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Administration

**FORD TAURUS BROADSIDE COLLISION WITH A
NARROW FIXED OBJECT
FOIL TEST NUMBER: 95S008**

Office of Safety and Traffic Operations R&D
Turner-Fairbank Highway Research Center
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16. Abstract This report contains the test procedures, test setup and test results from a crash test performed at the Federal Outdoor Impact Laboratory (FOIL) located at Turner Fairbank Highway Research Center (TFHRC) in McLean, Virginia. The test was conducted by the Federal Highway Administration (FHWA) for the National Highway Traffic Safety Administration (NHTSA). The test involved a 1990 Ford Taurus four door sedan and the FOIL's instrumented rigid pole. The test was a broadside collision between the Ford Taurus and the FOIL's rigid pole at a nominal test speed of 35 km/h. The objective of the test was to provide the NHTSA with data to support validation efforts of passenger vehicle Finite Element Models (FEM). In addition to the validation support, the test was conducted to provide insight into the relative strength of a mid-sized sedan and the degree of occupant risk during a broadside collision with a narrow fixed object. A 50 th percentile side impact dummy (SID) was used to measure occupant risk. Results from the test are presented as graphs of data from the transducers affixed to the test vehicle and dummy and photographs before and after the test. The data and high-speed test film provided support for the validation effort. The data shows that broadside collisions with narrow fixed objects cause high penetration which leads to an increased risk of occupant injury.			
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol	When You Know	Multiply By	To Find	Symbol
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LENGTH

in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km

AREA

in ²	square inches	645.2	square millimeters	mm ²
ft ²	square feet	0.093	square meters	m ²
yd ²	square yards	0.836	square meters	m ²
ac	acres	0.405	hectares	ha
mi ²	square miles	2.59	square kilometers	km ²

VOLUME

fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft ³	cubic feet	0.028	cubic meters	m ³
yd ³	cubic yards	0.765	cubic meters	m ³

NOTE: Volumes greater than 1000 l shall be shown in m³.

MASS

oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
			(or "metric ton")	(or "t")

TEMPERATURE (exact)

°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C
----	------------------------	-------------------------	---------------------	----

ILLUMINATION

fc	foot-candles	10.76	lux	lx
ft	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

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	megagrams	1.103	short tons (2000 lb)	T
	(or "metric ton")			

TEMPERATURE (exact)

°C	Celsius 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	ft

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.

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INTRODUCTION

The Federal Highway Administration (FHWA) and the National Highway Traffic Safety Administration (NHTSA) have developed finite element models (FEM) of passenger vehicles to be used as tools for improving the safety of passenger vehicles and the safety performance of roadside safety hardware. These vehicle FEMs have been developed for frontal and side impact collisions. The Ford Taurus is a vehicle which has been modeled for side impact collisions. Validation of the model has been performed by comparing computer generated data with data from an actual side impact collision. The model has been validated for vehicle-to-vehicle or wide object broadside collisions. Vehicle models of broadside collisions with narrow fixed objects has yet to be validated by actual test data. One validation test for narrow fixed-object collisions was conducted at the FHWA's Federal Outdoor Impact Laboratory (FOIL) using a Ford Taurus and the FOIL instrumented rigid pole.

SCOPE

This report documents the results from one broadside crash test between a Ford Taurus and the FOIL instrumented rigid pole. Validation of a FEM of the Ford Taurus in a broadside collision with narrow-fixed object was one objective of the crash test. In addition to the validation effort, the side impact integrity of a vehicle when striking a narrow-fixed object was investigated. The side impact integrity was determined from multiple variables. The FOIL rigid pole provided insight into the relative strength of the vehicle side structure and an anthropomorphic side impact dummy (SID) was used to measure occupant risk. A displacement transducer was used to measure maximum dynamic intrusion as well as rate of intrusion into the occupant compartment. The side impact integrity was also determined by how well door latches and fuel system components respond when involved in a narrow-fixed object collision. Steering column air-bag deployment sensors remained active to investigate whether or not frontal air-bag deployment occurs during a side impact collision.

TEST MATRIX

One crash test involving a 1990 Ford Taurus and the FOIL instrumented pole was conducted. The test parameters including speed, crab angle, and impact location were determined by the NHTSA from analysis of accident data. The Ford Taurus was oriented on the FOIL runway such that the vehicle centerline was perpendicular to the runway centerline. The nominal test speed was 35 km/h. The impact location was 1,150 mm rearward of the front axle centerline. This corresponds to a point on the door midway between the steering wheel and the SID's chest after the

SID was positioned in the driver seat in accordance with Federal Motor Vehicle Safety Standard 214 (FMVSS 214)¹. Table 1 outlines the test matrix for the side impact test.

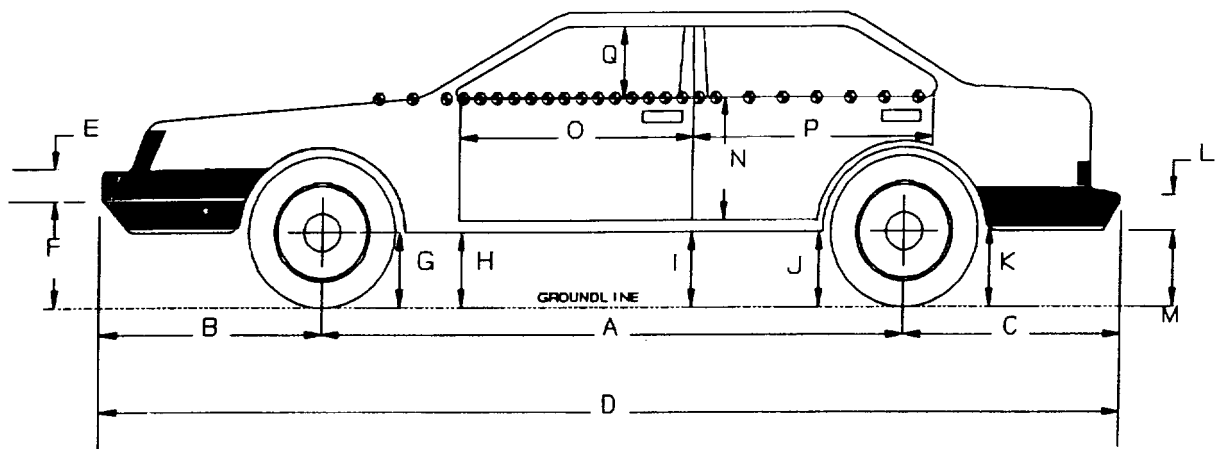
Table 1. Test matrix.	
FOIL number	95S008
Date	May 24, 1995
Vehicle	1990 Ford Taurus
Weight (total)	1,588 kg
SID (serial number 904)	One positioned in driver seat
Fuel tank	94% capacity with stodard solvent
Crab angle	90°
Speed	35 km/h
Impact location	1,150 mm rearward of front axle
Test article	FOIL instrumented rigid pole

VEHICLE

The test vehicle was a 1990 Ford Taurus four-door sedan with front-wheel drive and an automatic transmission. Prior to the test, the vehicle's fluids were drained and it's inertial properties measured. The vehicle was stripped of certain components to allow for the installation of transducers, high-speed cameras, data acquisition equipment, and side impact carriages. The side impact carriage consists of a 100-mm square aluminum box weldment with two spool-shaped wheels. The carriage weighs approximately 9 kg and remains bolted to the vehicle's undercarriage throughout the crash event. Once the vehicle had been instrumented it's test configuration inertial properties were determined. A SID was positioned in the driver seat and was restrained by the vehicle's seat belt restraint system. The fuel tank was filled (94% of capacity) with petroleum naphtha (stodard solvent) which has the same density as gasoline but is less volatile. The SID and stodard solvent were added to the vehicle after the ballasted inertial properties were determined. The original lead-acid battery in a charged state remained in the engine compartment. This was done to investigate frontal air-bag deployment during a side impact collision. The vehicle test weight, including the dummy, ballast, and stodard solvent was 1,588 kg. The SID weighed 80 kg. No brake system was installed in the test vehicle. Ballast was added to the trunk of the test vehicle to artificially move the longitudinal center-of-gravity (cg) to 1,070 mm rearward of the front axle. This enabled the vehicle to be fit on the FOIL inertial measurement device (IMD) and to enable the vehicle to fit between the two runway side impact rails. 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.

Table 2. Vehicle description and statistics.		
Vehicle make	Ford	
Vehicle model	1990 Taurus	
Vehicle identification number (VIN)	1FACP52UXLG137972	
Engine	3.0 L V6, 6 cylinder	
Transmission	4 speed automatic	
Drive chain	Front wheel drive	
Wheel base	2,692 mm	
Wheel track	1,525 mm	
Fuel capacity	68 l	
Tested capacity of stodard solvent	64 l (94%)	
Seat type	Split bench, electric	
Position of front seats for test	Center position	
Steering wheel adjustment for test	Center position	
Front seat arm rests	Up position	
	DELIVERED	TESTED
Weight (kg)	1,384	1,588
Left front (kg)	459	501
Right front (kg)	442	455
Total front (kg)	901	956
Left rear (kg)	243	321
Right rear (kg)	240	311
Total rear (kg)	483	632
Cg measurements (mm):		
Behind front axle	940	1,072
Lateral	750	750
Height	584	576
Pitch inertia (kg·m ²)*	2,302	2,414
Roll inertia (kg·m ²)*	365	276
Yaw inertia (kg·m ²)*	2,626	2,622
* Values do not include SID or stodard solvent.		



	PRE-TEST	POST-TEST	ΔCHANGE
A	2,692	2,325	-367
B	990	990	0
C	1,040	1,040	0
D	4,722	4,355	-367
E	152	152	0
F	342	497	155
G	305	215	-90
H	305	280	-25
I	290	345	55
J	285	330	45
K	270	290	20
L	203	203	0
M	405	450	45
O	1,066	609	-457
P	990	990	0
Q	431	355	-76

Figure 1. Vehicle physical parameters.

INSTRUMENTED DUMMY

One 50th percentile SID, serial number 904, was placed in the driver seat of the Ford Taurus. The SID was supplied by the NHTSA and was calibrated by a NHTSA approved SID calibration facility before shipment to the FOIL. The dummy was shipped with the necessary hardware for assembly. Tools at the FOIL were used to assemble the SID and clothing (not including shoes) from a dummy on location at the FOIL were used to clothe the dummy. Eighteen extension cables were supplied with the SID. The extensions allowed for installation of connectors necessary for attachment to the FOIL instrumentation package 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.

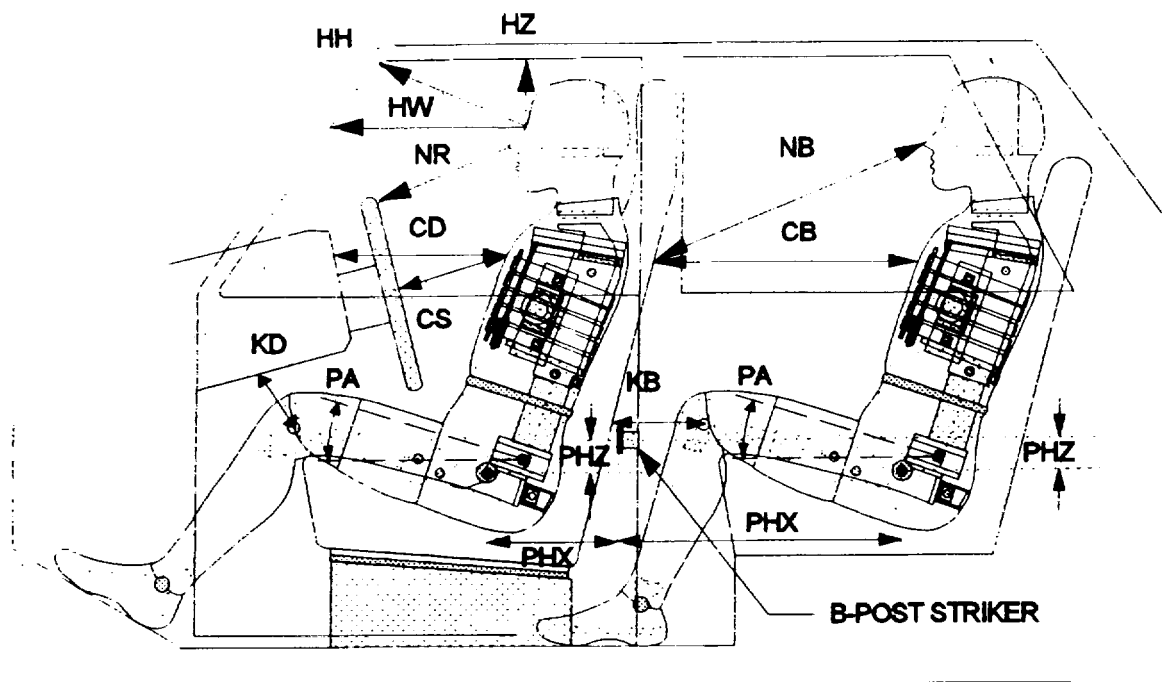
The SID was positioned in the driver seat in accordance with FMVSS 214. The driver seat was set in the center position with the back rest leaning back 25° from the vertical. Using FMVSS 214 as a guide, the SID's feet, legs, thighs, torso, and head were positioned. Pertinent SID-to-interior longitudinal and lateral clearance measurements are shown in figure 2 and figure 3. 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.

RIGID POLE

The FOIL instrumented rigid pole was designed to measure vehicle frontal and side crush characteristics. The rigid pole was setup in the side impact configuration. The side impact configuration consisted of three 220-mm-diameter semi-circular impact faces, installed vertically end-to-end at various heights above ground. Attached to each face via two high-strength connecting rods were two load cells. 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. Figure 4 is a sketch of the FOIL rigid pole (side impact mode).

INSTRUMENTATION

Electronic data from the crash test was recorded via two data acquisition systems, the FOIL tape recorder-umbilical cable system and the FOIL on-board data system (ODAS). A total of 51 channels of electronic data were recorded. The tape recorder system recorded 13 channels and the remaining 38 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 brief summary of the data collected:

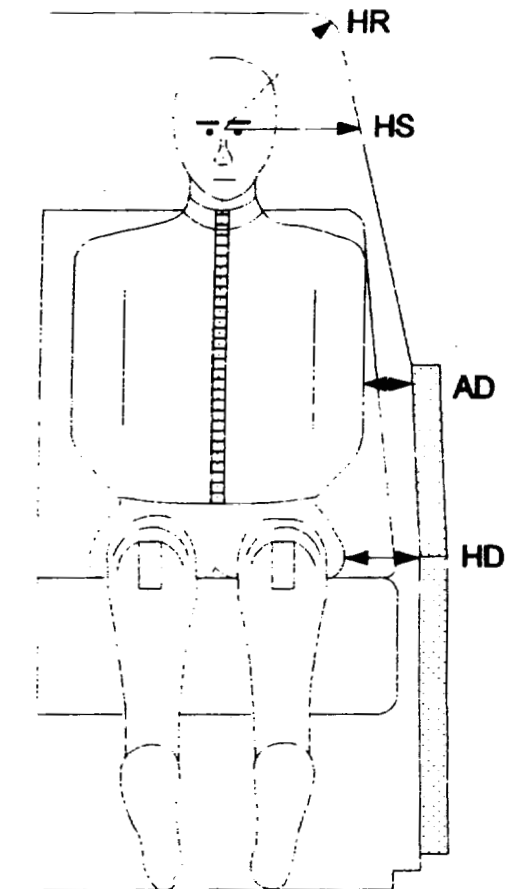


LEFT SIDE VIEW

NOTE: 2-DOOR VEHICLE SHOWN.
REAR DUMMY PHX & PHZ
MEASUREMENTS FOR A 4-DOOR
VEHICLE WOULD USE THE C-POST
STRIKER AS A REFERENCE POINT

MEASUREMENT (mm)	PRE DRIVER SID ID #	POST DRIVER SID ID#
HH	360 mm	520
HW	600 mm	780
HZ	195 mm	225
NR	400 mm	565
CD/CB	500 mm	600
CS	300 mm	375
NR/NB	70 mm	
KDL	100 mm	185
KDR	90 mm	140
PA°	25°	undetermined
PHX	200 mm	360
PHZ	70 mm	0

Figure 2. SID longitudinal clearance and position measurements.



MEASUREMENT (mm)	PRE DRIVER	POST DRIVER
HR	120 mm	490
HS	280 mm	75
AD	100 mm	0
HD	130 mm	0

Figure 3. SID lateral clearance and position measurements.

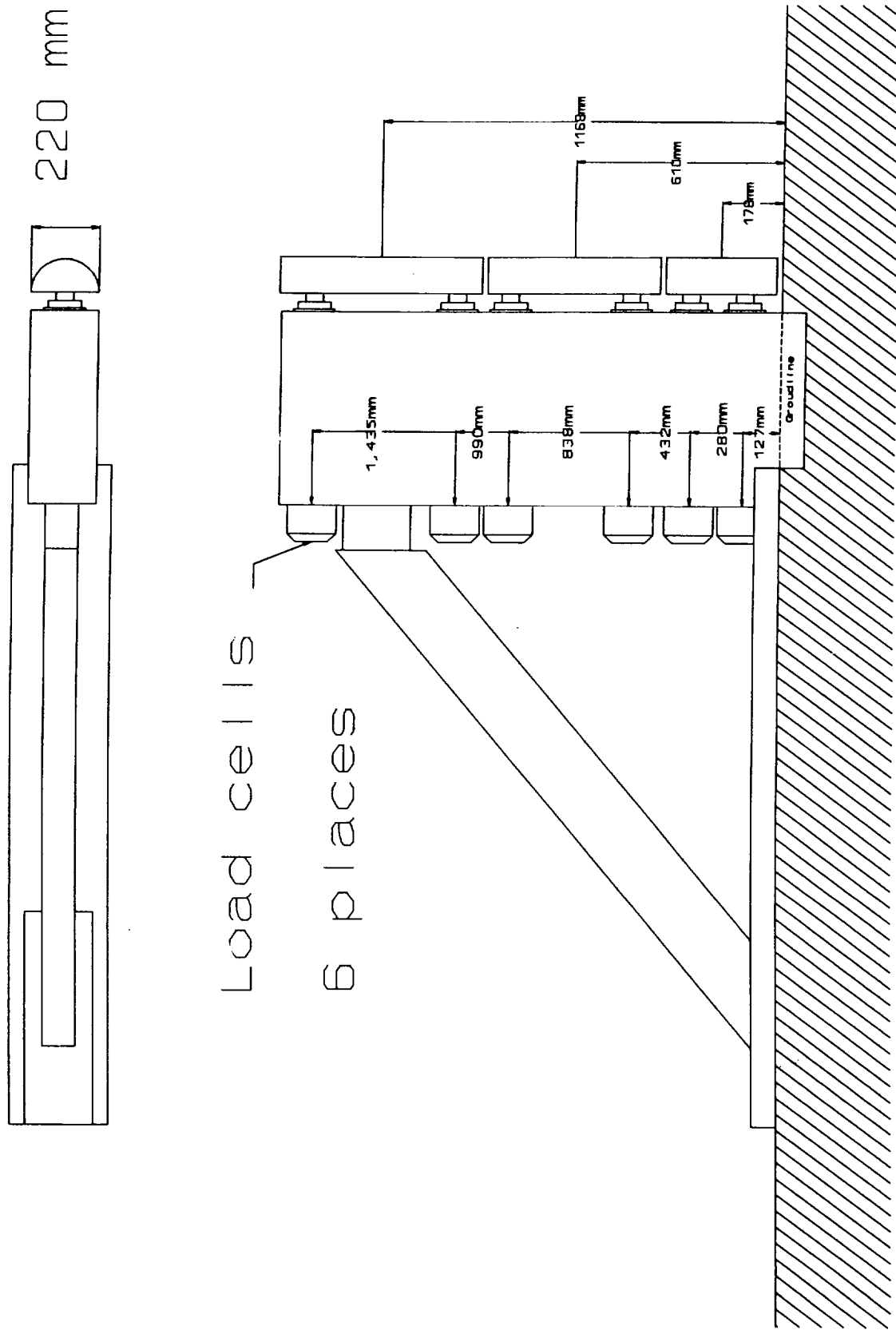


Figure 4. FOIL instrumented rigid pole, side impact configuration.

- 19 Localized vehicle accelerometers
- 14 SID accelerometer channels
- 6 Rigid pole load cell channels
- 4 center-of-gravity (cg) accelerometer channels
- 4 Rate sensor channels (located at the cg)
- 1 Displacement transducer channel
- 2 Channels for impact and speed trap switches
- 1 Channel for a tape recorder timing signal, 1 kHz

Tape recorder-umbilical

The FOIL tape recorder system recorded 13 channels of data of which 10 channels were conditioned using signal conditioning amplifiers. Output from the amplifiers was recorded on analog tape. Table 3 summarizes the data which was collected via the tape recorder-umbilical cable.

Table 3. Summary of tape recorder data channels.			
Channel	Transducer	Range	Data description
1	Load Cell	222 kN	Top segment, upper cell
2	Load Cell	222 kN	Top segment, lower cell
3	Load Cell	111 kN	Mid segment, upper cell
4	Load Cell	111 kN	Mid segment, lower cell
5	Load Cell	222 kN	Bottom segment, upper cell
6	Load Cell	222 kN	Bottom segment, lower cell
7	Accelerometer	100 g's	CG, Y-axis, primary
8	Mech. gyro	500 deg/s	CG, Yaw rate, redundant
9	Displacement transducer	1,770 mm	Between front doors, impact location, intrusion
10	Accelerometer	2000 g's	Mid firewall, Y-axis
11	Contact switch	1.5 Volts	Time of impact, T0
12	Micro switch	1.5 Volts	Rail speed
13	Generator	variable	1 kHz reference signal

On-board data acquisition (ODAS)

The ODAS system collected 38 channels of data. The data was from accelerometers and rate transducers positioned at various locations around the vehicle and within the SID. Table 4 summarizes the ODAS channel assignments. The first 6 channels are cg data, the shaded area designates 14 SID channels, and the remaining 18 channels are localized accelerometers. Figure 5 shows each accelerometer placement by channel number. Channel 29 was removed before the test due to possible contact with the head.

Table 4. Summary of ODAS channel assignments.			
Channel	Transducer	Max. range	Data description
1	Accelerometer	100 g's	CG, X-axis
2	Accelerometer	100 g's	CG, Y-axis Redundant
3	Accelerometer	100 g's	CG, Z-axis
4	Rate trans.	500 deg/s	CG, Pitch rate
5	Rate trans.	500 deg/s	CG, Roll rate
6	Rate trans.	500 deg/s	CG, Yaw rate
7	Accelerometer	2000 g's	Head, X-axis
8	Accelerometer	2000 g's	Head, Y-axis
9	Accelerometer	2000 g's	Head, Z-axis
10	Accelerometer	2000 g's	Upper rib, Y-axis (P)
11	Accelerometer	2000 g's	Upper rib, Y-axis (R)
12	Accelerometer	2000 g's	Lower rib, Y-axis (P)
13	Accelerometer	2000 g's	Lower rib, Y-axis (R)
14	Accelerometer	2000 g's	Spine T12, X-axis
15	Accelerometer	2000 g's	Spine T12, Y-axis (P)
16	Accelerometer	2000 g's	Spine T12, Z-axis
17	Accelerometer	2000 g's	Spine T12, Y-axis (R)
18	Accelerometer	2000 g's	Pelvis, X-axis
19	Accelerometer	2000 g's	Pelvis, Y-axis
20	Accelerometer	2000 g's	Neck T0, Y-axis
21	Accelerometer	2000 g's	Engine, top, X-axis
22	Accelerometer	2000 g's	Engine, top, Y-axis
23	Accelerometer	2000 g's	Under rear seat, Y-axis
24	Accelerometer	2000 g's	Driver door, Y-axis Knee height
25	Accelerometer	2000 g's	Driver door, Y-axis Shoulder height
26	Accelerometer	2000 g's	Driver door, Y-axis Pelvis height
27	Accelerometer	2000 g's	Driver seat, Y-axis Seat track
28	Accelerometer	2000 g's	A-Pillar upper, Y-axis

Table 4. Summary of ODAS channel assignments.			
Channel	Transducer	Max. range	Data description
29	Accelerometer	2000 g's	Driver roof rail, Y-axis Aft of impact
30	Accelerometer	2000 g's	B-pillar upper, Y-axis
31	Accelerometer	2000 g's	B-pillar middle, Y-axis
32	Accelerometer	2000 g's	B-pillar, Y-axis Door latch
33	Accelerometer	2000 g's	B-pillar driver floor sill Y-axis
34	Accelerometer	2000 g's	Driver floor sill, Y-axis Forward of impact
35	Accelerometer	2000 g's	A-pillar driver floor sill Y-axis
36	Accelerometer	2000 g's	A-pillar lower, Y-axis
37	Accelerometer	2000 g's	A-pillar middle, Y-axis
38	Accelerometer	2000 g's	Pass. roof rail, Y-axis in-line w/impact
39	Accelerometer	2000 g's	Pass. floor sill, Y-axis in-line w/impact

The localized accelerometers were attached to small aluminum blocks then small metal mounting plates which were attached to the vehicle frame by either tack welding the mounting plate to the frame or using 6 machine screws.

High-speed photography

A total of eight 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 Taurus and the rigid pole. Table 5 summarizes the camera placements. Included in table 5 are three 35-mm still-motion cameras and one 16-mm real-time telecine camera used for documenting the test. The documentation cameras were used to film the pre and post crash environment. Timing stickers 305 mm in length were placed on the Ford Taurus and rigid pole for film-data collection purposes. Timing sticker locations included:

- Several end-to-end along the front grill area for speed and initial roll angle measurements.
- Several end-to-end along the longitudinal and lateral roof centerlines through the cg for speed, displacement, and yaw angle measurements.

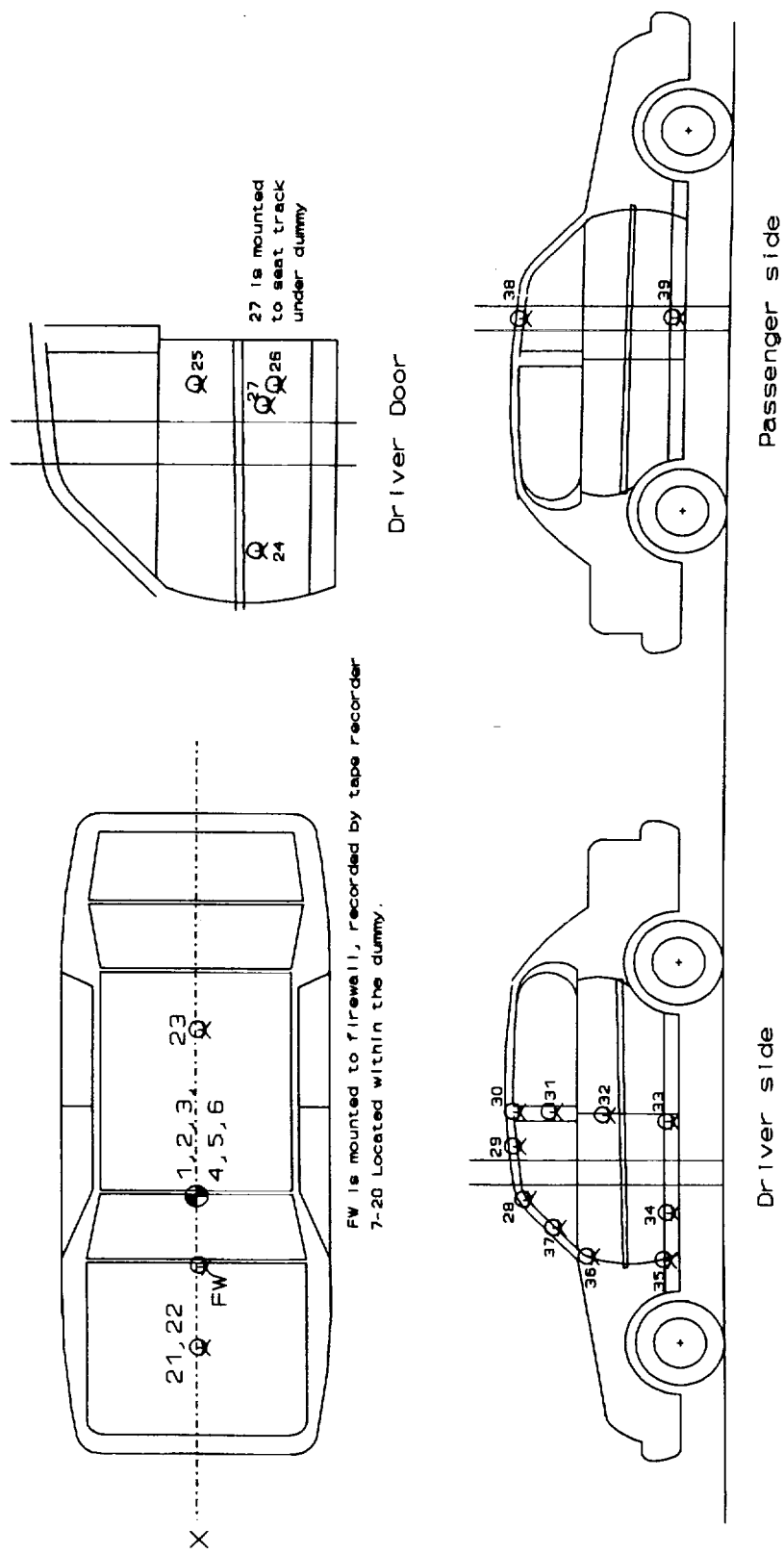


Figure 5. ODAS transducer locations.

- Several end-to-end along the driver-side roof-rail longitudinally.
- Several placed strategically along the impact side of the vehicle. Reference sticker for impact location and measure initial pitch angle.

Table 5. Summary of camera placements.				
NO.	Model	Film speed	Location/Lens focal length	Data
1	LOCAM II	500 F/S	90° to impact / 30 mm	Speed, roll angle
2	PHOTEC	1000 F/S	90° to impact / 80 mm	redundant camera 1
3	LOCAM II	500 F/S	On-board / 5.7 mm	behind driver
4	LOCAM II	500 F/S	On-board / 5.7 mm	90° to driver
5	LOCAM II	500 F/S	Overhead / 12.5 mm	Displacement, yaw angle
6	LOCAM II	500 F/S	45° to impact / 50 mm	visual
7	LOCAM II	500 F/S	45° to impact / 100 mm	visual
8	LOCAM II	500 F/S	180° to impact / 50 mm	visual, pitch angle
9	BOLEX	24 F/S	Zoom	documentary
10	CANNON	Still	Zoom	documentary
11	CANNON	Still	Zoom	documentary
12	NIKON	Still	Zoom	documentary

Positioned in each view was at least one strobe light. The lights flashed when the vehicle struck the pole. This synchronized the film with the electronic data.

DATA ANALYSIS

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

Umbilical cable. Data collected via the umbilical cable was recorded to analog tape during the test. The data included 6 channels of rigid pole data, 2 accelerometer channels (one located at the cg and one affixed to the firewall), a mechanical rate gyro, and one displacement transducer. The tape recorder data was input through an 8-pole low-pass Butterworth filter with a cut-off frequency of 4,000 Hz. The analog filter output was

input into a Data Translation analog-to-digital converter (ADC). The sample rate was set to 12,500 Hz. The digital data was converted to the ASCII format, zero-bias removed and digitally filtered to 300 Hz (SAE class 180). The filtered data was input into a spreadsheet for analysis and plotting.

ODAS system. The data from the ODAS system included 14 channels of SID data, 3 accelerometer channels (cg data), 18 localized accelerometer channels, and 3 rate transducer channels. The data was filtered and digitally stored with the ODAS unit during the test. The filter was factory set at 4000 Hz. The ADC sampling rate was factory set at 12,500 Hz. After the test, the data was down loaded to a portable computer for analysis. The data was converted to the ASCII format, zero-bias removed, and digitally filtered. The data from the SID was digitally filtered at 1650 Hz (SAE class 1000) while all vehicle accelerometer and rate transducer channels were filtered at 300 Hz (SAE class 180). The filtered data was input into a spreadsheet for analysis and plotting.

Vehicle accelerometers measuring y-axis accelerations were adjusted for the initial roll angle induced by the vehicle falling from the side impact monorail and by the frictional forces between the tires and the FOIL runway. Many accelerometers were mounted with the axis of sensitivity at an angle relative to the y-z plane. This adjustment was also made if necessary. The initial angle measurements are presented in the results section of this report.

High-speed film. The high-speed 16-mm film was analyzed via a NAC 160-F film motion analysis system in conjunction with and IBM PC-AT. The analyzer reduced the images to cartesian coordinates which were input into a spreadsheet for analysis. Using the data, a time-displacement history was produced. Differentiation of the time-displacement history produced the initial vehicle speed. Data measurements included impact speed, roll angle, yaw angle, and pitch angle.

RESULTS

The Ford Taurus was placed on the FOIL side impact monorail with it's longitudinal centerline perpendicular to the rigid pole centerline. The Taurus exited the monorail at 39.1 km/h. Due to the vehicle falling from the monorail and the frictional forces between the tires and the concrete runway, the vehicle struck the rigid pole at 36.5 km/h (initial energy of 81,640 N·m), at an initial roll angle of 4°, and an initial yaw angle of 89° (1° off perpendicular). At this time a direct measurement of initial vehicle speed is not taken during broadside crash tests. The initial speed is determined after the tests using high-speed film analysis. Table 6 summarizes the test conditions and selected results.

Table 6. Summary of test conditions and results.	
FOIL test number	95S008
Date of test	May 24, 1995
Test vehicle	1990 Ford Taurus, 4-door sedan
Vehicle weight	1588 kg
Test article	FOIL instrumented rigid pole
Ground conditions	Dry concrete runway
Temperature inside vehicle	34° C
Mono-rail exit speed	39.1 km/h
Impact speed (high-speed film)	36.5 km/h
Impact point	1,150 mm rearward of front axle
Traffic accident data, TAD	9-LP-7
Vehicle damage index, VDI	09LPAN5
Occupant impact velocities	
Design limit (Report 350)	9 m/s
Allowable limit (Report 350)	12 m/s
Calculated 0.3 m flail space	7.4 m/s
Impact time 0.30 m flail	0.091 s
Calculated for actual 0.23 m flail space	6.5 m/s
Impact time .23 m flail	0.081 s
Occupant ridedown accelerations	
Design limit (Report 350)	15 g's
Allowable limit (Report 350)	20 g's
Calculated value at 0.30 m flail space	6.1 g's
Calculated value at 0.23 m flail space	8.5 g's
Head Injury Criteria (HIC)	
Limit	1000 g's
Observed	387 g's
Start time	0.04064 s

Table 6. Summary of test conditions and results.	
Stop time	0.04952 s
Interval time	0.00888 s
Thoracic trauma	
Limit (4-door)	85 g's
Average upper rib*	52.9 g's
Average lower rib*	61.9 g's
T12 spine	no data
Thoracic Trauma Index (TTI)	undeterminable
* Data from the rib accelerometers was input into the FIR100 filter then average upper rib and average lower rib values were computed.	

Vehicle response. The vehicle made contact with rigid pole 1,150 mm rearward of the front axle. 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 inflate during the impact. The rigid pole shattered the window 0.006 s after impact and penetrated the occupant compartment collapsing the roof-rail, door, and floor-sill. Double integration of the cg acceleration trace yielded a maximum dynamic intrusion 760 mm. Due to an inadequate response time, the displacement transducer mounted between the front doors did not accurately measure the intrusion or intrusion rate. The displacement transducer recorded the recoil rate of the unit and not the rate of the door intruding into the occupant compartment.

The peak cg acceleration was determined to be 18.7 g's (290.6 kN) and occurred 0.0354 s after impact. As the vehicle frame collapsed around the rigid pole the front and rear of the vehicle acted independently, yawing about the rigid pole at different rates. The rate transducers were located inline with the rigid pole and therefore did not measure significant yaw. Integration of the two yaw transducers data yielded a yaw angle of 3° and 8.5°. From high-speed film, the front end yawed an angle of 15° while the rear of the vehicle yawed 9°. The angles were determined by using the impact point as the pivot point (vertex) and taking data points from the pivot point along the centerline through the center of the front bumper and from the pivot point rearward along the centerline to the center of the rear bumper. The wrap-around or bending of the vehicle around the rigid pole produced differences between the displacements measured by separate accelerometers. The rear-seat, engine, firewall, and cg accelerometers measured varying amounts of displacement depending on their proximity to the impact location. The farther from the impact point the farther the accelerometer traveled as the vehicle wrapped around the pole. The cg accelerometer represents the crush of the vehicle because it's displacement was coincident with the intrusion or travel of the

vehicle cg after contact. It's displacement was linear and inline with the rigid pole. The cg did not pass the rigid pole like the rear-seat, engine, or firewall accelerometers. Table 7 summarizes the data analysis of the localized transducers. Table 7 includes each localized transducer's peak value, displacement, determined by double integration of the acceleration trace, and it's initial and final position coordinates. The displacement values in table 7 marked by an asterisk were a result of the velocity trace never crossing 0 m/s. A positive velocity results in continuous displacement. These results may be skewed by a centripetal force which opposed the vehicle deceleration. This causes a lower acceleration measured by the accelerometer, leading to lower velocity changes and therefore increasing or large displacements. The right front wheel hub was used as the origin or reference point for all position measurements. Figure 6 depicts the damage profile of the Ford Taurus.

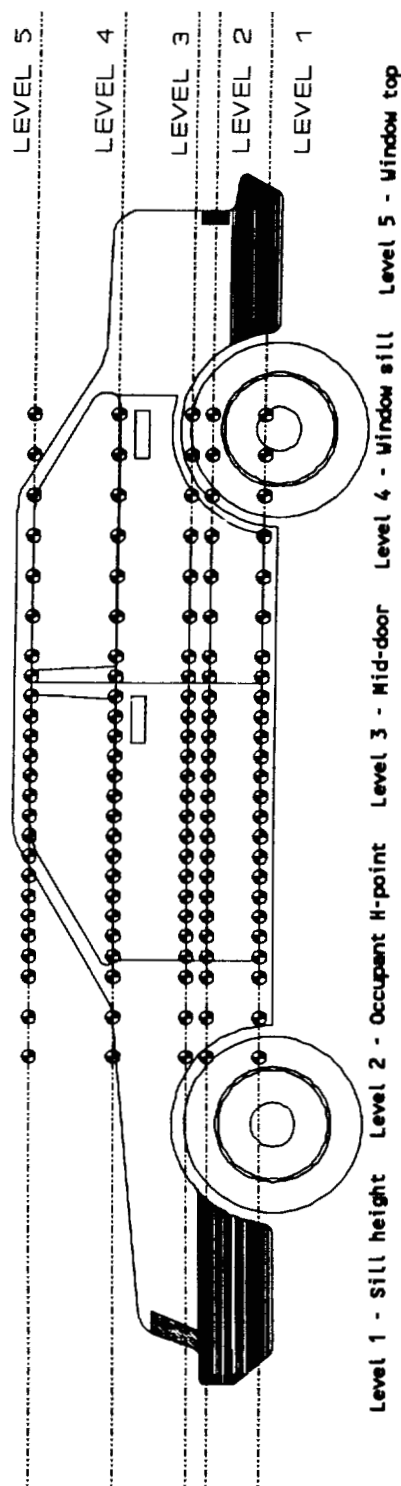
The driver-door accelerometers were not effective in measuring door intrusion or acceleration. The dummy may have made contact with the driver-door pelvic height and driver-door knee position accelerometers. The driver-door shoulder location accelerometer broke free during impact. All three accelerometers were subjected to an initial oscillation in the flimsy inner door panel induced by the sliding friction as the vehicle slid along the concrete runway. Displacement values obtained from double integration of the door accelerations are included in table 7. The door-pelvis-height accelerometer malfunctioned during the event therefore the velocity and displacement data was not computed. The initial mounted-angle of the B-pillar-top accelerometer was too significant and therefore did not produce dependable data. The velocity and displacement traces were not computed for the B-pillar-top acceleration.

Table 7 lists each accelerometers location and orientation before and after the crash test. Data plots from accelerometers (acceleration, velocity and displacement) mounted to the vehicle are presented in appendix A. The acceleration data plots were produced using accelerometer data which had been revised to account for the actual angle between the accelerometer axis of sensitivity and the horizontal plane. The revised data was produced by dividing the raw data by the cosine of the angle between the accelerometer axis of sensitivity and the horizontal plane. Velocity and displacement plots were produced using the revised acceleration data. Pre and post test photographs are presented in appendix B.

Table 7. Accelerometer location and orientation.											
Accelerometer position	Pre-test measurements				Post-test measurements						
	X(mm)	Y(mm)	Z(mm)	Ang. ¹	X(mm)	Y(mm)	Z(mm)	Ang. ¹	Ang. ²	Peak (g's)	Displacement (mm)
Firewall (Y)	205	912	575	0°	252	885	557	0°	0°	-18.1	810
Top of engine (X)	-199	753	665	0°	-141	740	615	16°	14°	-9.3	NA
Top of engine (Y)	-190	744	665	0°	-137	745	615	14	0°	-12.7	930
Rear seat (Y)	2,290	880	96	0°	2,275	625	110	0°	0°	-16.8	810
Door knee level (Y)	908	1,655	270	10°						-164.7	1,180*
Door shoulder (Y)	1,413	1,655	515	10°						-293.5	2,900*
Door pelvis (Y)	1,293	1,655	290	0°						-25.0	NA
Driver seat (Y)	1,405	1,330	125	0°						-235.2	680
A-pillar upper level(Y)	1,147	1,348	963	37°	1,192	980	838	20°	22°	-250.0	650
B-pillar upper level(Y)	1,645	1,455	1,020	50°						-28.2	NA
B-pillar middle level(Y)	1,580	1,625	735	18°	1,640	1,040	715	0°	0°	-38.8	1,400*
B-pillar lower latch (Y)	1,540	1,680	310	0°						-69.8	2,230*
B-pillar floor level(Y)	1,525	1,350	160	0°						-80.4	1,000*
Driver floor fwd. impact	850	1,350	160	0°						-66.2	1,100*
A-pillar floor level (Y)	550	1,540	100	20°	975	1,455	90	35°	15°	-38.9	1,700*
A-pillar lower level (Y)	555	1,340	690	38°	965	1,450	675	50°	20°	-42.4	5,000*
A-pillar middle level(Y)	878	1,336	815	35°						-200.2	570
Passenger roof at impact	1,157	330	963	25°	1,155	70	950	20°	0°	-37.8	940
Passenger floor at impact	1,157	160	160	0°	1,155	-60	70	13°	0°	-22.5	820
Vehicle cg (X)	890	810	120	0°	864	889	305	0°	15°	-12.9	NA
Vehicle cg (Y)	840	785	120	0°	814	864	305	15°	15°	-18.7	760
Vehicle cg (Z)	890	810	120	0°	864	889	305	75°	0°	-11.6	NA
Triaxial rate transducer	890	810	370	0°	814	889	395	15°	15°	NA	3.0°
Mechanical gyro (yaw)	750	740	170	0°	784	819	355	15°	15°	NA	8.5°

¹ Angle between accelerometer axis of sensitivity and the y-axis (Y-Z plane).

² Angle between accelerometer axis of sensitivity and the x-axis (X-Y plane).



		Distance from impact point (mm).																
LEVEL	HEIGHT	-900	-750	-600	-525	-450	-375	-300	-225	-150	-75	0	75					
1	320	PRE				680	681	680	677	675	675	670	670					
		POST		WHEEL	700	760	825	890	960	1,050	1,110	1,155	1,125					
		CRUSH				80	144	210	283	375	435	485	455					
2	510	PRE		620	625	622	622	620	620	620	615	610	610					
		POST		505	620	675	745	825	895	970	1,035	1,110	1,150					
		CRUSH	-115		-2	50	123	203	275	350	415	495	540					
3	505	PRE		615	612	615	615	610	610	610	605	600	600					
		POST		510	625	680	760	830	900	980	1,040	1,115	1,155					
		CRUSH	-105		13	65	145	215	290	370	430	510	555					
4	890	PRE		700	700	690	677	677	677	675	670	665	665					
		POST		560	650	710	775	850	910	980	1,050	1,120	1,200					
		CRUSH	-140		-50	20	98	175	233	305	375	450	535					
5	1,320	PRE										855	860					
		POST										1,230	1,225					
		CRUSH										375	365					
All units of measurement are in mm.																		

Figure 6. Vehicle profile measurements.

LEVEL	WEIGHT	Distance from impact point (mm).													
		150	225	300	375	450	525	600	675	750	825	900	975	1,050	1,125
1	320	PRE	670	665	660	660	660	660	665	665	665	666	666	645	1,350
		POST	1,050	990	895	895	820	780	730	730	695	640			
		CRUSH	380	320	270	235	160	120	65	29	-5				
2	510	PRE	605	605	605	605	607	608	610	610	620	580	580		
		POST	1,080	1,015	950	890	880	790	665	710	670	610	565		
		CRUSH	475	410	345	285	273	182	55	100	30	-15			
3	585	PRE	600	595	595	590	595	595	595	600	610	600	587	580	
		POST	1,090	1,030	960	885	890	810	675	730	680	625	585	580	
		CRUSH	490	435	365	295	215	80	130	70	25	-2	0		
4	890	PRE	665	665	665	665	665	666	667	667	670	670	665	658	
		POST	1,120	1,055	985	920	875	845	810	755	715	675	630		
		CRUSH	455	390	320	255	209	178	143	85	45	10	-28		
5	1,320	PRE	870	875	880	880	895	895	895	895	895	880	876	874	
		POST	1,210	1,150	1,110	1,075	1,045	1,000	1,030	995	970	915	895	875	
		CRUSH	340	275	230	195	155	105	135	100	75	35	19	-1	

All units of measurement are in mm.

Figure 6. Vehicle profile measurements (continued).

Occupant response. The SID began leaning towards the driver door as soon as the vehicle began falling from the side impact monorail and skidding towards the rigid pole. Clearance between the SID's head and shoulder and the vehicle interior was reduced to 100 mm and 25 mm respectively. The head made contact with the driver window 0.010 s after impact and after the rigid pole had shattered the driver window. The head protruded from the window frame and the forehead glanced the rigid pole (0.060 s). The neck rebounded retracting the head back into the vehicle with the back of the head striking the B-pillar (0.120 s). The rigid pole penetrated the occupant compartment collapsing the driver door into the SID. The SID's left upper leg was bent severely and was pinned between the door arm rest and seat. The SID was instrumented with 14 accelerometers. Due to errors installing completion resistors into the data acquisition connectors, legs of the resistors were allowed to touch causing an electrical short between the excitation pins resulting in no signal from 6 dummy channels. The accelerometers from the lower spine were some of the 6 unsuccessful channels and therefore a thoracic trauma index (TTI) calculation was not possible. The data from the head accelerometers was successfully recorded and a head injury criterion (HIC) calculation was performed. A HIC value of 387 g's was calculated and is well below the FMVSS 214 limit of 1000 g's. Table 8 is a summary of the SID data. Data plots from the 8 SID channels are presented in appendix C. The data is 1,650 Hz data.

Table 8. Summary of SID data.		
Accelerometer	Maximum positive	Maximum negative
Head X	83.8	-66.1
Head Y	16.6	-61.6
Head Z	14.9	-37.0
Neck T0 Y	No data	No data
Left upper rib (P)	36.5	-62.9
Left upper rib (R)	39.2	-60.3
Left lower rib (P)	No data	No data
Left lower rib (R)	82.5	-68.4
Spine T12 X	No data	No data
Spine T12 Y (P)	No data	No data
Spine T12 Z	No data	No data
Spine T12 Y (R)	No data	No data
Pelvis X	16.1	-23.1
Pelvis Y (0.03 s of data)	0.8	-19.5
All peak values were taken from 1650 Hz data. FIR100 data is not included in this table.		

Rigid pole. The load cells measured six separate forces on the rigid pole. The resultant load was 150.6 kN. The load was determined by summing the six load cell data traces together into a single resultant data trace and locating the peak value. Using torque equations, the resultant load height, above ground, was determined to be 450 mm. This location corresponds to a point on the driver door. The significant loads were contributed by the roof-rail, floor-sill, and middle-point of the door. The middle point of the driver door corresponds to the mid-point between the two door hinges and the height of the door latch. Summation of each segment's two load cell data traces shows that the roof-rail produced a peak force of 34.9 kN while the floor sill produced a total load of 70.9 kN. The middle segment measured a peak load of 61.6 kN. The resultant force data trace was scaled to acceleration by dividing by the vehicle mass and double integrated to determined displacement. The rigid pole recorded 970 mm of displacement. This result matches the results from localized accelerometers positioned towards the front and rear of the vehicle. The rigid pole displacement does not match the cg displacement because the cg stops relative to the front and rear of the vehicle. While the front and rear of the vehicle wrap around the pole, pressure or force is still applied to the pole but no motion is occurring at the cg. Table 9 summarizes the load cell data. Rigid pole data plots are presented in appendix D.

Because no significant angular motion occurred at the cg, the rate transducers and mechanical gyros positioned at the cg did not detect significant angular rates. The initial roll, pitch, and yaw angles and the total yaw angle of the front and rear of the vehicle were measured from high-speed film and is included in the vehicle response summary.

Table 9. Summary of rigid pole data.			
Load cell / height (mm)	Peak force (kN)	Time (ms)	Load Height (mm)
Top segment / 1,168	34.9	39.04	1,400
Upper load cell / 1,435	20.3	39.36	
Lower load cell / 990	15.0	38.80	
Middle segment / 610	61.6	42.40	585
Upper load cell / 838	30.7	42.80	
Lower load cell / 432	32.9	41.36	
Bottom segment / 178	70.9	35.28	170
Upper load cell / 280	45.4	35.28	
Lower load cell / 127	42.6	115.76	
Total, rigid pole	150.6	41.92	450

CONCLUSIONS AND OBSERVATIONS

Visual inspection of the Ford Taurus after the collision produced immediate conclusions. Fuel system and door latch integrity was not breached by the broadside collision with the FOIL instrumented rigid pole (narrow-fixed object). The air-bag sensors are not sensitive in the lateral direction as denoted by the lack of air-bag deployment. Data successfully recorded together with the high-speed film will help validate the Ford Taurus FEM for broadside impacts with narrow fixed objects.

The structural integrity of the Ford Taurus was compromised. The rigid pole penetrated the occupant compartment damaging the SID and the vehicle interior. The head struck the pole and B-pillar which dislodged the head access panel's cover and the left femur was bent. The calculated HIC value was below FMVSS 214 limits even though the SID's head protruded from the window and struck the rigid pole. Lateral femur loading was not measured during this test and should be considered for future narrow object testing. The NCHRP Report 350 occupant flail space model predicted low probability of injury. This model is typically used for non-deforming occupant compartments and therefore is not a reliable model for this test scenario.

The roof-rail, floor-sill, door latch, and door hinges contributed to the structural strength of the vehicle. The floor-sill provided the most stiffness as it collapsed in an accordion manner. The door hinges and latch provided the second most stiffness. The door thickness of 127 mm at its thickest cross-section collapses quickly then the resistance comes from the connection between the door and vehicle frame. The roof-rail provided the least amount of resistance. The roof buckled from a relatively low load. These three locations reached their peak force at approximately 0.04 s after impact. At this time the roof buckles and the hinges and latches move inward. The A-pillar and B-pillar get pulled in by the hinges and latch.

Accelerometers in-line with the impact provided the most useful data with respect to intrusion and intrusion rate. The displacement transducer used for this test was not capable of measuring the intrusion due to the insufficient recoil of the spring mechanism. Installing rate transducers at the front and rear of the vehicle would better measure the independent motion of the front and rear of the vehicle. The angular displacement at the cg or close to the impact point is minimal compared to the displacement at either end of the vehicle.

APPENDIX A. DATA PLOTS FROM VEHICLE ACCELEROMETERS.

TEST NO. 95S008

Acceleration vs. time, cg primary

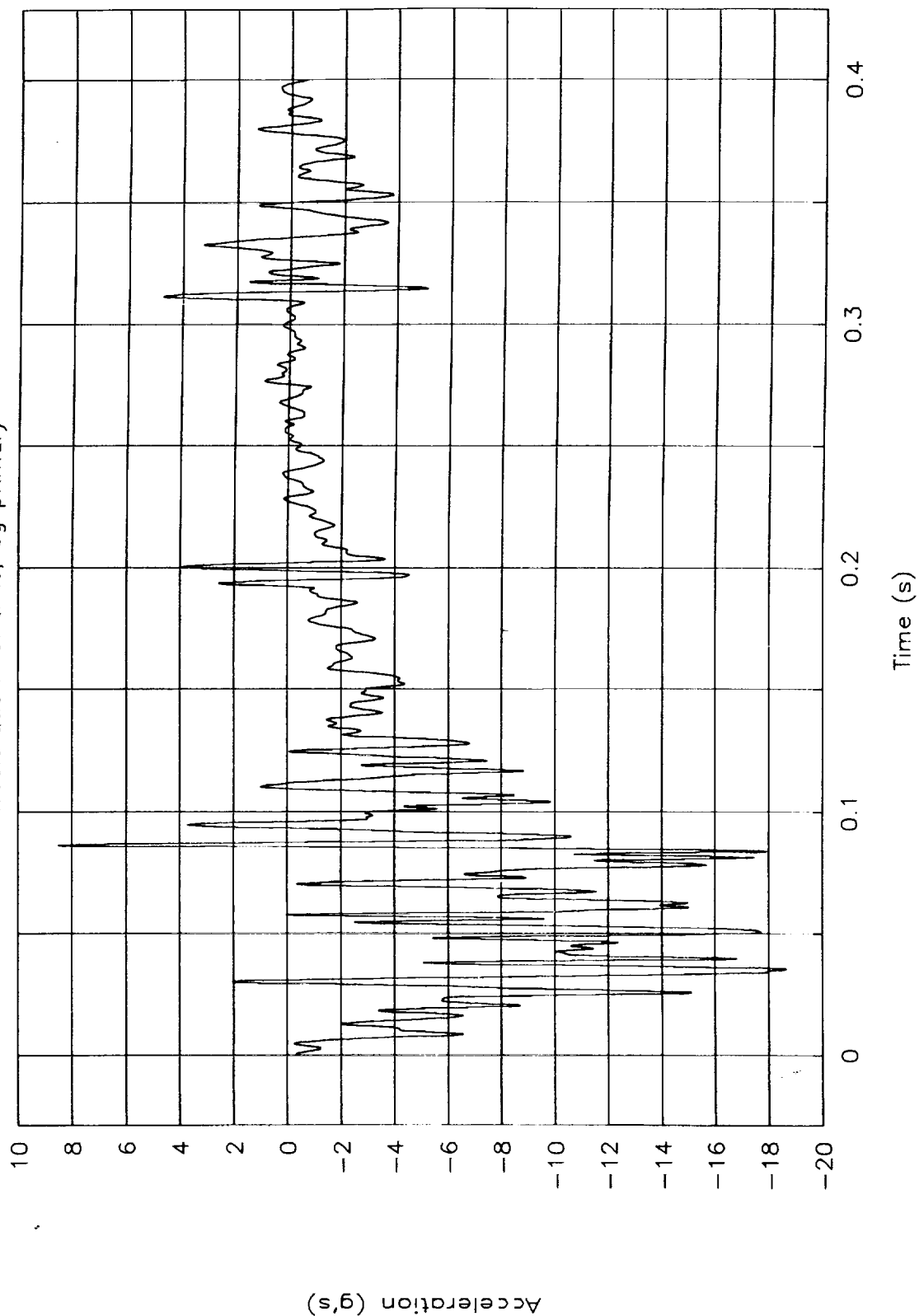


Figure 7. Acceleration vs. time, cg y-axis primary, test 95S008.

TEST NO. 95S008

Acceleration vs. time, y-axis redundant

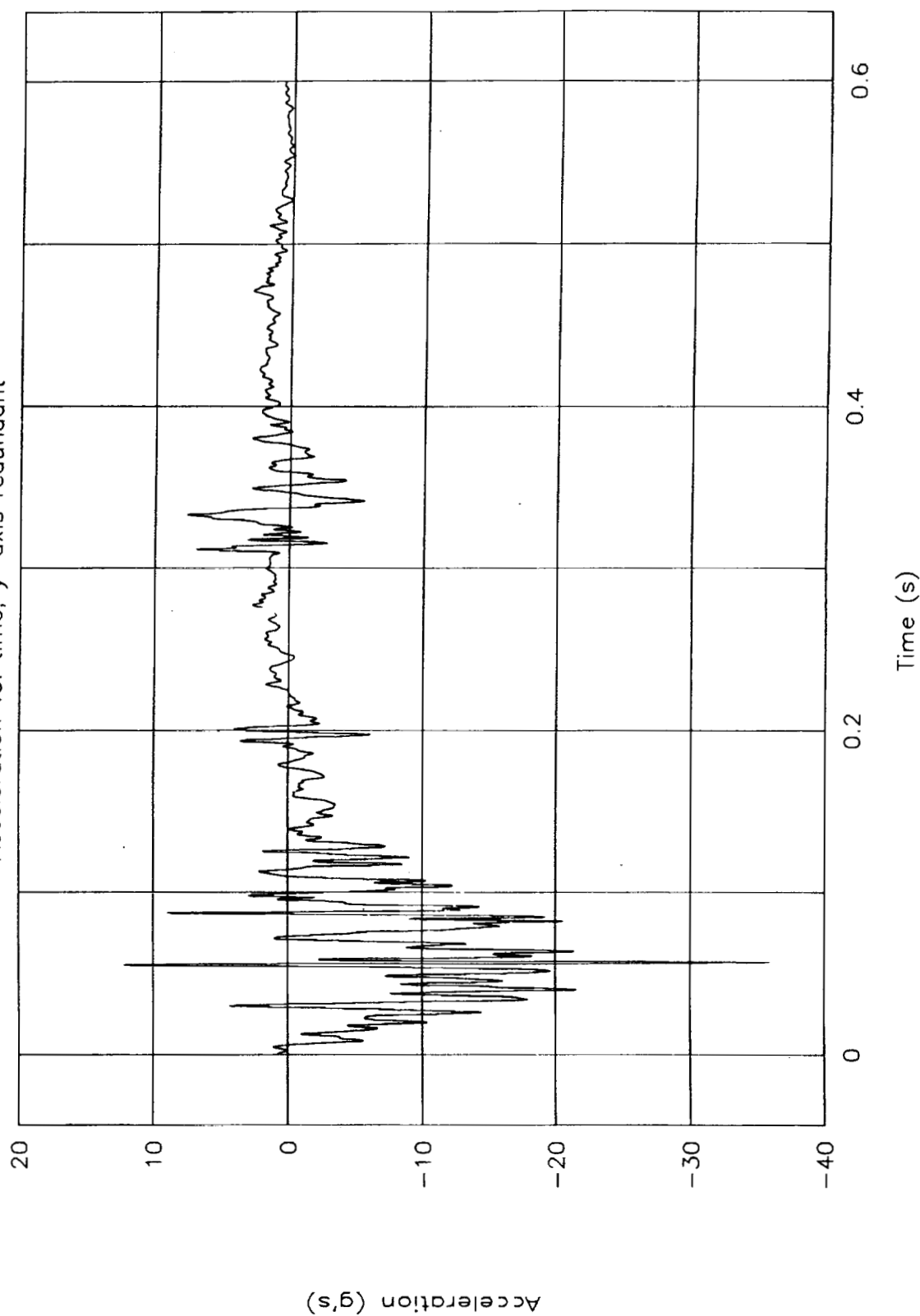


Figure 8. Acceleration vs. time, cg y-axis redundant, test 95S008.

TEST NO. 95S008

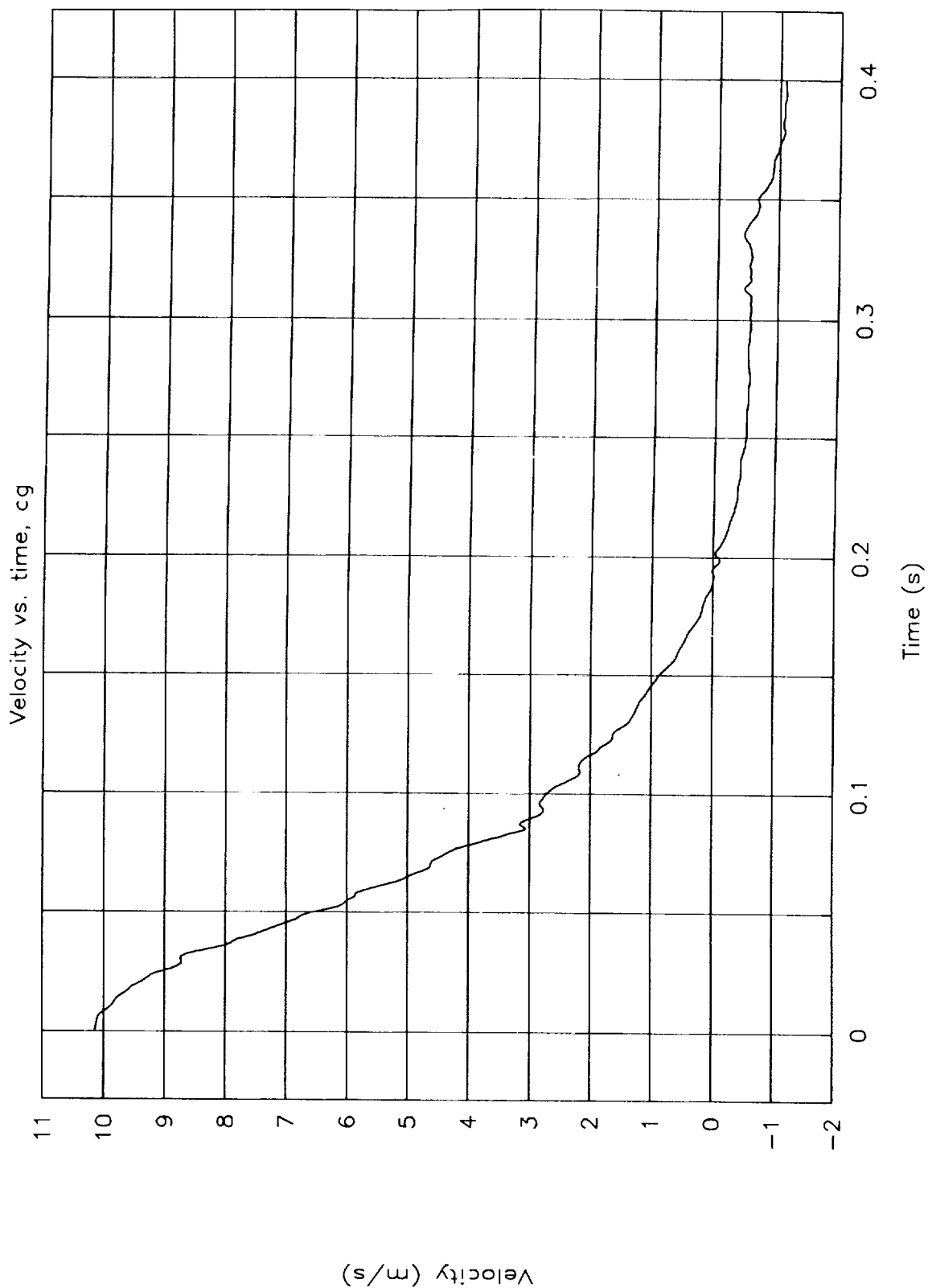


Figure 9. Velocity vs. time, cg y-axis, test 95S008.

TEST NO. 95S008

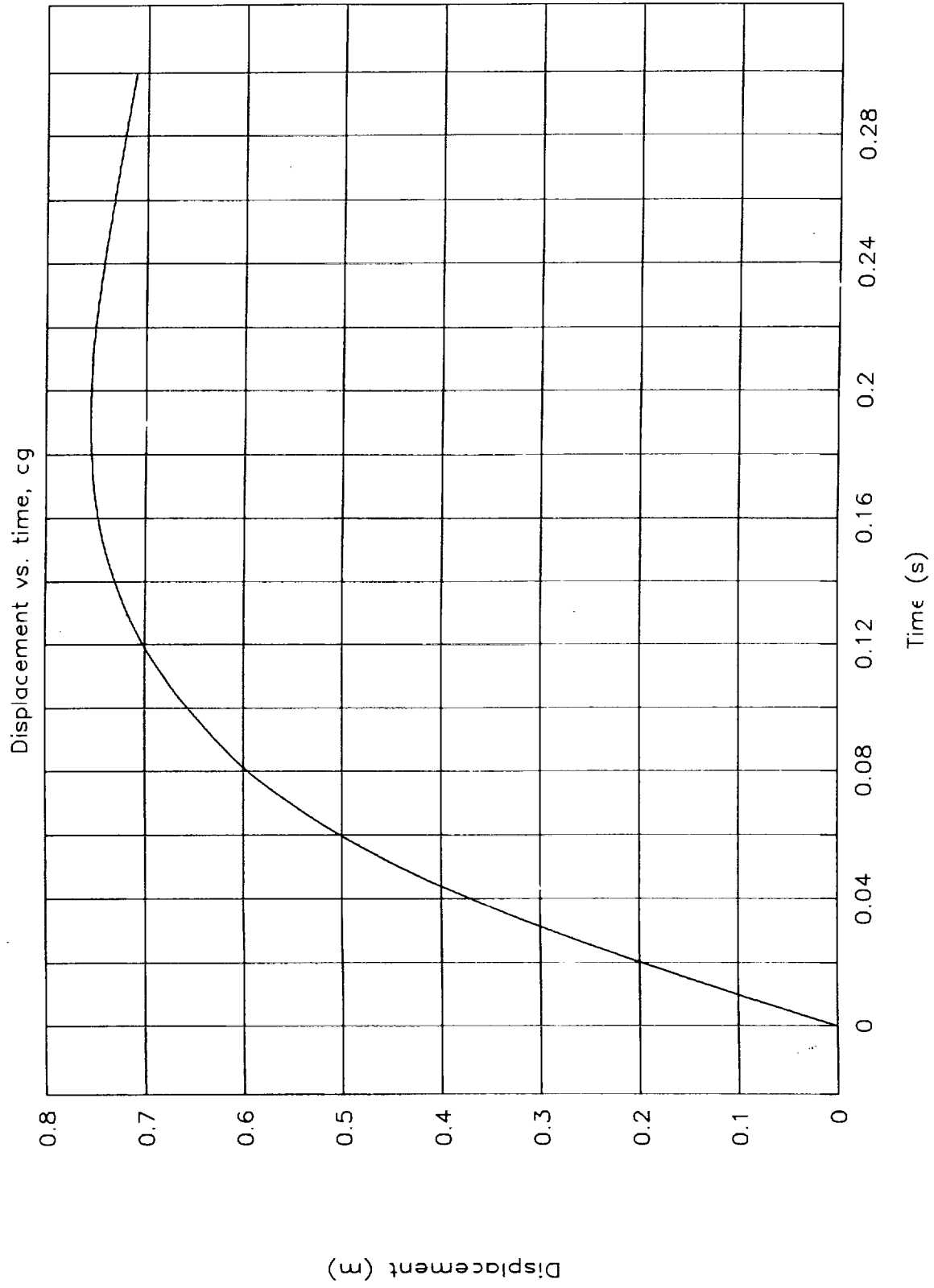


Figure 10. Displacement vs. time, cg y-axis, test 95S008.

TEST NO. 95S008

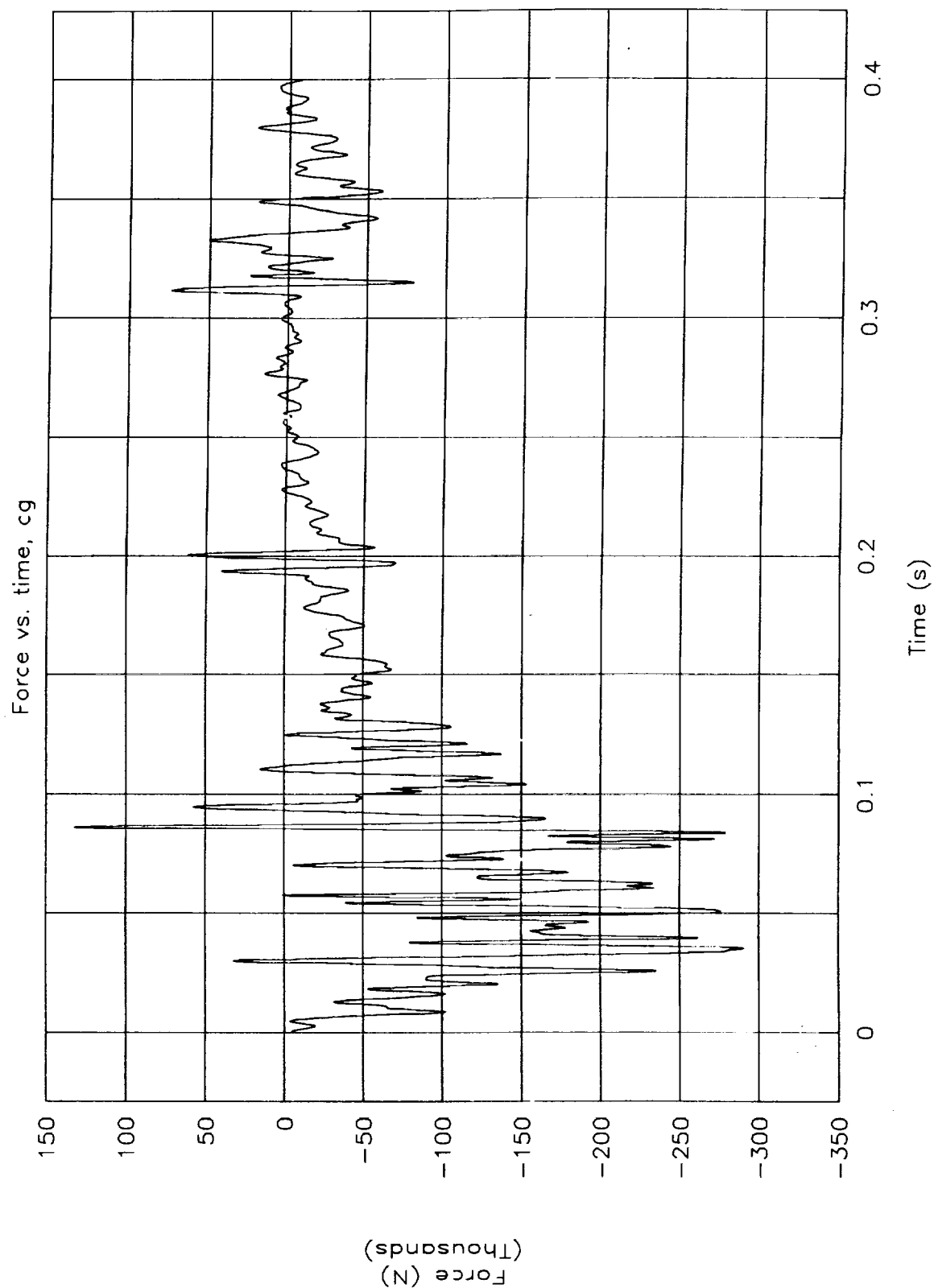


Figure 11. Force vs. time, cg y-axis, test 95S008.

TEST NO. 95S008

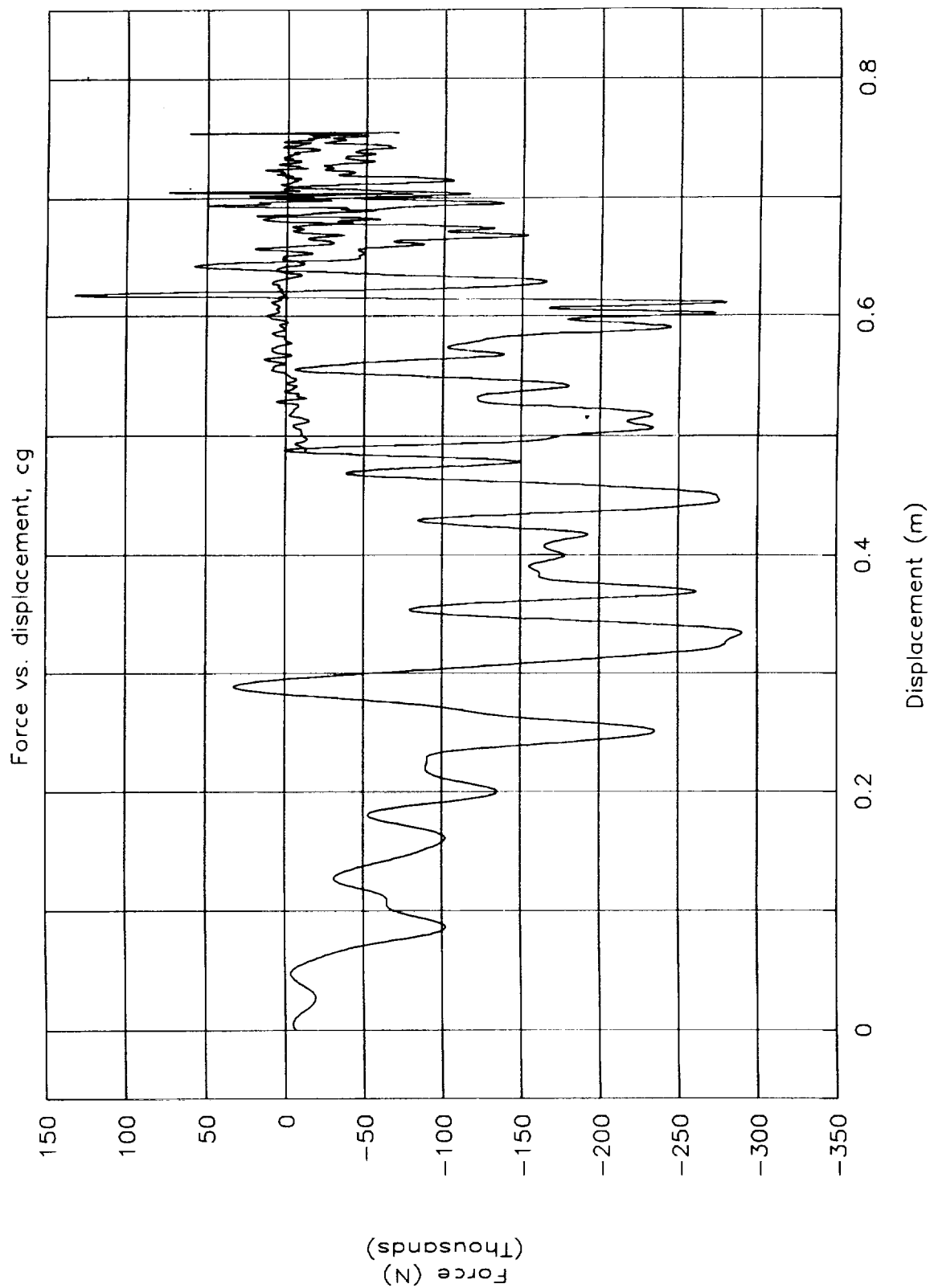


Figure 12. Force vs. displacement, cg y-axis, test 95S008.

TEST NO. 95S008

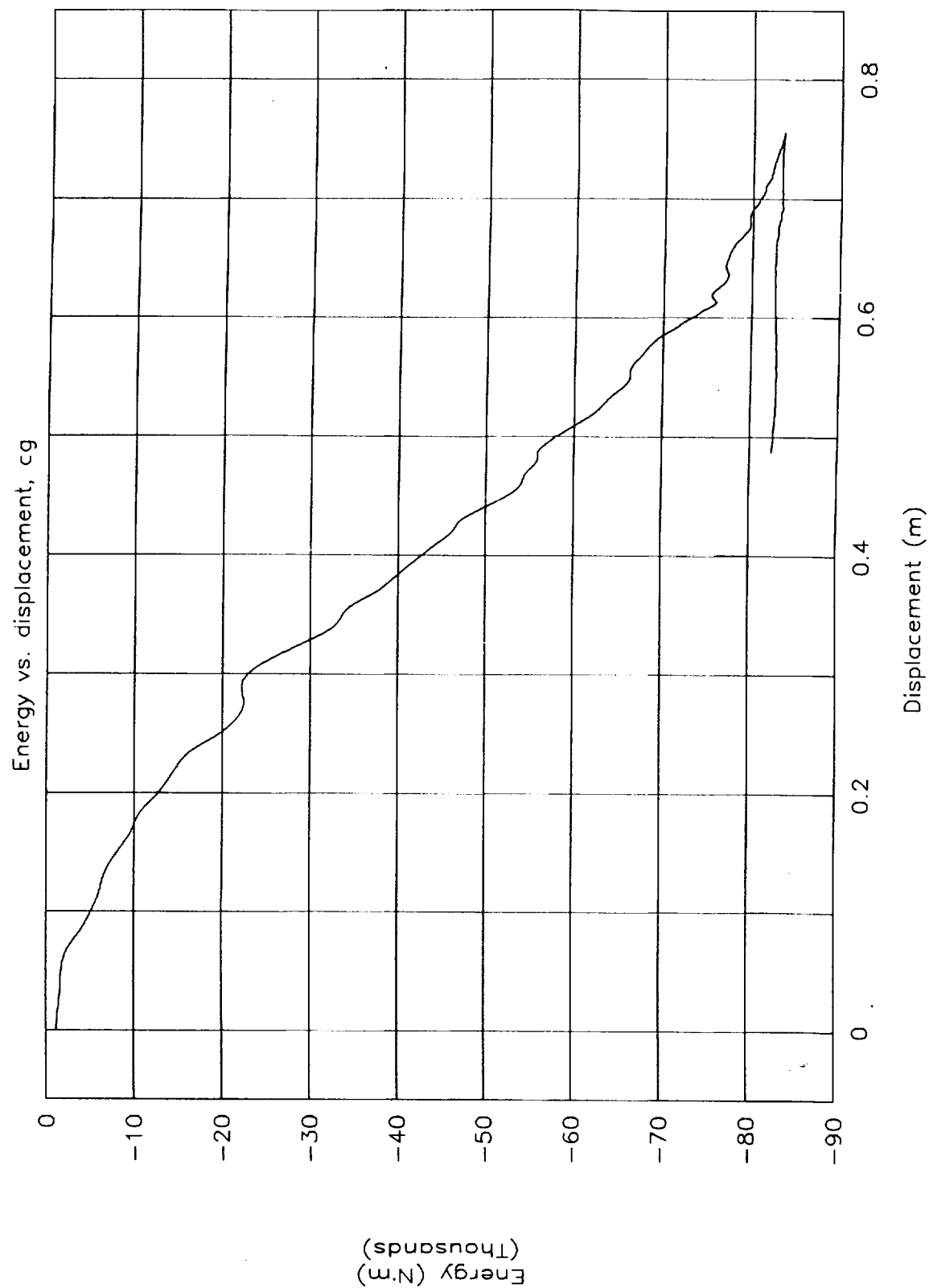


Figure 13. Energy vs. displacement, cg y-axis, test 95S008.

TEST NO. 95S008

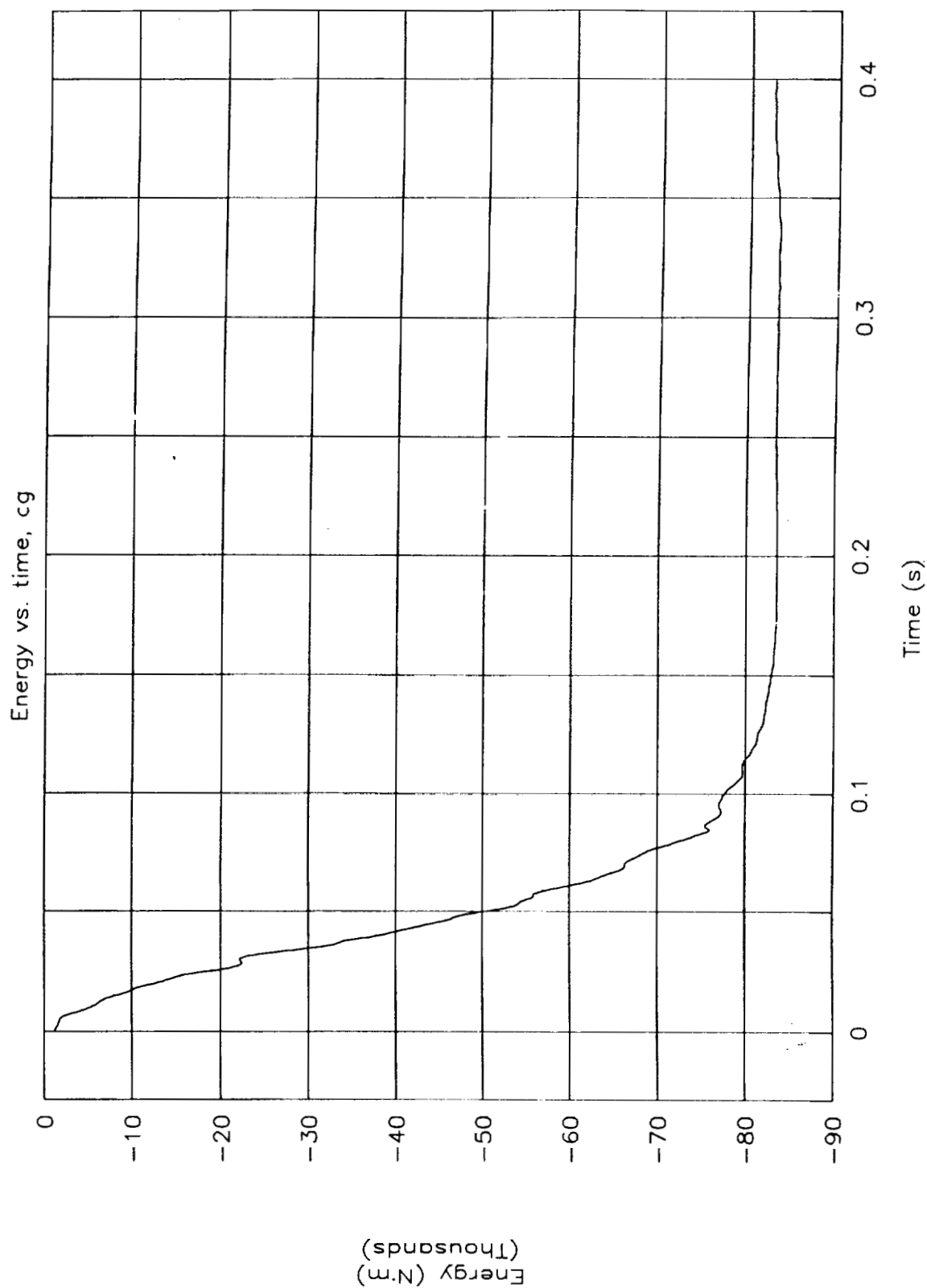


Figure 14. Energy vs. time, cg y-axis, test 95S008.

TEST NO. 95S008

Acceleration vs. time, x-axis

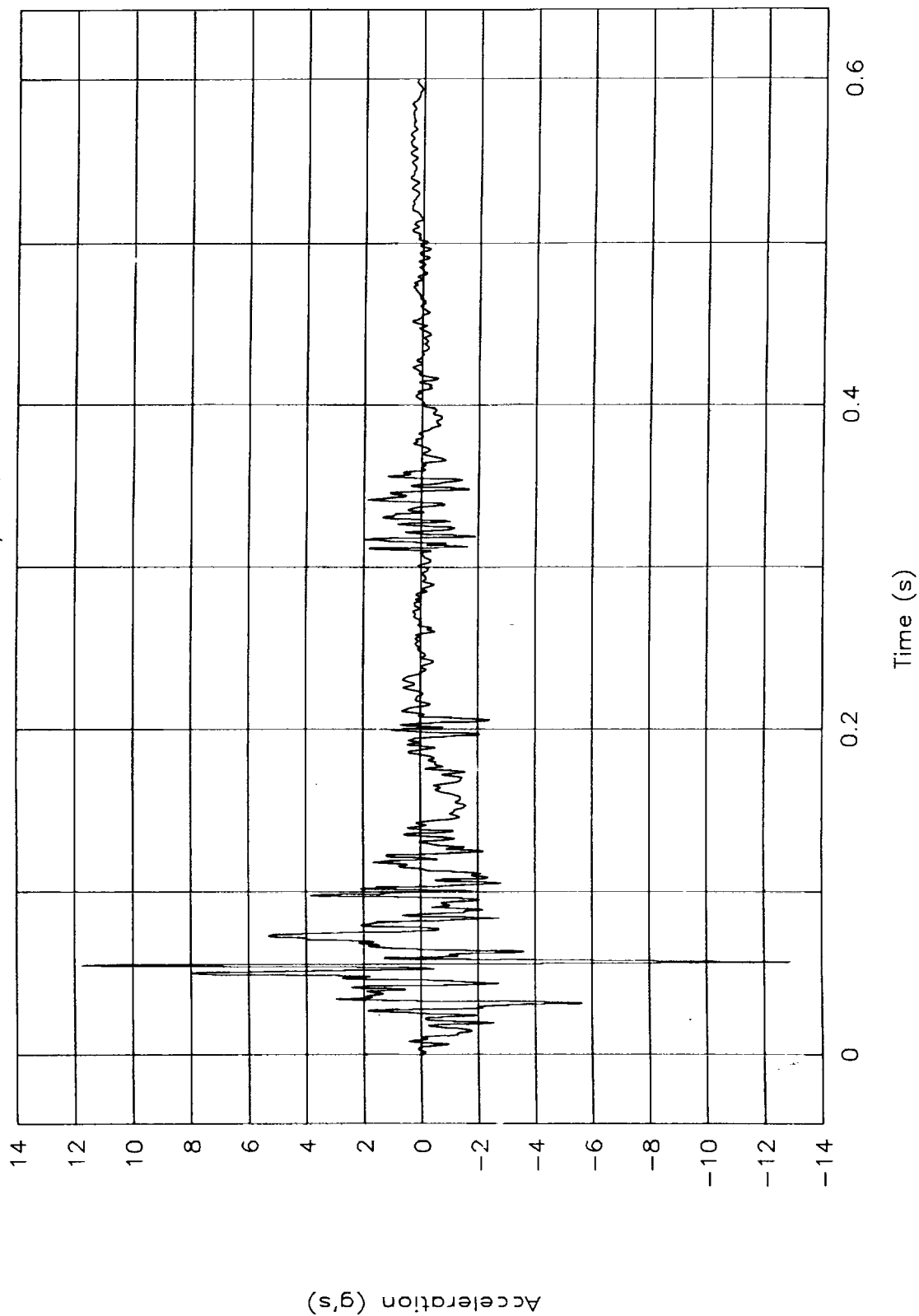


Figure 15. Acceleration vs. time, cg x-axis, test 95S008.

TEST NO. 95S008

Acceleration vs. time, z-axis

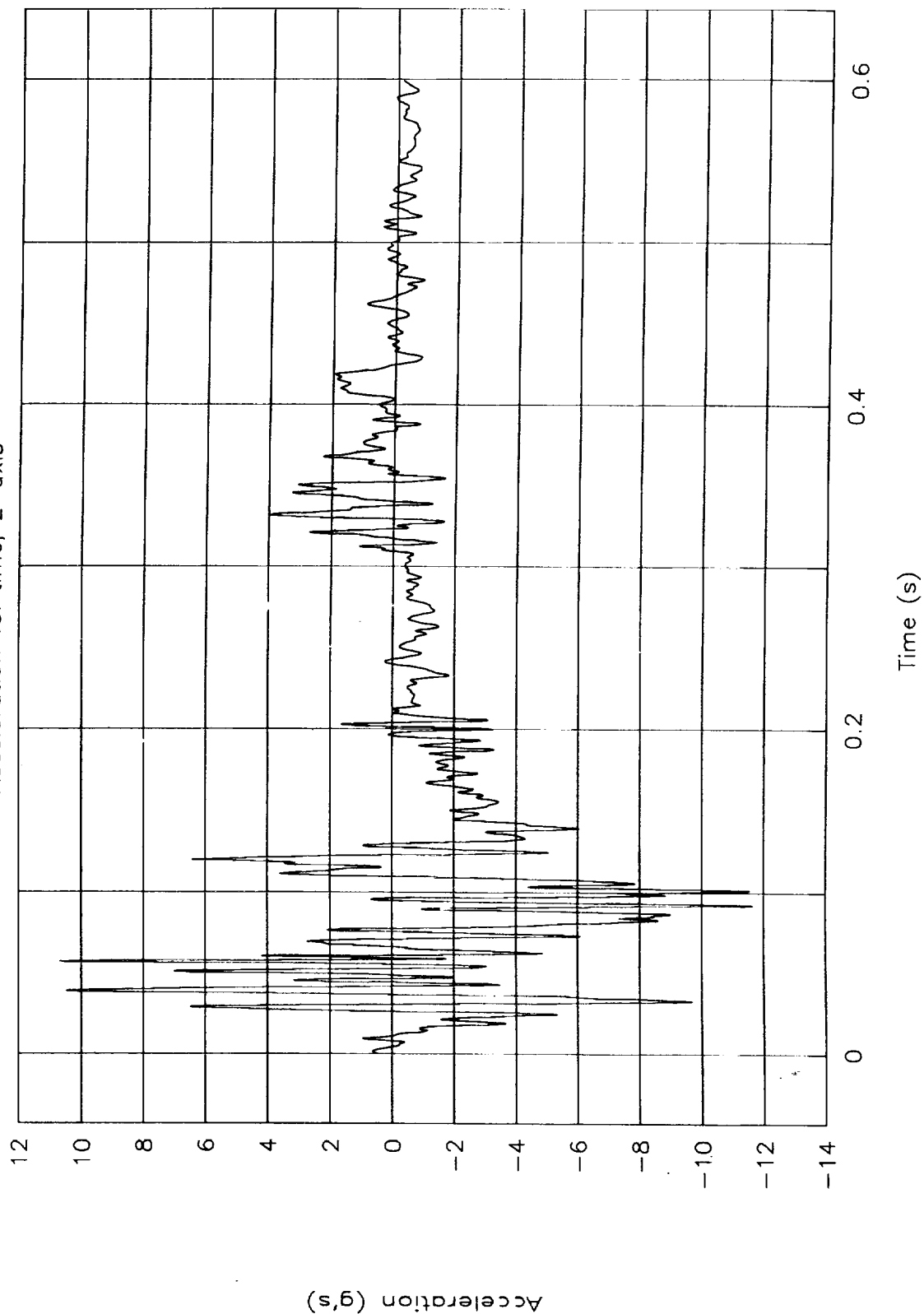


Figure 16. Acceleration vs. time, cg z-axis, test 95S008.

TEST NO. 95S008

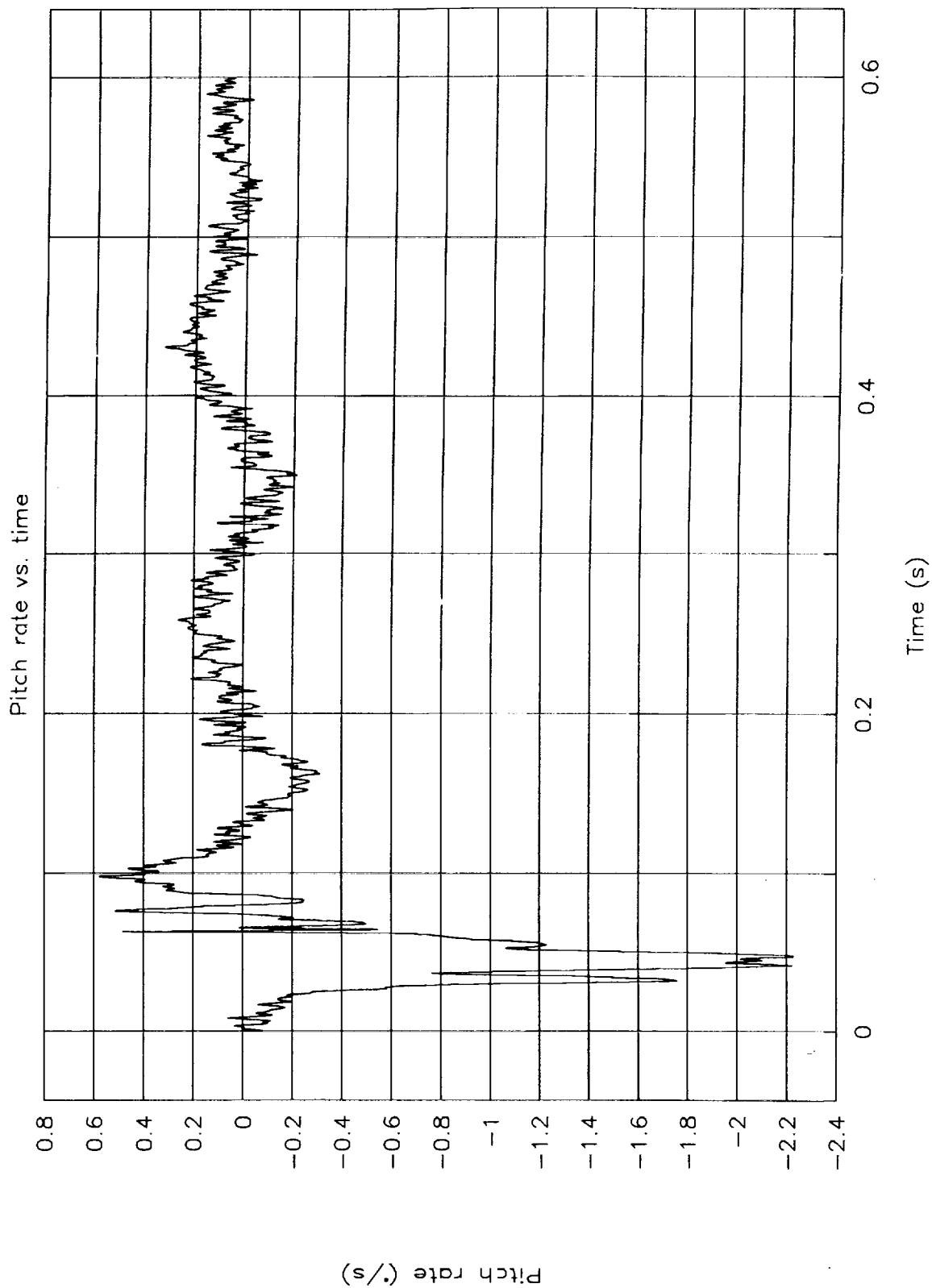


Figure 17. Pitch rate vs. time, test 95S008.

TEST NO. 95S008

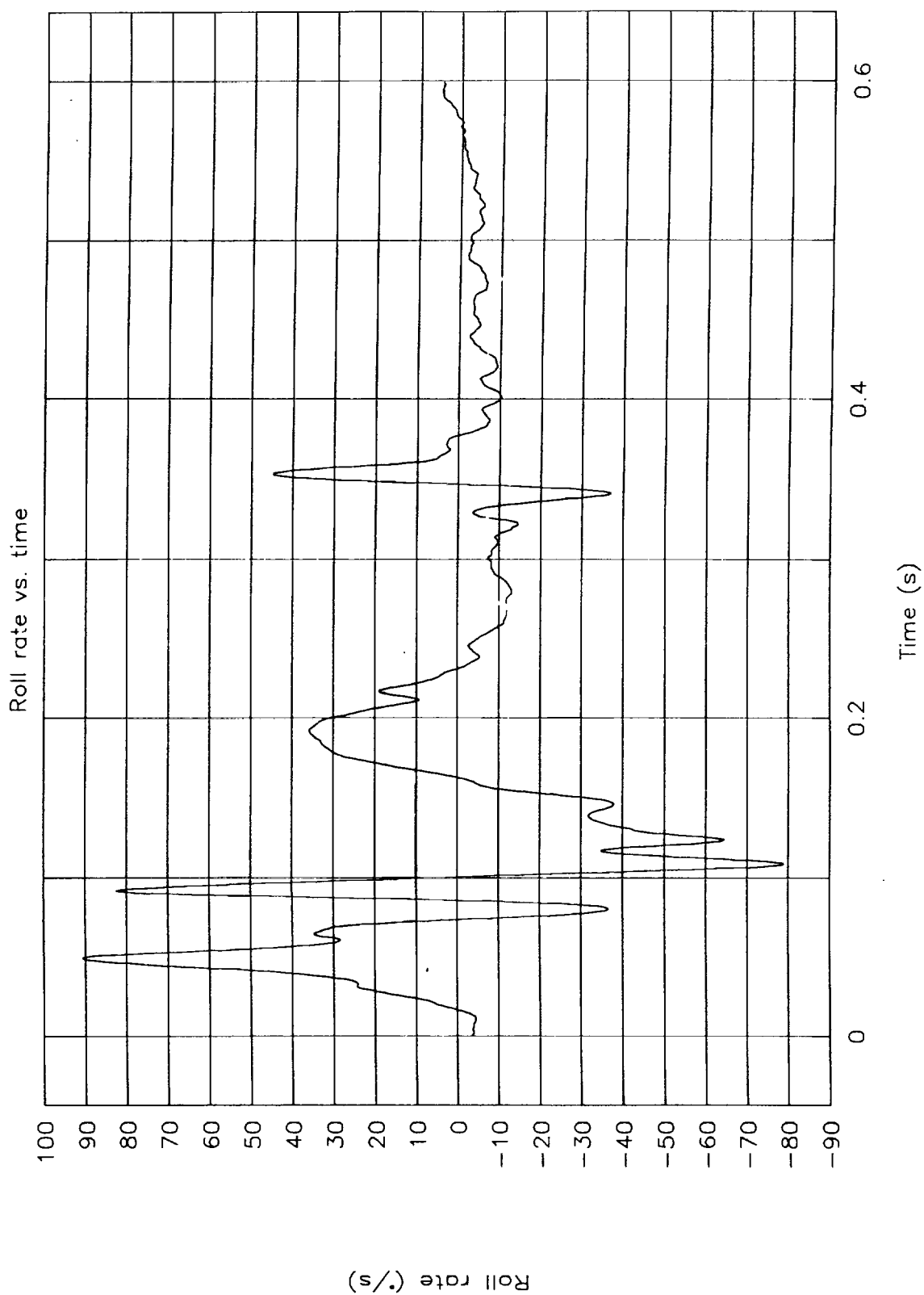


Figure 18. Roll rate vs. time, test 95S008.

TEST NO. 95S008

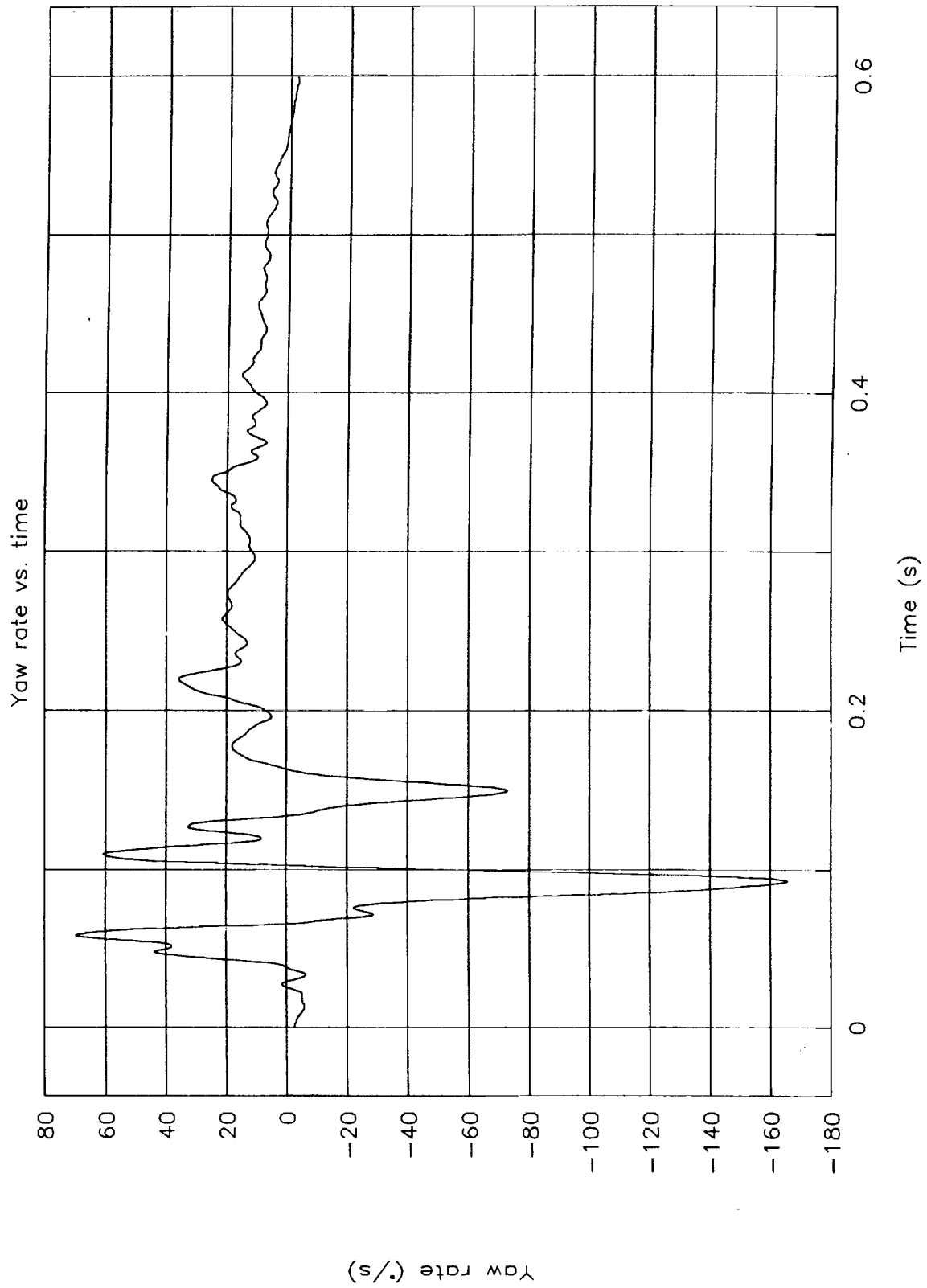


Figure 19. Yaw rate vs. time, test 95S008.

TEST NO. 95S008

Fire wall acceleration vs. time

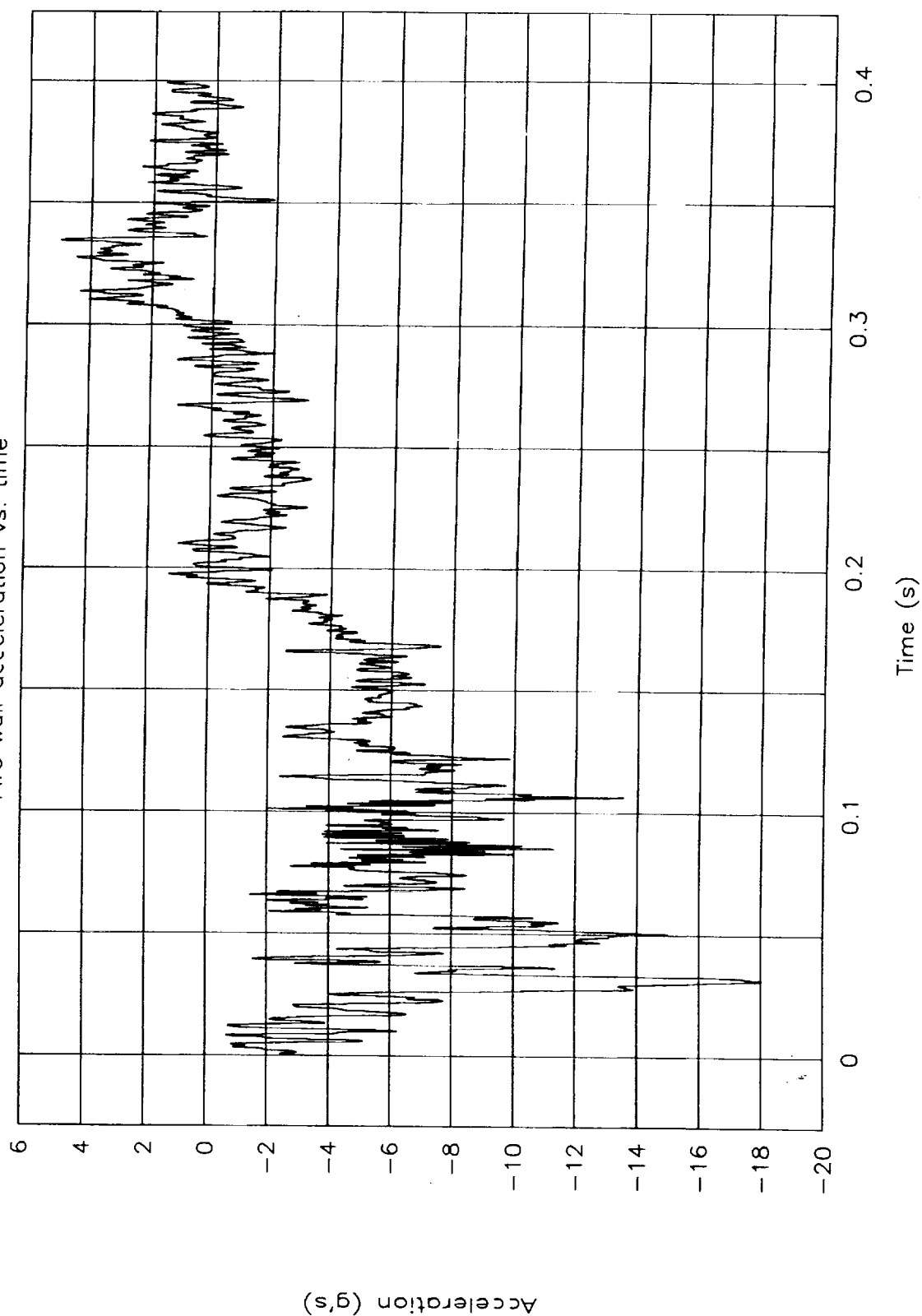


Figure 20. Firewall acceleration vs. time, test 95S008.

TEST NO. 95S008

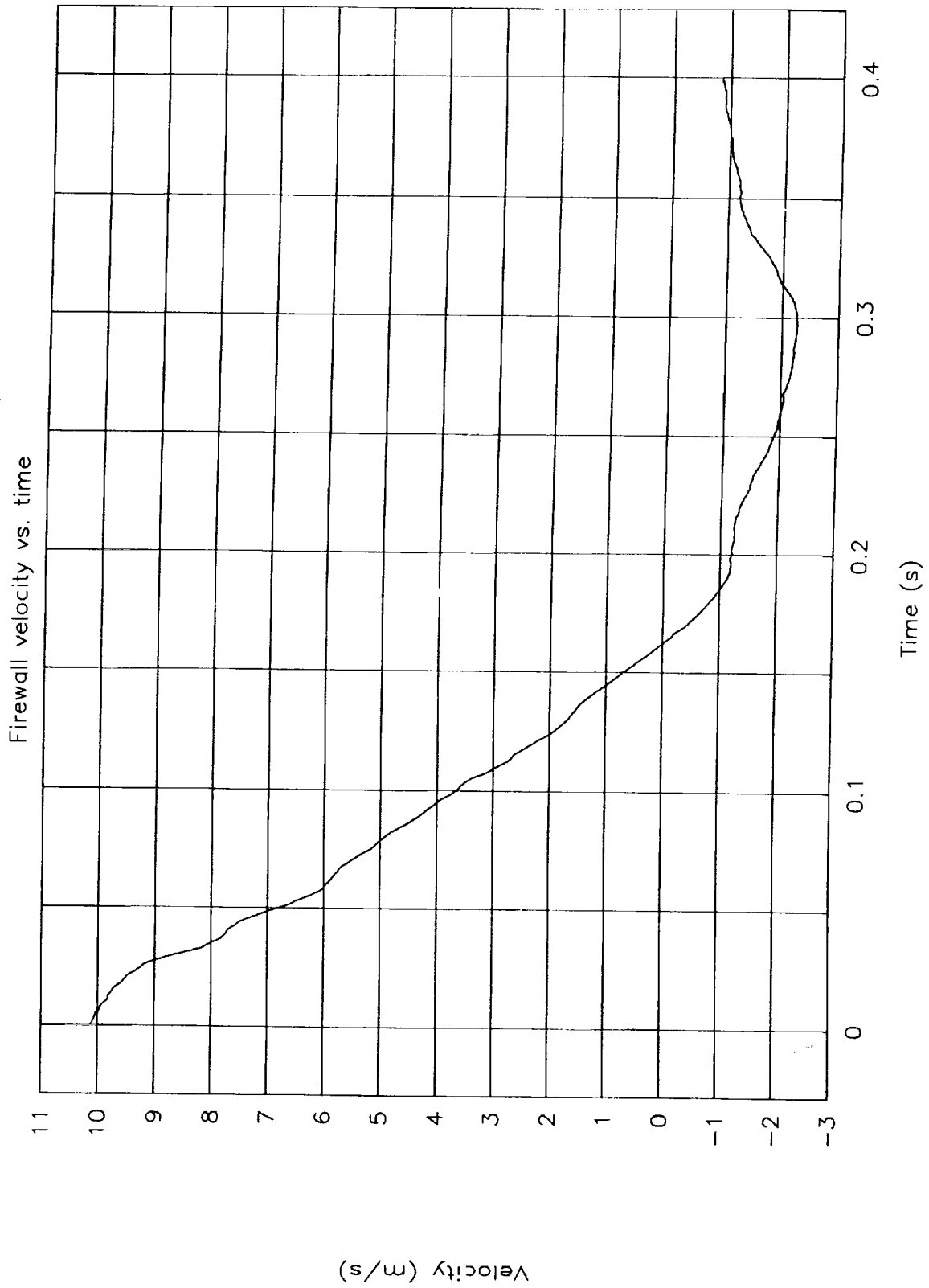


Figure 21. Firewall velocity vs. time, test 95S008.

TEST NO. 95S008

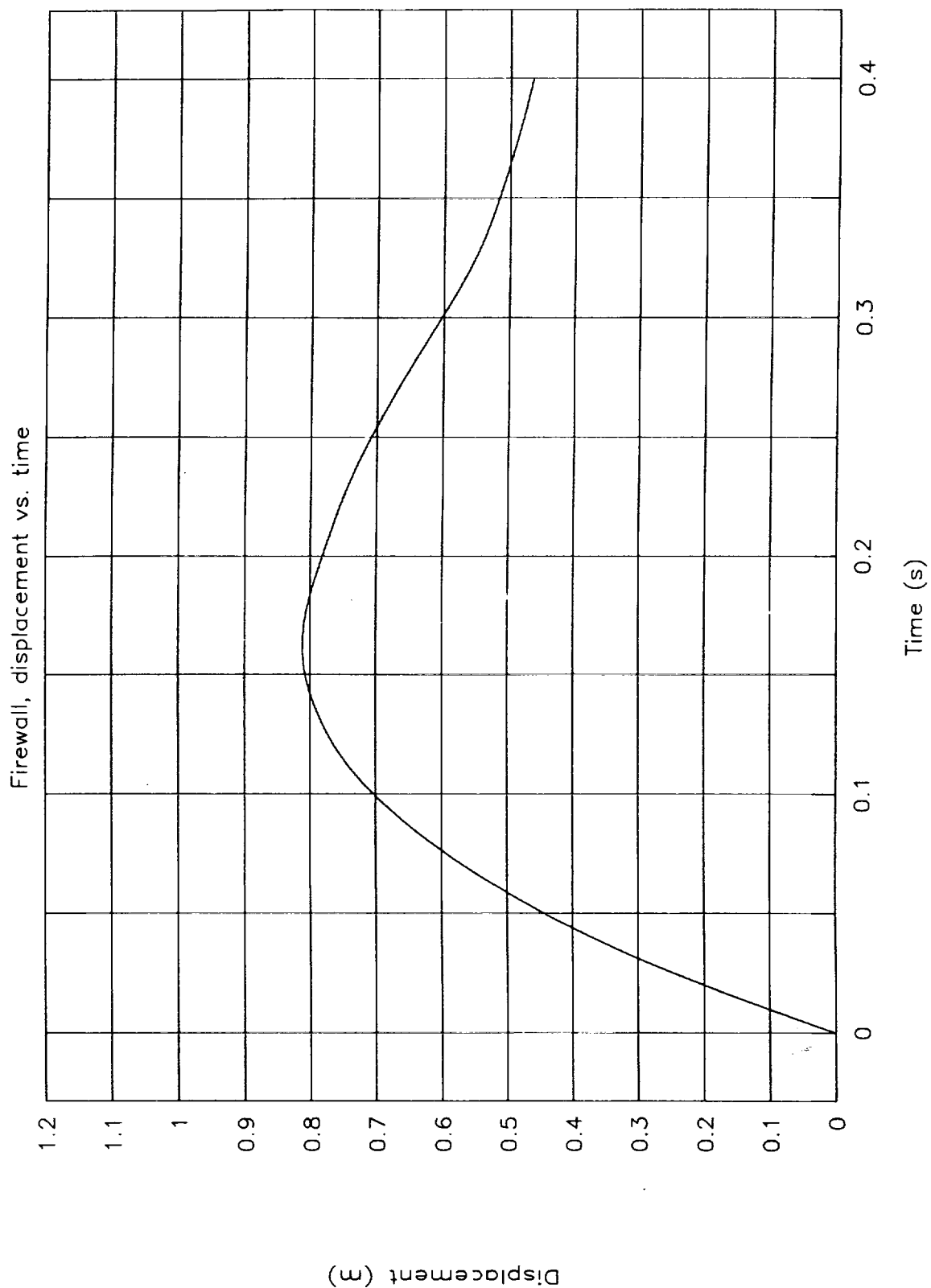


Figure 22. Firewall displacement vs. time, test 95S008.

TEST NO. 95S008

Rear seat acceleration vs. time

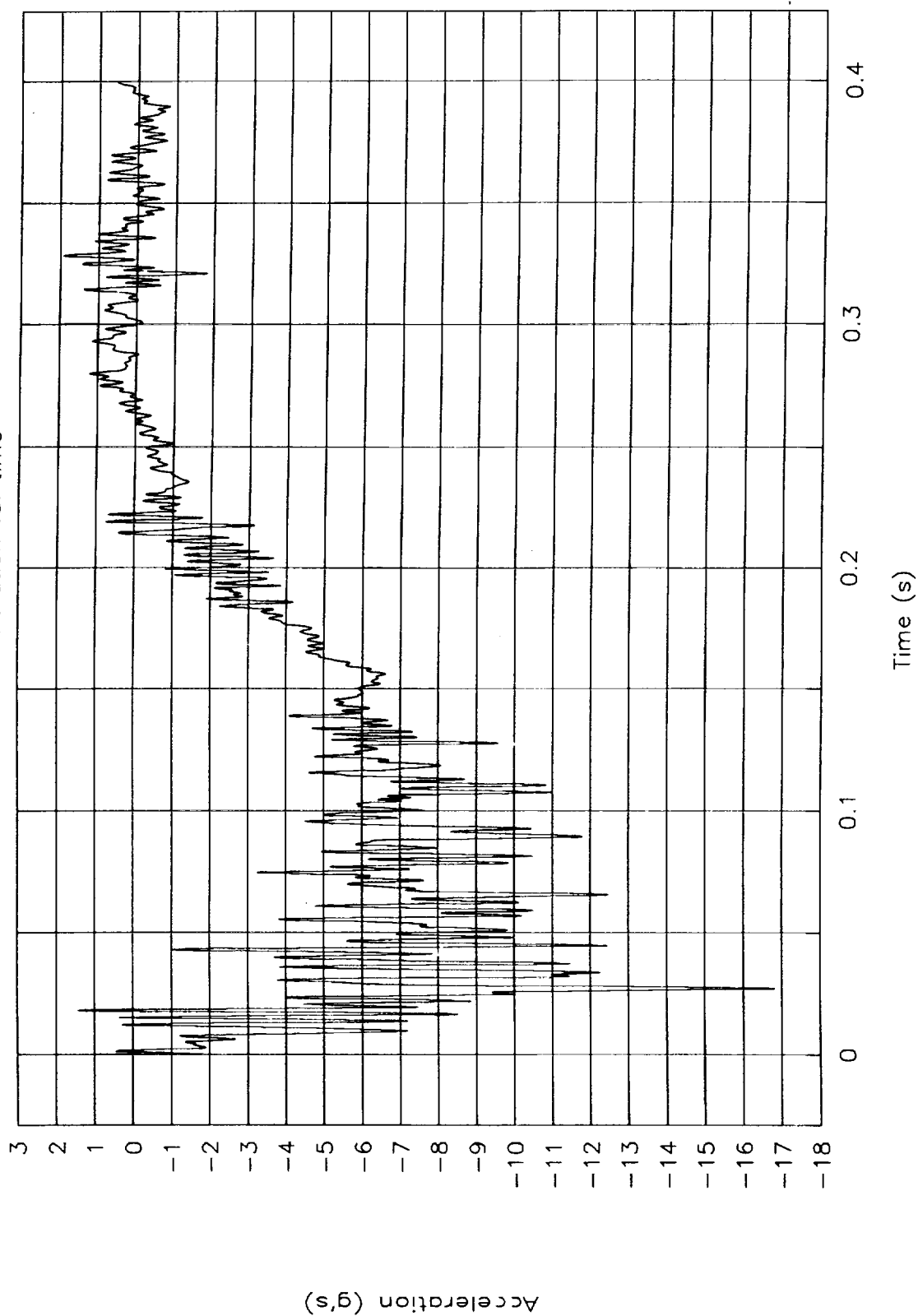


Figure 23. Rear seat acceleration vs. time, test 95S008.

TEST NO. 95S008

Rear seat velocity vs. time

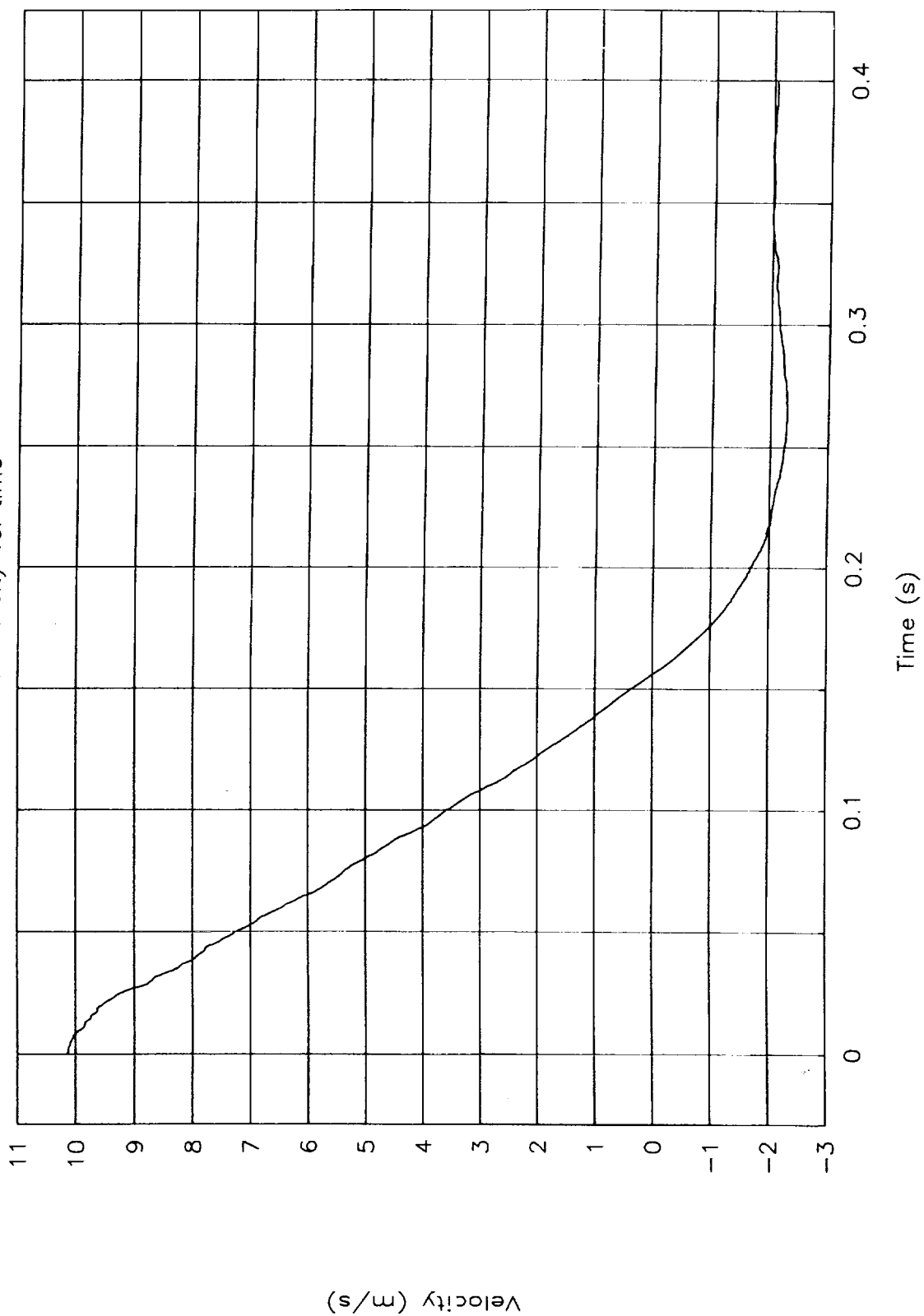


Figure 24. Rear seat velocity vs. time, test 95S008.

TEST NO. 95S008

Rear seat displacement vs. time

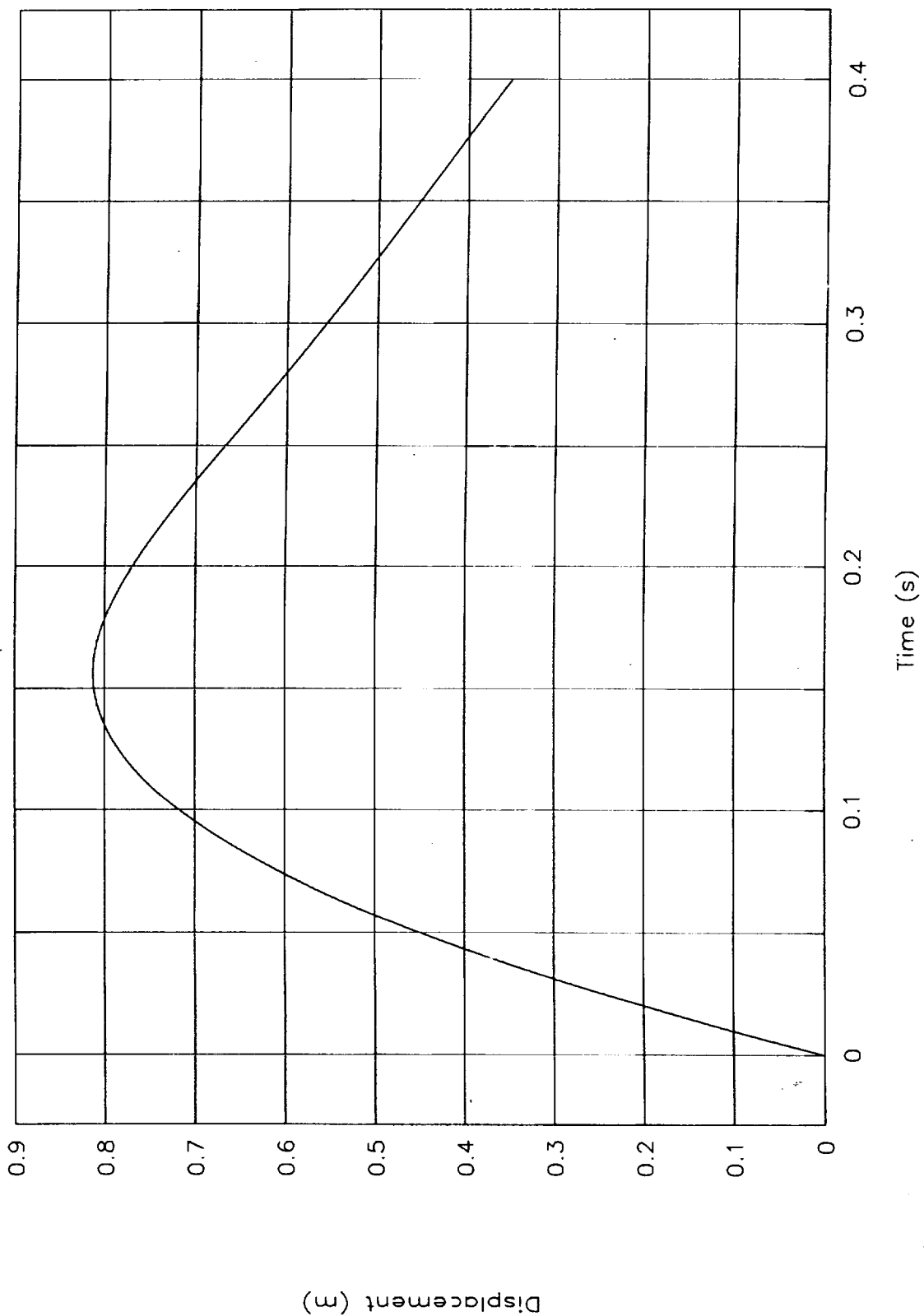


Figure 25. Rear seat displacement vs. time, test 95S008.

TEST NO. 95S008

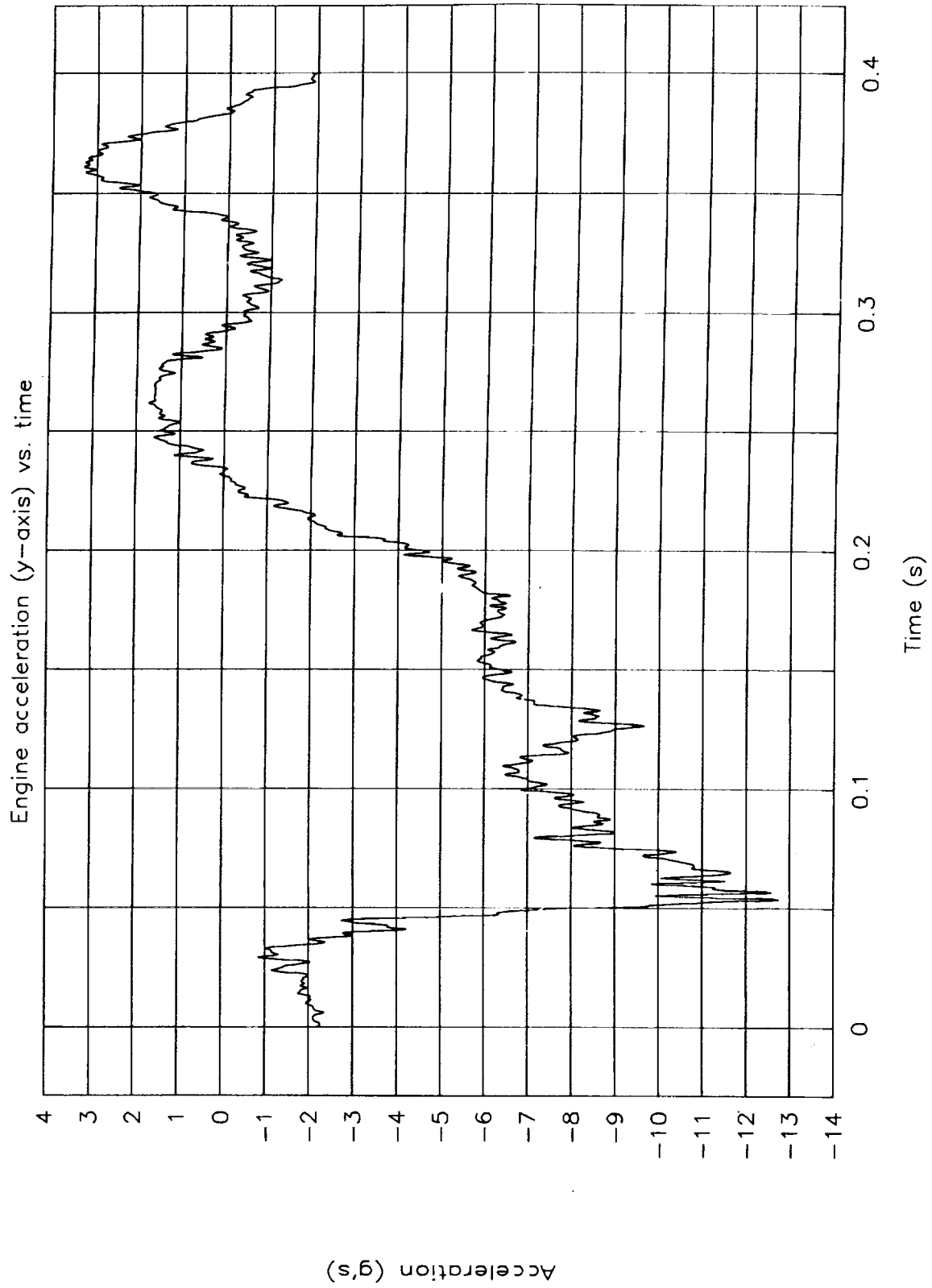


Figure 26. Engine acceleration vs. time, y-axis, test 95S008.

TEST NO. 95S008

Engine velocity (y-axis) vs. time

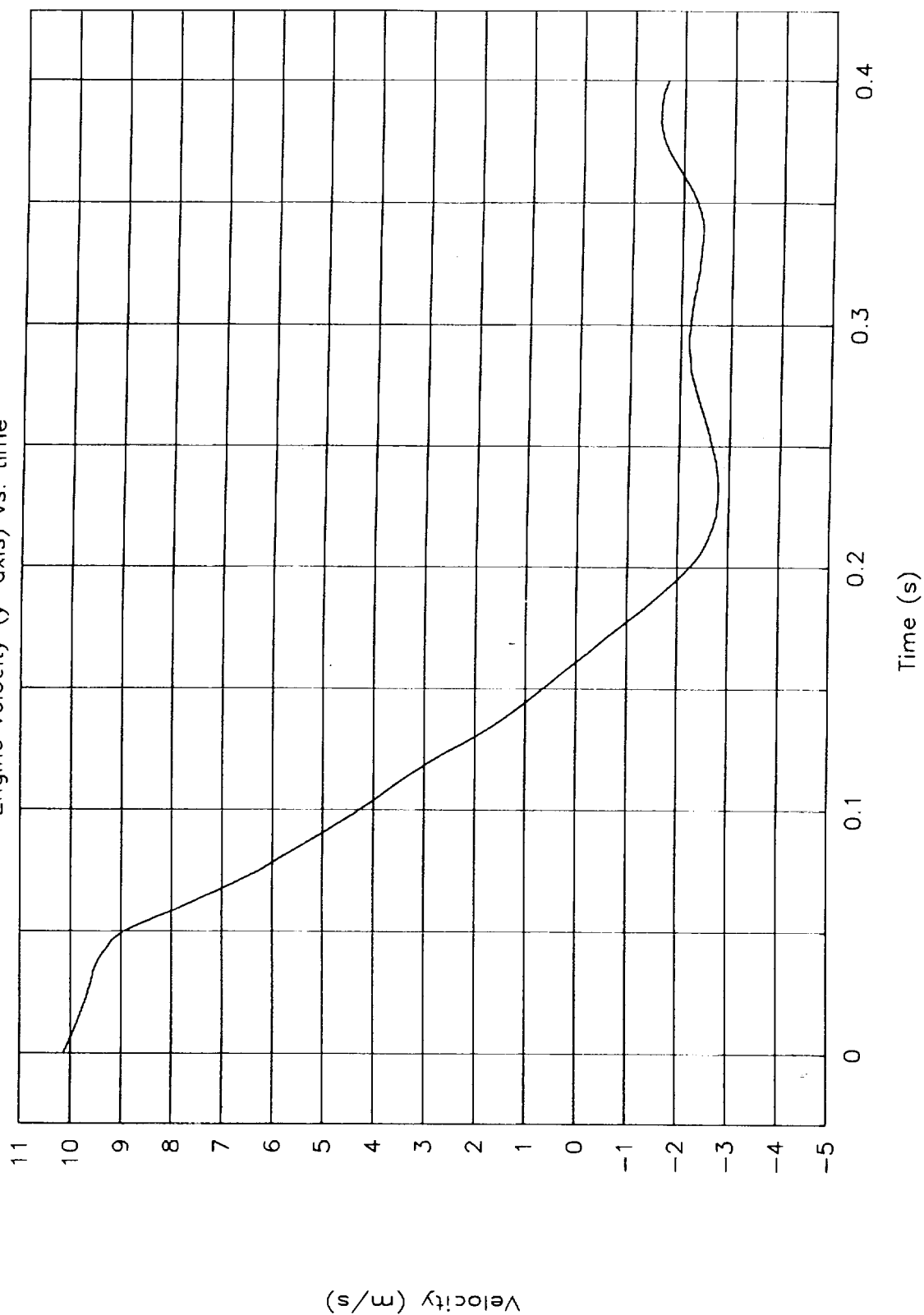


Figure 27. Engine velocity vs. time, y-axis, test 95S008.

TEST NO. 95S008

Engine displacement (y-axis) vs. time

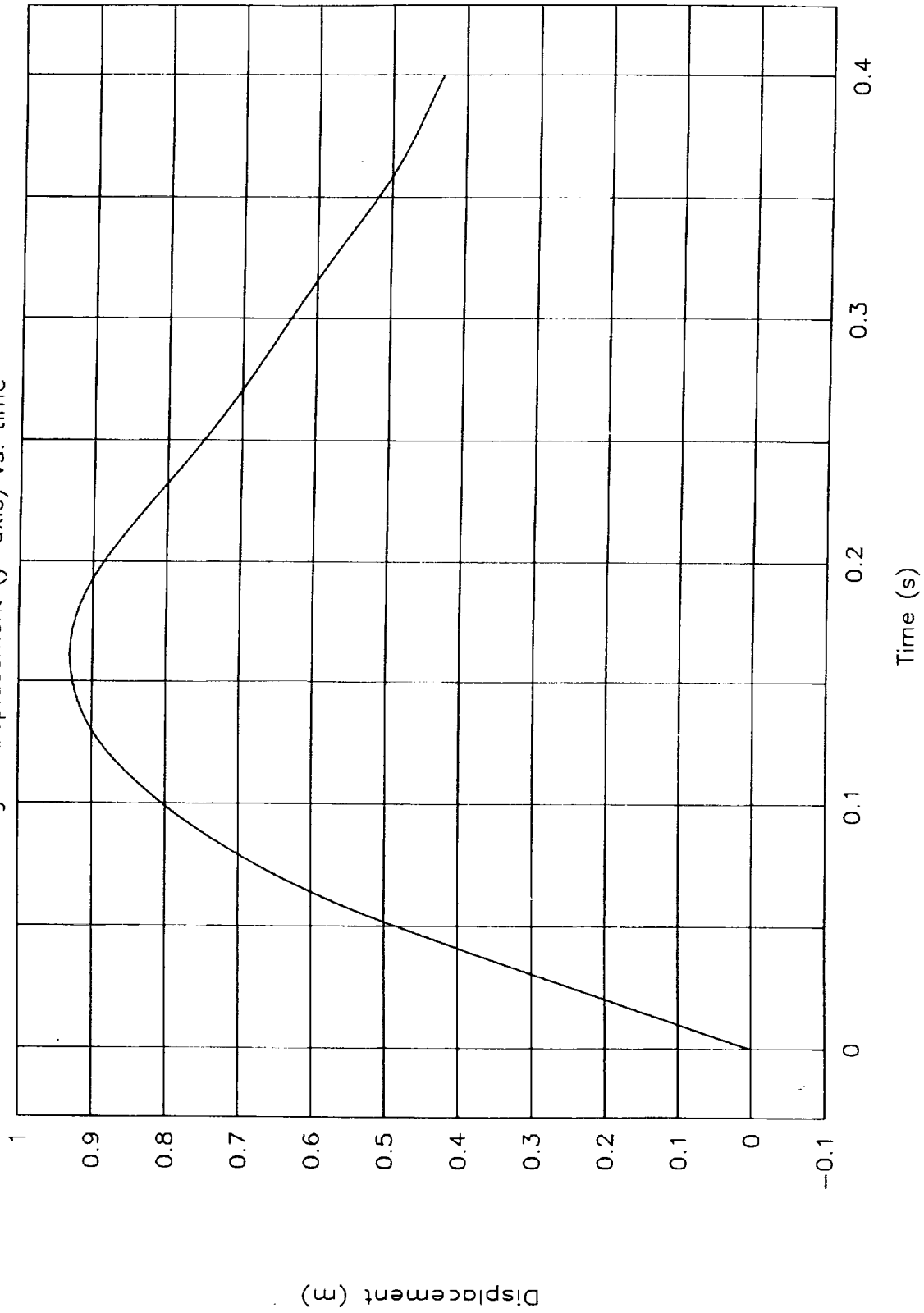


Figure 28. Engine displacement vs. time, y-axis, test 95S008.

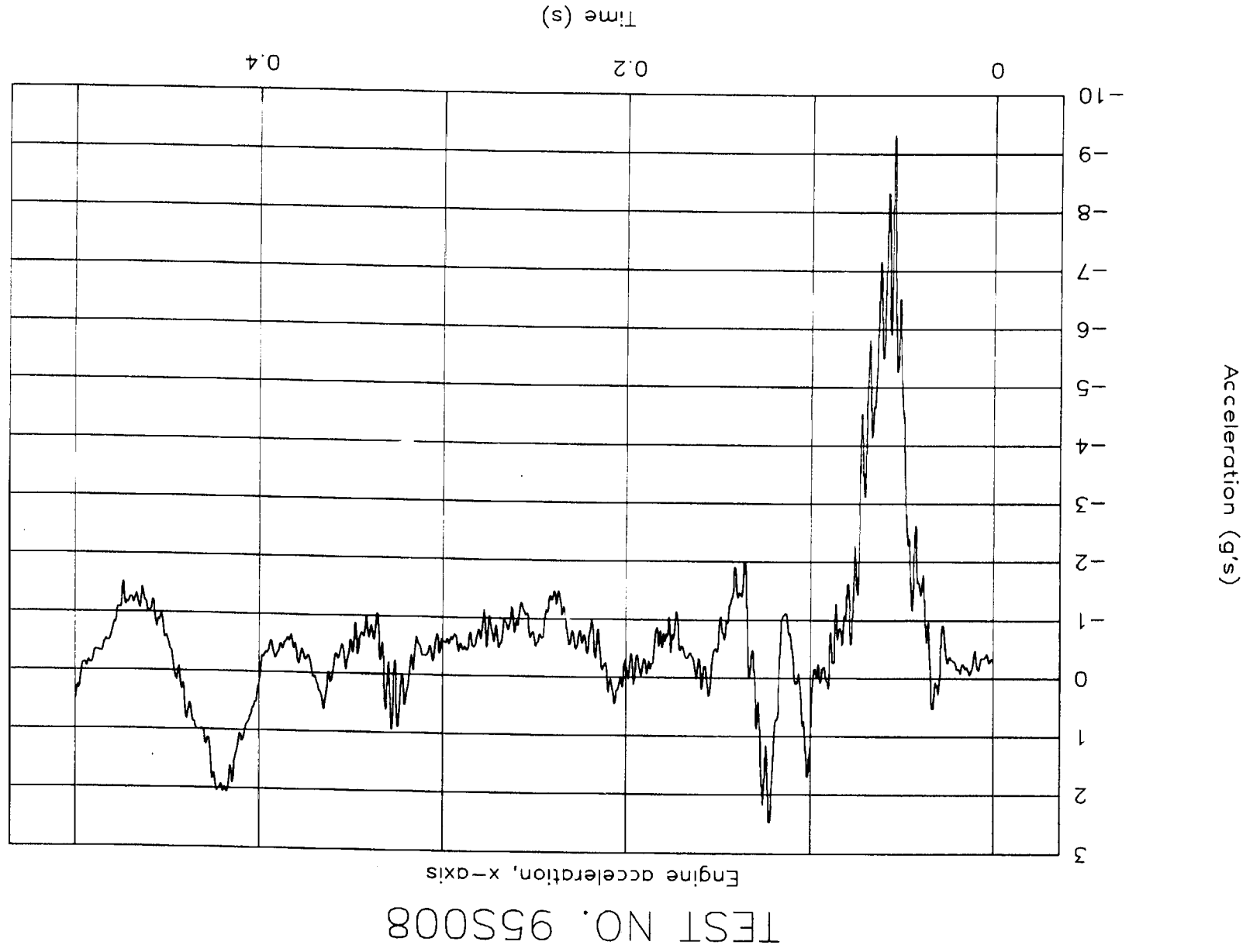


Figure 29. Engine acceleration vs. time, x-axis, test 95S008.

TEST NO. 95S008

Passenger roof-rail acceleration

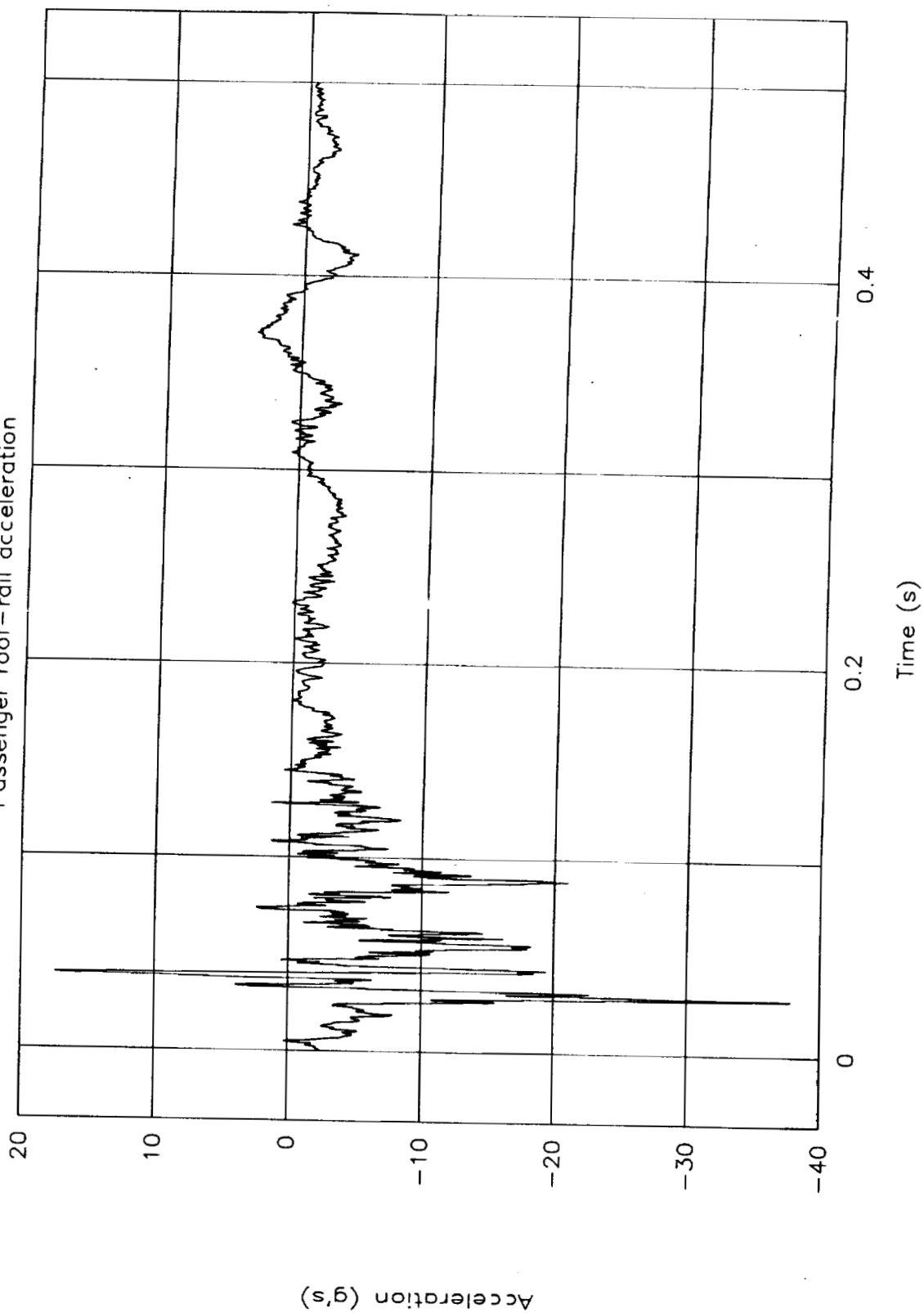


Figure 30. Passenger roof-rail acceleration vs. time, test 95S008.

TEST NO. 95S008

Passenger floor-sill acceleration

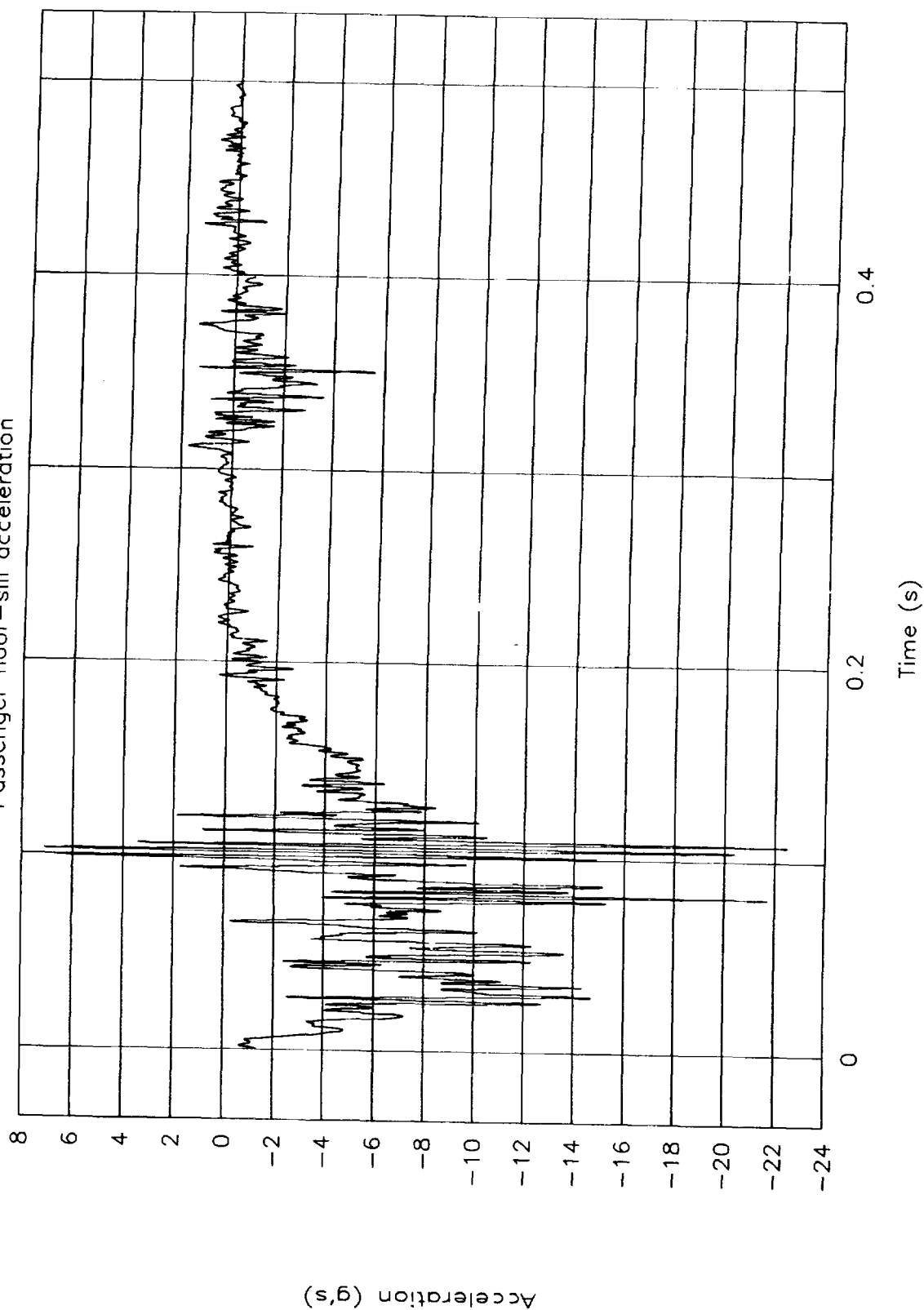


Figure 31. Passenger floor-sill acceleration vs. time, test 95S008.

TEST NO. 95S008

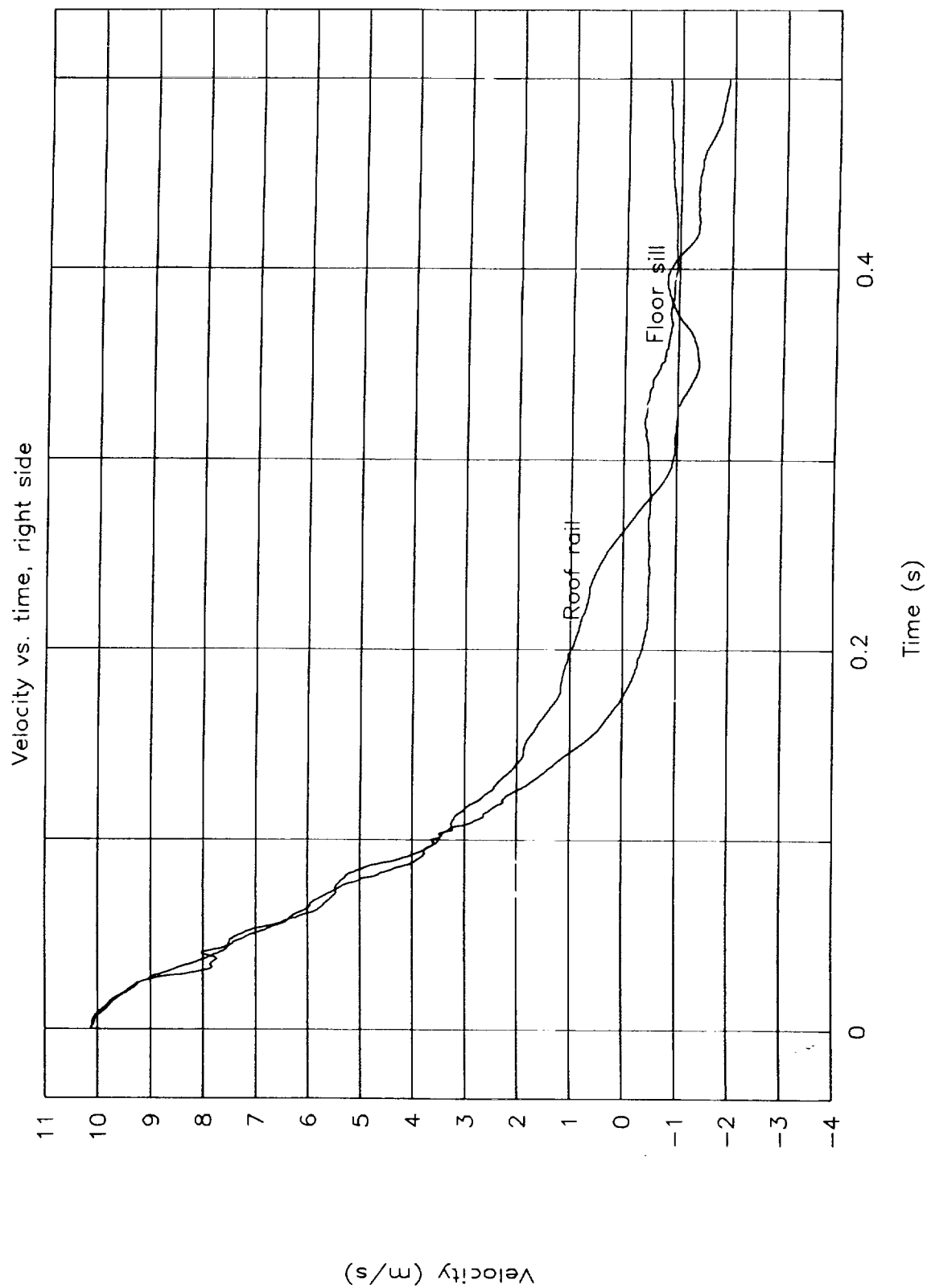


Figure 32. Velocity vs. time, passenger side, test 95S008.

TEST NO. 95S008

Displacement vs. time, right side

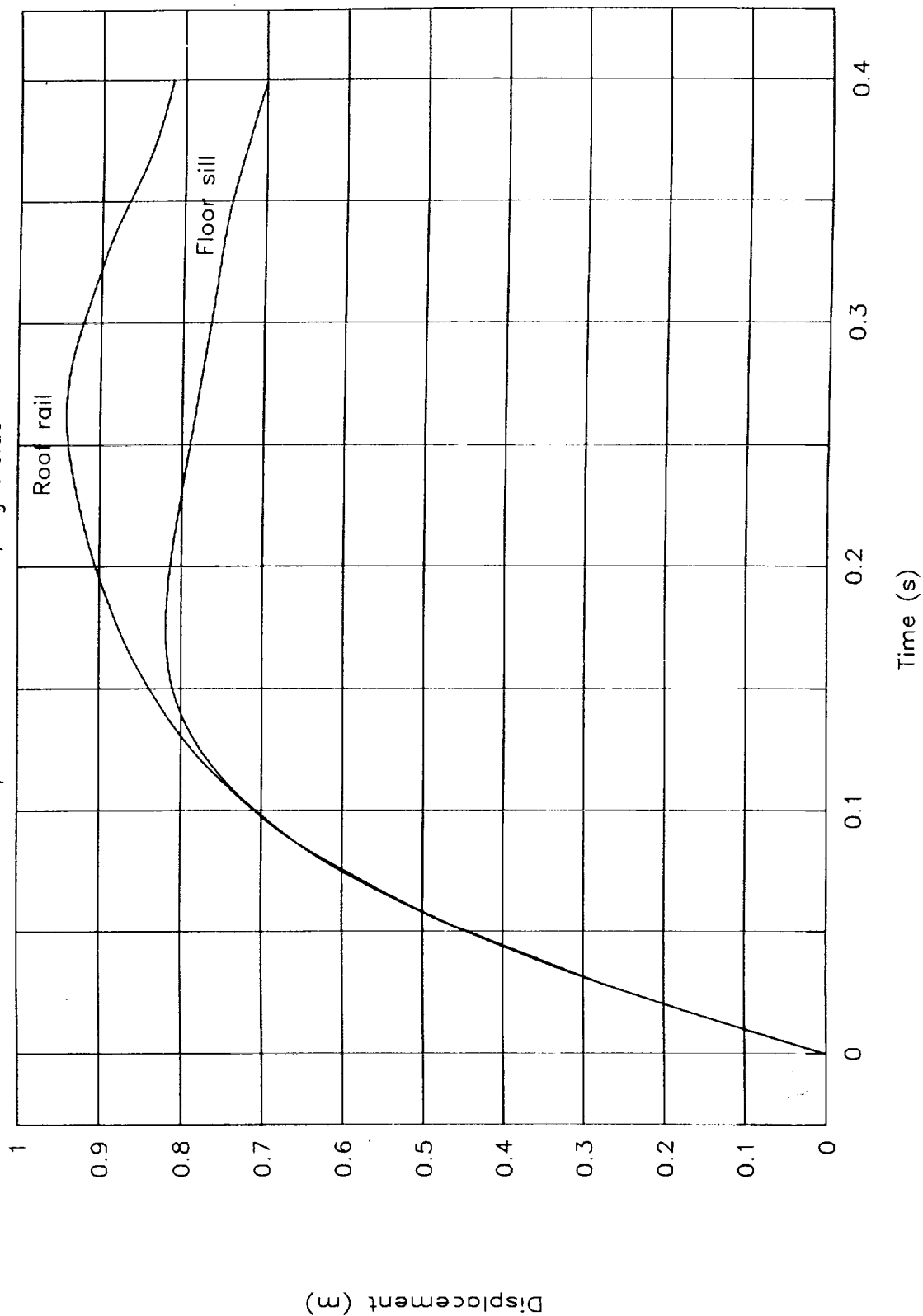


Figure 33. Displacement vs. time, passenger side, test 95S008.

TEST NO. 95S008

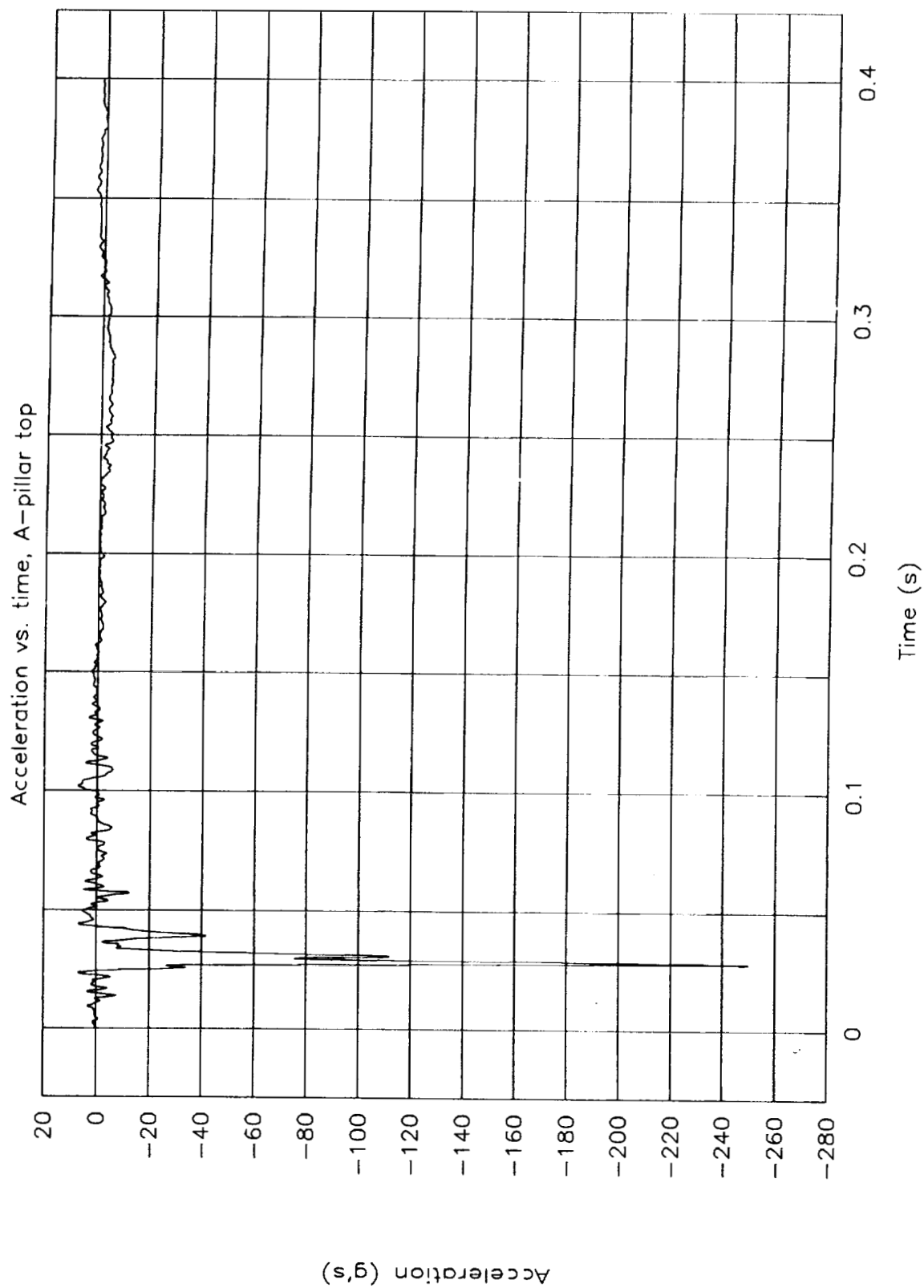


Figure 34. Acceleration vs. time, A-pillar-top, test 95S008.

TEST NO. 95S008

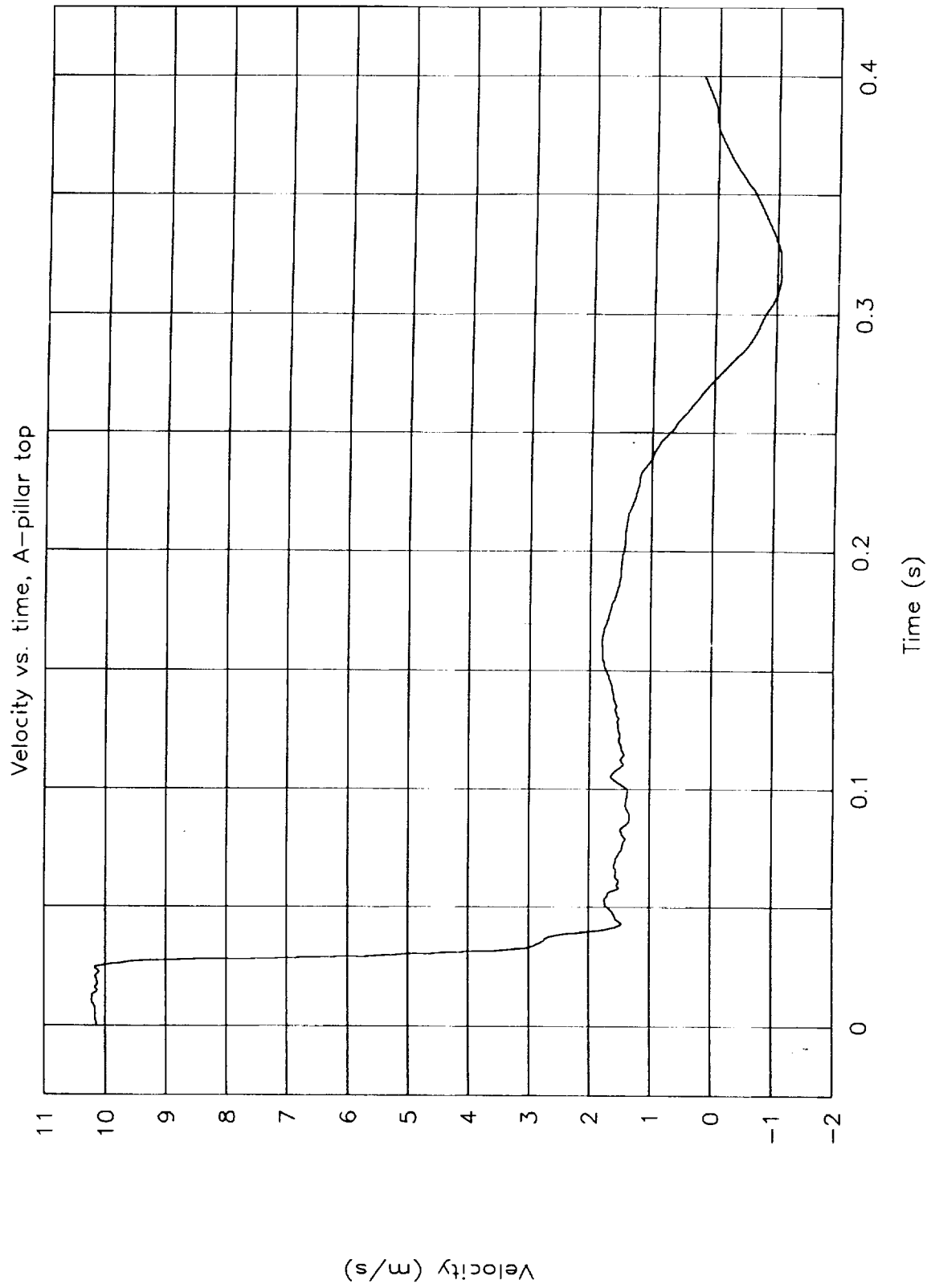


Figure 35. Velocity vs. time, A-pillar-top, test 95S008.

TEST NO. 95S008

Displacement vs. time, A-pillar top

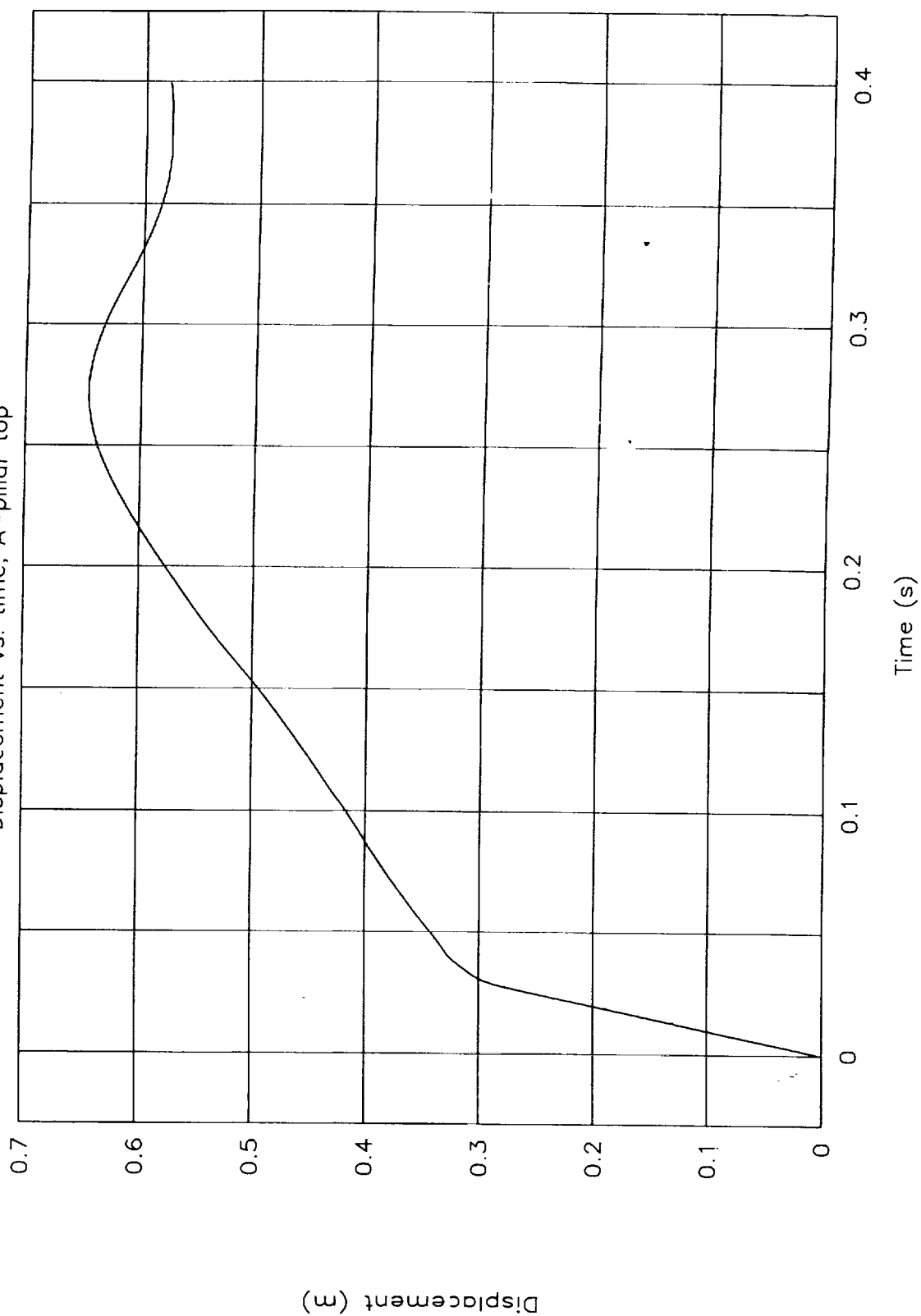


Figure 36. Displacement vs. time, A-pillar-top, test 95S008.

TEST NO. 95S008

Acceleration vs. time, A-pillar middle

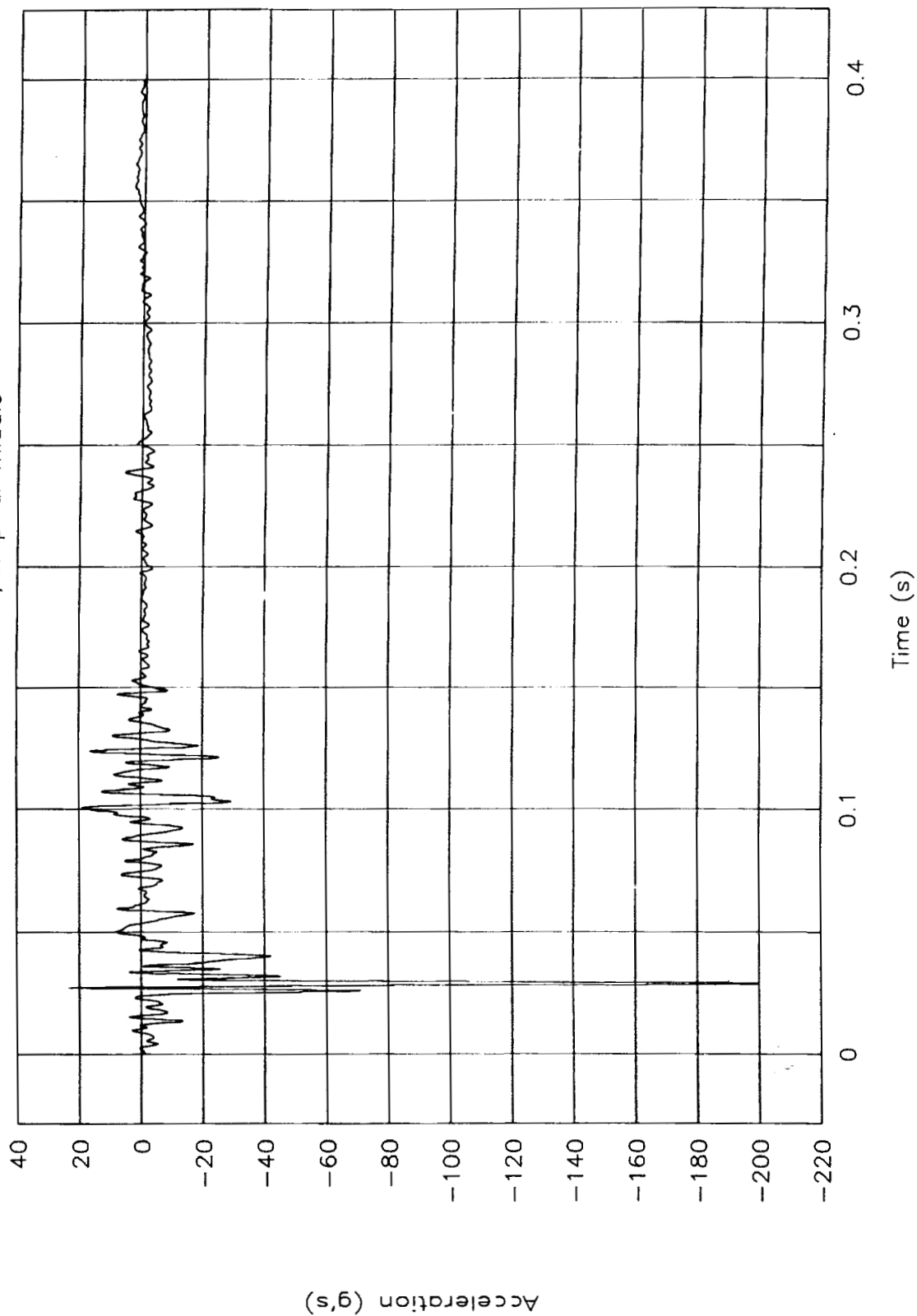


Figure 37. Acceleration vs. time, A-pillar-middle, test 95S008.

TEST NO. 95S008

Velocity vs. time, A-pillar middle

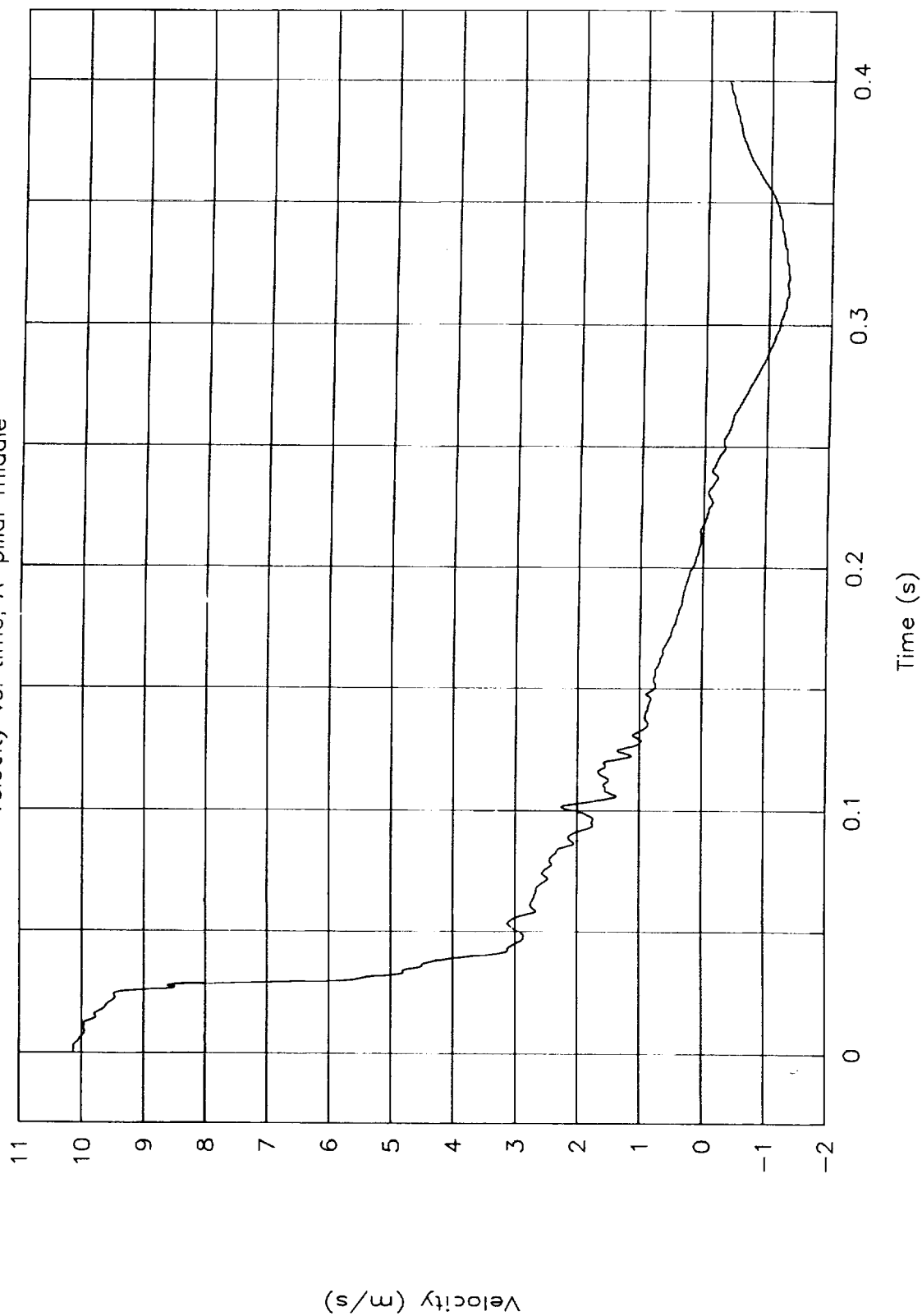


Figure 38. Velocity vs. time, A-pillar-middle, test 95S008.

TEST NO. 95S008

Displacement vs. time, A-pillar middle

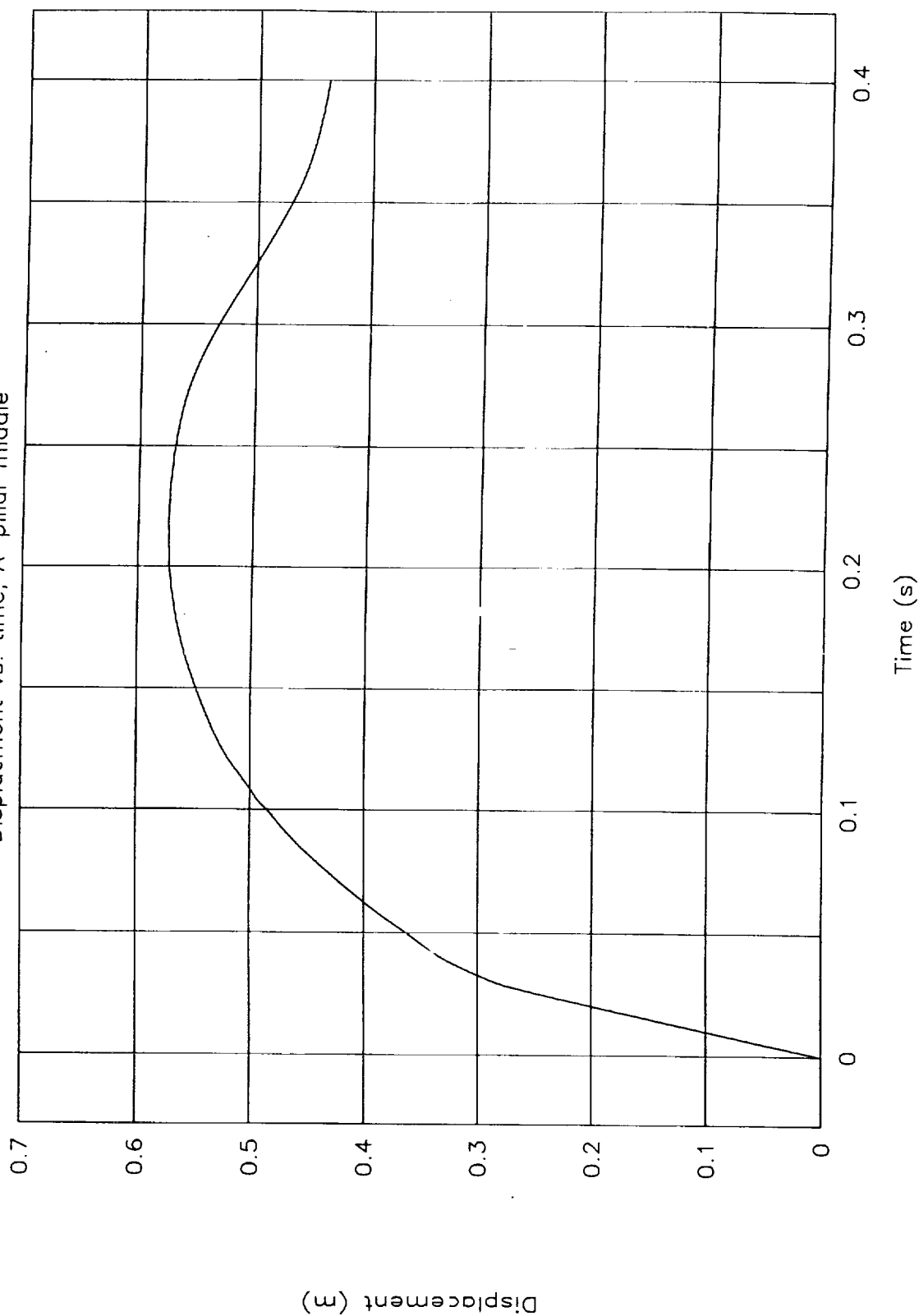


Figure 39. Displacement vs. time, A-pillar-middle, test 95S008.

TEST NO. 95S008

Acceleration vs. time, A-pillar lower

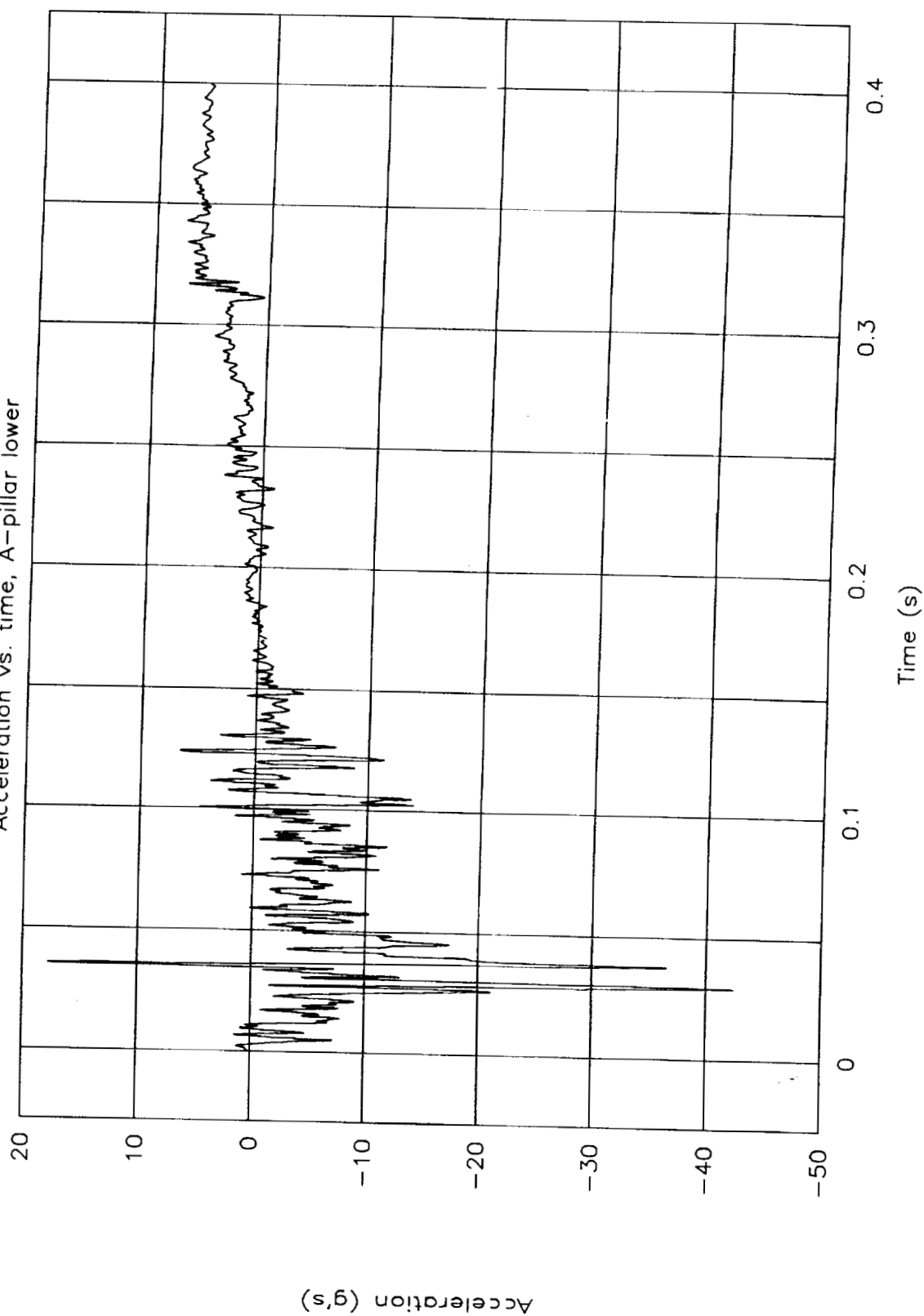


Figure 40. Acceleration vs. time, A-pillar-lower, test 95S008.

TEST NO. 95S008

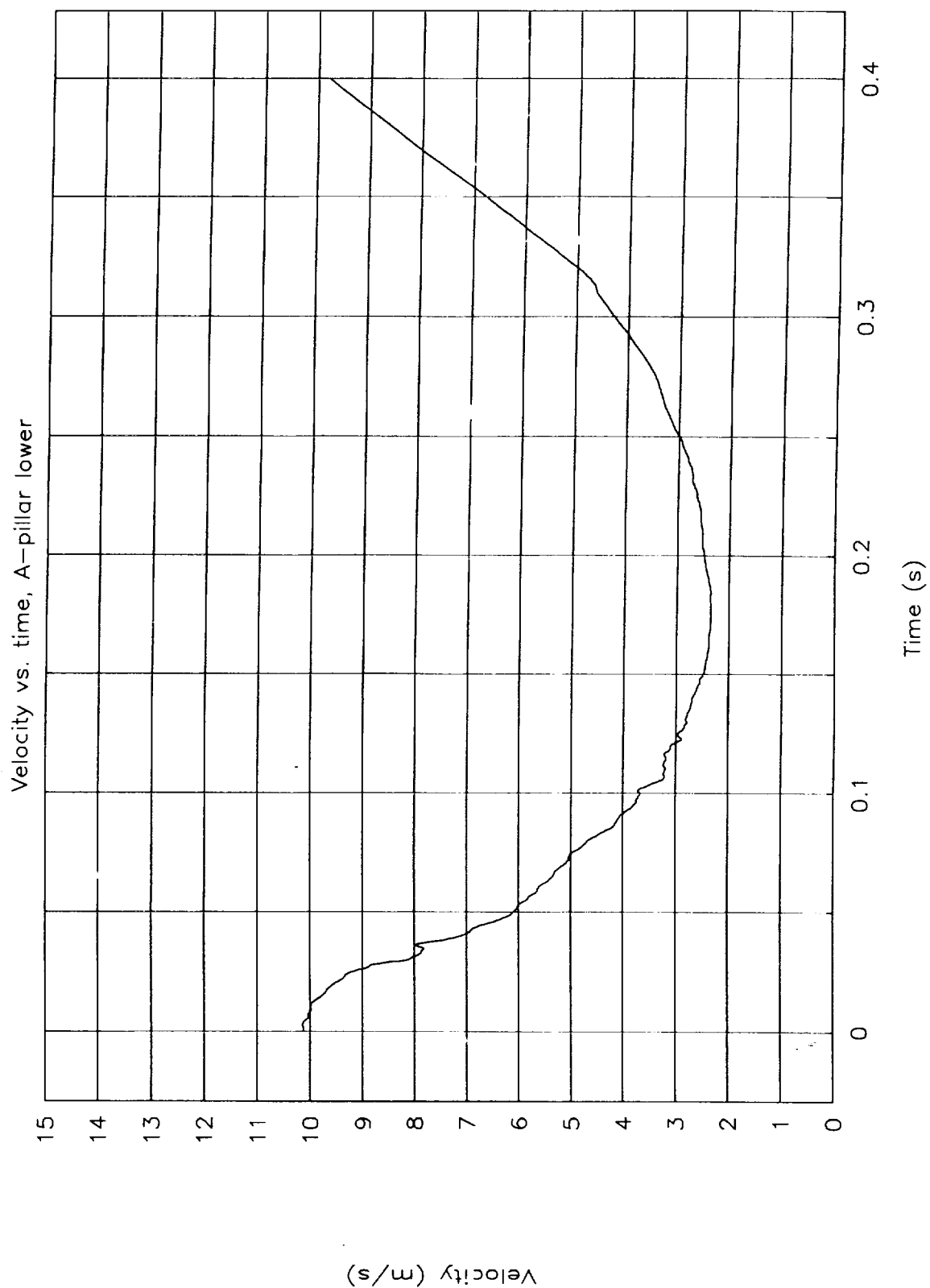


Figure 41. Velocity vs. time, A-pillar-lower, test 95S008.

TEST NO. 95S008

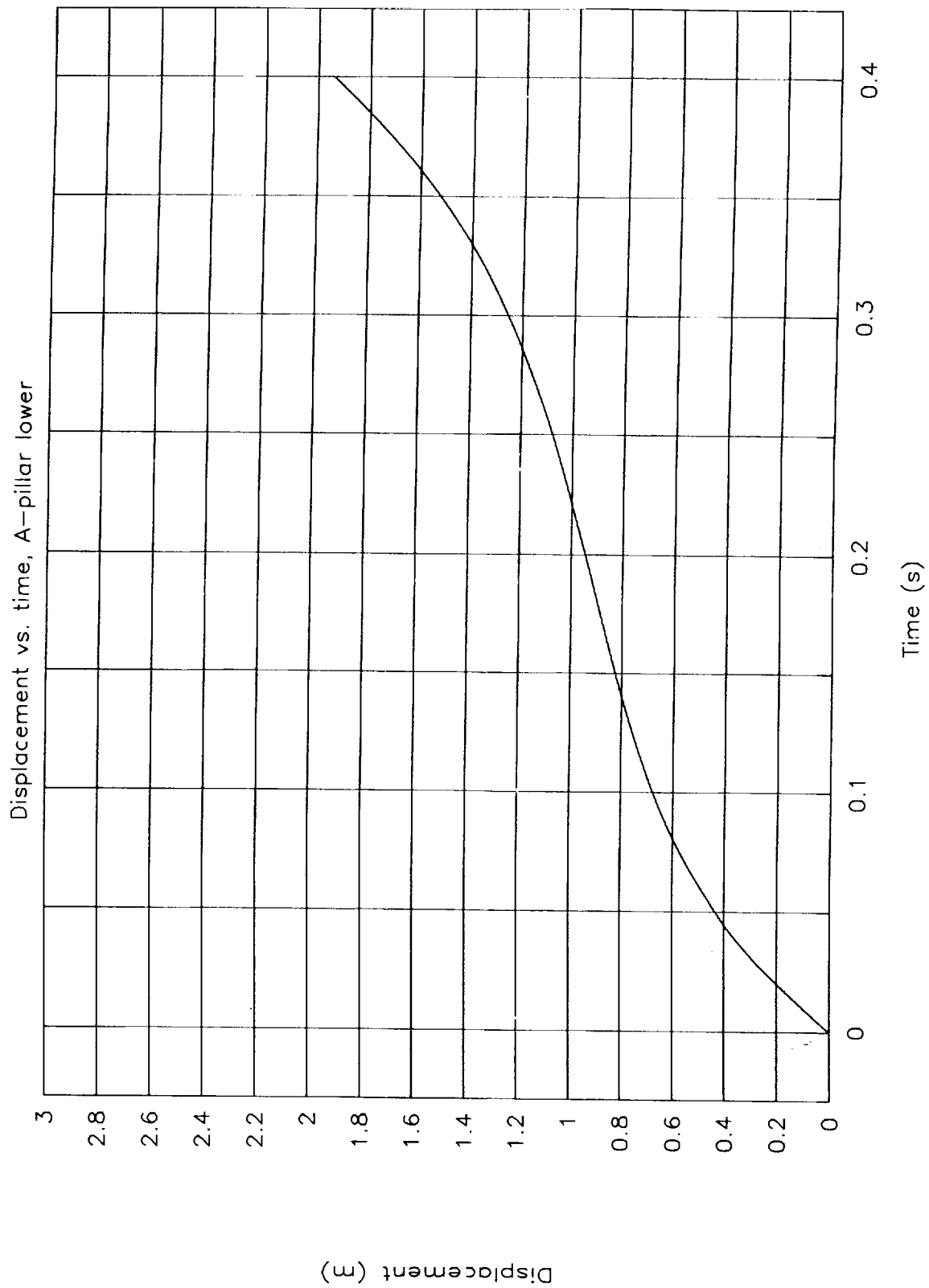


Figure 42. Displacement vs. time, A-pillar-lower, test 95S008.

TEST NO. 95S008

Acceleration vs. time, A-pillar floor

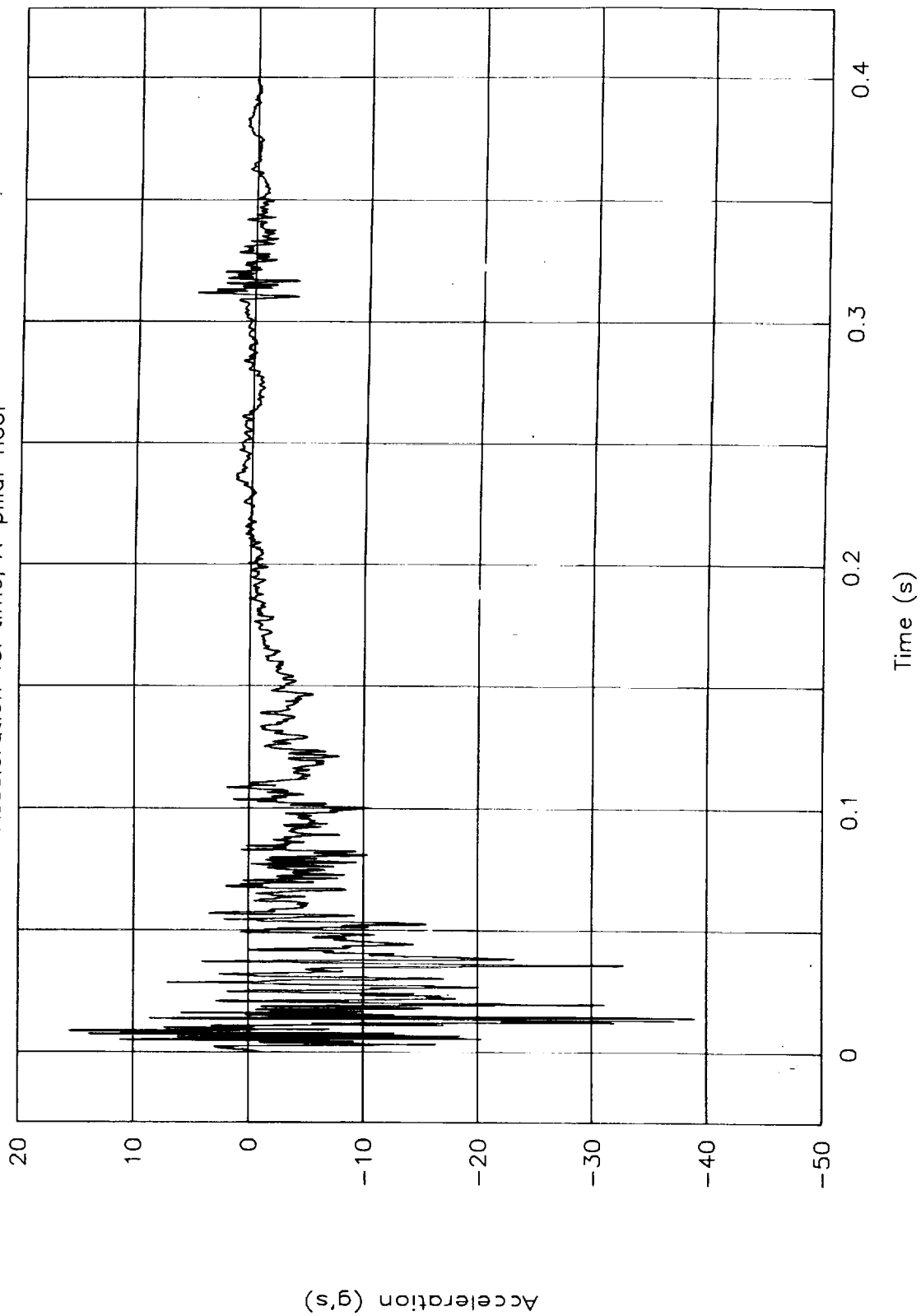


Figure 43. Acceleration vs. time, A-pillar-floor, test 95S008.

TEST NO. 95S008

Velocity vs. time, A-pillar floor

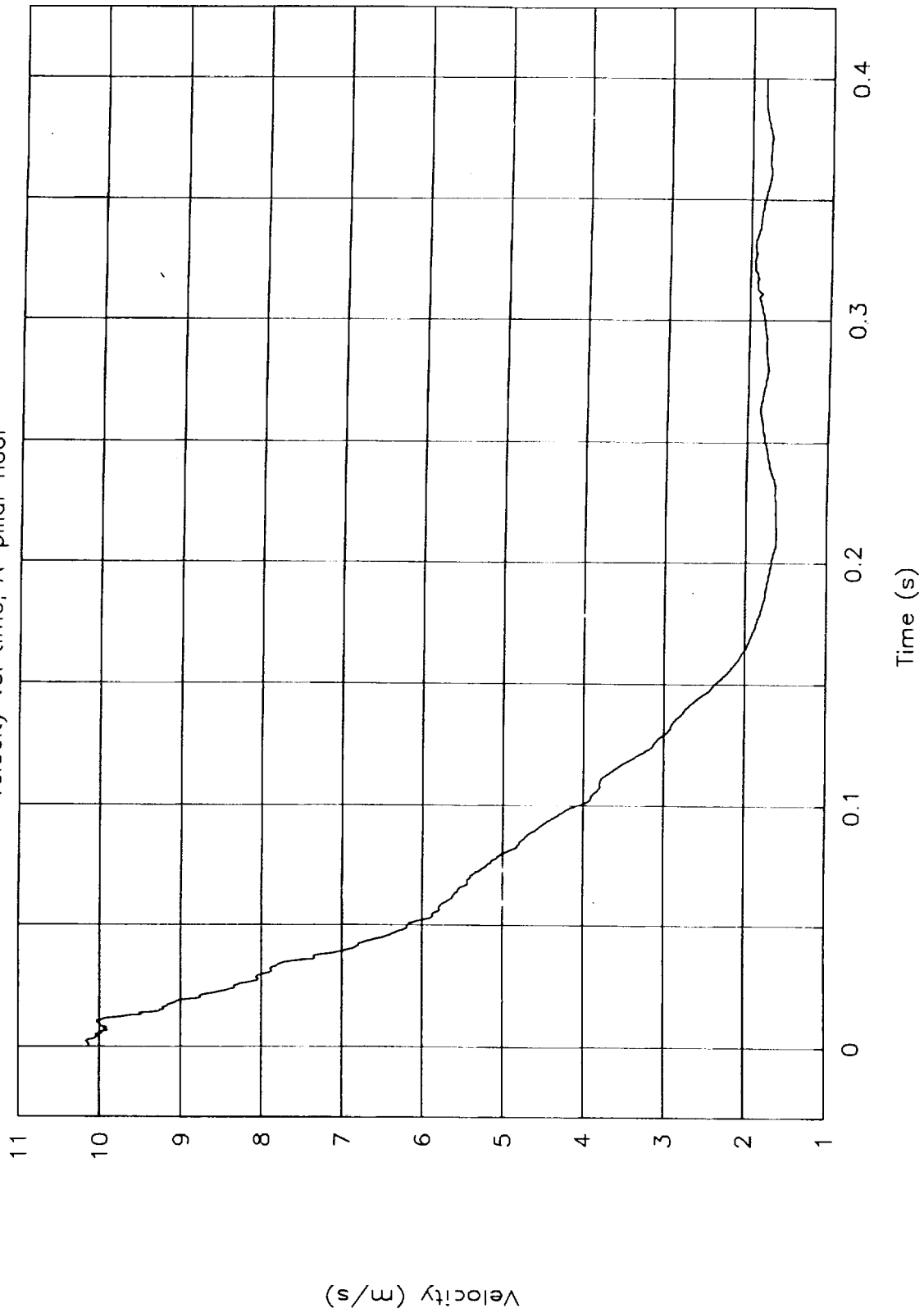


Figure 44. Velocity vs. time, A-pillar-floor, test 95S008.

TEST NO. 95S008

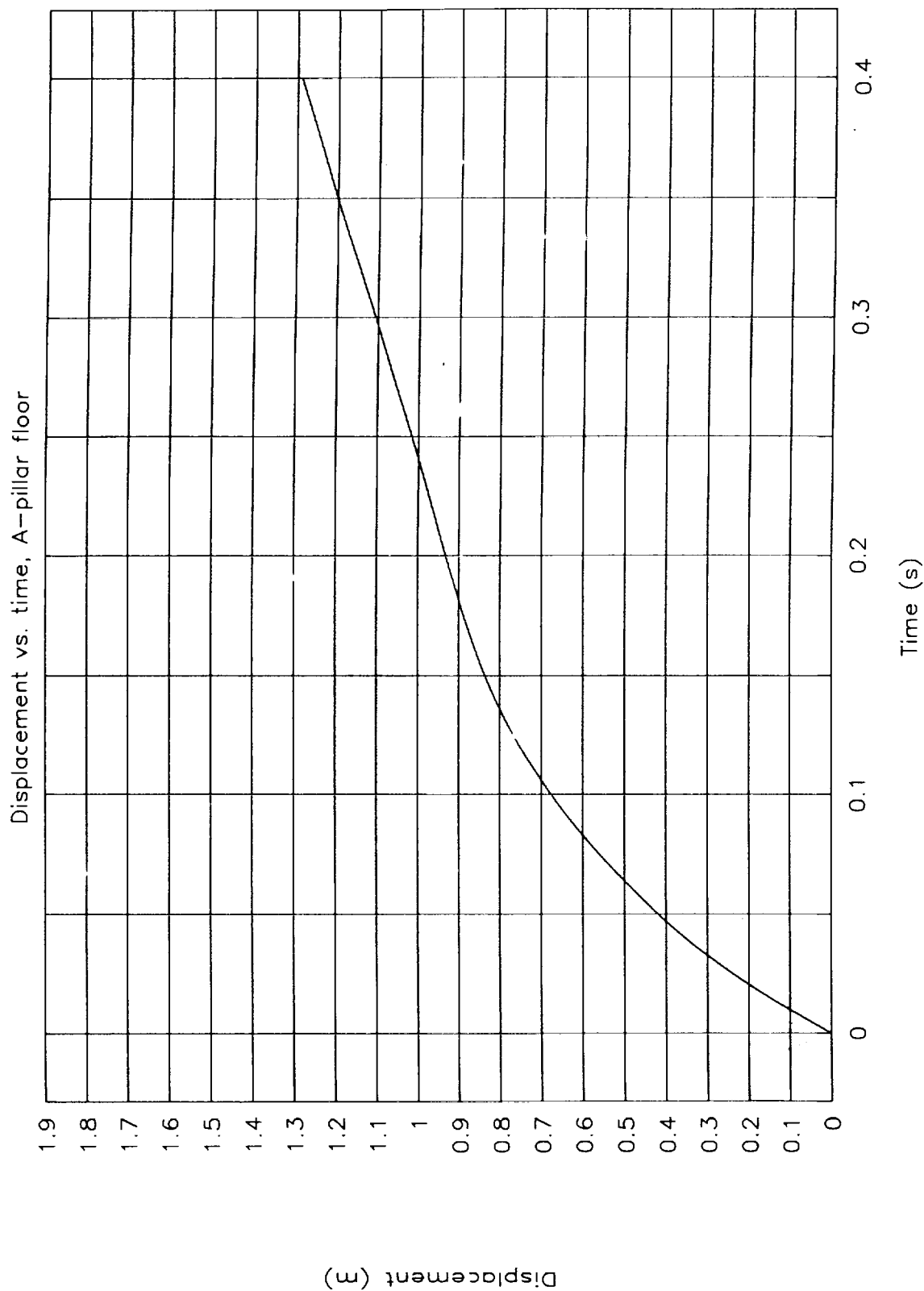


Figure 45. Displacement vs. time, A-pillar-floor, test 95S008.

TEST NO. 95S008

Driver floor sill acceleration vs. time

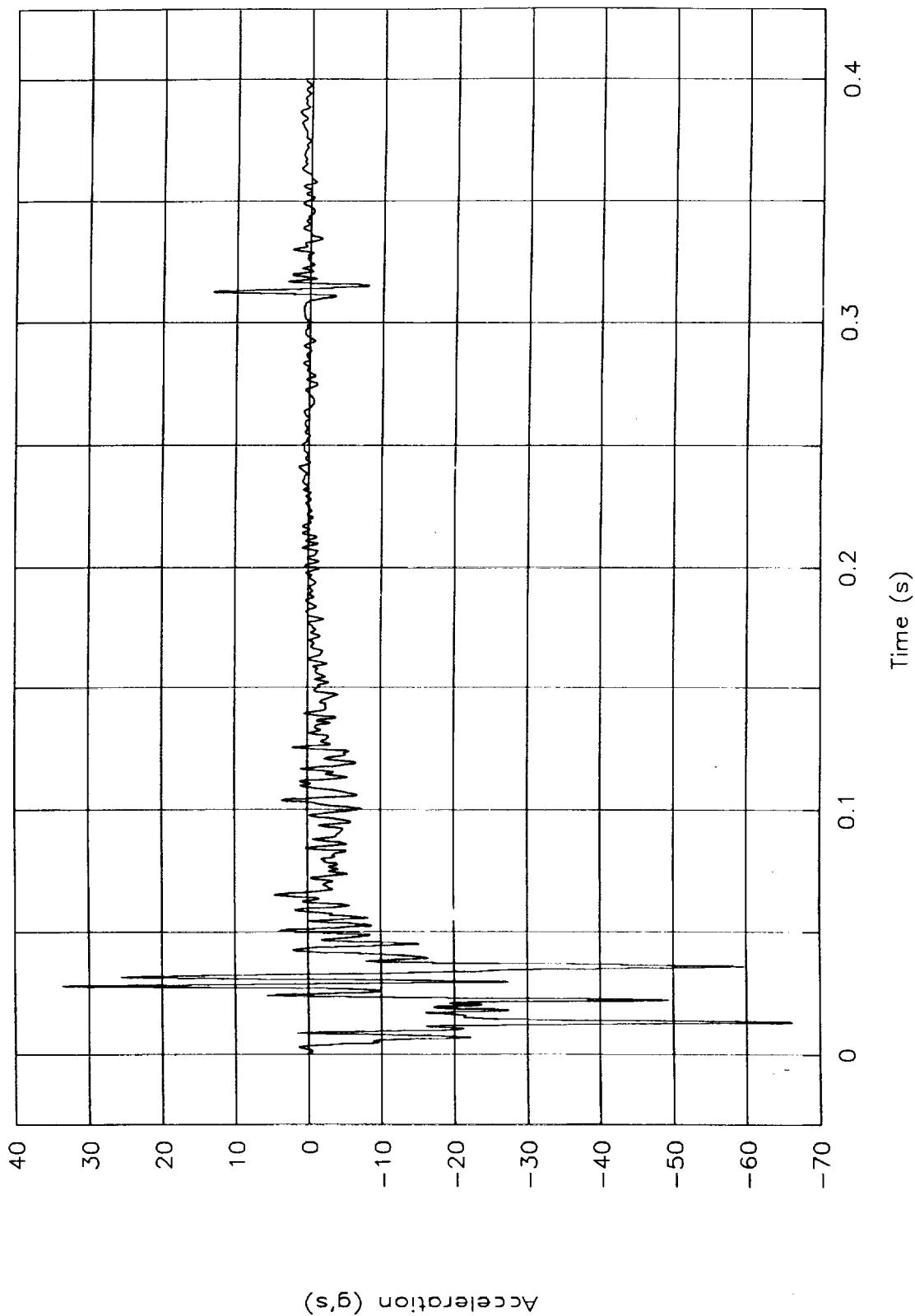


Figure 46. Acceleration vs. time, driver floor sill, test 95S008.

TEST NO. 95S008

Driver floor sill velocity vs. time

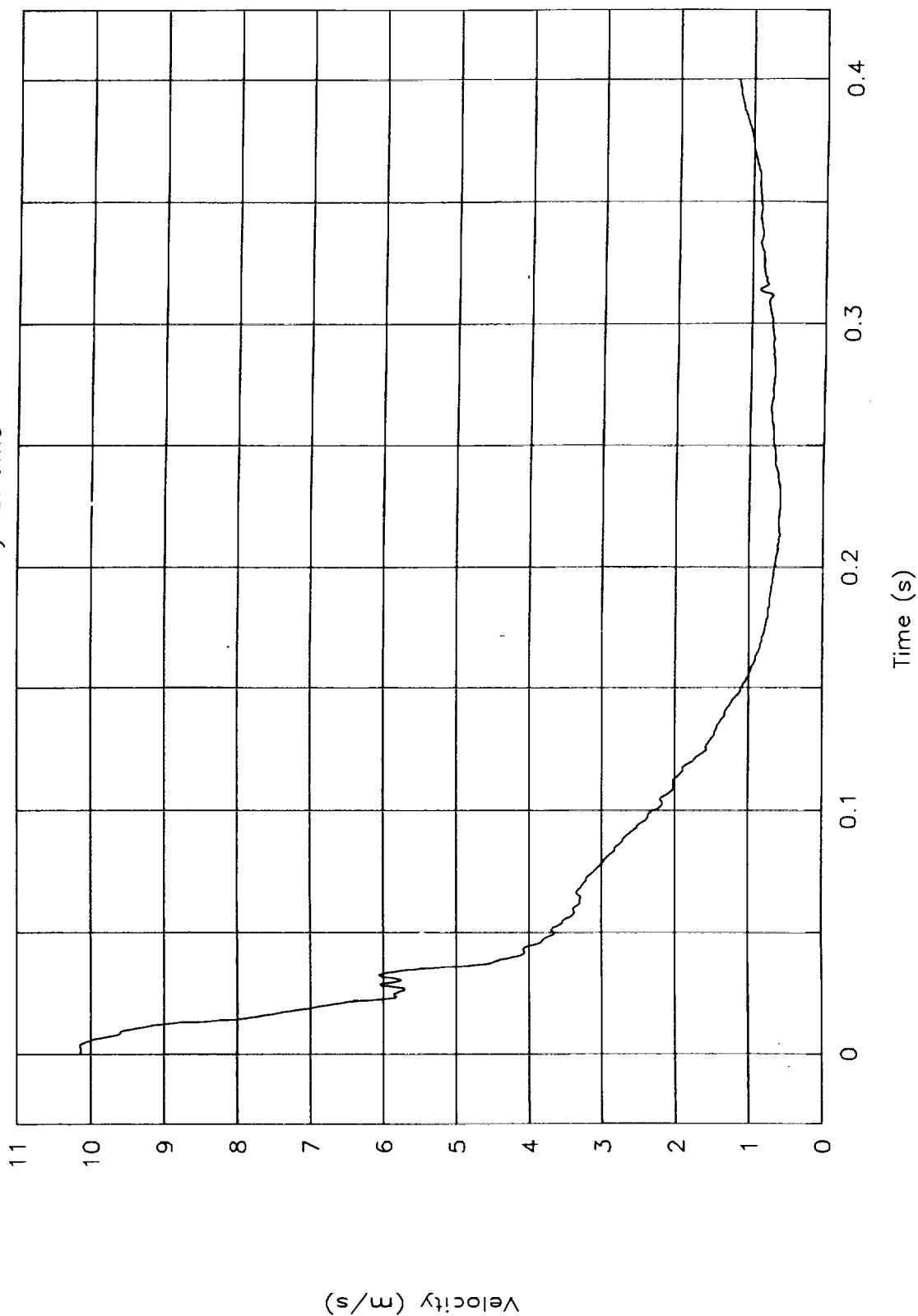


Figure 47. Velocity vs. time, driver floor sill, test 95S008.

TEST NO. 95S008

Driver floor sill displacement vs. time

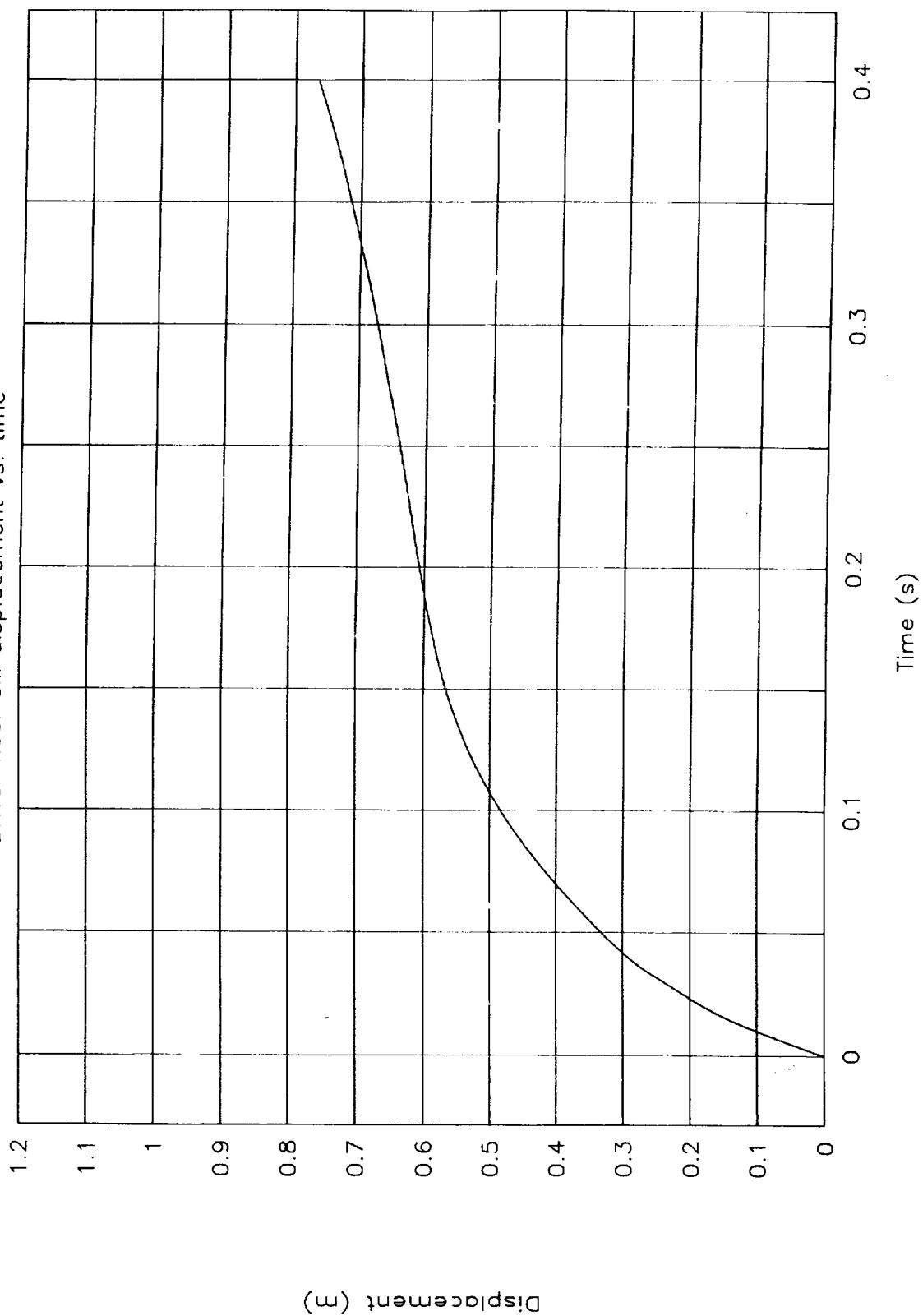


Figure 48. Displacement vs. time, driver floor sill, test 95S008.

TEST NO. 95S008

Driver seat, acceleration vs. time

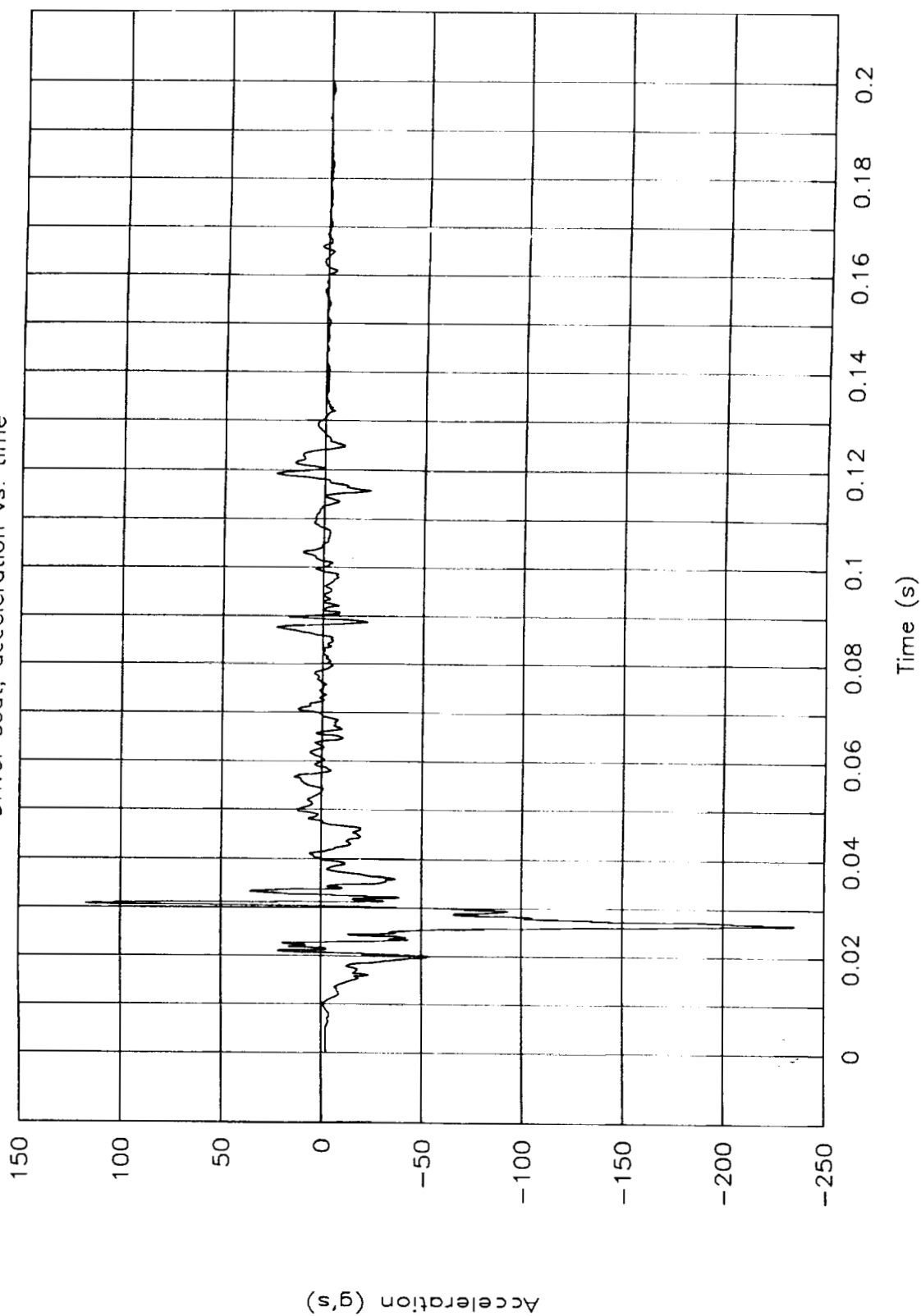


Figure 49. Acceleration vs. time, driver seat, test 95S008.

TEST NO. 95S008

Driver seat, velocity vs. time

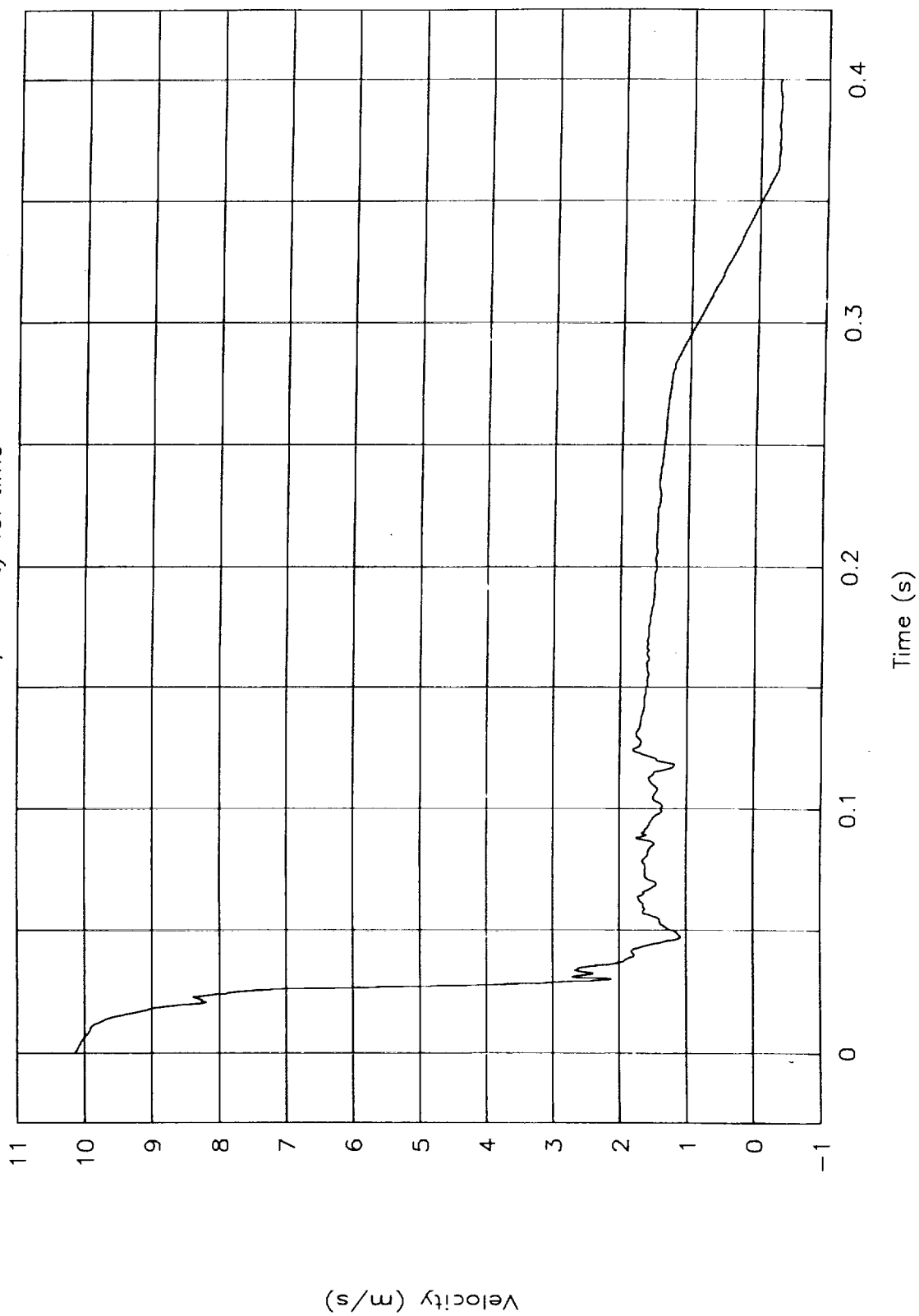


Figure 50. Velocity vs. time, driver seat, test 95S008.

TEST NO. 95S008

Driver seat, displacement vs. time

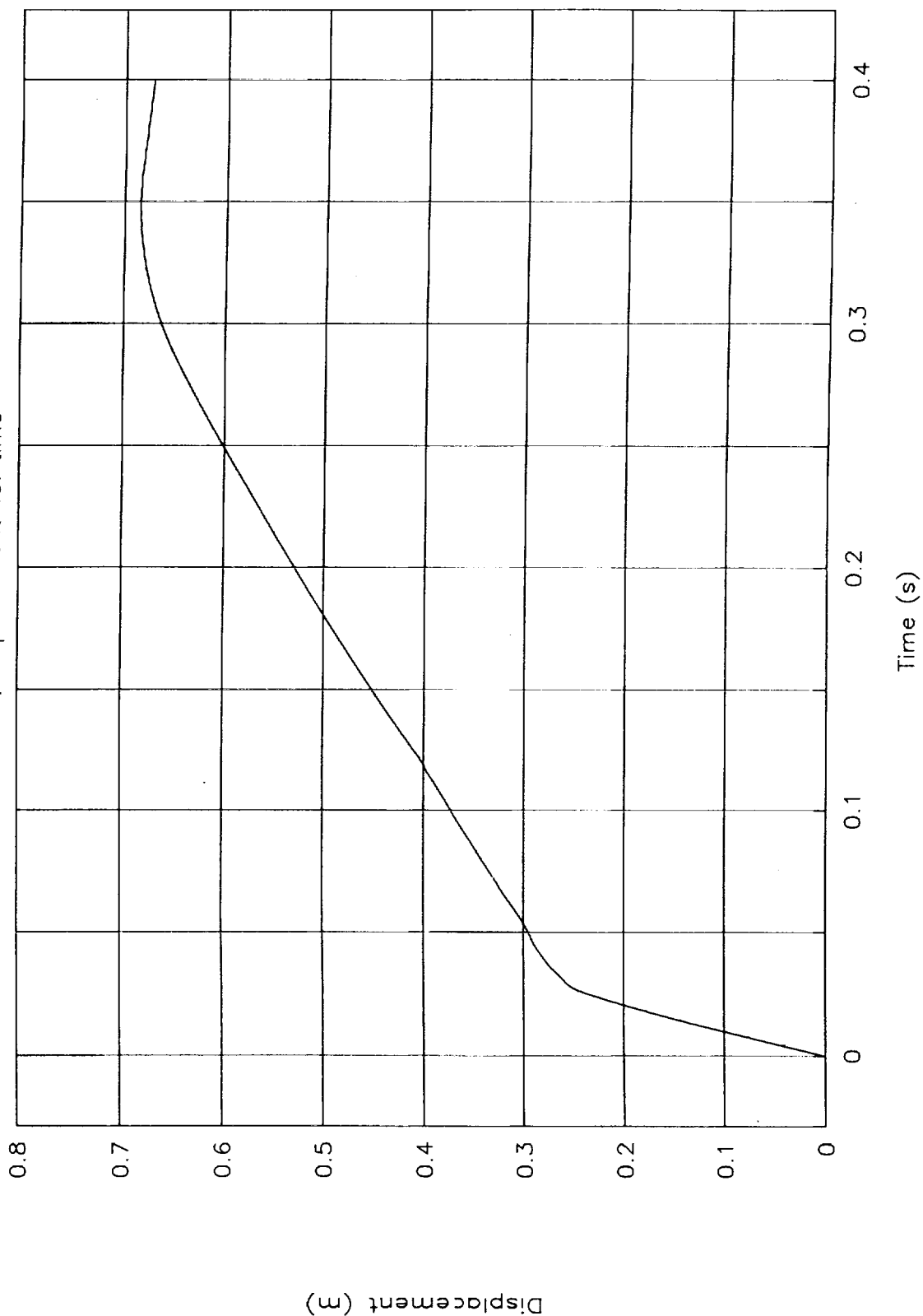


Figure 51. Displacement vs. time, driver seat, test 95S008.

TEST NO. 95S008

Acceleration vs. time, B-pillar floor

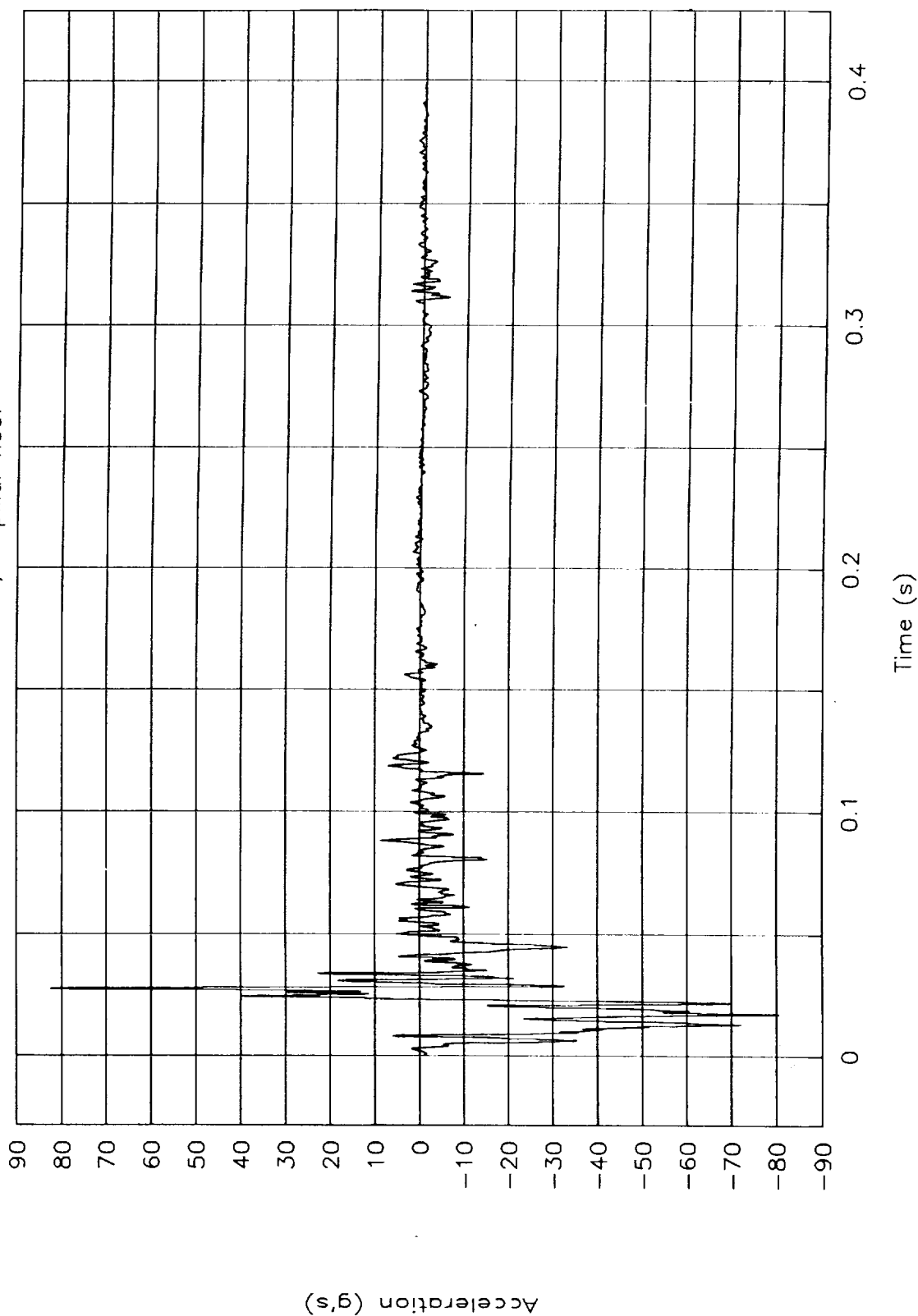


Figure 52. Acceleration vs. time, B-pillar-floor, test 95S008.

TEST NO. 95S008

Velocity vs. time, B-pillar floor

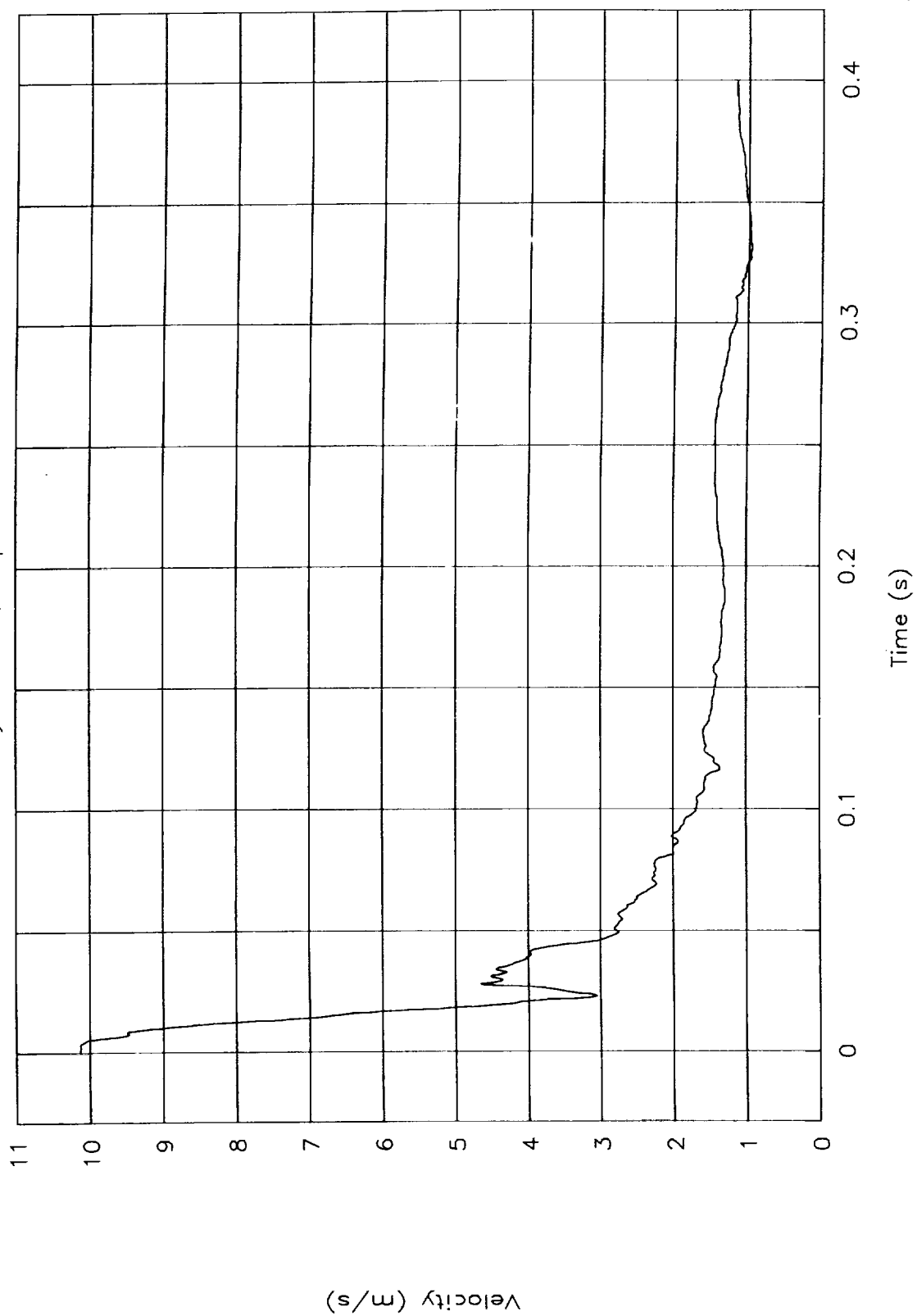


Figure 53. Velocity vs. time, B-pillar-floor, test 95S008.

TEST NO. 95S008

Displacement vs. time, B-pillar floor

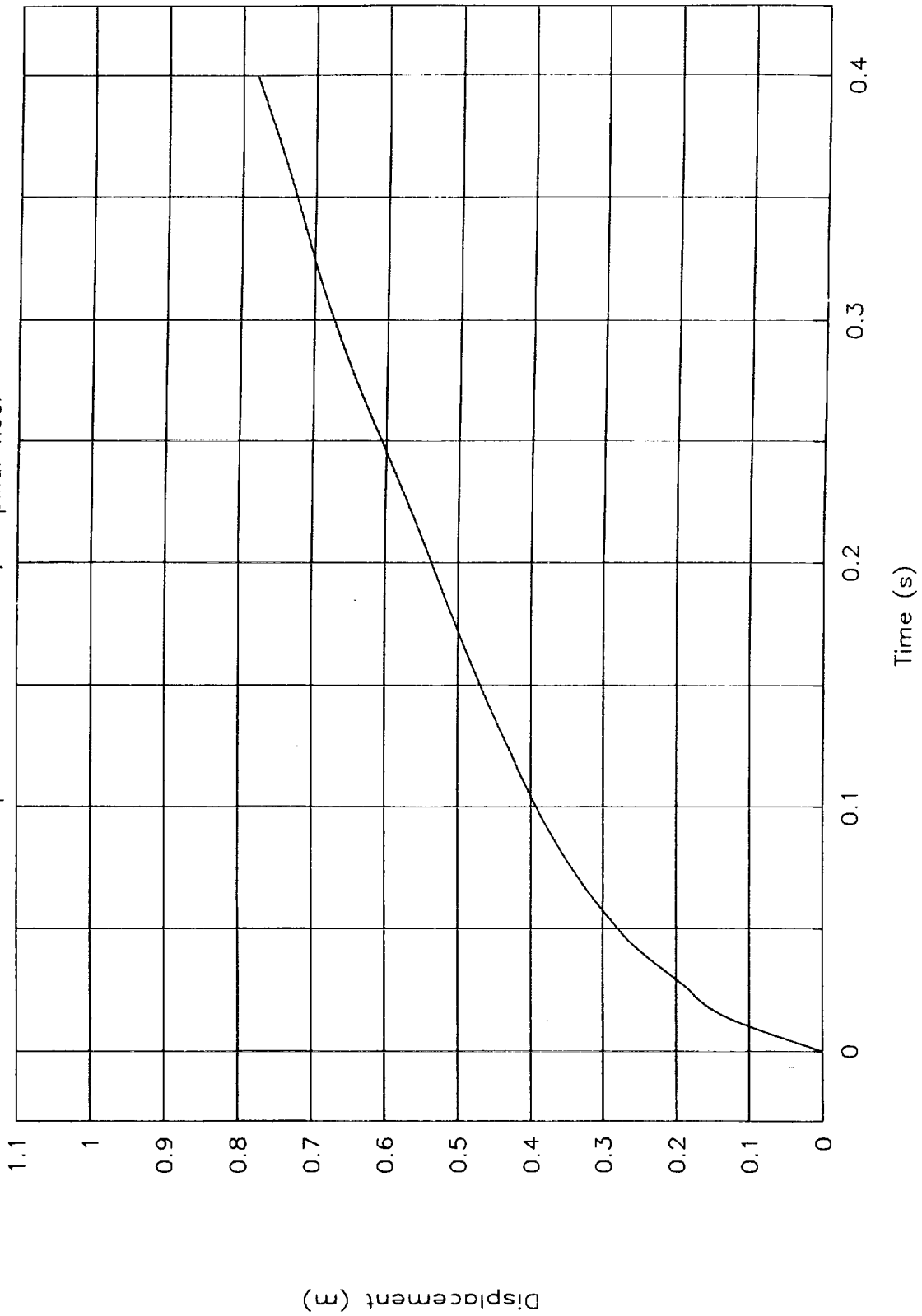


Figure 54. Displacement vs. time, B-pillar-floor, test 95S008.

TEST NO. 95S008

Acceleration vs. time, B-pillar latch

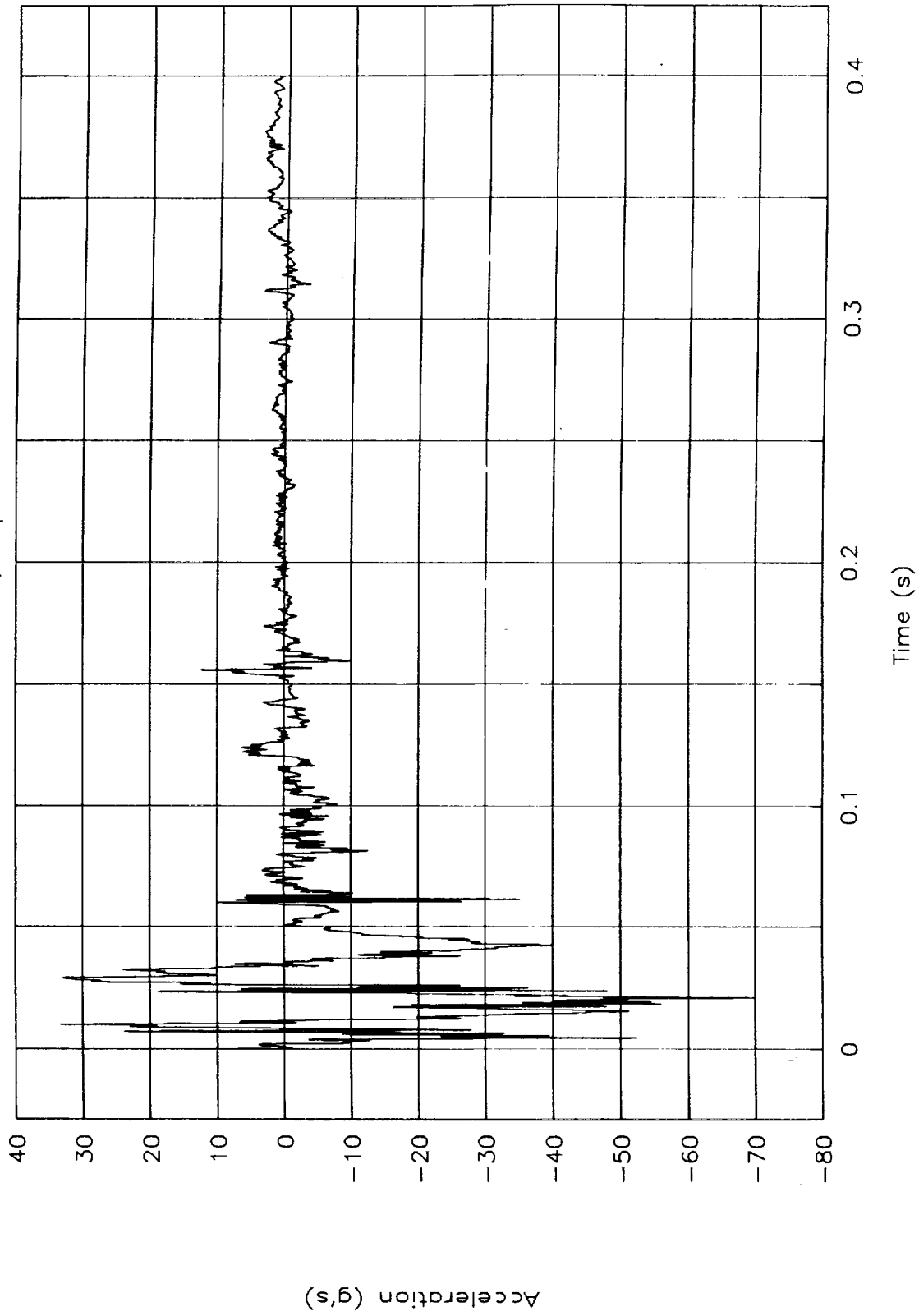


Figure 55. Acceleration vs. time, B-pillar-door latch, test 95S008.

TEST NO. 95S008

Velocity vs. time, B-pillar latch

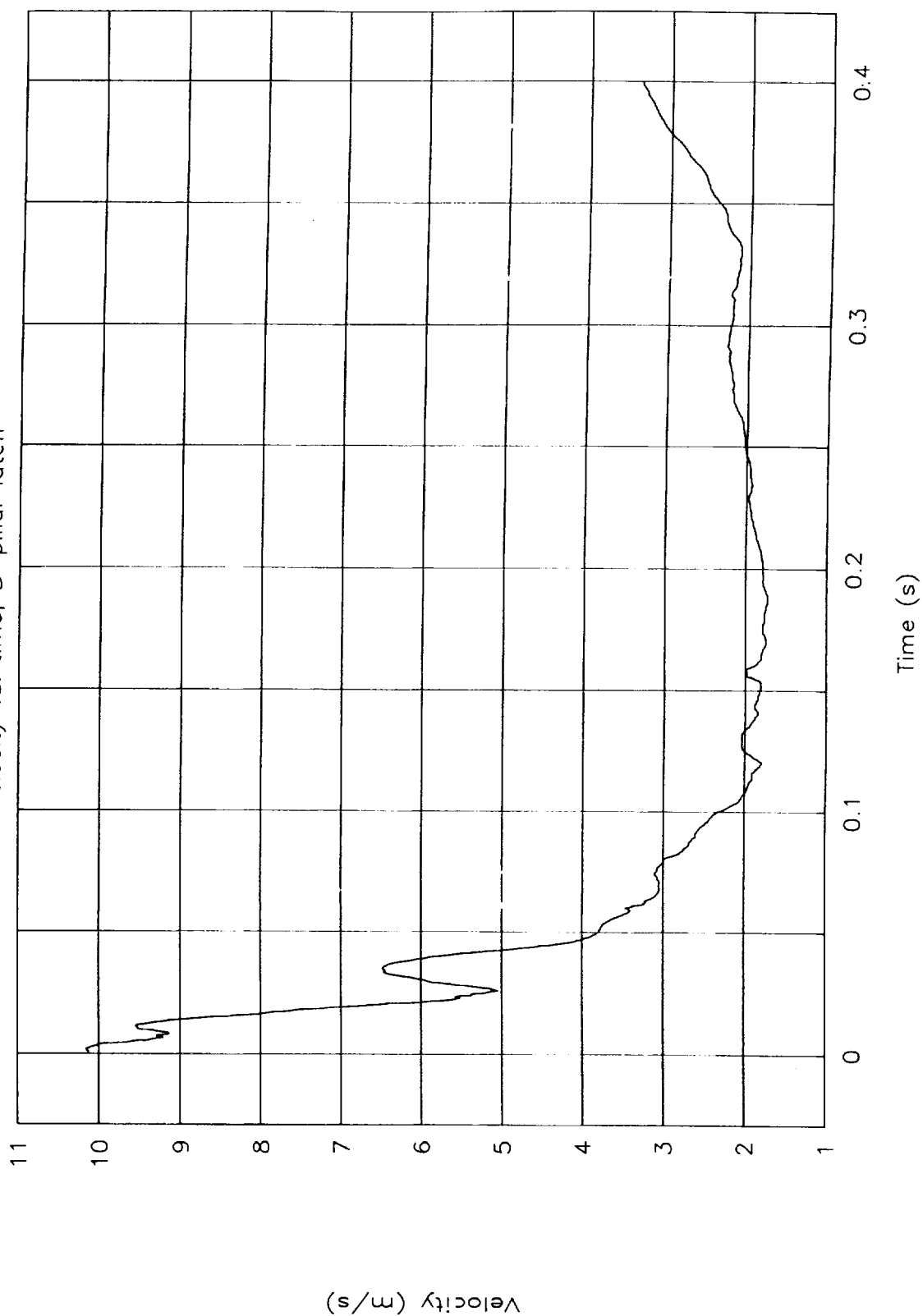


Figure 56. Velocity vs. time, B-pillar-door latch, test 95S008.

TEST NO. 95S008

Displacement vs. time, B-pillar latch

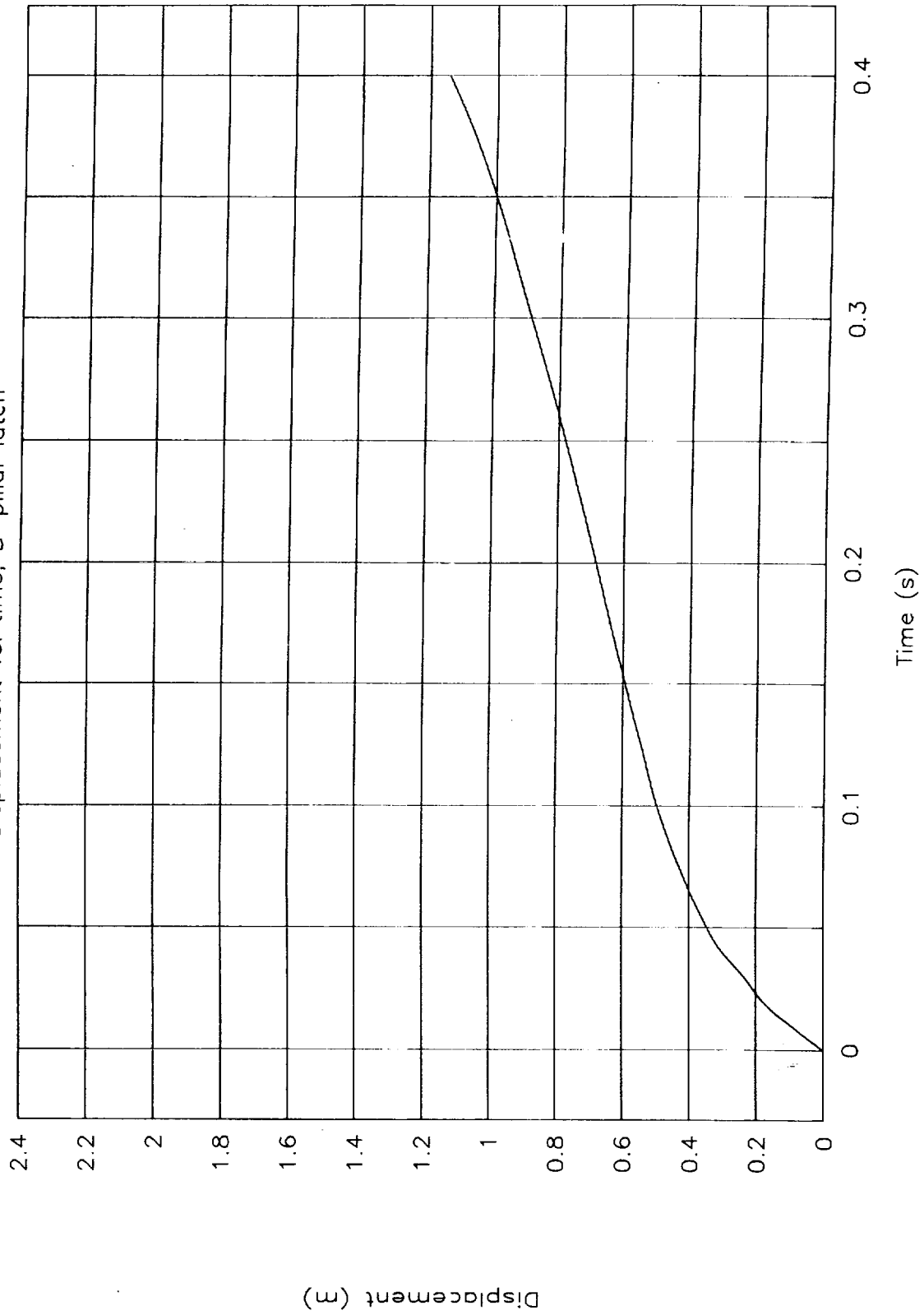


Figure 57. Displacement vs. time, B-pillar-door latch, test 95S008.

TEST NO. 95S008

Acceleration vs. time, B-pillar middle

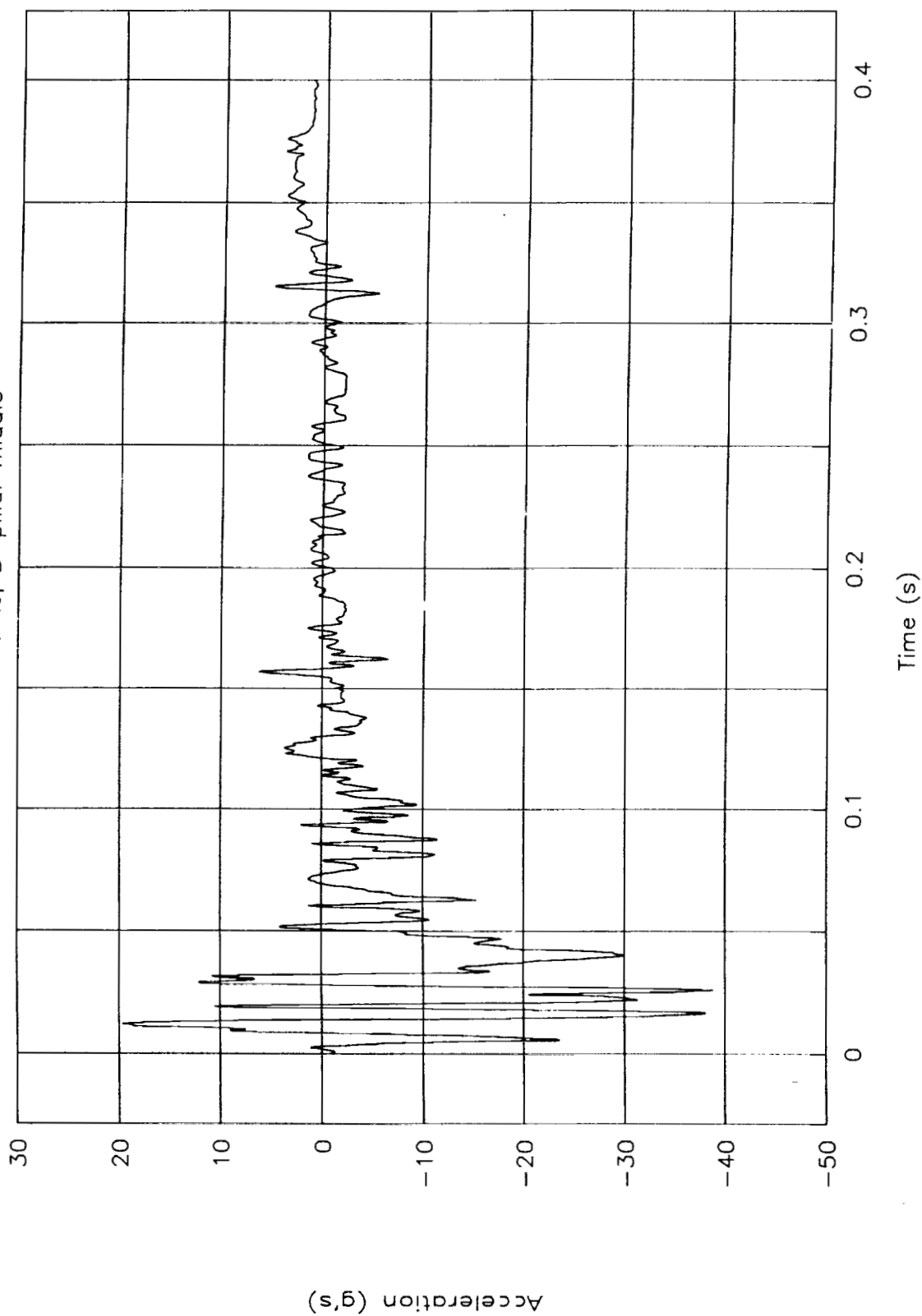


Figure 58. Acceleration vs. time, B-pillar-middle, test 95S008.

TEST NO. 95S008

Velocity vs. time, B-pillar middle

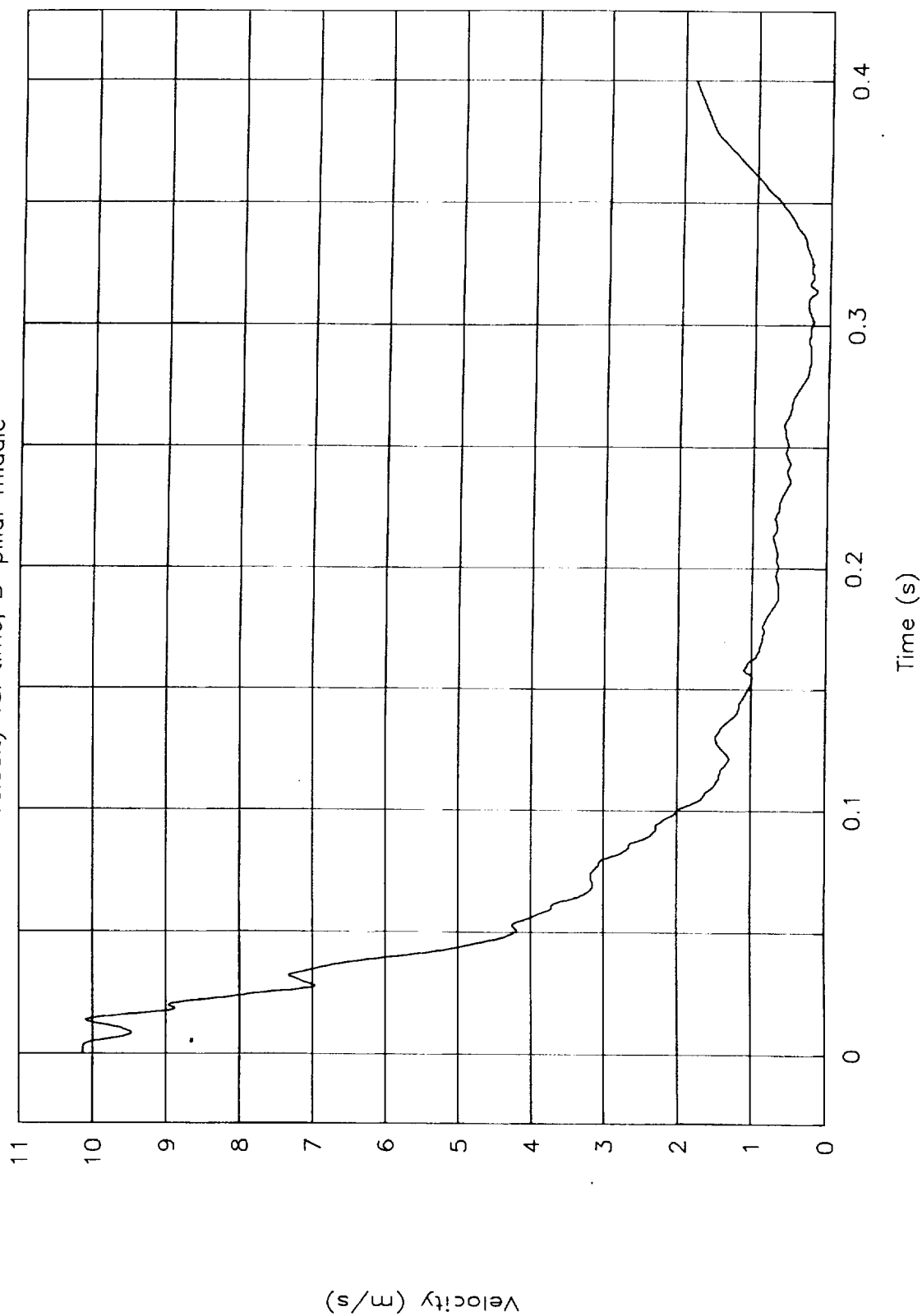


Figure 59. Velocity vs. time, B-pillar-middle, test 95S008.

TEST NO. 95S008

Displacement vs. time, B-pillar middle

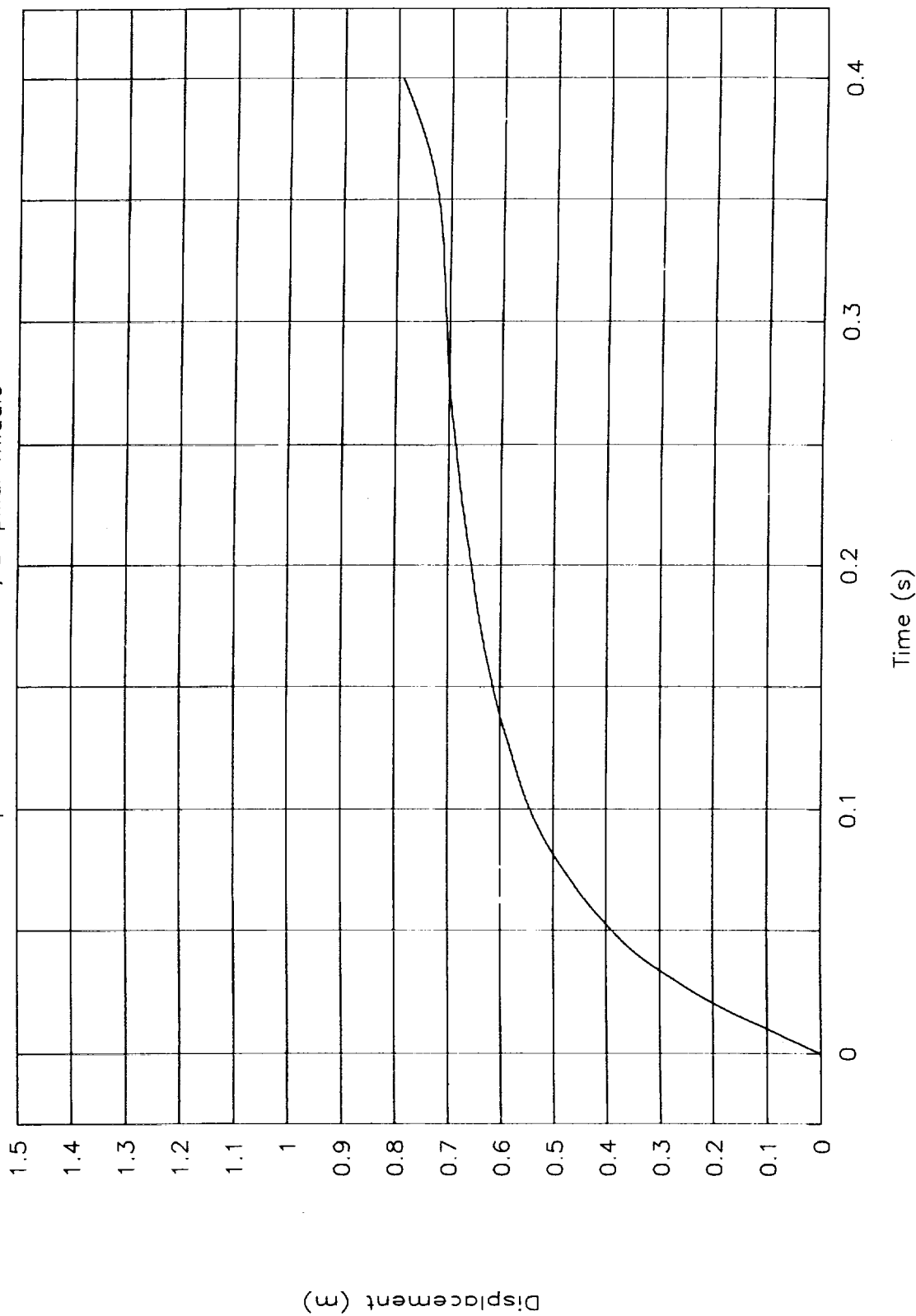


Figure 60. Displacement vs. time, B-pillar-middle, test 95S008.

TEST NO. 95S008

Acceleration vs. time, B-pillar top

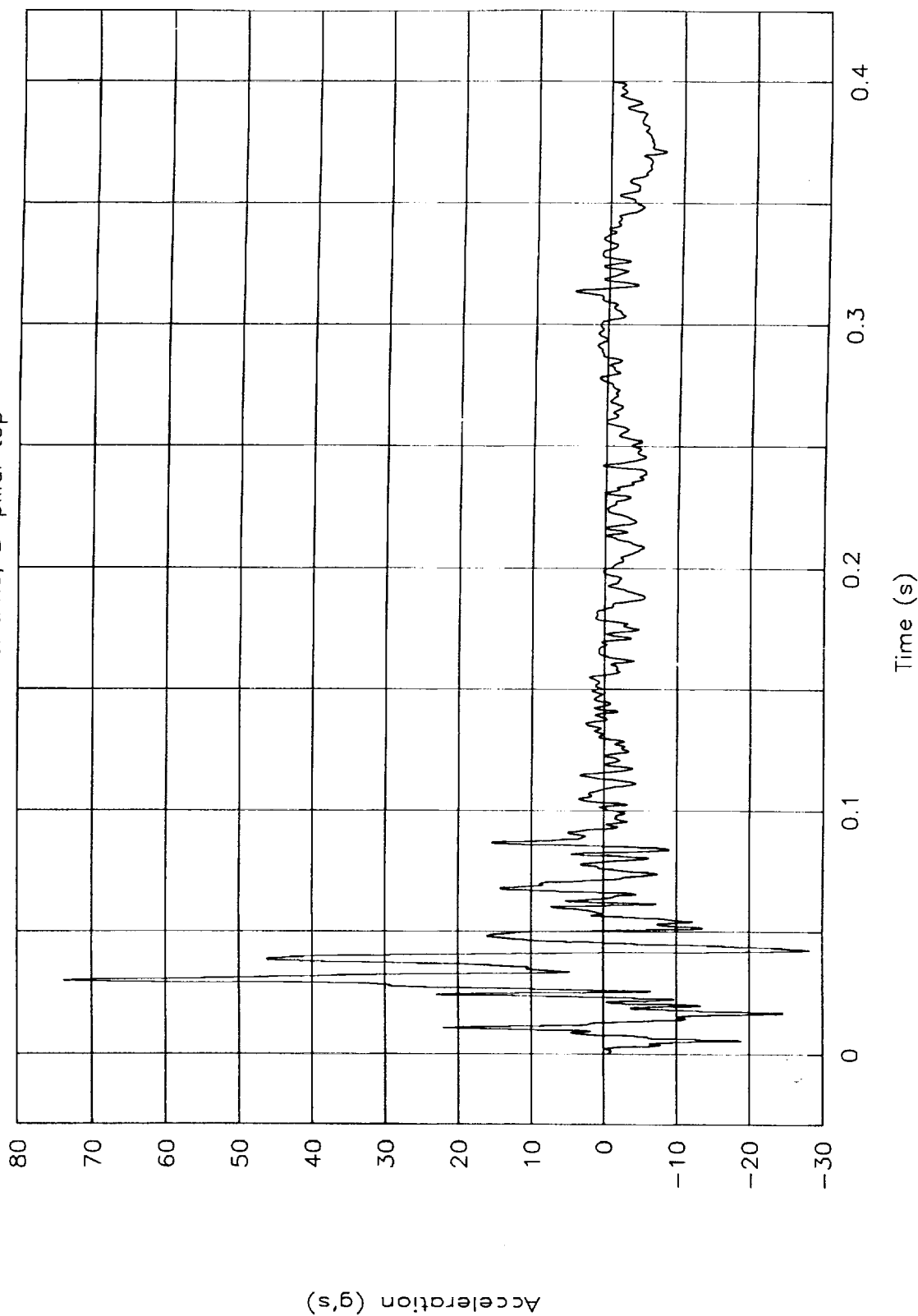


Figure 61. Acceleration vs. time, B-pillar-top, test 95S008.

TEST NO. 95S008

Acceleration vs. time, door at shoulder

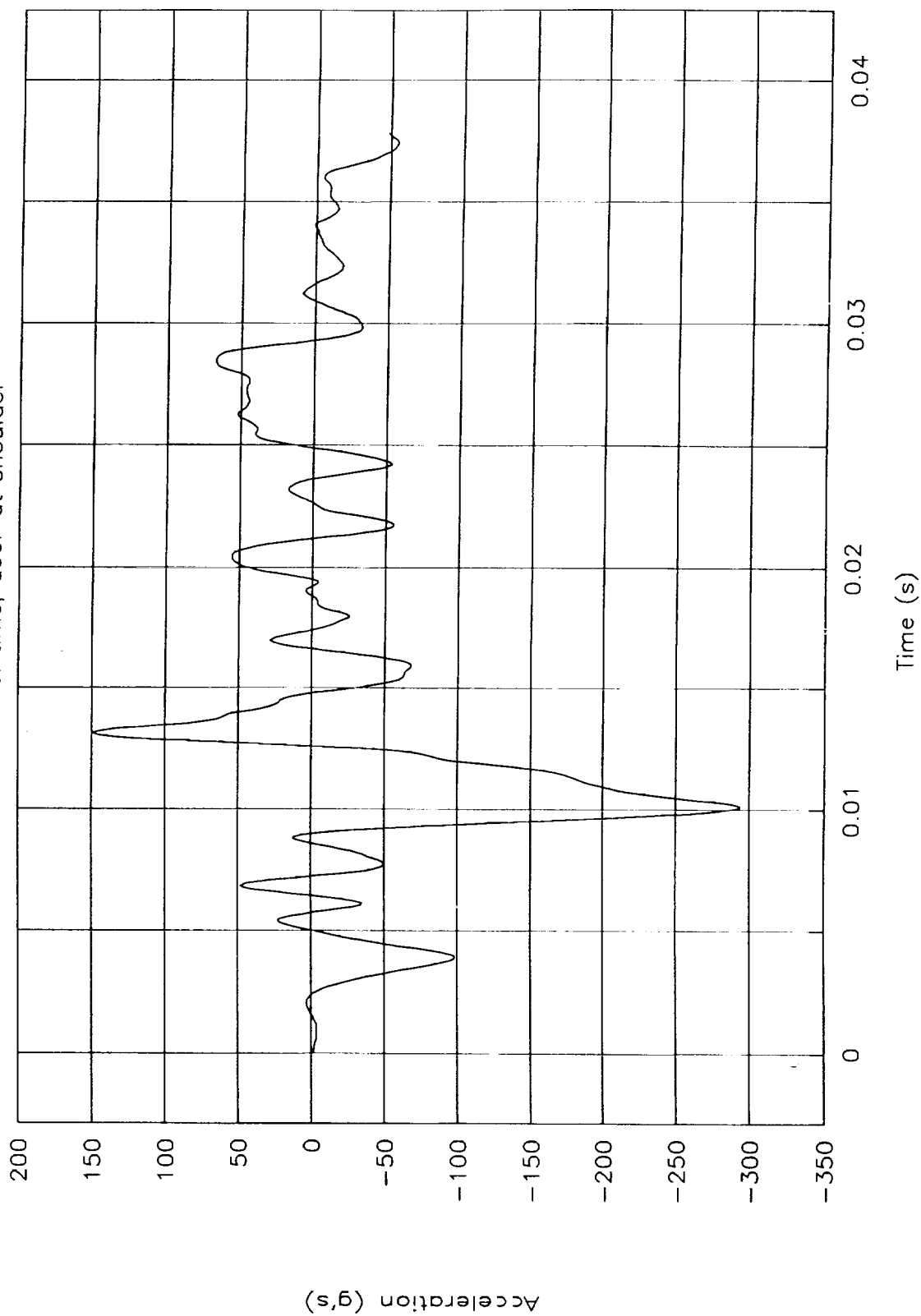


Figure 62. Acceleration vs. time, driver door at shoulder, test 95S008.

TEST NO. 95S008

Velocity vs. time, door at shoulder

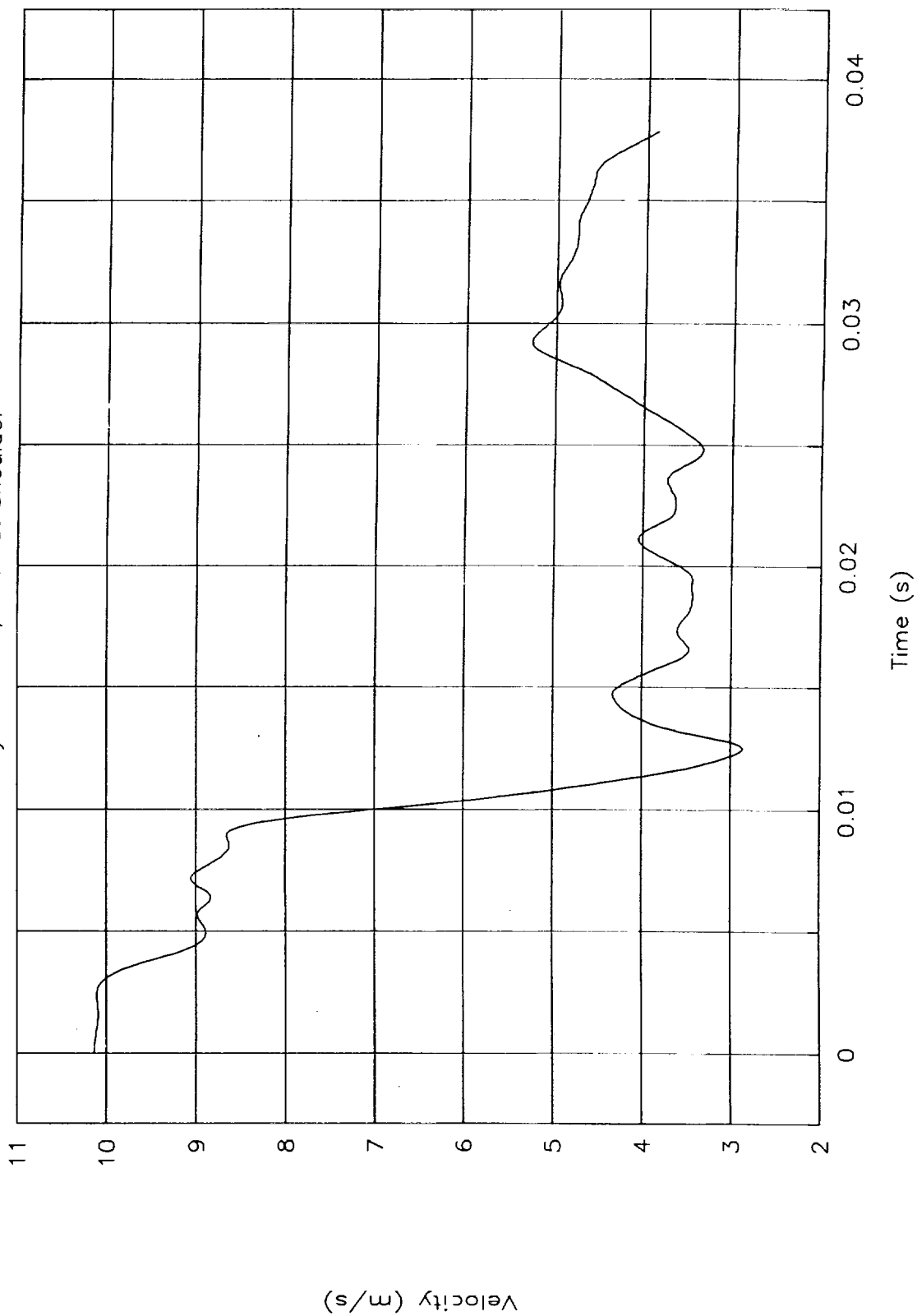


Figure 63. Velocity vs. time, driver door at shoulder, test 95S008.

TEST NO. 95S008

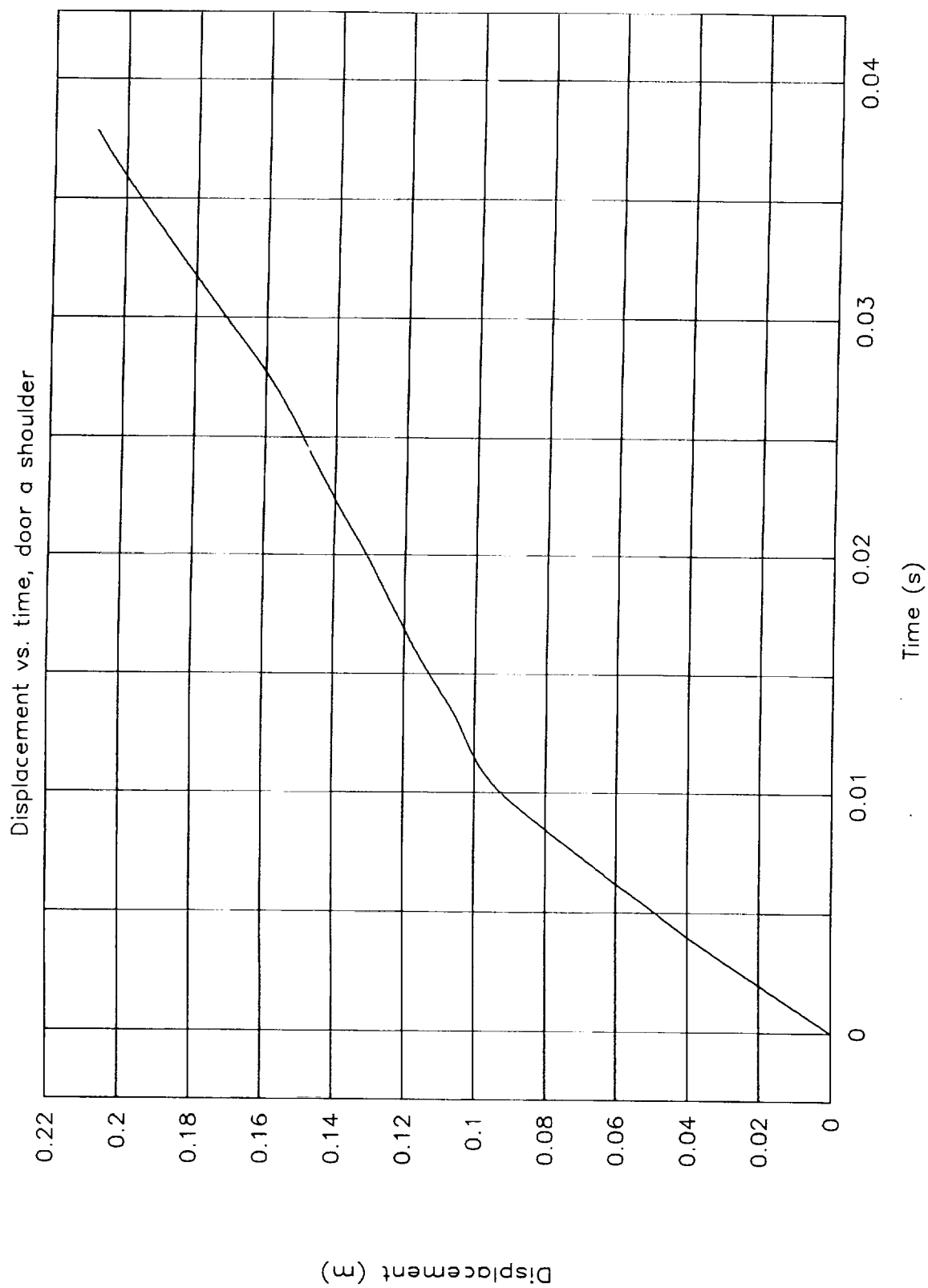


Figure 64. Displacement vs. time, driver door at shoulder, test 95S008.

TEST NO. 95S008

Acceleration vs. time, door at knee

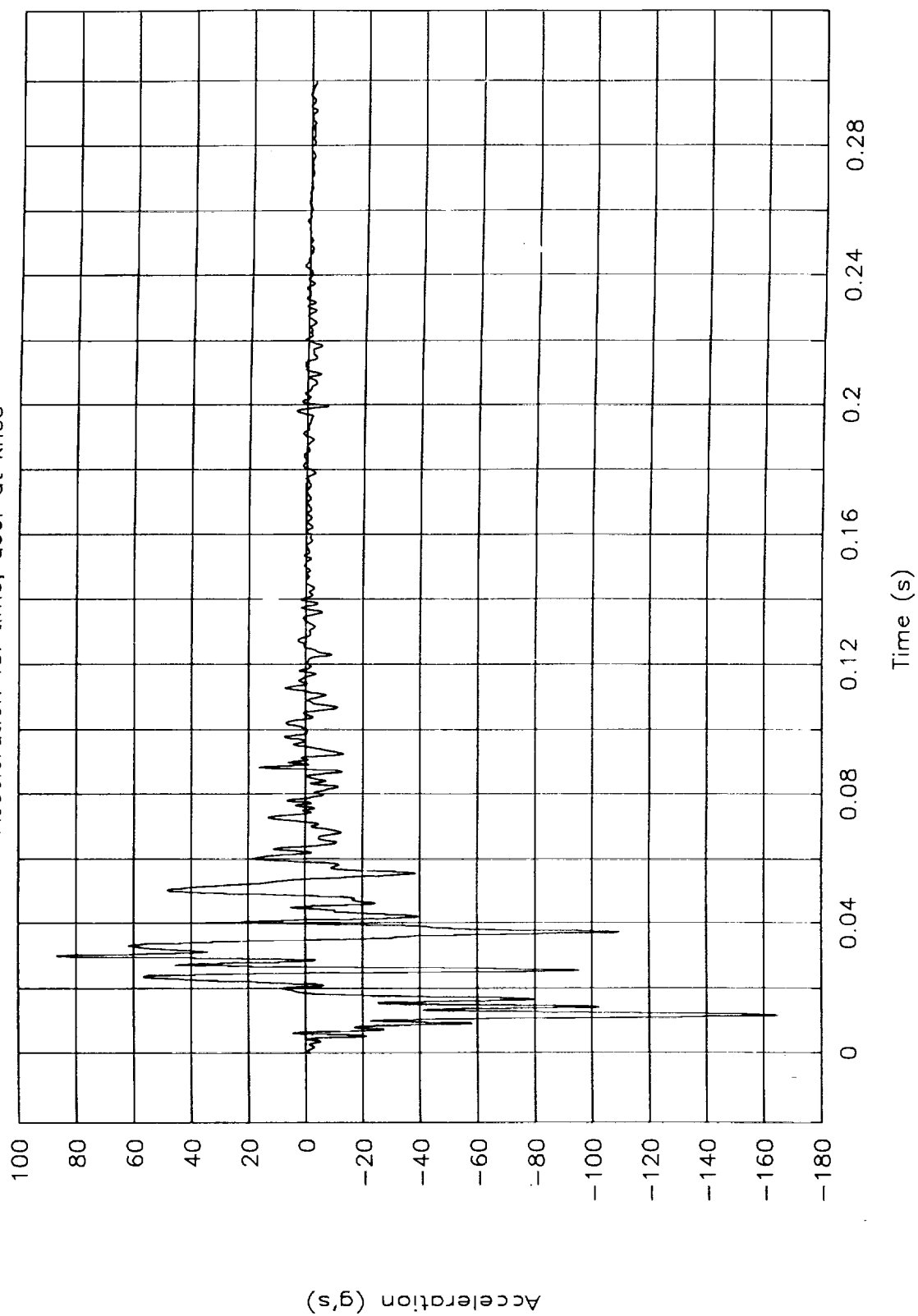


Figure 65. Acceleration vs. time, driver door at knee, test 95S008.

TEST NO. 95S008

Velocity vs. time, door at knee

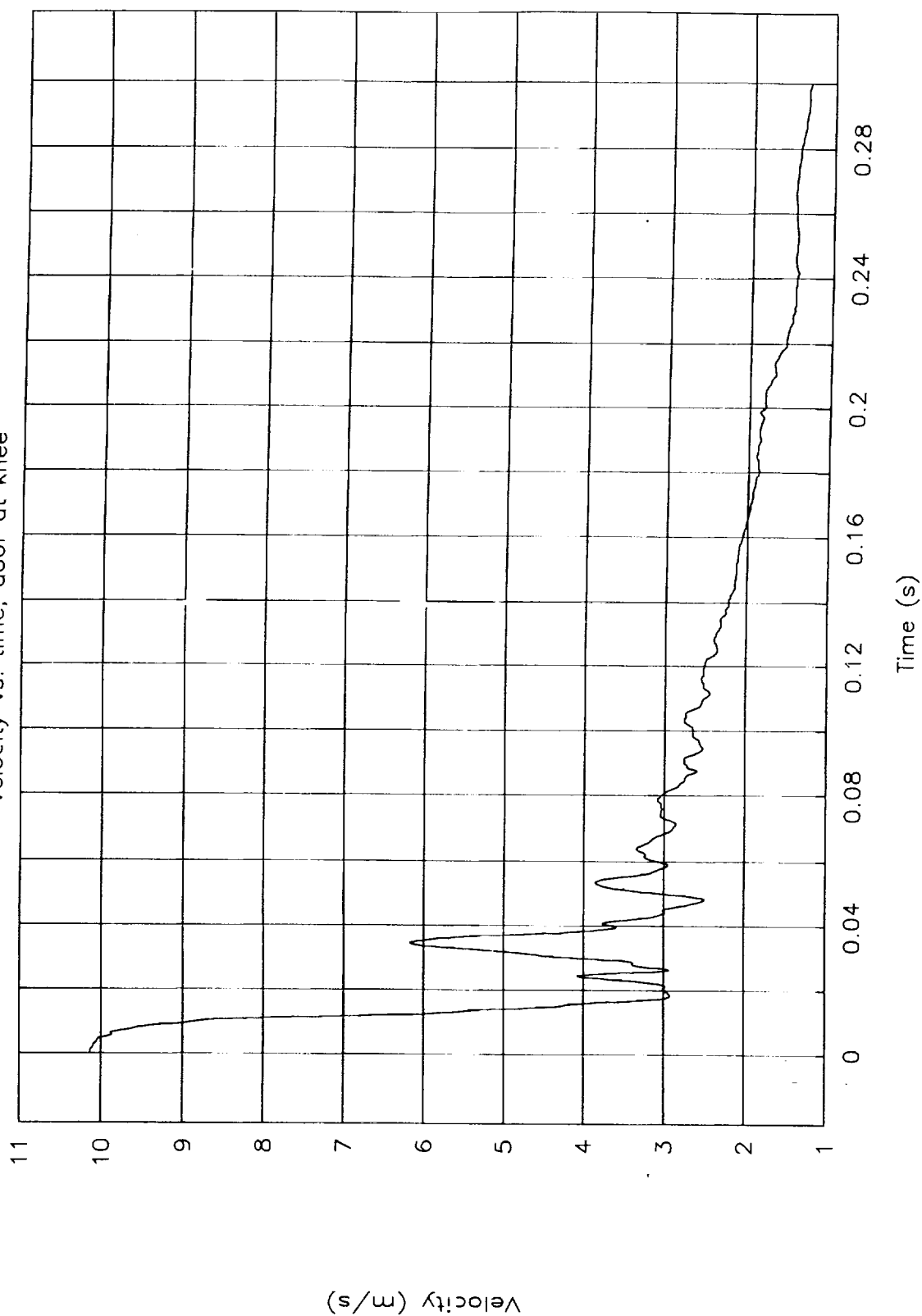


Figure 66. Velocity vs. time, driver door at knee, test 95S008.

TEST NO. 95S008

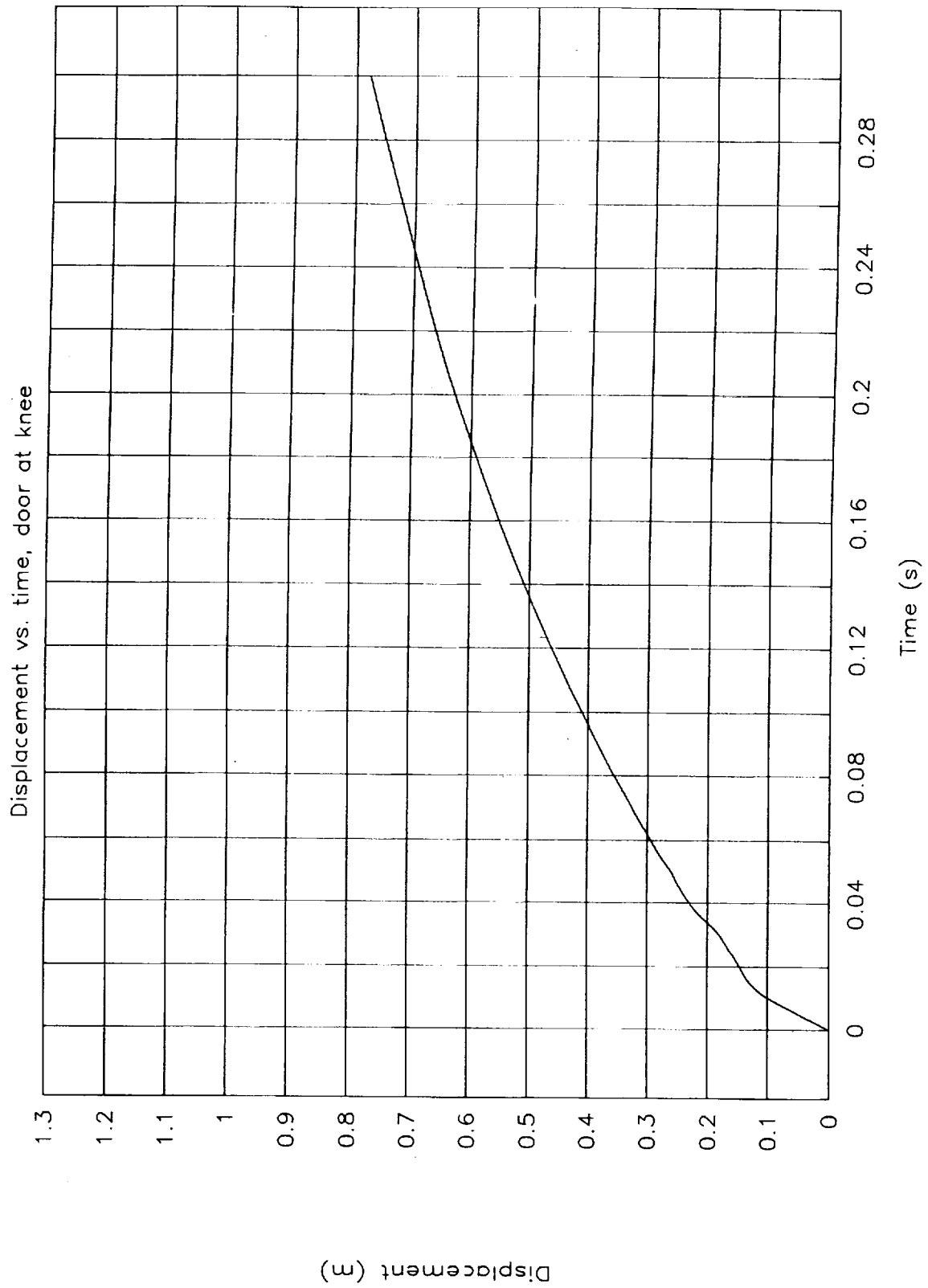


Figure 67. Displacement vs. time, driver door at knee, test 95S008.

TEST NO. 95S008

Acceleration vs. time, door at pelvis

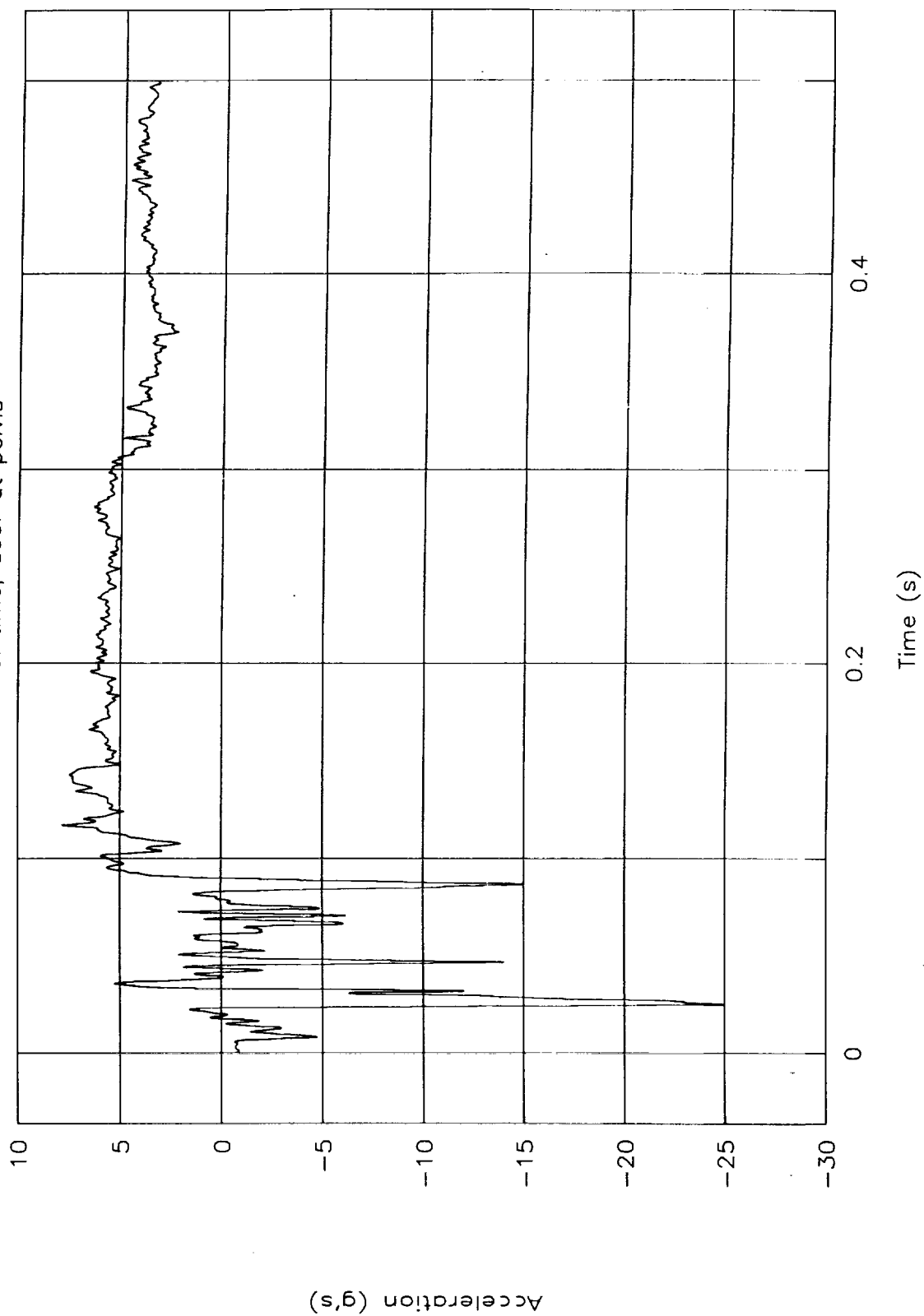


Figure 68. Acceleration vs. time, driver door at pelvis, test 95S008.

APPENDIX B. TEST PHOTOGRAPHS.

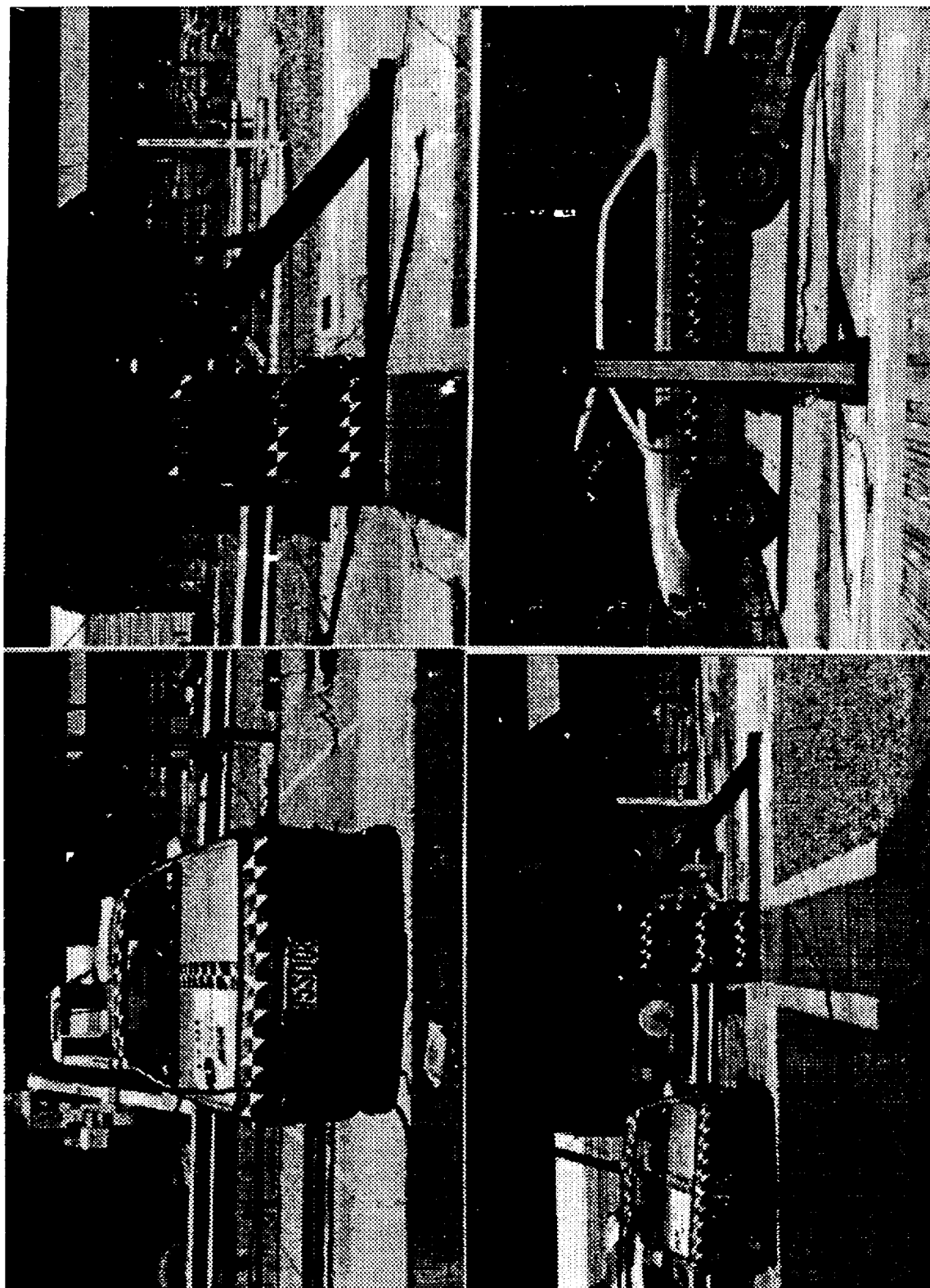


Figure 69. Pre test photographs, test 95S008.

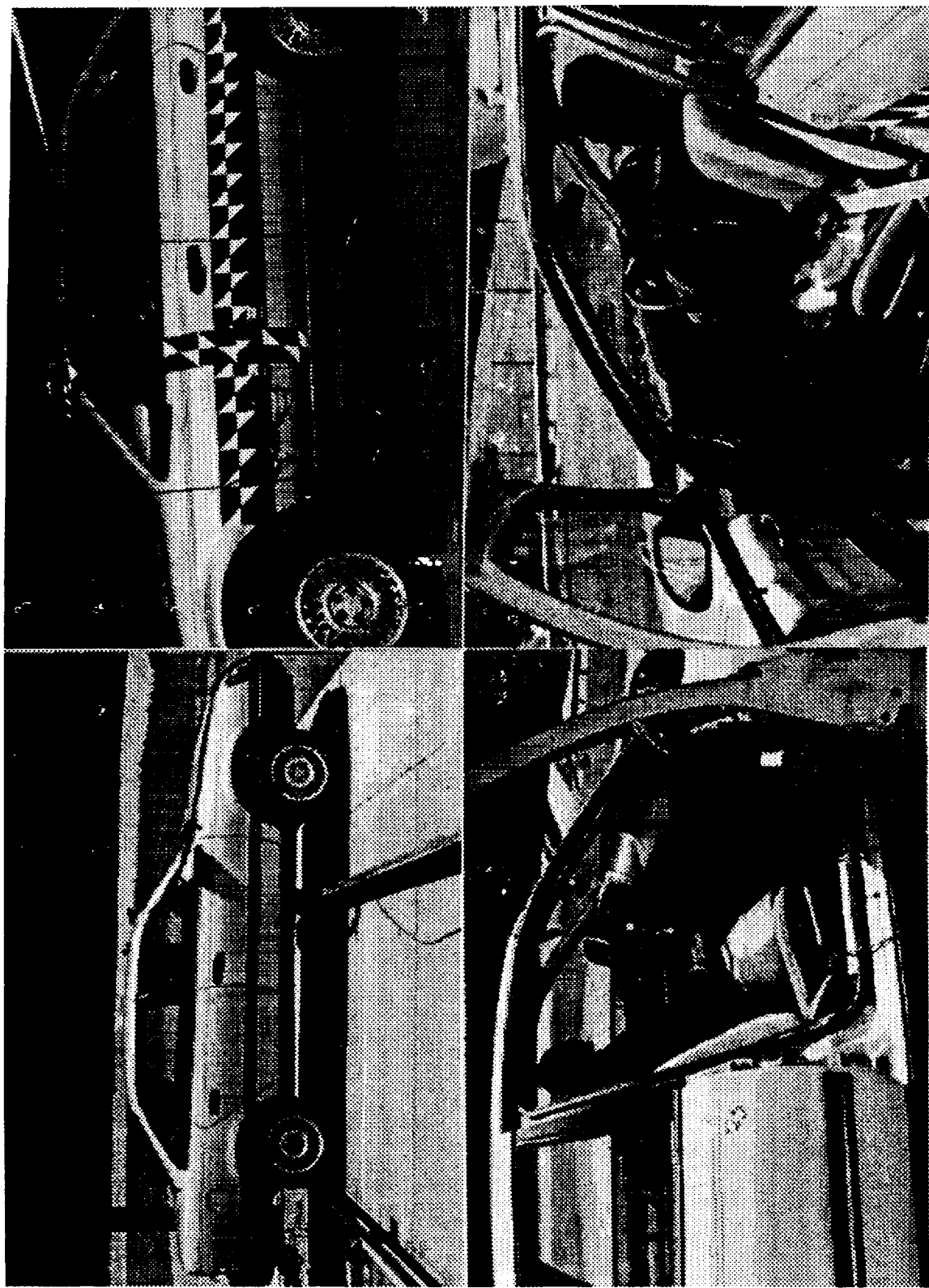


Figure 70. Pre test photographs continued, test 95S008.

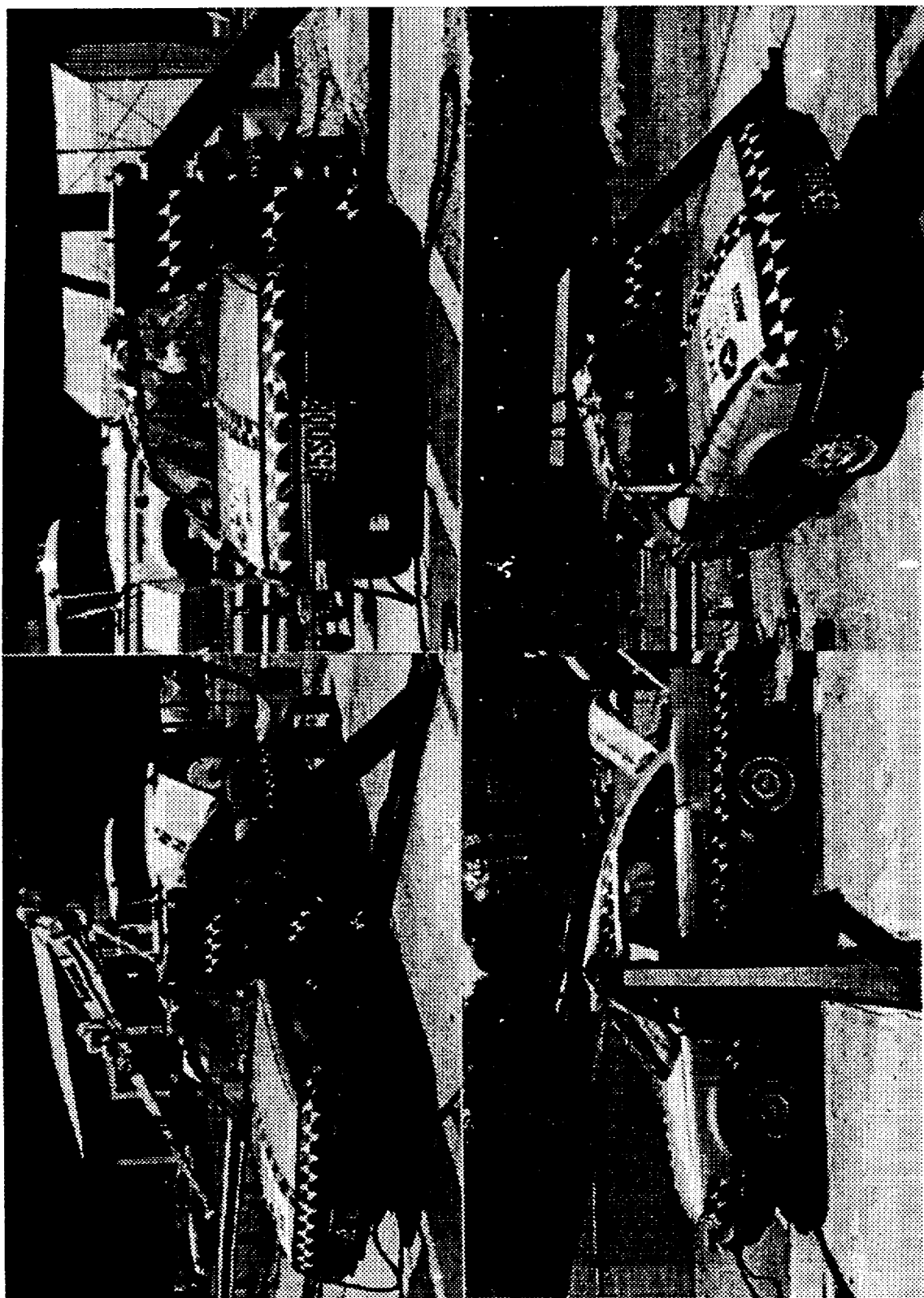


Figure 71. Post test photographs, test 95S008.

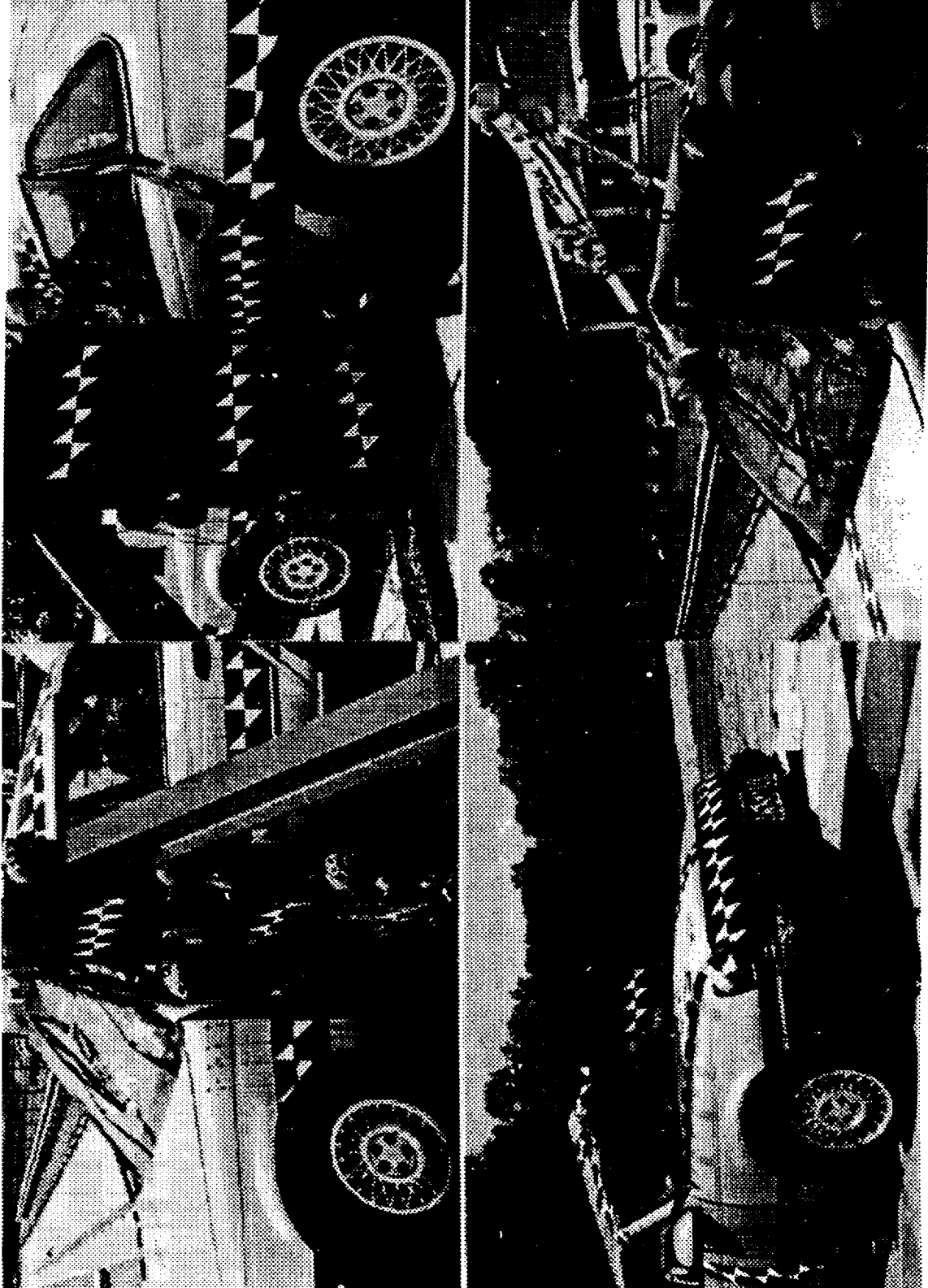


Figure 72. Post test photographs continued, test 95S008.

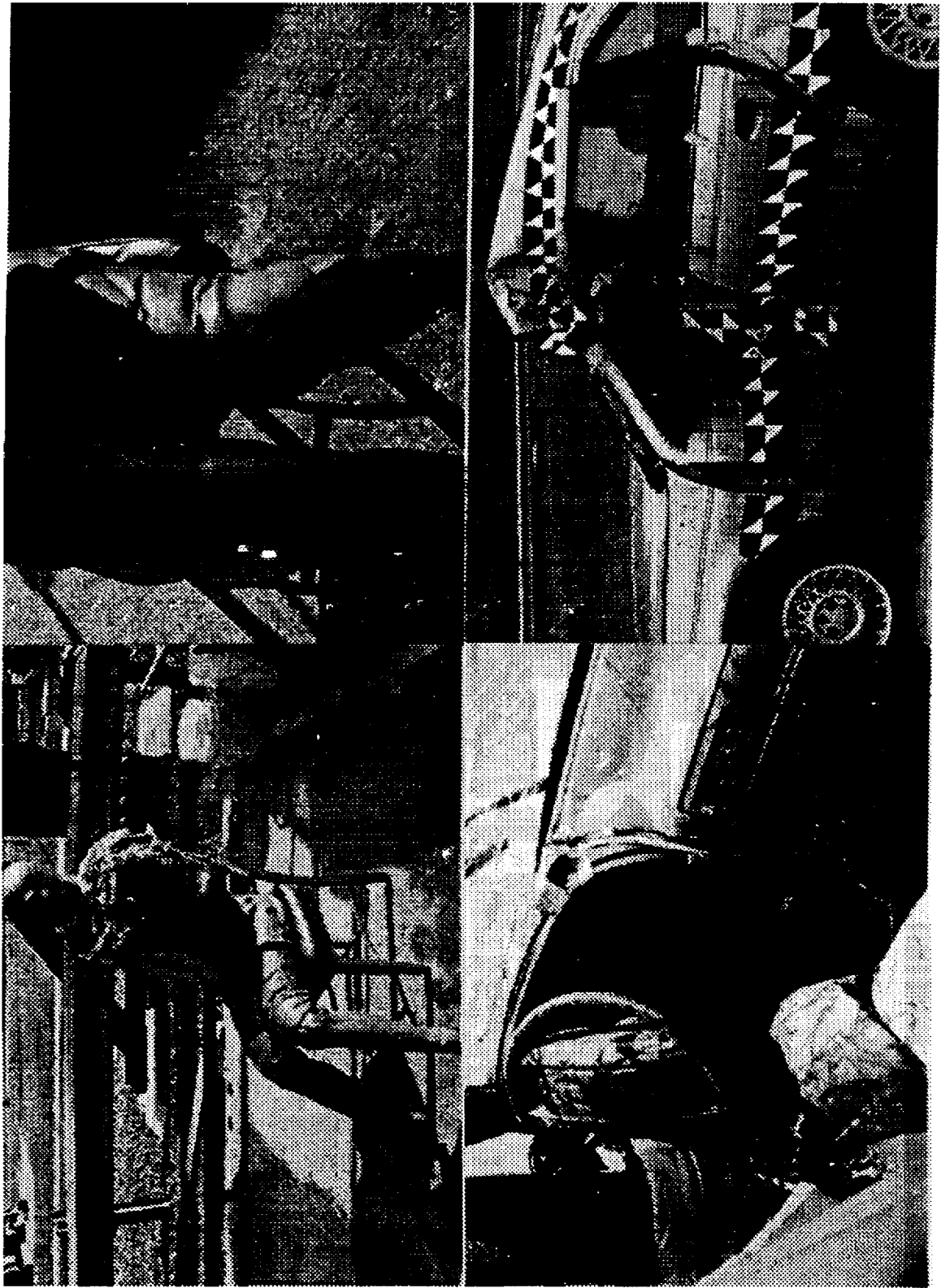


Figure 73. Post test photographs continued, test 95S008.

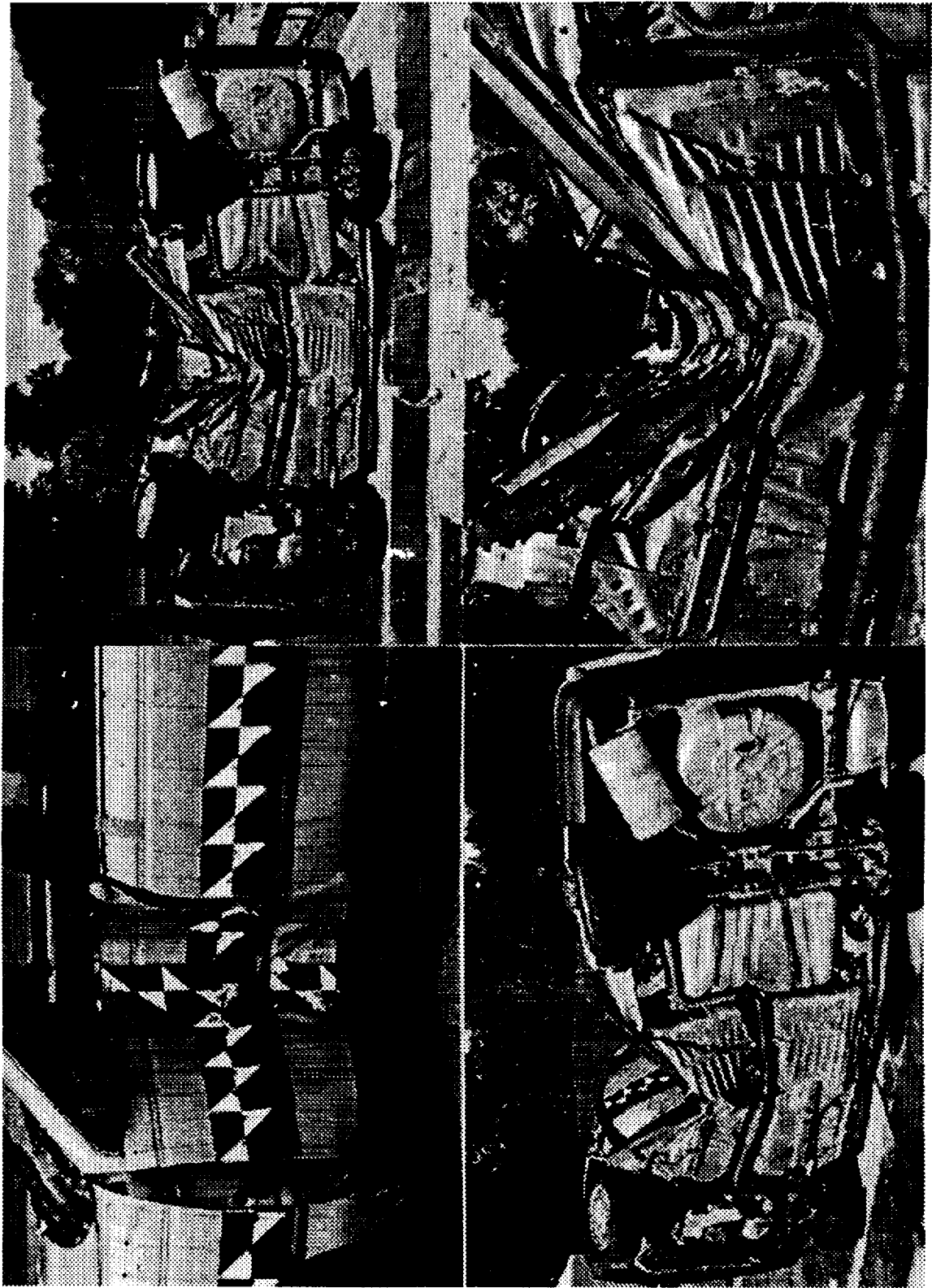


Figure 74. Post test photographs continued, test 95S008.

APPENDIX C. DATA PLOTS FROM INSTRUMENTED SID.

TEST NO. 95S008

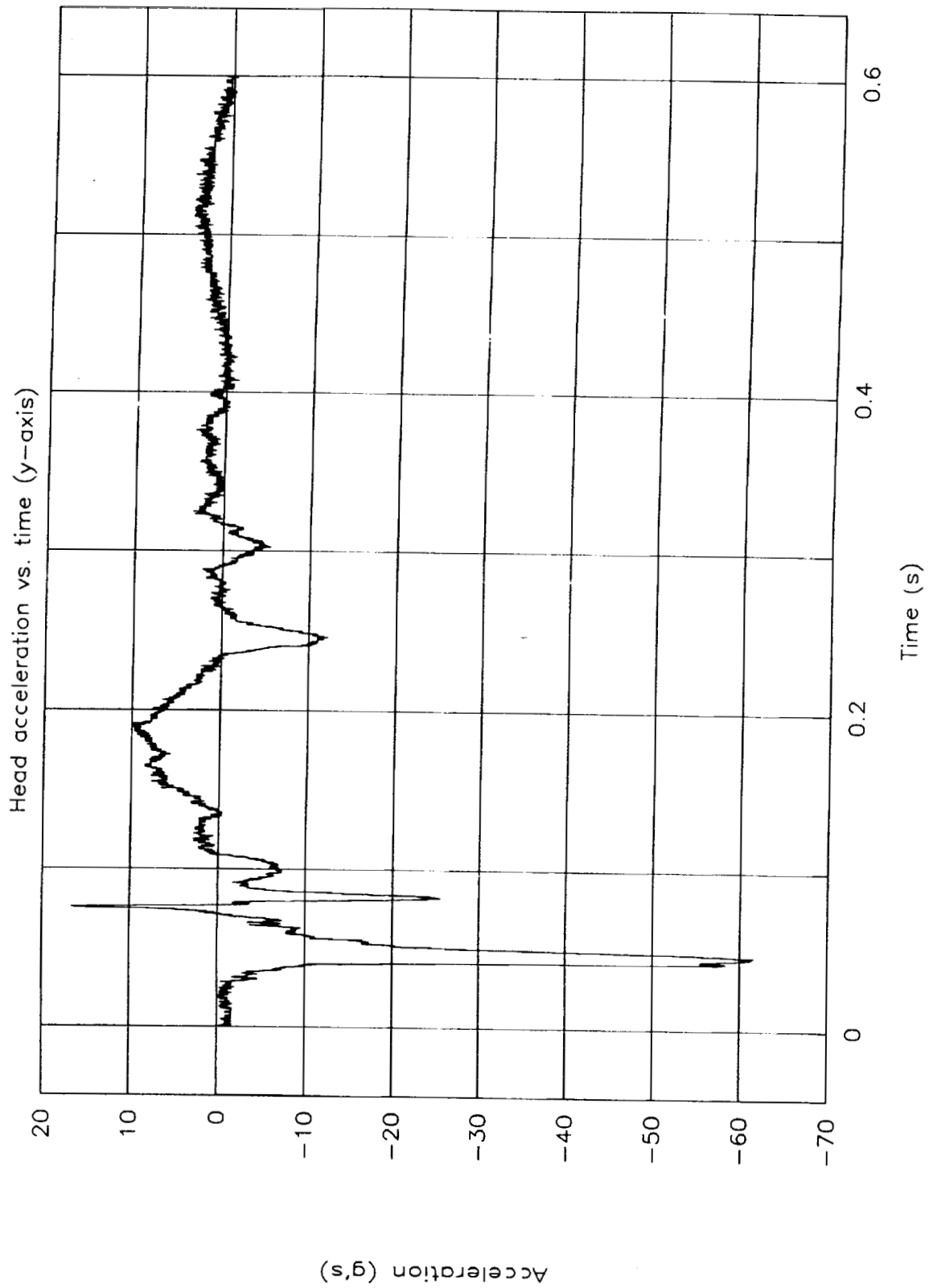


Figure 75. Head acceleration vs. time, y-axis, test 95S008.

TEST NO. 95S008

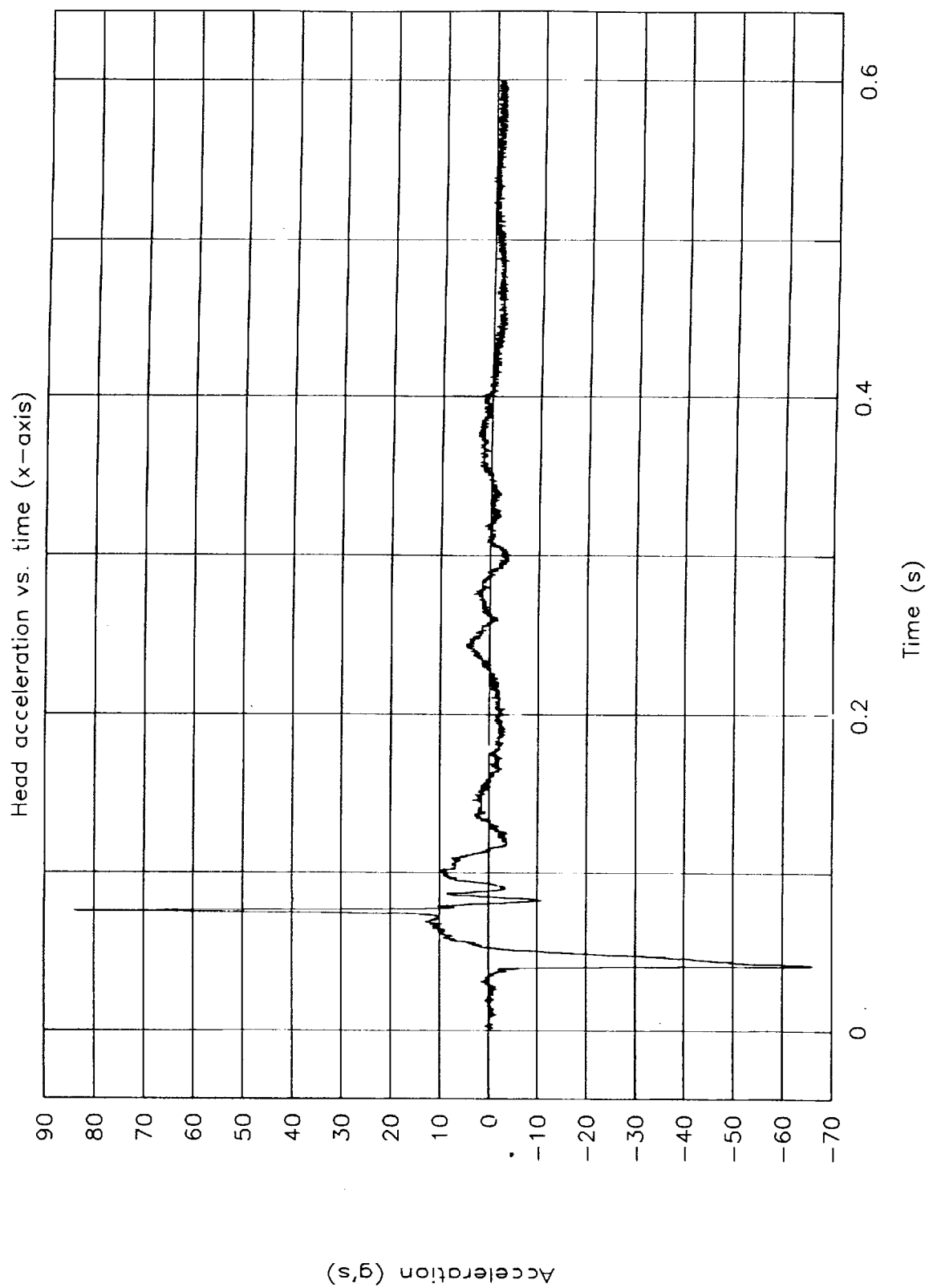


Figure 76. Head acceleration vs. time, x-axis, test 95S008.

TEST NO. 95S008

Head acceleration vs. time (z-axis)

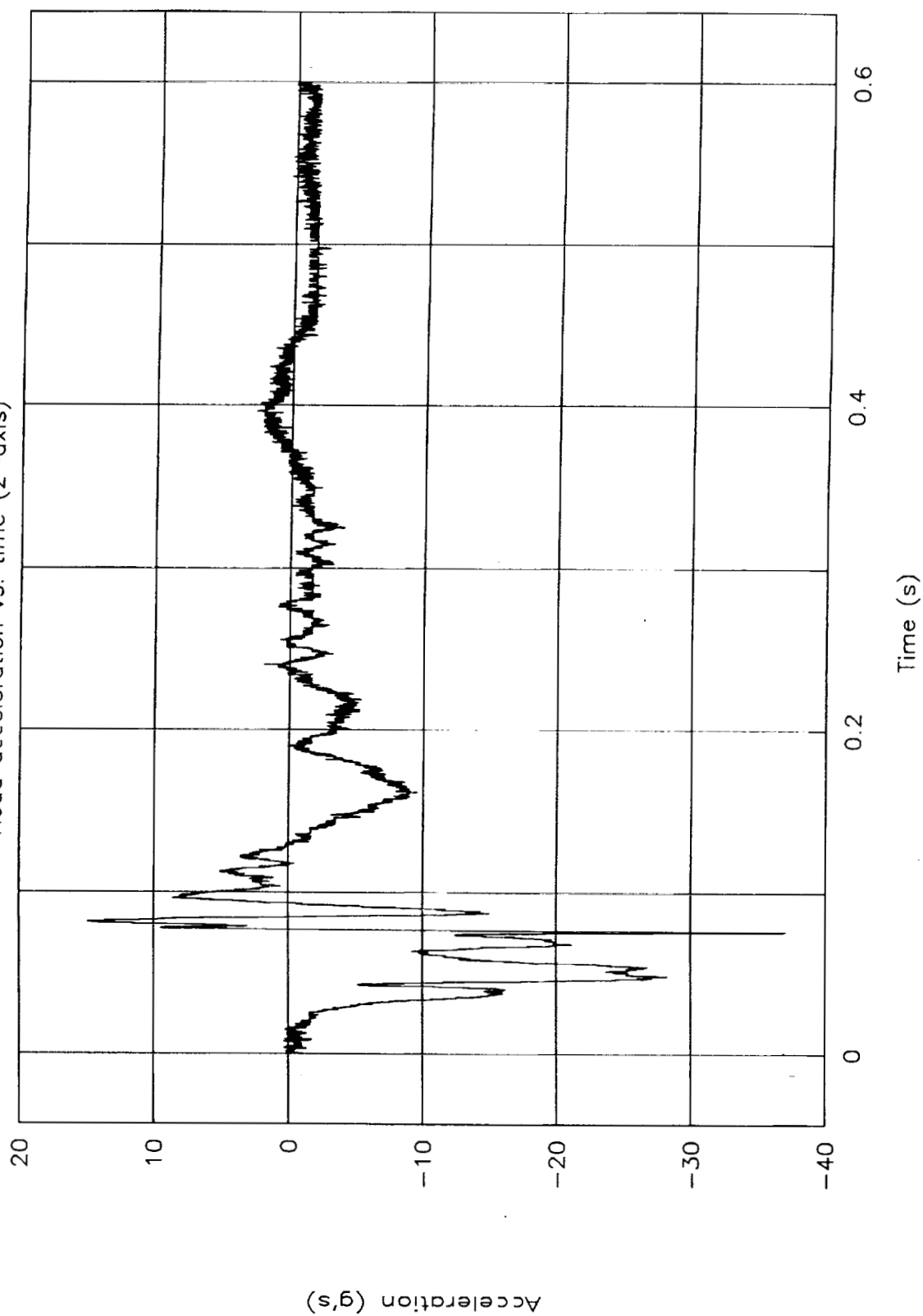


Figure 77. Head acceleration vs. time, z-axis, test 95S008.

TEST NO. 95S008

Resultant head acceleration vs. time

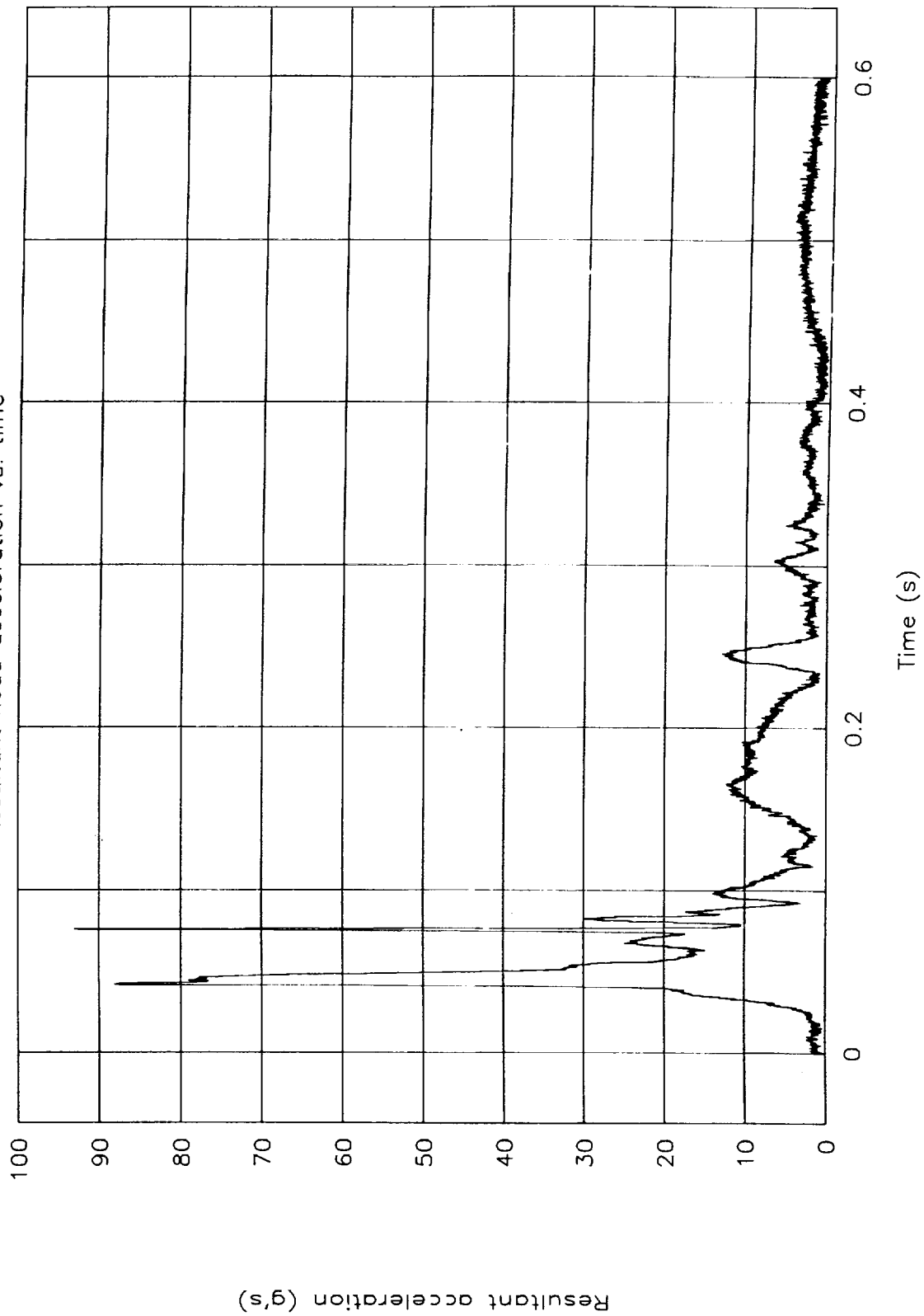


Figure 78. Resultant head acceleration vs. time (HIC data), test 95S008.

TEST NO. 95S008

Upper rib acceleration (primary)

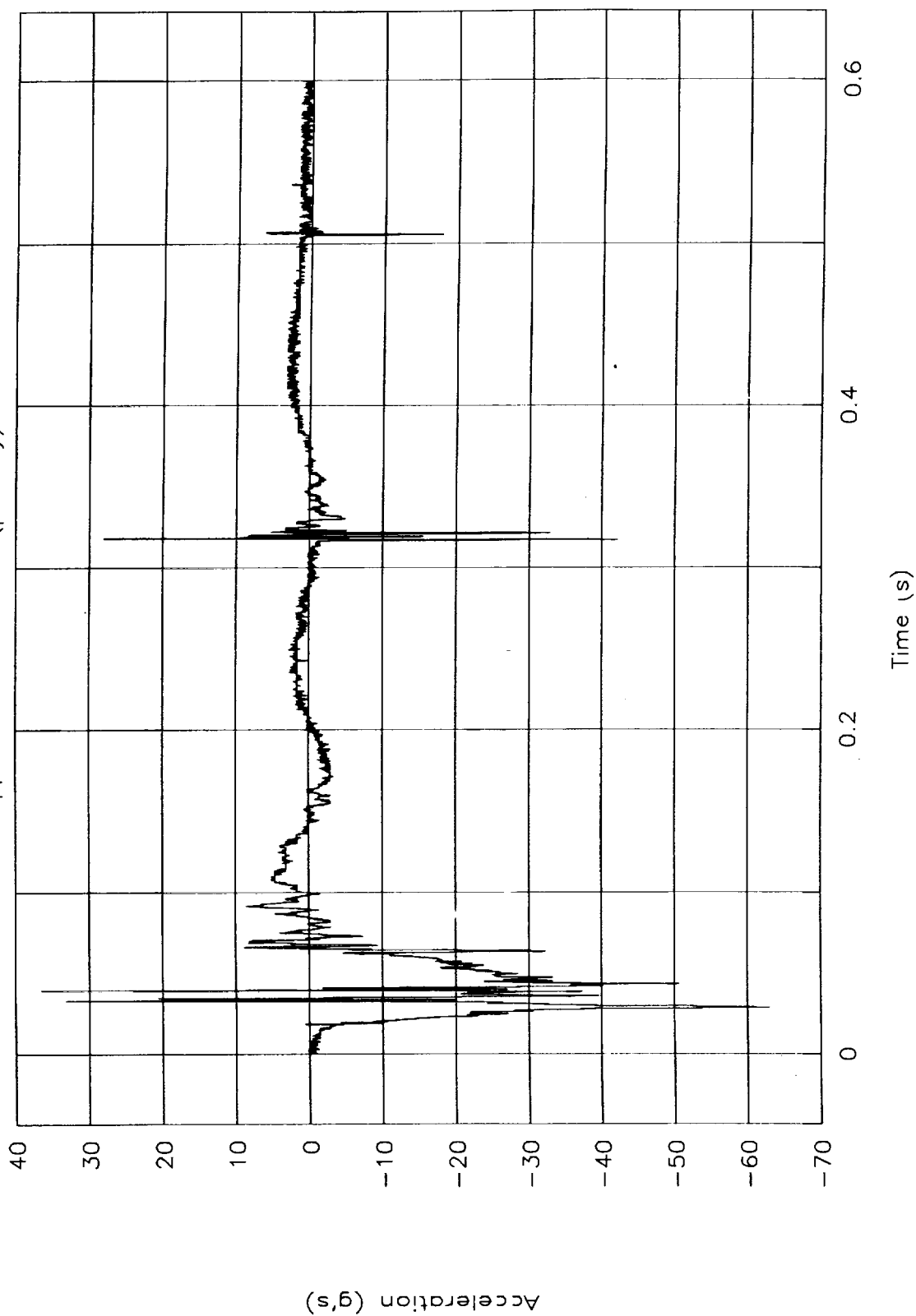


Figure 79. Upper rib acceleration vs. time (primary), test 95S008.

TEST NO. 95S008

Upper rib acceleration (redundant)

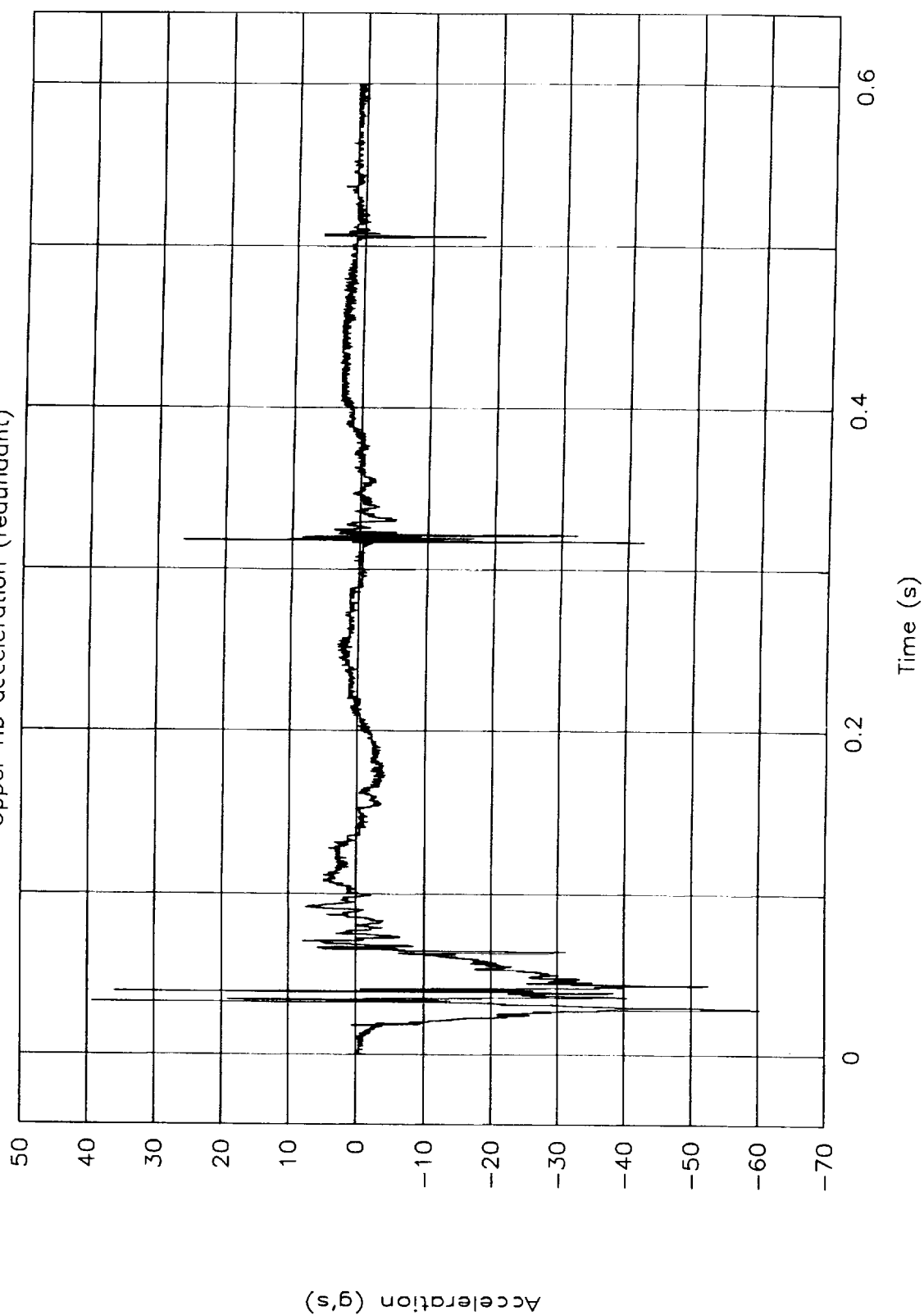


Figure 80. Upper rib acceleration vs. time (redundant), test 95S008.

TEST NO. 95S008

Lower rib acceleration (redundant)

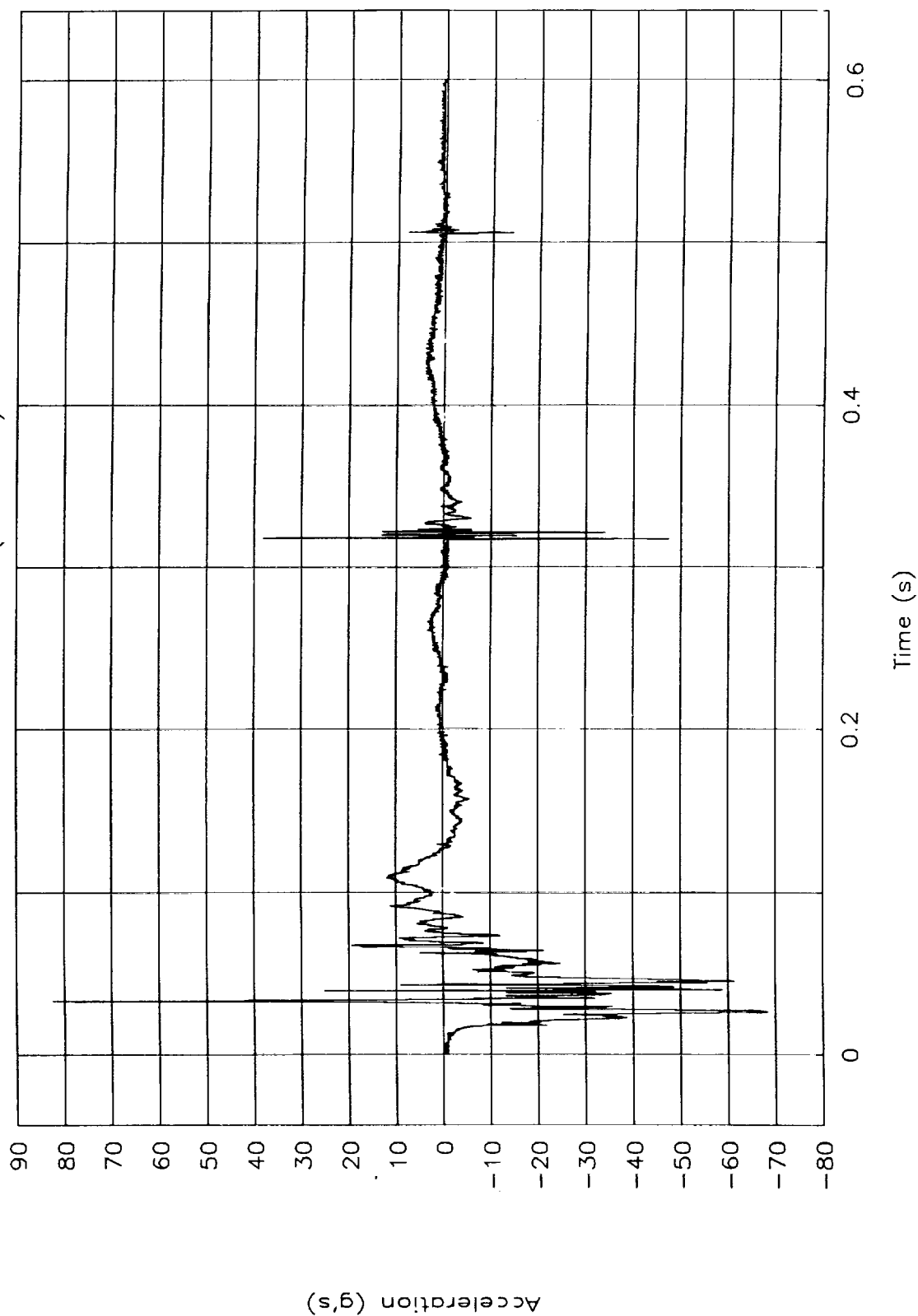


Figure 81. Lower rib acceleration vs. time (redundant), test 95S008.

TEST NO. 95S008

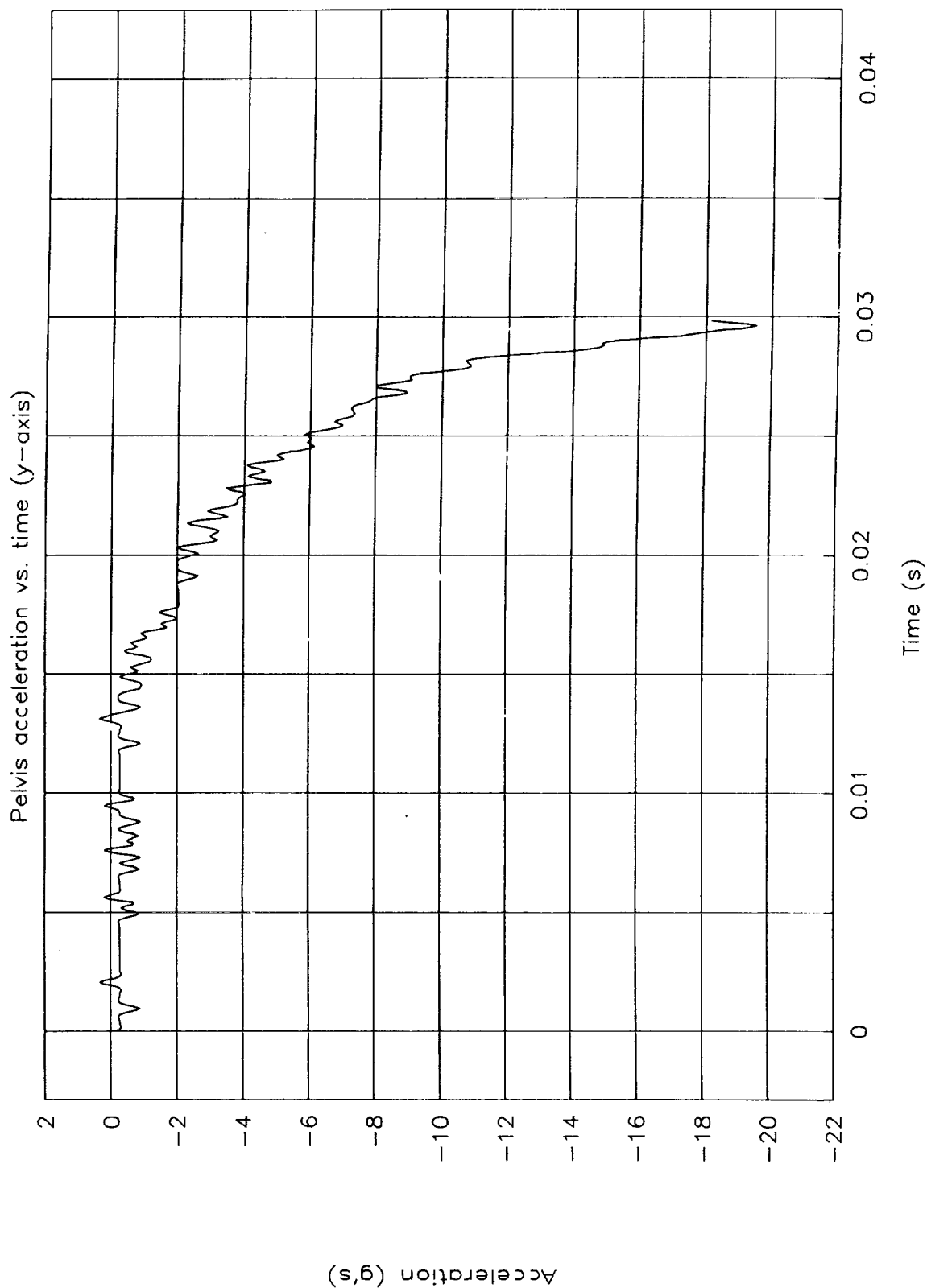


Figure 82. Pelvis acceleration vs. time, y-axis, test 95S008.

TEST NO. 95S008

Pelvis acceleration vs. time (x-axis)

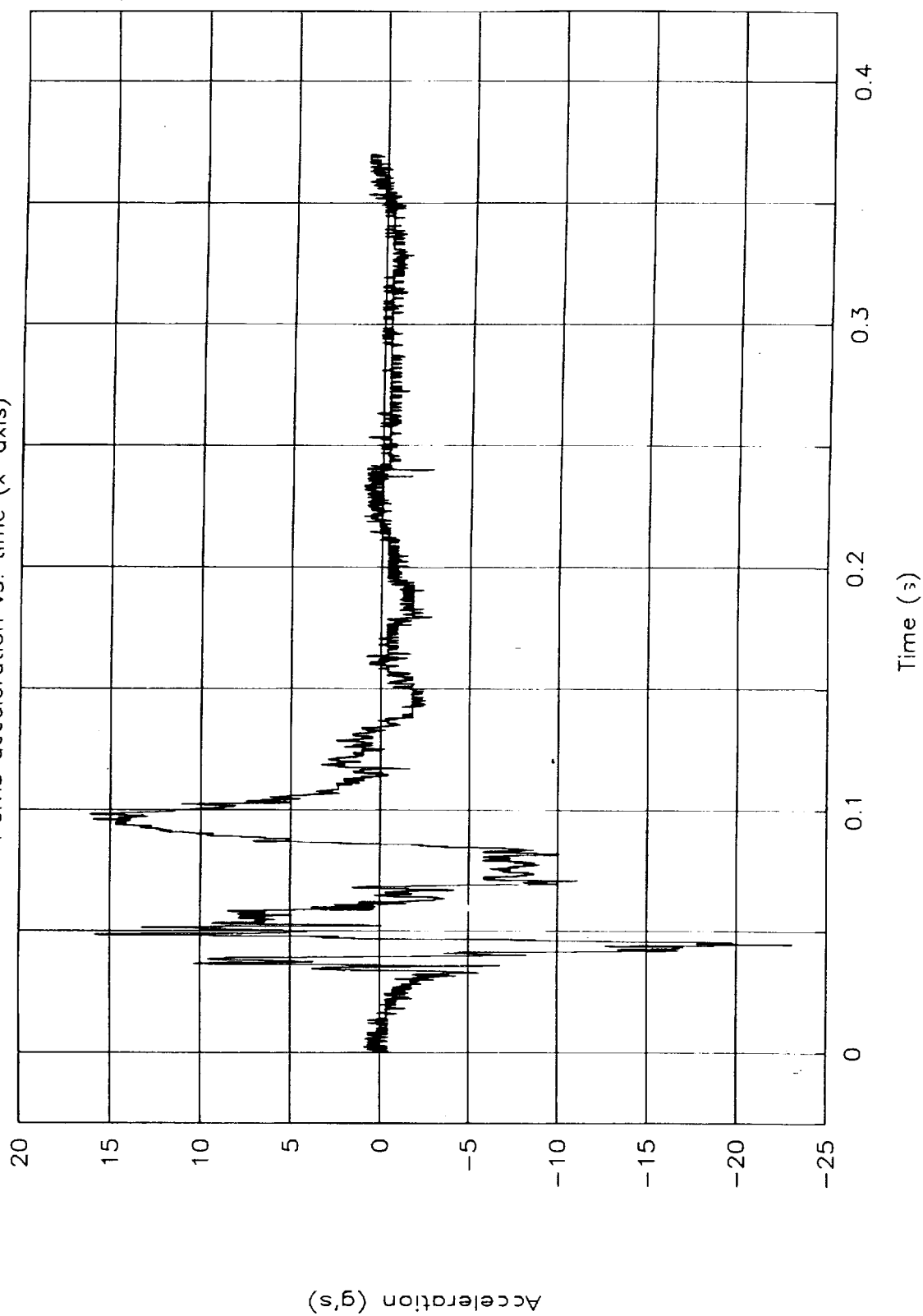


Figure 83. Pelvis acceleration vs. time, x-axis, test 95S008.

APPENDIX D. DATA PLOTS FROM RIGID POLE LOAD CELLS.

TEST NO. 95S008

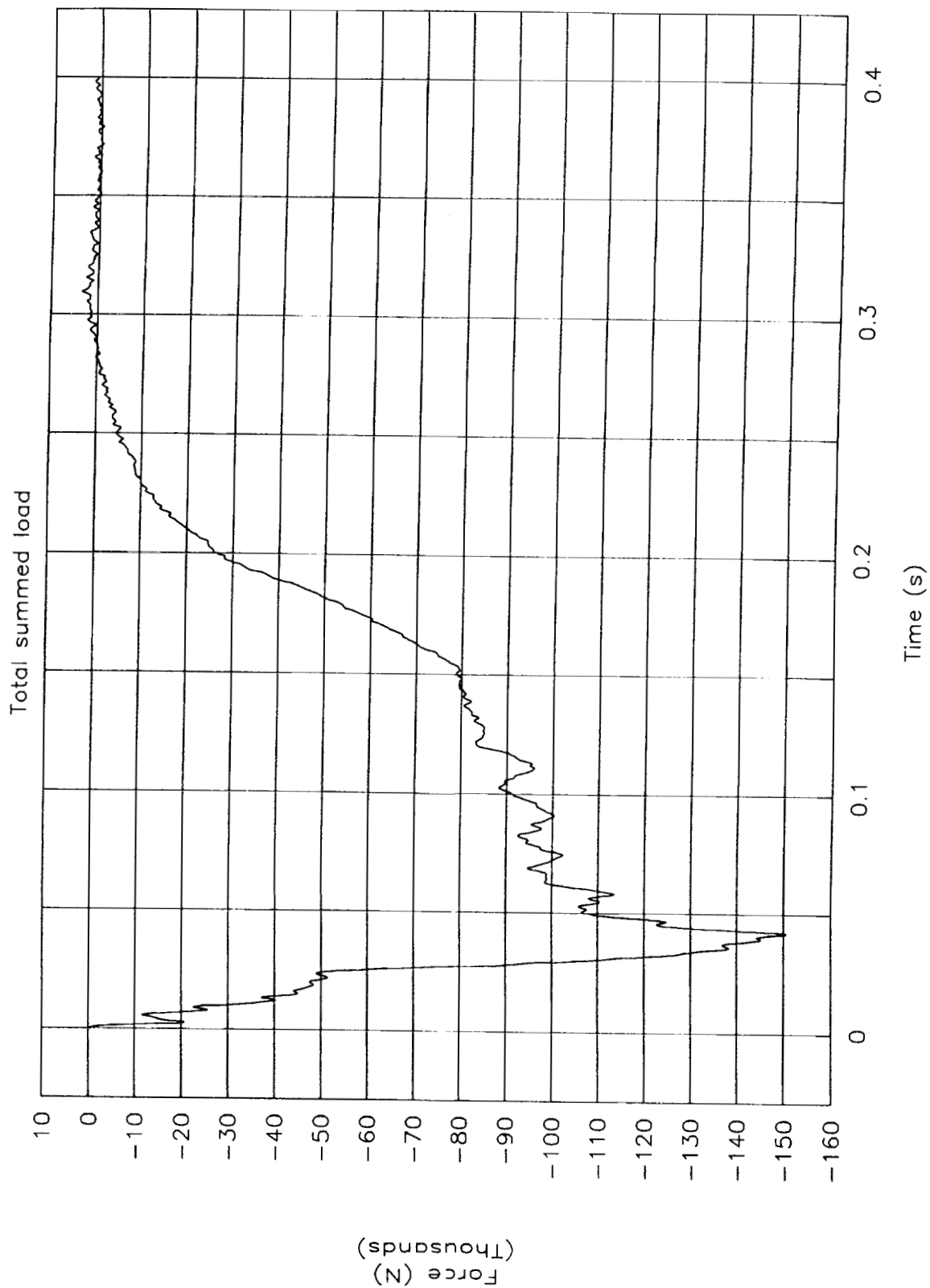


Figure 84. Rigid pole summed load, force vs. time, test 95S008.

TEST NO. 95S008

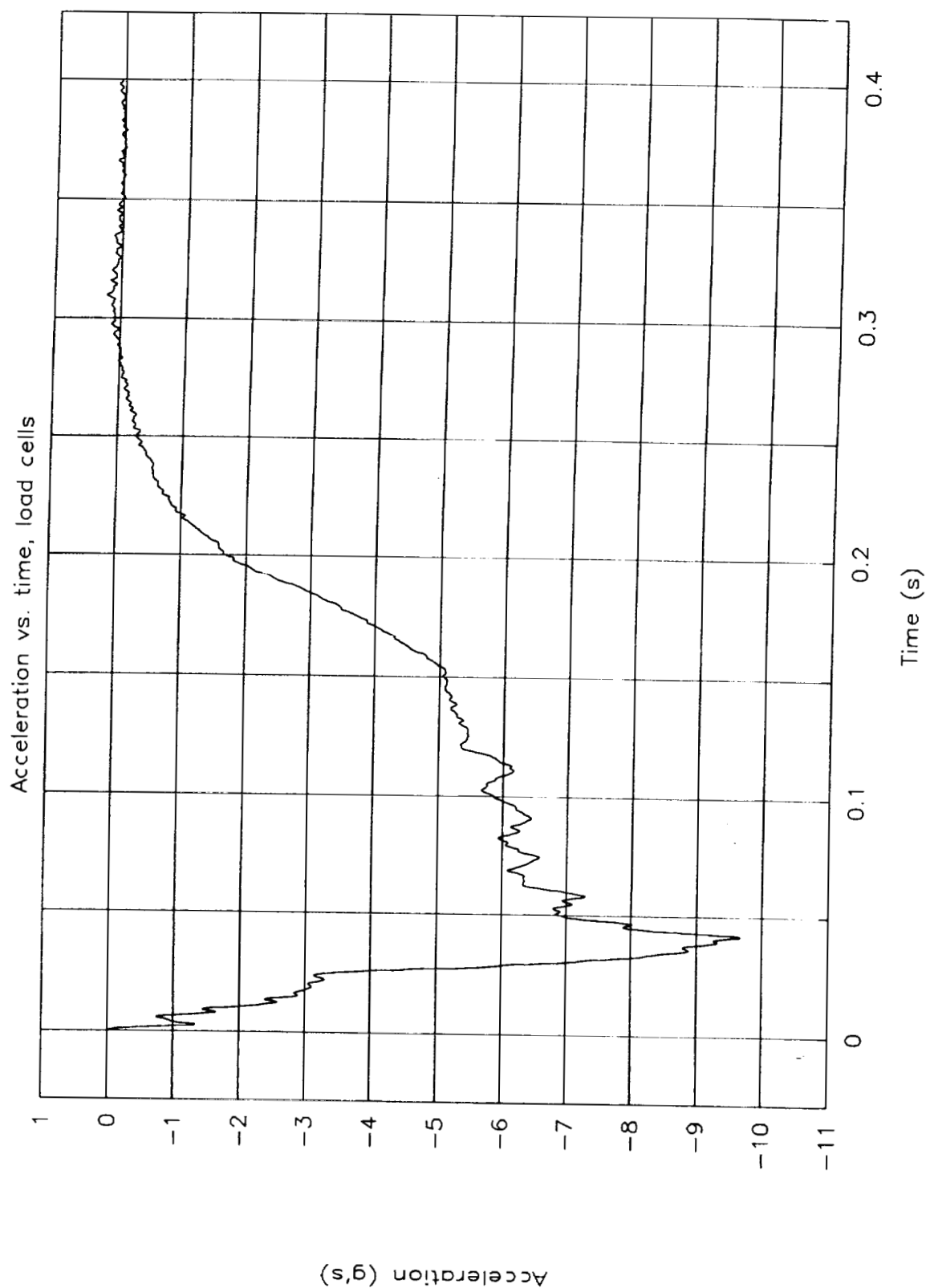


Figure 85. Rigid pole, acceleration vs. time, test 95S008.

Velocity (m/s)

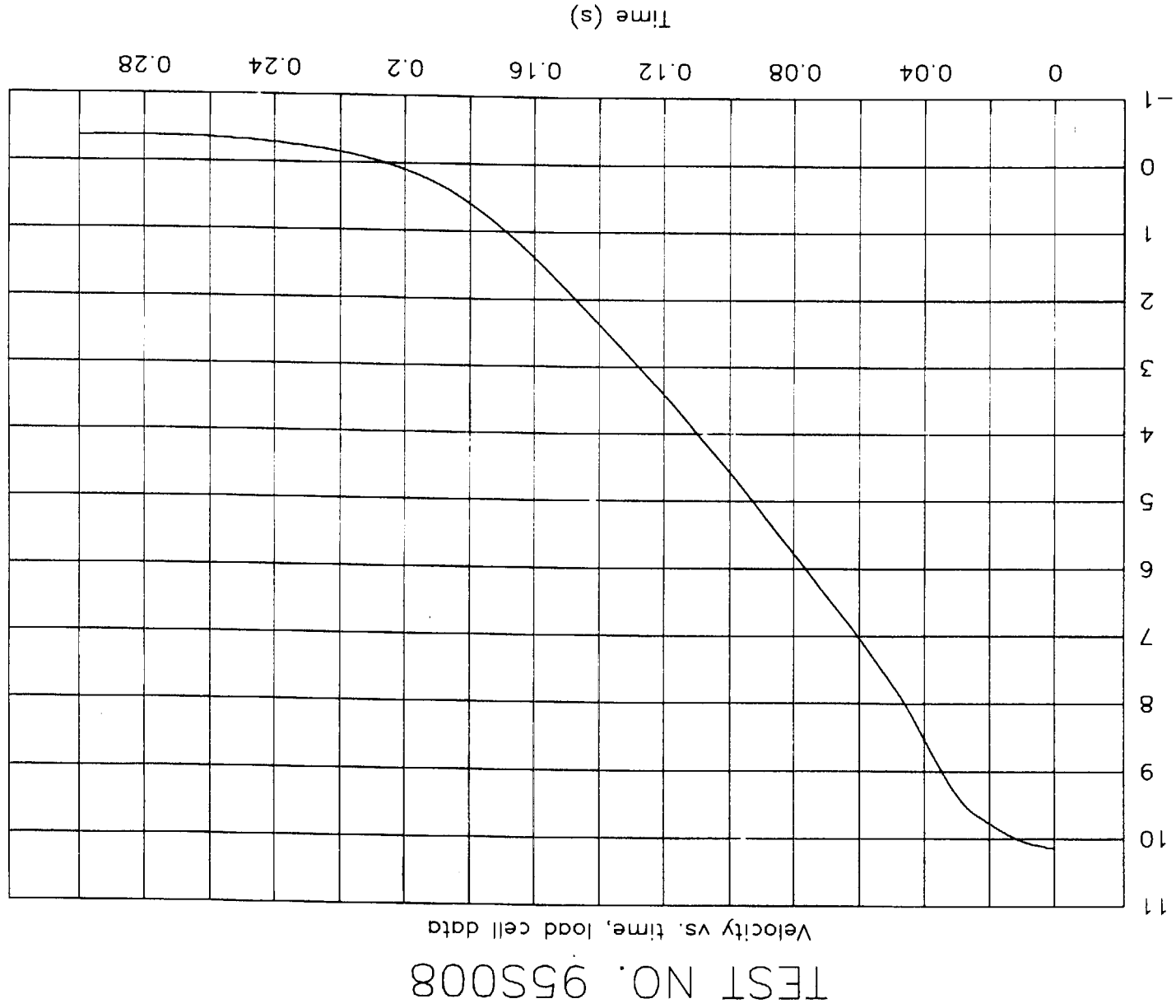


Figure 86. Rigid pole, velocity vs. time, test 95S008.

TEST NO. 95S008

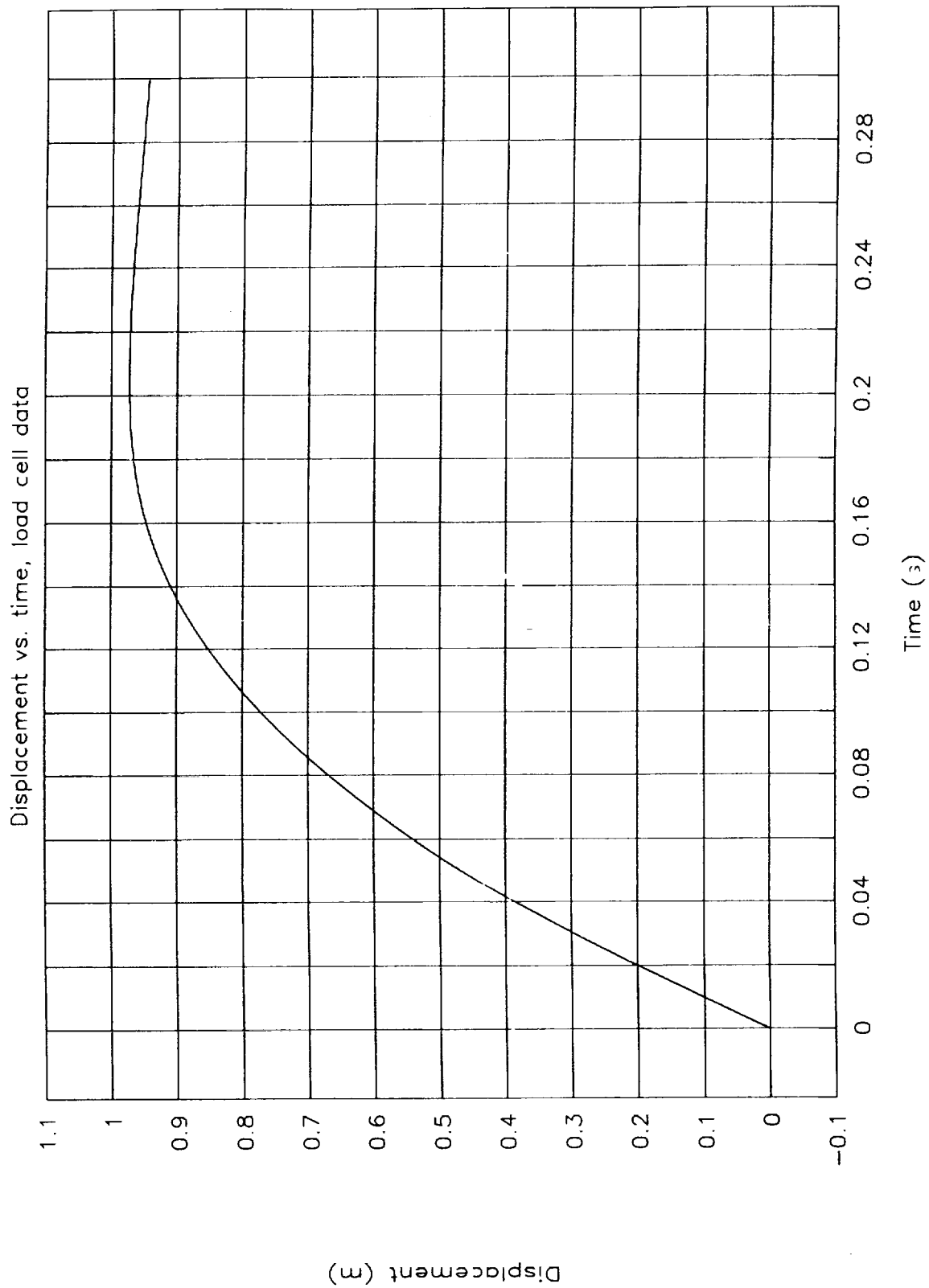


Figure 87. Rigid pole, displacement vs. time, test 95S008.

TEST NO. 95S008

Force vs. displacement, load cell data

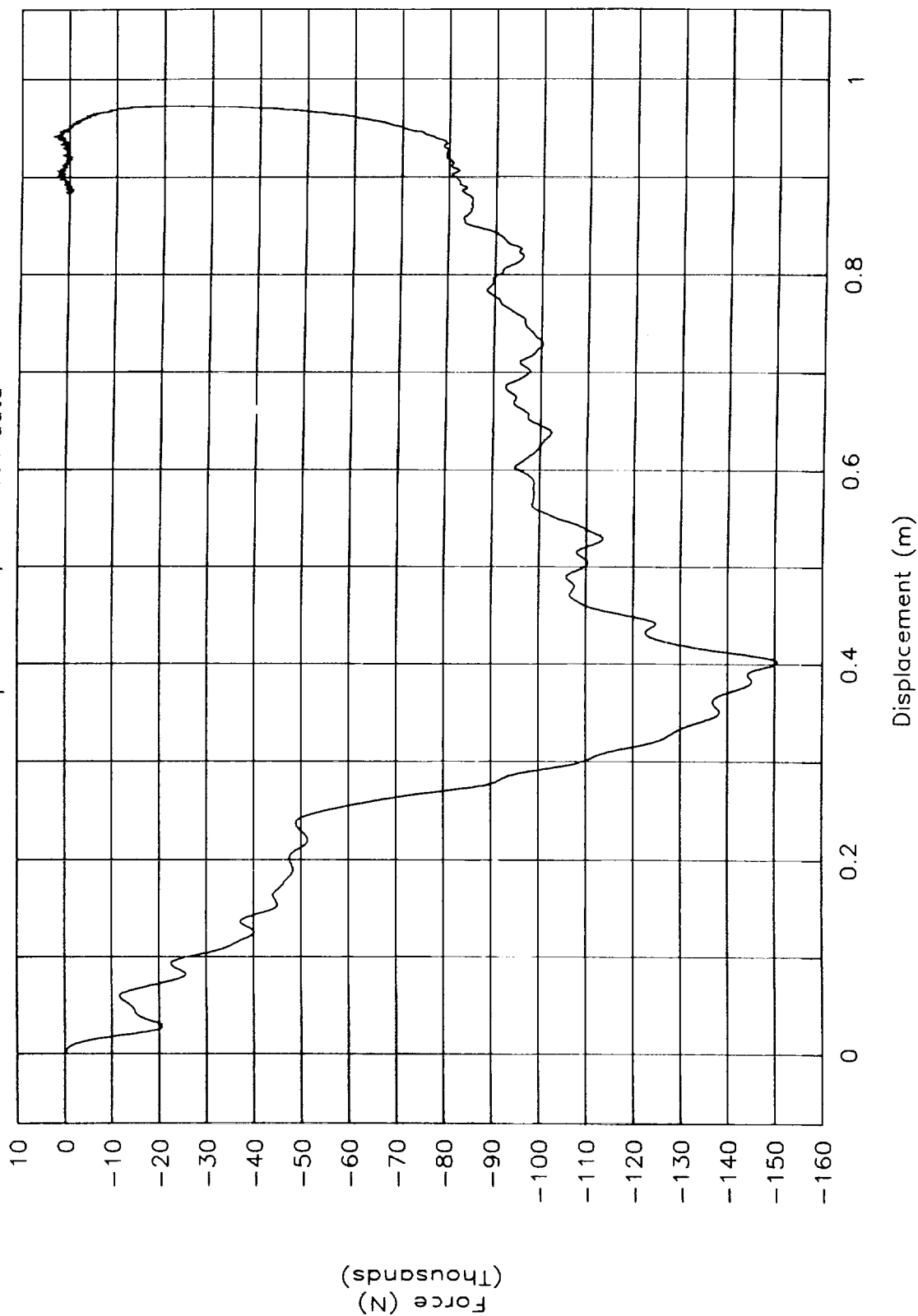


Figure 88. Rigid pole, force vs. displacement, test 95S008.

TEST NO. 95S008

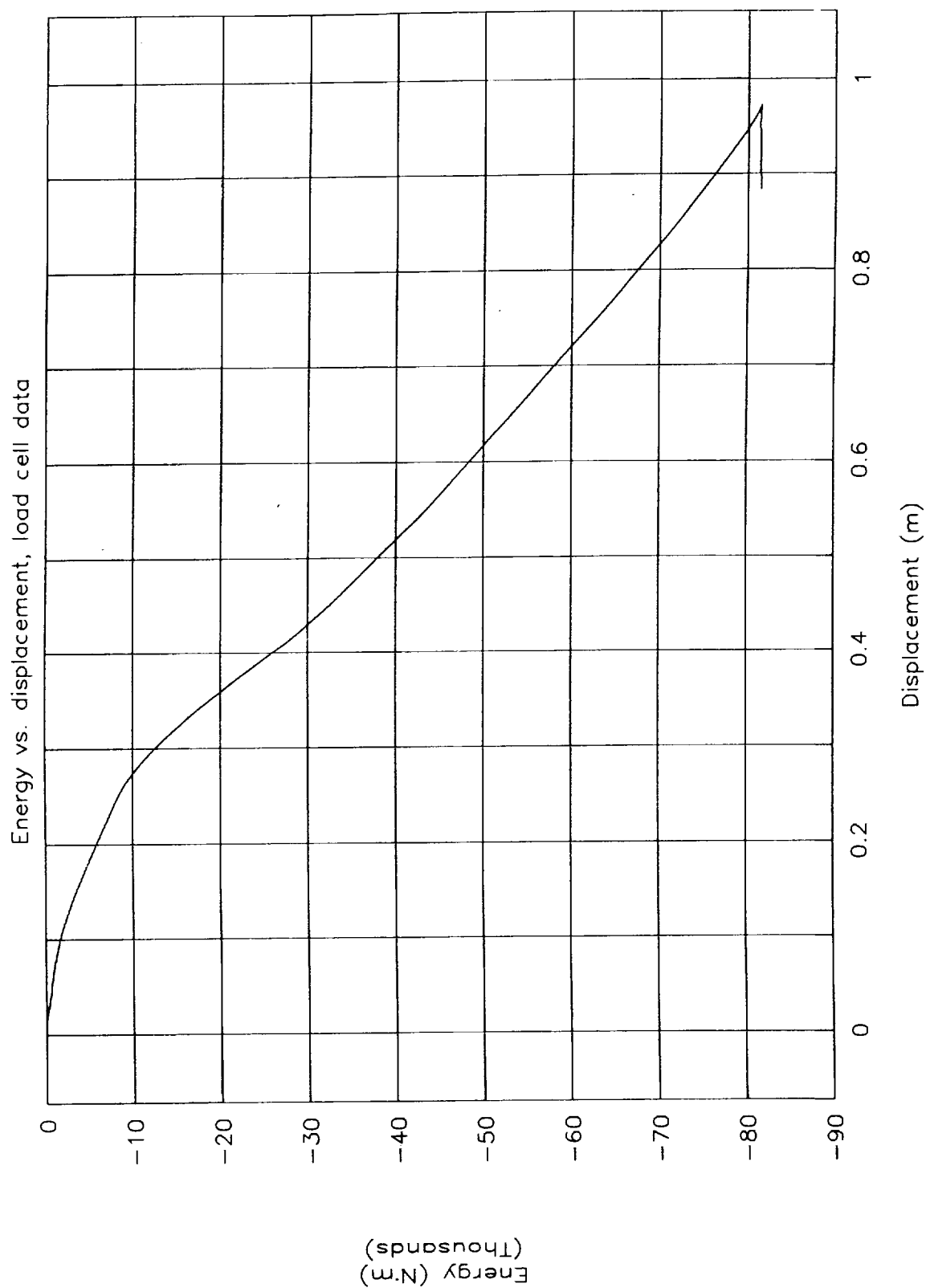


Figure 89. Rigid pole, energy vs. displacement, test 95S008.

TEST NO. 95S008

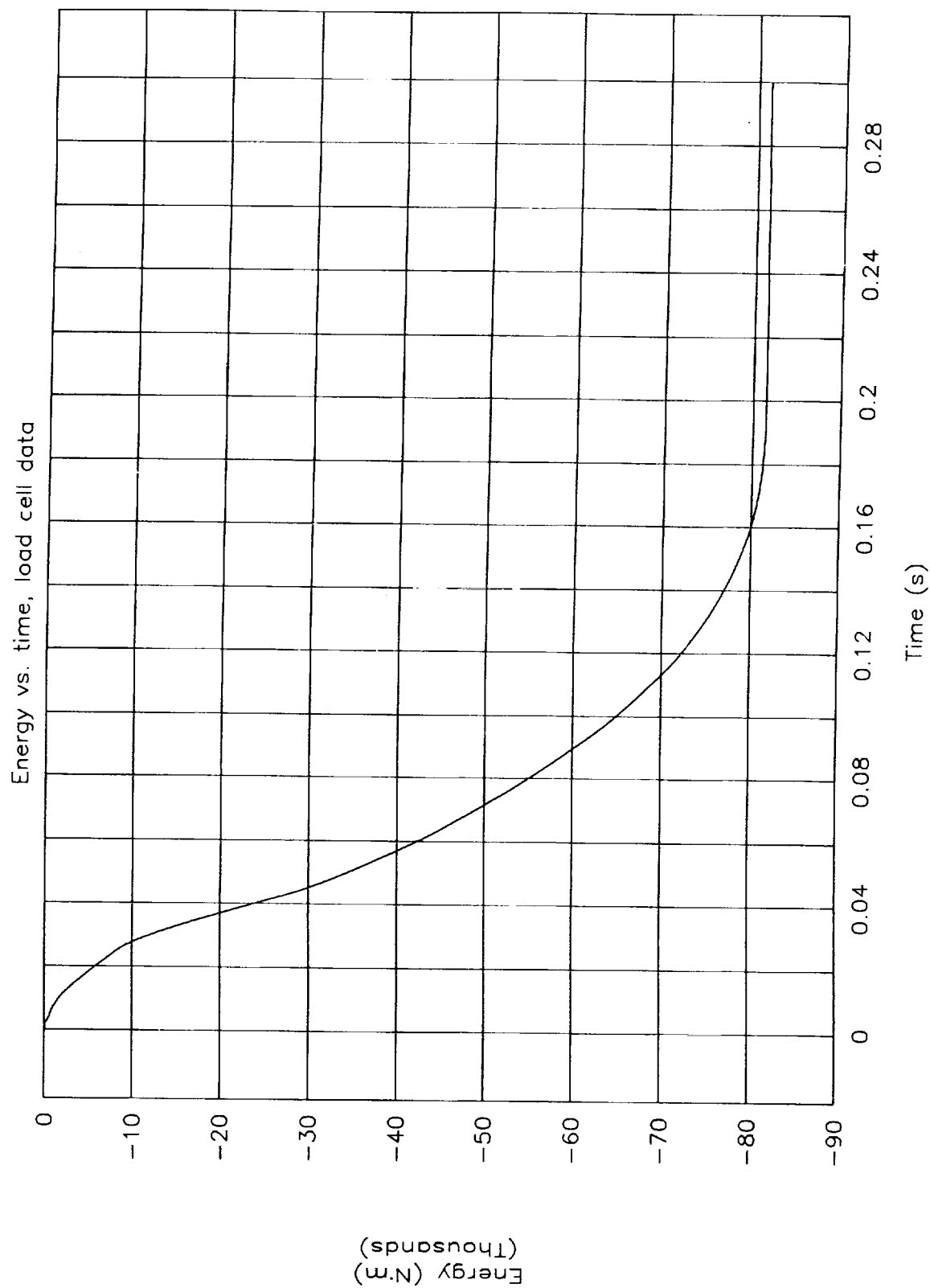


Figure 90. Rigid pole, energy vs. time, test 95S008.

TEST NO. 95S008

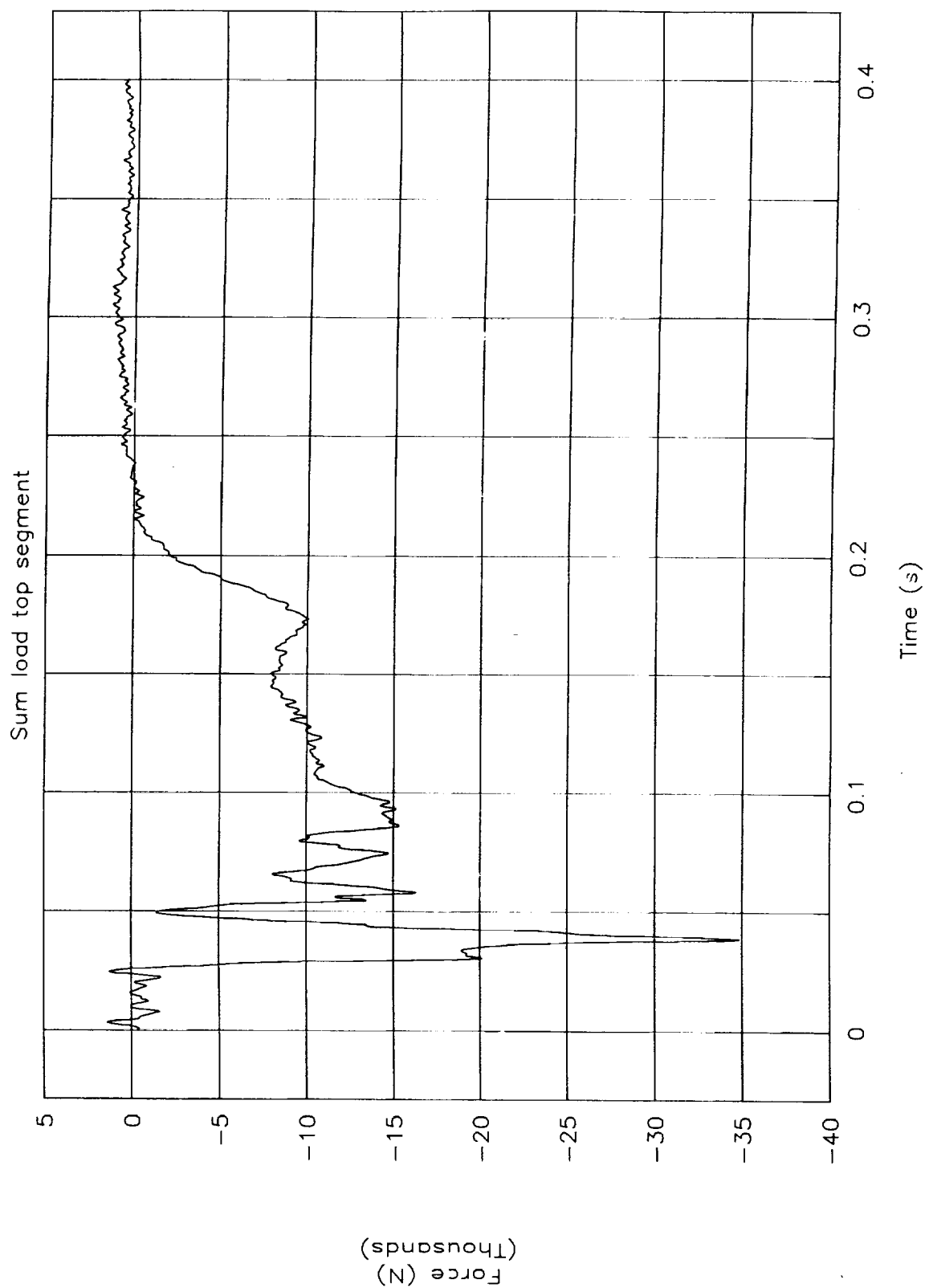


Figure 91. Rigid pole, top segment force vs. time, test 95S008.

TEST NO. 95S008

Sum load middle segment

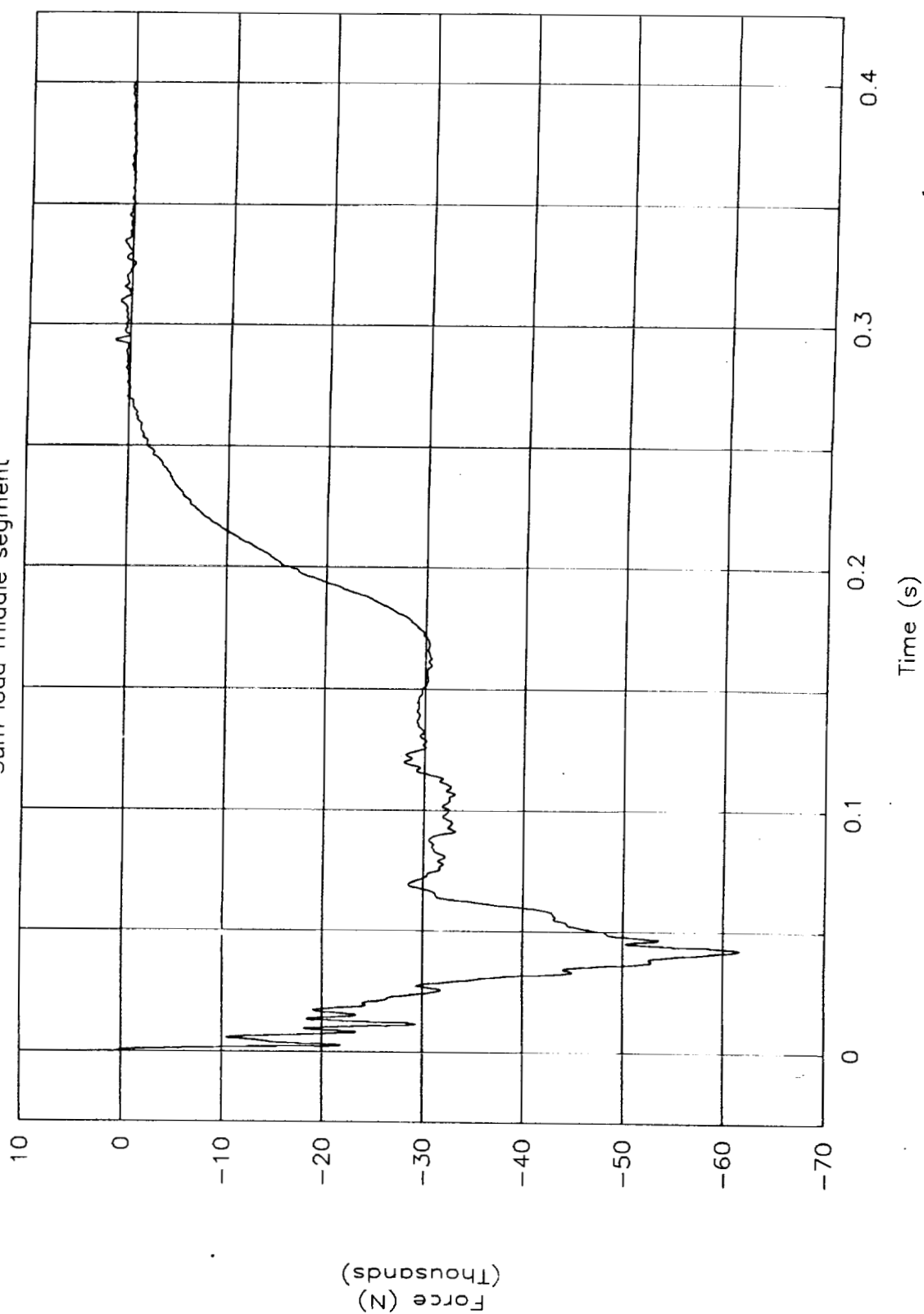


Figure 92. Rigid pole, middle segment force vs. time, test 95S008.

TEST NO. 95S008

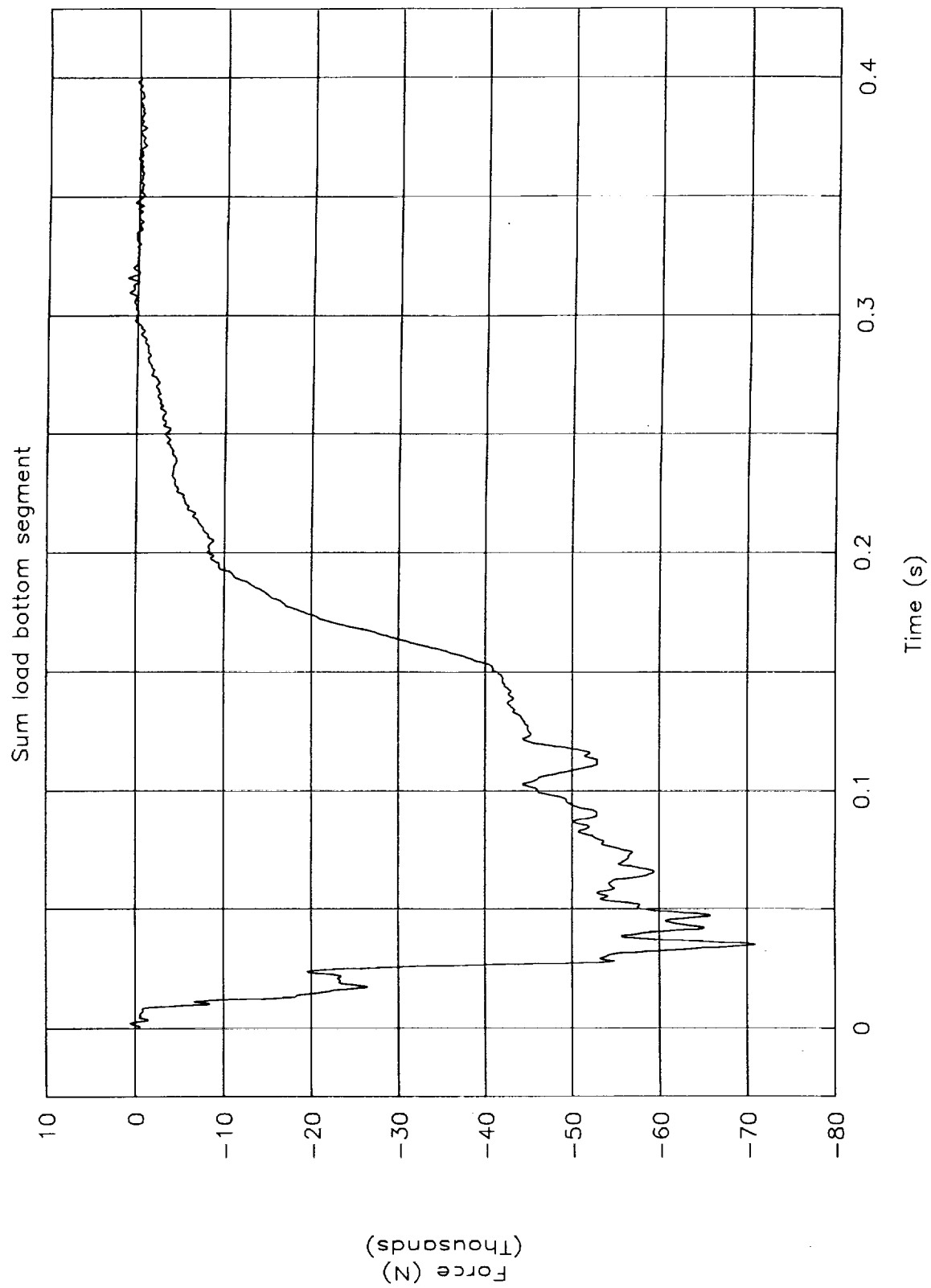


Figure 93. Rigid pole, bottom segment force vs. time, test 95S008.

TEST NO. 95S008

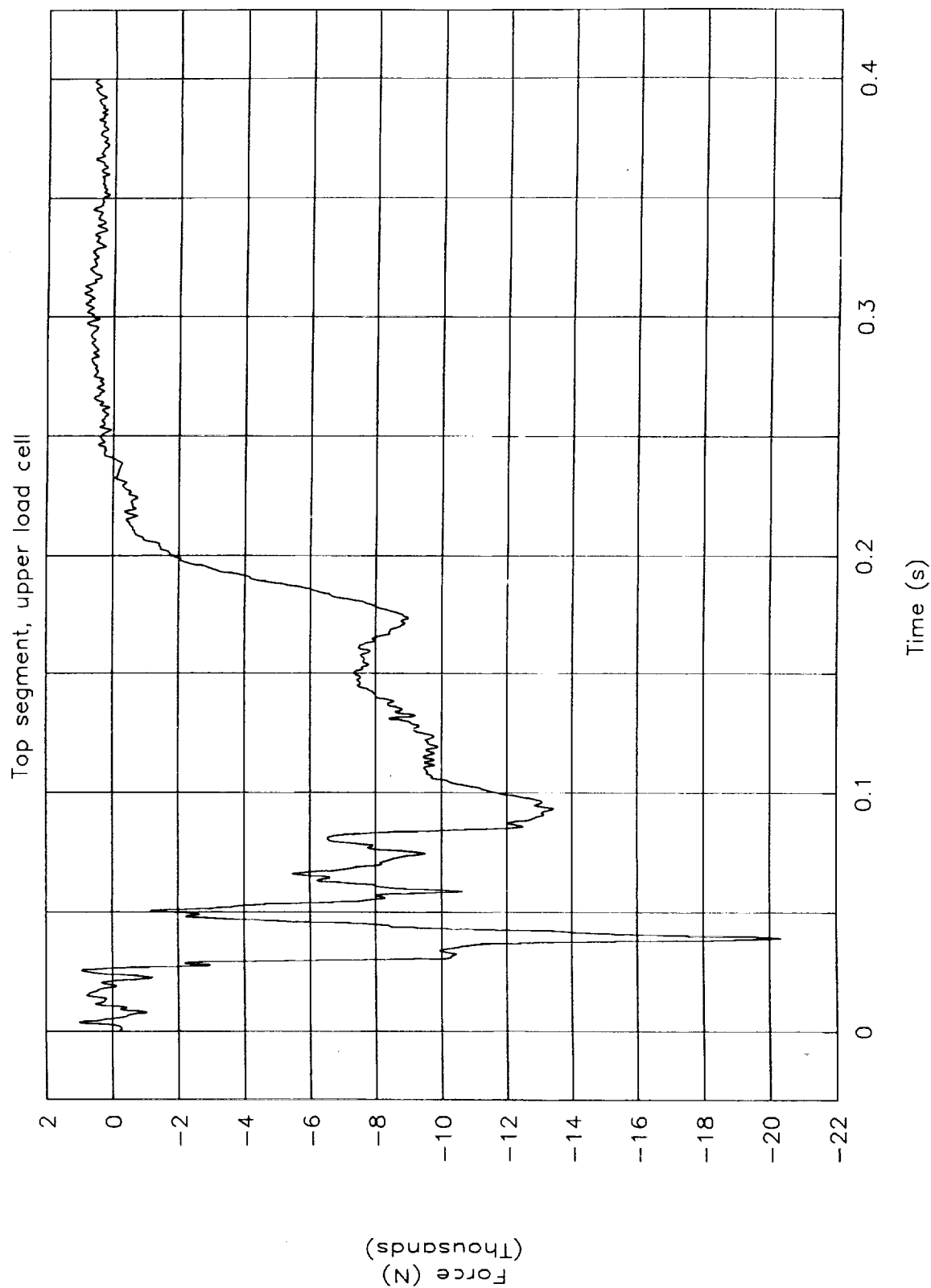


Figure 94. Rigid pole, top segment, upper load cell force vs. time, test 95S008.

TEST NO. 95S008

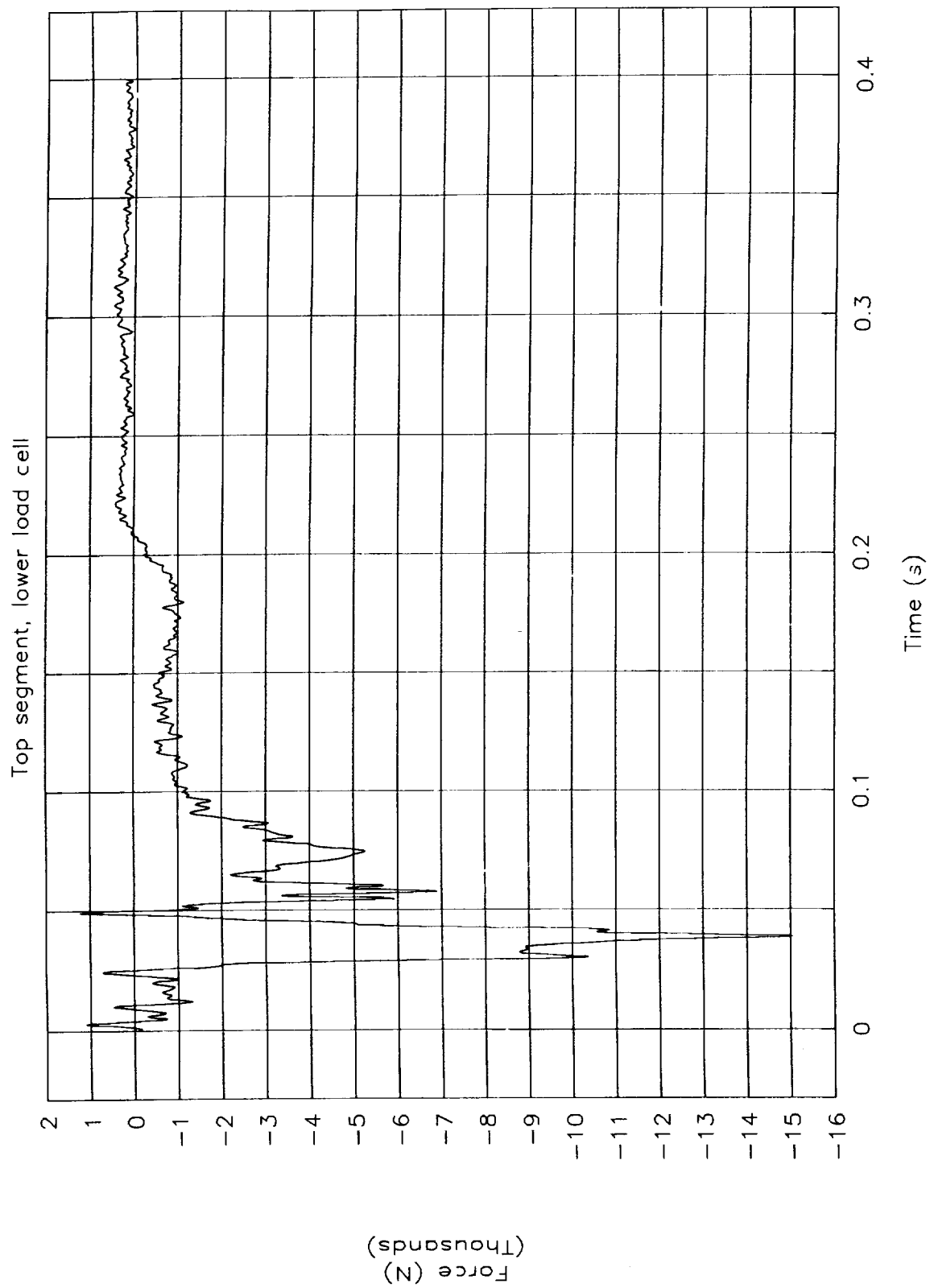


Figure 95. Rigid pole, top segment, lower load cell force vs. time, test 95S008.

TEST NO. 95S008

Middle segment, upper load cell

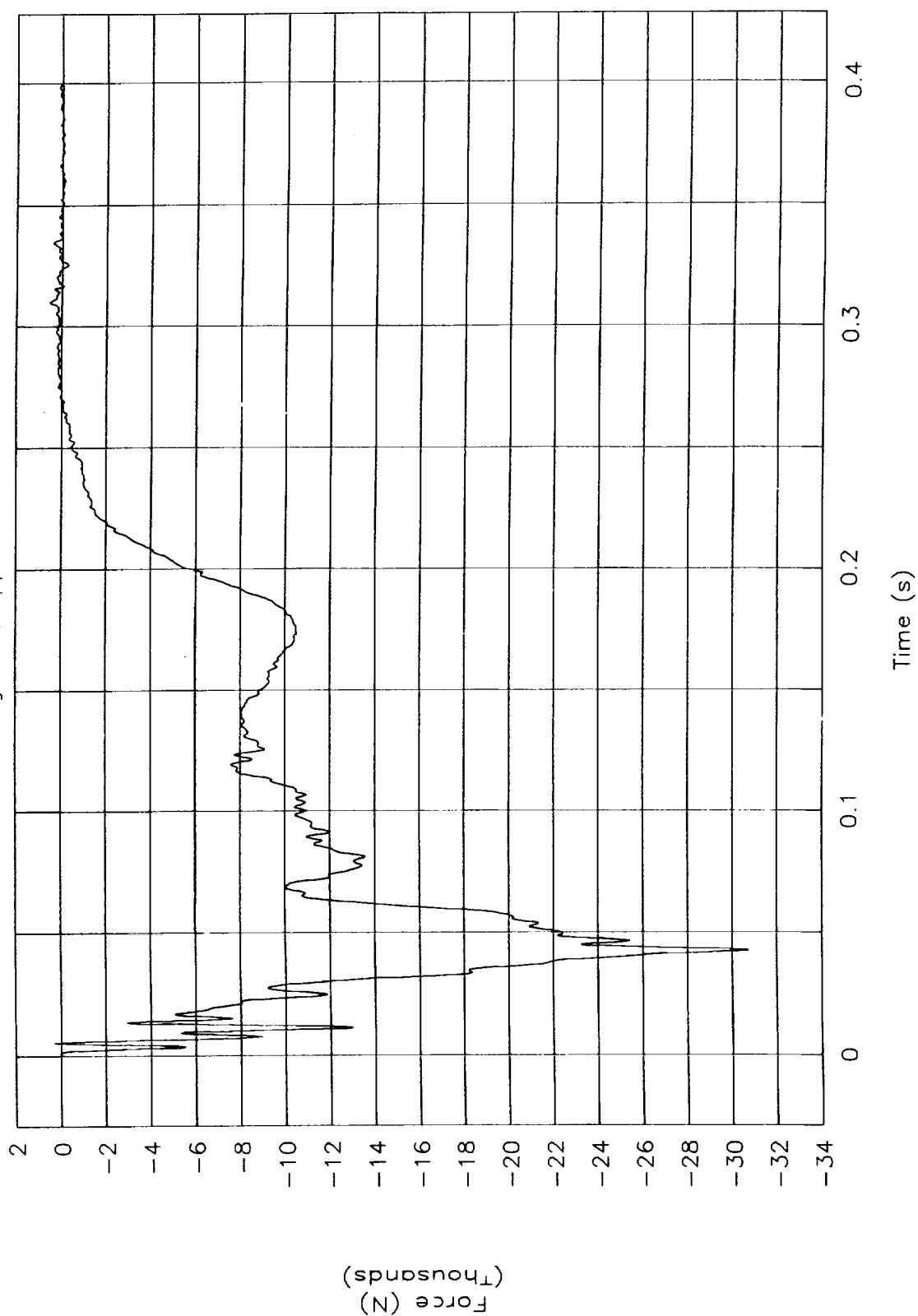


Figure 96. Rigid pole, middle segment, upper load cell force vs. time, test 95S008.

TEST NO. 95S008

Middle segment, lower load cell

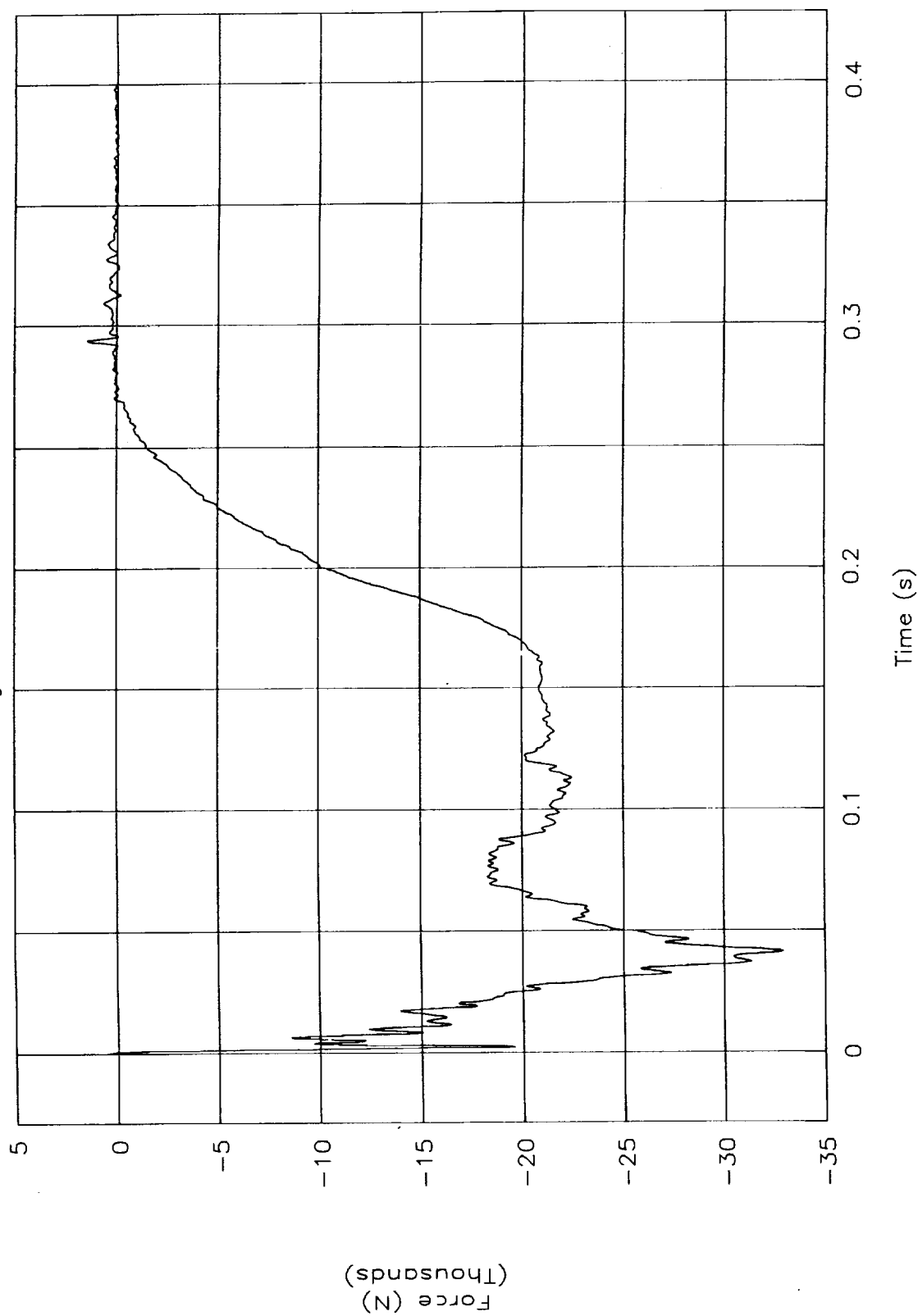


Figure 97. Rigid pole, middle segment, lower load cell force vs. time, test 95S008.

TEST NO. 95S008

Bottom segment, upper load cell

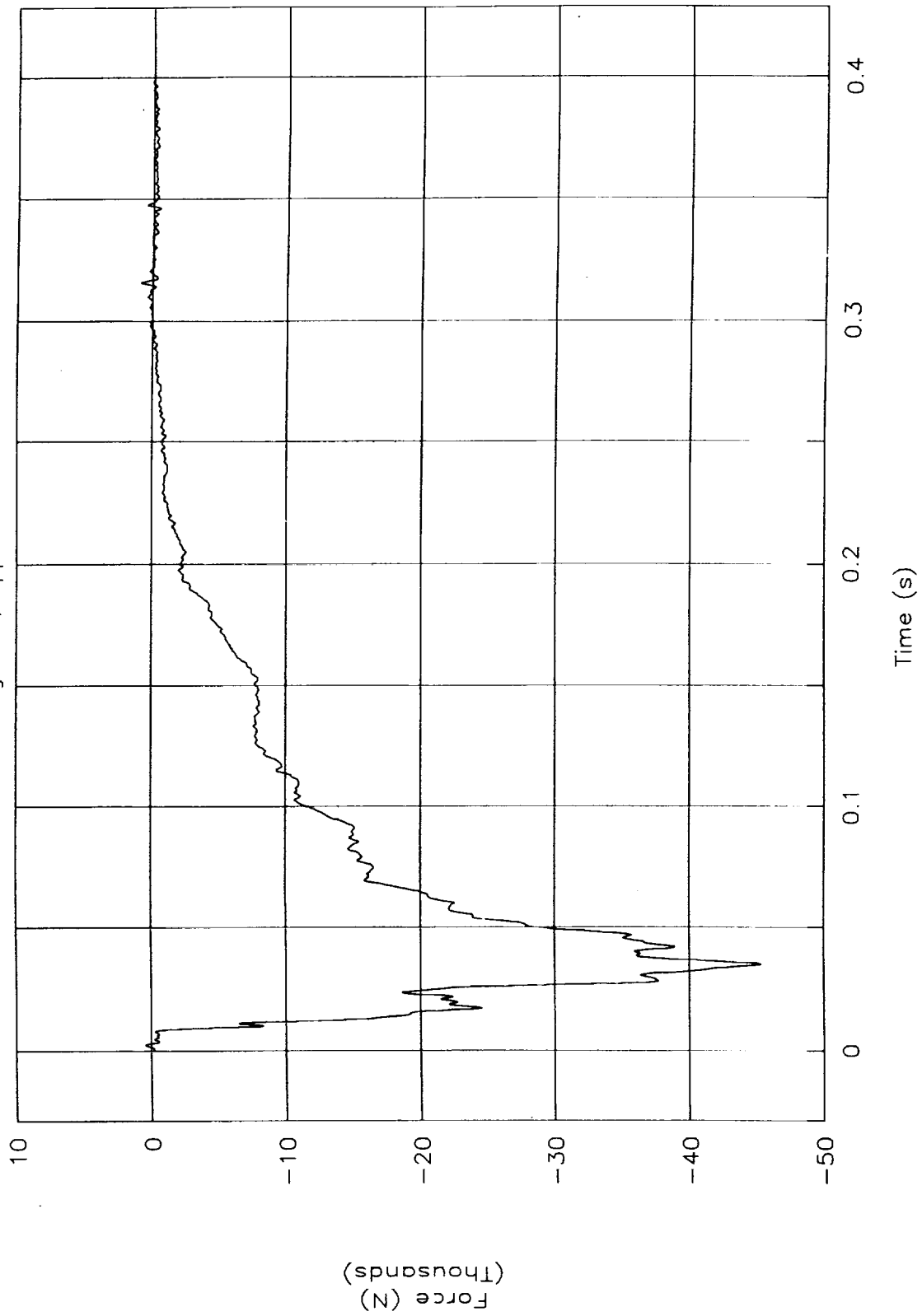


Figure 98. Rigid pole, bottom segment, upper load cell force vs. time, test 95S008.

TEST NO. 95S008

Bottom segment, lower load cell

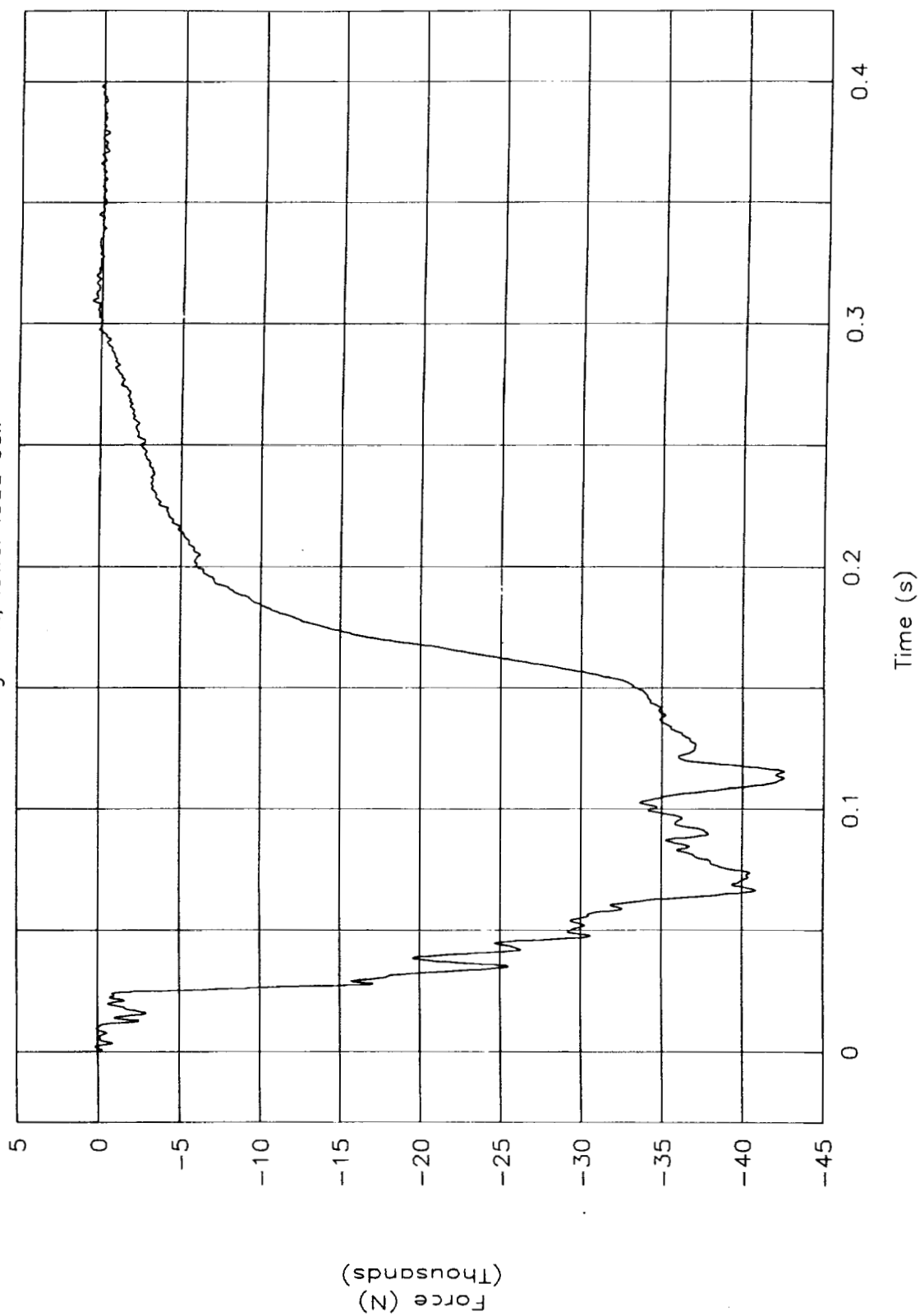


Figure 99. Rigid pole, bottom segment, lower load cell force vs. time, test 95S008.

TEST NO. 95S008

Load cells, force vs. time

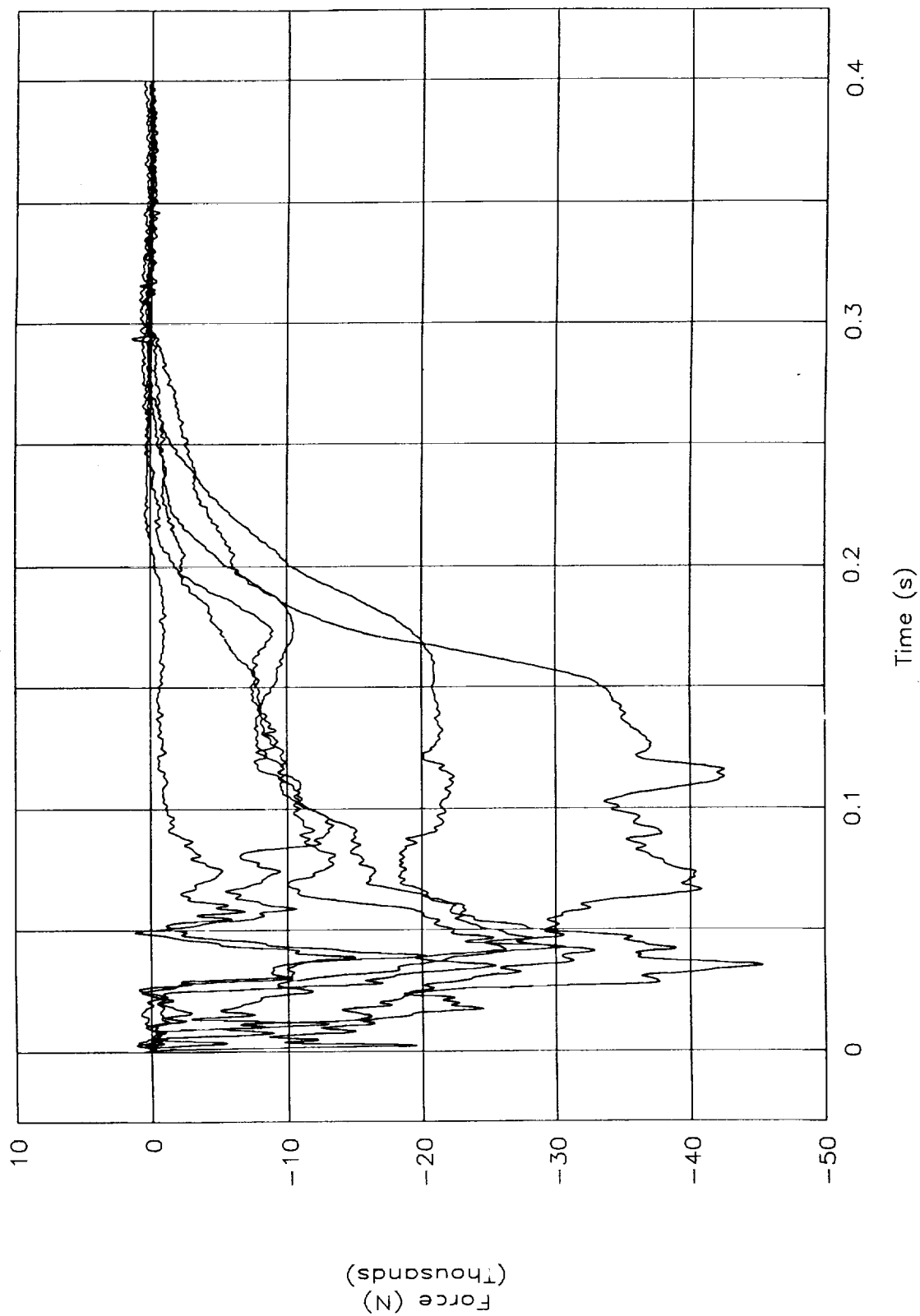


Figure 100. Rigid pole, all load cells, force vs. time, test 95S008.

TEST NO. 95S008

Resultant load height vs. time

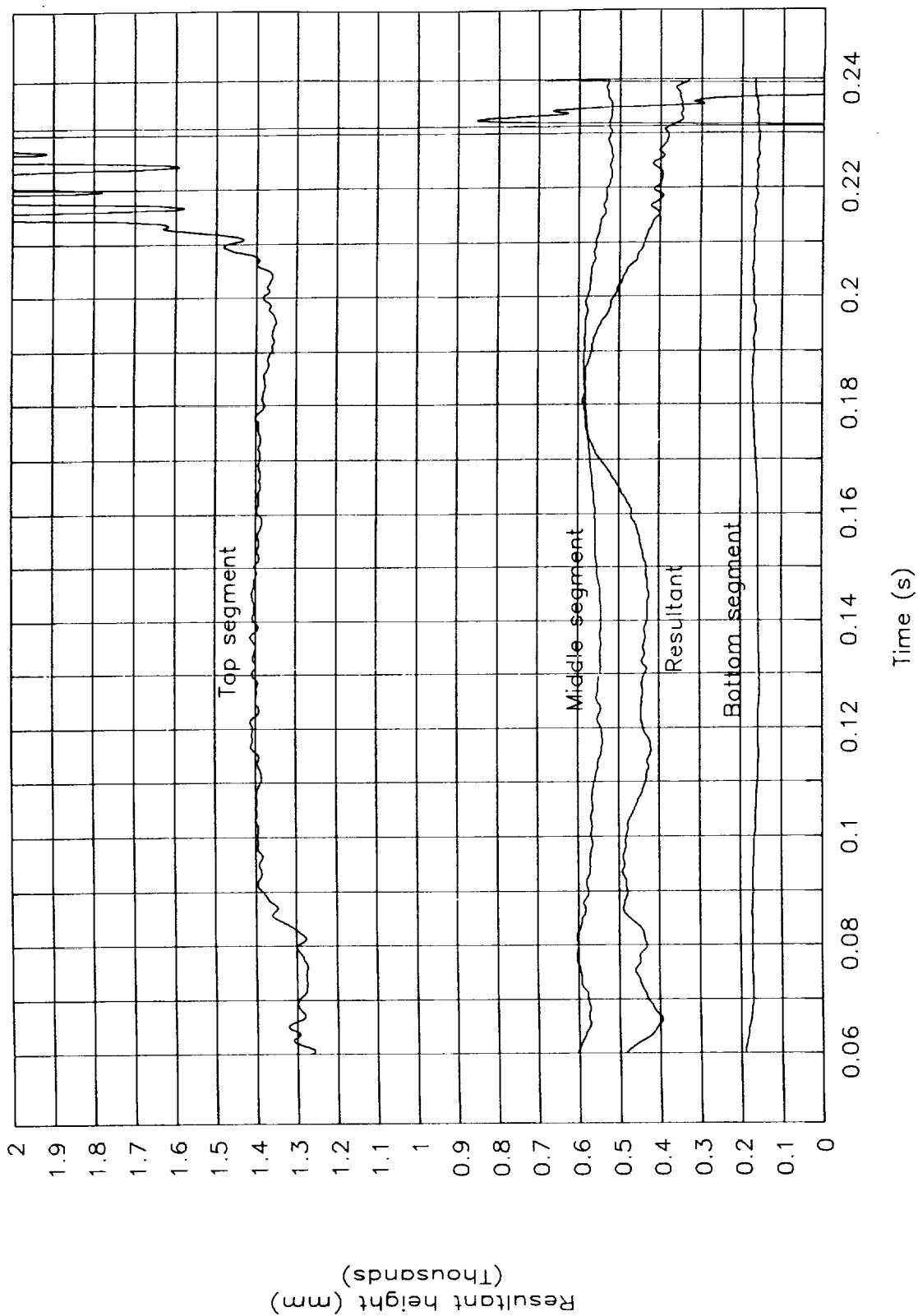


Figure 101. Rigid pole, resultant load heights vs. time, test 95S008.

TEST NO. 95S008

Resultant load height, top segment

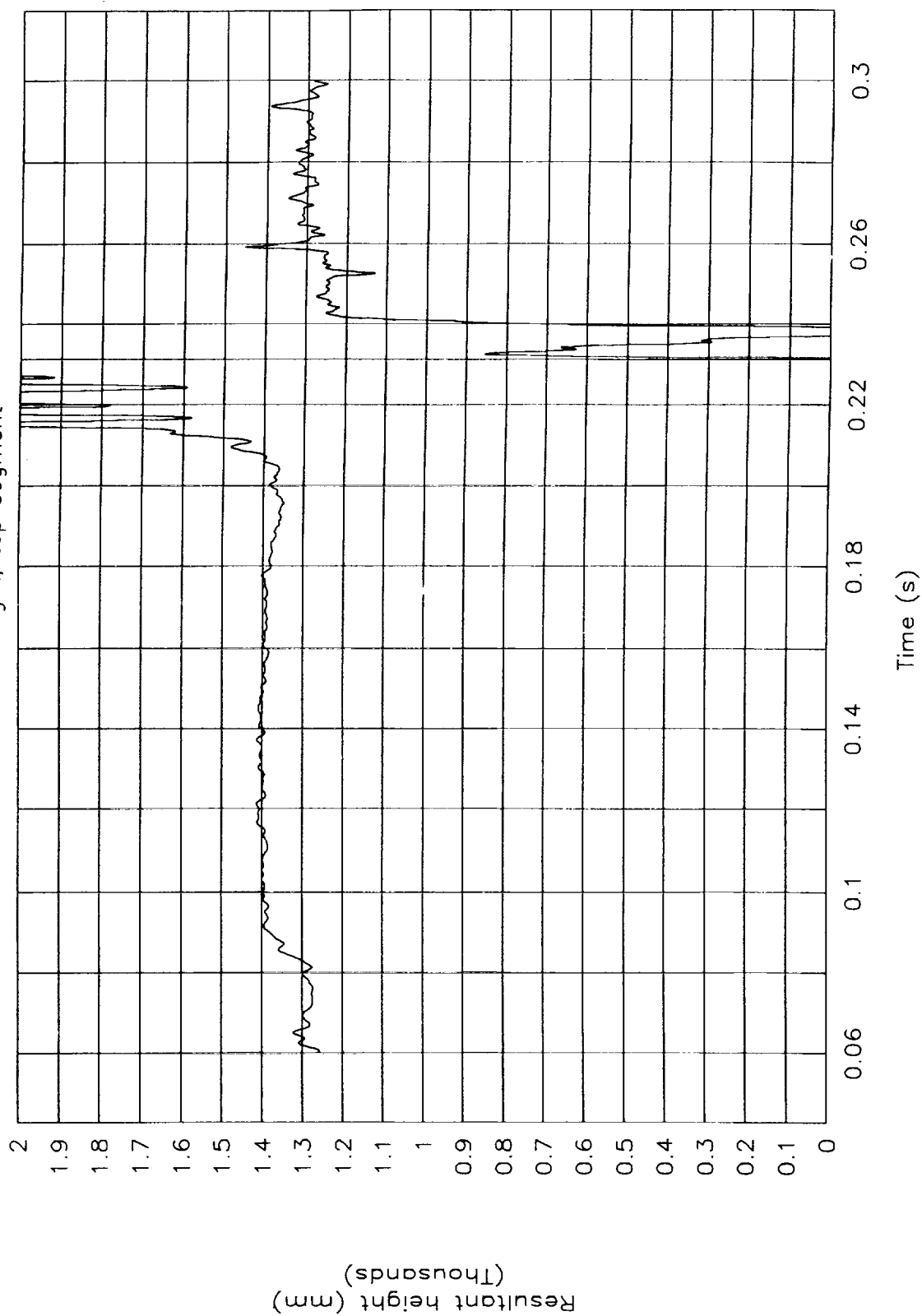


Figure 102. Rigid pole, resultant load height vs. time, top segment, test 95S008.

TEST NO. 95S008

Resultant load height, middle segment

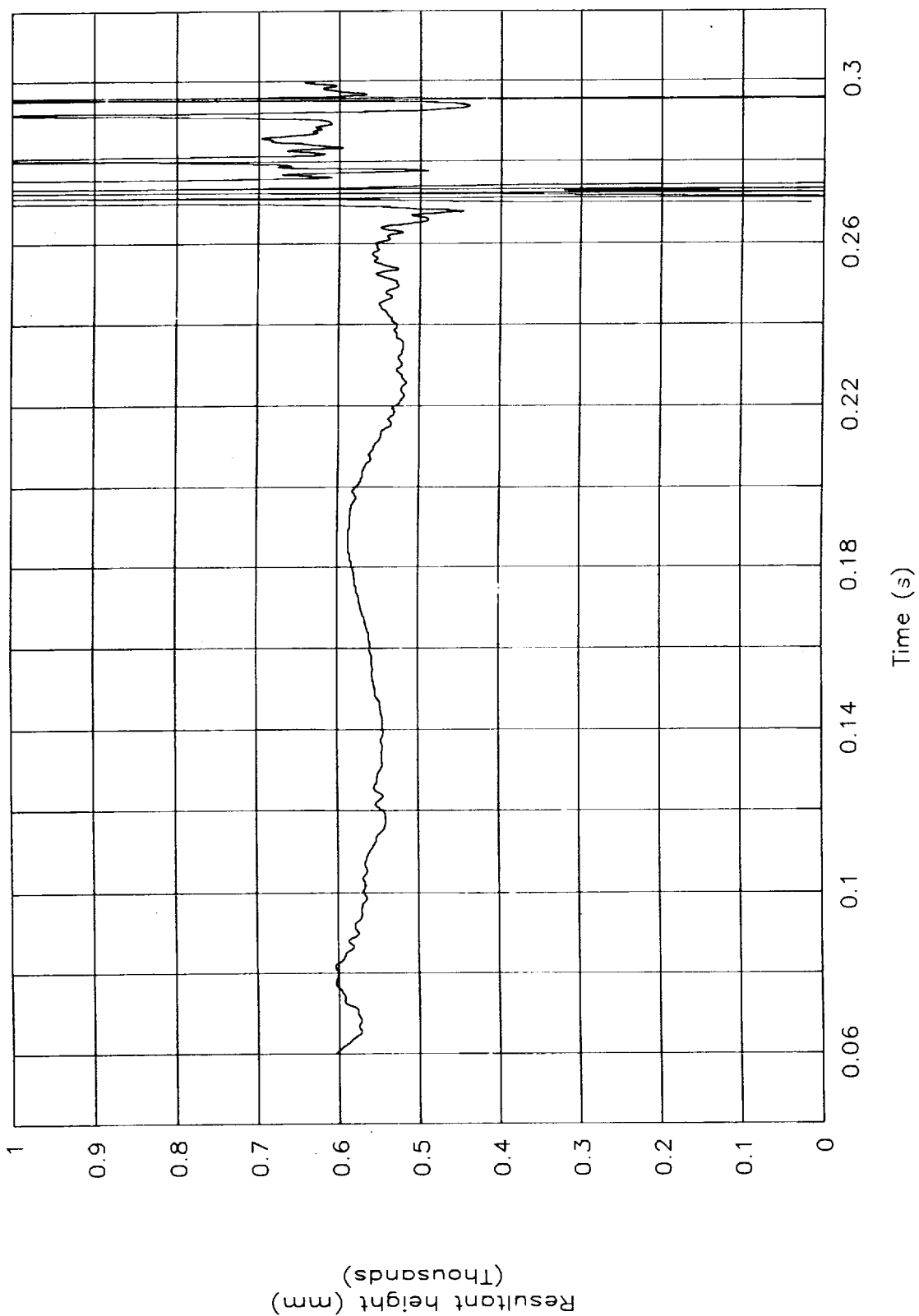


Figure 103. Rigid pole, resultant load height vs. time, middle segment, test 95S008.

TEST NO. 95S008

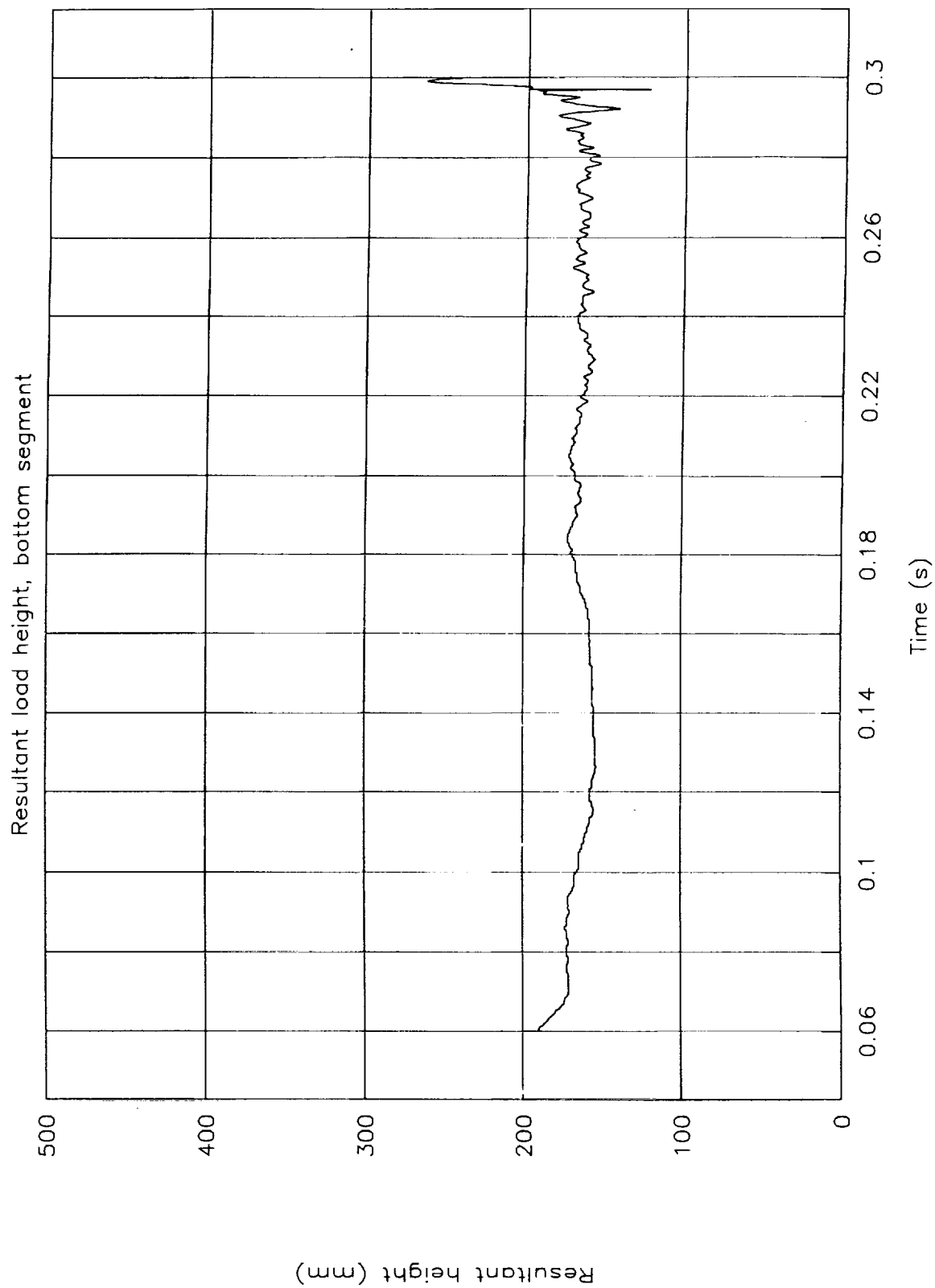


Figure 104. Rigid pole, resultant load height vs. time, bottom segment, test 95S008.

REFERENCES

Number

- (1) NHTSA. *Laboratory Test Procedure for Federal Motor Vehicle Safety Standard 214*, National Highway Traffic Safety Administration, Washington, D.C., May 1992.
- (2) H. E. Ross, Jr., D.L. Sicking, R.A. Zimmer, and J.D. Michie. *NCHRP Report 350: Recommended Procedures for the Safety Performance Evaluation of Highway Features*, Transportation Research Board, Washington, D.C., 1993.