Honda Accord LX Broadside Collision With a Narrow Fixed-Object: FOIL Test Number 97S004

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FOREWORD

This report documents the test procedures used and the test results from the second of four broadside crash tests between a 1995 Honda Accord LX four-door sedan and the Federal Outdoor Impact Laboratory (FOIL) 300K instrumented rigid pole. The test was conducted at the Federal Highway Administration (FHWA) FOIL located at the Turner-Fairbank Highway Research Center (TFHRC). The National Highway Traffic Safety Administration (NHTSA) enlisted the FHWA, specifically the FOIL, to aid in the development of laboratory test procedures to be used in a revised or amended version of Federal Motor Vehicle Safety Standard (FMVSS) 201. The revision or amendment would include a 90 degree broadside collision between a passenger vehicle and a narrow fixed-object. This new test procedure could be used in the evaluation of dynamic side-impact protection systems (e.g. air bags). One SIDH3 dummy was placed in the driver seat to measure occupant response data. The test procedures and test setup are the same as followed for the first test (FOIL test number 97S003). The second test, test 97S004, was conducted to determine the repeatability of the test procedures and test results from test 97S003.

This report (FHWA-RD-98-009) contains test data, photographs taken with high-speed film, and a summary of the test results. The test results for test 97S003 are contained in the report *Honda Accord LX Broadside Collision with a Narrow Fixed Object: FOIL Test Number 97S003*.

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.

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Operations Research and Development

NOTICE

Technical Report Documentation Page

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16. Abstract

This report contains the test procedures, test setup and test results from the second of four broadside crash tests between a 1995 Honda Accord LX four-door sedan and the Federal Outdoor Impact Laboratory (FOIL) 300K instrumented rigid pole. The test was conducted at the Federal Highway Administration (FHWA) FOIL located at the Turner-Fairbank Highway Research Center (TFHRC) in McLean, Virginia. The National Highway Traffic Safety Administration (NHTSA) enlisted the FHWA to aid in the development of laboratory test procedures to be used in a revised or amended version of Federal Motor Vehicle Safety Standard (FMVSS) 201 (Occupant Protection in Interior Impact). The test procedures and test setup are the same as followed for the first test (FOIL test number 97S003). The data from these two tests produced similar low HIC values, suggesting further examination of the impact location, crab angle, or seating position is needed to determine the best compliance test parameters for dynamic side-impact protection systems.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		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/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

NOTE: Volumes greater than 1000 l shall be shown in m^3.

APPROXIMATE CONVERSIONS FROM SI UNITS

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

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

(Revised September 1993)

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INTRODUCTION

The National Highway Traffic Safety Administration (NHTSA) enlisted the Federal Highway Administration (FHWA), specifically the Federal Outdoor Impact Laboratory (FOIL), to aid in the development of laboratory test procedures to be used in a revised or amended version of Federal Motor Vehicle Safety Standard (FMVSS) 201 (Occupant Protection in Interior Impact).[1] The revision or amendment would include a 90 degree broadside collision between a passenger vehicle and a narrow fixed-object. This new test procedure could be used in the evaluation of dynamic side impact protection systems (e.g. air bags).

Steps were taken to ensure accurate, repeatable test procedures so that test facilities abroad would achieve similar results given comparable test conditions. The series of tests conducted at the FOIL were broadside collisions between 1995 Honda Accord LX four-door sedans and the FOIL's 300K rigid pole. The vehicles were placed on the FOIL's dual rail side-impact system with the vehicle longitudinal centerline perpendicular to the rigid pole centerline. The two rails used for side-impact at the FOIL were extended to approximately 0.3 m from the rigid pole. This provided accuracy of the impact location as well as repeatability of the impact speed. One SIDH3 dummy was placed in the driver seat to measure occupant response data. The SIDH3 is a combination of the current side-impact dummy (SID) used in side-impact testing and the HYBRID III (H3)dummy used for frontal-impact testing. This report documents procedures followed and test results from one of four crash tests conducted in support of the FMVSS 201 amendment.

SCOPE

This report documents the results from the second of four broadside crash tests between a 1995 Honda Accord LX four-door sedan and the FOIL 300K instrumented rigid pole. The test was conducted at the FHWA's FOIL located at the Turner-Fairbank Highway Research Center (TFHRC) in McLean, Virginia. The test procedures and test setup are the same as followed for the first test of this test series (FOIL test number 97S003). The procedures, test setup, and test results for test 97S003 are contained in the report *Honda Accord LX Broadside Collision with a Narrow Fixed Object: FOIL Test Number 97S003.*[2] The second test, test 97S004, was conducted to determine the repeatability of the test procedures and test results from test 97S003. The FOIL utilizes a drop tower system for propulsion and two steel rails bolted to a concrete runway for vehicle guidance during broadside testing. The rails were extended 0.3 m from the rigid pole to ensure impact location, speed, and SIDH3 stability. The concept of the vehicle remaining on the two rails raised some concern. The concern was that the rails would impede the natural collapse or crush of the vehicle and thus interfere with the accuracy of SIDH3 data. However, the intent of these tests was to develop a procedure for head protection system evaluation and it was believed that the event of interest (dummy contact with the pole) would be complete before significant crush of the vehicle. The procedures followed for vehicle preparation, instrumentation, dummy preparation, and dummy seating procedures are outlined in FMVSS 214.[3] The NHTSA supplied a calibrated SIDH3 dummy for the crash test. Head injury criteria (HIC) and thoracic trauma index (TTI) calculations were performed on the data from the SIDH3's head and thorax accelerometers. The HIC and TTI values were used to determine the severity of the test and to compare previous and subsequent broadside tests to evaluate the repeatability of the test procedures.

TEST MATRIX

One broadside crash test involving a 1995 Honda Accord LX four-door sedan and FOIL's instrumented 300K rigid pole was conducted. The target vehicle test weight was intended to be between the vehicle curb weight (empty, as received from the dealership) and the fully loaded weight. The target test speed for this test was 29 km/h. The rigid pole was installed with its centerline aligned with the center-of-gravity (cg) of the SIDH3's head. Table 1 outlines the pertinent test parameters of the broadside crash test.

Table 1. Test matrix.

FOIL number	97S004
Date	June 17, 1997
Vehicle	1995 Honda Accord
Weight (total)	1,476 kg
SIDH3 Modified neck	One positioned in driver seat HYBRID III neck
Fuel tank	91% capacity with stoddard solvent
Crab angle	90°
Speed (nominal)	29 km/h
Impact location	Pole aligned with SIDH3 head
Test article	FOIL 300K instrumented rigid pole

TEST VEHICLE

The test vehicle was a 1995 Honda Accord four-door sedan with front wheel drive, an automatic transmission, and a four cylinder 2.2 L motor. Table 2 describes the vehicle and optional equipment.

Table 2. Vehicle description and statistics.

Vehicle make	Honda
Vehicle model	1995 Accord LX
Vehicle identification number (VIN)	1HGCD5633SA102634
Engine	2.2 L, 4 cylinder
Transmission	Automatic
Drive chain	Front wheel drive
Wheel base	2,718 mm
Wheel track	1,511 mm
Fuel capacity	64 L
Tested capacity of stoddard solvent	59 L (91%)
Seat type	Bucket, lever
Position of front seats for test	Center
Seat back angle	25.3°
Steering wheel adjustment for test	Center

OPTIONS

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

WEIGHTS (kg)	DELIVERED	FULLY LOADED	TEST MODE
Left front	410	440	446
Right front	415	418	442
Left rear	244	282	290
Right rear	250	305	298
TOTAL	**1,319**	**1,445**	**1,476**

Table 2. Vehicle description and statistics (continued).			
ATTITUDE (mm)	**DELIVERED**	**FULLY LOADED**	**TEST MODE**
Left front	689	670	679
Right front	687	686	670
Left rear	686	660	676
Right rear	686	667	686
ATTITUDE (degrees)	**DELIVERED**	**FULLY LOADED**	**TEST MODE**
Driver	.8 down/front	.2 down/front	.1 down/front
Passenger	.2 down/front	0	0
Front	.3 down/left	0	.6 up/left
Rear	0	.1 down/left	.4 down/right
Cg (mm) measurements	**DELIVERED**	**FULLY LOADED**	**TEST MODE**
Behind front axle	1,020	1,105	1,085
Lateral	750	755	753

The test vehicle was prepared for testing following procedures outlined in FMVSS 214. A NHTSA supplied OSCAR was used to determine the position of the SIDH3 for testing. The OSCAR defines a three dimensional location of the H-point (hip point) of a dummy in relation to the driver door striker. This measurement was used the morning of the test to place the dummy in the correct position.

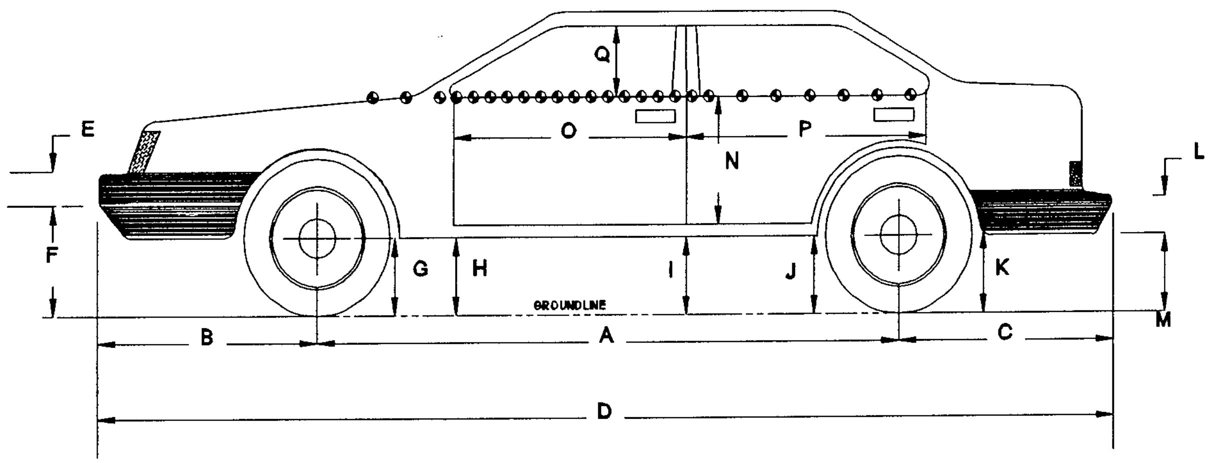
The vehicle weight and four sill attitudes were measured in each of the three modes or configurations described in FMVSS 214. The first was the "as delivered" mode. This configuration consisted of the test vehicle as delivered from a dealership with its fuel tank filled to 92 percent capacity with petroleum naphtha, a stoddard solvent. The second mode, cargo mode, consisted of the vehicle with one dummy placed in the driver seat and 45 kg of simulated cargo placed in the trunk along the vehicle centerline. The final mode was the "as tested" mode. This configuration consisted of the vehicle fully instrumented for testing. The four sill attitude measurements, vehicle weight distribution, and other measurements are presented in table 2. The vehicle attitudes up on the guidance rails were adjusted to within 0.5 degrees of the "test mode" measurements.

Included in the test mode 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 cg. The rear outrigger carriage was bolted to the rear bumper. The side-impact carriages were constructed from aluminum and remained fastened to the vehicle throughout the test.

The fuel tank useable capacity (from Honda of America) was 64.5 L. The fuel tank was filled with 58.7 L (91 percent of capacity) of petroleum naphtha (stoddard solvent) which has the same density as gasoline but is less volatile. The tank was filled to reflect a more realistic weight of a passenger vehicle on the road. The petroleum naphtha also provided a means to observe any fuel system component leakage after the test. The original lead-acid battery in a charged state remained in the engine compartment. The battery was disconnected to prevent frontal air bag deployment. The vehicle test weight, including the dummy, instrumentation, cameras, ballast, and stoddard solvent was 1,476 kg. The SIDH3 weight was 80 kg.

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 pre- 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 pre- and post-test profile measurements are shown in figure 7 later in this report.

A list and sketches of the vehicle's physical parameters are shown in table 2 and figure 1, respectively. Figure 1 includes post-test damage measurements.



	PRE-TEST	POST-TEST	△CHANGE
A	2,718	2,477	-241
B	914	902	-12
C	1,022	997	-25
D	4,655	4375	-280
E	114	114	0
F*	422 / 400	400	0
G*	279 / 273	260	-13
H*	286 / 273	260	-13
I*	286 / 281	286	5
J1*	187 / 191	324	133
J2*	286 / 286	216	-70
K*	356 / 357	362	5
L	267	254	-13
M*	387 / 368	368	0
N	635	648	13
O	1,083	946	-137
P	989	895	-94
Q	441	425	-16

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

Figure 1. Vehicle physical parameters in millimeters.

INSTRUMENTED DUMMY

One SIDH3, serial number 27, was placed in the driver seat of the Honda Accord. 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 the 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 SIDH3. The dummy was shipped with the necessary hardware for assembly. Tools at the FOIL were used to assemble the SIDH3. Clothing (not including shoes) consisting of white thermal underwear was purchased and put on the dummy. 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 back rest leaning back 25.3 degrees 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 the test. Pertinent SIDH3-to-interior longitudinal and lateral clearance measurements are shown in figure 3 and figure 4. Several different color chalks were put on the side surfaces of the dummy to determine the contact points between the dummy and the vehicle's interior, as shown in table 3 below.

Table 3. SIDH3 chalk colors.

DUMMY PART	COLOR
Face	Orange
Top of head	Blue
Left side of head	Yellow
Back of head	Red
Left hip	Red
Left shoulder	Blue

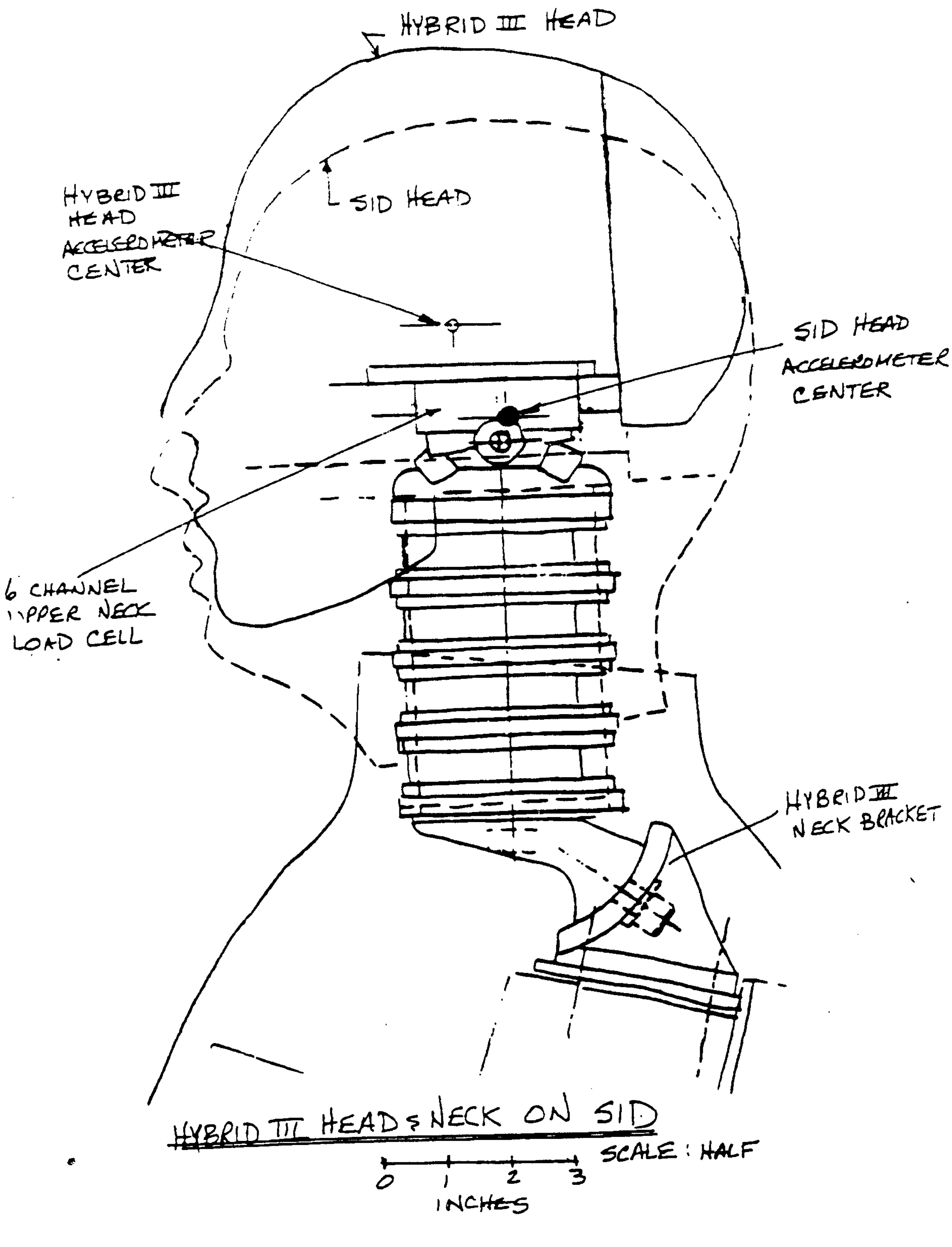
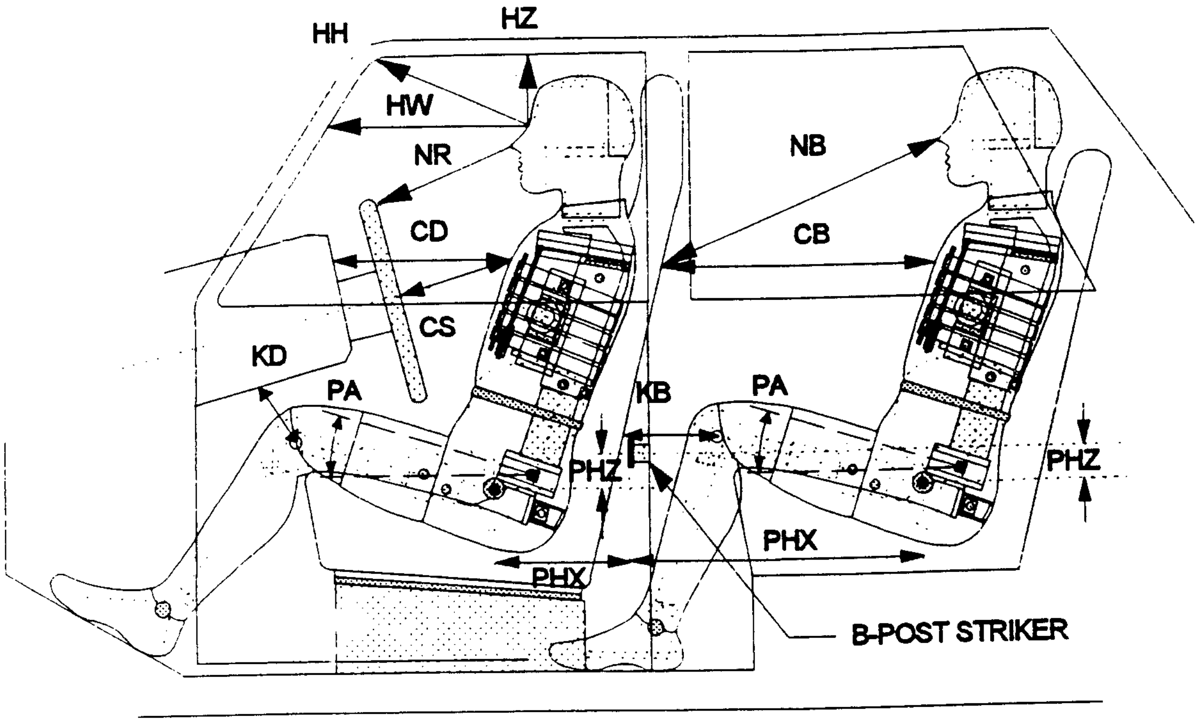
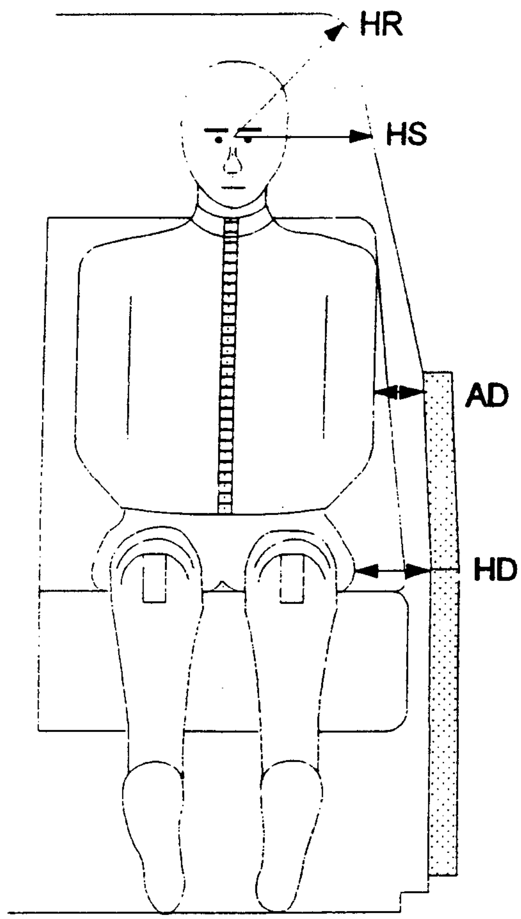


Figure 2. HYBRID III neck and head assembly on SIDH3 #27.



MEASUREMENT (mm)	DRIVER SIDH3 ID# 27
HH	442
HW	632
HZ	188
NR	525
CD	583
CS	365
KDL(KDA°)	127(24°)
KDR(KDA°)	124(24.7°)
PA°	23°
PHX	192
PHZ	160

Figure 3. SIDH3 longitudinal clearance and position measurements.



MEASUREMENT (mm)	DRIVER SIDH3 ID# 27
HR	220
HS	325
AD	102
HD	145

Figure 4. SIDH3 lateral clearance and position measurements.

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, aligned with the cg of the dummy'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).

INSTRUMENTATION

Electronic data from the crash test was recorded via two data acquisition systems, the FOIL umbilical cable system and the FOIL onboard data acquisition system (ODAS). A total of 39 channels of electronic data were recorded. The umbilical cable system recorded 13 data channels and the remaining 26 data channels were recorded by the ODAS system. In addition to electronic data, high-speed cameras were used to record the test on film, which was analyzed to acquire pertinent test data. The following is a summary of the electronic data collected:

Vehicle instrumentation.

• Cg triaxial accelerometer (A_x,A_y,A_z)	3 channels
• Cg redundant accelerometer for A_y	1 channel
• Biaxial accelerometer, Engine (A,A_y)	2 channels
• Biaxial accelerometer, Trunk (A_x,A_y)	2 channels
• An accelerometer on driver seat (A_y)	1 channel
• Cg triaxial rate sensor (pitch,roll,yaw)	3 channels

SIDH3 instrumentation.

• Triaxial accelerometer dummy head (A_x,A_y,A_z)	3 channels
• Four dummy rib accelerometers (A_y)	4 channels
• Two dummy T12 spine accelerometers (A_y)	2 channels
• One dummy pelvis accelerometer (A_y)	1 channel
• Six dummy neck sensors (F_x,F_y,F_z,M_x,M_y,M_z)	6 channels

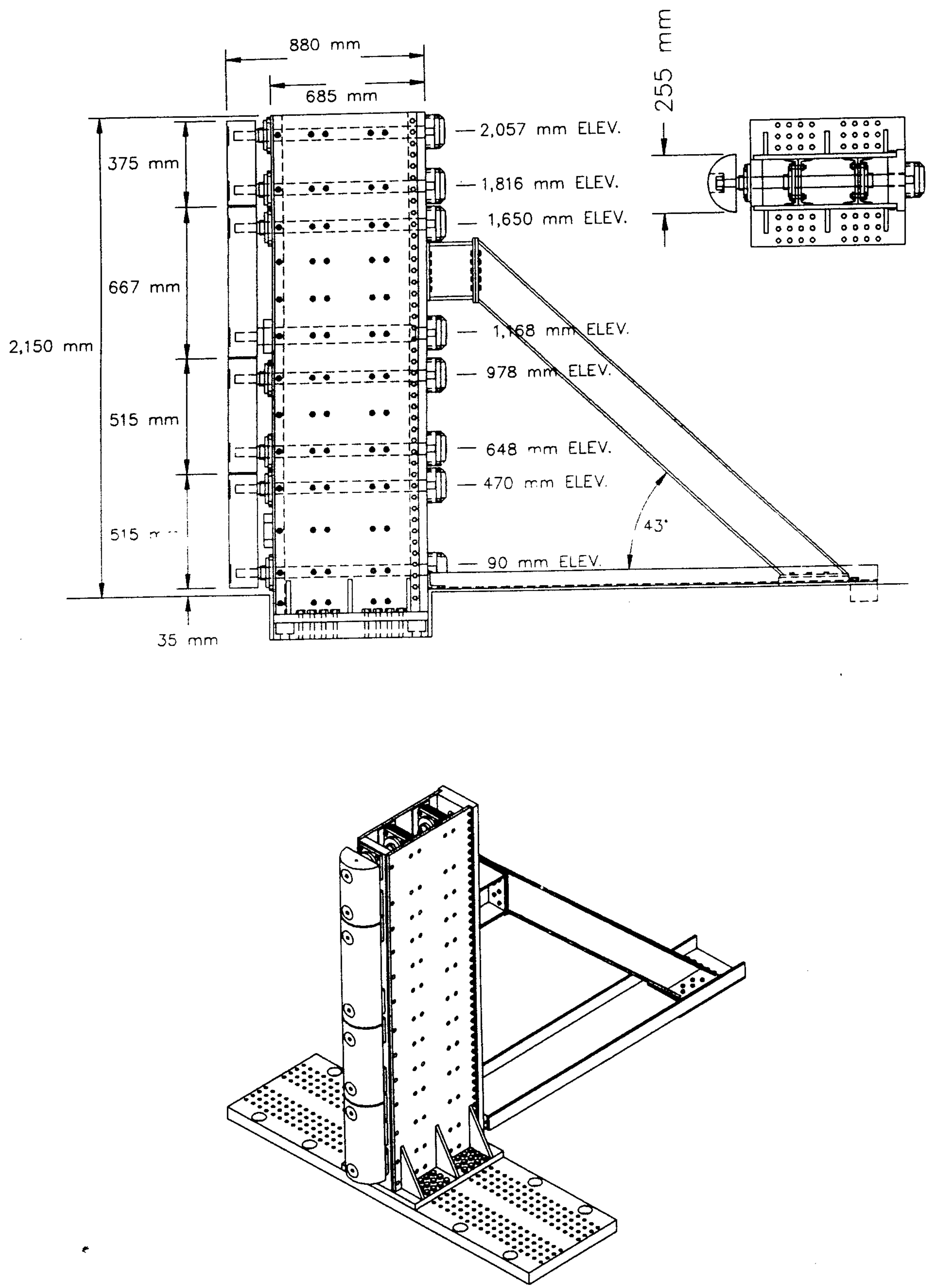


Figure 5. FOIL 300K instrumented rigid pole.

Rigid pole instrumentation.

- Eight rigid pole load cell channels (F_y) 8 channels

Miscellaneous.

- Impact and speed trap switches 2 channels
- 1 kHz timing signal for analog tape 1 channel

Table 4 provides specific channel assignments. The first 26 channels were ODAS channels including the 16 SIDH3 channels (shaded entries). The remaining channels were recorded via the umbilical cable tape recorder system.

Two methods for mounting accelerometers were used to affix the sensors to the test vehicle. The accelerometers were supplied with two small machine screws and a small 12-mm aluminum block. The first method used the accelerometer screws to mount the accelerometer to a small 25-mm^2, 6-mm thick steel plate, which was mounted to the vehicle using self-tapping sheet metal screws. This method was employed for the driver seat accelerometer. The second method used the aluminum block screwed to the small square-steel plate, which was welded to a larger, thicker plate. The larger plate was fastened to the vehicle using large self-tapping screws. This method was used for the accelerometers affixed to the engine block and in the trunk.

Onboard data acquisition system (ODAS)

The ODAS system collected 26 channels of data. The data was from cg, engine, driver seat, and trunk accelerometers, three rate transducers, and 16 SIDH3 channels. The output from the sensors were pre-filtered, digitally sampled, and digitally stored within the ODAS units mounted directly to the test vehicle inside the occupant compartment. The ODAS units are factory set with a 4000 Hz analog pre-filter 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 tape recorder. After the test, the tape was played back through anti-aliasing filters then input to a data translation analog-to-digital converter (ADC). The sample rate was set to 5,000 Hz. The system recorded outputs from the eight rigid pole load cells, two cg accelerometers, the monorail speed trap, and an impact contact switch to electronically mark first contact between the vehicle and rigid pole. The speed trap signals and the impact contact switch were not conditioned before being recorded.

The speed trap consisted of a single micro switch mounted to the monorail 4.2 m from the rigid 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 is 1,015 mm.

Table 4. Summary of instrumentation.			
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, cg data
17	Accelerometer	100 g's	Y-axis, cg data
18	Rate transducer	500 deg/s	Pitch rate, cg
19	Rate transducer	500 deg/s	Roll rate, cg
20	Rate transducer	500 deg/s	Yaw rate, cg
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

Table 4. Summary of instrumentation (continued).

24	Load cell	340 N·m	Neck moment, Z moment
25	Accelerometer	2000 g's	X-axis, in trunk
26	Accelerometer	2000 g's	Y-axis, in trunk
Umbilical cable, tape recorder system.			
1	Accelerometer	100 g's	Cg, X-axis
2	Accelerometer	100 g's	Cg, Y-axis
3	Load Cell	111 kN	Bottom face, lower load cell
4	Load Cell	222 kN	Bottom face, upper load cell
5	Load Cell	222 kN	Lower middle face, lower load cell
6	Load Cell	222 kN	Lower middle face, upper load cell
7	Load Cell	222 kN	Upper middle face, lower load cell
8	Load Cell	222 kN	Upper middle face, upper load cell
9	Load Cell	111 kN	Top face, lower load cell
10	Load Cell	111 kN	Top face, upper load cell
11	Contact switch	1.5 Volts	Time of impact, T0
12	Micro switch	1.5 Volts	Mono-rail speed trap
13	Generator	1.5 Volts	1 kHz reference signal

High-speed photography

A total of seven 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 per second and were positioned for best viewing of the contact between the Honda Accord and the 300K 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 5 lists each camera and lens used and the three-dimensional location of the camera lens. The three-dimensional coordinates were measured from the ground underneath the center of the semicircular impact faces of the rigid pole (origin) to the camera lenses. The camera numbers in table 5 are shown in figure 6. The interior of the driver door was painted flat white for better onboard camera image quality.

Table 5. Camera configuration and placement.

Camera Number	Type	Film speed (frames/s)	Lens (mm)	Orientation/ Location (m)
1	LOCAM II	500	45	90° to impact right side (15.4, 0.30, 1.2)
2	LOCAM II	500	100	90° to impact right side (15.7, 0.46, 1.4)
3	LOCAM II	500	40	45° oblique right side (7.9, 8.2, 1.0)
4	LOCAM II	500	50	45° left side (8.5, 7.9, 0.84)
5	L[illegible]CAM II	500	35	90° to impact left side (15.2, 0.30, 1.0)
6	LOCAM II	500	12.5	overhead, over rigid pole (0, 0, 6.6)
7	LOCAM II	500	5.7	on-board passenger window
8	BOLEX	24	zoom	documentary
9	CANON A-1 (prints)	still	zoom	documentary
10	CANON A-1 (slides)	still	zoom	documentary

Black and yellow circular targets, and black and yellow target tape 25-mm wide, were placed on the Honda Accord and rigid pole 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 the full length of the vehicle, excluding windows.
- Laterally across the roof perpendicular to the centerline tape and coincident with the rigid pole impact location.
- Laterally across the roof perpendicular to the centerline tape and coincident with the vehicle B-pillar.

Target tape was placed laterally on the front and rear bumpers in the YZ plane. Two vertical strips were placed on the rigid pole adjacent to and just rearward of the circular impact faces.

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 in the following locations:

- Driver door to denote the vehicle longitudinal cg.
- Driver door to denote the dummy H-point.
- The roof to denote the vehicle's longitudinal and later cg location.
- Two targets on the roof aligned with the vehicle longitudinal centerline 760 mm apart centered on the rigid pole centerline.
- Two targets aligned with the B-pillar centerline 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 on the trunk aligned with the vehicle's longitudinal centerline 255 mm apart.
- Two targets were placed on the front and back side of a vertical sheet metal stanchion fixed to the roof rearward of the B-pillar, centered on the longitudinal centerline and 610 mm apart.
- One target on top of the rigid pole's top semicircular impact face.
- Two targets on the front and rear bumper (YZ plane) 610 mm apart centered on the longitudinal centerline.

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, rigid 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.

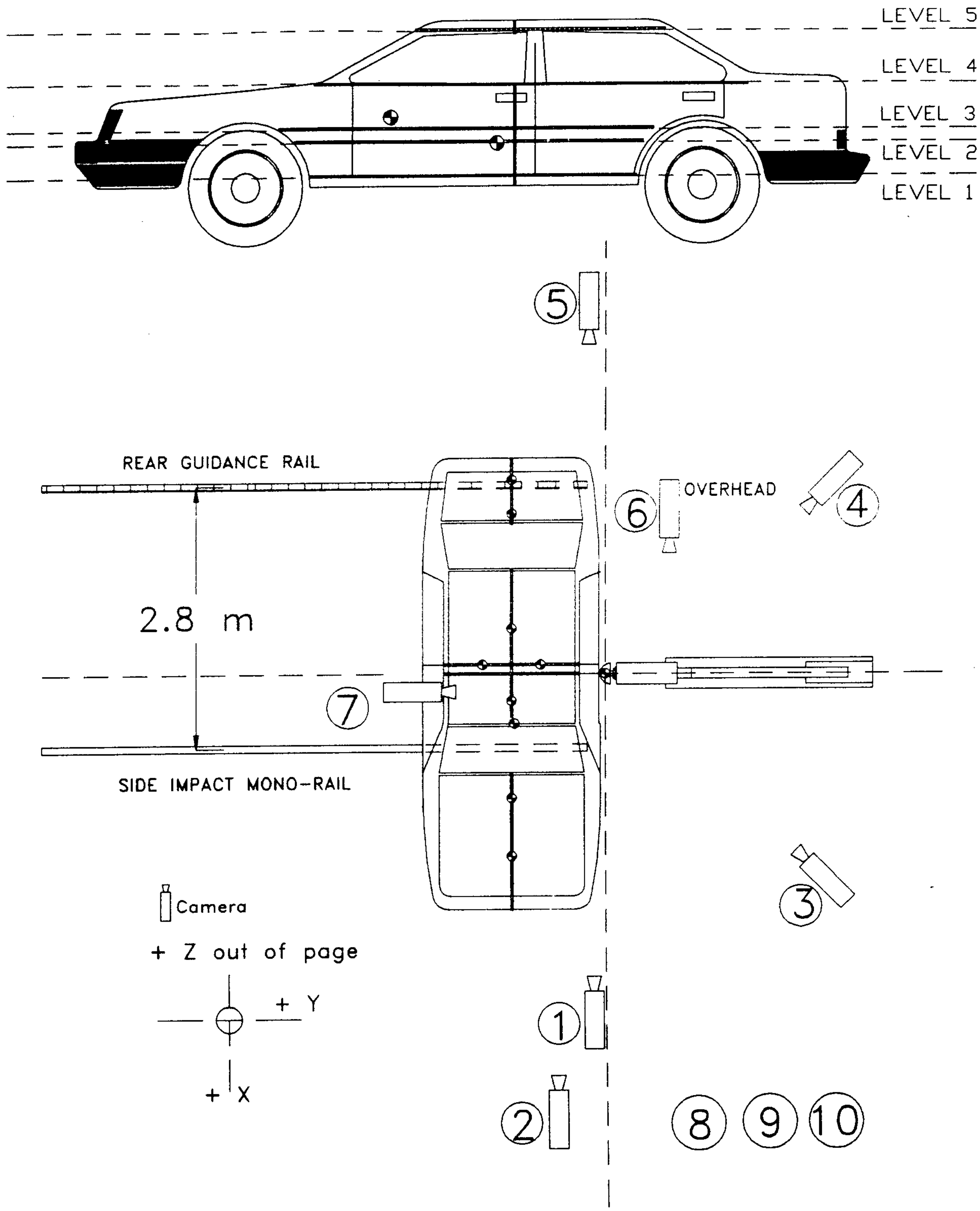


Figure 6. Camera locations and test setup.

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, seven localized accelerometer channels, and three rate transducer channels. The data was 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 was downloaded to a portable computer for analysis. The data was converted to the ASCII format, zero-bias removed, and digitally filtered at 1,650 Hz (Society of Automotive Engineers (SAE) class 1000). Rib, spine, and pelvic data were filtered a second time using a NHTSA-supplied FIR100 filter. The class-1000 data was 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 acceleration data file was fed into a HIC algorithm to compute the HIC value for the crash test. The 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 1000 Hz. The signal was then input to a data translation ADC. The data included eight load cell channels, two accelerometer channels (located at the cg), an impact switch, and a monorail speed trap signal. The sample rate was set to 5,000 Hz. The digital data was converted to the ASCII format, zero-bias removed and digitally filtered to 1,650 Hz (SAE class 1000). The filtered data was input into a spreadsheet for plotting. The total force exerted on the rigid pole was computed by adding all eight load cell data signals and reading a peak from the combined force-time history.

Two square wave pulses from the lone monorail micro switch 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 (1,015 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 and IBM PC-AT. The overhead and one 90-degree 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 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 Honda Accord was placed on the FOIL side impact monorail with its longitudinal centerline perpendicular to the rigid pole centerline. The morning of the test the dummy was positioned in the driver seat using the H-point data and FMVSS 214. The SIDH3's head cg was aligned with the rigid pole centerline. The dummy was restrained using the vehicle shoulder-lap belt restraining system. The rear third of the dummy's head overlapped the B-pillar. Just prior to testing, the following was noted: the emergency brake was placed in the engaged position, the head rests were positioned in the highest adjustment, the two front seats were aligned (mid-track position), the windows were down, the transmission was placed in neutral, and the key was placed in the "on" position. The Honda Accord passed over the monorail speed trap which measured a speed of 29.5 km/h. The initial yaw angle was 90 degrees. Table 6 summarizes the test conditions and selected results.

Table 6. Summary of test conditions and results.

FOIL test number	97S004
Date of test	June 17, 1997
Test vehicle	1995 Honda Accord LX, 4-door sedan
Vehicle weight	1,476 kg
Test article	FOIL instrumented 300K rigid pole
Temperature inside vehicle	25.7°C
Impact speed: speed trap	29.5 km/h
16-mm Film	29.6 km/h
Impact point (mm)	500 behind vehicle cg
Traffic accident data (TAD)	9-LP-7
Vehicle damage index (VDI)	09LPAN5
Head Injury Criteria (HIC)	
Limit	1000 g's
Observed	403 g's
Start time	0.05248 s

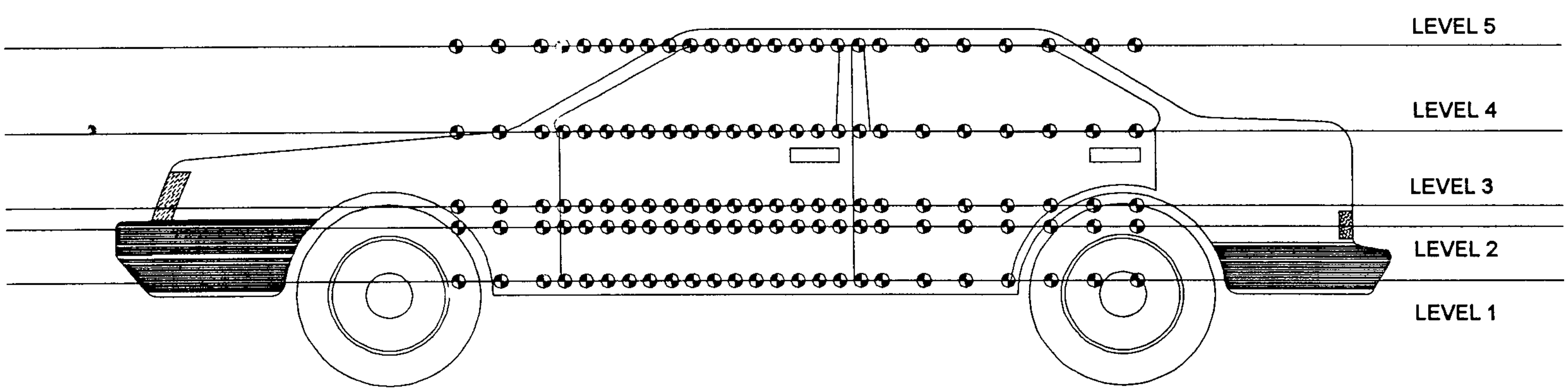
Table 6. Summary of test conditions and results (cont'd).	
Stop time	0.06248 s
Interval time	0.01000 s
Thoracic trauma data	
Limit (4-door)	85 g's
Peak rib acceleration (FIR100)	73.1 g's
T12 spine (FIR100)	62.9 g's
Thoracic Trauma Index (TTI)	68.0 g's

Vehicle response. The sharpened rod attached to the rigid pole punctured the vehicle on the vertical target tape, denoting the intended target location. The puncture verified that the intended impact location was the first point of contact. Because the dummy was positioned such that it was partially shielded by the B-pillar, alignment of the rigid pole placed the pole in contact with most of the B-pillar. The B-pillar, front and rear doors began to collapse, intruding into the occupant compartment. The pole began to rotate the driver seat clockwise (from overhead) and tip the seat rearward 0.044 s after initial contact. Double integration of the cg acceleration-time history and the total rigid pole force-time history yielded a maximum dynamic intrusion of 620 mm and 700 mm, respectively. The driver seat collapsed and pinched the dummy's lower torso in the seat. The seat was pushed into and leaning behind the passenger seat. The impact location was 500 mm behind the vehicle cg. The lever induced a yaw into the vehicle after the peak load was reached. Integration of the yaw rate transducer positioned under the dash panel on the floor tunnel at the longitudinal and lateral cg produced a maximum yaw angle of 48 degrees. The vehicle rebounded away from the pole as it continued to yaw counterclockwise (as seen from above). Contact between the main carriage and monorail impeded the vehicle motion, limiting the yaw and rebound. The four-door latches remained latched during the collision. No evidence of fuel leakage or fuel system component damage was observed. The driver air bag did not deploy during the test. The peak cg acceleration was determined to be 27.3 g's (374 kN) and occurred 0.058 s after impact. Table 7 lists the vehicle accelerometers and their three dimensional coordinate location referenced from the right front wheel hub. The right front wheel hub was 290 mm above ground (not on guidance rails). Included in the table are peak accelerations from each accelerometer.

Table 7. Vehicle sensor locations and peak measurements.				
Sensor	X (mm)	Y (mm)	Z (mm)	Peak g's
Cg accelerometer A_x	-1,005	710	125	-8.0
Cg accelerometer A_y	-1,005	710	125	-27.3
Cg accelerometer A_z	-1,005	710	125	13.6
Cg redundant A_y	-1,005	710	125	-19.8
Engine block A_x	180	880	485	-3.8
Engine block A_y	180	880	485	-8.2
Trunk A_x	-3,490	830	25	-12.0
Trunk A_y	-3,490	830	25	-20.4
Driver seat A_y	-1,500	135	25	-103.0

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 allowed the same reference line to be drawn 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 476 mm at the H-point height along the vertical impact target tape.

Data plots of the data from transducers mounted to the test vehicle are presented in appendix A. Photographs taken from high-speed film during impact 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

			Distance from impact point (mm).												
LEVEL	HEIGHT		1,067	-914	-762	-610	-533	-457	-381	-305	-229	-152	-76	0	-76
1	273	PRE	584	584	584	584	584	584	587	587	587	587	587	587	587
	292	POST	559	591	616	660	686	737	775	806	845	927	965	978	978
		CRUSH	-25	7	32	76	102	153	188	219	258	340	378	391	391
2	457	PRE	533	533	533	540	543	543	543	543	543	540	540	540	537
	468	POST	483	552	622	667	692	737	768	813	870	914	965	1,016	997
		CRUSH	-50	19	89	127	149	194	225	270	327	374	425	476	460
3	584	PRE	540	540	540	540	543	546	546	546	546	546	546	543	540
	591	POST	464	533	591	660	667	724	781	838	883	940	984	1,010	978
		CRUSH	-76	-7	51	120	124	178	235	292	337	394	438	467	438
4	883	PRE	610	597	613	613	616	616	619	619	619	619	619	629	622
	899	POST	521	549	616	686	737	768	813	864	902	997	991	1,029	1,041
		CRUSH	-89	-48	3	73	121	152	194	245	283	378	372	400	419
5	1,340	PRE							865	865	865	865	864	864	864
	1,372	POST							892	902	940	984	1,029	1,060	1,086
		CRUSH									75	119	165	196	222
All units of measurement are in mm.															

Figure 7. Vehicle profile measurements, test 97S004.

			Distance from impact point (mm).												
LEVEL	HEIGHT		152	229	305	381	457	610	762	914	1,067				
1		PRE	587	587	584	584	584	591	594						
		POST	914	832	781	730	654	584	514						
		CRUSH	327	245	197	146	70	-7	-80						
2		PRE	537	533	533	533	533	540	540						
		POST	940	895	832	787	718	616	540						
		CRUSH	403	362	299	254	185	76	0						
3		PRE	540	537	533	533	530	533	540						
		POST	940	889	826	781	724	622	546						
		CRUSH	400	352	293	248	194	89	6						
4		PRE	622	622	622	622	622	629	638	641	648				
		POST	1,003	959	921	876	838	762	679	622	616				
		CRUSH	381	337	299	254	216	133	41	-19	-32				
5		PRE	864	864	864	864	865	865	865						
		POST	1,067	1,054	1,022	994	965	914	876						
		CRUSH	203	190	158	130	100	49	11						

All units of measurement are in mm.

Figure 7. Vehicle profile measurements (continued).

Occupant response. The SIDH3 remained vertical in the driver seat with only minor vibration induced by the tow and guidance system. The first contact occurred 0.024 s after impact and was between the door and the SIDH3's shoulder region. The back third of the SID's head struck the B-pillar at 0.052 s. This prevented significant head protrusion from the window. The head rotated about the neck, and the face made slight contact with the pole at 0.072 s. The neck Z-moment load cell verified this event. The rotation away from the pole and energy absorption of the B-pillar did not allow significant contact between the SIDH3's head and the rigid pole. After the test, no physical damage to the SIDH3 was observed. The dummy was wedged between the door and the emergency brake handle. The dummy's final position was slumped over, leaning toward the passenger seat while his lower torso remained wedged in the driver seat. Yellow and red chalk was found on the upper seat belt anchor and B-pillar, indicating significant contact by the left side and rear of the SIDH3's head. A small amount of yellow chalk was found on the rigid pole, verifying contact between the dummy's head and the pole. Blue chalk was also found on the pole, indicating contact from the dummy's shoulder or the top of the head. After review of the test film, it was determined the chalk was a result of splatter and not from direct contact between the shoulder or top of the head and the rigid pole. Blue chalk from the dummy's side was on the B-pillar and door as expected. Red chalk from the dummy's femur and leg was found on the driver door.

The rib and spine produced a TTI of 68.0 g's. This is below the four-door sedan limit of 85 g's specified in the FMVSS 214. The three head accelerometers produced a HIC value of 403 g's. This value is below the 1000 g's required by FMVSS 214. Table 8 summarizes the data collected from the SIDH3.

Table 8. Summary of SIDH3 data.

Recorded Data	Maximum positive (g's)	Maximum negative (g's)
Head X-axis acceleration	12.0	-23.2
Head Y-axis acceleration	9.1	97.2
Head Z-axis acceleration	6.9	-40.3
X-axis neck force load cell (N)	62.0	-459.4
Y-axis neck force load cell (N)	354.4	-864.2
Z-axis neck force load cell (N)	189.6	-1831.5

Table 8. Summary of SIDH3 data (cont'd).

X-axis neck moment load cell (1000 mm·N)	29.9	-70.7
Y-axis neck moment load cell (1000 mm·N)	15.1	-13.1
Z-axis neck moment load cell (1000 mm·N)	10.9	-30.4
Left upper rib acceleration (P)	12.9	-72.9
Left upper rib acceleration (R)	12.5	-73.2
Left lower rib acceleration (P)	12.9	-57.0
Left lower rib acceleration (R)	11.9	-60.2
Spine T12 Y acceleration (P)	12.4	-62.9
Spine T12 Y acceleration (R)	13.3	-61.7
Pelvis Y acceleration	13.1	-40.6
Shaded area data is SAE class 1000. Remaining data obtained from FIR100 filter output.		

The values from the head accelerometers and the neck load cells were taken from class 1000 data while the remainder are from data filtered using a FIR100 filter. Data plots from the SIDH3 transducers are presented in appendix B. All data plots are of class 1000 data.

<u>Rigid pole.</u> The load cells measured eight separate forces on the rigid pole. The total load from summing the eight load cells was 98,400 N. The significant loads were contributed by the roof-rail, floor-sill, and middle-point of the driver door. Table 9 summarizes the load cell data. Data plots from the rigid pole load cells are presented in appendix D.

Table 9. Summary of rigid pole data.

Load cell/height (mm)	**Peak force (1000 N)**	**Time (ms)**
Top face	-5.0	
Upper load cell/2,057	-2.9	68.0
Lower load cell/1,816	-2.3	66.4

Table 9. Summary of rigid pole data (cont'd).		
Middle-upper face	-9.4	
Upper load cell/1,650	-5.3	67.6
Lower load cell/1,168	-4.8	89.6
Middle-lower face	-55.2	
Upper load cell/978	-19.0	11.0
Lower load cell/648	-36.2	11.0
Bottom face	-44.6	
Upper load cell/470	-28.3	50.0
Lower load cell/90	-19.5	85.8
Total, rigid pole	-98.4	55.0

CONCLUSIONS AND OBSERVATIONS

Visual inspection of the Honda Accord after the collision produced immediate conclusions. The speed was within reasonable tolerance and the vehicle struck the rigid pole at the intended impact location. These rsults are comparable to a previous broadside test, test 97S003, indicating repeatable laboratory test procedures.

Fuel system and door latch integrity were not breached by the broadside collision with the FOIL instrumented rigid pole (narrow-fixed object). Red and yellow chalk on the B-pillar indicated significant contact between the B-pillar and the dummy's head (side and rear). This contact caused the dummy to rotate away from the rigid pole, thus lowering contact with the rigid pole. The HIC value was below expected results for a broadside collision with a narrow object aligned with dummy's head cg. The test did not yield adequate results to show that a dynamic side-impact protection system would be of significant improvement. The injury criteria are below current safety standards without an air bag system present.

The data from this test and the first of this series, test 97S003, produced similar low HIC values, suggesting further examination of the impact location, crab angle, or seating position is needed to determine the best compliance test parameters for dynamic side-impact protection systems.

APPENDIX A. DATA PLOTS FROM VEHICLE ACCELEROMETERS.

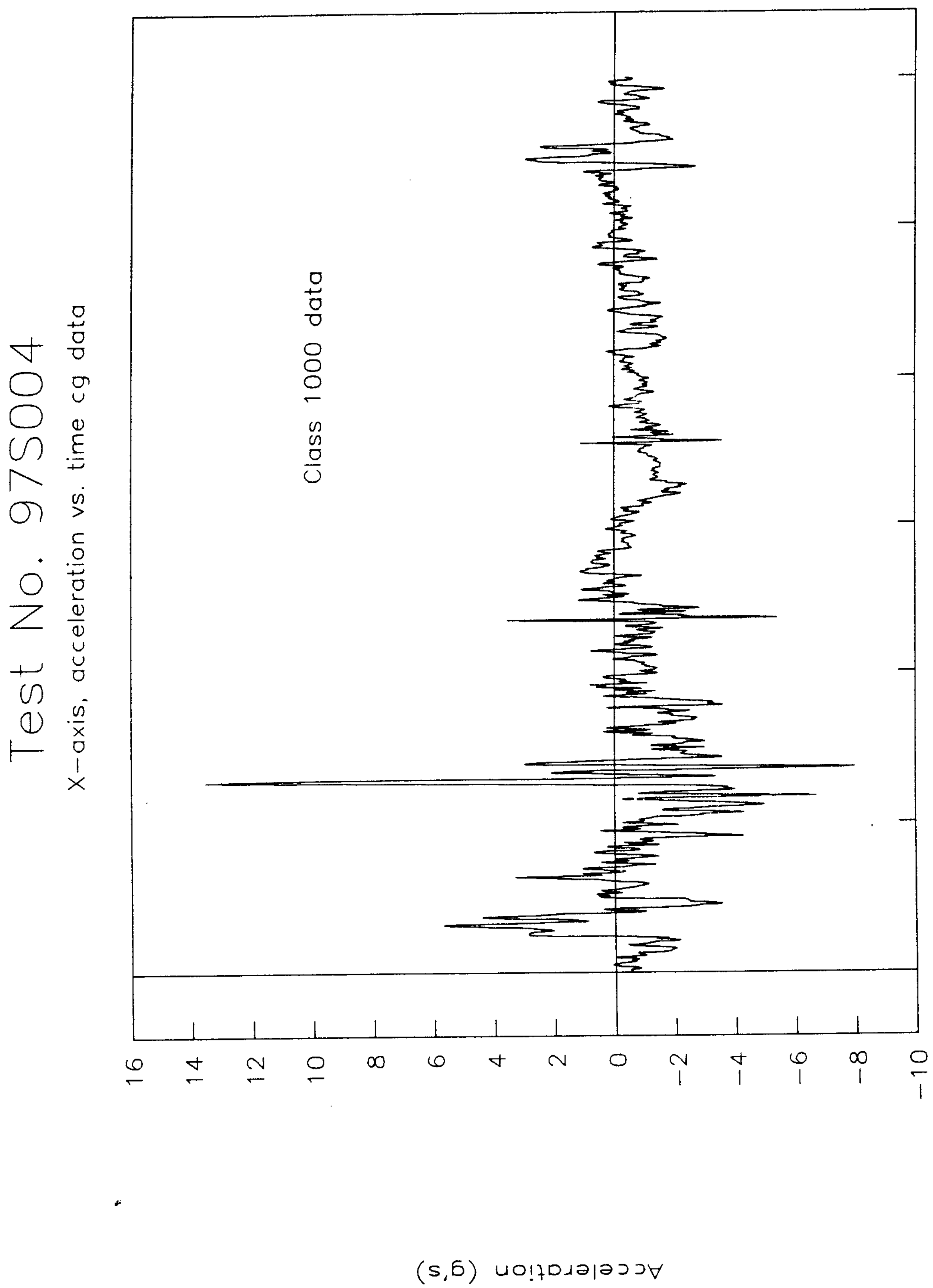


Figure 8. Acceleration vs. time, cg X-axis, test 97S004.

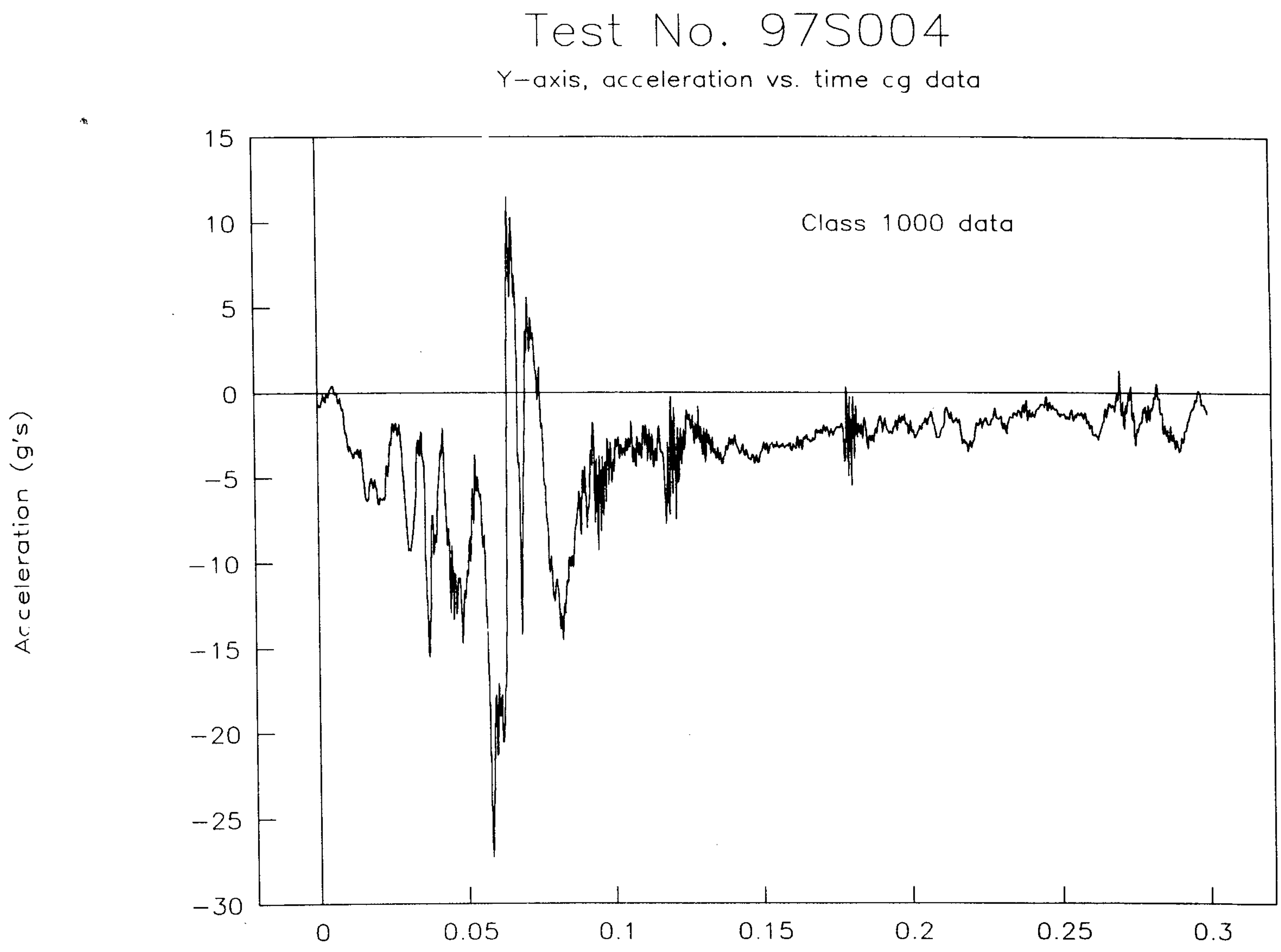


Figure 9. Acceleration vs. time, cg Y-axis, test 97S004.

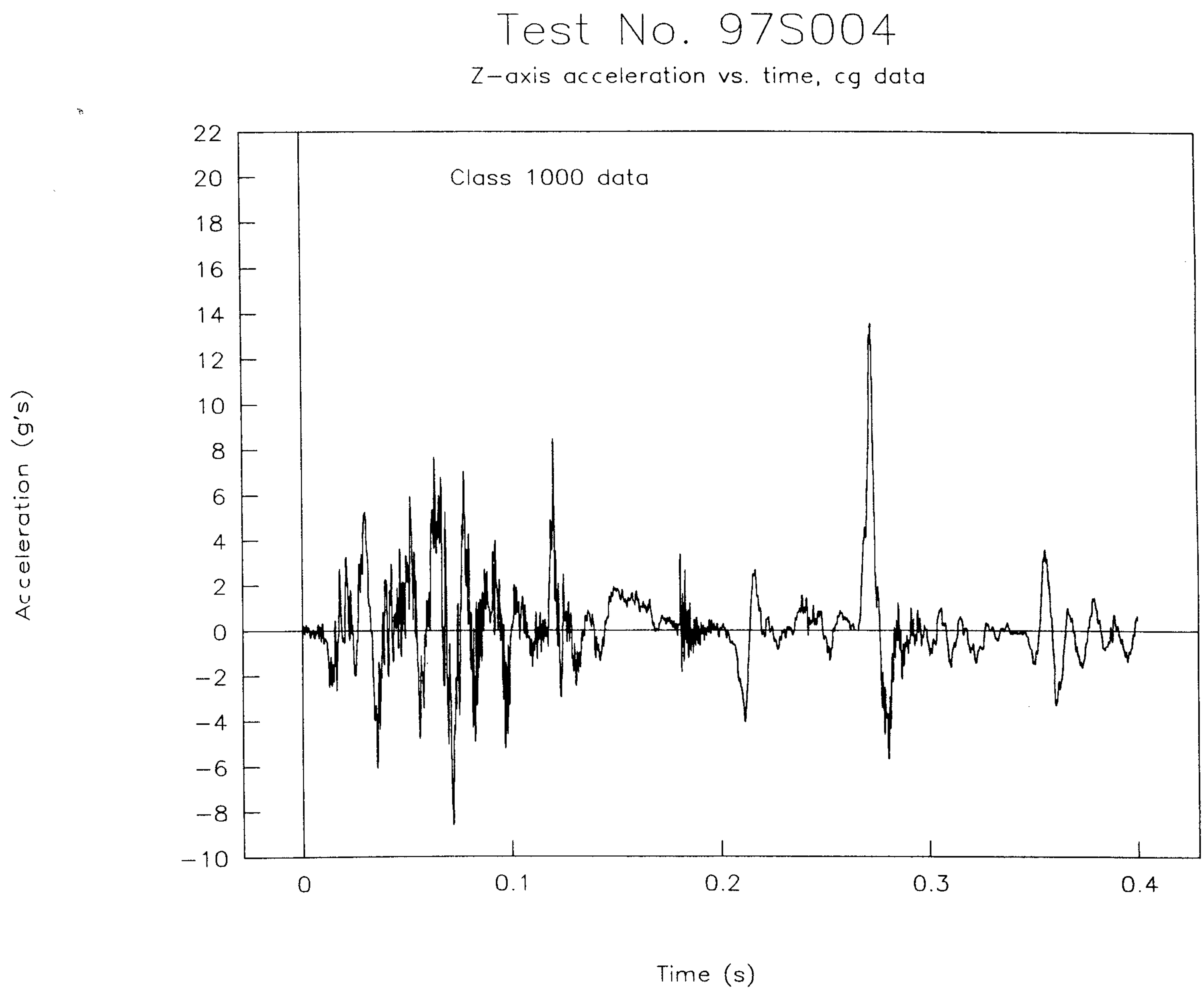


Figure 10. Acceleration vs. time, cg Z-axis, test 97S004.

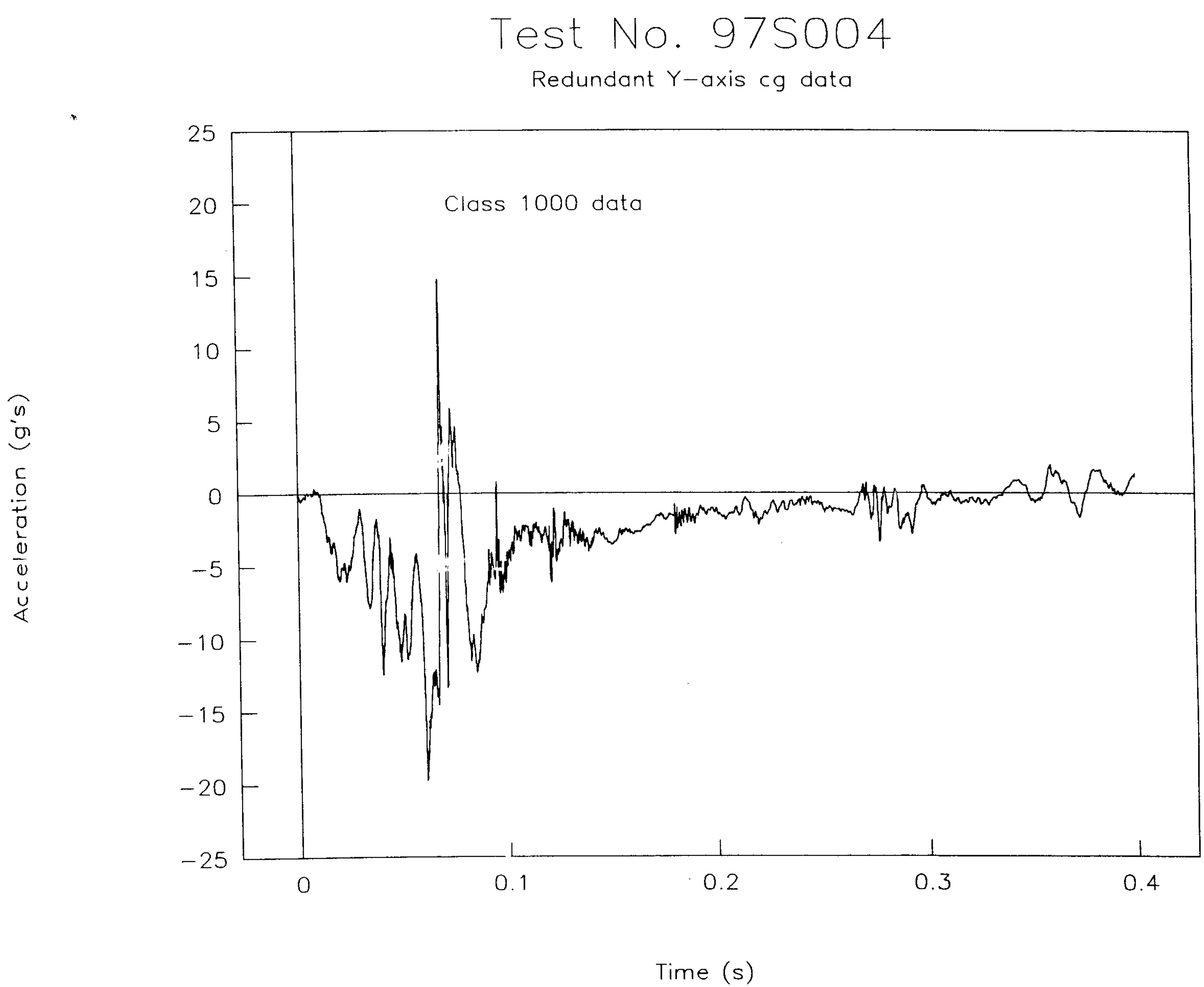


Figure 11. Acceleration vs. time, redundant Y-axis cg, test 97S004.

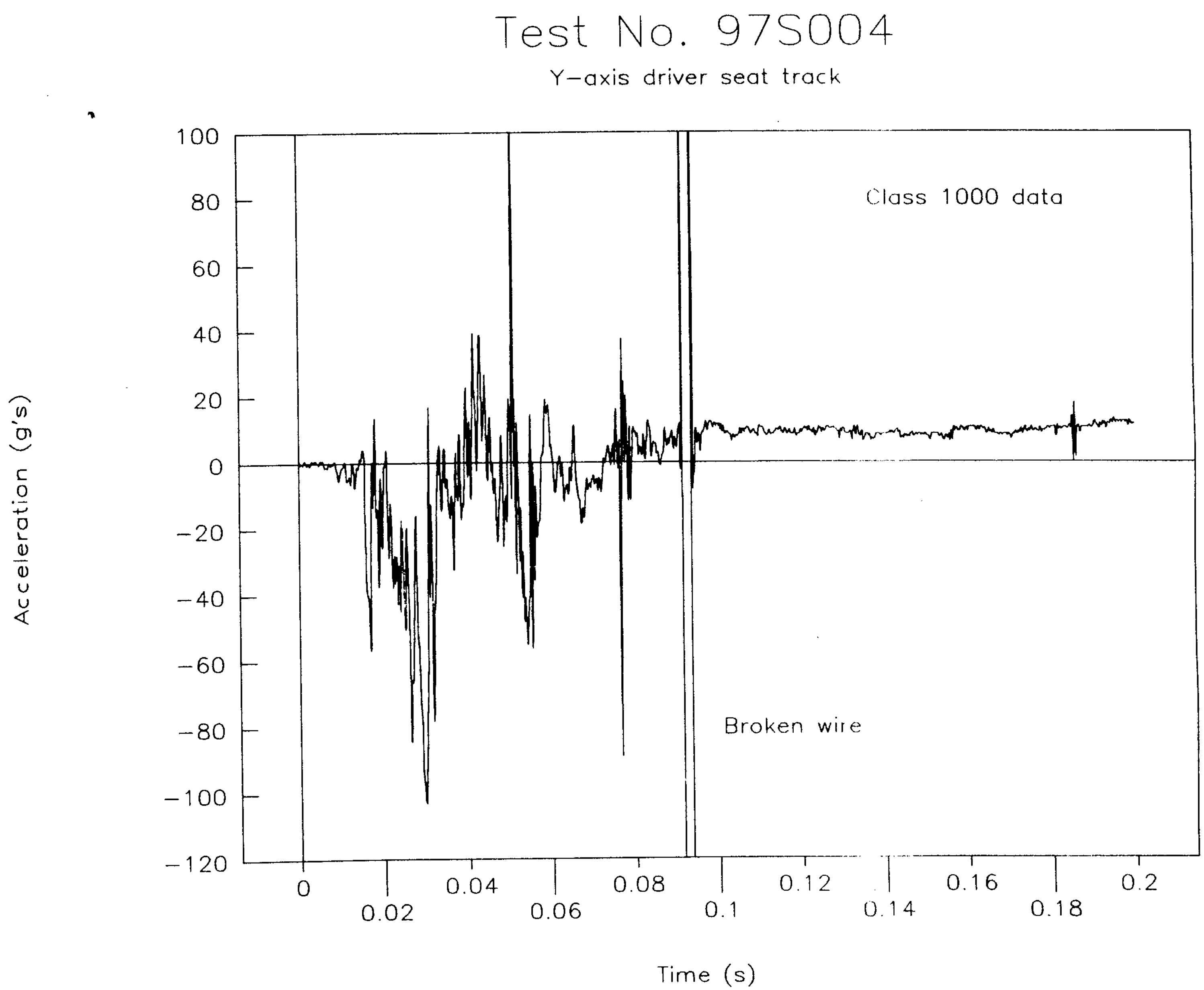


Figure 12. Acceleration vs. time, Y-axis driver seat track, test 97S004.

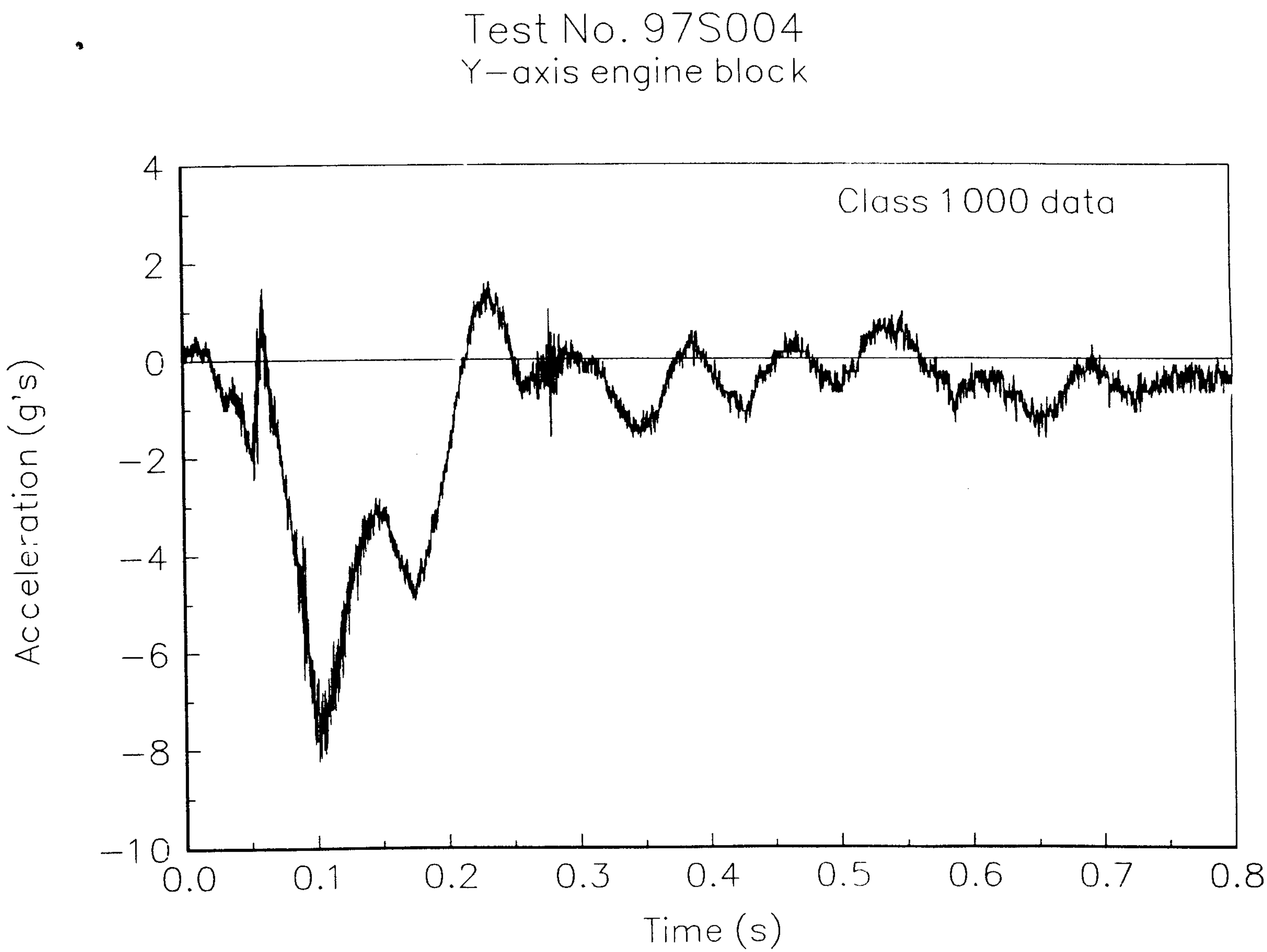


Figure 13. Acceleration vs. time, X-axis engine block, test 97S004.

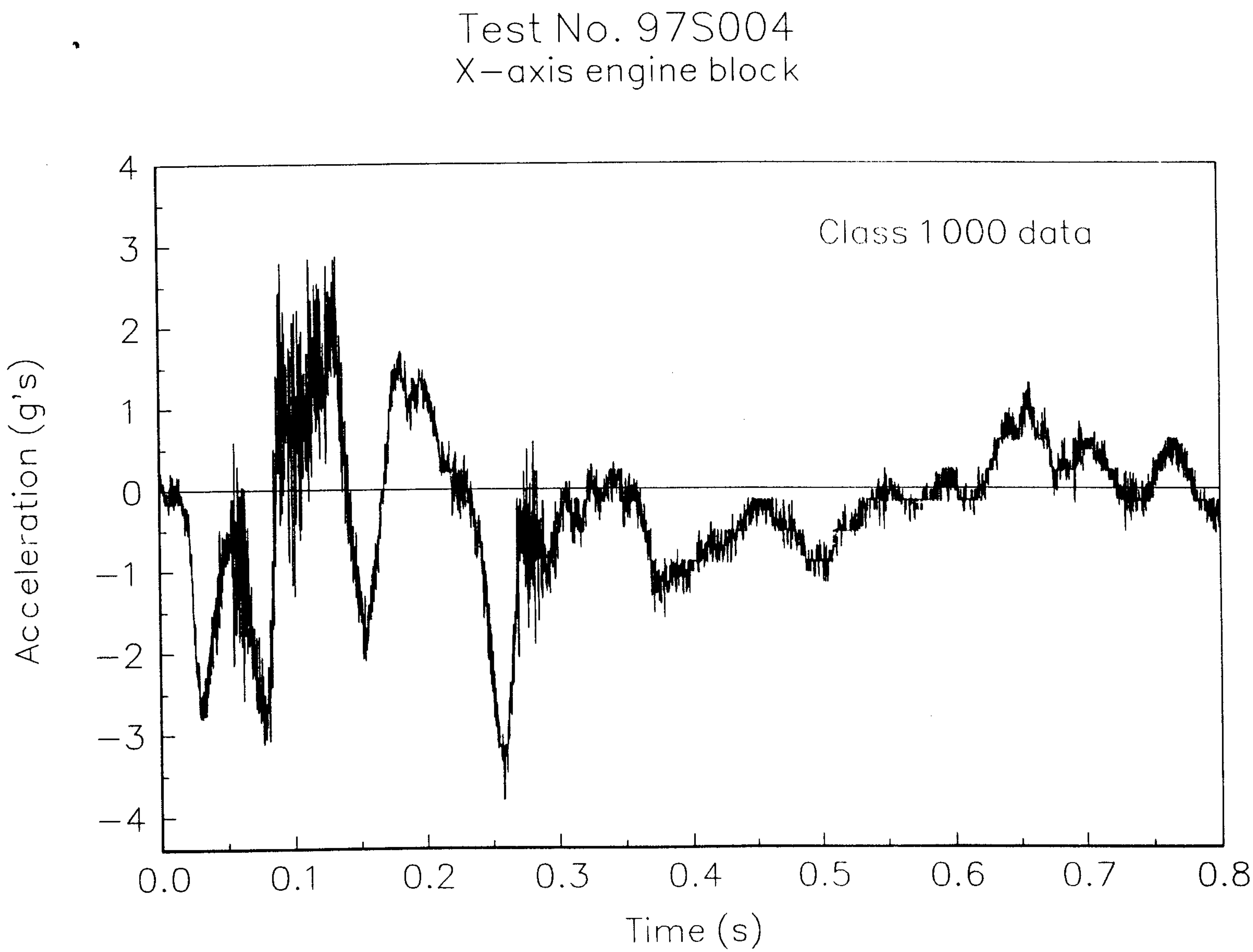


Figure 14. Acceleration vs. time, Y-axis engine block, test 97S004.

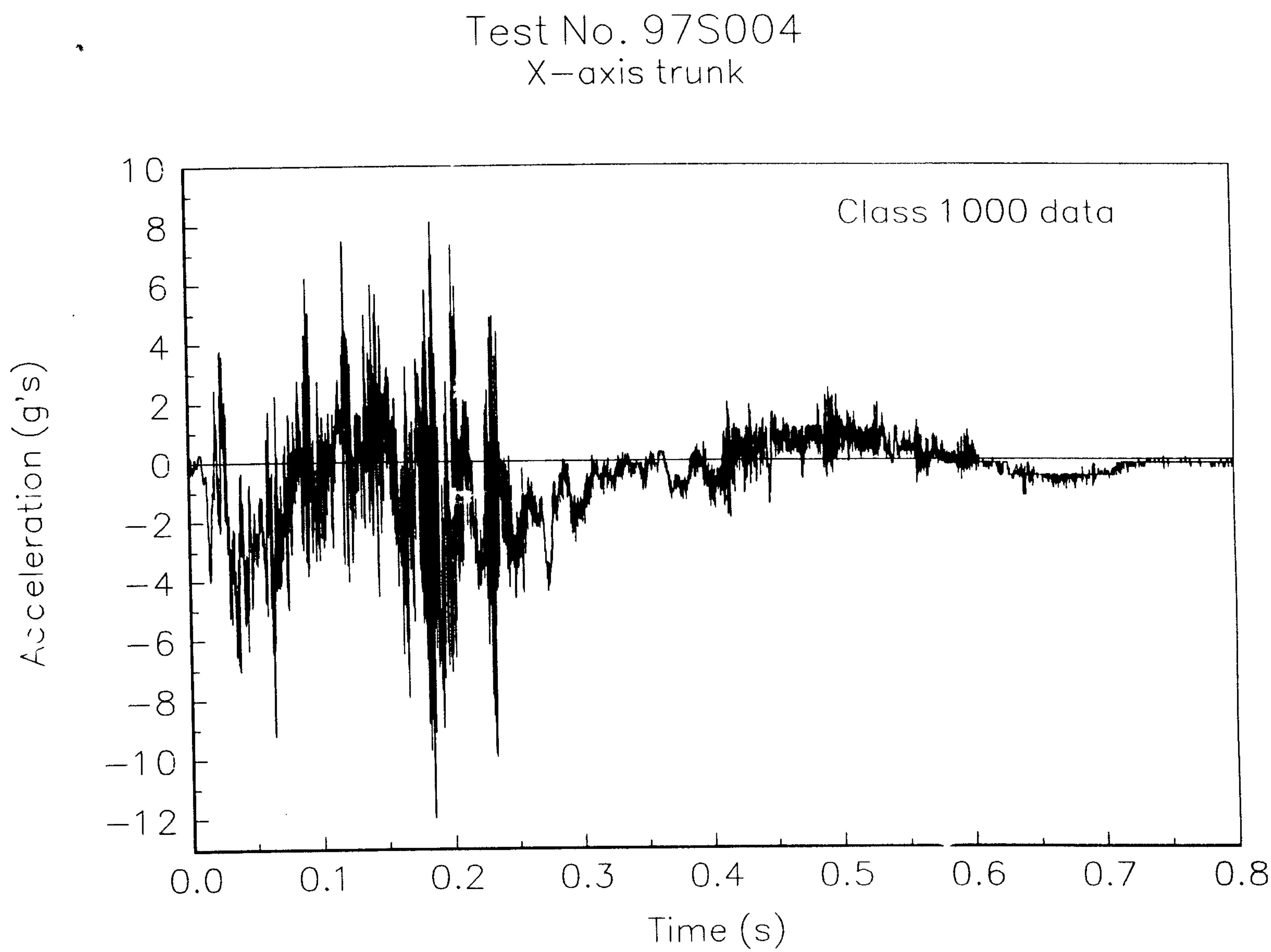


Figure 15. Acceleration vs. time, X-axis trunk, test 97S004.

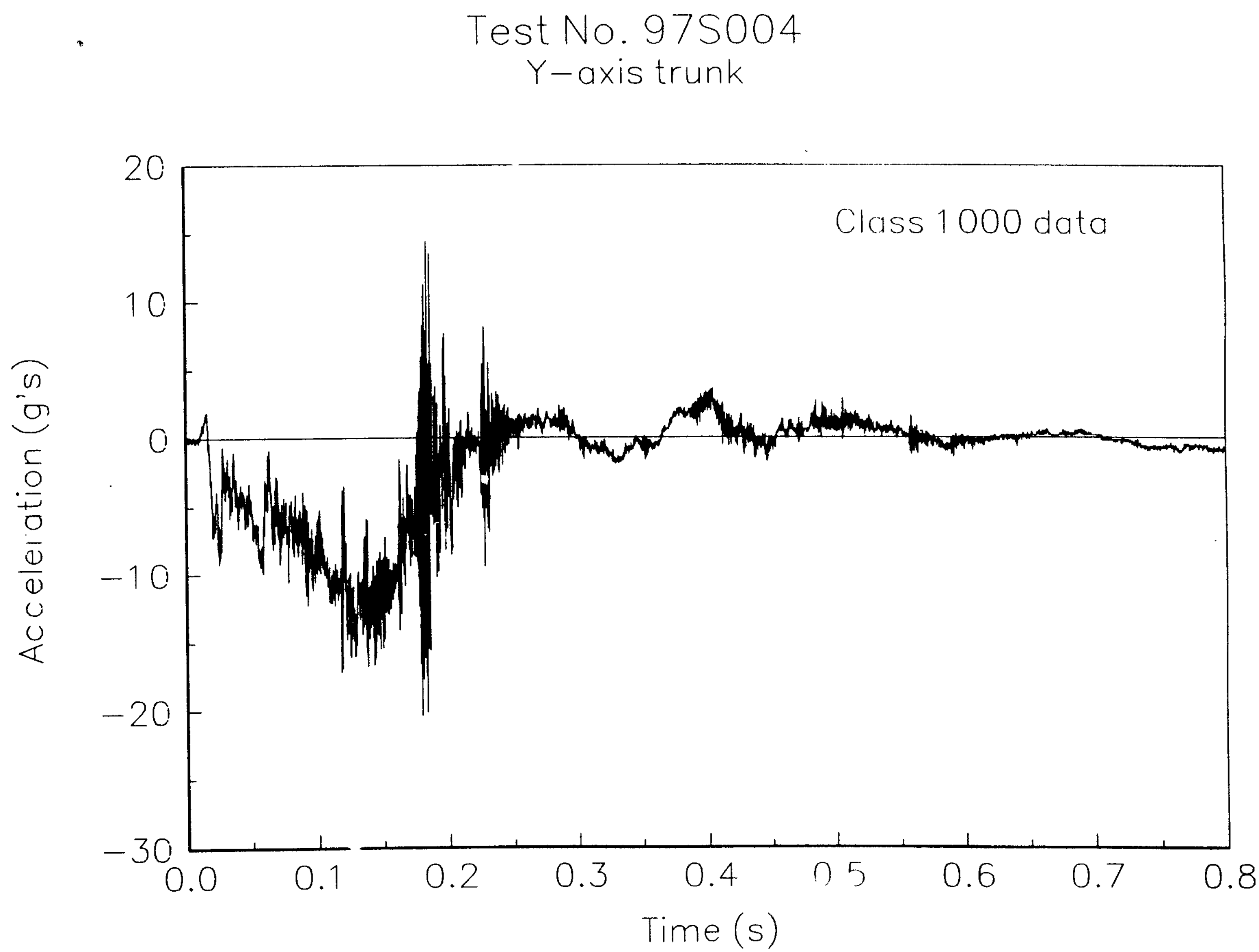


Figure 16. Acceleration vs. time, Y-axis trunk, test 97S004.

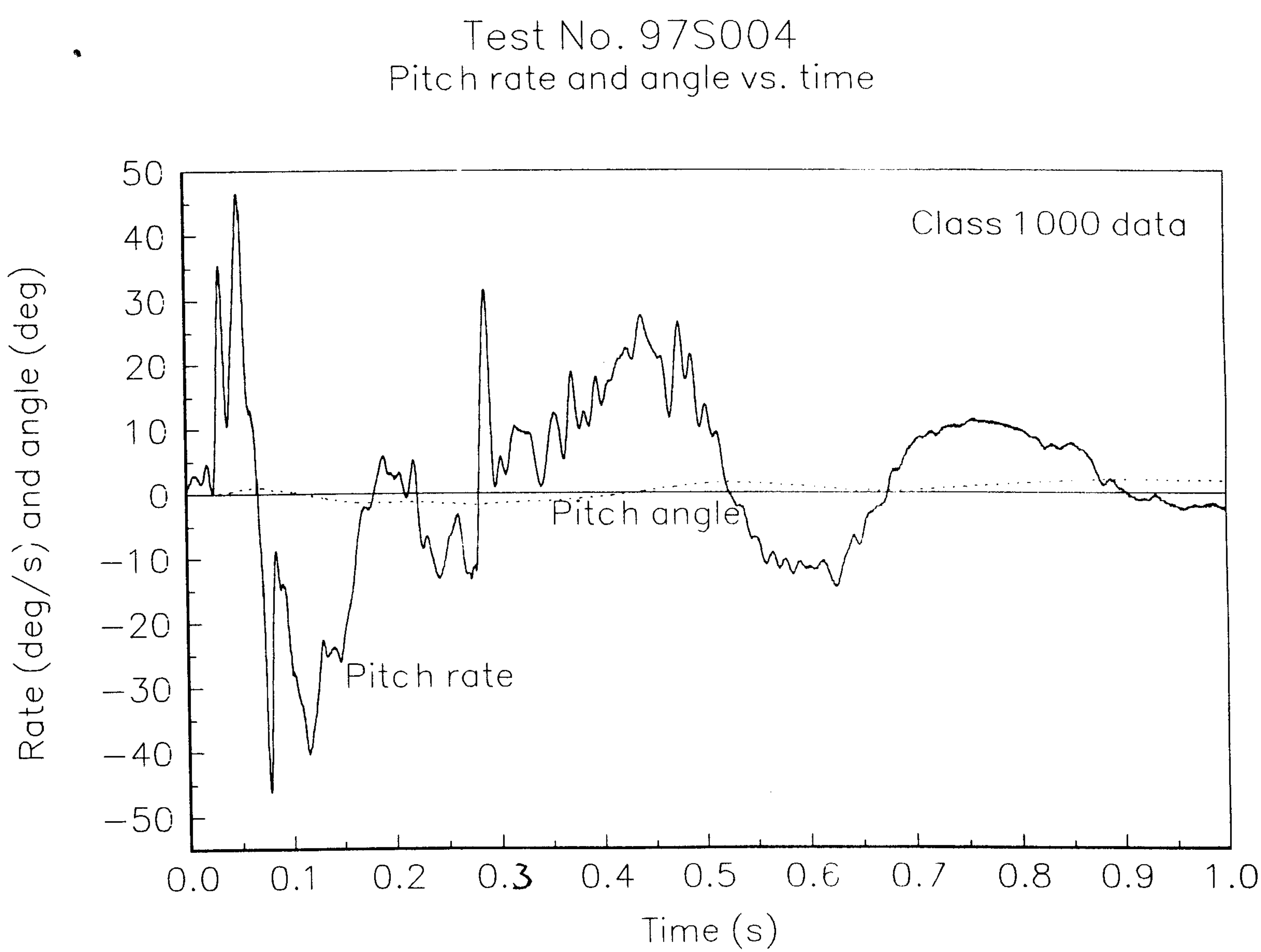


Figure 17. Pitch rate and angle vs. time, test 97S004.

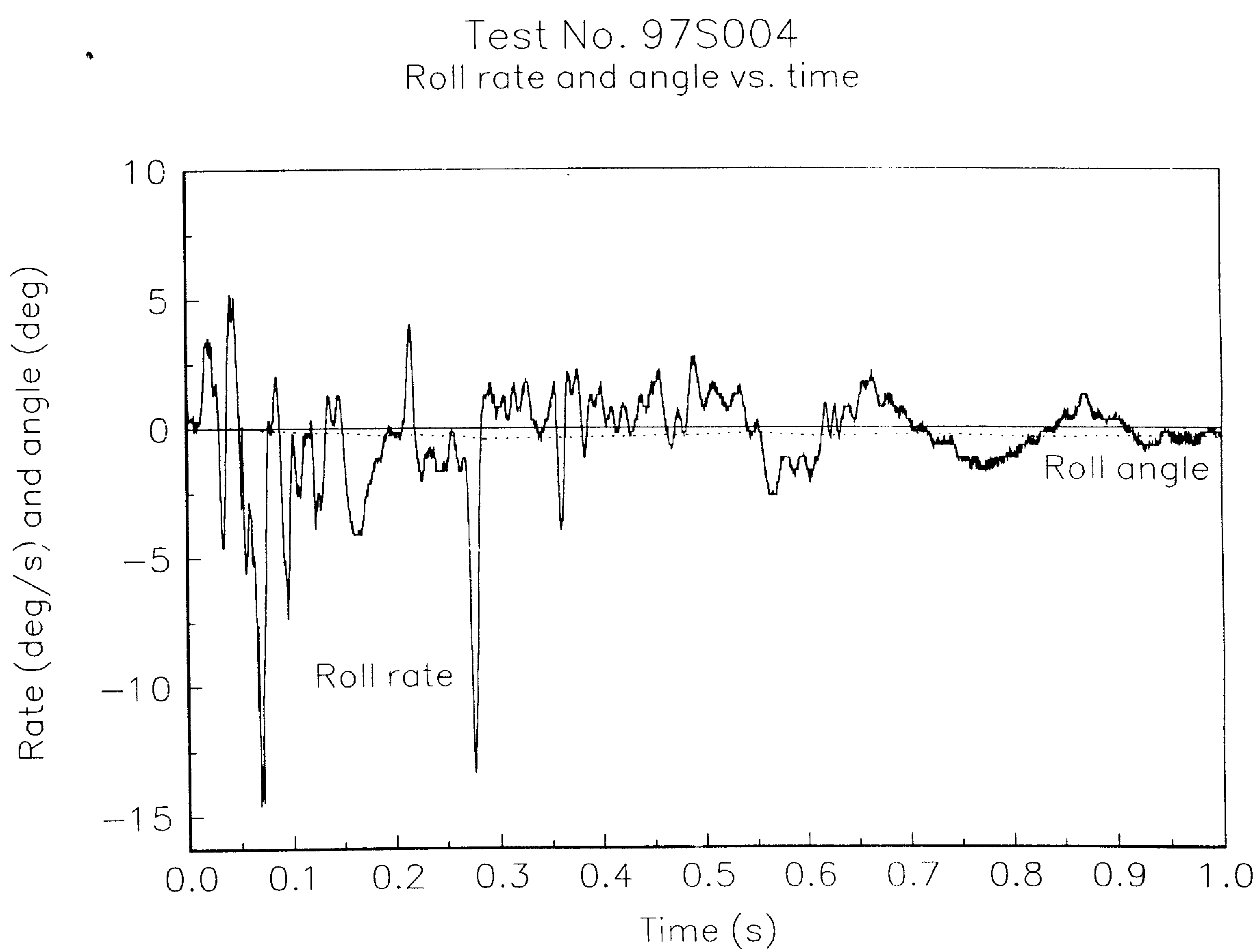


Figure 18. Roll rate and angle vs. time, test 97S004.

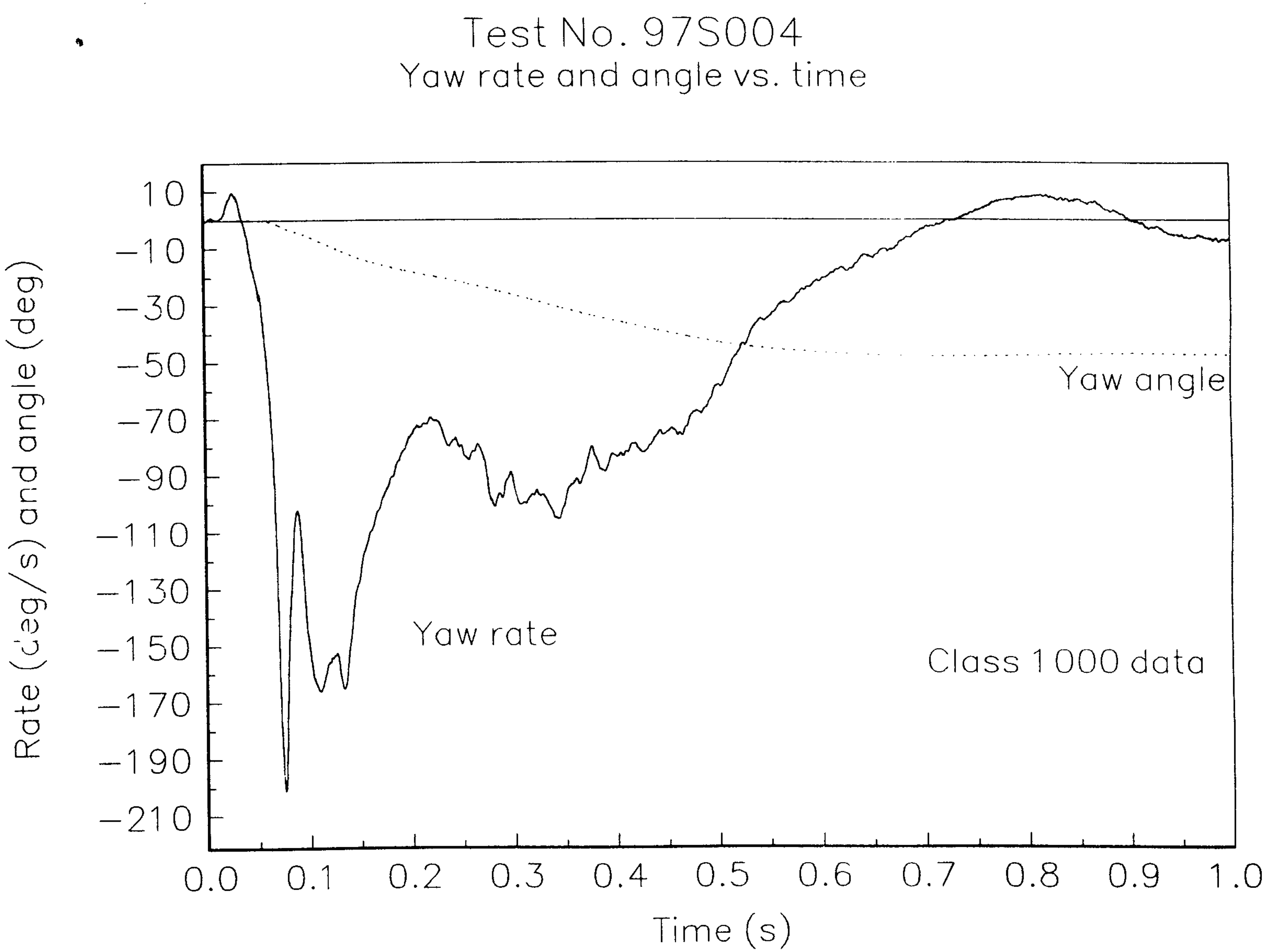


Figure 19. Yaw rate and angle vs. time, test 97S004.

APPENDIX B. DATA PLOTS FROM INSTRUMENTED SIDH3.

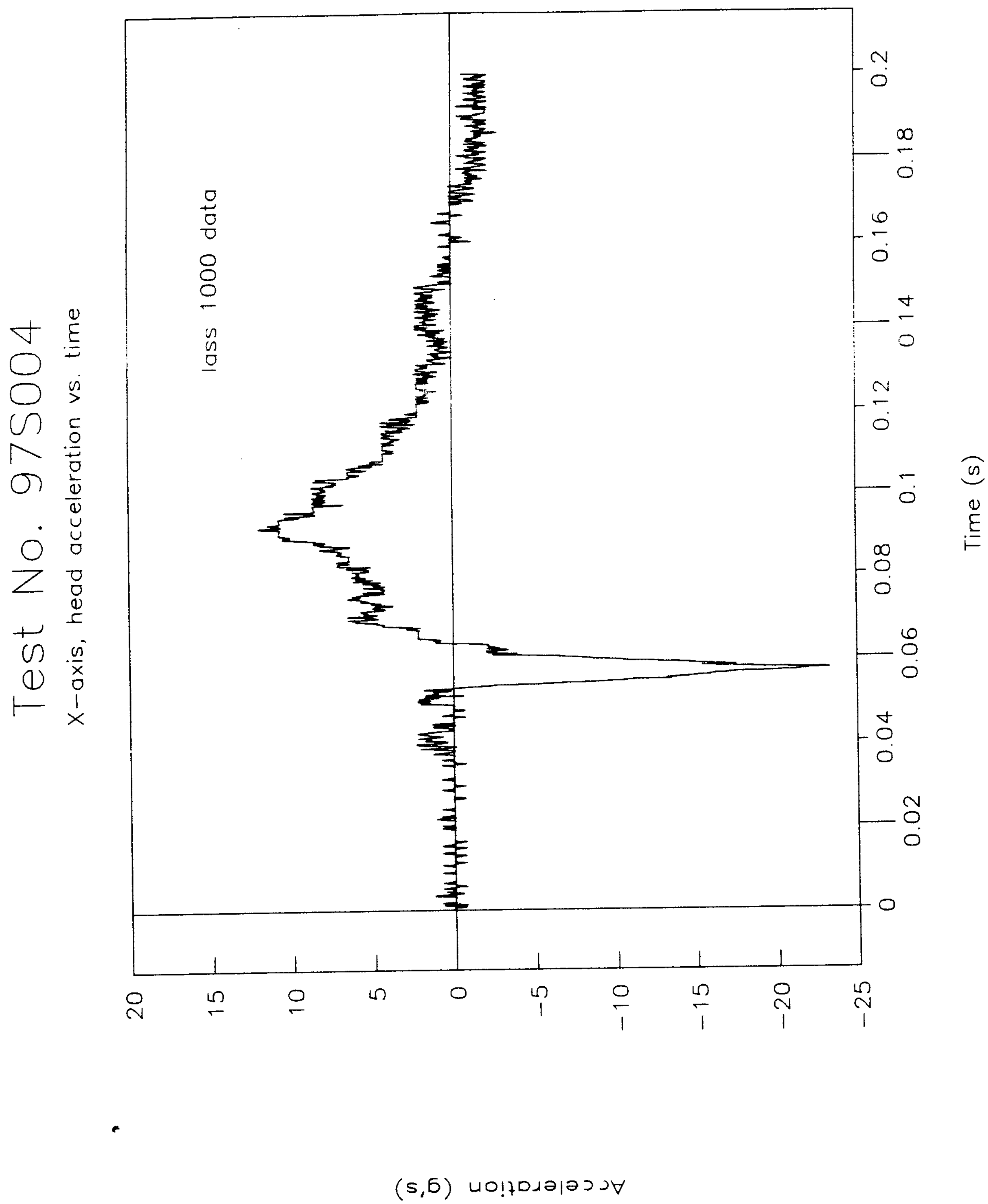


Figure 20. Acceleration vs. time, X-axis head, test 97S004.

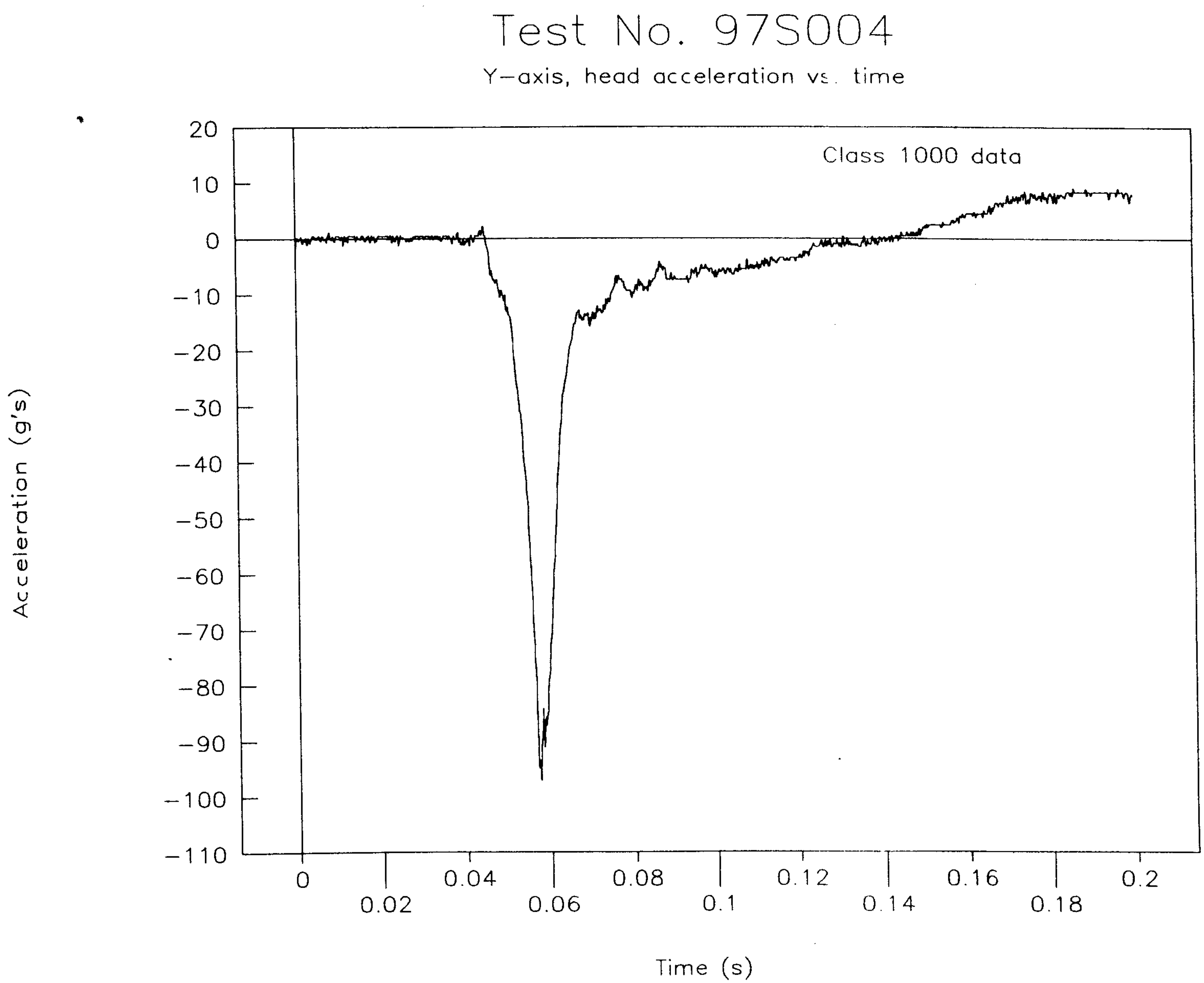


Figure 21. Acceleration vs. time, Y-axis head, test 97S004.

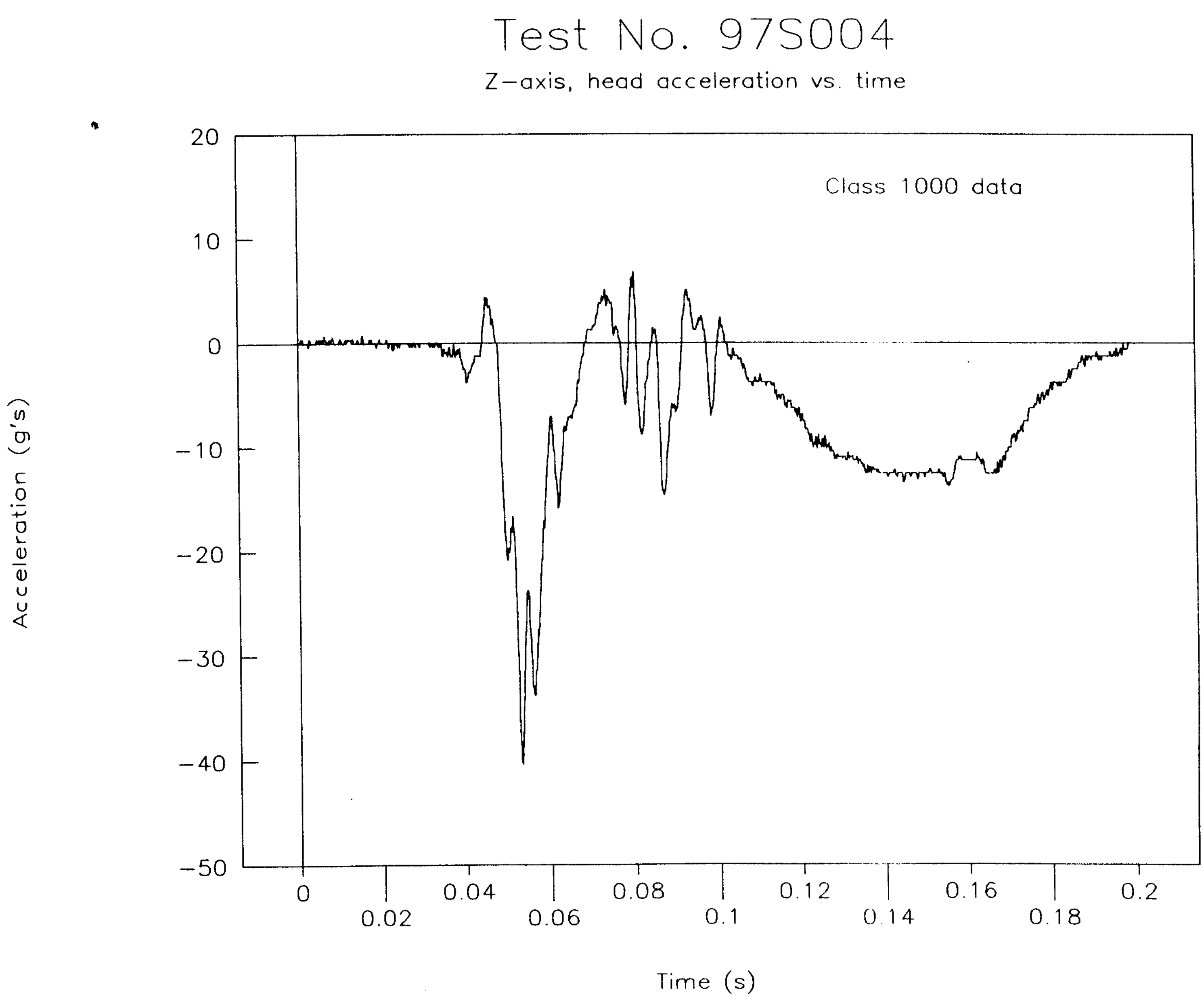


Figure 22. Acceleration vs. time, Z-axis head, test 97S004.

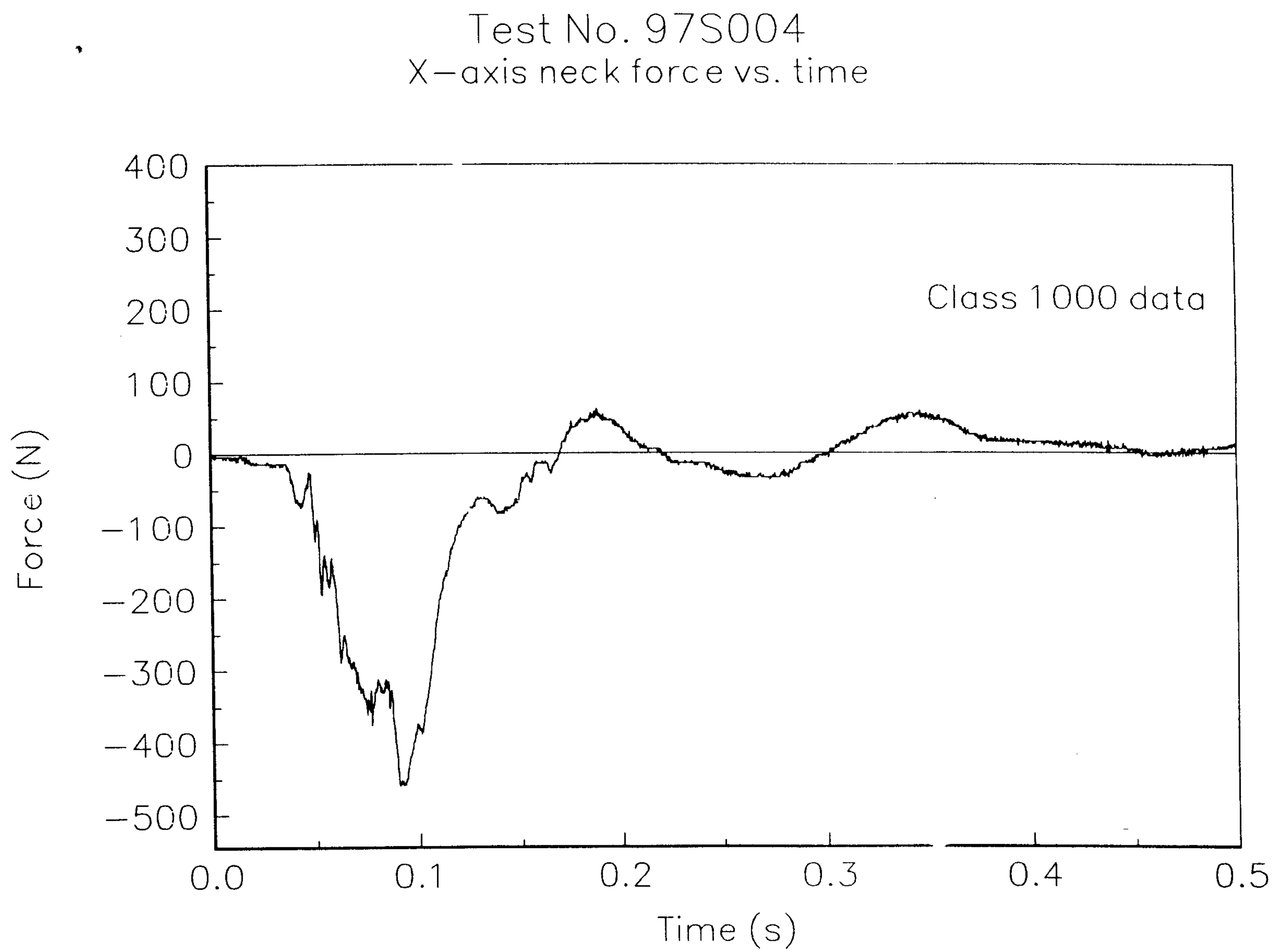


Figure 23. Force vs. time, X-axis neck, test 97S004.

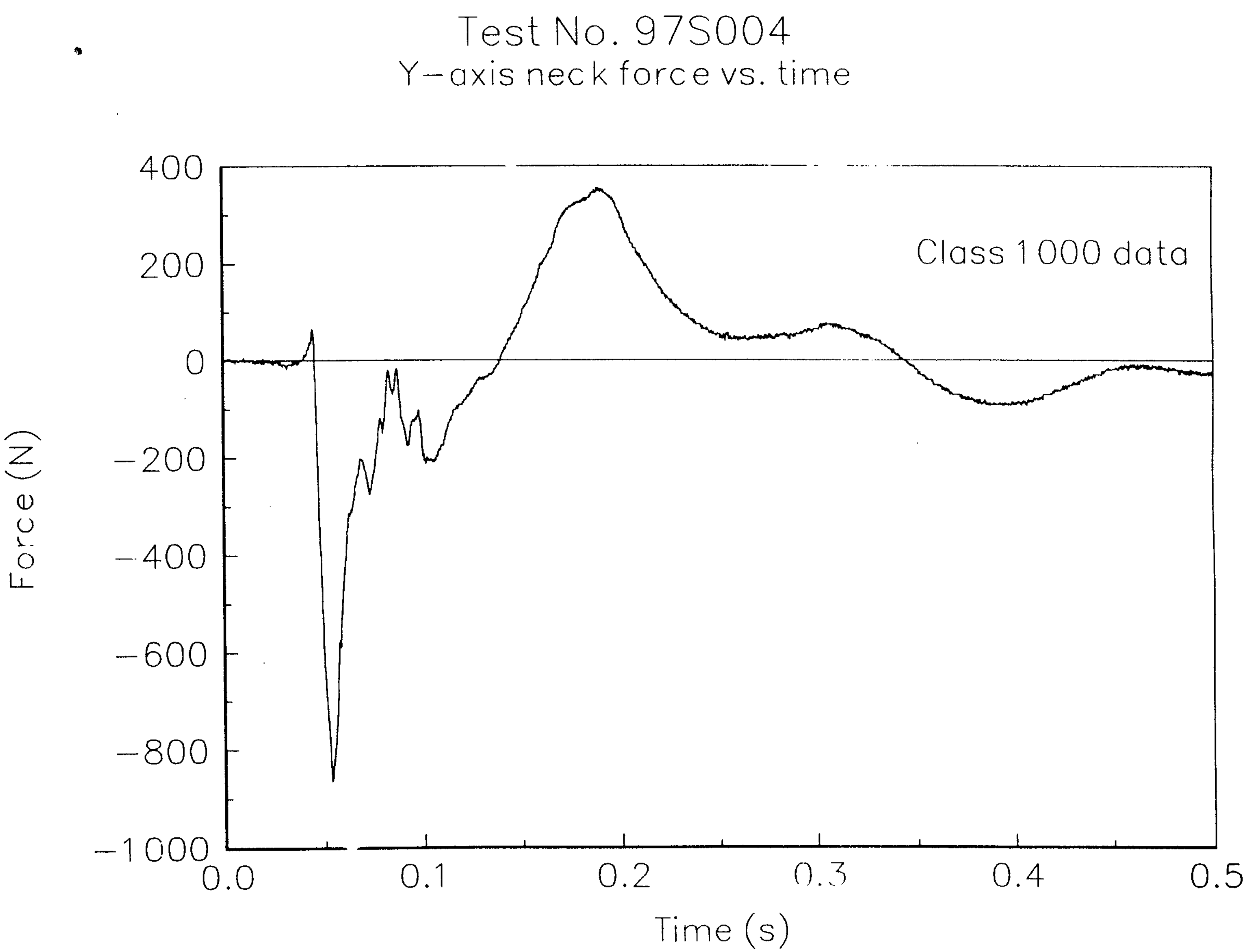


Figure 24. Force vs. time, Y-axis neck, test 97S004.

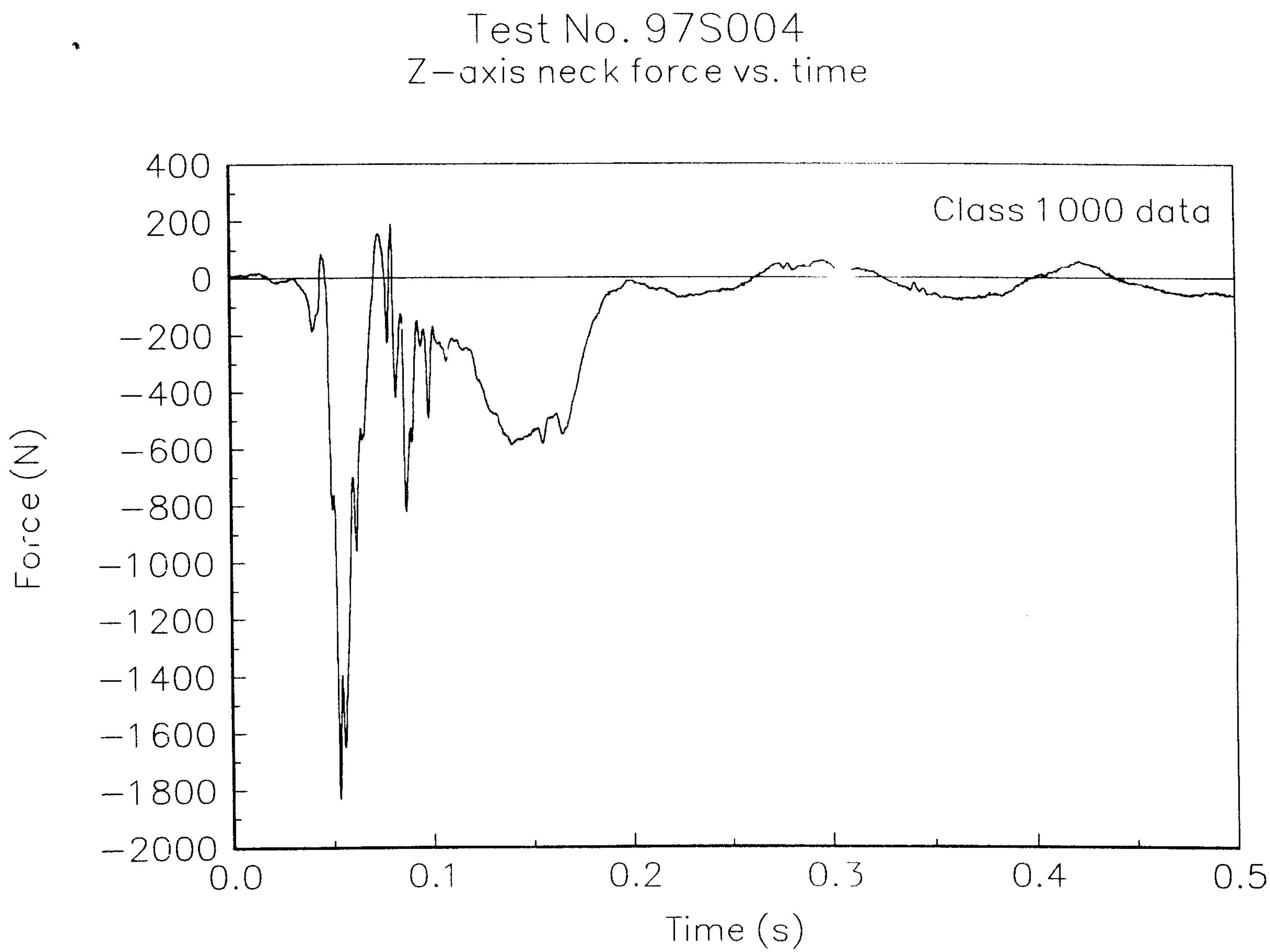


Figure 25. Force vs. time, Z-axis neck, test 97S004.

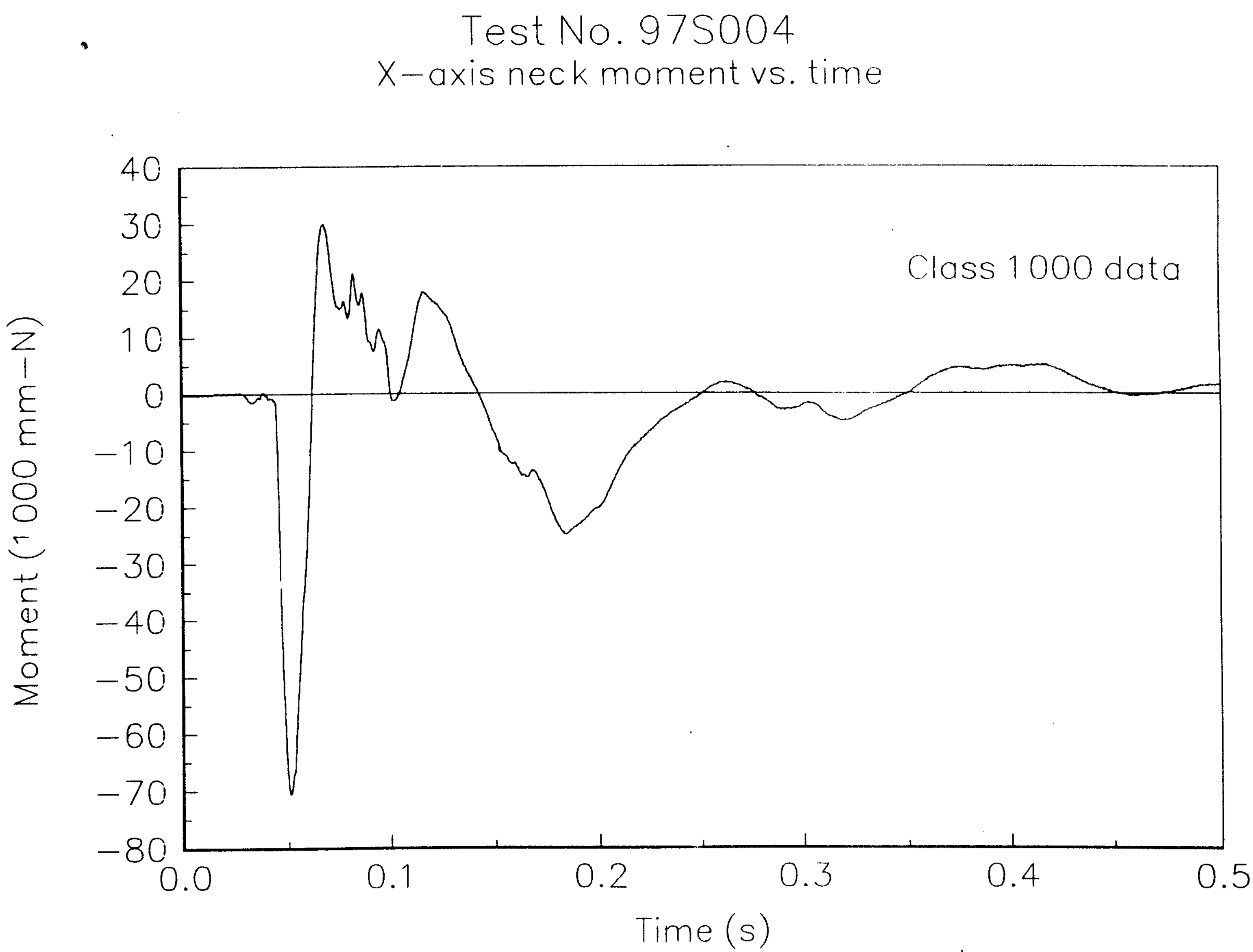


Figure 26. Moment vs. time, X-axis neck, test 97S004.

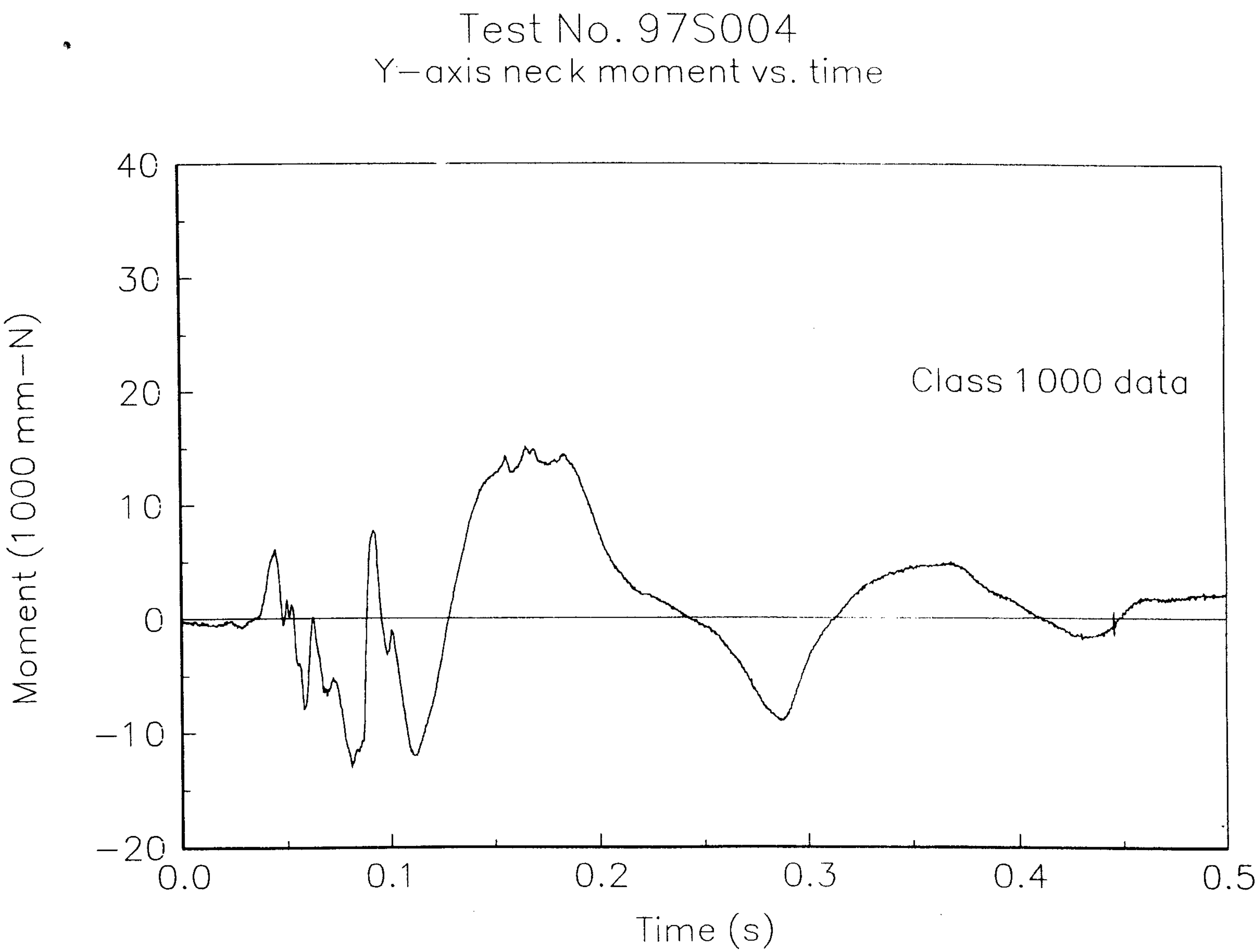


Figure 27. Moment vs. time, Y-axis neck, test 97S004.

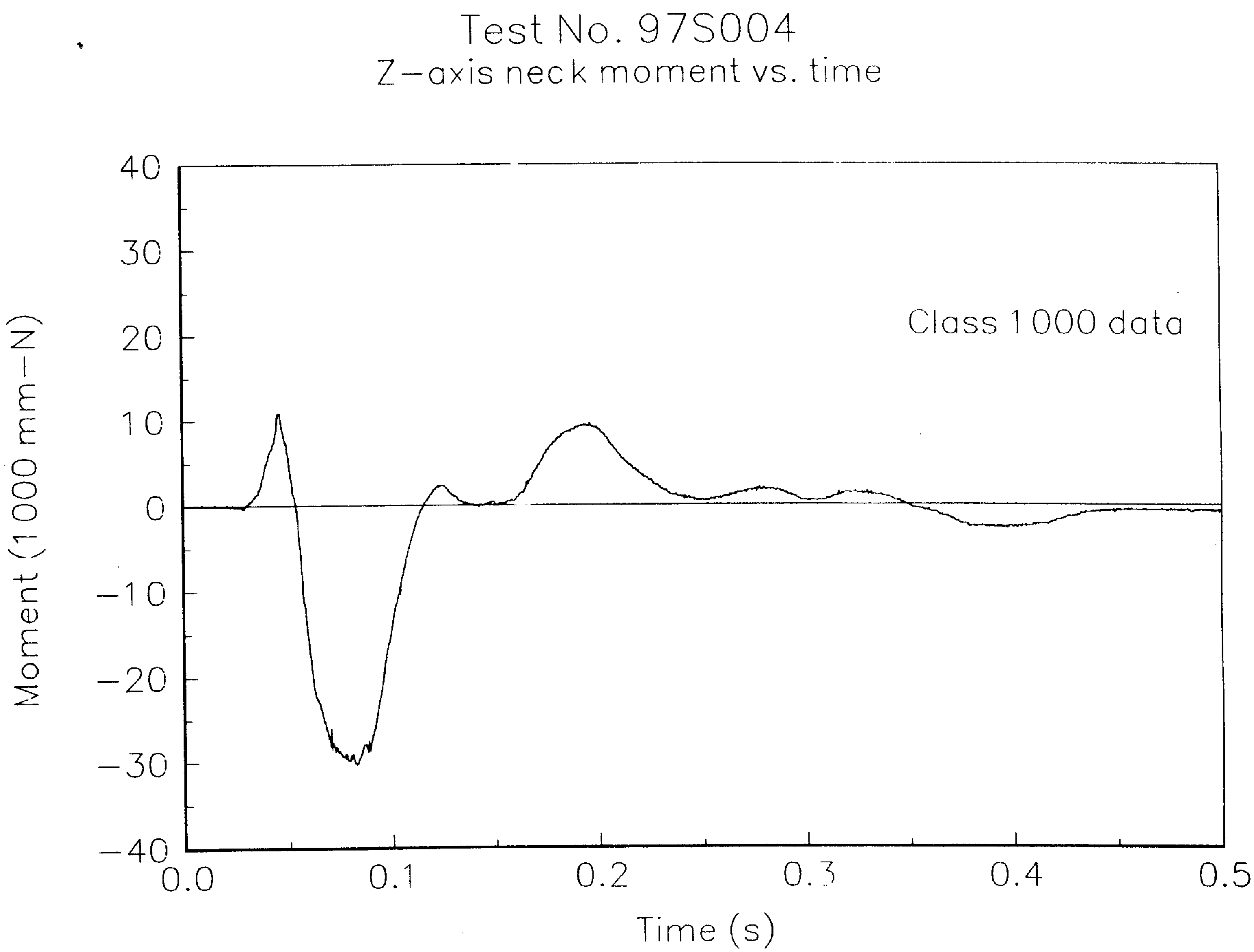


Figure 28. Moment vs. time, Z-axis neck, test 97S004.

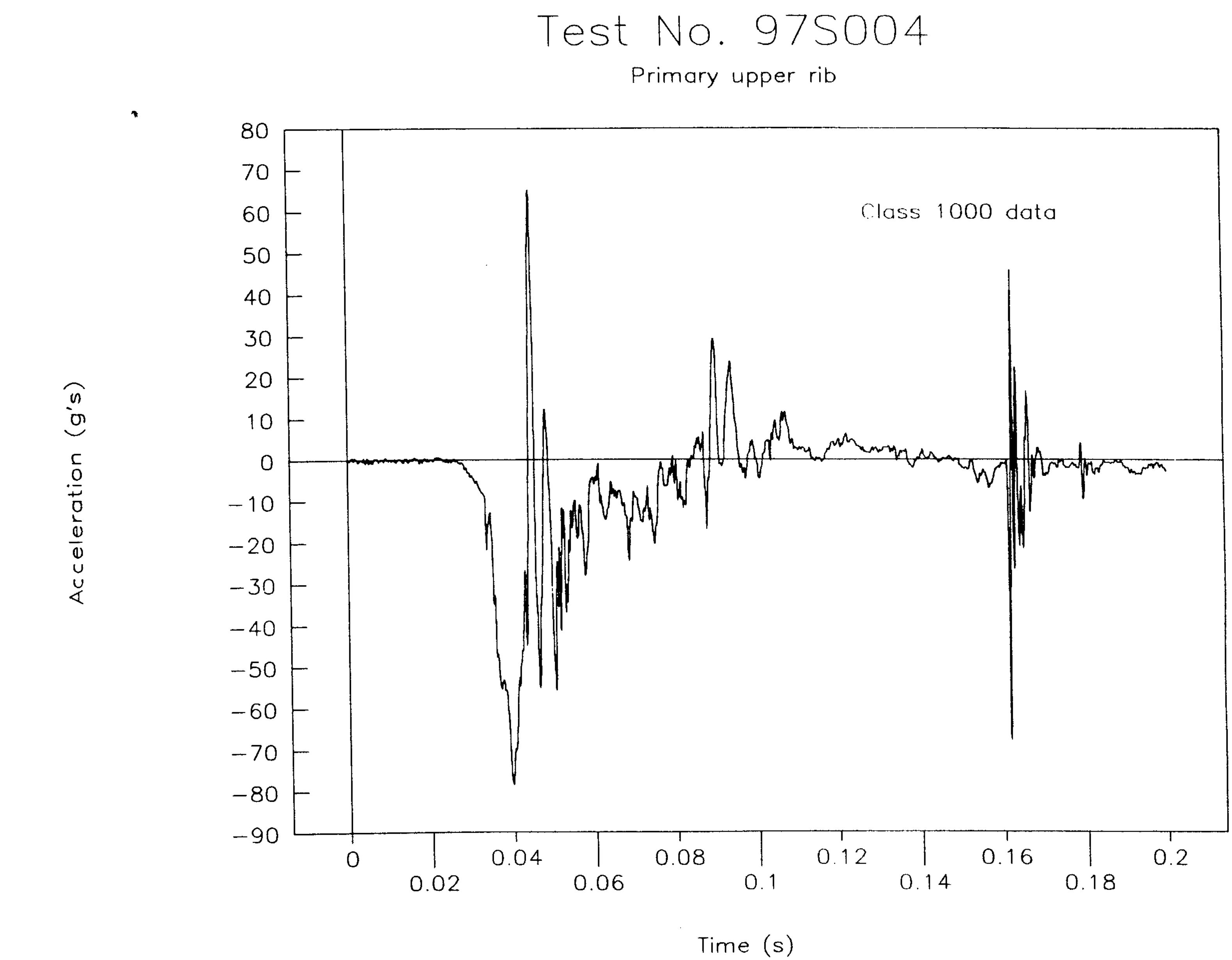


Figure 29. Acceleration vs. time, primary upper rib, test 97S004.

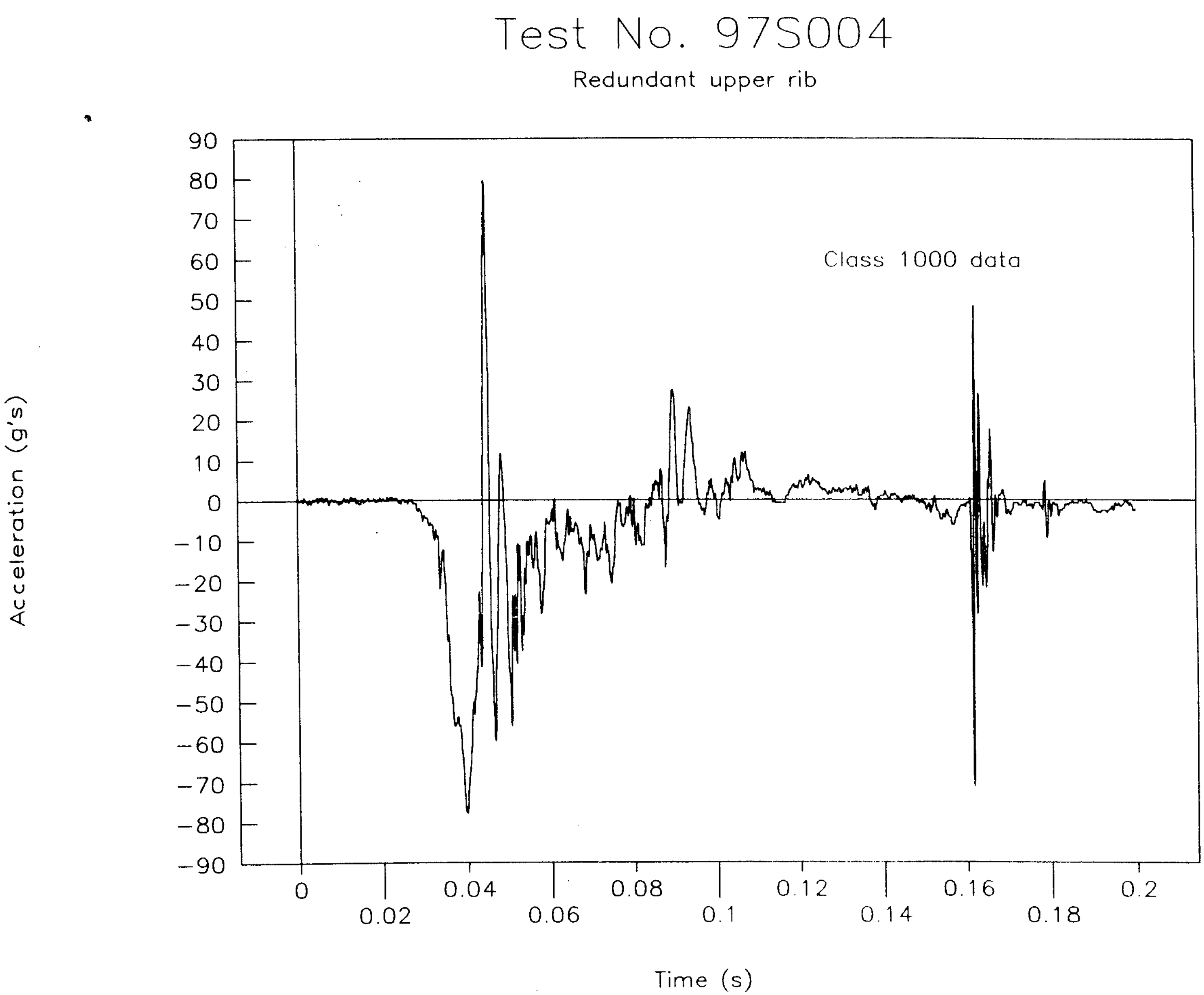


Figure 30. Acceleration vs. time, redundant upper rib, test 97S004.

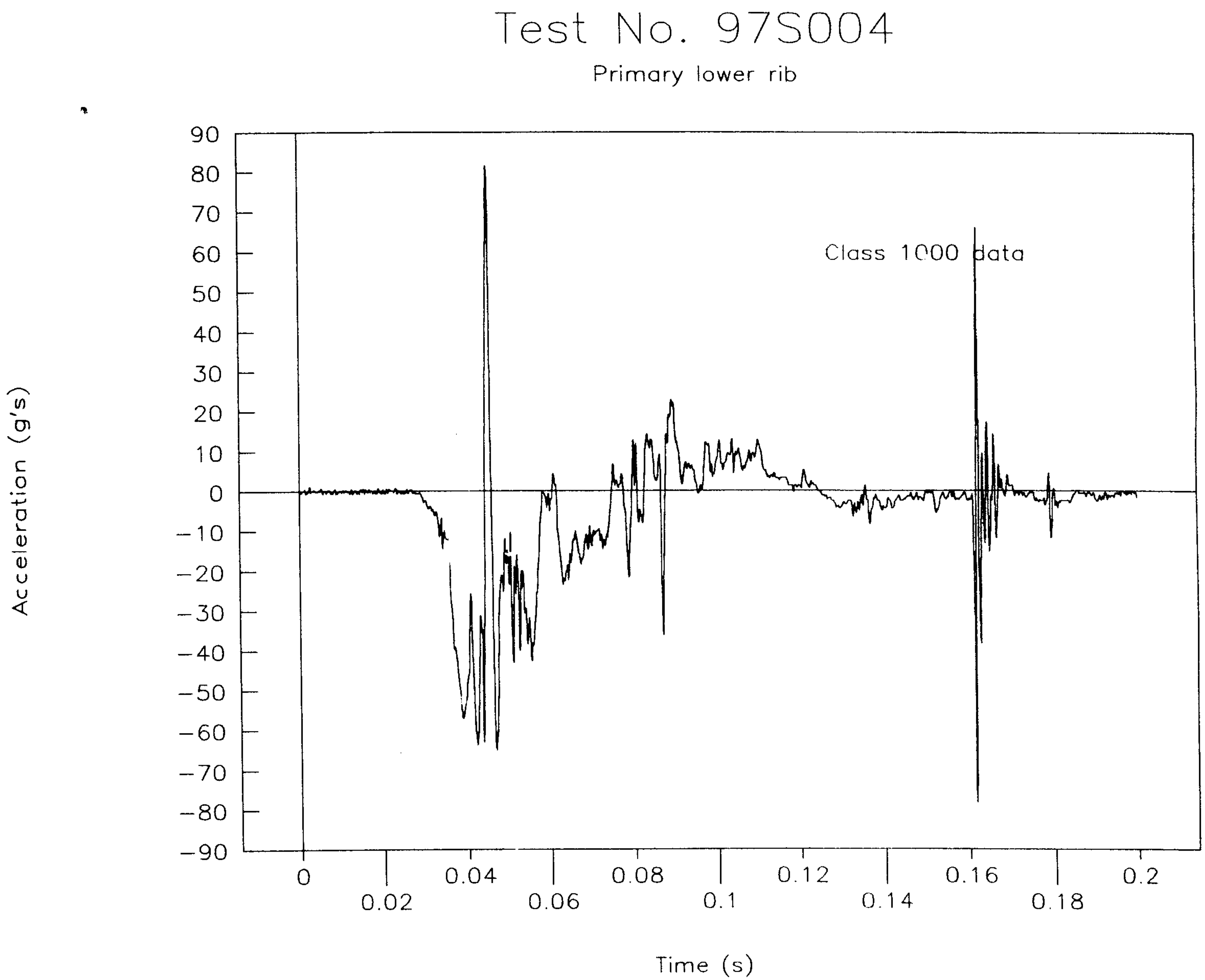


Figure 31. Acceleration vs. time, primary lower rib, test 97S004.

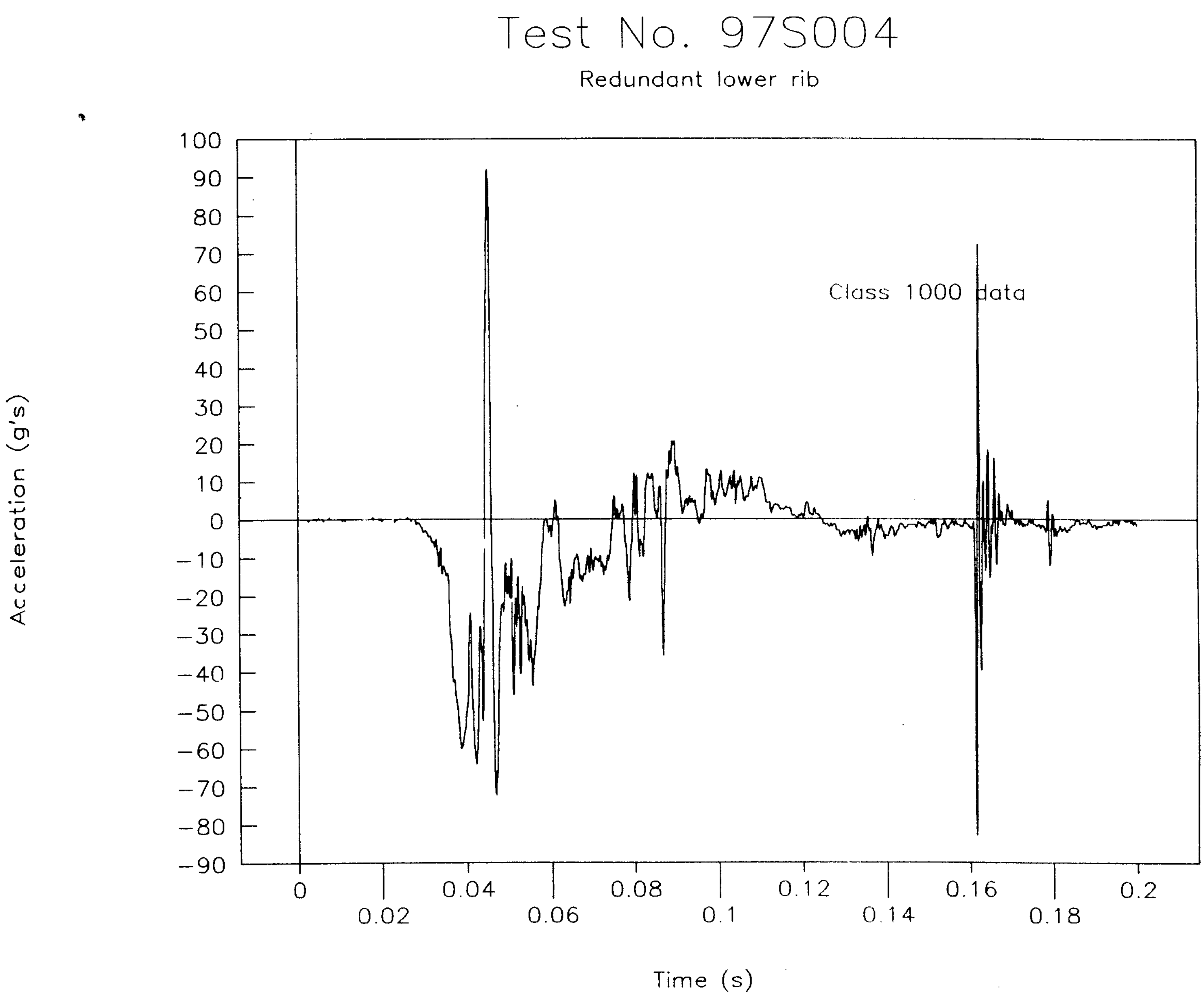


Figure 32. Acceleration vs. time, redundant lower rib, test 97S004.

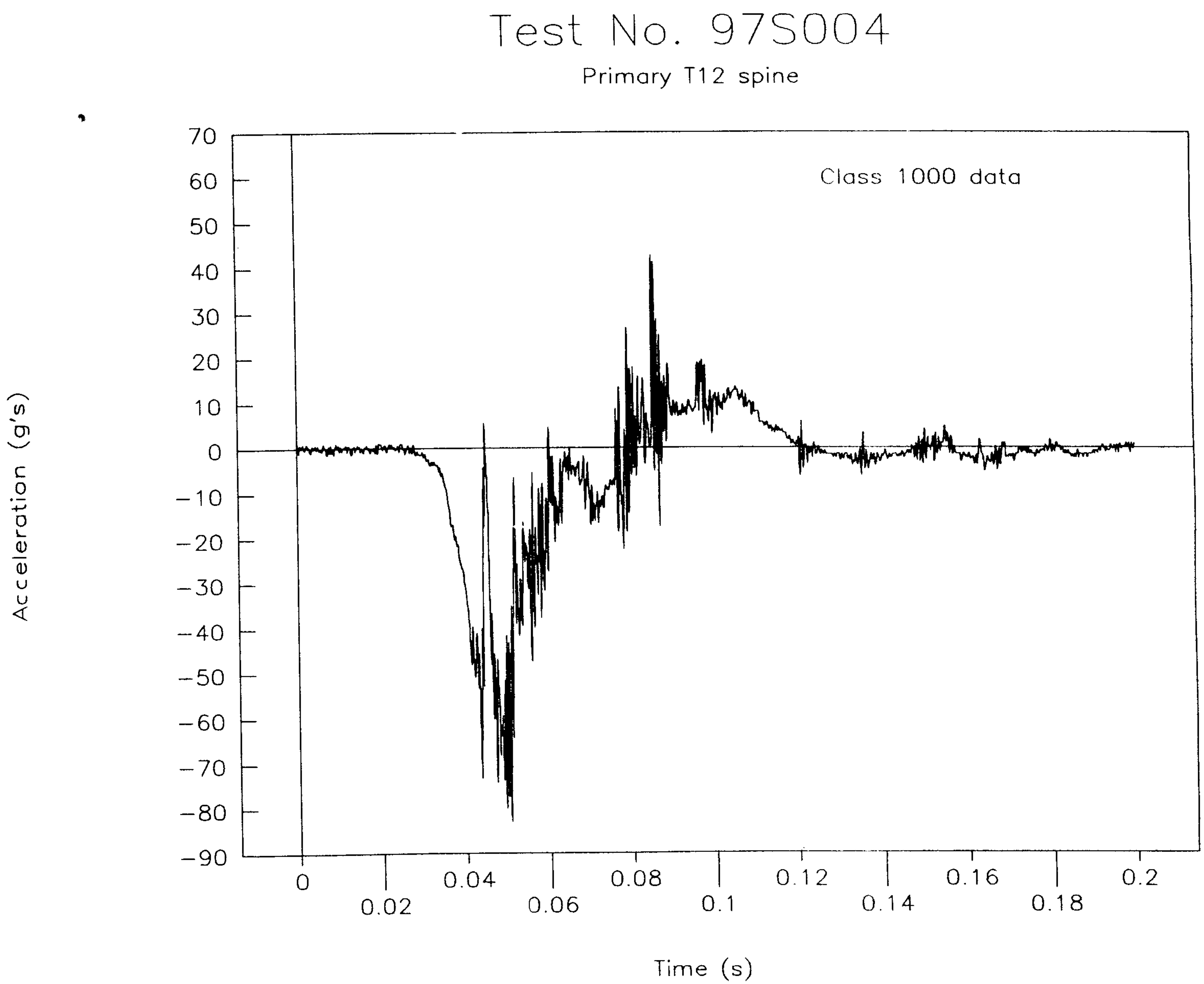


Figure 33. Acceleration vs. time, primary T12 spine, test 97S004.

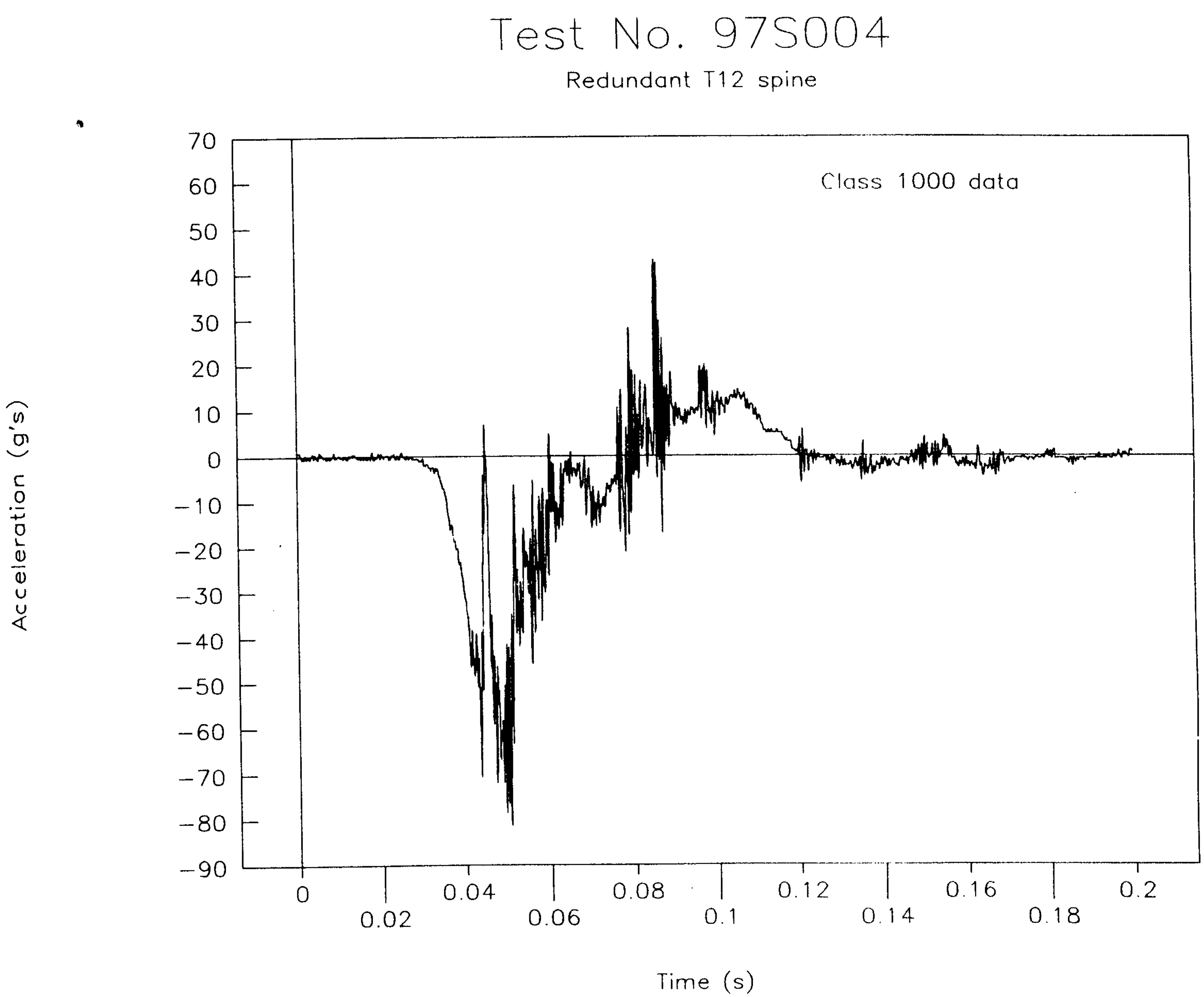


Figure 34. Acceleration vs. time, redundant T12 spine, test 97S004.

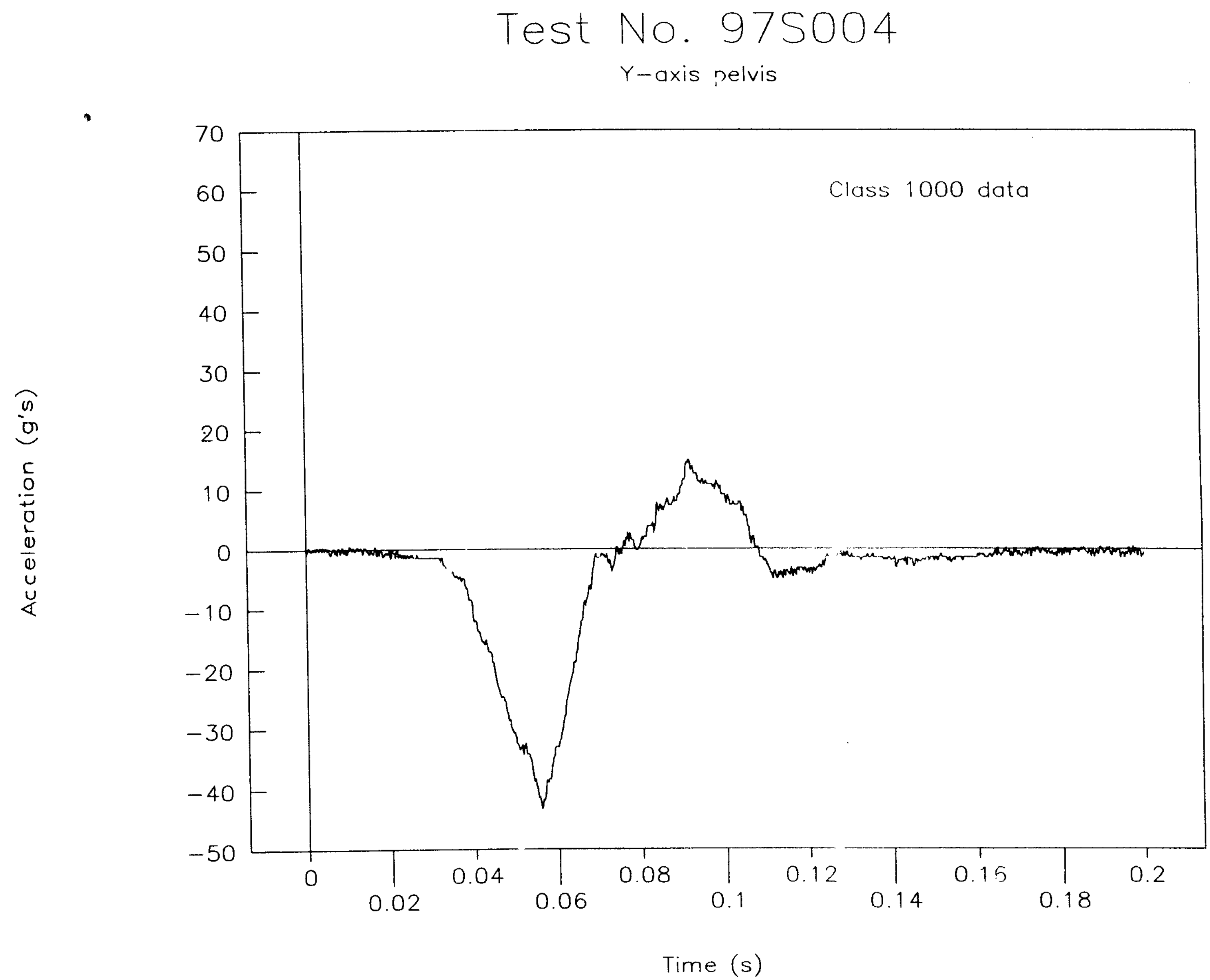


Figure 35. Acceleration vs. time, Y-axis pelvis, test 97S004.

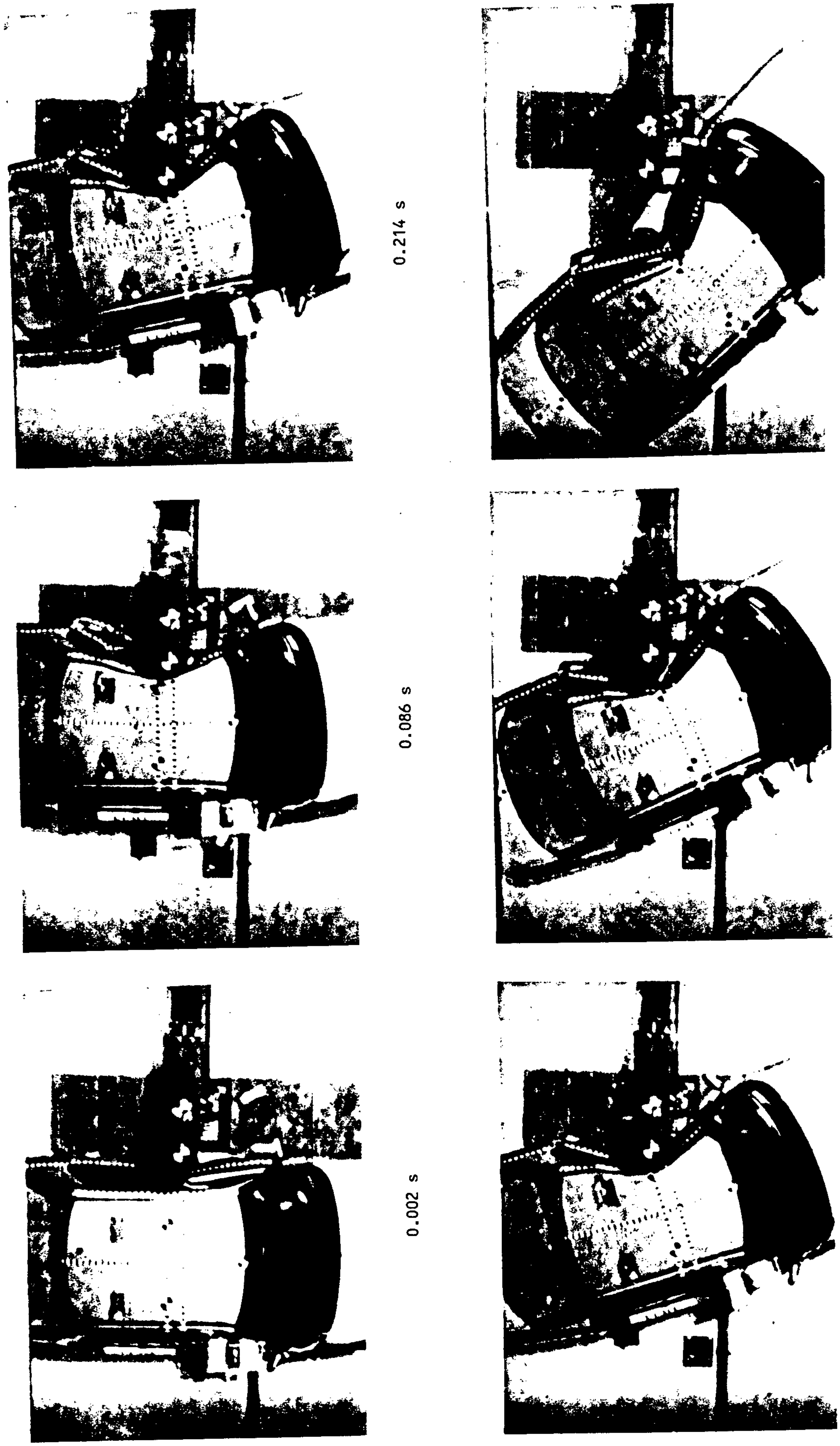


Figure 36. Test photographs during impact, test 97S004.

0.028 s

0.038s

0.048 s

0.056 s

0.072 s

0.098 s

Figure 36. Test photographs during impact, test 97S004 (continued).

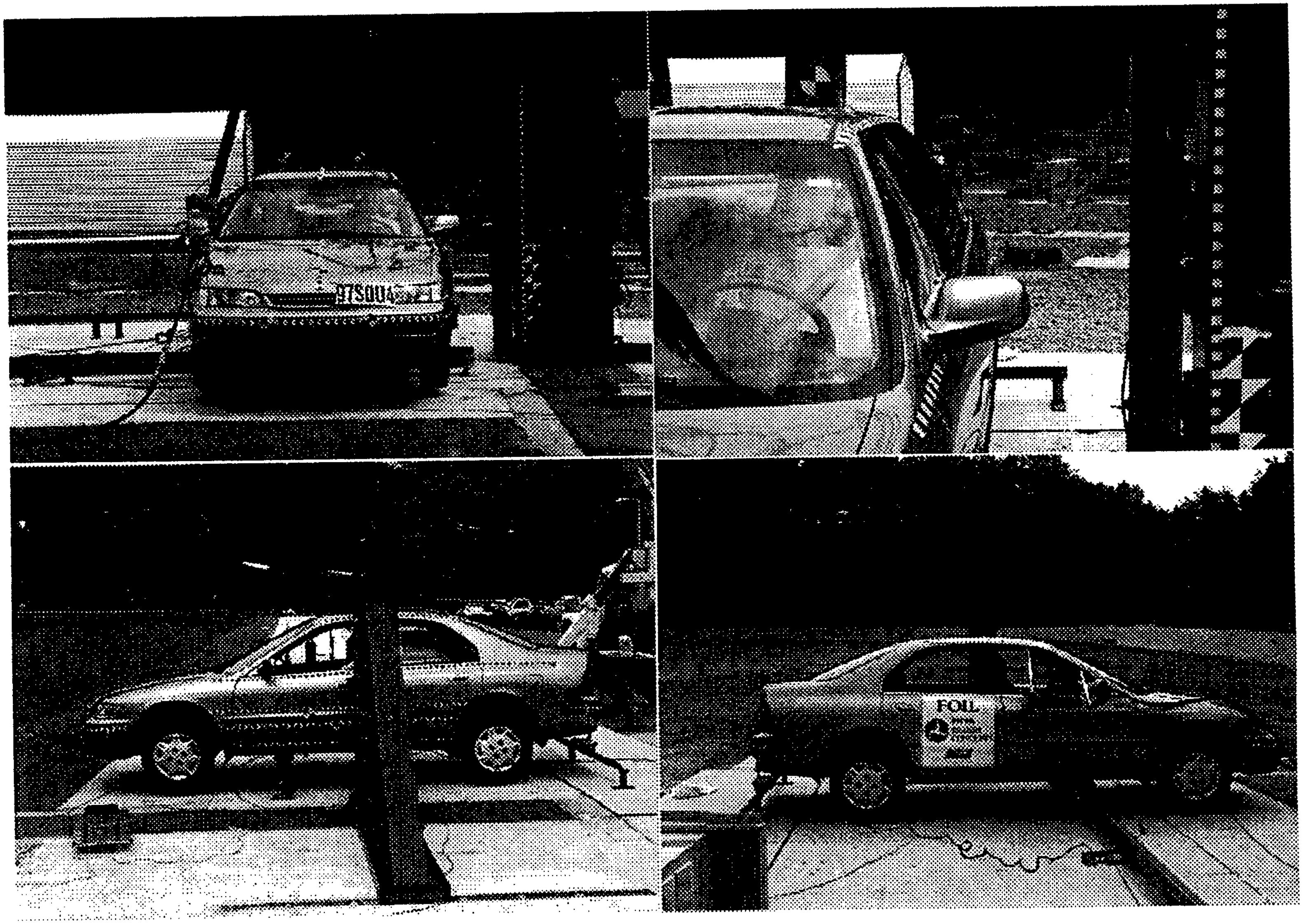


Figure 37. Pretest photographs, test 97S004.

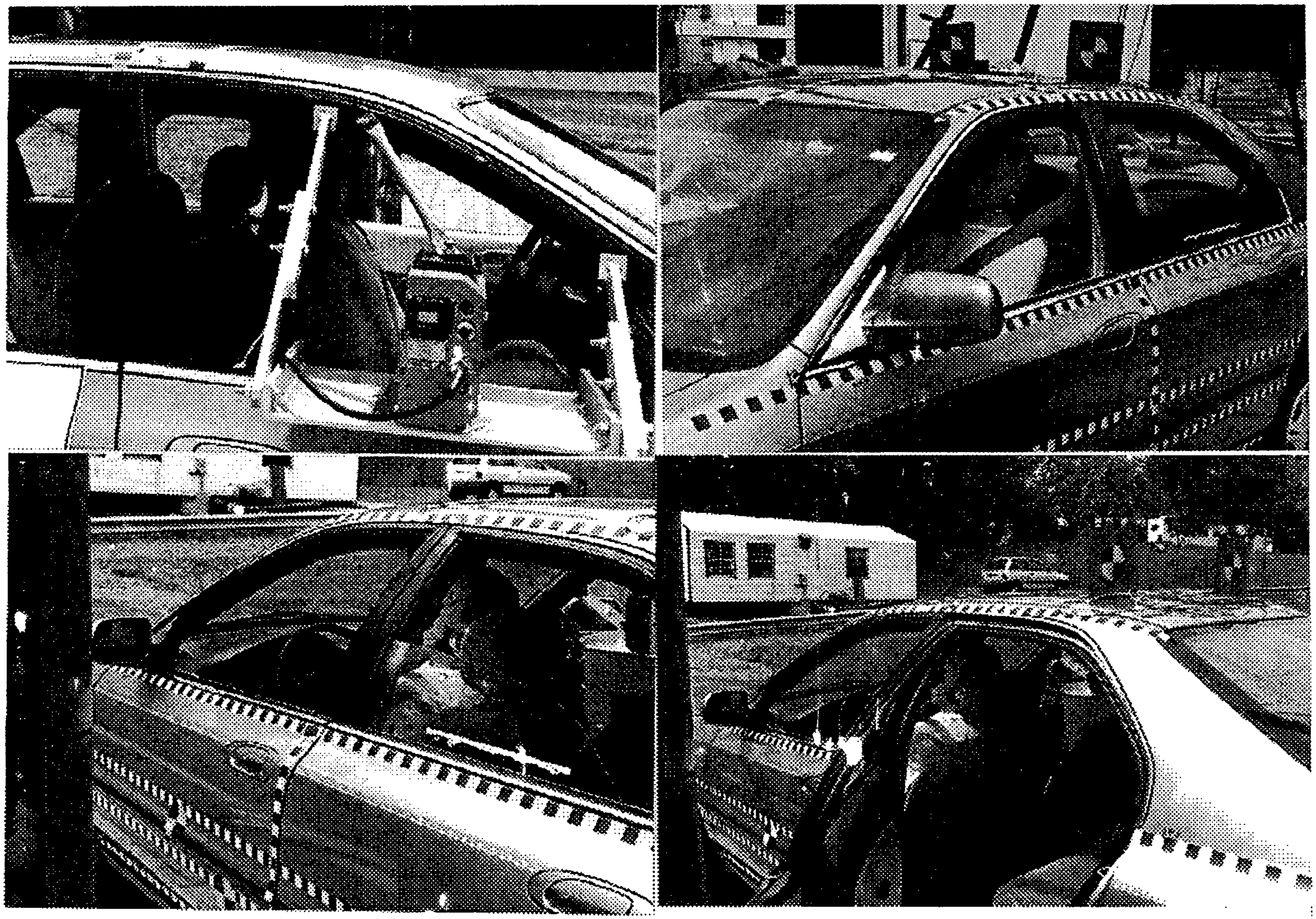


Figure 37. Pretest photographs, test 97S004 (continued).

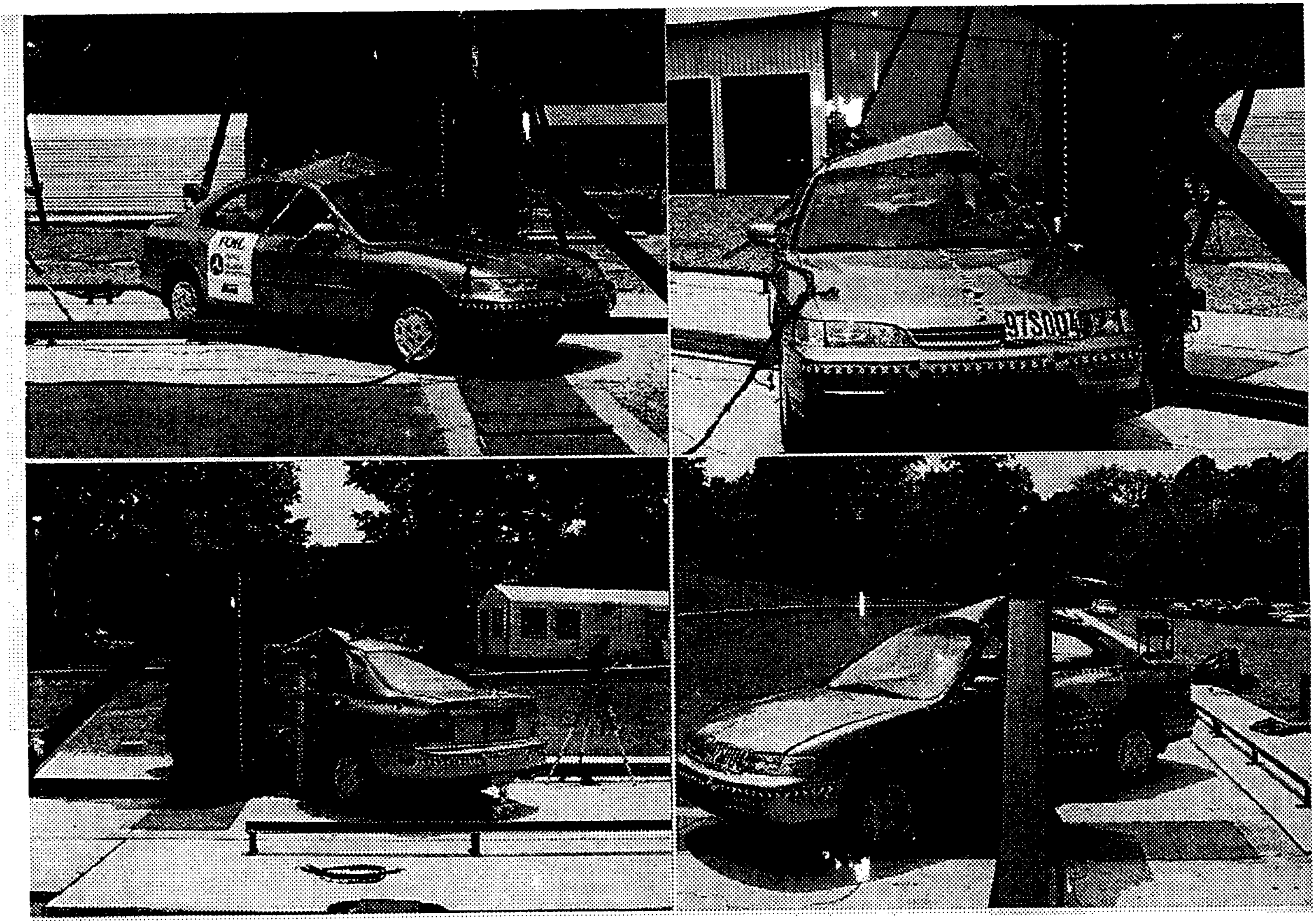


Figure 38. Post-test photographs, test 97S004.

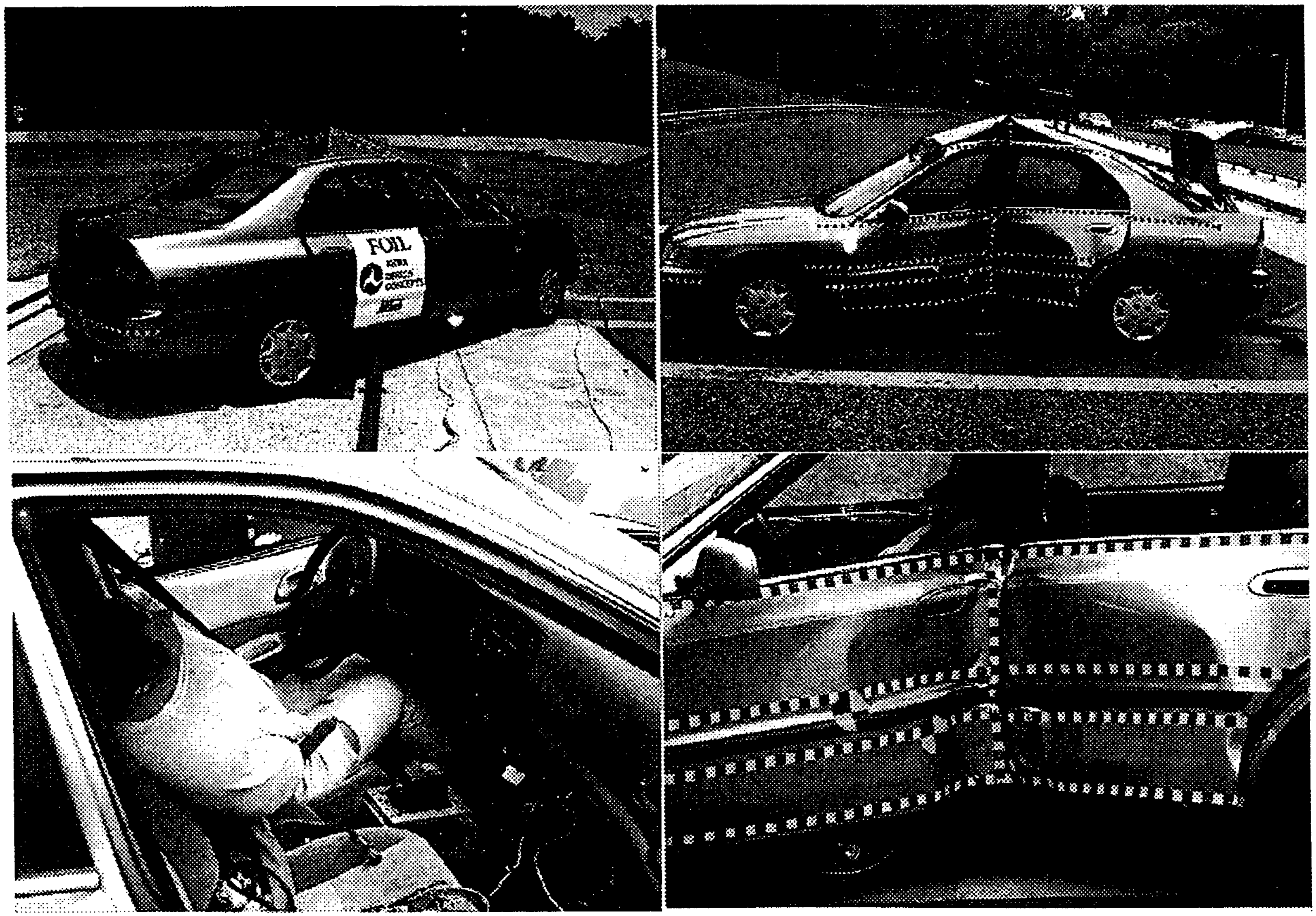


Figure 38. Post-test photographs, test 97S004 (continued).

Figure 38. Post-test photographs, test 97S004 (continued).

APPENDIX D. DATA PLOTS FROM RIGID POLE LOAD CELLS.

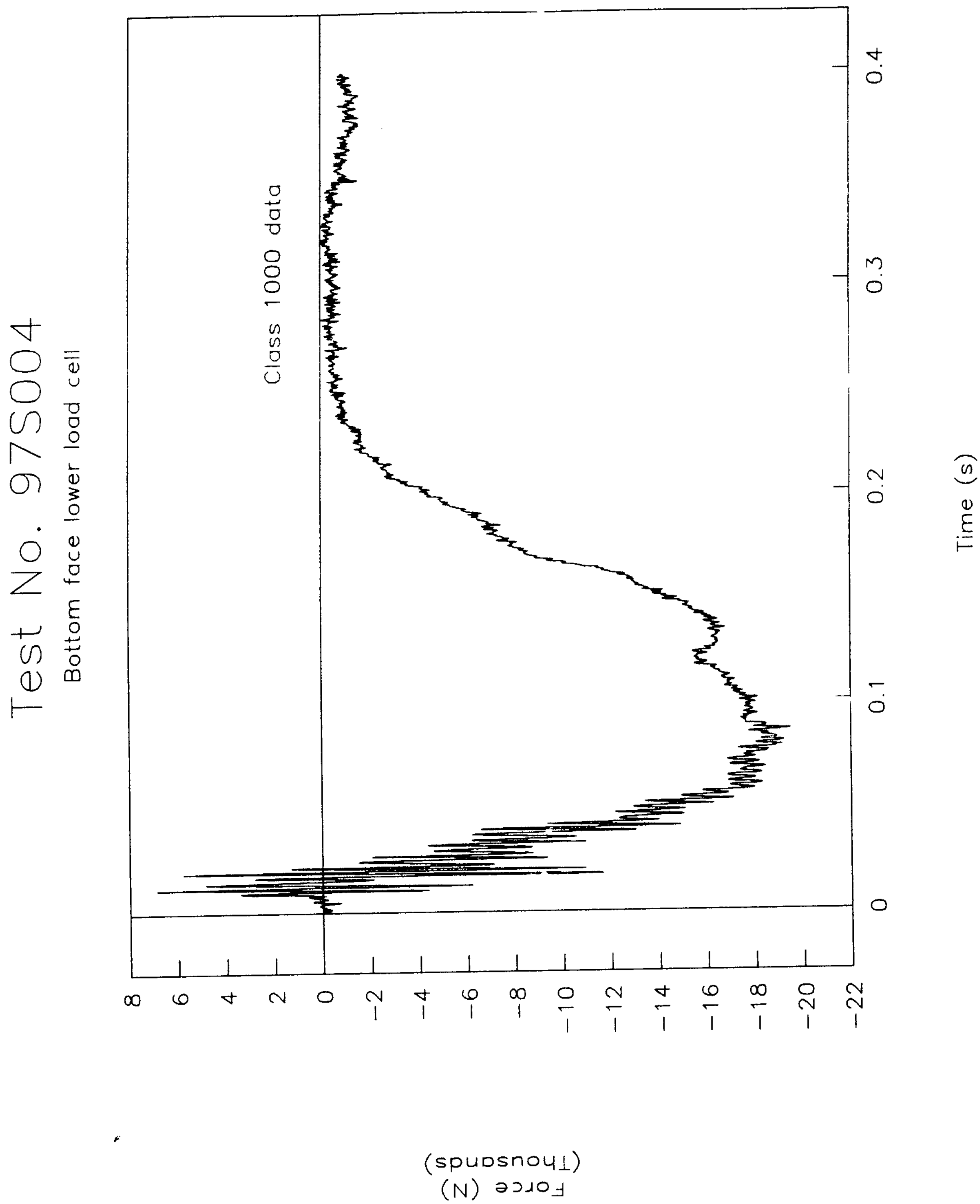


Figure 39. Rigid pole, force vs. time, bottom face lower load cell, test 97S004.

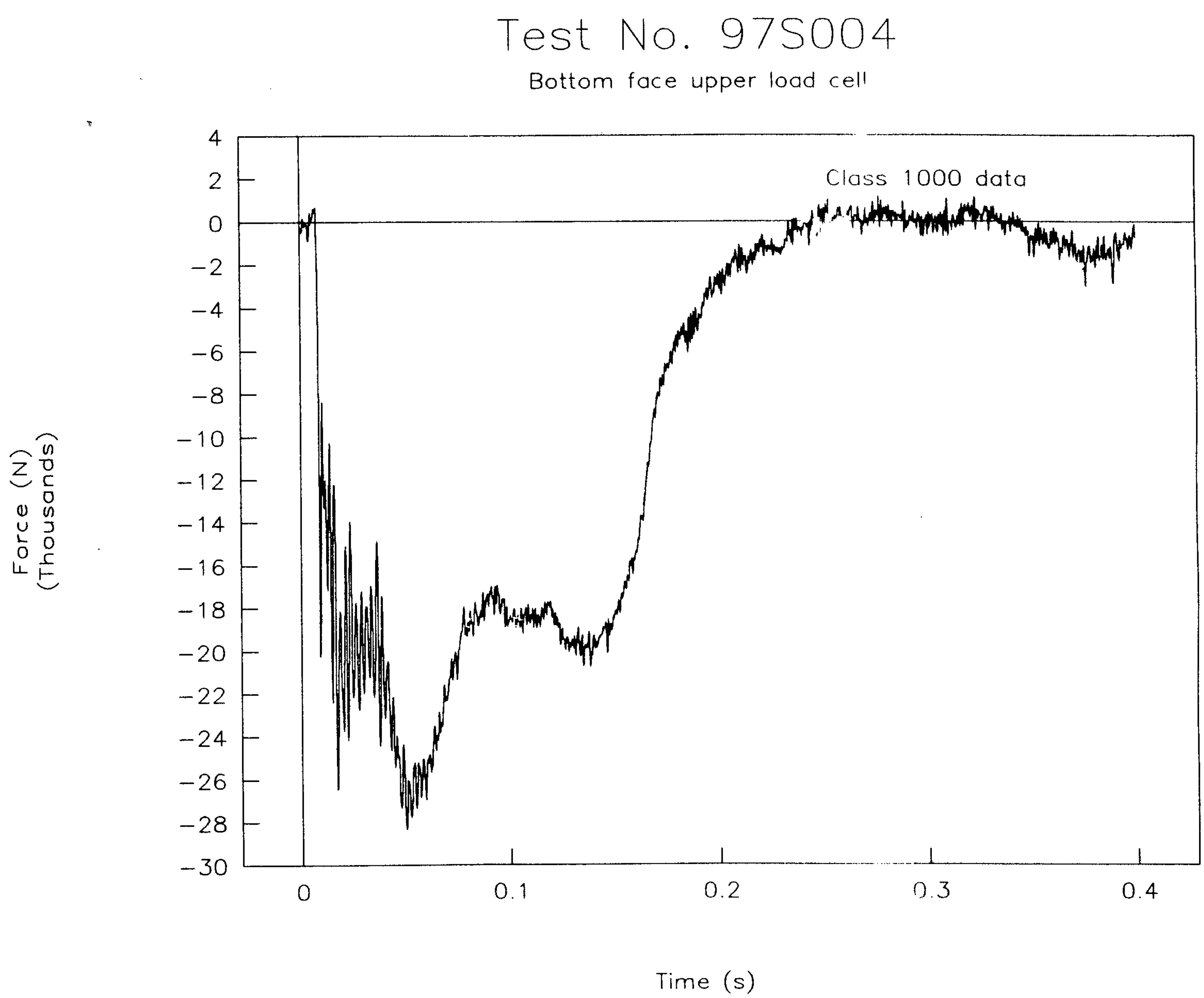


Figure 40. Rigid pole, force vs. time, bottom face upper load cell, test 97S004.

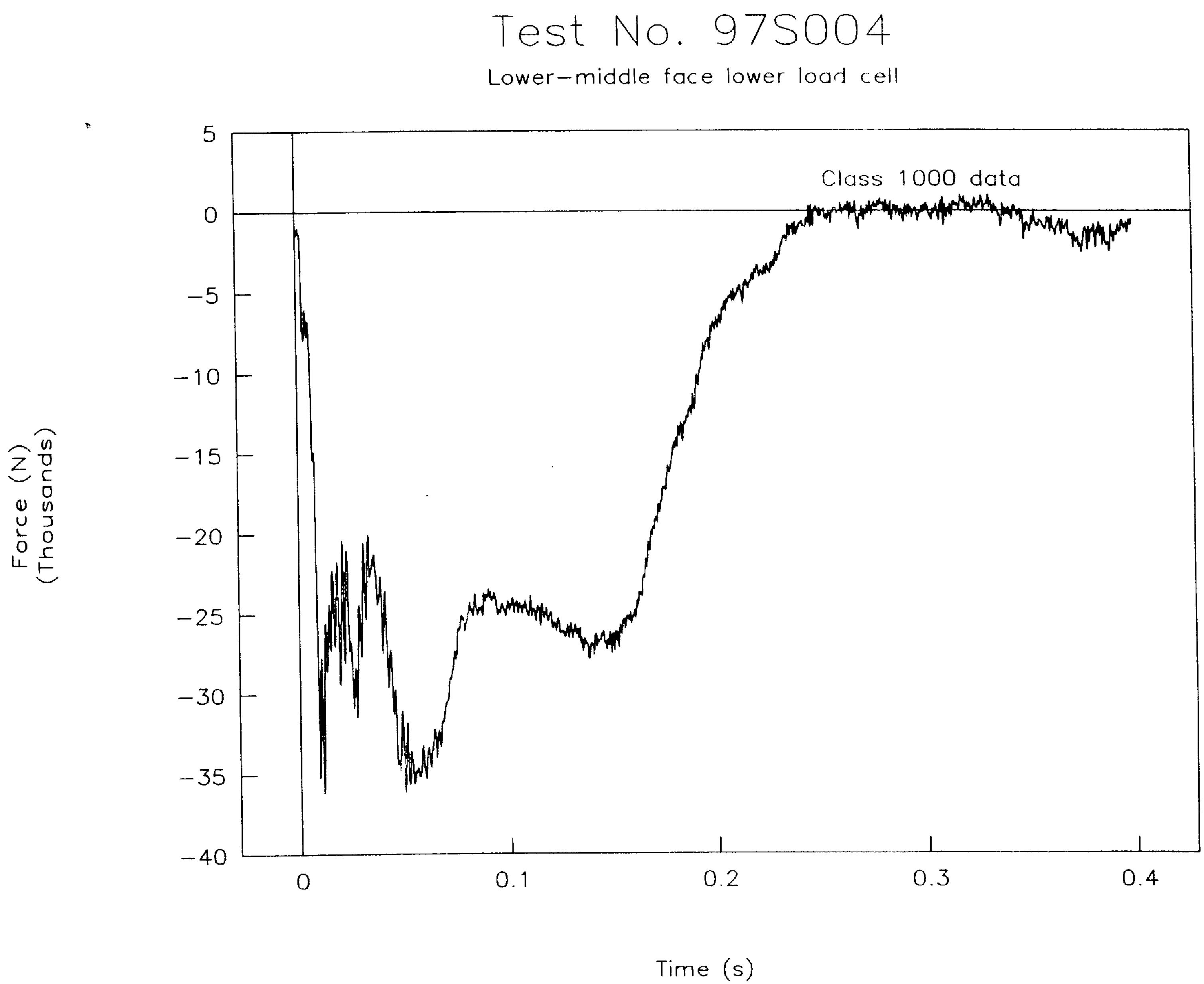


Figure 41. Rigid pole, force vs. time, lower-middle face lower load cell, test 97S004.

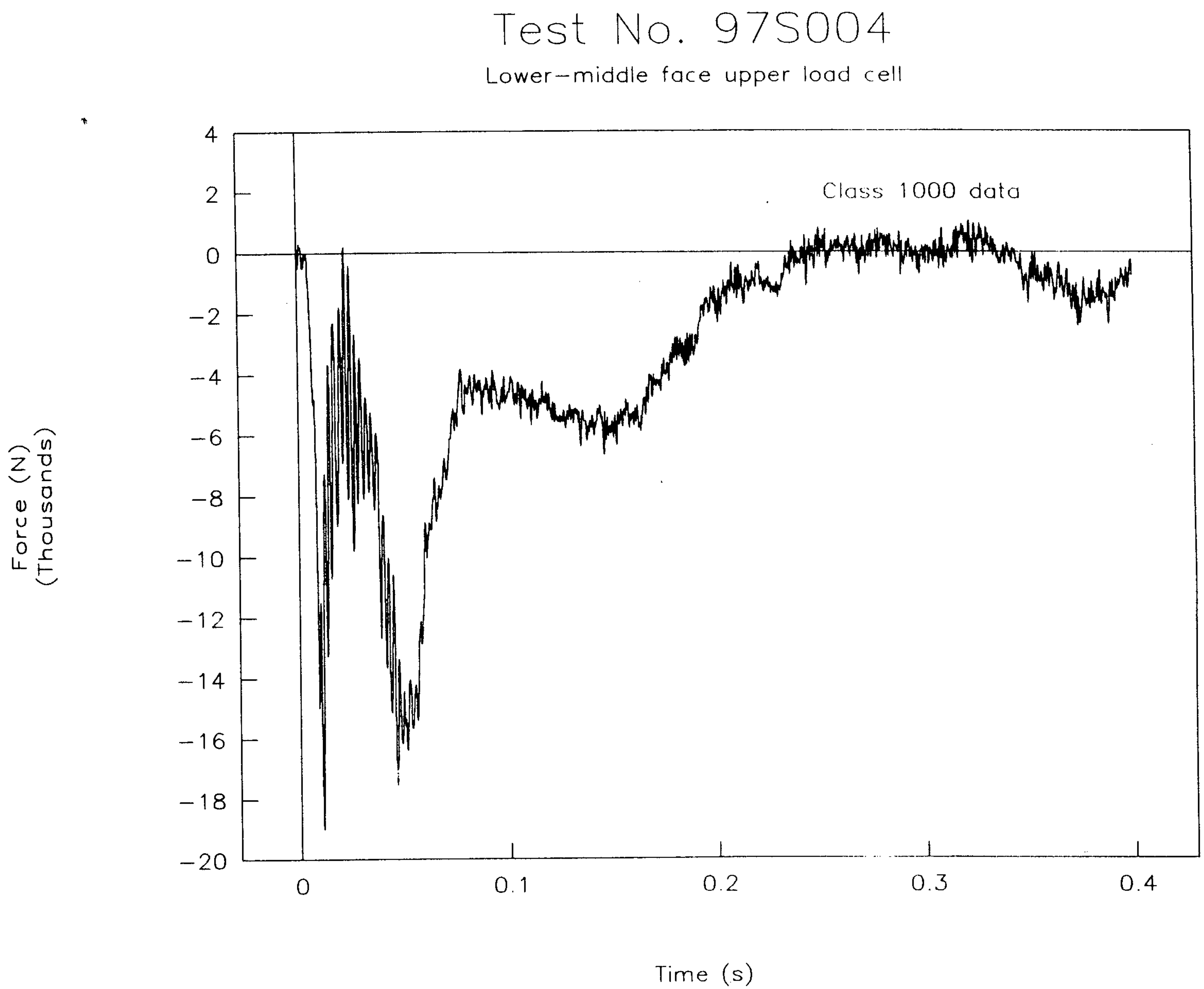


Figure 42. Rigid pole, force vs. time, lower-middle face upper load cell, test 97S004.

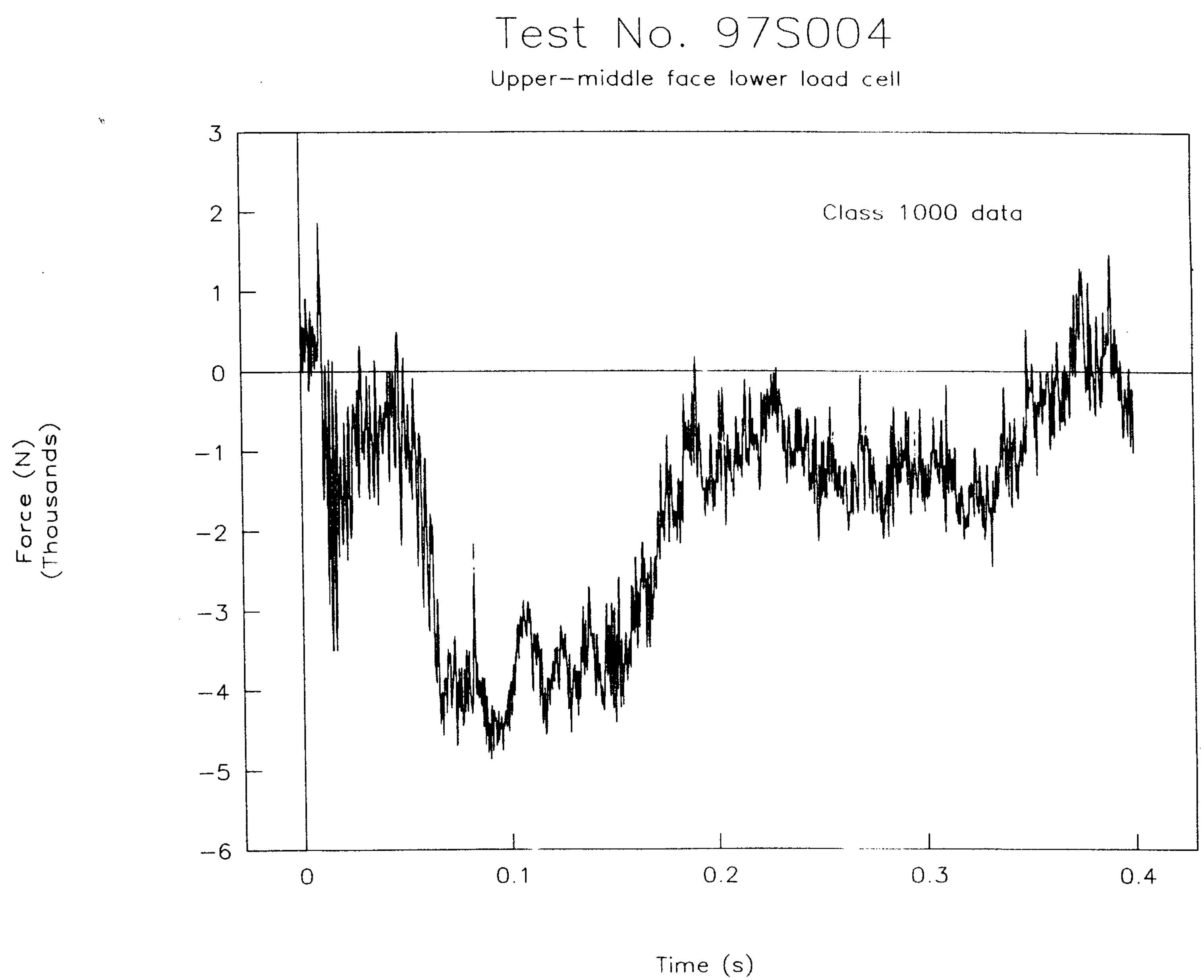


Figure 43. Rigid pole, force vs. time, upper-middle face lower load cell, test 97S004.

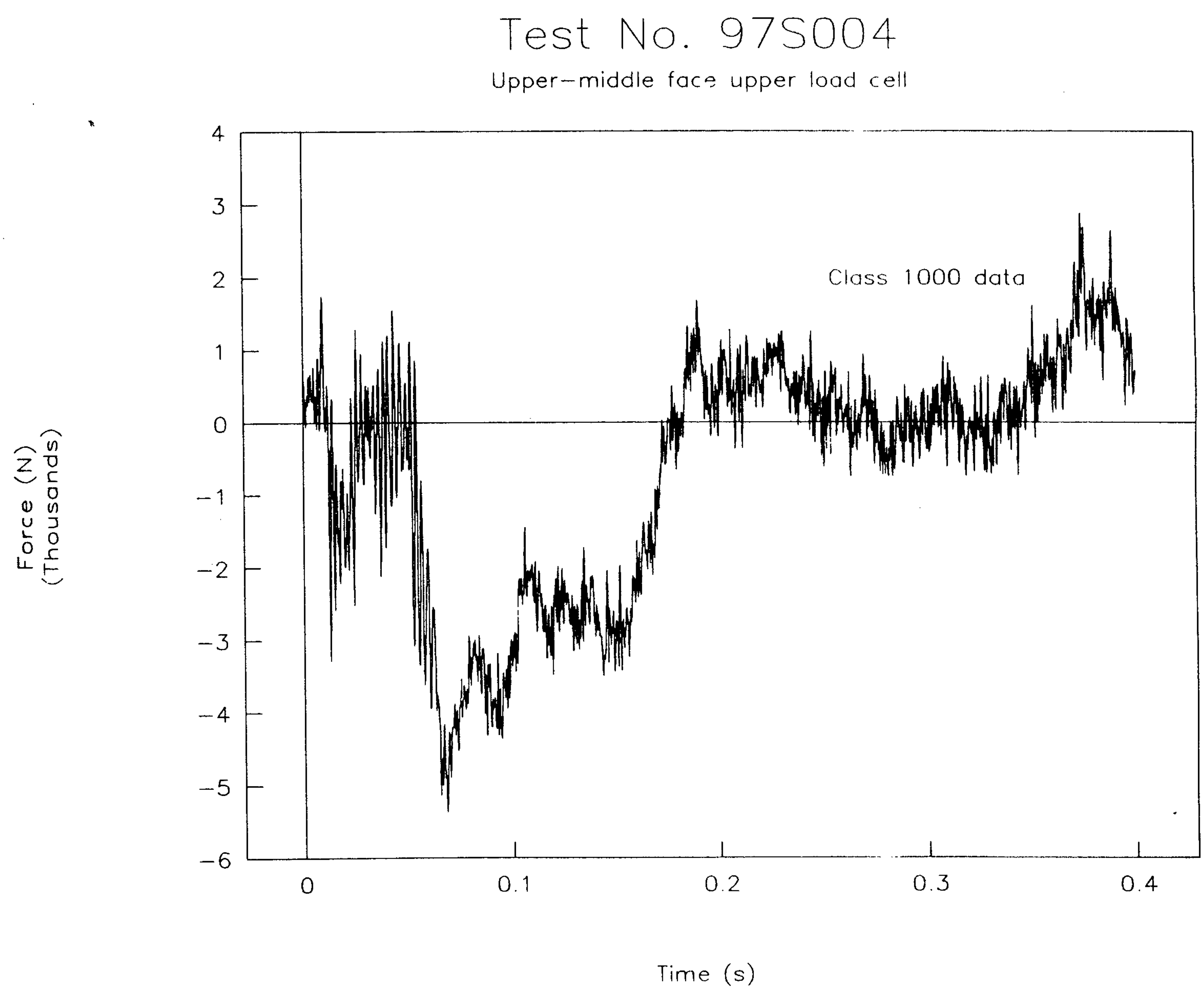


Figure 44. Rigid pole, force vs. time, upper-middle face upper load cell, test 97S004.

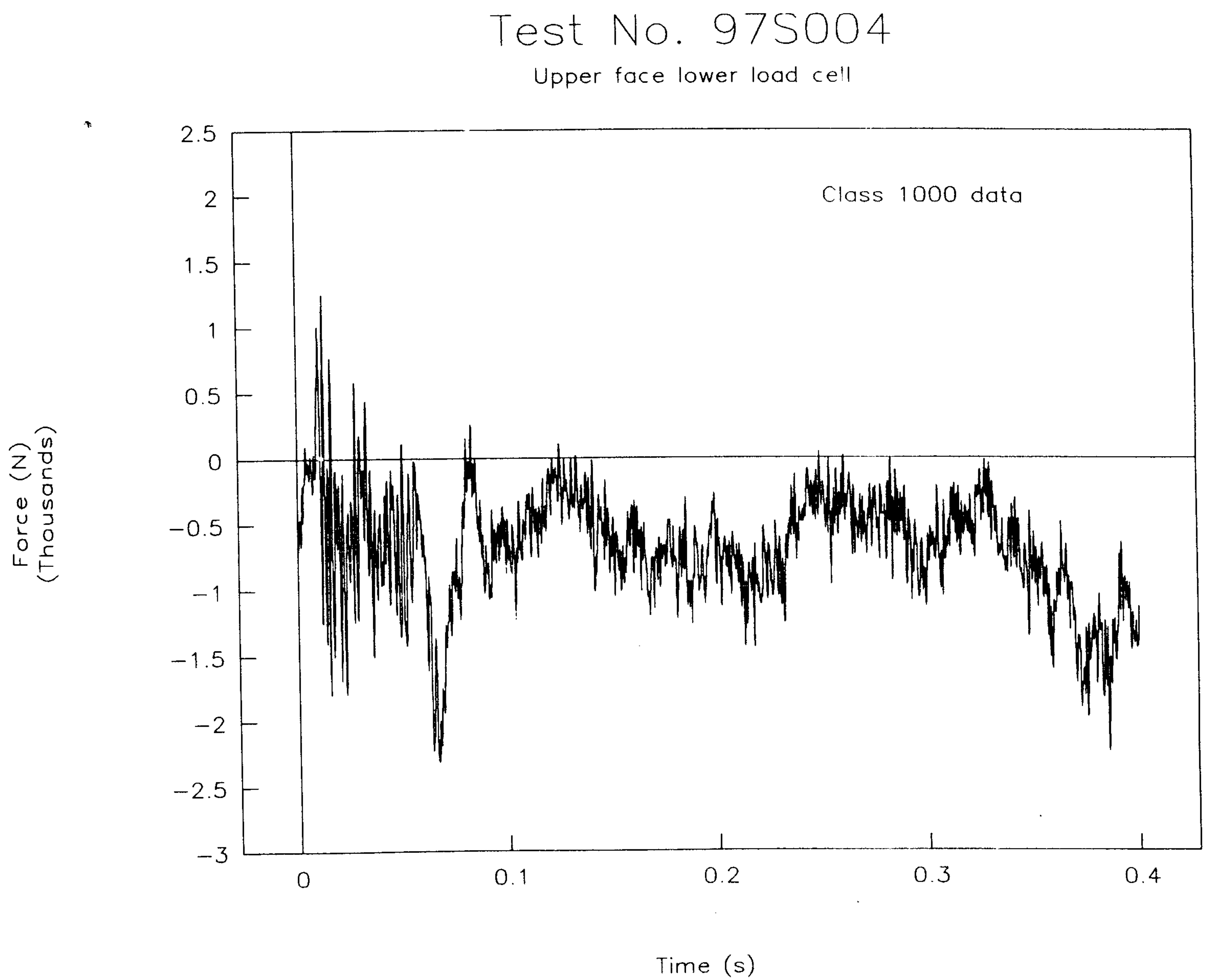


Figure 45. Rigid pole, force vs. time, upper face lower load cell, test 97S004.

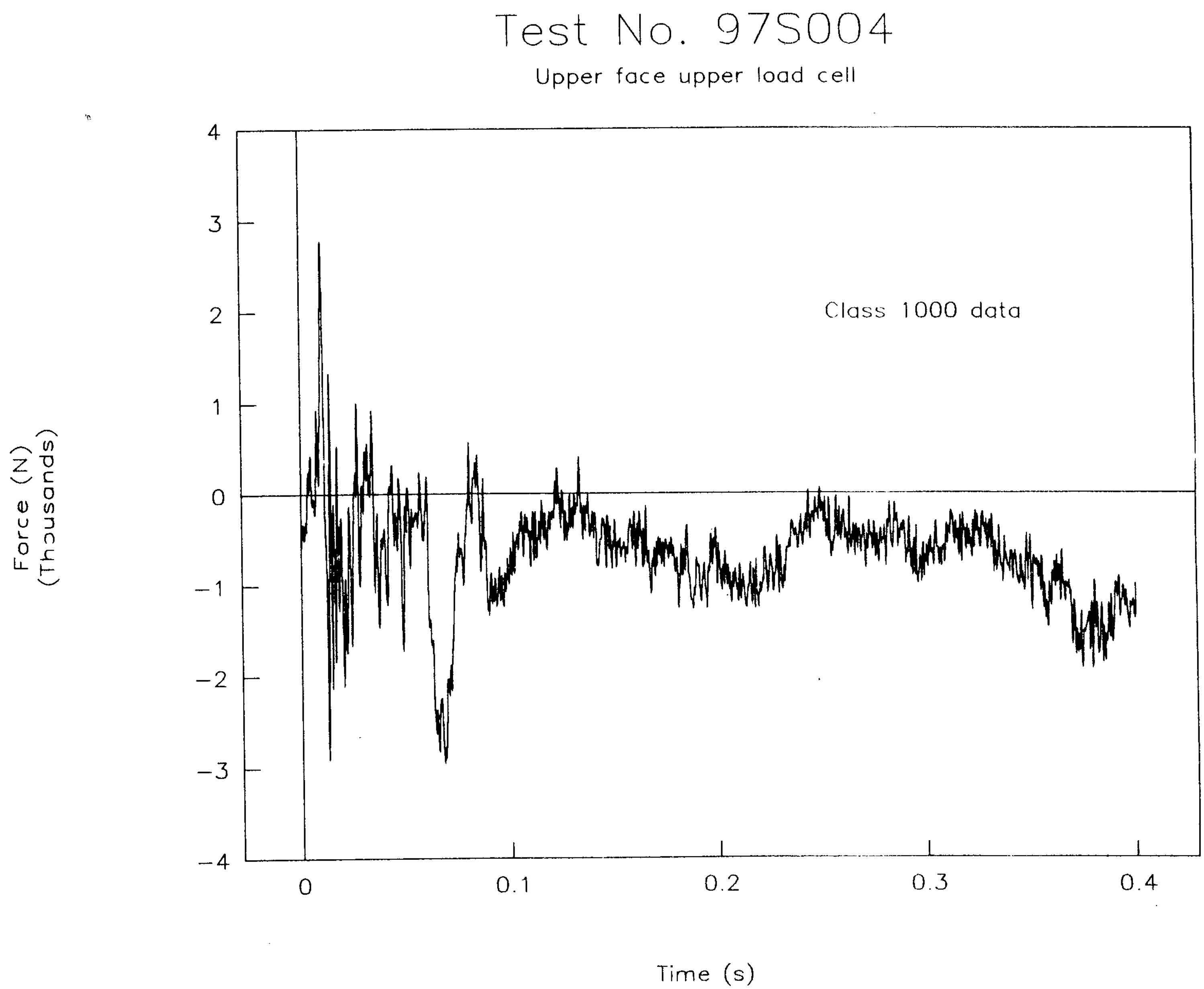


Figure 46. Rigid pole, force vs. time, upper face upper load cell, test 97S004.

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Number

(1) NHTSA. *Laboratory Test Procedure for Federal Motor Vehicle Safety Standard 201*, National Highway Traffic Safety Administration, Washington, DC, April 1997.

(2) Christopher M. Brown, *Honda Accord LX Broadside Collision with a Narrow Fixed Object: FOIL Test Number 97S003*, pending report, Federal Highway Administration, Washington, DC.

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