TTI: 9-1002-15

CRASH TEST AND EVALUATION OF 3-FT MOUNTING HEIGHT SIGN SUPPORT SYSTEM

ACCREDITED
ISO 17025 Laboratory
Testing Certificate # 2821.01

Crash testing performed at:
TTI Proving Ground
3100 SH 47, Building 7091
Bryan, TX 77807

Test Report 9-1002-15-1

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the
Federal Highway Administration and the
Texas Department of Transportation
http://tti.tamu.edu/documents/9-1002-15-1.pdf

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-15/9-1002-15-1		

4. Title and Subtitle	5. Report Date
CRASH TEST AND EVALUATION OF 3-FT MOUNTING HEIGHT SIGN SUPPORT SYSTEM	Published: July 2016
	6. Performing Organization Code
7. Author(s) N. M. Sheikh, R. P. Bligh, W. L. Menges, and D. L. Kuhn	8. Performing Organization Report No. Test Report No. 9-1002-15-1
9. Performing Organization Name and Address Texas A&M Transportation Institute Proving Ground The Texas A&M University System College Station, Texas 77843-3135	10. Work Unit No. (TRAIS) 11. Contract or Grant No. Project 9-1002-15
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080	13. Type of Report and Period Covered Test Report: September 2014 – June 2015 14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.
Project Title: Roadside Safety Device Crash Testing Program
URL: http://tti.tamu.edu/documents/9-1002-15-1.pdf

16. Abstract

The Texas Department of Transportation (TxDOT) and other transportation agencies continue to research potential countermeasure for mitigating wrong-way crashes. Because many drivers involved in wrong-way crashes are impaired, some highway safety engineers are proponents of using low-mounting height signs to communicate "Wrong Way" or "Do Not Enter" messages to these drivers. The Manual on Uniform Traffic Control Devices (MUTCD) has a provision for the use of a 3-ft sign mounting height. However, as with other sign support systems, any low-mounting height sign support system should meet impact performance criteria prior to its implementation on the national highway system.

The purpose of this research was to evaluate the impact performance of a 3-ft × 3-ft aluminum sign panel mounted at a reduced mounting height of 3 ft from the bottom of the panel to grade. The sign panel is supported by a wedge anchor system.

To evaluate the impact performance of the sign support system, two crash tests were performed under American Association of State Highway and Transportation Officials' (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) evaluation criteria. These were *MASH* Tests 3-60 and 3-61, which consist of a 2425-lb passenger car impacting the sign support system at nominal speeds of 19 mi/h and 62 mi/h, respectively. In both tests, the 3-ft mounting height sign support system performed acceptably and met all relevant *MASH* evaluation criteria.

MASH Test 3-62, which involves a 5000-lb pickup truck impacting the support structure at a speed of 62 mi/h, was not performed. The reduced mounting height of the sign support system eliminates any secondary contact between the sign support system and the windshield of the pickup truck.

17. Key Words	18. Distribution Statement
Breakaway, sign, aluminum, low-mounted, wrong way, sign support, aluminum panel, breakaway support, sign panel	No restrictions. This document is available to the public through NTIS: National Technical Information Service Springfield, Virginia 22161 http://www.ntis.gov

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	70	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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Report 9-1002-15-1
Project 9-1002-15
Project Title: Roadside Safety Device Crash Testing Program

Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

Published: July 2016

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation, and its contents are not intended for construction, bidding, or permit purposes. In addition, the above listed agencies assume no liability for its contents or use thereof. The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report. The engineer in charge of the project was Roger P. Bligh, P.E. (Texas, #78550).

TTI PROVING GROUND DISCLAIMER

The results of the crash testing reported herein apply only to the article being tested.

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ISO 17025 Laboratory
Testing Certificate # 2821.01

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ACKNOWLEDGMENTS

This research project was conducted under a cooperative program between the Texas A&M Transportation Institute, the Texas Department of Transportation, and the Federal Highway Administration. The TxDOT project manager for this research was Wade Odell, RTI. Technical support was provided by Michael Chacon of TxDOT's Traffic Operations Division. The authors acknowledge and appreciate their guidance and assistance.

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CHAPTER 1. INTRODUCTION

1.1 INTRODUCTION

This project was set up to provide the Texas Department of Transportation (TxDOT) with a mechanism to quickly and effectively evaluate high priority issues related to roadside safety devices. Roadside safety devices help shield motorists from roadside hazards such as non-traversable terrain and fixed objects. Some obstacles that cannot be moved out of the clear zone (e.g., mailboxes, sign supports) are designed to break away. To maintain the desired level of safety for the motoring public, these safety devices must be designed to accommodate a variety of site conditions, placement locations, and a changing vehicle fleet. Periodically, there is a need to assess the compliance of existing safety devices with current vehicle testing criteria.

Under this project, roadside safety issues are identified and prioritized for investigation. Each roadside safety issue is addressed with a separate work plan, and the results are summarized in an individual test report.

1.2 BACKGROUND

TxDOT proposes to use a low-mounted sign for alerting impaired motorists that inadvertently enter opposing traffic lanes or ramps from the wrong direction. The Manual on Uniform Traffic Control Devices (MUTCD) has a provision for the use of a 3-ft sign mounting height. However, there are currently no sign support systems that have been successfully crash tested under the American Association of State Highway and Transportation Officials' (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) (*1*) guidelines with a 3-ft tall sign panel mounted at a 3-ft mounting height.

1.3 OBJECTIVES/SCOPE OF RESEARCH

The objective of this research was to evaluate the impact performance of a 3-ft × 3-ft aluminum sign panel supported on a breakaway wedge-anchored sign support at a mounting height of 3 ft from the bottom of the panel to grade. It was desired to utilize existing TxDOT sign support and mounting hardware to the extent possible. The full-scale crash testing followed the procedures recommended in *MASH* for evaluation of breakaway support structures.

Reported herein are details of the testing and evaluation of a 3-ft mounting height sign support system, including a description of the tests performed, assessment of the test results, and implementation recommendations.

CHAPTER 2. SYSTEM DETAILS

2.1 TEST ARTICLE DESIGN AND CONSTRUCTION

Test articles in both tests were identical. They consisted of a single aluminum sign panel mounted on a single 2-inch nominal diameter thin-wall steel post that was installed in a steel tubular socket embedded in a concrete foundation. The sign panel was a 3-ft square panel fabricated from 0.100-inch thick aluminum sheet. The sign panel was mounted at a height of 3 ft from the bottom of the panel to grade. The top of the support post was flush with the top of the sign panel 6 ft above grade. The total weight of the assembled support post, sign panel, and attachment hardware was 27.4 lb.

The sign post was a 2-inch nominal diameter [2.375-inch outside diameter (OD)] thin-wall, 13-gauge Birmingham Wire Gauge (BWG) (0.0950-inch thick) pre-galvanized steel pipe. The post measured 84 inches in length and weighed 10.6 lb. The sign panel was attached to the post with two 0.25-inch diameter steel U-bolts and cast aluminum brackets. Each of the brackets was horizontally centered on the sign panel and vertically located 3 inches from the top and bottom edges of the sign, respectively.

The sign post was inserted approximately 12 inches into the embedded steel socket and secured in place with a 9-inch long steel locking wedge that was driven between the socket and impact side of the sign post. The embedded socket was a 27-inch long, 2½-inch nominal diameter (2.875-inch OD) thin-wall schedule 10 (0.120-inch thick) pre-galvanized steel pipe. The tubular socket was flattened at the bottom and was fully embedded in a 12-inch diameter × 30-inch deep drilled shaft concrete foundation such that the top of the socket was flush with the top of the concrete foundation. The concrete foundation contained no reinforcing steel and was drilled into compacted crushed limestone base.

Figure 2.1 shows details of the sign support test installation. Figure 2.2 provides photographs of the completed installation.

2.2 MATERIAL SPECIFICATIONS

The concrete foundation was specified as TxDOT Class A concrete with a required minimum compressive strength of 3000 psi at 28 days. The compressive strength of the concrete used in the sign support foundation measured an average of 4450 psi on the date of the test (7 days).

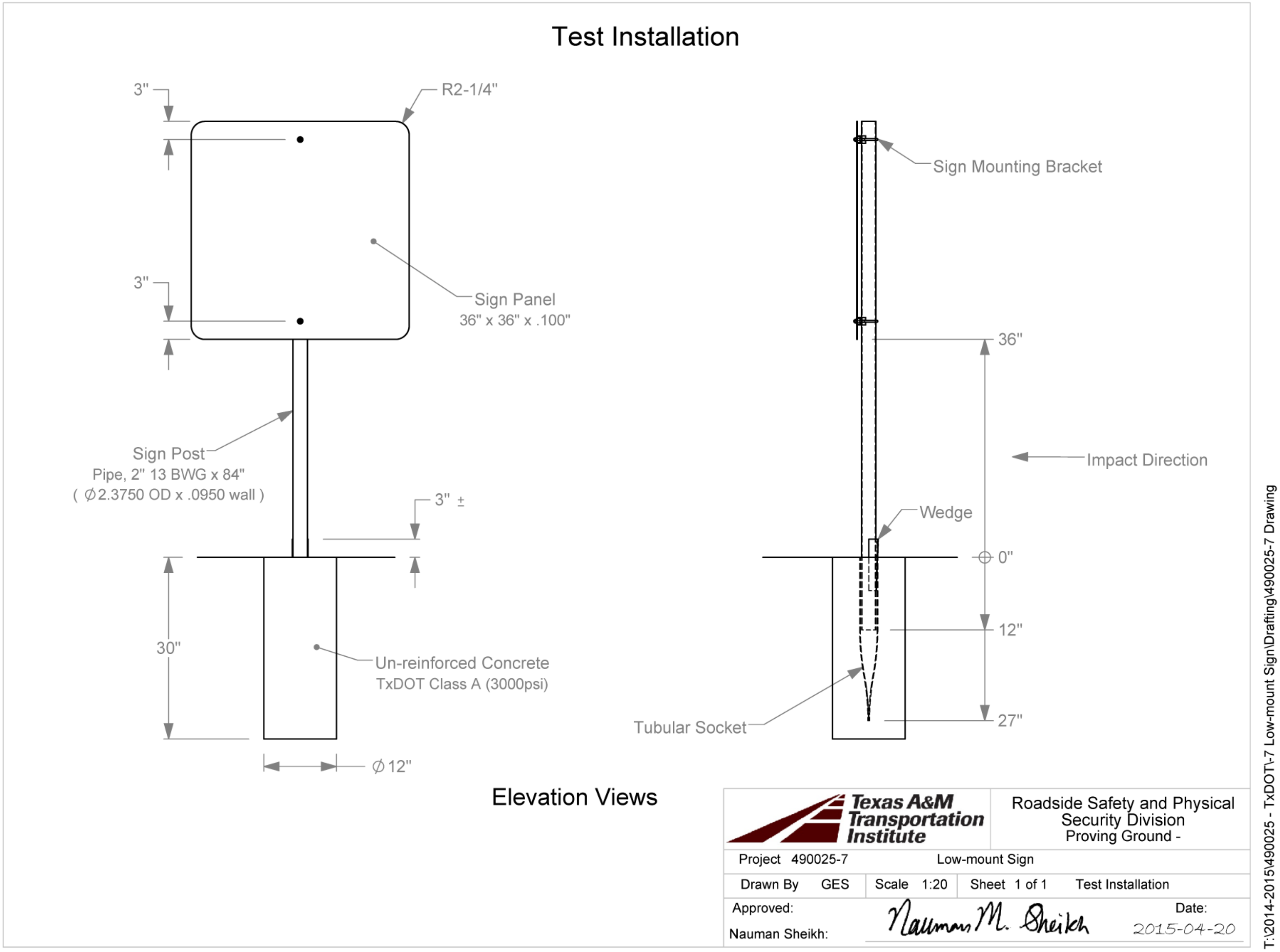


Figure 2.1. Details of 3-ft Mounting Height Sign Support System.

Figure 2.2. 3-ft Mounting Height Sign Support System before Testing.

CHAPTER 3. TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 CRASH TEST MATRIX

The full-scale crash testing performed under this project was in accordance with the guidelines and procedures set forth in *MASH*. The recommended matrix for evaluating breakaway support structures to test level three (TL-3) consists of three tests:

- ***MASH* Test 3-60** is a low-speed impact with an 1100C test vehicle striking the test article at the critical impact angle (CIA) at an impact speed of 19 mi/h.

  This test is designed to evaluate the kinetic energy required to activate the breakaway, fracture, or yielding mechanism of the support. The primary concern for this test is the potential for excessive velocity change and intrusion of structural components of the test article into the occupant compartment. Occupant risk is also a concern for this test.

- ***MASH* Test 3-61** is a high-speed impact with an 1100C test vehicle striking the test article at the CIA at a speed of 62 mi/h.
- ***MASH* Test 3-62** is a high-speed impact with a 2270P test vehicle striking the test article at the CIA at a speed of 62 mi/h.

The high-speed (62 mi/h) tests are intended to evaluate the behavior of the feature during high-speed impacts. The most common risks of failure for the high-speed tests include intrusion of structural components of the test article into the occupant compartment and the potential for vehicle instability. Occupant risk is also a concern for these two tests.

The CIA represents the worst case impact condition consistent with the manner in which the sign support will be installed on the roadway and judged to have the greatest potential for test failure.

MASH Tests 3-60 and 3-61 were performed on the 3-ft mounting height sign support system. The CIA was selected to be 0 degrees ± 1.5 degrees. Test 3-62 with the 2270P pickup truck was not performed. Due to the reduced mounting height, the sign panel is not expected to interact with the pickup truck's windshield or cause vehicle damage and occupant risk greater than Test 3-61 with the small car.

The crash test and data analysis procedures were in accordance with guidelines presented in *MASH*. Chapter 4 presents brief descriptions of these procedures.

3.2 EVALUATION CRITERIA

The crash tests were evaluated in accordance with the criteria presented in *MASH*. The performance of the 3-ft mounting height sign support system was judged on the basis of three factors: structural adequacy, occupant risk, and post-impact vehicle trajectory. Structural adequacy was judged on the ability of the 3-ft mounting height sign support system to yield to the vehicle in a controlled and predictable manner. Occupant risk criteria evaluate the potential risk of hazard to occupants in the impacting vehicle, and, to some extent, other traffic, pedestrians, or workers in construction zones, if applicable. Post-impact vehicle trajectory was assessed to determine the potential for secondary impact with other vehicles or fixed objects, creating further risk of injury to occupants of the impacting vehicle and/or risk of injury to occupants in other vehicles. The appropriate safety evaluation criteria from Table 5-1 of *MASH* were used to evaluate the crash test reported herein. This evaluation is presented in further detail under the assessment of each crash test.

CHAPTER 4. CRASH TEST PROCEDURES

4.1 TEST FACILITY

The full-scale crash tests reported herein were performed at Texas A&M Transportation Institute (TTI) Proving Ground. TTI Proving Ground is an International Standards Organization (ISO) 17025 accredited laboratory with American Association for Laboratory Accreditation (A2LA) Mechanical Testing certificate 2821.01. The full-scale crash test was performed according to TTI Proving Ground quality procedures and according to the *MASH* guidelines and standards.

The test facility at the TTI Proving Ground consists of a 2000 acre complex of research and training facilities situated 10 miles northwest of the main 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, durability and efficacy of highway pavements, and evaluation of roadside safety hardware. The site selected for the installation of the TxDOT 3-ft mounting height aluminum sign panel is along a wide out-of-service apron. The apron consists of an unreinforced jointed-concrete pavement in 12.5-ft × 15-ft blocks nominally 6 inches thick. The apron was built in 1942, and the joints have some displacement but are otherwise flat and level.

4.2 VEHICLE TOW AND GUIDANCE PROCEDURES

Each test vehicle 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, 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 two-to-one speed ratio between the test and tow vehicle existed with this system for the high-speed test. A one-to-one speed ratio existed for the low-speed test. Just prior to impact with the installation, the test vehicle was released to be free-wheeling and unrestrained. The vehicle remained freewheeling, i.e., no steering or braking inputs, until the vehicle cleared the immediate area of the test site, at which time brakes on the vehicle were activated, if needed, to bring it to a safe and controlled stop.

4.3 DATA ACQUISITION SYSTEMS

4.3.1 Vehicle Instrumentation and Data Processing

The test vehicle was instrumented with a self-contained, on-board data acquisition system. The signal conditioning and acquisition system is a 16-channel, Tiny Data Acquisition System (TDAS) Pro that Diversified Technical Systems, Inc. produced. The accelerometers, which measure the x, y, and z axes 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 TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 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 values per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark as well as initiates the recording process. After each test, the data are downloaded from the TDAS Pro 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 of the TDAS Pro units is returned to the factory annually for complete recalibration. Accelerometers and rate transducers are also calibrated annually with traceability to the National Institute for Standards and Technology. All accelerometers are calibrated annually according to SAE J211 *4.6.1* by means of an ENDEVCO® 2901, precision primary vibration standard. This device and its support instruments are returned to the factory annually for a National Institute of Standards Technology (NIST) traceable calibration. 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 any time data are suspect. Acceleration data is measured with an expanded uncertainty of ±1.7% at a confidence factor of 95 percent (k=2).

TRAP uses the data from the TDAS Pro to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the 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 a 60-Hz 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, 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 of the vehicle-fixed coordinate systems 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).

4.3.2 Anthropomorphic Dummy Instrumentation

A dummy was positioned in the 1100C vehicle on the side opposite impact to maximize the vehicle's post-impact instability. The Alderson Research Laboratories Hybrid II, 50th percentile male anthropomorphic dummy used for the tests was restrained with lap and shoulder belts. The dummy was not instrumented.

4.3.3 Photographic Instrumentation and Data Processing

Photographic coverage of the tests included two high-speed digital cameras: one overhead with a field of view perpendicular to the support structure/vehicle path and one placed behind the installation at an angle. A flashbulb activated by pressure-sensitive tape switches was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from each camera. The videos from these high-speed cameras were analyzed using motion analyzer software to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A real-time video camera and still cameras recorded and documented conditions of the test vehicle and installation before and after each test.

CHAPTER 5. CRASH TEST RESULTS FOR *MASH* TEST 3-60

5.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 3-60 involves an 1100C vehicle weighing 2425 lb ±55 lb impacting the support structure at a nominal impact speed of 19.0 mi/h ±2.5 mi/h and an angle of 0 degree ±1.5 degrees. The target impact point was the left quarter point of the front of the vehicle aligned with the centerline of the support structure. The 2009 Kia Rio used in the test weighed 2415 lb, and the actual impact speed and angle were 18.0 mi/h and 0 degree, respectively. The actual impact point was left quarter point of the front of the vehicle aligned with the centerline of the support structure.

5.2 WEATHER CONDITIONS

The crash test was performed on the afternoon of April 28, 2015. Weather conditions at the time of testing were: wind speed: 12 mi/h; wind direction: 360 degrees with respect to the vehicle (vehicle was traveling in a southerly direction); temperature: 59°F; relative humidity: 89 percent.

5.3 TEST VEHICLE

Figures 5.1 and 5.2 show the 2009 Kia Rio used for this crash test. The right quarter point of the vehicle was damaged in the previous high-speed test (Test No. 490025-7-2) conducted that morning. However, this damage was minimal and did not affect independent assessment of the sign panel in this low-speed test. Test inertia weight of the vehicle was 2415 lb, and its gross static weight was 2580 lb. The height to the lower edge of the vehicle front bumper was 9.50 inches, and the height to the upper edge of the front bumper was 21.5 inches. Additional dimensions and information on the vehicle are given in Appendix B1, Table B.1. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

Figure 5.1. Vehicle/Installation Geometrics for Test No. 490025-7-1.

Figure 5.2. Vehicle before Test No. 490025-7-1.

5.4 TEST DESCRIPTION

The 2009 Kia Rio, traveling at an impact speed of 18.0 mi/h, impacted the sign support structure at 0 degrees with the left quarter point of the vehicle aligned with the centerline of the sign support structure. The sign support began to deform around the front of the vehicle at 0.001 s, and the sign panel began rotating away from the vehicle at 0.003 s. At 0.025 s, the sign support developed a kink at bumper height of the vehicle and began rotating away from the vehicle. The sign support and sign panel became vertical at 0.078 s, and the sign panel U-brackets began to slip upward on the sign support at 0.094 s. At 0.112 s, the top U-bracket slipped off the sign support, and at 0.187 s, the sign panel contacted the ground surface. The top of the sign support contacted the undercarriage of the vehicle at 0.521 s. Exit speed at loss of contact with the sign support system was 15.4 mi/h. Brakes on the vehicle were applied 4.0 s after impact, and the vehicle subsequently came to rest 99 ft downstream of the point of impact. Figure B.1 in Appendix B2 shows sequential photographs of the test period.

5.5 DAMAGE TO TEST INSTALLATION

Figure 5.3 shows damage to the sign support structure. The sign support was deformed 90 degrees at ground level. The sign panel slid 20 inches upward on the sign support but remained attached to the support.

5.6 TEST VEHICLE DAMAGE

Figure 5.4 shows minimal damage to the driver side of the vehicle after the test. The damage to the passenger side occurred during the previous high-speed test (test no. 490025-7-2), which was performed earlier that morning. Scuff marks were noted on the bumper, but no other damage was obvious. No deformation or intrusion of the occupant compartment was noted. Figure 5.5 shows the interior of the vehicle. Exterior vehicle crush and occupant compartment measurements are shown in Appendix B1, Tables B.2 and B.3, respectively.

Figure 5.3. 3-ft Mounting Height Sign Support System after Test No. 490025-7-1.

Figure 5.4. Vehicle after Test No. 490025-7-1.

Before test After test

Figure 5.5. Interior of Vehicle for Test No. 490025-7-1.

5.7 OCCUPANT RISK FACTORS

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. In the longitudinal direction, the occupant impact velocity (OIV) was 3.6 ft/s at 0.660 s, the highest 0.010-s occupant ridedown acceleration (RDA) was 0.3 Gs from 0.669 to 0.679 s, and the maximum 0.050-s (50-ms) average vehicle acceleration was −1.0 Gs between 0.003 and 0.053 s. In the lateral direction, the OIV was 0.7 ft/s at 0.660 s, the highest 0.010-s occupant RDA was 0.3 Gs from 0.692 to 0.702 s, and the maximum 50-ms average vehicle acceleration was 0.2 Gs between 0.012 and 0.062 s. Theoretical Head Impact Velocity (THIV) was 3.9 km/h or 1.1 m/s at 0.660 s; Post-Impact Head Decelerations (PHD) was 0.3 Gs between 0.668 and 0.678 s; and Acceleration Severity Index (ASI) was 0.08 between 0.030 and 0.080 s. Figure 5.6 summarizes these data and other pertinent information from the test. Vehicle angular displacements are presented in Appendix B3, Figure B.2, and accelerations versus time traces are presented in Appendix B4, Figure B.3 through B.8.

5.8 ASSESSMENT OF TEST RESULTS

An assessment of the test based on applicable *MASH* safety evaluation criteria is presented below.

5.8.1 Structural Adequacy

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

<u>Results</u>: The 3-ft mounting height sign support system readily activated by yielding to the vehicle and deforming at the base. (PASS)

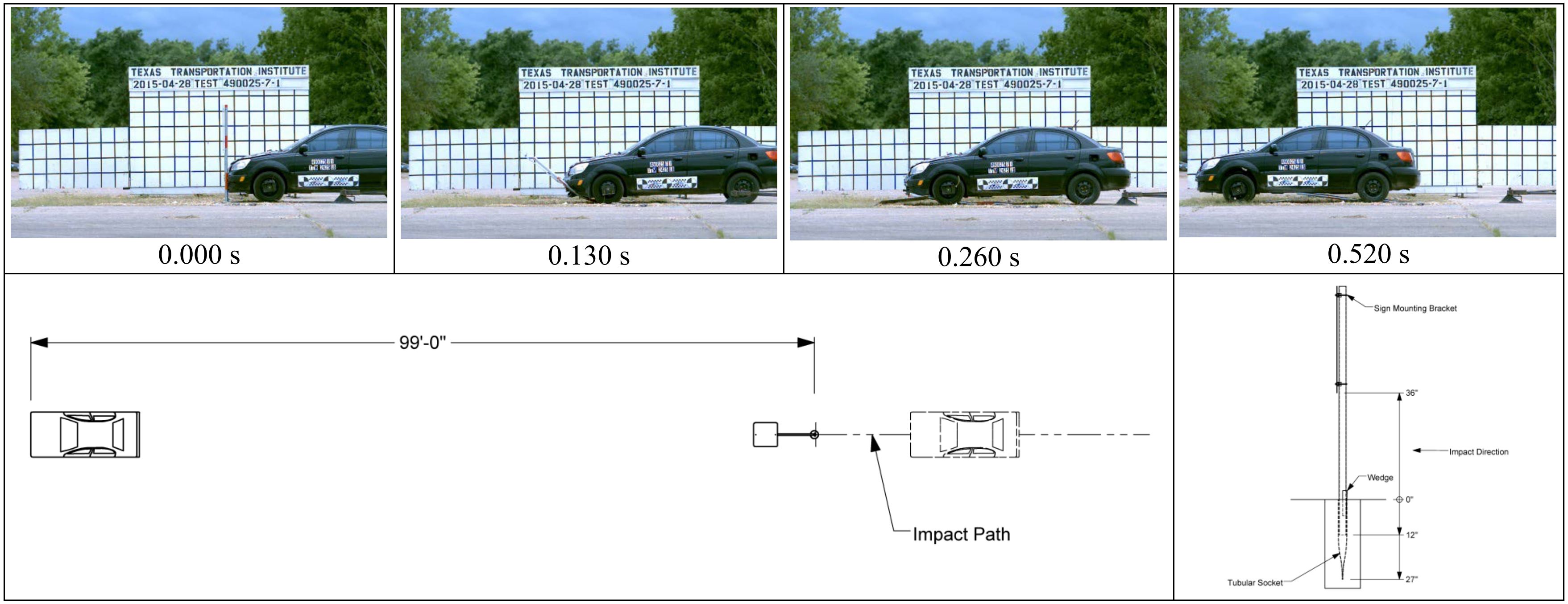
5.8.2 Occupant Risk

D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.

Deformation of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH. (roof $\leq$4.0 inches; windshield = $\leq$3.0 inches; side windows = no shattering by test article structural member; wheel/foot well/toe pan $\leq$9.0 inches; forward of A-pillar $\leq$12.0 inches; front side door area above seat $\leq$9.0 inches; front side door below seat $\leq$12.0 inches); floor pan/transmission tunnel area $\leq$12.0 inches).

<u>Results</u>: No detached elements, fragments, or other debris were present to penetrate or to show potential for penetrating the occupant compartment, or to present hazard to others in the area. (PASS)

There was no deformation of or intrusion into the occupant compartment. (PASS)



General Information
- Test Agency .... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. .... MASH Test 3-60
- TTI Test No. 490025-7-1
- Date 2015-04-28

Test Article
- Type.................................. Sign Support
- Name .... Low-Mounting Height Sign Support
- Installation Height................ 3 ft from bottom of sign panel to grade
- Material or Key Elements .... 3-ft square, 0.100-inch thick aluminum sign mounted on 2-inch diameter steel post

Soil Type and Condition....... Concrete foundation in crushed limestone

Test Vehicle
- Type/Designation 1100C
- Make and Model.................. 2009 Kia Rio
- Curb.................................. 2389 lb
- Test Inertial .... 2415 lb
- Dummy............................... 165 lb
- Gross Static........................ 2580 lb

Impact Conditions
- Speed....................................18.0 mi/h
- Angle.....................................0 degrees
- Location/Orientation ....Left qtr point

Exit Conditions
- Speed....................................15.4 mi/h
- Angle.....................................NA

Occupant Risk Values
- Longitudinal OIV.....................3.6 ft/s
- Lateral OIV.............................0.7 ft/s
- Longitudinal RDA....................0.3 G
- Lateral RDA............................0.3 G
- THIV.......................................3.9 km/h
- PHD ....0.3 G
- ASI 0.08
- Longitudinal 50-ms Average ...−1.0 G
- Lateral 50-ms Average .... 0.2 G
- Vertical 50-ms Average ....−0.3 G

Post-Impact Trajectory
- Stopping Distance .... 99 ft

Vehicle Stability
- Maximum Yaw Angle................. 1 degree
- Maximum Pitch Angle................ 2 degrees
- Maximum Roll Angle.................. 2 degrees
- Vehicle Snagging....................... No
- Vehicle Pocketing...................... No

Test Article Scatter
- Longitudinal .... Deformed at
- Lateral .... base in place
- Working Width ....

Vehicle Damage
- VDS... 12LF1
- CDC 12FLEN1
- Max. Exterior Deformation .... Not measureable
- OCDI FR0000000
- Max. Occupant Compartment Deformation......................... None

Figure 5.6. Summary of Results for *MASH* Test 3-60 on the 3-ft Mounting Height Sign Support System.

F. *The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.*

Results: The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were each 2 degrees. (PASS)

H. *Occupant impact velocities should satisfy the following:*

Longitudinal and Lateral Occupant Impact Velocity

Preferred	*Maximum*
10 ft/s	*16.4 ft/s*

Results: Longitudinal OIV was 3.6 ft/s, and lateral OIV was 0.7 ft/s. (PASS)

I. *Occupant ridedown accelerations should satisfy the following:*

Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15.0Gs	*20.49 Gs*

Results: Longitudinal RDA was 0.3 G, and lateral RDA was 0.3 G. (PASS)

5.8.3 Vehicle Trajectory

N. *Vehicle trajectory behind the test article is acceptable.*

Result: The 1100C vehicle came to rest behind the test article.

CHAPTER 6. CRASH TEST RESULTS FOR *MASH* TEST 3-61

6.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH test 3-61 involves an 1100C vehicle weighing 2425 lb ±55 lb impacting the support structure at a nominal impact speed of 62.2 mi/h ±2.5 mi/h and an angle of 0 degree ±1.5 degrees. The target impact point was the right quarter point of the front of the vehicle aligned with the centerline of the support structure. The 2009 Kia Rio used in the test weighed 2415 lb, and the actual impact speed and angle were 64.0 mi/h and 0 degree, respectively. The actual impact point was the right quarter point of the front of the vehicle aligned with the centerline of the support structure.

6.2 WEATHER CONDITIONS

The crash test was performed on the morning of April 28, 2015. Weather conditions at the time of testing were: wind speed: 9 mi/h; wind direction: 319 degrees with respect to the vehicle (vehicle was traveling in a southerly direction); temperature: 59°F; relative humidity: 97 percent.

6.3 TEST VEHICLE

Figures 6.1 and 6.2 show the 2009 Kia Rio used for this crash test. Test inertia weight of the vehicle was 2415 lb, and its gross static weight was 2580 lb. The height to the lower edge of the vehicle front bumper was 9.50 inches, and the height to the upper edge of the front bumper was 21.5 inches. Additional dimensions and information on the vehicle are given in Appendix C1, Table C.1. The vehicle was directed into the installation using a cable reverse tow and guidance system and was released to be freewheeling and unrestrained just prior to impact.

Figure 6.1. Vehicle/Installation Geometrics for Test No. 490025-7-2.

Figure 6.2. Vehicle before Test No. 490025-7-2.

6.4 TEST DESCRIPTION

The 2009 Kia Rio, traveling at an impact speed of 64.0 mi/h, impacted the sign support structure at 0 degrees with the right quarter point of the vehicle aligned with the centerline of the sign support structure. At 0.002 s after impact, the sign support began to deform around the front of the vehicle, and at 0.005 s, the sign panel began to rotate away from the vehicle. The sign support began to kink at bumper height and pull up from the foundation tube at 0.006 s. At 0.015 s, the sign support formed another kink at the foundation tube, and at 0.026 s, the sign support pulled out of the foundation tube. The sign support contacted the lower right edge of the windshield at 0.046 s. At 0.096 s, the vehicle lost contact with the sign support and was traveling at an exit speed of 63.6 mi/h. Brakes on the vehicle were applied 1.0 s after impact, and the vehicle subsequently came to rest 261 ft downstream of the point of impact. Figures C.1 and C.2 in Appendix C2 show sequential photographs of the test period.

6.5 DAMAGE TO TEST INSTALLATION

Figure 6.3 shows damage to the sign support structure. The sign support was partially flattened from its bottom edge to a point approximately 16 inches below the bottom edge of the sign panel. The support was bent at locations corresponding to ground level and vehicle bumper height. The sign panel remained attached to the sign support and the system came to rest 207 ft downstream of impact and 18 ft to the left of centerline of its original position relative to the path of the vehicle.

6.6 VEHICLE DAMAGE

Figure 6.4 shows damage to the vehicle after the test. There was a small indentation in the right side of the hood. The windshield was fractured in the lower right corner but remained intact. No deformation or intrusion of the occupant compartment was noted. Figure 6.5 shows the interior of the vehicle. Exterior vehicle crush and occupant compartment measurements are shown in Appendix C2, Tables C.2 and C.3.

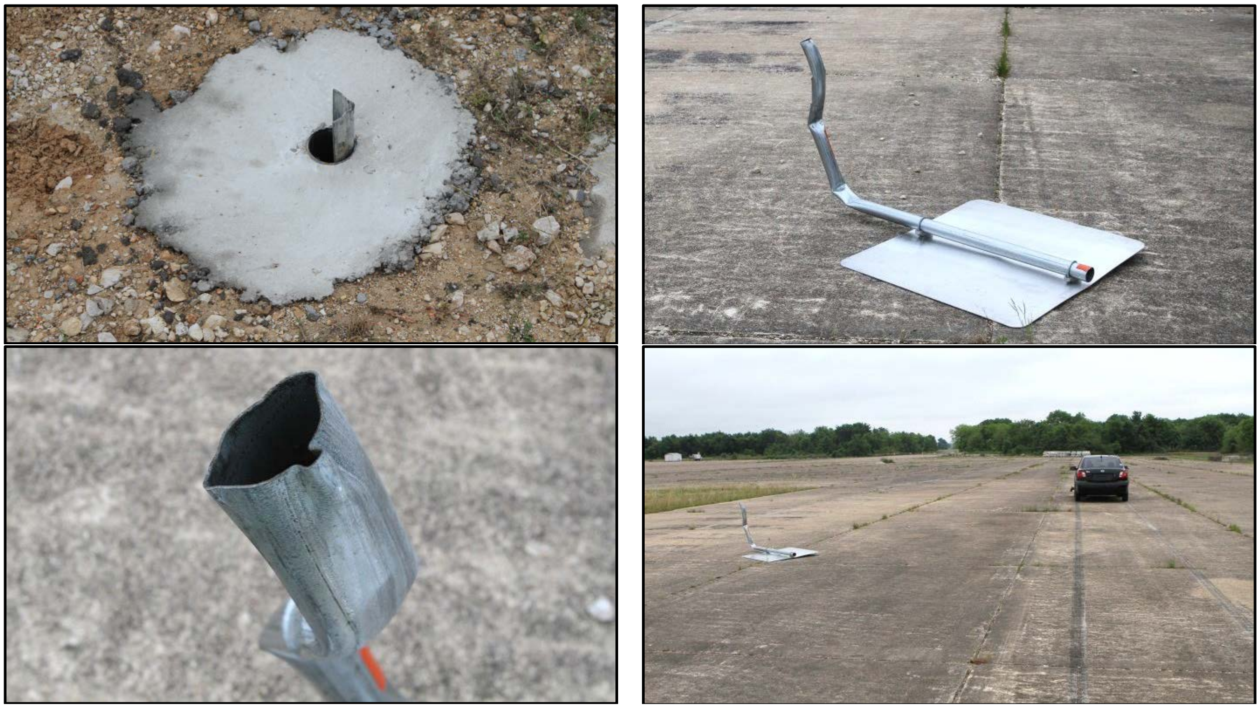


Figure 6.3. 3-ft Mounting Height Sign Support System after Test No. 490025-7-2.

Figure 6.4. Vehicle after Test No. 490025-7-2.

Before test

After test

Figure 6.5. Interior of Vehicle for Test No. 490025-7-2.

6.7 OCCUPANT RISK FACTORS

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. No occupant compartment contact was made occurred during the test, therefore, no OIV, RDA, THIV, or PHD were applicable. Maximum longitudinal 50-ms average acceleration of the vehicle was −1.0 G between 0.001 and 0.051 s, and maximum lateral 50-ms average acceleration was −0.3 G between 0.018 to 0.068 s. ASI was 0.09 between 0.014 and 0.064 s. Figure 6.6 summarizes the available data and other pertinent information from the test. Vehicle angular displacements are presented in Appendix C3, Figure C.3, and accelerations versus time traces are presented in Appendix C4, Figures C.4 through C.9.

6.8 ASSESSMENT OF TEST RESULTS

An assessment of the test based on applicable *MASH* safety evaluation criteria is presented below.

6.8.1 Structural Adequacy

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

Results: The 3-ft mounting height sign support system readily activated by yielding to the impacting vehicle and separating from its foundation. (PASS)

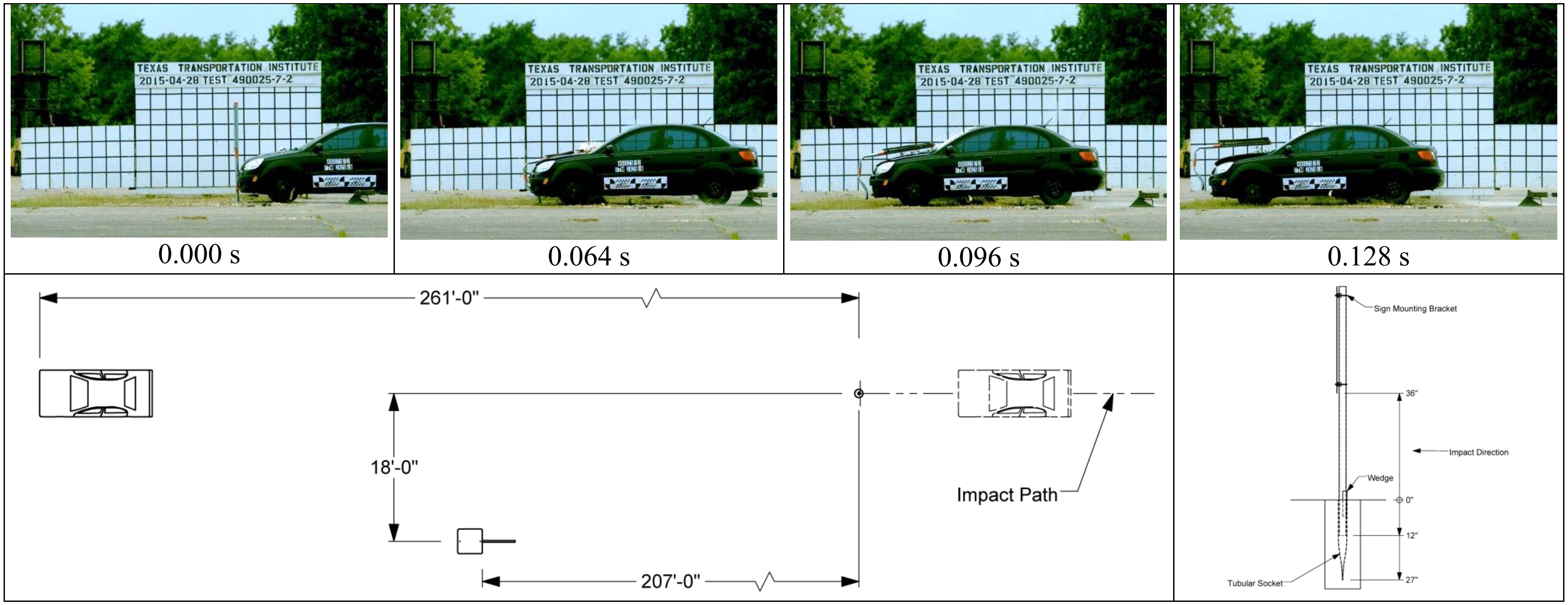
6.8.2 Occupant Risk

D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.

Deformation of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH. (roof ≤4.0 inches; windshield = ≤3.0 inches; side windows = no shattering by test article structural member; wheel/foot well/toe pan ≤9.0 inches; forward of A-pillar ≤12.0 inches; front side door area above seat ≤9.0 inches; front side door below seat ≤12.0 inches; floor pan/transmission tunnel area ≤12.0 inches).

Results: No detached elements, fragments, or other debris were present to penetrate or to show potential for penetrating the occupant compartment, or to present hazard to others in the area. (PASS)

No occupant compartment deformation or intrusion occurred. (PASS)



General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	MASH Test 3-61
TTI Test No.	490025-7-2
Date	2015-04-28

Test Article

Type	Sign Support
Name	TxDOT Low-Mounting Height Sign Support
Installation Height	3 ft from bottom of sign panel to grade
Material or Key Elements	3-ft square, 0.100-inch thick aluminum sign mounted on 2-inch diameter steel post
Soil Type and Condition	Concrete foundation in crushed limestone

Test Vehicle

Type/Designation	1100C
Make and Model	2009 Kia Rio
Curb	2389 lb
Test Inertial	2415 lb
Dummy	165 lb
Gross Static	2580 lb

Impact Conditions

Speed	64.0 mi/h
Angle	0 degrees
Location/Orientation	Right qtr pt

Exit Conditions

Speed	63.6 mi/h
Angle	NA

Occupant Risk Values

Longitudinal OIV	No contact
Lateral OIV	No contact
Longitudinal RDA	NA
Lateral RDA	NA
THIV	NA
PHD	NA
ASI	0.09 G
Longitudinal 50-ms Average	−1.0 G
Lateral 50-ms Average	−0.3 G
Vertical 50-ms Average	0.6 G

Post-Impact Trajectory

Stopping Distance	261 ft

Vehicle Stability

Maximum Yaw Angle	2 degrees
Maximum Pitch Angle	1degree
Maximum Roll Angle	1 degree
Vehicle Snagging	No
Vehicle Pocketing	No

Test Article Scatter

Longitudinal	207 ft
Lateral	18 ft
Working Width	

Vehicle Damage

VDS	12FR1
CDC	12FREN1
Max. Exterior Deformation	~0.5 inch
OCDI	RF0000000
Max. Occupant Compartment Deformation	None

Figure 6.6. Summary of Results for *MASH* Test 3-61 on the 3-ft Mounting Height Sign Support System.

F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.

Results: The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were each 1 degree. (PASS)

H. Occupant impact velocities should satisfy the following:

Longitudinal and Lateral Occupant Impact Velocity

Preferred	*Maximum*
10 ft/s	*16.4 ft/s*

Results: No occupant contact occurred during the test. (PASS)

I. Occupant ridedown accelerations should satisfy the following:

Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
16.0Gs	*20.49 Gs*

Results: No occupant contact occurred during the test. (PASS)

6.8.3 Vehicle Trajectory

N. Vehicle trajectory behind the test article is acceptable.

Result: The 1100C vehicle came to rest behind the test article.

CHAPTER 7. SUMMARY AND CONCLUSIONS

7.1 SUMMARY OF TEST RESULTS

7.1.1 *MASH* Test 3-60 (Crash Test No. 490025-7-1)

The 3-ft mounting height sign support system readily activated by yielding to the vehicle and deforming at the base. No detached elements, fragments, or other debris were present to penetrate or to show potential for penetrating the occupant compartment or to present hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were each 2 degrees. Occupant risk factors were within the preferred limits specified in *MASH*. The 1100C vehicle came to rest behind the test article.

7.1.2 *MASH* Test 3-61 (Crash Test No. 490025-7-2)

The 3-ft mounting height sign support system readily activated by yielding to the vehicle and separating from its base. No detached elements, fragments, or other debris were present to penetrate or to show potential for penetrating the occupant compartment or to present hazard to others in the area. Though the windshield was fractured in the lower right corner, it remained intact. No occupant compartment deformation or intrusion occurred. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were each 1 degree. No occupant contact occurred during the test; therefore, occupant risk factors were well below the preferred limits specified in *MASH*. The 1100C vehicle came to rest behind the test article.

7.2 CONCLUSIONS

The 3-ft mounting height sign support system performed acceptably for *MASH* Test 3-60 and 3-61, as shown in Tables 7.1 and 7.2. Test 3-62 with the 2270P pickup truck was not performed. Due to the reduced mounting height, the sign panel is not expected to interact with the pickup truck's windshield or cause vehicle damage and occupant risk greater than Test 3-61 with the small car.

Table 7.1. Performance Evaluation Summary for *MASH* Test 3-60 on the 3-ft Mounting Height Sign Support System.

Test Agency: Texas A&M Transportation Institute | Test No.: 490025-7-1 | Test Date: 2015-04-28

***MASH* Test 3-60 Evaluation Criteria**	**Test Results**	**Assessment**
<u>Structural Adequacy</u> *B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*	The 3-ft Mounting Height Sign Support System readily activated by yielding to the vehicle and deforming at the base.	Pass
<u>Occupant Risk</u> *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	No detached elements, fragments, or other debris were present to penetrate or to show potential for penetrating the occupant compartment or to present hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No occupant compartment deformation or intrusion occurred.	Pass
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 2 degrees each.	Pass
H. Longitudinal and lateral occupant impact velocities should fall below the preferred value of 10 ft/s, or at least below the maximum allowable value of 16.4 ft/s.	Longitudinal OIV was 3.6 ft/s, and lateral OIV was 0.7 ft/s.	Pass
I. Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 Gs or at least below the maximum allowable value of 20.49 Gs.	Longitudinal RDA was 0.3 G, and lateral RDA was 0.3 G.	Pass
<u>Vehicle Trajectory</u> *N. Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest behind the test article.	Pass

Table 7.2. Performance Evaluation Summary for *MASH* Test 3-61 on the 3-ft Mounting Height Sign Support System.

Test Agency: Texas A&M Transportation Institute | Test No.: 490025-7-2 | Test Date: 2015-04-28

***MASH* Test 3-61 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy *B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*	The 3-ft Mounting Height Sign Support System readily activated by yielding to the vehicle and separating from its base.	Pass
Occupant Risk *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	No detached elements, fragments, or other debris were present to penetrate or to show potential for penetrating the occupant compartment, or to present hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No occupant compartment deformation or intrusion occurred.	Pass
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1 degree each.	Pass
H. Longitudinal and lateral occupant impact velocities should fall below the preferred value of 10 ft/s, or at least below the maximum allowable value of 16.4 ft/s.	No occupant contact occurred during the test.	Pass
I. Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 Gs or at least below the maximum allowable value of 20.49 Gs.	No occupant contact occurred during the test.	Pass
Vehicle Trajectory *N. Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest behind the test article.	Pass

CHAPTER 8. IMPLEMENTATION STATEMENT*

The 3-ft × 3-ft aluminum sign panel supported on a wedge anchored sign support at a mounted height of 3 ft from grade to the bottom of the sign panel is acceptable under *MASH* impact performance guidelines and is considered suitable for implementation. A possible application for this support system is to help alert motorists that have inadvertently entered opposing traffic lanes or ramps from the wrong direction.

It should be noted that the successful performance of the sign at a 3-ft mounting height is dependent on the type of sign support used in these tests (i.e., TxDOT's wedge anchored support). Other breakaway sign supports are designed to function differently. Therefore, the 3-ft mounting height should not be used in conjunction with other breakaway sign supports, such as the slip-base design, without further evaluation through full-scale testing.

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

REFERENCES

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

APPENDIX A. CERTIFICATION DOCUMENTATION

MATERIAL USED

TEST NUMBER	490025-7
TEST NAME	Low-mount Sign
DATE	2015-04-28

#	DATE RECEIVED	DESCRIPTION	GRADE	YIELD	TENSILE	SUPPLIER
14-054	2015-04-14	Sign Parts		see list		N-Line

Texas A&M Transportation Institute Proving Ground - 3100 SH 47, Bldg 7091, Bryan, TX 77807 Texas A&M University, College Station, TX 77843, Phone 979-845-6375	4.6P Purchasing Request	Doc. No. QPF 4.6P	Revision Date: 2013-01-15
Quality Policy Form	Revised by: R. A. Zimmer Approved by: R. A. Zimmer	Revision: 1	Page: 1 of 1

Name of Person Making Request: GERKE	Name of Person to be Shipped to: (if different than Requestor)
Project Number or Name: 490025-7	Order Date: 2015-04-14
Vendor: N-LINE	Phone or E-mail Address:
Vendor Agent Name:	Expected Delivery Date (if given):

Describe Item(s), and Part No(s) if known:	Estimated Cost(s):
2- POZ-LOCK SOCKET & WEDGE	
2- 10' 2⅜ 13 GAUGE POST	
4- U BOLT SIGN BRACKET	
2- 36"x36" x 0.1 ALUM ~~STD~~ SIGNS.	

Section Supervisor Approval: Signature: ______ Date: ______	If Major Purchase, Office Manager Approval: Signature: ______ Date: ______

The section below shall be used to verify receipt and inspection of ordered items.

Received on (date):	Qty. Received	Inspected by (print name):	☐ Item received in good condition
Comments (if necessary):			☐ Item received in poor condition
			☐ Other (specify in Comments section)

Please attach copies of all related material/certificates and give to Inventory Manager.

APPENDIX B. *MASH* TEST 3-60 (CRASH TEST 4900205-7-1)

B1 TEST VEHICLE DOCUMENTATION

Table B.1. Vehicle Properties for Test No. 490025-7-1.

Date: 2015-04-28 Test No.: 490025-7-1 VIN No.: KNADE223696494829

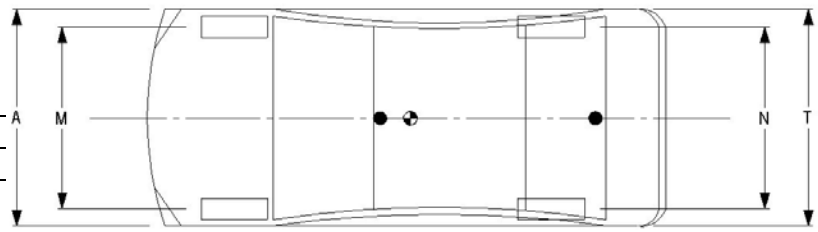
Year: 2009 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 96953 Tire Size: 185/65R14

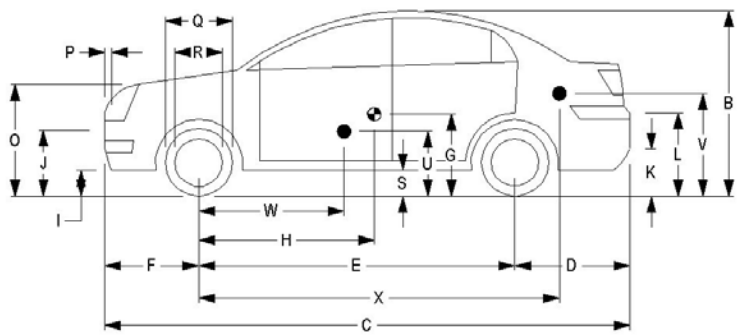
Describe any damage to the vehicle prior to test: Small indentation in right side hood and windshield shattered in lower right side but remained intact (from Test No. 490025-7-2, which was performed first)

● Denotes accelerometer location.

NOTES: None



Engine Type: 4 cylinder
Engine CID: 1.6 liter
Transmission Type:
____ Auto or x Manual
x FWD ____ RWD ____ 4WD
Optional Equipment:
NA



Dummy Data:
Type: 50th percentile male
Mass: 165 lb
Seat Position: Passenger side

Geometry: inches

A	66.38	F	33.00	K	12.75	P	4.12	U	14.50
B	58.25	G	-----	L	25.00	Q	22.19	V	21.50
C	165.75	H	39.13	M	57.75	R	15.38	W	44.00
D	34.00	I	9.50	N	57.12	S	9.00	X	109.00
E	98.75	J	21.50	O	31.50	T	66.12		
	Wheel Center Ht Front		11.00	Wheel Center Ht Rear			11.00		

RANGE LIMIT: A = 65 ±3 inches; C = 168 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; G = 39 ±4 inches; O = 24 ±4 inches; M+N/2 = 56 ±2 inches

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1918	M_{front}	1469	1458	1545
Back	1874	M_{rear}	920	957	1035
Total	3638	M_{Total}	2389	2415	2580

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

Mass Distribution:
lb LF: 709 RF: 749 LR: 488 RR: 469

Table B.2. Exterior Crush Measurements for Test No. 490025-7-1.

Date:	2015-04-28	Test No.:	490025-7-1	VIN No.:	KNADE223696494829
Year:	2009	Make:	Kia	Model:	Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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	None measureable										
	Measurements recorded										
	in inches										

[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).

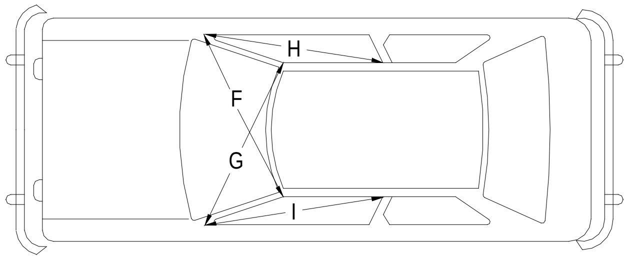
***Measure and document on the vehicle diagram the location of the maximum crush.

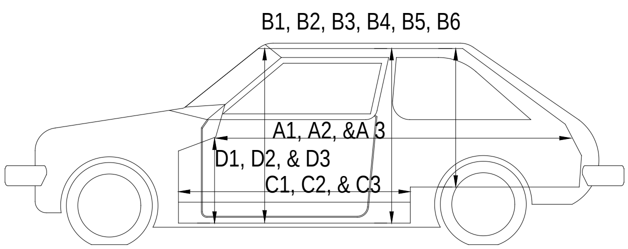
Note: Use as many lines/columns as necessary to describe each damage profile.

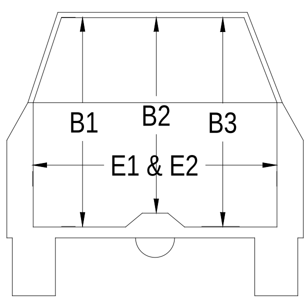
Table B.3. Occupant Compartment Measurements for Test No. 490025-7-1.

Date: 2015-04-28 Test No.: 490025-7-1 VIN No.: KNADE223696494829

Year: 2009 Make: Kia Model: Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	**After** (inches)
A1	67.75	67.75
A2	67.25	67.25
A3	68.00	68.00
B1	40.50	40.50
B2	35.75	35.75
B3	40.50	40.50
B4	32.75	32.75
B5	32.75	32.75
B6	32.75	32.75
C1	27.50	27.50
C2	-----	-----
C3	26.75	26.75
D1	9.75	9.75
D2	-----	-----
D3	9.75	9.75
E1	51.25	51.25
E2	51.00	51.00
F	50.50	50.50
G	50.50	50.50
H	38.00	38.00
I	38.00	38.00
J*	50.75	50.75

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

B2 SEQUENTIAL PHOTOGRAPHS

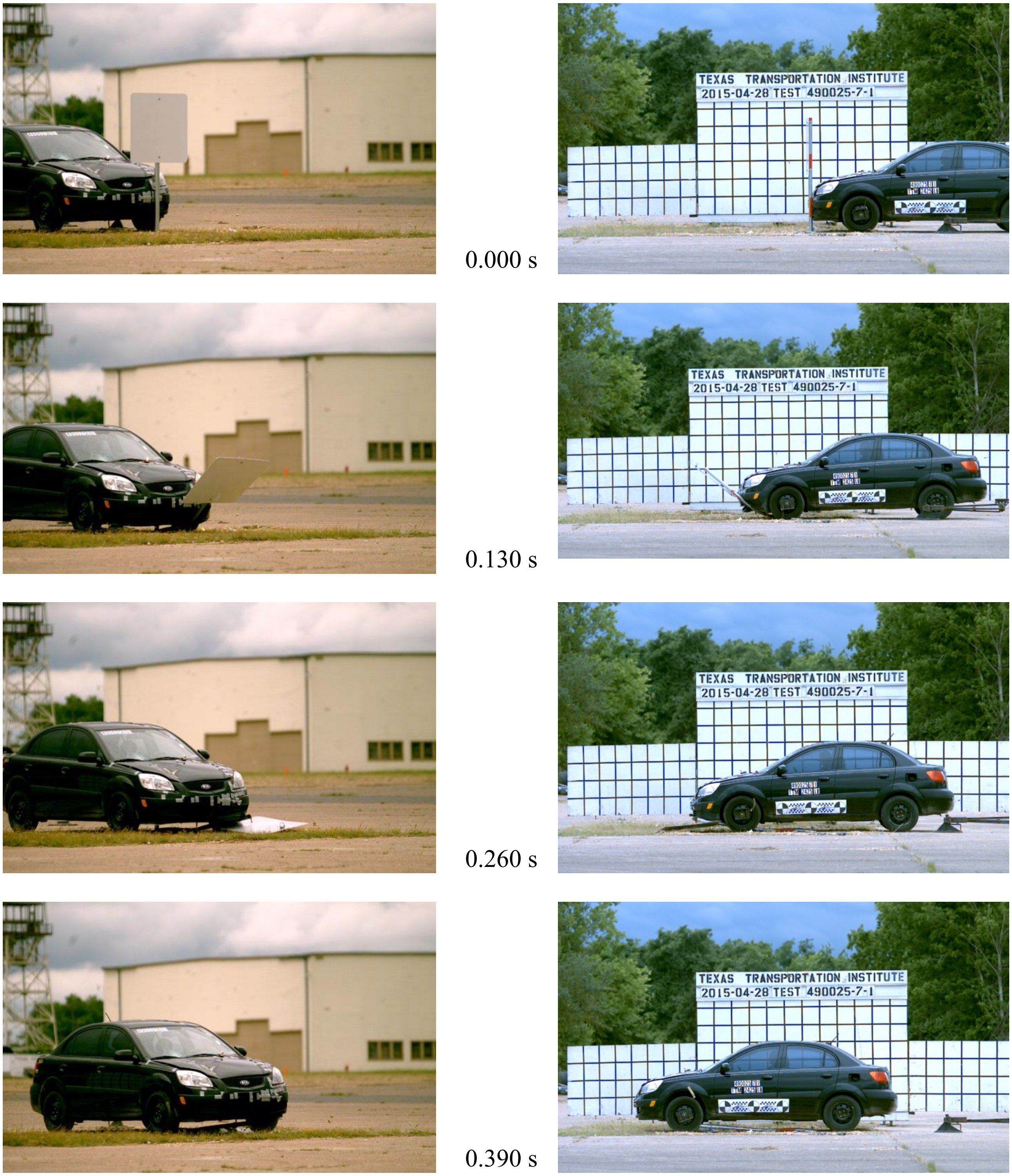


Figure B.1. Sequential Photographs for Test No. 490025-7-1 (Frontal Views).

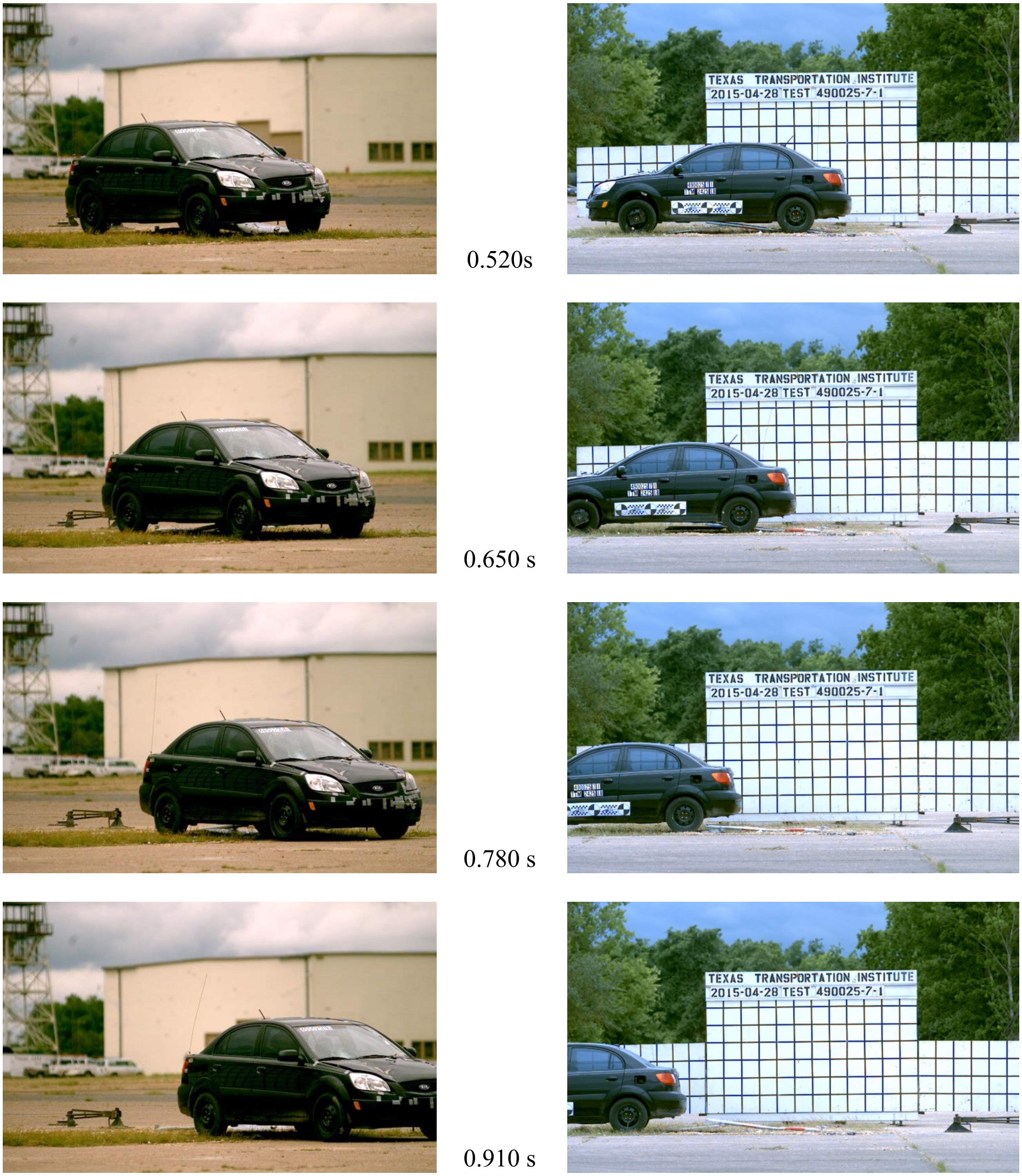


Figure B.1. Sequential Photographs for Test No. 490025-7-1 (Frontal Views) (continued).

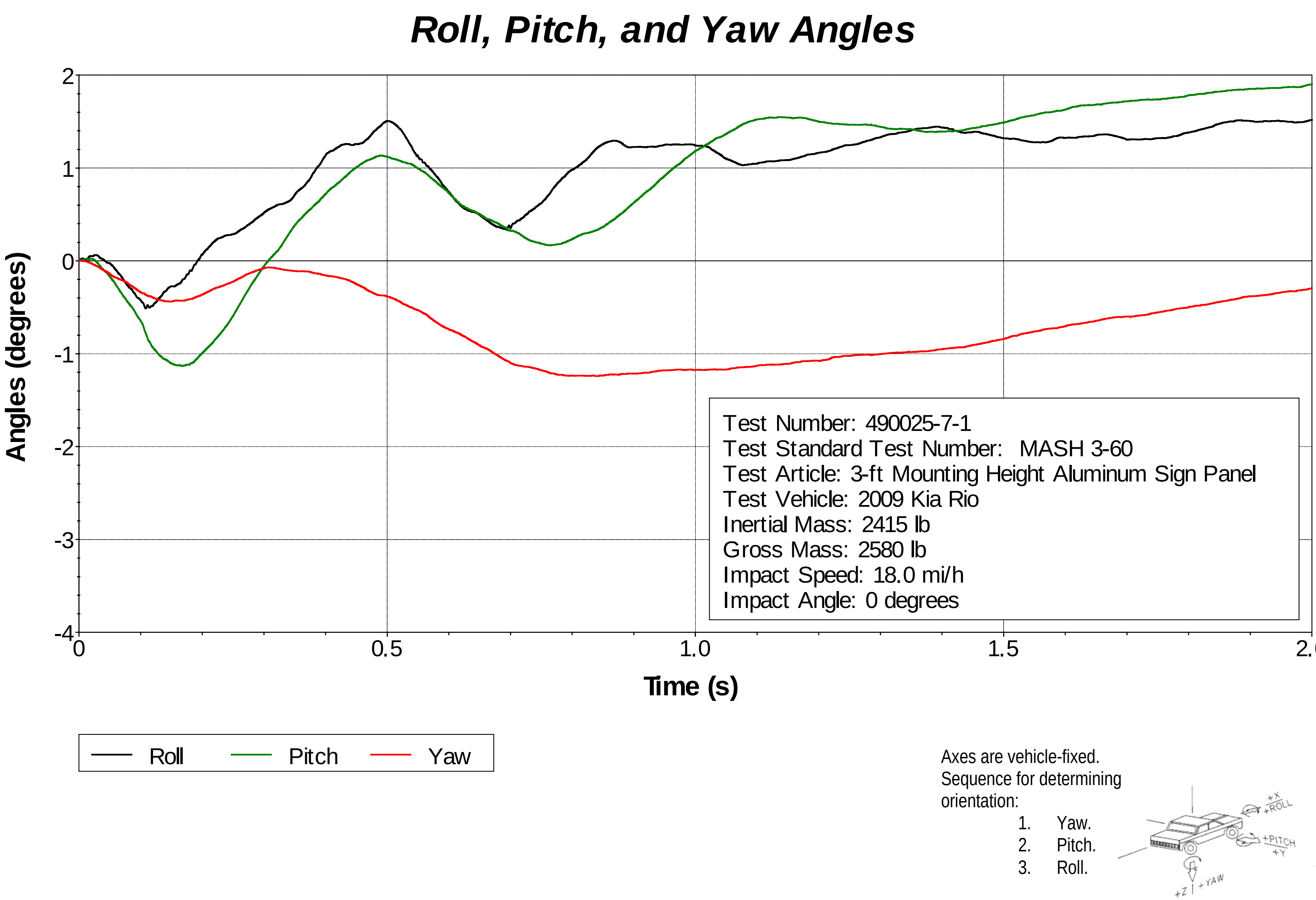


Figure B.2. Vehicle Angular Displacements for Test No. 490025-7-1.

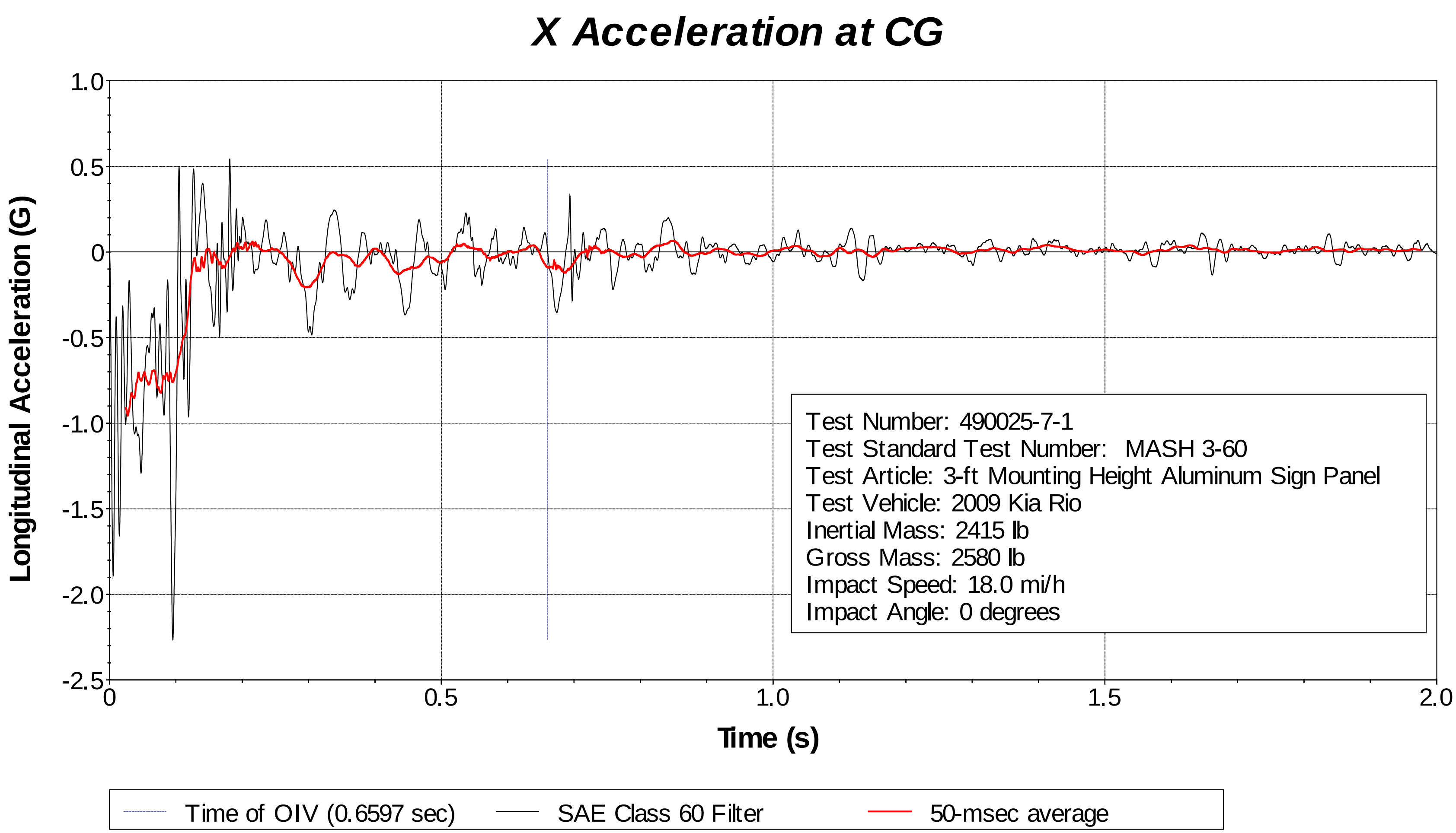


Figure B.3. Vehicle Longitudinal Accelerometer Trace for Test No. 490025-7-1 (Accelerometer Located at Center of Gravity).

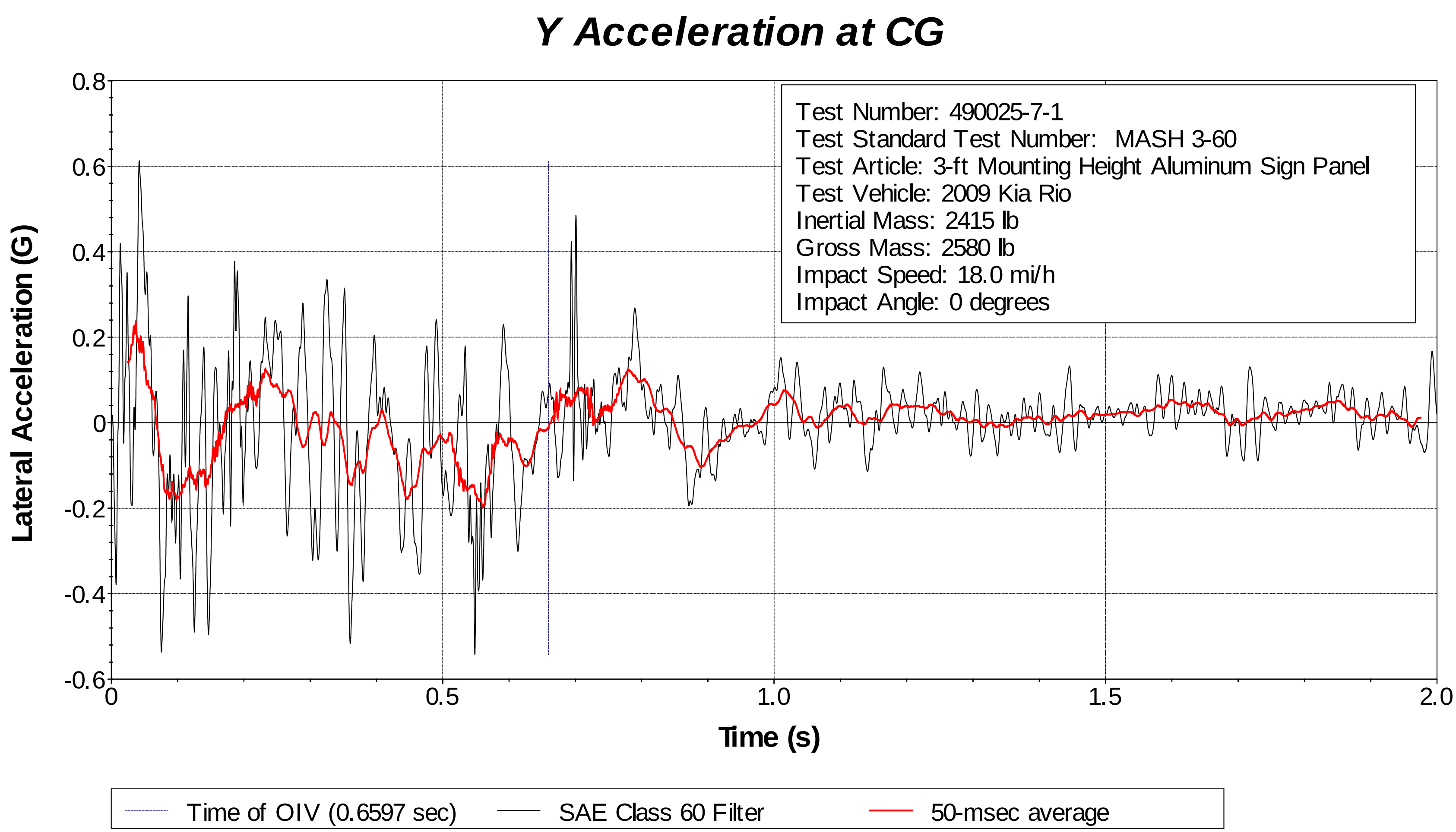


Figure B.4. Vehicle Lateral Accelerometer Trace for Test No. 490025-7-1 (Accelerometer Located at Center of Gravity).

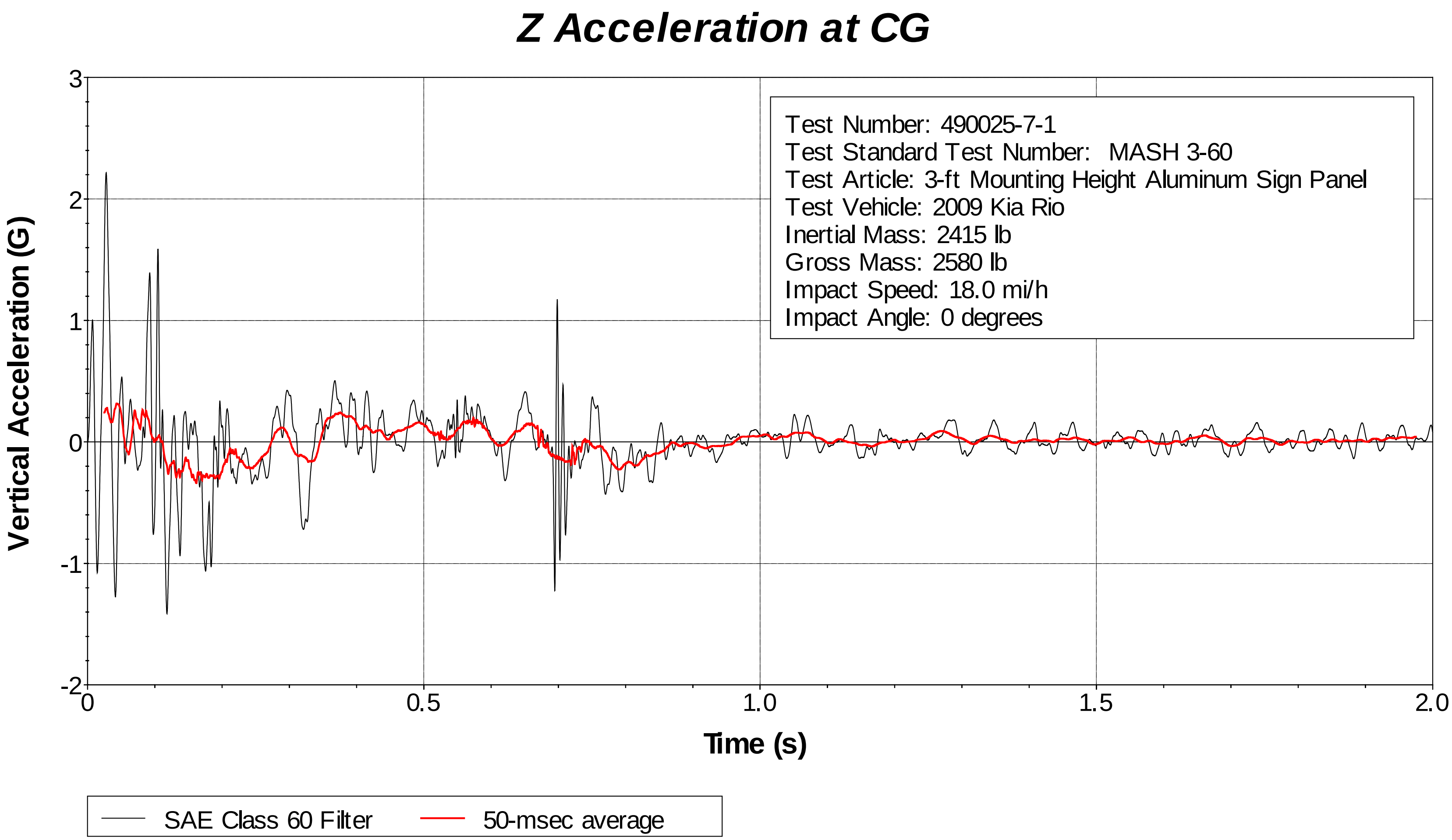


Figure B.5. Vehicle Vertical Accelerometer Trace for Test No. 490025-7-1 (Accelerometer Located at Center of Gravity).

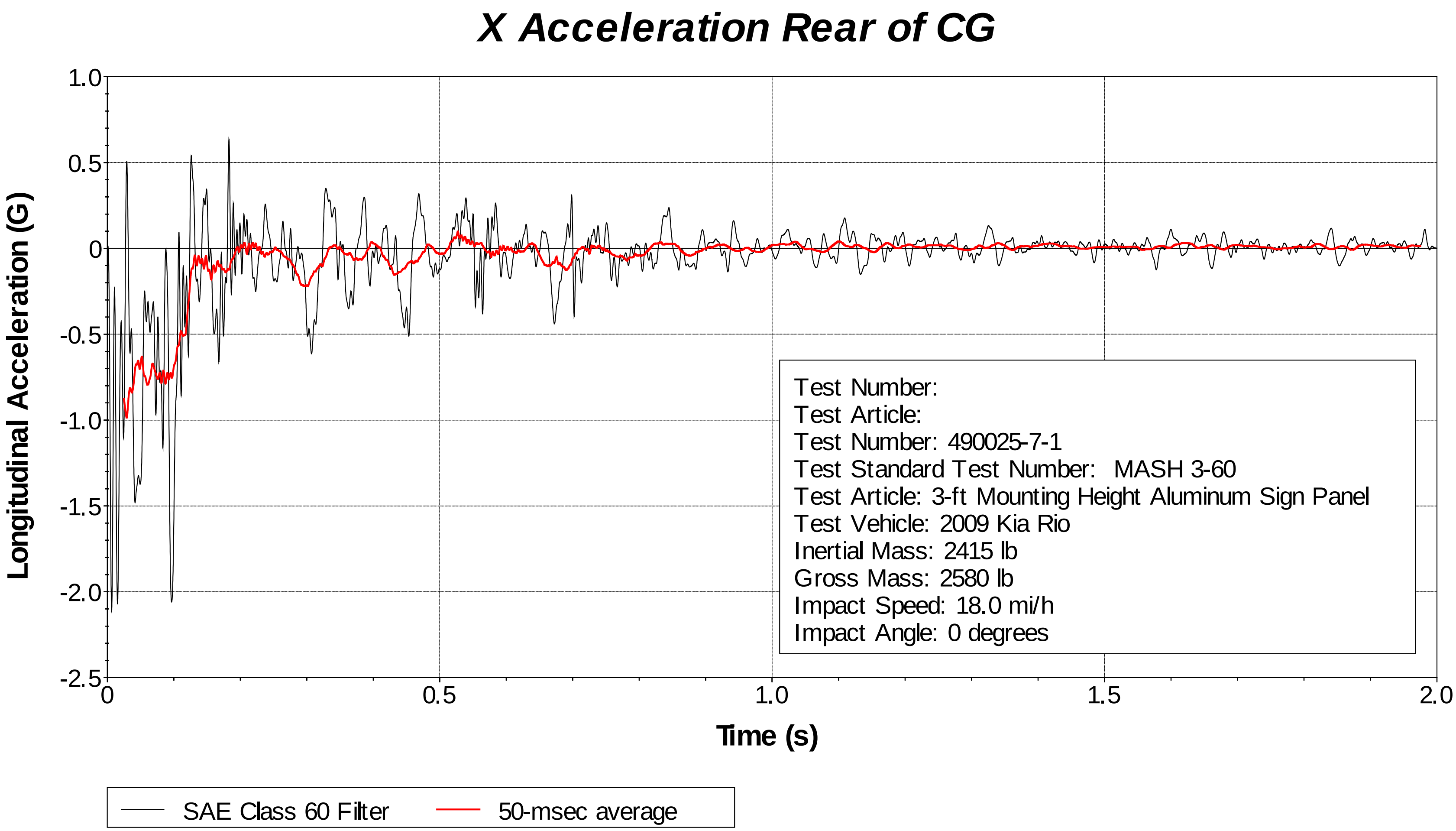


Figure B.6. Vehicle Longitudinal Accelerometer Trace for Test No. 490025-7-1 (Accelerometer Located Rear of Center of Gravity).

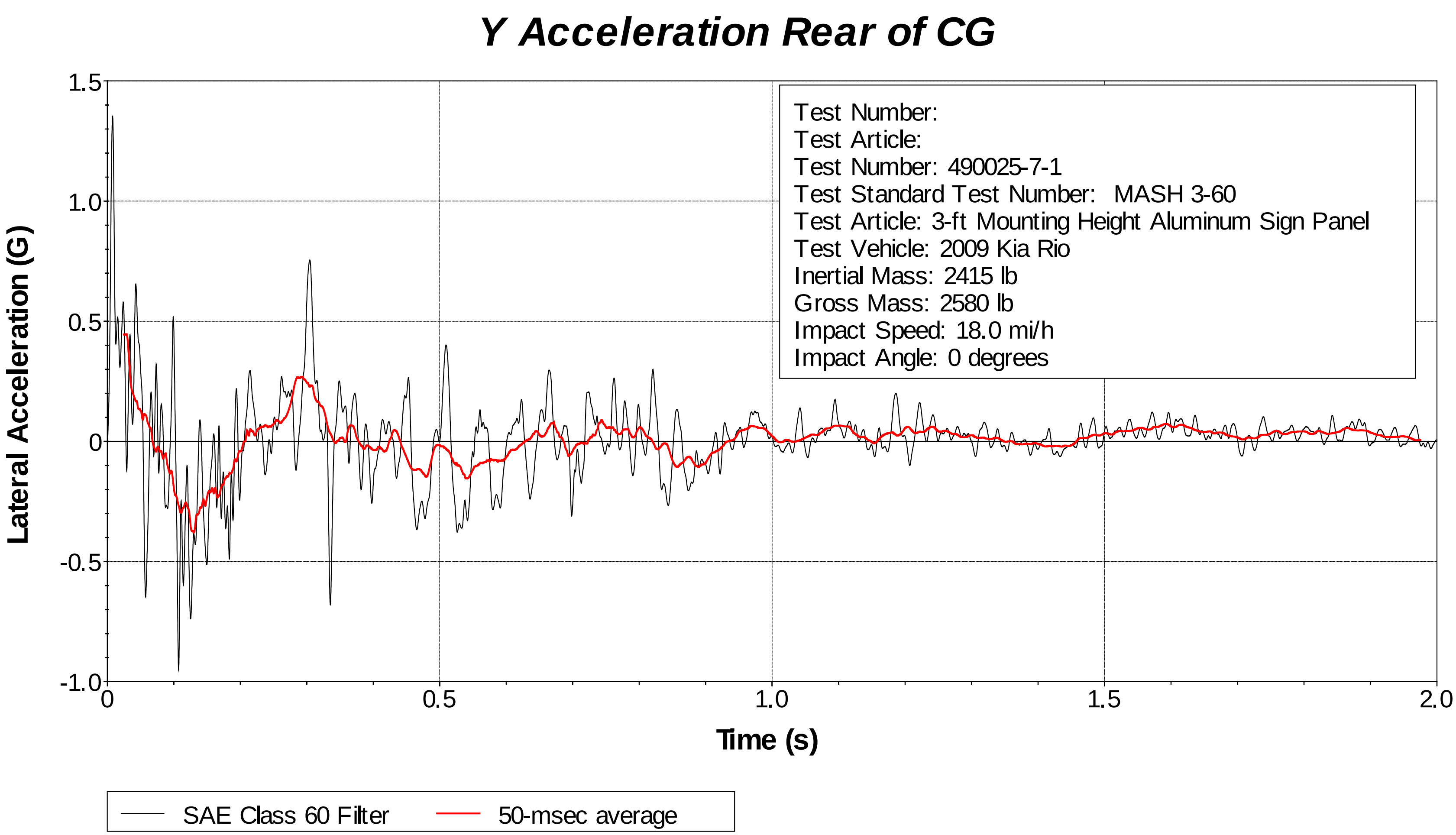


Figure B.7. Vehicle Lateral Accelerometer Trace for Test No. 490025-7-1 (Accelerometer Located Rear of Center of Gravity).

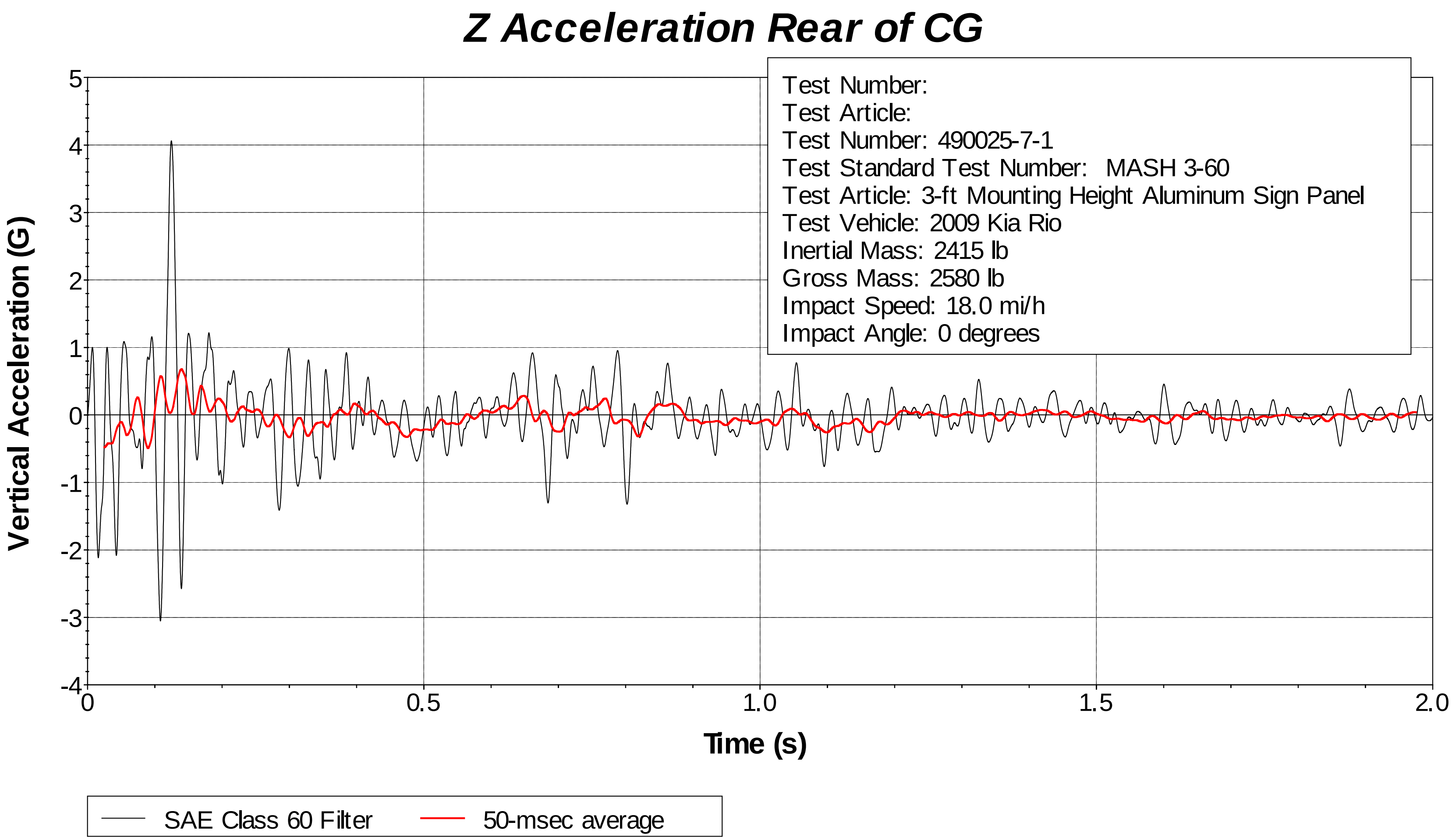


Figure B.8. Vehicle Vertical Accelerometer Trace for Test No. 490025-7-1 (Accelerometer Located Rear of Center of Gravity).

APPENDIX C. *MASH* TEST 3-61 (CRASH TEST 4900205-7-2)

C1 TEST VEHICLE DOCUMENTATION

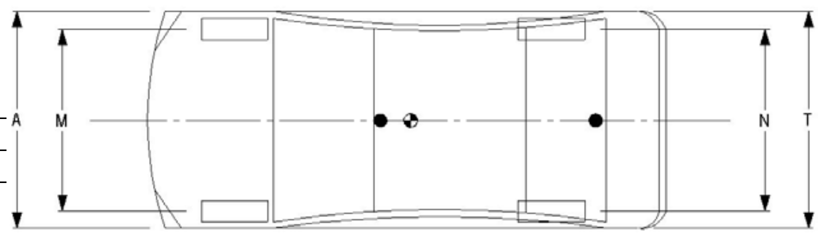
Table C.1. Vehicle Properties for Test No. 490025-7-2.

Date: 2015-04-28 Test No.: 490025-7-2 VIN No.: KNADE223696494829

Year: 2009 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 96953 Tire Size: 185/65R14

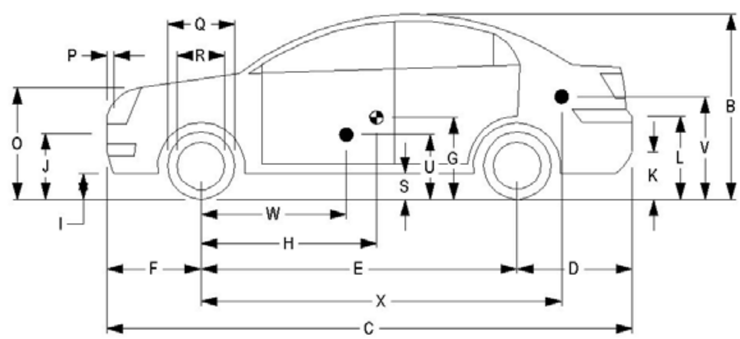
Describe any damage to the vehicle prior to test: None



● Denotes accelerometer location.

NOTES: None

Engine Type: 4 cylinder
Engine CID: 1.6 liter
Transmission Type:
____ Auto or x Manual
x FWD ____ RWD ____ 4WD
Optional Equipment:
NA



Dummy Data:
Type: 50th percentile male
Mass: 165 lb
Seat Position: Passenger side

Geometry: inches

A	66.38	F	33.00	K	12.75	P	4.12	U	14.50
B	58.25	G	-----	L	25.00	Q	22.19	V	21.50
C	165.75	H	39.13	M	57.75	R	15.38	W	44.00
D	34.00	I	9.50	N	57.12	S	9.00	X	109.00
E	98.75	J	21.50	O	31.50	T	66.12		
Wheel Center Ht Front			11.00	Wheel Center Ht Rear			11.00		

RANGE LIMIT: A = 65 ±3 inches; C = 168 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; G = 39 ±4 inches;
O = 24 ±4 inches; M+N/2 = 56 ±2 inches

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1918	M_{front}	1469	1458	1545
Back	1874	M_{rear}	920	957	1035
Total	3638	M_{Total}	2389	2415	2580

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

Mass Distribution:
lb LF: 709 RF: 749 LR: 488 RR: 469

Table C.2. Exterior Crush Measurements for Test No. 490025-7-2.

Date: 2015-04-28 Test No.: 490025-7-2 VIN No.: KNADE223696494829

Year: 2009 Make: Kia Model: Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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	None measureable										
	Measurements recorded										
	in inches										

[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).

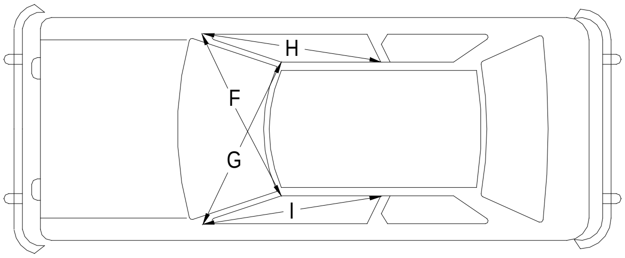
***Measure and document on the vehicle diagram the location of the maximum crush.

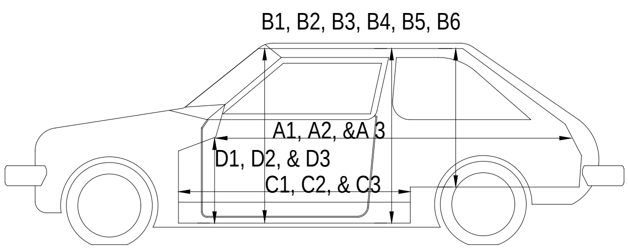
Note: Use as many lines/columns as necessary to describe each damage profile.

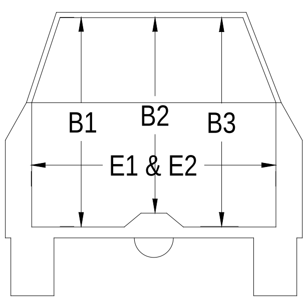
Table C.3. Occupant Compartment Measurements for Test No. 490025-7-2.

Date: 2015-04-28 Test No.: 490025-7-2 VIN No.: KNADE223696494829

Year: 2009 Make: Kia Model: Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	67.75	67.75
A2	67.25	67.25
A3	68.00	68.00
B1	40.50	40.50
B2	35.75	35.75
B3	40.50	40.50
B4	32.75	32.75
B5	32.75	32.75
B6	32.75	32.75
C1	27.50	27.50
C2	-----	-----
C3	26.75	26.75
D1	9.75	9.75
D2	-----	-----
D3	9.75	9.75
E1	51.25	51.25
E2	51.00	51.00
F	50.50	50.50
G	50.50	50.50
H	38.00	38.00
I	38.00	38.00
J*	50.75	50.75

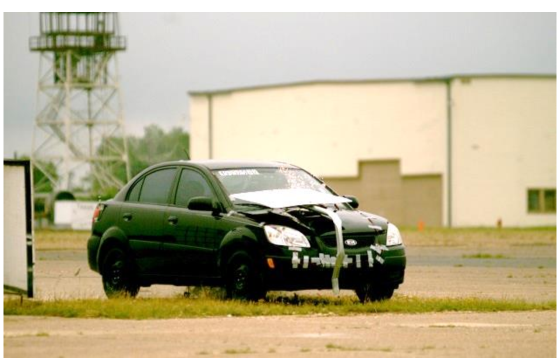
*Lateral area across the cab from
driver’s side kickpanel to passenger’s side kickpanel.

C2 SEQUENTIAL PHOTOGRAPHS

0.000 s

0.032 s

0.064 s



0.096 s

Figure C.1. Sequential Photographs for Test No. 490025-7-2 (Frontal Views).

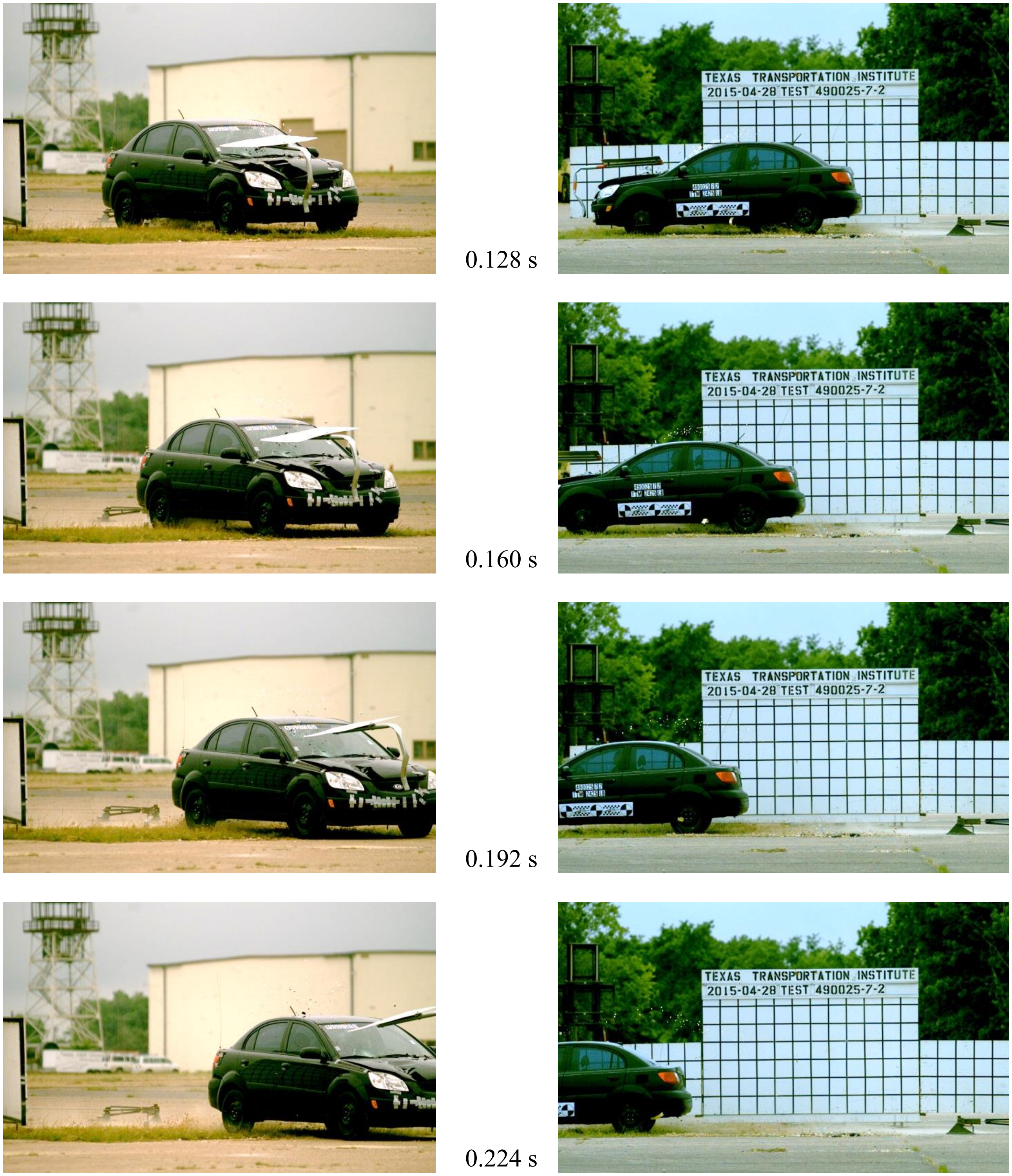


Figure C.1. Sequential Photographs for Test No. 490025-7-2 (Frontal Views) (continued).

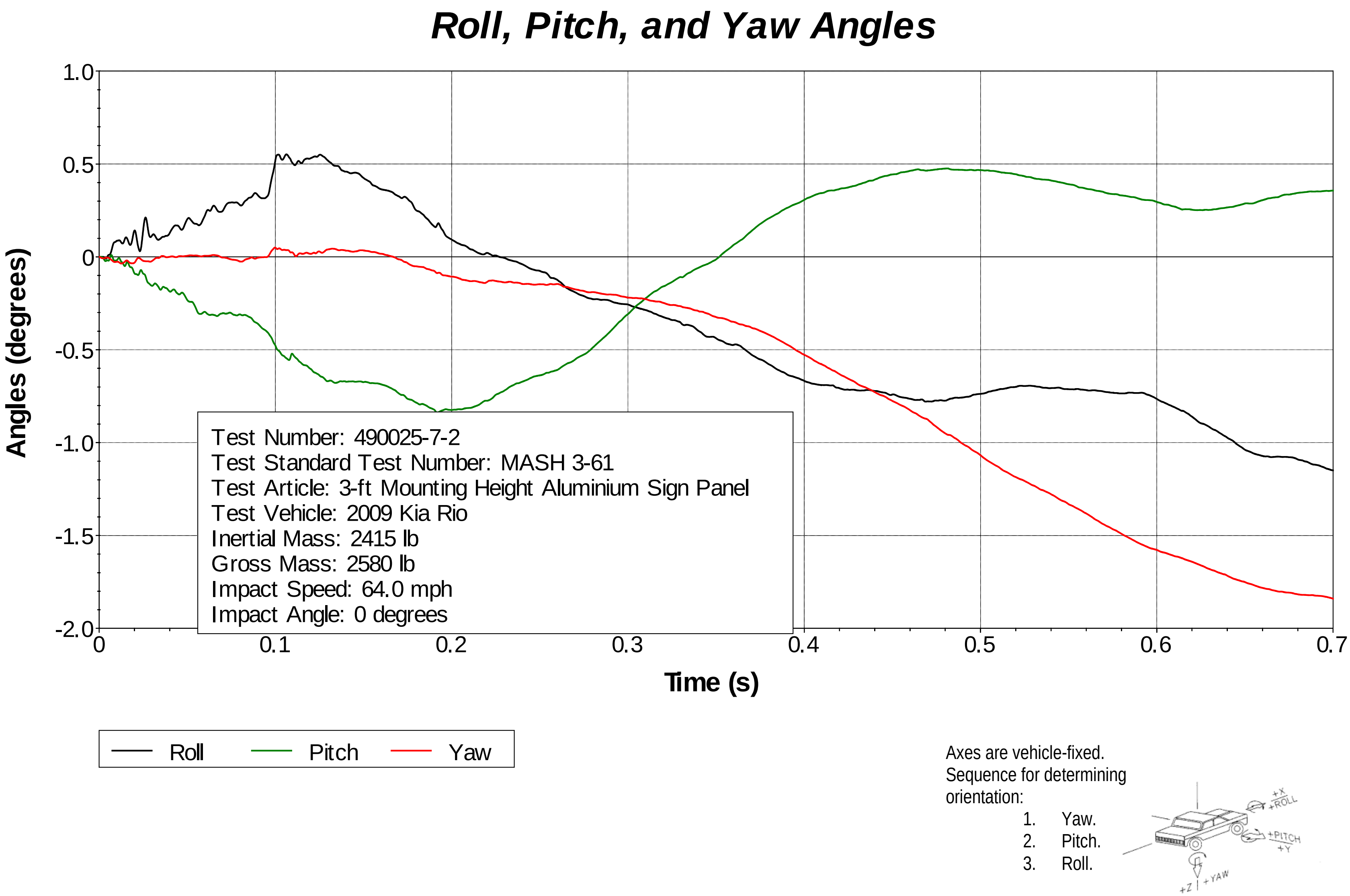


Figure C.2. Vehicle Angular Displacements for Test No. 490025-7-2.

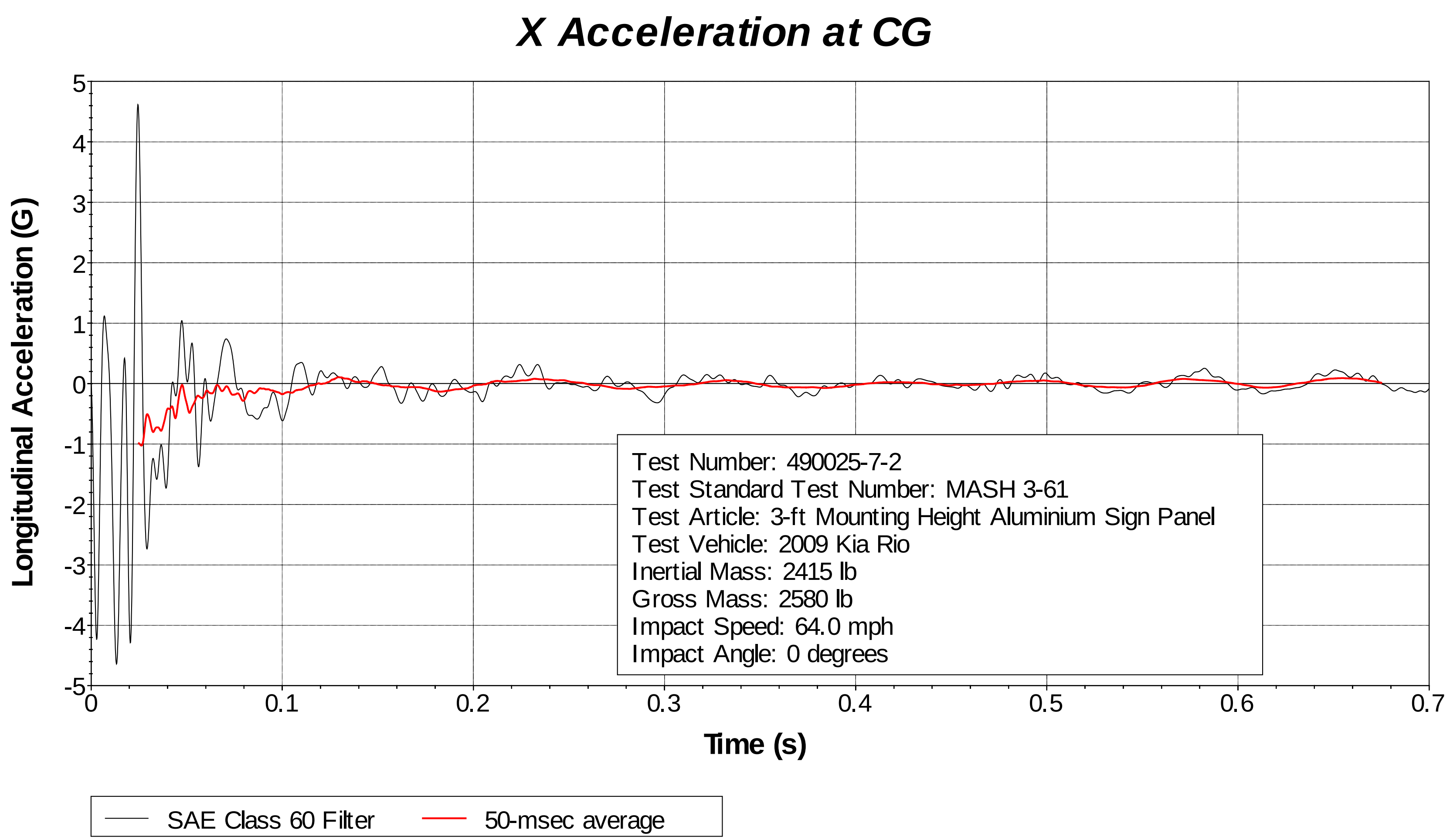


Figure C.3. Vehicle Longitudinal Accelerometer Trace for Test No. 490025-7-2 (Accelerometer Located at Center of Gravity).

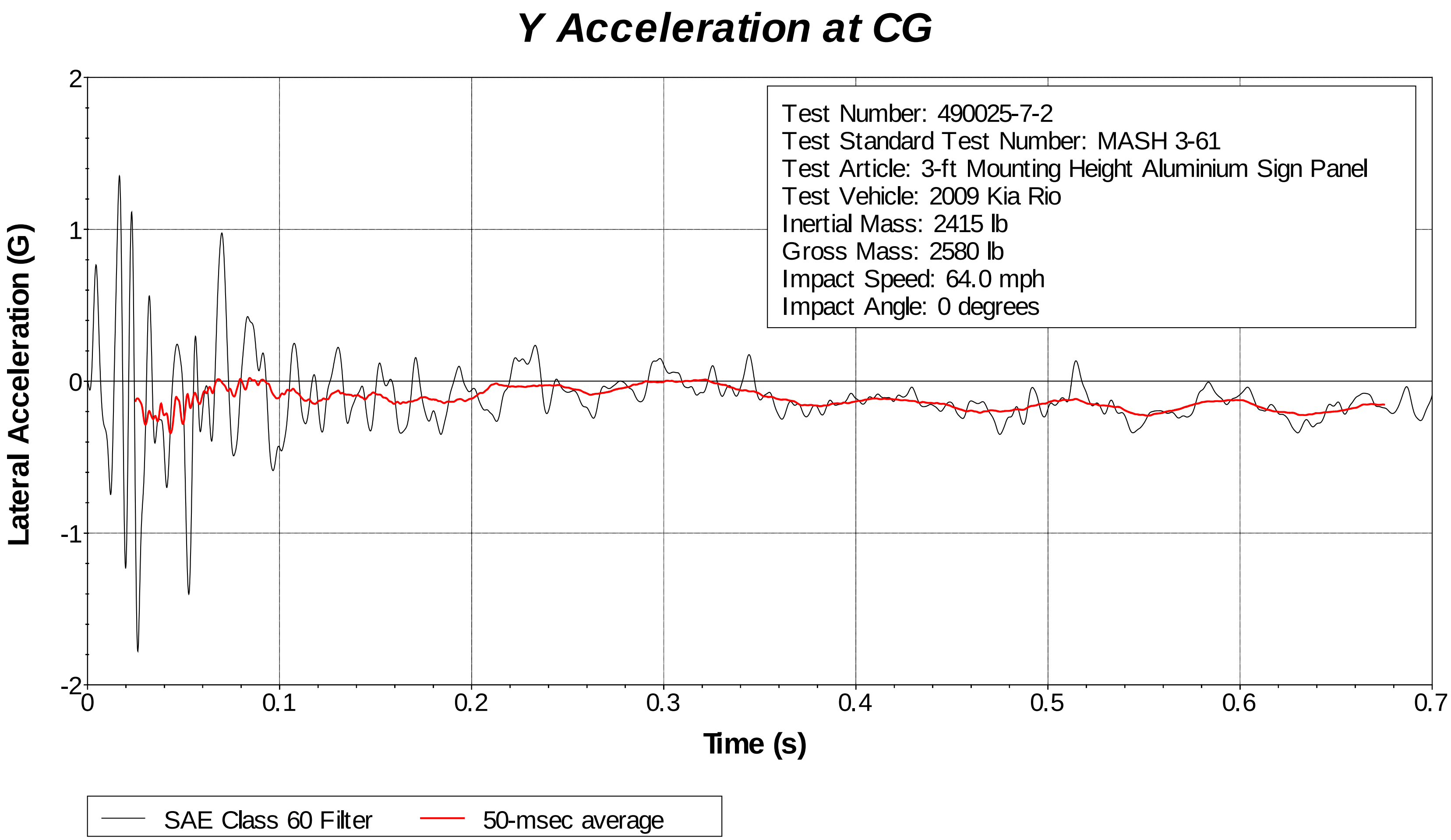


Figure C.4. Vehicle Lateral Accelerometer Trace for Test No. 490025-7-2 (Accelerometer Located at Center of Gravity).

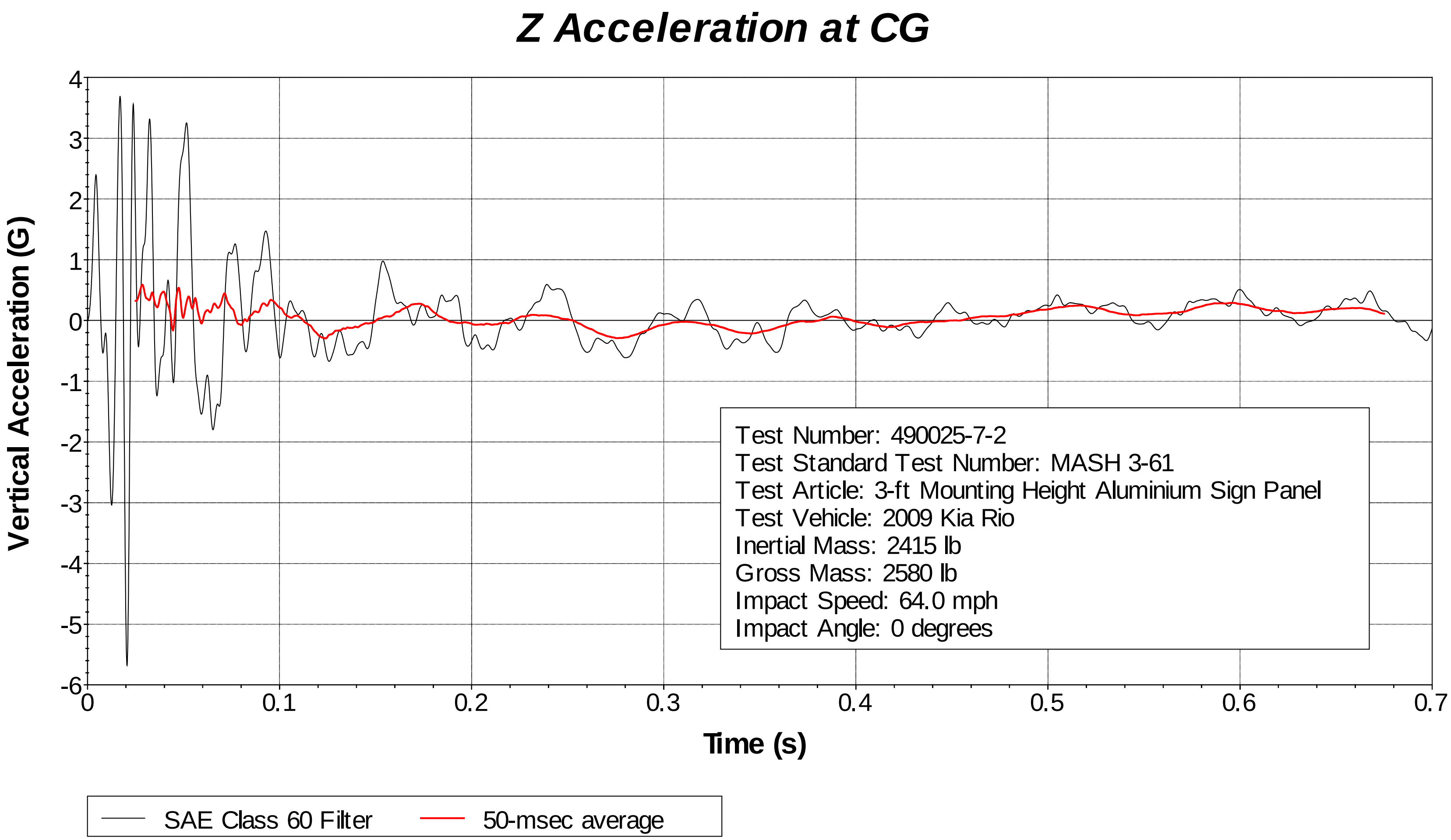


Figure C.5. Vehicle Vertical Accelerometer Trace for Test No. 490025-7-2 (Accelerometer Located at Center of Gravity).

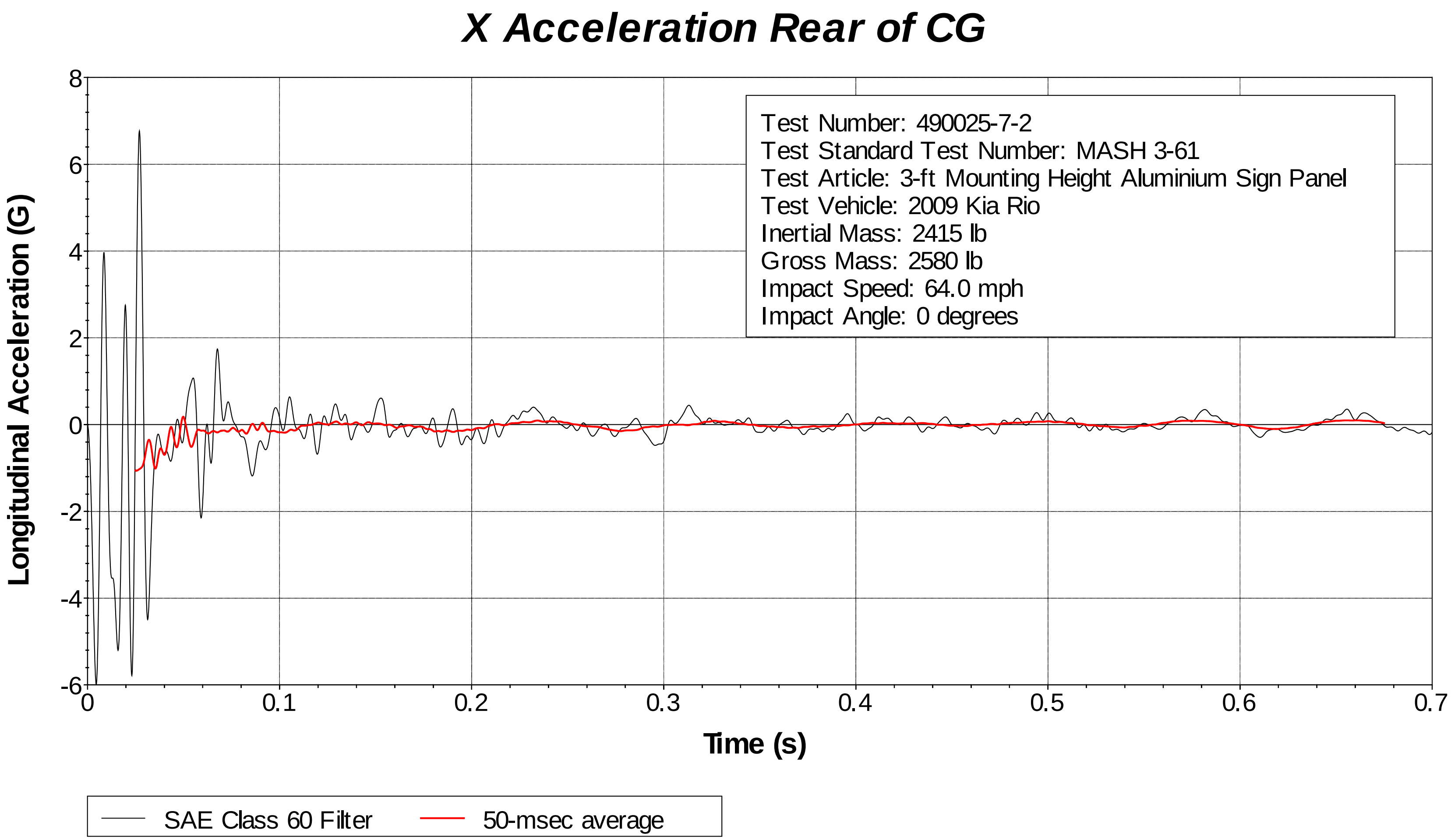


Figure C.6. Vehicle Longitudinal Accelerometer Trace for Test No. 490025-7-2 (Accelerometer Located Rear of Center of Gravity).

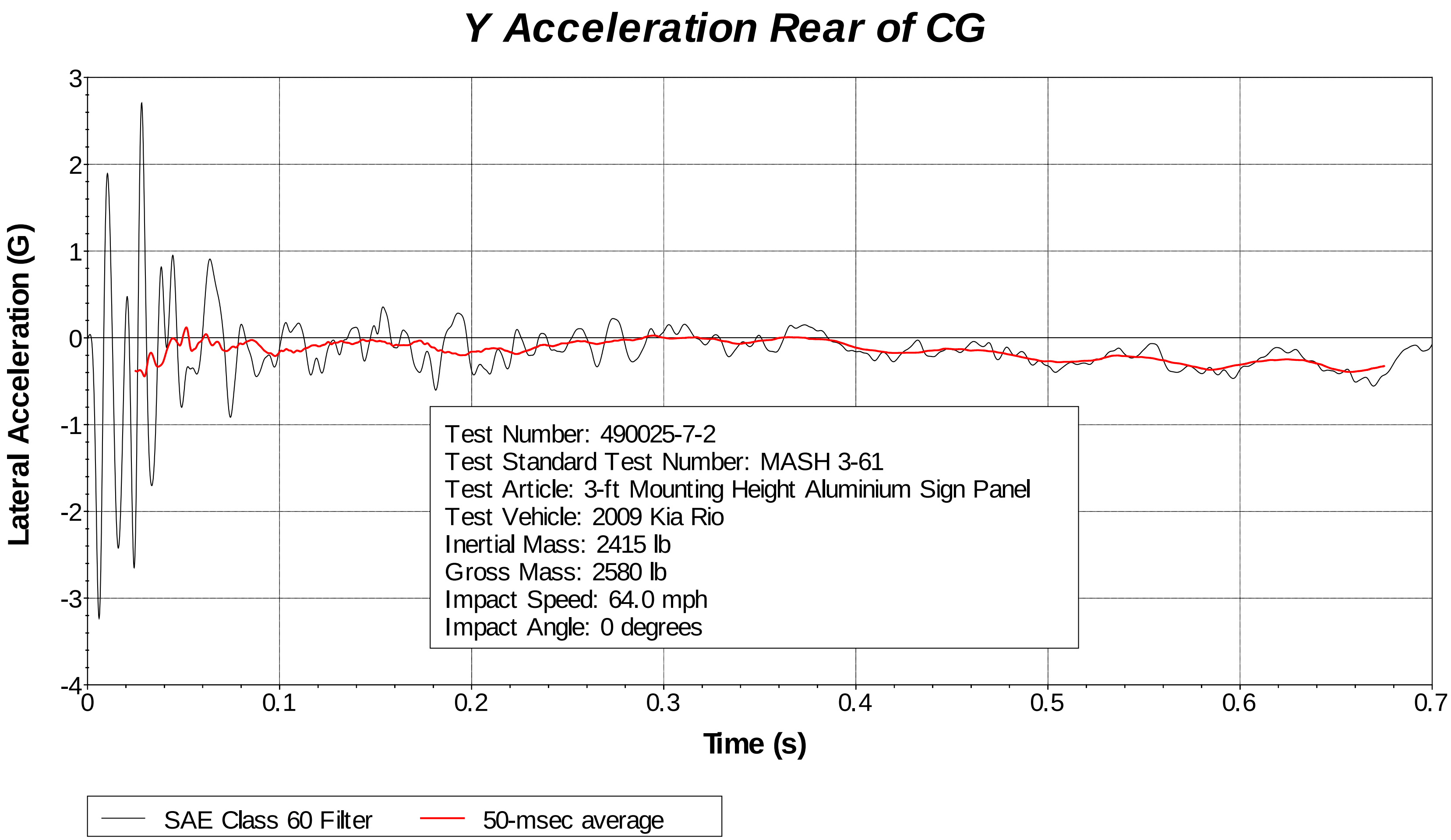


Figure C.7. Vehicle Lateral Accelerometer Trace for Test No. 490025-7-2 (Accelerometer Located Rear of Center of Gravity).

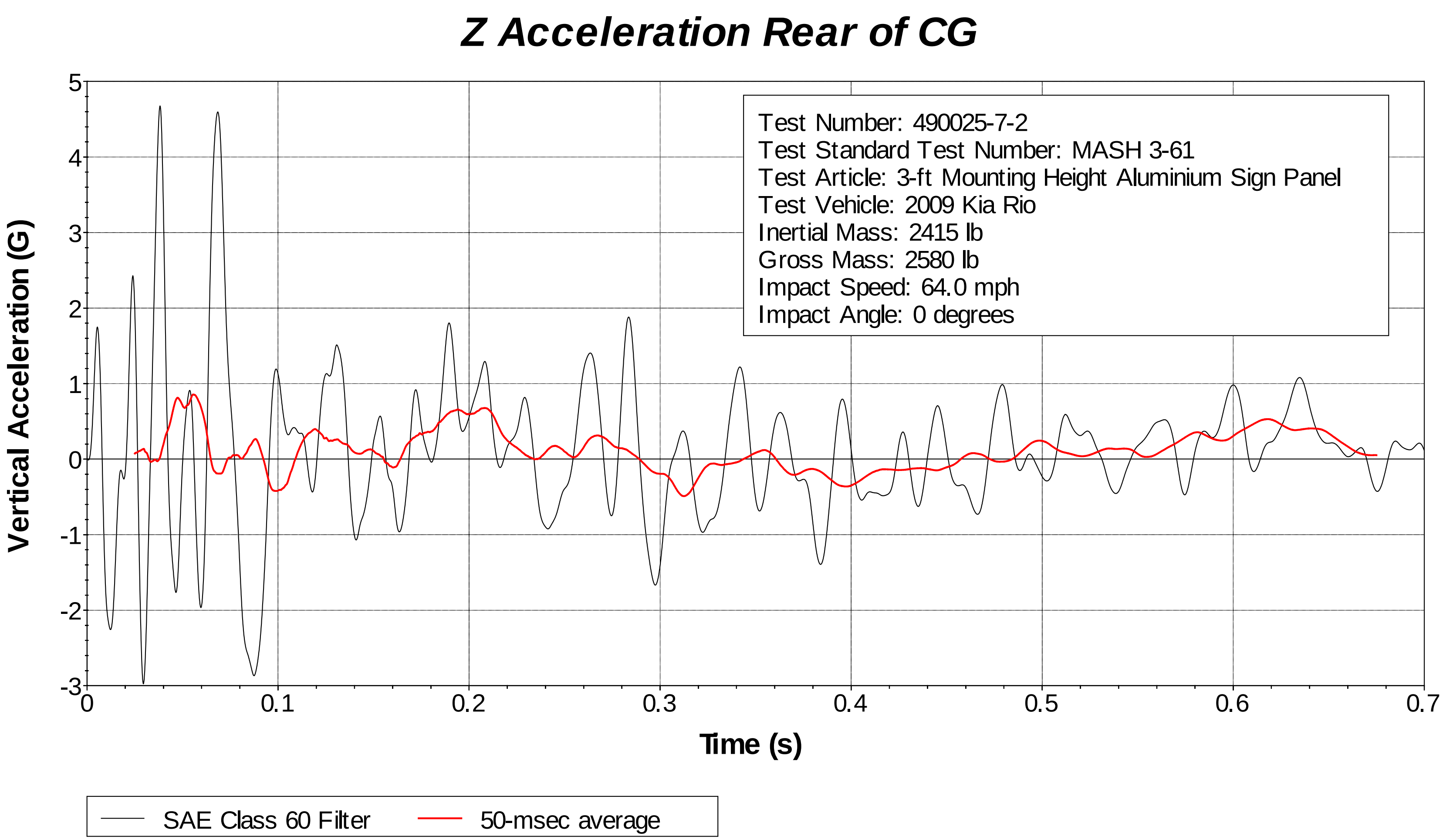


Figure C.8. Vehicle Vertical Accelerometer Trace for Test No. 490025-7-2 (Accelerometer Located Rear of Center of Gravity).