R0197

35-km/h Broadside Crash Test of a 1994 Chevrolet C2500 and the FOIL 300K Rigid Pole: FOIL Test Number 97S016

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Technical Report Documentation Page

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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	milliliters	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 (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit 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	poundforce	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	hectares	2.47	acres	ac
km²	square kilometers	0.386	square miles	mi²
		VOLUME		
mL	milliliters	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 (2000 lb)	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	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in²

* 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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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 35 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 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 1,320 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
97S016	Chevrolet C2500 pickup truck	2,000 kg, w/SIDH3 2,080 kg	35 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 w... 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., and pertinent physical parameters were measured and recorded. The fuel tank was empty during the test.

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, which 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 its physical dimensions.

Table 2. Vehicle description and statistics.

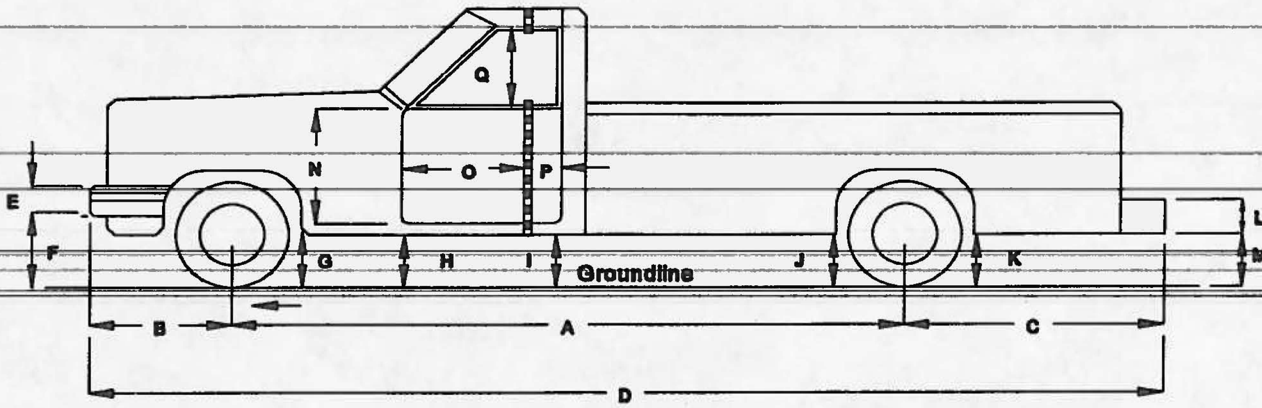
Vehicle make	Chevrolet
Vehicle model	1994 C2500 pickup
Vehicle identification number (VIN)	1GCFC24H3RE239250
Engine	5.0 L, 8 cylinder
Transmission	Automatic
Drive chain	Rear wheel drive
Wheel base	3,353 mm
Wheel track	1,607 mm
Fuel capacity	No fuel used
Tested capacity of stodard solvent	N/A
Seat type	Bench
Position of front seat for test	Center
Seat back angle	Fixed 18.0° 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	x	AM/FM radio		Other

WEIGHTS (kg)	DELIVERED	TEST MODE
Left front	543	602
Right front	513	590
Left rear	382	444
Right rear	406	440
TOTAL	1,844	2,076

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 2	pitch up 1.5
Passenger	pitch up 1.5	pitch down 1.2
Front	roll down 0.1	roll up 0.2
Rear	0	roll up 0.2
C.g. (mm) measurements	**DELIVERED**	**TEST MODE**
Behind front axle	1,433	1,428
Lateral	801	797



	PRE-TEST	POST-TEST	⌂CHANGE
A	3,353	3,100	-253
B	838	1,050	212
C	1,295	1,295	0
D	5,487	5,445	-42
E	202	202	0
F*	386 / 388	437	49
G*	350 / 350	367	17
H*	350 / 350	346	-4
I*	389 / 390	332	-58
J*	425 / 415	400	-15
K*	488 / 490	549	59
L	183	183	0
M*	565 / 566	670	104
N	762	762	0
O	762	515	-247
P	470	180	-290
Q	525	500	-25

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

Figure 1. Vehicle physical parameters in mm.

INSTRUMENTED DUMMY

One SIDH3, serial number 28, 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 was 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.

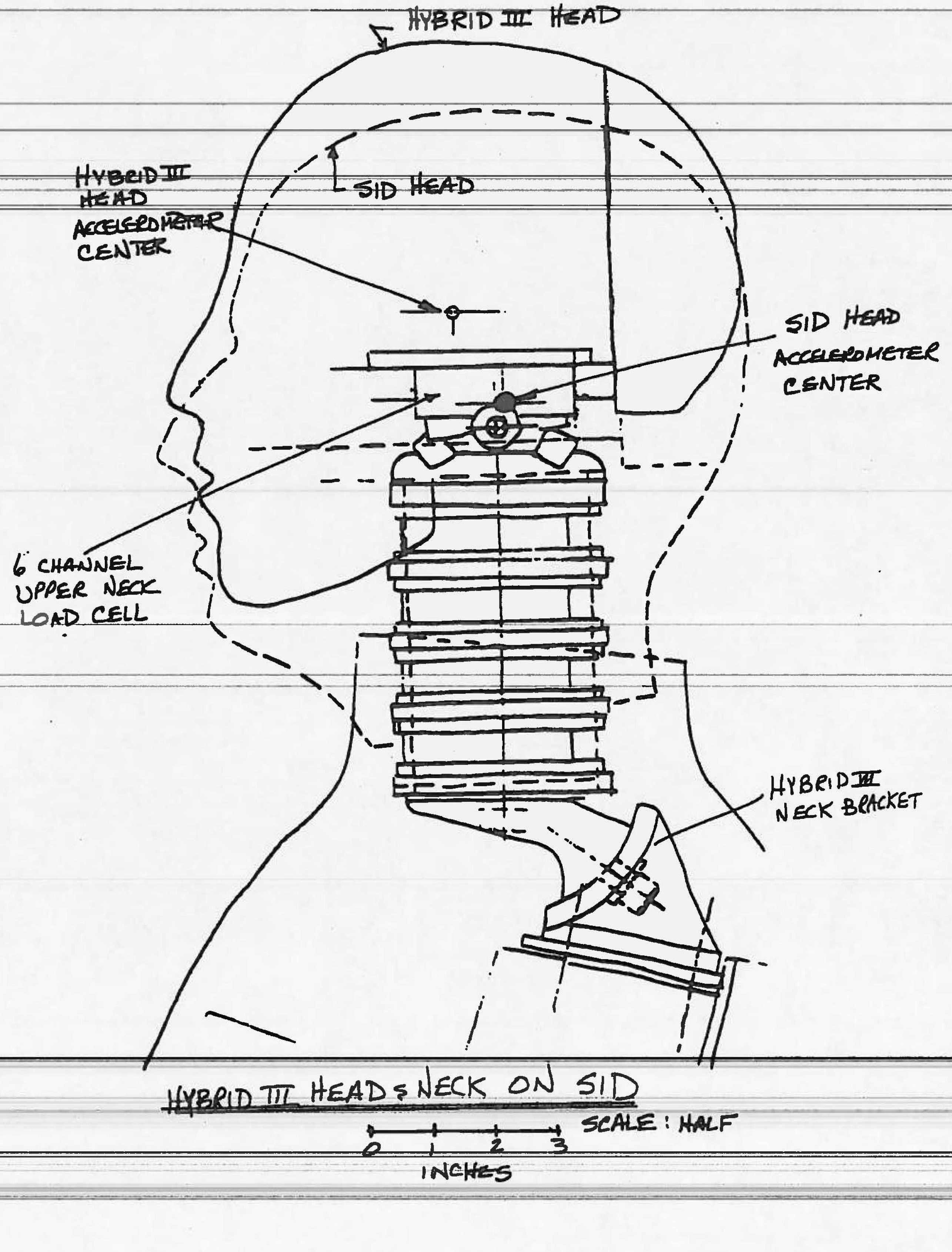
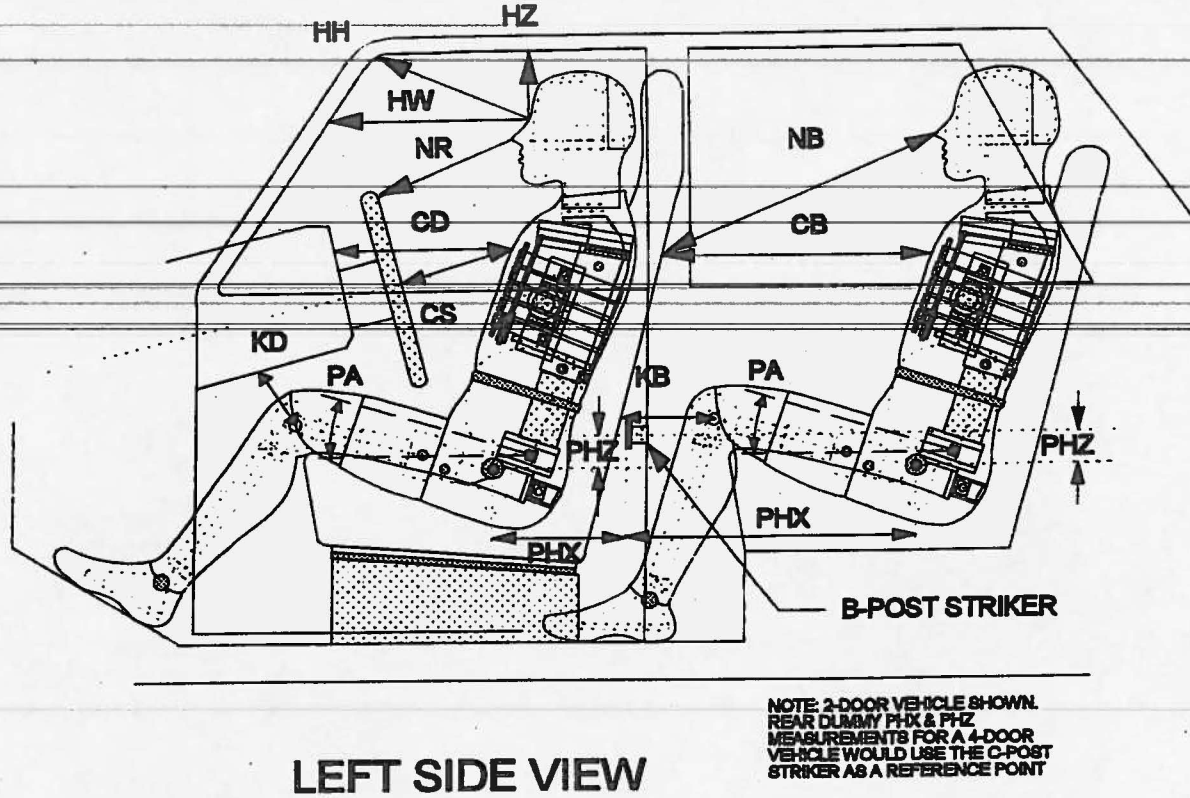
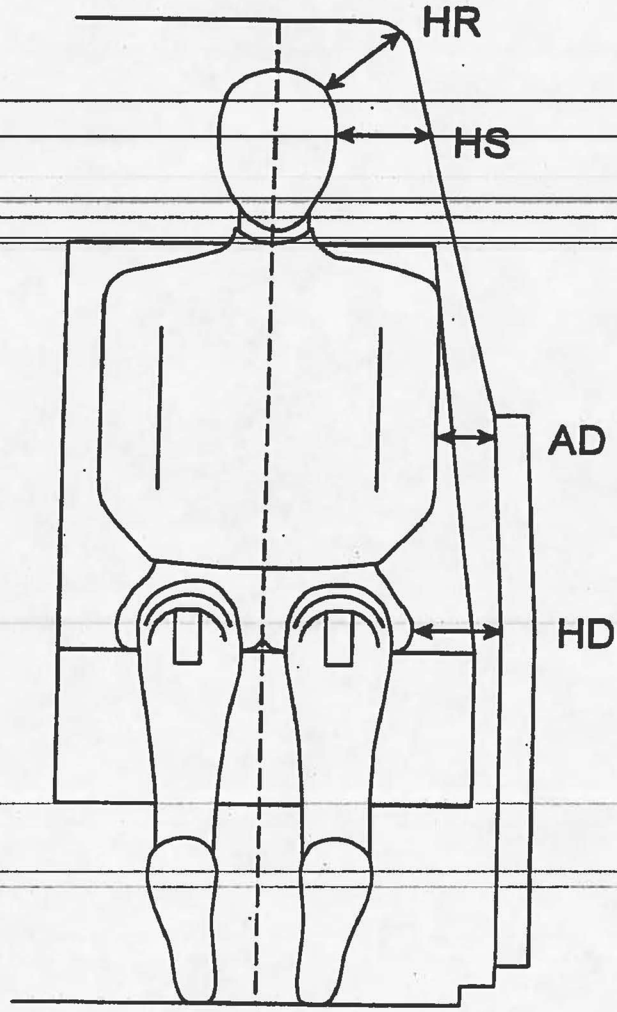


Figure 2. HYBRID III neck and head assembly on SIDH3 #28.



MEASUREMENT (mm)	DRIVER SIDH3 ID# 28
HH	480
HW	693
HZ	194
NR	398
CD	561
CS	249
KDL(KDA°)	175(16.5°)
KDR(KDA°)	177(16.7°)
PA°	15°
PHX	324
PHZ	7
PHY	267

Figure 3. SIDH3 longitudinal clearance and position measurements.



MEASUREMENT (mm)	DRIVER SIDH3 ID# 28
HR	280
HS	609
AD	171
HD	245

Figure 4. SIDH3 lateral clearance and position measurements.

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

The SIDH3 instrumentation recorded during the test was as follows:

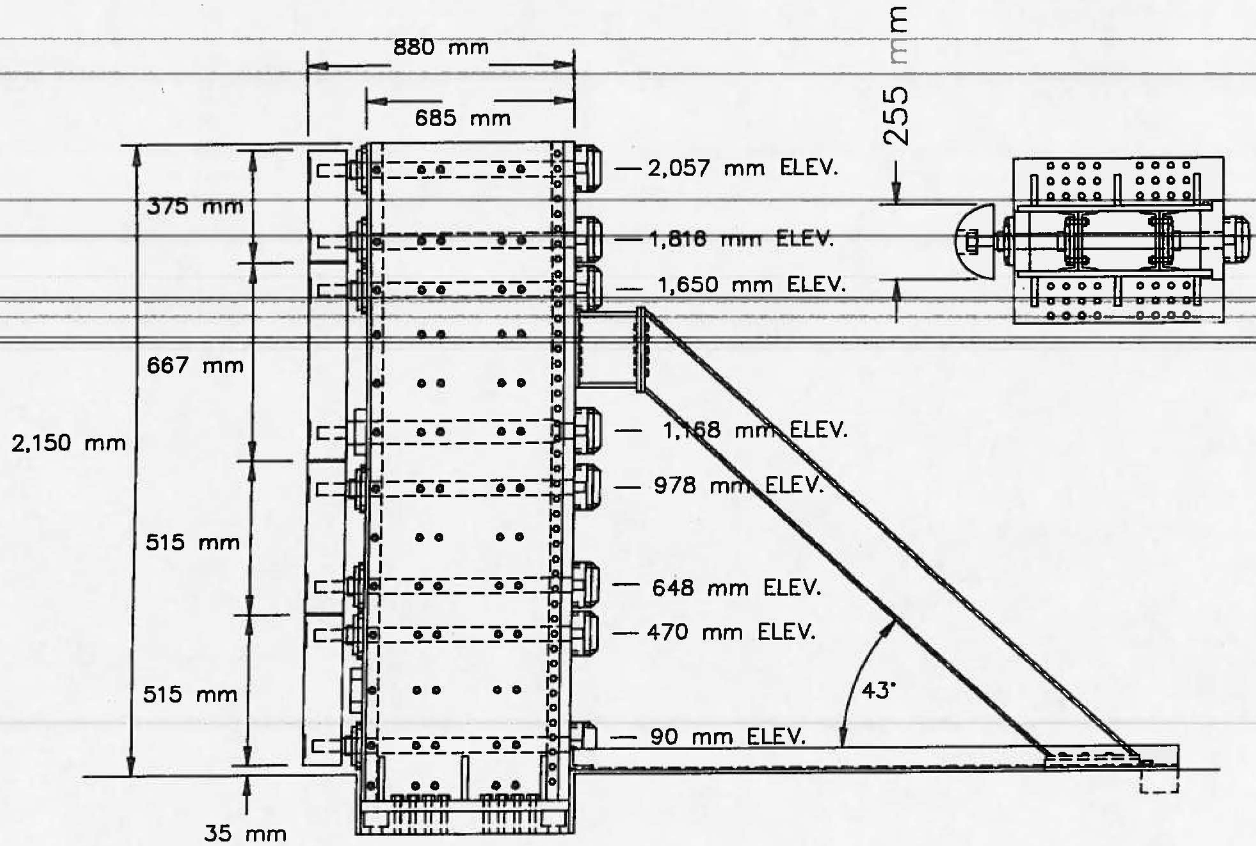
	Number of Channels
• Head triaxial accelerometer (A_x, A_y, A_z)	3
• Neck 3-axis force load cell (F_x, F_y, F_z)	3
• Neck 3-axis neck moment load cell (M_x, M_y, M_z) No completion resistors required	3
• Upper and lower rib and redundant (A_y)	4
• T12 and redundant (A_y)	2
• Pelvis (A_y)	1
TOTAL SIDH3 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 4,000 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).



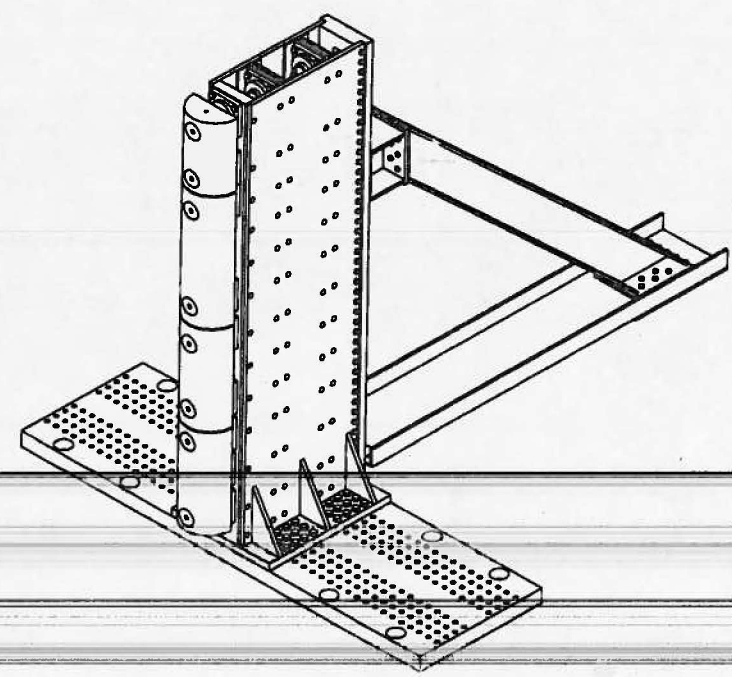


Figure 5. Sketch of FOIL instrumented 300K rigid pole.

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

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-ailiasing 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.

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 Vo ts	1 kHz re erence s gnal

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

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.

HIGH-SPEED PHOTOGRAPHY

A total of 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:

- 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.

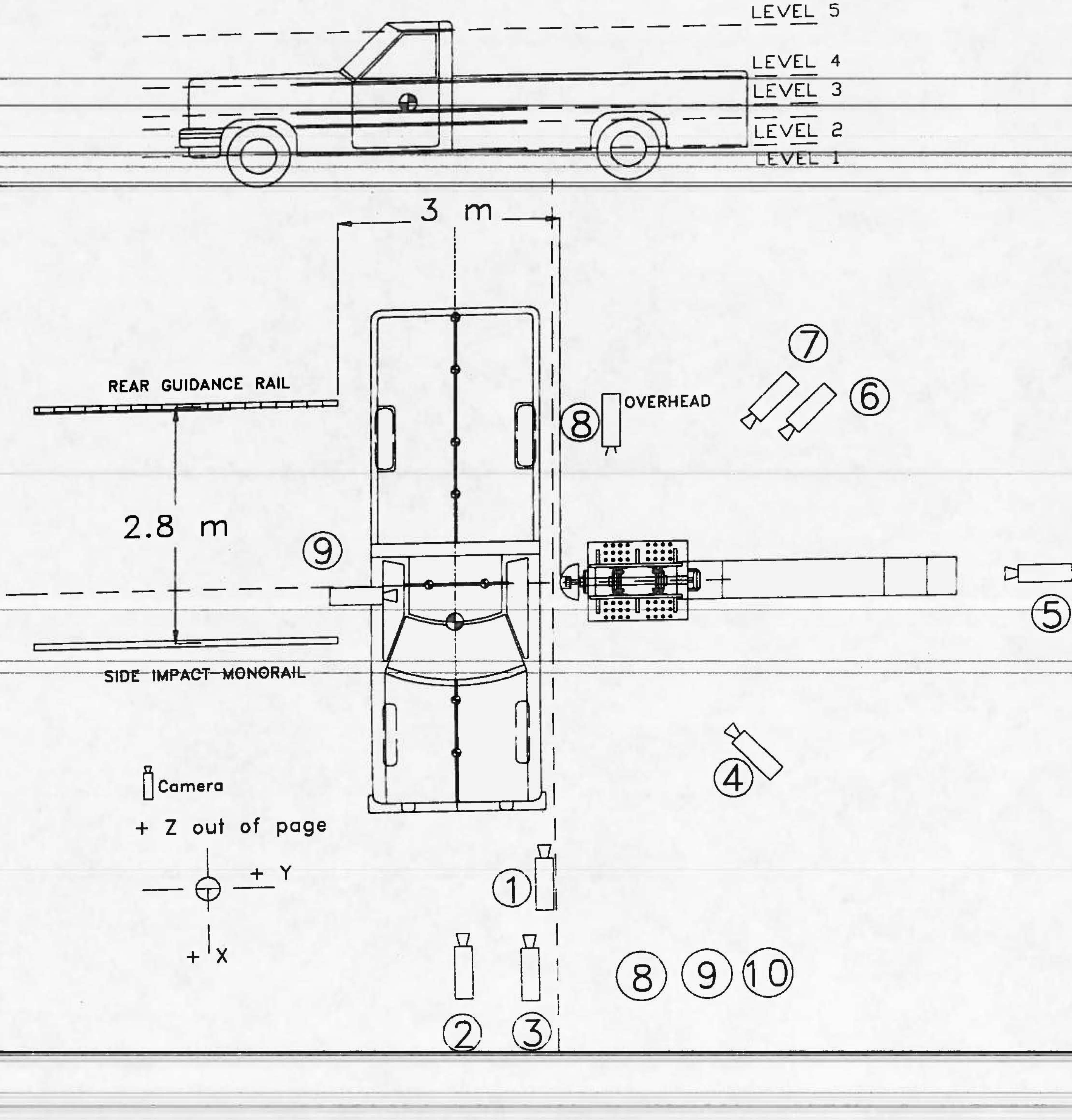


Figure 6. Test setup and camera locations.

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:

$$TTI = [\text{Maximum}(4 \text{ rib channels}) + \text{Maximum}(\text{spine})] \div 2$$

Umbilical cable. Data collected via the umbilical cable tape recorder system was 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 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 38.3 km/h. Due to the frictional forces between the truck tires and the wet pavement, the vehicle speed was reduced to 36.5 km/h at impact and the truck leaned or rolled toward the pole at 3.9°. The initial yaw angle was 87°. Table 7 summarizes the test conditions and selected results.

Table 7. Summary of test conditions and results.

FOIL test number	97S016
Date of test	October 22, 1997
Test vehicle	1994 Chevrolet C2500 2-door pickup truck
Weight: C2500 Truck SIDH3 Total	1,996 kg 80 kg 2,076 kg
Test article	FOIL 300K instrumented rigid pole
Temperature inside vehicle	25° C
Impact speed: 16-mm film	36.5 km/h
Impact point (mm)	100 forward of vehicle c.g.
Initial roll angle	3.8°
Initial yaw angle	87°

Table 7. Summary of test conditions and results (continued).	
Total rigid pole load observed (load cells)	247,300 N
Traffic accident data (TAD)	9-LP-7
Vehicle damage index (VDI)	09LPAN5
Lateral occupant impact velocity	7.3 m/s
Lateral ridedown acceleration	8.5 g's
Head injury criteria	
Limit	1000 g's
Observed	952 g's
Start time	0.0429 s
Stop time	0.0608 s
Interval time	0.0179 s
Thoracic trauma data	
Limit (2-door)	90 g's
Peak rib acceleration (FIR100)	59.1 g's
T12 spine (FIR100)	77.7 g's
Thoracic trauma index (TTI)	68.4 g's
Pelvic injury	112.5 g's

Vehicle response. 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 0.008 s after contact with the rigid pole. The door was pushed inward and struck the SIDH3's lower torso and pelvic region. After 0.030 s, the B-pillar was drawn forward toward the rigid pole, making contact with the rear portion of the SIDH3's head. The rigid pole made contact and bent the truck's longitudinal frame rail at approximately 0.033 s (from the acceleration trace). The pole continued to penetrate the occupant compartment, causing the dashboard and bench seat to buckle. The bench seat was forced into the passenger door, causing the door to bulge outward. The door remained latched throughout the test. The truck bed and front end continued to wrap around the pole until approximately 0.200 s. Double integration of the c.g. accelerometer yielded a maximum deflection of 800 mm. This may be exaggerated due to the extreme buckling of the floor pan. The maximum static deflection was 562 mm. The intrusion was limited by the 170-mm-wide transmission mount cross member. The C-shape frame deflected back until the breadth of the deflection included the transmission mount cross member. The center of the transmission mount was 350 mm forward of the impact location. When contact was made with the transmission mount, the transmission housing fractured, releasing transmission fluid onto the runway. 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. The static intrusion into the occupant compartment was calculated by measuring the interior distance between the doors before and after the test. The static intrusion was 500 mm.

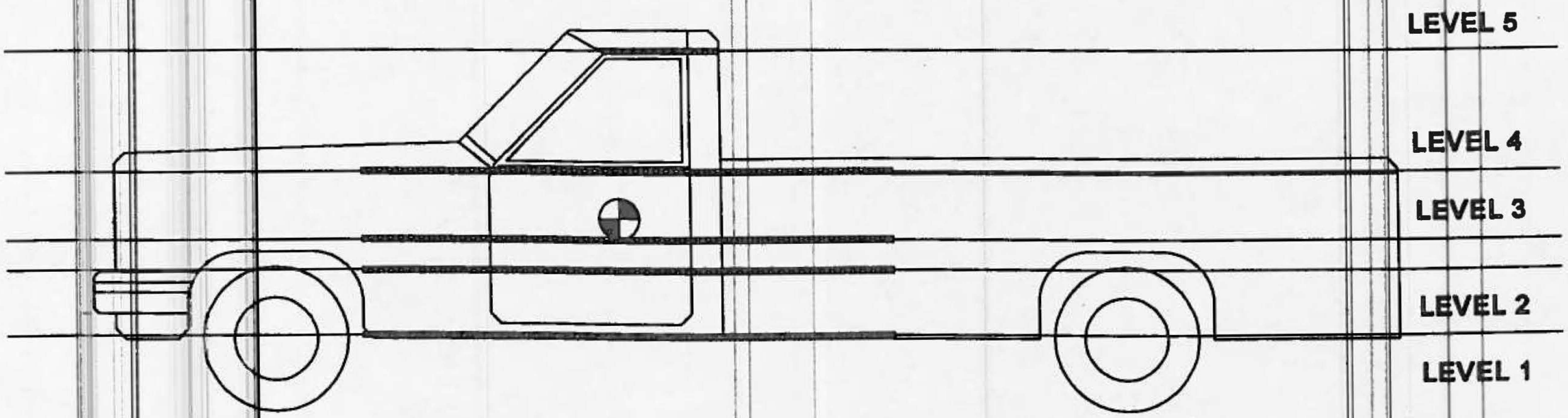
Damage to the pickup truck was extensive. The driver door caved, the B-pillar was drawn inward, the windshield shattered, the dash and bench seat buckled, the left frame rail bent, and the fuel tank was punctured. The two doors remained latched during the test. The peak c.g. acceleration recorded was 17.1 g's (334,600 N) and occurred 0.0724 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	9.9	-10.7
C.g. accelerometer A_y, primary	1.9	-17.1
C.g. accelerometer A_z, primary	15.3	-12.7
C.g. accelerometer A_y, redundant	2.0	-15.9
Engine block, A_x	3.6	-12.6
Engine block, A_y	2.1	-11.6
Driver seat, A_y	34.3	-62.7
Right lower sill, A_y	35.6	-28.7
Right roof rail, A_y	6.0	-21.1
Driver door-beam, A_y	No data	-685.5
Longitudinal frame member, A_y	187.6	-263.6
Transmission mount, A_y	41.7	-75.5
Bed cross member #1, A_y	39.3	-31.7
Bed cross member #2 A_y	4.3	-29.0
Bed cross member #3 A_y	6.5	-21.1
Rear bumper, A_x	18.7	-20.2
Rear bumper, A_y	14.6	-18.9

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, rather than measuring at the same increments. From the figure, the maximum static deflection recorded was 562 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.



Level 1 - Sill height   Level 2 - Occupant H-point   Level 3 - Mid-door   Level 4 - Window sill   Level 5 - Window top

LEVEL	HEIGHT		Distance from impact point (mm).															
			-762	-610	-457	-381	-305	-229	-152	-76	0	76	152	229	305	381	457	533
1	438	PRE	590	582	580	580	578	578	575	575	570	568	568	565	565	565	565	564
	381	POST	511	591	695	756	825	881	963	1024	1054	1051	998	932	845	795	717	660
		CRUSH	-79	9	115	176	247	303	388	449	484	483	430	367	280	230	152	96
2	876	PRE	530	522	520	520	520	520	521	521	521	520	520	520	520	520	521	520
	835	POST	481	598	725	790	851	912	978	1045	1078	1068	1011	945	868	792	714	629
		CRUSH	-49	76	205	270	331	392	457	524	557	548	491	425	348	272	193	109
3	775	PRE	527	519	517	517	517	517	518	518	518	517	517	517	517	517	518	517
	734	POST	483	599	732	790	855	909	985	1044	1080	1065	1012	942	865	792	724	635
		CRUSH	-44	80	215	273	338	392	467	526	562	548	495	425	348	275	206	118
4	1162	PRE	570	566	567	565	564	563	560	561	560	560	560	561	560	561	561	561
	1084	POST	483	609	725	787	848	925	981	1041	1074	1057	1006	948	863	792	709	651
		CRUSH	-87	43	158	222	284	362	421	480	514	497	446	387	303	231	148	90
5	1683	PRE						765	765	765	763	762	762	760	760	762	762	
	1653	POST						991	1048	1098	1115	1093	1043	971	903	841	820	
		CRUSH	0	0	0	0	0	226	283	333	352	331	281	211	143	79	58	0
All units of measurement are in mm.																		

Figure 7. Vehicle profile measurements, test 97S016.

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 3.9° at impact. The roll angle and vehicle deceleration caused the SIDH3 to lean toward the driver door and make slight contact. 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 0.020 s after impact. The dummy torso was wedged between the seat and intruding door, the head continued toward the door and window and contacted the B-pillar before protruding through the open window (0.032 s). The femur and shoulder area made contact with the intruding door as anticipated. While the dummy's head was outside the window, the truck continued to wrap around the rigid pole. The B-pillar was drawn toward the pole and struck the rear of the dummy's head, forcing the head into the side of the rigid pole (0.058 s). The head was pinched between the B-pillar and rigid pole for approximately 0.050 s. While the head was pinched and stationary, the torso continued to bounce and recoil from the pole, bending and twisting the neck. The dummy rose up and leaned out the window enough that the left shoulder made contact with the rigid pole.

Inspection of the pole and vehicle interior revealed red, green, yellow, 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, before the head exited the window. The purple chalk (shoulder/torso region) was found on the pole and the interior door panel. Yellow 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 bench seat. As shown in table 8, the HIC (952 g's), TTI (68 g's), and pelvic injury (112 g's) values are below the current side-impact safety performance standards specified in FMVSS 214.

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 7.3 m/s.

Table 9. Summary of SIDH3 data.		
Recorded Data	**Maximum positive (g's)**	**Maximum negative (g's)**
Head X-axis acceleration	210.5	-73.9
Head Y-axis acceleration	35.8	-84.2
Head Z-axis acceleration	23.8	-44.2
X-axis neck force load cell(N)	466.6	-496.6
Y-axis neck force load cell(N)	941.5	-168.0
Z-axis neck force load cell(N)	897.9	-1,384.8
X-axis neck moment load cell (1000 mm·N)	7.9	-116.0
Y-axis neck moment load cell (1000 mm·N)	27.0	-56.3
Z-axis neck moment load cell (1000 mm·N)	5.3	-24.2
Left upper rib acceleration(P)	5.7	-45.7
Left upper rib acceleration(R)	6.3	-44.4
Left lower rib acceleration(P)	9.1	-59.1
Left lower rib acceleration(R)	10.4	-55.5
Spine T12 Y acceleration (P)	15.3	-71.6
Spine T12 Y acceleration (R)	17.5	-77.7
Pelvis Y acceleration	17.1	-112.5
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.

Rigid pole. The load cells measured eight separate forces on the rigid pole. The total load from summing the eight load cells was 247,300 N. The significant loads were contributed by the roof-rail, floor-sill, and middle-point of the driver door. The peak loads from the roof-rail, mid-door, and lower sill were 26,000 N, 67,300 N, and 184,600 N, respectively. Using torque equations, the height of the resultant load was determined to be 570 mm. This corresponds to a point 120 mm above the lower sill height (level 1). The resultant load is shifted toward the lower sill because the truck frame (which hangs below level 1) contributes 75 percent of the peak force (184,600 N of 247,300N). 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	-10.4	54.8
Upper load cell/ 2,057	-2.6	70.0
Lower load cell/ 1,816	-9.5	54.6
Middle-upper face	-23.9	53.6
Upper load cell / 1,650	-19.7	58.6
Lower load cell / 1,168	-8.6	53.8
Middle-lower face	-67.3	41.8
Upper load cell / 978	-30.7	41.6
Lower load cell / 648	-36.7	42.0
Bottom face	-184.6	51.8
Upper load cell / 470	-68.0	54.2
Lower load cell / 90	-120.3	51.8
Total, rigid pole	-247.3	51.8

CONCLUSIONS AND OBSERVATIONS

Visual inspection of the Chevrolet C2500 and pole after the collision produced immediate conclusions. The door latches remained latched throughout the test. The vehicle deformation was greater than 305 mm—the distance to the truck's frame—which was deep enough to cause significant bending of the truck frame rail and to fracture the transmission housing. Chalk marks on various vehicle components and the rigid pole confirmed both expected and unexpected dummy contact. The chalk signified contact between the dummy's head and the side of the rigid pole, which was not anticipated. Previous crash tests using similar impact conditions between a Chevrolet C2500 pickup truck and a Valmont Industries slip away lighting standard produced lower head injury values. The breakaway performance of the light pole prevented any contact between the light pole and the SIDH3's head. The results from the broadside crash tests with a slip away lighting standard can be found 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*[3] and *50 km/h Broadside Crash Test of a 1994 Chevrolet C2500 and a Valmont Industries Slip Away Lighting Standard: FOIL Test Number 97S015*[4]. The head acceleration data from test 97S016 revealed a high longitudinal (X-axis) peak acceleration compared with the light pole tests. The peak X-axis head acceleration was produced from the B-pillar forcing the head into the rigid pole. The peak X-axis acceleration contributed to a higher HIC (952 g's) than recorded during test with the break away light pole. Because the pole was not intended to break away, the pickup truck deformed around the pole much farther and longer than during the break away light pole tests. The extensive wrap around the rigid pole and prolonged head protrusion led to the eventual direct contact between the head and the rigid 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.

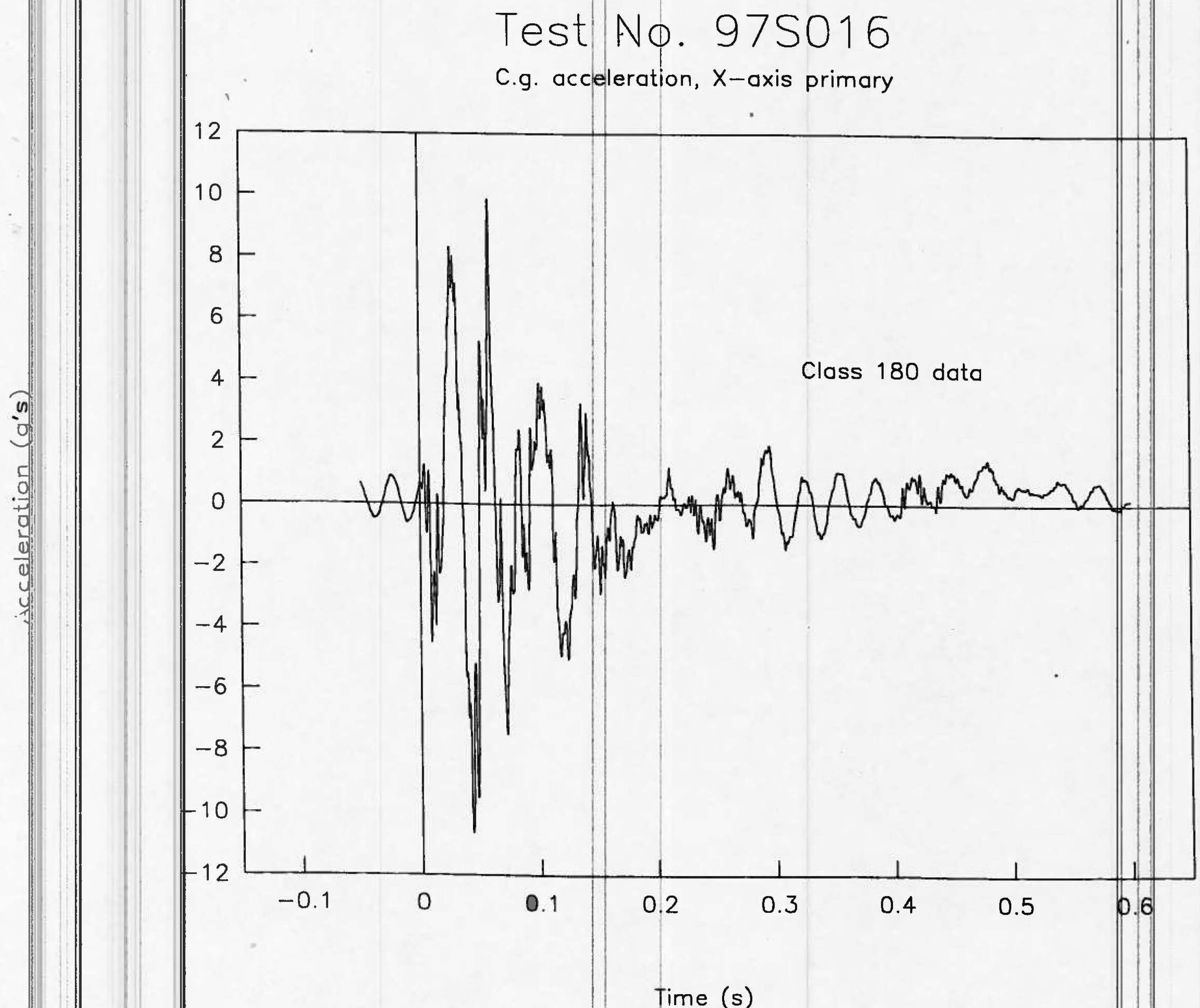


Figure 8. Acceleration vs. time, c.g. X-axis primary, test 97S016.

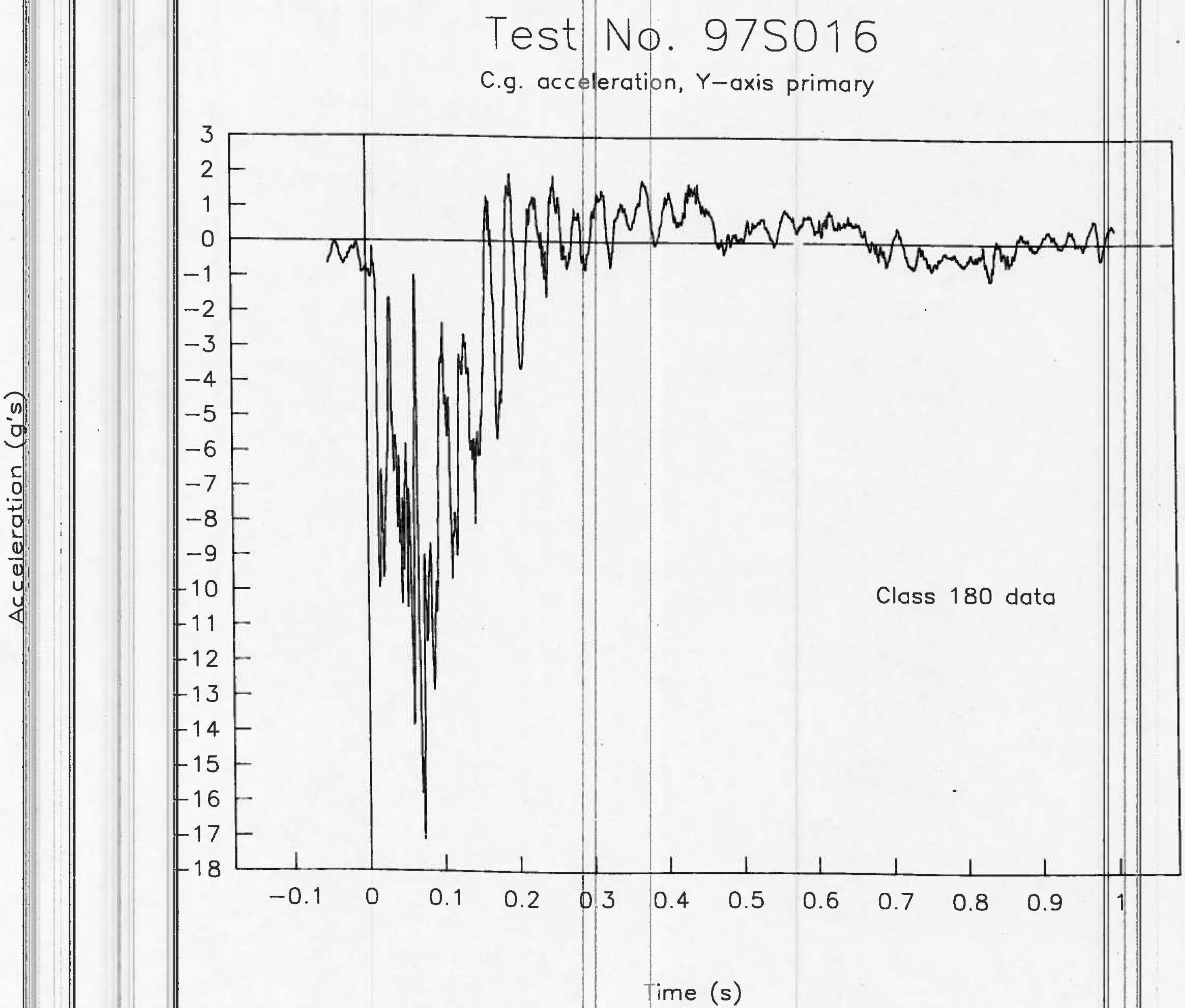


Figure 9. Acceleration vs. time, c.g. Y-axis primary, test 97S016.

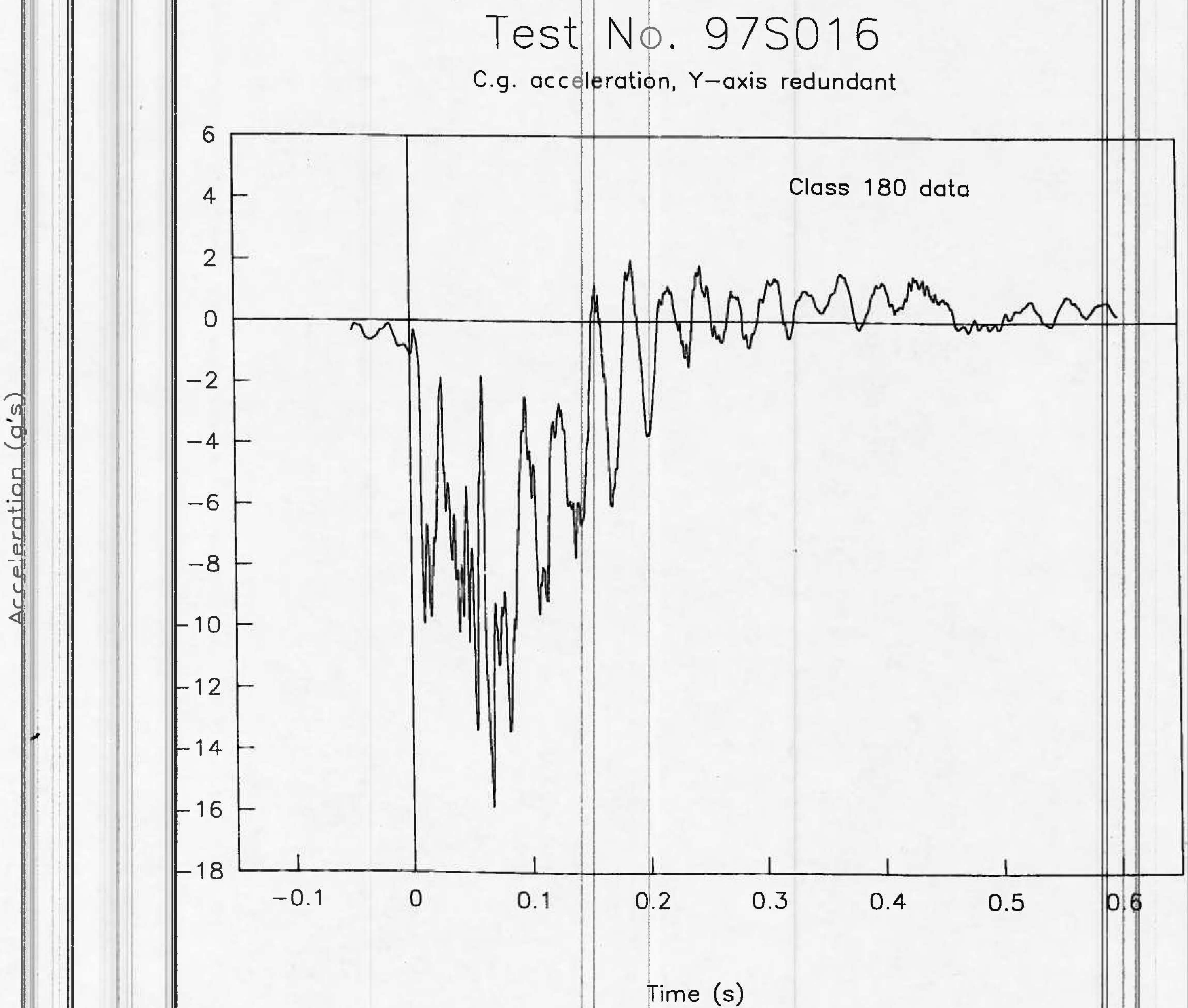


Figure 10. Acceleration vs. time, c.g. Y-axis redundant, test 97S016.

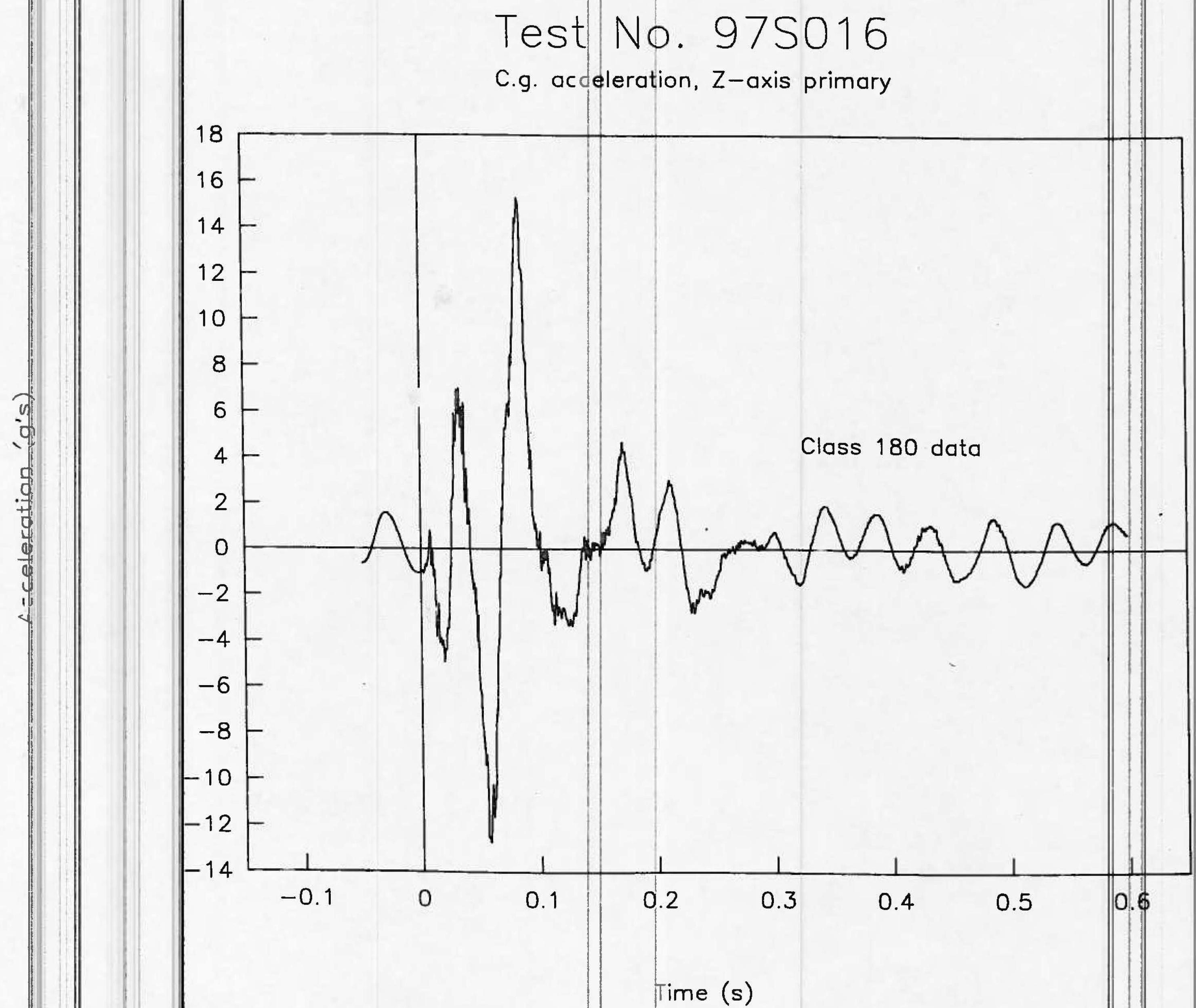


Figure 11. Acceleration vs. time, c.g. Z-axis primary, test 97S016.

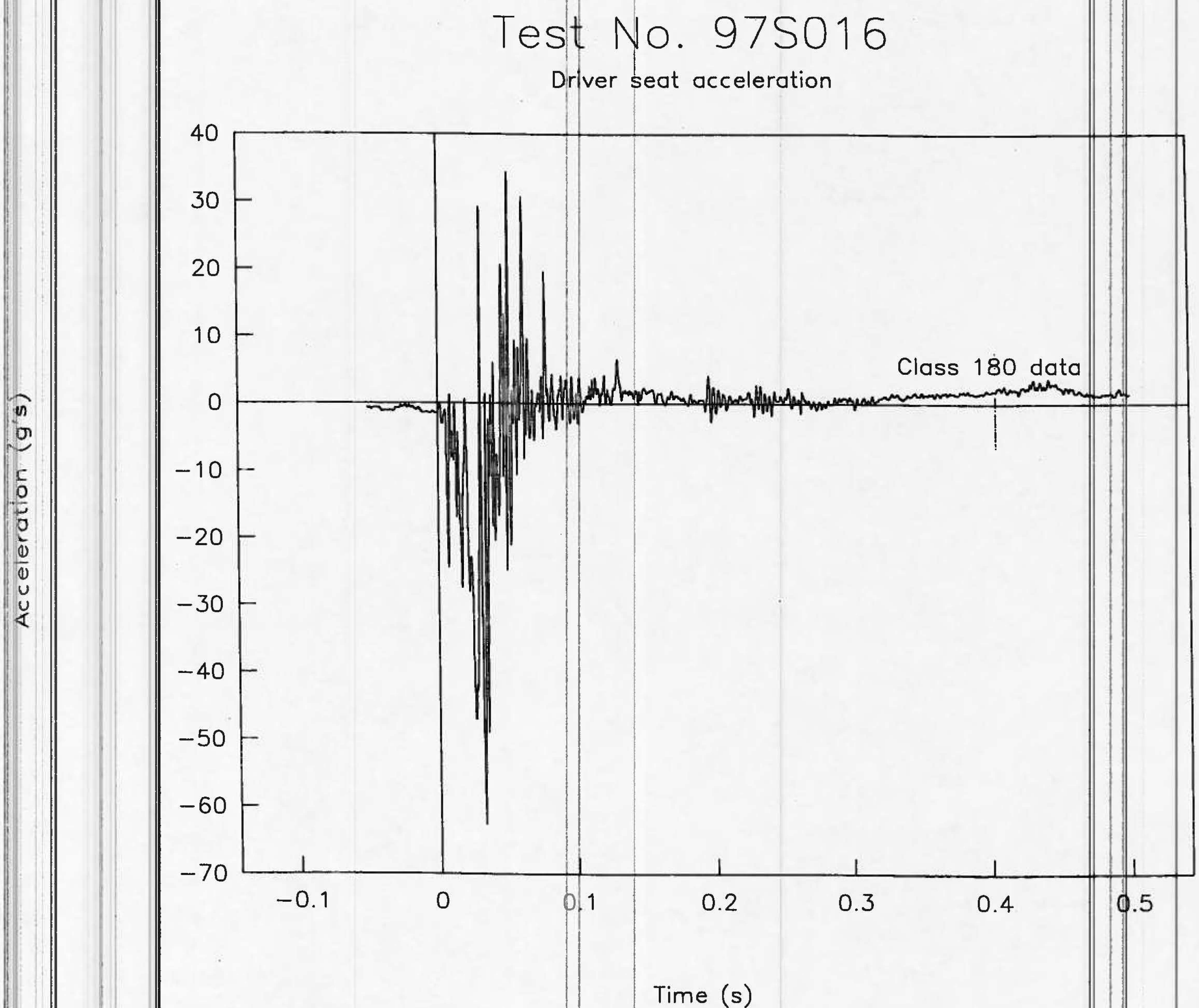


Figure 12. Acceleration vs. time, driver seat, test 97S016.

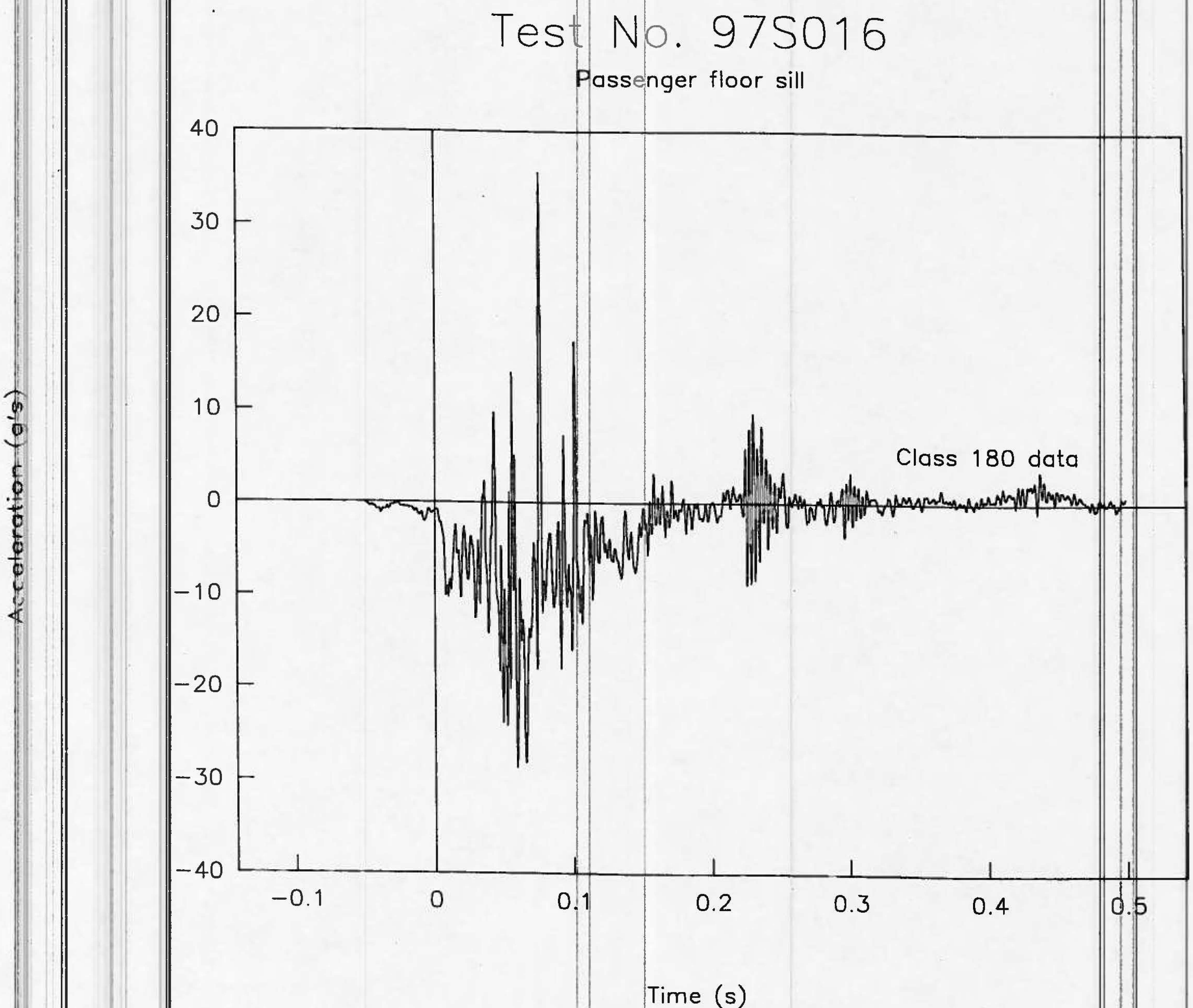


Figure 13. Acceleration vs. time, passenger floor sill, test 97S016.

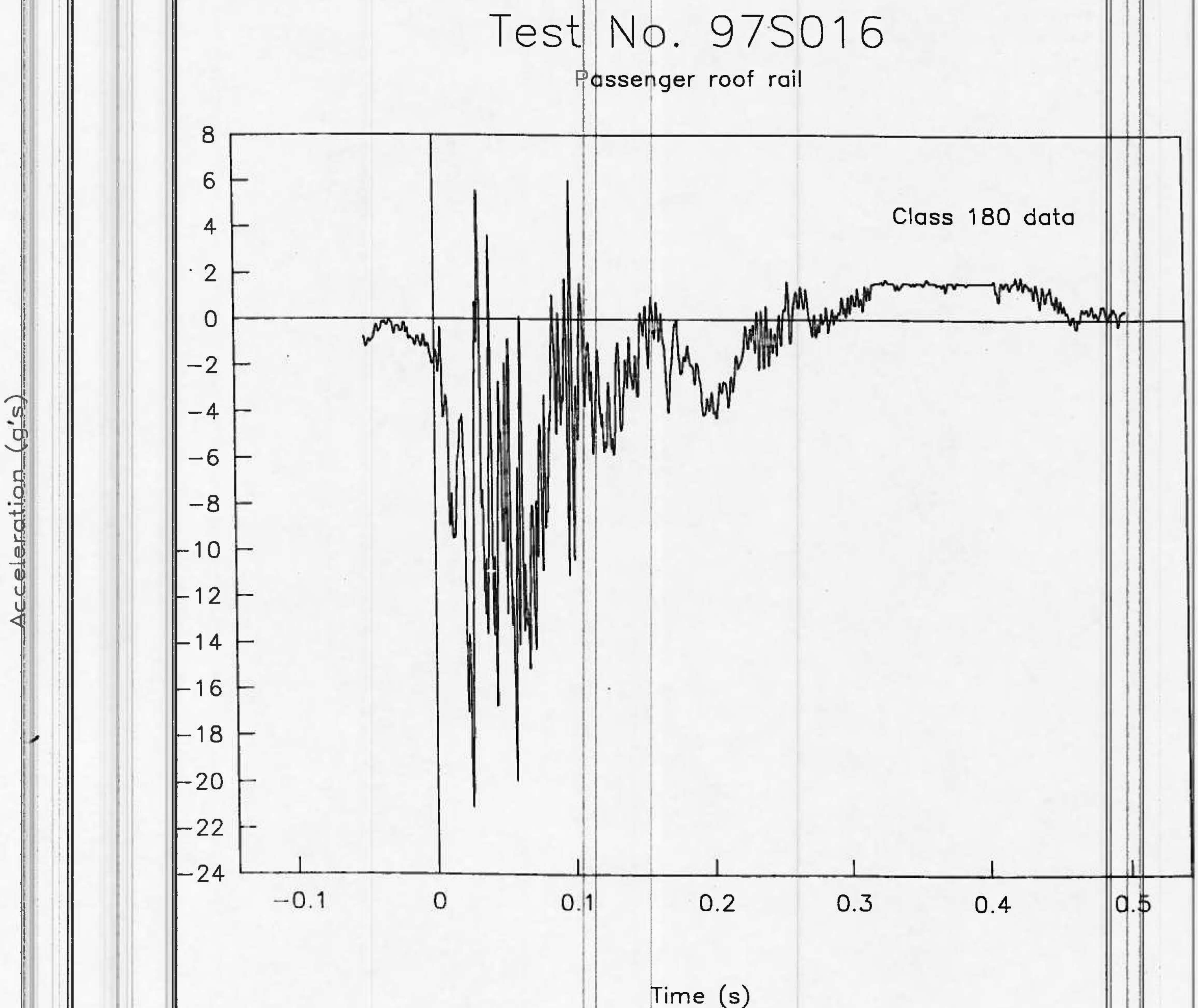


Figure 14. Acceleration vs. time, passenger roof rail, test 97S016.

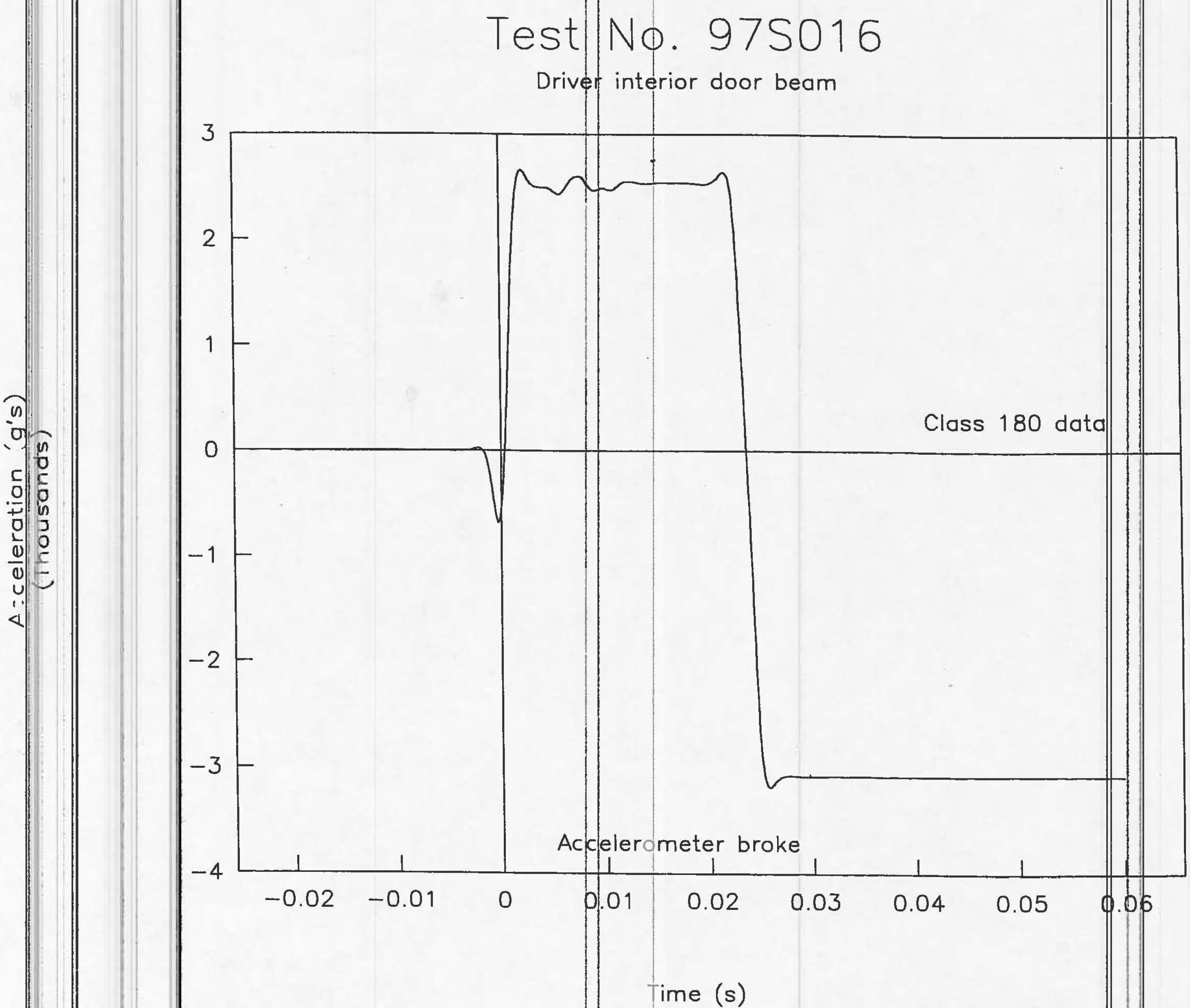


Figure 15. Acceleration vs. time, driver interior door beam, test 97S016.

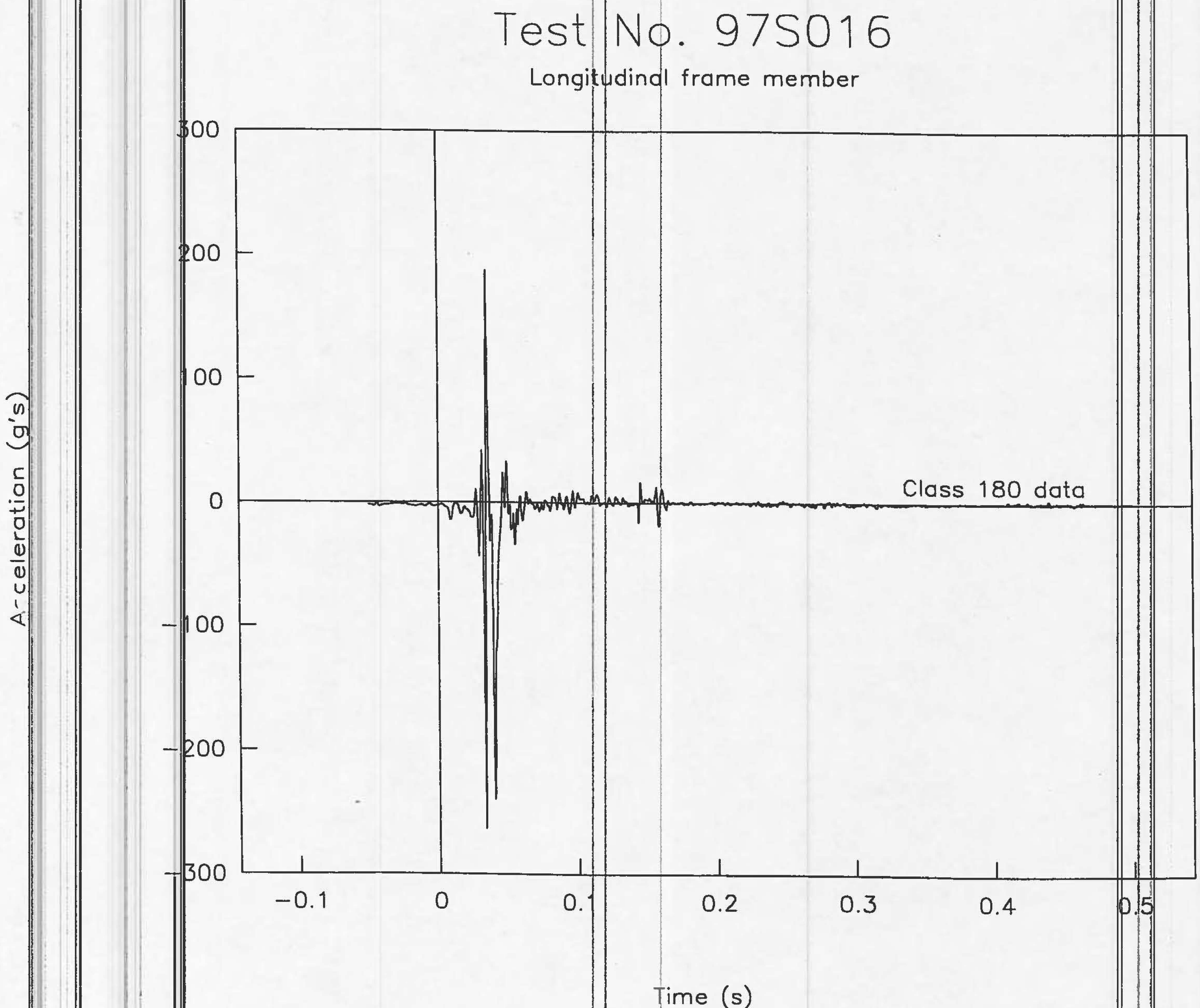


Figure 16. Acceleration vs. time, longitudinal frame member, test 97S016.

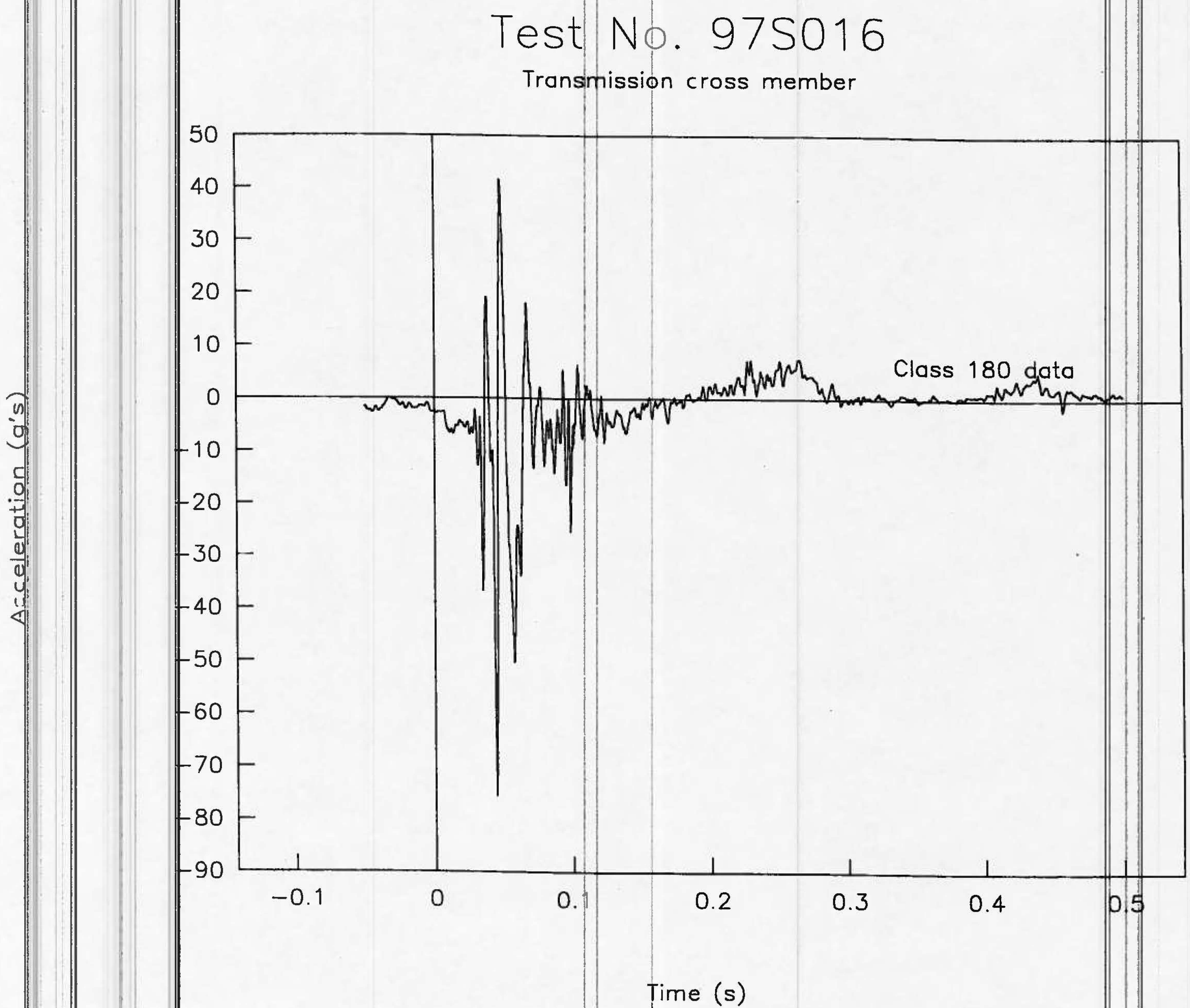


Figure 17. Acceleration vs. time, transmission cross member, test 97S016.

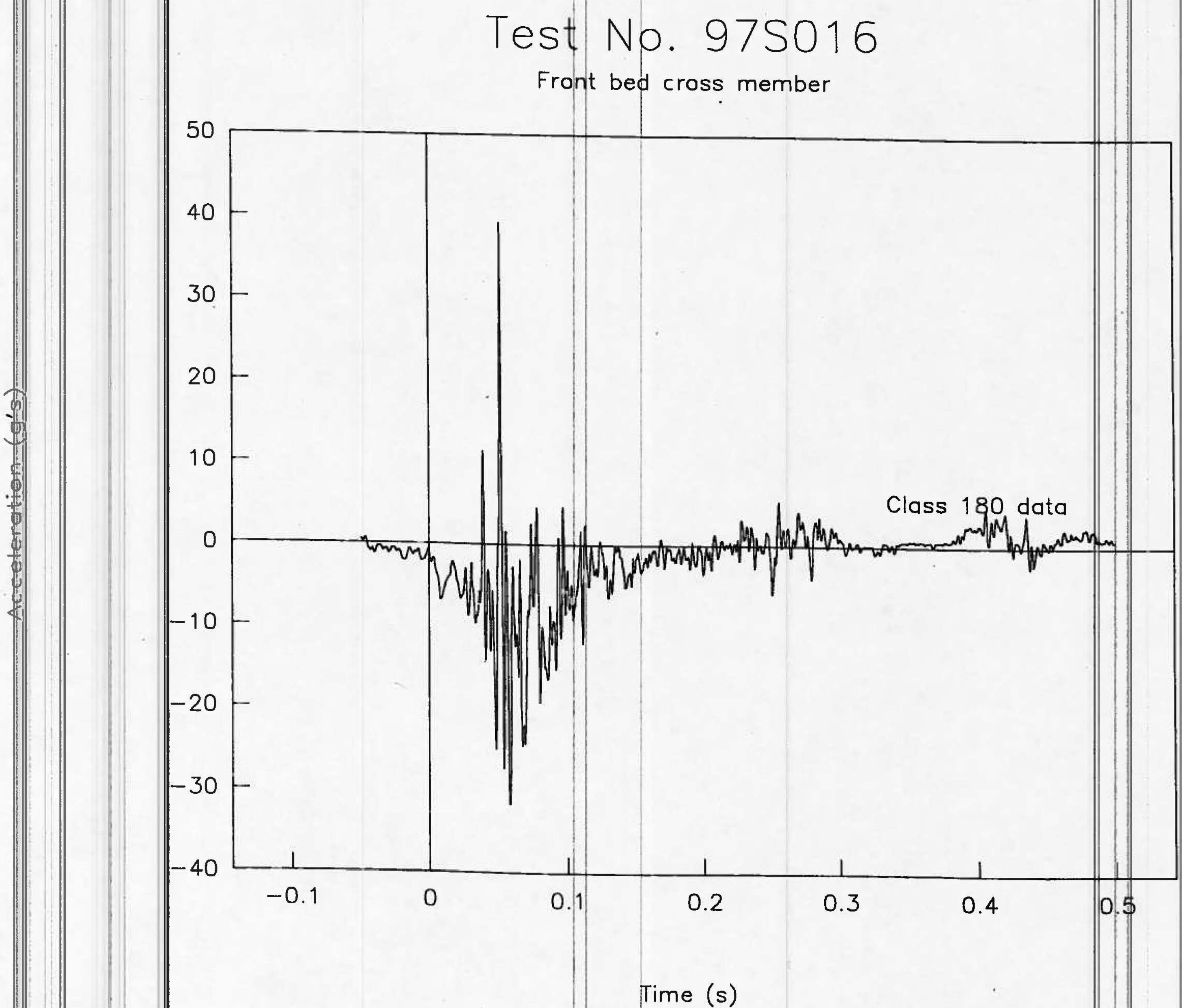


Figure 18. Acceleration vs. time, front bed cross member, test 97S016.

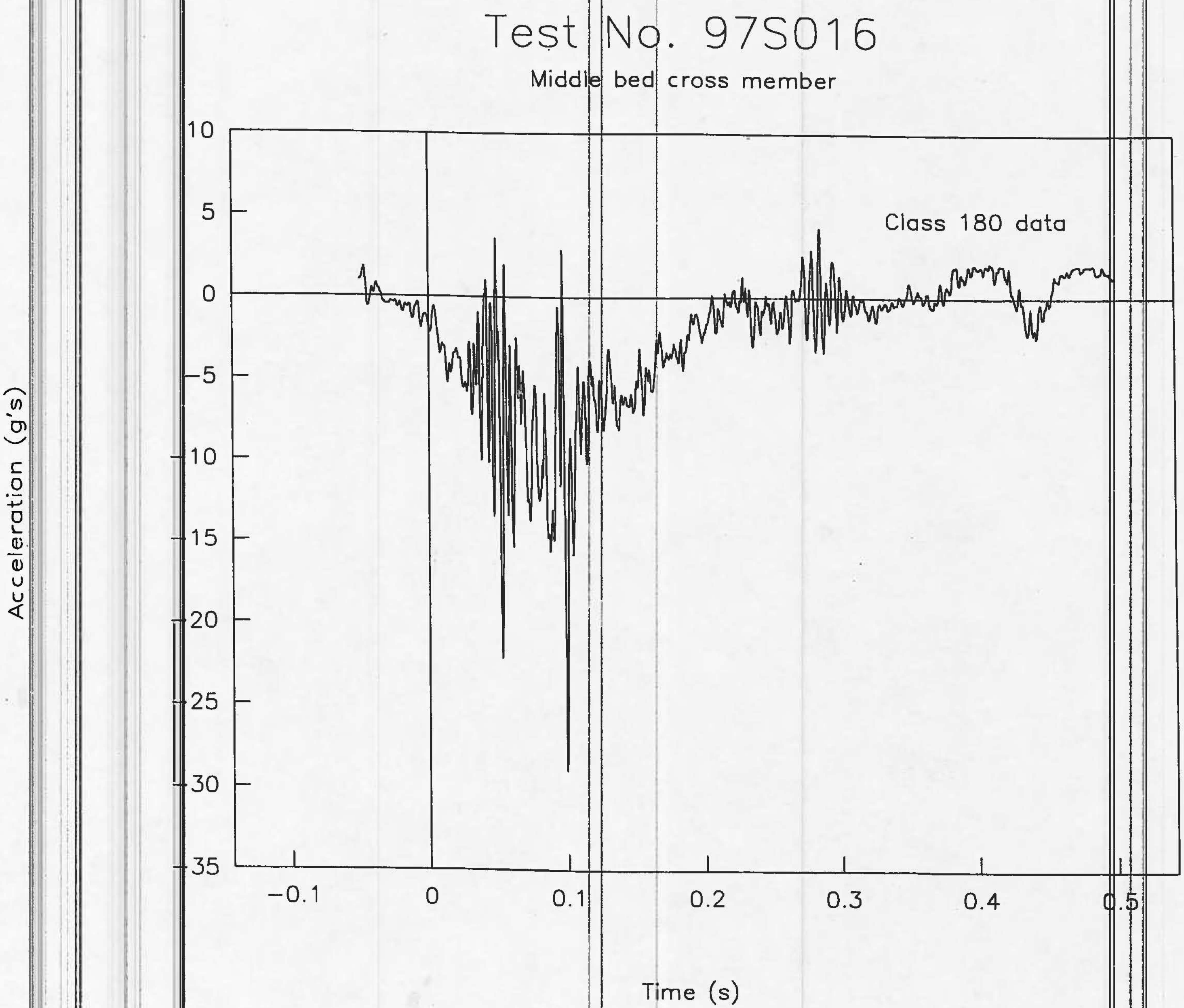


Figure 19. Acceleration vs. time, middle bed cross member, test 97S016.

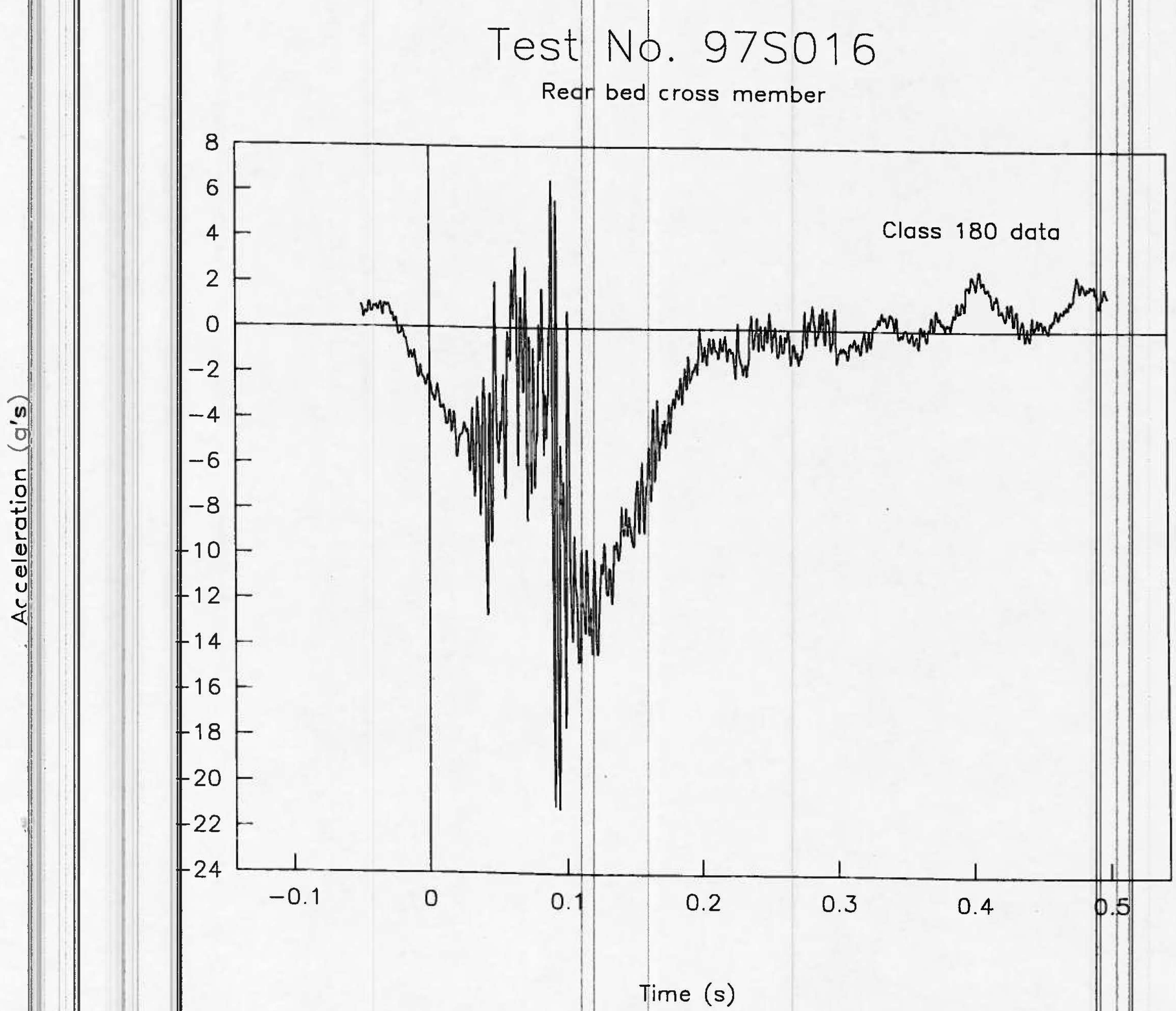


Figure 20. Acceleration vs. time, rear bed cross member, test 97S016.

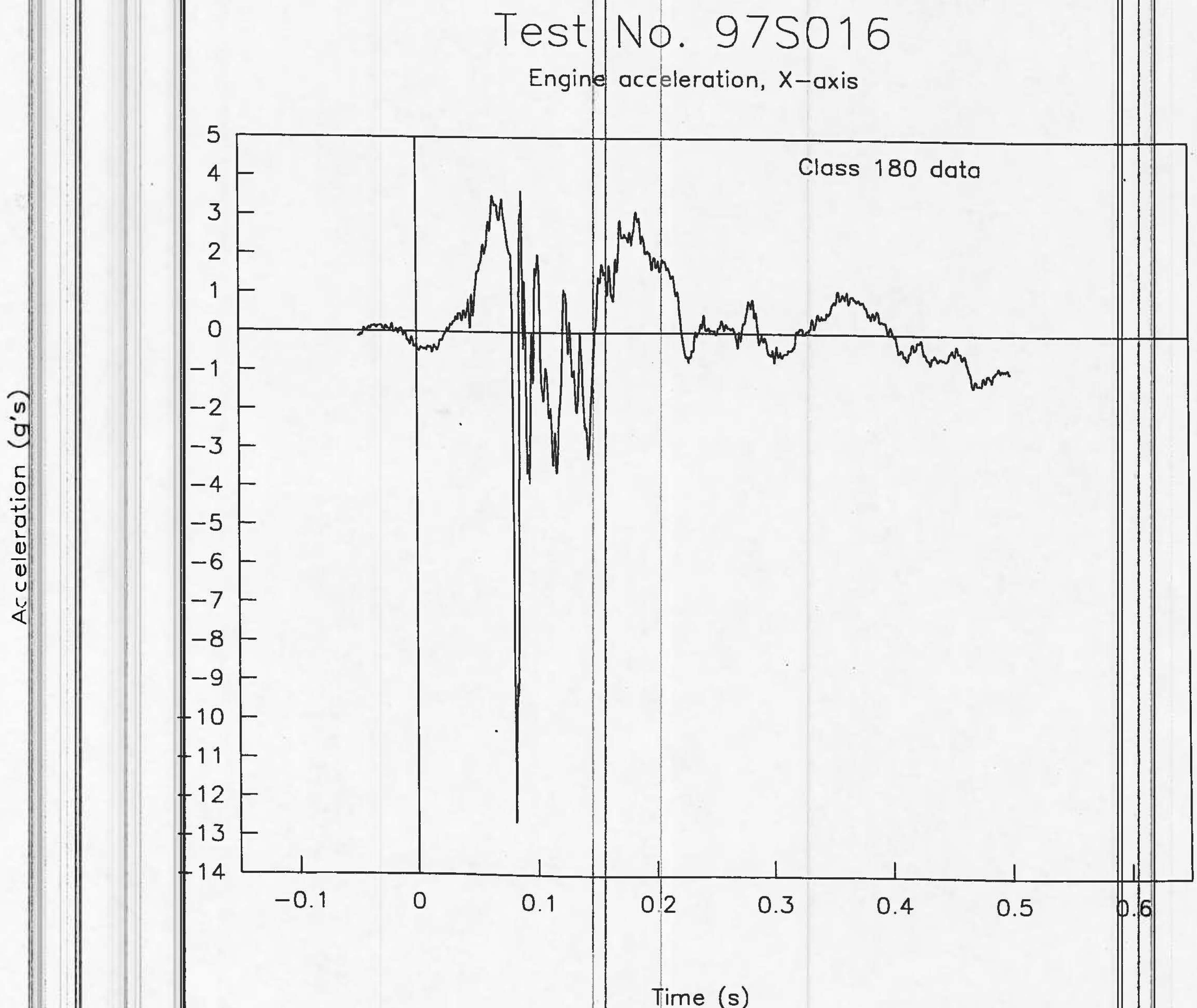


Figure 21. Acceleration vs. time, engine X-axis, test 97S016.

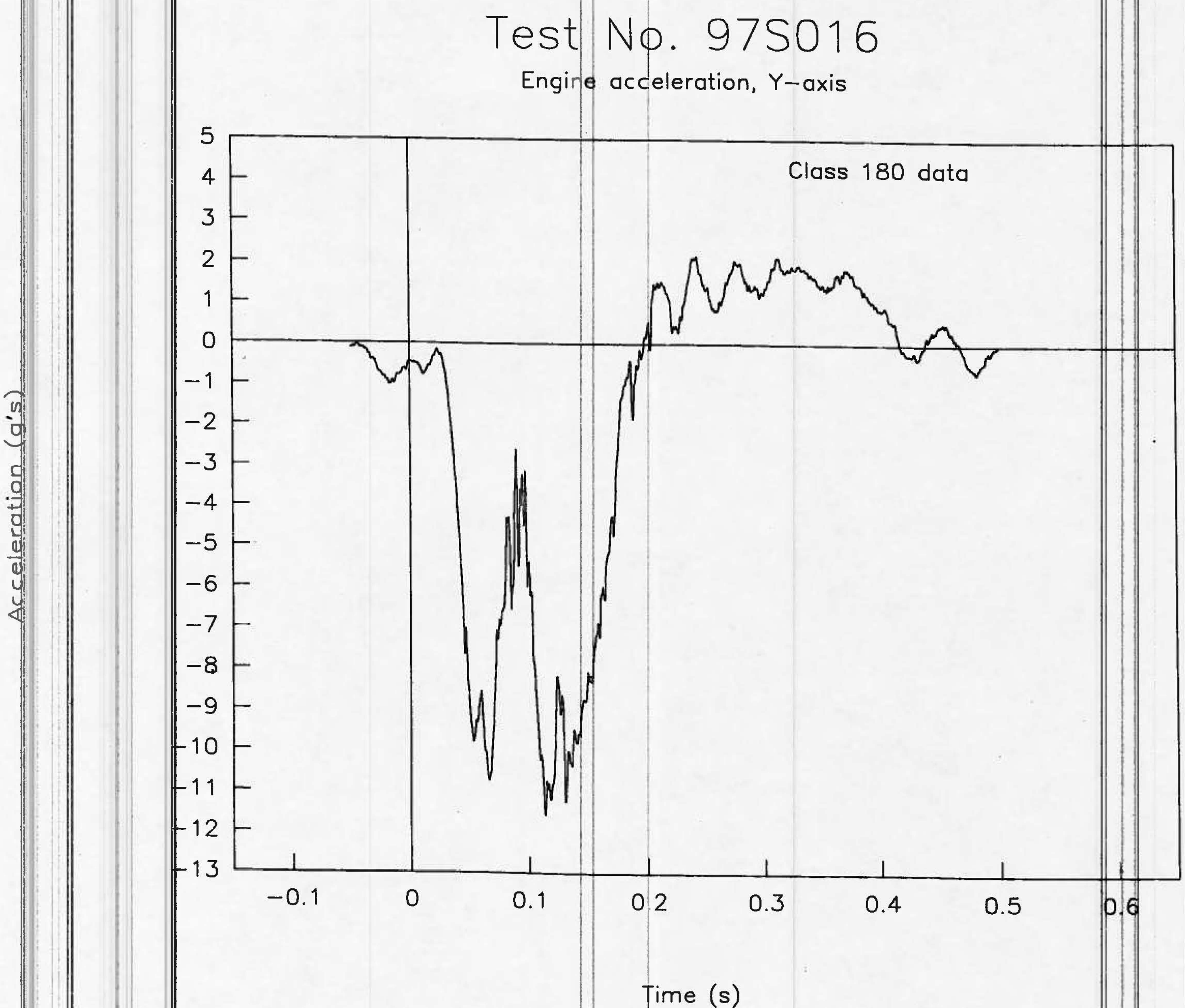


Figure 22. Acceleration vs. time, engine Y-axis, test 97S016.

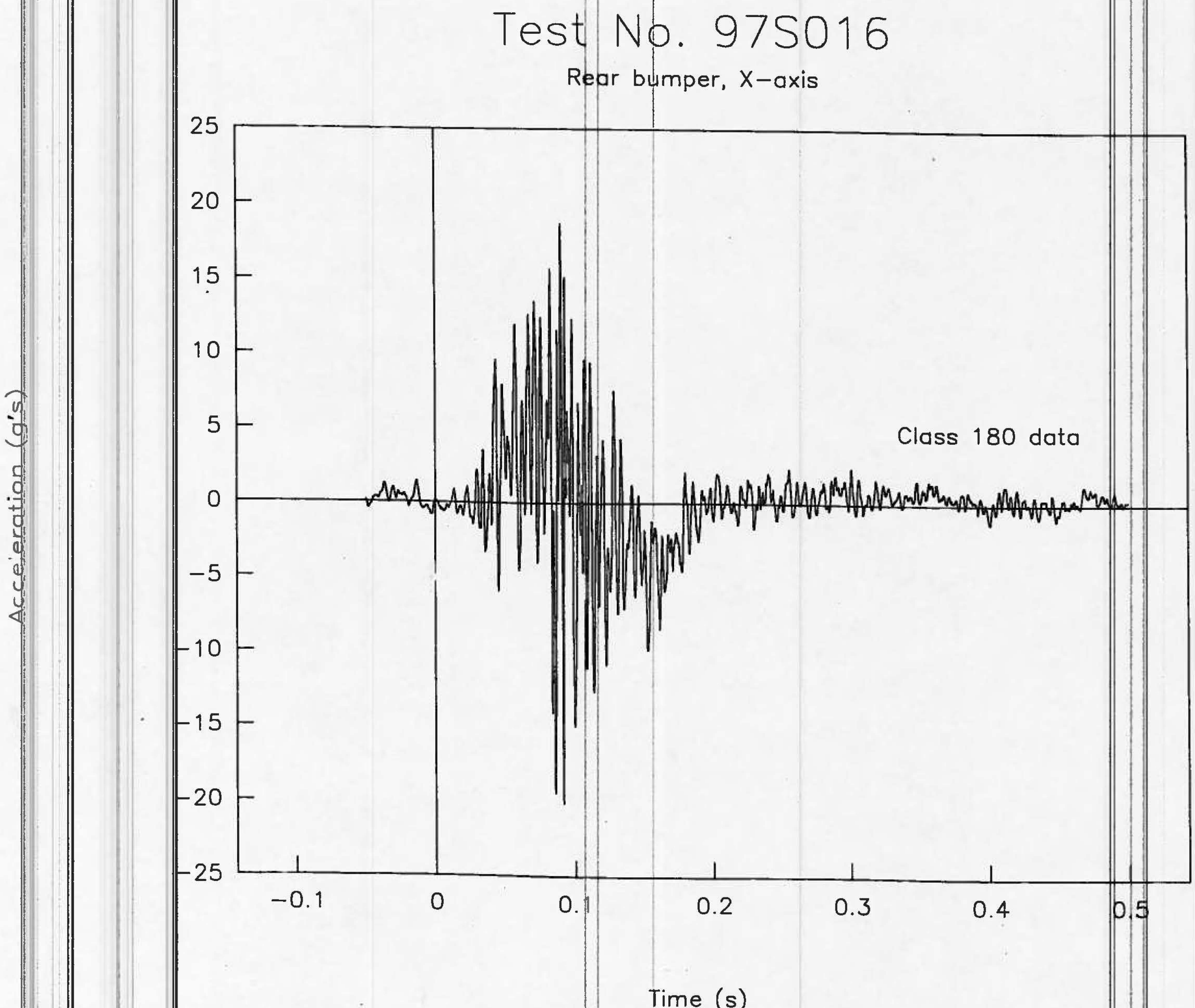


Figure 23. Acceleration vs. time, rear bumper X-axis, test 97S016.

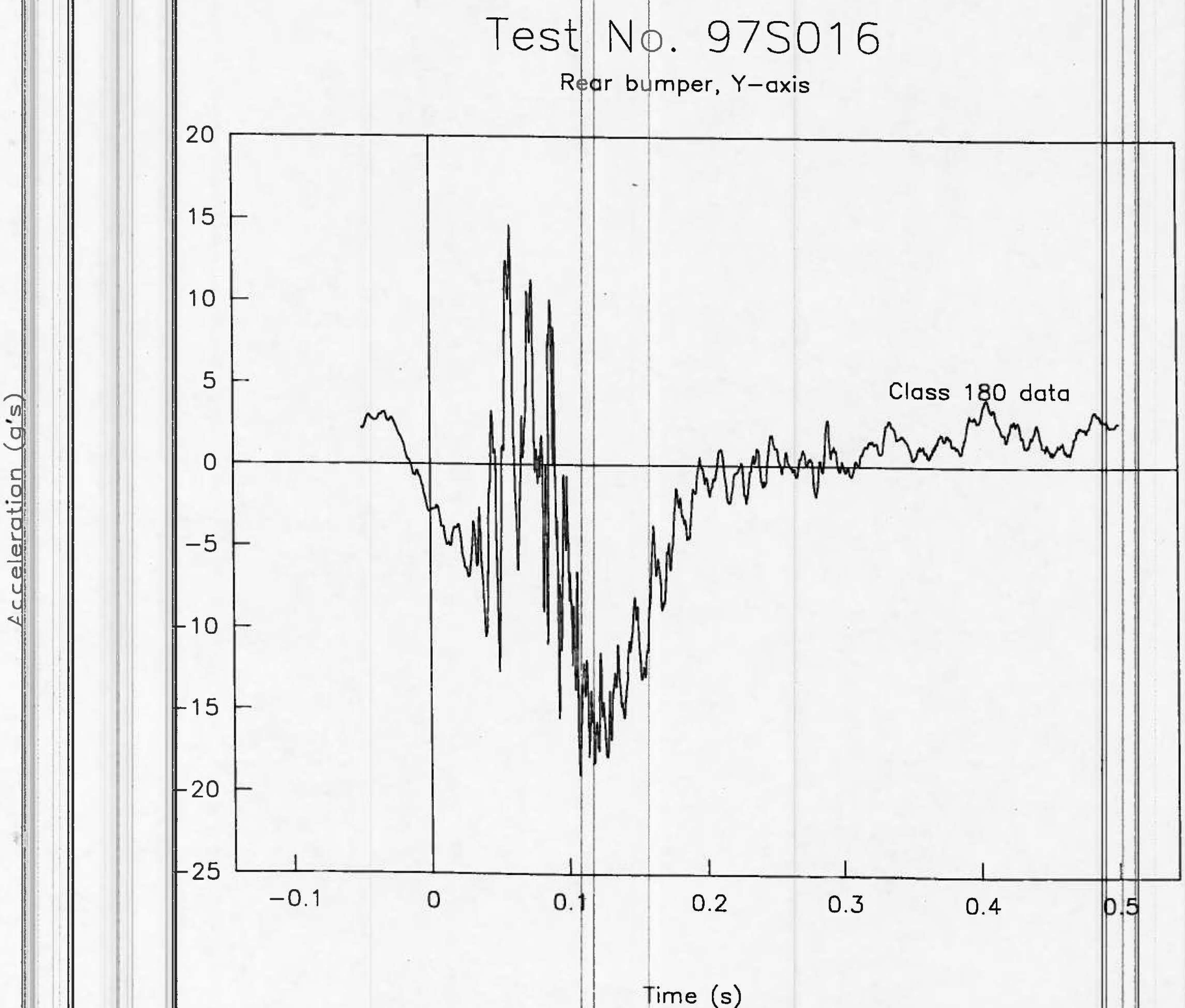


Figure 24. Acceleration vs. time, rear bumper Y-axis, test 97S016.

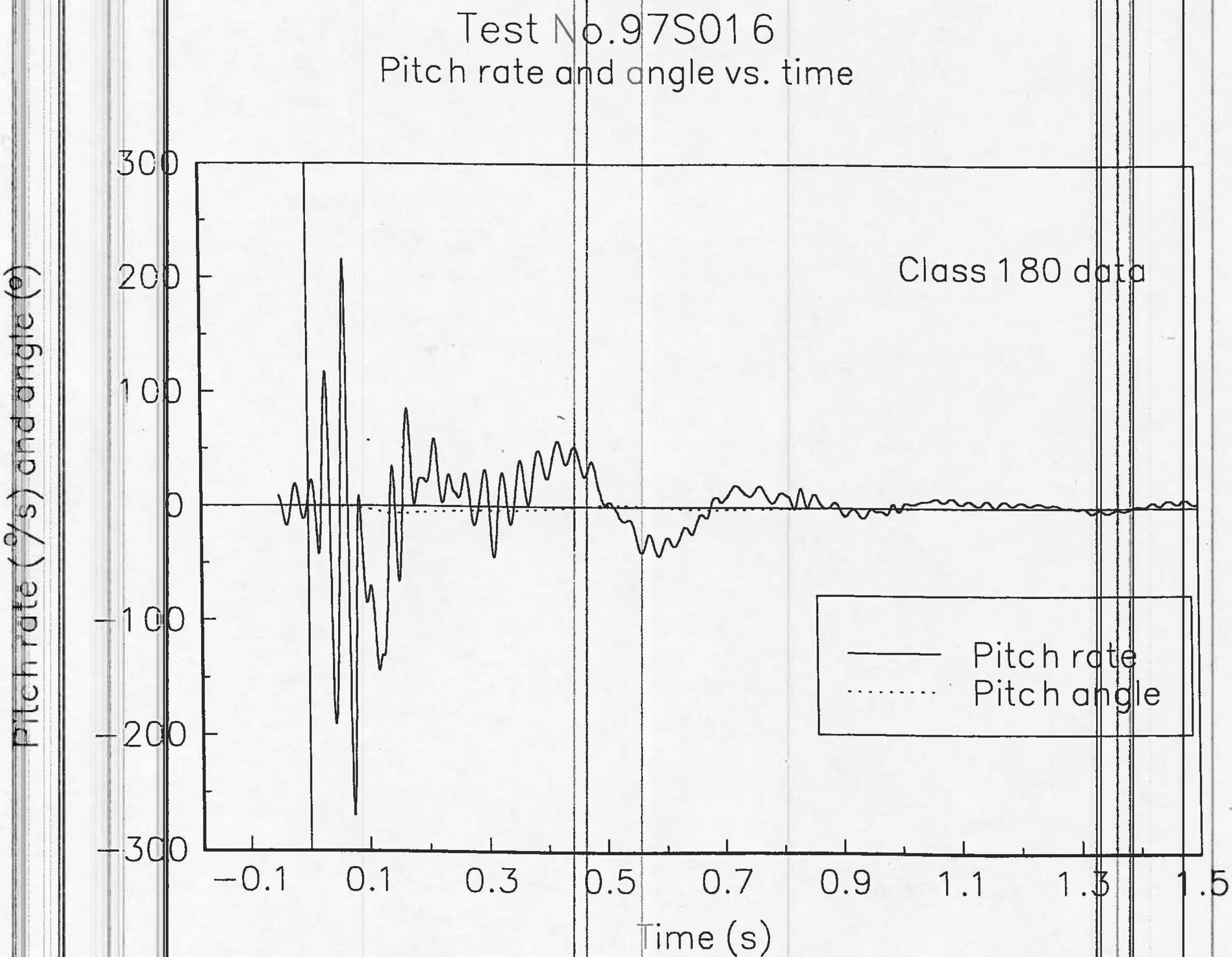


Figure 25. Pitch rate and angle vs. time, test 97S016.

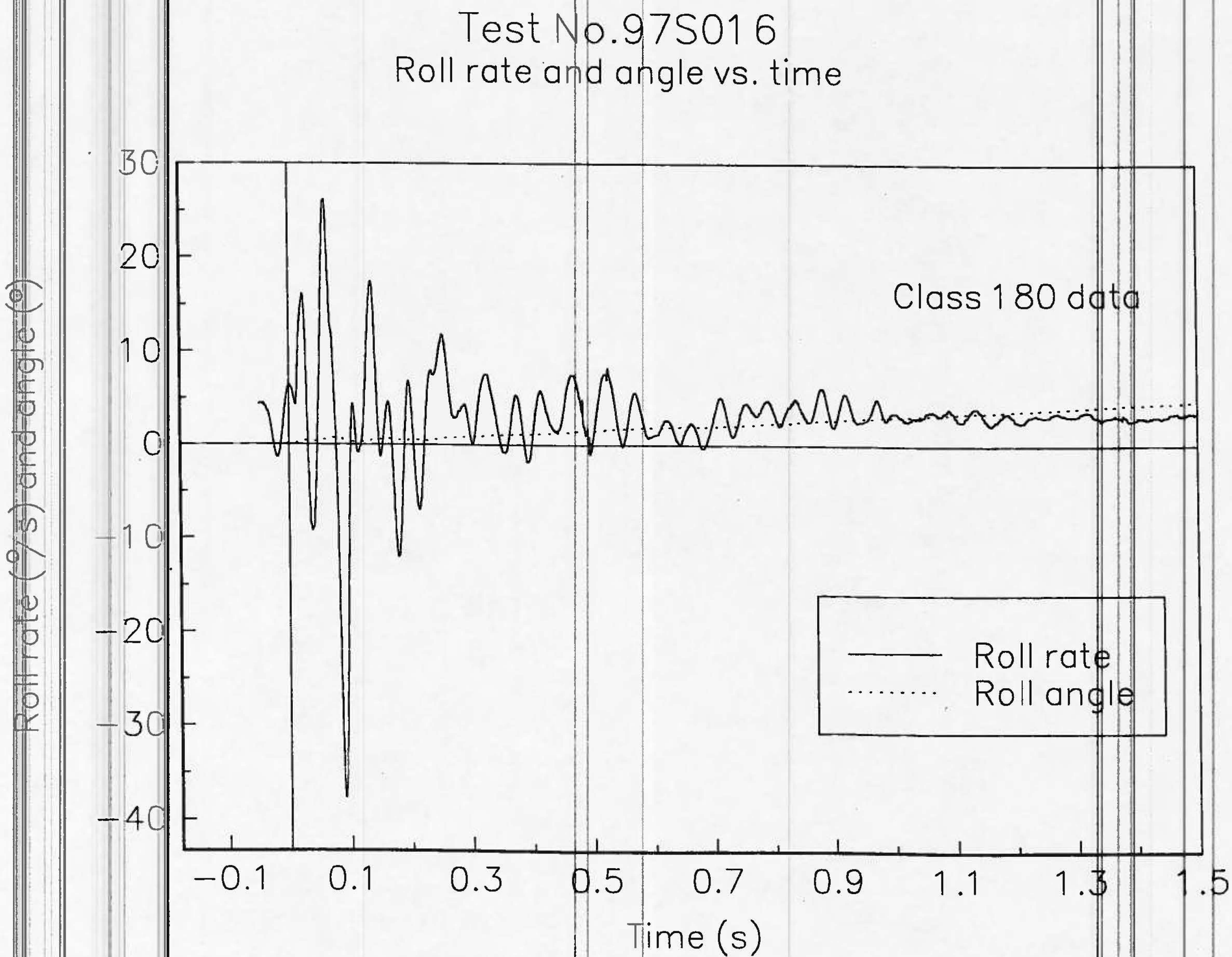


Figure 26. Roll rate and angle vs. time, test 97S016.

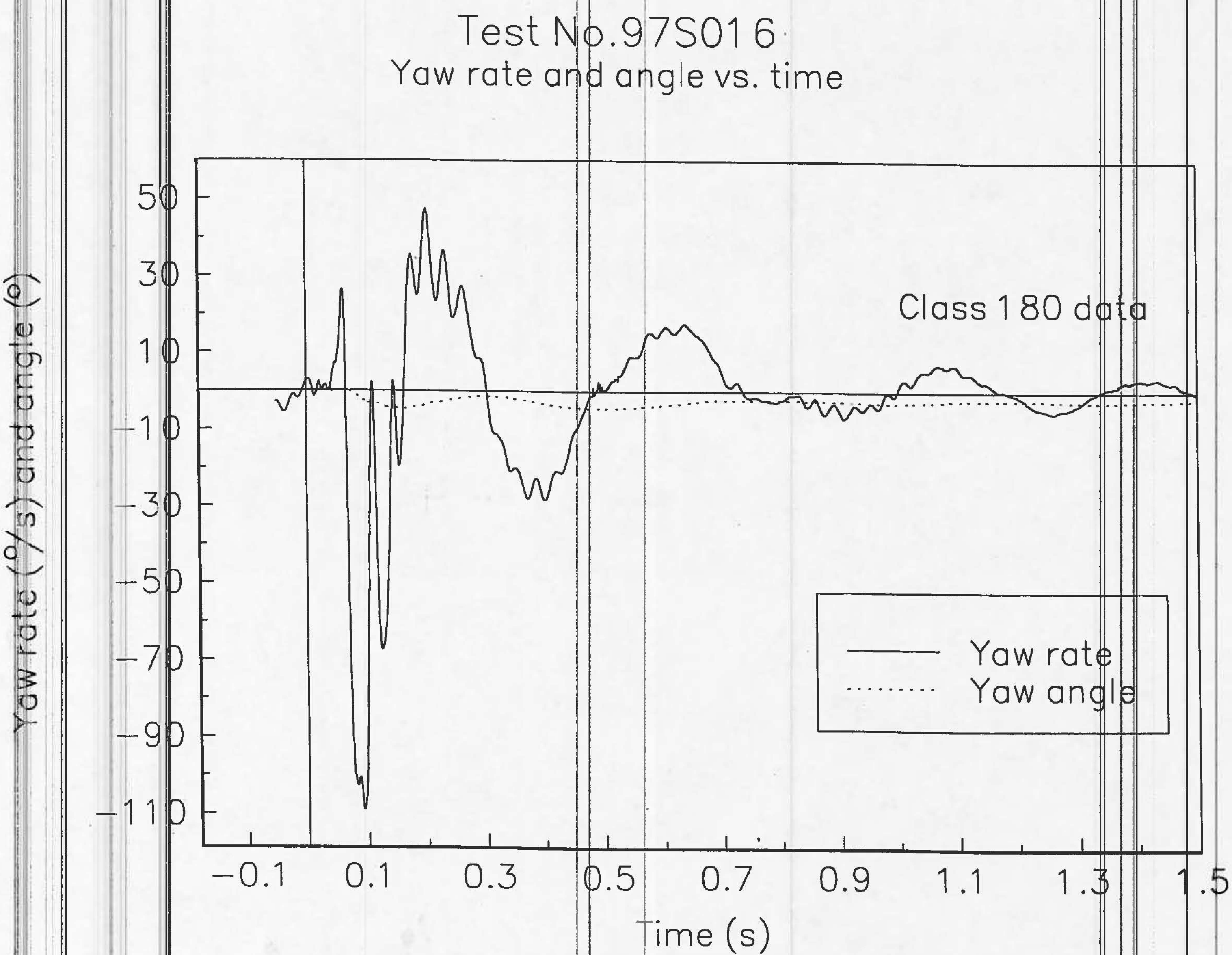


Figure 27. Yaw rate and angle vs. time, test 97S016.

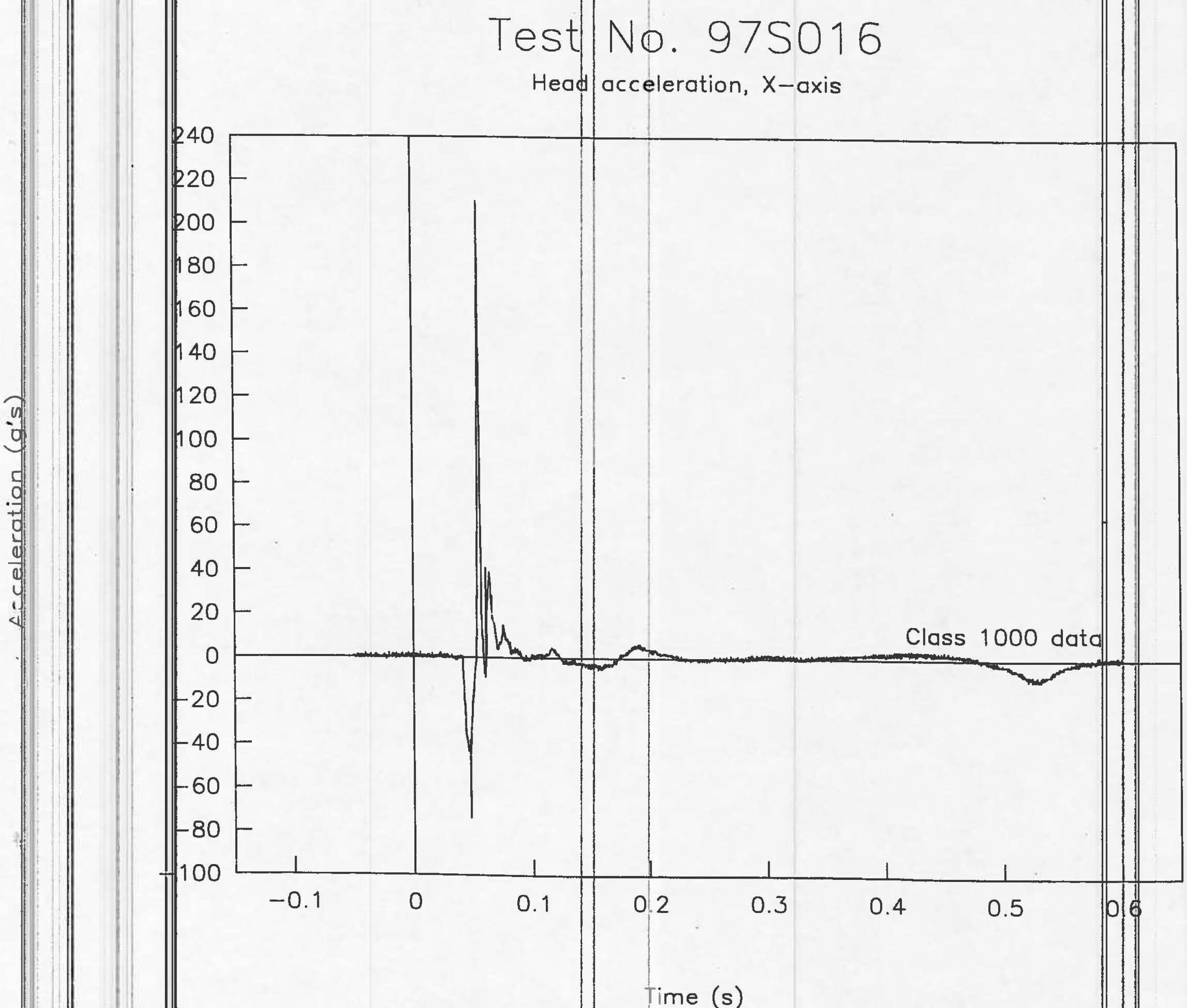


Figure 28. Acceleration vs. time, head X-axis, test 97S016.

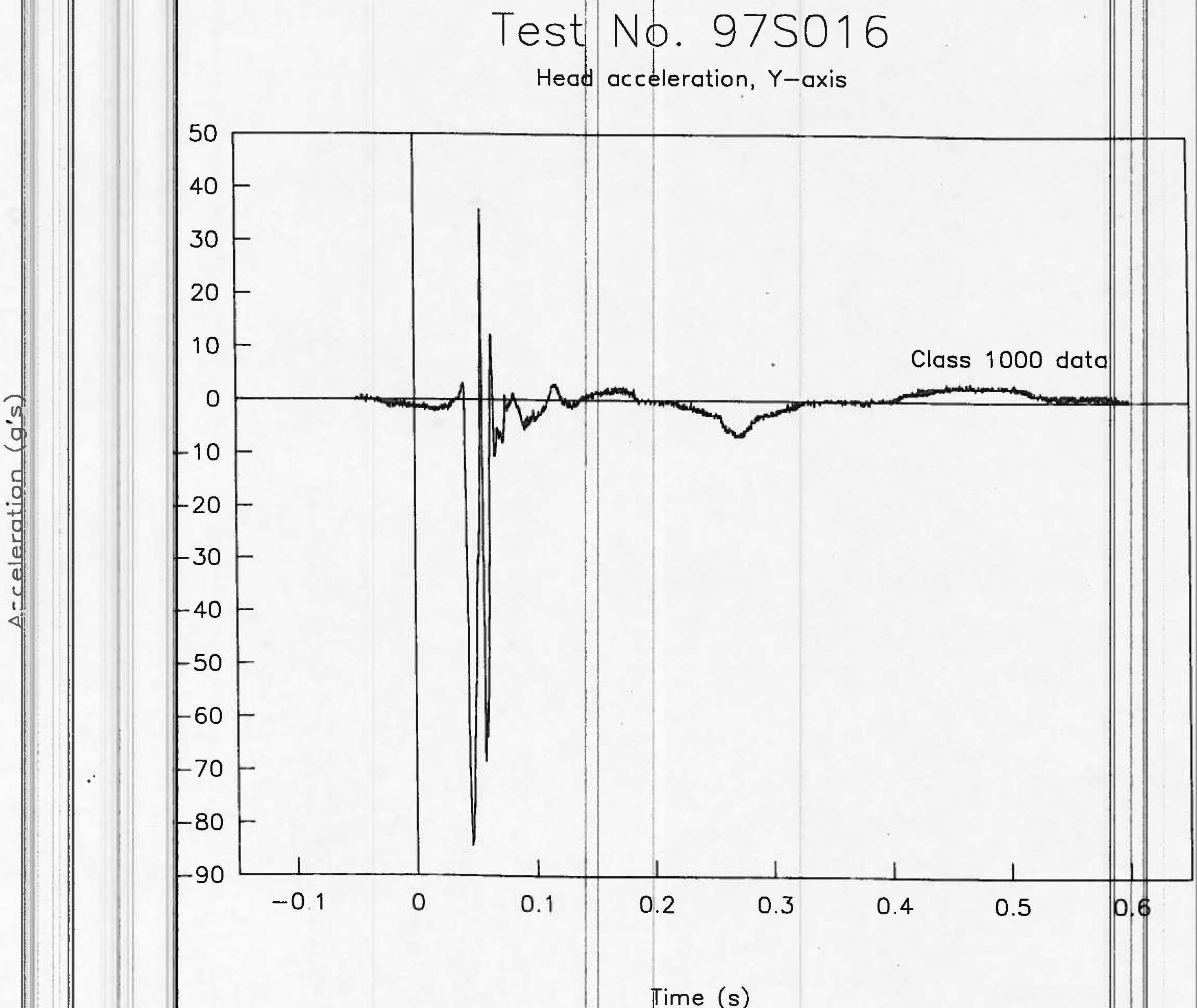


Figure 29. Acceleration vs. time, head Y-axis, test 97S016.

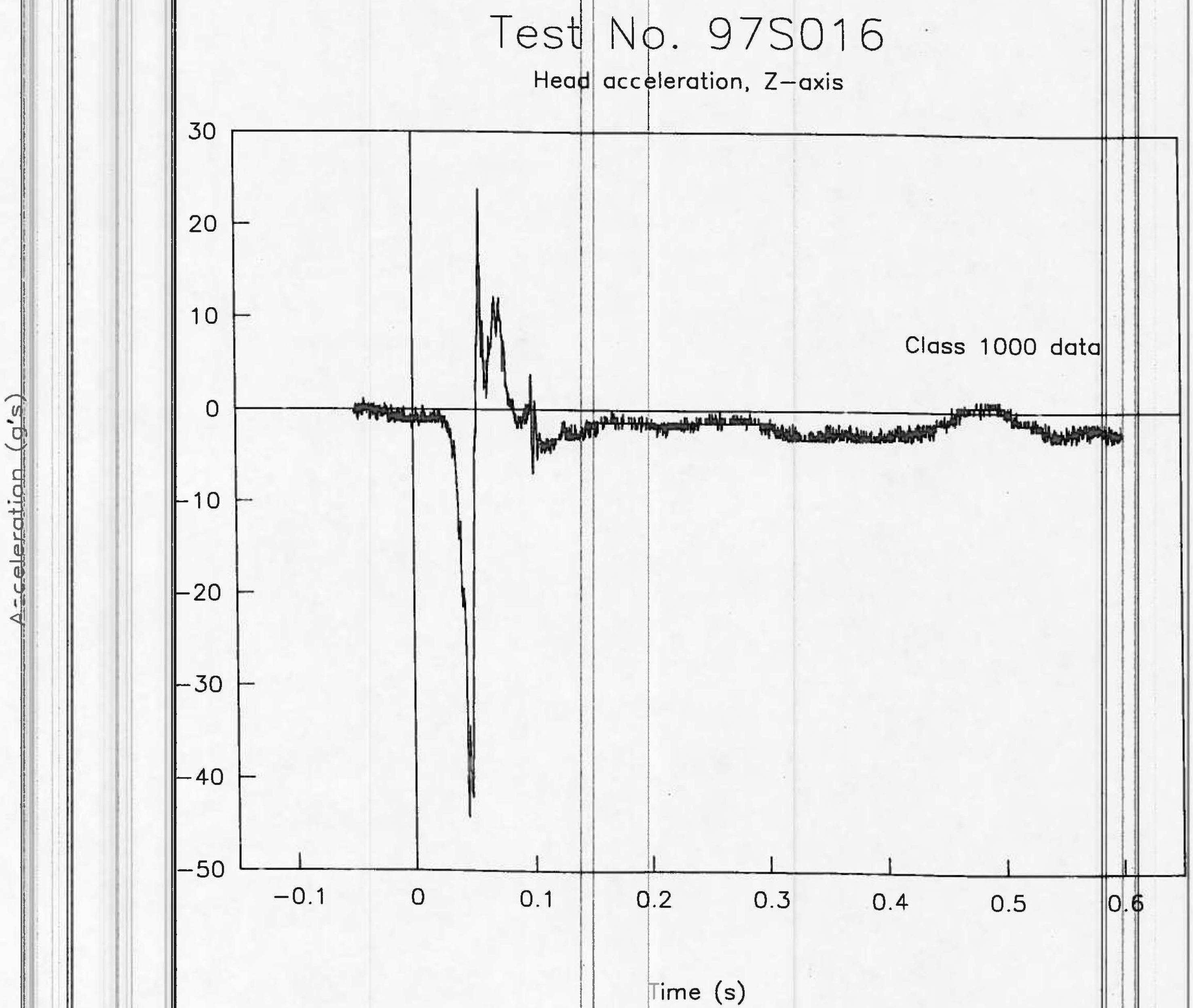


Figure 30. Acceleration vs. time, head Z-axis, test 97S016.

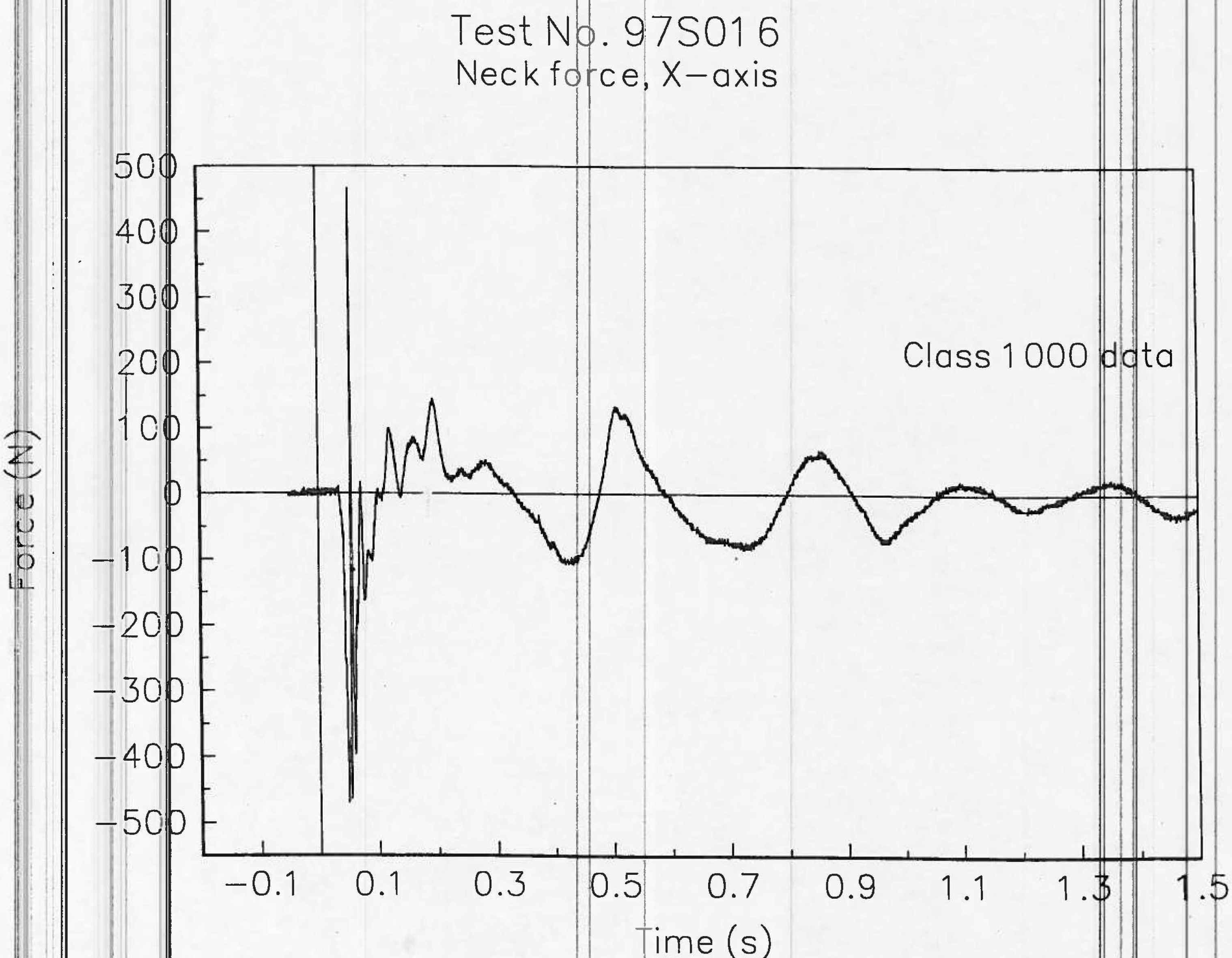


Figure 31. Force vs. time, neck X-axis, test 97S016.

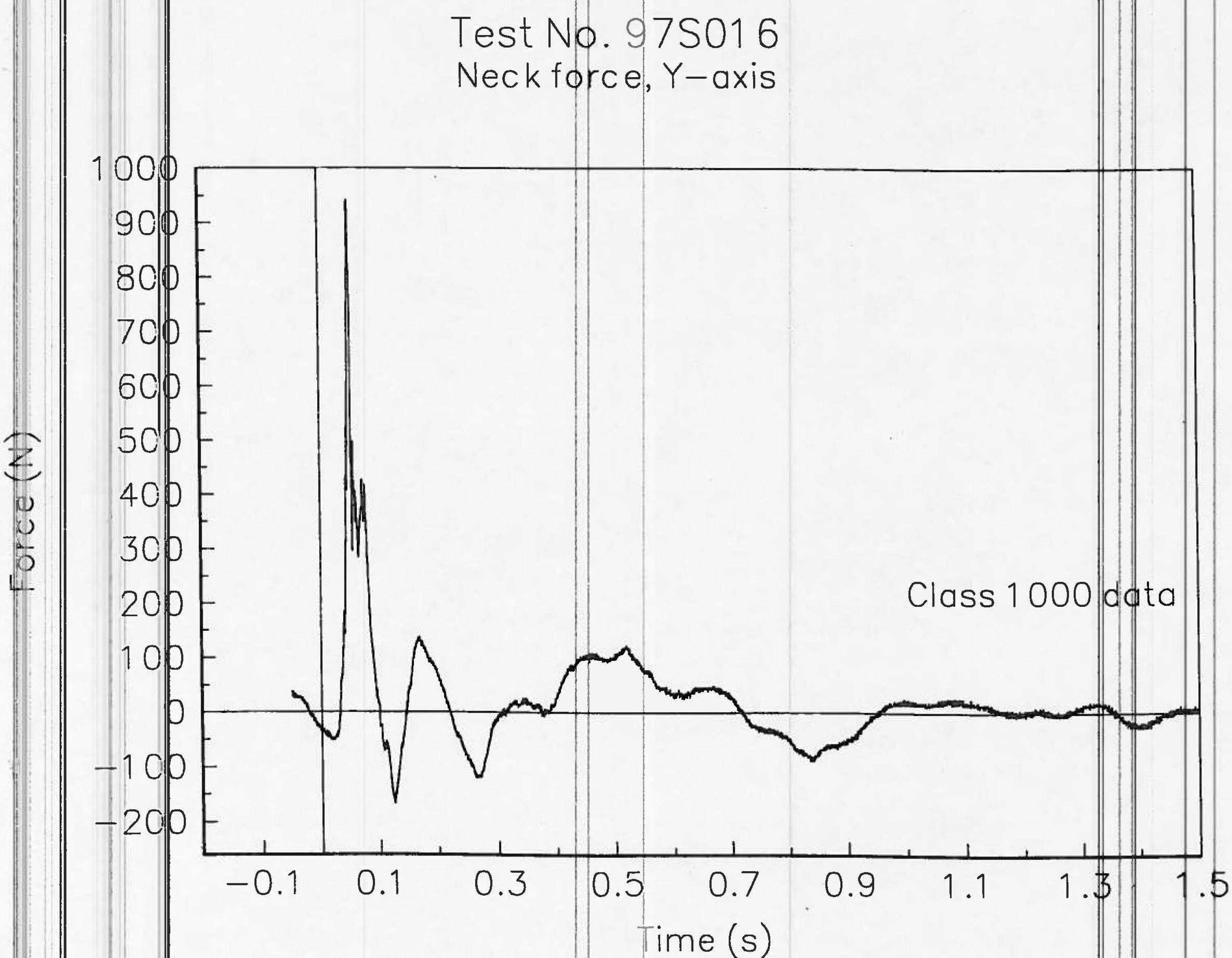


Figure 32. Force vs. time, neck Y-axis, test 97S016.

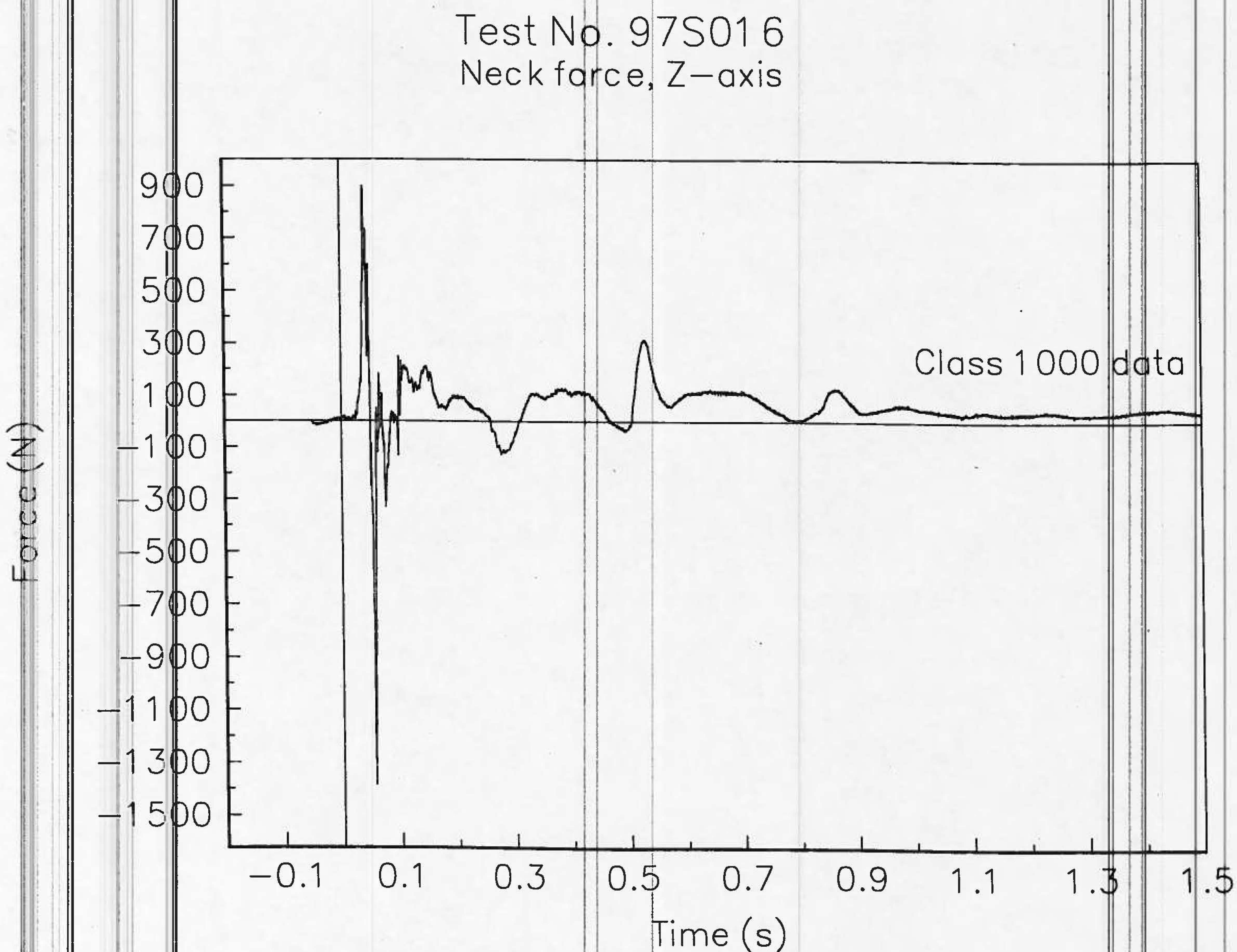


Figure 33. Force vs. time, neck Z-axis, test 97S016.

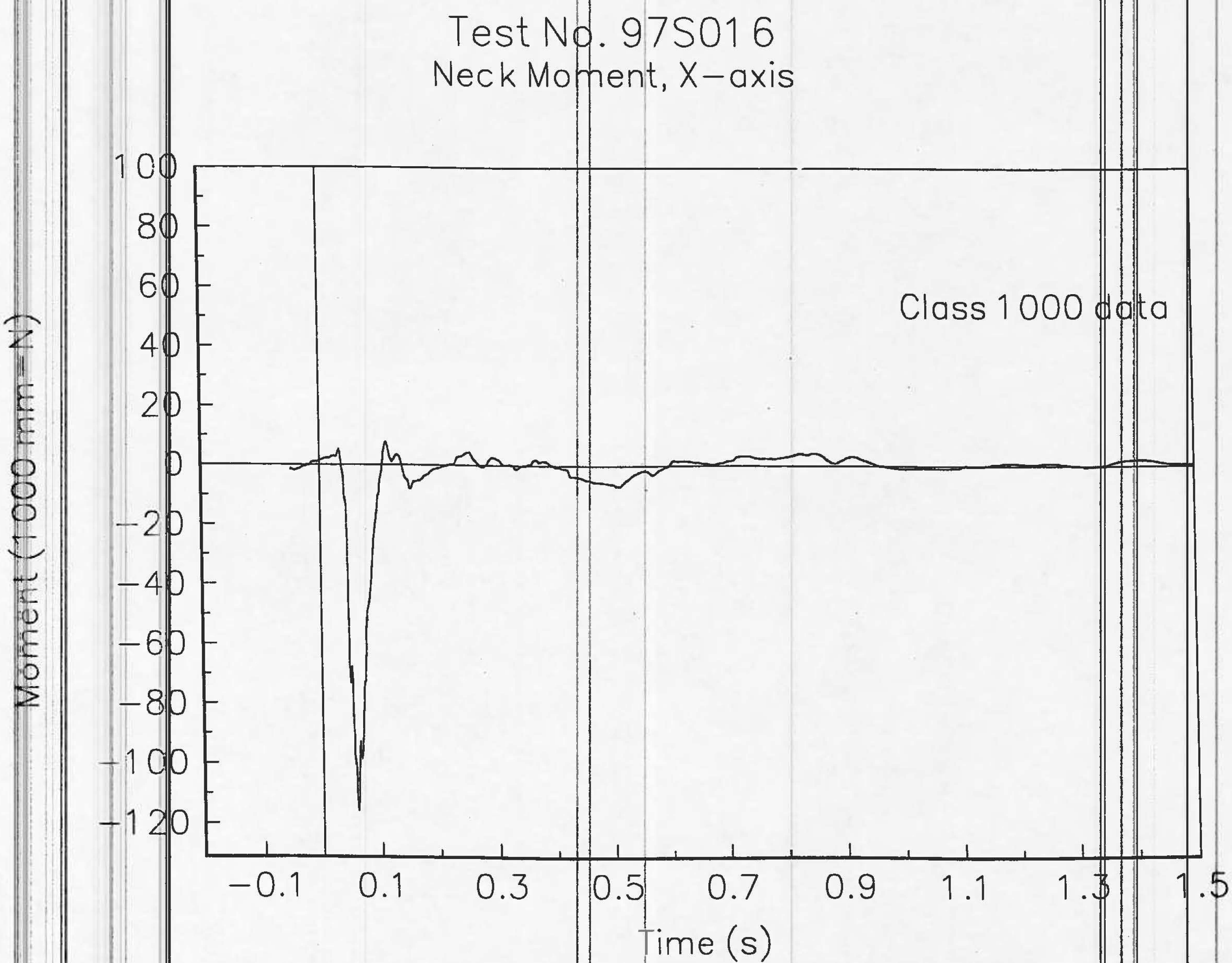


Figure 34. Moment vs. time, neck X-axis, test 97S016.

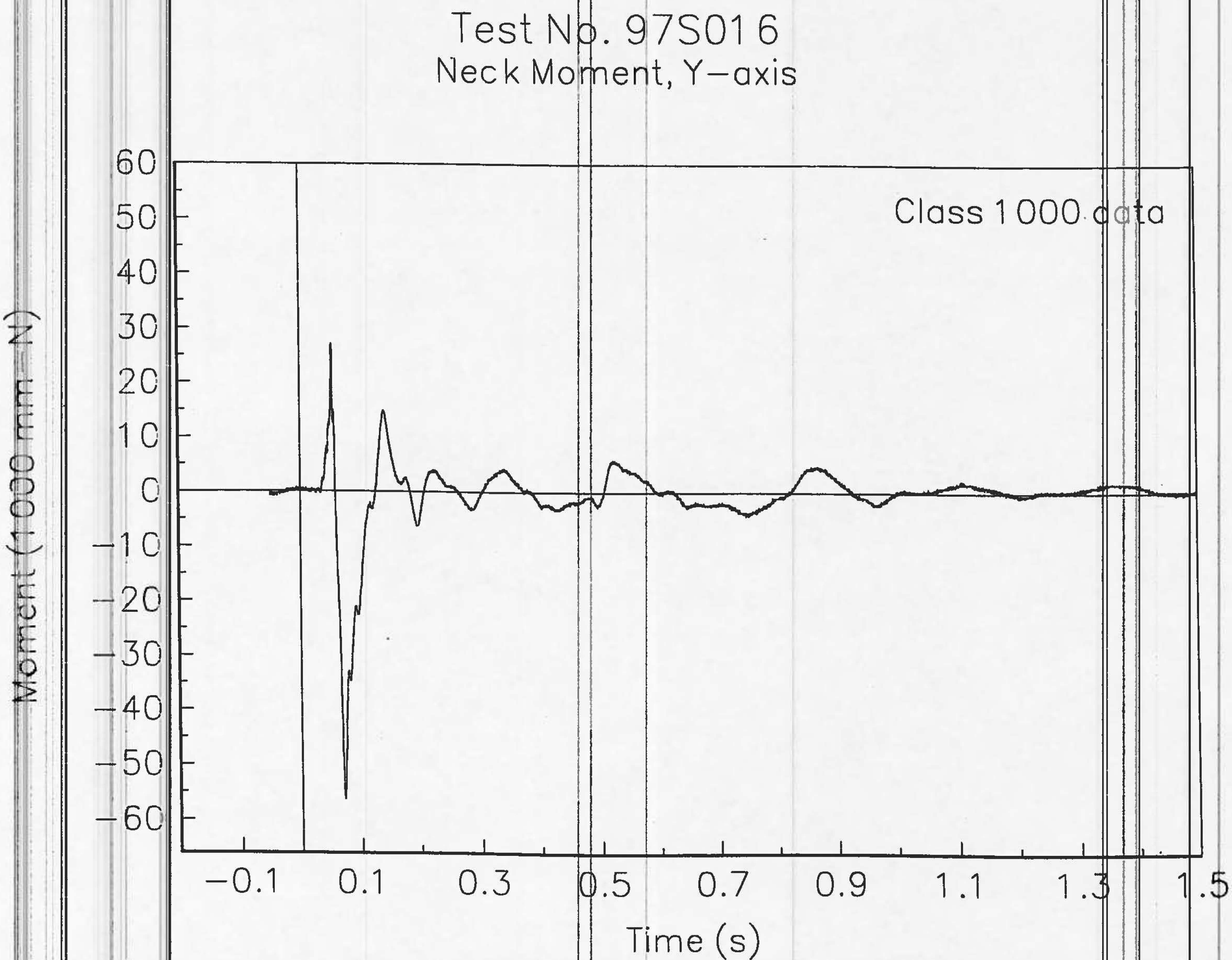


Figure 35. Moment vs. time, neck Y-axis, test 97S016.

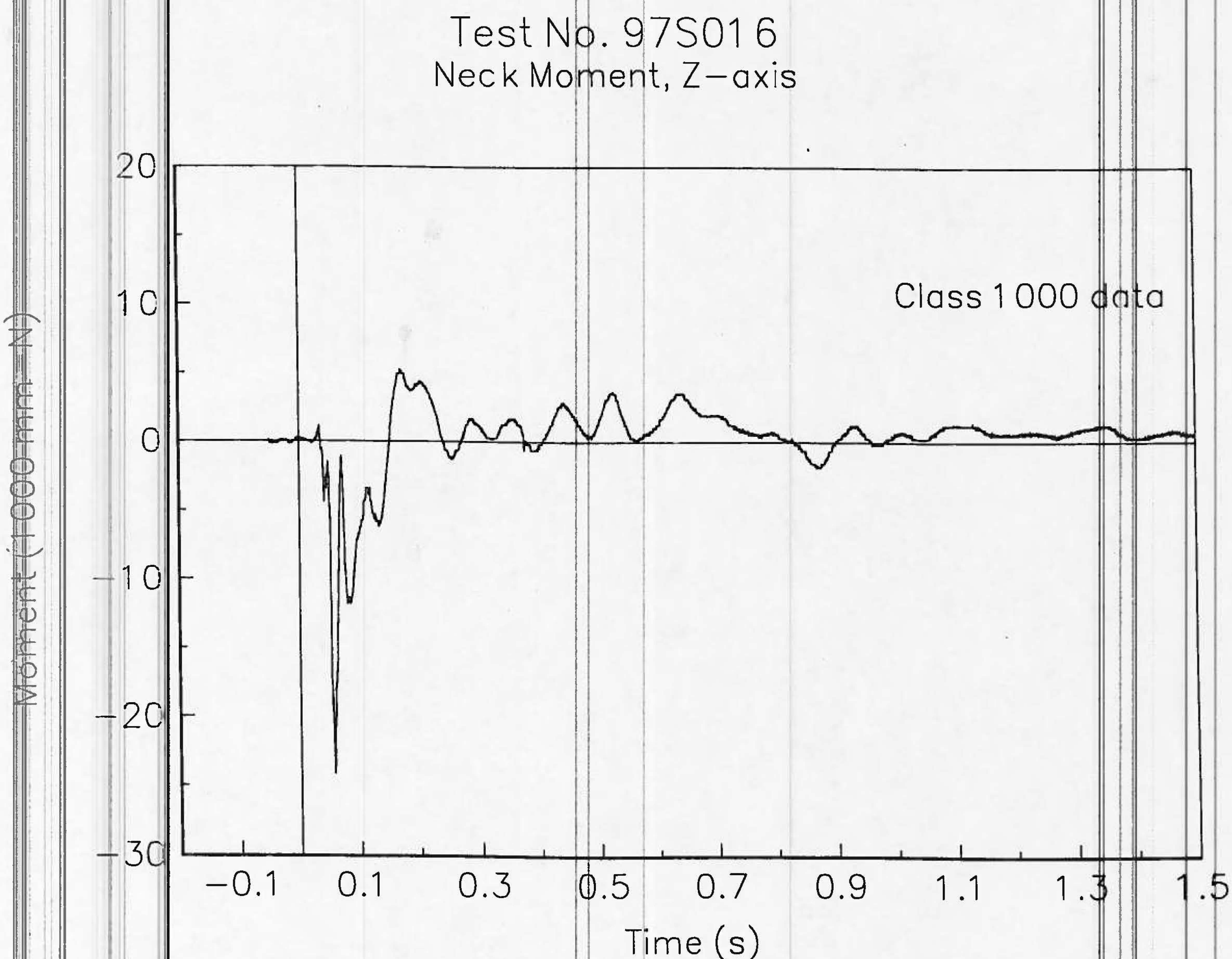


Figure 36. Moment vs. time, neck Z-axis, test 97S016.

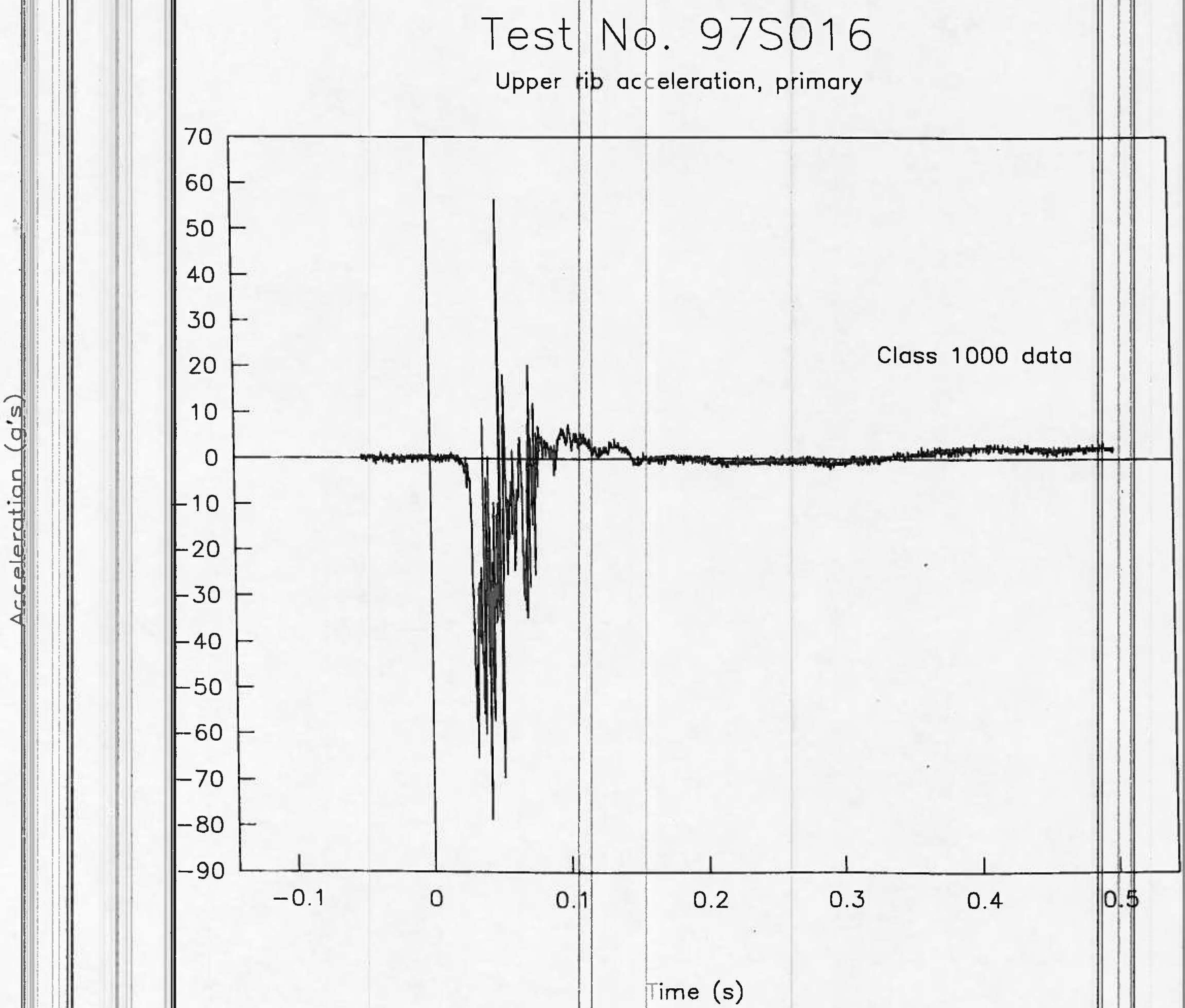


Figure 37. Acceleration vs. time, upper rib primary, test 97S016.

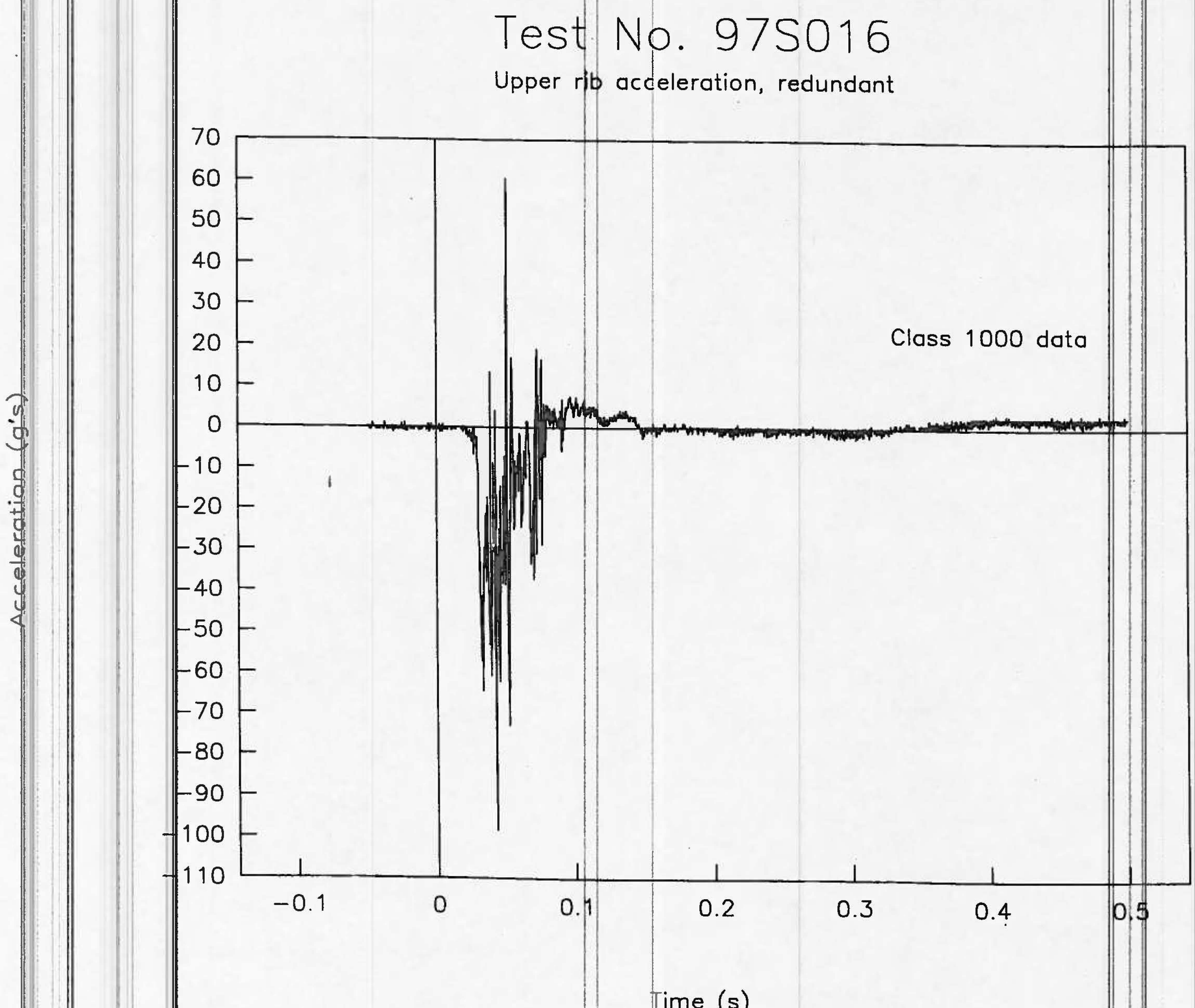


Figure 38. Acceleration vs. time, upper rib redundant, test 97S016.

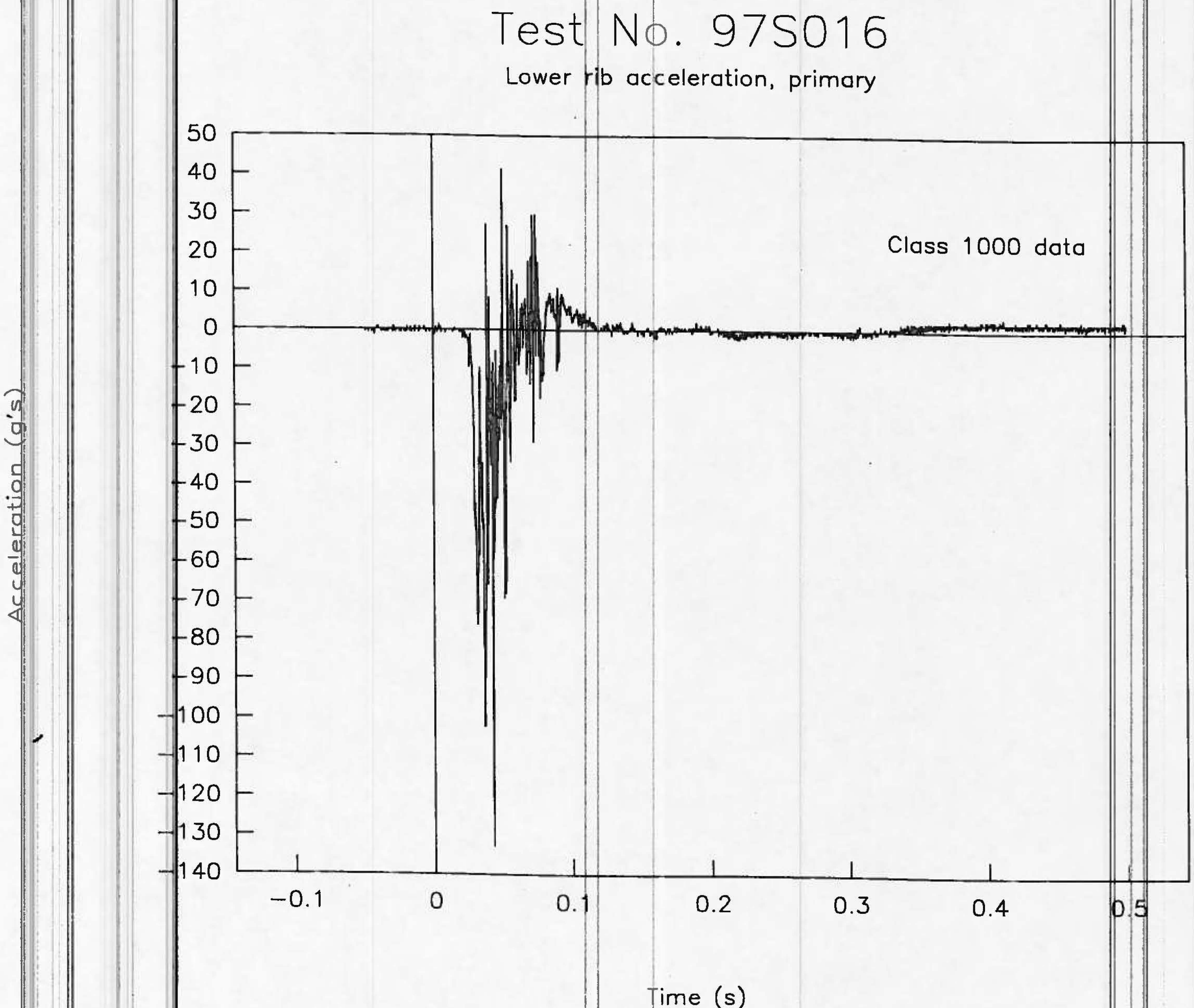


Figure 39. Acceleration vs. time, lower rib primary, test 97S016.

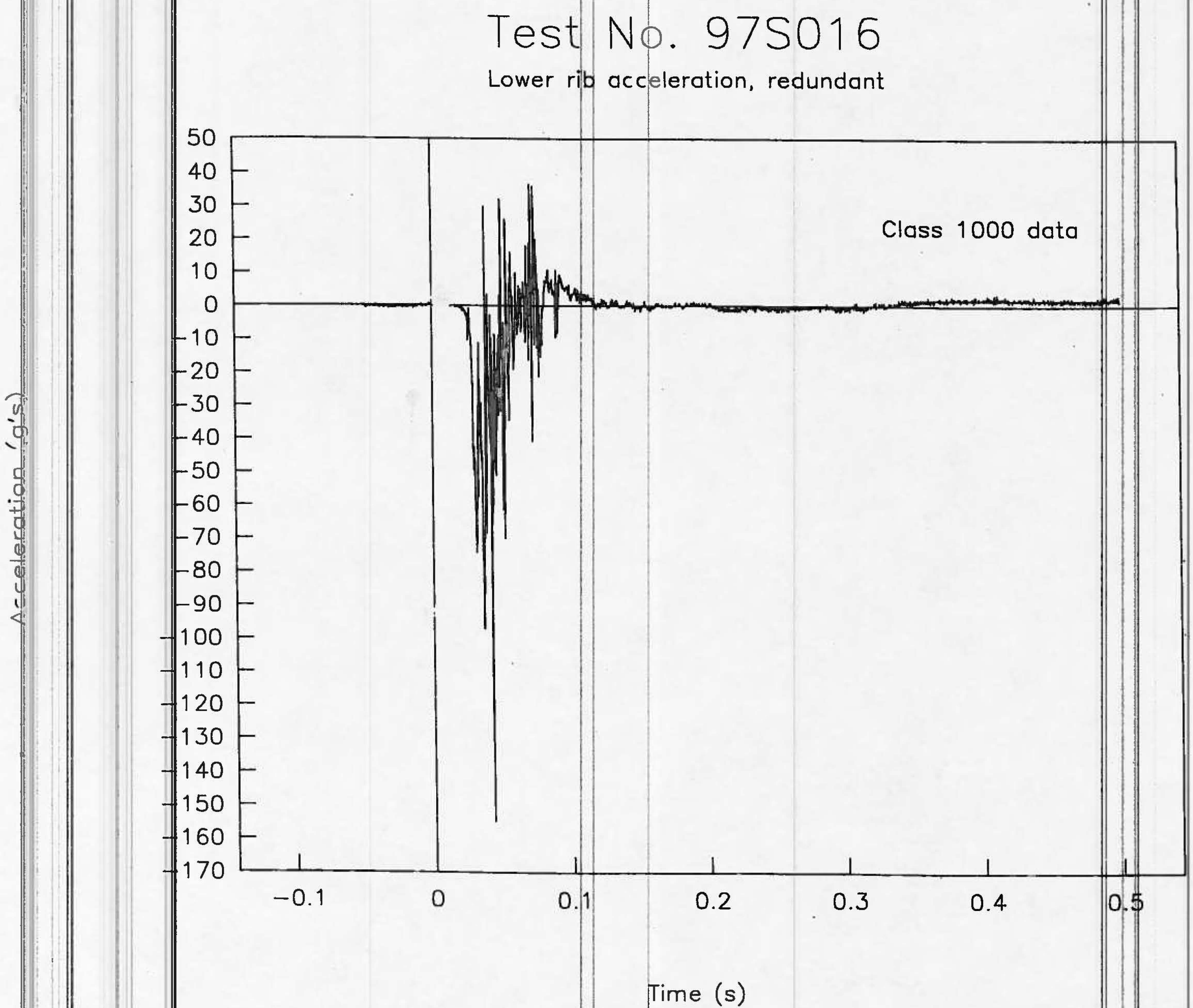


Figure 40. Acceleration vs. time, lower rib redundant, test 97S016.

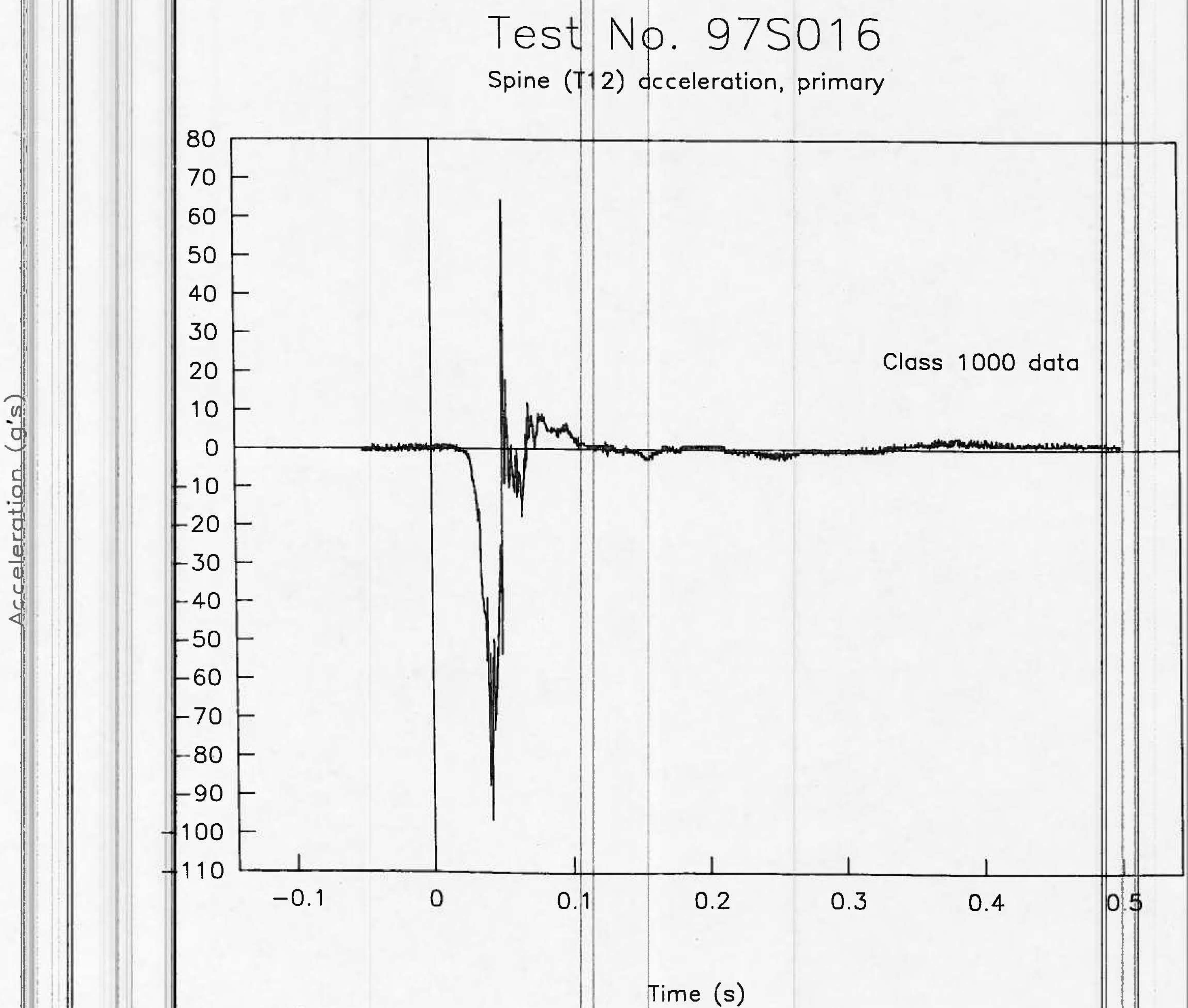


Figure 41. Acceleration vs. time, spine T12 primary, test 97S016.

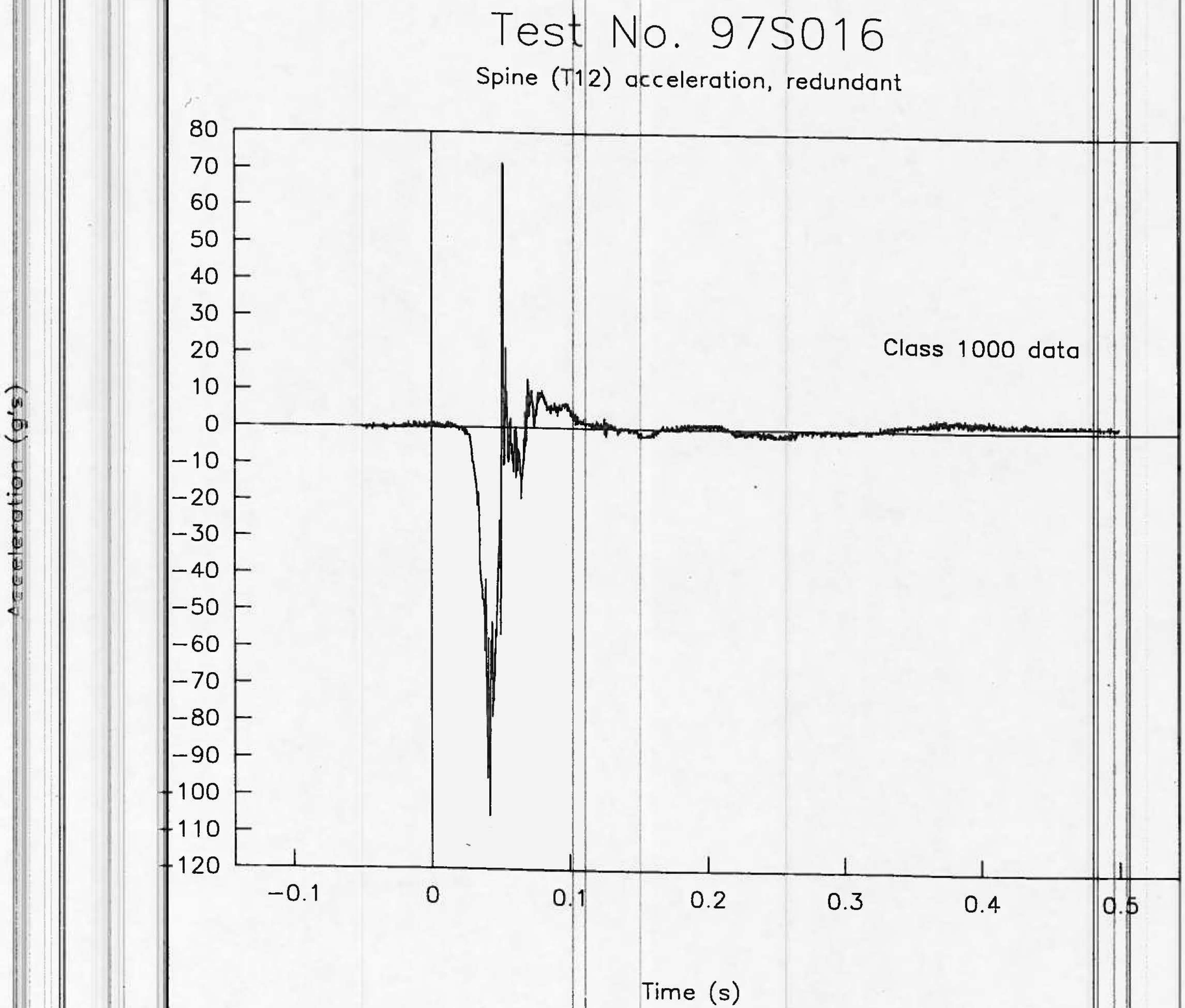


Figure 42. Acceleration vs. time, spine T12 redundant, test 97S016.

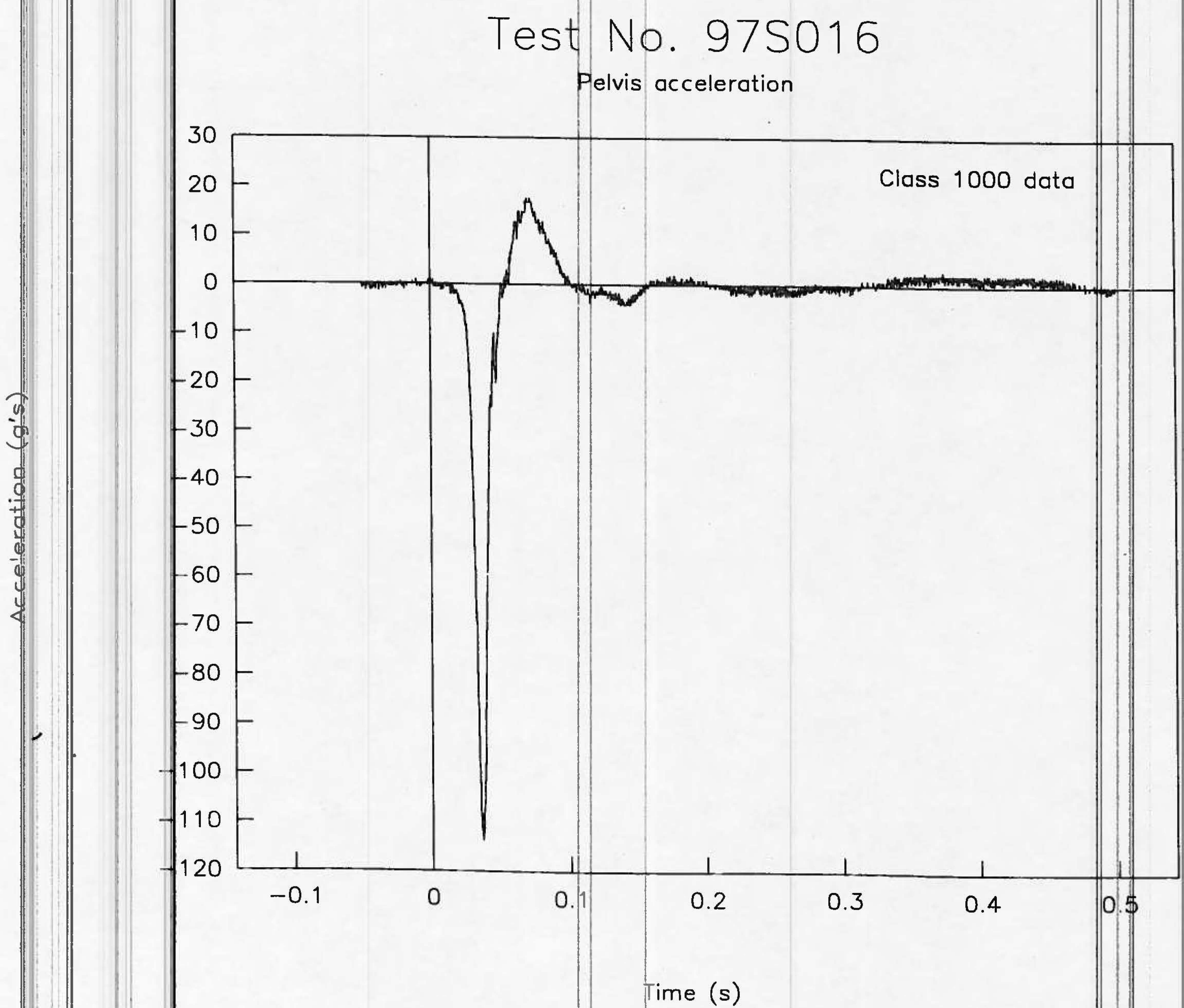


Figure 43. Acceleration vs. time, pelvis, test 97S016.

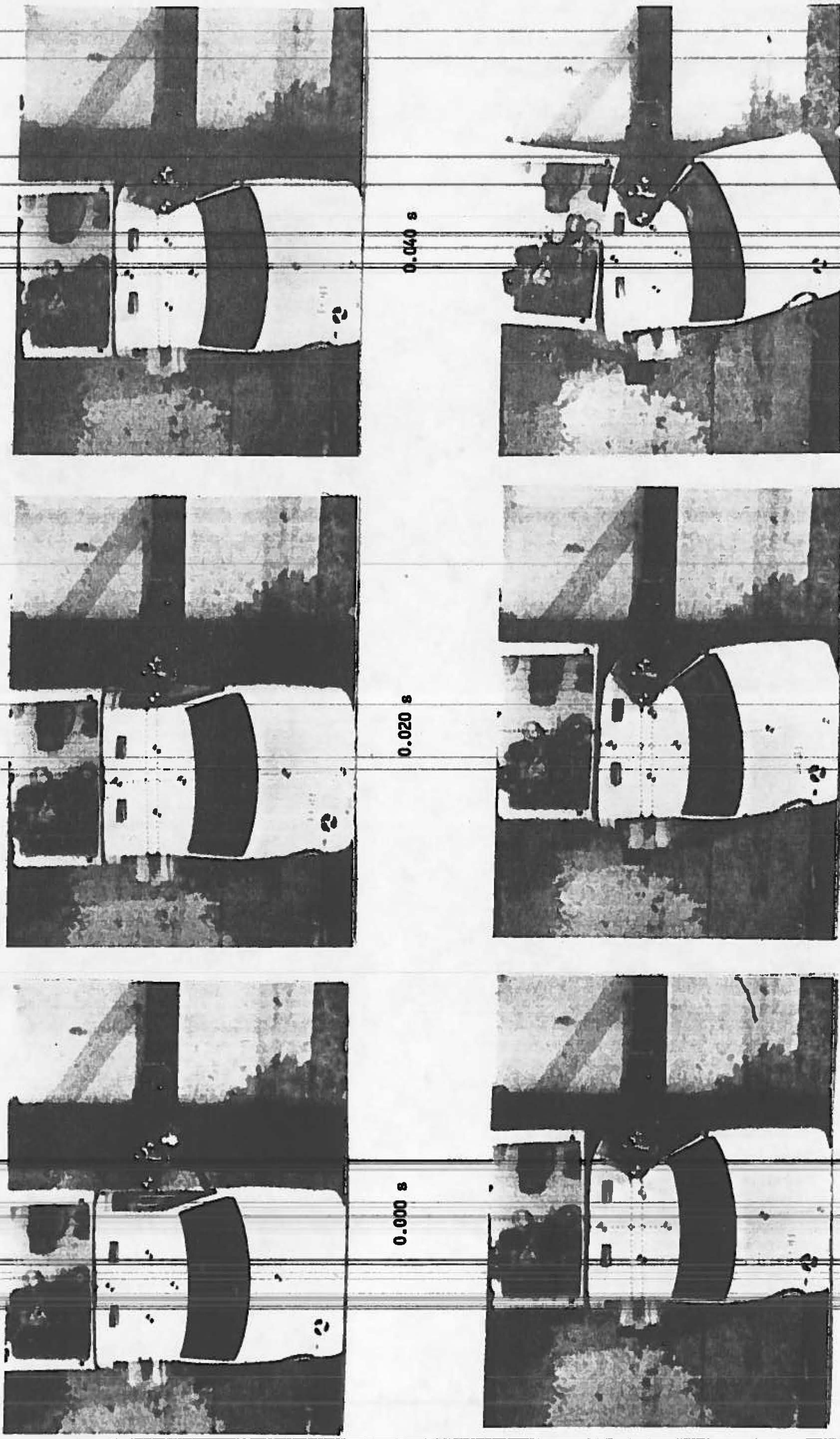


Figure 44. Test photographs during impact, test 97S016.

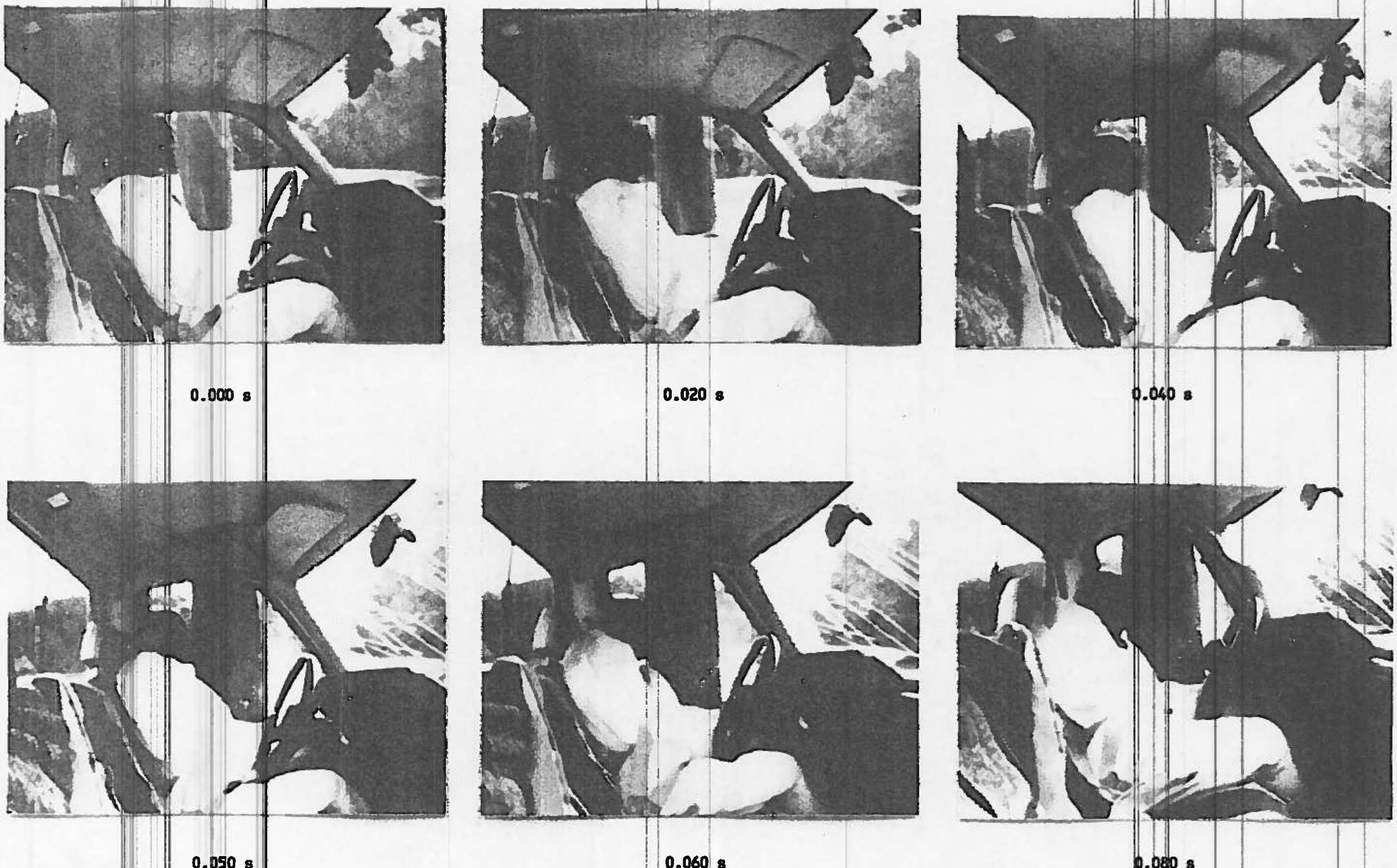


Figure 44. Test photographs during impact, test 97S016 (continued).

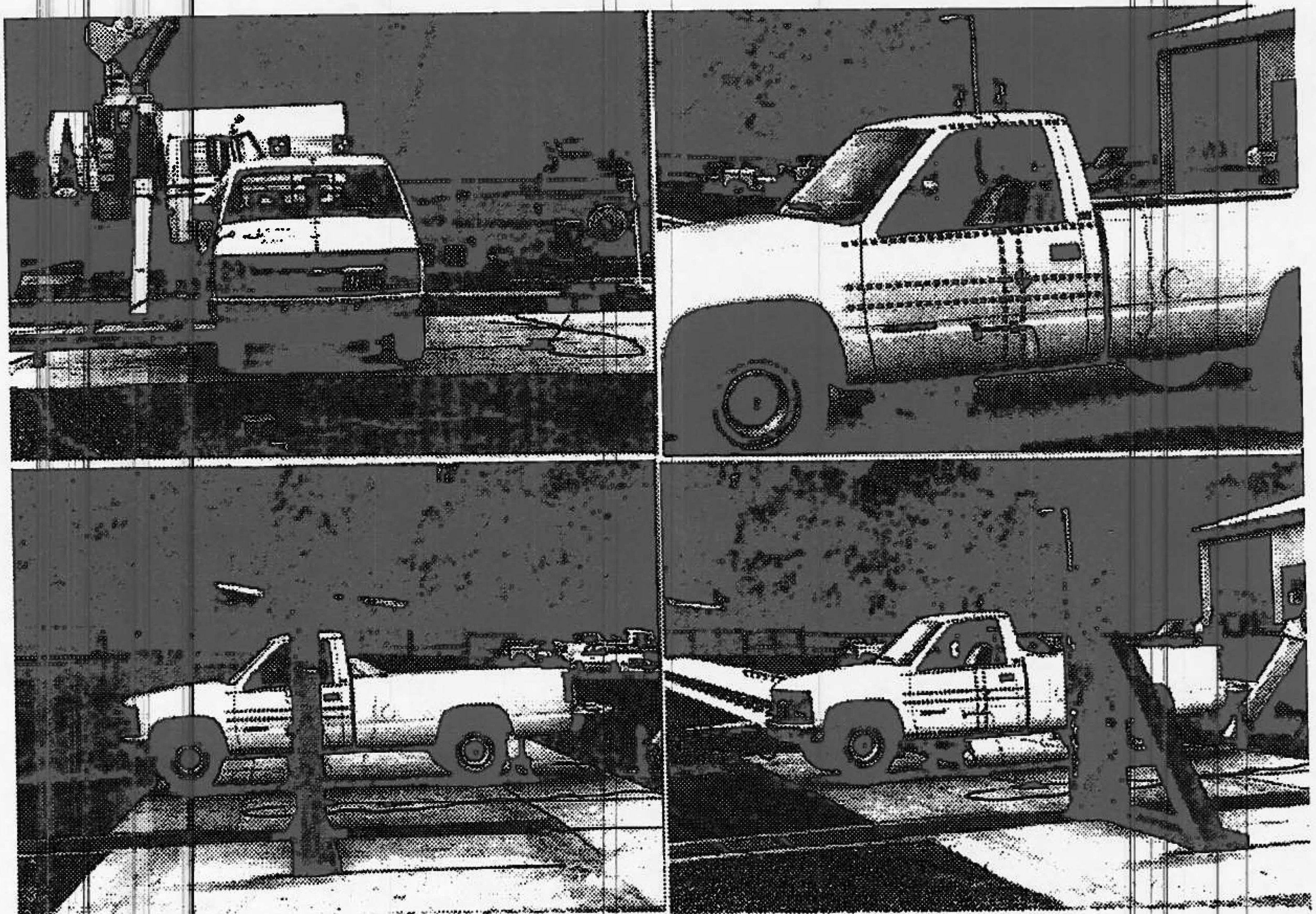


Figure 45. Pretest photographs, test 97S016.

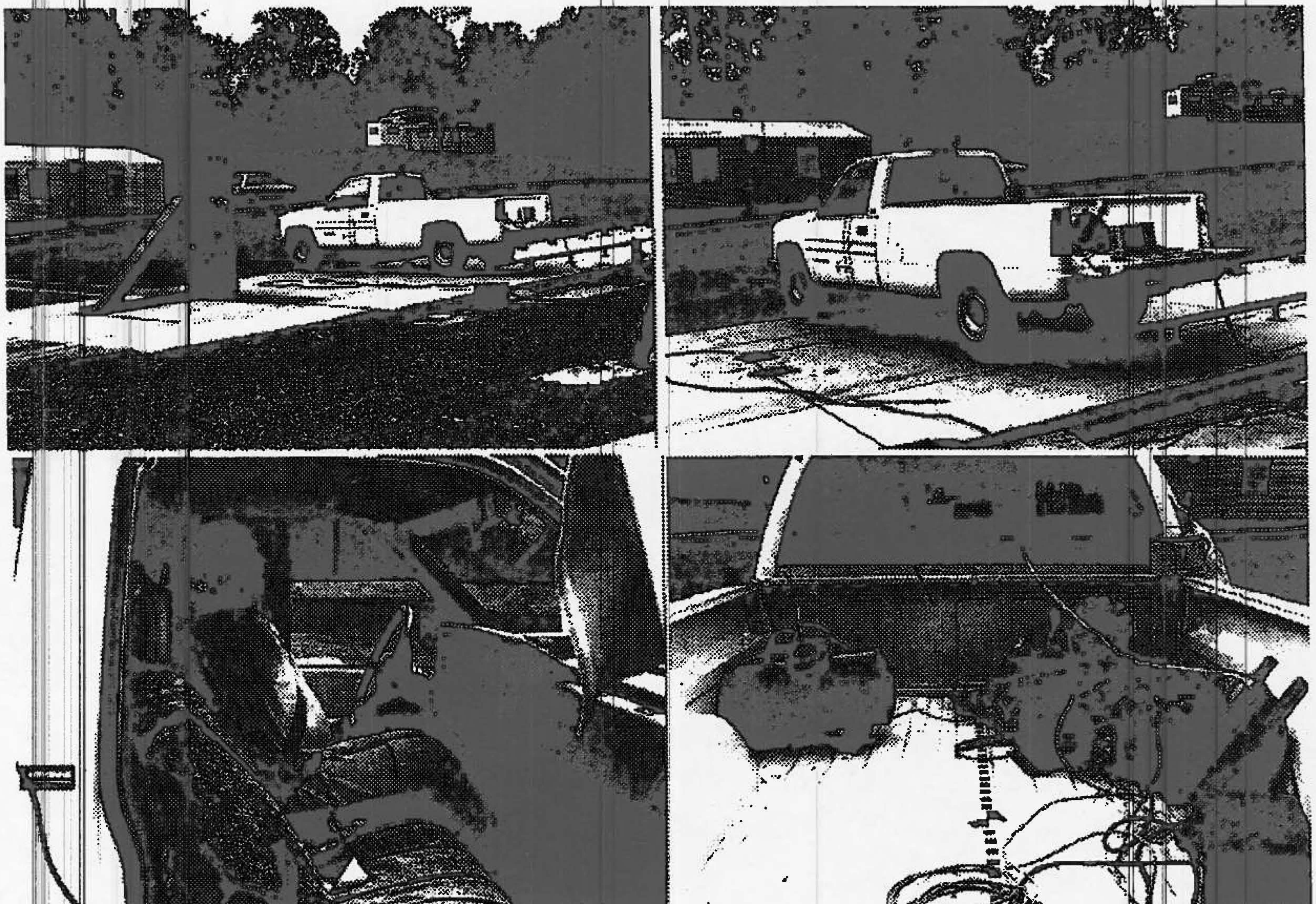


Figure 45. Pretest photographs, test 97S016 (continued).

Figure 46. Post-test photographs, test 97S016.

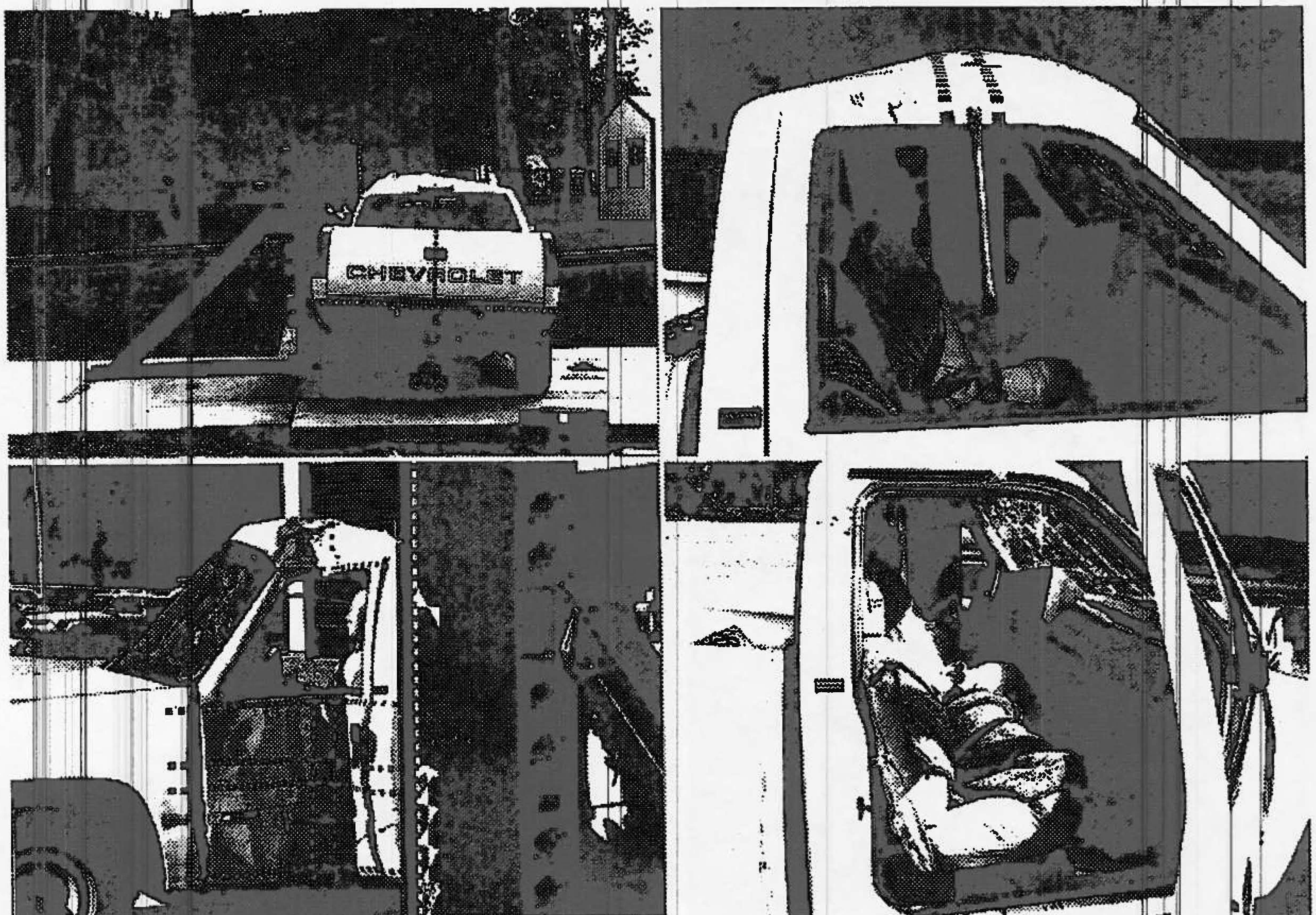


Figure 46. Post-test photographs, test 97S016 (continued).

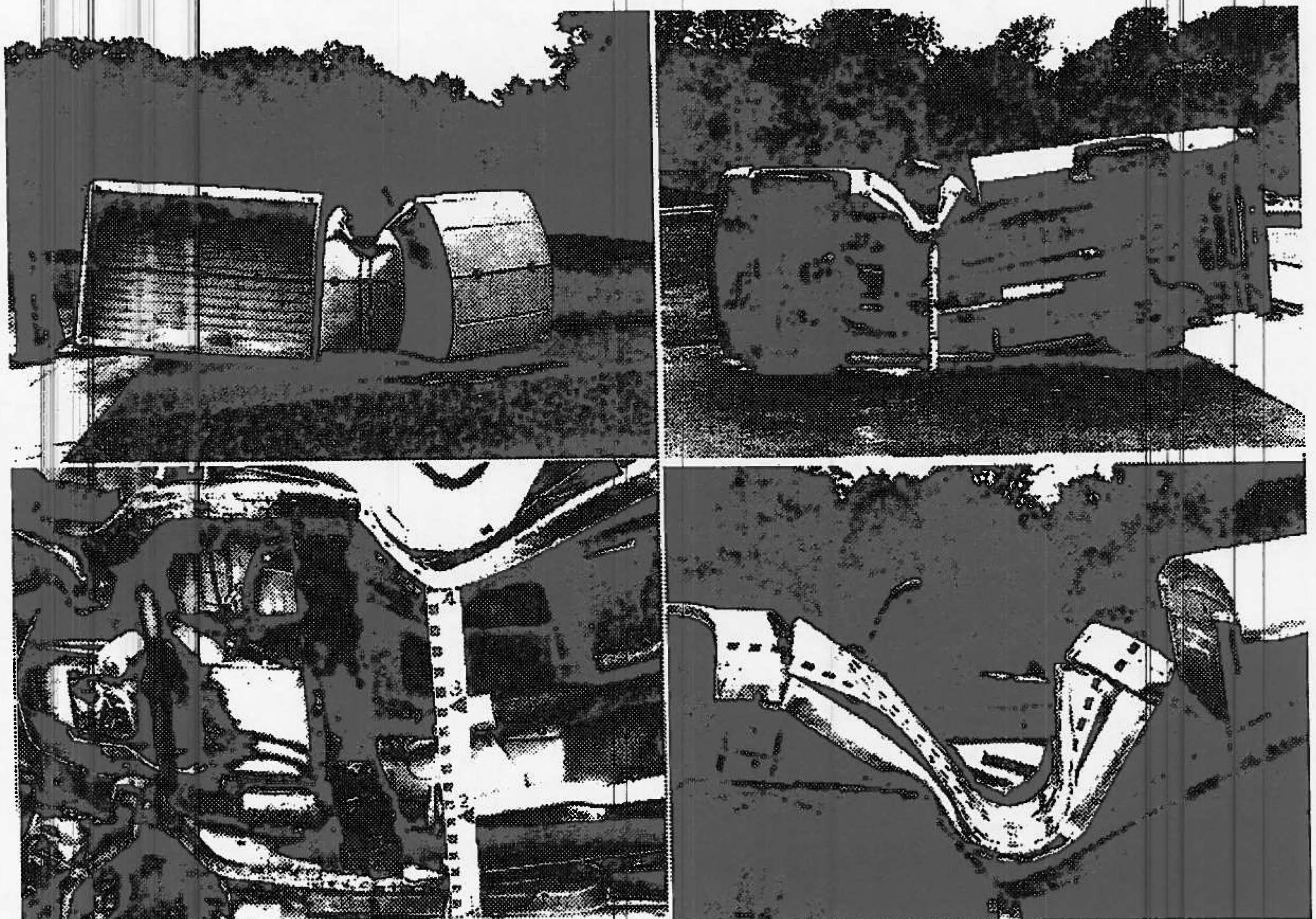


Figure 46. Post-test photographs, test 97S016 (continued).

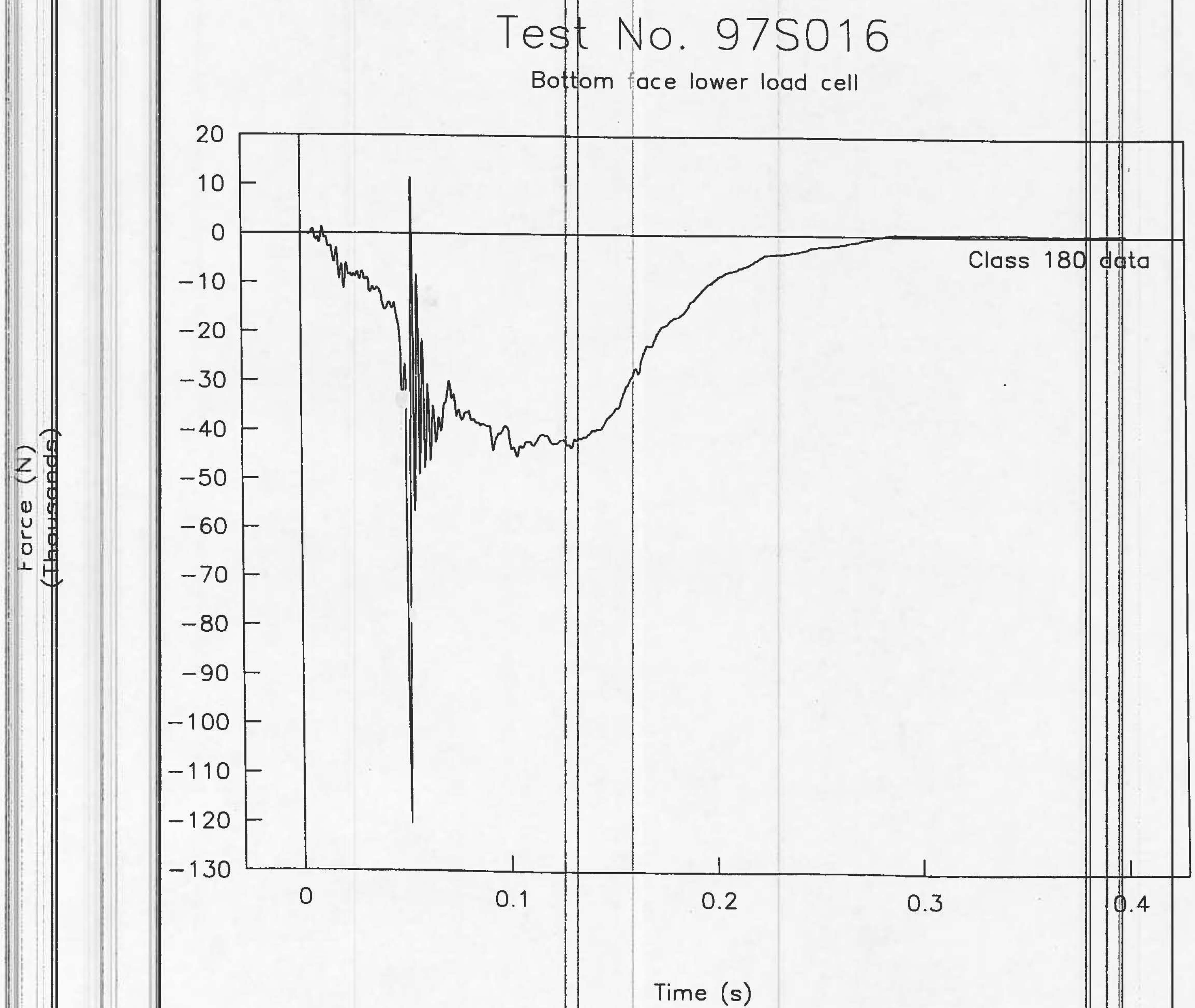


Figure 47. Rigid pole, force vs. time, bottom face lower load cell, test 97S016.

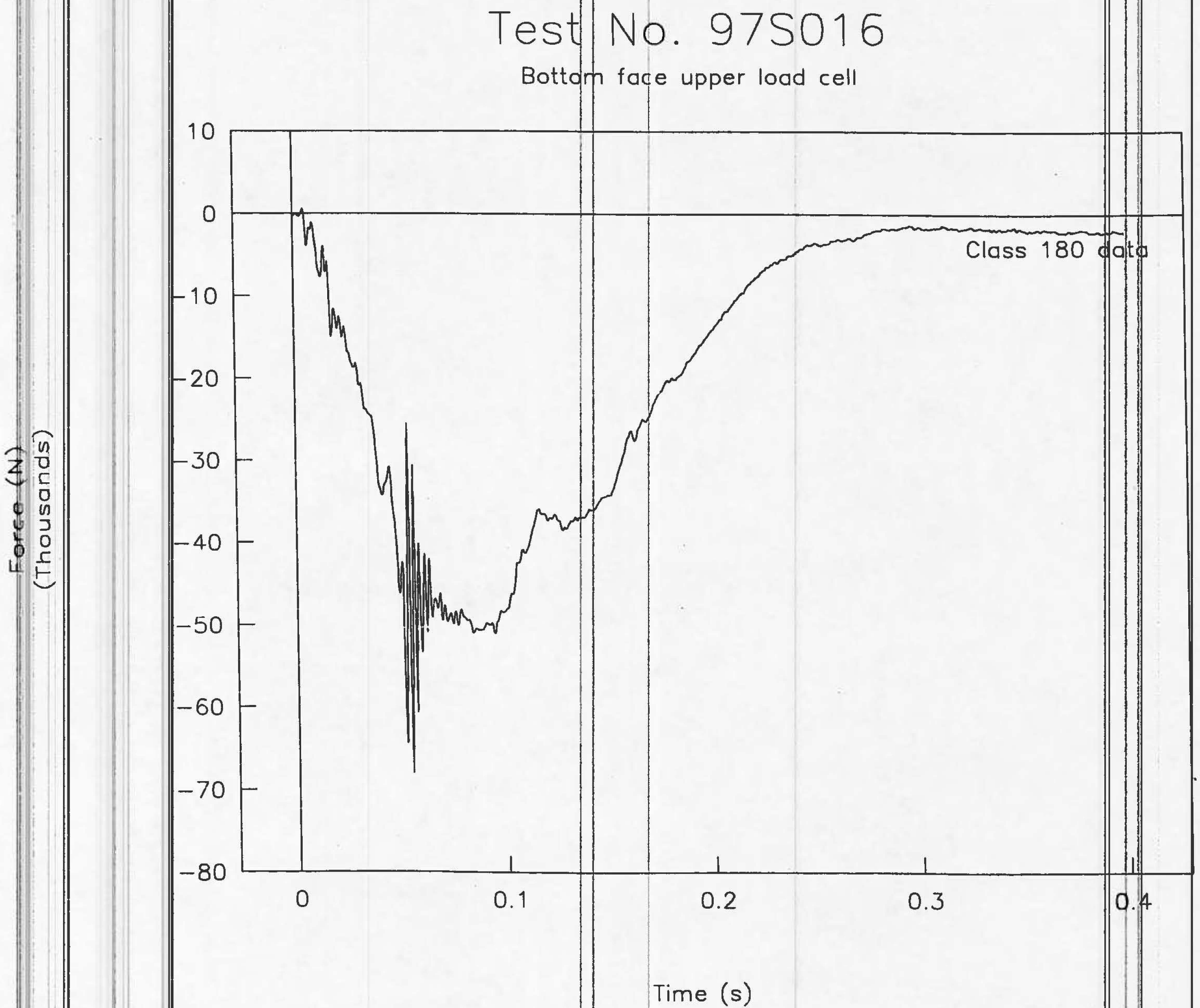


Figure 48. Rigid pole, force vs. time, bottom face upper load cell, test 97S016.

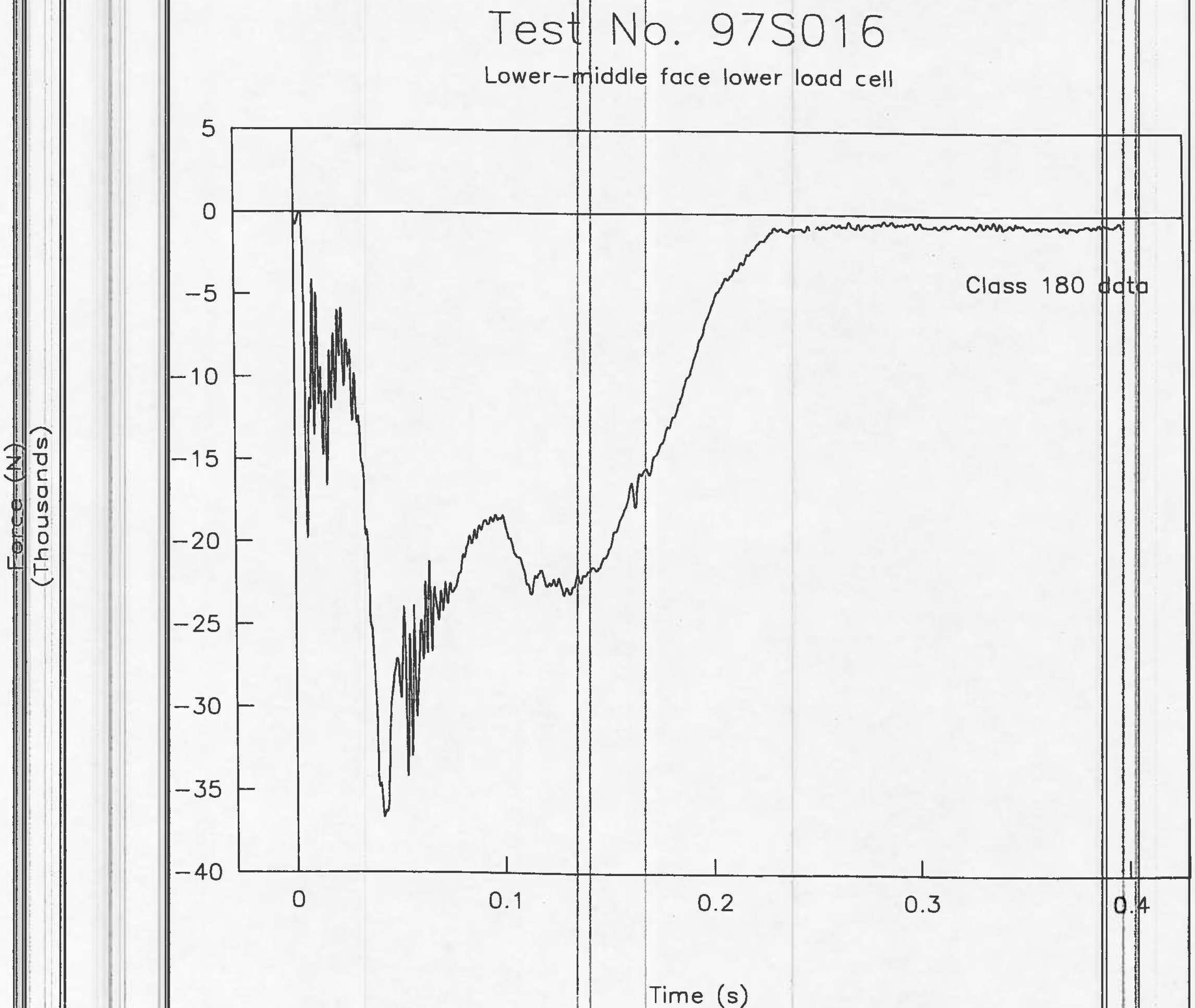


Figure 49. Rigid pole, force vs. time, lower-middle face lower load cell, test 97S016.

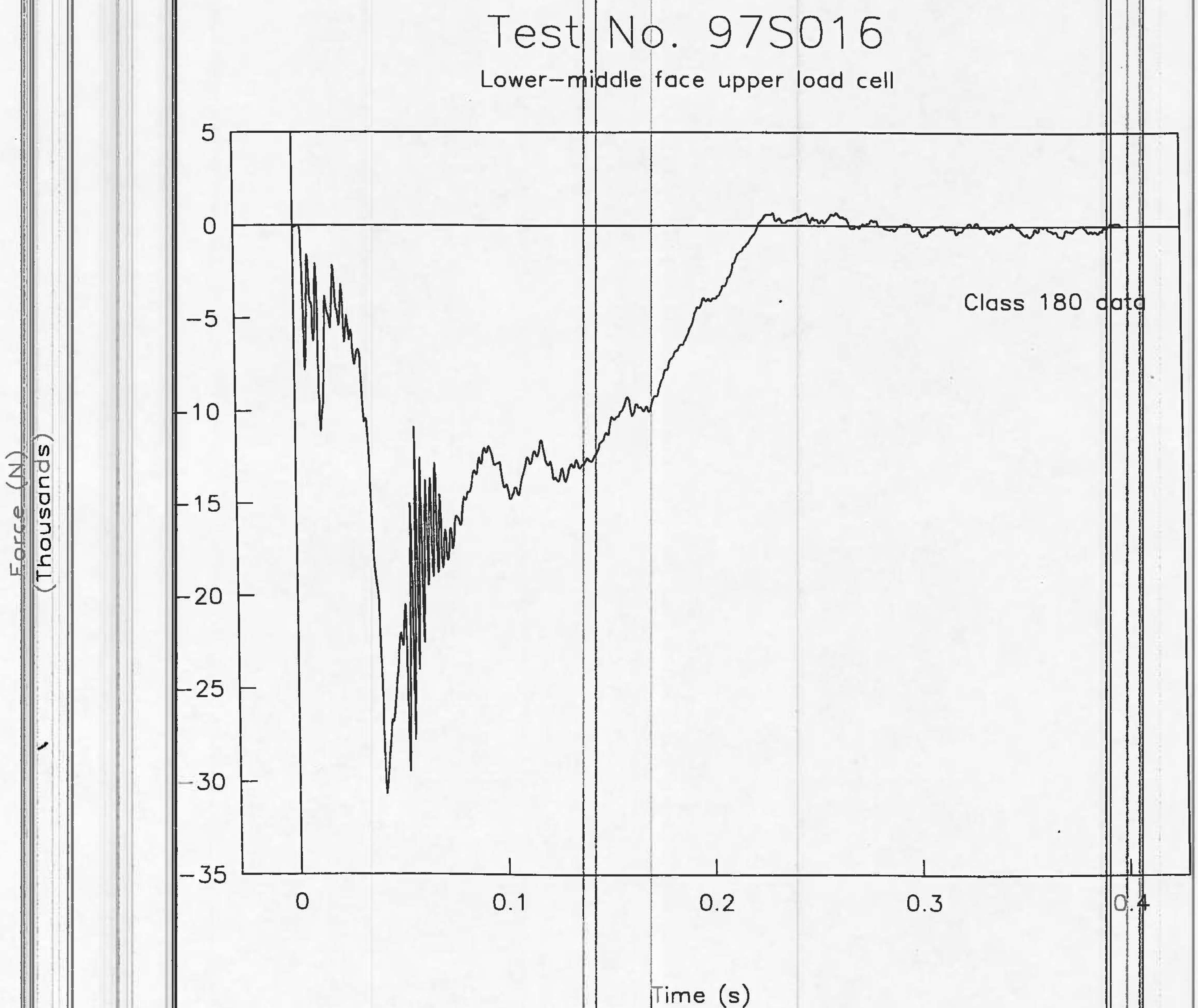


Figure 50. Rigid pole, force vs. time, lower-middle face upper load cell, test 97S016.

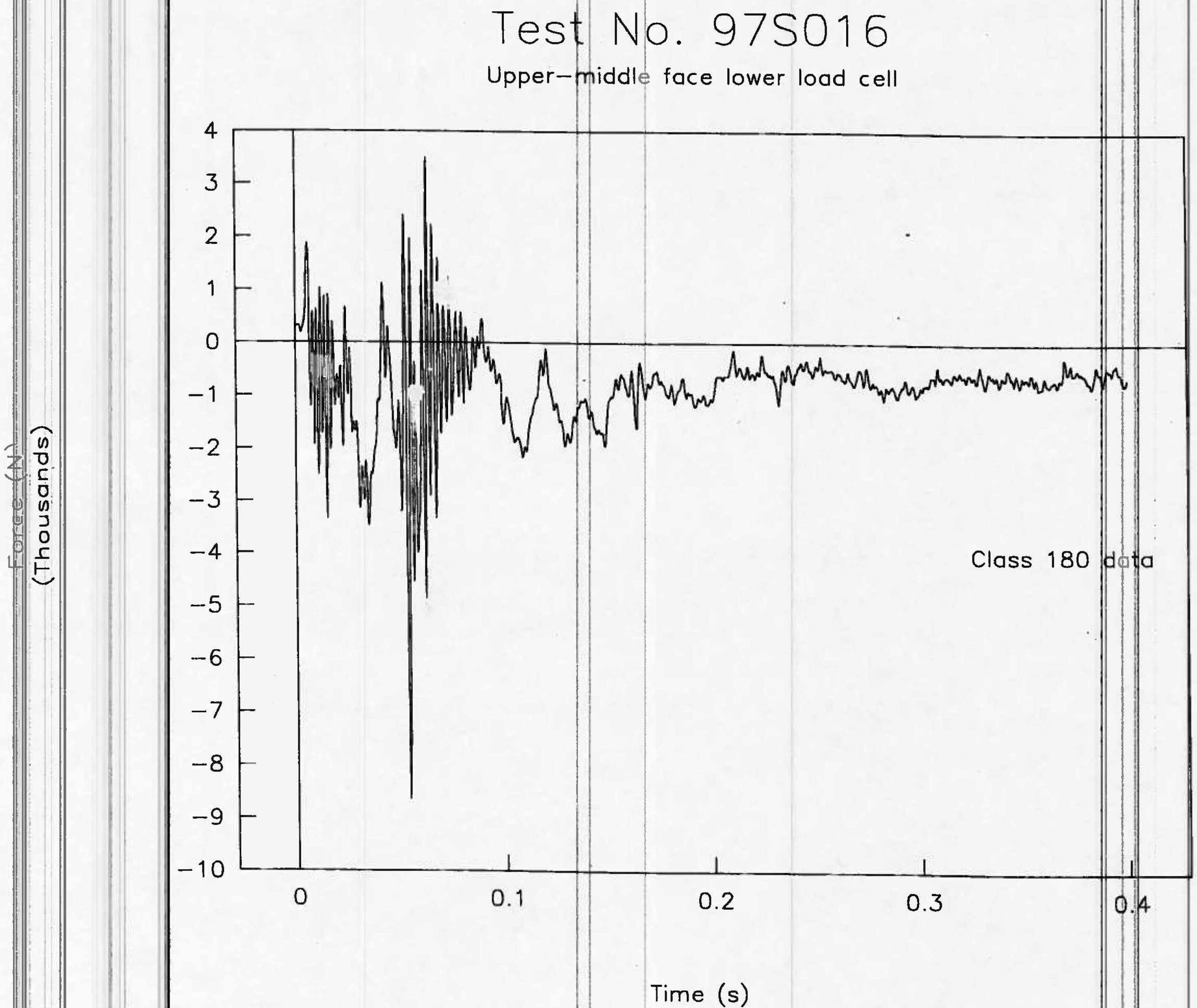


Figure 51. Rigid pole, force vs. time, upper-middle face lower load cell, test 97S016.

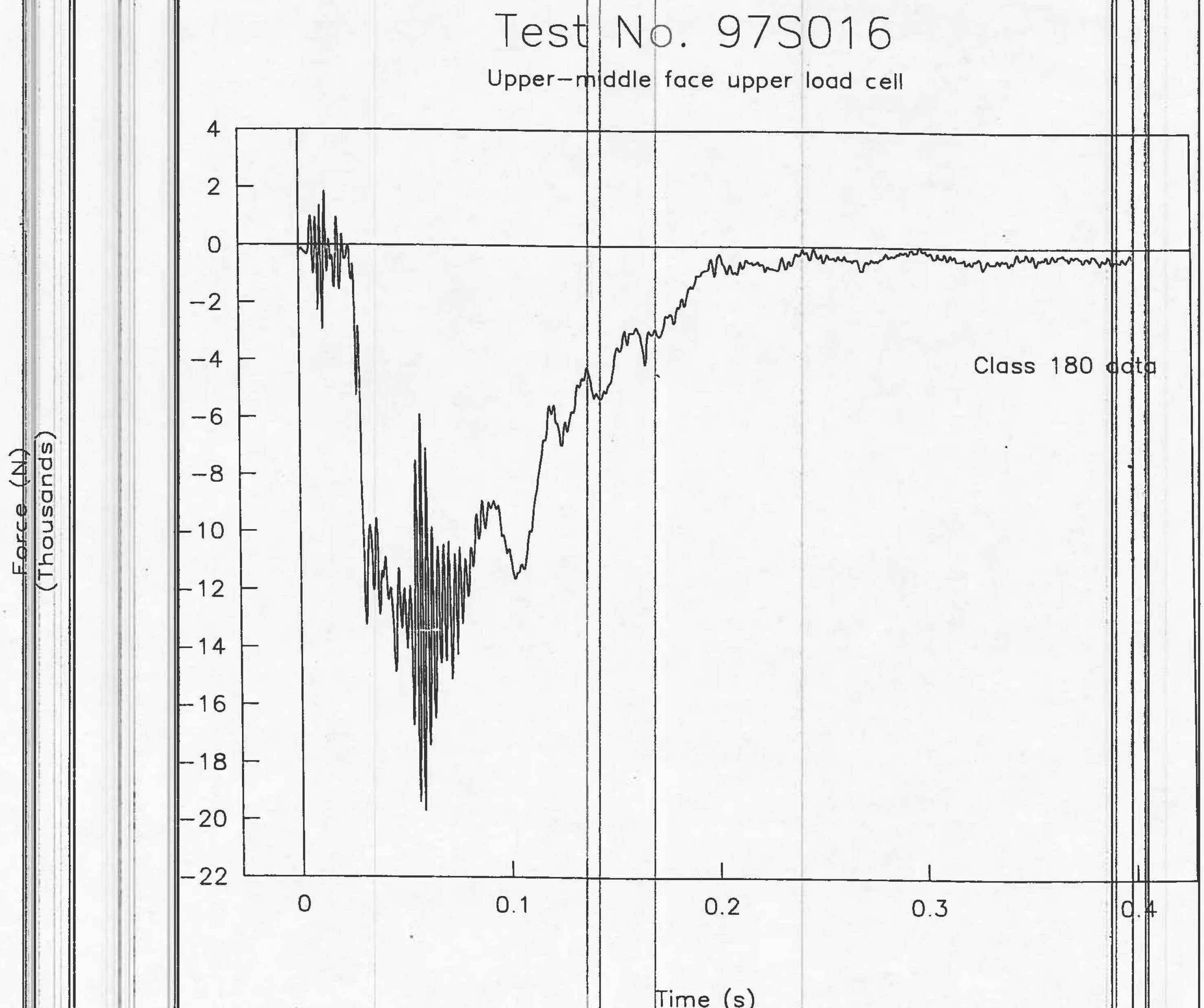


Figure 52. Rigid pole, force vs. time, upper-middle face upper load cell, test 97S016.

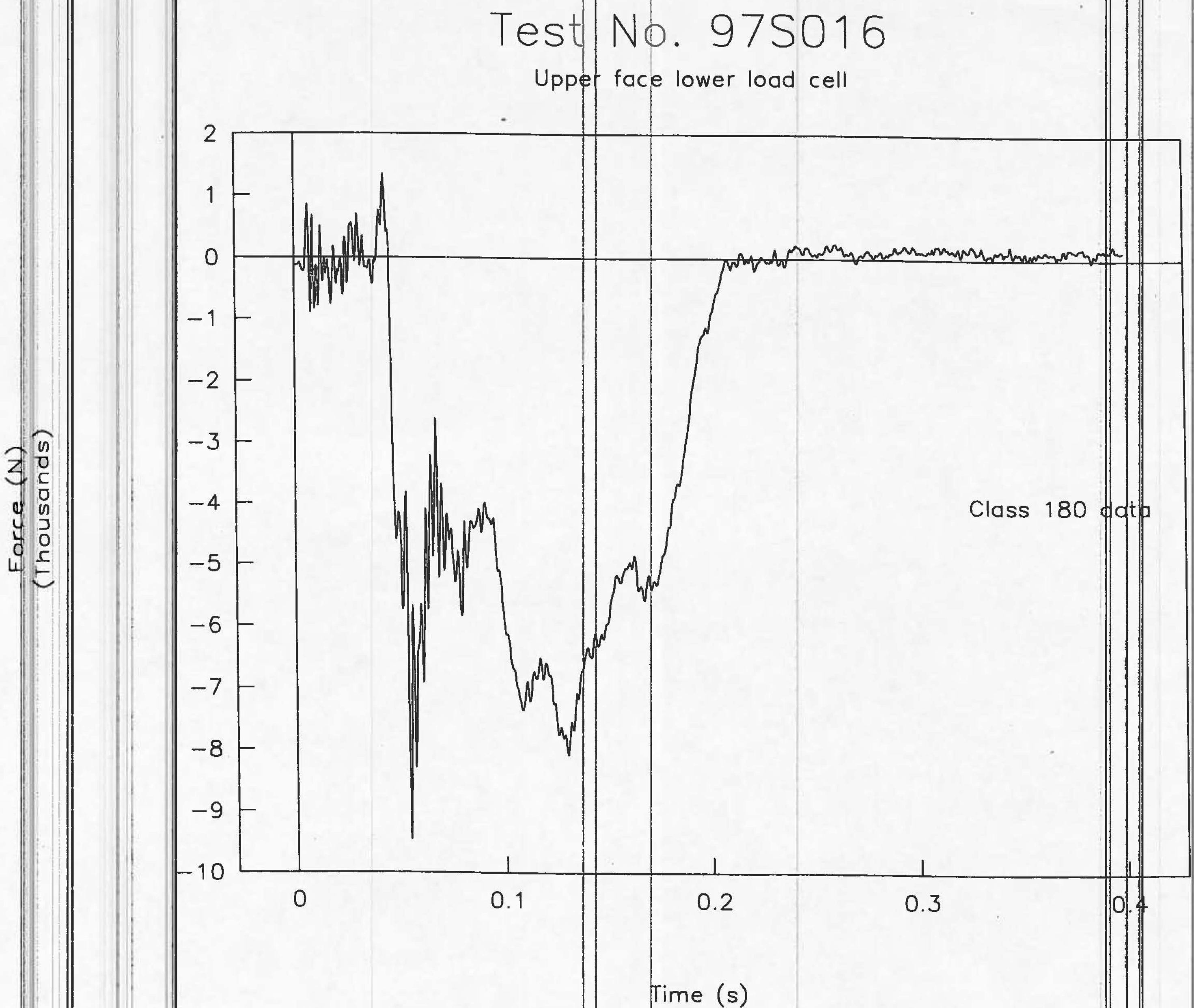


Figure 53. Rigid pole, force vs. time, upper face lower load cell, test 97S016.

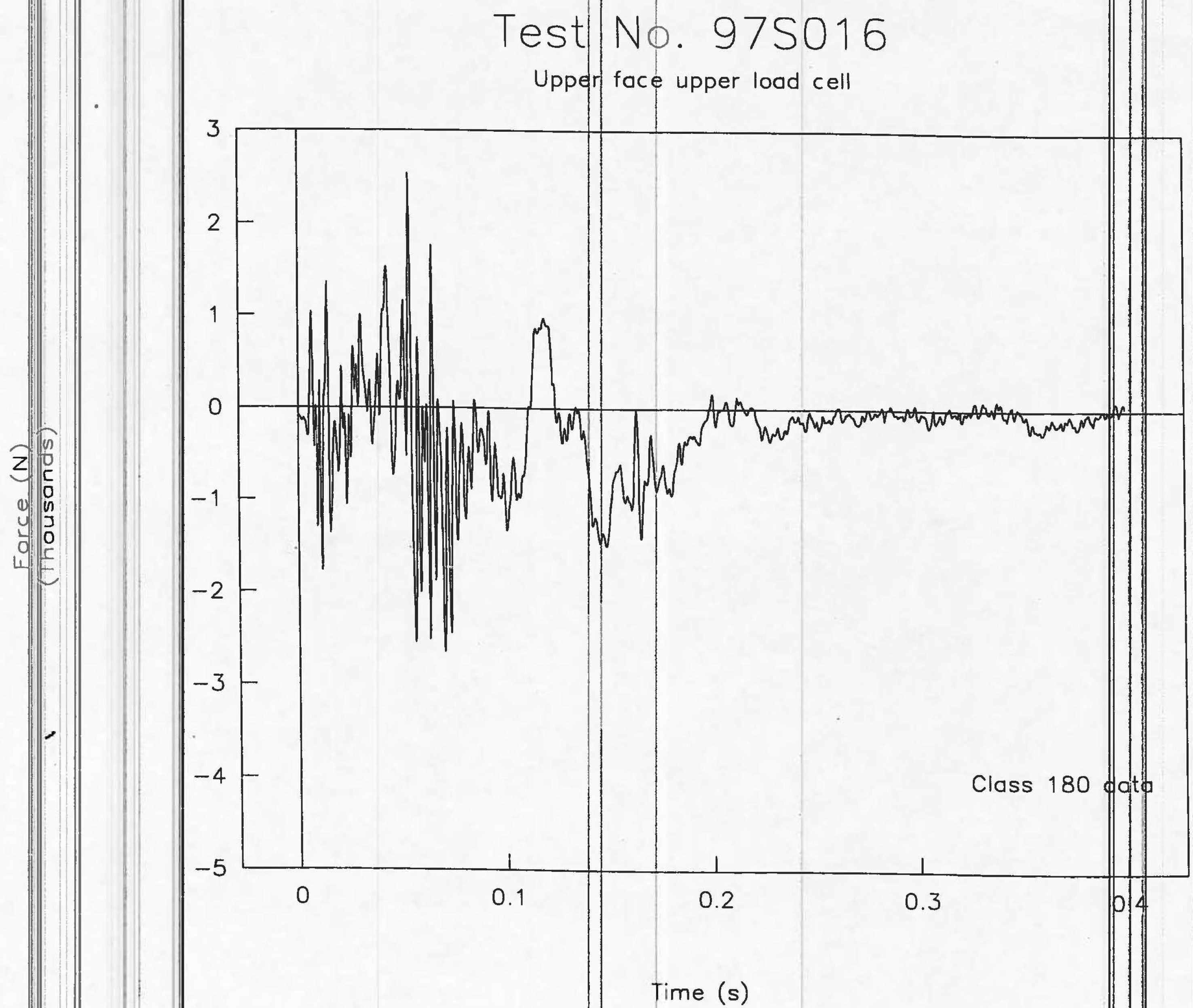


Figure 54. Rigid pole, force vs. time, upper face upper load cell, test 97S016.

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