V2899

1994 Ford Explorer XLT Broadside Collision with a Narrow Fixed Object: FOIL Test Number 98S005

PUBLICATION NO. FHWA-RD-98-150

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U.S. Department of Transportation
Federal Highway Administration

Research and Development
Turner-Fairbank Highway Research Center
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McLean, VA 22101-2296

FOREWORD

The National Highway Traffic Safety Administration (NHTSA) enlisted the Federal Highway Administration (FHWA) to aid in the development of laboratory test procedures to be used in an amended version of Federal Motor Vehicle Safety Standard (FMVSS) 201. This new test procedure could be used in the evaluation of dynamic side-impact protection systems (e.g., air bags). A test methodology was produced from four crash tests between 1995 Honda Accord LX four-door sedans and the FOIL 300K rigid pole (test numbers 97S003, 97S004, 97S005, and 97S006), referenced in this report. Once the test procedures were established, three additional broadside crash tests were conducted to demonstrate the practicality and feasibility of the new test procedures. The three vehicles used for these tests were a 1994 Ford Explorer XLT, a 1994 Toyota pickup truck, and a 1995 Honda Accord LX. This report documents the test procedures and test results from the first in the series between the 1994 Ford Explorer XLT and the FOIL 300K instrumented rigid pole. The test was conducted at the FHWA Turner-Fairbank Highway Research Center in McLean, Virginia. The NHTSA supplied a calibrated SID/HIII dummy for the crash test.

This report (FHWA-RD-98-150) contains test data, photographs taken with high-speed film, and a summary of the test results.

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

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

NOTICE

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16. Abstract

This report contains the test procedures, test setup and test results from the first of three broadside crash tests conducted at the Federal Highway Administration (FHWA) Federal Outdoor Impact Laboratory (FOIL), located at the Turner-Fairbank Highway Research Center (TFHRC) in McLean, Virginia. The National Highway Traffic Safety Administration (NHTSA) enlisted the FHWA to aid in the development of laboratory test procedures to be used in an amended version of Federal Motor Vehicle Safety Standard (FMVSS) 201. Four crash tests with a Honda Accord LX and the(FOIL) 300K instrumented rigid pole (test numbers 97S003, 97S004, 97S005, 97S006) produced a test methodology for conducting broadside vehicle crash tests of dynamic side-impact head protection systems (e.g., air bags). Once the test procedures were established, these three additional broadside crash tests were conducted to demonstrate the practicality and feasibility of the new test procedures. The three vehicles used for these tests were a 1994 Ford Explorer XLT (this report), a 1994 Toyota pickup truck, and a 1995 Honda Accord LX.

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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.

Symbol	When You Know	Multiply By	To Find	Symbol
		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 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 an amended version of Federal Motor Vehicle Safety Standard (FMVSS) 201 (Occupant Protection in Interior Impact).[1] The 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). Four crash tests were conducted in support of this research. The four tests conducted at the FOIL were broadside collisions between 1995 Honda Accord LX four-door sedans and the FOIL's 300K rigid pole. The results from the four Honda Accord tests can be found in four separate test reports, one for each test conducted: *Honda Accord LX Broadside Collision with a Narrow Fixed Object: FOIL Test Number 97S003,*[2] *Honda Accord LX Broadside Collision with a Narrow Fixed Object: FOIL Test Number 97S004,*[3] *Honda Accord LX Broadside Collision with a Narrow Fixed Object: FOIL Test Number 97S005,*[4] and *Honda Accord LX Broadside Collision with a Narrow Fixed-Object: FOIL Test Number 97S006.*[5] These four crash tests produced a test methodology for conducting broadside vehicle crash tests of dynamic side-impact head protection systems (air bags). Once the test procedures were established, three additional broadside crash tests were conducted. The tests were conducted to demonstrate the practicality and feasibility of the new test procedures. Three different types of vehicles were represented in this series of tests. The three vehicles used for these tests were a 1994 Ford Explorer XLT (sport utility), a 1994 Toyota pickup truck (small pickup truck), and a 1995 Honda Accord LX (four-door sedan).

SCOPE

This report documents the test procedures and test results from a single broadside crash test between a 1994 Ford Explorer XLT 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 purpose of this test was to assess the level of practicality, repeatability, and feasibility of the new FMVSS 201 test procedures. The test procedures and test setup were similar to procedures followed for a previously conducted crash test of a 1995 Honda Accord LX (FOIL test number 97S005). The test procedures for vehicle preparation, dummy preparation and calibration, and photographic coverage follow directly from FMVSS 214.[6] However, the new FMVSS 201 test procedures included propelling a vehicle in a sideways manner into a fixed 255-mm diameter pole. The seating procedure used for this type of test utilized FMVSS 214 seating procedures as an initial dummy position, then altered the position according to recently established procedures. The dummy was positioned in the final location by altering the seat back angle and seat track adjustment until a minimum clearance of 50 mm between the rear of the dummy's head and the vehicle B-pillar was achieved.

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 to within 0.3 m of the rigid pole to ensure impact location, speed, and SID/HIII 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 the SID/HIII data. However, the intent of these tests was to validate a test procedure for head protection system evaluation and it was determined that the event of interest (dummy contact with the pole) would be complete before significant crush of the vehicle. The FOIL broadside test 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 Explorer's ground clearance, the side-impact monorail was raised 100 mm. A 100-mm x 100-mm wood block was placed under each monorail support. Increasing the rail height (to 305 mm) allowed the tires of the Explorer to hang free without contact with the ground.

The NHTSA supplied a calibrated SID/HIII dummy for the crash test. Head injury criteria (HIC) and thoracic trauma index (TTI) calculations were performed on the data from the SID/HIII'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 1994 Ford Explorer XLT and the 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(curb weight plus ballast to simulate the vehicle cargo capacity and one SID/HIII). 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 SID/HIII's head. Table 1 outlines the pertinent test parameters of the broadside crash test.

Table 1. Test matrix.	
FOIL number	98S005
Date	March 30, 1998
Vehicle	1994 Ford Explorer XLT
Weight (total)	2046 kg
SID/HIII Modified neck bracket	One positioned in driver seat HYBRID III neck
Fuel tank	93% capacity with stodard solvent
Crab angle	90°
Speed (nominal)	29 km/h
Impact location	Pole aligned with SID/HIII head
Test article	FOIL 300K instrumented rigid pole

TEST VEHICLE

The test vehicle was a 1994 Ford Explorer XLT four-door sport utility vehicle with an automatic transmission, and a six cylinder 4.0 L motor. Table 2 describes the vehicle and optional equipment.

Table 2. Vehicle description and statistics.	
Vehicle make	Ford
Vehicle model	1994 Ford Explorer XLT 4x4
Vehicle identification number (VIN)	1FMDV34X1RUB20311
Engine	4.0 L, 6 cylinder
Transmission	Automatic
Drive chain	Rear wheel drive 4-wheel drive equipped
Wheel base	2858 mm
Wheel track	1473 mm
Fuel capacity	73 L
Tested capacity of stodard solvent	68 L (93%)
Seat type	Bucket, lever
Position of front seats for test	92 mm forward of center
Seat back angle	18.3°
Steering wheel adjustment for test	Center

Table 2. Vehicle description and statistics (continued).					
OPTIONS					
x	Air conditioning		Traction control	x	Clock
x	Tinted glass	x	All wheel drive	x	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		Passenger air bag
	Power seat(s)	x	Tachometer	x	Front disc brakes
x	Power brakes	x	Tilt steering		Rear disc brakes
x	Anti-lock brakes	x	AM/FM radio		Other

WEIGHTS (kg)	**DELIVERED**	**FULLY LOADED**	**TEST MODE**
Left front	524	547	570
Right front	483	486	521
Left rear	441	527	477
Right rear	442	542	478
TOTAL	**1890**	**2102**	**2046**
ATTITUDE (mm)	**DELIVERED**	**FULLY LOADED**	**TEST MODE**
Left front	841	842	840
Right front	859	860	859
Left rear	819	809	819
Right rear	825	815	825
ATTITUDE (degrees)	**DELIVERED**	**FULLY LOADED**	**TEST MODE**
Driver	.1 positive	.2 negative	.1 positive
Passenger	1.5 negative	.9 negative	1.5 negative
Front	.9 negative	.4 negative	.9 negative
Rear	.5 negative	.5 negative	.5 negative
cg (mm) measurements	**DELIVERED**	**FULLY LOADED**	**TEST MODE**
Behind front axle	1335	1453	1334
Lateral	752	753	754

The test vehicle was prepared for testing following procedures outlined in FMVSS 201 (similar to FMVSS 214). The NHTSA supplied an OSCAR to measure the three-dimensional coordinate of the SID/HIII's hip-point (H-point) relative to the vehicle's driver door striker. This H-point measurement was used the morning of the test to place the SID/HIII in its initial position before final positioning.

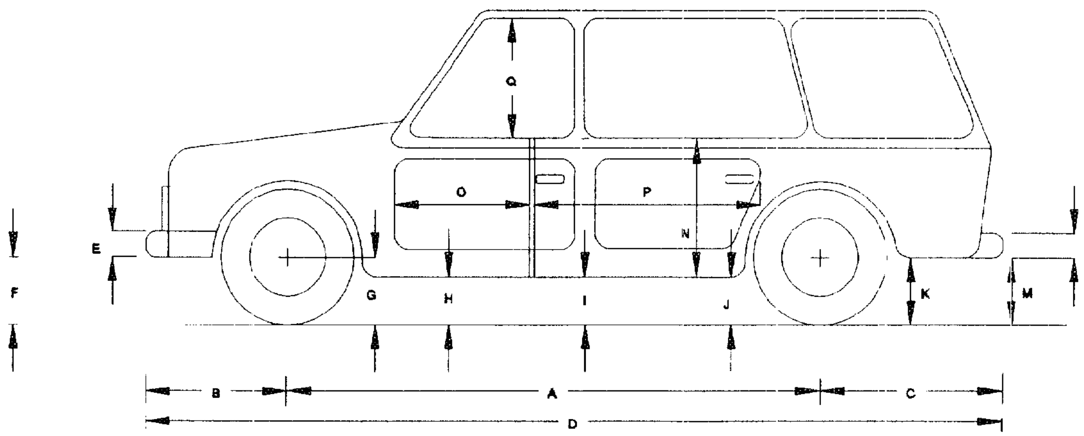
The vehicle weight and four sill attitudes were measured in each of the three modes or configurations described in FMVSS 201. The first was the "as delivered" mode. This configuration consisted of the test vehicle as delivered from a dealership with its fuel tank filled to between 92 percent and 94 percent capacity with petroleum naphtha, a stoddard solvent. The second mode, cargo or "fully loaded" mode, consisted of the vehicle with one dummy placed in the driver seat and 135 kg of simulated cargo placed in the rear cargo space along the vehicle centerline. The final mode was the "as tested" mode. This configuration consisted of the vehicle fully instrumented for testing, excluding the 135 kg of simulated cargo but including instrumentation, guidance carriages, and one SID/HIII dummy. The four sill attitude measurements, vehicle weight distribution, and other measurements are presented in table 2. The vehicle attitudes while in position on the guidance rails were adjusted to within 0.5 degrees of the "test mode" measurements recorded while the vehicle was on the ground.

Included in the test mode configuration were the two side-impact carriages. The main monorail carriage rides down the main I-section monorail. The monorail carriage was bolted 200 mm forward of the vehicle's longitudinal cg. The main monorail carriage supports approximately 95 percent of the total vehicle weight. The monorail carriage includes a tow pin protruding out 200 mm rearward such that the tow cable pulled at the vehicle cg. The tow location allows for the least possible yaw to be induced by the tow system. The propulsion used was a gravity assist system. The FOIL utilizes a weight stack and a 6-to-1 mechanical advantage to accelerate the test vehicle. The total weight on the weight stack was reduced to 2,310 kg to prevent the SID/HIII from tipping during acceleration. The rear carriage was bolted to the bumper of the test vehicle and rides along a 50-mm steel angle. The rear carriages typically supports 5 percent of the total vehicle weight. Each carriage was constructed from aluminum and remained fastened to the test vehicle throughout the test. To prevent significant interference by the carriages, the carriages were bolted to the test vehicle using small diameter hardware quality bolts. The bolts were to shear quickly in the event the carriages made substantial contact with a structural member.

The fuel tank usable capacity (obtained from the NHTSA) was 73 L. The fuel tank was filled with 68 L (93 percent of capacity) of petroleum naphtha (stodard 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 stodard solvent was 2046 kg. The SID/HIII weight was 80 kg.

Target tape and circular targets were placed on the test vehicle in accordance with FMVSS 201. 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	2850	2770	-80
B	752	750	-2
C	1042	1012	-30
D	4644	4482	-162
E	195	195	0
F*	480 / 480	495	15
G*	328 / 328	334	6
H*	328 / 328	340	12
I*	329 / 329	335	6
J*	325 / 325	371	46
K*	430 / 430	472	42
L	198	198	0
M*	440 / 440	484	44
N	670	682	12
O	1050	923	-127
P	940	838	-102
Q	485	454	-31

* 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 SID/HIII, serial number 26, was placed in the driver seat of the Ford Explorer. The SID/HIII was supplied by the NHTSA and was calibrated by a NHTSA-approved dummy calibration facility before shipment to the FOIL. The SID/HIII 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 a new neck bracket specifically designed for the SID/HIII. This provided the necessary bolt pattern and alignment for a HYBRID III neck and head assembly. The dummy is a surrogate occupant representing a 50^{th} percentile male. 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 SID/HIII. The dummy was shipped with the necessary hardware for assembly. Tools at the FOIL were used to assemble the SID/HIII. The SID/HIII was clothed using white thermal underwear and hard sole leather shoes supplied by the NHTSA. Eighteen extension cables were supplied with the SID/HIII. 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 SID/HIII 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. After the dummy was positioned in the standard FMVSS 214 position, the seat back and seat track were adjusted to place the SID/HIII forward of the B-pillar. The target minimum clearance between the rear of the dummy's head and the B-pillar was 50 mm. The following procedure was followed for dummy positioning:

1. Position the SID/HIII per FMVSS 214. This position served as a baseline starting position.

2. If the minimum head-to-B-pillar clearance of 50 mm was not present, then the seat back angle was adjusted (if adjustment was possible) as much as 5 degrees.

3. If the minimum head-to-B-pillar clearance of 50 mm was not achieved, the seat track was adjusted in one detent increments until either the minimum clearance was achieved, or the most forward adjustment was reached, or until there was knee interference between the dash or steering column.

4. If the minimum head-to-B-pillar clearance of 50 mm was not achieved, the seat back angle was adjusted in one notch increments until either the minimum clearance was achieved, or the full upright locked position was reached.

5. If the minimum head-to-B-pillar clearance of 50 mm could not be achieved after the above 4 steps, the test would be conducted without the minimum clearance.

The minimum clearance was achieved after step 3. The seat back angle was adjusted approximately 5 degrees and the seat track was adjusted to the most forward position. No interference between the SID/HIII's knees and the dash was observed, however, the knees made slight contact with the steering column. The knees were spread enough to eliminate knee-steering column contact. The final seat back angle was 5 degrees (measured on the back of the seat) from vertical, a 5.3 degree difference from the original FMVSS 214 angle of 10.3 degrees. Using FMVSS 214 as a guide and alignment tools supplied by the NHTSA, the SID/HIII's feet, legs, thighs, pelvis, torso, and head were positioned just before the test. Pertinent SID/HIII-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. SID/HIII chalk colors.

DUMMY PART	**COLOR**
Face	Blue
Top of head	White
Left side of head	Red
Back of head	Black
Left hip	Lime green
Left shoulder	Orange

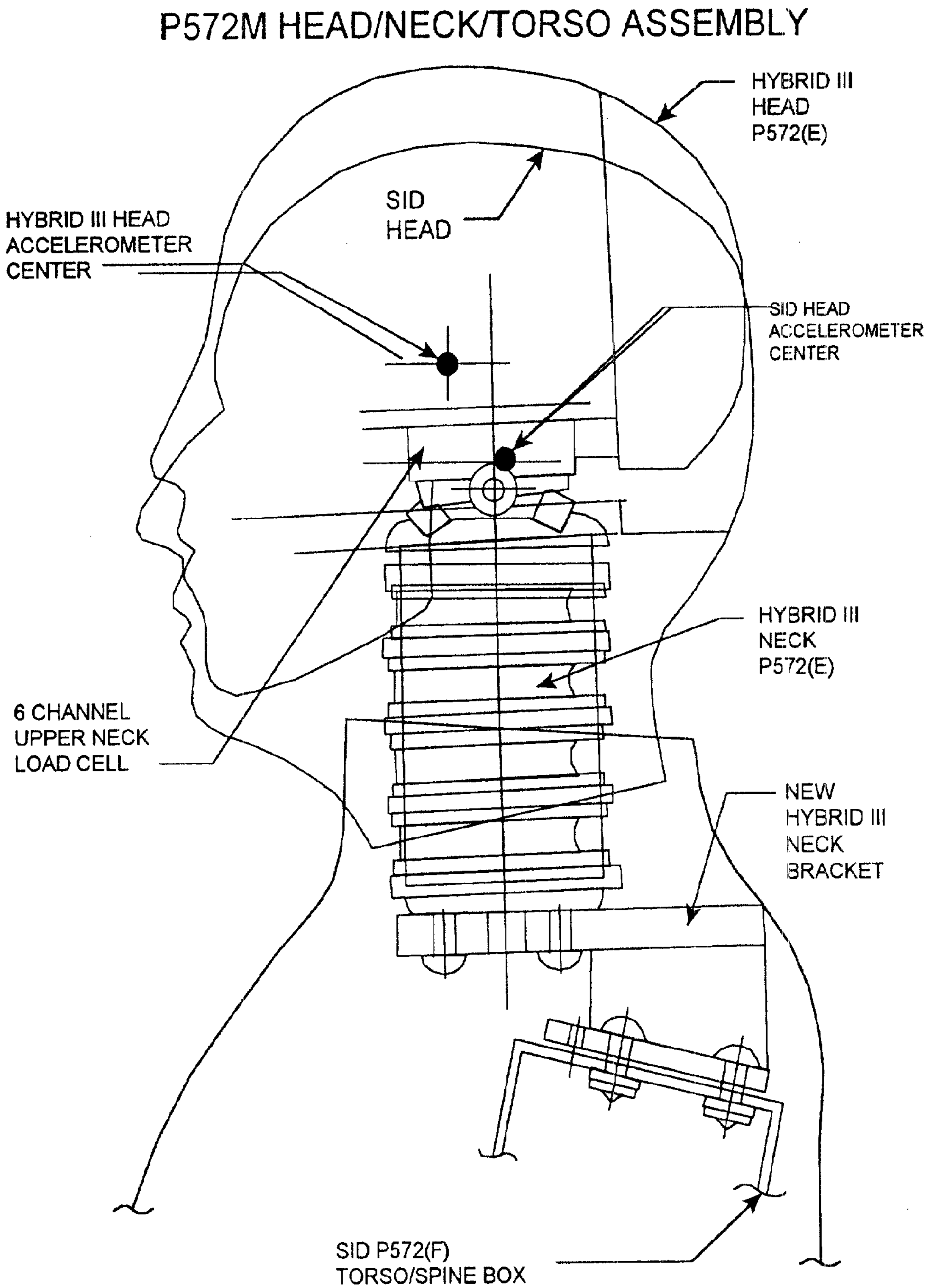
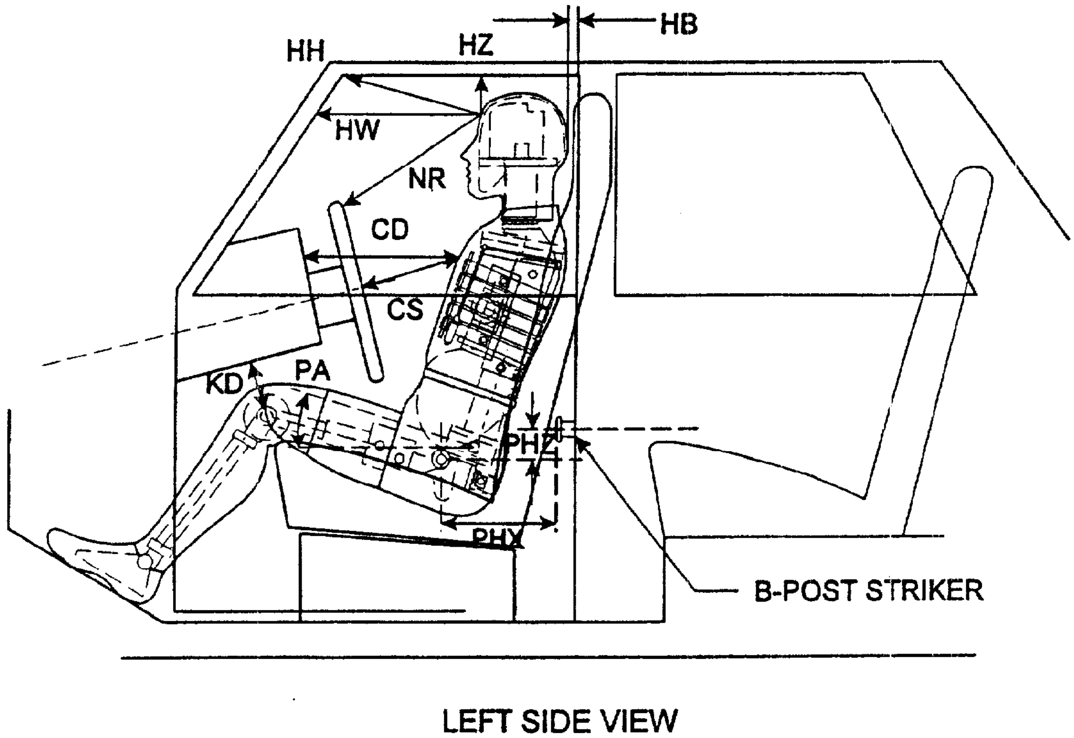
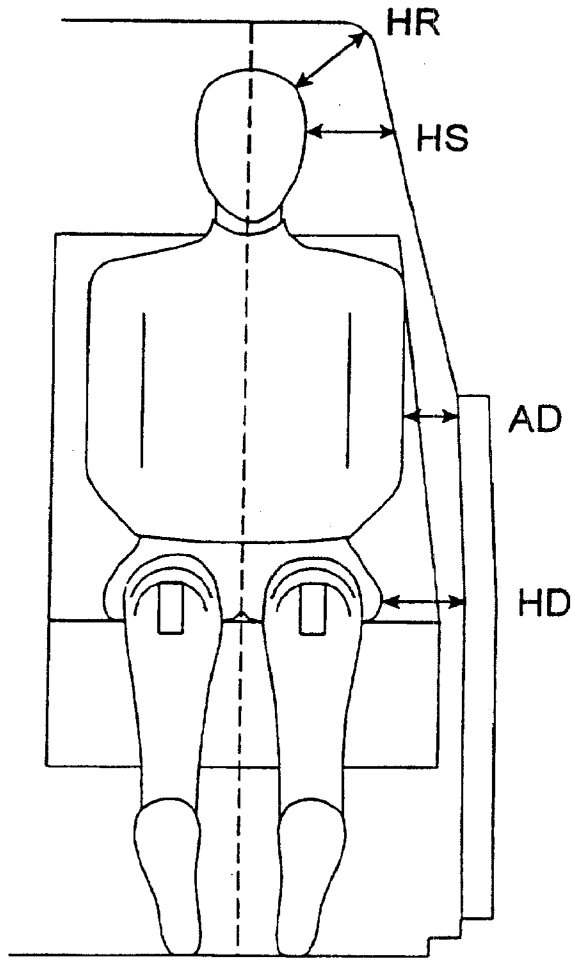


Figure 2. HYBRID III neck and head assembly on SID/HIII #26.



MEASUREMENT (mm)	DRIVER SID/HIII ID# 26
HB	83
HH	331
HW	508
HZ	211
NR	400
CD	537
CS	235
KDL(KDA°)	1601(45°)
KDR(KDA°)	1531(46°)
PA°	22.1°
PHX	165
PHY	257
PHZ	-95

Figure 3. SID/HIII longitudinal clearance and position measurements.



MEASUREMENT (mm)	DRIVER SID/HIII ID# 26
HR	275
HS	360
AD	122
HD	160

Figure 4. SID/HIII 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. The rigid pole can be moved laterally in either direction in 50-mm increments. The pole was placed in the FOIL foundation pit aligned with the dummy head cg. If the rigid pole mounting plate did not align properly with the holes of the foundation base plate, it was moved to the closest bolt hole position. This pole position restriction can produce a maximum ±25-mm misalignment between the dummy head cg and the rigid pole centerline.

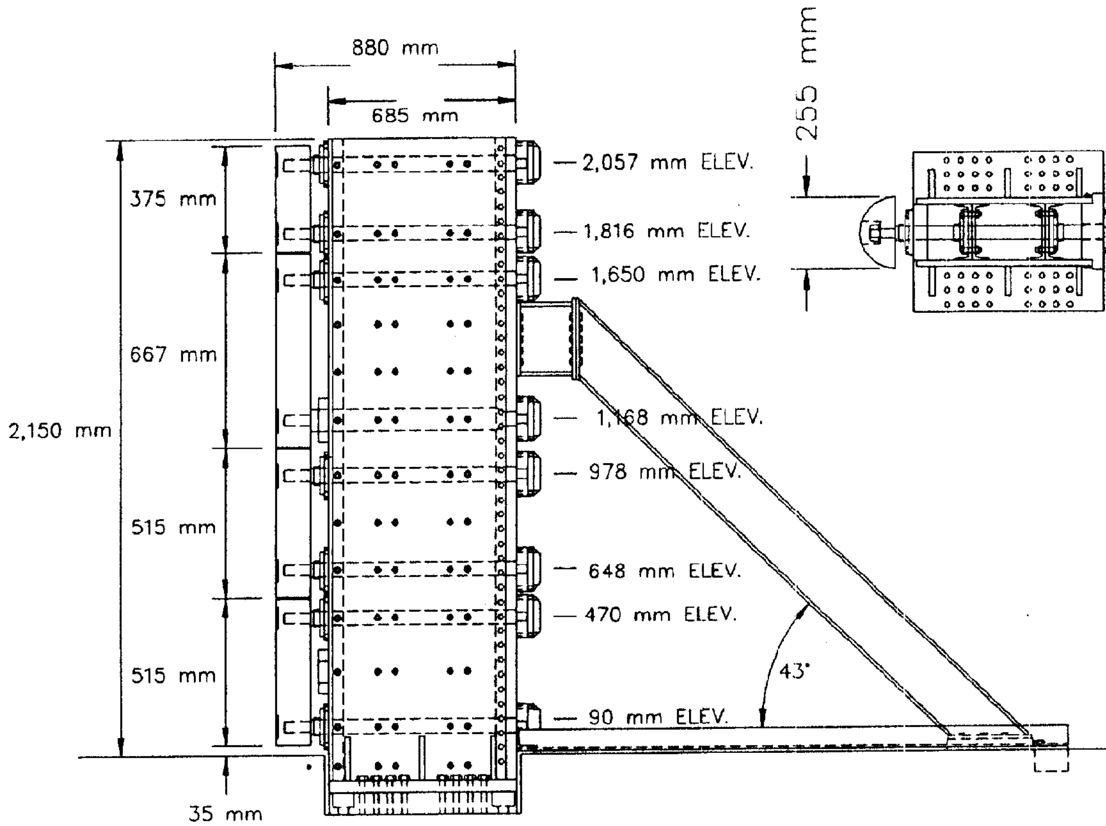
A spike (e.g., sharpened welding rod) was affixed to one impact face to verify the impact location by physically puncturing the vehicle body. Figure 5 is a sketch of the FOIL 300K rigid pole (side-impact configuration).

INSTRUMENTATION

Electronic data from the crash test were recorded via two data acquisition systems, the FOIL umbilical cable system and the FOIL onboard data acquisition system (ODAS). A total of 40 channels of electronic data were recorded. The umbilical cable system recorded 13 data channels and the remaining 27 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_x,A_y — 2 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



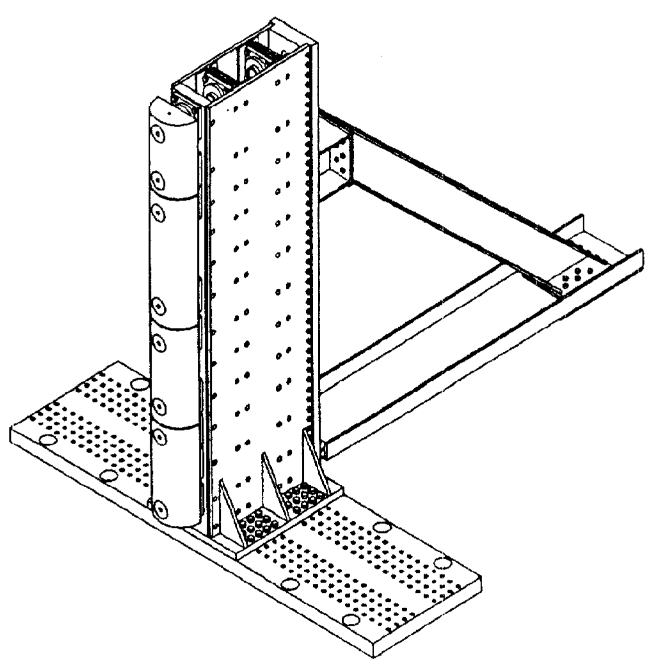


Figure 5. FOIL 300K instrumented rigid pole.

SID/HIII 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

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 27 channels were ODAS channels including the 16 SID/HIII 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 27 channels of data. The data were from cg, engine, driver seat, and trunk accelerometers, three rate transducers, and 16 SID/HIII 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 4,000 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 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 965 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	Load cell	340 N·m	Neck moment, Z moment
17	Accelerometer	100 g's	X-axis, cg data
18	Accelerometer	100 g's	Y-axis, cg data
19	Accelerometer	100 g's	Z-axis, cg data

Table 4. Summary of instrumentation (continued).			
20	Rate transducer	500 deg/s	Pitch rate, cg
21	Rate transducer	500 deg/s	Roll rate, cg
22	Rate transducer	500 deg/s	Yaw rate, cg
23	Accelerometer	2000 g's	X-axis, engine block
24	Accelerometer	2000 g's	Y-axis, engine block
25	Accelerometer	2000 g's	Driver seat track
26	Accelerometer	2000 g's	X-axis, in trunk
27	Accelerometer	2000 g's	Y-axis, in trunk
Umbilical cable, tape recorder system.			
1	Accelerometer	100 g's	Cg, Y-axis
2	Accelerometer	100 g's	Cg, X-axis
3	Load Cell	111 kN	Top face, upper load cell
4	Load Cell	111 kN	Top face, lower load cell
5	Load Cell	222 kN	Upper middle face, upper load cell
6	Load Cell	111 kN	Upper middle face, lower load cell
7	Load Cell	222 kN	Lower middle face, upper load cell
8	Load Cell	222 kN	Lower middle face, lower load cell
9	Load Cell	222 kN	Bottom face, upper load cell
10	Load Cell	222 kN	Bottom face, lower load cell
11	Contact switch	1.5 Volts	Time of impact, TO
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 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 per second and were positioned for best viewing of the contact between the Ford Explorer 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	50	90° to impact right side (0.30, 0.60, 0.91)
2	LOCAM II	500	100	90° to impact right side (22.2, 0.23, 1.7)
3	LOCAM II	500	50	45° oblique right side (9.4, 12.6, 1.2)
4	PHOTEC	500	80	45° oblique right side (21.2, 16.2, 1.1)
5	LOCAM II	500	75	45° left side (10.7, 17.4, 1.2)
6	LOCAM II	500	35	45° left side (10.8, 17.8, 0.84)
7	LOCAM II	500	25	180° to impact behind pole (0, 19.3, 1.4)
8	LOCAM II	500	12.5	overhead, over rigid pole (0, 0, 8.5)
9	LOCAM II	500	5.7	on-board 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 black and yellow target tape 25 mm wide, were placed on the Ford Explorer 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:

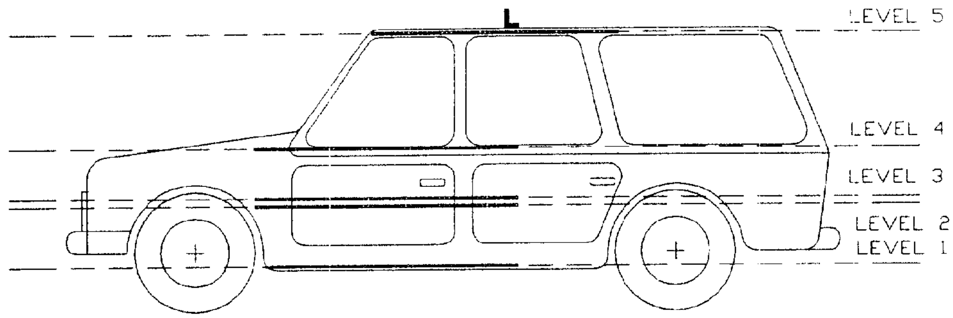
- Along the longitudinal centerline the full length of the vehicle, excluding windows.
- Laterally across the roof perpendicular to the centerline tape and coincident with the rigid pole impact location.
- Laterally across the roof perpendicular to the centerline tape and coincident with the vehicle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



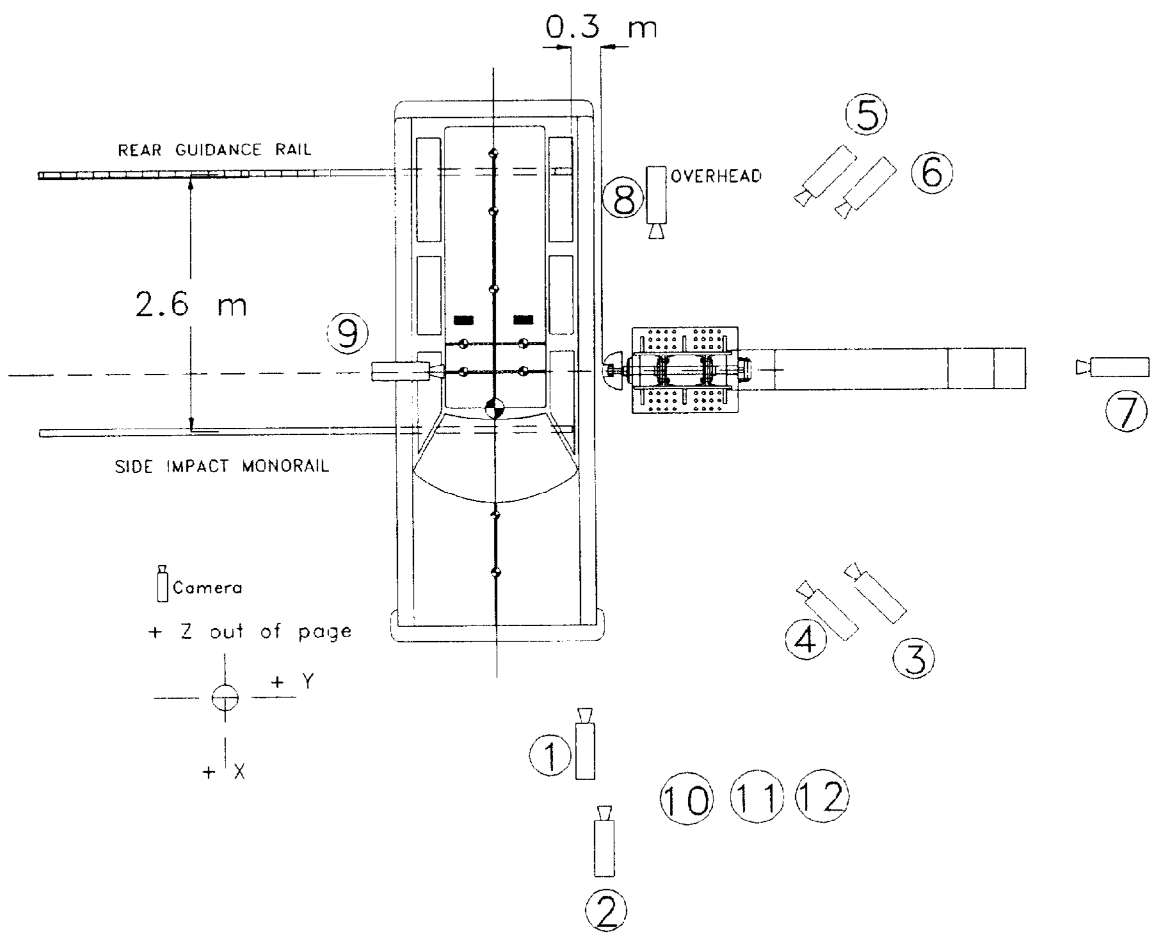


Figure 6. Camera locations and test setup.

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 SID/HIII data, eight 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 1,650 Hz (Society of Automotive Engineers (SAE) class 1000). Rib, spine, and pelvic data were filtered a second time using an 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 SID/HIII's head. The resultant acceleration data file was fed into a HIC algorithm to compute the HIC value for the crash test. The pelvic injury was equal to the peak pelvic acceleration data. The pelvic data were filtered using the FIR100 filter and the peak was located. 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 1,000 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 were converted to the ASCII format, zero-bias removed, and digitally filtered to 1,650 Hz (SAE class 1000). The filtered data were 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 (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 an 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 that 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, impact roll angle, impact yaw angle, and impact pitch angle.

RESULTS

The Ford Explorer 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 dummy was repositioned to the final position by adjusting the seat back angle and seat track until the proper head-to-B-pillar clearance was achieved. The final head clearance was 83 mm. Due to the rigid pole position limitations, the rigid pole centerline was 12 mm rearward of the SID/HIII head cg. The dummy was restrained using the vehicle three-point shoulder-lap belt restraining system. 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, the windows were down, the transmission was placed in neutral, and the key was placed in the "on" position. The Ford Explorer passed over the monorail speed trap, which malfunctioned, resulting in an errant speed measurement. The initial speed was determined from high-speed film and was 28.2 km/h. The initial roll angle was found to be equal to the original roll attitude measured prior to testing (approx. 0.5 degrees). The impact yaw angle was 89 degrees, confirmed from high-speed film. Table 6 summarizes the test conditions and selected results.

Table 6. Summary of test conditions and results.

FOIL test number	98S005
Date of test	March 30, 1998
Test vehicle	1994 Ford Explorer XLT 4x4
Vehicle weight	2046 kg
Test article	FOIL instrumented 300K rigid pole
Temperature inside vehicle	27.8°C
Impact speed: speed trap	No data
16-mm film	28.2 km/h
Impact yaw angle	89°
Head impact point	25 mm rearward of head cg
Vehicle impact point (mm)	105 rearward of vehicle cg
Head-to-B-pillar clearance	83 mm
Traffic accident data (TAD)	9-LP-6
Vehicle damage index (VDI)	09LPAN4
Head Injury Criteria (HIC)	
Limit	1000 g's
Observed	4908 g's

Table 6. Summary of test conditions and results (cont'd).	
Start time	0.05896 s
Stop time	0.05984 s
Interval time	0.00088 s
Thoracic trauma data	
Limit (4-door)	85 g's
Peak rib acceleration (FIR100)	77.9 g's
T12 spine (FIR100)	70.4 g's
Thoracic Trauma Index (TTI)	74.2 g's
Pelvic injury	55.7 g's

Vehicle response. The sharpened rod attached to the rigid pole punctured the vehicle 12 mm rearward of the vertical target tape centerline, denoting the intended target location. The driver door cross section and floor sill began to collapse on contact with the rigid pole. The door had collapsed by 0.014 s. The intruding door struck the dummy's shoulder at approximately 0.024 s. The rigid pole continued to penetrate the occupant compartment, collapsing the B-pillar and rear door inward. The driver seat began to tip, drop down, and rotate 0.030 s after initial contact. The roof rail made contact with the rigid pole at 0.030 s. Double integration of the cg acceleration-time history and the total rigid pole force-time history yielded a maximum dynamic intrusion of 680 mm and 630 mm, respectively. A static measurement was taken between the front door interior surfaces before and after the test. The net change (static intrusion) was 380 mm. 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 Ford Explorer's undercarriage consisted of two 165-mm by 50-mm C-shape channel frame rails spaced 1030 mm apart. After the test, the distance between frame rails was reduced to 750 mm. The static frame rail deflection was 280 mm. The impact location was 105 mm rearward of 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 12 degrees, which occurred at 0.840 s. 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 34.3 g's (688 kN) and occurred 0.0402 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 340 mm above ground (not on guidance rails). Included in the table are peak accelerations from each accelerometer (SAE class 60 data).

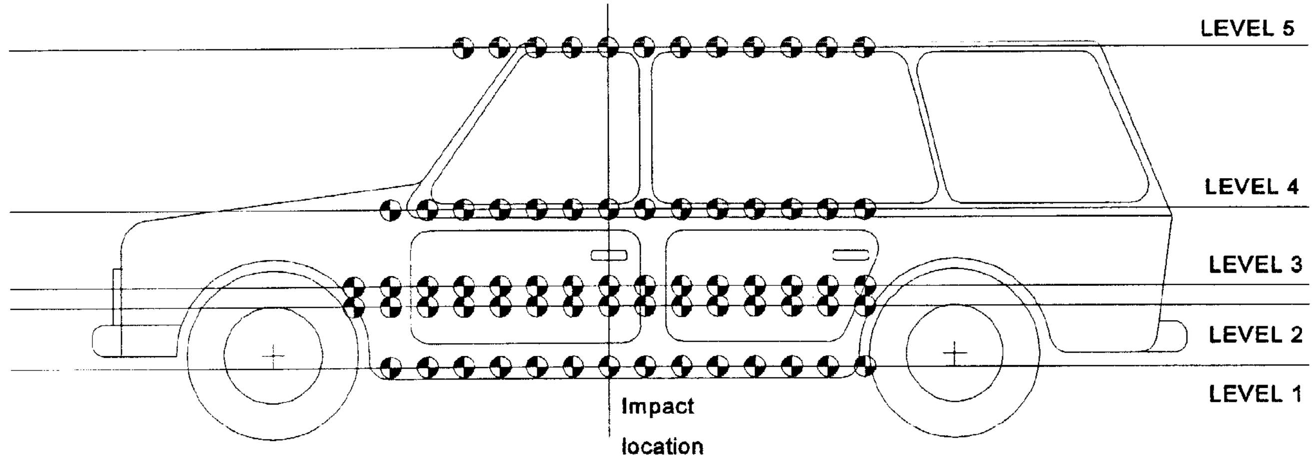
Table 7. Vehicle sensor locations and peak measurements.					
Sensor	X (mm)	Y (mm)	Z (mm)	Peak g's (+)	(-)
cg accelerometer A_x	-1515	762	245	10.6	9.5
cg accelerometer A_y	-1515	762	245	9.8	34.5
cg accelerometer A_z	-1515	762	245	21.7	17.6
cg redundant A_x	-1515	762	125	10.4	10.1
cg redundant A_y	-1515	762	245	10.1	33.8
Engine block A_x	0	875	750	23.2	7.32
Engine block A_y	0	875	750	3.12	16.4
Trunk A_x	-3085	960	280	4.64	3.36
Trunk A_y	-3085	960	280	2.28	14.0
Driver seat A_y	-1420	1304	240	28.7	37.1

After the test, damage profile measurements were taken using two techniques. Table 8 summarizes the damage profile distance (DPD) technique. 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 530 mm at the mid-door height 76 mm rearward of 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.

Table 8. DPD crush measurments (mm).										
L	D	Max	LF	C1	C2	C3	C4	C5	C6	LR
1824	-297	500	-720	0	231	495	234	48	0	1104

L = tctal length of crush.
D = distance from vehicle cg to mid-point of L
Max = maximum crush
LF, LR = distance from impact point to points forward and rearward where no damage was observed.
C1-6 = incremental crush measurements along L, equally spaced.



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		-1219	-1067	-914	-762	-610	-533	-457	-381	-305	-229	-152	-76	0
1	435	PRE				658	660	660	660	660	665	665	665	665	665
	433	POST				718	775	809	842	873	912	948	1011	1065	1094
		CRUSH	0	0	0	60	115	149	182	213	247	283	346	400	429
2	800	PRE		570	580	575	576	576	577	578	579	579	579	579	579
	814	POST		595	617	655	727	769	814	862	908	957	1012	1068	1098
		CRUSH	0	25	37	80	151	193	237	284	329	378	433	489	519
3	729	PRE		570	580	575	576	576	577	578	579	579	579	579	579
	741	POST		603	622	651	728	779	828	881	928	975	1017	1072	1092
		CRUSH	0	33	42	76	152	203	251	303	349	396	438	493	513
4	1066	PRE	618	611	608	605	608	607	608	608	608	608	608	607	607
	1078	POST	630	630	630	650	720	760	810	850	900	950	1004	1057	1093
		CRUSH	12	19	22	45	112	153	202	242	292	342	396	450	486
5	1628	PRE									810	810	800	797	797
	1164	POST									920	980	1020	1080	1130
		CRUSH	0	0	0	0	0	0	0	0	110	170	220	283	333
All units of measurement are in mm.															

Figure 7. Vehicle profile measurements, test 98S005.

			Distance from impact point (mm).										
LEVEL	HEIGHT		76	152	229	305	381	457	610	762	914	1067	1219
1	435	PRE	662	662	662	662	662	665	670	664	654		
	433	POST	1073	1018	968	919	901	864	798	752	648		
		CRUSH	411	356	306	257	239	199	128	88	-6	0	0
2	800	PRE	579	580	581	581	581	580	578	578	578	570	
	814	POST	1103	1046	938	905	865	822	749	682	603	558	
		CRUSH	524	466	357	324	284	242	171	104	25	-12	0
3	729	PRE	579	580	581	581	581	580	578	578	578	570	
	741	POST	1109	1043	941	903	868	834	765	691	628	598	
		CRUSH	530	463	360	322	287	254	187	113	50	28	0
4	1066	PRE	608	608	609	609	610	610	610	610	610	610	615
	1078	POST	1090	1047	1021	968	938	903	836	772	712	645	628
		CRUSH	482	439	412	359	328	293	226	162	102	35	13
5	1628	PRE	797	797	797	795	795	795	795	795	795		
	1164	POST	1100	1080	1050	1010	1080	980	950	890	850		
		CRUSH	303	283	253	215	285	185	155	95	55	0	0
All units of measurement are in mm.													

Figure 7. Vehicle profile measurements, test 98S005 (continued).

Occupant response. The SID/HIII remained vertical in the driver seat with cnly 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 SID/HIII's shoulder region. The driver door continued to collapse as the dummy moved toward the pole. The rigid pole centerline was aligned 12 mm rearward of the head cg and the pole struck the vehicle 12 mm rearward of the intended location on the vehicle. These factors, coupled with the slight oscillating motion of the dummy, induced an actual head contact point 25 mm rearward of the head cg. The dummy's head did not contact the B-pillar before striking the rigid pole approximately 0.058 s after impact. The neck bent over to the left as the dummy's shoulder was stopped by the door contact. The rigid pole made contact with the dummy's head where the side of the face ends and the top or crown of the head begins. Due to the rearward contact on the head, the head rotated slightly about the neck away from the pole, then rebounded back away from the pole after 0.002 s. The dummy's torso was first to rebound back across the vehicle over the passenger side seat, and the neck whipped the head over, making the right side of the dummy's head hit the right shoulder. After the test, no physical damage to the SID/HIII 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. The dummy's feet remained free and were not pinched or crushed. However, the dummy's knees were wedged under and between the steering column, door panel, and dash panel. Red chalk was found on the rigid pole, verifying contact between the dummy's head and the pole. Orange chalk from the dummy's side was on the door as expected. Green chalk from the dummy's femur and leg was found on the driver door along and underneath the arm rest.

The rib and spine acceleration data produced a TTI of 74 g's. This is below the four-door vehicle limit of 85 g's specified in the FMVSS 214. The three head accelerometers produced a HIC value of 4908 g's. This value is above the 1000 g's required in the proposed FMVSS 201 amendment. Table 9 summarizes the data collected from the SID/HIII.

Table 9. Summary of SID/HIII data.

Recorded Data	Maximum positive	Maximum negative
Head X-axis acceleration (g's)	27.1	-16.3
Head Y-axis acceleration (g's)	11.7	-601.7
Head Z-axis acceleration (g's)	60.7	-131.2
X-axis neck force load cell (N)	166.2	-312.7
Y-axis neck force load cell (N)	1572.2	-465.4

Table 9. Summary of SID/HIII data (continued).		
Z-axis neck force load cell (N)	2911.8	-1023.6
X3.6is neck moment load cell (1000 mm·N)	21.9	-71.6
Y-axis neck moment load cell (1000 mm·N)	17.7	-12.9
Z-axis neck moment load cell (1000 mm·N)	12.5	-26.0
Left upper rib acceleration (P)	5.7	-75.0
Left upper rib acceleration (R)	5.7	-77.9
Left lower rib acceleration (P)	11.6	-67.6
Left lower rib acceleration (R)	12.1	-70.6
Spine T12 Y acceleration (P)	19.3	-70.4
Spine T12 Y acceleration (R)	19.8	-68.3
Pelvis Y acceleration	13.0	-55.7
Head and neck load data are SAE class 1000. Shaded area data are SAE class 600 (neck moment data). Remaining data obtained from FIR100 filter output.		

The values from the head accelerometers and the neck load cells were taken from class 1000 data (neck moments class 600) while the remainder are from data filtered using a FIR100 filter. Data plots from the SID/HIII 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 157,600 N. The significant loads were contributed by the roof-rail, floor-sill, and middle-point of the driver door. Table 10 summarizes the load cell data (SAE class 60). 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	-8.9	43.2
Upper load cell/2,057	-2.0	140.6
Lower load cell/1,816	-9.4	43.8
Middle-upper face	-28.7	59.8

Table 10. Summary of rigid pole data (cont'd).		
Upper load cell/1,650	-12.3	60.0
Lower load cell/1,168	-19.7	52.4
Middle-lower face	-113.3	65.0
Upper load cell/978	-39.3	65.4
Lower load cell/648	-76.6	33.4
Bottom face	-15.5	51.2
Upper load cell/470	-14.9	67.8
Lower load cell/90	-1.2	33.4
Total, rigid pole	-157.6	60.0

CONCLUSIONS AND OBSERVATIONS

Visual inspection of the Ford Explorer after the collision produced some immediate observations and conclusions. Fuel system and door latch integrity were not breached by the broadside collision with the FOIL instrumented rigid pole. The impact speed and impact location were within reasonable tolerances, indicating accurate test procedures and setup. The dummy made direct contact with the rigid pole without interference from any vehicle structures, specifically the B-pillar. The direct contact yielded an HIC value (4908 g's) five times larger than values obtained during previous tests conducted where the dummy was seated with its head partially behind the B-pillar. The HIC (4908 g's), TTI (74 g's), and PELVIC injury (56 g's) values from this test are similar to those computed after FOIL test number 97S005, which was conducted using similar test procedures. The HIC, TTI, and PELVIC injury for test 97S005 were 8824 g's, 68 g's, and 37.8 g's.

In cases where the B-pillar cannot serve as a countermeasure against injury during a broadside collision, a side dynamic head restraint system may aid in reducing occupant risk. The laboratory test procedures and setup described in this report may be used to evaluate the safety performance of side dynamic head restraint systems.

APPENDIX A. DATA PLOTS FROM VEHICLE ACCELEROMETERS

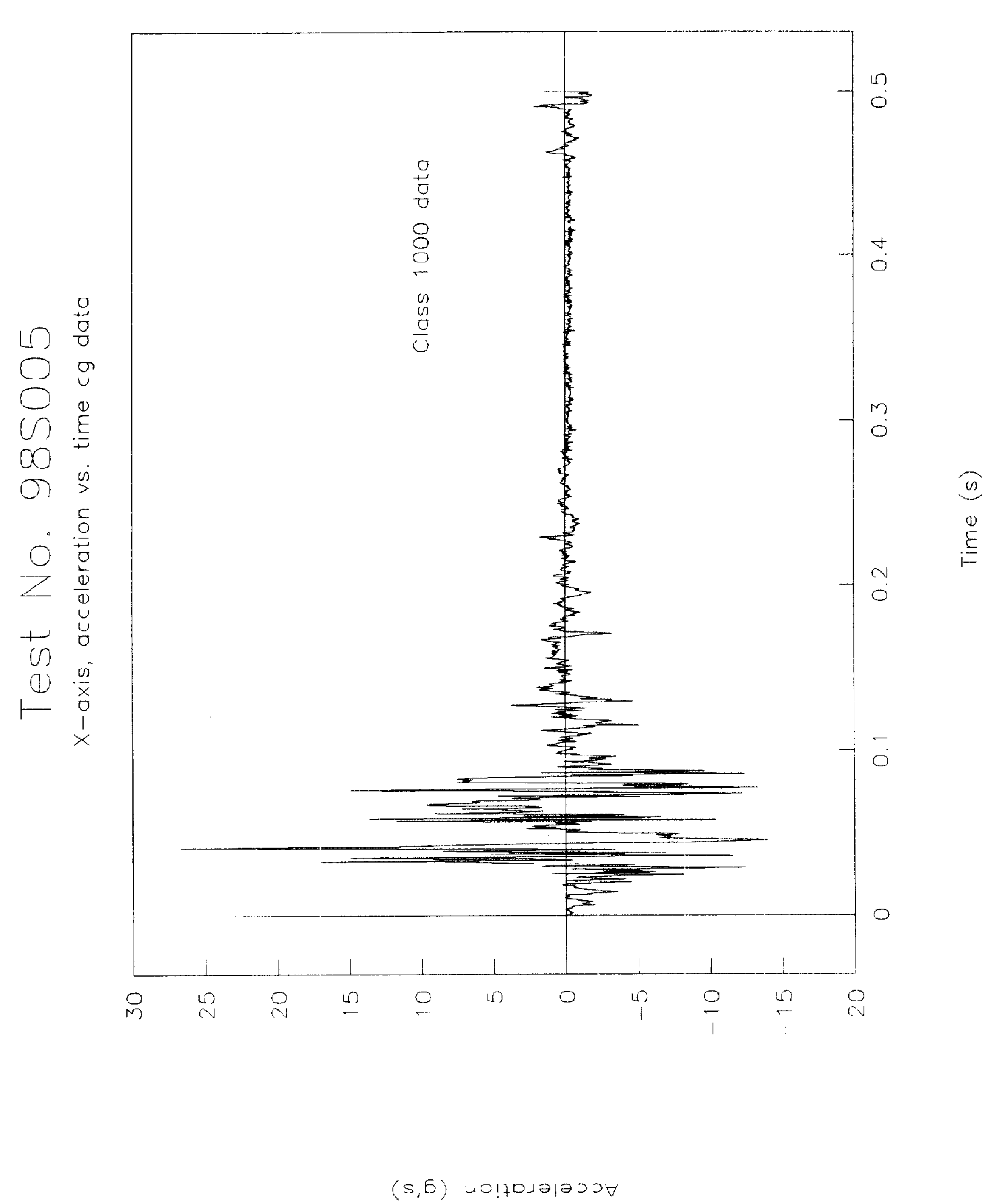


Figure 8. Acceleration vs. time, X-axis cg, test 98S005.

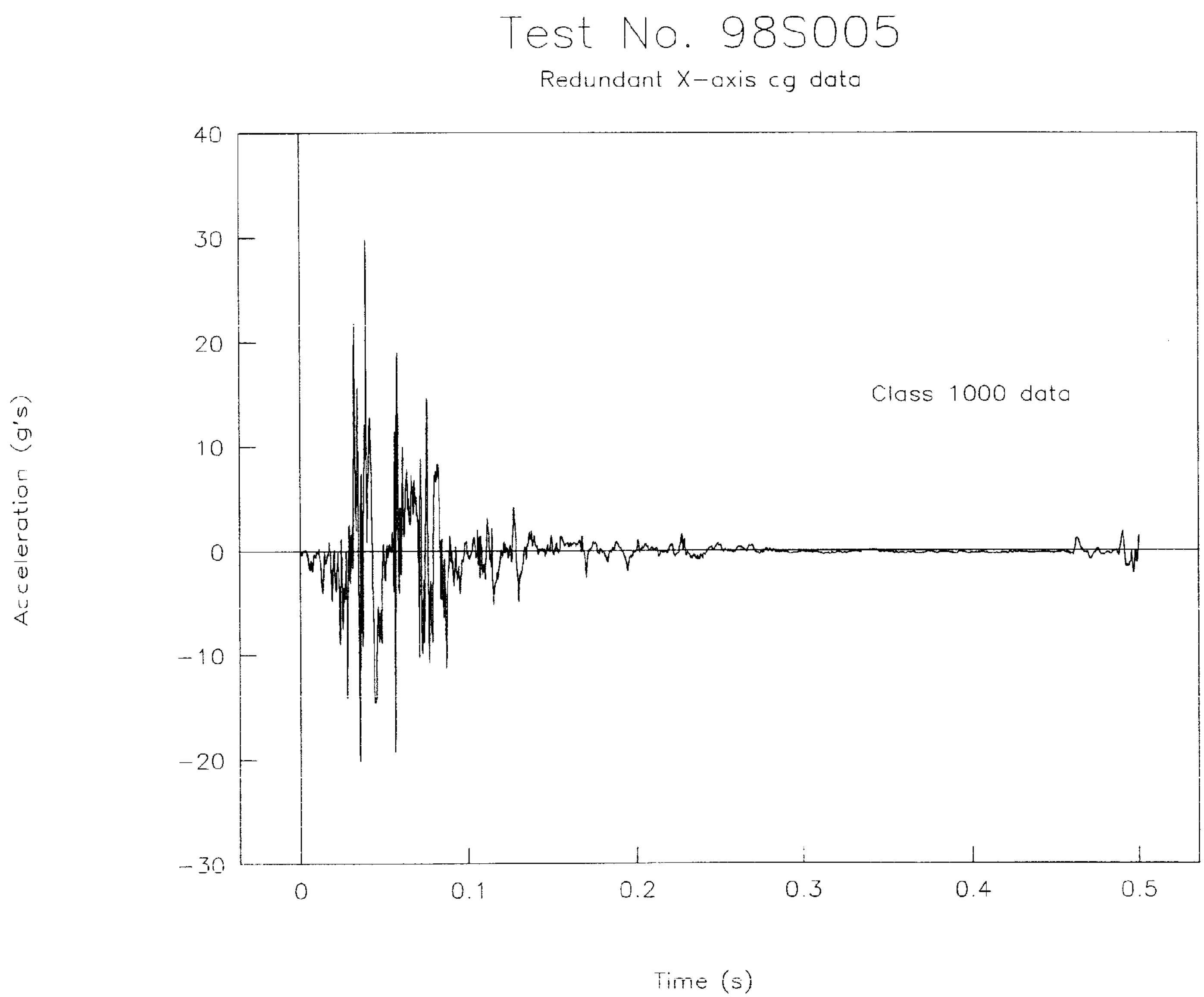


Figure 9. Acceleration vs. time, redundant X-axis cg, test 98S005.

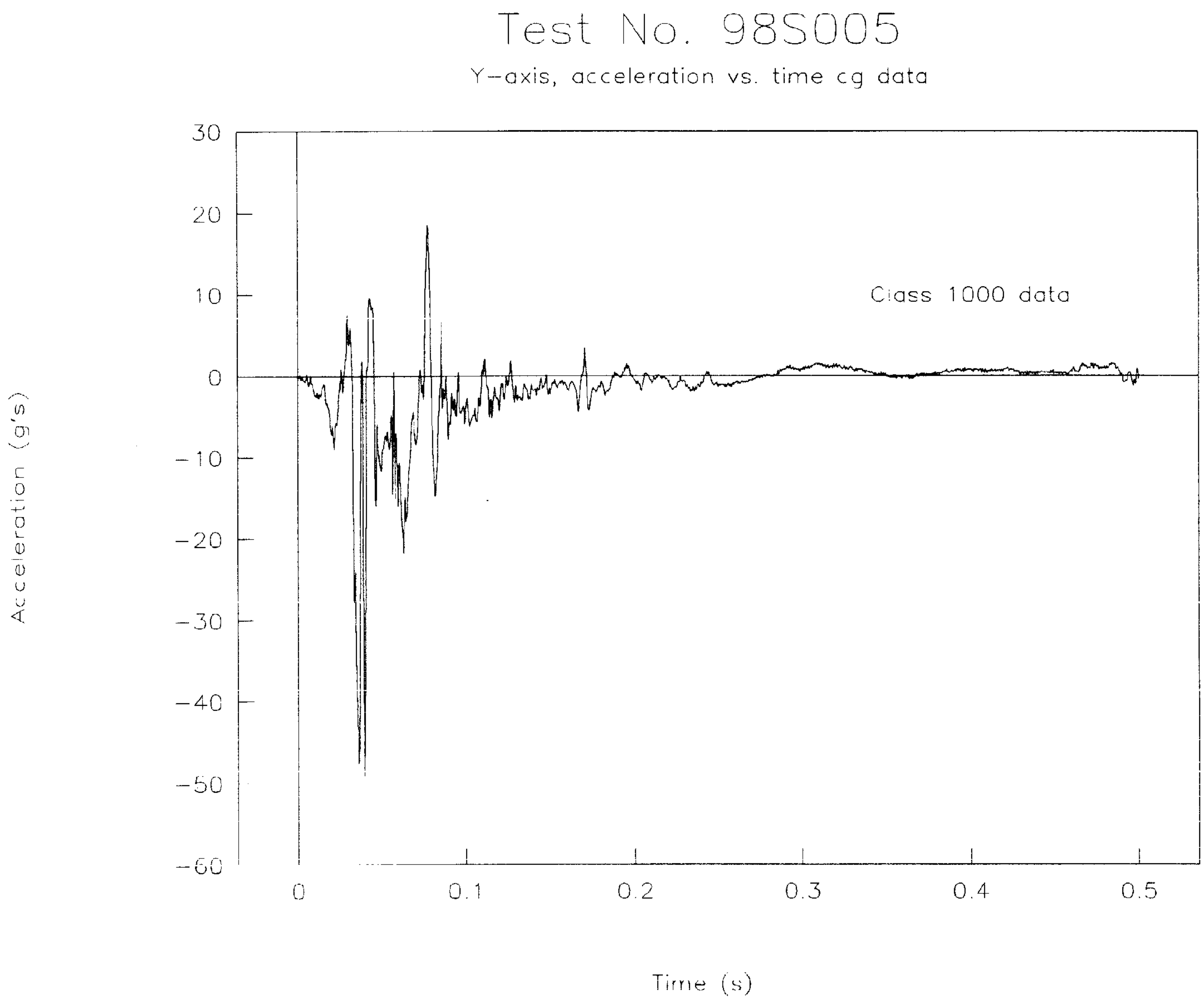


Figure 10. Acceleration vs. time, Y-axis cg, test 98S005.

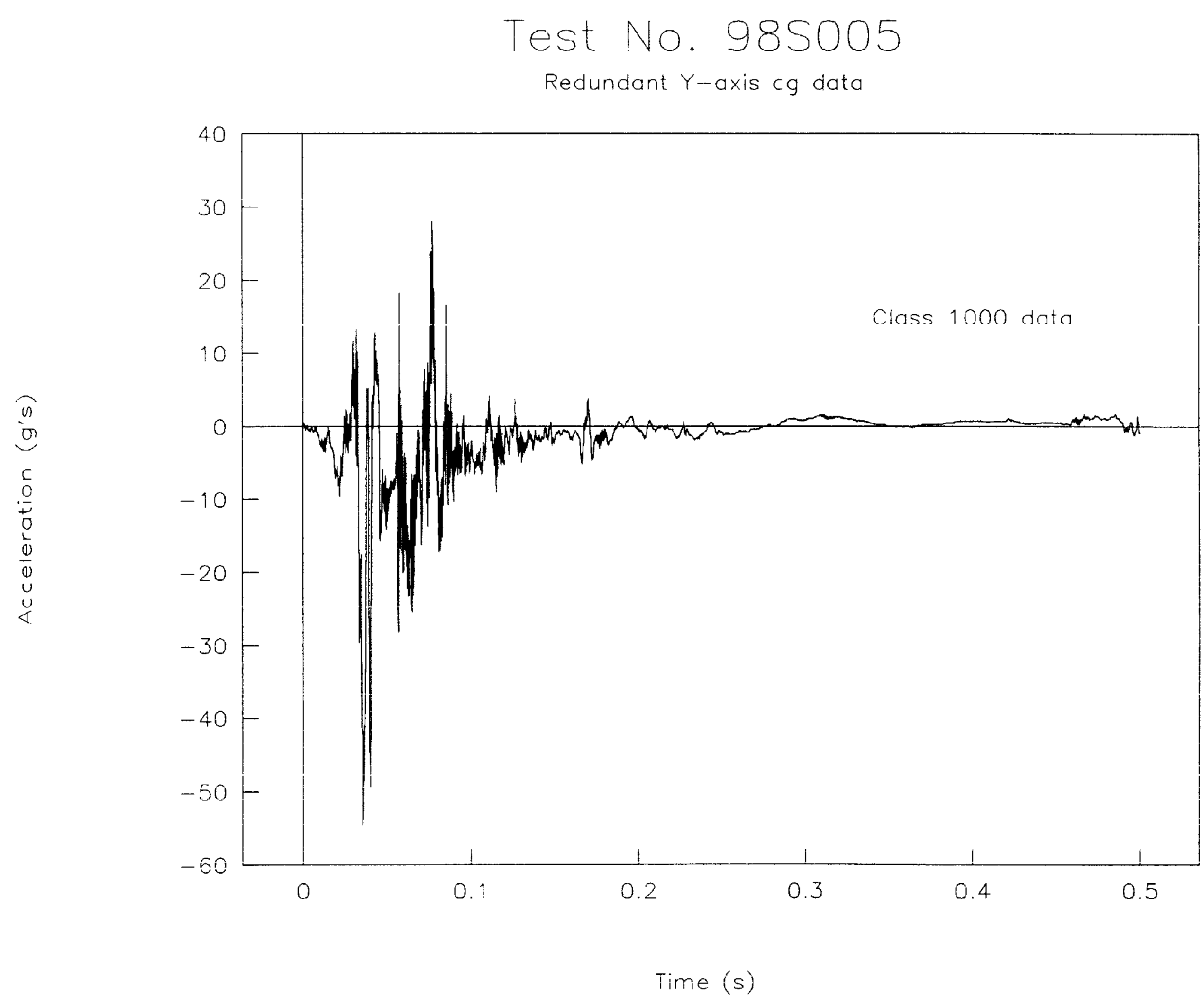


Figure 11. Acceleration vs. time, redundant Y-axis cg, test 98S005.

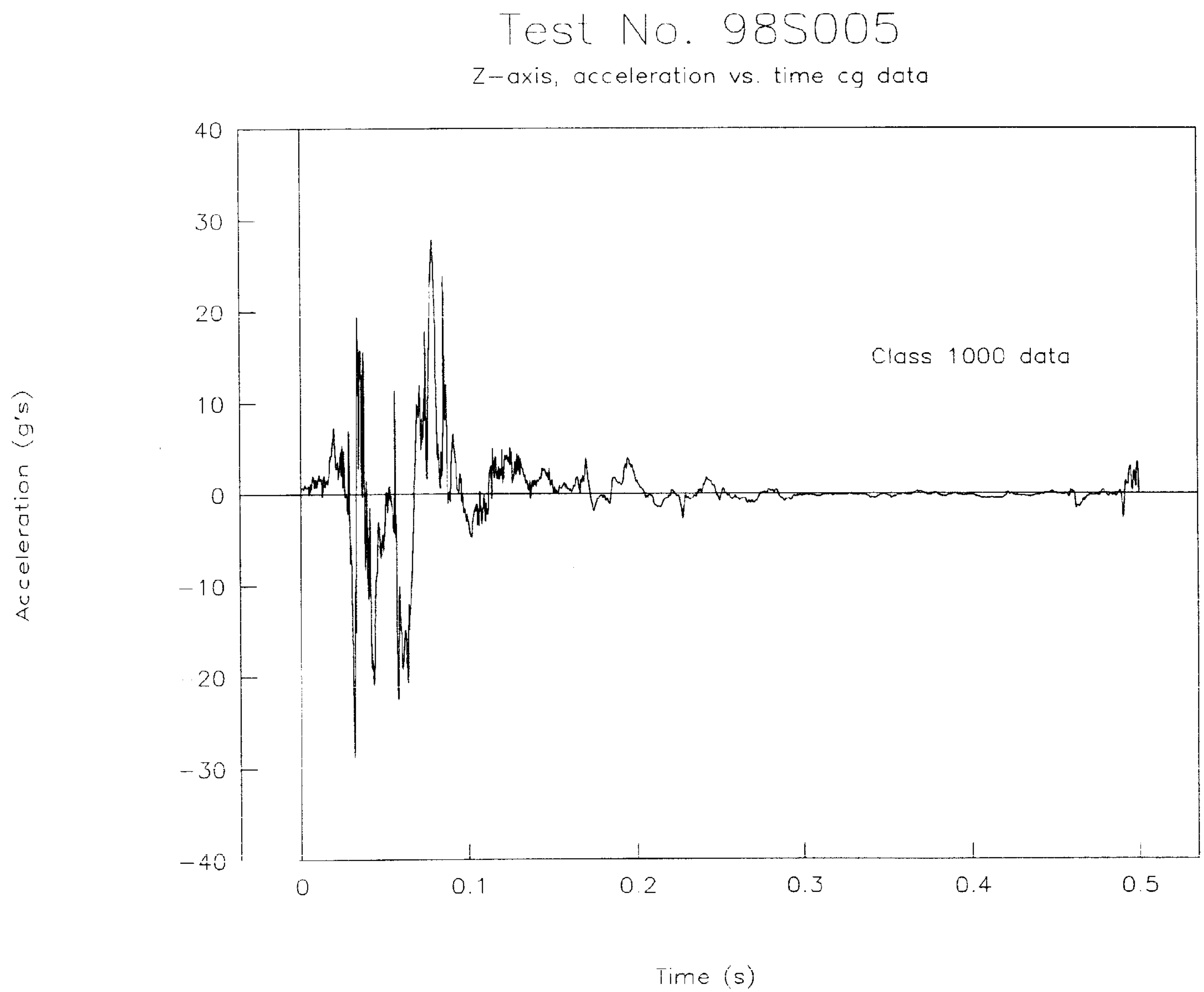


Figure 12. Acceleration vs. time, Z-axis cg, test 98S005.

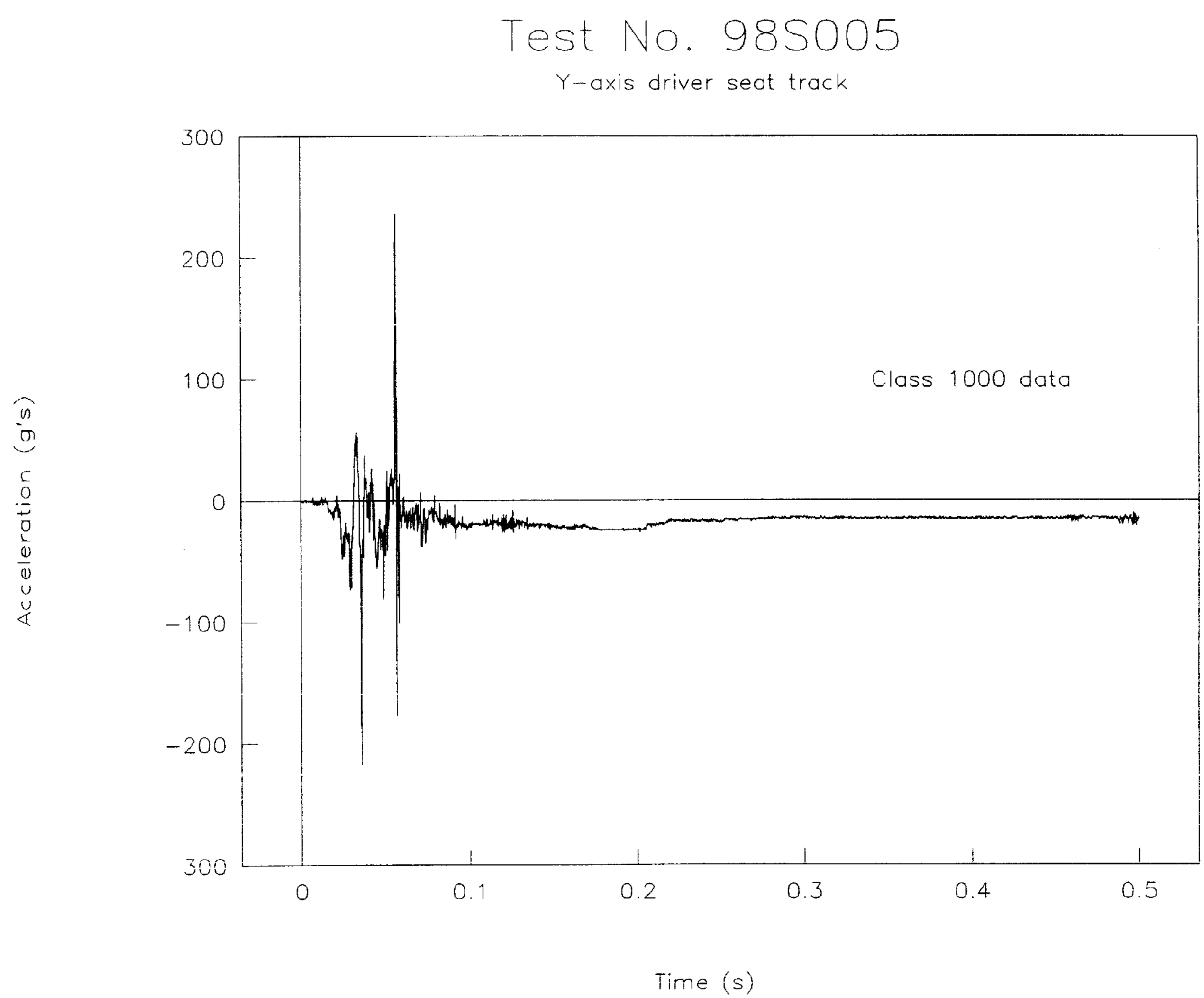


Figure 13. Acceleration vs. time, Y-axis driver seat track, test 98S005.

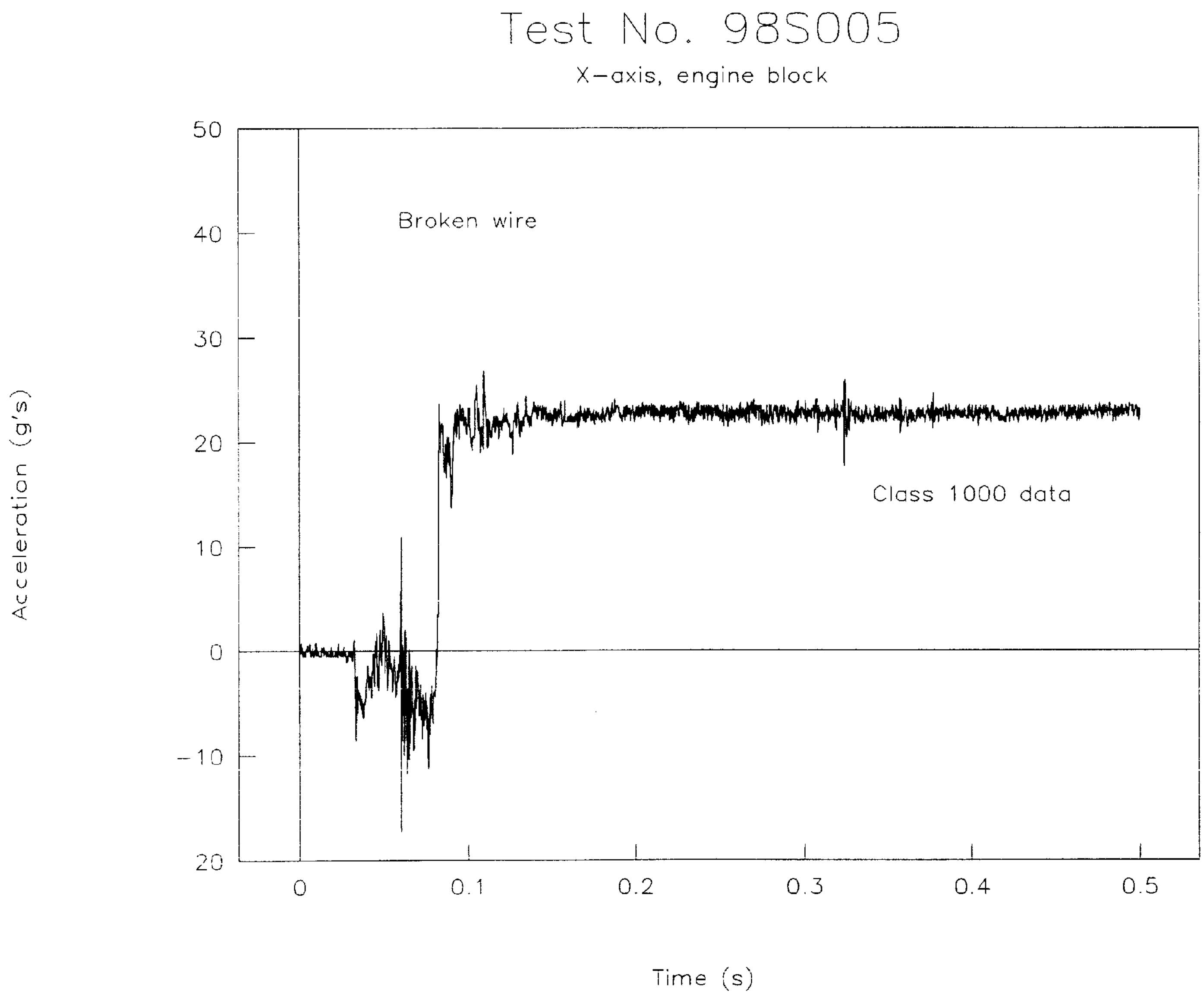


Figure 14. Acceleration vs. time, X-axis engine block, test 98S005.

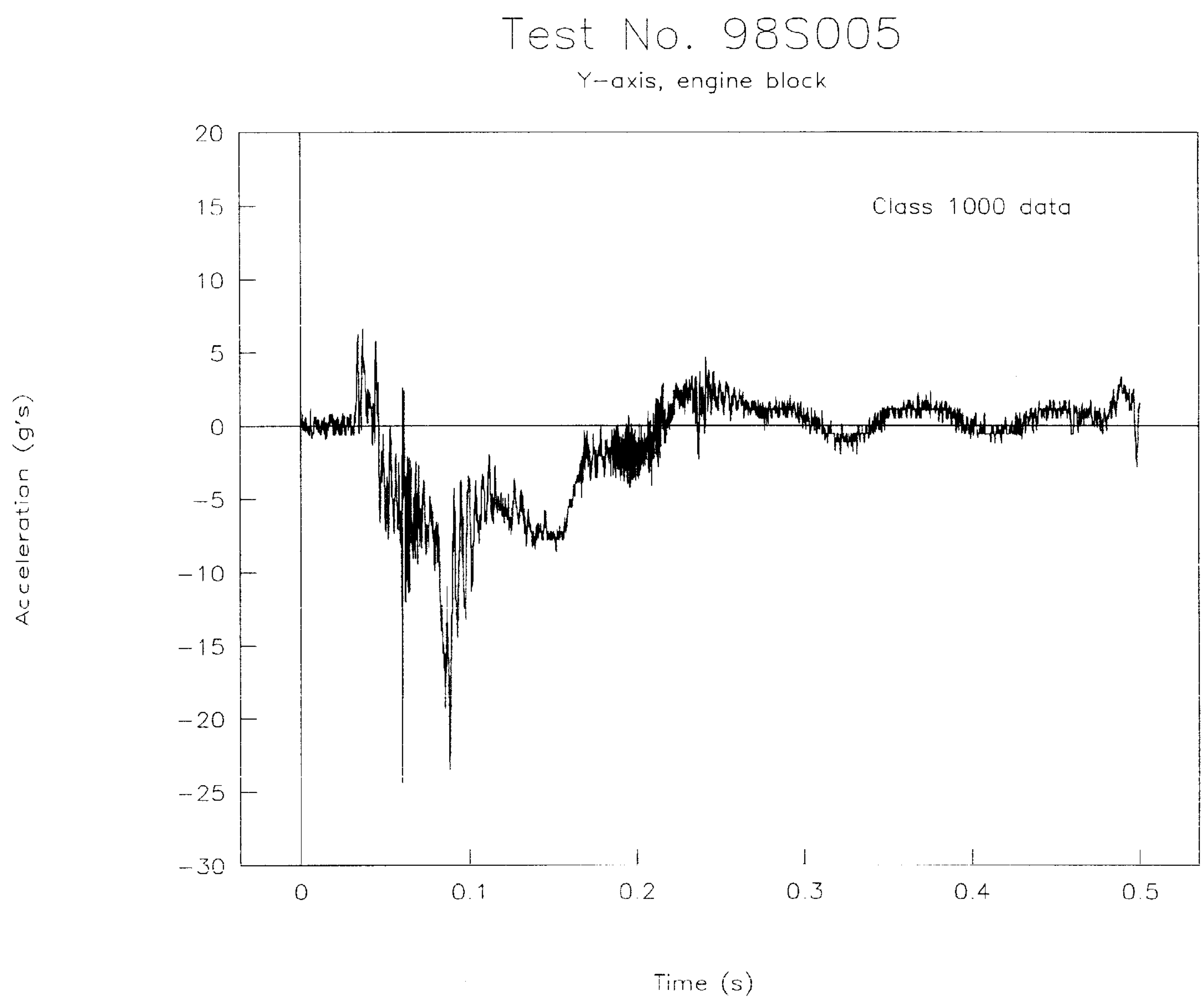


Figure 15. Acceleration vs. time, Y-axis engine block, test 98S005.

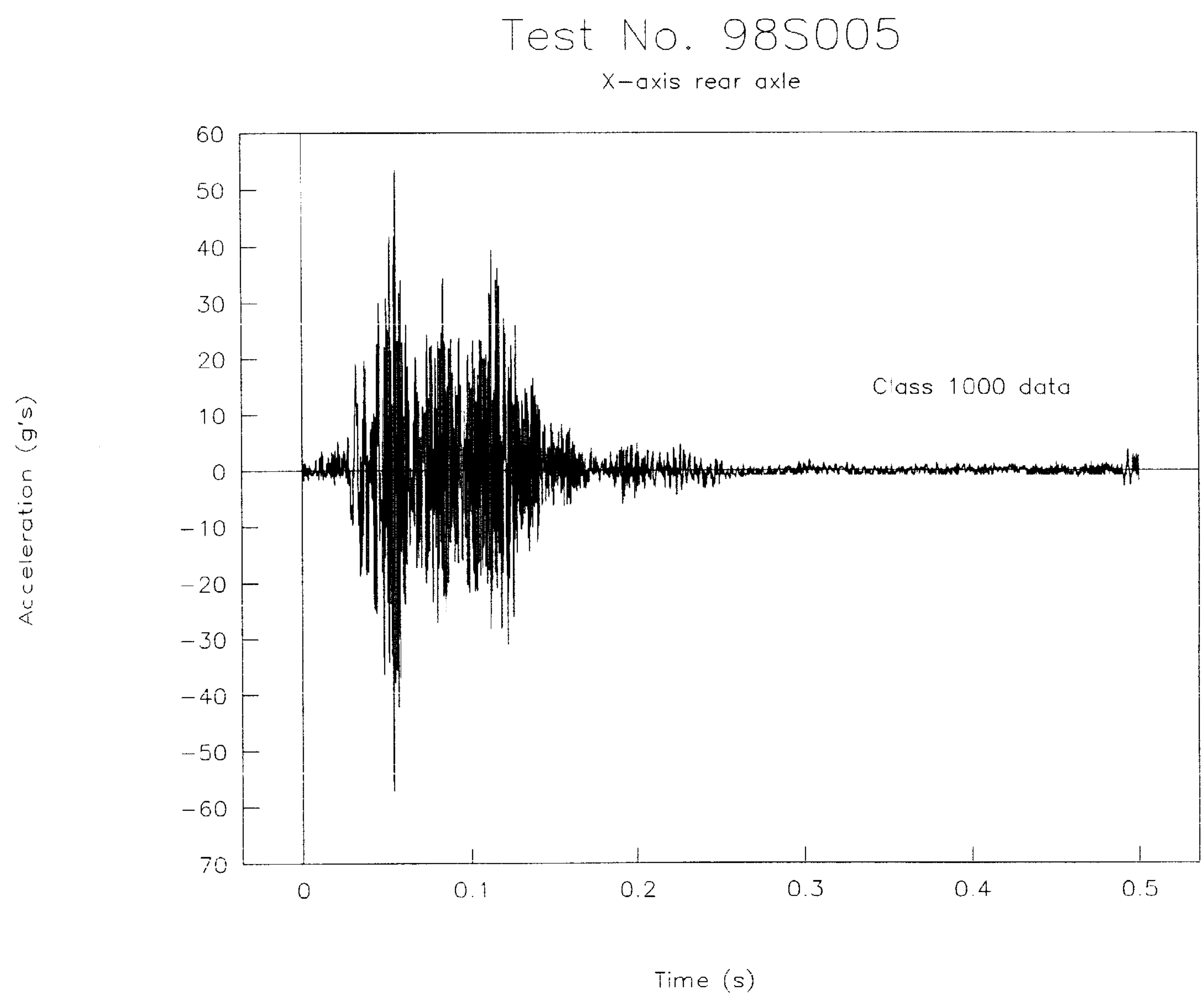


Figure 16. Acceleration vs. time, X-axis rear axle, test 98S005.

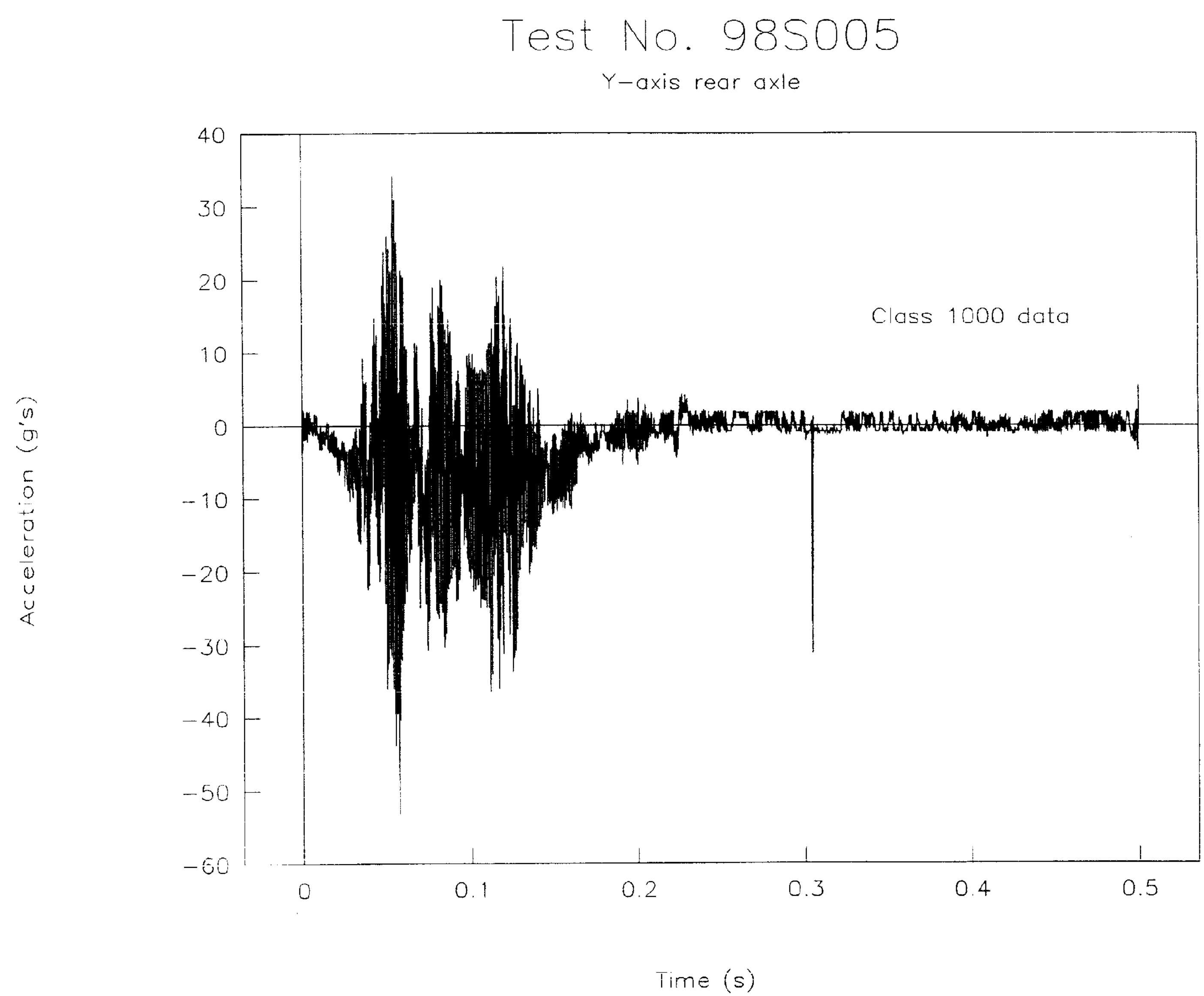


Figure 17. Acceleration vs. time, Y-axis rear axle, test 98S005.

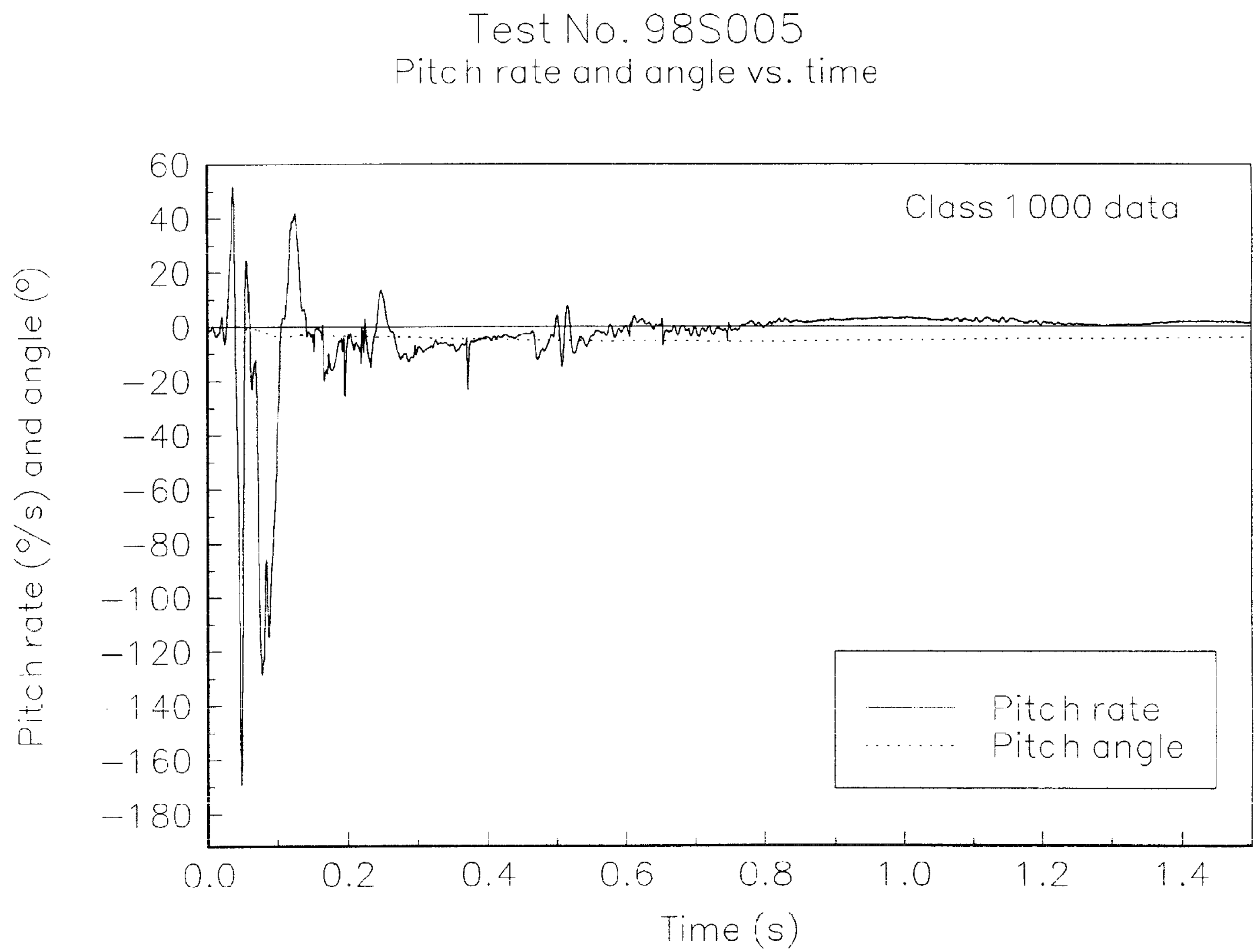


Figure 18. Pitch rate and angle vs. time, test 98S005.

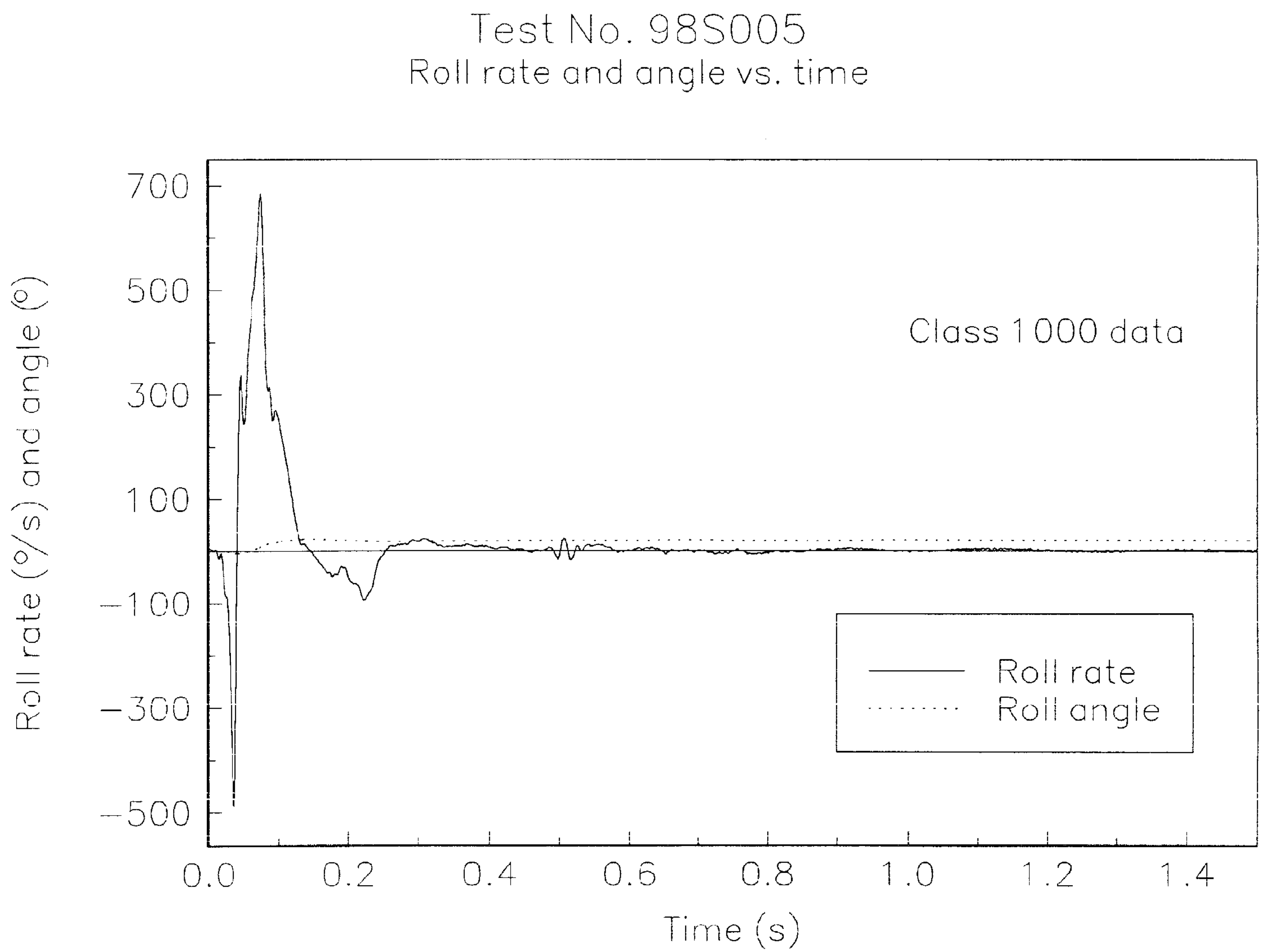


Figure 19. Roll rate and angle vs. time, test 98S005.

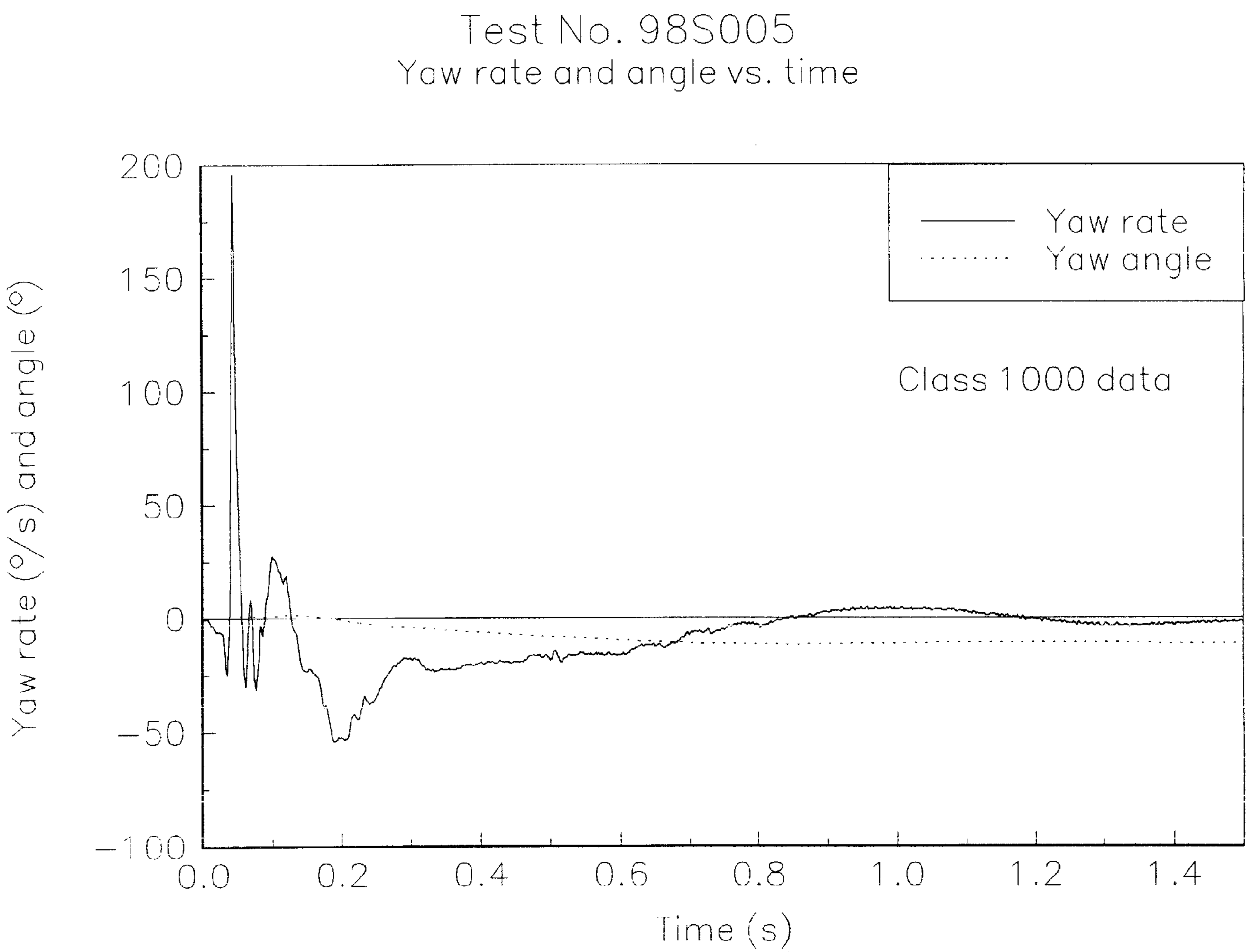


Figure 20. Yaw rate and angle vs. time, test 98S005.

APPENDIX B. DATA PLOTS FROM INSTRUMENTED SID/HIII

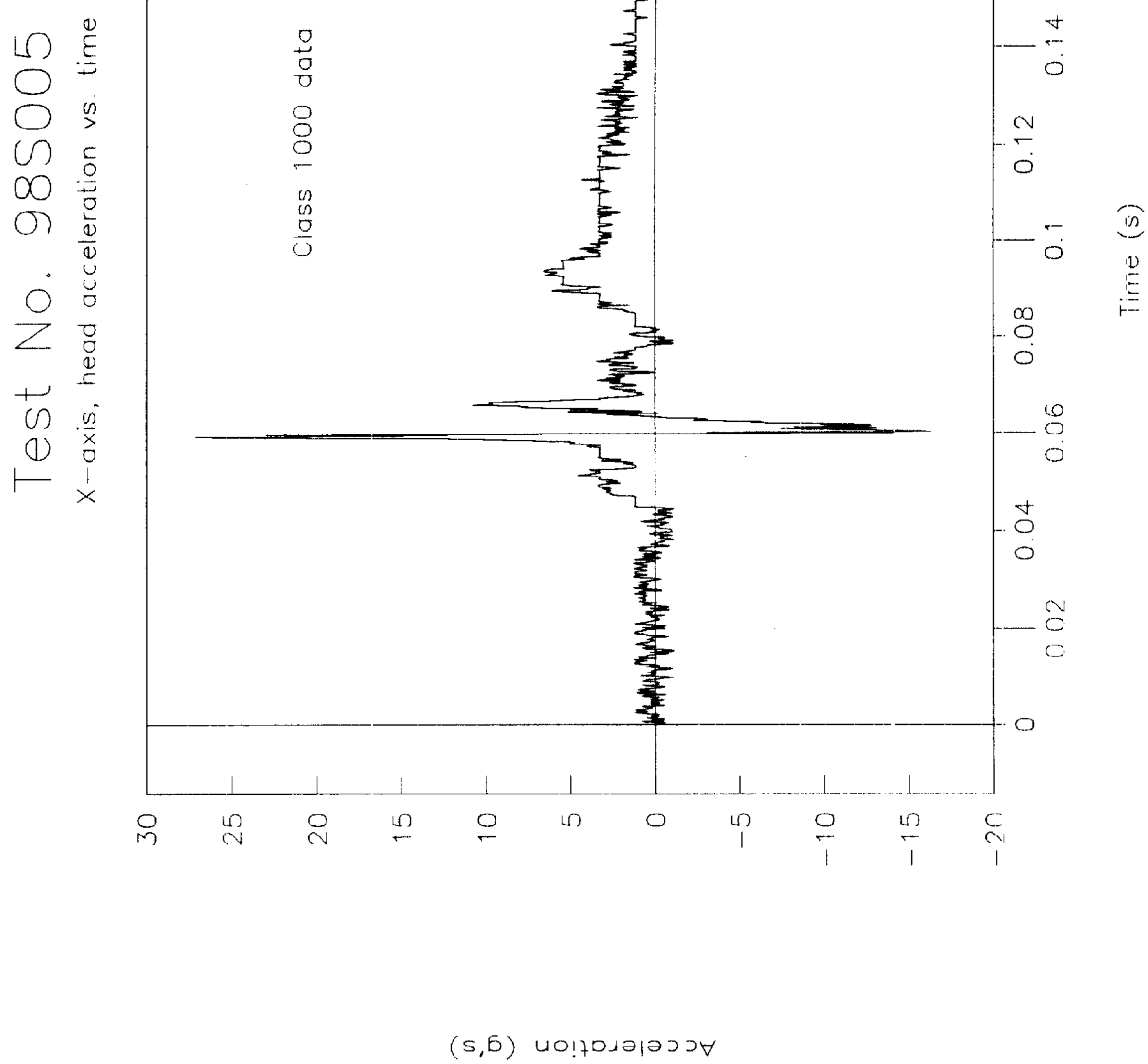


Figure 21. Acceleration vs. time, X-axis head, test 98S005.

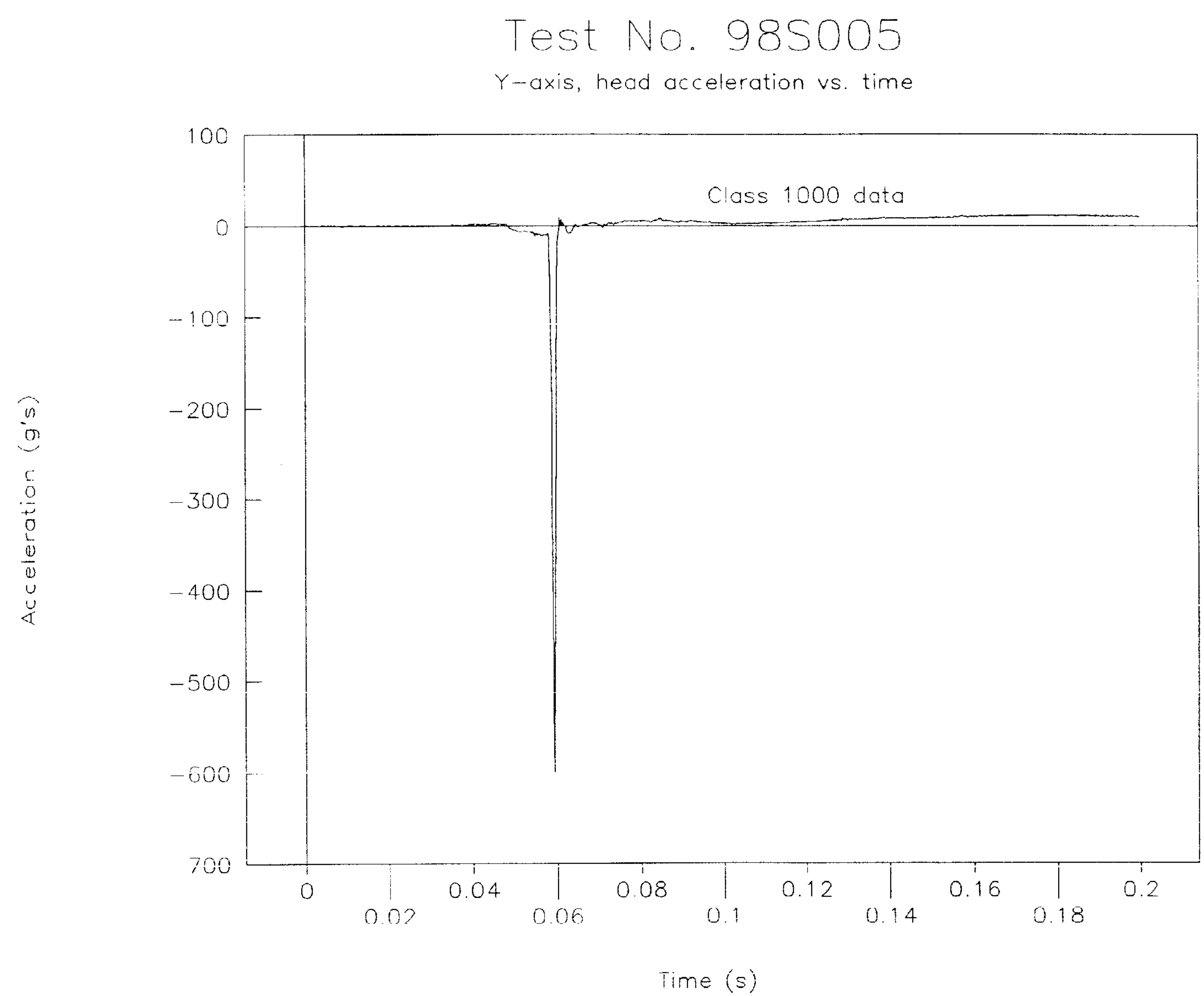


Figure 22. Acceleration vs. time, Y-axis head, test 98S005.

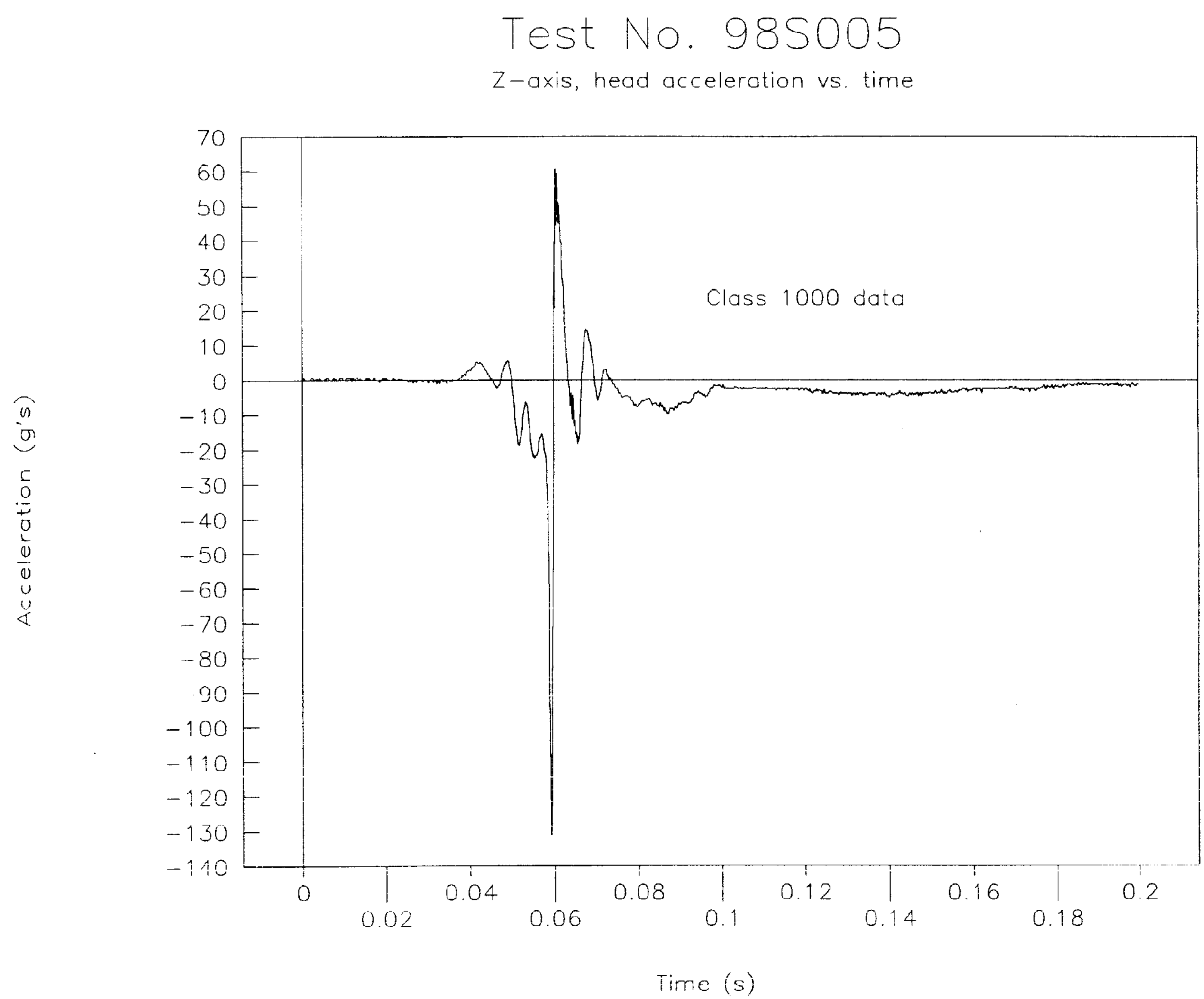


Figure 23. Acceleration vs. time, Z-axis head, test 98S005.

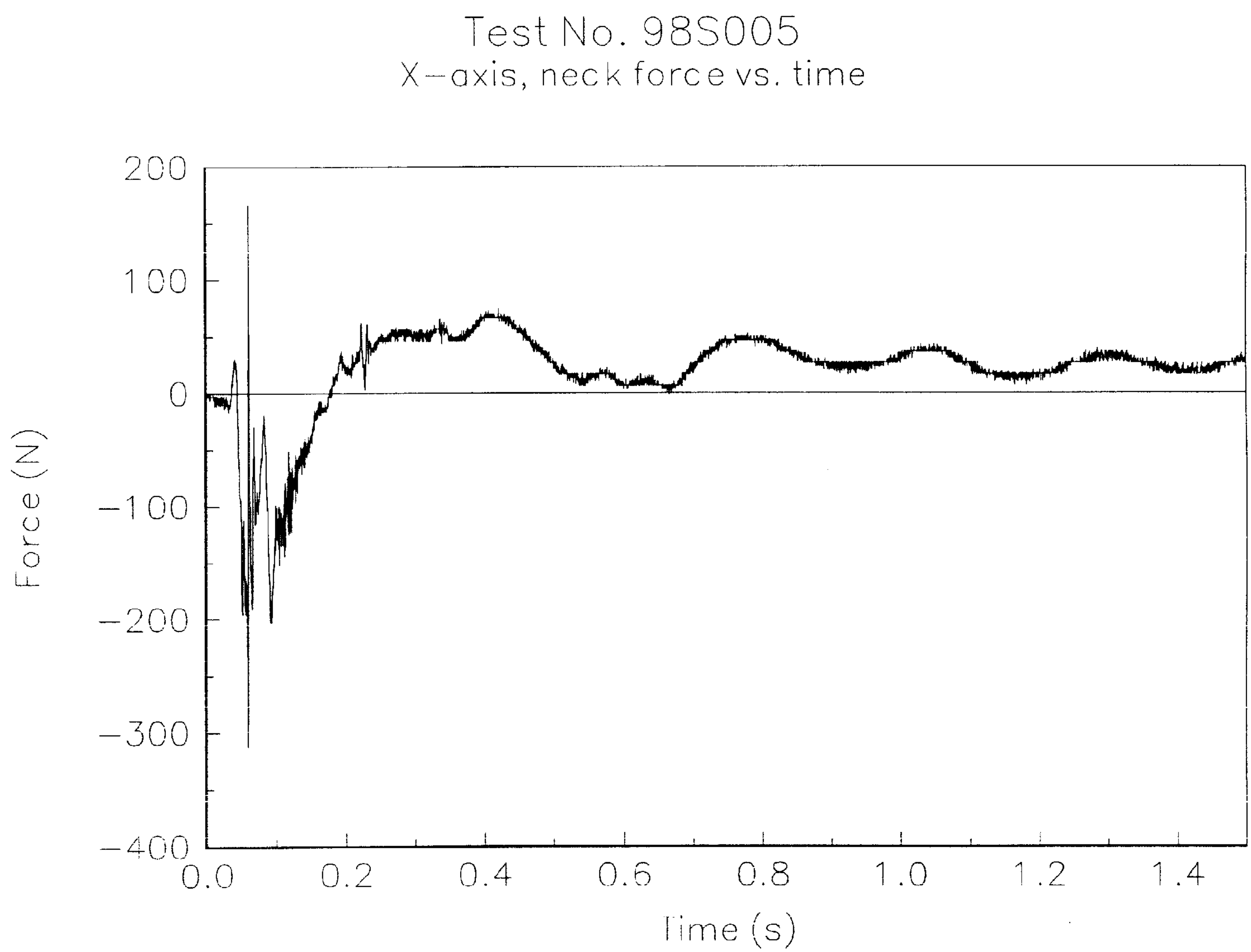


Figure 24. Force vs. time, X-axis neck, test 98S005.

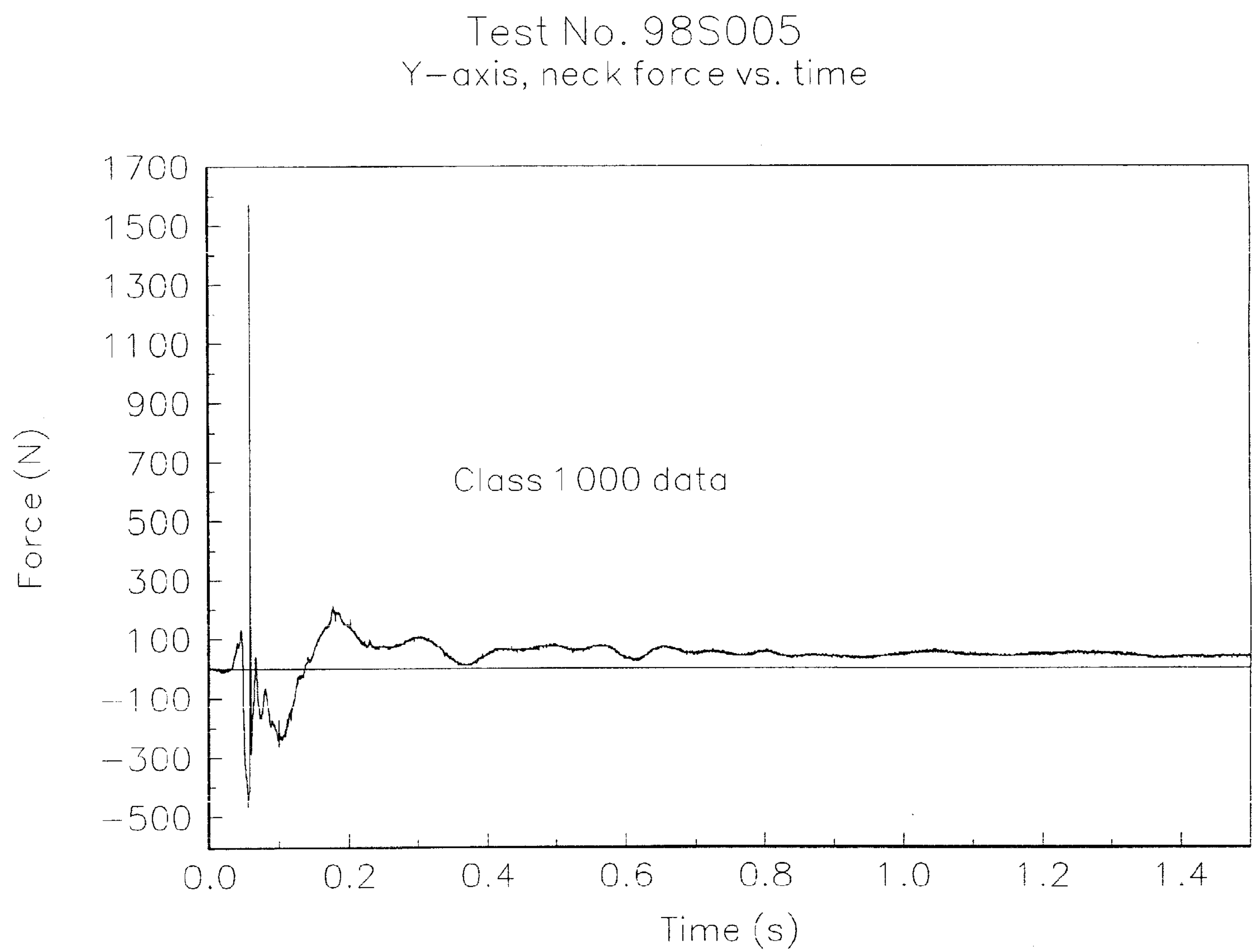


Figure 25. Force vs. time, Y-axis neck, test 98S005.

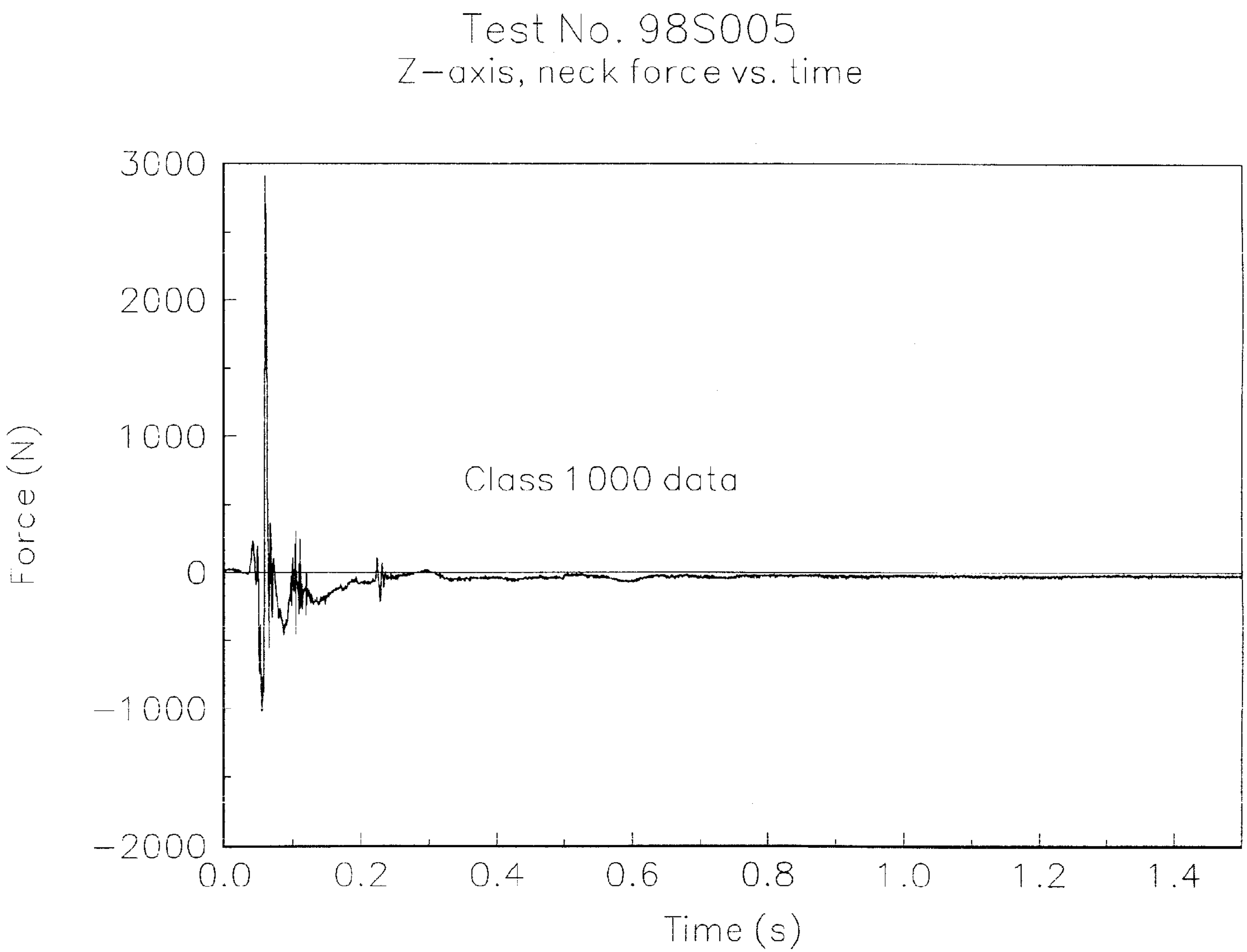


Figure 26. Force vs. time, Z-axis neck, test 98S005.

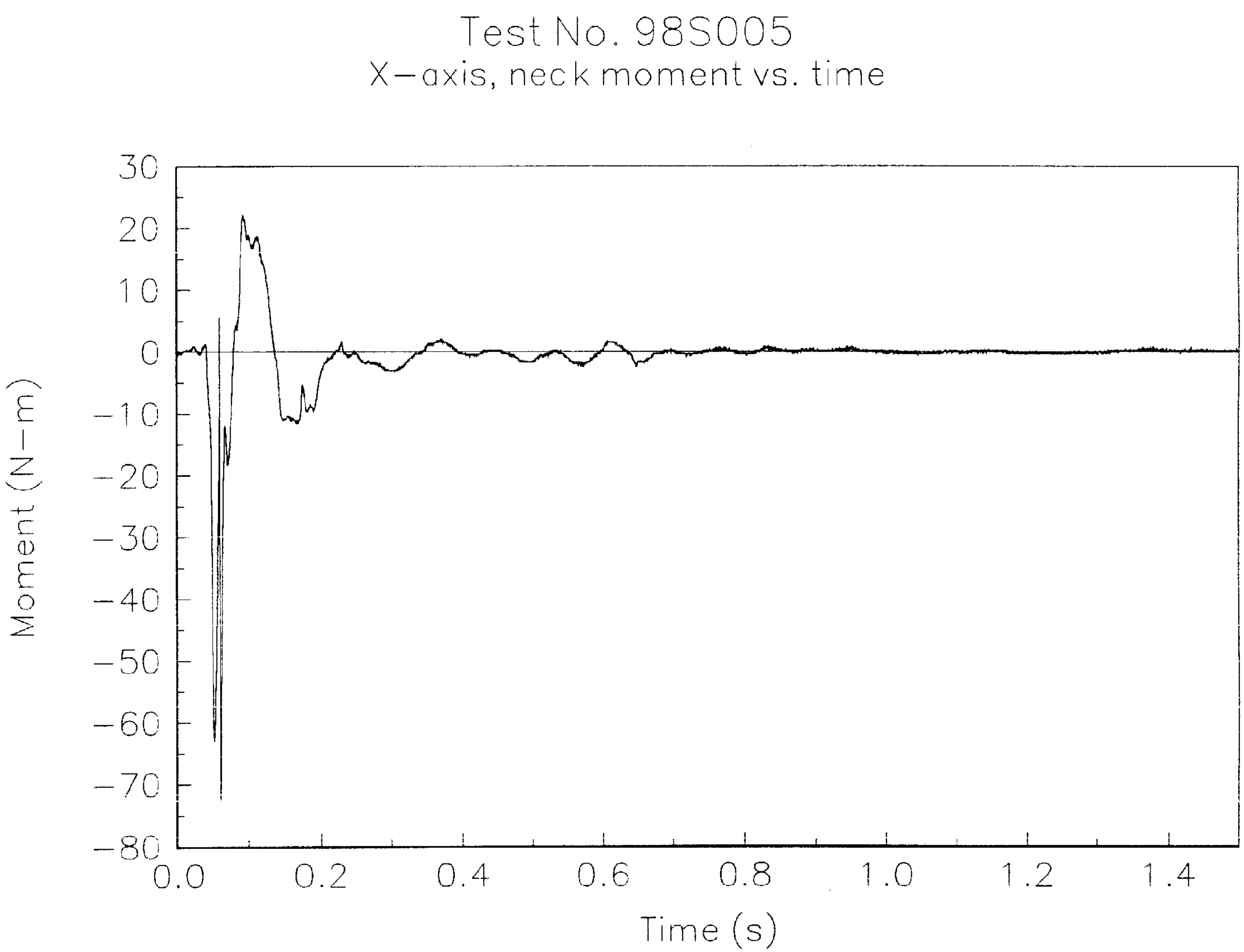


Figure 27. Moment vs. time, X-axis neck, test 98S005.

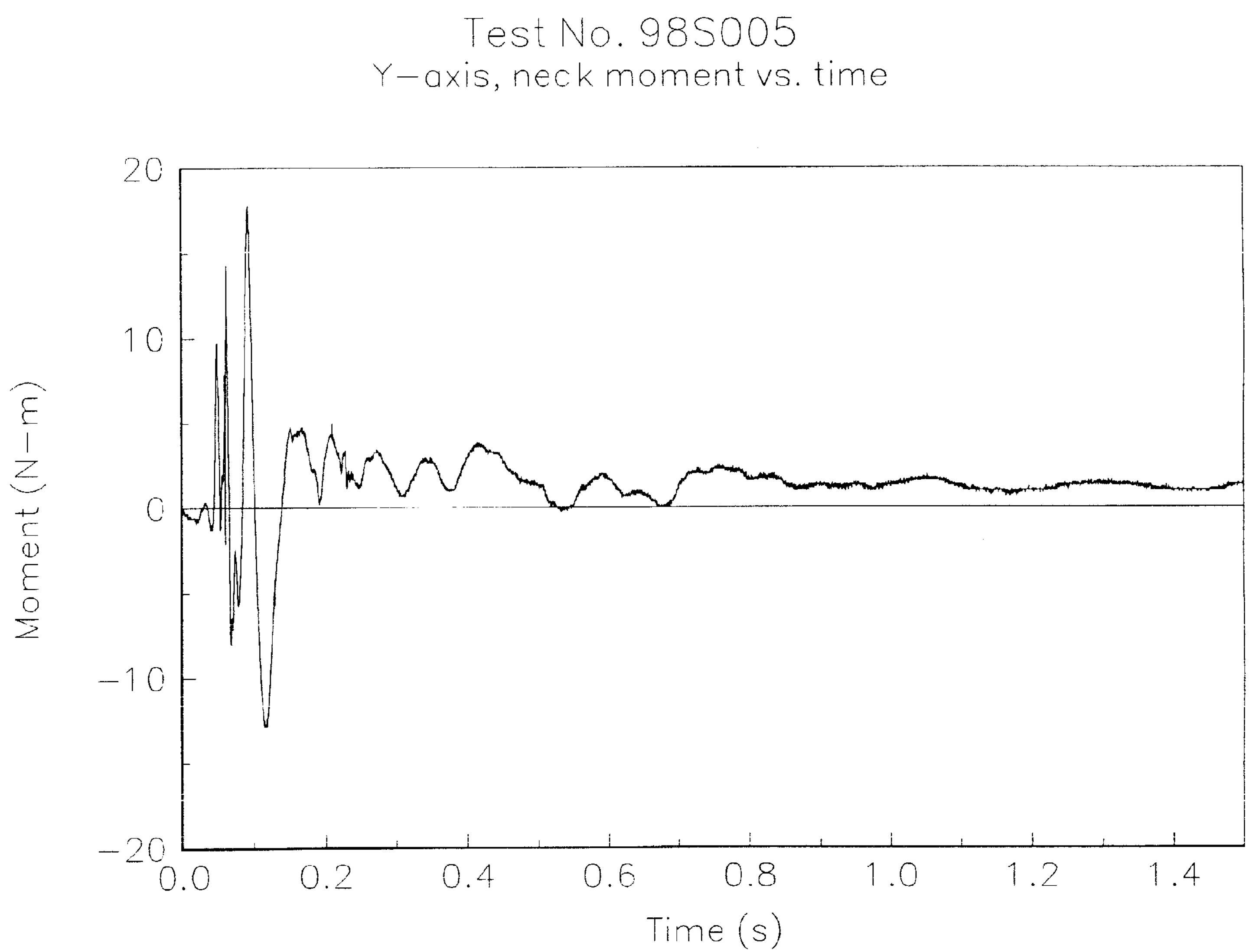


Figure 28. Moment vs. time, Y-axis neck, test 98S005.

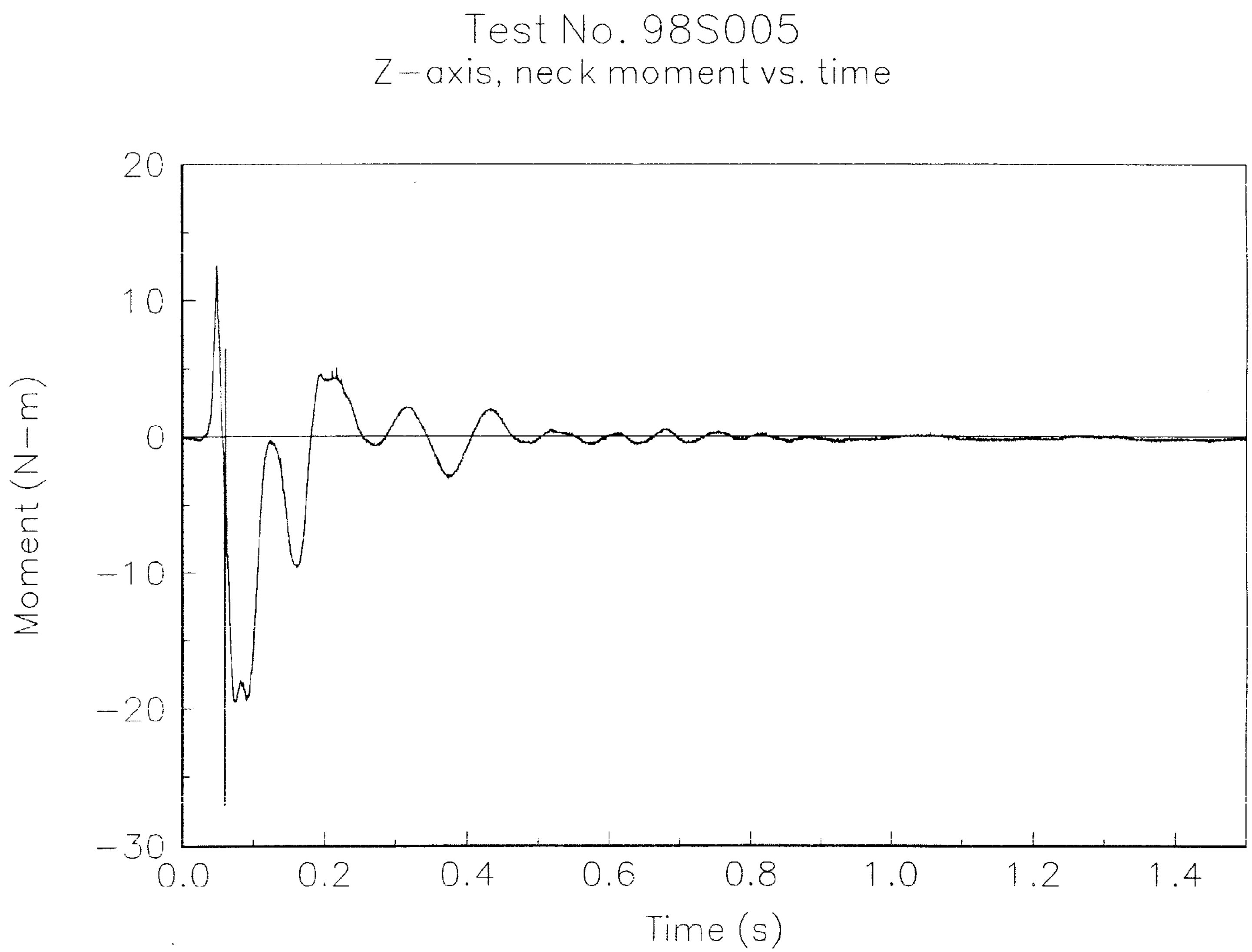


Figure 29. Moment vs. time, Z-axis neck, test 98S005.

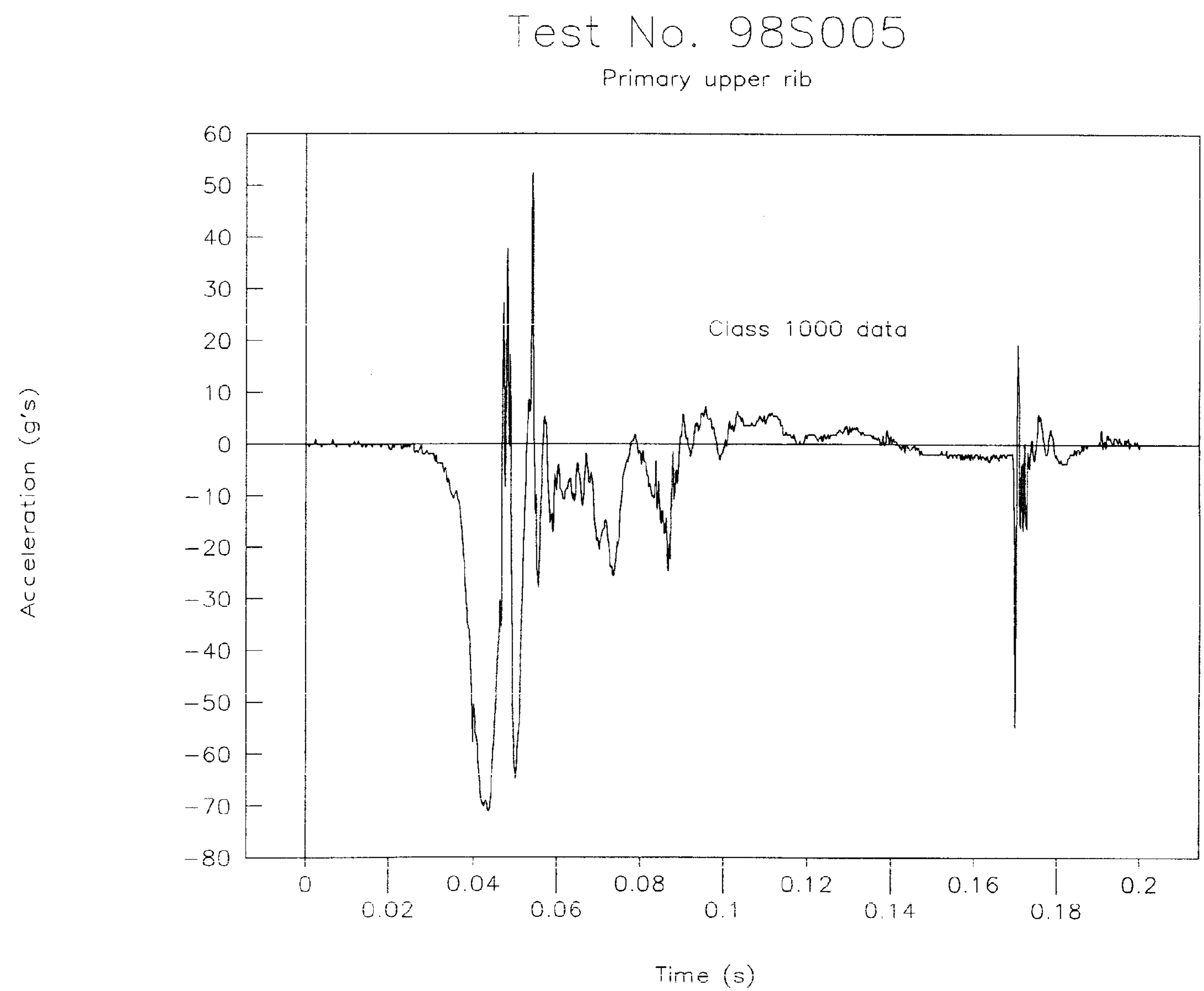


Figure 30. Acceleration vs. time, primary upper rib, test 98S005.

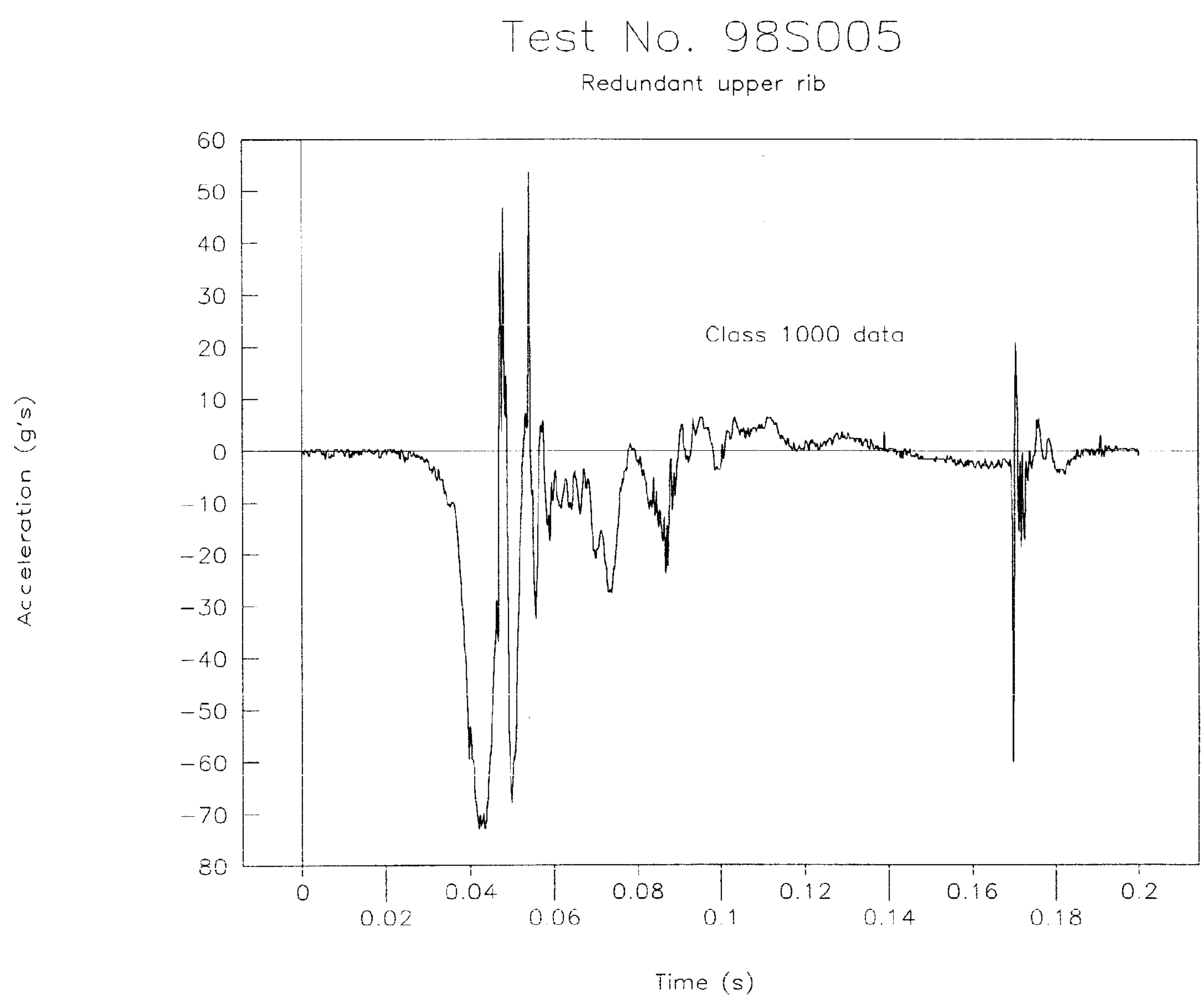


Figure 31. Acceleration vs. time, redundant upper rib, test 98S005.

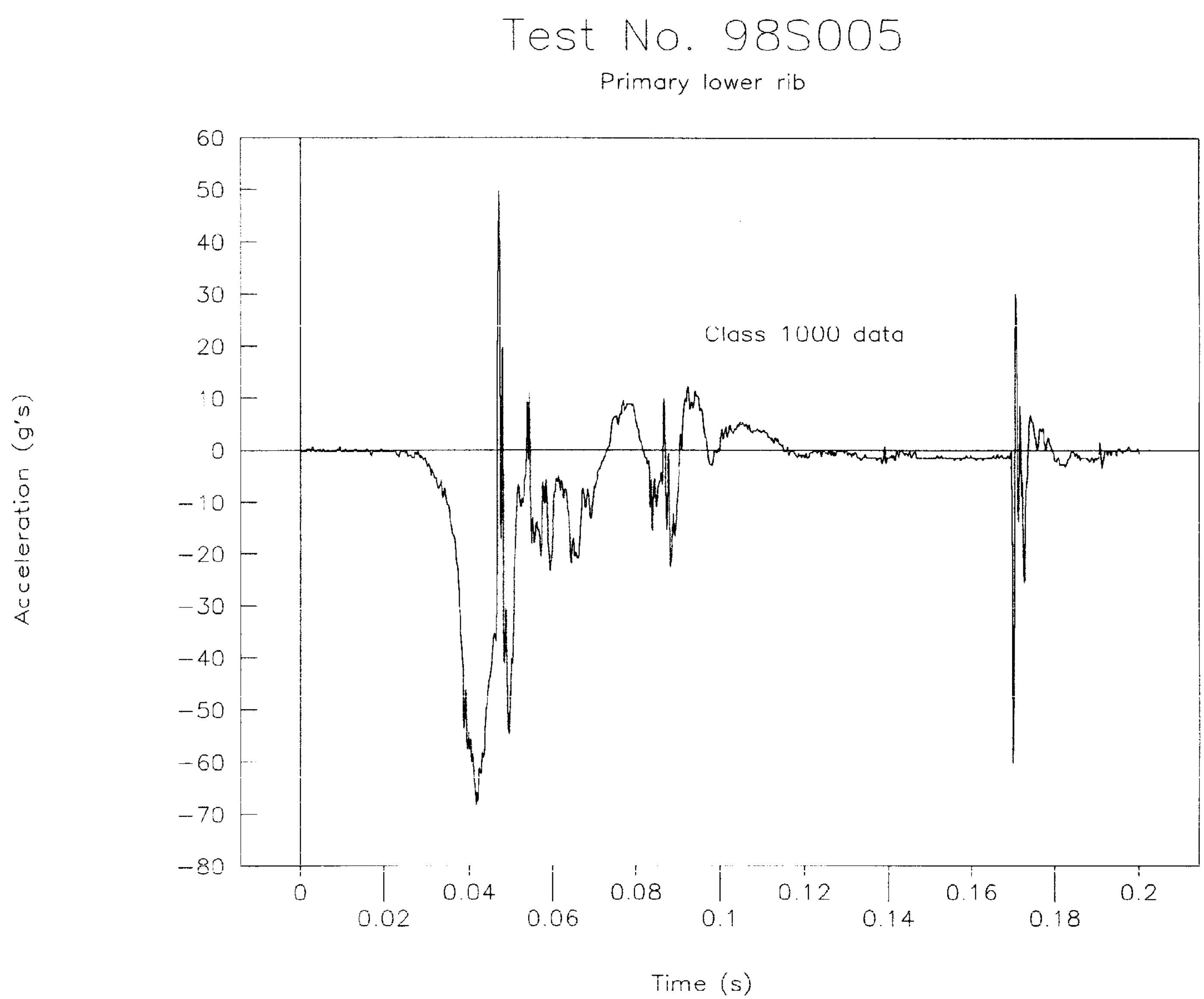


Figure 32. Acceleration vs. time, primary lower rib, test 98S005.

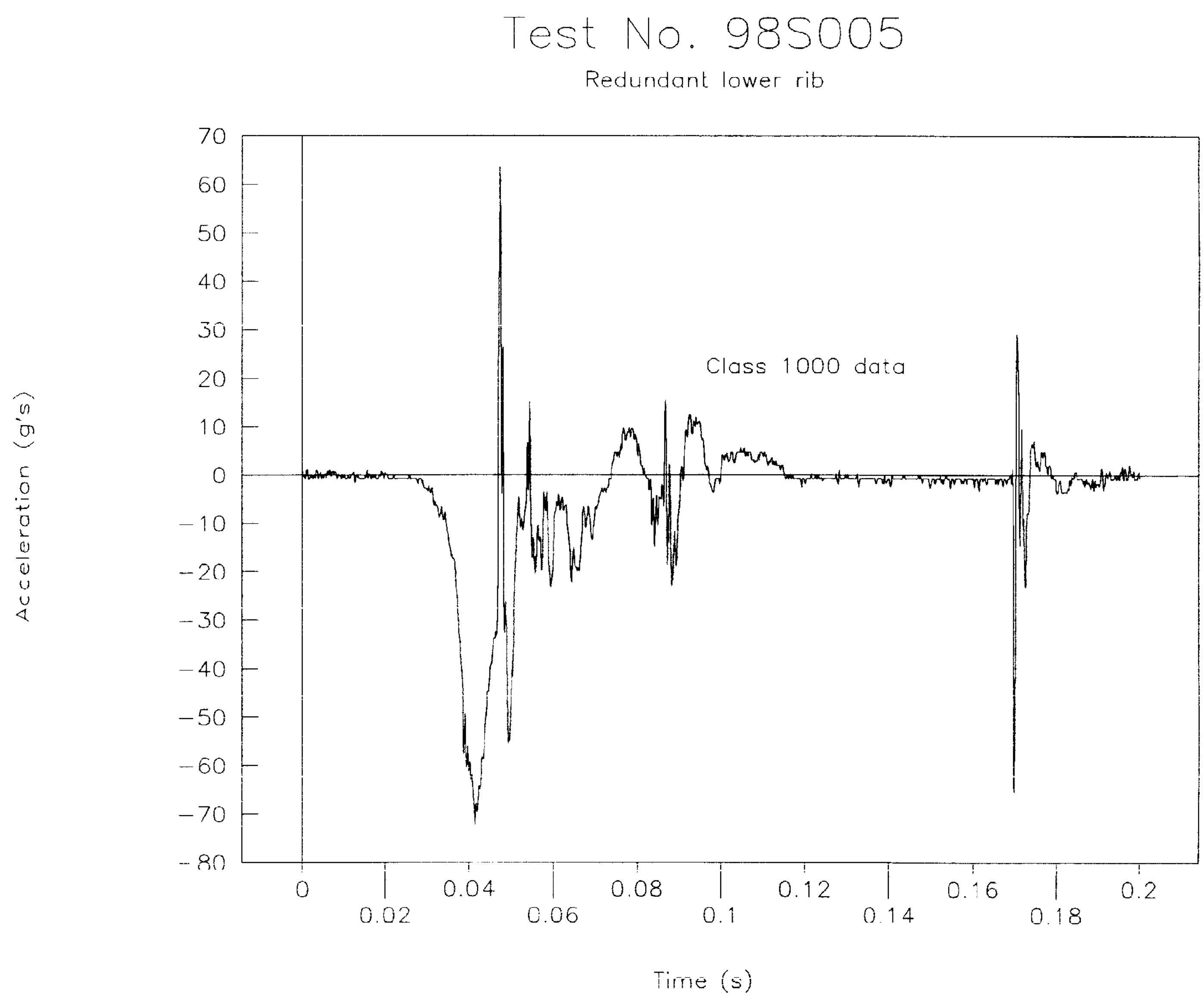


Figure 33. Acceleration vs. time, redundant lower rib, test 98S005.

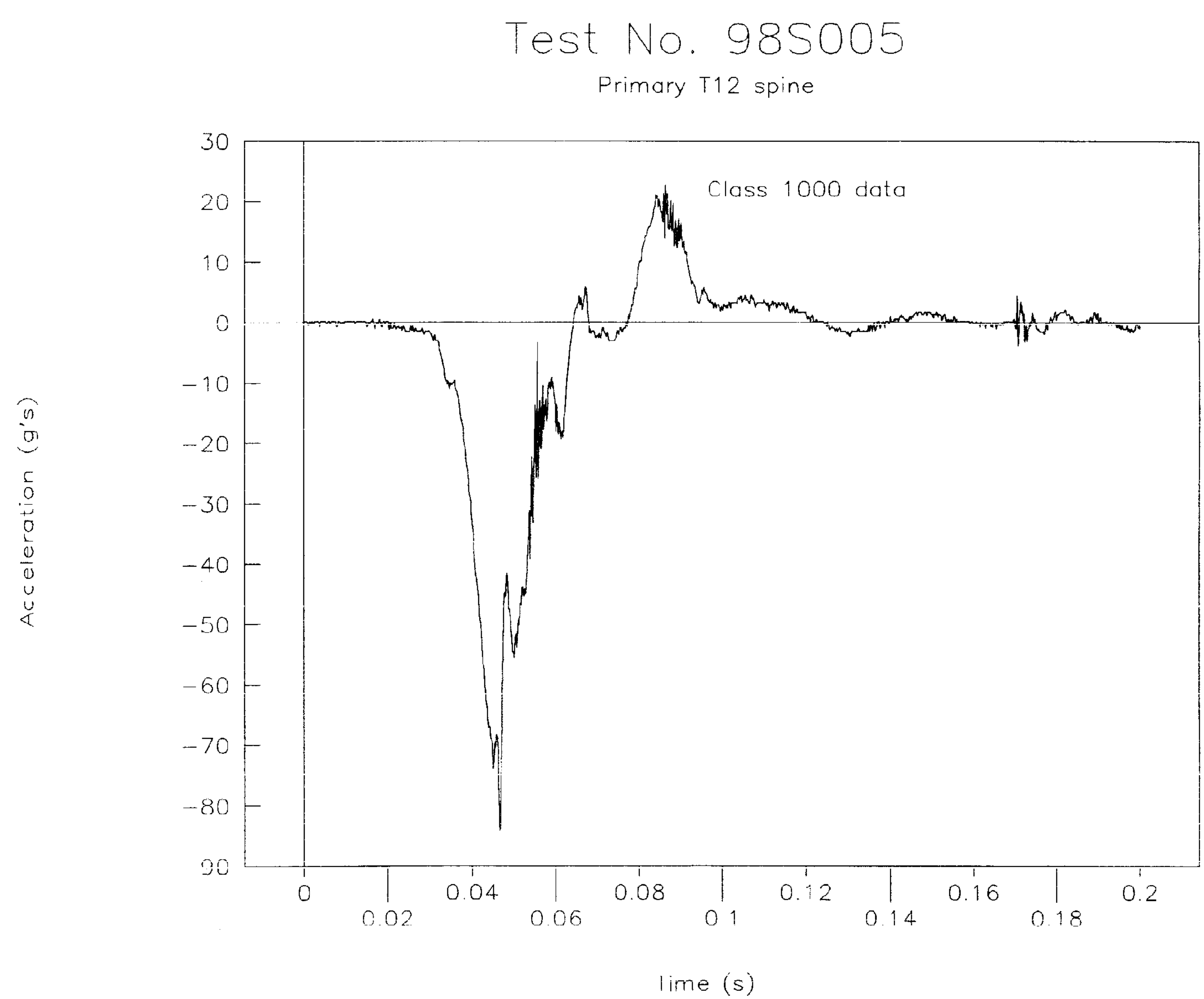


Figure 34. Acceleration vs. time, primary T12 spine, test 98S005.

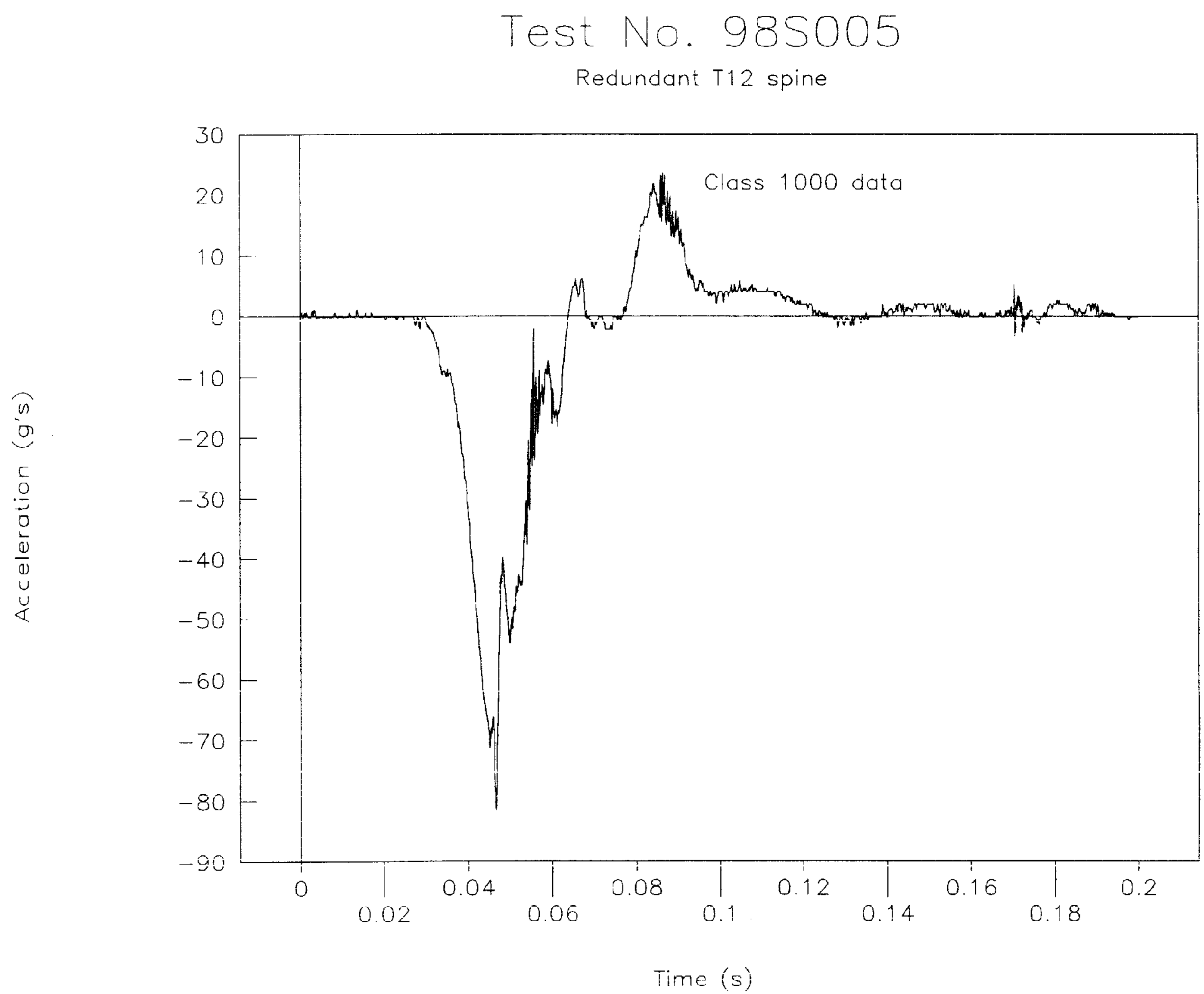


Figure 35. Acceleration vs. time, redundant T12 spine, test 98S005.

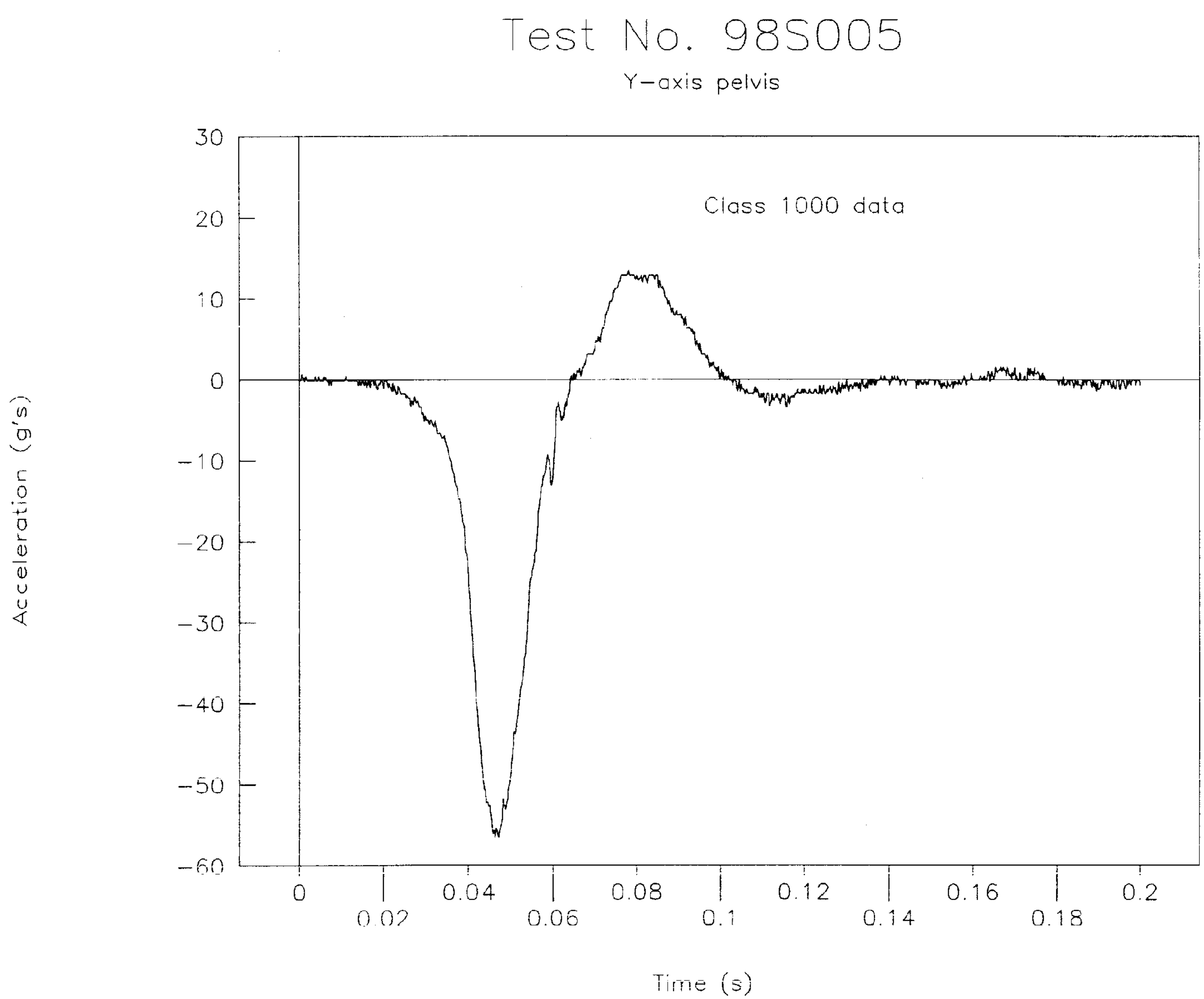


Figure 36. Acceleration vs. time, Y-axis pelvis, test 98S005.

APPENDIX C. TEST PHOTOGRAPHS

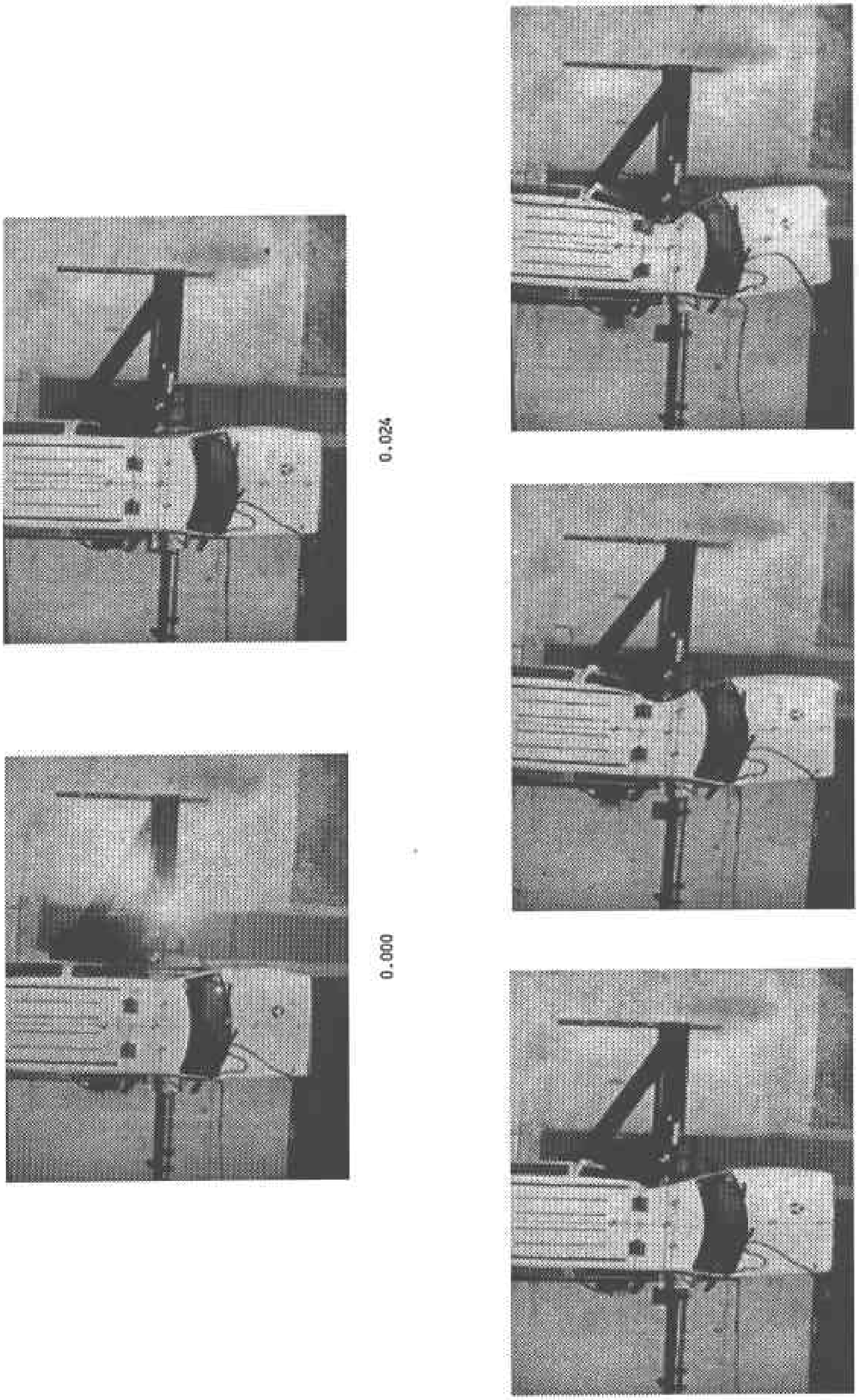


Figure 37. Test photographs during impact, test 98S005.

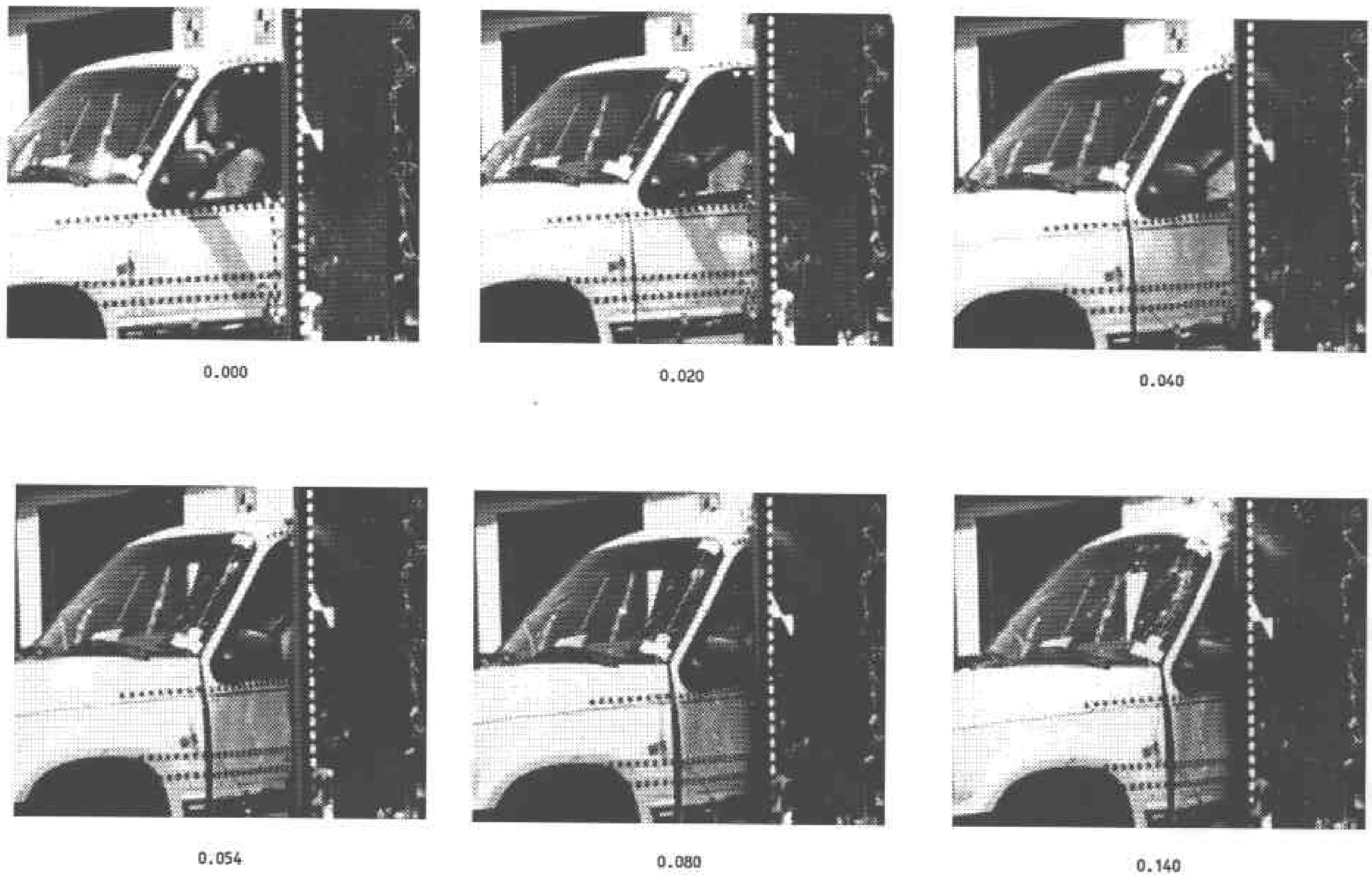
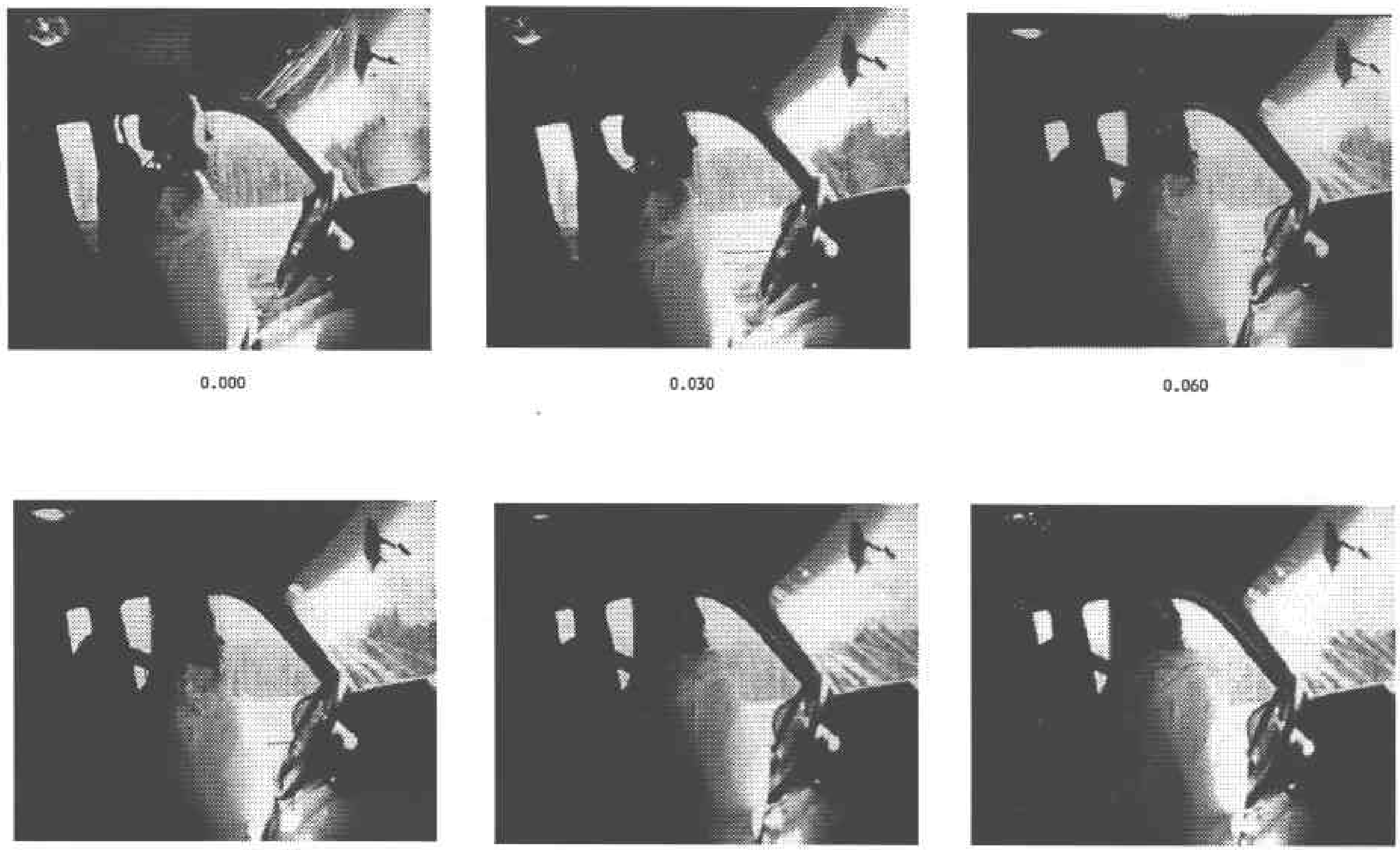


Figure 37. Test photographs during impact, test 98S005 (continued).



0.000 0.030 0.060

0.062 0.070 0.072

Figure 37. Test photographs during impact, test 98S005 (continued).

Figure 38. Pretest photographs, test 98S005.

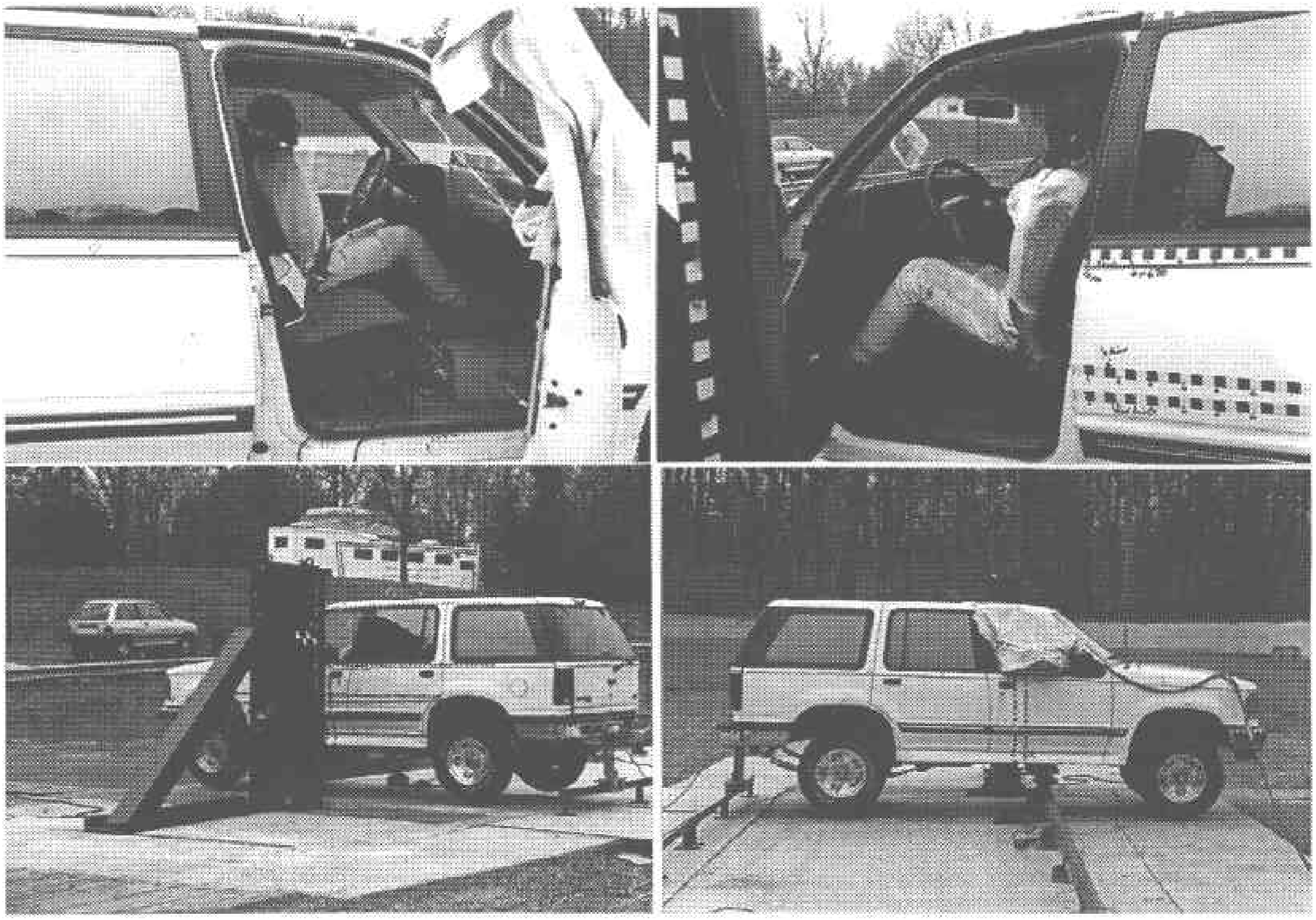


Figure 38. Pretest photographs, test 98S005 (continued).

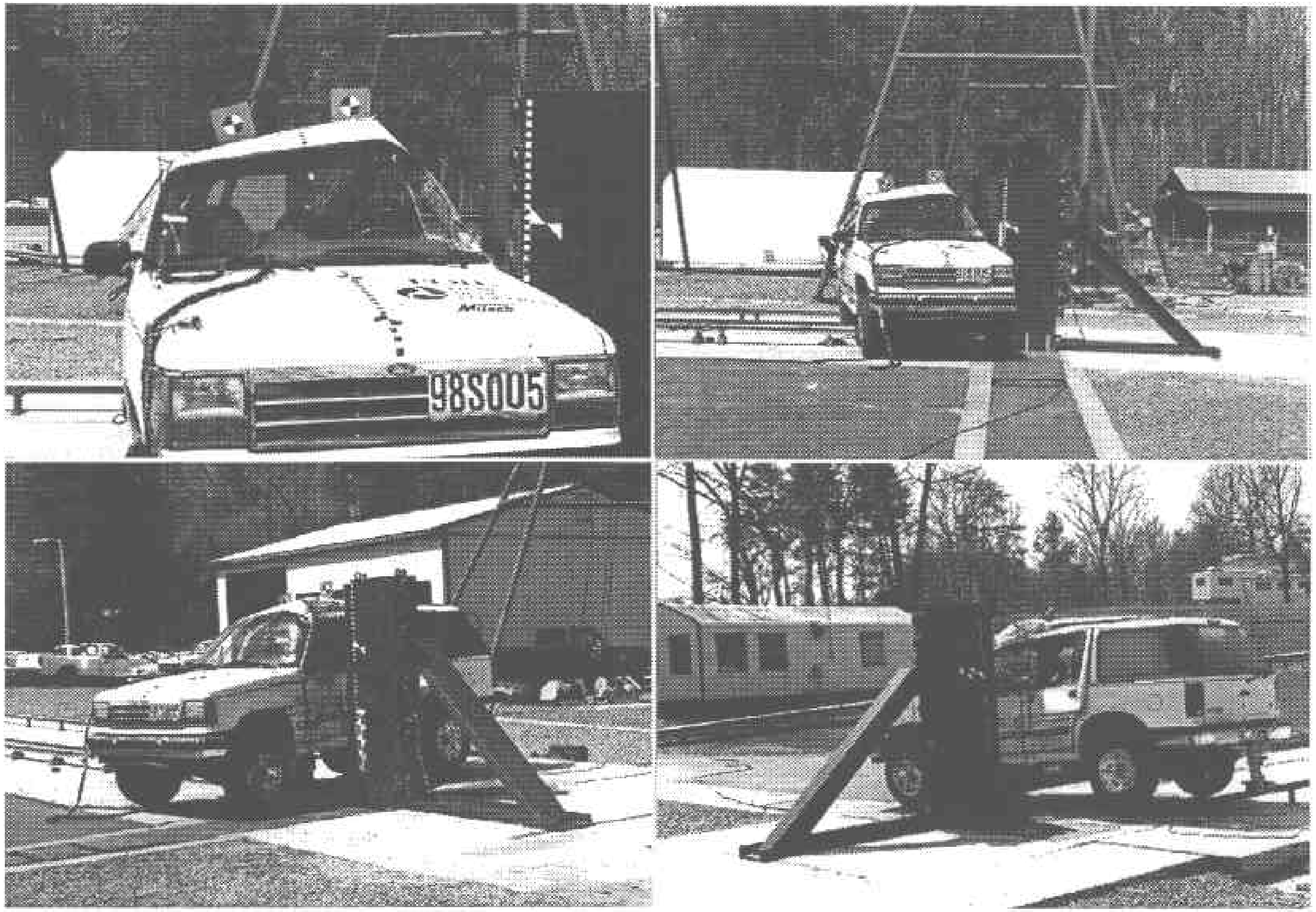


Figure 39. Post-test photographs, test 98S005.

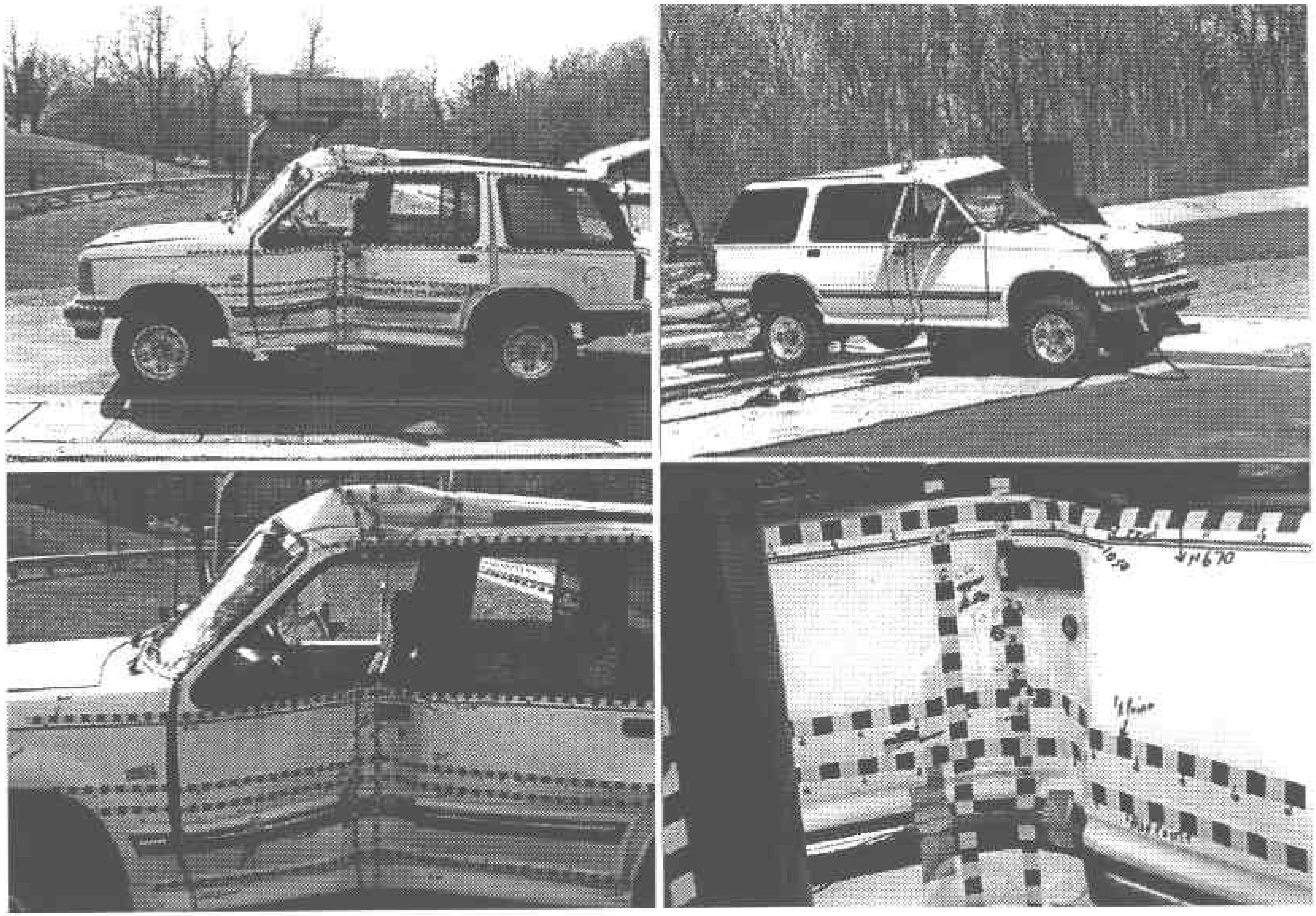


Figure 39. Post-test photographs, test 98S005 (continued).

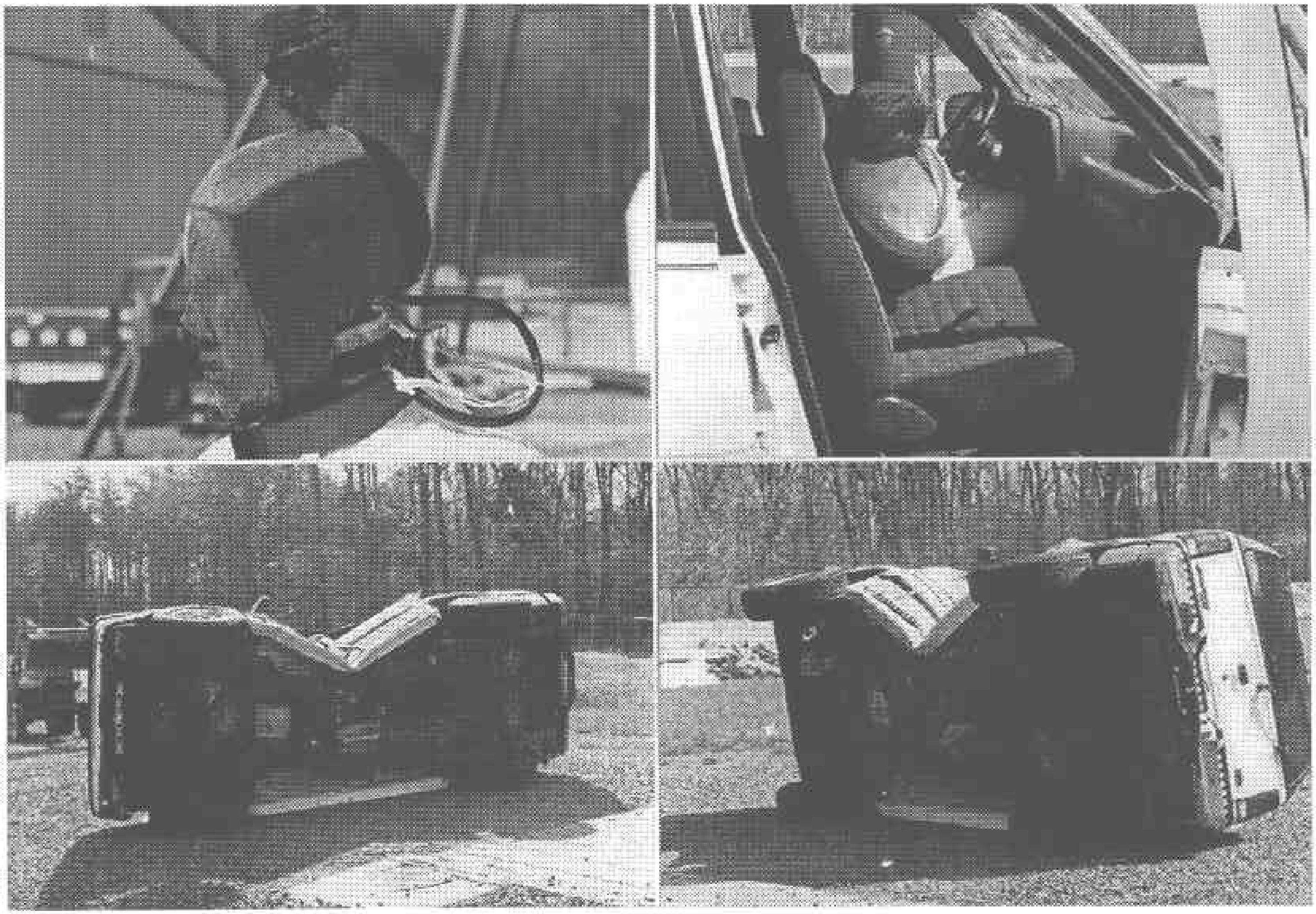


Figure 39. Post-test photographs, test 98S005 (continued).

APPENDIX D. DATA PLOTS FROM RIGID POLE LOAD CELLS

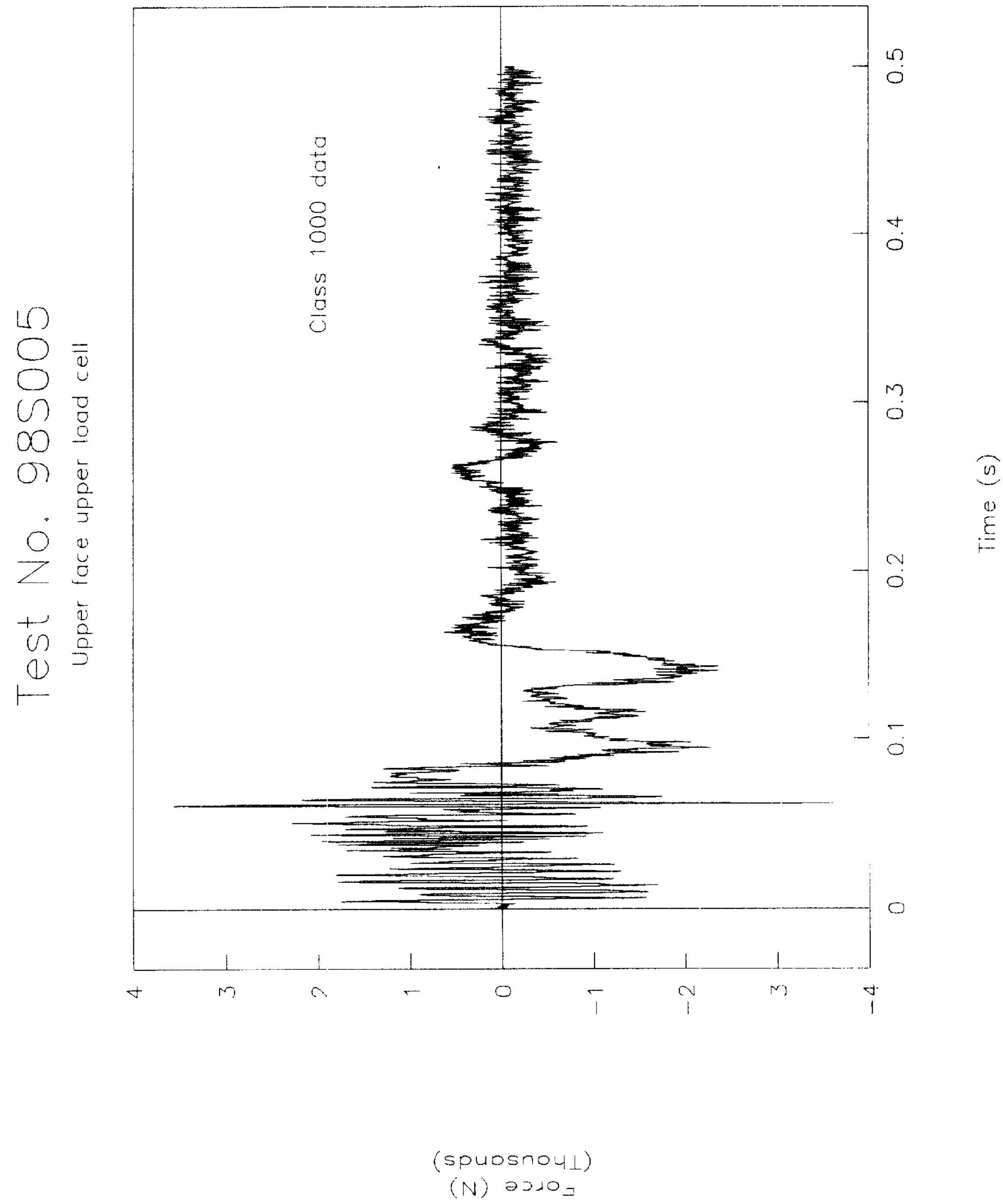


Figure 40. Rigid pole, force vs. time, upper face upper load cell, test 98S005.

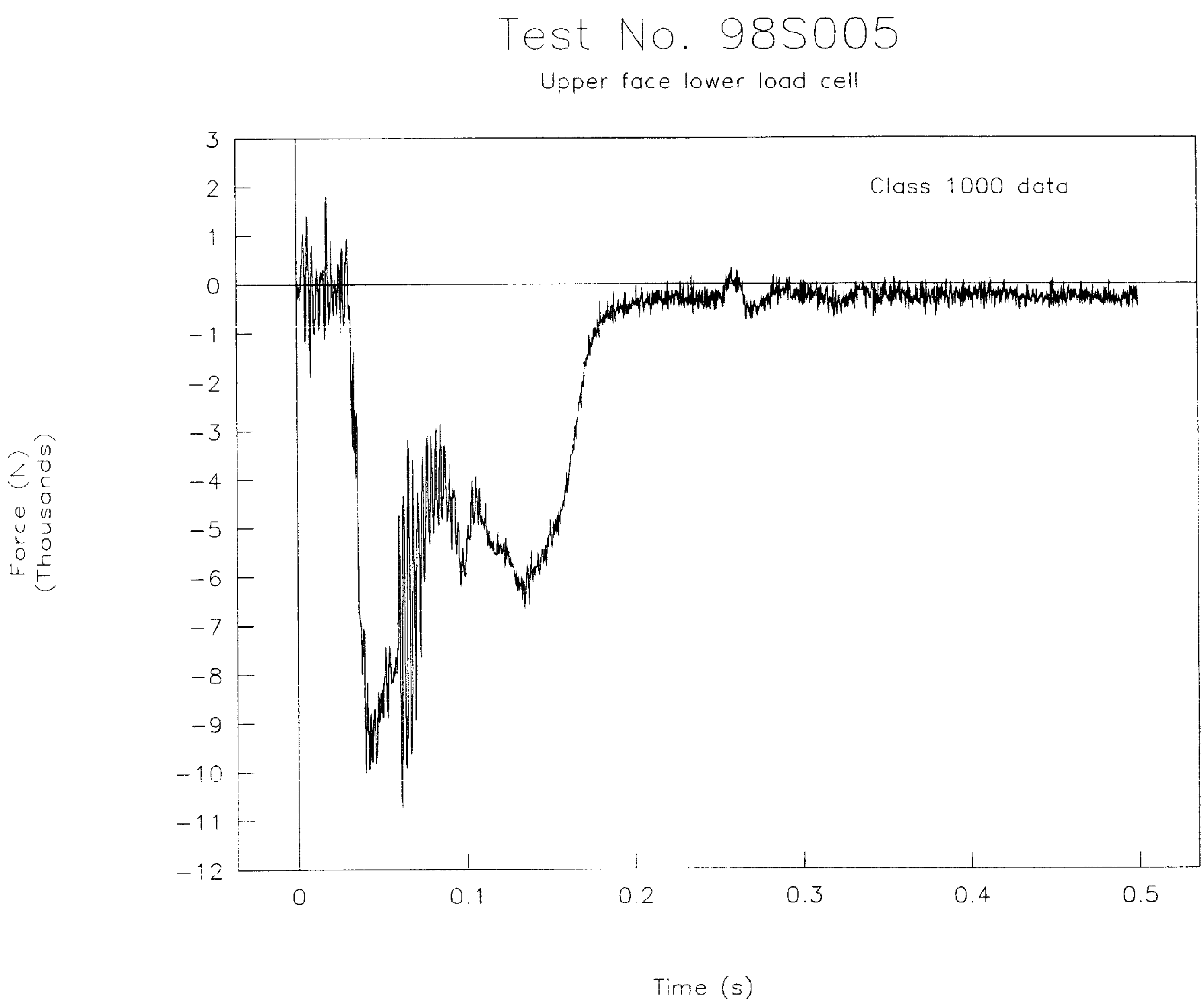


Figure 41. Rigid pole, force vs. time, upper face lower load cell, test 98S005.

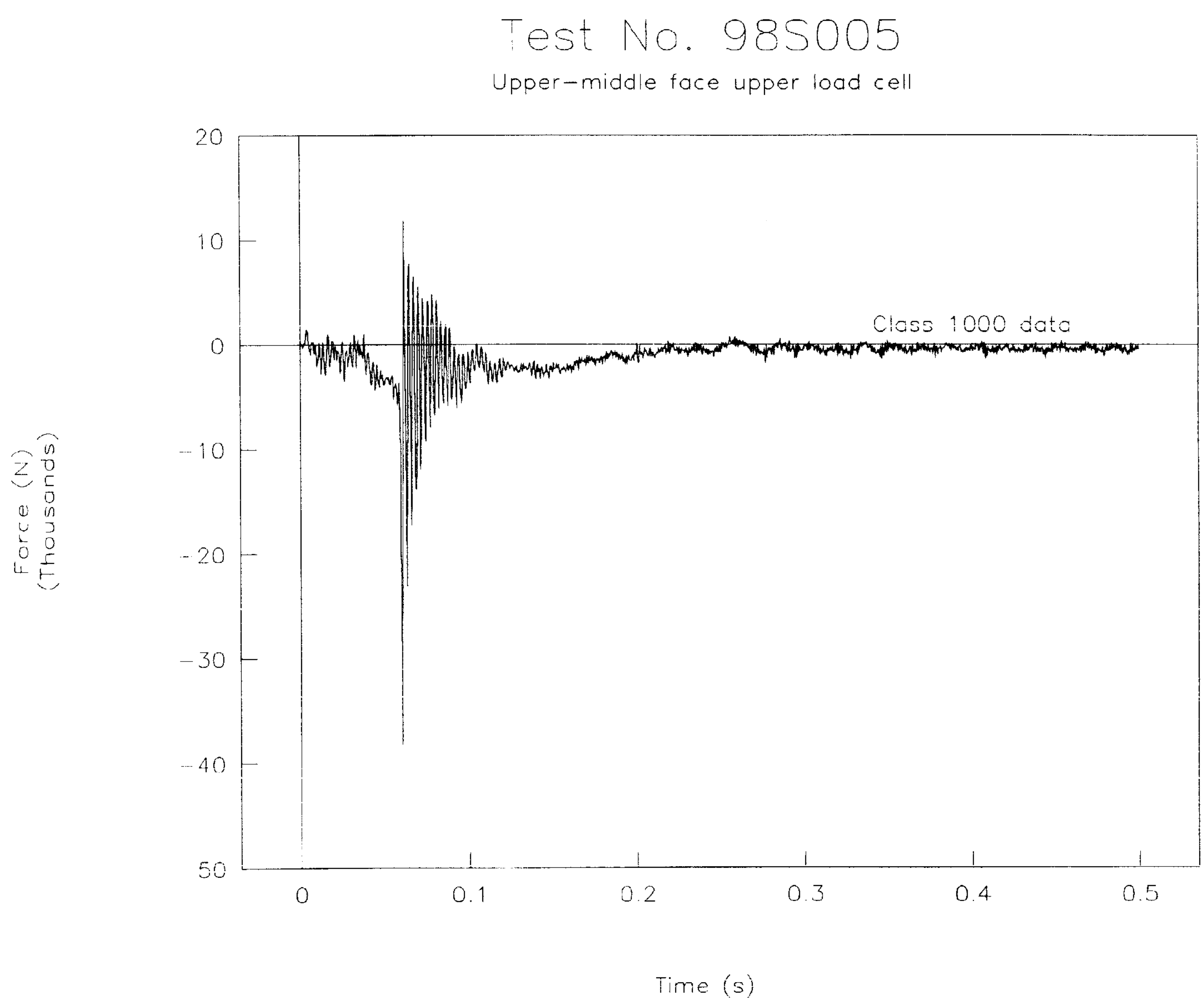


Figure 42. Rigid pole, force vs. time, upper-middle face upper load cell, test 98S005.

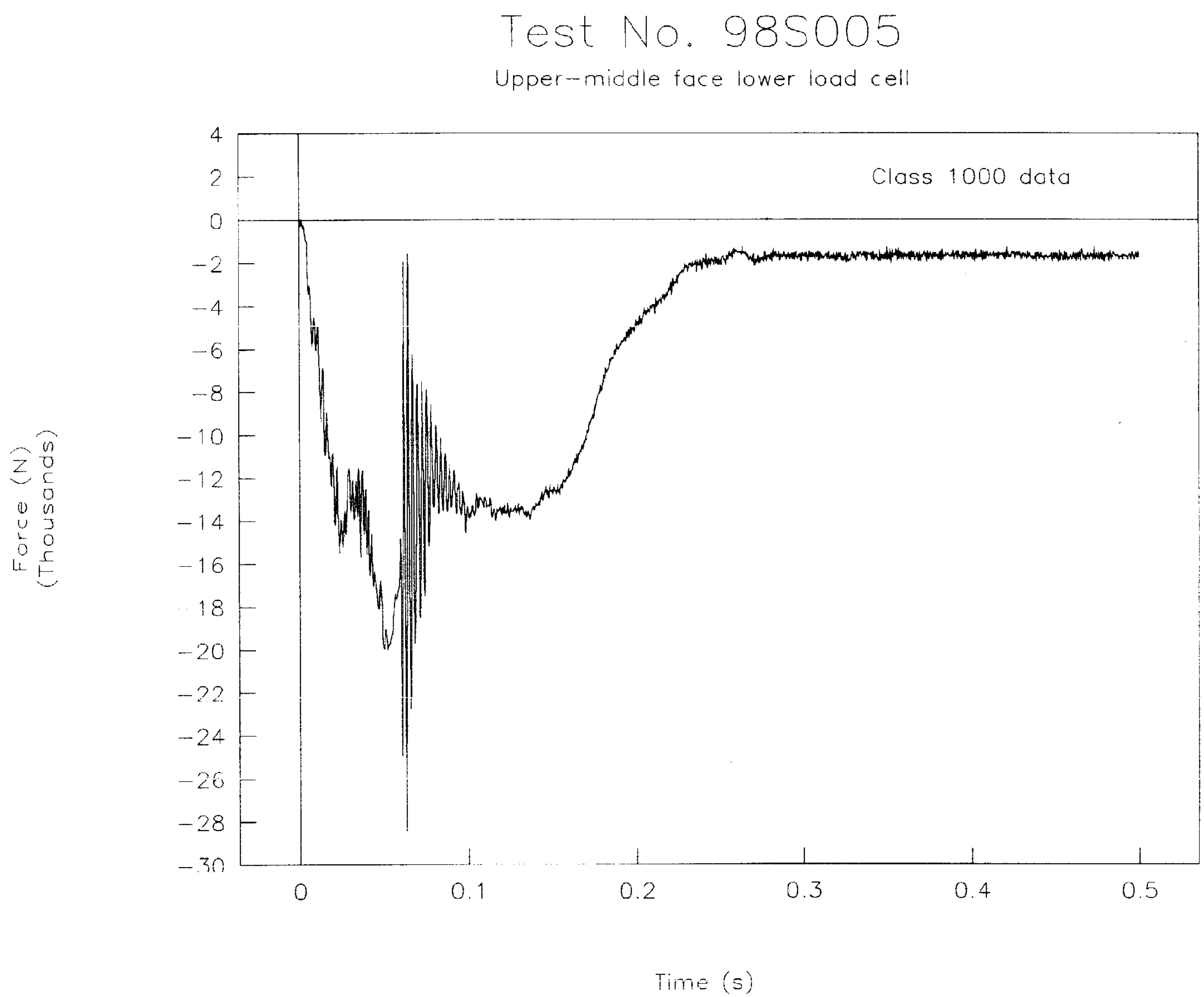


Figure 43. Rigid pole, force vs. time, upper-middle face lower load cell, test 98S005.

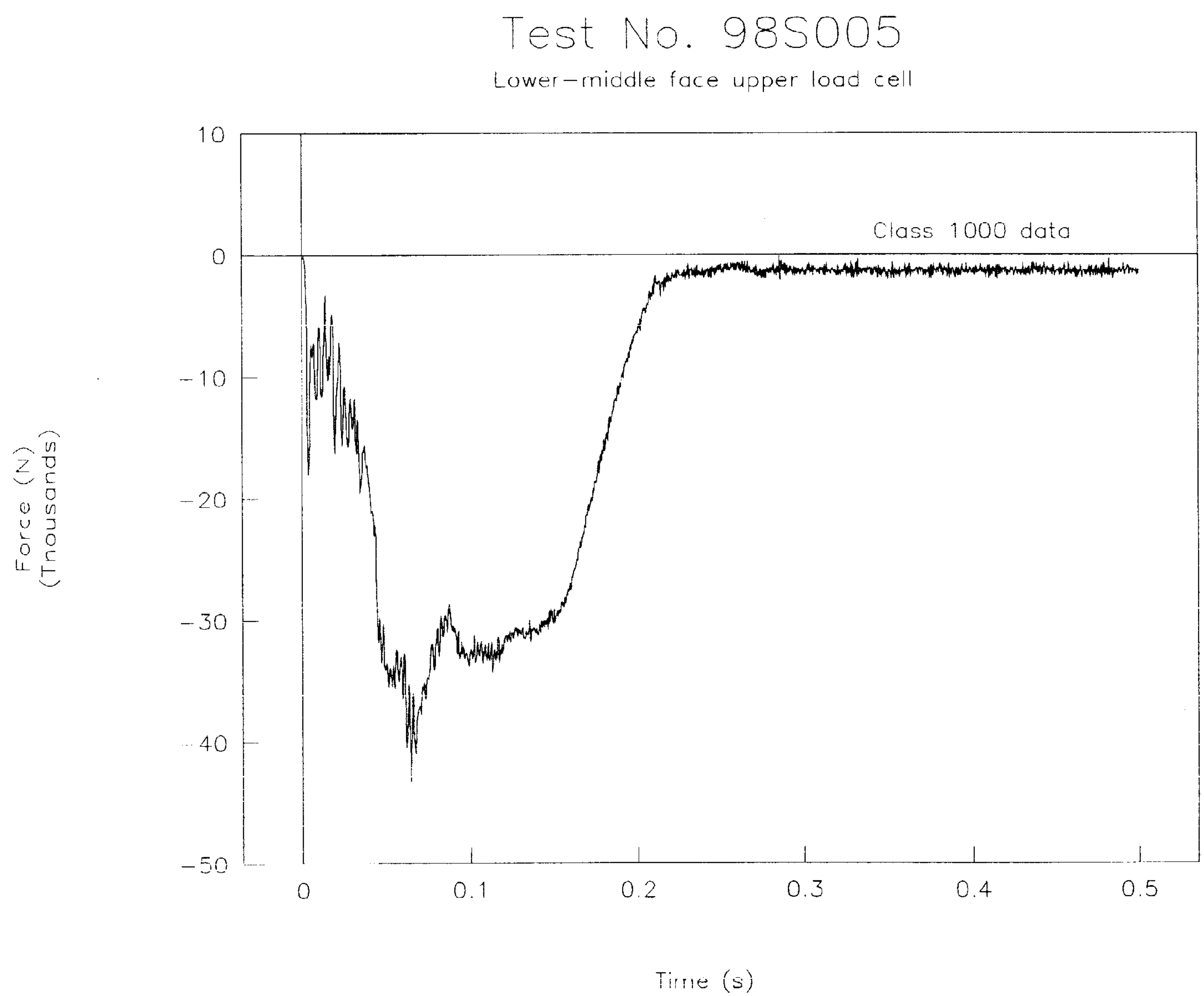


Figure 44. Rigid pole, force vs. time, lower-middle face upper load cell, test 98S005.

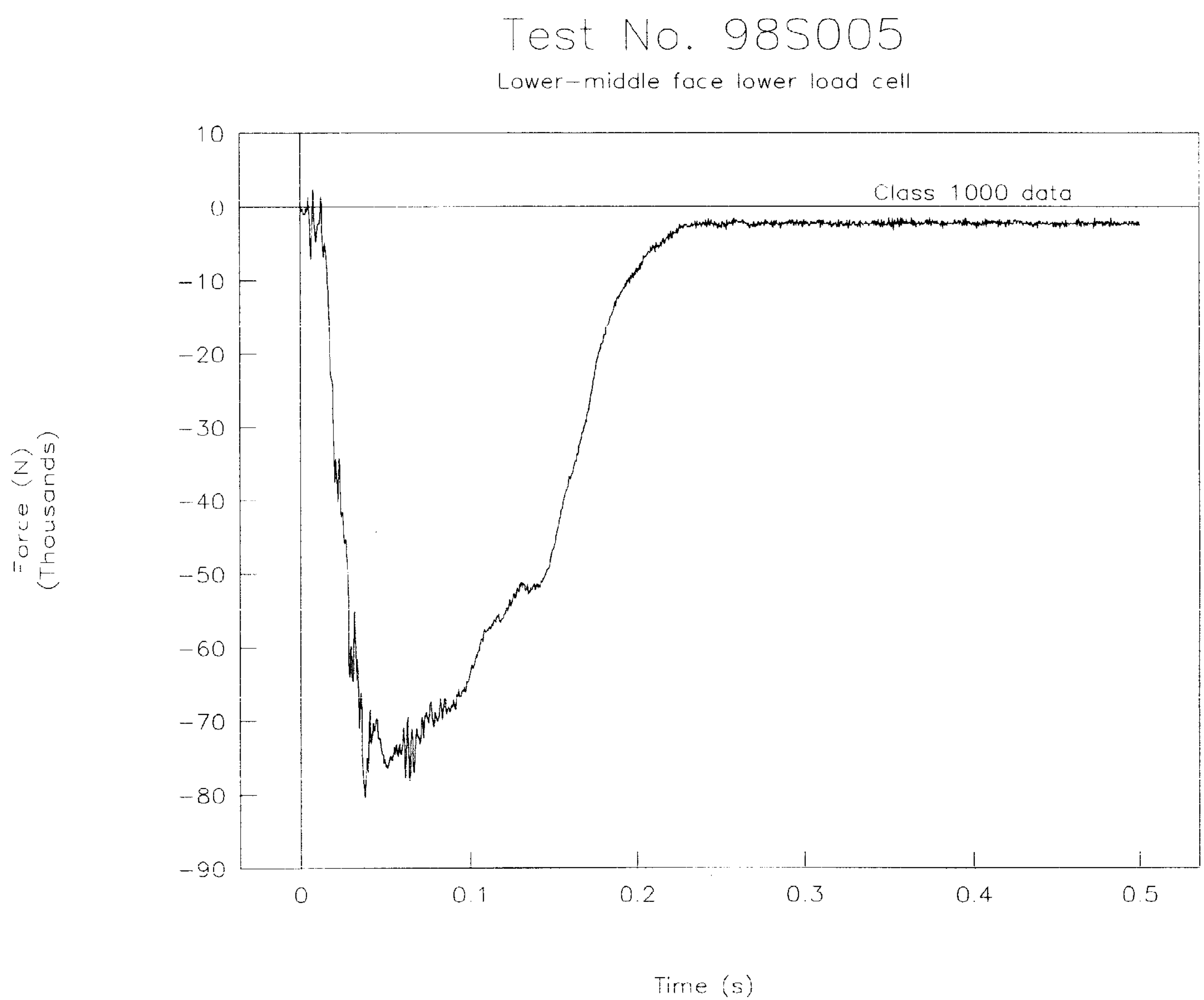


Figure 45. Rigid pole, force vs. time, lower-middle face lower load cell, test 98S005.

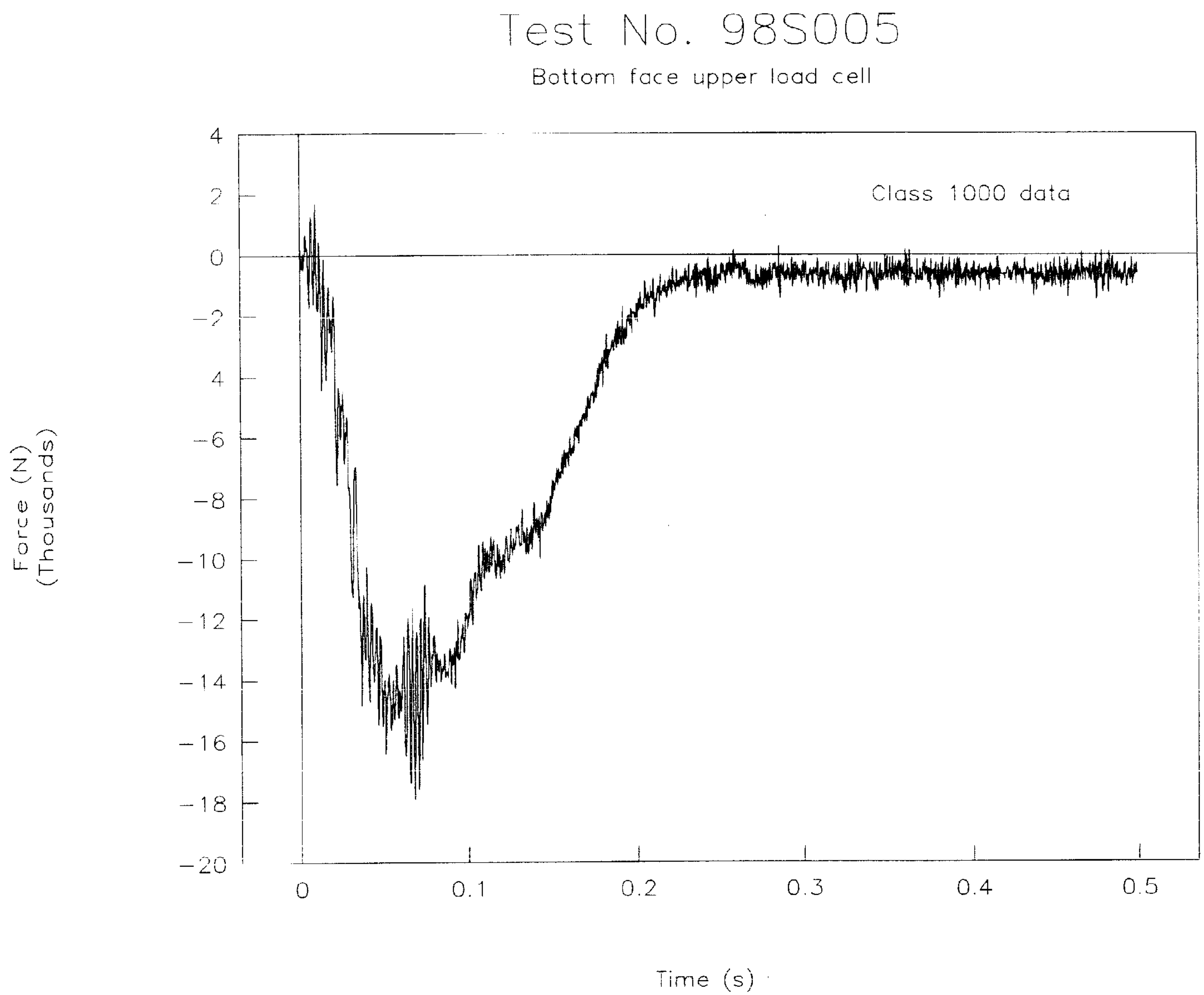


Figure 46. Rigid pole, force vs. time, bottom face upper load cell, test 98S005.

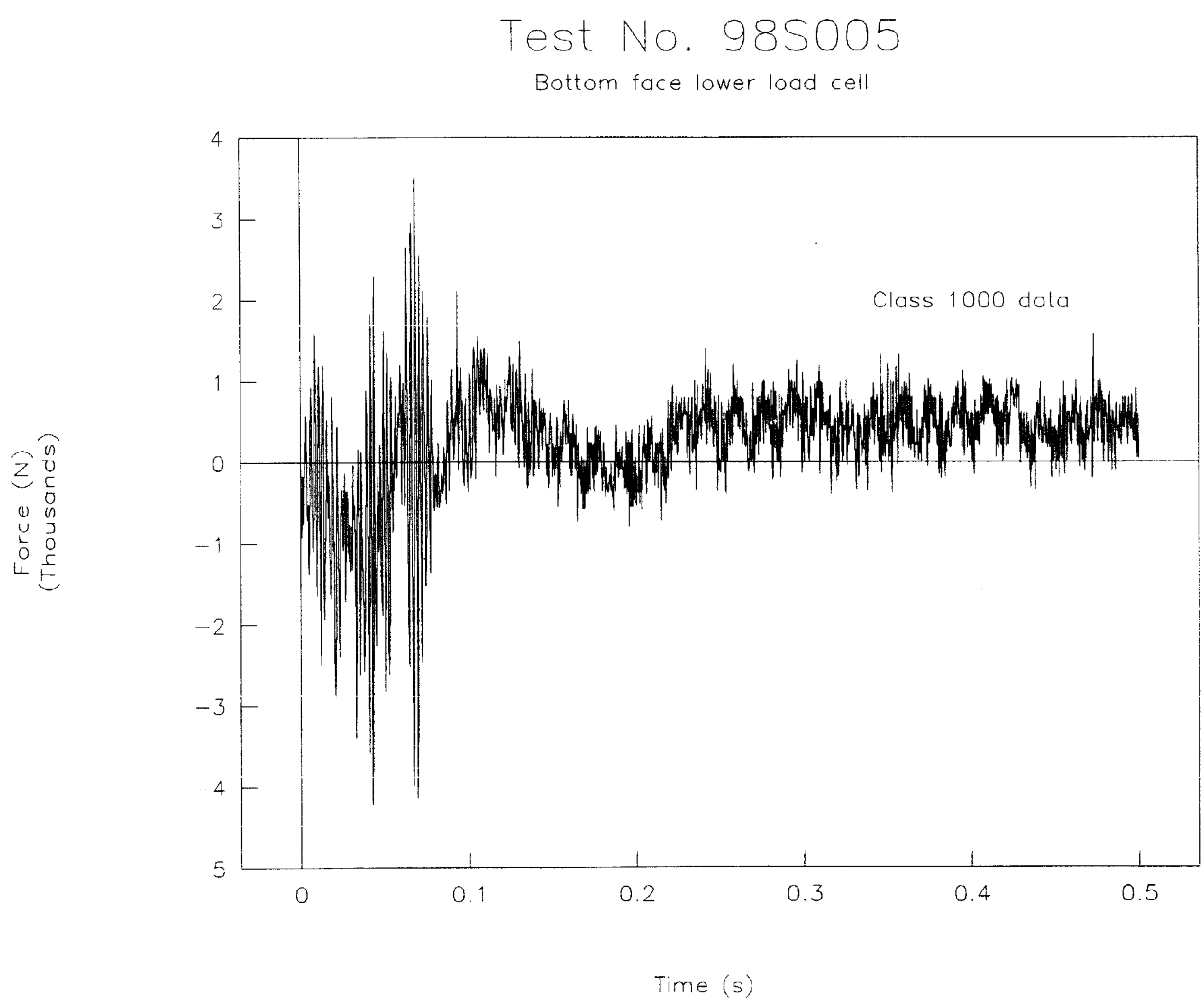


Figure 47. Rigid pole, force vs. time, bottom face lower load cell, test 98S005.

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(2) Christopher M. Brown, *Honda Accord LX Broadside Collision with a Narrow Fixed Object: FOIL Test Number 97S003*, Publication No. FHWA-RD-98-008, Federal Highway Administration, Washington, DC, January 1998.

(3) Christopher M. Brown, *Honda Accord LX Broadside Collision with a Narrow Fixed Object: FOIL Test Number 97S004*, Publication No. FHWA-RD-98-009, Federal Highway Administration, Washington, DC, January 1998.

(4) Christopher M. Brown, *Honda Accord LX Broadside Collision with a Narrow Fixed Object: FOIL Test Number 97S005*, Publication No. FHWA-RD-98-010, Federal Highway Administration, Washington, DC, January 1998.

(5) Christopher M. Brown, *Honda Accord LX Broadside Collision with a Narrow Fixed Object: FOIL Test Number 97S006*, Publication No. FHWA-RD-98-011, Federal Highway Administration, Washington, DC, January 1998.

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