PB95263844

RESOURCE MATERIALS

Ford Festiva Center Impacts with a Narrow Fixed Object (Rigid Pole)

U.S. Department of Transportation
Federal Highway Administration

Publication No. FHWA-RD-95-040
August 1995

REPRODUCED BY: NTIS
U.S. Department of Commerce
National Technical Information Service
Springfield, Virginia 22161

Technical Report Documentation Page

1. Report No.	2. G[illegible]	3. Recipient's Catalog No.
FHWA-RD-95-040	PB95-263844	

4. Title and Subtitle	5. Report Date
FORD FESTIVA CENTER IMPACTS WITH A NARROW FIXED OBJECT (RIGID POLE)	August 1995
	6. Performing Organization Code
7. Author(s) Christopher M. Brown	8. Performing Organization Report No.
9. Performing Organization Name and Address Mitech Incorporated 9430 Key West Avenue Rockville, MD 20850	10. Work Unit No. (TRAIS) 3A5F3142
	11. Contract or Grant No. DTFH61-94-C-00008
12. Sponsoring Agency Name and Address Office of Safety and Traffic Operations R&D Federal Highway Administration 6300 Georgetown Pike McLean, VA 22101-2296	13. Type of Report and Period Covered Test Report, Summer 1991-Spring 1994
	14. Sponsoring Agency Code

15. Supplementary Notes

Contracting Officer's Technical Representative (COTR) - Richard King, HSR-20

16. Abstract

This document contains the results from five crash tests conducted at the Federal Outdoor Impact Laboratory (FOIL) located at the Turner-Fairbank Highway Research Center in McLean, Virginia. The crash tests involved five Ford Festiva two-door sedans,which have been chosen as the 820C class vehicle, impacting an instrumented rigid pole. One test was performed in the summer of 1991, two tests in the fall of 1992, and two tests in the spring of 1994. The tests were performed to obtain a representative data set of Ford Festiva crush characteristics. The final results are presented as average data plots of the Ford Festiva's crush characteristics. The average curves will represent the Ford Festiva's crush characteristics to be replicated by a surrogate test vehicle and modeled using computer simulation.

17. Key Words	18. Distribution Statement
Acceleration, crush characteristics, peak force, energy, FOIL, load cell.	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

[illegible]y Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
[illegible]lassified	Unclassified	52	

OT F 1700.7 (8-72) Reproduction of completed page authorized

Preceding Page Blank

FOREWORD

This report documents a research study conducted at the Federal Outdoor Impact Laboratory (FOIL) to determine the crush characteristics of the 820c class vehicle. Ford Festiva two-door sedans were used as representative vehicles in this class for NCHRP 350 testing. Five tests were conducted in support of the computer simulation effort to model this vehicle. All of the vehicles were crash tested in the frontal collision condition into the FOIL's instrumented rigid pole. Each vehicle was aligned differently to the right and left of center to strike the "hard" and "soft" spots of the vehicle. The results of the rigid pole tests function as a baseline for modeling the front-end crush of the Ford Festiva.

This report (FHWA-RD-95-040) contains test data, photographs taken with high-speed film, and a summary of the test results for each of the 5 tests conducted. All of the tests were conducted at a nominal speed of 32 km/h (20 mi/h).

This report will be of interest to all States DOT's, FHWA headquarters, regional and division personnel, and highway safety researchers interested in the crashworthiness of roadside sign systems.

Lyle Saxton
Director, Office of Safety and Traffic
Operations Research and Development

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof. This report does not constitute a standard, specification, or regulation.

The United States Government does not endorse products or manufacturers. Trade and manufacturers' names appear in this report only because they are considered essential to the object of the document.

Preceding Page Blank

Preceding Page Blank

ii

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
	AREA			
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
	VOLUME			
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
	ILLUMINATION			
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
	FORCE and PRESSURE or STRESS			
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

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

APPROXIMATE CONVERSIONS FROM SI UNITS

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

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

(Revised September 1993)

TABLE OF CONTENTS

Preceding Page Blank

LIST OF FIGURES

Figure No. Page

LIST OF TABLES

1. BACKGROUND

In the summer of 1991, four crash tests were performed using four different lightweight vehicles and the Federal Outdoor Impact Laboratory's (FOIL) instrumented rigid pole. The vehicles used were a 1989 Daihatsu Charade, a 1990 Geo Metro, a 1988 Ford Festiva, and a 1989 Subaru Justy. The tests were performed to obtain the frontal crush characteristics of each vehicle. One of the vehicles—the Ford Festiva—was selected as the model for the development of a surrogate vehicle to be used for testing roadside safety hardware. In the fall of 1992, two additional crash tests were conducted to obtain more data on the frontal crush characteristics of the Ford Festiva. The data from the crash tests were used to model a surrogate vehicle and to provide electronic data in support of the development and validation of a computer simulation model of the Ford Festiva.[1] Three Festiva crash tests provided a baseline data base for modeling; however, to ensure the repeatability between vehicles as well as to further broaden the data base of the Festiva crash test data, two more Festiva crash tests were conducted during the spring of 1994 using the same test parameters as the previously mentioned tests.

2. SCOPE

This document contains results from five crash tests performed at the Federal Outdoor Impact Laboratory (FOIL) located at the Turner-Fairbank Highway Research Center (TFHRC) in McLean, Virginia. The five crash tests were conducted over a period of 2.5 years. One test was performed in the summer of 1991 and the other two tests were performed in the fall of 1992. The remaining two crash tests were conducted in the spring of 1994. The five crash tests involved a Ford Festiva impacting the FOIL instrumented rigid pole. The tests were performed to obtain a representative data set of Ford Festiva crush characteristics. This report concentrates on the results from the two tests conducted in 1994. Details on the first three Festiva crash tests are contained within the report *Crush Characteristics of the Ford Festiva.* The results from each of the two crash tests are presented as acceleration vs. time, displacement vs. time, force vs. displacement, and peak force vs. delta velocity data plots derived from accelerometers positioned at the vehicle center of gravity. In addition to results from each individual test, the crush characteristics of each Festiva are overlaid in data plots of force vs. time, acceleration vs. time, displacement vs. time, force vs. displacement, and energy vs. time to demonstrate the consistent behavior between Festivas. The final results are presented as average data plots of the Ford Festiva's crush characteristics. The average curves will represent the Ford Festiva's crush characteristics to be replicated by a surrogate test vehicle as well as modeled by computer simulation. All five crash tests are included in the average curves and discussions.

3. MATRIX

Five vehicle crash tests were performed using five Ford Festiva vehicles impacting a rigid pole head-on. Each Festiva was accelerated to a nominal

Preceding Page Blank

test speed of 32 km/h with the centerline of the vehicle striking the centerline of the rigid pole. Table 1 summarizes the test conditions.

Table 1. Test matrix.

Test Number	Test Date	Test Vehicle	Test Speed	Test Article
91F049	10-08-91	Ford Festiva	32 km/h	FOIL Rigid Pole
92F032	10-13-92	Ford Festiva	32 km/h	FOIL Rigid Pole
92F033	10-15-92	Ford Festiva	32 km/h	FOIL Rigid Pole
94F001	03-07-94	Ford Festiva	32 km/h	FOIL Rigid Pole
94F002	03-16-94	Ford Festiva	32 km/h	FOIL Rigid Pole

4. VEHICLE

The test vehicles used for these tests were two 1988, a 1989, and two 1990 Ford Festivas. The Ford Festivas were front-wheel drive, two-door sedans with gasoline engines and manual transmissions. Prior to the tests, the vehicles' fluids were drained and the inertial properties were measured. The inertial properties were measured twice. The first set of measurements was taken with the vehicles in an "as-received" condition. That is, the condition in which the FOIL received the vehicles. The vehicles were then ballasted for testing with instrumentation and ballast weight (added if needed) to increase the vehicle test weight to 816 kg. The inertial properties were then remeasured. The vehicles' inertial properties and other physical characteristics "as received" and "as ballasted" are presented in table 2 and table 3, respectively.

Table 2. Inertial properties of the Ford Festivas "as received."

Test Number	Curb Weight (kg)	Cg Height (mm)	Cg behind front axle (mm)	Moments of Inertia ($kg-m^2$) Roll	Pitch	Yaw	Bumper Height (mm)	Wheel Base (mm)
91F049	763	572	851	270	884	999	483	2260
92F032	812	533	818	271	982	1297	483	2260
92F033	783	584	856	336	1026	1248	483	2260
94F001	782	523	818	292	994	1215	483	2260
94F002	784	536	813	281	994	1296	483	2260

Table 3. Inertial properties of the Ford Festivas "as ballasted."								
Test Number	Test Weight (kg)	Cg Height (mm)	Cg behind front axle (mm)	Moments of Inertia ($kg-m^2$)			Bumper Height (mm)	Wheel Base (mm)
				Roll	Pitch	Yaw		
91F049	816	576	830	211	898	967	483	2260
92F032	816	564	830	228	949	1297	483	2260
92F033	816	533	856	298	1033	1296	483	2260
94F001	816	548	851	192	910	1262	483	2260
94F002	816	574	820	160	876	1277	483	2260

5. RIGID POLE

For each of these tests, the Ford Festivas struck the FOIL instrumented rigid pole. The centerline of each automobile was aligned with the centerline of the rigid pole.

The pole was designed as a narrow rigid object mounted to the FOIL runway. The rigid pole was designed to measure vehicle crush characteristics. The impact face consisted of a semicircular section of extra-heavy-walled, 203-mm pipe (219mm in diameter) supported by two connecting rods that ran through guide bearings and were attached to load cells. The force from both load cells were added together to obtain the total force. A sketch of the rigid pole is presented in figure 1.

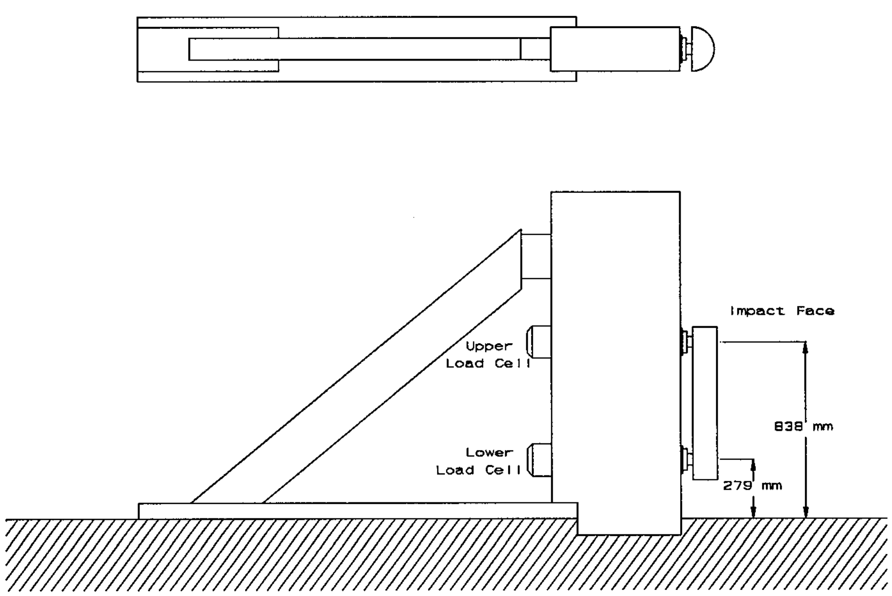


Figure 1. FOIL instrumented rigid pole.

6. DATA ACQUISITION

For each of the five tests, speed trap, accelerometer, load cell, and high-speed film data were collected to measure the crush characteristics of the Ford Festiva.

a. Speed Trap. The speed trap was used to determine the vehicular speed just prior to impact. The center of the speed trap was placed approximately 3.7 m before the rigid pole. The speed trap consisted of a set of five contact switches fastened to the runway at 0.3-m intervals. As the vehicles passed over the switches, electronic pulses were recorded on analog tape.

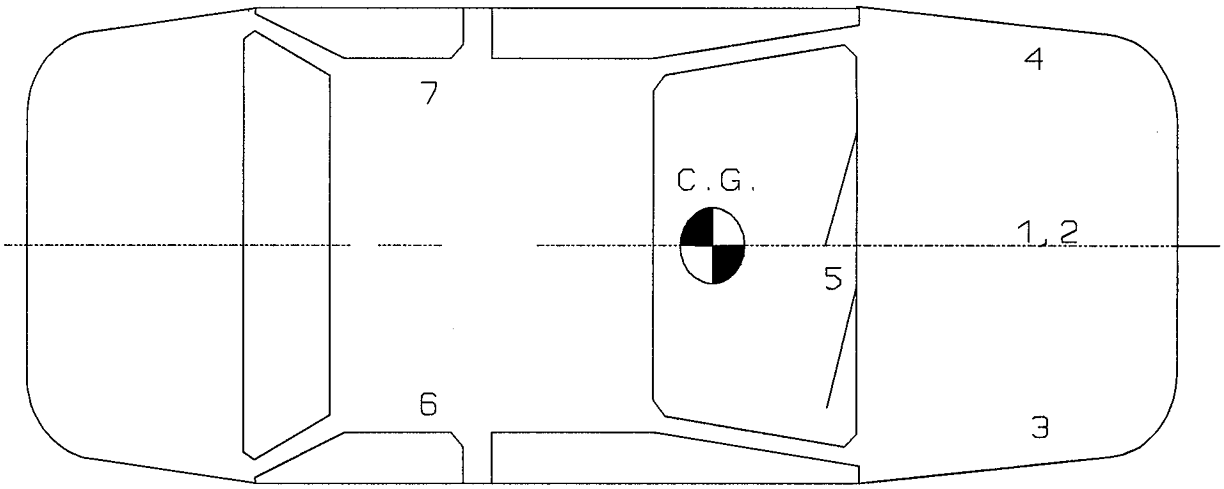
b. Accelerometers and Load Cells. For the five Festiva crash tests, data from four 100-g accelerometers and two load cells were recorded on the FOIL analog tape recorder via umbilical cables. The 100-g accelerometers were mounted to a steel block located as close as possible to the Festiva's center of gravity. The two load cells were attached to the rigid pole 280 mm and 838 mm above ground (figure 1). The data were collected via two umbilical cables, one between the test vehicle's accelerometers and the recording system, and one between the instrumented rigid pole's load cells and the recording system. For tests 94F001 and 94F002, an additional seven 2000-g accelerometers and a triaxial rate transducer were affixed to vehicles in accordance with Federal Motor Vehicle Safety Standard 208 (FMVSS 208).[2] The data from the 2000-g accelerometers and the rate transducer were recorded by the FOIL on-board data acquisition system. The on-board data acquisition system (ODAS) is a self-contained system. The ODAS pre-filters data at 4000 Hz digitally samples the signals at 12,500 Hz and stores 64,000 samples per channel. A summary of the transducers used, their limits and their locations, is presented in figure 2. A contact switch was taped to the impact face of the rigid pole in order to synchronize all the transducer data with the time of impact. The pulse from the contact switch was recorded by the analog tape recorder. In addition to the speed traps, transducers, and the impact contact switch, a 1-kHz timing signal was recorded to ensure that the tape drive system of the tape recorder was functioning properly.

c. High-Speed Photography. The tests were photographed using five high-speed cameras and one real-time camera. All high-speed cameras used Kodak high-speed daylight 2253 color film, while the real-time camera used Kodak 7239 color film. Black-and-white 35-mm prints and color slides were also obtained. Camera configuration and placement is summarized in table 4.

7. DATA ANALYSIS

Data were gathered and analyzed from speed traps, transducers, and high-speed photography.

a. Speed Trap. As the vehicles passed over the speed trap, electronic pulses from the five contact switches were recorded to analog tape. The tape was played back through a Data Translation A/D converter in conjunction with a COMPAQ SYSTEMPRO computer. The time intervals between the first pulse and



Location	Data	Full scale	(X,Y,Z) position* (mm)
1	Top of motor	2000 g	203, 648, 495
2	Bottom of motor	2000 g	200, 750, 10
3	Right control arm	2000 g	127, 64, 25
4	Left control arm	2000 g	127, 1435, 25
5	Top of instrument panel	2000 g	-520, 750, 584
6	Right side under rear seat	2000 g	-1778, 394, 140
7	Left side under rear seat	2000 g	-1778, 1105, 140
CG	Triaxial rate transducer, pitch, roll, yaw	500 deg/s	-787, 750, 216
CG	Longitudinal acceleration	100 g	-787, 750, 51
CG	Lateral acceleration	100 g	-813, 660, 51
CG	Vertical acceleration	100 g	-813, 750, 102
CG	Longitudinal acceleration	100 g	-787, 750, 76
Pole	Load cell, pole force	111 kN	Upper load cell 838 mm above ground
Pole	Load cell, pole force	222 kN	Lower load cell 279 mm above ground
na	Tape switches	1.5 V	Runway
* Referenced from the center of the right wheel hub.			

Figure 2. Summary of transducers and their locations.

Table 4. Camera configuration and placement.				
Camera	Type	Film speed frames/s	Lens (mm)	Location
1	LOCAM II	500	75	Right 90° to impact
2	LOCAM II	500	50	Right 90° to impact
3	LOCAM II	500	80	Right side 45° to impact
4	LOCAM II	500	50	Left side 45° to impact
5	LOCAM II	500	10	Overhead
6	BOLEX	24	ZOOM	Documentary
7	CANNON AE-1	still	ZOOM	Documentary
8	CANNON AE-1	still	ZOOM	Documentary

each of the subsequent four pulses were then obtained using the analysis software provided with the A/D converter. The displacement vs. time data were then entered into a computer spreadsheet and a linear regression was performed to determine the best-line fit of the data points. The impact velocity was then determined from the slope of the best-line fit of the displacement vs. time-curve data.

b. Accelerometers and Load Cells. Data from the transducers listed in figure 2 were either recorded on analog tape or by the ODAS system during the crash test. The data recorded on tape were played back from the analog tape through an 8-pole Butterworth low-pass filter with a cut-off frequency of 500 Hz and input to an A/D converter with a sampling rate of 2000 Hz. The data from each system were converted to the ASCII format and were processed using an array of FORTRAN algorithms to determine and remove the zero-bias of each data signal and to filter each signal. The filter applied was a digital Butterworth low-pass filter with a cut-off frequency of 300 Hz. The final processed data were imported into a computer spreadsheet for analysis.

The accelerometer data from accelerometers located at the vehicle's center of gravity were integrated twice to produce velocity and displacement traces. A force vs. displacement trace was generated by multiplying the acceleration data by the mass of the vehicle and plotting the product with the previously produced displacement data. The peak force was determined by holding the force constant until a higher force was reached. The peak force was then plotted with the change in velocity of the vehicle to obtain the peak force vs. delta velocity trace.

The load cells measured forces at two separate locations on the rigid pole. The two forces obtained were summed together to generate the entire force for the event. Using the force vs. time trace, an acceleration trace was produced by dividing the force vs. time trace by the mass of the vehicle. Velocity and displacement traces were generated by a single and double integration of the acceleration trace. Using the same calculations and methods as performed on the accelerometer data, a force vs. displacement and a peak force vs. delta velocity trace were generated for the load cell data.

c. <u>High-Speed Photography.</u> Each crash event was recorded on 16-mm film by five high-speed cameras. Primarily, the camera perpendicular to the vehicle trajectory with a 50-mm lens was the only camera used for high-speed film analysis. Analysis of each crash event was performed using an NAC Film Motion Analyzer model 160-F in conjunction with an IBM PC-AT. The motion analyzer digitized the 16-mm film, reducing the image to cartesian coordinates. The cartesian coordinate data were then imported into a computer spreadsheet for analysis. Using the cartesian coordinate data, a displacement vs. time plot of each test was obtained. A linear regression was performed on the first 20 data points of the displacement vs. time traces to determine the impact velocities of the vehicles. The entire displacement vs. time traces were then differentiated to produce a velocity trace. The velocity data were then exported from the spreadsheet and filtered using a digital Butterworth low-pass filter with a cut-off frequency of 20 Hz. The filtered velocity was imported into the original spreadsheet and a second differentiation was performed on the filtered velocity trace to produce an acceleration trace.

The impact force was determined by multiplying the acceleration trace by the mass of the vehicle. A force vs. displacement trace was produced by plotting the force data with the displacement data. Using the same calculations and methods as performed on the accelerometer and load cell data, a force vs. displacement and a peak force vs. delta velocity trace were generated for the film data.

8. RESULTS

The Ford Festivas were accelerated to a nominal velocity of 32 km/h prior to impacting the rigid pole. The centerline of each Festiva was aligned with the centerline of the rigid pole. During each of the tests, the test vehicles rebounded with a small negative velocity. Table 5 summarizes the impact speed, static crush measured after the test, load cell data, and accelerometer data. The crush values under the load cell data, accelerometer data, and film data headings in table 5 were the maximum values obtained from the double integration of the acceleration traces.

Table 5. Summary of results from Festiva testing.

Test Number	Impact Speed (m/s)		Load cell data			Accelerometer data			Film data			Static Crush (m)
	Speed Trap	Film	Max Force (kN)	ΔV m/s	Max Crush (mm)	Max Force (kN)	ΔV m/s	Max Crush (mm)	Max Force (kN)	ΔV m/s	Max Crush (mm)	
91F049	9.4	9.4	183	12.0	470	274	12.4	523	210	11.7	510	419
92F032	9.4	9.3	180	12.3	447	250	12.2	518	206	11.3	490	394
92F033	9.3	9.3	182	12.3	470	270	12.4	536	191	11.7	508	394
94F001	9.4	9.4	158	11.6	440	261	12.3	500	204	11.0	460	394
94F002	9.8	9.6	178	12.2	460	287	12.4	530	196	11.7	490	400

Data plots of acceleration vs. time, displacement vs. time, force vs. displacement, and peak force vs. delta velocity from tests 94F001 and 94F002 are presented in figures 3 through 10. All three data systems are shown for each test. Acceleration data from the seven FMVSS 208 accelerometers (locations 1 through 7 from figure 2) are presented in figures 11 through 22. The accelerometers at locations 1 and 3 were damaged during test 94F001. Pre- and post-test photographs of each test are shown in figures 23 through 26.

9. DISCUSSION

The three methods for measuring the impact event agree up until the vehicles reach their maximum crush and begin to rebound. This is evident in the displacement traces. The traces diverge just as they begin to reach the maximum crush. All of the plots will show this difference between methods because the accelerometer and the film data tend to exaggerate the true force. The vehicles are extremely flexible relative to the rigid pole, and both the accelerometer and the film data measure the shock wave as it vibrates through the vehicle. The shock wave produces a "ringing" in the accelerometer and high-speed film data and is what causes exaggeration in the true force.

The crush characteristic curves for each Festiva are compared in figures 27 through 34. The Festivas show repeatable results between vehicles. The five crash tests represent the Festiva well. If a surrogate vehicle could be modeled such that its results would fall within the results of these five crash tests, it would be reasonable to believe that the Festiva was successfully modeled. Therefore, average curves representing the crush characteristics of the Ford Festiva would be a good target data set to be replicated by a surrogate vehicle and to be modeled by computer simulation. Average plots of the Ford Festiva's crush characteristics are presented in figures 35 through 40. The average plots were generated by averaging the five acceleration vs. time (accelerometer data) traces and the five force vs. time (load cell data) traces from the Festiva crash tests then double integrating the traces to produce the crush characteristic curves. The energy curves were generated by multiplying the vehicle or pole forces by the incremental displacement (crush) of the vehicle.

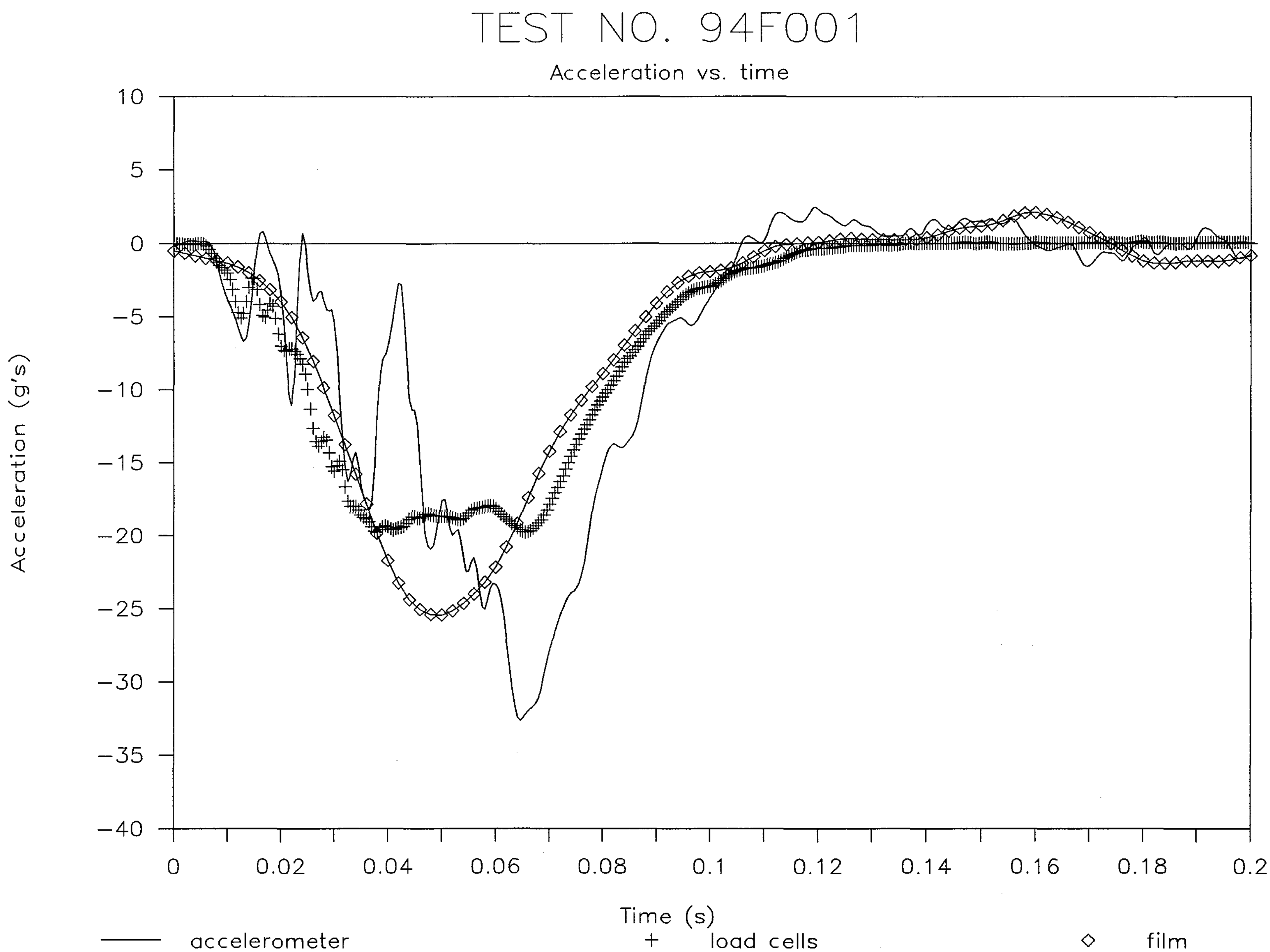


Figure 3. Acceleration vs. time for test 94F001.

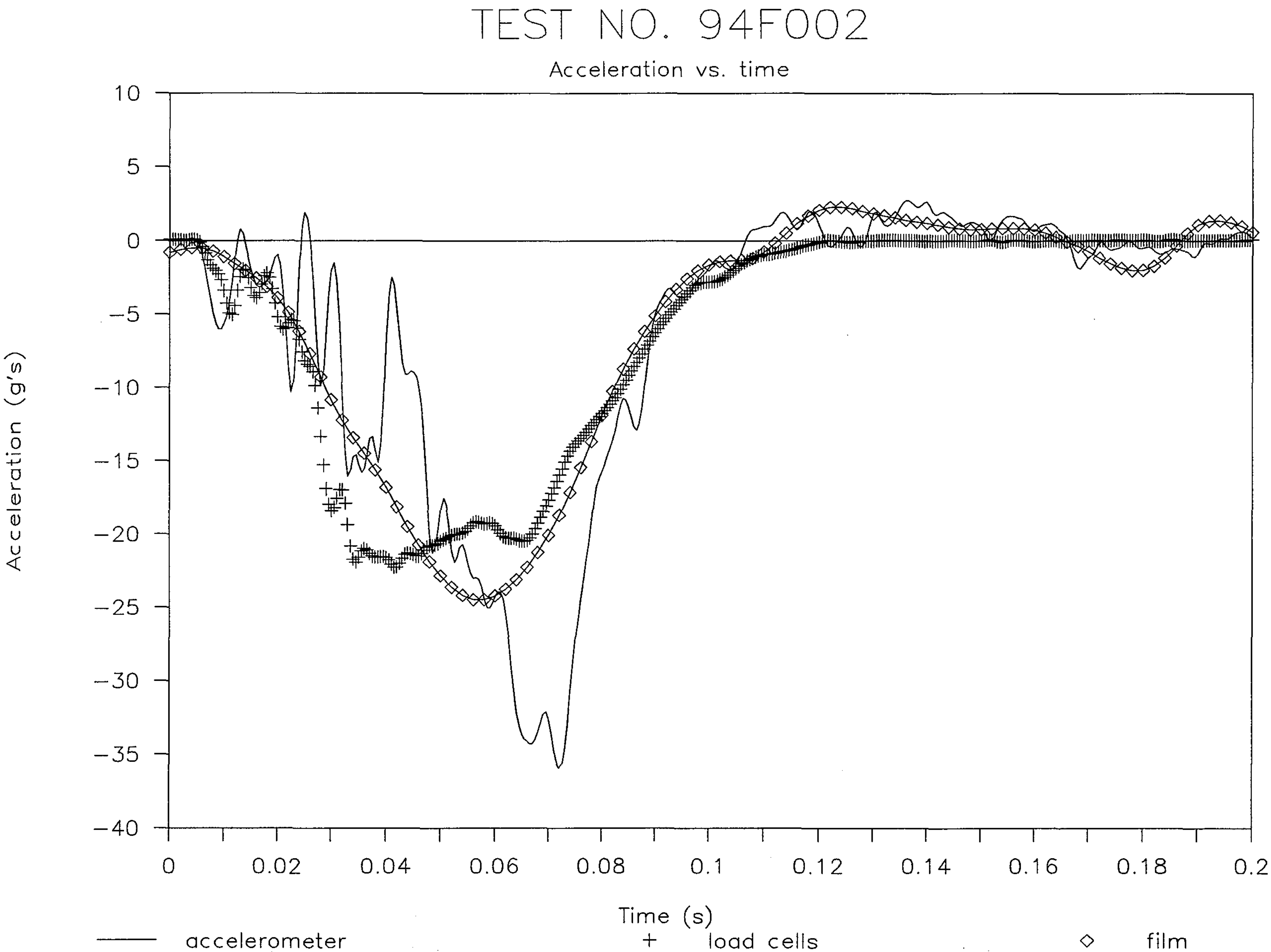


Figure 4. Acceleration vs. time for test 94F002.

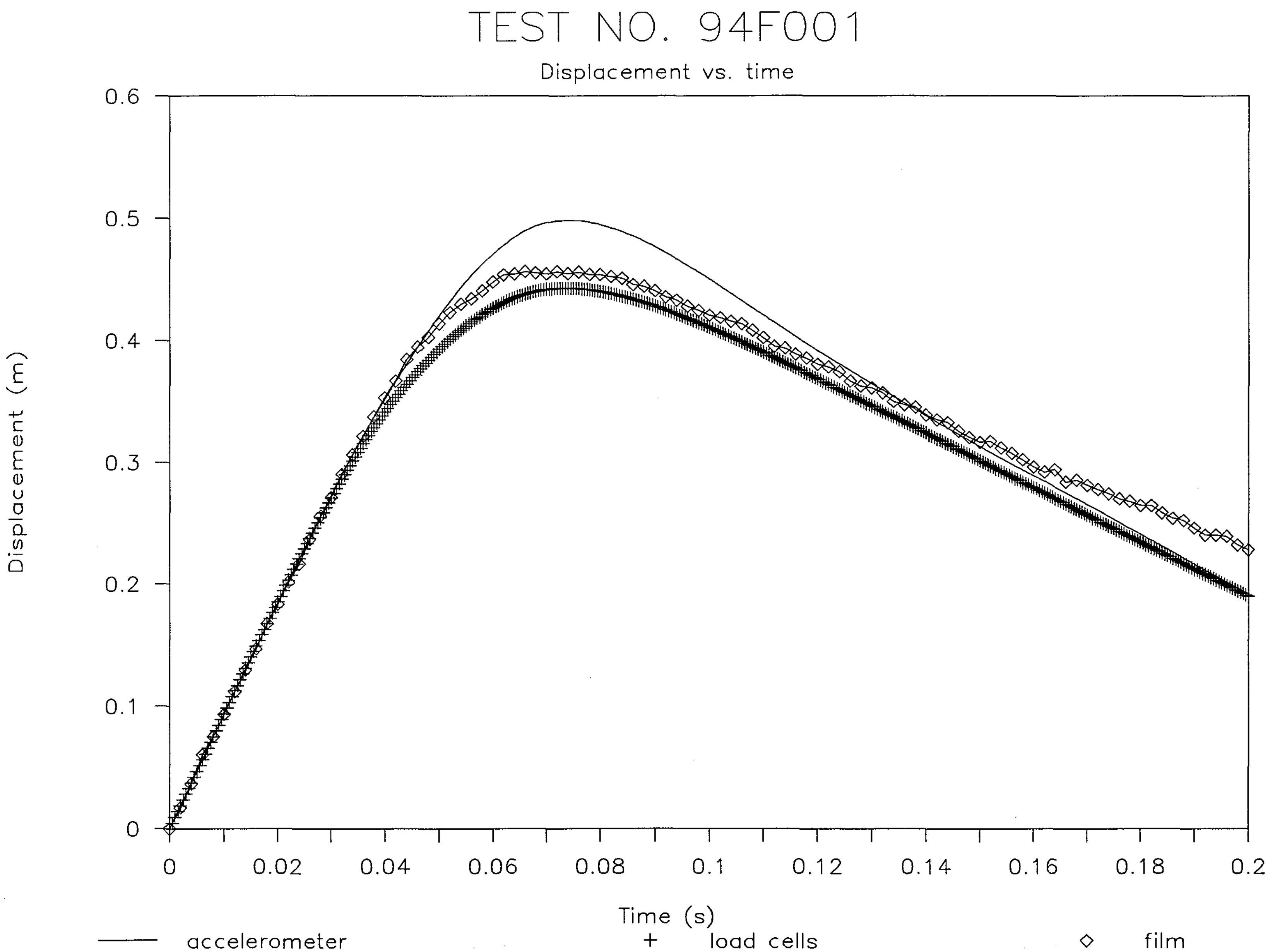


Figure 5. Displacement vs. time for test 94F001.

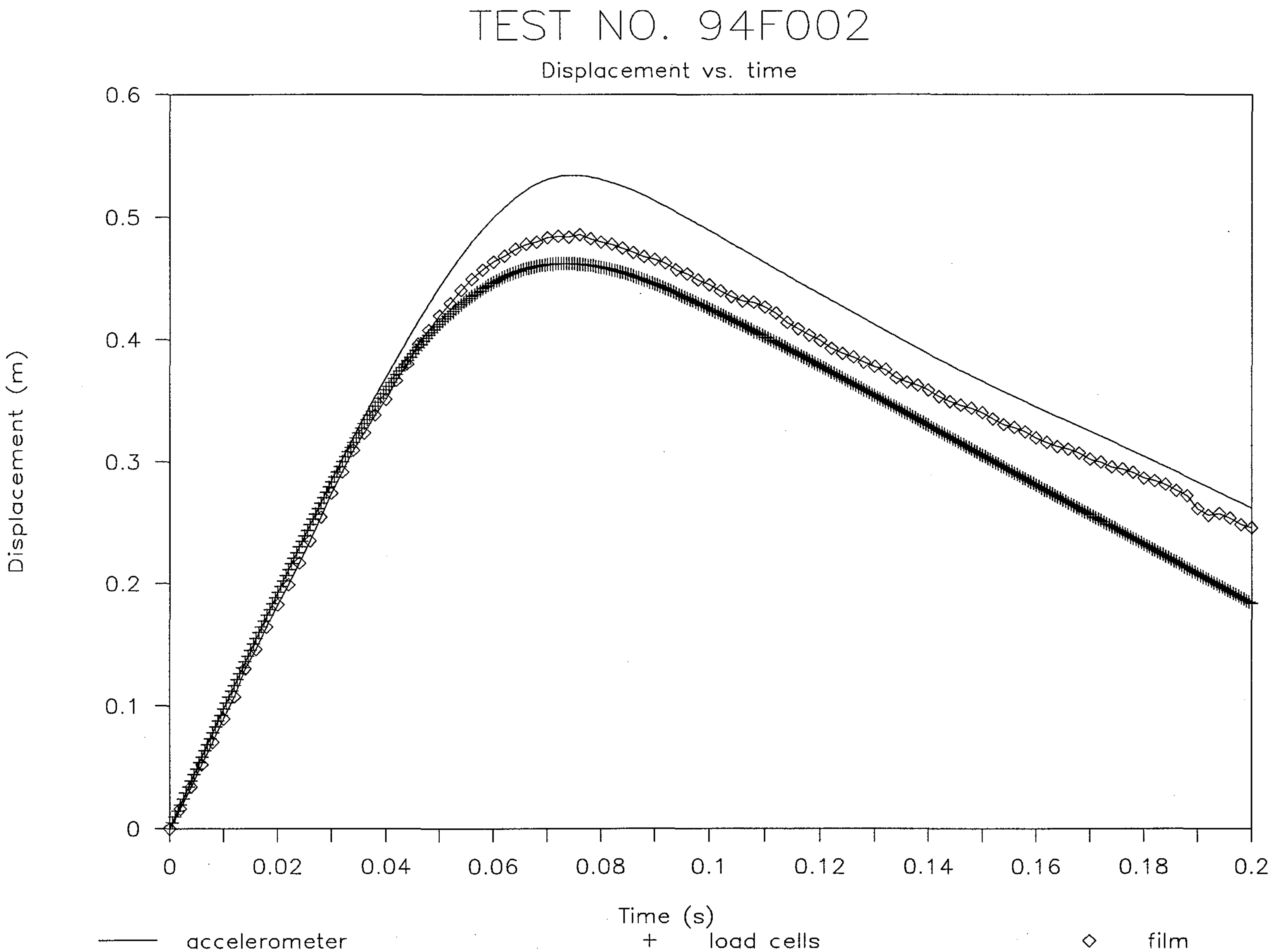


Figure 6. Displacement vs. time for test 94F002.

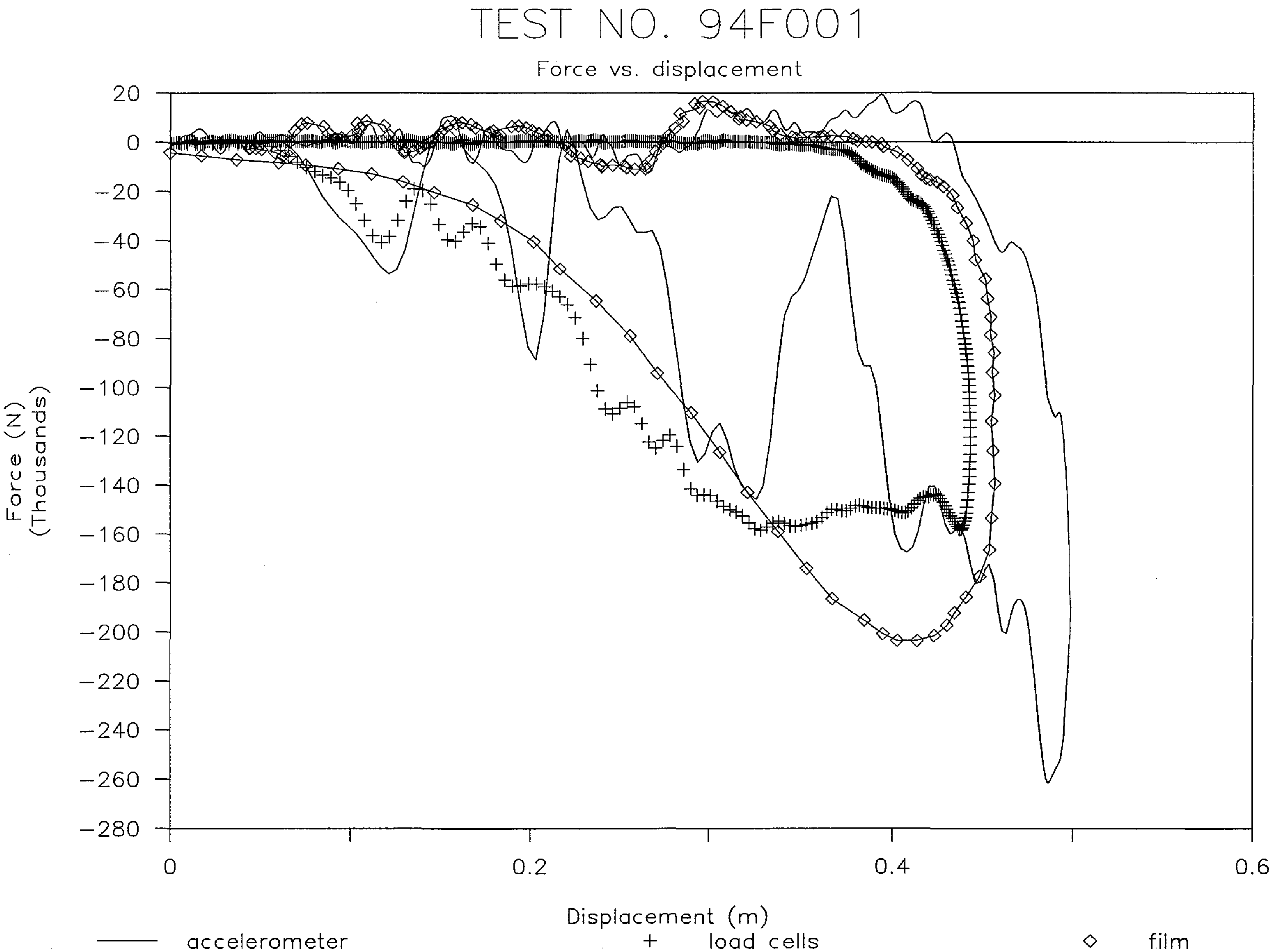


Figure 7. Force vs. displacement for test 94F001.

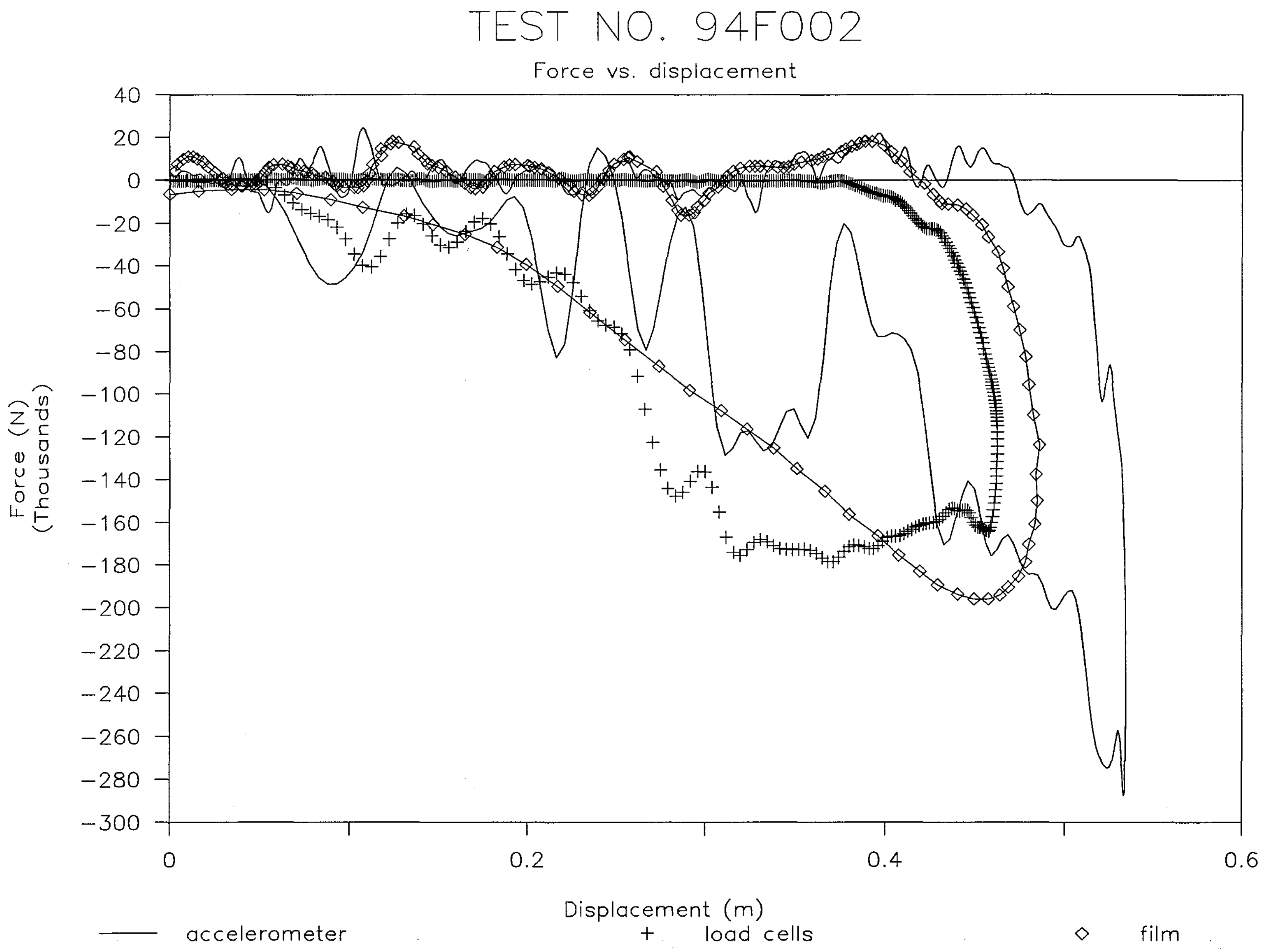


Figure 8. Force vs. displacement for test 94F002.

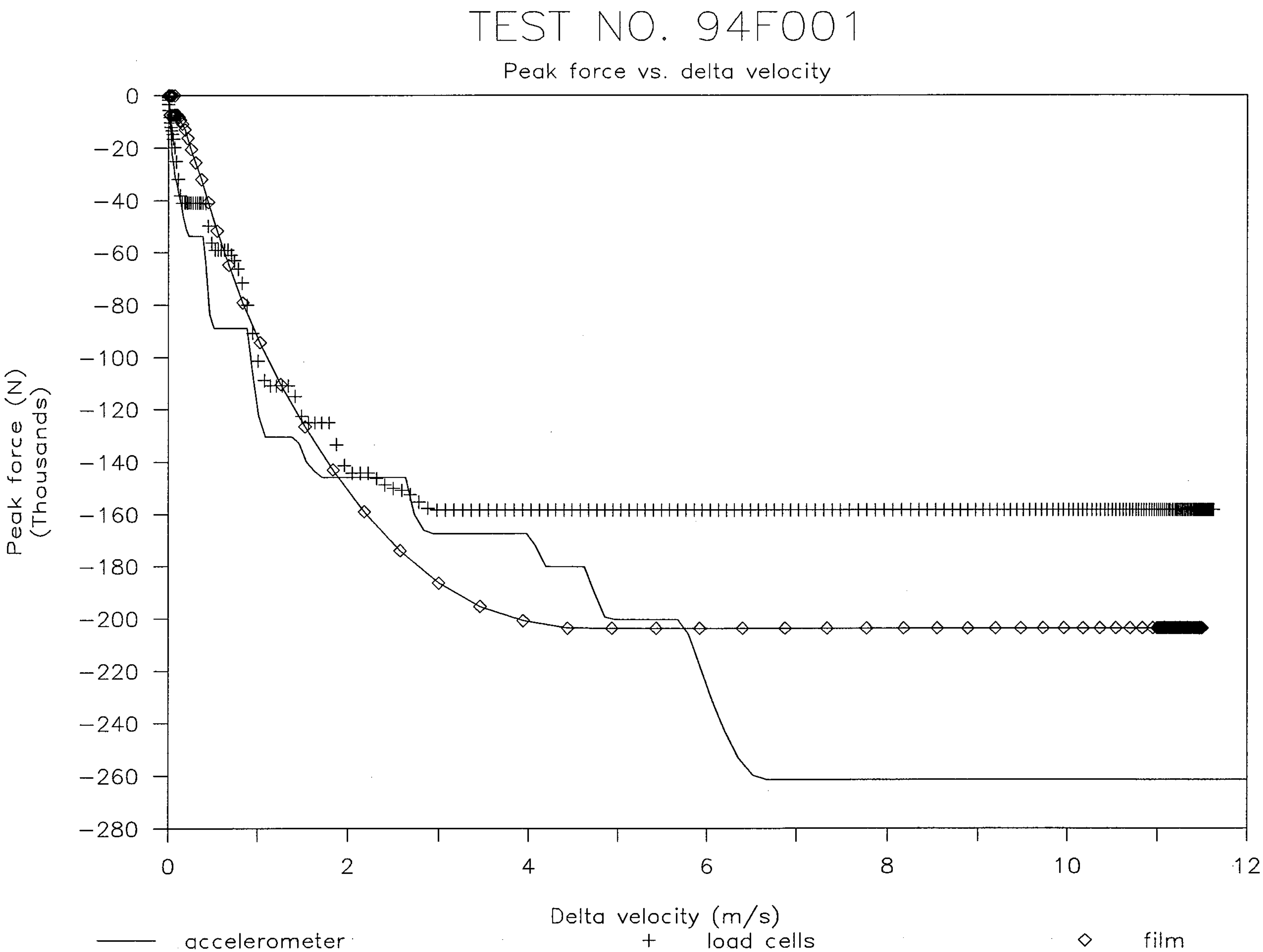


Figure 9. Peak force vs. delta velocity for test 94F001.

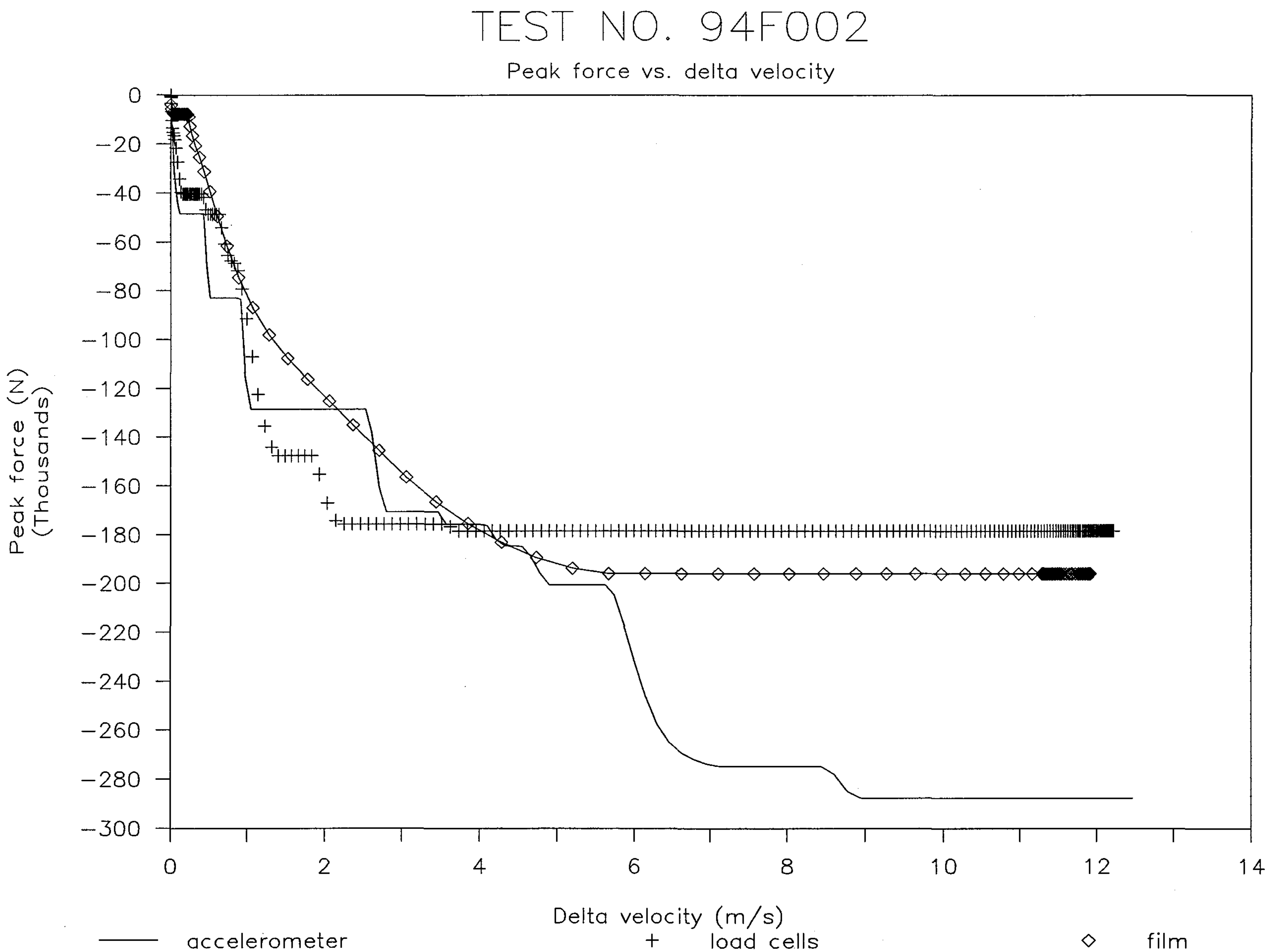


Figure 10. Peak force vs. delta velocity for test 94F002.

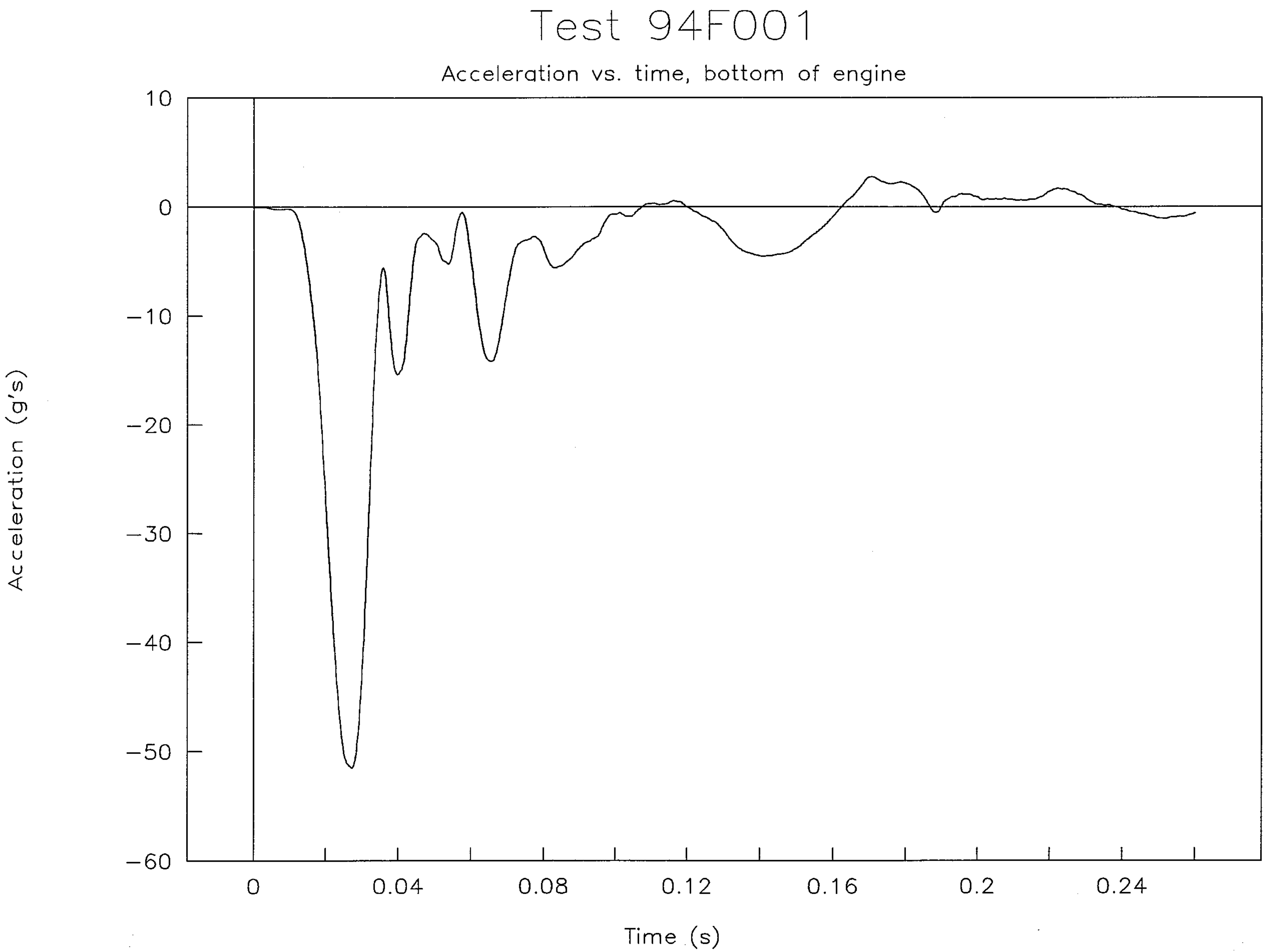


Figure 11. Bottom of engine, acceleration vs. time, test 94F001.

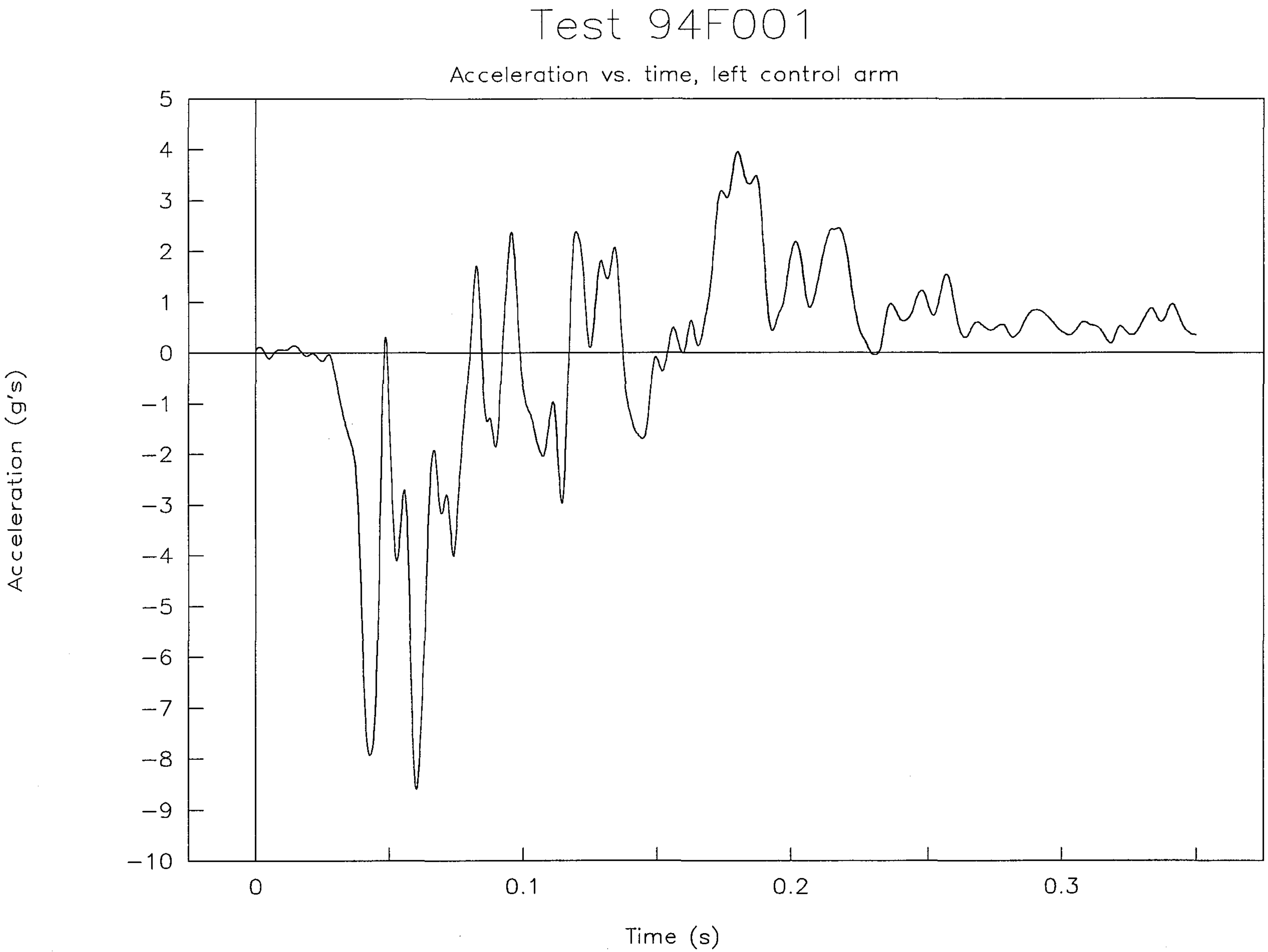


Figure 12. Left control arm, acceleration vs. time, test 94F001.

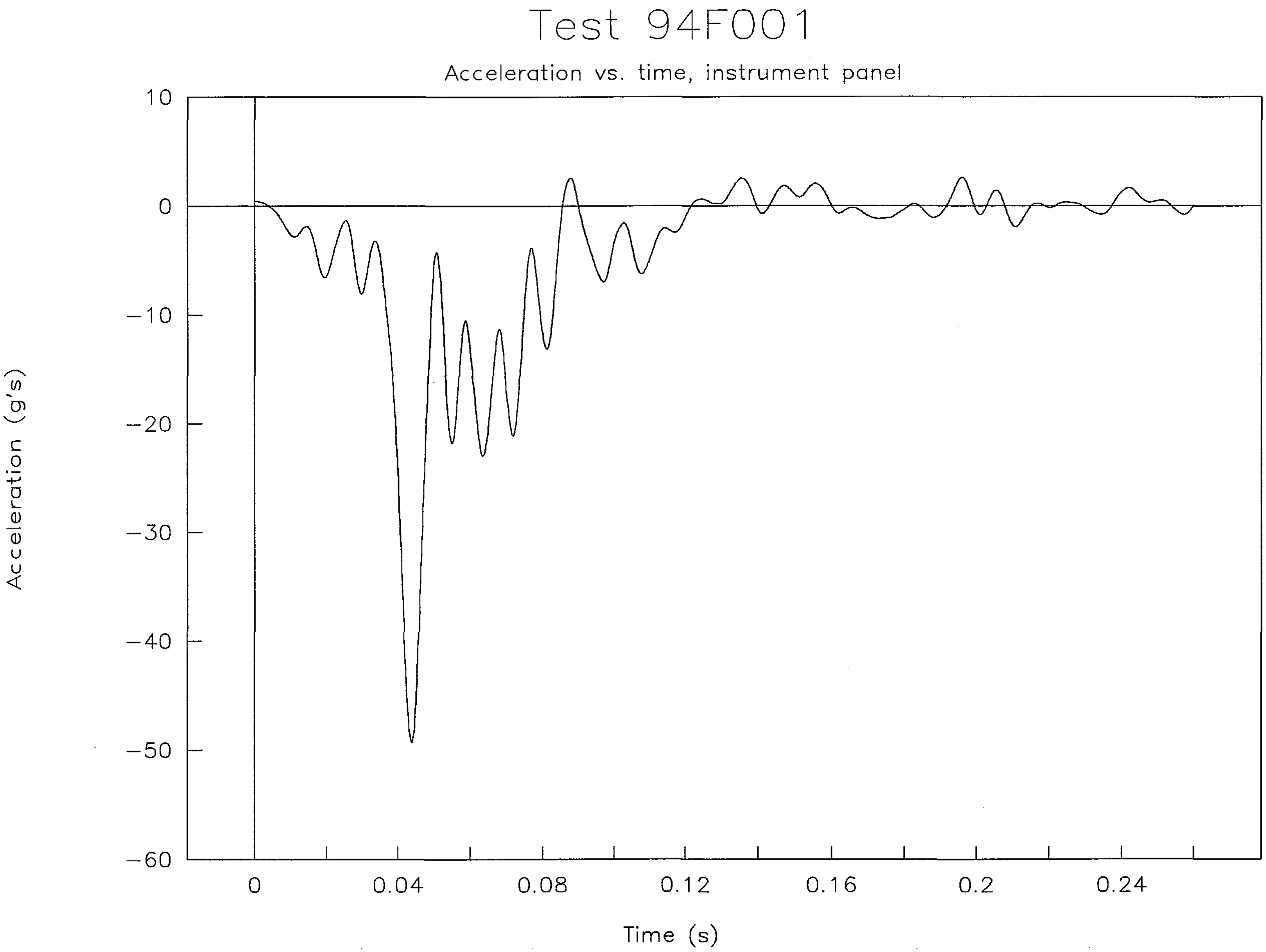


Figure 13. Instrument panel, acceleration vs. time, test 94F001.

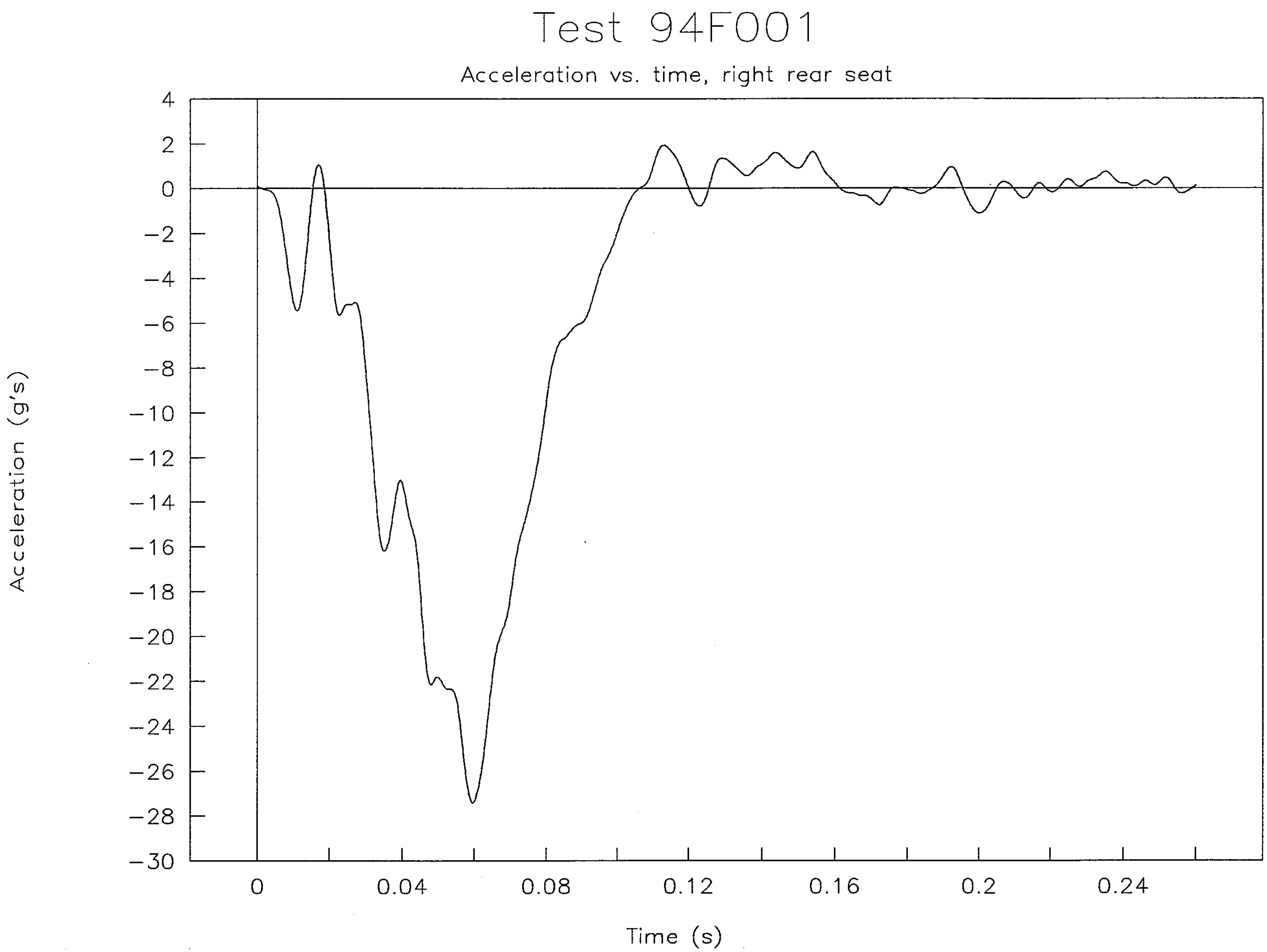


Figure 14. Right rear seat, acceleration vs. time, test 94F001.

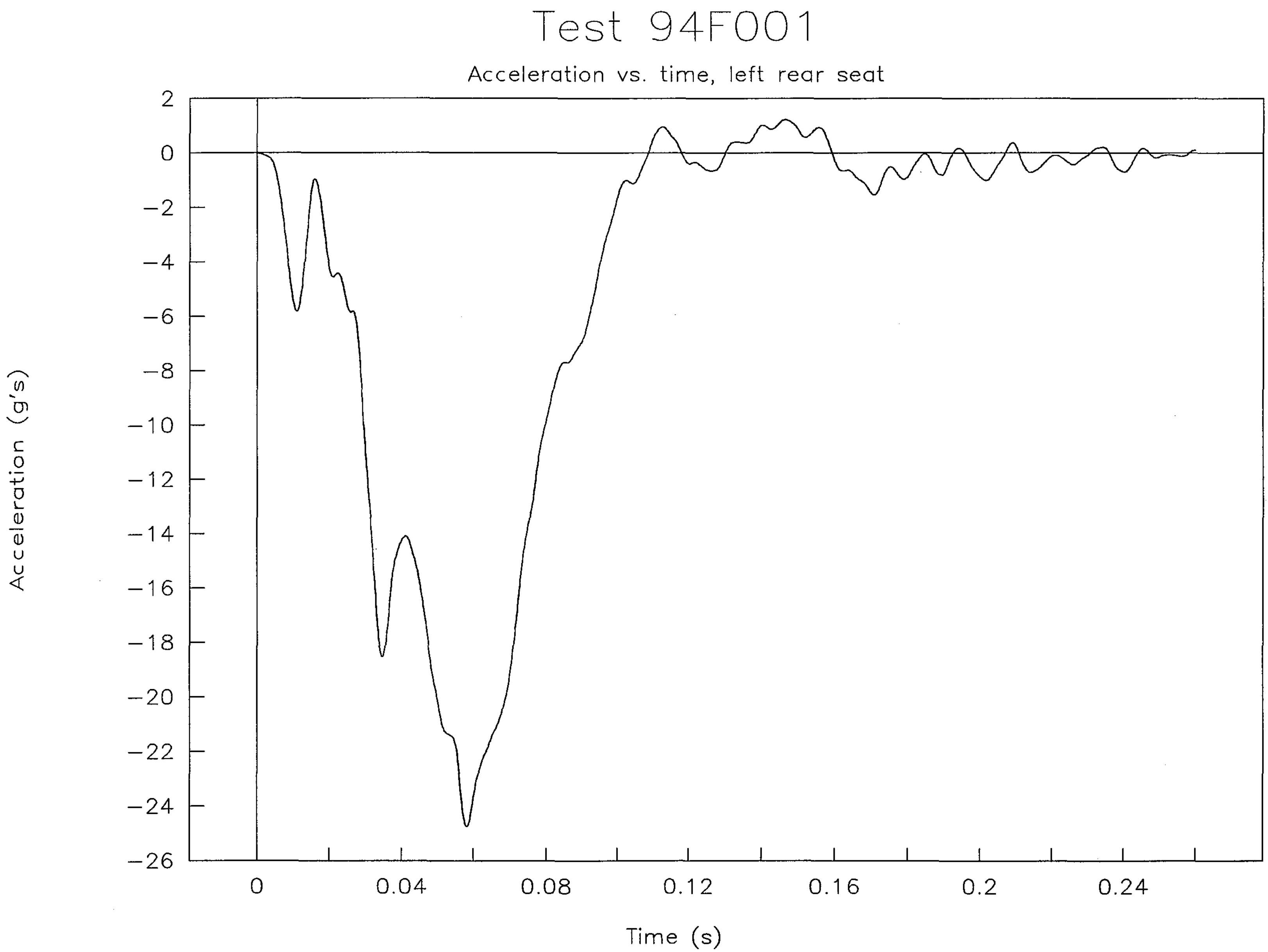


Figure 15. Left rear seat, acceleration vs. time, test 94F001.

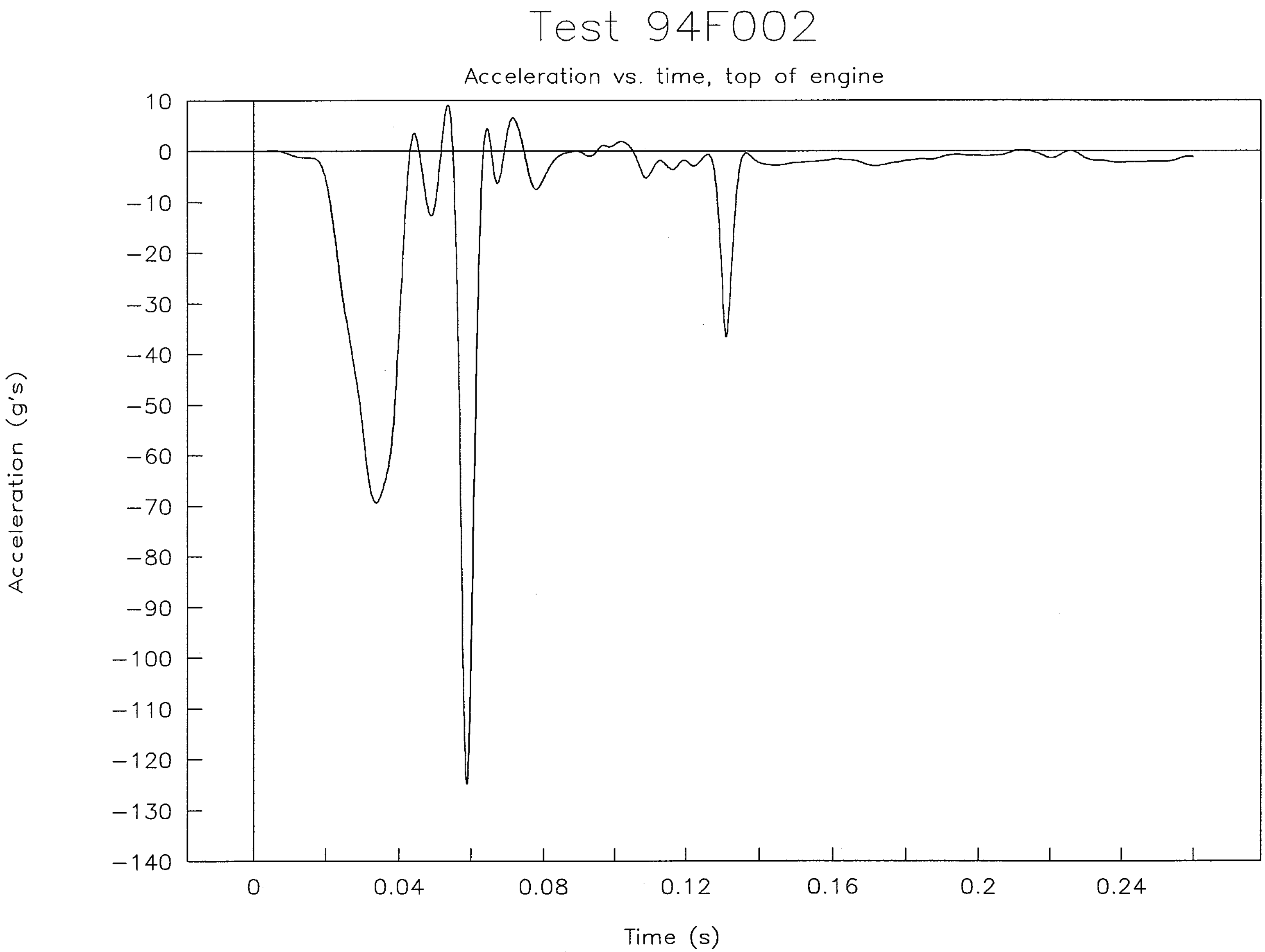


Figure 16. Top of engine, acceleration vs. time, test 94F002.

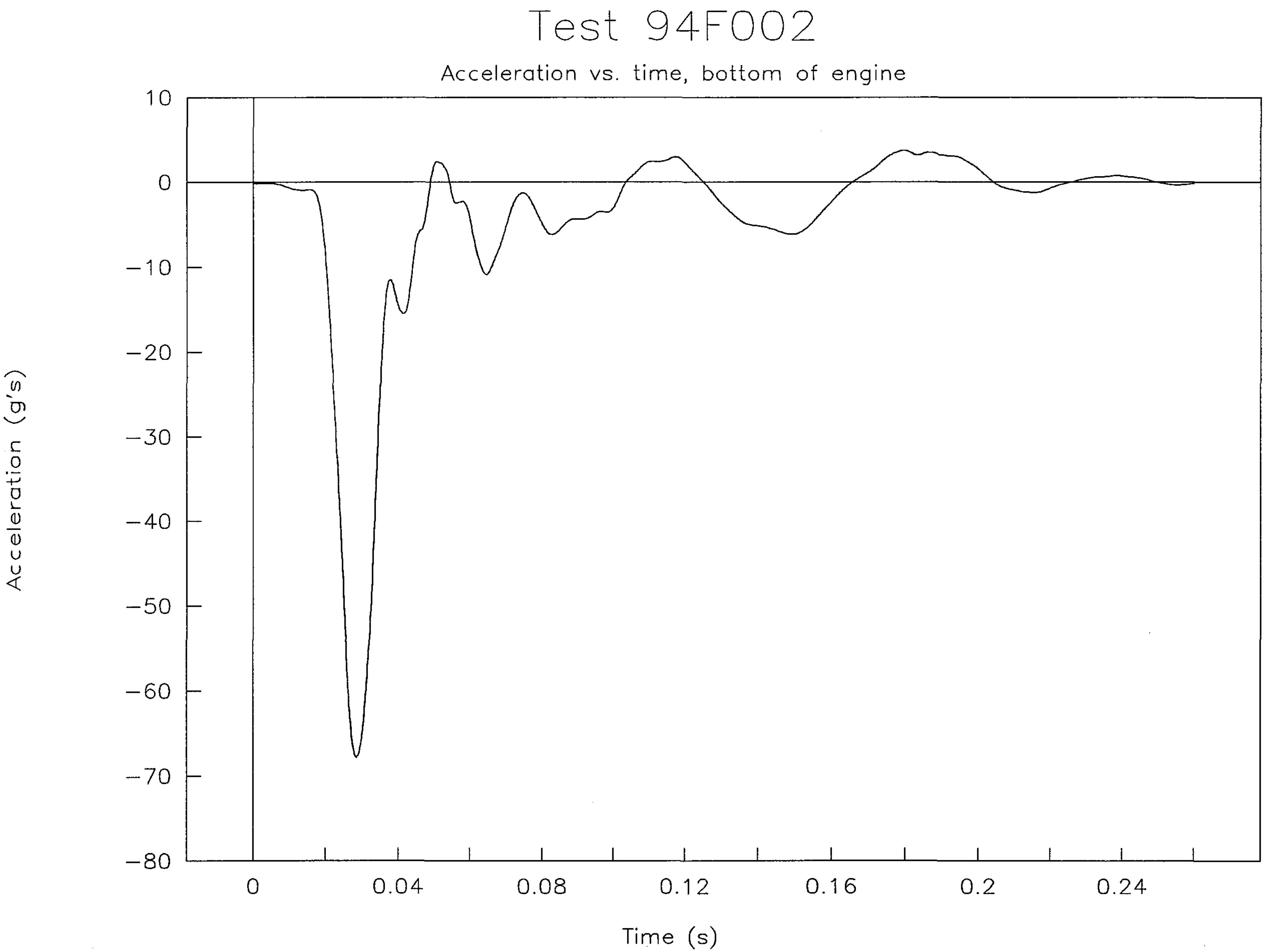


Figure 17. Bottom of engine, acceleration vs. time, test 94F002.

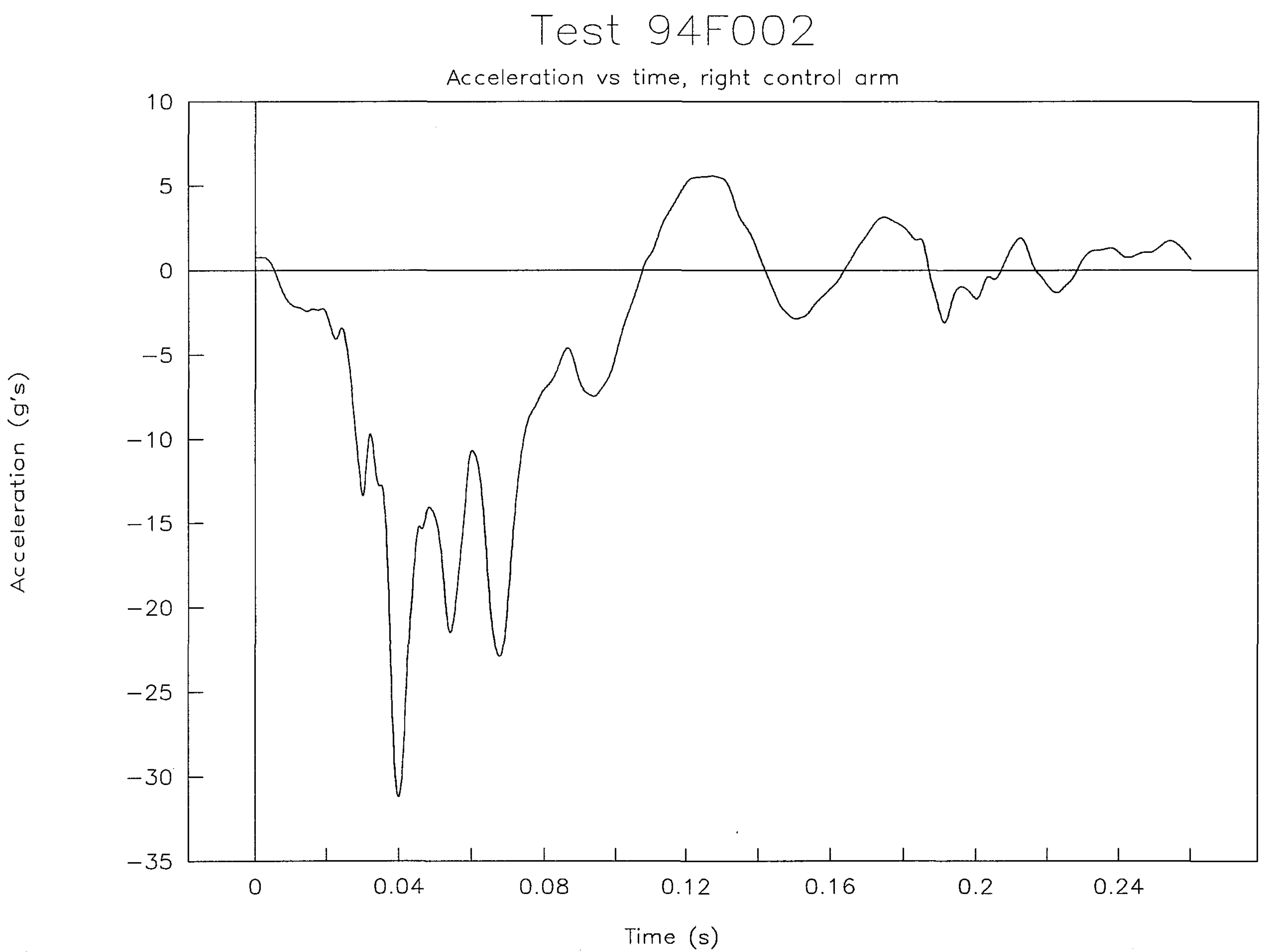


Figure 18. Right control arm, acceleration vs. time, test 94F002.

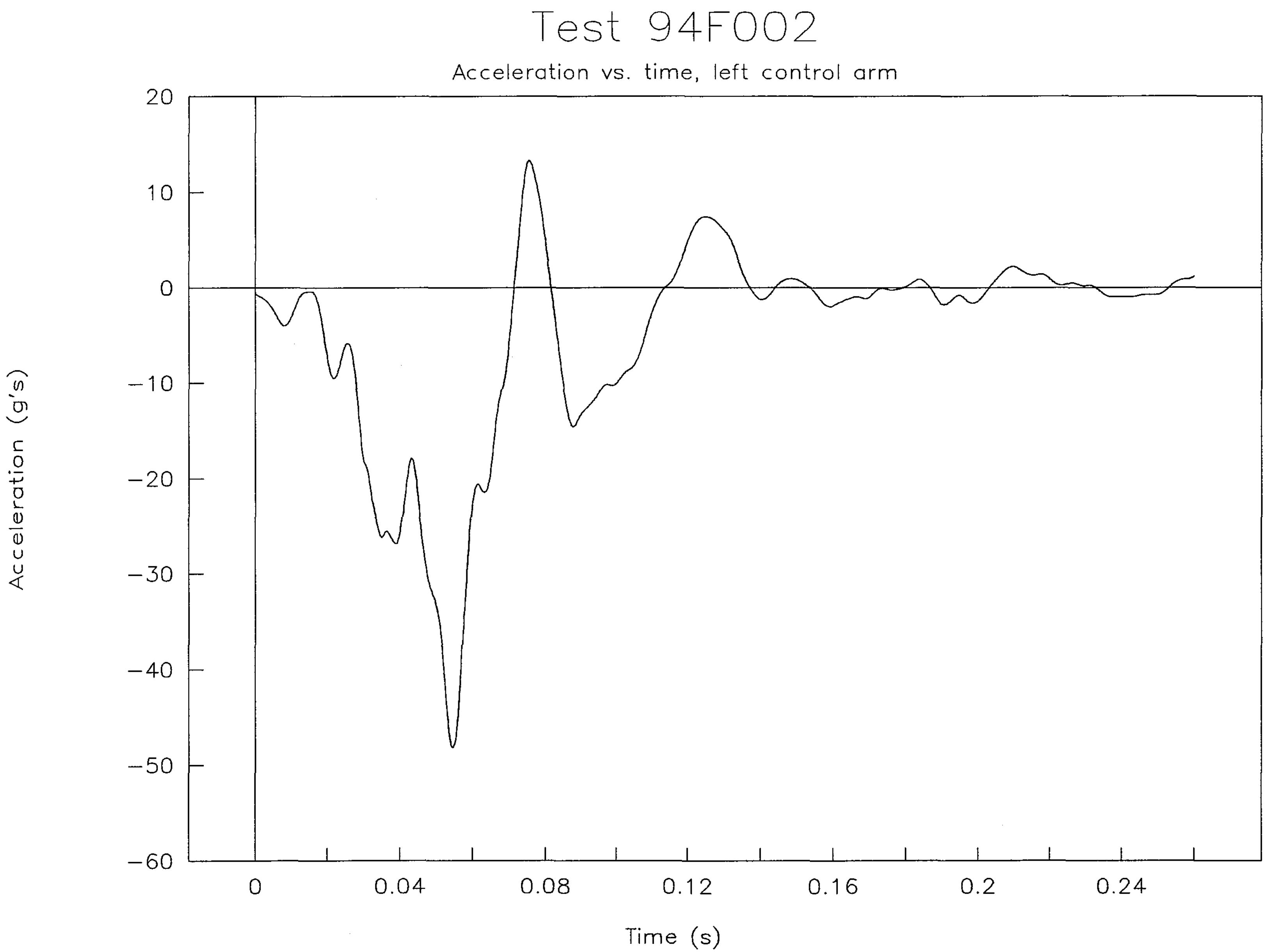


Figure 19. Left control arm, acceleration vs. time, test 94F002.

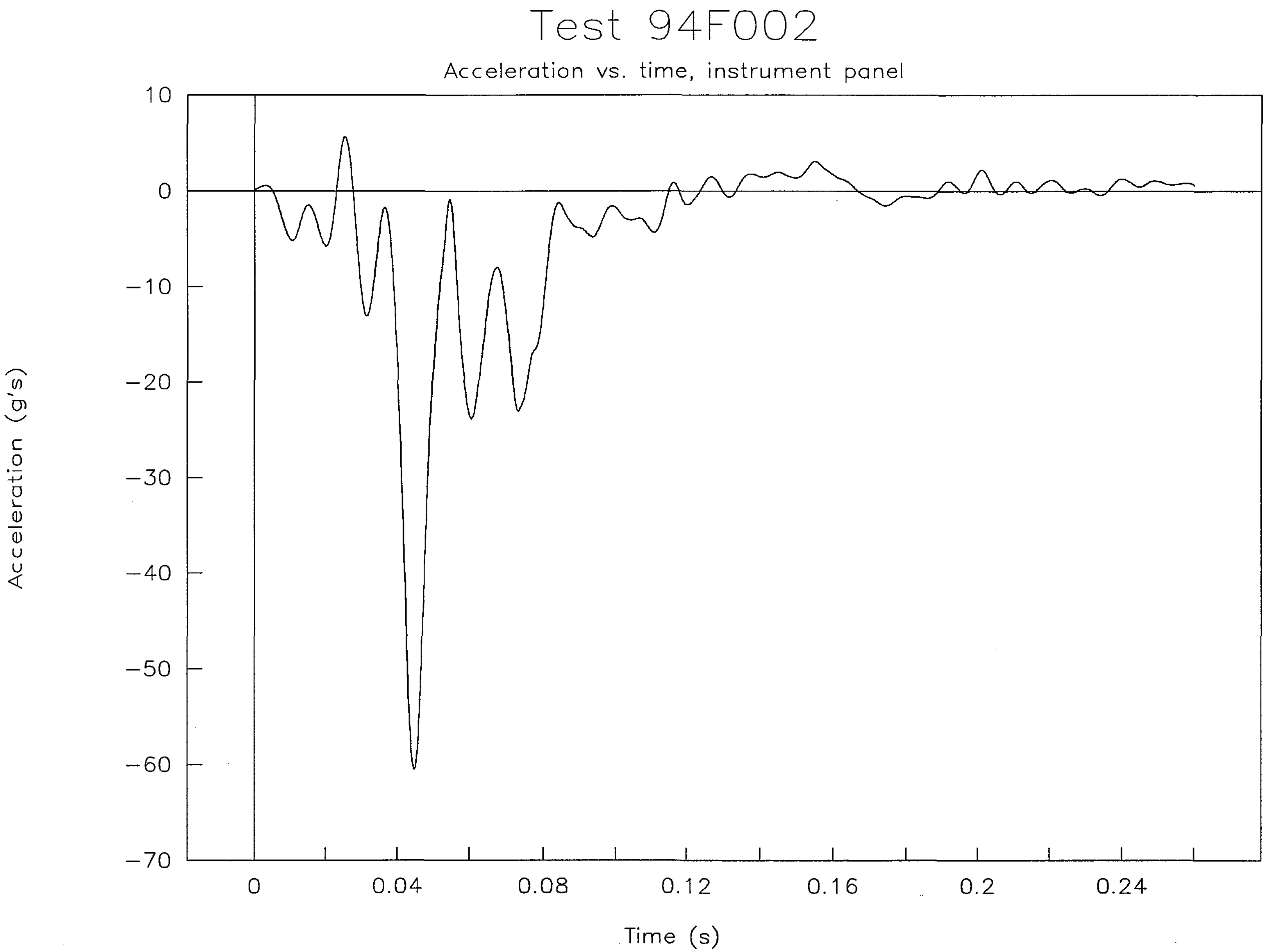


Figure 20. Instrument panel, acceleration vs. time, test 94F002.

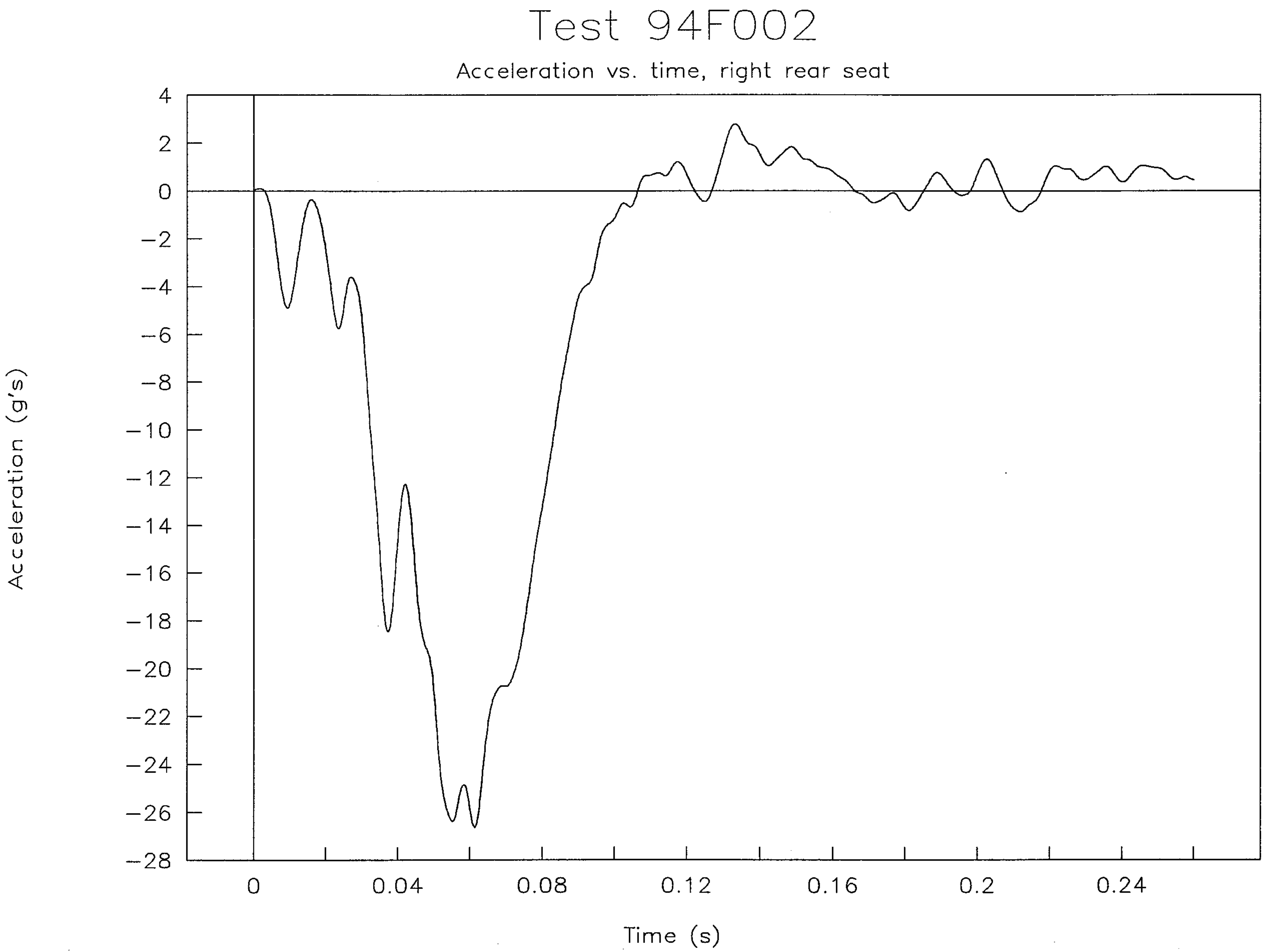


Figure 21. Right rear seat, acceleration vs. time, test 94F002.

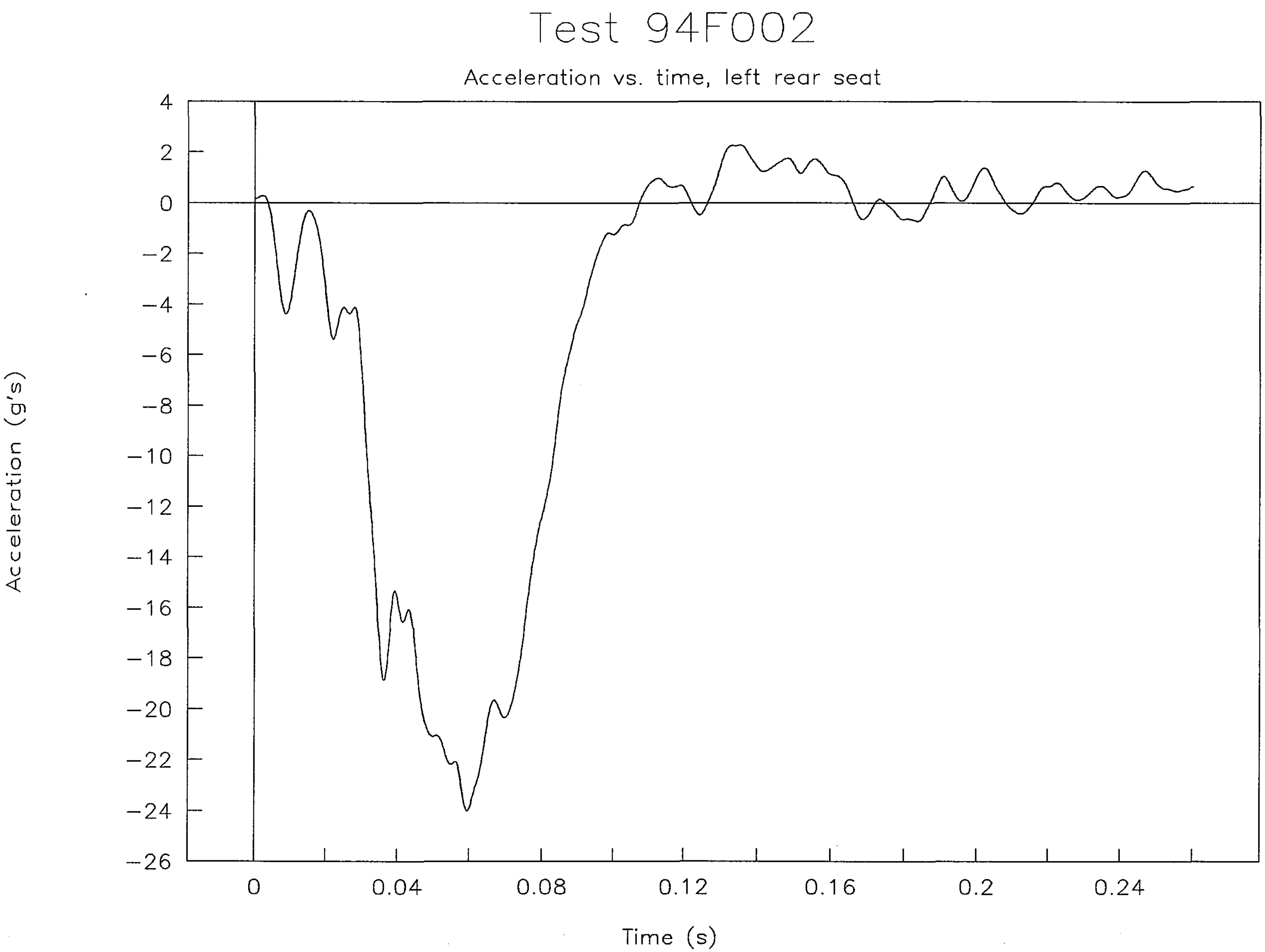


Figure 22. Left rear seat, acceleration vs. time, test 94F002.

Figure 23. Pre-test photographs, test 94F001.

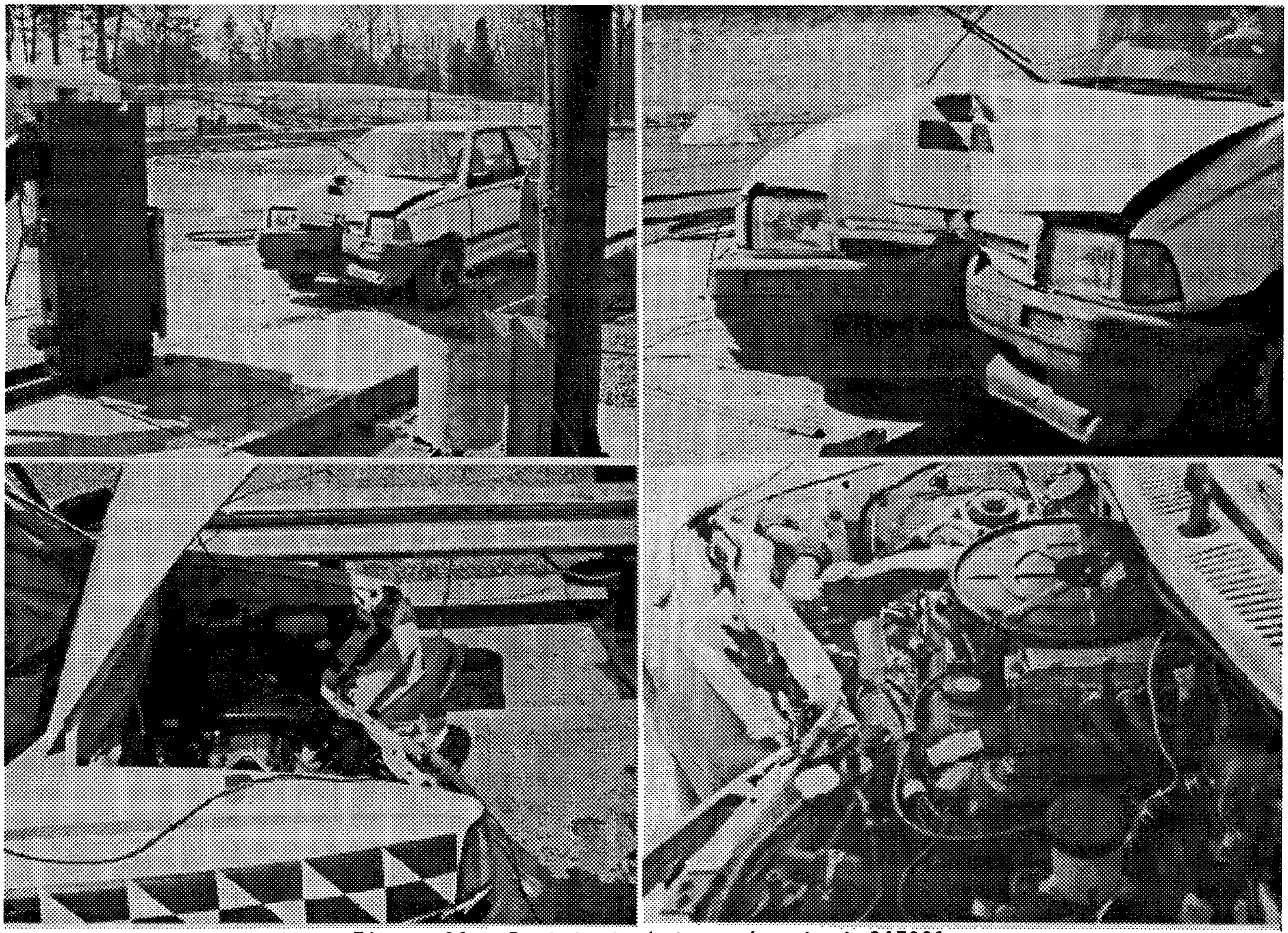


Figure 24. Post-test photographs, test 94F001.

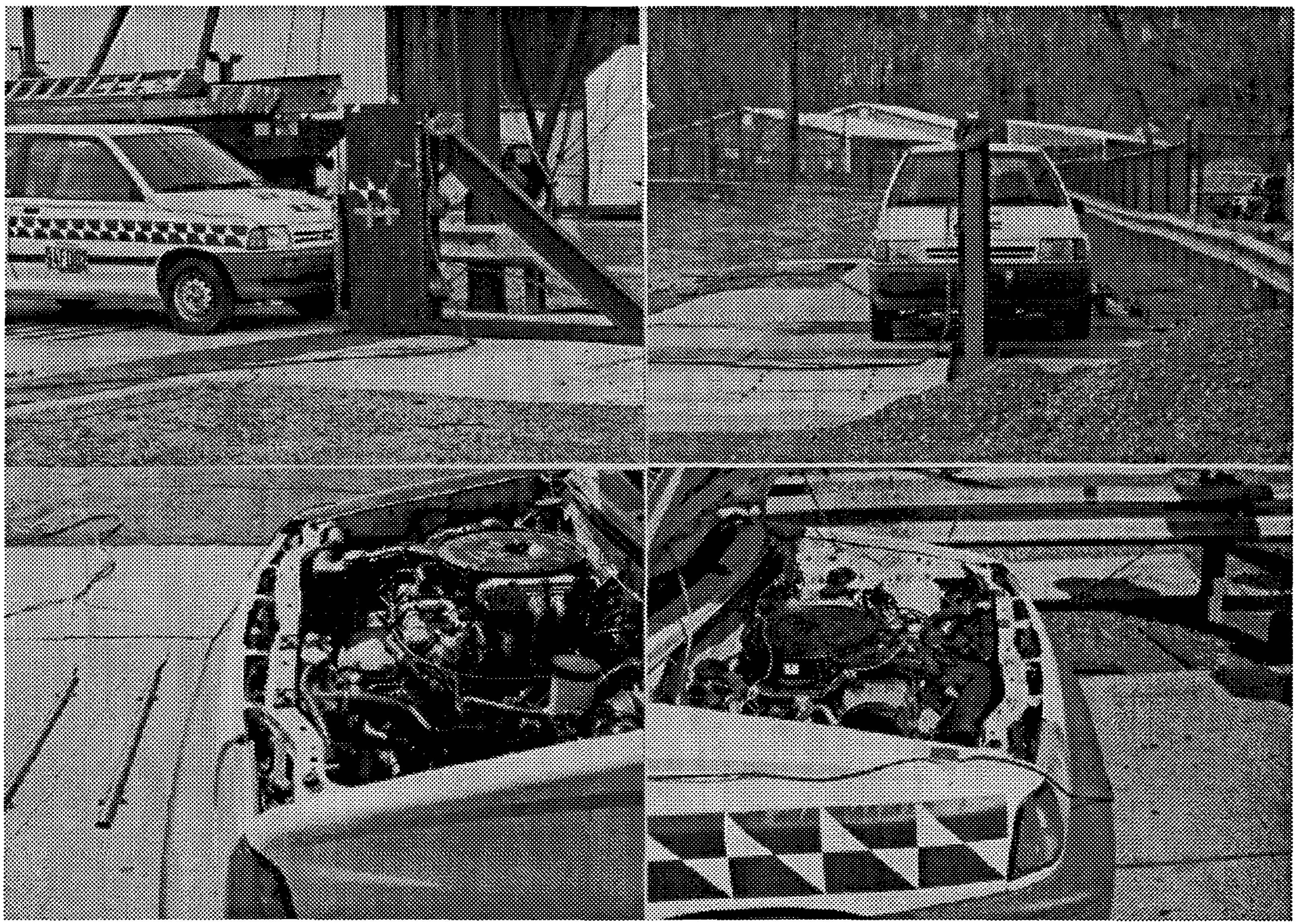


Figure 25. Pre-test photographs, test 94F002.

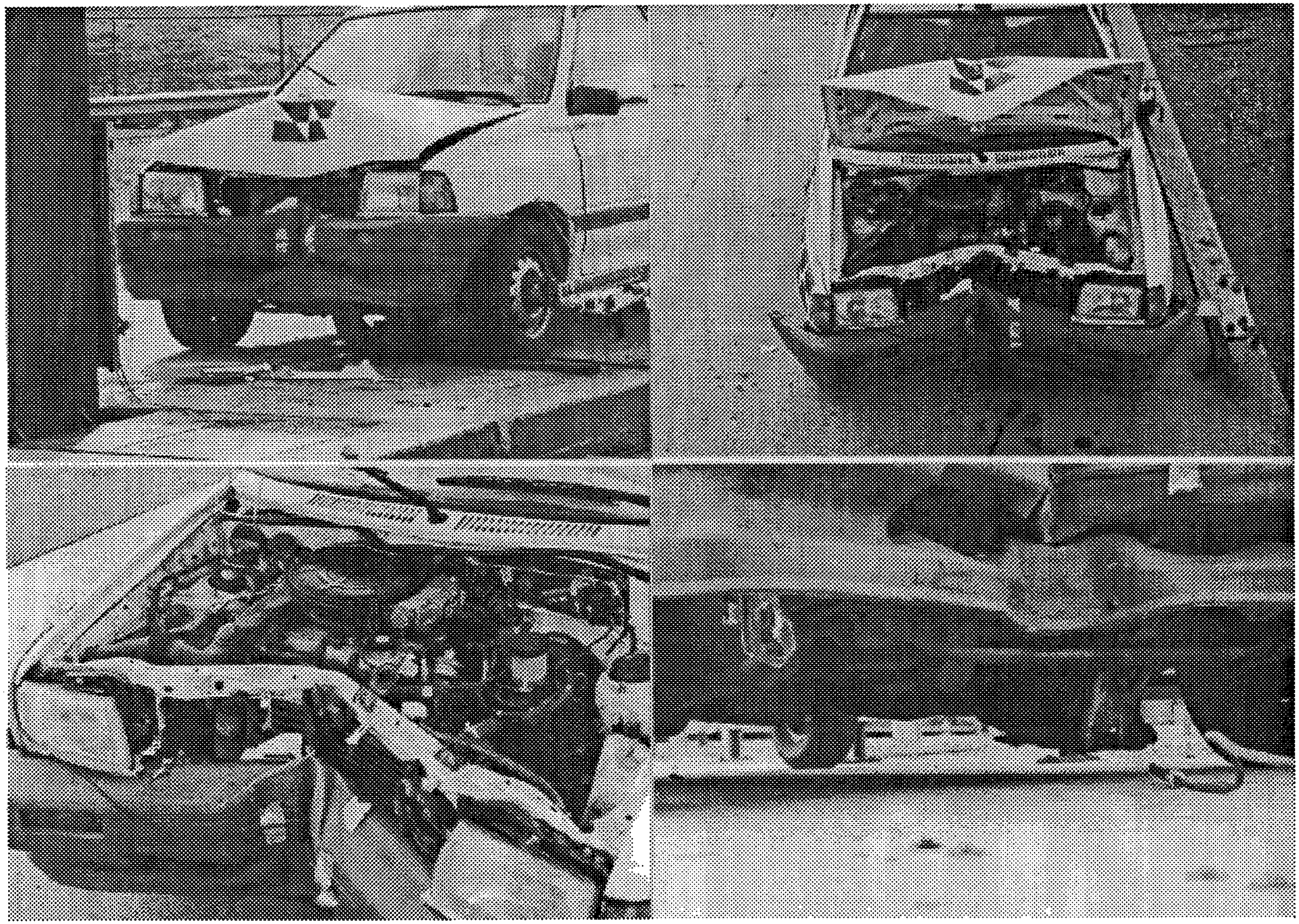


Figure 26. Post-test photographs, test 94F002.

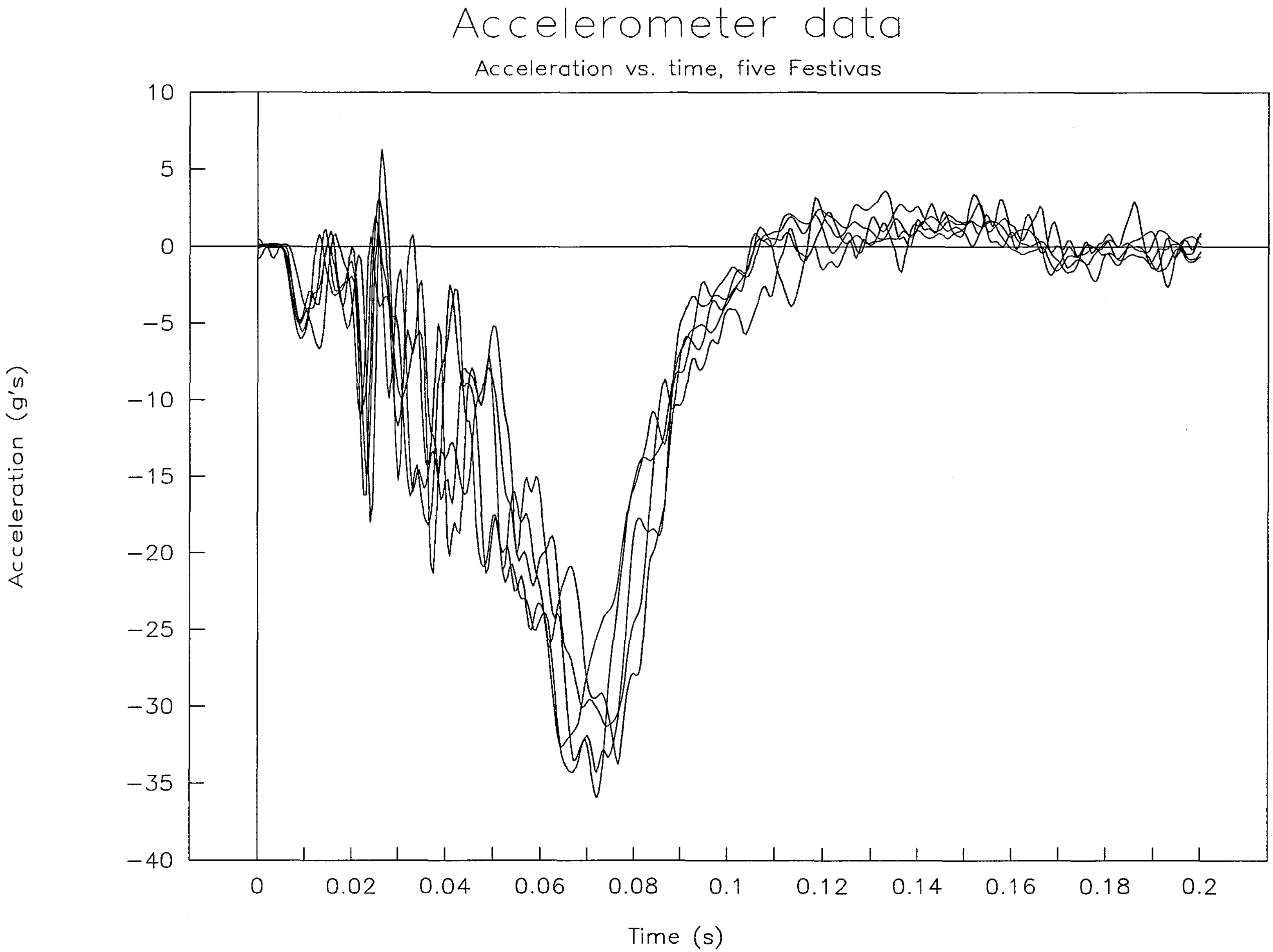


Figure 27. Five Ford Festiva tests, acceleration vs. time, accelerometer data.

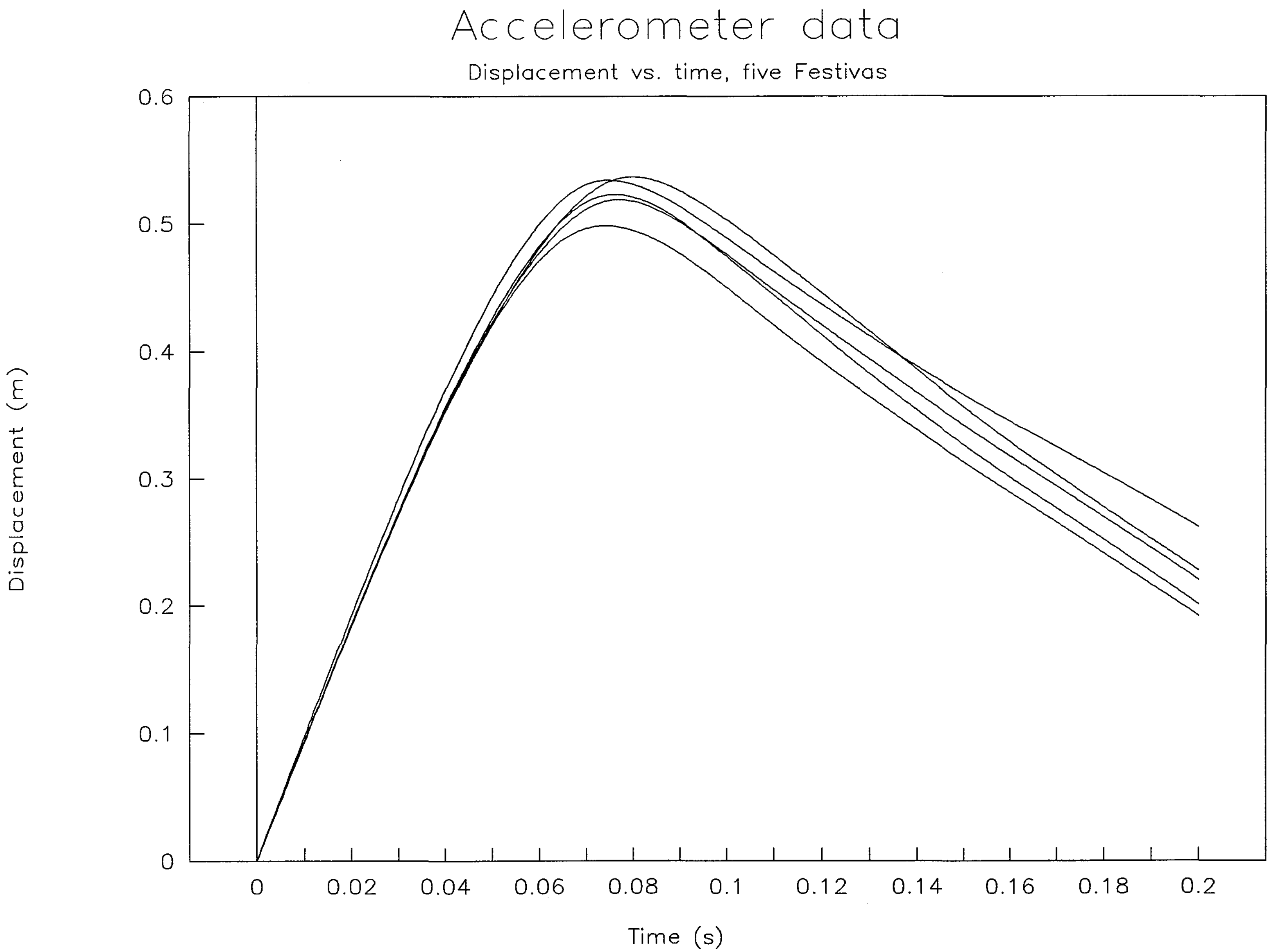


Figure 28. Five Ford Festiva tests, displacement vs. time, accelerometer data.

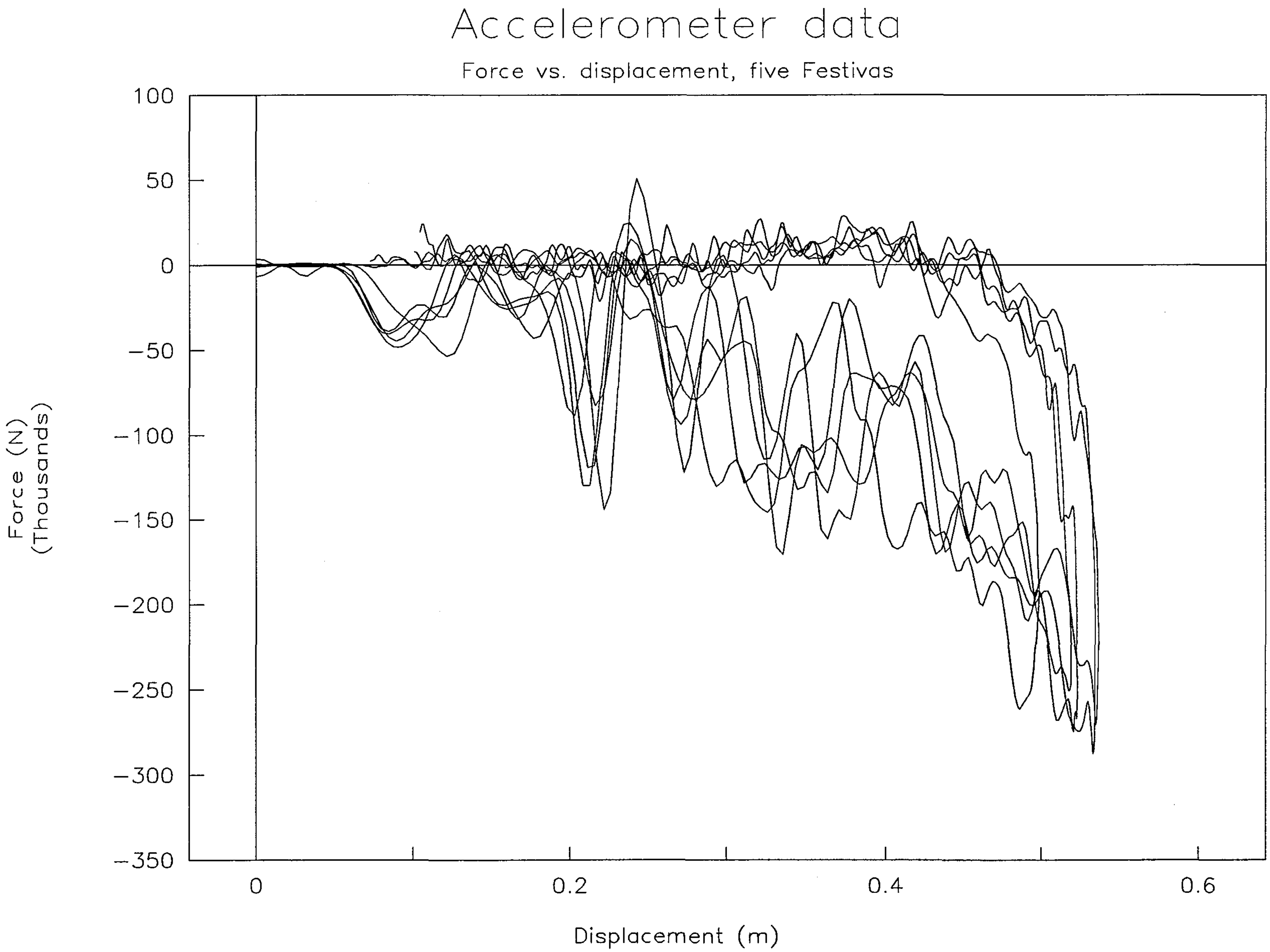


Figure 29. Five Ford Festiva tests, force vs. displacement, accelerometer data.

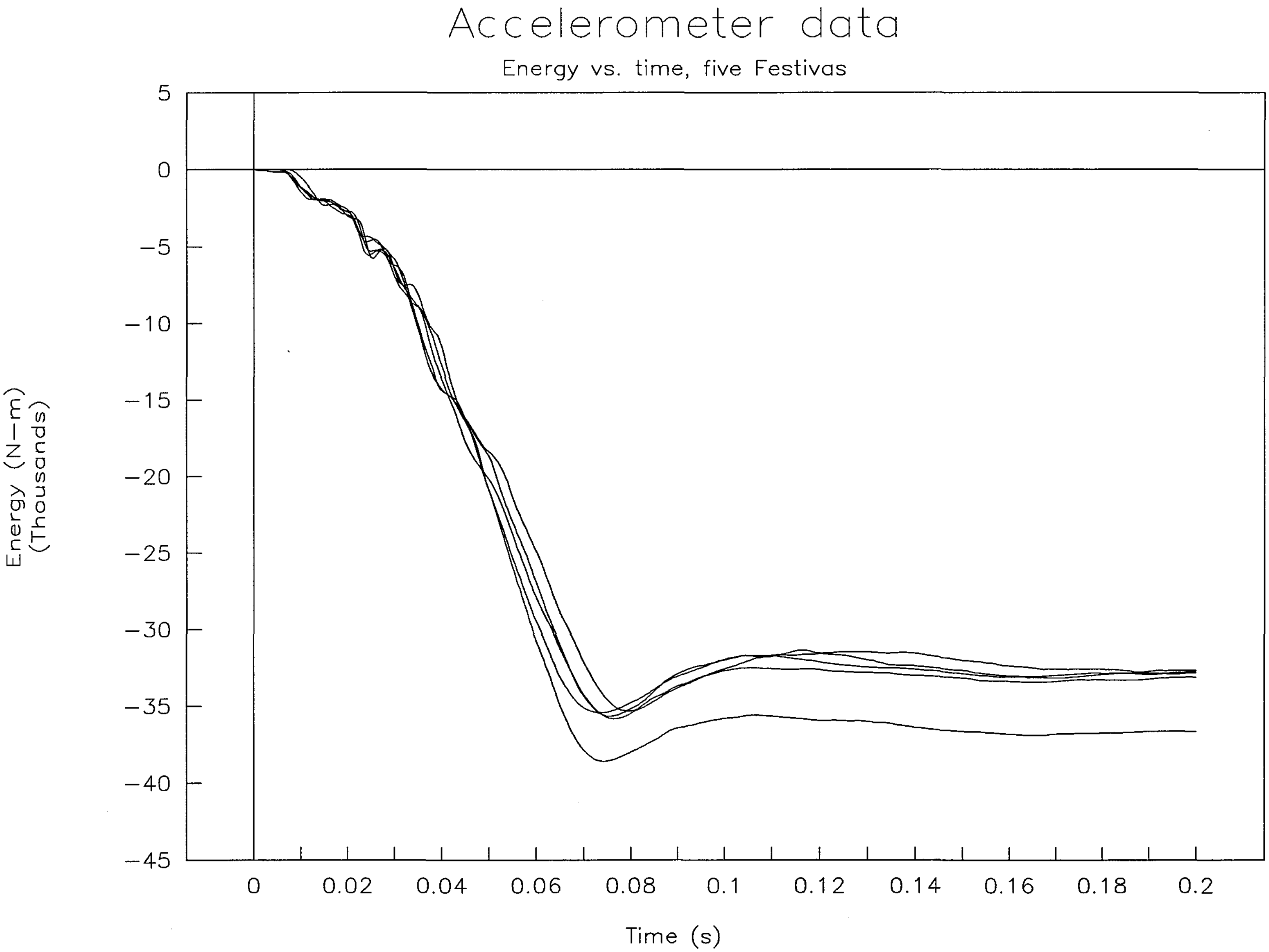


Figure 30. Five Ford Festiva tests, energy vs. time, accelerometer data.

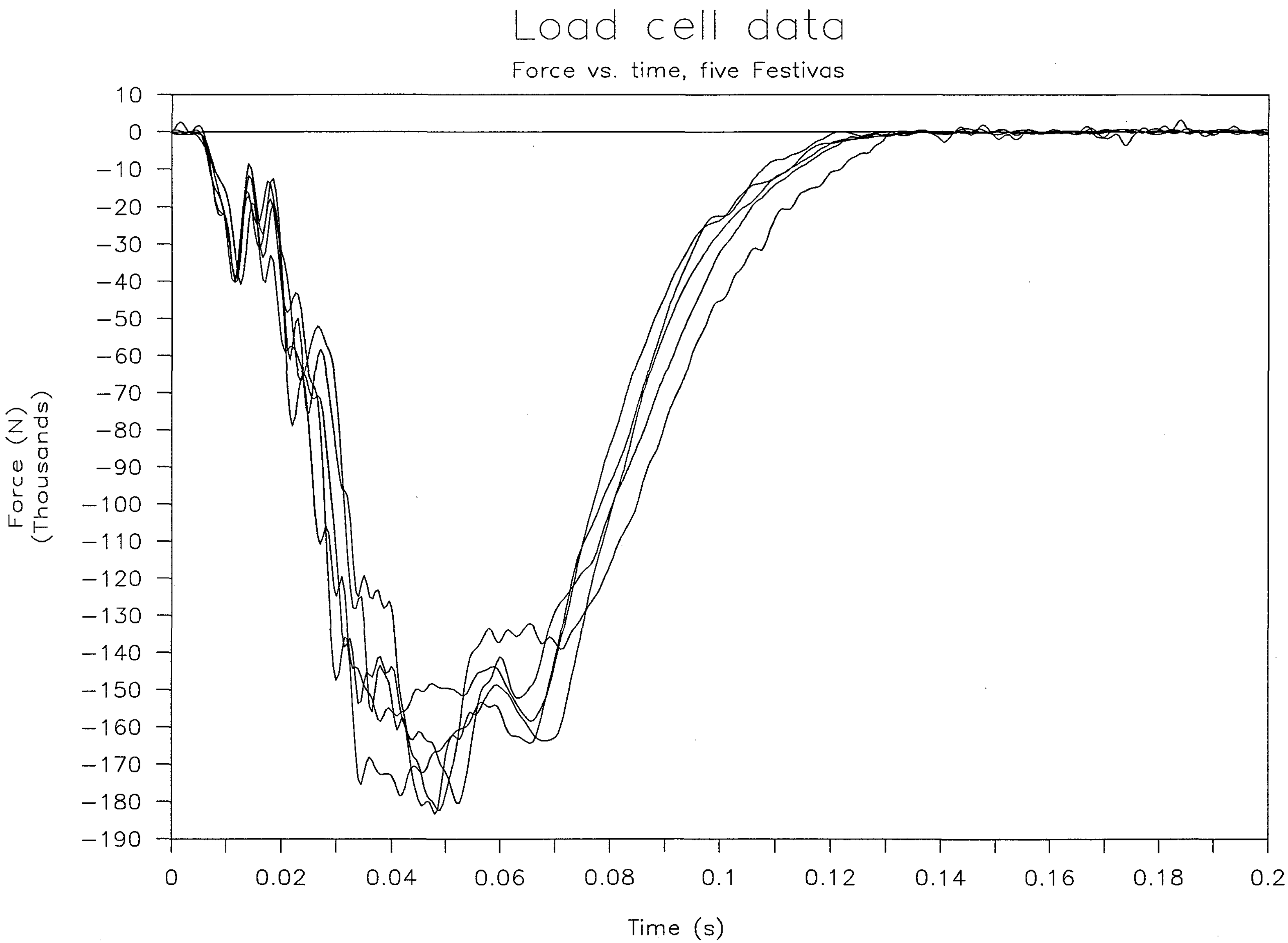


Figure 31. Five Ford Festiva tests, force vs. time, load cell data.

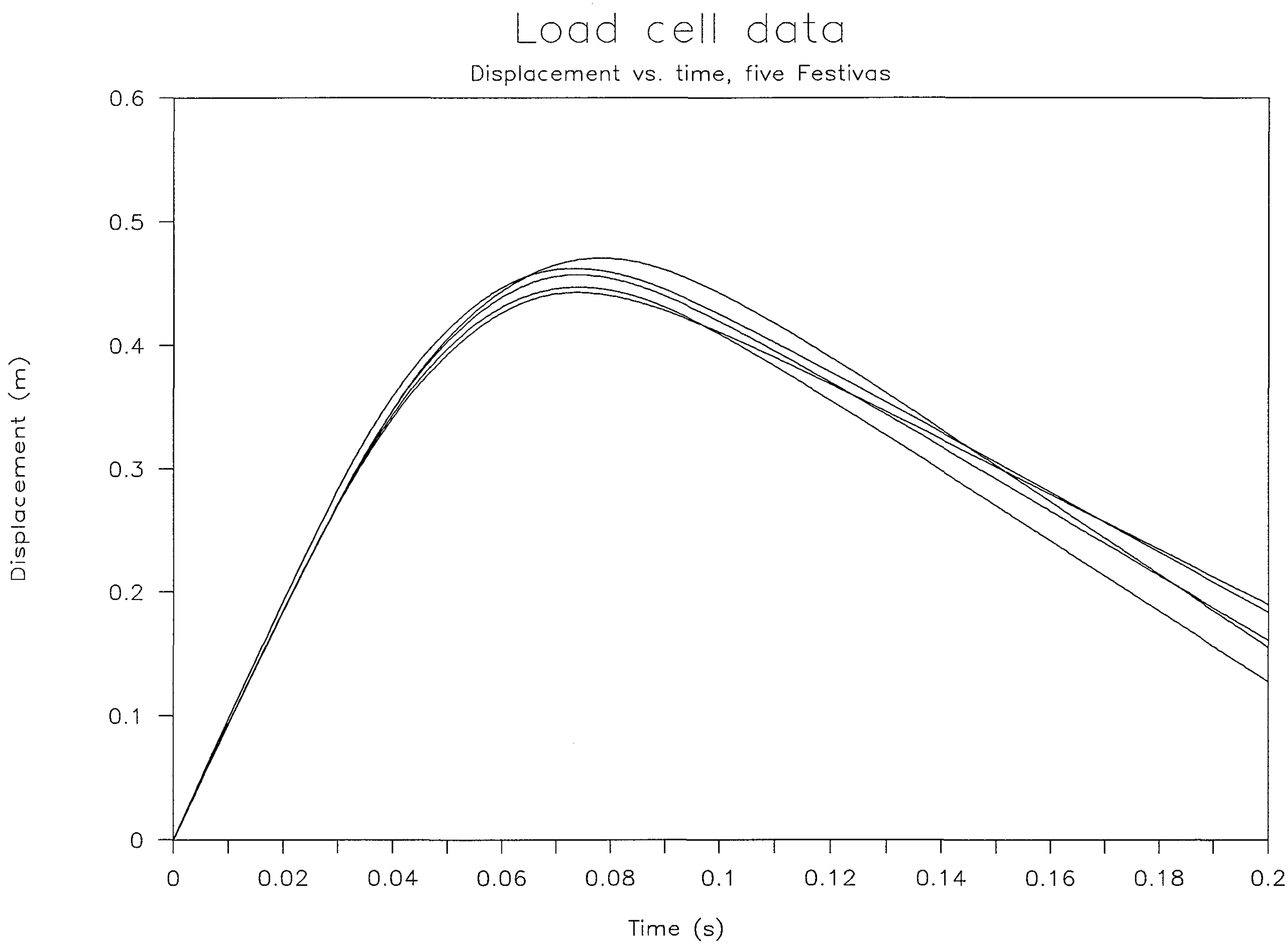


Figure 32. Five Ford Festiva tests, displacement vs. time, load cell data.

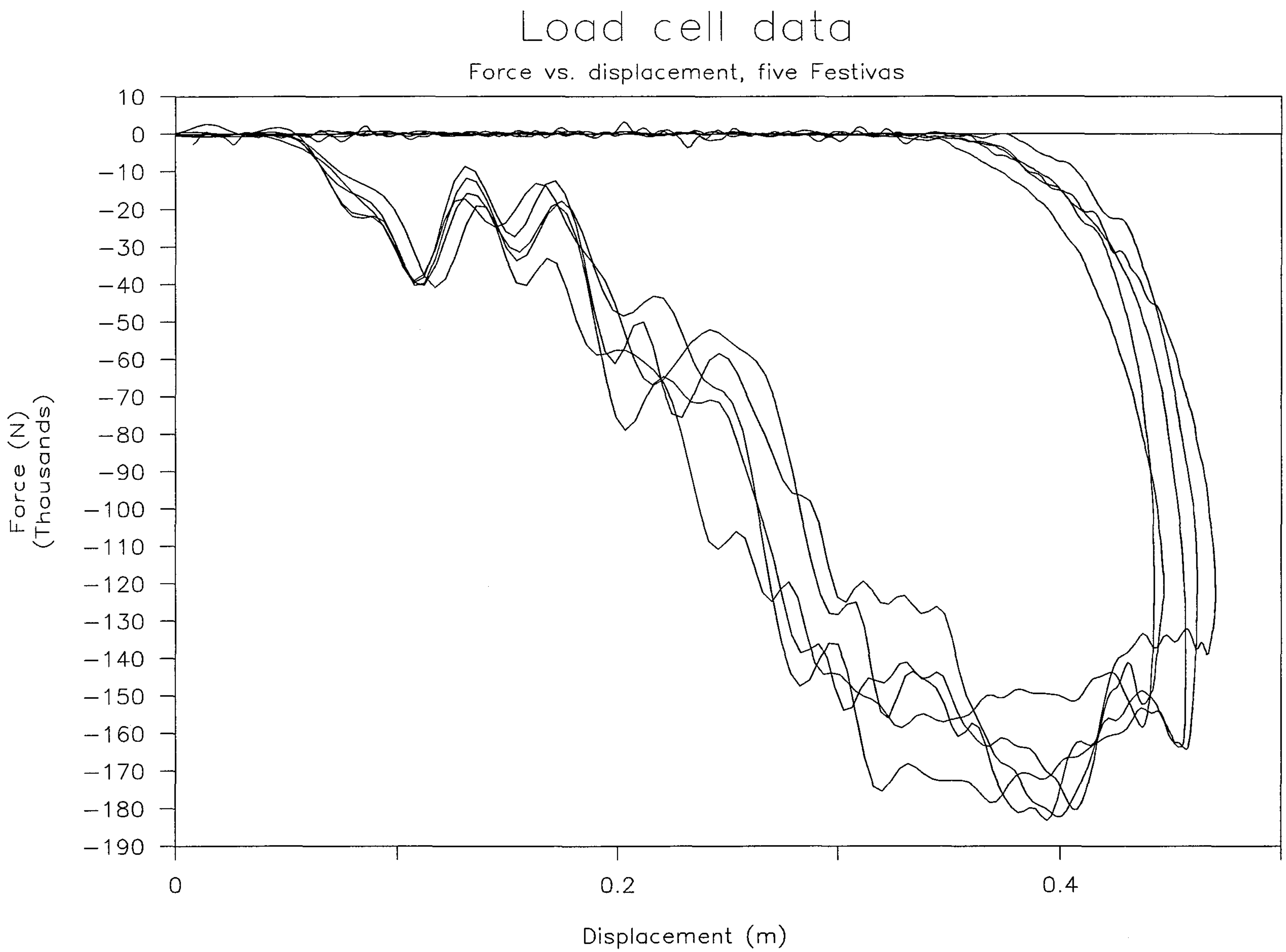


Figure 33. Five Ford Festiva tests, force vs. displacement, load cell data.

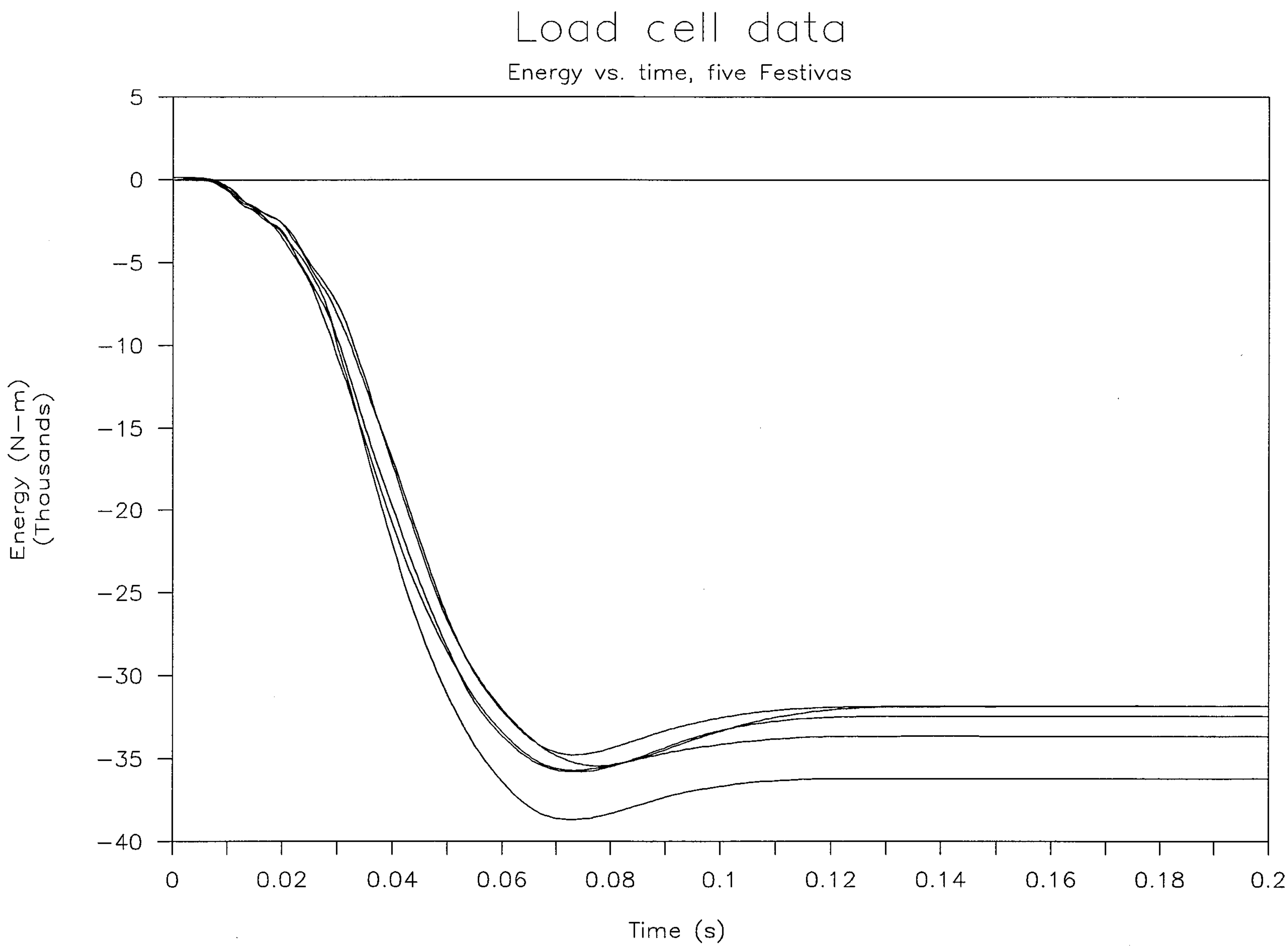


Figure 34. Five Ford Festiva tests, energy vs. time, load cell data.

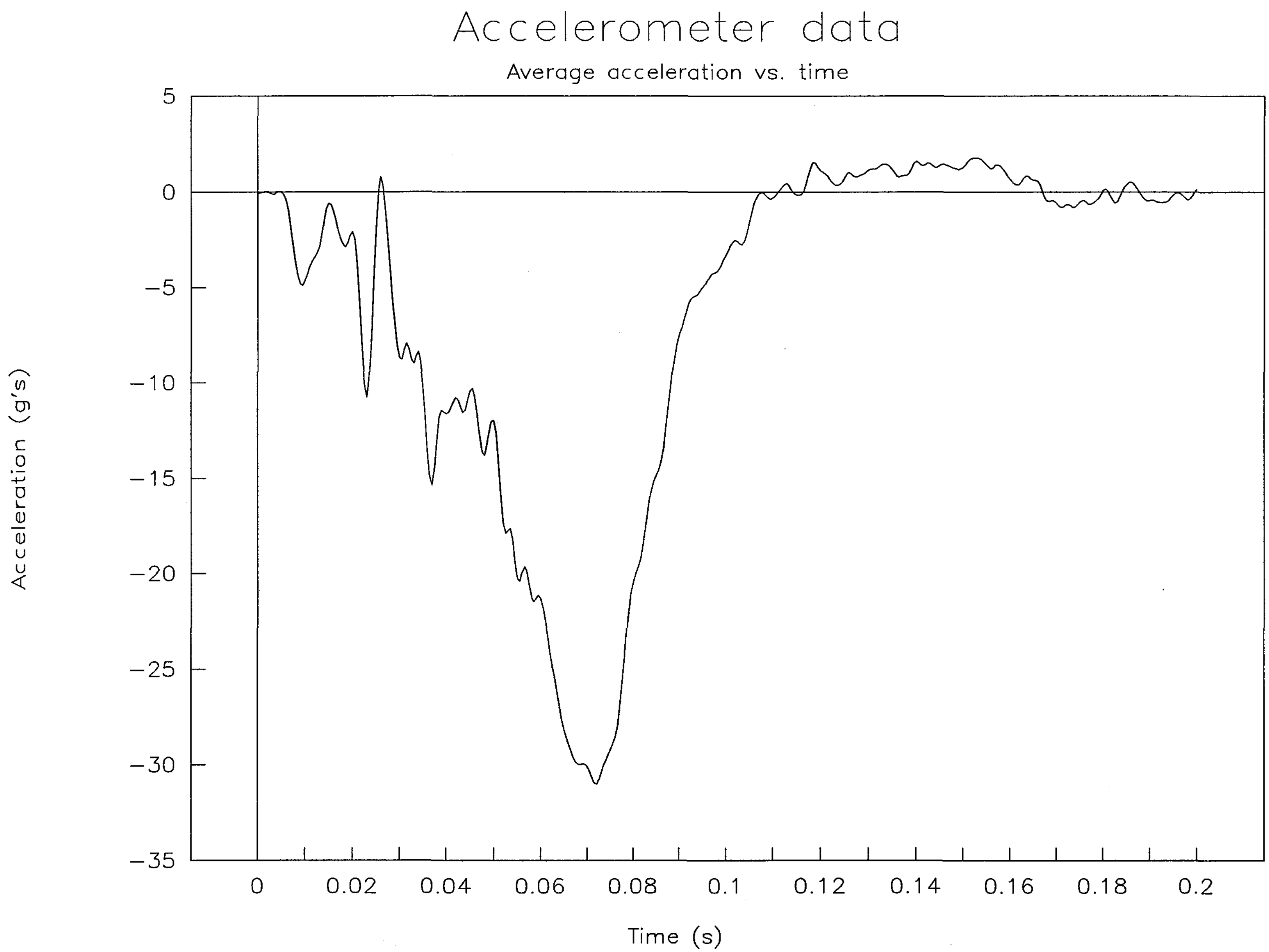


Figure 35. Average acceleration vs. time, accelerometer data.

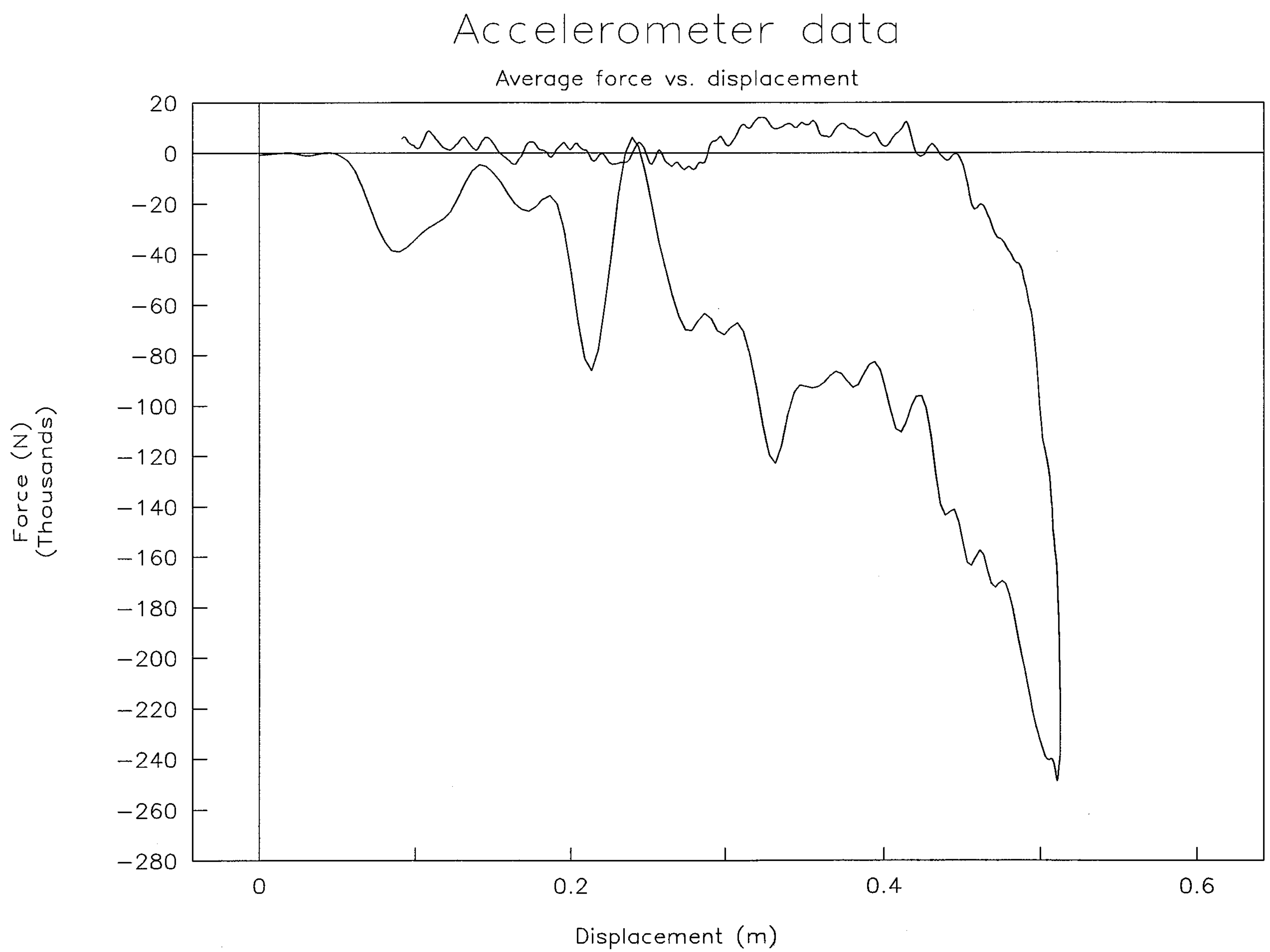


Figure 36. Average force vs. displacement, accelerometer data.

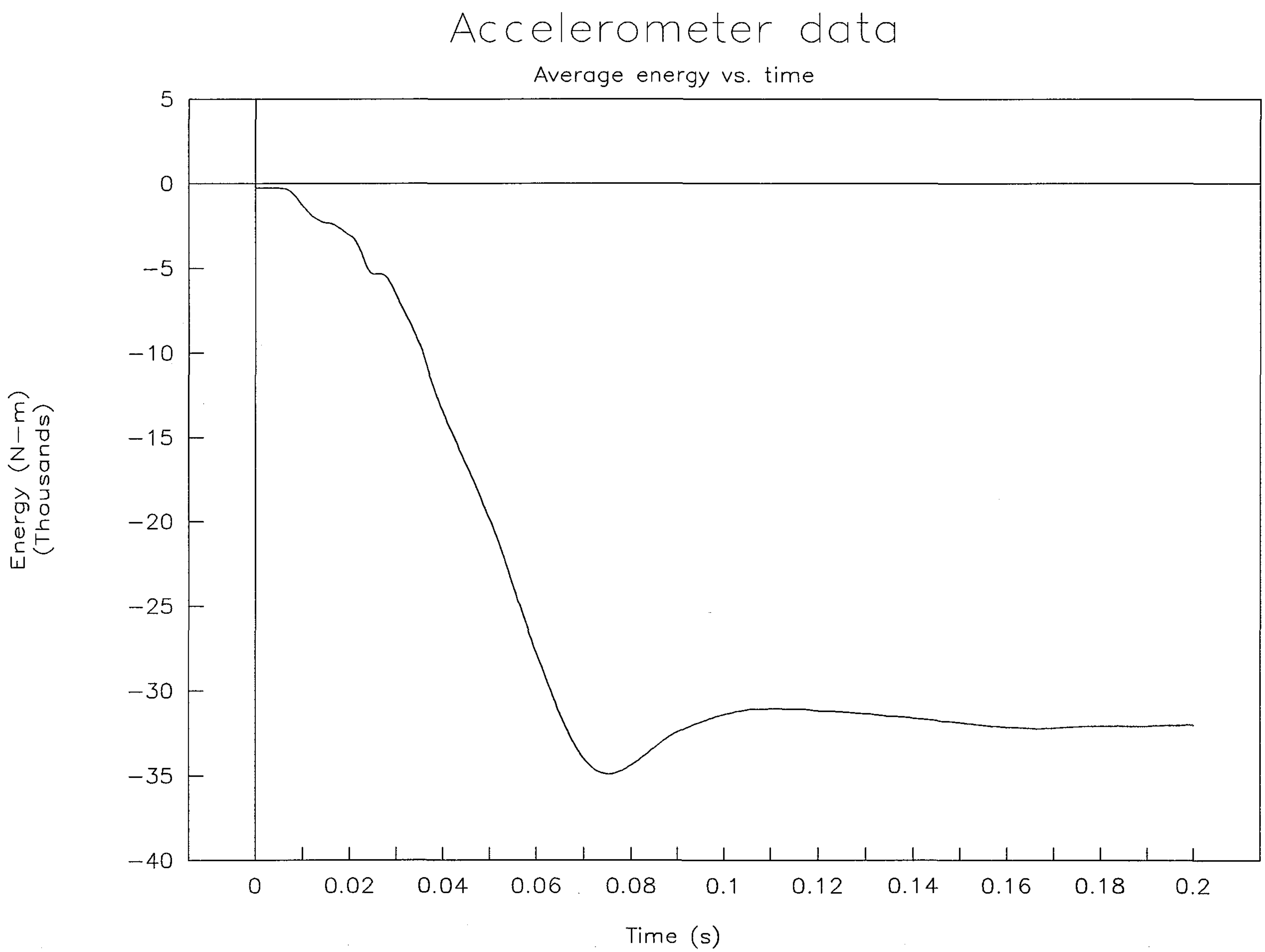


Figure 37. Average energy vs. time, accelerometer data.

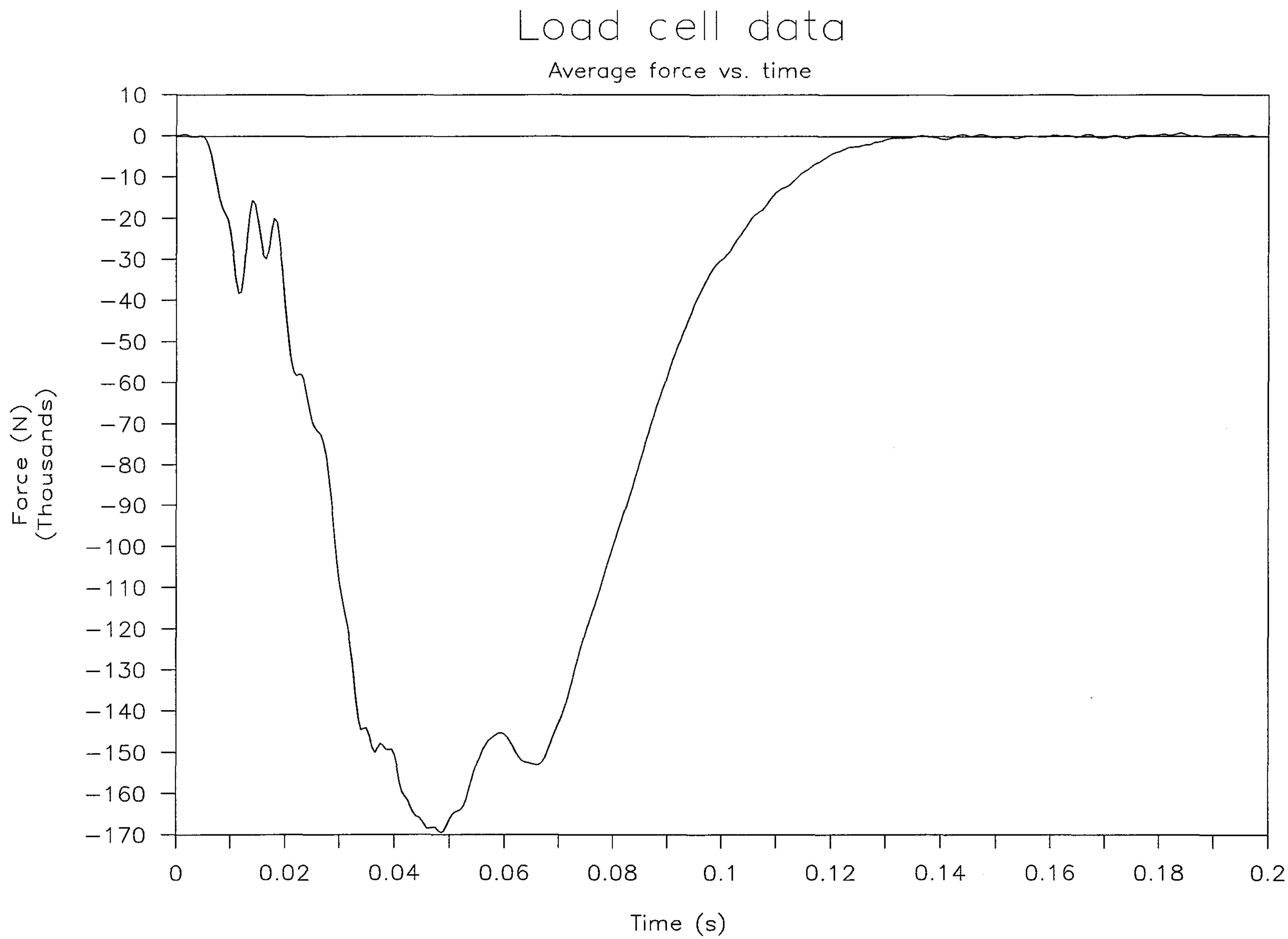


Figure 38. Average force vs. time, load cell data.

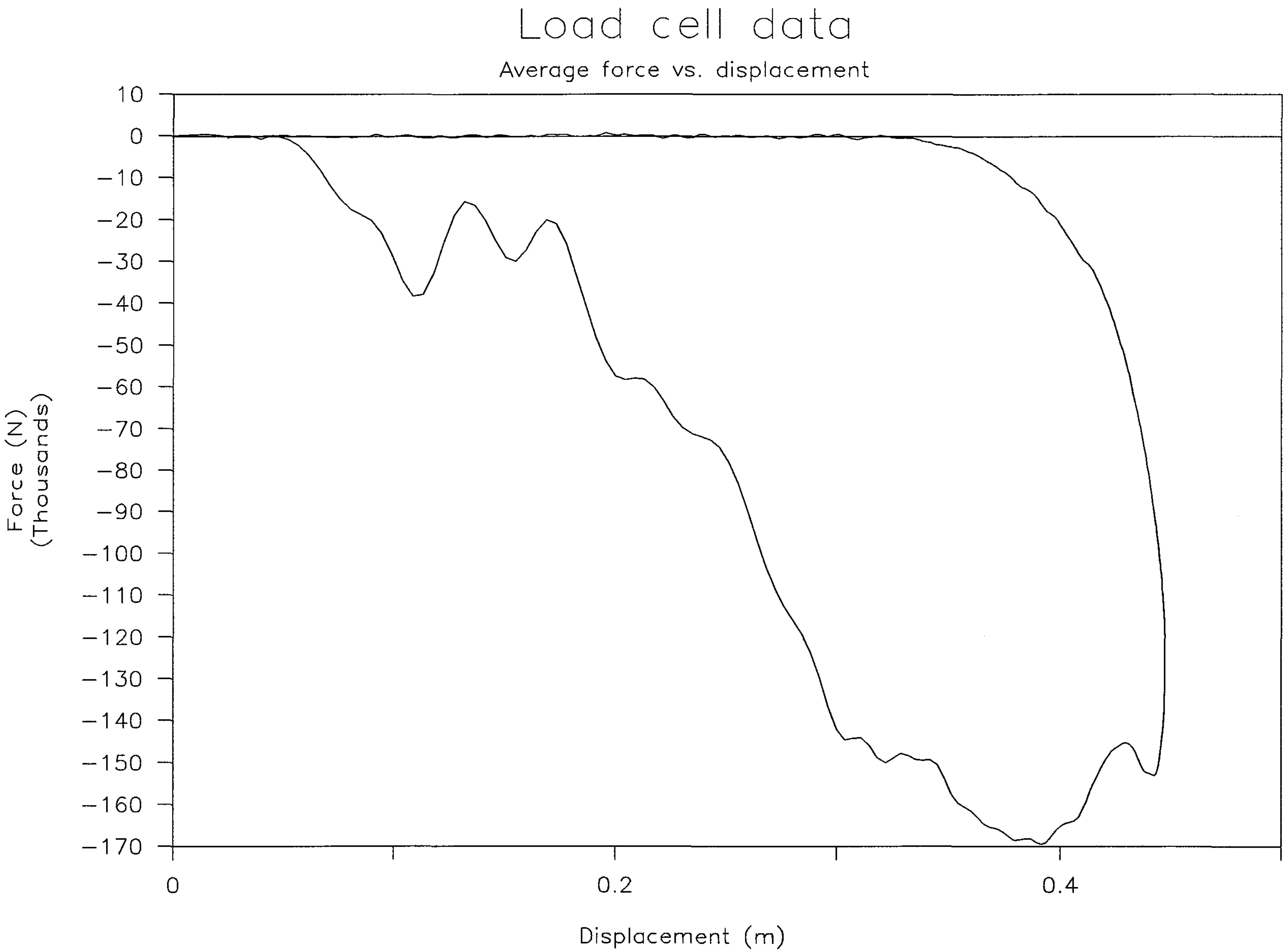


Figure 39. Average force vs. displacement, load cell data.

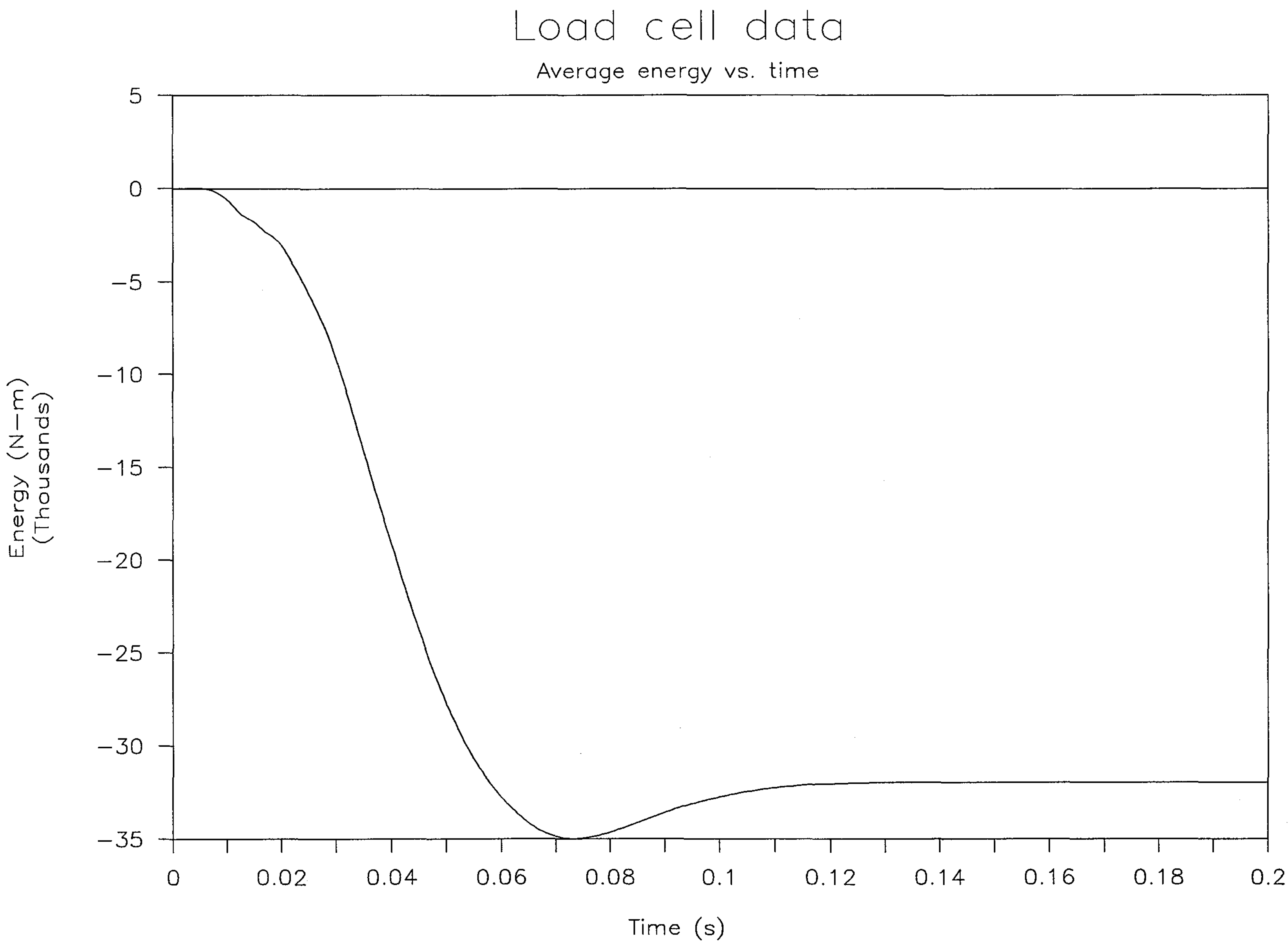


Figure 40. Average energy vs. time, load cell data.

REFERENCES

(1) Christopher M. Brown, *Crush Characteristics of the Ford Festiva, FOIL Test Numbers: 91F049, 92F032, 92F033,* Report No. FHWA-RD-93-075, Federal Highway Administration, Washington, D.C., May 1993.

(2) NHTSA. *Laboratory Test Procedure for Federal Motor Vehicle Safety Standard 208,* National Highway Traffic Safety Administration, Washington, D.C., May 1992.