NCHRP Report 350 Test 3-11 of the Strong Wood Post Thrie Beam Guardrail

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U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

FOREWORD

This report will be of interest to those State and local highway officials who select, locate, and design traffic barriers. It documents the results of a crash test of a strong wood post thrie beam guardrail with a 2000-kg pickup truck impacting at a nominal speed and angle of 100 km/h and 25 degrees. This is the strength test for Test Level Three (TL-3) in NCHRP Report 350. It was found that the test results met all of the evaluation criteria. The pickup truck was smoothly redirected and remained upright.

Detailed drawings are presented for documentation and to facilitate implementation.

Michael F. Trentacoste
Director, Office of Safety
Research and Development

NOTICE

Technical Report Documentation Page

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16. Abstract

Officials at the Federal Highway Administration (FHWA) decided that the strong wood post thrie beam guardrail should be tested to test level three (TL-3). The test performed (test designation 3-11) involves the 2000P (pickup truck) traveling at a nominal speed and angle of 100 km/h and 25 degrees impacting the critical impact point. This test is intended to evaluate the strength of the section in containing and redirecting the pickup truck.

This report presents the details and results of National Cooperative Highway Research Program (NCHRP) Report 350 test designation 3-11 for evaluation of the strong wood post thrie beam to TL-3. The strong wood post thrie beam guardrail met all required criteria for NCHRP Report 350 test designation 3-11.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or “metric ton”)	Mg (or “t”)
		TEMPERATURE		
EF	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	EC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or “t”)	megagrams (or “metric ton”)	1.103	short tons (2000 lb)	T
		TEMPERATURE		
EC	Celcius temperature	1.8C+32	Fahrenheit temperature	EF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

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I. INTRODUCTION

The Federal Highway Administration (FHWA) has recently adopted the new performance evaluation guidelines for roadside safety features set forth in National Cooperative Highway Research Program (NCHRP) Report 350.[1] In addition, FHWA has required that all new roadside safety features to be installed on the National Highway System (NHS) after September 1998 meet the NCHRP Report 350 performance evaluation guidelines. Most of the existing roadside safety features were tested according to the previous guidelines contained in NCHRP Report 230.[2] Testing existing roadside safety features to evaluate how they would perform under the new guidelines is, therefore, necessary.

Officials at FHWA decided that the strong wood post thrie beam guardrail should be tested to test level three (TL-3). The test performed (test designation 3-11) involves the 2000P (pickup truck) traveling at a nominal speed and angle of 100 km/h and 25 degrees impacting the critical impact point. This test is intended to evaluate the strength of the section in containing and redirecting the pickup truck.

This report presents the details and results of NCHRP Report 350 test designation 3-11 for evaluation of the strong wood post thrie beam to TL-3. The strong wood post thrie beam guardrail met all required criteria for NCHRP Report 350 test designation 3-11.

II. STUDY APPROACH

TEST ARTICLE

The strong wood post thrie beam guardrail system consisted of 1.98-m-long, 150-mm by 200-mm wood posts spaced 1.9 m apart with 150-mm by 200-mm by 554-mm blockouts. A cross-section of the strong wood post thrie beam guardrail system is shown in figure 1. The blockout and rail element were attached to each post with two 16-mm-diameter button head bolts without a washer under the head. One flat washer was used under the nut. The mounting height of the thrie beam rail was 550 mm to the center and 804 mm to the top of the thrie beam rail element.

The test installation consisted of a 45.7-m-long length-of-need section of strong wood post thrie-beam guardrail with a 1.9-m-long transition section from the thrie beam to the W-beam rail element, and a 15.2-m-long ET-2000 at each end, for a total installation length of 80.0 m. The details and layout of the test installation are shown in figure 1. Photographs of the completed test installation are shown in figure 2.

CRASH TEST CONDITIONS

According to NCHRP Report 350, two crash tests are required for evaluation of longitudinal barriers to test level three (TL-3):

NCHRP Report 350 test designation 4-10: An 820-kg passenger car impacting the critical impact point (CIP) in the length of need (LON) of the longitudinal barrier at a nominal speed and angle of 100 km/h and 20 degrees. The purpose of this test is to evaluate the overall performance of the LON section in general, and occupant risks in particular.

NCHRP Report 350 test designation 4-11: A 2000-kg pickup truck impacting the CIP in the LON of the longitudinal barrier at a nominal speed and angle of 100 km/h and 25 degrees. The test is intended to evaluate the strength of the section in containing and redirecting the pickup truck.

The test reported herein (test 404211-11) corresponds to NCHRP Report 350 test designation 3-11. The CIP for this test was determined using information contained in NCHRP Report 350 and accordingly was determined to be the midpoint of the span between posts 15 and 16 of the strong wood post thrie beam guardrail.

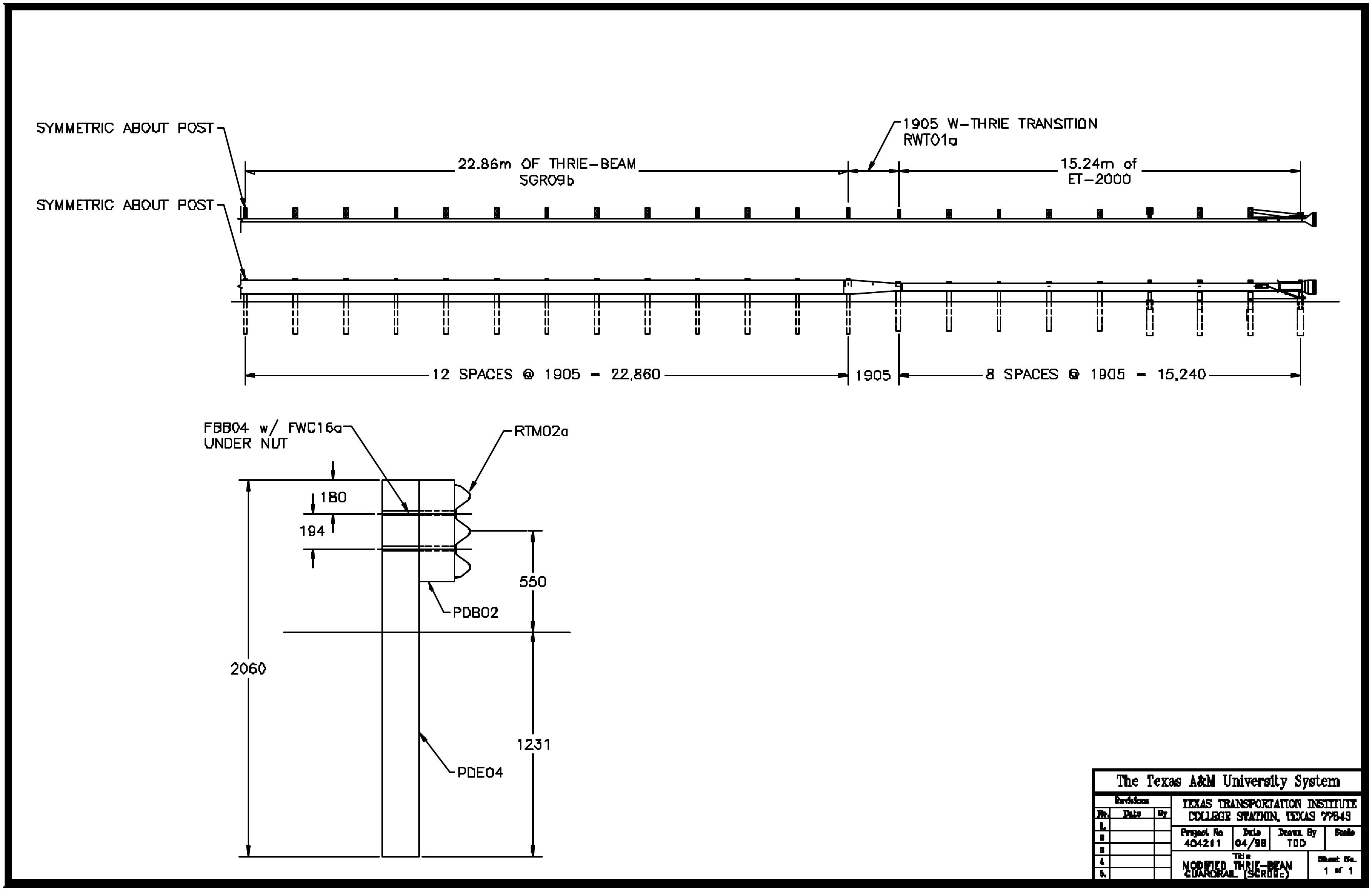


Figure 1. Details of the Strong Wood Post Thrie Beam guardrail installation.

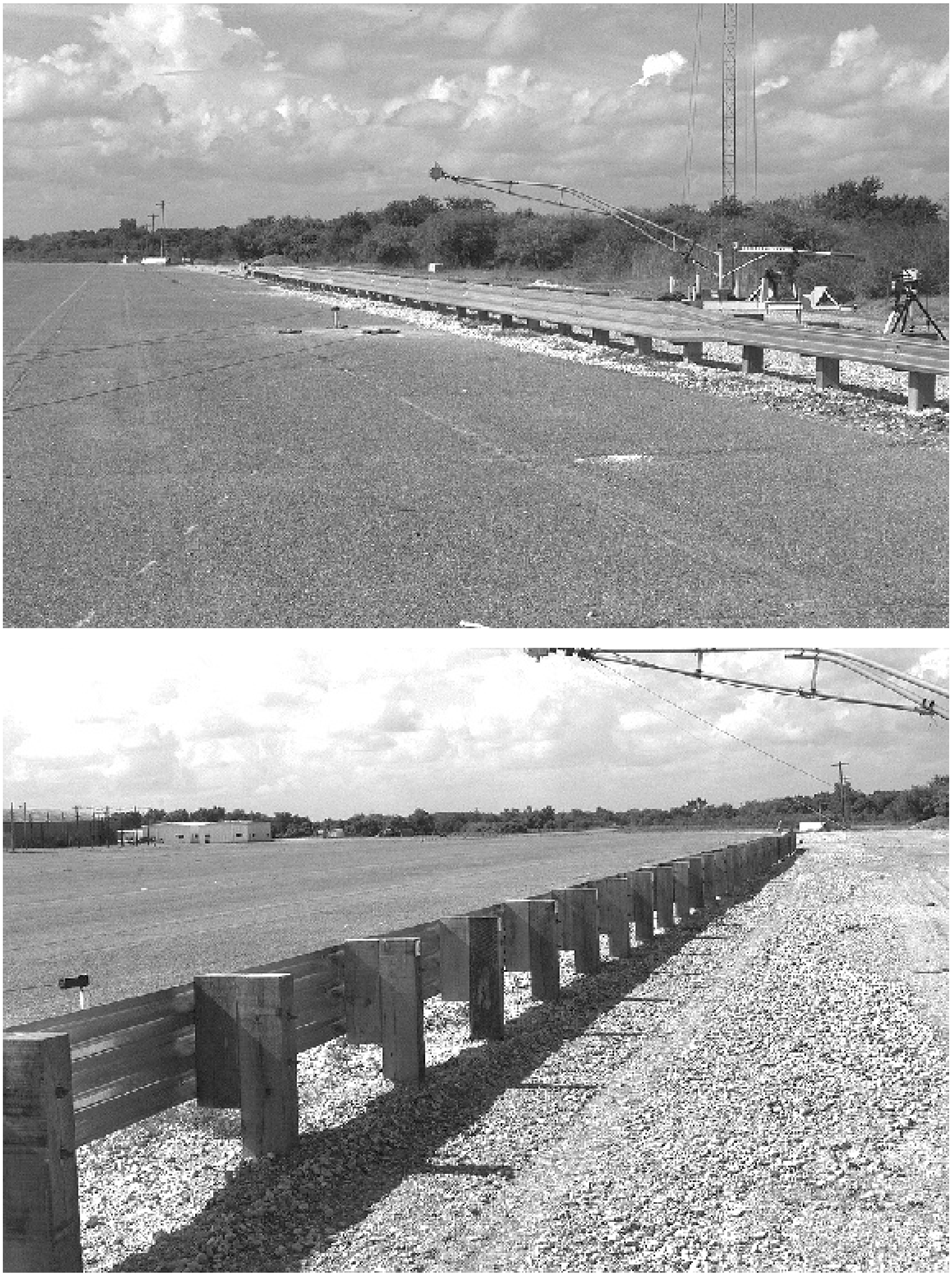


Figure 2. Strong Wood Post Thrie Beam Guardrail installation before test 404211-11.

EVALUATION CRITERIA

The crash test performed was evaluated in accordance with the criteria presented in 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, the following safety evaluation criteria from table 5.1 of NCHRP Report 350 were used to evaluate the crash test reported herein:

- **Structural Adequacy**

  A. Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation, although controlled lateral deflection of the test article is acceptable.

- **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.

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

- **Vehicle Trajectory**

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

  L. The occupant impact velocity in the longitudinal direction should not exceed 12 m/s and the occupant ridedown acceleration in the longitudinal direction should not exceed 20 g's.

  M. The exit angle from the test article preferably should be less than 60 percent of the test impact angle, measured at time of vehicle loss of contact with the test device.

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 to measure longitudinal, lateral, and vertical acceleration levels; and a triaxial accelerometer over the rear axle of the vehicle to measure longitudinal, lateral, and vertical acceleration levels. The accelerometers were strain-gauge type with a linear millivolt output proportional to acceleration.

The electronic signals from the accelerometers and transducers were transmitted to a base station by means of constant bandwidth FM/FM telemetry link for recording on magnetic tape and for display on a real-time strip chart. Calibration signals were recorded before and after the test, and an accurate time reference signal was simultaneously recorded with the data. Pressure- sensitive switches on the bumper of the impacting vehicle were actuated just 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 produced an “event” mark on the data record to establish the exact instant of contact with the installation.

The multiplex of data channels, transmitted on one radio frequency, was received at the data acquisition station, and demultiplexed into separate tracks of Inter-Range Instrumentation Group (I.R.I.G.) tape recorders. After the test, the data were played back from the tape machines, filtered with an SAE J211 filter, and digitized using a microcomputer for analysis and evaluation of impact performance.

The test vehicle was instrumented with five uniaxial accelerometers mounted in the following locations: (1) center top surface of the instrument panel; (2) inside end of right front wheel spindle; (3) inside end of left front wheel spindle; (4) top of engine block; and (5) bottom of engine block. The exact location of each accelerometer was measured and is reported in table 1. These accelerometers were ENDEVCO Model 7264A low-mass piezoresistive accelerometers with a ±2000-g range.

Table 1. Locations of vehicle accelerometers for test 404211-11.

Location	X (mm) (distance from front axle)	Y (mm) (distance from centerline)	Z (mm) (distance from ground)	Data Axis
Instrument panel	-690	0	-1270	+X
Right front brake caliper	0	+720	-350	-Y
Left front brake caliper	0	-720	-350	+X
Top of engine block	+90	0	-865	+X
Bottom of engine block	-270	-50	-320	+X
Vehicle c.g.	-1380	0	-670	+X,+Y,+Z
Vehicle rear axle	-3320	0	-855	+X,+Y,+Z

*Reference point: X=0 at front axle Y=0 at centerline Z=0 at ground
Sign convention: +X=forward +Y=right +Z=down

The data from these uniaxial accelerometers were captured using a Prosig P4000 data acquisition system. The P4000 is a modular, distributed data acquisition system based on independent data collection elements called PODs. Each POD has four high-speed analog, three digital, and time-zero inputs. The PODs sample synchronously at up to 10,000 samples per second, per channel, with 12-bit resolution. The nonvolatile memory holds up to 13 s at the maximum data rate. Analog inputs have integral, strain-gauge accelerometer signal conditioning and anti-aliasing filters. Each channel has a fully programmable amplifier and input offset adjustment. After extracting the data from the POD units to the host computer, fourth-order Bessel digital filtering is used to produce SAE J211 data for processing. Data capture is started by a trigger pulse from a bumper switch or a predefined g level. Twenty-five percent of the captured data is prior to the trigger signal.

The digitized data were then processed using two computer programs: DIGITIZE and PLOTANGLE. Brief descriptions of the functions of these two computer programs are provided as follows:

The DIGITIZE program uses digitized data from vehicle-mounted linear accelerometers to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-ms average ridedown acceleration. The DIGITIZE program also calculates a vehicle impact velocity and the change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers were then filtered with a 60-Hz digital filter and acceleration versus time curves for the longitudinal, lateral, and vertical directions were plotted using a commercially available software package (Excel 97).

The PLOTANGLE program used the digitized data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.00067-s intervals and then instructed a plotter to draw a reproducible plot: 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 system being that which existed at 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 not instrumented.

Photographic Instrumentation and Data Processing

Photographic coverage of the test included three high-speed cameras: one overhead with a field of view perpendicular to the ground and directly over the impact point; one placed behind the installation at an angle; and a third placed to have a field of view parallel to and aligned with the installation at the downstream end. 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 Betacam, a VHS-format video camera and recorder, and still cameras were used to record and document the condition of the test vehicle and installation before and after the test.

Test Vehicle Propulsion and Guidance

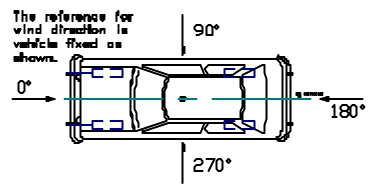
The test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable 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 brakes on the vehicle were activated to bring it to a safe and controlled stop.

III. CRASH TEST RESULTS

TEST 404211-11 (NCHRP Report 350 Test No. 3-11)

A 1993 Chevrolet 2500 pickup truck, shown in figures 3 and 4, was used for the crash test. Test inertia weight of the vehicle was 2000 kg, and its gross static weight was 2075 kg. The height to the lower edge of the vehicle bumper was 370 mm and it was 600 mm to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in figure 5. 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.

The test was performed on the morning of July 3, 1998. A total of 10 mm of rain occurred 4 days before the test. No other rain occurred during the 10 days prior to the test. Moisture content at posts 16, 18, and 20 was 7.7%, 9.7%, and 9.6%, respectively. Weather conditions during the time of the test were as follows: Wind Speed: 0 km/h; Wind Direction: N/A (vehicle was traveling in a southwesterly direction); Temperature: 33EC; Relative Humidity: 82 percent.



Test Description

The vehicle, traveling at 99.6 km/h, impacted the strong wood post thrie beam guardrail 609 mm before post 16 at an impact angle of 23.6 degrees. Shortly after impact, posts 16 and 15 moved, followed by movement in the thrie beam element, and then movement at post 17 at 0.017 s. The vehicle contacted post 16 at 0.030 s and the vehicle redirected at 0.048 s. Post 18 moved at 0.083 s, and post 19 moved shortly after. The front of the vehicle contacted post 17 at 0.094 s and the right front tire impacted post 17 at 0.115 s, which caused the post to fracture just below ground level. At 0.144 s, post 20 moved and at 0.165 s, the vehicle contacted post 18. The right front tire impacted post 18 at 0.205 s, which caused the post to split along the longitudinal axis. The rear of the vehicle contacted the thrie beam rail element at 0.197 s. At 0.238 s, the vehicle was traveling parallel with the guardrail at a speed of 75.8 km/h. The front of the vehicle contacted post 19 at 0.257 s and the front of the vehicle lost contact with the rail element at 0.314 s. The vehicle lost contact with the rail at 0.511 s and was traveling at an exit speed of 73.6 km/h and an exit angle of 14.7 degrees. The vehicle immediately steered back into the rail and contacted the guardrail again at post 41 at 2.802 s. The vehicle rode off the end of the terminal and rotated counterclockwise. Brakes on the vehicle were not applied. The vehicle subsequently came to rest 68.6 m down and 1.8 m behind the installation. Sequential photographs of the test period are shown in figures 6 and 7.

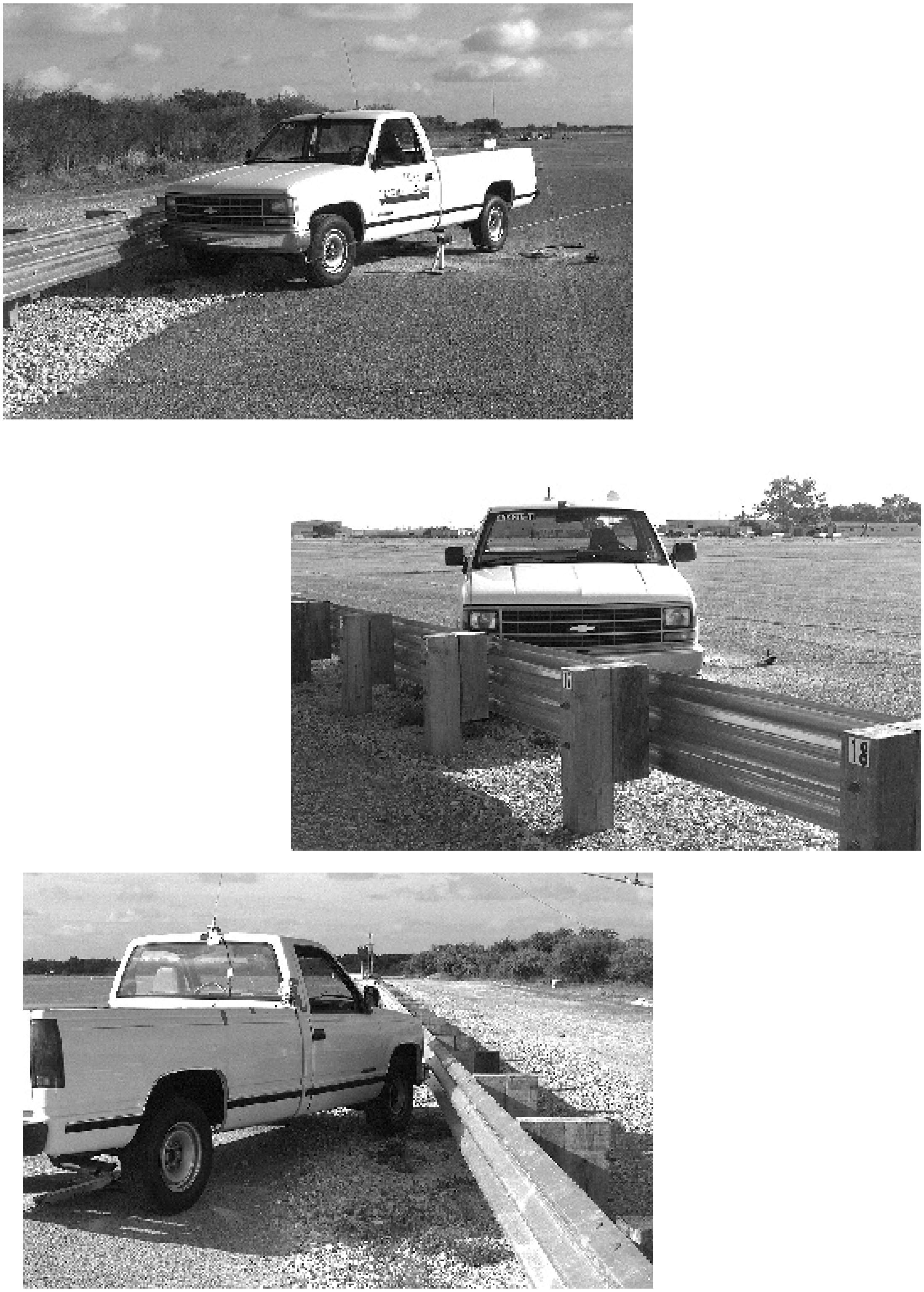


Figure 3. Vehicle/installation geometrics for test 404211-11.

Figure 4. Vehicle before test 404211-11.

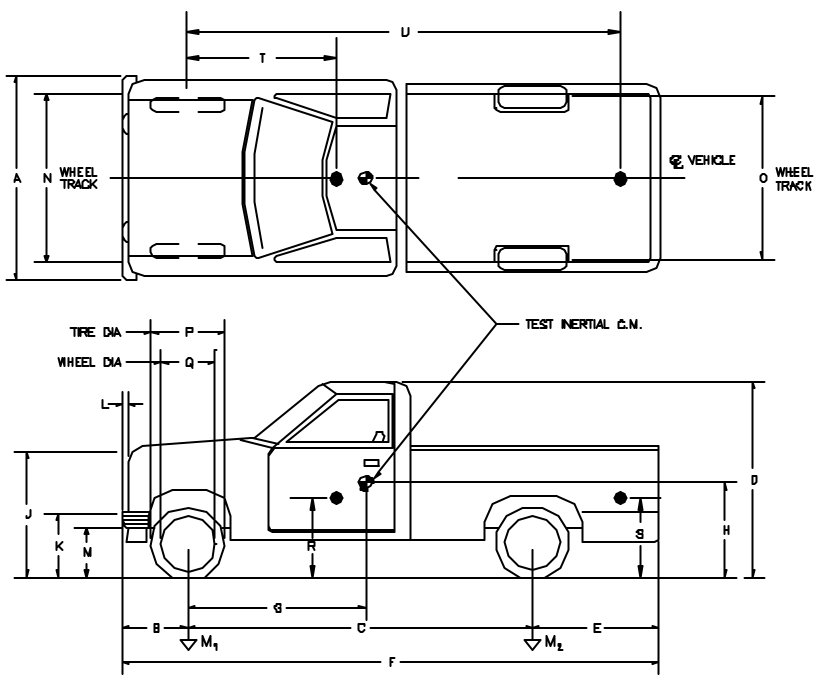
DATE: 7-3-98 TEST NO.: 404211-11 VIN NO.: 1GCFG24KET2169844

YEAR: 1993 MAKE: Chevrolet MODEL: 2500 Pickup Truck

TIRE INFLATION PRESSURE: ________ ODOMETER: 162202 TIRE SIZE: LT 245 75R16

MASS DISTRIBUTION (kg) LF 551 RF 519 LR 468 RR 462

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



● Denotes accelerometer location.

NOTES:

ENGINE TYPE: 8 CYL

ENGINE CID: 5.7 L

TRANSMISSION TYPE:

X AUTO

__ MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: 50th percentile male

MASS: 75 kg

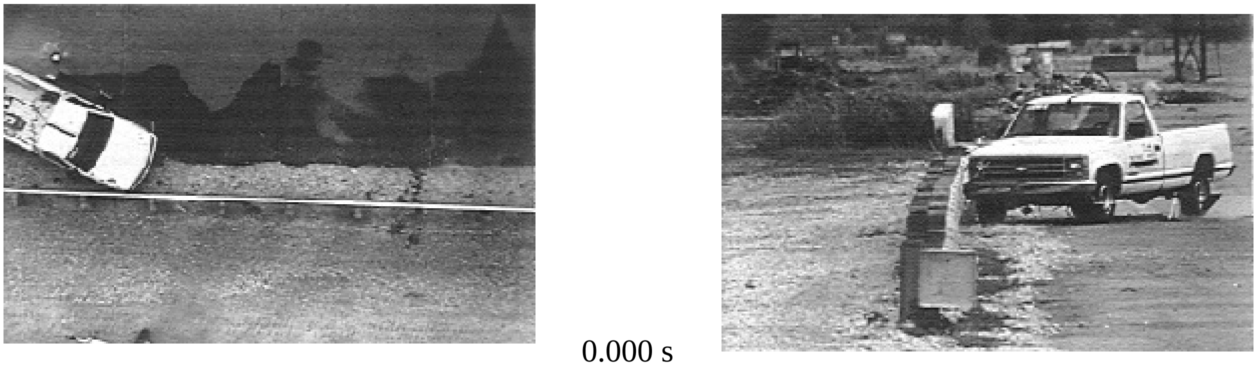
SEAT POSITION: Driver

GEOMETRY – (mm)

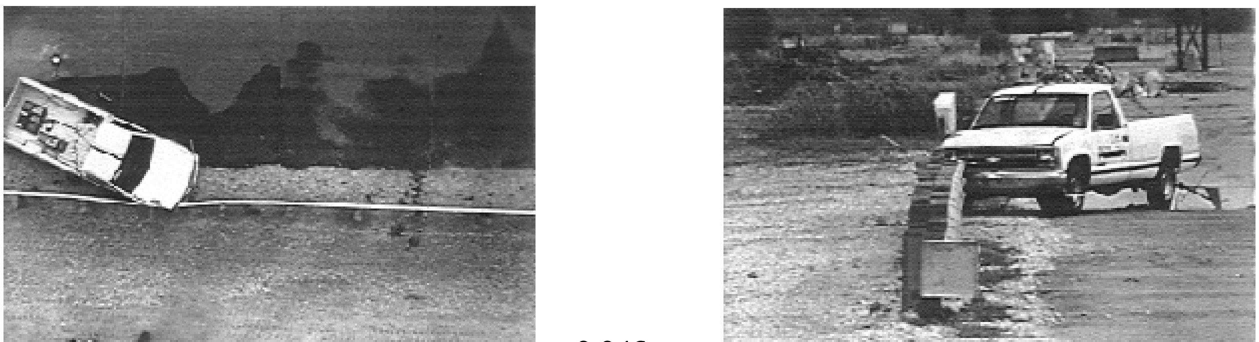
A	1900	E	1330	J	1040	N	1575	R	650
B	785	F	5465	K	600	O	1615	S	860
C	3350	G	1557.8	L	70	P	730	T	1500
D	1790	H		M	370	Q	440	U	3350

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	1092	1070	1118
M_2	769	930	957
M_T	1861	2000	2075

Figure 5. Vehicle properties for test 404211-11.

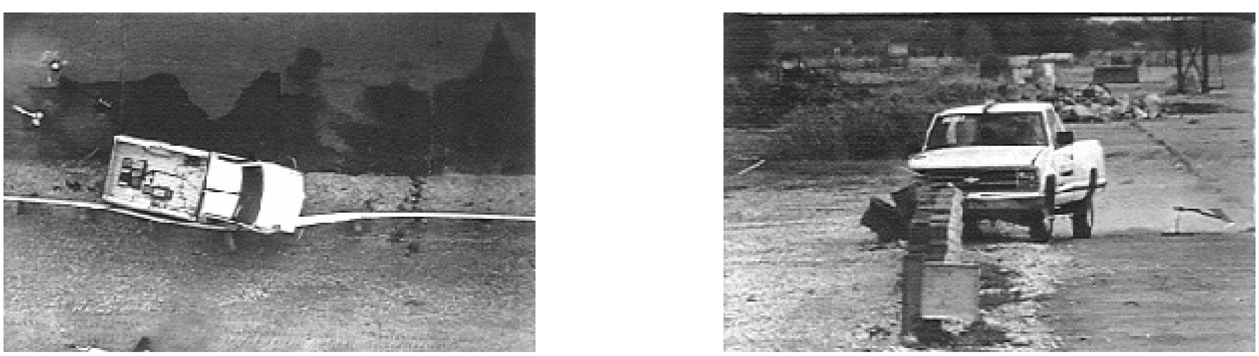


0.000 s



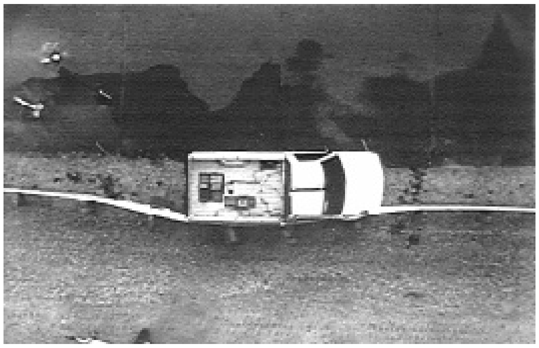
0.046 s

0.103 s

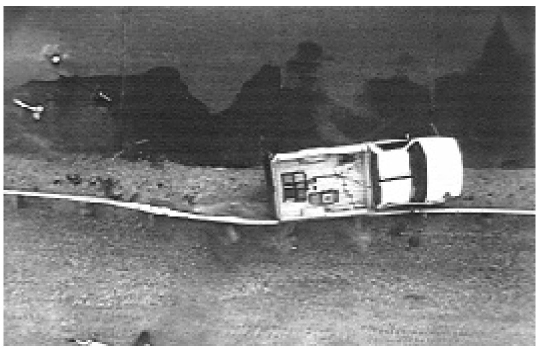


0.172 s

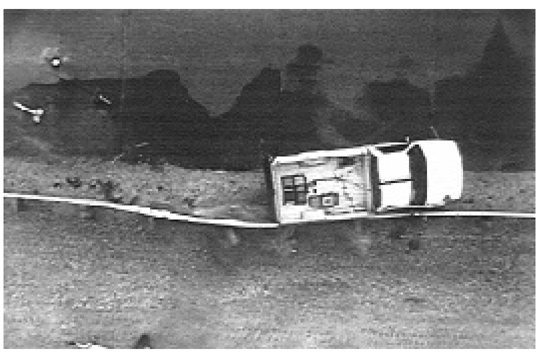
Figure 6. Sequential photographs for test 404211-11 (overhead and frontal views).



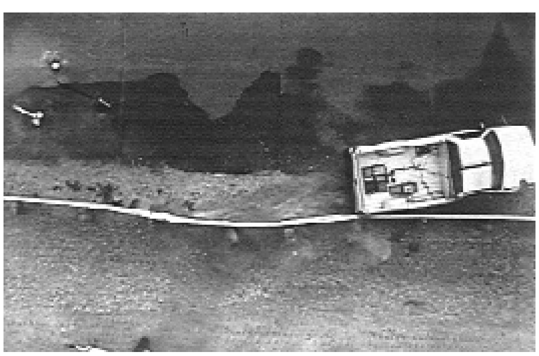

0.275 s




0.390 s




0.505 s




0.642 s

Figure 6. Sequential photographs for test 404211-11
(overhead and frontal views) (continued).

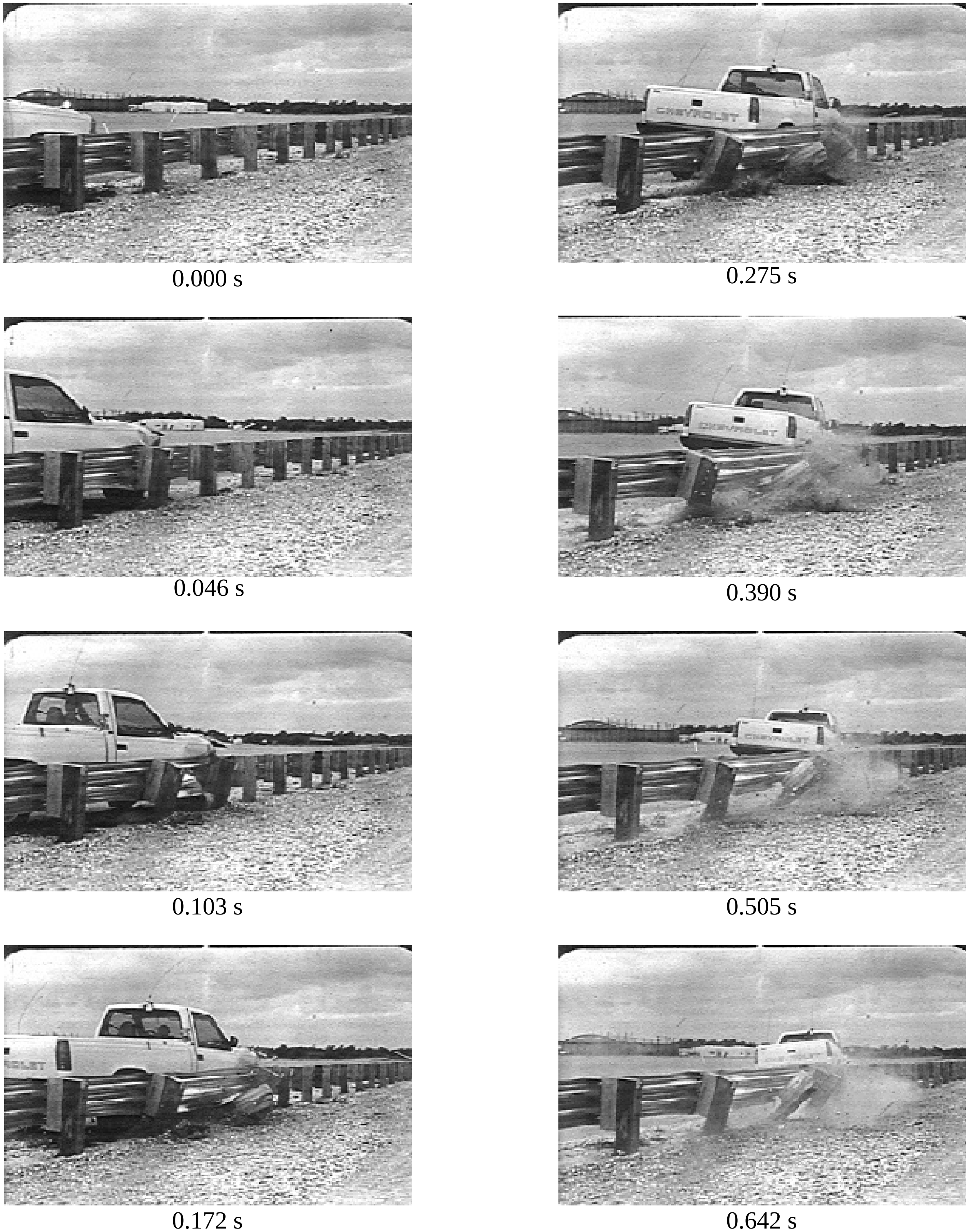


Figure 7. Sequential photographs for test 404211-11
(rear view).

Damage to Test Installation

Damage to the strong wood post thrie beam guardrail is shown in figures 8 and 9. Post 17 fractured just below ground level and post 18 split along the longitudinal axis. As shown in figure 10, the bolts pulled out of the rail element at posts 17 and 18. The ET-2000 end terminal on the downstream end was disturbed as were posts 6 through 14. Posts 15 through 20 were pushed back with a maximum displacement of 110 mm at post 16. Maximum dynamic deflection of the guardrail was 676 mm and the maximum permanent deformation was 390 mm between posts 16 and 17. Total length of contact during the initial impact was 6.3 m. The vehicle contacted the installation again at post 40 and rode off the end (post 43).

Vehicle Damage

The bumper, hood, grill, fan, radiator, right front tire and wheel, right door, right front and rear quarter panels, and left door were damaged and the windshield was shattered as shown in figure 11. Structural damage included the right upper and lower A-arms, right spindle and rod ends, stabilizer bar, right front frame, firewall, and floor pan. Maximum exterior crush to the vehicle was 470 mm at the right front corner of the bumper. Maximum occupant compartment deformation was 30 mm (32% reduction of space) in the center floor pan area under the instrument panel. The interior of the vehicle is shown in figure 12. Exterior crush measurements and occupant compartment measurements are shown in tables 2 and 3.

Occupant Risk Values

Data from the tri-axial accelerometer, located at the vehicle center of gravity, were digitized to compute occupant impact velocity and ridedown accelerations. The occupant impact velocity and ridedown accelerations in the longitudinal axis only are required from these data for evaluation of criterion L of NCHRP Report 350. In the longitudinal direction, the occupant impact velocity was 6.3 m/s at 0.198 s, the highest 0.010-s occupant ridedown acceleration was -8.4 g's from 0.223 to 0.233 s, and the maximum 0.050-s average acceleration was -5.5 g's between 0.082 and 0.132 s. In the lateral direction, the occupant impact velocity was 5.6 m/s at 0.130 s, the highest 0.010-s occupant ridedown acceleration was -9.0 g's from 0.202 to 0.212 s, and the maximum 0.050-s average was -5.8 g's between 0.068 and 0.118 s. These data and other pertinent information from the test are summarized in figure 12. Vehicle angular displacements are displayed in figure 13. Vehicular accelerations versus time traces are presented in figures 14 through 25.

Figure 8. After-impact trajectory for test 404211-11.

Figure 9. Installation after test 404211-11.

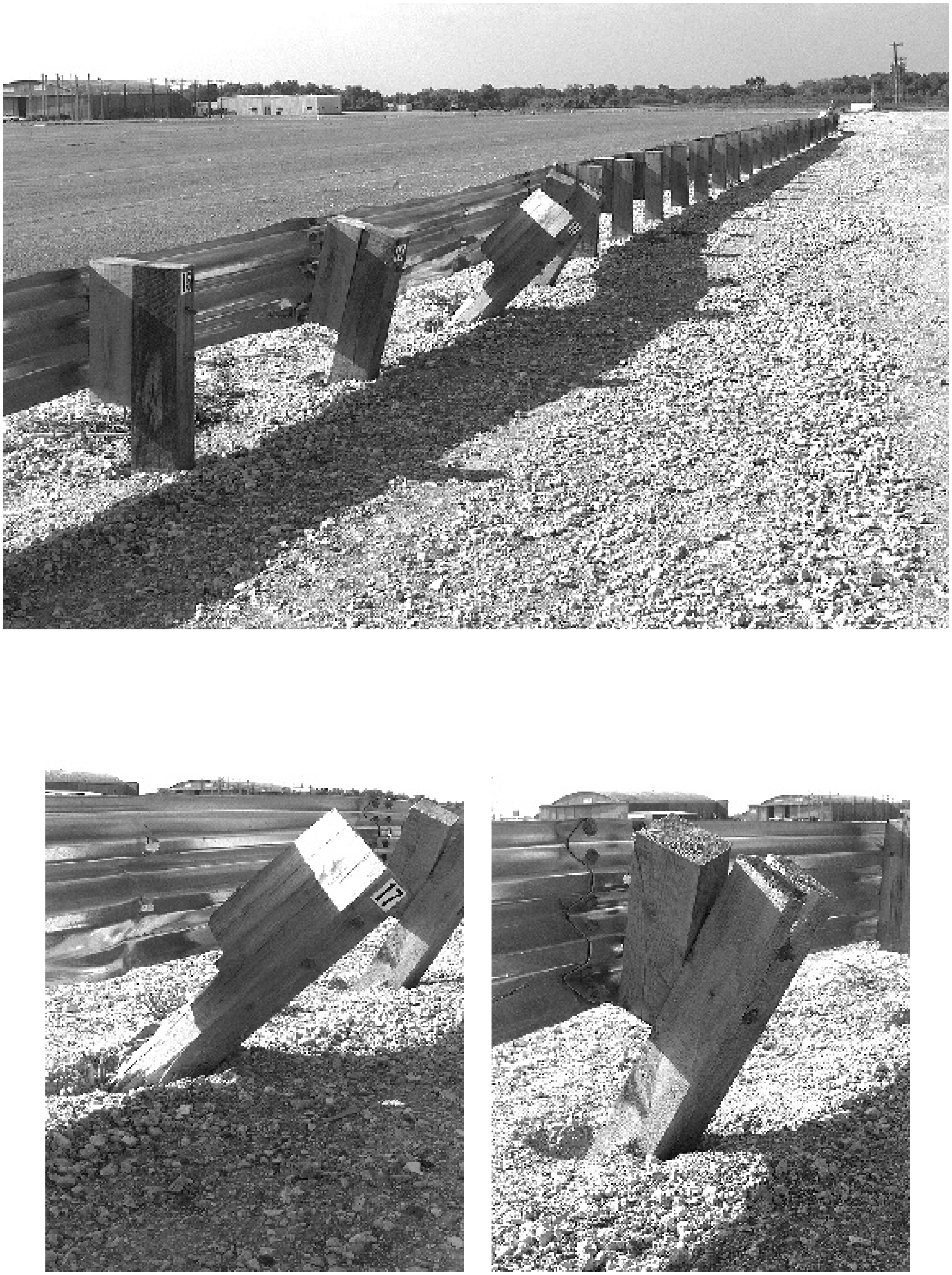


Figure 10. Posts 17 and 18 after test 404211-11.

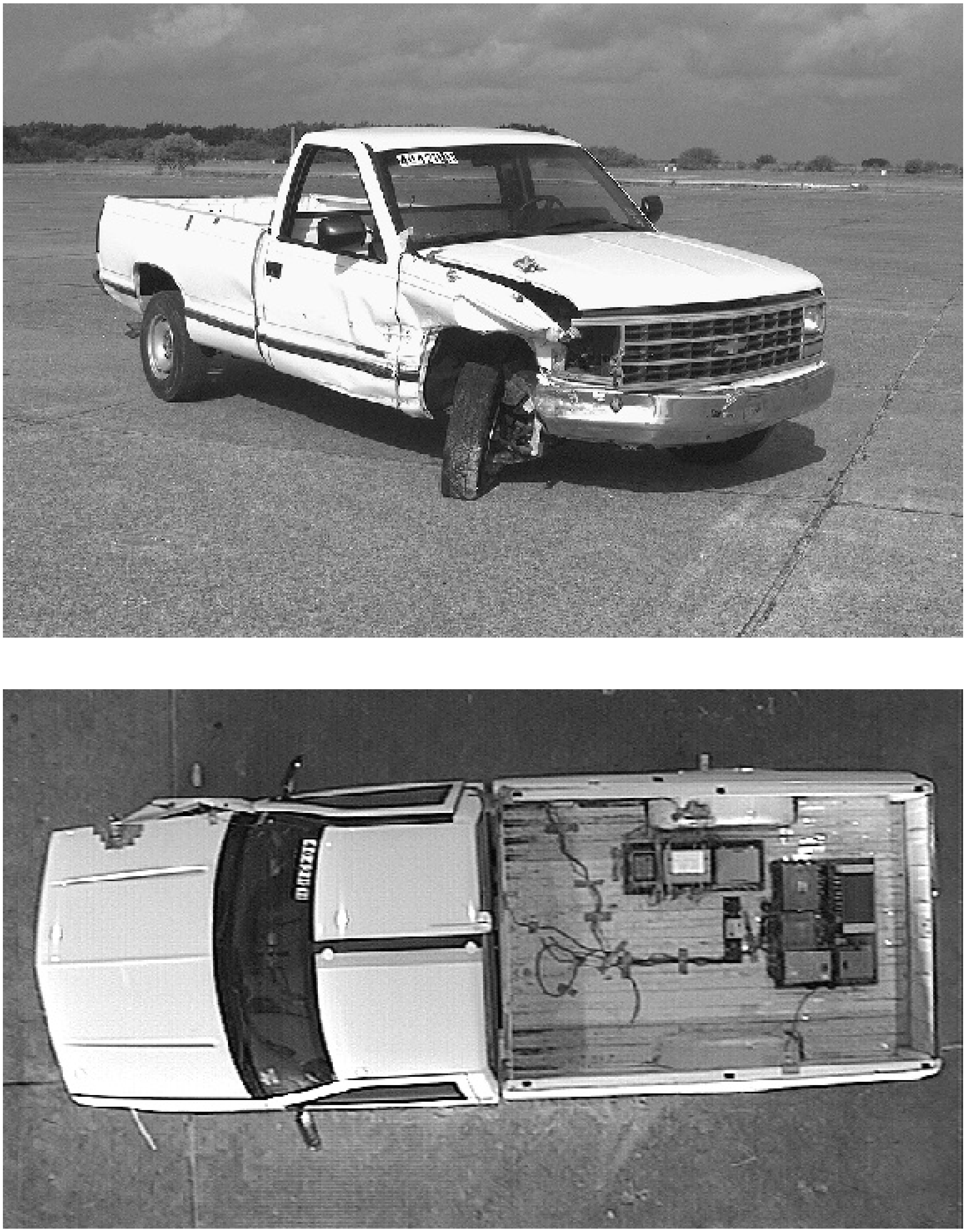


Figure 11. Vehicle after test 404211-11.

Before test

After test

Figure 12. Interior of vehicle for test 404211-11.

Table 2. Exterior crush measurements for test 404211-11.

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 C1 to C6 from Driver to Passenger side in Front or Rear impacts–
Rear to Front in Side impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width ** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	Top front bumper	800	470	660	0	70	120	180	290	470	+330
2	Top front wheel well	800	300	2150	0	15	30	85	60	300	+1130

[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).

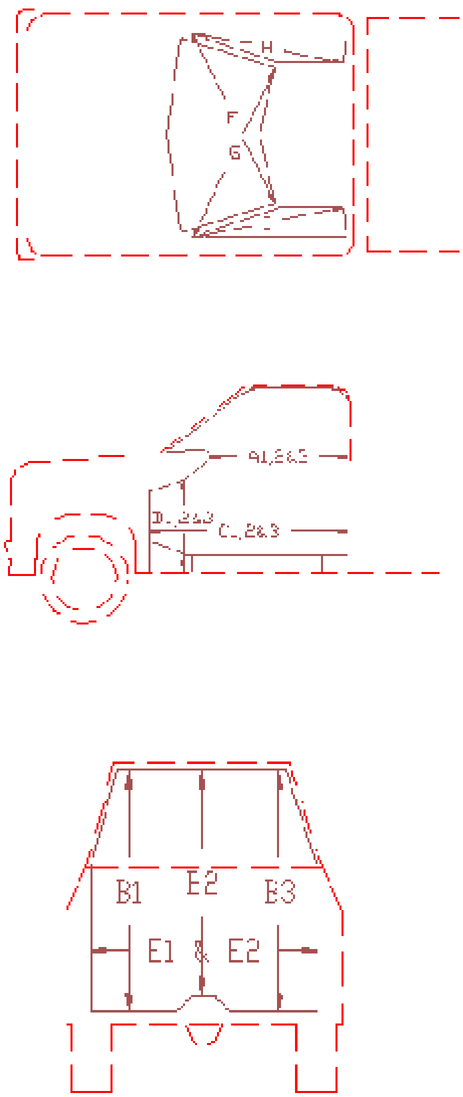
***Measure and document on the vehicle diagram the location of the maximum crush.

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

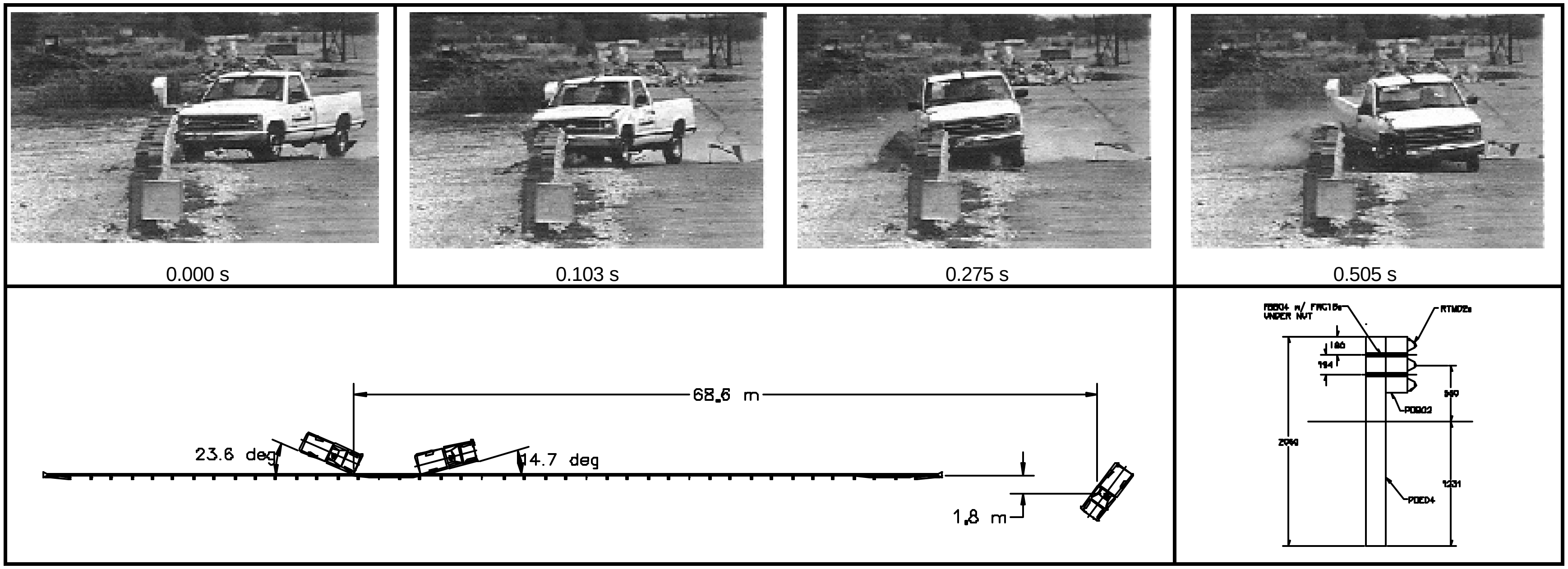
Table 3. Occupant compartment measurements (in mm) for test 404211-11.

Truck

Occupant Compartment Deformation



	BEFORE	AFTER
A1	1040	1040
A2	1077	1077
A3	1040	1040
B1	1075	1075
B2	1020	980
B3	1086	1077
C1	1380	1380
C2	1240	1240
C3	1370	1370
D1	306	306
D2	95	65
D3	310	302
E1	1600	1588
E2	1595	1598
F	1075	1465
G	1075	1075
H	1100	1100
I	1100	1100



General Information	
Test Agency	Texas Transportation Institute
Test No.	404211-11
Date	06/03/98
Test Article	
Type	Guardrail
Name	Strong Wood Post Thrie Beam Guardrail
Installation Length (m)	83.8
Material or Key Elements	12-ga Thrie Beam on Strong Wood Posts With Wood Blockouts
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Type	Production
Designation	2000P
Model	1993 Chevrolet 2500 pickup truck
Mass (kg)	
Curb	1861
Test Inertial	2000
Dummy	75
Gross Static	2075

Impact Conditions	
Speed (km/h)	99.6
Angle (deg)	23.6
Exit Conditions	
Speed (km/h)	73.6
Angle (deg)	14.7
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	6.3
y-direction	5.6
THIV (km/h)	24.7
Ridedown Accelerations (g's)	
x-direction	-8.4
y-direction	-9.0
PHD (g's)	25.4
ASI	0.75
Max. 0.050-s Average (g's)	
x-direction	-5.5
y-direction	-5.8
z-direction	2.1

Test Article Deflections (m)	
Dynamic	0.68
Permanent	0.39
Vehicle Damage	
Exterior	
VDS	01RFQ4
CDC	01FREK3 & 01RYEW3
Maximum Exterior Vehicle Crush (mm)	470
Interior	
OCDI	FS0104000
Max. Occ. Compart. Deformation (mm)	30
Post-Impact Behavior (during 1.0 s after impact)	
Max. Yaw Angle (deg)	-31
Max. Pitch Angle (deg)	3
Max. Roll Angle (deg)	6

Figure 13. Summary of results for test 404211-11, NCHRP Report 350 test 3-11.

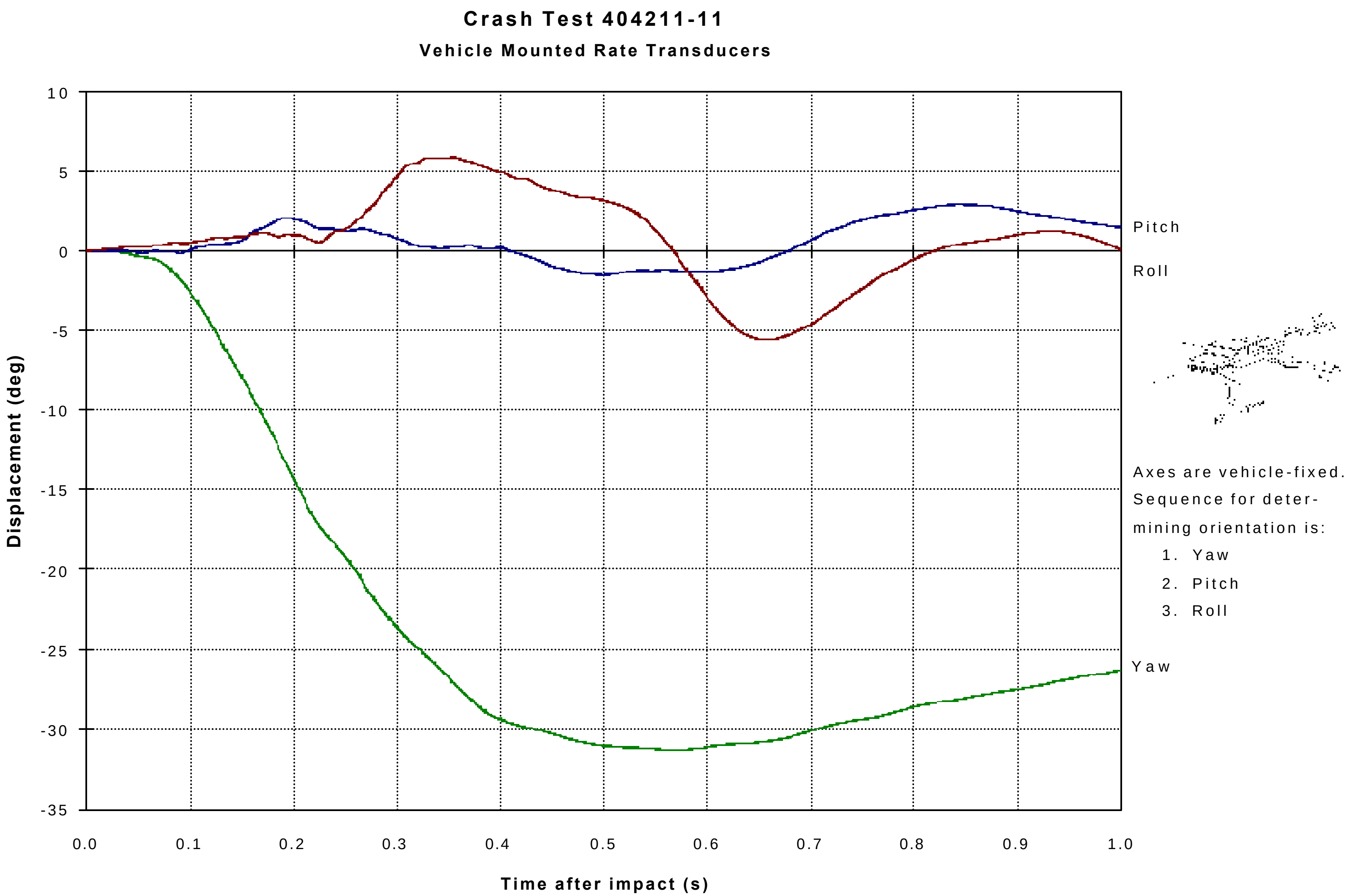


Figure 14. Vehicle angular displacements for test 404211-11.

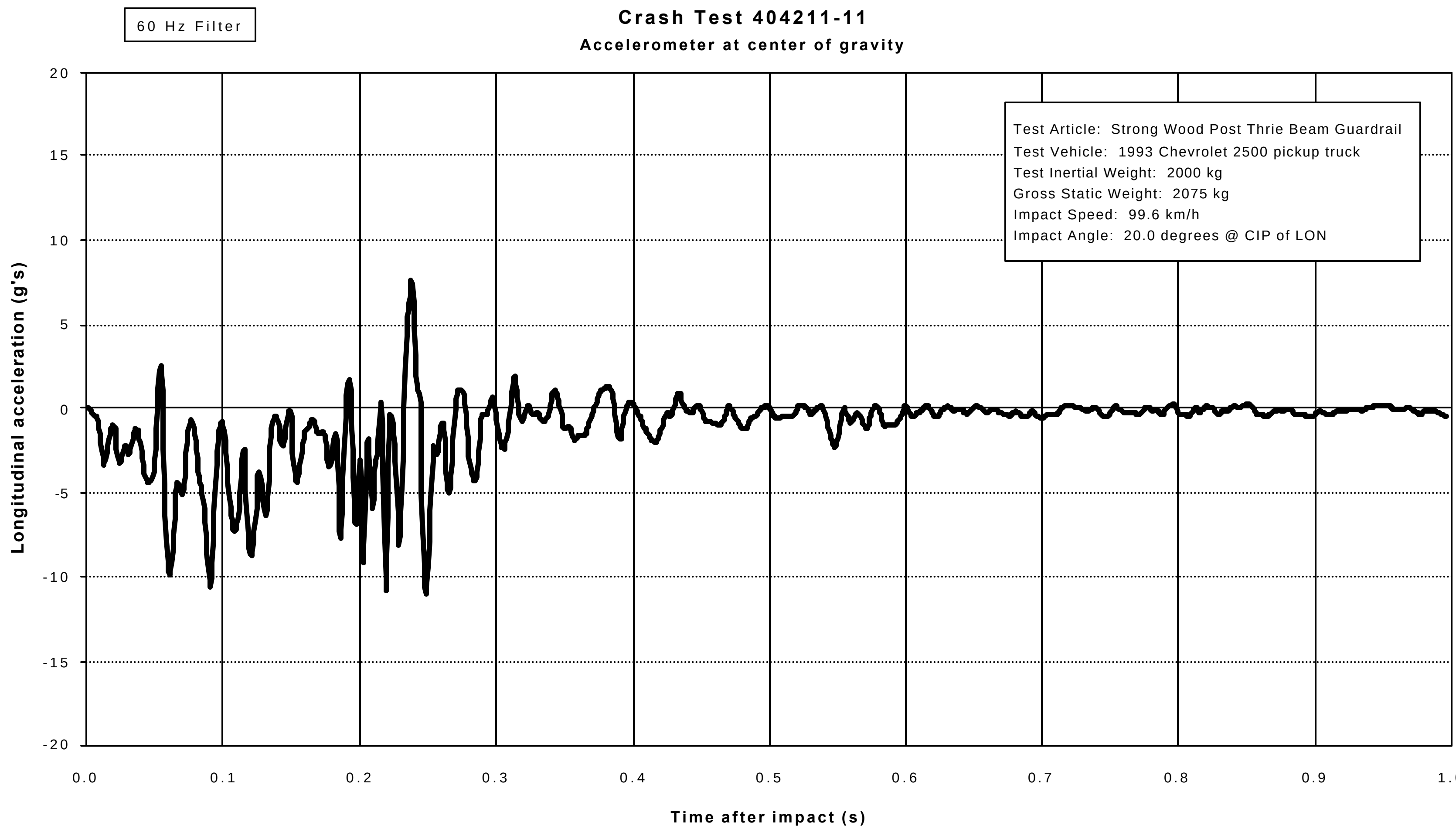


Figure 15. Vehicle longitudinal accelerometer trace for test 404211-11 (accelerometer located at center of gravity).

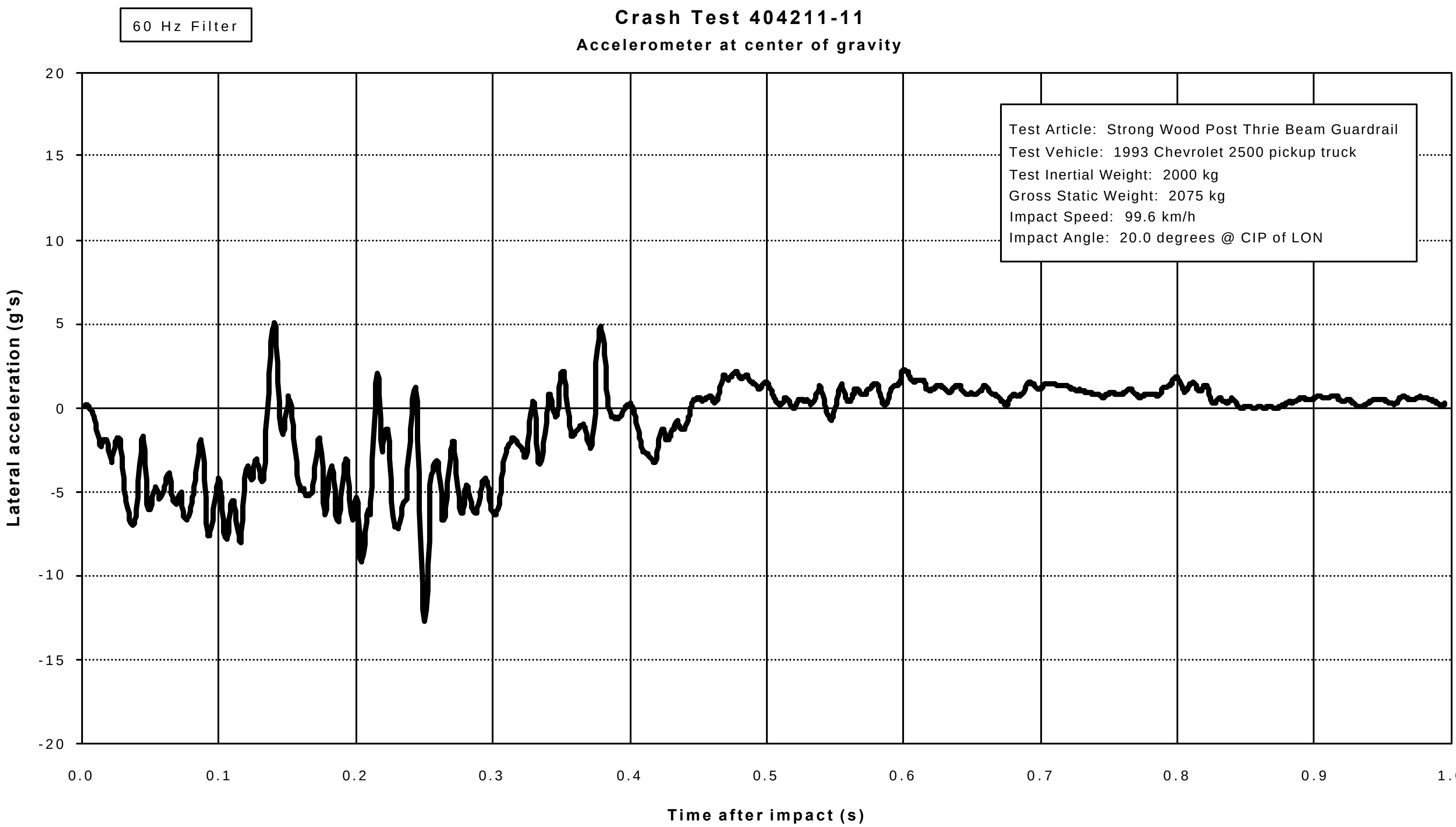


Figure 16. Vehicle lateral accelerometer traces for test 404211-11 (accelerometer located at center of gravity).

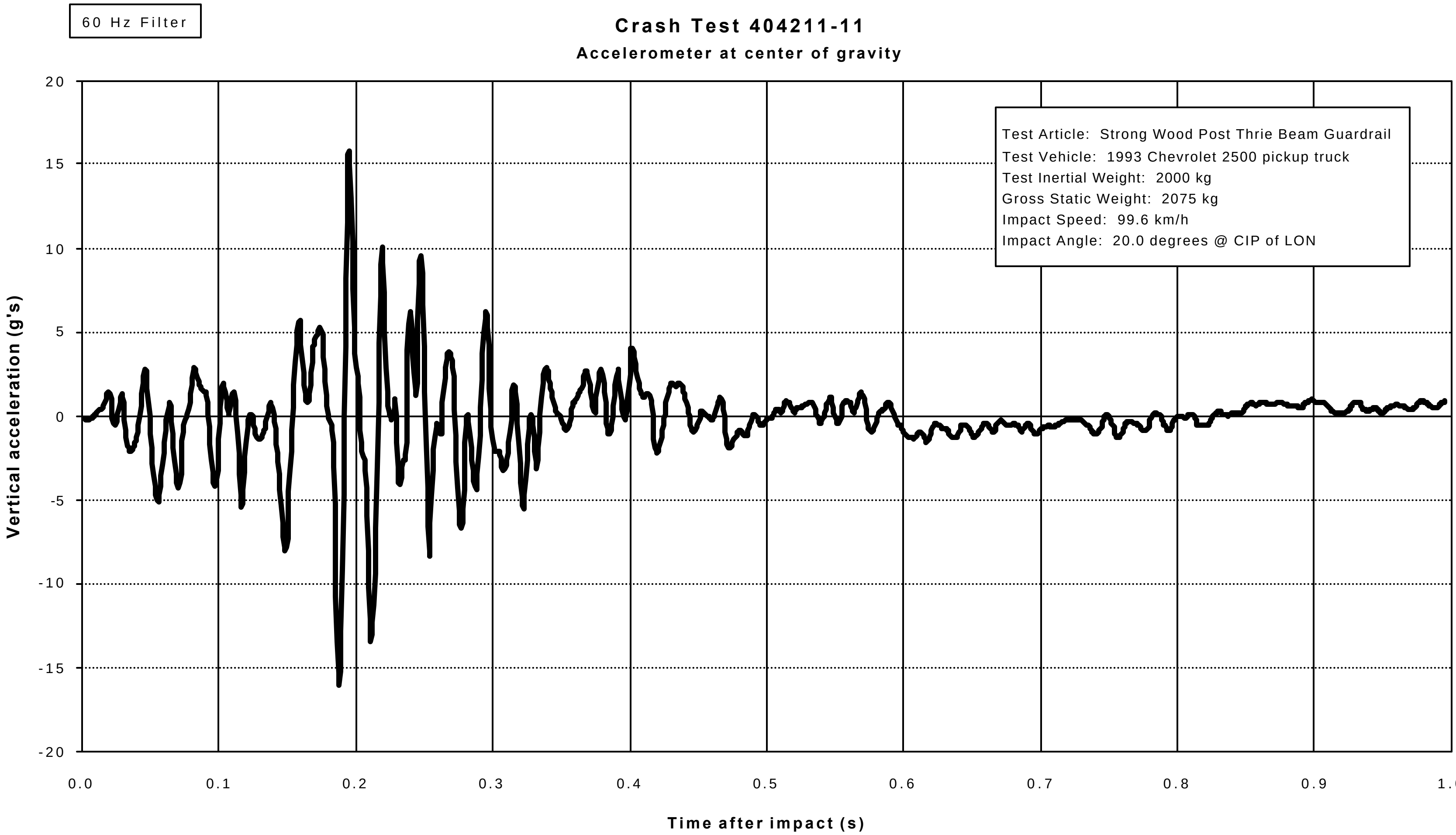


Figure 17. Vehicle vertical accelerometer trace for test 404211-11 (accelerometer located at center of gravity).

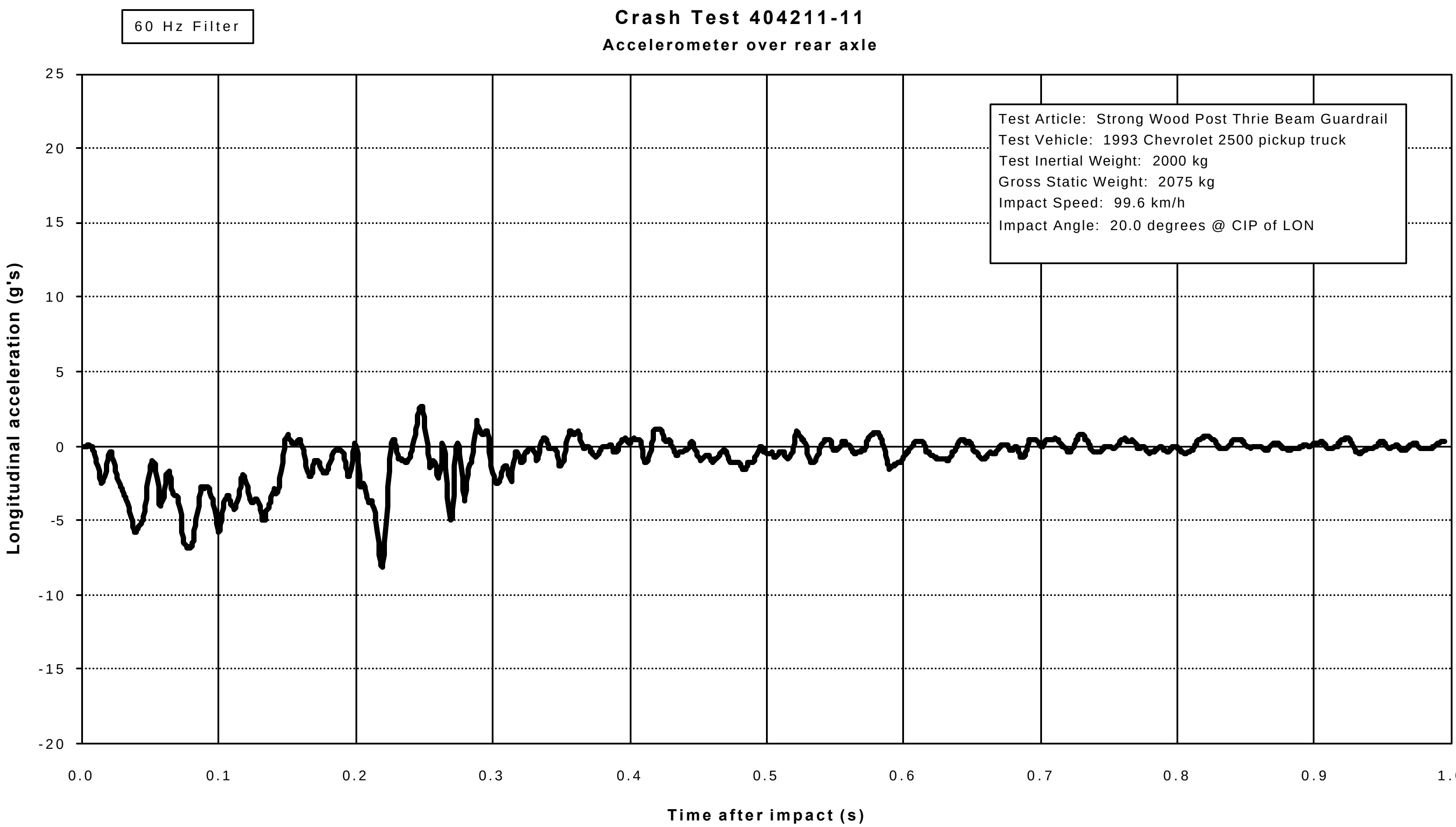


Figure 18. Vehicle longitudinal accelerometer trace for test 404211-11
(accelerometer located over rear axle).

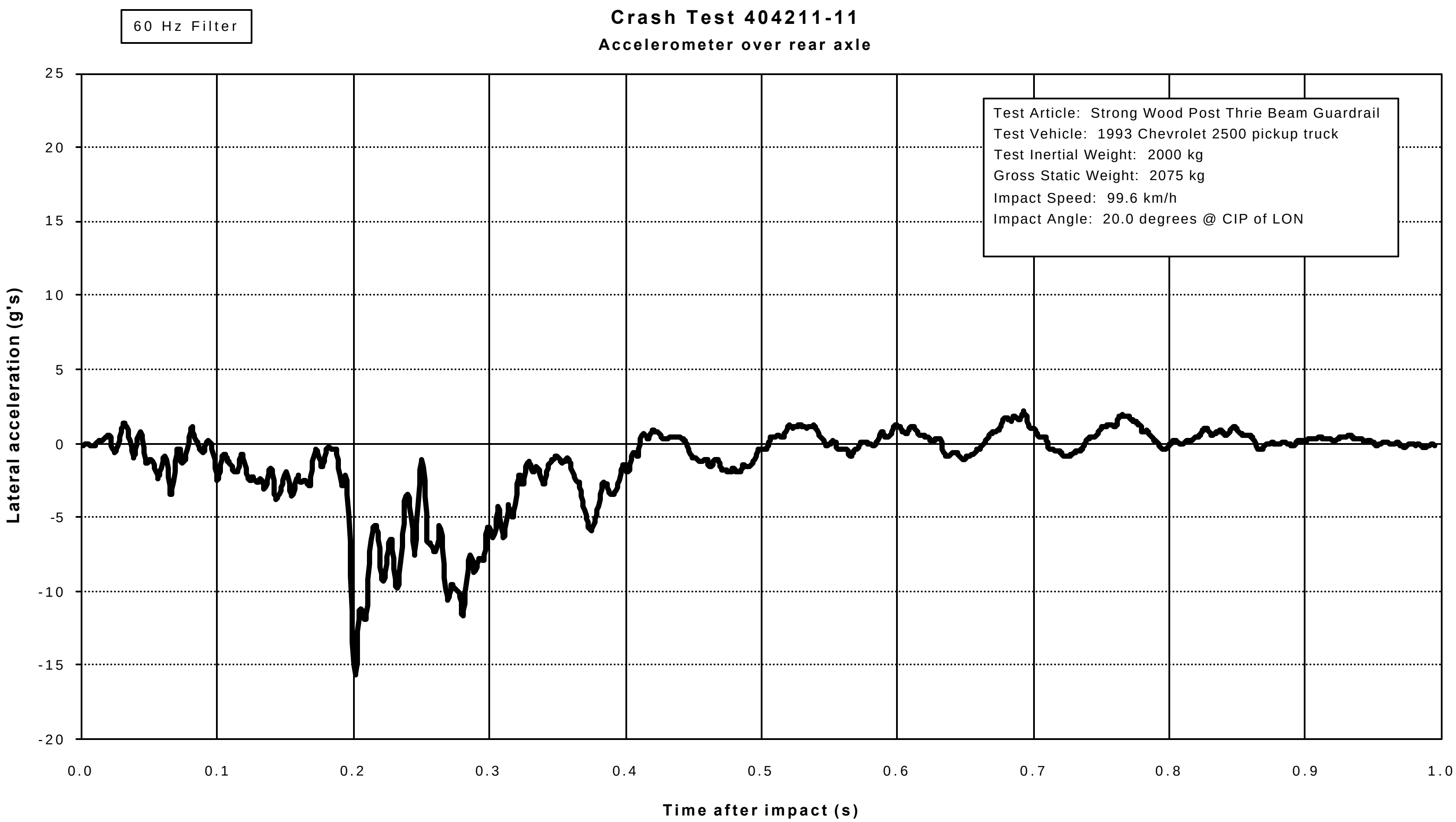


Figure 19. Vehicle lateral accelerometer traces for test 404211-11 (accelerometer located over rear axle).

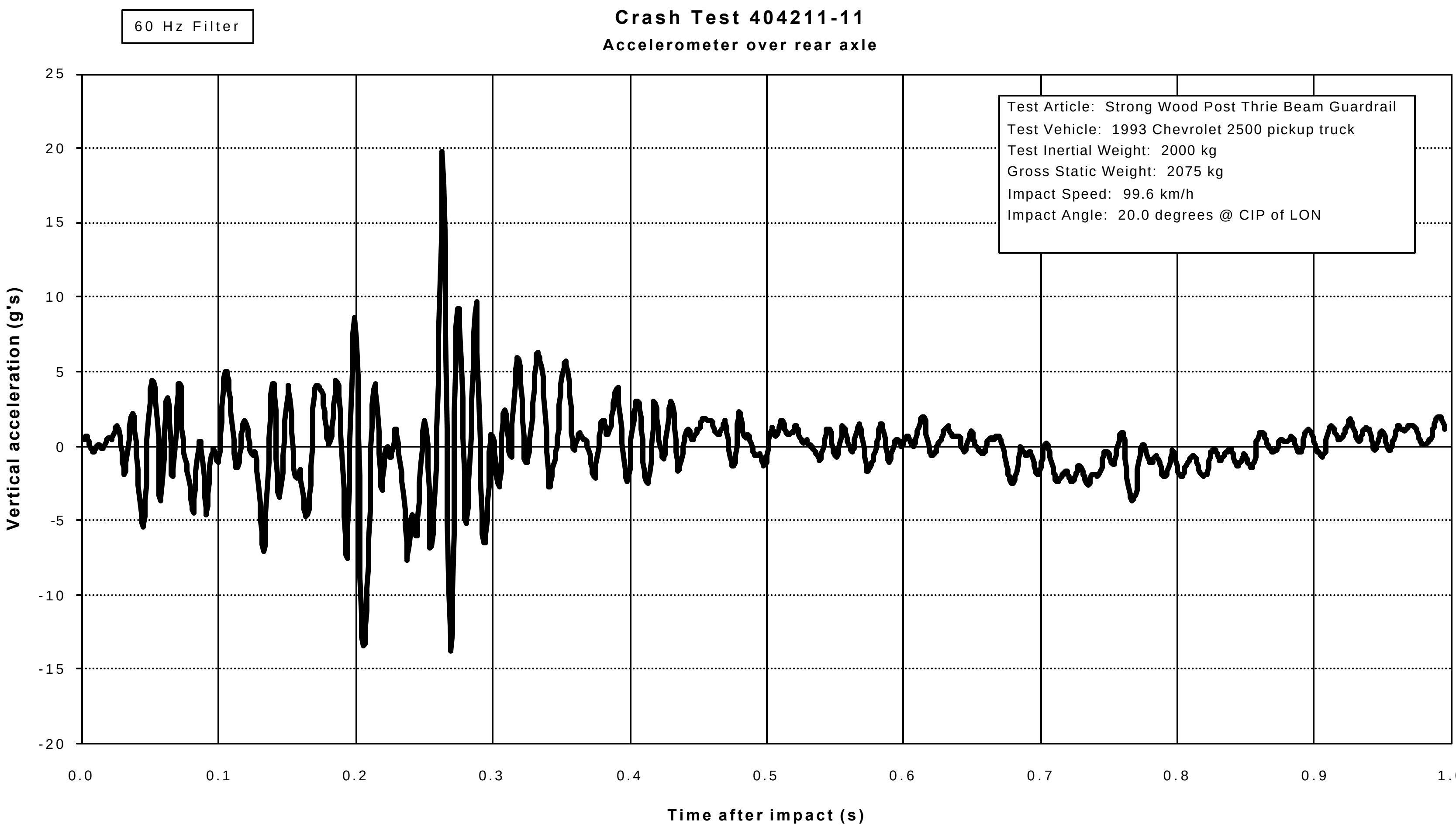


Figure 20. Vehicle vertical accelerometer traces for test 404211-11
(accelerometer located over rear axle).

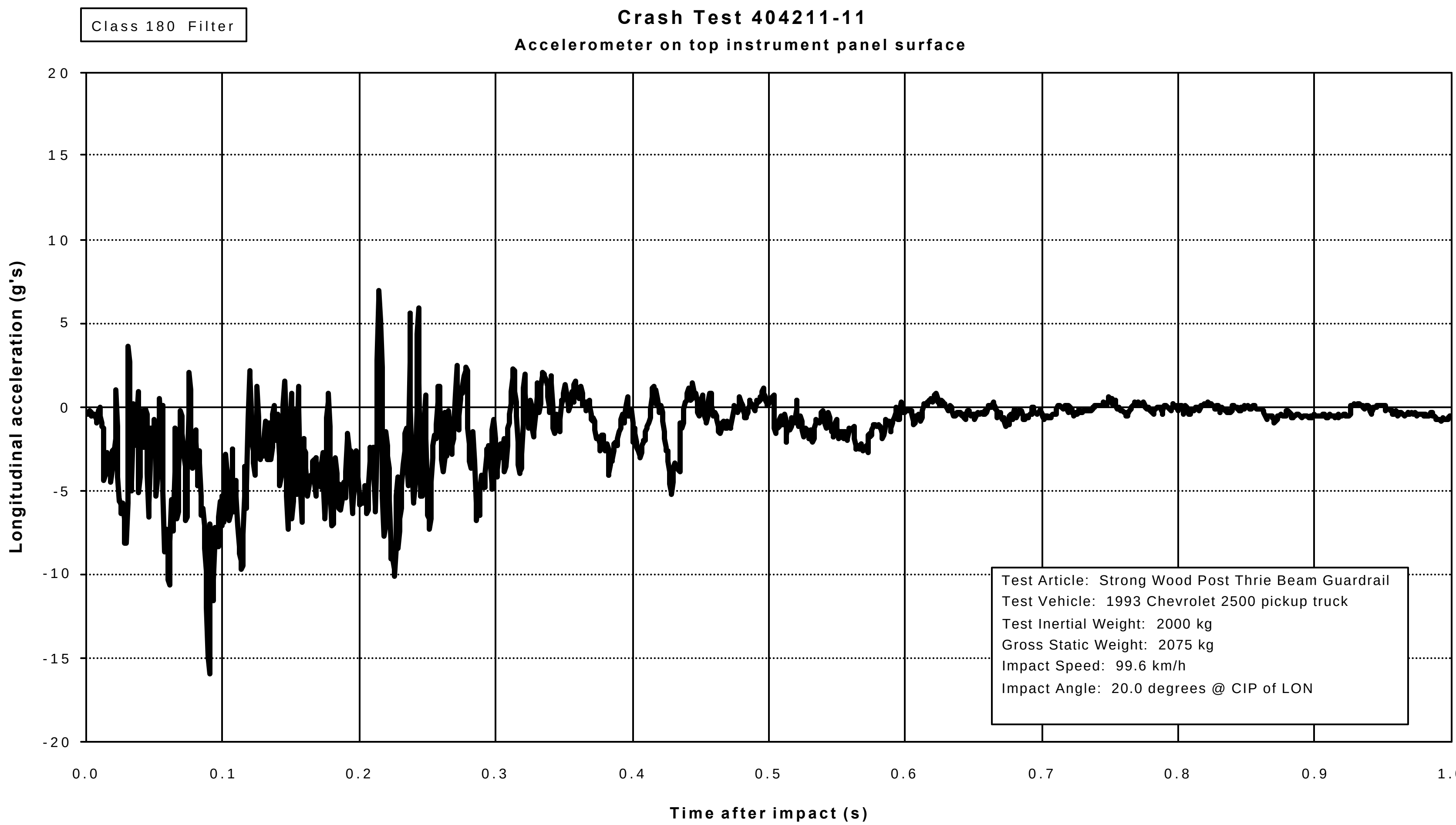


Figure 21. Vehicle longitudinal accelerometer trace for test 404211-11
(accelerometer located on top surface of instrument panel).

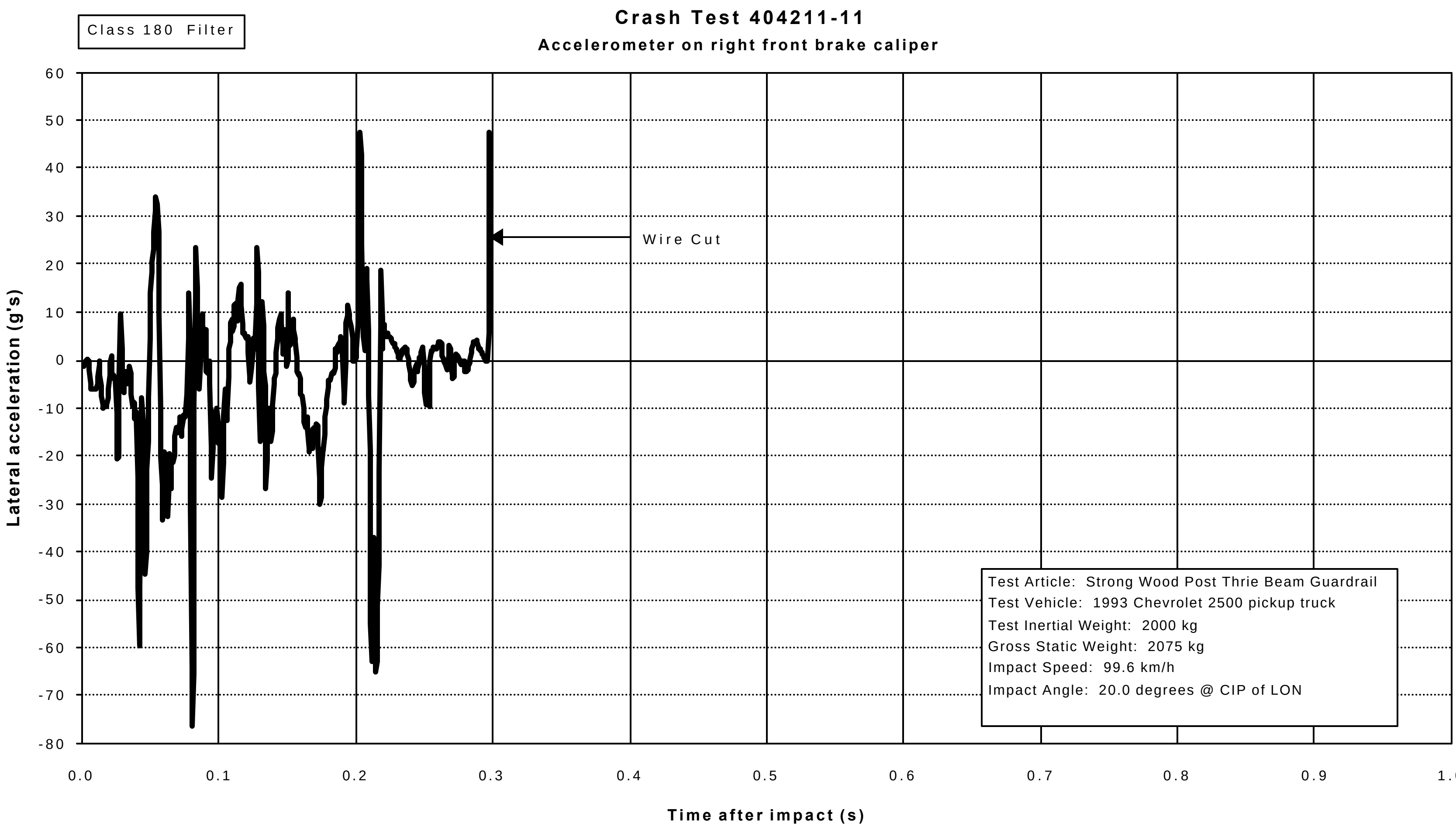


Figure 22. Vehicle lateral accelerometer trace for test 404211-11
(accelerometer located on right front brake caliper).

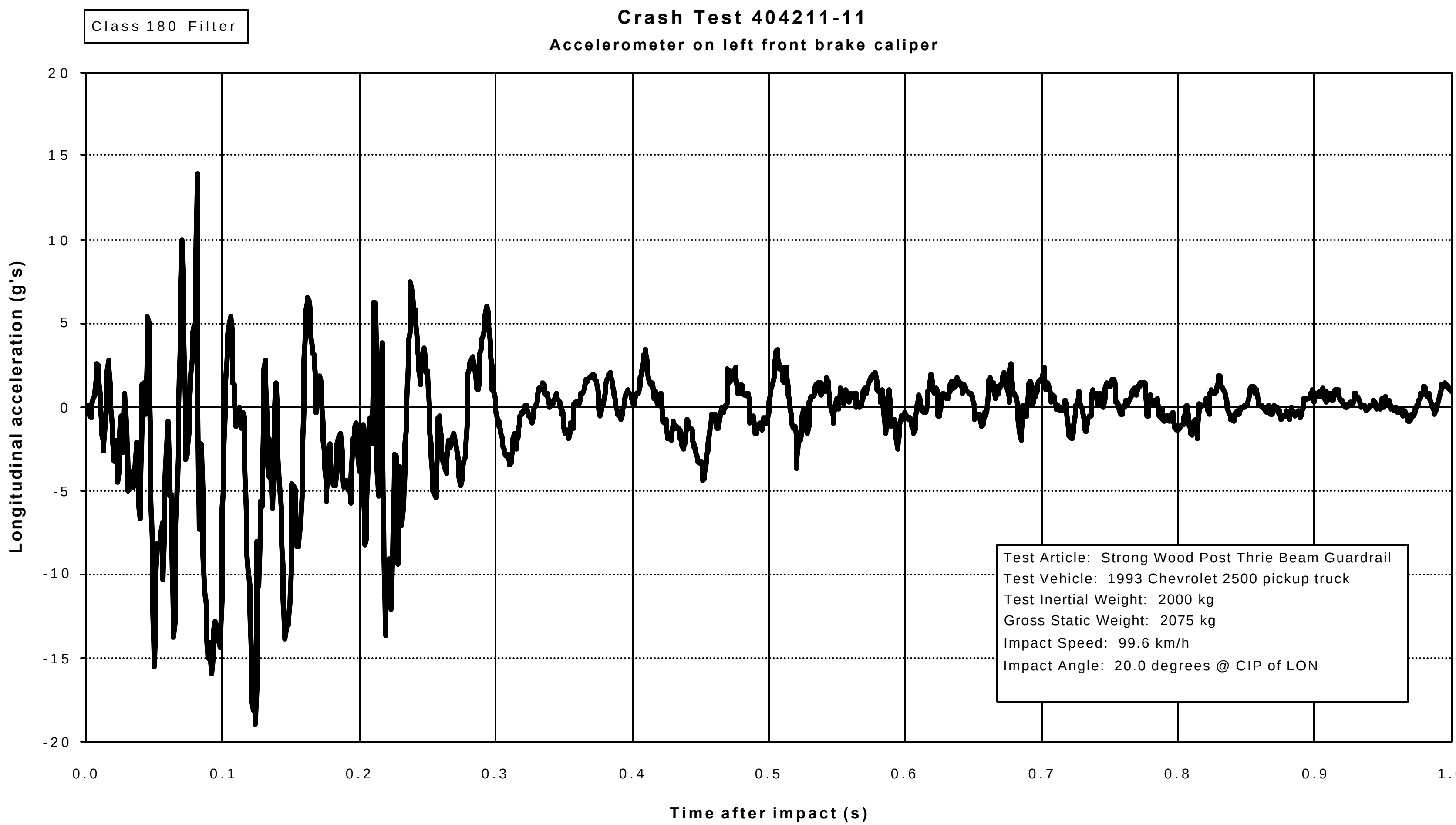


Figure 23. Vehicle longitudinal accelerometer traces for test 404211-11
(accelerometer located on left front brake caliper).

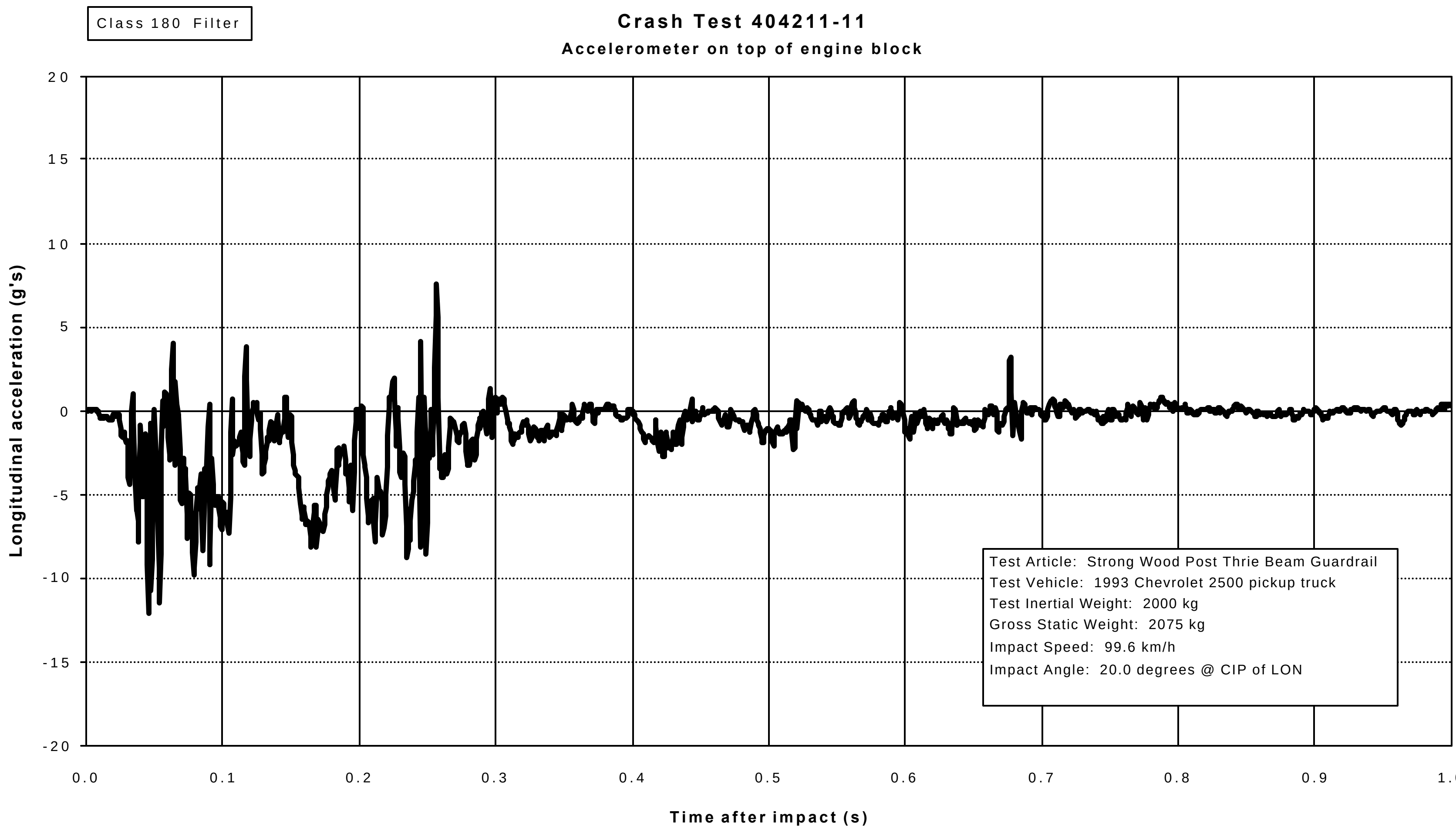


Figure 24. Vehicle longitudinal accelerometer trace for test 404211-11 (accelerometer located on top of engine block).

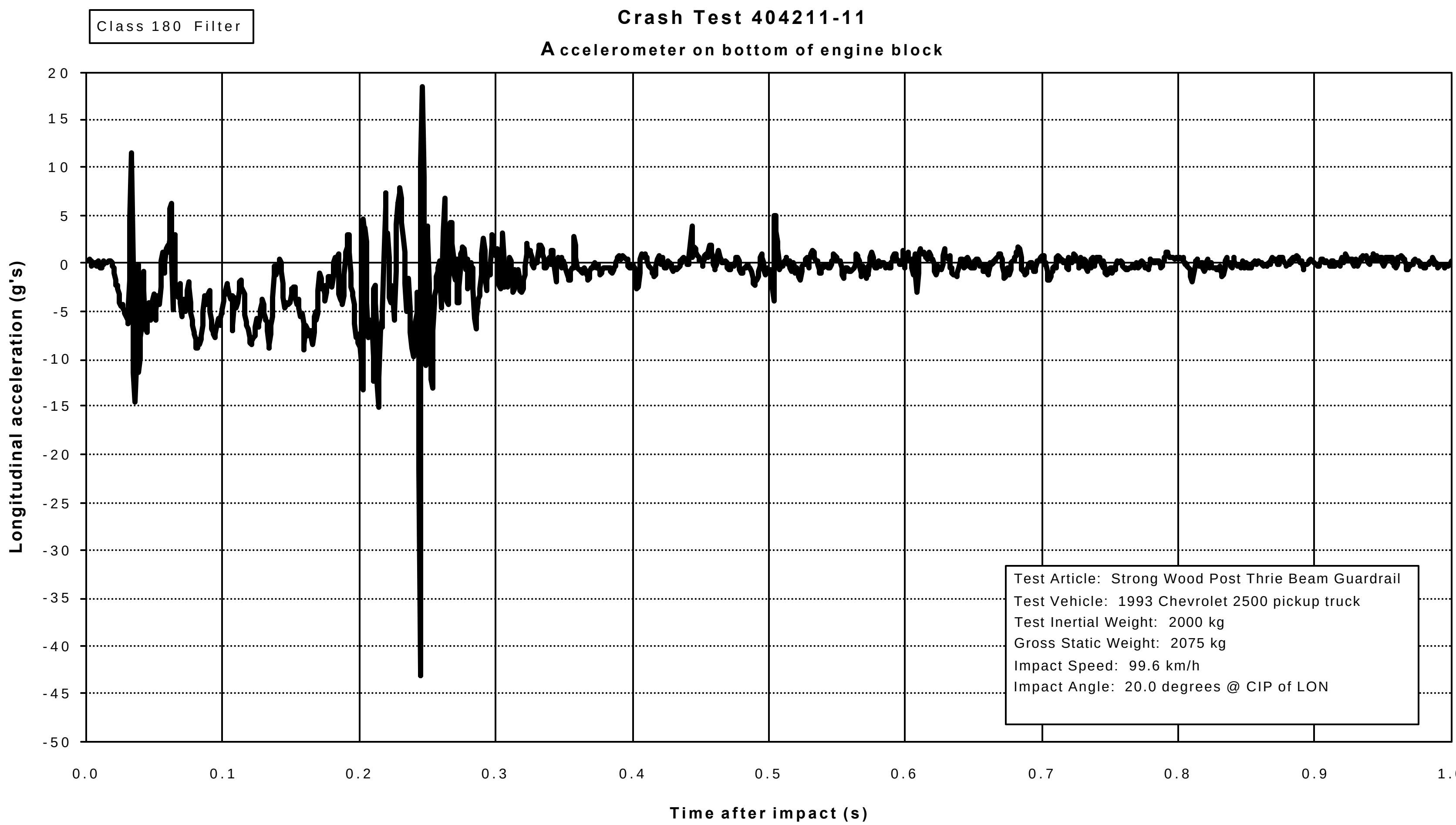


Figure 25. Vehicle longitudinal accelerometer trace for test 404211-11
(accelerometer located on bottom of engine block).

IV. SUMMARY OF FINDINGS AND CONCLUSIONS

SUMMARY OF FINDINGS

The strong wood post thrie beam guardrail contained and redirected the vehicle. The vehicle did not penetrate, underride, or override the installation. No detached elements, fragments, or other debris were present to penetrate or to show potential for penetrating the occupant compartment, nor to present undue hazard to others in the area. Maximum occupant compartment deformation was 30 mm in the center front floor pan area under the instrument panel and should not cause serious injury. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes. Longitudinal occupant impact velocity was 6.3 m/s and longitudinal ridedown acceleration was -8.4 g's. The exit angle at loss of contact was 14.7 degrees, which was 62 percent of the impact angle; however, the vehicle steered back toward the installation.

CONCLUSIONS

As can be seen in table 4, the strong wood post thrie beam guardrail met all required criteria for NCHRP Report 350 test designation 3-11.

Table 4. Performance evaluation summary for test 404211-11, NCHRP Report 350 test 3-11.

Test Agency: Texas Transportation Institute	Test No.: 404211-11	Test Date: 07/03/98
NCHRP Report 350 Evaluation Criteria	**Test Results**	**Assessment**
Structural Adequacy A. Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation, although controlled lateral deflection of the test article is acceptable.	The strong wood post thrie beam guardrail contained and redirected the vehicle. The vehicle did not penetrate, underride, or override the installation.	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. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.	No detached elements, fragments, or other debris were present to penetrate or to show potential for penetrating the occupant compartment, nor to present undue hazard to others in the area. Maximum occupant compartment deformation was 30 mm in the center front floor pan area under the instrument panel and should not cause serious injury.	Pass
F. The vehicle should remain upright during and after collision, although moderate rolling, pitching, and yawing are acceptable.	The vehicle remained upright during and after the collision.	Pass
Vehicle Trajectory K. After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.	The vehicle did not intrude into adjacent traffic lanes.	Pass*
L. The occupant impact velocity in the longitudinal direction should not exceed 12 m/s and the occupant ridedown acceleration in the longitudinal direction should not exceed 20 g's.	Longitudinal occupant impact velocity was 6.3 m/s and longitudinal ridedown acceleration was -8.4 g's.	Pass
M. The exit angle from the test article preferably should be less than 60 percent of test impact angle, measured at time of vehicle loss of contact with test device.	The exit angle at loss of contact was 14.7 degrees which was 62 percent of the impact angle; however the vehicle steered back toward the installation.	Fail*

*Criterion preferable, not required.

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*, NCHRP Report 350, Transportation Research Board, Washington, D.C., 1993.

2. J. D. Michie, *Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances*, NCHRP Report 230, Transportation Research Board, Washington, D.C., 1980.