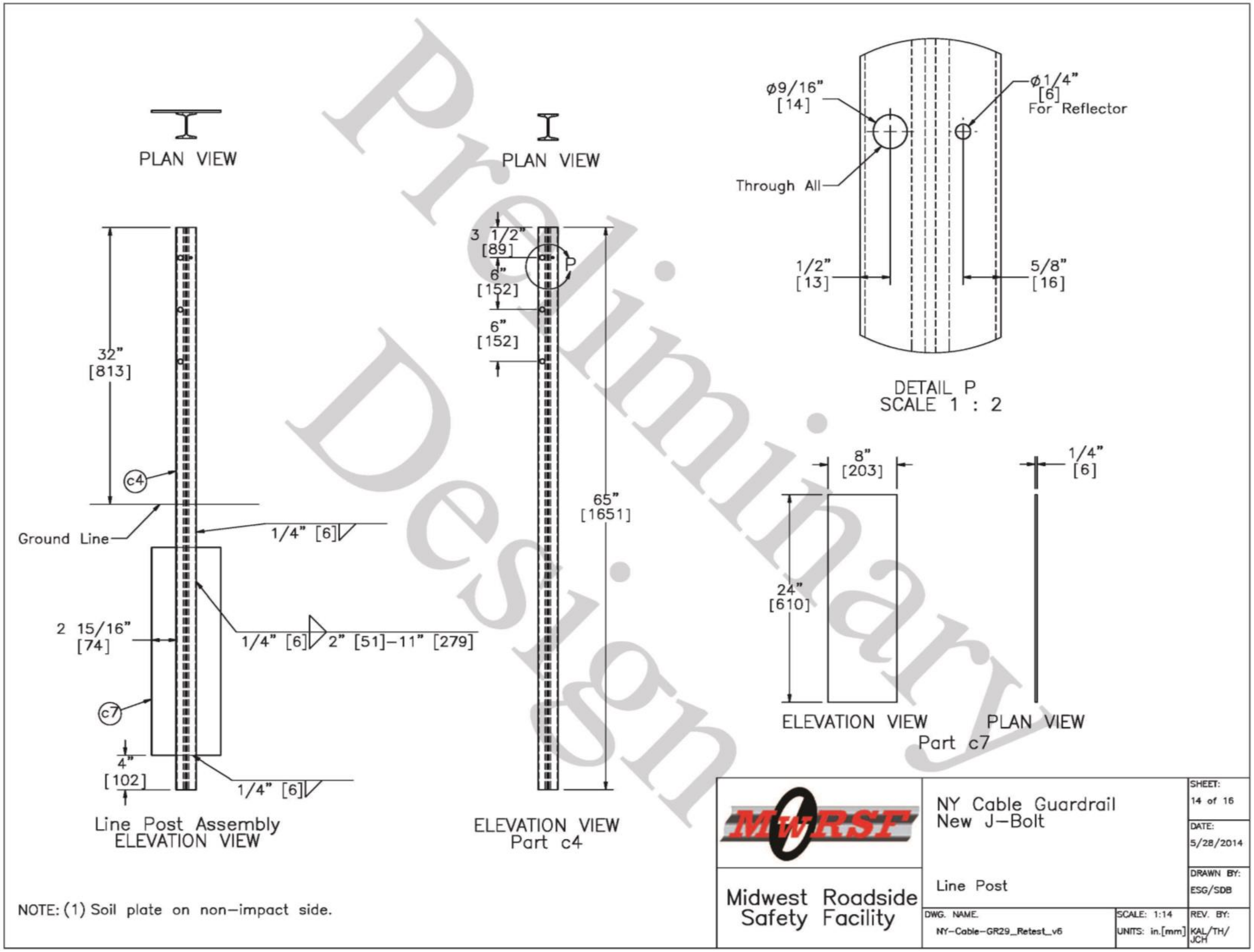


Figure 70. Line Post, Test No. NYJ-2

Item No.	QTY.	Description	Material Specification	Hardware Guide
a1	2	S3x5.7 [S76x8.5] 29 3/4" [756] Long Anchor Post	ASTM A36 Galv.	–
a2	24	3/4" [19] Dia. UNC, Hooked Anchor J–Bolt and Nut	ASTM A307 Gr. C and ASTM A563 DH Galv.	FRH20a
a3	6	3/16" [5] Dia. 5 1/4" [133] Long Brass Rod	ASTM B16–00	–
a4	32	3/4" [19] Dia. Plain Round Washer (OD 1.5" [38])	ASTM F844/SAE Gr. 2	FWC20a
a5	2	W4x13 [W102x19.3] Anchor Post Stub	ASTM A36 Galv.	–
a6	4	7"x4 1/2"x3/8" [178x114x10] Slip Impact Base	ASTM A36 Galv.	–
a7	2	7"x4 1/2"x28 Gauge [178x144x0.38] Keeper Plate	ASTM A36 Galv.	–
a8	8	1/2" [13] Dia. UNC, 2" [51] Long Bolt and Nut	ASTM A307 Gr. A/ASTM F1554 Gr. 36/SAE Gr. 2 and ASTM A563 Gr. A	FBX14a
a9	24	1/2" [13] Dia. Narrow Washer (OD 1" [25])	ASTM 844/SAE Gr. 2	FWC12a
a10	2	18"x2"x3/4" [457x51x19] Anchor Post Cable Hanger	ASTM A707 Gr. 36 Galv.	–
a11	2	12"x12"x1/2" [305x305x13] Anchor Post Base	ASTM A709 Gr. 36 Galv.	–
b1	2	14"x9"x1/2" [356x229x13] Cable Anchor Base Plate	ASTM A709 Gr. 36 Galv.	–
b2	4	3 1/2"x3 1/2"x1/2" [89x89x13] Cable Anchor External Gusset	ASTM A709 Gr. 36 Galv.	–
b3	2	1/4" [6] Dia. 16" [406] Long Brass Rod	ASTM B16–00	–
b4	4	2 3/4"x2 3/4"x1/4" [70x70x6] Cable Anchor Internal Gusset	ASTM A709 Gr. 36 Galv.	–
b5	2	14"x1"x1/2" [356x25x13] Cable Anchor Front Plate	ASTM A709 Gr. 36 Galv.	–
b6	2	14"x4"x1/2" [356x102x13] Cable Anchor Top Plate	ASTM A709 Gr. 36 Galv.	–
c1	12	Cable End Fitting	ASTM A27 Galv.	RCE03
c2	4	3/4" [19] Plain Round Washer (OD 2" [51])	ASTM F844/SAE Gr. 2 Galv.	FWC20a
c3	3	Cable Turnbuckle	AASHTO M269/ASTM F1145	–
c4	38	S3x5.7 [S76x8.5] 65" [1651] Long Line Post	ASTM A36	–
c5	114	1/2" [13] J–Bolt and Nut	Bolt ASTM A36 and Nut ASTM A563DH Galv.	–
c6	3	3/4" [19] Dia. Cable Approx. 600' [183 m]	AASHTO M30 Type 1 Class A Galv.	RCM01
c7	38	2'x8"x0.25" Soil Plate	ASTM A36 Galv.	–
c8	2	1" [25] Dia. Beveled Washer	ASTM A36	–
d1	2	Concrete Anchor Block	3000 psi [20.68 MPa] Compressive Strength	–
d2	12	32 1/2" [826] Long #3 [#10] Rebar	ASTM A36	–
d3	12	44 1/2" [1130] Long #3 [#10] Rebar	ASTM A36	–
d4	16	30" [762] Long #3 [#10] Rebar	ASTM A36	–
e1	18	Cable Wedge	ASTM A47 Gr. 32510	–
e2	3	50,000–lb Load Cell	N/A	–
e3	12	3/4" [19] Dia. UNC Threaded Rod	ASTM A449	–
e4	3	3/4" [19] Dia. UNC Left–Handed Threaded Rod	ASTM A449	–
e5	3	3/4" [19] Cable Splice	ASTM A536	–

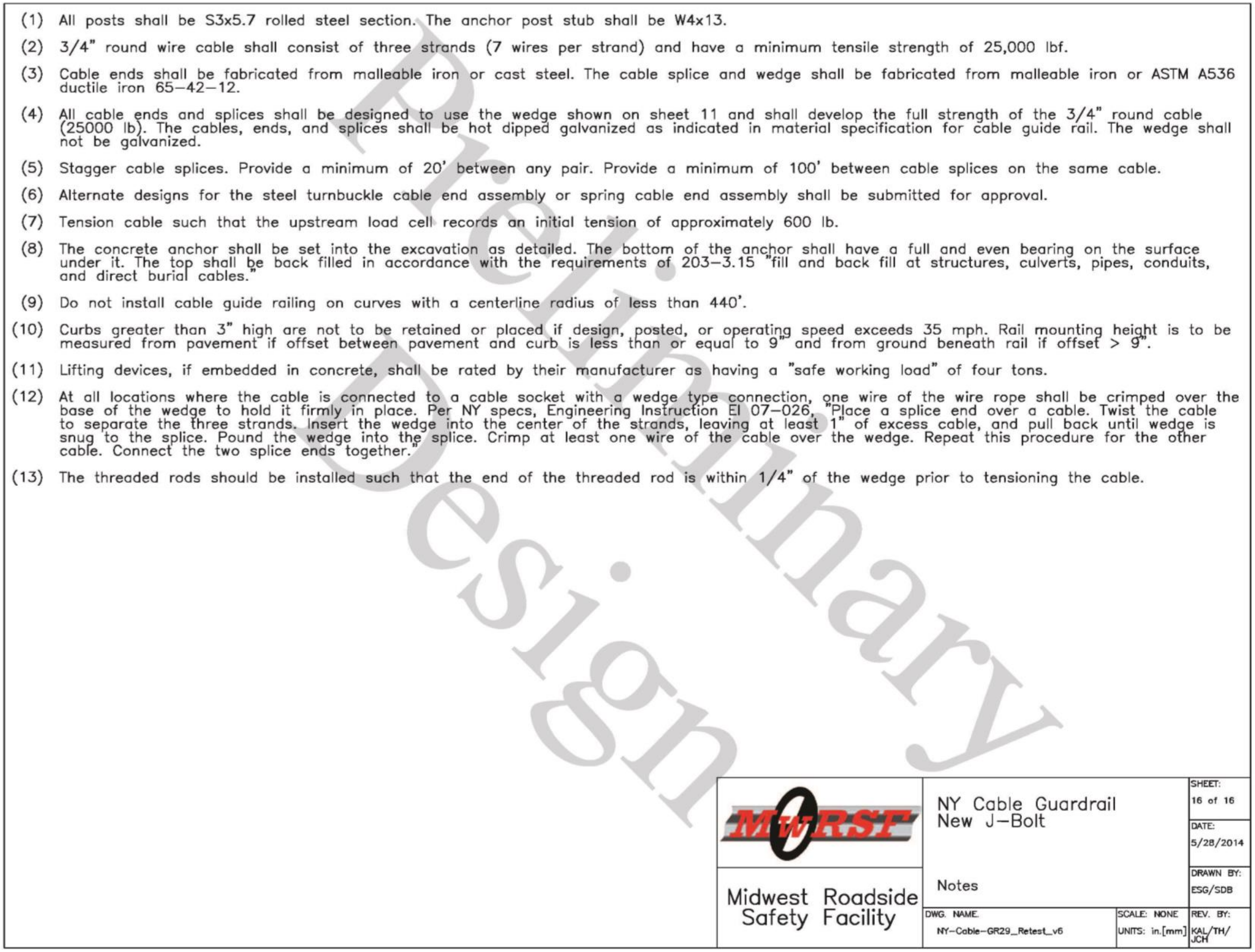
Midwest Roadside Safety Facility

NY Cable Guardrail
New J–Bolt

Bill of Materials

SHEET: 15 of 16
DATE: 5/28/2014
DRAWN BY: ESG/SDB
DWG. NAME. NY–Cable–GR29_Retest_v6
SCALE: NONE
UNITS: in.[mm]
REV. BY: KAL/TH/JCH

Figure 71. Bill of Materials, Test No. NYJ-2



(1) All posts shall be S3x5.7 rolled steel section. The anchor post stub shall be W4x13.

(2) 3/4" round wire cable shall consist of three strands (7 wires per strand) and have a minimum tensile strength of 25,000 lbf.

(3) 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 iron 65–42–12.

(4) All cable ends and splices shall be designed to use the wedge shown on sheet 11 and shall develop the full strength of the 3/4" round cable (25000 lb). 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.

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

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

(7) Tension cable such that the upstream load cell records an initial tension of approximately 600 lb.

(8) 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."

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

(10) 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".

(11) Lifting devices, if embedded in concrete, shall be rated by their manufacturer as having a "safe working load" of four tons.

(12) 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. Per NY specs, Engineering Instruction EI 07–026, "Place a splice end over a cable. Twist the cable to separate the three strands. Insert the wedge into the center of the strands, leaving at least 1" of excess cable, and pull back until wedge is snug to the splice. Pound the wedge into the splice. Crimp at least one wire of the cable over the wedge. Repeat this procedure for the other cable. Connect the two splice ends together."

(13) The threaded rods should be installed such that the end of the threaded rod is within 1/4" of the wedge prior to tensioning the cable.

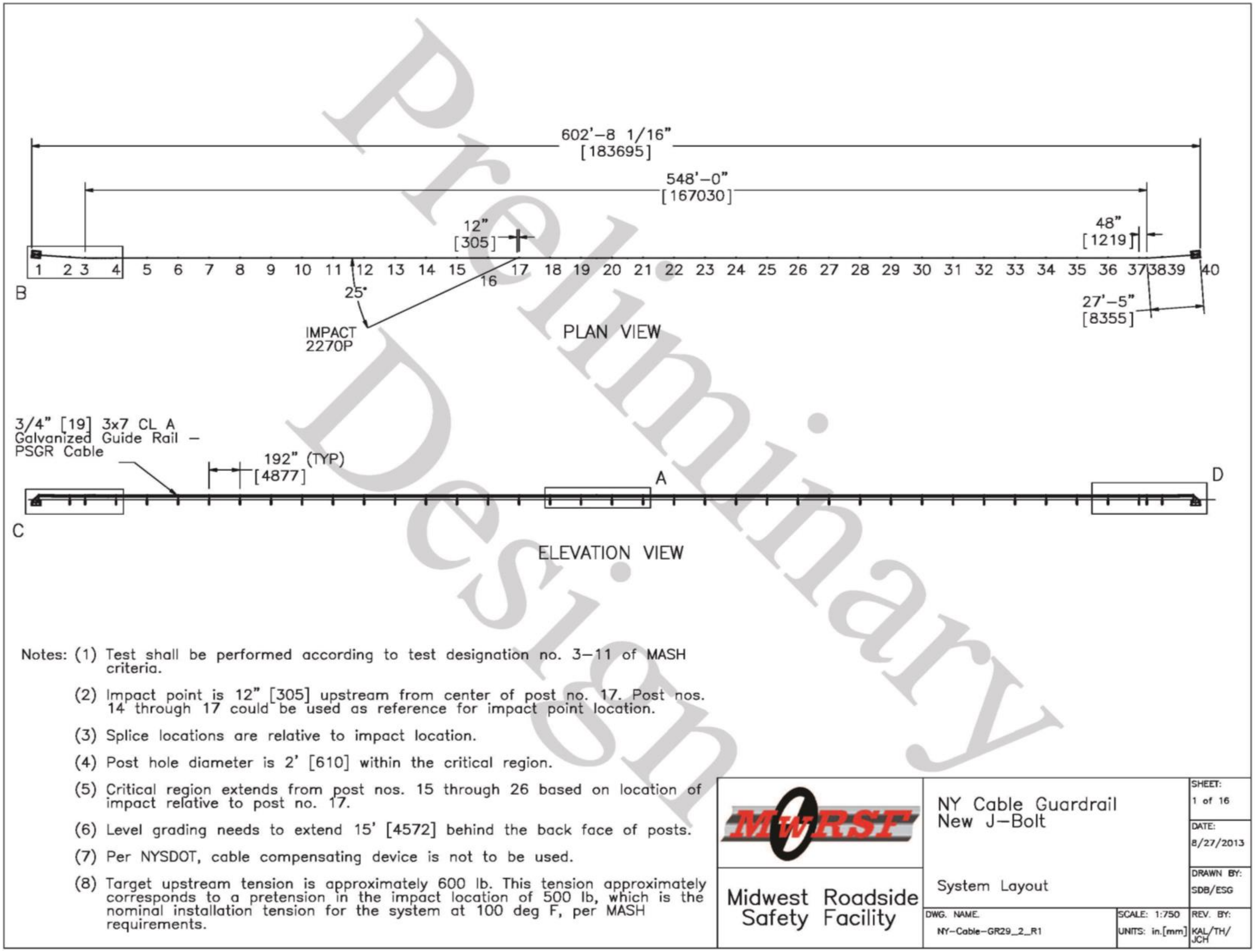
Midwest Roadside Safety Facility

NY Cable Guardrail
New J–Bolt

Notes

SHEET: 16 of 16
DATE: 5/28/2014
DRAWN BY: ESG/SDB
DWG. NAME. NY–Cable–GR29_Retest_v6
SCALE: NONE
UNITS: in.[mm]
REV. BY: KAL/TH/JCH

Figure 72. Additional Notes, Test No. NYJ-2



Notes:
(1) Test shall be performed according to test designation no. 3–11 of MASH criteria.
(2) Impact point is 12" [305] upstream from center of post no. 17. Post nos. 14 through 17 could be used as reference for impact point location.
(3) Splice locations are relative to impact location.
(4) Post hole diameter is 2' [610] within the critical region.
(5) Critical region extends from post nos. 15 through 26 based on location of impact relative to post no. 17.
(6) Level grading needs to extend 15' [4572] behind the back face of posts.
(7) Per NYSDOT, cable compensating device is not to be used.
(8) Target upstream tension is approximately 600 lb. This tension approximately corresponds to a pretension in the impact location of 500 lb, which is the nominal installation tension for the system at 100 deg F, per MASH requirements.

Figure 73. Test Installation Layout, Test No. NYJ-3

8 FULL-SCALE CRASH TEST NO. NYJ-2

8.1 Static Soil Test

Before full-scale crash test no. NYJ-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 D, 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.

8.2 Test No. NYJ-2

The 3,254-lb (1,476-kg) passenger car impacted the cable guardrail system at a speed of 62.7 mph (100.9 km/h) and at an angle of 25.3 degrees. A summary of the test results and sequential photographs are shown in Figure 74. Additional sequential photographs are shown in Figures 75 and 76.

The vehicle pitch angle at impact with the cable barrier system was estimated to be 2.9 degrees, based on available rate gyro data collected before impact. The increased pitch angle during full-scale crash testing was surprising when compared to prior testing on the concrete tarmac and soil pit. Differences may have been attributable to two different 2006 Ford Taurus vehicles used for the crash tests versus the braking tests, with different dive stiffnesses and amounts of shock and strut wear. In addition, the braking coefficient of friction, estimated using longitudinal acceleration data recorded before impact, was approximately 0.78 prior to impact. This result was higher than the average friction value obtained from physical tests, equal to 0.64.

8.3 Weather Conditions

Test no. NYJ-2 was conducted on August 14, 2013 at approximately 4:00 pm. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 10.

Table 10. Weather Conditions, Test No. NYJ-2

Temperature	77°F
Humidity	62%
Wind Speed	10 mph
Wind Direction	Variable
Sky Conditions	Overcast
Visibility	8 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.9 in.

8.4 Test Description

Initial vehicle impact was to occur 64 in. (1,626 mm) downstream from post no. 16, as shown in Figure 77, which was selected based on previous testing [10]. The actual point of impact was 65 in. (1,651 mm) downstream from post no. 16. A sequential description of the impact events is contained in Table 11. The vehicle came to rest 82 ft – 4 in. (25.1 m) downstream from impact and 22 in. (559 mm) laterally behind the system. The vehicle trajectory and final position are shown in Figures 74 and 78.

Table 11. Sequential Description of Impact Events, Test No. NYJ-2

TIME (sec)	EVENT
0.000	The vehicle impacted system.
0.008	The vehicle’s left-front bumper contacted bottom cable and began to deform.
0.014	The vehicle’s left fender contacted top cable between post nos. 16 and 17.
0.038	Post no. 16 began to deflect backward.
0.040	Post no. 17 began to deflect backward.
0.054	The top cable contacted left A-pillar and left-side mirror.
0.078	The middle cable contacted left-side mirror.
0.094	The vehicle’s right-front bumper contacted post no. 17.
0.096	Post no. 18 began to deflect backward.
0.160	The vehicle’s left-side mirror was detached.
0.190	The middle cable contacted vehicle’s windshield.

TIME (sec)	EVENT
0.200	The vehicle’s left-front window shattered.
0.204	The top cable contacted vehicle’s left-front windshield.
0.232	The top cable contacted vehicle’s roof, and roof began to deform.
0.270	Post no. 12 began to deflect backward.
0.272	The windshield was further crushed by cable slap from the top and middle cables.
0.282	Post no. 15 began to deflect backward.
0.340	The vehicle’s right-front bumper contacted post no. 18.
0.404	The vehicle was parallel with the system.
0.440	The top cable lost contact with vehicle.
0.642	The vehicle was yawing toward the barrier.
0.946	The vehicle redirected into the back side of the cables and made second contact.
1.902	The vehicle was at rest.

8.5 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 79 through 84. Barrier damage consisted of fractured J-bolts, deformed posts, and cables disengaged from posts. Cables disengaged from multiple posts in the system. At post no. 1, all three cables disengaged from the cable hanger bracket. At post no. 16, the top cable disengaged, and the J-bolt fractured at the top cable location. At post nos. 17 through 21, all three cables disengaged from the posts. At post no. 20, the bottom J-bolt fractured. At the upstream cable anchor, all three threaded anchor rods were bent. At the downstream cable anchor, the bottom cable threaded anchor rod was bent. Also, the downstream end of the concrete anchor block deflected and partially lifted. A ⅝-in. (16 mm) gap was observed on the downstream side of the downstream anchor block, and a ⅛-in. (3-mm) gap was observed on the back side of the block.

Separations at the cable splices were noted, but they were small. The bottom cable slipped $^1/_{16}$ in. (2 mm) from the end fitting at the upstream anchor. The bottom cable slip measured at the upstream and downstream ends of the load cell between post nos. 3 and 4 was ⅜ in. (10 mm) and ¼ in. (6 mm), respectively. At the midspan between post nos. 20 and 21 and downstream of the splice, there was ½-in. (13-mm) of slip at the bottom cable end fitting. At the downstream anchor, the top cable slipped ⅛ in. (3 mm) from the end fitting, and the bottom cable slipped $^{1}/_{16}$ in. (2 mm) from the end fitting. Contact marks and scrapes were observed on the cables beginning at impact and continuing until 115 in. (2,921 mm) upstream from post no. 22.

Post no. 1 bent and twisted backward and downstream. All three of the brass clips disengaged, and two of the three clips fractured. Post no. 16 deflected backward and upstream with gouges on the front flange at all three cable locations. Post no. 17 twisted backward and downstream, and bent to the groundline. Post no. 18 twisted downstream and bent backward and downstream at the groundline. Post nos. 19 and 20 bent backward and downstream at groundline. Post no. 21 twisted 180 degrees and bent downstream at groundline, underneath the vehicle. Post no. 40 deflected slightly upstream.

Soil gaps were also present in the system, as shown in Table 12. The maximum lateral dynamic barrier deflection was 82.0 in. (2,083 mm) at post no. 17, as determined from high-speed digital video analysis. The working width of the system was found to be 85.0 in. (2,159 mm), also determined from high-speed digital video analysis.

Table 12. Soil Gap Location, Test No. NYJ-2

Soil Gap Location				
Post Number	Upstream	Downstream	Front	Back
-	in. (mm)	in. (mm)	in. (mm)	in. (mm)
3			¼ (6.4)	
6				⅛ (3.2)
8			⅛ (3.2)	
15		⅛ (3.2)	⅛ (3.2)	¼ (6.4)
16			⅞ (22.2)	¾ (19.1)
22				½ (12.7)
38			¾ (19.1)	

8.6 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 85 and 86. The maximum occupant compartment deformations are listed in Table 13 along with the deformation limits established in MASH for various areas of the occupant compartment. Note that the maximum deformation on the windshield location exceeded MASH established deformation limits. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix E.

Table 13. Maximum Occupant Compartment Deformations by Location

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)	¼ (6)	≤ 12 (305)
Side Door (Above Seat)	½ (13)	≤ 9 (229)
Side Door (Below Seat)	¼ (6)	≤ 12 (305)
Roof	2¼ (57)	≤ 4 (102)
Windshield	4½ (114)	≤ 3 (76)

The majority of the damage was concentrated on the left-front corner and left side of the vehicle where the impact occurred. Several 34-in. (864-mm) long striations occurred on the top of the left-front fender. Several 13-in. (330-mm) long striations occurred along the bottom of the A-pillar, and the left side mirror disengaged during impact. Cable contact marks were observed from the left-front wheel well to the left-rear wheel well. A 16-in. (406-mm) gouge was observed along the left side of the B-pillar, and 42-in. (1,067-mm) long striations were observed above the left-rear window and across the C-pillar. In addition, a 9-in. (229-mm) long dent occurred in the C-pillar.

Near the front of the car, contact marks extended from the left-side front wheel well to the front of the bumper. There was scraping and tearing along the left-front of the bumper, and a 28-in. (711-mm) long tear in the bumper was observed, extending from the front corner to the left side. There was a 6-in. (152-mm) long horizontal tear in the bumper below the left side of the headlight and a 4-in. (102-mm) long horizontal fracture in the left-front headlight. There was also 9 in. (229 mm) of horizontal scraping from the left wheel well toward the front of the bumper

On the front of the car, there was moderate damage to the hood, windshield, and roof. A 35-in. (889-mm) long crease extended from the left-rear of the hood to the center of the hood. Additional cable contact marks and striations were observed. A 35-in. (889-mm) long crease was observed in the windshield, which was the most severe of four distinctive cable impacts. Tears measuring 1 in. (25 mm) and 2 in. (51 mm) occurred in the windshield near the left-side A-pillar. Damage to the roof consisted of a 32-in. by 32-in. (813-mm by 813-mm) dent in the left-front section of the roof that was approximately 1½-in. (38-mm) deep.

On the right side of the vehicle, the right-rear hub cap and tire were scraped and gouged. Cable contact marks extended from the right-rear wheel well through to the right-front wheel well. Horizontal striations measuring 32-in. (813-mm) long were observed on the right A-pillar. A 1½-in. (38-mm) gouge was found in the right-front wheel well on the back side, and the right-front tire was deflated due to a 1½-in. (38-mm) tear.

The rear window fractured, and a 35-in. (889-mm) long scrape occurred in the left side of the rear bumper beginning at the wheel well. The left-front window also fractured. Inside the car, the left-front A-pillar housing was partially disengaged and protruding into the occupant compartment. The roof crush protruded 2¼ in. (57 mm) into the occupant compartment.

8.7 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 14. 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 14.

The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 74. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix G. Due to technical difficulties, the SLICE and EDR-3 units did not collect acceleration data.

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

Evaluation Criteria		**DTS**	**Mash Limit**
OIV ft/s (m/s)	Longitudinal	-15.98 (-4.87)	≤ 40 (12.2)
	Lateral	-3.81 (1.16)	≤40 (12.2)
ORA g's	Longitudinal	-6.84	≤ 20.49
	Lateral	-10.91	≤ 20.49
THIV ft/s (m/s)		16.37 (4.99)	not required
PHD g's		9.08	not required
ASI		0.53	not required

8.8 Load Cell and String Potentiometer Results

Tension load cell data was processed and analyzed. The maximum load values measured by the transducers are summarized in Table 15. The individual cable loads, along with the total combined cable load imparted to the upstream end anchor, were determined and are shown graphically in Figure 87.

Anchor displacement was also of primary concern in the evaluation of the three cable guardrail system. The displacement-time history of the upstream anchor is shown in Figure 87. The anchor on the upstream end had a maximum displacement of 0.54 in. (14 mm) at 0.294 sec after impact.

Table 15. Load Cell Results, Test No. NYJ-2

Cable Location	Sensor Location	Maximum Cable Load		Time After Impact (sec)
		kips	kN	
Combined Cables	Upstream Anchor	26.98	120.01	0.224
Top Cable	Upstream End	8.26	36.74	0.306
Middle Cable	Upstream End	10.34	45.99	0.291
Bottom Cable	Upstream End	18.63	82.87	0.199

8.9 Discussion

The analysis of the test results for test no. NYJ-2 showed that the cable guardrail with ½-in. (13-mm) diameter J-bolts and redesigned anchor post stub contained the 1500A vehicle. After impact, the vehicle remained engaged with cable guardrail and became trapped between the cables. The test vehicle did not underride, penetrate through, nor override the barrier but 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. However, cable slap contributed to significant windshield crush, which exceeded the maximum deformation allowed by MASH safety performance criteria. Therefore, test no. NYJ-2 was determined to be unacceptable according to the MASH safety performance criteria for the modified test designation no. 3-10.

8.10 Analysis of Test No. NYJ-2

Although the vehicle was captured during test no. NYJ-2, excessive occupant compartment deformations were observed. Those deformations were related to cable slap against the windshield and roof. Although similar deformations and cable slap were observed in test no. NYJ-1, it was uncertain whether that cable slap was related to cable release from upstream and downstream end fitters or if cable tension and cable-to-post attachment release was the primary contributor to cable slap.

In comparison with other low-tension, cable barrier full-scale crash tests, more high-amplitude cable waves were observed during test nos. NYJ-1 and NYJ-2. It is believed that the increased wave amplitude may have occurred, in part, due to the large cable release loads from the S3x5.7 (S76x8.5) posts. The estimated vertical and horizontal release loads of the ½-in. (13-mm) cable-to-post attachments were approximately 2,600 lb (11.6 kN) and 3,000 lb (13.3 kN), respectively, which was estimated by scaling results obtained from previous low-tension cable-to-post attachment strengths for the increased bolt size [13]. Thus, vertical or horizontal loads had to exceed the estimated release loads before cables disengaged away from the posts. Those loads resulted from a combination of deflected cable geometries and increased cable tensions. Thus, high-amplitude bending oscillations were propagated between adjacent posts and the vehicle after cables released from the posts. Those bending waves contributed to the windshield crush in test no. NYJ-2.

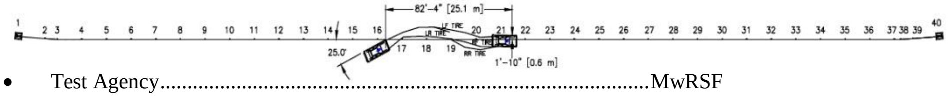
Nonetheless, the bottom cable did not disengage away from the vehicle throughout impact, even though the middle and top cables slipped up the vehicle’s hood and over the top of the vehicle. The 2006 Ford Taurus body style was associated with an elevated rate of penetrations as compared to other vehicles [5]. Thus, the continued engagement of the bottom cable throughout impact could help prevent cable barrier penetrations.

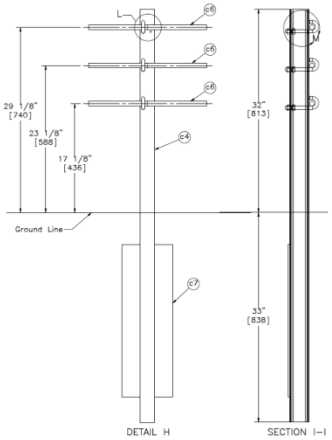
During test no. NYJ-2, the upstream hanger post buckled and bent toward impact. As a result, the angle between the cables and the cable anchor decreased from approximately 45 degrees to approximately 11 degrees. The change in cable approach angle to the anchor resulted in the threaded anchor rods bending at the cable anchor bracket bearing plate interface.

Significantly more anchor rod deformation occurred at the upstream anchor than the downstream anchor, as shown in Figure 88.

Test no. NYJ-2 was determined to be unsuccessful according to MASH due to occupant compartment deformations exceeding threshold limits. Nonetheless, the NYSDOT believed that if the system demonstrated potential to reduce passenger car underrides or through-cable penetrations, as well as pickup truck overrides, then the system warranted further consideration. It was believed that the system could be modified to improve impact performance with the passenger car, as long as the 2270P test successfully captured the vehicle. Therefore, the system was repaired, cable splices were re-set in cable end fittings, and test no. NYJ-3 was conducted with a 2270P vehicle in accordance with MASH test no. 3-11.

0.000 sec 0.050 sec 0.108 sec 0.194 sec 0.346 sec





- Test Agency .... MwRSF
- Test Number NYJ-2
- Date 8/14/2013
- MASH Test Designation .... Modified 3-10
- Test Article .... Cable Guardrail with ½-in. (13-mm) diameter J-Bolts
- Total Length .... 602.7 ft (183.7 m)
- Key Component – Cable
  - Size .... 3x7, ¾-in. (19-mm) diameter
  - Top Cable Height .... 29⅛ in. (740 mm)
  - Bottom Cable Height .... 17⅛ in. (435 mm)
  - Incremental Cable Spacing .... 6 in. (152 mm)
  - Number of Cables 3
- Key Component - Post
  - Length .... 65 in. (1,651 mm)
  - Shape .... S3x5.7 (S76x8.5) with soil plate
  - Spacing .... 16 ft (4.9 m)
- Soil Type .... Grading B – AASHTO 147-65
- Vehicle Make/Model .... 2006 Ford Taurus
  - Curb .... 3,189 lb (1,447 kg)
  - Test Inertial .... 3,254 lb (1,476 kg)
  - Gross Static .... 3,419 lb (1,551 kg)
- Impact Conditions
  - Speed .... 62.7 mph (100.9 km/h)
  - Angle .... 25.3 deg
  - Impact Severity (IS) .... 78.0 kip-ft (105.8 kJ)
  - Impact Location .... 65 in. (1,651 mm) downstream of post no. 16
- Exit Box Criterion .... Stayed in contact with system
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 82.3 ft (25.1 m) downstream of impact
  22 in. (559 mm) laterally behind system
- Vehicle Damage .... Moderate
  - VDS[11] 11-FD-1
  - CDC[12] 51-TYYW-3
- Test Article Damage .... Moderate
- Maximum Test Article Deflections
  - Permanent Set .... NA
  - Dynamic .... 82.0 in. (2,083 mm)
  - Working Width .... 85.0 in. (2,159 mm)
- Maximum Windshield Deformation .... 4½ in. (114 mm)
- Maximum Angular Displacements
  - Roll .... 5.5° < 75°
  - Pitch .... -2.9° < 75°
  - Yaw .... 33.1°
- Transducer Data

Evaluation Criteria		DTS	Mash Limit
OIV ft/s (m/s)	Longitudinal	-15.98 (-4.87)	≤ 40 (12.2)
	Lateral	-3.81 (1.16)	≤ 40 (12.2)
ORA g's	Longitudinal	-6.84	≤ 20.49
	Lateral	-10.91	≤ 20.49
THIV – ft/s (m/s)		16.37 (4.99)	not required
PHD – g's		9.08	not required
ASI		0.53	not required

Figure 74. Summary of Test Results and Sequential Photographs, Test No. NYJ-2

0.000 sec

0.060 sec

0.102 sec

0.154 sec

0.210 sec

0.288 sec

0.000 sec

0.058 sec

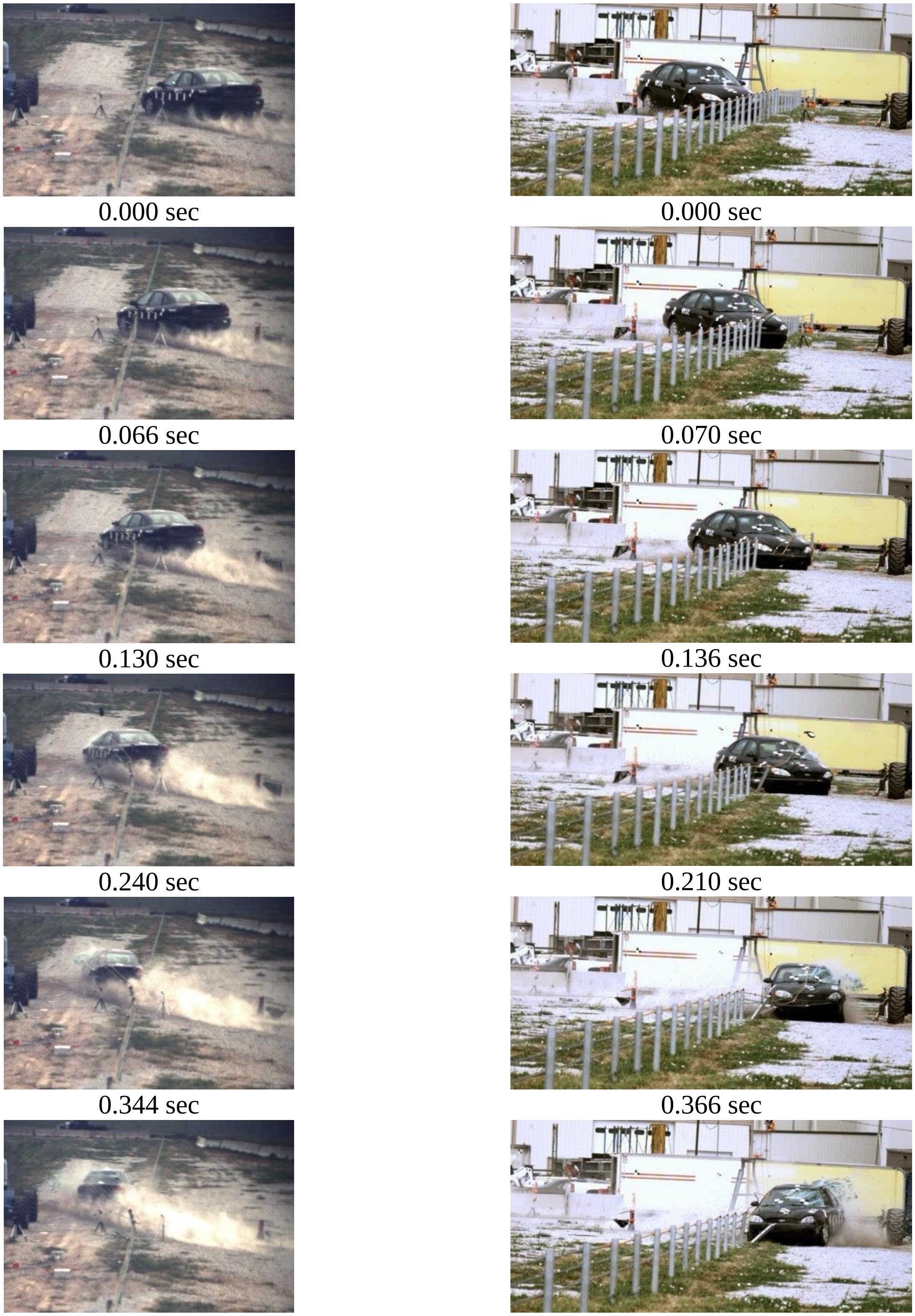
0.118 sec

0.174 sec

0.254 sec

0.386 sec

Figure 75. Sequential Photographs, Test No. NYJ-2



0.000 sec

0.000 sec

0.066 sec

0.070 sec

0.130 sec

0.136 sec

0.240 sec

0.210 sec

0.344 sec

0.366 sec

0.470 sec

0.586 sec

Figure 76. Additional Sequential Photographs, Test No. NYJ-2

Figure 77. Impact Location, Test No. NYJ-2

Figure 78. Vehicle Final Position, Test No. NYJ-2

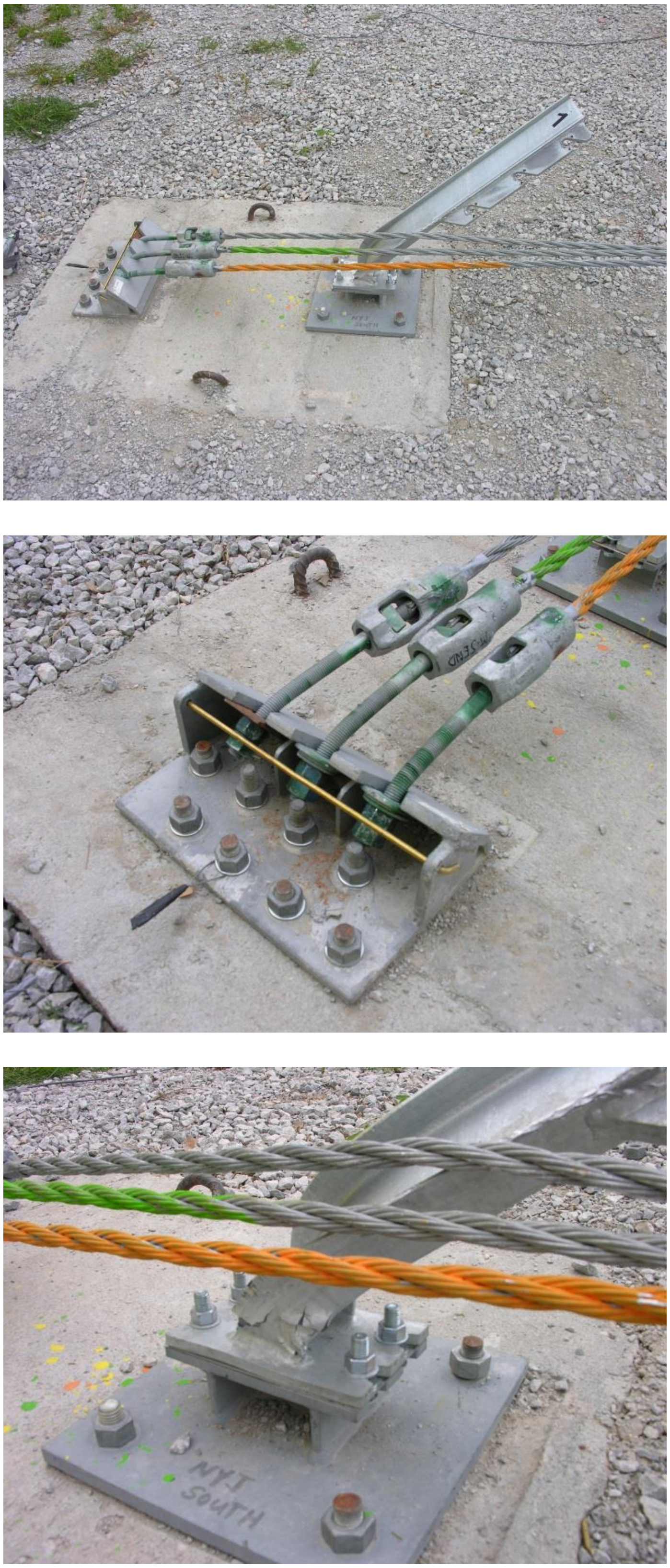


Figure 79. Upstream Anchor Damage, Test No. NYJ-2

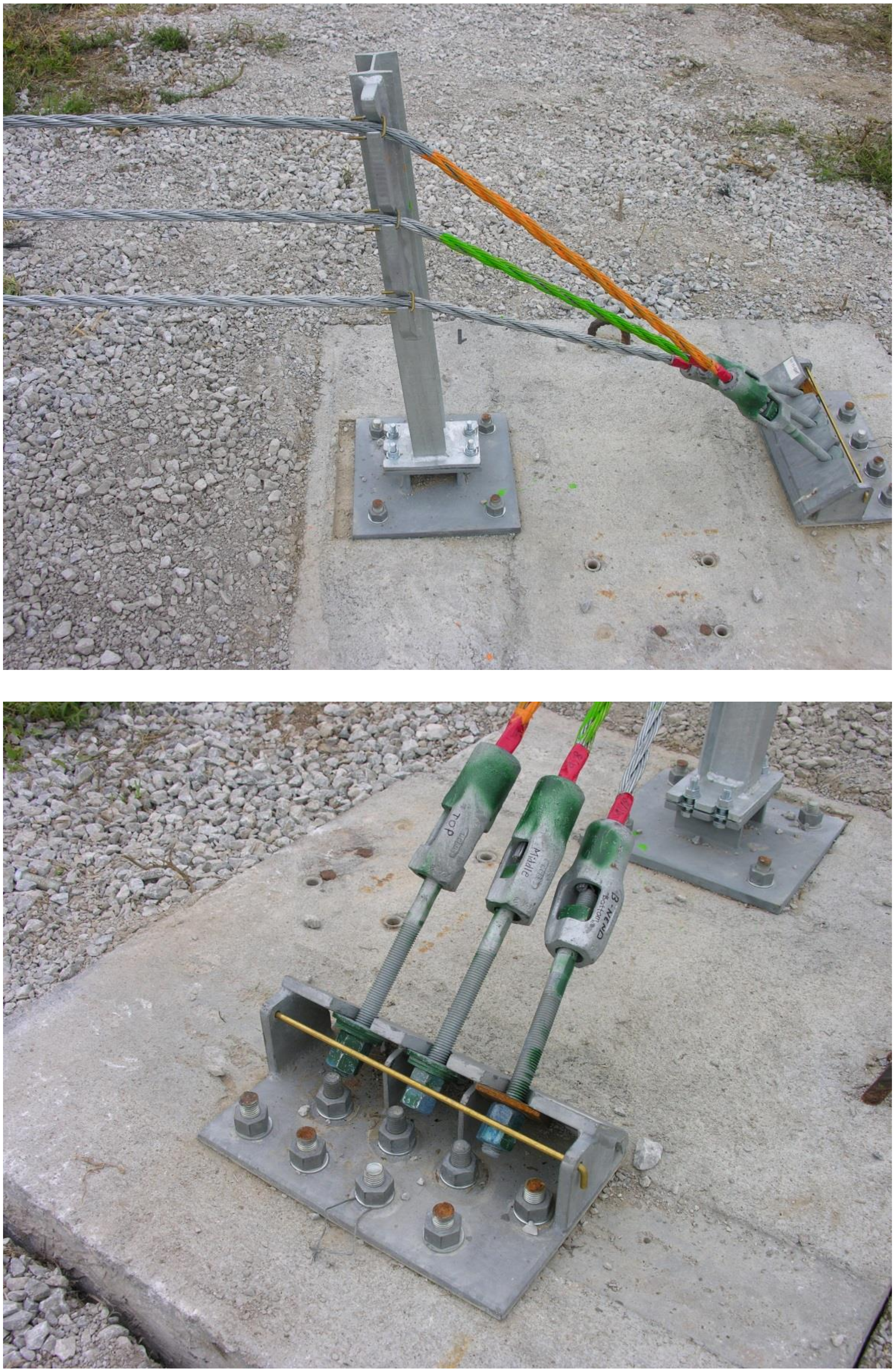


Figure 80. Downstream Anchor Damage, Test No. NYJ-2

Figure 81. Post Damage in Impact Region, Test No. NYJ-2

Figure 82. Post Damage for Post Nos. 1, 16, 17, and 18, Test No. NYJ-2

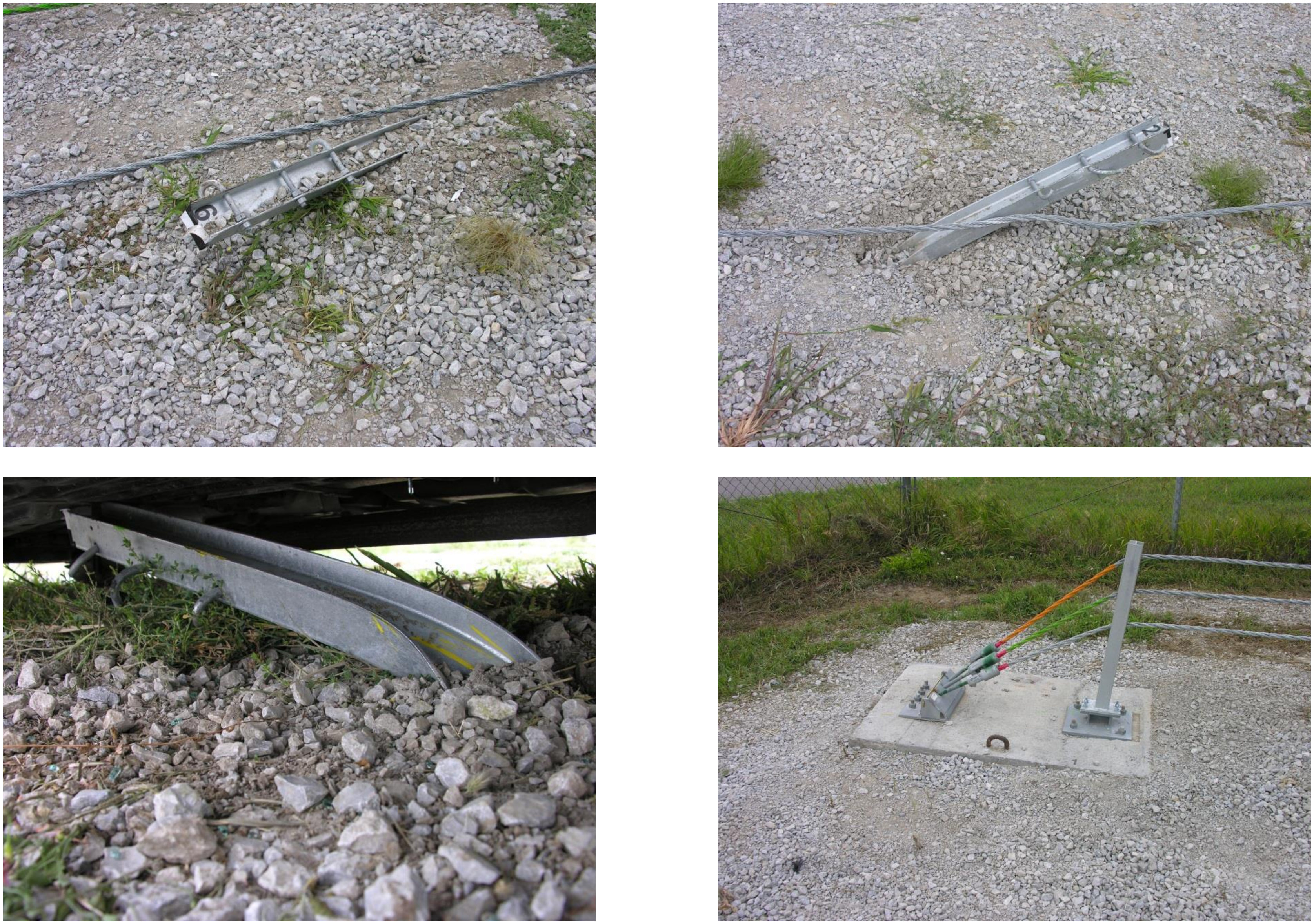


Figure 83. Post Damage for Post Nos. 19, 20, 21, and 40, Test No. NYJ-2

Figure 84. J-Bolt Damage at Post Nos. 18 and 19, Test No. NYJ-2

Figure 85. Vehicle Damage, Test No. NYJ-2

Figure 86. Vehicle Damage, Test No. NYJ-2

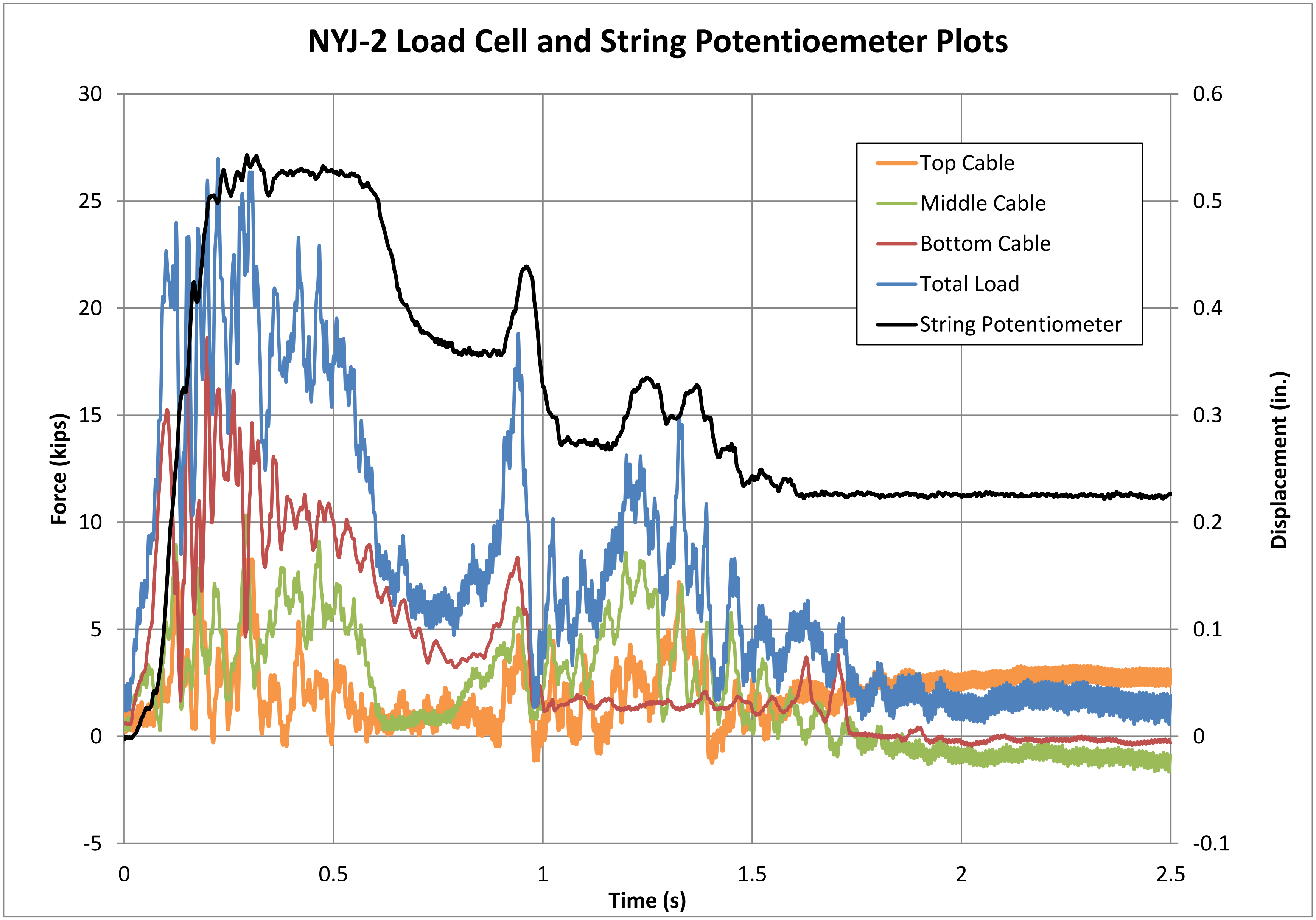


Figure 87. Load Cell and String Pot Plots, Test No. NYJ-2

Figure 88. Top, Middle, and Bottom Cable Barrier Termination Threaded Rods for Upstream and Downstream Anchors

9 FULL-SCALE CRASH TEST NO. NYJ-3

9.1 Static Soil Test

Before full-scale crash test no. NYJ-3 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 D, 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.

9.2 Test No. NYJ-3

The 5,173-lb (2,346-kg) pickup truck impacted the cable guardrail system at a speed of 62.9 mph (101.2 km/h) and at an angle of 26.9 degrees. A summary of the test results and sequential photographs are shown in Figure 89. Additional sequential photographs are shown in Figures 90 and 91.

9.3 Weather Conditions

Test no. NYJ-3 was conducted on September 25, 2013 at approximately 12:00 pm. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 16.

Table 16. Weather Conditions, Test No. NYJ-3

Temperature	76°F
Humidity	56%
Wind Speed	11 mph
Wind Direction	Variable
Sky Conditions	Clear
Visibility	8 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.25 in.

9.4 Test Description

Initial vehicle impact was to occur 12 in. (305 mm) upstream from post no. 17, as shown in Figure 92, which was selected based on MASH recommendations. The actual point of impact was at the targeted impact point. A sequential description of the impact events is contained in Table 17. The vehicle came to rest 142 ft – 1 in. (43.3 m) downstream from impact and 40 ft – 1 in. (12.2 m) laterally behind the system. The vehicle trajectory and final position are shown in Figures 89 and 93.

Table 17. Sequential Description of Impact Events, Test No. NYJ-3

TIME (sec)	EVENT
0.000	The vehicle impacted system.
0.020	The vehicle’s left-front bumper contacted post no. 17 and deformed.
0.024	Post no. 17 deflected backward and twisted downstream.
0.028	Vehicle’s left-front tire deflated due to contact with upstream front flange of post no. 17.
0.032	The top and middle cables disengaged from post no. 17.
0.058	Post nos. 16 and 18 began to deflect backward.
0.098	The vehicle’s left headlight disengaged.
0.140	The top and middle cables disengaged from J-bolt on post no. 18.
0.152	Post no. 15 deflected backward.
0.156	Post no. 19 deflected and rotated backward.
0.170	Post no. 14 deflected backward.
0.176	The vehicle overrode post no. 18.
0.184	The top and middle cables disengaged from post no. 19.
0.200	Post no. 20 rotated backward.
0.226	Post no. 21 deflected backward.
0.268	The vehicle began to roll toward the barrier.
0.274	The vehicle began to yaw away from the barrier.
0.308	The middle cable disengaged from post no. 20.
0.336	The top and bottom cables disengaged from post no. 20.
0.372	The middle cable failed.

TIME (sec)	EVENT
0.436	The top cable failed.
0.438	The bottom cable disengaged from post no. 19.
0.466	The middle and bottom cables disengaged from post no. 16.
0.468	The vehicle was parallel with the system.
0.482	The bottom cable wrapped around the right-rear tire and caused it to become airborne.
0.486	The vehicle’s left headlight disengaged.
0.678	The top cable began sliding over roof of vehicle.
0.698	The top and bottom cables disengaged from post no. 21.
0.700	The end fitting fractured, causing the bottom cable to release.
0.706	The top cable contacted the roof of vehicle.
0.734	The vehicle began to yaw toward the barrier.
1.174	The top and middle cables disengaged at post no. 22
1.396	All three cables disengaged from post no. 23.

9.5 Barrier Damage

Damage to the barrier was severe, as shown in Figures 94 through 97. Barrier damage consisted of fractured J-bolts, deformed posts, and disengaged cables. The permanent set, dynamic deflection, and working width were not recorded due to failure of the cable guardrail system. The permanent displacement of the upstream anchors was 0.15 in. (4 mm).

The top cable disengaged from the upstream and downstream anchors, post nos. 1, 17 through 26, 39, and 40. The middle cable disengaged from post nos. 17 through 26, 38 through 40, and the downstream anchor. The bottom cable disengaged from post nos. 1, 4 through 6, 17 through 21, and 40. J-bolts fractured at the middle cable of post no. 19, the middle cable of post no. 20, the top cable of post no. 23, and the middle cable of post no. 24.

The top cable anchor rod fractured at the upstream anchor. Also, the bottom and middle cable anchor rods bent at the upstream anchor. The anchor rods for the top and middle cables fractured at the downstream anchor. The bottom anchor rod bent at the downstream anchor.

The cables slipped in several cable splices. The largest cable movement occurred in the bottom cable. The bottom cable experienced a 1-in. (25-mm) end fitting slip at the upstream load cells between post nos. 3 and 4. The bottom cable also slipped $^{1}/_{16}$ in. (2 mm) at the end fittings located at the upstream anchor, at the splice between post nos. 20 and 21, and at the downstream anchor. Middle cable end fitting slip was $^{3}/_{16}$ in. (5 mm) at the upstream anchor, $^{1}/_{16}$ in. (2 mm) at the upstream load cells, and ¼ in. (6 mm) and ⅛ in. (3 mm) on the upstream and downstream end fittings of the splice between post nos. 20 and 21. Top cable end fitting slip was $^{1}/_{16}$ in. (2 mm) at both the splice between post nos. 20 and 21 and at the downstream anchor.

Post no. 1 bent at the post base and twisted downstream, and buckling occurred at the bottom of the post. Post nos. 4, 6, and 10 bent and twisted downstream. Post nos. 15 through 17 bent and twisted upstream. Post nos. 18 through 25 and 28 bent backward and downstream. Post nos. 35 and 37 through 40 bent and twisted upstream.

9.6 Vehicle Damage

The damage to the vehicle was minimal, as shown in Figures 98 and 99. The maximum occupant compartment deformations are listed in Table 18 along with the deformation limits established in MASH for various areas of the occupant compartment. Note that none of the maximum deformation values exceeded MASH established deformation limits. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix E.

Table 18. Maximum Occupant Compartment Deformations by Location

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)	0 (0)	≤ 12 (305)
Roof	0 (0)	≤ 4 (102)
Windshield	0 (0)	≤ 3 (76)

The majority of the damage was concentrated on the left-front corner and left side of the vehicle where the impact occurred. The left-front headlight was broken, and cable striations occurred along the left side of the vehicle. The left-front tire was deflated, and a 12-in. (305-mm) long gouge was observed near the bottom of the left-rear door. A ¼-in. (6-mm) gap was observed at the top of the front left-side door. A gouge was also observed near the front of the front door.

Both front headlights were disengaged and striations, dents, and a gouge were observed on the left-front bumper. A 4-in. (102-mm) crack occurred in the lower-center of the grill, and striations were observed along the top of the grill from the top cable. The right-front fender was dented and gouged from the cables as well.

A large dent occurred in the right-front door, extending the length of the door at the bottom. Cable striations occurred on the right-rear door, and a ½-in. (13-mm) gap was found at the top of the right-front door. The right-rear tire was deflated.

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 19. 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 19. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 89. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix H.

Table 19. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NYJ-3

Evaluation Criteria		**Transducer**			**MASH Limits**
		DTS	**SLICE**	**EDR-3**	
OIV ft/s (m/s)	Longitudinal	-9.21 (-2.81)	-10.54 (-3.21)	-10.97 (-3.34)	≤ 40 (12.2)
	Lateral	9.03 (2.75)	9.62 (2.93)	8.06 (2.46)	≤40 (12.2)
ORA g’s	Longitudinal	-5.94	-6.07	4.93	≤ 20.49
	Lateral	4.03	3.96	-3.37	≤ 20.49
THIV ft/s (m/s)		12.73 (3.88)	13.32 (4.06)	NA	not required
PHD g’s		5.94	6.07	NA	not required
ASI		0.29	0.30	0.34	not required

9.8 Load Cell and String Potentiometer Results

Tension load cells were installed within the cables at the upstream end of the system in order to monitor the total load transferred to the anchor. The maximum load values measured by the transducers are summarized in Table 20. The individual cable loads, along with the total combined cable load imparted to the upstream end anchor, are shown graphically in Figure 100.

Upstream anchor displacement was also tracked using a string potentiometer. The displacement-time history of the upstream anchor is also shown in Figure 100. The anchor on the upstream end had a maximum displacement of 0.15 in. (4 mm).

Table 20. Load Cell Results, Test No. NYJ-3

Cable Location	Sensor Location	Maximum Cable Load		Time After Impact (sec)
		kips	kN	
Combined Cables	Upstream Anchor	32.42	144.21	0.310
Top Cable	Upstream End	12.91	57.43	0.312
Middle Cable	Upstream End	17.64	78.47	0.309
Bottom Cable	Upstream End	18.11	80.56	0.676

9.9 Discussion

The cable guardrail with ½-in. (13-mm) diameter J-bolts and redesigned anchor post stub did not adequately contain the 2270P vehicle in test no. NYJ-3. The cable system ruptured after the vehicle impacted the system and several threaded end termination rods fractured. The test vehicle remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix H, were deemed acceptable because they did not adversely influence occupant risk safety criteria nor cause rollover. Therefore, test no. NYJ-3 was determined to be unacceptable according to the MASH safety performance criteria for the test designation no. 3-11.

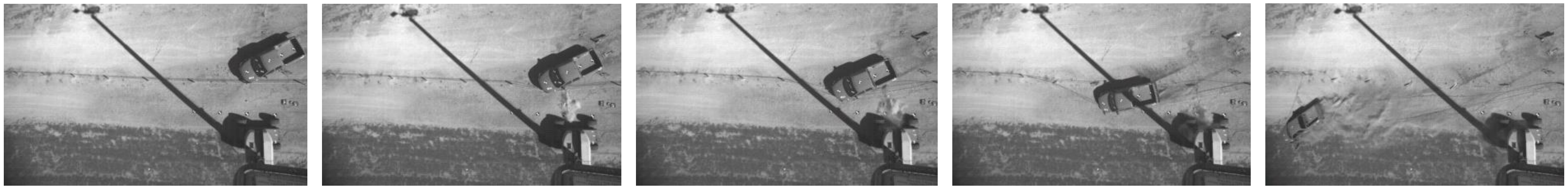
9.10 Analysis of Test No. NYJ-3

Test results from test no. NYJ-3 were analyzed to determine what modifications, if any, could be made leading to successful performance of the low-tension, three-cable roadside barrier.

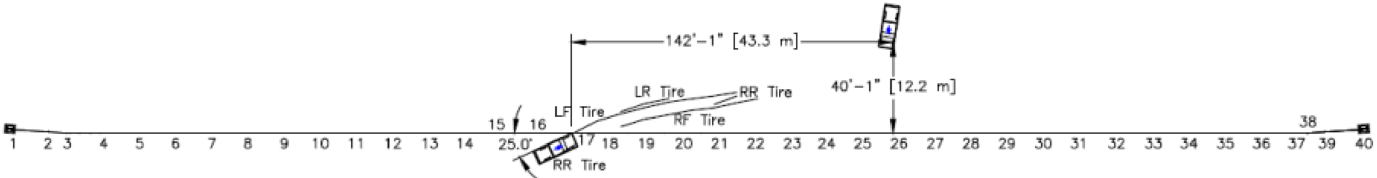
Two factors were determined to contribute to the failure of test no. NYJ-3: (1) the upstream and downstream cable hanger posts bent toward impact and released the cables and (2) the threaded rods at the end terminations were partially constrained against rotation by the tops of the threaded J-hooks and nuts that are used to attach the cable anchor bracket to the concrete block.

After the hanger posts buckled and bent downstream, the angle formed between the cables and the anchor bracket was reduced. The top, middle, and bottom cable pre-test approach angles transitioned from 43, 36, and 26 degrees, to 7, 5, and 3 degrees, respectively, after the hanger post buckled and released the cables. The top, middle, and bottom cables therefore experienced 36, 31, and 23 degrees changes in approach angles, respectively. The anchor rods were bent due to the contributions of the cable tension, angled cable anchor plate, and partial constraint against rotation due to the presence of the vertical J-hooks and nuts. The threaded anchor rods are shown in Figure 101 and Figure 102. Figure 103 provides a schematic representation of the forces acting on the threaded anchor rods and indicates how the interference with the J-hook anchor bolts can significantly increase the bending stresses.

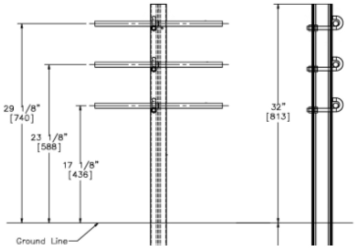
Several threaded end termination rods fractured due to the cable ends being constrained by the threaded J-hooks in the concrete anchor block. It was believed that if the height of the J-hooks in the end anchorage were reduced, and if the hanger post had not bent toward impact, the cable ends may not have fractured. The cable threaded ends may have been constrained against rotation during test nos. NYJ-1 and NYJ-2 as well. Recall, 4 of 6 anchor rods were bent in test no. NYJ-2. Cable tensions never reached maximum levels during test no. NYJ-1 due to failure of the end fittings and splices.



0.000 sec | 0.033 sec | 0.078 sec | 0.169 sec | 0.567 sec



- Test Agency……MwRSF
- Test Number……NYJ-3
- Date ……9/25/2013
- MASH Test Designation……Modified 3-11
- Test Article……Cable Guardrail with ½-in. (13-mm) diameter J-Bolts
- Total Length ……602.7 ft (183.7 m)
- Key Component – Cable
  - Size ……3x7, ¾-in. (19-mm) diameter
  - Top Cable Height……29⅛ in. (740 mm)
  - Bottom Cable Height ……17⅛ in. (435 mm)
  - Incremental Cable Spacing……6 in. (152 mm)
  - Number of Cables ……3
- Key Component - Post
  - Length……65 in. (1,651 mm)
  - Shape ……S3x5.7 (S76x8.5) with soil plate
  - Spacing ……16 ft (4.9 m)
  - Embedment Depth ……33 in. (838 mm)
- Soil Type ……Grading B – AASHTO 147-65
- Vehicle Make/Model ……2007 Dodge Ram 1500
  - Curb ……5,016 lb (2,275 kg)
  - Test Inertial……5,006 lb (2,271 kg)
  - Gross Static……5,173 lb (2,346 kg)
- Impact Conditions
  - Speed ……62.9 mph (101.2 km/h)
  - Angle ……26.9 deg
  - Impact Severity (IS)……135.4 kip-ft (183.6 kJ) > 106 kip-ft (144 kJ)
  - Impact Location……12 in. (305 mm) upstream of post no. 17
- Exit Box Criterion ……Vehicle penetration
- Vehicle Stability ……Satisfactory
- Vehicle Stopping Distance……142.1 ft (43.3 m) downstream of impact
  40.1 ft (12.2 m) laterally behind system
- Vehicle Damage ……Moderate
  - VDS[11] ……11-FD-1
  - CDC[12] ……11-LFEW-1
- Test Article Damage……Moderate



- Maximum Test Article Deflections
  - Permanent Set……NA
  - Dynamic ……NA
  - Working Width……NA
- Maximum Interior Deformation……½ in. (13 mm)
- Maximum Angular Displacements
  - Roll ……15.6° < 75°
  - Pitch……12.3° < 75°
  - Yaw ……-204.1°
- Transducer Data

Evaluation Criteria		Transducer			MASH Limit
		DTS	SLICE	EDR-3	
OIV ft/s (m/s)	Longitudinal	-9.21 (-2.81)	-10.54 (-3.21)	-10.97 (-3.34)	≤ 40 (12.2)
	Lateral	9.03 (2.75)	9.62 (2.93)	8.06 (2.46)	≤ 40 (12.2)
ORA g's	Longitudinal	-5.94	-6.07	4.93	≤ 20.49
	Lateral	4.03	3.96	-3.37	≤ 20.49
THIV – ft/s (m/s)		12.73 (3.88)	13.32 (4.06)	NA	not required
PHD – g's		5.94	6.07	NA	not required
ASI		0.29	0.30	0.34	not required

Figure 89. Summary of Test Results and Sequential Photographs, Test No. NYJ-3

0.000 sec

0.016 sec

0.053 sec

0.078 sec

0.088 sec

0.219 sec

0.000 sec

0.013 sec

0.030 sec

0.059 sec

0.092 sec

0.233 sec

Figure 90. Sequential Photographs, Test No. NYJ-3

0.000 sec

0.020 sec

0.085 sec

0.169 sec

0.339 sec

0.589 sec

0.000 sec

0.014 sec

0.029 sec

0.067 sec

0.134 sec

0.205 sec

Figure 91. Additional Sequential Photographs, Test No. NYJ-3

Figure 92. Impact Location, Test No. NYJ-3

Figure 93. Vehicle Final Position, Test No. NYJ-3

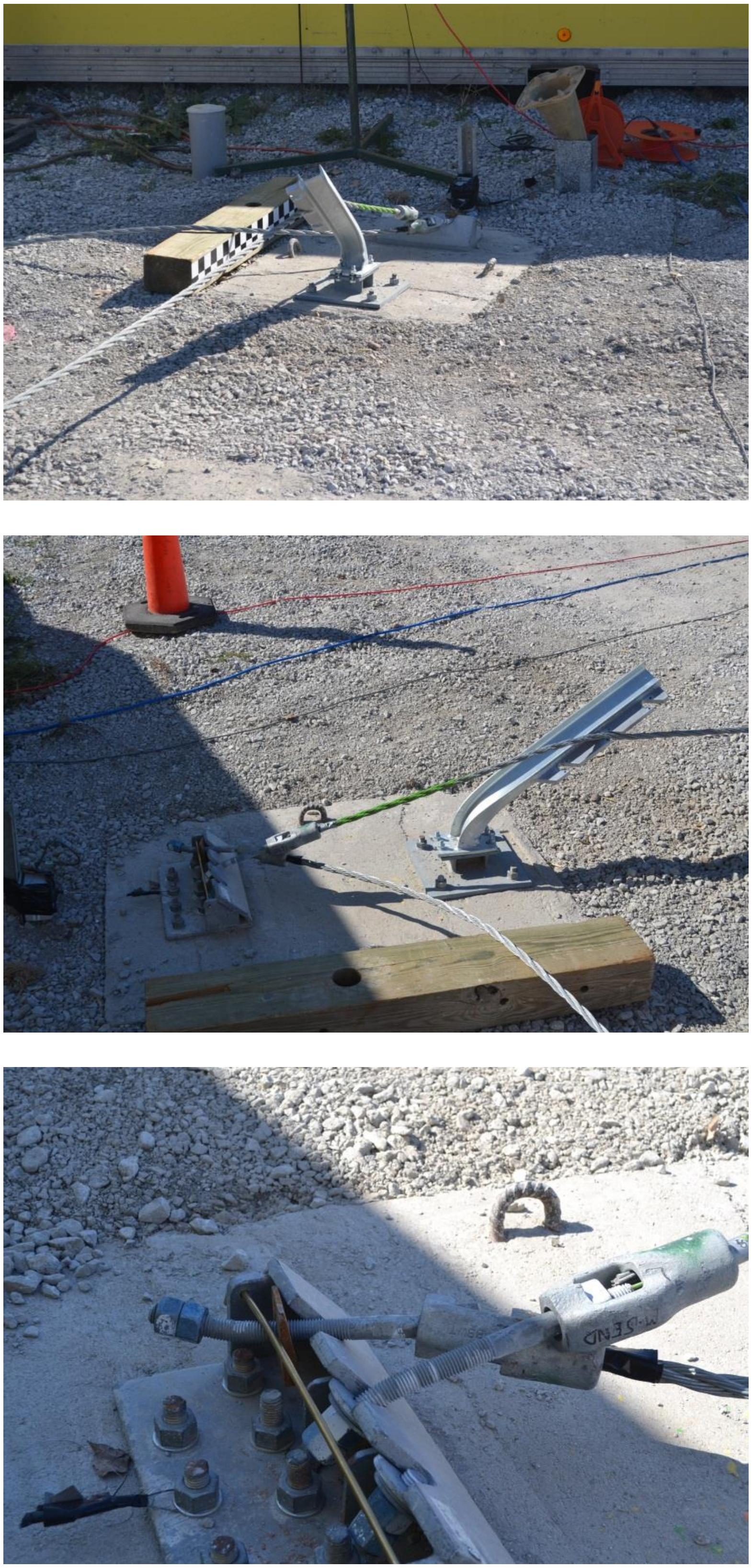


Figure 94. Upstream Anchor Damage, Test No. NYJ-3

Figure 95. Downstream Anchor Damage, Test No. NYJ-3

Figure 96. Post Damage in Impact Region, Test No. NYJ-3

Figure 97. Cable End Fitting Damage, Test No. NYJ-3

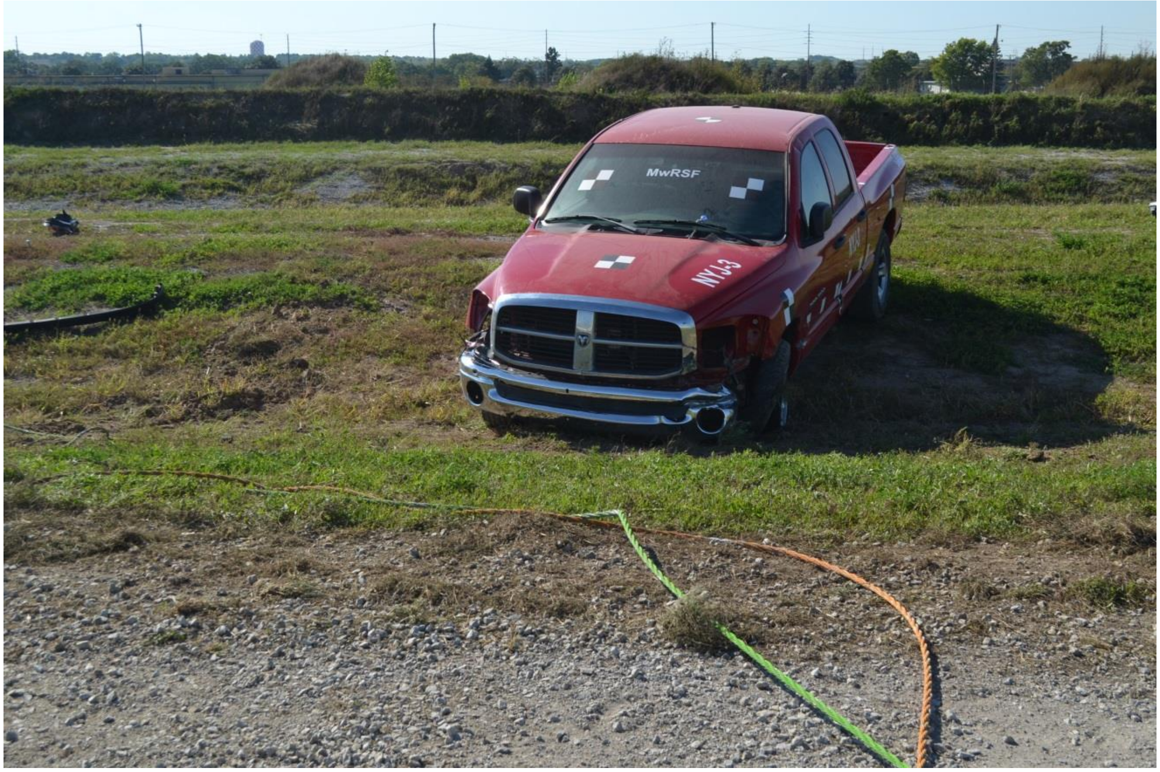


Figure 98. Vehicle Damage, Test No. NYJ-3

Figure 99. Vehicle Damage, Test No. NYJ-3

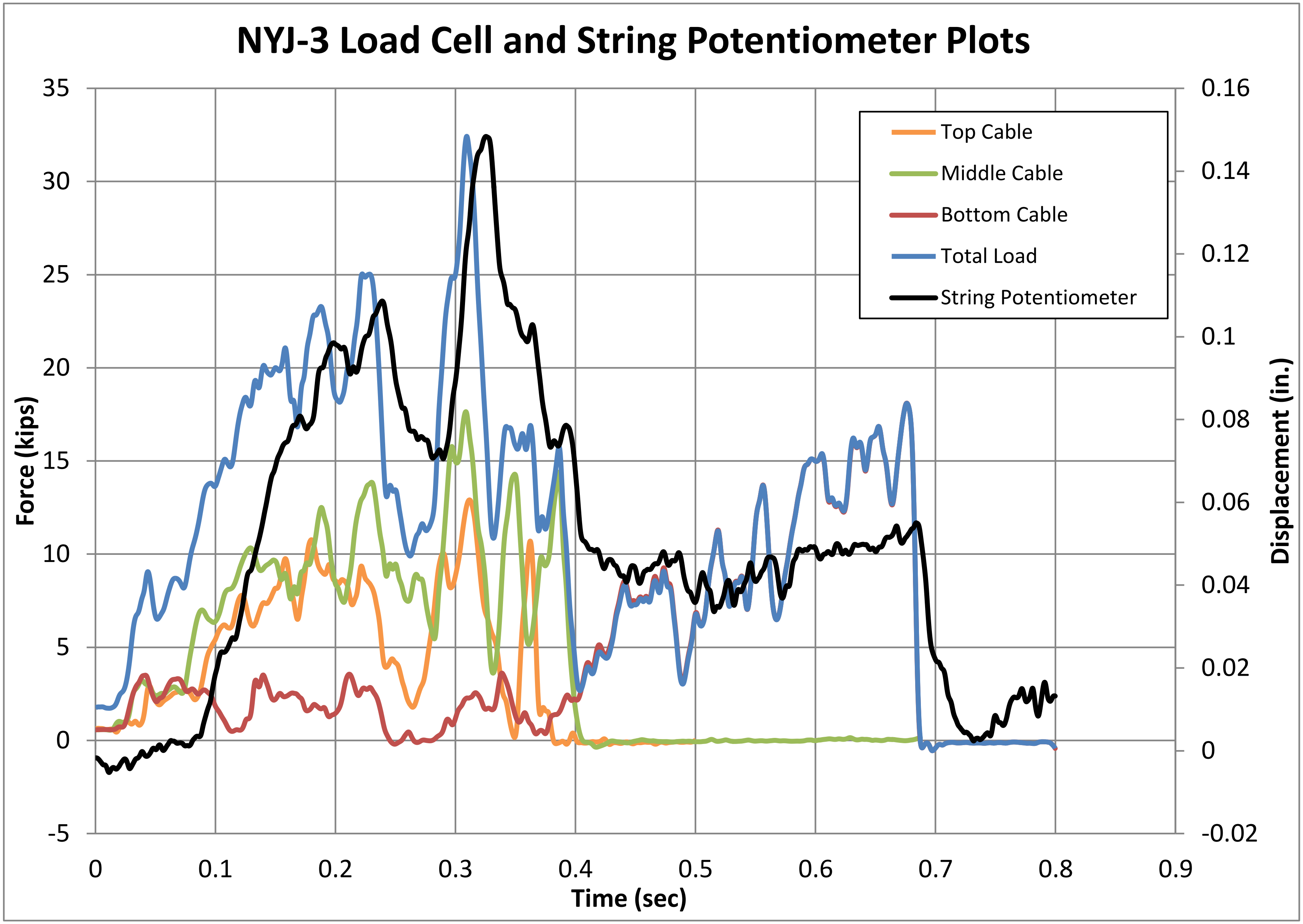
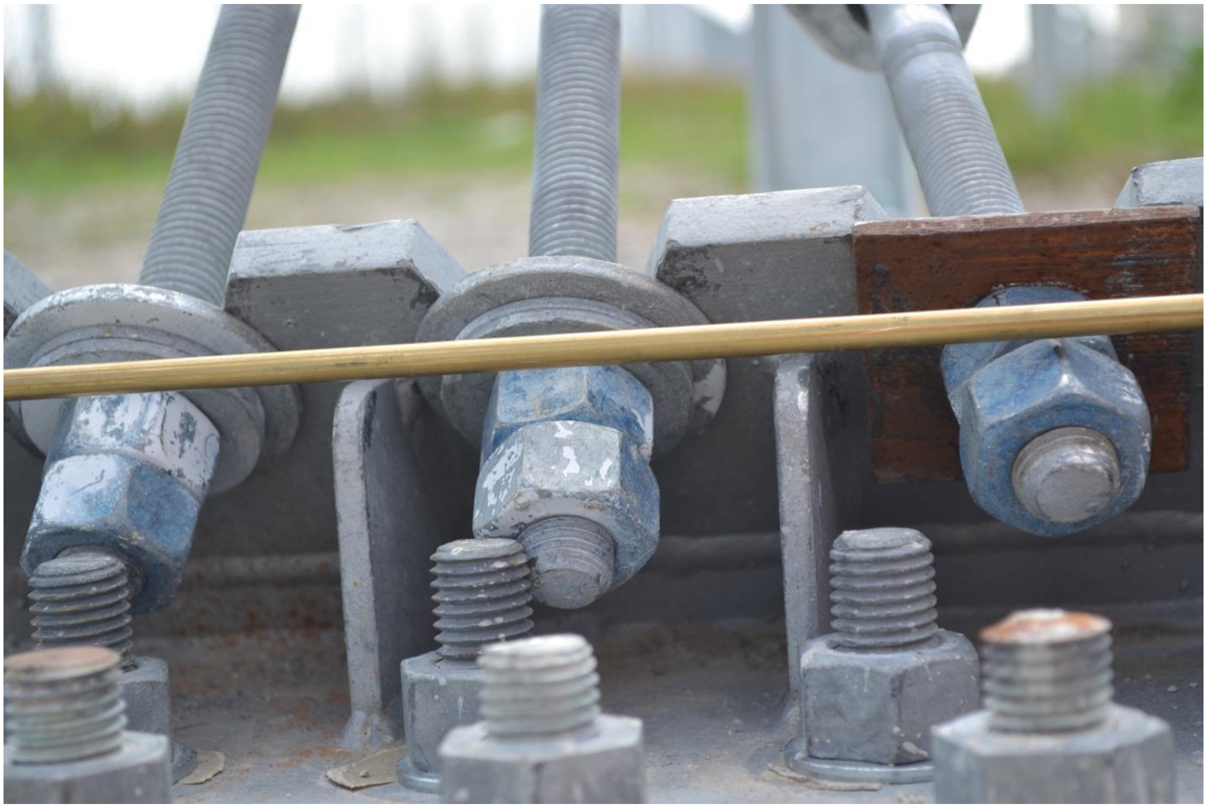


Figure 100. Load Cell and String Pot Plots, Test No. NYJ-3

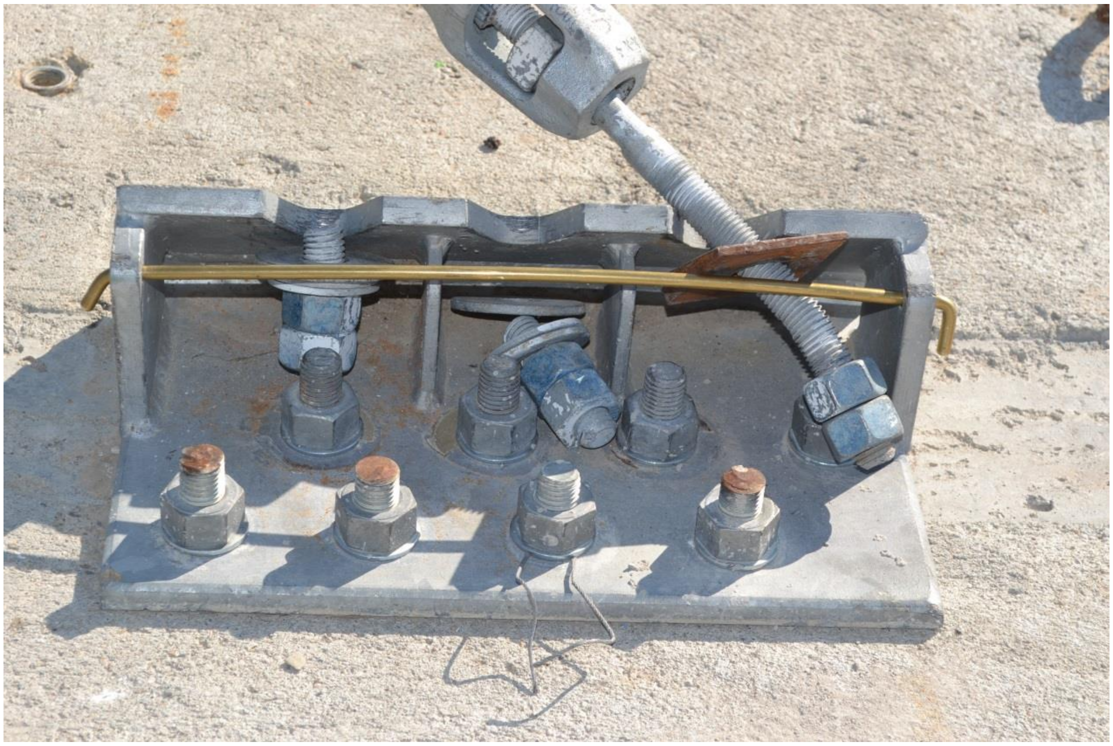
(a) Before Impact

(b) After Impact

Figure 101. Upstream Threaded Rod End Fittings Constrained by Anchor Block Anchorage

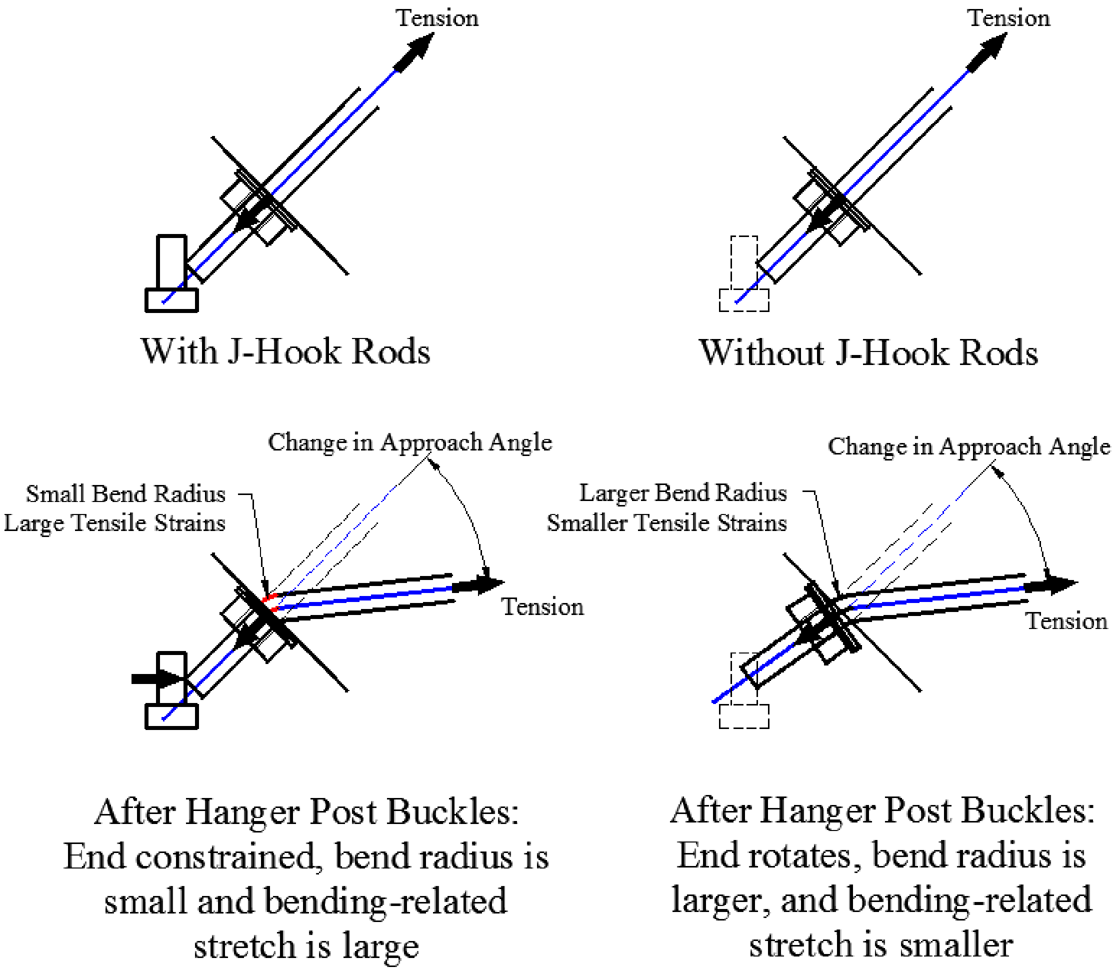


(a) Before Impact



(b) After Impact

Figure 102. Downstream Threaded Rod End Fittings Constrained by Anchor Block Anchorage



With J-Hook Rods

Without J-Hook Rods

After Hanger Post Buckles:
End constrained, bend radius is small and bending-related stretch is large

After Hanger Post Buckles:
End rotates, bend radius is larger, and bending-related stretch is smaller

Figure 103. Effect of Constrained Cable Ends on Threaded Rod Deformation

10 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

10.1 Summary

The objectives of the research project were to: (1) determine whether the use of stronger J-bolts can reduce dynamic deflections for NYSDOT's standard, three-strand, cable guide rail system; (2) determine whether the use of stronger J-bolts can increase the likelihood of capturing small car passenger vehicles with low-profile, aerodynamic front ends, particularly those that are braking; (3) determine whether the use of stronger J-bolts can decrease the propensity of barrier override for light truck passenger vehicles and/or increase vehicle decelerations with cables more firmly attached to the support posts; (4) verify that the proposed revisions to the cable barrier system do not result in any MASH TL-3 crash criteria failures or maintenance problems; (5) determine the maximum dynamic barrier deflection for the baseline, three-strand, cable barrier system with an overall system length in excess of 600 ft (183 m); (6) develop a stiffened stub design for the end posts that will limit damage to acceptable amounts; and (7) estimate the amount of bumper drop due to vehicular braking prior to impact.

The New York State Department of Transportation three-cable guardrail system was constructed and modified to use ½-in. (13-mm) diameter cable-to-post attachment bolts (i.e., J-bolts) in lieu of the standard $^{5}/_{16}$-in. (8-mm) diameter J-bolts. It was evaluated according to MASH TL-3 requirements using three full-scale crash tests, two modified test designation no. 3-10 using a fully-braked 1500A test vehicle in lieu of a standard free-wheeling 1100C small car vehicle and one test designation no. 3-11. The Ford Taurus 1500A mid-size vehicle was selected due to its sharp-nosed profile, increased mass, and its involvement in a high percentage of cable barrier penetration crashes [5]. The guardrail system also utilized a modified cable hanger post stub that was capable of being re-used after an impact event. A summary of the safety performance evaluations is shown in Table 21.

Table 21. Summary of Safety Performance Evaluation – Test Nos. NYJ-1 to NYJ-3

<table>
<tr><th>Evaluation Factors</th><th colspan="4">Evaluation Criteria</th><th>Test No. NYJ-1</th><th>Test No. NYJ-2</th><th>Test No. NYJ-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>U</td><td>S</td><td>U</td></tr>
<tr><td rowspan="10">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.</td><td>U</td><td>U</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</td><td>Modified
3-10</td><td>Modified
3-10</td><td>Modified
3-11</td></tr>
<tr><td colspan="5">Pass/Fail</td><td>Fail</td><td>Fail</td><td>Fail</td></tr>
</table>

S – Satisfactory U – Unsatisfactory NA - Not Applicable

Vehicle braking during test nos. NYJ-1 and NYJ-2 were intended to evaluate the probability of vehicle penetration by maximizing forward pitch just before impact. In preparation for the full-scale crash tests, thirteen vehicle braking tests were performed with a 2006 Ford Taurus. Onboard accelerometers and a rate gyro were used to record frontal pitch, and high-speed digital video was also collected to back up rate transducer data. On the concrete tarmac, the average power-assisted, ABS-enabled brake coefficient was 0.858, but the hydraulically-actuated, remotely-controlled piston which depressed the brake pedal of non-power assisted, non-ABS only developed a coefficient of 0.677. The braking coefficient of friction on soil was 0.441 with power-assisted brakes and ABS enabled, and 0.656 without power-assisted brakes or ABS. The quasi-equilibrium vehicle pitch at maximum brake force was approximately 2 degrees when the vehicle was fully braked, and the corresponding front-end dive was between 1.7 and 2.0 in. (43 and 51 mm). In each test, the brake force ramped up for approximately 0.25 sec, and then remained approximately static. The initial peak pitch angle occurred between 0.30 and 0.48 sec, and occurred later for tests occurring on concrete than soil.

In test no. NYJ-1, a 3,294-lb (1,494-kg) passenger car impacted the cable guardrail system at a speed of 62.7 mph (100.9 km/h) and at an angle of 25.5 degrees. Prior to impact, the brakes on the vehicle were activated, and the front end pitched downward. The approximate vehicle pitch at impact was 2.2 degrees. During test no. NYJ-1, all cables released from various wedge-end fittings throughout the system. As a result, the vehicle was not captured or redirected and came to rest behind the system. An analysis of data collected in the test indicated that the cable end fittings likely released due to three factors, or combinations thereof: (1) wires were not bent over the wedges in the end fittings; (2) multiple cycles of low-load tensioning between 0 and 1,000 lb (0 and 4.4 kN) occurred prior to testing and as part of other evaluation processes and likely loosened the wedges; and (3) cable release loads away from the posts were amplified due to stronger cable-to-post attachments. Test installation methods were altered to alleviate wedge disengagement while still evaluating the performance of the ½-in. (13-mm) diameter cable-to-post attachments.

Prior to test no. NYJ-2, a chisel and sledge hammer were used to pound wedges into the cable ends, wires were bent over the wedges, and the number of cable end fittings in the system were reduced. In test no. NYJ-2, a retest of test no. NYJ-1, a 3,419-lb (1,551-kg) passenger car impacted the cable guardrail system at a speed of 62.7 mph (100.9 km/h) and at an angle of 25.3 degrees, and was fully-braked before impact. The downward pitch was approximately 2.9 degrees at impact. The vehicle was successfully captured and came to rest within the system. Windshield crush of 4½ in. (114 mm) was found to exceed MASH limits of 4 in. (102 mm), and failed to minimize adverse risk to impacting vehicles. However, the bottom cable was engaged with the car throughout the impact event.

In test no. NYJ-3, a 5,173-lb (2,346-kg) pickup truck impacted the cable guardrail system at a speed of 62.9 mph (101.2 km/h) and at an angle of 26.9 degrees. Shortly after impact, hanger post nos. 1 and 39 bent toward impact. At the upstream terminal, the top cable threaded rod fractured, and the middle and bottom cable threaded rods bent. At the downstream terminal, the top and middle cable threaded rods fractured, and the bottom cable threaded rod bent. The bottom cable was released when the wedge end fitting just downstream of the load cell fractured. Therefore, the cables did not remain engaged with the pickup truck, and the pickup truck came to rest behind the system.

Because the pickup truck was not redirected during test no. NYJ-3, the maximum dynamic deflections of the modified system could not be determined. As a result, the capacity of the cable barrier system with J-bolts to redirect a pickup truck and reduce deflections were inconclusive. The middle and top cables both engaged the bumper of the pickup truck and remained engaged until the cable anchor rods fractured. Even though the middle cable was significantly below the top bumper height, the cables maintained their height and seated into the pliable bumper cover. However, due to the unsuccessful performance of the strong J-bolt cable system, NYSDOT decided to forego evaluating the standard three-cable system according to MASH.

The modified hanger post stub was not damaged in test nos. NYJ-1 through NYJ-3. The hanger posts plastically yielded and bent over in each test. After each test, the stub was examined for cracking in the weld, plastic deformation or bending, and/or other damage, but no damage was observed after each crash test.

10.2 Conclusions

Based on test results, the threaded cable anchor rod failures were determined to be caused by two factors: (1) the upstream and downstream cable hanger posts bent downward toward impact and released the cables and (2) the threaded cable anchor rods were restrained against rotation by the threaded J-hook ends and nuts extending from the concrete anchor block. The deformation of the hanger post and tension in the cables contributed to plastic bending and large tensile strains on the top surface of the threaded cable anchor rods. It is possible that the anchor rods may not have fractured if the threaded ends were free to rotate instead of being constrained by the threaded J-hook ends and nuts.

Based on high-speed video analysis, test results suggested that if the threaded cable anchor rods had not fractured and released from the anchor plate in test no. NYJ-3, it is likely that the pickup would have been satisfactorily redirected. Increased lateral cable release loads may improve vehicle capture in future applications.

In comparison to prior full-scale tests with low-tension, cable barriers, more high-frequency cable tension waves were observed during test nos. NYJ-1 through NYJ-3. It is believed that the increased tension may have occurred, in part, due to large cable release loads away from the S3x5.7 (S76x8.5) posts. The estimated vertical and horizontal release loads of the ½-in. (13-mm) diameter cable-to-post attachments were approximately 2,600 lb (11.6 kN) and 3,000 lb (13.3 kN), respectively, based on results from previous low-tension cable-to-post attachment testing [13]. Those loads resulted from a combination of deflected cable geometries and increased cable tensions. After the cables released from the posts, high-amplitude bending waves were propagated between adjacent posts and the vehicle and contributed to the windshield crush in test no. NYJ-2.

Despite an adverse reaction from large cable-to-post attachment release loads for the upper and middle cables, the increased cable-to-post attachment release loads allowed the bottom cable to engage the vehicle below the headlight and remain engaged with the vehicle throughout test no. NYJ-2. In addition, during test no. NYJ-3, the middle cable engaged the pickup truck's bumper and remained engaged until the cable anchor rod fractured. Therefore, increased cable-to-post attachment strength of lower cables may be beneficial for decreasing cable barrier penetrations. Varied cable-to-post attachment strength for each cable has the potential to improve the performance of low-tension cable barrier systems [5]. Nonetheless, the modified three-cable, low-tension cable barrier system with ½-in. (13-mm) diameter cable-to-post attachments was determined to be unsuccessful according to MASH TL-3 safety performance criteria.

10.3 Recommendations

Several solutions were evaluated which could reduce or eliminate some issues observed with the performance of the cable end anchorage. First, the J-hook studs used to secure the cable anchor bracket to the concrete anchor could be modified to not conflict with the threaded cable end terminations. Second, the location of the cable hanger post could be shifted downstream to decrease the effective angle change in the cables between the bracket and the first terminal post.

MwRSF successfully tested a low-tension cable guardrail terminal design, with a hanger post spaced approximately 5 ft (1.5 m) from the anchor, without observing hanger post failure [14]. Lastly, testing is recommended on a modified NYSDOT cable guardrail system which utilizes ½-in. (13-mm) diameter cable-to-post attachments only with the bottom cable. Both middle and top cables should utilize $^{5}/_{16}$-in. (8-mm) diameter attachments.

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12 APPENDICES

Appendix A. Vehicle Braking Test Results

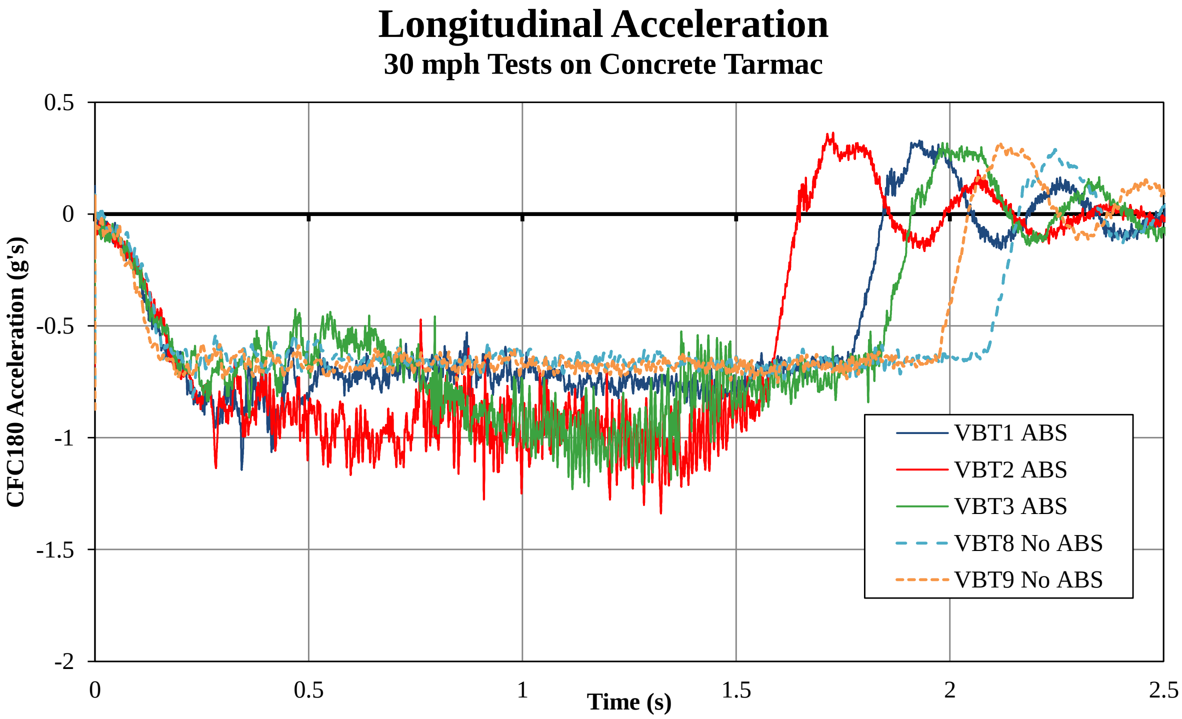


Figure A-1. CFC180 Longitudinal Acceleration, 30-mph (48-km/h) Tests on Concrete

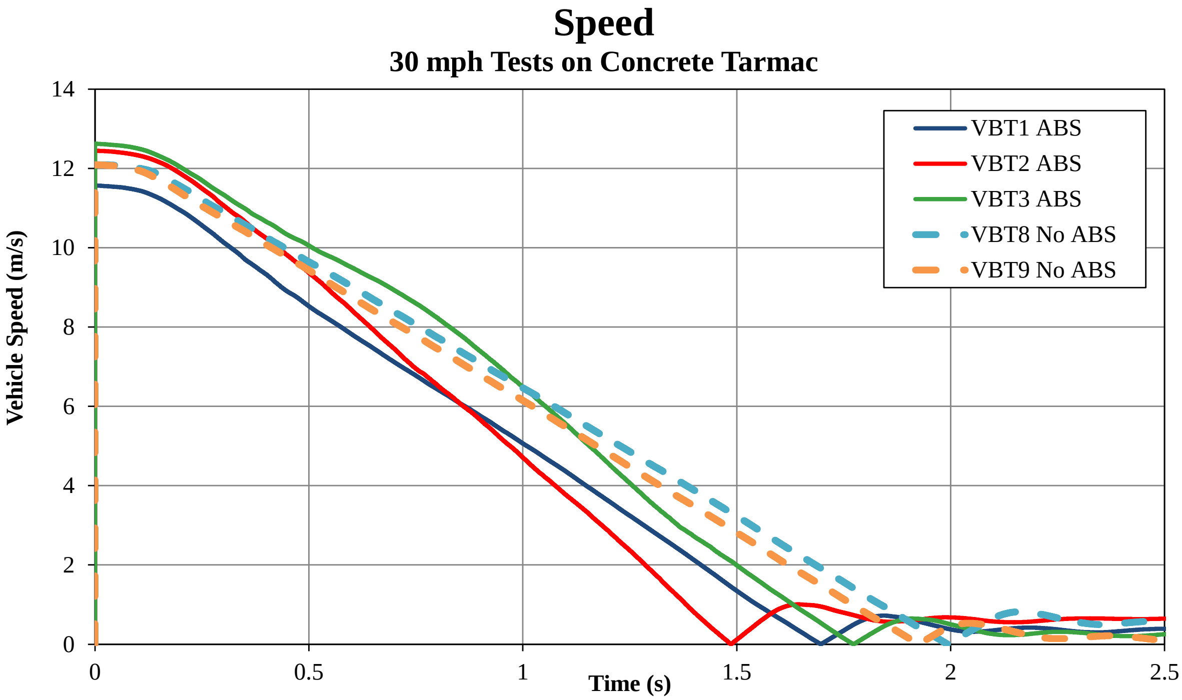


Figure A-2. Vehicle Speed, 30-mph (48-km/h) Tests on Concrete

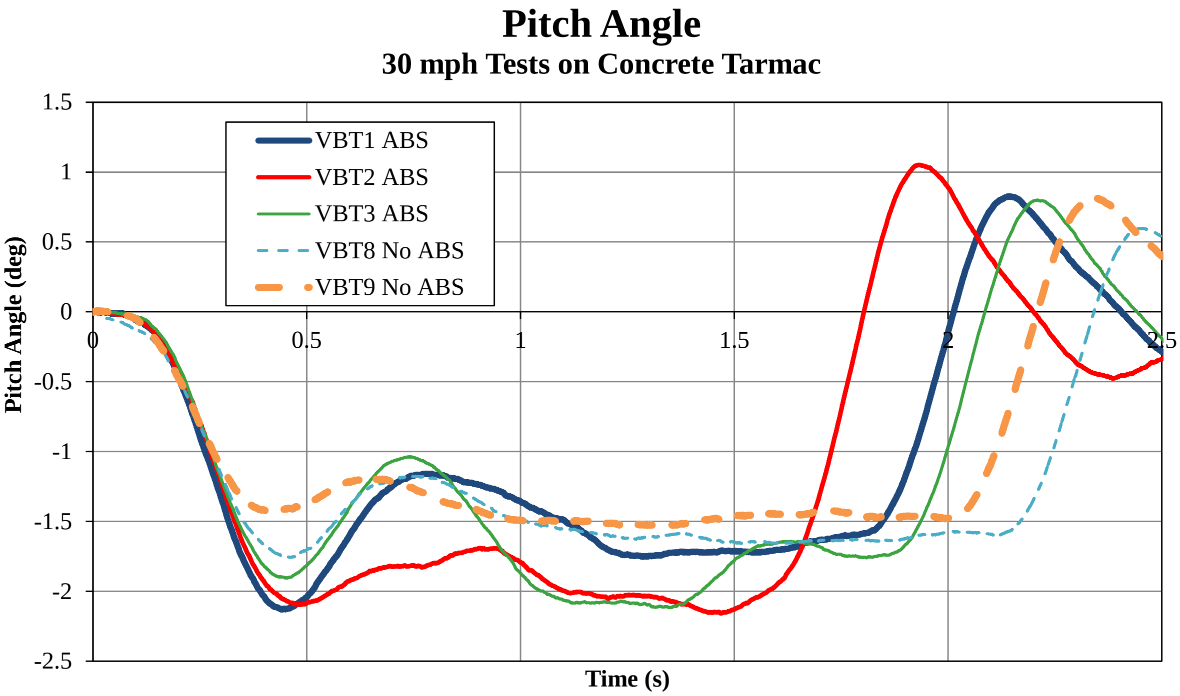


Figure A-3. Vehicle Pitch Angle, 30-mph (48-km/h) Tests on Concrete

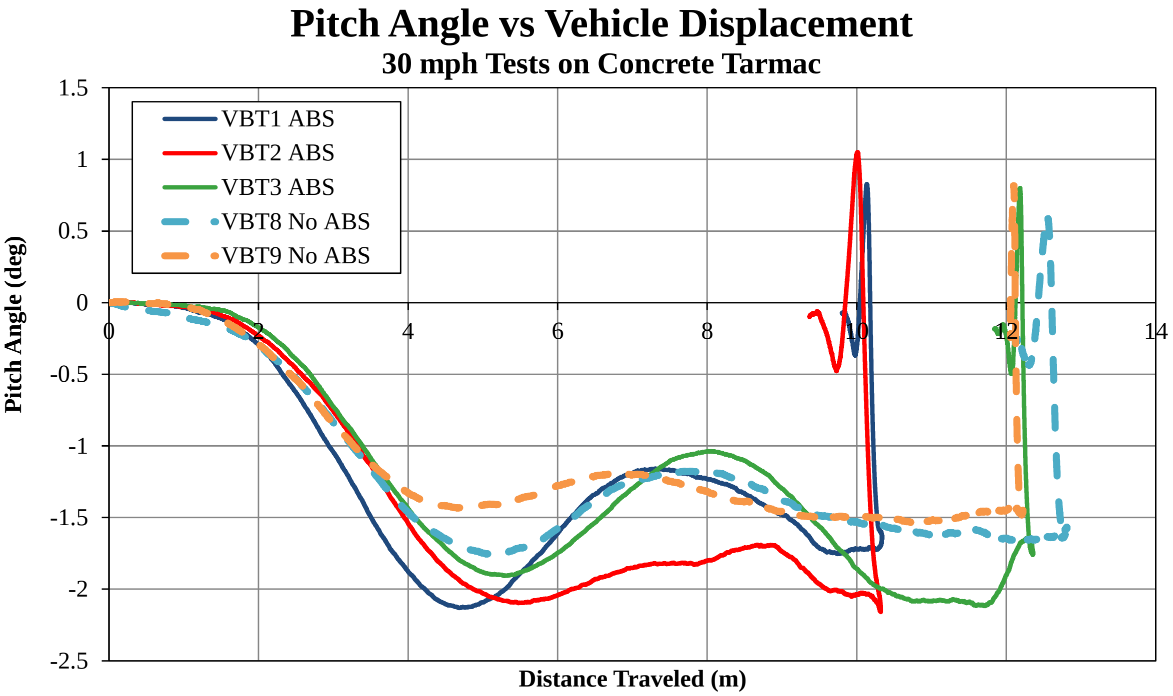


Figure A-4. Pitch vs. Displacement, 30-mph (48-km/h) Tests on Concrete

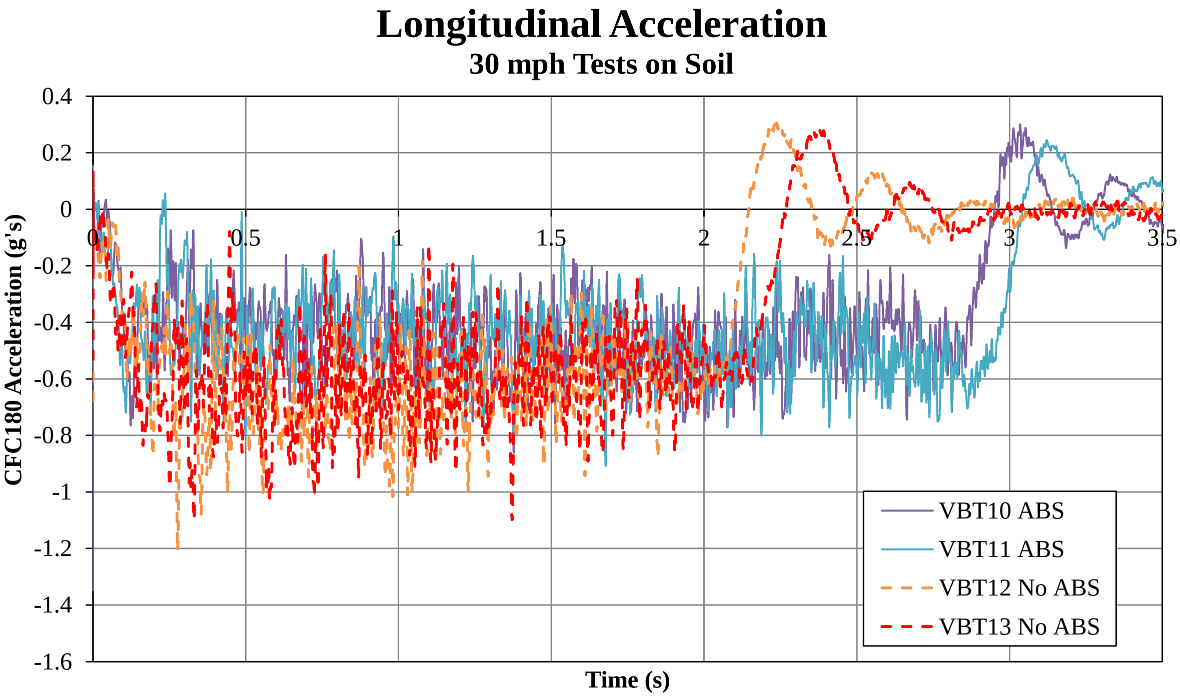


Figure A-5. CFC180 Longitudinal Acceleration, 30-mph (48-km/h) Tests on Soil

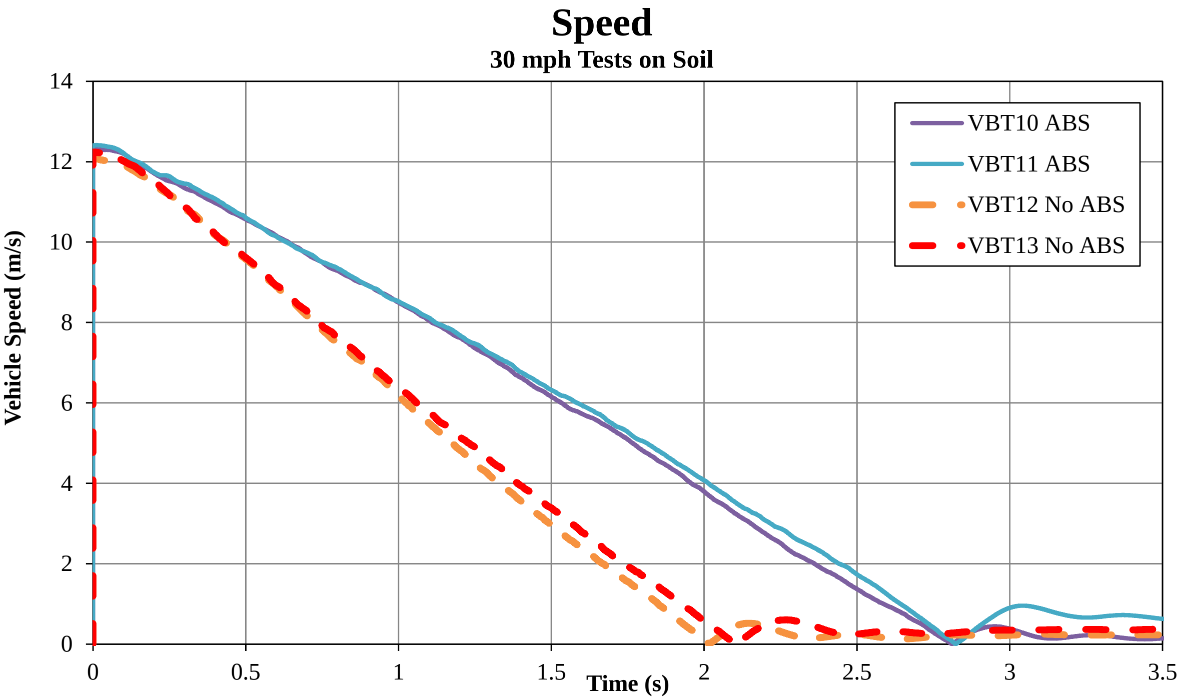


Figure A-6. Vehicle Speed, 30-mph (48-km/h) Tests on Soil

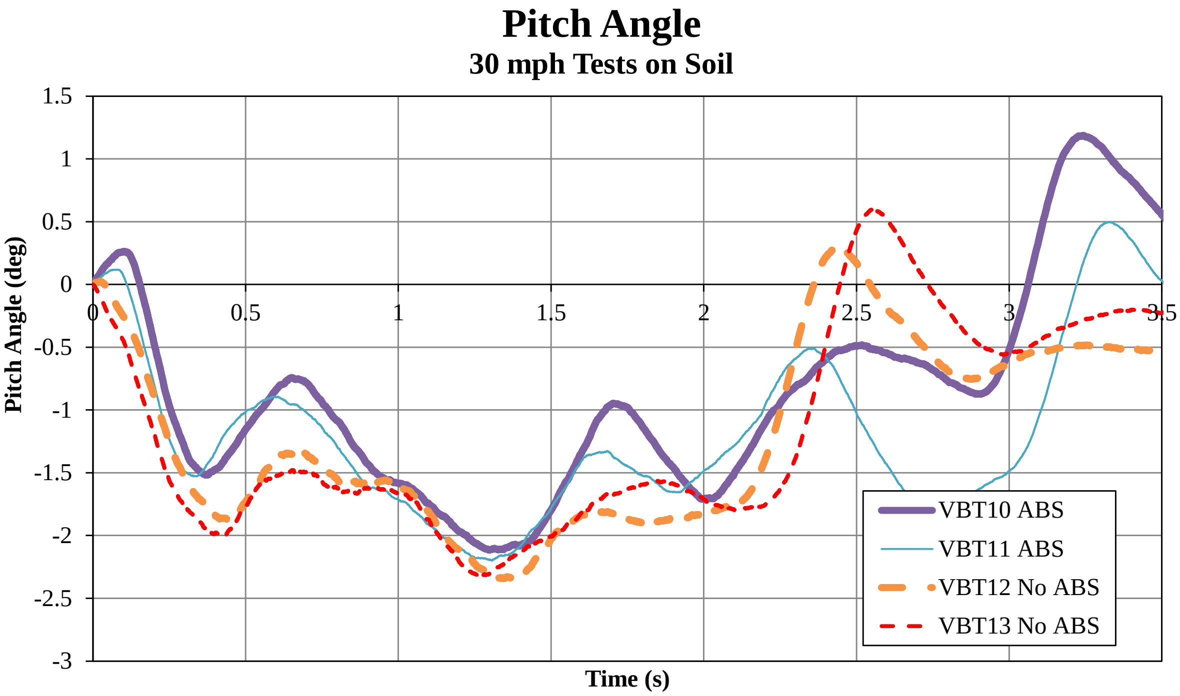


Figure A-7. Pitch Angle, 30-mph (48-km/h) Tests on Concrete

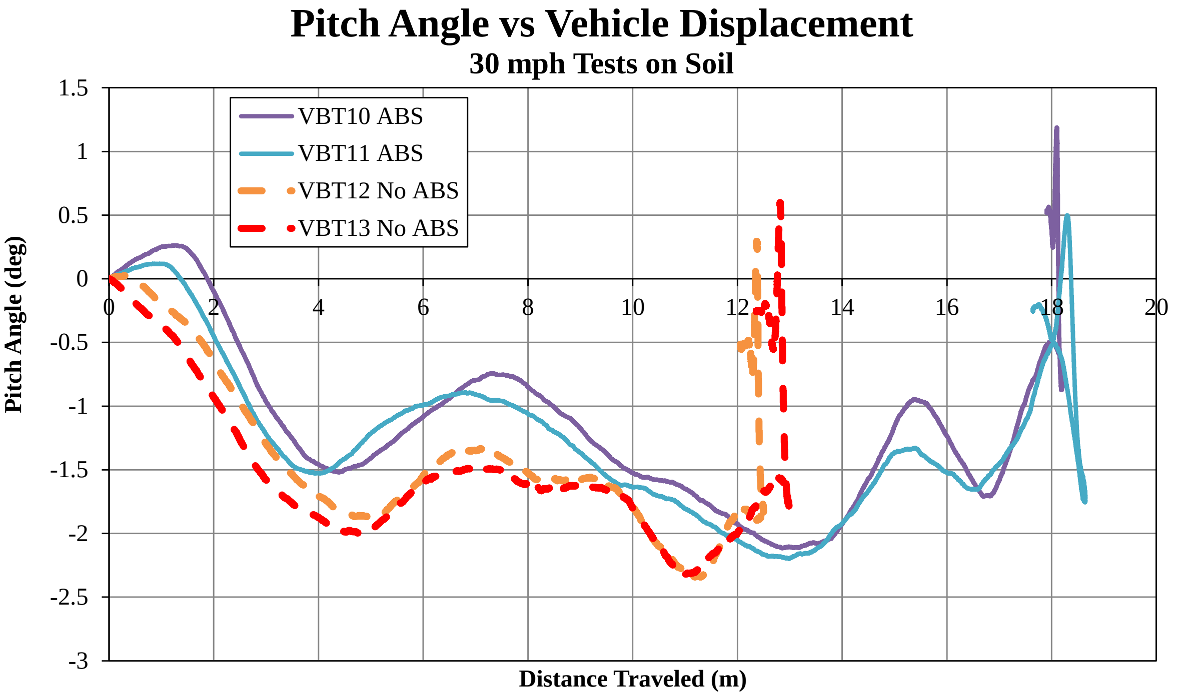


Figure A-8. Pitch vs. Displacement, 30-mph (48-km/h) Tests on Soil

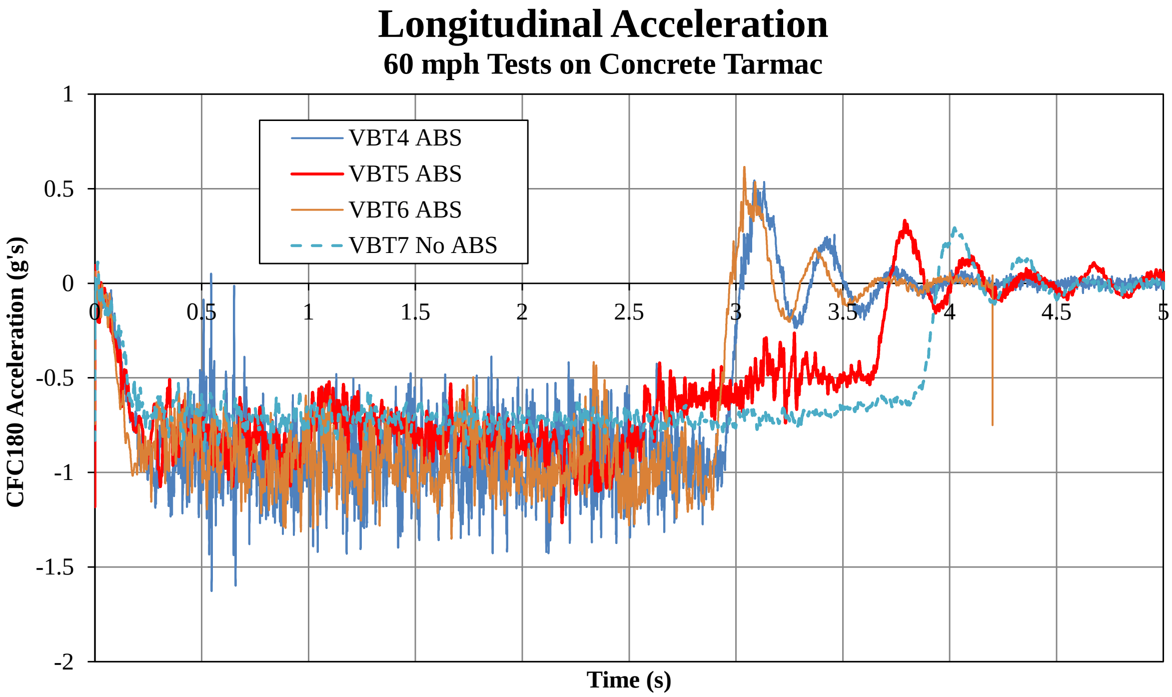


Figure A-9. CFC180 Longitudinal Acceleration, 60-mph (97-km/h) Tests on Concrete

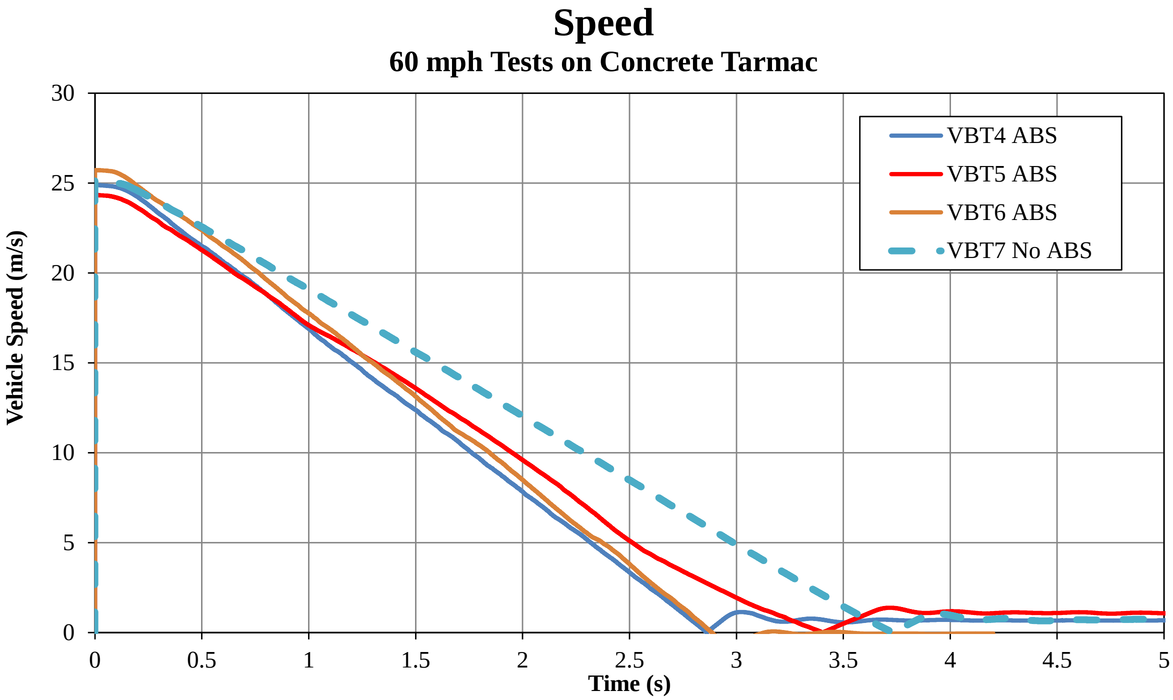


Figure A-10. Vehicle Speed, 60-mph (97-km/h) Tests on Concrete

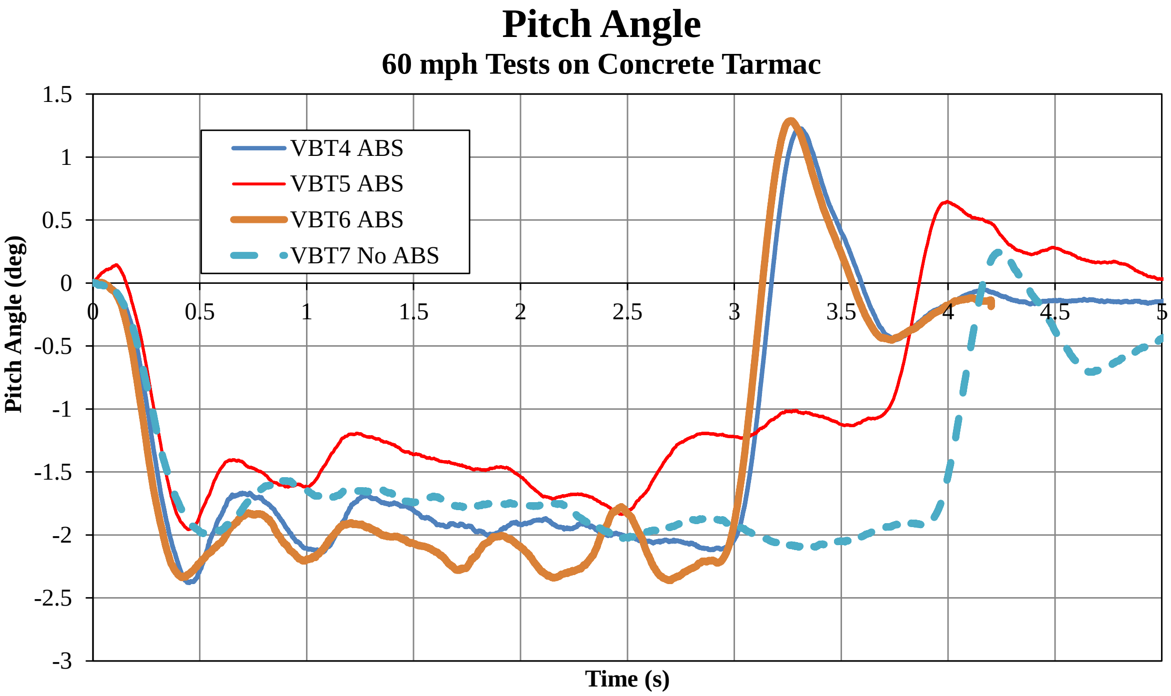


Figure A-11. Pitch Angle, 60-mph (97-km/h) Tests on Concrete

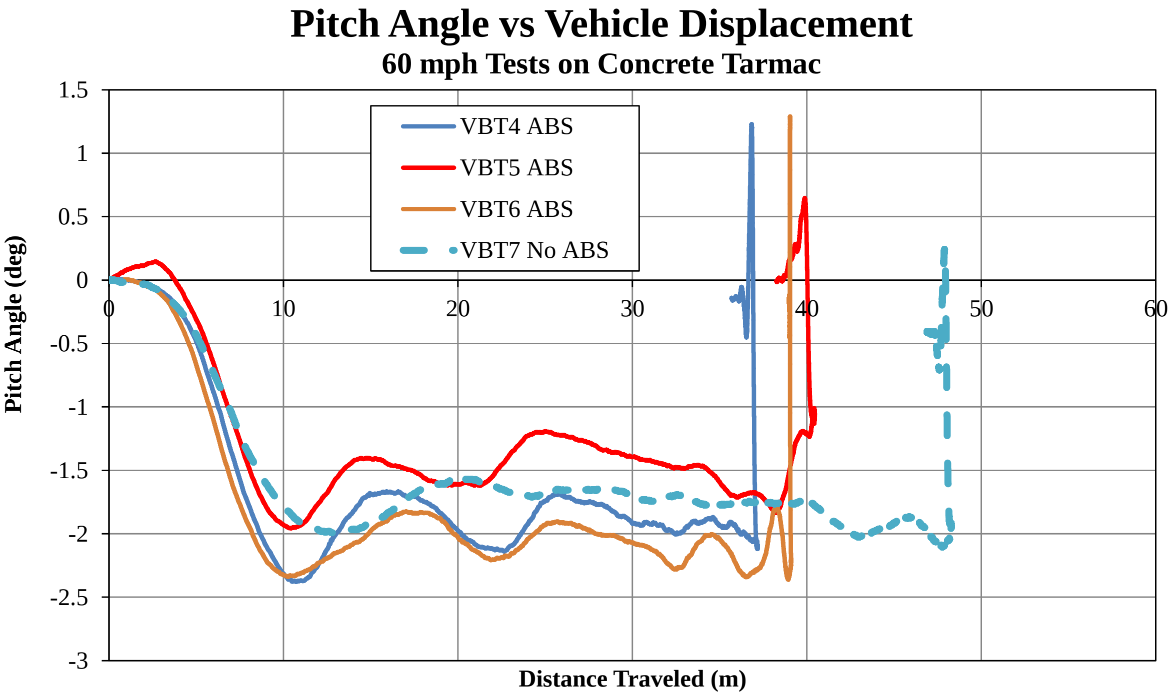


Figure A-12. Pitch vs. Displacement, 60-mph (97-km/h) Tests on Concrete

Appendix B. Vehicle Center of Gravity Determination

Test: NYJ-1 Vehicle: Taurus

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb)
+	Unbalasted Car (curb)	3179
+	Brake receivers/wires	9
+	Brake Frame	11
+	Brake Cylinder	22
+	Strobe Battery	7
+	Hub	20
+	CG Plate (EDRs)	10
+	DTS	17
-	Battery	-31
-	Oil	-5
-	Interior	-27
-	Fuel	0
-	Coolant	-18
-	Washer fluid	-4
BALLAST	Water	106
	Misc.	
	Misc.	

Estimated Total Weight 3296 lb

wheel base 108.5 in.

MASH targets		**Test Inertial**	**Difference**
Test Inertial Wt (lb)	3300 (+/-)220	3296	-4.0
Long CG (in.)	N/A	40.12	NA
Lateral CG (in.)	N/A	-0.07468	NA

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

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

CURB WEIGHT (lb)

	Left	Right
Front	1051	1053
Rear	537	538

FRONT	2104	lb
REAR	1075	lb
TOTAL	3179	lb

Dummy = 166lbs.

TEST INERTIAL WEIGHT (lb)

(from scales)

	Left	Right
Front	1042	1034
Rear	609	609

FRONT	2076	lb
REAR	1218	lb
TOTAL	3294	lb

Figure B-1. Vehicle Mass Distribution, Test No. NYJ-1

Test: NYJ-2 Vehicle: Taurus

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb)
+	Unbalasted Car (curb)	3189
+	Brake receivers/wires	9
+	Brake Frame	11
+	Brake Cylinder	28
+	Strobe Battery	5
+	Hub	20
+	CG Plate (EDRs)	10
+	DTS	17
-	Battery	-32
-	Oil	-6
-	Interior	-57
-	Fuel	0
-	Coolant	-19
-	Washer fluid	-4
BALLAST	Water	77
	Misc.	
	Misc.	

Estimated Total Weight 3248 lb

wheel base 108.75 in.

MASH targets		**Test Inertial**	**Difference**
Test Inertial Wt (lb)	3300 (+/-)220	3248	-52.0
Long CG (in.)	N/A	39.77	NA
Lateral CG (in.)	N/A	0.412415	NA

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

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

CURB WEIGHT (lb)

	Left	Right
Front	1054	1044
Rear	533	558

FRONT	2098	lb
REAR	1091	lb
TOTAL	3189	lb

Dummy = 162lbs.

TEST INERTIAL WEIGHT (lb)

(from scales)

	Left	Right
Front	1020	1044
Rear	585	605

FRONT	2064	lb
REAR	1190	lb
TOTAL	3254	lb

Figure B-2. Vehicle Mass Distribution, Test No. NYJ-2

Test: NYJ-3 Vehicle: Ram 1500

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb)	Vert CG (in.)	Vert M (lb-in.)
+	Unbalasted Truck (Curb)	5016	28.30313	141968.5
+	Brake receivers/wires	6	52	312
+	Brake Frame	9	26	234
+	Brake Cylinder (Nitrogen)	28	27.5	770
+	Strobe/Brake Battery	6	32	192
+	Hub	27	15	405
+	Data recorders	8	33.5	268
-	Battery	-42	41.5	-1743
-	Oil	-5	15.5	-77.5
-	Interior	-64	24	-1536
-	Fuel	-152	18	-2736
-	Coolant	-13	36	-468
-	Washer fluid	-2	40	-80
BALLAST	Water	181	18	3258
	Misc.			0
	Misc.			0
				140767

Estimated Total Weight (lb)	5003
Vertical CG Location (in.)	28.13652

wheel base (in.) 140.5

MASH Targets		**Targets**	**Test Inertial**	**Difference**
Test Inertial Weight (lb)		5000 ± 110	5006	6.0
Long CG (in.)		63 ± 4	64.64	1.63674
Lat CG (in.)		NA	0.080903	NA
Vert CG (in.)	≥	28	28.14	0.13652

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	1437	1316
Rear	1144	1119

FRONT	2753 lb
REAR	2263 lb
TOTAL	5016 lb

TEST INERTIAL WEIGHT (lb)

(from scales)

	Left	Right
Front	1361	1342
Rear	1136	1167

FRONT	2703 lb
REAR	2303 lb
TOTAL	5006 lb

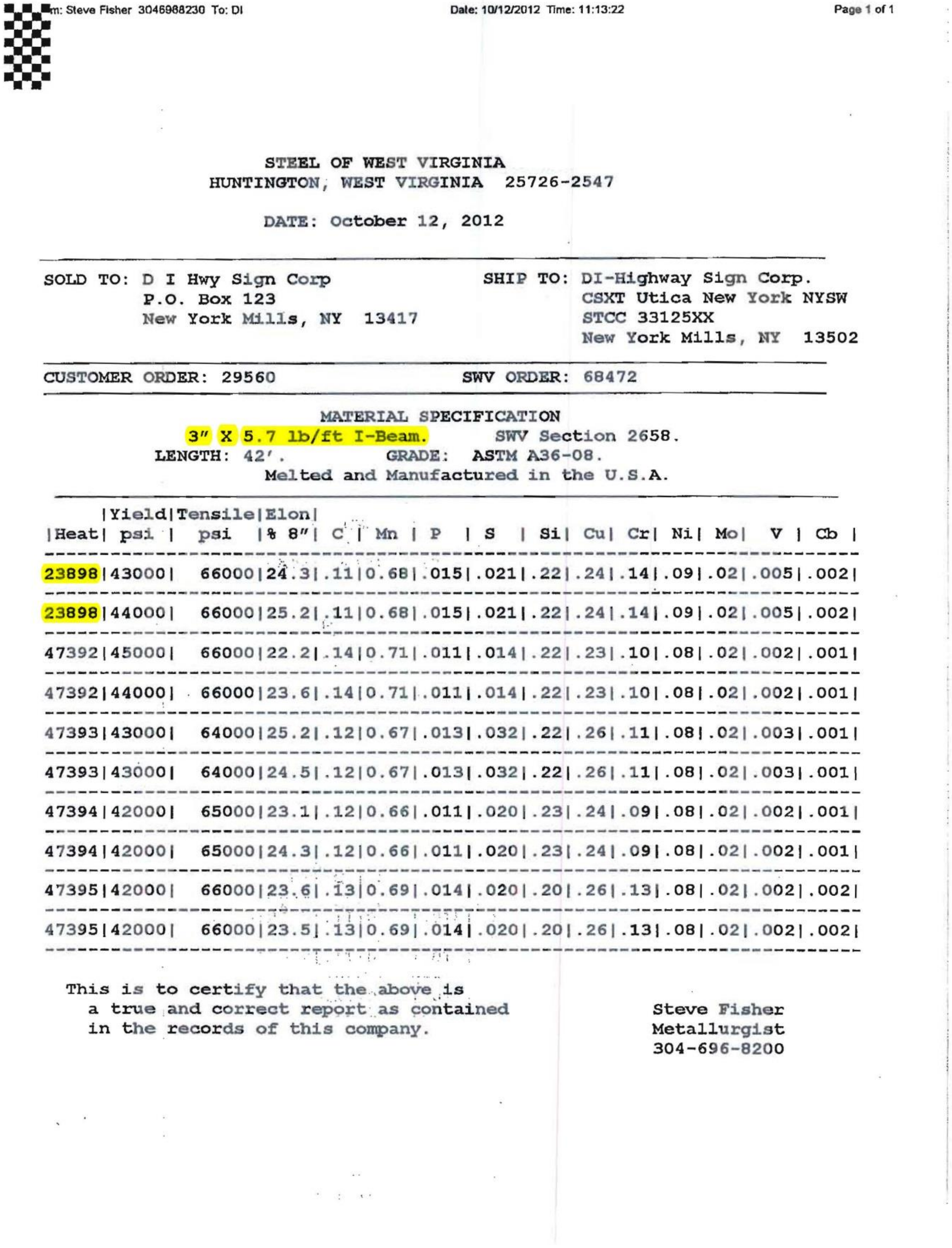
Figure B-3. Figure 104. Vehicle Mass Distribution, Test No. NYJ-3

Appendix C. Material Specifications

Table C-1. Bill of Materials for Test Nos. NYJ-1 through NYJ-3

Item No.	Description	Material Spec	Reference	Test
a1	S3x5.7 [S76x8.5] 29 3/4" [756] Long Anchor Post	ASTM A36 Galv.	H#23898	NYJ-1 thru 3
a2	3/4" [19] Dia. UNC, Hooked Anchor J-Bolt and Nut	ASTM A307 Gr. C and ASTM A563 DH Galv.	LOT#170277	NYJ-1 thru 3
a3	3/16" [5] Dia. 5 1/4" [133] Long Brass Rod	ASTM B16-00	COC#1175759108	NYJ-1 thru 3
a4	3/4" [19] Dia. Plain Round Washer (OD 1.5" [38])	ASTM F844/SAE Gr. 2	COC#1175759108	NYJ-1 thru 3
a5	W4x13 [W102x19.3] Anchor Post Stub	ASTM A36 Galv.	H#22479840	NYJ-1 thru 3
a6	7"x4 1/2"x3/8" [178x114x10] Slip Impact Base	ASTM A36 Galv.	H#B300976	NYJ-1 thru 3
a7	7"x4 1/2"x28 Gauge [178x144x0.38] Keeper Plate	ASTM A36 Galv.	NO CERTS	NYJ-1 thru 3
a8	1/2" [13] Dia. UNC, 2" [51] Long Bolt and Nut	ASTM A307 Gr. A/ASTM F1554 Gr. 36/SAE Gr. 2 and ASTM A563 Gr. A	LOT#1N1070407	NYJ-1 thru 3
a9	1/2" [13] Dia. Narrow Washer (OD 1" [25])	ASTM 844/SAE Gr. 2	LOT#504612	NYJ-1 thru 3
a10	18"x2"x3/4" [457x51x19] Anchor Post Cable Hanger	ASTM A707 Gr. 36 Galv.	H#2506111	NYJ-1 thru 3
a11	12"x12"x1/2" [305x305x13] Anchor Post Base	ASTM A709 Gr. 36 Galv.	H#F5-5531	NYJ-1 thru 3
b1	14"x9"x1/2" [356x229x13] Cable Anchor Base Plate	ASTM A709 Gr. 36 Galv.	H#G107094	NYJ-1 thru 3
b2	3 1/2"x3 1/2"x1/2" [89x89x13] Cable Anchor External Gusset	ASTM A709 Gr. 36 Galv.	H#G107094	NYJ-1 thru 3
b3	1/4" [6] Dia. 16" [406] Long Brass Rod	ASTM B16-00	COC#1175759108	NYJ-1 thru 3
b4	2 3/4"x2 3/4"x1/4" [70x70x6] Cable Anchor Internal Gusset	ASTM A709 Gr. 36 Galv.	H#G107118	NYJ-1 thru 3
b5	14"x1"x1/2" [356x25x13] Cable Anchor Front Plate	ASTM A709 Gr. 36 Galv.	H#G107094	NYJ-1 thru 3
b6	14"x4"x1/2" [356x102x13] Cable Anchor Top Plate	ASTM A709 Gr. 36 Galv.	H#G107094	NYJ-1 thru 3
c1	Cable End Fitting	ASTM A27 Galv.	H#BU1	NYJ-1 thru 3
c2	3/4" [19] Plain Round Washer (OD 2" [51])	ASTM F844/SAE Gr. 2 Galv.	H#2408593	NYJ-1 thru 3
c3	Cable Turnbuckle	AASHTO M269/ASTM F1145	LOT#M21549	NYJ-1 thru 3
c4	S3x5.7 [S76x8.5] 65" [1651] Long Line Post	ASTM A36	H#23898	NYJ-1 thru 3
c5	1/2" [13] J-Bolt and Nut	Bolt ASTM A36 and Nut ASTM A563DH Galv.	H#AU12102983 and H#5078089	NYJ-1 and 2
			H#AU12102983 and H#5170424	NYJ-3
c6	3/4" [19] Dia. Cable Approx. 600' [183 m]	AASHTO M30 Type 1 Class A Galv.	H#59586/87 AND H#61926/27	NYJ-1 thru 3
c7	2'x8"x0.25" Soil Plate	ASTM A36 Galv.	H#A63816	NYJ-1 thru 3
c8	1" [25] Dia. Beveled Washer	ASTM A36	NO CERTS	NYJ-1 thru 3
d1	Concrete Anchor Block	3000 psi [20.68 MPa] Compressive Strength	RM Mix Code: 23033000	NYJ-1 thru 3
d2	32 1/2" [826] Long #3 [#10] Rebar	ASTM A36	H#11898510	NYJ-1 thru 3
d3	44 1/2" [1130] Long #3 [#10] Rebar	ASTM A36	H#11898510	NYJ-1 thru 3
d4	30" [762] Long #3 [#10] Rebar	ASTM A36	H#11898510	NYJ-1 thru 3

e1	Cable Wedge	ASTM A47 Gr. 32510	H#BR1	NYJ-2
			H#1S7	NYJ-1 and 3
e2	50,000-lb Load Cell	N/A	NO CERTS	NYJ-1 thru 3
e3	3/4" [19] Dia. UNC Threaded Rod	ASTM A449	H#B9049 and H#T7958	NYJ-1 thru 3
e4	3/4" [19] Dia. UNC Left-Handed Threaded Rod	ASTM A449	H#B9049	NYJ-1 thru 3
e5	3/4" [19] Cable Splice	ASTM A536	LOT#73501	NYJ-1 thru 3



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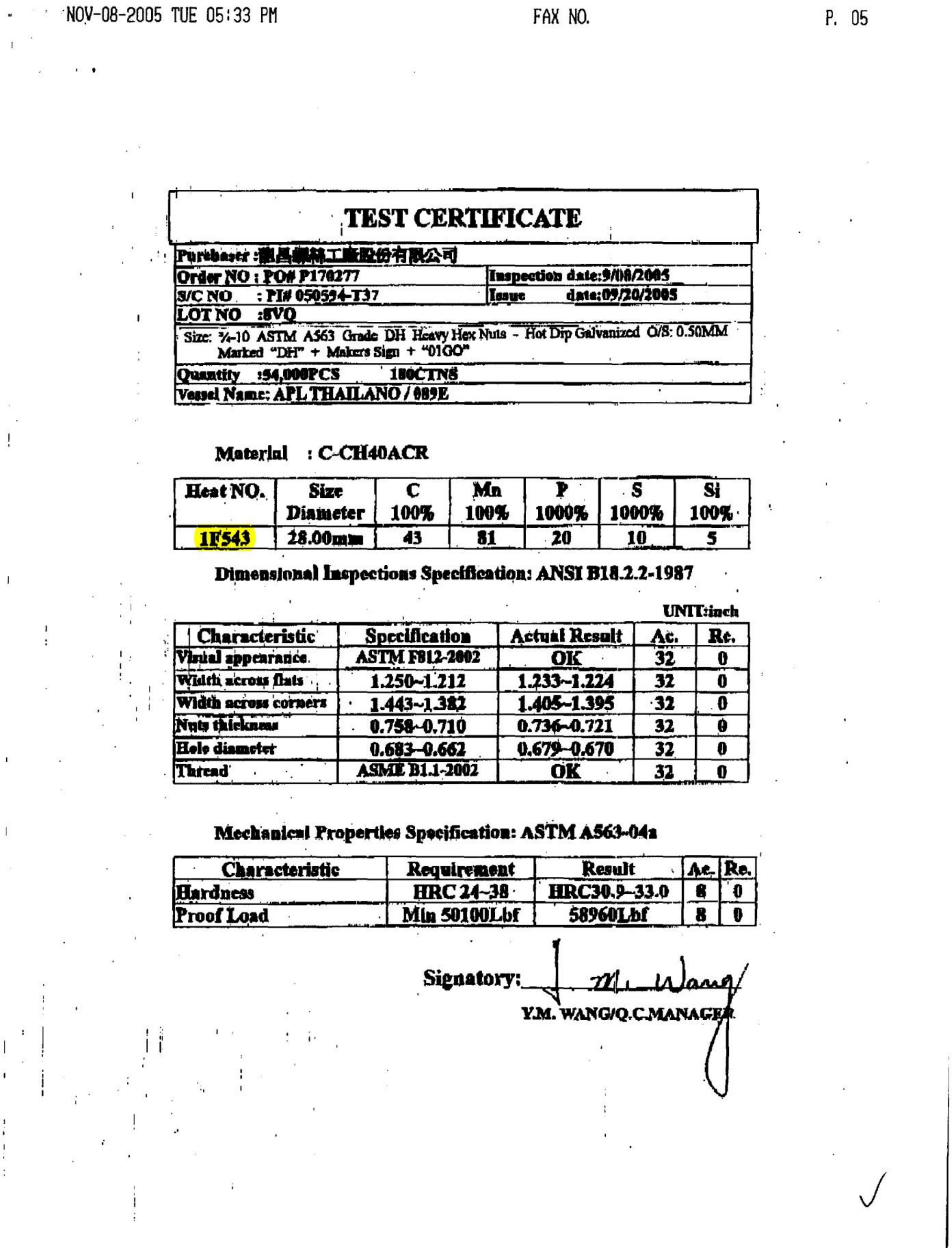
MATERIAL SPECIFICATION
3" X 5.7 lb/ft I-Beam. SWV Section 2658.
LENGTH: 42'. GRADE: ASTM A36-08.
Melted and Manufactured in the U.S.A.

	Yield	Tensile	Elon											
Heat	psi	psi	% 8"	C	Mn	P	S	Si	Cu	Cr	Ni	Mo	V	Cb
23898	43000	66000	24.3	.11	0.68	.015	.021	.22	.24	.14	.09	.02	.005	.002
23898	44000	66000	25.2	.11	0.68	.015	.021	.22	.24	.14	.09	.02	.005	.002
47392	45000	66000	22.2	.14	0.71	.011	.014	.22	.23	.10	.08	.02	.002	.001
47392	44000	66000	23.6	.14	0.71	.011	.014	.22	.23	.10	.08	.02	.002	.001
47393	43000	64000	25.2	.12	0.67	.013	.032	.22	.26	.11	.08	.02	.003	.001
47393	43000	64000	24.5	.12	0.67	.013	.032	.22	.26	.11	.08	.02	.003	.001
47394	42000	65000	23.1	.12	0.66	.011	.020	.23	.24	.09	.08	.02	.002	.001
47394	42000	65000	24.3	.12	0.66	.011	.020	.23	.24	.09	.08	.02	.002	.001
47395	42000	66000	23.6	.13	0.69	.014	.020	.20	.26	.13	.08	.02	.002	.002
47395	42000	66000	23.5	.13	0.69	.014	.020	.20	.26	.13	.08	.02	.002	.002

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 C-1. S3x5.7 (S76x8.5) Long Anchor and Line Posts, Test Nos. NYJ-1 through NYJ-3



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

TEST CERTIFICATE

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

Material : C-CH40ACR

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

Dimensional Inspections Specification: ANSI B18.2.2-1987

UNIT:inch

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

Mechanical Properties Specification: ASTM A563-04a

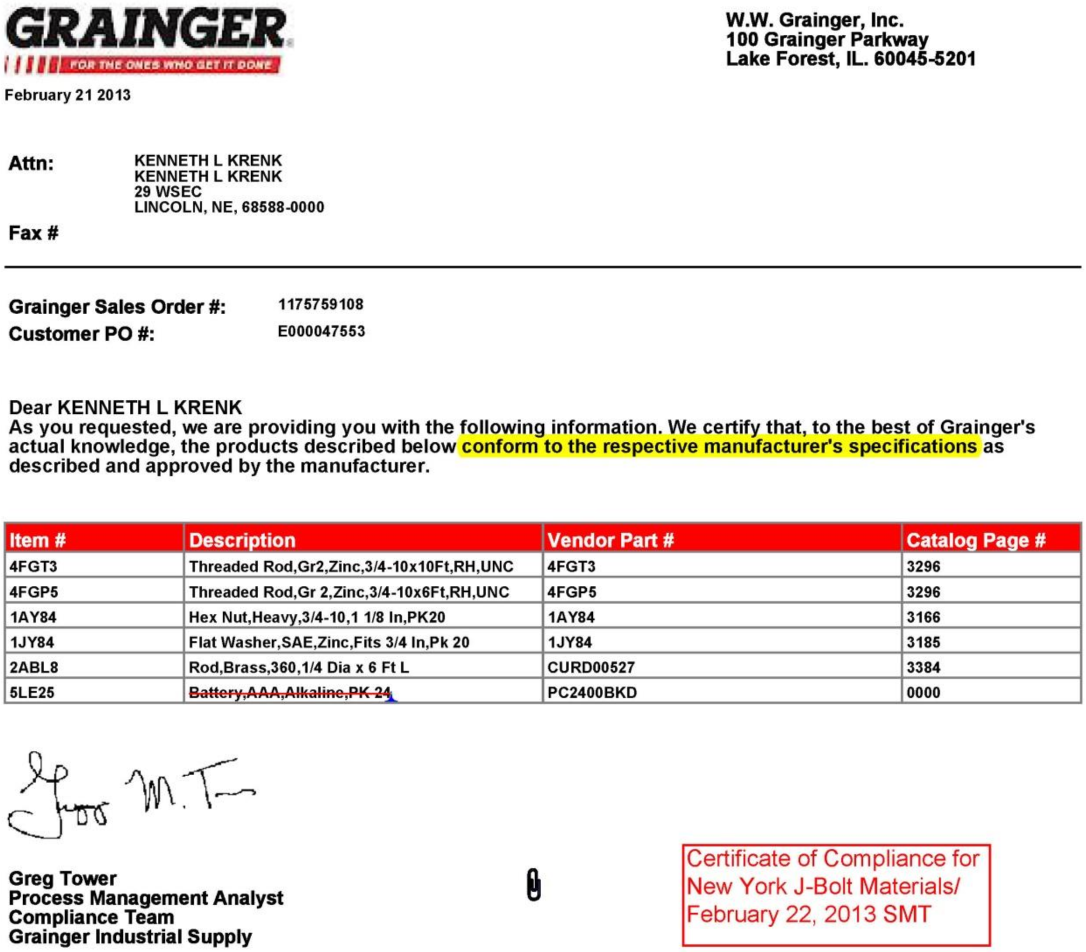
Characteristic	Requirement	Result	Ac.	Re.
Hardness	HRC 24~38	HRC30.9~33.0	8	0
Proof Load	Min 50100Lbf	58960Lbf	8	0

Signatory: M. Wang

Y.M. WANG/Q.C.MANAGER

✓

Figure C-2. ¾-in. (19-mm) Dia. Hooked Anchor J-Bolt and Nut, Test Nos. NYJ-1 through NYJ-3



GRAINGER
FOR THE ONES WHO GET IT DONE

W.W. Grainger, Inc.
100 Grainger Parkway
Lake Forest, IL. 60045-5201

February 21 2013

Attn:
KENNETH L KRENK
KENNETH L KRENK
29 WSEC
LINCOLN, NE, 68588-0000

Fax #

Grainger Sales Order #: 1175759108
Customer PO #: E000047553

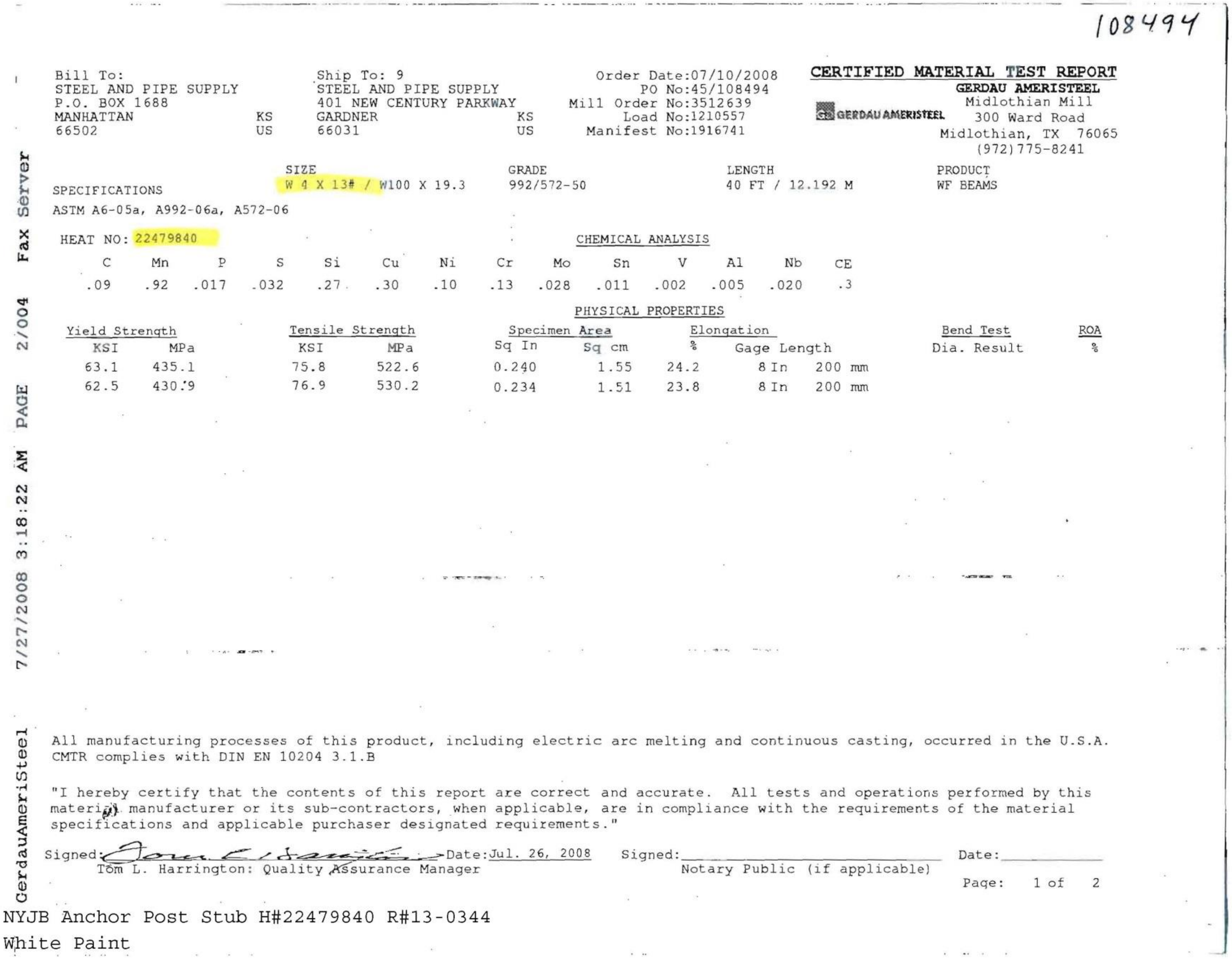
Dear KENNETH L KRENK
As you requested, we are providing you with the following information. We certify that, to the best of Grainger's actual knowledge, the products described below conform to the respective manufacturer's specifications as described and approved by the manufacturer.

Item #	Description	Vendor Part #	Catalog Page #
4FGT3	Threaded Rod,Gr2,Zinc,3/4-10x10Ft,RH,UNC	4FGT3	3296
4FGP5	Threaded Rod,Gr 2,Zinc,3/4-10x6Ft,RH,UNC	4FGP5	3296
1AY84	Hex Nut,Heavy,3/4-10,1 1/8 In,PK20	1AY84	3166
1JY84	Flat Washer,SAE,Zinc,Fits 3/4 In,Pk 20	1JY84	3185
2ABL8	Rod,Brass,360,1/4 Dia x 6 Ft L	CURD00527	3384
5LE25	~~Battery,AAA,Alkaline,PK 24~~	PC2400BKD	0000

Greg Tower
Process Management Analyst
Compliance Team
Grainger Industrial Supply

Certificate of Compliance for
New York J-Bolt Materials/
February 22, 2013 SMT

Figure C-3. Long Brass Rods and ¾-in (19-mm) Dia. Round Washer, Test Nos. NYJ-1 through NYJ-3



108494

7/27/2008 3:18:22 AM PAGE 2/004 Fax Server

Bill To:
STEEL AND PIPE SUPPLY
P.O. BOX 1688
MANHATTAN KS
66502 US

Ship To: 9
STEEL AND PIPE SUPPLY
401 NEW CENTURY PARKWAY
GARDNER KS
66031 US

Order Date:07/10/2008
PO No:45/108494
Mill Order No:3512639
Load No:1210557
Manifest No:1916741

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

SPECIFICATIONS	SIZE	GRADE	LENGTH	PRODUCT
	W 4 X 13# / W100 X 19.3	992/572-50	40 FT / 12.192 M	WF BEAMS

ASTM A6-05a, A992-06a, A572-06

HEAT NO: 22479840

CHEMICAL ANALYSIS

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	V	Al	Nb	CE
.09	.92	.017	.032	.27	.30	.10	.13	.028	.011	.002	.005	.020	.3

PHYSICAL PROPERTIES

Yield Strength		Tensile Strength		Specimen Area		Elongation			Bend Test		ROA
KSI	MPa	KSI	MPa	Sq In	Sq cm	%	Gage Length		Dia.	Result	%
63.1	435.1	75.8	522.6	0.240	1.55	24.2	8 In	200 mm			
62.5	430.9	76.9	530.2	0.234	1.51	23.8	8 In	200 mm			

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

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

Signed: Tom L. Harrington Date: Jul. 26, 2008
Tom L. Harrington: Quality Assurance Manager

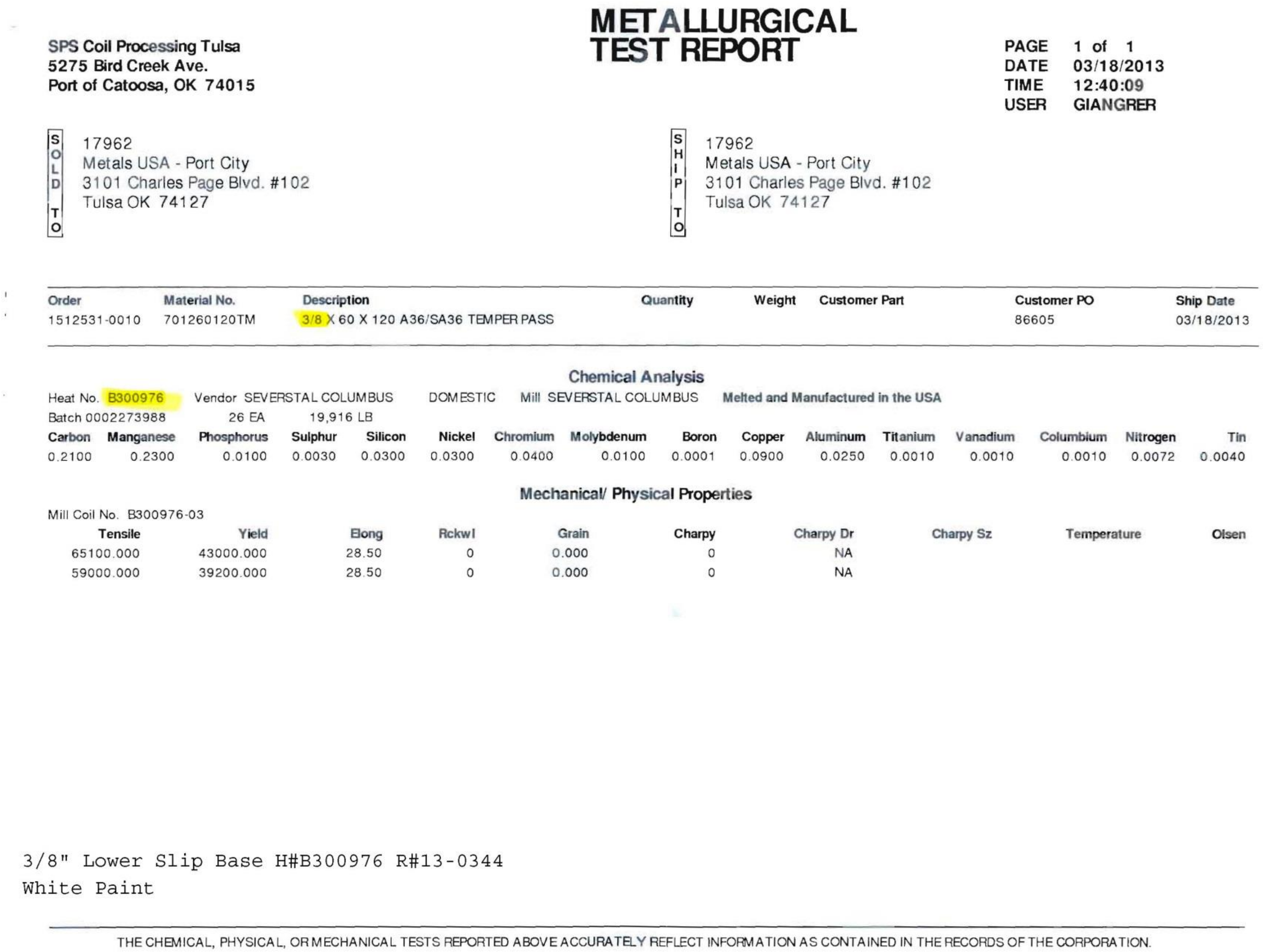
Signed: ______________________ Date: __________
Notary Public (if applicable)

Page: 1 of 2

GerdauAmeriSteel

NYJB Anchor Post Stub H#22479840 R#13-0344
White Paint

Figure C-4. W4x13 (W102x19.3) Anchor Post Stub, Test Nos. NYJ-1 through NYJ-3



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

METALLURGICAL TEST REPORT

PAGE 1 of 1
DATE 03/18/2013
TIME 12:40:09
USER GIANGRER

SOLD TO
17962
Metals USA - Port City
3101 Charles Page Blvd. #102
Tulsa OK 74127

SHIP TO
17962
Metals USA - Port City
3101 Charles Page Blvd. #102
Tulsa OK 74127

Order	Material No.	Description	Quantity	Weight	Customer Part	Customer PO	Ship Date
1512531-0010	701260120TM	3/8 X 60 X 120 A36/SA36 TEMPER PASS				86605	03/18/2013

Chemical Analysis

Heat No. B300976 Vendor SEVERSTAL COLUMBUS DOMESTIC Mill SEVERSTAL COLUMBUS **Melted and Manufactured in the USA**
Batch 0002273988 26 EA 19,916 LB

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.2100	0.2300	0.0100	0.0030	0.0300	0.0300	0.0400	0.0100	0.0001	0.0900	0.0250	0.0010	0.0010	0.0010	0.0072	0.0040

Mechanical/ Physical Properties

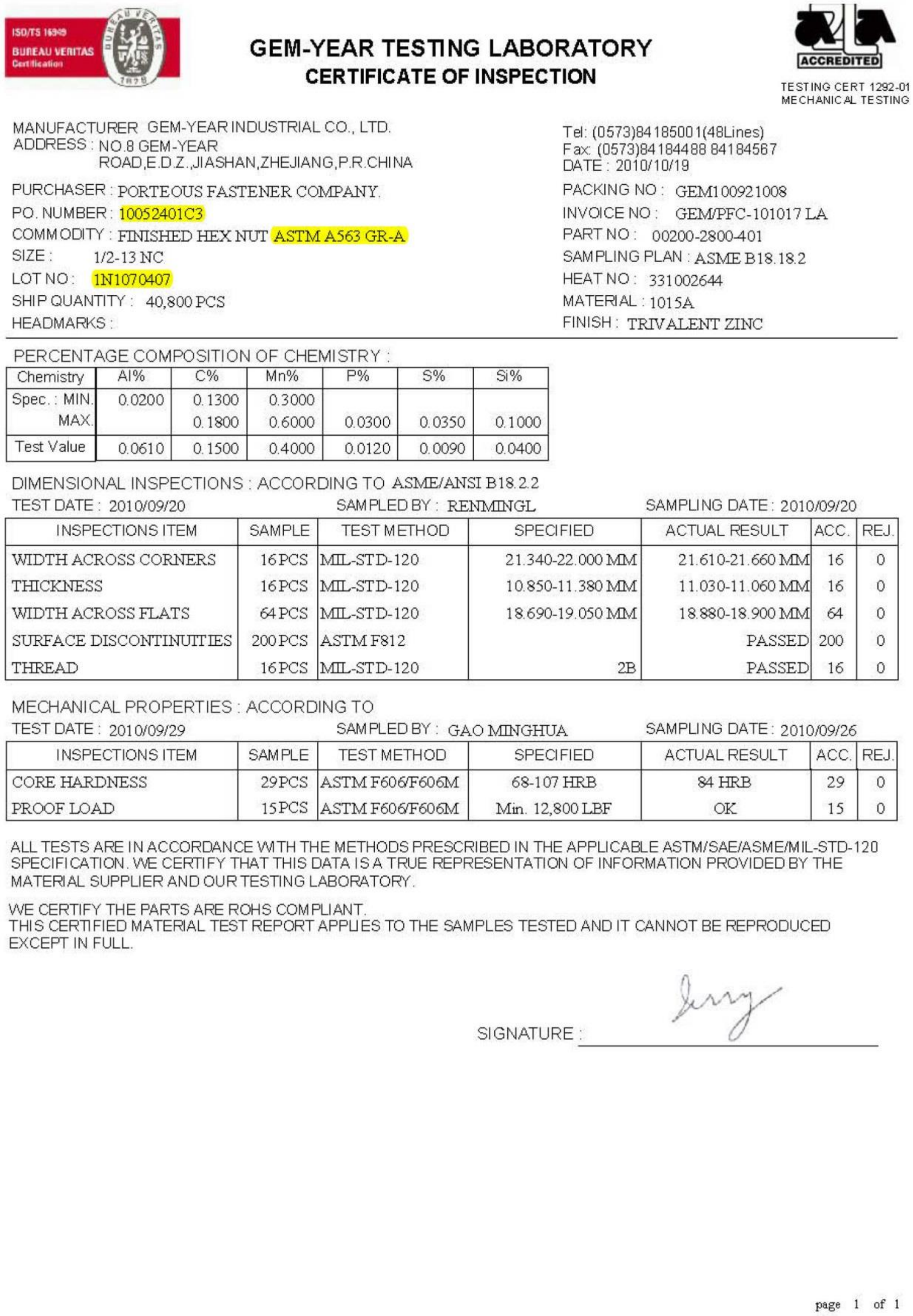
Mill Coil No. B300976-03

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
65100.000	43000.000	28.50	0	0.000	0	NA			
59000.000	39200.000	28.50	0	0.000	0	NA			

3/8" Lower Slip Base H#B300976 R#13-0344
White Paint

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

Figure C-5. Slip Impact Base, Test Nos. NYJ-1 through NYJ-3



ISO/TS 16949
BUREAU VERITAS
Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

ACCREDITED
TESTING CERT 1292-01
MECHANICAL TESTING

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

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2010/10/19

PURCHASER : PORTEOUS FASTENER COMPANY.
PO. NUMBER : 10052401C3
COMMODITY : FINISHED HEX NUT ASTM A563 GR-A
SIZE : 1/2-13 NC
LOT NO : 1N1070407
SHIP QUANTITY : 40,800 PCS
HEADMARKS :

PACKING NO : GEM10092100 8
INVOICE NO : GEM/PFC-101017 LA
PART NO : 00200-2800-401
SAMPLING PLAN : ASME B18.18.2
HEAT NO : 331002644
MATERIAL : 1015A
FINISH : TRIVALENT ZINC

PERCENTAGE COMPOSITION OF CHEMISTRY :

Chemistry	Al%	C%	Mn%	P%	S%	Si%
Spec. : MIN.	0.0200	0.1300	0.3000			
MAX.		0.1800	0.6000	0.0300	0.0350	0.1000
Test Value	0.0610	0.1500	0.4000	0.0120	0.0090	0.0400

DIMENSIONAL INSPECTIONS : ACCORDING TO ASME/ANSI B18.2.2
TEST DATE : 2010/09/20 SAMPLED BY : RENMINGL SAMPLING DATE : 2010/09/20

INSPECTIONS ITEM	SAMPLE	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
WIDTH ACROSS CORNERS	16PCS	MIL-STD-120	21.340-22.000 MM	21.610-21.660 MM	16	0
THICKNESS	16PCS	MIL-STD-120	10.850-11.380 MM	11.030-11.060 MM	16	0
WIDTH ACROSS FLATS	64PCS	MIL-STD-120	18.690-19.050 MM	18.880-18.900 MM	64	0
SURFACE DISCONTINUITIES	200PCS	ASTM F812		PASSED	200	0
THREAD	16PCS	MIL-STD-120	2B	PASSED	16	0

MECHANICAL PROPERTIES : ACCORDING TO
TEST DATE : 2010/09/29 SAMPLED BY : GAO MINGHUA SAMPLING DATE : 2010/09/26

INSPECTIONS ITEM	SAMPLE	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	29PCS	ASTM F606/F606M	68-107 HRB	84 HRB	29	0
PROOF LOAD	15PCS	ASTM F606/F606M	Min. 12,800 LBF	OK	15	0

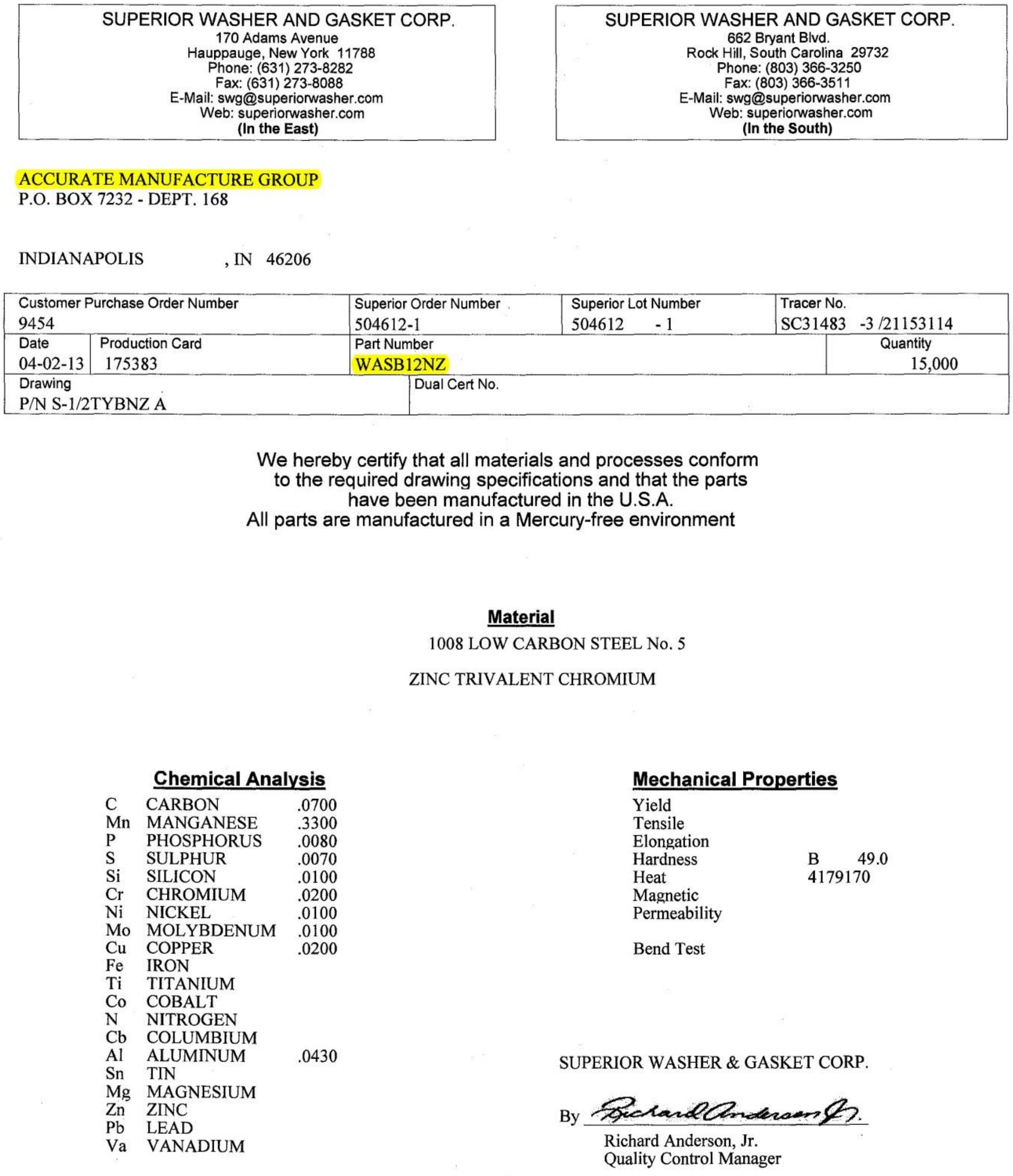
ALL TESTS ARE IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM/SAE/ASME/MIL-STD-120 SPECIFICATION. WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.

WE CERTIFY THE PARTS ARE ROHS COMPLIANT.
THIS CERTIFIED MATERIAL TEST REPORT APPLIES TO THE SAMPLES TESTED AND IT CANNOT BE REPRODUCED EXCEPT IN FULL.

SIGNATURE :

page 1 of 1

Figure C-6. ½-in. (13-mm) Dia. Long Bolt and Nut, Test Nos. NYJ-1 through NYJ-3



SUPERIOR WASHER AND GASKET CORP.
170 Adams Avenue
Hauppauge, New York 11788
Phone: (631) 273-8282
Fax: (631) 273-8088
E-Mail: swg@superiorwasher.com
Web: superiorwasher.com
(In the East)

SUPERIOR WASHER AND GASKET CORP.
662 Bryant Blvd.
Rock Hill, South Carolina 29732
Phone: (803) 366-3250
Fax: (803) 366-3511
E-Mail: swg@superiorwasher.com
Web: superiorwasher.com
(In the South)

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

INDIANAPOLIS , IN 46206

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

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

Material

1008 LOW CARBON STEEL No. 5

ZINC TRIVALENT CHROMIUM

Chemical Analysis

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

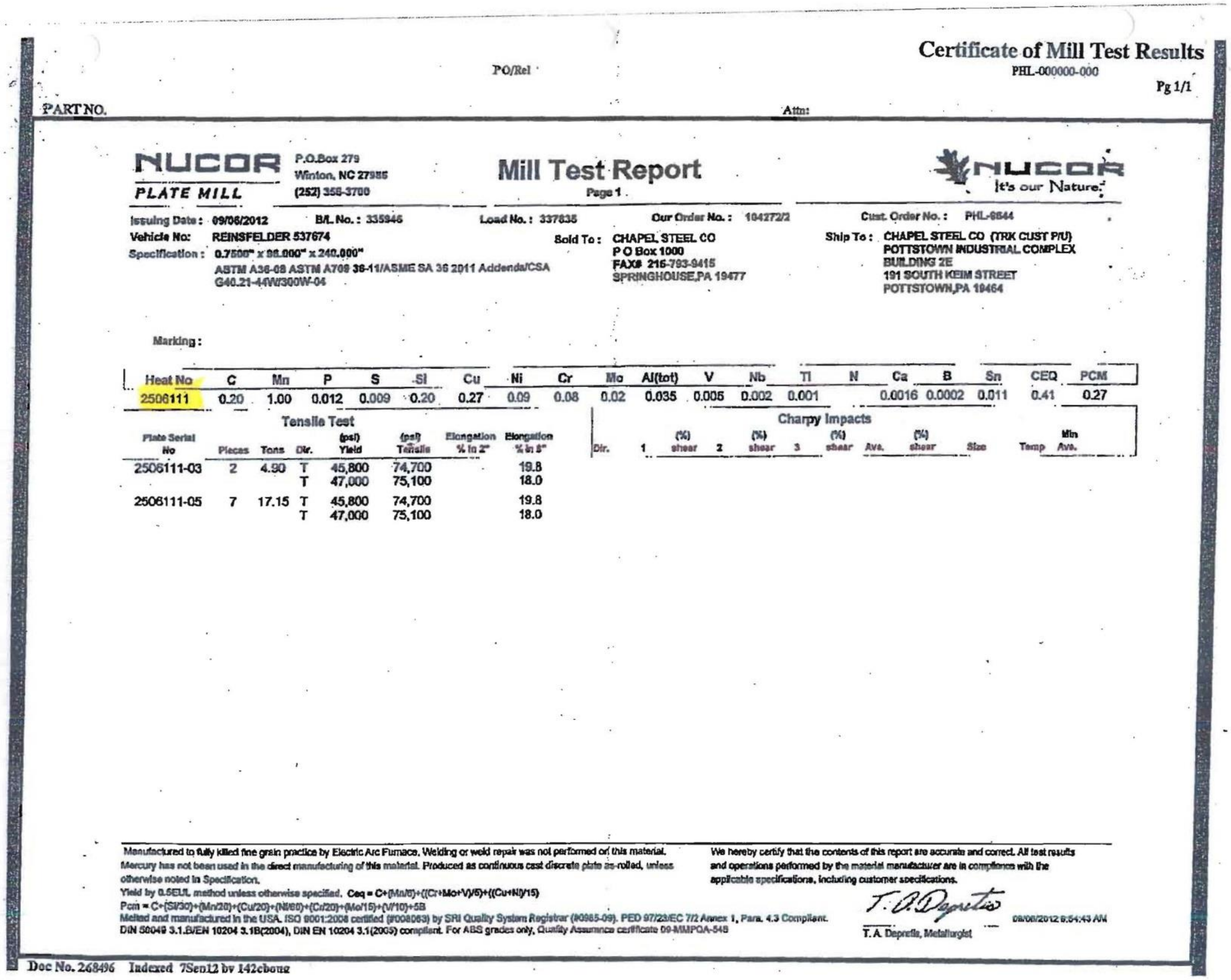
Mechanical Properties

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

SUPERIOR WASHER & GASKET CORP.

By Richard Anderson Jr.
Richard Anderson, Jr.
Quality Control Manager

Figure C-7. ½-in. (13-mm) Dia. Narrow Washer, Test Nos. NYJ-1 through NYJ-3



Certificate of Mill Test Results
PHL-000000-000
Pg 1/1

PO/Rel

PART NO.

Attn:

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 : 09/06/2012 B/L No. : 335946 Load No. : 337835 Our Order No. : 104272/2 Cust. Order No. : PHL-9844

Vehicle No: REINSFELDER 537674

Specification : 0.7500" x 96.000" x 240.000"
ASTM A36-08 ASTM A709 36-11/ASME SA 36 2011 Addenda/CSA
G40.21-44W/300W-04

Sold To : CHAPEL STEEL CO
P O Box 1000
FAX# 215-793-9415
SPRINGHOUSE,PA 19477

Ship To : CHAPEL STEEL CO (TRK CUST P/U)
POTTSTOWN INDUSTRIAL COMPLEX
BUILDING 2E
191 SOUTH KEIM STREET
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
2506111	0.20	1.00	0.012	0.009	0.20	0.27	0.09	0.08	0.02	0.035	0.005	0.002	0.001		0.0016	0.0002	0.011	0.41	0.27

Tensile Test

Plate Serial No	Pieces	Tons	Dir.	(psi) Yield	(psi) Tensile	Elongation % in 2"	Elongation % in 8"
2506111-03	2	4.90	T	45,800	74,700		19.8
			T	47,000	75,100		18.0
2506111-05	7	17.15	T	45,800	74,700		19.8
			T	47,000	75,100		18.0

Charpy Impacts

Dir.	1	(%) shear	2	(%) shear	3	(%) shear	Ave.	(%) shear	Size	Temp	Min Ave.

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 9001:2008 certified (#008063) by SRI Quality System Registrar (#0985-09). 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 09-MMPQA-548

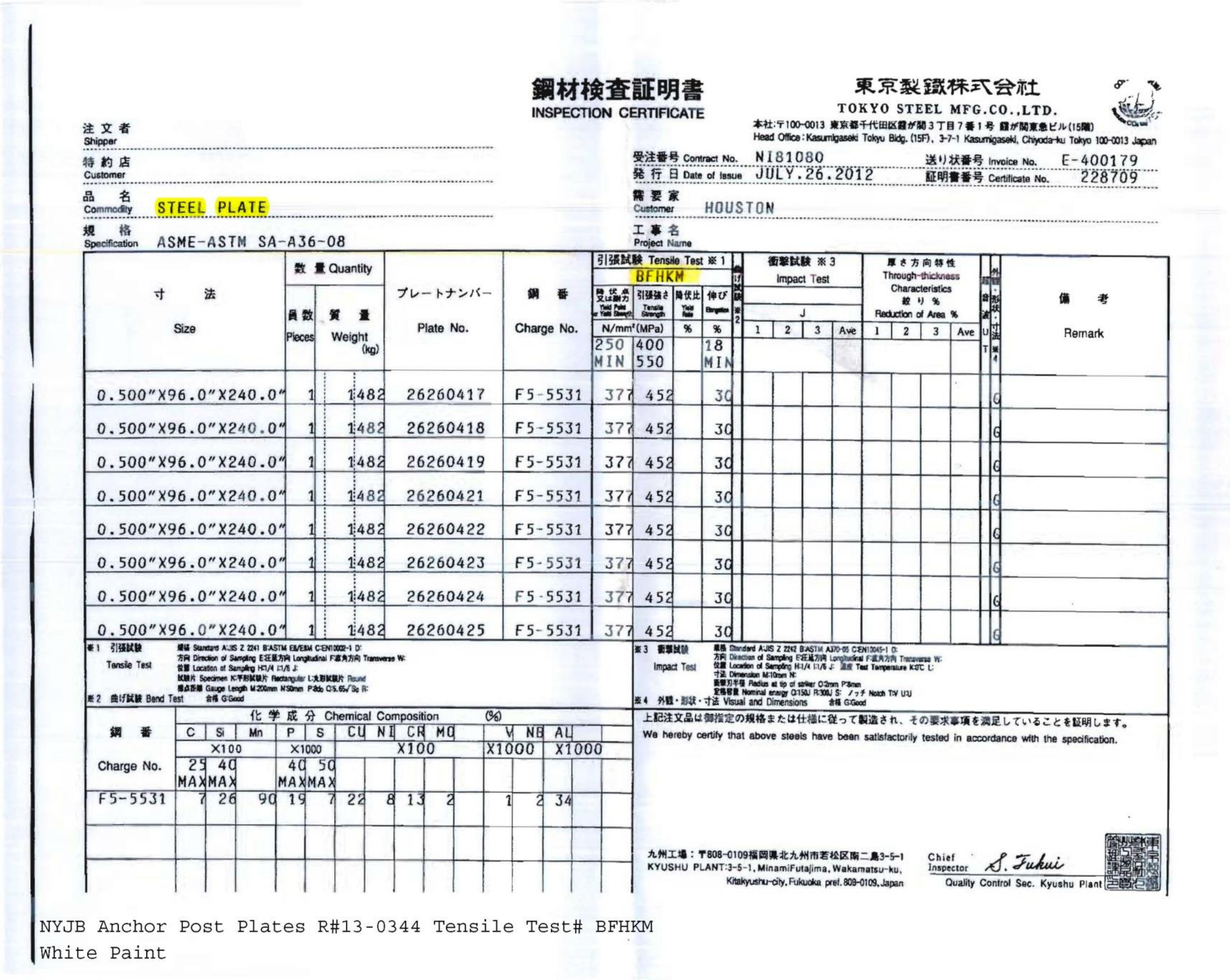
We hereby certify that the contents of this report are accurate and correct. All test results and operations performed by the material manufacturer are in compliance with the applicable specifications, including customer specifications.

T. A. Depretis
T.A. Depretis, Metallurgist

09/06/2012 6:54:43 AM

Doc No. 268496 Indexed 7Sep12 by 142cboug

Figure C-8. Anchor Post Cable Hanger, Test Nos. NYJ-1 through NYJ-3



鋼材検査証明書
INSPECTION CERTIFICATE

東京製鐵株式会社
TOKYO STEEL MFG.CO.,LTD.
本社:〒100-0013 東京都千代田区霞が関3丁目7番1号 霞が関東急ビル(15階)
Head Office: Kasumigaseki Tokyu Bldg. (15F), 3-7-1 Kasumigaseki, Chiyoda-ku Tokyo 100-0013 Japan

注文者 Shipper
特約店 Customer
品名 Commodity: STEEL PLATE
規格 Specification: ASME-ASTM SA-A36-08

受注番号 Contract No.: NI81080
送り状番号 Invoice No.: E-400179
発行日 Date of Issue: JULY.26.2012
証明書番号 Certificate No.: 228709
需要家 Customer: HOUSTON
工事名 Project Name

寸法 Size	数量 Quantity 員数 Pieces	数量 Quantity 質量 Weight (kg)	プレートナンバー Plate No.	鋼番 Charge No.	引張試験 Tensile Test ※1 BFHKM 降伏点又は耐力 Yield Point or Yield Strength N/mm² (MPa)	引張強さ Tensile Strength N/mm² (MPa)	降伏比 Yield Ratio %	伸び Elongation %	曲げ試験 ※2	衝撃試験 ※3 Impact Test J 1	2	3	Ave	厚さ方向特性 Through-thickness Characteristics 絞り% Reduction of Area % 1	2	3	Ave	超音波 UT	外観・形状・寸法 ※4	備考 Remark
					250 MIN	400 550		18 MIN												
0.500"X96.0"X240.0"	1	1482	26260417	F5-5531	377	452		30											G	
0.500"X96.0"X240.0"	1	1482	26260418	F5-5531	377	452		30											G	
0.500"X96.0"X240.0"	1	1482	26260419	F5-5531	377	452		30											G	
0.500"X96.0"X240.0"	1	1482	26260421	F5-5531	377	452		30											G	
0.500"X96.0"X240.0"	1	1482	26260422	F5-5531	377	452		30											G	
0.500"X96.0"X240.0"	1	1482	26260423	F5-5531	377	452		30											G	
0.500"X96.0"X240.0"	1	1482	26260424	F5-5531	377	452		30											G	
0.500"X96.0"X240.0"	1	1482	26260425	F5-5531	377	452		30											G	

※1 引張試験 Tensile Test
規格 Standard A:JIS Z 2241 B:ASTM E8/E8M C:EN10002-1 D:
方向 Direction of Sampling E:圧延方向 Longitudinal F:直角方向 Transverse W:
位置 Location of Sampling H:1/4 I:1/6 J:
試験片 Specimen K:平形試験片 Rectangular L:丸形試験片 Round
標点距離 Gauge Length M:200mm N:50mm P:8do Q:5.65√So R:

※2 曲げ試験 Bend Test 合格 G:Good

※3 衝撃試験 Impact Test
規格 Standard A:JIS Z 2242 B:ASTM A370-05 C:EN10045-1 D:
方向 Direction of Sampling E:圧延方向 Longitudinal F:直角方向 Transverse W:
位置 Location of Sampling H:1/4 I:1/6 J: 温度 Test Temperature K:0℃ L:
寸法 Dimension M:10mm N:
衝撃刃半径 Radius at tip of striker O:2mm P:8mm
定格容量 Nominal energy Q:150J R:300J S: ノッチ Notch T:V U:U

※4 外観・形状・寸法 Visual and Dimensions 合格 G:Good

化学成分 Chemical Composition (%)

鋼番 Charge No.	C	Si	Mn	P	S	CU	NI	CR	MO		V	NB	AL
	×100			×1000		X100					X1000		X1000
	25 MAX	40 MAX		40 MAX	50 MAX								
F5-5531	7	26	90	19	7	22	8	13	2		1	2	34

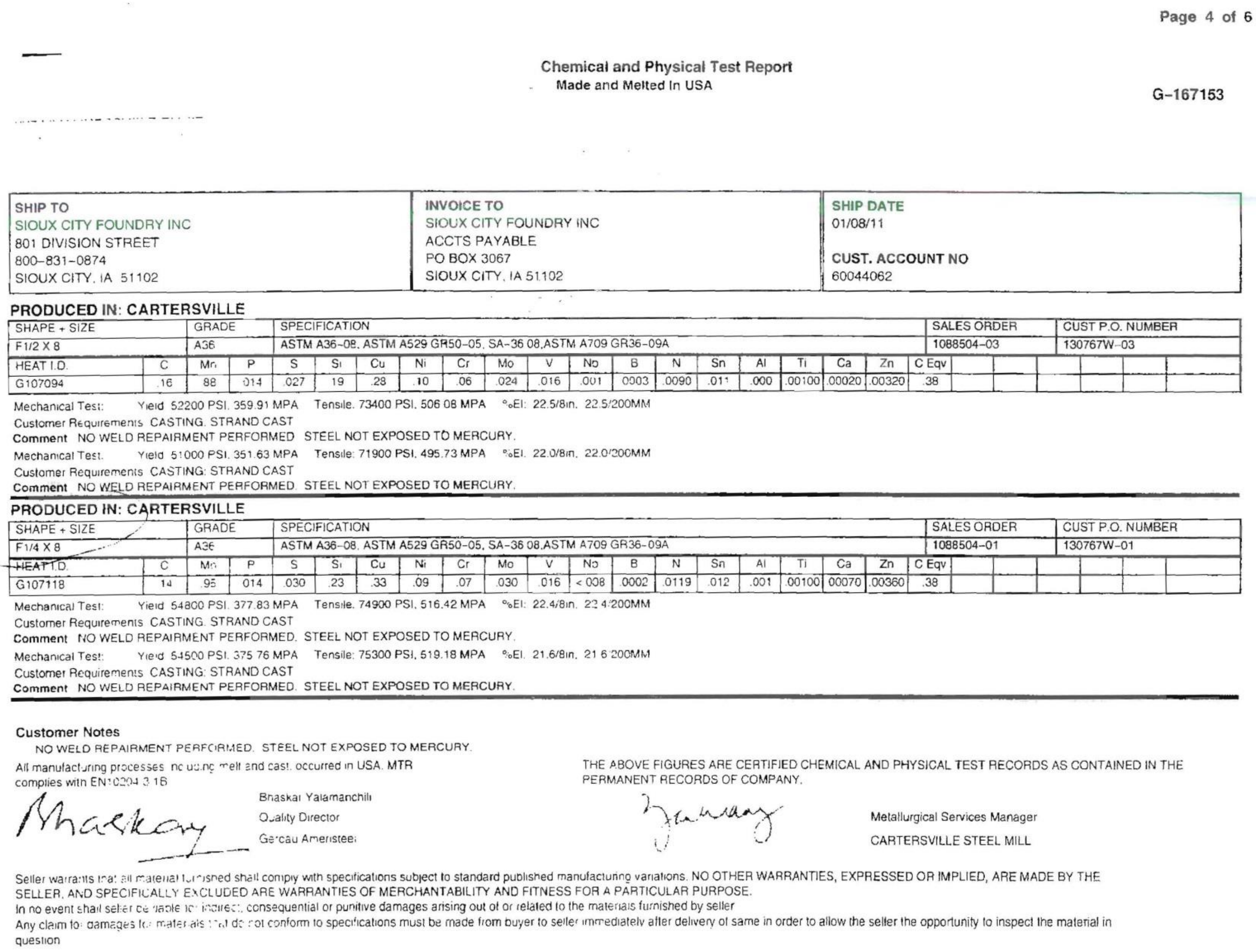
上記注文品は御指定の規格または仕様に従って製造され、その要求事項を満足していることを証明します。
We hereby certify that above steels have been satisfactorily tested in accordance with the specification.

九州工場：〒808-0109福岡県北九州市若松区南二島3-5-1
KYUSHU PLANT:3-5-1, MinamiFutajima, Wakamatsu-ku,
Kitakyushu-city, Fukuoka pref. 808-0109, Japan

Chief Inspector S. Fukui
Quality Control Sec. Kyushu Plant

NYJB Anchor Post Plates R#13-0344 Tensile Test# BFHKM
White Paint

Figure C-9. Anchor Post Base, Test Nos. NYJ-1 through NYJ-3



Page 4 of 6

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

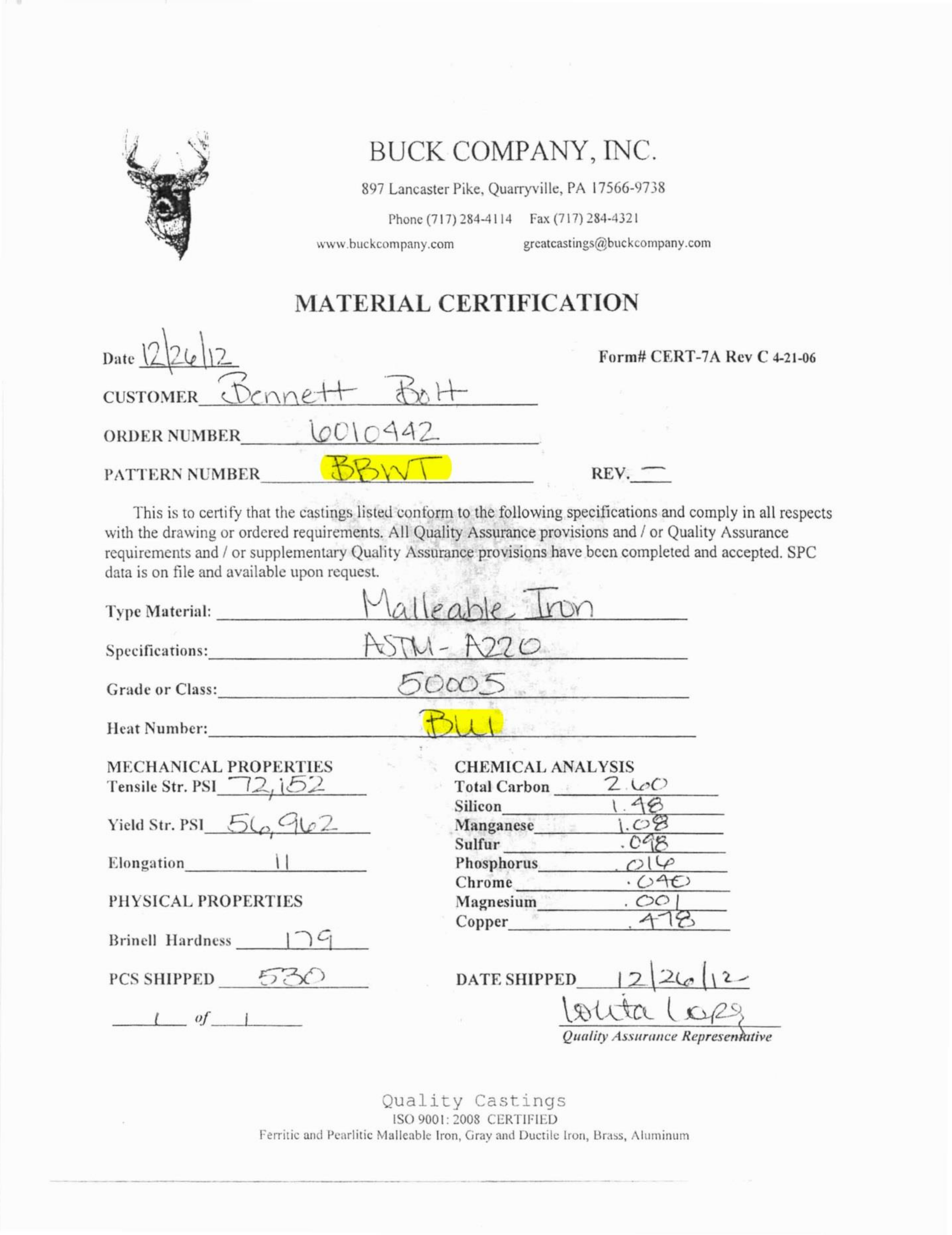
Bhaskar Yalamanchili
Quality Director
Gerdau Ameristeel

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 C-10. Cable Anchor Plates and Gussets, Test Nos. NYJ-1 through NYJ-3



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

MATERIAL CERTIFICATION

Date 12/26/12

Form# CERT-7A Rev C 4-21-06

CUSTOMER Bennett Bolt

ORDER NUMBER 6010442

PATTERN NUMBER BBWT

REV. –

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

Type Material: Malleable Iron

Specifications: ASTM-A220

Grade or Class: 50005

Heat Number: BLL

MECHANICAL PROPERTIES

Tensile Str. PSI 72,152

Yield Str. PSI 56,962

Elongation 11

PHYSICAL PROPERTIES

Brinell Hardness 179

PCS SHIPPED 530

1 of 1

CHEMICAL ANALYSIS

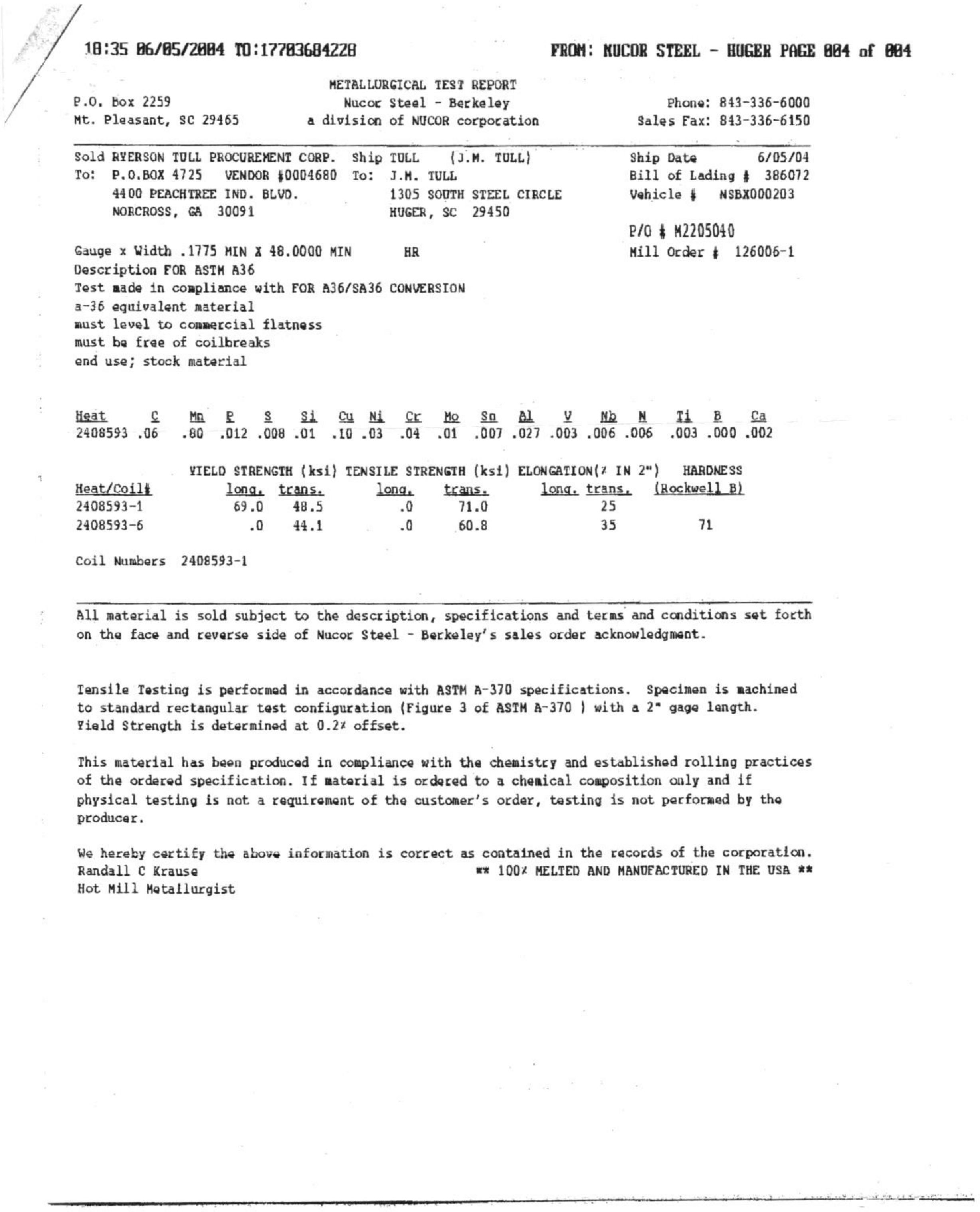
Total Carbon 2.60
Silicon 1.48
Manganese 1.08
Sulfur .098
Phosphorus .016
Chrome .040
Magnesium .001
Copper .478

DATE SHIPPED 12/26/12

Lolita Lopez
Quality Assurance Representative

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

Figure C-11. Cable End Fitting, Test Nos. NYJ-1 through NYJ-3



10:35 06/05/2004 TO:17703684228 **FROM: NUCOR STEEL - HUGER PAGE 004 of 004**

METALLURGICAL TEST REPORT

P.O. Box 2259
Mt. Pleasant, SC 29465

Nucor Steel - Berkeley
a division of NUCOR corporation

Phone: 843-336-6000
Sales Fax: 843-336-6150

Sold To: RYERSON TULL PROCUREMENT CORP.
P.O.BOX 4725 VENDOR #0004680
4400 PEACHTREE IND. BLVD.
NORCROSS, GA 30091

Ship To: TULL (J.M. TULL)
J.M. TULL
1305 SOUTH STEEL CIRCLE
HUGER, SC 29450

Ship Date 6/05/04
Bill of Lading # 386072
Vehicle # NSBX000203

P/O # M2205040
Mill Order # 126006-1

Gauge x Width .1775 MIN X 48.0000 MIN HR
Description FOR ASTM A36
Test made in compliance with FOR A36/SA36 CONVERSION
a-36 equivalent material
must level to commercial flatness
must be free of coilbreaks
end use; stock material

Heat	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	Al	V	Nb	N	Ti	B	Ca
2408593	.06	.80	.012	.008	.01	.10	.03	.04	.01	.007	.027	.003	.006	.006	.003	.000	.002

	YIELD STRENGTH (ksi)		TENSILE STRENGTH (ksi)		ELONGATION(% IN 2")		HARDNESS
Heat/Coil#	long.	trans.	long.	trans.	long.	trans.	(Rockwell B)
2408593-1	69.0	48.5	.0	71.0		25	
2408593-6	.0	44.1	.0	60.8		35	71

Coil Numbers 2408593-1

All material is sold subject to the description, specifications and terms and conditions set forth on the face and reverse side of Nucor Steel - Berkeley's sales order acknowledgment.

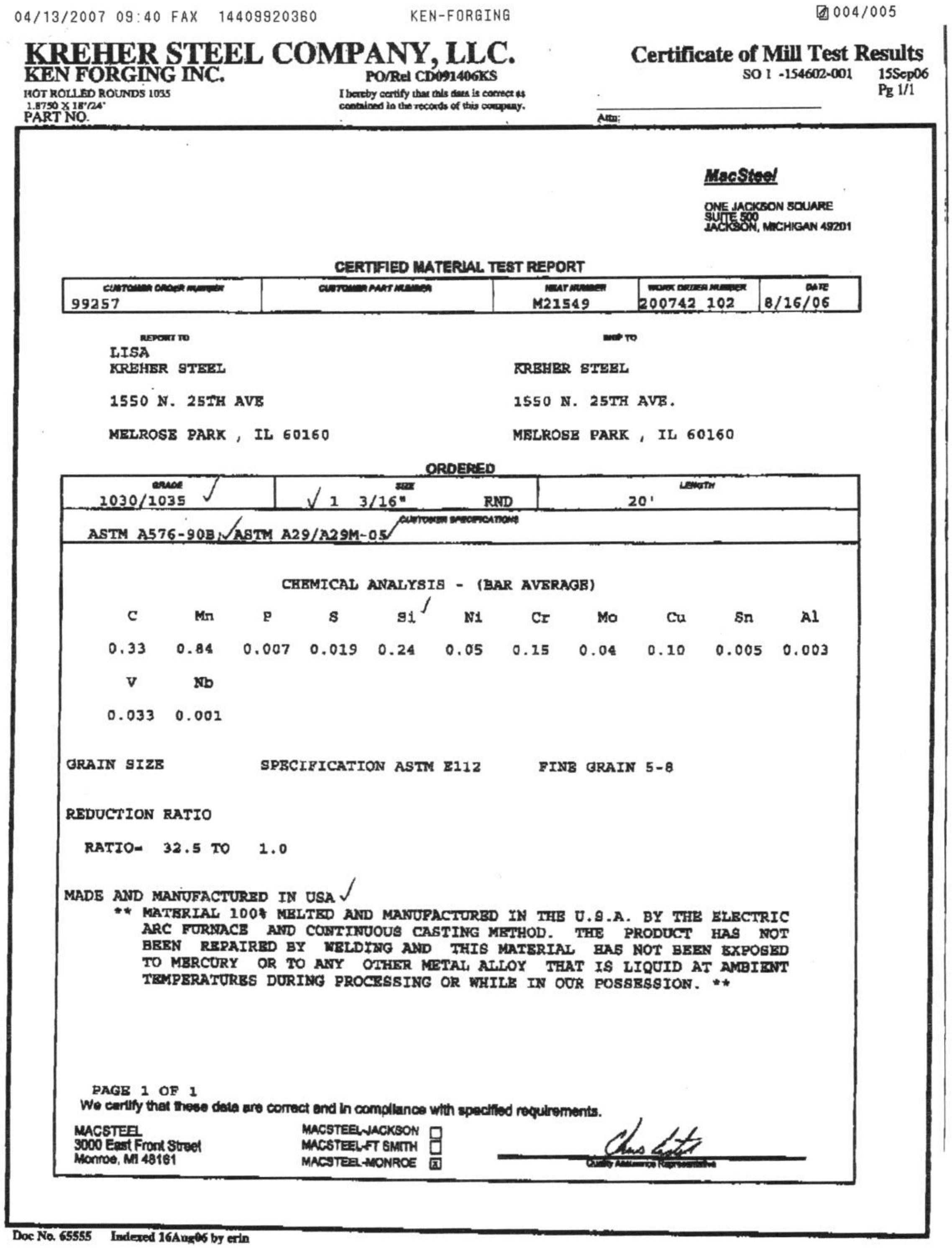
Tensile Testing is performed in accordance with ASTM A-370 specifications. Specimen is machined to standard rectangular test configuration (Figure 3 of ASTM A-370) with a 2" gage length. Yield Strength is determined at 0.2% offset.

This material has been produced in compliance with the chemistry and established rolling practices of the ordered specification. If material is ordered to a chemical composition only and if physical testing is not a requirement of the customer's order, testing is not performed by the producer.

We hereby certify the above information is correct as contained in the records of the corporation.
Randall C Krause
Hot Mill Metallurgist

** 100% MELTED AND MANUFACTURED IN THE USA **

Figure C-12. ¾-in. (19-mm) Plain Round Washer, Test Nos. NYJ-1 through NYJ-3



04/13/2007 09:40 FAX 14409920360 KEN-FORGING ☑004/005

KREHER STEEL COMPANY, LLC.
KEN FORGING INC.
HOT ROLLED ROUNDS 1035
1.8750 X 18'/24'
PART NO.

PO/Rel CD091406KS
I hereby certify that this data is correct as contained in the records of this company.

Certificate of Mill Test Results
SO 1 -154602-001 15Sep06
Pg 1/1

Attn:

MacSteel
ONE JACKSON SQUARE
SUITE 500
JACKSON, MICHIGAN 49201

CERTIFIED MATERIAL TEST REPORT

CUSTOMER ORDER NUMBER	CUSTOMER PART NUMBER	HEAT NUMBER	WORK ORDER NUMBER	DATE
99257		M21549	200742 102	8/16/06

REPORT TO
LISA
KREHER STEEL

1550 N. 25TH AVE

MELROSE PARK , IL 60160

SHIP TO
KREHER STEEL

1550 N. 25TH AVE.

MELROSE PARK , IL 60160

ORDERED

GRADE	SIZE	LENGTH
1030/1035 ✓	✓ 1 3/16" RND	20'

CUSTOMER SPECIFICATIONS
ASTM A576-90B ✓ASTM A29/A29M-05✓

CHEMICAL ANALYSIS - (BAR AVERAGE)

C	Mn	P	S	Si✓	Ni	Cr	Mo	Cu	Sn	Al
0.33	0.84	0.007	0.019	0.24	0.05	0.15	0.04	0.10	0.005	0.003

V	Nb
0.033	0.001

GRAIN SIZE SPECIFICATION ASTM E112 FINE GRAIN 5-8

REDUCTION RATIO

RATIO= 32.5 TO 1.0

MADE AND MANUFACTURED IN USA ✓
** MATERIAL 100% MELTED AND MANUFACTURED IN THE U.S.A. BY THE ELECTRIC ARC FURNACE AND CONTINUOUS CASTING METHOD. THE PRODUCT HAS NOT BEEN REPAIRED BY WELDING AND THIS MATERIAL HAS NOT BEEN EXPOSED TO MERCURY OR TO ANY OTHER METAL ALLOY THAT IS LIQUID AT AMBIENT TEMPERATURES DURING PROCESSING OR WHILE IN OUR POSSESSION. **

PAGE 1 OF 1
We certify that these data are correct and in compliance with specified requirements.

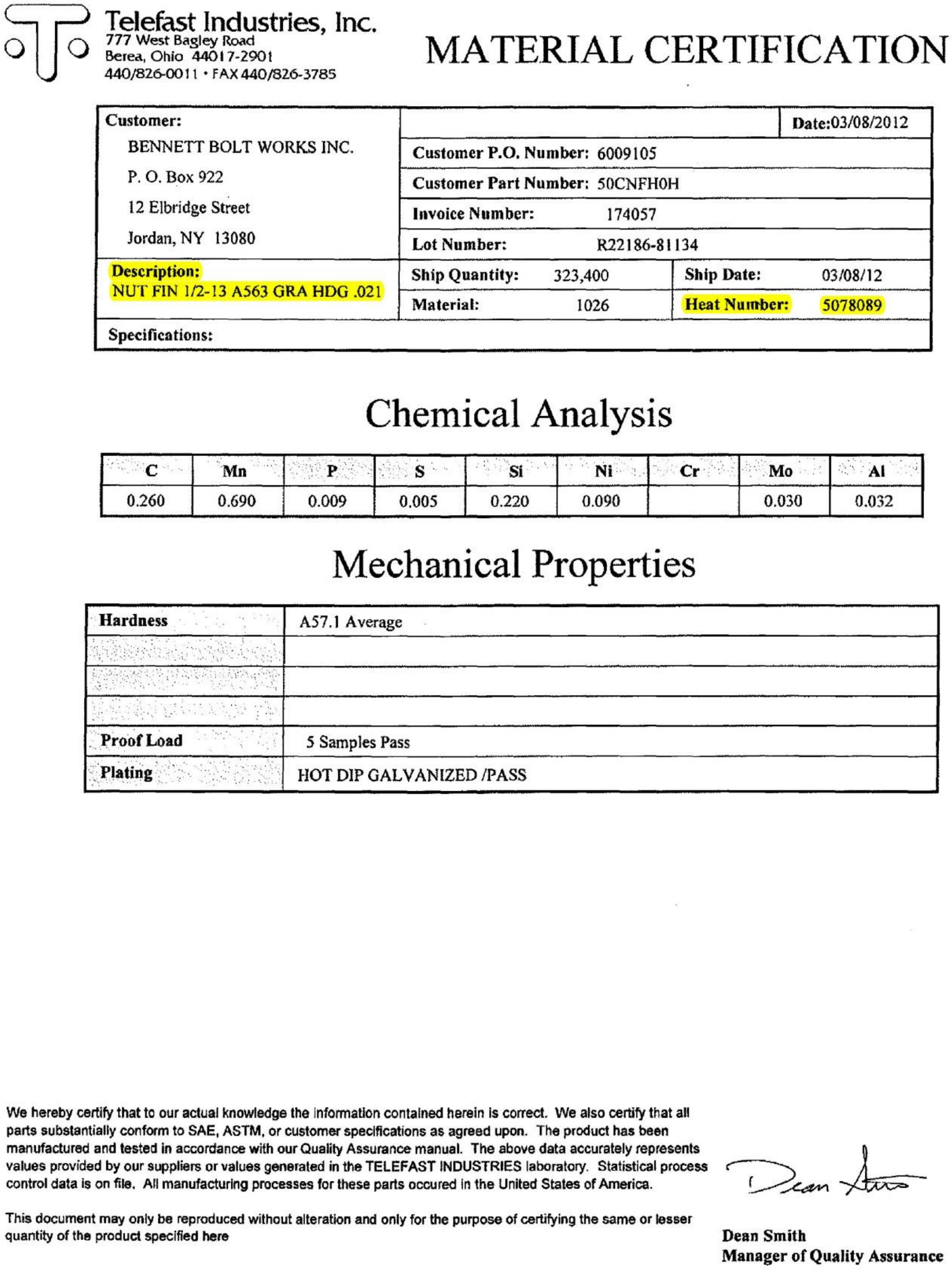
MACSTEEL
3000 East Front Street
Monroe, MI 48161

MACSTEEL-JACKSON ☐
MACSTEEL-FT SMITH ☐
MACSTEEL-MONROE ☒

Quality Assurance Representative

Doc No. 65555 Indexed 16Aug06 by erin

Figure C-13. Cable Turnbuckle, Test Nos. NYJ-1 through NYJ-3



Telefast Industries, Inc.
777 West Bagley Road
Berea, Ohio 44017-2901
440/826-0011 • FAX 440/826-3785

MATERIAL CERTIFICATION

Customer: BENNETT BOLT WORKS INC. P. O. Box 922 12 Elbridge Street Jordan, NY 13080		**Date:** 03/08/2012	
	Customer P.O. Number: 6009105		
	Customer Part Number: 50CNFH0H		
	Invoice Number: 174057		
	Lot Number: R22186-81134		
Description: NUT FIN 1/2-13 A563 GRA HDG .021	**Ship Quantity:** 323,400	**Ship Date:** 03/08/12	
	Material: 1026	**Heat Number:** 5078089	
Specifications:			

Chemical Analysis

C	Mn	P	S	Si	Ni	Cr	Mo	Al
0.260	0.690	0.009	0.005	0.220	0.090		0.030	0.032

Mechanical Properties

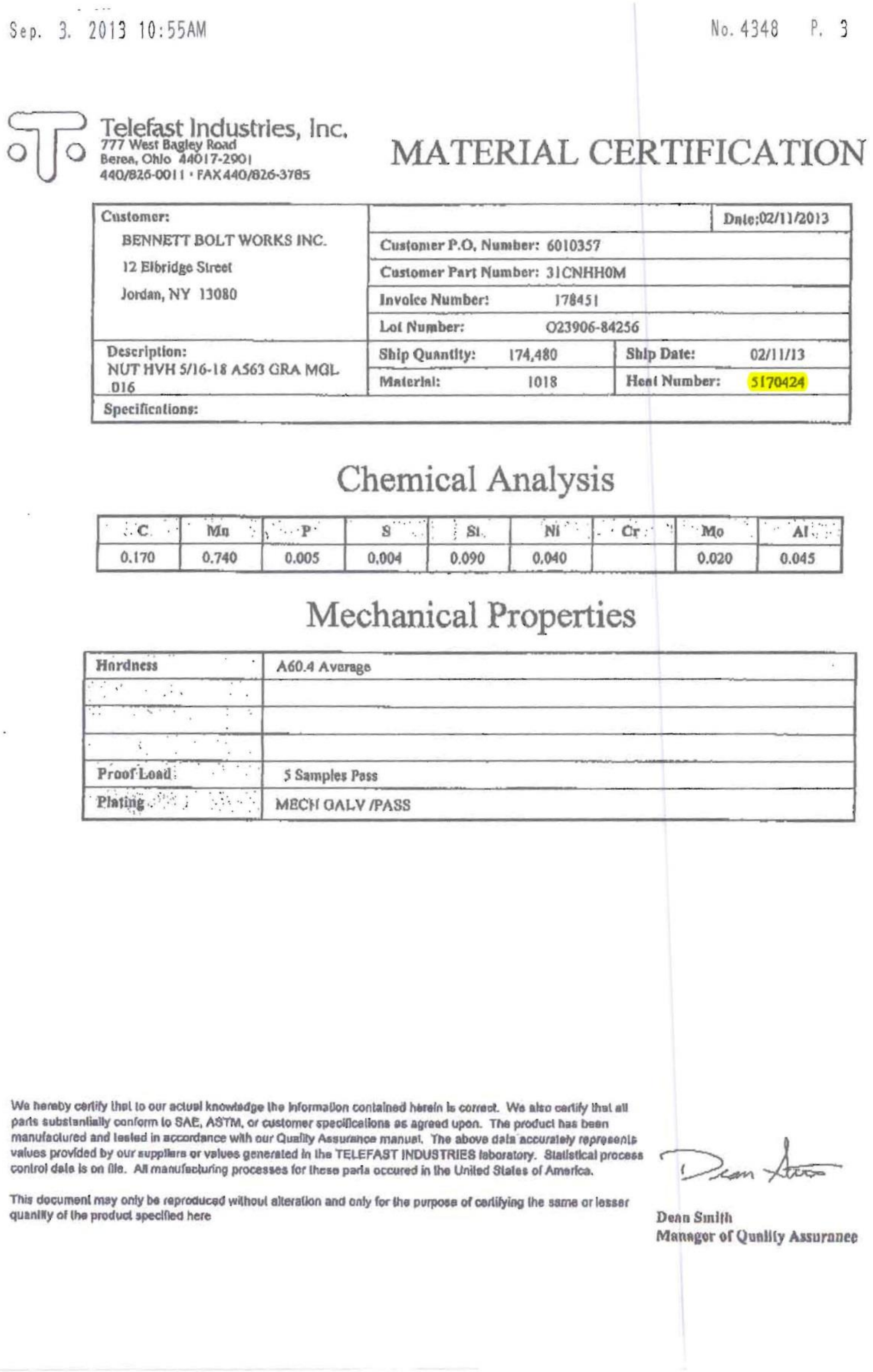
Hardness	A57.1 Average
Proof Load	5 Samples Pass
Plating	HOT DIP GALVANIZED /PASS

We hereby certify that to our actual knowledge the information contained herein is correct. We also certify that all parts substantially conform to SAE, ASTM, or customer specifications as agreed upon. The product has been manufactured and tested in accordance with our Quality Assurance manual. The above data accurately represents values provided by our suppliers or values generated in the TELEFAST INDUSTRIES laboratory. Statistical process control data is on file. All manufacturing processes for these parts occured in the United States of America.

This document may only be reproduced without alteration and only for the purpose of certifying the same or lesser quantity of the product specified here

Dean Smith
Manager of Quality Assurance

Figure C-14. ½-in. (13-mm) J-Bolt and Nut, Test Nos. NYJ-1 and NYJ-2



Sep. 3. 2013 10:55AM No. 4348 P. 3

Telefast Industries, Inc.
777 West Bagley Road
Berea, Ohio 44017-2901
440/826-0011 • FAX 440/826-3785

MATERIAL CERTIFICATION

Customer:
BENNETT BOLT WORKS INC.
12 Elbridge Street
Jordan, NY 13080

Date: 02/11/2013
Customer P.O. Number: 6010357
Customer Part Number: 31CNHH0M
Invoice Number: 178451
Lot Number: O23906-84256

Description: NUT HVH 5/16-18 A563 GRA MGL .016
Ship Quantity: 174,480
Ship Date: 02/11/13
Material: 1018
Heat Number: 5170424
Specifications:

Chemical Analysis

C	Mn	P	S	Si	Ni	Cr	Mo	Al
0.170	0.740	0.005	0.004	0.090	0.040		0.020	0.045

Mechanical Properties

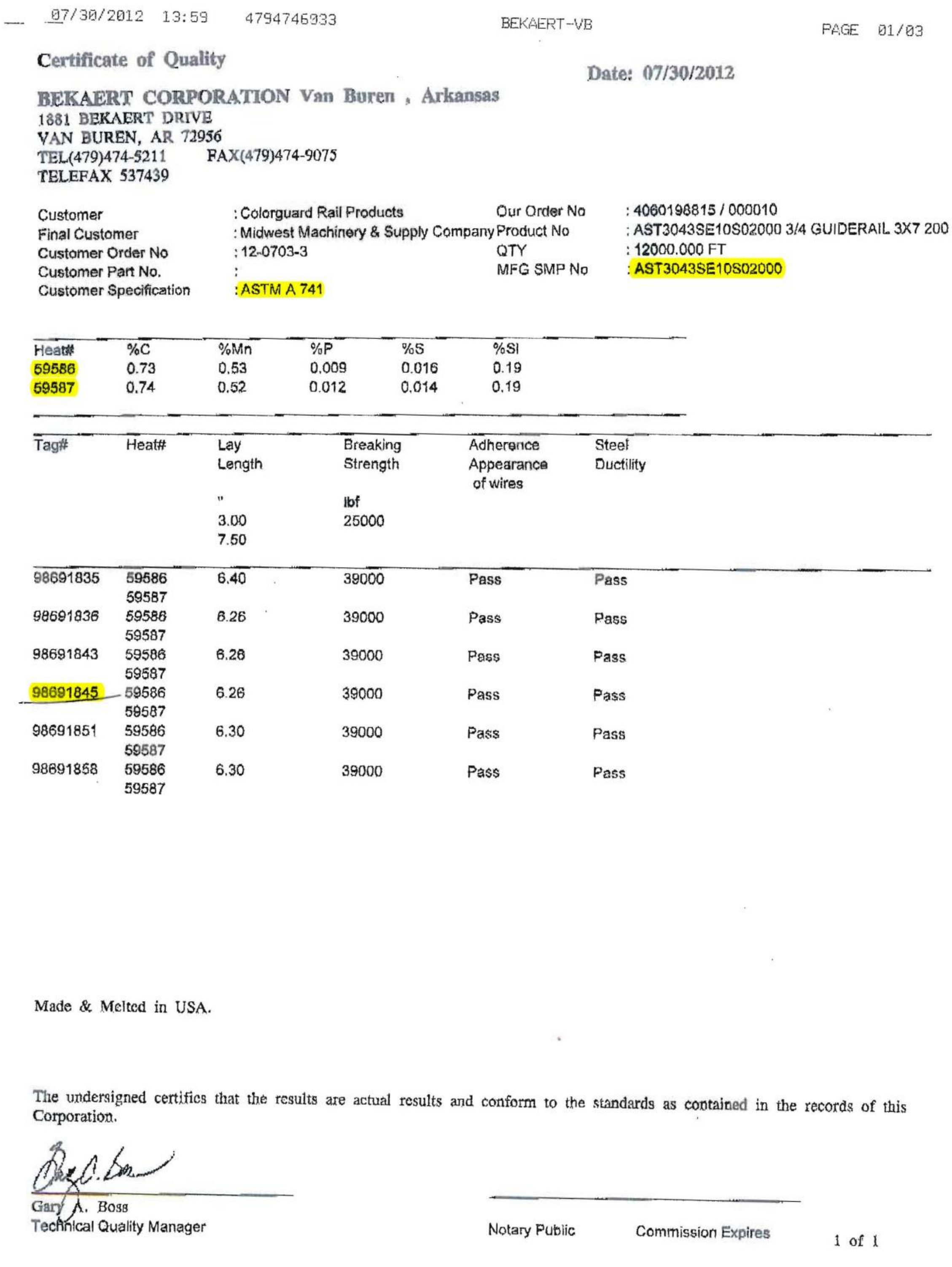
Hardness	A60.4 Average
Proof Load	5 Samples Pass
Plating	MECH GALV /PASS

We hereby certify that to our actual knowledge the information contained herein is correct. We also certify that all parts substantially conform to SAE, ASTM, or customer specifications as agreed upon. The product has been manufactured and tested in accordance with our Quality Assurance manual. The above data accurately represents values provided by our suppliers or values generated in the TELEFAST INDUSTRIES laboratory. Statistical process control data is on file. All manufacturing processes for these parts occured in the United States of America.

This document may only be reproduced without alteration and only for the purpose of certifying the same or lesser quantity of the product specified here

Dean Smith
Manager of Quality Assurance

Figure C-15. ½-in. (13-mm) J-Bolt and Nut, Test No. NYJ-3



07/30/2012 13:59 4794746033 BEKAERT-VB PAGE 01/03

Certificate of Quality

Date: 07/30/2012

BEKAERT CORPORATION Van Buren , Arkansas
1881 BEKAERT DRIVE
VAN BUREN, AR 72956
TEL(479)474-5211 FAX(479)474-9075
TELEFAX 537439

Customer : Colorguard Rail Products
Final Customer : Midwest Machinery & Supply Company
Customer Order No : 12-0703-3
Customer Part No. :
Customer Specification : ASTM A 741

Our Order No : 4060198815 / 000010
Product No : AST3043SE10S02000 3/4 GUIDERAIL 3X7 200
QTY : 12000.000 FT
MFG SMP No : AST3043SE10S02000

Heat#	%C	%Mn	%P	%S	%Si
59586	0.73	0.53	0.009	0.016	0.19
59587	0.74	0.52	0.012	0.014	0.19

Tag#	Heat#	Lay Length " 3.00 7.50	Breaking Strength lbf 25000	Adherence Appearance of wires	Steel Ductility
98691835	59586 59587	6.40	39000	Pass	Pass
98691836	59586 59587	6.26	39000	Pass	Pass
98691843	59586 59587	6.28	39000	Pass	Pass
98691845	59586 59587	6.26	39000	Pass	Pass
98691851	59586 59587	6.30	39000	Pass	Pass
98691858	59586 59587	6.30	39000	Pass	Pass

Made & Melted in USA.

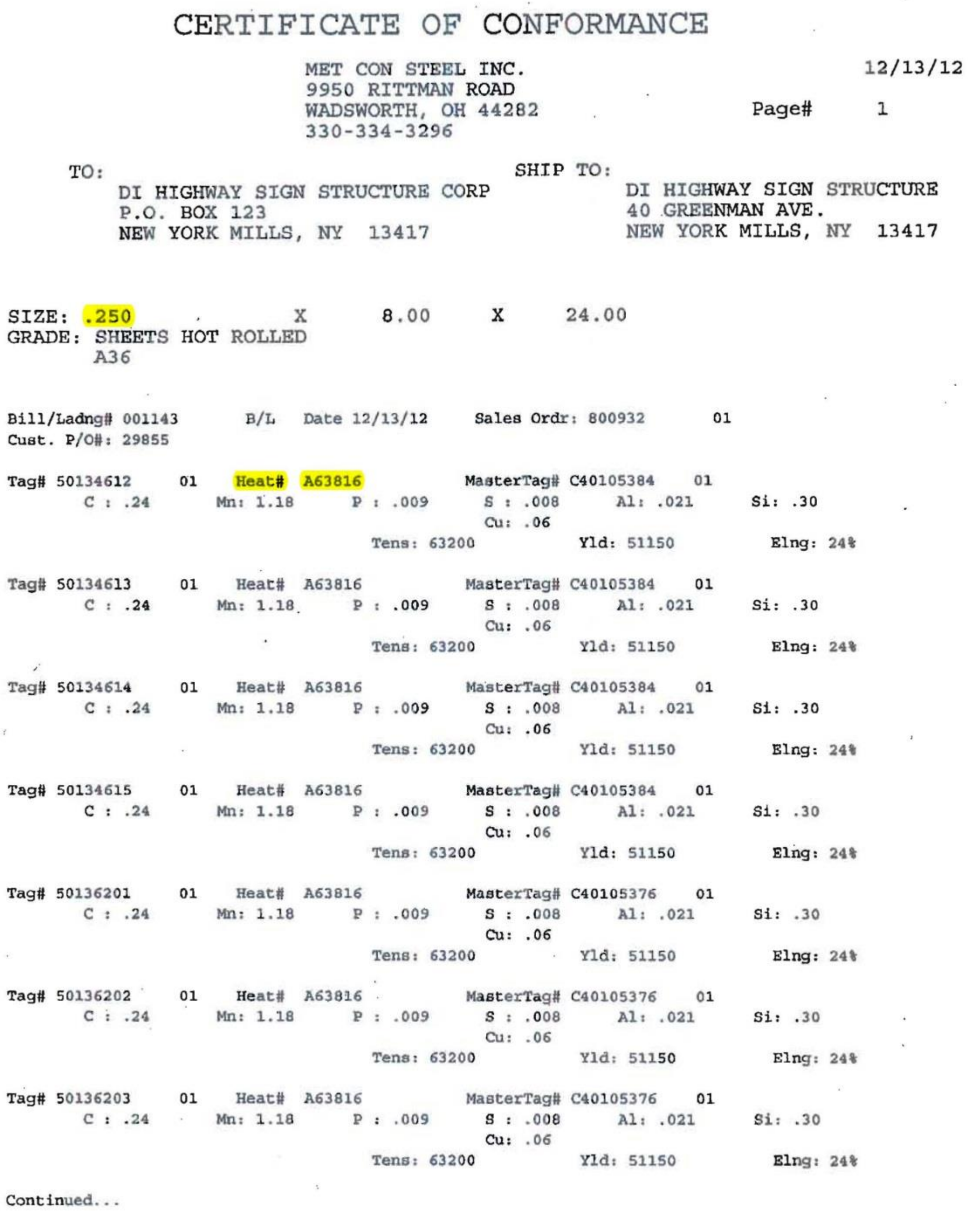
The undersigned certifies that the results are actual results and conform to the standards as contained in the records of this Corporation.

Gary A. Boss
Technical Quality Manager

Notary Public Commission Expires

1 of 1

Figure C-16. ¾-in. (19-mm) Dia. Cable, Test Nos. NYJ-1 through NYJ-3



CERTIFICATE OF CONFORMANCE

MET CON STEEL INC.
9950 RITTMAN ROAD
WADSWORTH, OH 44282
330-334-3296

12/13/12

Page# 1

TO:
DI HIGHWAY SIGN STRUCTURE CORP
P.O. BOX 123
NEW YORK MILLS, NY 13417

SHIP TO:
DI HIGHWAY SIGN STRUCTURE
40 GREENMAN AVE.
NEW YORK MILLS, NY 13417

SIZE: .250 X 8.00 X 24.00
GRADE: SHEETS HOT ROLLED
A36

Bill/Ladng# 001143 B/L Date 12/13/12 Sales Ordr: 800932 01
Cust. P/O#: 29855

Tag# 50134612 01 Heat# A63816 MasterTag# C40105384 01
C : .24 Mn: 1.18 P : .009 S : .008 Al: .021 Si: .30
Cu: .06
Tens: 63200 Yld: 51150 Elng: 24%

Tag# 50134613 01 Heat# A63816 MasterTag# C40105384 01
C : .24 Mn: 1.18 P : .009 S : .008 Al: .021 Si: .30
Cu: .06
Tens: 63200 Yld: 51150 Elng: 24%

Tag# 50134614 01 Heat# A63816 MasterTag# C40105384 01
C : .24 Mn: 1.18 P : .009 S : .008 Al: .021 Si: .30
Cu: .06
Tens: 63200 Yld: 51150 Elng: 24%

Tag# 50134615 01 Heat# A63816 MasterTag# C40105384 01
C : .24 Mn: 1.18 P : .009 S : .008 Al: .021 Si: .30
Cu: .06
Tens: 63200 Yld: 51150 Elng: 24%

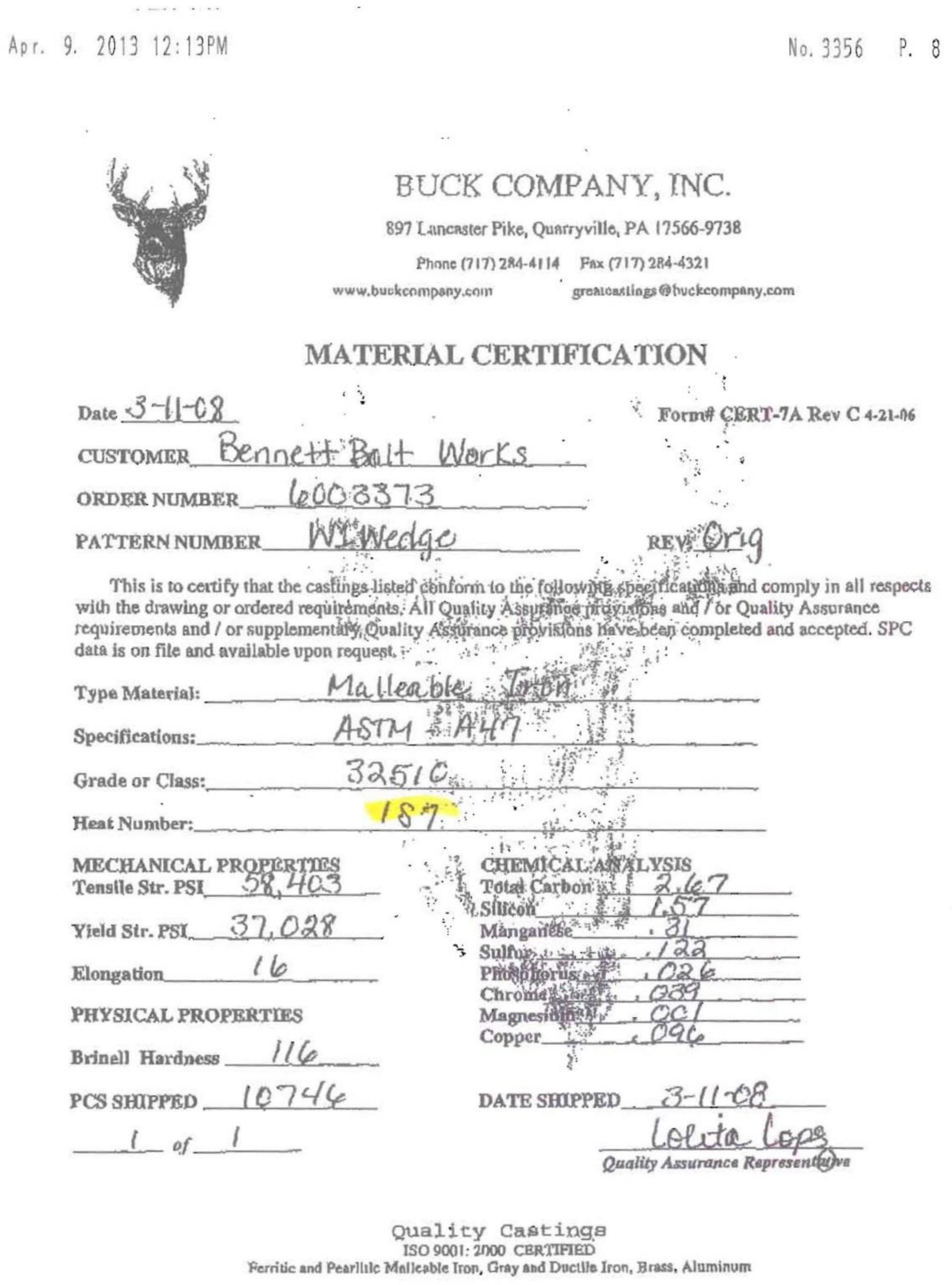
Tag# 50136201 01 Heat# A63816 MasterTag# C40105376 01
C : .24 Mn: 1.18 P : .009 S : .008 Al: .021 Si: .30
Cu: .06
Tens: 63200 Yld: 51150 Elng: 24%

Tag# 50136202 01 Heat# A63816 MasterTag# C40105376 01
C : .24 Mn: 1.18 P : .009 S : .008 Al: .021 Si: .30
Cu: .06
Tens: 63200 Yld: 51150 Elng: 24%

Tag# 50136203 01 Heat# A63816 MasterTag# C40105376 01
C : .24 Mn: 1.18 P : .009 S : .008 Al: .021 Si: .30
Cu: .06
Tens: 63200 Yld: 51150 Elng: 24%

Continued...

Figure C-17. Soil Plate, Test Nos. NYJ-1 through NYJ-3



Apr. 9. 2013 12:13PM No. 3356 P. 8

BUCK COMPANY, INC.

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

MATERIAL CERTIFICATION

Date 3-11-08 **Form# CERT-7A Rev C 4-21-06**

CUSTOMER Bennett Bolt Works

ORDER NUMBER 6003373

PATTERN NUMBER WI Wedge **REV.** Orig

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

Type Material: Malleable Iron

Specifications: ASTM A47

Grade or Class: 32510

Heat Number: 187

MECHANICAL PROPERTIES

Tensile Str. PSI 58,403

Yield Str. PSI 37,028

Elongation 16

PHYSICAL PROPERTIES

Brinell Hardness 116

PCS SHIPPED 10746

1 of 1

CHEMICAL ANALYSIS

Total Carbon 2.67

Silicon 1.57

Manganese .31

Sulfur .122

Phosphorus .026

Chrome .039

Magnesium .001

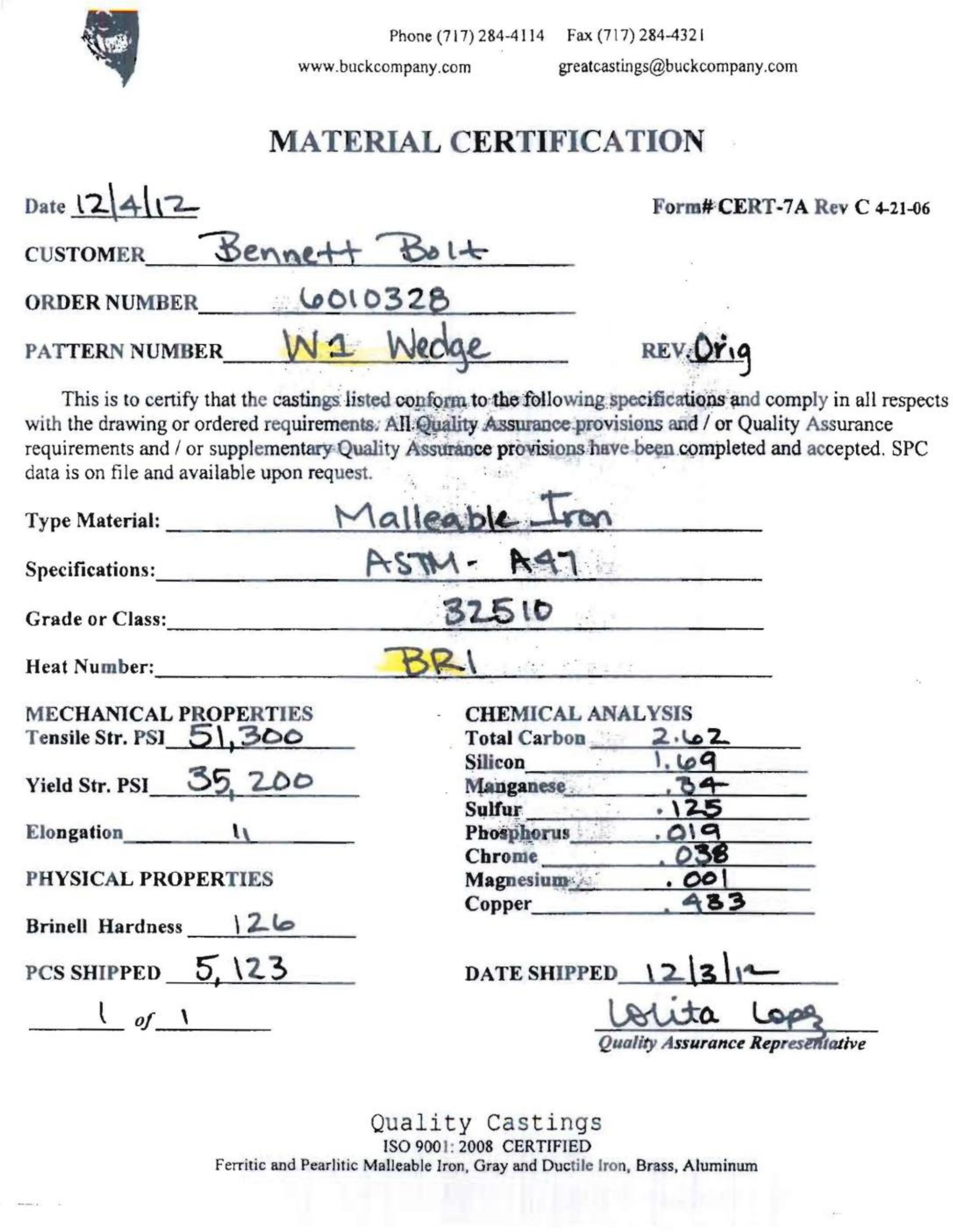
Copper .096

DATE SHIPPED 3-11-08

Lolita Lops
Quality Assurance Representative

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

Figure C-18. Cable Wedge, Test Nos. NYJ-1 and NYJ-3



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

MATERIAL CERTIFICATION

Date 12/4/12

Form# CERT-7A Rev C 4-21-06

CUSTOMER Bennett Bolt

ORDER NUMBER 6010328

PATTERN NUMBER W1 Wedge

REV. Orig

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

Type Material: Malleable Iron

Specifications: ASTM- A47

Grade or Class: 32510

Heat Number: BR1

MECHANICAL PROPERTIES

Tensile Str. PSI 51,300

Yield Str. PSI 35,200

Elongation 11

PHYSICAL PROPERTIES

Brinell Hardness 126

CHEMICAL ANALYSIS

Total Carbon	2.62
Silicon	1.69
Manganese	.34
Sulfur	.125
Phosphorus	.019
Chrome	.038
Magnesium	.001
Copper	.483

PCS SHIPPED 5,123

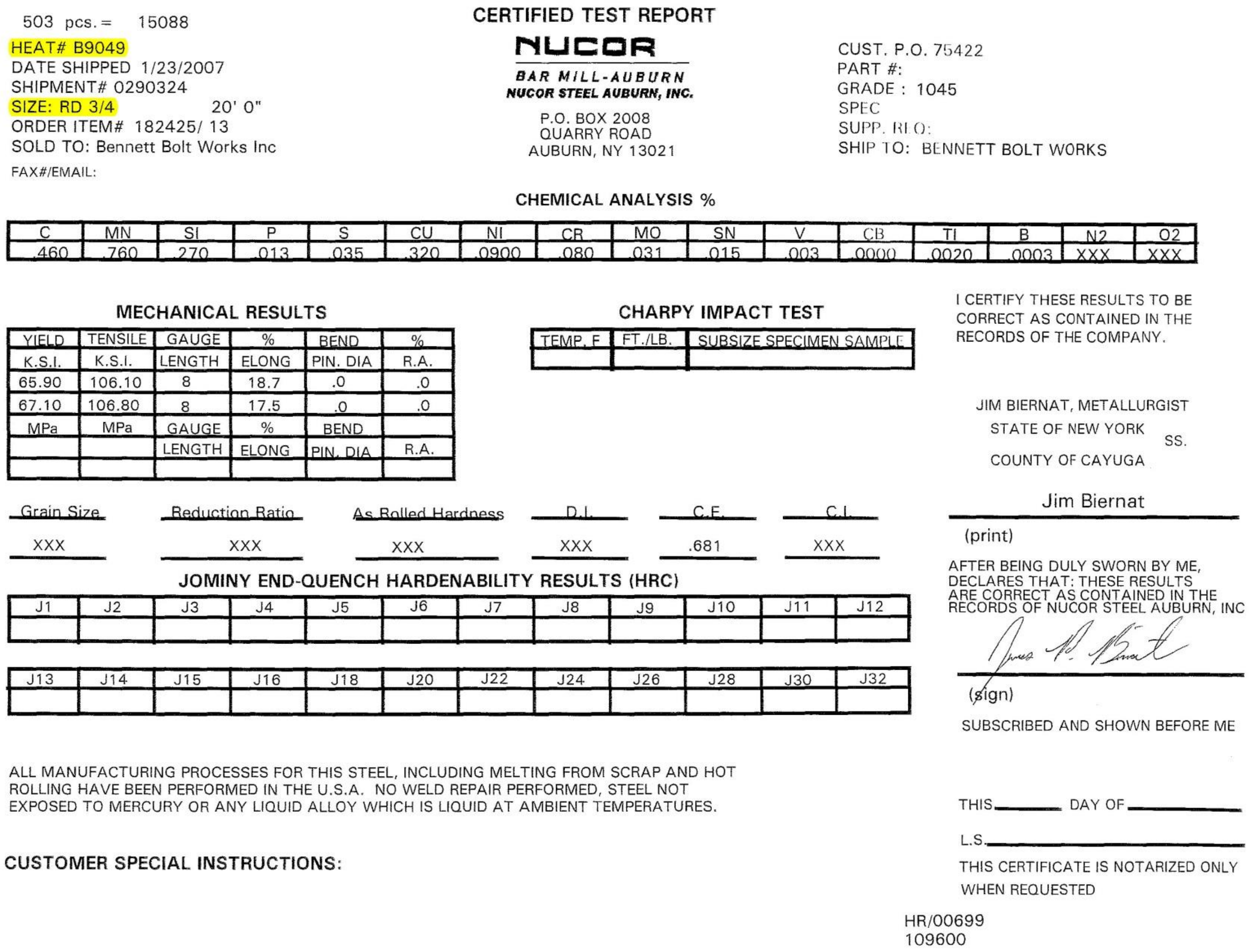
DATE SHIPPED 12/3/12

1 of 1

Lolita Lopez
Quality Assurance Representative

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

Figure C-19. Cable Wedge, Test No. NYJ-2



503 pcs. = 15088

HEAT# B9049
DATE SHIPPED 1/23/2007
SHIPMENT# 0290324
SIZE: RD 3/4 20' 0"
ORDER ITEM# 182425/ 13
SOLD TO: Bennett Bolt Works Inc
FAX#/EMAIL:

CERTIFIED TEST REPORT

NUCOR
BAR MILL-AUBURN
NUCOR STEEL AUBURN, INC.

P.O. BOX 2008
QUARRY ROAD
AUBURN, NY 13021

CUST. P.O. 75422
PART #:
GRADE : 1045
SPEC
SUPP. REQ:
SHIP TO: BENNETT BOLT WORKS

CHEMICAL ANALYSIS %

C	MN	SI	P	S	CU	NI	CR	MO	SN	V	CB	TI	B	N2	O2
.460	.760	.270	.013	.035	.320	.0900	.080	.031	.015	.003	.0000	.0020	.0003	XXX	XXX

MECHANICAL RESULTS

YIELD	TENSILE	GAUGE	%	BEND	%
K.S.I.	K.S.I.	LENGTH	ELONG	PIN. DIA	R.A.
65.90	106.10	8	18.7	.0	.0
67.10	106.80	8	17.5	.0	.0
MPa	MPa	GAUGE	%	BEND	
		LENGTH	ELONG	PIN. DIA	R.A.

CHARPY IMPACT TEST

TEMP. F	FT./LB.	SUBSIZE SPECIMEN SAMPLE

Grain Size	Reduction Ratio	As Rolled Hardness	D.I.	C.E.	C.I.
XXX	XXX	XXX	XXX	.681	XXX

JOMINY END-QUENCH HARDENABILITY RESULTS (HRC)

J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12

J13	J14	J15	J16	J18	J20	J22	J24	J26	J28	J30	J32

I CERTIFY THESE RESULTS TO BE CORRECT AS CONTAINED IN THE RECORDS OF THE COMPANY.

JIM BIERNAT, METALLURGIST
STATE OF NEW YORK
SS.
COUNTY OF CAYUGA

Jim Biernat
(print)

AFTER BEING DULY SWORN BY ME, DECLARES THAT: THESE RESULTS ARE CORRECT AS CONTAINED IN THE RECORDS OF NUCOR STEEL AUBURN, INC

(sign)

SUBSCRIBED AND SHOWN BEFORE ME

THIS______ DAY OF________

L.S.________________

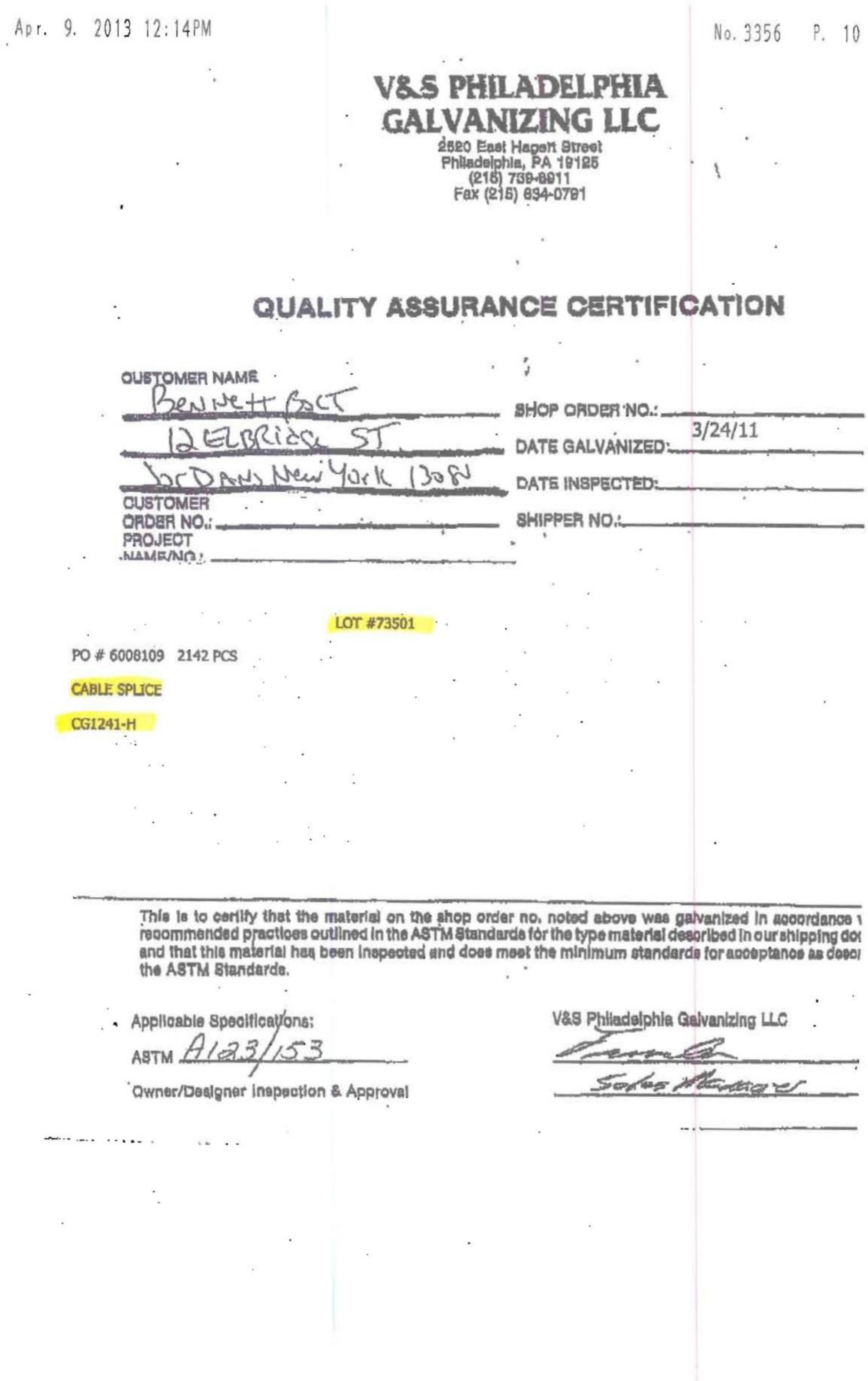
THIS CERTIFICATE IS NOTARIZED ONLY WHEN REQUESTED

ALL MANUFACTURING PROCESSES FOR THIS STEEL, INCLUDING MELTING FROM SCRAP AND HOT ROLLING HAVE BEEN PERFORMED IN THE U.S.A. NO WELD REPAIR PERFORMED, STEEL NOT EXPOSED TO MERCURY OR ANY LIQUID ALLOY WHICH IS LIQUID AT AMBIENT TEMPERATURES.

CUSTOMER SPECIAL INSTRUCTIONS:

HR/00699
109600

Figure C-20. ¾-in. (19-mm) Dia. Threaded Rod and Left-Handed Threaded Rod, Test Nos. NYJ-1 through NYJ-3



Apr. 9. 2013 12:14PM

No. 3356 P. 10

V&S PHILADELPHIA GALVANIZING LLC

2520 East Hagert Street
Philadelphia, PA 19125
(215) 739-8911
Fax (215) 634-0791

QUALITY ASSURANCE CERTIFICATION

CUSTOMER NAME
Bennett Bolt
12 Elbridge St
Jordan New York 13080

SHOP ORDER NO.:
DATE GALVANIZED: 3/24/11
DATE INSPECTED:
SHIPPER NO.:

CUSTOMER ORDER NO.:
PROJECT NAME/NO.:

LOT #73501

PO # 6008109 2142 PCS

CABLE SPLICE

CG1241-H

This is to certify that the material on the shop order no. noted above was galvanized in accordance
recommended practices outlined in the ASTM Standards for the type material described in our shipping do
and that this material has been inspected and does meet the minimum standards for acceptance as desc
the ASTM Standards.

Applicable Specifications:
ASTM A123/153
Owner/Designer Inspection & Approval

V&S Philadelphia Galvanizing LLC
Sales Manager

Figure C-21. ¾-in. (19-mm) Cable Splice, Test Nos. NYJ-1 through NYJ-3

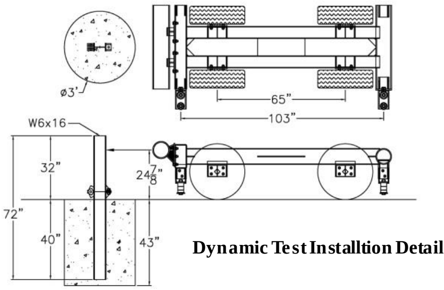
Appendix D. Static Soil Tests

Dynamic Set up

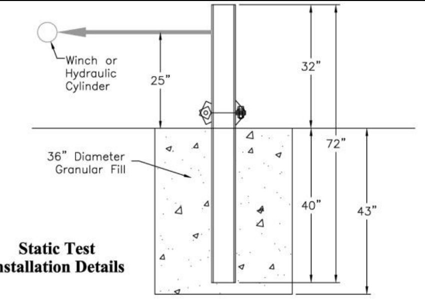
Post-Test Photo of Post

Static Load Test

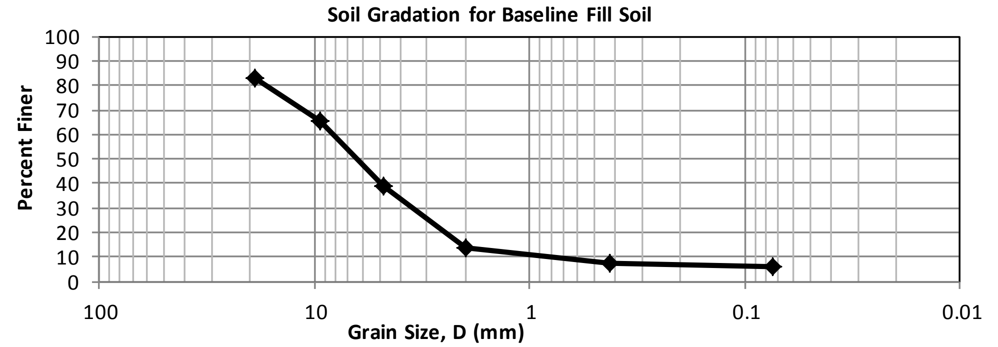
Post-Test Photo of Post

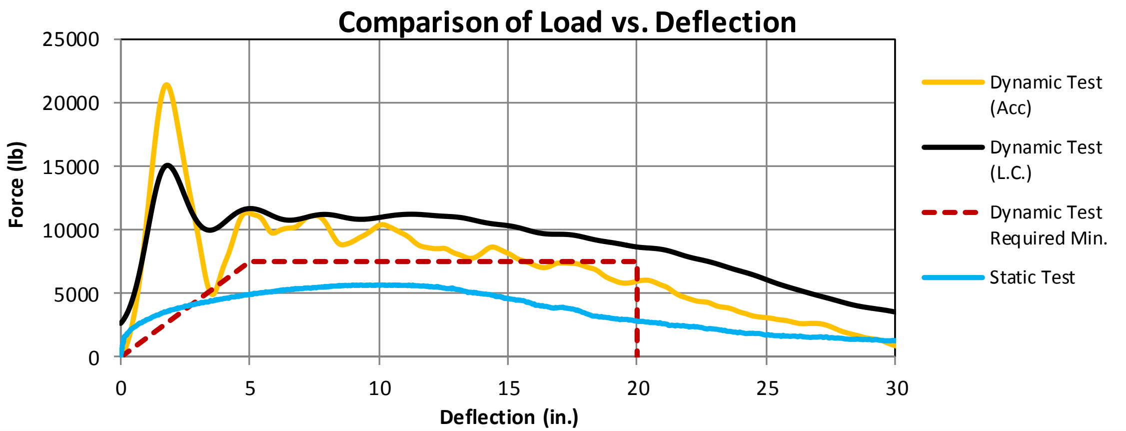


Dynamic Test Installtion Details



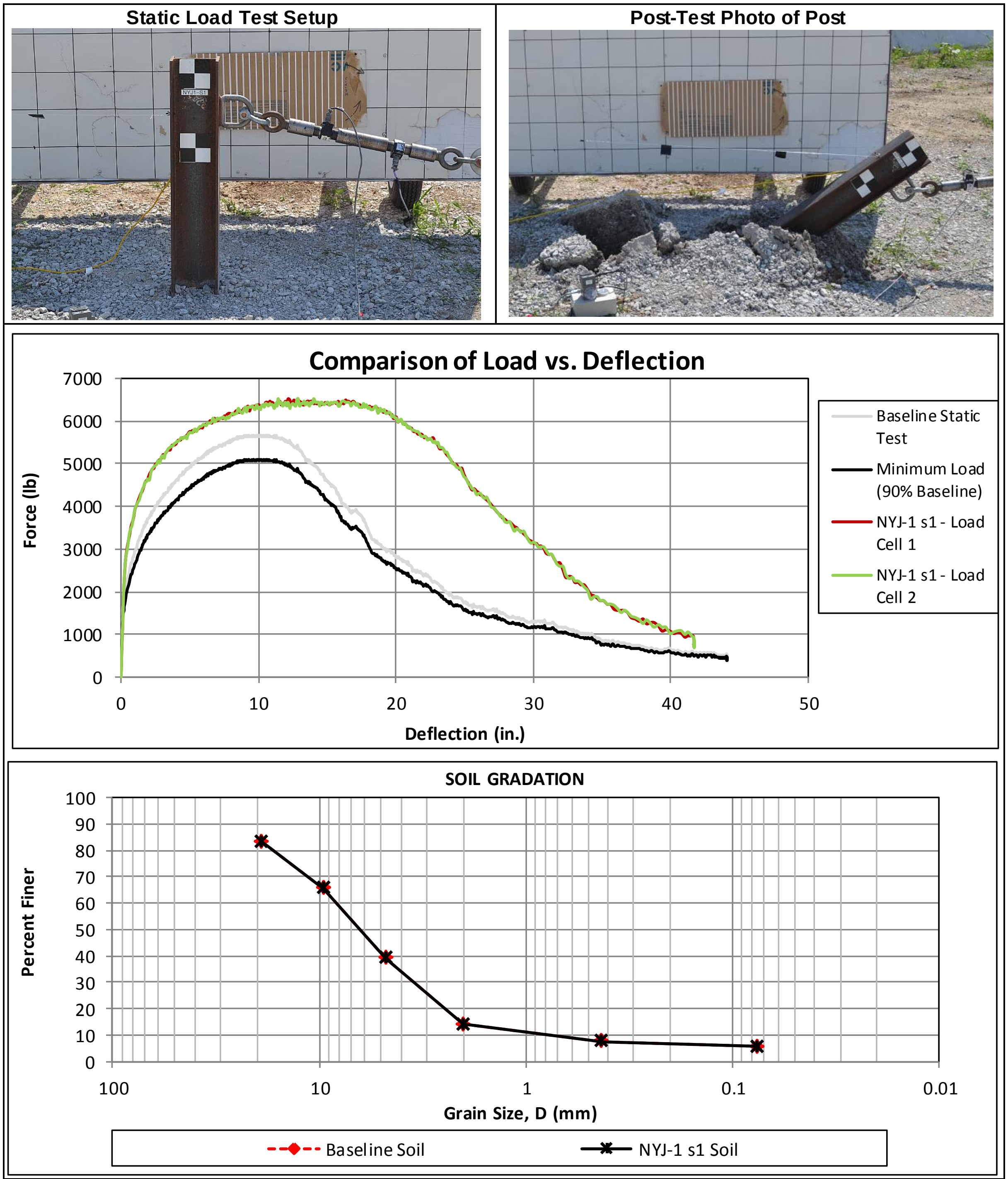
Static Test Installation Details





Date..	5/17/2013
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..	1,857 lb
Impact Velocity......................................	20.6 mph

Figure D-1. Soil Strength, Initial Calibration Tests


Static Load Test Setup

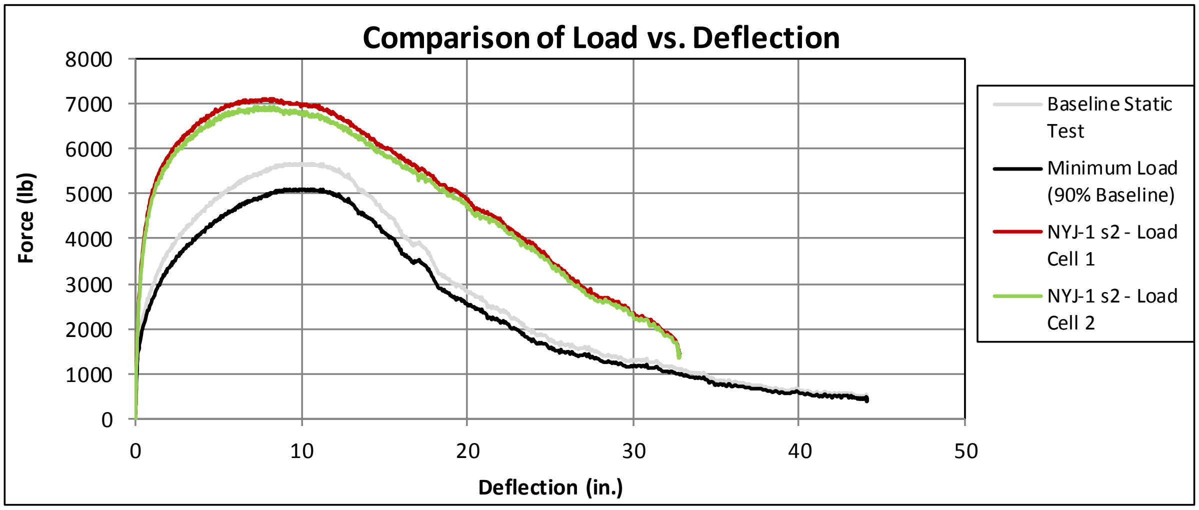
Post-Test Photo of Post

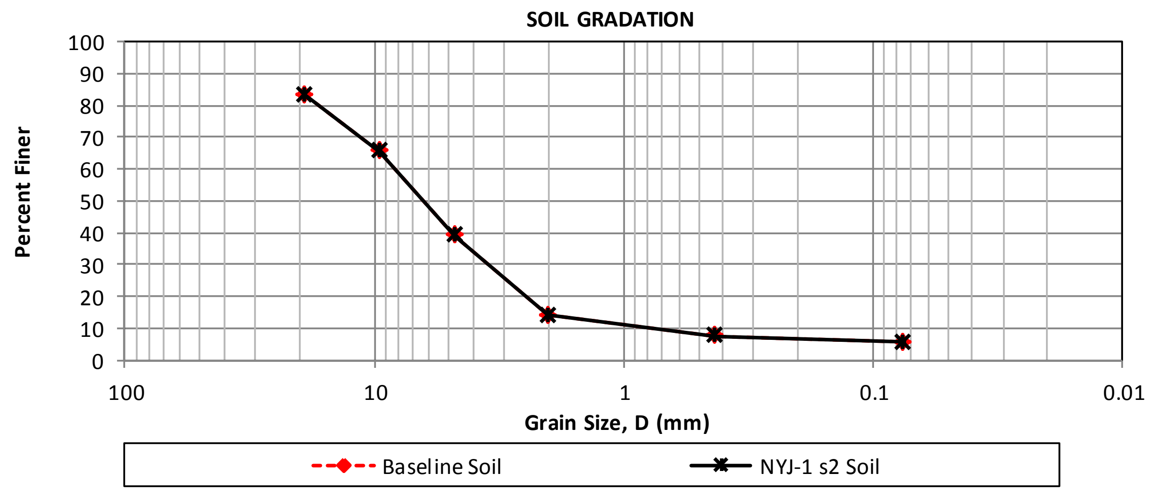
Date.. 6/13/2013
Test Facility & Site Location.................... Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)......... Low Plasticity Silt (ML)
Fill material description (ASTM D2487)...... Well Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure..... 8-inch lifts tamped with a pneumatic compactor

Figure D-2. Static Soil Test 1, Test No. NYJ-1

Static Load Test Setup

Post-Test Photo of Post



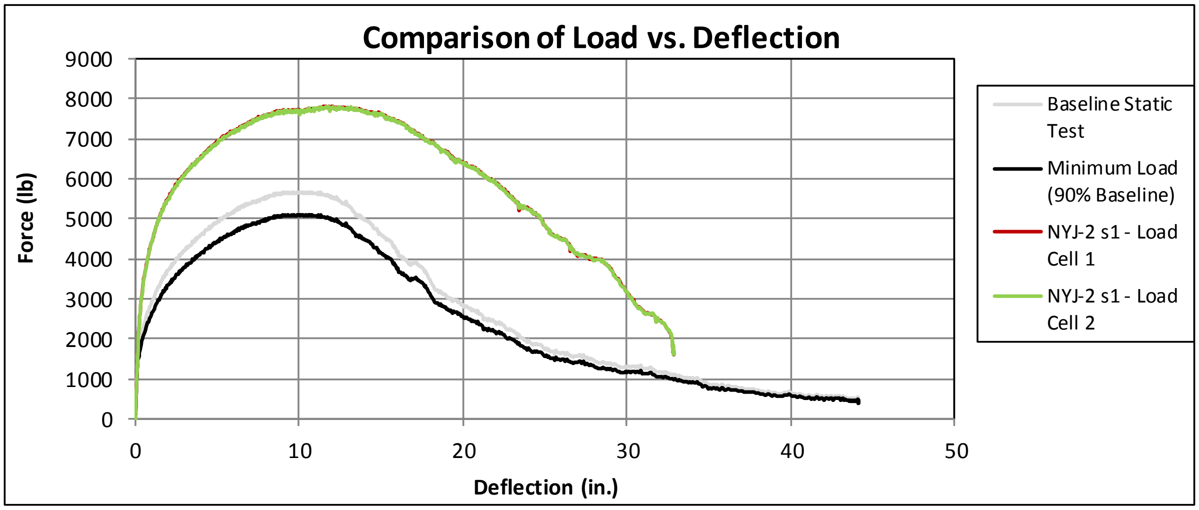


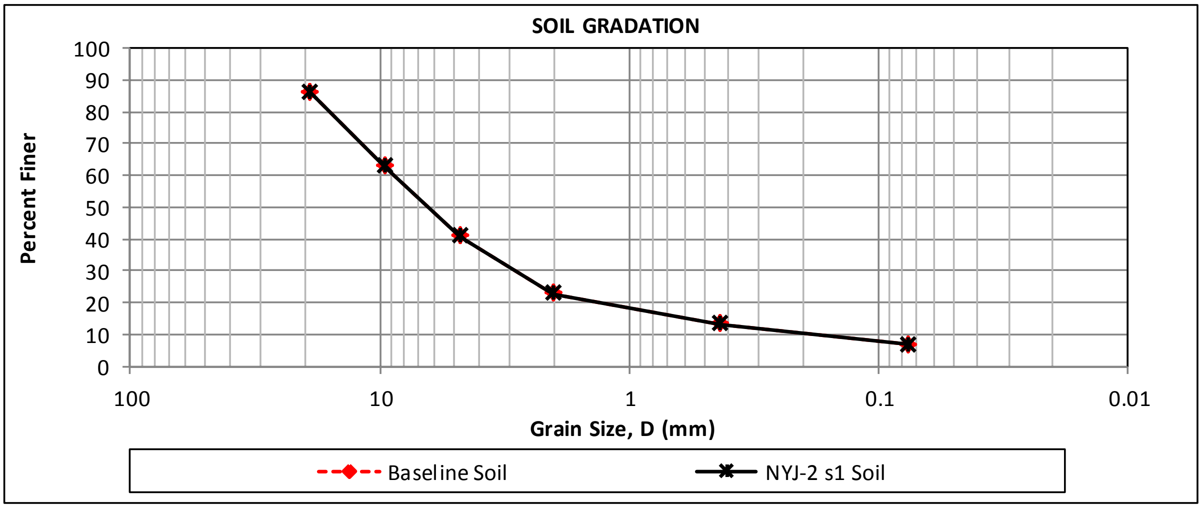
Date..	6/18/2013
Test Facility & Site Location.....................	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487).........	Low Plasticity Silt (ML)
Fill material description (ASTM D2487)......	Well Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure.....	8-inch lifts tamped with a pneumatic compactor

Figure D-3. Static Soil Test 2, Test No. NYJ-1


Static Load Test Setup

Post-Test Photo of Post


Comparison of Load vs. Deflection

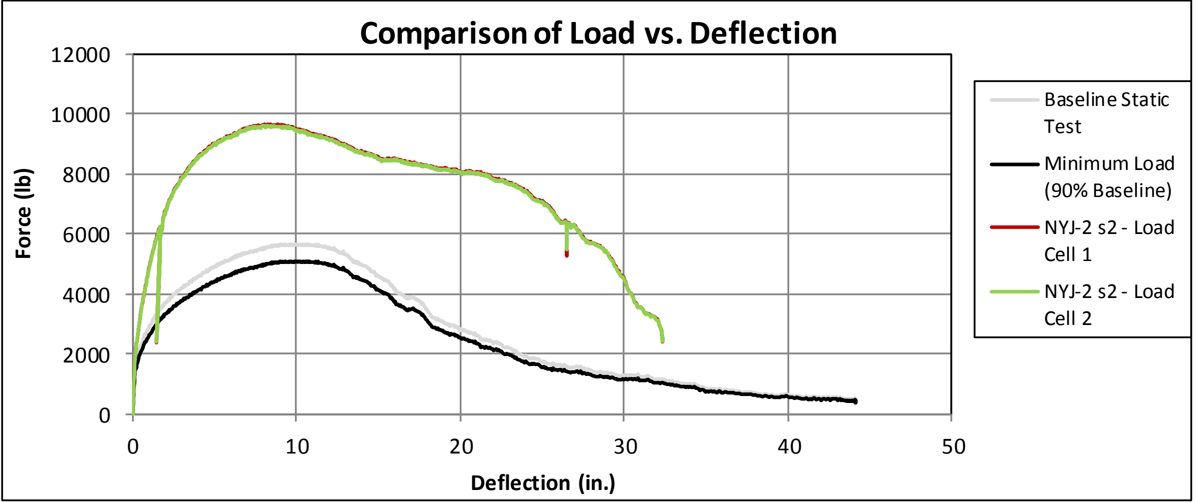

SOIL GRADATION

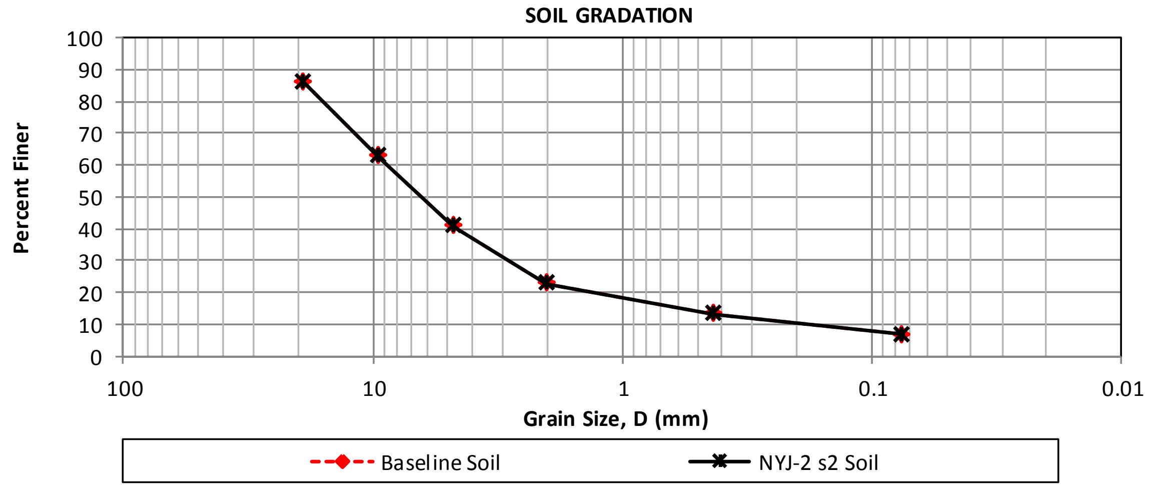
Date.. 8/14/2013
Test Facility & Site Location..................... Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)......... Low Plasticity Silt (ML)
Fill material description (ASTM D2487)...... Well Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure..... 8-inch lifts tamped with a pneumatic compactor

Figure D-4. Static Soil Test 1, Test No. NYJ-2


Static Load Test Setup

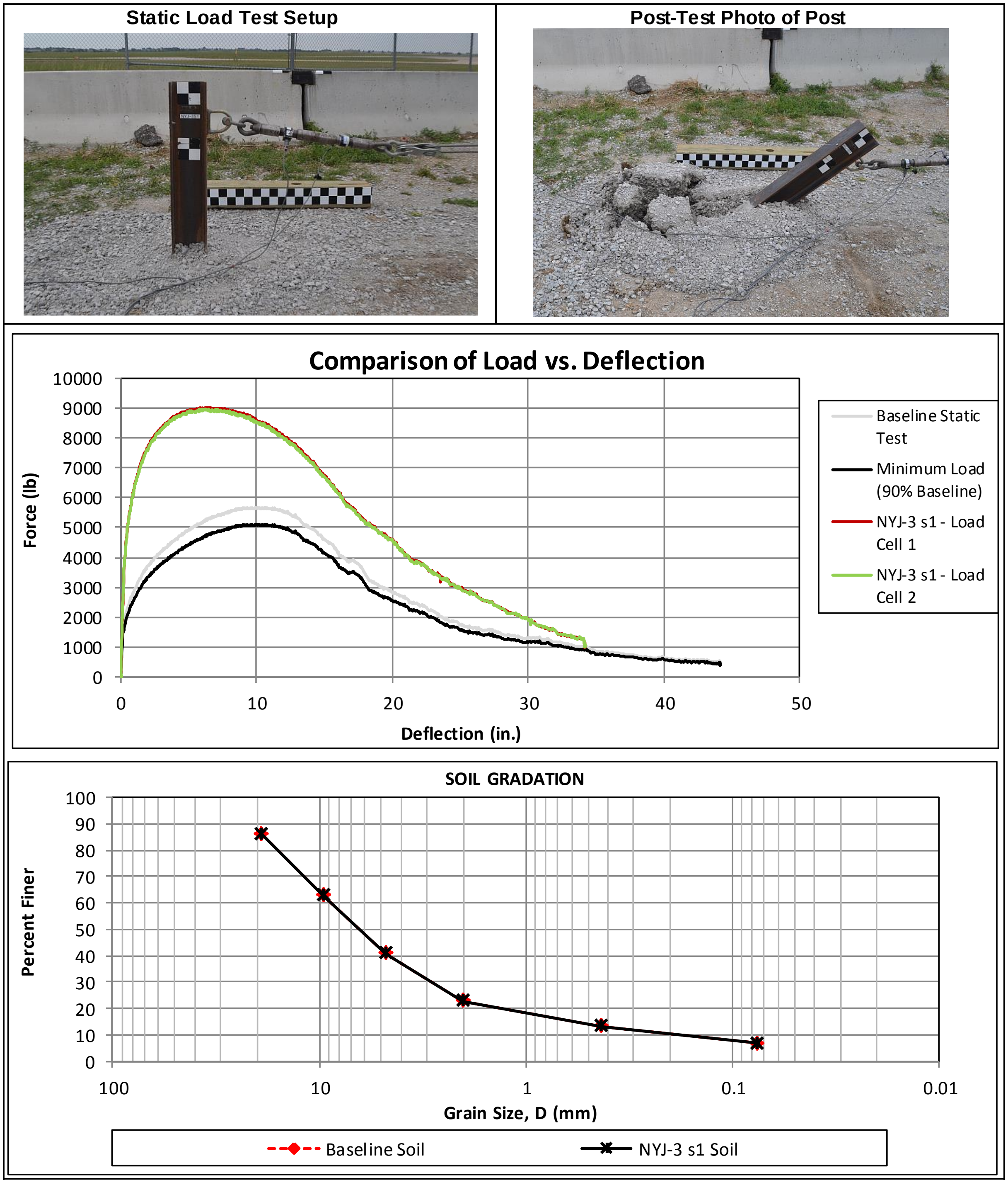
Post-Test Photo of Post





Date.. 8/14/2013
Test Facility & Site Location...................... Midwest Roadside Safety Facility
In situ soil description (ASTM D2487).......... Low Plasticity Silt (ML)
Fill material description (ASTM D2487)...... Well Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure..... 8-inch lifts tamped with a pneumatic compactor

Figure D-5. Static Soil Test 2, Test No. NYJ-2



Date.. 9/24/2013
Test Facility & Site Location..................... Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)......... Low Plasticity Silt (ML)
Fill material description (ASTM D2487)...... Well Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure..... 8-inch lifts tamped with a pneumatic compactor

Figure D-6. Static Soil Test, Test No. NYJ-3

Appendix E. Vehicle Deformation Records

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 1

TEST: NYJ-1
VEHICLE: 1500A

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	28	-21 3/4	- 1/2	28	-21 1/2	- 1/2	0	1/4	0
2	30 1/2	-18	-2 1/4	30 1/2	-18 1/4	-2	0	- 1/4	1/4
3	30 3/4	-12	-2 1/2	31	-12 1/2	-2 1/4	1/4	- 1/2	1/4
4	30 1/2	-10	-2 1/2	30 1/2	-10	-2 1/2	0	0	0
5	25 3/4	-20 3/4	-4 1/4	26	-21 1/2	-4 1/4	1/4	- 3/4	0
6	26 3/4	-18	-5	26 3/4	-18	-5	0	0	0
7	28 1/4	-12	-4	28 1/2	-12 3/4	-4	1/4	- 3/4	0
8	28	-7 3/4	-4 1/2	28	-8 1/2	-4 1/4	0	- 3/4	1/4
9	23	-24	-5	23	-24	-5	0	0	0
10	23 1/2	-18	-5 3/4	23 1/2	-18 1/2	-5 3/4	0	- 1/2	0
11	23 1/2	-12	-6	23 1/2	-12 3/4	-6	0	- 3/4	0
12	23	-7 1/2	-6	23	-8 1/4	-6	0	- 3/4	0
13	22 1/2	-1 3/4	-1	22 1/2	-2	-1	0	- 1/4	0
14	17	-24 3/4	-4 1/2	17	-25 1/4	-4 1/2	0	- 1/2	0
15	17 1/4	-18	-5 3/4	17 1/4	-18 1/4	-5 3/4	0	- 1/4	0
16	17 1/4	-12 1/4	-6 1/4	17 1/4	-13	-6	-0	- 3/4	1/4
17	16 3/4	-7	-6	16 3/4	-7 1/2	-6	0	- 1/2	0
18	15	-1 3/4	-1 3/4	15	-1 3/4	-1 3/4	0	0	0
19	10 1/2	-25	-4 1/2	10 1/2	-25 1/4	-4 1/2	0	- 1/4	0
20	10 3/4	-18 3/4	-5 3/4	10 3/4	-19	-5 3/4	0	- 1/4	0
21	11 1/4	-13 1/2	-6 1/4	11	-13 3/4	-6 1/4	- 1/4	- 1/4	0
22	8 1/2	-9	-5	8 1/2	-9 1/4	-5	0	- 1/4	0
23	9 3/4	-2	-2	10	-1 3/4	-2	1/4	1/4	0
24	1	-24	-3	1	-23 3/4	-3	0	1/4	0
25	1 3/4	-18	-3 1/2	1 3/4	-17 3/4	-3 1/2	0	1/4	0
26	1 3/4	-11 3/4	-3 1/2	2	-11 1/4	-3 1/2	1/4	1/2	0
27	1 3/4	-5 1/2	-3	1 3/4	-5 1/2	-3	0	0	0
28							0	0	0
29							0	0	0
30							0	0	0
31							0	0	0

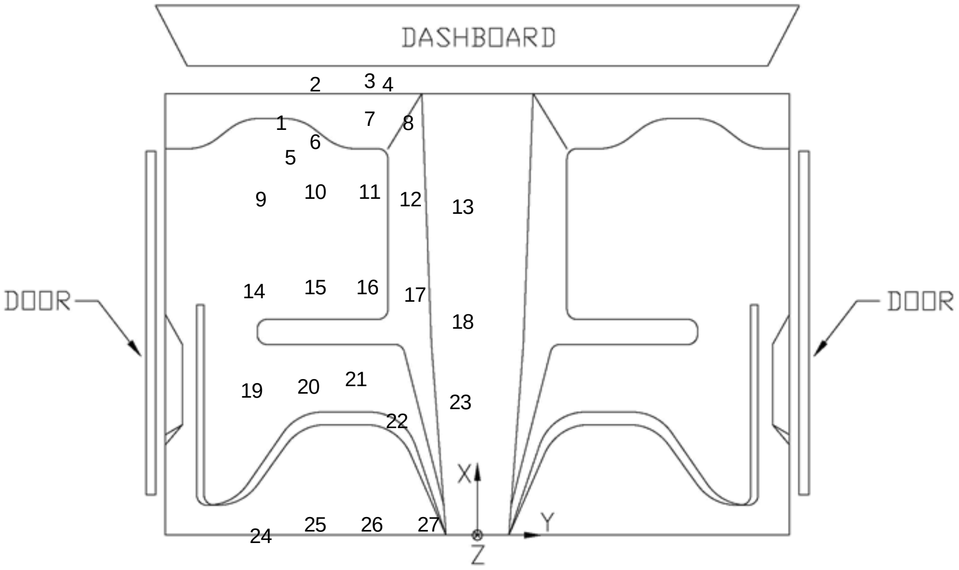


Figure E-1. Floor Pan Deformation Data – Set 1, Test No. NYJ-1

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 2

TEST: NYJ-1
VEHICLE: 1500A

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	35 3/4	-24	- 1/2	35 3/4	-24	- 1/2	0	0	0
2	38 1/4	-20 1/4	-2	38 1/4	-20 3/4	-2 1/4	0	- 1/2	- 1/4
3	38 1/2	-14 1/2	-2 1/4	38 1/2	-15	-2	0	- 1/2	1/4
4	38 1/4	-13	-2 1/2	38 1/4	-13	-2 1/2	0	0	0
5	33 3/4	-23 1/2	-4 1/4	33 3/4	-23 1/2	-4 1/2	0	0	- 1/4
6	34 1/2	-20 1/4	-5	34 1/2	-20 3/4	-5	0	- 1/2	0
7	36	-14 3/4	-4	36	-14 3/4	-4	0	0	0
8	35 3/4	-9 3/4	-4 1/4	35 3/4	-10 1/2	-4 1/4	0	- 3/4	0
9	30 3/4	-25 3/4	-5	31	-25 3/4	-5	1/4	0	0
10	31 1/2	-20	-5 3/4	31 1/2	-20 1/2	-5 3/4	0	- 1/2	0
11	30 1/2	-14 1/2	-6	31 1/4	-14 3/4	-6	3/4	- 1/4	0
12	31	-10 1/4	-6	31	-10 1/4	-6	0	0	0
13	30 1/4	-4 1/4	-1	30 1/2	-4 1/4	-1	1/4	0	0
14	24 3/4	-27 1/4	-4 3/4	25	-27 3/4	-4 3/4	1/4	- 1/2	0
15	25	-20 1/2	-5 3/4	25 1/4	-20 3/4	-5 3/4	1/4	- 1/4	0
16	25 1/4	-15 1/4	-6	25 1/4	-15 1/4	-6 1/4	0	0	- 1/4
17	24 1/2	-9 1/4	-6	24 3/4	-10	-6	1/4	- 3/4	0
18	22 3/4	-4 1/4	-1 1/2	22 3/4	-4 1/4	-1 3/4	0	0	- 1/4
19	18 1/2	-27 1/4	-4 1/2	18 1/2	-27 3/4	-4 1/2	0	- 1/2	0
20	18 1/2	-21 1/4	-5 3/4	18 3/4	-21 1/2	-5 3/4	1/4	- 1/4	0
21	19 1/4	-15 1/2	-6 1/4	19	-16 1/4	-6 1/4	- 1/4	- 3/4	0
22	16 1/2	-11 3/4	-5	16 1/4	-12	-5	- 1/4	- 1/4	0
23	17 1/2	-4 1/2	-2	17 3/4	-4 1/2	-2	1/4	0	0
24	9	-26 3/4	-3	9	-26 1/2	-3	0	1/4	0
25	9 1/2	-20 1/2	-3 1/4	9 1/2	-20 1/2	-3 1/4	0	0	0
26	9 3/4	-14 1/2	-3 1/2	9 3/4	-14	-3 1/2	0	1/2	0
27	9 1/2	-8	-3	9 1/2	-8	-3	0	0	0
28							0	0	0
29							0	0	0
30							0	0	0
31							0	0	0

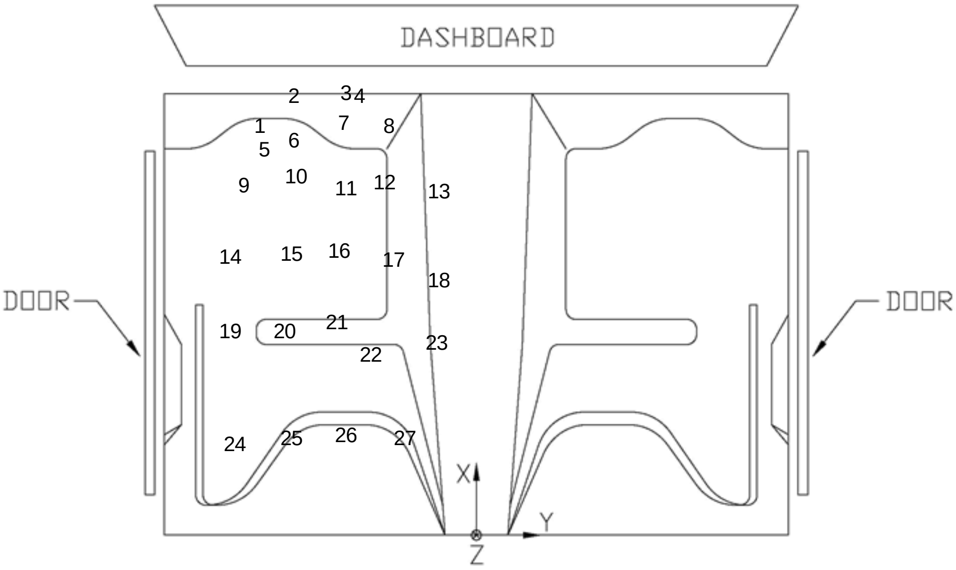


Figure E-2. Floor Pan Deformation Data – Set 2, Test No. NYJ-1

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1

TEST: NYJ-1
VEHICLE: 1500A

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	33	-49 1/4	24	33	-49	24 1/4	0	1/4	1/4
	A2	34 3/4	-39 3/4	25 1/2	35	-39 1/2	26	1/4	1/4	1/2
	A3	34 3/4	-28	23 1/2	34 1/2	-28	23 1/2	- 1/4	0	0
	A4	29 1/4	-51 3/4	20	29 1/4	-52	20	0	- 1/4	0
	A5	30	-33 1/2	20	30 1/2	-33 1/2	19 3/4	1/2	0	- 1/4
	A6	29 3/4	-28	19 1/4	29 3/4	-28	19 1/4	0	0	0
SIDE PANEL	B1	22 1/4	-24 3/4	1 1/4	22 1/4	-24 1/2	1 1/2	0	1/4	1/4
	B2	24 1/4	-22 3/4	3/4	24 1/4	-22 1/2	1/2	0	1/4	- 1/4
	B3	22 1/2	-23	-3	22 1/4	-23	-2 3/4	- 1/4	0	1/4
IMPACT SIDE DOOR	C1	10	-38	21 1/2	10	-38 1/4	21 1/2	0	- 1/4	0
	C2	21 1/2	-38 1/4	21	21 1/2	-38 1/4	21	0	0	0
	C3	28 1/4	-36 1/4	20 1/2	28 1/4	-36	20 1/4	0	1/4	- 1/4
	C4	16 1/2	-31 1/2	6 3/4	17	-31 1/2	6 1/4	1/2	0	- 1/2
	C5	19 3/4	-33	10 1/4	20 1/4	-33	10 1/4	1/2	0	0
	C6	24 1/2	-33 1/4	7 1/4	24 1/2	-33 1/4	7	0	0	- 1/4
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

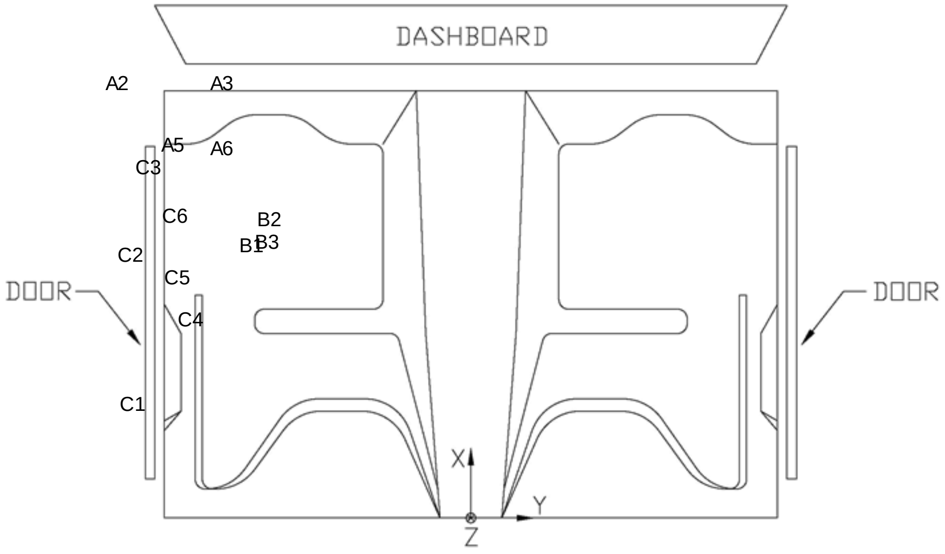


Figure E-3. Occupant Compartment Deformation Data – Set 1, Test No. NYJ-1

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2

TEST: NYJ-1
VEHICLE: 1500A

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	50	-49 3/4	23 3/4	50	-49 3/4	24	0	0	1/4
	A2	51 1/2	-40	25 3/4	51 1/4	-40	26	- 1/4	0	1/4
	A3	51	-27 3/4	23 3/4	51	-27 1/2	24	0	1/4	1/4
	A4	47 1/2	-52 1/4	20	47 1/2	-52 1/2	20	0	- 1/4	0
	A5	47 1/2	-33 1/4	20	47 1/2	-33 1/2	20	0	- 1/4	0
	A6	47	-27 1/2	19 1/4	46 3/4	-27 1/2	19 1/2	- 1/4	0	1/4
SIDE PANEL	B1	34 1/2	-24 1/2	1 1/4	34 1/2	-24 3/4	1 1/4	0	- 1/4	0
	B2	36 1/4	-23 1/4	1/2	36 1/4	-23	1/2	0	1/4	0
	B3	34 3/4	-23	-3	34 3/4	-23 1/4	-3	0	- 1/4	0
IMPACT SIDE DOOR	C1	14	-39 3/4	21 1/2	14	-39 1/4	21 1/2	0	1/2	0
	C2	25 1/2	-39	21	25 3/4	-38 3/4	21	1/4	1/4	0
	C3	32 1/2	-38 3/4	20 1/2	32 1/4	-38 1/2	20 1/2	- 1/4	1/4	0
	C4	22 3/4	-33 1/2	6 1/2	22 3/4	-33 1/4	6 1/2	0	1/4	0
	C5	25 3/4	-34 1/4	10	25 3/4	-34	10 1/4	0	1/4	1/4
	C6	30	-33 1/4	7	30 1/2	-33 1/4	7	1/2	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

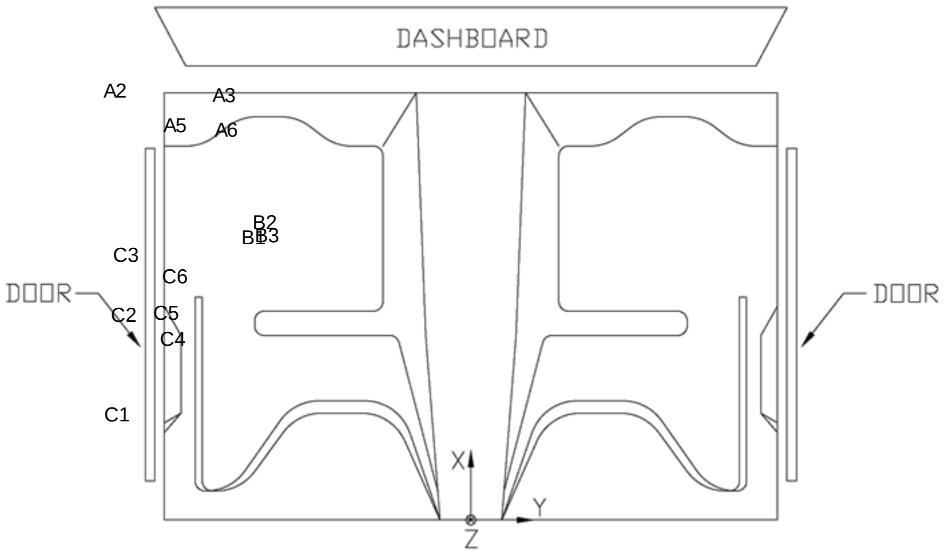
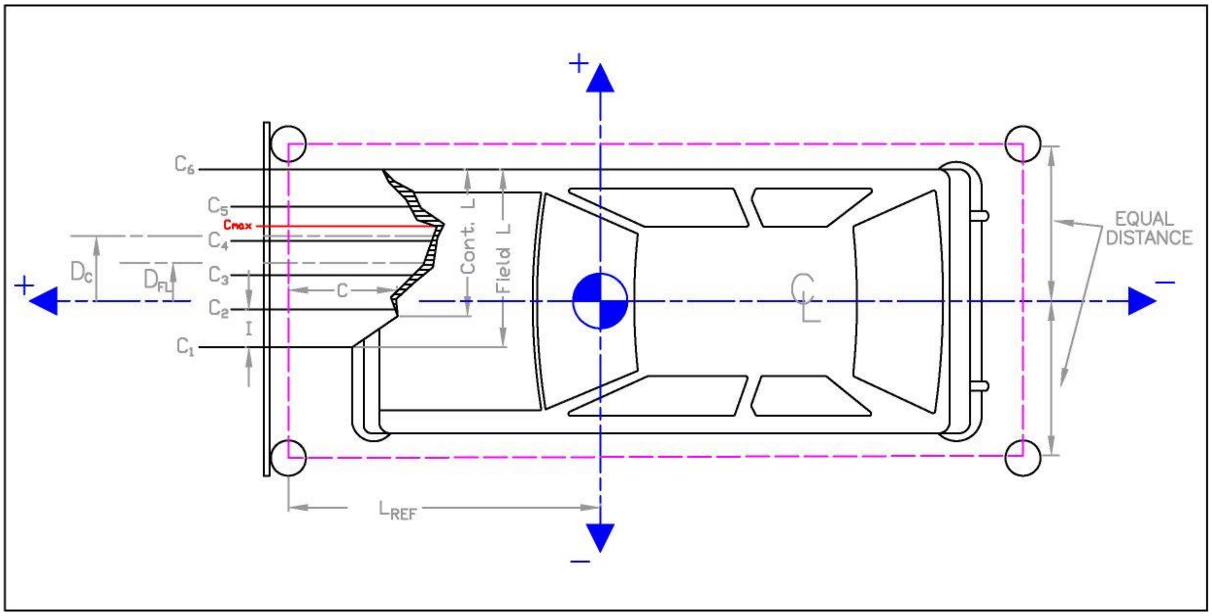


Figure E-4. Occupant Compartment Deformation Data – Set 2, Test No. NYJ-1

Date: 7/9/2013 **Test Number:** NYJ-1

Make: Ford Taurus **Model:** 1500A **Year:** 2006



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	87 7/8	(2232)
Width of contact and induced crush - Field L:	67 1/4	(1708)
Crush measurement spacing interval (L/5) - I:	13.45	(342)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	67 1/4	(1708)
Distance from center of vehicle to center of contect damage - D_C:	0	()

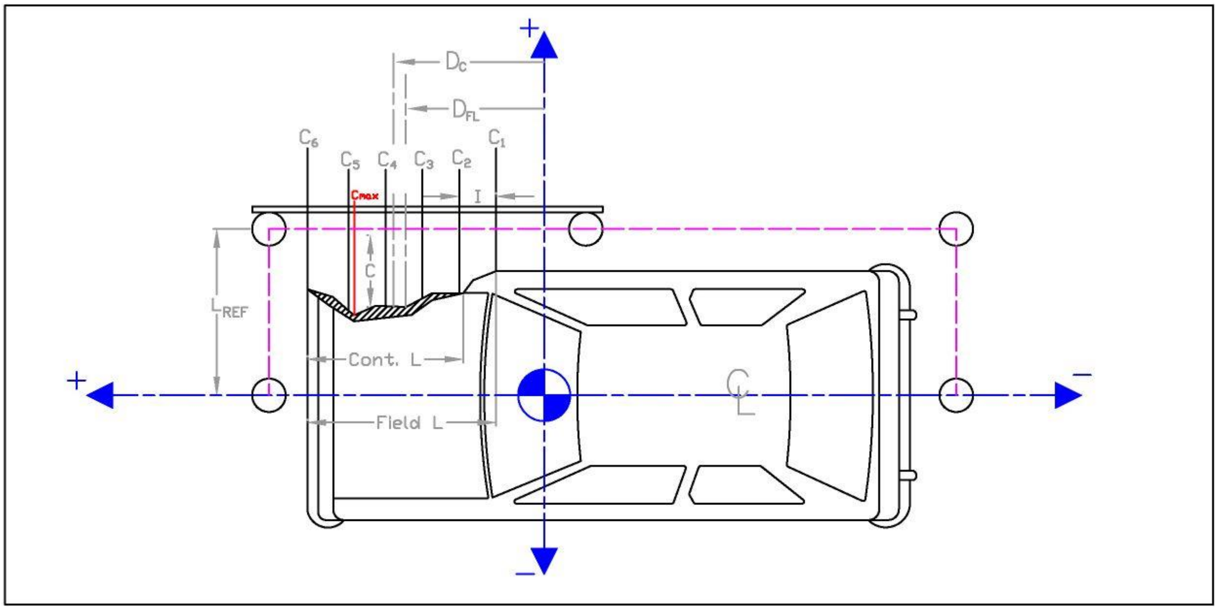
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)

	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	-33 5/8	-(854)	31 1/3	(795)	- 1/8	-(3)	NA	NA
C_2	10 1/4	(260)	-20 1/6	-(512)	9 1/3	(237)			1	(26)
C_3	7	(178)	-6 5/7	-(171)	6 5/7	(170)			2/5	(11)
C_4	6 7/8	(175)	6 5/7	(171)	6 5/7	(171)			2/7	(7)
C_5	9 3/4	(248)	20 1/6	(512)	9 1/4	(235)			5/8	(16)
C_6	na	NA	33 5/8	(854)	29 7/8	(759)			NA	NA
C_{MAX}	10 1/4	(260)	-20 1/6	-(512)	9 1/3	(237)			1	(26)

Figure E-5. Exterior Vehicle Crush (NASS) - Front, Test No. NYJ-1

Date: 7/9/2013 **Test Number:** NYJ-1

Make: Ford Taurus **Model:** 1500A **Year:** 2006



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	40 1/4	(1022)
Width of contact and induced crush - Field L:	27 1/4	(692)
Crush measurement spacing interval (L/5) - I:	5.45	(138)
Distance from vehicle c.g. to center of Field L - D_{FL}:	67.75	(1721)
Width of Contact Damage:	27 1/4	(692)
Distance from vehicle c.g. to center of contect damage - D_C:	67 3/4	(1721)

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	6 1/2	(165)	54 1/8	(1375)	8 1/8	(206)	-2 3/4	-(70)	1 1/8	(29)
C_2	7 3/4	(197)	59 4/7	(1513)	8 1/8	(206)			2 3/8	(60)
C_3	8 3/4	(222)	65	(1652)	8 1/8	(206)			3 3/8	(86)
C_4	10 1/4	(260)	70 1/2	(1790)	8 1/8	(206)			4 7/8	(124)
C_5	na	NA	76	(1928)	8 1/8	(206)			NA	NA
C_6	na	NA	81 3/8	(2067)	8 1/8	(206)			NA	NA
C_{MAX}	10 1/4	(260)	70 1/2	(1791)	8 1/8	(206)			4 7/8	(124)

Figure E-6. Exterior Vehicle Crush (NASS) - Side, Test No. NYJ-1

Windshield crush measurements

Test: NYJ-1

Date Measured: 7/9/2013

Crush measurments:

Reference location from the top passenger side roof corner of windshield

	Lateral (X)	Longitudina	Pre test	Post test	Crush
Point A	15.75	15.25	4	10.25	6.25
Point B	21.5	10	4.125	8.75	4.625
Point C	9.75	22.5	4	9.75	5.75
Point D	19.75	23.5	3.125	9	5.875
Max Crush	15.75	15.25	4	10.25	6.25

Figure E-7. Windshield Crush, Test No. NYJ-1

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 1

TEST: NYJ-2
VEHICLE: Taurus

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	29	-20 3/4	0	29 1/4	-21 1/4	1/4	1/4	- 1/2	1/4
2	30 1/4	-17 1/4	-3 1/4	30 1/2	-17	-3	1/4	1/4	1/4
3	30 1/4	-9	-3 3/4	30 1/2	-9	-3 1/2	1/4	0	1/4
4	29 3/4	-4	-4 1/2	29 3/4	-3 3/4	-4 1/2	0	1/4	0
5	26	-21	-4 1/2	26 1/4	-20 1/2	-4 1/2	1/4	1/2	0
6	26 1/2	-17 1/2	-6	26 1/2	-17 3/4	-5 3/4	0	- 1/4	1/4
7	28	-11 1/2	-5 1/4	28	-11 1/2	-5 1/4	0	0	-0
8	26 3/4	-7 1/4	-6 1/4	27	-7 1/2	-6 1/4	1/4	- 1/4	0
9	22 1/4	-21 1/2	-6 1/4	22 1/4	-21 3/4	-6	0	- 1/4	1/4
10	22	-17 3/4	-6 3/4	22	-17 3/4	-6 1/2	0	0	1/4
11	21 3/4	-12 1/2	-7	22	-12 1/2	-7	1/4	0	0
12	21 1/2	-6 3/4	-7 1/4	21 1/2	-6 1/4	-7	0	1/2	1/4
13	22 1/4	-1 3/4	-2 1/2	22 1/4	-2	-2 1/2	0	- 1/4	0
14	17 1/4	-22 3/4	-6	17 1/4	-22 3/4	-6	0	0	0
15	16 1/2	-18 1/4	-6 3/4	16 3/4	-18 1/2	-6 1/2	1/4	- 1/4	1/4
16	16 3/4	-13 3/4	-7	16 3/4	-14	-7	0	- 1/4	0
17	16 3/4	-8 1/4	-7 1/4	17	-8 1/4	-7 1/4	1/4	0	0
18	16	-2 3/4	-2 3/4	16 1/4	-3	-2 3/4	1/4	- 1/4	0
19	12 3/4	-24 1/2	-5 1/4	13	-24 1/2	-5 1/4	1/4	0	0
20	12 3/4	-18 1/2	-6 1/2	12 3/4	-18 1/2	-6 1/2	0	0	0
21	13	-10 3/4	-7	13 1/4	-10 3/4	-7	1/4	0	0
22	11	-2 1/2	-3	11	-2 1/2	-3	0	0	0
23	7 1/2	-24 1/2	-5 1/4	7 1/2	-24 1/2	-5 1/4	0	0	0
24	7	-16 3/4	-6 3/4	7	-16 3/4	-6 3/4	0	0	0
25	7 1/2	-10 3/4	-6	7 1/4	-10 3/4	-6	- 1/4	0	0
26	1	-24 1/2	-3 3/4	1	-24 1/2	-3 1/2	0	0	1/4
27	1 1/2	-15 1/4	-4 1/4	1 3/4	-15	-4 1/4	1/4	1/4	0
28	2	-7 3/4	-4	2	-7 3/4	-4	0	0	0
29							0	0	0
30							0	0	0
31							0	0	0

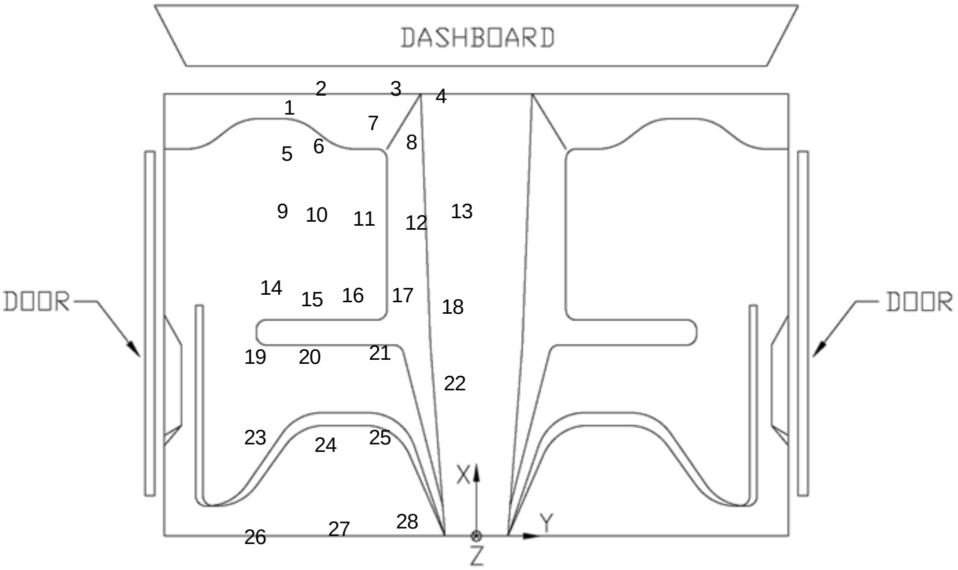


Figure E-8. Floor Pan Deformation Data – Set 1, Test No. NYJ-2

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 2

TEST: NYJ-2
VEHICLE: Taurus

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	43	-23 3/4	0	42 3/4	-23	1/4	- 1/4	3/4	1/4
2	44 1/2	-19 1/4	-3 1/2	44 1/2	-19 1/4	-3 1/4	0	0	1/4
3	44 1/2	-11 1/2	-4	44 1/2	-11 1/2	-3 3/4	0	0	1/4
4	43 3/4	-7	-4 1/2	43 1/2	-6 1/2	-4 1/2	- 1/4	1/2	0
5	40 1/4	-23 1/2	-4 1/2	40 1/4	-22 3/4	-4 1/4	0	3/4	1/4
6	40 1/2	-20 1/2	-6 1/4	40 1/2	-20	-5 3/4	0	1/2	1/2
7	42	-14 1/2	-5 3/4	42	-14 1/4	-5 1/2	0	1/4	1/4
8	41	-9 3/4	-6 1/2	40 3/4	-9 3/4	-6 1/2	- 1/4	0	0
9	36 1/2	-24	-6 1/4	36 1/4	-23 3/4	-6	- 1/4	1/4	1/4
10	36	-19 3/4	-6 3/4	36	-19 1/2	-6 1/2	0	1/4	1/4
11	36	-14 3/4	-7 1/4	35 3/4	-14 1/4	-7	- 1/4	1/2	1/4
12	35 1/2	-9	-7 1/4	35 1/2	-8 3/4	-7 1/4	0	1/4	0
13	36 1/4	-4 1/4	-2 3/4	36	-4	-2 3/4	- 1/4	1/4	0
14	31 1/4	-25	-6	31	-25	-6	- 1/4	0	0
15	30 3/4	-20 3/4	-6 1/2	30 3/4	-20 3/4	-6 1/2	0	0	0
16	30 3/4	-16	-7	30 3/4	-16 1/4	-7	0	- 1/4	0
17	31	-10 3/4	-7 1/4	31	-10 1/2	-7 1/4	0	1/4	0
18	30	-5 1/4	-2 3/4	30	-5	-3	0	1/4	- 1/4
19	27	-27 1/4	-5	26 3/4	-27	-5	- 1/4	1/4	0
20	26 3/4	-21 1/4	-6 1/2	26 3/4	-20 3/4	-6 1/2	0	1/2	0
21	27 1/4	-13 1/4	-7	27 1/4	-12 3/4	-6 3/4	0	1/2	1/4
22	25	-5 1/4	-3 1/4	25	-5	-3	0	1/4	1/4
23	21 3/4	-27	-5	21 1/2	-26 3/4	-5	- 1/4	1/4	0
24	21	-18 1/2	-6 3/4	21	-18 3/4	-6 1/2	0	- 1/4	1/4
25	21 1/2	-13 1/4	-6	21 1/4	-13 1/4	-6	- 1/4	0	0
26	15	-27	-3 1/4	15	-26 3/4	-3 1/4	0	1/4	0
27	15 1/2	-17 1/2	-4	15 1/2	-17 1/2	-4	0	0	0
28	15 3/4	-10 1/2	-3 3/4	15 3/4	-9 3/4	-3 3/4	0	3/4	0
29							0	0	0
30							0	0	0
31							0	0	0

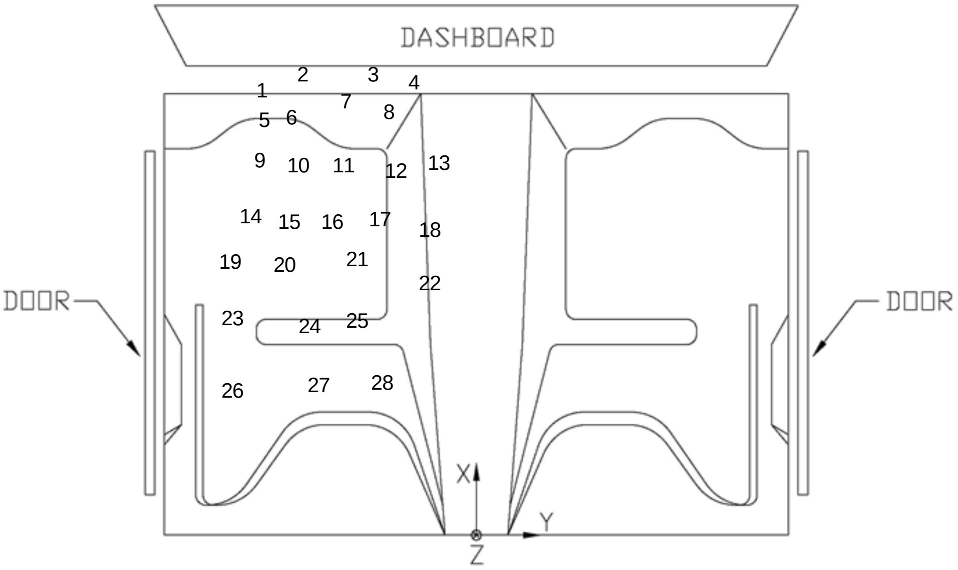


Figure E-9. Floor Pan Deformation Data – Set 2, Test No. NYJ-2

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1

TEST: NYJ-2
VEHICLE: Taurus

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	38 1/4	-47 3/4	24	38	-47 3/4	24	- 1/4	0	0
	A2	39	-35	23 1/2	39	-34 3/4	23 1/2	0	1/4	0
	A3	38 3/4	-25 3/4	22	38 3/4	-26	22	0	- 1/4	0
	A4	35 1/4	-35 1/4	21 1/4	35	-35	21 1/4	- 1/4	1/4	0
	A5	32 3/4	-34 1/2	15 3/4	33	-34 3/4	15 3/4	1/4	- 1/4	0
	A6	34 1/4	-27 3/4	17 3/4	34	-28	17 3/4	- 1/4	- 1/4	0
SIDE PANEL	B1	21	-26 3/4	- 1/4	21 1/4	-26 1/2	- 1/4	1/4	1/4	0
	B2	19	-26 1/2	-3 1/4	19	-26 1/2	-3	0	0	1/4
	B3	22 3/4	-25	-2 1/2	22 3/4	-24 3/4	-2 1/2	0	1/4	0
IMPACT SIDE DOOR	C1	11	-37	21	10 3/4	-36 3/4	21	- 1/4	1/4	0
	C2	22 1/2	-35	20 3/4	22 1/2	-35 1/4	21	0	- 1/4	1/4
	C3	28 3/4	-36 1/4	20	28 1/2	-35 3/4	20	- 1/4	1/2	0
	C4	16 1/2	-29 1/2	10	16 1/2	-29 1/2	10	0	0	0
	C5	20 3/4	-29 3/4	10 1/2	21	-29 3/4	10 3/4	1/4	0	1/4
	C6	25	-31 1/4	9 3/4	25	-31	9 1/2	0	1/4	- 1/4
ROOF	D1							0	0	0
	D2							0	0	0
	D3							0	0	0
	D4	Omitted, additional crush documentation performed						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

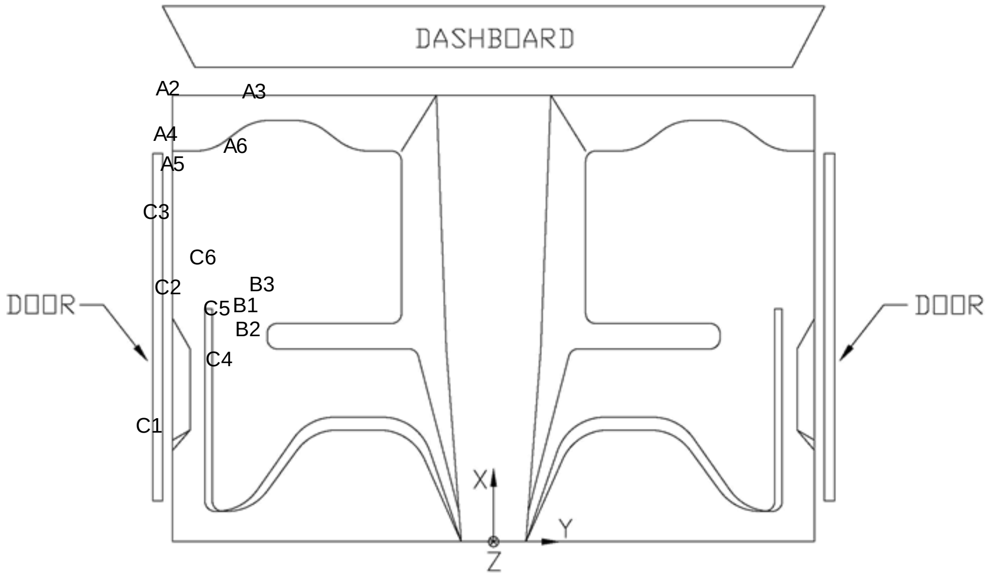


Figure E-10. Occupant Compartment Deformation Data – Set 1, Test No. NYJ-2

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2

TEST: NYJ-2
VEHICLE: Taurus

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	51 1/2	-46 1/2	24 1/4	51 1/2	-46 3/4	24 1/4	0	- 1/4	0
	A2	51	-34	23 1/2	51 1/4	-34 1/4	24	1/4	- 1/4	1/2
	A3	50 1/2	-25 3/4	22 1/4	51	-26	22	1/2	- 1/4	- 1/4
	A4	49	-52	21 1/2	49	-52	21 1/2	0	0	0
	A5	45 3/4	-34	15 1/2	46	-34 1/4	16	1/4	- 1/4	1/2
	A6	46 1/2	-27 3/4	17 1/2	46 3/4	-27 3/4	17 3/4	1/4	0	1/4
SIDE PANEL	B1	38	-27 1/2	- 1/4	38	-27 1/4	0	0	1/4	1/4
	B2	36	-26 3/4	-3 1/4	36	-26 1/2	-3	0	1/4	1/4
	B3	39 3/4	-26	-2 1/2	39 3/4	-26	-2 1/2	0	0	0
IMPACT SIDE DOOR	C1	15 1/4	-38 3/4	21 1/2	14 3/4	-38 1/2	21 3/4	- 1/2	1/4	1/4
	C2	26 3/4	-38 3/4	21	26 1/2	-38 1/2	21 1/4	- 1/4	1/4	1/4
	C3	33	-38 1/4	20 1/4	32 3/4	-38	20	- 1/4	1/4	- 1/4
	C4	23	-34	10 1/4	22 3/4	-33 3/4	10 1/2	- 1/4	1/4	1/4
	C5	27	-34 1/4	10 3/4	27 1/4	-34	11	1/4	1/4	1/4
	C6	31	-33 3/4	9 1/2	31	-33 3/4	9 1/2	0	0	0
ROOF	D1							0	0	0
	D2							0	0	0
	D3							0	0	0
	D4	Omitted, additional crush documentation performed						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

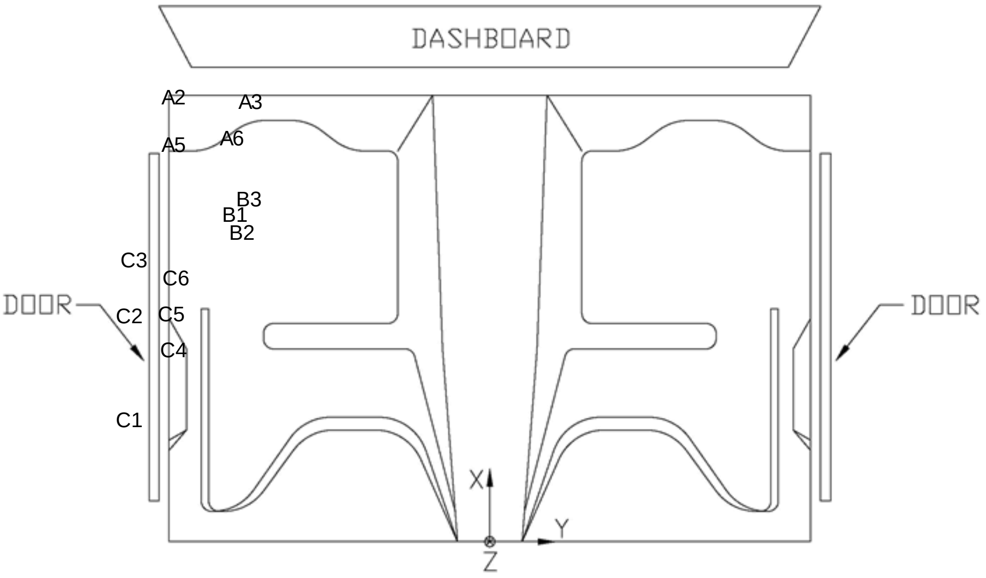
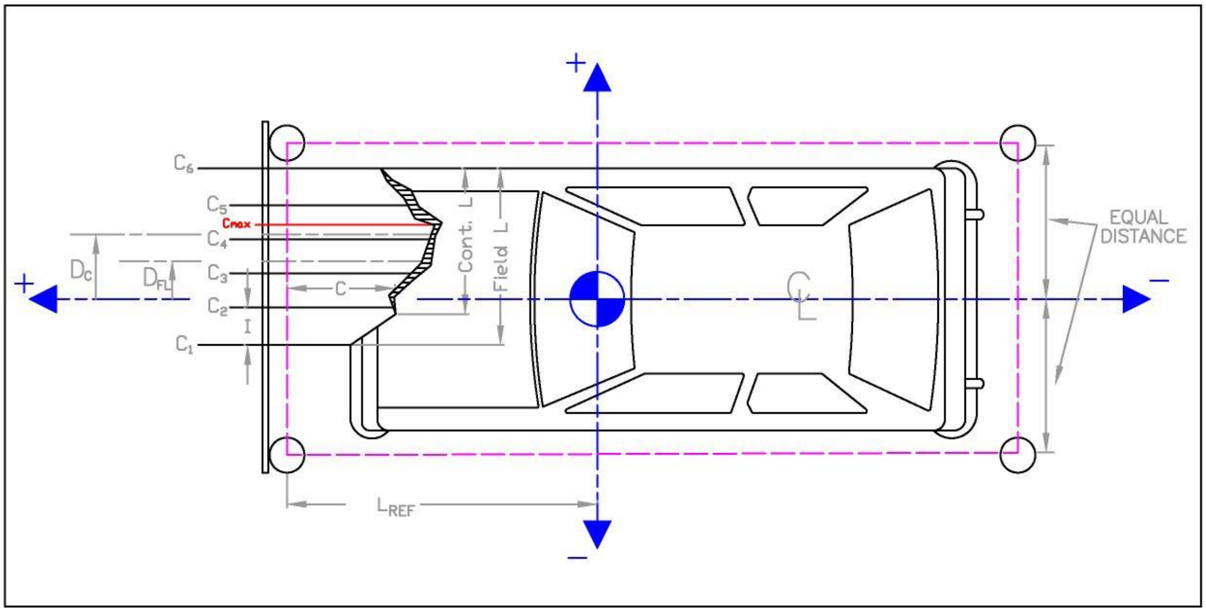


Figure E-11. Occupant Compartment Deformation Data – Set 2, Test No. NYJ-2

Date: 8/19/2013 **Test Number:** NYJ-2

Make: Ford **Model:** Taurus **Year:** 2006



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	84 1/4	(2140)
Width of contact and induced crush - Field L:	69	(1753)
Crush measurement spacing interval (L/5) - I:	13.8	(351)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	69	(1753)
Distance from center of vehicle to center of contect damage - D_C:	0	()

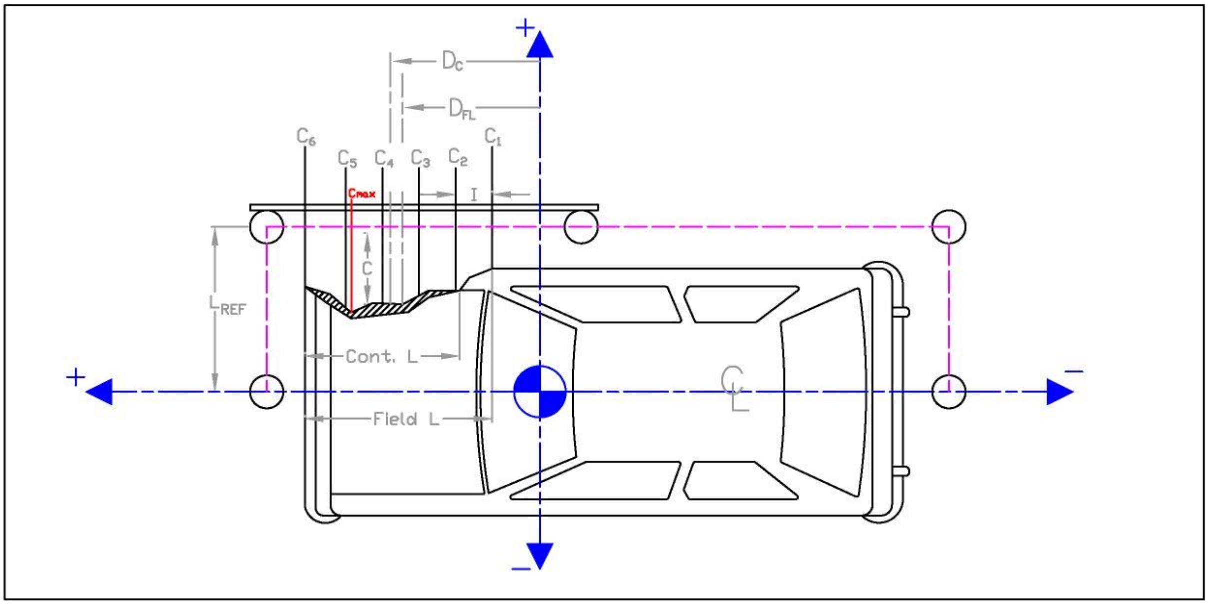
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)

	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	-34 1/2	-(876)	32 3/4	(832)	-3 2/3	-(93)	NA	NA
C_2	5 1/2	(140)	-20 2/3	-(526)	9 1/2	(242)			- 2/5	-(10)
C_3	3	(76)	-6 8/9	-(175)	6 2/3	(170)			-0	-(1)
C_4	2 1/2	(64)	7	(175)	6 5/7	(170)			- 5/9	-(14)
C_5	7 1/4	(184)	20 5/7	(526)	9 4/9	(240)			1 1/2	(37)
C_6	na	NA	34 1/2	(876)	32 3/4	(832)			NA	NA
C_{MAX}	11	(279)	-25 1/4	-(641)	11 3/8	(289)			3 1/4	(83)

Figure E-12. Exterior Vehicle Crush (NASS) - Front, Test No. NYJ-2

Date: 8/19/2013 **Test Number:** NYJ-2

Make: Ford **Model:** Taurus **Year:** 2006



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	43 3/8	(1102)
Width of contact and induced crush - Field L:	198	(5029)
Crush measurement spacing interval (L/5) - I:	39.6	(1006)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-17.5	-(445)
Width of Contact Damage:	198	(5029)
Distance from vehicle c.g. to center of contect damage - D_C:	17 1/2	(445)

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	-116 1/2	-(2959)	12 1/3	(314)	3/8	(10)	NA	NA
C_2	7 3/4	(197)	-77	-(1953)	8 5/8	(219)			-1 1/4	-(32)
C_3	6 1/2	(165)	-37 1/3	-(947)	6 3/4	(171)			- 5/8	-(16)
C_4	7	(178)	2 2/7	(58)	7	(175)			- 2/7	-(7)
C_5	9	(229)	41 8/9	(1064)	8 1/8	(206)			1/2	(13)
C_6	na	NA	81 1/2	(2070)	8 1/8	(206)			NA	NA
C_{MAX}	12 1/4	(311)	-63 1/2	-(1613)	8 2/9	(209)			3 2/3	(93)

Figure E-13. Exterior Vehicle Crush (NASS) - Side, Test No. NYJ-2

Windshield crush measurements

Test: NYJ-2

Date Measured: 8/20/2013

Crush measurments:

Reference location from the top passenger side roof corner of windshield

	Lateral (X)	Longitudinal (Y)	Pre test	Post test	Crush
Point A	35	11	4.25	8	3.75
Point B	34.25	21	3.25	7.75	4.5
Point C	41.5	18.5	4.625	8.25	3.625
Point D	37.75	25.25	3.5	7.125	3.625
Max Crush	34.25	21	3.25	7.75	4.5

Figure E-14. Windshield Crush, Test No. NYJ-2

Roof crush measurements

Test: NYJ-2

Date Measured: 8/20/2013

Crush measurments:

Reference location from the top passenger side roof corner of windshield

	Lateral (X)	Longitudinal (Y)	Pre test	Post test	Crush
Point A	19.5	19.5	4.875	7	2.125
Point B	29.5	19	5.25	7.5	2.25
Point C	33.5	23.75	5.375	7.25	1.875
Point D	30.5	11	5.25	6.75	1.5
Max Crush	29.5	19	5.25	7.5	2.25

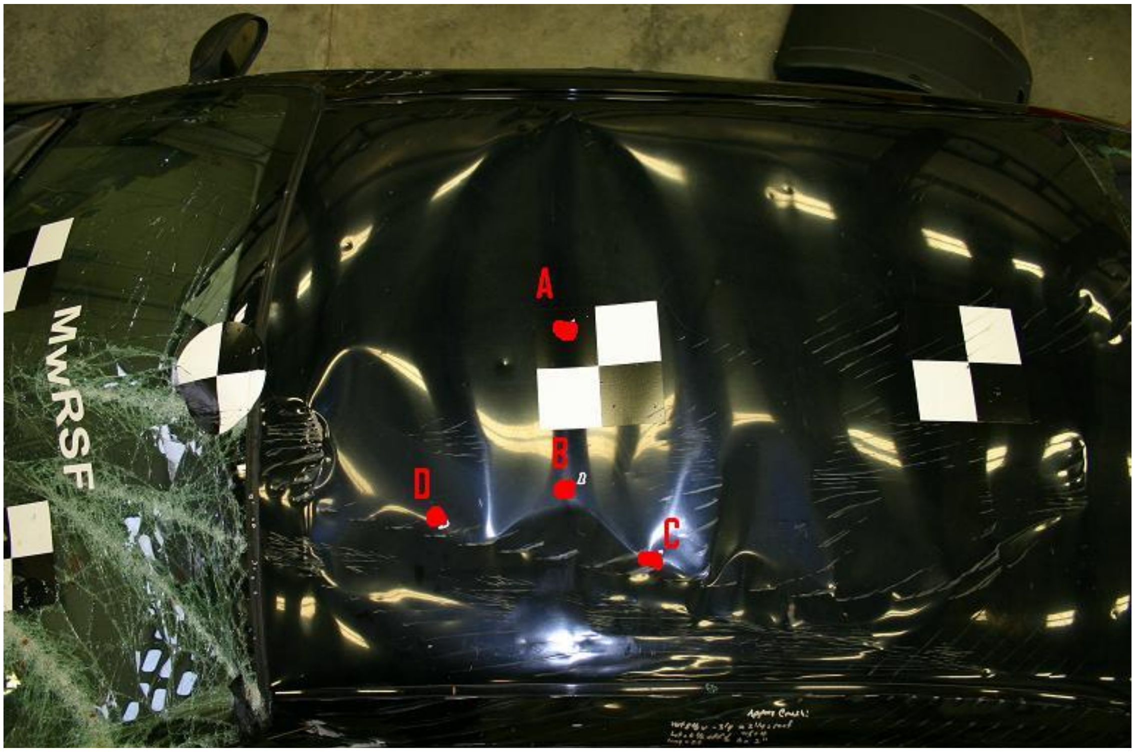


Figure E-15. Roof Crush, Test No. NYJ-2

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 1

TEST: NYJ-3
VEHICLE: Ram 1500

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	28 1/2	-26	-2 1/2	28 1/2	-25 1/2	-2 1/2	0	1/2	0
2	30 1/4	-22	-3	30 1/4	-21	-3	0	1	0
3	29 3/4	-15 3/4	-3	29 3/4	-16	-3	0	- 1/4	0
4	29 1/2	-13	-2 1/2	29 1/2	-12 1/2	-3	0	1/2	- 1/2
5	23 3/4	-26 1/2	-6 1/2	24	-26 1/4	-6 3/4	1/4	1/4	- 1/4
6	23 3/4	-22	-6 1/4	24	-21 3/4	-6 1/2	1/4	1/4	- 1/4
7	24	-16	-5 3/4	24	-15 3/4	-5 3/4	0	1/4	0
8	23 1/4	-11 3/4	-6	23 1/4	-11 1/4	-6 1/4	0	1/2	- 1/4
9	17	-27 1/4	-8 3/4	17 1/4	-26 3/4	-8 3/4	1/4	1/2	0
10	17 1/4	-22 3/4	-8 1/4	17 1/2	-22 1/4	-8 1/2	1/4	1/2	- 1/4
11	17 1/2	-17	-8	17 1/2	-16 1/2	-8	0	1/2	0
12	17 1/4	-11	-7 1/2	17	-10 1/2	-7 3/4	- 1/4	1/2	- 1/4
13	14	-5 1/4	- 1/4	14	-5 1/4	- 1/2	0	0	- 1/4
14	13	-27 1/4	-9	13	-27 1/4	-9	0	0	0
15	13 1/2	-22	-8 1/2	13 1/2	-22	-8 1/2	0	0	0
16	14	-16 1/2	-8	14	-16 1/4	-8 1/4	0	1/4	- 1/4
17	14 1/4	-11 1/4	-7 3/4	14	-11 1/2	-8	- 1/4	- 1/4	- 1/4
18	11	-5 1/4	- 3/4	11	-5 1/4	- 3/4	0	0	0
19	8 1/4	-27 1/2	-9	8 1/4	-27	-9	0	1/2	0
20	8 3/4	-21 1/2	-8 1/2	8 1/2	-21 1/2	-8 1/2	- 1/4	0	0
21	8 3/4	-17	-8 1/4	8 3/4	-17	-8 1/4	0	0	0
22	8 1/2	-11 1/4	-8	8 1/2	-11	-8	0	1/4	0
23	8 1/2	-6 1/2	-1 3/4	8 1/2	-6 1/2	-1 3/4	0	0	0
24	1	-27	-5 1/4	1	-26	-5 1/4	0	1	0
25	1 1/4	-22 1/2	-4 3/4	1	-22 1/2	-4 3/4	- 1/4	0	0
26	1	-16 1/2	-4 1/2	1	-17	-4 1/2	0	- 1/2	0
27	1	-12 1/2	-4 1/4	1	-12 1/2	-4 1/4	0	0	0
28							0	0	0
29							0	0	0
30							0	0	0
31							0	0	0

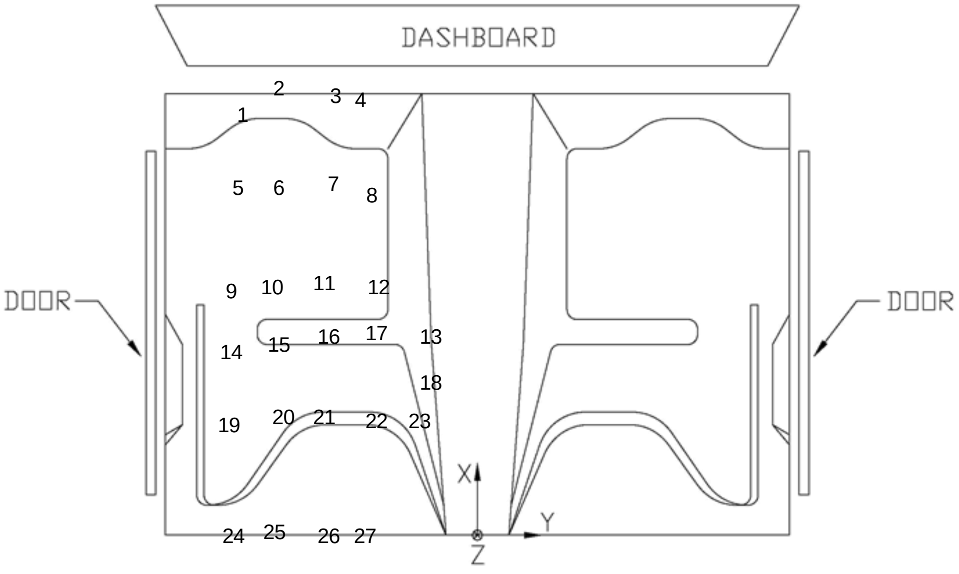


Figure E-16. Floor Pan Deformation Data – Set 1, Test No. NYJ-3

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 2

TEST: NYJ-3
VEHICLE: Ram 1500

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	44 3/4	-32 1/4	0	44 1/4	-32	0	- 1/2	1/4	0
2	46 1/4	-27 3/4	-1	46 1/4	-27 1/2	-1	0	1/4	0
3	45 3/4	-22 1/2	-1 1/2	45 3/4	-22 1/4	-1 1/2	0	1/4	0
4	45 1/2	-19 1/2	-1 1/2	45 3/4	-19	-1 1/2	1/4	1/2	0
5	40	-33	-4	40	-32 3/4	-4	0	1/4	0
6	40	-28	-4 1/4	39 3/4	-28 1/4	-4 1/4	- 1/4	- 1/4	0
7	40 1/4	-22	-4 1/2	40 1/4	-22	-4 1/2	0	0	0
8	39 1/2	-18	-5 1/4	39 1/2	-17 3/4	-5 1/2	0	1/4	- 1/4
9	33 1/2	-33 1/4	-5 3/4	33 1/4	-33 1/4	-6	- 1/4	0	- 1/4
10	33 1/2	-29 1/4	-6	33 1/4	-29	-6	- 1/4	1/4	0
11	33 1/2	-23 1/2	-6 1/2	33 1/4	-23 1/4	-6 1/2	- 1/4	1/4	0
12	33 1/2	-17 3/4	-6 3/4	33 1/4	-17 3/4	-6 3/4	- 1/4	0	0
13	30 1/4	-12	- 1/4	30 1/4	-12	- 1/4	0	0	0
14	29 1/2	-33 1/2	-6	29 1/2	-33 3/4	-6	0	- 1/4	0
15	29 3/4	-29	-6 1/4	29 3/4	-28 3/4	-6 1/4	0	1/4	0
16	30	-23	-6 1/2	30	-23 1/4	-6 1/2	0	- 1/4	0
17	30 1/4	-18	-7	30 1/4	-18 1/4	-7	0	- 1/4	0
18	27	-12	- 1/2	27 1/4	-12	- 1/2	1/4	0	0
19	25	-34 1/4	-6 1/4	25	-34	-6 1/4	0	1/4	0
20	25 1/2	-28 1/4	-6 1/2	25 1/2	-28 1/4	-6 1/2	0	0	0
21	25 1/2	-23 3/4	-6 3/4	25 1/2	-24	-6 3/4	0	- 1/4	0
22	25 1/2	-18	-7	25 1/2	-18 1/4	-7	0	- 1/4	0
23	24 1/2	-13 1/4	-1 1/2	24 1/2	-13 1/4	-1 1/2	0	0	0
24	17	-33 1/2	-2 1/2	17	-33 1/2	-2 1/2	0	0	0
25	17 1/4	-29	-2 1/2	17 1/4	-29 1/4	-2 1/2	0	- 1/4	0
26	17 1/4	-23 1/4	-2 3/4	17 1/4	-23 1/2	-3	0	- 1/4	- 1/4
27	17	-19	-3	17	-19 1/4	-3 1/4	0	- 1/4	- 1/4
28							0	0	0
29							0	0	0
30							0	0	0
31							0	0	0

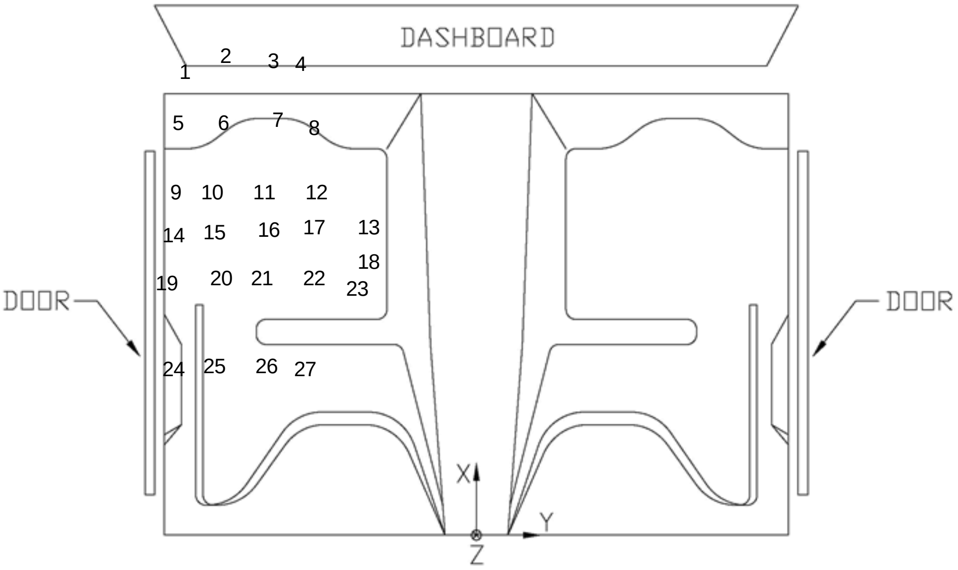


Figure E-17. Floor Pan Deformation Data – Set 2, Test No. NYJ-3

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1

TEST: NYJ-3
VEHICLE: Ram 1500

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	-55 1/2	24	39 3/4	-55 1/2	24 1/4	0	0	1/4
	A2	39 3/4	-41 3/4	25 1/4	39 1/2	-42	25 1/4	- 1/4	- 1/4	0
	A3	39 1/2	-31 3/4	26 1/2	39 1/2	-31 3/4	26 3/4	0	0	1/4
	A4	36 1/4	-56 3/4	19 1/2	36	-56 3/4	19 1/2	- 1/4	0	0
	A5	32 1/2	-44 1/2	15 1/4	32 1/2	-44 1/2	15 1/4	0	0	0
	A6	33 3/4	-36 1/2	18 3/4	33 3/4	-36 1/2	18 3/4	0	0	0
SIDE PANEL	B1	20 3/4	-24 1/4	0	21	-24 1/4	0	1/4	0	0
	B2	23	-24 1/4	-2	23	-24 1/4	-2	0	0	0
	B3	20	-24 1/2	-5	20	-24 1/2	-5 1/4	0	0	- 1/4
IMPACT SIDE DOOR	C1	8 3/4	-42	18 1/4	8 3/4	-42	18 1/2	0	0	1/4
	C2	19 1/2	-41 1/4	18	19 1/2	-41 1/4	18	0	0	0
	C3	29	-39 1/2	18	29	-39 1/2	18	0	0	0
	C4	17 1/4	-35 1/2	3 1/2	17 1/4	-35 1/2	3 1/2	0	0	0
	C5	19 1/2	-34 3/4	-2 1/4	19 1/2	-34 3/4	-2 1/2	0	0	- 1/4
	C6	23 1/2	-33 1/4	3/4	23 1/2	-33 1/4	3/4	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

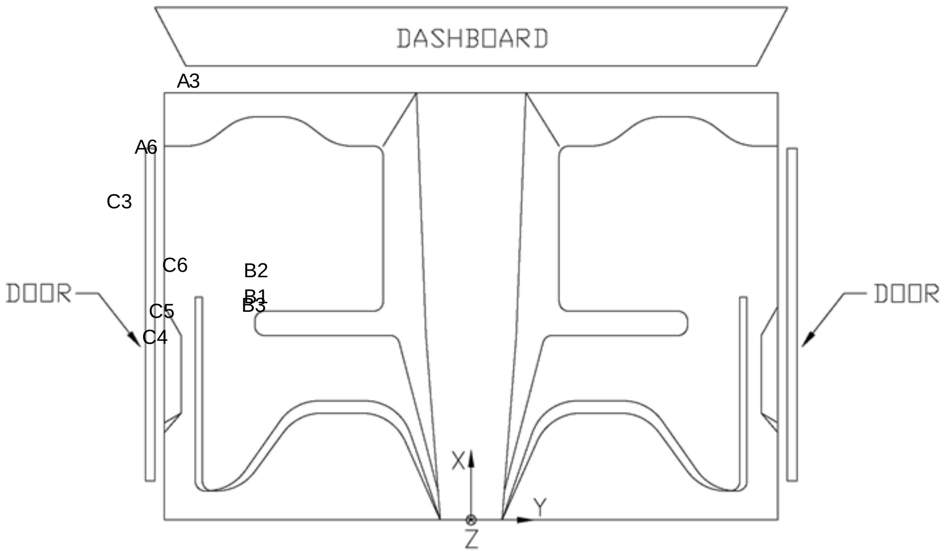


Figure E-18. Occupant Compartment Deformation Data – Set 1, Test No. NYJ-3

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2

TEST: NYJ-3
VEHICLE: Ram 1500

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	55	-55 1/4	26 1/2	54 1/2	-55 1/4	26 1/2	- 1/2	0	0
	A2	53	-41 3/4	26	52 1/4	-41 3/4	26 1/4	- 3/4	0	1/4
	A3	49 1/4	-31 3/4	26	49 1/4	-31 3/4	26 1/4	0	0	1/4
	A4	52	-56 1/2	21 3/4	52	-56 3/4	22	0	- 1/4	1/4
	A5	47	-45	16 1/4	47 1/4	-45	16 1/4	1/4	0	0
	A6	44 3/4	-37	18 3/4	44 1/2	-37	18 3/4	- 1/4	0	0
SIDE PANEL	B1	37 1/4	-28 3/4	3 1/4	37 1/4	-28 3/4	3 1/4	0	0	0
	B2	40	-29 1/2	1	40	-29 1/2	1	0	0	0
	B3	37	-28 3/4	-2	37	-28 3/4	-2 1/4	0	0	- 1/4
IMPACT SIDE DOOR	C1	12 1/4	-45	21 1/2	12	-45 1/4	21	- 1/4	- 1/4	- 1/2
	C2	23	-44 1/2	21	23	-44 3/4	21 1/2	0	- 1/4	1/2
	C3	32 1/2	-44	21 1/4	32 1/2	-44 1/4	21 1/4	0	- 1/4	0
	C4	22 1/2	-40	6 3/4	22 1/2	-40	7	0	0	1/4
	C5	24 3/4	-39 1/4	1	24 1/2	-39 1/4	1	- 1/4	0	0
	C6	28 3/4	-39 1/4	4	28 1/2	-39 1/4	4	- 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

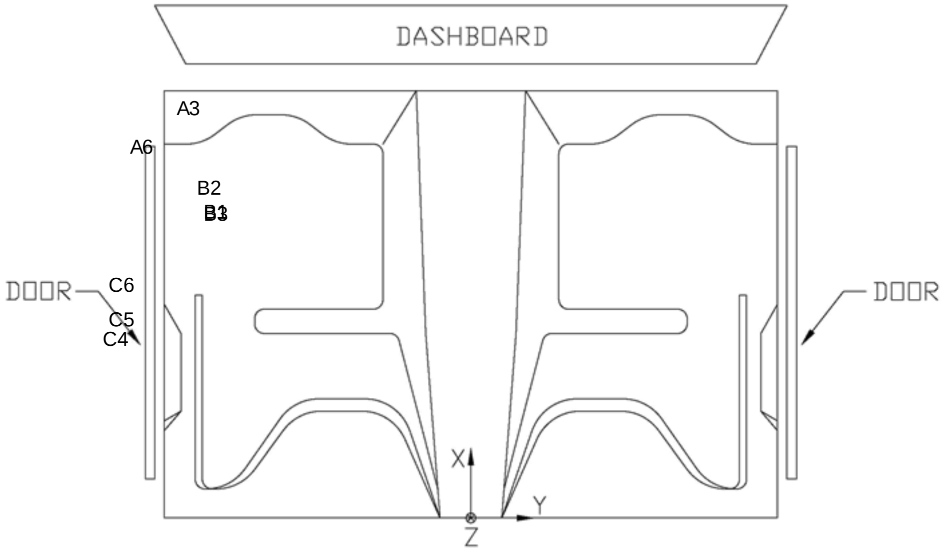
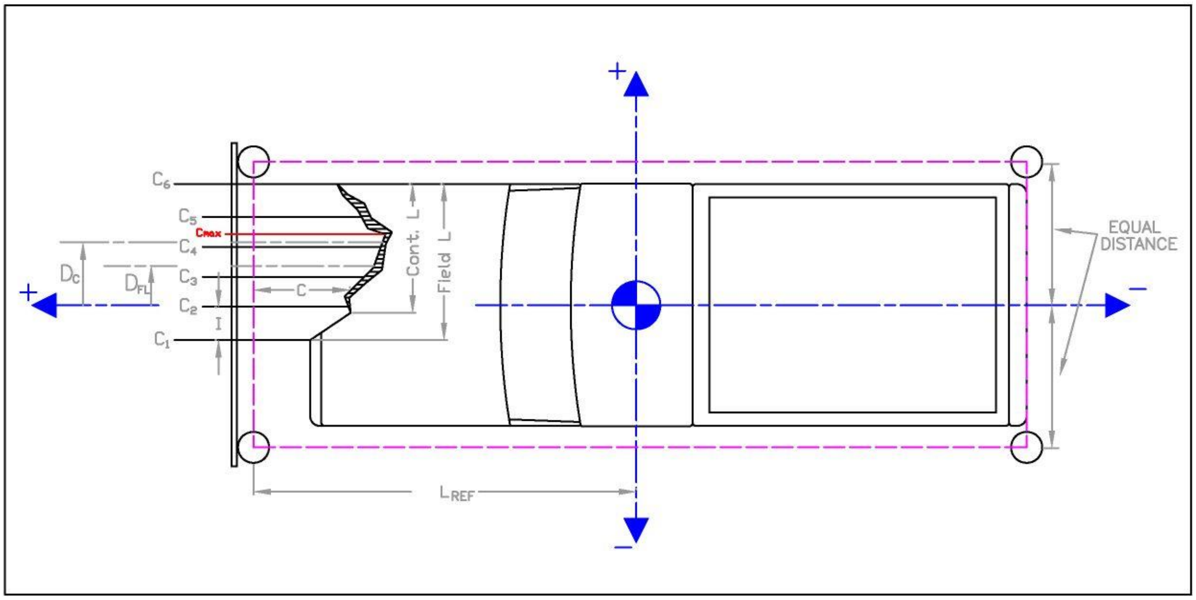


Figure E-19. Occupant Compartment Deformation Data – Set 2, Test No. NYJ-3

Date: 1/7/2014 **Test Number:** NYJ-3

Make: Dodge **Model:** Ram 1500 **Year:** 2007



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	107	(2718)
Width of contact and induced crush - Field L:	21	(533)
Crush measurement spacing interval (L/5) - I:	4.2	(107)
Distance from center of vehicle to center of Field L - D_{FL}:	-28.5	-(724)
Width of Contact Damage:	17	(432)
Distance from center of vehicle to center of contect damage - D_C:	33 1/2	(851)

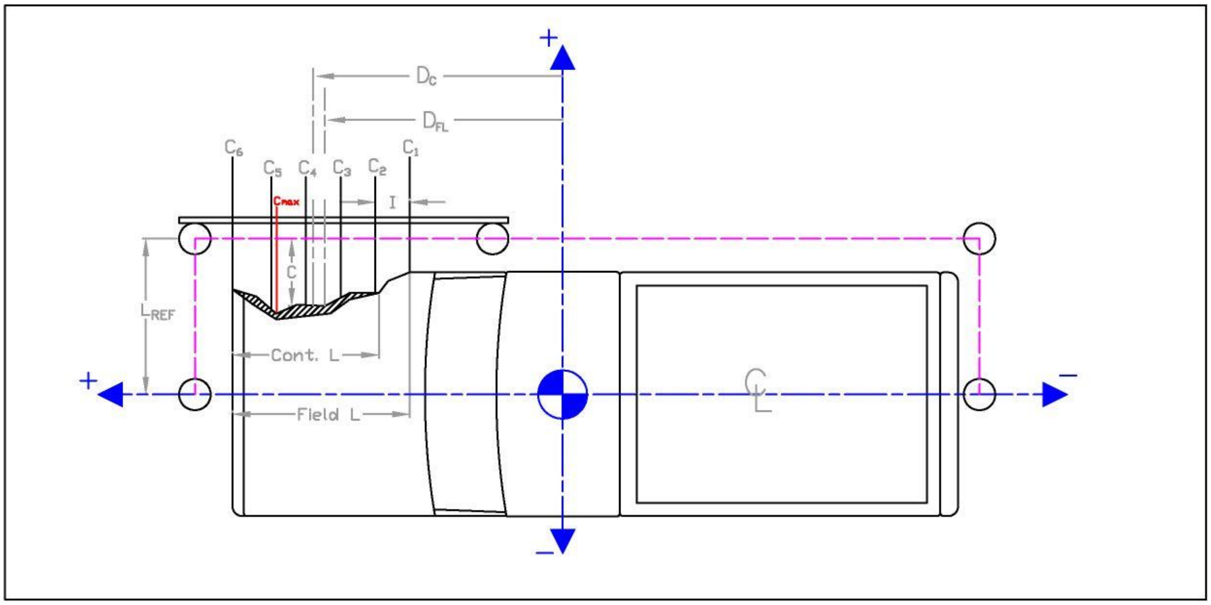
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)

	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	(737)	-7 1/7	-(181)	NA	NA
C_2	na	NA	-34 4/5	-(884)	20 5/8	(524)			NA	NA
C_3	16 1/8	(410)	-30 3/5	-(777)	16 2/3	(423)			6 5/8	(168)
C_4	10 1/4	(260)	-26 2/5	-(671)	14 2/3	(373)			2 2/3	(69)
C_5	7 1/4	(184)	-22 1/5	-(564)	13	(332)			1 1/3	(33)
C_6	6 3/4	(171)	-18	-(457)	12 1/8	(308)			1 3/4	(45)
C_{MAX}	18 1/8	(460)	30 3/5	(777)	16 1/2	(418)			8 4/5	(223)

Figure E-20. Exterior Vehicle Crush (NASS) - Front, Test No. NYJ-3

Date: 1/7/2014 **Test Number:** NYJ-3

Make: Dodge **Model:** Ram 1500 **Year:** 2007



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	44	(1118)
Width of contact and induced crush - Field L:	104 3/4	(2661)
Crush measurement spacing interval (L/5) - I:	20.95	(532)
Distance from vehicle c.g. to center of Field L - D_{FL}:	52.375	(1330)
Width of Contact Damage:	104 3/4	(2661)
Distance from vehicle c.g. to center of contect damage - D_C:	52 3/8	(1330)

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	5 1/2	(140)	0	()	11 1/4	(286)	-6	-(152)	1/4	(6)
C_2	5 3/4	(146)	21	(532)	11 1/4	(286)			1/2	(13)
C_3	6 1/4	(159)	41 8/9	(1064)	11 1/4	(286)			1	(25)
C_4	6	(152)	62 6/7	(1596)	10 1/2	(267)			1 1/2	(38)
C_5	12 1/2	(318)	83 4/5	(2129)	11 3/8	(289)			7 1/8	(181)
C_6	na	NA	104 3/4	(2661)	37	(940)			NA	NA
C_{MAX}	12 1/2	(318)	83 4/5	(2129)	11 3/8	(289)			7 1/8	(181)

Figure E-21. Exterior Vehicle Crush (NASS) - Side, Test No. NYJ-3

Appendix F. Accelerometer and Rate Transducer Data Plots, Test No. NYJ-1

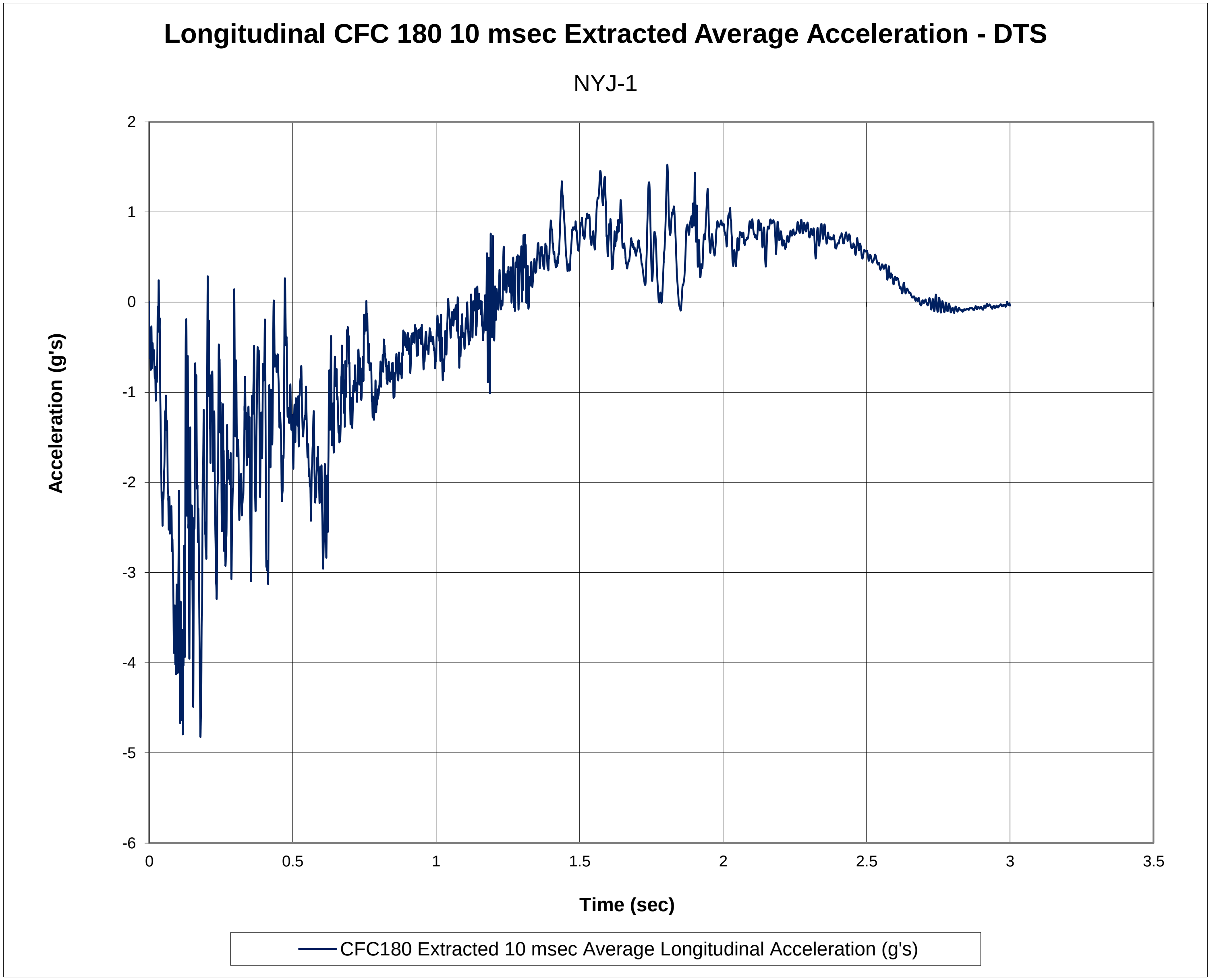


Figure F-1. 10-ms Average Longitudinal Deceleration (DTS), Test No. NYJ-1

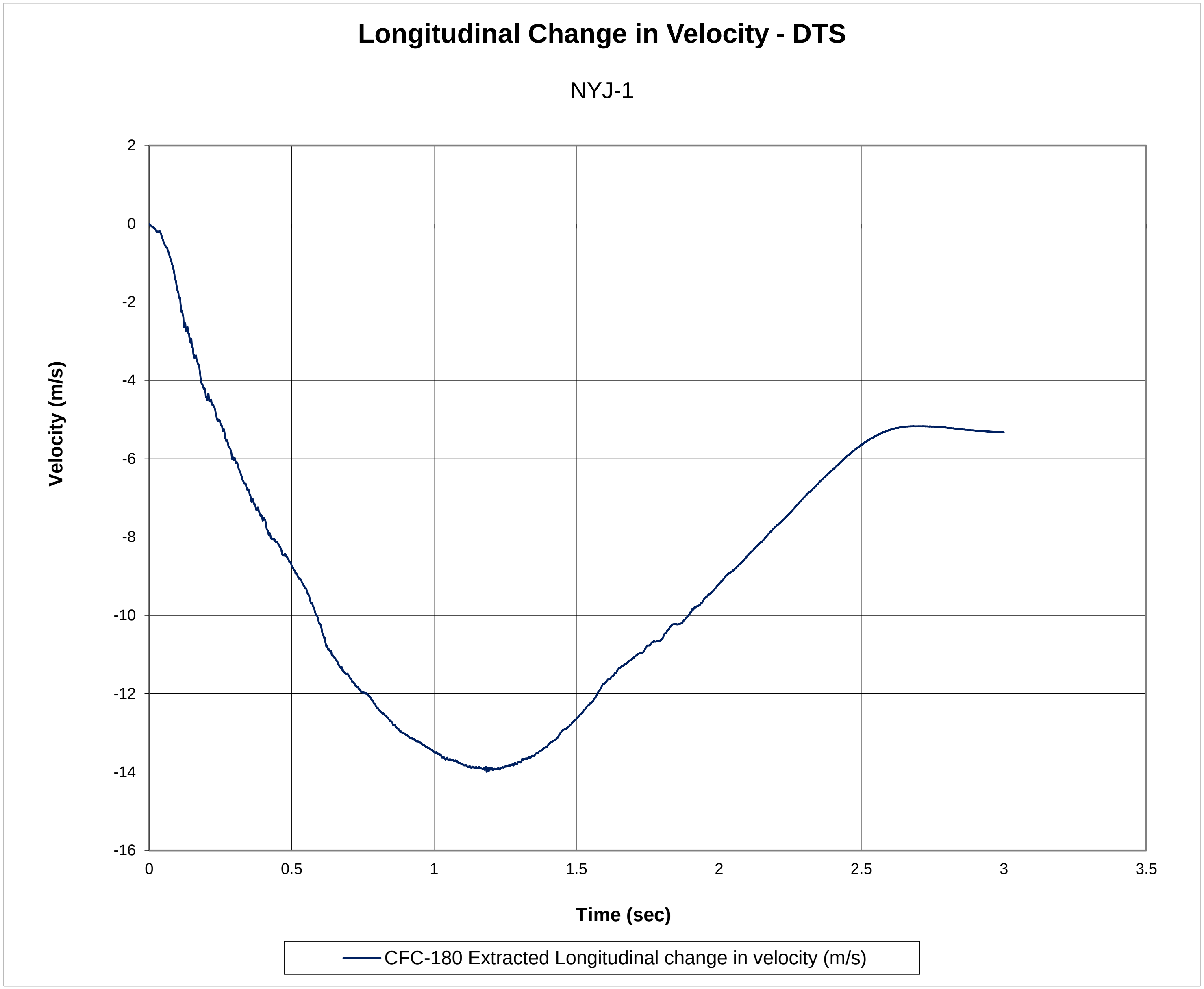


Figure F-2. Longitudinal Occupant Impact Velocity (DTS), Test No. NYJ-1

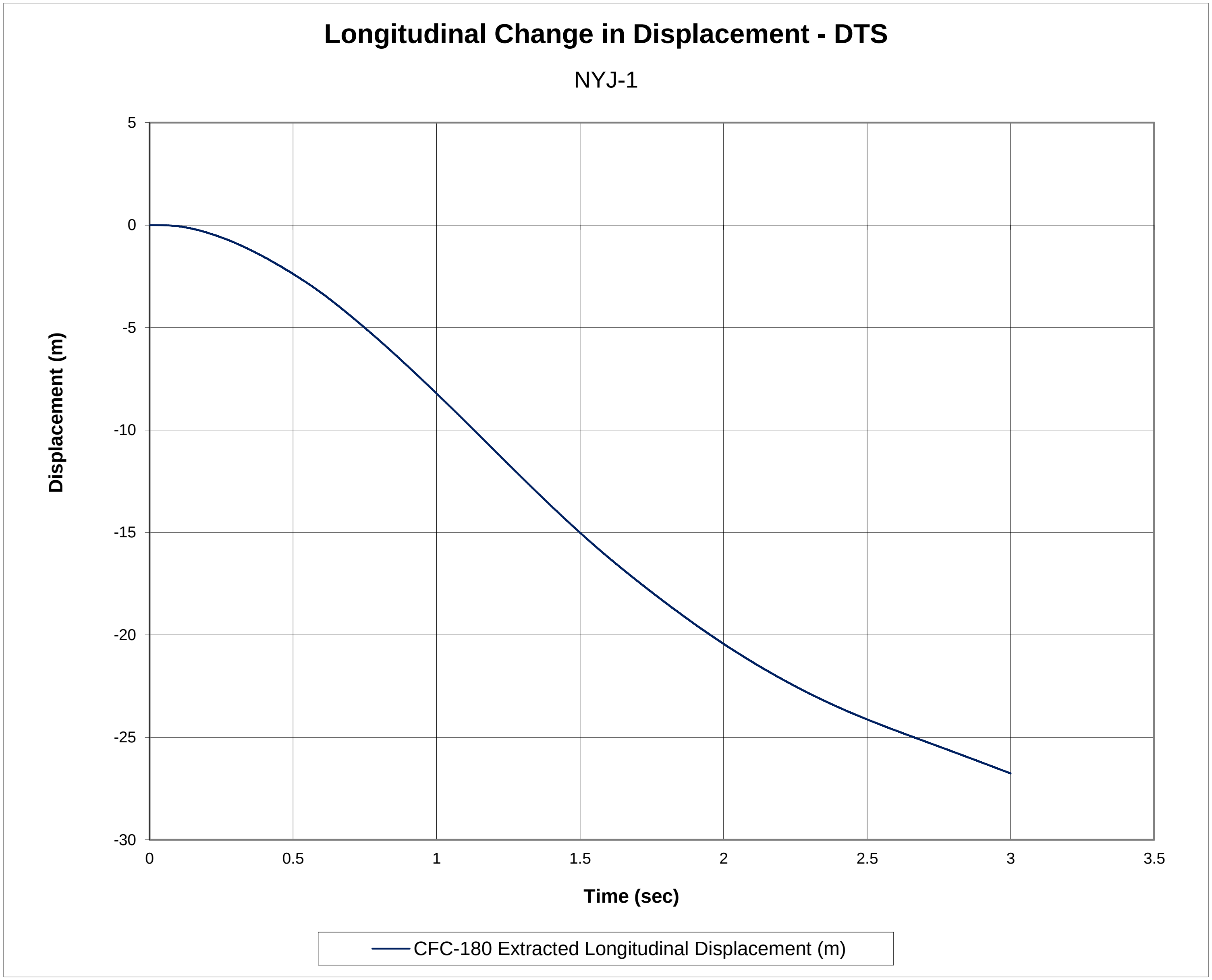


Figure F-3. Longitudinal Occupant Displacement (DTS), Test No. NYJ-1

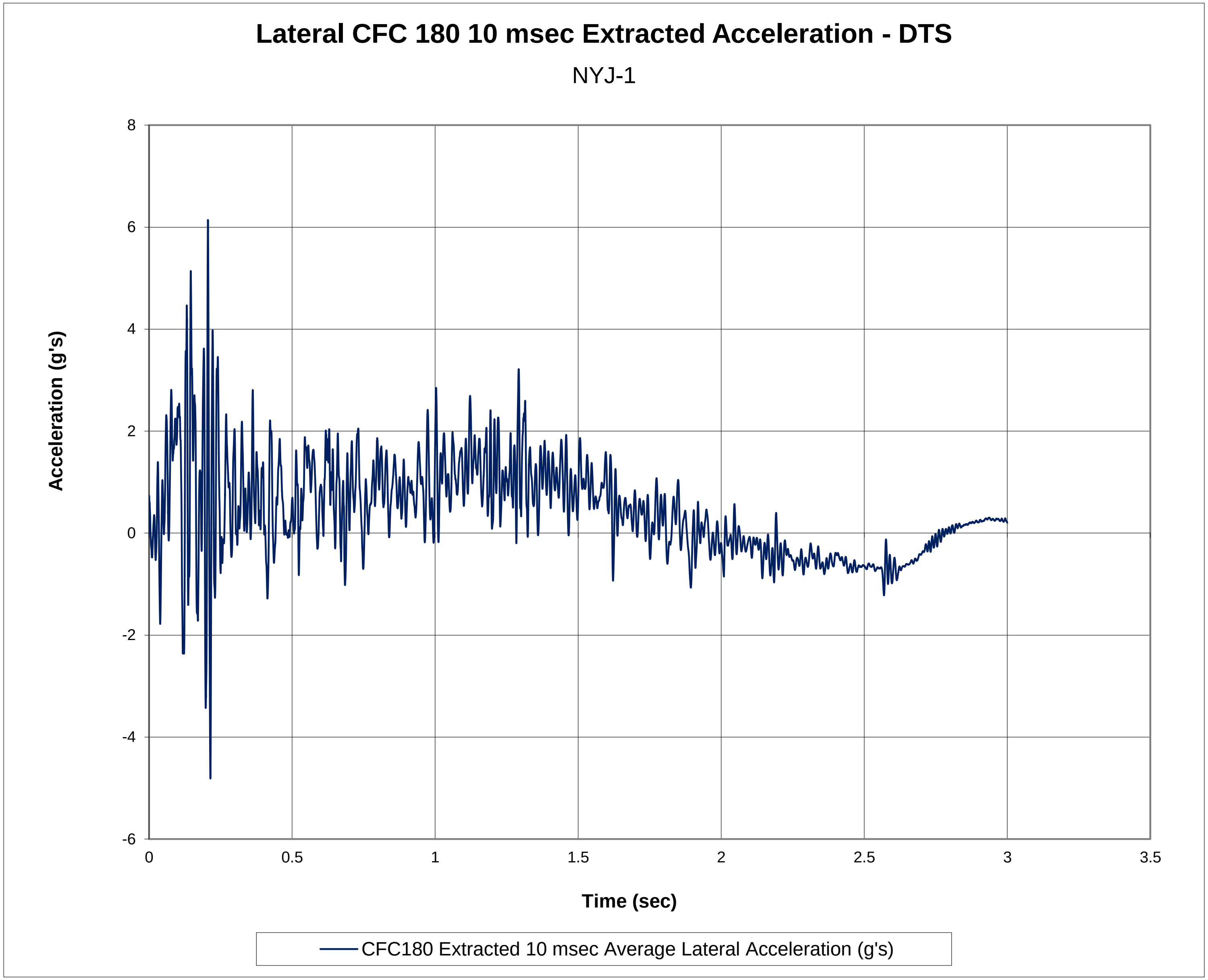


Figure F-4. 10-ms Average Lateral Deceleration (DTS), Test No. NYJ-1

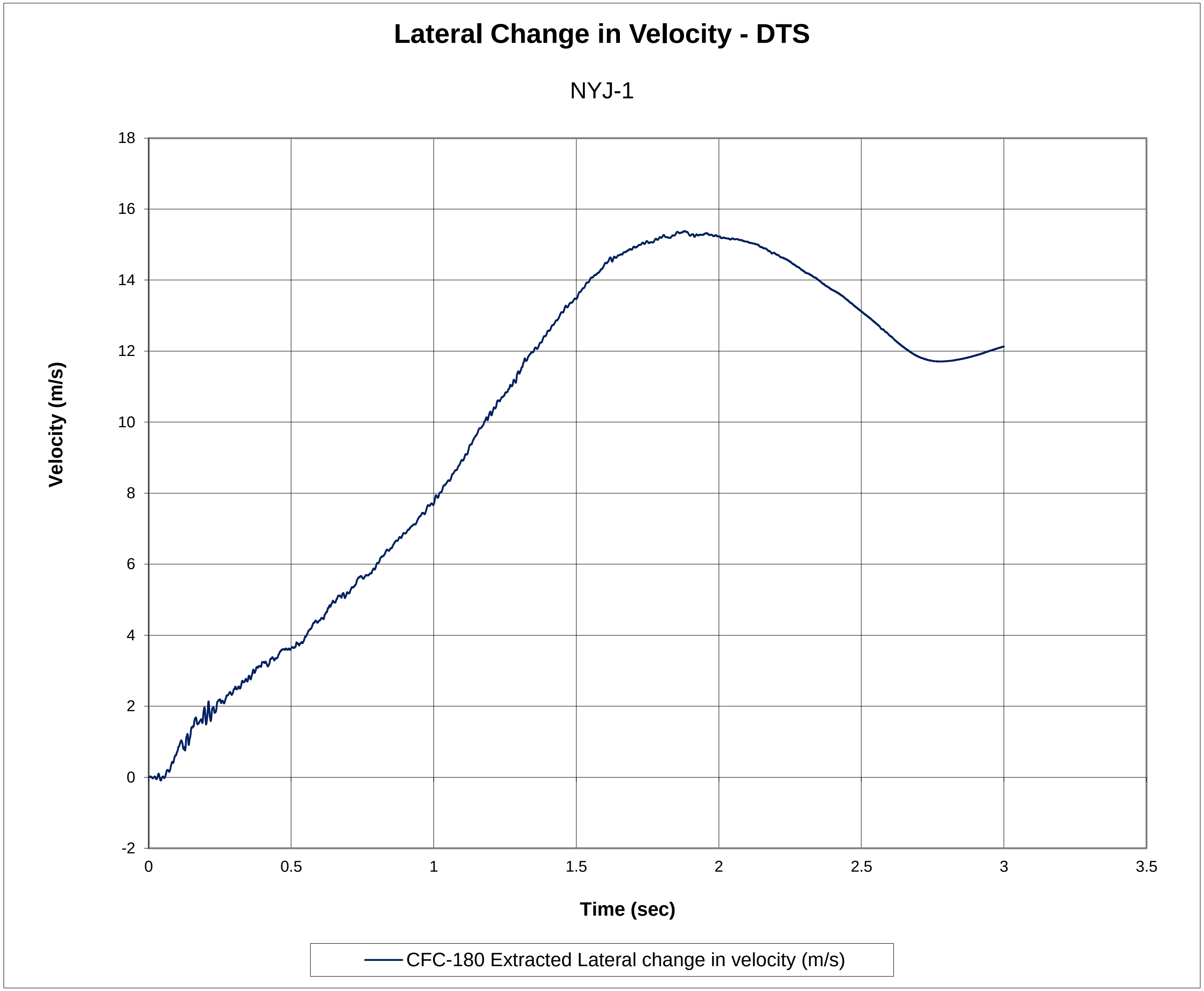


Figure F-5. Lateral Occupant Impact Velocity (DTS), Test No. NYJ-1

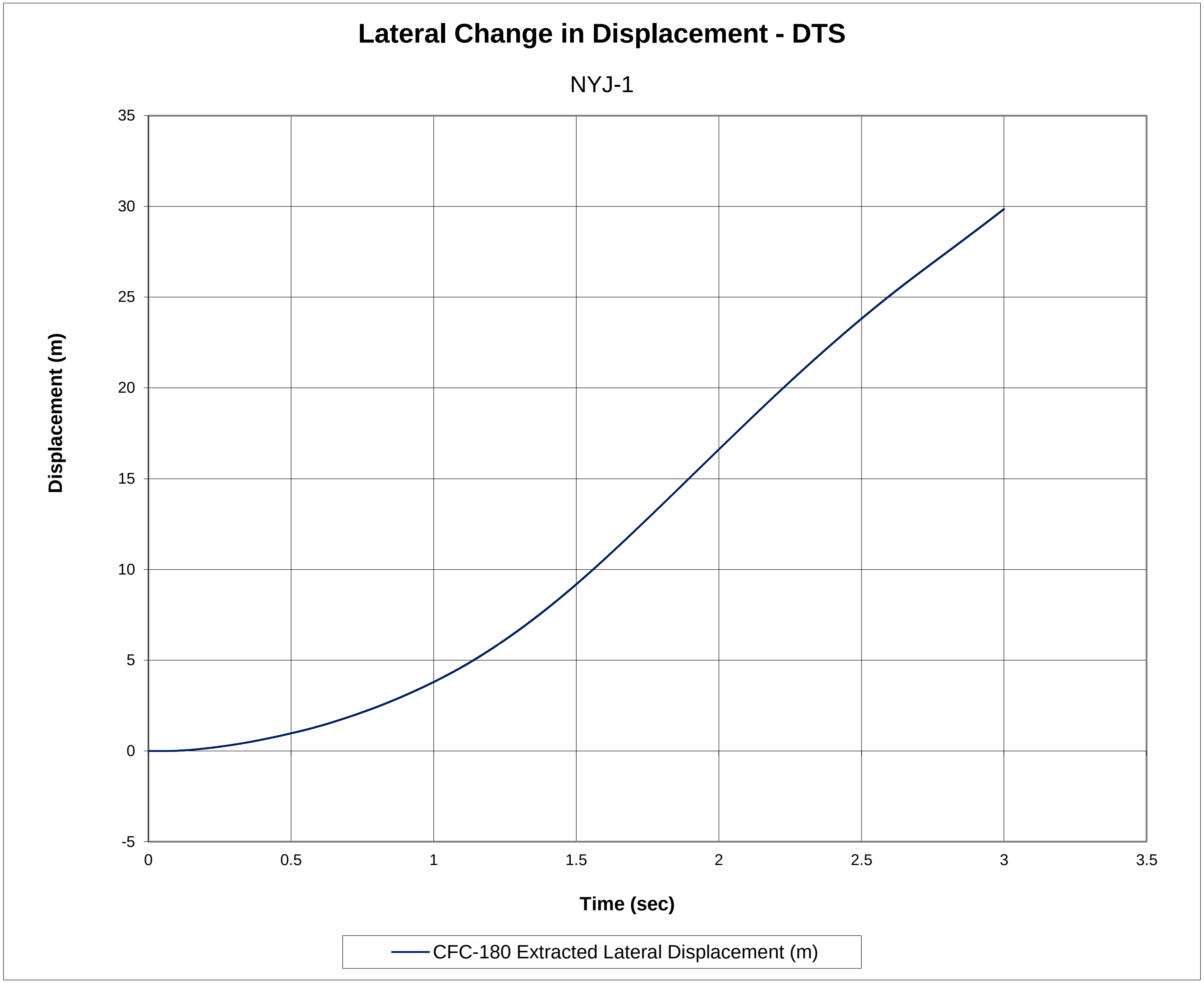


Figure F-6. Lateral Occupant Displacement (DTS), Test No. NYJ-1

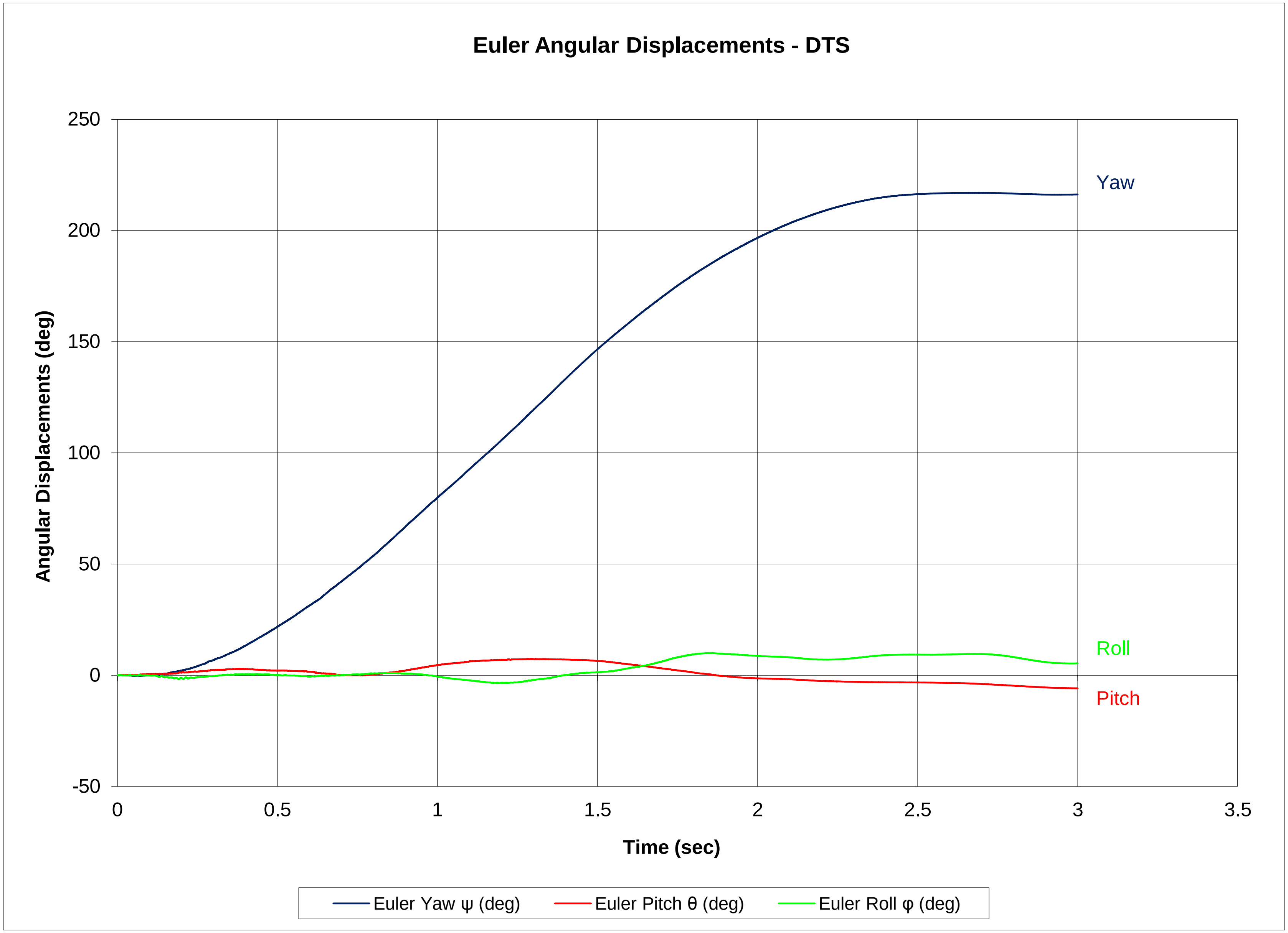


Figure F-7. Vehicle Angular Displacements (DTS), Test No. NYJ-1

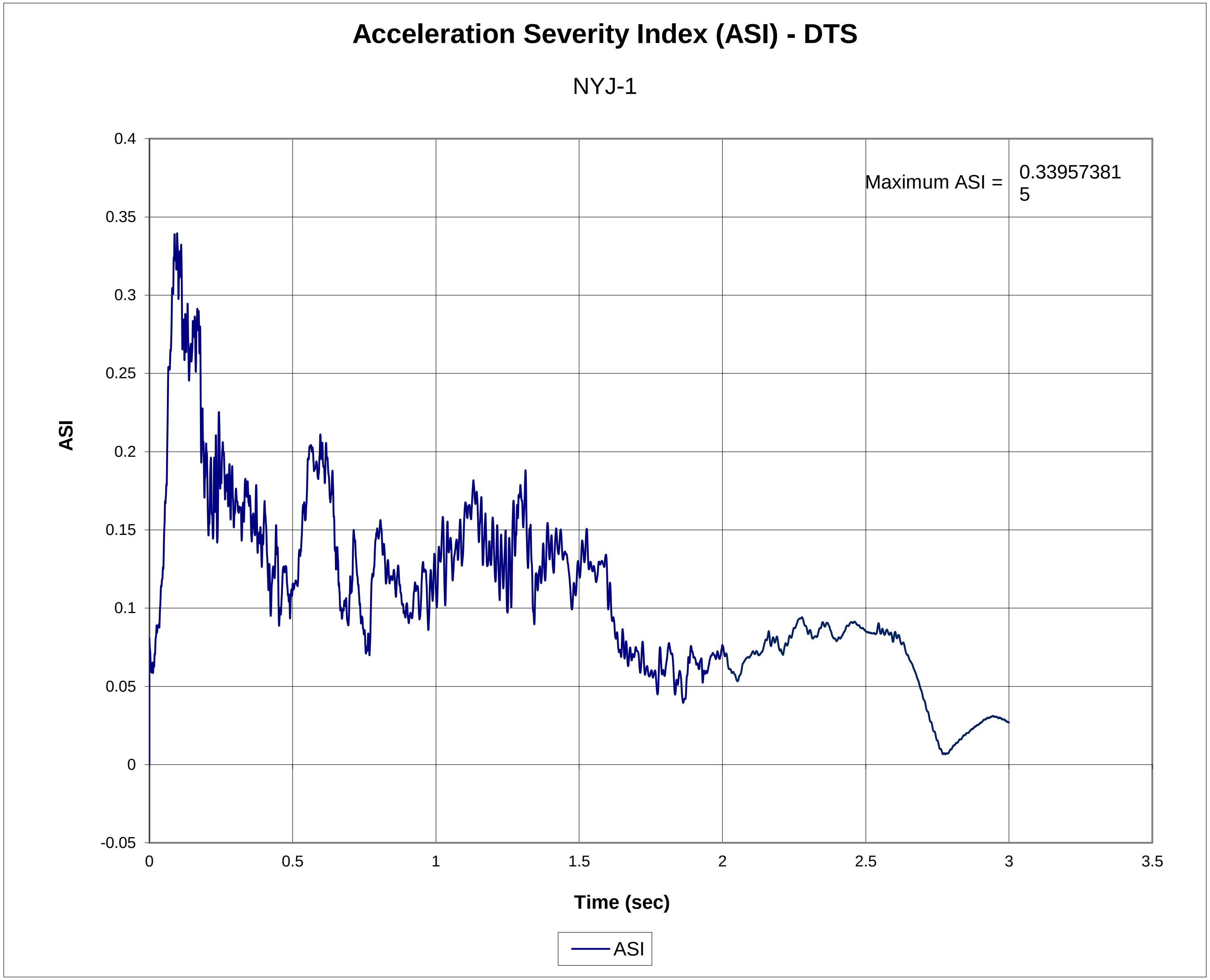


Figure F-8. Acceleration Severity Index (DTS), Test No. NYJ-1

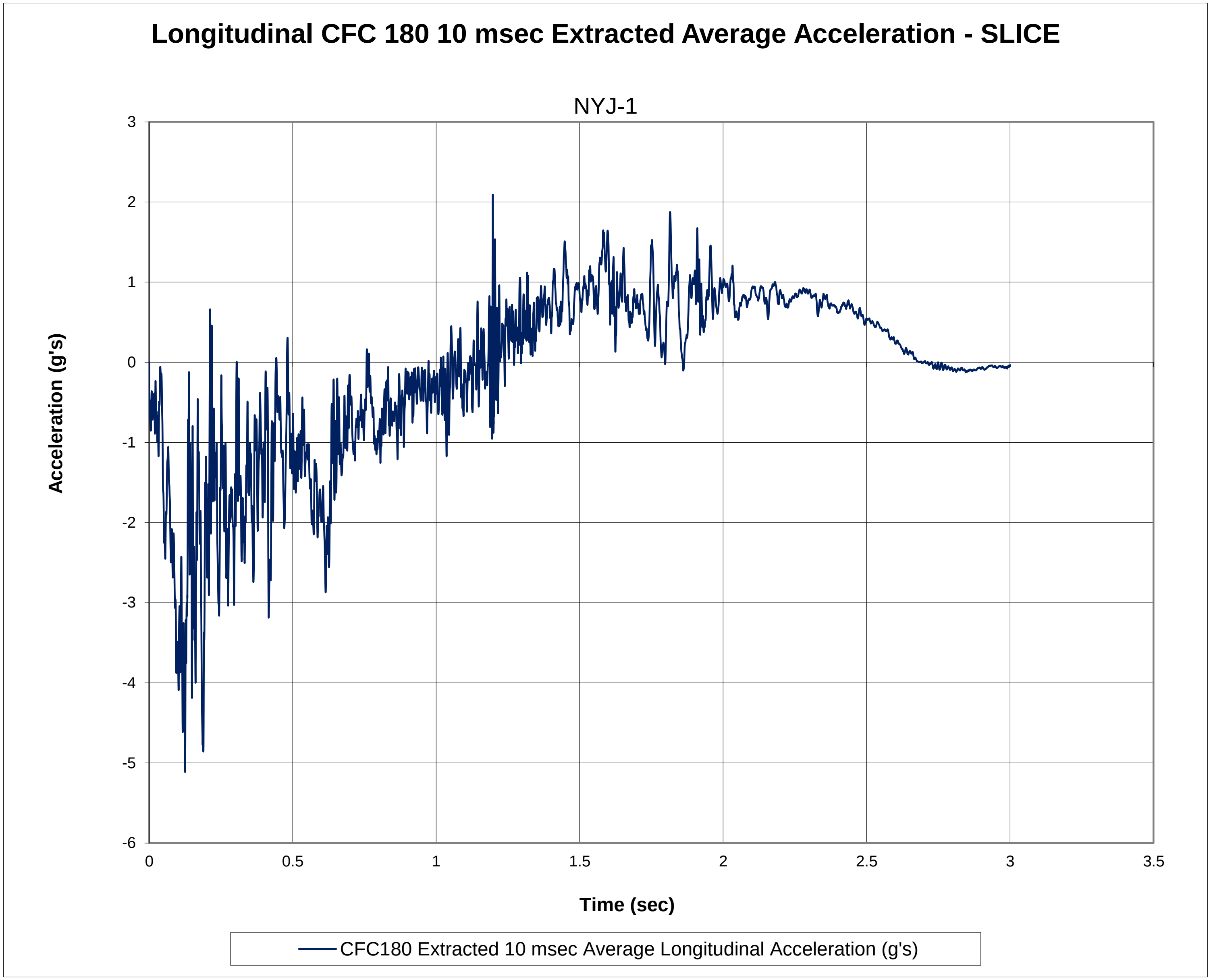


Figure F-9. 10-ms Average Longitudinal Deceleration (SLICE), Test No. NYJ-1

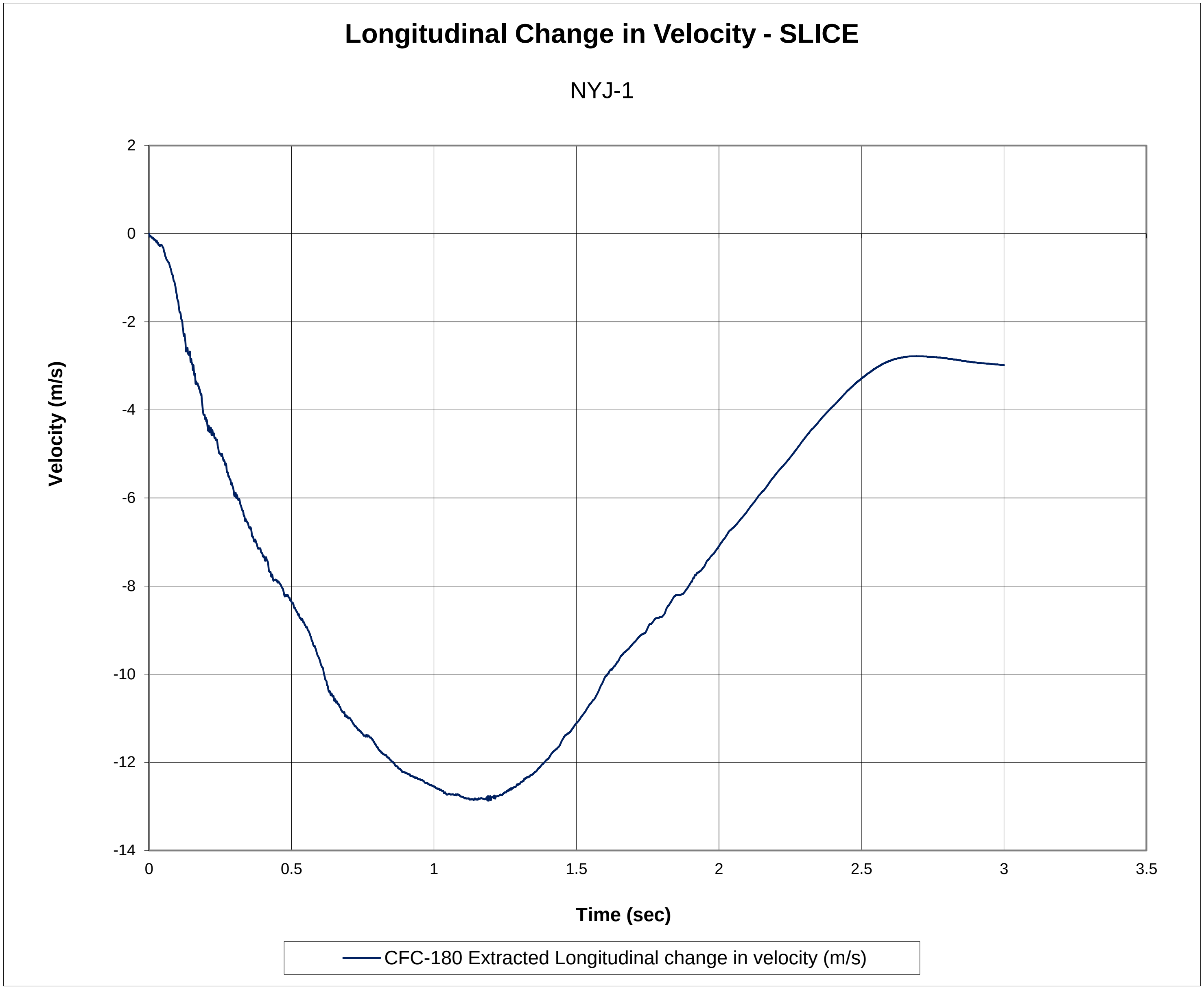


Figure F-10. Longitudinal Occupant Impact Velocity (SLICE), Test No. NYJ-1

Figure F-11. Longitudinal Occupant Displacement (SLICE), Test No. NYJ-1

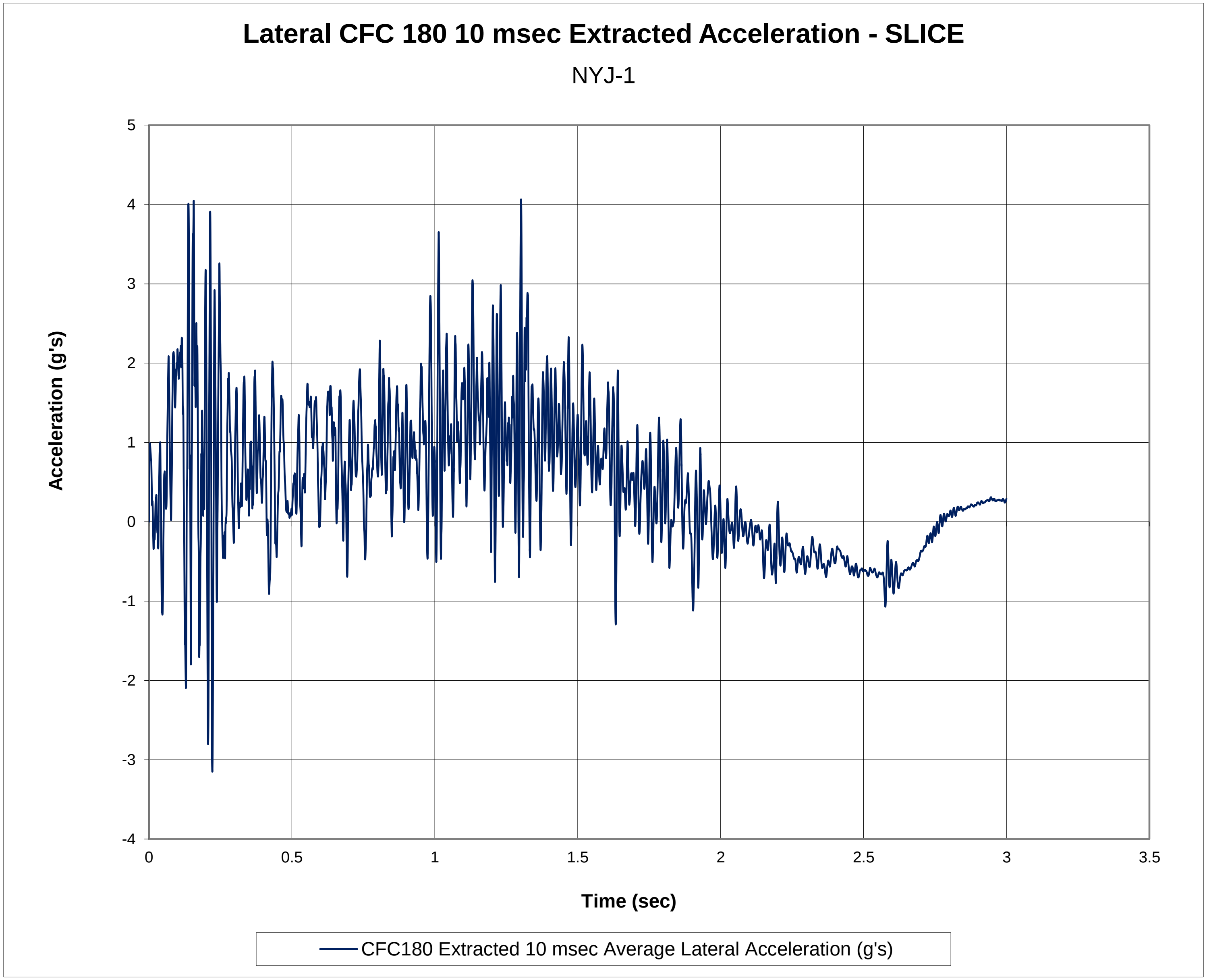


Figure F-12. 10-ms Average Lateral Deceleration (SLICE), Test No. NYJ-1

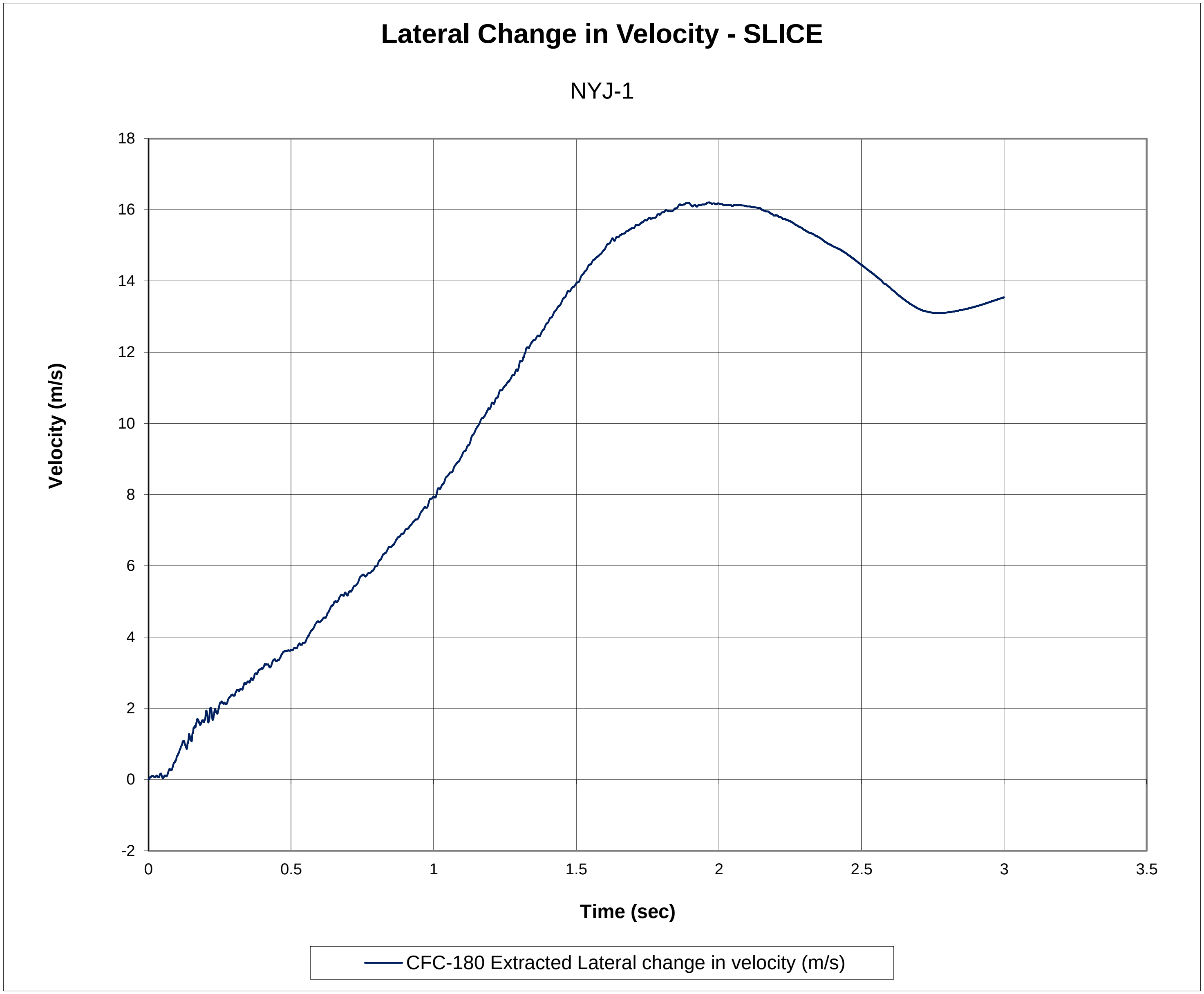


Figure F-13. Lateral Occupant Impact Velocity (SLICE), Test No. NYJ-1

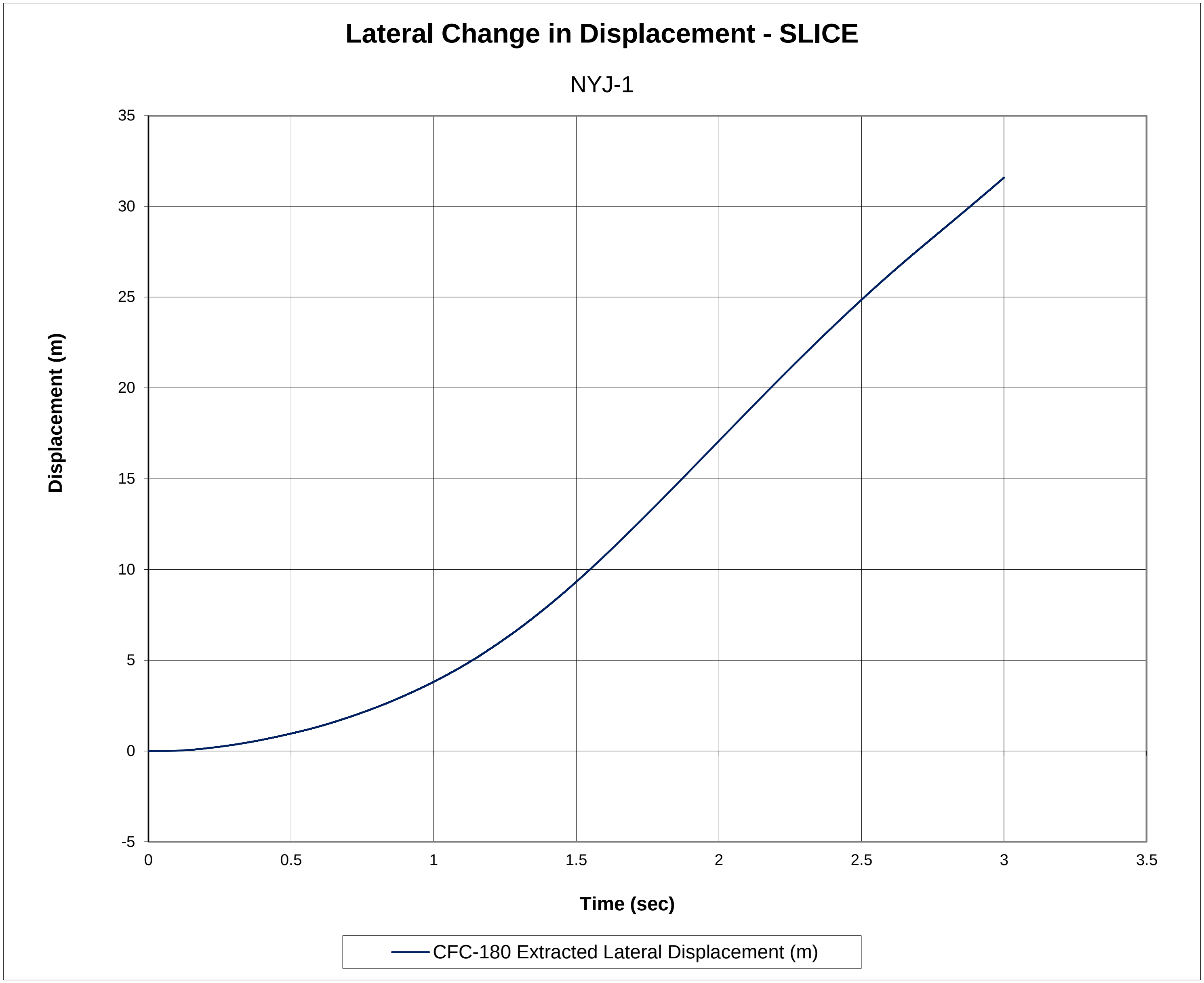


Figure F-14. Lateral Occupant Displacement (SLICE), Test No. NYJ-1

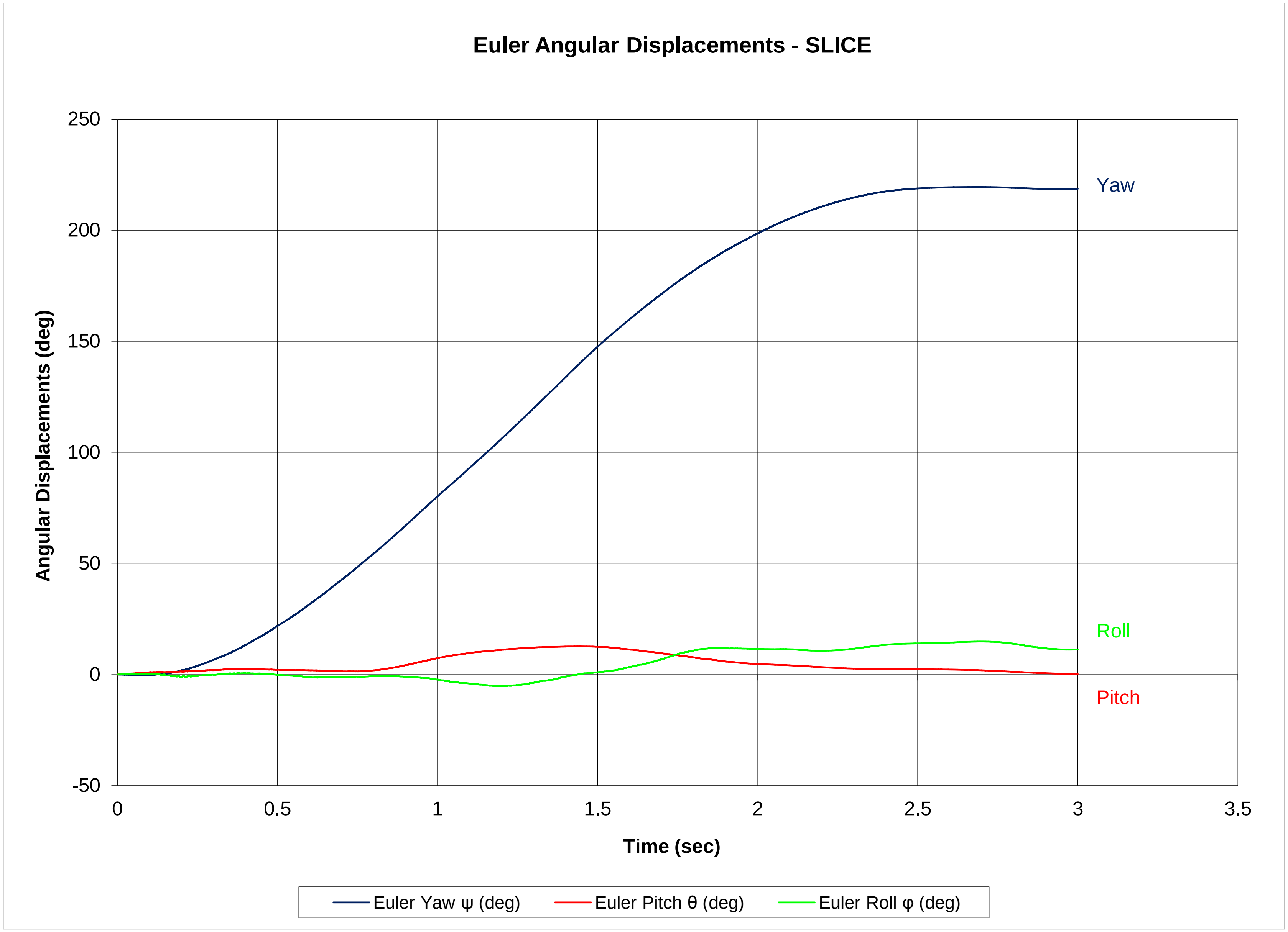


Figure F-15. Vehicle Angular Displacements (SLICE), Test No. NYJ-1

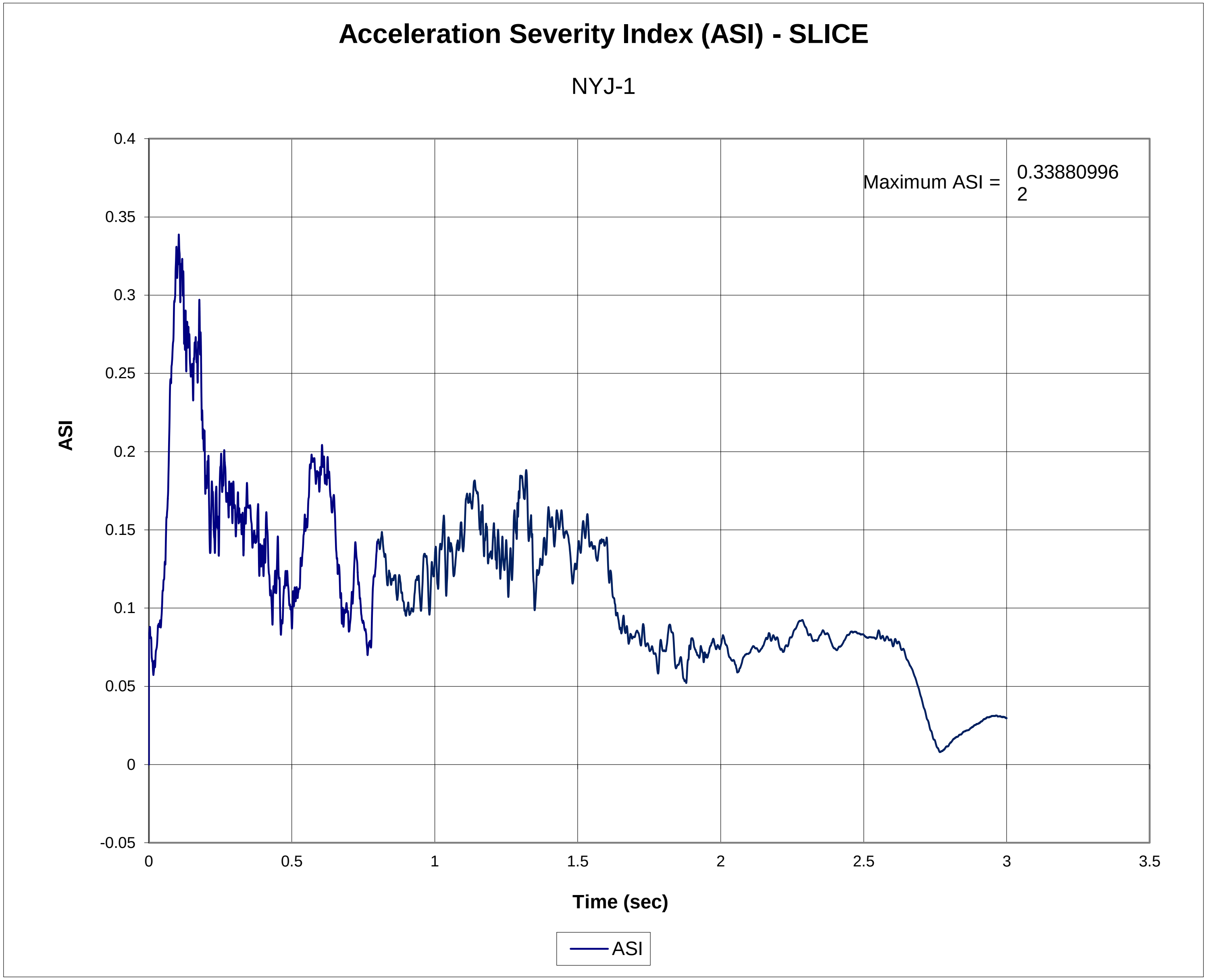


Figure F-16. Acceleration Severity Index (SLICE), Test No. NYJ-1

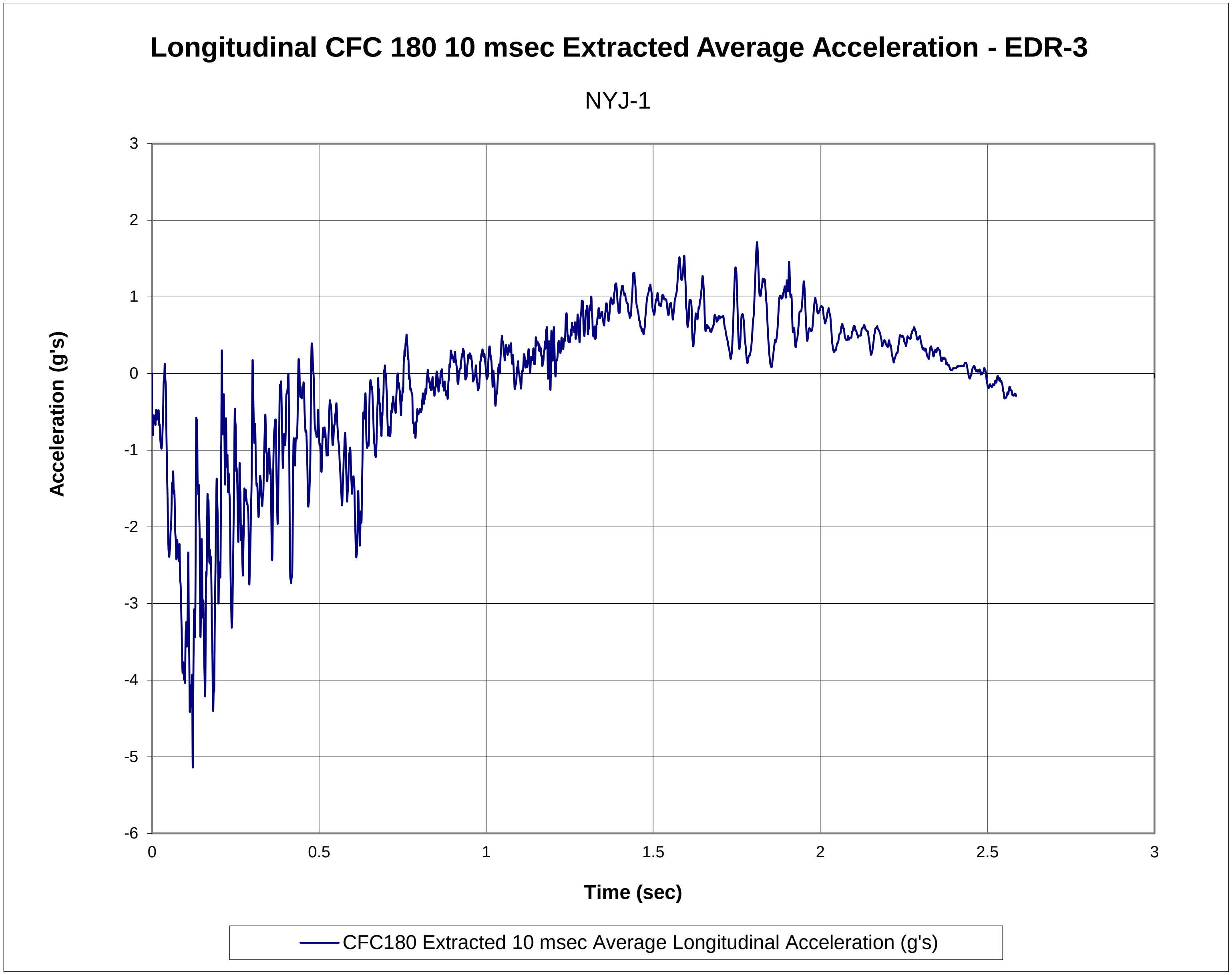


Figure F-17. 10-ms Average Longitudinal Deceleration (EDR-3), Test No. NYJ-1

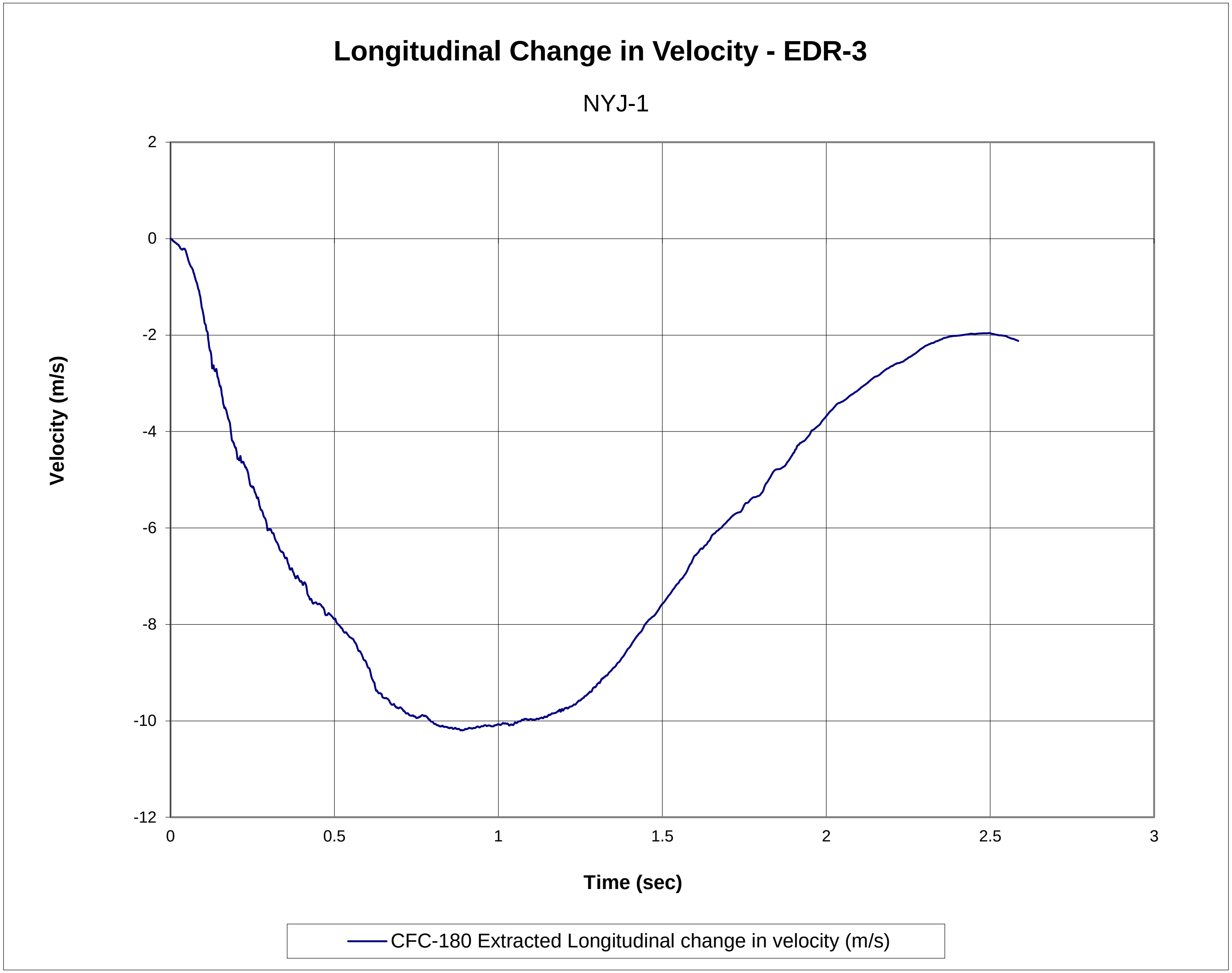


Figure F-18. Longitudinal Occupant Impact Velocity (EDR-3), Test No. NYJ-1

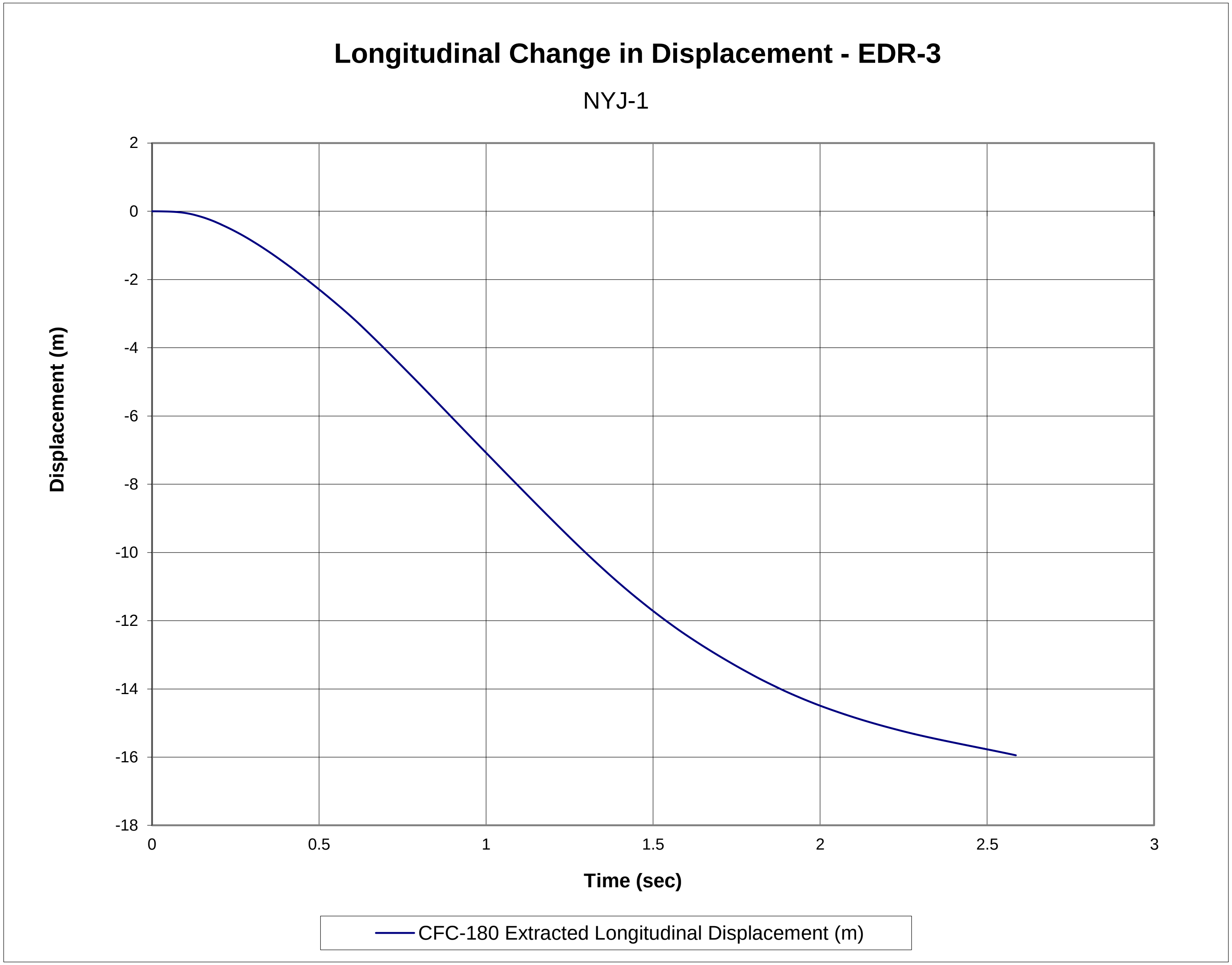


Figure F-19. Longitudinal Occupant Displacement (EDR-3), Test No. NYJ-1

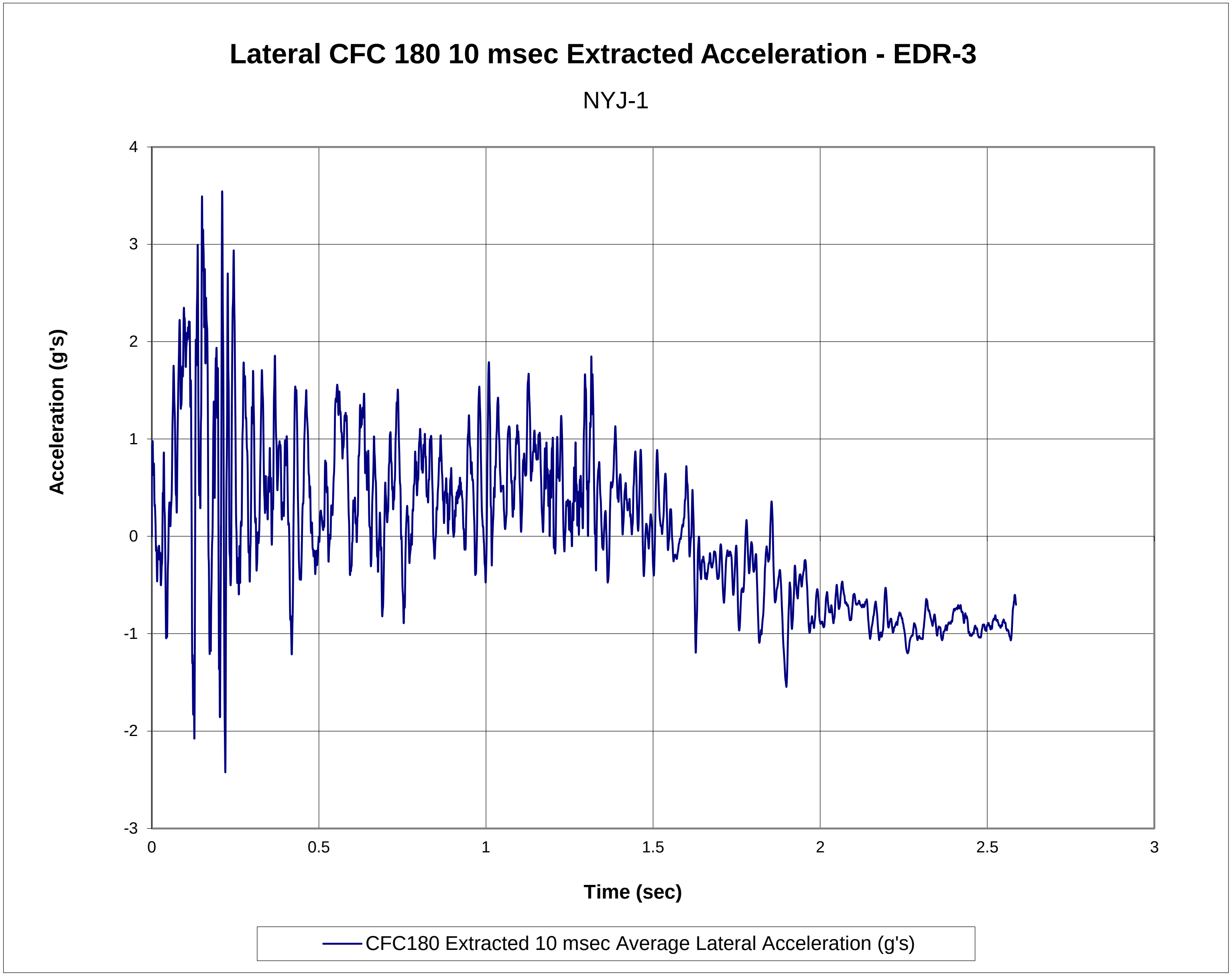


Figure F-20. 10-ms Average Lateral Deceleration (EDR-3), Test No. NYJ-1

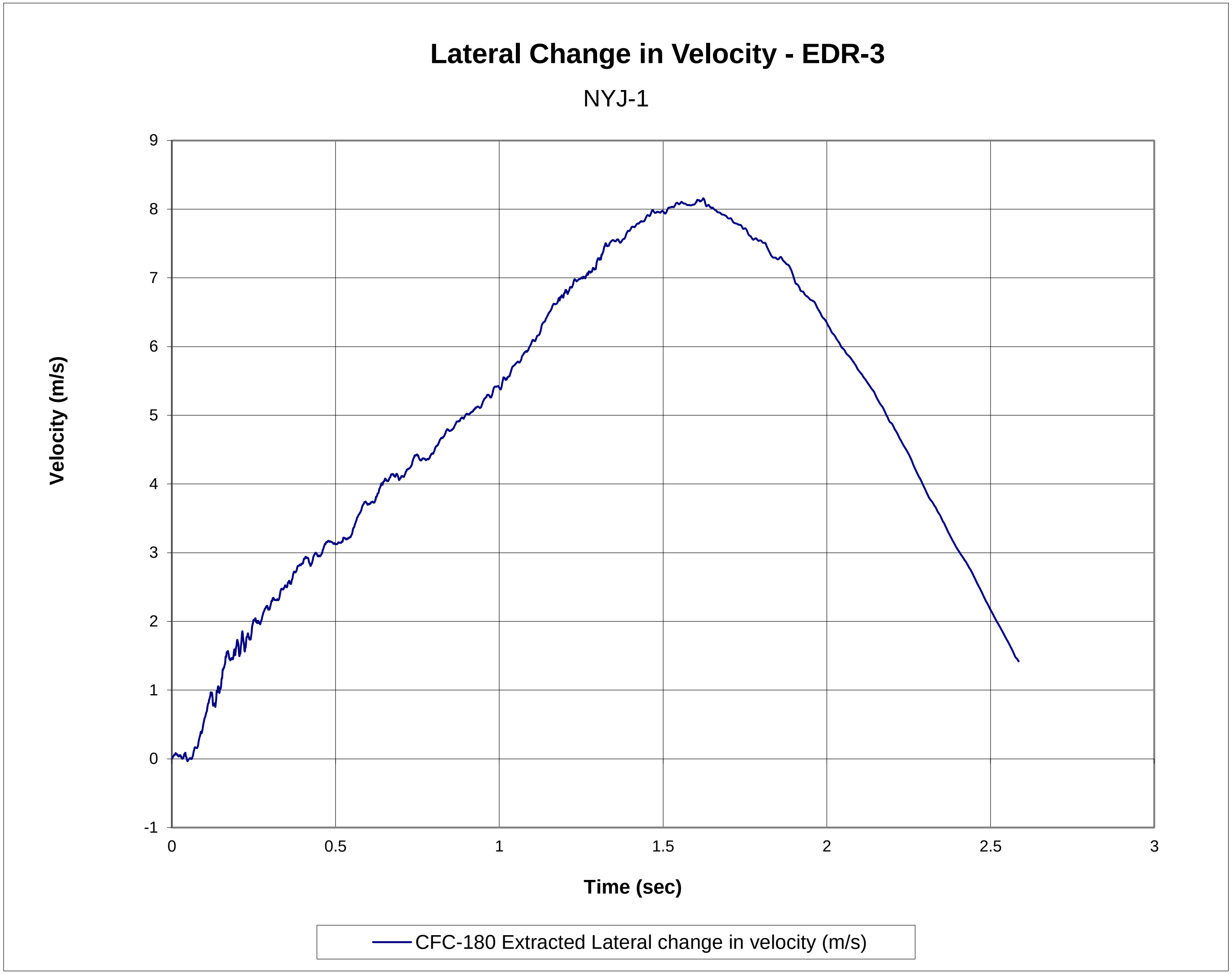


Figure F-21. Lateral Occupant Impact Velocity (EDR-3), Test No. NYJ-1

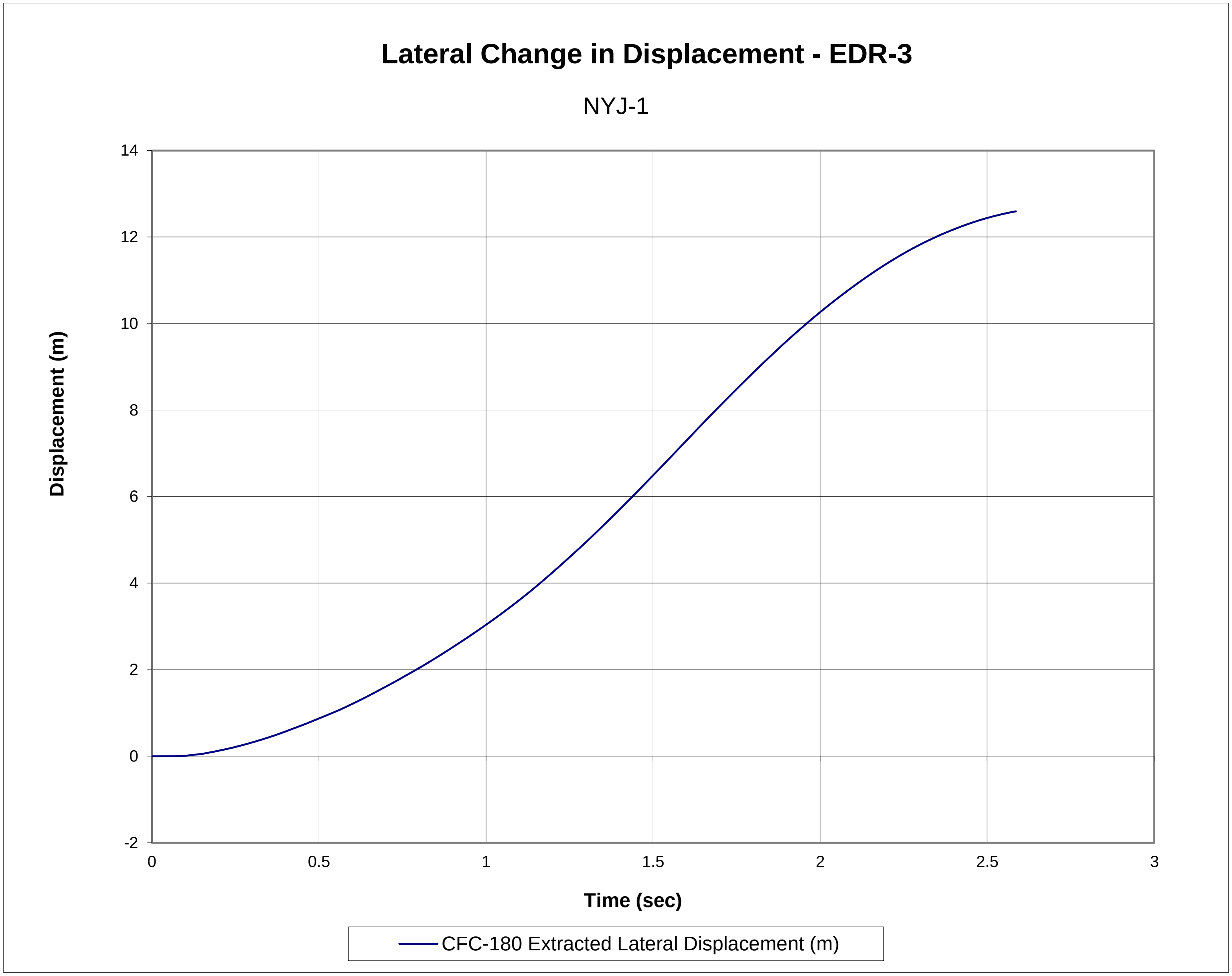


Figure F-22. Lateral Occupant Displacement (EDR-3), Test No. NYJ-1

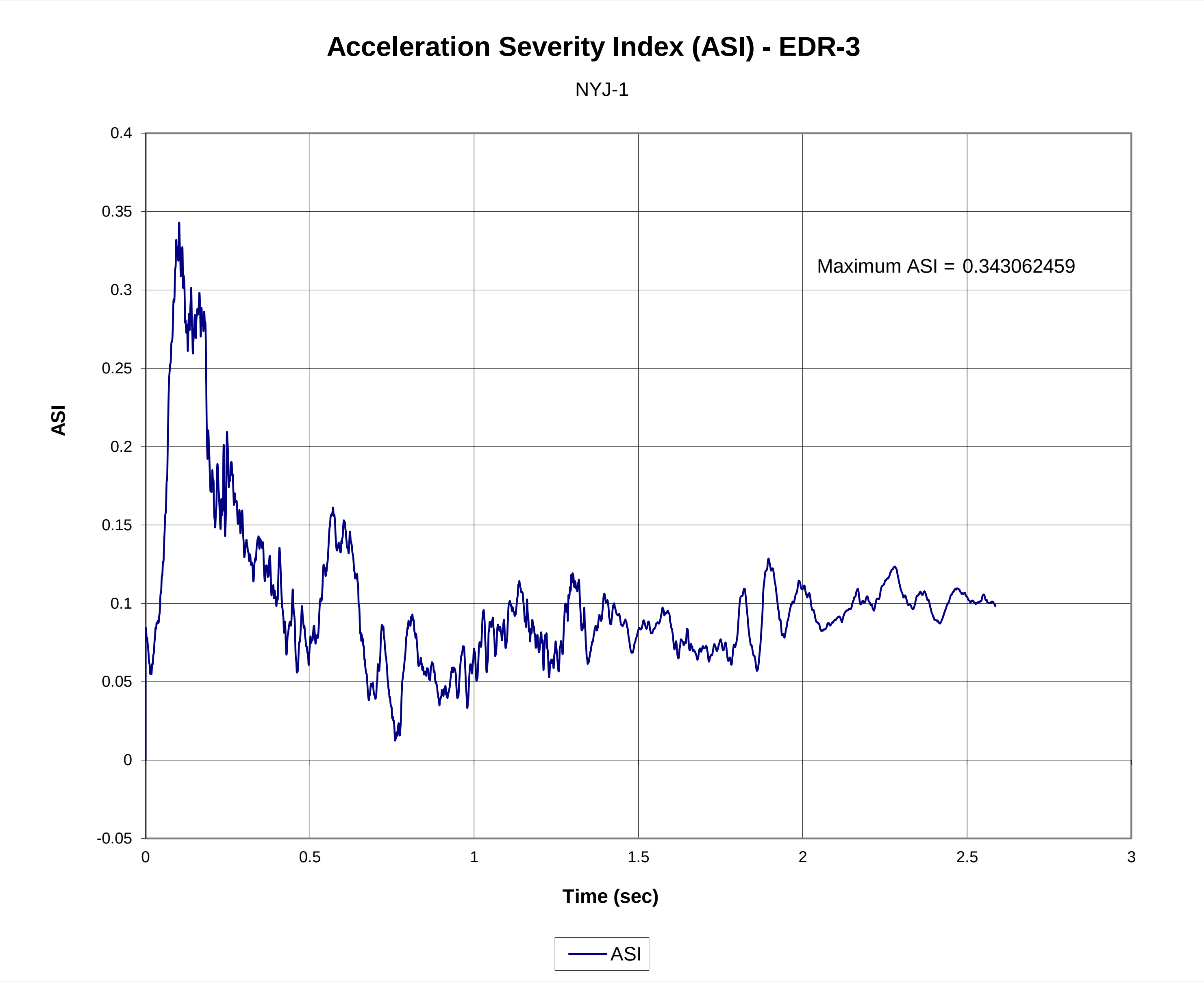


Figure F-23. Acceleration Severity Index (EDR-3), Test No. NYJ-1

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

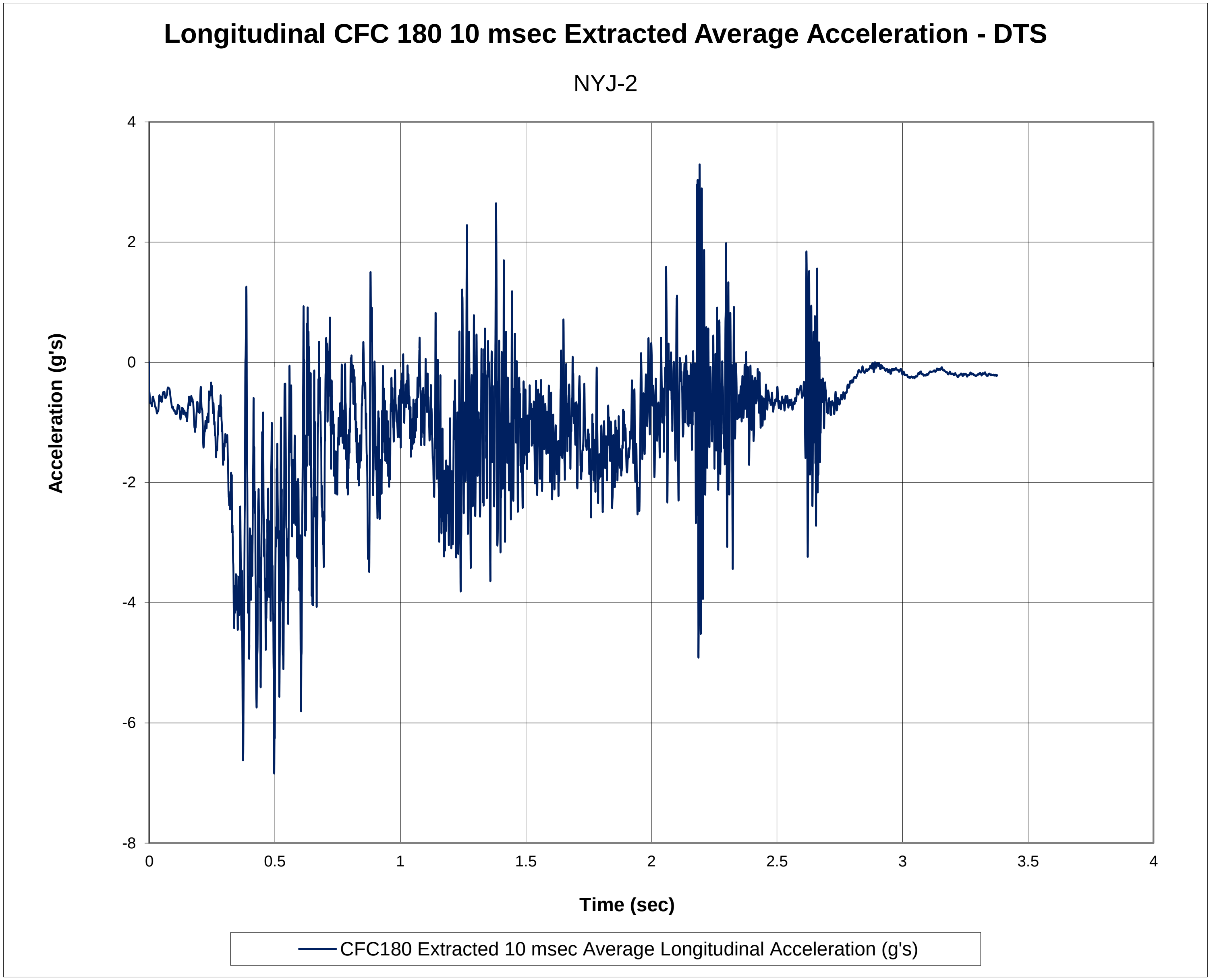


Figure G-1. 10-ms Average Longitudinal Deceleration (DTS), Test No. NYJ-2

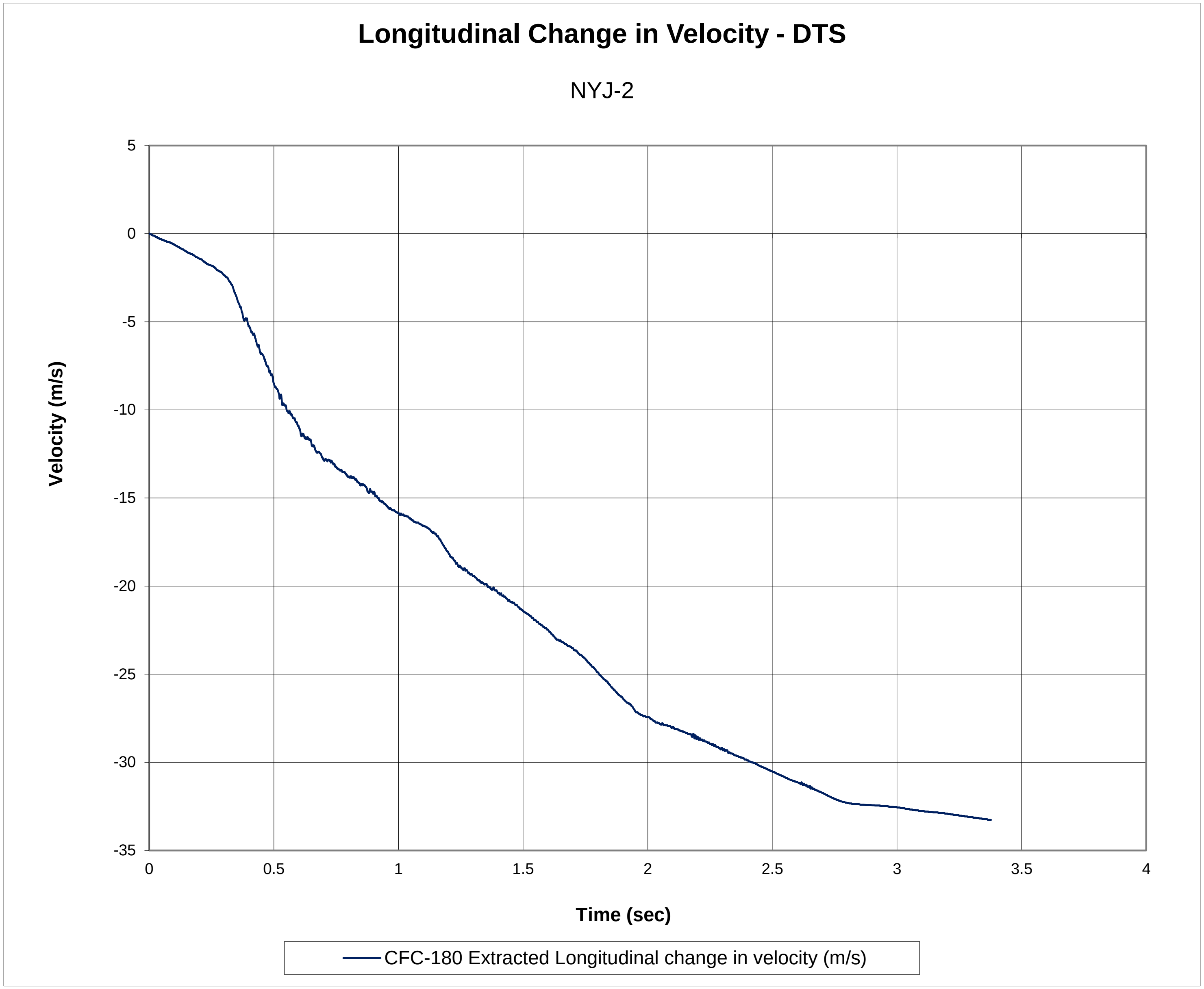


Figure G-2. Longitudinal Occupant Impact Velocity (DTS), Test No. NYJ-2

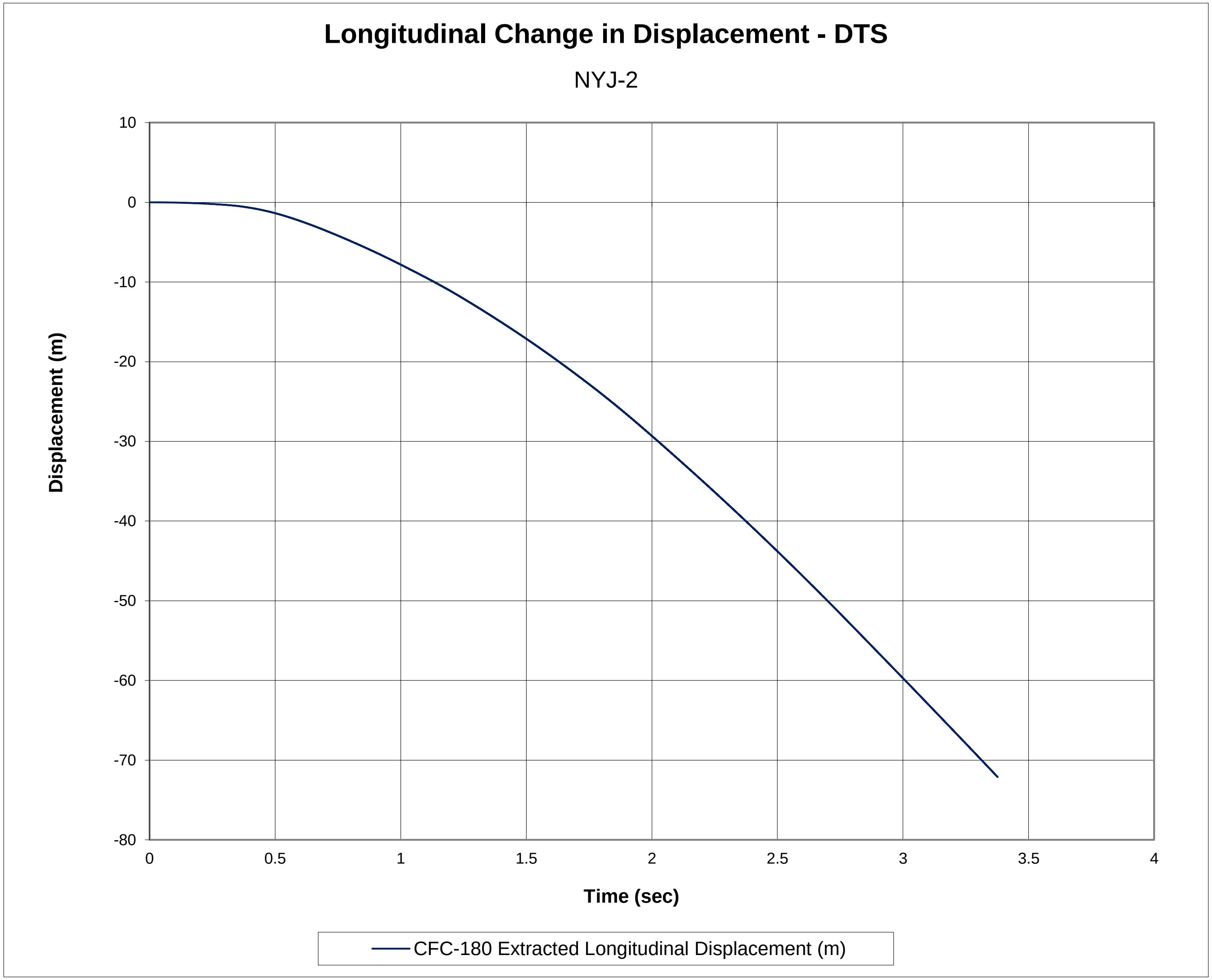


Figure G-3. Longitudinal Occupant Displacement (DTS), Test No. NYJ-2

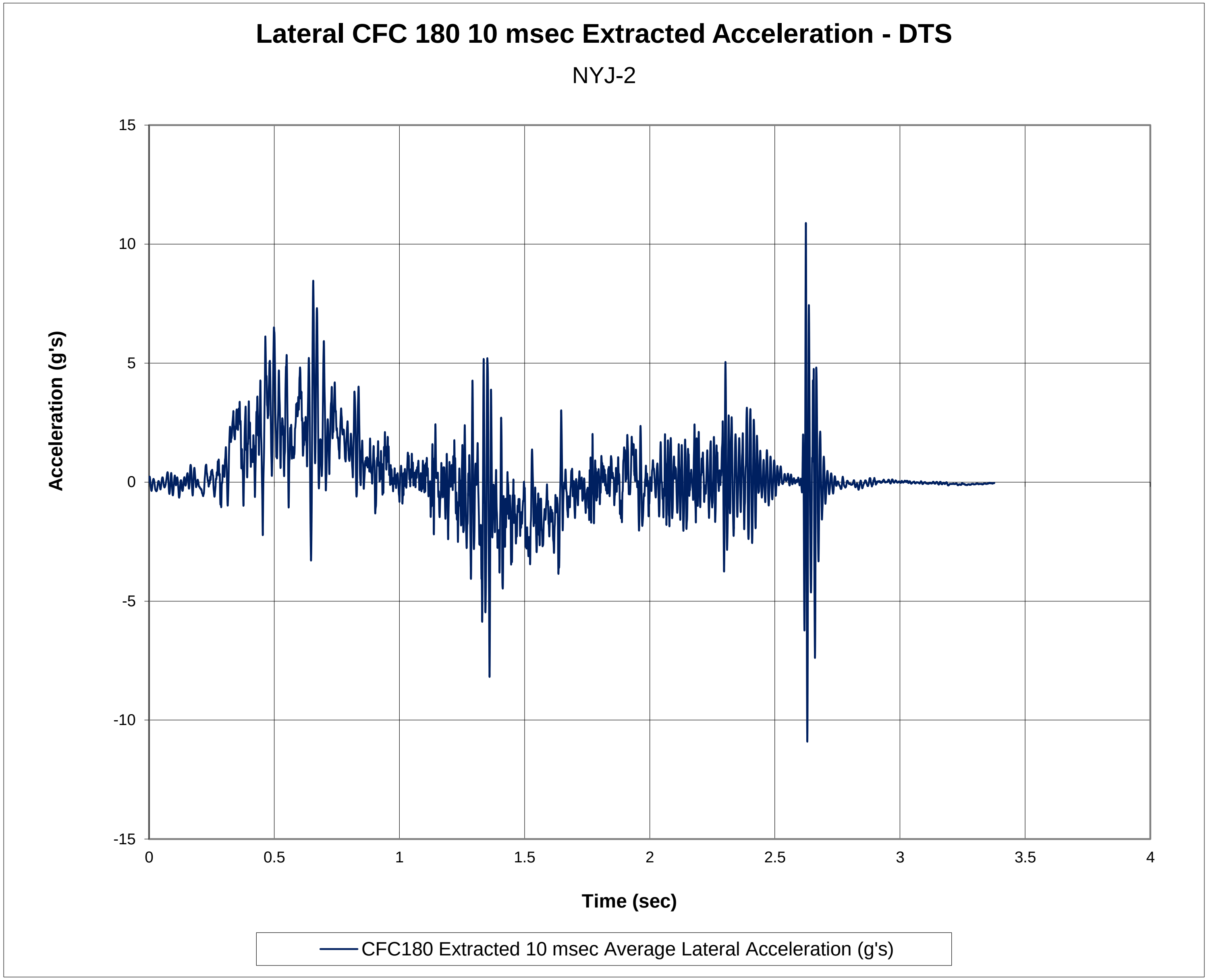


Figure G-4. 10-ms Average Lateral Deceleration (DTS), Test No. NYJ-2

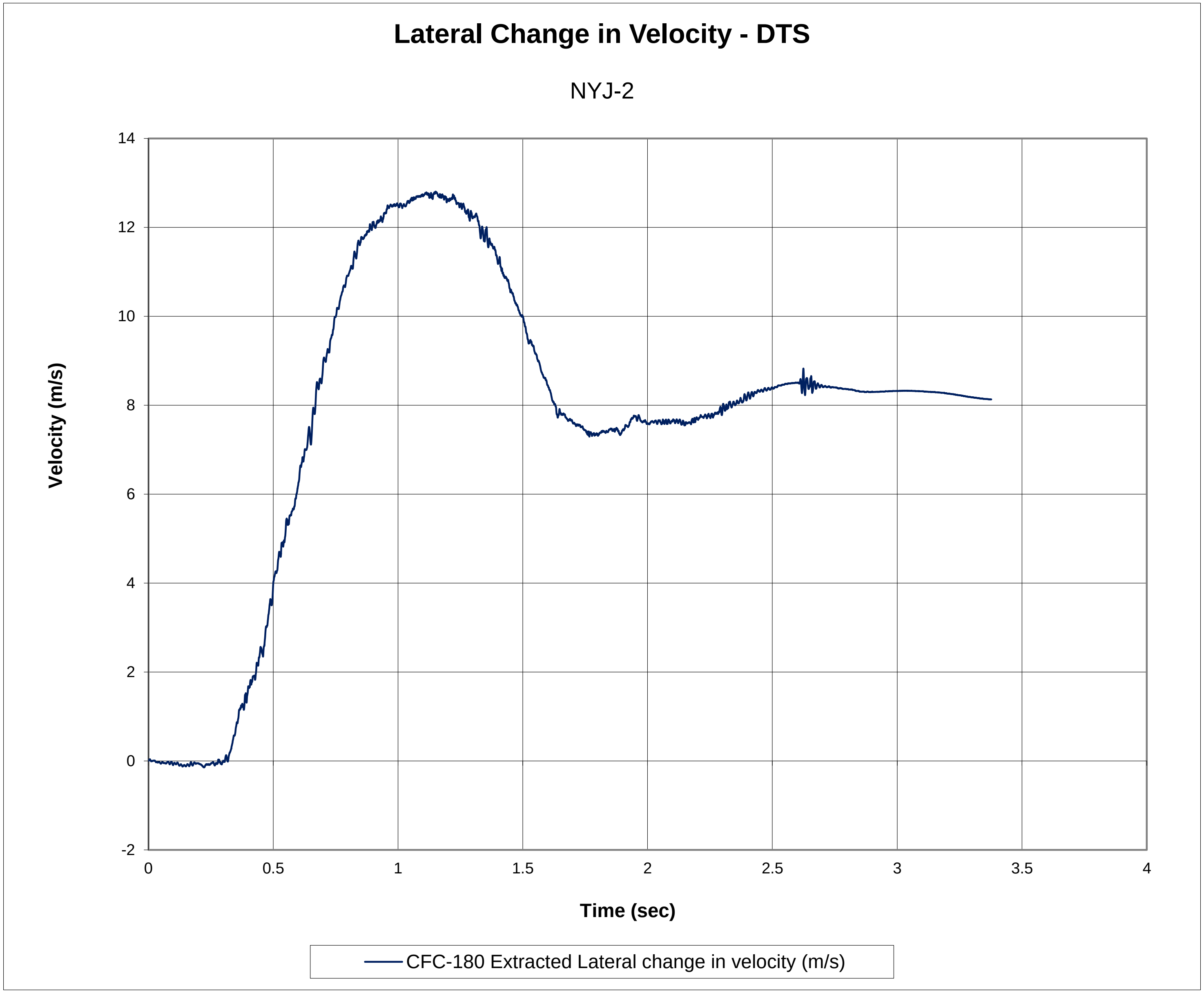


Figure G-5. Lateral Occupant Impact Velocity (DTS), Test No. NYJ-2

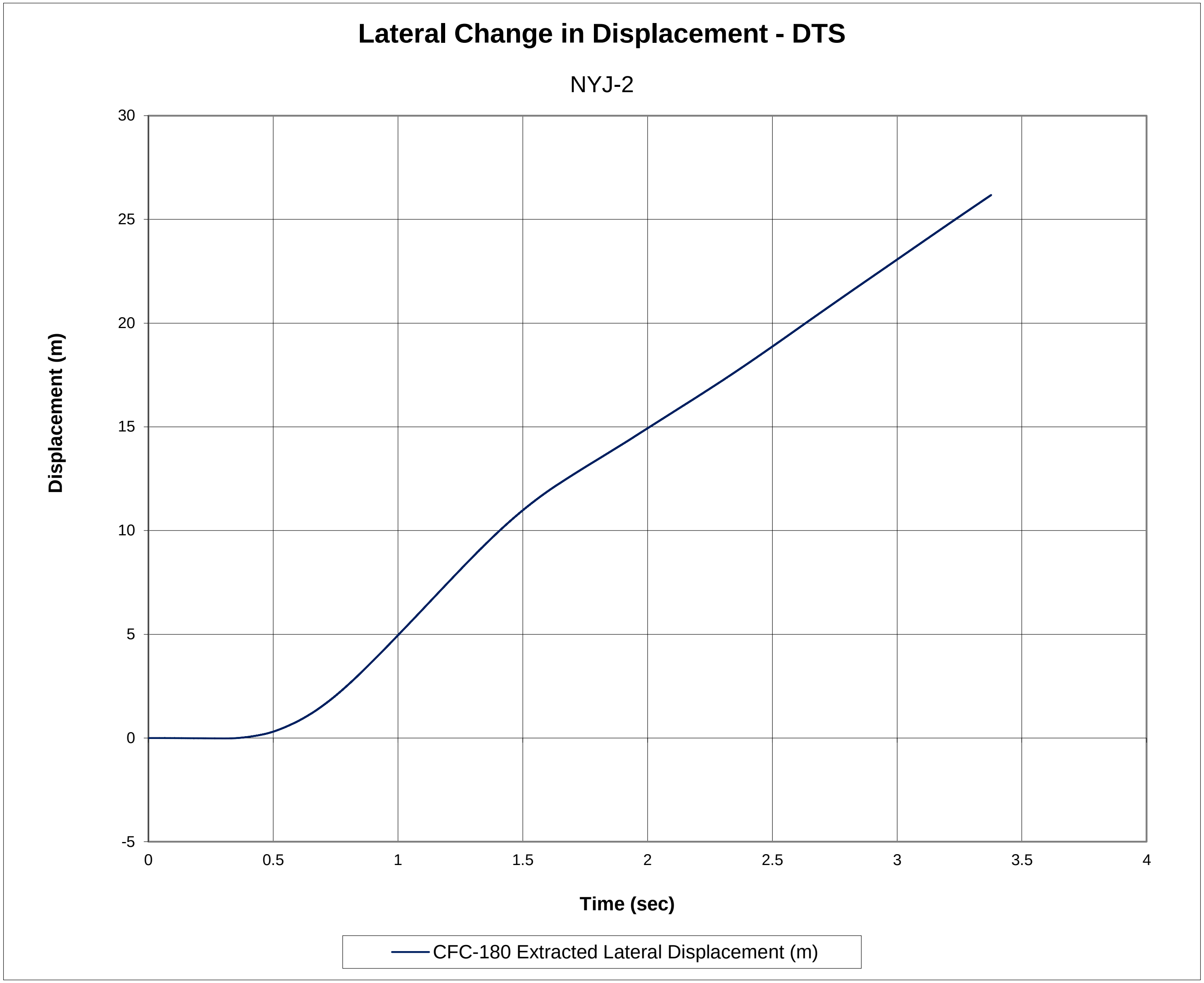


Figure G-6. Lateral Occupant Displacement (DTS), Test No. NYJ-2

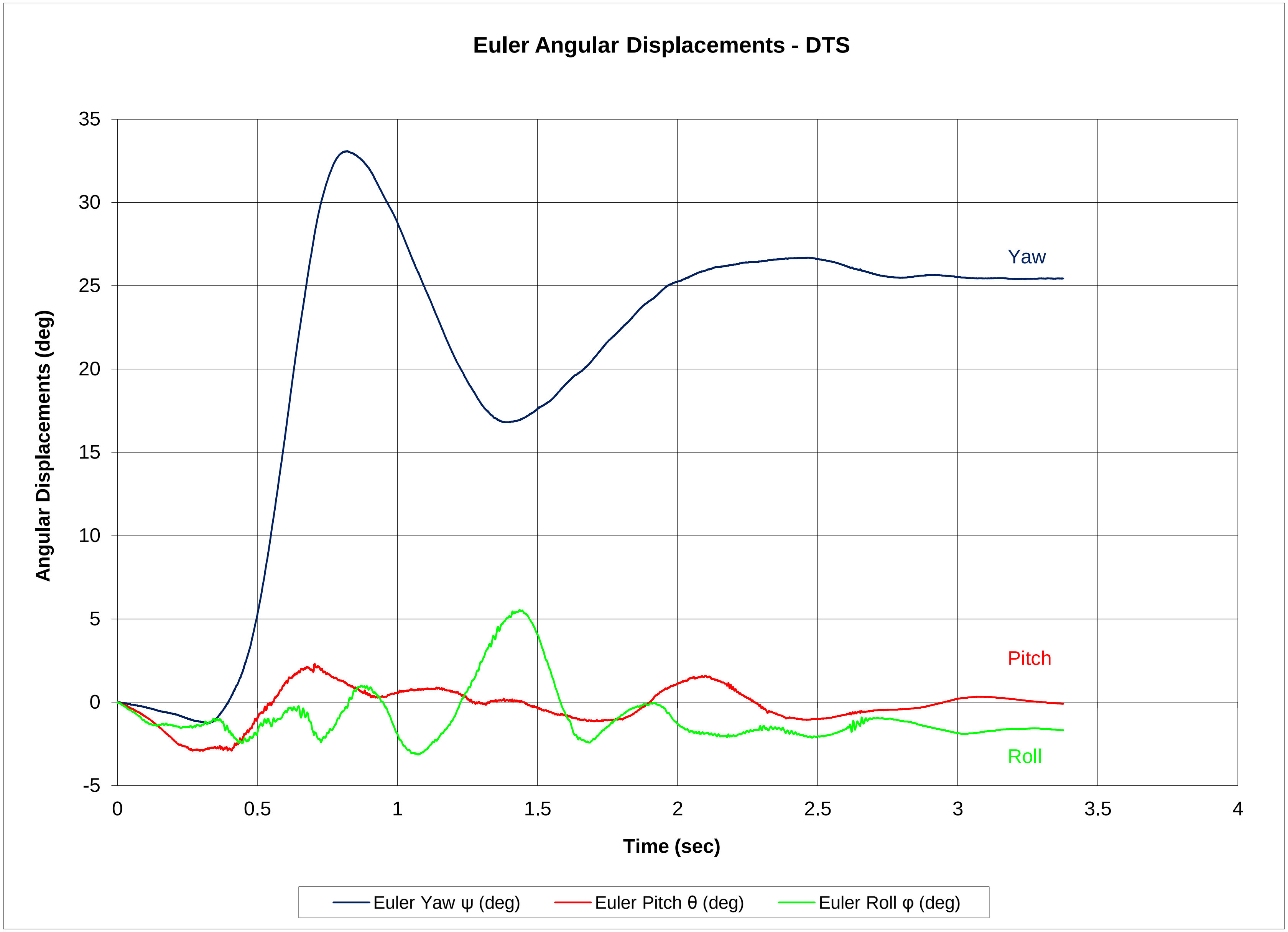


Figure G-7. Vehicle Angular Displacements (DTS), Test No. NYJ-2

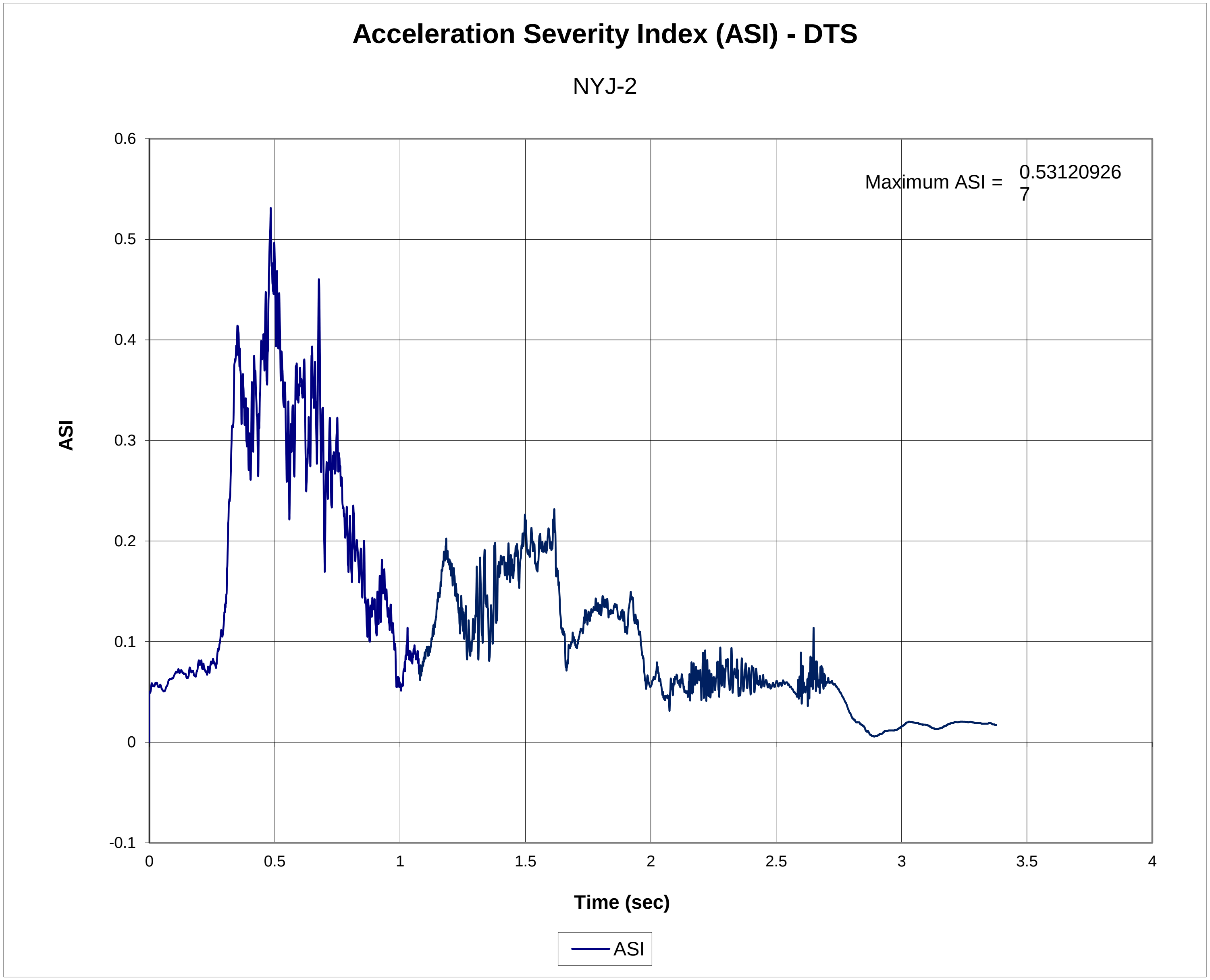


Figure G-8. Acceleration Severity Index (DTS), Test No. NYJ-2

Appendix H. Accelerometer and Rate Transducer Data Plots, Test No. NYJ-3

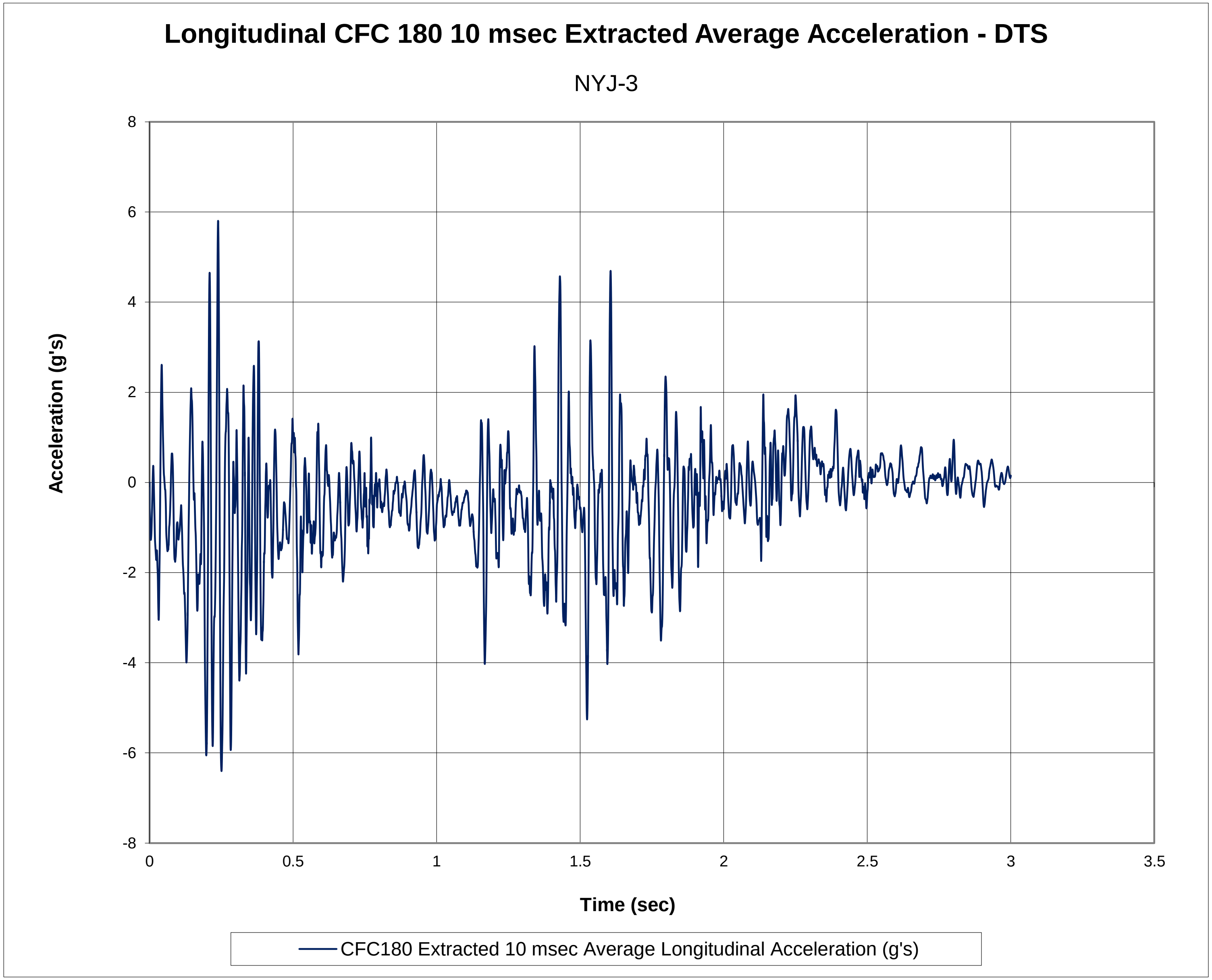


Figure H-1. 10-ms Average Longitudinal Deceleration (DTS), Test No. NYJ-3

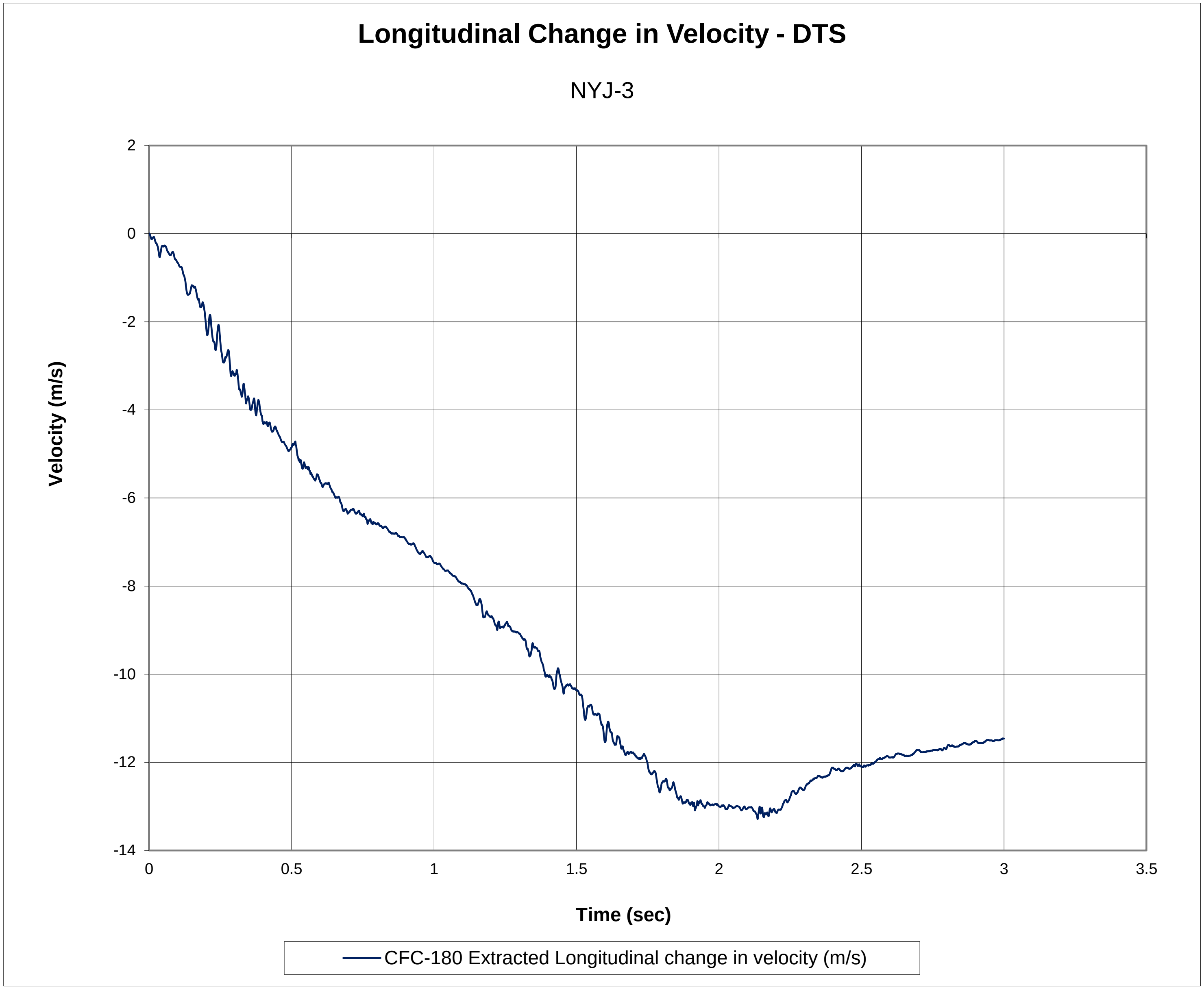


Figure H-2. Longitudinal Occupant Impact Velocity (DTS), Test No. NYJ-3

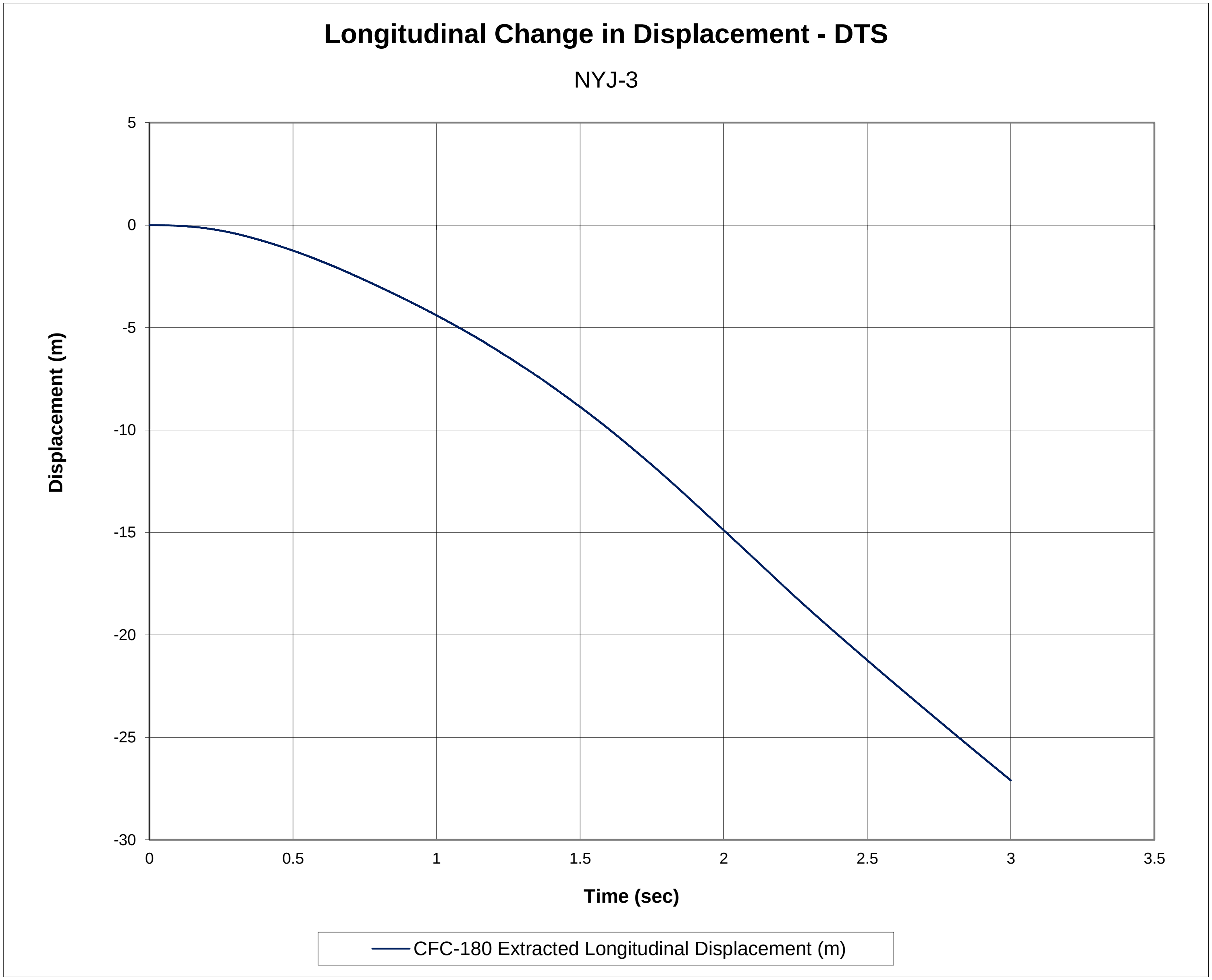


Figure H-3. Longitudinal Occupant Displacement (DTS), Test No. NYJ-3

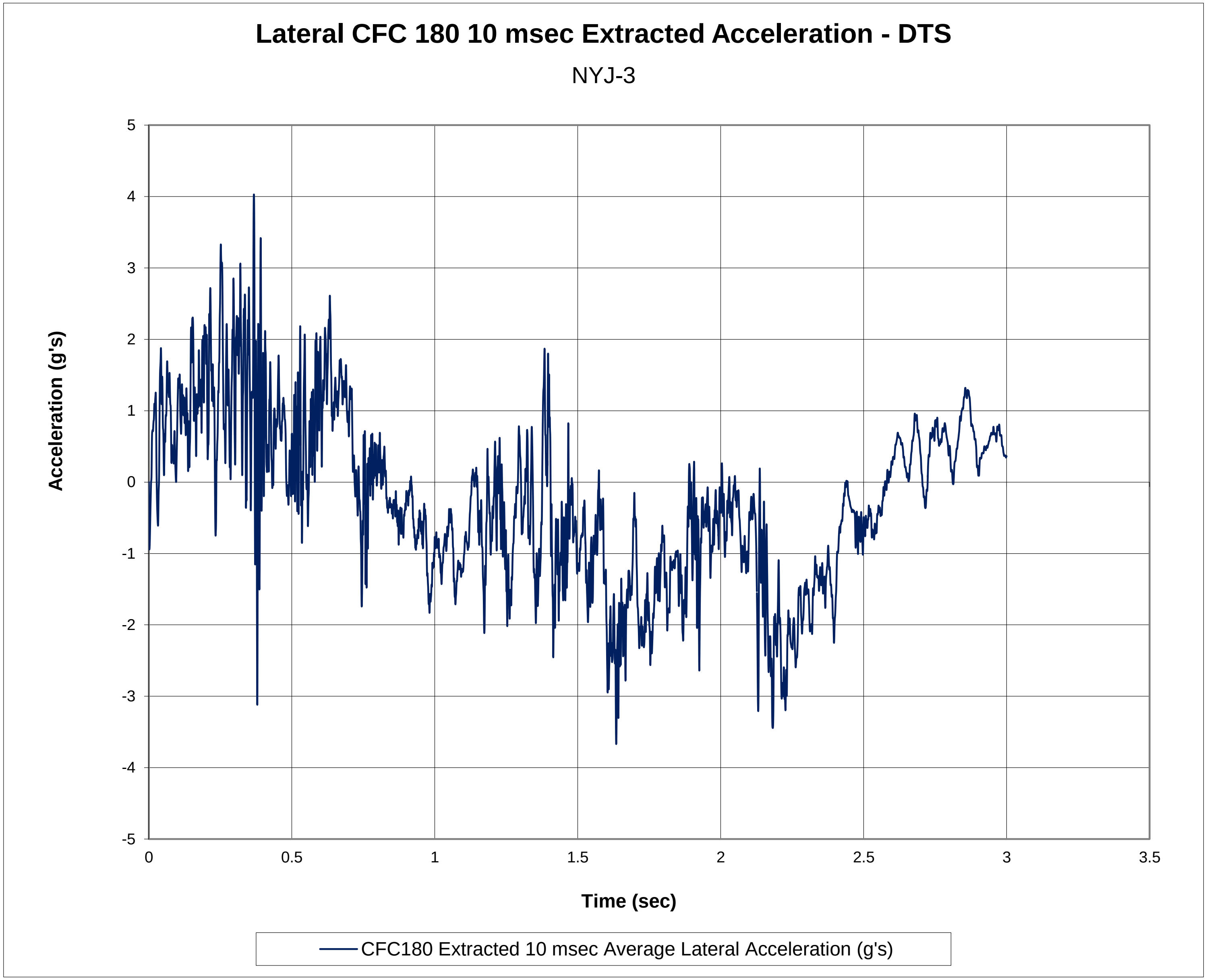


Figure H-4. 10-ms Average Lateral Deceleration (DTS), Test No. NYJ-3

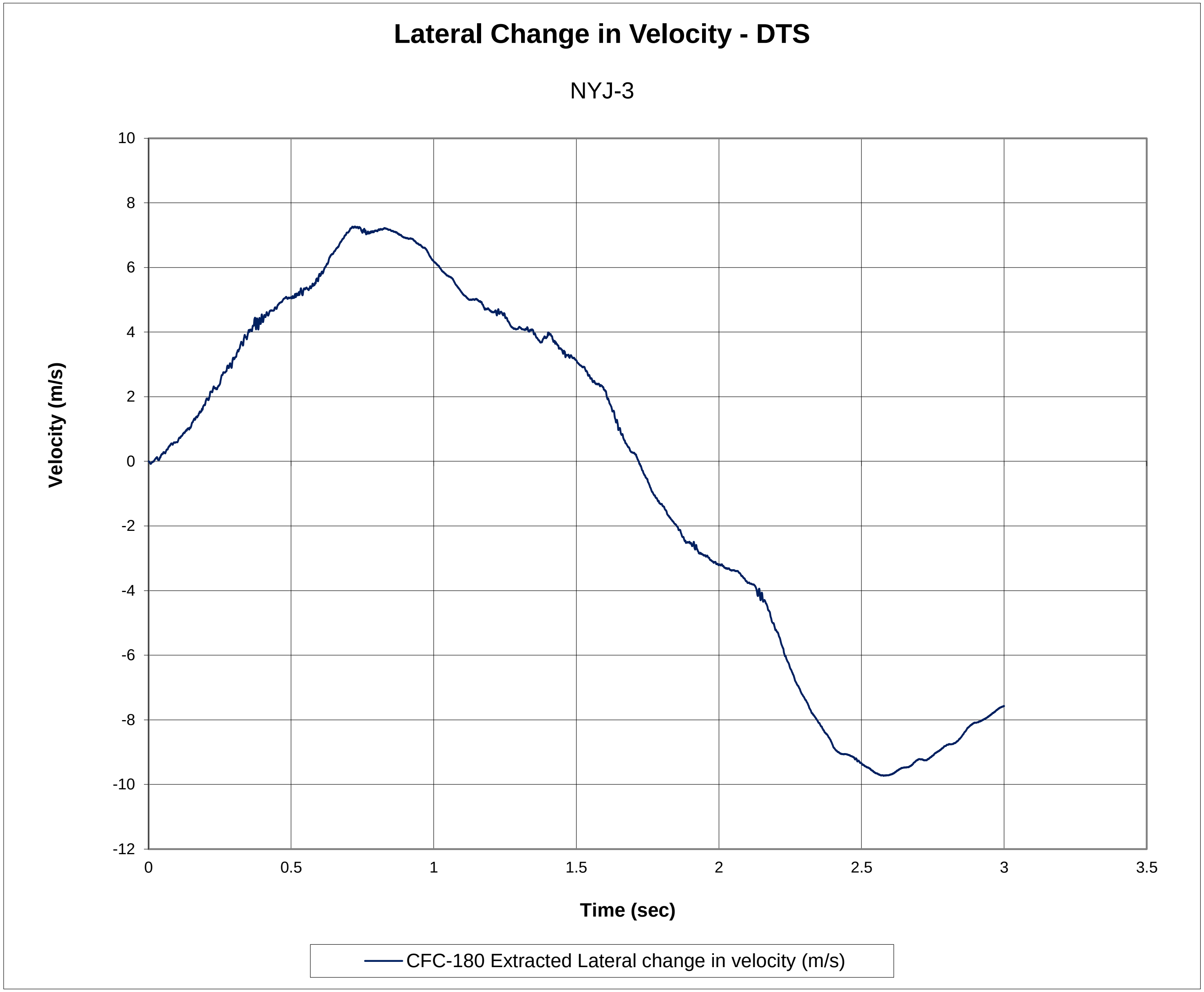


Figure H-5. Lateral Occupant Impact Velocity (DTS), Test No. NYJ-3

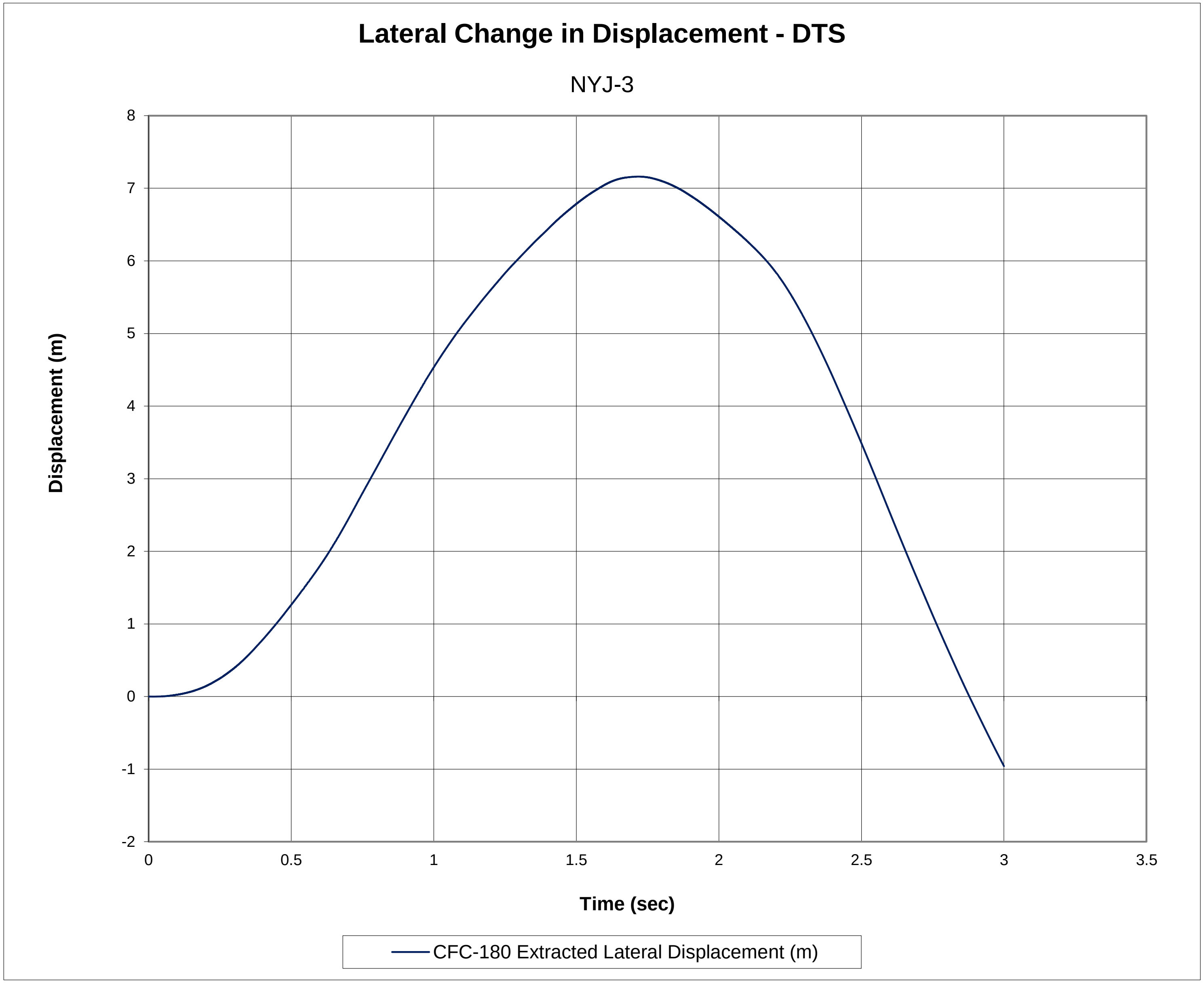


Figure H-6. Lateral Occupant Displacement (DTS), Test No. NYJ-3

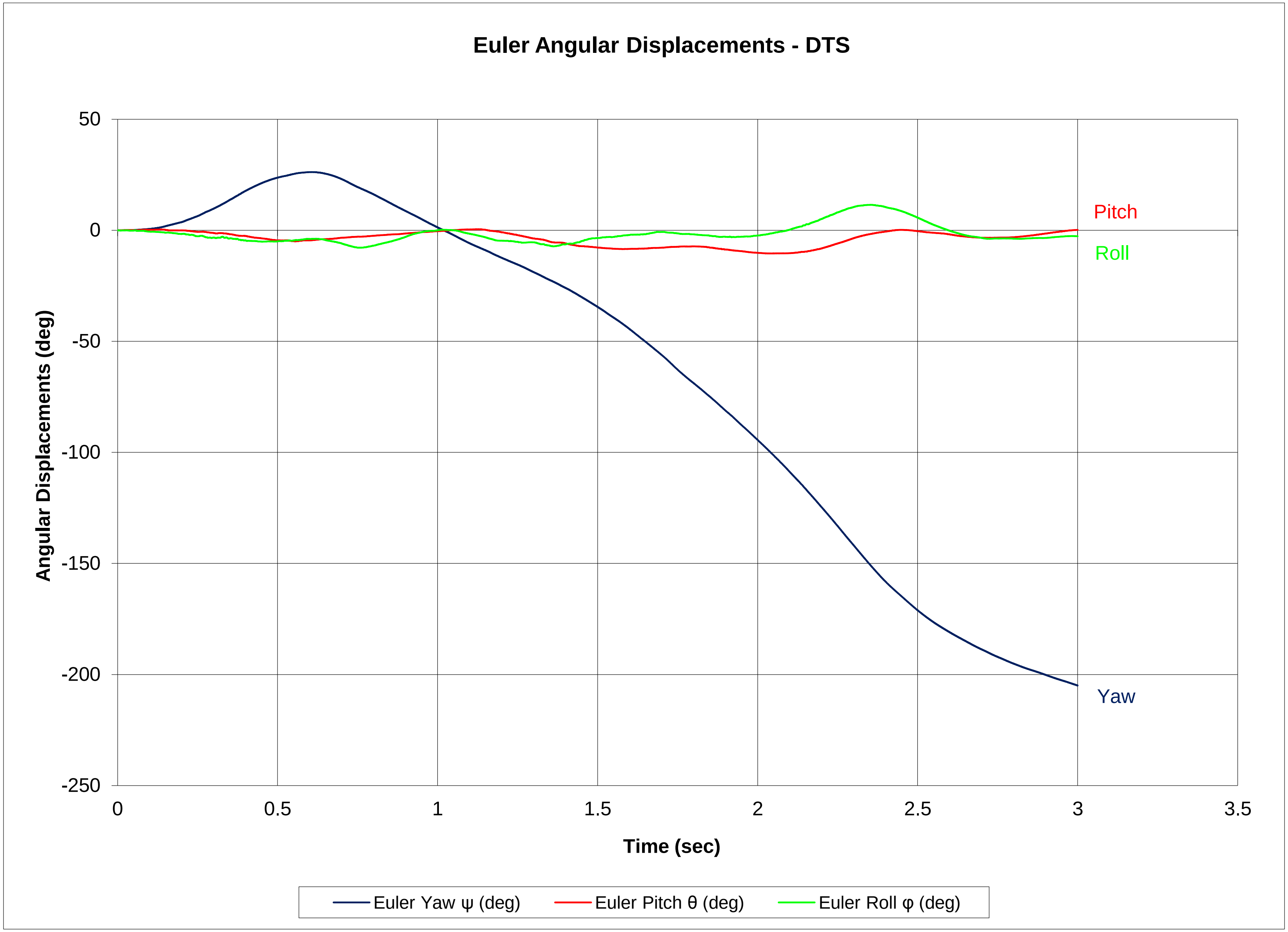


Figure H-7. Vehicle Angular Displacements (DTS), Test No. NYJ-3

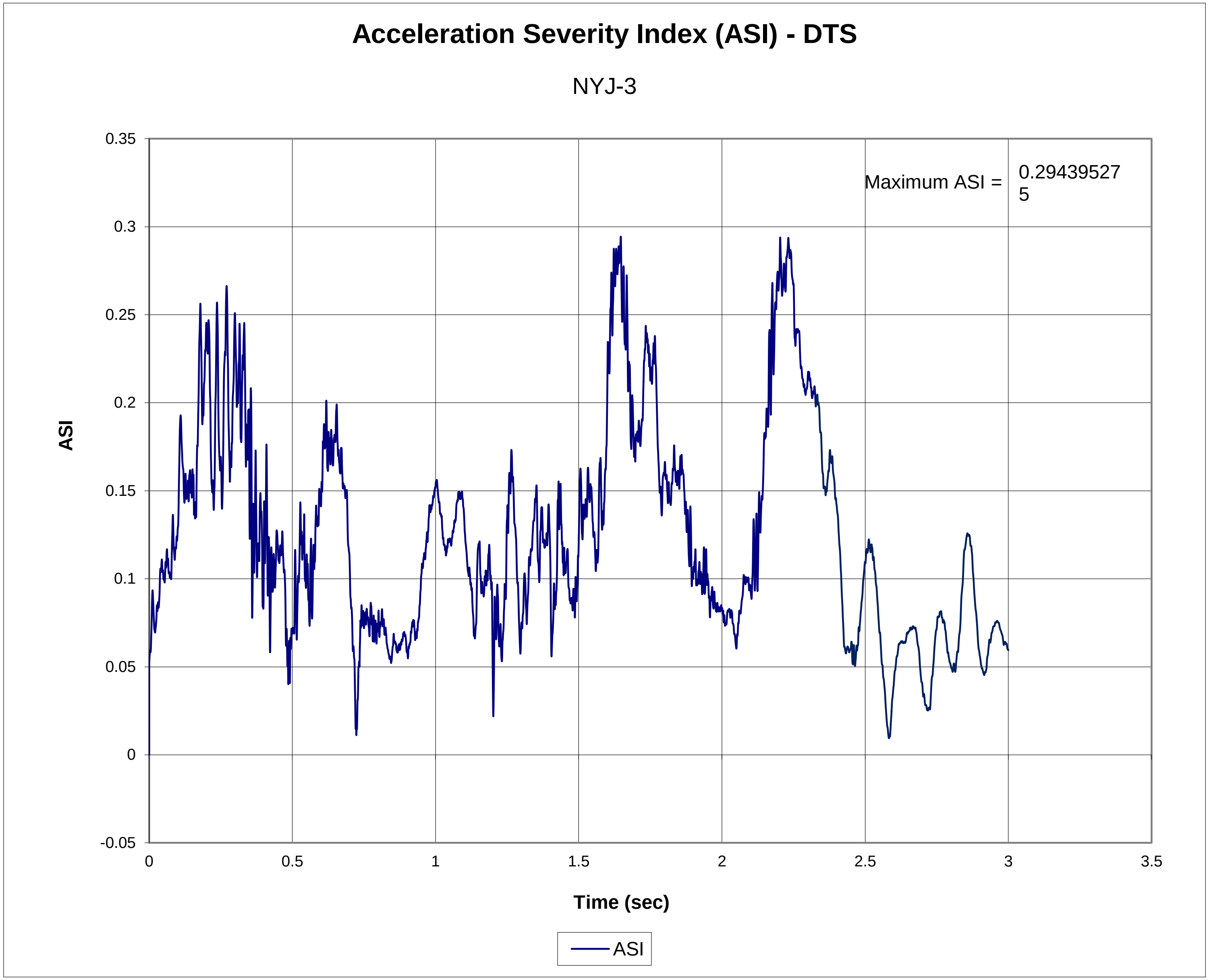


Figure H-8. Acceleration Severity Index (DTS), Test No. NYJ-3

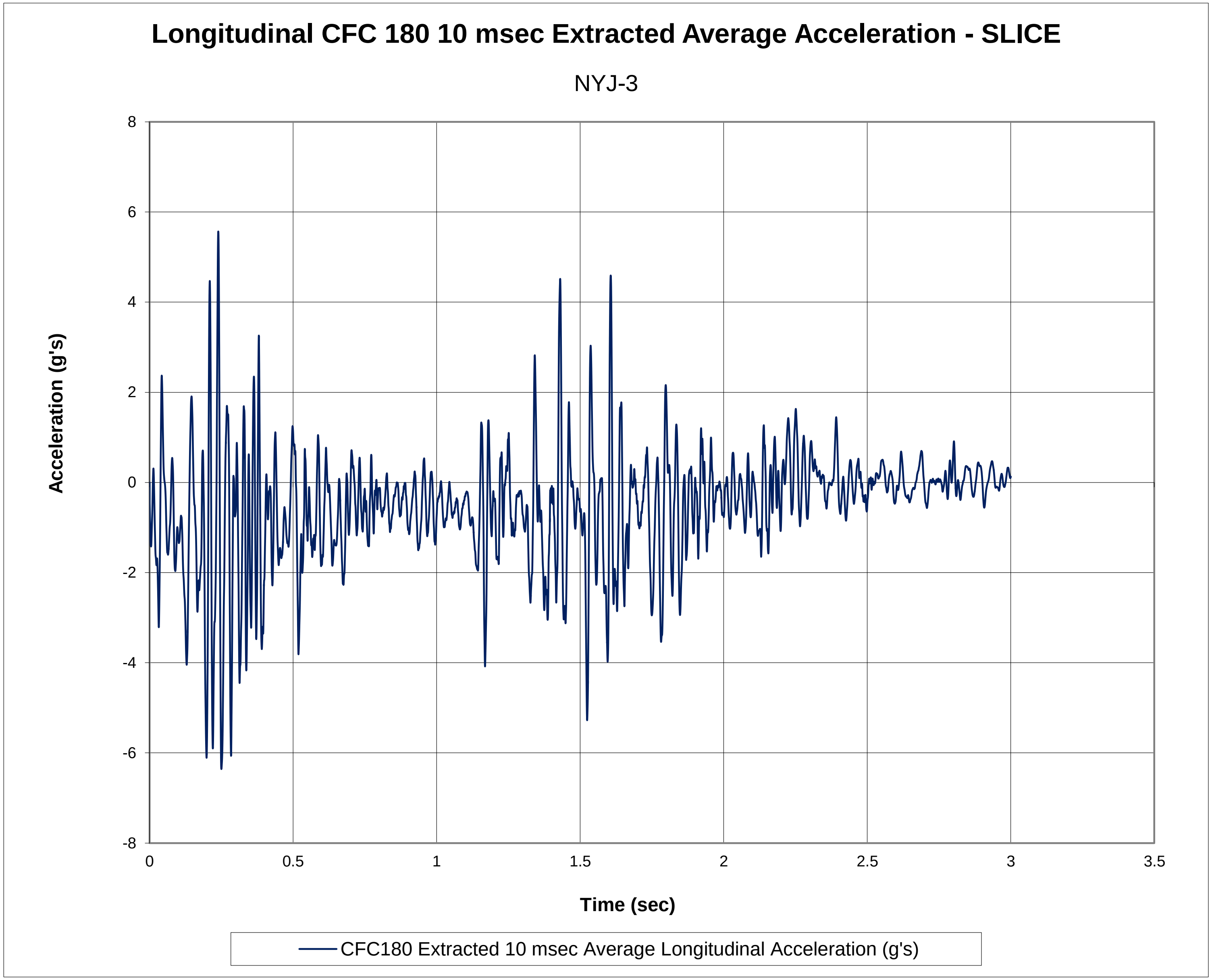


Figure H-9. 10-ms Average Longitudinal Deceleration (SLICE), Test No. NYJ-3

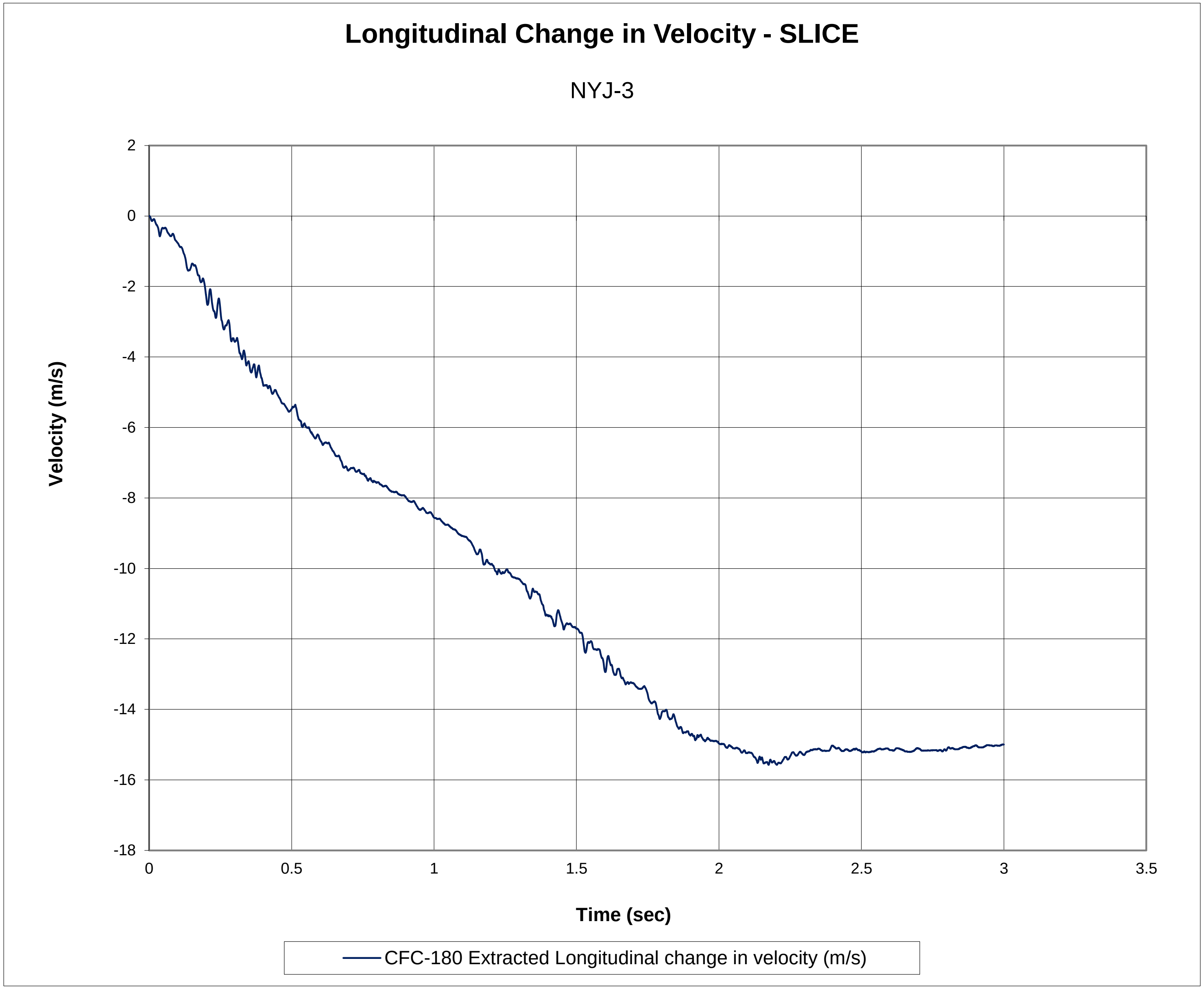


Figure H-10. Longitudinal Occupant Impact Velocity (SLICE), Test No. NYJ-3

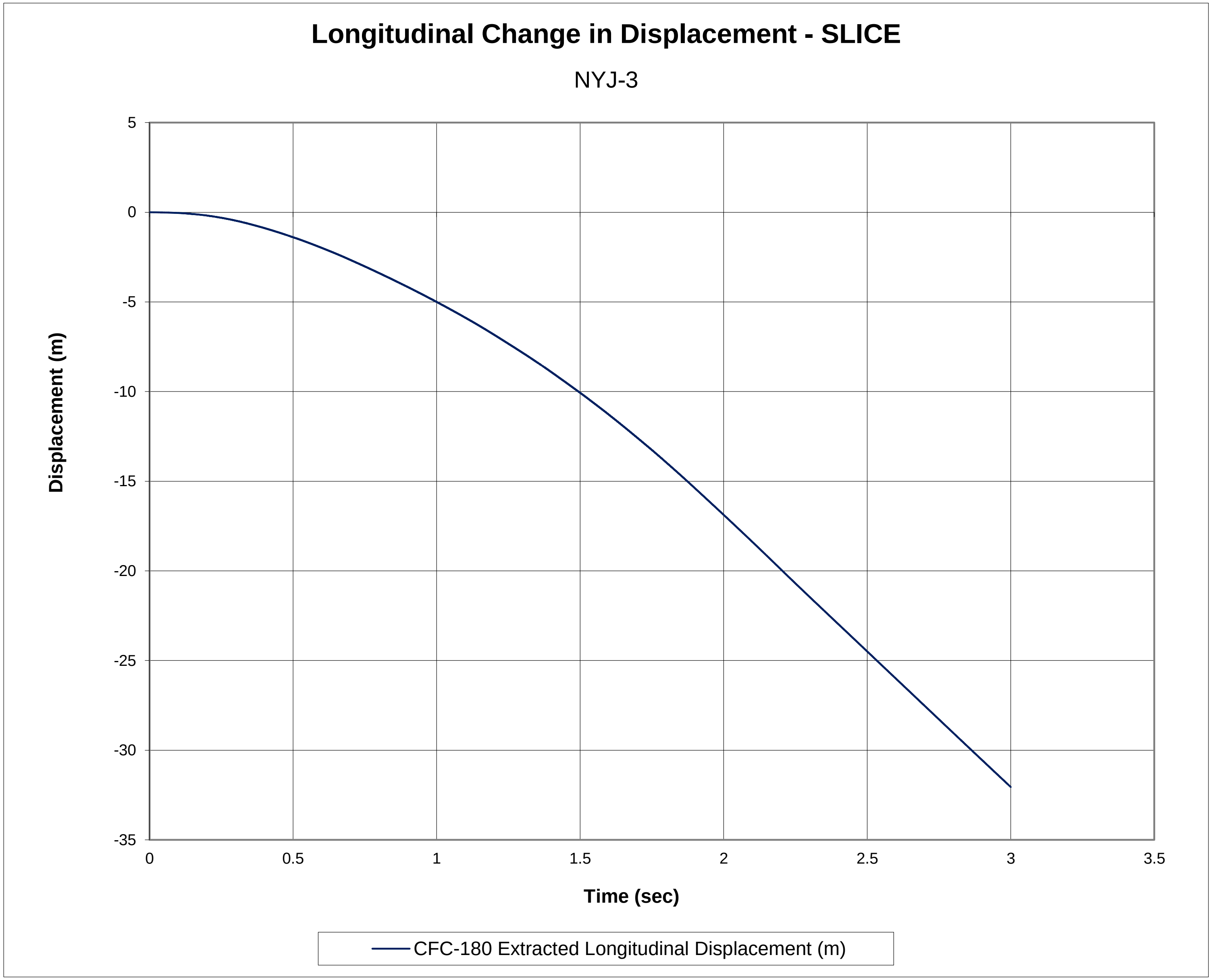


Figure H-11. Longitudinal Occupant Displacement (SLICE), Test No. NYJ-3

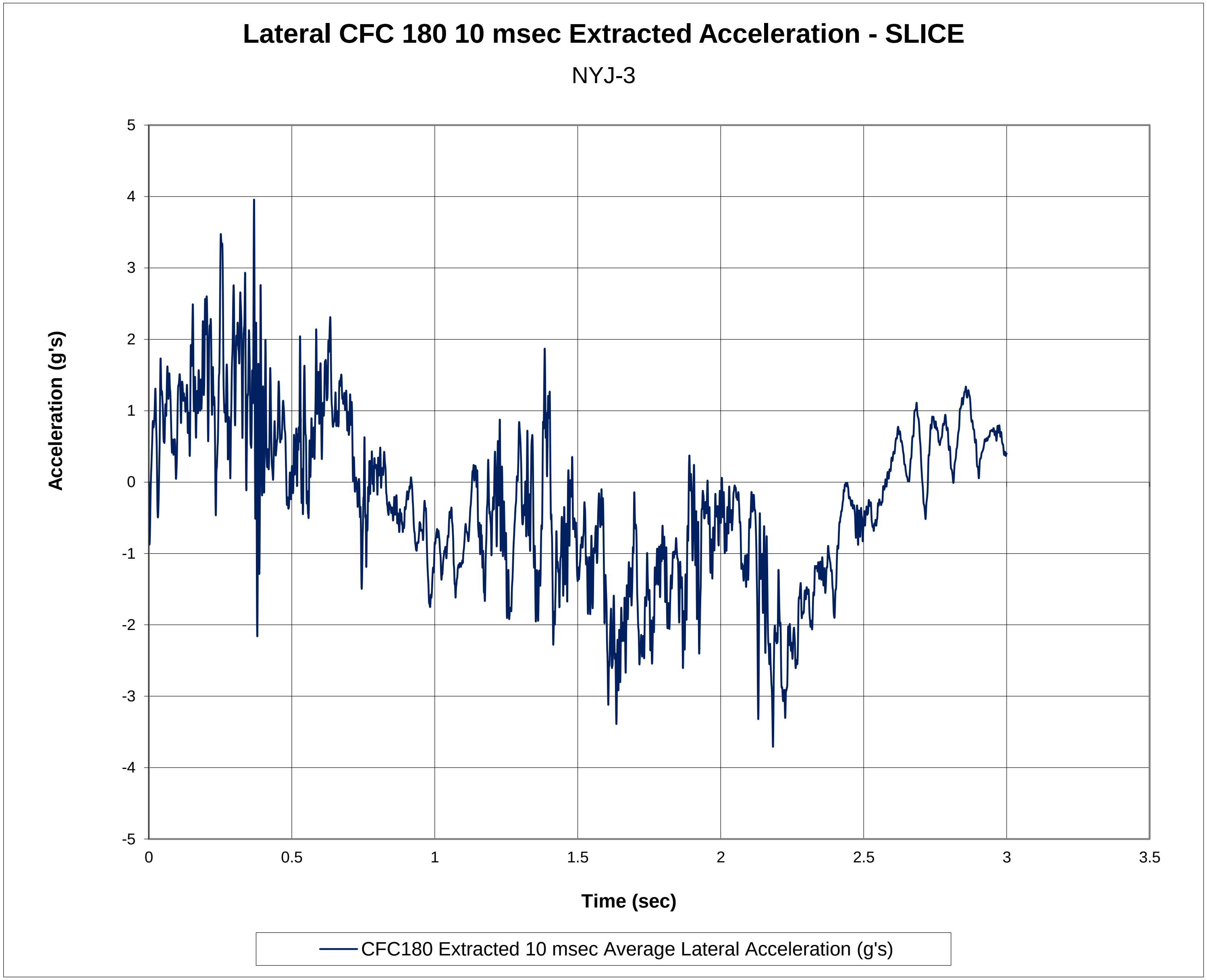


Figure H-12. 10-ms Average Lateral Deceleration (SLICE), Test No. NYJ-3

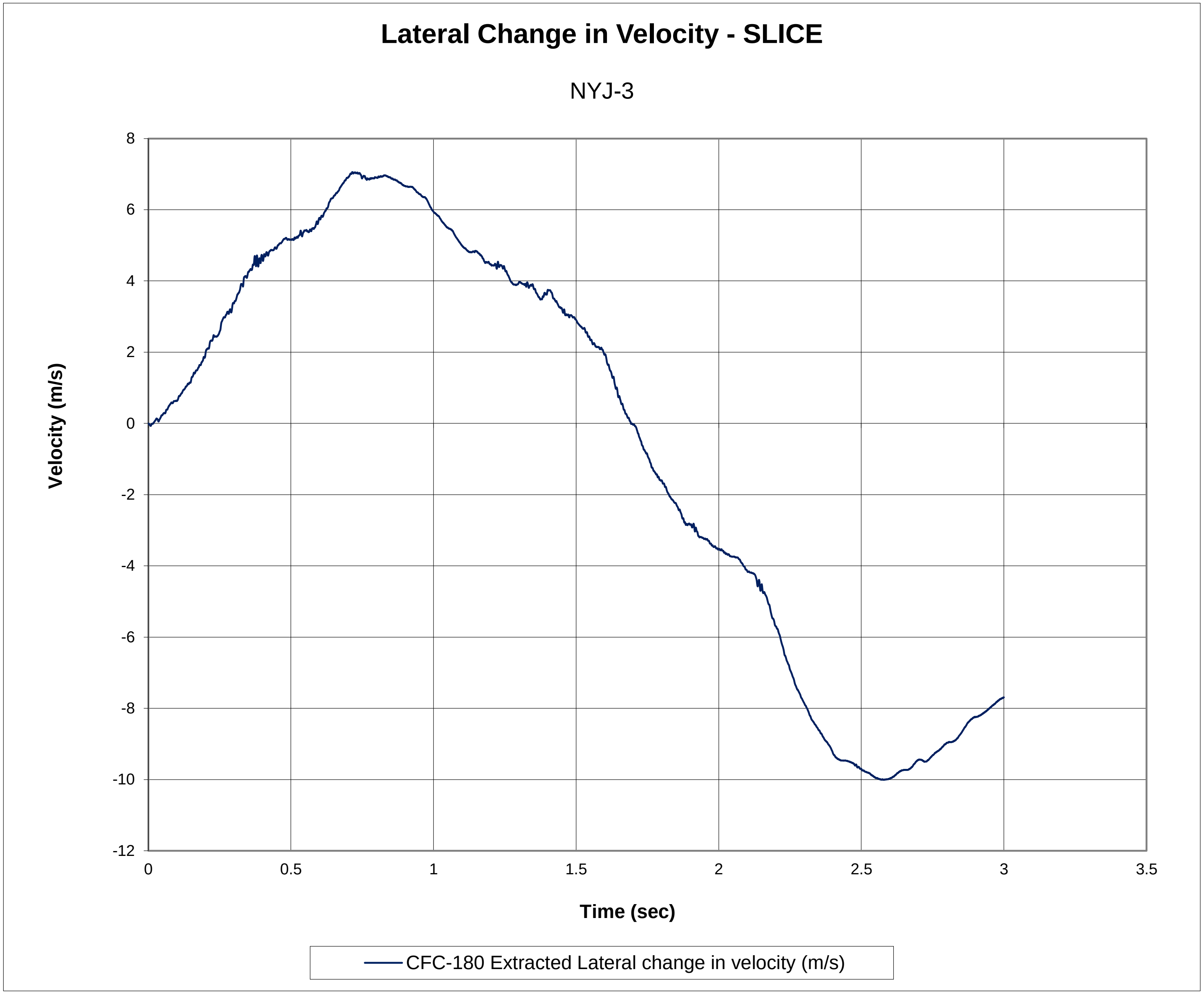


Figure H-13. Lateral Occupant Impact Velocity (SLICE), Test No. NYJ-3

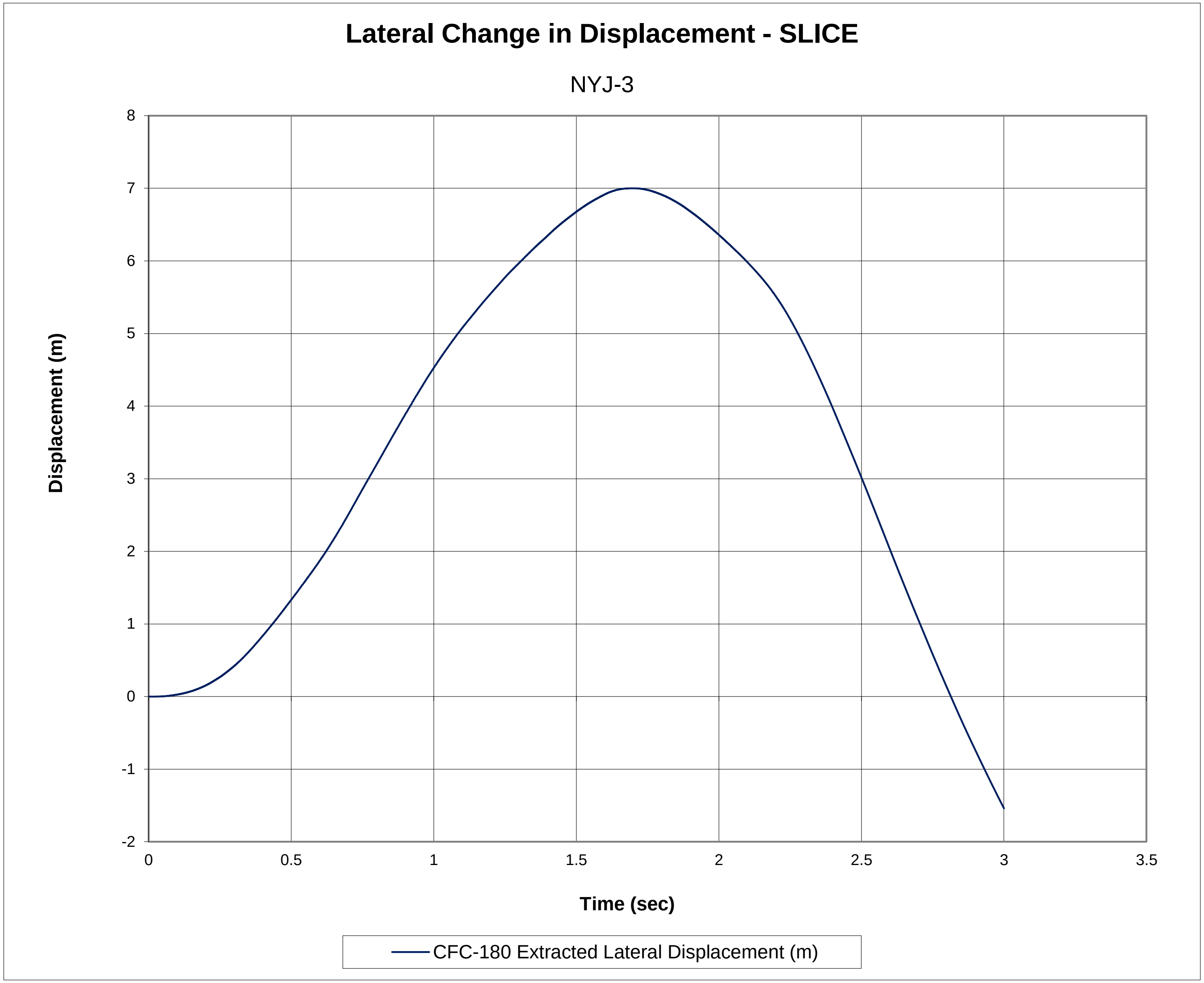


Figure H-14. Lateral Occupant Displacement (SLICE), Test No. NYJ-3

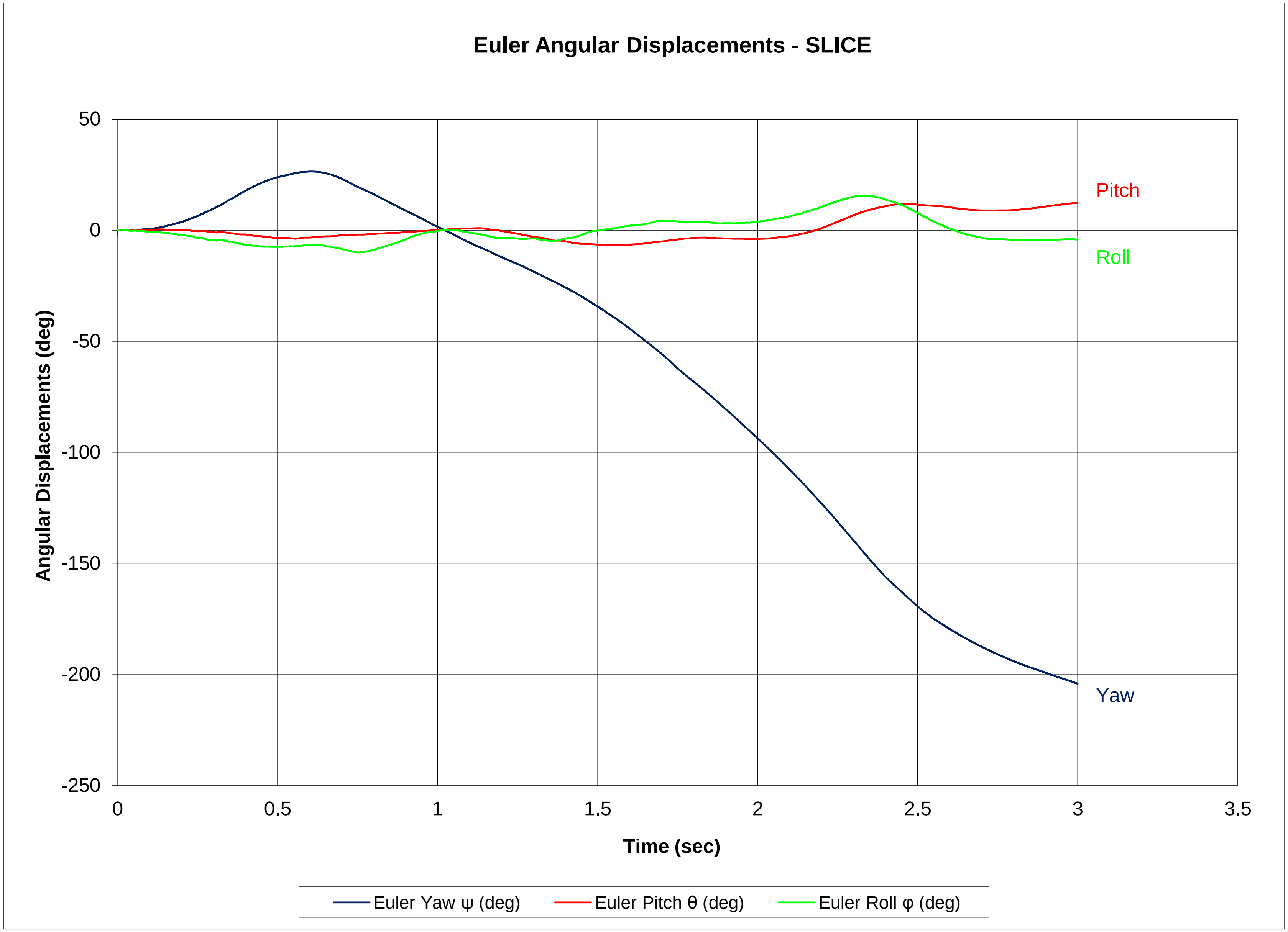


Figure H-15. Vehicle Angular Displacements (SLICE), Test No. NYJ-3

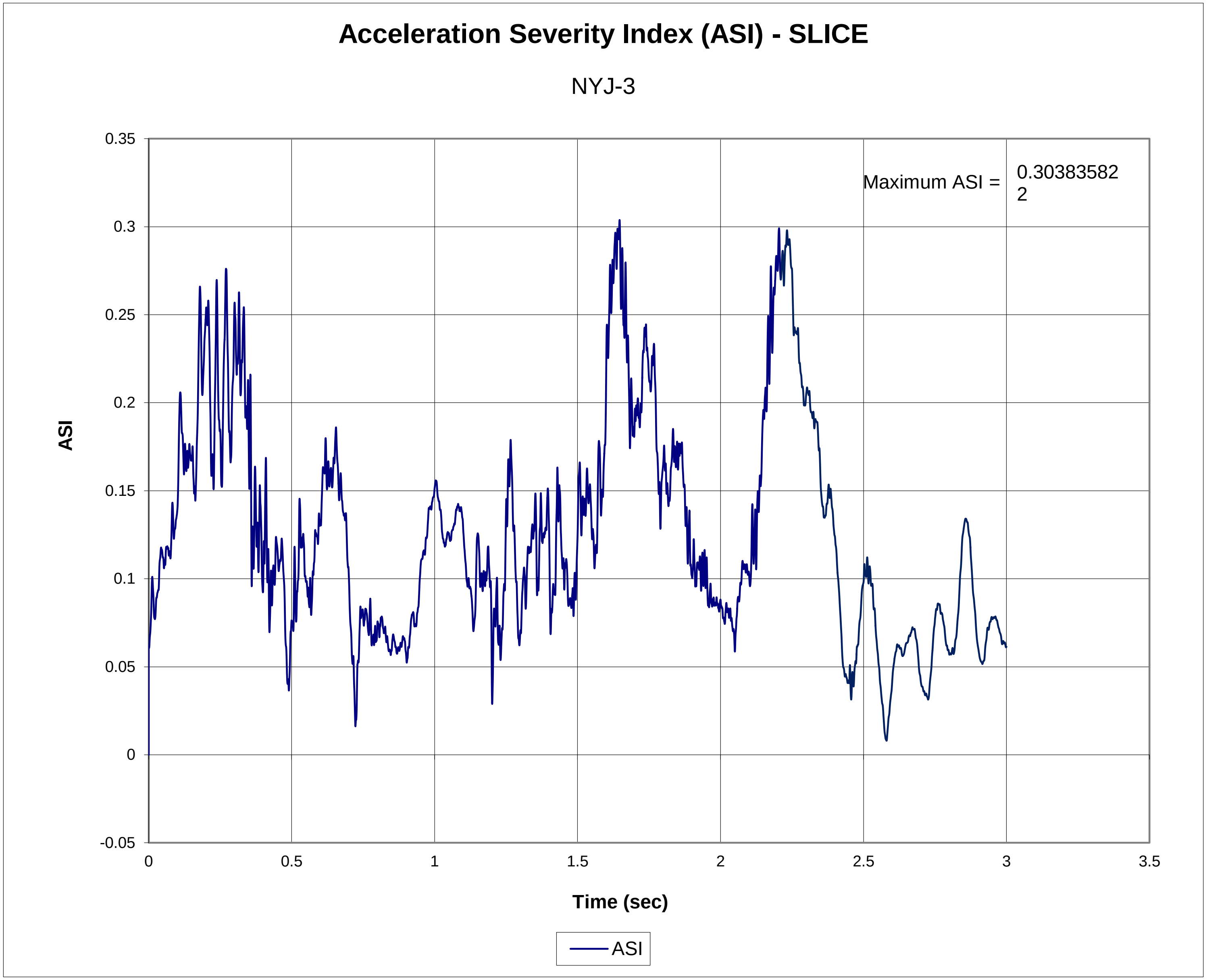


Figure H-16. Acceleration Severity Index (SLICE), Test No. NYJ-3

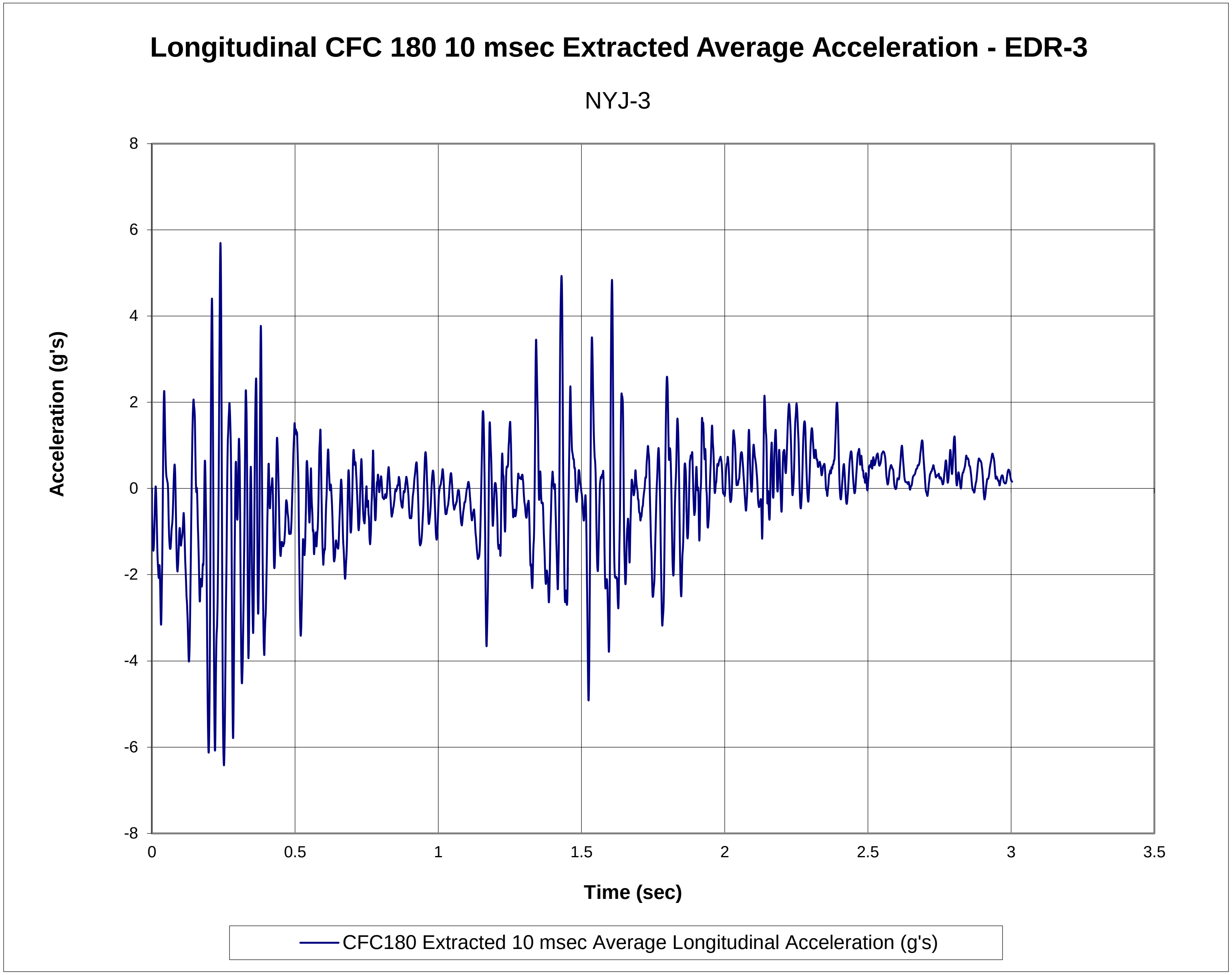


Figure H-17. 10-ms Average Longitudinal Deceleration (EDR-3), Test No. NYJ-3

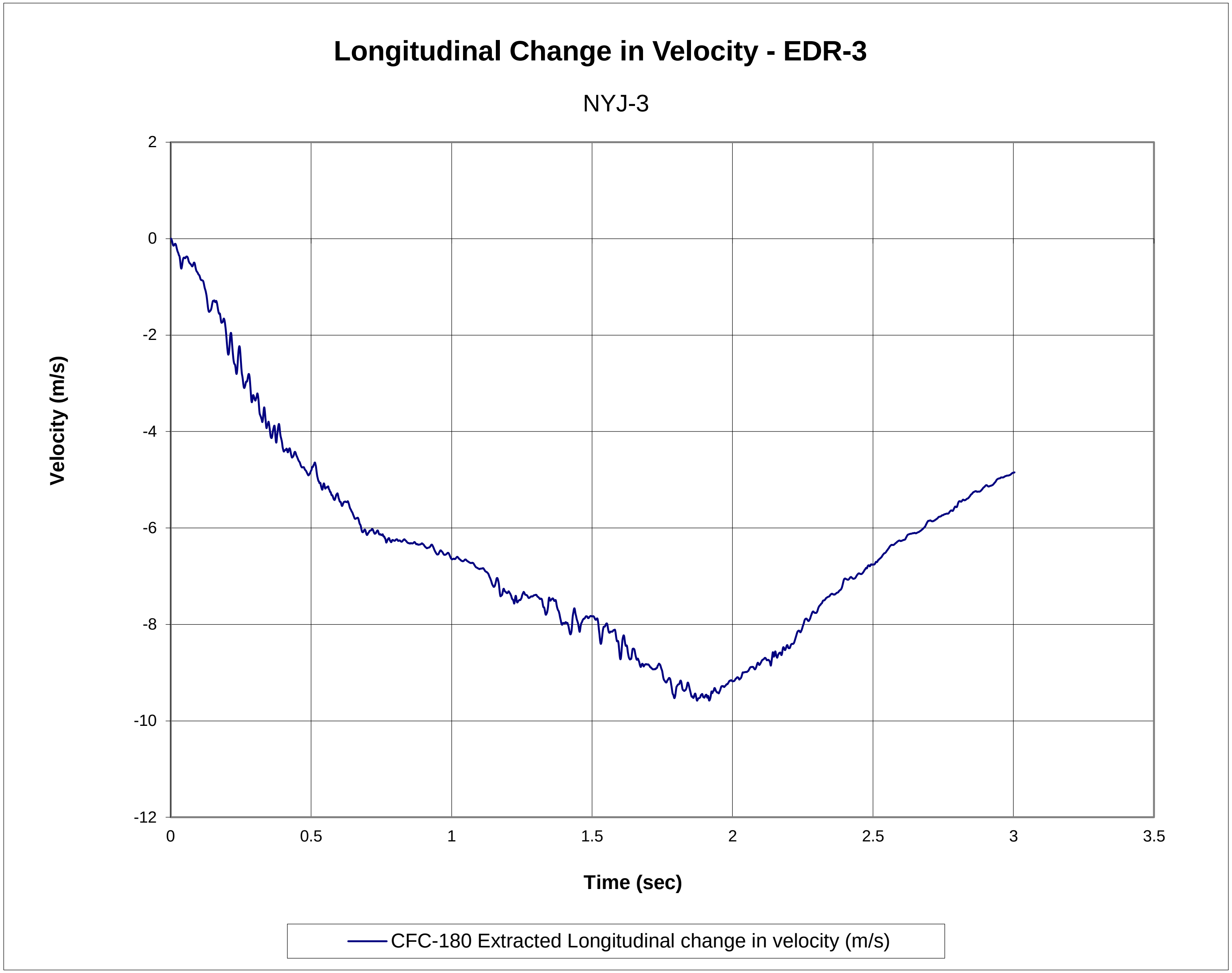


Figure H-18. Longitudinal Occupant Impact Velocity (EDR-3), Test No. NYJ-3

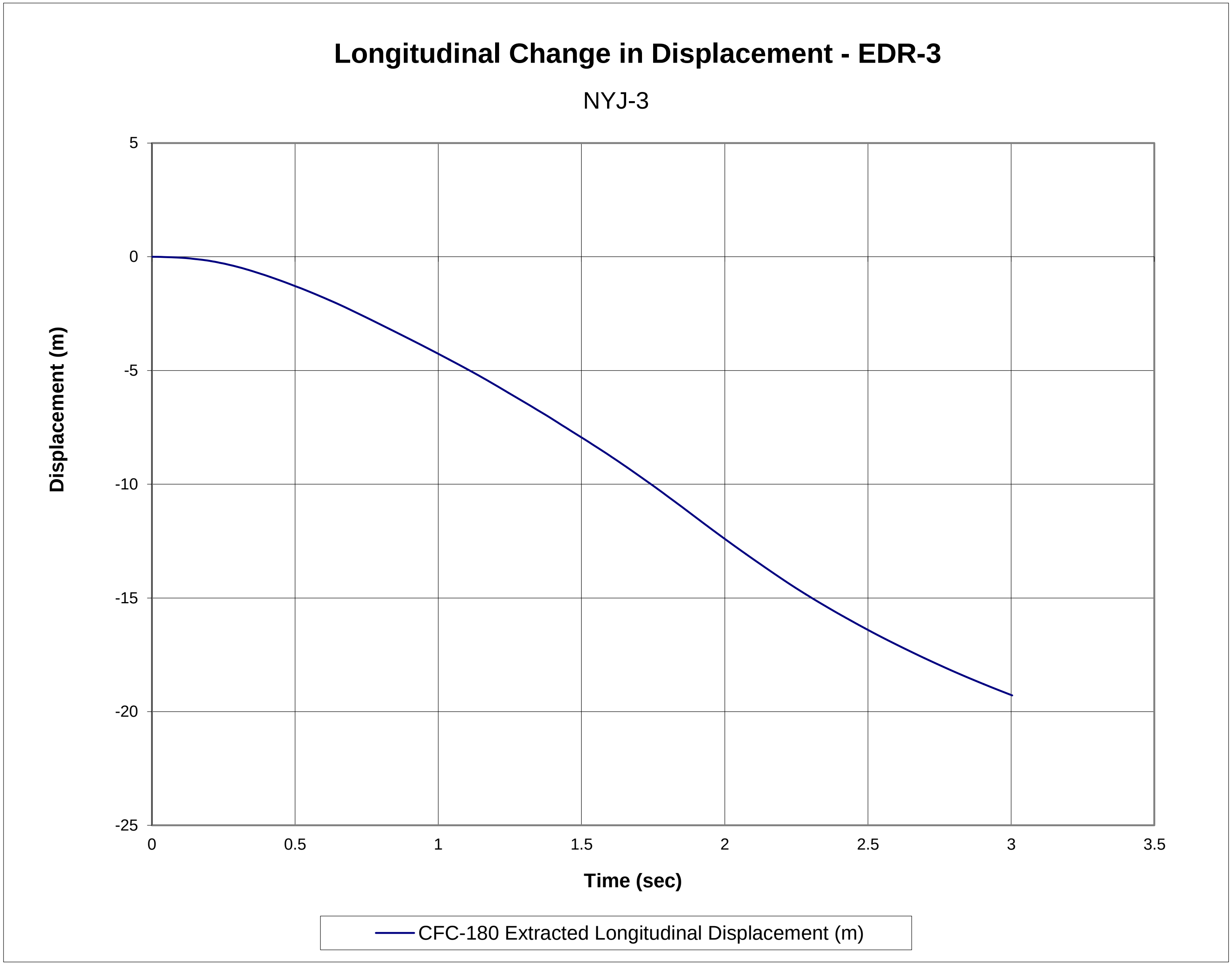


Figure H-19. Longitudinal Occupant Displacement (EDR-3), Test No. NYJ-3

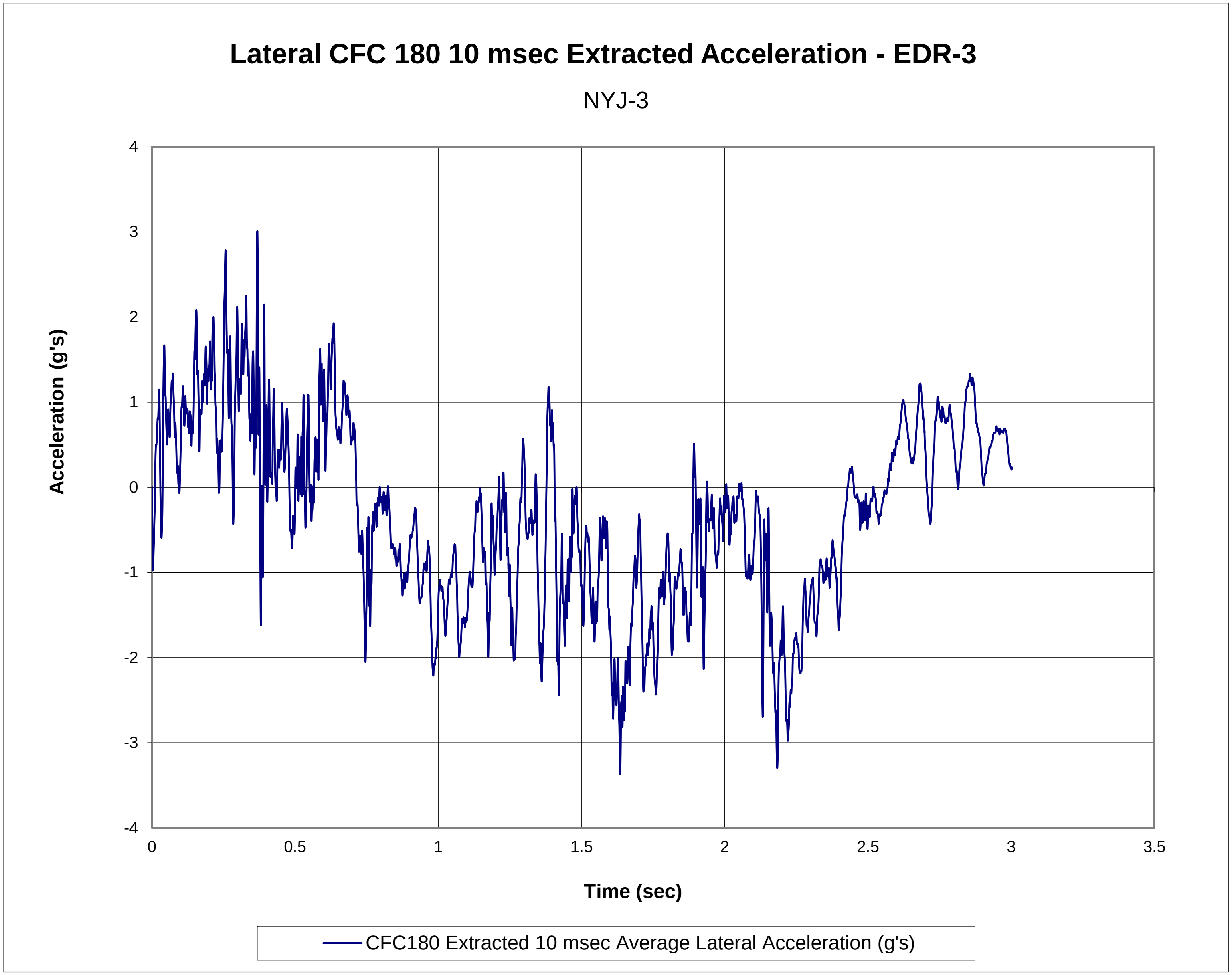


Figure H-20. 10-ms Average Lateral Deceleration (EDR-3), Test No. NYJ-3

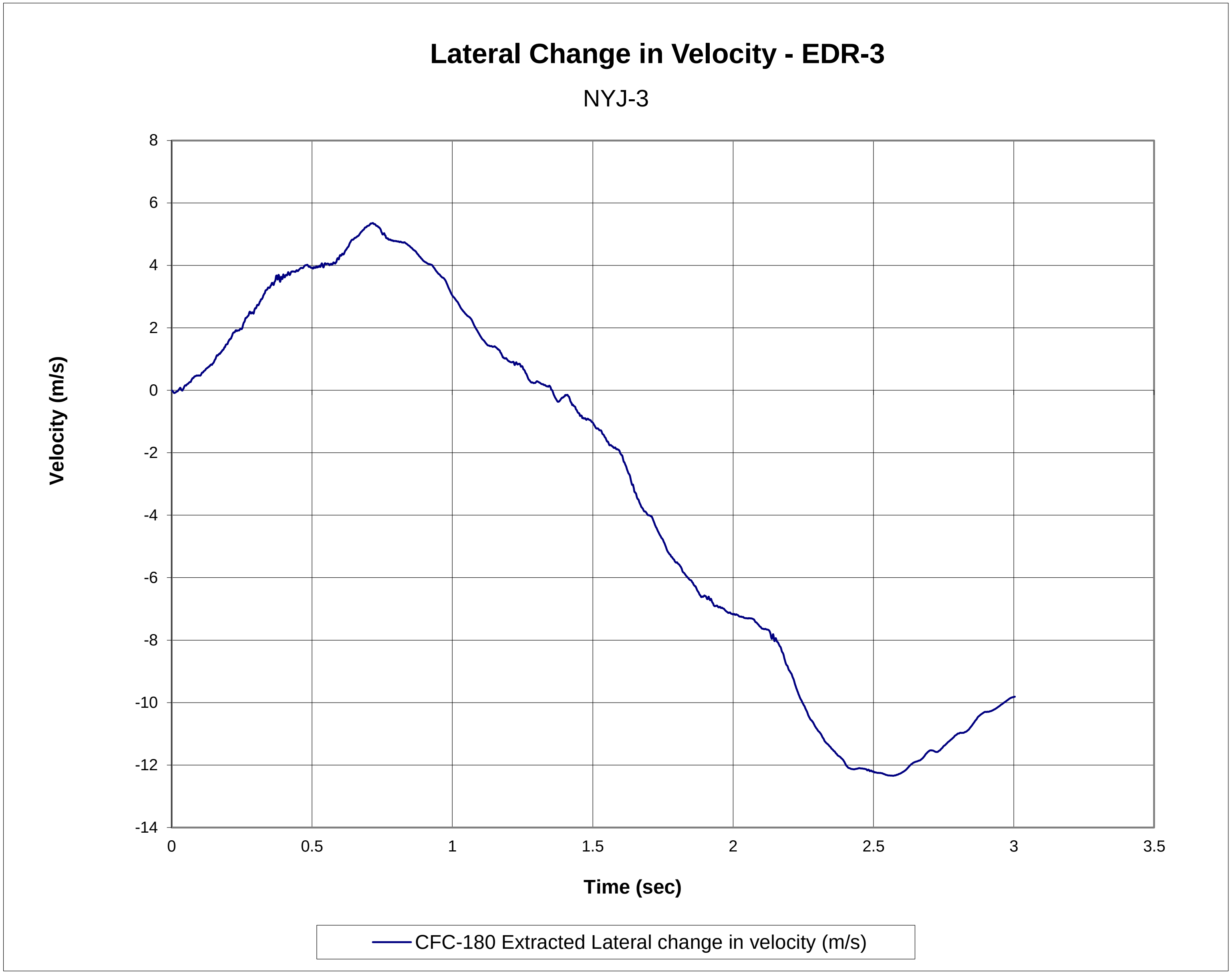


Figure H-21. Lateral Occupant Impact Velocity (EDR-3), Test No. NYJ-3

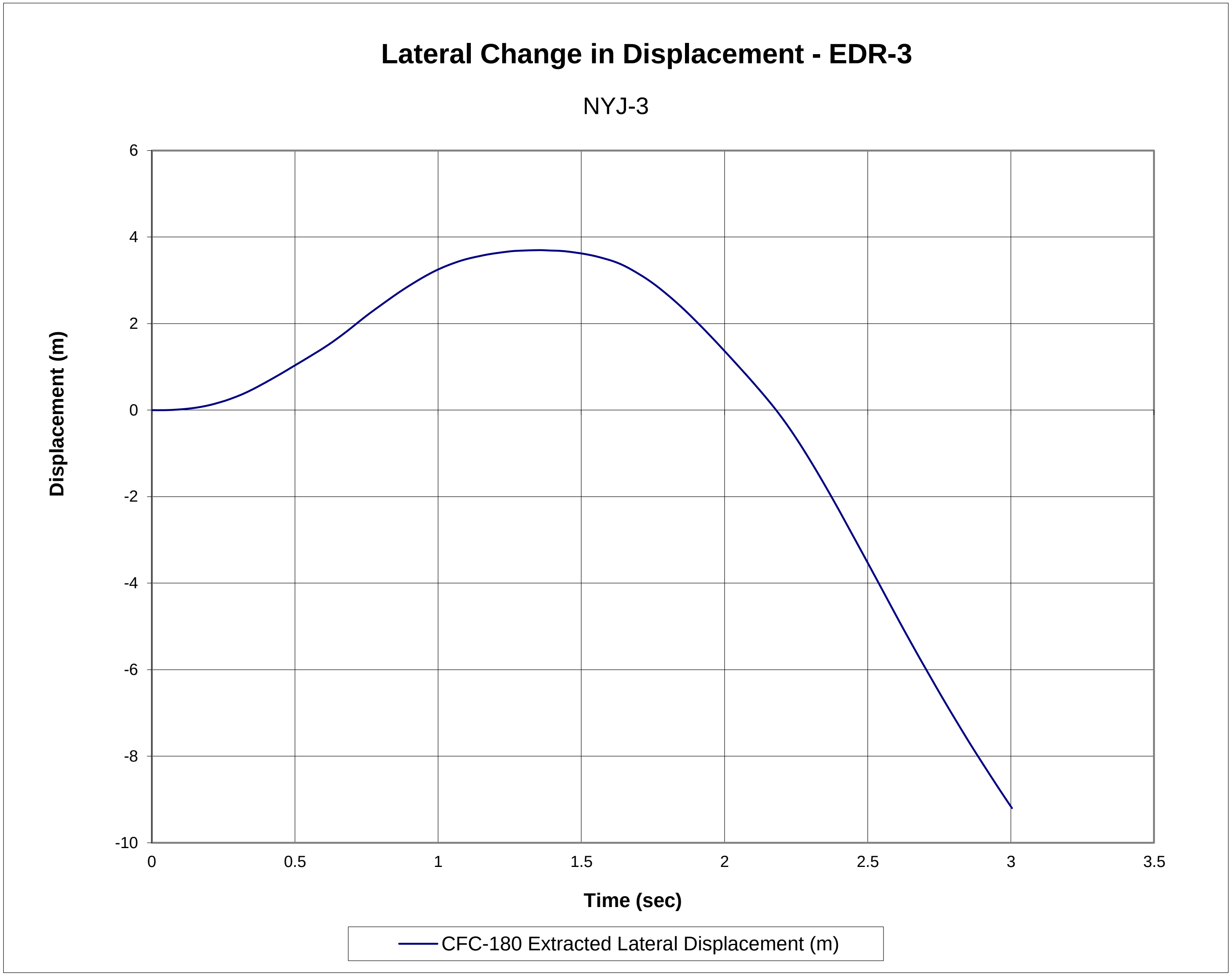


Figure H-22. Lateral Occupant Displacement (EDR-3), Test No. NYJ-3

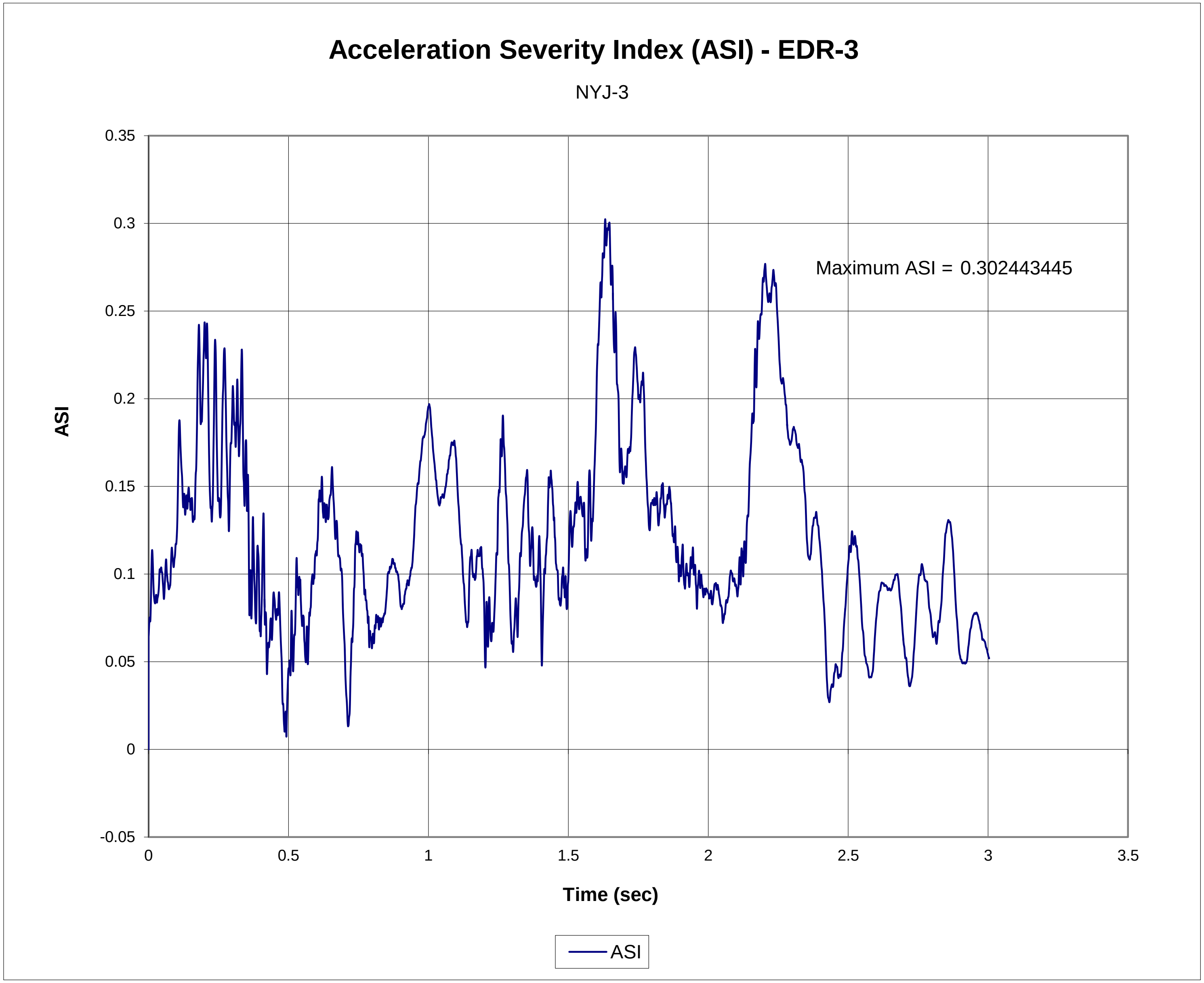


Figure H-23. Acceleration Severity Index (EDR-3), Test No. NYJ-3

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