MASH 2016 EVALUATION OF A NON-PROPRIETARY TYPE III BARRICADE: MASH TEST DESIGNATION NO. 3-72

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16. Abstract

Several work-zone traffic control devices have not yet been evaluated to the American Association of State Highway and Transportation Officials' (AASHTO's) *Manual for Assessing Safety Hardware, Second Edition* (MASH 2016) safety performance criteria. In this study, two identical Type III barricades were evaluated in the same crash test, according to MASH 2016, test designation no. 3-72. In test no. WZNP-2, a 5,001-lb (2,268-kg) pickup truck impacted System A, oriented at 90 degrees or perpendicular to the vehicle, at a speed of 64.7 mph (104.2 km/h) and System B, oriented at 0 degrees or head on to the vehicle, at a speed of 62.6 mph (100.8 km/h), respectively. The devices were spaced 60 ft (18.3 m) apart and each device impacted at the quarter-points on the front bumper. Each Type III barricade consisted of three horizontal High Density Polyethylene (HDPE) panels, measuring 96 in. (2,428 mm) in length, with a 48-in. x 30-in. x 0.08-in. (1,219-mm x 762-mm x 2-mm) aluminum sign attached to the top two barricade panels. The barricade panel was targeted to have a cross-sectional dimension of 8 in. (203 mm) x 1 in. (25 mm). During test no. WZNP-2, the 2270P pickup truck readily disengaged both barricades from their support. Both tests successfully met all evaluation criteria in MASH 2016 for test designation no. 3-72.

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DISCLAIMER

UNCERTAINTY OF MEASUREMENT STATEMENT

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

INDEPENDENT APPROVING AUTHORITY

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

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1 INTRODUCTION

1.1 Background

Through a project funded jointly by Dicke Safety Products, the Mid-America Transportation Center, and the Smart Work Zone Deployment Initiative (SWZDI) from 2008 to 2010, several work-zone sign stands were evaluated [1-2]. These sign stands were crashworthy according to the crash testing and safety performance criteria in National Cooperative Highway Research Program (NCHRP) Report No. 350 [3]. In 2009,

the American Association of State Highway and Transportation Officials (AASHTO) implemented an updated standard for the evaluation of roadside hardware [4]. The new standard, entitled the *Manual for Assessing Safety Hardware* (MASH 2009), improved the criteria for evaluating roadside hardware beyond the previous NCHRP Report No. 350 standard through updates to test vehicles, test matrices, and impact conditions. However, when NCHRP Report No. 350 work-zone devices were subjected to the new MASH 2009 crash testing and safety performance criteria, several of the work-zone sign stands produced undesirable results, including windshield and floorboard penetration and excessive windshield and roof deformation [1-2]. This testing indicated that devices tested under previous NCHRP Report No. 350 safety performance standards may not perform acceptably with the new MASH safety performance standards. Subsequently, an updated version of MASH, MASH 2016, was published, which contained no changes to the impact conditions or evaluation criteria for work-zone devices [5].

In an effort to encourage state departments of transportation (DOTs) and hardware developers to advance hardware designs, the Federal Highway Administration (FHWA) and AASHTO collaborated to develop a MASH implementation policy that included sunset dates for various roadside hardware categories. The new policy by the FHWA and AASHTO required that temporary work-zone devices manufactured after December 31, 2019 be evaluated to MASH 2016.

SWZDI and the Midwest Roadside Safety Facility (MwRSF) collaborated to conduct testing on a Type III barricade in accordance with MASH 2016 [6]. Three full-scale crash tests are required to evaluate a Type III barricade to MASH 2016 Test Level 3 (TL-3) criteria. According to MASH Section 2.2.4.2, test designations nos. 3-70, 3-71, and 3-72 are required, although test designation no. 3-70 is optional since the Type III barricade weighs less than 220 lb (100 kg) [5]. Test designation no. 3-71 (test no. WZNP-1) was conducted, which involved a 2,420-lb (1,100-kg) car (designated 1100C) impacting the barricade at 62 mph (100 km/h) at both 0 and 90 degrees [6]. Test designation no. 3-72, which involves a 5,000-lb (2,270-kg) pickup truck (designated 2270P) impacting the barricade at 62 mph (100 km/h) at both 0 and 90 degrees, was not conducted as part of the previous research effort with SWZDI.

The Type III barricade consisted of three reflective panels connected to two steel upright legs, which was held to the ground by sandbags placed on the legs. The panels supported a “Road Closed” aluminum sign and two lights, which were not connected to the legs. In test no. WZNP-1, two Type III barricades were placed 60 ft (18.3 m) apart on level terrain with one sandbag on the end of each leg. During the test, the 1100C small car impacted and disengaged both barricades from their supports. The systems readily activated in a predicable manner and allowed the 1100C vehicle to continue traveling without any major obstruction of the windshield. There were no

detached elements or fragments which showed potential for penetrating the occupant compartment or presented undue hazard to other traffic. No penetration or deformation of the occupant compartment that could have caused serious injury occurred. Therefore, test no. WZNP-1 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-71. Test designation no. 3-72 was still required to complete the evaluation of the system to MASH TL-3 criteria.

1.2 Objective

The objective of this research effort was to evaluate the Type III barricade to MASH 2016 TL-3 safety criteria through two full-scale crash tests at 0-degree and 90-degree impact angles. For test designation no. 3-72, the Type III barricade was impacted by a 2270P pickup truck at an impact speed of 62 mph (100 km/h), as required by MASH 2016.

1.3 Scope

The research objective was achieved through the completion of several tasks. Two full-scale crash tests were conducted on a Type III barricade according to MASH 2016 test designation no. 3-72. Next, vehicle crash test results were analyzed, evaluated, and documented. Conclusions and recommendations were then made pertaining to the safety performance of the Type III barricade.

2 TEST REQUIREMENTS AND EVALUATION CRITERIA

2.1 Test Requirements

Category 2 work-zone traffic control devices, such as Type III barricades, must satisfy impact safety standards in order to be declared eligible for federal reimbursement by the Federal Highway Administration (FHWA) for use on the National Highway System (NHS). For new hardware, these safety standards consist of the guidelines and procedures published in MASH 2016 [5]. Note that there is no difference between MASH 2009 [4] and MASH 2016 for work-zone traffic control devices, such as Type III barricades tested in this project. According to TL-3 of MASH 2016, work-zone traffic control devices must be subjected to three full-scale vehicle crash tests, as summarized in Table 1. Note, only one of the prescribed full-scale crash tests, test designation no. 3-72, was conducted with two critical impact angles and reported herein.

Table 1. MASH 2016 TL-3 Crash Test Conditions for Work-Zone Traffic Control Devices

Test Article	Test Designation No.	Test Vehicle	Vehicle Weight, lb (kg)	Impact Conditions		Evaluation Criteria [1]
				Speed, mph (km/h)	Angle, (degrees)	
Work-Zone Traffic Control Devices	3-70	1100C	2,425 (1,100)	19 (30)	CIA	B,D,E,F,H,I,N
	3-71	1100C	2,425 (1,100)	62 (100)	CIA	B,D,E,F,H,I,N
	3-72	2270P	5,000 (2,270)	62 (100)	CIA	B,D,E,F,H,I,N

[1] Evaluation criteria explained in Table 2.
CIA= Critical Impact Angle

The low-speed test, test designation no. 3-70, was not required, since the Type III barricade weighed less than 220 lb (100 kg) [5]. Test designation no. 3-71 was previously successfully conducted on the barricade [6]. MASH 2016 recommends test designation no. 3-72 be conducted both perpendicular to the device (0 degrees) and parallel to the device (90 degrees), as both orientations may occur along roadsides. MwRSF has developed a procedure for testing multiple work-zone traffic control devices in one test run. The barricade was evaluated at two impact angles, 90 degrees (System A) and 0 degrees (System B), in one full-scale crash test. The devices were spaced 60 ft (18.3 m) apart and each device impacted at the quarter points on the front bumper. Thus, two MASH 2016 test designation no. 3-72 crash tests were conducted at two critical impact angles (CIAs) and are reported herein.

2.2 Evaluation Criteria

Evaluation criteria for full-scale vehicle crash testing are based on three appraisal areas: (1) structural adequacy; (2) occupant risk; and (3) vehicle trajectory after collision. Criteria for structural adequacy are intended to evaluate the ability of the work-zone traffic control device to break away, fracture, or yield in a predictable manner. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Post-impact vehicle trajectory is a measure of the potential

of the vehicle to result in a secondary collision with other vehicles and/or fixed objects, thereby increasing the risk of injury to the occupants of the impacting vehicle and/or other vehicles. These evaluation criteria are summarized in Table 2 and defined in greater detail in MASH 2016. The full-scale vehicle crash test documented herein was conducted and reported in accordance with the procedures provided in MASH 2016.

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

Table 2. MASH 2016 Evaluation Criteria for Work-Zone Traffic Control Devices

<table>
<tr><th>Appraisal area</th><th colspan="4">Evaluation criteria</th></tr>
<tr><td>Structural Adequacy</td><td>B.</td><td colspan="3">The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.</td></tr>
<tr><td rowspan="6">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.</td></tr>
<tr><td>E.</td><td colspan="3">Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver’s vision or otherwise cause the driver to lose control of the vehicle.</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>H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:
<table>
<tr><th colspan="3">Occupant Impact Velocity Limits</th></tr>
<tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr>
<tr><td>Longitudinal</td><td>10 ft/s
(3.0 m/s)</td><td>16 ft/s
(4.9 m/s)</td></tr>
</table></td></tr>
<tr><td>I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:
<table>
<tr><th colspan="3">Occupant Ridedown Acceleration Limits</th></tr>
<tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
</table></td></tr>
<tr><td>Post-Impact Vehicular Response</td><td>N.</td><td colspan="3">Vehicle trajectory behind the test article is acceptable.</td></tr>
</table>

3 DESIGN DETAILS

The test installation consisted of two Type III barricades, as shown in Figures 1 through 8. Photographs of the test installation are shown in Figures 9 and 10. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix A.

Each Type III barricade consisted of three horizontal High Density Polyethylene (HDPE) panels, measuring 96 in. (2,428 mm) in length, with a 48-in. x 30-in. x 0.08-in. (1,219-mm x 762-mm x 2-mm) aluminum sign attached to the top two barricade panels. The barricade panel was targeted to have nominal cross-sectional dimensions of 8 in. (203 mm) tall x 1 in. (25 mm) thick. However, the dimensions vary between manufacturers, and the supplied barricade panel was 8¼ in. (210 mm) x ¾ in. (19 mm). The barricade panels were attached to two 1¾-in. (44-mm) x 14-ga (1.9-mm) thick Perforated Square Steel Tubing (PSST) uprights, which were inserted into two 2-in. (51-mm) x 14-ga (1.9-mm) thick x 6-in. (152-mm) long PSST vertical stubs that were each welded to one of the two legs. The legs were 2-in. (51-mm) x 14-ga (1.9-mm) thick x 60-in. (1,524-mm) long PSST. All PSST used was galvanized ASTM 1011 Grade 55 steel with a minimum yield strength of 60 ksi (414 MPa). A 50-lb (23-kg) sandbag was placed on top of both ends of each leg. A Type A/C warning light was attached to the front of the top barricade panel and to the upright at both upright locations.

Two identical Type III barricades were evaluated. System A was oriented at 90 degrees, end-on to the vehicle. System B was oriented at 0 degrees, or head-on to the vehicle. Initial vehicle impact with System A was to occur with a right quarter-point offset from the centerline of the vehicle and initial vehicle impact with System B was to occur with a left quarter-point offset from the centerline of the vehicle, as shown in Figure 11.

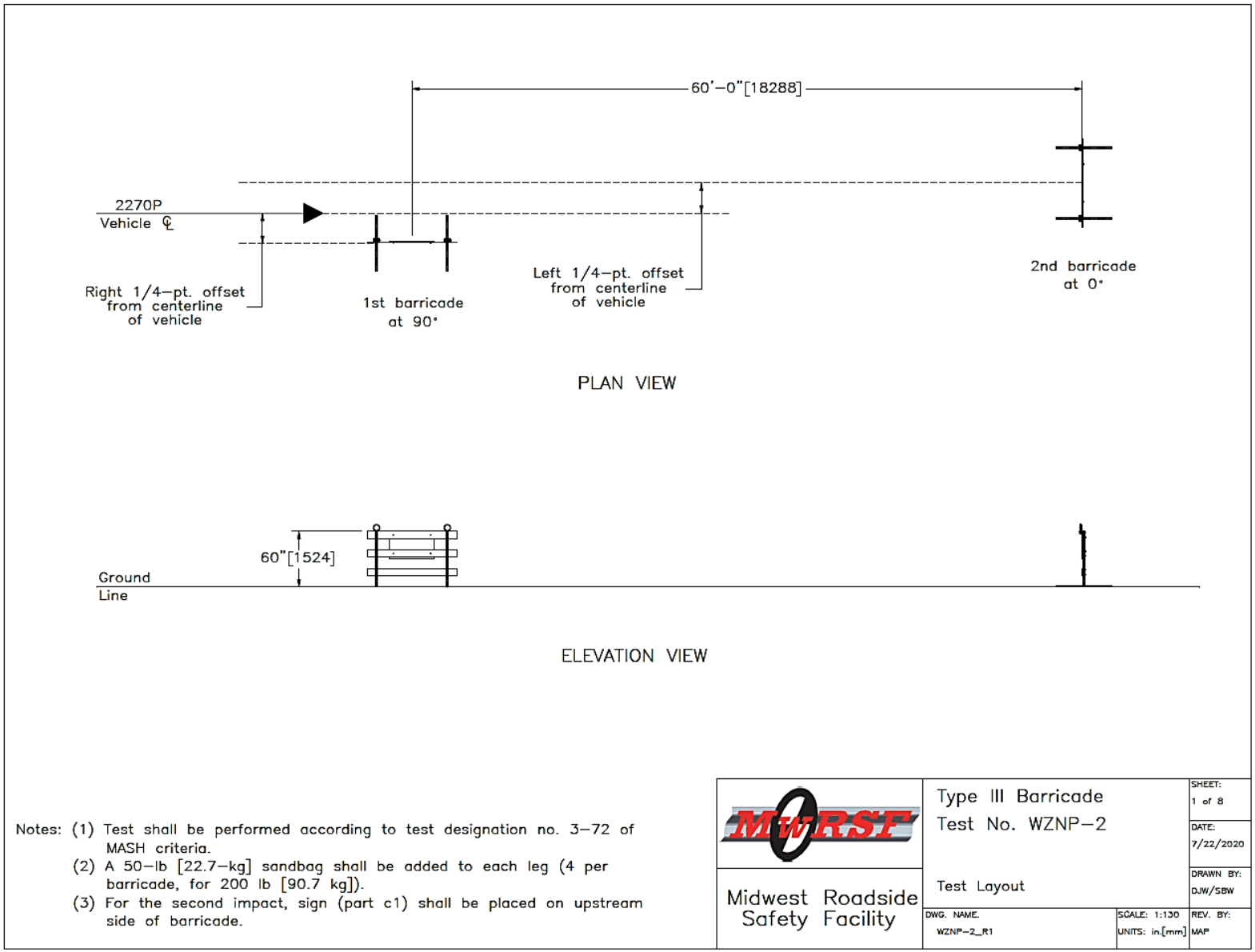


Figure 1. Test Installation Layout, Test No. WZNP-2

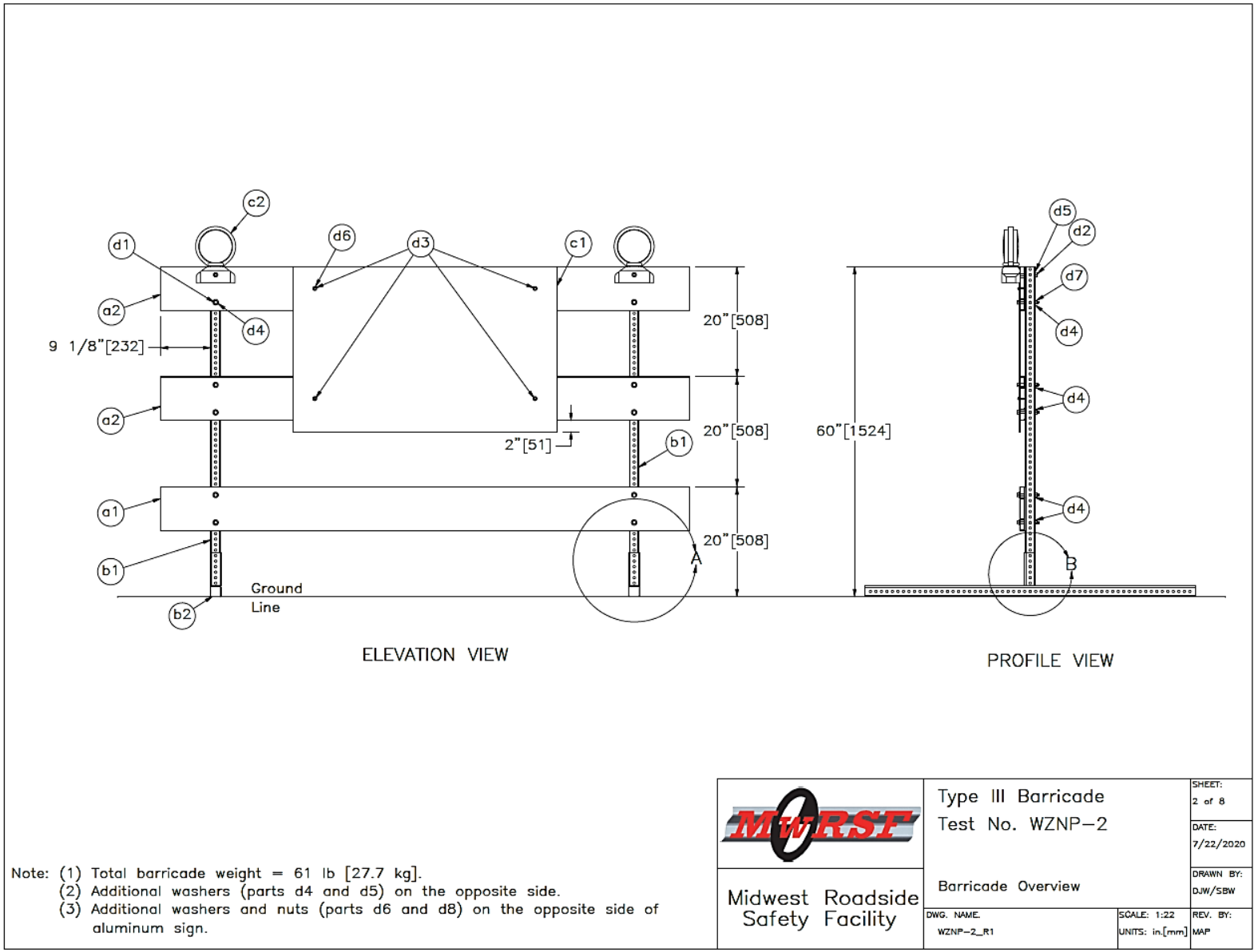


Figure 2. Barricade Overview, Test No. WZNP-2

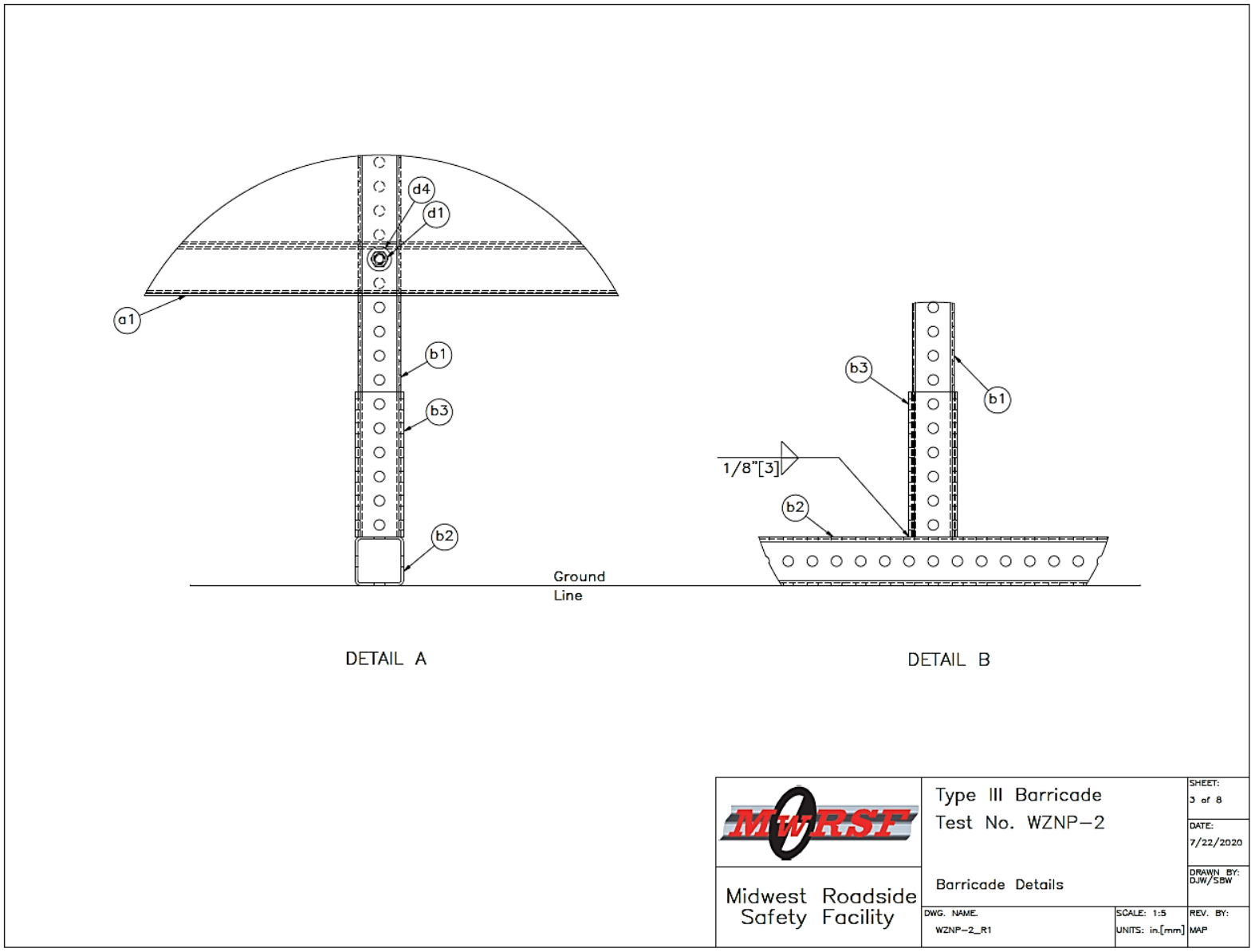


Figure 3. Barricade Details, Test No. WZNP-2

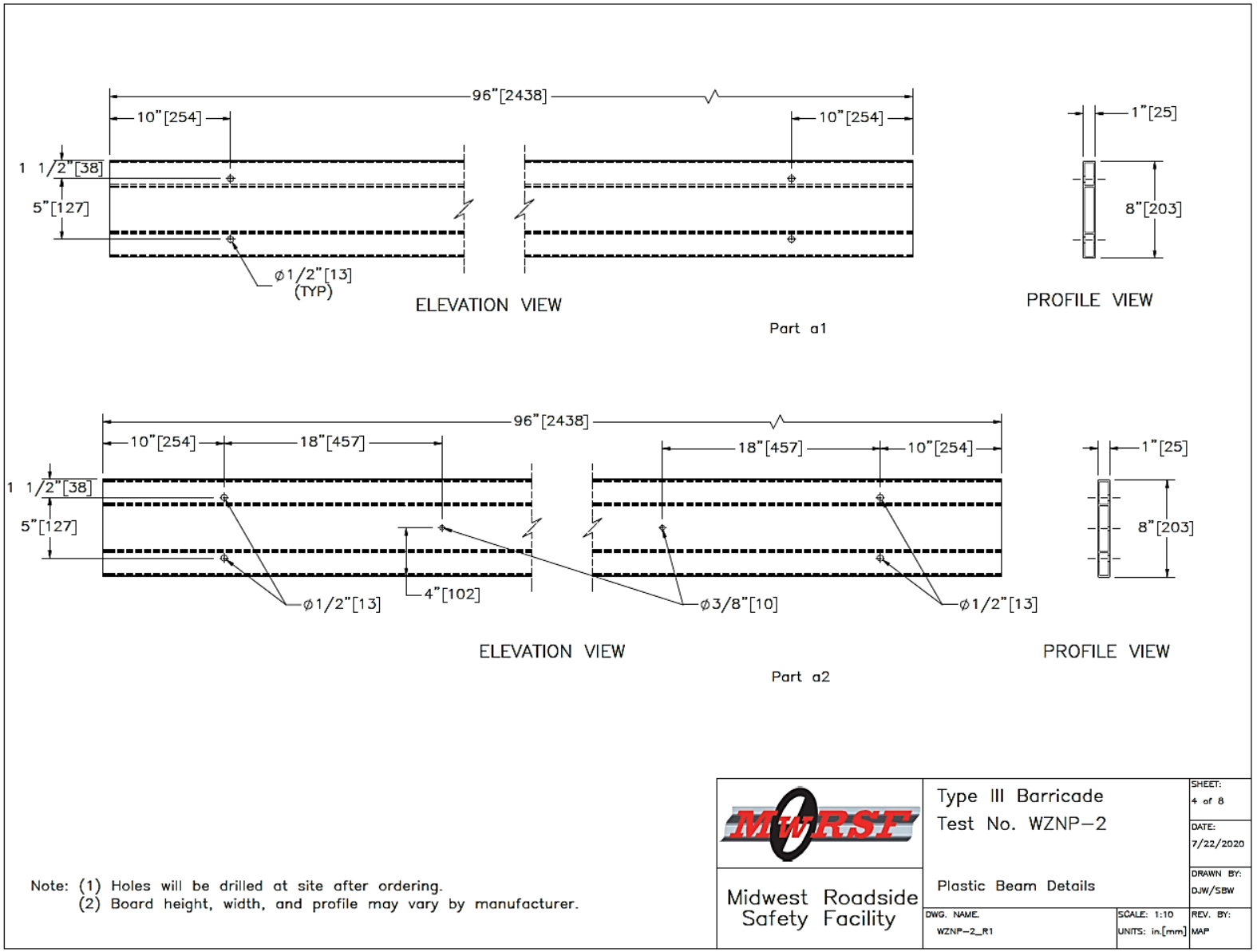


Figure 4. Plastic Beam Details, Test No. WZNP-2

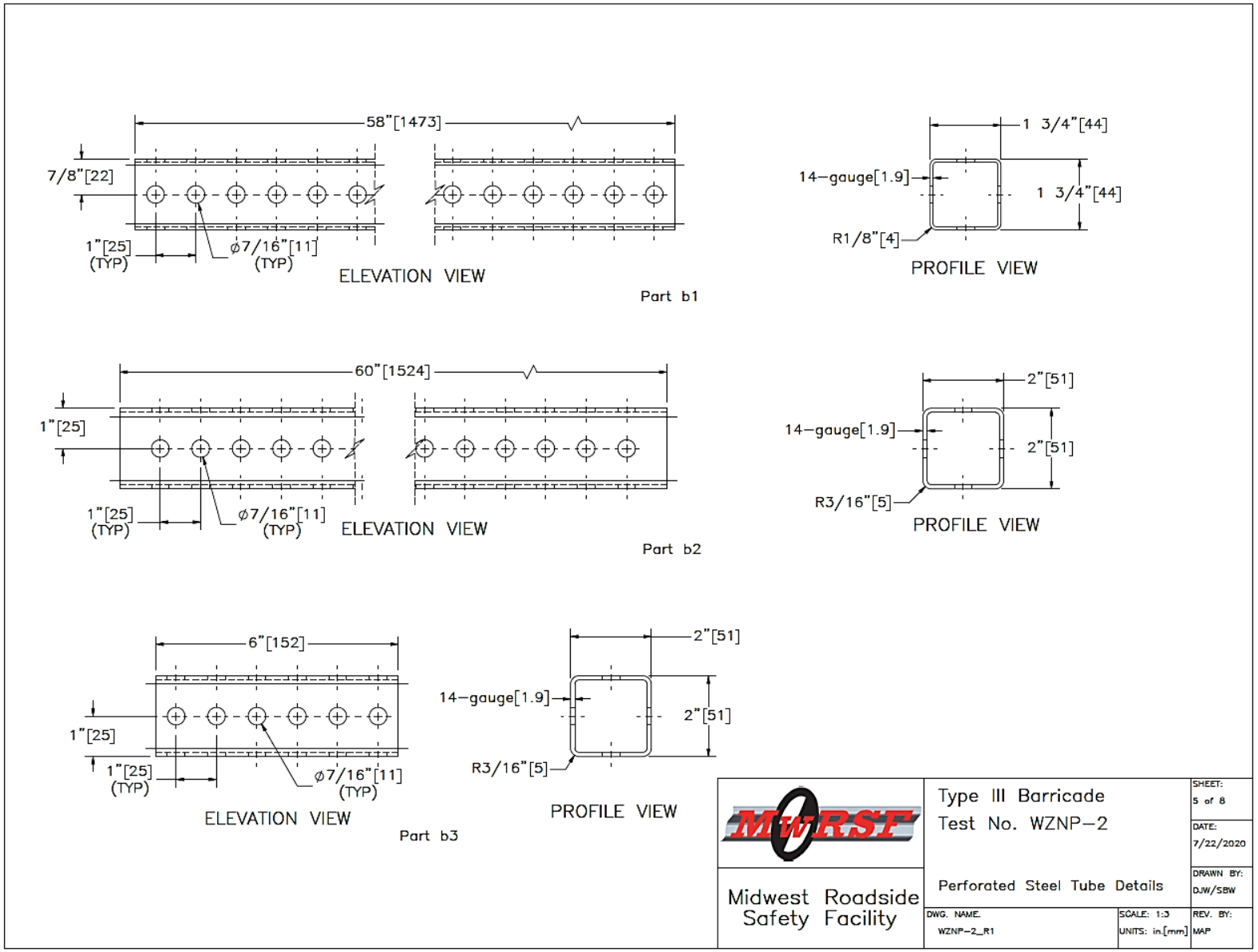


Figure 5. Perforated Steel Tube Details, Test No. WZNP-2

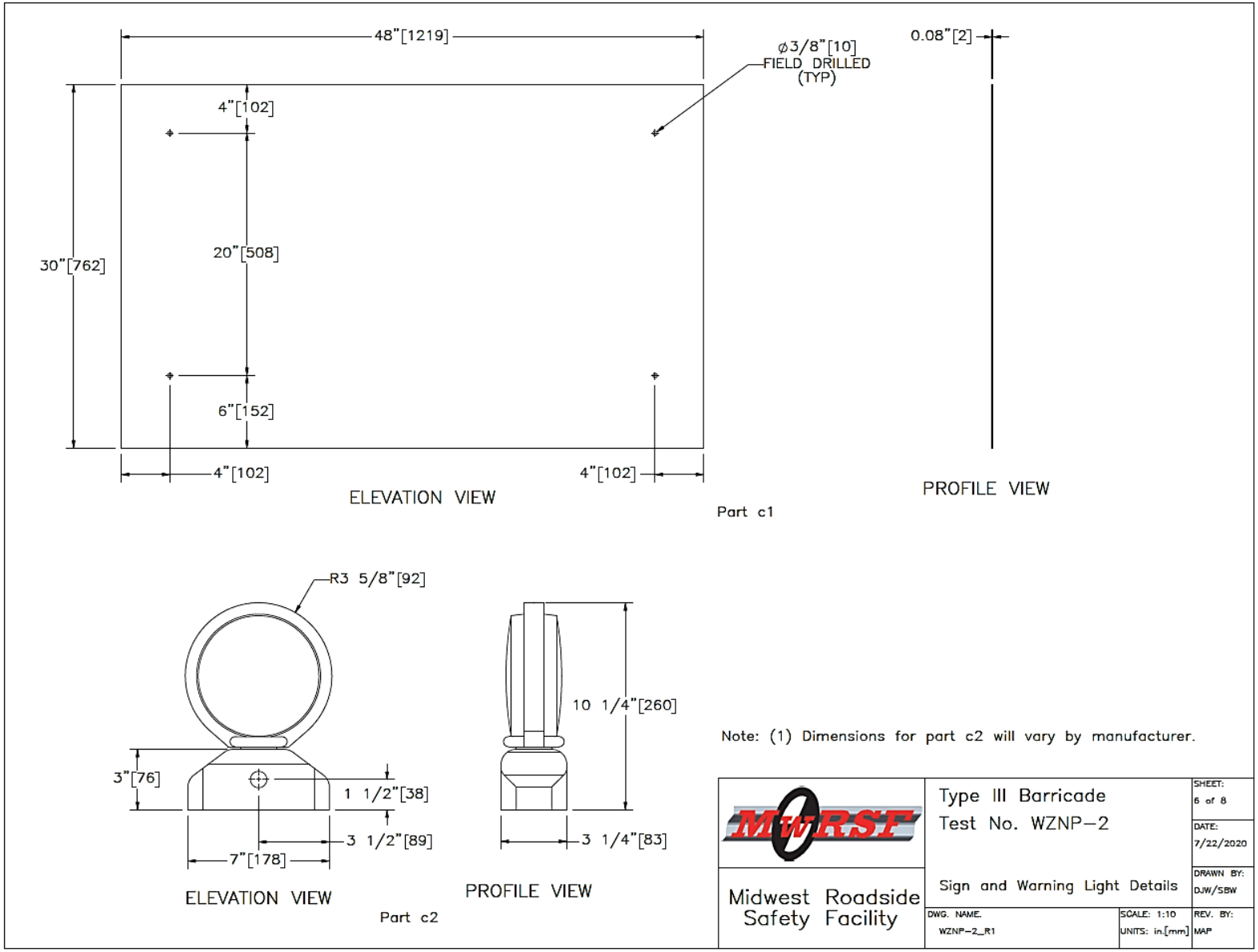


Figure 6. Sign and Warning Light Details, Test No. WZNP-2

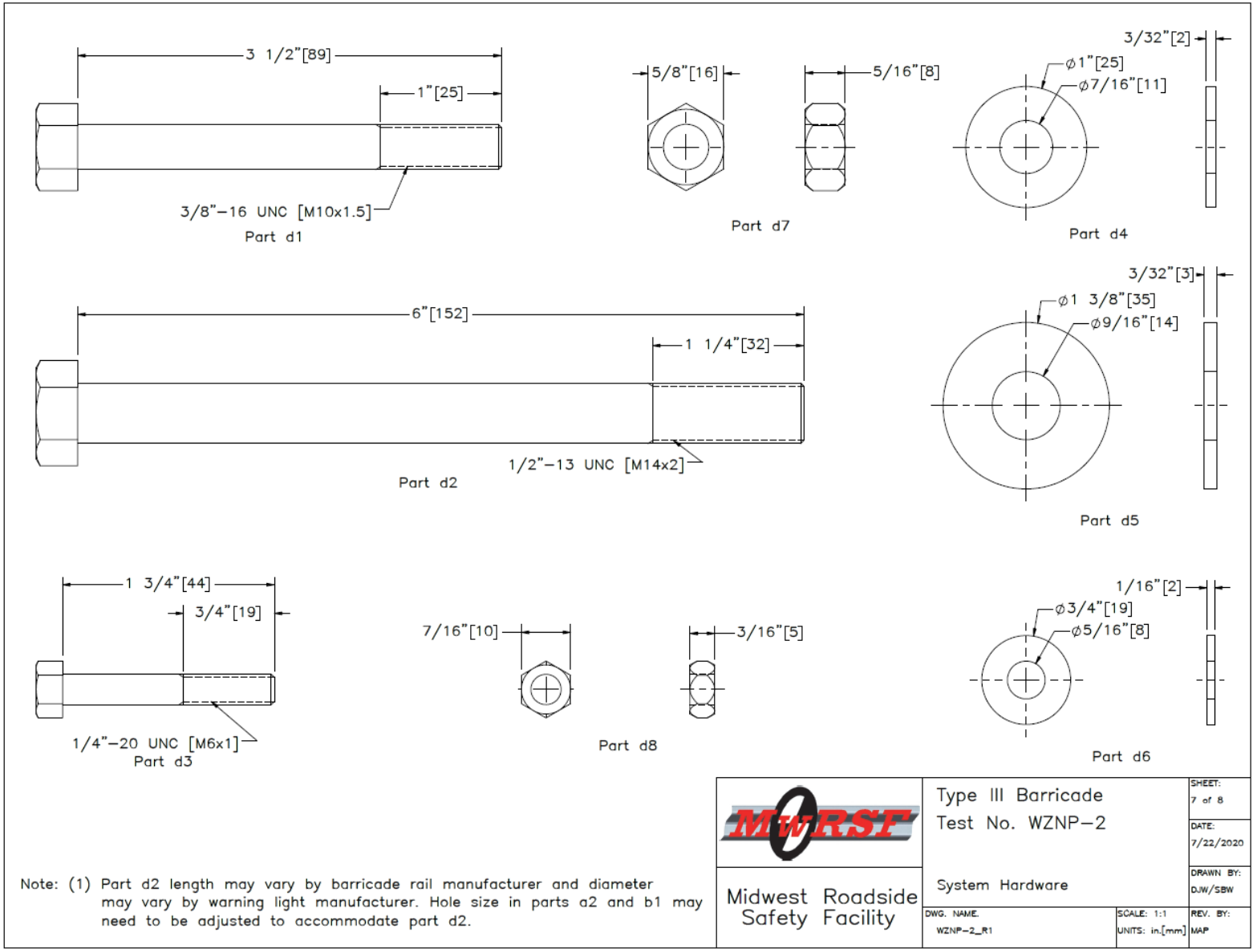


Figure 7. System Hardware, Test No. WZNP-2

Item No.	QTY.	Description	Material Specification	Treatment Specification
a1	2	Plastic Panel, 96" [2,438] Long	High Density Polyethylene	–
a2	4	Plastic Panel, 96" [2,438] Long	High Density Polyethylene	–
b1	4	1 3/4"x1 3/4"x14–gauge [44x44x1.9], 58" [1,473] Long Perforated Square Tubing	ASTM 1011 Gr. 55 Min. yield 60 ksi [414 MPa]	ASTM A653–G90 or AASHTO M–120
b2	4	2"x2"x14–gauge [51x51x1.9], 60" [1,524] Long Perforated Square Tubing	ASTM 1011 Gr. 55 Min. yield 60 ksi [414 MPa]	ASTM A653–G90 or AASHTO M–120
b3	4	2"x2"x14–gauge [51x51x1.9], 6" [152] Long Perforated Square Tubing	ASTM 1011 Gr. 55 Min. yield 60 ksi [414 MPa]	ASTM A653–G90 or AASHTO M–120
c1	2	48"x30"x0.08" [1,219x762x2] Sign with Reflective Sheeting	Aluminum Alloy 5052 or similar	–
c2	4	Warning Light (Type A or C)	As Supplied	–
d1	20	3/8"–16 UNC [M10x1.5], 3 1/2" [89] Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	Fe/Zn 3AN per ASTM F1941
d2	4	1/2"–13 UNC [M14x2], 6" [152] Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	Fe/Zn 3AN per ASTM F1941
d3	8	1/4"–20 UNC [M6x1], 1 3/4" [44] Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	Fe/Zn 3AN per ASTM F1941
d4	40	3/8" [10] Dia. Plain USS Washer	Low Carbon Steel	Fe/Zn 3AN per ASTM F1941
d5	4	1/2" [13] Dia. Plain USS Washer	Low Carbon Steel	Fe/Zn 3AN per ASTM F1941
d6	16	1/4" [6] Dia. Plain USS Washer	Low Carbon Steel	Fe/Zn 3AN per ASTM F1941
d7	20	3/8"–16 UNC [M10x1.5] Lock Nut	SAE J995 Gr. 2 or equivalent	Fe/Zn 3AN per ASTM F1941
d8	8	1/4"–20 UNC [M6x1] Lock Nut	SAE J995 Gr. 2 or equivalent	Fe/Zn 3AN per ASTM F1941

Note: (1) Part c1 shall have a reflective sheeting.
(2) Parts a1 & a2 will have orange and white striped reflective sheeting on at least one side (sign panel side).

MwRSF

Midwest Roadside Safety Facility

Type III Barricade
Test No. WZNP–2

Bill of Materials

SHEET: 8 of 8
DATE: 7/22/2020
DRAWN BY: DJW/SBW
REV. BY: MAP
DWG. NAME. WZNP–2_R1
SCALE: None
UNITS: in.[mm]

Figure 8. Bill of Materials, Test No. WZNP-2

Figure 9. Test Installation, Test No. WZNP-2

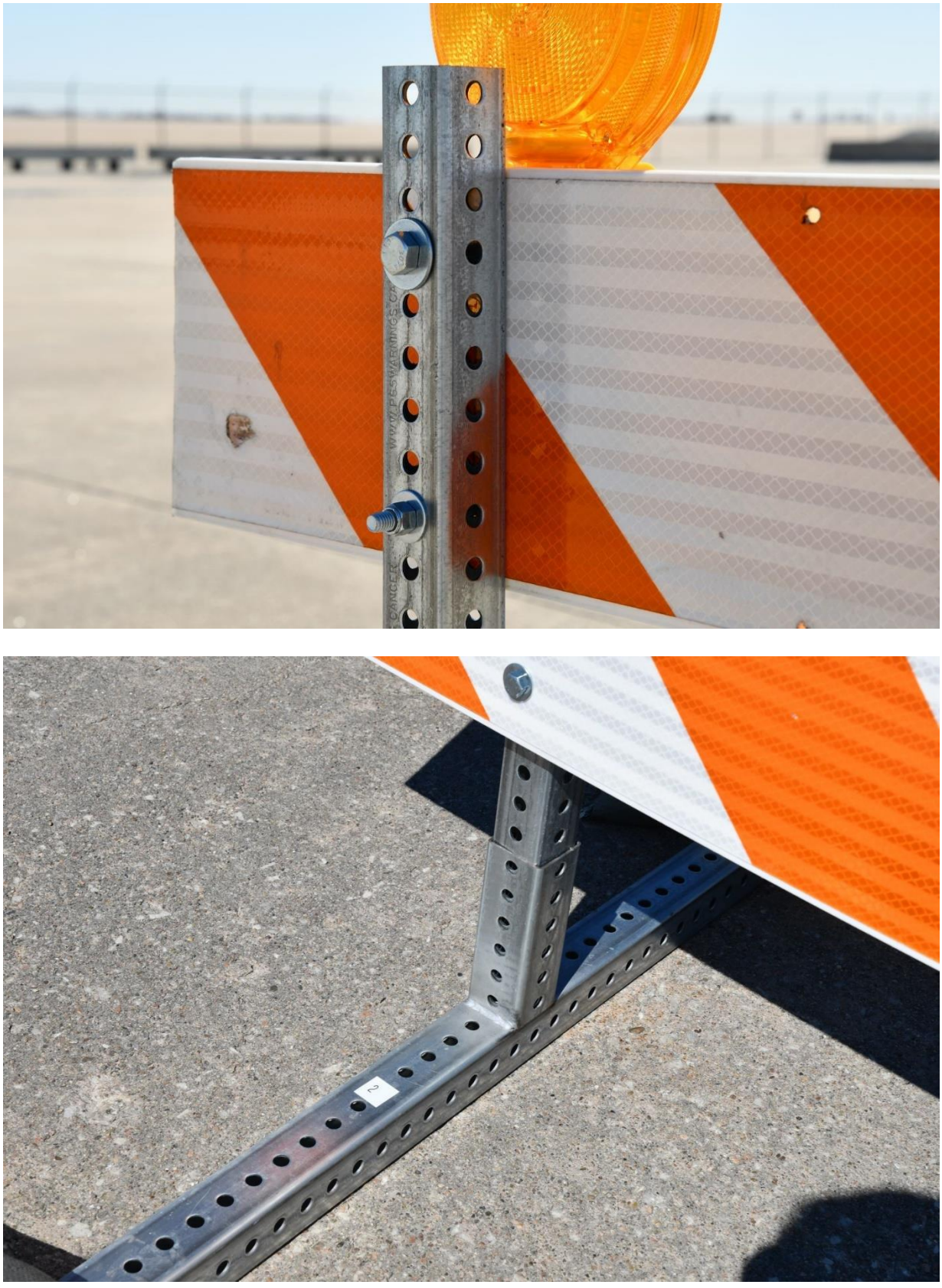


Figure 10. Test Installation, Test No. WZNP-2

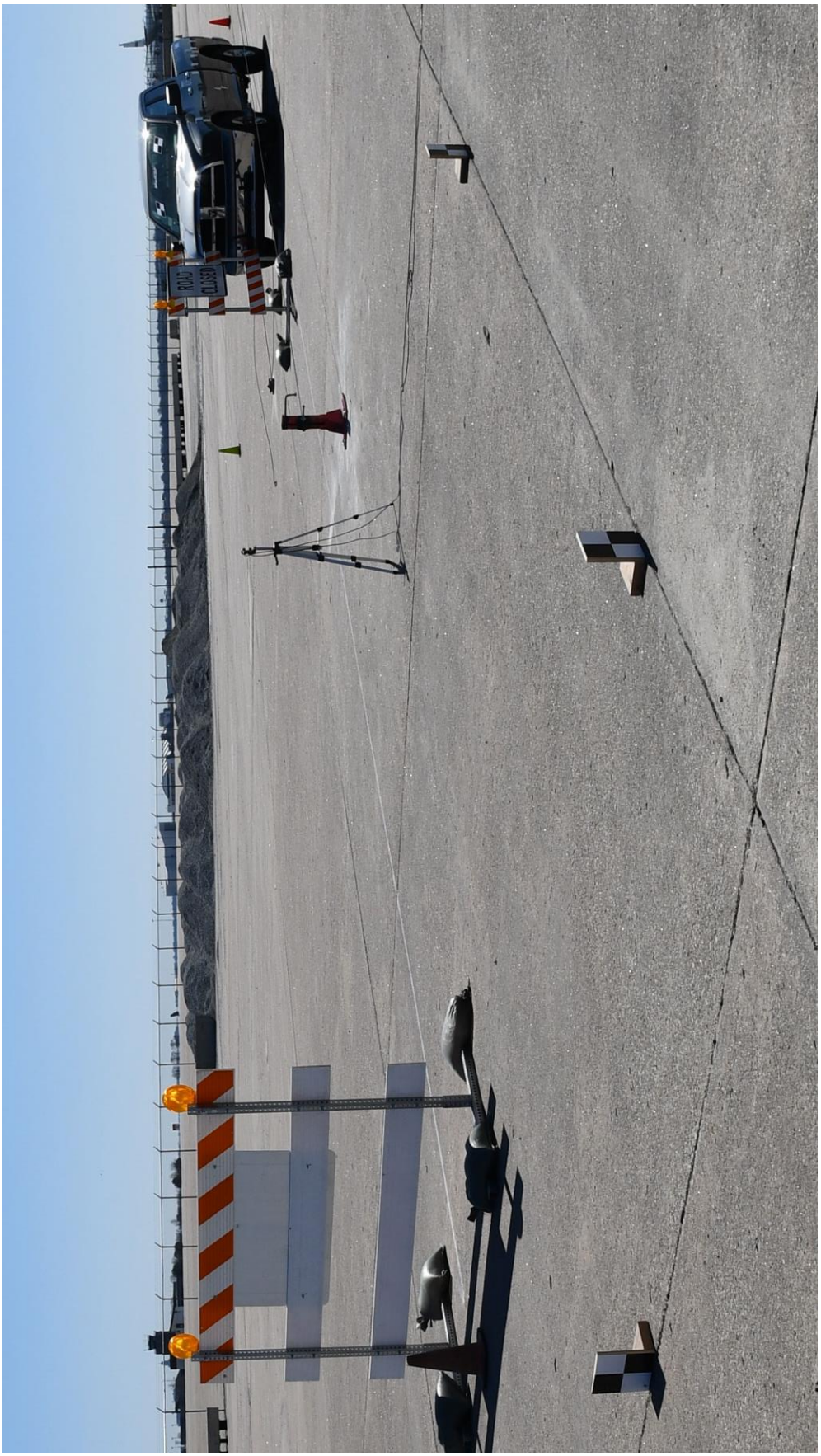


Figure 11. Test Impact Point, Test No. WZNP-2

4 TEST CONDITIONS

4.1 Test Facility

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

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 first barricade. 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 left-front wheel and the guide cable, was sheared off before impact with the second 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 Vehicle

For test no. WZNP-2 a 2011 Dodge Ram 1500 quad cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,105 lb (2,316 kg), 5,001 lb (2,268 kg), and 5,165 lb (2,343 kg), respectively. MASH recommends using test vehicles within 6 model years on the day the test is conducted. Additionally, vehicles within 6 model years of the award date of the research project, which was in 2015, were allowed at the time. Thus, a test vehicle older than 6 years from the test date was utilized, and all dimensions and properties of the test vehicle met the requirements in MASH. The test vehicle is shown in Figures 12 and 13, and vehicle dimensions are shown in Figure 14.

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [7] 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 location of the final c.g. is shown in Figures 14 and 15. Data used to calculate the location of the c.g. and ballast information are shown in Appendix B.

Square, black- and white-checkered targets were placed on the vehicle for reference to be viewed from the high-speed digital video cameras and aid in the video analysis, as shown in Figure 15. Round, checkered targets were placed at the c.g. on the left-side door, the right-side door, and the roof of the vehicle.

Figure 12. Test Vehicle, Test No. WZNP-2

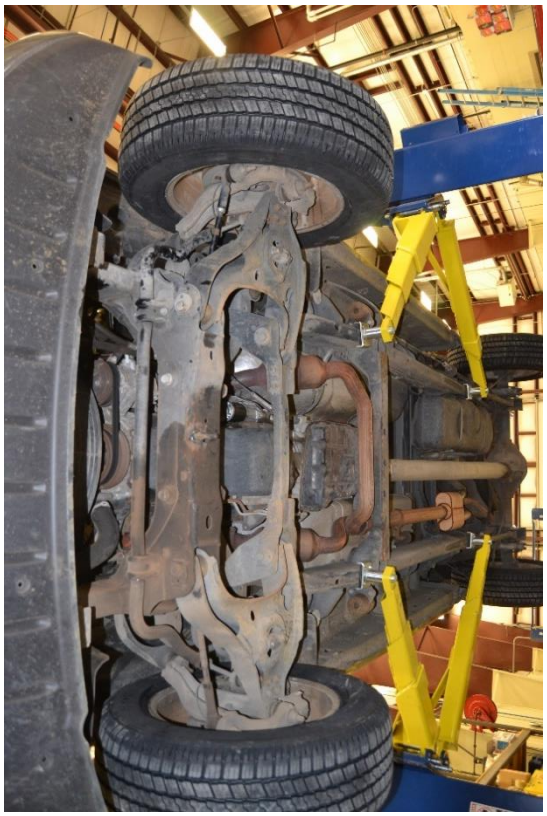
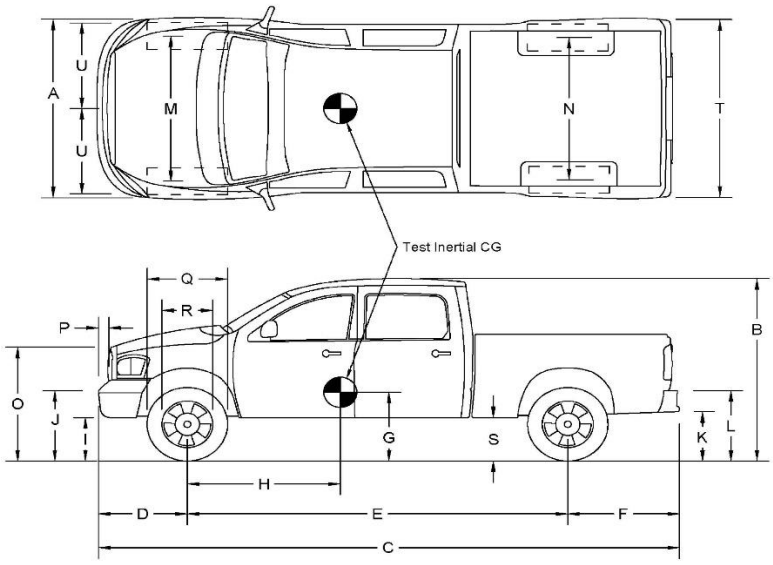


Figure 13. Test Vehicle's Interior Floorboards and Undercarriage

Date:	3/21/2019	**Test Name:**	WZNP-2	**VIN No:**	1D7RB1GP6BS634520
Year:	2011	**Make:**	Dodge	**Model:**	Ram 1500
Tire Size:	P265/70R17	**Tire Inflation Pressure:**	40 psi	**Odometer:**	262517



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

A:	77 1/8 (1959) 78±2 (1950±50)	**B:**	74 1/4 (1886)
C:	229 1/2 (5829) 237±13 (6020±325)	**D:**	38 3/8 (975) 39±3 (1000±75)
E:	140 3/4 (3575) 148±12 (3760±300)	**F:**	48 1/4 (1226)
G:	28 5/16 (719) min: 28 (710)	**H:**	61 9/16 (1564) 63±4 (1575±100)
I:	10 1/2 (267)	**J:**	27 (686)
K:	20 3/8 (518)	**L:**	29 7/8 (759)
M:	67 7/8 (1724) 67±1.5 (1700±38)	**N:**	67 3/8 (1711) 67±1.5 (1700±38)
O:	43 7/8 (1114) 43±4 (1100±75)	**P:**	4 1/2 (114)
Q:	31 1/4 (794)	**R:**	18 1/2 (470)
S:	13 7/8 (352)	**T:**	77 1/4 (1962)

U (impact width): 38 4/7 (979)

Mass Distribution - lb (kg)

Gross Static	**LF**	1422 (645)	**RF**	1485 (674)	
	LR	1131 (513)	**RR**	1127 (511)	

Weights lb (kg)	**Curb**	**Test Inertial**	**Gross Static**
W-front	2875 (1304)	2814 (1276)	2907 (1319)
W-rear	2230 (1012)	2187 (992)	2258 (1024)
W-total	5105 (2316)	5001 (2268) 5000±110 (2270±50)	5165 (2343) 5165±110 (2343±50)

Wheel Center Height (Front):	15 1/4 (387)
Wheel Center Height (Rear):	15 1/4 (387)
Wheel Well Clearance (Front):	35 1/4 (895)
Wheel Well Clearance (Rear):	37 7/8 (962)
Bottom Frame Height (Front):	9 1/2 (241)
Bottom Frame Height (Rear):	10 3/8 (264)
Engine Type:	Gasoline
Engine Size:	4.7L V8
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Quad Cab
Bed Length:	76"

GVWR Ratings - lb

Front	3700
Rear	3900
Total	6700

Surrogate Occupant Data

Type:	Hybrid II
Mass:	164 lb
Seat Position:	Right/Passenger

Note any damage prior to test: Right front bumper cover is deformed slightly.

Figure 14. Vehicle Dimensions, Test No. WZNP-2

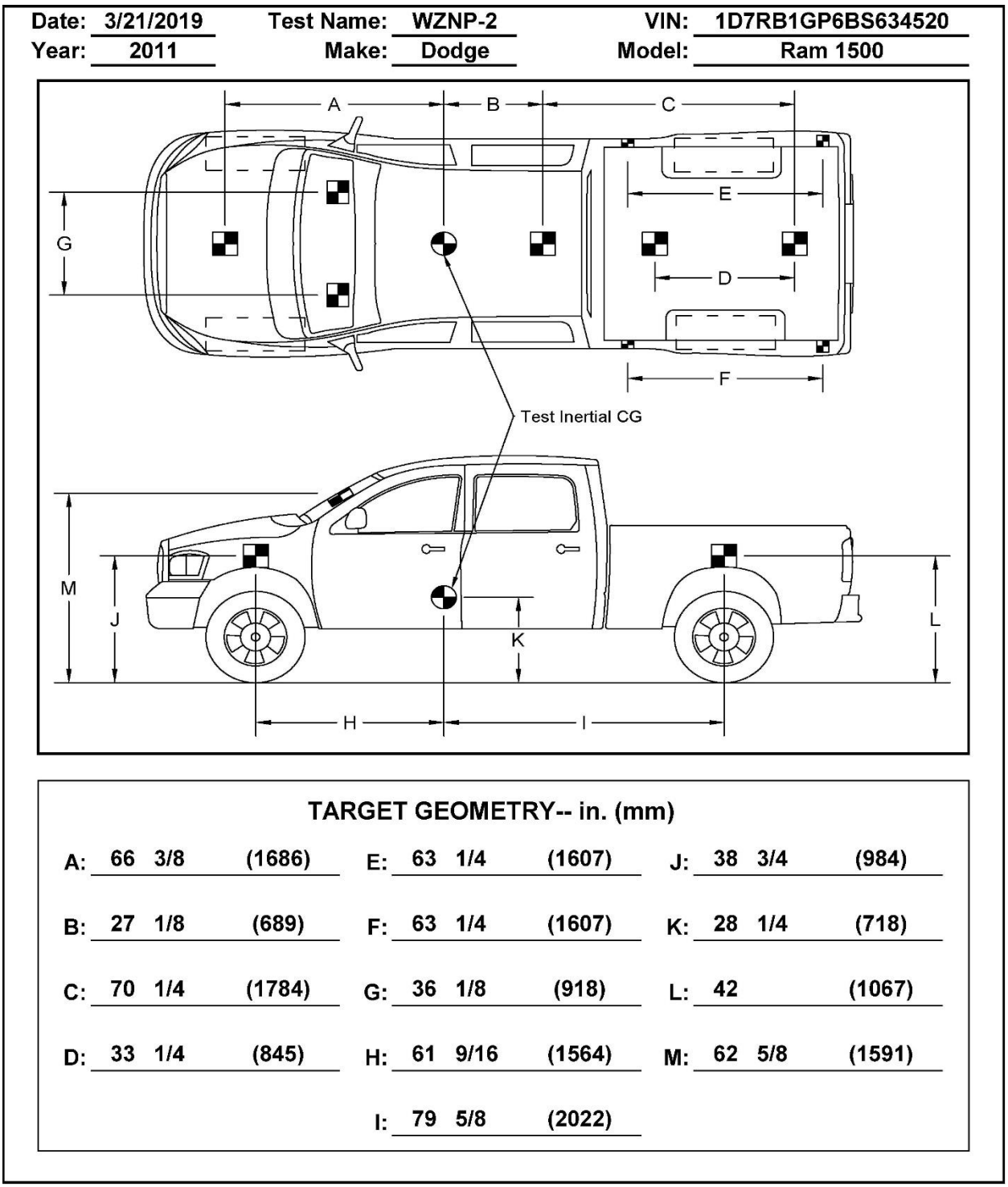


Figure 15. Target Geometry, Test No. WZNP-2

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

4.4 Simulated Occupant

For test no. WZNP-2, a Hybrid II 50th-Percentile, Adult Male Dummy, equipped with clothing and footwear, was placed in the right-front seat of the test vehicle with the seat belt fastened. The dummy had a final weight of 164 lb (74 kg). As recommended by MASH 2016, the dummy was not included in calculating the c.g. location.

4.5 Data Acquisition Systems

4.5.1 Accelerometers

Two environmental shock and vibration sensor/recorder systems were used to measure the accelerations in the longitudinal, lateral, and vertical directions. Both accelerometer systems were mounted near the c.g. of the test vehicle. The electronic accelerometer data obtained in dynamic testing was filtered using SAE Class 60 and SAE Class 180 Butterworth filters conforming to the SAE J211/1 specifications [8].

The two systems, the SLICE-1 and SLICE-2 units, were modular data acquisition systems manufactured by Diversified Technical Systems, Inc. (DTS) of Seal Beach, California. The SLICE-2 unit was designated as the primary system. The acceleration sensors were mounted inside the bodies of custom-built, SLICE 6DX event data recorders and recorded data at 10,000 Hz to the onboard microprocessor. 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.

4.5.2 Rate Transducers

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

4.5.3 Retroreflective Optic Speed Trap

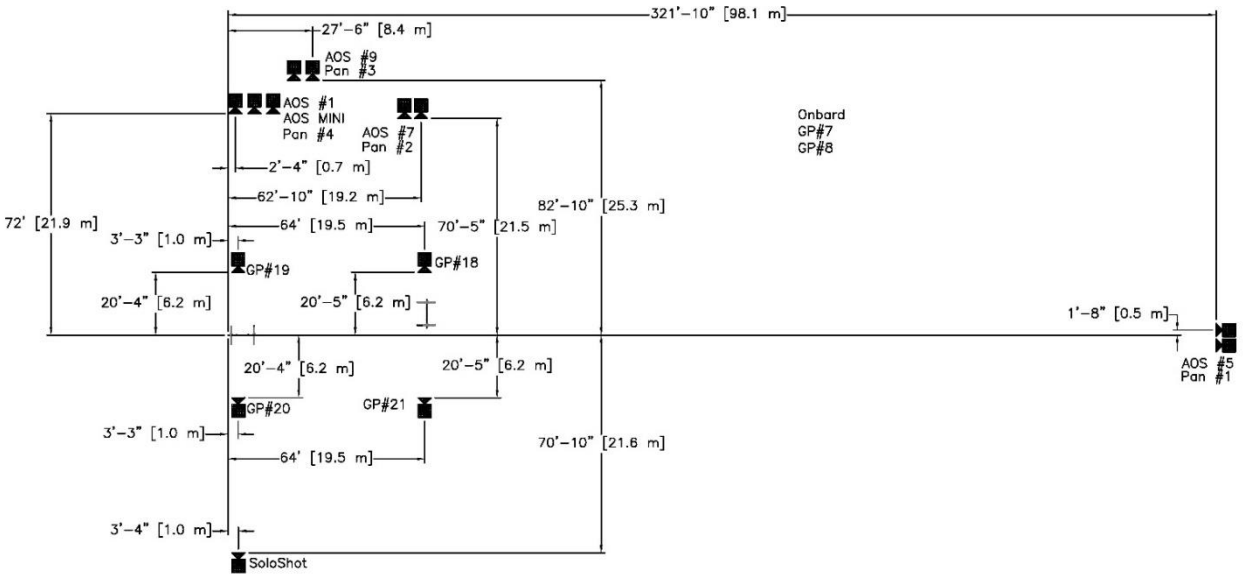
The retroreflective optic speed trap was used to determine the speed of the test vehicle before impact. Four retroreflective targets, spaced at approximately 18-in. (457-mm) intervals,

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

4.5.4 Digital Photography

Five AOS high-speed digital video cameras, six GoPro digital video cameras, four Panasonic digital video cameras, and one SoloShot digital video camera were utilized to film test no. WZNP-2. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 16.

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



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-1	AOS Vitcam CTM	500	KOWA 25 mm	-
AOS-5	AOS X-PRI Gigabit	500	100 mm	-
AOS-7	AOS X-PRI Gigabit	500	Fujinon 50 mm	-
AOS-9	AOS TRI-VIT	500	KOWA 12 mm	-
AOS MINI	AOS Smize	500	Fujinon 35mm	-
GP-7	GoPro Hero 4	120		
GP-8	GoPro Hero 4	120		
GP-18	GoPro Hero 6	240		
GP-19	GoPro Hero 6	240		
GP-20	GoPro Hero 6	240		
GP-21	GoPro Hero 6	240		
PAN-1	Panasonic HC-V770	60		
PAN-2	Panasonic HC-V770	60		
PAN-3	Panasonic HC-V770	60		
PAN-4	Panasonic HC-V770	60		
SoloShot	SoloShot	120		

Figure 16. Camera Locations, Speeds, and Lens Settings, Test No. WZNP-2

5 FULL-SCALE CRASH TEST NO. WZNP-2

5.1 Weather Conditions

Test no. WZNP-2 was conducted on March 21, 2019 at approximately 3:00 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 3.

Table 3. Weather Conditions, Test No. WZNP-2

Temperature	59° F
Humidity	38 %
Wind Speed	7 mph
Wind Direction	Variable
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.34 in.
Previous 7-Day Precipitation	0.40 in.

5.2 Test Description

MwRSF has developed a procedure for testing multiple work-zone traffic control devices in one test run. However, in order to have two devices impacted in one test run using the previously established method, it was necessary to align the systems with the quarter points of the vehicle to distinguish damage between the two systems. Additionally, MASH 2016 does not provide specific guidance on how to align the test vehicle and test article. Therefore, impacting the centerline of each barricade with a quarter point of the test vehicle seemed adequate.

During test no. WZNP-2, initial vehicle impact with System A was to occur with a right quarter-point offset from the centerline of the vehicle, and initial vehicle impact with System B was to occur with a left quarter-point offset from the centerline of the vehicle, as shown in Figure 17. The centerlines of both Systems A and B impacted the vehicle at the right and left quarter-point offsets from the centerline of the vehicle, respectively. The 5,001-lb (2,268-kg) 2011 Dodge Ram 1500 quad cab pickup truck impacted System A at a speed of 64.7 mph (104.2 km/h). The pickup truck impacted System B 0.694 seconds after the initial impact with System A at a speed of 62.6 mph (100.8 km/h). Note, the HDPE panel from System A impacted the outer edge of the middle panel on System B 0.002 seconds before the vehicle impacted System B as System A was sliding off to the right side of the pickup truck. The contact lasted approximately 0.004 seconds. However, this contact occurred outside of the vehicle contact area on System B. The System B uprights and base did not move due to this contact. Thus, the debris from System A did not affect the evaluation of System B. The vehicle came to rest 277 ft – 6 in. (84.6 m) downstream after brakes were applied.

A detailed description of the sequential impact events is contained in Tables 4 and 5. Sequential photographs are shown in Figure 18. Documentary photographs of the crash test are shown in Figures 20 through 22. The vehicle trajectory and final position are shown in Figure 23.

Figure 17. Impact Location, Test No. WZNP-2

Table 4. Sequential Description of Impact Events, Test No. WZNP-2, System A

TIME (sec)	EVENT
0.000	Vehicle's front bumper contacted System A's bottom panel.
0.002	Vehicle's grille contacted System A's middle panel.
0.010	Vehicle's front bumper contacted System A's upstream support, and System A deflected downstream.
0.012	Vehicle's hood contacted System A's upstream support, and System A's upstream support bent upstream.
0.014	System A's middle panel deformed.
0.016	Vehicle's front bumper deformed.
0.018	System A's top panel contacted vehicle's hood, and bottom panel of System A deformed.
0.020	System A's top panel deformed.
0.022	System A's upstream leg detached, and downstream support rotated downstream.
0.028	System A's sign deformed from contact with vehicle's grille.
0.032	Vehicle's hood contacted System A's sign.
0.054	System A's middle panel detached from upstream support.
0.080	System A's downstream leg detached, and System A became airborne.
0.164	Bottom panel of System A contacted ground.

Table 5. Sequential Description of Impact Events, Test No. WZNP-2, System B

TIME (sec)	EVENT
-0.002	System A's middle panel contacted System B's middle panel, and System B's middle panel slightly deformed.
0.000	Vehicle's front bumper contacted System B's bottom panel; vehicle's front bumper contacted System B's right support.
0.002	Vehicle's hood contacted System B's sign.
0.004	Vehicle's grille contacted System B's middle panel, System B's right support bent upstream, and System B's bottom panel deformed.
0.006	Vehicle's hood deformed, and System B's top panel and sign deformed.
0.012	Vehicle's left headlight contacted System B's sign.
0.014	System B's right support deflected left.
0.016	System B's left leg deflected downstream.
0.022	System A lost contact with vehicle and became airborne.
0.030	System B's right leg detached.
0.056	System B's left support contacted vehicle's left fender.
0.058	Vehicle's left fender deformed.
0.072	System B's left support snagged on left-front fender deformations.
0.106	System B's left leg detached, and System B became airborne.
0.114	System B's left support contacted vehicle's left-side mirror.
0.228	System A contacted ground target.
0.358	Vehicle's right headlight became disengaged.
0.412	System B contacted ground.
0.440	System B's left light detached.
0.448	System B's middle panel detached from left support.
1.210	Vehicle yawed clockwise.


0.000 sec

0.000 sec


0.250 sec

0.050 sec


0.450 sec


0.100 sec

0.700 sec


0.150 sec

0.750 sec


0.200 sec


1.100 sec


0.250 sec

Figure 18. Sequential Photographs, Test No. WZNP-2

Figure 19. Documentary Photographs, Test No. WZNP-2

Figure 20. Additional Documentary Photographs, Test No. WZNP-2

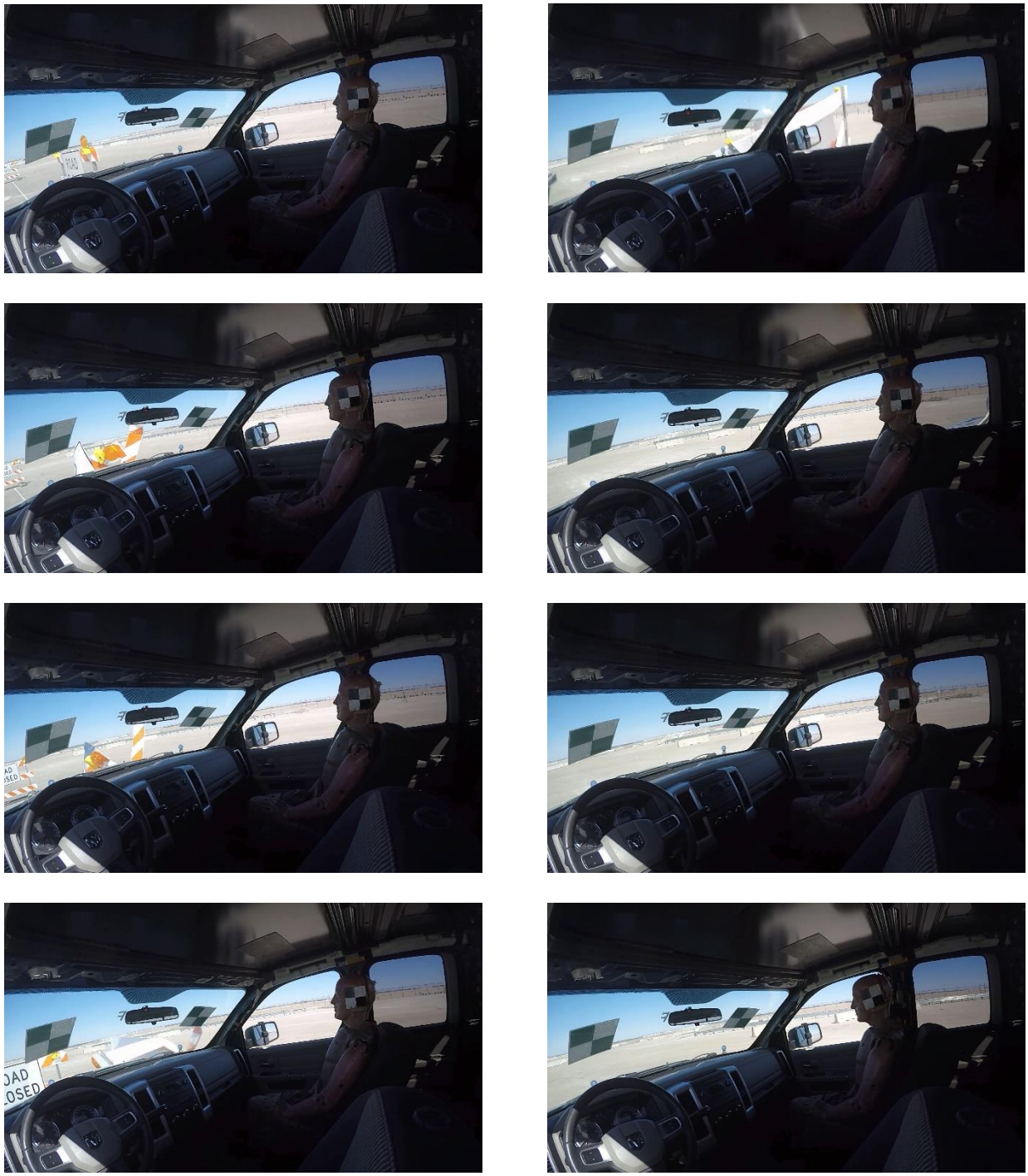


Figure 21. Additional Documentary Photographs, Test No. WZNP-2

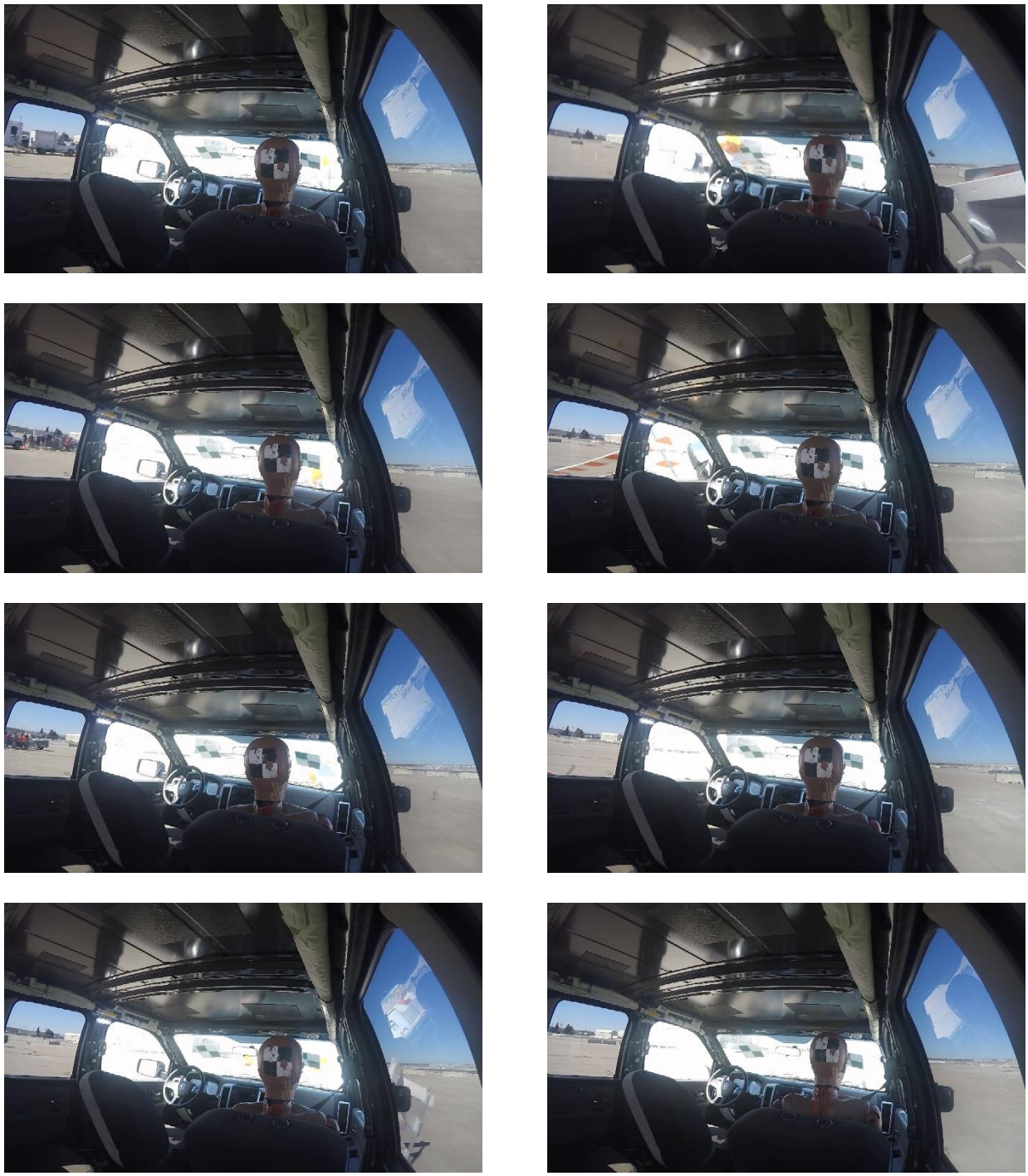


Figure 22. Additional Documentary Photographs, Test No. WZNP-2

Figure 23. Vehicle Trajectory and Final Position, Test No. WZNP-2

5.3 System Damage

Damage to the barricades was extensive, as shown in Figures 24 through 28. Barricade damage consisted of punctured sandbags, bent uprights and legs, bent and torn barricade panels, and bolts pulled through the barricade panels. The vehicle readily disengaged both barricades from their bases.

System A was facing perpendicular to the direction of travel. The centerline of the system was aligned to the right quarter-point and offset from the centerline of the vehicle. The two uprights disengaged from each leg upon impact. The upstream left and downstream left sandbags were torn open. The upstream end of the middle barricade panel tore. The upstream upright was bent inward toward the center of the sign. The bottom barricade panel was deformed. Three bolts were partially pulled out of the bottom barricade panel. Two bolts were pulled out of the middle barricade panel, and one was partially pulled out. Three bolts were pulled out of the aluminum sign.

System B was oriented to face the direction of travel. The centerline of the system was aligned to the left quarter-point and offset from the centerline of the vehicle. The downstream right and the downstream left sandbags were torn open. The upstream leg was deformed. The right upright was bent 17 in. (432 mm) from the bottom. The aluminum sign was bent. Both warning lights were rotated, and the left light lens disengaged from the warning light system. One bolt was pulled out of the bottom barricade panel, and three bolts were partially pulled out. The two left side bolts on the middle barricade panel were pulled out. The aluminum sign bolts were partially pulled out of the middle barricade panel and thoroughly pulled out of the top barricade panel.

Figure 24. Overall System A and System B Damage, Test No. WZNP-2

Figure 25. System A Damage, Test No. WZNP-2

Figure 26. Additional System A Damage, Test No. WZNP-2

Figure 27. System B Damage, Test No. WZNP-2

Figure 28. Additional System B Damage, Test No. WZNP-2

5.4 Vehicle Damage

The damage to the vehicle was minimal, as shown in Figures 29 through 31. The maximum occupant compartment intrusions are listed in Table 6 along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. Note that none of the established MASH 2016 deformation limits were violated. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix C.

The majority of the damage was concentrated on the right-front corner where the vehicle impacted System A. The torn piece of the middle panel from System A was stuck inside the right side of the grille. A small dent was found on the left side of the front bumper. A vertical crush line extending from the bottom of the bumper to the top of the hood was found on the vehicle. The right headlight was disengaged from the vehicle. A dent was found on the left-front fender. The left mirror was partially disengaged from the vehicle. The roof, remaining window glass, and undercarriage remained undamaged.

Figure 29. Vehicle Damage, Test No. WZNP-2

Figure 30. Vehicle Damage Details, Test No. WZNP-2

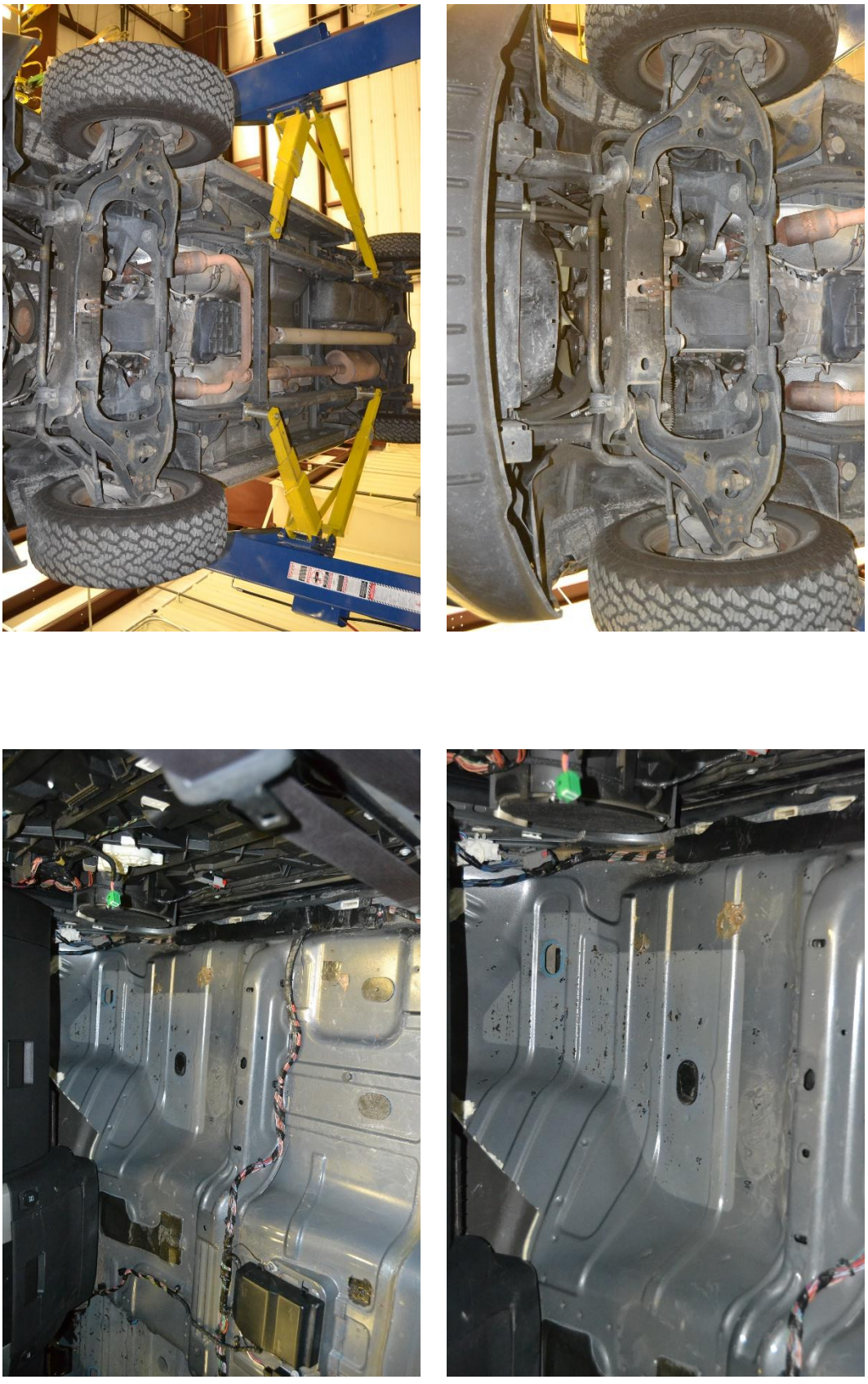


Figure 31. Occupant Compartment and Undercarriage Damage, Test No. WZNP-2

Table 6. Maximum Occupant Compartment Intrusion by Location, Test No. WZNP-2

LOCATION	MAXIMUM INTRUSION in. (mm)	MASH 2016 ALLOWABLE INTRUSION in. (mm)
Wheel Well & Toe Pan	0.2 (5.1)	≤ 9 (229)
Floor Pan & Transmission Tunnel	0.1 (2.5)	≤ 12 (305)
A-Pillar	0.6 (15.2)	≤ 5 (127)
B-Pillar	0.6 (15.2)	≤ 5 (127)
A-Pillar (Lateral)	0.3 (7.6)	≤ 3 (76)
B-Pillars (Lateral)	0.3 (7.6)	≤ 3 (76)
Side Front Panel (in Front of A-Pillar)	1.2 (30.5)	≤ 12 (305)
Side Door (Above Seat)	0.2 (5.1)	≤ 9 (229)
Side Door (Below Seat)	0.1 (2.5)	≤ 12 (305)
Roof	0.3 (7.6)	≤ 4 (102)
Windshield	0.0 (0)	≤ 3 (76)
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	1.5 (38.1)	N/A

Note: Negative values denote outward deformation
N/A – Not applicable

5.5 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, for System A and System B are shown in Table 7. Note that lateral and longitudinal occupant displacements do not meet the required distances specified in MASH. Therefore, the ORA values are not applicable, and the OIV numbers are determined from the change in velocity at the time where the vehicle clears the footing according to MASH 2016. The calculated THIV, PHD, and ASI values for each system are also shown in Table 7. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix D.

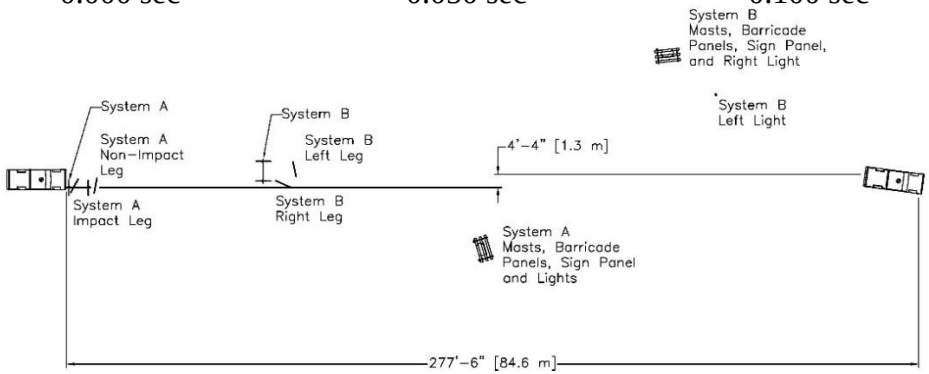
Table 7. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. WZNP-2

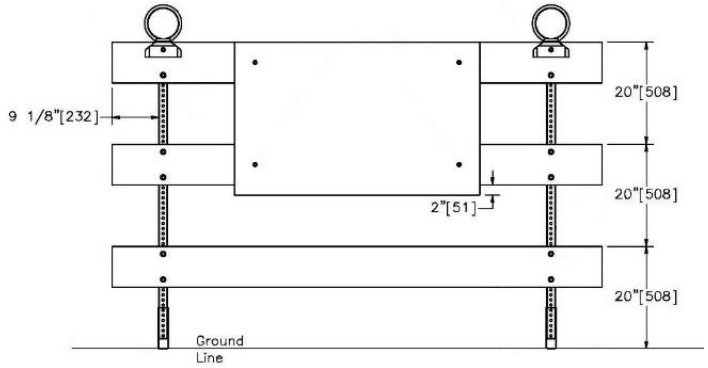
Evaluation Criteria		Transducer				MASH 2016 Limits
		SYSTEM A		SYSTEM B		
		SLICE-1	SLICE-2 (primary)	SLICE-1	SLICE-2 (primary)	
OIV ft/s (m/s)	Longitudinal	-1.44 (-0.44)	-1.34 (-0.41)	-1.28 (-0.39)	-1.13 (-0.34)	±16 (4.9)
	Lateral	0.91 (0.28)	0.72 (0.22)	-0.39 (-0.12)	-0.23 (-0.07)	±16 (4.9)
ORA g's	Longitudinal	N/A	N/A	N/A	N/A	±20.49
	Lateral	N/A	N/A	N/A	N/A	±20.49
MAX. ANGULAR DISPL. deg.	Roll	-0.78	1.16	-0.78	1.16	±75
	Pitch	5.93	2.87	5.93	2.87	±75
	Yaw	1.22	-2.45	1.22	-2.45	not required
THIV ft/s (m/s)		N/A	N/A	N/A	N/A	not required
PHD g's		N/A	N/A	N/A	N/A	not required
ASI		0.054	0.055	0.087	0.065	not required

N/A – Not applicable (due to reasons explained in section 5.5)

5.6 Discussion

A summary of the test results and sequential photographs for System A and System B are shown in Figures 32 and 33, respectively. The analysis of the test results for test no. WZNP-2 showed that both systems readily activated in a predicable manner and allowed the 2270P vehicle to continue traveling without any major obstruction of the windshield. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix D, were deemed acceptable because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle's trajectory did not violate the bounds of the exit box. Therefore, test no. WZNP-2 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-72.





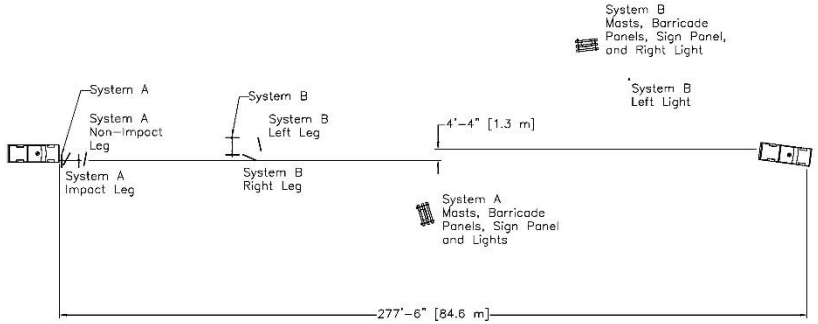
- Test Agency ..... MwRSF
- Test Number WZNP-2
- Date 3/21/2019
- MASH 2016 Test Designation No. 3-72
- Test Article ..... Type III Barricade
- System ..... A (oriented at 90 degrees)
- Key Component – Plastic Barricade Panel
  - Length ..... 96 in. (2,438 mm)
  - Height ..... 8.25 in. (210 mm)
  - Thickness ..... 0.75 in. (19 mm)
- Key Component – Aluminum Sign
  - Length ..... 48 in. (1,219 mm)
  - Width ..... 30 in. (762 mm)
  - Thickness ..... 0.08 in. (2 mm)
- Soil Type ..... Concrete Surface
- Vehicle Make /Model ..... 2011 Dodge Ram 1500 quad cab pickup truck
  - Curb ..... 5,105 lb (2,316 kg)
  - Test Inertial ..... 5,001 lb (2,268 kg)
  - Gross Static ..... 5,165 lb (2,343 kg)
- Impact Conditions
  - Speed ..... 64.7 mph (104.2 km/h)
  - Angle ..... 0 degrees
  - Impact Location ..... Right quarter-point offset from centerline of vehicle
- Exit Conditions
  - Angle ..... 0 degrees
- Exit Box Criterion ..... Pass
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 277 ft – 6 in. (84.6 m) downstream
- Vehicle Damage ..... Minimal
  - VDS [9] 12-FR-1
  - CDC [10] 12FREN8
  - Maximum Interior Deformation ..... 1.5 in. (38.1 mm)
- Test Article Damage ..... Moderate
- Transducer Data

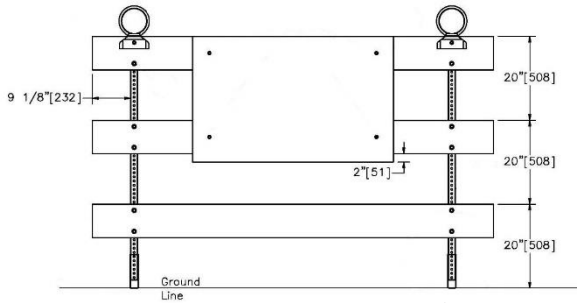
Evaluation Criteria		Transducer		MASH 2016 Limit
		SLICE-1	SLICE-2 (primary)	
OIV ft/s (m/s)	Longitudinal	-1.44 (-0.44)	-1.34 (-0.41)	±16 (4.9)
	Lateral	0.91 (0.28)	0.72 (0.22)	±16 (4.9)
ORA g's	Longitudinal	N/A	N/A	±20.49
	Lateral	N/A	N/A	±20.49
MAX ANGULAR DISP. deg.	Roll	-0.78	1.16	±75
	Pitch	5.93	2.87	±75
	Yaw	1.22	-2.45	Not required
THIV – ft/s (m/s)		N/A	N/A	Not required
PHD – g's		N/A	N/A	Not required
ASI		0.054	0.055	Not required

N/A – Not applicable (due to reasons explained in section 5.5)

Figure 32. Summary of Test Results and Sequential Photographs for System A, Test No. WZNP-2

0.000 sec 0.050 sec 0.100 sec 0.150 sec 0.200 sec





- Test Agency ..... MwRSF
- Test Number WZNP-2
- Date 3/21/2019
- MASH 2016 Test Designation No. 3-72
- Test Article ..... Type III Barricade
- System ..... B (oriented at 0 degrees)
- Key Component – Plastic Barricade Panel
  - Length ..... 96 in. (2,438 mm)
  - Height ..... 8.25 in. (210 mm)
  - Thickness ..... 0.75 in. (19 mm)
- Key Component – Aluminum Sign
  - Length ..... 48 in. (1,219 mm)
  - Width ..... 30 in. (762 mm)
  - Thickness ..... 0.08 in. (2 mm)
- Soil Type ..... Concrete Surface
- Vehicle Make /Model ..... 2011 Dodge Ram 1500 quad cab pickup truck
  - Curb ..... 5,105 lb (2,316 kg)
  - Test Inertial ..... 5,001 lb (2,268 kg)
  - Gross Static ..... 5,165 lb (2,343 kg)
- Impact Conditions
  - Speed ..... 62.6 mph (100.8 km/h)
  - Angle ..... 0 degrees
  - Impact Location ..... Left quarter-point offset from centerline of vehicle
- Exit Conditions
  - Angle ..... 0 degrees
- Exit Box Criterion ..... Pass
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 277 ft – 6 in. (84.6 m) downstream
- Vehicle Damage ..... Minimal
  - VDS [9] 12-FL-1
  - CDC [10] 12FLEW3
  - Maximum Interior Deformation ..... 1.5 in. (38.1 mm)
- Test Article Damage ..... Moderate
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limit
		SLICE-1	SLICE-2 (primary)	
OIV ft/s (m/s)	Longitudinal	-1.28 (-0.39)	-1.13 (-0.34)	±16 (4.9)
	Lateral	-0.39 (-0.12)	-0.23 (-0.07)	±16 (4.9)
ORA g's	Longitudinal	N/A	N/A	±20.49
	Lateral	N/A	N/A	±20.49
MAX ANGULAR DISP. deg.	Roll	-0.78	1.16	±75
	Pitch	5.93	2.87	±75
	Yaw	1.22	-2.45	Not required
THIV – ft/s (m/s)		N/A	N/A	Not required
PHD – g's		N/A	N/A	Not required
ASI		0.087	0.065	Not required

N/A – Not applicable (due to reasons explained in section 5.5)

Figure 33. Summary of Test Results and Sequential Photographs for System B, Test No. WZNP-2

6 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Test no. WZNP-2 was conducted on a non-proprietary Type III barricade according to MASH 2016 test designation no. 3-72. Two barricades were impacted sequentially by the same test vehicle. In test no. WZNP-2, the 5,001-lb (2,268-kg) 2011 Dodge Ram 1500 quad cab pickup truck impacted System A, oriented at 90 degrees or perpendicular to the vehicle, at a speed of 64.7 mph (104.2 km/h) and System B, oriented at 0 degrees or head-on to the vehicle, at a speed of 62.6 mph (100.8 km/h), respectively. During test no. WZNP-2, the 2270P pickup truck impacted and disengaged both barricades from their bases. The systems readily activated and allowed the 2270P vehicle to continue travelling without any major obstruction of the windshield. There were no detached elements or fragments that showed potential for penetrating the occupant compartment nor present undue hazard to other traffic. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle remained upright during and after the collisions. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix D, were deemed acceptable, because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle's trajectory did not violate the bounds of the exit box. Therefore, test no. WZNP-2 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-72. A summary of the test evaluation and sequential photos are shown in Table 8.

When assembling this Type III barricade, hardware parts and materials that are similar to those used in the as-tested system should be utilized. Sandbags, weighing approximately 50 lb, should be placed on the ends of each leg. One Type A/C warning light was attached to the top and front-side of the HDPE panels at each PSST upright on each barricade to evaluate a worst-case configuration with attachments. Thus, two warning lights were attached to each barricade. Utilizing one or no warning lights would also be acceptable. The warning lights were attached to the front side of the top barricade panel but could also be attached to the backside of the top barricade panel, as that would be a less critical configuration.

An aluminum sign panel can be attached to the Type III, with a maximum sign size and location similar to the as-tested installation. Smaller aluminum sign panels attached with a top height that is even with the top barricade panel or lower, or omitting the aluminum sign panel would also be acceptable configurations.

The Type III barricade panels consisted of three horizontal High Density Polyethylene (HDPE) panels, measuring 96 in. (2,428 mm) in length. The barricade panel was targeted to have nominal cross-sectional dimensions of 8 in. (203 mm) tall x 1 in. (25 mm) thick. However, the dimensions vary between manufacturers, and the supplied barricade panel was 8¼ in. (210 mm) x ¾ in. (19 mm). HDPE panels that are similar to those in the as-tested installation or with the nominal dimensions could also be used for this Type III barricade.

Table 8. Summary of Safety Performance Evaluation

Evaluation Factors	Evaluation Criteria				Test No. WZNP-2
Structural Adequacy	B	The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.			S
Occupant Risk	D.	1. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.			S
		2. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.			S
	E.	Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle			S
	F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.			S
	H.	Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:			S
		Occupant Impact Velocity Limits			
		Component	Preferred	Maximum	
		Longitudinal and Lateral	30 ft/s (9.1 m/s)	16 ft/s (4.9 m/s)	
	I.	The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:			S
		Occupant Ridedown Acceleration Limits			
		Component	Preferred	Maximum	
		Longitudinal and Lateral	15.0 g's	20.49 g's	
MASH 2016 Test Designation No.					3-72
Final Evaluation (Pass or Fail)					Pass

S – Satisfactory U – Unsatisfactory N/A – Not Applicable

7 MASH EVALUATION

This Type III barricade had three horizontal High Density Polyethylene (HDPE) panels, measuring 96 in. (2,428 mm) in length, with a 48-in. x 30-in. x 0.08-in. (1,219-mm x 762-mm x 2-mm) aluminum sign attached to the top two barricade panels. The barricade panel was targeted to have nominal cross-sectional dimensions of 8 in. (203 mm) x 1 in. (25 mm). However, the dimensions vary between manufacturers, and the supplied barricade panel was 8¼ in. (210 mm) x ¾ in. (19 mm). The barricade panels were attached to two 1¾-in. (44-mm) x 14-ga (1.9-mm) thick Perforated Square Steel Tubing (PSST) uprights, which were inserted into two 2-in. (51-mm) x 14-ga (1.9-mm) thick x 6-in. (152-mm) long PSST vertical stubs that were welded to two legs. The legs were 2-in. (51-mm) x 14-ga (1.9-mm) thick x 60-in. (1,524-mm) long PSST. All PSST used was galvanized ASTM 1011 Grade 55 steel with a minimum yield strength of 60 ksi (414 MPa). A 50-lb (23-kg) sandbag was placed on top of the end of each leg. A Type A/C warning light was attached to the front of the top barricade panel and upright at both upright locations.

According to TL-3 of MASH 2016, work-zone traffic control devices, such as a Type III barricade, must be subjected to three full-scale vehicle crash tests, as summarized in Table 9. The low-speed test, test designation no. 3-70, was optional according to MASH Section 2.2.4.2 and was not conducted, since the Type III barricade weighed less than 220 lb (100 kg) [5]. MASH 2016 recommends these tests be conducted both perpendicular to the device (0 degrees) and parallel to the device (90 degrees), as both orientations may occur along roadsides. Test designation no. 3-71 was previously successfully conducted on the barricade at two critical impact angles, both perpendicular to the device (0 degrees) and parallel to the device (90 degrees) [6]. Test designation no. 3-72 was successfully conducted on the barricade at two critical impact angles, both perpendicular to the device (0 degrees) and parallel to the device (90 degrees), as reported herein.

Table 9. MASH 2016 TL-3 Crash Test Conditions for Work-Zone Traffic Control Devices

Test Article	Test Designation No.	Test Vehicle	Vehicle Weight, lb (kg)	Impact Conditions	
				Speed, mph (km/h)	Angle, (degrees)
Work-Zone Traffic Control Devices	3-70*	1100C	2,425 (1,100)	19 (30)	CIA
	3-71	1100C	2,425 (1,100)	62 (100)	CIA
	3-72	2270P	5,000 (2,270)	62 (100)	CIA

* Optional for devices weighing less than 220 lb (100 kg)
CIA= Critical Impact Angle

In test no. WZNP-1, two identical Type III barricades were impacted by an 1100C small car in accordance with MASH 2016 test designation no. 3-71 [6]. The two Type III barricades were placed 60 ft (18.3 m) apart on level terrain with one sandbag on the end of each leg. Initial vehicle impact with System A, oriented at 90 degrees or perpendicular to the vehicle, was to occur with a right quarter-point and offset from the centerline of the car and initial vehicle impact with

System B, oriented at 0 degrees or head on to the vehicle, was to occur with a left quarter-point and offset from the centerline of the car. The 2,426-lb (1,100-kg) small car impacted System A at a speed of 64.7 mph (104.2 km/h) and System B at a speed of 61.2 mph (98.6 km/h). During the test, the 1100C small car impacted and disengaged both barricades from their bases. The systems readily activated in a predictable manner and allowed the 1100C vehicle to continue traveling without any major obstruction of the windshield. There were no detached elements or fragments which showed potential for penetrating the occupant compartment or presented undue hazard to other traffic

In test no. WZNP-2, two identical Type III barricades were impacted by a 2270P pickup truck in accordance with MASH 2016 test designation no. 3-72. The two Type III barricades were placed 60 ft (18.3 m) apart on level terrain with one sandbag on the end of each leg. Initial vehicle impact with System A, oriented at 90 degrees or perpendicular to the vehicle, was to occur with a right quarter-point and offset from the centerline of the car and initial vehicle impact with System B, oriented at 0 degrees or head on to the vehicle, was to occur with a left quarter-point and offset from the centerline of the car. The 5,001-lb (2,268-kg) 2011 Dodge Ram 1500 quad cab pickup truck impacted System A at a speed of 64.7 mph (104.2 km/h) and System B at a speed of 62.6 mph (100.8 km/h). During the test, the 2270P pickup truck impacted and disengaged both barricades from their bases. The systems readily activated and allowed the 2270P vehicle to continue travelling without any major obstruction of the windshield. Thus, this Type III barricade satisfied all of the requirements for the crash tests in the TL-3 test matrix and, therefore, is a MASH TL-3 crashworthy device.

8 REFERENCES

1. Schmidt, J.D., Sicking, D.L., Lechtenberg, K.A., Faller, R.K., and Holloway, J.C., *Analysis of Existing Work-Zone Devices with MASH Safety Performance Criteria*, Mid-America Transportation Center, University of Nebraska-Lincoln, Lincoln, NE, 2009.

2. Schmidt, J.D., Faller, R.K., Lechtenberg, K.A., and Sicking, D.L., *Analysis of Existing Work-Zone Sign Supports Using Manual for Assessing Safety Hardware Safety Performance Criteria*, Journal of Transportation Safety & Security, Taylor & Francis, Volume 3, Number 4, December 2011, DOI: 10.1080/19439962.2011.599015, pp. 237-251.

3. Ross, H.E., Sicking, D.L., Zimmer, R.A., and Michie, J.D., *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, National Cooperative Highway Research Program (NCHRP) Report 350, Transportation Research Board, Washington, D.C., 1993. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_350-a.pdf.

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

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

6. Schmidt, J.D., Langel, T.J., Asselin, N., Pajouh, M.A., and Faller, R.K., *MASH 2016 Evaluation of a Non-Proprietary Type III Barricade*, Report No. TRP-03-394-18, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, September 19, 2018.

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

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

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

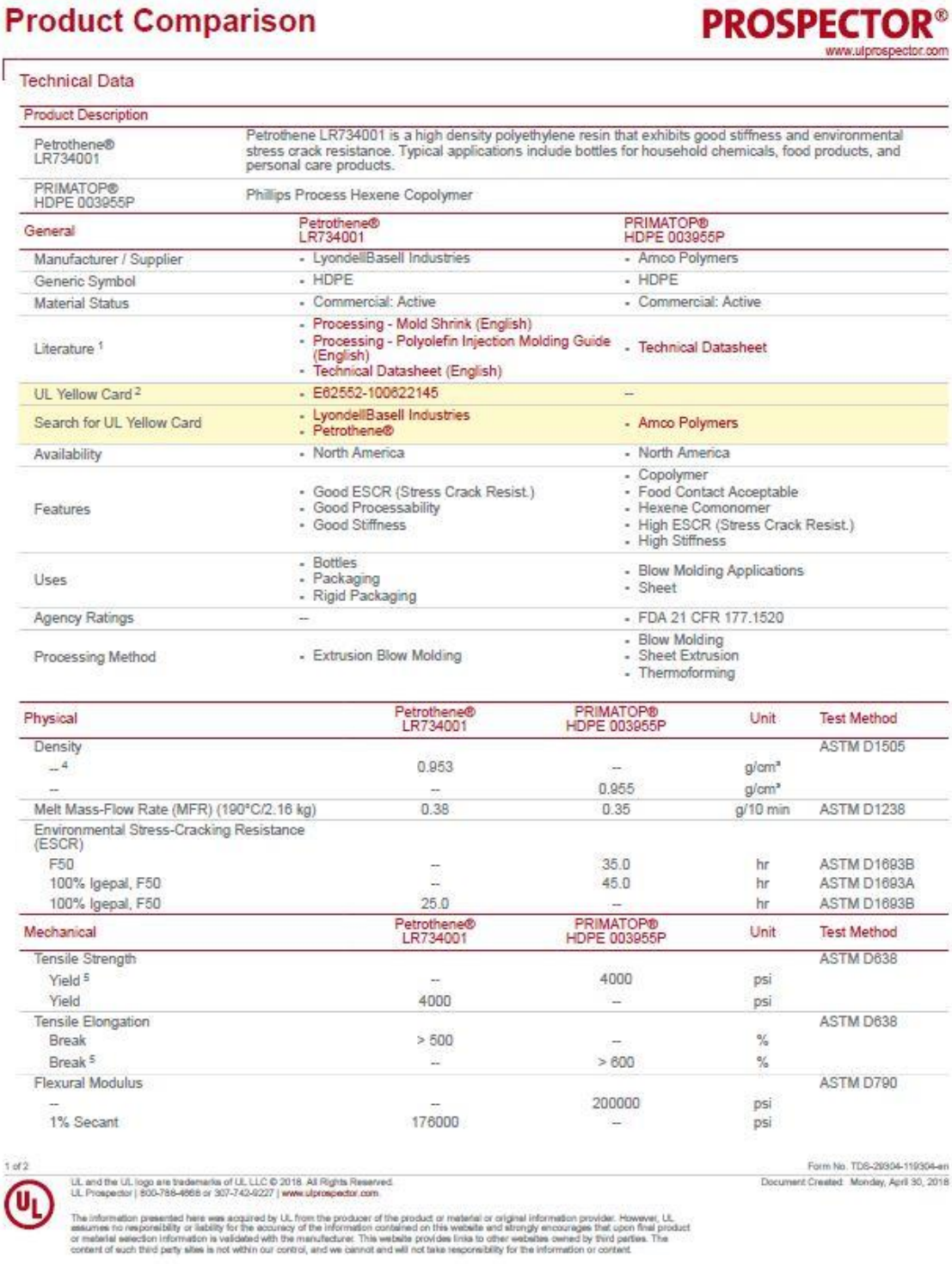
10. *Collision Deformation Classification – Recommended Practice J224 March 1980*, Handbook Volume 4, Society of Automotive Engineers (SAE), Warrendale, Pennsylvania, 1985.

9 APPENDICES

Appendix A. Material Specifications

Table A-1. Bill of Materials, Test No. WZNP-2

Item No.	Description	Material Specification	Reference
a1	Plastic Panel, 96" [2,438] Long	Petrothene LR734001	Technical Data Sheet
a2	Plastic Panel, 96" [2,438] Long	Petrothene LR734001	Technical Data Sheet
b1	1 3/4"x1 3/4"x14-gauge [44x44x1.9], 58" [1,473] Long Perforated Square Tubing	ASTM 1011 Gr. 55	H#A90050 (Coil#168755)
b2	2"x2"x14-gauge [51x51x1.9], 60" [1,524] Long Perforated Square Tubing	ASTM 1011 Gr. 55	H#C87907 (Coil#4169112)
b3	2"x2"x14-gauge [51x51x1.9], 6" [152] Long Perforated Square Tubing	ASTM 1011 Gr. 55	H#C87907 (Coil#4169112)
c1	48" x 30" x 0.08" [1,219 x 762 x 2] Sign with Reflective Sheeting	Aluminum Alloy 5052	RTS-154299 COC
c2	Warning Light (Type A or C)	As Supplied	Fastenal COC
d1	3/8"-16 UNC [M10x1.5], 3 1/2" [89] Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	H#18205931-3 (Coil#130075362)
d2	1/2"-13 UNC [M14x2], 6" [152] Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	H#G1808306001 (Coil#210170612)
d3	1/4"-20 UNC [M6x1], 1 3/4" [44] Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	H#18300616-3 (Coil#180154274)
d4	3/8" [10] Dia. Plain Round Washer	Low Carbon Steel	L#1831501 (C#210163871) (P#133008)
d5	1/2" [13] Dia. Plain Round Washer	Low Carbon Steel	C#480006818 (P#1133012)
d6	1/4" [6] Dia. Plain Round Washer	Low Carbon Steel	L#M-SWE0412056-1 (C#110243322) (P#1133004)
d7	3/8"-16 UNC [M10x1.5] Lock Nut	SAE J995 Gr. 2 or equivalent	H#321605150 (Coil#210115915)
d8	1/4"-20 UNC [M6x1] Lock Nut	SAE J995 Gr. 2 or equivalent	H#G1711322002 (Coil#210151171)



Product Comparison

PROSPECTOR®
www.ulprospector.com

Technical Data

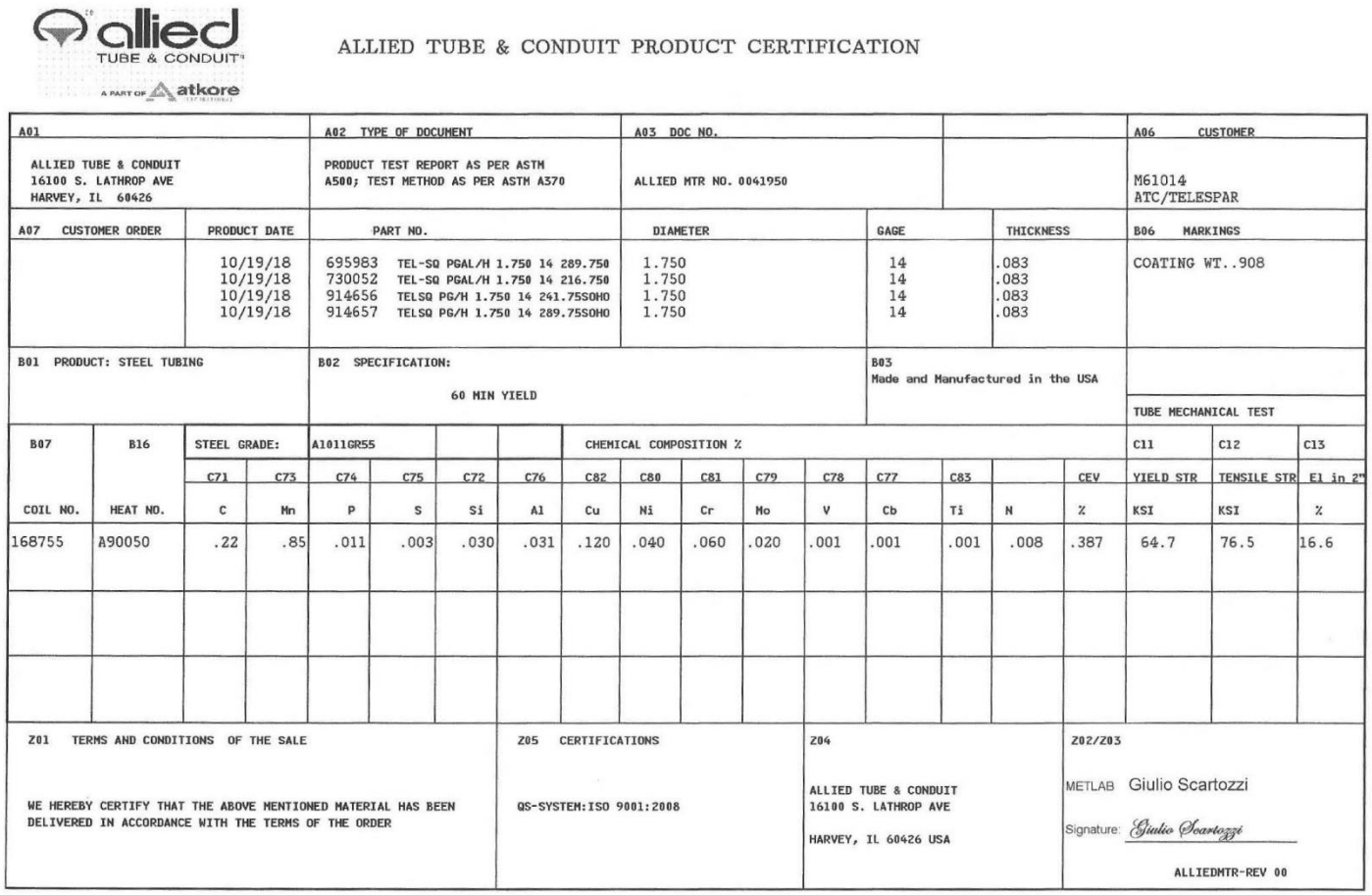
Product Description	
Petrothene® LR734001	Petrothene LR734001 is a high density polyethylene resin that exhibits good stiffness and environmental stress crack resistance. Typical applications include bottles for household chemicals, food products, and personal care products.
PRIMATOP® HDPE 003955P	Phillips Process Hexene Copolymer

General	Petrothene® LR734001	PRIMATOP® HDPE 003955P
Manufacturer / Supplier	• LyondellBasell Industries	• Amco Polymers
Generic Symbol	• HDPE	• HDPE
Material Status	• Commercial: Active	• Commercial: Active
Literature [1]	• Processing - Mold Shrink (English) • Processing - Polyolefin Injection Molding Guide (English) • Technical Datasheet (English)	• Technical Datasheet
UL Yellow Card [2]	• E82552-100622145	--
Search for UL Yellow Card	• LyondellBasell Industries • Petrothene®	• Amco Polymers
Availability	• North America	• North America
Features	• Good ESCR (Stress Crack Resist.) • Good Processability • Good Stiffness	• Copolymer • Food Contact Acceptable • Hexene Comonomer • High ESCR (Stress Crack Resist.) • High Stiffness
Uses	• Bottles • Packaging • Rigid Packaging	• Blow Molding Applications • Sheet
Agency Ratings	--	• FDA 21 CFR 177.1520
Processing Method	• Extrusion Blow Molding	• Blow Molding • Sheet Extrusion • Thermoforming

Physical	Petrothene® LR734001	PRIMATOP® HDPE 003955P	Unit	Test Method
Density				ASTM D1505
-- [4]	0.953	--	g/cm³	
--	--	0.955	g/cm³	
Melt Mass-Flow Rate (MFR) (190°C/2.16 kg)	0.38	0.35	g/10 min	ASTM D1238
Environmental Stress-Cracking Resistance (ESCR)				
F50	--	35.0	hr	ASTM D1693B
100% Igepal, F50	--	45.0	hr	ASTM D1693A
100% Igepal, F50	25.0	--	hr	ASTM D1693B

Mechanical	Petrothene® LR734001	PRIMATOP® HDPE 003955P	Unit	Test Method
Tensile Strength				ASTM D638
Yield [5]	--	4000	psi	
Yield	4000	--	psi	
Tensile Elongation				ASTM D638
Break	> 500	--	%	
Break [5]	--	> 600	%	
Flexural Modulus				ASTM D790
--	--	200000	psi	
1% Secant	176000	--	psi	

Figure A-1. Plastic Panel Material Certificate, Test No. WZNP-2



ALLIED TUBE & CONDUIT PRODUCT CERTIFICATION

A01	A02 TYPE OF DOCUMENT	A03 DOC NO.		A06 CUSTOMER
ALLIED TUBE & CONDUIT 16100 S. LATHROP AVE HARVEY, IL 60426	PRODUCT TEST REPORT AS PER ASTM A500; TEST METHOD AS PER ASTM A370	ALLIED MTR NO. 0041950		M61014 ATC/TELESPAR

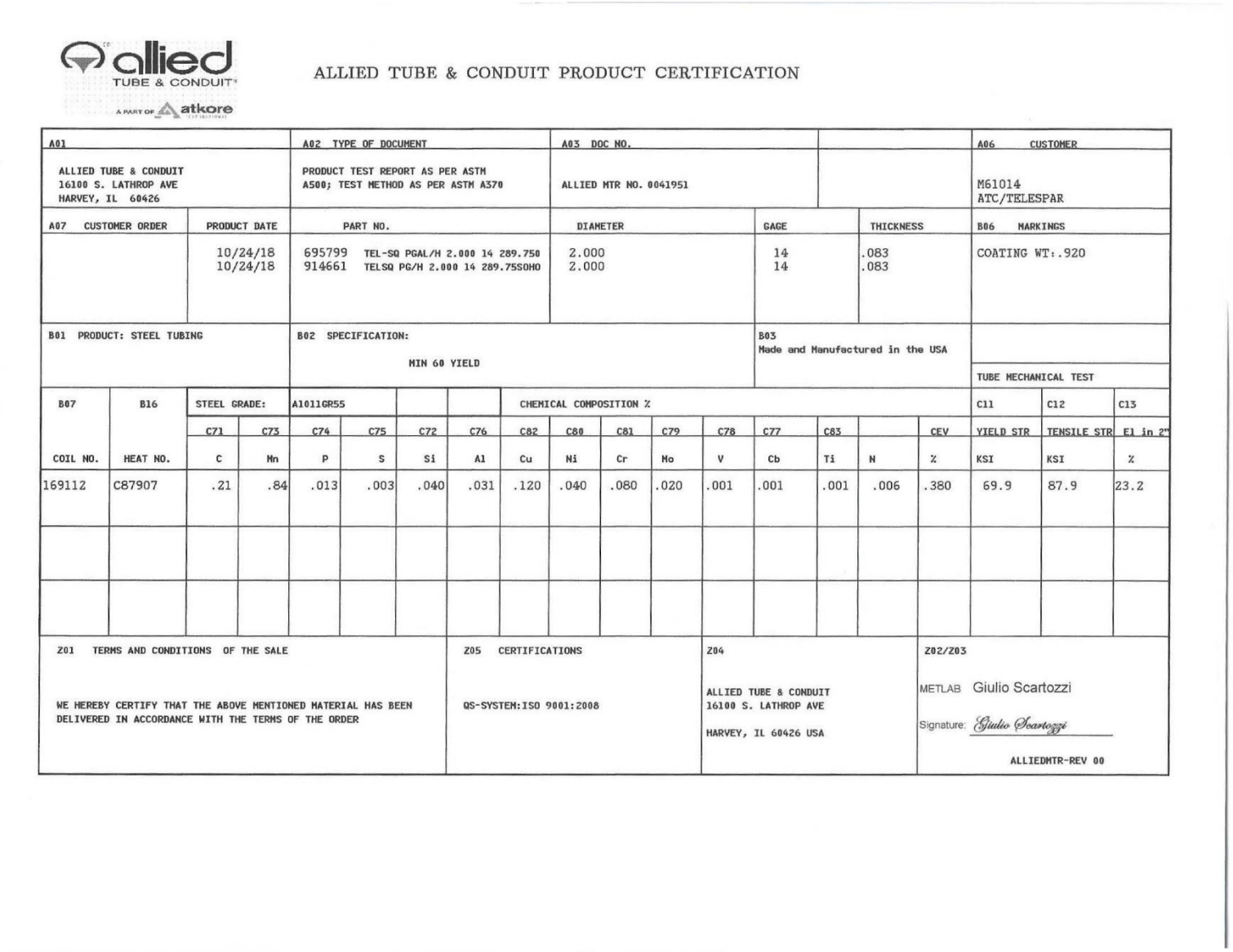
A07 CUSTOMER ORDER	PRODUCT DATE	PART NO.	DIAMETER	GAGE	THICKNESS	B06 MARKINGS
	10/19/18	695983 TEL-SQ PGAL/H 1.750 14 289.750	1.750	14	.083	COATING WT..908
	10/19/18	730052 TEL-SQ PGAL/H 1.750 14 216.750	1.750	14	.083	
	10/19/18	914656 TELSQ PG/H 1.750 14 241.75SOHO	1.750	14	.083	
	10/19/18	914657 TELSQ PG/H 1.750 14 289.75SOHO	1.750	14	.083	

B01 PRODUCT: STEEL TUBING	B02 SPECIFICATION:	B03
	60 MIN YIELD	Made and Manufactured in the USA

B07	B16	STEEL GRADE:		A1011GR55				CHEMICAL COMPOSITION %									C11	C12	C13
		C71	C73	C74	C75	C72	C76	C82	C80	C81	C79	C78	C77	C83		CEV	YIELD STR	TENSILE STR	El in 2"
COIL NO.	HEAT NO.	C	Mn	P	S	Si	Al	Cu	Ni	Cr	Mo	V	Cb	Ti	N	%	KSI	KSI	%
168755	A90050	.22	.85	.011	.003	.030	.031	.120	.040	.060	.020	.001	.001	.001	.008	.387	64.7	76.5	16.6

Z01 TERMS AND CONDITIONS OF THE SALE	Z05 CERTIFICATIONS	Z04	Z02/Z03
WE HEREBY CERTIFY THAT THE ABOVE MENTIONED MATERIAL HAS BEEN DELIVERED IN ACCORDANCE WITH THE TERMS OF THE ORDER	QS-SYSTEM:ISO 9001:2008	ALLIED TUBE & CONDUIT 16100 S. LATHROP AVE HARVEY, IL 60426 USA	METLAB Giulio Scartozzi Signature: Giulio Scartozzi ALLIEDMTR-REV 00

Figure A-2. Square Tubing Material Certificate, Test No. WZNP-2



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ALLIED TUBE & CONDUIT PRODUCT CERTIFICATION

A01	A02 TYPE OF DOCUMENT	A03 DOC NO.		A06 CUSTOMER
ALLIED TUBE & CONDUIT 16100 S. LATHROP AVE HARVEY, IL 60426	PRODUCT TEST REPORT AS PER ASTM A500; TEST METHOD AS PER ASTM A370	ALLIED MTR NO. 0041951		M61014 ATC/TELESPAR

A07 CUSTOMER ORDER	PRODUCT DATE	PART NO.	DIAMETER	GAGE	THICKNESS	B06 MARKINGS
	10/24/18 10/24/18	695799 TEL-SQ PGAL/H 2.000 14 289.750 914661 TELSQ PG/H 2.000 14 289.75SOHO	2.000 2.000	14 14	.083 .083	COATING WT:.920

B01 PRODUCT: STEEL TUBING	B02 SPECIFICATION:	B03
	MIN 60 YIELD	Made and Manufactured in the USA

B07	B16	STEEL GRADE:		A1011GR55				CHEMICAL COMPOSITION %									TUBE MECHANICAL TEST C11	C12	C13
		C71	C73	C74	C75	C72	C76	C82	C80	C81	C79	C78	C77	C83		CEV	YIELD STR	TENSILE STR	El in 2"
COIL NO.	HEAT NO.	C	Mn	P	S	Si	Al	Cu	Ni	Cr	Mo	V	Cb	Ti	N	%	KSI	KSI	%
169112	C87907	.21	.84	.013	.003	.040	.031	.120	.040	.080	.020	.001	.001	.001	.006	.380	69.9	87.9	23.2

Z01 TERMS AND CONDITIONS OF THE SALE	Z05 CERTIFICATIONS	Z04	Z02/Z03
WE HEREBY CERTIFY THAT THE ABOVE MENTIONED MATERIAL HAS BEEN DELIVERED IN ACCORDANCE WITH THE TERMS OF THE ORDER	QS-SYSTEM:ISO 9001:2008	ALLIED TUBE & CONDUIT 16100 S. LATHROP AVE HARVEY, IL 60426 USA	METLAB Giulio Scartozzi Signature: Giulio Scartozzi ALLIEDMTR-REV 00

Figure A-3. Square Tubing Material Certificate, Test No. WZNP-2

SmartSign

300 Cadman Plaza West, ste 1303
Brooklyn NY 11201
Phone: 1-800-952-1457

2/13/19

CERTIFICATE OF COMPLIANCE

Smartsign hereby certifies that all materials supplied against purchase order PO: WZNP-2 / RTS-154299 shipped on 2/7/19 conforms to the material and/ or manufacturing specifications as called on this said purchase order without expectations.

Item #
x-R11-2

Description:
Road Closed Engineer Grade Reflective Aluminum Sign, 80 mil]

Sincerely,

Tahyna Colon
Call Center Manager
tahyna@smartsign.com
800-952-1457 x 7140

Figure A-4. Sign Certificate of Conformance, Test No. WZNP-2

FASTENAL®

Certificate of Compliance

Sold To:

UNL TRANSPORTATION/Midwest Roadside Safe

Purchase Order: WZNP-2

Job: Item#c2, d1, d2, d3, d4

Invoice Date: 02/8/2019

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

4 PCS 7" 3V D-Cell Polycarbonate Flashing or Steady Barricade Light SUPPLIED UNDER OUR TRACE NUMBER Ilne38754 AND UNDER PART NUMBER 1076058

24 PCS 3/8"-16 x 3-1/2" ASTM A307 Grade A Zinc Finish Hex Bolt SUPPLIED UNDER OUR TRACE NUMBER 130075362 AND UNDER PART NUMBER 11117

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

Fastenal Account Representative Signature

Ashly Stanczyk

Printed Name

2/11/19

Date

Please check current revision to avoid using obsolete copies.

This document was printed on 02/11/2019 and was current at that time.

Fastenal Store Location/Address

3201 N. 23rd Street STE 1
LINCOLN, NE 68521
Phone #: (402)476-7900
Fax #: 402/476-7958

Page 1 of 1

Figure A-5. Warning Light Certificate of Compliance, Test No. WZNP-2

IATF 16949:2016 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER : GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA
Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2019/02/13

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 130075362
COMMODITY : HEX MACHINE BOLT GR-A
SIZE : 3/8-16X3-1/2 NC
LOT NO : 1B1862839
SHIP QUANTITY : 24,400 PCS
LOT QUANTITY 65,045 PCS
HEADMARKS : CYI & 307A
MANUFACTURE DATE : 2018/08/14
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM181024041
INVOICE NO : GEM/FNL-181112SL
PART NO : 11117
SAMPLING PLAN :
ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : 18205931-3
MATERIAL : X1008A
FINISH : Fe/Zn 3AN ASTM F1941/F1941M-2016

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A307-2014

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0.3300	1.2500	0.0410		
Test Value	0.0300	0.0600	0.2900	0.0090	0.0100	0.0200

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.1-2012

SAMPLED BY : HQIN

INSPECTIONS ITEM	SAMPLE	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
THREAD LENGTH	15 PCS	1.0000 inch	1.1200-1.1250 inch	15	0
MAJOR DIAMETER	15 PCS	0.3640-0.3740 inch	0.3650-0.3720 inch	15	0
BODY DIAMETER	5 PCS	0.3600-0.3880 inch	0.3690-0.3730 inch	5	0
WIDTH ACROSS CORNERS	5 PCS	0.6200-0.6500 inch	0.6240-0.6490 inch	5	0
HEIGHT	5 PCS	0.2260-0.2680 inch	0.2380-0.2430 inch	5	0
NOMINAL LENGTH	15 PCS	3.4400-3.5400 inch	3.4630-3.4750 inch	15	0
WIDTH ACROSS FLATS	5 PCS	0.5440-0.5620 inch	0.5460-0.5550 inch	5	0
SURFACE DISCONTINUITIES	29 PCS	ASTM F788-2013	PASSED	29	0
THREAD	15 PCS	ASME B1.1-2003 3A GO 2A NOGO	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A 307-2014

SAMPLED BY : GDAN LIAN

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15 PCS	ASTM F606-2016		Max. 100 HRB	82-84 HRB	15	0
TENSILE STRENGTH	4 PCS	ASTM F606-2016		Min. 60 KSI	77-78 KSI	4	0
PLATING THICKNESS(μm)	29 PCS	ASTM B568-1998		>=3	3.63-3.89	29	0
SALT SPRAY TEST	15 PCS	ASTM B117-16		6 HOURS NO WHITE RUST, 12 HOURS NO RED RUST	OK	15	0

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

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Figure A-6. Hex Bolt Material Certificate, Test No. WZNP-2

IATF 16949:2016 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER : GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA
Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2019/01/31

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 210170612
COMMODITY : HEX MACHINE BOLT GR-A
SIZE : 1/2-13X6 NC
LOT NO : 1B1891613
SHIP QUANTITY : 4,320 PCS
LOT QUANTITY 17,397 PCS
HEADMARKS : CYI & 307A
MANUFACTURE DATE : 2018/11/07
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM181114014
INVOICE NO : GEM/FNL-181128ED
PART NO : 11225
SAMPLING PLAN : ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : G1808306001
MATERIAL : ML08
FINISH : Fe/Zn 3AN ASTM F1941/F1941M-2016

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A307-2014

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0.3300	1.2500	0.0410		
Test Value	0.0330	0.0800	0.3900	0.0210	0.0040	0.0400

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.1-2012

SAMPLED BY : HQIN

INSPECTIONS ITEM	SAMPLE	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
THREAD LENGTH	15 PCS	1.2500 inch	1.3570-1.3590 inch	15	0
MAJOR DIAMETER	15 PCS	0.4880-0.4980 inch	0.4910-0.4930 inch	15	0
BODY DIAMETER	4 PCS	0.4820-0.5150 inch	0.5040-0.5070 inch	4	0
WIDTH ACROSS CORNERS	4 PCS	0.8260-0.8660 inch	0.8350-0.8400 inch	4	0
HEIGHT	4 PCS	0.3020-0.3640 inch	0.3360-0.3390 inch	4	0
NOMINAL LENGTH	15 PCS	5.9000-6.0000 inch	5.9160-5.9630 inch	15	0
WIDTH ACROSS FLATS	4 PCS	0.7250-0.7500 inch	0.7390-0.7450 inch	4	0
SURFACE DISCONTINUITIES	29 PCS	ASTM F788-2013	PASSED	29	0
THREAD	15 PCS	ASME B1.1-2003 3A GO 2A NOGO	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A 307-2014

SAMPLED BY : ZLINGLING

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15 PCS	ASTM F606-2016		Max. 100 HRB	82-86 HRB	15	0
TENSILE STRENGTH	4 PCS	ASTM F606-2016		Min. 60 KSI	76-81 KSI	4	0
PLATING THICKNESS(μm)	4 PCS	ASTM B568-1998		>=3	3.22-3.36	4	0
SALT SPRAY TEST	15 PCS	ASTM B117-16		6 HOURS NO WHITE RUST, 12 HOURS NO RED RUST	OK	15	0

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

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Figure A-7. Hex Bolt Material Certificate, Test No. WZNP-2

IATF 16949:2016 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER : GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA
Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2019/01/31

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 180154274
COMMODITY : HEX MACHINE BOLT GR-A
SIZE : 1/4-20X1-3/4 NC
LOT NO : 1B1840908
SHIP QUANTITY : 115,200 PCS
LOT QUANTITY 173,017 PCS
HEADMARKS : CYI & 307A
MANUFACTURE DATE : 2018/07/03
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM180718006
INVOICE NO : GEM/FNL-180806DE
PART NO : 11010
SAMPLING PLAN :
ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : 18300616-3
MATERIAL : X1008A
FINISH : Fe/Zn 3AN ASTM F1941/F1941M-2016

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A307-2014

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0.3300	1.2500	0.0410		
Test Value	0.0500	0.0700	0.2900	0.0140	0.0090	0.0300

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.1-2012

SAMPLED BY : WDANDAN

INSPECTIONS ITEM	SAMPLE	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
THREAD LENGTH	15 PCS	0.7500 inch	0.8260-0.8420 inch	15	0
MAJOR DIAMETER	15 PCS	0.2410-0.2490 inch	0.2460-0.2480 inch	15	0
BODY DIAMETER	6 PCS	0.2370-0.2600 inch	0.2450-0.2480 inch	6	0
WIDTH ACROSS CORNERS	6 PCS	0.4840-0.5050 inch	0.4910-0.4930 inch	6	0
HEIGHT	6 PCS	0.1500-0.1880 inch	0.1570-0.1600 inch	6	0
NOMINAL LENGTH	15 PCS	1.7100-1.7700 inch	1.7330-1.7400 inch	15	0
WIDTH ACROSS FLATS	6 PCS	0.4250-0.4380 inch	0.4320-0.4340 inch	6	0
SURFACE DISCONTINUITIES	29 PCS	ASTM F788-2013	PASSED	29	0
THREAD	15 PCS	ASME B1.1-2003 3A GO 2A NOGO	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A 307-2014

SAMPLED BY : ZLINGLING

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15 PCS	ASTM F606-2016		Max. 100 HRB	76-78 HRB	15	0
TENSILE STRENGTH	5 PCS	ASTM F606-2016		Min. 60 KSI	67-70 KSI	5	0
PLATING THICKNESS(μm)	4 PCS	ASTM B568-1998		>=3	3.21-3.44	4	0
SALT SPRAY TEST	15 PCS	ASTM B117-16		6 HOURS NO WHITE RUST, 12 HOURS NO RED RUST	OK	15	0

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

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Figure A-8. Hex Bolt Material Certificate, Test No. WZNP-2

CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS ZP

FACTORY: IFI & Morgan Ltd
ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan,Zhejiang, China
REPORT DATE: 12/2/2019
MFG LOT NUMBER: 1831501

SAMPLING PLAN PER ASME B18.18-11
SIZE: USS 3/8 ZP QNTY(Lot size): 144000PCS
HEADMARKS: NO MARK
PO NUMBER: 210163871
PART NO: 133008

DIMENSIONAL INSPECTIONS — SPECIFICATION: ASTM B18.21.1-2011

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F844	PASSED	100	0
OUTSIDE DIA	0.993-1.030	0.996-1.004	10	0
INSIDE DIA	0.433-0.453	0.443-0.450	10	0
THICKNESS	0.064-0.104	0.064-0.079	10	0

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
ZINC PLATED	ASTM F1941	Min 3 um	3-4um	8	0

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

IFI & MORGAN LTD.
检验专用章
QUANLITY CONTROL
(SIGNATURE OF Q.A. LAB MGR.)

Figure A-9. Flat Washer Material Certificate, Test No. WZNP-2

CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS ZP

FACTORY: IFI & Morgan Ltd
ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan,Zhejiang, China
REPORT DATE: 2018-05-09
MANUFACTURE DATE:
CUSTOMER:
MFG LOT NUMBER:
SAMPLING PLAN PER ASME B18.18-11
PO NUMBER: 480006818
SIZE: USS 1/2 ZP QNTY(Lot size): 26250PCS
HEADMARKS: NO MARK
PART NO: 1133012

DIMENSIONAL INSPECTIONS SPECIFICATION: ASTM B18.21.1-2011

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F844	PASSED	100	0
OUTSIDE DIA	1.368-1.405	1.370-1.378	10	0
INSIDE DIA	0.557-0.577	0.567-0.575	10	0
THICKNESS	0.086-0.132	0.086-0.102	10	0

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
ZINC PLATED	ASTM F1941	Min 3 um	3-4um	8	0

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.
MFG ISO9002 CERTIFICATE NO. HK04/0105

IFI & MORGAN LTD
检验专用章
QUANLITY CONTROL

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

Figure A-10. Flat Washer Material Certificate, Test No. WZNP-2

TEST REPORT

USS FLAT WASHER, ZP

CUSTOMER:

DATE: **2018-11-12**

PO NUMBER: **110243322**

MFG LOT NUMBER: **M-SWE0412056-1**

SIZE: **1/4**

PART NO: **1133004**

HEADMARKS:

QNTY: **540,000 PCS**

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

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	**ASTM F788-07**	**PASSED**	**100**	**0**
OUTSIDE DIA	**0.727-0.749**	**0.730-0.732**	**8**	**0**
INSIDE DIA	**0.307-0.327**	**0.321-0.323**	**8**	**0**
THICKNESS	**0.051-0.080**	**0.053-0.056**	**8**	**0**

ZINC PLATED	**ASTM F1941/F1941M FE/ZN 3AN**	**Min 3 µm**	**3.6-4.1 µm**	**8**	**0**
Salt Spray test result	**ASTM B117**	**Min 6 hrs No White Rust**	**Pass**	**8**	**0**

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

IFI & MORGAN LTD. 检验专用章 QUANLITY CONTROL

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

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

Figure A-11. Flat Washer Test Report, Test No. WZNP-2

ISO/TS 16949 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA
Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2018/05/09

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 210115915
COMMODITY : NYLON INSERT NUT GR-A
SIZE : 3/8-16 NC
LOT NO : IN1680060
SHIP QUANTITY : 150,000 PCS
LOT QUANTITY 378,534 PCS
HEADMARKS : GENIUS SYMBOL
MANUFACTURE DATE : 2016/09/06
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM161201020
INVOICE NO : GEM/FNL-161213ED
PART NO : 1137024
SAMPLING PLAN :
ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : 321605150
MATERIAL : ML08
FINISH : Fe/Zn 3AN ASTM F1941/F1941M-2016

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO IFI 100/107 GR-A

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0.5800		0.1300	0.2300	
Test Value	0.0380	0.0800	0.4300	0.0130	0.0040	0.0600

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.16.6-2014

SAMPLED BY : LXQING

INSPECTIONS ITEM	SAMPLE	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
WIDTH ACROSS CORNERS	6 PCS	Min. 0.6220 inch	0.6250-0.6290 inch	6	0
THICKNESS	6 PCS	0.4380-0.4680 inch	0.4410-0.4640 inch	6	0
WIDTH ACROSS FLATS	6 PCS	0.5510-0.5640 inch	0.5540-0.5610 inch	6	0
SURFACE DISCONTINUITIES	29 PCS	ASTM F812-2012	PASSED	29	0
THREAD	15 PCS	GAGING SYSTEM 21	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO IFI 100/107 GR-A

SAMPLED BY : GDAN LIAN

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15 PCS	ASTM F606-2014		Max.104 HRB	86-87 HRB	15	0
PROOF LOAD	5 PCS	ASTM F606-2014		Min. 7,000 LBF	OK	5	0
PLATING THICKNESS(μm)	29 PCS	ASTM B568-1998		>=3	3.21-5	29	0
SALT SPRAY TEST	15 PCS	ASTM B117-16		6 HOURS NO WHITE RUST, 12 HOURS NO RED RUST	OK	15	0

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

Quality Supervisor:

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Figure A-12. Material Certification ⅜-16 UNC Lock Nut, Test No. WZNP-2

IATF 16949:2016 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER : GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA
Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2019/01/31

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 210151171
COMMODITY : NYLON INSERT NUT GR-A
SIZE : 1/4-20 NC
LOT NO : 1N1820357
SHIP QUANTITY : 120,000 PCS
LOT QUANTITY 481,402 PCS
HEADMARKS : GENIUS SYMBOL
MANUFACTURE DATE : 2018/05/10
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM180628004
INVOICE NO : GEM/FNL-180713ED-1
PART NO : 1137018
SAMPLING PLAN : ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : G1711322002
MATERIAL : ML08
FINISH : Fe/Zn 3AN ASTM F1941/F1941M-2016

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2015

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0.5800		0.1300	0.2300	
Test Value	0.0510	0.0700	0.3900	0.0110	0.0060	0.0200

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.16.6-2014

SAMPLED BY : WANGYAN

INSPECTIONS ITEM	SAMPLE	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
WIDTH ACROSS CORNERS	6 PCS	Min. 0.4860 inch	0.4950-0.4960 inch	6	0
THICKNESS	6 PCS	0.2980-0.3270 inch	0.3090-0.3110 inch	6	0
WIDTH ACROSS FLATS	6 PCS	0.4300-0.4370 inch	0.4330-0.4350 inch	6	0
SURFACE DISCONTINUITIES	29 PCS	ASTM F812-2012	PASSED	29	0
THREAD	15 PCS	GAGING SYSTEM 21	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO IFI 100/107 GR-A-2002

SAMPLED BY : PAN LU

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
PROOF LOAD	7 PCS	ASTM F606-2014		Min. 2,900 LBF	OK	7	0
FIRST INSTALL	7 PCS			Max. 40 LB.IN	12.3-13.9 LB.IN	7	0
FIRST REMOVAL	7 PCS			Min. 5 LB.IN	10.2-11.99 LB.IN	7	0
THIRD REMOVAL	7 PCS			Min. 1.5 LB.IN	6.3-7.8 LB.IN	7	0
CORE HARDNESS	15 PCS	ASTM F606-2014		Max. 104 HRB		15	0
PLATING THICKNESS(μm)	29 PCS	ASTM B568-1998		>=3	3.06-3.6	29	0
SALT SPRAY TEST	15 PCS	ASTM B117-16		6 HOURS NO WHITE RUST, 12 HOURS NO RED RUST	OK	15	0

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

Quality Supervisor:

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Figure A-13. Material Certification ¼-20 UNC Lock Nut, Test No. WZNP-2

Appendix B. Vehicle Center of Gravity Determination

Date:	3/21/2019	Test Name:	WZNP-2	VIN:	1D7RB1GP6BS634520
Year:	2011	Make:	Dodge	Model:	Ram 1500

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	5105	28.378869	144874.13
+	Hub	19	15.25	289.75
+	Brake activation cylinder & frame	8	31 1/8	249
+	Pneumatic tank (Nitrogen)	31	29 1/2	914.5
+	Strobe/Brake Battery	5	27 1/4	136.25
+	Brake Receiver/Wires	6	52 1/4	313.5
+	CG Plate including DAQ	42	30 7/8	1296.75
-	Battery	-42	38 1/4	-1606.5
-	Oil	-10	8 1/2	-85
-	Interior	-104	33 7/8	-3523
-	Fuel	-166	18 1/2	-3071
-	Coolant	-11	36 1/2	-401.5
-	Washer fluid	-6	37 1/8	-222.75
+	Water Ballast (In Fuel Tank)	110	17 7/8	1966.25
+	Onboard Supplemental Battery	14	24 1/2	343
				0
				0
				141473.38

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

Estimated Total Weight (lb)	5001
Vertical CG Location (in.)	28.289

Vehicle Dimensions for C.G. Calculations

Wheel Base:	140.75	in.	Front Track Width:	67.875	in.
			Rear Track Width:	67.375	in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb)	5000 ± 110	5001	1.0
Longitudinal CG (in.)	63 ± 4	61.55174	-1.44826
Lateral CG (in.)	NA	-0.223118	NA
Vertical CG (in.)	28 or greater	28.29	0.28902

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	1439	1436	
Rear	1132	1098	
FRONT	2875		lb
REAR	2230		lb
TOTAL	5105		lb

TEST INERTIAL WEIGHT (lb)

	Left	Right	
Front	1418	1396	
Rear	1099	1088	
FRONT	2814		lb
REAR	2187		lb
TOTAL	5001		lb

Figure B-1. Vehicle Mass Distribution, Test No. WZNP-2

Appendix C. Vehicle Deformation Records

Date: 3/14/2019 Test Name: WZNP-2 VIN: 1D7RB1GP6BS634520
Year: 2011 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	51.8916	-6.6450	2.5037	51.9362	-6.5510	2.6133	-0.0446	0.0940	-0.1096	0.1511	0.0000	NA
	2	51.8723	-10.9186	2.5255	51.9275	-10.8757	2.6115	-0.0552	0.0429	-0.0860	0.1108	0.0000	NA
	3	52.0198	-14.9467	2.4394	52.0644	-14.7746	2.5336	-0.0446	0.1721	-0.0942	0.2012	0.0000	NA
	4	52.1428	-18.7576	2.3779	52.2189	-18.6352	2.4563	-0.0761	0.1224	-0.0784	0.1641	0.0000	NA
	5	52.2128	-23.3626	2.3547	52.2589	-23.3181	2.4527	-0.0461	0.0445	-0.0980	0.1171	0.0000	NA
	6	48.8720	-7.3045	4.1454	48.9605	-7.2282	4.2111	-0.0885	0.0763	-0.0657	0.1341	0.0000	NA
	7	48.7919	-12.3588	4.1818	48.8456	-12.2710	4.2676	-0.0537	0.0878	-0.0858	0.1340	0.0000	NA
	8	48.6769	-15.8111	4.2517	48.7174	-15.7080	4.3454	-0.0405	0.1031	-0.0937	0.1451	0.0000	NA
	9	48.6398	-20.5447	4.2734	48.7246	-20.4539	4.3451	-0.0848	0.0908	-0.0717	0.1434	0.0000	NA
	10	48.6334	-23.2506	4.2853	48.6774	-23.2441	4.3807	-0.0440	0.0065	-0.0954	0.1053	0.0000	NA
FLOOR PAN (Z)	11	45.6275	-7.0316	4.9671	45.6655	-6.9442	5.0526	-0.0380	0.0874	-0.0855	0.1280	-0.0855	Z
	12	45.3625	-10.6772	4.9531	45.4544	-10.6120	5.0407	-0.0919	0.0652	-0.0876	0.1427	-0.0876	Z
	13	45.3505	-14.8207	4.9455	45.4544	-14.7488	5.0288	-0.1039	0.0719	-0.0833	0.1513	-0.0833	Z
	14	45.1717	-18.8420	4.9357	45.2436	-18.7276	5.0216	-0.0719	0.1144	-0.0859	0.1601	-0.0859	Z
	15	44.9526	-23.1484	4.9350	45.0728	-23.0885	5.0214	-0.1202	0.0599	-0.0864	0.1597	-0.0864	Z
	16	40.0968	-7.0930	5.0053	40.1746	-6.9956	5.0845	-0.0778	0.0974	-0.0792	0.1477	-0.0792	Z
	17	39.7516	-10.1620	5.0081	39.8443	-10.0536	5.0920	-0.0927	0.1084	-0.0839	0.1655	-0.0839	Z
	18	39.6125	-14.8832	4.9861	39.7387	-14.8093	5.0701	-0.1262	0.0739	-0.0840	0.1687	-0.0840	Z
	19	39.3352	-18.6599	4.9736	39.4107	-18.5685	5.0588	-0.0755	0.0914	-0.0852	0.1460	-0.0852	Z
	20	39.0867	-22.8627	4.9777	39.2563	-22.8507	5.0617	-0.1696	0.0120	-0.0840	0.1896	-0.0840	Z
	21	34.6751	-7.2307	5.0420	34.7866	-7.1182	5.1202	-0.1115	0.1125	-0.0782	0.1766	-0.0782	Z
	22	34.7240	-10.4481	5.0430	34.8201	-10.3638	5.1355	-0.0961	0.0843	-0.0925	0.1578	-0.0925	Z
	23	34.7073	-13.6927	5.0213	34.8027	-13.6150	5.1115	-0.0954	0.0777	-0.0902	0.1526	-0.0902	Z
	24	34.6600	-17.8361	4.9983	34.7723	-17.7863	5.0860	-0.1123	0.0498	-0.0877	0.1509	-0.0877	Z
	25	34.9396	-22.9962	5.0184	35.0635	-22.9491	5.1074	-0.1239	0.0471	-0.0890	0.1597	-0.0890	Z
	26	30.9602	-8.1917	4.3196	31.0421	-8.0920	4.3975	-0.0819	0.0997	-0.0779	0.1507	-0.0779	Z
	27	31.0995	-11.5599	4.3043	31.1627	-11.5403	4.3879	-0.0632	0.0196	-0.0836	0.1066	-0.0836	Z
	28	31.2355	-14.9993	4.0673	31.3688	-14.9636	4.1619	-0.1333	0.0357	-0.0946	0.1673	-0.0946	Z
	29	31.2803	-18.6329	4.2668	31.3556	-18.5869	4.3467	-0.0753	0.0460	-0.0799	0.1190	-0.0799	Z
	30	31.3844	-23.5078	4.2554	31.4496	-23.4208	4.3373	-0.0652	0.0870	-0.0819	0.1361	-0.0819	Z

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

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

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

Pretest Floor Pan	Posttest Floor Pan
	

Figure C-1. Left Floor Pan Deformation Data – Set 1, Test No. WZNP-2

Date: 3/14/2019 Test Name: WZNP-2 VIN: 1D7RB1GP6BS634520
Year: 2011 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	54.2791	-25.1445	-1.3346	54.0635	-25.1045	-1.1867	0.2156	0.0400	-0.1479	0.2645	0.2156	X
	2	54.3452	-29.4529	-1.3265	54.1264	-29.4287	-1.2028	0.2188	0.0242	-0.1237	0.2525	0.2188	X
	3	54.5516	-33.4574	-1.3945	54.3286	-33.3245	-1.2922	0.2230	0.1329	-0.1023	0.2790	0.2230	X
	4	54.7471	-37.2543	-1.4512	54.5475	-37.1818	-1.3809	0.1996	0.0725	-0.0703	0.2237	0.1996	X
	5	54.8732	-41.9008	-1.4484	54.6651	-41.8634	-1.3994	0.2081	0.0374	-0.0490	0.2170	0.2081	X
	6	51.2412	-25.8844	0.2952	51.0862	-25.8362	0.3838	0.1550	0.0482	-0.0886	0.1849	0.1550	X
	7	51.2340	-30.8952	0.3501	51.0544	-30.8804	0.4228	0.1796	0.0148	-0.0727	0.1943	0.1796	X
	8	51.1895	-34.3910	0.4205	50.9825	-34.3193	0.4884	0.2070	0.0717	-0.0679	0.2293	0.2070	X
	9	51.2450	-39.0883	0.4480	51.0682	-39.0644	0.4726	0.1768	0.0239	-0.0246	0.1801	0.1768	X
	10	51.2992	-41.8327	0.4597	51.0669	-41.8551	0.4987	0.2323	-0.0224	-0.0390	0.2366	0.2323	X
FLOOR PAN (Z)	11	47.9996	-25.6892	1.0933	47.7801	-25.6096	1.1985	0.2195	0.0796	-0.1052	0.2561	-0.1052	Z
	12	47.7716	-29.3258	1.0948	47.6298	-29.2803	1.1729	0.1418	0.0455	-0.0781	0.1682	-0.0781	Z
	13	47.8531	-33.4732	1.0886	47.6984	-33.4165	1.1475	0.1547	0.0567	-0.0589	0.1750	-0.0589	Z
	14	47.7344	-37.4559	1.0886	47.5536	-37.3981	1.1255	0.1808	0.0578	-0.0369	0.1934	-0.0369	Z
	15	47.6623	-41.8009	1.0949	47.4550	-41.7613	1.1096	0.2073	0.0396	-0.0147	0.2116	-0.0147	Z
	16	42.4830	-25.8186	1.1129	42.2907	-25.7518	1.1842	0.1923	0.0668	-0.0713	0.2157	-0.0713	Z
	17	42.1521	-28.9059	1.1195	42.0110	-28.8149	1.1790	0.1411	0.0910	-0.0595	0.1781	-0.0595	Z
	18	42.1579	-33.6165	1.1081	41.9843	-33.5716	1.1407	0.1736	0.0449	-0.0326	0.1823	-0.0326	Z
	19	41.8901	-37.3951	1.1028	41.7187	-37.3357	1.1143	0.1714	0.0594	-0.0115	0.1818	-0.0115	Z
	20	41.7933	-41.6316	1.1170	41.6352	-41.6198	1.1019	0.1581	0.0118	0.0151	0.1593	0.0151	Z
	21	37.0754	-26.0307	1.1270	36.9053	-25.9636	1.1743	0.1701	0.0671	-0.0473	0.1889	-0.0473	Z
	22	37.1407	-29.2867	1.1390	36.9925	-29.2083	1.1793	0.1482	0.0784	-0.0403	0.1724	-0.0403	Z
	23	37.2109	-32.5154	1.1222	37.0291	-32.4592	1.1446	0.1818	0.0562	-0.0224	0.1916	-0.0224	Z
	24	37.2474	-36.6499	1.1068	37.0680	-36.6303	1.1051	0.1794	0.0196	0.0017	0.1805	0.0017	Z
	25	37.6381	-41.8321	1.1419	37.4444	-41.7877	1.1121	0.1937	0.0444	0.0298	0.2009	0.0298	Z
	26	33.3372	-27.0516	0.3880	33.1836	-26.9967	0.4171	0.1536	0.0549	-0.0291	0.1657	-0.0291	Z
	27	33.5837	-30.4838	0.3852	33.3614	-30.4425	0.3972	0.2223	0.0413	-0.0120	0.2264	-0.0120	Z
	28	33.7798	-33.8859	0.1593	33.6261	-33.8611	0.1618	0.1537	0.0248	-0.0025	0.1557	-0.0025	Z
	29	33.8447	-37.5328	0.3623	33.6713	-37.4848	0.3346	0.1734	0.0480	0.0277	0.1820	0.0277	Z
	30	34.0531	-42.3419	0.3665	33.8453	-42.3164	0.3102	0.2078	0.0255	0.0563	0.2168	0.0563	Z

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

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

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

Pretest Floor Pan	Posttest Floor Pan
	

Figure C-2. Left Floor Pan Deformation Data – Set 2, Test No. WZNP-2

Date: 3/14/2019 Test Name: WZNP-2 VIN: 1D7RB1GP6BS634520
Year: 2011 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
DRIVER SIDE INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	42.5702	4.5249	-28.2140	41.9196	5.8818	-28.1181	0.6506	-1.3569	0.0959	1.5079	1.5079	X, Y, Z
	2	41.5971	-7.2976	-28.8657	41.3715	-5.9213	-28.7664	0.2256	1.3763	0.0993	1.3982	1.3982	X, Y, Z
	3	41.5465	-19.1544	-29.3166	41.7347	-17.7839	-29.2481	-0.1882	1.3705	0.0685	1.3851	1.3851	X, Y, Z
	4	35.6517	4.6981	-17.5158	34.8472	5.9183	-17.4292	0.8045	-1.2202	0.0866	1.4641	1.4641	X, Y, Z
	5	37.6341	-7.2334	-16.2971	37.3010	-5.9388	-16.2327	0.3331	1.2946	0.0644	1.3383	1.3383	X, Y, Z
	6	39.1395	-26.2796	-16.3221	39.5667	-24.9395	-16.2239	-0.4272	1.3401	0.0982	1.4100	1.4100	X, Y, Z
SIDE PANEL (Y)	7	47.5542	-27.5193	-5.2855	47.8794	-26.2779	-5.1591	-0.3252	1.2414	0.1264	1.2895	1.2414	Y
	8	47.9185	-27.5146	-1.6335	48.2353	-26.2665	-1.5720	-0.3168	1.2481	0.0615	1.2891	1.2481	Y
	9	50.5436	-27.4827	-3.2542	50.6240	-27.3303	-3.0751	-0.0804	0.1524	0.1791	0.2485	0.1524	Y
IMPACT SIDE DOOR (Y)	10	37.4857	-29.5002	-20.4868	37.5496	-29.4106	-20.3134	-0.0639	0.0896	0.1734	0.2054	0.0896	Y
	11	27.2071	-29.5339	-19.9798	27.2741	-29.4229	-19.7373	-0.0670	0.1110	0.2425	0.2750	0.1110	Y
	12	16.7630	-29.7056	-19.9075	16.8035	-29.6267	-19.6613	-0.0405	0.0789	0.2462	0.2617	0.0789	Y
	13	37.6688	-28.5055	-6.6801	37.6853	-28.4368	-6.5801	-0.0165	0.0687	0.1000	0.1224	0.0687	Y
	14	30.1439	-30.9640	-4.4468	30.2273	-30.8305	-4.3370	-0.0834	0.1335	0.1098	0.1919	0.1335	Y
	15	19.1626	-30.1845	-2.9504	19.2257	-30.0645	-2.8783	-0.0631	0.1200	0.0721	0.1536	0.1200	Y
ROOF - (Z)	16	34.0372	5.0018	-43.0528	33.9973	4.9580	-42.9492	0.0399	0.0438	0.1036	0.1193	0.1036	Z
	17	34.1631	0.2956	-42.9584	34.1774	0.2547	-42.8143	-0.0143	0.0409	0.1441	0.1505	0.1441	Z
	18	33.5288	-6.2644	-42.8976	33.6289	-6.2684	-42.7059	-0.1001	-0.0040	0.1917	0.2163	0.1917	Z
	19	32.4830	-12.4984	-42.7376	32.5197	-12.5469	-42.5614	-0.0367	-0.0485	0.1762	0.1864	0.1762	Z
	20	31.1678	-17.3893	-42.5472	31.2054	-17.3985	-42.3665	-0.0376	-0.0092	0.1807	0.1848	0.1807	Z
	21	23.9012	6.1360	-46.3854	23.9337	6.0155	-46.2387	-0.0325	0.1205	0.1467	0.1926	0.1467	Z
	22	24.3543	-0.2128	-46.3046	24.4254	-0.3341	-46.1419	-0.0711	-0.1213	0.1627	0.2150	0.1627	Z
	23	24.4740	-5.4586	-46.1537	24.4506	-5.4517	-45.9968	0.0234	0.0069	0.1569	0.1588	0.1569	Z
	24	24.3476	-10.3012	-45.9301	24.4739	-10.3455	-45.7394	-0.1263	-0.0443	0.1907	0.2330	0.1907	Z
	25	24.1382	-14.9843	-45.6031	24.2392	-14.8808	-45.4245	-0.1010	0.1035	0.1786	0.2298	0.1786	Z
	26	9.9818	5.9860	-47.2072	9.9838	5.8614	-47.0841	-0.0020	0.1246	0.1231	0.1752	0.1231	Z
	27	9.8055	0.1268	-47.2130	9.8672	-0.0308	-47.0619	-0.0617	0.1576	0.1511	0.2269	0.1511	Z
	28	10.0330	-4.8152	-47.1161	10.0448	-4.9025	-46.9507	-0.0118	-0.0873	0.1654	0.1874	0.1654	Z
	29	10.3868	-10.5979	-46.8817	10.4111	-10.7159	-46.7043	-0.0243	-0.1180	0.1774	0.2144	0.1774	Z
	30	10.8370	-15.1470	-46.6073	10.8517	-15.3077	-46.4182	-0.0147	-0.1607	0.1891	0.2486	0.1891	Z
A-PILLAR Maximum (X, Y, Z)	31	45.6407	-25.7164	-29.8767	45.7496	-25.6074	-29.7473	-0.1089	0.1090	0.1294	0.2012	0.1692	Y, Z
	32	44.1371	-25.4046	-31.0885	44.2832	-25.3097	-30.9141	-0.1461	0.0949	0.1744	0.2465	0.1985	Y, Z
	33	42.1968	-24.8757	-32.5073	42.3406	-24.8011	-32.3623	-0.1438	0.0746	0.1450	0.2174	0.1631	Y, Z
	34	38.9986	-24.1896	-34.7739	39.1458	-24.1230	-34.6371	-0.1472	0.0666	0.1368	0.2117	0.1522	Y, Z
	35	35.3881	-23.5093	-37.2879	35.4288	-23.3987	-37.1758	-0.0407	0.1106	0.1121	0.1627	0.1575	Y, Z
	36	30.9643	-22.7542	-40.0225	31.1187	-22.6767	-39.8678	-0.1544	0.0775	0.1547	0.2319	0.1730	Y, Z
A-PILLAR Lateral (Y)	31	45.6407	-25.7164	-29.8767	45.7496	-25.6074	-29.7473	-0.1089	0.1090	0.1294	0.2012	0.1090	Y
	32	44.1371	-25.4046	-31.0885	44.2832	-25.3097	-30.9141	-0.1461	0.0949	0.1744	0.2465	0.0949	Y
	33	42.1968	-24.8757	-32.5073	42.3406	-24.8011	-32.3623	-0.1438	0.0746	0.1450	0.2174	0.0746	Y
	34	38.9986	-24.1896	-34.7739	39.1458	-24.1230	-34.6371	-0.1472	0.0666	0.1368	0.2117	0.0666	Y
	35	35.3881	-23.5093	-37.2879	35.4288	-23.3987	-37.1758	-0.0407	0.1106	0.1121	0.1627	0.1106	Y
	36	30.9643	-22.7542	-40.0225	31.1187	-22.6767	-39.8678	-0.1544	0.0775	0.1547	0.2319	0.0775	Y
B-PILLAR Maximum (X, Y, Z)	37	6.4496	-24.5877	-36.2592	6.4471	-24.4975	-36.1022	0.0025	0.0902	0.1570	0.1811	0.1811	X, Y, Z
	38	4.2047	-27.5121	-23.7134	4.3044	-27.4138	-23.5763	-0.0997	0.0983	0.1371	0.1960	0.1687	Y, Z
	39	8.6498	-27.6698	-19.6973	8.7277	-27.5675	-19.6103	-0.0779	0.1023	0.0870	0.1553	0.1343	Y, Z
	40	4.8321	-27.8480	-14.7507	4.8897	-27.7408	-14.6389	-0.0576	0.1072	0.1118	0.1653	0.1549	Y, Z
B-PILLAR Lateral (Y)	37	6.4496	-24.5877	-36.2592	6.4471	-24.4975	-36.1022	0.0025	0.0902	0.1570	0.1811	0.0902	Y
	38	4.2047	-27.5121	-23.7134	4.3044	-27.4138	-23.5763	-0.0997	0.0983	0.1371	0.1960	0.0983	Y
	39	8.6498	-27.6698	-19.6973	8.7277	-27.5675	-19.6103	-0.0779	0.1023	0.0870	0.1553	0.1023	Y
	40	4.8321	-27.8480	-14.7507	4.8897	-27.7408	-14.6389	-0.0576	0.1072	0.1118	0.1653	0.1072	Y

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

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

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

Figure C-3. Left Interior Crush Data – Set 1, Test No. WZNP-2

Date: 3/14/2019 Test Name: WZNP-2 VIN: 1D7RB1GP6BS634520
Year: 2011 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
DRIVER SIDE INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	44.8609	-14.2196	-32.1349	44.1167	-12.7395	-31.9402	0.7442	1.4801	0.1947	1.6681	1.6681	X, Y, Z
	2	44.1037	-26.0595	-32.7580	43.7691	-24.5478	-32.6325	0.3346	1.5117	0.1255	1.5534	1.5534	X, Y, Z
	3	44.2688	-37.9165	-33.1768	44.3320	-36.4011	-33.1503	-0.0632	1.5154	0.0265	1.5169	1.5169	X, Y, Z
	4	37.8990	-14.1430	-21.4637	36.9509	-12.8564	-21.3143	0.9481	1.2866	0.1494	1.6052	1.6052	X, Y, Z
	5	40.0917	-26.0335	-20.2049	39.5892	-24.6757	-20.1354	0.5025	1.3578	0.0695	1.4495	1.4495	X, Y, Z
	6	41.9406	-45.0494	-20.1722	42.1676	-43.6364	-20.1696	-0.2270	1.4130	0.0026	1.4311	1.4311	X, Y, Z
SIDE PANEL (Y)	7	50.3336	-46.1077	-9.1002	50.4036	-44.8762	-9.0362	-0.0700	1.2315	0.0640	1.2351	1.2315	Y
	8	50.6836	-46.0866	-5.4469	50.7277	-44.8713	-5.4460	-0.0441	1.2153	0.0009	1.2161	1.2153	Y
	9	53.3140	-46.0117	-7.0577	53.1468	-45.8905	-6.9314	0.1672	0.1212	0.1263	0.2421	0.1212	Y
IMPACT SIDE DOOR (Y)	10	40.3612	-48.3103	-24.3344	40.2606	-48.1259	-24.2916	0.1006	0.1844	0.0428	0.2144	0.1844	Y
	11	30.0831	-48.5283	-23.8665	29.9820	-48.3093	-23.8066	0.1011	0.2190	0.0599	0.2485	0.2190	Y
	12	19.6435	-48.8884	-23.8336	19.5159	-48.6856	-23.8240	0.1276	0.2028	0.0096	0.2398	0.2028	Y
	13	40.4730	-47.2758	-10.5298	40.2594	-47.1976	-10.5545	0.2136	0.0782	-0.0247	0.2288	0.0782	Y
	14	32.9851	-49.8639	-8.3186	32.8224	-49.7214	-8.3855	0.1627	0.1425	-0.0669	0.2264	0.1425	Y
	15	21.9859	-49.2788	-6.8662	21.7972	-49.1416	-7.0218	0.1887	0.1372	-0.1556	0.2804	0.1372	Y
ROOF - (Z)	16	36.3780	-13.9363	-47.0074	36.3416	-13.7422	-46.8439	0.0364	0.1941	0.1635	0.2564	0.1635	Z
	17	36.5884	-18.6392	-46.8997	36.5980	-18.4424	-46.7229	-0.0096	0.1968	0.1768	0.2647	0.1768	Z
	18	36.0724	-25.2094	-46.8234	36.1561	-24.9740	-46.6411	-0.0837	0.2354	0.1823	0.3093	0.1823	Z
	19	35.1386	-31.4608	-46.6503	35.1494	-31.2703	-46.5272	-0.0108	0.1905	0.1231	0.2271	0.1231	Z
	20	33.9111	-36.3742	-46.4516	33.9136	-36.1435	-46.3601	-0.0025	0.2307	0.0915	0.2482	0.0915	Z
	21	26.2361	-12.9942	-50.3817	26.2912	-12.8391	-50.2188	-0.0551	0.1551	0.1629	0.2316	0.1629	Z
	22	26.8034	-19.3335	-50.2818	26.8866	-19.1800	-50.1388	-0.0832	0.1535	0.1430	0.2257	0.1430	Z
	23	27.0172	-24.5759	-50.1162	26.9950	-24.2971	-50.0104	0.0222	0.2788	0.1058	0.2990	0.1058	Z
	24	26.9774	-29.4194	-49.8799	27.0966	-29.1907	-49.7691	-0.1192	0.2287	0.1108	0.2807	0.1108	Z
	25	26.8512	-34.1046	-49.5409	26.9340	-33.7302	-49.4713	-0.0828	0.3744	0.0696	0.3897	0.0696	Z
	26	12.3251	-13.3976	-51.2562	12.3537	-13.2198	-51.1883	-0.0286	0.1778	0.0679	0.1925	0.0679	Z
	27	12.2545	-19.2590	-51.2467	12.3341	-19.1132	-51.1866	-0.0796	0.1458	0.0601	0.1767	0.0601	Z
	28	12.5707	-24.1959	-51.1355	12.5910	-23.9816	-51.0900	-0.0203	0.2143	0.0455	0.2200	0.0455	Z
	29	13.0279	-29.9705	-50.8840	13.0509	-29.7891	-50.8597	-0.0230	0.1814	0.0243	0.1845	0.0243	Z
	30	13.5590	-34.5101	-50.5954	13.5646	-34.3739	-50.5849	-0.0056	0.1362	0.0105	0.1367	0.0105	Z
A-PILLAR Maximum (X, Y, Z)	31	48.4829	-44.4049	-33.7034	48.4795	-44.1557	-33.6399	0.0034	0.2492	0.0635	0.2572	0.2572	X, Y, Z
	32	46.9786	-44.1236	-34.9218	47.0187	-43.8781	-34.8186	-0.0401	0.2455	0.1032	0.2693	0.2663	Y, Z
	33	45.0346	-43.6335	-36.3494	45.0808	-43.3965	-36.2823	-0.0462	0.2370	0.0671	0.2506	0.2463	Y, Z
	34	41.8333	-43.0113	-38.6301	41.8954	-42.7632	-38.5830	-0.0621	0.2481	0.0471	0.2601	0.2525	Y, Z
	35	38.2209	-42.4030	-41.1596	38.1895	-42.0913	-41.1521	0.0314	0.3117	0.0075	0.3134	0.3134	X, Y, Z
	36	33.7948	-41.7352	-43.9131	33.8919	-41.4311	-43.8797	-0.0971	0.3041	0.0334	0.3210	0.3059	Y, Z
A-PILLAR Lateral (Y)	31	48.4829	-44.4049	-33.7034	48.4795	-44.1557	-33.6399	0.0034	0.2492	0.0635	0.2572	0.2492	Y
	32	46.9786	-44.1236	-34.9218	47.0187	-43.8781	-34.8186	-0.0401	0.2455	0.1032	0.2693	0.2455	Y
	33	45.0346	-43.6335	-36.3494	45.0808	-43.3965	-36.2823	-0.0462	0.2370	0.0671	0.2506	0.2370	Y
	34	41.8333	-43.0113	-38.6301	41.8954	-42.7632	-38.5830	-0.0621	0.2481	0.0471	0.2601	0.2481	Y
	35	38.2209	-42.4030	-41.1596	38.1895	-42.0913	-41.1521	0.0314	0.3117	0.0075	0.3134	0.3117	Y
	36	33.7948	-41.7352	-43.9131	33.8919	-41.4311	-43.8797	-0.0971	0.3041	0.0334	0.3210	0.3041	Y
B-PILLAR Maximum (X, Y, Z)	37	9.3028	-44.0010	-40.2384	9.2215	-43.6706	-40.3388	0.0813	0.3304	-0.1004	0.3548	0.3403	X, Y
	38	7.0625	-46.9321	-27.6934	7.0170	-46.6652	-27.8422	0.0455	0.2669	-0.1488	0.3089	0.2708	X, Y
	39	11.4942	-46.9988	-23.6600	11.4072	-46.7598	-23.8377	0.0870	0.2390	-0.1777	0.3103	0.2543	X, Y
	40	7.6613	-47.2327	-18.7274	7.5290	-47.0134	-18.9011	0.1323	0.2193	-0.1737	0.3095	0.2561	X, Y
B-PILLAR Lateral (Y)	37	9.3028	-44.0010	-40.2384	9.2215	-43.6706	-40.3388	0.0813	0.3304	-0.1004	0.3548	0.3304	Y
	38	7.0625	-46.9321	-27.6934	7.0170	-46.6652	-27.8422	0.0455	0.2669	-0.1488	0.3089	0.2669	Y
	39	11.4942	-46.9988	-23.6600	11.4072	-46.7598	-23.8377	0.0870	0.2390	-0.1777	0.3103	0.2390	Y
	40	7.6613	-47.2327	-18.7274	7.5290	-47.0134	-18.9011	0.1323	0.2193	-0.1737	0.3095	0.2193	Y

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

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

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

Figure C-4. Left Interior Crush Data – Set 2, Test No. WZNP-2

Date: 3/14/2019 Test Name: WZNP-2 VIN: 1D7RB1GP6BS634520
Year: 2011 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	55.2346	32.0113	-1.5403	55.2220	32.0556	-1.3620	0.0126	-0.0443	-0.1783	0.1842	0.0126	X
	2	56.0127	29.1949	-0.2558	56.0140	29.2546	-0.1220	-0.0013	-0.0597	-0.1338	0.1465	0.0000	NA
	3	55.7108	25.9067	0.0439	55.6973	25.9444	0.1734	0.0135	-0.0377	-0.1295	0.1355	0.0135	X
	4	55.4657	23.3568	-0.0348	55.4549	23.4429	0.0786	0.0108	-0.0861	-0.1134	0.1428	0.0108	X
	5	54.2642	21.6627	-1.5696	54.2668	21.8255	-1.3988	-0.0026	-0.1628	-0.1708	0.2360	0.0000	NA
	6	50.8912	32.6256	2.7549	50.9063	32.7508	2.8586	-0.0151	-0.1252	-0.1037	0.1633	0.0000	NA
	7	50.8806	28.6701	2.7721	50.9231	28.8273	2.8624	-0.0425	-0.1572	-0.0903	0.1862	0.0000	NA
	8	51.0141	25.6962	2.7273	51.0467	25.8328	2.8224	-0.0326	-0.1366	-0.0951	0.1696	0.0000	NA
	9	50.8971	23.1290	2.5518	50.9127	23.2613	2.6733	-0.0156	-0.1323	-0.1215	0.1803	0.0000	NA
	10	50.0692	21.1014	0.2794	50.0565	21.2626	0.4505	0.0127	-0.1612	-0.1711	0.2354	0.0127	X
FLOOR PAN (Z)	11	45.2116	34.2453	5.0508	45.2639	34.3217	5.1505	-0.0523	-0.0764	-0.0997	0.1361	-0.0997	Z
	12	44.9768	29.8539	5.0172	45.0207	29.9183	5.1155	-0.0439	-0.0644	-0.0983	0.1254	-0.0983	Z
	13	44.7672	26.3345	5.0305	44.8177	26.4063	5.1287	-0.0505	-0.0718	-0.0982	0.1317	-0.0982	Z
	14	44.7369	23.2152	5.0178	44.7441	23.3043	5.1172	-0.0072	-0.0891	-0.0994	0.1337	-0.0994	Z
	15	44.5559	20.3186	4.7805	44.5602	20.3955	4.8803	-0.0043	-0.0769	-0.0998	0.1261	-0.0998	Z
	16	40.5707	34.4791	5.1106	40.6098	34.5679	5.2072	-0.0391	-0.0888	-0.0966	0.1369	-0.0966	Z
	17	40.1689	30.3747	5.0711	40.2249	30.4823	5.1670	-0.0560	-0.1076	-0.0959	0.1546	-0.0959	Z
	18	39.6967	26.0647	5.0719	39.7652	26.1659	5.1673	-0.0685	-0.1012	-0.0954	0.1550	-0.0954	Z
	19	39.2462	22.9082	5.0733	39.2909	22.9482	5.1683	-0.0447	-0.0400	-0.0950	0.1124	-0.0950	Z
	20	39.1815	17.8692	5.0741	39.2358	17.9557	5.1698	-0.0543	-0.0865	-0.0957	0.1400	-0.0957	Z
	21	34.6625	34.3302	5.1387	34.7189	34.4115	5.2302	-0.0564	-0.0813	-0.0915	0.1348	-0.0915	Z
	22	34.6595	30.7932	5.1376	34.6915	30.8611	5.2287	-0.0320	-0.0679	-0.0911	0.1180	-0.0911	Z
	23	34.9819	25.4563	5.1017	35.0209	25.5320	5.1938	-0.0390	-0.0757	-0.0921	0.1254	-0.0921	Z
	24	34.8232	21.6166	5.1091	34.8772	21.6812	5.2006	-0.0540	-0.0646	-0.0915	0.1243	-0.0915	Z
	25	35.0005	17.2748	5.1075	35.0093	17.3250	5.1997	-0.0088	-0.0502	-0.0922	0.1053	-0.0922	Z
	26	30.6182	33.8089	4.1514	30.6254	33.8889	4.2399	-0.0072	-0.0800	-0.0885	0.1195	-0.0885	Z
	27	30.7718	30.0524	4.3797	30.8101	30.1038	4.4667	-0.0383	-0.0514	-0.0870	0.1081	-0.0870	Z
	28	31.0939	25.0769	4.3685	31.1283	25.1438	4.4550	-0.0344	-0.0669	-0.0865	0.1146	-0.0865	Z
	29	31.1409	20.8643	4.3656	31.2175	20.9748	4.4565	-0.0766	-0.1105	-0.0909	0.1623	-0.0909	Z
	30	31.1655	16.6633	4.3721	31.2053	16.6826	4.4605	-0.0398	-0.0193	-0.0884	0.0988	-0.0884	Z

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

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

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

Pretest Floor Pan	Posttest Floor Pan
	

Figure C-5. Right Floor Pan Deformation Data – Set 1, Test No. WZNP-2

Date: 3/14/2019 Test Name: WZNP-2 VIN: 1D7RB1GP6BS634520
Year: 2011 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	56.9506	13.5389	-5.4618	56.7813	13.5184	-5.0272	0.1693	0.0205	-0.4346	0.4669	0.1693	X
	2	57.7727	10.7397	-4.1671	57.6069	10.7264	-3.7886	0.1658	0.0133	-0.3785	0.4134	0.1658	X
	3	57.5274	7.4474	-3.8606	57.3396	7.4108	-3.5052	0.1878	0.0366	-0.3554	0.4036	0.1878	X
	4	57.3275	4.8934	-3.9341	57.1372	4.9062	-3.6090	0.1903	-0.0128	-0.3251	0.3769	0.1903	X
	5	56.1624	3.1747	-5.4698	55.9867	3.2747	-5.1007	0.1757	-0.1000	-0.3691	0.4208	0.1757	X
	6	52.5790	14.0869	-1.1863	52.4209	14.1336	-0.8402	0.1581	-0.0467	-0.3461	0.3834	0.1581	X
	7	52.6378	10.1319	-1.1594	52.4991	10.2108	-0.8473	0.1387	-0.0789	-0.3121	0.3505	0.1387	X
	8	52.8237	7.1607	-1.1964	52.6699	7.2187	-0.8947	0.1538	-0.0580	-0.3017	0.3436	0.1538	X
	9	52.7527	4.5914	-1.3661	52.5774	4.6459	-1.0522	0.1753	-0.0545	-0.3139	0.3636	0.1753	X
	10	51.9701	2.5443	-3.6370	51.7708	2.6406	-3.2876	0.1993	-0.0963	-0.3494	0.4136	0.1993	X
FLOOR PAN (Z)	11	46.8621	15.6120	1.0818	46.7361	15.6093	1.4098	0.1260	0.0027	-0.3280	0.3514	-0.3280	Z
	12	46.7047	11.2171	1.0579	46.5622	11.2027	1.3603	0.1425	0.0144	-0.3024	0.3346	-0.3024	Z
	13	46.5569	7.6946	1.0790	46.4141	7.6880	1.3620	0.1428	0.0066	-0.2830	0.3171	-0.2830	Z
	14	46.5815	4.5752	1.0738	46.3891	4.5852	1.3411	0.1924	-0.0100	-0.2673	0.3295	-0.2673	Z
	15	46.4524	1.6753	0.8428	46.2528	1.6746	1.0945	0.1996	0.0007	-0.2517	0.3212	-0.2517	Z
	16	42.2177	15.7643	1.1215	42.0784	15.7825	1.4290	0.1393	-0.0182	-0.3075	0.3381	-0.3075	Z
	17	41.8881	11.6534	1.0904	41.7578	11.6915	1.3741	0.1303	-0.0381	-0.2837	0.3145	-0.2837	Z
	18	41.4918	7.3357	1.0998	41.3658	7.3685	1.3584	0.1260	-0.0328	-0.2586	0.2895	-0.2586	Z
	19	41.0968	4.1718	1.1071	40.9420	4.1438	1.3465	0.1548	0.0280	-0.2394	0.2865	-0.2394	Z
	20	41.1207	-0.8675	1.1200	40.9650	-0.8489	1.3334	0.1557	0.0186	-0.2134	0.2648	-0.2134	Z
	21	36.3129	15.5117	1.1253	36.1907	15.5340	1.4032	0.1222	-0.0223	-0.2779	0.3044	-0.2779	Z
	22	36.3721	11.9751	1.1327	36.2189	11.9836	1.3914	0.1532	-0.0085	-0.2587	0.3008	-0.2587	Z
	23	36.7883	6.6446	1.1113	36.6320	6.6604	1.3442	0.1563	-0.0158	-0.2329	0.2809	-0.2329	Z
	24	36.6971	2.8028	1.1275	36.5485	2.8078	1.3389	0.1486	-0.0050	-0.2114	0.2585	-0.2114	Z
	25	36.9507	-1.5353	1.1373	36.7488	-1.5458	1.3268	0.2019	-0.0105	-0.1895	0.2771	-0.1895	Z
	26	32.2826	14.9169	0.1223	32.1141	14.9503	0.3779	0.1685	-0.0334	-0.2556	0.3080	-0.2556	Z
	27	32.5012	11.1643	0.3604	32.3561	11.1680	0.5955	0.1451	-0.0037	-0.2351	0.2763	-0.2351	Z
	28	32.9107	6.1952	0.3628	32.7521	6.2136	0.5724	0.1586	-0.0184	-0.2096	0.2635	-0.2096	Z
	29	33.0318	1.9841	0.3704	32.9065	2.0465	0.5629	0.1253	-0.0624	-0.1925	0.2380	-0.1925	Z
	30	33.1301	-2.2158	0.3873	32.9616	-2.2454	0.5547	0.1685	-0.0296	-0.1674	0.2394	-0.1674	Z

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

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

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

Pretest Floor Pan	Posttest Floor Pan
	

Figure C-6. Right Floor Pan Deformation Data – Set 2, Test No. WZNP-2

Date: 3/14/2019 Test Name: WZNP-2 VIN: 1D7RB1GP6BS634520
Year: 2011 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	42.5805	4.4646	-28.2357	42.2176	4.8593	-28.1835	0.3629	-0.3947	0.0522	0.5387	0.5387	X, Y, Z
	2	42.1795	16.4458	-27.7750	41.7185	16.8600	-27.6837	0.4610	-0.4142	0.0913	0.6264	0.6264	X, Y, Z
	3	43.5913	32.7279	-27.1442	42.9760	33.1676	-27.0547	0.6153	-0.4397	0.0895	0.7615	0.7615	X, Y, Z
	4	35.6580	4.6833	-17.4948	35.2623	4.9981	-17.3774	0.3957	-0.3148	0.1174	0.5191	0.5191	X, Y, Z
	5	37.4704	16.6508	-16.4511	36.9732	16.9862	-16.3518	0.4972	-0.3354	0.0993	0.6079	0.6079	X, Y, Z
	6	38.3435	33.1453	-16.3397	37.6990	33.5380	-16.2161	0.6445	-0.3927	0.1236	0.7648	0.7648	X, Y, Z
SIDE PANEL (Y)	7	47.6294	37.0809	-5.0823	47.0114	37.4463	-4.9683	0.6180	-0.3654	0.1140	0.7269	-0.3654	Y
	8	47.7156	37.0587	-0.3821	47.0999	37.4223	-0.2615	0.6157	-0.3636	0.1206	0.7251	-0.3636	Y
	9	49.6820	37.0614	-2.5690	49.0159	37.4433	-2.4376	0.6661	-0.3819	0.1314	0.7790	-0.3819	Y
IMPACT SIDE DOOR (Y)	10	38.0588	38.9786	-19.3935	37.4222	39.2742	-19.2810	0.6366	-0.2956	0.1125	0.7108	-0.2956	Y
	11	26.2088	38.8460	-18.3675	25.5596	39.0287	-18.2752	0.6492	-0.1827	0.0923	0.6807	-0.1827	Y
	12	15.6850	39.5418	-17.7652	15.0435	39.6241	-17.6065	0.6415	-0.0823	0.1587	0.6659	-0.0823	Y
	13	37.4303	37.6034	-6.8585	36.8095	37.9271	-6.8258	0.6208	-0.3237	0.0327	0.7009	-0.3237	Y
	14	28.4348	40.1436	-3.6056	27.7637	40.3459	-3.4959	0.6711	-0.2023	0.1097	0.7095	-0.2023	Y
	15	16.0051	39.2685	-2.9015	15.3206	39.3644	-2.7729	0.6845	-0.0959	0.1286	0.7030	-0.0959	Y
ROOF - (Z)	16	34.0213	4.8882	-43.0854	33.6278	5.1938	-42.9189	0.3935	-0.3056	0.1665	0.5253	0.1665	Z
	17	33.8603	10.2997	-43.0419	33.4764	10.6199	-42.8464	0.3839	-0.3202	0.1955	0.5368	0.1955	Z
	18	33.3936	15.7737	-42.8907	32.9275	16.0228	-42.7119	0.4661	-0.2491	0.1788	0.5579	0.1788	Z
	19	32.4106	20.8193	-42.7611	31.9143	21.1067	-42.5706	0.4963	-0.2874	0.1905	0.6043	0.1905	Z
	20	30.9663	26.3807	-42.4575	30.4283	26.7114	-42.2454	0.5380	-0.3307	0.2121	0.6662	0.2121	Z
	21	23.8955	5.9450	-46.4042	23.5442	6.1664	-46.2193	0.3513	-0.2214	0.1849	0.4546	0.1849	Z
	22	23.9585	11.1828	-46.2978	23.5277	11.3361	-46.1171	0.4308	-0.1533	0.1807	0.4917	0.1807	Z
	23	23.8953	16.3896	-46.0906	23.3412	16.6121	-45.9195	0.5541	-0.2225	0.1711	0.6211	0.1711	Z
	24	23.3865	22.1010	-45.7694	22.8928	22.3236	-45.5752	0.4937	-0.2226	0.1942	0.5753	0.1942	Z
	25	22.8205	27.0259	-45.3638	22.2982	27.2645	-45.1594	0.5223	-0.2386	0.2044	0.6095	0.2044	Z
	26	9.9701	5.9491	-47.2094	9.6094	6.0093	-47.0474	0.3607	-0.0602	0.1620	0.4000	0.1620	Z
	27	9.6380	11.1704	-47.1363	9.1472	11.2215	-46.9728	0.4908	-0.0511	0.1635	0.5198	0.1635	Z
	28	10.5125	16.4959	-46.9329	9.9894	16.5480	-46.7743	0.5231	-0.0521	0.1586	0.5491	0.1586	Z
	29	11.2036	20.9736	-46.6785	10.6607	21.0097	-46.5196	0.5429	-0.0361	0.1589	0.5668	0.1589	Z
	30	11.8980	25.3162	-46.3502	11.3269	25.4388	-46.1856	0.5711	-0.1226	0.1646	0.6069	0.1646	Z
A-PILLAR Maximum (X, Y, Z)	31	45.3664	35.5243	-30.4379	44.8803	35.9235	-30.2628	0.4861	-0.3992	0.1751	0.6529	0.5167	X, Z
	32	43.4673	35.0927	-31.8196	42.9247	35.4579	-31.6796	0.5426	-0.3652	0.1400	0.6689	0.5604	X, Z
	33	41.3102	34.6061	-33.3831	40.7147	34.9308	-33.2486	0.5955	-0.3247	0.1345	0.6915	0.6105	X, Z
	34	39.2185	34.0691	-34.9434	38.6873	34.3951	-34.8236	0.5312	-0.3260	0.1198	0.6347	0.5445	X, Z
	35	36.1268	33.4921	-37.1928	35.5284	33.7716	-37.0881	0.5984	-0.2795	0.1047	0.6687	0.6075	X, Z
	36	31.5301	32.4782	-39.9912	31.0119	32.7305	-39.8273	0.5182	-0.2523	0.1639	0.5992	0.5435	X, Z
A-PILLAR Lateral (Y)	31	45.3664	35.5243	-30.4379	44.8803	35.9235	-30.2628	0.4861	-0.3992	0.1751	0.6529	-0.3992	Y
	32	43.4673	35.0927	-31.8196	42.9247	35.4579	-31.6796	0.5426	-0.3652	0.1400	0.6689	-0.3652	Y
	33	41.3102	34.6061	-33.3831	40.7147	34.9308	-33.2486	0.5955	-0.3247	0.1345	0.6915	-0.3247	Y
	34	39.2185	34.0691	-34.9434	38.6873	34.3951	-34.8236	0.5312	-0.3260	0.1198	0.6347	-0.3260	Y
	35	36.1268	33.4921	-37.1928	35.5284	33.7716	-37.0881	0.5984	-0.2795	0.1047	0.6687	-0.2795	Y
	36	31.5301	32.4782	-39.9912	31.0119	32.7305	-39.8273	0.5182	-0.2523	0.1639	0.5992	-0.2523	Y
B-PILLAR Maximum (X, Y, Z)	37	5.9475	33.7852	-35.5795	5.3917	33.7843	-35.4461	0.5558	0.0009	0.1334	0.5716	0.5716	X, Y, Z
	38	3.7464	36.3412	-24.4609	3.1336	36.3293	-24.2579	0.6128	0.0119	0.2030	0.6457	0.6457	X, Y, Z
	39	8.2263	36.6378	-18.4434	7.6033	36.6596	-18.3177	0.6230	-0.0218	0.1257	0.6359	0.6356	X, Z
	40	4.3314	36.7277	-13.2758	3.7079	36.7138	-13.1541	0.6235	0.0139	0.1217	0.6354	0.6354	X, Y, Z
B-PILLAR Lateral (Y)	37	5.9475	33.7852	-35.5795	5.3917	33.7843	-35.4461	0.5558	0.0009	0.1334	0.5716	0.0009	Y
	38	3.7464	36.3412	-24.4609	3.1336	36.3293	-24.2579	0.6128	0.0119	0.2030	0.6457	0.0119	Y
	39	8.2263	36.6378	-18.4434	7.6033	36.6596	-18.3177	0.6230	-0.0218	0.1257	0.6359	-0.0218	Y
	40	4.3314	36.7277	-13.2758	3.7079	36.7138	-13.1541	0.6235	0.0139	0.1217	0.6354	0.0139	Y

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

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

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

Figure C-7. Right Interior Crush Data – Set 1, Test No. WZNP-2

Date: 3/14/2019 Test Name: WZNP-2 VIN: 1D7RB1GP6BS634520
Year: 2011 Make: Dodge Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	44.8857	-14.2855	-32.1464	44.9318	-14.0979	-32.0439	-0.0461	0.1876	0.1025	0.2187	0.2187	X, Y, Z
	2	44.2717	-2.3122	-31.7159	44.2666	-2.1068	-31.5096	0.0051	0.2054	0.2063	0.2912	0.2912	X, Y, Z
	3	45.3936	13.9937	-31.1183	45.2986	14.2141	-30.8182	0.0950	-0.2204	0.3001	0.3843	0.3843	X, Y, Z
	4	37.9173	-14.1641	-21.4337	37.8892	-14.0887	-21.2936	0.0281	0.0754	0.1401	0.1616	0.1616	X, Y, Z
	5	39.5141	-2.1641	-20.4113	39.4297	-2.0821	-20.2158	0.0844	0.0820	0.1955	0.2282	0.2282	X, Y, Z
	6	40.0958	14.3435	-20.3358	39.9307	14.4774	-20.0212	0.1651	-0.1339	0.3146	0.3797	0.3797	X, Y, Z
SIDE PANEL (Y)	7	49.2654	18.4684	-9.0509	49.0994	18.4736	-8.6866	0.1660	-0.0052	0.3643	0.4004	-0.0052	Y
	8	49.3331	18.4585	-4.3504	49.1507	18.4352	-3.9793	0.1824	0.0233	0.3711	0.4142	0.0233	Y
	9	51.3080	18.4909	-6.5295	51.0835	18.4893	-6.1399	0.2245	0.0016	0.3896	0.4497	0.0016	Y
IMPACT SIDE DOOR (Y)	10	39.7206	20.1638	-23.4047	39.6009	20.2195	-23.0698	0.1197	-0.0557	0.3349	0.3600	-0.0557	Y
	11	27.8707	19.8245	-22.4256	27.7351	19.8108	-22.1601	0.1356	0.0137	0.2655	0.2984	0.0137	Y
	12	17.3340	20.3359	-21.8669	17.2069	20.2620	-21.5739	0.1271	0.0739	0.2930	0.3278	0.0739	Y
	13	39.0659	18.8067	-10.8691	38.9071	18.8230	-10.6244	0.1588	-0.0163	0.2447	0.2922	-0.0163	Y
	14	30.0140	21.1954	-7.6581	29.8031	21.1085	-7.3594	0.2109	0.0869	0.2987	0.3758	0.0869	Y
	15	17.5989	20.1027	-7.0014	17.3691	19.9569	-6.7394	0.2298	0.1458	0.2620	0.3778	0.1458	Y
ROOF - (Z)	16	36.3802	-14.0473	-47.0311	36.4561	-13.8304	-46.8466	-0.0759	0.2169	0.1845	0.2947	0.1845	Z
	17	36.1237	-8.6394	-47.0012	36.2309	-8.4071	-46.7579	-0.1072	0.2323	0.2433	0.3531	0.2433	Z
	18	35.5599	-3.1742	-46.8649	35.6079	-3.0126	-46.6105	-0.0480	0.1616	0.2544	0.3052	0.2544	Z
	19	34.4876	1.8536	-46.7512	34.5251	2.0566	-46.4610	-0.0375	-0.2030	0.2902	0.3561	0.2902	Z
	20	32.9443	7.3893	-46.4667	32.9609	7.6397	-46.1298	-0.0166	-0.2504	0.3369	0.4201	0.3369	Z
	21	26.2509	-13.1770	-50.3927	26.3870	-12.9829	-50.2247	-0.1361	0.1941	0.1680	0.2906	0.1680	Z
	22	26.2210	-7.9387	-50.2986	26.2998	-7.8143	-50.1060	-0.0788	0.1244	0.1926	0.2424	0.1926	Z
	23	26.0652	-2.7334	-50.1041	26.0404	-2.5420	-49.8931	0.0248	0.1914	0.2110	0.2860	0.2110	Z
	24	25.4545	2.9689	-49.7984	25.5122	3.1618	-49.5340	-0.0577	-0.1929	0.2644	0.3323	0.2644	Z
	25	24.8001	7.8839	-49.4069	24.8476	8.0928	-49.1071	-0.0475	-0.2089	0.2998	0.3685	0.2998	Z
	26	12.3309	-13.4204	-51.2534	12.4626	-13.3252	-51.1650	-0.1317	0.0952	0.0884	0.1850	0.0884	Z
	27	11.9065	-8.2057	-51.1941	11.9295	-8.1200	-51.0775	-0.0230	0.0857	0.1166	0.1465	0.1166	Z
	28	12.6861	-2.8651	-50.9999	12.6980	-2.7833	-50.8551	-0.0119	0.0818	0.1448	0.1667	0.1448	Z
	29	13.2971	1.6246	-50.7535	13.3069	1.6861	-50.5807	-0.0098	-0.0615	0.1728	0.1837	0.1728	Z
	30	13.9135	5.9796	-50.4327	13.9105	6.1228	-50.2273	0.0030	-0.1432	0.2054	0.2504	0.2054	Z
A-PILLAR Maximum (X, Y, Z)	31	47.1323	16.8134	-34.4116	47.1910	17.0061	-34.0021	-0.0587	-0.1927	0.4095	0.4564	0.4095	Z
	32	45.2468	16.3451	-35.7998	45.2533	16.5188	-35.4360	-0.0065	-0.1737	0.3638	0.4032	0.3638	Z
	33	43.1049	15.8169	-37.3707	43.0632	15.9672	-37.0244	0.0417	-0.1503	0.3463	0.3798	0.3488	X, Z
	34	41.0293	15.2395	-38.9380	41.0559	15.4095	-38.6174	-0.0266	-0.1700	0.3206	0.3639	0.3206	Z
	35	37.9573	14.6028	-41.1984	37.9238	14.7509	-40.9091	0.0335	-0.1481	0.2893	0.3267	0.2912	X, Z
	36	33.3904	13.5016	-44.0127	33.4438	13.6581	-43.6879	-0.0534	-0.1565	0.3248	0.3645	0.3248	Z
A-PILLAR Lateral (Y)	31	47.1323	16.8134	-34.4116	47.1910	17.0061	-34.0021	-0.0587	-0.1927	0.4095	0.4564	-0.1927	Y
	32	45.2468	16.3451	-35.7998	45.2533	16.5188	-35.4360	-0.0065	-0.1737	0.3638	0.4032	-0.1737	Y
	33	43.1049	15.8169	-37.3707	43.0632	15.9672	-37.0244	0.0417	-0.1503	0.3463	0.3798	-0.1503	Y
	34	41.0293	15.2395	-38.9380	41.0559	15.4095	-38.6174	-0.0266	-0.1700	0.3206	0.3639	-0.1700	Y
	35	37.9573	14.6028	-41.1984	37.9238	14.7509	-40.9091	0.0335	-0.1481	0.2893	0.3267	-0.1481	Y
	36	33.3904	13.5016	-44.0127	33.4438	13.6581	-43.6879	-0.0534	-0.1565	0.3248	0.3645	-0.1565	Y
B-PILLAR Maximum (X, Y, Z)	37	7.7713	14.3671	-39.7060	7.7775	14.3518	-39.5090	-0.0062	0.0153	0.1970	0.1977	0.1976	Y, Z
	38	5.4807	16.9097	-28.6024	5.3960	16.8290	-28.3311	0.0847	0.0807	0.2713	0.2954	0.2954	X, Y, Z
	39	9.9304	17.2991	-22.5679	9.8134	17.1998	-22.3543	0.1170	0.0993	0.2136	0.2630	0.2630	X, Y, Z
	40	6.0138	17.3323	-17.4161	5.8765	17.1844	-17.2220	0.1373	0.1479	0.1941	0.2800	0.2800	X, Y, Z
B-PILLAR Lateral (Y)	37	7.7713	14.3671	-39.7060	7.7775	14.3518	-39.5090	-0.0062	0.0153	0.1970	0.1977	0.0153	Y
	38	5.4807	16.9097	-28.6024	5.3960	16.8290	-28.3311	0.0847	0.0807	0.2713	0.2954	0.0807	Y
	39	9.9304	17.2991	-22.5679	9.8134	17.1998	-22.3543	0.1170	0.0993	0.2136	0.2630	0.0993	Y
	40	6.0138	17.3323	-17.4161	5.8765	17.1844	-17.2220	0.1373	0.1479	0.1941	0.2800	0.1479	Y

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

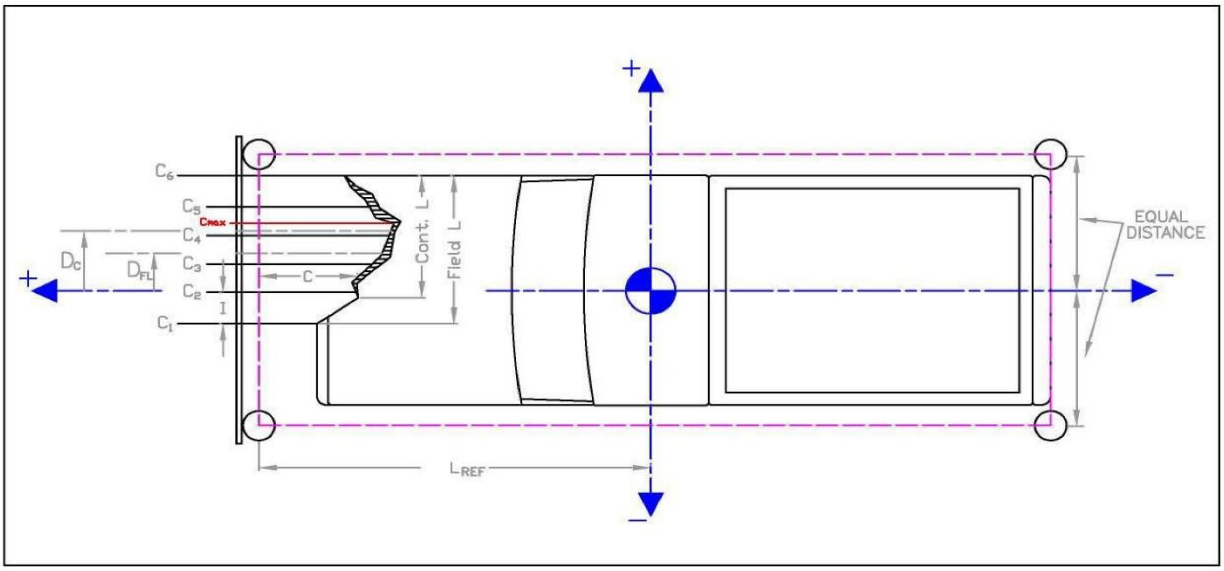
[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

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

Figure C-8. Right Interior Crush Data – Set 2, Test No. WZNP-2

Date: 4/4/2019 Test Name: WZNP-2 VIN: 1D7RB1GP6BS634520

Year: 2011 Make: Dodge Model: Ram 1500



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	118	(2997)
Total Vehicle Width:	77 1/8	(1959)
Width of contact and induced crush - Field L:	77 1/8	(1959)
Crush measurement spacing interval (L/5) - I:	15 3/8	(391)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	77 1/8	(1959)
Distance from center of vehicle to center of contact damage - D_C:	0	()

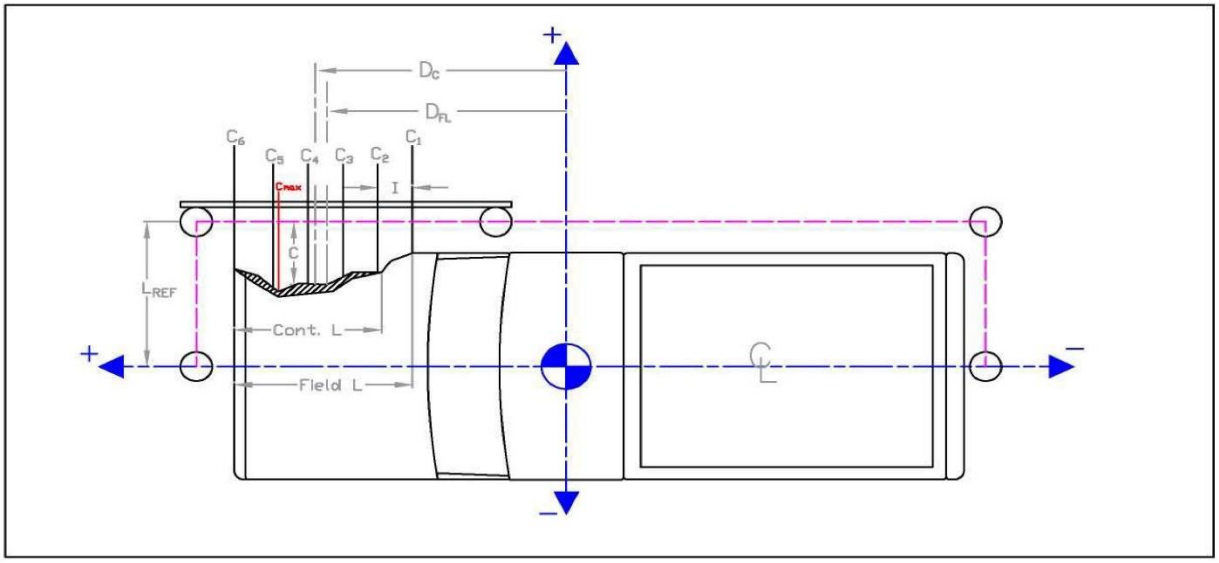
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/A	N/A	-38 5/8	-(981)	22 1/2	(572)	12 2/3	(322)	N/A	N/A
C_2	18 1/2	(470)	-23 1/4	-(591)	6 1/2	(165)			- 2/3	-(17)
C_3	16 5/8	(422)	-7 7/8	-(200)	4 1/4	(108)			- 1/3	-(8)
C_4	16 3/4	(425)	7 1/2	(191)	4 1/4	(108)			- 1/5	-(5)
C_5	19 1/4	(489)	22 7/8	(581)	6 1/8	(156)			4/9	(11)
C_6	N/A	N/A	38 1/4	(972)	20 1/2	(521)			N/A	N/A
C_{MAX}	19 1/4	(489)	22 7/8	(581)	6 1/8	(156)			4/9	(11)

Figure C-9. Exterior Vehicle Crush (NASS) - Front, Test No. WZNP-2

Date: 4/4/2019 Test Name: WZNP-2 VIN: 1D7RB1GP6BS634520

Year: 2011 Make: Dodge Model: Ram 1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:		()
Total Vehicle Length:	229 1/2	(5829)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-5	-(125)
Width of contact and induced crush - Field L:		()
Crush measurement spacing interval (L/5) - I:	0	()
Distance from vehicle c.g. to center of Field L - D_{FL}:		()
Width of Contact Damage:		()
Distance from vehicle c.g. to center of contact damage - D_C:		()

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

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual	Crush
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1		()	0	()	5	(127)	-44	-(1118)	39	(991)
C_2		()	0	()	5	(127)			39	(991)
C_3		()	0	()	5	(127)			39	(991)
C_4		()	0	()	5	(127)			39	(991)
C_5		()	0	()	5	(127)			39	(991)
C_6		()	0	()	5	(127)			39	(991)
C_{MAX}		()		()	5	(127)			39	(991)

Figure C-10. Exterior Vehicle Crush (NASS) - Side, Test No. WZNP-2

Appendix D. Accelerometer and Rate Transducer Data Plots, Test No. WZNP-2

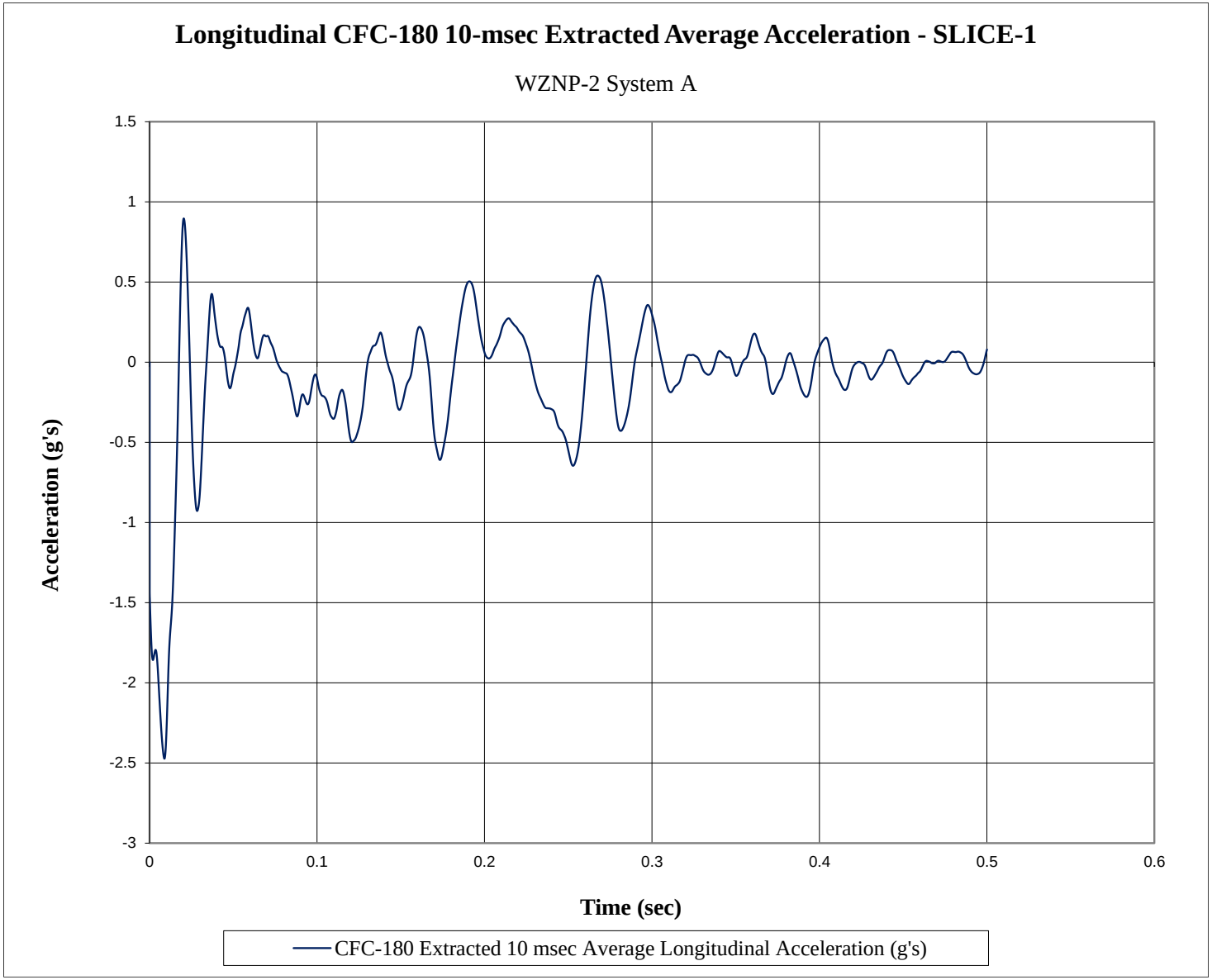


Figure D-1. 10-ms Average Longitudinal Deceleration System A (SLICE-1), Test No. WZNP-2

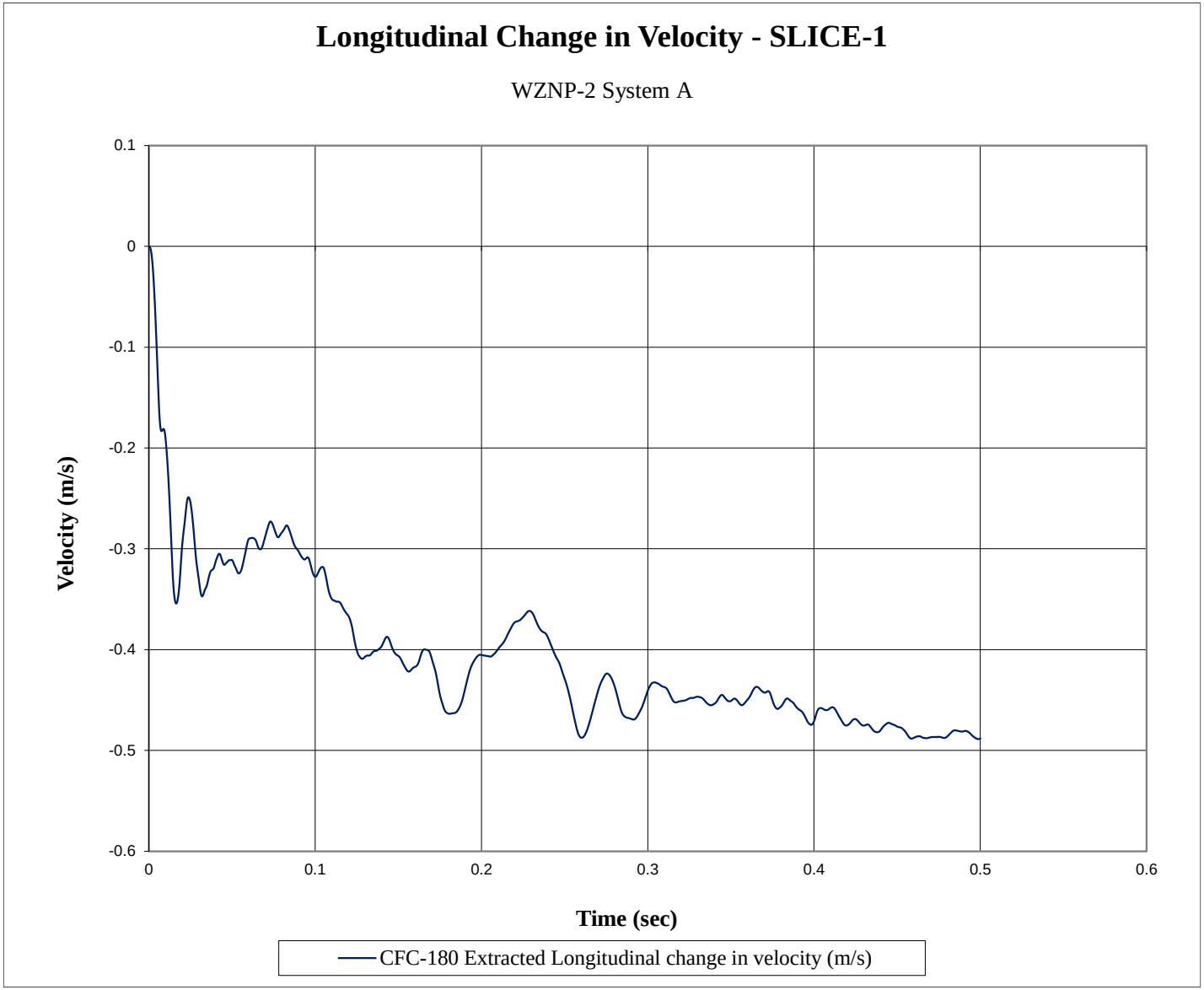


Figure D-2. Longitudinal Occupant Impact Velocity System A (SLICE-1), Test No. WZNP-2

Figure D-3. Longitudinal Occupant Displacement System A (SLICE-1), Test No. WZNP-2

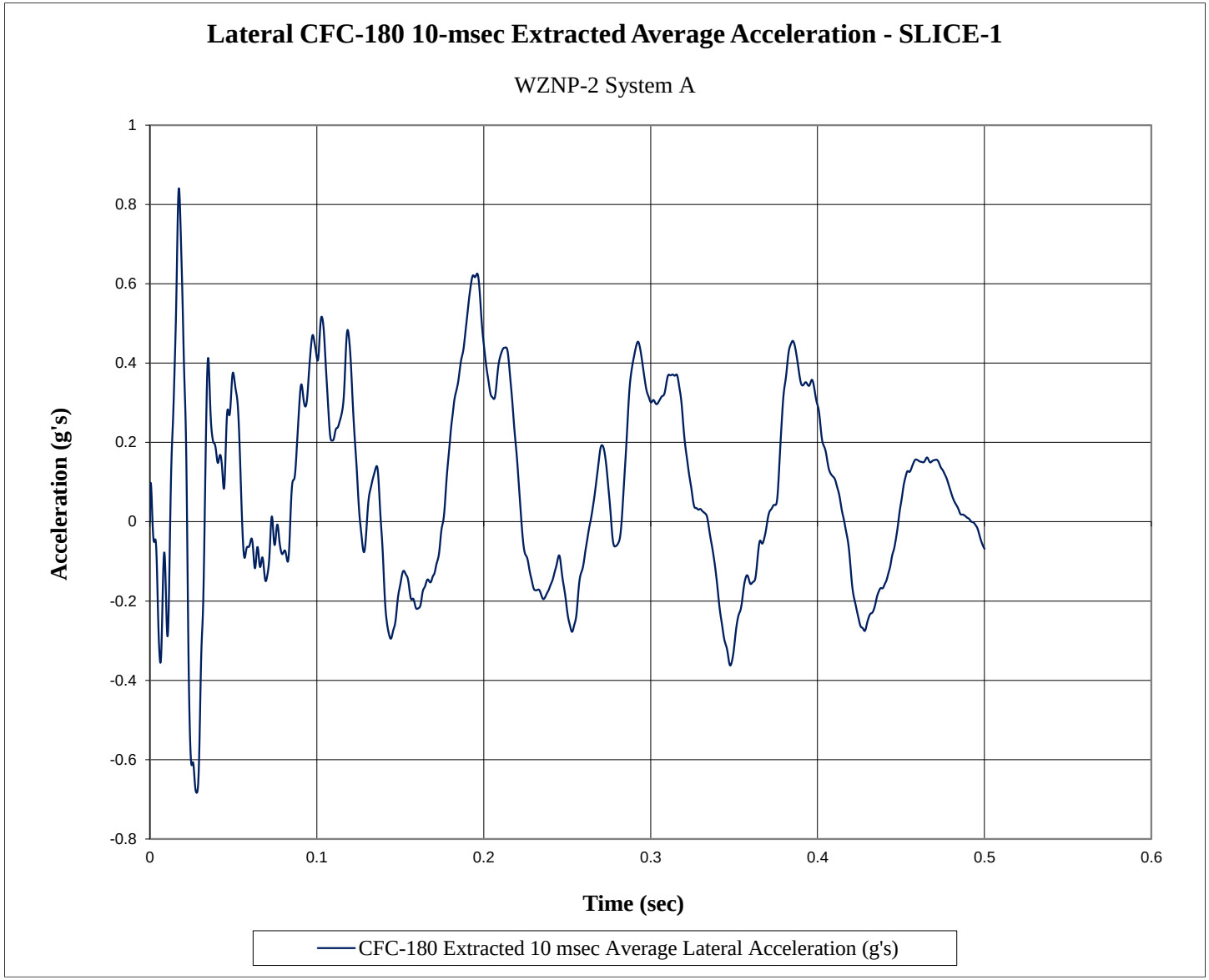


Figure D-4. 10-ms Average Lateral Deceleration System A (SLICE-1), Test No. WZNP-2

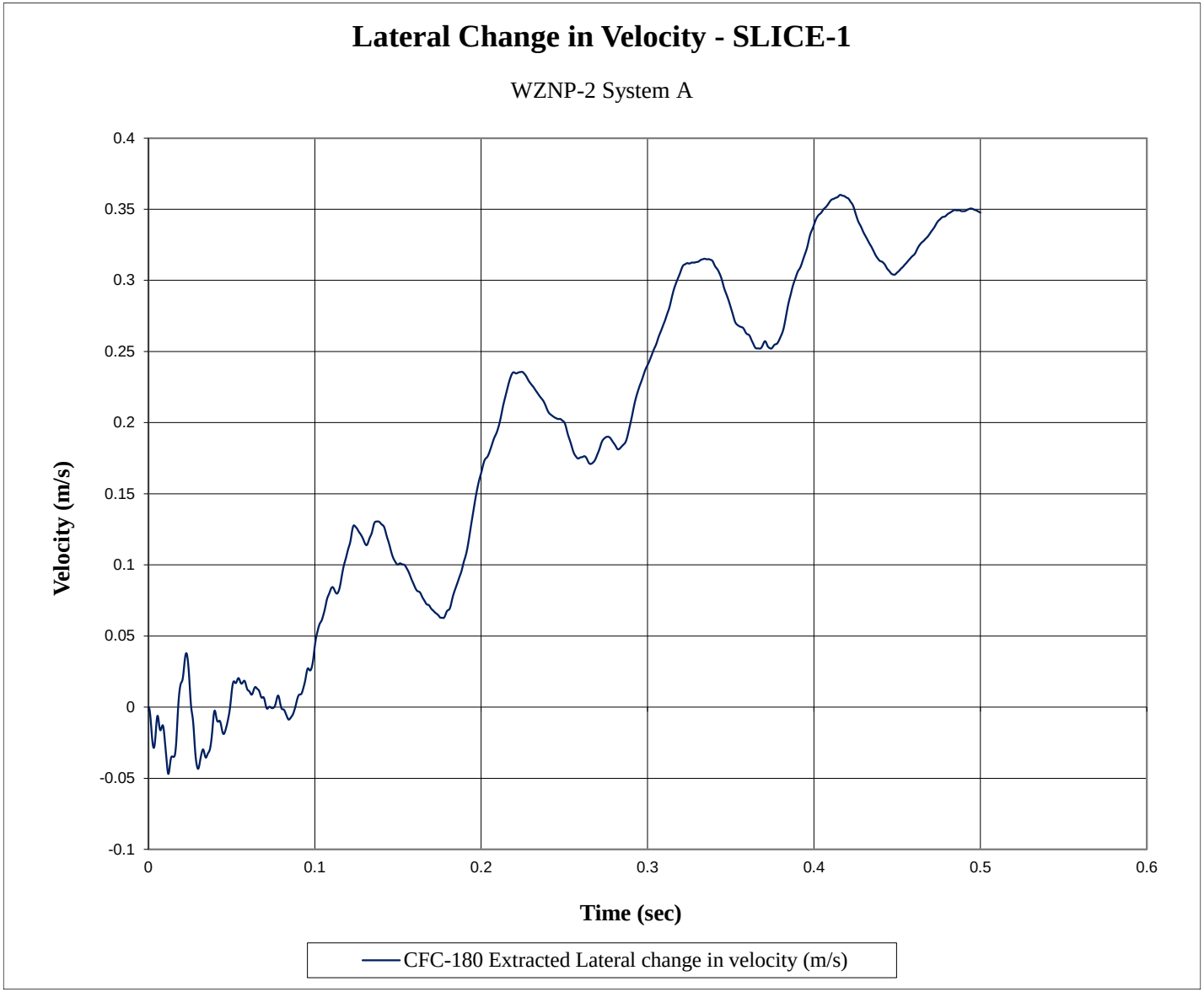


Figure D-5. Lateral Occupant Impact Velocity System A (SLICE-1), Test No. WZNP-2

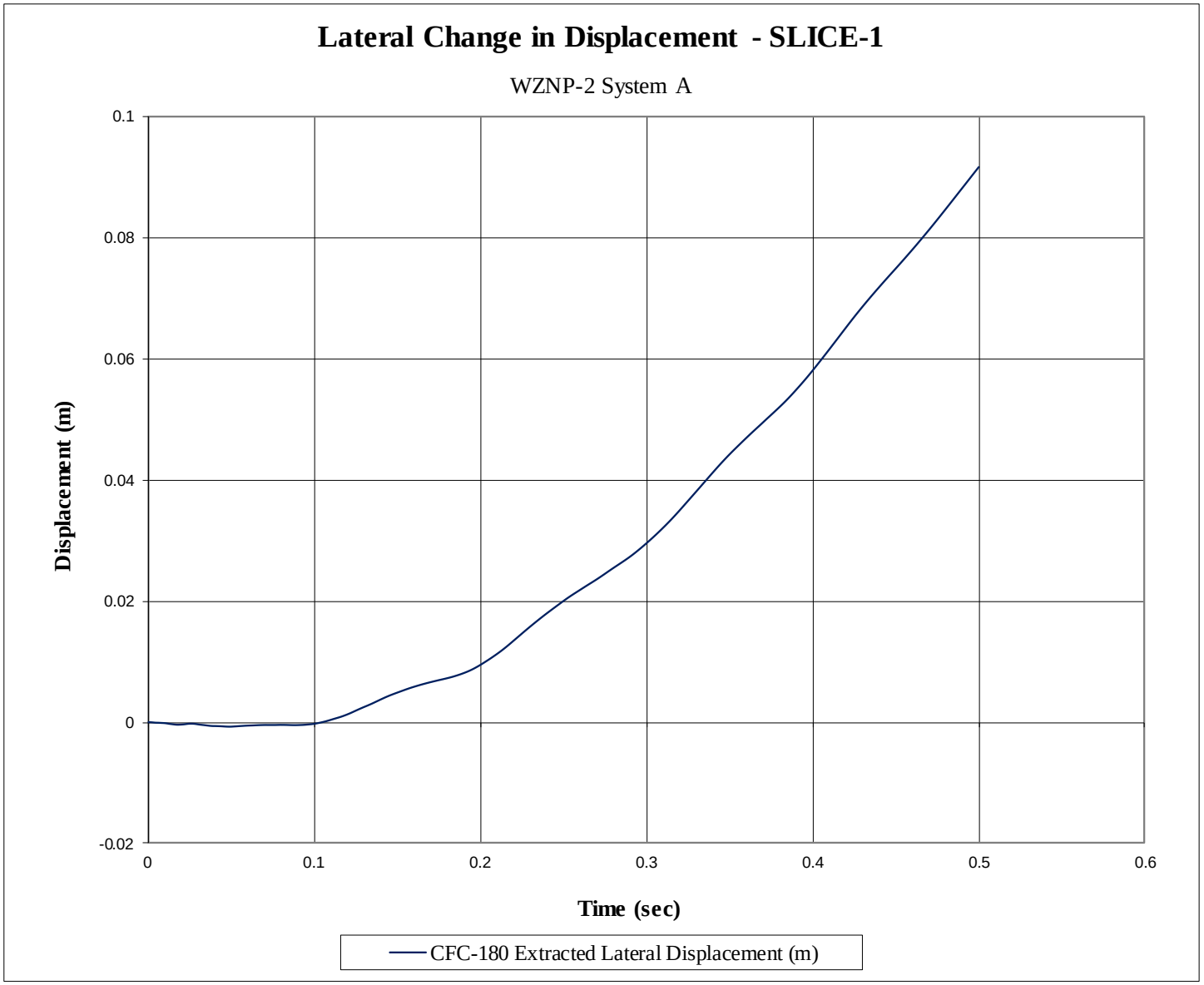


Figure D-6. Lateral Occupant Displacement System A (SLICE-1), Test No. WZNP-2

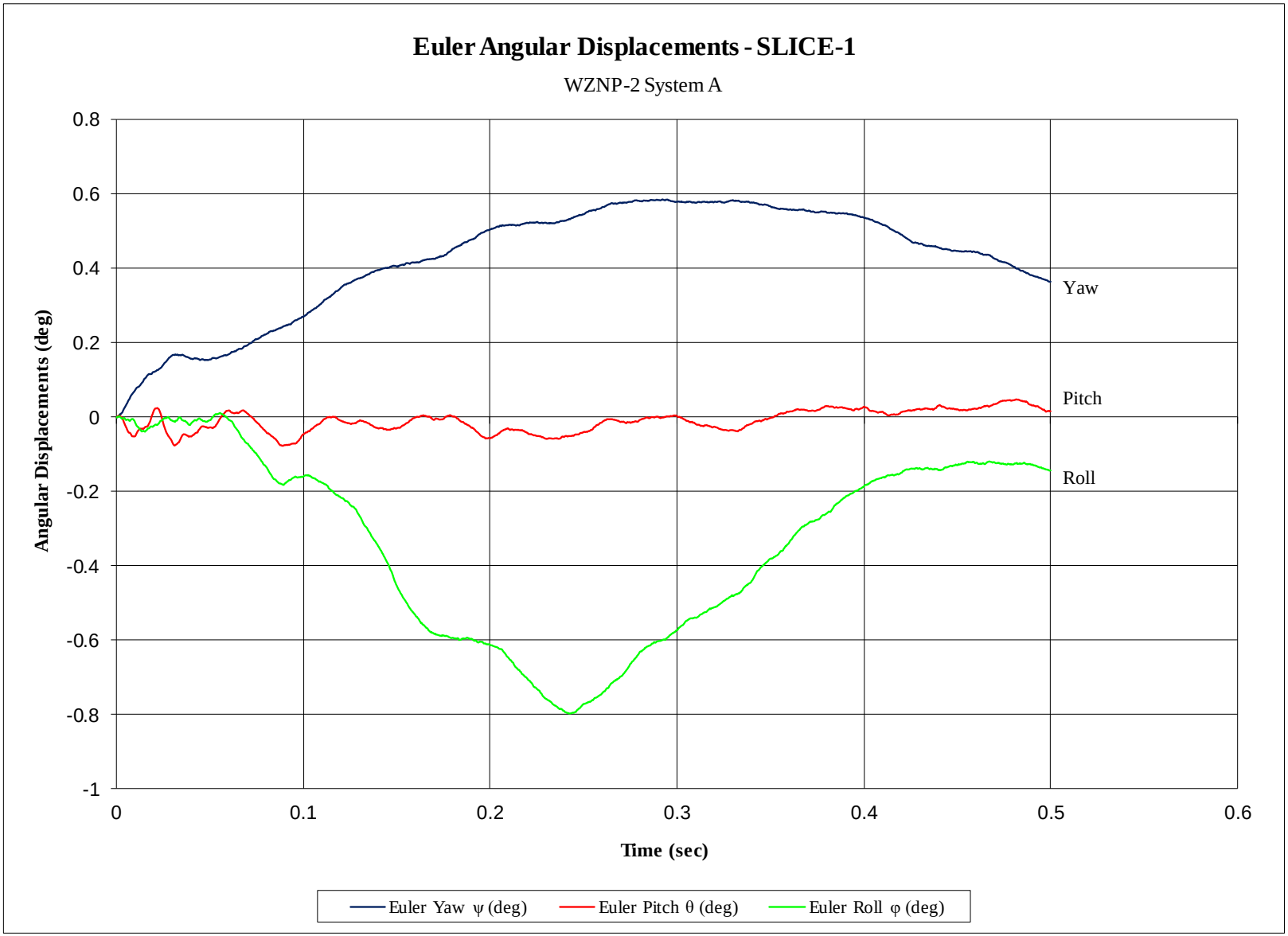


Figure D-7. Vehicle Angular Displacements System A (SLICE-1), Test No. WZNP-2

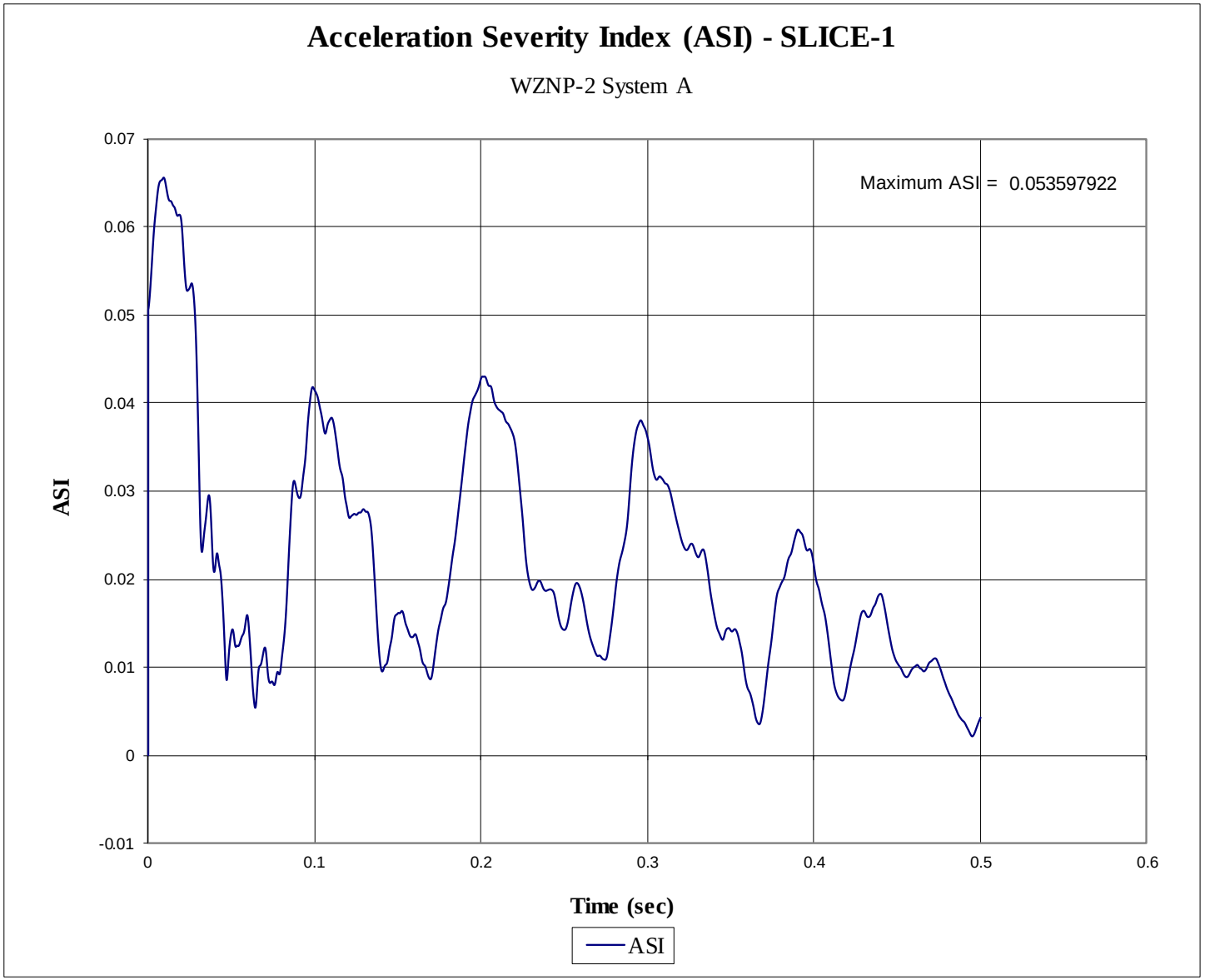


Figure D-8. Acceleration Severity Index System A (SLICE-1), Test No. WZNP-2

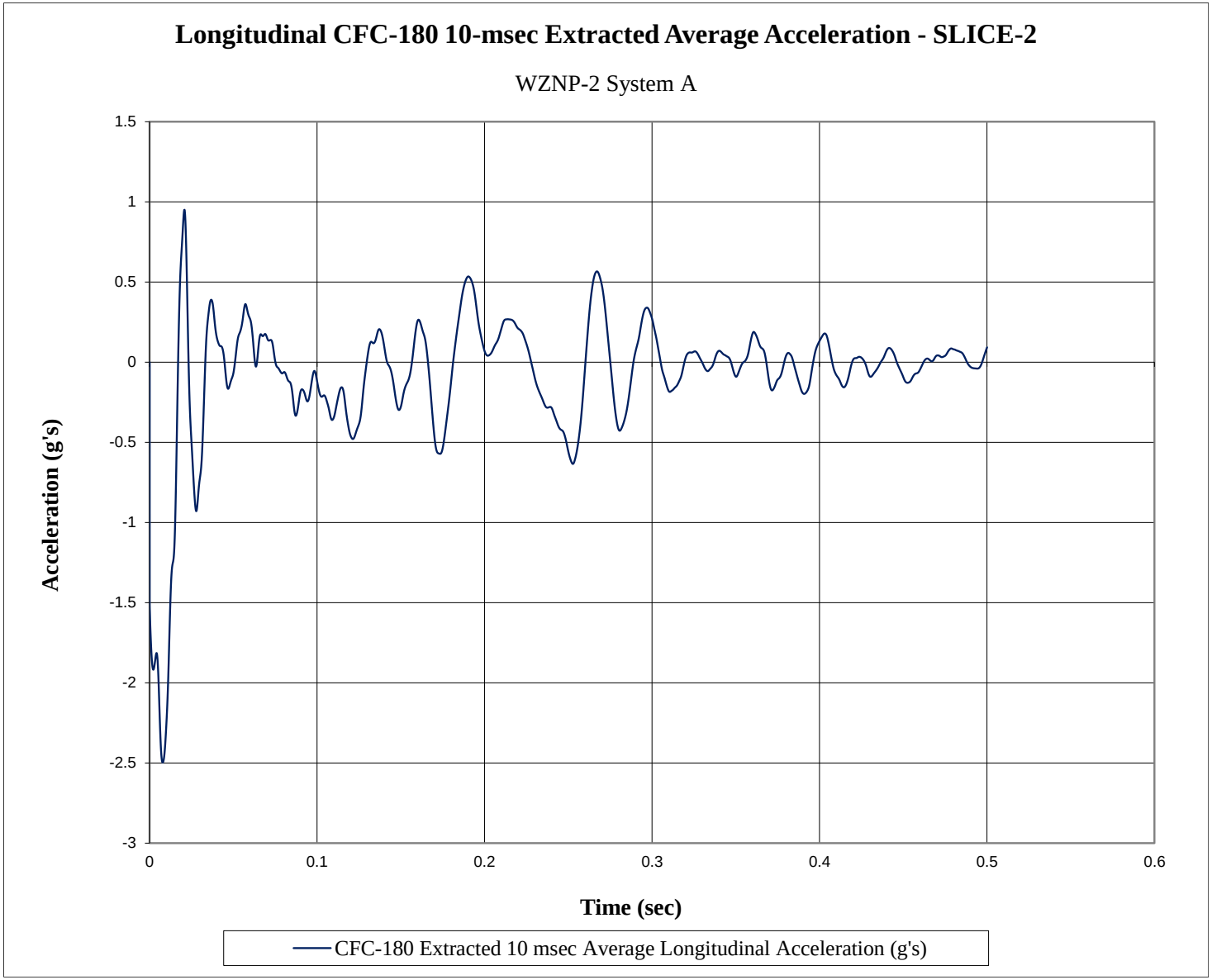


Figure D-9. 10-ms Average Longitudinal Deceleration System A (SLICE-2), Test No. WZNP-2

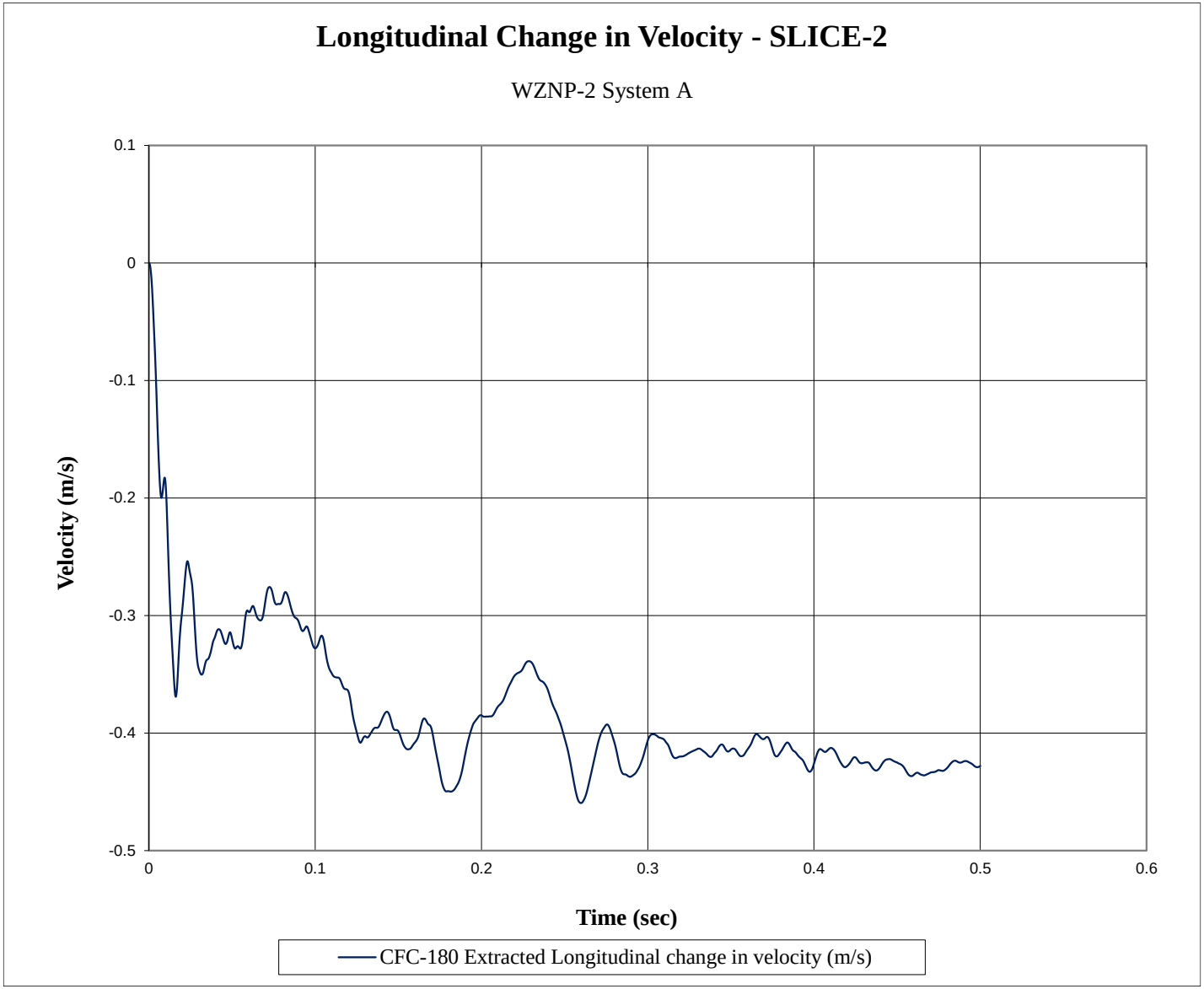


Figure D-10. Longitudinal Occupant Impact Velocity System A (SLICE-2), Test No. WZNP-2

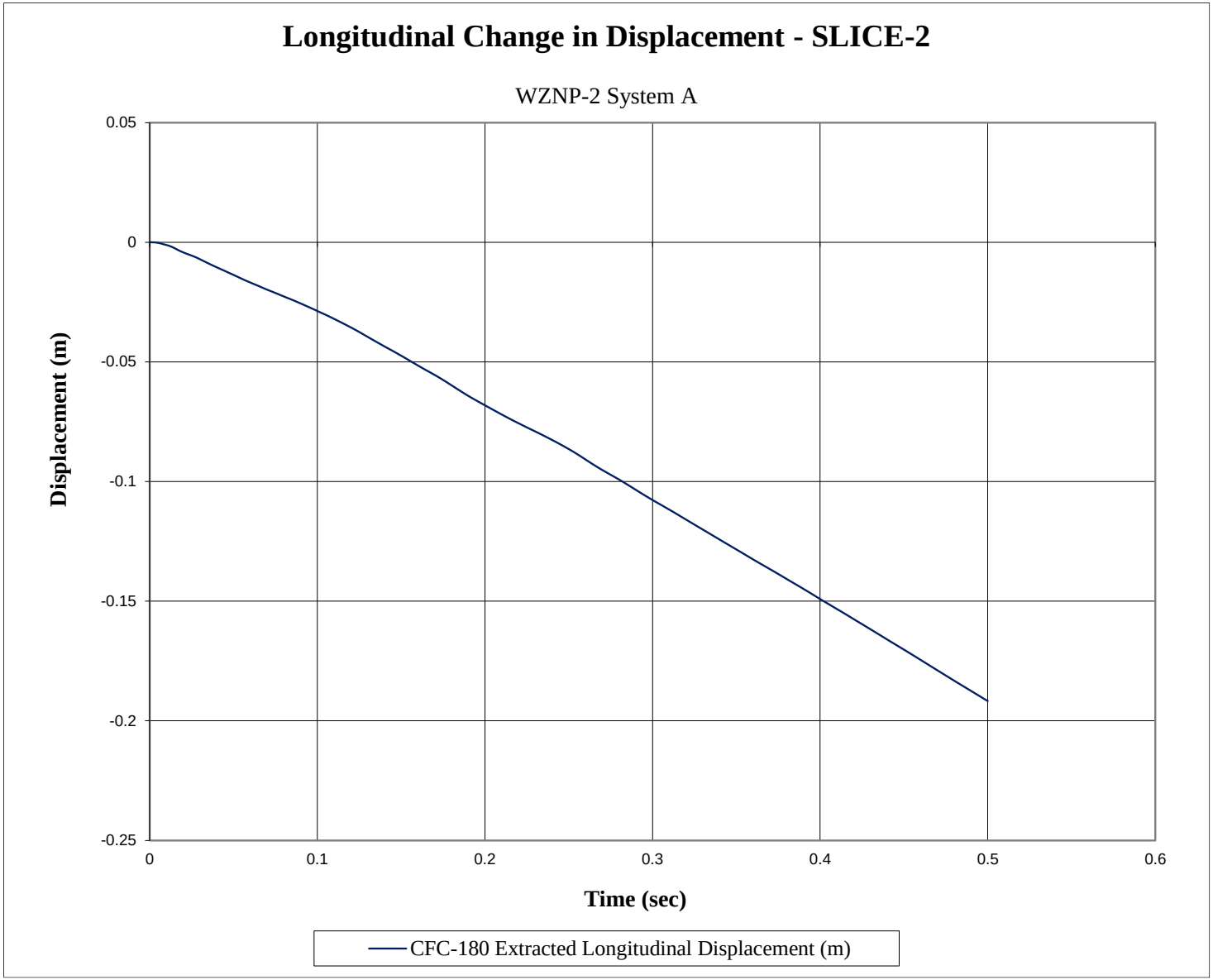


Figure D-11. Longitudinal Occupant Displacement System A (SLICE-2), Test No. WZNP-2

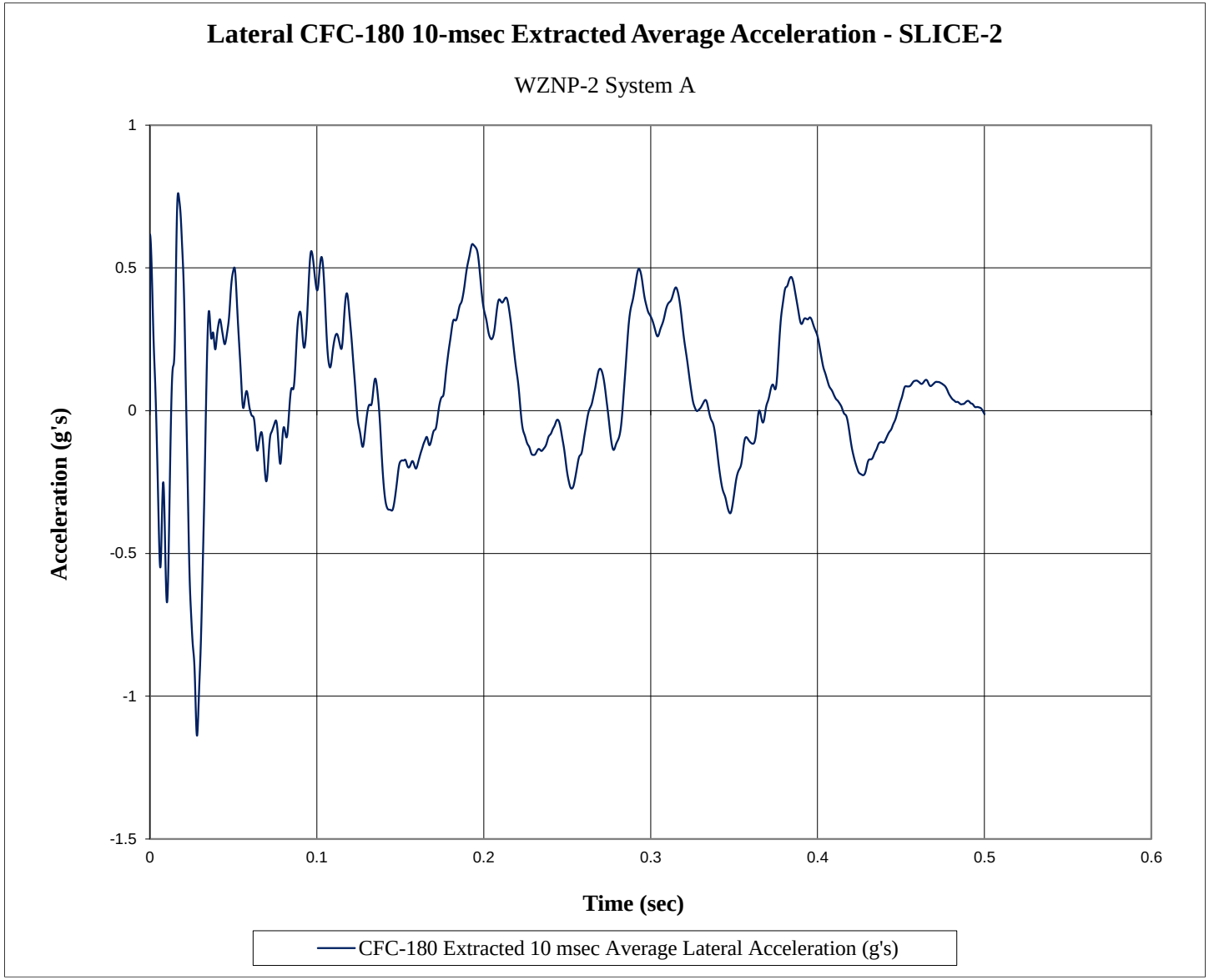


Figure D-12. 10-ms Average Lateral Deceleration System A (SLICE-2), Test No. WZNP-2

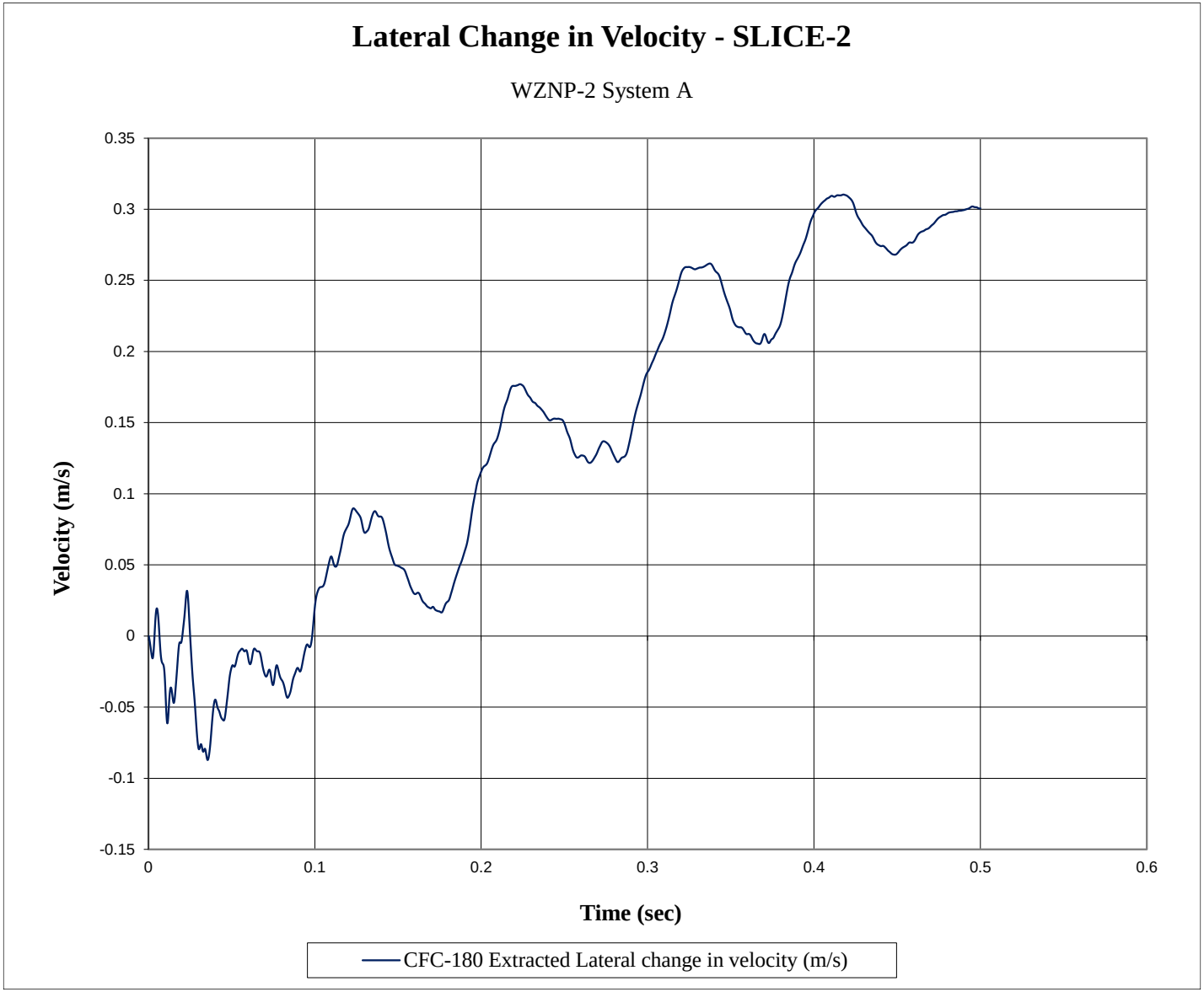


Figure D-13. Lateral Occupant Impact Velocity System A (SLICE-2), Test No. WZNP-2

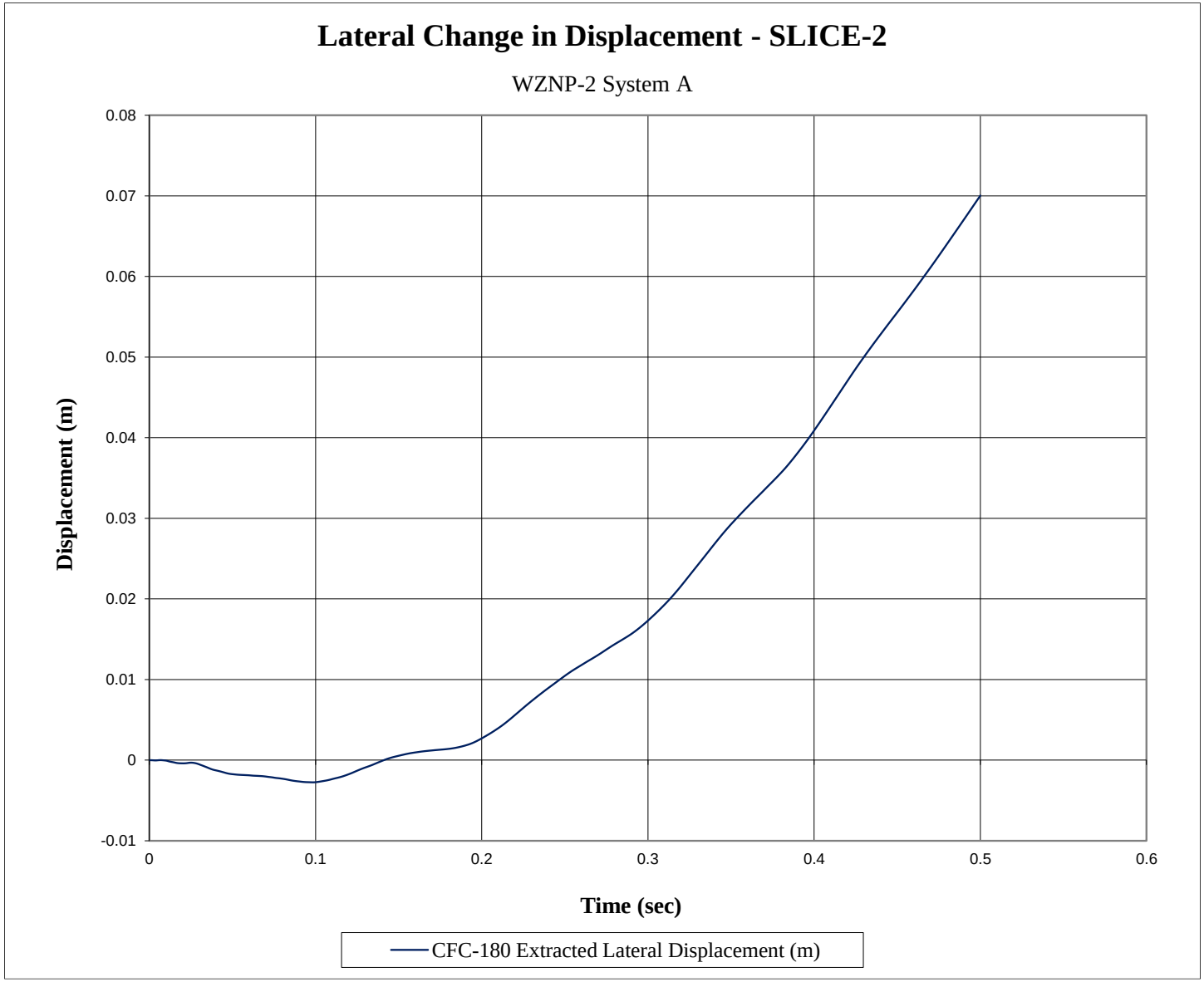


Figure D-14. Lateral Occupant Displacement System A (SLICE-2), Test No. WZNP-2

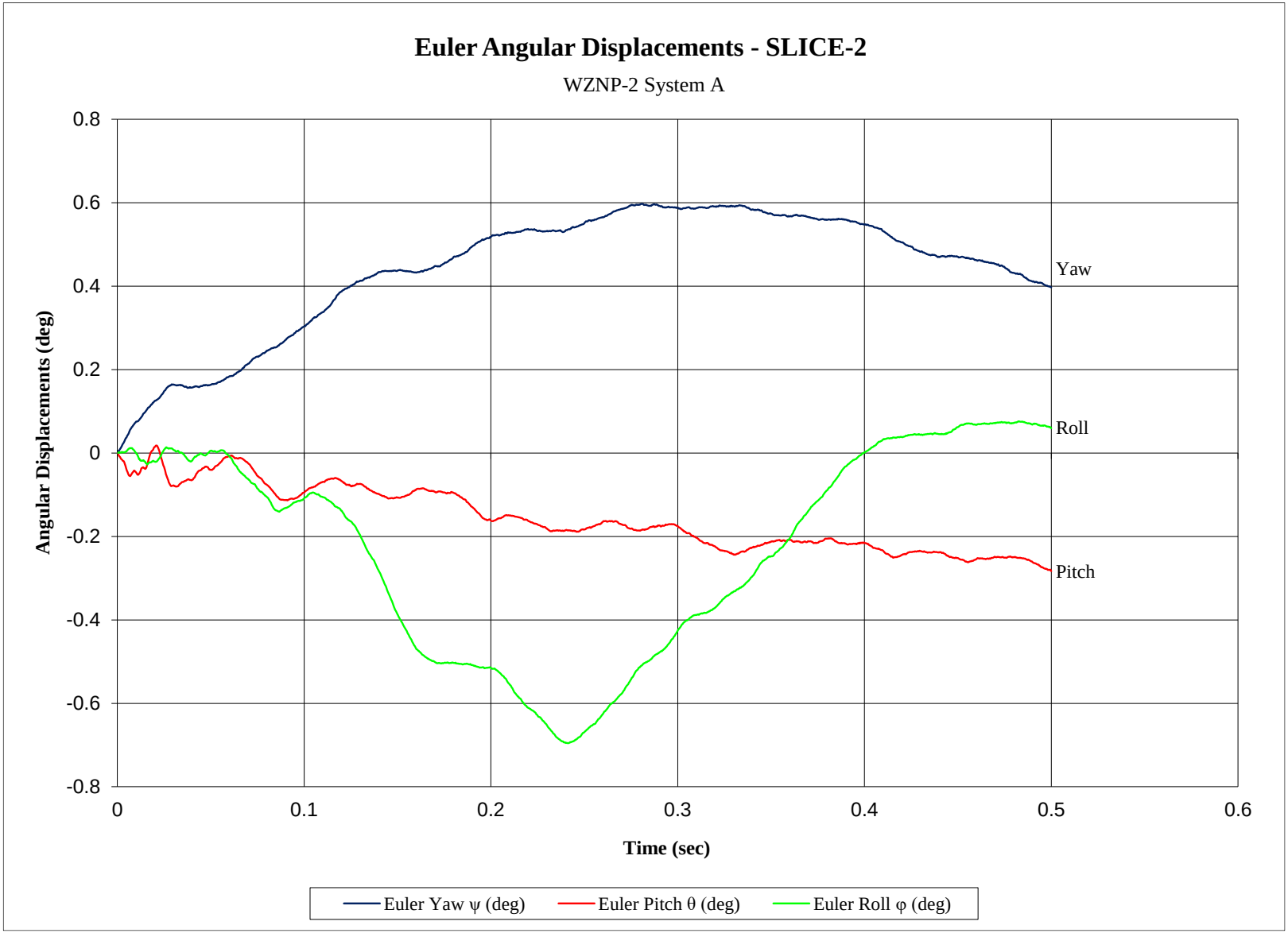


Figure D-15. Vehicle Angular Displacements System A (SLICE-2), Test No. WZNP-2

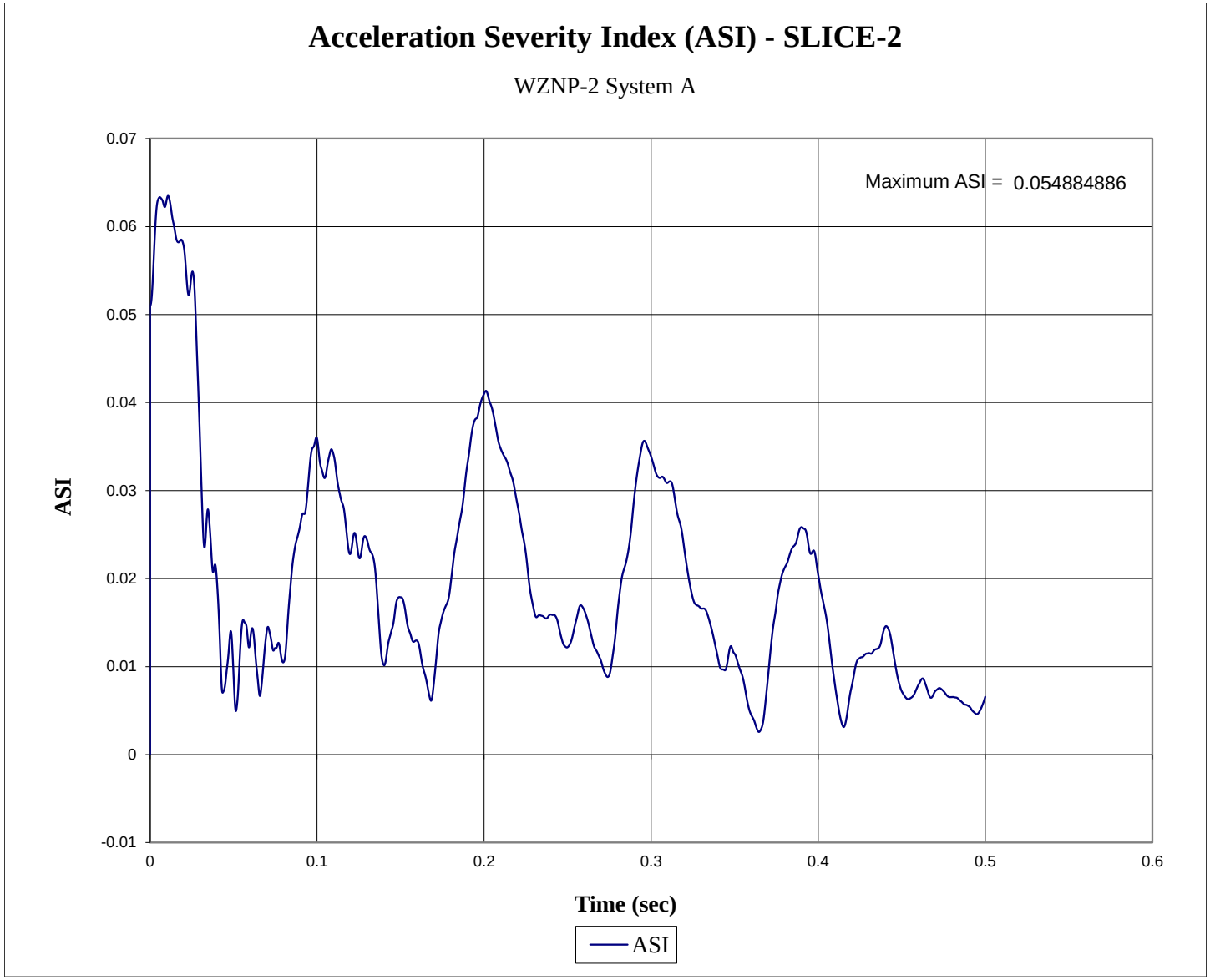


Figure D-16. Acceleration Severity Index System A (SLICE-2), Test No. WZNP-2

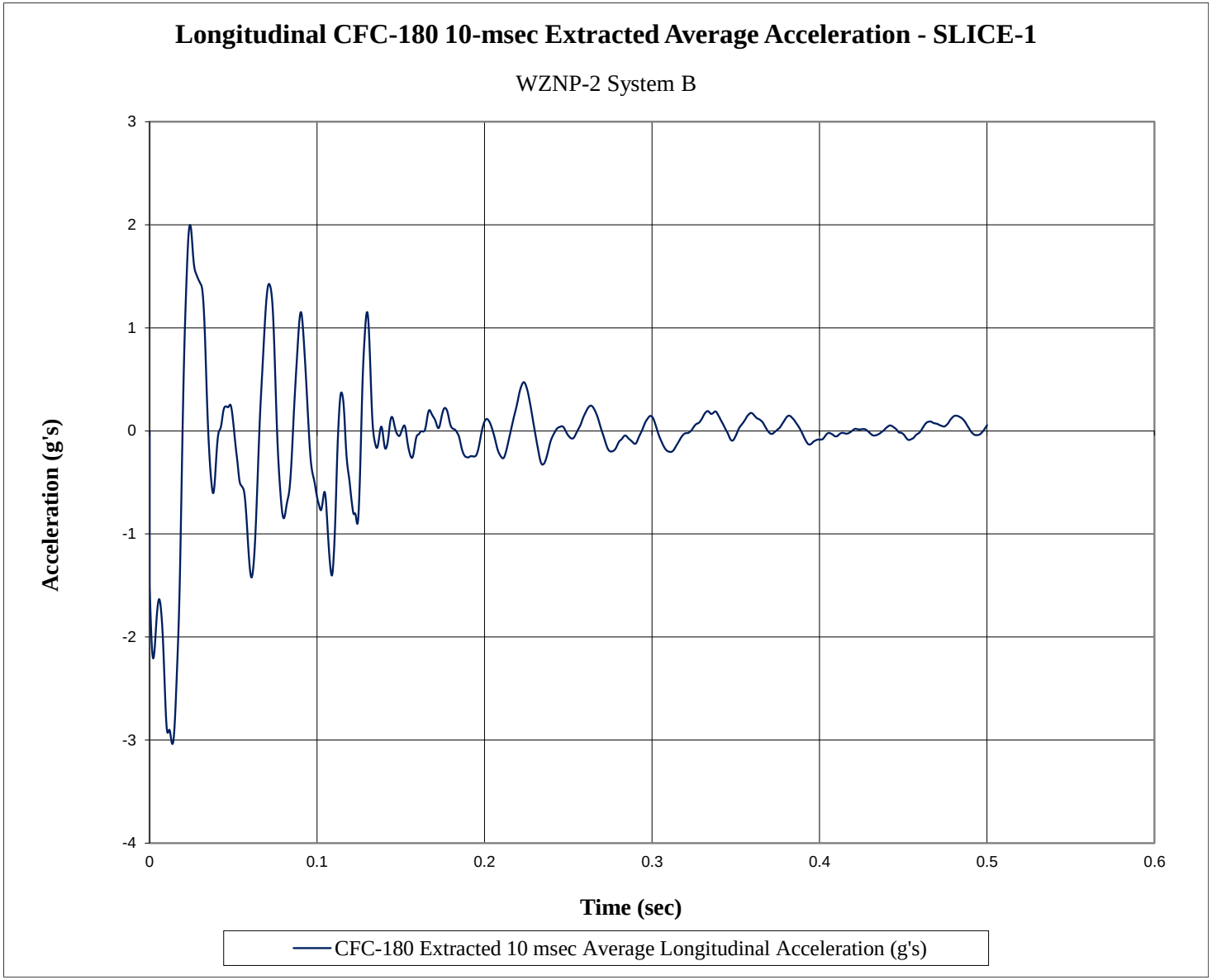


Figure D-17. 10-ms Average Longitudinal Deceleration System B (SLICE-1), Test No. WZNP-2

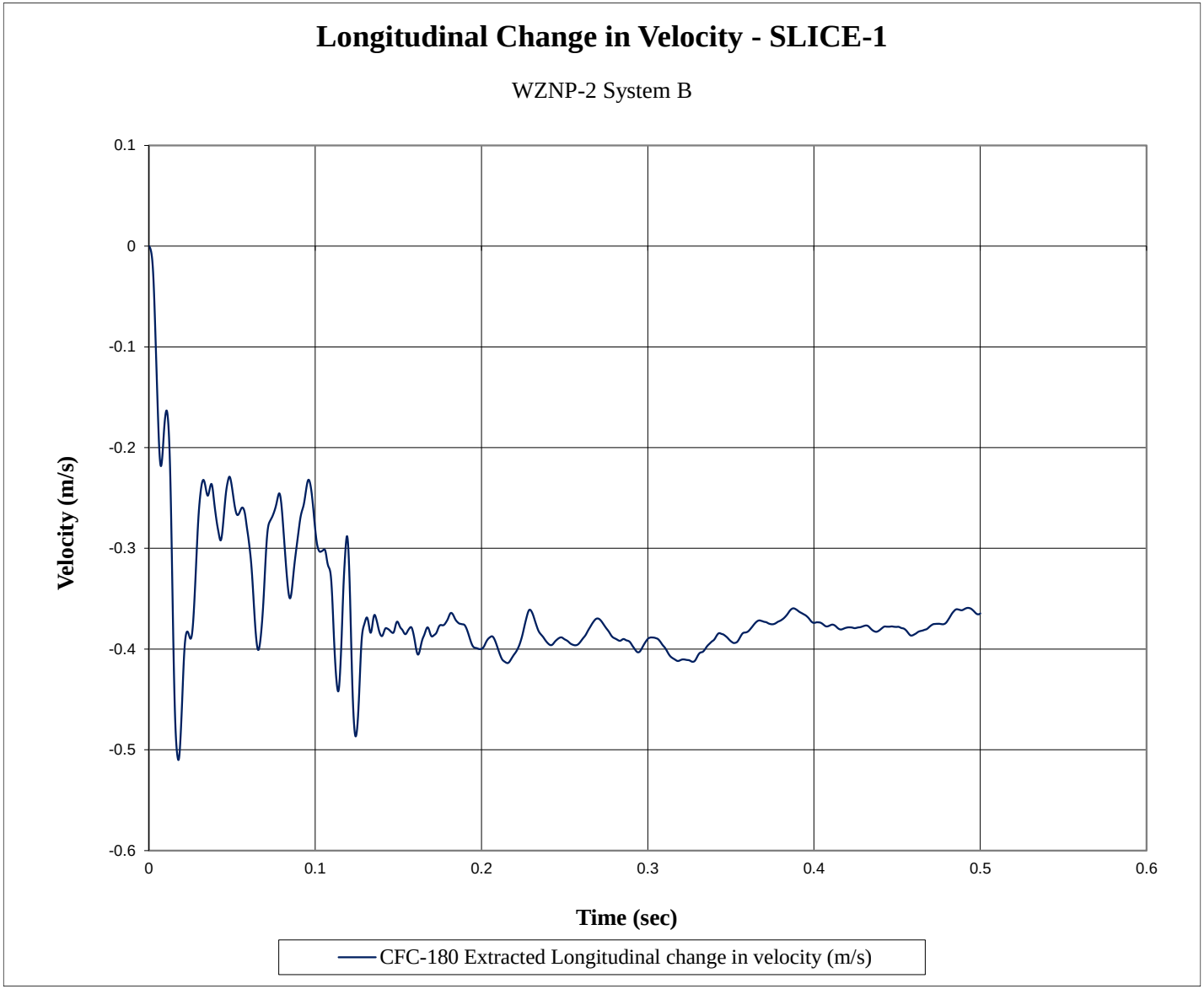


Figure D-18. Longitudinal Occupant Impact Velocity System B (SLICE-1), Test No. WZNP-2

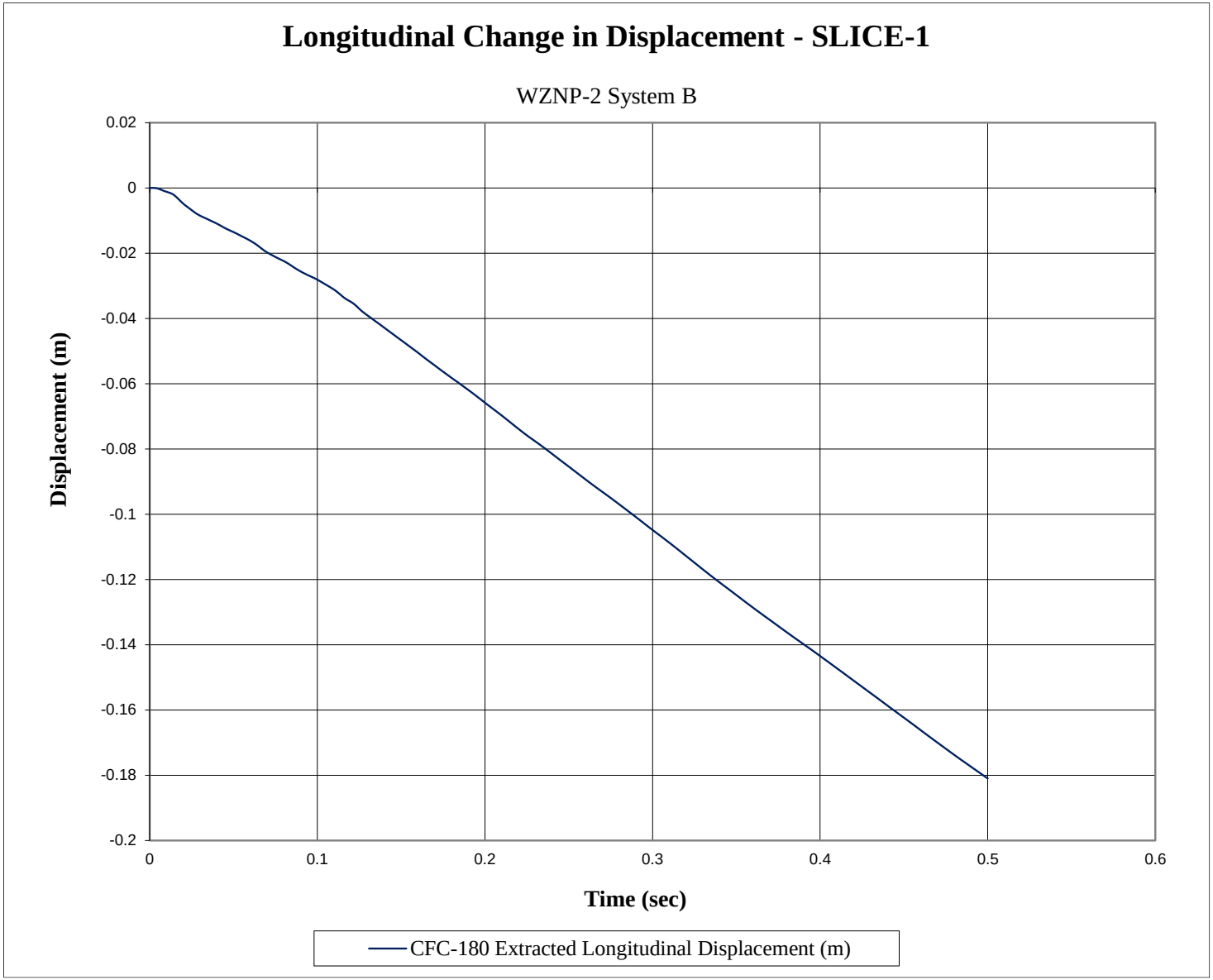


Figure D-19. Longitudinal Occupant Displacement System B (SLICE-1), Test No. WZNP-2

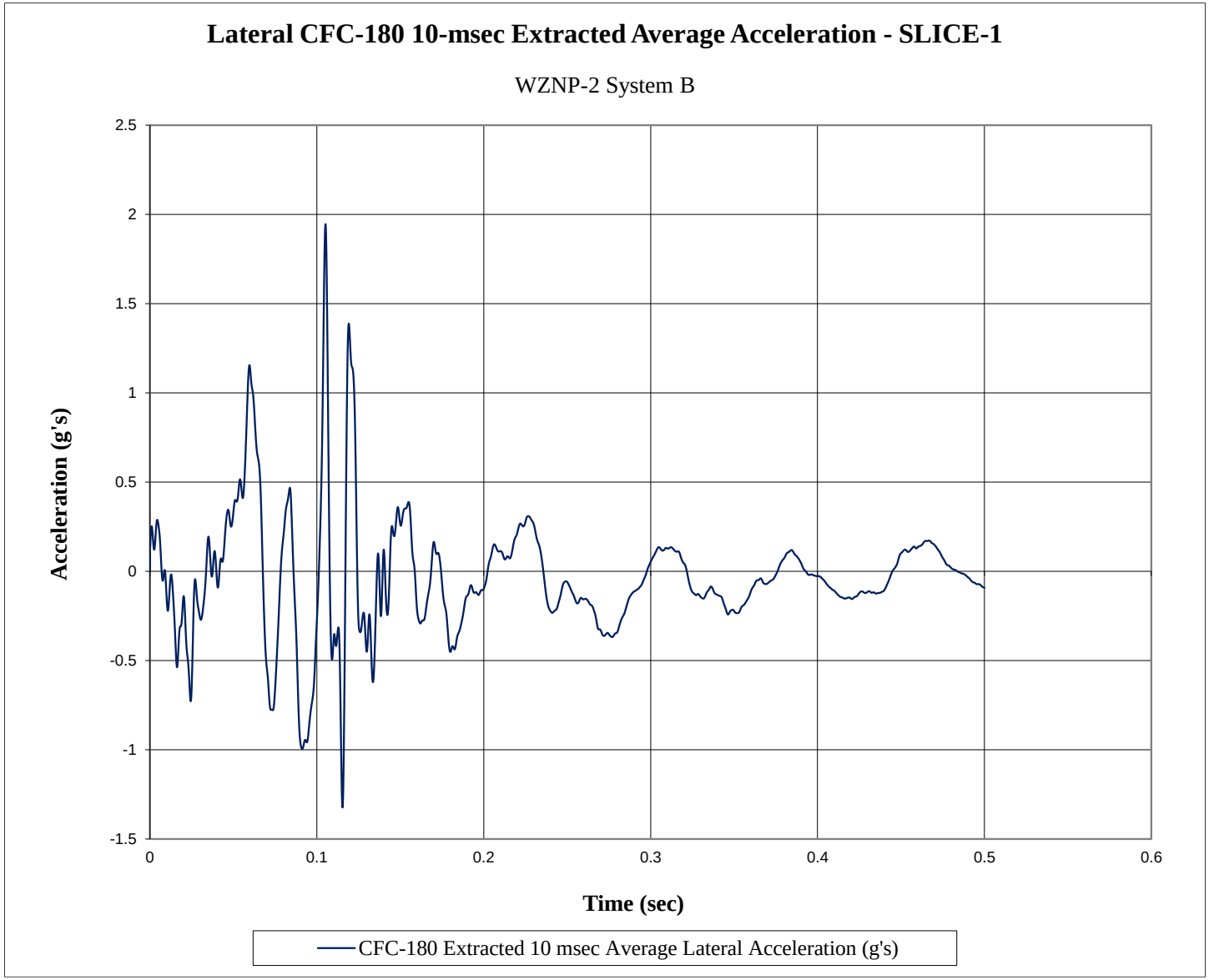


Figure D-20. 10-ms Average Lateral Deceleration System B (SLICE-1), Test No. WZNP-2

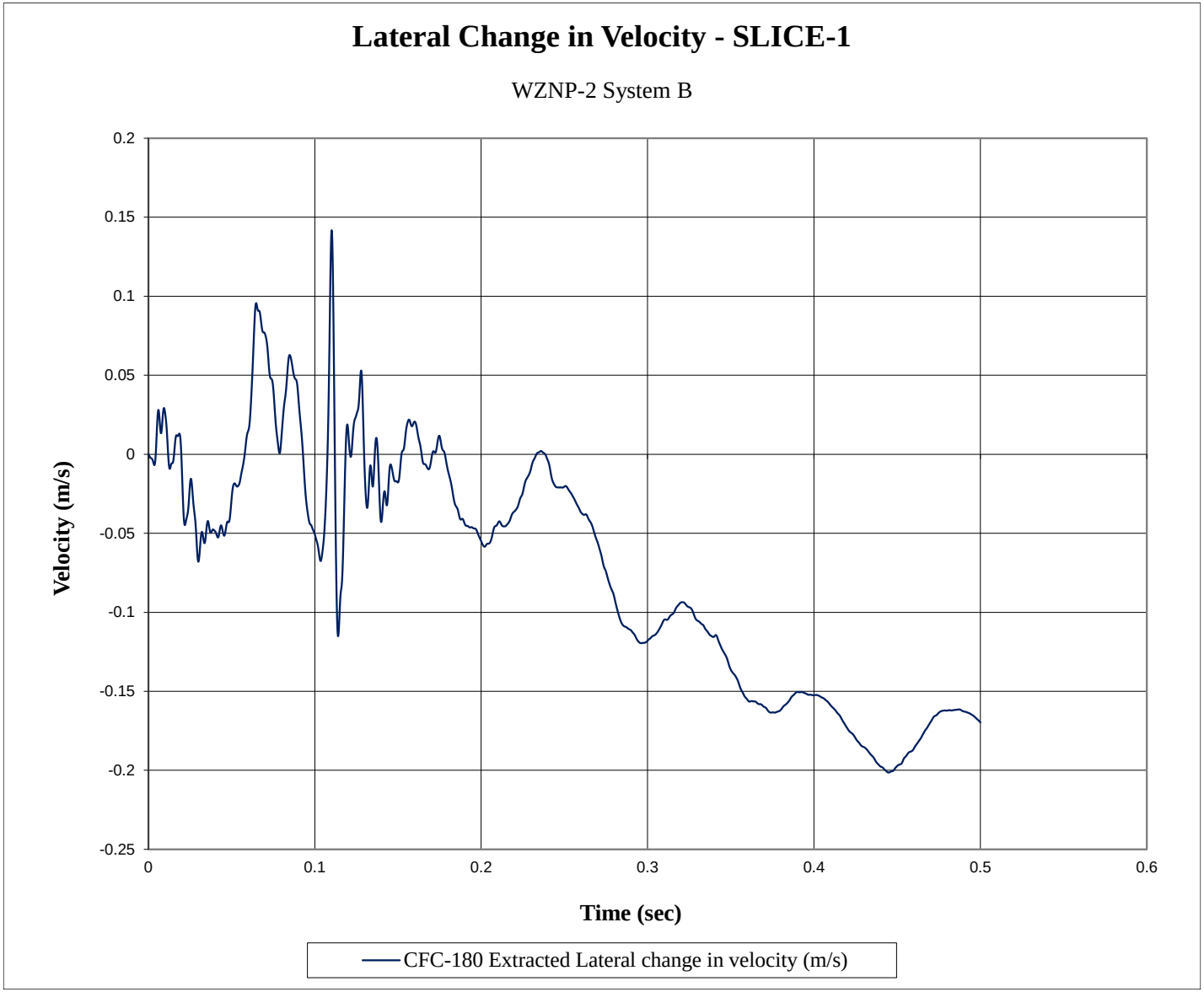


Figure D-21. Lateral Occupant Impact Velocity System B (SLICE-1), Test No. WZNP-2

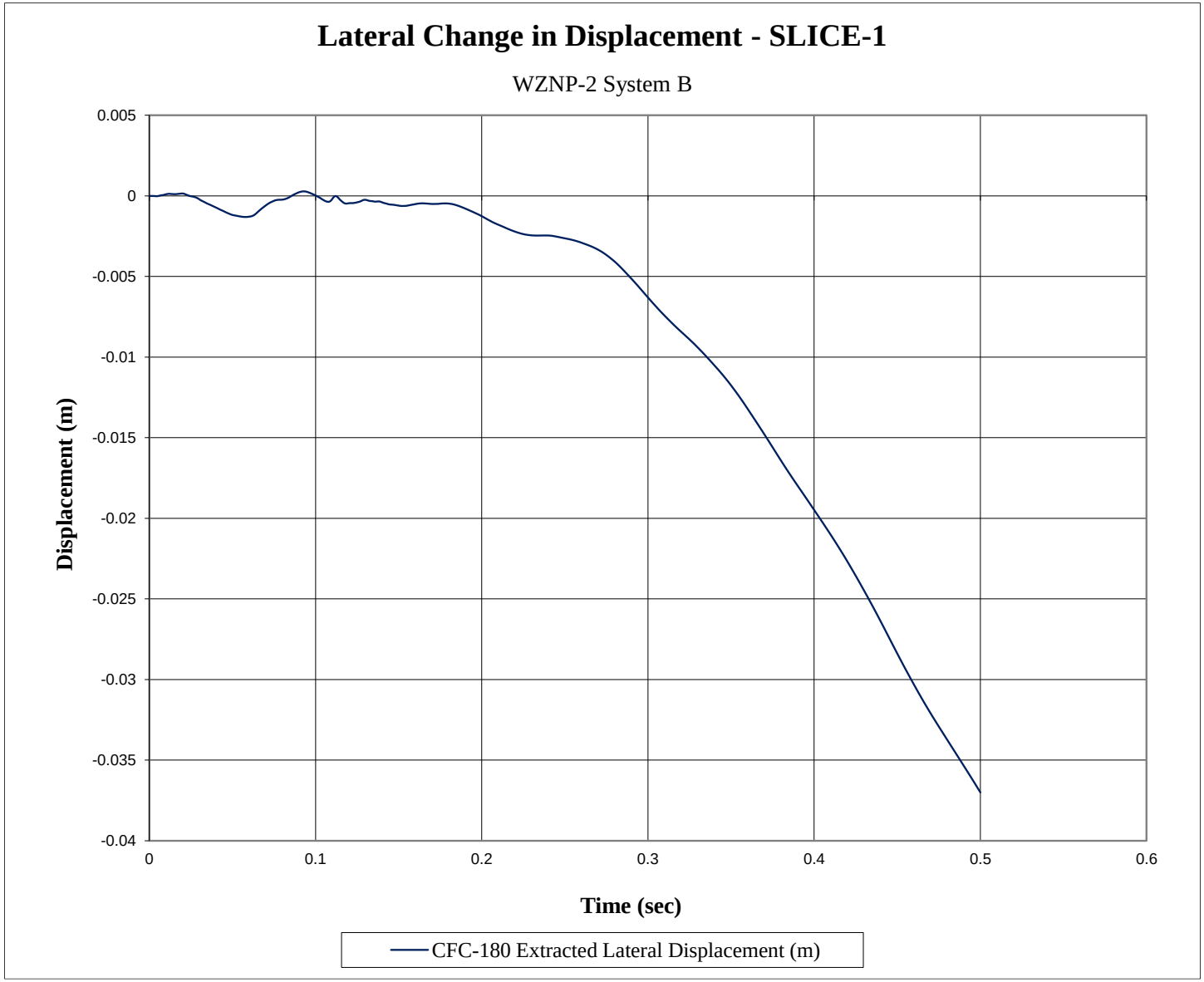


Figure D-22. Lateral Occupant Displacement System B (SLICE-1), Test No. WZNP-2

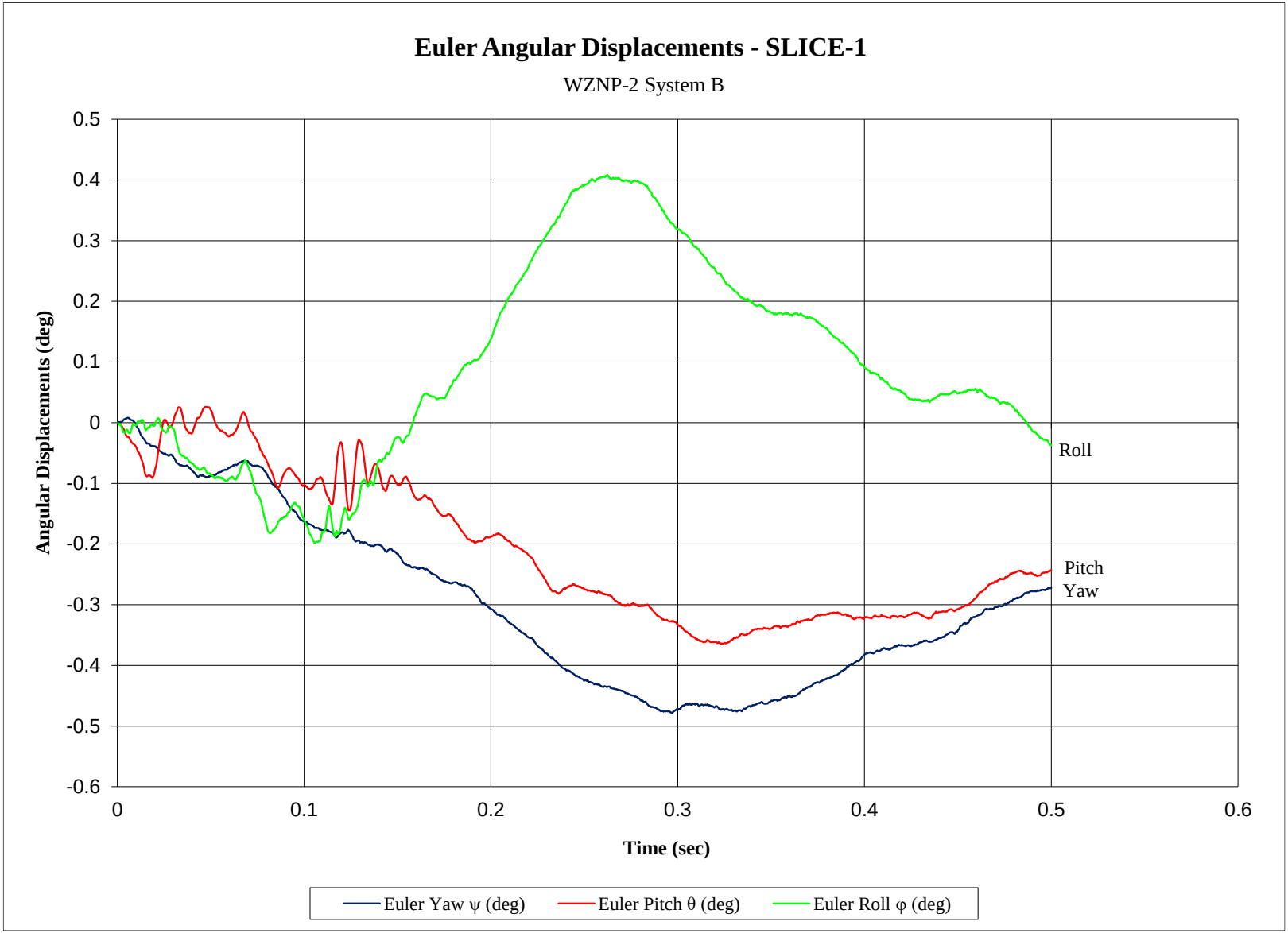


Figure D-23. Vehicle Angular Displacements System B (SLICE-1), Test No. WZNP-2

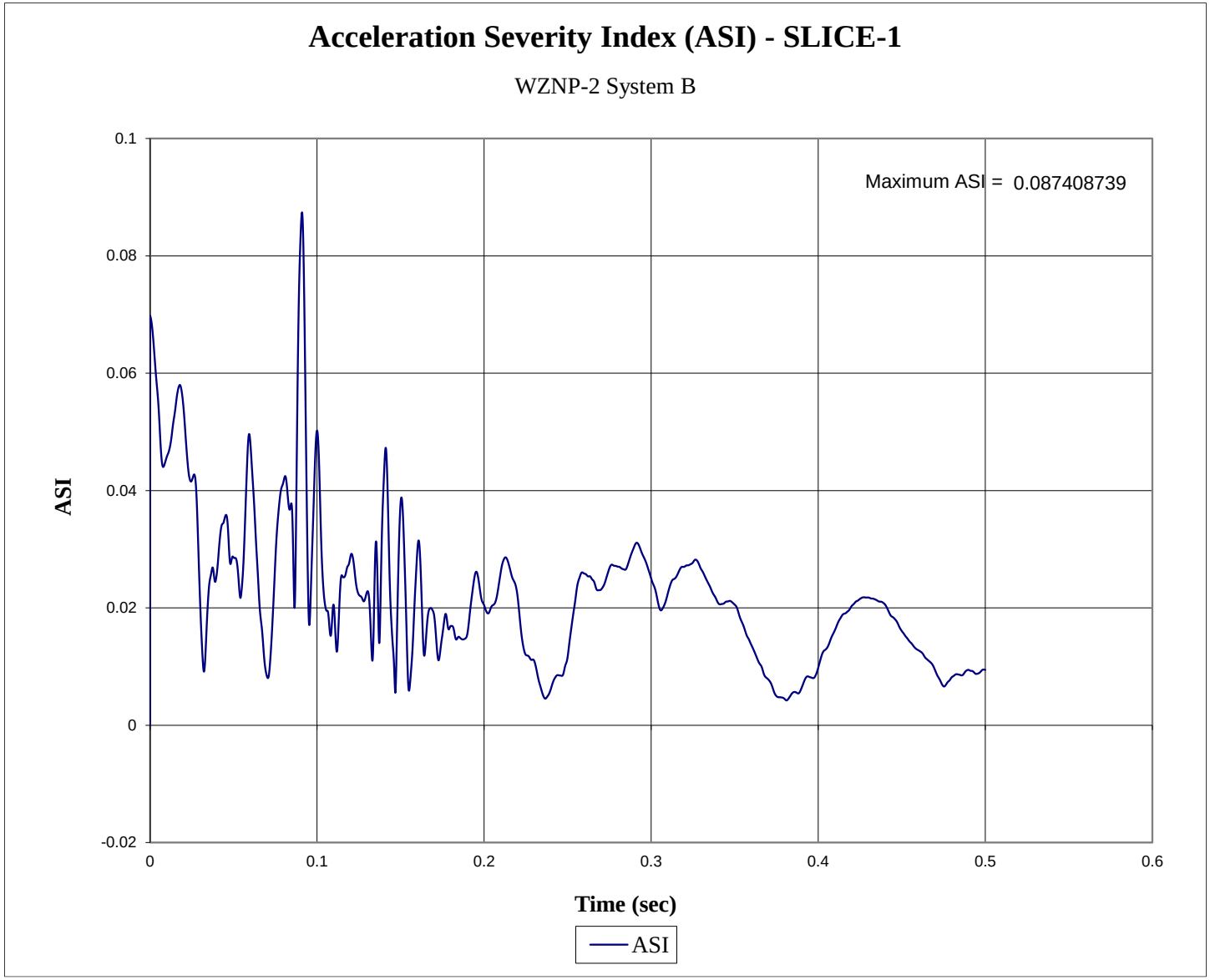


Figure D-24. Acceleration Severity Index System B (SLICE-1), Test No. WZNP-2

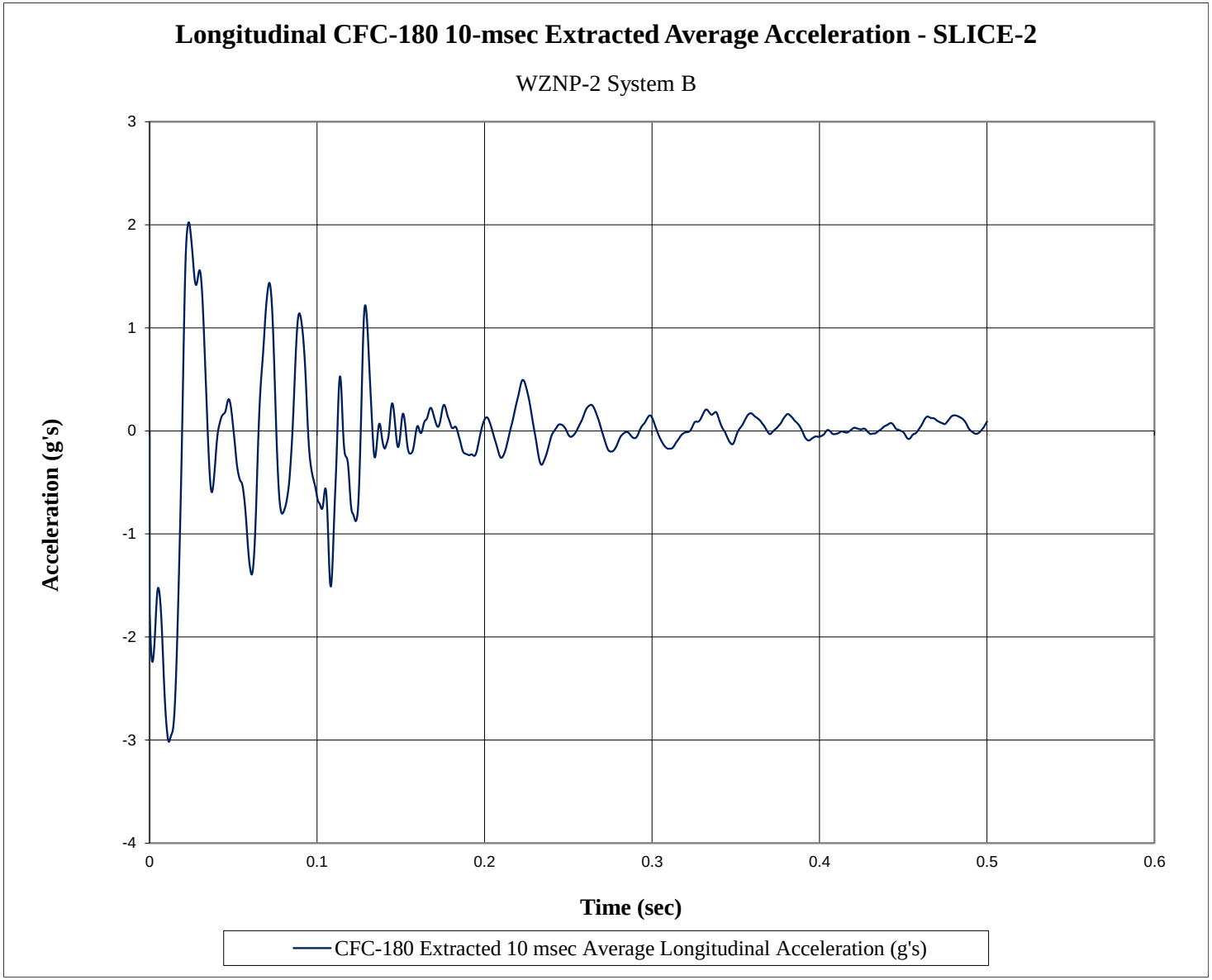


Figure D-25. 10-ms Average Longitudinal Deceleration System B (SLICE-2), Test No. WZNP-2

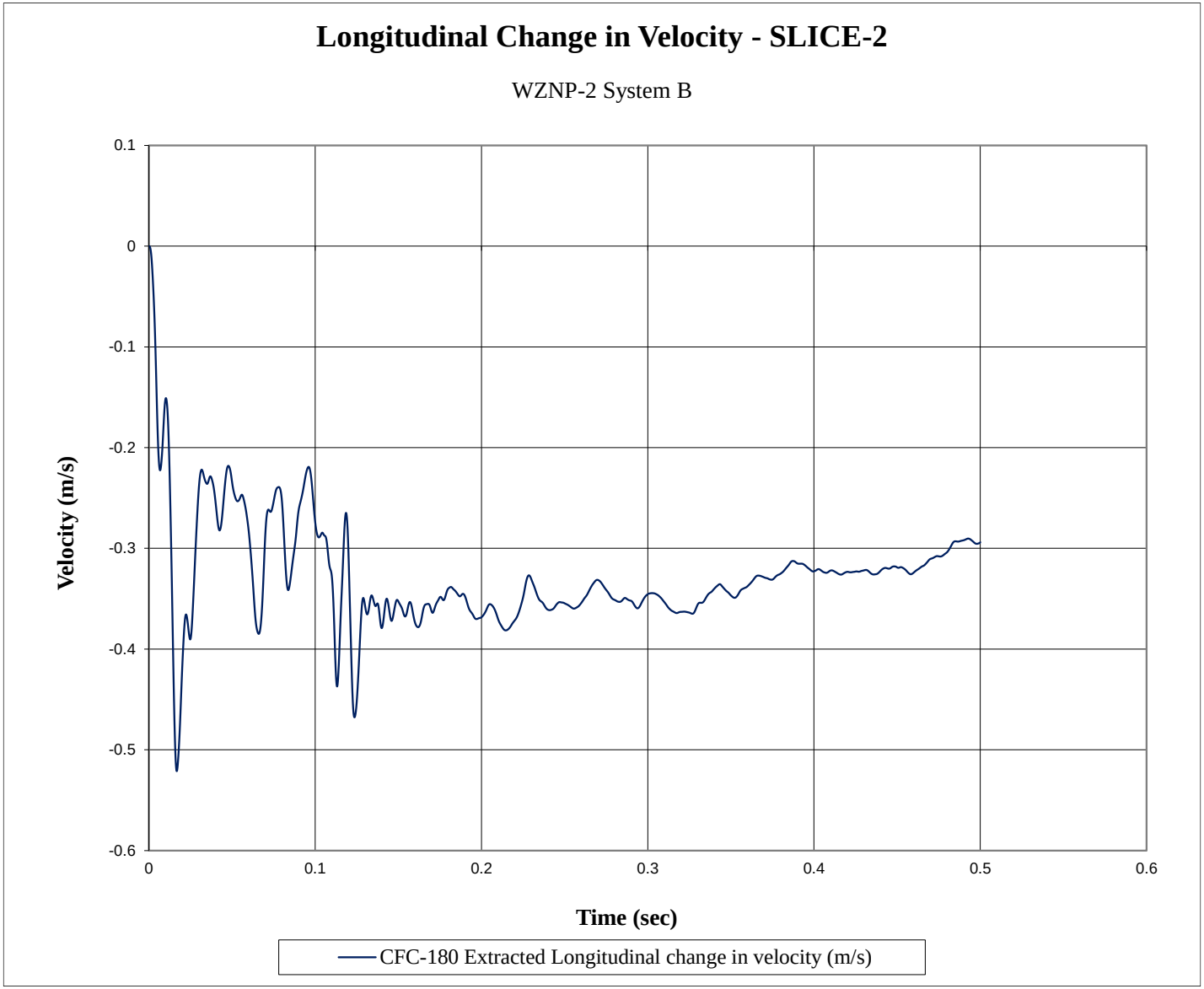


Figure D-26. Longitudinal Occupant Impact Velocity System B (SLICE-2), Test No. WZNP-2

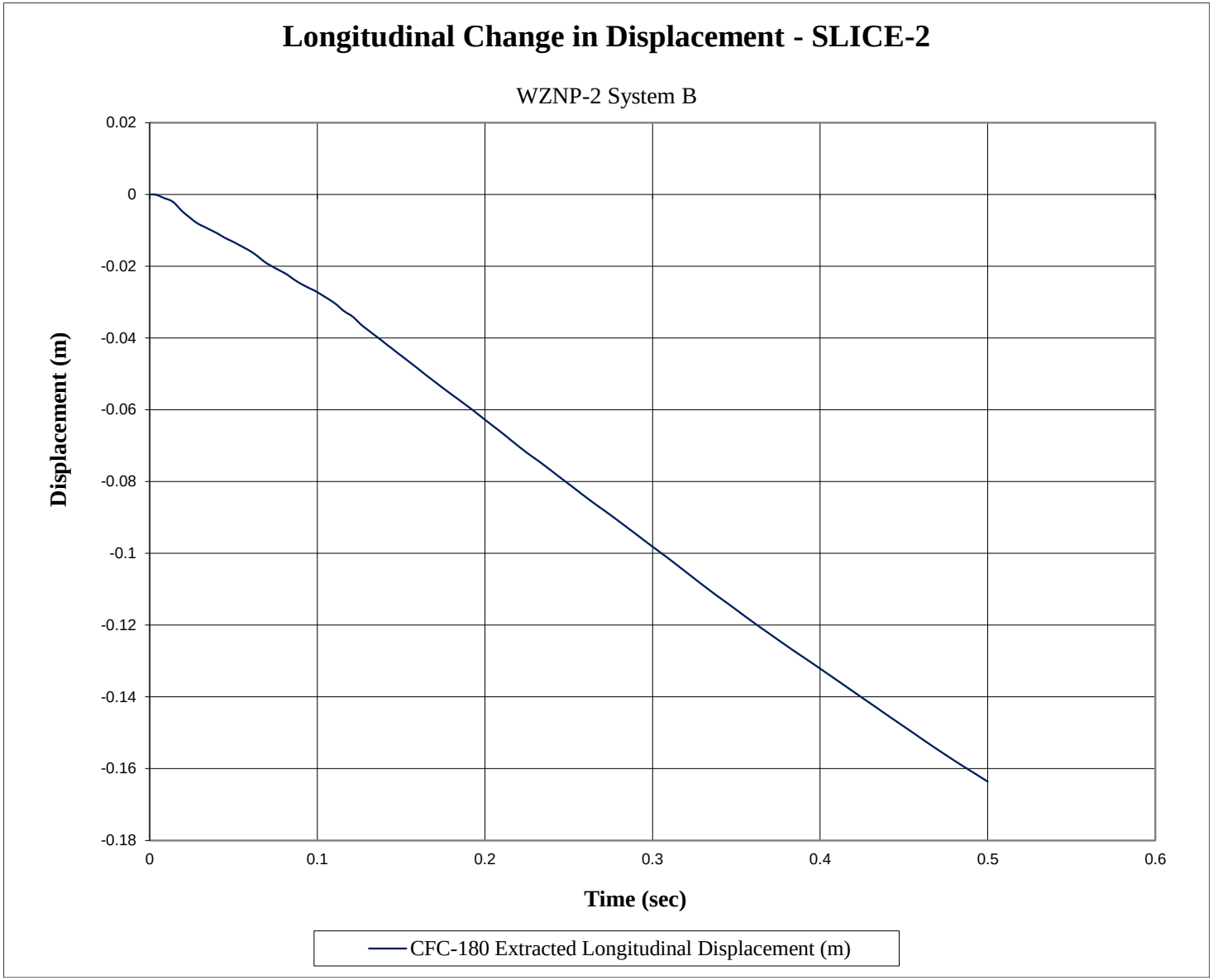


Figure D-27. Longitudinal Occupant Displacement System B (SLICE-2), Test No. WZNP-2

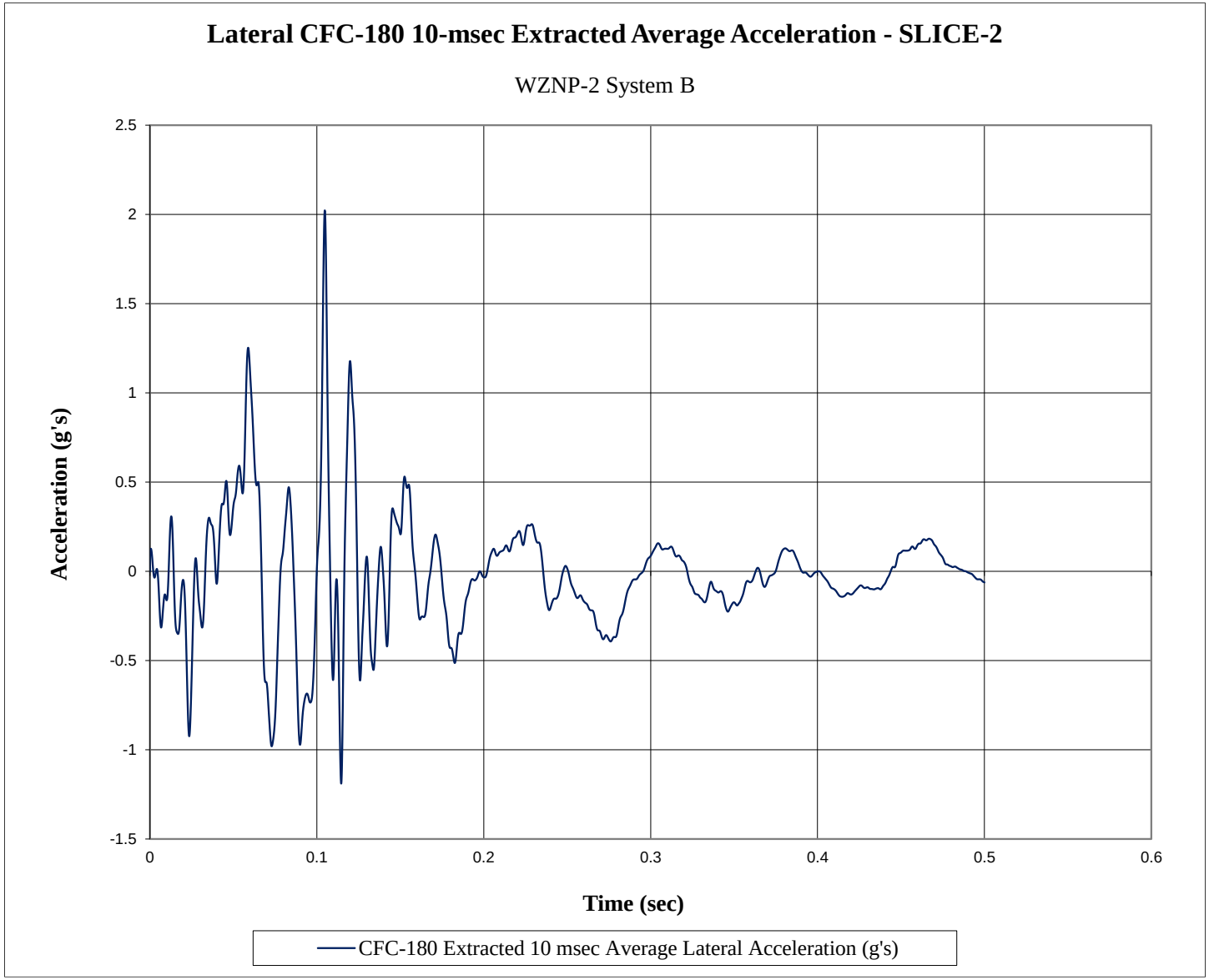


Figure D-28. 10-ms Average Lateral Deceleration System B (SLICE-2), Test No. WZNP-2

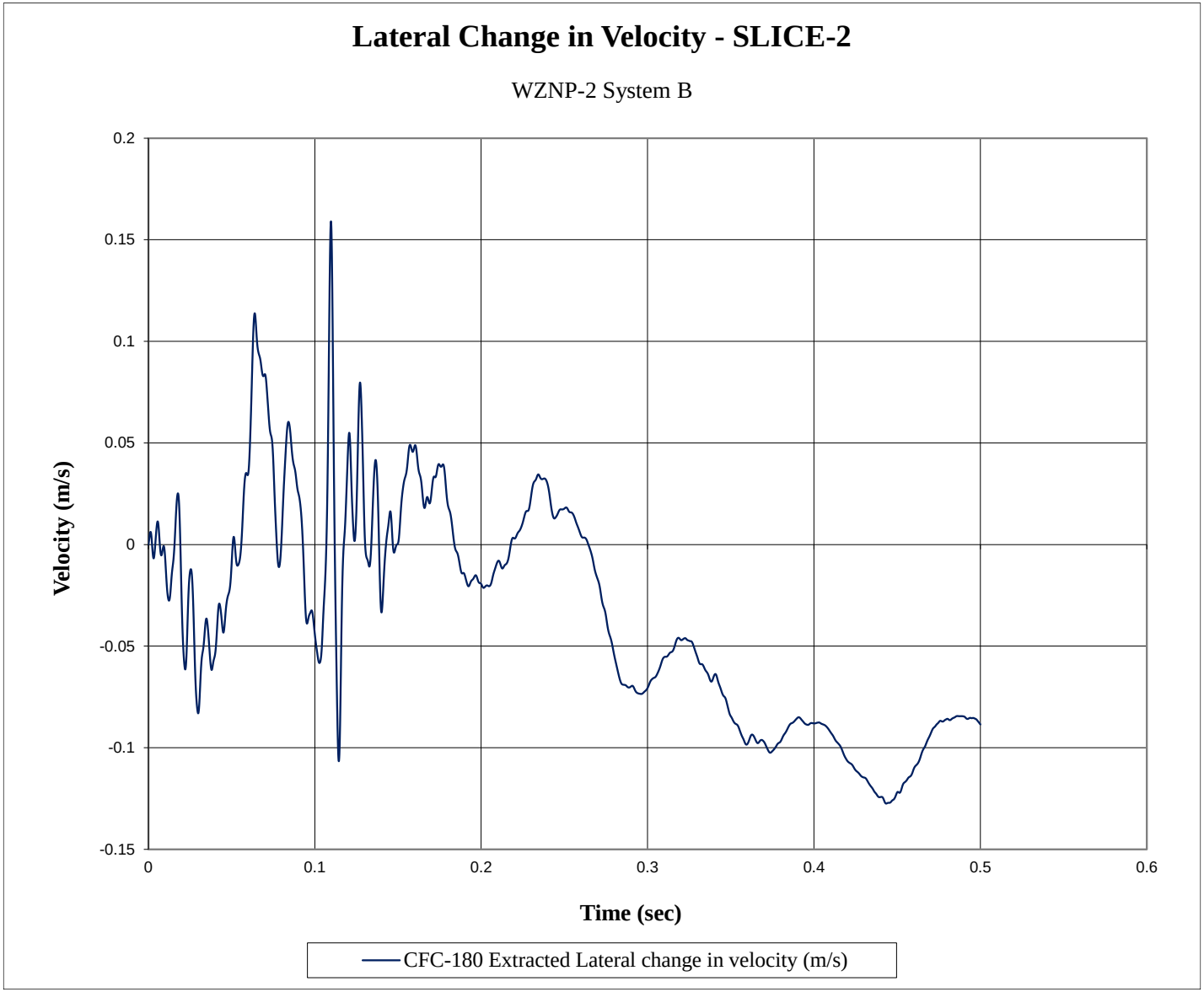


Figure D-29. Lateral Occupant Impact Velocity System B (SLICE-2), Test No. WZNP-2

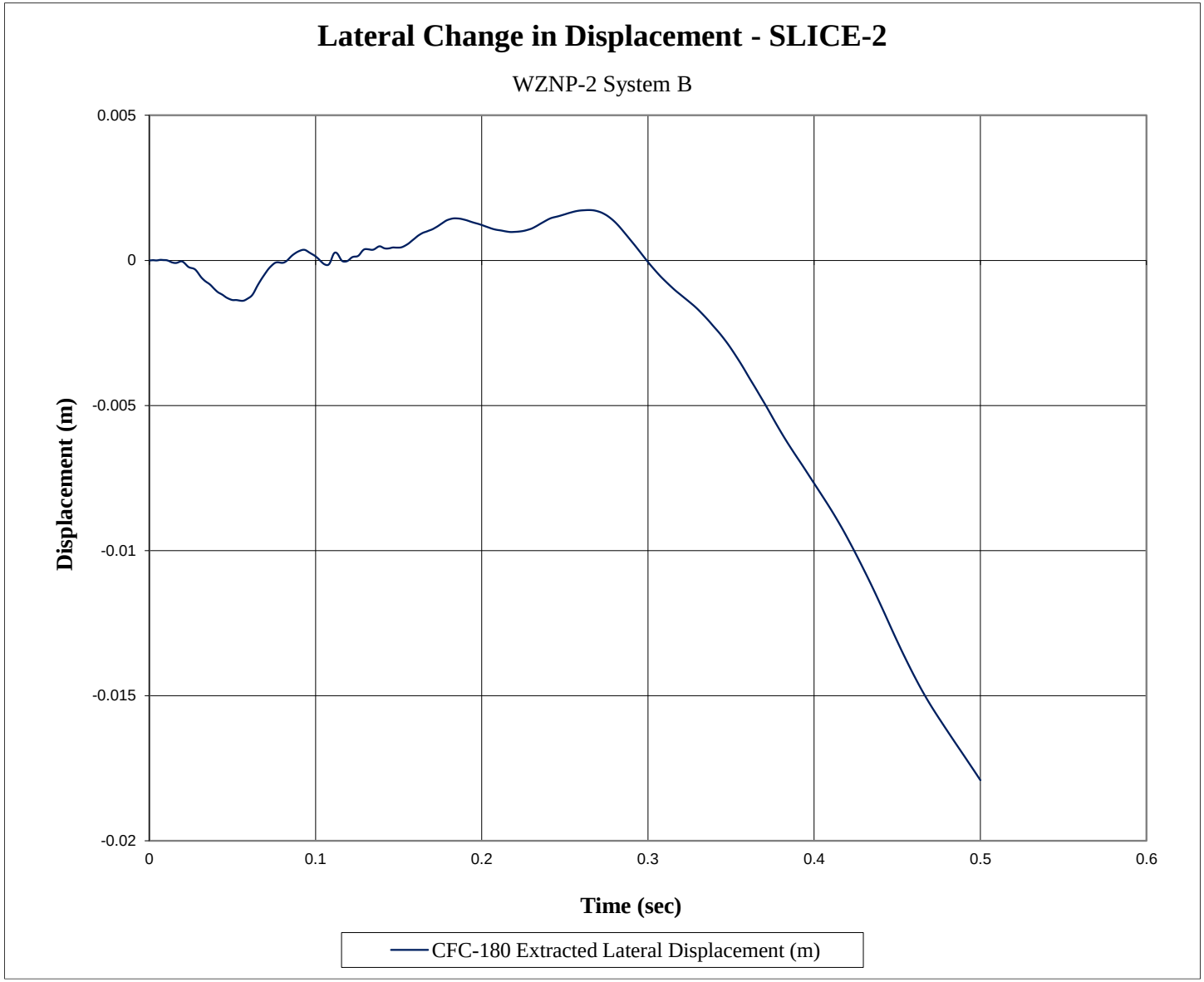


Figure D-30. Lateral Occupant Displacement System B (SLICE-2, Test No. WZNP-2

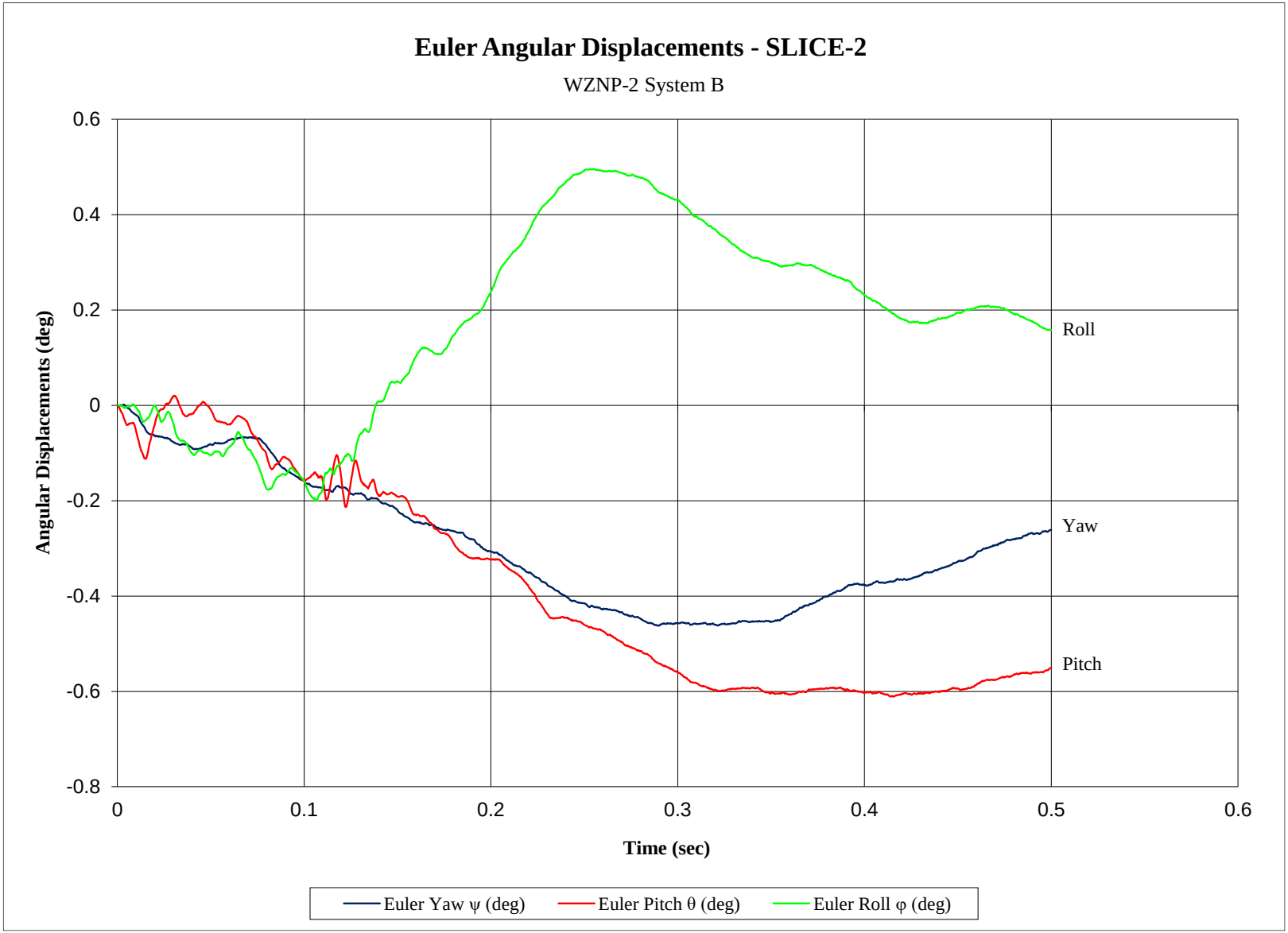


Figure D-31. Vehicle Angular Displacements System B (SLICE-2), Test No. WZNP-2

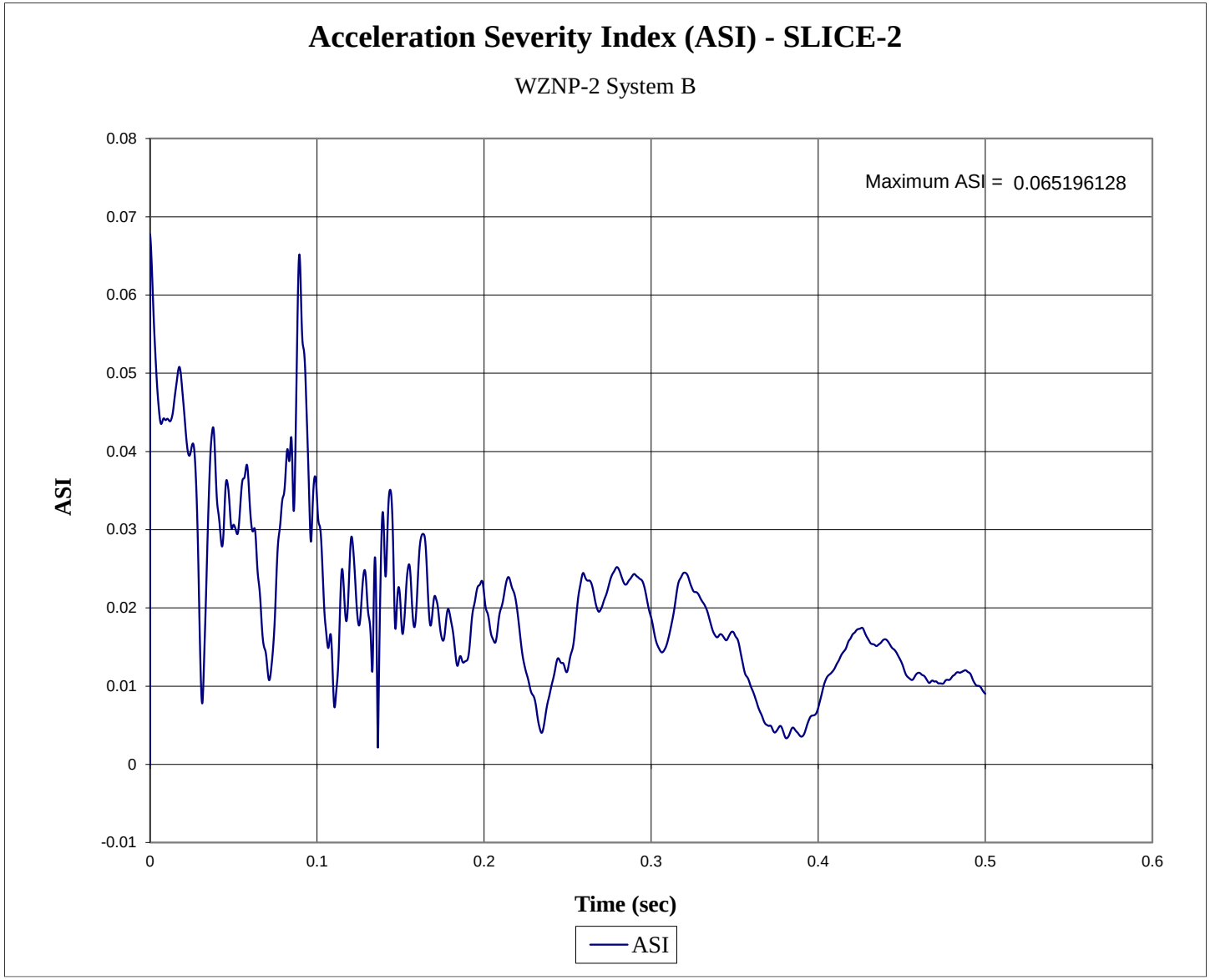


Figure D-32. Acceleration Severity Index System B (SLICE-2), Test No. WZNP-2

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