50-km/h Broadside Crash Test of a 1994 Chevrolet C2500 and the FOIL300K Rigid Pole: FOIL Test Number 97S017

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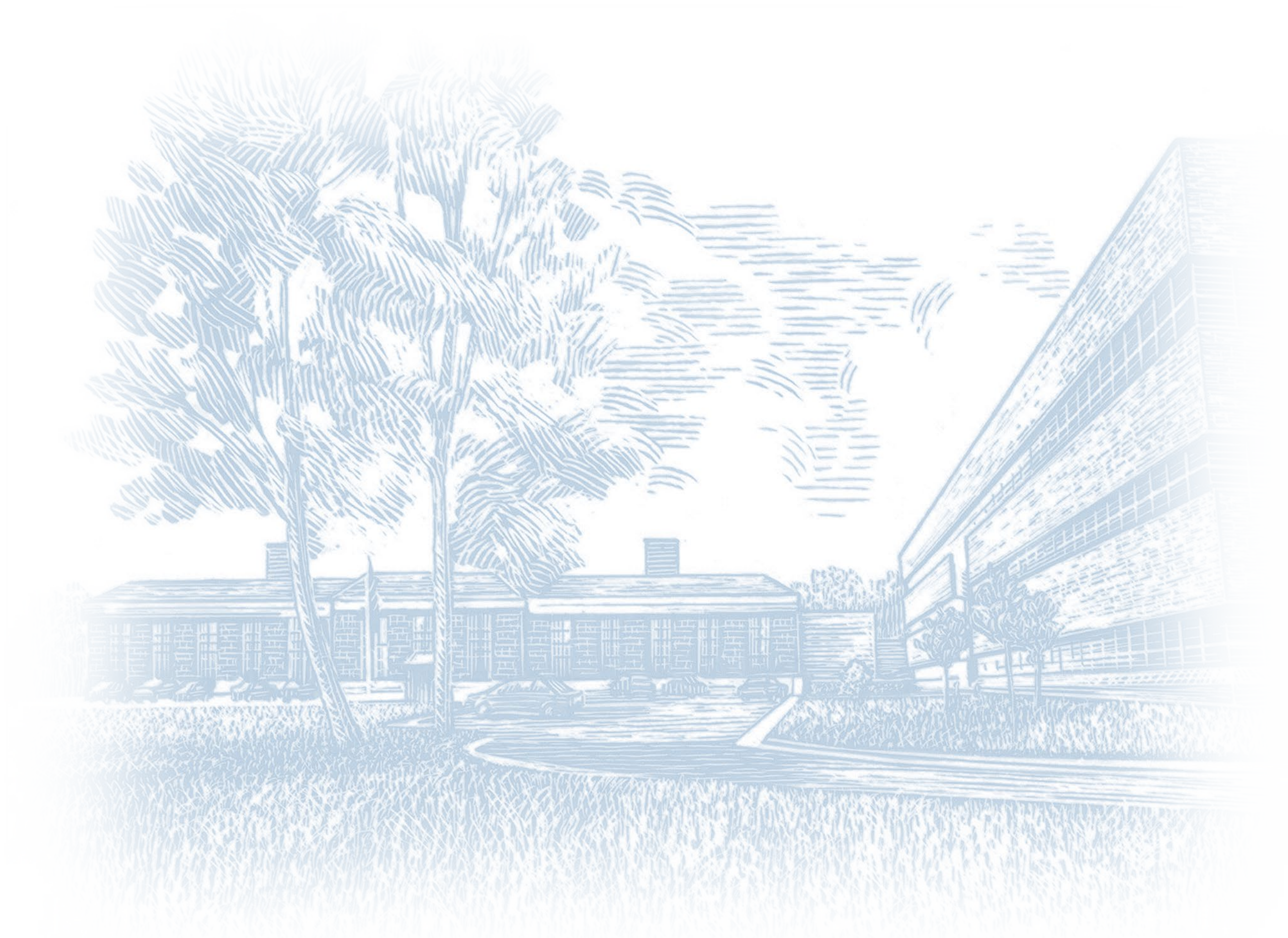

U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration
Turner-Fairbank Highway Research Center
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FOREWORD

This report documents the results from one broadside crash test between a Chevrolet C2500 pickup truck and the FOIL 300K rigid pole. The Federal Highway Administration (FHWA) has invested many resources in the development of finite element models (FEM) of passenger vehicles, pickup trucks, and roadside safety hardware. Computer simulations using these FEM's of collisions between the vehicles and roadside safety hardware are used to investigate the behavior of and improve the safety performance of roadside safety hardware. An essential step for developing the FEM is to validate the models by comparing data from simulation output with data collected from full-scale vehicle crash tests with roadside safety hardware. The FHWA's Federal Outdoor Impact Laboratory (FOIL) was used to conduct this 50-km/h rigid pole test. The results from a similar crash test can be found in the report *35-km/h Broadside Crash Test of a 1994 Chevrolet C2500 and the FOIL 300K Rigid Pole: FOIL Test Number 97S016.* Results from additional pickup truck broadside crash tests are contained in the reports *35-km/h Broadside Crash Test of a 1994 Chevrolet C2500 and a Valmont Industries Slip Away Lighting Standard: FOIL Test 97S012,* and *50-km/h Broadside Crash Test of a 1994 Chevrolet C2500 and a Valmont Industries Slip Away Lighting Standard: FOIL Test Number 97S015.*

This report (FHWA-RD-98-082) contains test data, photographs taken with high-speed film, and a summary of the test results.

This report will be of interest to all State departments of transportation; FHWA headquarters; region and division personnel; and highway safety researchers interested in the crashworthiness of roadside safety hardware.

A. George Ostensen, Director
Office of Safety and Traffic
Operations Research and Development

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16. Abstract

This report contains the test procedures followed and test results from a broadside crash test between a Chevrolet C2500 pickup truck and the FOIL instrumented 300K rigid pole. The test was conducted at the Federal Highway Administration (FHWA) Federal Outdoor Impact Laboratory (FOIL) located at the Turner-Fairbank Highway Research Center (TFHRC) in McLean, Virginia. The National Highway Traffic Safety Administration (NHTSA) supplied a calibrated SIDH3 dummy for the test. The target test speed for the test was 50 km/h and the target test weight, including the SIDH3 dummy, was 2,080 kg. The results from a similar test, conducted at 35 km/h, can be found in the report *35-km/h Broadside Crash Test of a 1994 Chevrolet C2500 and the FOIL 300K Rigid Pole: FOIL Test Number 97S016.* In both tests, the extensive wrap around the 255-mm-diameter rigid pole led to contact between the dummy's head and the rigid pole. The crush profile, electronic data, and high-speed film from these tests will aid computer simulation engineers in developing and validating side-impact finite element models of pickup trucks.

17. Key Words Chevrolet, C2500 pickup, FOIL, rigid pole, broadside, HIC, FEM		18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.	
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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				
in2	square inches	645.2	square millimeters	mm2
ft2	square feet	0.093	square meters	m2
yd2	square yards	0.836	square meters	m2
ac	acres	0.405	hectares	ha
mi2	square miles	2.59	square kilometers	km2
VOLUME				
fl oz	fluid ounces	29.57	millileters	mL
gal	gallons	3.785	liters	L
ft3	cubic feet	0.028	cubic meters	m3
yd3	cubic yards	0.765	cubic meters	m3
NOTE: Volumes greater than 1000 L shall be shown in m3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000lb)	0.907	megagrams (or "metric ton")	MG (or "t")
TEMPERATURE (exact)				
°F	farenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m2	cd/m2
FORCE and PRESSURE or STRESS				
lbf	pundforce	4.45	newtons	N
lbf/in2	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				
mm2	square millimeters	0.0016	square inches	in2
m2	square meters	10.764	square feet	ft2
m2	square meters	1.195	square yards	yd2
ha	hecteares	2.47	acres	ac
km2	square kilometers	0.386	square miles	mi2
VOLUME				
mL	millileters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m3	cubic meters	35.71	cubic feet	ft3
m3	cubic meters	1.307	cubic yards	yd3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000lb)	T
TEMPERATURE (exact)				
°C	Celcius temperature	1.8C +32	Fahrenheit temperature	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m2	candela/m2	0.2919	footLamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in2

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INTRODUCTION

The Federal Highway Administration (FHWA) has invested many resources in the development of finite element models (FEM) of passenger vehicles, pickup trucks, and roadside safety hardware. Computer simulations using these FEM's of collisions between the vehicles and roadside safety hardware are used to investigate the behavior of and improve the safety performance of roadside safety hardware. An essential step for developing the FEM is to validate the models by comparing data from simulation output with data collected from full-scale vehicle crash tests with roadside safety hardware. The FHWA's Federal Outdoor Impact Laboratory (FOIL) was used to conduct several crash tests to provide simulation engineers with data for the FEM validation process. The test vehicles used for the crash tests were 1994 Chevrolet C2500 pickup trucks. The C2500 pickup truck tests were broadside collisions between the pickup trucks and a narrow object. The narrow fixed object in these tests was either the FOIL's instrumented rigid pole or a Valmont Industries three-bolt Slip Away lighting standard. The rigid pole tests were conducted to provide side-impact crush characteristics of the Chevrolet C2500 to support validation of the truck FEM. The lighting standard tests were conducted to provide data in support of validation of a simulated collision between the pickup truck and a common roadside safety device. This test report outlines the laboratory test procedures, test setup, and results from one of the broadside crash tests.

SCOPE

This report documents the test procedures followed and test results from one broadside crash test between a Chevrolet C2500 pickup truck and the FOIL instrumented 300K rigid pole. Many of the test procedures followed (dummy positioning and vehicle preparation) are outlined in the Federal Motor Vehicle Safety Standard (FMVSS) 214.(1) The test was conducted at the FHWA's FOIL facility located at the Turner-Fairbank Highway Research Center (TFHRC) in McLean, Virginia. The crash test will provide simulation engineers with data that will aid in the development and validation of a finite element side-impact model of a

2,000-kg pickup truck. The target test speed for the test and target vehicle inertial weight of the Chevrolet C2500 were

50 km/h and 2,000 kg, respectively. The target test weight, including one anthropometric dummy, was 2,080 kg. The dummy used was a calibrated SIDH3 dummy supplied by the National Highway Traffic Safety Administration (NHTSA). A SIDH3 dummy is a combination of a Hybrid III dummy used for frontal crash testing and a side-impact dummy (SID) used for side-impact testing. In addition, the NHTSA supplied an OSCAR to determine the three-dimensional location of a dummy's hip point (H-point). This information was used the morning of the test to place the dummy

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in the proper position. The dummy, pickup truck, and rigid pole were instrumented with various transducers to record pertinent test data.

TEST MATRIX

One broadside crash test was conducted in support of the FHWA's computer simulation program. The vehicle used was a 1994 Chevrolet C2500 pickup truck. The pickup truck was oriented on the FOIL runway perpendicular to the runway centerline (broadside-impact). The FOIL 300K rigid pole was erected on the FOIL runway foundation base plate in the impact zone. A SIDH3 dummy was placed in the driver seat in accordance with FMVSS 214. The 300K rigid pole was aligned with a point on the driver door just forward of the SIDH3's head so as not to allow contact between the SIDH3's head and the pole. This point was later determined to be 1320 mm rearward of the pickup truck's front axle or 102 mm forward of the pickup truck's longitudinal center of gravity (c.g.). Table 1 outlines the test matrix followed for the broadside crash test.

Table 1. Test matrix.

Test No.	**Test Vehicle**	**Vehicle weight**	**Vehicle speed**	**Test article**	**Impact location**
97S017	Chevrolet C2500 pickup truck	2,000 kg, w/SIDH3 2,080 kg	50 km/h	300K rigid pole	Forward of SIDH3 head

TEST VEHICLE

The test vehicle used was a 1994 Chevrolet C2500 pickup truck. The pickup truck was equipped with standard equipment and options. Prior to the test, the truck was drained of all fluids and the curb weight, sill attitudes, and the vehicle's physical parameters were measured. A NHTSA-supplied OSCAR was used to determine the three-dimensional coordinate of the SIDH3's H-point relative to the driver door-striker. The measurement was recorded and was used the day of the test to position the dummy in the driver seat just before the test. The test vehicle was loaded with instrumentation, guidance system components, a high-speed camera, and ballast (if needed) to attain the proper test weight. The target test weight (not including the SIDH3) for the pickup truck was 2,000 kg (SIDH3 weighed 80 kg). The test vehicle was reweighed; the new sill attitudes, lateral and longitudinal c.g.'s, and pertinent physical parameters were measured and recorded. The fuel tank was empty during the test.

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No components were removed from the engine compartment during vehicle preparations. The truck was not equipped with a driver- side air bag.

Included in the final test configuration were the two side-impact carriages. The main monorail carriage was bolted to the test vehicle 200 mm forward of the vehicle's longitudinal c.g. The rear outrigger carriage was bolted 2,770 mm rearward of the monorail carriage centerline (a point within the truck bed rearward of the rear axle). The side-impact carriages were constructed from aluminum and remained fastened to the vehicle throughout the test, although the main monorail carriage was fastened to the truck using long, small-diameter bolts that allowed the carriage to swing away from impact in the event the carriage made contact with a substantial structure.

The FOIL broadside test setup procedures require that the test vehicle's tires are off the ground while the test vehicle rests on the side-impact monorail. Due to the truck's ground clearance and the truck suspension system, the tires remained in contact with the ground after typical guidance system installation procedures. Therefore, the suspension system at each wheel was tied to the vehicle frame using 5-mm wire rope and cable clamps. The amount necessary to raise the tires was minimal and the suspension system retained the majority of its range of motion. Applying an oscillating load to the front and rear of the truck (while on the ground) demonstrated that the truck suspension's range of motion was not hindered. Once the truck was placed on the side-impact rails, the sill attitudes were adjusted to within 0.5° of the final sill attitudes measured while the truck was on the ground.

Target tape and circular targets were placed on the test vehicle in accordance with FMVSS 214. The 25-mm yellow and black target tape was placed along the struck side of the vehicle at five elevations. The elevations included the lower door sill, the mid-door height, occupant H-point height, top-door sill, and roof sill. The target tape was used to measure pretest and post- test side profile measurements to determine vehicle damage or crush. The FOIL used a 2.5-m-long by 1.4-m-high peg board placed along the driver (left) side of the vehicle to measure the vehicle profile. The board's position was referenced from two points directly across from the impact location on the right side of the vehicle. This was done to ensure that the reference location would not be severely damaged. The two points were chosen directly across from impact because the least amount of bowing occurs directly across from impact. It was necessary to position the board in the same position relative to the vehicle after the crash test to obtain accurate crush measurements. The pretest and post-test profile measurements are shown in figure 7 later in this report.

Table 2 lists the pickup truck’s optional equipment and physical parameters. Figure 1 is a sketch of the C2500 pickup truck with it’s physical dimensions.

Table 2. Vehicle description and statistics	
Vehicle make	Chevrolet
Vehicle model	1994 C2500 pickup
Vehicle identification number (VIN)	1GCFC24H2RZ232069
Engine	5.0 L, 8 cylinder
Transmission	Automatic
Drive chain	Rear wheel drive
Wheel base	3,353 mm
Wheel track	1,607 mm
Fuel capacity	No fuel used
Tested capacity of stoddard solvent	N/A
Seat type	Bench
Position of front seat for test	Center
Seat back angle	Fixed 18.0E in front
Steering wheel adjustment for test	Fixed

OPTIONS					
x	Air conditioning		Traction control	x	Clock
	Tinted glass		All wheel drive		Roof rack
x	Power steering		Cruise control		Console
	Power windows		Rear defroster		Driver air bag
	Power door locks		Sun roof/T-top		Passenger air bag
	Power seat(s)	x	Tachometer	x	Front disc brakes
x	Power brakes		Tilt steering		Rear disc brakes
x	Anti-lock brakes		AM/FM radio		Other

WEIGHTS (kg)	**DELIVERED**	**TEST MODE**
Left front	526	600
Right front	540	585
Left rear	403	458
Right rear	384	431
TOTAL	**1,853**	**2,074**

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Table 2. Vehicle description and statistics (continued).

ATTITUDE (mm)	DELIVERED	TEST MODE
Left front	822	830
Right front	838	829
Left rear	891	899
Right rear	902	902
ATTITUDE (degrees)	**DELIVERED**	**TEST MODE**
Driver	pitch down 0.1	pitch up 0.2
Passenger	pitch up 0.2	pitch down 0.1
Front	roll up 0.2	roll up 0.2
Rear	roll down 0.1	n/a
C.g. (mm) measurements	**DELIVERED**	**TEST MODE**
Behind front axle	1,424	1,437
Lateral	805	820

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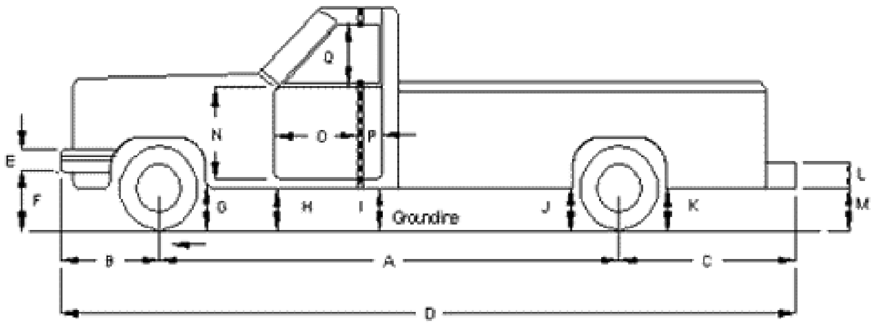

	PRE-TEST	POST-TEST	-CHANGE
A	3353	2540	-813
B	838	800	-38
C	1295	1295	0
D	5487	4635	-852
E	202	202	0
F*	386 / 400	440	40
G*	350 / 355	372	17
H*	350 / 356	349	-7
I*	389 / 393	350	-43
J*	425 / 420	422	2
K*	488 / 500	575	75
L	183	183	0
M*	565 / 554	654	100
N	762	770	8
O	784	340	-444
P	444	188	-256
Q	540	510	-30

* These measurements were taken in the "as delivered" and in the "as tested" configuration, respectively.

Figure 1. Vehicle physical parameters in mm.

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INSTRUMENTED DUMMY

One SIDH3, serial number 26, was placed in the driver seat. The SIDH3 was supplied by the NHTSA and was calibrated by a NHTSA-approved dummy calibration facility before shipment to the FOIL. The SIDH3 is a combination of the standard SID torso with the neck and head replaced with a Hybrid III dummy's neck and head. The neck bracket was removed from the SID and replaced with the neck bracket from a Hybrid III. This provided the necessary bolt pattern and alignment for a Hybrid III neck and head assembly. It was noted that the dummy’s head had a slight twist about the neck. This may have been a result of the attachment between the neck and head or between the neck and head assembly and the dummy’s torso. Figure 2 is a sketch of the modifications made to the SID. The dummy was shipped with the necessary hardware for assembly. Tools at the FOIL were used to assemble the SIDH3. Clothing consisting of white thermal underwear was purchased and placed on the dummy, along with a pair of brown hard leather shoes. Eighteen extension cables were supplied with the SIDH3. The extensions allowed for installation of connectors necessary for attachment to the FOIL data acquisition system without removing the standard dummy connectors. The transducers within the dummy were of the half bridge type and therefore completion resistors were soldered into the connectors at the data acquisition system interface.

The morning of the test, the SIDH3 was positioned in the driver seat in accordance with FMVSS 214. The data acquired from the OSCAR were used to place the dummy H-point at the correct location. The driver seat was set in the center position with the seat back at 18.0° from the vertical. Using FMVSS 214 as a guide and alignment tools supplied by the NHTSA, the SIDH3's feet, legs, thighs, pelvis, torso, and head were positioned just before test. While the dummy was positioned in the test vehicle, a tent was used to prevent direct sunlight from striking the dummy. The dummy is best used in a specific temperature range of 20.5° C to 22.2° C. Temperature measurements, using a thermocouple positioned near the dummy’s head, were taken in 15-min intervals during the hour prior to the test. Pertinent SIDH3-to-interior longitudinal and lateral clearance measurements are shown in figure 3 and figure 4. The SIDH3 was belted in the driver seat using the pickup truck’s seatbelt restraining system. Several different color chalks, listed in table 3, were put on the side surfaces of the dummy to determine the contact points between the dummy and the vehicle's interior.

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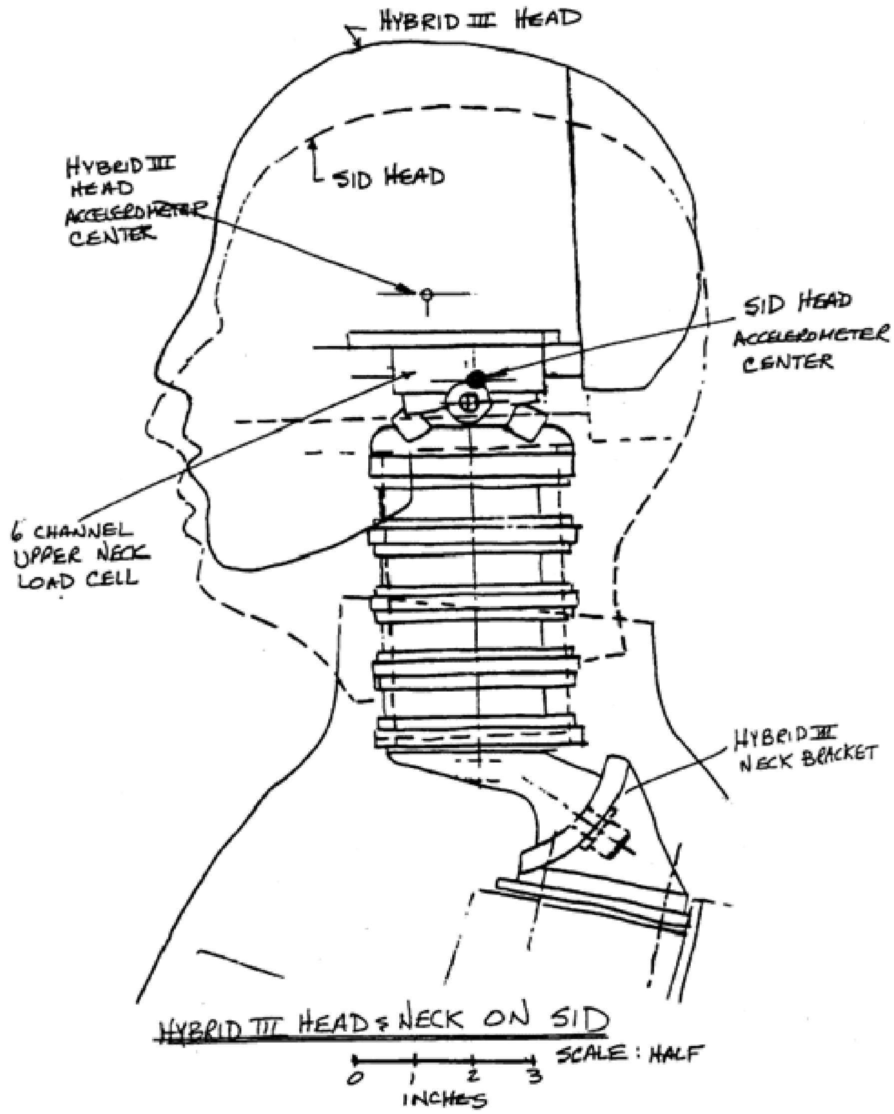

Figure 2. HYBRID III neck and head assembly on SIDH3 #28

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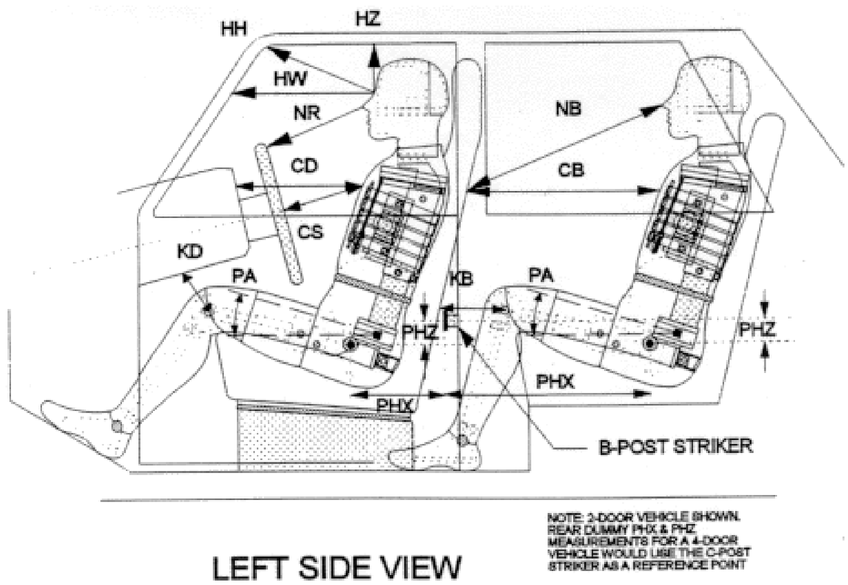

MEASUREMENT (mm)	DRIVER SIDH3 ID# 26
HH	470
HW	718
HZ	210
NR	416
CD	575
CS	265
KDL(KDA°)	167(17°)
KDR(KDA°)	169(14°)
PA°	14°
PHX	325
PHZ	8
PHY	267

Figure 3. SIDH3 longitudinal clearance and position measurements.

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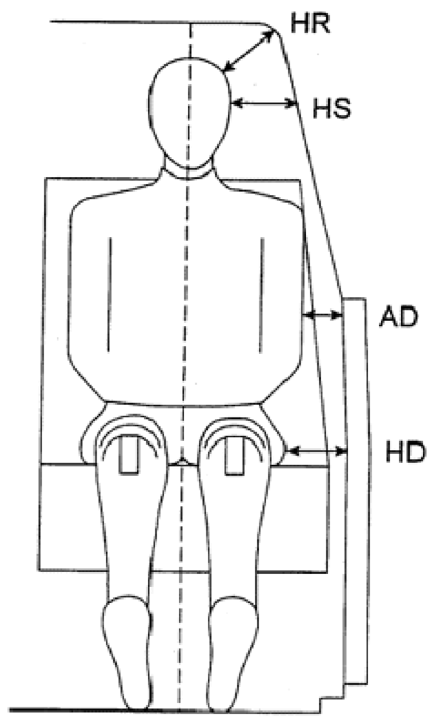

MEASUREMENT (mm)	DRIVER SIDH3 ID# 26
HR	216
HS	270
AD	179
HD	191

Figure 4. SIDH3 lateral clearance and position measurements.

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Table 3. SIDH3 chalk colors.	
DUMMY PART	**COLOR**
Face	Blue
Top of head	Purple
Left side of head	Green
Back of head	Red
Left hip	Red
Left shoulder	Purple

The SIDH3 instrumentation recorded during the test was as follows:

	Number of Channels
Head triaxial accelerometer (A_x,A_y,A_z)	3
Neck 3-axis force load cell (F_x,F_y,F_z)	3
Neck 3-axis neck moment load cell (M_x,M_y,M_z) No completion resistors required	3
Upper and Lower Rib and redundant (A_y)	4
T12 and redundant (A_y)	2
Pelvis (A_y)	1
TOTAL SIDH3 channels	**16**

Data from the SIDH3 dummy were recorded by the FOIL ODAS III data acquisition system from DSP Technologies. The sample rate was factory set at 12,500 Hz with an analog prefilter with a cutoff frequency of 4000 Hz.

RIGID POLE

The FOIL instrumented 300K rigid pole was designed to measure vehicle frontal and side crush characteristics. The rigid pole was set up in the side-impact configuration. The rigid pole side-impact configuration consisted of four solid half-circle steel impact faces mounted to two load cells via two high-strength connecting rods per face (eight load cells total). The diameter of the pole impact faces was 255 mm. The load cells measured the forces exerted on the pole at each location. This provided insight into what structures on the vehicle produced the significant loads. The 300K rigid pole was mounted in line with the target impact location, forward of SIDH3's head.

A spike (e.g.. sharpened welding rod) was affixed to one impact face to verify the impact location by physically puncturing the vehicle body. Figure 5 is a sketch of the FOIL 300K rigid pole (side-impact configuration).

Figure 5. Sketch of FOIL instrumented 300K ridig pole.

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INSTRUMENTATION

A monorail speed trap, transducers attached to the pickup truck and SIDH3, and rigid pole load cells were used to collect data during the broadside crash test. The output from the transducers, load cells, and speed trap were recorded via two data acquisition systems, the ODAS III onboard system and an umbilical cable/FM tape recorder system. Table 4 summarizes the channel assignments for each data system.

Onboard data acquisition system (ODAS)

The ODAS III system collected 35 channels of data. The data were from accelerometers, a triaxial rate transducer, and 16 SIDH3 channels. The output from the sensors was prefiltered, digitally sampled, and digitally stored within the ODAS III units mounted directly to the test vehicle outside the occupant compartment in the truck bed. The ODAS III units are factory set with a 4,000 Hz analog prefilter and a digital sampling rate of 12,500 Hz.

Tape recorder-umbilical cable

The FOIL umbilical cable system utilizes a 90-m cable between the vehicle transducers, rigid pole load cells, or other sensors and a rack of 10 signal conditioning amplifiers. The output from the amplifiers was recorded on 25-mm magnetic tape via a Honeywell 5600E FM tape recorder. After the test, the tape is played back through anti-aliasing filters, then input to a data translation analog-to-digital converter. The sample rate was set to 5,000 Hz. The tape recorded signals from 12 transducers. The system recorded outputs from one c.g. accelerometer, one displacement transducer, eight rigid pole load cells, the monorail speed trap, and an impact contact switch to electronically mark first contact between the vehicle and the pole. The speed trap signals and the impact contact switch were not conditioned before being recorded.

The speed trap consisted of a single microswitch mounted to the monorail 4.2 m from the pole. The wheels from the main side-impact carriage trip the switch as the vehicle passes over the speed trap. The distance between the two main carriage wheels was 965 mm.

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Table 4. Summary of instrumentation and channel assignments			
ODAS III onboard data system			
Reference & Channel	**Transducer**	**Max. range**	**Data description**
1	Accelerometer	2000 g's	Head, X-axis
2	Accelerometer	2000 g's	Head, Y-axis
3	Accelerometer	2000 g's	Head, Z-axis
4	Accelerometer	2000 g's	Upper rib, Y-axis (P)
5	Accelerometer	2000 g's	Upper rib, Y-axis (R)
6	Accelerometer	2000 g's	Lower rib, Y-axis (P)
7	Accelerometer	2000 g's	Lower rib, Y-axis (R)
8	Accelerometer	2000 g's	Lower spine, Y-axis, T12 (P)
9	Accelerometer	2000 g's	Lower spine, Y-axis, T12 (R)
10	Accelerometer	2000 g's	Pelvis, Y-axis
11	Load cell	9000 N	Neck force, X-axis
12	Load cell	9000 N	Neck force, Y-axis
13	Load cell	9000 N	Neck force, Z-axis
14	Load cell	282 N·m	Neck moment, X moment
15	Load cell	282 N·m	Neck moment, Y moment
16	Accelerometer	100 g's	Z-axis, c.g. data
17	Accelerometer	100 g's	Y-axis, c.g. data
18	Rate transducer	500 deg/s	Pitch rate, c.g.
19	Rate transducer	500 deg/s	Roll rate, c.g.
20	Rate transducer	500 deg/s	Yaw rate, c.g.
21	Accelerometer	2000 g's	X-axis, engine block
22	Accelerometer	2000 g's	Y-axis, engine block
23	Accelerometer	2000 g's	Driver seat track
24	Load cell	340 N·m	Neck moment, Z moment
25	Accelerometer	2000 g's	Right side lower sill
26	Accelerometer	2000 g's	Right side roof rail

Table 4. Summary of instrumentation and channels (continued).			
27	Accelerometer	2000 g's	Driver door-beam
28	Accelerometer	2000 g's	Longitudinal frame member
29	Accelerometer	2000 g's	Transmission cross member/mount
30	Accelerometer	2000 g's	Truck bed cross member #1
31	Accelerometer	2000 g's	Truck bed cross member #2
32	Accelerometer	2000 g's	Truck bed cross member #3
33	Accelerometer	2000 g's	Rear bumper, X-axis
34	Accelerometer	2000 g's	Rear bumper, Y-axis
35	Accelerometer	100 g's	X-axis, c.g. data
Umbilical cable, tape recorder system.			
1	Accelerometer	100 g's	c.g., Y-axis
2	Displacement transducer	1,905 g's	Span between left and right door interior
3	Load cell	111,000 N	Pole force, Y-axis
4	Load cell	222,000 N	Pole force, Y-axis
5	Load cell	222,000 N	Pole force, Y-axis
6	Load cell	222,000 N	Pole force, Y-axis
7	Load cell	222,000 N	Pole force, Y-axis
8	Load cell	222,000 N	Pole force, Y-axis
9	Load cell	222,000 N	Pole force, Y-axis
10	Load cell	222,000 N	Pole force, Y-axis
11	Contact switch	1.5 Volts	Time of impact, T0
12	Micro switch	1.5 Volts	Monorail speed trap
13	Generator	1.5 Volts	1 kHz reference signal

The shaded entries in table 4 represent SIDH3 data channels. The displacement transducer malfunctioned during test preparation and was omitted before the test.

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Table 5 contains the three-dimensional location of each vehicle sensor. The origin for these measurements was the right front wheel hub. The hub was 370 mm above ground.

Table 5. Vehicle sensor location.

Sensor	**Data**	**Location (X,Y,Z) (mm)**
Six c.g. accelerometers	(A_{x1},A_{y1},A_{z1}, A_{x2},A_{y2},A_{z2})	(-965,840,290)
Angular rate sensor at c.g.	(pitch, roll, yaw rate)	(-965,840,290)
Top of engine	(A_x,A_y)	(30,900,515)
Seat under SIDH3	(A_y)	(-1550,1525,265)
Right side door sill across from impact	(A_y)	(-1310,25,100)
Right side roof rail across from impact	(A_y)	(-1310,185,1345)
Driver door-beam	(A_y)	(-1310,1815,455)
Longitudinal frame under driver at impact point	(A_y)	(-1310,1450,-20)
Transmission mount cross member	(A_y)	(-870,855,-65)
Lateral cross member #1 under truck bed	(A_y)	(-1980,840,190)
Lateral cross member #2 under truck bed	(A_y)	(-2705,800,260)
Lateral cross member #3 under truck bed	(A_y)	(-3990,865,310)
Rear bumper	(A_x,A_y)	(-4545,900,220)

The coordinate system used for the sensor location measurements and transducer polarity was as follows:

X-axis -	Front to rear of vehicle, longitudinal centerline. Positive direction toward the front end.
Y-axis -	Laterally door to door. Positive direction toward driver door.
Z-axis -	Floor to roof. Positive upward out of roof.

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HIGH-SPEED PHOTOGRAPHY

Nine high-speed cameras were used to record the side-impact collision. All high-speed cameras were loaded with Kodak color daylight film 2253. The cameras operated at 500 frames/s and were positioned for best viewing of the contact between the Chevrolet C2500 and the rigid pole. Three 35-mm still cameras and one 16-mm real-time telecine camera were used to document the pre- and post-crash environment. Table 6 lists the position and lens used for each camera. The camera numbers in table 6 are shown in figure 6. The interior of the driver door was painted flat white for better onboard camera image quality.

Table 6. Camera configuration and placement

Camera Number	Type	Film Speed (frames/s)	Lens (mm)	Location
1	LOCAM II	500	100	90° to impact right side
2	LOCAM II	500	75	90° to impact right side
3	PHOTEC	500	45	90° to impact right side
4	LOCAM II	500	50	45° right side
5	LOCAM II	500	25	180° mounted behind rigid pole
6	LOCAM II	500	50	45° left side oblique
7	LOCAM II	500	75	45° left side oblique
8	LOCAM II	500	12.5	overhead, over pole
9	LOCAM II	500	5.7	onboard in passenger window
10	Bolex	24	zoom	documentary
11	Canon A-1 (prints)	still	zoom	documentary
12	Canon A-1 (slides)	still	zoom	documentary

Black and yellow circular targets and 25-mm-wide black and yellow target tape were placed on the Chevrolet pickup truck for film data collection purposes. Circular targets and target tape were placed on the vehicle for certain vehicle measurements and for film analysis. The 25-mm tape was placed on the driver side of the vehicle at five levels or elevations referenced from the ground. The levels included:

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LEVEL 1 -- Axle centerline or lower door sill top height
LEVEL 2 -- Occupant H-point height
LEVEL 3 -- Mid-door height
LEVEL 4 -- Window sill height
LEVEL 5 -- Top of window height on roof rail

In addition, target tape was placed vertically on the driver side of the vehicle coincident with the pole impact location. Target tape was also placed on top of the vehicle in the following locations:

- Along the longitudinal centerline for the full length of the vehicle, excluding windows.
- Laterally across the roof perpendicular to the centerline tape and coincident with the pole impact location.

Target tape was placed laterally on the front and rear bumpers in the YZ plane. Black and yellow circular targets 100 mm in diameter were placed at various locations on the test vehicle for film data collection purposes. The targets were placed as follows:

- Driver door to denote the vehicle's longitudinal c.g.
- Driver door to denote the dummy H-point.
- The roof to denote the vehicle's longitudinal and later c.g. location.
- Two targets on the roof aligned with the vehicle's longitudinal centerline 610 mm apart centered on the impact line.
- Two targets aligned with the impact line 610 mm apart centered on the vehicle's longitudinal centerline.
- Two targets on the hood aligned with the vehicle's longitudinal centerline 610 mm apart.
- Two targets placed on the front and back side of two vertical sheet metal stanchions affixed to the rear half of the roof, centered on the longitudinal centerline and 610 mm apart.
- Two targets on the front and rear bumper (YZ plane) 610 mm apart centered on the longitudinal centerline.
- Targets were placed in 610-mm increments along the bottom of the truck bed for the length of the bed.

Figure 6 presents a side view of the test vehicle showing the target tape locations. Figure 6 also contains an overhead sketch of the facility depicting the setup of the vehicle, pole, test track, and the location of each high-speed camera. Positioned in each camera's view was at least one strobe light. The lights flashed when the vehicle struck the pole. This synchronized the film with the electronic data.

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Figure 6. Test setup and camera locations.

DATA ANALYSIS

Two data acquisition systems, the ODAS system and the umbilical cable system, along with high-speed cameras, were used to record the data during the side-impact crash test.

ODAS system. The data from the ODAS system included 16 channels of SIDH3 data, 16 localized accelerometer channels, and three rate transducer channels. The data were filtered and digitally stored within the ODAS unit during the test. The filter was factory set at 4,000 Hz. The ADC sampling rate was factory set at 12,500 Hz. After the test, the data were down- loaded to a portable computer for analysis. The data were converted to the ASCII format, zero-bias removed, and digitally filtered at either 1,650 Hz (Society of Automotive Engineers (SAE) class 1000) for SIDH3 data, or at 300 Hz (SAE class 180) for vehicle data. Rib, spine, and pelvic data were filtered a second time using a NHTSA-supplied FIR100 filter. The class-1000 data were input into a spreadsheet for plotting. The resultant head acceleration was calculated via a spreadsheet containing the data from the triaxial accelerometer inside the SIDH3's head. The resultant data file was fed into a head injury criteria (HIC) algorithm to compute the HIC value for the crash test. The pelvic injury criteria were determined from the pelvic acceleration data. The pelvic acceleration was filtered using the FIR100 filter and the peak was located. The thoracic trauma index (TTI) was calculated from the FIR100 filtered rib and spine (T12) data. The following formula was used to compute the TTI:

TTI = [Maximum(4 rib channels) + Maximum(spine)] ũ 2

Umbilical cable. Data collected via the umbilical cable tape recorder system were played back through an analog filter set at 1,000 Hz. The signal was then input to a data translation ADC. The data included one accelerometer channel (located at the c.g.), eight rigid pole load cell channels, an impact switch, and a monorail speed trap signal. The sample rate was set to

5,000 Hz. The digital data were converted to the ASCII format, zero-bias removed, and digitally filtered to 300 Hz (SAE class 180). The filtered data were input into a spreadsheet for plotting. Using techniques outlined in the National Cooperative Highway Research Program Report Number 350 (NCHRP Report 350)[2] the lateral occupant impact velocity (OIV) was computed.

Two square wave pulses from the lone monorail microswitch were recorded on analog tape during the crash test. The time between pulses was determined and the speed was calculated by dividing the wheel spacing (965 mm) by the time between micro- switch pulses.

High-speed film. The high-speed 16-mm film was analyzed via an NAC 160-F film motion analysis system in conjunction with a desktop personal computer. The overhead and one 90°-camera were used to acquire pertinent test data. The analyzer reduced the

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test film frame by frame to Cartesian coordinates, which were input into a spreadsheet for analysis. Using the coordinate data and the known time between frames (operating speed of the cameras), a displacement-time history was produced. Differentiation of the displacement-time history produced the initial vehicle speed. Data measurements included initial vehicle impact speed, roll angle, yaw angle, and pitch angle.

RESULTS

The Chevrolet C2500 pickup truck was placed on the FOIL side-impact monorail with its longitudinal centerline perpendicular to the runway centerline, ensuring alignment of the target impact point with the rigid pole. The morning of the test the dummy was positioned in the driver seat using the H-point data and FMVSS 214. The dummy was restrained using the vehicle shoulder-lap belt restraining system. Just prior to testing, the following was noted: the emergency brake was released (not engaged), the head rests were positioned in the highest adjustment, the windows were down, the transmission was placed in neutral, the battery was disconnected, and the key was placed in the "on" position. The Chevrolet C2500 passed over the monorail speed trap, which measured a speed of 52.8 km/h. Due to the frictional forces between the truck tires and the wet pavement, the vehicle speed was reduced to 50.8 km/h at impact and the truck leaned or rolled toward the pole at 1.8°. The initial yaw angle was 87°. Table 7 summarizes the test conditions and selected results.

Table .	
FOIL test number	97S017
Date of test	December 11, 1997
Test vehicle	1994 Chevrolet C2500 2-door pickup truck
Weight: C2500 Truck SIDH3 **Total**	1,994 kg 80 kg **2,074 kg**
Test article	FOIL 300K instrumented rigid pole
Temperature inside vehicle	22.3° C
Impact speed: 16-mm film	50.8 km/h
Impact point (mm)	100 forward of vehicle c.g.
Initial roll angle	1.8°
Initial yaw angle	87°

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Table 7. Summary of test conditions and results (continued).	
Total rigid pole load observed (load cells)	301,280 N
Traffic accident data (TAD)	9-LP-7
Vehicle damage index (VDI)	09LPAN6
Lateral occupant impact velocity	10.2 m/s
Lateral ridedown acceleration	9.7 g’s
Head injury criteria	
Limit	1000 g's
Observed	2518 g’s
Start time	0.0488 s
Stop time	0.0546 s
Interval time	0.0058 s
Thoracic trauma data	
Limit (2-door)	90 g's
Peak rib acceleration (FIR100)	130.6 g’s
T12 spine (FIR100)	93.0 g’s
Thoracic trauma index (TTI)	112 g’s
Pelvic injury	284 g’s

Vehicle response. The C2500 truck exited the monorail at 52.8 km/h. The two left tires made contact with the ground first, as the truck started to slide sideways toward the rigid pole. The two right tires landed just before impact. A sharpened rod attached to the rigid pole punctured the vehicle on the vertical target tape, denoting the intended impact location. The door cross section collapsed 0.006 s after impact. The intruding door first made contact with the dummy’s lower torso and pelvic region. Initial roof contact was made after 0.018 s. After 0.020 s, the penetration by the pole pulled the B-pillar inward and forward toward the dummy and pole. The action of the B-pillar prevented the dummy’s head from protruding from the window. The pole continued to penetrate the occupant compartment, bending and contorting the floor pan and roof rail. The dashboard and bench seat buckled. The bench seat was forced into the passenger door and the latch failed, which allowed the door to swing open. The truck’s C-section longitudinal frame rail failed in bending and was flattened. As the frame rail buckled, the cab dislodged from the frame mounts on both sides of the truck. The breadth of the bending frame rail reached the transmission mount, which was located 350 mm forward of the impact location, and enough energy remained to fail the transmission mount cross member. The cross member buckled downward and struck the ground. The severe deformation led to direct contact with the monorail guidance carriage. The carriage was mounted to the truck with small bolts, which allowed the carriage to break away without damage or significant contribution to the truck's undercarriage performance. The front end and bed of the pickup truck moved independently; the bed continued to wrap around the pole and struck the load cells bolted to the back face of the rigid pole. The wrapping action of the front end and bed was stopped by the pole itself. The width of the door was reduced to the diameter of the pole impact faces before rebounding. Double integration of the c.g. acceleration trace for the total event time yielded a maximum deflection of 1.0 m. Double integration of the c.g. acceleration trace, for the time up to when the cab started to rotate and became dislodged from the frame, yielded a maximum deflection of 840 mm. Both accelerometer deflection values may be exaggerated due to the extreme buckling of the floor pan and floor tunnel. The maximum static deflection measured after the test was 1156 mm. However, the points used to position the reference plane for measuring the post-test profile had been displaced. The distance between the two parallel longitudinal frame rails before the test was

1140 mm, and after the test, the frame rails were 510 mm apart. The static deflection of the left frame rail was 630 mm. The total frame rail deflection cannot be equated to the occupant compartment deformation because the cab dislodged from the frame. The cab was displaced approximately 305 mm (static measure). The interior distance between the doors was 1730 mm before the test and 995 mm afterward, which indicates a static intrusion of 735 mm. As the C-shape frame rail deflected, one leg of the C-shape ripped a hole in the fuel tank located on the left side of the vehicle and inboard of the frame rail.

Damage to the pickup truck was extensive. The driver door caved, the B-pillar drew inward, the windshield shattered, the dashboard and bench seat buckled, the left frame rail bent and punctured the fuel tank, the transmission mount cross member buckled, the aluminum drive shaft bent, and the cab dislodged from the frame mounts. The passenger door latch failed, which allowed the door to swing open. The driver door remained latched. The peak lateral c.g. acceleration recorded was

30.4 g's (595,000 N) and occurred 0.0494 s after impact. Table 8 lists the positive and negative peak accelerations from each vehicle accelerometer.

Table 8. Vehicle sensor peak accelerations

Sensor	Maximum positive (g's)	Maximum negative (g's)
C.g. accelerometer A_x, primary	12.3	-13.6
C.g. accelerometer A_y, primary	5.5	-30.4

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Table 8. Vehicle sensor peak accelerations (continued).		
C.g. accelerometer A_z, primary	17.1	-17.5
C.g. accelerometer A_y, redundant	4.8	-27.8
Engine block, A_x	16.4	-1.4
Engine block, A_y	15.3	-5.0
Driver seat, A_y	54.5	-219.2
Right lower sill, A_y	24.1	-75.7
Right roof rail, A_y	9.1	-42.0
Driver door-beam, A_y	1186.4	-1542.5
Longitudinal frame member, A_y	12.7	-739.2
Transmission mount, A_y	31.0	-91.6
Bed cross member #1, A_y	161.1	-69.9
Bed cross member #2 A_y	25.9	-36.3
Bed cross member #3 A_y	17.6	-33.4
Rear bumper, A_x	18.9	-23.9
Rear bumper, A_y	26.1	-21.9

After the test, a damage profile of the vehicle was produced. Figure 7 depicts the driver-side profile measurements before and after the test. The measurements were made using a reference line parallel to the driver side of the vehicle. The parallel line was drawn a certain distance from and perpendicular to a line formed by the passenger side sill across from the impact location. This ensured that the same reference plane was used after the test to measure the post-test measurements. The measurements were made in 75-mm and 150-mm increments forward and aft of the impact point. After the test, measurements were taken at the same points forward and aft. However, due to the extensive vehicle damage, the new distances or increments forward and aft of the impact line were also recorded in the figure. From the figure, the maximum static deflection recorded was 1149 mm at mid-door height along the vertical impact target tape.

Data plots from the transducers mounted to the test vehicle are presented in appendix A. Photographs taken from high-speed film and photographs of the pre- and post-test environment are presented in appendix C.

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figure7.gif (4104 bytes)

			Distance from impact point (mm).											
LEVEL	**HEIGHT**		**-1067**	**-914**	**-762**	**-610**	**-457**	**-381**	**-305**	**-229**	**-152**	**-76**	**0**	**76**
1	438	**PRE**			582	582	580	580	578	578	575	575	570	568
	380	**POST**			965	1127	1258	1340	1405	1490	1556	1620	1631	1618
		CRUSH	0	0	383	545	678	760	827	912	981	1045	1061	1050
2	876	**PRE**	524	524	524	522	520	520	521	520	520	520	521	521
	834	**POST**	796	862	1023	1156	1312	912	978	1384	1450	1540	1612	1661
		CRUSH	272	338	499	634	792	392	457	864	930	1020	1091	1140
3	775	**PRE**	520	520	520	519	517	517	517	517	518	518	518	517
	737	**POST**	795	858	1012	1155	1298	1381	1468	1510	1603	1656	1667	1647
		CRUSH	275	338	492	636	781	864	951	993	1085	1138	1149	1130
4	1162	**PRE**	570	570	566	567	565	564	563	563	560	561	560	560
	1069	**POST**	832	893	1040	1175	1316	1392	1465	1542	1618	1674	1697	1657
		CRUSH	262	323	474	608	751	828	902	979	1058	1113	1137	1097
5	1683	**PRE**								765	765	765	763	762
	1640	**POST**								1612	1695	1745	1740	1725
		CRUSH	0	0	0	0	0	0	0	847	930	980	977	963
Post-test increments forward/aft from impact			-622	-484	-311	-241	-191	-178	-156	-140	-121	-70	0	70
All units of measurement are in mm.														

Figure 7. Vehicle profile measurements, test 907S017.

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			Distance from impact point (mm).											
LEVEL	**HEIGHT**		**152**	**229**	**305**	**381**	**457**	**533**	**686**	**838**	**991**			
1	438	**PRE**	568	565	565	565	565	564	565	567	567			
	380	**POST**	1560	1490	1417	1333	1257	1186	677	643	611			
		CRUSH	992	925	852	768	692	622	112	76	44	0	0	0
2	876	**PRE**	520	520	520	520	521	520	520	521	521			
	834	**POST**	1591	1515	1444	1362	1285	1214	658	623	588			
		CRUSH	1071	995	924	842	764	694	138	102	67	0	0	0
3	775	**PRE**	517	517	517	517	518	517	518	518	519			
	737	**POST**	1597	1522	1445	1363	1283	1212	660	626	585			
		CRUSH	1080	1005	928	846	765	695	142	108	66	0	0	0
4	1162	**PRE**	560	561	560	561	561	561	560	560	560			
	1069	**POST**	1604	1523	1452	1377	1321	1243	687	650	624			
		CRUSH	1044	962	892	816	760	682	127	90	64	0	0	0
5	1683	**PRE**	762	760	760	762	762							
	1640	**POST**	1680	1622	1500	1430	1455							
		CRUSH	918	862	740	668	693	0	0	0	0	0	0	0
Post-test increments forward /aft from impact			114	117	133	140	178	210	311	460	600			
All units of measurement are in mm.														

Figure 7. Vehicle profile measurements, test 97S017 (continued).

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Occupant response. The SIDH3 remained upright during the vehicle propulsion stage. The vehicle exited the side-impact monorail and began to slide sideways along the wet concrete runway. The drop off the monorail, coupled with the frictional forces between the tires and the wet runway, slowed the vehicle and induced a vehicle roll angle of 1.8° at impact. The roll angle and vehicle deceleration caused the SIDH3 to lean toward the driver door. The pole intruded into the occupant compartment, forward of the dummy’s head and in line with the dummy’s pelvic region. Contact between the door and the dummy’s lower torso and pelvis occurred approximately 0.016 s after impact. The penetrating door and pole propelled the pelvis to the right, rotating the dummy’s head toward the B-pillar and pole. The force imparted on the pelvis also rotated the dummy in the seat and was high enough to shear the thigh-lower leg connecting bolt in each leg. The separation was not at the knee. The first indication of leg separation was at 0.042 s. The lower legs remained within the thermal underwear clothing. The seat belt buckle remained fastened throughout the test. The impact force buckled the bench seat upward (0.052 s), which imparted an upward velocity into the dummy. The B-pillar was drawn inward and forward toward the pole. The B-pillar was drawn in quick enough so as not to allow the dummy’s head to protrude from the window. However, the side of the dummy’s head made significant contact with the B-pillar, as indicated by large amounts of green chalk residue. The motion of the B-pillar forced the head into the side of the rigid pole within the truck cab. The head was pinched between the B-pillar and the pole. Blue chalk residue was found on the side surface of the rigid pole. The cab wrapped around the rigid pole enough to cause the dummy’s head and head rest to punch out the rear window. The head was pinched between the B-pillar and the rigid pole for approximately 0.100 s. While the head was pinched and stationary, the torso continued to bounce and recoil from the pole, bending and twisting the neck.

Inspection of the pole and vehicle interior revealed red, green, blue, and purple chalk on various surfaces, confirming contact from specific dummy parts. Blue chalk from the dummy’s face was found on the side of the rigid pole, and red chalk from the rear surface of the head was found on the B-pillar, confirming the pinching action between the B-pillar and the rigid pole. Red chalk was also found on the interior surface of the

B-pillar, along with some green chalk. These colors indicate contact between the rear and side surface of the dummy’s head and the B-pillar. Red from the thigh was found along the interior door panel and arm rest. The SIDH3 remained upright in the driver seat after the test. The dummy remained wedged between the collapsed door and the bench seat. The shoulder/lap belt became highly tensioned and pressed the dummy into the seat; however, the buckle remained latched. As shown in table 7, the HIC (2518 g’s), TTI (112 g’s), and pelvic injury (284 g’s) values exceed the current side-impact safety performance standards specified in FMVSS 214, which suggests a high probability of severe occupant injury.

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Using the techniques outlined in NCHRP Report 350, the lateral OIV was calculated. The lateral OIV is based on vehicle c.g. lateral acceleration data. The computed lateral OIV was 10.2 m/s, below current FHWA safety performance levels.

Table 9. Summary of SIDH3 data.

Recorded Data	**Maximum positive (g's)**	**Maximum negative (g's)**
Head X-axis acceleration	27.5	-53.1
Head Y-axis acceleration	18.4	-272.7
Head Z-axis acceleration	35.1	-69.3
X-axis neck force load cell(N)	433.5	-802.0
Y-axis neck force load cell(N)	1616.2	-62.2
Z-axis neck force load cell(N)	1605.2	-3030.3
X-axis neck moment load cell (1000 mm·N)	28.7	-157.0
Y-axis neck moment load cell (1000 mm·N)	41.7	-43.4
Z-axis neck moment load cell (1000 mm·N)	26.1	-12.6
Left upper rib acceleration(P)	42.5	-130.6
Left upper rib acceleration(R)	41.4	-127.3
Left lower rib acceleration(P)	9.1	-121.2
Left lower rib acceleration(R)	4.2	-115.4
Spine T12 Y acceleration (P)	26.4	-93.0
Spine T12 Y acceleration (R)	27.7	-88.6
Pelvis Y acceleration	30.5	-284.5

Shaded values from output of FIR100 filter, other values class 1000.

Data plots from the SIDH3 transducers are presented in appendix B. All data plots are of class 1000 data.

The load cells measured eight separate forces on the rigid pole. The total load from summing the eight load cell signals was 301,280 N. The significant loads were contributed by the roof-rail, floor-sill, and the mid-point of the driver door. The peak loads from the roof-rail, mid-door, and floor-sill were 26,600 N, 110,400 N, and 193,600 N, respectively. Using torque equations, the height of the

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resultant load was determined to be 485 mm. The resultant load height started at an elevation of 600 mm, then shifted down to 400 mm, which is approximately the height of the frame rail. Table 10 summarizes the load cell data. Data plots from the rigid pole load cells are presented in appendix D.

Table 10. Summary of rigid pole data.

Load cell / height (mm)	**Peak force (1000 N)**	**Time (ms)**
Top face	-13.3	95.4
Upper load cell/ 2,057	-4.6	38.6
Lower load cell/ 1,816	-10.7	89.0
Middle-upper face	-50.1	32.2
Upper load cell / 1,650	-20.0	52.0
Lower load cell / 1,168	-34.9	36.8
Middle-lower face	-110.4	27.2
Upper load cell / 978	-29.3	27.2
Lower load cell / 648	-81.1	27.4
Bottom face	-193.6	34.6
Upper load cell / 470	-94.6	69.4
Lower load cell / 90	-102.8	34.6
Total, rigid pole	-301.3	34.6

CONCLUSIONS AND OBSERVATIONS

Visual inspection of the Chevrolet C2500 and rigid pole after the test produced immediate conclusions. The forces on the right door latch from the displaced bench seat caused the latch to fail, allowing the door to swing open. The vehicle wrapped around the rigid pole, conforming to the shape of the pole. The cab was dislodged from the frame and displaced 320 mm. The left frame rail bent and the transmission cross member buckled, touching the ground. Chalk residue on the B-pillar, pole, and door interior verified dummy contact. Both of the dummy's legs broke above the knee, at the connection between the knee joint and thigh. A similar test, test number 97S016, produced similar but much less catastrophic results. This test was conducted at 50 km/h, which is twice the energy as in test 97S016, conducted at 35 km/h. The deformation in test 97S016 was limited by the transmission mount cross member. With twice the energy present in test 97S017, the transmission mount cross member buckled, leaving minimal resistance to extended deformation. The results from test 97S016 are presented in the report *35-km/h Broadside Crash Test of a 1994 Chevrolet C2500 and the FOIL 300K Rigid Pole: FOIL Test Number 97S016*.[3] In both tests, the extensive wrap around the 255-mm-diameter pole led to contact between the dummy's head and the rigid pole. The higher initial energy in test 97S017, coupled with the rotation of the head induced by the pole accelerating the pelvis to the right, contributed to an HIC value 2.5 times greater than the HIC observed in test 97S016. The pelvic injury for test 97S017 was 2.2 times greater than that observed in the lower speed test (97S016). The deformation in each test was great enough to cause the left C-section frame rail to tear the fuel tank.

Results from additional pickup truck broadside crash tests conducted with similar impact conditions into the Valmont Industries Slip Away lighting standards are contained in the reports *35-km/h Broadside Crash Test of a 1994 Chevrolet C2500 and a Valmont Industries Slip Away Lighting Standard: FOIL Test Number 97S012,*[4] and *50-km/h Broadside Crash Test of a 1994 Chevrolet C2500 and a Valmont Industries Slip Away Lighting Standard: FOIL Test Number 97S015.*[5] The results from these broadside tests are much less severe because of the breakaway performance of the slip base pole.

The crush profile, electronic data, and high-speed film will aid computer simulation engineers in developing and validating side-impact FEM's of pickup trucks.

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APPENDIX A. DATA PLOTS FROM VEHICLE ACCELEROMETERS

figure8.gif (12343 bytes)

Figure 8. Acceleration vs. time, c.g. X-axis primary, test 97S017.

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Figure 9. Acceleration vs. time, c.g. Y-axis primary, test 97S017.

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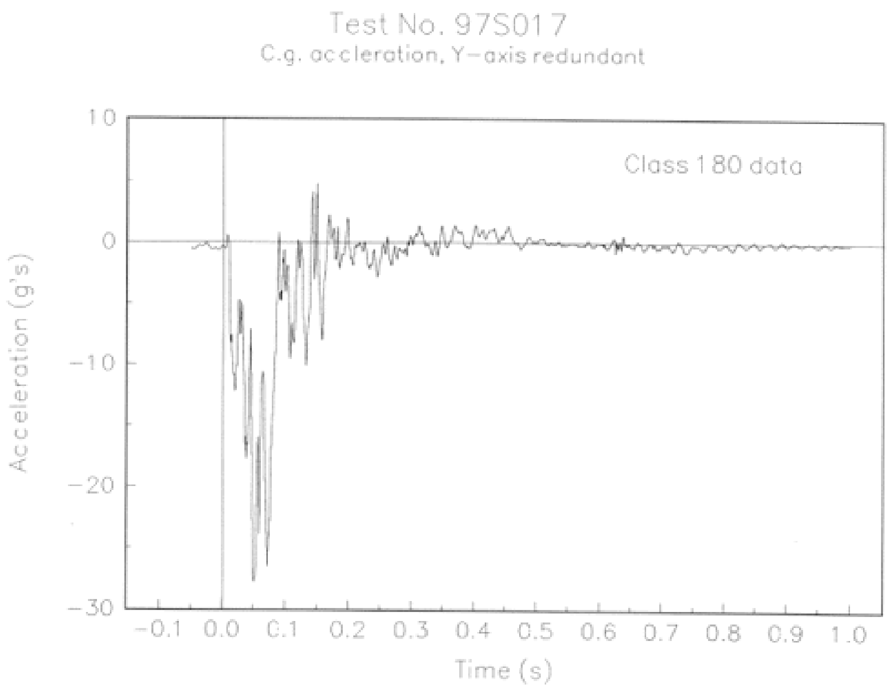

Figure 10. Acceleration vs. time, c.g. Y-axis redundant, test 97S017.

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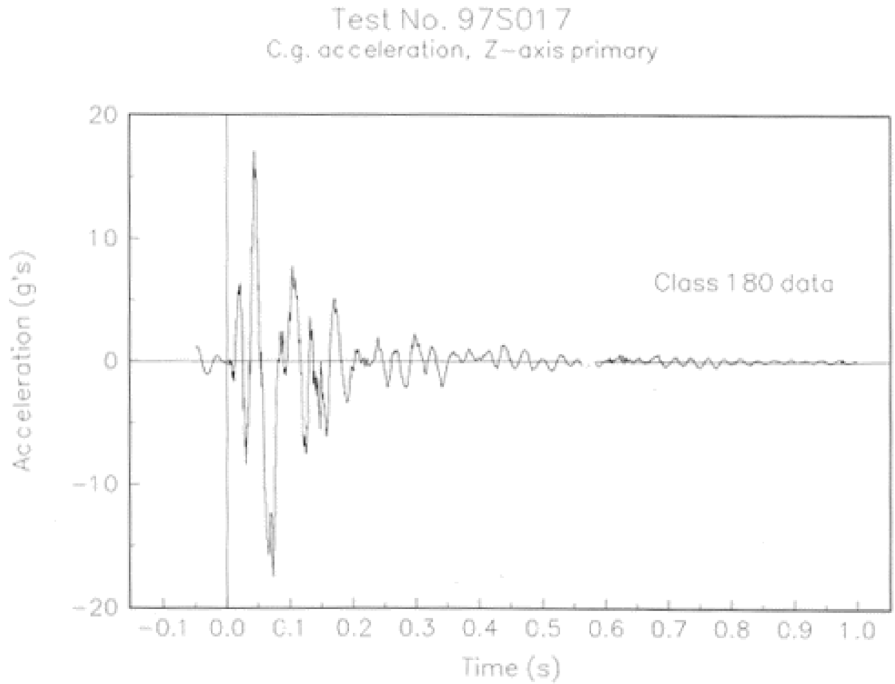

Figure 11. Acceleration vs time, c.g. Z-axis primary, test 97S017.

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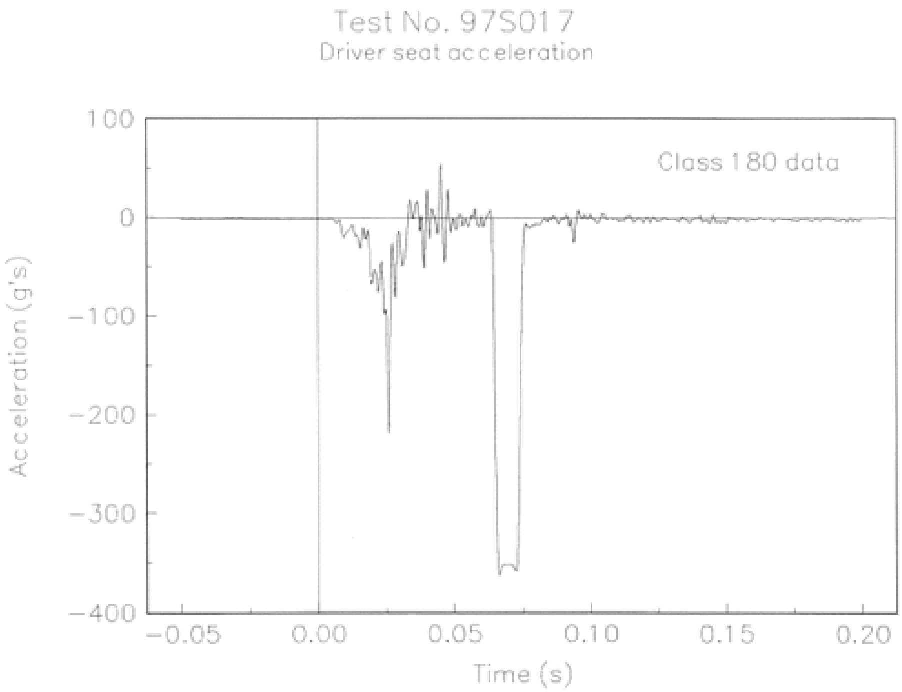

Figure 12. Acceleration vs time, driver seat, test 97S017.

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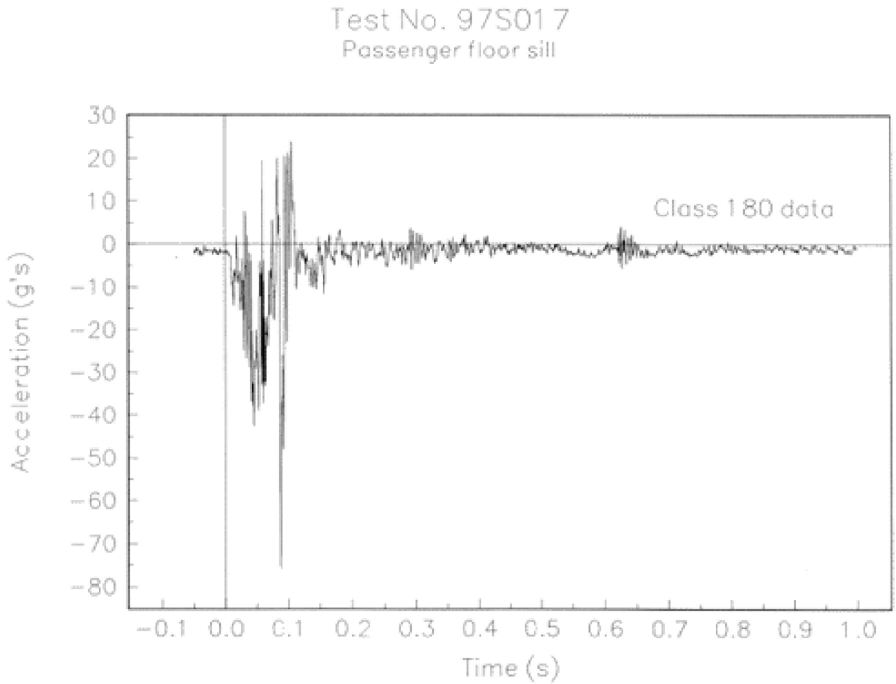

Figure 13. Acceleration vs time, passenger floor sill, test 97S017.

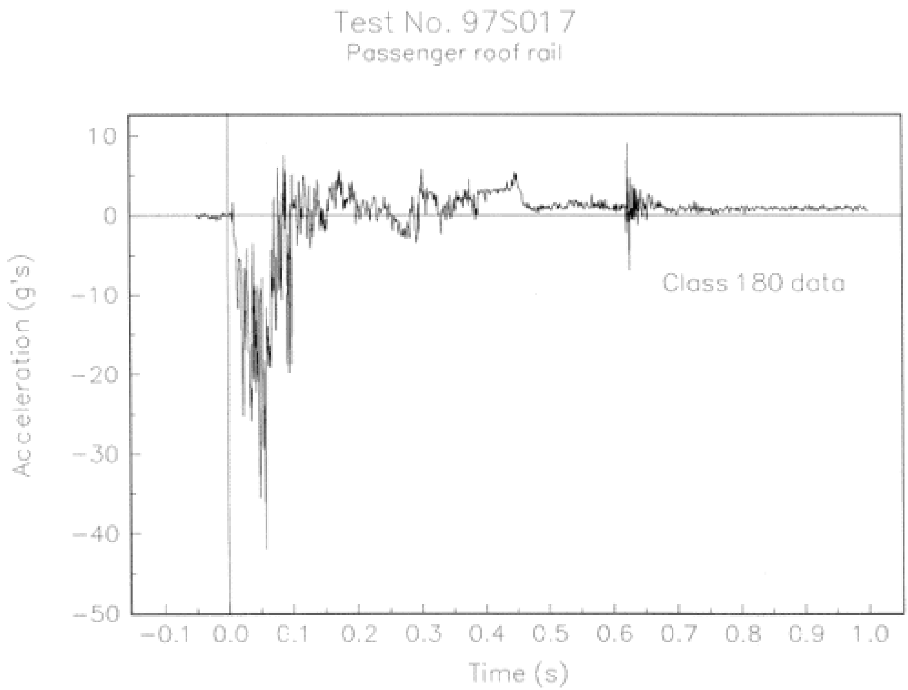

Figure 14. Acceleration vs time, passenger roof rail, test 97S017.

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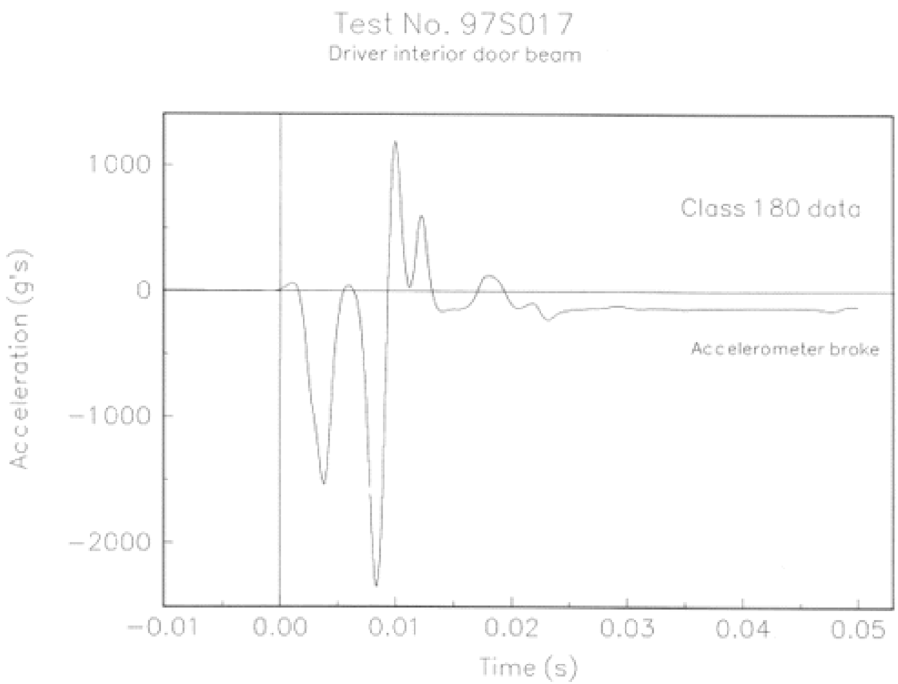

Figure 15. Acceleration vs. time, driver interior door beam, test 97S017.

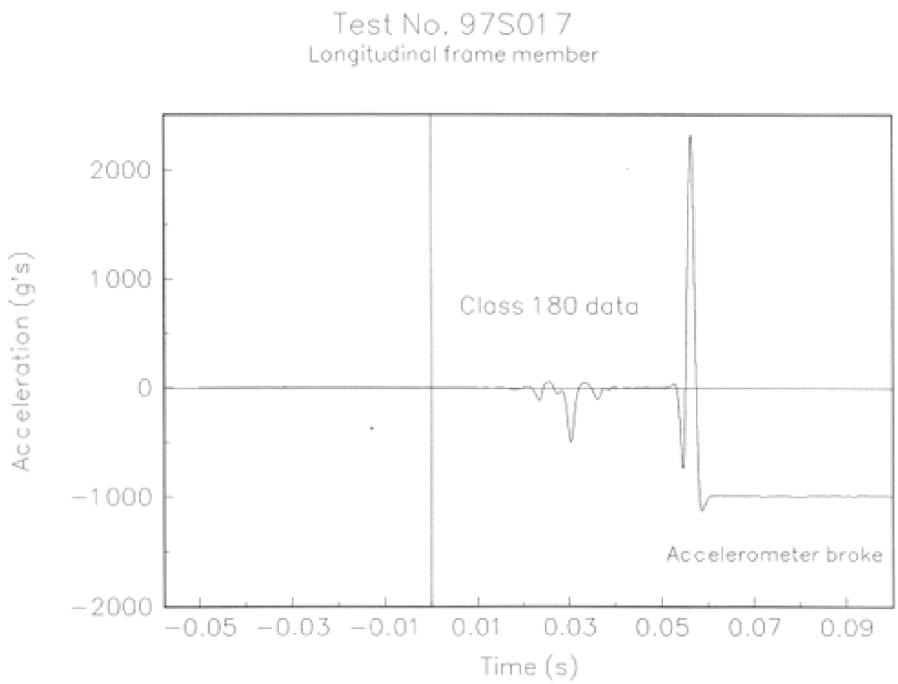

Figure 16. Acceleration vs time, longitudinal frame member, test 97S017.

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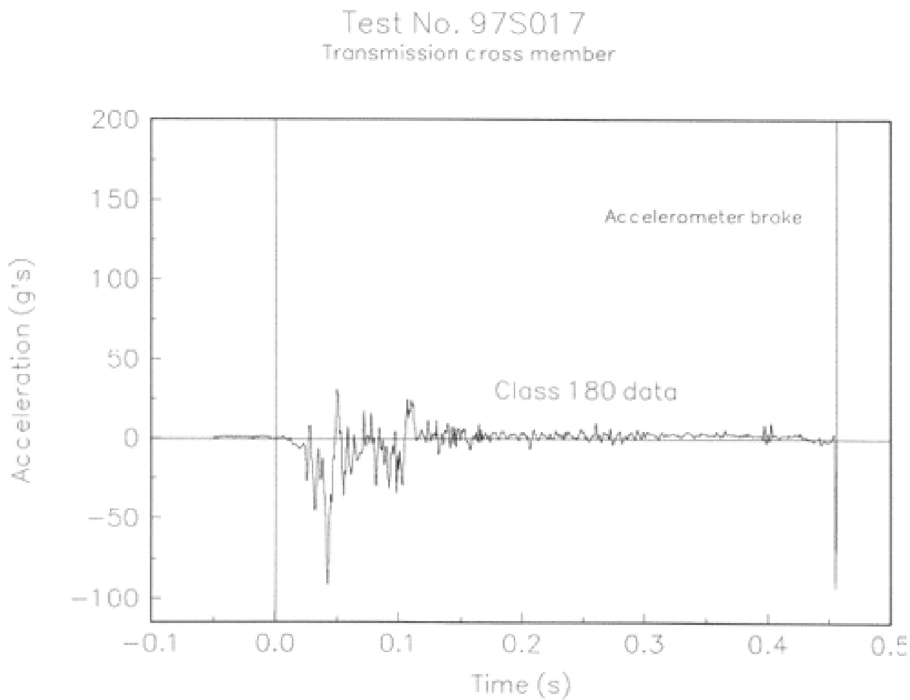

Figure 17. Acceleration vs time, transmission cross member, test 97S017.

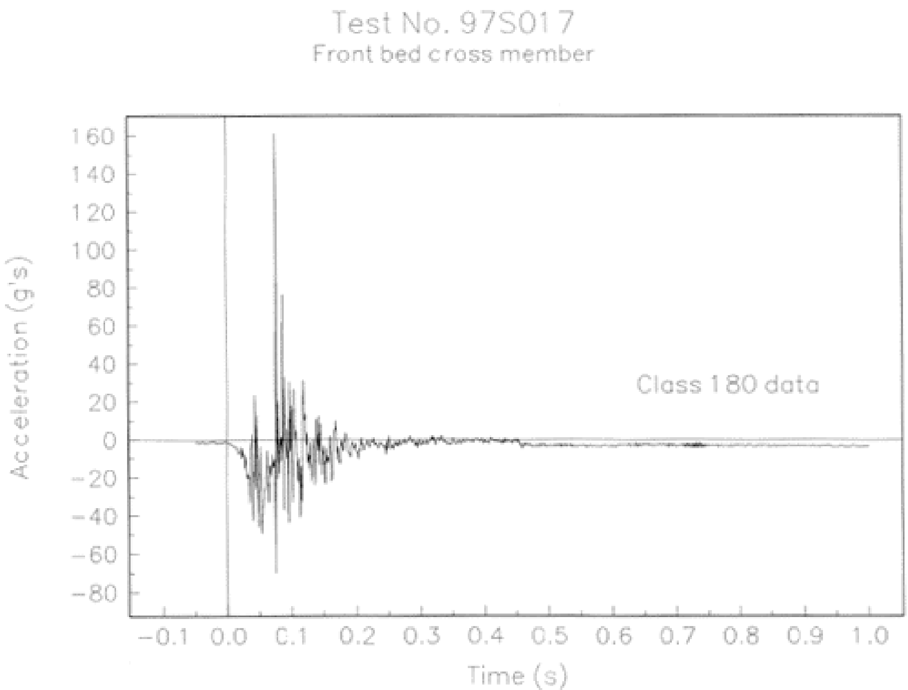

Figure 18. Acceleration vs time, front bed cross member, test 97S017.

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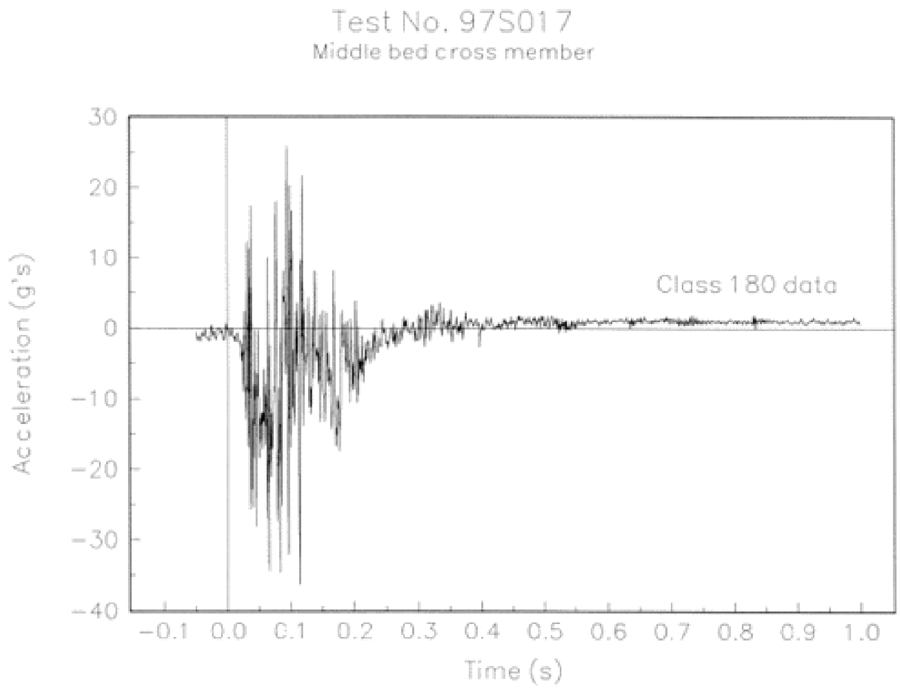

Figure 19. Acceleration vs time, middle bed cross member, test 97S017.

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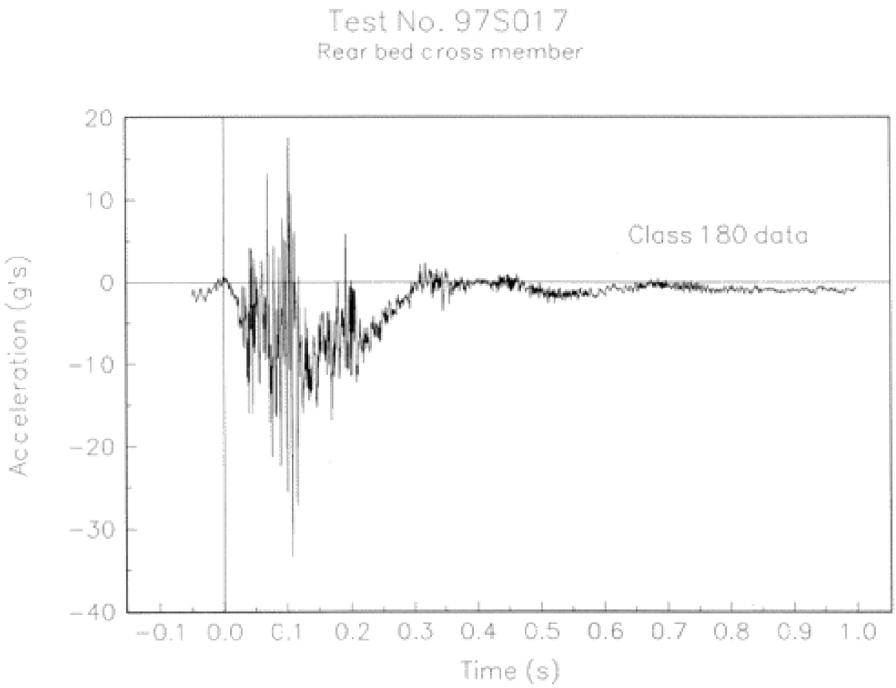

Figure 20. Acceleration vs time, rear bed cross member, test 97S017.

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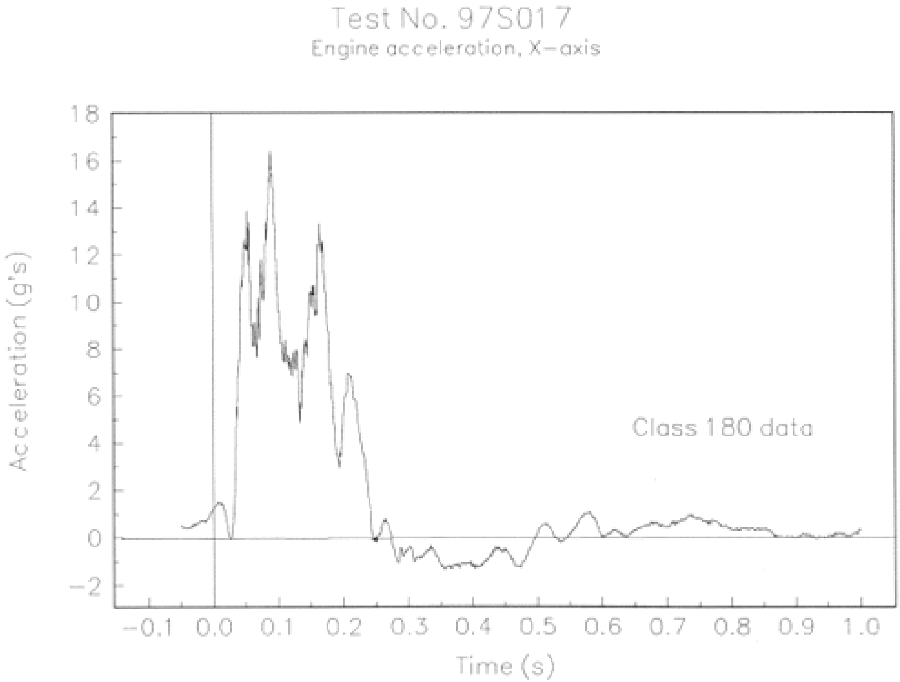

Figure 21. Acceleration vs time, engine X-axis, test 97S017.

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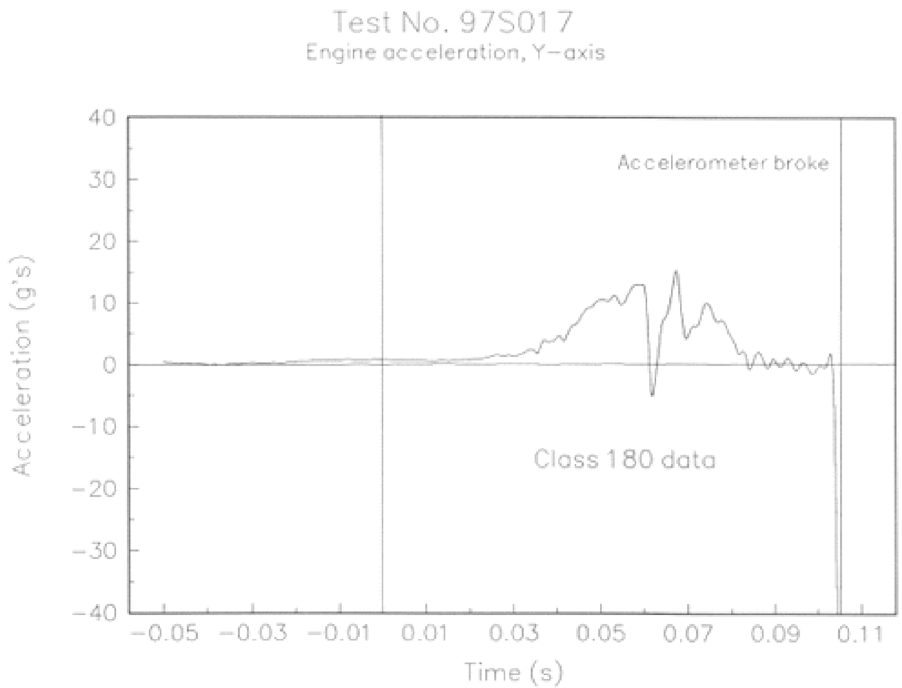

Figure 22. Acceleration vs time, engine Y-axis, test 97S017.

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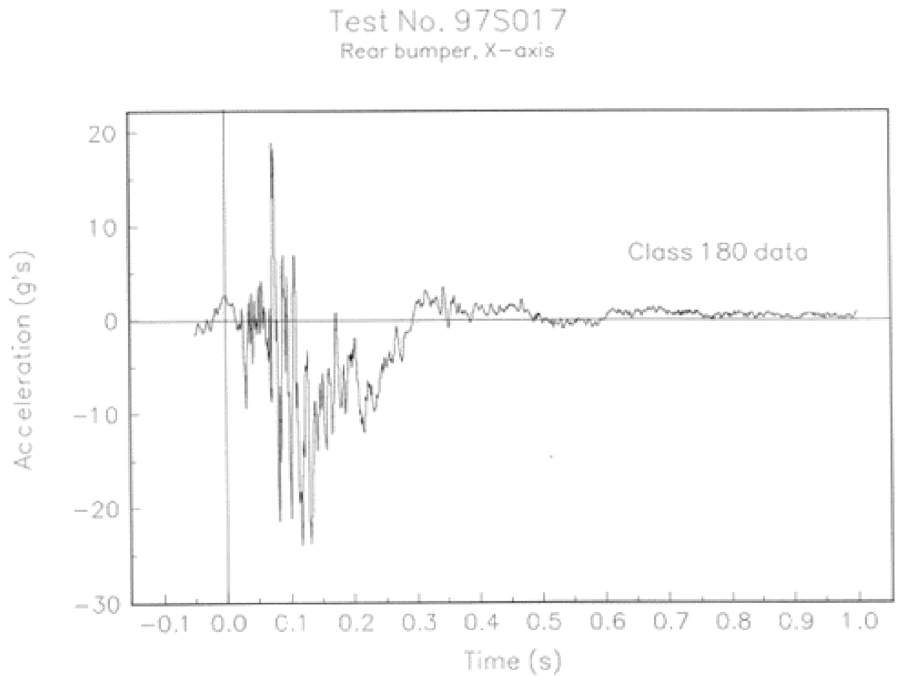

Figure 23. Acceleration vs time, rear bumper X-axis, test 97S017.

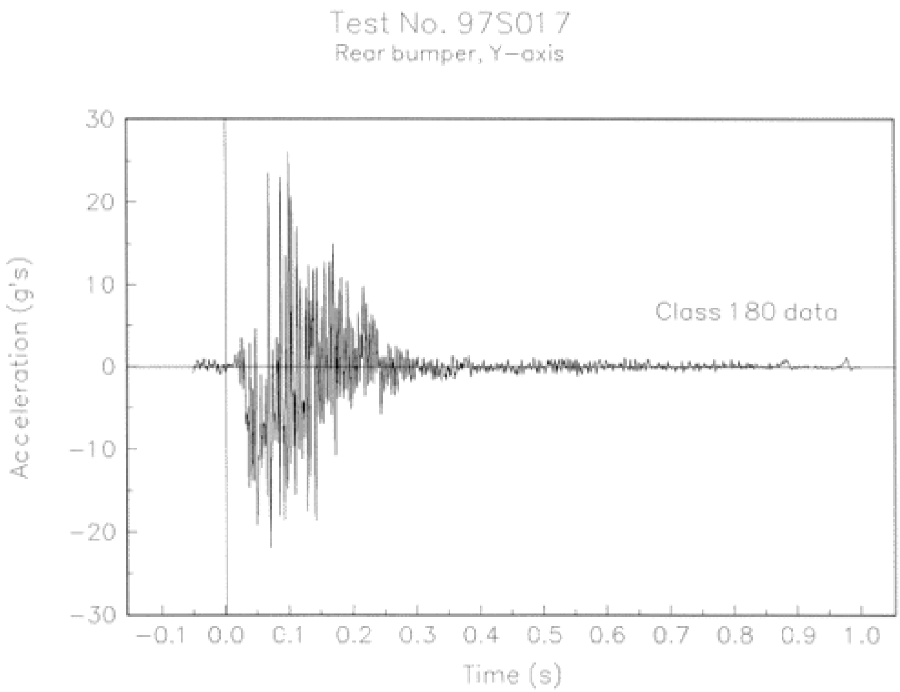

Figure 24. Acceleration vs. time, rear bumper Y-axis, test 97S017.

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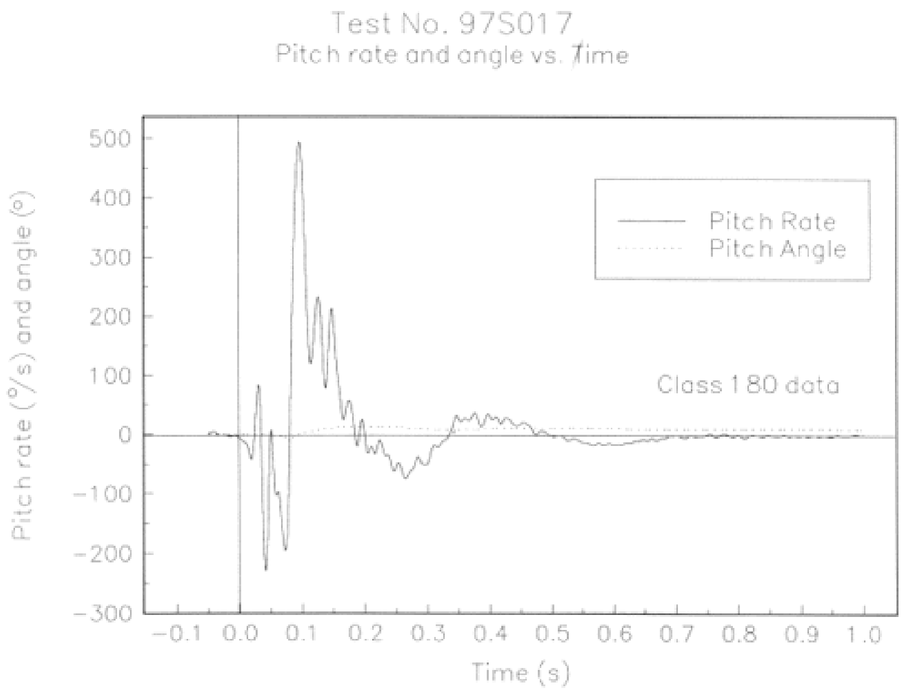

Figure 25. Pitch rate and angle vs. time, test 97S017.

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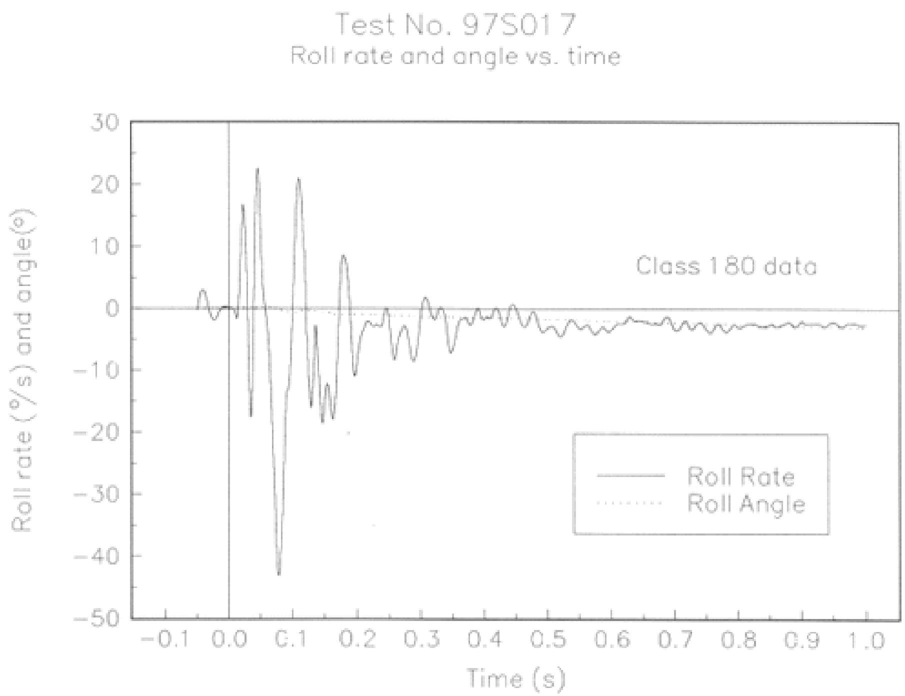

Figure 26. Roll rate and angle vs. time, test 97S017.

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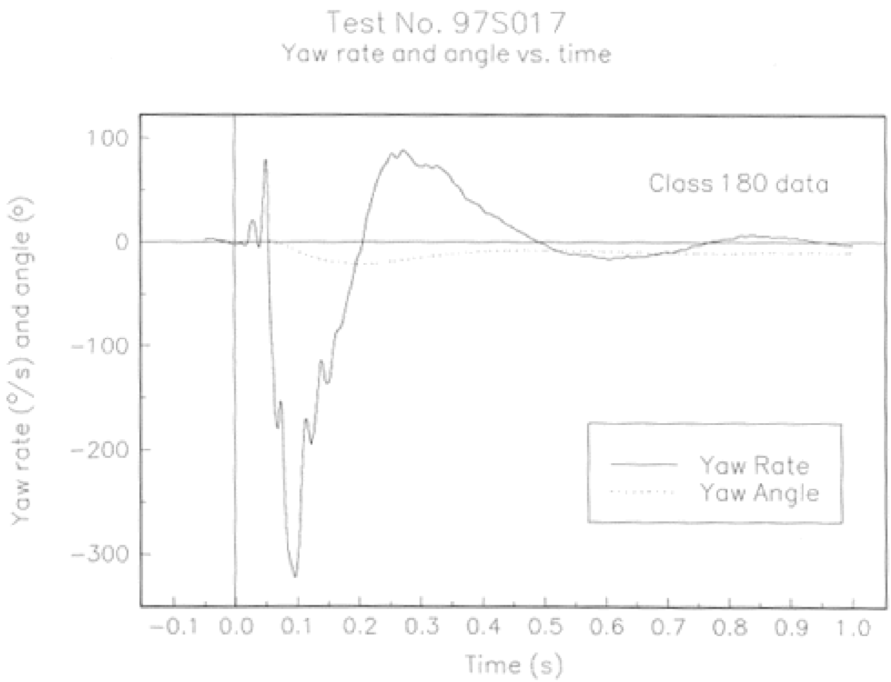

Figure 27. Yaw rate and angle vs. time, test 97S017.

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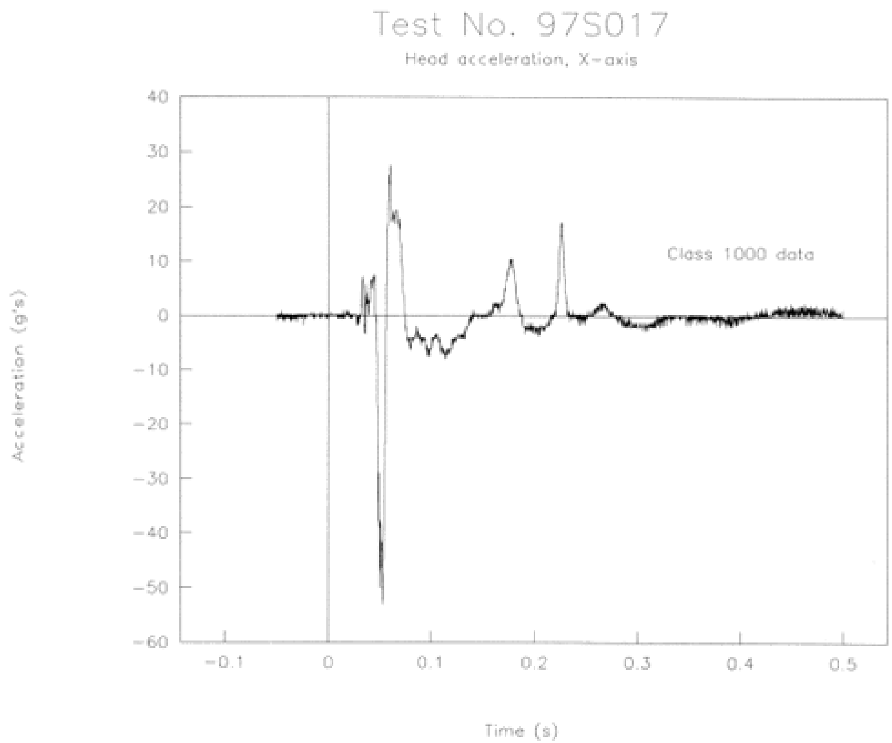

Figure 28. Acceleration vs time, head X-axis, test 97S017.

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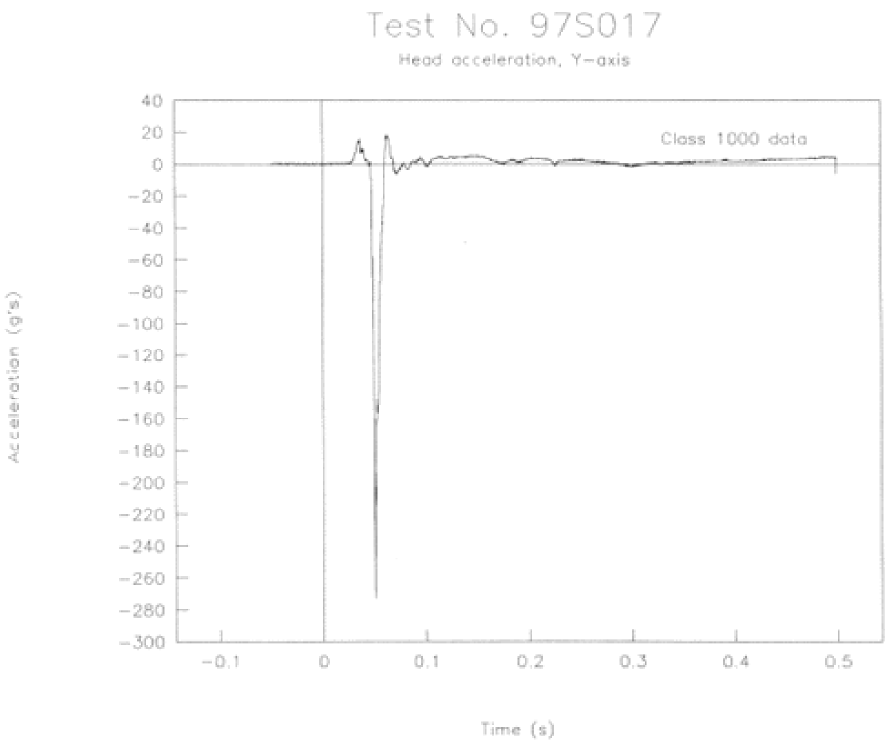

Figure 29. Acceleration vs. time, head Y-axis, test 97S017.

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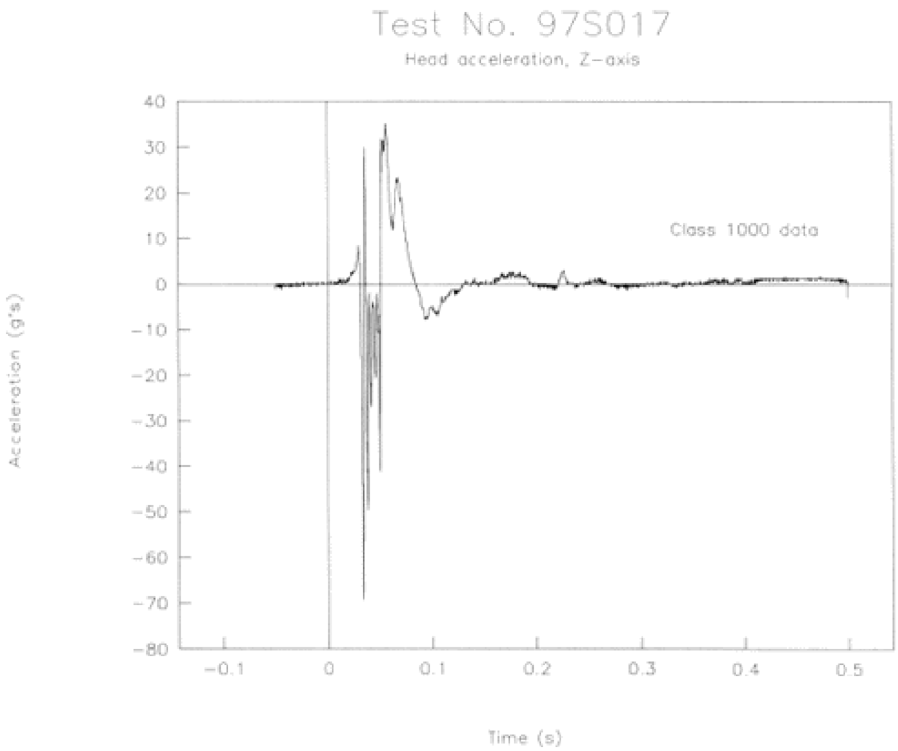

Figure 30. Acceleration vs. time, head Z-axis, test 97S017.

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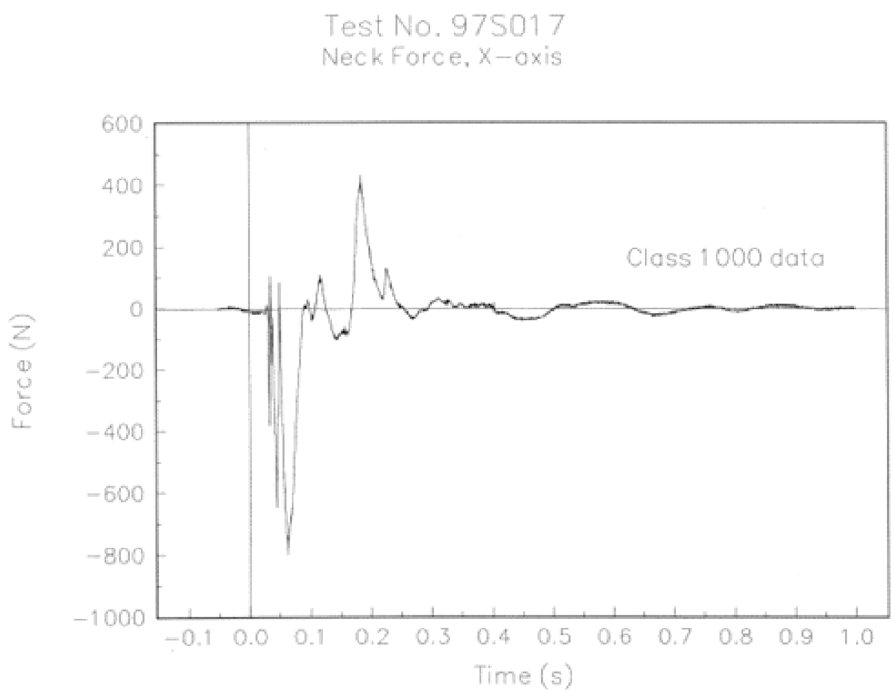

Figure 31. Force vs. time, neck X-axis, test 97S017.

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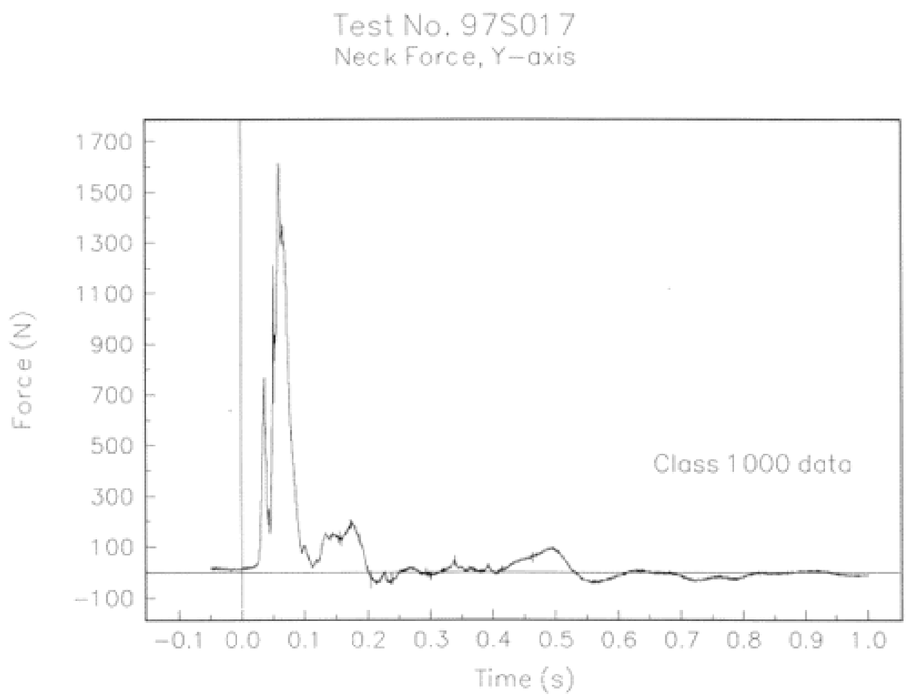

Figure 32. Force vs. time, neck Y-axis, test 97S017.

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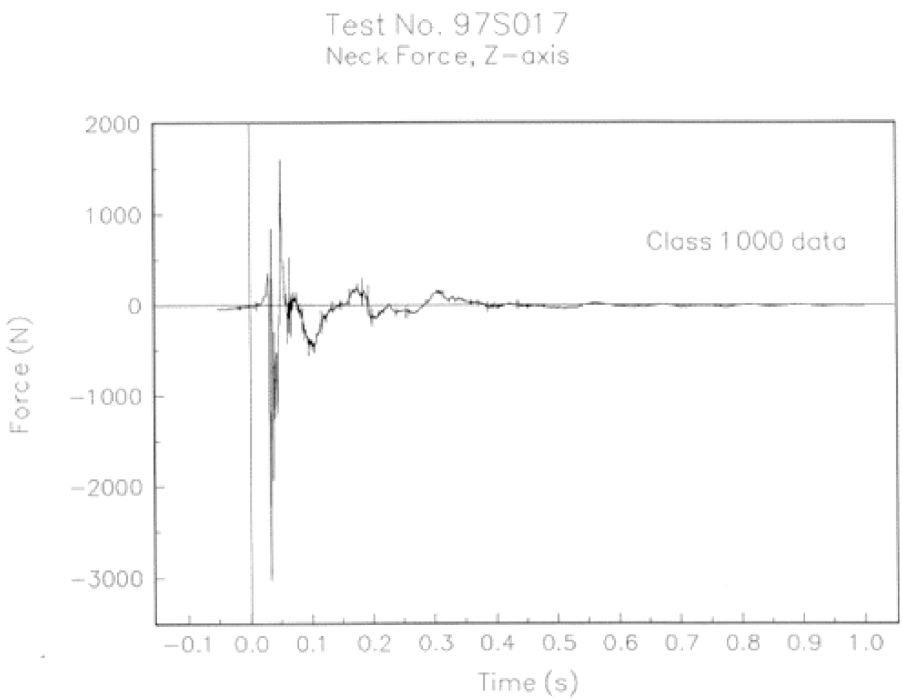

Figure 33. Moment vs. time, neck X-axis, test 97S017.

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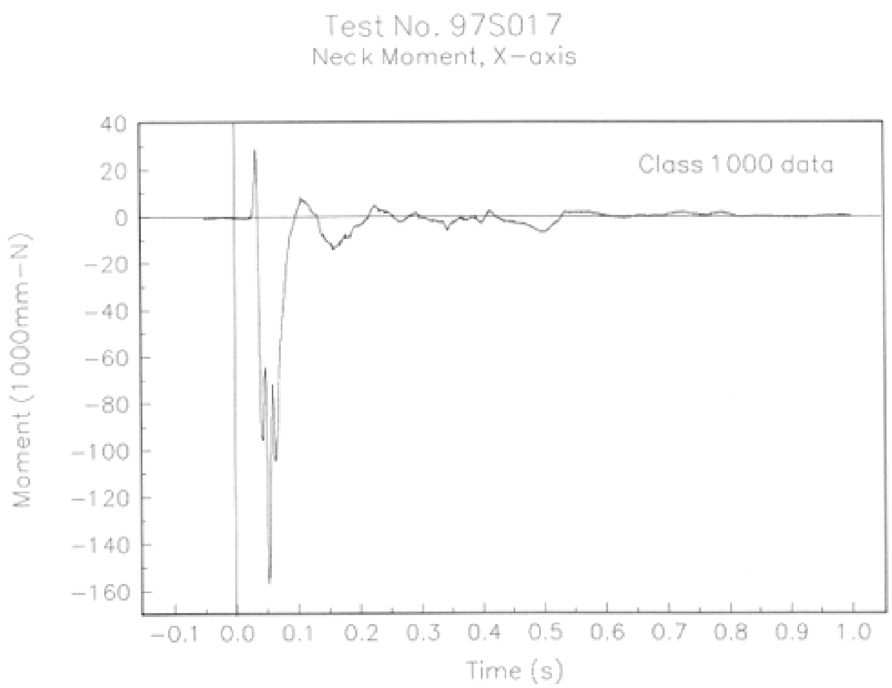

Figure 34. Moment vs. time, neck X-axis, test 97S017.

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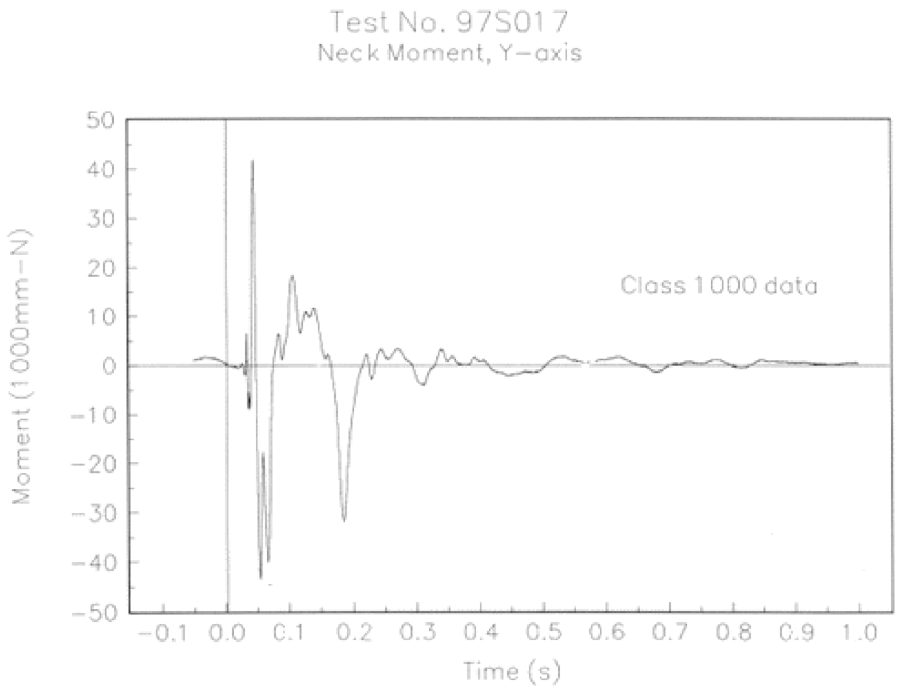

Figure 35. Moment vs. time, neck Y-axis, test 97S017.

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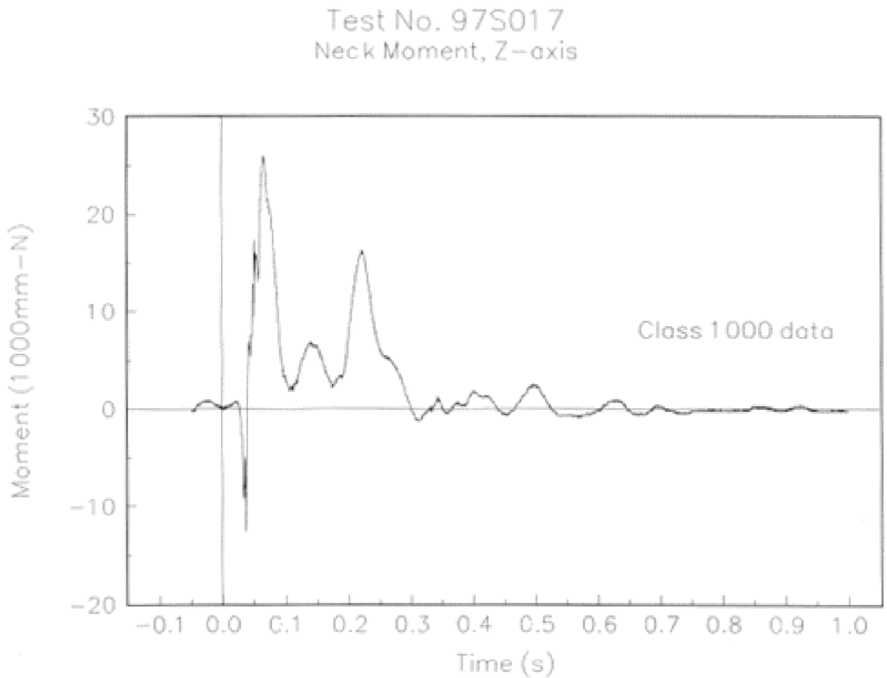

Figure 36. Moment vs. time, neck Z-axis, test 97S017.

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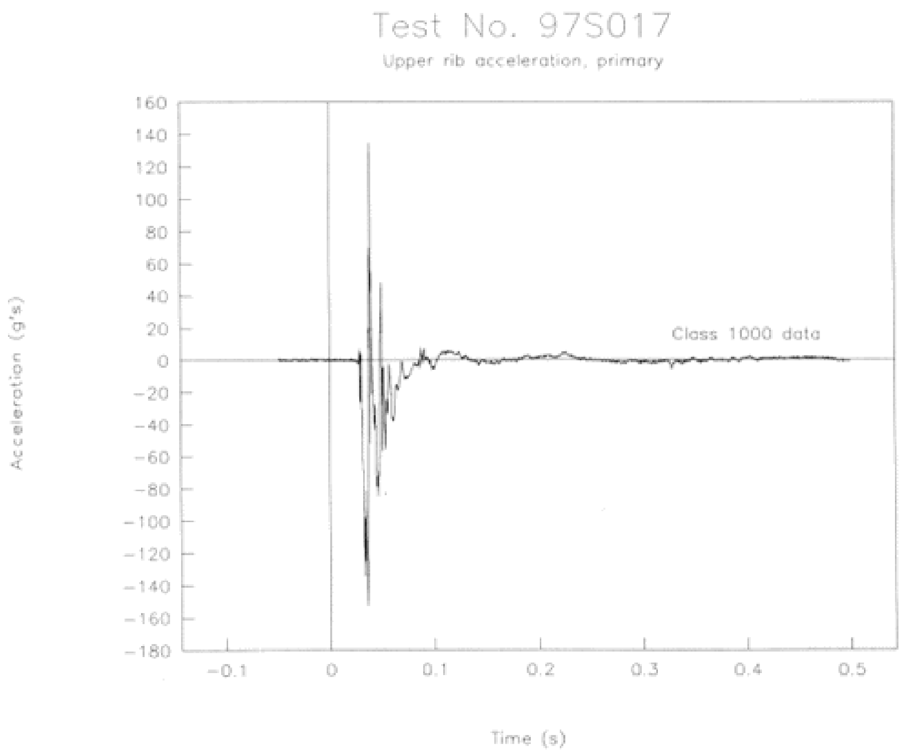

Figure 37. Acceleration vs. time, upper rib primary, test 97S017.

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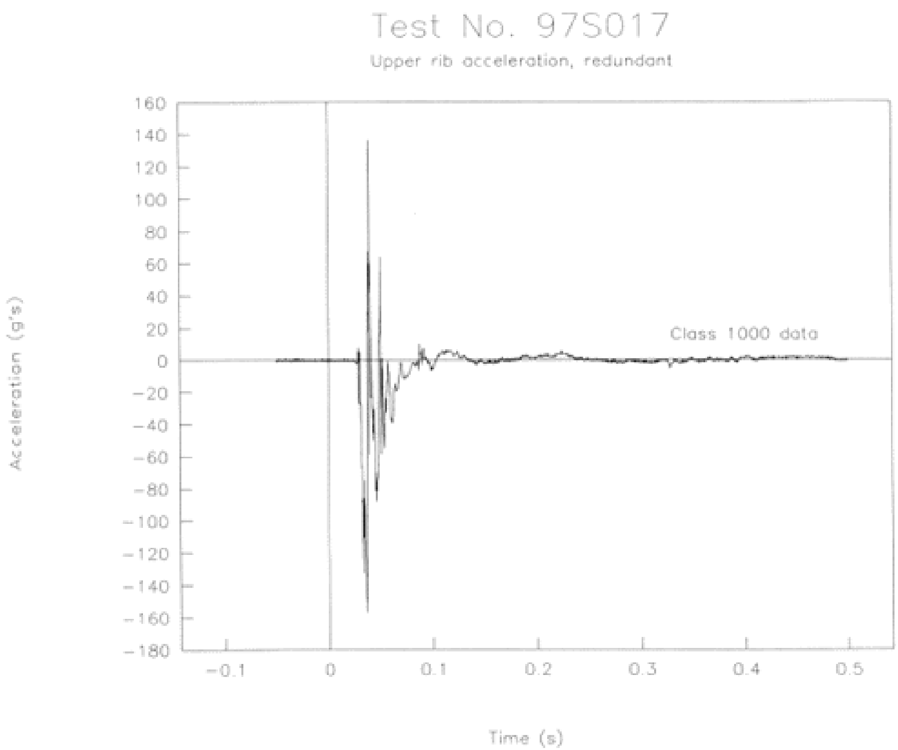

Figure 38. Acceleration vs. time, upper rib redundant, test 97S017.

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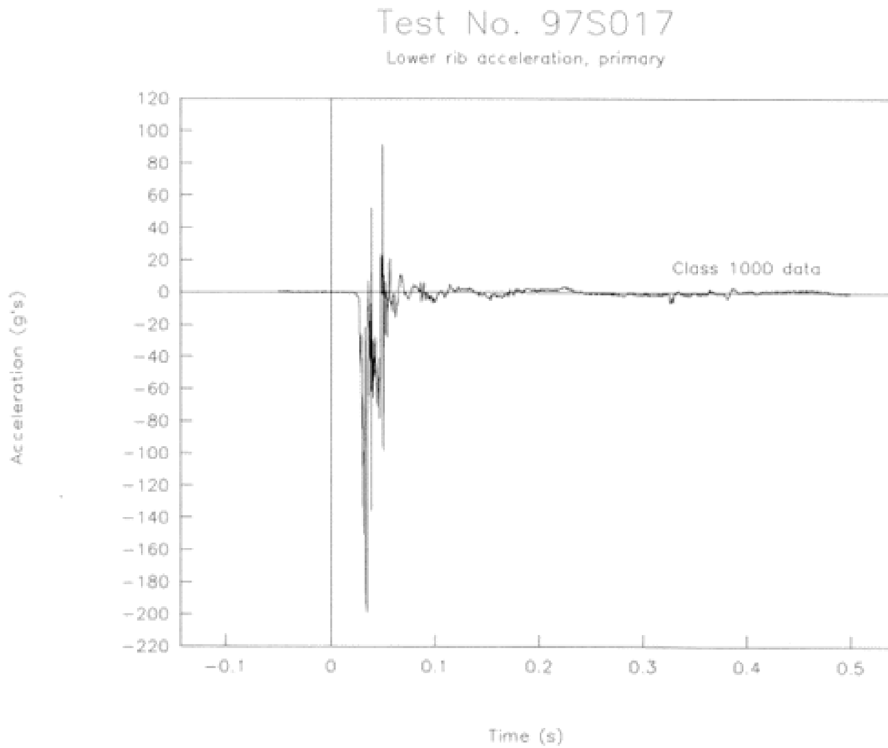

Figure 39. Acceleration vs. time, lower rib primary, test 97S017.

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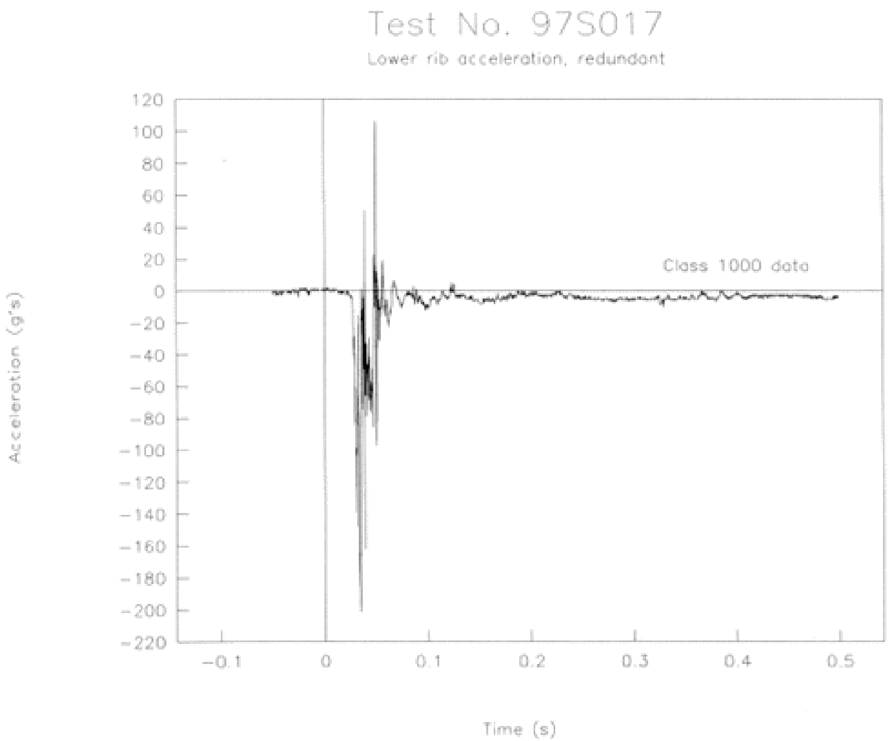

Figure 40. Acceleration vs. time, lower rib redundant, test 97S017.

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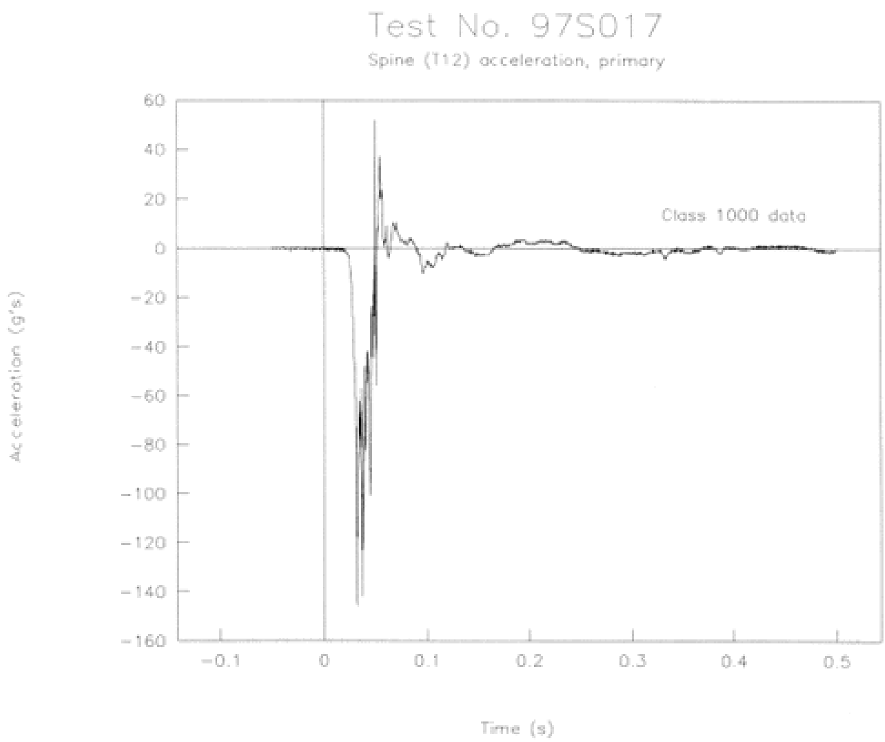

Figure 41. Acceleration vs. time, spline T12 primary, test 97S017.

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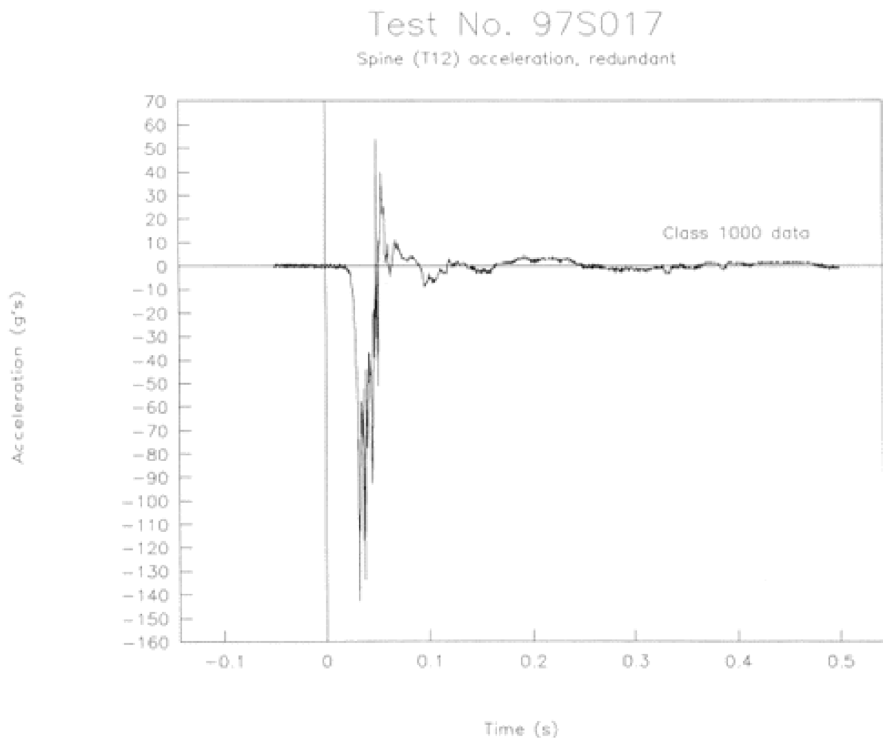

Figure 42. Acceleration vs. time, spline T12 redundant, test 97S017.

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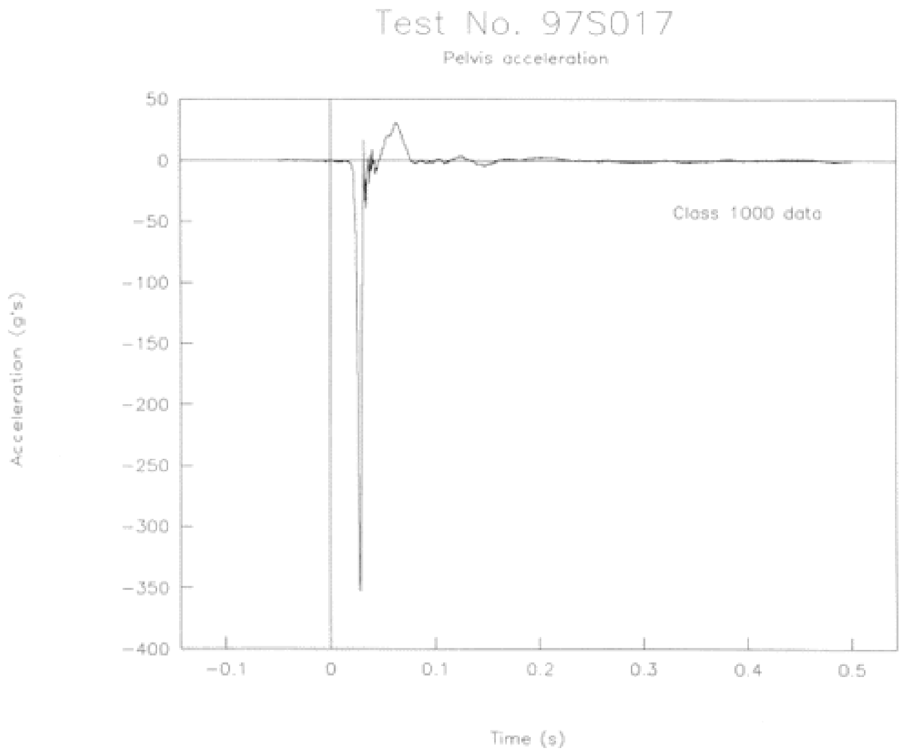

Figure 43. Acceleration vs. time, pelvis, test 97S017.

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APPENDIX C. TEST PHOTOGRAPHS

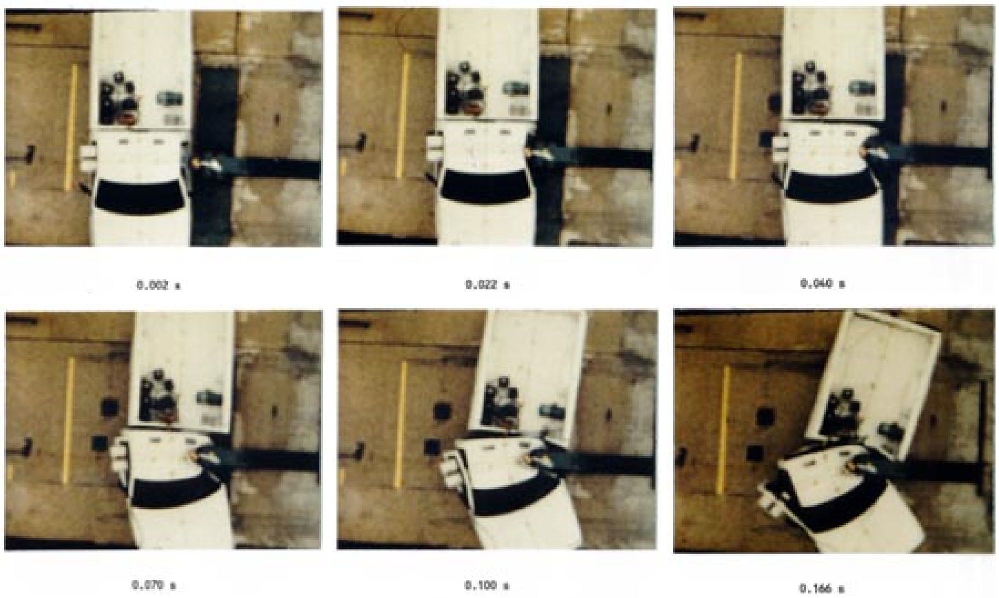

Figure 44. Test photographs during impact, test 97S017.

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Figure 44. Test photographs during impact, test 97S017 (continued).

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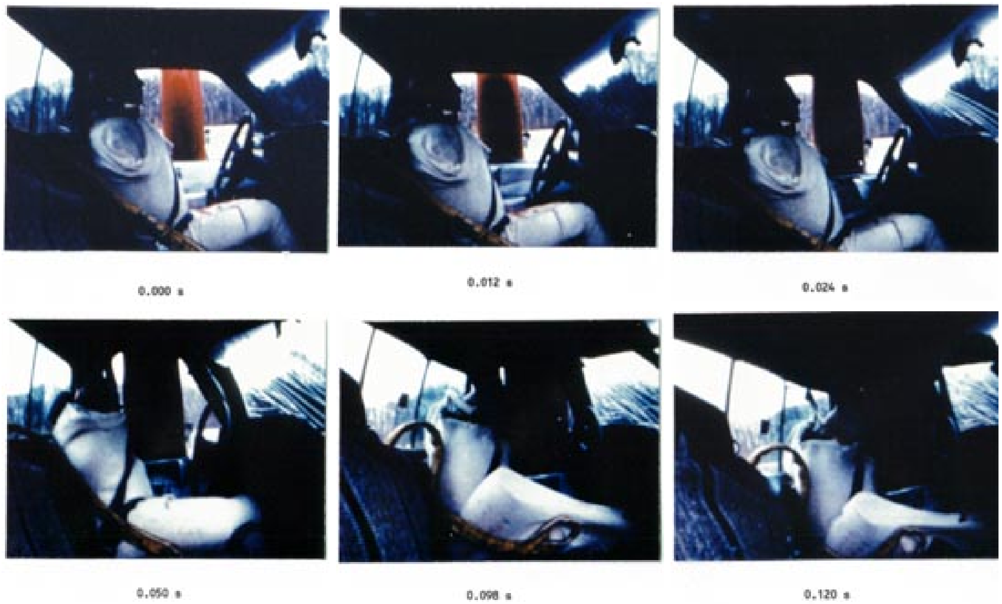

Figure 44. Test photographs during impact, test 97S017 (continued).

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Figure 45. Pretest photographs, test 97S017 (continued).

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Figure 46. Post-test photographs, test 97S017.

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Figure 46. Post-test photographs, test 97S017 (continued).

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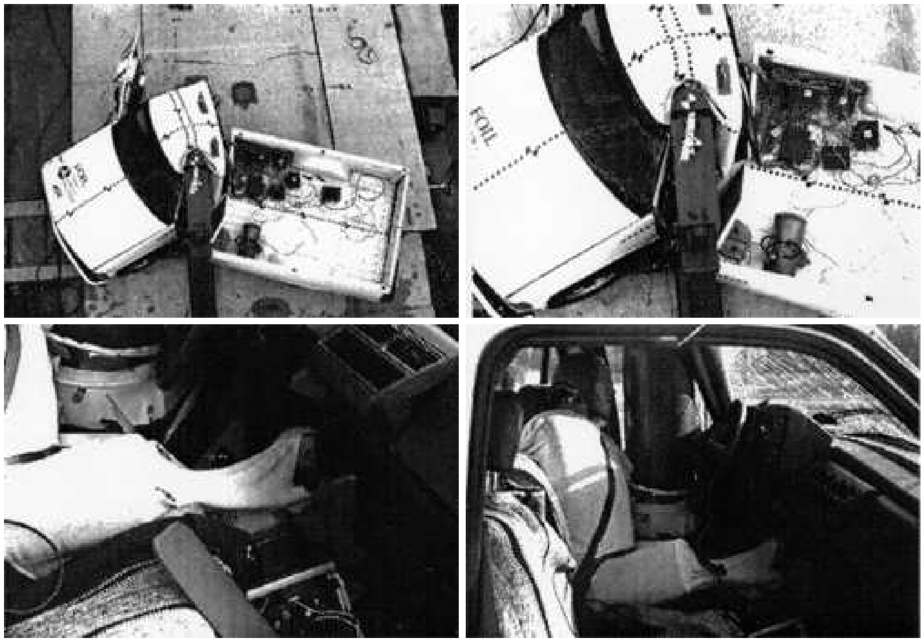

Figure 46. Post-test photographs, test 97S017 (continued).

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Figure 46. Post-test photographs, test 97S017 (continued).

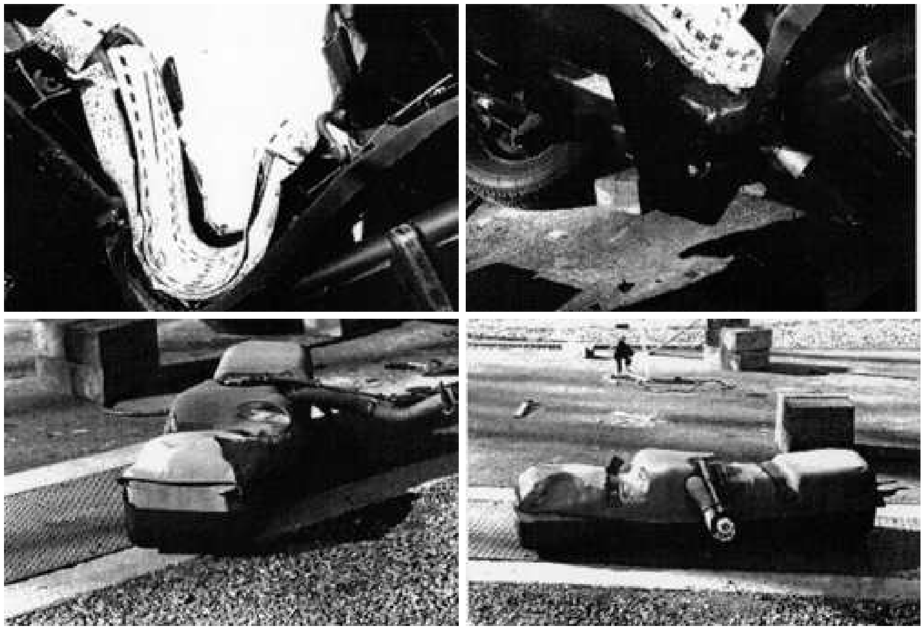

Figure 46. Post-test photographs, test 97S017 (continued).

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APPENDIX D. DATA PLOTS FROM RIGID POLE LOAD CELLS

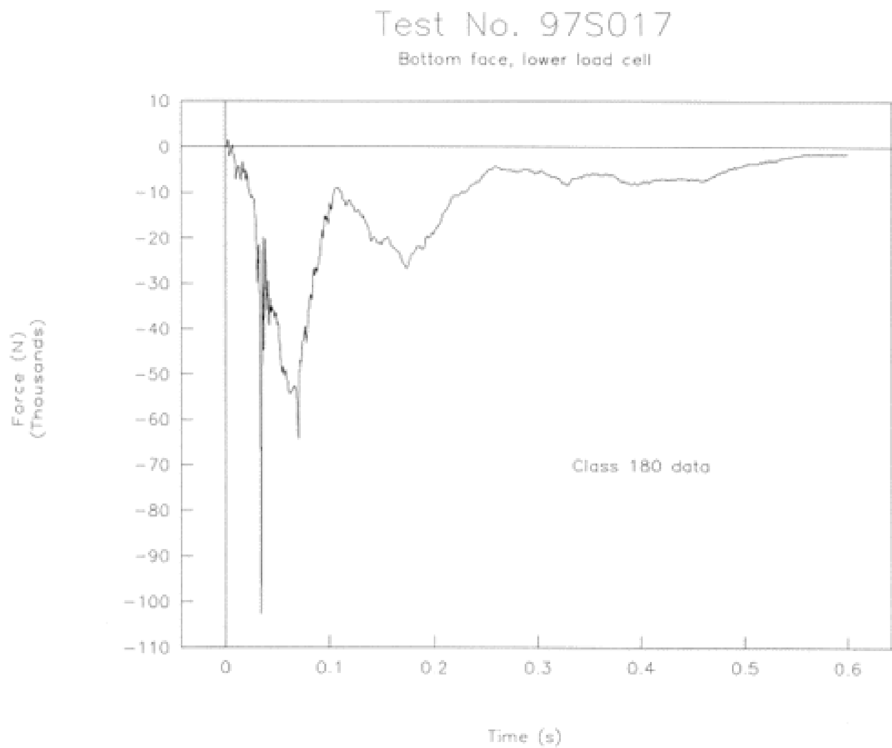

Figure 47. Rigid pole, force vs. time, bottom face lower load cell, test 97S017.

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Figure 48. Rigid Pole, force vs. time, bottom face upper load cell, test 97S017.

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Figure 49. Rigid pole, force vs. time, lower-middle face lower load cell, test 97S017.

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Figure 50. Rigid pole, force vs. time, lower-middle face upper load cell, test 97S017.

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Figure 51. Rigid pole, force vs. time, upper-middle face lower load cell, test 97S017.

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Figure 52. Rigid pole, force vs. time, upper-middle face upper load cell, test 97S017.

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Figure 53. Rigid pole, force vs. time, top face lower load cell, test 97S017.

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Figure 54. Rigid pole, force vs. time, top face upper load cell, test 97S017.

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REFERENCES

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(1) NHTSA. *Laboratory Test Procedure for Federal Motor Vehicle Safety Standard 214,* National Highway Traffic Safety Administration, Washington, DC, May 1992.

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

(3) Brown, Christopher M., *35-km/h Broadside Crash Test of a 1994 Chevrolet C2500 and the FOIL 300K Rigid Pole: FOIL Test Number 97S016,* Report Number FHWA-RD-98-081, Federal Highway Administration, McLean, VA, October 1997.

(4) Brown, Christopher M., *35-km/h Broadside Crash Test of a 1994 Chevrolet C2500 and a Valmont Industries Slip Away Lighting Standard: FOIL Test Number 97S012*, Report Number FHWA-RD-98-032, Federal Highway Administration, McLean, VA, September 1997.

(5) Brown, Christopher M., *50-km/h Broadside Crash Test of a 1994 Chevrolet C2500 and a Valmont Industries Slip Away Lighting Standard: FOIL Test Number 97S015*, Report Number FHWA-RD-98-054, Federal Highway Administration, McLean, VA, October 1997.