TTI: 9-1002-12

CRASH TEST AND EVALUATION OF LOCKING ARCHITECTURAL MAILBOXES

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 No. 9-1002-12-9

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
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16. Abstract

Some homeowners and businesses are becoming increasingly concerned about mail-identity theft. Consequently, there is a growing demand for the use of locking mailboxes for theft deterrence and vandal resistance. There are a number of mailbox products on the market that offer enhanced security for mail and small parcels. They typically feature an upper hopper for incoming mail, and a lower lockable compartment for mail retrieval.

These lockable mailboxes are significantly larger and can be 4–5 times heavier than standard mailboxes. Therefore, TxDOT requested evaluation of their crashworthiness before permitting their use on the state highway system.

Under this project, crash tests were performed following *MASH* guidelines and procedures to assess the impact performance of lockable, secure mailboxes on both single and multiple mount configurations. A single locking mailbox was successfully crash tested on a thin-wall steel tube support post installed in a releasable wedge-and-socket foundation. Testing of the larger, heavier locking mailboxes on multiple-mount support posts was unsuccessful due to windshield deformation and intrusion.

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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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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 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 breakaway. 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

Some homeowners and businesses are becoming increasingly concerned about mail-identity theft. Consequently, there is a growing demand for the use of locking mailboxes for theft deterrence and vandal resistance. There are a number of mailbox products on the market that offer enhanced security for mail and small parcels. They typically feature an upper hopper for incoming mail, and a lower lockable compartment for mail retrieval.

The dual compartment security feature makes the lockable mailboxes larger and heavier than standard mailboxes. As an example, the Oasis Jr. locking architectural mailbox is 15 inches tall × 11.5 inches wide × 18 inches deep and weighs 22.4 lb. By contrast, a common sized rural mailbox (T1) is approximately 6 inches tall × 5 inches wide × 18.5 inches long and weighs less than 5 lb.

Currently, TxDOT mailbox mounting standards (MB-11(*1*)) do not permit the use of heavy steel or decorative/architectural mailboxes. Concerns exist that the mailbox attachment hardware may be inadequate for these heavy mailboxes. Unacceptable occupant compartment intrusion can result if a mailbox detaches from its support during a vehicle impact.

1.3 OBJECTIVES/SCOPE OF RESEARCH

The objective of this research task was to evaluate the impact performance of lockable, secure mailboxes on both single and multiple mount configurations. It was desired to use existing TxDOT supports and mounting hardware to the extent possible. The full-scale crash testing followed the procedures recommended in the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware (MASH)* (*2*).

Reported herein are details of the lockable mailbox installations evaluated, descriptions of the tests performed, assessment of test results, and implementation recommendations.

CHAPTER 2. TEST REQUIREMENTS AND EVALUATION CRITERIA

2.1 CRASH TEST MATRIX

According to *MASH*, three tests are recommended for evaluation of breakaway support structures to test level three (TL-3). Details of these tests are described below.

> ***MASH* Test 3-60**: A 2420-lb passenger car (denoted 1100C) impacting the support structure at a nominal speed of 19 mi/h. The purpose of this test is to evaluate the breakaway, fracture, or yielding mechanism of the support, as well as occupant risk.
>
> ***MASH* Test 3-61**: A 2420-lb passenger car impacting the support structure at a nominal speed of 62 mi/h. The test is intended to evaluate the behavior of the support structure, vehicle trajectory, and occupant risk during high-speed impacts.
>
> ***MASH* Test 3-62**: A 5000-lb pickup truck (denoted 2270P) impacting the support structure at a nominal speed of 62 mi/h. The test is intended to evaluate the behavior of the support structure, vehicle trajectory, and occupant risk during high-speed impacts.

The impact performance of the lockable, secure mailbox configurations was evaluated using Tests 3-60 and 3-61 with the small passenger car. The small passenger car is considered the critical design vehicle based on the mailbox mounting height. The taller hood height and longer wrap-around distance (i.e., the distance from the ground, around the front end, and across the hood to the base of the windshield) of the pickup truck significantly decrease the probability of windshield impact and occupant compartment intrusion.

The crash test and data analysis procedures were in accordance with guidelines presented in *MASH*. Chapter 3 presents brief descriptions of these procedures.

2.2 EVALUATION CRITERIA

The crash tests were evaluated in accordance with applicable criteria presented in *MASH*. The performance of breakaway support structures is judged primarily on the basis of structural adequacy and occupant risk. Structural adequacy is judged upon the ability of the support to readily activate in a predicable manner by breaking away, fracturing, or yielding. Occupant risk is evaluated based on factors such as occupant compartment deformation, intrusion of structural components into the vehicle windshield, vehicle stability, and occupant impact velocity. The appropriate safety evaluation criteria from Table 5-1 of *MASH* were used to evaluate the crash tests reported herein. These criteria are listed in further detail under the assessment of the crash tests.

CHAPTER 3. CRASH TEST PROCEDURES

3.1 TEST FACILITY

The full-scale crash tests reported here were performed at the Texas A&M Transportation Institute Proving Ground, an International Standards Organization (ISO) 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 and according to *MASH* guidelines.

The Texas A&M Transportation Institute Proving Ground is a 2000-acre complex of research and training facilities located 10 miles northwest of the main campus of Texas A&M University. The site, formerly an Air Force 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 safety evaluation of roadside safety hardware. The site selected for construction and testing of the Locking Architectural Mailboxes evaluated under this project was within a broken out section of an out-of-service apron that had been backfilled with crushed limestone. The apron consists of an unreinforced jointed-concrete pavement in 12.5-ft × 15-ft blocks nominally 6 inches deep. The apron is over 50 years old, and the joints have some displacement, but are otherwise flat and level.

3.2 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. In the low-speed tests, a steel tow cable was connected to the test vehicle, passed around a pulley near the impact point, and then attached to the tow vehicle, providing a one-to-one speed ratio between the test and tow vehicles. In the high-speed tests, the steel tow 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. A two-to-one speed ratio between the test and tow vehicle existed with this system. Just prior to impact with the installation, the test vehicle was released to be unrestrained. The vehicle remained freewheeling (i.e., no steering or braking inputs) until it cleared the immediate area of the test site, after which the brakes were activated to bring it to a safe and controlled stop.

3.3 DATA ACQUISITION SYSTEMS

3.3.1 Vehicle Instrumentation and Data Processing

Each 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 manufactured by Diversified Technical Systems, Inc. The accelerometers used to measure the x, y, and z axes of vehicle acceleration are strain gauge type with linear millivolt output proportional to acceleration. The angular rate sensors that measure 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 each 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. Internal batteries back up the recorded inside the unit until it can be downloaded after the test. Initial contact of a pressure tape 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 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. Acceleration data are measured with an expanded uncertainty of ±1.7 percent at a confidence factor of 95 percent (k=2).

TRAP uses the data from the TDAS Pro to compute occupant impact velocities, time of occupant impact after vehicle impact, and the highest 10-millisecond (ms) average ridedown acceleration. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. The data from the vehicle-mounted accelerometers are filtered with a 60-Hz digital filter for reporting purposes, 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).

3.3.2 Anthropomorphic Dummy Instrumentation

An Alderson Research Laboratories Hybrid II, 50^{th} percentile male anthropomorphic dummy, restrained with lap and shoulder belts, was placed in the driver's position of each 1100C vehicle. The dummy was uninstrumented.

3.3.3 Photographic Instrumentation and Data Processing

Photographic coverage of each test included two high-speed cameras: one placed perpendicular to the vehicle path/installation; and a second placed to have a field of view in front of the installation at a 45 degree angle. A flashbulb activated by a pressure-sensitive tape switch was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from each camera. The films from these high-speed cameras were analyzed on a computer-linked motion analyzer to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A mini-DV camera and still cameras recorded and documented conditions of the test vehicle and installation before and after the test.

CHAPTER 4. LOCKING ARCHITECTURAL MAILBOX ON SHUR-TITE® SINGLE-MOUNT POST

4.1 TEST ARTICLE DESIGN AND CONSTRUCTION

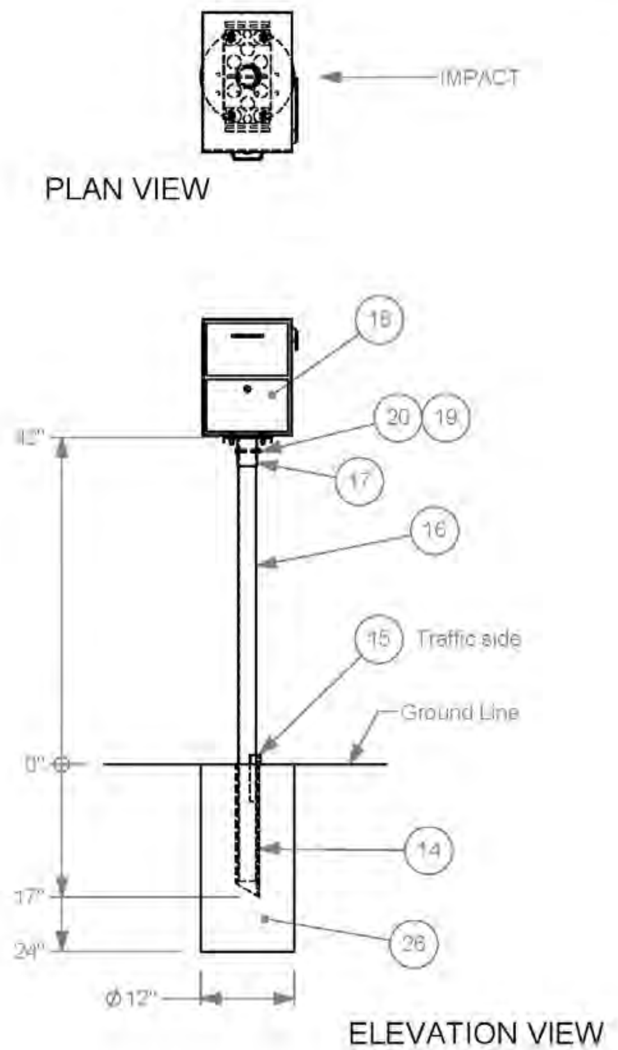
The test installation consisted of a single, locking architectural mailbox mounted on a single 2.375-inch outside diameter (OD) thin-wall steel tube (DHT# 162911), which was installed in a plastic socket (DHT# 160891) that was embedded in a concrete footing. The mailbox tested was an Oasis Jr manufactured by Architectural Mailboxes, LLC. It was fabricated from 16-gauge and 14-gauge galvanized steel and had a black powder-coat finish. The mailbox was 15 inches tall × 11½ inches wide × 18 inches deep, and weighed 22.6 lb. The mailbox had two distinct compartments: an upper hopper for receiving incoming mail, and a lower lockable compartment for mail retrieval. The mailbox was tested with the lower door locked and no "mail" in the compartment.

A bracket (DHT# 161443), weighing approximately 1.8 lb, was attached to the bottom of the locking mailbox using four ⅜-inch diameter × 1¼-inch long Society of Automotive Engineers (SAE) Grade 5 bolts using existing holes in the mailbox and bracket. A 2-inch wide × 5½-inch long × ⅛-inch thick plate washer was positioned over the bracket to help secure each set of two bolts toward the front and back of the mailbox. The plate washers were fabricated using American Society of Testing and Materials (ASTM) A36 steel. A ⅜-inch flat washer, lock washer, and nut were used for each bolt. The collar of the mailbox bracket (DHT# 161443) was secured to the support post using a $^{5}/_{16}$-inch × 3 inch long SAE Grade 5 bolt and $^{5}/_{16}$-inch hex nut.

The mailbox support post was a SHUR-TITE® Products single mailbox post (DHT# 162911) fabricated from 2-inch nominal, 13-gauge, galvanized steel tube with a white powder coat. The steel tube had a 2⅜ inch OD, a 0.095 inch wall thickness, a 55-inch length, and a weight of 10.0 lb. The support post was installed with a SHUR-TITE® Products plastic wedge anchor system. The socket (DHT# 160891) was 3½ inches OD × $^{7}/_{16}$ inch wall thickness × 17 inches long. The socket was embedded in a non-reinforced concrete footing that was approximately 12 inches in diameter × 24 inches deep. The concrete was specified as Class B having a minimum 28-day unconfined compressive strength of 2000 psi. The support post inserted approximately 13 inches into the socket and was secured in place with a plastic locking wedge (DHT# 160892) that was driven between the socket and impact side of the support post. The total mass of the mailbox and post assembly was 34.4 lb.

Figures 4.1 and 4.2 show details of the mailbox connection and installation. Figure 4.3 provides photographs of the completed installation.

Single-mount Install



Single-mount Installation Parts			
#	Part Name	Part/DHT #	QTY.
14	Socket, Type 4 Foundation	160891	1
15	Wedge for Type 4 Foundation	160892	1
16	Thin-wall White Steel Tube 2.375 OD	162911	1
17	Bracket for Attaching Mailbox	161443	1
18	Locking Mailbox	see note	1
19	Nut, 5/16" hex		1
20	Bolt, 5/16 x 3 hex	grade 5	1
21	Plate Washer for Architectural Mailbox	see sheet 3	2
22	Washer, 3/8 flat		8
23	Washer, 3/8 lock		4
24	Nut, 3/8 hex		4
25	Bolt, 3/8 x 1-1/4 hex	grade 5	4
26	Concrete, Class B (2000 psi)		1

2a. Architectural Mailboxes® Oasis Junior.
http://www.architecturalmailboxes.com/products/locking-mailboxes/oasis-locking-mailboxes/oasis-jr/default.aspx

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project 490023-9	Architectural Mailbox		2013-08-07
Drawn By GES	Scale 1:20	Sheet 2 of 3	Single-mount Install

T:\2012-2013\490023 TxDOT\1-9 Mailbox\Drafting\490023-9 Drawing

Figure 4.1. Details of the Locking Architectural Mailbox on the SHUR-TITE® Single-Mount Post.

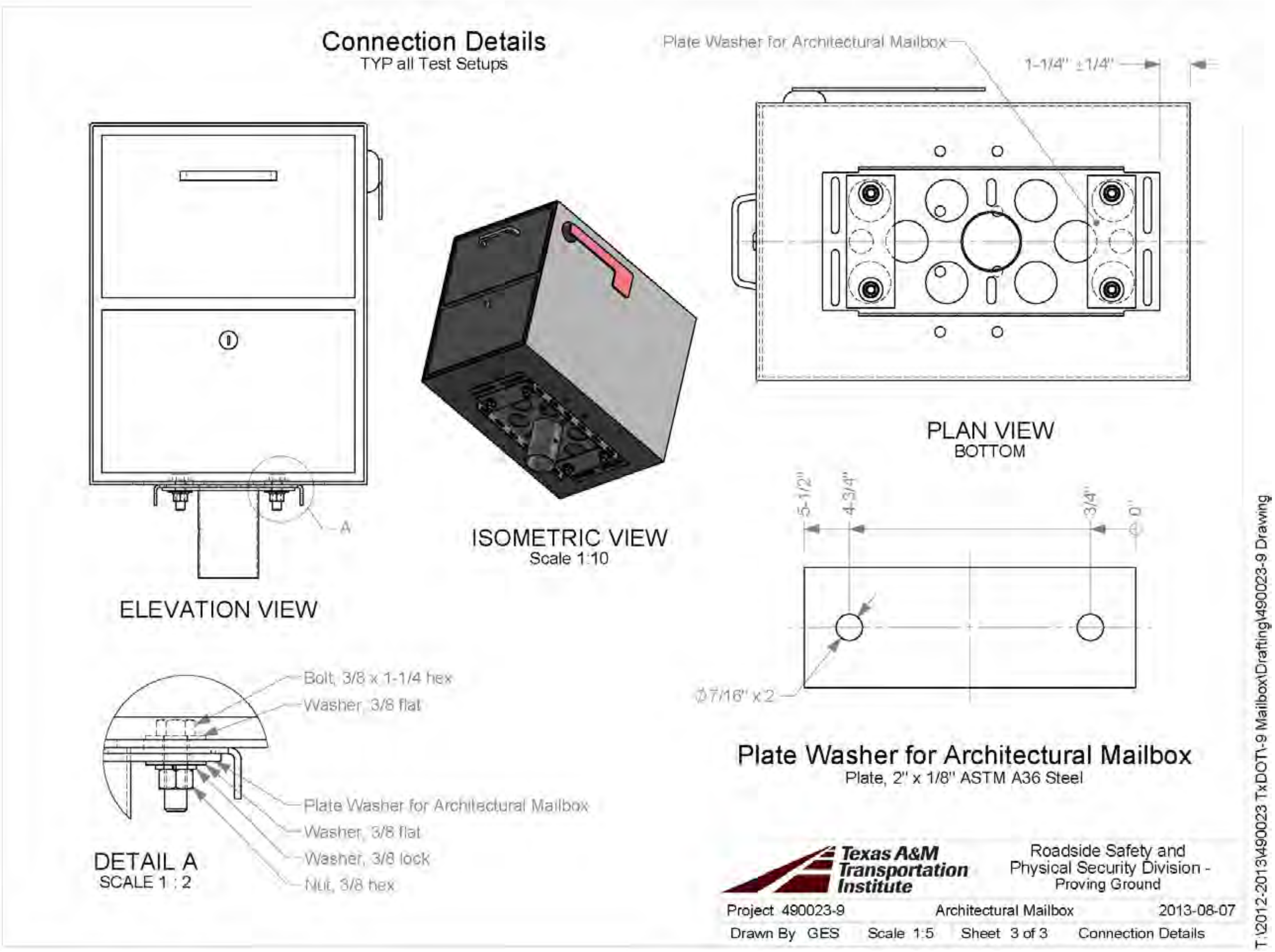


Figure 4.2. Connection Details for the Locking Architectural Mailbox.

Figure 4.3. Locking Architectural Mailbox on the SHUR-TITE® Single Mount Post before Testing.

4.2 *MASH* TEST 3-60 (CRASH TEST NO. 490023-9-1)

4.2.1 Test Designation and Actual Impact Conditions

MASH Test 3-60 involves an 1100C passenger car weighing 2420 lb ±55 lb impacting the support structure at the critical impact angle at an impact speed of 19 mi/h. The critical impact angle (CIA) was determined to be center of car aligned with center of mailbox support post with the mailbox oriented perpendicular to path of vehicle. The 2009 Kia Rio used in the test weighed 2451 lb, and the actual impact speed was 19.2 mi/h. The actual impact point was at the CIA as stated above.

4.2.2 Test Vehicle

Figures 4.4 and 4.5 show the 2009 Kia Rio used for the crash test. Test inertia weight of the vehicle was 2451 lb, and its gross static weight was 2628 lb. The height to the lower edge of the vehicle bumper was 6.75 inches, and the height to the upper edge of the bumper was 22.0 inches. Table A1 in Appendix A gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Figure 4.4. Vehicle/Installation Geometrics for Test No. 490023-9-1.

Figure 4.5. Vehicle before Test No. 490023-9-1.

4.2.3 Weather Conditions

The test was performed on the morning of August 12, 2013. Weather conditions at the time of testing were as follows: (a) wind speed: 6 mi/h; (b) wind direction: 222 degrees with respect to the vehicle (vehicle was traveling in a southerly direction); (c) temperature: 84°F; (d) relative humidity: 74 percent.

4.2.4 Test Description

The 1100C vehicle, traveling at an impact speed of 19.2 mi/h, impacted the locking architectural mailbox on the SHUR-TITE® single-mount post at 0 degrees with the centerline of the vehicle aligned with the centerline of the mailbox. At approximately 0.029 s, the mailbox support post began to deform and the mailbox began to rotate toward the vehicle. The vehicle began to ride over the mailbox support post at 0.074 s. The vehicle subsequently rode over the mailbox support and mailbox. At 0.346 s, the mailbox snagged under the front part of the vehicle and detached from the support post. At 0.847 s, the vehicle lost contact with the support post, and the mailbox traveled under the vehicle as it continued forward. At 1.908 s, the vehicle lost contact with the mailbox and was traveling at an exit speed of 11.6 mi/h. Brakes on the vehicle were applied at 2.25 s, and the vehicle came to rest 45 ft downstream of impact. Figure A1 in Appendix A shows sequential photographs of the test period.

4.2.5 Damage to Test Installation

Figure 4.6 and 4.7 show damage to the locking architectural mailbox installation. The post was deformed and bent over at ground line. The connection bracket was torn from the support and the mailbox came to rest 21 ft downstream of impact. Several pieces of the mailbox became detached and lay along the path of the vehicle.

Figure 4.6. Vehicle/Installation Positions after Test No. 490023-9-1.

Figure 4.7. Installation after Test No. 490023-9-1.

4.2.6 Vehicle Damage

Figure 4.8 shows damage to the exterior of the vehicle, and Figure 4.9 shows the interior of the vehicle. A very small dent was noted on the hood and bumper. There was no contact of any components of the mailbox system with the windshield. Tables A2 and A3 in Appendix A provide exterior crush and occupant compartment measurements for the vehicle.

Figure 4.8. Vehicle after Test No. 490023-9-1.

Before Test **After Test**

Figure 4.9. Interior of Vehicle for Test No. 490023-9-1.

4.2.7 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 was 6.9 ft/s at 0.460 s, the highest 0.010-s occupant ridedown acceleration was 1.9 Gs from 0.585 to 0.595 s, and the maximum 0.050-s average acceleration was −1.5 Gs between 0.162 and 0.212 s. In the lateral direction, the occupant impact velocity was 0.7 ft/s at 0.460 s, the highest 0.010-s occupant ridedown acceleration was 0.8 Gs from 0.635 to 0.645 s, and the maximum 0.050-s average was −0.4 Gs between 0.624 and 0.674 s. Theoretical Head Impact Velocity (THIV) was 7.4 km/h or 2.1 m/s at 0.460 s; Post-Impact Head Decelerations (PHD) was 1.9 Gs between 0.585 and 0.595 s; and Acceleration Severity Index (ASI) was 0.15 between 0.593 and 0.643 s. Figure 4.10 summarizes these data and other pertinent information from the test. Figures A2 through A8 in Appendix A show the vehicle angular displacements and accelerations versus time traces.

4.2.8 Assessment of Test Results

An assessment of the test based on the applicable *MASH* safety evaluation criteria for Test 3-60 is provided below.

4.2.8.1 Structural Adequacy

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

Results: The locking architectural mailbox on the SHUR-TITE® single-mount post yielded to the vehicle. (PASS)

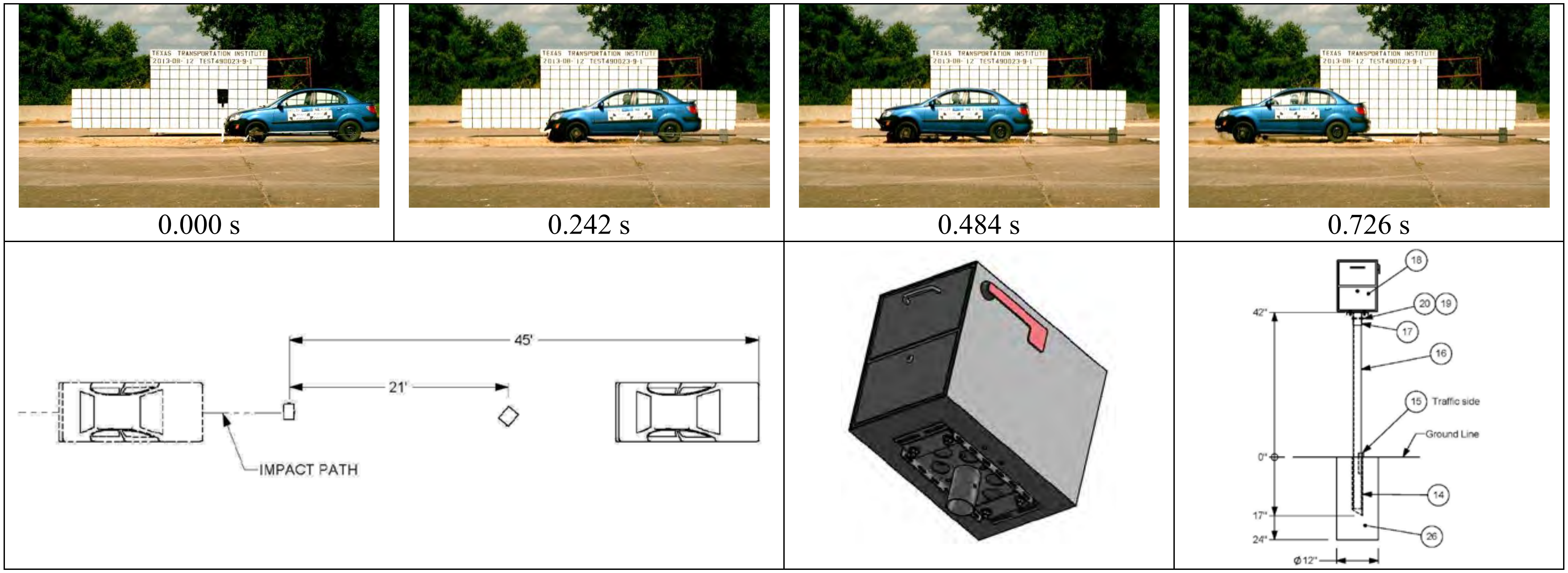
4.2.8.2 Occupant Risk

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: The locking architectural mailbox detached from the support post and separated into several pieces while being carried along beneath the vehicle. The detached pieces did not penetrate or show potential for penetrating the occupant compartment, nor present hazard to others in the area. (PASS)
No occupant compartment deformation occurred. (PASS)

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 5 degrees and 4 degrees, respectively. (PASS)



General Information
- Test Agency .... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. .... MASH Test 3-60
- TTI Test No. 490023-9-1
- Test Date 2013-08-12

Test Article
- Type.................................... Mailbox
- Name .... Locking Architectural Mailbox on SURE-TITE® Single-Mount Post
- Installation Height................ 42 inches
- Material or Key Elements .... Locking mailbox on thin-wall steel tube; secured in concrete footing using plastic wedge and socket

Soil Type and Condition....... Concrete footing in crushed limestone, dry

Test Vehicle
- Type/Designation 1100C
- Make and Model.................. 2009 Kia Rio
- Curb .... 2459 lb
- Test Inertial .... 2451 lb
- Dummy................................ 177 lb
- Gross Static......................... 2628 lb

Impact Conditions
- Speed.................................19.2 mi/h
- Angle.................................0 degrees
- Location/Orientation ....Perpendicular

Exit Conditions
- Speed.................................11.6 mi/h
- Angle.................................~0 degrees

Occupant Risk Values
- Impact Velocity
  - Longitudinal.....................6.9 ft/s
  - Lateral ....0.7 ft/s
- Ridedown Accelerations
  - Longitudinal.....................1.9 G
  - Lateral ....0.8 G
- THIV..................................7.4 km/h (2.1 m/s)
- PHD ....1.9 G
- ASI 0.15
- Max. 0.050-s Average
  - Longitudinal.....................−1.5 G
  - Lateral ....−0.4 G
  - Vertical ....−1.3 G

Post-Impact Trajectory
- Stopping Distance .... 45 ft downstream

Vehicle Stability
- Maximum Yaw Angle................ 1 degree
- Maximum Pitch Angle............... 4 degrees
- Maximum Roll Angle................. 5 degrees
- Vehicle Snagging .... NA
- Vehicle Pocketing...................... NA

Debris Pattern
- Longitudinal............................... 45 ft
- Lateral .... 1.5 ft

Vehicle Damage
- VDS 12FC1
- CDC 12FCEN1
- Max. Exterior Deformation......... None
- OCDI FS0000000
- Max. Occupant Compartment Deformation .... None

Figure 4.10. Summary of Results for *MASH* Test 3-60 on the Locking Architectural Mailbox on the SHUR-TITE® Single-Mount Post.

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 occupant impact velocity was 6.9 ft/s, and lateral occupant impact velocity was 0.7 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:
Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15.0 Gs	*20.49 Gs*

Results: Longitudinal ridedown acceleration was 1.9 Gs, and lateral ridedown acceleration was 0.8 Gs. (PASS)

4.2.8.3 Vehicle Trajectory
N. Vehicle trajectory behind the test article is acceptable.

Result: The 1100C vehicle came to rest behind the mailbox installation. (PASS)

4.3 *MASH* TEST 3-61 (CRASH TEST NO. 490023-9-2)

4.3.1 Test Designation and Actual Impact Conditions

MASH Test 3-61 involves an 1100C passenger car weighing 2420 lb ±55 lb impacting the support structure at the critical impact angle at an impact speed of 62 mi/h. The critical impact angle (CIA) was determined to be center of car aligned with center of mailbox support post with the mailbox oriented perpendicular to path of vehicle. The 2008 Kia Rio used in the test weighed 2437 lb, and the actual impact speed was 63.8 mi/h. The actual impact point was at the CIA as stated above.

4.3.2 Test Vehicle

Figures 4.11 and 4.12 show the 2008 Kia Rio used for the crash test. Test inertia weight of the vehicle was 2437 lb, and its gross static weight was 2617 lb. The height to the lower edge of the vehicle bumper was 6.75 inches, and the height to the upper edge of the bumper it was 22.0 inches. Table B1 in Appendix B gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Figure 4.11. Vehicle/Installation Geometrics for Test No. 490023-9-2.

Figure 4.12. Vehicle before Test No. 490023-9-2.

4.3.3 Weather Conditions

The test was performed on the afternoon of August 12, 2013. Weather conditions at the time of testing were as follows: (a) wind speed: 4 mi/h; (b) wind direction: 161 degrees with respect to the vehicle (vehicle was traveling in a southerly direction); (c) temperature: 93°F; (d) relative humidity: 52 percent.

4.3.4 Test Description

The 1100C vehicle, traveling at an impact speed of 63.8 mi/h, impacted the locking architectural mailbox installation at 0 degrees with the centerline of the vehicle aligned with the centerline of the mailbox. At approximately 0.016 s, the support post began to deform at bumper height, and at 0.032 s, the mailbox rotated onto the hood of the vehicle. The support post pulled out of the socket at 0.042 s and began traveling along the front of the vehicle. The mailbox began to slide off the hood of the vehicle at 0.081 s. At 0.102 s, the vehicle lost contact with the mailbox and was traveling at an exit speed of 61.9 mi/h. Brakes on the vehicle were applied at 0.600 s, and the vehicle came to rest 245 ft downstream of impact. Figure B1 in Appendix B shows sequential photographs of the test period.

4.3.5 Damage to Test Installation

Figures 4.13 and 4.14 show damage to the mailbox installation. The support post pulled out of the socket and was deformed. The mailbox came apart at several connection seams, but all the pieces remained together and the mailbox remained attached to the support post. The mailbox and support post came to rest in front of the vehicle 245 ft downstream of impact.

Figure 4.13. Vehicle/Installation Positions after Test No. 490023-9-2.

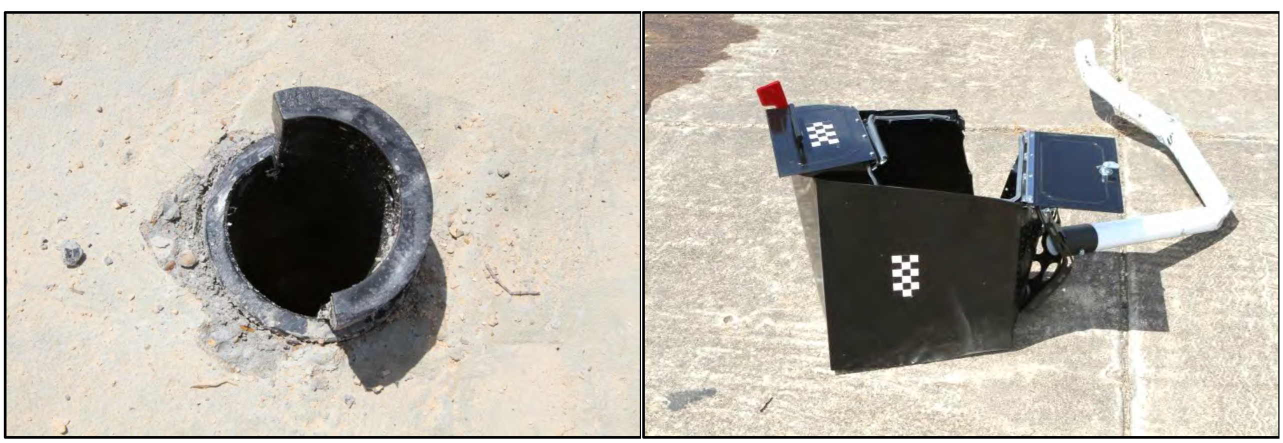


Figure 4.14. Installation after Test No. 490023-9-2.

4.3.6 Vehicle Damage

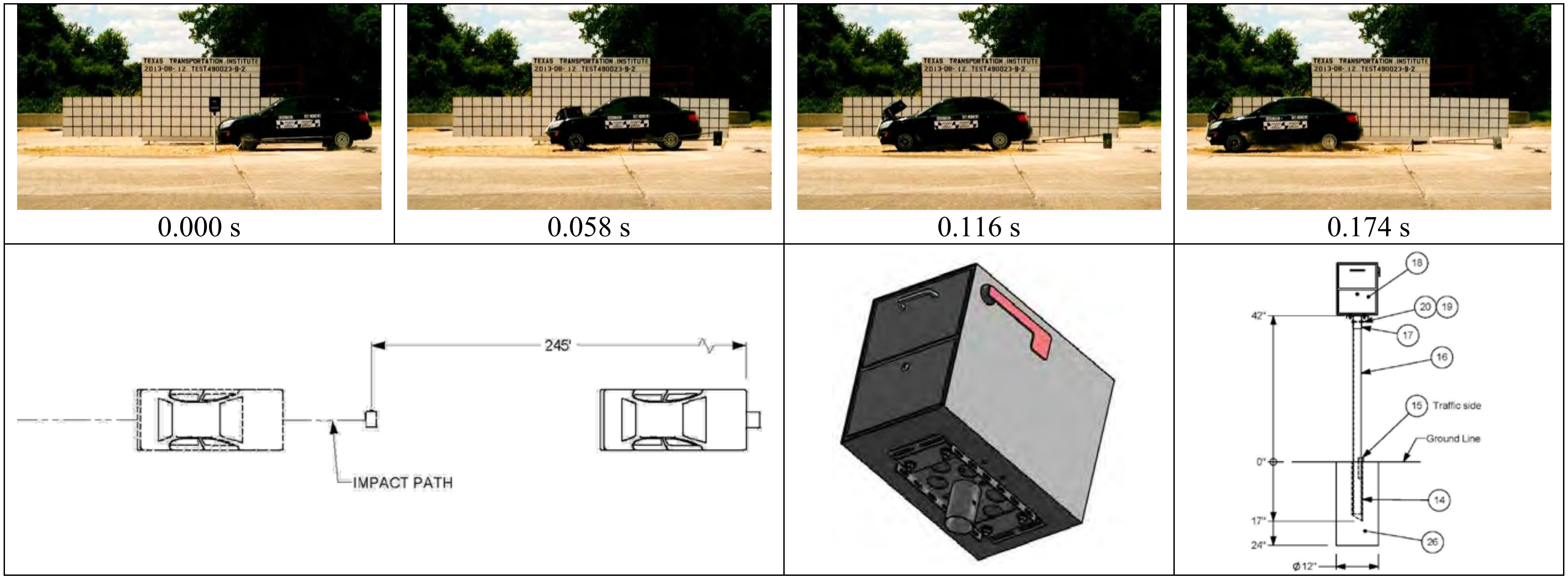
Figure 4.15 shows damage to the exterior of the vehicle, and Figure 4.16 shows the interior of the vehicle. The vehicle sustained a small cut on the hood, and the hood was deformed inward 1.25 inches. There was no contact of any components of the mailbox system with the windshield. Tables B2 and B3 in Appendix B provide exterior crush and occupant compartment measurements.

Figure 4.15. Vehicle after Test No. 490023-9-2.

Figure 4.16. Interior of Vehicle after Test No. 490023-9-2.

4.3.7 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 was 4.9 ft/s at 0.820 s, the highest 0.010-s occupant ridedown acceleration was 1.0 Gs from 0.836 to 0.846 s, and the maximum 0.050-s average acceleration was −1.6 Gs between 0.000 and 0.050 s. No occupant contact occurred in the lateral direction, and the maximum 0.050-s average was −0.3 Gs between 0.085 and 0.135 s. THIV was 5.5 km/h or 1.5 m/s at 0.819 s; PHD was 1.0 Gs between 0.836 and 0.846s; and ASI was 0.13 between 0.016 and 0.066 s. Figure 4.17 summarizes these data and other pertinent information from the test. Figures B2 through B8 in Appendix B show the vehicle angular displacements and accelerations versus time traces.



General Information
- Test Agency .... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. ...... MASH Test 3-61
- TTI Test No. 490023-9-2
- Test Date 2013-08-12

Test Article
- Type .... Mailbox
- Name .... Locking Architectural Mailbox on SURE-TITE® Single-Mount Post
- Installation Height.............. 42 inches
- Material or Key Elements .. Locking mailbox on thin-wall steel tube; secured in concrete footing using plastic wedge and socket

Soil Type and Condition..... Concrete footing in crushed limestone, dry

Test Vehicle
- Type/Designation 1100C
- Make and Model................ 2008 Kia Rio
- Curb .... 2301 lb
- Test Inertial .... 2437 lb
- Dummy............................. 180 lb
- Gross Static....................... 2617 lb

Impact Conditions
- Speed.................................63.8 mi/h
- Angle..................................0 degrees
- Location/Orientation ....Perpendicular

Exit Conditions
- Speed.................................61.9 mi/h
- Angle..................................~0 degree

Occupant Risk Values
- Impact Velocity
  - Longitudinal.....................4.9 ft/s
  - Lateral ....No contact
- Ridedown Accelerations
  - Longitudinal......................1.0 G
  - Lateral ....0.2 G
- THIV...................................5.5 km/h (1.5 m/s)
- PHD ....1.0 G
- ASI 0.13
- Max. 0.050-s Average
  - Longitudinal.....................−1.6 G
  - Lateral ....−0.3 G
  - Vertical ....0.8 G

Post-Impact Trajectory
- Stopping Distance .... 245 ft downstram

Vehicle Stability
- Maximum Yaw Angle................ 4 degrees
- Maximum Pitch Angle................ 3 degrees
- Maximum Roll Angle.................. 7 degrees
- Vehicle Snagging .... NA
- Vehicle Pocketing...................... NA

Debris Pattern
- Longitudinal............................... 245 ft
- Lateral .... Centerline

Vehicle Damage
- VDS 12FC1
- CDC 12FCEN1
- Max. Exterior Deformation .... 1.25 inches
- OCDI FS0000000
- Max. Occupant Compartment Deformation .... None

Figure 4.17. Summary of Results for *MASH* Test 3-61 on the Locking Architectural Mailbox on the SHUR-TITE® Single-Mount Post.

4.3.8 Assessment of Test Results

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

4.3.8.1 Structural Adequacy

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

Results: The locking architectural mailbox on the SHUR-TITE® single-mount post yielded to the vehicle and released from its foundation. (PASS)

4.3.8.2 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: The locking architectural mailbox separated at several connection seams; however, the pieces remained connected and attached to the support post and traveled along the front of the vehicle. The mailbox installation did not penetrate or show potential for penetrating the occupant compartment, nor present hazard to others in the area. (PASS)

Results: No occupant compartment deformation occurred. (PASS)

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 7 degrees and 3 degrees, respectively. (PASS)

I. Occupant impact velocities should satisfy the following:

Longitudinal and Lateral Occupant Impact Velocity

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

Results: Longitudinal occupant impact velocity was 4.9 ft/s, and no contact occurred in the lateral direction. (PASS)

I. Occupant ridedown accelerations should satisfy the following:

Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15.0 Gs	*20.49 Gs*

Results: Longitudinal ridedown acceleration was 1.0 Gs, and no contact occurred in the lateral direction. (PASS)

4.3.8.3 Vehicle Trajectory

N. Vehicle trajectory behind the test article is acceptable.

Result: The 1100C vehicle came to rest behind the mailbox installation. (PASS)

CHAPTER 5. DUAL LOCKING ARCHITECTURAL MAILBOXES ON SHUR-TITE® MULTIPLE-MOUNT POST

5.1 TEST ARTICLE DESIGN AND CONSTRUCTION

The test installation consisted of two locking architectural mailbox mounted on a SHUR-TITE® Products multiple mailbox post (DHT# 164116) installed in a concrete footing using a plastic socket (DHT# 160891) and wedge (DHT# 160892). The mailboxes were Oasis Jr. models manufactured by Architectural Mailboxes, LLC. They were fabricated from 16-gauge and 14-gauge galvanized steel and had a black powder-coat finish. The mailboxes were 15 inches tall × 11½ inches wide × 18 inches deep, and weighed 22.6 lb. The mailboxes had two distinct compartments: an upper hopper for receiving incoming mail and a lower lockable compartment for mail retrieval. The mailboxes was tested with the lower door locked and no "mail" in the compartment.

A bracket (DHT# 161443), weighing approximately 1.8 lb, was attached to the bottom of each locking mailbox using four ⅜-inch diameter × 1¼-inch long SAE Grade 5 bolts using existing holes in the mailbox and bracket. A 2-inch wide × 5½-inch long × ⅛-inch thick plate washer was positioned over the bracket to help secure each set of two bolts toward the front and back of the mailbox. The plate washers were fabricated using ASTM A36 steel. A ⅜-inch flat washer, lock washer, and nut were used for each bolt.

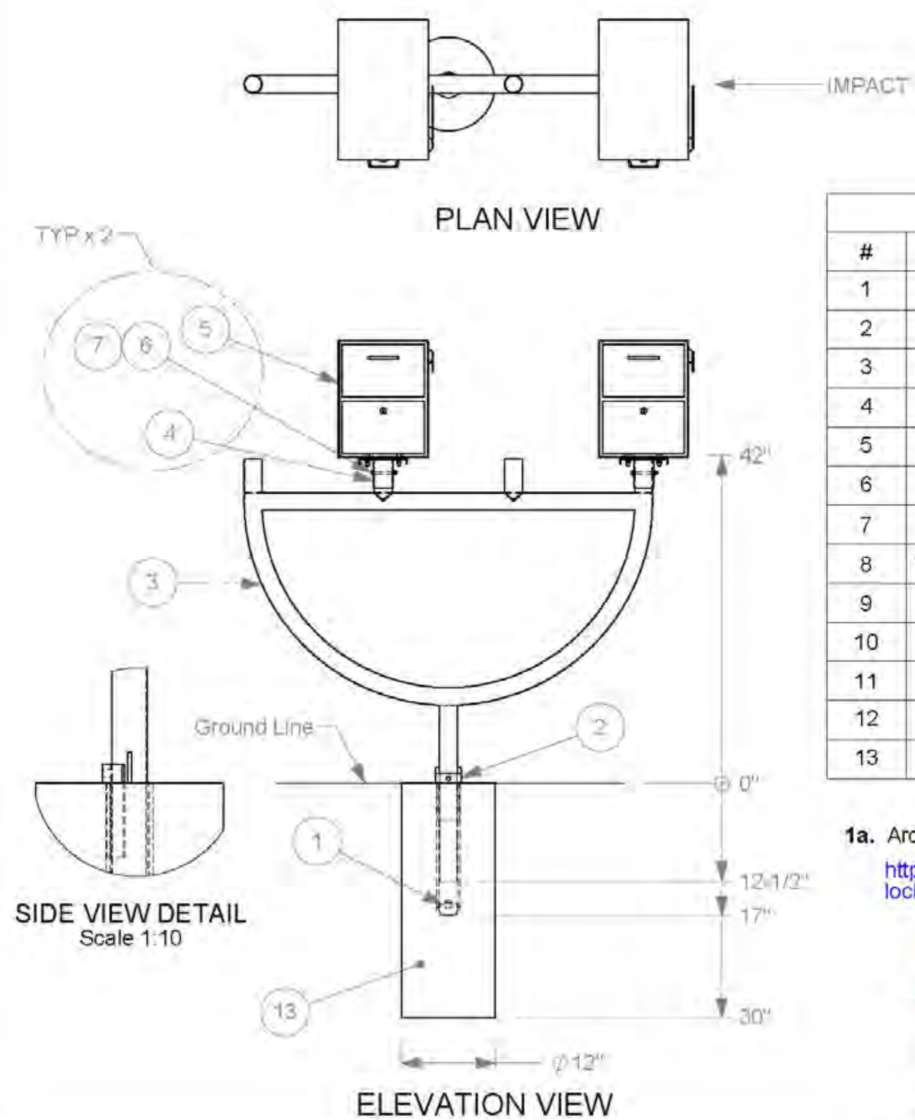
The mailbox support post was a SHUR-TITE® Products Multiple Mailbox Support (DHT# 164116). The support is comprised of semi-circular tube with a 25-inch centerline radius and horizontal cross member fabricated from 2⅜ inch OD × 0.065 thick galvanized steel tube with a white powder coat. The ends of the semi-circular tube were designed to accept mailbox attachments. Additional, two intermediate thin-wall steel tube stubs were vertically welded to the horizontal cross member to accept two additional mailboxes. The lockable, secure mailboxes were positioned at the upstream end adjacent to impact, and at the interior location adjacent to the downstream end. A 22½-inch long thin-wall steel tube was vertically welded at the bottom center of the semi-circular steel tube. The weight of the fabricated multiple mailbox support was 23.6 lb.

The vertical steel tube at the bottom of the support was installed with a SHUR-TITE® Products plastic wedge anchor system. The socket (DHT# 160891) was 3½ inches OD × $^{7}/_{16}$ inch wall thickness × 17 inches long. The socket was embedded in a non-reinforced concrete footing that was approximately 12 inches in diameter × 30 inches deep. The concrete was specified as Class B having a minimum 28-day unconfined compressive strength of 2000 psi. The compressive strength of the batch of concrete used in the post foundation footing measured an average of 4360 psi (at 6 days).

The support post was inserted approximately 13 inches into the socket and secured in place with a plastic locking wedge (DHT# 160892) that was driven between the socket and front face of the support post. The total mass of the two mailboxes and post assembly was 72.4 lb.

Figures 5.1 and 5.2 show details of the installation and connection, and Figure 5.3 provides photographs of the completed installation.

Multiple-mount Install



Multiple-mount Installation Parts			
#	Part Name	Part/DHT #	QTY.
1	Socket, Type 4 Foundation	160891	1
2	Wedge for Type 4 Foundation	160892	1
3	Multiple Mailbox Post, White	164116	1
4	Bracket for Attaching Mailbox	161443	2
5	Locking Mailbox	see note	2
6	Bolt, 5/16 x 3 hex	grade 5	2
7	Nut, 5/16" hex		2
8	Plate Washer for Architectural Mailbox	see sheet 3	4
9	Washer, 3/8 flat		16
10	Washer, 3/8 lock		8
11	Nut, 3/8 hex		8
12	Bolt, 3/8 x 1-1/4 hex	grade 5	8
13	Concrete, Class B (2000 psi)		1

1a. Architectural Mailboxes® Oasis Junior.
http://www.architecturalmailboxes.com/products/locking-mailboxes/oasis-locking-mailboxes/oasis-jr/default.aspx

Texas A&M Transportation Institute

Roadside Safety and Physical Security Division
Proving Ground -

Project 490023-9 Architectural Mailbox
Drawn By GES Scale 1:20 Sheet 1 of 3 Multiple-mount Install
Approved: Date:
Roger Bligh: 2013-08-07

T:\2012-2013\490023 TxDOT-9 Mailbox\Drafting\490023-9 Drawing

Figure 5.1. Details of the Dual Locking Architectural Mailbox on SHUR-TITE® Multiple-Mount Post.

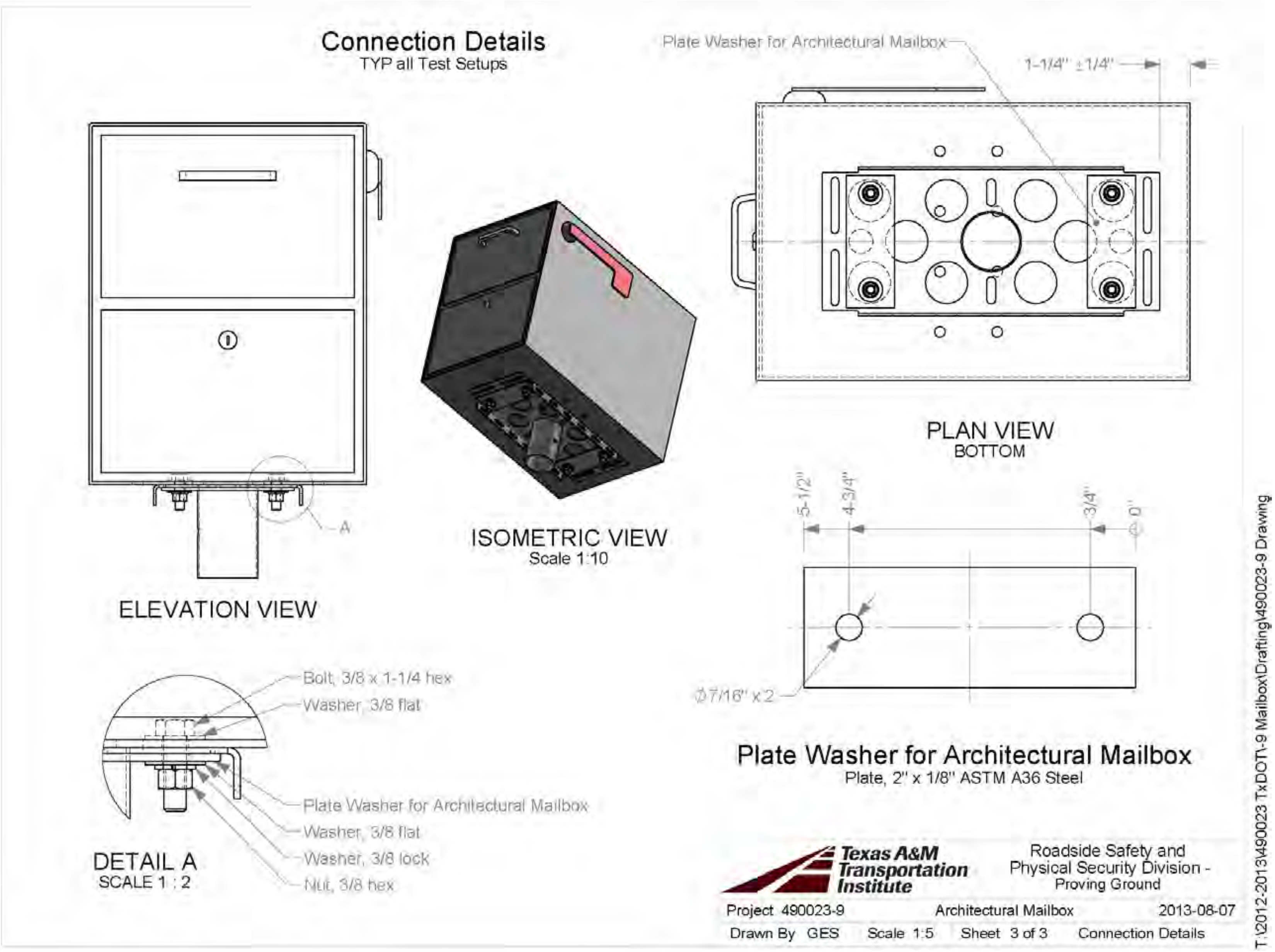


Figure 5.2. Connection Details for the Locking Architectural Mailbox.

Figure 5.3. Dual Locking Architectural Mailboxes on SHUR-TITE® Multiple-Mount Post before Testing.

5.2 *MASH* TEST 3-60 (CRASH TEST NO. 490023-9-3)

5.2.1 Test Designation and Actual Impact Conditions

MASH Test 3-60 involves an 1100C passenger car weighing 2420 lb ±55 lb and impacting the support structure at the critical impact angle at an impact speed of 19 mi/h. The critical impact angle (CIA) was determined to be center of car aligned with center of mailbox support post with the mailbox oriented perpendicular to path of vehicle The 2009 Kia Rio used in the test weighed 2451 lb, and the actual impact speed was 19.5 mi/h. The actual impact point was at the CIA as stated above.

5.2.2 Test Vehicle

Figures 5.4 and 5.5 shows the 2009 Kia Rio used for the crash test. Test inertia weight of the vehicle was 2451 lb, and its gross static weight was 2628 lb. The height to the lower edge of the vehicle bumper was 6.75 inches, and the height to the upper edge of the bumper was 22.0 inches. Table C1 in Appendix C gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Figure 5.4. Vehicle/Installation Geometrics for Test No. 490023-9-3.

Figure 5.5. Vehicle before Test No. 490023-9-3.

5.2.3 Weather Conditions

The test was performed on the morning of August 16, 2013. Weather conditions at the time of testing were as follows: (a) wind speed: 2 mi/h; (b) wind direction: 53 degrees with respect to the vehicle (vehicle was traveling in a southerly direction); (c) temperature: 83°F; (d) relative humidity: 78 percent.

5.2.4 Test Description

The 2009 Kia Rio, traveling at an impact speed of 19.5 mi/h, impacted the SHUR-TITE® multiple-mount post with two locking architectural mailboxes at 0 degrees with the centerline of the vehicle aligned with the centerline of the support. At approximately 0.077 s after impact, the support post lifted and pulled out of the ground. At 0.169 s, the mailboxes and support post began to rotate away from the vehicle. The mailboxes contacted the ground surface at 0.389 s. As the bottom of the support rotated upward, it caught on the front bumper at 0.412 s. At 0.535 s, the vehicle lost contact with the mailboxes while traveling at a speed of 17.0 mi/h. Brakes on the vehicle were applied at 1.4 s after impact, and the vehicle came to rest 50 ft downstream of impact with the mailboxes in front of the vehicle. Figure C1 in Appendix C shows sequential photographs of the test period.

5.2.5 Damage to Test Installation

Figures 5.6 and 5.7 show damage to the locking architectural mailbox installation. The support post lifted out of the socket and was carried in front of the vehicle. The support post was deformed as well as the bracket attaching the mailboxes to the support post. The mailboxes remained attached to the support post and the assembly came to rest in front of the vehicle 58 ft downstream of impact.

Figure 5.6. Vehicle/Installation Positions after Test No. 490023-9-3.

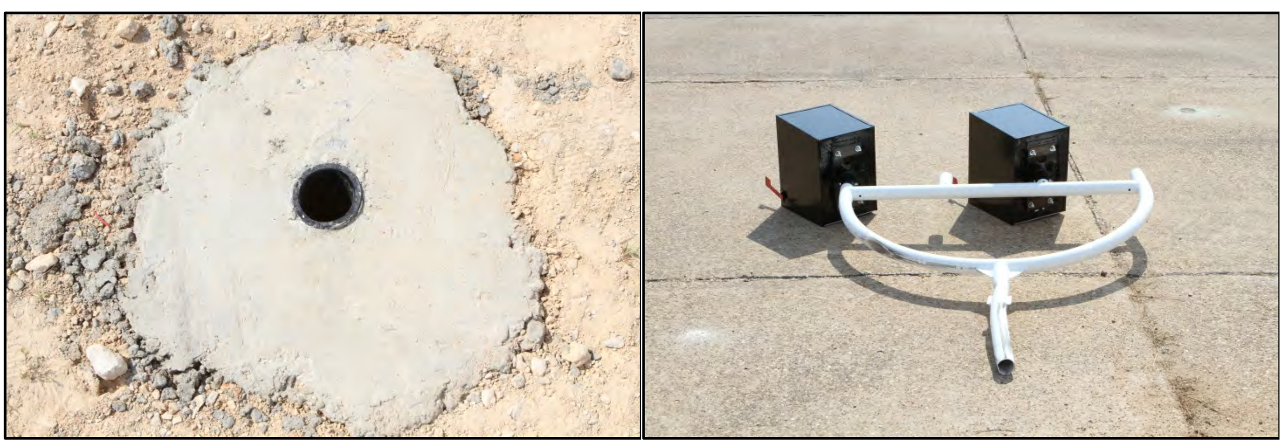


Figure 5.7. Installation after Test No. 490023-9-3.

5.2.6 Vehicle Damage

Figure 5.8 shows damage to the exterior of the vehicle, and Figure 5.9 shows the interior of the vehicle. The hood and bumper were dented. There was no contact of any components of the mailbox system with the windshield. Tables C2 and C3 in Appendix C provide exterior crush and occupant compartment measurements.

Figure 5.8. Vehicle after Test No. 490023-9-3.

Before Test

After Test

Figure 5.9. Interior of Vehicle for Test No. 490023-9-3.

5.2.7 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 was 3.0 ft/s at 0.719 s, the highest 0.010-s occupant ridedown acceleration was 1.4 Gs from 1.577 to 1.587 s, and the maximum 0.050-s average acceleration was −1.0 Gs between 0.000 and 0.050 s. In the lateral direction, the occupant impact velocity was 0.3 ft/s at 0.719 s, the highest 0.010-s occupant ridedown acceleration was 0.3 Gs from 1.570 to 1.580 s, and the maximum 0.050-s average was 0.1 Gs between 0.091 and 0.141 s. THIV was 3.4 km/h or 0.9 m/s at 0.720 s; PHD was 1.4 Gs between 1.577 and 1.587 s; and ASI was 0.12 between 0.016 and 0.066 s. Figure 5.10 summarizes these data and other pertinent information from the test. Figures C2 through C8 in Appendix C show the vehicle angular displacements and accelerations versus time traces.

5.2.8 Assessment of Test Results

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

5.2.8.1 Structural Adequacy

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

Results: The locking architectural mailboxes on the SHUR-TITE® multiple-mount post activated by yielding to the vehicle and lifting out of the foundation socket. (PASS)

5.2.8.2 Occupant Risk

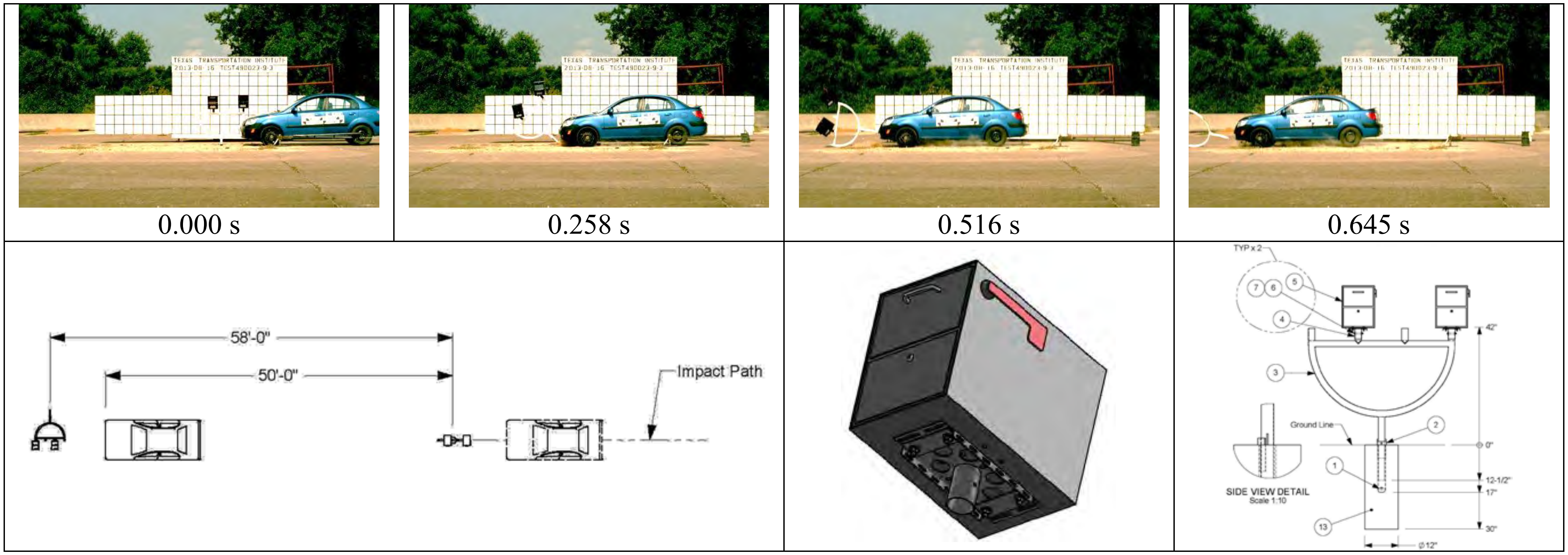
D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.
Deformation of, or intrusions into, the occupant compartment should 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: The locking architectural mailbox separated at several connection seams, however, the pieces remained together and attached to the support post and traveled along the front of the vehicle. The mailbox installation did not penetrate or show potential for penetrating the occupant compartment, nor present hazard to others in the area. (PASS)

Results: No occupant compartment deformation occurred. (PASS)

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 4 degrees and 2 degrees, respectively. (PASS)



General Information
Test Agency .... Texas A&M Transportation Institute (TTI)
Test Standard Test No. .... MASH Test 3-60
TTI Test No. 490023-9-3
Test Date 2013-08-16
Test Article
Type................................... Mailbox
Name .... Locking Architectural Mailboxes on SURE-TITE® Multiple-Mount Post
Installation Height................ 42 inches
Material or Key Elements .... Two locking mailboxes on semi-circular steel tube support inserted into concrete footing and secured using plastic wedge and socket
Soil Type and Condition....... Concrete footing in crushed limestone, dry
Test Vehicle
Type/Designation 1100C
Make and Model.................. 2009 Kia Rio
Curb .... 2459 lb
Test Inertial .... 2451 lb
Dummy................................ 177 lb
Gross Static........................ 2628 lb

Impact Conditions
Speed ....19.5 mi/h
Angle ....0 degrees
Location/Orientation ....Perpendicular
Exit Conditions
Speed ....17.0 mi/h
Angle ....1 degree
Occupant Risk Values
Impact Velocity
Longitudinal.....................3.0 ft/s
Lateral ....0.3 ft/s
Ridedown Accelerations
Longitudinal.....................1.4 G
Lateral ....0.3 G
THIV ....3.4 km/h (0.9 m/s)
PHD ....1.4 G
ASI 0.12
Max. 0.050-s Average
Longitudinal.....................−1.0 G
Lateral ....0.1 G
Vertical ....−0.6 G

Post-Impact Trajectory
Stopping Distance .... 50 ft downstream

Vehicle Stability
Maximum Yaw Angle................ 2 degrees
Maximum Pitch Angle............... 2 degrees
Maximum Roll Angle................. 4 degrees
Vehicle Snagging .... NA
Vehicle Pocketing..................... NA

Debris Pattern
Longitudinal.............................. 58 ft
Lateral .... 3.5 ft
Vehicle Damage
VDS 12FC1
CDC 12FCEN1
Max. Exterior Deformation......... None
OCDI FS0000000
Max. Occupant Compartment Deformation .... None

Figure 5.10. Summary of Results for *MASH* Test 3-60 on the Dual Locking Architectural Mailboxes on the SHUR-TITE® Multiple-Mount Post.

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 occupant impact velocity was 3.0 ft/s, and lateral occupant impact velocity was 0.3 ft/s. (PASS)

I. *Occupant ridedown accelerations should satisfy the following:*
Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15.0 Gs	*20.49 Gs*

Results: Longitudinal ridedown acceleration was 1.4 Gs, and lateral ridedown acceleration was 0.3 Gs. (PASS)

5.2.8.3 Vehicle Trajectory
N. Vehicle trajectory behind the test article is acceptable.

Result: The 1100C vehicle came to rest behind the mailbox installation. (PASS)

5.3 *MASH* TEST 3-61 (CRASH TEST NO. 490023-9-4)

5.3.1 Test Designation and Actual Impact Conditions

MASH Test 3-61 involves an 1100C passenger car weighing 2420 lb ±55 lb and impacting the support structure at the critical impact angle at an impact speed of 62 mi/h. The critical impact angle (CIA) was determined to be center of car aligned with center of mailbox support post with the mailbox oriented perpendicular to path of vehicle. The 2009 Kia Rio used in the test weighed 2423 lb and the actual impact speed was 63.0 mi/h. The actual impact point was at the CIA as stated above.

5.3.2 Test Vehicle

Figures 5.11 and 5.12 show the 2009 Kia Rio used for the crash test. Test inertia weight of the vehicle was 2423 lb, and its gross static weight was 2588 lb. The height to the lower edge of the vehicle bumper was 7.0 inches, and height to the lower edge of the bumper was 22.0 inches. Table D1 in Appendix D gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Figure 5.11. Vehicle/Installation Geometrics for Test No. 490023-9-4.

Figure 5.12. Vehicle before Test No. 490023-9-4.

5.3.3 Weather Conditions

The test was performed on the afternoon of August 16, 2013. Weather conditions at the time of testing were as follows: (a) wind speed: 6 mi/h; (b) wind direction: 211 degrees with respect to the vehicle (vehicle was traveling in a southerly direction); (c) temperature: 92°F; (d) relative humidity: 54 percent.

5.3.4 Test Description

The 1100C vehicle, traveling at an impact speed of 63.0 mi/h, impacted the locking architectural mailbox installation at 0 degrees with the centerline of the vehicle aligned with the centerline of the mailboxes. Shortly after impact, the semi-circular support began to deform and collapse and the mailboxes began to rotate toward the vehicle. At approximately 0.014 s, the support post began to pull out of the socket, and at 0.031 s, it began to ride up on the hood of the vehicle. The mailbox nearest the vehicle upon impact contacted the windshield at 0.061 s, and the windshield shattered and deformed inward. At 0.087 s, the mailboxes and support post began to rotate upward and over the vehicle, and at 0.138 s, the mailbox in the windshield began to rotate out of the windshield. The vehicle lost contact with the mailbox installation at 0.176 s, and was traveling at an exit speed of 60.1 mi/h. Brakes on the vehicle were applied at 0.4 s after impact, and the vehicle came to rest 238 ft downstream of impact. Figures D1 and D2 in Appendix D show sequential photographs of the test period.

5.3.5 Damage to Test Installation

Figures 5.13 and 5.14 show damage to the mailbox installation. The support post collapsed inward and was pulled out of the socket. The mailboxes remained attached to the support post, however, the doors separated from the mailboxes. The mailboxes and support post came to rest 110 ft downstream of impact.

Figure 5.13. Vehicle/Installation Positions after Test No. 490023-9-4.

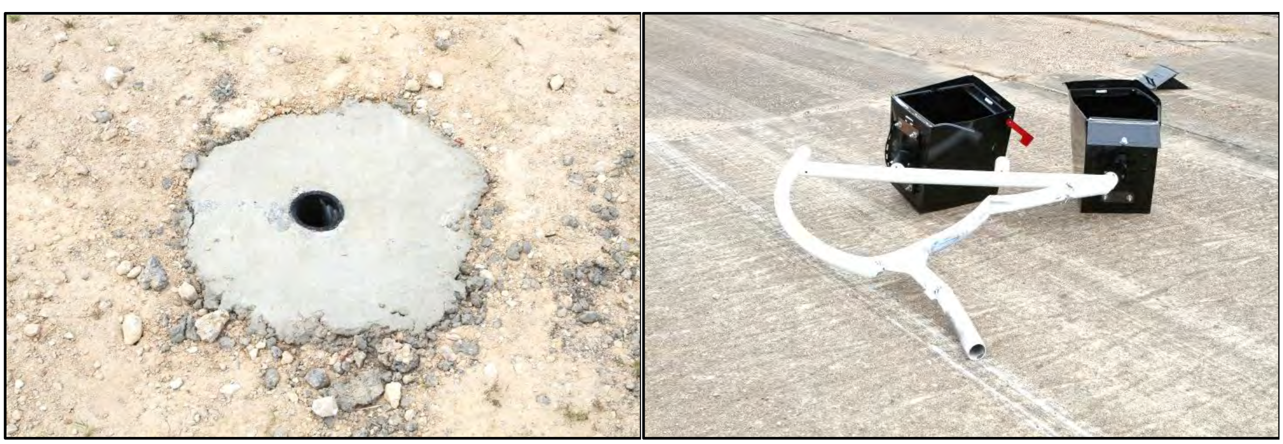


Figure 5.14. Installation after Test No. 490023-9-4.

5.3.6 Vehicle Damage

The windshield sustained four cuts. One cut was 19 inches long, a second was 4.5 inches long, a third was 2 inches long, and the fourth was 3 inches long. The windshield was depressed 4.5 inches toward the occupant compartment over an area measuring 30 inches × 36 inches. Figure 5.15 shows damage to the exterior of the vehicle, and Figure 5.16 shows the interior of the vehicle. Tables D2 and D3 in Appendix D provide exterior crush and occupant compartment measurements.

Figure 5.15. Vehicle after Test No. 490023-9-4.

Figure 5.16. Interior of Vehicle after Test No. 490023-9-4.

5.3.7 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 was 5.6 ft/s at 0.649 s, the highest 0.010-s occupant ridedown acceleration was 1.0 Gs from 0.674 to 0.684s, and the maximum 0.050-s average acceleration was −1.6 Gs between 0.003 and 0.053 s. In the lateral direction, the occupant impact velocity was 0.3 ft/s at 0.649 s, the highest 0.010-s occupant ridedown acceleration was 0.3 Gs from 0.764 to 0.774 s, and the maximum 0.050-s average was −0.2 Gs between 0.121 and 0.171 s. THIV was 6.0 km/h or 1.7 m/s at 0.648 s; PHD was 1.0 Gs between 0.674 and 0.684 s; and ASI was 0.14 between 0.011 and 0.061 s. Figure 5.17 summarizes these data and other pertinent information from the test. Figures D2 through D8 in Appendix D show the vehicle angular displacements and accelerations versus time traces.

5.3.8 Assessment of Test Results

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

5.3.8.1 Structural Adequacy

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

Results: The locking architectural mailbox installation yielded to the vehicle and pulled out of the ground socket. (PASS)

5.3.8.2 Occupant Risk

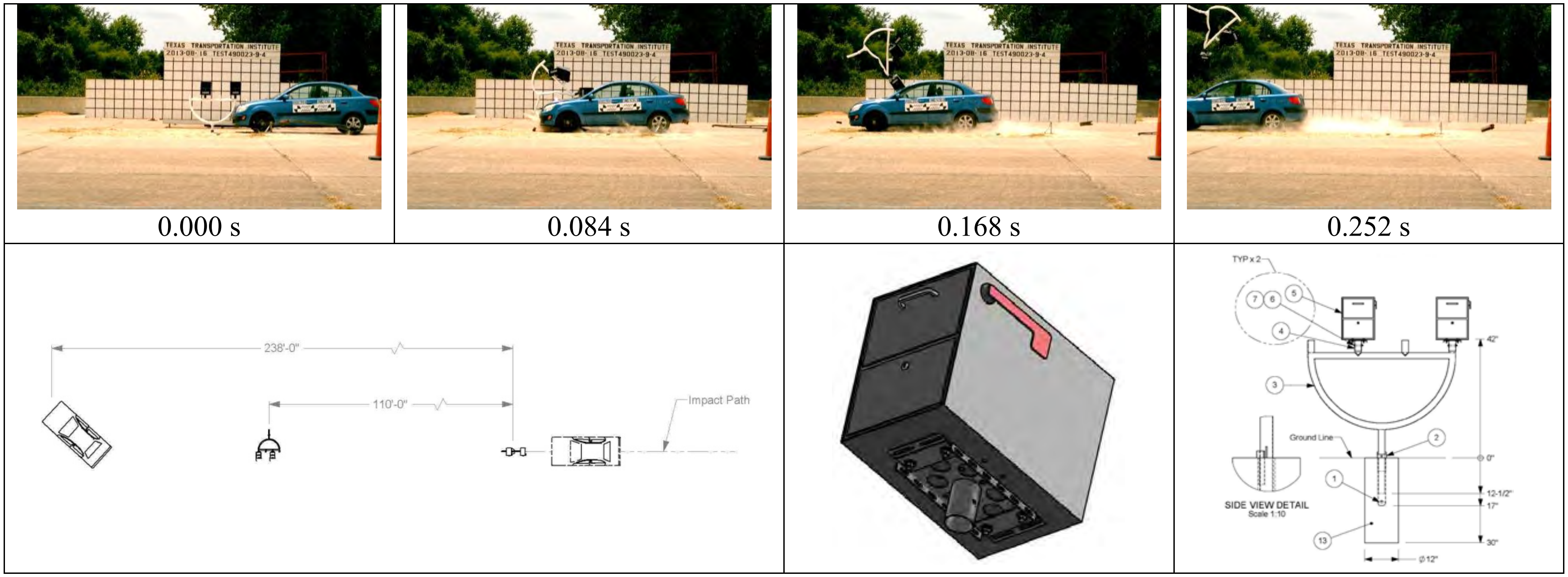
D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.

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: The mailboxes and support contacted and penetrated the windshield. (FAIL)
Maximum occupant compartment deformation was 4.5 inches in the windshield area. (FAIL)

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 both 2 degrees. (PASS)



General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	MASH Test 3-61
TTI Test No.	490023-9-4
Test Date	2013-08-16

Test Article

Type	Mailbox
Name	Locking Architectural Mailbox on SURE-TITE® Multiple-Mount Post
Installation Height	42 inches
Material or Key Elements	Two locking mailboxes on semi-circular steel tube support inserted into concrete footing and secured using plastic wedge and socket

Soil Type and Condition ..... Concrete footing in crushed limestone, dry

Test Vehicle

Type/Designation	1100C
Make and Model	2009 Kia Rio
Curb	2418 lb
Test Inertial	2423 lb
Dummy	165 lb
Gross Static	2588 lb

Impact Conditions

Speed	63.8 mi/h
Angle	0 degrees
Location/Orientation	Perpendicular

Exit Conditions

Speed	61.9 mi/h
Angle	~0 degree

Occupant Risk Values

Impact Velocity	
Longitudinal	4.9 ft/s
Lateral	No contact
Ridedown Accelerations	
Longitudinal	1.0 G
Lateral	0.2 G
THIV	5.5 km/h (1.5 m/s)
PHD	1.0 G
ASI	0.13
Max. 0.050-s Average	
Longitudinal	−1.6 G
Lateral	−0.3 G
Vertical	0.8 G

Post-Impact Trajectory

Stopping Distance	238 ft dw

Vehicle Stability

Maximum Yaw Angle	4 degrees
Maximum Pitch Angle	3 degrees
Maximum Roll Angle	7 degrees
Vehicle Snagging	NA
Vehicle Pocketing	NA

Debris Pattern

Longitudinal	110 ft
Lateral	Centerline

Vehicle Damage

VDS	NA
CDC	12FCEN6
Max. Exterior Deformation	4.5 inches (windshield)
OCDI	FS0000011
Max. Occupant Compartment Deformation	4.5 inches (windshield)

Figure 5.17. Summary of Results for *MASH* Test 3-61 on the Dual Locking Architectural Mailboxes on the SHUR-TITE® Multiple-Mount Post.

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 occupant impact velocity was 5.6 ft/s, and lateral occupant impact velocity was 0.3 ft/s. (PASS)

I. *Occupant ridedown accelerations should satisfy the following:*
Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15.0 Gs	*20.49 Gs*

Results: Longitudinal ridedown acceleration was 1.0 G, and lateral ridedown acceleration was 0.3 G. (PASS)

5.3.8.3 Vehicle Trajectory

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

Result: The 1100C vehicle came to rest behind the mailbox installation. (PASS)

CHAPTER 6. LOCKING ARCHITECTURAL MAILBOXES AND STANDARD MAILBOXES ON MULTIPLE-MOUNT SUPPORTS

6.1 TEST ARTICLE DESIGN AND CONSTRUCTION – CRASH TEST NO. 490023-9-5

Except for the mailbox configuration, the test installation was identical to that used in the previous multiple mailbox tests described in Chapter 5. In this test, four mailboxes (two architectural and two standard) were attached to the SHUR-TITE® Products Multiple Mailbox Support.

The two architectural mailboxes were Oasis Jr. manufactured by Architectural Mailboxes, LLC. The architectural mailboxes were attached to the two inside mounting posts.

Two standard mailboxes were attached to the outside mounting posts. The standard mailboxes were “PostMaster Classic” from Solar Group, Inc., a division of Gibraltar Industries: Each of the standard mailboxes was 8¾ inches tall × 6¾ inches wide × 20⅛ inches deep, and weighed 4.4 lb. All of the mailboxes were empty.

The total mass of the four mailboxes, attachment hardware, and post assembly was 86.2 lb. Figures 6.1 through 6.3 show details of the mailbox installation, and Figure 6.4 provides photographs of the completed installation.

6.2 *MASH* TEST 3-61 (CRASH TEST NO. 490023-9-5)

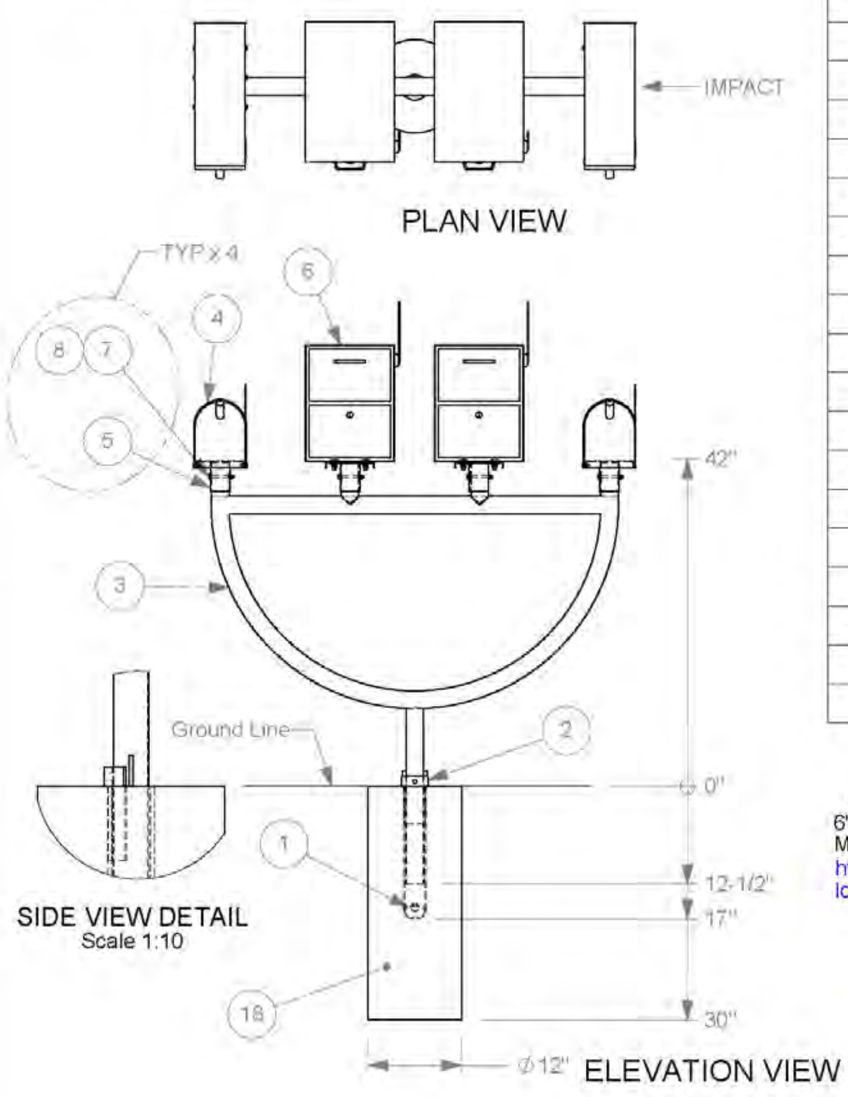
6.2.1 Test Designation and Actual Impact Conditions

MASH Test 3-60 involves an 1100C passenger car weighing 2420 lb ±55 lb and impacting the support structure at the critical impact angle at an impact speed of 62 mi/h. The critical impact angle (CIA) was determined to be center of car aligned with center of mailbox support post with the mailbox oriented perpendicular to path of vehicle The 2008 Kia Rio used in the test weighed 2420 lb, and the actual impact speed was 62.0 mi/h. The actual impact point was at the CIA as stated above.

6.2.2 Test Vehicle

Figures 6.5 and 6.6 show the 2008 Kia Rio used for the crash test. Test inertia weight of the vehicle was 2420 lb, and its gross static weight was 2585 lb. The height to the lower edge of the vehicle bumper was 7.50 inches, and the height to the upper edge of the bumper was 22.0 inches. Table E1 in Appendix E gives additional dimensions and information on the vehicle. 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.

Multiple-mount Install



Multiple-mount Installation Parts			
#	Part Name	Part/DHT #	QTY.
1	Socket, Type 4 Foundation	160891	1
2	Wedge for Type 4 Foundation	160892	1
3	Multiple Mailbox Post, White	164116	1
4	Standard Mailbox	see note	2
5	Bracket for Attaching Mailbox	161443	4
6	Architectural Mailbox	see note	2
7	Bolt, 5/16 x 3 hex	grade 5	4
8	Nut, 5/16" hex	Nut, 5/16 hex	4
9	Plate Washer for Architectural Mailbox	see sheet 3	4
10	Washer, 3/8 flat		16
11	Washer, 3/8 lock		8
12	Nut, 3/8 hex		8
13	Bolt, 3/8 x 1-1/4 hex	grade 5	8
14	Washer, 1/4 flat		14
15	Bolt, 1/4 x 3/4 hex		7
16	Washer, 1/4 lock		7
17	Nut, 1/4 hex		7
18	Concrete, Class B (2000 psi)		1

1a. Outside mailboxes are standard lightweight mailboxes, approximately 6" wide x 8" tall x 19" long. Architectural Mailboxes are Architectural Mailboxes® Oasis Junior.
http://www.architecturalmailboxes.com/products/locking-mailboxes/oasis-locking-mailboxes/oasis-jr/default.aspx

Texas A&M Transportation Institute
Roadside Safety and Physical Security Division
Proving Ground -

Project 490023-9-5 Architectural Mailbox
Drawn By GES Scale 1:20 Sheet 1 of 3 Multiple-mount Install
Approved: Date:
Roger Bligh: 2013-08-29

T:\2012-2013\490023 TxDOT\-9 Mailbox\490023-9-5\Drafting\490023-9 Drawing

Figure 6.1. Details of the Locking Architectural Mailboxes and Standard Mailboxes Installation.

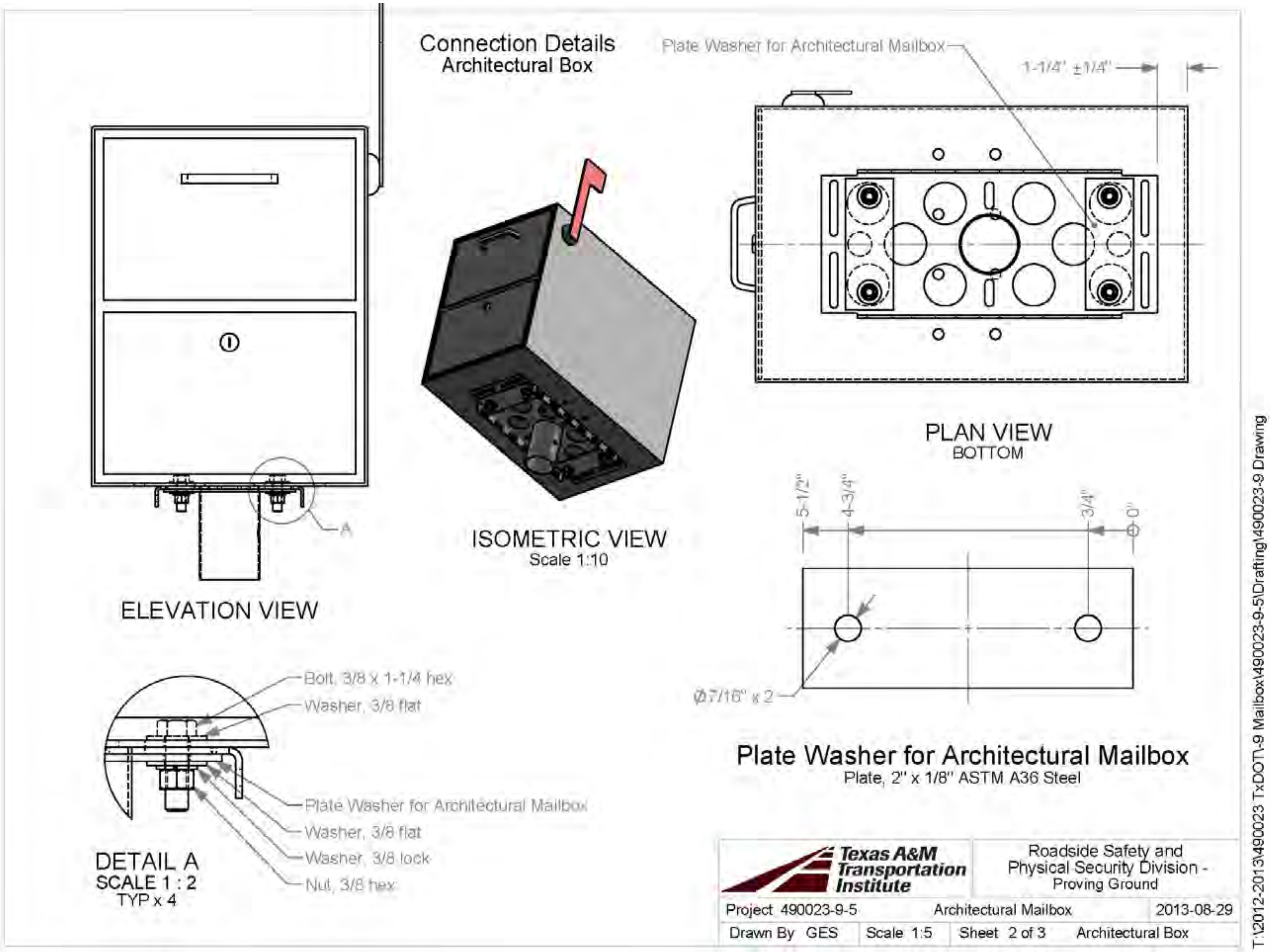


Figure 6.2. Connection Details for the Locking Architectural Mailbox.

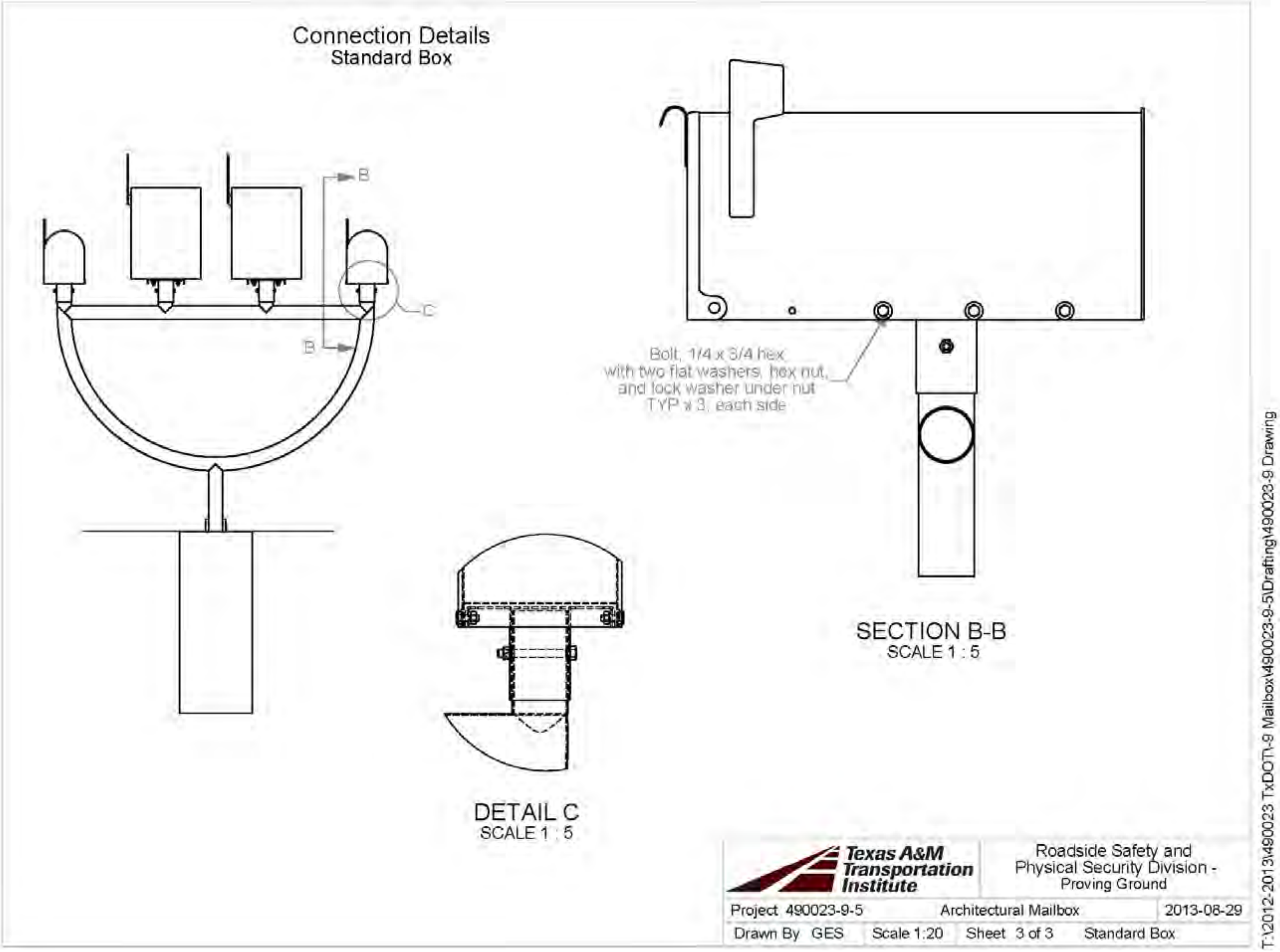


Figure 6.3. Connection Details for the Standard Mailbox.

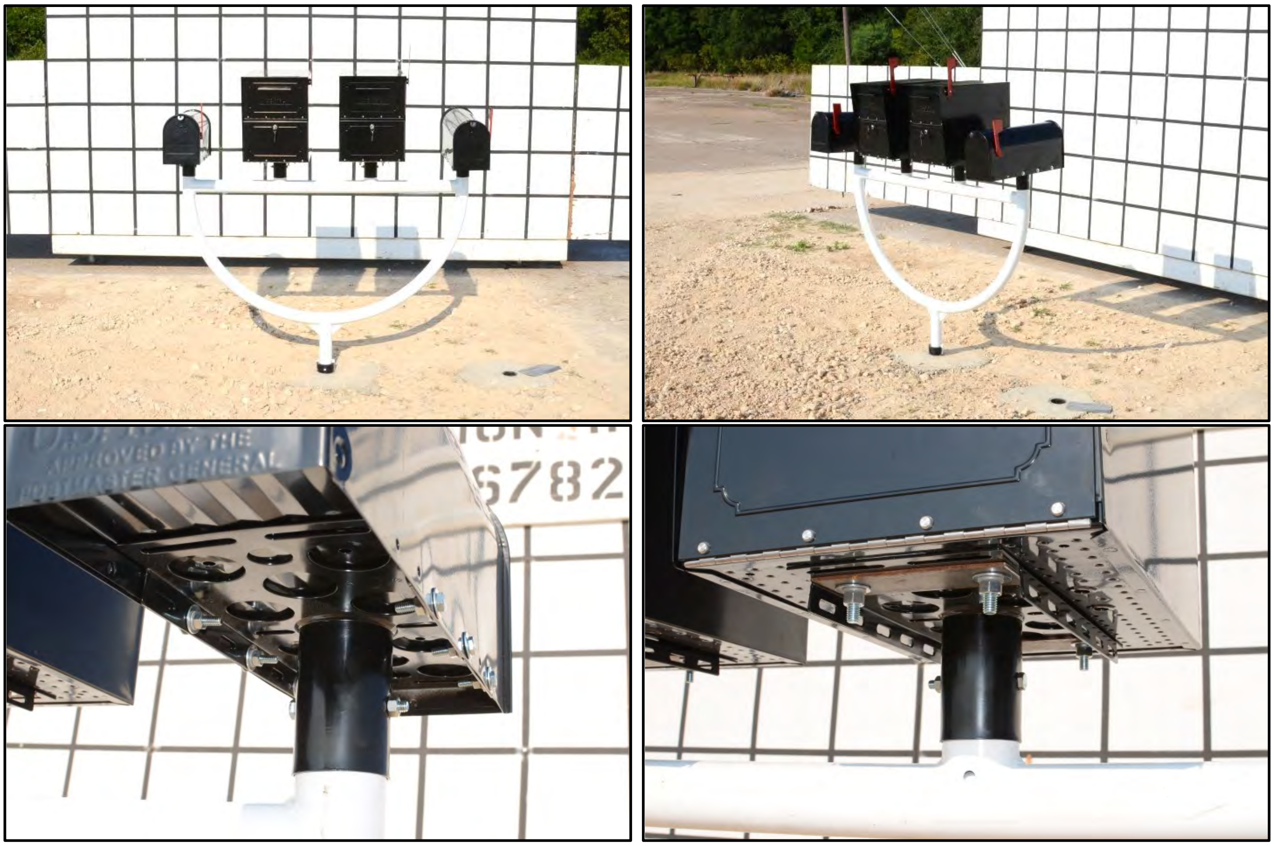


Figure 6.4. Locking Architectural Mailboxes and Standard Mailboxes before Crash Test No. 490023-9-5.

Figure 6.5. Vehicle/Installation Geometrics for Test No. 490023-9-5.


Figure 6.6. Vehicle before Test No. 490023-9-5.

6.2.3 Weather Conditions

The test was performed on the morning of August 30, 2013. Weather conditions at the time of testing were as follows: (a) wind speed: 6 mi/h; (b) wind direction: 222 degrees with respect to the vehicle (vehicle was traveling in a southerly direction); (c) temperature: 84°F; (d) relative humidity: 74 percent.

6.2.4 Test Description

The 2008 Kia Rio, traveling at an impact speed of 62.0 mi/h, impacted the multiple mailbox installation at 0 degrees with the centerline of the vehicle aligned with the centerline of the mailbox. At approximately 0.015 s, the semi-circular tube separated from the lower vertical ground stub that extended into the socket, and at 0.029 s, the hood rode up under the released mailboxes and upper support. The lower ground stub caught on the vehicle at 0.041 s, began to pull out of the ground, and subsequently bent over 90 degrees at ground level. At 0.052 s, the mailboxes and upper support post contacted the windshield, and at 0.069 s, the windshield began to deflect into the occupant compartment. The mailboxes penetrated the windshield at 0.080 s, and then rotated upward into the roof at 0.125 s. At 0.298 s, the support and mailboxes rotated up and out of the windshield, and at 0.409 s, the vehicle lost contact with the mailboxes. Figure E1 in Appendix E shows sequential photographs of the test period.

6.2.5 Damage to Test Installation

Figures 6.7 and 6.8 show damage to the mailbox installation. The mailboxes remained attached to the support post; however, the support post fractured into three pieces. The support post pulled up inside the socket, but did not completely pull out of the socket. The piece remaining in the socket was deformed 90 degrees at ground level. One of the standard mailboxes and a piece of the support post came to rest 177 ft downstream of impact and 14 ft to the left of centerline of the vehicle path. The two locking architectural mailboxes, the second standard mailbox, and a section of the support post came to rest 192 ft downstream of impact and 10 ft to the left of centerline of the vehicle path.

Figure 6.7. Vehicle/Installation Positions after Test No. 490023-9-5.

Figure 6.8. Installation after Test No. 490023-9-5.

6.2.6 Vehicle Damage

The windshield of the vehicle sustained an open tear measuring 14 inches × 24 inches. The roof of the vehicle was deformed downward into the occupant compartment 4.75 inches. Figure 6.9 shows damage to the exterior of the vehicle, and Figure 6.10 shows the interior of the vehicle. Tables E2 and E3 in Appendix E provide exterior crush and occupant compartment measurements.

Figure 6.9. Vehicle after Test No. 490023-9-5.

Figure 6.10. Interior of Vehicle for Test No. 490023-9-5.

6.2.7 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 was 6.2 ft/s at 0.493 s, the highest 0.010-s occupant ridedown acceleration was 1.2 Gs from 0.660 to 0.670 s, and the maximum 0.050-s average acceleration was −1.7 Gs between 0.019 and 0.069 s. In the lateral direction, the occupant impact velocity was 1.0 ft/s at 0.493 s, the highest 0.010-s occupant ridedown acceleration was 0.5 Gs from 0.586 to 0.596 s, and the maximum 0.050-s average was −0.2 Gs between 0.024 and 0.074 s. THIV was 6.9 km/h or 1.9 m/s at 0.494 s; PHD was 1.2 Gs between 0.660 and 0.670 s; and ASI was 0.16 between 0.145 and 0.195 s. Figure 6.11 summarizes these data and other pertinent information from the test. Figures E2 through E8 in Appendix E show the vehicle angular displacements and accelerations versus time traces.

6.2.8 Assessment of Test Results

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

6.2.8.1 Structural Adequacy

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

Results: The multiple-mailbox support initially yielded to the 1100C vehicle and released by rupturing. (PASS)

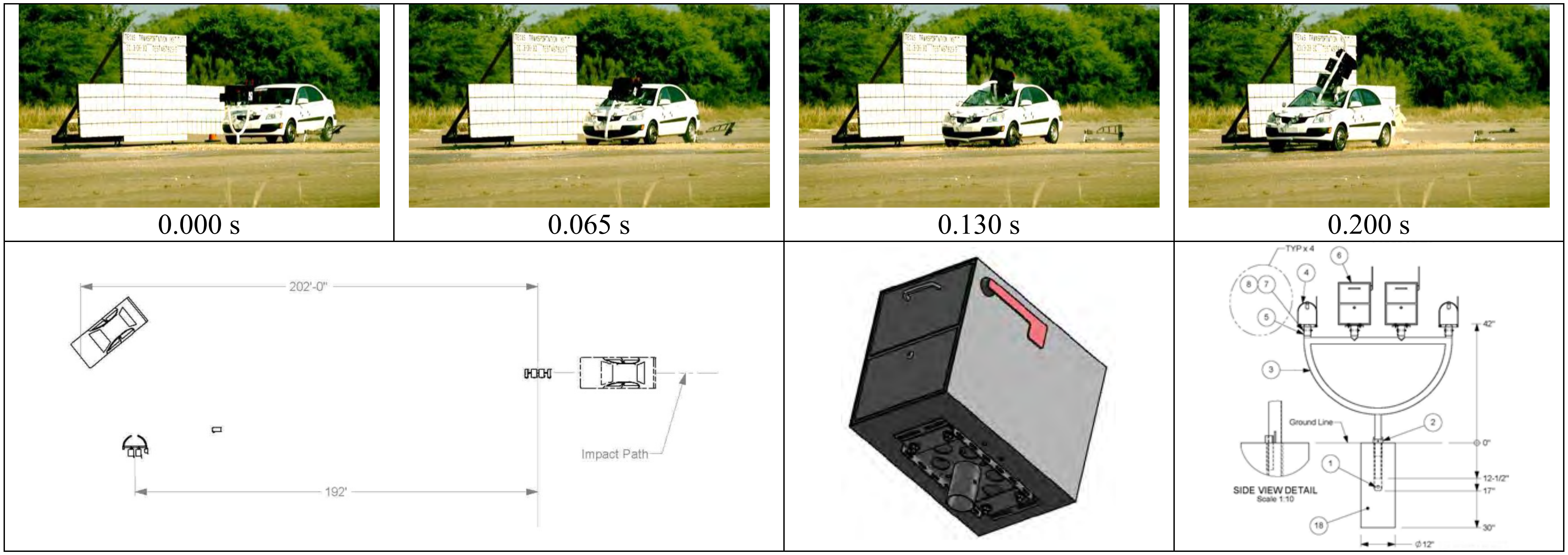
6.2.8.2 Occupant Risk

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: The mailbox support fractured just above ground level and the fractured support and all four mailboxes traveled up the hood and into the windshield creating a large hole in the windshield. (FAIL)
Maximum occupant compartment deformation/intrusion was 4.75 inches in the roof and the windshield had a large hole measuring 14 inches × 24 inches. (FAIL)

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 1 degree and 2 degrees, respectively. (PASS)



General Information
- Test Agency .... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. .... MASH Test 3-60
- TTI Test No. 490023-9-5
- Test Date 2013-08-30

Test Article
- Type .... Mailbox
- Name .... Locking Architectural Mailbox
- Installation Height .... 42 inches
- Material or Key Elements .... Two locking mailboxes and two standard mailboxes on semi-circular support; concrete footing and plastic wedge and socket

Soil Type and Condition....... Concrete footing in crushed limestone, dry

Test Vehicle
- Type/Designation 1100C
- Make and Model.................. 2008 Kia Rio
- Curb .... 2344 lb
- Test Inertial .... 2420 lb
- Dummy................................ 165 lb
- Gross Static......................... 2585 lb

Impact Conditions
- Speed ....62.0 mi/h
- Angle ....0 degrees
- Location/Orientation ....Perpendicular

Exit Conditions
- Speed ....Out of view
- Angle ....Out of view

Occupant Risk Values
- Impact Velocity
  - Longitudinal.....................6.2 ft/s
  - Lateral ....1.0 ft/s
- Ridedown Accelerations
  - Longitudinal.....................1.2 G
  - Lateral ....0.5 G
- THIV ....6.9 km/h (1.9 m/s)
- PHD ....1.2 G
- ASI 0.16
- Max. 0.050-s Average
  - Longitudinal.....................−1.7 G
  - Lateral ....−0.2 G
  - Vertical ....1.4 G

Post-Impact Trajectory
- Stopping Distance .... 202 ft

Vehicle Stability
- Maximum Yaw Angle................. 2 degrees
- Maximum Pitch Angle................ 2 degrees
- Maximum Roll Angle.................. 1 degree
- Vehicle Snagging .... NA
- Vehicle Pocketing...................... NA

Debris Pattern
- Longitudinal............................... 177 ft
- Lateral .... 14 ft

Vehicle Damage
- VDS .... NA
- CDC 12FCEN6
- Max. Exterior Deformation .... 4.75 (windshield)
- OCDI FS0000011
- Max. Occupant Compartment Deformation .... 4.75 inches (windshield)

Figure 6.11. Summary of Results for *MASH* Test 3-60 on the Combination Locking Architectural Mailboxes and Standard Mailboxes on the SHUR-TITE® Multiple-Mount Post.

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 occupant impact velocity was 6.2 ft/s, and lateral occupant impact velocity was 1.0 ft/s. (PASS)

I. *Occupant ridedown accelerations should satisfy the following:*
Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15.0 Gs	*20.49 Gs*

Results: Longitudinal ridedown acceleration was 1.2 G, and lateral ridedown acceleration was 0.5 G. (PASS)

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

Result: The 1100C vehicle came to rest 202 ft behind the mailbox installation. (PASS)

6.3 TEST ARTICLE DESIGN AND CONSTRUCTION – CRASH TEST NO. 490023-9-6

The mailbox configuration used in this test was the same as used in Test 490023-9-5. Two Oasis Jr. locking architectural mailboxes manufactured by Architectural Mailboxes, LLC were attached to the interior of the multiple mount support with the centerline of each box located 8 inches from the centerline of the support post. Two PostMaster Classic standard mailboxes from Solar Group, Inc., a division of Gibraltar Industries, were attached on either side of the locking mailboxes with the centerline of each box located 21 inches from the centerline of the support post. All of the mailboxes were empty.

The attachment of the locking architectural mailboxes to the horizontal segment of the thin-wall steel mounting post was accomplished using two mailbox brackets (DHT# 148939), two Part "A" angle bracket connectors (DHT# 159489), and two plate washers per mailbox. One mailbox bracket was attached flush with the bottom of the locking mailbox (flanges pointed outward) using four ⅜-inch diameter × 1¼-inch long SAE Grade 5 bolts using existing holes in the mailbox and bracket. A 2-inch wide ×5 ½-inch long × ⅛-inch thick ASTM A36 steel plate washer was positioned over the bracket to help secure each set of two bolts toward the front and back of the mailbox. A ⅜-inch flat washer, lock washer, and nut were used for each bolt.

The two angle bracket connectors were attached to the second mailbox bracket using a ⅜ inch diameter × 1-inch long SAE Grade 5 bolt through existing slots in the mailbox bracket. The flanges of the second mailbox bracket faced away from the angle bracket connectors. The two mailbox brackets were then nested together and connected using four ¼-inch diameter ×

¾-inch long SAE Grade 5 bolts on each side using hand holes through the bottom of the bracket. A hole was drilled through the horizontal section of the thin-wall steel tube support post at the desired mailbox position. The angle connection brackets were clamped to the thin-wall steel tube support using a ⅜-inch diameter × 4-inch long SAE Grade 5 bolt through the support post and connection brackets.

The standard mailboxes were attached to the horizontal segment of the thin-wall steel mounting post using a mailbox bracket (DHT# 148939) and two Part "A" angle bracket connectors (DHT# 159489) per mailbox. The two angle bracket connectors were attached to the mailbox bracket using a ⅜-inch diameter × 1-inch long SAE Grade 5 bolt through existing slots in the mailbox bracket. The flanges of the mailbox bracket faced away from the angle bracket connectors. The mailbox bracket was nested inside the flanges at the bottom of the mailbox and connected together with three ¼-inch diameter × ¾-inch long SAE Grade 5 bolts on each side. A hole was drilled through the horizontal section of the thin-wall steel tube support post at the desired mailbox position. The angle connection brackets were clamped to the thin-wall steel tube support using a ⅜-inch diameter × 4-inch long SAE Grade 5 bolt through the support post and connection brackets.

The thin-wall steel tube mailbox support post (DHT# 149339) was formed from 2-inch OD × 0.065 thick galvanized welded mechanical tubing. The support post had outwardly sloping sides and a horizontal section on top to which the mailboxes were attached. The support had an overall width of 56 inches and weighed 18 lb. The shorter end of the bent support post was bolted to the longer end using two $^{5}/_{16}$-inch diameter × 5-inch long SAE Grade 5 bolts.

The longer end of the support was inserted approximately 9 inches into a V-wing socket (DHT# 160446) that was embedded flush with the top of a non-reinforced concrete footing that was approximately 12 inches in diameter × 30 inches deep. The concrete was specified as Class B having a minimum 28-day unconfined compressive strength of 2000 psi. A triangular wedge (DHT# 46625) was driven into the V-wind socket on the impact side of the support post to secure it inside the foundation.

The total mass of the four mailboxes, connection hardware, and post assembly was 88.0 lb. Figures 6.12 through 6.16 show details of the installation, and Figure 6.17 provides photographs of the completed installation.

6.4 *MASH* TEST 3-61 (CRASH TEST NO. 490023-9-6)

6.4.1 Test Designation and Actual Impact Conditions

MASH Test 3-61 involves an 1100C passenger car weighing 2420 lb ±55 lb impacting the support structure at the critical impact angle at an impact speed of 62 mi/h. The critical impact angle (CIA) was determined to be center of car aligned with center of mailbox support post with the mailbox oriented perpendicular to path of vehicle The 2008 Kia Rio used in the test weighed 2425 and the actual impact speed was 62.4 mi/h. The actual impact point was at the CIA as stated above.

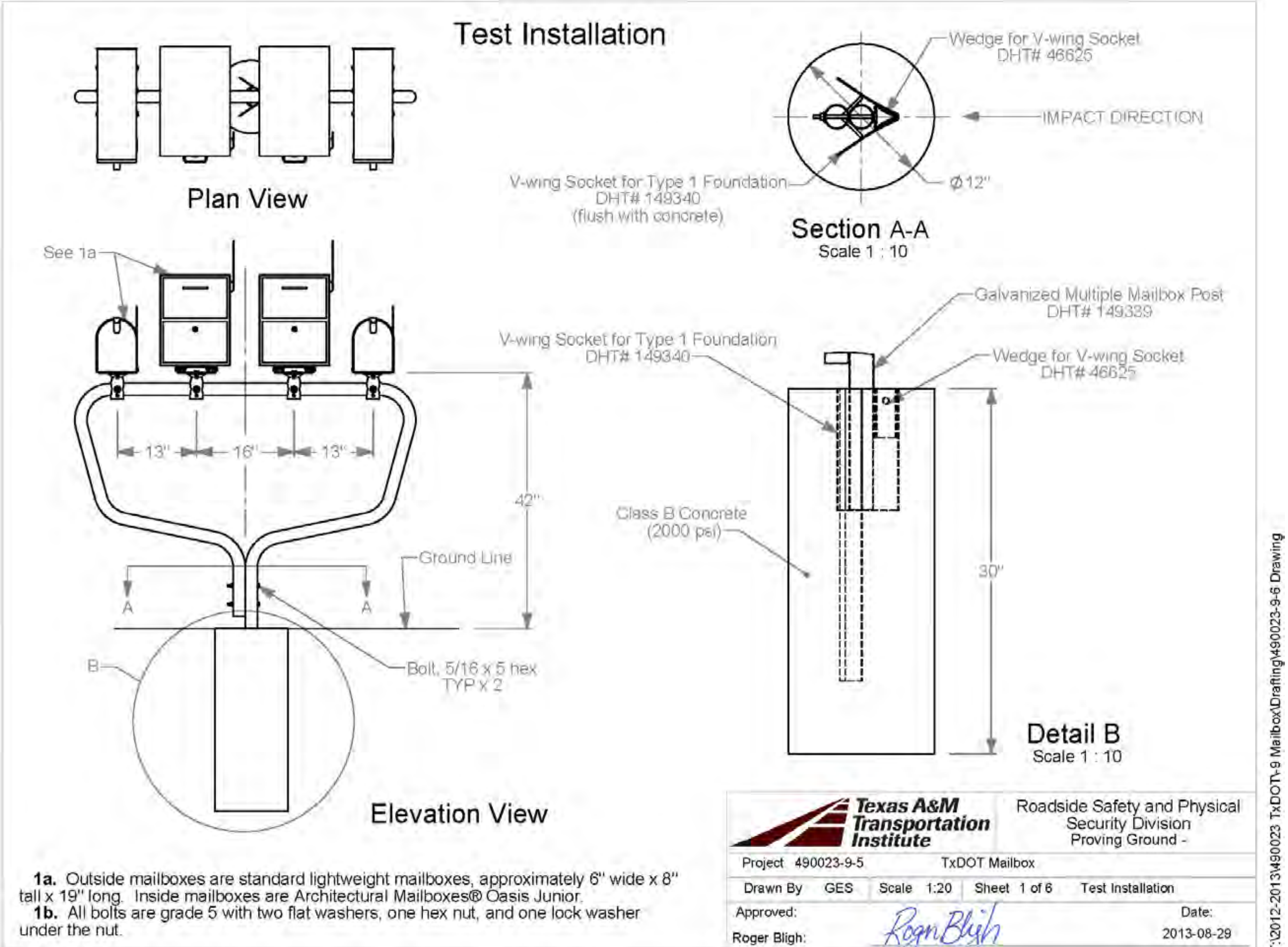


Figure 6.12. Details of the Locking Architectural Mailboxes and Standard Mailboxes Installation.

INSTALLATION PARTS		
PART NAME	DHT Number	QTY
Galvanized Multiple Mailbox Support	149339	1
Standard Mailbox		2
Architectural Mailbox		2
Plate Washer for Architectural Mailbox		4
Bracket for Mailbox	148939	6
Angle Bracket Part A	159489	8
Washer, 3/8 flat		40
Washer, 3/8 lock		20
Nut, 3/8 hex		20
Bolt, 3/8 x 1 hex		16
Bolt, 3/8 x 4 hex		4
Washer, 1/4 flat		56
Washer, 1/4 lock		28
Nut, 1/4 hex		28
Bolt, 1/4 x 3/4 hex		28
V-wing Socket for Type 1 Foundation	149340	1
Wedge for V-wing Socket	46625	1

Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project 490023-9-5 TxDOT Mailbox 2013-08-29

Drawn By GES No Scale Sheet 2 of 6 Parts List

T:\2012-2013\490023 TxDOT\-9 Mailbox\Drafting\490023-9-6 Drawing

Figure 6.12. Details of the Locking Architectural Mailboxes and Standard Mailboxes Installation (continued).

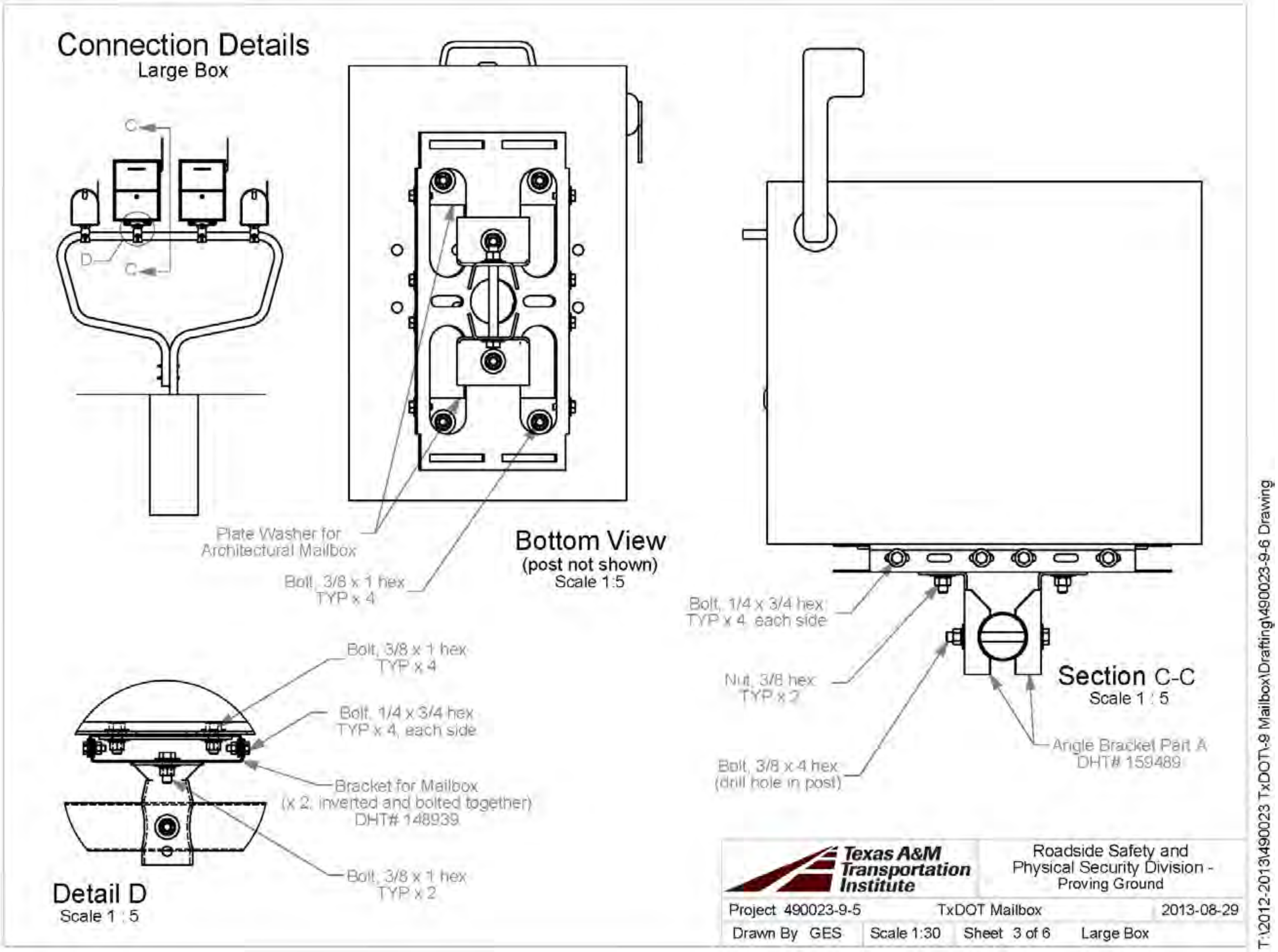


Figure 6.13. Details of the Connection for the Locking Architectural Mailboxes.

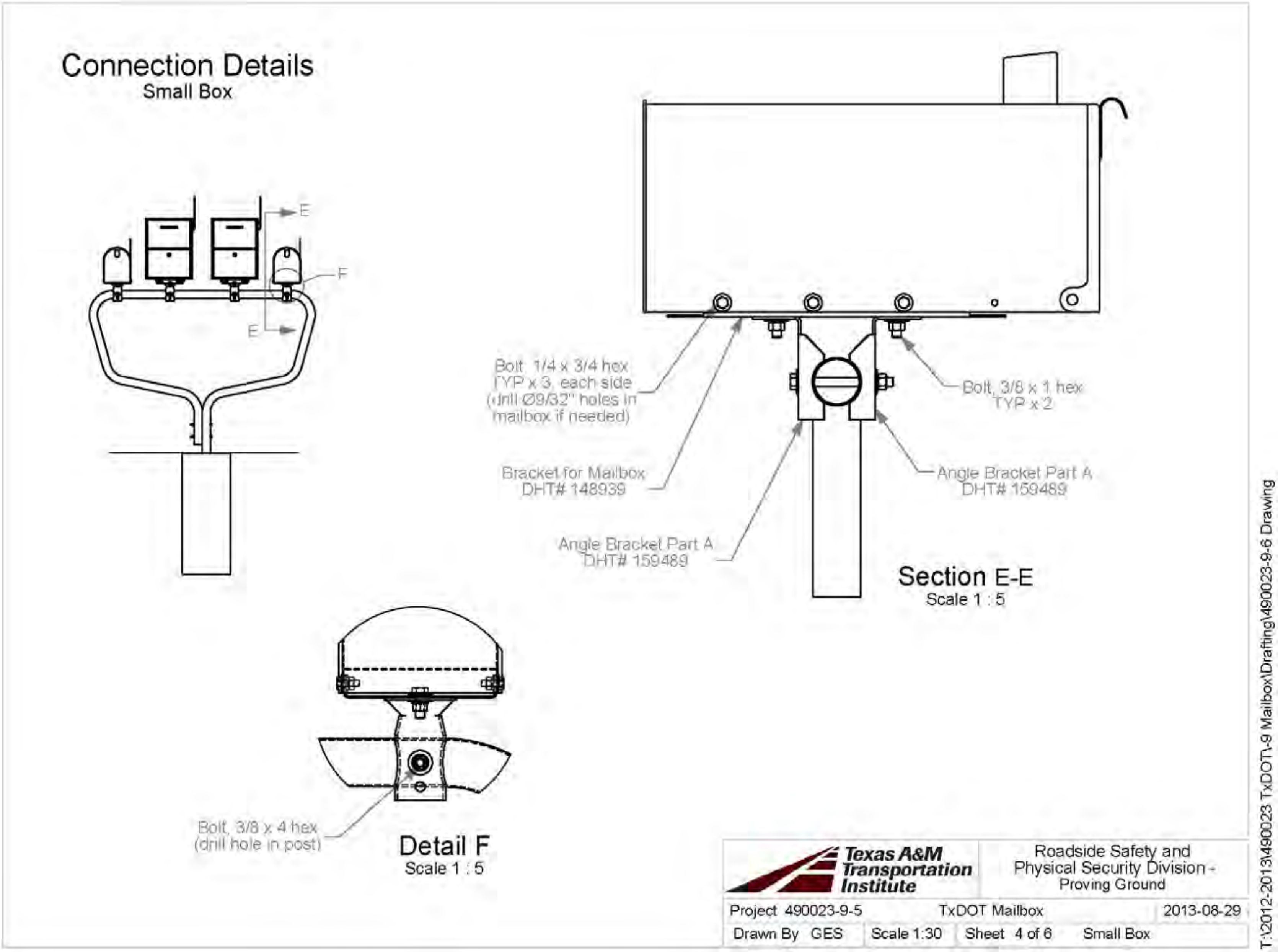


Figure 6.14. Details of the Connection for the Standard Mailboxes.

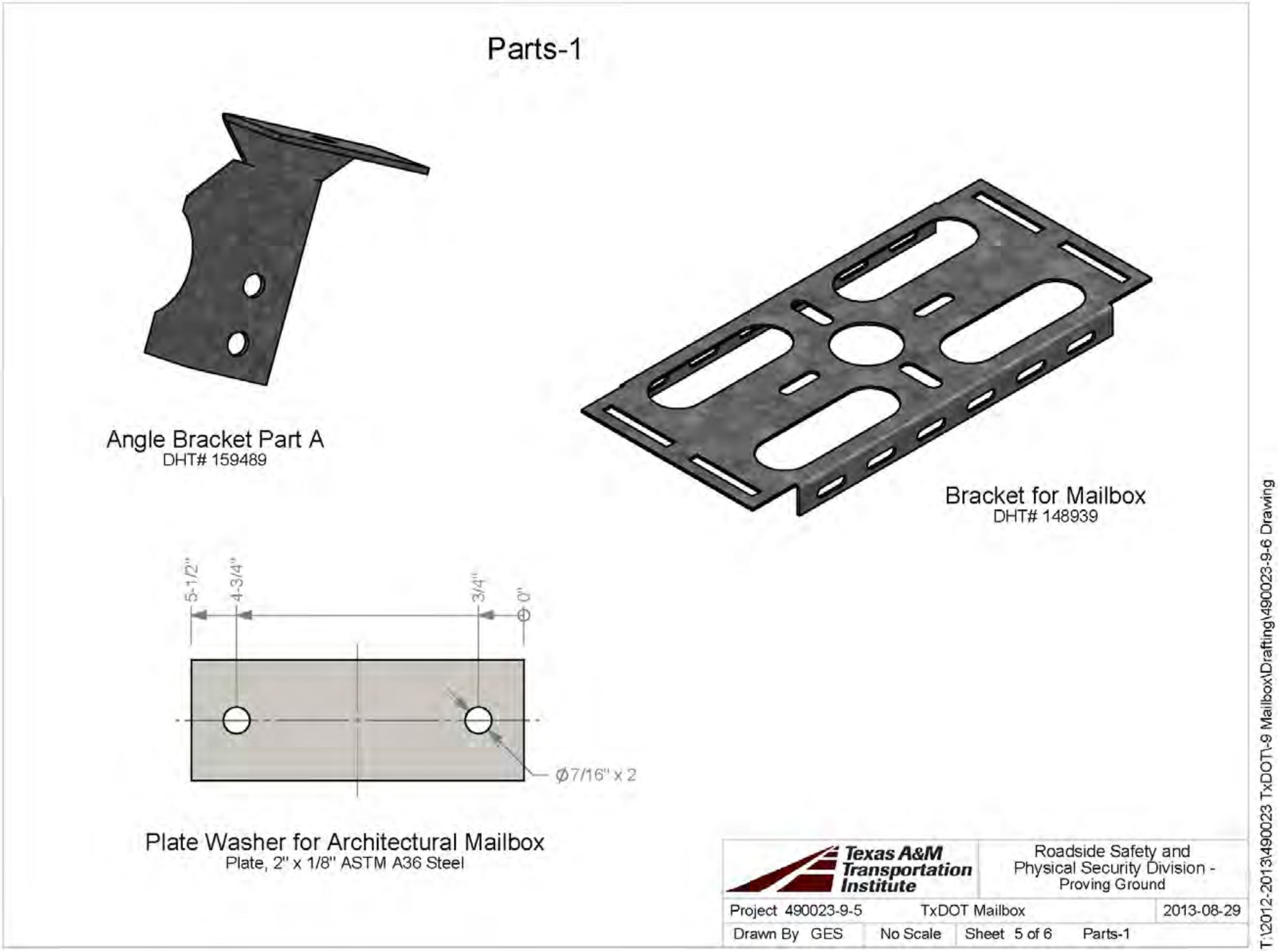


Figure 6.15. Details of the Brackets.

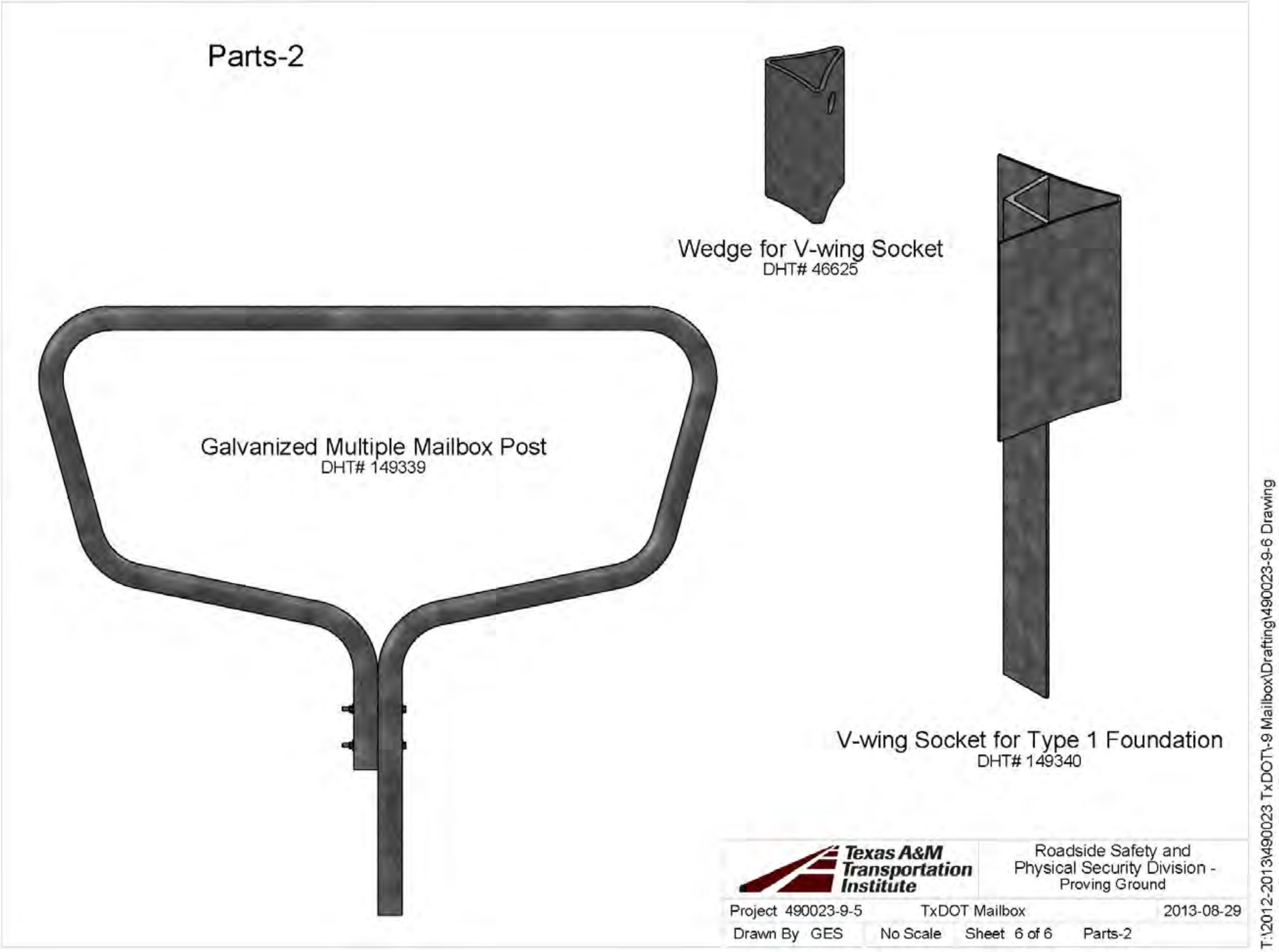


Figure 6.16. Details of the Formed Thin-Wall Steel Tube Multiple-Mount Support Post.

Figure 6.17. Locking Architectural Mailboxes and Standard Mailboxes before Crash Test No. 490023-9-6.

6.4.2 Test Vehicle

Figures 6.18 and 6.19 show the 2008 Kia Rio used in the crash test. Test inertia weight of the vehicle was 2425 lb, and its gross static weight was 2590 lb. The height to the lower edge of the vehicle bumper was 7.50 inches, and the height to the upper edge of the bumper was 21.75 inches. Table F1 in Appendix F gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

6.4.3 Weather Conditions

The test was performed on the afternoon of August 30, 2013. Weather conditions at the time of testing were as follows: (a) wind speed: 2 mi/h; (b) wind direction: 276 degrees with respect to the vehicle (vehicle was traveling in a southerly direction); (c) temperature: 100°F; (d) relative humidity: 37 percent.

Figure 6.18. Vehicle/Installation Geometrics for Test No. 490023-9-6.

Figure 6.19. Vehicle before Test No. 490023-9-6.

6.4.4 Test Description

The 2008 Kia Rio, traveling at an impact speed of 62.4 mi/h, impacted the multiple mailbox installation at 0 degrees with the centerline of the vehicle aligned with the centerline of the mailbox. At approximately 0.007 s, the support tube began to deform on impact side, and at 0.014 s, the support post and wedge began to pull out of the ground socket. The support tube on the impact side began to fracture at 0.023 s, and the post and wedge pulled out the ground socket at 0.035 s. At 0.057 s, the mailbox contacted the windshield, and at 0.0150 s, the vehicle lost contact with the mailbox as it traveled up and over the vehicle. Brakes on the vehicle were applied 1.6 s after impact, and the vehicle came to rest 272 ft downstream from impact. Figures F1 and F2 in Appendix F show sequential photographs of the test period.

6.4.5 Damage to Test Installation

Figures 6.20 and 6.21 show damage to the mailbox installation. The support pulled out of the foundation socket and was fractured on the impact side. The mailboxes remained attached to the support post. The system came to rest 188 ft downstream of impact and 8 ft to the left of centerline of the vehicle path.

Figure 6.20. Vehicle/Installation Positions after Test No. 490023-9-6.

Figure 6.21. Installation after Test No. 490023-9-6.

6.4.6 Vehicle Damage

The hood of the vehicle was dented and pushed downward. The windshield was shattered and pushed into the occupant compartment 3.5 inches and there were several small tears at the bottom edge of the windshield behind the dashboard. Figure 6.22 shows damage to the exterior of the vehicle, and Figure 6.23 shows the interior of the vehicle. Tables F2 and F3 in Appendix F provide exterior crush and occupant compartment measurements.

Figure 6.22. Vehicle after Test No. 490023-9-6.

Figure 6.23. Interior of Vehicle for Test No. 490023-9-6.

6.4.7 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 was 4.9 ft/s at 0.462 s, the highest 0.010-s occupant ridedown acceleration was 0.5 Gs from 0.687 to 0.697 s, and the maximum 0.050-s average acceleration was −1.7 Gs between 0.036 and 0.086 s. In the lateral direction, the occupant impact velocity was 5.2 ft/s at 0.462 s, the highest 0.010-s occupant ridedown acceleration was 1.0 Gs from 0.533 to 0.543 s, and the maximum 0.050-s average was −0.8 Gs between 0.117 and 0.167 s. THIV was 7.6 km/h or 2.1 m/s at 0.419 s; PHD was 1.1 Gs between 0.451 and 0.461 s; and ASI was 0.16 between 0.064 and 0.114 s. Figure 6.24 summarizes these data and other pertinent information from the test. Figures F2 through F8 in Appendix F show the vehicle angular displacements and accelerations versus time traces.

6.4.8 Assessment of Test Results

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

6.4.8.1 Structural Adequacy

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

Results: The multiple-mount support yielded to the 1100C vehicle and pulled out of the foundation socket. (PASS)

6.4.8.2 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: Contact of the locking architectural mailboxes and standard mailboxes on multiple-mount support with the windshield caused several small tears at the base of the windshield. (FAIL)
Maximum occupant compartment deformation was 3.5 inches in the windshield on the driver's side. (FAIL)

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 were 4 degrees and 1 degree, respectively. (PASS)

I. Occupant impact velocities should satisfy the following:

Longitudinal and Lateral Occupant Impact Velocity

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

Results: Longitudinal occupant impact velocity was 4.9 ft/s, and lateral occupant impact velocity was 5.2 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:

Longitudinal and Lateral Occupant Ridedown Accelerations

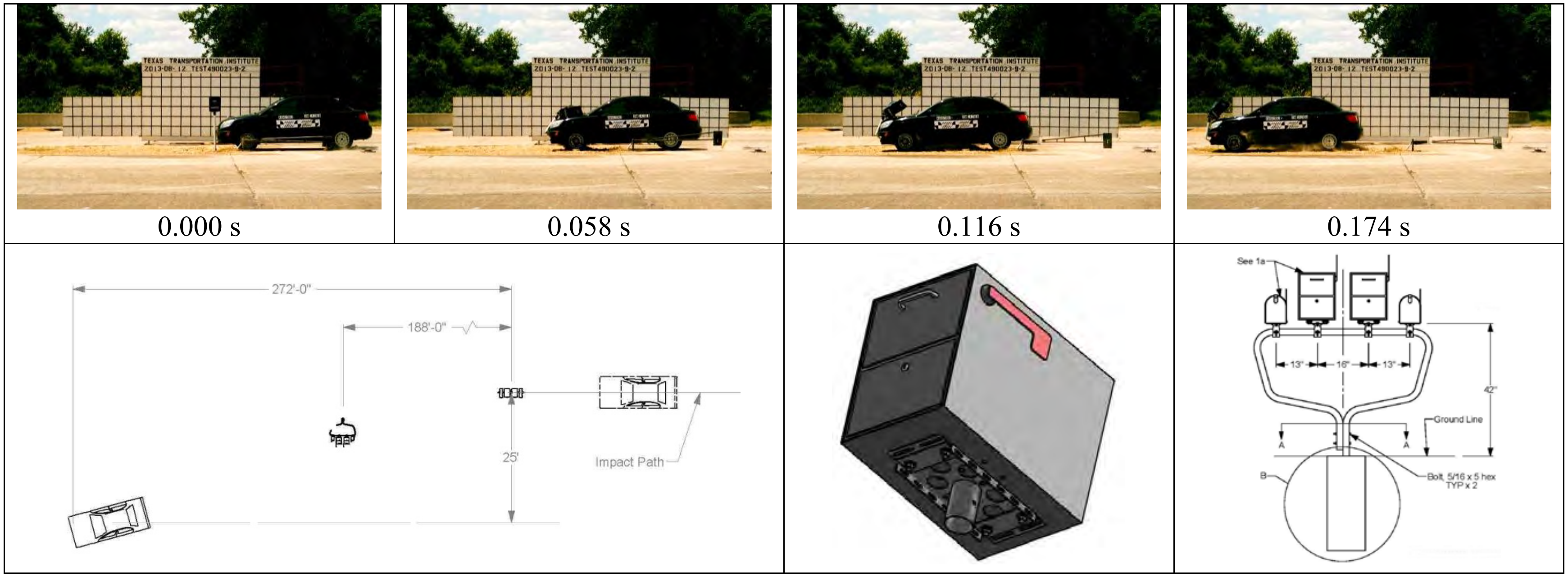
Preferred	*Maximum*
15.0 Gs	*20.49 Gs*

Results: Longitudinal ridedown acceleration was 0.5 G, and lateral occupant ridedown acceleration was 1.0 G. (PASS)

6.4.8.3 Vehicle Trajectory

N. Vehicle trajectory behind the test article is acceptable.

Result: The 1100C vehicle came to rest 272 ft behind the test installation. (PASS)



General Information
- Test Agency .... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. ..... MASH Test 3-61
- TTI Test No. 490023-9-6
- Test Date 2013-08-30

Test Article
- Type................................. Mailbox
- Name .... Formed multiple mailbox support
- Installation Height.............. 42 inches
- Material or Key Elements .. Two locking mailboxes and two standard mailboxes on formed thin-wall support; V-loc wedge and socket in concrete footing

Soil Type and Condition..... Concrete footing in crushed limestone, dry

Test Vehicle
- Type/Designation 1100C
- Make and Model................ 2008 Kia Rio
- Curb .... 2437 lb
- Test Inertial .... 2425 lb
- Dummy............................. 165 lb
- Gross Static....................... 2590 lb

Impact Conditions
- Speed..............................62.4 mi/h
- Angle...............................0 degree
- Location/Orientation ....Perpendicular

Exit Conditions
- Speed..............................58.9 mi/h
- Angle...............................2 degrees

Occupant Risk Values
- Impact Velocity
  - Longitudinal...................4.9 ft/s
  - Lateral ....5.2 ft/s
- Ridedown Accelerations
  - Longitudinal...................0.5 G
  - Lateral ....1.0 G
- THIV.................................7.6 km/h (2.1 m/s)
- PHD ....1.1 G
- ASI 0.16

Max. 0.050-s Average
- Longitudinal...................−1.7 G
- Lateral ....−0.8 G
- Vertical ....1.0 G

Post-Impact Trajectory
- Stopping Distance .... 272 ft dwnstrm 25 ft twd traffic

Vehicle Stability
- Maximum Yaw Angle................ 8 degrees
- Maximum Pitch Angle................ 1 degree
- Maximum Roll Angle.................. 4 degrees
- Vehicle Snagging .... NA
- Vehicle Pocketing...................... NA

Debris Pattern
- Longitudinal.............................. 188 ft
- Lateral .... 8 ft

Vehicle Damage
- VDS .... NA
- CDC 12FCEN6
- Max. Exterior Deformation......... 3.5 inches (windshield)
- OCDI FS0000011
- Max. Occupant Compartment Deformation .... 3.5 inches (windshield)

Figure 6.24. Summary of Results for *MASH* Test 3-61 on the Locking Architectural Mailboxes and Standard Mailboxes on the Formed Thin-Wall Steel Tube Multiple-Mount Post.

CHAPTER 7. SUMMARY AND CONCLUSIONS

Concern about mail-identity theft has increased the demand for locking mailboxes. The dual compartment security feature incorporated into these lockable mailboxes makes them considerably larger and heavier than standard mailboxes. Therefore, before TxDOT can permit use of these mailboxes on the state highway system, their crashworthiness had to be evaluated.

Under this project, crash tests were performed following *MASH* guidelines and procedures to assess the impact performance of lockable, secure mailboxes on both single and multiple mount configurations. A summary of the findings is presented below.

7.1 LOCKING ARCHITECTURAL MAILBOX ON SINGLE-MOUNT POST

An Oasis Jr. locking architectural mailbox was successfully tested on a steel thin-wall single-mount post with a passenger car impacting at both low speed (Test 3-60) and high speed (Test 3-61). In the low-speed test, the mailbox support yielded to the vehicle, and the vehicle overrode the installation. There was minimal vehicle damage and no contact with the vehicle windshield. Occupant risk parameters were below preferred values. As summarized in Table 7.1, the single mailbox support with locking architectural mailbox met all applicable *MASH* criteria for Test 3-60.

In the high-speed test, the mailbox support released from the wedge and socket foundation as designed. The locking architectural mailbox remained attached to the support, and there was no contact with the vehicle windshield. Vehicle damage was minor, and occupant risk parameters were below preferred values. As summarized in Table 7.2, the single mailbox support with locking architectural mailbox met all applicable *MASH* criteria for Test 3-61.

7.2 LOCKING ARCHITECTURAL MAILBOX ON MULTIPLE-MOUNT POST

7.2.1 Dual Locking Architectural Mailboxes on the SHUR-TITE® Multiple-Mount Post

Two locking architectural mailboxes were evaluated on a SHUR-TITE® multiple-mount support post. One mailbox was placed at the critical location at the upstream exterior mount position adjacent to the impacting vehicle, and the second was positioned at an interior location. This configuration was tested with a passenger car at both low speed (Test 3-60) and high speed (Test 3-61).

In the low-speed test, the vehicle lifted the support out of the foundation socket as designed and pushed it forward of the vehicle. The mailboxes remained attached to the support, and there was no contact with the vehicle windshield. Vehicle damage was minor and occupant risk parameters were below preferred values. As summarized in Table 7.3, the SHUR-TITE® multiple-mount support post with dual locking architectural mailboxes met all applicable *MASH* criteria for Test 3-60.

Table 7.1. Performance Evaluation Summary for *MASH* Test 3-60 on the Locking Architectural Mailbox on the SHUR-TITE® Single-Mount Post.

Test Agency: Texas A&M Transportation Institute | Test No.: 490023-9-1 | Test Date: 2013-08-12

***MASH* Test 3-60 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 locking architectural mailbox on the SHUR-TITE® single-mount post yielded to the vehicle.	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.*	The locking architectural mailbox detached from the support post and separated into several pieces while being carried along beneath the vehicle. The detached pieces did not penetrate or show potential for penetrating the occupant compartment, nor 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 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 angels were 5 degrees and 4 degrees, respectively.	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 occupant impact velocity was 6.9 ft/s, and lateral occupant impact velocity 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 ridedown acceleration was 1.9 Gs, and lateral ridedown acceleration was 0.8 Gs.	Pass
Vehicle Trajectory *N. Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest behind the mailbox installation.	Pass

Table 7.2. Performance Evaluation Summary for *MASH* Test 3-60 on the Locking Architectural Mailbox on the SHUR-TITE® Single-Mount Post.

Test Agency: Texas A&M Transportation Institute | Test No.: 490023-9-2 | Test Date: 2013-08-12

***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 locking architectural mailbox on the SHUR-TITE® single-mount post yielded to the vehicle and released from its foundation.	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.*	The locking architectural mailbox separated at several connection seams; however, the pieces remained connected and attached to the support post and traveled along the front of the vehicle. The mailbox installation did not penetrate or show potential for penetrating the occupant compartment, nor 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 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 7 degrees and 3 degrees, respectively.	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 occupant impact velocity was 4.9 ft/s, and no contact occurred in the lateral direction.	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 ridedown acceleration was 1.0 Gs, and no contact occurred in the lateral direction.	Pass
Vehicle Trajectory *N.* *Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest behind the mailbox installation.	Pass

Table 7.3. Performance Evaluation Summary for *MASH* Test 3-60 on the Dual Locking Architectural Mailbox on the SHUR-TITE® Multiple-Mount Post.

Test Agency: Texas A&M Transportation Institute | Test No.: 490023-9-3 | Test Date: 2013-08-16

***MASH* Test 3-60 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 locking architectural mailboxes on the SHUR-TITE® multiple-mount post activated by yielding to the vehicle and lifting out of the foundation socket.	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.*	The locking architectural mailbox separated at several connection seams; however, the pieces remained together and attached to the support post and traveled along the front of the vehicle. The mailbox installation did not penetrate or show potential for penetrating the occupant compartment, nor 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 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 4 degrees and 2 degrees, respectively.	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 occupant impact velocity was 3.0 ft/s, and lateral occupant impact velocity was 0.3 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 ridedown acceleration was 1.4 Gs, and lateral ridedown acceleration was 0.3 Gs.	Pass
Vehicle Trajectory *N. Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest behind the mailbox installation.	Pass

In the high-speed test, the mailbox support released from the foundation socket. However, the support post collapsed in the region in contact with the vehicle, and the released mailbox system rotated into the vehicle windshield. The windshield had 4.5 inches of deformation, which exceeds the *MASH* threshold. Consequently, as summarized in Table 7.4, the SHUR-TITE® multiple-mount support post with dual locking architectural mailboxes did not satisfy *MASH* criteria for Test 3-61.

7.2.2 Combination Locking Architectural Mailboxes and Standard Mailboxes on Multiple-Mount Posts

Given the failure encountered in the test of dual locking architectural mailboxes in the critical placement location, additional testing was performed to determine if impact performance would be improved if the locking architectural mailboxes were placed on the interior of the multiple mailbox mounting post. Standard mailboxes were placed on the exterior of the multiple mailbox support post for a total of four mailboxes. It was theorized that the small outer mailbox might restrict the rotation of the heavier, taller lockable mailboxes and, thereby, help limit windshield engagement. This mailbox combination was evaluated on two different multiple mailbox mounts at high-speed with the passenger car (Test 3-61). The previous low-speed test of the multiple mailbox mount was successful with the lockable architectural mailboxes in their critical locations. Therefore, it was concluded that the low-speed tests did not need to be performed for what was considered to be a less critical mailbox configuration.

7.2.2.1 SHUR-TITE® Multiple-Mount Support Post

In the high-speed test of the combination mailbox configuration on the SHUR-TITE® multiple-mount support post, the support did not release from the foundation socket. It fractured into multiple pieces, leaving the foundation stub partially embedded in the foundation socket. The fractured support and mailboxes impacted and created a large hole in the vehicle windshield. Consequently, as summarized in Table 7.5, the SHUR-TITE® multiple-mount support post with a combination of standard and locking architectural mailboxes did not satisfy *MASH* criteria for Test 3-61.

7.2.2.2 Formed Thin-Wall Steel Tube Multiple-Mount Support Post

In the high-speed test of the combination mailbox configuration on the formed thin-wall steel tube multiple-mount support post, the support released from the foundation socket as designed but fractured in the impacted region. The ruptured support and attached mailboxes contacted and shattered the windshield of the vehicle. Maximum deformation of the windshield was 3.5 inches which exceeds the *MASH* threshold. Also, there were several small tears at the base of the windshield behind the dashboard. Consequently, as summarized in Table 7.6, the formed thin-wall steel tube multiple-mount support post with a combination of standard and locking architectural mailboxes did not satisfy *MASH* criteria for Test 3-61.

Table 7.4. Performance Evaluation Summary for *MASH* Test 3-60 on the Dual Locking Architectural Mailbox on the SHUR-TITE® Multiple-Mount Post.

Test Agency: Texas A&M Transportation Institute | Test No.: 490023-9-4 | Test Date: 2013-08-16

***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 locking architectural mailbox installation yielded to the vehicle and pulled out of the ground socket.	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.*	The mailboxes and support contacted and penetrated the windshield.	Fail
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	Maximum occupant compartment deformation was 4.5 inches in the windshield area.	Fail
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 both were 2 degrees.	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 occupant impact velocity was 5.6 ft/s, and lateral occupant impact velocity was 0.3 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 ridedown acceleration was 1.0 G, and lateral ridedown acceleration was 0.3 G.	Pass
Vehicle Trajectory N. *Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest behind the mailbox installation.	Pass

Table 7.5. Performance Evaluation Summary for *MASH* Test 3-60 on the Combination Locking Architectural Mailboxes and Standard Mailboxes on the SHUR-TITE® Multiple-Mount Post.

Test Agency: Texas A&M Transportation Institute | Test No.: 490023-9-5 | Test Date: 2013-08-30

***MASH* Test 3-60 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 multiple-mailbox support initially yielded to the 1100C vehicle and released by rupturing.	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.*	The mailbox support fractured just above ground level and the fractured support and all four mailboxes traveled up the hood and into the windshield creating a large hole in the windshield.	Fail
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	Maximum occupant compartment deformation/intrusion was 4.75 inches in the roof and the windshield had a large hole measuring 14 inches × 24 inches.	Fail
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 and 2 degrees, respectively.	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 occupant impact velocity was 6.2 ft/s, and lateral occupant impact velocity was 1.0 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 ridedown acceleration was 1.2 G, and lateral ridedown acceleration was 0.5 G.	Pass
Vehicle Trajectory *N. Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest 202 ft behind the mailbox installation.	Pass

Table 7.6. Performance Evaluation Summary for *MASH* Test 3-60 on the Combination Locking Architectural Mailboxes and Standard Mailboxes on the Formed Thin-Wall Steel Tube Multiple Mailbox Support.

Test Agency: Texas A&M Transportation Institute — Test No.: 490023-9-6 — Test Date: 2013-08-30

***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 multiple-mount support yielded to the 1100C vehicle and pulled out of the foundation socket.	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.*	Contact of the locking architectural mailboxes and standard mailboxes on multiple-mount support with the windshield caused several small tears at the base of the windshield.	Fail
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	Maximum occupant compartment deformation was 3.5 inches in the windshield on the driver's side.	Fail
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 was 4 degrees and 1 degree, respectively.	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 occupant impact velocity was 4.9 ft/s, and lateral occupant impact velocity was 5.2 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 ridedown acceleration was 0.5 G, and lateral occupant ridedown acceleration was 1.0 G.	Pass
Vehicle Trajectory N. *Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest 272 ft behind the test installation.	Pass

CHAPTER 8. IMPLEMENTATION STATEMENT

Mail-identity theft is a rising concern among homeowners. Consequently, there is an increased demand for locking mailboxes. These mailboxes contain a mail receiving hopper above a lockable compartment that is used for mail retrieval. Under this project, the crashworthiness of lockable mailboxes was evaluated in both single and multiple-mount configurations to determine if TxDOT can permit their use on the state highway system. The crash tests were performed following the latest *MASH* guidelines and procedures.

8.1 LOCKING ARCHITECTURAL MAILBOX ON SINGLE-MOUNT POST

An Oasis Jr. locking architectural mailbox manufactured by Architectural Mailboxes, LLC was successfully crash tested on a SHUR-TITE® Single-Mount Post (DHT# 162911) in a Type 4 foundation with a plastic wedge (DHT# 160892) and socket (DHT# 160891) system. This single-mount configuration is, therefore, considered suitable for implementation and use on the state highway system. Implementation can be accomplished through appropriate revision of the TxDOT Mailbox Mounting and Spacing standard (MB-11(1)) by the Maintenance Division.

There are a variety of lockable mailboxes on the market. The mailbox that was selected for testing was an Oasis Jr. locking architectural mailbox manufactured by Architectural Mailboxes, LLC. This mailbox is 15 inches tall × 11½ inches wide × 18 inches deep, and weighs approximately 22.4 lb without connection hardware attached. Other lockable mailboxes are considered acceptable alternatives provided the size and weight are not exceeded. The use of larger, heavier mailboxes than the model tested will require further evaluation.

In addition to the SHUR-TITE® Single-Mount Post, other single mailbox support posts with similar flexural capacity installed in a crashworthy breakaway foundation system are also considered acceptable. The SHUR-TITE® Single-Mount Post is a thin-wall steel tube with a 2⅜ inch outside diameter (OD) and a 0.095 inch wall thickness. The thin-wall galvanized steel tube (DHT# 143426) in a Type 2 foundation with a steel wedge (DHT# 143433) and steel anchor socket (DHT# 143434) system is considered an acceptable alternative. This support has a similar OD and wall thickness to the support that was crash tested. Other crashworthy single support posts with equal or greater moment capacity are also considered acceptable for use with a lockable mailbox.

Due to the heavier lockable mailbox, the thin-wall galvanized steel tube (DHT# 143426) may experience some long-term movement when installed in the soil embedded Type 2 foundation. To avoid this long-term movement and associated maintenance, it is recommended that the steel anchor socket (DHT# 143434) be embedded in a 12-inch diameter × 24-inch deep unreinforced concrete footer similar to the Type 4 foundation. In fact, this modification can be applied to all mailbox configurations installed in a Type 2 foundation regardless of size or weight.

The connection of the mailbox to the support post is of critical importance. The lockable mailbox should be attached to the single support using the improved connection developed and tested under this project. A mailbox bracket (DHT# 161443) was attached to the bottom of the locking mailbox using four ⅜-inch diameter × 1¼-inch long SAE Grade 5 bolts using existing holes in the mailbox and bracket. A 2-inch wide × 5½-inch long × 1/8-inch thick plate washer fabricated from ASTM A36 steel (or equivalent) was positioned over each end of the bracket to help secure each set of two bolts at the front and back of the mailbox. A ⅜-inch flat washer, lock washer, and nut were used for each bolt. The collar on the mailbox bracket was secured to the support post using a $^{5}/_{16}$-inch diameter × 3-inch long SAE Grade 5 bolt.

This same connection detail can be used with the galvanized thin-wall steel support post (DHT# 143426). Similar connections can be adapted to other acceptable support types provided they have equal or greater strength than the tested connection.

8.2 LOCKING ARCHITECTURAL MAILBOX ON MULTIPLE-MOUNT POST

The Oasis Jr. lockable mailbox was evaluated on two different multiple mailbox supports in combination with standard mailboxes. Both systems failed to satisfy *MASH* criteria due to windshield damage and penetration. Further research is required to develop a multiple mailbox support that can be used with the larger, heavier lockable mailboxes. Possible modifications may include increasing the strength of the support post to facilitate release of the support from the foundation and prevent localized collapse and/or rupture of the support.

REFERENCES

1. H. E. Ross, Jr., D. L. Sicking, R. A. Zimmer and J. D. Michie. *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, National Cooperative Highway Research Program Report 350, Transportation Research Board, National Research Council, Washington, D.C., 1993.

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

APPENDIX A. CRASH TEST NO. 490023-9-1

A1. VEHICLE INFORMATION

Table A1. Vehicle Properties for Test No. 490023-9-1.

Date: 2013-08-05 Test No.: 490023-9-1 VIN No.: KNADE223996535907

Year: 2009 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 96956 Tire Size: 165/65R14

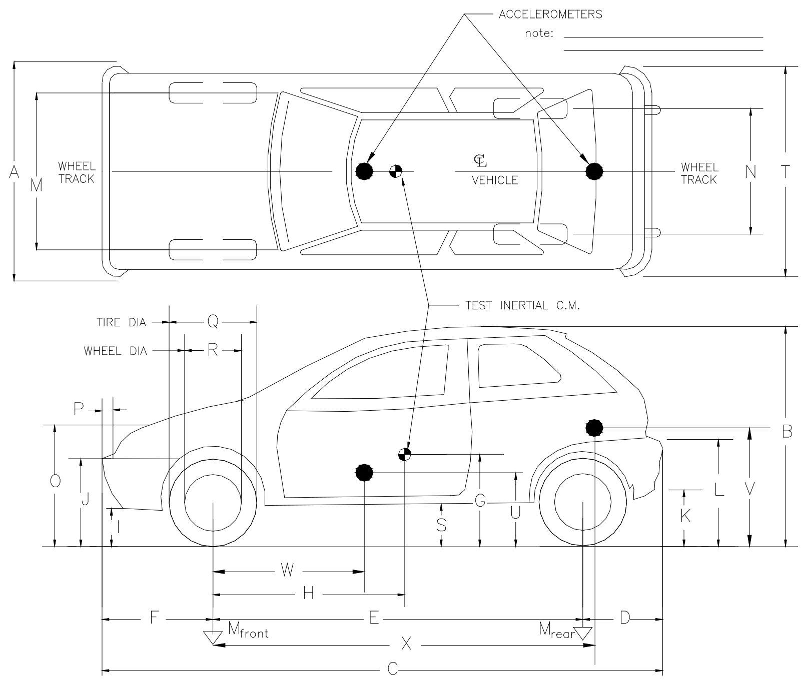
Describe any damage to the vehicle prior to test: ______

● Denotes accelerometer location.

NOTES: ______

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

Dummy Data:
Type: 50th percentile male
Mass: ______
Seat Position: Driver side



Geometry: inches

A	66.38	F	33.00	K	11.75	P	4.12	U	15.50
B	57.75	G	----	L	25.25	Q	22.18	V	22.00
C	165.75	H	35.17	M	57.75	R	15.38	W	39.50
D	34.00	I	6.75	N	57.12	S	8.00	X	108.00
E	98.75	J	22.00	O	31.25	T	66.18		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1918	M_{front}	1603	1578	1668
Back	1874	M_{rear}	856	873	960
Total	3638	M_{Total}	2459	2451	2628

Mass Distribution:
lb LF: 793 RF: 785 LR: 454 RR: 419

Table A2. Exterior Vehicle Crush Measurements for Test No. 490023-9-1.

Date: 2013-08-05 Test No.: 490023-9-1 VIN No.: KNADE223996535907

Year: 2009 Make: Kia Model: Rio

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								
----	No measurable deformation noted	----	----	----	----	----	----	----	----	----	----
	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).

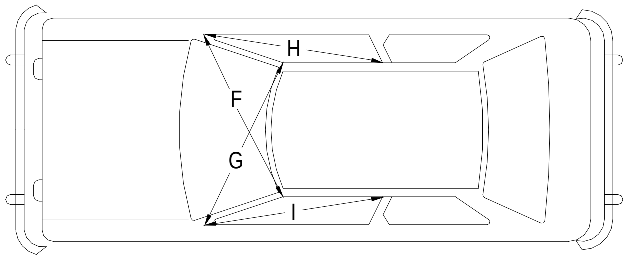
***Measure and document on the vehicle diagram the location of the maximum crush.

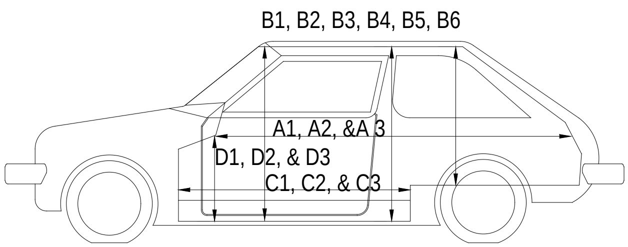
Note: Use as many lines/columns as necessary to describe each damage profile.

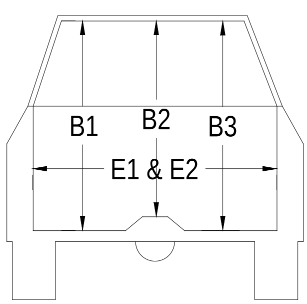
Table A3. Occupant Compartment Measurements for Test No. 490023-9-1.

Date: 2013-08-05 Test No.: 490023-9-1 VIN No.: KNADE223996535907

Year: 2009 Make: Kia Model: Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	67.75	67.75
A2	37.25	37.25
A3	37.50	37.50
B1	40.50	40.50
B2	36.50	36.50
B3	40.50	40.50
B4	36.25	36.25
B5	37.25	37.25
B6	36.25	36.25
C1	27.00	27.00
C2	----	----
C3	27.50	27.50
D1	9.75	9.75
D2	----	----
D3	9.75	9.75
E1	48.25	48.25
E2	51.00	51.00
F	50.00	50.00
G	50.00	50.00
H	36.50	36.50
I	36.50	36.50
J*	51.00	51.00

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

A2. SEQUENTIAL PHOTOGRAPHS

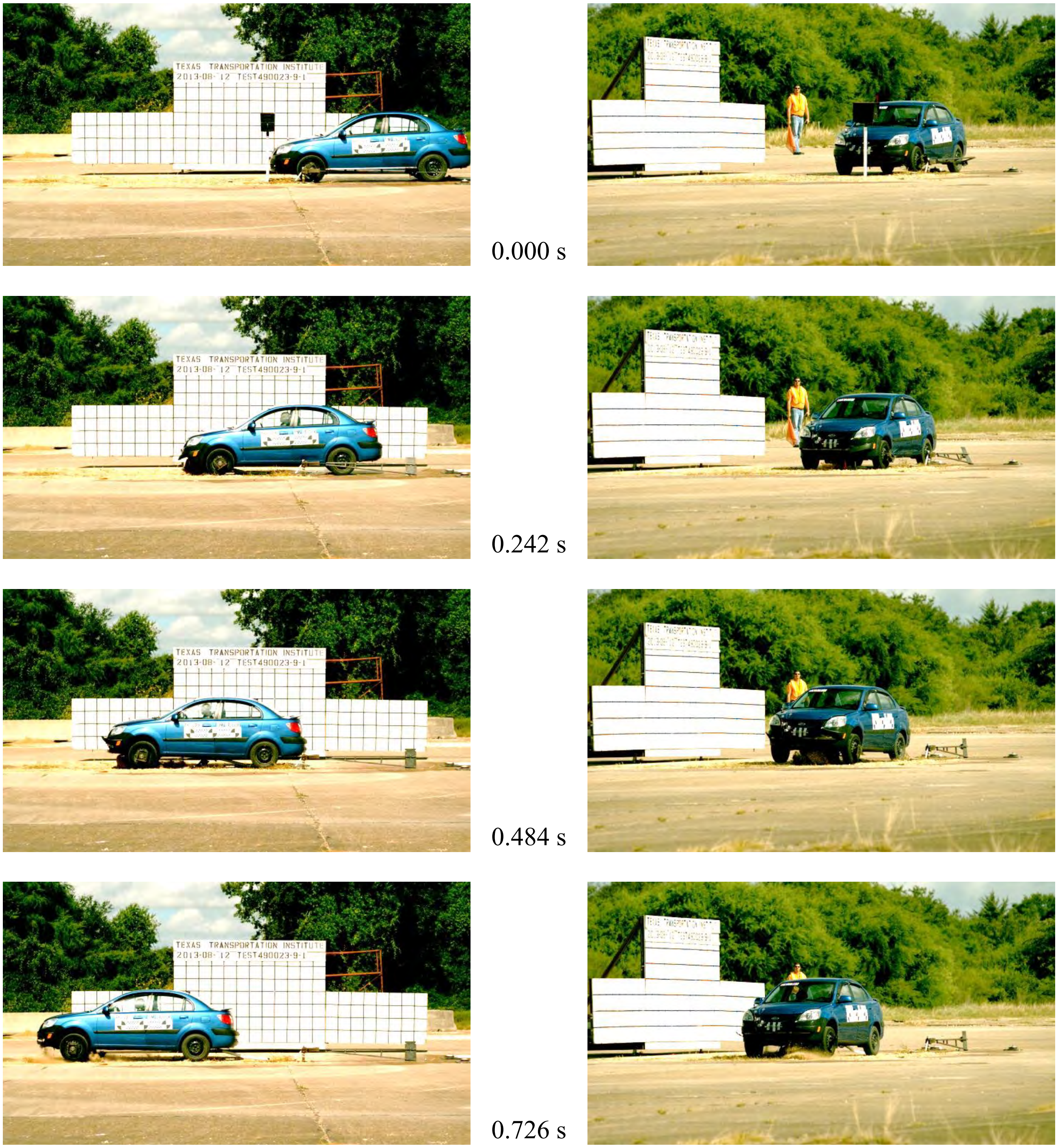


Figure A1. Sequential Photographs for Test No. 490023-9-1 (Perpendicular and Oblique Views).

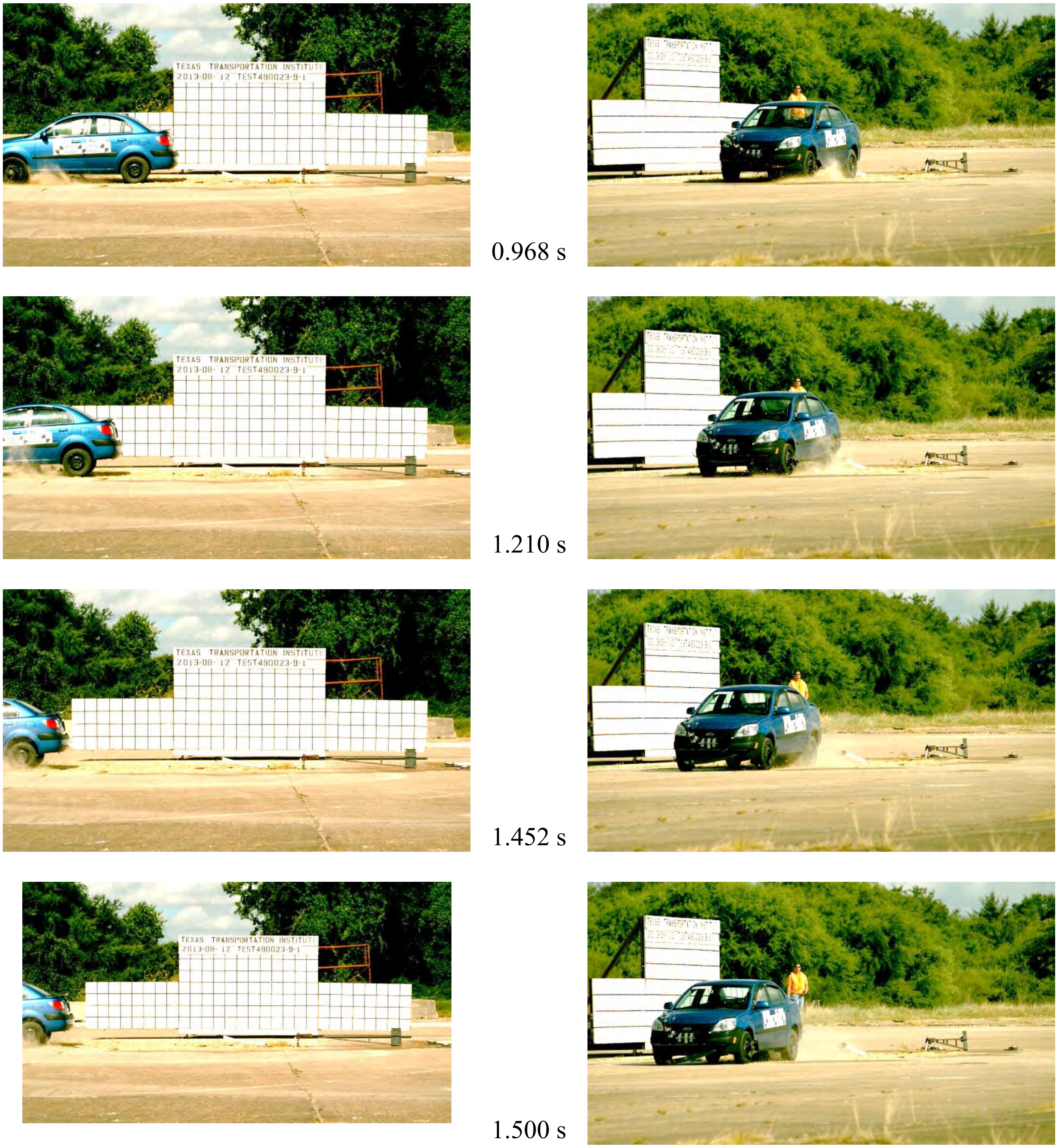
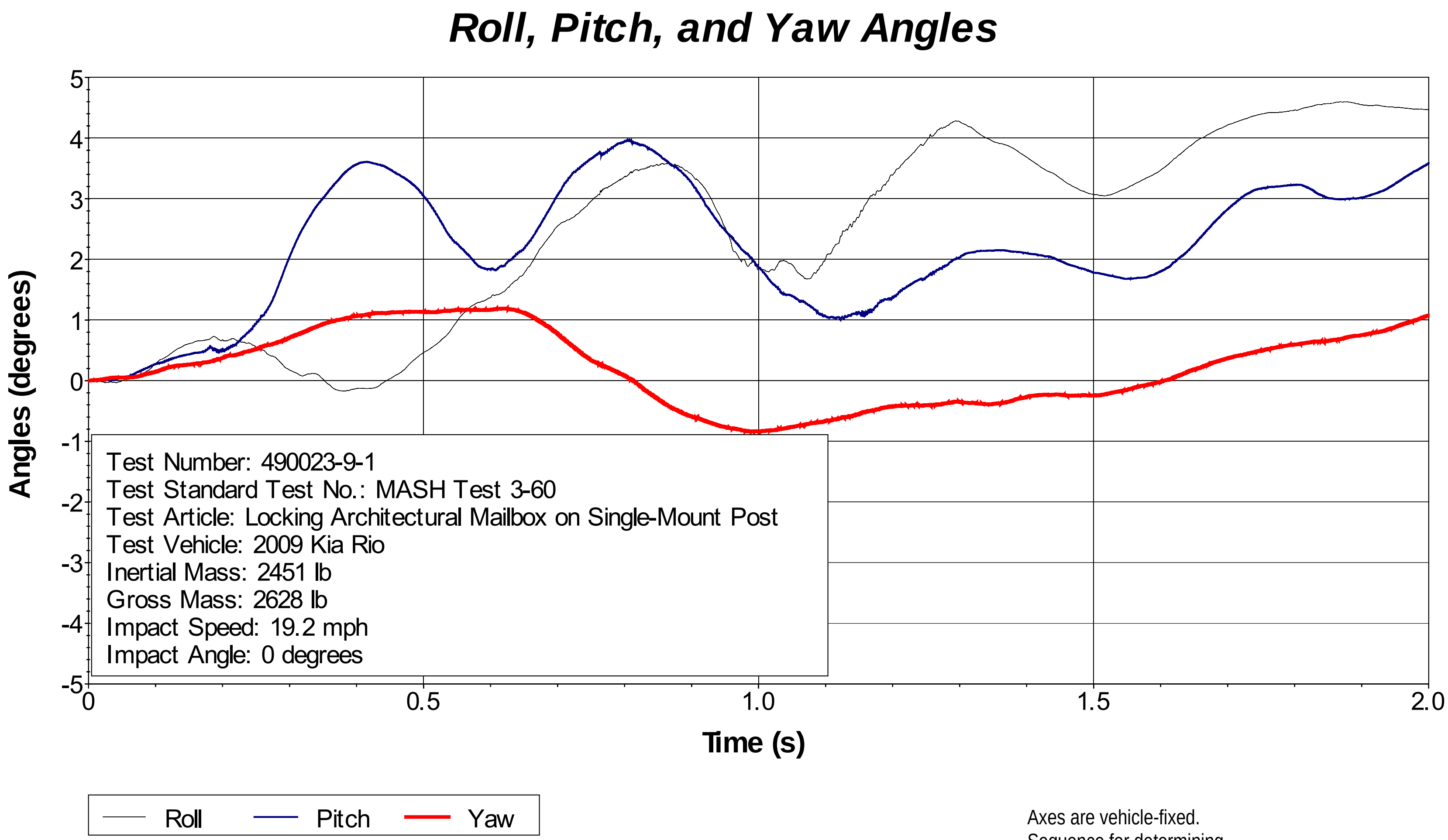


Figure A1. Sequential Photographs for Test No. 490023-9-1 (Perpendicular and Oblique Views) (Continued).



Axes are vehicle-fixed.
Sequence for determining orientation:

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

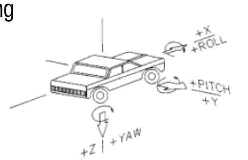


Figure A2. Vehicle Angular Displacements for Test No. 490023-9-1.

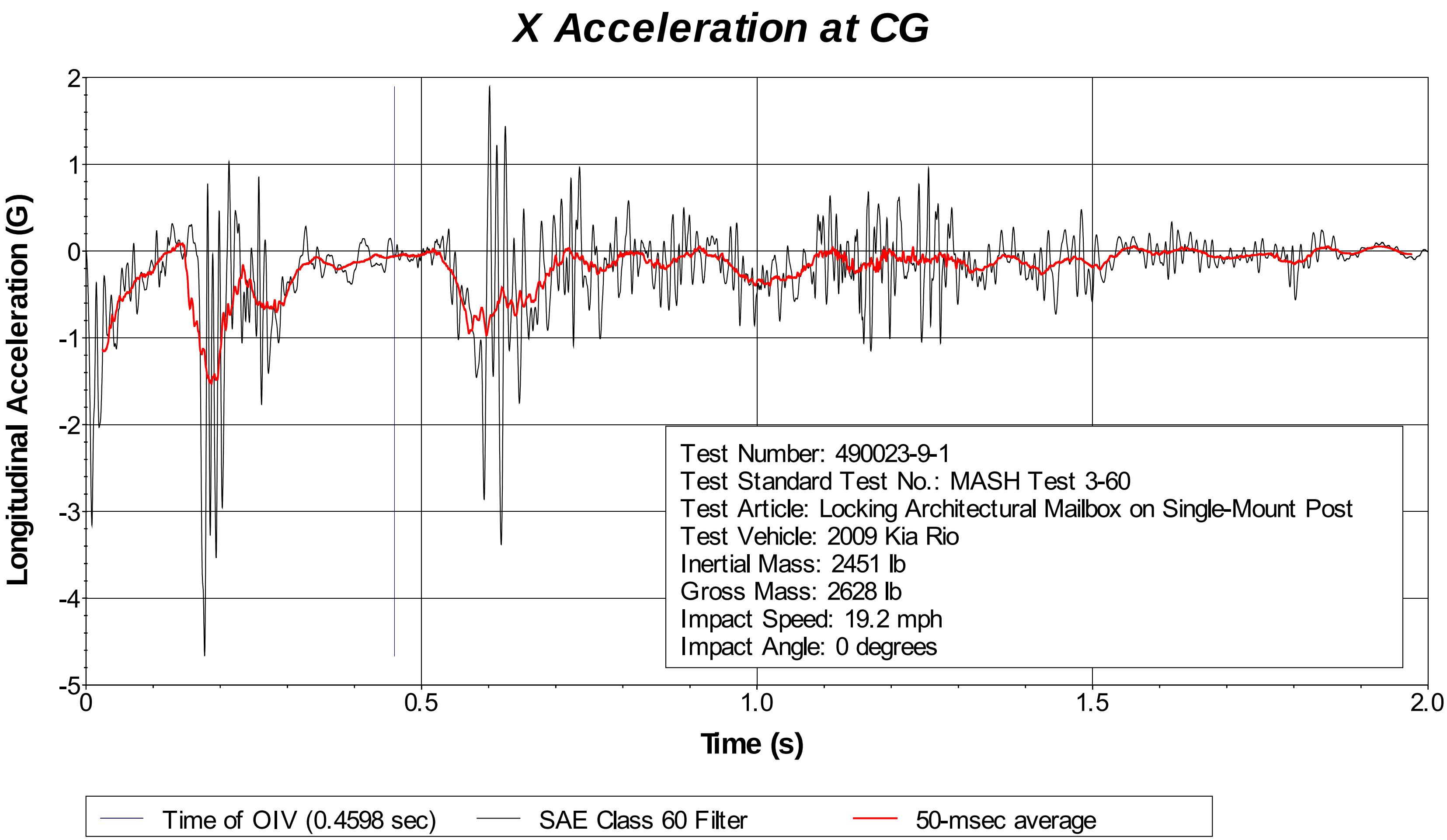


Figure A3. Vehicle Longitudinal Accelerometer Trace for Test No. 490023-9-1 (Accelerometer Located at Center of Gravity).

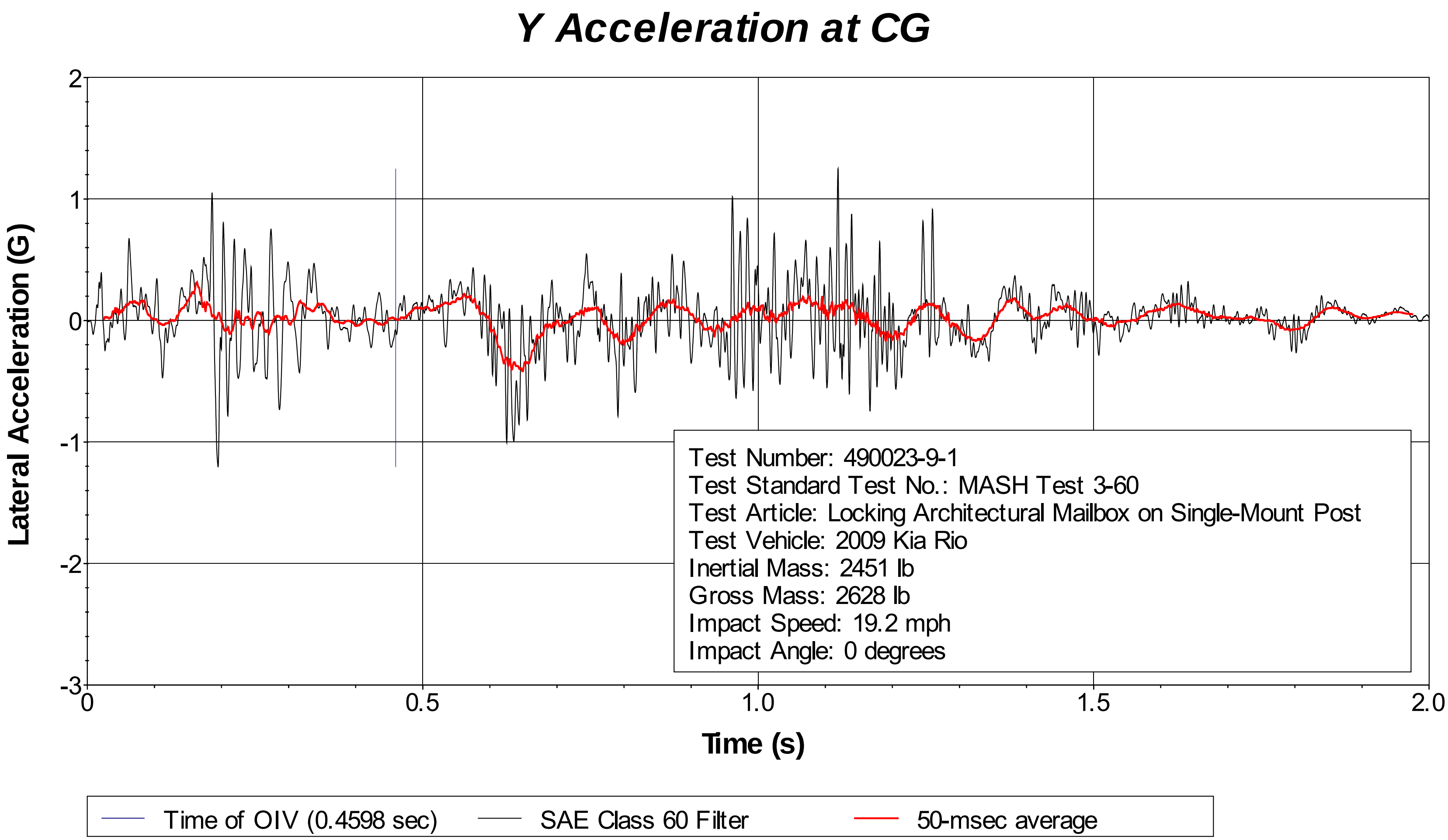


Figure A4. Vehicle Lateral Accelerometer Trace for Test No. 490023-9-1 (Accelerometer Located at Center of Gravity).

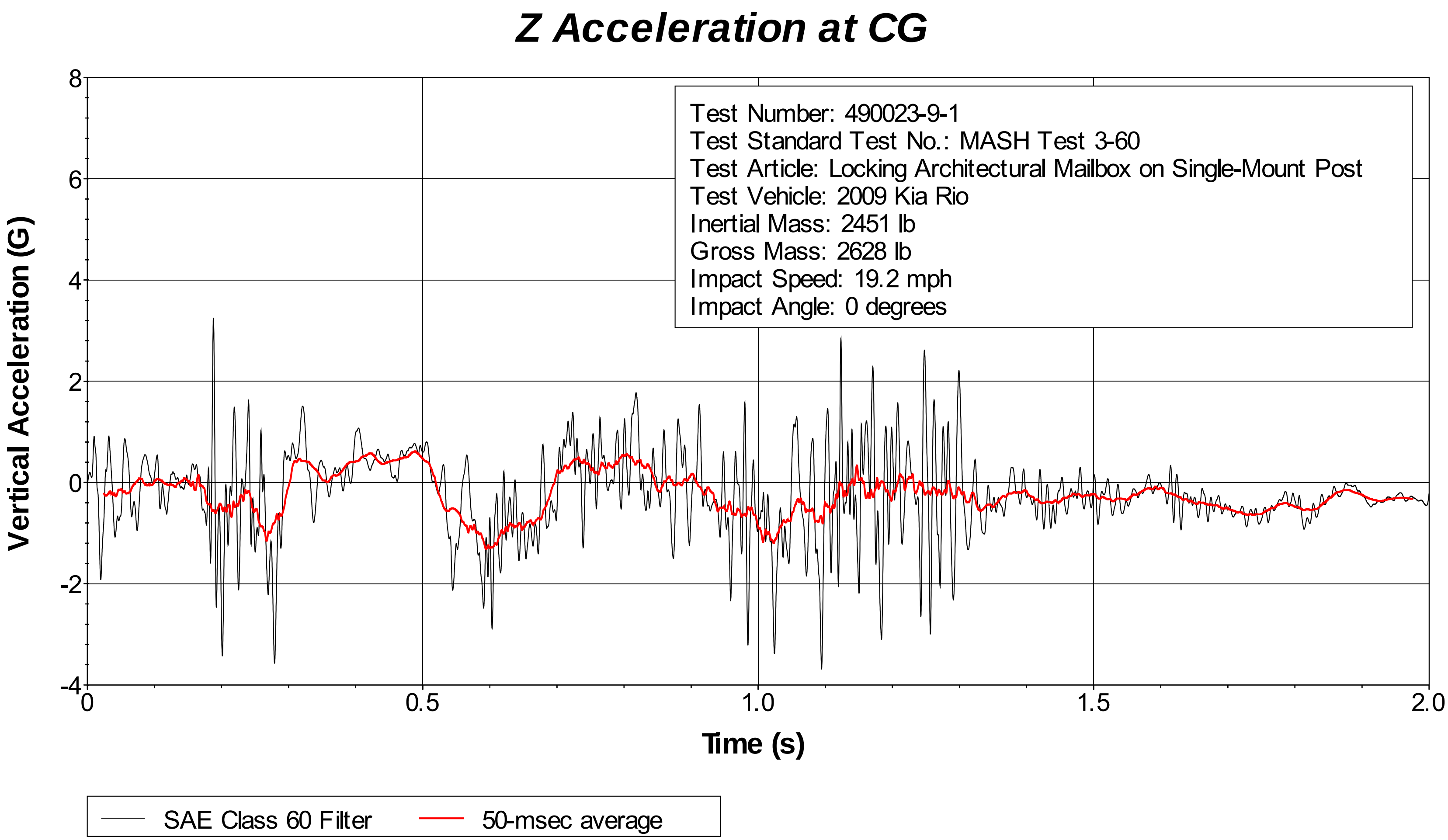


Figure A5. Vehicle Vertical Accelerometer Trace for Test No. 490023-9-1 (Accelerometer Located at Center of Gravity).

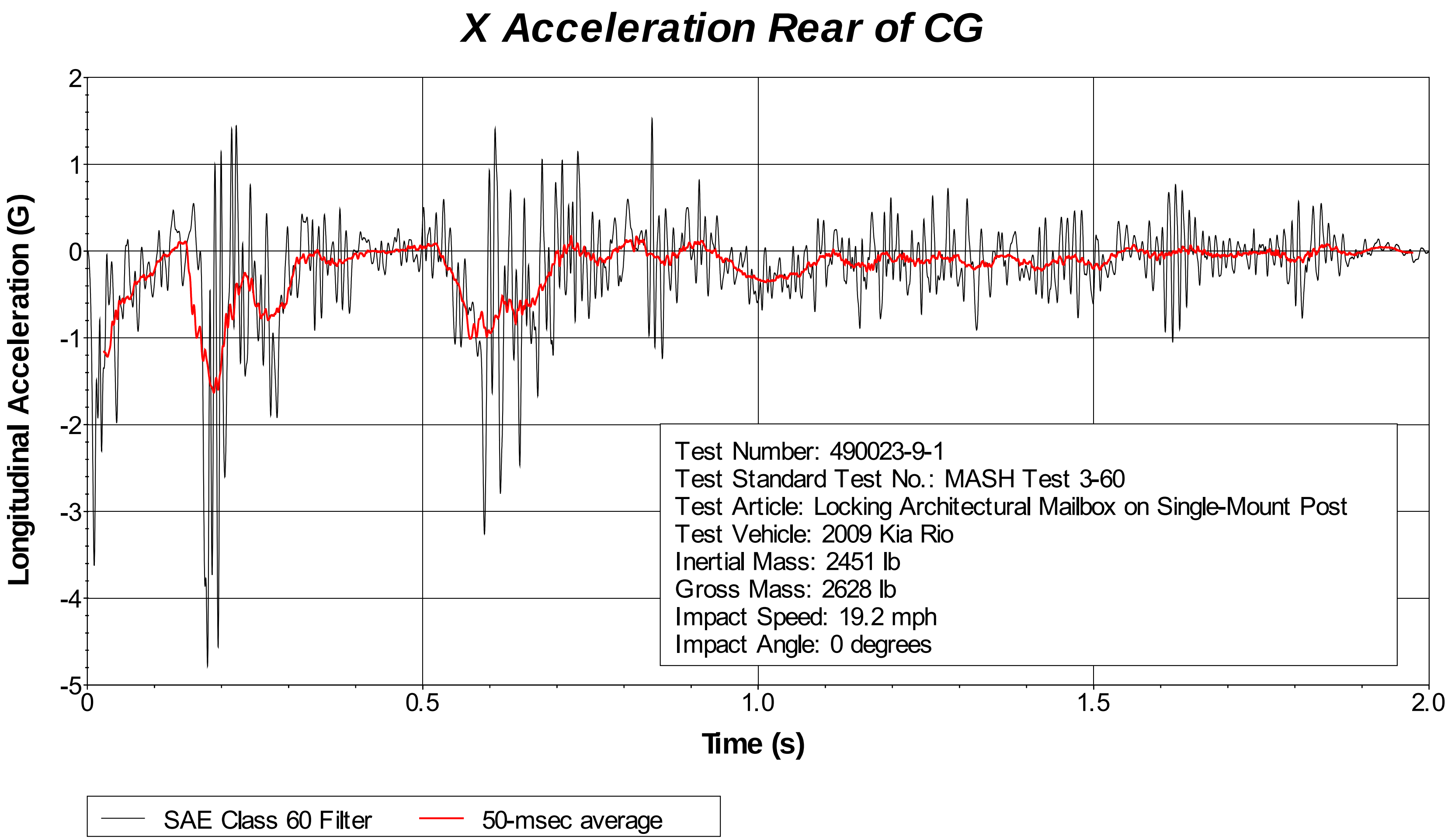


Figure A6. Vehicle Longitudinal Accelerometer Trace for Test No. 490023-9-1 (Accelerometer Located Rear of Center of Gravity).

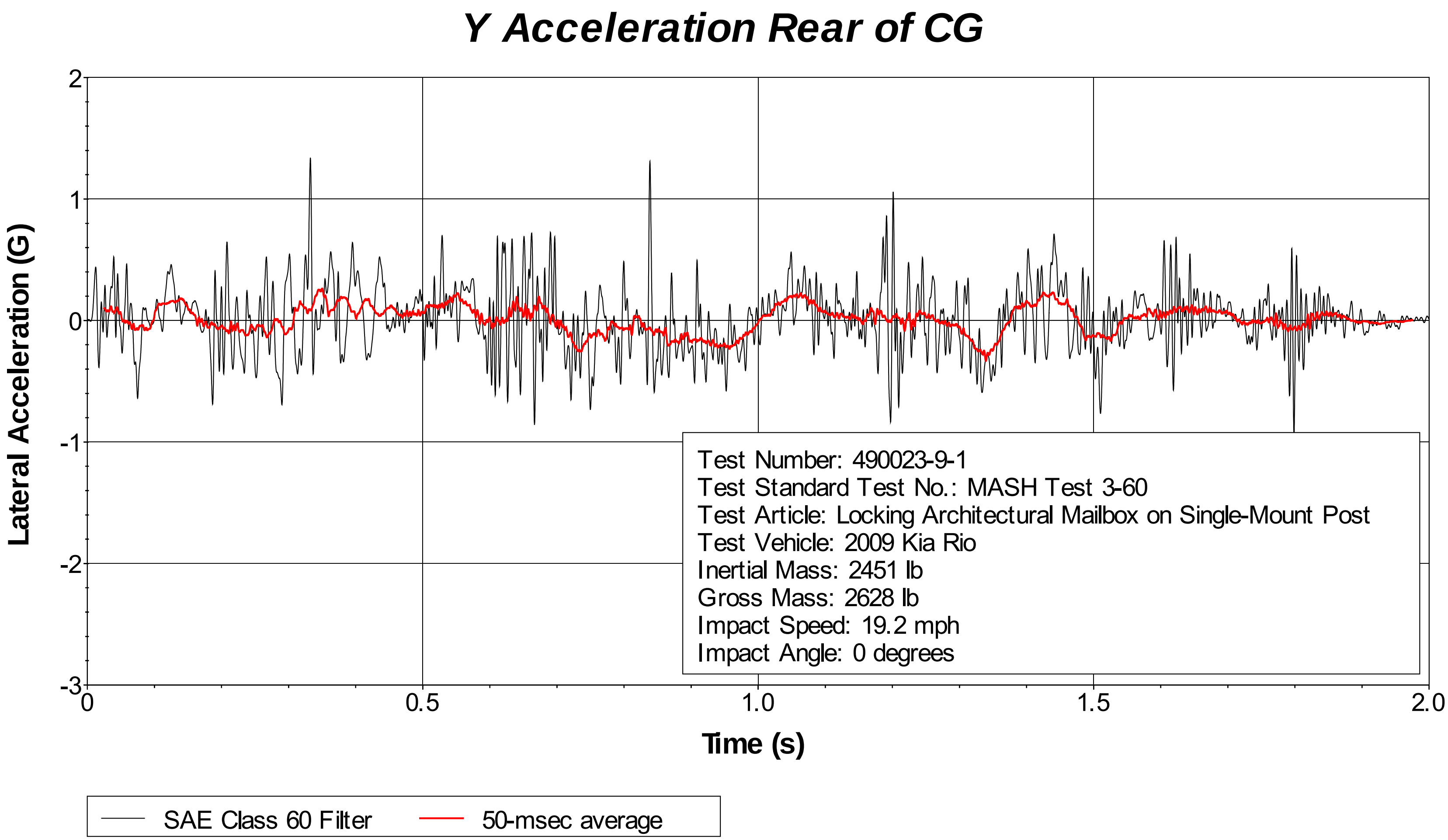


Figure A7. Vehicle Lateral Accelerometer Trace for Test No. 490023-9-1 (Accelerometer Located Rear of Center of Gravity).

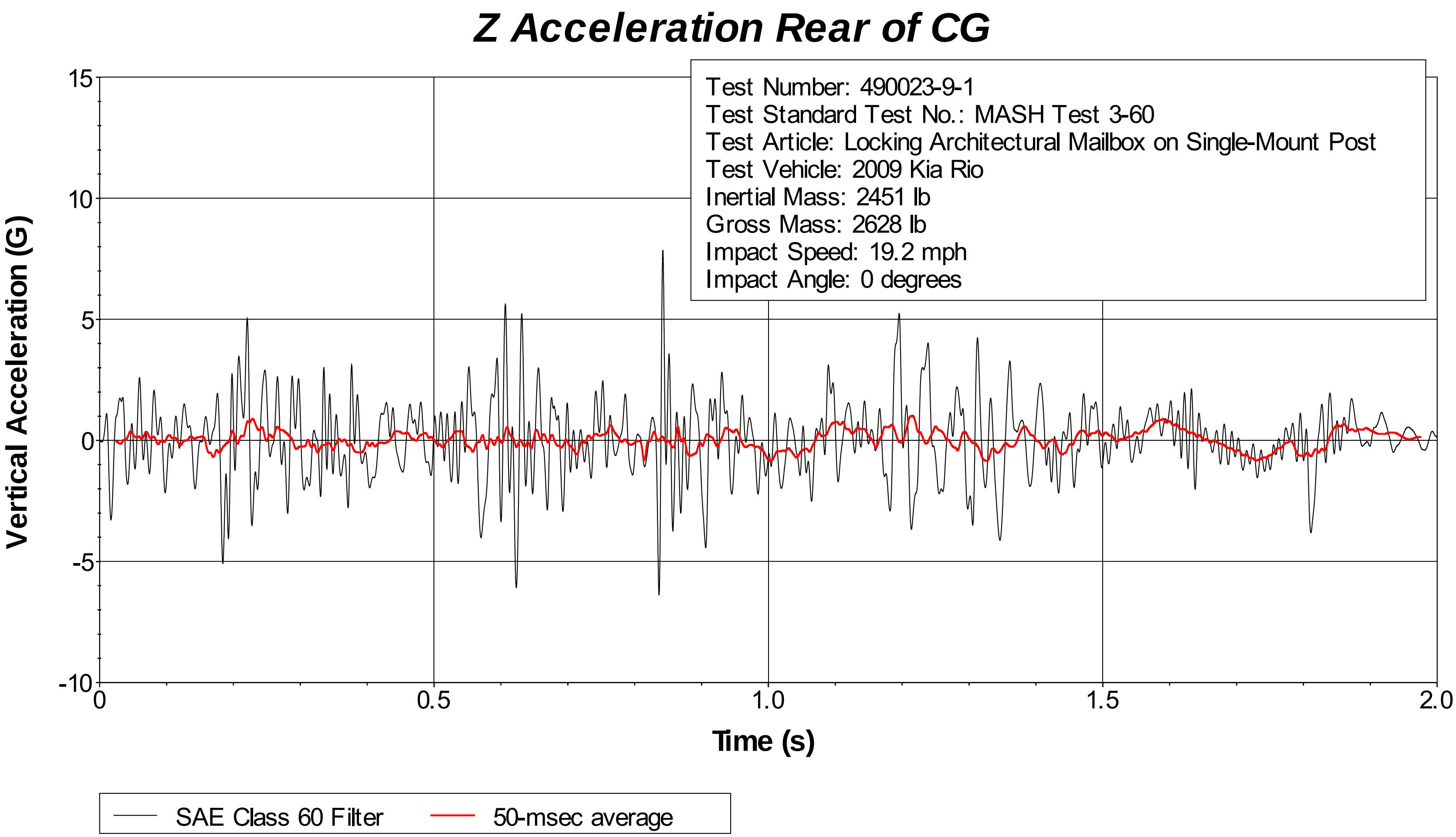


Figure A8. Vehicle Vertical Accelerometer Trace for Test No. 490023-9-1 (Accelerometer Located Rear of Center of Gravity).

APPENDIX B. CRASH TEST NO. 490023-9-2

B1. VEHICLE INFORMATION

Table B1. Vehicle Properties for Test No. 490023-9-2.

Date: 2013-08-05 Test No.: 490023-9-2 VIN No.: KNADE123786431909

Year: 2008 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 64862 Tire Size: 165/65R14

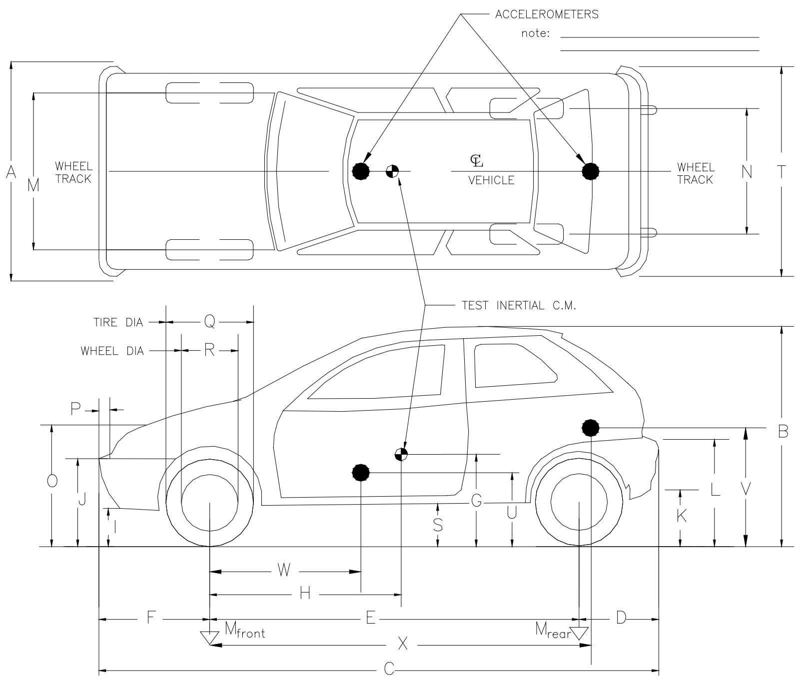
Describe any damage to the vehicle prior to test: ____________

● Denotes accelerometer location.

NOTES: ____________

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

Dummy Data:
Type: 50th percentile
Mass: 180 lb
Seat Position: Driver side



Geometry: inches

A	66.38	F	33.00	K	11.75	P	4.12	U	15.50
B	57.75	G	----	L	25.25	Q	22.18	V	22.00
C	165.75	H	40.16	M	57.75	R	15.38	W	40.00
D	34.00	I	6.75	N	51.12	S	8.00	X	108.00
E	98.75	J	22.00	O	31.35	T	66.12		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1918	M_{front}	1440	1446	1541
Back	1874	M_{rear}	861	991	1076
Total	3638	M_{Total}	2301	2437	2617

Mass Distribution:
lb LF: 732 RF: 714 LR: 493 RR: 498

Table B2. Exterior Vehicle Crush Measurements for Test No. 490023-9-2.

Date: 2013-08-05 Test No.: 490023-9-2 VIN No.: KNADE123786431909

Year: 2008 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								
----	No measurable deformation noted	----	----	----	----	----	----	----	----	----	----
	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).

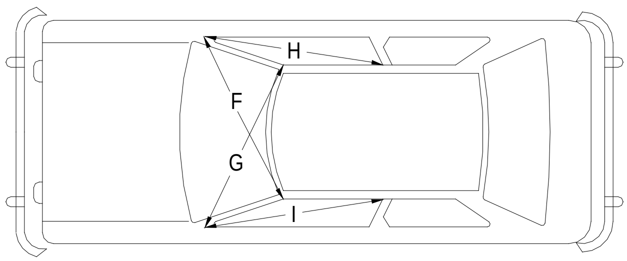
***Measure and document on the vehicle diagram the location of the maximum crush.

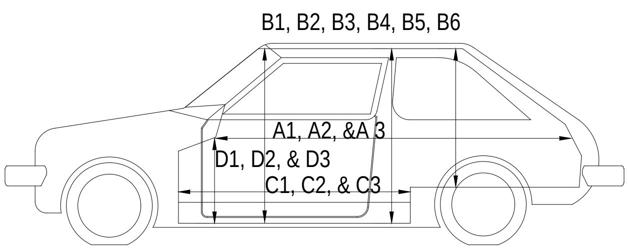
Note: Use as many lines/columns as necessary to describe each damage profile.

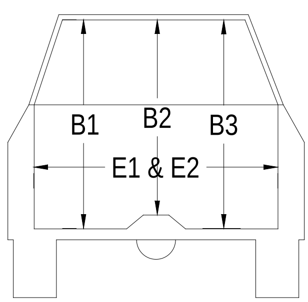
Table B3. Occupant Compartment Measurements for Test No. 490023-9-2.

Date: 2013-08-05 Test No.: 490023-9-2 VIN No.: KNADE123786431909

Year: 2008 Make: Kia Model: Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	67.75	67.75
A2	67.75	67.75
A3	57.50	57.50
B1	40.75	40.75
B2	35.75	35.75
B3	40.75	40.75
B4	35.75	35.75
B5	37.00	37.00
B6	35.75	35.75
C1	27.00	27.00
C2	----	----
C3	27.50	27.50
D1	9.75	9.75
D2	----	----
D3	9.75	9.75
E1	48.25	48.25
E2	51.00	51.00
F	50.00	50.00
G	50.00	50.00
H	35.50	35.50
I	36.50	36.50
J*	51.00	51.00

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

B2. SEQUENTIAL PHOTOGRAPHS

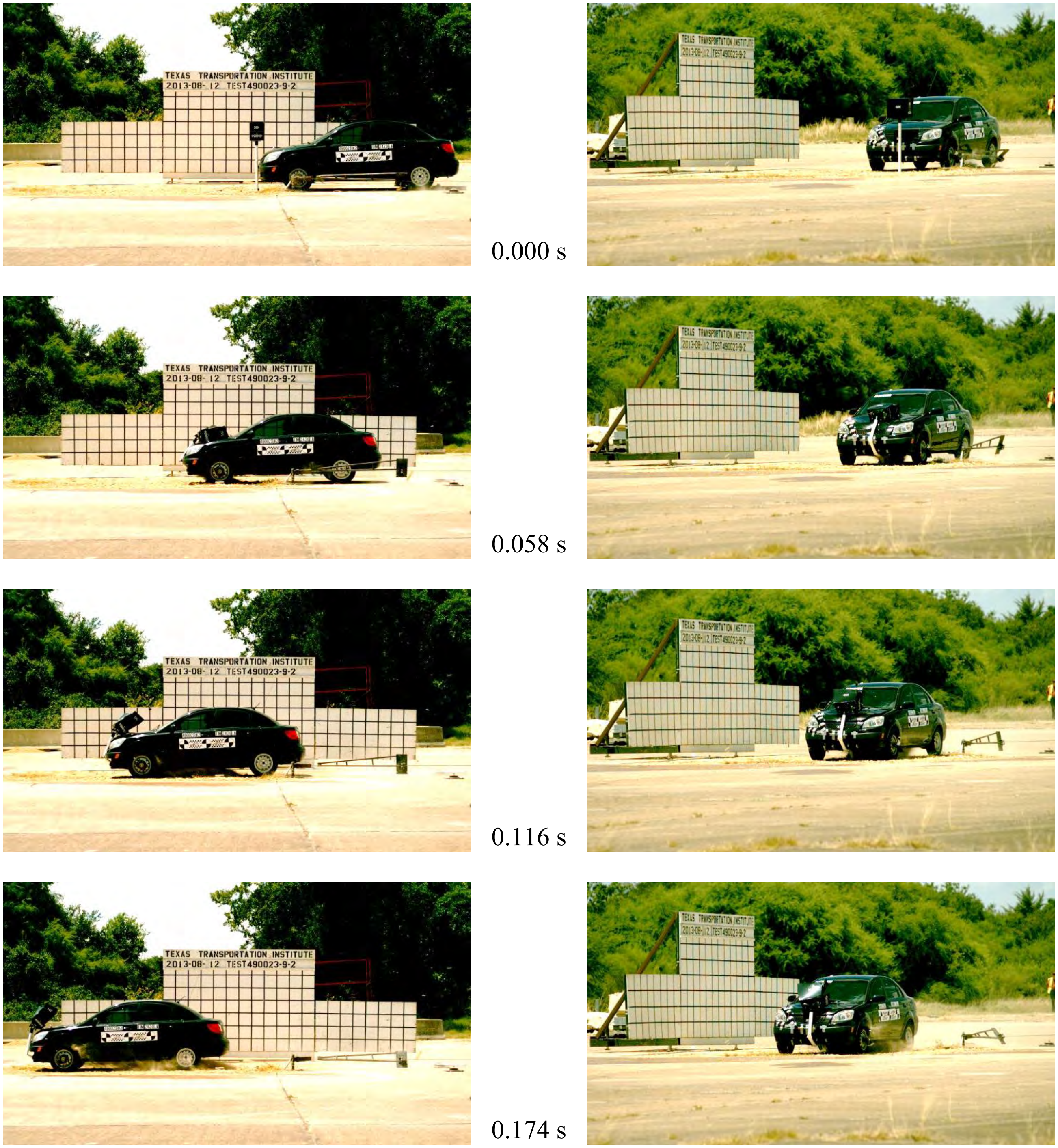


Figure B1. Sequential Photographs for Test No. 490023-9-2 (Perpendicular and Oblique Views).

0.232 s

0.290 s

0.348 s

Vehicle out of view

0.406 s

Figure B1. Sequential Photographs for Test No. 490023-9-2 (Perpendicular and Oblique Views) (Continued).

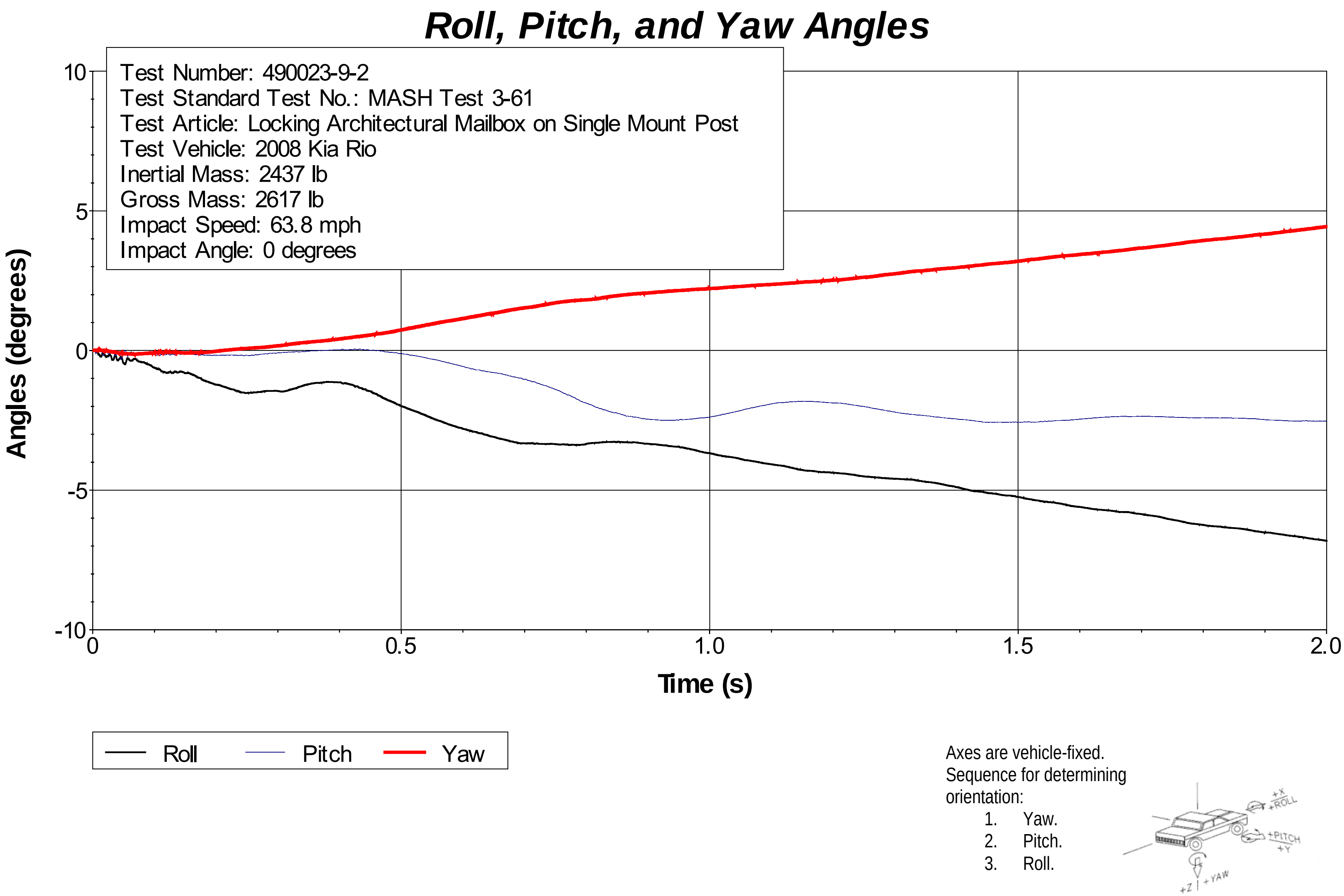


Figure B2. Vehicle Angular Displacements for Test No. 490023-9-2.

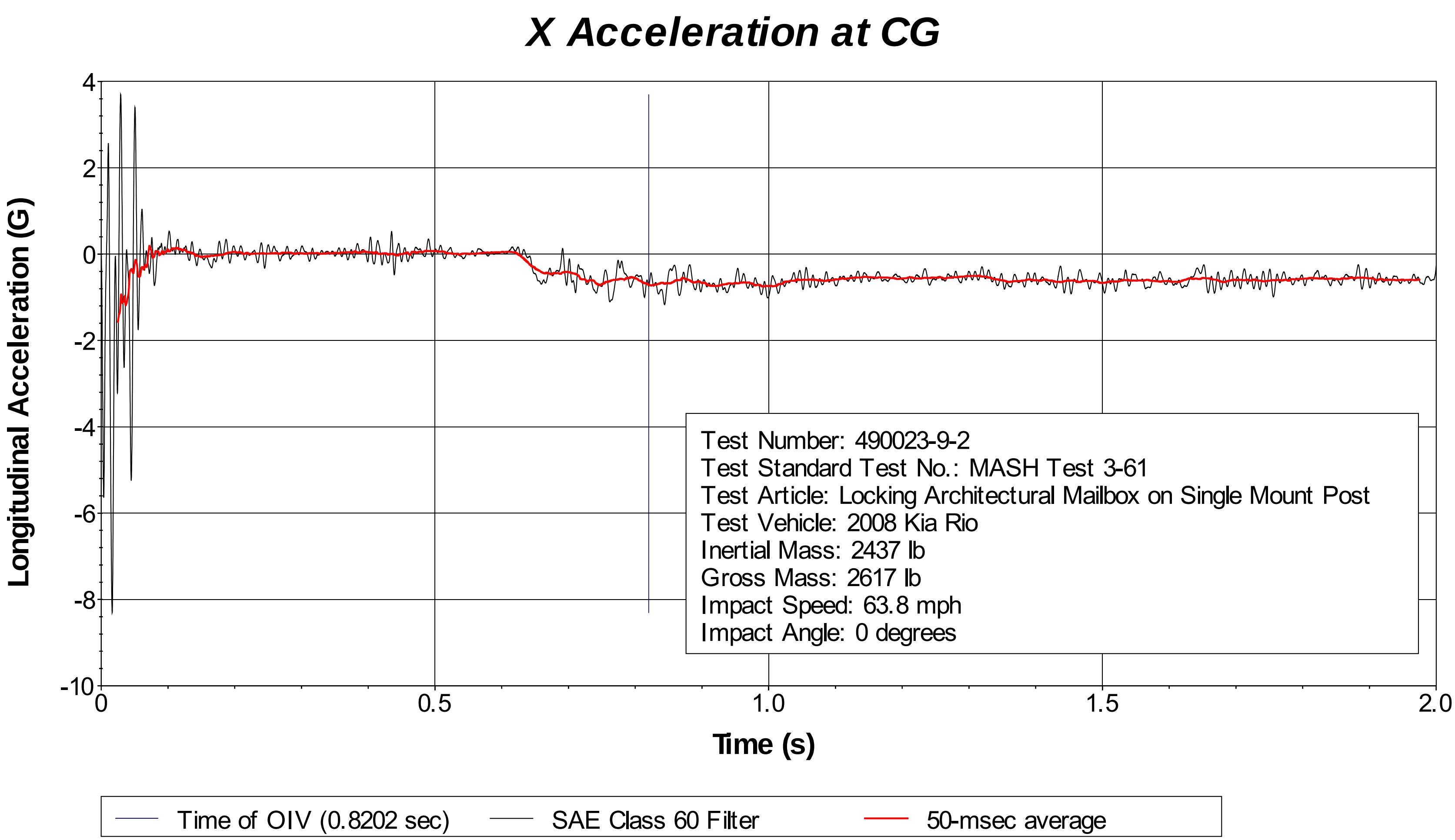


Figure B3. Vehicle Longitudinal Accelerometer Trace for Test No. 490023-9-2 (Accelerometer Located at Center of Gravity).

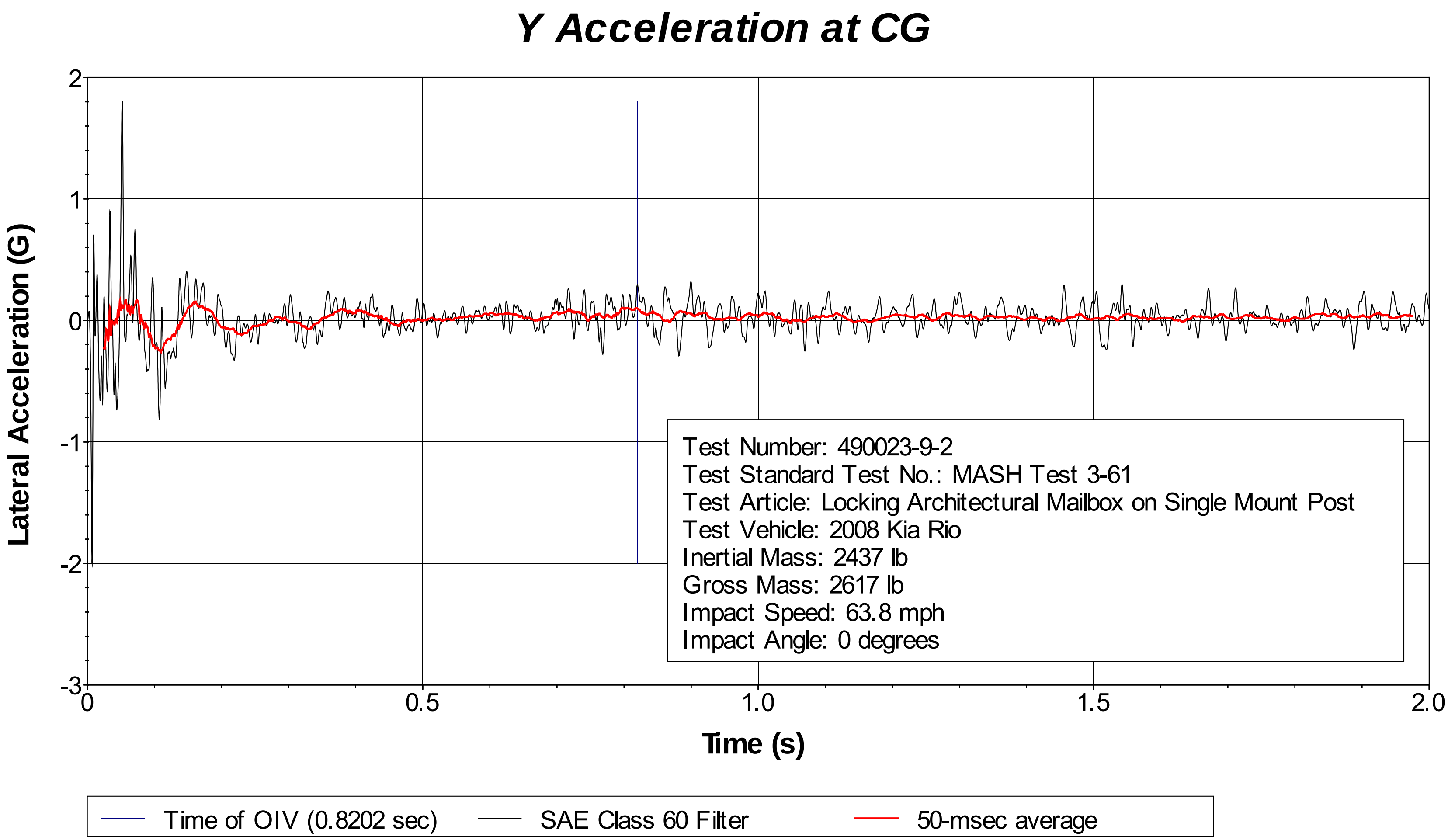


Figure B4. Vehicle Lateral Accelerometer Trace for Test No. 490023-9-2 (Accelerometer Located at Center of Gravity).

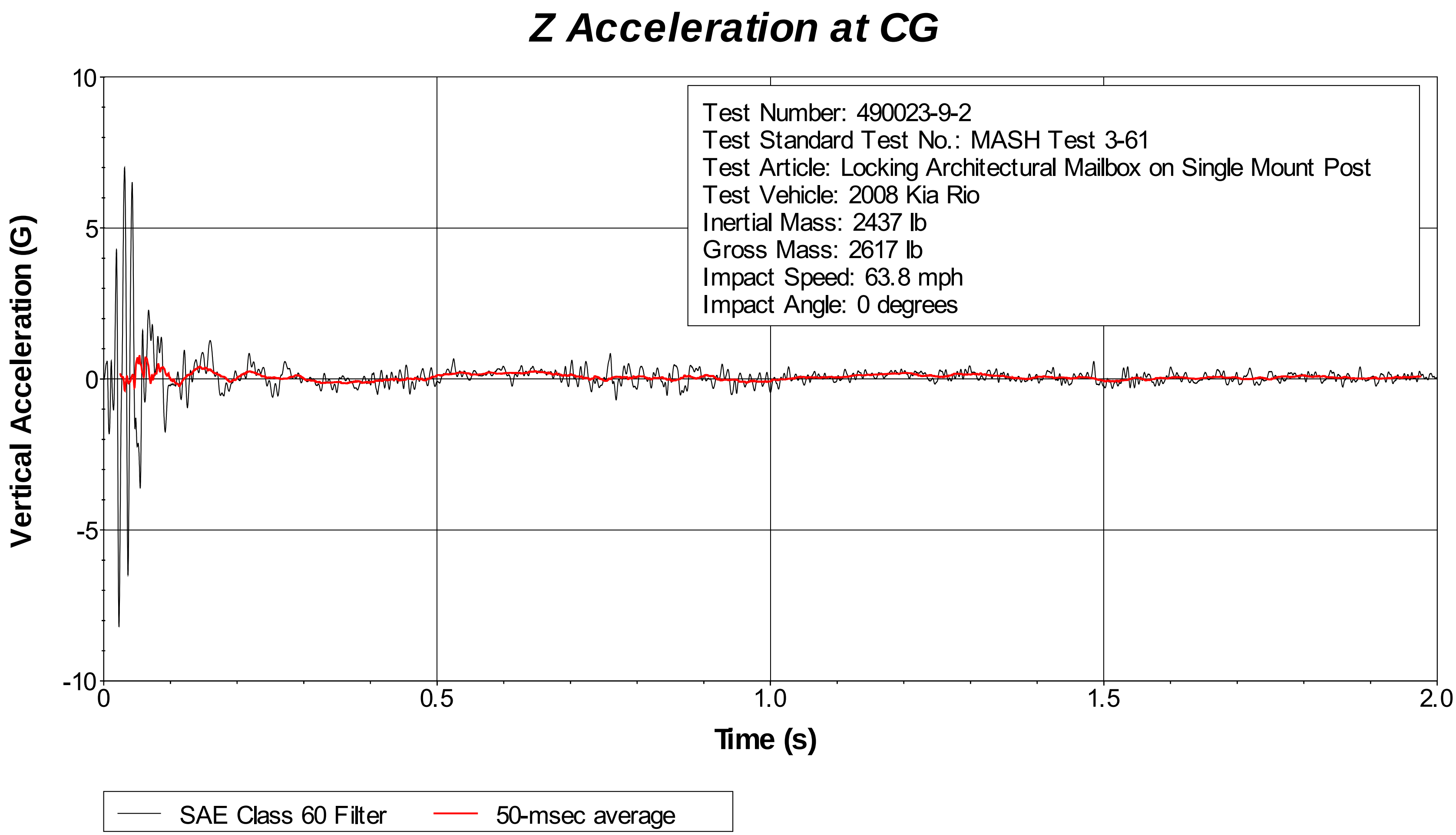


Figure B5. Vehicle Vertical Accelerometer Trace for Test No. 490023-9-2 (Accelerometer Located at Center of Gravity).

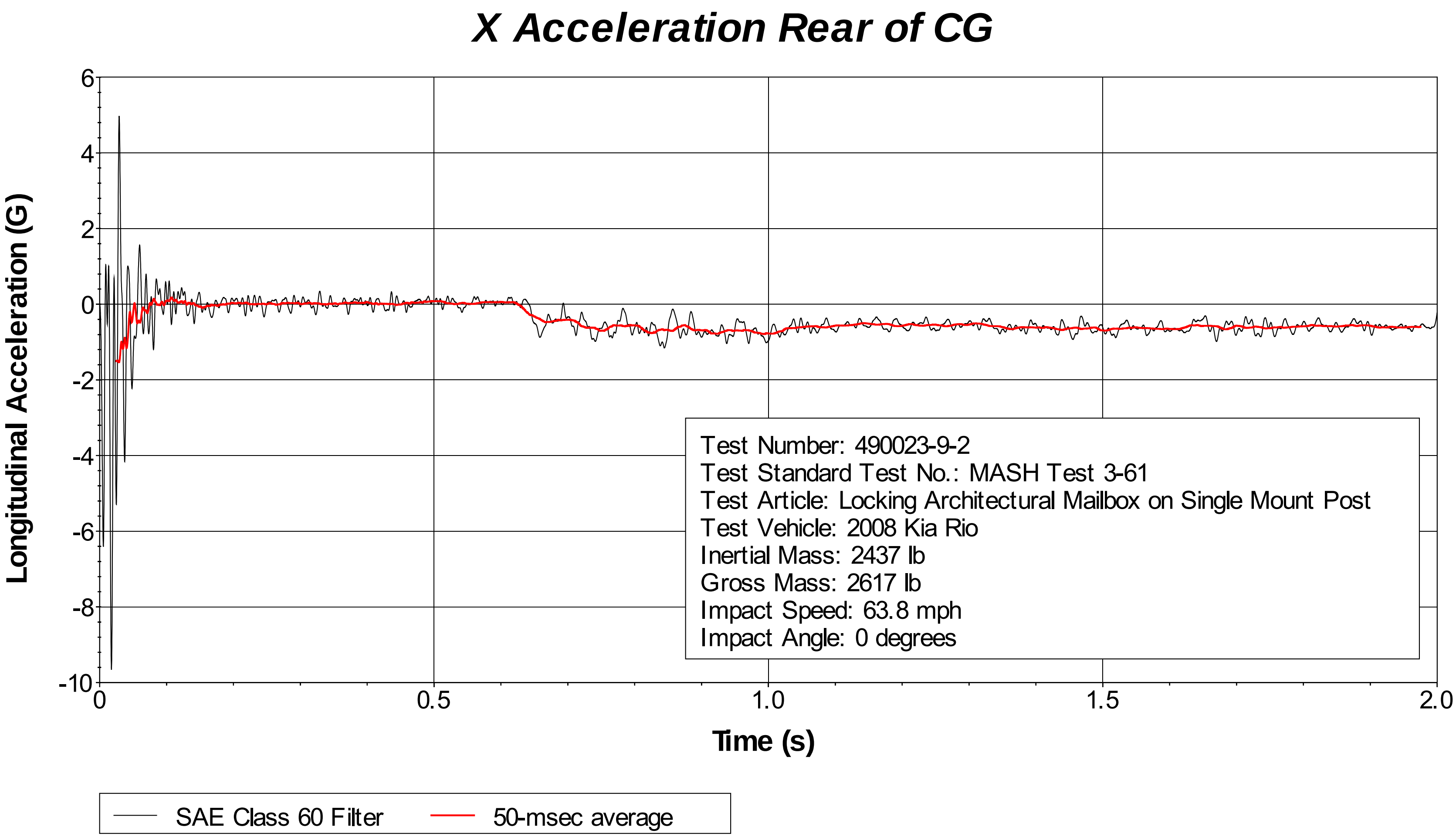


Figure B6. Vehicle Longitudinal Accelerometer Trace for Test No. 490023-9-2 (Accelerometer Located Rear of Center of Gravity).

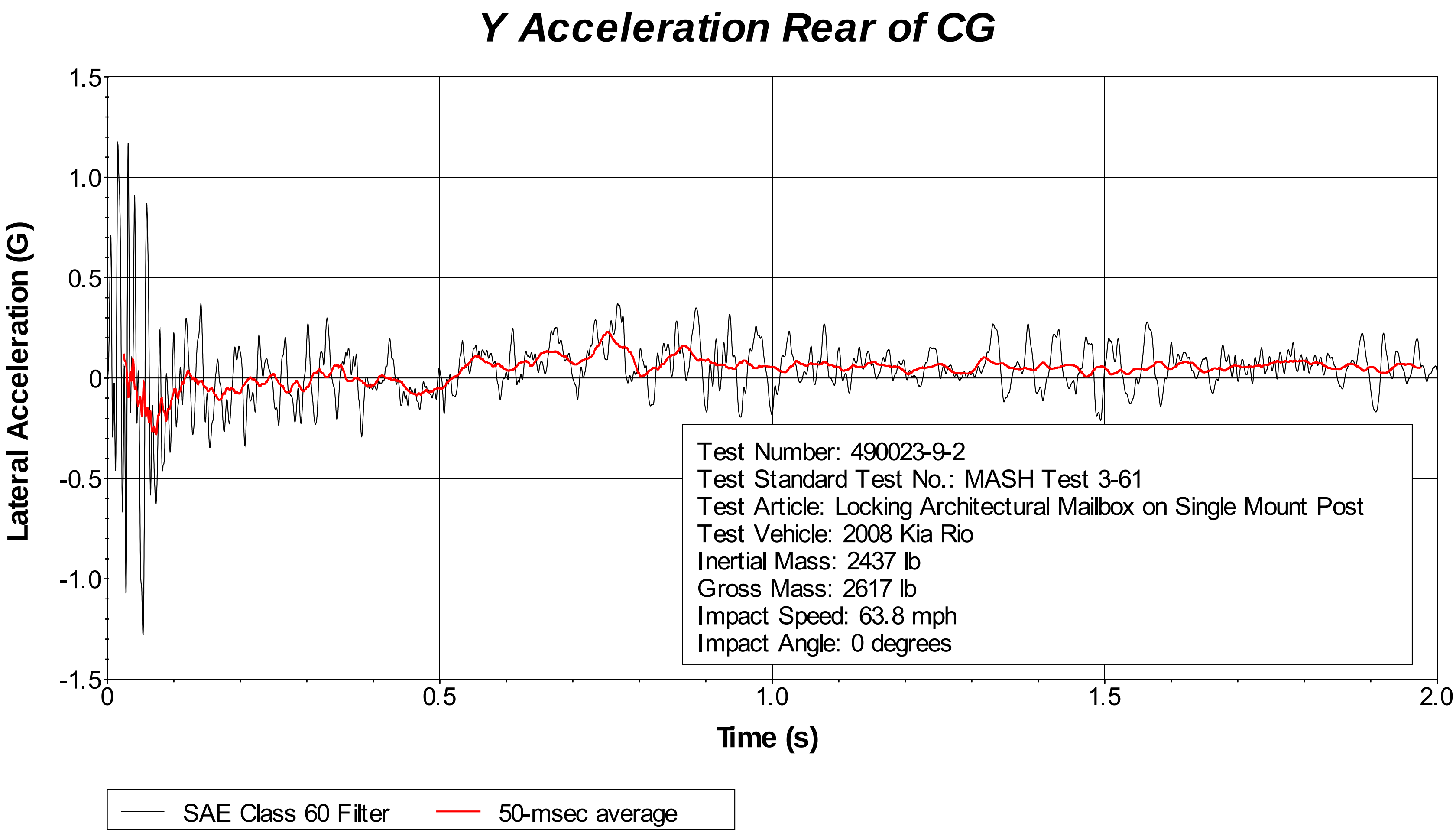


Figure B7. Vehicle Lateral Accelerometer Trace for Test No. 490023-9-2 (Accelerometer Located Rear of Center of Gravity).

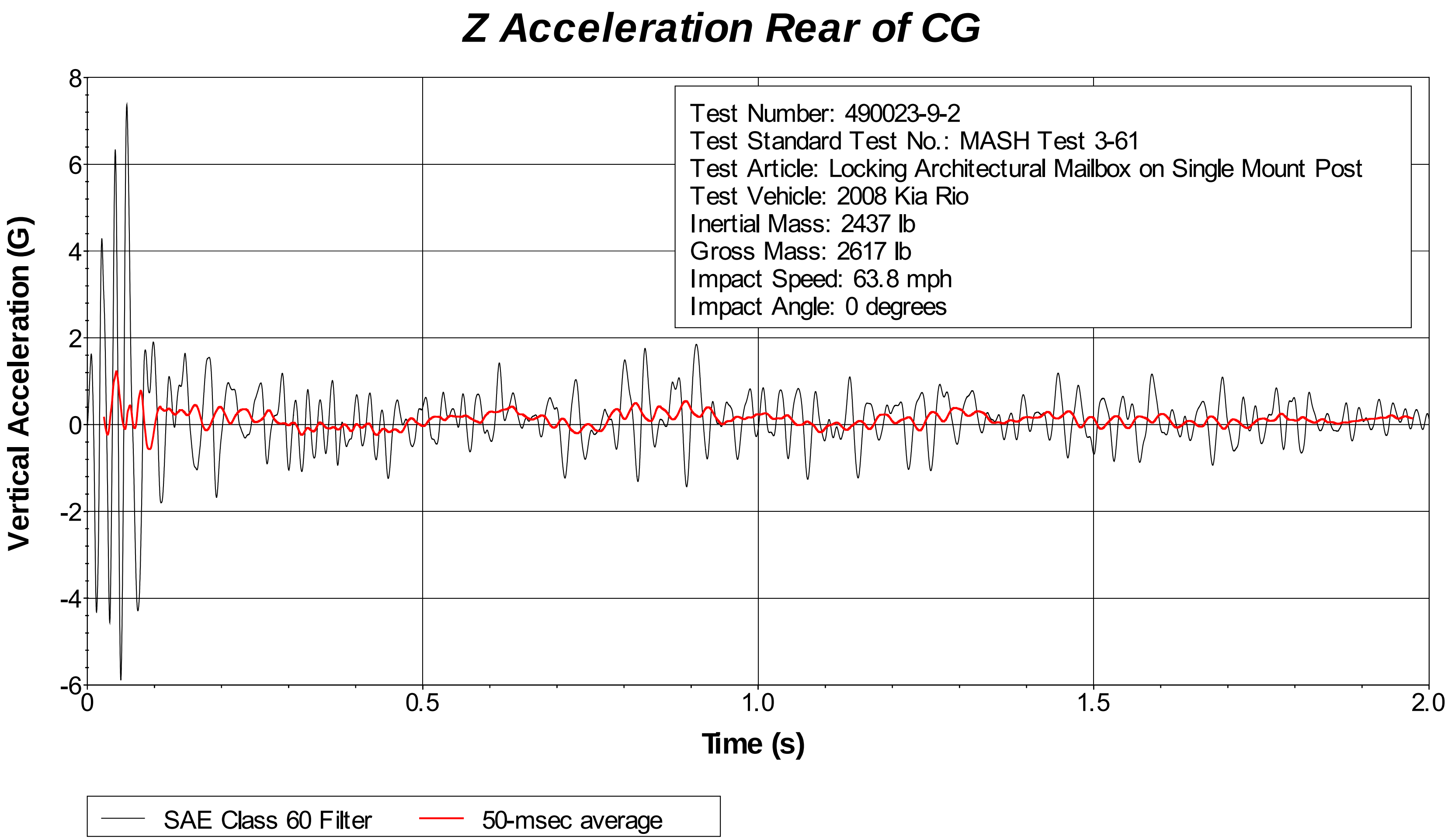


Figure B8. Vehicle Vertical Accelerometer Trace for Test No. 490023-9-2 (Accelerometer Located Rear of Center of Gravity).

APPENDIX C. CRASH TEST NO. 490023-9-3

C1. VEHICLE INFORMATION

Table C1. Vehicle Properties for Test No. 490023-9-3.

Date: 2013-08-16 Test No.: 490023-9-3 VIN No.: KNADE223996535907

Year: 2009 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 96956 Tire Size: 165/65R14

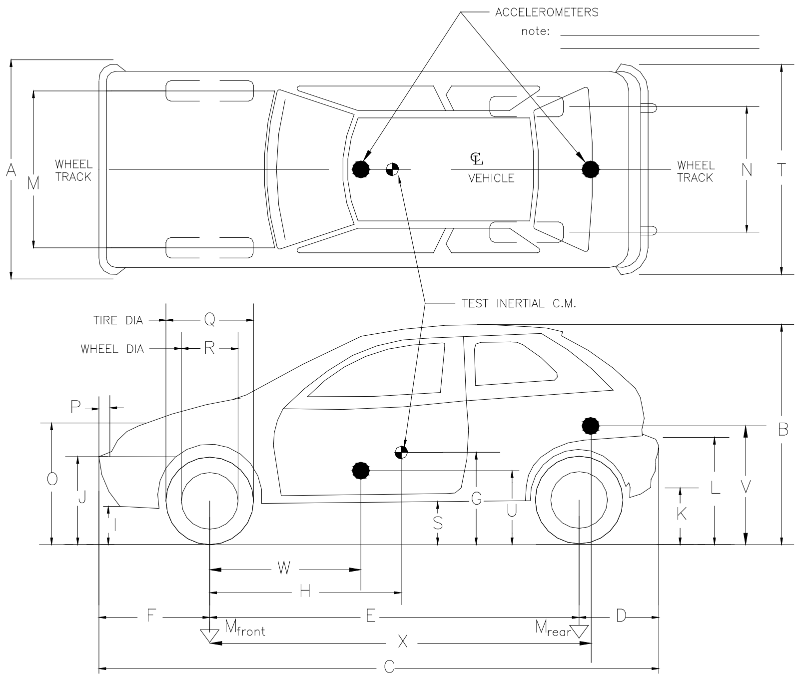
Describe any damage to the vehicle prior to test: ______

● Denotes accelerometer location.

NOTES: ______

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

Dummy Data:
Type: 50th percentile male
Mass: 177 lb
Seat Position: Driver side



Geometry: inches

A	66.38	F	33.00	K	11.75	P	4.12	U	25.50
B	57.75	G	----	L	25.25	Q	22.18	V	22.00
C	165.75	H	35.17	M	57.75	R	15.38	W	38.50
D	34.00	I	6.75	N	57.12	S	8.00	X	108.00
E	98.75	J	22.00	O	31.25	T	66.18		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1918	M_{front}	1603	1578	1668
Back	1874	M_{rear}	856	873	960
Total	2638	M_{Total}	2459	2451	2628

Mass Distribution:
lb LF: 793 RF: 785 LR: 454 RR: 419

Table C2. Exterior Vehicle Crush Measurements for Test No. 490023-9-3.

Date: 2013-08-16 Test No.: 490023-9-3 VIN No.: KNADE223996535907

Year: 2009 Make: Kia Model: Rio

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
----	No measurable deformation noted	----	----	----	----	----	----	----	----	----	----
	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.

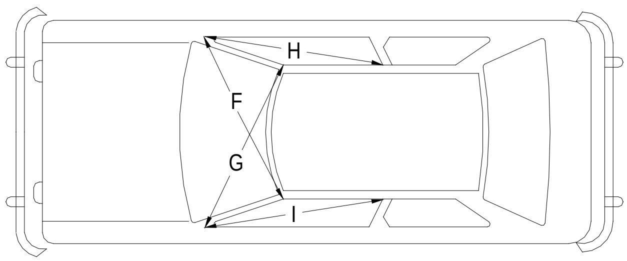
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

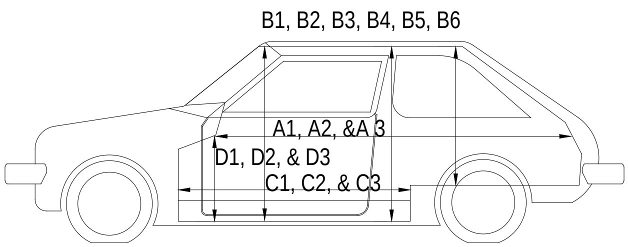
***Measure and document on the vehicle diagram the location of the maximum crush.

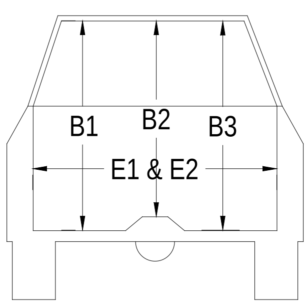
Note: Use as many lines/columns as necessary to describe each damage profile.

Table C3. Occupant Compartment Measurements for Test No. 490023-9-2.

Date:	2013-08-16	Test No.:	490023-9-3	VIN No.:	KNADE223996535907
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	67.50	67.50
B1	40.50	40.50
B2	36.50	36.50
B3	40.50	40.50
B4	36.25	36.25
B5	37.25	37.25
B6	36.25	36.25
C1	27.00	27.00
C2	----	----
C3	27.50	27.50
D1	9.75	9.75
D2	----	----
D3	9.75	9.75
E1	48.25	48.25
E2	51.00	51.00
F	50.00	50.00
G	50.00	50.00
H	36.50	36.50
I	36.50	36.50
J*	51.00	51.00

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

C2. SEQUENTIAL PHOTOGRAPHS

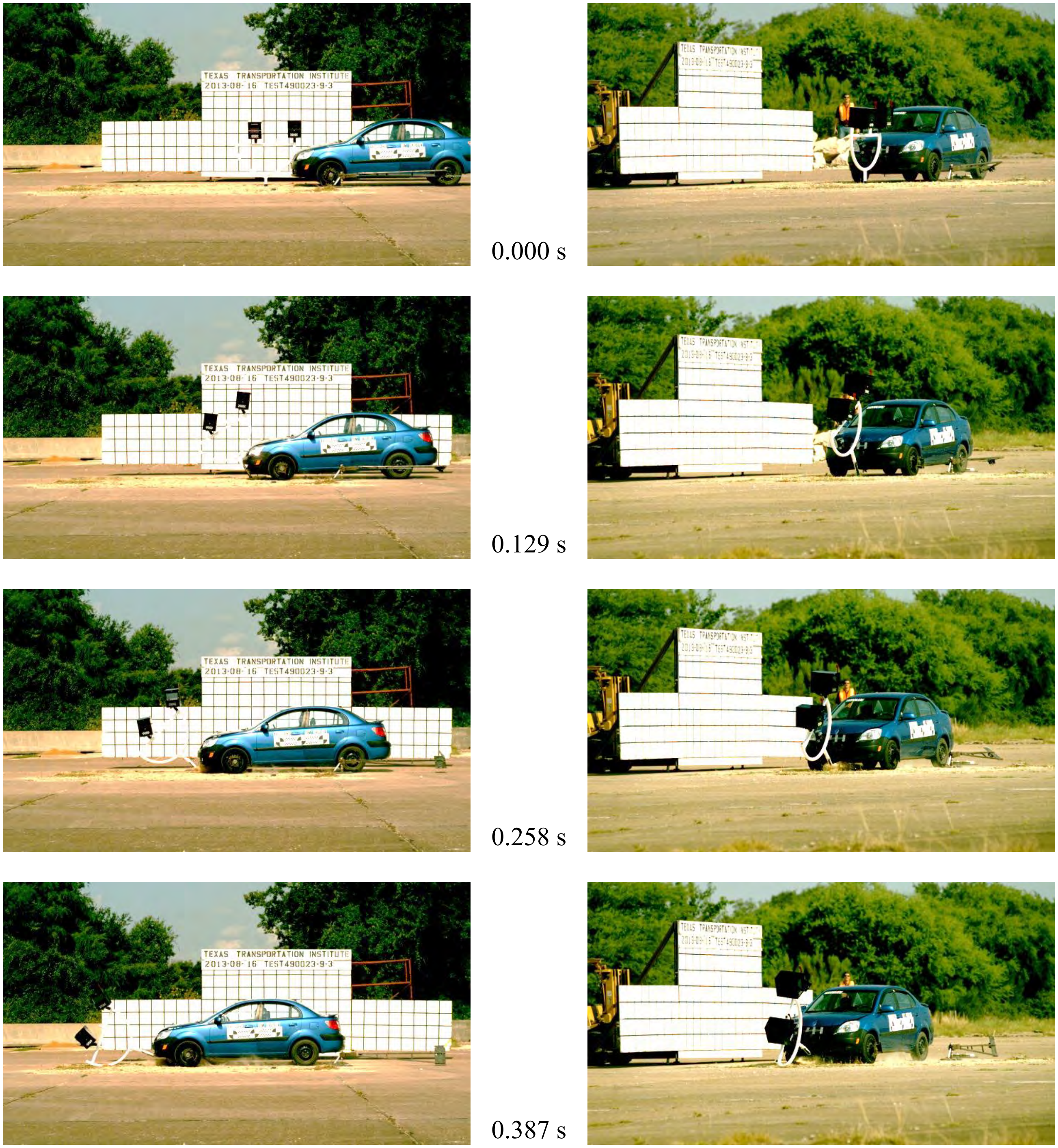


Figure C1. Sequential Photographs for Test No. 490023-9-3 (Perpendicular and Oblique Views).

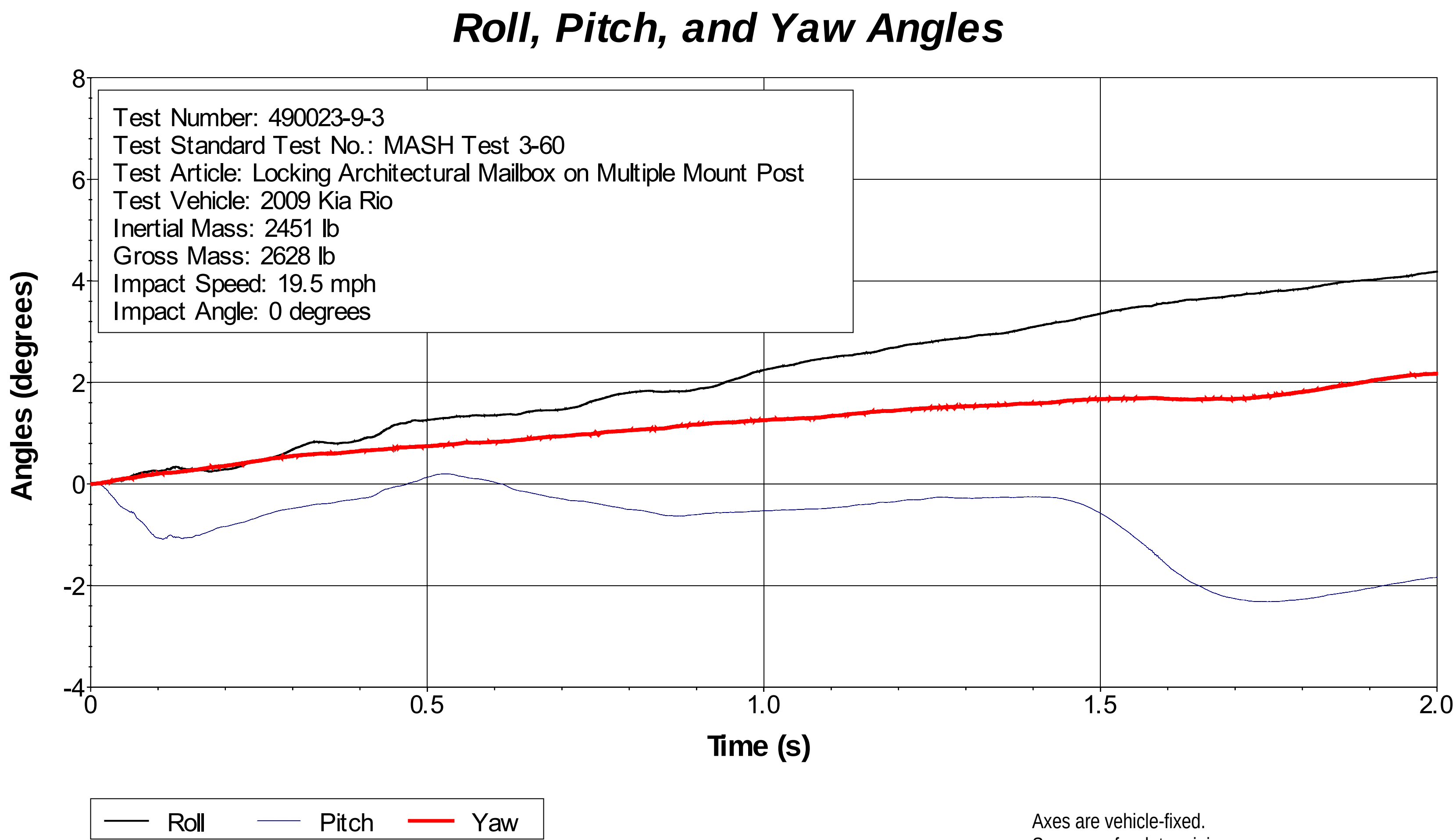
0.516 s

0.645 s

0.774 s

0.800 s

Figure C1. Sequential Photographs for Test No. 490023-9-3 (Perpendicular and Oblique Views) (Continued).



Axes are vehicle-fixed.
Sequence for determining orientation:

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

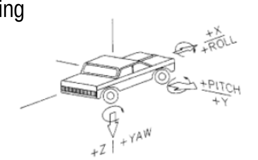


Figure C2. Vehicle Angular Displacements for Test No. 490023-9-3.

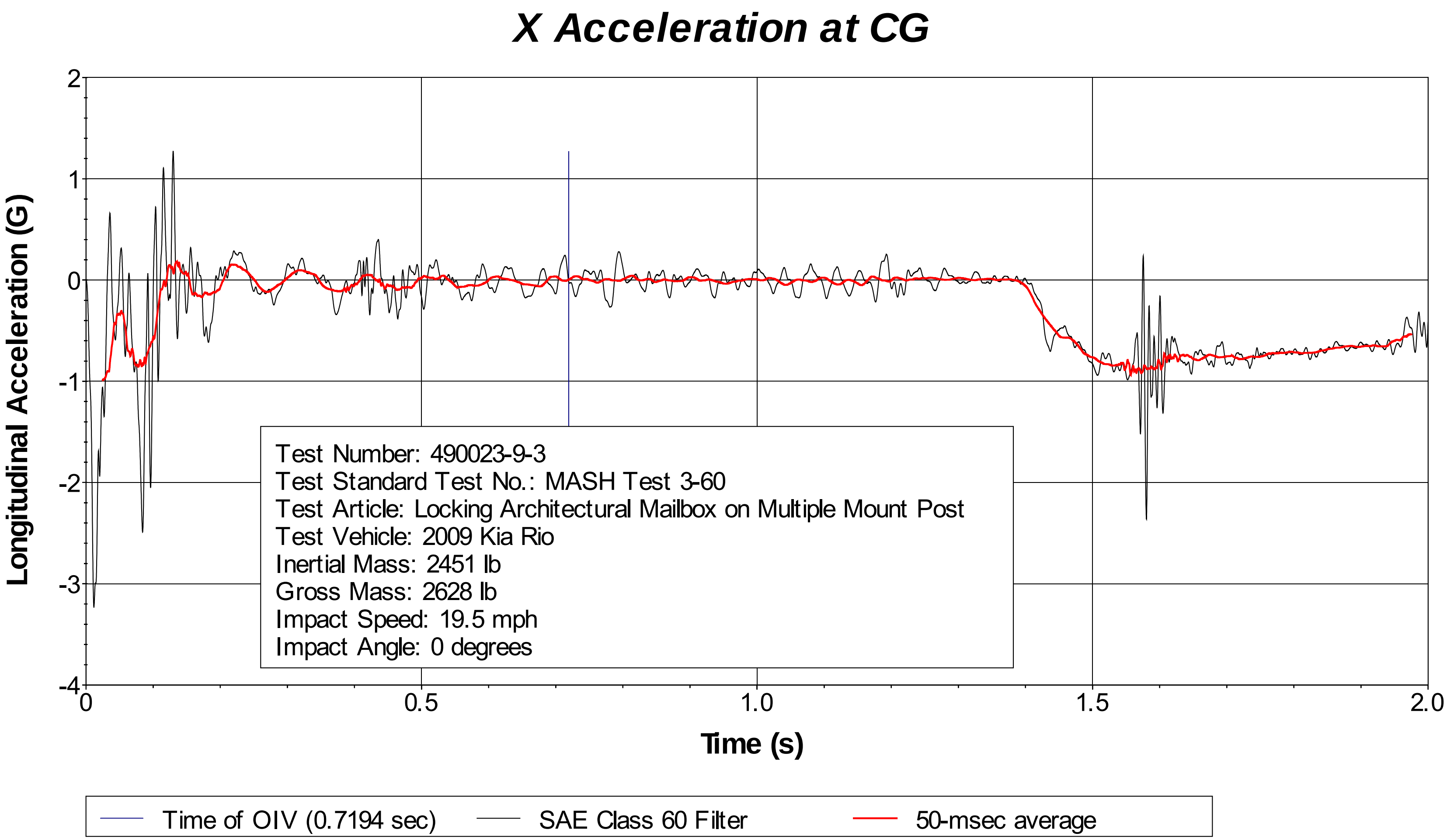


Figure C3. Vehicle Longitudinal Accelerometer Trace for Test No. 490023-9-3 (Accelerometer Located at Center of Gravity).

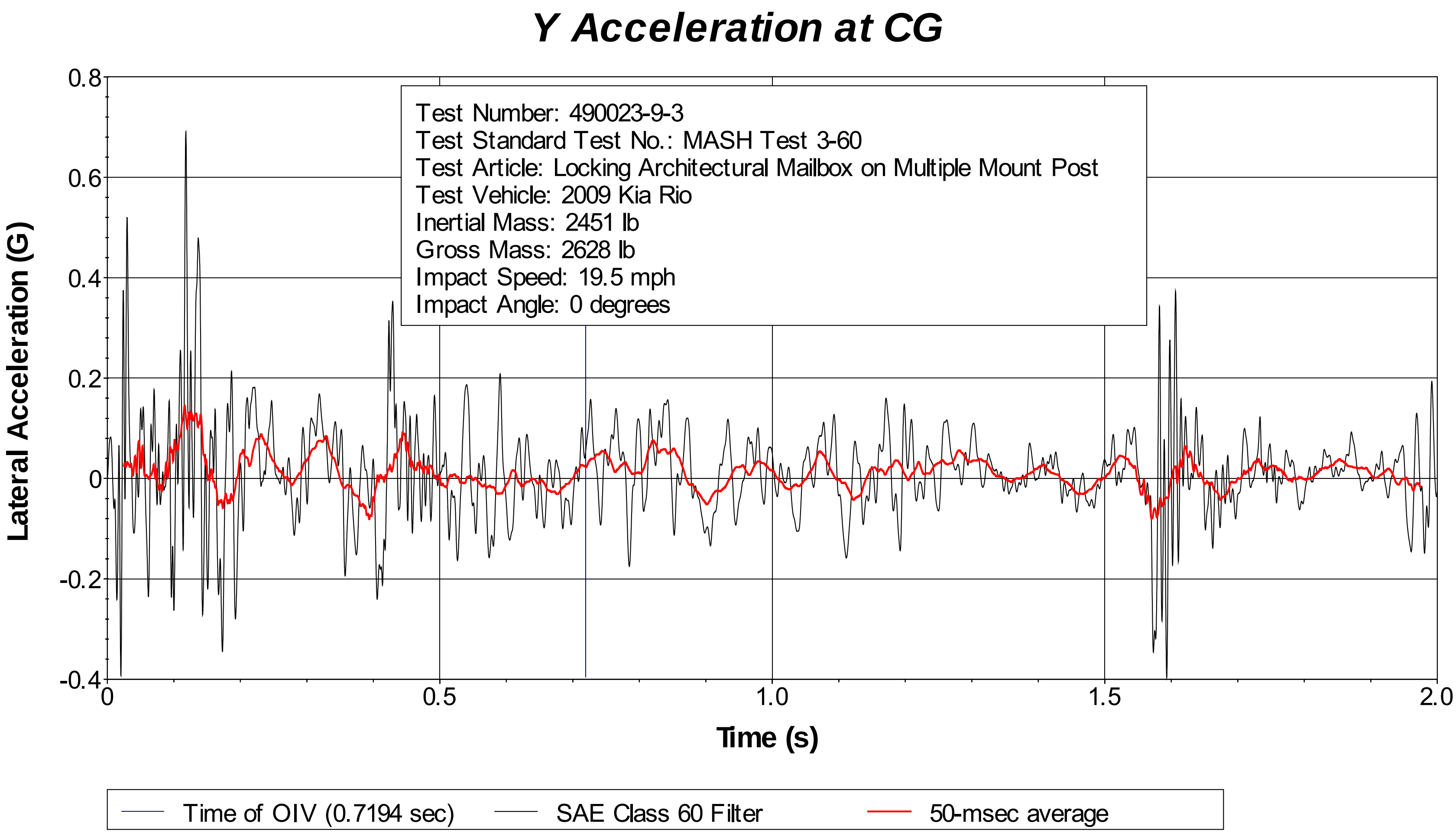


Figure C4. Vehicle Lateral Accelerometer Trace for Test No. 490023-9-3 (Accelerometer Located at Center of Gravity).

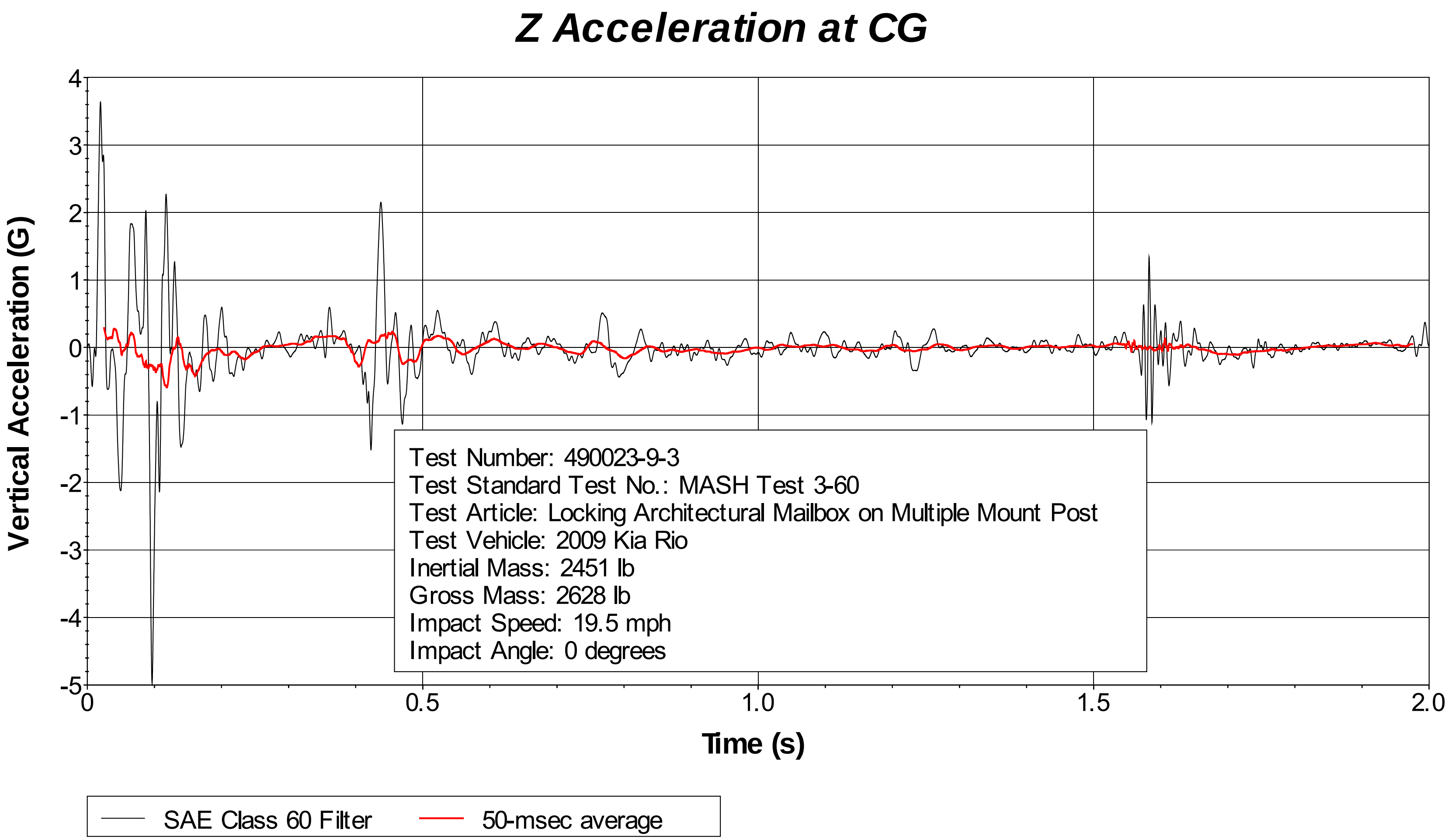


Figure C5. Vehicle Vertical Accelerometer Trace for Test No. 490023-9-3 (Accelerometer Located at Center of Gravity).

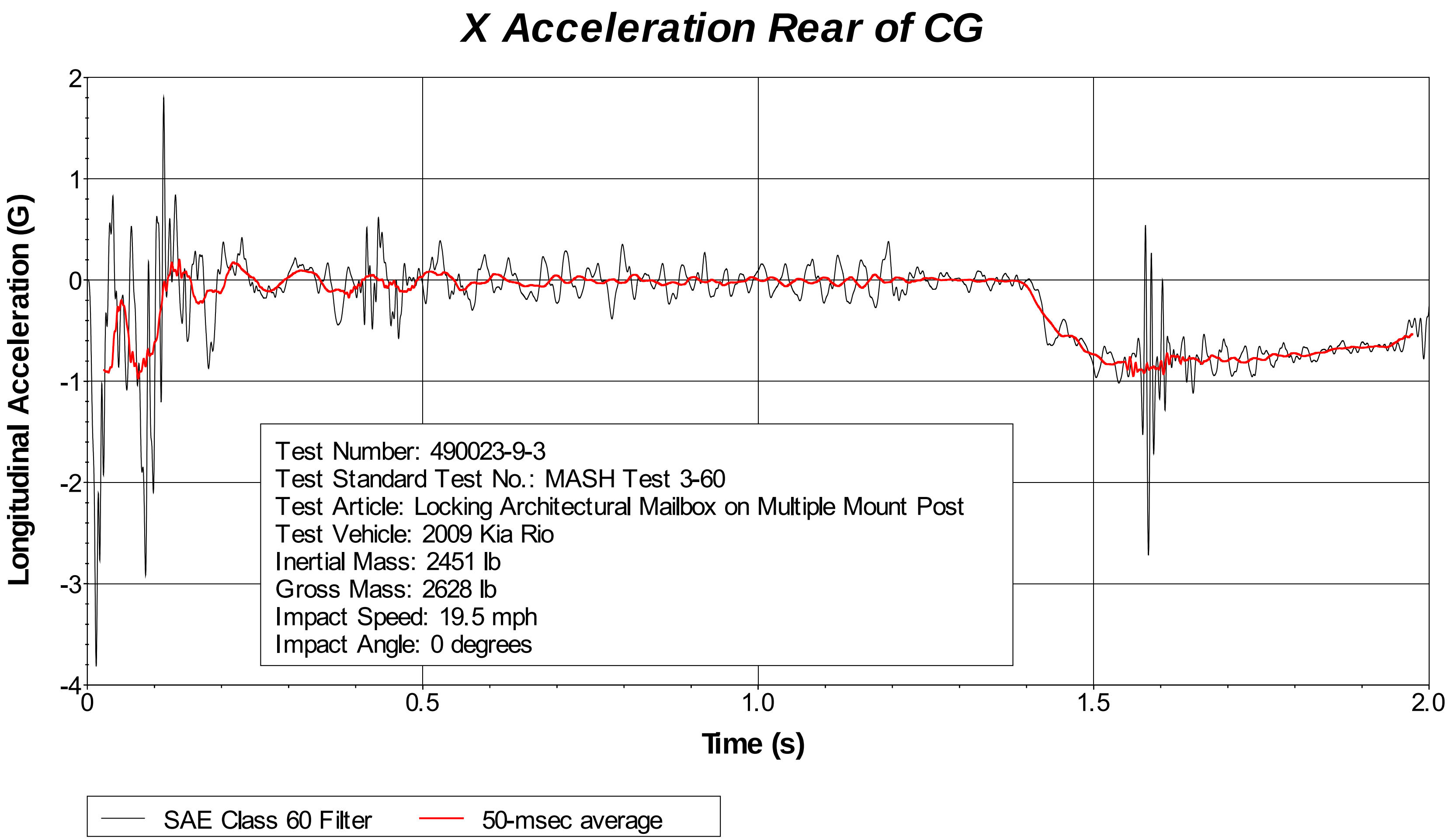


Figure C6. Vehicle Longitudinal Accelerometer Trace for Test No. 490023-9-3 (Accelerometer Located Rear of Center of Gravity).

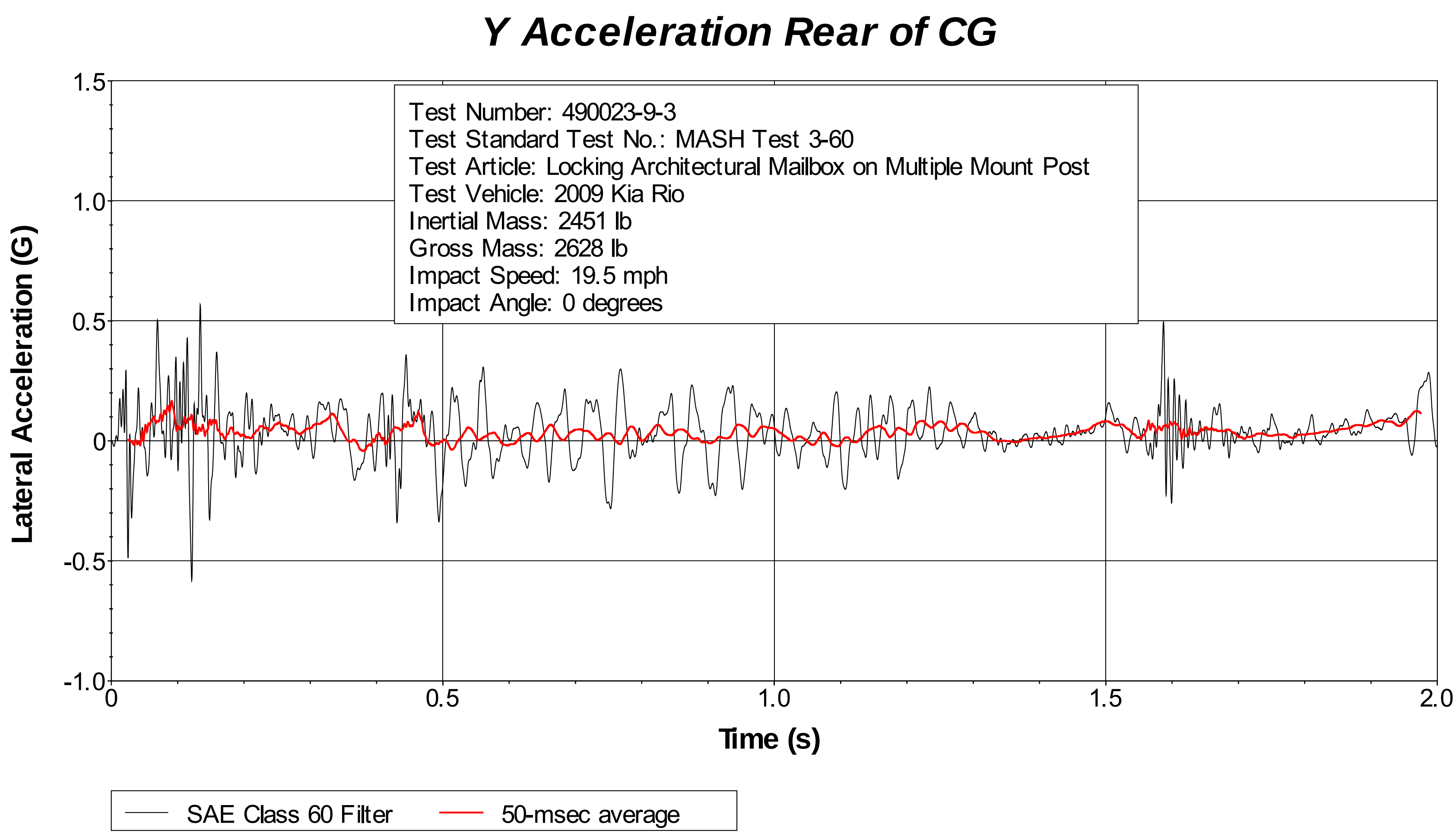


Figure C7. Vehicle Lateral Accelerometer Trace for Test No. 490023-9-3 (Accelerometer Located Rear of Center of Gravity).

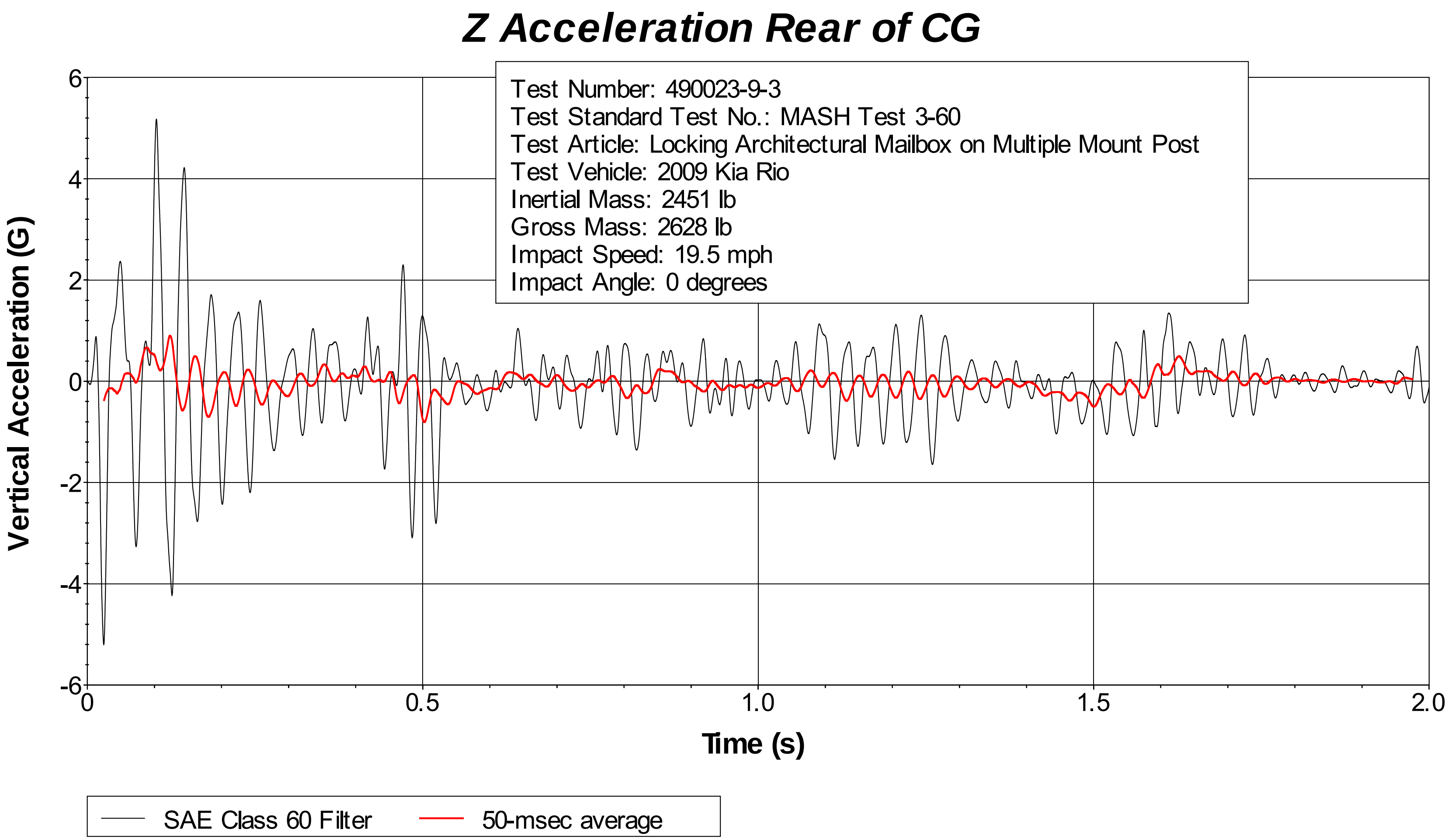


Figure C8. Vehicle Vertical Accelerometer Trace for Test No. 490023-9-3 (Accelerometer Located Rear of Center of Gravity).

APPENDIX D. CRASH TEST NO. 490023-9-4

D1. VEHICLE INFORMATION

Table D1. Vehicle Properties for Test No. 490023-9-4.

Date: 2013-08-16 Test No.: 490023-9-3 VIN No.: KNADE223496567602

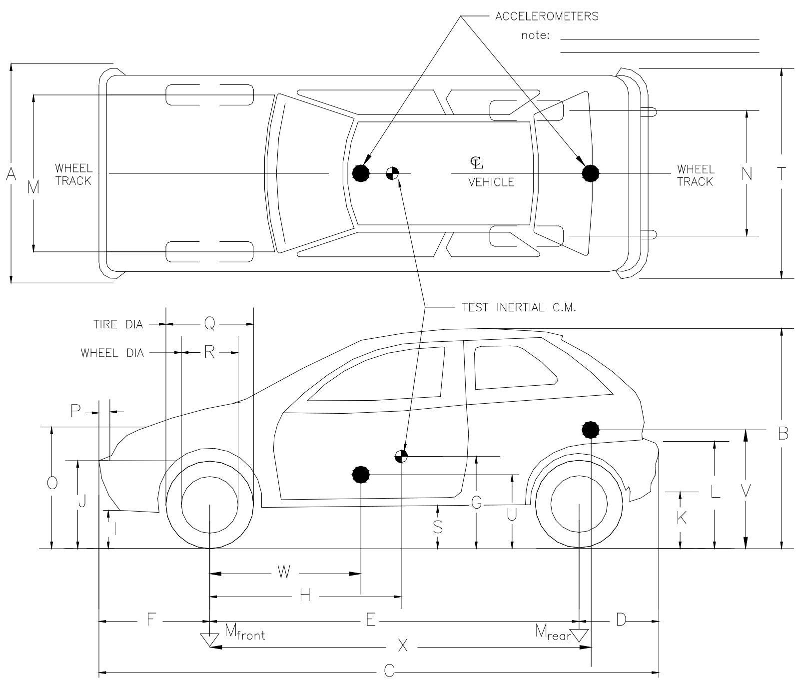
Year: 2009 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 62695 Tire Size: 165/65R14

Describe any damage to the vehicle prior to test: ______

● Denotes accelerometer location.

NOTES: ______



Engine Type: Inline 4 cylinder

Engine CID: 1.6 liter

Transmission Type:

____ Auto or x Manual

x FWD ____ RWD ____ 4WD

Optional Equipment: ______

Dummy Data:

Type: 50th percentile male

Mass: 165 lb

Seat Position: Driver side

Geometry: inches

A	66.38	F	33.00	K	11.75	P	4.12	U	15.38
B	57.75	G	----	L	25.25	Q	22.18	V	22.00
C	165.75	H	37.05	M	57.75	R	15.38	W	48.25
D	34.00	I	7.00	N	57.12	S	8.00	X	109.00
E	98.75	J	21.00	O	31.25	T	66.18		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00

GVWR Ratings:		Mass: lb	Curb	Test Inertial	Gross Static
Front	1918	M_{front}	1523	1514	1604
Back	1874	M_{rear}	895	909	984
Total	3638	M_{Total}	2418	2423	2588

Mass Distribution:

lb LF: 757 RF: 757 LR: 453 RR: 456

Table D2. Exterior Vehicle Crush Measurements for Test No. 490023-9-4.

Date: 2013-08-16 Test No.: 490023-9-3 VIN No.: KNADE223496567602

Year: 2009 Make: Kia Model: Rio

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								
----	No measurable deformation noted	----	----	----	----	----	----	----	----	----	----
	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).

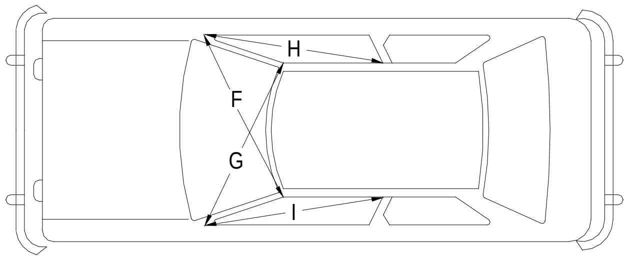
***Measure and document on the vehicle diagram the location of the maximum crush.

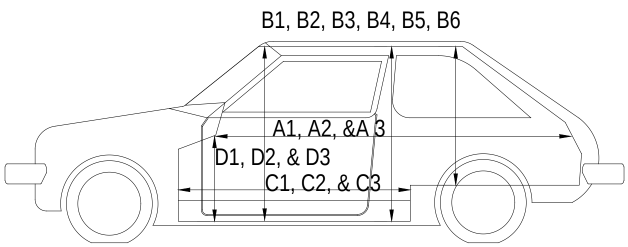
Note: Use as many lines/columns as necessary to describe each damage profile.

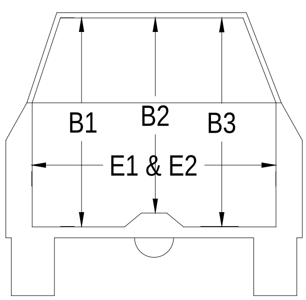
Table D3. Occupant Compartment Measurements for Test No. 490023-9-4.

Date: 2013-08-16 Test No.: 490023-9-3 VIN No.: KNADE223496567602

Year: 2009 Make: Kia Model: Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	71.50	71.50
A2	70.50	70.50
A3	71.50	71.50
B1	42.50	42.50
B2	34.75	34.75
B3	43.00	43.00
B4	34.75	34.75
B5	35.25	35.25
B6	34.75	34.75
C1	55.00	55.00
C2	43.50	43.50
C3	55.00	55.00
D1	12.00	12.00
D2	6.75	6.75
D3	12.00	12.00
E1	53.75	53.75
E2	53.75	53.75
F	53.50	53.50
G	53.50	53.50
H	35.75	35.75
I	35.75	35.75
J*	52.75	52.75

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

D2. SEQUENTIAL PHOTOGRAPHS

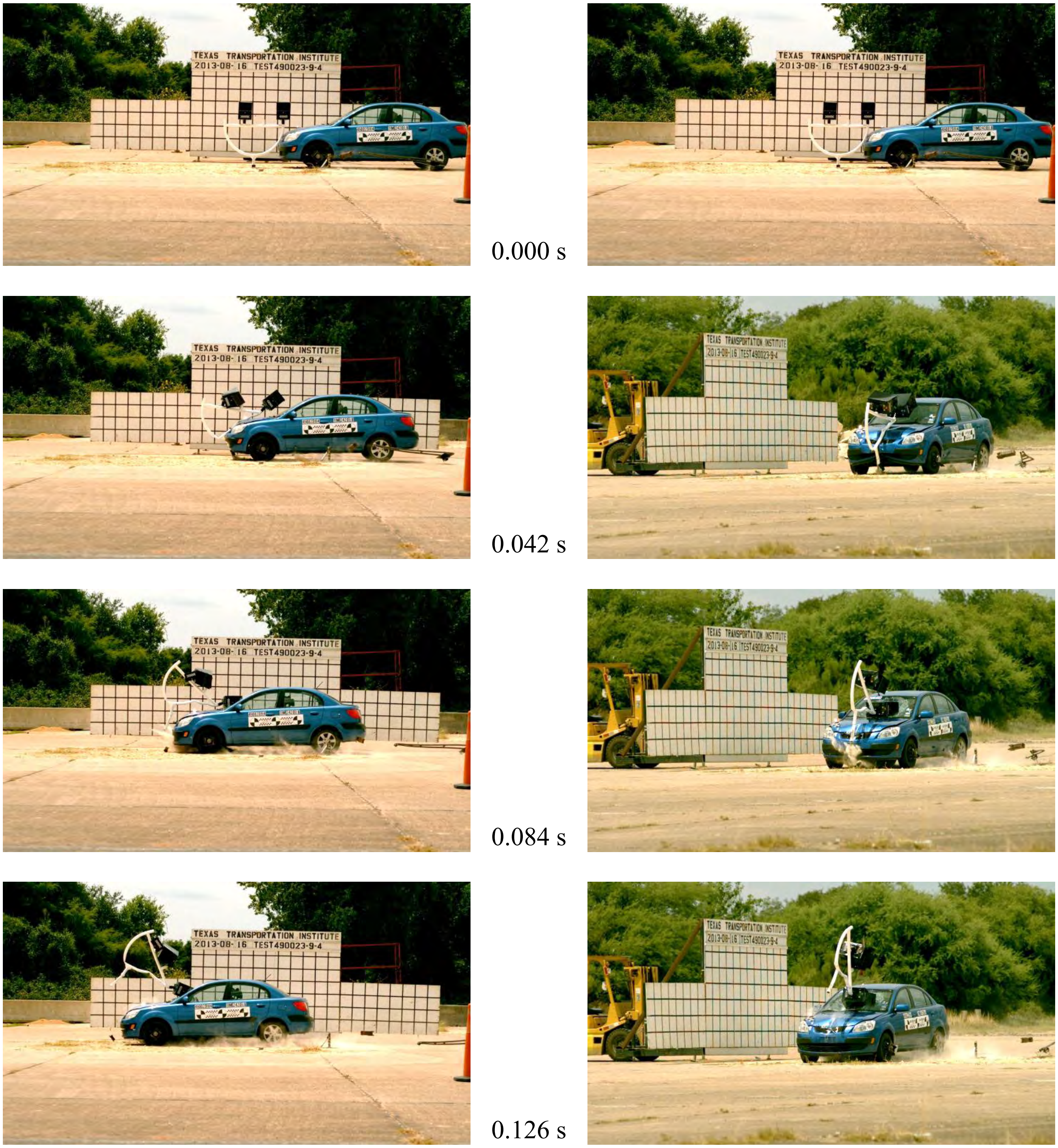


Figure D1. Sequential Photographs for Test No. 490023-9-4 (Perpendicular and Oblique Views).

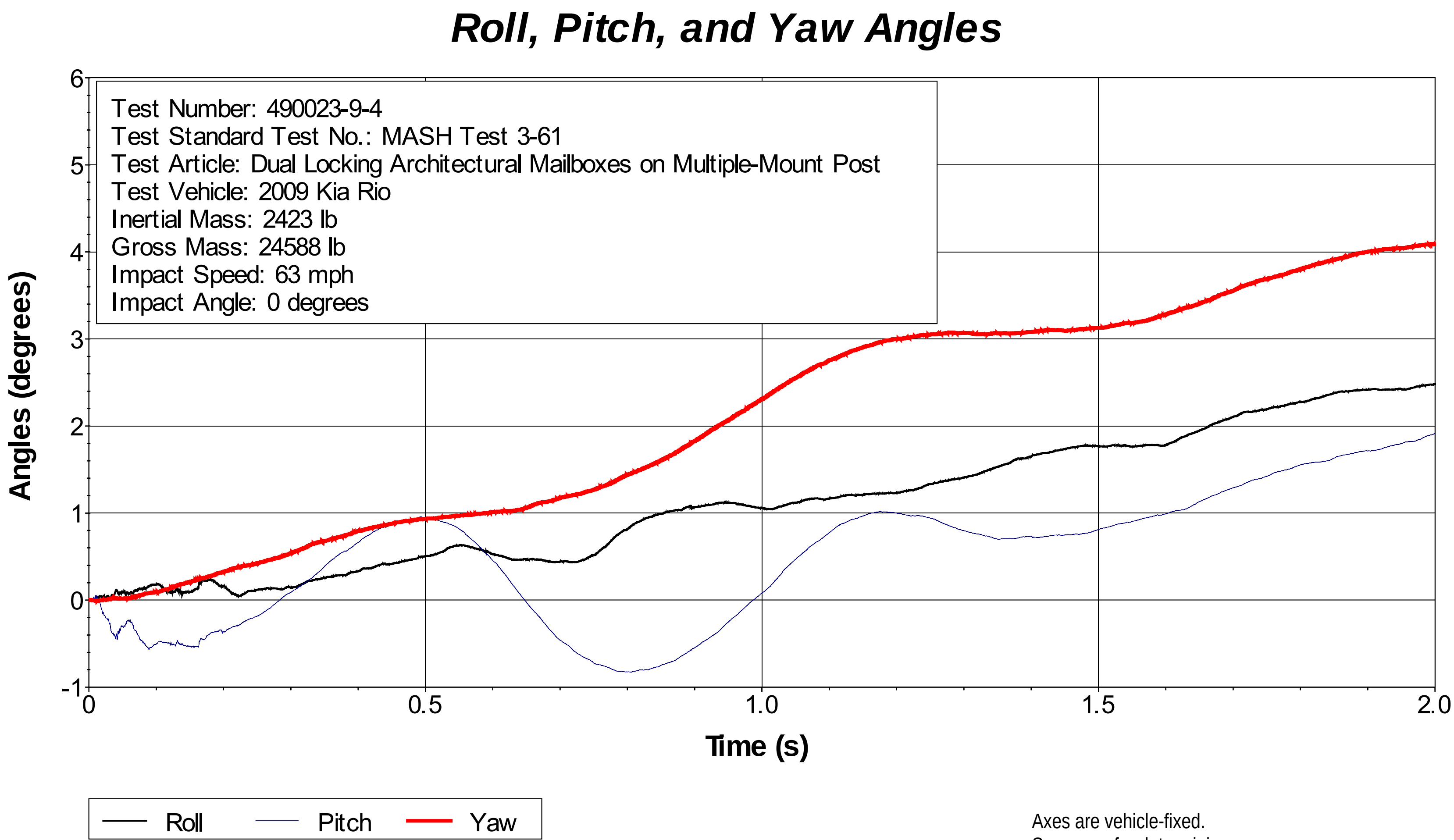
0.168 s

0.210 s

0.252 s

0.294 s

Figure D1. Sequential Photographs for Test No. 490023-9-4 (Perpendicular and Oblique Views) (Continued).



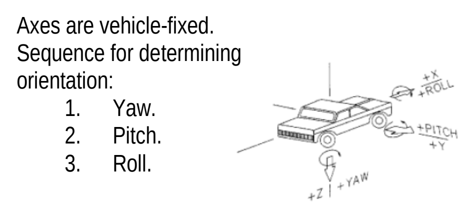


Figure D2. Vehicle Angular Displacements for Test No. 490023-9-4.

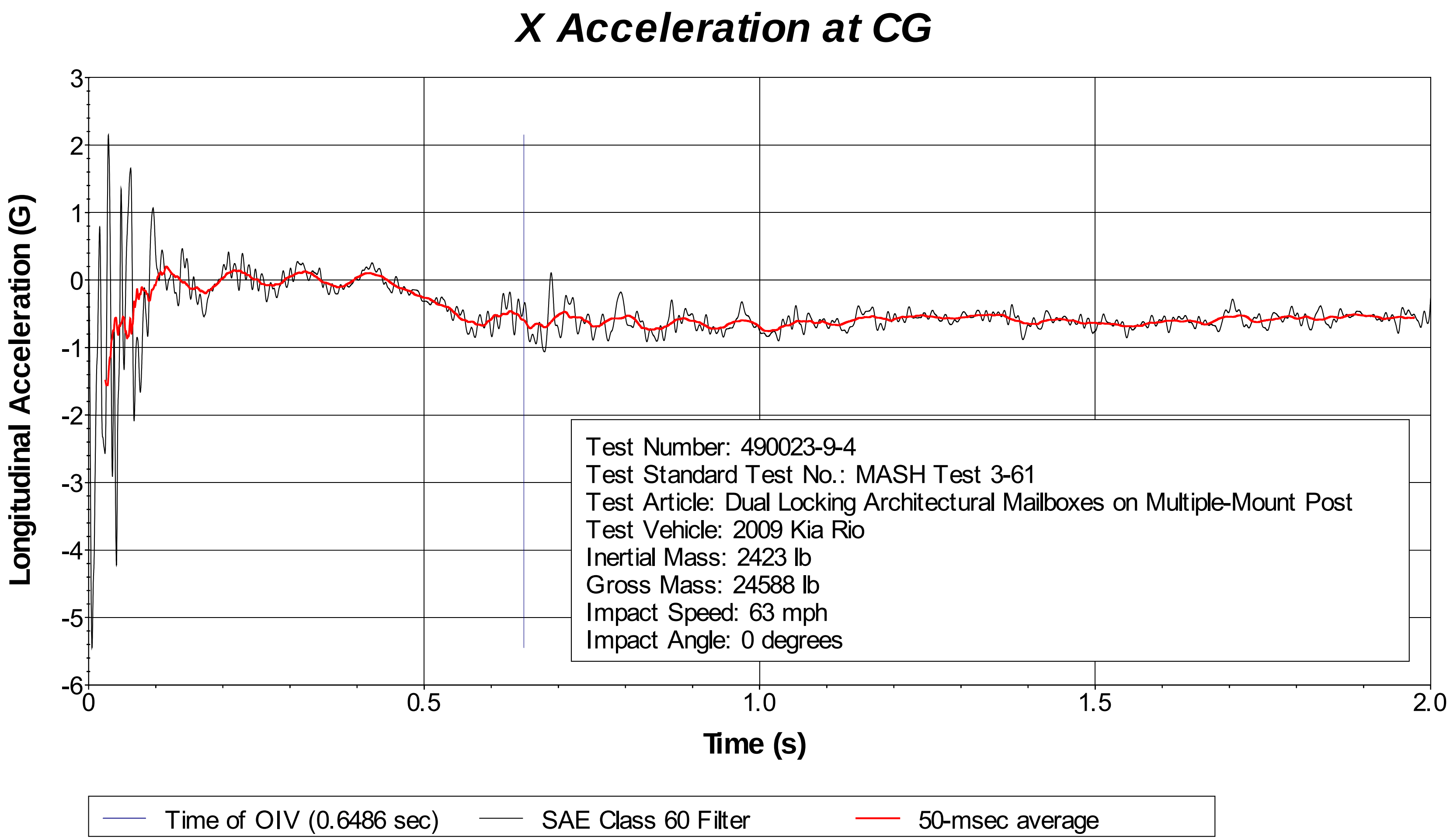


Figure D3. Vehicle Longitudinal Accelerometer Trace for Test No. 490023-9-4 (Accelerometer Located at Center of Gravity).

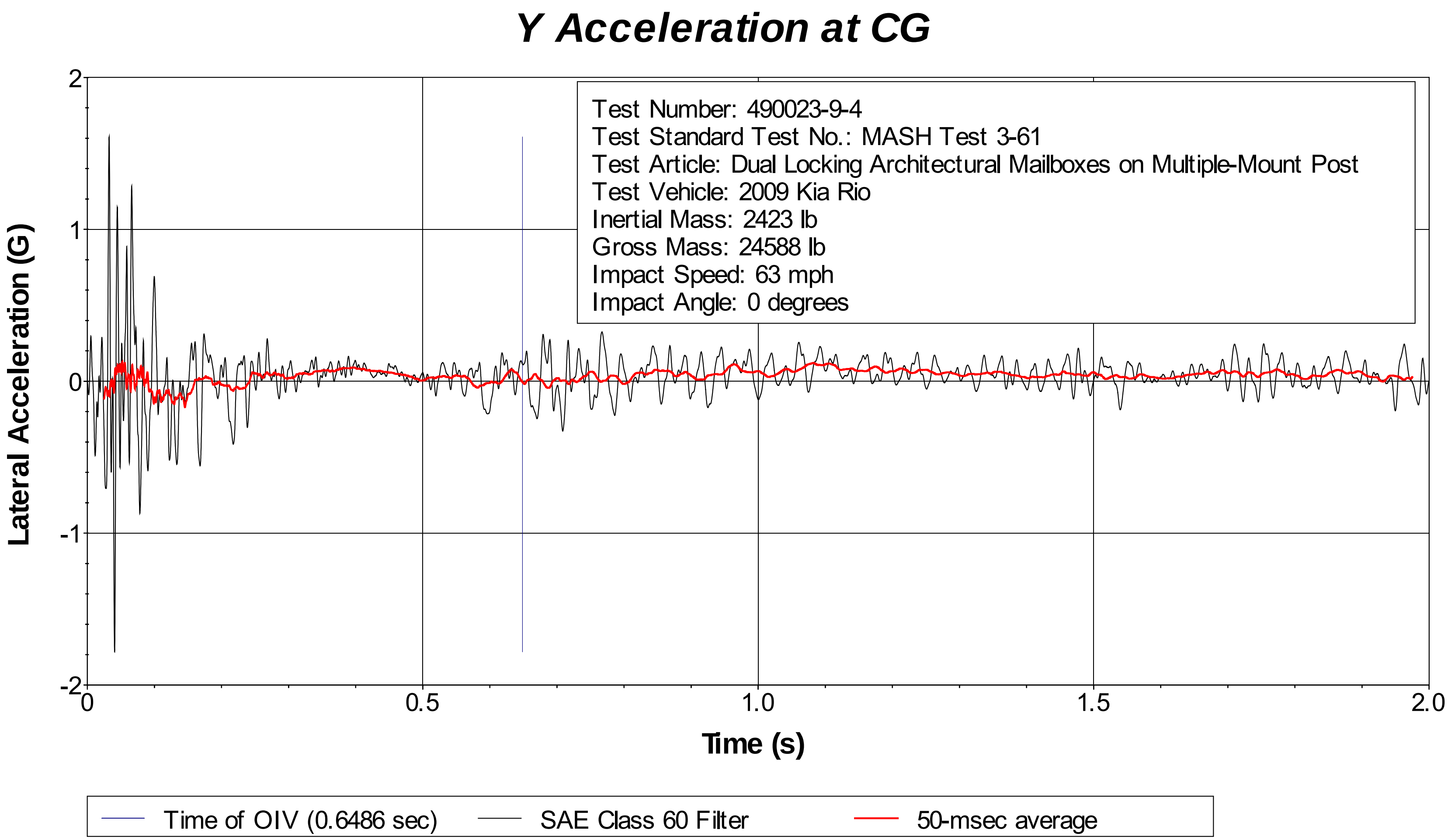


Figure D4. Vehicle Lateral Accelerometer Trace for Test No. 490023-9-4 (Accelerometer Located at Center of Gravity).

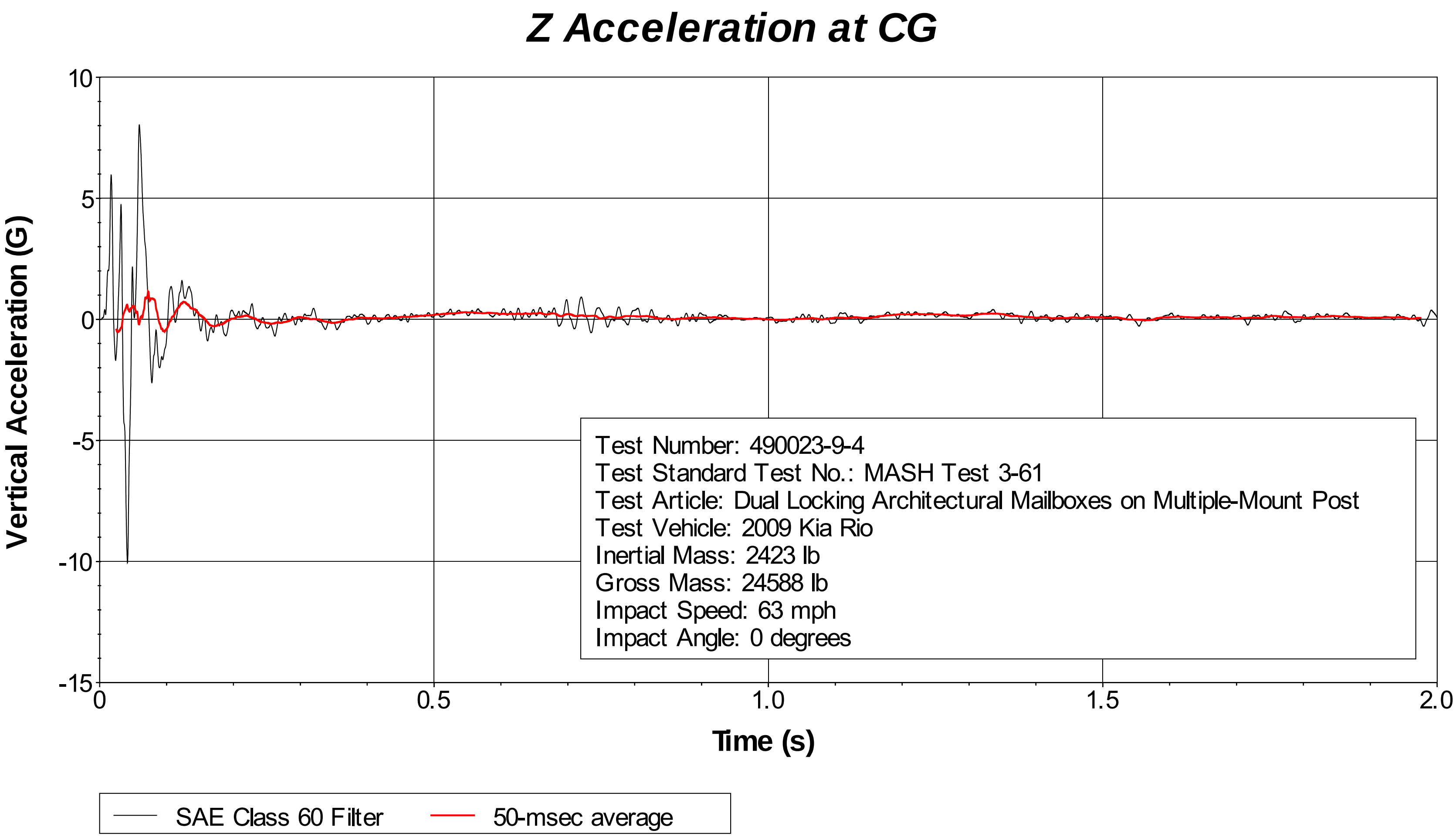


Figure D5. Vehicle Vertical Accelerometer Trace for Test No. 490023-9-4 (Accelerometer Located at Center of Gravity).

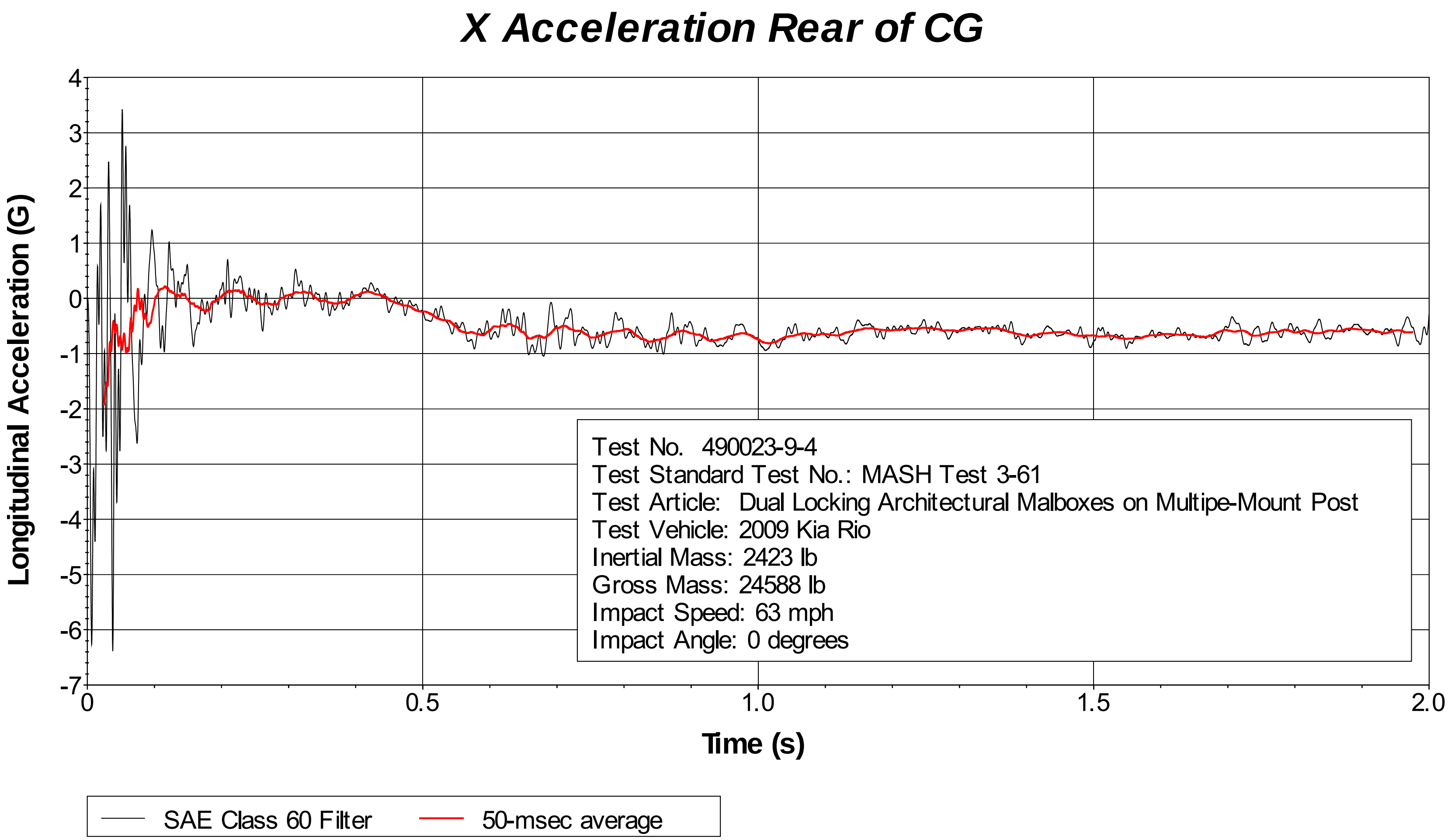


Figure D6. Vehicle Longitudinal Accelerometer Trace for Test No. 490023-9-4 (Accelerometer Located Rear of Center of Gravity).

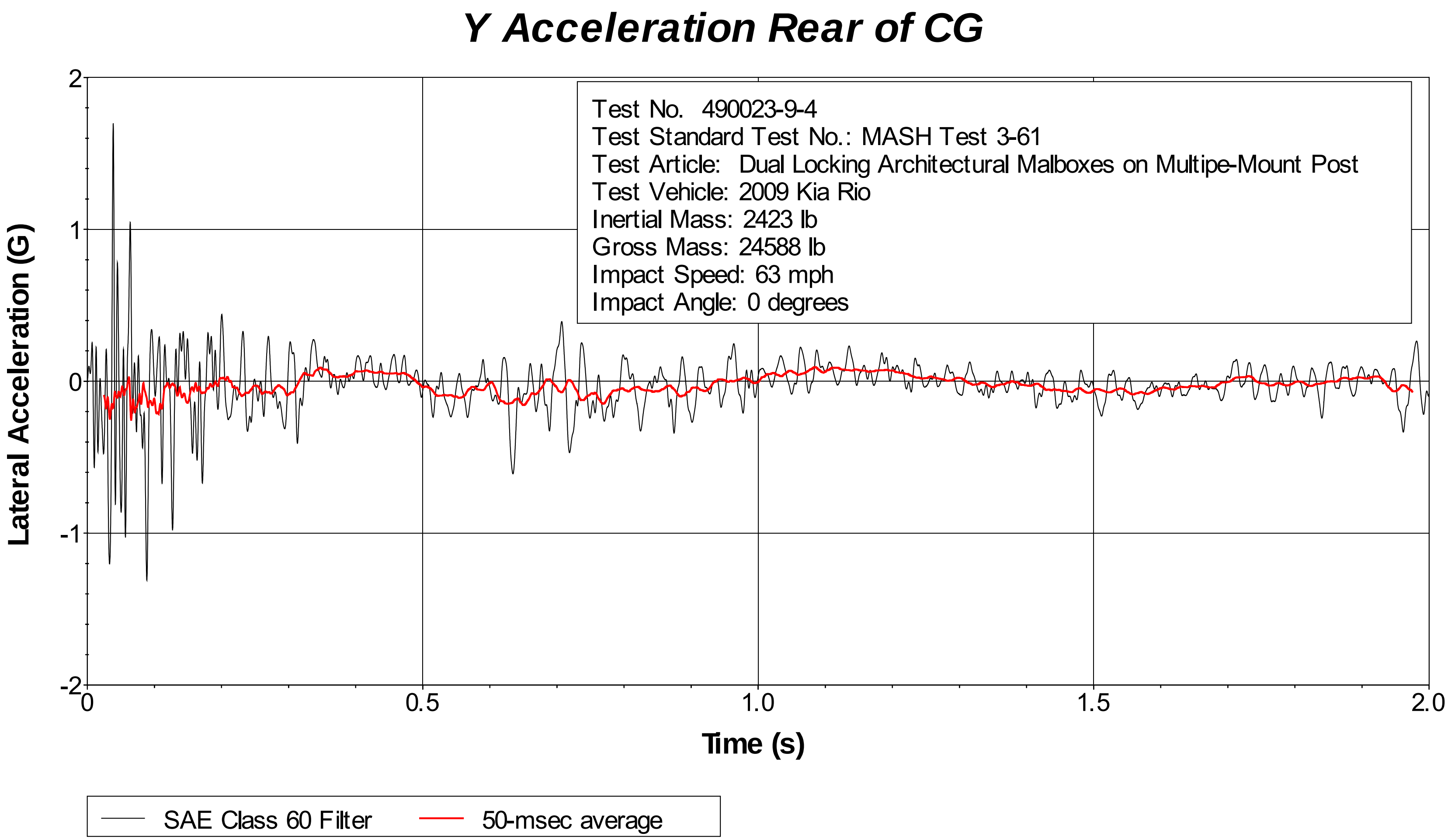


Figure D7. Vehicle Lateral Accelerometer Trace for Test No. 490023-9-4 (Accelerometer Located Rear of Center of Gravity).

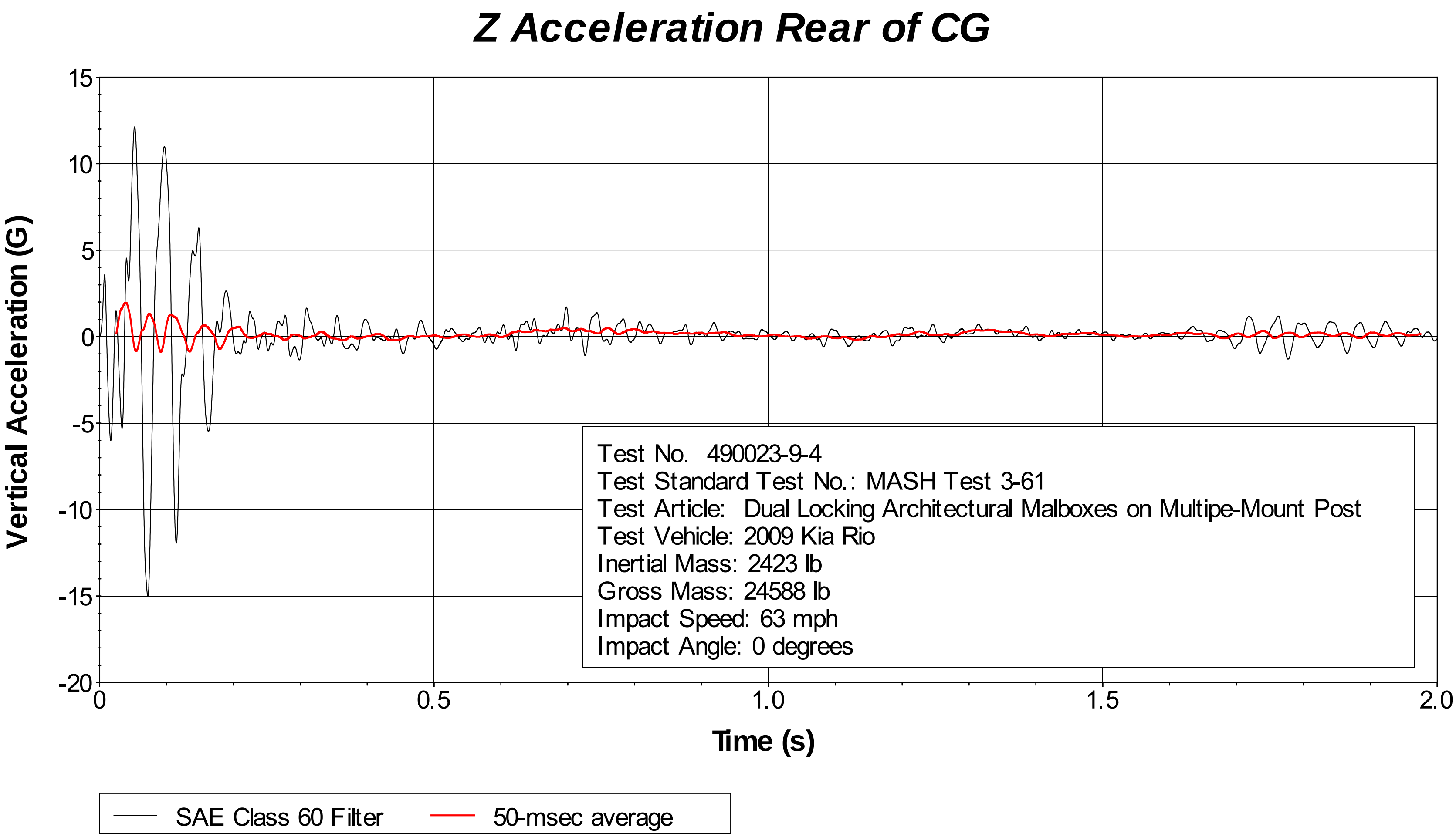


Figure D8. Vehicle Vertical Accelerometer Trace for Test No. 490023-9-4 (Accelerometer Located Rear of Center of Gravity).

APPENDIX E. CRASH TEST NO. 490023-9-5

E1. VEHICLE INFORMATION

Table E1. Vehicle Properties for Test No. 490023-9-5.

Date: 2013-08-30 Test No.: 490023-9-5 VIN No.: KNADE123486361219

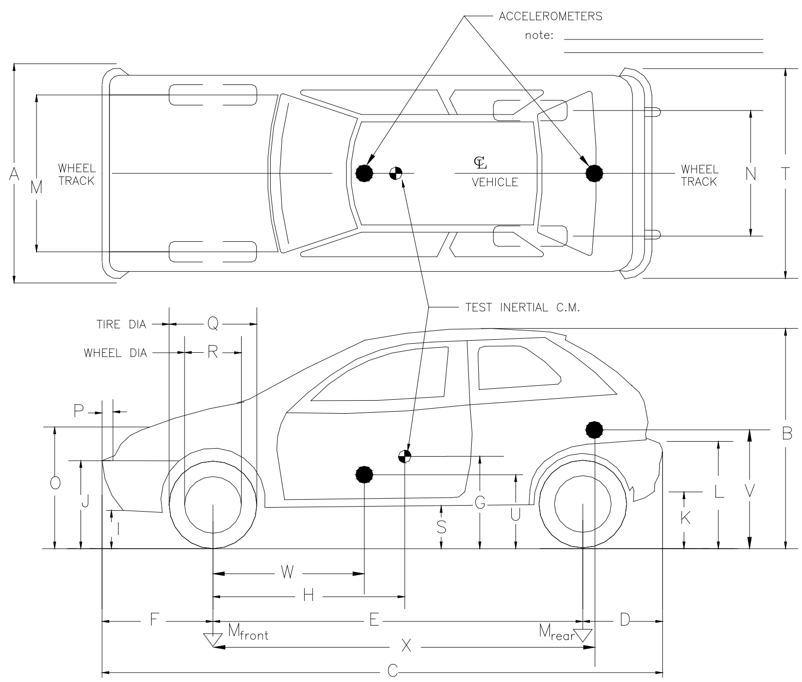
Year: 2008 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 37198 Tire Size: 165/65R14

Describe any damage to the vehicle prior to test: ______________________

● Denotes accelerometer location.

NOTES: ______________________



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

Dummy Data:
Type: 50th percentile male
Mass: 165 ;n
Seat Position: Driver side

Geometry: inches

A	66.38	F	33.00	K	12.00	P	4.12	U	15.50
B	57.75	G	----	L	24.25	Q	22.19	V	22.00
C	165.75	H	37.09	M	57.75	R	15.38	W	42.50
D	34.00	I	7.50	N	57.12	S	9.00	X	108.00
E	98.75	J	22.00	O	31.50	T	66.18		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1918	M_{front}	1473	1517	1589
Back	1874	M_{rear}	871	909	996
Total	3638	M_{Total}	2344	2720	2585

Mass Distribution:
lb LF: 751 RF: 760 LR: 482 RR: 427

Table E2. Exterior Vehicle Crush Measurements for Test No. 490023-9-5.

Date: 2013-08-30 Test No.: 490023-9-5 VIN No.: KNADE123486361219

Year: 2008 Make: Kia Model: Rio

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								
----	No measurable deformation noted	----	----	----	----	----	----	----	----	----	----
	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.

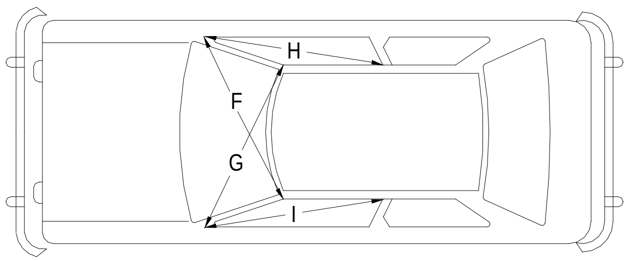
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

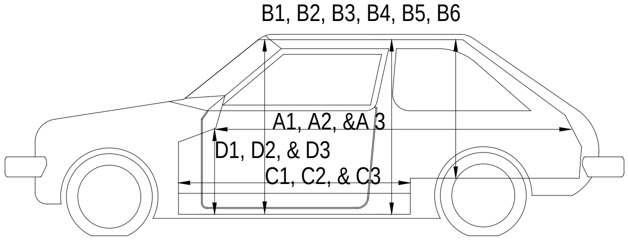
***Measure and document on the vehicle diagram the location of the maximum crush.

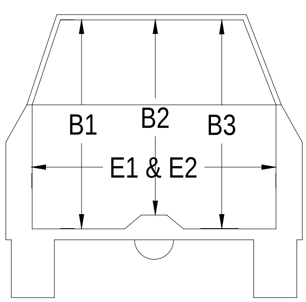
Note: Use as many lines/columns as necessary to describe each damage profile.

Table E3. Occupant Compartment Measurements for Test No. 490023-9-5.

Date:	2013-08-30	Test No.:	490023-9-5	VIN No.:	KNADE123486361219
Year:	2008	Make:	Kia	Model:	Rio





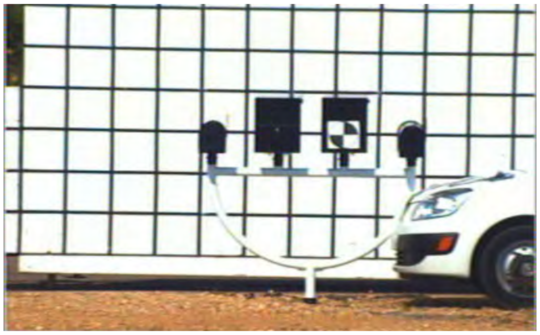


OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	**After** (inches)
A1	67.50	67.50
A2	64.50	64.50
A3	67.50	67.50
B1	40.50	36.50
B2	35.75	31.00
B3	40.50	36.50
B4	36.75	36.75
B5	32.75	32.75
B6	36.75	36.75
C1	26.50	26.50
C2	----	----
C3	27.75	27.75
D1	9.50	9.50
D2	----	----
D3	9.75	9.75
E1	51.50	51.50
E2	51.25	51.25
F	50.50	50.50
G	50.50	50.50
H	38.25	38.25
I	38.25	38.25
J*	51.00	51.00

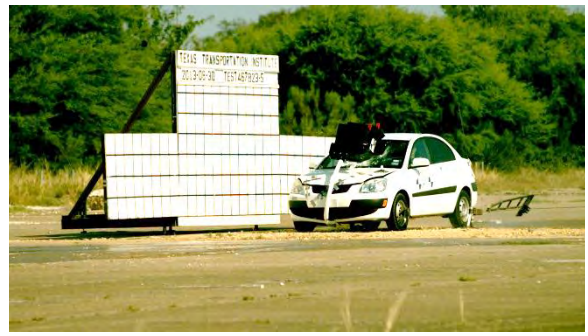
*Lateral area across the cab from driver's side kick panel to passenger's side kick panel.

E2. SEQUENTIAL PHOTOGRAPHS



0.000 s

0.065 s



0.130 s

0.195 s

Figure E1. Sequential Photographs for Test No. 490023-9-5 (Perpendicular and Oblique Views).

0.260 s

Out of view

0.325 s

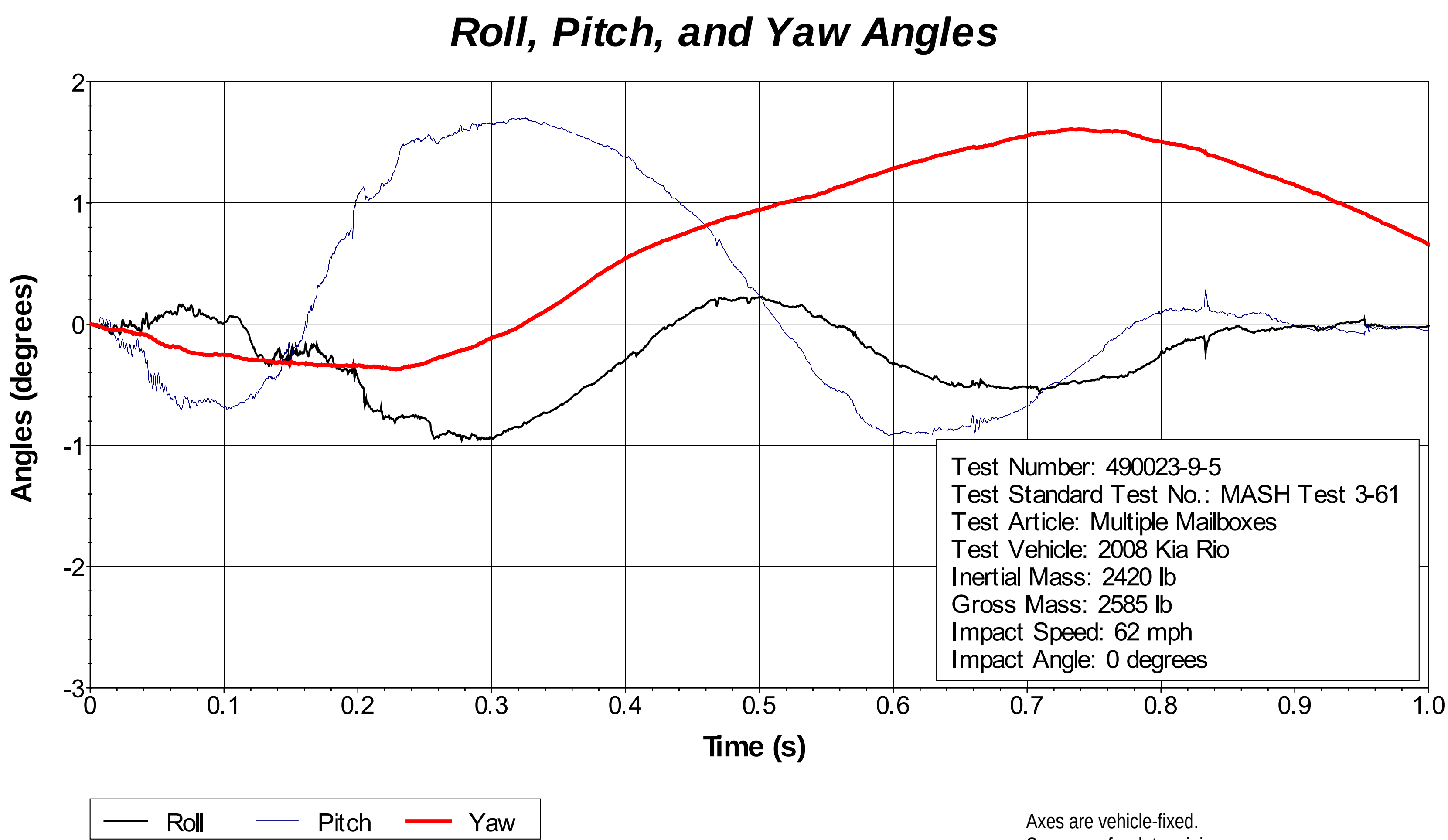
Out of view

0.390 s

Out of view

0.455 s

Figure E1. Sequential Photographs for Test No. 490023-9-5 (Perpendicular and Oblique Views) (Continued).



Axes are vehicle-fixed.
Sequence for determining orientation:

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

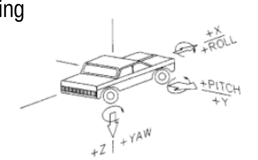


Figure E2. Vehicle Angular Displacements for Test No. 490023-9-5.

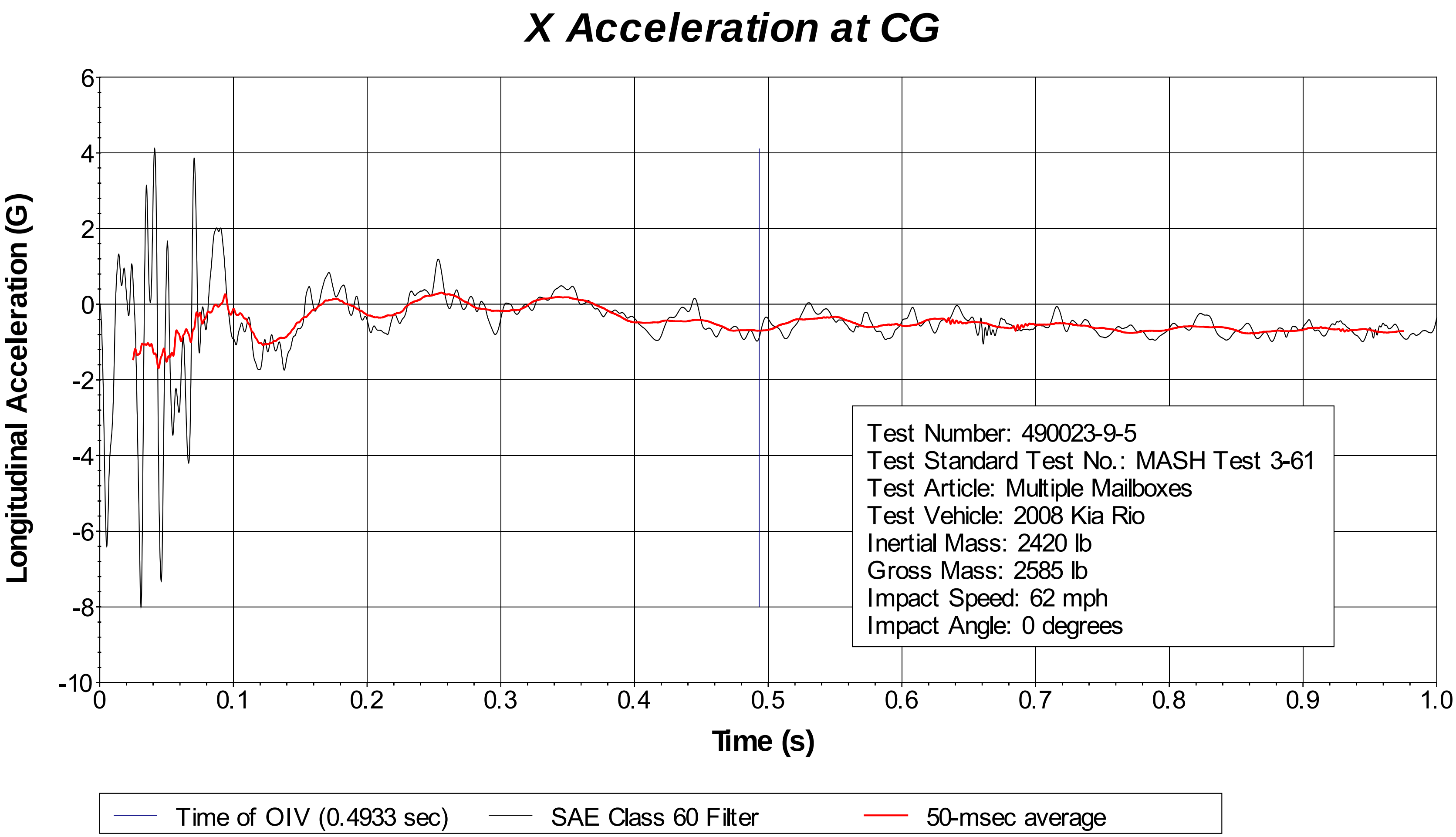


Figure E3. Vehicle Longitudinal Accelerometer Trace for Test No. 490023-9-5 (Accelerometer Located at Center of Gravity).

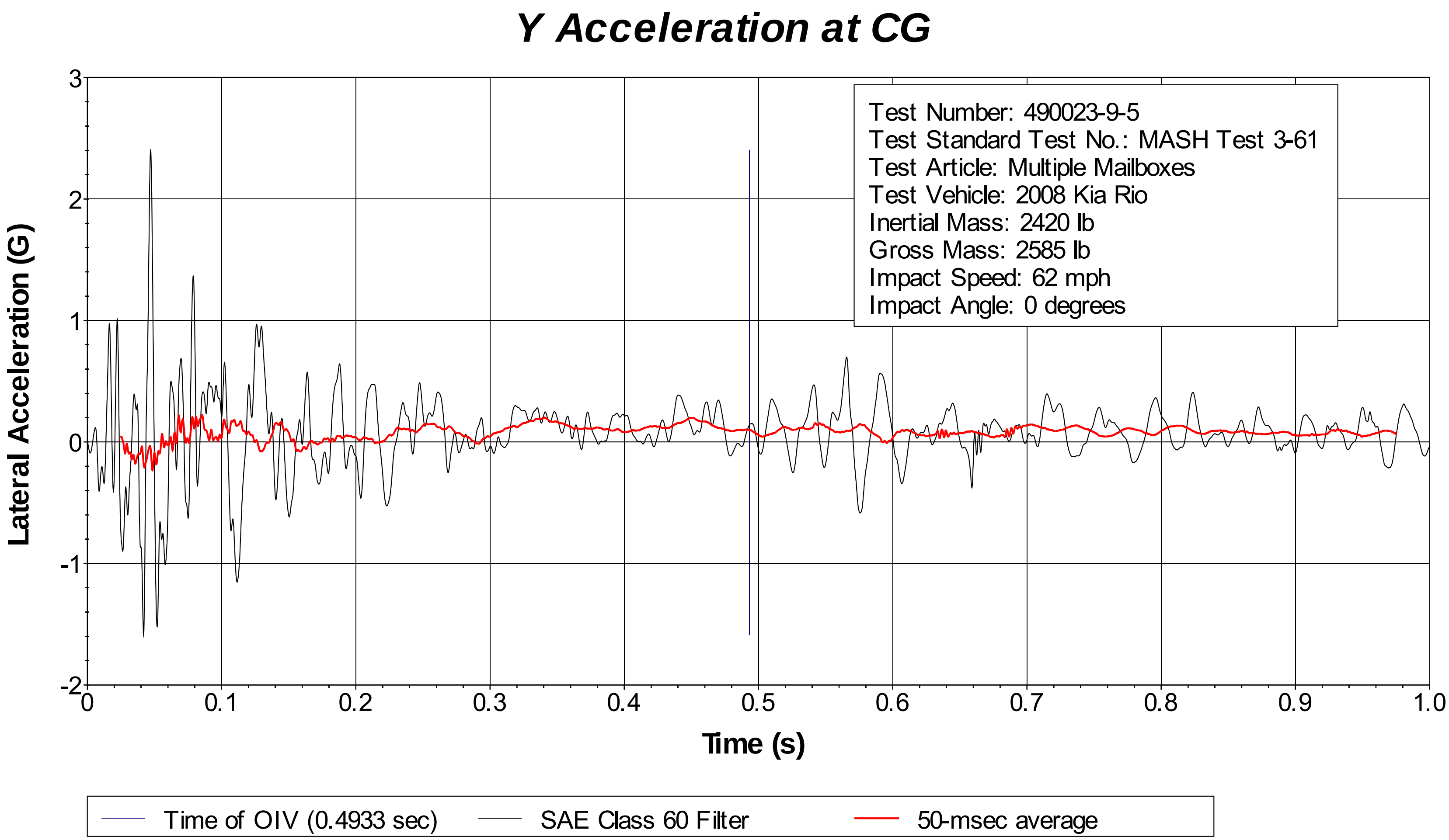


Figure E4. Vehicle Lateral Accelerometer Trace for Test No. 490023-9-5 (Accelerometer Located at Center of Gravity).

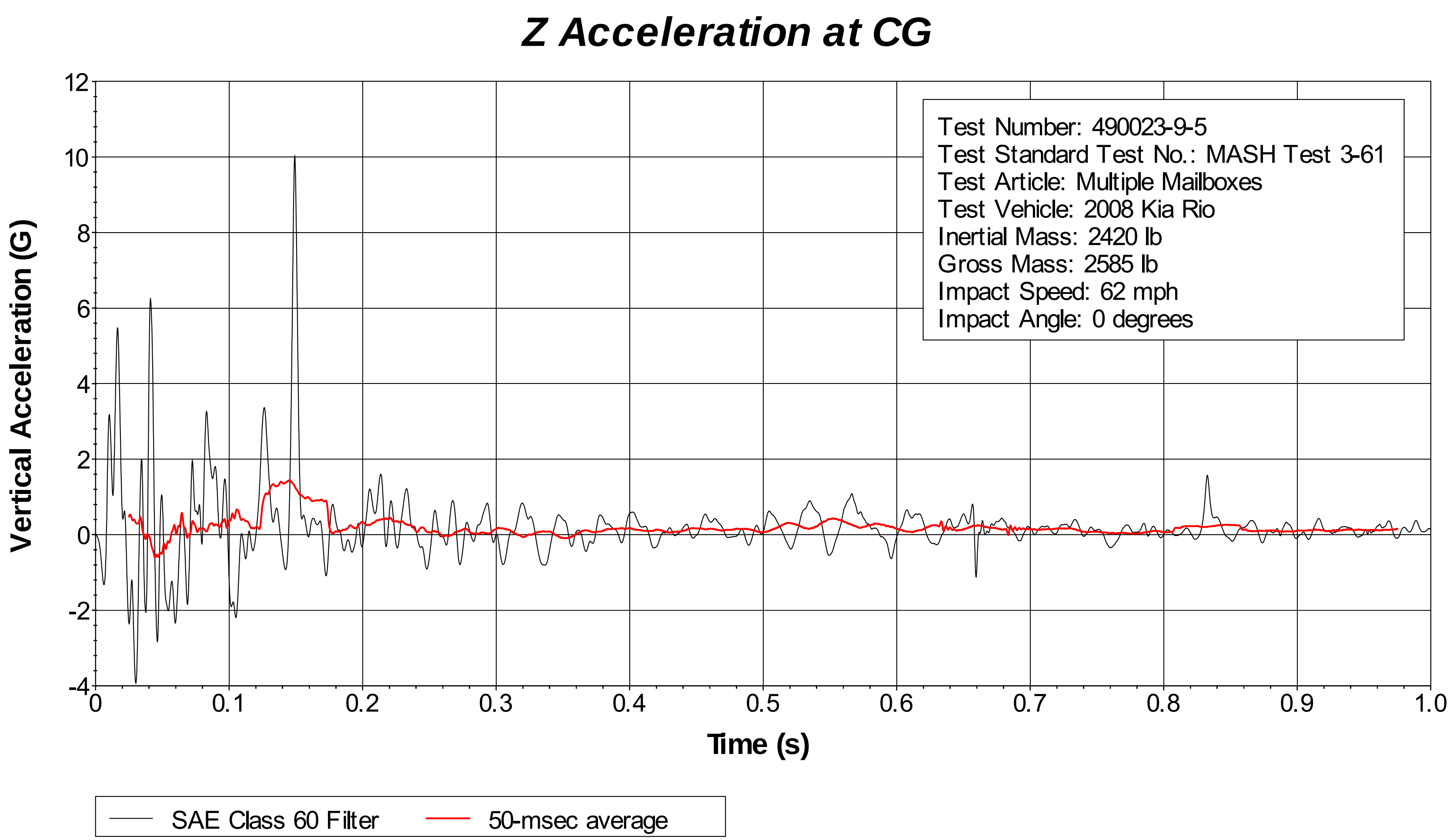


Figure E5. Vehicle Vertical Accelerometer Trace for Test No. 490023-9-5 (Accelerometer Located at Center of Gravity).

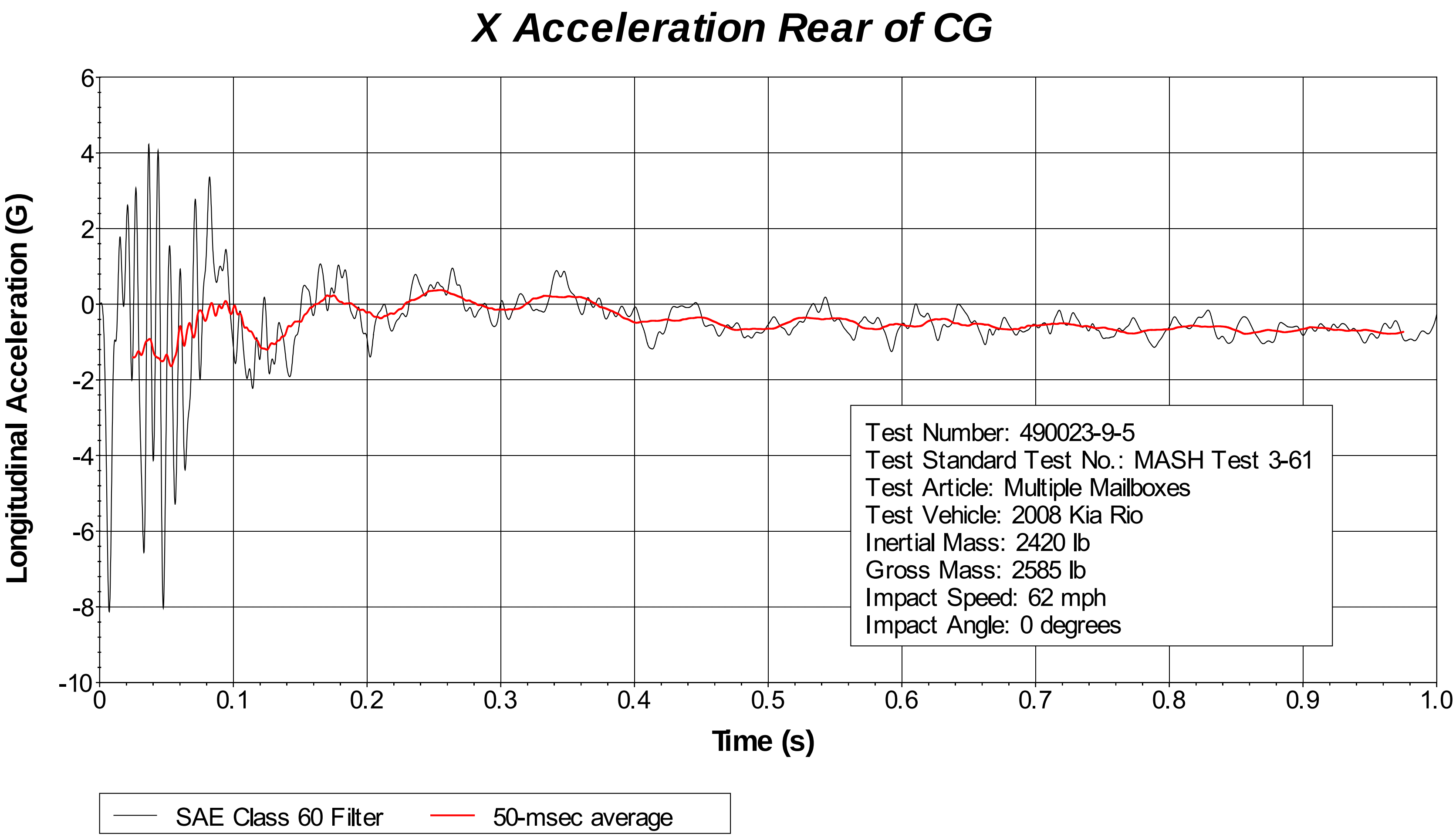


Figure E6. Vehicle Longitudinal Accelerometer Trace for Test No. 490023-9-5 (Accelerometer Located Rear of Center of Gravity).

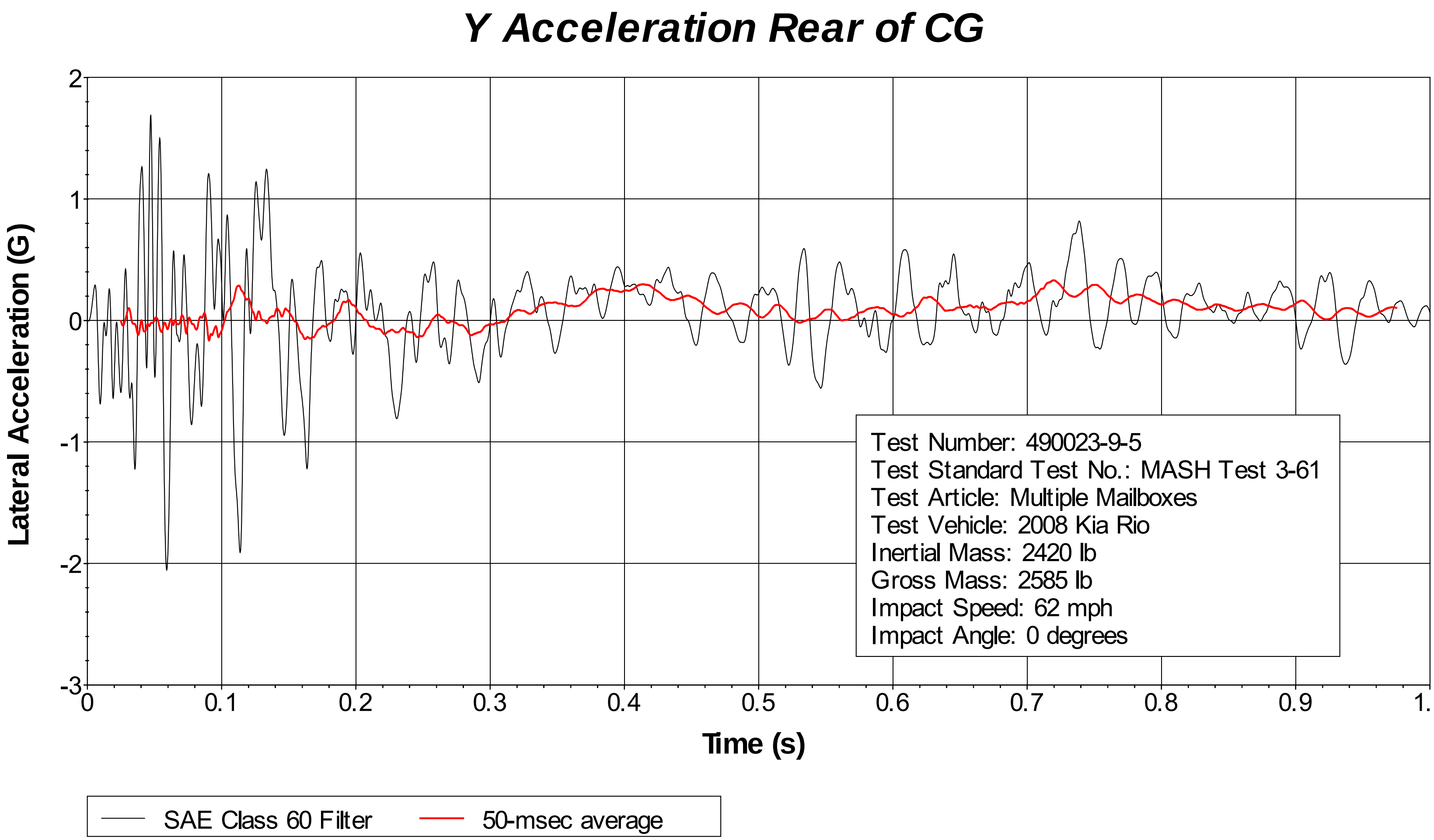


Figure E7. Vehicle Lateral Accelerometer Trace for Test No. 490023-9-5 (Accelerometer Located Rear of Center of Gravity).

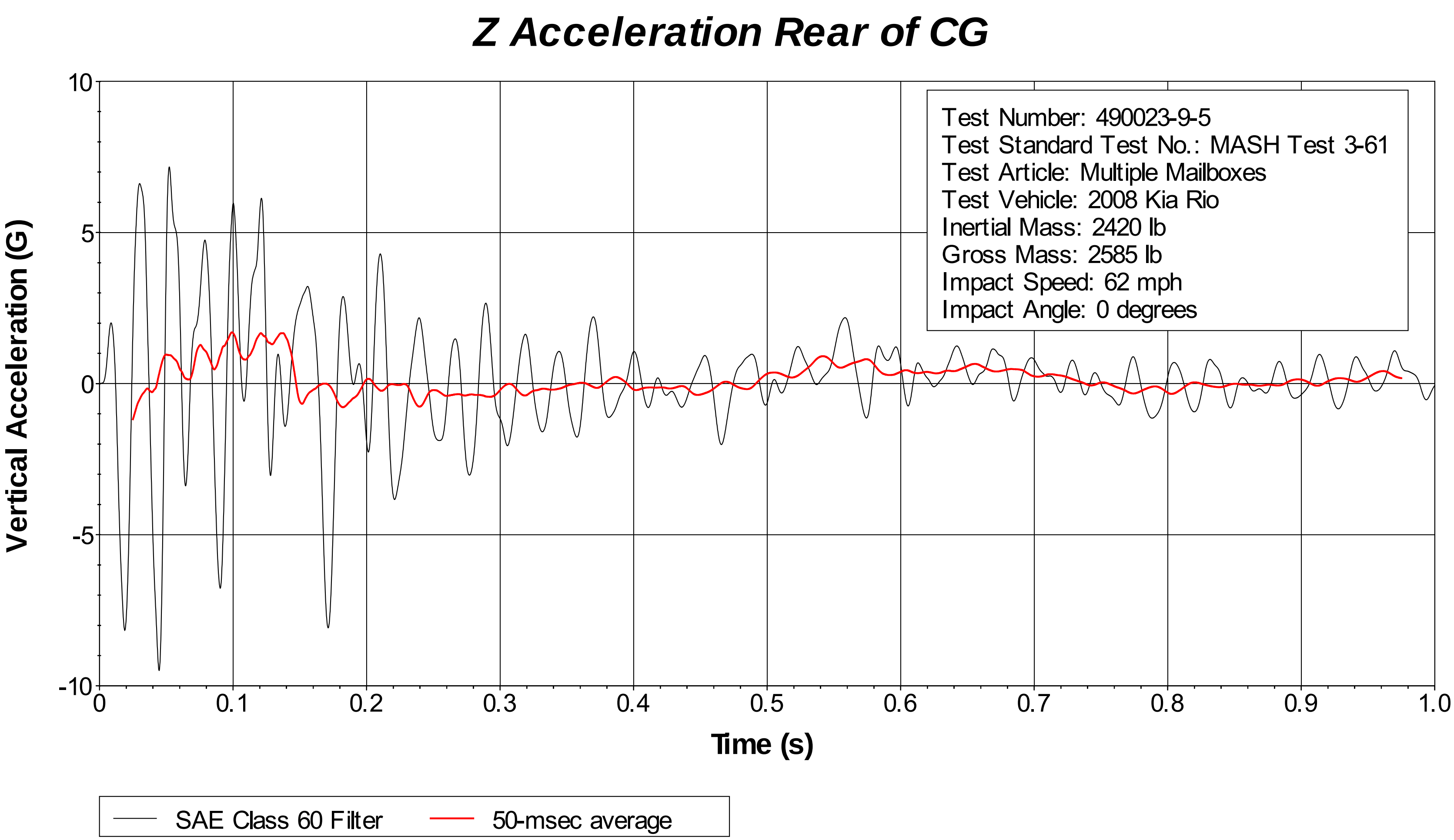


Figure E8. Vehicle Vertical Accelerometer Trace for Test No. 490023-9-5 (Accelerometer Located Rear of Center of Gravity).

APPENDIX F. CRASH TEST NO. 490023-9-6

F1. VEHICLE INFORMATION

Table F1. Vehicle Properties for Test No. 490023-9-6.

Date: 2013-08-30 Test No.: 490023-9-6 VIN No.: KNADE123686431979

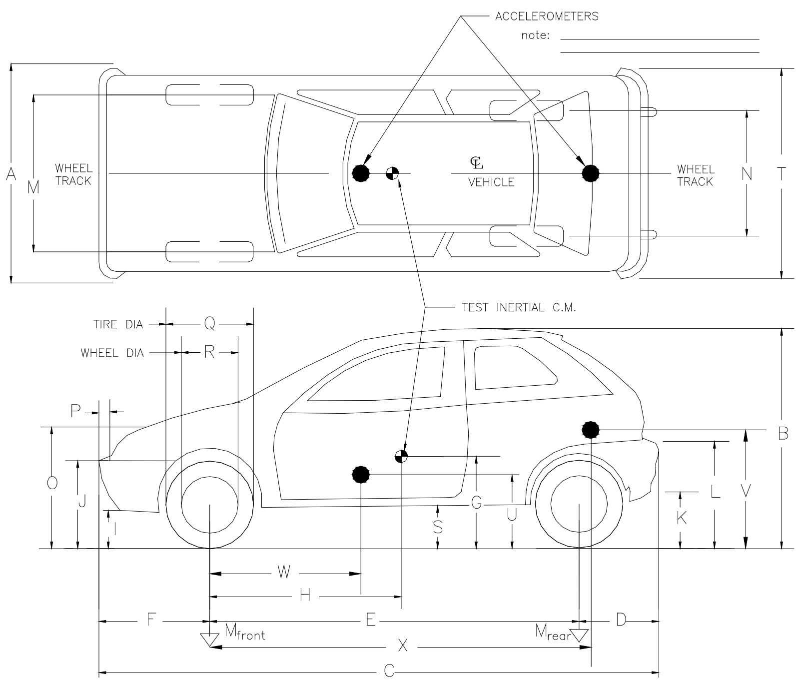
Year: 2008 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 103678 Tire Size: 185/65R14

Describe any damage to the vehicle prior to test: ________

● Denotes accelerometer location.

NOTES: ________



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

Dummy Data:
Type: 50th percentile male
Mass: 165 lb
Seat Position: Driver Side

Geometry: inches

A	66.38	F	33.00	K	11.205	P	4.12	U	15.50
B	58.00	G	----	L	24.75	Q	22.18	V	22.00
C	165.75	H	35.96	M	57.75	R	15.38	W	42.50
D	34.00	I	7.50	N	57.12	S	8.00	X	10.800
E	98.75	J	21.75	O	31.50	T	66.12		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1918	M_{front}	1555	1542	1630
Back	1874	M_{rear}	882	883	960
Total	3638	M_{Total}	2437	2425	2590

Mass Distribution:
lb LF: 779 RF: 763 LR: 427 RR: 456

Table F2. Exterior Vehicle Crush Measurements for Test No. 490023-9-6.

Date: 2013-08-30 Test No.: 490023-9-6 VIN No.: KNADE123686431979

Year: 2008 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								
----	No measurable deformation noted	----	----	----	----	----	----	----	----	----	----
	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).

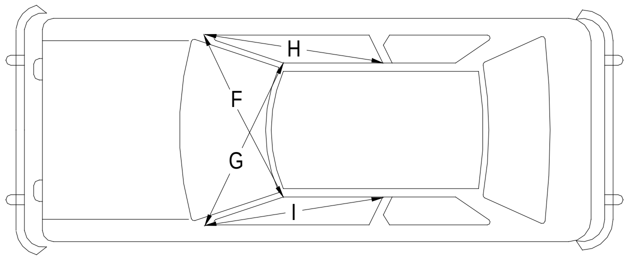
***Measure and document on the vehicle diagram the location of the maximum crush.

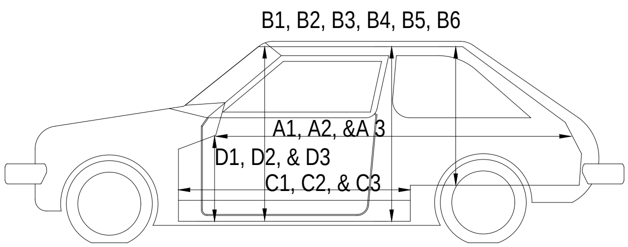
Note: Use as many lines/columns as necessary to describe each damage profile.

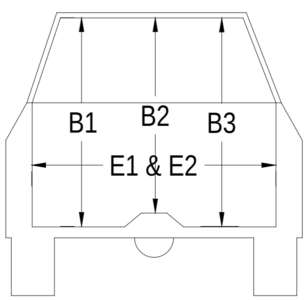
Table F3. Occupant Compartment Measurements for Test No. 490023-9-6.

Date: 2013-08-30 Test No.: 490023-9-6 VIN No.: KNADE123686431979

Year: 2008 Make: Kia Model: Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	**After** (inches)
A1	67.75	67.75
A2	64.50	64.50
A3	67.50	67.50
B1	40.50	40.50
B2	35.75	35.75
B3	40.50	40.50
B4	36.25	36.25
B5	33.25	33.25
B6	36.25	36.25
C1	25.75	25.75
C2	----	----
C3	25.75	25.75
D1	9.50	9.50
D2	----	----
D3	9.75	9.75
E1	51.50	51.50
E2	51.00	51.00
F	50.75	50.75
G	50.75	50.75
H	37.50	37.50
I	37.50	37.50
J*	51.25	51.25

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

F2. SEQUENTIAL PHOTOGRAPHS

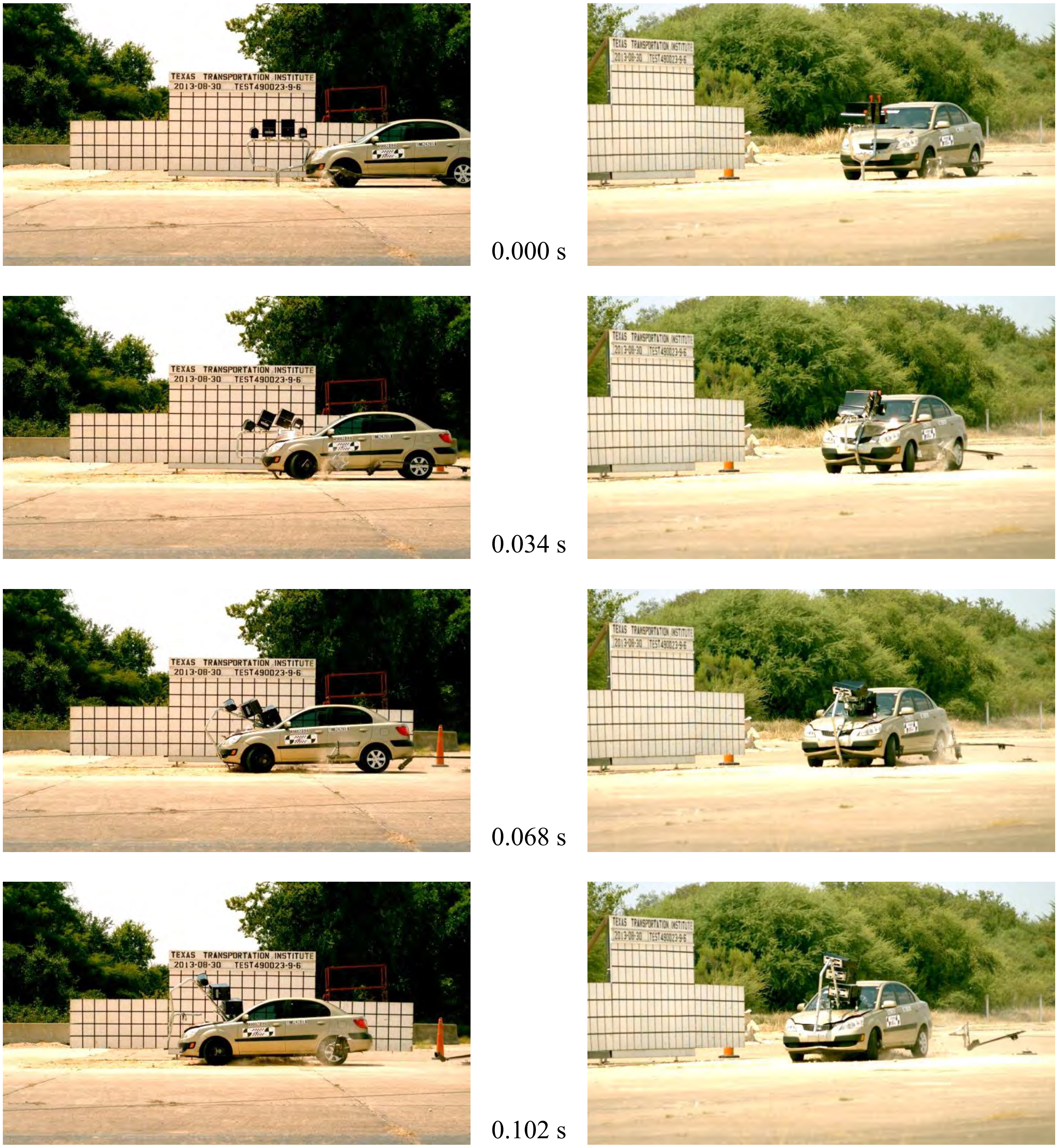


Figure F1. Sequential Photographs for Test No. 490023-9-6 (Perpendicular and Oblique Views).

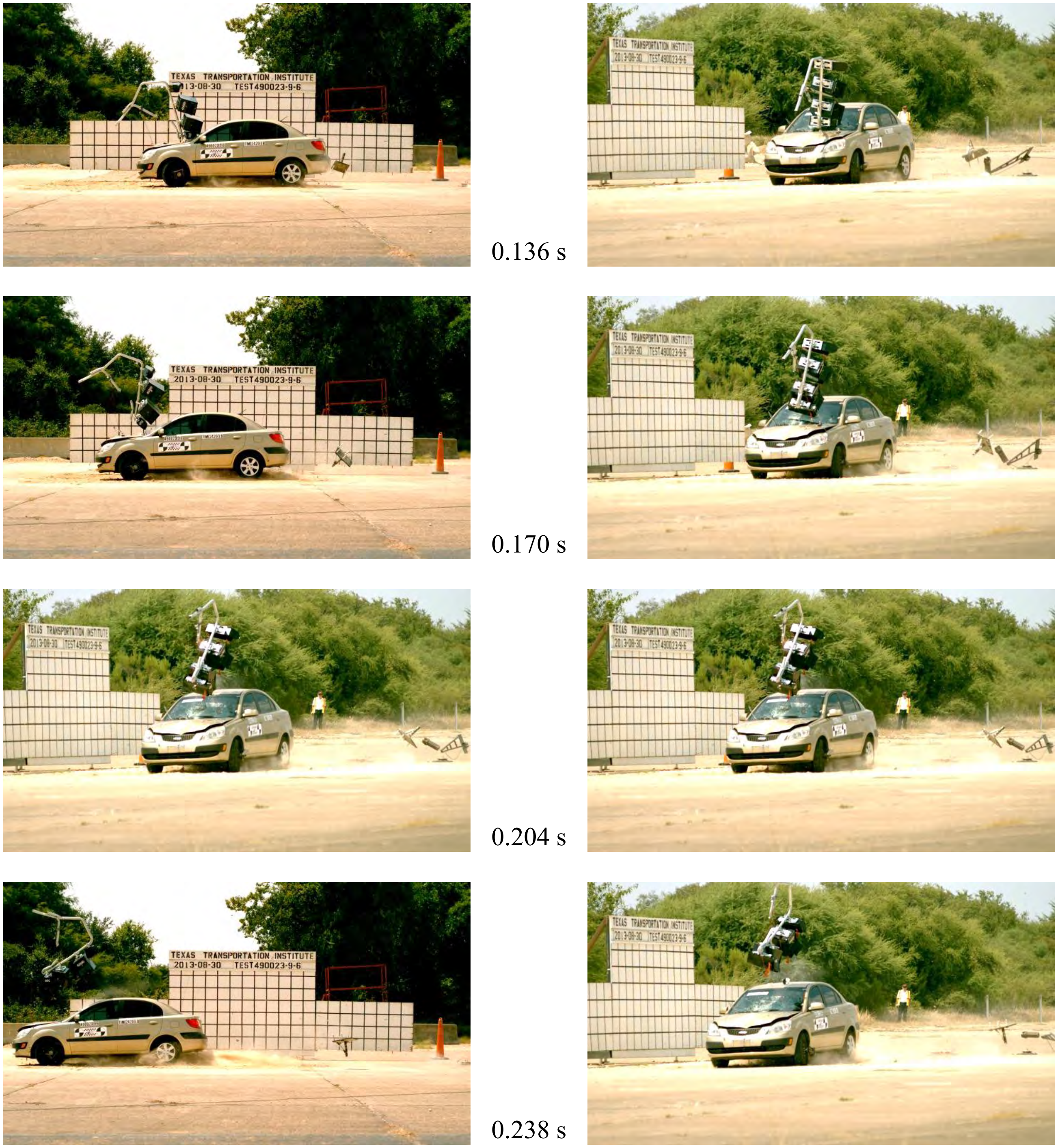


Figure F1. Sequential Photographs for Test No. 490023-9-6 (Perpendicular and Oblique Views) (Continued).

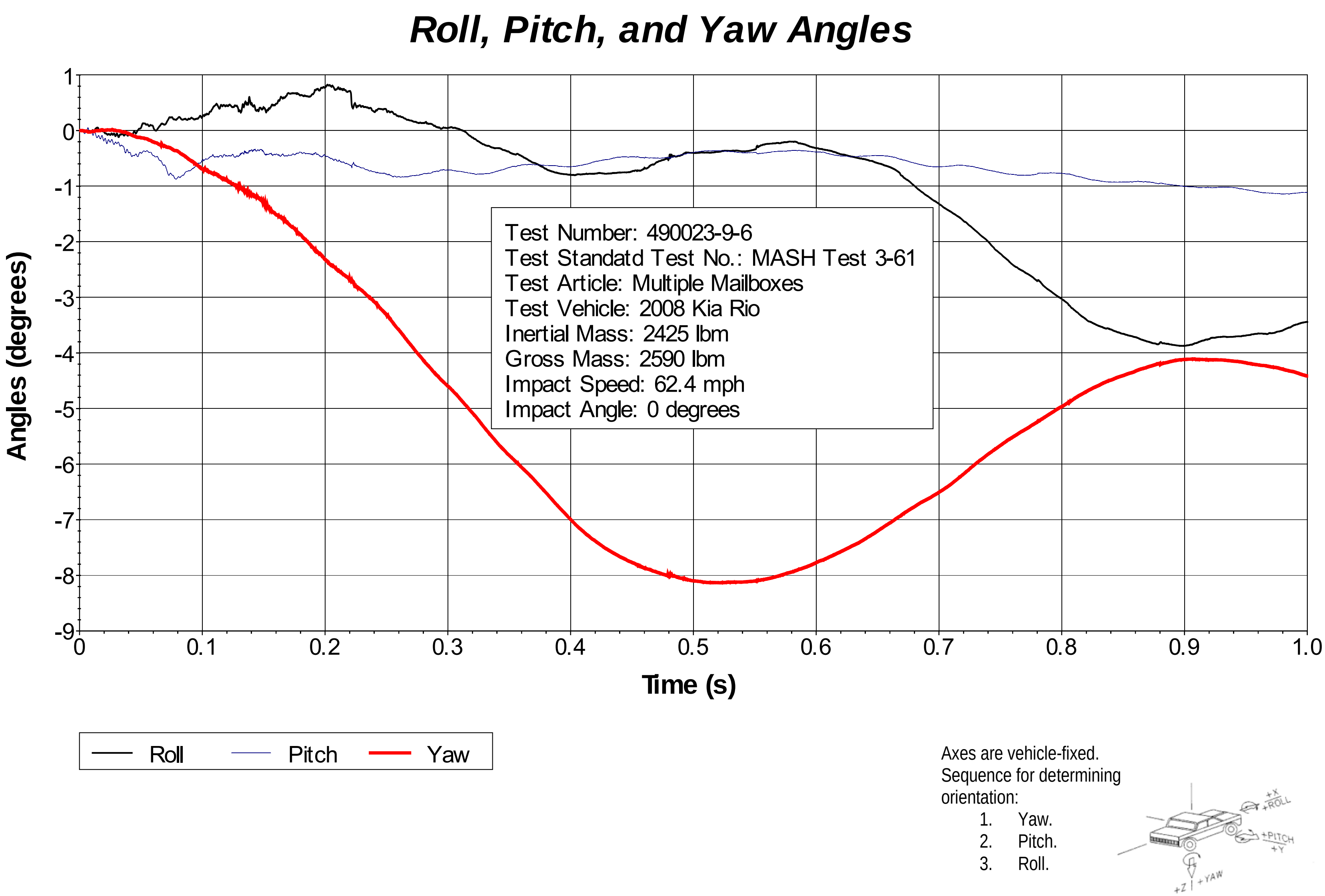


Figure F2. Vehicle Angular Displacements for Test No. 490023-9-6.

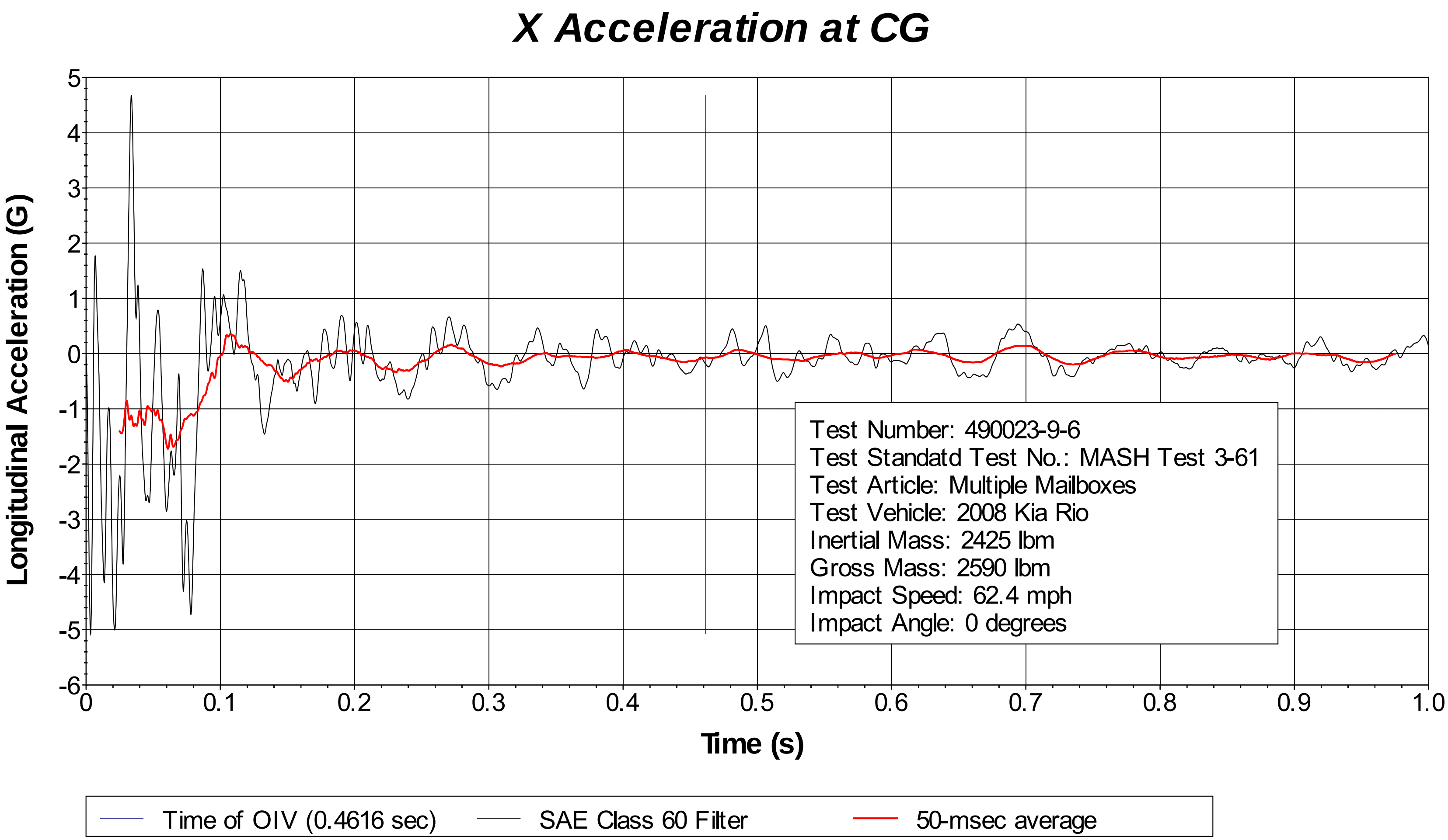


Figure F3. Vehicle Longitudinal Accelerometer Trace for Test No. 490023-9-6 (Accelerometer Located at Center of Gravity).

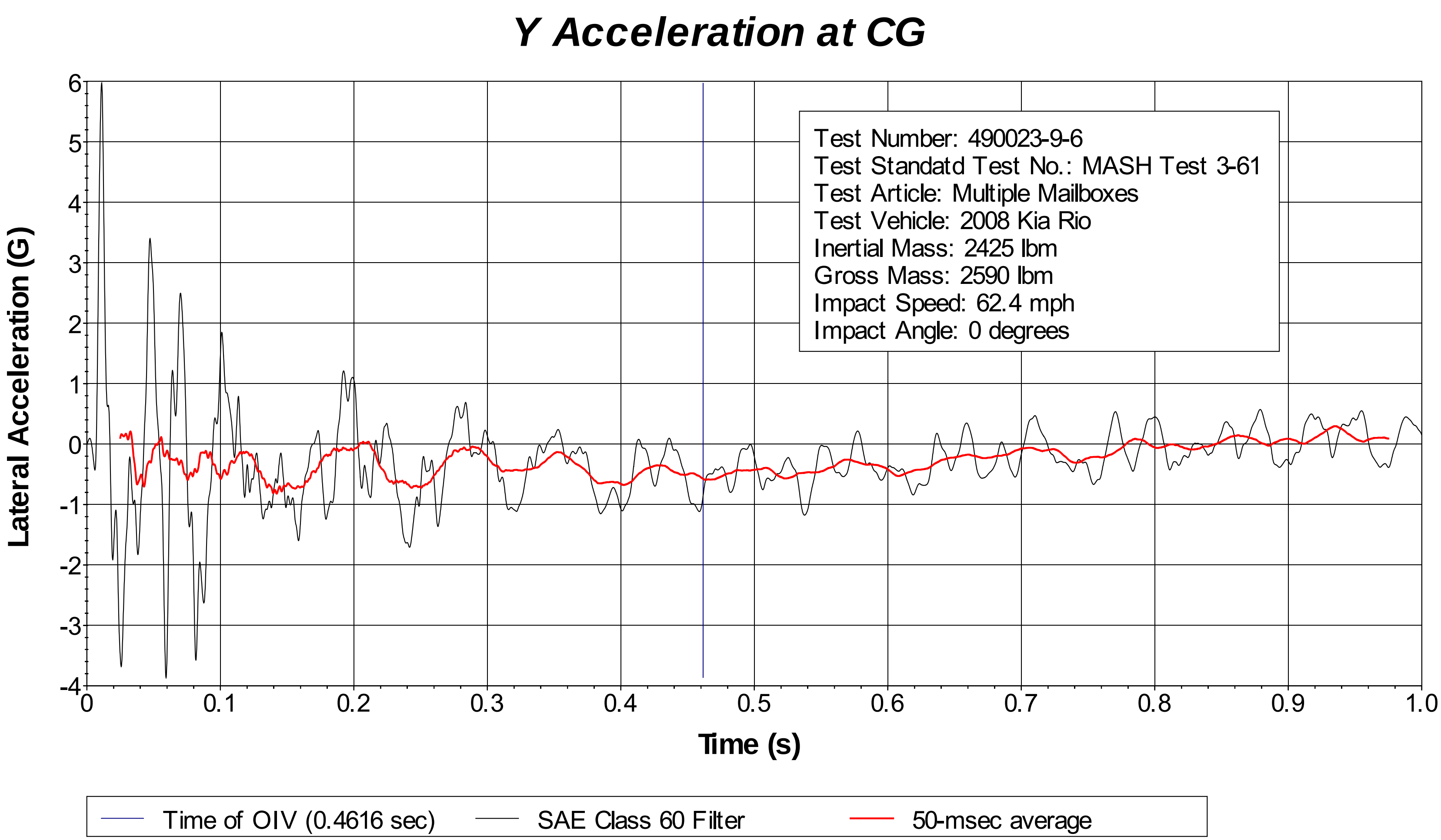


Figure F4. Vehicle Lateral Accelerometer Trace for Test No. 490023-9-6 (Accelerometer Located at Center of Gravity).

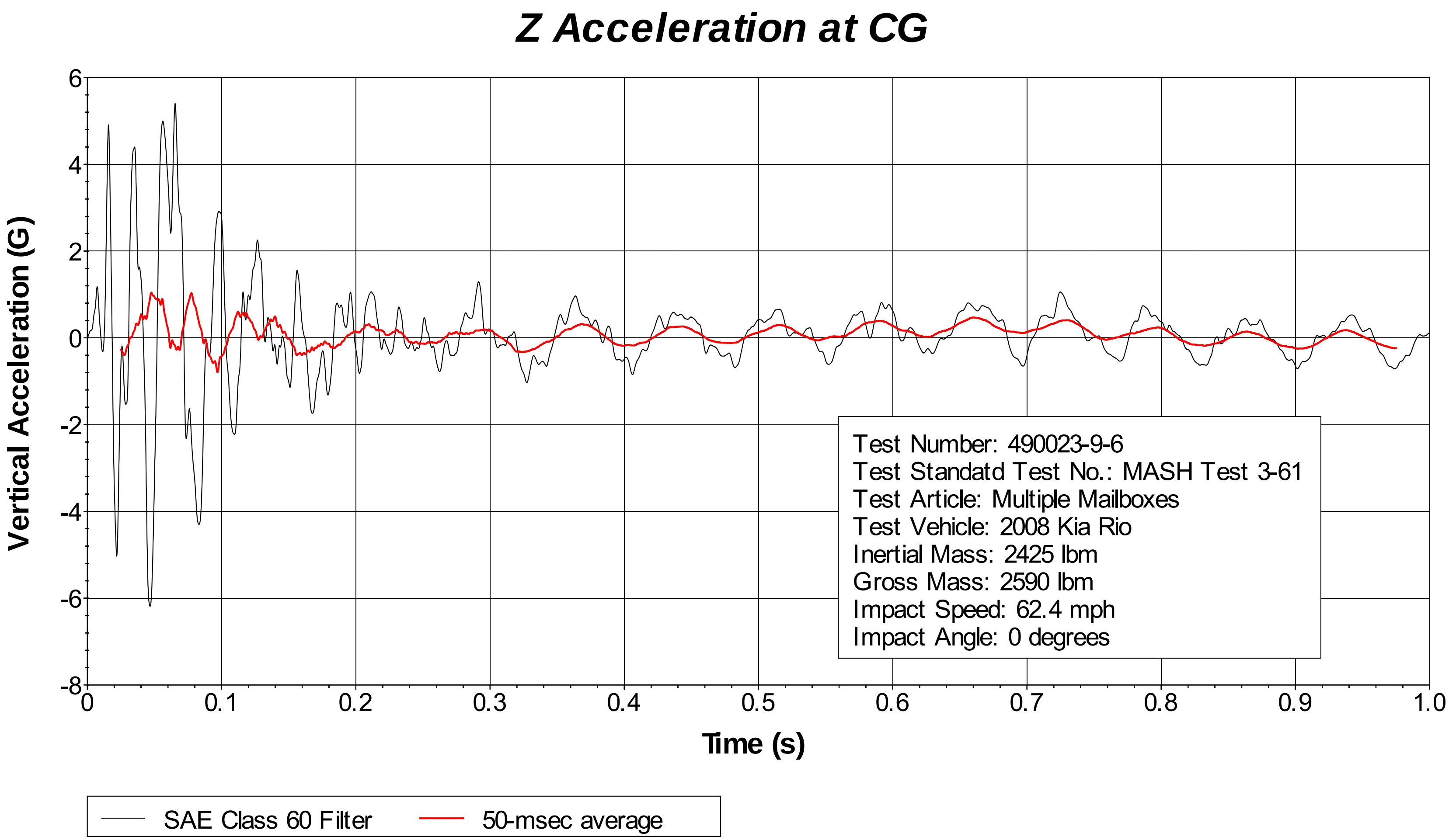


Figure F5. Vehicle Vertical Accelerometer Trace for Test No. 490023-9-6 (Accelerometer Located at Center of Gravity).

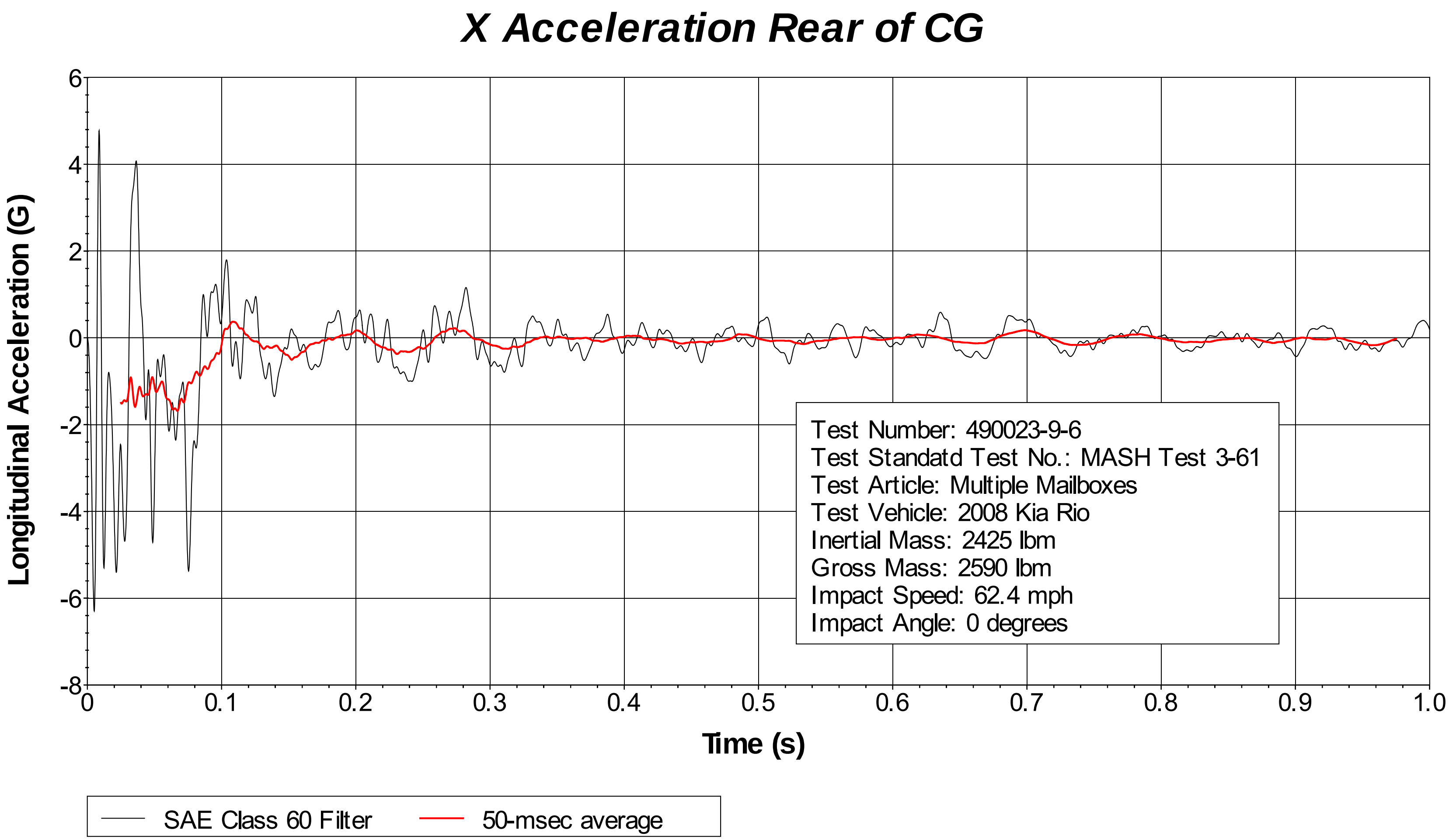


Figure F6. Vehicle Longitudinal Accelerometer Trace for Test No. 490023-9-6 (Accelerometer Located Rear of Center of Gravity).

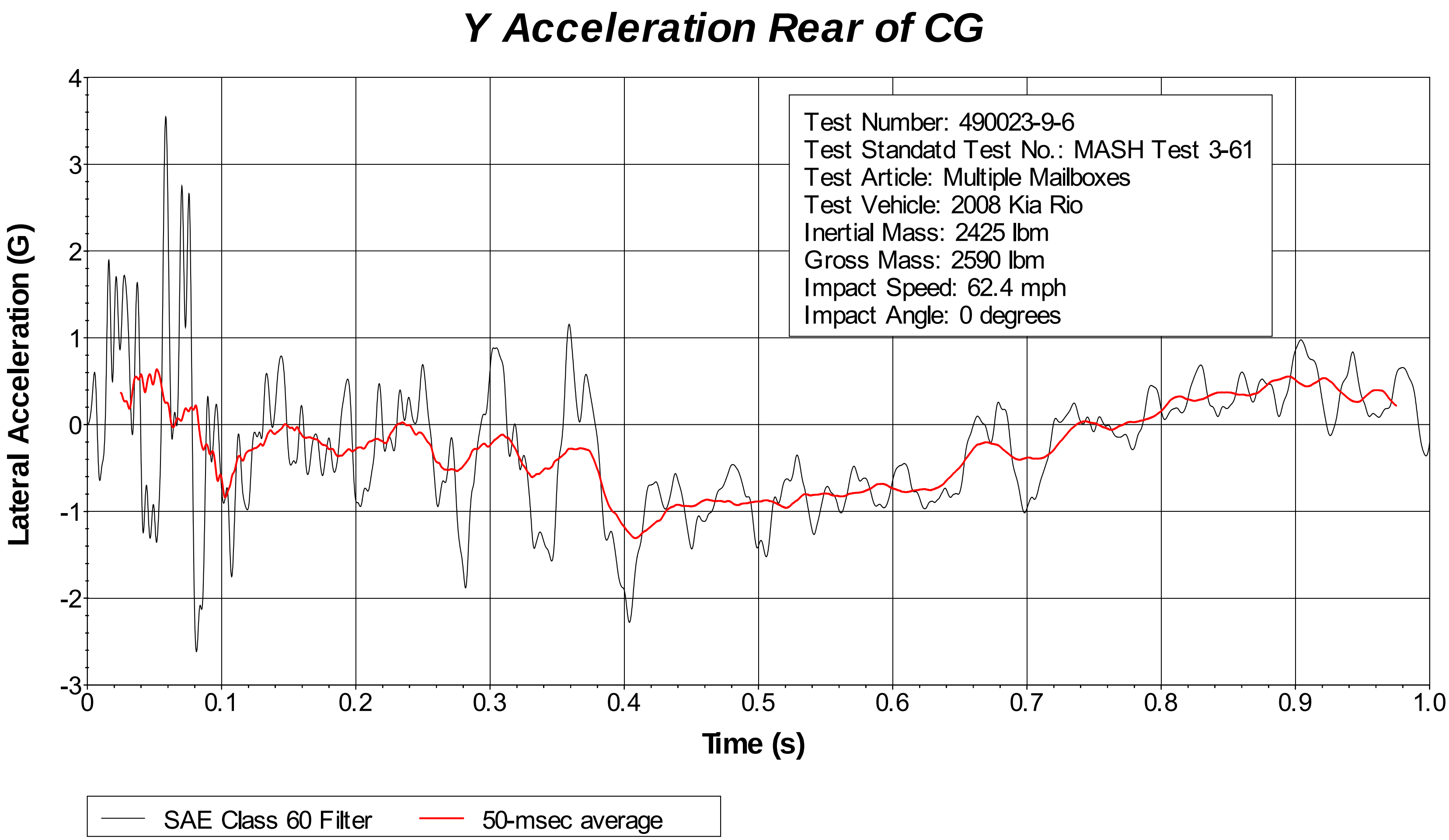


Figure F7. Vehicle Lateral Accelerometer Trace for Test No. 490023-9-6 (Accelerometer Located Rear of Center of Gravity).

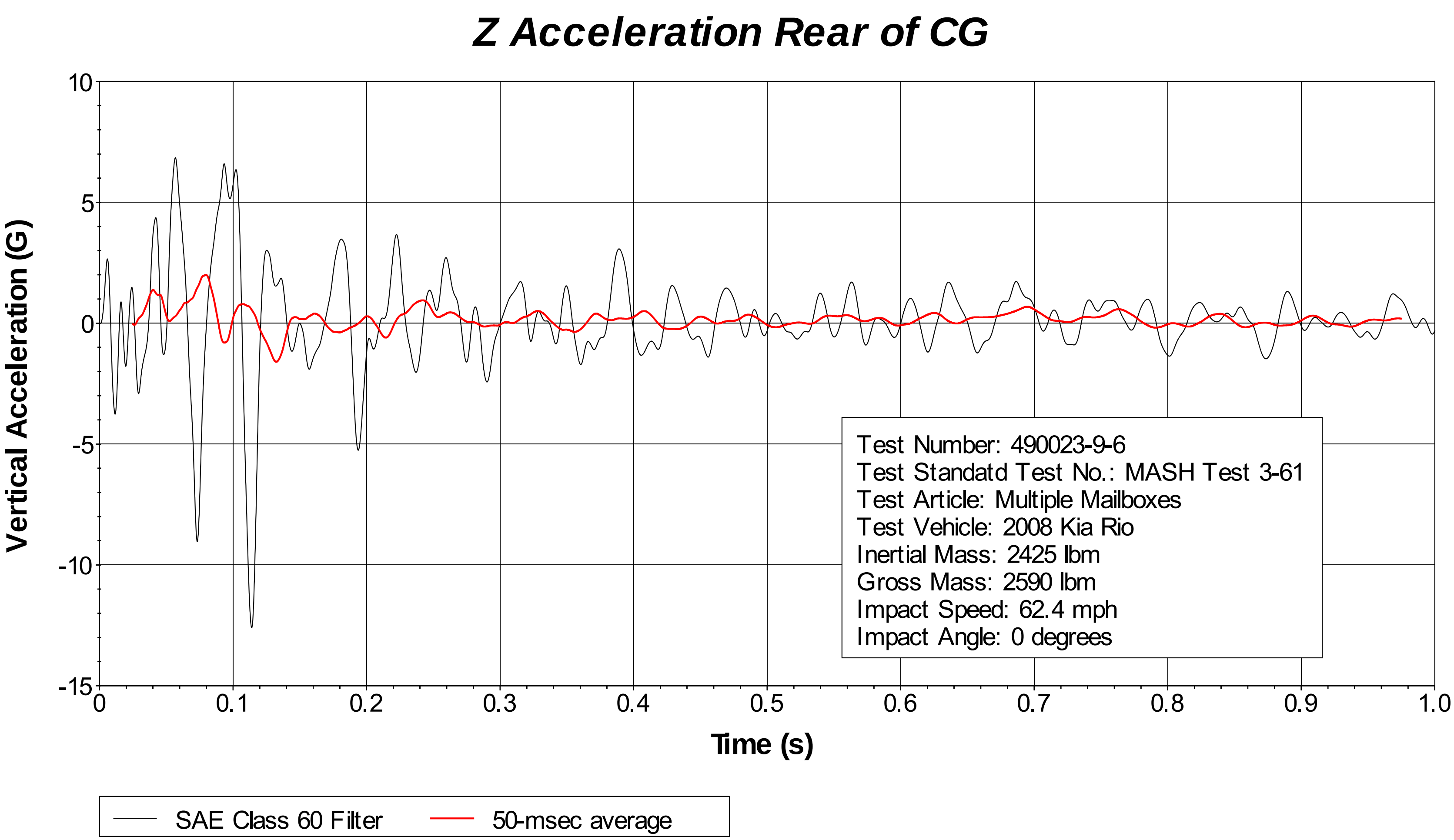


Figure F8. Vehicle Vertical Accelerometer Trace for Test No. 490023-9-6 (Accelerometer Located Rear of Center of Gravity).