Technical Report Documentation Page

1. Report No. FHWA/TX-06/0-5210-2	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle CRASH TESTING AND EVALUATION OF THE SHUR-TITE® MULTIPLE-MAILBOX MOUNT		5. Report Date August 2006 Published: November 2006
		6. Performing Organization Code
7. Author(s) Nauman M. Sheikh, Roger P. Bligh, Wanda L. Menges, and Rebecca R. Haug		8. Performing Organization Report No. Report 0-5210-2
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. Project 0-5210
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080		13. Type of Report and Period Covered Technical Report: September 2004 – June 2006
		14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

Project Title: Roadside Crash Testing Program for Design Guidance and Standard Detail Development

URL: http://tti.tamu.edu/documents/0-5210-2.pdf

16. Abstract

Texas Department of Transportation desires to adopt a new multiple-mailbox mount design that provides improved ease of installation and maintenance. Shur-Tite® has developed a design that is considered to provide the desired ease of installation and maintenance. Two full-scale crash tests were conducted to evaluate the safety performance of the Shur-Tite® multiple-mailbox support in accordance with *NCHRP Report 350*.

The Shur-Tite® Multiple-Mailbox Mount design successfully passed all requirements of *NCHRP Report 350* and is ready for field implementation.

17. Key Words Mailbox, Support Structure, Crash Testing, Roadside Safety		18. Distribution Statement No restrictions. This document is available to the public through NTIS: National Technical Information Service Springfield, Virginia 22161 http://www.ntis.gov	
19. Security Classif.(of this report) Unclassified	20. Security Classif.(of this page) Unclassified	21. No. of Pages 78	22. Price

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

CRASH TESTING AND EVALUATION OF THE SHUR-TITE® MULTIPLE-MAILBOX MOUNT

by

Nauman M. Sheikh
Assistant Transportation Researcher
Texas Transportation Institute

Roger P. Bligh
Associate Research Engineer
Texas Transportation Institute

Wanda L. Menges
Research Specialist
Texas Transportation Institute

and

Rebecca R. Haug
Assistant Research Specialist
Texas Transportation Institute

Report 0-5210-2
Project 0-5210
Project Title: Roadside Crash Testing Program
for Design Guidance and Standard Detail Development

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

August 2006
Published: November 2006

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data, and the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official view or policies of the Texas Department of Transportation (TxDOT), Federal Highway Administration (FHWA), The Texas A&M University System, or the Texas Transportation Institute. 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 names of specific products or manufacturers listed herein do not imply endorsement of those products or manufacturers. The engineer in charge of the project was Roger P. Bligh, P.E. (Texas, #78550).

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.

ACKNOWLEDGMENTS

This research project was conducted under a cooperative program between the Texas Transportation Institute, the Texas Department of Transportation, and the Federal Highway Administration. The TxDOT project director for this research was Rory Meza, P.E. (DES). Joe Graff, P.E. (MNT) served on the project advisory committee and helped guide the testing. The authors acknowledge and appreciate their assistance.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

Page

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1. INTRODUCTION

INTRODUCTION

Roadside safety devices perform the important function of preventing serious injury to motorists during roadside encroachments. In order to maintain the desired level of safety for the motoring public, these safety appurtenances must be designed to accommodate a variety of site conditions, placement locations, and a changing vehicle fleet. As changes are made or in-service problems encountered, there is a need to assess the compliance of the specific safety device with current vehicle testing criteria, and modify the device or develop a new device with enhanced performance and maintenance characteristics.

BACKGROUND

Mailboxes used along roadsides present a level of hazard to the motoring public and therefore must meet crashworthiness standards set by the Texas Department of Transportation (TxDOT). Even though crashworthy multiple-mailbox designs are available and in use, the Maintenance Division of TxDOT desired to use a new design that is easier to install and maintain.

A multiple-mailbox system designed by Shur-Tite® was considered a candidate to provide ease of installation and maintenance desired by TxDOT. However, before it could be used on Texas roadways, the impact performance of the design needed to be evaluated through full-scale vehicle crash testing as specified in the National Cooperative Highway Research Program (NCHRP) *Report 350* criteria *(1)*.

OBJECTIVES/SCOPE OF RESEARCH

The objective of this project is to evaluate the impact performance of the Shur-Tite® multiple-mailbox support. The design was evaluated using *NCHRP Report 350* criteria. The test matrix for breakaway support structures such as a mailbox support includes two full-scale crash tests with 1800-lb (820 kg) vehicles impacting at speeds of 22 mi/h and 62 mi/h (35 km/h and 100 km/h).

Chapter 2 presents the testing methodologies followed for these tests. The results of full-scale crash testing are presented in Chapter 3. A summary of findings, conclusions, and implementation recommendations are presented in Chapter 4.

CHAPTER 2. CRASH TEST PROCEDURES

TEST FACILITY

The Texas Transportation Institute Proving Ground is a 2000-acre (809 hectare) complex of research and training facilities located 10 mi 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 installation and testing of the mailboxes evaluated under this project is along the edge of an out-of-service aircraft apron. The apron consists of an unreinforced jointed-concrete pavement in 12.5 ft × 15 ft blocks nominally 8-12 inches deep. The aprons and runways are over 50 years old, and the joints have some displacement, but are otherwise flat and level.

TEST ARTICLE

The test article was a Shur-Tite® multiple-mailbox system that had four mailboxes mounted on its top (see Figure 1). Two of these mailboxes were small, measuring approximately 9 inches × 7 inches × 19 inches and weighing 7 lb. The remaining two mailboxes were large size measuring approximately 15 inches × 11.5 inches × 23.5 inches and weighing 13 lb 10 oz. The small mailboxes were directly attached to the standard TxDOT bracket mount (DHT 161443) using four 1/4 inch diameter bolts. The large mailboxes were attached to the bracket mounts using the standard TxDOT bracket extensions (DHT 148938). Bracket extensions and the brackets were also connected using the 1/4 inch diameter bolts. Bracket mounts were attached to the mailbox support frame using 5/16 inch diameter bolts.

The support frame was fabricated from 2-3/8 inch diameter × 0.065 inch thick steel tubing. The top portion of the support frame consisted of a horizontal tube, which was welded at both ends to a 25 inch radius, semi-circular shaped tube. The bottom-center of the semi-circular tube was welded to a 22-1/2 inch long vertical tube as shown in Figure 1. Two rectangular tabs were welded onto this vertical tube at a distance of 8 inches from the semi-circular tube. These tabs maintained the specified height of the mailbox system (42 inches) above the ground by controlling the depth the vertical tube can be inserted into the footing socket.

The mailbox frame was placed into a 12 inch diameter × 30 inch deep concrete footing. At the center of this concrete footing, a 3 inch diameter and 17 inch long plastic tube socket (DHT 160891) was used to create a hole for insertion of the mailbox support frame. Once the mailbox support frame was placed into the footing, it was secured in place using a plastic wedge (DHT 160892) inserted between the vertical support frame tube and the plastic socket in the concrete footing.

Test articles for both crash tests were identical. Figure 2 shows photographs of the completed installation.

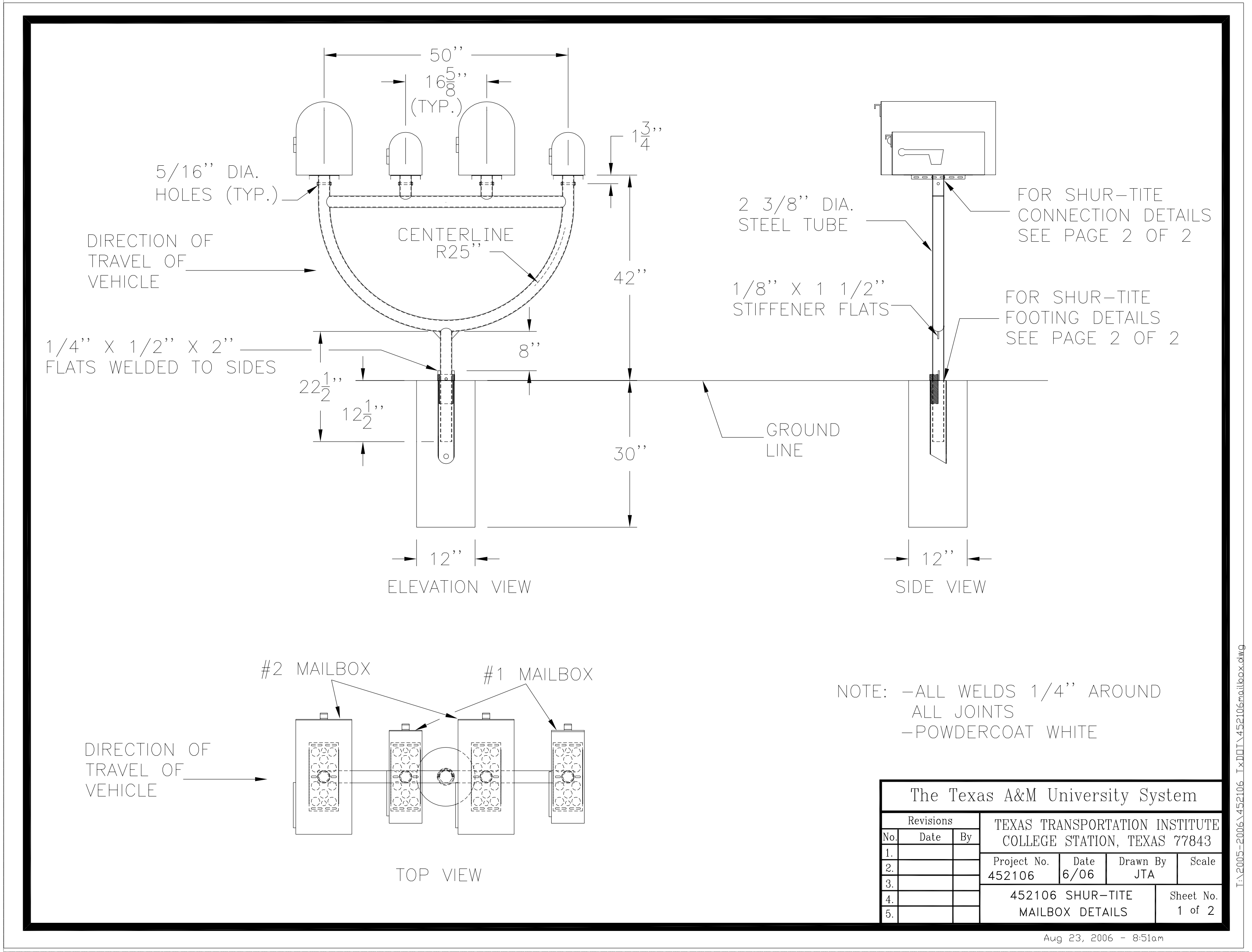


Figure 1. Details of the Shur-Tite® Multiple-Mailbox Mount Installation.

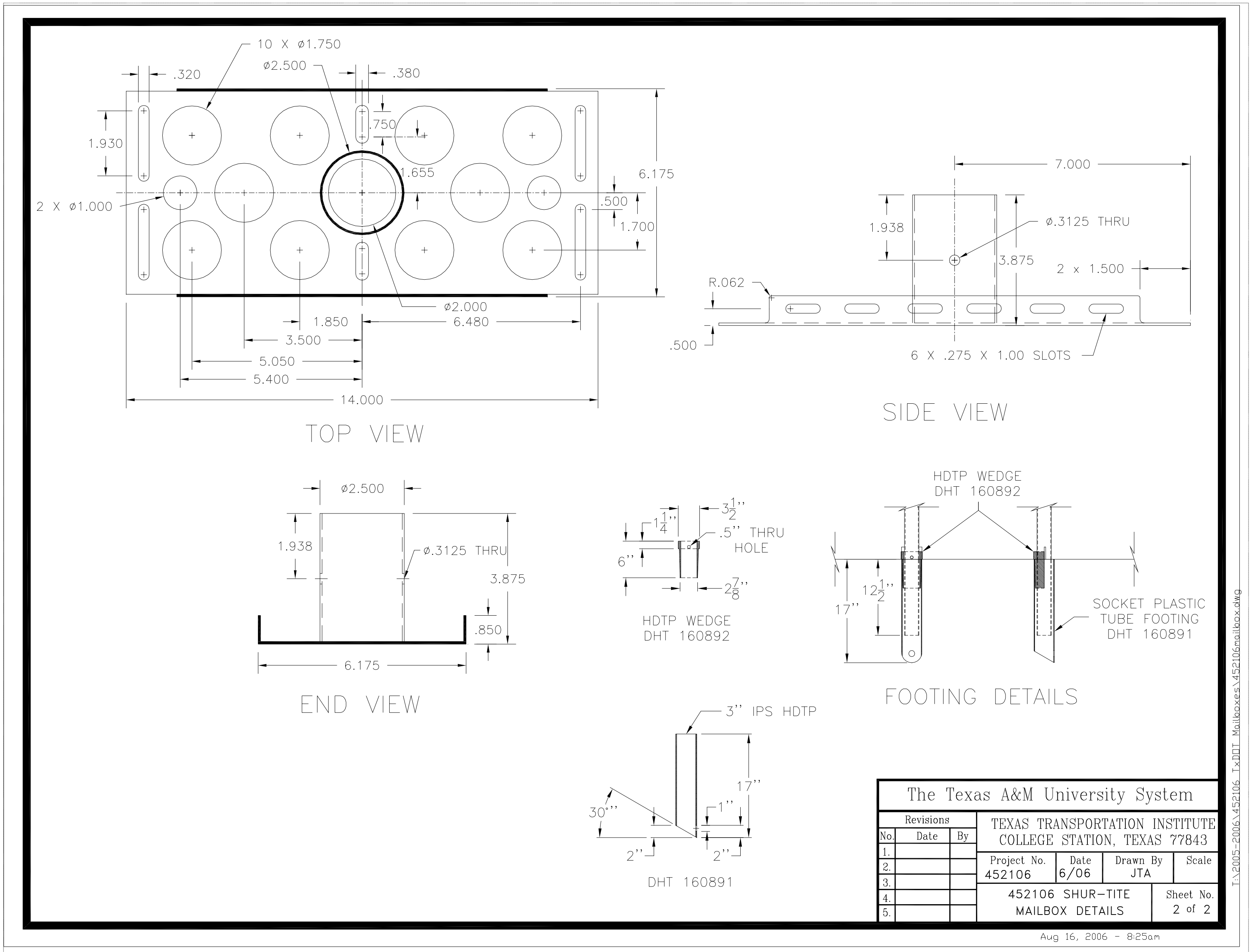


Figure 1. Details of the Shur-Tite® Multiple-Mailbox Mount Installation (Continued).

Figure 2. Shur-Tite® Multiple-Mailbox Mount before Testing.

CRASH TEST CONDITIONS

The recommended test matrix for breakaway support structures, such as the Shur-Tite® Multiple-Mailbox Mount, consists of:

> ***NCHRP Report 350* test designation 3-60**: This test involves an 1808-lb (820 kg) passenger vehicle (820C) impacting the support structure at a nominal speed of 22 mi/h (35 km/h) and an angle ranging from 0-20 degrees. The purpose of this test is to evaluate the breakaway, fracture, or yielding mechanism of the support, as well as occupant risk.
>
> ***NCHRP Report 350* test designation 3-61**: This test involves an 1808-lb (820 kg) passenger vehicle (820C) impacting the support structure at a nominal speed of 62 mi/h (100 km/h) and an angle ranging from 0-20 degrees. The test is intended to evaluate vehicle and test article trajectory and occupant risk.

Researchers performed both tests on the Shur-Tite® Multiple-Mailbox Mount with two small and two large mailboxes attached.

All crash test, data analysis, and evaluation and reporting procedures followed under this project were performed in accordance with guidelines presented in *NCHRP Report 350*. Appendix A presents brief descriptions of these procedures.

EVALUATION CRITERIA

The crash tests performed were evaluated in accordance with *NCHRP Report 350*. As stated in *NCHRP Report 350*, “Safety performance of a highway appurtenance cannot be measured directly but can be judged on the basis of three factors: structural adequacy, occupant risk, and vehicle trajectory after collision.” Accordingly, researchers used the safety evaluation criteria from Table 5.1 of *NCHRP Report 350* to evaluate the crash tests reported herein.

CHAPTER 3. CRASH TEST RESULTS

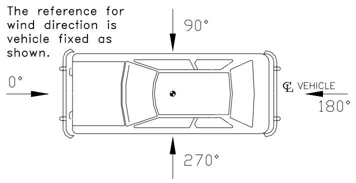
TEST NO. 452106-1 (*NCHRP REPORT 350* TEST DESIGNATION 3-60)

Test Vehicle

A 1995 Geo Metro, shown in Figures 3 and 4, was used for the crash test. Test inertia weight of the vehicle was 1808 lb, and its gross static weight was 1978 lb. The height to the lower edge of the vehicle bumper was 15.75 inches, and it was 20.7 inches to the upper edge of the bumper. Figure 17 in Appendix B gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed on the morning of March 3, 2006. Rainfall of 0.52 inches was recorded six days prior to the test. No other rainfall was recorded within 10 days prior to the date of the test. Moisture content of the soil was 6.5 percent. Weather conditions at the time of testing were as follows: Wind speed: 10 mi/h; Wind direction: 90 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); Temperature: 70 ^{o}F, Relative humidity: 39 percent.



Test Description

The 1995 Geo Metro, traveling at an impact speed of 22.1 mi/h, contacted the Shur-Tite® multiple-mailbox mount at an impact angle of 0 degree, with the left quarter point of the vehicle aligned with the centerline of the mount. At 0.080 s after impact, the upright support pulled out of the ground socket. At 0.264 s, the vehicle (while still in contact with the support) exited the view of the camera used to calculate the exit speed at loss of contract. The corner of the end mailbox contacted the windshield at 0.673 s. The mailbox mount traveled along with the vehicle and subsequently came to rest in front of the vehicle 73 ft downstream of impact and 3 ft to the left of the original position of the mount. Figure 18 in Appendix C shows sequential photographs from the test.

Figure 3. Vehicle/Installation Geometrics for Test No. 452106-1.

Figure 4. Vehicle before Test No. 452106-1.

Damage to Test Installation

The support pulled out of the ground base, as designed, and rode along with the vehicle. The ground base was only slightly disturbed. The support was deformed 15.75 inches above the end of the support and on the impact side of the curved portion. The mailboxes remained attached, but were deformed, as shown in Figures 5 and 6.

Vehicle Damage

The vehicle sustained minimal damage as shown in Figure 7. The front bumper had a slight indention at point of contact with the support, and the hood had two indentations; one at 5.1 inches to the right of centerline measuring 2.75 inches × 3.75 inches, and the second at 8.25 inches to the left at center (impact side) measuring 6.25 inches × 1.6 inches. No occupant compartment deformation occurred during the test. Photographs of the interior of the vehicle are shown in Figure 8. Exterior vehicle crush and occupant compartment measurements are shown in Appendix B, Tables 3 and 4.

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 3.9 ft/s at 0.640 s, the highest 0.010-s occupant ridedown acceleration was -0.2 g's from 0.643 to 0.653 s, and the maximum 0.050-s average acceleration was -1.1 g's between 0.000 and 0.050 s. In the lateral direction, the occupant impact velocity was 1.0 ft/s at 0.640 s, the highest 0.010-s occupant ridedown acceleration was -0.2 g's from 0.813 to 0.823 s, and the maximum 0.050-s average was -0.4 g's between 0.022 and 0.072 s. Figure 9 presents these data and other pertinent information from the test. Figures 20 through 26 in Appendix D present vehicle angular displacements and accelerations versus time traces.

Figure 5. After Impact Trajectory Path for Test No. 452106-1.

Figure 6. Installation after Test No. 452106-1.

Figure 7. Vehicle after Test No. 452106-1.

Before Test

After Test

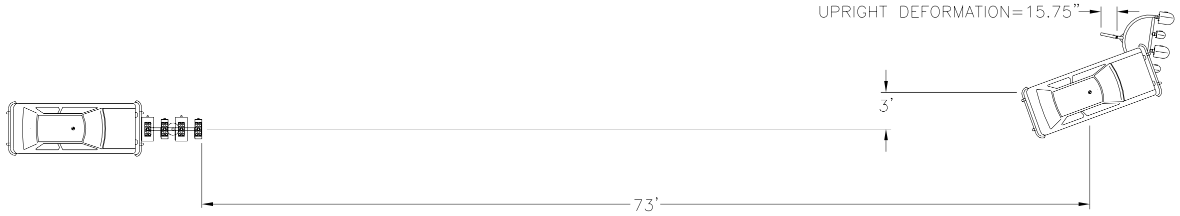
Figure 8. Interior of Vehicle for Test No. 452106-1.

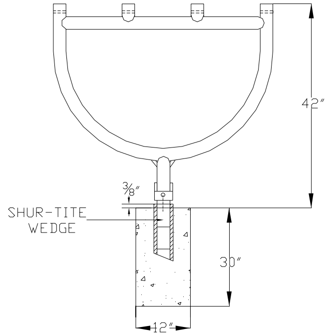
0.000 s

0.248 s

0.497 s

0.745 s





General Information	
Test Agency	Texas Transportation Institute
Test No.	452106-1
Date	03-03-2006
Test Article	
Type	Mailbox Support
Name	Shur-Tite® Multiple-Mailbox Mount
Installation Height (inches)	42.0 to Bottom of Mailboxes
Material or Key Elements	Four Mailboxes Mounted using Standard TxDOT Hardware
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Type	Production
Designation	820C
Model	1995 Geo Metro
Mass (lb)	
Curb	1755
Test Inertial	1808
Dummy	170
Gross Static	1978

Impact Conditions	
Speed (mi/h)	22.1
Angle (deg)	0
Exit Conditions	
Speed (mi/h)	N/A
Angle (deg)	0
Occupant Risk Values	
Impact Velocity (ft/s)	
Longitudinal	3.9
Lateral	1.0
THIV (km/h)	4.4
Ridedown Accelerations (g's)	
Longitudinal	-0.2
Lateral	-0.2
PHD (g's)	0.3
ASI	0.09
Max. 0.050-s Average (g's)	
Longitudinal	-1.1
Lateral	-0.4
Vertical	-0.7

Test Article Debris Pattern (ft)	
Longitudinal	73.0
Lateral	3.0
Vehicle Damage	
Exterior	
VDS	12FD1
CDC	12FDEW1
Maximum Exterior Vehicle Crush (inches)	nil
Interior	
OCDI	FS0000000
Maximum Occupant Cmpt. Deformation (inches)	0
Post-Impact Behavior	
(during 1.0 sec after impact)	
Max. Yaw Angle (deg)	-1
Max. Pitch Angle (deg)	1
Max. Roll Angle (deg)	-1

Figure 9. Summary of Results for *NCHRP Report 350* Test 3-60 on the Shur-Tite® Multiple-mailbox Mount.

Assessment of Test Results

An assessment of the test based on the applicable *NCHRP Report 350* safety evaluation criteria is provided below.

Structural Adequacy

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

Result: The Shur-Tite® Multiple-Mailbox Mount yielded to the vehicle by pulling out of the ground base. (PASS)

Occupant Risk

D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.

Result: The Shur-Tite® Multiple-mailbox Mount pulled out of the ground socket and rode along with the vehicle. The support did not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others in the area. No occupant compartment deformation occurred. (PASS)

E. Detached element, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.

Result: The Shur-Tite® Multiple-Mailbox Mount with mailboxes rode up into the windshield, but did not block the driver's vision. (PASS)

F. The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.

Result: The vehicle remained upright during and after the collision event. (PASS)

H. Occupant impact velocities should satisfy the following:

Longitudinal and Lateral Occupant Impact Velocity – m/s

Preferred	*Maximum*
3 (9.8 ft/s)	*5* (16.4 ft/s)

Result: Longitudinal occupant impact velocity was 3.9 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 – g's

Preferred	*Maximum*
15	*20*

Result: Longitudinal ridedown acceleration was -0.2 g, and lateral ridedown acceleration was -0.2 g. (PASS)

Vehicle Trajectory

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

Result: The vehicle traveled straightforward and did not intrude into adjacent traffic lanes. (PASS)

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

Result: The vehicle came to rest behind the test installation. (PASS)

The following supplemental evaluation factors and terminology, as presented in the FHWA memo entitled "ACTION: Identifying Acceptable Highway Safety Features," were used for visual assessment of test results *(2)*. Factors underlined below pertain to the results of the crash test reported herein.

Passenger Compartment Intrusion

1. *Windshield Intrusion*
    - *a. No windshield contact*
    - *b. Windshield contact, no damage*
    - *c. Windshield contact, no intrusion*
    - *d. Device embedded in windshield, no significant intrusion*
    - *e. Complete intrusion into passenger compartment*
    - *f. Partial intrusion into passenger compartment*
2. *Body Panel Intrusion* *yes* *or* *no*

Loss of Vehicle Control

1. *Physical loss of control*
2. *Loss of windshield visibility*
3. *Perceived threat to other vehicles*
4. *Debris on pavement*

Physical Threat to Workers or Other Vehicles

1. *Harmful debris that could injure workers or others in the area*
2. *Harmful debris that could injure occupants in other vehicles*

The Shur-Tite® Multiple-Mailbox Mount pulled out of the ground socket and rode along with the vehicle, but did not present a hazard.

Vehicle and Device Condition

1. *Vehicle Damage*
    - *a. None*
    - *b. Minor scrapes, scratches, or dents*
    - [✓ *c. Significant cosmetic dents*]
    - *d. Major dents to grill and body panels*
    - *e. Major structural damage*
2. *Windshield Damage*
    - [✓ *a. None*]
    - *b. Minor chip or crack*
    - *c. Broken, no interference with visibility*
    - *d. Broken or shattered, visibility restricted but remained intact*
    - *e. Shattered, remained intact but partially dislodged*
    - *f. Large portion removed*
    - *g. Completely removed*
3. *Device Damage*
    - *a. None*
    - *b. Superficial*
    - *c. Substantial, but can be straightened*
    - [✓ *d. Substantial, replacement parts needed for repair*]
    - *e. Cannot be repaired*

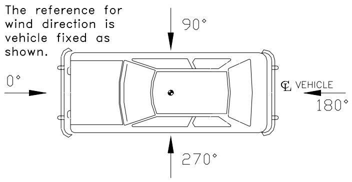
TEST NO. 452106-2 (*NCHRP REPORT 350* TEST DESIGNATION 3-61)

Test Vehicle

The 1995 Geo Metro used in the previous test, and shown in Figures 10 and 11, was used for the crash test. Test inertia weight of the vehicle was 1808 lb, and its gross static weight was 1978 lb. The height to the lower edge of the vehicle bumper was 15.75 inches, and it was 20.7 inches to the upper edge of the bumper. Figure 17 in Appendix B gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed on the afternoon of March 3, 2006. Rainfall of 0.52 inches was recorded six days prior to the test. No other rainfall was recorded during the 10 days prior to the test. Moisture content of the soil was 6.5 percent. Weather conditions at the time of testing were as follows: Wind speed: 2.5 mi/h; Wind direction: 10 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); Temperature: 74 ^{o}F, Relative humidity: 34 percent.



Test Description

The 1995 Geo Metro, traveling at an impact speed of 62.6 mi/h, contacted the Shur-Tite® Multiple-mailbox Mount at an impact angle of 0 degree, with the right quarter point of the vehicle aligned with the centerline of the support. Shortly after impact, the support pulled out of the ground base as designed, and at 0.047 s, the mailboxes contacted the windshield of the vehicle. At 0.072 s, the mailbox support lost contact with the front bumper of the vehicle, as the vehicle was traveling at a speed of 57.7 mi/h. The mailboxes lost contact with the windshield at 0.152 s. Brakes on the vehicle were applied 130 ft downstream of impact, and the mailboxes fell from the vehicle 143 ft downstream of impact. The vehicle came to rest 276 ft downstream of impact and 2 ft to the left of centerline. Figure 19 in Appendix C shows sequential photographs of the test period.

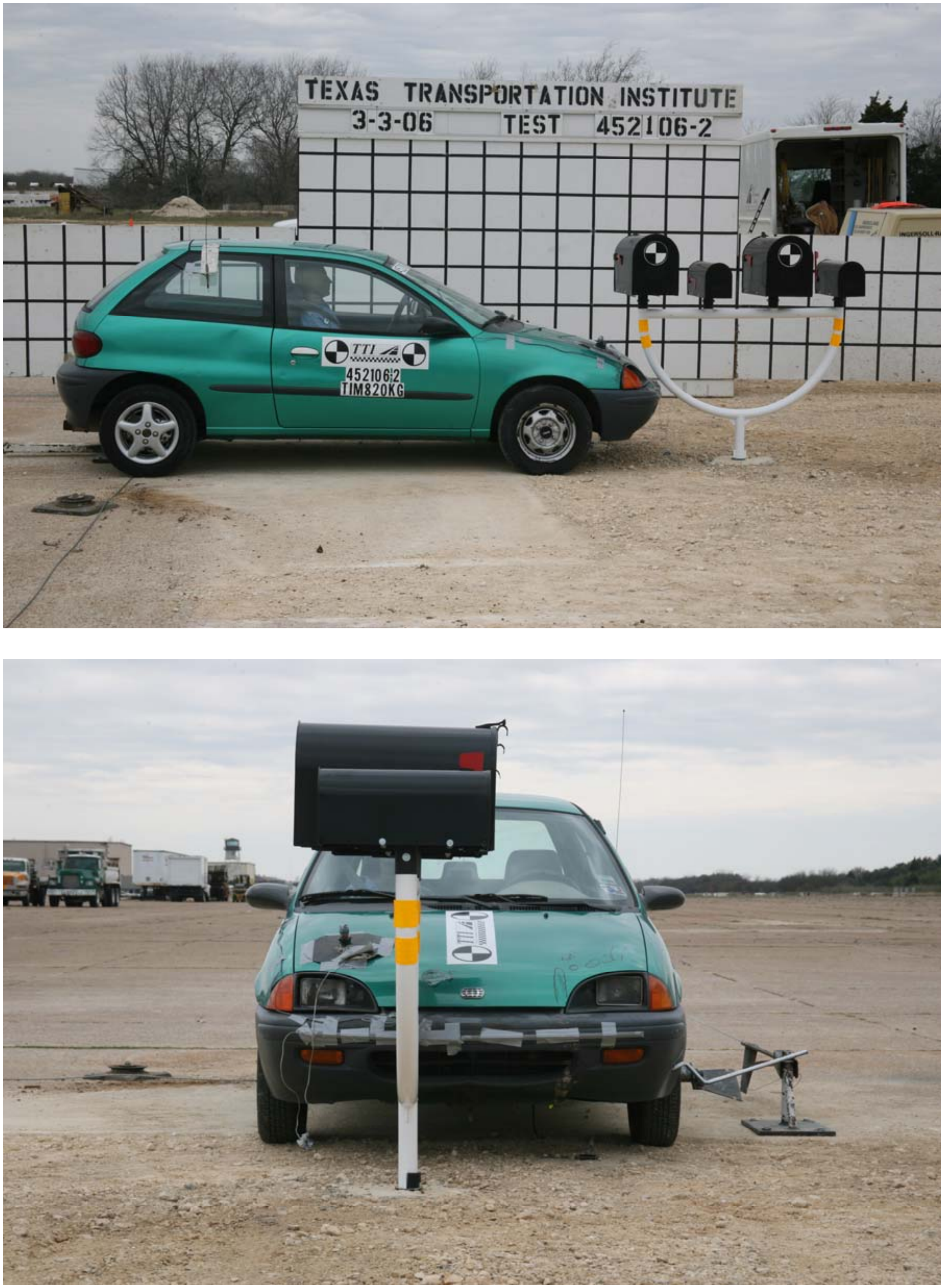


Figure 10. Vehicle/Installation Geometrics for Test No. 452106-2.

Figure 11. Vehicle before Test No. 452106-2.

Damage to Test Installation

As shown in Figures 12 and 13, the support pulled out of the ground base as designed. All the mailboxes remained attached to the support; however, the mailboxes were deformed. The upright support was deformed at 11.8 inches from the end, and the arc of the support was severely deformed.

Vehicle Damage

The vehicle sustained minimal damage to the hood and bumper as shown in Figure 14. The front bumper has a slight indention at point of contact with the support, and the hood had one indentation on the impact side which measured 33.5 inches x 5.9 inches. The windshield was shattered over an area of 31.5 inches in diameter and depressed 3.2 inches inward toward the occupant compartment. Photographs of the interior of the vehicle are shown in Figure 15. Exterior vehicle crush and occupant compartment measurements are shown in Appendix B, Tables 5 and 6.

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 0.505 s, the highest 0.010-s occupant ridedown acceleration was -0.3 g's from 0.578 to 0.588 s, and the maximum 0.050-s average acceleration was -2.1 g's between 0.000 and 0.050 s. In the lateral direction, the occupant impact velocity was 2.3 ft/s at 0.505 s, the highest 0.010-s occupant ridedown acceleration was -0.4 g's from 0.741 to 0.751 s, and the maximum 0.050-s average was 0.3 g's between 0.138 and 0.188 s. Figure 16 presents these data and other pertinent information from the test. Figures 27 through 33 in Appendix D present vehicle angular displacements and accelerations versus time traces.

Figure 12. After Impact Trajectory Path for Test No. 452106-2.

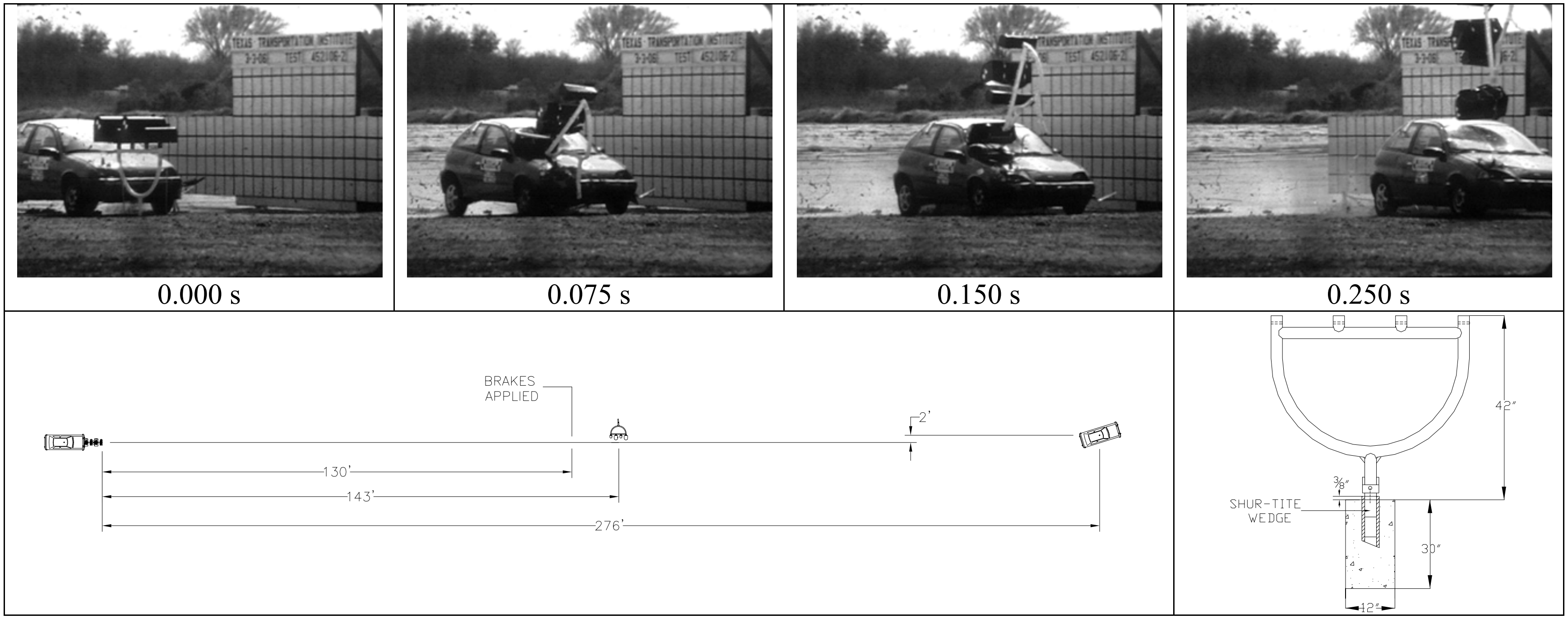
Figure 13. Installation after Test No. 452106-2.

Figure 14. Vehicle after Test No. 452106-2.

Before Test

After Test

Figure 15. Interior of Vehicle for Test No. 452106-2.


0.000 s
0.075 s
0.150 s
0.250 s

General Information

Test Agency	Texas Transportation Institute
Test No.	452106-2
Date	03-03-2006

Test Article

Type	Mailbox Suport
Name	Shur-Tite® Multiple-mailbox Mount
Installation Height (inches)	42.0 to Bottom of Mailboxes
Material or Key Elements	Four Mailboxes Mounted using Standard TxDOT Hardware
Soil Type and Condition	Standard Soil, Dry

Test Vehicle

Type	Production
Designation	820C
Model	1995 Geo Metro
Mass (lb (kg))	
Curb	1755
Test Inertial	1808
Dummy	170
Gross Static	1978

Impact Conditions

Speed (mi/h)	62.6
Angle (deg)	0

Exit Conditions

Speed (mi/h)	57.7
Angle (deg)	0

Occupant Risk Values

Impact Velocity (ft/s)	
Longitudinal	4.9
Lateral	2.3
THIV (km/h))	5.8
Ridedown Accelerations (g's)	
Longitudinal	-0.3
Lateral	-0.4
PHD (g's)	0.5
ASI	0.18
Max. 0.050-s Average (g's)	
Longitudinal	-2.1
Lateral	0.3
Vertical	0.9

Test Article Debris Pattern (ft)

Dynamic	276.0
Permanent	2.0

Vehicle Damage

Exterior	
VDS	12FD2
CDC	12FDEW2
Maximum Exterior Vehicle Crush (inches)	nil
Interior	
OCDI	RF0000000
Maximum Occupant Cmpt. Deformation (inches)	3.2 (windshield)

Post-Impact Behavior

(during 1.0 sec after impact)	
Max. Yaw Angle (deg)	3
Max. Pitch Angle (deg)	-2
Max. Roll Angle (deg)	2

Figure 16. Summary of Results for *NCHRP Report 350* Test 3-61 on the Shur-Tite® Multiple-mailbox Mount.

Assessment of Test Results

An assessment of the test based on the applicable *NCHRP Report 350* safety evaluation criteria is provided below.

Structural Adequacy

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

Result: The Shur-Tite® Multiple-mailbox Mount yielded to the vehicle by pulling out of the ground base. (PASS)

Occupant Risk

D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.

Result: The Shur-Tite® Multiple-mailbox Mount pulled out of the ground socket and rode along with the vehicle. The support did not penetrate or show potential for penetrating the occupant compartment, or to present undue hazard to others in the area. The mailboxes deformed the windshield inward by 3.2 inches, but did not penetrate. (PASS)

E. Detached element, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.

Result: Even though windshield damage was imparted by the mailboxes, the driver can still readily see through the damage and bring the vehicle to a controlled stop. (PASS)

F. The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.

Result: The vehicle remained upright during and after the collision event. (PASS)

I. Occupant impact velocities should satisfy the following:

Longitudinal and Lateral Occupant Impact Velocity – m/s

Preferred	*Maximum*
3 (9.8 ft/s)	*5* (16.4 ft/s)

Result: Longitudinal occupant impact velocity was 4.9 ft/s, and lateral occupant impact velocity was 2.3 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:

Longitudinal and Lateral Occupant Ridedown Accelerations – g's

Preferred	*Maximum*
16	*20*

Result: Longitudinal ridedown acceleration was -0.3 g, and lateral ridedown acceleration was -0.4 g. (PASS)

Vehicle Trajectory

K. After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.

Result: The vehicle traveled straightforward and did not intrude into adjacent traffic lanes. (PASS)

N. Vehicle trajectory behind the test article is acceptable.

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

The following supplemental evaluation factors and terminology, as presented in the FHWA memo entitled "ACTION: Identifying Acceptable Highway Safety Features," were used for visual assessment of test results (2). Factors underlined below pertain to the results of the crash test reported herein.

Passenger Compartment Intrusion

1. *Windshield Intrusion*
   - *a. No windshield contact*
   - *b. Windshield contact, no damage*
   - *c. Windshield contact, no intrusion*
   - *d. Device embedded in windshield, no significant intrusion*
   - *e. Complete intrusion into passenger compartment*
   - *f. Partial intrusion into passenger compartment*
2. *Body Panel Intrusion* *yes or no*

Loss of Vehicle Control

1. *Physical loss of control*
2. *Loss of windshield visibility*
3. *Perceived threat to other vehicles*
4. *Debris on pavement*

Physical Threat to Workers or Other Vehicles

1. *Harmful debris that could injure workers or others in the area*
2. *Harmful debris that could injure occupants in other vehicles*

The Shur-Tite® Multiple-mailbox Mount pulled out of the ground socket and rode along with the vehicle.

Vehicle and Device Condition

1. *Vehicle Damage*
    - *a. None*
    - *b. Minor scrapes, scratches or dents*
    - *c. Significant cosmetic dents*
    - *d. Major dents to grill and body panels*
    - *e. Major structural damage*
2. *Windshield Damage*
    - *a. None*
    - *b. Minor chip or crack*
    - *c. Broken, no interference with visibility*
    - *d. Broken or shattered, visibility restricted but remained intact*
    - *e. Shattered, remained intact but partially dislodged*
    - *f. Large portion removed*
    - *g. Completely removed*
3. *Device Damage*
    - *a. None*
    - *b. Superficial*
    - *c. Substantial, but can be straightened*
    - *d. Substantial, replacement parts needed for repair*
    - *e. Cannot be repaired*

CHAPTER 4. SUMMARY AND CONCLUSIONS

SUMMARY OF TEST RESULTS

NCHRP Report 350 Test 3-60 Results (452106-1)

The Shur-Tite® Multiple-mailbox Mount yielded to the vehicle by pulling out of the ground socket. The support did not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others in the area. No occupant compartment deformation occurred. The Shur-Tite® Multiple-mailbox Mount with mailboxes rode up into the windshield, but did not block the driver's vision. The vehicle remained upright during and after the collision event. Occupant risk factors were within preferred limits. The vehicle traveled straightforward and did not intrude into adjacent traffic lanes. The vehicle came to rest behind the test installation.

NCHRP Report 350 Test 3-61 Results (452106-2)

The Shur-Tite® Multiple-Mailbox Mount yielded to the vehicle by pulling out of the ground socket. The support did not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others in the area. The Shur-Tite® Multiple-mailbox Mount with mailboxes rode up into and shattered the windshield, but did not block the driver's vision. The windshield was deformed inward 3.2 inches without any holes or penetration. The vehicle remained upright during and after the collision event. Occupant risk factors were within preferred limits. The vehicle traveled straightforward and did not intrude into adjacent traffic lanes. The vehicle came to rest behind the installation.

CONCLUSIONS

TxDOT desired to adopt a new multiple-mailbox mount design that would provide improved installation and maintenance. Shur-Tite® had developed a design that was considered to provide these characteristics. However, before this multiple-mailbox mount design could be used, it had to be evaluated using the *NCHRP Report 350* safety evaluation criteria. Two full-scale crash tests required by the *NCHRP Report 350* criteria were conducted, and the safety performance of the Shur-Tite® Multiple-mailbox Mount was evaluated.

Tables 1 and 2 summarize the test results and the final assessment of the researchers for each of the specified criterion. Based on these crash test results, the researchers conclude that the Shur-Tite® Multiple-mailbox Mount successfully passed all requirements of the *NCHRP Report 350* safety evaluation criteria and is ready for field installation.

Table 1. Performance Evaluation Summary for *NCHRP Report 350* Test 3-60 on the Shur-Tite® Multiple-Mailbox Mount.

Test Agency: Texas Transportation Institute | Test No.: 452106-1 | Test Date: 03-03-2006

<table>
<tr><th colspan="3"><i>NCHRP Report 350</i> 3-60 Evaluation Criteria</th><th>Test Results</th><th>Assessment</th></tr>
<tr><td colspan="3">Structural Adequacy</td><td></td><td></td></tr>
<tr><td colspan="3">B. <i>The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.</i></td><td>The Shur-Tite® Multiple-mailbox Mount yielded to the vehicle by pulling out of the ground base. The mount pulled out of the ground and rode along with the vehicle.</td><td>Pass</td></tr>
<tr><td colspan="3">Occupant Risk</td><td></td><td></td></tr>
<tr><td colspan="3">D. <i>Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.</i></td><td>The support did not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others in the area. No occupant compartment deformation occurred.</td><td>Pass</td></tr>
<tr><td colspan="3">E. <i>Detached elements, fragments, or other debris from the test article, of vehicular damage should not block the driver’s vision or otherwise cause the driver to lose control of the vehicle.</i></td><td>The Shur-Tite® Multiple-mailbox Mount with mailboxes did not block the driver’s vision.</td><td>Pass</td></tr>
<tr><td colspan="3">F. <i>The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.</i></td><td>The vehicle remained upright during and after the collision event.</td><td>Pass</td></tr>
<tr><td colspan="3">H. <i>Occupant impact velocities should satisfy the following:</i></td><td rowspan="4">Longitudinal occupant impact velocity was 3.9 ft/s, and lateral occupant impact velocity was 1.0 ft/s.</td><td rowspan="4">Pass</td></tr>
<tr><td colspan="3"><i>Occupant Velocity Limits (m/s)</i></td></tr>
<tr><td><i>Component</i></td><td><i>Preferred</i></td><td><i>Maximum</i></td></tr>
<tr><td><i>Longitudinal</i></td><td><i>3</i></td><td><i>5</i></td></tr>
<tr><td colspan="3">I. <i>Occupant ridedown accelerations should satisfy the following:</i></td><td rowspan="4">Longitudinal ridedown acceleration was -0.2 g, and lateral ridedown acceleration was -0.2 g.</td><td rowspan="4">Pass</td></tr>
<tr><td colspan="3"><i>Occupant Ridedown Acceleration Limits (g’s)</i></td></tr>
<tr><td><i>Component</i></td><td><i>Preferred</i></td><td><i>Maximum</i></td></tr>
<tr><td><i>Longitudinal and lateral</i></td><td><i>15</i></td><td><i>20</i></td></tr>
<tr><td colspan="3">Vehicle Trajectory</td><td></td><td></td></tr>
<tr><td colspan="3">K. <i>After collision, it is preferable that the vehicle’s trajectory not intrude into adjacent traffic lanes.</i></td><td>The vehicle traveled straightforward and did not intrude into adjacent traffic lanes.</td><td>Pass*</td></tr>
<tr><td colspan="3">N. <i>Vehicle trajectory behind the test article is acceptable.</i></td><td>The vehicle came to rest behind the installation.</td><td>Pass</td></tr>
</table>

* Criterion K is preferable, not required.

Table 2. Performance Evaluation Summary for *NCHRP Report 350* Test 3-61 on the Shur-Tite® Multiple-Mailbox Mount.

Test Agency: Texas Transportation Institute   Test No.: 452106-2   Test Date: 03-03-2006

<table>
<tr><th colspan="4">*NCHRP Report 350* 3-61 Evaluation Criteria</th><th>Test Results</th><th>Assessment</th></tr>
<tr><td colspan="4"><u>Structural Adequacy</u></td><td></td><td></td></tr>
<tr><td>*B.*</td><td colspan="3">*The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*</td><td>The Shur-Tite® Multiple-mailbox Mount yielded to the vehicle by pulling out of the ground base. The mount pulled out of the ground and rode along with the vehicle.</td><td>Pass</td></tr>
<tr><td colspan="4"><u>Occupant Risk</u></td><td rowspan="2">The support did not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others in the area. The mailboxes deformed the windshield inward by 3.2 inches, but did not penetrate.</td><td rowspan="2">Pass</td></tr>
<tr><td>*D.*</td><td colspan="3">*Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*</td></tr>
<tr><td>*E.*</td><td colspan="3">*Detached elements, fragments, or other debris from the test article, of vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*</td><td>The Shur-Tite® Multiple-mailbox Mount with mailboxes rode up into the windshield, which shattered, but did not block the driver's vision.</td><td>Pass</td></tr>
<tr><td>*F.*</td><td colspan="3">*The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*</td><td>The vehicle remained upright during and after the collision event.</td><td>Pass</td></tr>
<tr><td>*H.*</td><td colspan="3">*Occupant impact velocities should satisfy the following:*</td><td rowspan="4">Longitudinal occupant impact velocity was 4.9 ft/s, and lateral occupant impact velocity was 2.3 ft/s.</td><td rowspan="4">Pass</td></tr>
<tr><td></td><td colspan="3">*Occupant Velocity Limits (m/s)*</td></tr>
<tr><td></td><td>*Component*</td><td>*Preferred*</td><td>*Maximum*</td></tr>
<tr><td></td><td>*Longitudinal*</td><td>*3*</td><td>*5*</td></tr>
<tr><td>*I.*</td><td colspan="3">*Occupant ridedown accelerations should satisfy the following:*</td><td rowspan="4">Longitudinal ridedown acceleration was -0.3 g, and lateral ridedown acceleration was -0.4 g.</td><td rowspan="4">Pass</td></tr>
<tr><td></td><td colspan="3">*Occupant Ridedown Acceleration Limits (g's)*</td></tr>
<tr><td></td><td>*Component*</td><td>*Preferred*</td><td>*Maximum*</td></tr>
<tr><td></td><td>*Longitudinal and lateral*</td><td>*15*</td><td>*20*</td></tr>
<tr><td colspan="4"><u>Vehicle Trajectory</u></td><td rowspan="2">The vehicle traveled straightforward and did not intrude into adjacent traffic lanes.</td><td rowspan="2">Pass*</td></tr>
<tr><td>*K.*</td><td colspan="3">*After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*</td></tr>
<tr><td>*N.*</td><td colspan="3">*Vehicle trajectory behind the test article is acceptable.*</td><td>The vehicle came to rest behind the installation.</td><td>Pass</td></tr>
</table>

* Criterion K is preferable, not required.

CHAPTER 5. IMPLEMENTATION STATEMENT

The Shur-Tite® Multiple-Mailbox Mount design is ready for implementation. Implementation can be achieved by revising the TxDOT's Maintenance Standard Plan Sheets through the Maintenance Division.

The Shur-Tite® Multiple-Mailbox Support was tested in a configuration that included two small mailboxes weighing 7 lb each and two large mailboxes weighing 13 lb 10 oz each. Total weight of the mailboxes was approximately 41 lb. Alternate mailbox arrangements are considered acceptable provided the total weight of the mailboxes does not exceed the total tested weight of 41 lb and sufficient space is available on the horizontal member of the support. For example, three large mailboxes (total weight 41 lb) or 5 small mailboxes (total weight 35 lb) would be considered acceptable alternatives to the tested configuration.

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. Federal Highway Administration Memorandum from the Director, Office of Engineering, entitled: “ACTION: Identifying Acceptable Highway Safety Features,” dated July 25, 1997.

APPENDIX A. CRASH TEST AND DATA ANALYSIS PROCEDURES

The crash test and data analysis procedures were in accordance with guidelines presented in *NCHRP Report 350*. Brief descriptions of these procedures are presented as follows.

ELECTRONIC INSTRUMENTATION AND DATA PROCESSING

The test vehicle was instrumented with three solid-state angular rate transducers to measure roll, pitch, and yaw rates; a triaxial accelerometer near the vehicle center of gravity (c.g.) to measure longitudinal, lateral, and vertical acceleration levels; and a backup biaxial accelerometer in the rear of the vehicle to measure longitudinal and lateral acceleration levels. These accelerometers were ENDEVCO® Model 2262CA, piezoresistive accelerometers with a ±100 g range.

The accelerometers are strain gage type with a linear millivolt output proportional to acceleration. Angular rate transducers are solid state, gas flow units designed for high-"g" service. Signal conditioners and amplifiers in the test vehicle increase the low-level signals to a ±2.5 volt maximum level. The signal conditioners also provide the capability of a resistive calibration (R-cal) or shunt calibration for the accelerometers and a precision voltage calibration for the rate transducers. The electronic signals from the accelerometers and rate transducers are transmitted to a base station by means of a 15-channel, constant bandwidth, Inter-Range Instrumentation Group (I.R.I.G.), FM/FM telemetry link for recording and for display. Calibration signals from the test vehicle are recorded before the test and immediately afterwards. A crystal-controlled time reference signal is simultaneously recorded with the data. Wooden dowels actuate pressure-sensitive switches on the bumper of the impacting vehicle prior to impact by wooden dowels to indicate the elapsed time over a known distance to provide a measurement of impact velocity. The initial contact also produces an "event" mark on the data record to establish the instant of contact with the installation.

The multiplex of data channels, transmitted on one radio frequency, is received and demultiplexed onto a TEAC® instrumentation data recorder. After the test, the data are played back from the TEAC® recorder and digitized. A proprietary software program (WinDigit) converts the analog data from each transducer into engineering units using the R-cal and pre-zero values at 10,000 samples per second per channel. WinDigit also provides Society of Automotive Engineers (SAE) J211 class 180 phaseless digital filtering and vehicle impact velocity.

All accelerometers are calibrated annually according to the SAE J211 *4.6.1* by means of an ENDEVCO® 2901, precision primary vibration standard. This device and its support instruments are returned to the factory annually for a National Institute of Standards Technology (NIST) traceable calibration. The subsystems of each data channel are also evaluated annually, using instruments with current NIST traceability, and the results are factored into the accuracy of the total data channel, per SAE J211. Calibrations and evaluations are made any time data are suspect.

The Test Risk Assessment Program (TRAP) uses the data from WinDigit to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-millisecond (ms) average ridedown acceleration. WinDigit calculates change in vehicle velocity at the end of a given impulse period. In addition, WinDigit computes maximum average accelerations over 50-ms intervals in each of the three directions. For reporting purposes, the data from the vehicle-mounted accelerometers are filtered with a 60-Hz digital filter, and acceleration versus time curves for the longitudinal, lateral, and vertical directions are plotted using TRAP.

TRAP uses the data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0001-s intervals and then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation of the vehicle-fixed coordinate systems being initial impact.

ANTHROPOMORPHIC DUMMY INSTRUMENTATION

An Alderson Research Laboratories Hybrid II, 50th percentile male anthropomorphic dummy, restrained with lap and shoulder belts, was placed in the driver's position of the 820C vehicle. The dummy was uninstrumented.

PHOTOGRAPHIC INSTRUMENTATION AND DATA PROCESSING

Photographic coverage of the test included two high-speed cameras: one placed behind the installation at an angle; and a second placed to have a field-of-view perpendicular to the vehicle path/installation. A flash bulb activated by pressure-sensitive tape switches was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from each camera. The 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 DV-format video camera recorder and still cameras were used to record and document conditions of the test vehicle and installation before and after the test.

TEST VEHICLE PROPULSION AND GUIDANCE

The test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point, through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A 2-to-1 speed ratio between the test and tow vehicle existed with this system. Just prior to impact with the installation, the test vehicle was released to be free-wheeling and unrestrained. The vehicle remained free-wheeling, i.e., no steering or braking inputs, until the vehicle cleared the immediate area of the test site, at which time the vehicle's brakes were activated to bring it to a safe and controlled stop.

APPENDIX B. TEST VEHICLE PROPERTIES AND INFORMATION

Date: 3-3-2006 Test No.: 452106-1 & 2 VIN No.: 2C1MR2265S6748481

Year: 1995 Make: Geo Model: Metro

Tire Inflation Pressure: 32 psi Odometer: 111470 Tire Size: P155 80 R13

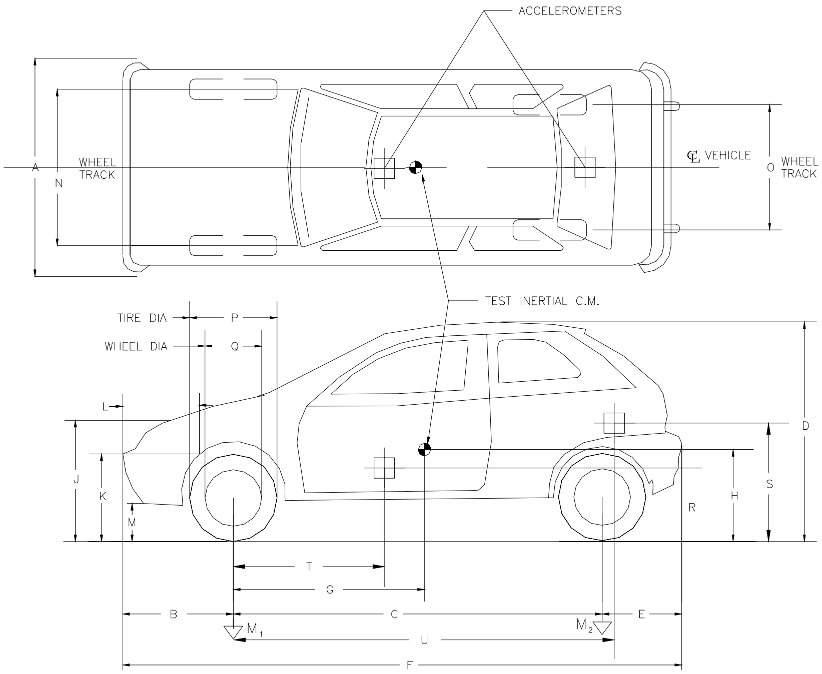
Describe any damage to the vehicle prior to test:

⌖ Denotes accelerometer location.

NOTES:

Engine Type: 3 CYL
Engine CID: 1.0 L
Transmission Type:
___ Auto
X Manual
Optional Equipment:

Dummy Data:
Type: 1 DRN
Mass: 77 kg
Seat Position: Passenger



Geometry (mm)

A	1450	E	560	J	610	N	1380	R	400
B	790	F	3715	K	525	O	1365	S	550
C	2365	G	931.6	L	160	P	570	T	960
D	1400	H		M	400	Q	365	U	2400

Mass (kg)	Curb	Test Inertial	Gross Static
M_1	505	497	537
M_2	291	323	360
M_{Total}	796	820	897

Mass Distribution (kg): LF: 253 RF: 244 LR: 163 RR: 160

Figure 17. Vehicle Properties for Test No. 452106-1 and 452106-2.

Table 3. Exterior Crush Measurements for Test No. 452106-1.

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
	Not Applicable										

[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).

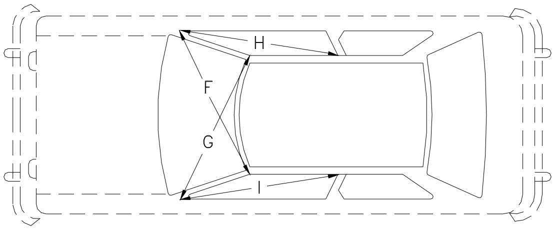
***Measure and document on the vehicle diagram the location of the maximum crush.

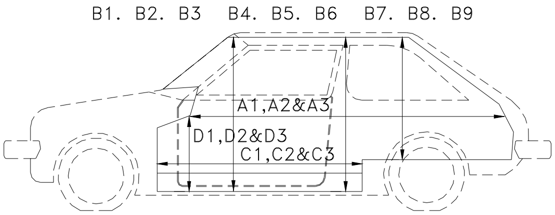
Note: Use as many lines/columns as necessary to describe each damage profile.

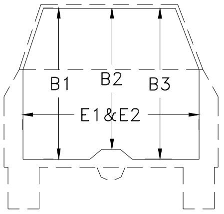
Table 4. Occupant Compartment Measurements for Test No. 452106-1.

Small Car

Occupant Compartment Deformation







	BEFORE (mm)	AFTER (mm)
A1	1440	1440
A2	1999	1999
A3	1426	1426
B1	960	960
B2	903	903
B3	967	967
B4	920	920
B5	896	896
B6	920	920
B7		
B8		
B9		
C1	565	565
C2		
C3	560	560
D1	231	231
D2	203	203
D3	247	247
E1	1217	1217
E2	1175	1175
F	1214	1214
G	1214	1214
H	1030	1030
I	1030	1030
J*	1193	1193

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

Table 5. Exterior Crush Measurements for Test No. 452106-2.

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

Note: Measure C_1 to C_6 from driver to passenger side in front or rear impacts – rear to front in side impacts.

<table>
<tr><th rowspan="2">Specific Impact Number</th><th rowspan="2">Plane* of C-Measurements</th><th colspan="2">Direct Damage</th><th rowspan="2">Field L**</th><th rowspan="2">C_1</th><th rowspan="2">C_2</th><th rowspan="2">C_3</th><th rowspan="2">C_4</th><th rowspan="2">C_5</th><th rowspan="2">C_6</th><th rowspan="2">±D</th></tr>
<tr><th>Width** (CDC)</th><th>Max*** Crush</th></tr>
<tr><td></td><td>Not Applicable</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

[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).

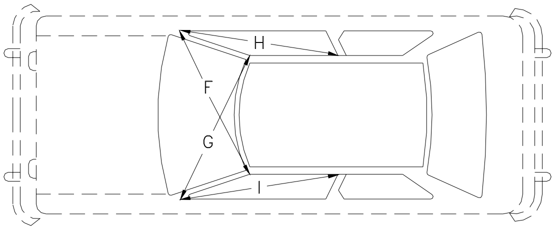
***Measure and document on the vehicle diagram the location of the maximum crush.

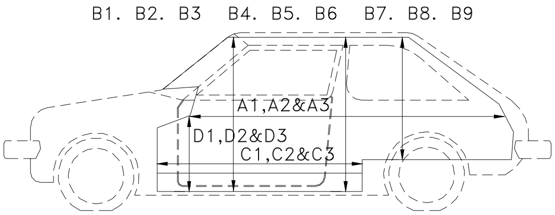
Note: Use as many lines/columns as necessary to describe each damage profile.

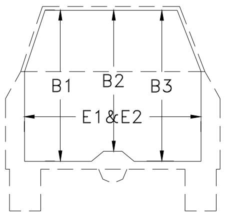
Table 6. Occupant Compartment Measurements for Test No. 452106-2.

Small Car

Occupant Compartment Deformation







	BEFORE (mm)	AFTER (mm)
A1	1440	1440
A2	1999	1999
A3	1426	1426
B1	960	960
B2	903	903
B3	967	967
B4	920	920
B5	896	896
B6	920	920
B7		
B8		
B9		
C1	565	565
C2		
C3	560	560
D1	231	231
D2	203	203
D3	247	247
E1	1217	1217
E2	1175	1175
F	1214	1214
G	1214	1214
H	1030	1030
I	1030	1030
J*	1193	1193

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

APPENDIX C. SEQUENTIAL PHOTOGRAPHS

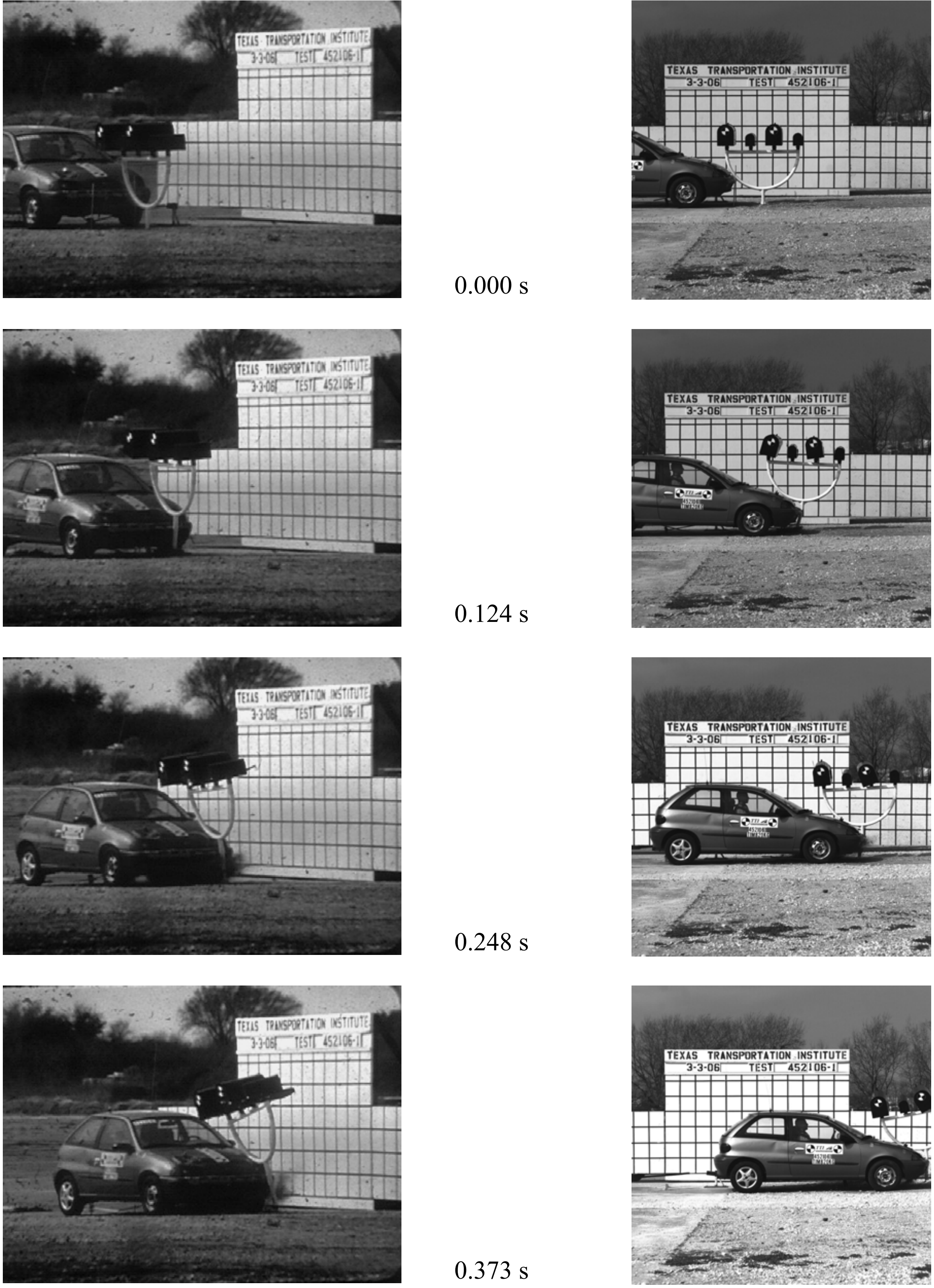
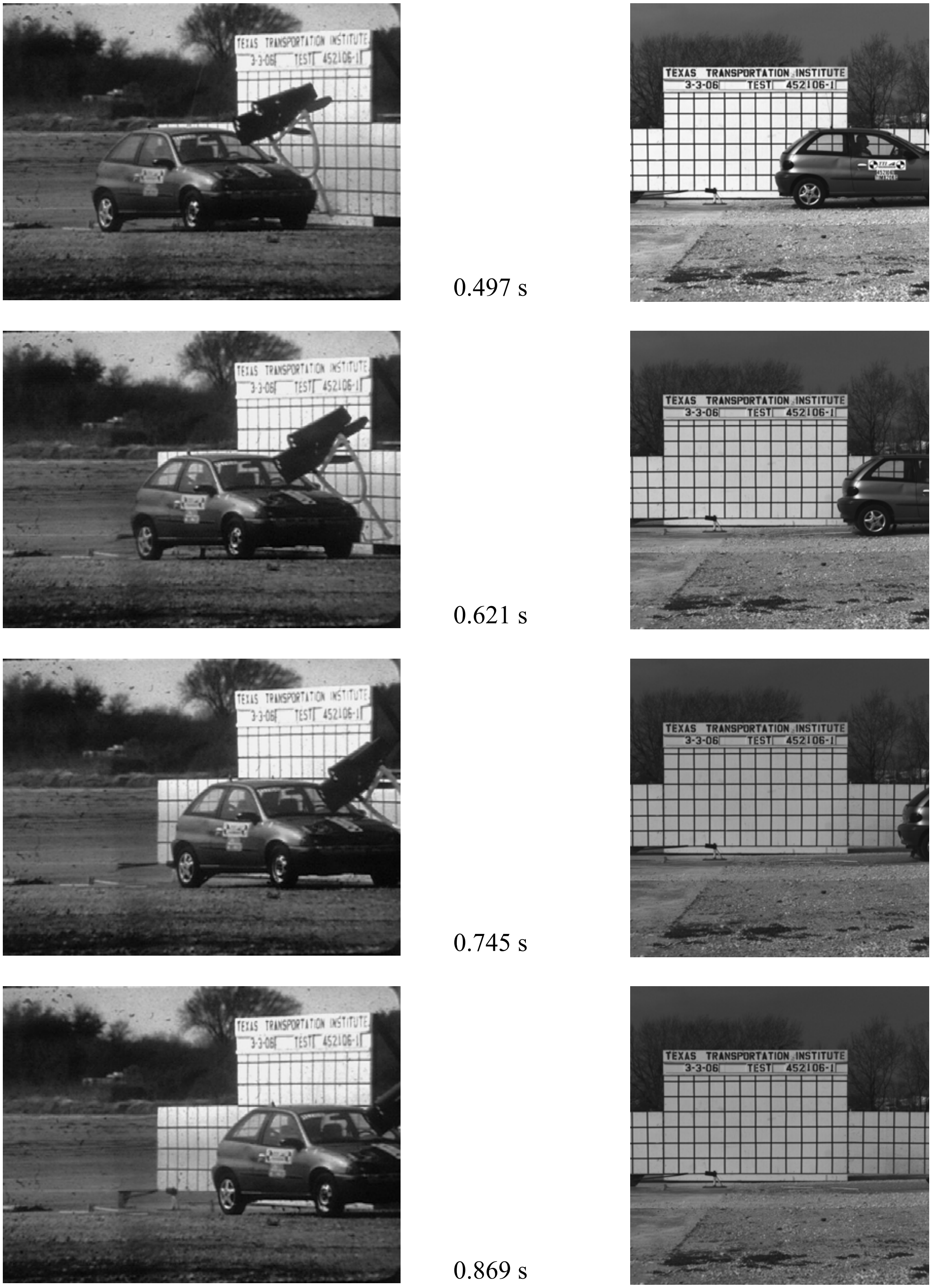


Figure 18. Sequential Photographs for Test 452106-1 (Oblique and Perpendicular Views).



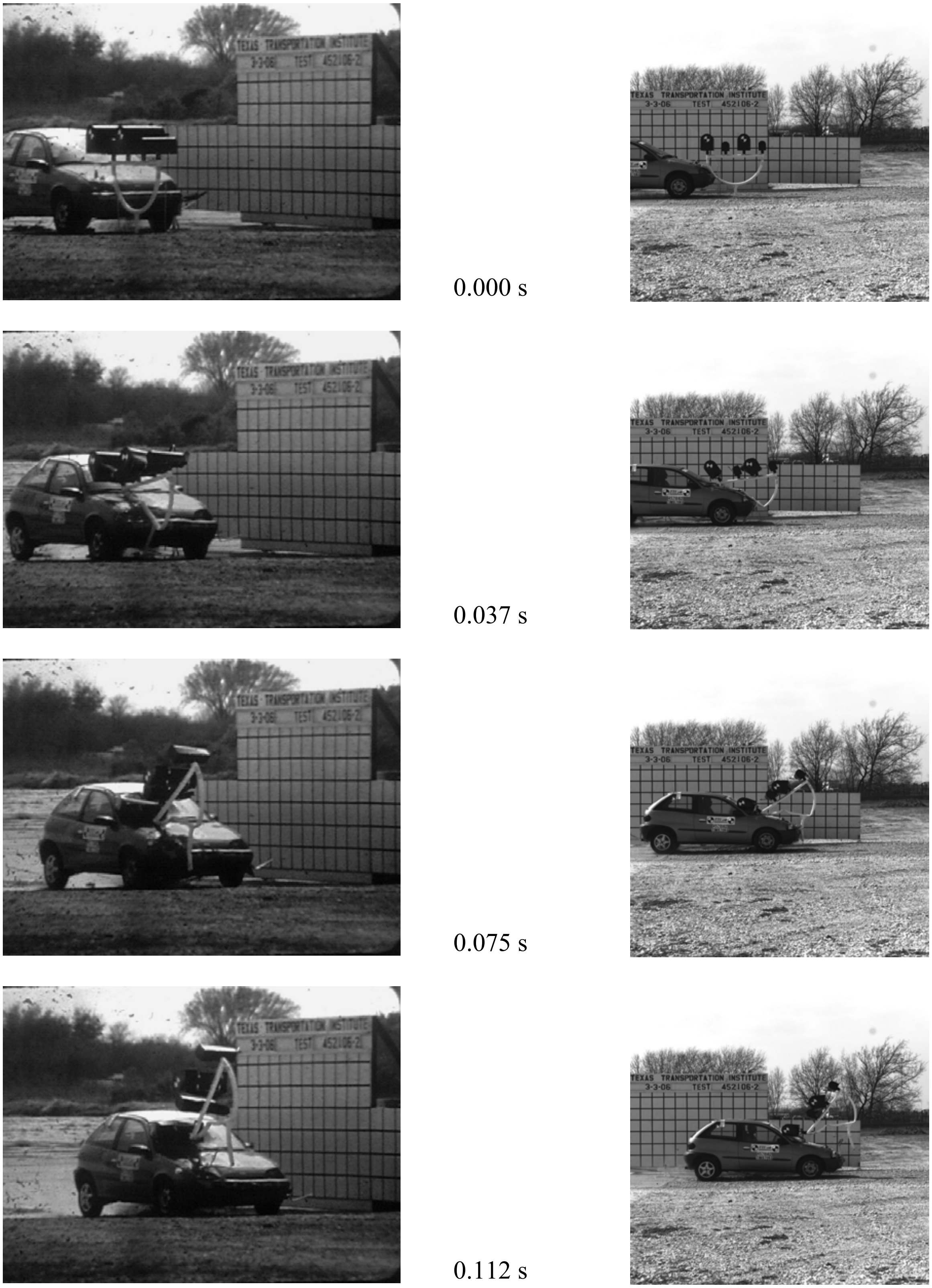
0.497 s

0.621 s

0.745 s

0.869 s

Figure 18. Sequential Photographs for Test 452106-1 (Oblique and Perpendicular Views) (continued).



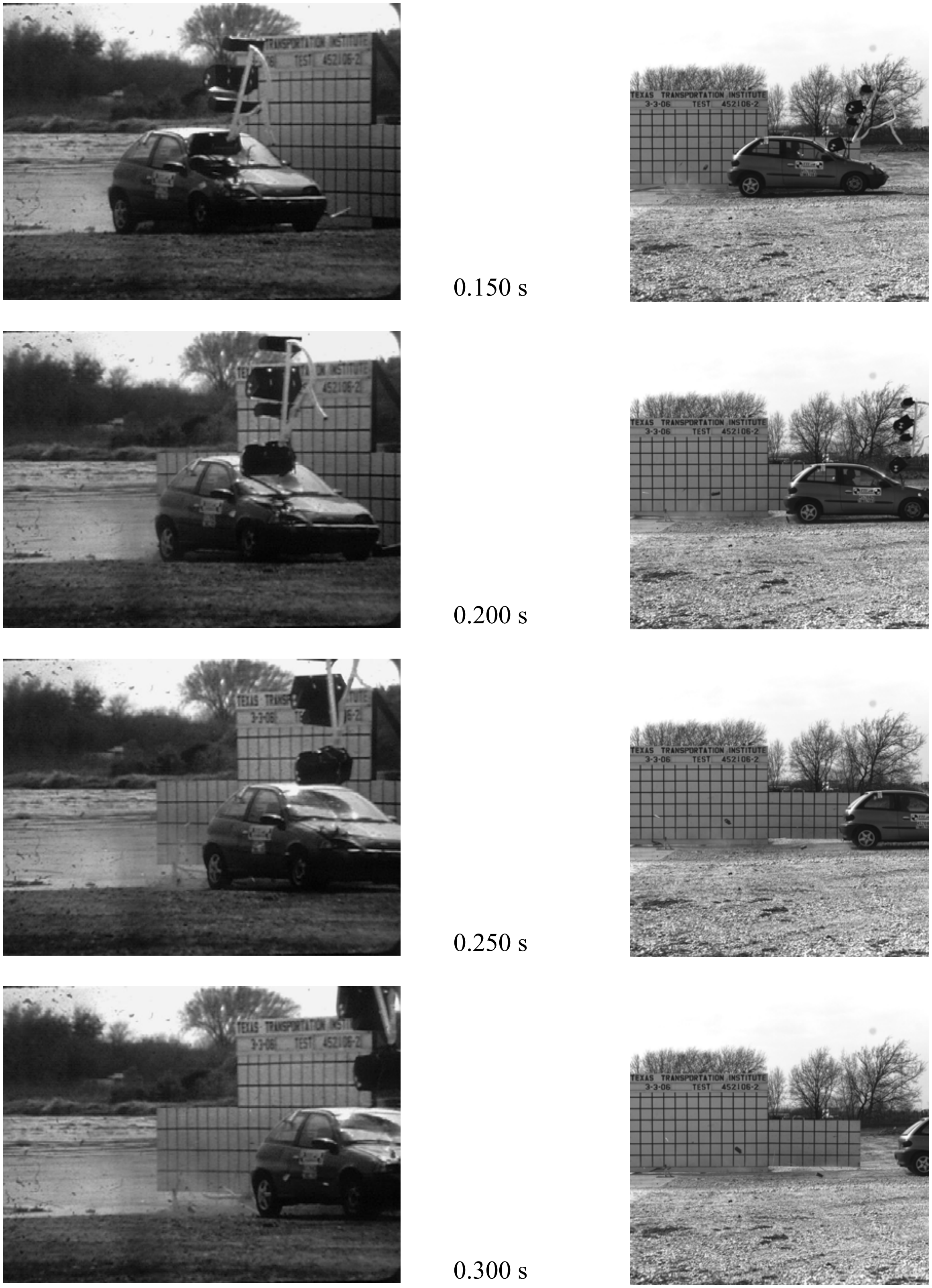
0.000 s

0.037 s

0.075 s

0.112 s

Figure 19. Sequential Photographs for Test 452106-2
(Oblique and Perpendicular Views).



0.150 s

0.200 s

0.250 s

0.300 s

Figure 19. Sequential Photographs for Test 452106-2 (Oblique and Perpendicular Views) (continued).

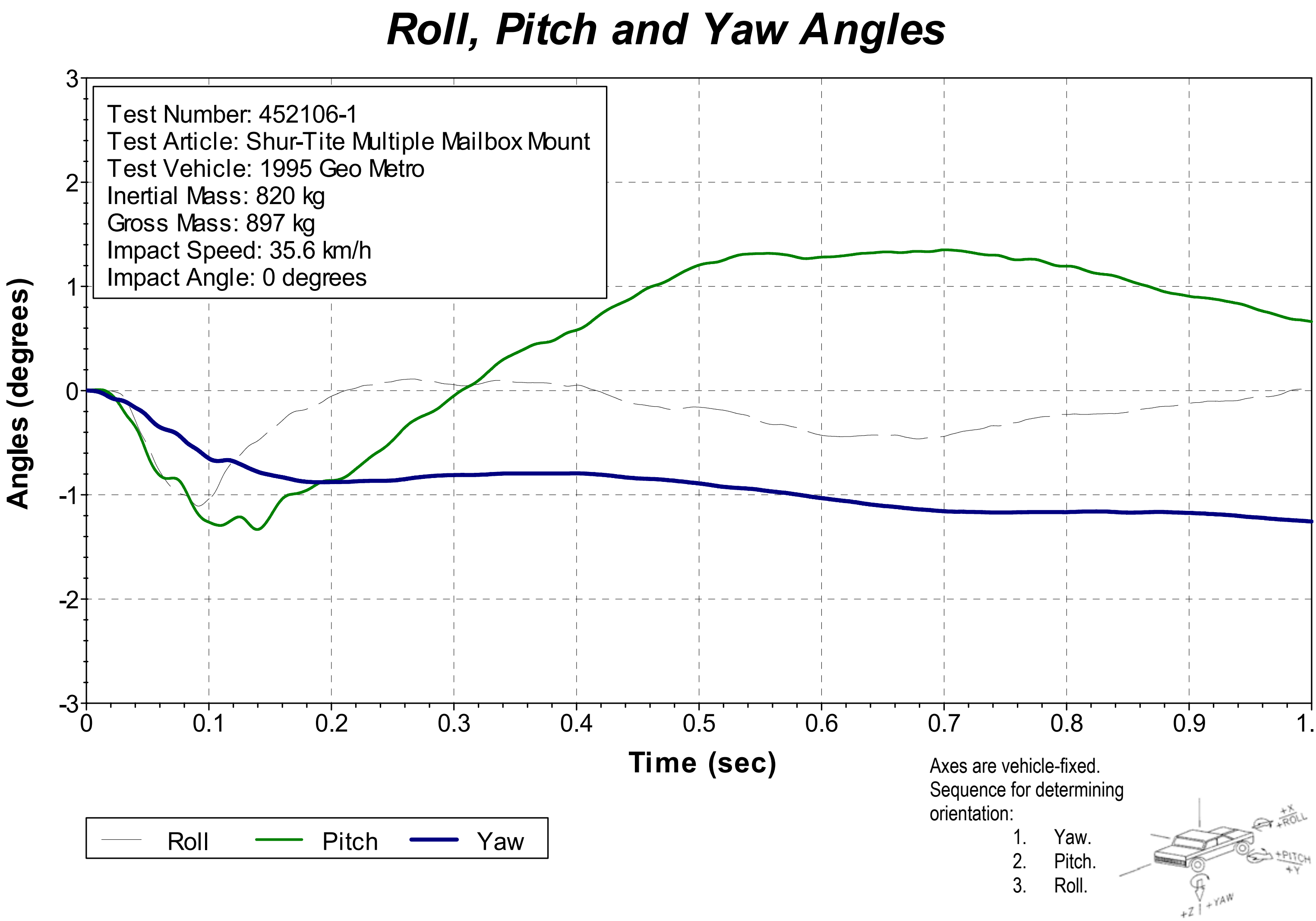


Figure 20. Vehicle Angular Displacements for Test No. 452106-1.

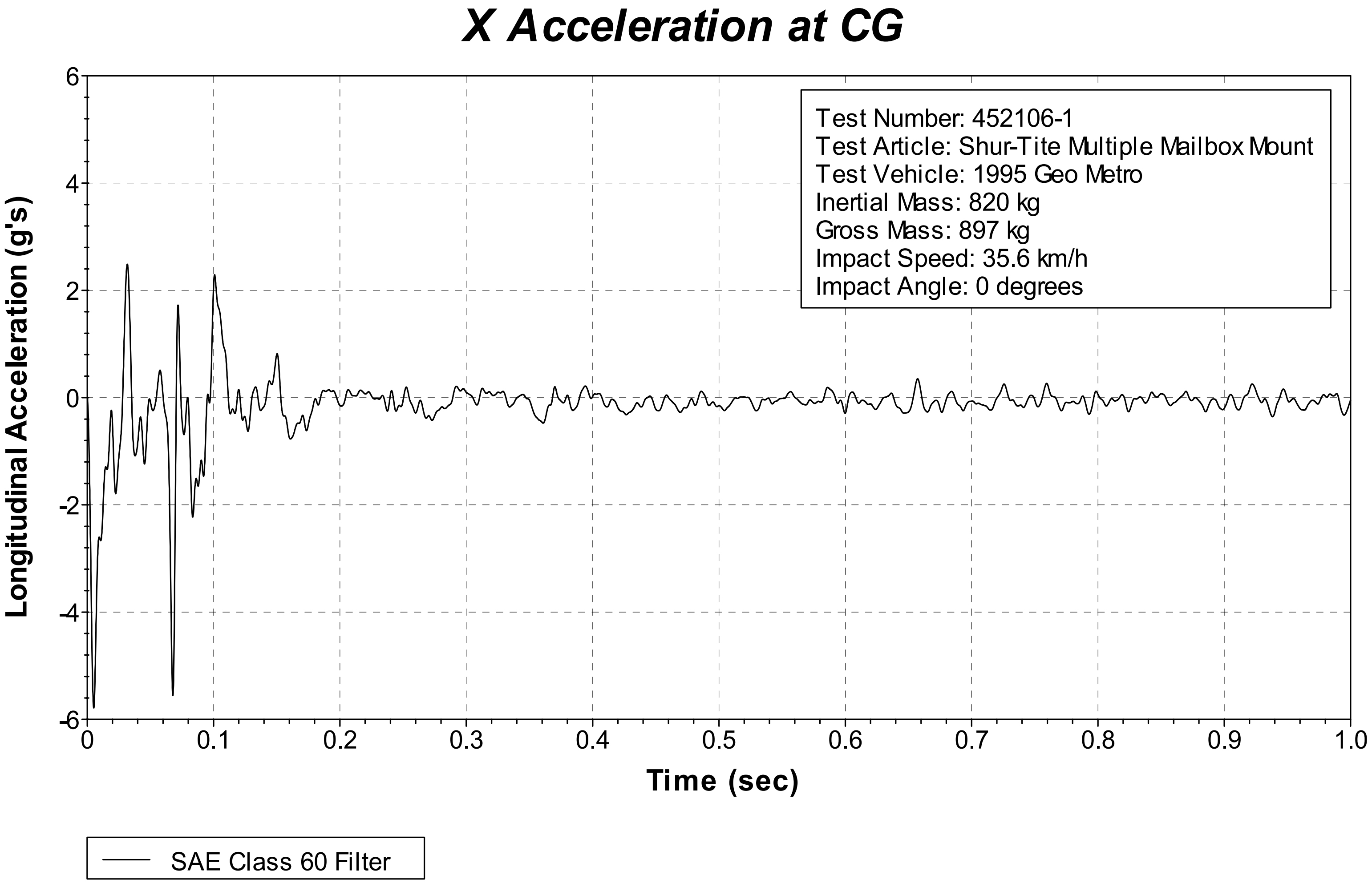


Figure 21. Vehicle Longitudinal Accelerometer Trace for Test No. 452106-1 (Accelerometer Located at Center of Gravity).

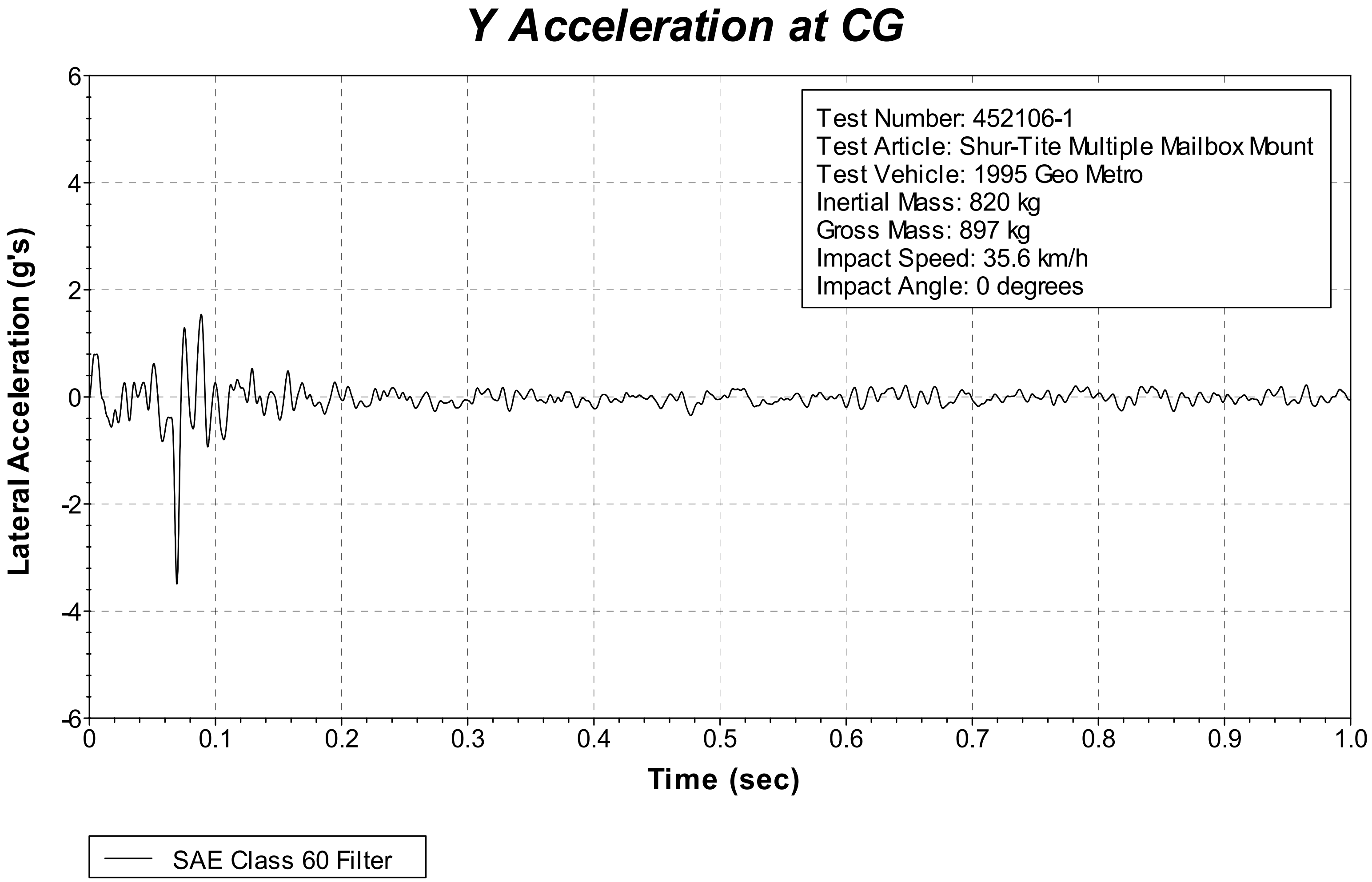


Figure 22. Vehicle Lateral Accelerometer Trace for Test No. 452106-1 (Accelerometer Located at Center of Gravity).

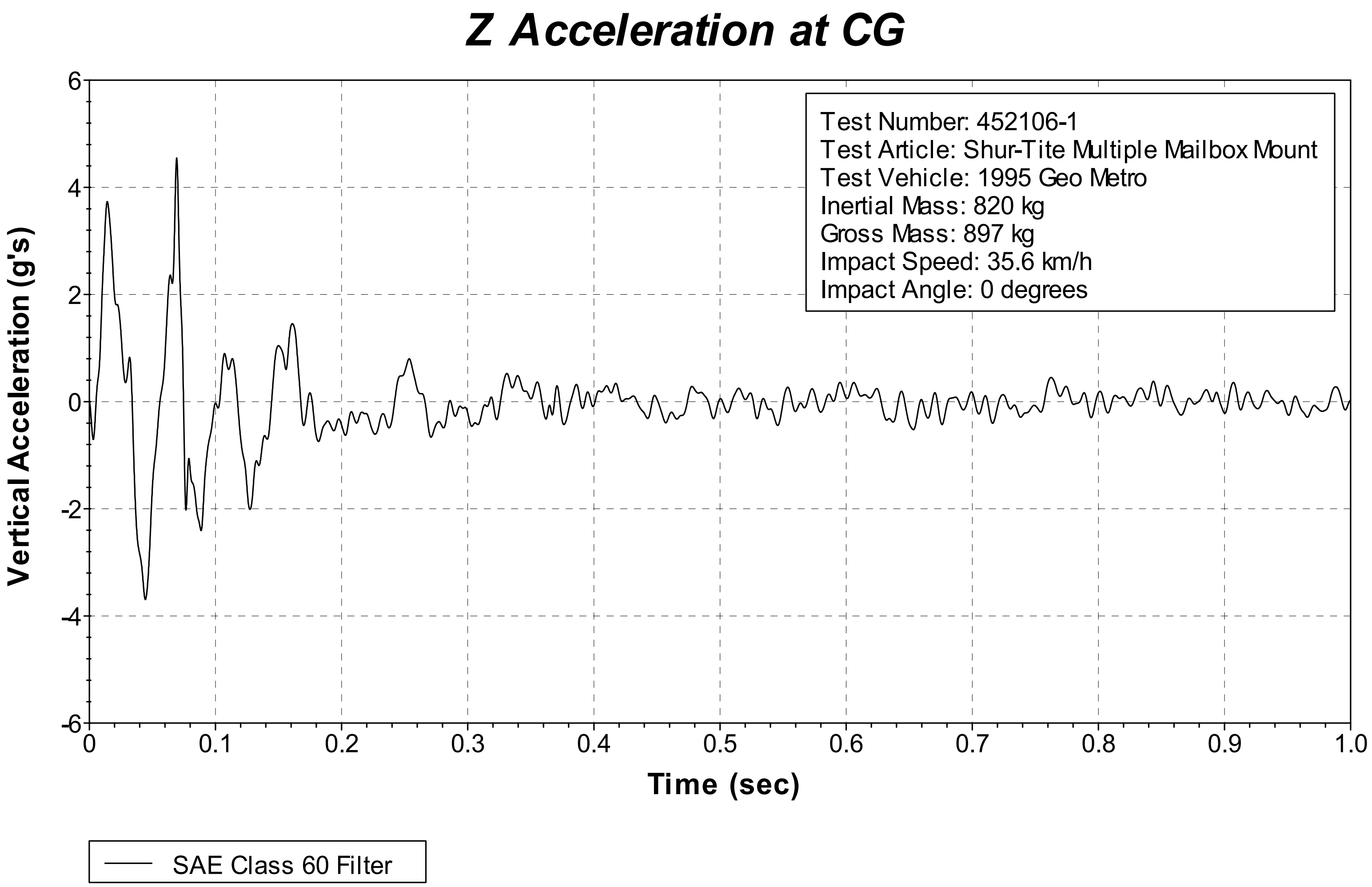


Figure 23. Vehicle Vertical Accelerometer Trace for Test No. 452106-1 (Accelerometer Located at Center of Gravity).

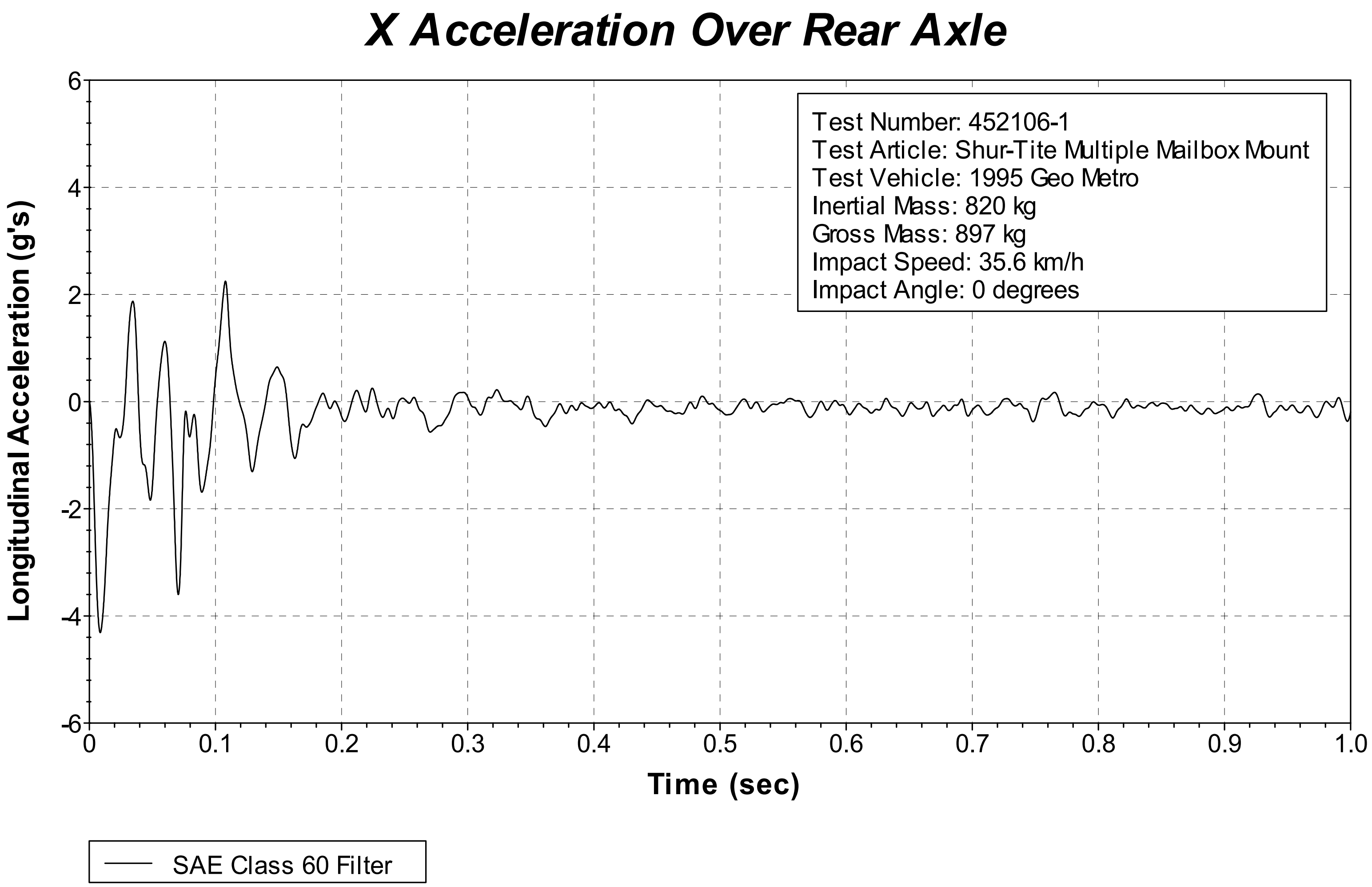


Figure 24. Vehicle Longitudinal Accelerometer Trace for Test No. 452106-1 (Accelerometer Located Over Rear Axle).

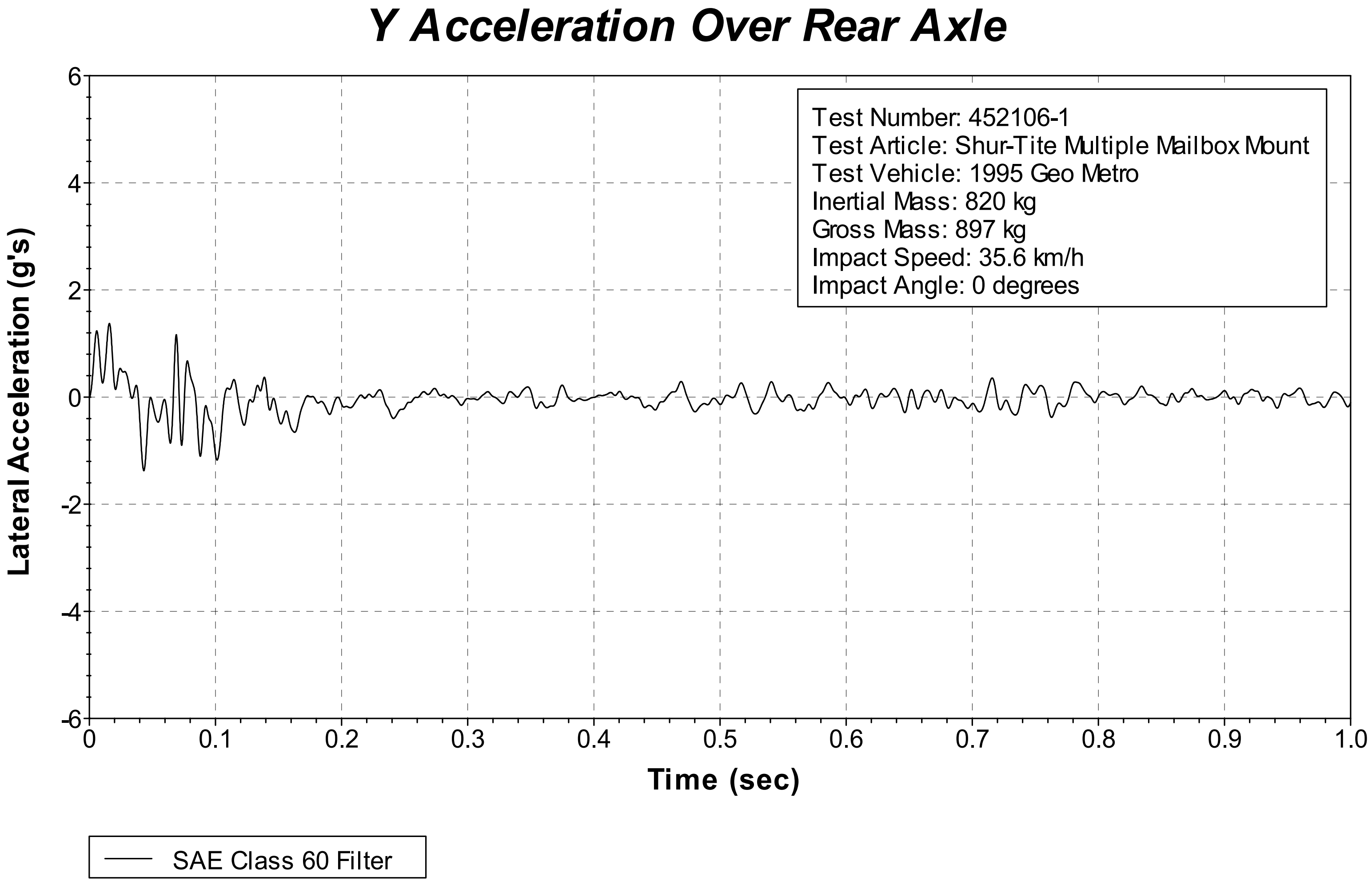


Figure 25. Vehicle Lateral Accelerometer Trace for Test No. 452106-1 (Accelerometer Located Over Rear Axle).

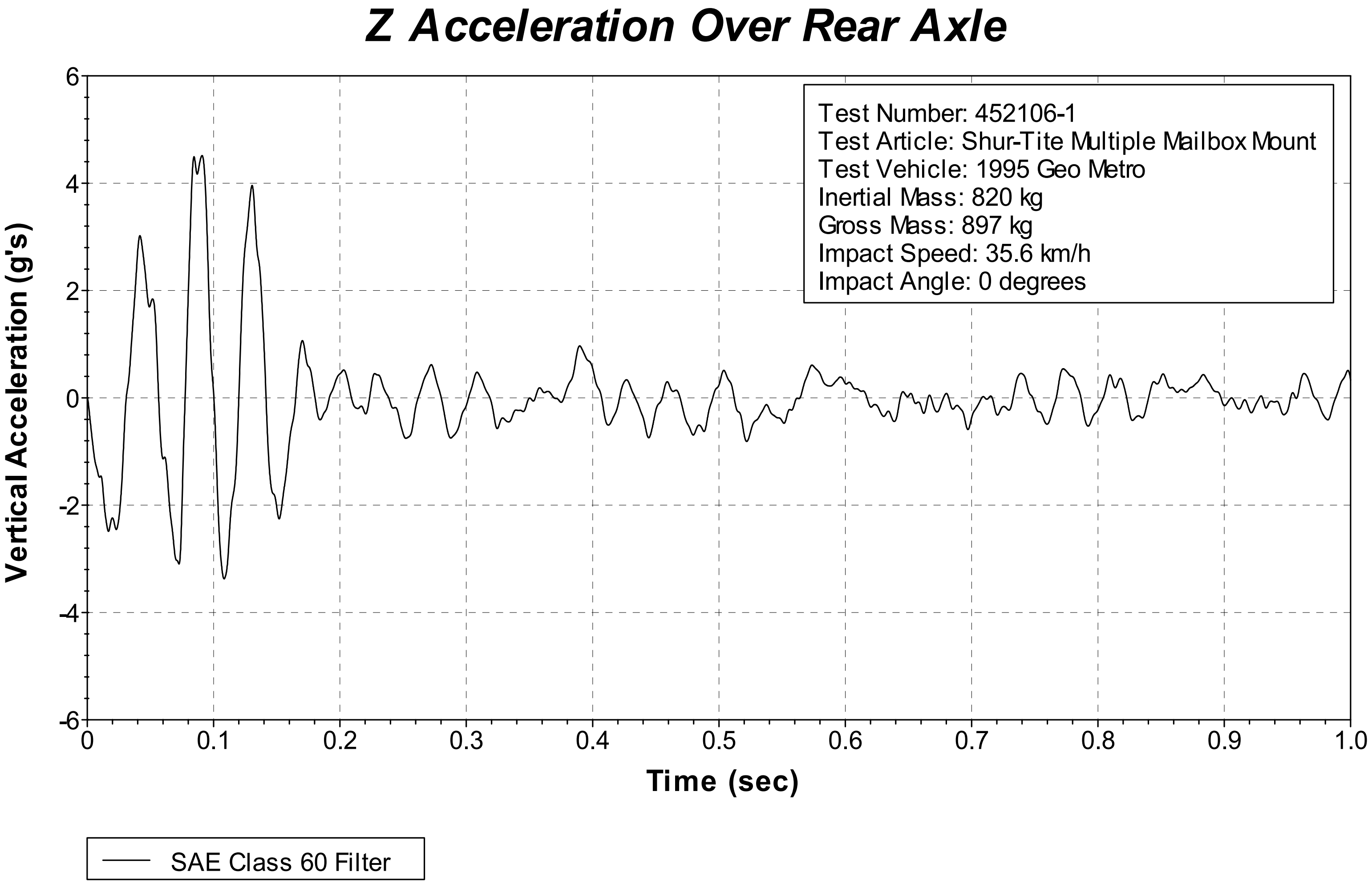


Figure 26. Vehicle Vertical Accelerometer Trace for Test No. 452106-1 (Accelerometer Located Over Rear Axle).

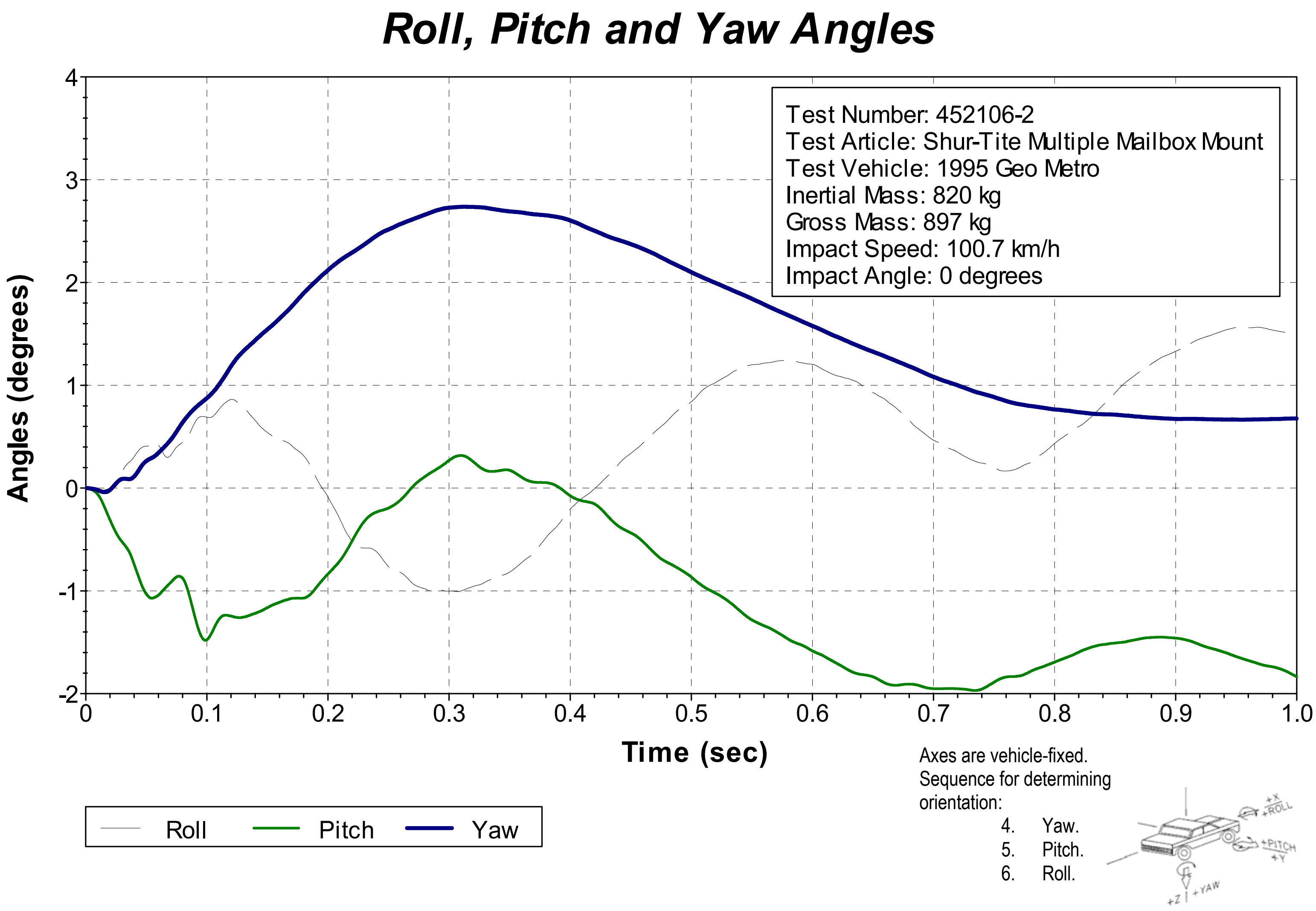


Figure 27. Vehicle Angular Displacements for Test 452106-2.

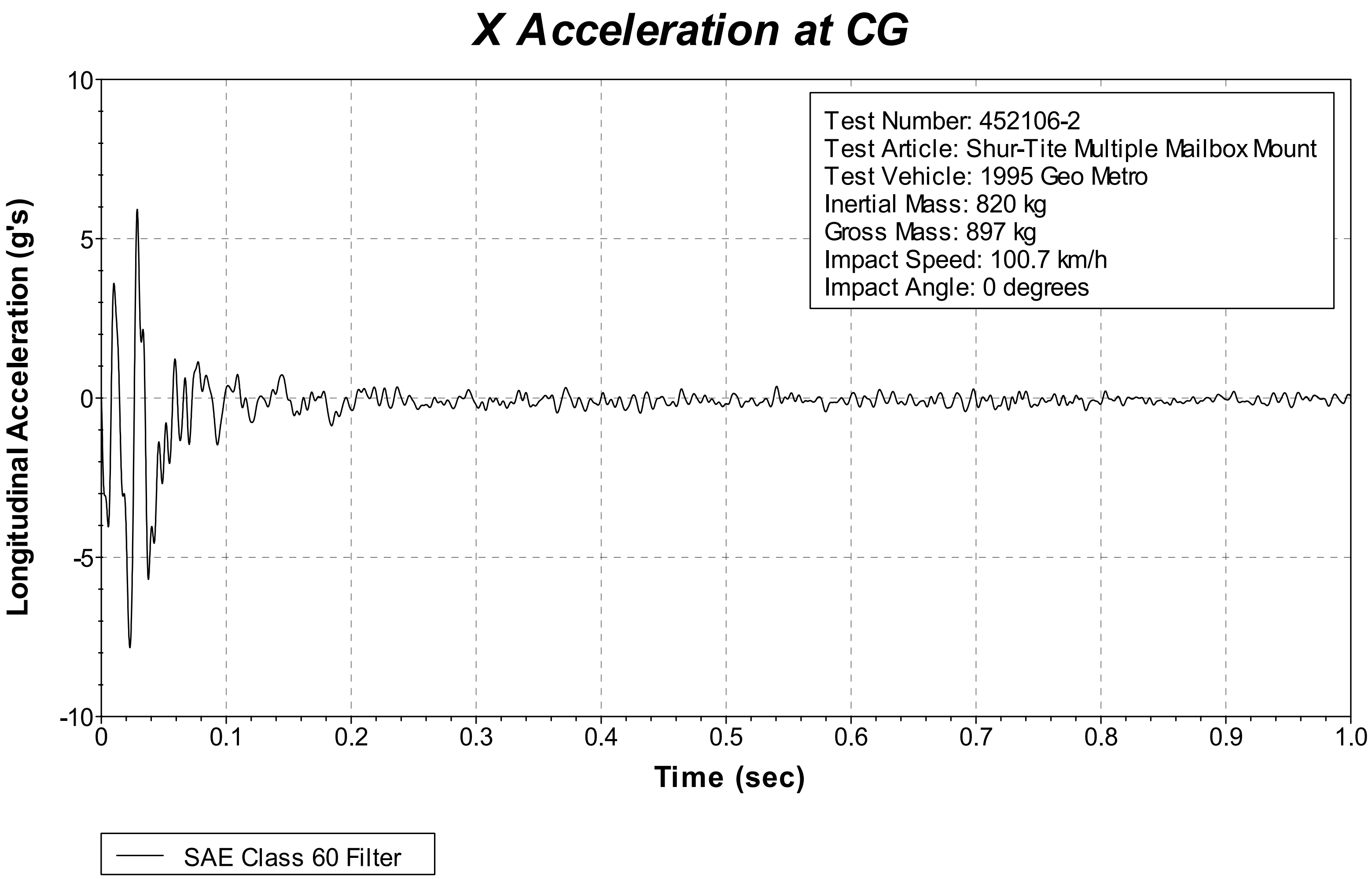


Figure 28. Vehicle Longitudinal Accelerometer Trace for Test 452106-2 (Accelerometer Located at Center of Gravity).

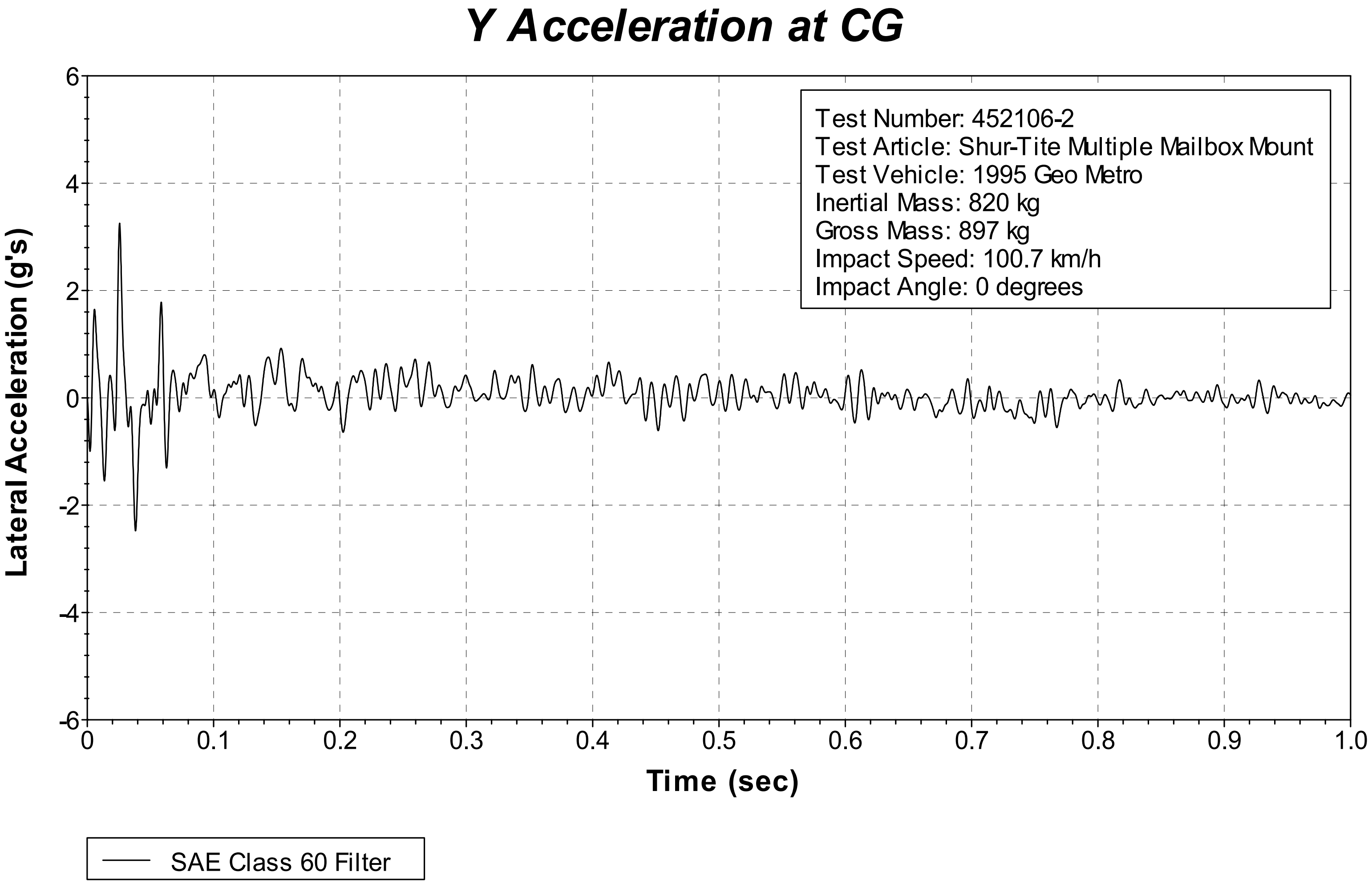


Figure 29. Vehicle Lateral Accelerometer Trace for Test 452106-2 (Accelerometer Located at Center of Gravity).

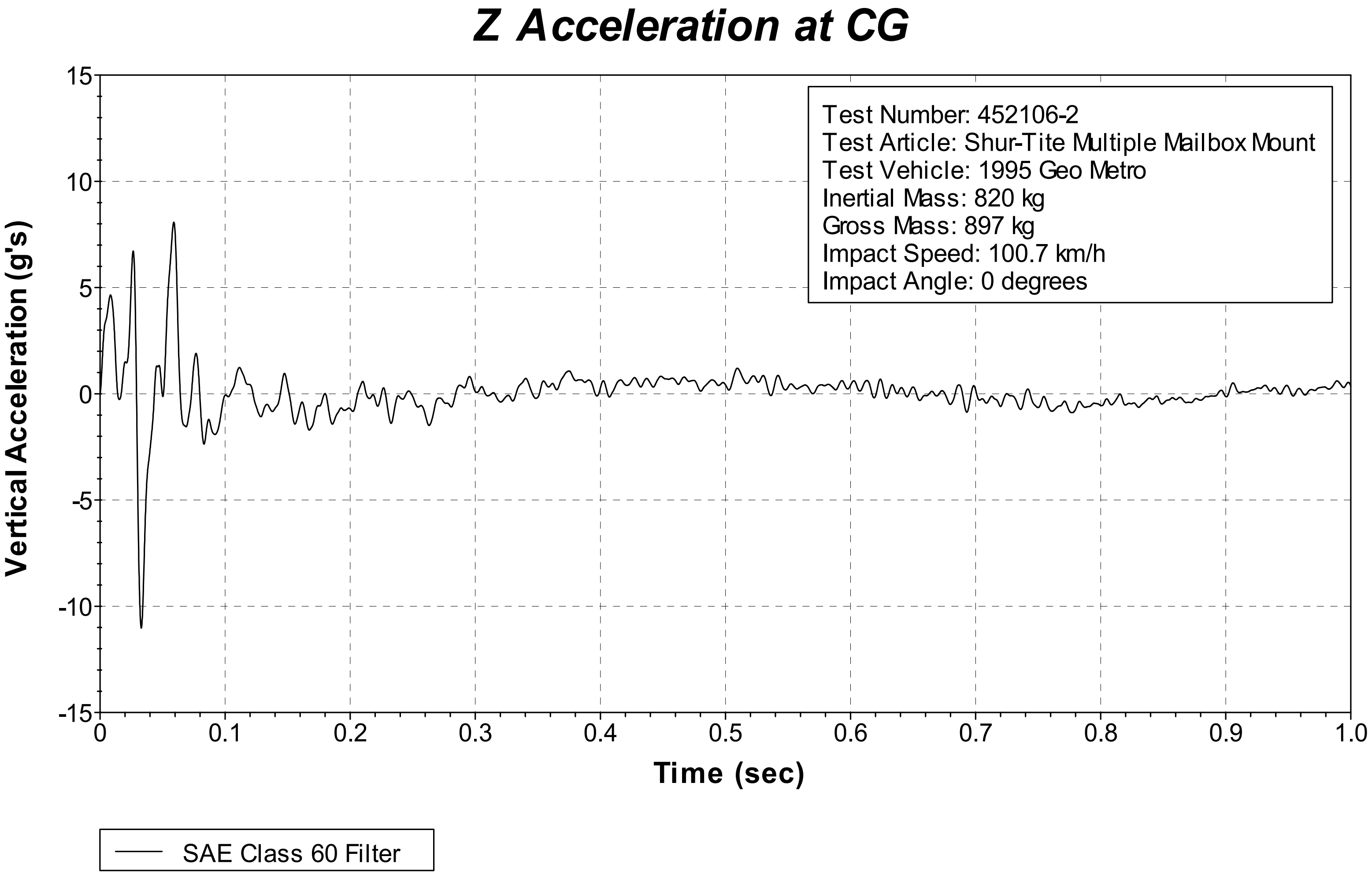


Figure 30. Vehicle Vertical Accelerometer Trace for Test 452106-2 (Accelerometer Located at Center of Gravity).

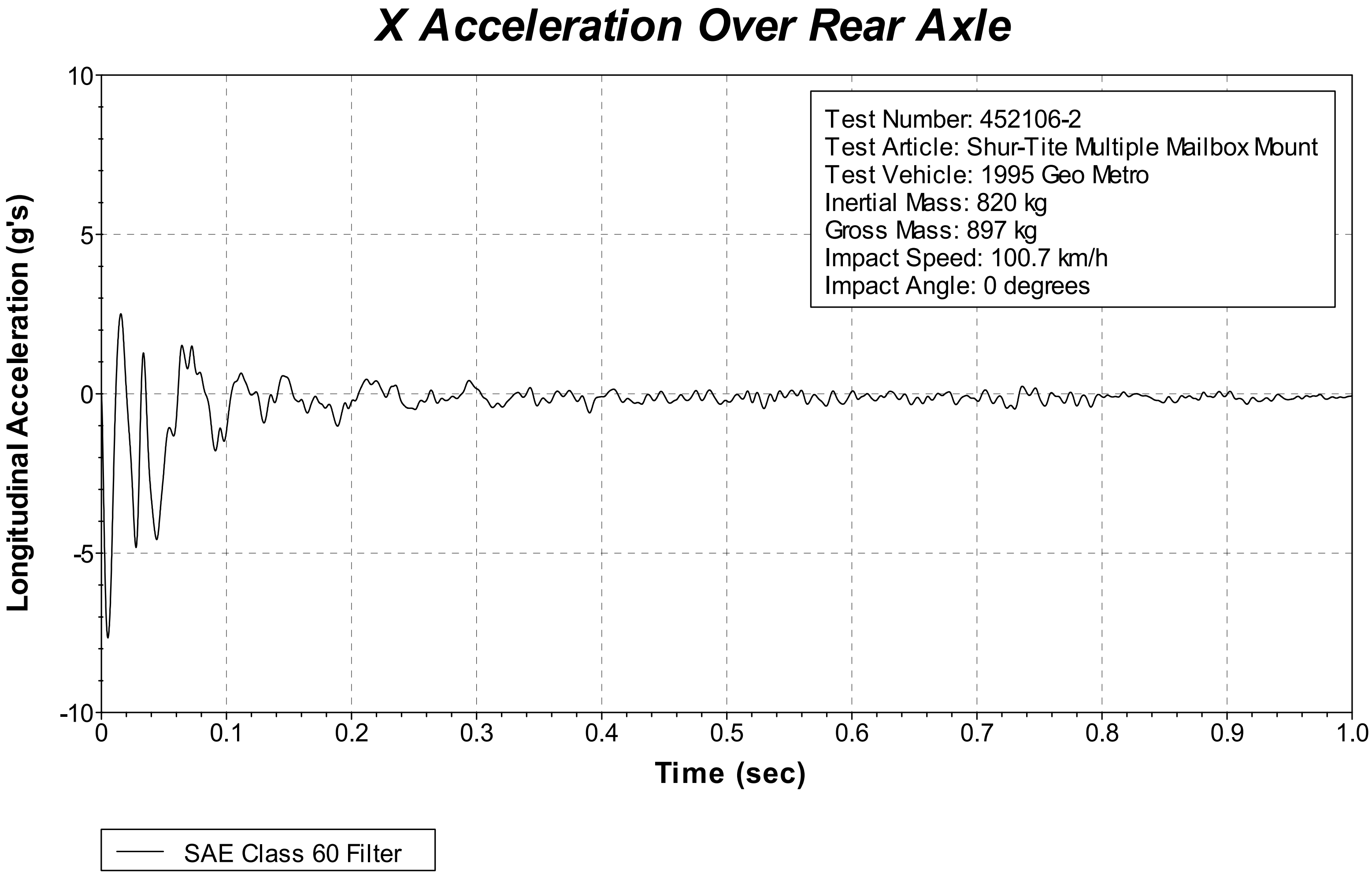


Figure 31. Vehicle Longitudinal Accelerometer Trace for Test 452106-2 (Accelerometer Located Over Rear Axle).

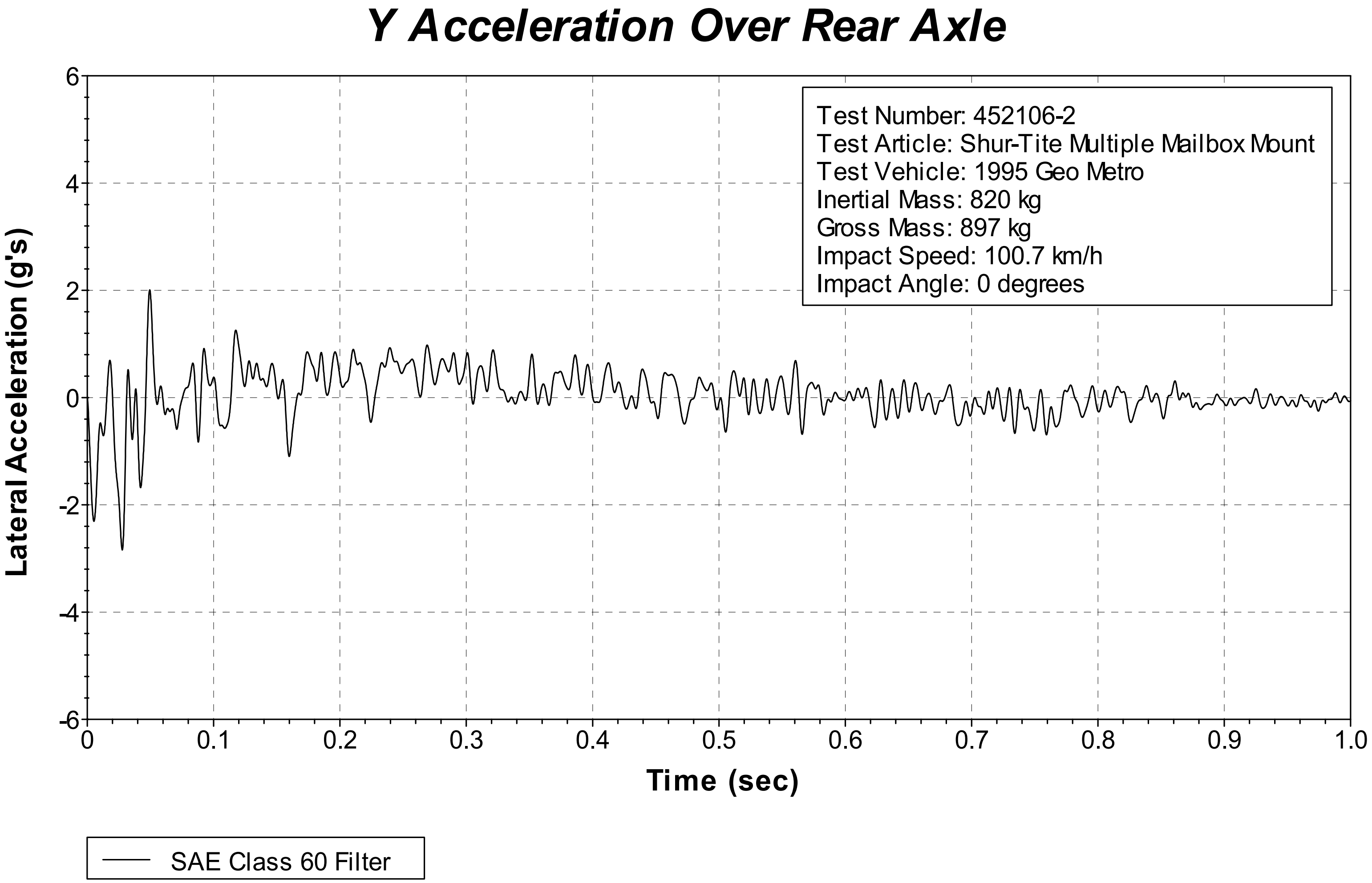


Figure 32. Vehicle Lateral Accelerometer Trace for Test 452106-2 (Accelerometer Located Over Rear Axle).

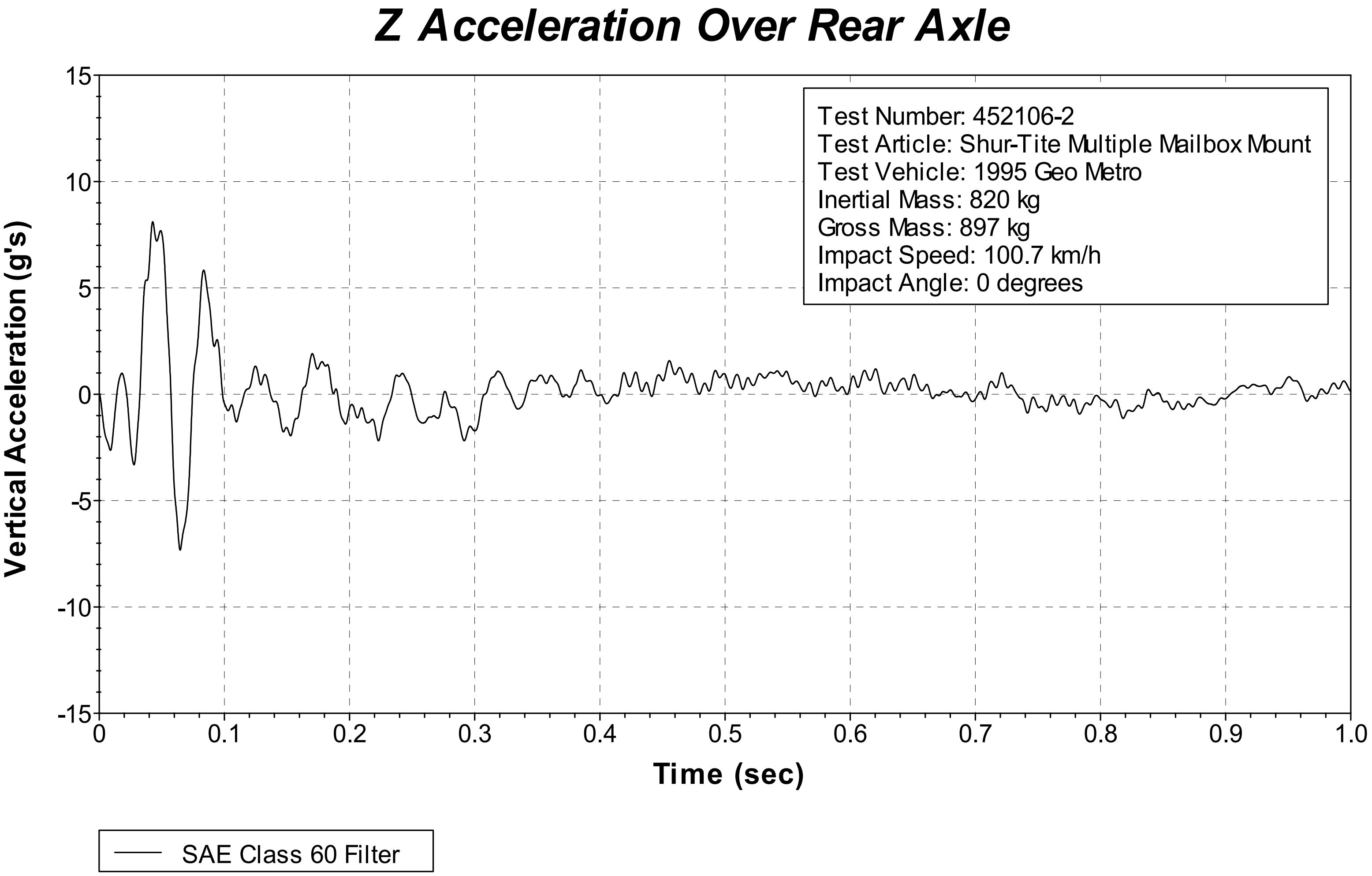


Figure 33. Vehicle Vertical Accelerometer Trace for Test 452106-2 (Accelerometer Located Over Rear Axle).