Texas A&M Transportation Institute
Proving Ground

Test Report No. 617891-01 1-4



MASH EVALUATION OF PEDESTRIAN TRAFFIC SIGNALS

Sponsored by
Roadside Safety Pooled Fund

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16. Abstract

The purpose of the study reported herein was to assess the performance of Manual on Uniform Traffic Control Devices (MUTCD) standard pedestrian signal assemblies according to the safety-performance evaluation guidelines included in the second edition of the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) (1). A survey of the Roadside Safety Pooled Fund members was conducted to gather current practices and identify common configurations of the pedestrian signal assemblies. Engineering analysis was performed to predict the behavior of the assemblies during and after impact. Three selected configurations were evaluated with full-scale crash testing. The crash tests were performed in accordance with *MASH* Test 3-61 and *MASH* Test 3-62 conditions.

This report provides details of the survey results, the engineering analysis, and the performance assessment of the MUTCD Pedestrian signal assemblies in accordance with *MASH* TL-3 evaluation criteria for support structures.

The first two pedestrian signal configurations crash tested did not meet the performance criteria for *MASH* TL-3 support structures. A third pedestrian signal configuration was investigated through research and development (R&D) tests based upon *MASH* Test 3-61 and 3-62 conditions. The R&D tests met the *MASH* evaluation criteria for TL-3 support systems that were able to be assessed.

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MASH Evaluation of Pedestrian Traffic Signals

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The results reported herein apply only to the article tested. The full-scale crash tests were performed according to TTI Proving Ground quality procedures and American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware, Second Edition (*MASH*) guidelines and standards.

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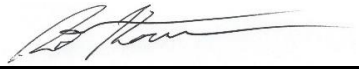

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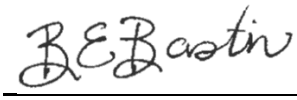

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REVISION LOG

Revision Number	Change(s) Made	Date

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1000L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	Square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lb/in^2

*SI is the symbol for the International System of Units

Chapter 1. INTRODUCTION*

In 2016, the American Association of State Highway and Transportation Officials (AASHTO) published an updated edition of the Manual for Assessing Safety Hardware (*MASH*) document. Along with this, the Federal Highway Administration (FHWA) and AASHTO developed a revised joint implementation agreement that established dates for new installations and full replacements of safety hardware on the National Highway System (NHS) to meet *MASH* criteria. Although some testing of support structures has been performed, many breakaway systems have yet to be evaluated to *MASH*.

Pedestrian signals are needed at many intersections and pedestrian crossings. MUTCD and NCHRP Web-Only Document 150 recommend providing separate poles with pushbuttons at the end of each crosswalk, which may pose additional risk for errant vehicles (2,3). Therefore, there is a need to evaluate the crashworthiness of these structures under *MASH* criteria.

In this project, a survey was conducted to gather the current standards and best practices of member states for different elements of the pedestrian signal assemblies. The most common design features were identified among the reported configurations. A summary of these results is provided in Chapter 2.

An engineering analysis, presented in Chapter 3, was used for the preliminary evaluation of the trajectory of common pedestrian signal configurations during an impact. Some of the configurations with a pedestrian signal head mounted at or below 10 ft above grade and with a pole length of less than 15 ft did not meet the preliminary crashworthiness evaluation due to the likelihood of significant secondary contact between the released pedestrian signal and the vehicle. However, because MUTCD Section 4I.03 limits the height of the pedestrian signal head to 10 ft, the research team recommended crash testing three standard design configurations with the pedestrian signal head mounted at the maximum allowable height of 10 ft above grade.

Details of the pedestrian signal assemblies selected for crash testing are presented in Chapter 4. *MASH* test requirements and evaluation criteria for these support structures are presented in Chapter 5. Details of test conditions, such as facility and vehicle tow, are presented in Chapter 6.

The first two crash tested MUTCD standard pedestrian signal configurations did not meet the performance criteria for *MASH* TL-3 Support Structures. These tests are documented in Chapter 7 and Chapter 8.

The impact performance of a third pedestrian signal configuration was investigated through Research and Development (R&D) tests based upon *MASH* test 3-61 and 3-62 impact conditions (Chapter 9 and Chapter 10). The results of the R&D crash tests showed that the third configuration is likely to pass *MASH* TL-3 criteria.

Conclusions and recommendations for future research are presented in Chapter 11.

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* *The opinions/interpretations identified/expressed in this section of the report are outside the scope of TTI Proving Ground's A2LA Accreditation.*

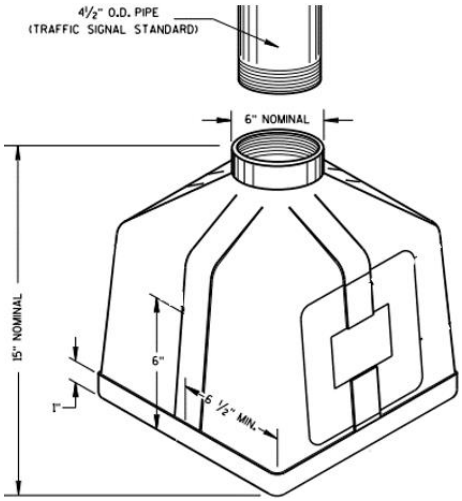
Chapter 2. SURVEY RESULTS

A survey of the Roadside Safety Pooled Fund members was conducted to gather current state standards and identify the most common designs. The survey was disseminated via email to the members and was open for 8 weeks. There was a total of 18 responses from 17 states (two entries were submitted by the same entity, Utah DoT).

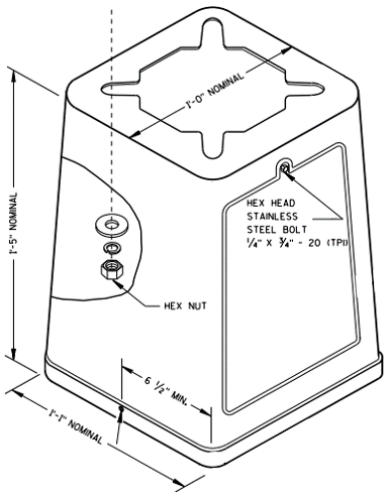
The predominant signal pole base used by the states was the square cast pedestal (11 states). The next most used base was the transformer base with three states. The most common pole size was a 4-inch Schedule 40 (12 states). Nine states preferred an aluminum pole while eight states opted for the steel pole. Table 2.1 presents a summary of the survey results. Figure 2.1 presents some of the breakaway bases reported by the states.

Table 2.1. Summary of Survey Results

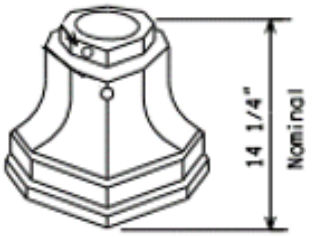
		Number of Selections
Number of States Participating in Survey		17
Pole Size	3.5-Inch Sch.40	2
	4-inch Sch. 40	12
	4-inch Sch. 80	1
Pole Material	Aluminum	9
	Steel	8
Base Type	Square Cast Pedestal	11
	Transformer	3
	Octagonal Cast Pedestal	2
	Slip Base & Other	3



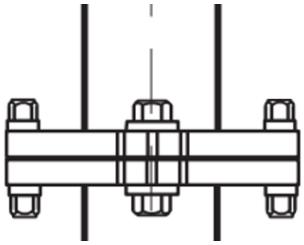
(a) Typical Square Cast Pedestal Base



(b) Transformer Base



(c) Octagonal Cast Pedestal



(d) 4-Bolt Slip Base

Figure 2.1. Breakaway Bases Used by Member States

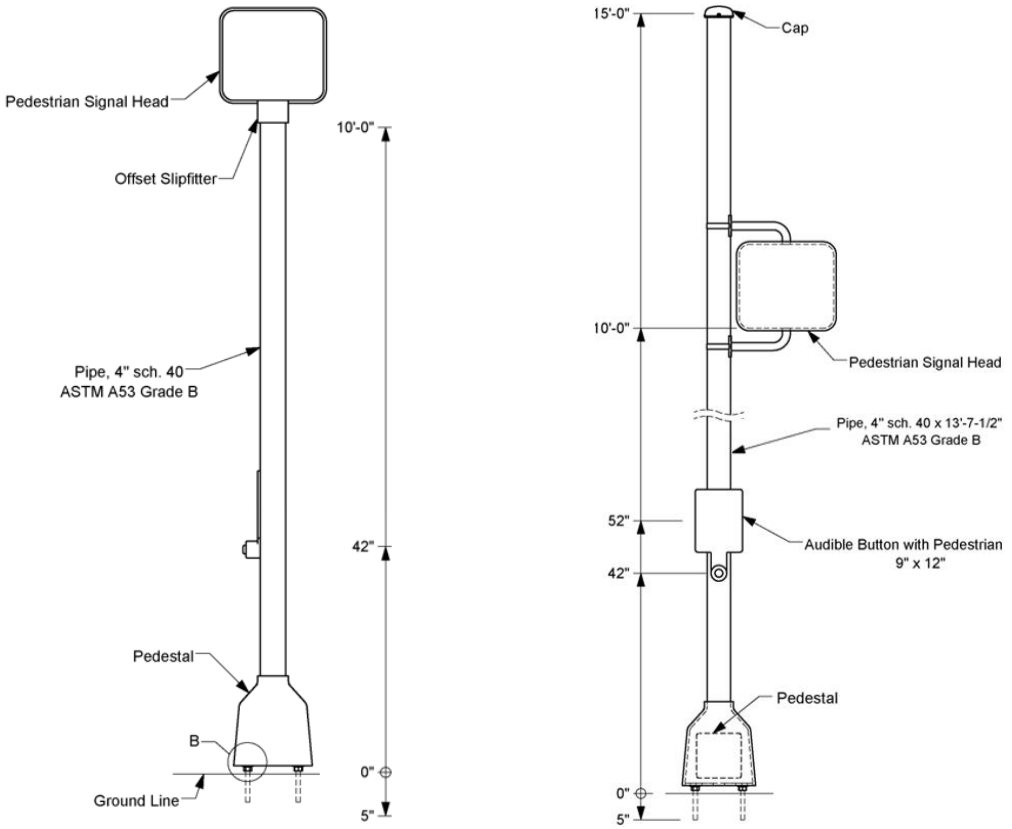
The survey results indicate that the predominant base used by the member states is a pedestal base with a height of 15 inches and width of 13 inches. Given the different types of pedestal bases available, the researchers initially planned to conduct pendulum tests to obtain the activation force of each type. However, after further analysis of the survey results, the researchers noticed that most of the states use the square cast base with typical dimensions (15 in x 13 in). Therefore, the research team decided to use the pedestal square cast base with typical dimensions for all configurations in this project.

Chapter 3. ENGINEERING ANALYSIS

An engineering analysis method based on the principals of conservation of energy and conservation of momentum was used to investigate the post impact trajectory of the most common pedestrian signal configurations. This engineering methodology was originally developed under TxDOT Research Project 0-1792 and has been used to evaluate pedestal base supports in previous TTI research projects (4,5).

The researchers used two previous *MASH* crash tests conducted by TTI on traffic signals with the same square cast aluminum pedestal base to determine the activation force (breakaway force) of the pedestal base and calibrate the analysis method (5).

The first system to be analytically investigated was the typical MUTCD standard pedestrian signal assembly, which consists of a pedestrian signal head mounted on top of a pole 10 ft above grade, as shown in Figure 3.1(a). The second configuration that was evaluated analytically had a pole that extended 15 ft above grade with a pedestrian signal head attached 10 ft above grade with two mounting arms, as shown in Figure 3.1(b).

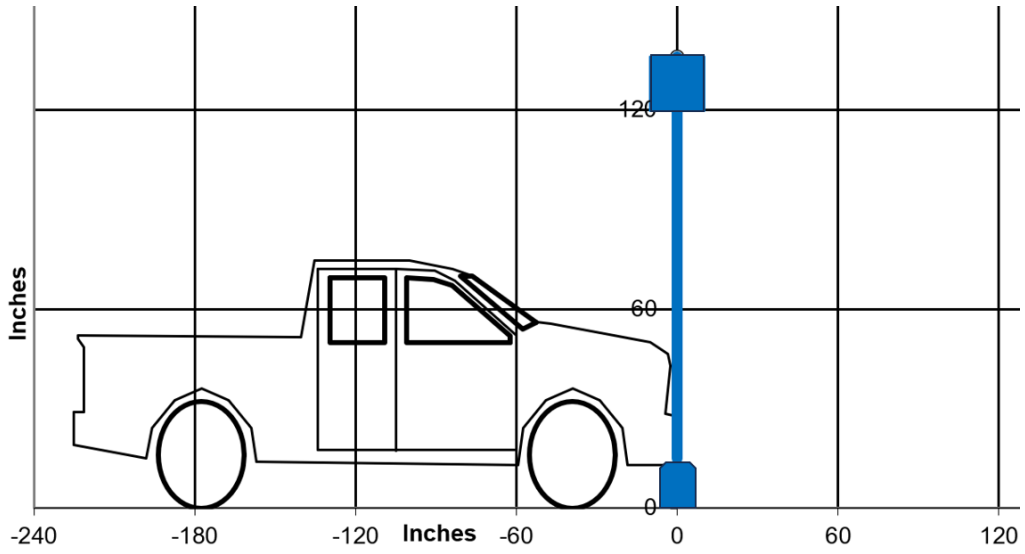


(a) Configuration 1 (b) Configuration 2

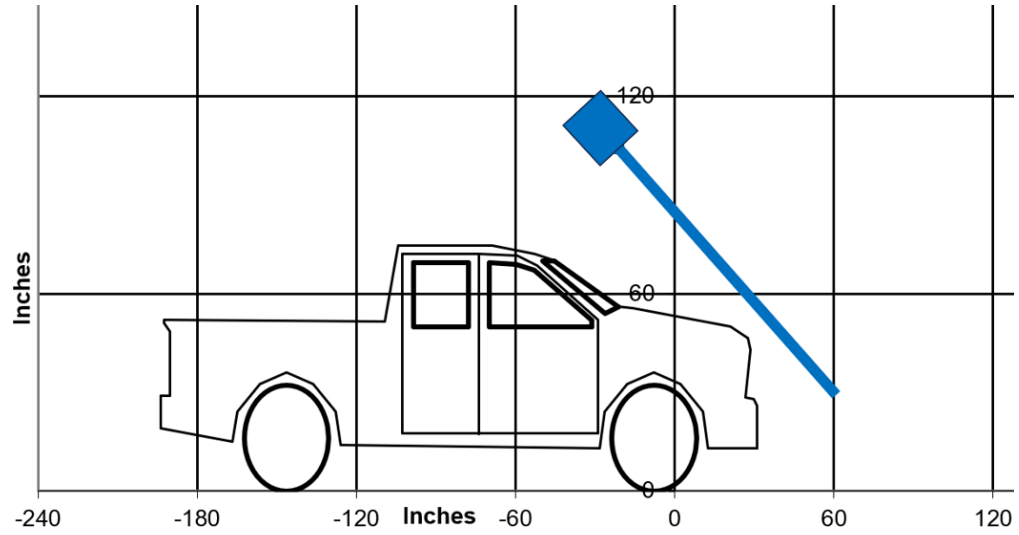
Figure 3.1. Configurations Evaluated Via Implicit Engineering Analysis

The analytical evaluation of the first configuration showed that the pole was very likely to impact the windshield and the roof of the vehicle for *MASH* Test 3-62 conditions, as shown in Figure 3.2. Note that this model is a typical MUTCD standard pedestrian signal assembly. To improve the post impact performance of the assembly and possibly avoid secondary contact with the roof of the pickup, the research team recommended increasing the mounting height of the pedestrian signal to 13 ft or higher above grade. However, this height exceeds the MUTCD limits of Section 4I.03. The researchers further determined that, in order to sufficiently increase the center of mass of the pedestrian signal support system to avoid secondary roof contact with the signal head mounted 10 ft above grade, an additional weight in excess of 100 lb needs to be attached to the top of the pole, which is an impractical solution.

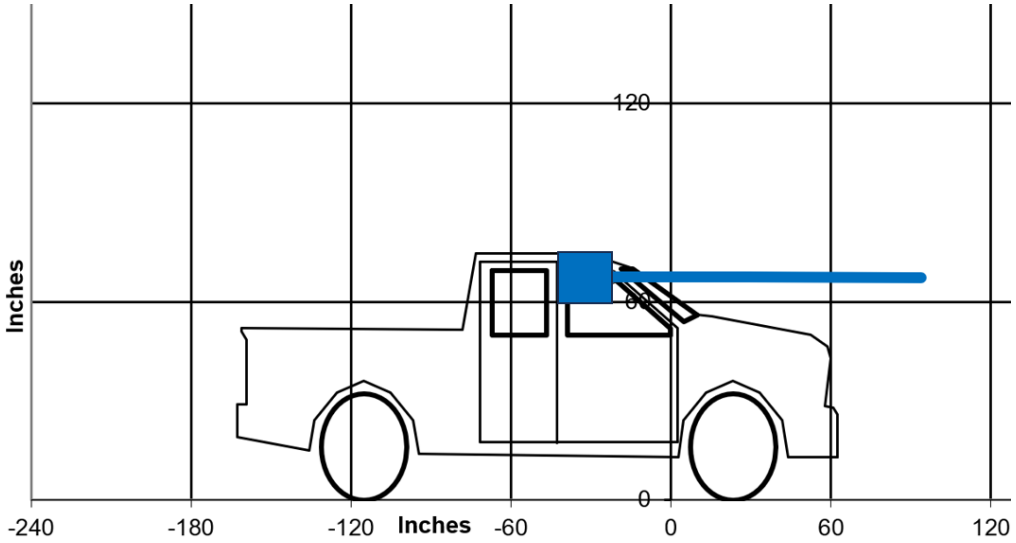
The member states thus decided to select the typical MUTCD standard pedestrian signal assembly as the first configuration for *MASH* TL-3 full scale crash testing.



(a) 0 degrees of rotation



(b) 45 degrees of rotation



(c) 90 degrees of rotation

Figure 3.2. Implicit Engineering Crashworthiness Evaluation of Configuration 1

Configuration 1 (Figure 3.1(a)) was crash tested under *MASH* Test 3-62 conditions and failed to satisfy the evaluation criteria. Details of the crash test are presented in Chapter 7.

The research team used the pole trajectory and accelerometer data from this crash test to further validate the engineering analysis model. Pedestrian signal Configuration 2 (Figure 3.1(b)) was then evaluated for *MASH* Test 3-62 and Test 3-61 impact conditions using the engineering analysis method, and the results are shown in Figure 3.3 and Figure 3.4, respectively.

In the crash test of the first configuration, the pedestrian signal head broke off when the vehicle impacted the pole. Therefore, when analyzing the second configuration, the research team investigated both scenarios, with and without detachment of the signal head upon impact. However, given the total weight of the signal head (about 20 lbs), the effect on the trajectory of the pole after activation of the breakaway base was not significant.

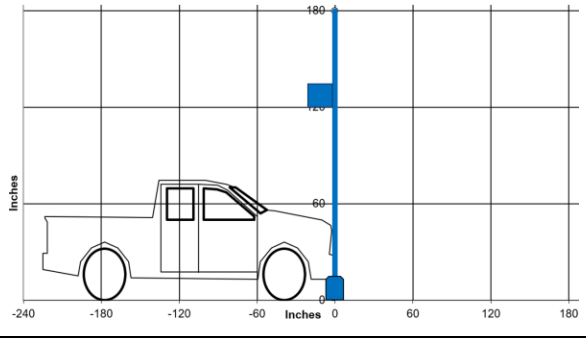
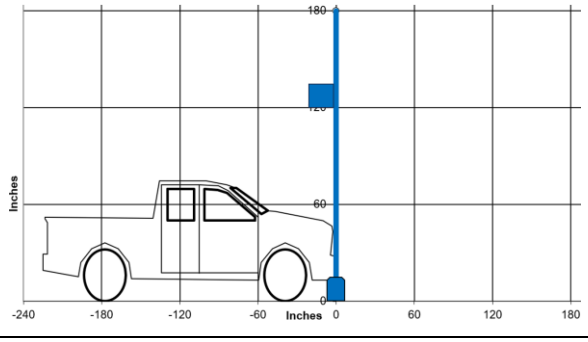
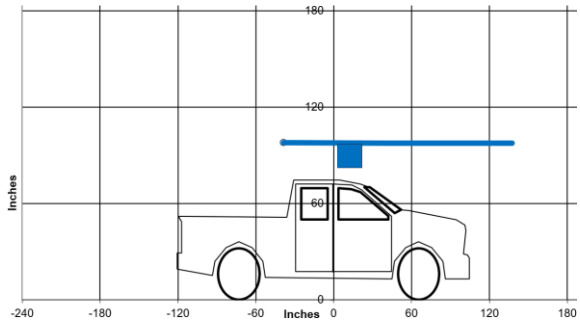
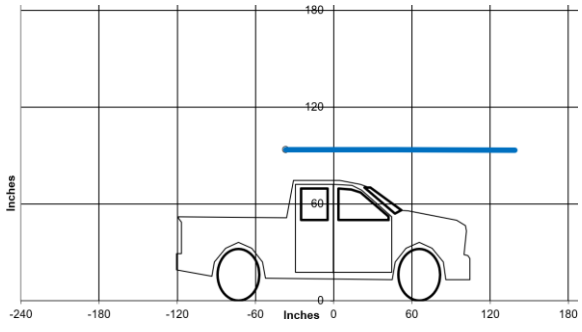
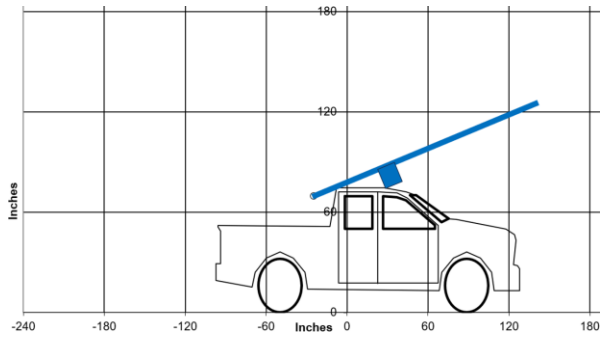
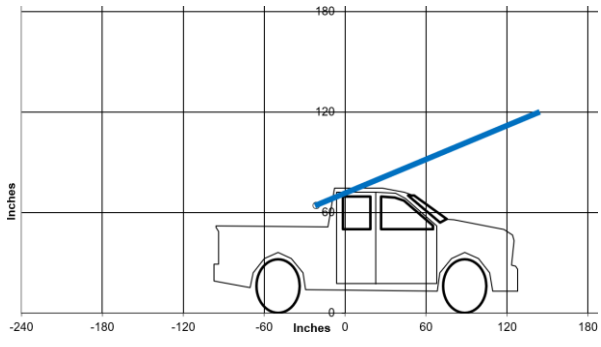
Pedestrian signal head remains attached throughout impact	Pedestrian signal head breaks off at impact
	
(a) 0 degrees of rotation	
	
(b) 90 degrees of rotation	
	
(c) 110 degrees of rotation	

Figure 3.3. Implicit Engineering Crashworthiness Evaluation of Configuration 2 for *MASH* Test 3-62

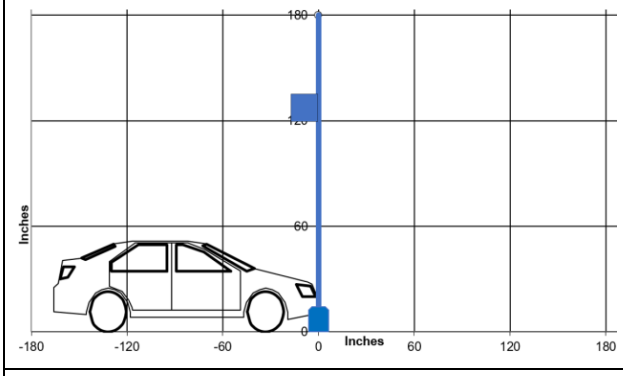
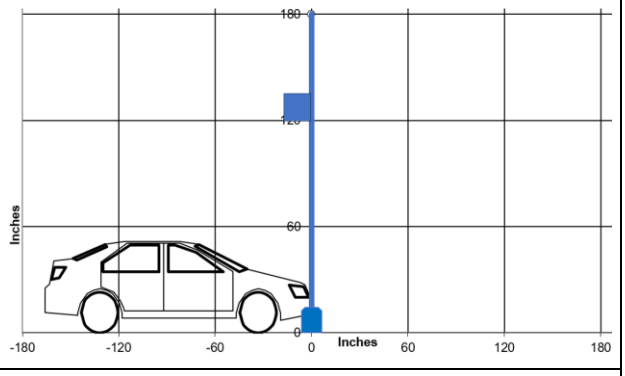
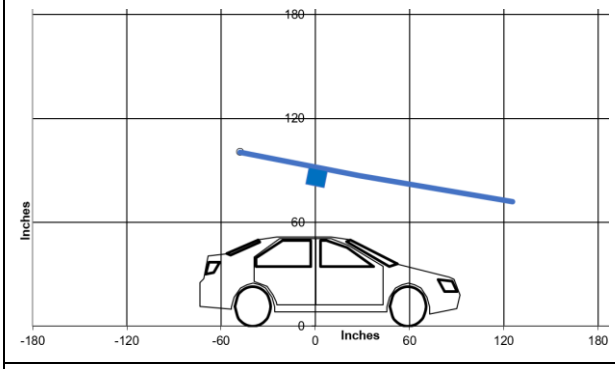
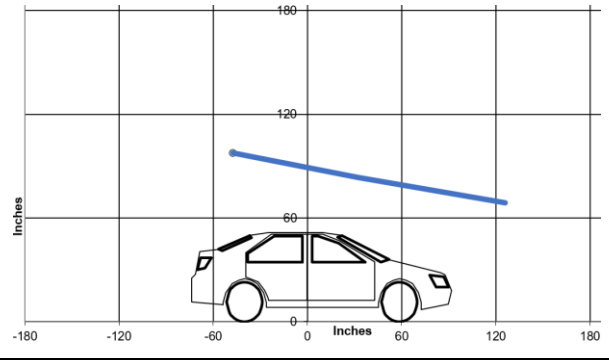
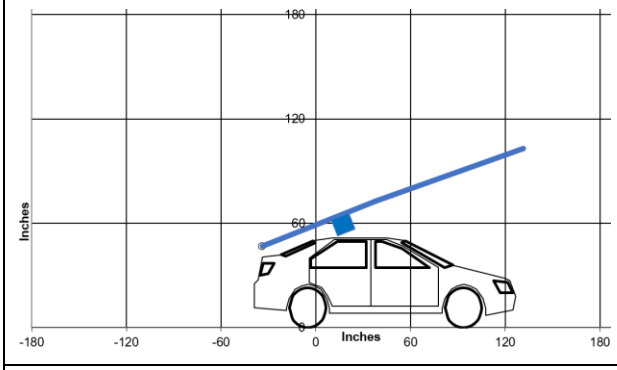
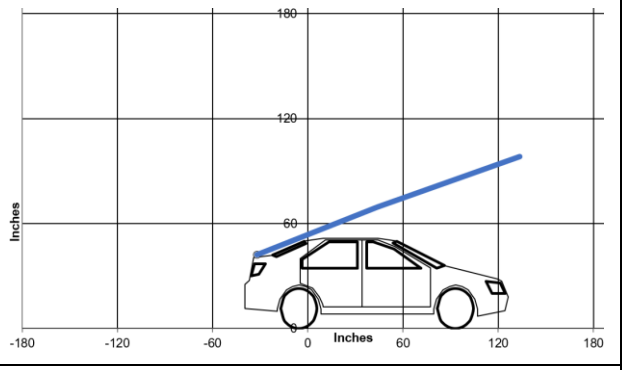
Pedestrian signal head remains attached throughout impact	Pedestrian signal head breaks off at impact
	
(a) 0 degrees of rotation	
	
(b) 80 degrees of rotation	
	
(c) 110 degrees of rotation	

Figure 3.4. Implicit Engineering Crashworthiness Evaluation of Configuration 2 for *MASH* Test 3-61

The engineering analysis showed that the taller pole incorporated into the second pedestrian signal configuration was likely to impact the rear part of the roof for both *MASH* design vehicles. However, this simplified analysis method cannot predict the

extent of roof deformation caused by the secondary impact with the pole or pedestrian signal head.

Based on the marginal results from the engineering analysis, the research team recommended crash testing Configuration 2 under *MASH* Test 3-62 conditions. Details of the crash test are presented in Chapter 8.

Chapter 4. SYSTEM DETAILS

4.1. TEST ARTICLE AND INSTALLATION DETAILS

Due to failures encountered during testing, a total of three different design configurations were crash tested.

For Test 617891-01-1, the installation was a 4-inch schedule 40 steel pipe attached to a pedestal base, with a pedestrian signal head mounted to the top, and an audible button with pedestrian sign mounted to the pole 42 inches from the ground to the base of the sign and facing perpendicular to the front of the signal head. The height to the base of the pedestrian signal head was 10 feet.

For Test 617891-01-2, the installation was a 4-inch schedule 40 steel pipe attached to a pedestal base, with a pedestrian signal head mounted via two brackets to the side of the pipe and an audible button with pedestrian sign mounted to the pole 42 inches from the ground to the center of the audible button and facing the same direction as the signal head. The height to the base of the pedestrian signal head was 10 feet, and the height to the top of the pole was 15 feet.

For Tests 617891-01 3&4, both R&D tests, the installation was the same as the installation for 617891-01-2, but the signal head was a clamshell mount as opposed to the bracket mounts used in the previous test.

Figure 4.1 presents the overall information on the MUTCD standard pedestrian signal for test 617891-01-1, and Figure 4.2 thru Figure 4.7 provide photographs of the installation. Figure 4.1 presents the overall information on the MUTCD standard pedestrian signal for test 617891-01-2, and Figure 4.2 thru Figure 4.7 provide photographs of the installation. Figure 4.15 presents the overall information on the MUTCD standard pedestrian signal for tests 617891-01 3&4, and Figure 4.2 thru Figure 4.7 provide photographs of the installation. Appendix A provides further details on the crash tested MUTCD standard pedestrian signal assemblies. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel.

4.2. DESIGN MODIFICATIONS DURING TESTS

No modifications were made to the installation during the testing phase.

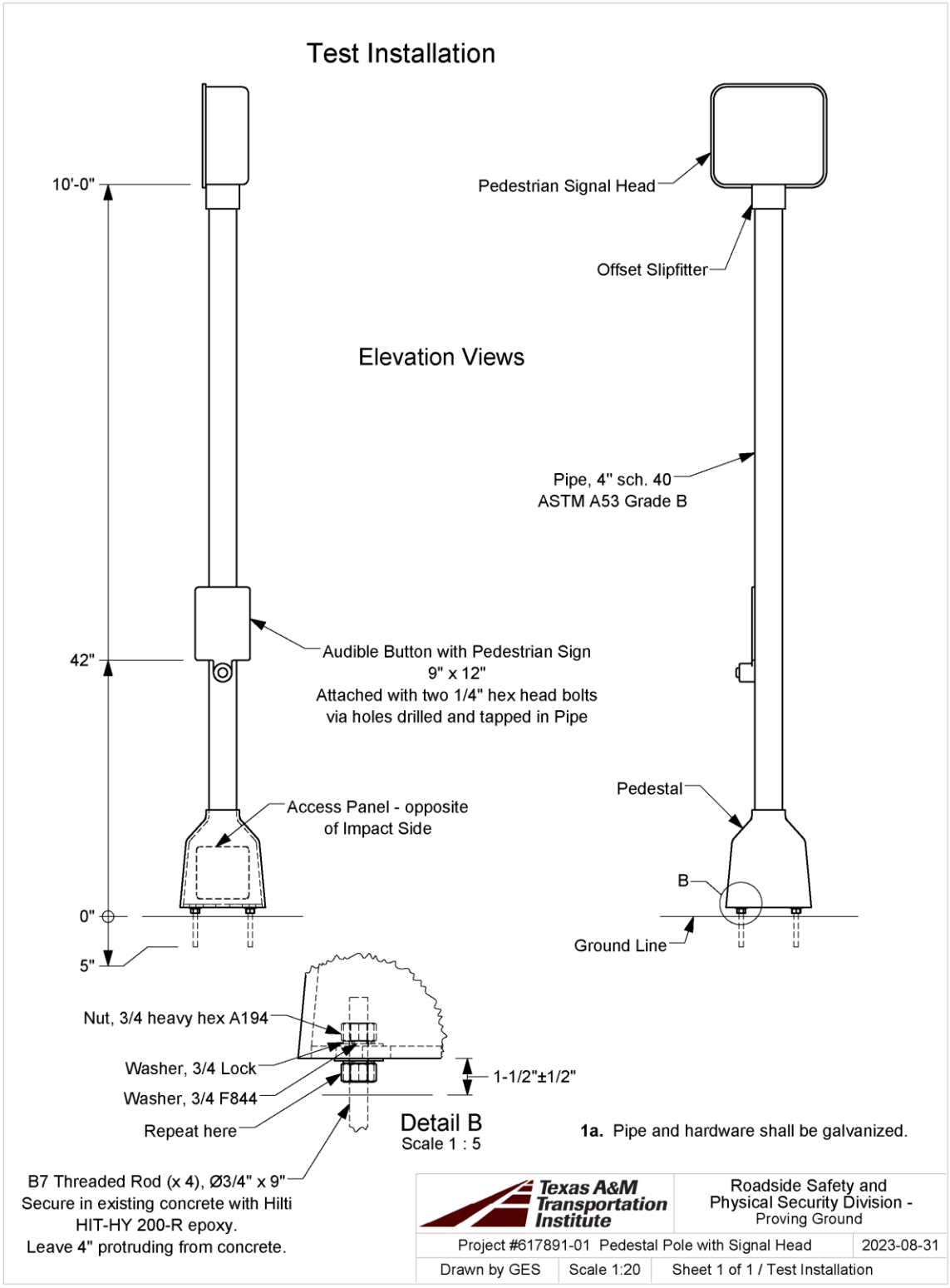


Figure 4.1. Details of MUTCD Standard Pedestrian Signal for Crash Test 617891-01-1.

Figure 4.2. 90 Degree View of the MUTCD Standard Pedestrian Signal Prior to Crash Test 617891-01-1.

Figure 4.3. MUTCD Standard Pedestrian Signal Base Prior to Crash Test 617891-01-1.

Figure 4.4. 0 Degree Angle of the MUTCD Standard Pedestrian Signal Prior to Crash Test 617891-01-1.

Figure 4.5. 180 Degree View of the MUTCD Standard Pedestrian Signal Prior to Crash Test 617891-01-1.

Figure 4.6. MUTCD Standard Pedestrian Signal Signal Head Prior to Crash Test 617891-01-1.

Figure 4.7. MUTCD Standard Pedestrian Signal and Audible Button Prior to Crash Test 617891-01-1.

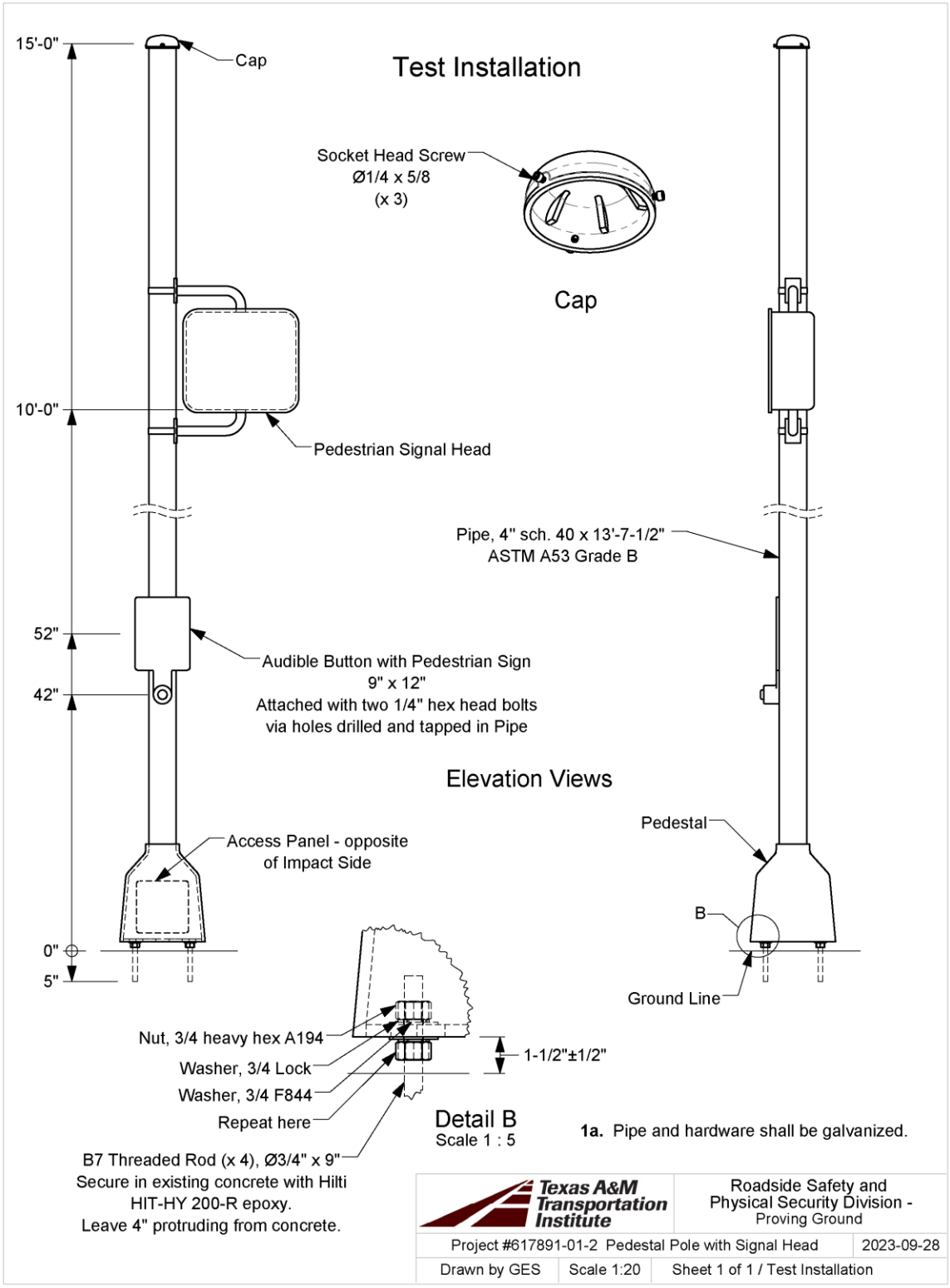


Figure 4.8. Details of MUTCD Standard Pedestrian Signal for Crash Test 617891-01-2.

Figure 4.9. 90 Degree View of the MUTCD Standard Pedestrian Signal Prior to Crash Test 617891-01-2.

Figure 4.10. Oblique View of the MUTCD Standard Pedestrian Signal Prior to Crash Test 617891-01-2.

Figure 4.11. MUTCD Standard Pedestrian Signal Base Prior to Crash Test 617891-01-2.

Figure 4.12. MUTCD Standard Pedestrian Signal Head Prior to Crash Test 617891-01-2.

Figure 4.13. MUTCD Standard Pedestrian Signal Head Attachment Straps Prior to Crash Test 617891-01-2.

Figure 4.14. MUTCD Standard Pedestrian Signal with Audible Button Prior to Crash Test 617891-01-2.

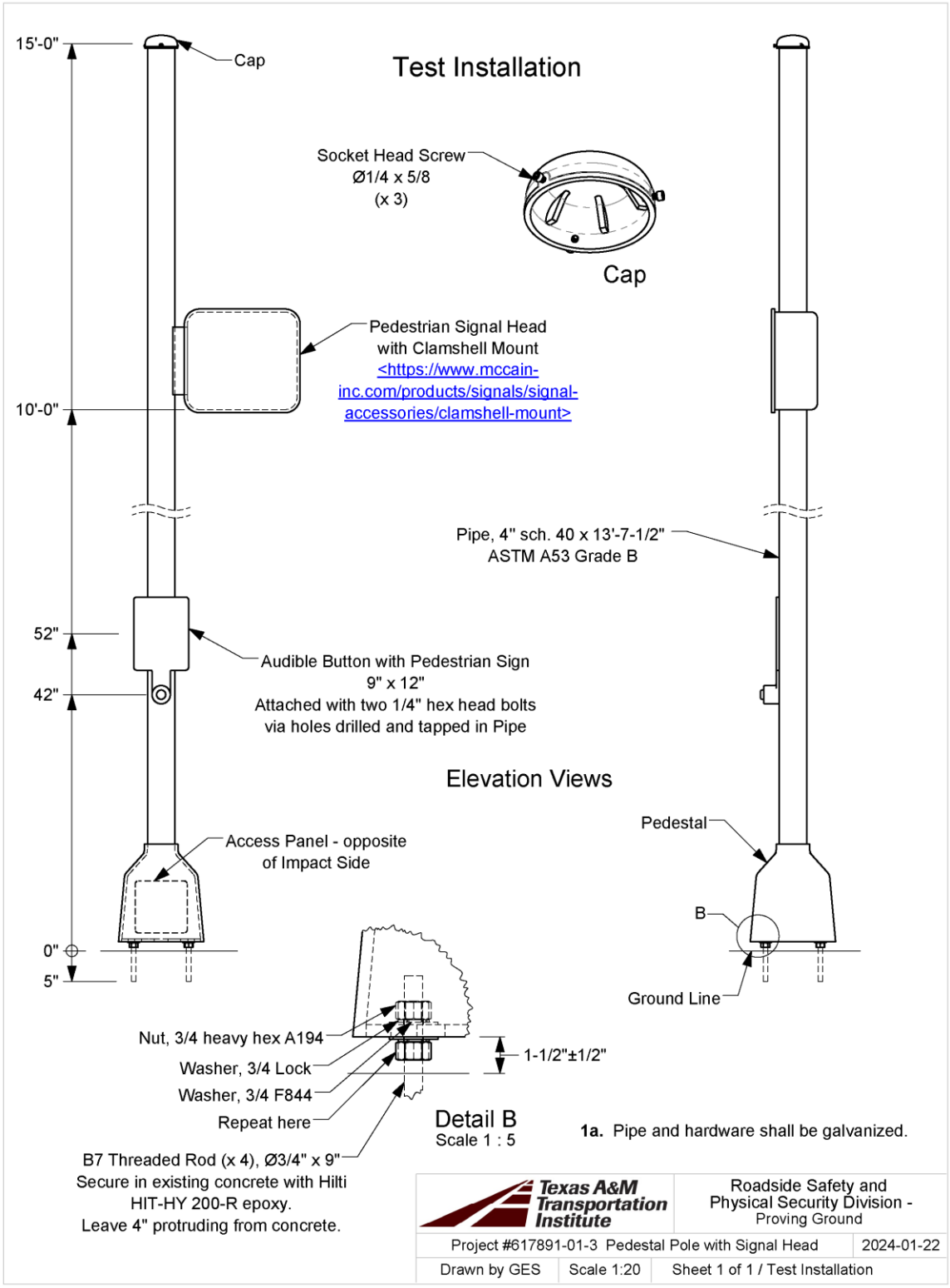


Figure 4.15. Details of MUTCD Standard Pedestrian Signal for Crash Tests 617891-01 3&4.

Figure 4.16. MUTCD Standard Pedestrian Signal Prior to Crash Tests 617891-01 3&4.

Figure 4.17. MUTCD Standard Pedestrian Signal with Audible Button Prior to Crash Tests 617891-01 3&4.

Figure 4.18. MUTCD Standard Pedestrian Signal Head Prior to Crash Tests 617891-01 3&4.

Figure 4.19. MUTCD Standard Pedestrian Signal Base Prior to Crash Tests 617891-01 3&4.

Figure 4.20. MUTCD Standard Pedestrian Signal Anchor Bolts Prior to Crash Tests 617891-01 3&4.

Figure 4.21. Oblique View of the MUTCD Standard Pedestrian Signal Prior to Crash Tests 617891-01 3&4.

4.3. MATERIAL SPECIFICATIONS

Appendix B provides material certification documents for the materials used to install/construct the MUTCD standard pedestrian signal assemblies.

Chapter 5. TEST REQUIREMENTS AND EVALUATION CRITERIA

5.1. CRASH TEST CONDITIONS

Table 5.1 shows the test conditions and evaluation criteria for *MASH* 3-62 for Support Structures. The target critical impact points (CIPs) for each test were determined using the information provided in *MASH* Section 2.2.4. Figure 5.1 shows the target CIP for test 617891-01-1 on the MUTCD standard pedestrian signal assembly. Figure 5.2 shows the target CIP for test 617891-01-2 on the MUTCD standard pedestrian signal assembly. Tests 617891-01 3&4 were conducted for research purposes only and were not evaluated using all *MASH* evaluation criteria for Support Structures. Figure 5.3 shows the target CIP for tests 617891-01 3&4.

An impact angle of 90 degrees was selected for all four crash tests with the pedestrian signal head installed on the impact side of the pole. This testing configuration was considered the most critical based on the geometry of the pedestrian signal head and its mounting details, and the likelihood of post impact secondary contact with the vehicles.

Table 5.1. Test Conditions and Evaluation Criteria Specified for *MASH* 3-62 Support Structures.

Test Designation	Test Vehicle	Impact Speed	Impact Angle	Evaluation Criteria
3-62	2270P	62 mi/h	90º	B, D, F, H, I, N
3-62 (R&D)	2270P	62 mi/h	90º	B, D, F, N
3-61 (R&D)	1100C	62 mi/h	90º	B, D, F, N

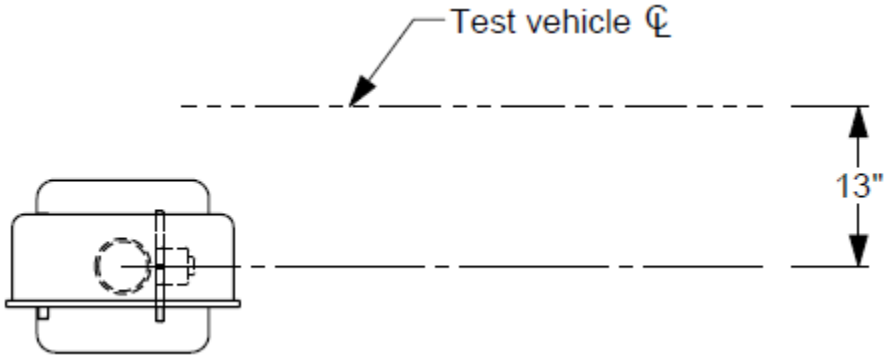


Figure 5.1. Target CIP for *MASH* TL-3 Test 617891-01-1 on MUTCD Standard Pedestrian Signal.

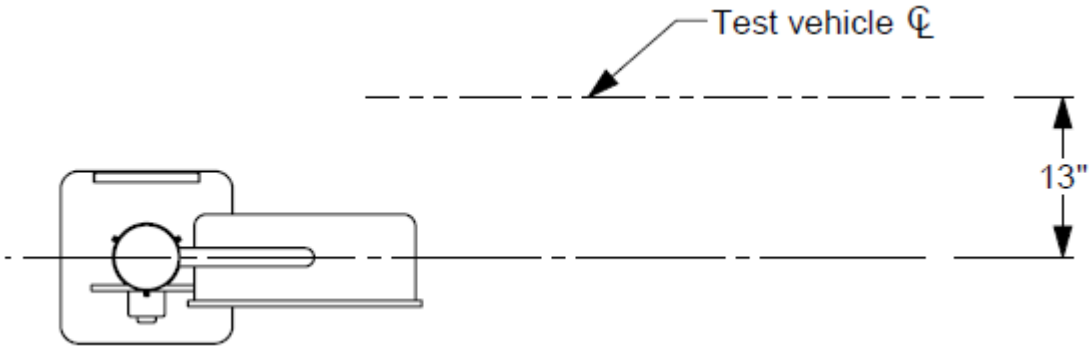


Figure 5.2. Target CIP for *MASH* TL-3 Test 617891-01-2 on MUTCD Standard Pedestrian Signal.

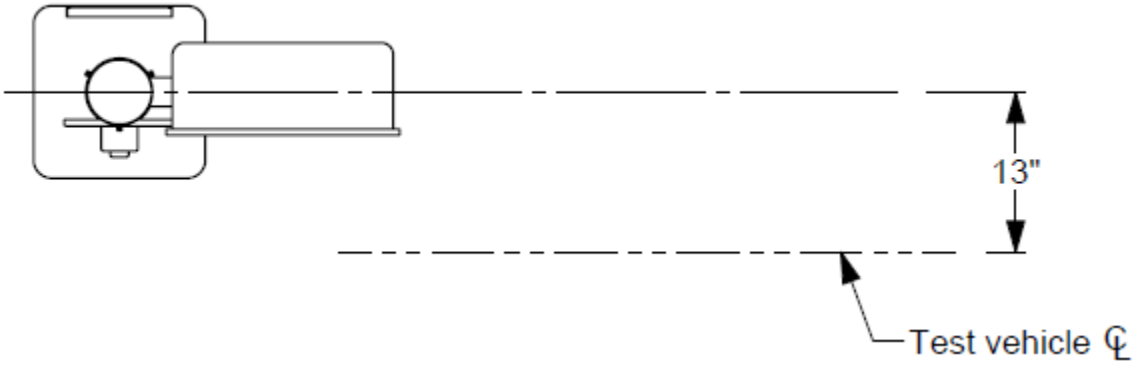


Figure 5.3. Target CIP for *MASH* TL-3 Tests 617891-01 3&4 on MUTCD Standard Pedestrian Signal.

The crash tests and data analysis procedures were in accordance with guidelines presented in *MASH*. Chapter 6 presents brief descriptions of these procedures.

5.2. EVALUATION CRITERIA

The appropriate safety evaluation criteria from Tables 2-5 and 5-1 of *MASH* were used to evaluate crash tests 617891-01-1 and 617891-01-2, reported herein. Table 5.1 lists the test conditions and evaluation criteria required for *MASH* TL-3, and Table 5.2 provides detailed information on the evaluation criteria.

Table 5.2. Evaluation Criteria Required for *MASH* Testing.

Evaluation Factors	Evaluation Criteria
B.	The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.

Evaluation Factors	Evaluation Criteria
D.	Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present 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*.
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16 ft/s.
I.	The occupant ridedown accelerations should satisfy the following: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.
N.	Vehicle trajectory behind the test article is acceptable.

Chapter 6. TEST CONDITIONS

6.1. TEST FACILITY

The full-scale crash tests reported herein were performed at the TTI Proving Ground, an International Standards Organization (ISO)/International Electrotechnical Commission (IEC) 17025-accredited laboratory with American Association for Laboratory Accreditation (A2LA) Mechanical Testing Certificate 2821.01. The full-scale crash tests were performed according to TTI Proving Ground quality procedures, as well as *MASH* guidelines and standards.

The test facilities of the TTI Proving Ground are located on The Texas A&M University System RELLIS Campus, which consists of a 2000-acre complex of research and training facilities situated 10 mi northwest of the flagship campus of Texas A&M University. The site, formerly a United States Army Air Corps base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, highway pavement durability and efficacy, and roadside safety hardware and perimeter protective device evaluation. The sites selected for construction and testing are along the edge of an out-of-service apron/runway. The apron/runway consists of an unreinforced jointed-concrete pavement in 12.5-ft × 15-ft blocks nominally 6 inches deep. The aprons were built in 1942, and the joints have some displacement but are otherwise flat and level.

6.2. VEHICLE TOW AND GUIDANCE SYSTEM

For the testing utilizing the 1100C and 2270P vehicles, each was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point and through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A 2:1 speed ratio between the test and tow vehicle existed with this system. Just prior to impact with the installation, the test vehicle was released and ran unrestrained. The vehicle remained freewheeling (i.e., no steering or braking inputs) until it cleared the immediate area of the test site.

6.3. DATA ACQUISITION SYSTEMS

6.3.1. Vehicle Instrumentation and Data Processing

The test vehicles used in crash tests 617891-01-1 and 617891-01-2 were instrumented with a self-contained onboard data acquisition system. The signal conditioning and acquisition system is a multi-channel data acquisition system (DAS) produced by Diversified Technical Systems Inc. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt

output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid-state units designed for crash test service. The data acquisition hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 samples per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit in case the primary battery cable is severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark and initiates the recording process. After each test, the data are downloaded from the DAS unit into a laptop computer at the test site. The Test Risk Assessment Program (TRAP) software then processes the raw data to produce detailed reports of the test results.

Each DAS is returned to the factory annually for complete recalibration and to ensure that all instrumentation used in the vehicle conforms to the specifications outlined by SAE J211. All accelerometers are calibrated annually by means of an ENDEVCO® 2901 precision primary vibration standard. This standard and its support instruments are checked annually and receive a National Institute of Standards Technology (NIST) traceable calibration. The rate transducers used in the data acquisition system receive calibration via a Genisco Rate-of-Turn table. The subsystems of each data channel are also evaluated annually, using instruments with current NIST traceability, and the results are factored into the accuracy of the total data channel per SAE J211. Calibrations and evaluations are also made anytime data are suspect. Acceleration data are measured with an expanded uncertainty of ±1.7 percent at a confidence factor of 95 percent (k = 2).

TRAP uses the DAS-captured data to compute the occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and highest 10-millisecond (ms) average ridedown acceleration. TRAP calculates change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers are filtered with an SAE Class 180-Hz low-pass digital filter, and acceleration versus time curves for the longitudinal, lateral, and vertical directions are plotted using TRAP.

TRAP uses the data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0001-s intervals, and then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation being initial impact. Rate of rotation data is measured with an expanded uncertainty of ±0.7 percent at a confidence factor of 95 percent (k = 2).

Crash Tests 617891-01-3 and 617891-01-4 used expired or previously used vehicles to impact the pedestrian signal assembly under *MASH* TL-3 impact conditions. These vehicles were uninstrumented and either expired as defined by *MASH* (older than six model years) or previously used but intact in areas essential for the outcome of the test. R&D tests are a less expensive way to provide high confidence crashworthiness evaluation of secondary contact between the support system and the vehicle, without the vehicle data instrumentation required in *MASH* compliant tests.

6.3.2. Anthropomorphic Dummy Instrumentation

According to *MASH*, use of a dummy in the 2270P vehicle is optional, and no dummy was used in the test.

As test 617891-01-4 was an R&D test, no dummy was used.

6.3.3. Photographic Instrumentation Data Processing

Photographic coverage of each test included two digital high-speed cameras:

- One placed with a field of view perpendicular to the impact path and in-line with the point of impact
- One placed downstream from the impact point at an oblique angle to the impact path

A flashbulb on the impacting vehicle was activated by a pressure-sensitive tape switch to indicate the instant of contact with the MUTCD standard pedestrian signal . The flashbulb was visible from each camera. The video files from these digital high-speed cameras were analyzed to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A digital camera recorded and documented conditions of each test vehicle and the installation before and after the test.

Chapter 7. *MASH* TEST 3-62 (CRASH TEST 617891-01-1)

7.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 7.1 for details of the impact conditions for this test and Table 7.2 for the exit parameters. Figure 7.1 and Figure 7.2 depict the target impact setup.

Table 7.1. Impact Conditions for *MASH TEST 3-62,* Crash Test 617891-01-1.

Test Parameter	Specification	Tolerance	Measured
Impact Speed	62 mi/h	±2.5 mi/h	63.6 mi/h
Impact Angle	90°	±1.5°	90°
Kinetic Energy	594 kip-ft	≥594 kip-ft	680 kip-ft
Impact Location	Centerline of the pedestrian signal pole aligned 13 inches off of the centerline of the vehicle towards the driver's side	±6 inches	Centerline of the pedestrian signal pole aligned 13 inches off of the centerline of the vehicle towards the driver's side

Table 7.2. Exit Parameters for *MASH TEST 3-62,* Crash Test 617891-01-1.

Exit Parameter	Measured
Speed	61.4 mi/h
Brakes applied post impact	1.6 seconds
Vehicle at rest position	291 ft downstream of impact point 2 ft to the left side Vehicle positioned 15° right relative to the impact path
Comments:	Vehicle remained upright and stable.

Figure 7.1. MUTCD Standard Pedestrian Signal /Test Vehicle Geometrics for Test 617891-01-1.

Figure 7.2. MUTCD Standard Pedestrian Signal /Test Vehicle Impact Location 617891-01-1.

7.2. WEATHER CONDITIONS

Table 7.3 provides the weather conditions for 617891-01-1.

Table 7.3. Weather Conditions 617891-01-1.

Date of Test	9/6/2023
Wind Speed	5 mi/h
Wind Direction	213°
Temperature	86 °F
Relative Humidity	82 %
Vehicle Traveling	350°

7.3. TEST VEHICLE

Figure 7.3 and Figure 7.4 show the 2019 RAM 1500 used for the crash test. Table 7.4 shows key vehicle measurements. Figure C.1 in Appendix C.1 gives additional dimensions and information on the vehicle.

Figure 7.3. Front of Test Vehicle before Test 617891-01-1.

Figure 7.4. Interior of the Test Vehicle before Test 617891-01-1.

Table 7.4. Vehicle Measurements for Test 617891-01-1.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a]	165 lb	N/A	N/A
Test Inertial Mass	5000 lb	±110 lb	5029 lb
Gross Static[a] Mass	5000 lb	±110 lb	5029 lb
Wheelbase	148 inches	±12 inches	140.5 inches
Front Overhang	39 inches	±3 inches	40 inches
Overall Length	237 inches	±13 inches	227.5 inches
Overall Width	78 inches	±2 inches	78.5 inches
Hood Height	43 inches	±4 inches	46 inches
Track Width[b]	67 inches	±1.5 inches	68.3 inches
CG aft of Front Axle[c]	63 inches	±4 inches	60.2 inches
CG above Ground[c,d]	28 inches	≥28 inches	28.4 inches

Note: N/A = not applicable; CG = center of gravity.
[a] If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.
[b] Average of front and rear axles.
[c] For test inertial mass.
[d] 2270P vehicle must meet minimum CG height requirement.

7.4. TEST DESCRIPTION

Table 7.5 lists events that occurred during Test 617891-01-1. Figures C.4, C.5, and C.6 in Appendix C.2 present sequential photographs during the test.

Table 7.5. Events during Test 617891-01-1.

Time	Events
0.000 s	Vehicle impacted the installation
0.004 s	Post and Base began to shift away from impact
0.010 s	Base began to crack at anchor bolts
0.014 s	Post released from base completely
0.017 s	Case of Signal on Post began to crack
0.085 s	Lower signal box connection and pipe impacted roof
0.140 s	Maximum deformation of roof from contact with signal pole

7.5. DAMAGE TO TEST INSTALLATION

The base fractured, and the remainer of the base was trapped under the vehicle. The anchor bolts on the impact side were bent downstream. The pedestrian signal head fell three feet upstream and broke. The signal pole landed 510 feet downstream and 15 feet to the left of the point of impact. The threads at the end of the pole were damaged and the end of the pole was dented. There was scuffing on the pole and the push buttons on the sign, and the top of the sign bracket was gouged. Figure 7.5 and Figure 7.6 show the damage to the MUTCD standard pedestrian signal assembly.

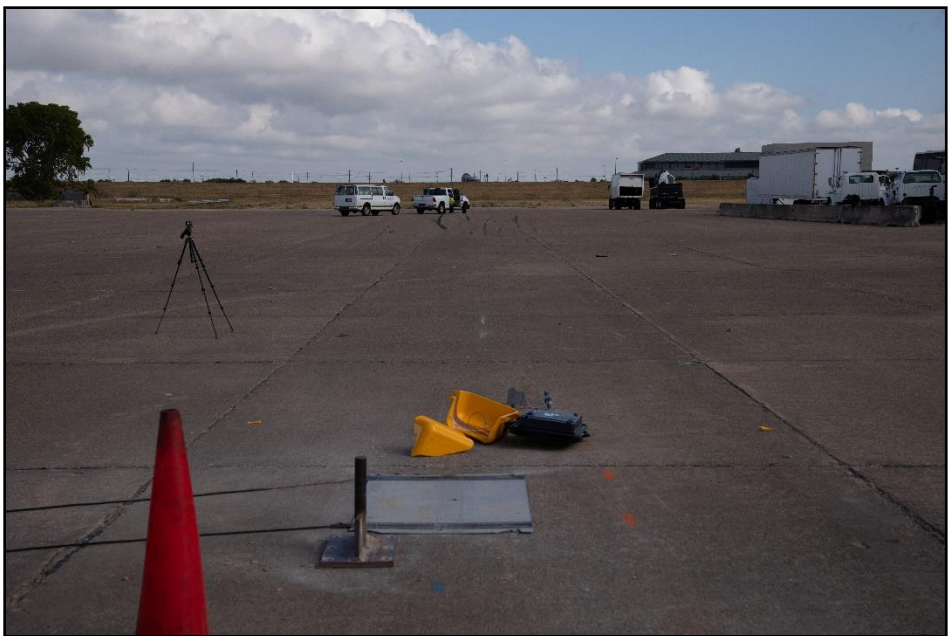


Figure 7.5. MUTCD Standard Pedestrian Signal at Impact Location after Test 617891-01-1.

Figure 7.6. MUTCD Standard Pedestrian Signal at its Landing Location after Test 617891-01-1.

7.6. DAMAGE TO TEST VEHICLE

Figure 7.7 and Figure 7.8 show the damage sustained by the vehicle. Figure 7.9 and Figure 7.10 show the interior of the test vehicle. Table 7.6 and Table 7.7 provide details on the occupant compartment deformation and exterior vehicle damage. Figures C.2 and C.3 in Appendix C.1 provide exterior crush and occupant compartment measurements.

Figure 7.7. Front of the Test Vehicle after Test 617891-01-1.

Figure 7.8. Roof and Windshield of the Test Vehicle after Test 617891-01-1.

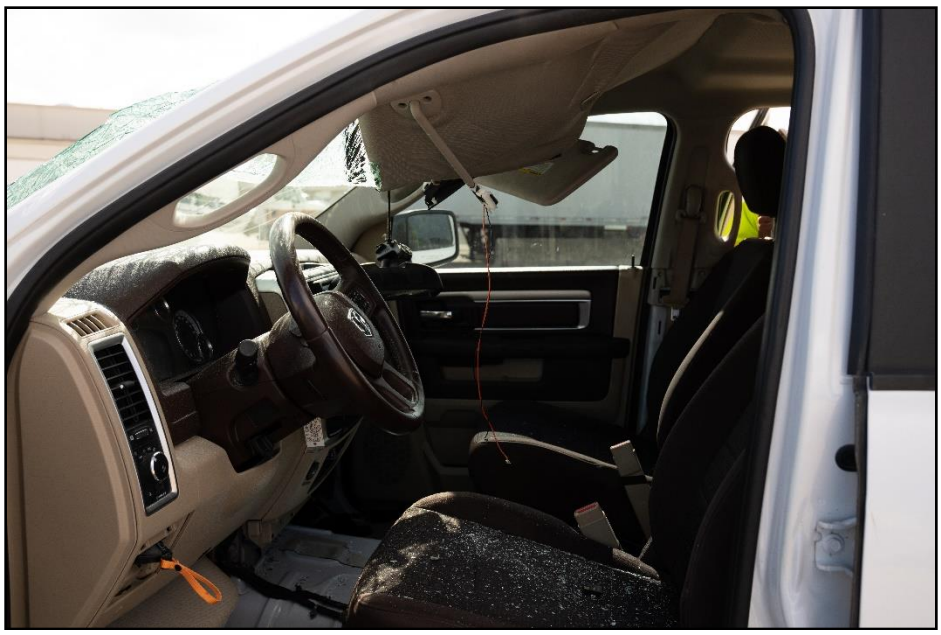


Figure 7.9. Overall Interior of Test Vehicle after Test 617891-01-1.

Figure 7.10. Upper Interior of Test Vehicle after Test 617891-01-1.

Table 7.6. Occupant Compartment Deformation 617891-01-1.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	9.5 inches
Windshield	≤3.0 inches	10.5 inches
A and B Pillars	≤5.0 overall/≤3.0 lateral inches	0 inches
Foot Well/Toe Pan	≤9.0 inches	0 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0 inches
Side Front Panel	≤12.0 inches	0 inches
Front Door (above Seat)	≤9.0 inches	0 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 7.7. Exterior Vehicle Damage 617891-01-1.

Side Windows	The side windows remained intact
Maximum Exterior Deformation	7.5 inches in the front plane at bumper height
VDS	12FL5
CDC	12FLAW2
Fuel Tank Damage	None
Description of Damage to Vehicle:	The bumper, grill, and hood were damaged. The windshield was shattered and deformed, and there was a tear in the laminate at the top of the windshield on the left side. There were two holes and a tear in the front, left side of the roof, one hole on the back left side of the roof, and the hood was severely deformed. The left side A-pillar was bent outward, and there was a 1.5-inch gap at the top of the left front door.

7.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 7.8. Figure C.7 in Appendix C.3 shows the vehicle angular displacements, and Figures C.8 through C.10 in Appendix C.4 show acceleration versus time traces.

Table 7.8. Occupant Risk Factors for Test 617891-01-1.

Test Parameter	Specification [a]	Measured	Time
OIV, Longitudinal	≤16.0 ft/s *10.0* ft/s	3 ft/s	0.6955 seconds on right side of interior
OIV, Lateral	≤40.0 ft/s *30.0* ft/s	2.9 ft/s	0.6955 seconds on right side of interior
Ridedown, Longitudinal	≤20.49 g *15.0* g	0.2 g	1.2420 - 1.2520 seconds
Ridedown, Lateral	≤20.49 g *15.0* g	0.5 g	1.3275 - 1.3375 seconds
Theoretical Head Impact Velocity (THIV)	N/A	1.3 m/s	0.6728 seconds on right side of interior
Acceleration Severity Index	N/A	0.2	0.0131 - 0.0631 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal	N/A	-1.2 g	0.0000 - 0.0500 seconds
50-ms MA Lateral	N/A	-0.4 g	0.0832 - 0.1332 seconds
50-ms MA Vertical	N/A	1 g	0.0830 - 0.1330 seconds
Roll	≤75°	1.4°	1.4906 seconds
Pitch	≤75°	2.2°	1.4028 seconds
Yaw	N/A	5.2°	1.4985 seconds

[a] *Values in italics are the preferred MASH values*

7.8. TEST SUMMARY

Figure 7.11 summarizes the results of *MASH* Test 617891-01-1. Due to excessive occupant compartment deformation, the test did not meet *MASH* evaluation criteria D.

0.000 s

0.050 s

0.100 s

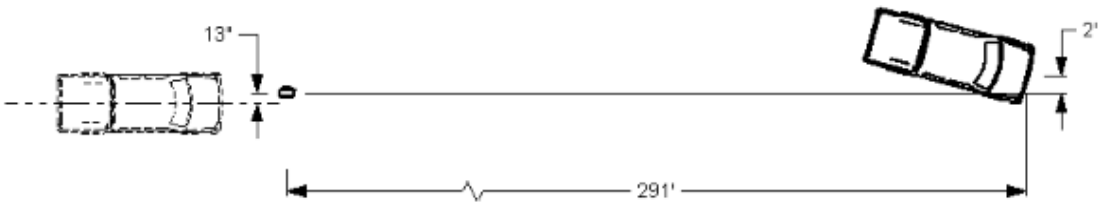
0.150 s

GENERAL INFORMATION	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-62
TTI Project No.	617891-01-1
Test Date	9/6/2023
TEST ARTICLE	
Type	Support Structures
Name	MUTCD standard pedestrian signal
Height	10 ft to the base of the signal head
Key Materials	4-inch sch. 40 steel pipe, signal head, pedestrian sign and button
Soil Type and Condition	Concrete, dry
TEST VEHICLE	
Type/Designation	2270P
Year, Make and Model	2019 RAM 1500
Inertial Mass	5029 lb
Dummy Mass	N/A
Gross Static Mass	5029 lb
IMPACT CONDITIONS	
Impact Speed / Impact Angle	63.6 mi/h / 90°
Impact Location	Centerline of the pedestrian signal pole aligned 13 inches off of the centerline of the vehicle towards the driver's side
Kinetic Energy	680 kip-ft

EXIT CONDITIONS	
Exit Speed	61.4 mi/h
Stopping Distance	291 ft downstream 2 ft to the left side

VEHICLE DAMAGE	
VDS	12FL5
CDC	12FLAW2
Max. Ext. Deformation	7.5 inches
Max Occupant Compartment Deformation	10.5 inches in the windshield

OCCUPANT RISK VALUES			
Long. OIV	3 ft/s	Max 50-ms Long.	-1.2 g
Lat. OIV	2.9 ft/s	Max 50-ms Lat.	-0.4 g
Long. Ridedown	0.2 g	Max 50-ms Vert.	1 g
Lat. Ridedown	0.5 g	Max Roll	1.4°
THIV	1.3 m/s	Max Pitch	2.2°
ASI	0.2	Max Yaw	5.2°



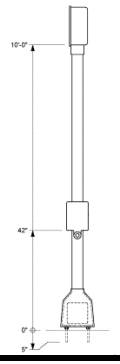


Figure 7.11. Summary of Results for *MASH* Test 3-62 on MUTCD Standard Pedestrian Signal .

Chapter 8. *MASH* TEST 3-62 (CRASH TEST 617891-01-2)

8.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 8.1 for details of *MASH* impact conditions for this test and Table 8.2 for the exit parameters. Figure 8.1 and Figure 8.2 depict the target impact setup.

Table 8.1. Impact Conditions for *MASH* TEST 3-62, Crash Test 617891-01-2.

Test Parameter	Specification	Tolerance	Measured
Impact Speed	62 mi/h	±2.5 mi/h	61.9 mi/h
Impact Angle	90°	±1.5°	90°
Kinetic Energy	594 kip-ft	≥594 kip-ft	642.5 kip-ft
Impact Location	Centerline of the pedestrian signal pole aligned 13 inches off of the centerline of the vehicle towards the driver's side	±6 inches	Centerline of the pedestrian signal pole aligned 13 inches off of the centerline of the vehicle towards the driver's side

Table 8.2. Exit Parameters for *MASH* TEST 3-62, Crash Test 617891-01-2.

Exit Parameter	Measured
Speed	59.8 mi/h
Brakes applied post impact	1.26 seconds
Vehicle at rest position	325 ft downstream of impact point 2 ft to the left side Vehicle positioned 15° right relative to the installation
Comments:	Vehicle remained upright and stable

Figure 8.1. MUTCD Standard Pedestrian Signal /Test Vehicle Geometrics for Test 617891-01-2.

Figure 8.2. MUTCD Standard Pedestrian Signal /Test Vehicle Impact Location 617891-01-2.

8.2. WEATHER CONDITIONS

Table 8.3 provides the weather conditions for 617891-01-2.

Table 8.3. Weather Conditions 617891-01-2.

Date of Test	11/13/2023
Wind Speed	8 mi/h
Wind Direction	52°
Temperature	59 °F
Relative Humidity	92 %
Vehicle Traveling	350°

8.3. TEST VEHICLE

Figure 8.3 and Figure 8.4 show the 2019 RAM 1500 used for the crash test. Table 8.4 shows the vehicle measurements. Figure D.1 in Appendix D.1 gives additional dimensions and information on the vehicle.

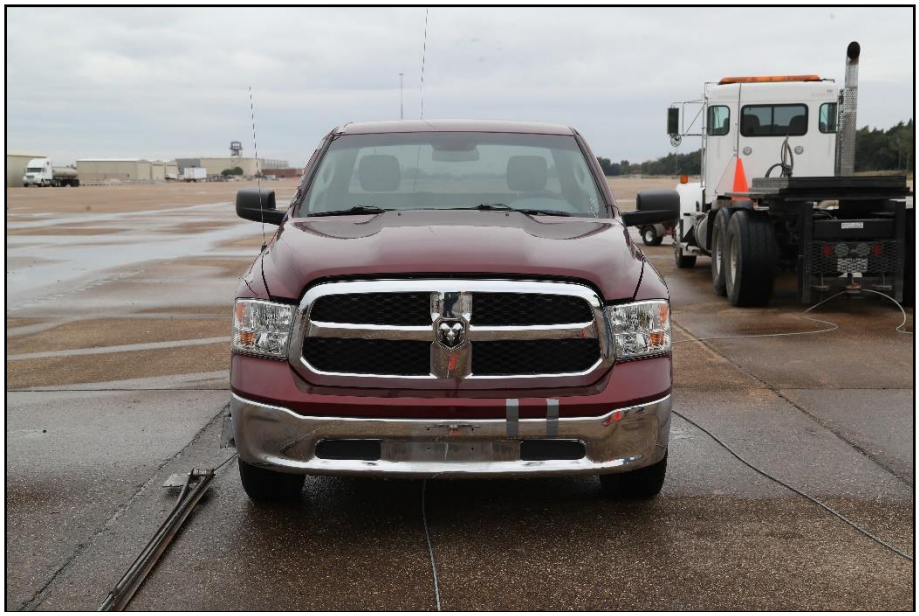


Figure 8.3. Front of the Test Vehicle before Test 617891-01-2.

Figure 8.4. Interior of the Test Vehicle before Test 617891-01-2.

Table 8.4. Vehicle Measurements 617891-01-2.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a]	165 lb	N/A	N/A
Test Inertial Mass	5000 lb	±110 lb	5016 lb
Gross Static[a] Mass	5000 lb	±110 lb	5016 lb
Wheelbase	148 inches	±12 inches	140.5 inches
Front Overhang	39 inches	±3 inches	40 inches
Overall Length	237 inches	±13 inches	227.5 inches
Overall Width	78 inches	±2 inches	78.5 inches
Hood Height	43 inches	±4 inches	46 inches
Track Width[b]	67 inches	±1.5 inches	68.3 inches
CG aft of Front Axle[c]	63 inches	±4 inches	62.1 inches
CG above Ground[c,d]	28 inches	≥28 inches	28.4 inches

Note: N/A = not applicable; CG = center of gravity.
[a] If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.
[b] Average of front and rear axles.
[c] For test inertial mass.
[d] 2270P vehicle must meet minimum CG height requirement.

8.4. TEST DESCRIPTION

Table 8.5 lists events that occurred during Test 617891-01-2. Figures D.4, D.5, and D.6 in Appendix D.2 present sequential photographs during the test.

Table 8.5. Events during Test 617891-01-2.

Time (s)	Events
0.00000 s	Vehicle impacted the installation
0.00375 s	Post and Base began to shift away from impact
0.00625 s	Base began to crack at anchor bolts
0.00750 s	Post released from base completely
0.02125 s	Case of Signal on Post began to crack at lower connection
0.13400 s	Lower signal box connection impacted roof
0.15125 s	Post impacted rear corner of roof

8.5. DAMAGE TO TEST INSTALLATION

The signal pole landed 166 feet downstream and in-line with the impact path. The debris field extended 47 feet to the left of impact, 24 feet to the right, and 188 feet downstream of the point of impact. A piece of the signal head support was stuck in the roof of the vehicle. Figure 8.5 and Figure 8.6 show the damage to the MUTCD standard pedestrian signal assembly.

Figure 8.5. MUTCD Standard Pedestrian Signal at Impact Location after Test 617891-01-2.

Figure 8.6. MUTCD Standard Pedestrian Signal at its Landing Location after Test 617891-01-2.

8.6. DAMAGE TO TEST VEHICLE

Figure 8.7 and Figure 8.8 show the damage sustained by the vehicle. Figure 8.9 and Figure 8.10 show the interior of the test vehicle. Table 8.6 and Table 8.7 provide details on the occupant compartment deformation and exterior vehicle damage. Figures D.2 and D.3 in Appendix D.1 provide exterior crush and occupant compartment measurements.

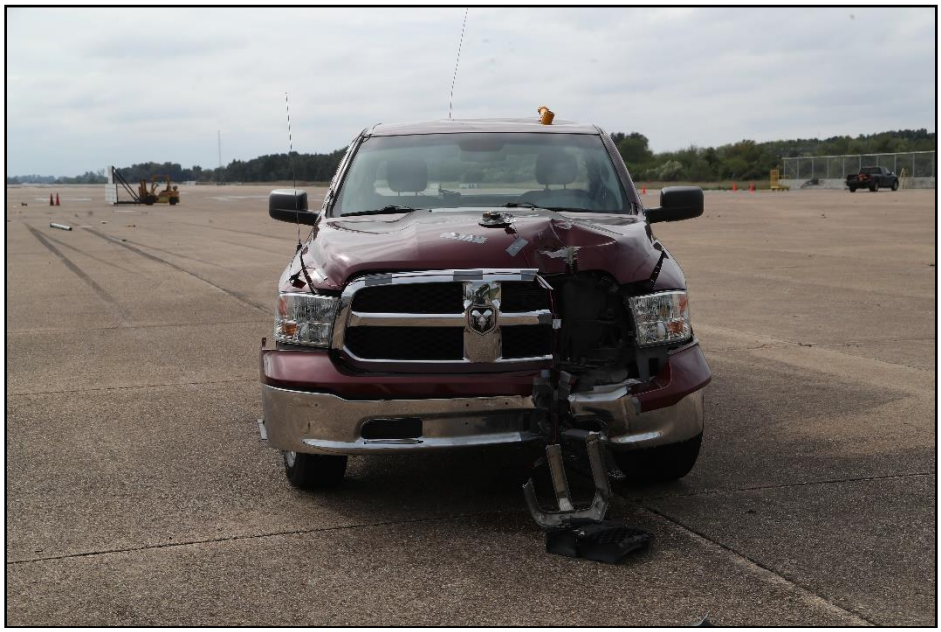


Figure 8.7. Front of the Test Vehicle after Test 617891-01-2.

Figure 8.8. Roof of the Test Vehicle after Test 617891-01-2.

Figure 8.9. Upper Interior of Test Vehicle after Test 617891-01-2.

Figure 8.10. Test Article Penetration into the Test Vehicle after Test 617891-01-2.

Table 8.6. Occupant Compartment Deformation 617891-01-2.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	4 inches
Windshield	≤3.0 inches	0 inches
A and B Pillars	≤5.0 overall/≤3.0 inches lateral	0 inches
Foot Well/Toe Pan	≤9.0 inches	0 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0 inches
Side Front Panel	≤12.0 inches	0 inches
Front Door (above Seat)	≤9.0 inches	0 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 8.7. Exterior Vehicle Damage 617891-01-2.

Side Windows	The side windows remained intact
Maximum Exterior Deformation	5.5 inches in the front plane at bumper height
VDS	12FL4
CDC	12FLAW1
Fuel Tank Damage	None
Description of Damage to Vehicle:	The bumper, grill, and roof were damaged. The roof had several holes and a tear. The back glass was shattered, and the roof was dented in.

8.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 8.8. Figure D.7 in Appendix D.3 shows the vehicle angular displacements, and Figures D.8 through D.10 in Appendix D.4 show acceleration versus time traces.

Table 8.8. Occupant Risk Factors for Test 617891-01-2.

Test Parameter	***Specification*** [a]	Measured	Time
OIV, Longitudinal	≤16.0 ft/s *10.0* ft/s	1.6 ft/s	1.1142 seconds on front of interior
OIV, Lateral	≤40.0 ft/s *30.0* ft/s	0.8 ft/s	1.1142 seconds on front of interior
Ridedown, Longitudinal	≤20.49 g *15.0* g	0.1 g	1.1999 - 1.2099 seconds
Ridedown, Lateral	≤20.49 g *15.0* g	0.3 g	1.2016 - 1.2116 seconds
Theoretical Head Impact Velocity (THIV)	N/A	0.5 m/s	1.1091 seconds on front of interior
Acceleration Severity Index	N/A	0.2	0.2417 - 0.2917 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal	N/A	-1.2 g	0.0000 - 0.0500 seconds
50-ms MA Lateral	N/A	-0.4 g	0.1744 - 0.2244 seconds
50-ms MA Vertical	N/A	1.5 g	0.2040 - 0.2540 seconds
Roll	≤75°	3°	1.0217 seconds
Pitch	≤75°	1°	0.7234 seconds
Yaw	N/A	0.4°	0.1819 seconds

[a.] Values in italics are the preferred *MASH* values

8.8. TEST SUMMARY

Figure 8.11 summarizes the results of *MASH* Test 617891-01-2. Due to penetration of the test article into the occupant compartment through the roof, the test did not meet *MASH* evaluation criteria D.

0.000 s

0.050 s

0.100 s

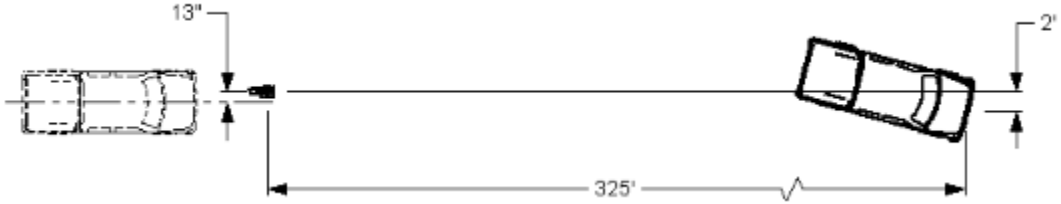
0.150 s

GENERAL INFORMATION	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-62
TTI Project No.	617891-01-2
Test Date	11/13/2023
TEST ARTICLE	
Type	Support Structures
Name	MUTCD standard pedestrian signal
Height	15 ft
Key Materials	4-inch sch. 40 pipe, signal head, pedestrian sign and button
Soil Type and Condition	Concrete, dry
TEST VEHICLE	
Type/Designation	2270P
Year, Make and Model	2019 RAM 1500
Inertial Mass	5016 lb
Dummy Mass	N/A
Gross Static Mass	5016 lb
IMPACT CONDITIONS	
Impact Speed / Impact Angle	61.9 mi/h / 90°
Impact Location	Centerline of the pedestrian signal pole aligned 13 inches off of the centerline of the vehicle towards the driver's side
Kinetic Energy	642.5 kip-ft

EXIT CONDITIONS	
Exit Speed	59.8 mi/h
Stopping Distance	325 ft downstream 2 ft to the left side

VEHICLE DAMAGE	
VDS	12FL4
CDC	12FLAW1
Max. Ext. Deformation	5.5 inches
Max Occupant Compartment Deformation	4 inches in the roof

OCCUPANT RISK VALUES			
Long. OIV	1.6 ft/s	Max 50-ms Long.	-1.2 g
Lat. OIV	0.8 ft/s	Max 50-ms Lat.	-0.4 g
Long. Ridedown	0.1 g	Max 50-ms Vert.	1.5 g
Lat. Ridedown	0.3 g	Max Roll	3°
THIV	0.5 m/s	Max Pitch	1°
ASI	0.2	Max Yaw	0.4°



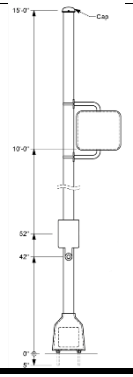


Figure 8.11. Summary of Results for *MASH* Test 3-62 on MUTCD Standard Pedestrian Signal .

Chapter 9. *MASH* R&D TEST 3-62 (CRASH TEST 617891-01-3)

9.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 9.1 for details of *MASH* impact conditions for this test and Table 9.2 for the exit parameters. Figure 9.1 and Figure 9.2 depict the target impact setup.

Table 9.1. Impact Conditions for *MASH* R&D TEST 3-62, Crash Test 617891-01-3.

Test Parameter	Specification	Tolerance	Measured
Impact Speed	62 mi/h	±2.5 mi/h	63.8 mi/h
Impact Angle	90°	±1.5°	90°
Kinetic Energy	594 kip-ft	≥594 kip-ft	689.2 kip-ft
Impact Location	Centerline of the pedestrian signal pole aligned 13 inches off of the centerline of the vehicle towards the passenger's side	±6 inches	Centerline of the pedestrian signal pole aligned 13 inches off of the centerline of the vehicle towards the passenger's side

Table 9.2. Exit Parameters for *MASH* R&D TEST 3-62, Crash Test 617891-01-3.

Exit Parameter	Measured
Speed	62 mi/h
Brakes applied post impact	Brakes not applied
Vehicle at rest position	443 ft downstream of impact point 13 ft to the left side Vehicle positioned 5° left relative to the installation
Comments:	Vehicle remained upright and stable

Figure 9.1. MUTCD Standard Pedestrian Signal /Test Vehicle Geometrics for Test 617891-01-3.

Figure 9.2. MUTCD Standard Pedestrian Signal /Test Vehicle Impact Location 617891-01-3.

9.2. WEATHER CONDITIONS

Table 9.3 provides the weather conditions for 617891-01-3.

Table 9.3. Weather Conditions 617891-01-3.

Date of Test	2/15/2024
Wind Speed	1 mi/h
Wind Direction	188°
Temperature	70 °F
Relative Humidity	86 %
Vehicle Traveling	350°

9.3. TEST VEHICLE

Figure 9.3 and Figure 9.4 show the 2015 RAM 1500 used for the crash test. Table 9.4 shows the vehicle measurements. Figure E.1 in Appendix E.1 gives additional dimensions and information on the vehicle.

Figure 9.3. Front of the Test Vehicle before Test 617891-01-3.

Figure 9.4. Windshield and Roof of the Test Vehicle before Test 617891-01-3.

Table 9.4. Vehicle Measurements 617891-01-3.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a]	165 lb	N/A	N/A
Test Inertial Mass	5000 lb	±110 lb	5065 lb
Gross Static[a] Mass	5000 lb	±110 lb	5065 lb
Wheelbase	148 inches	±12 inches	140.5 inches
Front Overhang	39 inches	±3 inches	40.3 inches
Overall Length	237 inches	±13 inches	229 inches
Overall Width	78 inches	±2 inches	78.5 inches
Hood Height	43 inches	±4 inches	46 inches
Track Width[b]	67 inches	±1.5 inches	68.3 inches
CG aft of Front Axle[c]	63 inches	±4 inches	62.7 inches
CG above Ground[c,d]	28 inches	≥28 inches	28.3 inches

Note: N/A = not applicable; CG = center of gravity.

[a] If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.

[b] Average of front and rear axles.

[c] For test inertial mass.

[d] 2270P vehicle must meet minimum CG height requirement.

9.4. TEST DESCRIPTION

Table 9.5 lists events that occurred during Test 617891-01-3. Figures E.4, E.5, and E.6 in Appendix E.2 present sequential photographs during the test.

Table 9.5. Events during Test 617891-01-3.

Time (s)	Events
0 s	Vehicle impacted the installation
0.002 s	Post and Base began to shift away from impact
0.005 s	Base began to crack at anchor bolts
0.008 s	Post released from base completely
0.016 s	Case of Signal on Post began to crack at lower connection
0.1646 s	Upper signal pole impacted corner of rear roof

9.5. DAMAGE TO TEST INSTALLATION

The signal pole landed 180 feet downstream and in-line with the installation. The signal head broke off. Figure 9.5 and Figure 9.6 show the damage to the MUTCD standard pedestrian signal assembly.

Figure 9.5. MUTCD Standard Pedestrian Signal at Impact Location after Test 617891-01-3.

Figure 9.6. MUTCD Standard Pedestrian Signal Landing Location after Test 617891-01-3.

9.6. DAMAGE TO TEST VEHICLE

Figure 9.7 and Figure 9.8 show the damage sustained by the vehicle. Figure 9.9 shows the interior of the test vehicle. Table 9.6 and Table 9.7 provide details on the occupant compartment deformation and exterior vehicle damage. Figures E.2 and E.3 in Appendix E.1 provide exterior crush and occupant compartment measurements.

Figure 9.7. Impact Side of Test Vehicle after Test 617891-01-3.

Figure 9.8. Rear Impact Side of Test Vehicle after Test 617891-01-3.

Figure 9.9. Upper Interior of Test Vehicle after Test 617891-01-3.

Table 9.6. Occupant Compartment Deformation 617891-01-3.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	3 inches
Windshield	≤3.0 inches	0 inches
A and B Pillars	≤5.0 overall/≤3.0 inches lateral	0 inches
Foot Well/Toe Pan	≤9.0 inches	0 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0 inches
Side Front Panel	≤12.0 inches	0 inches
Front Door (above Seat)	≤9.0 inches	0 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 9.7. Exterior Vehicle Damage 617891-01-3.

Side Windows	The side windows remained intact
Maximum Exterior Deformation	6 inches in the front plane at bumper height
VDS	12FL2
CDC	12FLAW1
Fuel Tank Damage	None
Description of Damage to Vehicle:	The bumper, grill, hood, roof, and rear window were damaged. There was one dent on the back passenger side of the roof and a small tear in the hood.

9.7. OCCUPANT RISK FACTORS

No instrumentation was used for this test, therefore there is no occupant risk data.

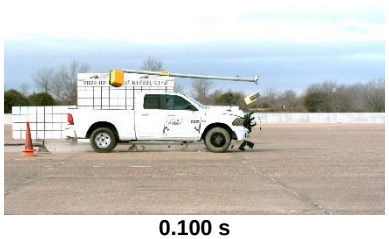
9.8. TEST SUMMARY

Figure 9.10 summarizes the results of *MASH* R&D Test 617891-01-3. The 3-inch roof deformation was less than the *MASH* limit of 4 inches.

This test met occupant compartment deformation criteria for *MASH* Test 3-62.

0.000 s

0.050 s



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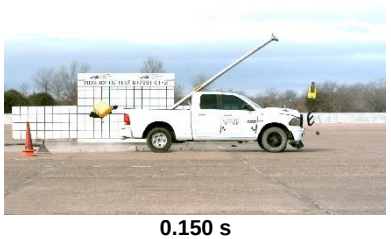

0.150 s

GENERAL INFORMATION	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-62
TTI Project No.	617891-01-3
Test Date	2/15/2024
TEST ARTICLE	
Type	Support Structures
Name	MUTCD standard pedestrian signal
Height	15 ft
Key Materials	4-inch sch. 40 pipe, signal head, pedestrian sign and button
Soil Type and Condition	Concrete, dry
TEST VEHICLE	
Type/Designation	2270P
Year, Make and Model	2015 RAM 1500
Inertial Mass	5065 lb
Dummy Mass	N/A
Gross Static Mass	5065 lb
IMPACT CONDITIONS	
Impact Speed / Impact Angle	63.8 mi/h / 90°
Impact Location	Centerline of the pedestrian signal pole aligned 13 inches off of the centerline of the vehicle towards the driver's side
Kinetic Energy	689.2 kip-ft

EXIT CONDITIONS	
Exit Speed	62 mi/h
Stopping Distance	443 ft downstream 13 ft to the left side
VEHICLE DAMAGE	
VDS	12FL2
CDC	12FLAW1
Max. Ext. Deformation	6 inches
Max Occupant Compartment Deformation	3 inches in the roof

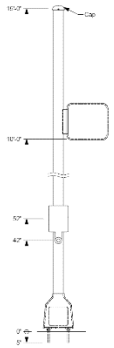

Figure 9.10. Summary of Results for *MASH* R&D Test 3-62 on MUTCD Standard Pedestrian Signal .

Chapter 10. *MASH* R&D TEST 3-61 (CRASH TEST 617891-01-4)

10.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 10.1 for details of *MASH* impact conditions for this test and Table 10.2 for the exit parameters. Figure 10.1 and Figure 10.2 depict the target impact setup.

Table 10.1. Impact Conditions for *MASH* R&D TEST 3-61, Crash Test 617891-01-4.

Test Parameter	Specification	Tolerance	Measured
Impact Speed	62 mi/h	±2.5 mi/h	64.4 mi/h
Impact Angle	90°	±1.5°	90°
Kinetic Energy	288 kip-ft	≥288 kip-ft	340.0 kip-ft
Impact Location	Centerline of the pedestrian signal pole aligned 13 inches off of the centerline of the vehicle towards the passenger's side	±6 inches	Centerline of the pedestrian signal pole aligned 13 inches off of the centerline of the vehicle towards the passenger's side

Table 10.2. Exit Parameters for *MASH* R&D TEST 3-61, Crash Test 617891-01-4.

Exit Parameter	Measured
Speed	60.9mi/h
Brakes applied post impact	Brakes not applied
Vehicle at rest position	285 ft downstream of impact point In-line with impact path Vehicle positioned 90° left relative to the installation
Comments:	Vehicle remained upright and stable

Figure 10.1. MUTCD Standard Pedestrian Signal /Test Vehicle Geometrics for Test 617891-01-4.

Figure 10.2. MUTCD Standard Pedestrian Signal /Test Vehicle Impact Location 617891-01-4.

10.2. WEATHER CONDITIONS

Table 10.3 provides the weather conditions for 617891-01-4.

Table 10.3. Weather Conditions 617891-01-4.

Date of Test	2/15/2024
Wind Speed	1 mi/h
Wind Direction	186°
Temperature	70 °F
Relative Humidity	77 %
Vehicle Traveling	350°

10.3. TEST VEHICLE

Figure 10.3 and Figure 10.4 show the 2018 Nissan Versa used for the crash test. Table 10.4 shows the vehicle measurements. Figure F.1 in Appendix F.1 gives additional dimensions and information on the vehicle.

Figure 10.3. Impact Side of Test Vehicle before Test 617891-01-4.

Figure 10.4. Test Vehicle Windshield before Test 617891-01-4.

Table 10.4. Vehicle Measurements 617891-01-4.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a]	165 lb	N/A	165 lb
Test Inertial Mass	2420 lb	±55 lb	2452 lb
Gross Static[a] Mass	2585 lb	±55 lb	2617 lb
Wheelbase	98 inches	±5 inches	102.4 inches
Front Overhang	35 inches	±4 inches	32.5 inches
Overall Length	169 inches	±8 inches	175.4 inches
Overall Width	65 inches	±3 inches	66.7 inches
Hood Height	28 inches	±4 inches	30.5 inches
Track Width[b]	59 inches	±2 inches	58.4 inches
CG aft of Front Axle[c]	39 inches	±4 inches	42.8 inches
CG above Ground[c,d]	N/A	N/A	N/A

Note: N/A = not applicable; CG = center of gravity.

[a] If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.

[b] Average of front and rear axles.

[c] For test inertial mass.

[d] 2270P vehicle must meet minimum CG height requirement.

10.4. TEST DESCRIPTION

Table 10.5 lists events that occurred during Test 617891-01-4. Figures F.4, F.5, and F.6 in Appendix F.2 present sequential photographs during the test.

Table 10.5. Events during Test 617891-01-4.

Time (s)	Events
0.0000 s	Vehicle impacted the installation
0.0060 s	Post and Base began to shift away from impact
0.0090 s	Base began to crack at anchor bolts
0.0160 s	Post released from base completely
0.0260 s	Case of Signal on Post began to crack at connection to signal pole
0.1646 s	Upper signal pole impacted corner of rear roof

10.5. DAMAGE TO TEST INSTALLATION

The signal pole landed 82.5 feet downstream and in-line. The signal head broke off and shattered. Figure 10.5 and Figure 10.6 show the damage to the MUTCD standard pedestrian signal assembly.

Figure 10.5. MUTCD Standard Pedestrian Signal at Impact Location after Test 617891-01-4.

Figure 10.6. MUTCD Standard Pedestrian Signal at its Landing Location after Test 617891-01-4.

10.6. DAMAGE TO TEST VEHICLE

Figure 10.7 through Figure 10.9 show the damage sustained by the vehicle. Table 10.6 and Table 10.7 provide details on the occupant compartment deformation and exterior vehicle damage. Figures F.2 and F.3 in Appendix F.1 provide exterior crush and occupant compartment measurements.

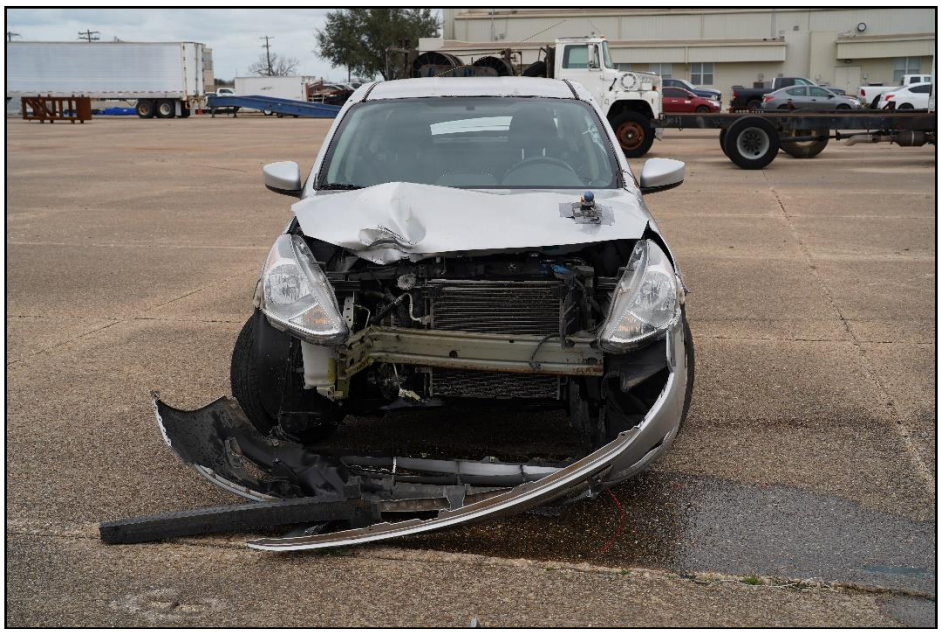

Figure 10.7. Impact Side of Test Vehicle after Test 617891-01-4.

Figure 10.8. Rear of Test Vehicle after Test 617891-01-4.

Figure 10.9. Trunk Lid of Test Vehicle after Test 617891-01-4.

Table 10.6. Occupant Compartment Deformation 617891-01-4.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	0 inches
Windshield	≤3.0 inches	0 inches
A and B Pillars	≤5.0 overall/≤3.0 inches lateral	0 inches
Foot Well/Toe Pan	≤9.0 inches	0 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0 inches
Side Front Panel	≤12.0 inches	0 inches
Front Door (above Seat)	≤9.0 inches	0 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 10.7. Exterior Vehicle Damage 617891-01-4.

Side Windows	The side windows remained intact
Maximum Exterior Deformation	10 inches in the front plane at bumper height
VDS	12FR3
CDC	12FREW2
Fuel Tank Damage	None
Description of Damage to Vehicle:	The bumper, hood, grill, radiator and support were damaged. The back glass was shattered/missing and the passenger side trunk lid and spoiler were damaged.

10.7. OCCUPANT RISK FACTORS

No instrumentation was used for this test, therefore there is no occupant risk data.

10.8. TEST SUMMARY

Figure 10.10 summarizes the results of *MASH* R&D Test 617891-01-4. The pole shattered the rear window. However, the pole spanned across the roof and trunk and therefore did not penetrate the occupant compartment or pose a risk to the occupants.

This test passed the occupant compartment deformation criteria for *MASH* Test 3-61.

0.000 s

0.050 s

0.100 s

0.150 s

GENERAL INFORMATION	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-61
TTI Project No.	617891-01-4
Test Date	2/15/2024
TEST ARTICLE	
Type	Support Structures
Name	MUTCD standard pedestrian signal
Height	15 ft
Key Materials	4-inch sch. 40 pipe, signal head, pedestrian sign and button
Soil Type and Condition	Concrete, dry
TEST VEHICLE	
Type/Designation	1100C
Year, Make and Model	2018 Nissan Versa
Inertial Mass	2452 lb
Dummy Mass	165 lb
Gross Static Mass	2617 lb
IMPACT CONDITIONS	
Impact Speed / Impact Angle	64.4 mi/h / 90°
Impact Location	Centerline of the pedestrian signal pole aligned 13 inches off of the centerline of the vehicle towards the driver's side
Kinetic Energy	340.0 kip-ft

EXIT CONDITIONS	
Exit Speed	60.9 mi/h
Stopping Distance	285 ft downstream In-line with impact path
VEHICLE DAMAGE	
VDS	12FR3
CDC	12FREW2
Max. Ext. Deformation	10 inches
Max Occupant Compartment Deformation	No occupant compartment deformation

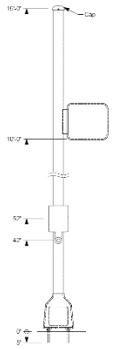

Figure 10.10. Summary of Results for *MASH* R&D Test 3-61 on MUTCD Standard Pedestrian Signal .

Chapter 11. CONCLUSIONS AND RECOMMENDATIONS

The crash tests reported herein were performed in accordance with *MASH* TL-3, on the MUTCD standard pedestrian signal assemblies.

Table 11.1 shows that the first two MUTCD standard pedestrian signal assembly configurations tested did not satisfy *MASH* evaluation criteria for support structures. Subsequent R&D testing of a third configuration satisfied Criteria B, D, F, and N. Because the test vehicles in the R&D tests were not instrumented, occupant risk indices could not be calculated. [*]However, based on the risk indices calculated in Test 617891-01-2, which used the same pedestal base and pole, this system is likely to meet the crashworthiness performance criteria for *MASH* TL-3 Support Structures.

[*]Full-scale *MASH* TL-3 compliant tests can be performed under future research to confirm this pedestrian signal assembly configuration is *MASH* compliant.

[*] *The opinions/interpretations identified/expressed in this section of the report are outside the scope of TTI Proving Ground's A2LA Accreditation.*

Table 11.1. Assessment Summary for *MASH* TL-3 Tests on MUTCD Standard Pedestrian Signal Assembly.

Evaluation Criteria	Description	**Test 617891-01-1** (*MASH* Test 3-62)	**Test 617891-01-2** (*MASH* Test 3-62)	**Test 617891-01-3** (*MASH* R&D Test 3-62)	**Test 617891-01-4** (*MASH* R&D Test 3-61)
B	Test Article Broke Away, Fractured, Yielded	S	S	S	S
D	No Excessive Deformation or Penetration into Occupant Compartment	Fail	Fail	S	S
F	Roll and Pitch Limit	S	S	S	S
H	OIV Threshold	S	S	Not Measured	Not Measured
I	Ridedown Threshold	S	S	Not Measured	Not Measured
N	Vehicle Trajectory Behind Test Article Acceptable	S	S	S	S
Overall	Evaluation	Fail	Fail	N/A	N/A

Note: S = Satisfactory; N/A = Not Applicable

[1] See Table 5.2 for details

REFERENCES

1. AASHTO. *Manual for Assessing Safety Hardware*, 2nd Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2016.
2. FHWA. *Manual on Uniform Traffic Control Devices for Streets and Highways.* 11th Edition. Federal Highway Administration, Washington, DC, 2023.
3. Harkey, D. L., Carter, D., Bentzen, B. L., and Barlow, J. M. *Web-Only Document 150: Accessible Pedestrian Signals: A Guide to Best Practices (Workshop Edition 2010)*. Transportation Research Board, Washington, DC, 2010.
4. Bullard, D. L., Bligh, R. P., Menges, W. L., and Schoeneman, S. K. *Testing and Evaluation of the Solar Panel Sign Support System*. Texas A&M Transportation Institute, 2001.
5. Kiani, M., Schroeder, W.L., and Kuhn, D.L. *Evaluation of Crashworthy Enhanced Highway Sign Assemblies.* Texas A&M Transportation Institute, 2023.

APPENDIX A. DETAILS OF MUTCD STANDARD PEDESTRIAN SIGNAL

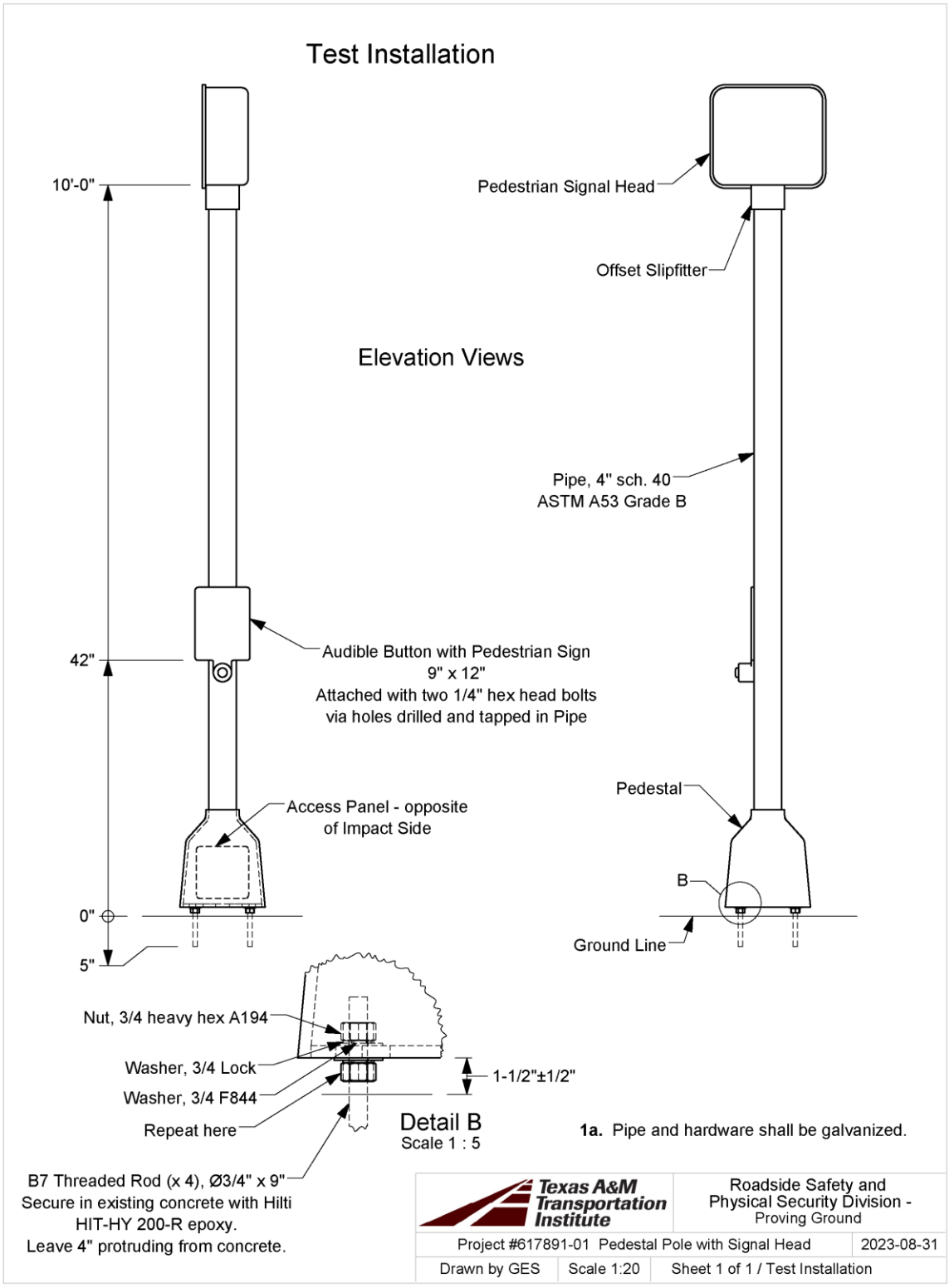

Figure A.1. Details of the MUTCD Standard Pedestrian Signal for Crash Test 617891-01-1

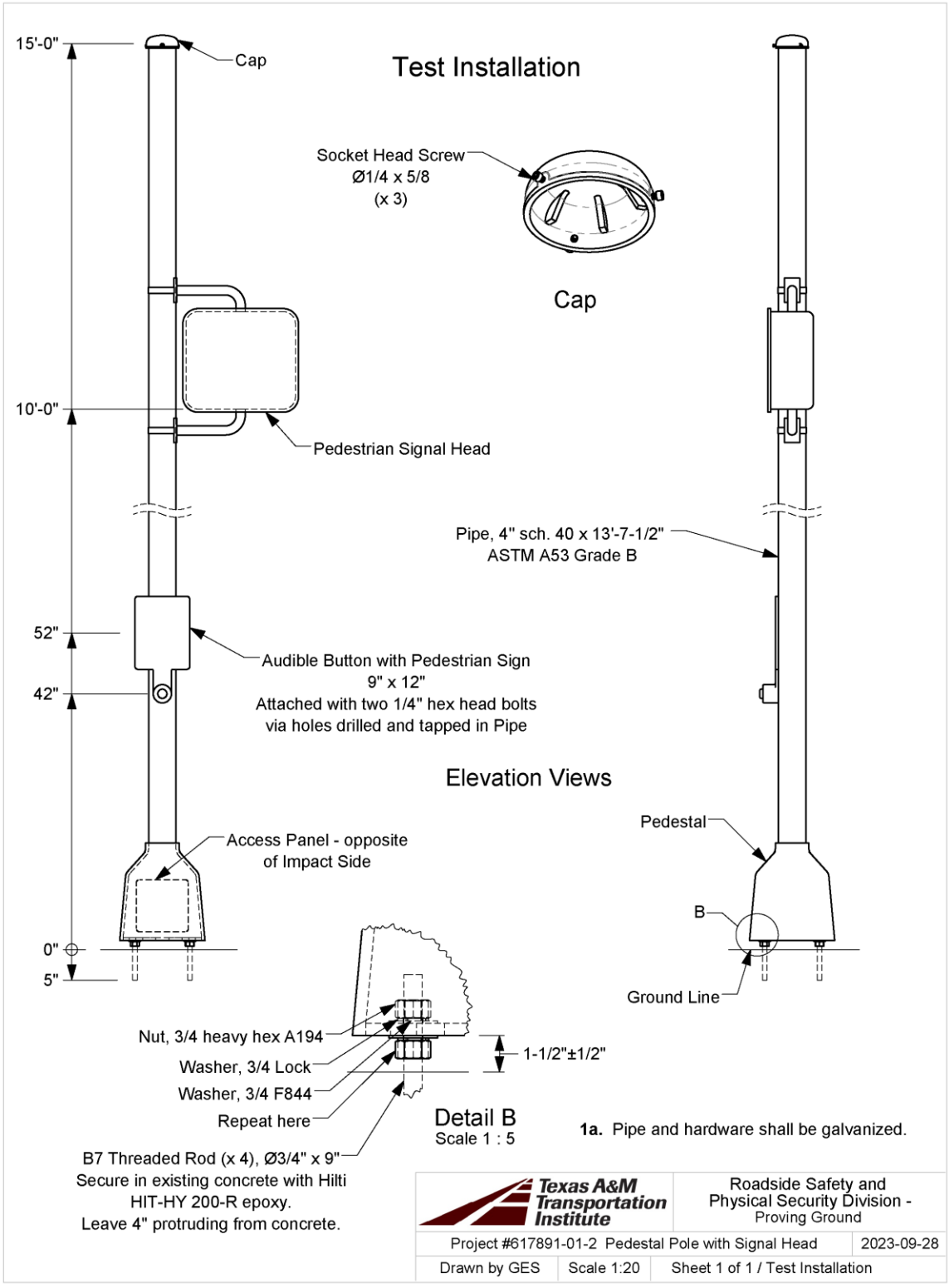

Figure A.2. Details of the MUTCD Standard Pedestrian Signal for Crash Test 617891-01-2

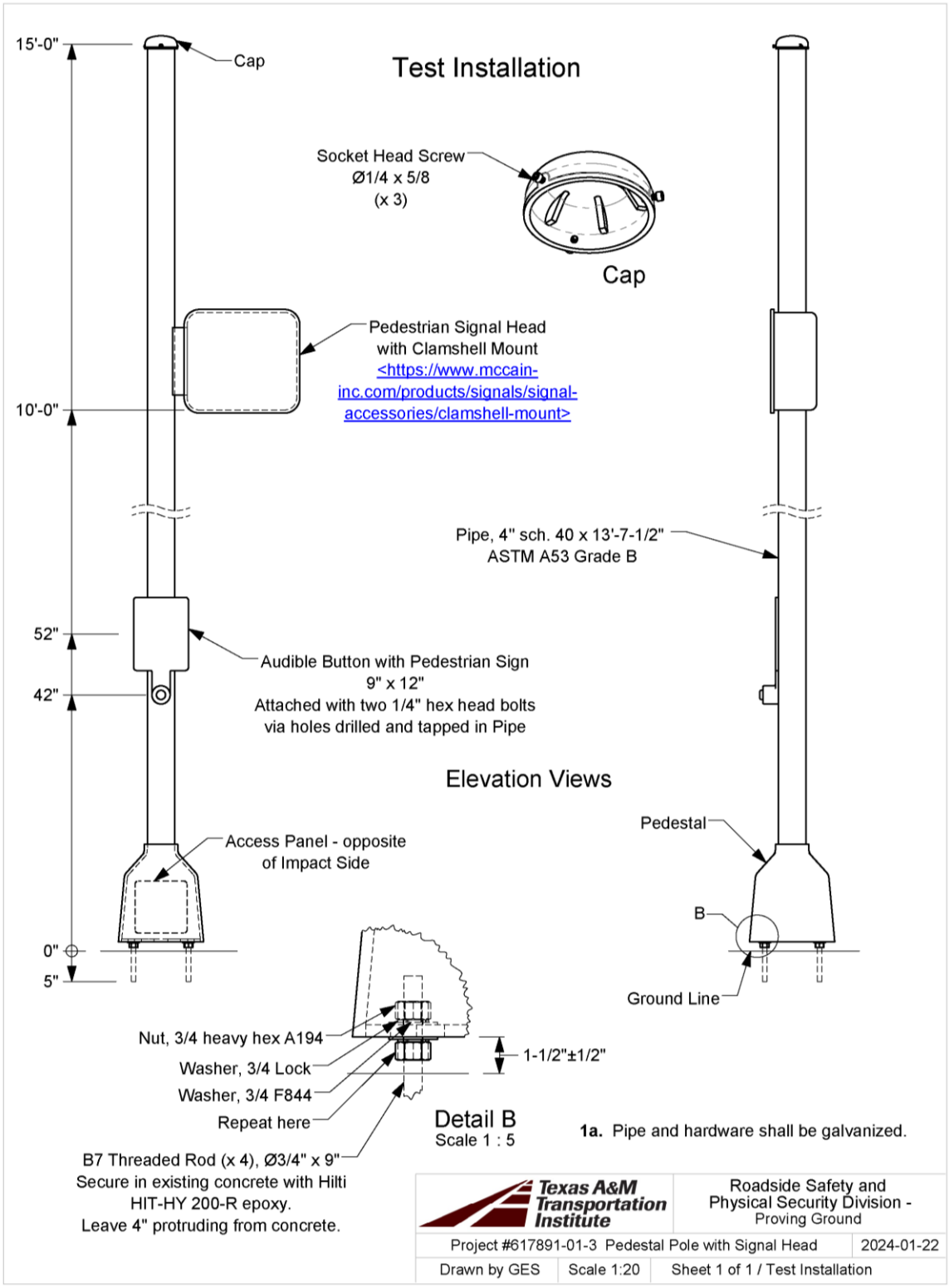

Figure A.3. Details of the MUTCD Standard Pedestrian Signal for Crash Tests 617891-01 3&4

APPENDIX B. SUPPORTING CERTIFICATION DOCUMENTS

Portland Bolt
& MANUFACTURING COMPANY
800-547-6758 | www.portlandbolt.com

FOR	TEXAS A&M TRANSPORTATION INST
PB INVOICE	170546
CUSTOMER PO	619891
SHIP DATE	2/7/2024

Certificate of Conformance

We certify that the following items were manufactured and tested in accordance with the chemical, mechanical, dimensional and thread fit requirements of the specifications referenced.

Products

- ASTM A193 GRADE B7 ALL THREAD ROD

Nuts

- ASTM A194 GRADE 2H HEAVY HEX NUT

Washers

- ASTM F844 CUT WASHER

Coatings

- ITEMS HOT-DIP GALVANIZED PER ASTM F2329 AND A153 CL.C

Certification Department Quality Assurance
Dane McKinnon

Vulcan
THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 817956 **Job Information** **Certified Date:** 6/26/23

Containers: S21606916 S21607102 S21608025 S21608153

Customer: Conklin and Conklin
PORTLAND BOLT
PO 65038
INV 089589
100 3/4" X 144" B7 ATR HDG
JAN 12, 2024
1OF3

Ship To: 34201 Seventh Street
Union City, CA 94587

Vulcan Part No: BAR B7 .6813x144 SC
Customer Part No: BAR B7 .680x144
Customer PO No: 021733
Order No: 482288
Note:

Shipped Qty: 12060 lbs
Line No: 1

Applicable Specifications

Type	Specification	Rev	Amend	Option
-	ASTM F1554 Gd 105 S4	2020		
Heat Treat	ASME SA-193/SA-193M B7	2019		
	ASTM A193 B7 S11	2022		
	Decarburization			

Test Results

See following pages for tests

Certified Chemical Analysis

Heat No: 10819360 Lot 3/4 Origin: USA

C	Mn	P	S	Si	Cr	Mo	Ni	V	Cu
0.41	0.84	0.009	0.003	0.26	0.88	0.160	0.07	0.002	0.18
Al	**Nb**	**Sn**	**Ti**	**N**	**B**	**DI**	**RR**	**G.S.**	**Macro S**
0.029	0.001	0.008	0.002	0.0080	0.0001	4.54	68:1	fine	1
Macro R	**Macro C**	**J1**	**J2**	**J3**	**J4**	**J5**	**J6**	**J7**	**J8**
1	1	57	57	57	57	57	54	52	51
J9	**J10**	**J12**	**J14**	**J16**	**J18**	**J20**	**J24**	**J28**	**J32**
50	48	46	43	41	40	39	37	34	33

Notes

Processed material is Tempered - Stress Relieved. No welding performed on the material. No Mercury used in the production of this material. Melted and Manufactured in the USA.
Grade - 4140/42
EAF Melted

65038-5

SEP 0 1 2023

PORTLAND BOLT
PO 65038
INV 089589
100 3/4" X 144" B7 ATR HDG
JAN 12, 2024
2OF3

Vulcan
THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 817956 **Job Information** **Certified Date:** 6/26/23

Containers: S21606916 S21607102 S21608025 S21608153

Test Results

Part No: BAR B7 .6813x292 HT

Test No: 79611 **Test:** Heat Treat Info

Description	Austenitizing Temp (F)	Tempering Temp (F)	Run Speed (ft/min)	Quench Water Temp (F)	Note
	1,690	1,335	40	88	

Test No: 79612 **Test:** Tensile Test

Description	Tensile Strength (ksi)	Yield Strength (0.2% Offset) (ksi)	Elongation (4D) (%)	ROA (%)	Note
	139	127	22	59	
	140	128	21	57	
	139	127	21	59	
	140	128	18	60	
	140	128	19	61	
	141	127	21	62	
	140	128	21	58	

Test No: 79613 **Test:** Hardness Test

Description	Midradius Hardness	Surface Hardness	Core Hardness	Hardness Scale	Note
	29	28	30	HRC	
	29	28	29	HRC	
	29	28	28	HRC	
	29	28	29	HRC	
	29	29	29	HRC	
	30	28	30	HRC	
	30	29	29	HRC	

Test No: 79614 **Test:** Charpy Test

Description	Test Temp (F)	Test 1 (ft-lb)	Test 2 (ft-lb)	Test 3 (ft-lb)	Average (ft-lb)	Note
	-20	75	78	78	77	

Test No: 79615 **Test:** Carb/ Decarb Test

Description	Surface Carb.	Partial Surface Decarb.	Note
	Pass	Pass	

Test No: 79616 **Test:** Full-Sized Tensile Test

Description	Tensile Strength (ksi)	Yield Strength (ksi)	Elongation (%)	Elongation Gauge Length	ROA (%)	Note
	137	126	13	8 in.	58	tested by external provider

The reported test results conform to the specifications listed above.
The reported test results are the actual values measured on the samples taken from the production lot.
Material was manufactured, tested, and inspected as required by the product standard and in accordance with Vulcans ISO 9001:2015 Quality Management System registered June 30th, 2017.
Vulcan Steel Products lab is ISO 17025:2017 accredited for tensile, Brinell and Rockwell hardness, Charpy impact, and carb/decarb testing.
Material was tested in accordance with the current revision of ASTM A370, F606, and F2328 test methods.
All Q&T material is demagnetized.

Sallie Norwood SEP 01 2023 6/26/23

PORTLAND BOLT
PO 65038
INV 089589

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

100 3/4" X 144" B7 ATR HDG
JAN 12, 2024
3OF3

Vulcan
THREADED PRODUCTS, INC.

JOB MATERIAL CERTIFICATION

Job No: 817956 **Job Information** **Certified Date:** 6/26/23

Containers: S21606916 S21607102 S21608025 S21608153

Document is in accordance with EN 10204 - 3.1B of 2004 (3.1). | Norwood, Sallie - Certification Engineer Date

Plex 6/26/23 2:03 PM vulc.sano Page 2 of 2

SEP 0 1 2023

SANMA FASTENER (ZHEJIANG) CO.,LTD

The report is issued according to EN 10204:2004 3.1and ISO 16228 F3.1

地址：浙江省嘉兴市海盐县于城镇振兴路 313 号
NO.313 Zhenxing Road, Yucheng Town, Haiyan County, Jiaxing City, Zhejiang Province

电话(Tel)：0573-86466128

传真(Fax)：0573-86466118

合同号 Po No: O-212134

Country of Origin:China

日期 Report Date:2023.05.03
发票号码 INV NO:SF23137

客户名称 Customer：STELFAST INC

品 名 Product：ASTMA194-2017a-2H Heavy Hex Nuts
数 量 Quantity:144.00mpcs
标 记 Marker: SHS 2HZN
规 格 Size：3/4-10+0.020
检验标准 Inspection Standard：ASTM A194-2017a
表面处理 Finish: HDG W/WAX ASTM F2329-15
尺寸标准 Dimensional Specification:ASME B18.2.2-2015
货号 PATR No：A2HHGB0750CSK
批 号 Lot No：N2022122303HHW

一、钢材性质 STEEL PROPERTIES:
材质 Material: SWRCH45K 热处理批号 Heat No:G231009584 规格 Steel Size:ø 28mm

ELEMENT (成份)	C%	Mn%	P%	S%	Si%	Cr%	Ni%
TEST Facility :S	0.44	0.64	0.014	0.003	0.21		

二、项目检测 Inspections Item：

检测项目 Item	标 准 值 Specified(in)	实 测 值 Actual Result	判定 Judgement
TEST Facility :M Appearance	Passed	Passed	OK
TEST Facility :M Across Flat(in)	1.212-1.250	1.221-1.236	OK
TEST Facility :M Across Corner(in)	1.382-1.443	1.391-1.420	OK
TEST Facility :M Thickness(in)	0.710-0.758	0.722-0.746	OK
TEST Facility :M Thread	2B GO	OK	OK
	2B NOGO	OK	OK
TEST Facility :M Hardness	24-35	30-33	OK
TEST Facility :M Proof Load	175KSI	175KSI	OK
TEST Facility :M Hardness After 24H AT 540℃	MIN 89	94-97	OK
TEST Facility :M Tempering Temperature	Min 455	530-545	OK
TEST Facility :M Macro Etch Test	S1/R1/C1-S4/R4/C4	S2/R2/C2	OK
TEST Facility :M ASTM F2329-15 Coating thickness(μ m)	Min 43	55-65	OK

品保主管 Signature: HU SHAOQING

MFG ISO9001 CERTIFICATE NO：04308Q12140R0M

TR No. 617891-01-1-4

91

2024-07-12

江苏沙钢集团有限公司
Jiangsu Shagang Group CO.,LTD.

高速线材质量证明书
沙钢 High-speed Wire Rod Quality Certificate

SG03B-1914E

江苏省张家港市锦丰镇 邮编：215625
Jinfeng, Zhangjiagang, Jiangsu, P. R. CHINA
TEL: (0512) 58568866, 58568829
FAX: (0512) 58550366, 58550818

订货单位CUSTOMER	浙江沙钢物资贸易有限公司库	用户代码CUSTOMER CODE		合同号CONTRACT NO.	X2BD0002Q023
牌号STEEL GRADE	SWRCH45K	提货单号DELIVERY	VA9500	发货日期DATE OF DELIVERY	20221118
交货标准 SPECIFICATION	Q/320582 SGY303-2018	质证书号CERTIFICATE NO.	VA95002250 7	签发日期DATE OF ISSUE	20221118
		用途USE		精炼方式REFINING MATHOD	炉外精炼

序号 NO	炉批号 HEAT NO.	直径 Dia. mm	盘数 Coils	重量 kg	化学成分CHEMICAL COMPOSITION % C	Si	Mn	P	S	Cr	Ni	Cu	Al	拉伸试验TENSILE TEST Rm	ReL	A	A11.3	Z	顶端试验 H.T.	硬度试验 HRB	脱碳层 D.of.D	晶粒度 Micro-Grade	索氏体 Sorbite %	备注 REMARKS
					2	2	2	3	3	2	2	2	3	MPa		%								
					1=×10⁻¹ 2=×10⁻² 3=×10⁻³ 4=×10⁻⁴ 5=×10⁻⁵																			
12	G231009584	28.0	11	24367	44	21	64	14	3	2	1	1	27	626	389			35.0	完好	83.00	0.12	8		
														635	393			37.0		87.40	0.13	8		
13	G231009584	28.0	22	47963	44	21	64	14	3	2	1	1	27	626	389			35.0	完好	83.00	0.12	8		
														635	393			37.0		87.40	0.13	8		
14	G232009760	30.0	1	2172	45	21	64	14	2	2	1	2	34	629	369			28.0	完好	87.50		8		
														634	385			37.0		88.30		8		
15	G232009861	30.0	2	4370	44	21	65	17	1	2	1	2	28	622	353			32.0	完好	86.60		8		
														630	393			33.0		86.90		8		
16	G232009861	30.0	20	43489	44	21	65	17	1	2	1	2	28	622	353			32.0	完好	86.60		8		
														630	393			33.0		86.90		8		
合计 Total			56	122361																				

说明 NOTES

本质量证明书适用于合金类线材;本产品不含有任何辐射元素。It is guaranteed that the products don't contain radiochemical imparities.

*1. H.T.—Head-colding Test; *2 D.of D.—Depth of Decarburization;

综合判定 FINAL RESULT	合格 PASS	注意事项 ATTENTIVE ITEMS	质检印章 SEAL	签证人 VISA

1. 质量证明书复印件不作有效证明文件，除非盖章；The copy of this Certificate is not valid except stamped.
2. 用户验货后使用如有异议应及时告知炉号、牌号，并保留实物及标志。Please inform us the steel grade and the heat number of under quanlified material(s) found in inspection on time, and keep the material(s) and the marking card
3. 离扎丝纽结处近端为轧制成品头部。The coil head is marked by the binding

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SALESPERSON **Shanna McKee**
DIRECT PHONE 888.602.8920
EMAIL shanna@portlandbolt.com

SOLD TO	SHIP TO
TEXAS A&M TRANSPORTATION INST TTI FINANCIAL SERVICES 3135 TAMU COLLEGE STATION, TX, 77843-3135 Phone: 979.317.2755 | Fax: 979.227.7710	Adam Mayer @ 5126353115 Adam Mayer 1111 Rellis Parkway Bryan, TX, 77807

ATTN	**Adam Mayer** <a-mayer@tti.tamu.edu>	CUSTOMER PO	619891
SHIP DATE	2/7/2024	SHIP VIA	UPS Ground

LINE	QTY. ORDERED	DESCRIPTION
1	8	3/4"-10 x 9" domestic hot-dip galvanized ASTM A193 Grade B7 all thread rod
2	16	3/4" import hot-dip galvanized ASTM A194 Grade 2H heavy hex nut
3	16	3/4" import hot-dip galvanized ASTM F844 cut washer
4	16	3/4" import hot-dip galvanized lock washer

***

APPENDIX C. *MASH* TEST 3-62 (CRASH TEST 617891-01-1)

C.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2023-09-06 Test No.: 617891-01-1 VIN No.: 1C6RR6GT4KS712459

Year: 2019 Make: RAM Model: 1500

Tire Size: 265/70 R 17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 105725

Note any damage to the vehicle prior to test: None

• Denotes accelerometer location.

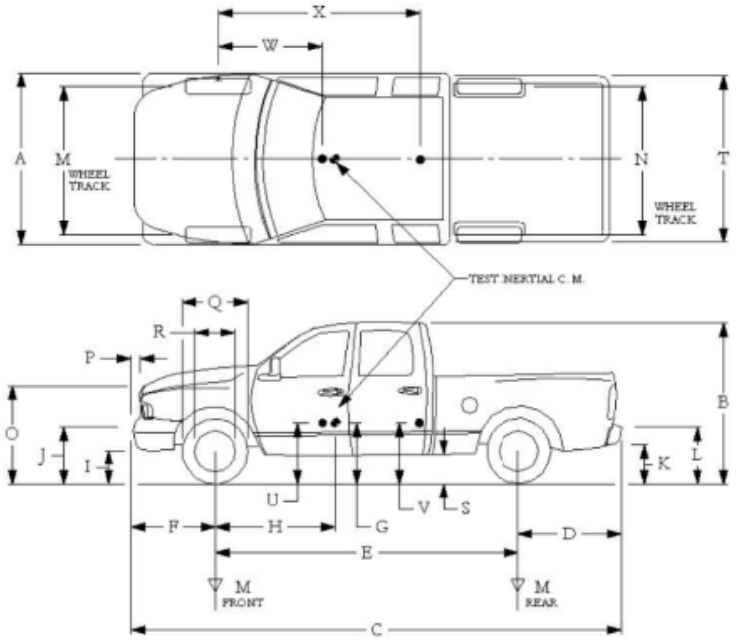
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

Transmission Type:
☑ Auto or ☐ Manual
☐ FWD ☑ RWD ☐ 4WD

Optional Equipment:
None

Dummy Data:
Type: -
Mass: -
Seat Position: -



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.38	L	30.00	Q	30.50	V	30.25
C	227.50	H	60.23	M	68.50	R	18.00	W	60.20
D	44.00	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	12.50
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	22.50

RANGE LIMIT: A=78 ±2 inches; C=237 ±13 inches; E=148 ±12 inches; F=39 ±3 inches; G = > 28 inches; H = 63 ±4 inches; O=43 ±4 inches; (M+N)/2=67 ±1.5 inches

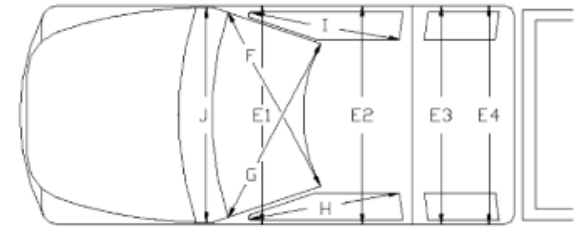
GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2969	2873	
Back	3900	M_{rear}	2088	2156	
Total	6700	M_{Total}	5057	5029	5029

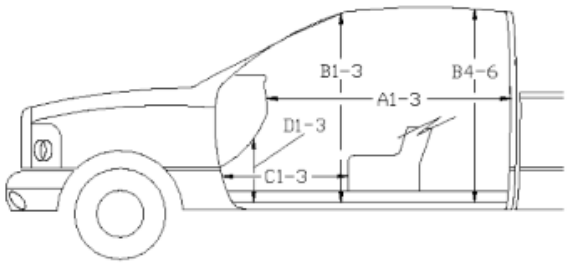
(Allowable Range for TIM and GSM = 5000 lb ±110 lb)

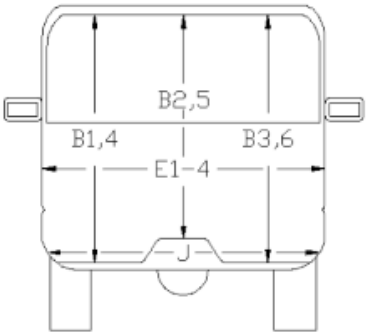
Mass Distribution:
lb LF: 1390 RF: 1483 LR: 1160 RR: 996

Figure C.1. Vehicle Properties for Test 617891-01-1.

Date:	2023-09-06	Test No.:	617891-01-1	VIN No.:	1C6RR6GT4KS712459
Year:	2019	Make:	RAM	Model:	1500







*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	35.50	-9.50
B2	38.00	32.50	-5.50
B3	45.00	41.00	-4.00
B4	39.50	37.00	-2.50
B5	43.00	39.50	-3.50
B6	39.50	37.50	-2.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	58.50	0.00
E2	63.50	63.50	0.00
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	60.00	1.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	25.00	0.00

Figure C.2. Exterior Crush Measurements for Test 617891-01-1.

Date: 2023-09-06 Test No.: 617891-01-1 VIN No.: 1C6RR6GT4KS712459

Year: 2019 Make: RAM Model: 1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width _____	Bowing: B1 _____ X1 _____
Corner shift: A1 _____	B2 _____ X2 _____
A2 _____	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1+X2}{2}$ = _____
< 4 inches _____	
≥ 4 inches _____	

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	AT FRONT BUMPER	15	7.5	24	--	--	--	--	--	--	-18
2	AT HOOD	47	3.5	16	-	-	-	-	-	-	20
	Measurements recorded										
	☑ inches or ☐ mm										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Figure C.3. Occupant Compartment Measurements for Test 617891-01-1.

C.2. SEQUENTIAL PHOTOGRAPHS

(a) 0.000 s (b) 0.050 s

(c) 0.100 s (d) 0.150 s

(e) 0.200 s (f) 0.250 s

(g) 0.300 s (h) 0.350 s

Figure C.4. Sequential Photographs for Test 617891-01-1 (Overhead Views).

(a) 0.000 s (b) 0.050 s

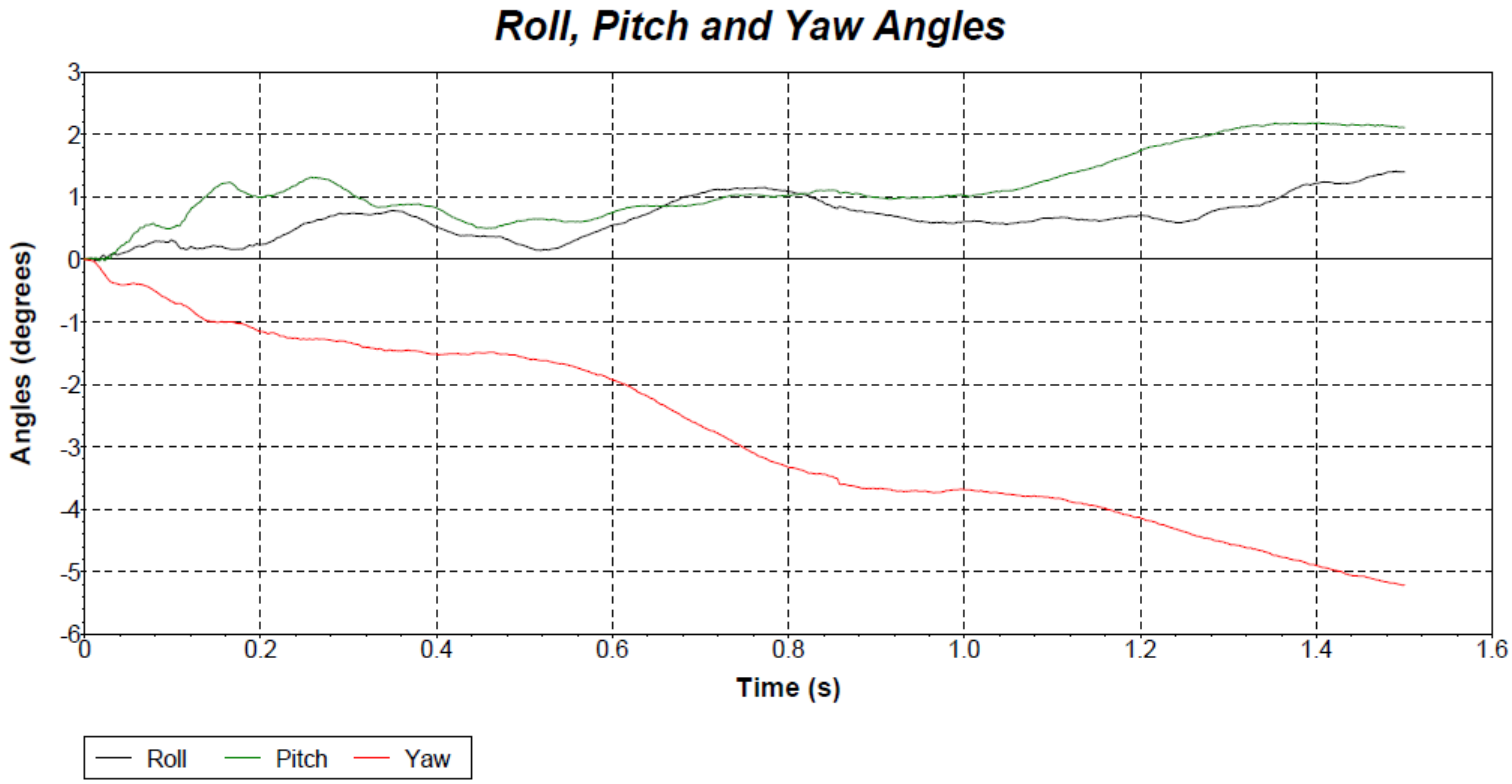
(c) 0.100 s (d) 0.150 s

(e) 0.200 s (f) 0.250 s

(g) 0.300 s (h) 0.350 s

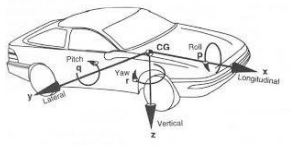
Figure C.5. Sequential Photographs for Test 617891-01-1 (Frontal Views).

C.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

1. Yaw.
2. Pitch.
3. Roll.



Test Number: 617891-01-1
Test Standard Test Number: *MASH* Test 3-62
Test Article: MUTCD standard pedestrian signal
Test Vehicle: 2019 RAM 1500
Inertial Mass: 5029 lbs
Gross Mass: 5029 lbs
Impact Speed: 63.6 mi/h
Impact Angle: 90°

Figure C.7. Vehicle Angular Displacements for Test 617891-01-1.

C.4. VEHICLE ACCELERATIONS

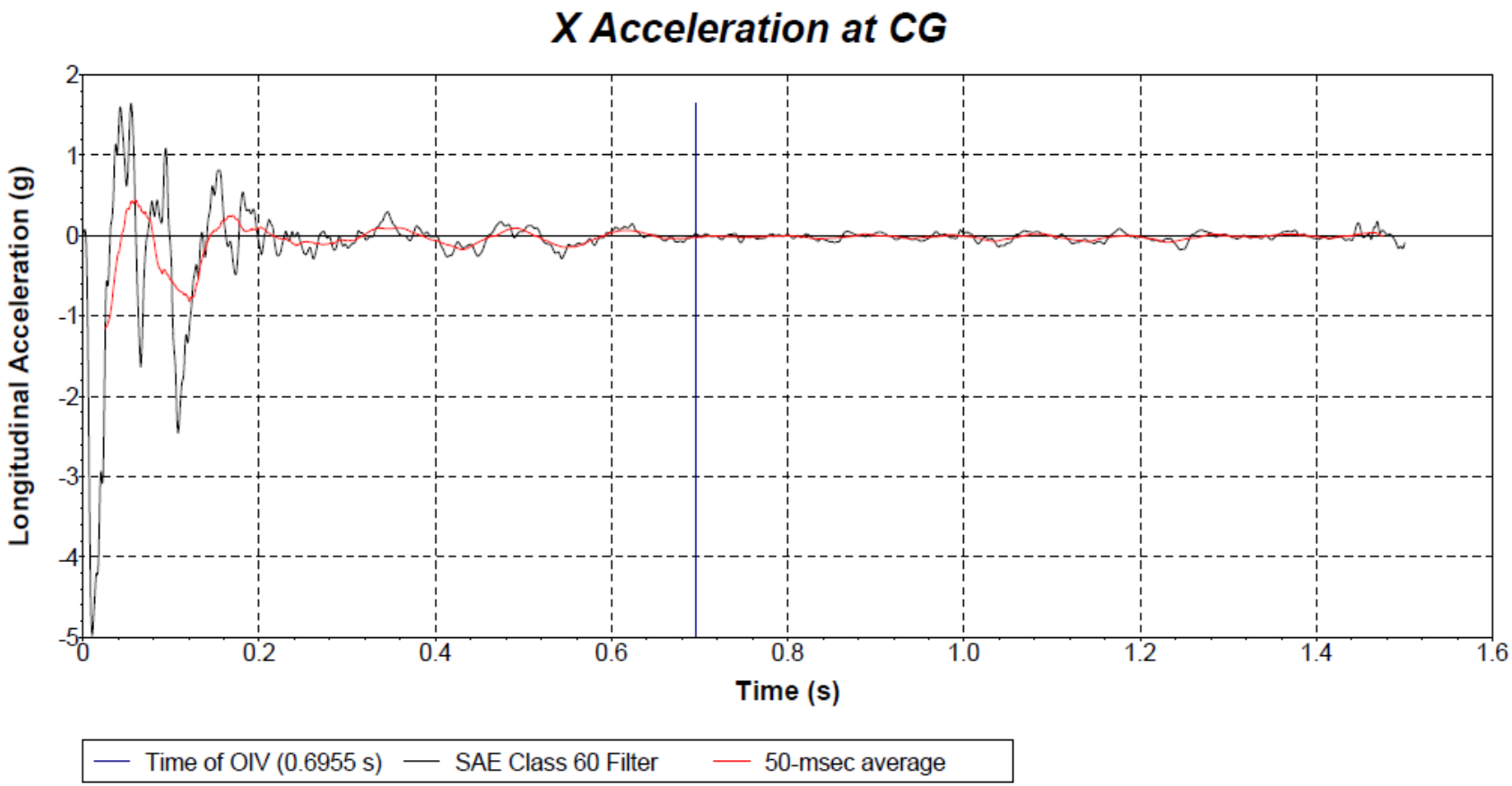


Figure C.8. Vehicle Longitudinal Accelerometer Trace for Test 617891-01-1 (Accelerometer Located at Center of Gravity).

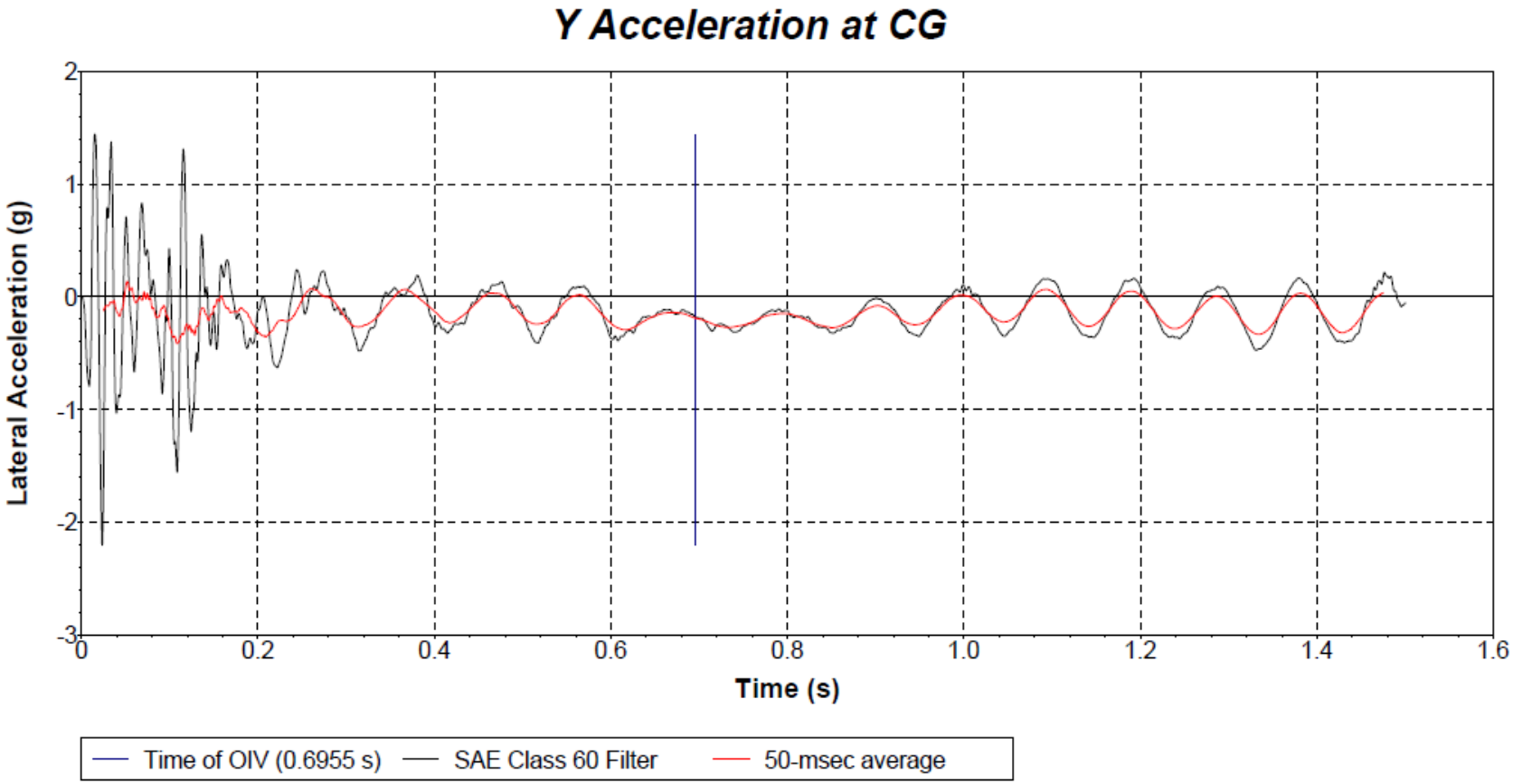


Figure C.9. Vehicle Lateral Accelerometer Trace for Test 617891-01-1 (Accelerometer Located at Center of Gravity).

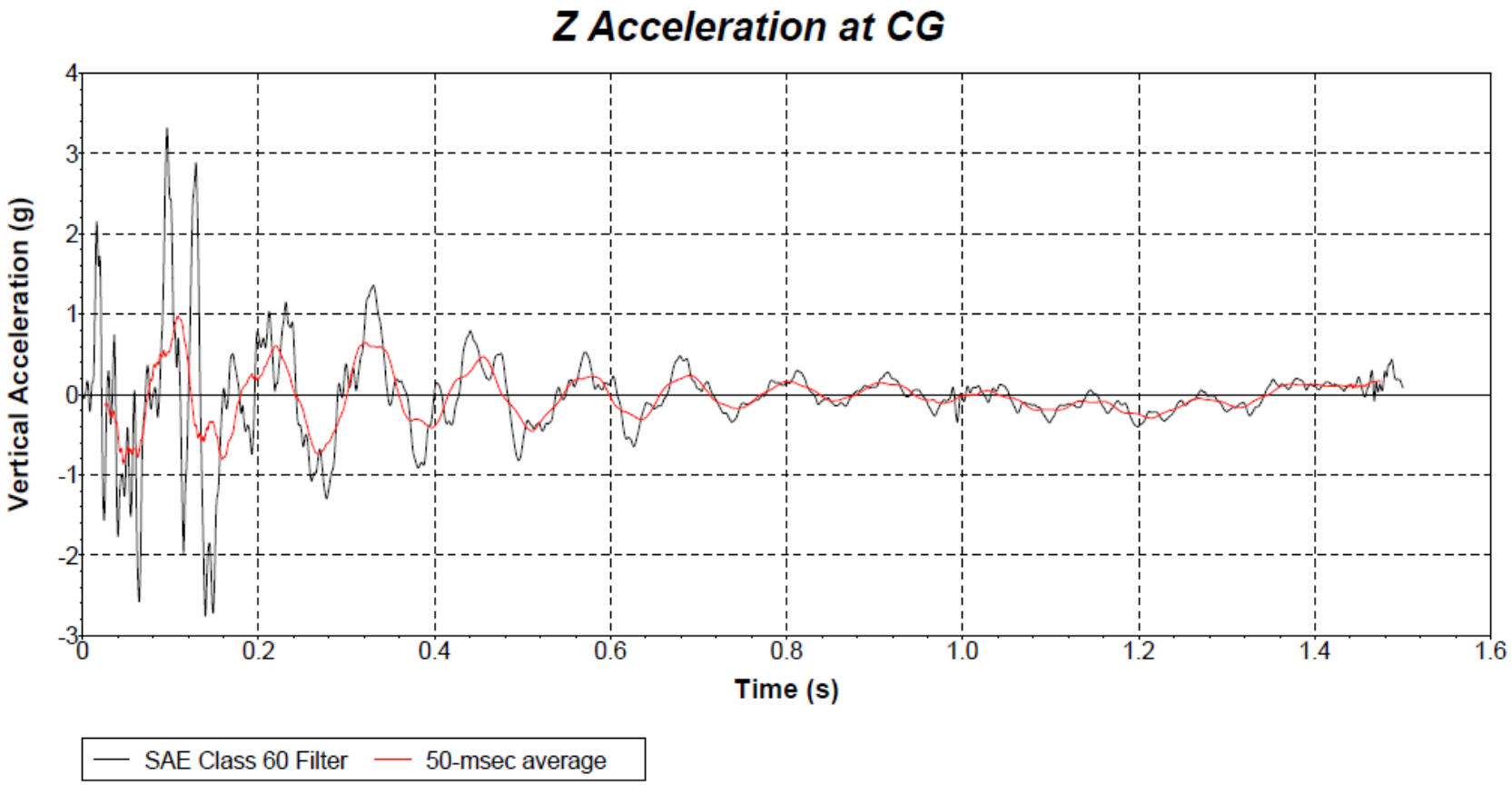


Figure C.10. Vehicle Vertical Accelerometer Trace for Test 617891-01-1 (Accelerometer Located at Center of Gravity).

APPENDIX D. *MASH* TEST 3-62 (CRASH TEST 617891-01-2)

D.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2023-11-13 Test No.: 617891-01-2 VIN No.: 1C6RR6FT6KS638043

Year: 2019 Make: RAM Model: 1500

Tire Size: 265/70 R 17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 77839

Note any damage to the vehicle prior to test: None

• Denotes accelerometer location.

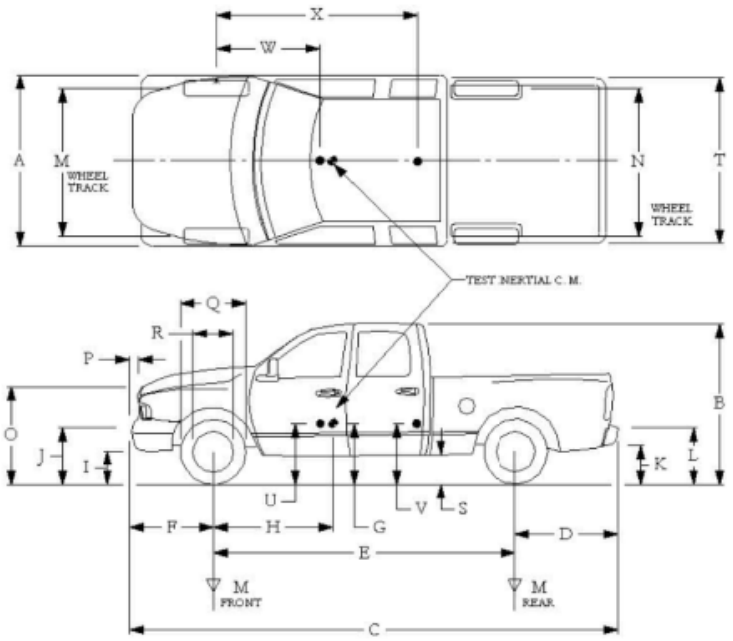
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

Transmission Type:
☑ Auto or ☐ Manual
☐ FWD ☑ RWD ☐ 4WD

Optional Equipment:
None

Dummy Data:
Type:
Mass:
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.37	L	30.00	Q	30.50	V	30.25
C	227.50	H	62.10	M	68.50	R	18.00	W	62.00
D	44.00	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	12.50
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	22.50

RANGE LIMIT: A=78 ±2 inches; C=237 ±13 inches; E=148 ±12 inches; F=39 ±3 inches; G = > 28 inches; H = 63 ±4 inches; O=43 ±4 inches; (M+N)/2=67 ±1.5 inches

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2900	2805	2805
Back	3900	M_{rear}	2110	2211	2211
Total	6700	M_{Total}	5010	5016	5016

(Allowable Range for TIM and GSM = 5000 lb ±110 lb)

Mass Distribution:
lb LF: 1399 RF: 1406 LR: 1120 RR: 1091

Figure D.1. Vehicle Properties for Test 617891-01-2.

Date:	2023-11-13	Test No.:	617891-01-2	VIN No.:	1C6RR5FT6KS638043
Year:	2019	Make:	RAM	Model:	1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width _____	Bowing: B1 _____ X1 _____
Corner shift: A1 _____	B2 _____ X2 _____
A2 _____	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1+X2}{2}$ = _____
< 4 inches _____	
≥ 4 inches _____	

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width*** (CDC)	Max**** Crush								
1	AT FRONT BUMPER	19	5.5	5	-	-	-	-	-	-	-13
2	ABOVE FNT BUMPER	45	3.5	6.5	-	-	-	-	-	-	13
	Measurements recorded										
	☑ inches or ☐ mm										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

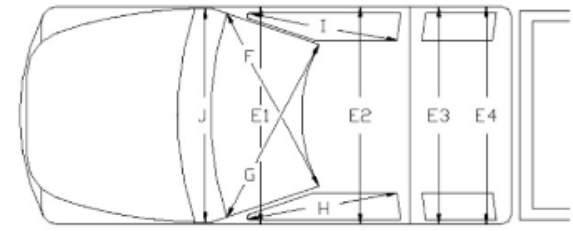
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

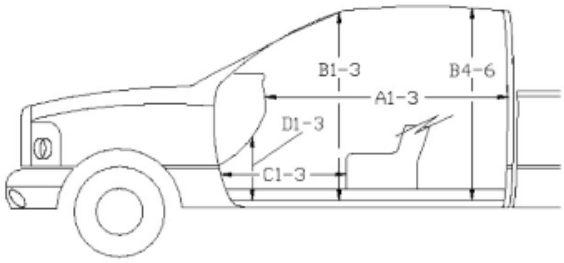
***Measure and document on the vehicle diagram the location of the maximum crush.

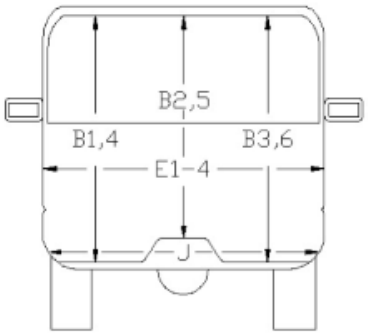
Note: Use as many lines/columns as necessary to describe each damage profile.

Figure D.2. Exterior Crush Measurements for Test 617891-01-2.

Date:	2023-11-13	Test No.:	617891-01-2	VIN No.:	1C6RR6FT6KS638043
Year:	2019	Make:	RAM	Model:	1500







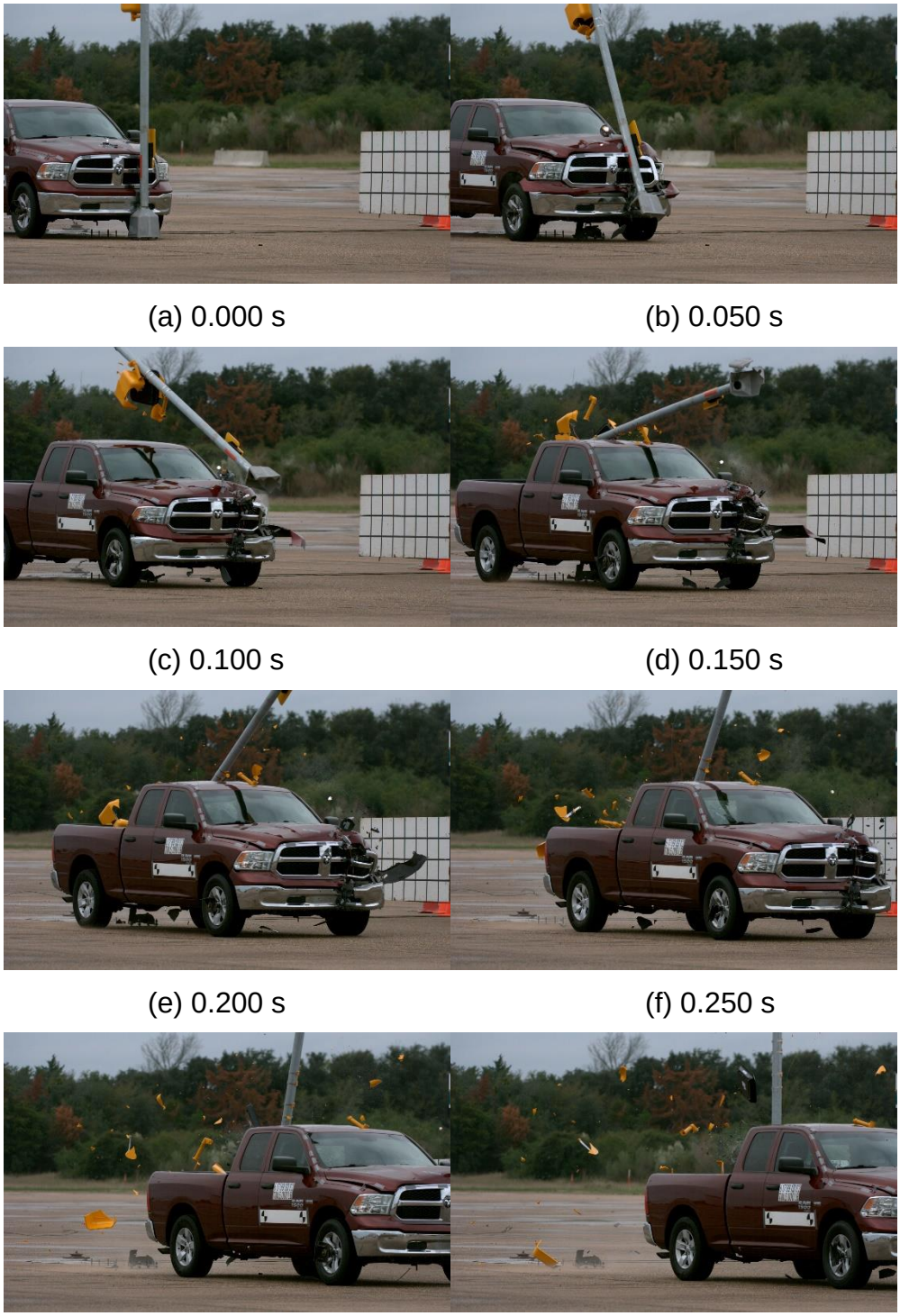
*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	43.00	-2.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	35.50	-4.00
B5	43.00	41.25	-1.75
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	58.50	0.00
E2	63.50	63.50	0.00
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	25.00	0.00

Figure D.3. Occupant Compartment Measurements for Test 617891-01-2.

D.2. SEQUENTIAL PHOTOGRAPHS



(a) 0.000 s (b) 0.050 s

(c) 0.100 s (d) 0.150 s

(e) 0.200 s (f) 0.250 s

(g) 0.300 s (h) 0.350 s

Figure D.4. Sequential Photographs for Test 617891-01-2 (Overhead Views).

(a) 0.000 s (b) 0.050 s

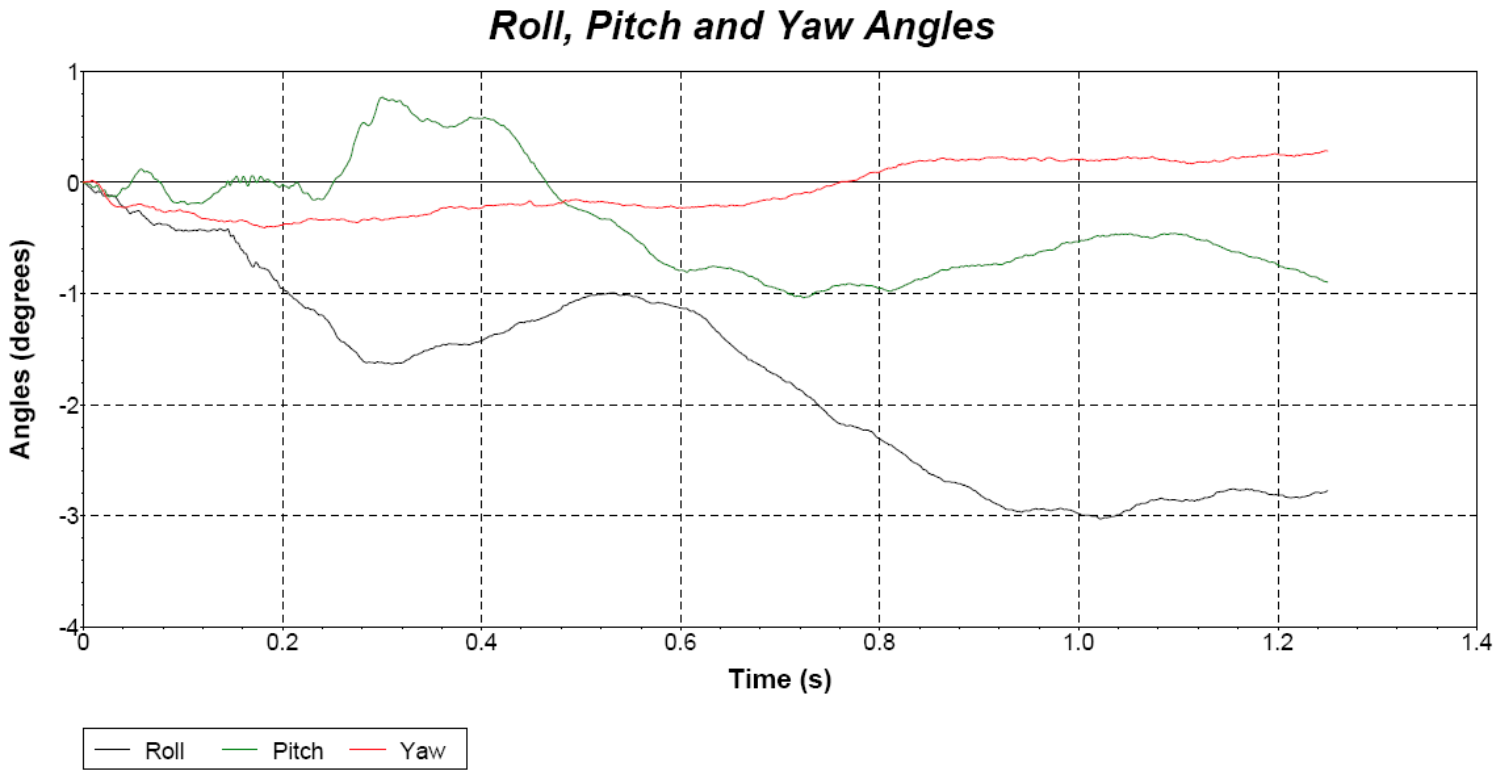
(c) 0.100 s (d) 0.150 s

(e) 0.200 s (f) 0.250 s

(g) 0.300 s (h) 0.350 s

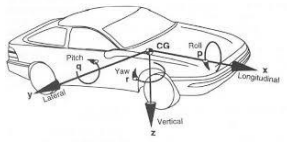
Figure D.5. Sequential Photographs for Test 617891-01-2 (Frontal Views).

D.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

4. Yaw.
5. Pitch.
6. Roll.



Test Number: 617891-01-2
Test Standard Test Number: *MASH* Test 3-62
Test Article: MUTCD standard pedestrian signal
Test Vehicle: Test Vehicle #2]
Inertial Mass: 5016 lbs
Gross Mass: 5016 lbs
Impact Speed: 61.9 mi/h
Impact Angle: 90°

Figure D.7. Vehicle Angular Displacements for Test 617891-01-2.

D.4. VEHICLE ACCELERATIONS

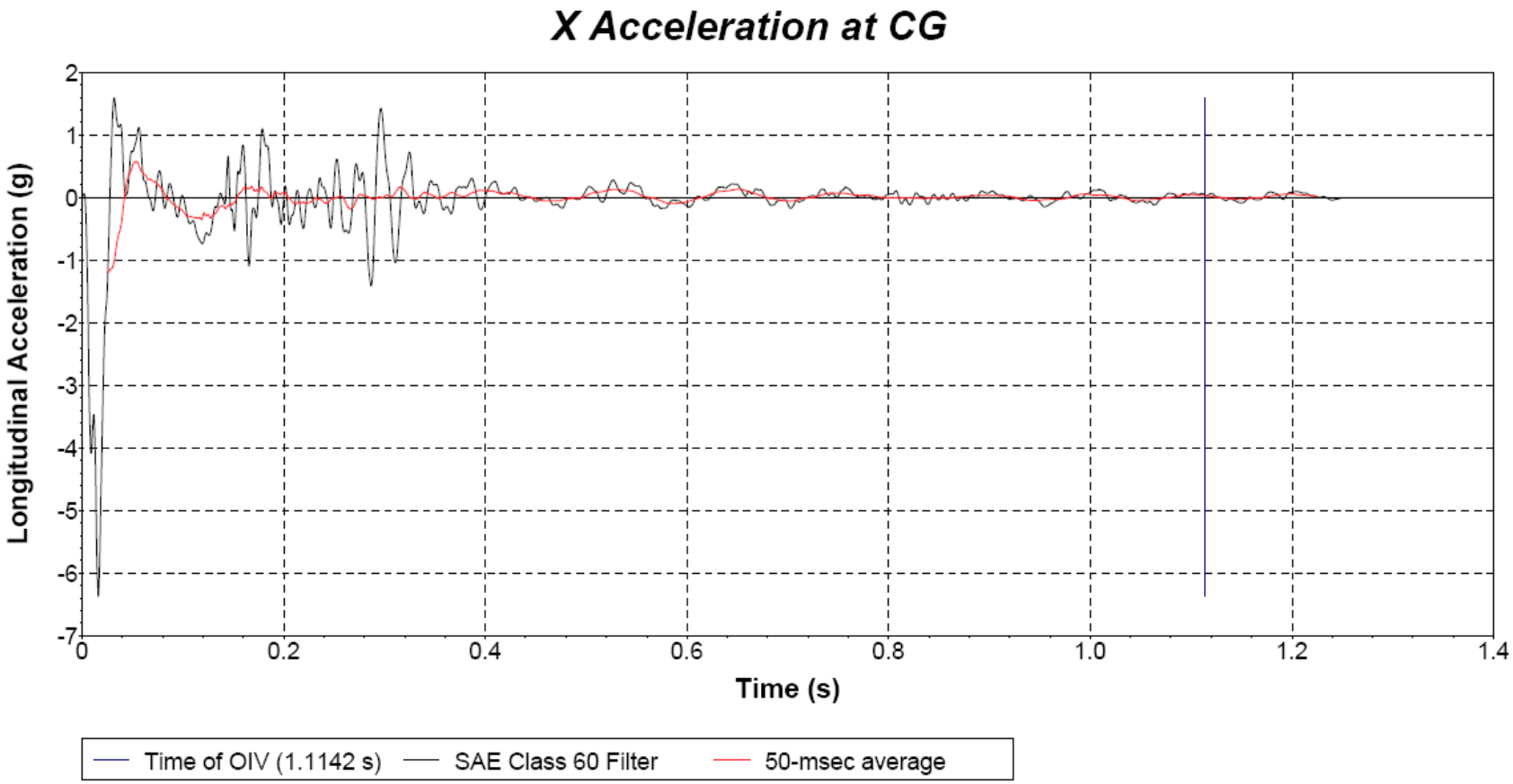


Figure D.8. Vehicle Longitudinal Accelerometer Trace for Test 617891-01-2 (Accelerometer Located at Center of Gravity).

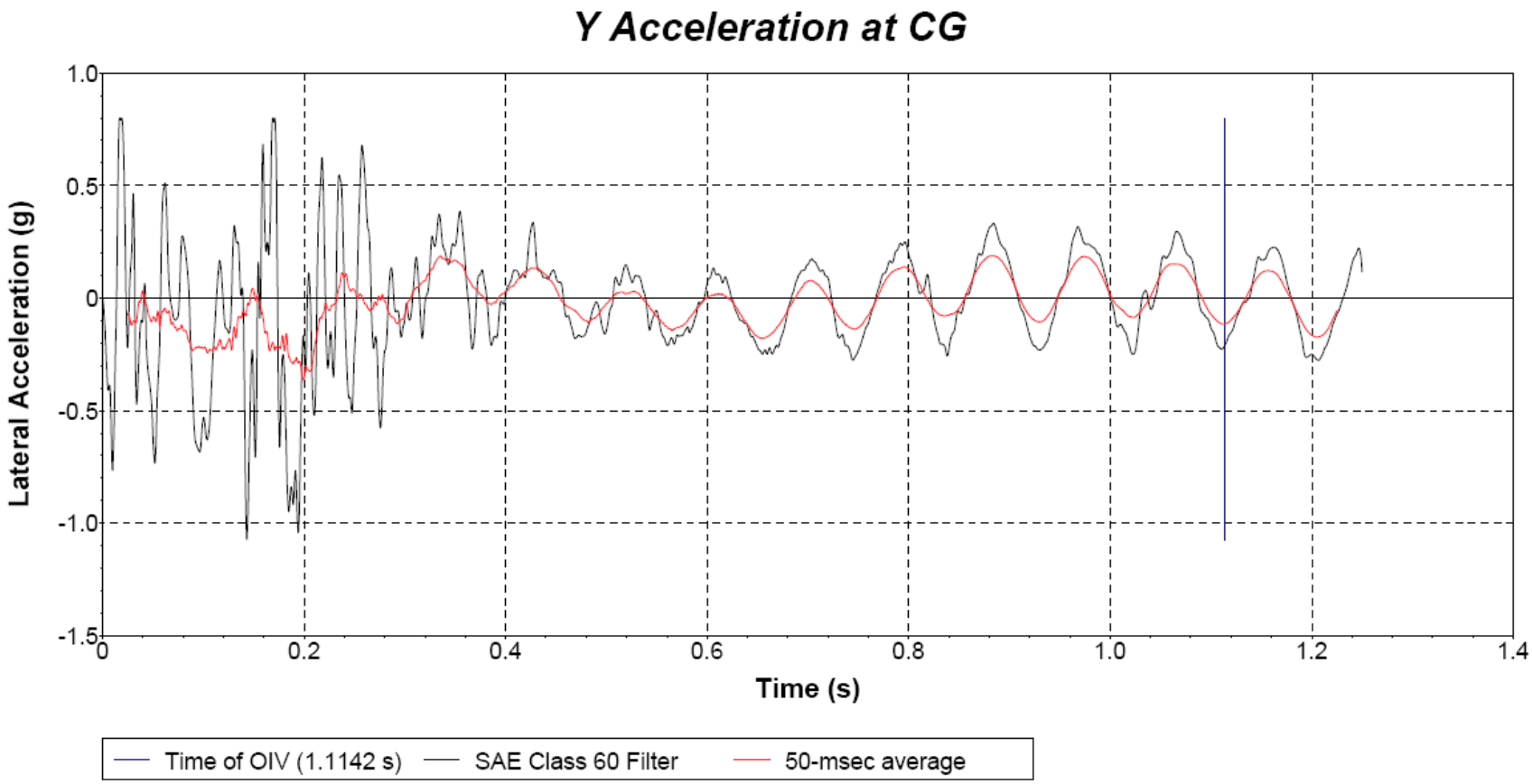


Figure D.9. Vehicle Lateral Accelerometer Trace for Test 617891-01-2 (Accelerometer Located at Center of Gravity).

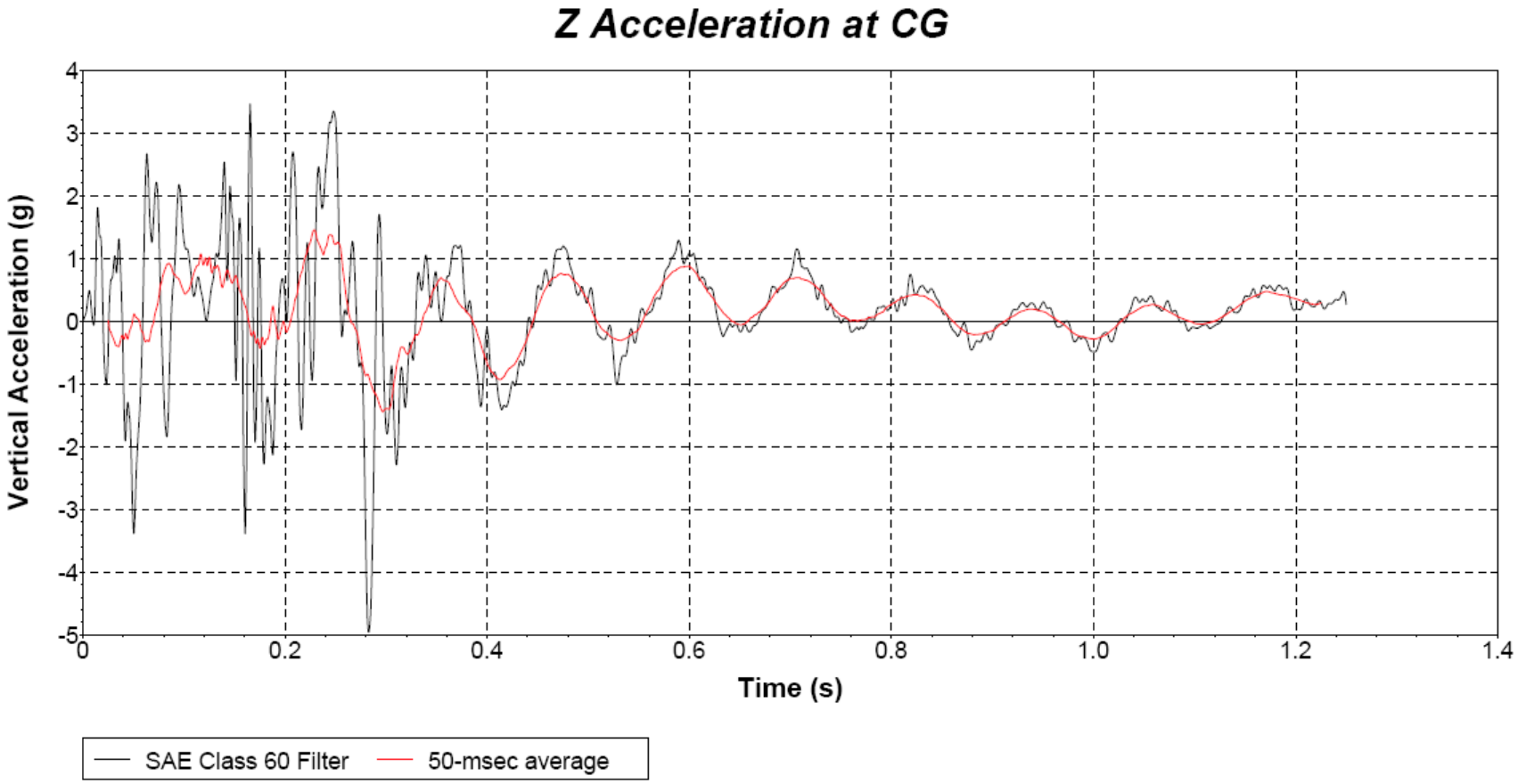


Figure D.10. Vehicle Vertical Accelerometer Trace for Test 617891-01-2 (Accelerometer Located at Center of Gravity).

APPENDIX E. *MASH* TEST 3-62 (CRASH TEST 617891-01-3)

E.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2024-02-15 Test No.: 617891-01-3 VIN No.: 1C6RR6GT8FS569750

Year: 2015 Make: RAM Model: 1500

Tire Size: 265/70 R 17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 213347

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

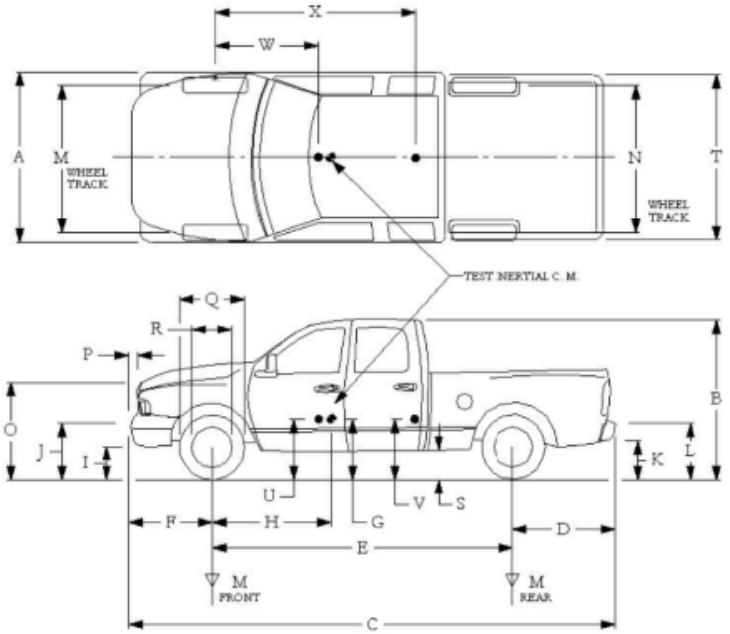
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

Transmission Type:
☑ Auto or ☐ Manual
☐ FWD ☑ RWD ☐ 4WD

Optional Equipment:
None

Dummy Data:
Type:
Mass:
Seat Position:



Geometry: inches

A	78.50	F	40.25	K	20.00	P	3.00	U	26.75
B	74.00	G	28.75	L	30.00	Q	30.50	V	30.25
C	229.00	H	62.70	M	68.50	R	18.00	W	62.50
D	48.25	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	12.50
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	22.50

RANGE LIMIT: A=78 ±2 inches; C=237 ±13 inches; E=148 ±12 inches; F=39 ±3 inches; G = > 28 inches; H = 63 ±4 inches; O=43 ±4 inches; (M+N)/2=67 ±1.5 inches

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2955	2805	
Back	3900	M_{rear}	2181	2260	
Total	6700	M_{Total}	5136	5065	5065

(Allowable Range for TIM and GSM = 5000 lb ±110 lb)

Mass Distribution:
lb LF: 1420 RF: 1385 LR: 1145 RR: 1115

Figure E.1. Vehicle Properties for Test 617891-01-3.

Date: 2024-02-15 Test No.: 617891-01-3 VIN No.: 1C6RR6GT8FS569750

Year: 2015 Make: RAM Model: 1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width _____	Bowing: B1 _____ X1 _____
Corner shift: A1 _____	B2 _____ X2 _____
A2 _____	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1+X2}{2}$ = _____
< 4 inches _____	
≥ 4 inches _____	

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FRONT BUMPER	20	6	10	-	-	-	-	-	-	-7
	Measurements recorded										
	☑ inches or ☐ mm										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

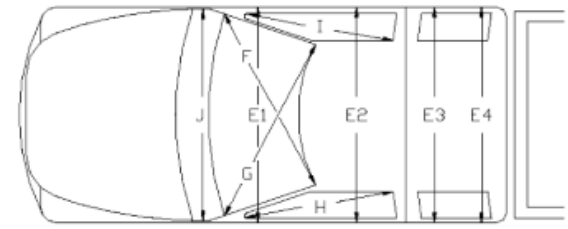
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

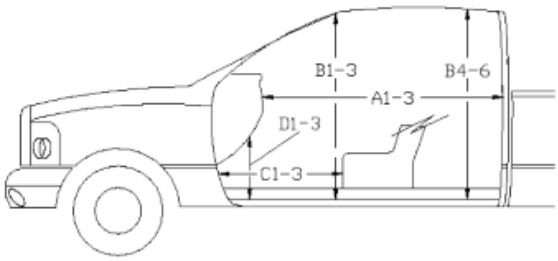
***Measure and document on the vehicle diagram the location of the maximum crush.

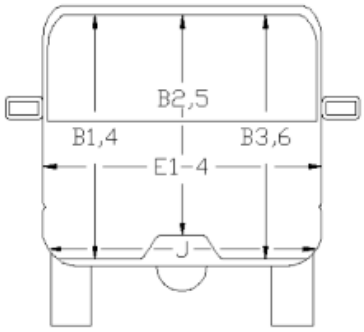
Note: Use as many lines/columns as necessary to describe each damage profile.

Figure E.2. Exterior Crush Measurements for Test 617891-01-3.

Date:	2024-02-15	Test No.:	617891-01-3	VIN No.:	1C6RR6GT8FS569750
Year:	2015	Make:	RAM	Model:	1500







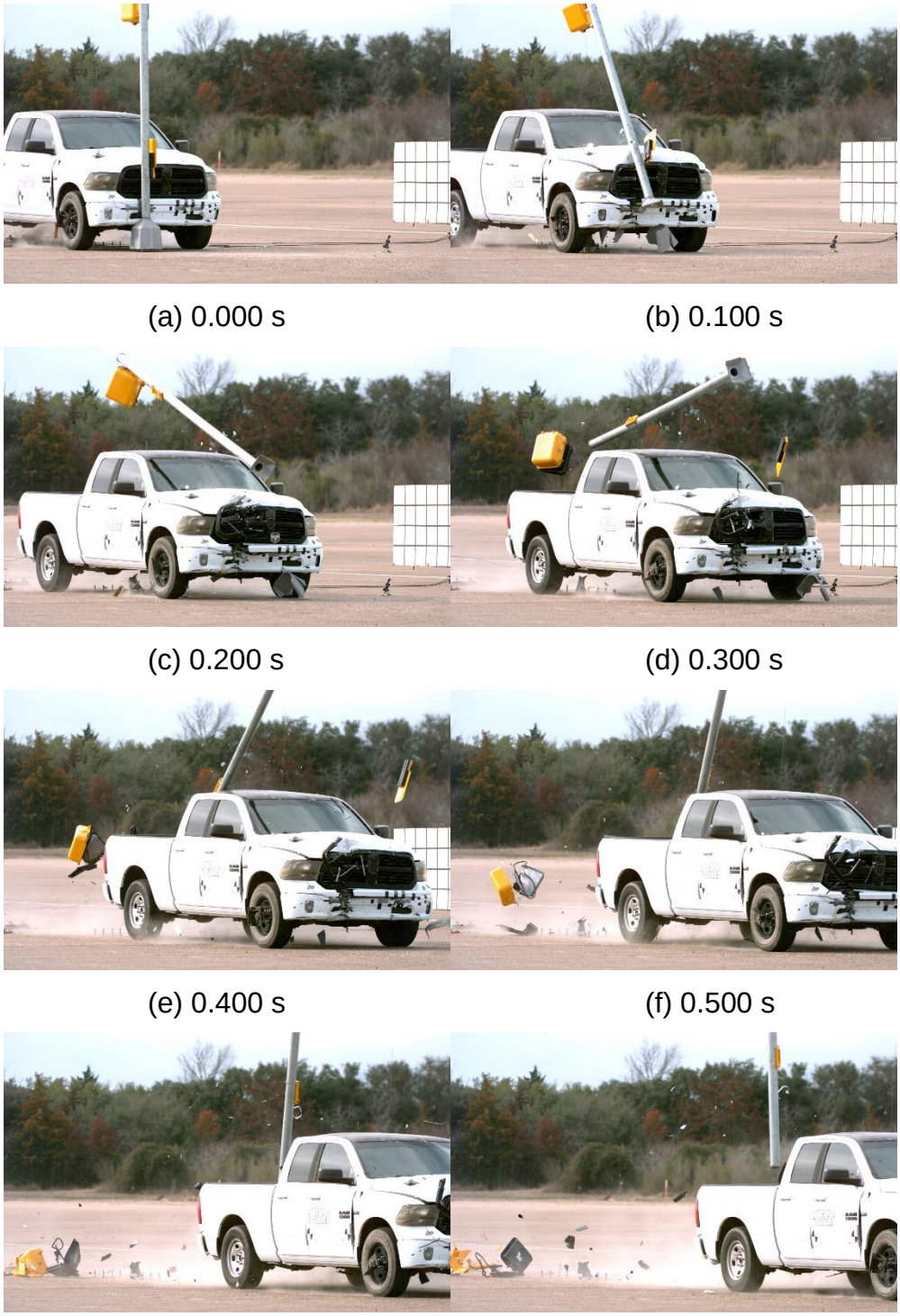
*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	36.50	-3.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	58.50	0.00
E2	63.50	63.50	0.00
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	25.00	0.00

Figure E.3. Occupant Compartment Measurements for Test 617891-01-3.

E.2. SEQUENTIAL PHOTOGRAPHS



(a) 0.000 s (b) 0.100 s

(c) 0.200 s (d) 0.300 s

(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

Figure E.4. Sequential Photographs for Test 617891-01-3 (Overhead Views).

(a) 0.000 s (b) 0.100 s

(c) 0.200 s (d) 0.300 s

(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

Figure E.5. Sequential Photographs for Test 617891-01-3 (Frontal Views).

APPENDIX F. *MASH* TEST 3-61 (CRASH TEST 617891-01-4)

F.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2024-02-15 Test No.: 617891-01-4 VIN No.: 3N1CN7AP6JL859782

Year: 2018 Make: Nissan Model: Versa

Tire Inflation Pressure: 36 PSI Odometer: 89791 Tire Size: P185/65R15

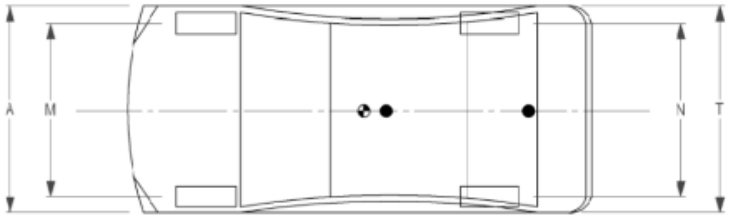
Describe any damage to the vehicle prior to test: None

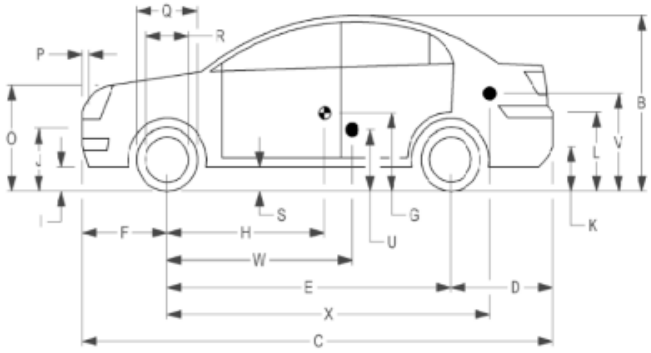
• Denotes accelerometer location.

NOTES: None

Engine Type: 4 CYL
Engine CID: 1.6 L
Transmission Type:
☑ Auto or ☐ Manual
☑ FWD ☐ RWD ☐ 4WD
Optional Equipment:
None

Dummy Data:
Type: NO DUMMY
Mass:
Seat Position:





Geometry: inches

A	66.70	F	32.50	K	12.50	P	4.50	U	15.50
B	59.60	G	0.00	L	26.00	Q	24.00	V	21.25
C	175.40	H	42.80	M	58.30	R	16.25	W	0.00
D	40.50	I	7.00	N	58.50	S	7.50	X	79.75
E	102.40	J	22.50	O	30.50	T	64.50		

Wheel Center Ht Front 11.50 Wheel Center Ht Rear 11.50 W-H -42.80

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Top of Radiator Support) = 28 ±4 inches
(M+N)/2 = 59 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1750	M_{front}	1374	1425	0
Back	1687	M_{rear}	964	1027	0
Total	3389	M_{Total}	2338	2452	0

Allowable TIM = 2420 lb ±55 lb | Allowable GSM = 2585 lb ±55 lb

Mass Distribution:
lb LF: 751 RF: 674 LR: 518 RR: 509

Figure F.1. Vehicle Properties for Test 617891-01-4.

Date: 2024-02-15 Test No.: 617891-01-4 VIN No.: 3N1CN7AP6JL859782

Year: 2018 Make: Nissan Model: Versa

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width _____	Bowing: B1 _____ X1 _____
Corner shift: A1 _____	B2 _____ X2 _____
A2 _____	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1+X2}{2}$ = _____
< 4 inches _____	
≥ 4 inches _____	

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width*** (CDC)	Max**** Crush								
1	AT FERONT BUMPER	18	10	8	-	-	-	-	-	-	-6
	Measurements recorded										
	☑ **inches or** ☐ **mm**										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

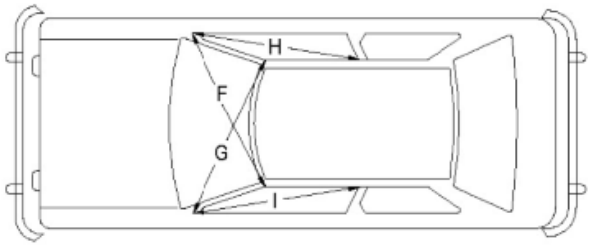
***Measure and document on the vehicle diagram the location of the maximum crush.

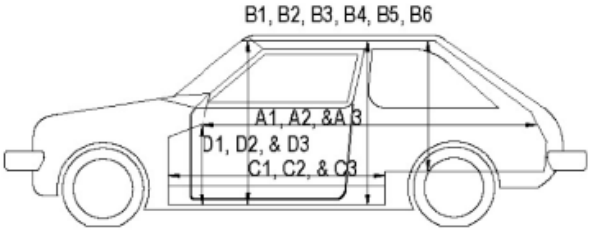
Note: Use as many lines/columns as necessary to describe each damage profile.

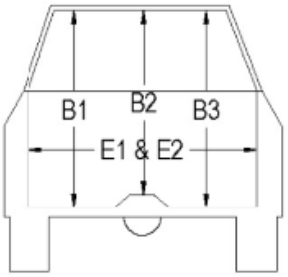
Figure F.2. Exterior Crush Measurements for Test 617891-01-4.

Date: 2024-02-15 Test No.: 617891-01-4 VIN No.: 3N1CN7AP6JL859782

Year: 2018 Make: Nissan Model: Versa







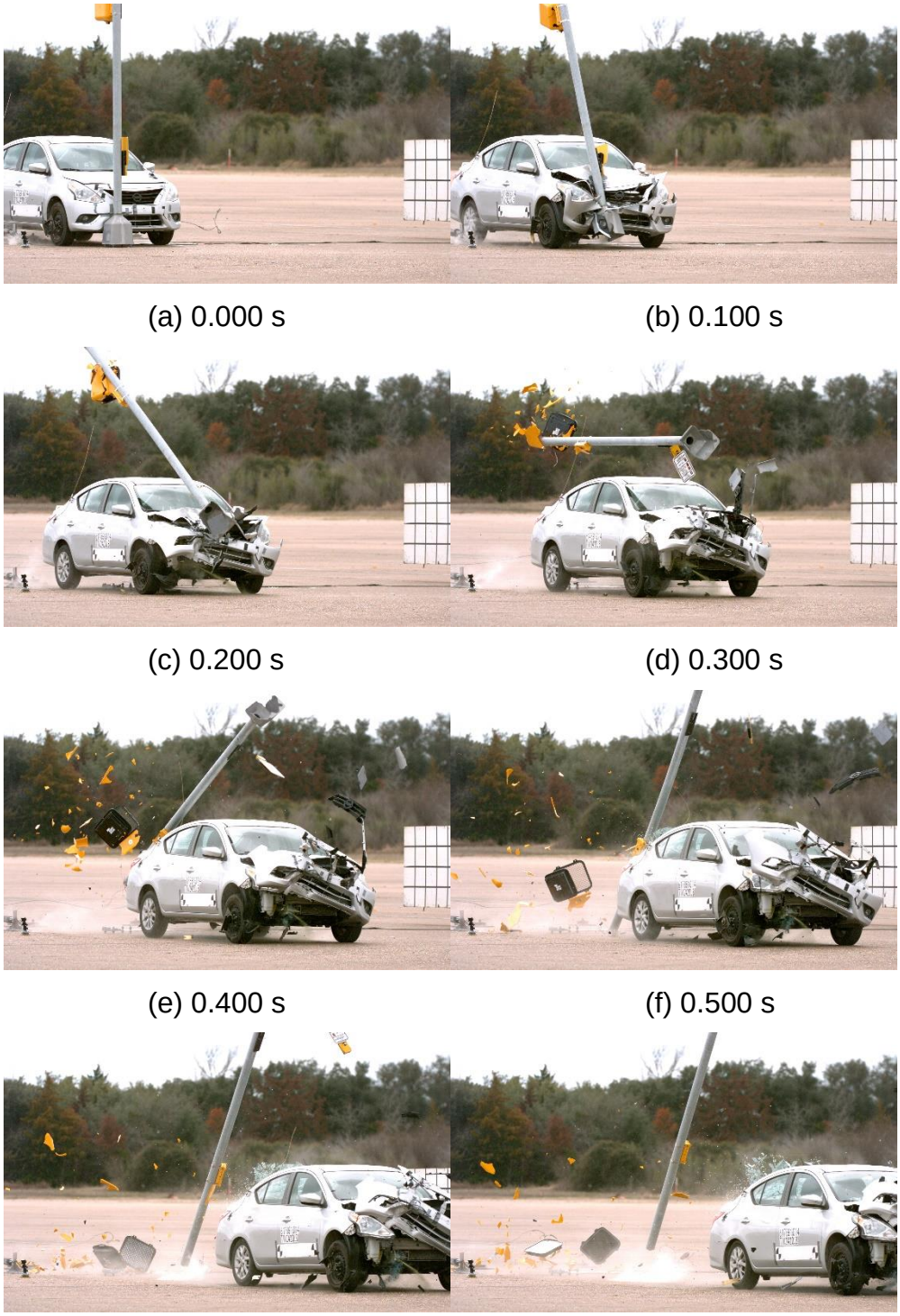
*Lateral area across the cab from driver's side kick panel to passenger's side kick panel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.50	0.00
A2	67.25	67.25	0.00
A3	67.75	67.75	0.00
B1	40.50	40.50	0.00
B2	39.00	39.00	0.00
B3	40.50	40.50	0.00
B4	36.25	36.25	0.00
B5	36.00	36.00	0.00
B6	36.25	36.25	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	9.50	9.50	0.00
D2	0.00	0.00	0.00
D3	9.50	9.50	0.00
E1	51.50	51.50	0.00
E2	51.00	51.00	0.00
F	51.00	51.00	0.00
G	51.00	51.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	51.00	51.00	0.00

Figure F.3. Occupant Compartment Measurements for Test 617891-01-4.

F.2. SEQUENTIAL PHOTOGRAPHS



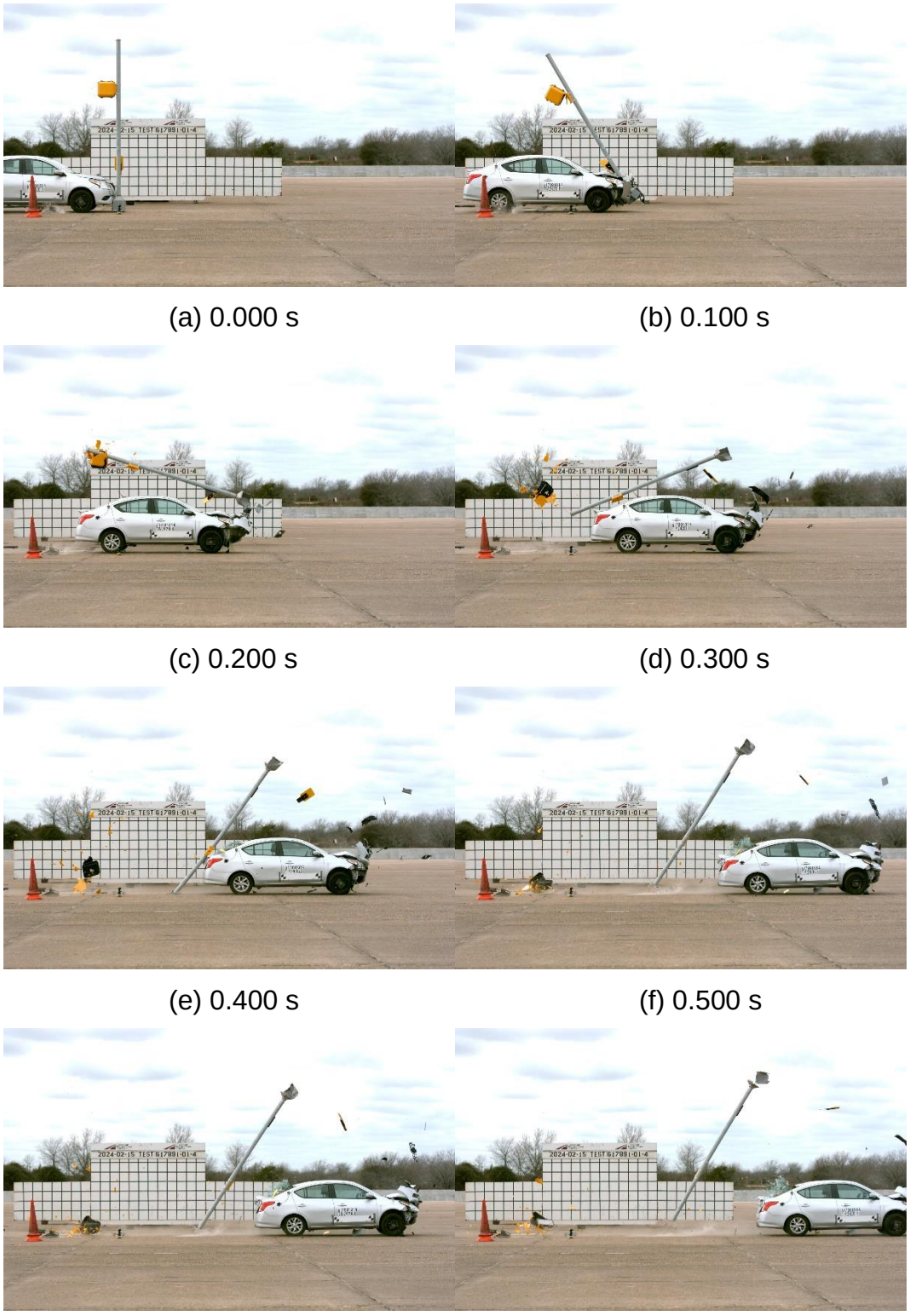
(a) 0.000 s (b) 0.100 s

(c) 0.200 s (d) 0.300 s

(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

Figure F.4. Sequential Photographs for Test 617891-01-4 (Overhead Views).



(a) 0.000 s (b) 0.100 s

(c) 0.200 s (d) 0.300 s

(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

Figure F.5. Sequential Photographs for Test 617891-01-4 (Frontal Views)