Safety Performance Testing of a Modified Oregon Multidirectional Slip-Base Sign Support: FOIL Test Numbers 98F002 and 98F004

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Research and Development
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FOREWORD

This report documents the test procedures used and the test results from two crash tests conducted at the Federal Outdoor Impact Laboratory (FOIL) located at the Turner-Fairbank Highway Research Center (TFHRC) in McLean, Virginia. The objective of these tests was to evaluate the safety performance of a small sign support system provided by the Oregon Department of Transportation (DOT). Previous tests on large Oregon slip-base sign supports conducted at the FOIL demonstrated an improvement in safety performance by increasing the previous bolt-notch angle from 60° to 90°. The change was implemented into a small slip-base sign support design and tested at the FOIL. This report documents the results from two crash tests using the FOIL bogie vehicle and the Oregon DOT's 3X3 TBB sign support. The sign support met the FHWA safety performance criteria outlined in National Cooperative Highway Research Program (NCHRP) report number 350.

This report (FHWA-RD-98-111) contains test data, photographs taken with high-speed film, and a summary of the test results.

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

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

NOTICE

Technical Report Documentation Page

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16. Abstract

This report contains the test procedures, test setup, and test results from two crash tests performed at the Federal Outdoor Impact Laboratory (FOIL) located at the Turner-Fairbank Highway Research Center (TFHRC) in McLean, Virginia. The objective of these tests was to evaluate the safety performance of a small sign support system provided by the Oregon Department of Transportation (DOT) and to provide Federal Highway Administration (FHWA) finite element model simulation engineers with data on the performance of a slip-base sign support. Previous tests on large Oregon slip-base sign supports conducted at the FOIL demonstrated an improvement in safety performance by increasing the previous bolt-notch angle from 60° and 90°. The change was implemented into a small slip-base sign support design and tested at the FOIL. This report documents the results from two crash tests using the FOIL bogie vehicle and the Oregon DOT's 3X3 TBB sign support. The tests were conducted at nominal test speeds of 35 km/h and 100 km/h. The sign support met the FHWA safety performance criteria outlined in National Cooperative Highway Research (NCHRP) Report Number 350.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
	AREA			
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
	VOLUME			
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in 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

APPROXIMATE CONVERSIONS FROM SI UNITS

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

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

(Revised September 1993)

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BACKGROUND

Two Oregon Multidirectional Slip-Base sign support systems were tested at the Federal Outdoor Impact Laboratory (FOIL) in McLean, Virginia. The results were reported in the report *Testing of the Oregon Multidirectional Slip-Base Sign Support Systems, FOIL Test Numbers: 93F014, 93F015, and 93F019.*[1] The results indicated that neither sign support met the Federal Highway Administration's (FHWA) safety standards as outlined in *National Cooperative Highway Research Program Report Number 350 (NCHRP 350).*[2] The Oregon Department of Transportation's (ODOT) 6X6 TBB sign support did not meet the requirement for the low-speed test. The ODOT's 8X8 TBB met the low-speed test requirements but did not meet the high-speed test requirements. The ODOT 8X8 TBB sign support did not activate as anticipated. A possible cause of this problem was that the slip-base bolts were unable to slip from their notches fast enough to allow for disengagement of the slip-base sign stub. Modifications were made to the slip-base and sign stub notches. The notches were increased from a 60° opening to a 90° opening. The ODOT 8X8 slip-base sign support met the FHWA safety performance criteria after the notch modifications. The results from the compliance tests can be found in the report *Testing of a Modified Oregon Multidirectional Slip-Base Sign Support, FOIL Test Numbers: 95F007 and 95F009.*[3] The same technique was also applied to a smaller version of the sign support, the ODOT 3X3 triangular slip-base sign support. This report presents the test results from two crash tests on the ODOT 3X3 sign support.

SCOPE

This report documents the results of two crash tests conducted at the FHWA FOIL facility located at the Turner-Fairbank Highway Research Center (TFHRC). The objective of these tests was to evaluate the safety performance of a small sign support system provided by the ODOT and to provide FHWA finite element model (FEM) simulation engineers with data on the performance of a slip-base sign support. The data aided simulation engineers in developing and validating computer models of vehicle collisions with slip-base appurtenances. The sign support was the ODOT's 3X3 TBB multidirectional, triangular slip-base with 90° notches. *NCHRP Report 350, Recommended Procedures for the Safety Performance Evaluation of Highway Features*, was used as a guide for the test procedures followed and for the safety performance evaluation of the sign support. The safety performance evaluation criteria specify, in part, that the occupant change in velocity must be 5 m/s or less, that the significant test article stub height remaining after impact be no greater than 100 mm, and that there can be no occupant compartment intrusion. These three major evaluation criteria are used in this report to determine whether or not the sign support meets the FHWA's acceptable performance level for sign supports.

This document does not "pass or fail" the sign support for use on the National Highway System (NHS). The FHWA determines "pass or fail" based on this report and other performance criteria.

TEST MATRIX

Two tests were conducted for this test program, one low-speed test and one high-speed test. Each test utilized the FOIL bogie vehicle. The tests were frontal, 0 degree, center impact tests. One crash test was conducted at a nominal test speed of 35 km/h and one was conducted at a nominal test speed of 100 km/h. The high-speed test was conducted provided the sign support met the performance criteria during the low-speed test. Table 1 summarizes the test parameters.

Table 1. Summary of test parameters.

Test Number	Test Date	Test Vehicle	Nominal Speed	Test Article	Impact Angle
98F002	01-26-98	Bogie	35 km/h	Oregon 3X3 TBB	0°
98F004	02-25-98	Bogie	100 km/h	Oregon 3X3 TBB	0°

VEHICLE

The test vehicle was the FOIL's reusable breakaway bogie vehicle. The bogie vehicle uses a honeycomb material in a sliding nose to simulate the crush characteristics of an 839-kg small vehicle, more specifically a 1979 VW Rabbit.[4] The height of the bogie vehicle's nose was 444 mm, which corresponds to the bumper height of a VW Rabbit. Figure 1 is a sketch of the bogie vehicle. Frontal crush of the bogie vehicle, which simulates the crush of an actual vehicle, is accomplished using multiple cartridges of expendable aluminum honeycomb material in the sliding nose. After each test, the honeycomb material was replaced and the vehicle reused for the next sign test. Figure 2 depicts the honeycomb configuration used in the low-speed test and figure 3 is a sketch of the honeycomb configuration for the high-speed test. The bogie vehicle had four 1.8-m 100-mm by 100-mm boards mounted on top of its frame to protect it from the falling support or other debris. Ballasted and instrumented the bogie weighed 839 kg. A dummy is not used in bogie vehicle tests.

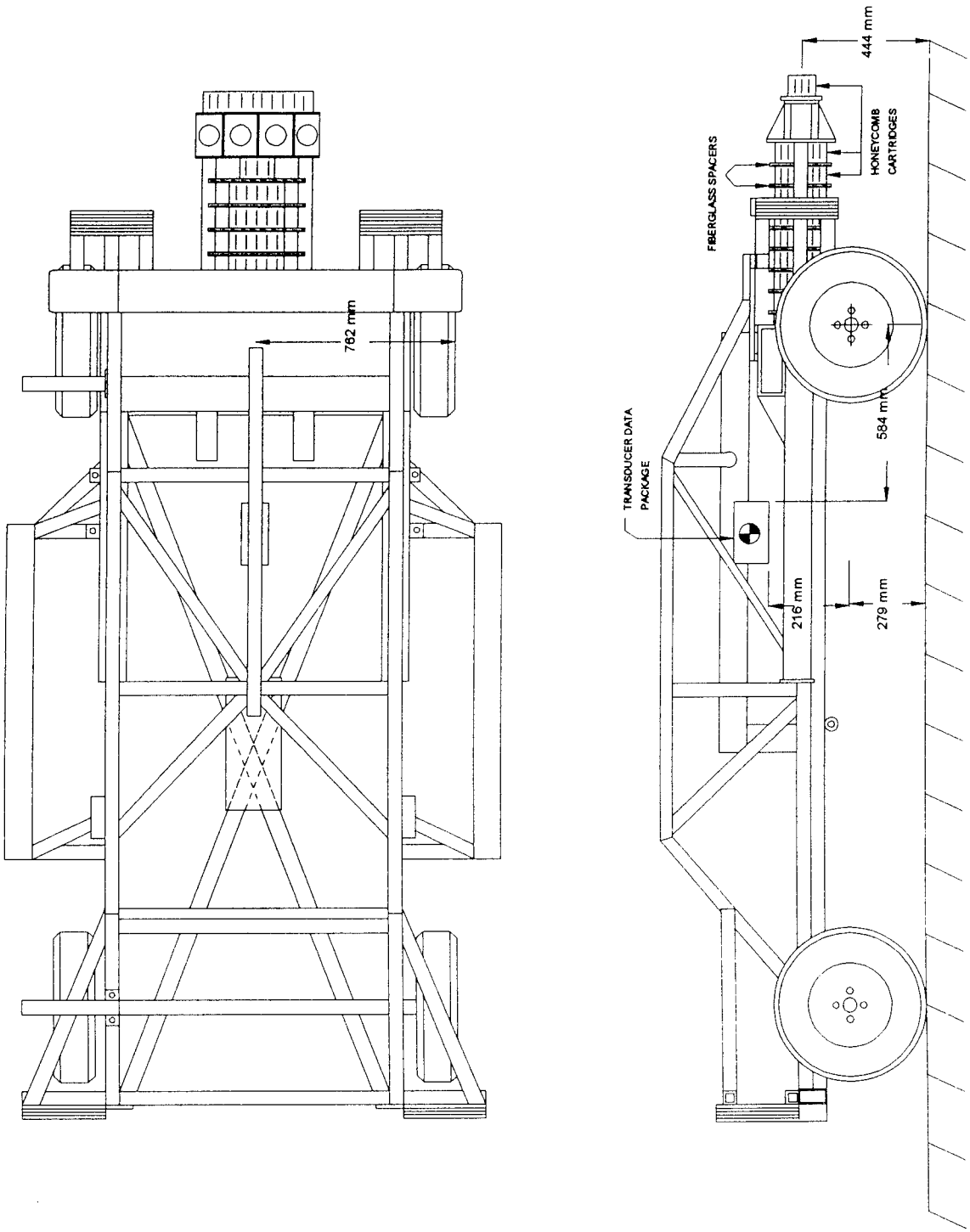
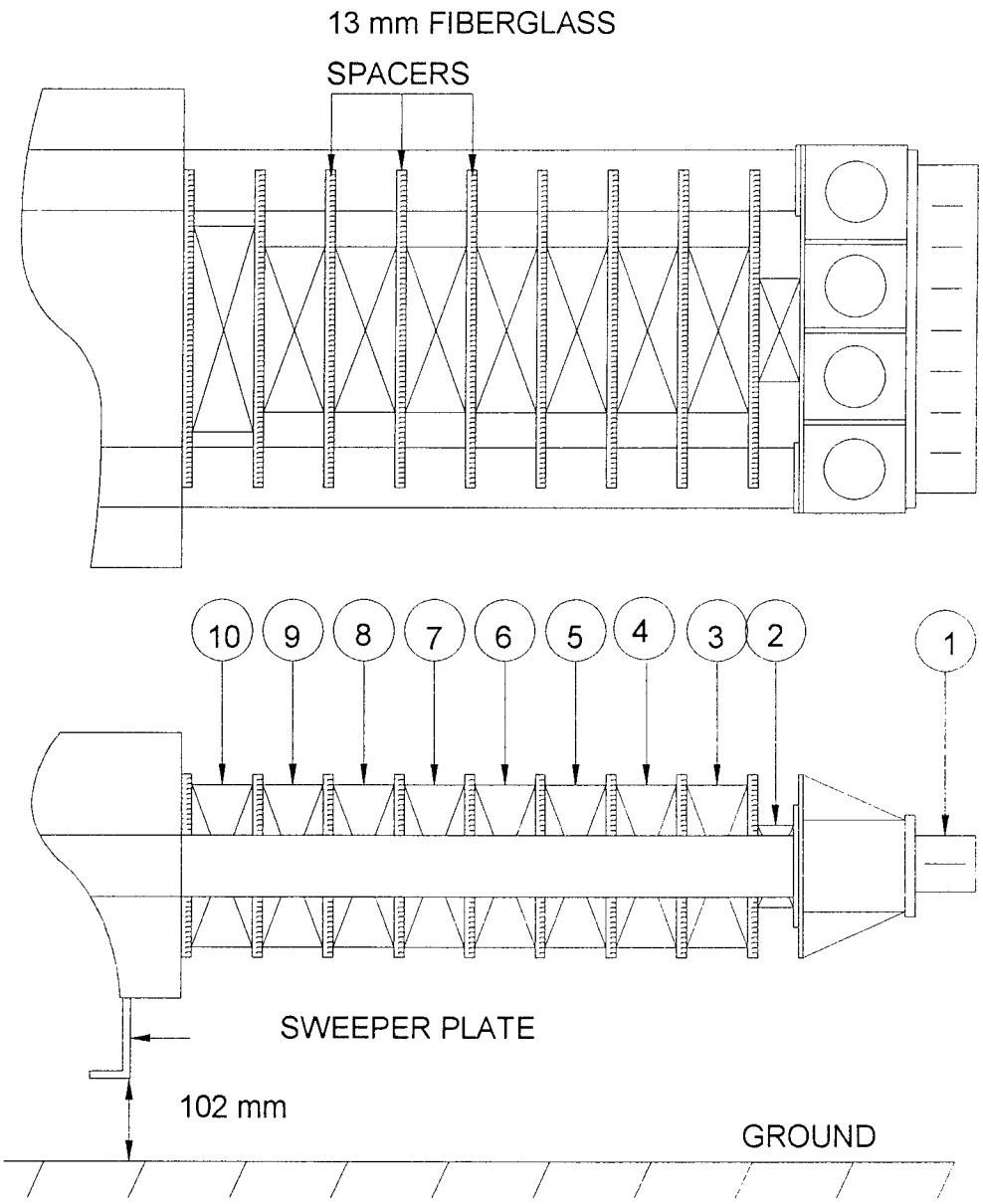
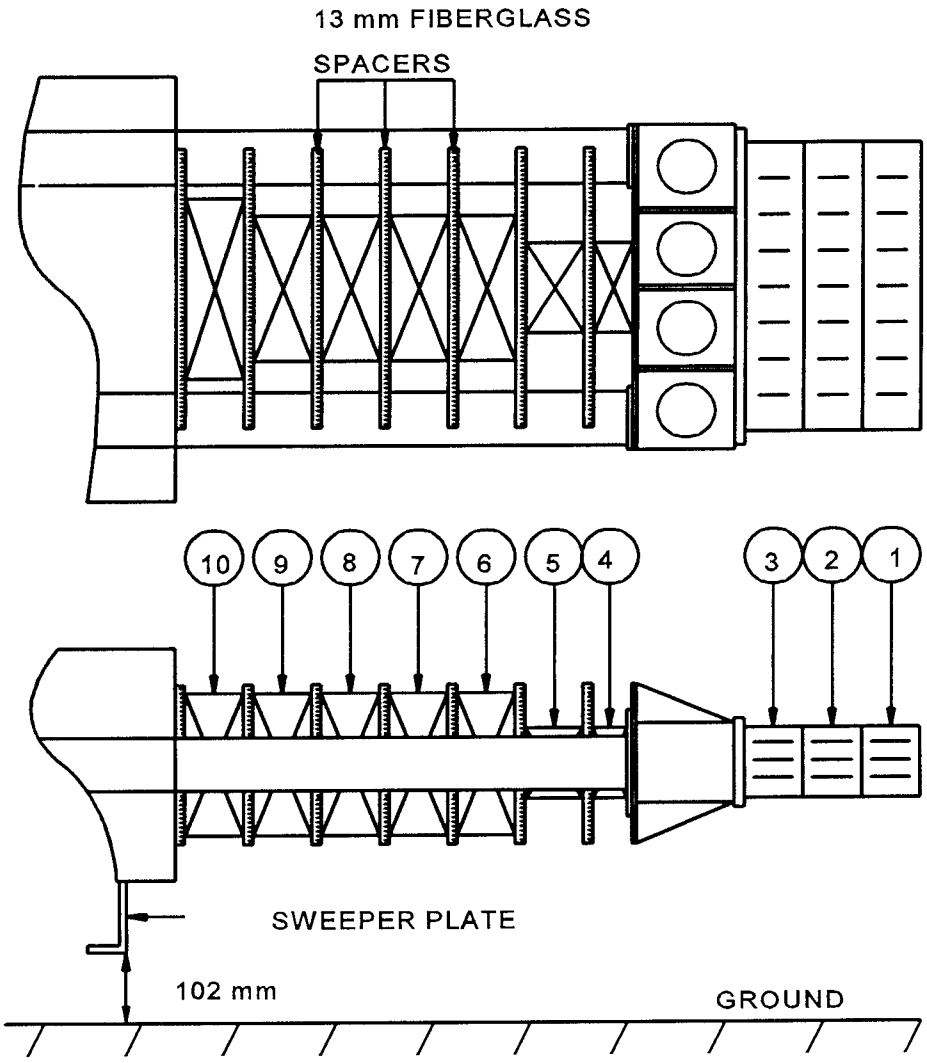


Figure 1. Sketch of the FOIL bogie vehicle.



Cartridge Number	Size (mm) / punch (mm^2)	Static Crush Strength(kPa)
1	70 x 406 x 76	896
2	102 x 127 x 51	172
3	203 x 203 x 76 / 13,545	896
4	203 x 203 x 76 / 9,675	1,585
5	203 x 203 x 76 / 3,870	1,585
6	203 x 203 x 76	1,585
7	203 x 203 x 76 / 13,545	2,756
8	203 x 203 x 76 / 7,740	2,756
9	203 x 203 x 76	2,756
10	203 x 254 x 76	2,756

Figure 2. Sketch of low-speed honeycomb configuration.



Cartridge Number	Size (mm) / punch (mm^2)	Static Crush Strength (kPa)
1	102 x 406 x 76	896
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5	102 x 127 x 76	172
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7	203 x 203 x 76 / 13,545	2,756
8	203 x 203 x 76 / 7,740	2,756
9	203 x 203 x 76	2,756
10	203 x 254 x 76	2,756

Figure 3. Sketch of high-speed honeycomb configuration.

SIGN SUPPORT

Two multidirectional triangular slip-base sign supports were provided by the ODOT for testing. The sign supports consisted of a 75-mm by 75-mm box-tube post welded to a triangular slip-base. The base had three 90° notches to accept three 13-mm-diameter strain gage bolts. A 1.5-m by 1.5-m aluminum sign panel was attached to a 150-mm wide by 5-mm thick steel plate welded to the top 1.5-m of the sign stub. The extruded panel was clamped to the plate using eight aluminum sign panel clips supplied by the ODOT. The three bolts clamped the sign post to the sign stub (slip plane) and were torqued to the manufacturer's recommended torque value of 41 N·m. The increase in the bolt-notch size precipitated the need for longer and thicker clamp-washers. The washers used were 25 mm thick, 25 mm wide and 50 mm long. The thicker washers precipitated the need for 125-mm-long bolts. Strain gage bolts were used for tests 98F002 and 98F004 to measure the bolt tension during the crash tests. The bolts in these tests were pre-tensioned to a nominal tension of 22 kN each. This corresponds to 41 N·m torque. This relationship was derived from the results reported in the report *Slip-Base Clamping Force Tests.*[5] The bolts in each test were lubricated before sign installation. A slip-bolt keeper plate was sandwiched between the sign post slip-base and the sign stub. The sign stub was bolted to the FOIL runway's foundation plate using 10 20-mm bolts. Table 2 summarizes the details of the sign support. Figure 4 is a sketch of the sign support system.

Table 2. Summary of sign support parameters.

Test Number	Sign Support	Bolt Diameter (mm)	Bolt Torque (N·m)	Keeper Plate Gage	Panel Size (m x m)	Sign Weight (kg)
98F002	3X3 TBB	13	41	25	1.5 x 1.5	100
98F004	3X3 TBB	13	41	25	1.5 x 1.5	100

DATA ACQUISITION

The two sign support tests were conducted in accordance with NCHRP Report 350. Electronic and photographic instrumentation were used to measure pertinent test parameters used to evaluate the sign support system.

Accelerometers, rate gyros, and strain gage bolts were mounted to the bogie vehicle's center of gravity and to the sign support. An accelerometer was also mounted inside the bogie

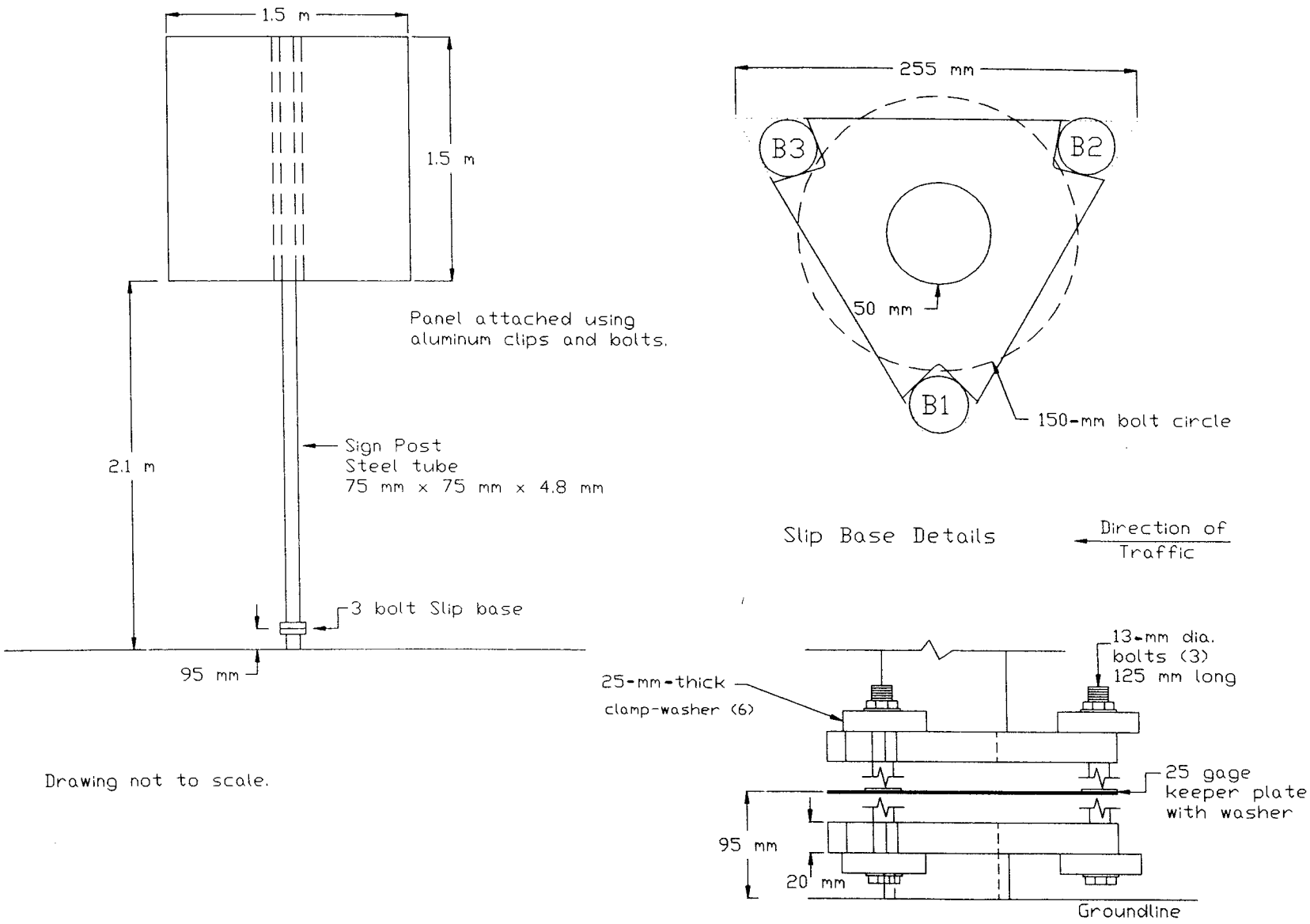


Figure 4. Sketch of the Oregon 3x3 TBB sign support.

nose. In addition to the bogie vehicle and sign support data, speed trap signals were recorded to determine vehicular speed before and after impact. A contact tape switch signal was recorded to synchronize electronic data channels to time zero.

Accelerometer, speed trap, contact switch signal, and strain gage bolt data were recorded by a Honeywell 5600E analog tape recorder. To ensure the tape drive was functioning properly, a 1 kHz timing signal was recorded by the analog tape recorder. The recorded signals were played back after the test through an analog filter set to 1000 Hz into a Data Translation analog-to-digital converter (ADC). The sample rate of the ADC was 5000 Hz. The data were digitally filtered at 300 Hz.

The rate transducer data were recorded by the FOIL ODAS III system. The ODAS III system is a fully self-contained system that supplies the transducers with excitation voltage and pre-filters the data. The onboard system pre-filters the data at 4000 Hz and digitally samples the signals at 12,500 Hz. The data are digitally stored in the onboard system's memory, which is downloaded after the test for analysis. Table 3 summarizes the data channels for tests 98F002 and 98F004.

Table 3. Summary of data channels.

ODAS III			
Channel No.	Transducer and Range	Data	Location* (mm)
1 2 3	Humphrey Triaxial 500°/s	Pitch rate Roll rate Yaw rate	center-of-gravity (-812,762,267)
Analog tape recorder			
1	100-g Endevco 2262A-100	X-axis	center-of-gravity (-711,762,245)
2	100-g Endevco 2262A-100	X-axis	center-of-gravity (-711,762,273)
3	100-g Endevco 2262A-100	Z-axis	center-of-gravity (-711,762,245)
4	2000-g Endevco 7264A-2000	X-axis	Bogie Nose (686,762,165)
5	Strainsert Strain gage bolt	Tension	Sign base
6	Strainsert Strain gage bolt	Tension	Sign base

Table 3. Summary of data channels (continued).			
7	Strainsert Strain gage bolt	Tension	Sign base
8	Tape switch 1.5 V	Speed	
9	Tape switch 1.5 V	Speed	Runway
10	Tape switch 1.5 V	Synchronize impact	Sign support
11	Signal Generator	1 kHz Reference	Tape recorder
* Location, referenced from the bogie's right front wheel hub, except for strain gage and bolt data.			

Photographic instrumentation was used to evaluate certain performance criteria. The criteria include vehicle trajectory, vehicular speed, break away mechanism performance, impact angle, and impact location. Six high-speed cameras, operating at 500 f/s were used during the tests. In addition to the high-speed cameras, one real-time camera and two 35-mm still cameras were used to document the test. Table 4 summarizes the cameras used and their respective placement.

Table 4. Summary of camera placement.				
Camera	Type	Film speed frames/s	Lens (mm)	Location
1	LOCAM II	500	75	Right 90° to impact
2	LOCAM II	500	25	Right 90° to impact
3	LOCAM II	500	50	Right side 45° to impact
4	LOCAM II	500	100	Left side 45° to impact
5	LOCAM II	500	150	180° to impact, berm
6	PHOTEC	500	110	Tight on base, bolts
7	BOLEX	24	ZOOM	Documentary
8	CANNON AE-1	still	ZOOM	Documentary
9	CANNON AE-1	still	ZOOM	Documentary

DATA ANALYSIS

After each crash test, the digital data were converted to the ASCII format for processing. The FOIL Data Processing System (FOILDPS) software package was used to crop the data down to the region of interest, remove the zero-bias, and digitally filter the signals. The digital filter applied had a cut-off frequency of 300 Hz. Acceleration vs. time plots were generated from the accelerometer data. The acceleration data were single and double integrated to obtain velocity and displacement traces. Using the single and double integration, the occupant risk was calculated. The occupant risk model is outlined in NCHRP Report 350. The impact speed for each test was calculated by a best line fit of displacement vs. time data obtained from the speed trap contact switches mounted to the runway. High-speed film analysis was used as a second technique for measuring impact speed. However, the speed trap value was used as the primary measurement.

TEST RESULTS, TEST 98F002

a. Performance: The bogie vehicle was accelerated to 35.3 km/h prior to striking the Oregon 3X3 TBB sign support's centerline. The honeycomb material crushed as the bogie continued forward. The slip-base slid at 0.010 s after initial contact; however, the base did not slip completely from the foundation stub. The bogie continued to push on the sign post and at 0.014 s. the base hesitated, then slipped free of the foundation stub at 0.024 s. The peak acceleration recorded by the accelerometers was 14.6 g's. Multiplying the peak acceleration by the mass of the bogie, the peak force required to activate the slip-base was 120 kN. The bogie vehicle continued to push on the sign post rotating the sign post upward. The top of the sign panel rotated around and struck the rear of the bogie vehicle as the bogie passed underneath. The sign support fell to the ground. The brakes were applied to the bogie and the bogie came to rest 45 m downrange.

Figure 5 is photographs of the sign support during the crash test. Figure 6 presents a summary of the test data and the location of the bogie vehicle and sign support after the test. Figures 7 through 14 present data plots of data obtained from accelerometers and strain gage bolts. Figure 15 is photographs taken before the crash test, and figure 16 shows photographs of the vehicle and sign system after the test.

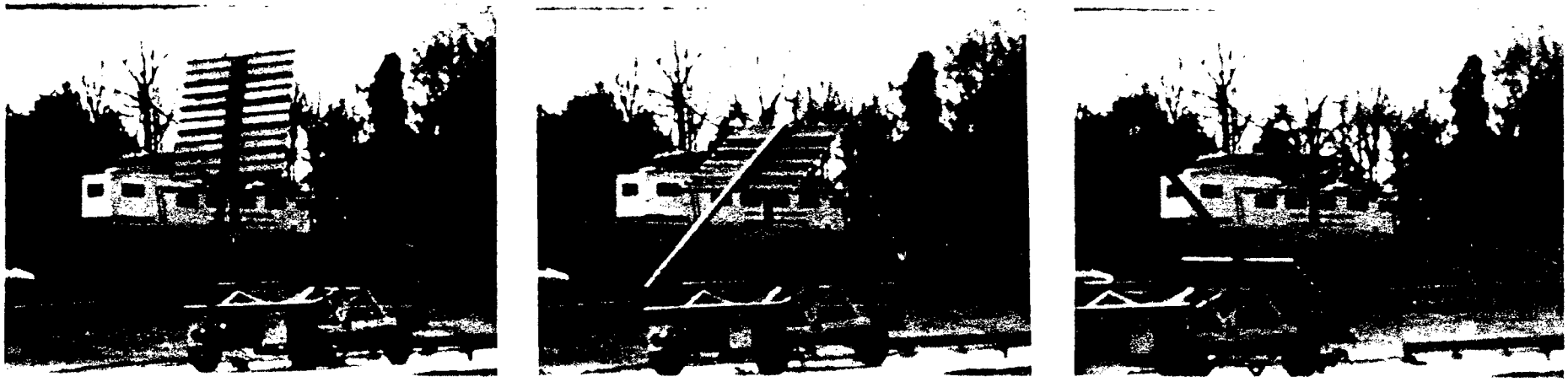
The longitudinal vehicle change in velocity was determined to be 0.84 m/s. The triaxial rate transducer measured no significant pitch, roll, or yaw rates during the test.

b. Occupant Responses: The longitudinal occupant impact velocity for the test was determined to be 0.84 m/s and occurred 0.8 s after initial contact. The longitudinal 10-ms average ridedown acceleration was determined to be 0.3 g's. There was no lateral occupant impact during the bogie/sign interaction.

c. Vehicle Damage: The bogie vehicle damage consisted of crushed honeycomb. The measured honeycomb crush was 150 mm. Due to the nature of crush, no figure depicting vehicle crush is included in this report. This amount of crush would denote that a minimum of 65.5 kN of force was reached during the test.

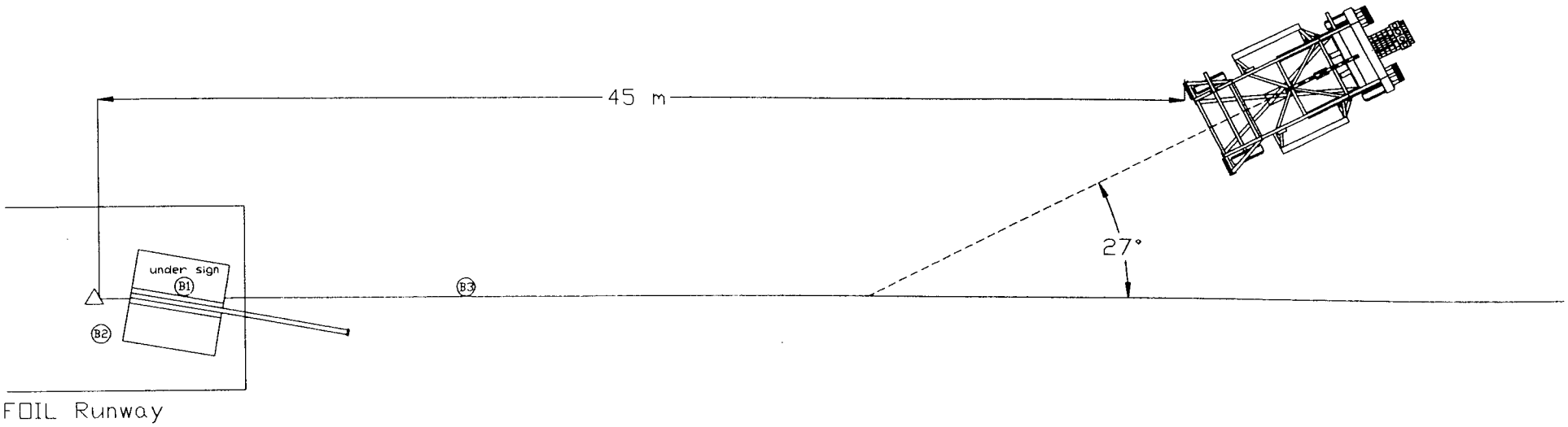
d. Test Article Damage: Damage to the test article was minor. The post disconnected from the base and tore the keeper plate. The sign panel remained fastened to the sign post with no damage. The sign system could be used again after installation of a new keeper plate. The stub height was measured to be 95 mm.

0.000 s | 0.020 s | 0.030 s



0.080 s | 0.240 s | 0.520 s

Figure 5. Test photographs during impact, test 98F002.



Test number.....98F002

Date.....January 26, 1998

Test article.....Single-leg sign support

Support.....3X3 TB on a triangular slip-base

Total clamp load.....62.6 kN

Sign panel.....Aluminum 1.5 m by 1.5 m

Foundation.....FOIL Universal Foundation

Vehicle.....FOIL Bogie

Weight: Inertial.....839 kg
Gross.....839 kg

Impact speed.....35.3 km/h

Impact location.....Single-leg center

Impact angle.....0 degrees

Vehicle front-end crush (honeycomb).....150 mm

Vehicle damage.....N/A

Vehicle analysis
Longitudinal:
Vehicle Delta-V.....0.84 m/s
Occupant Delta-V at 0.6 m
(acceptable 5.0 m/s).....0.84 m/s
Ridedown Acceleration
(acceptable 15 g's).....0.3 g's
Lateral:
Occupant Delta-V at 0.3 m.....No contact
Ridedown Acceleration.....No contact

Vertical stub height (100-mm limit).....95 mm

Figure 6. Summary of results, test 98F002.

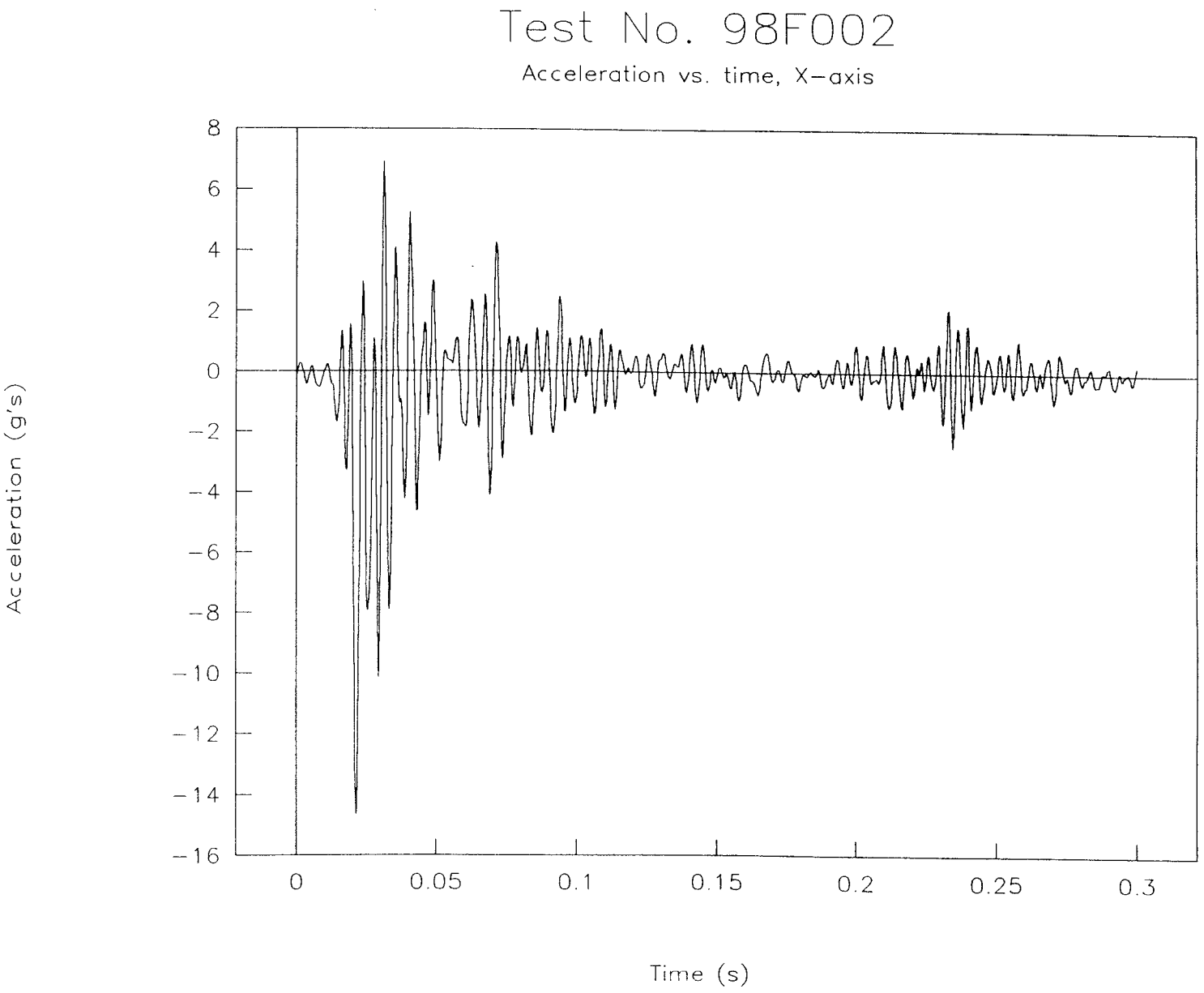


Figure 7. Acceleration vs. time, X-axis, test 98F002.

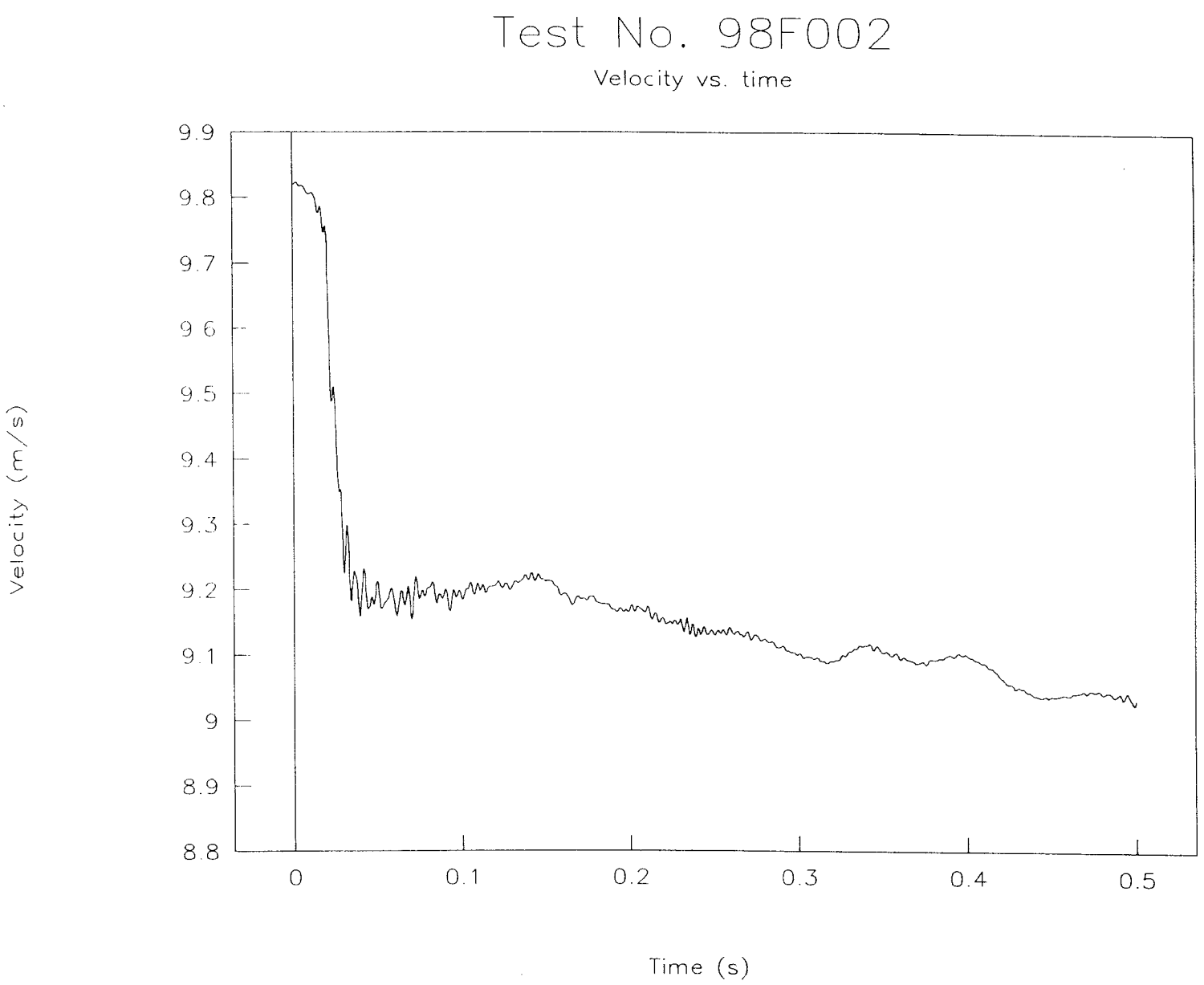


Figure 8. Velocity vs. time, Test 98F002.

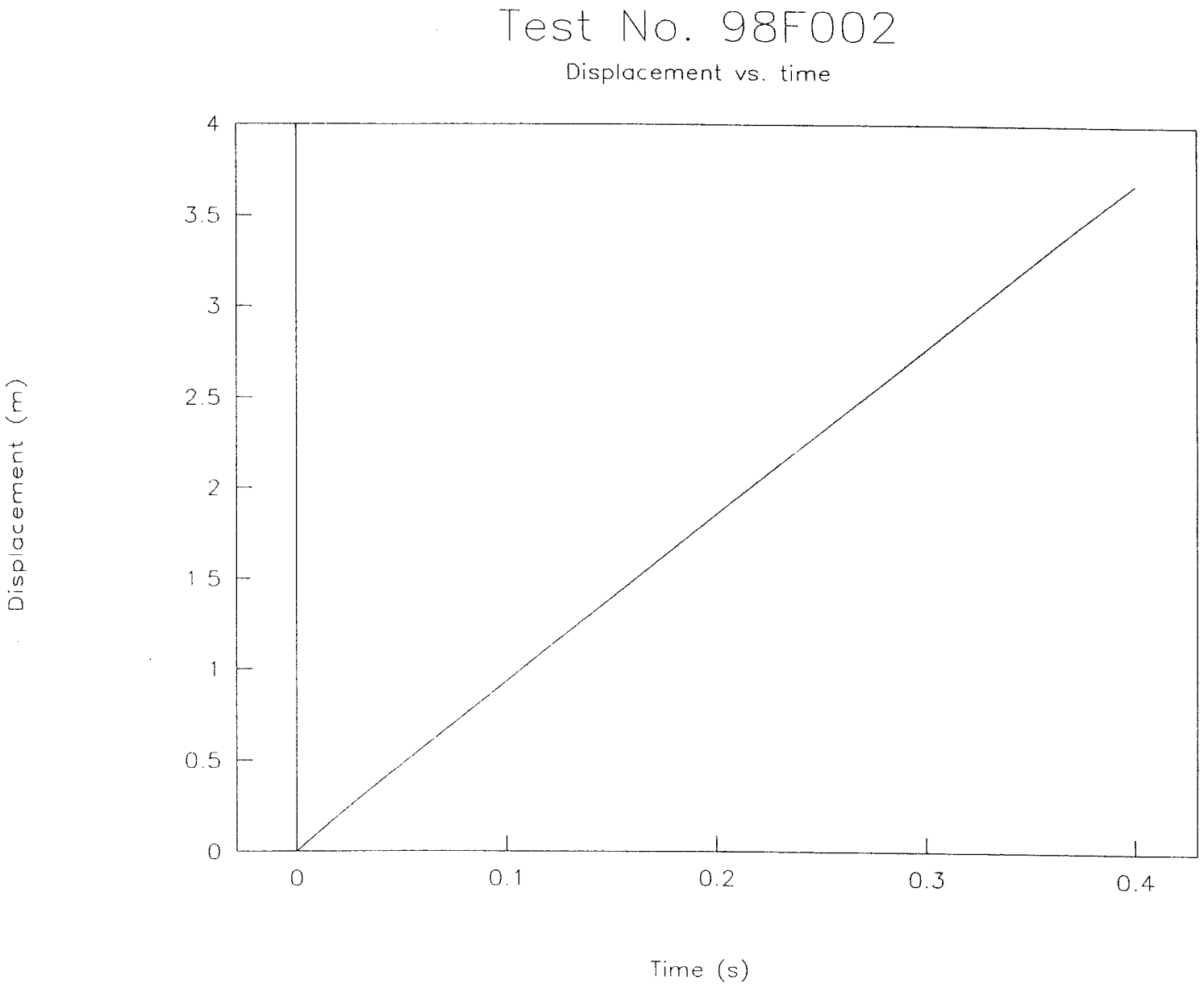


Figure 9. Displacement vs. time, test 98F002.

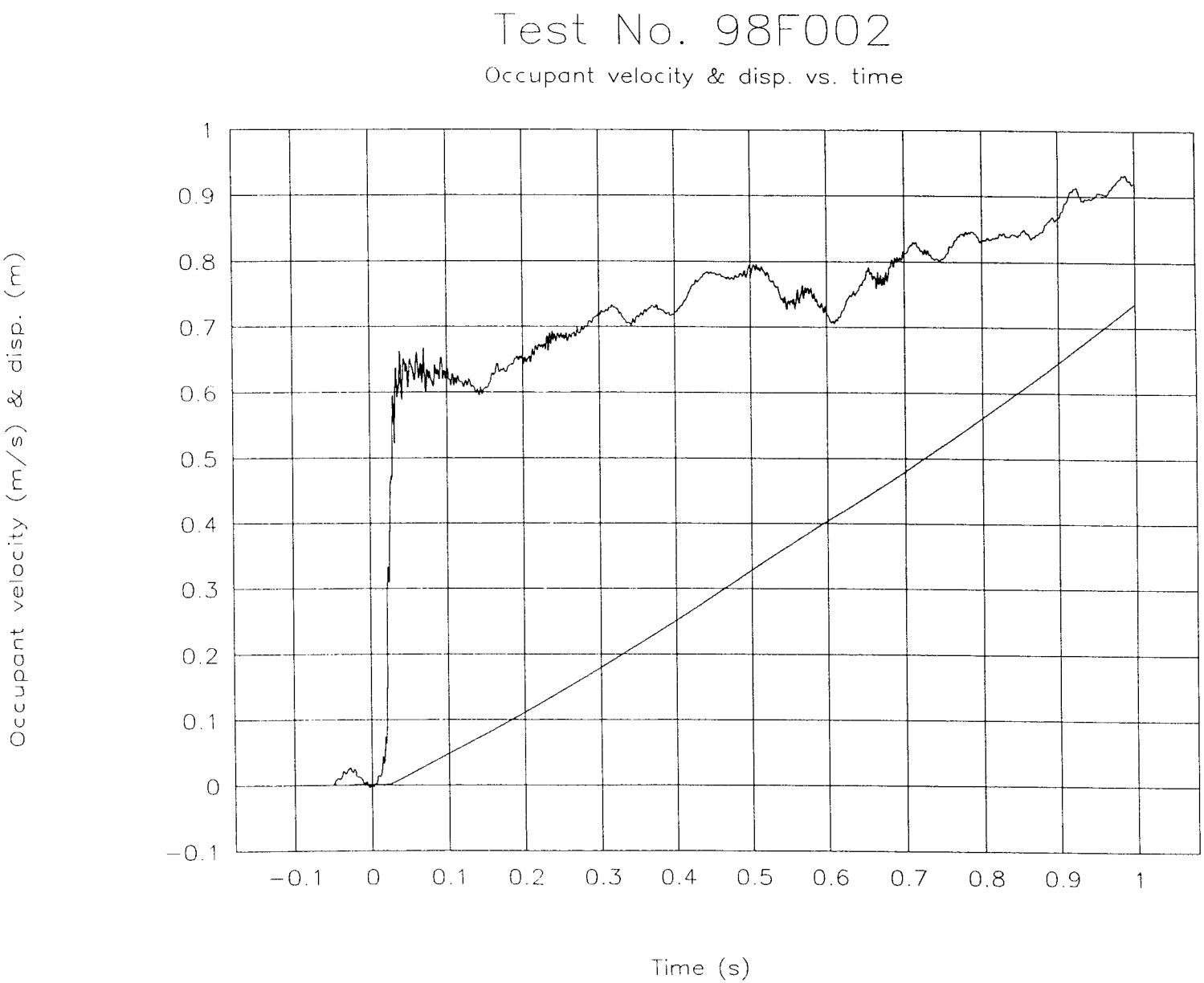


Figure 10. Occupant velocity and displacement vs. time, test 98F002.

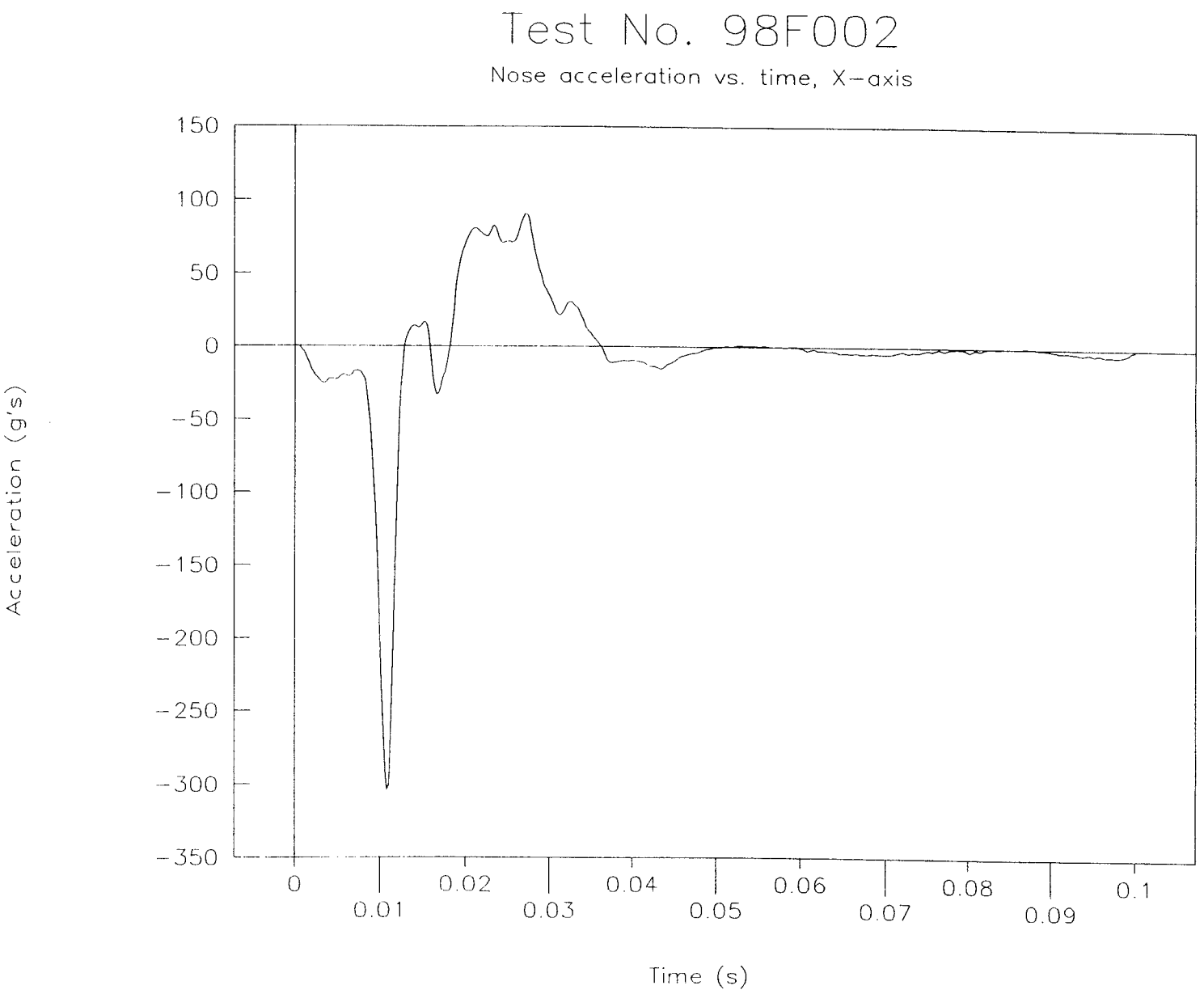


Figure 11. Acceleration vs. time, nose X-axis, test 98F002.

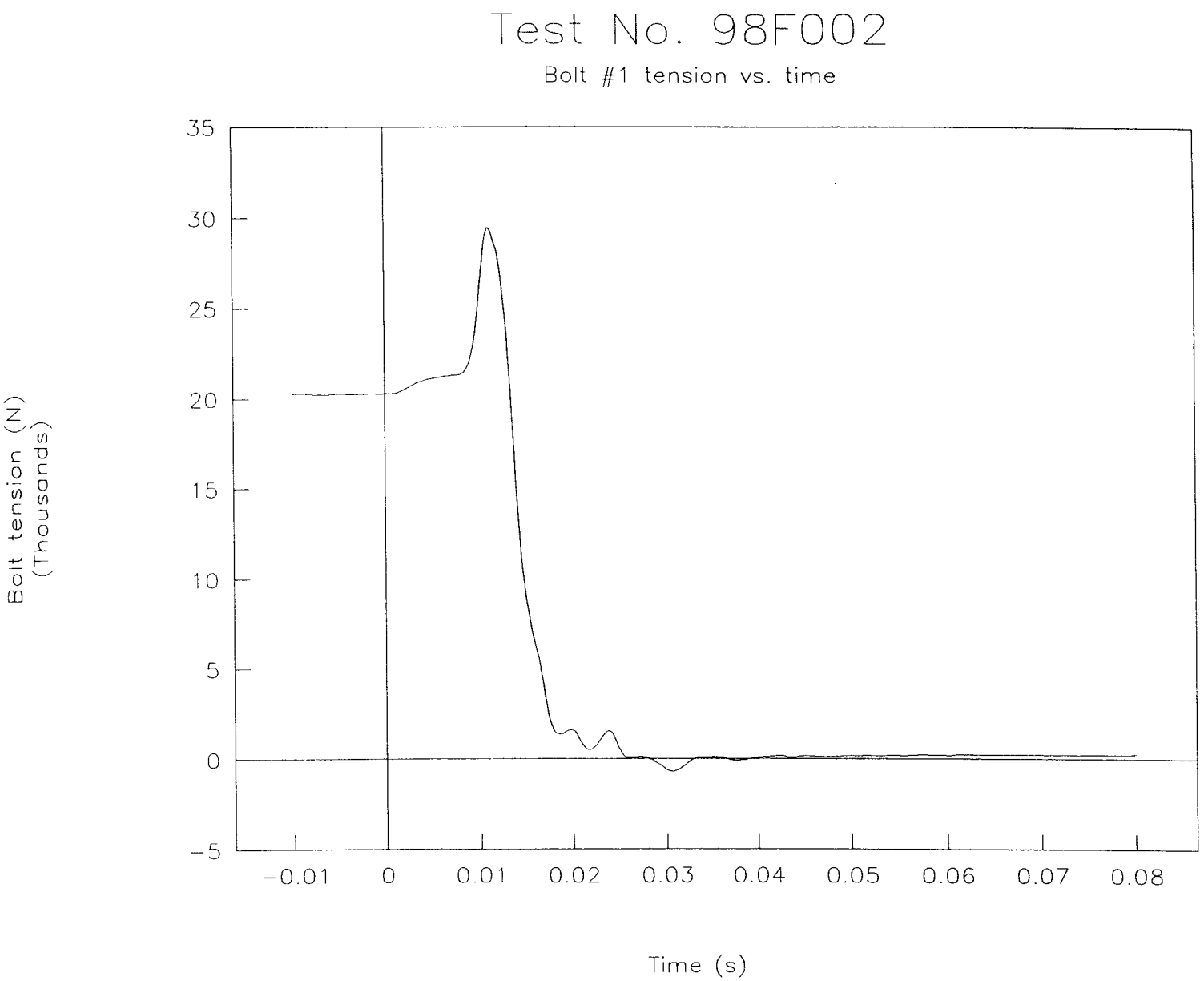


Figure 12. Bolt tension vs. time, bolt #1, test 98F002.

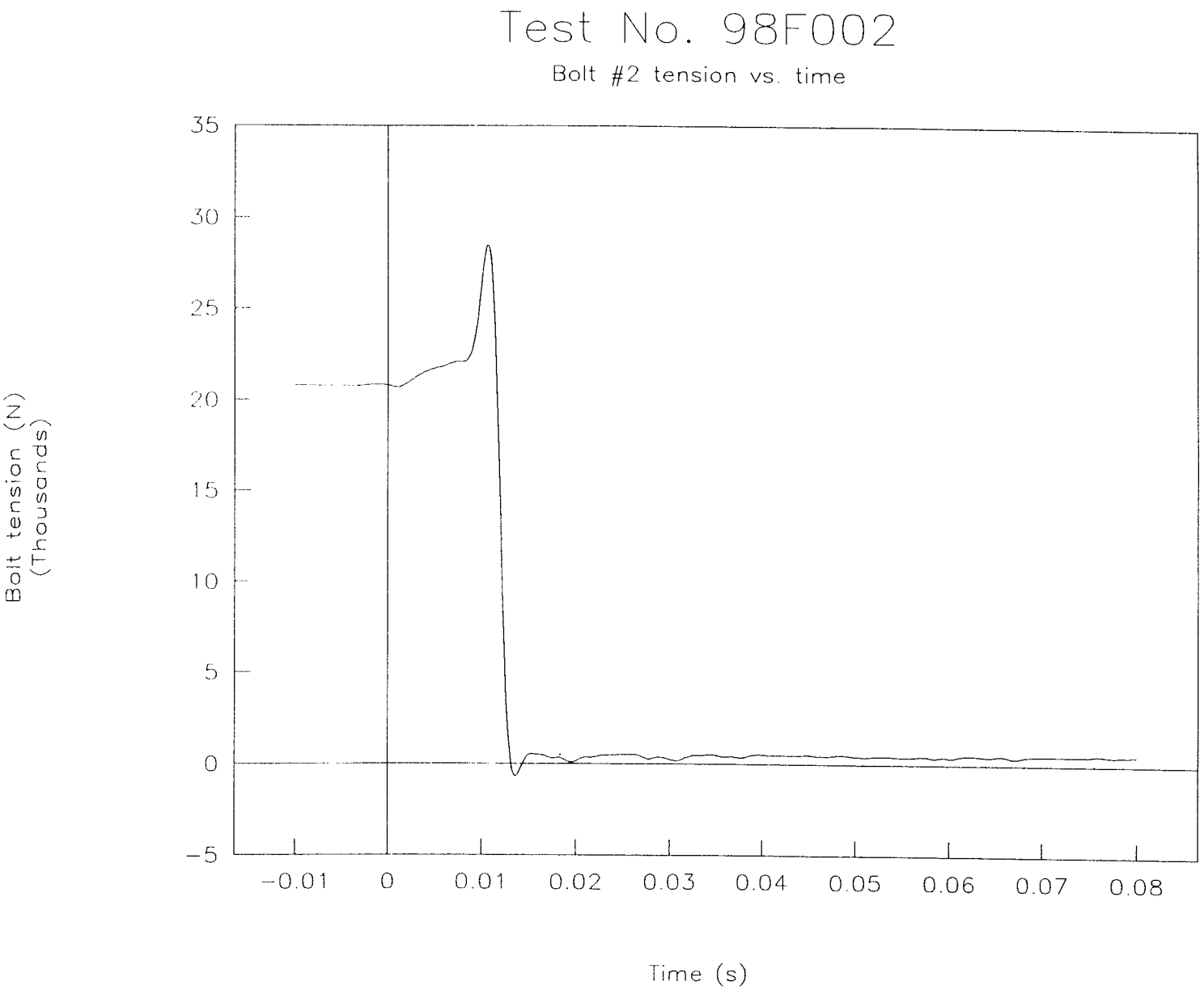


Figure 13. Bolt tension vs. time, bolt #2, test 98F002.

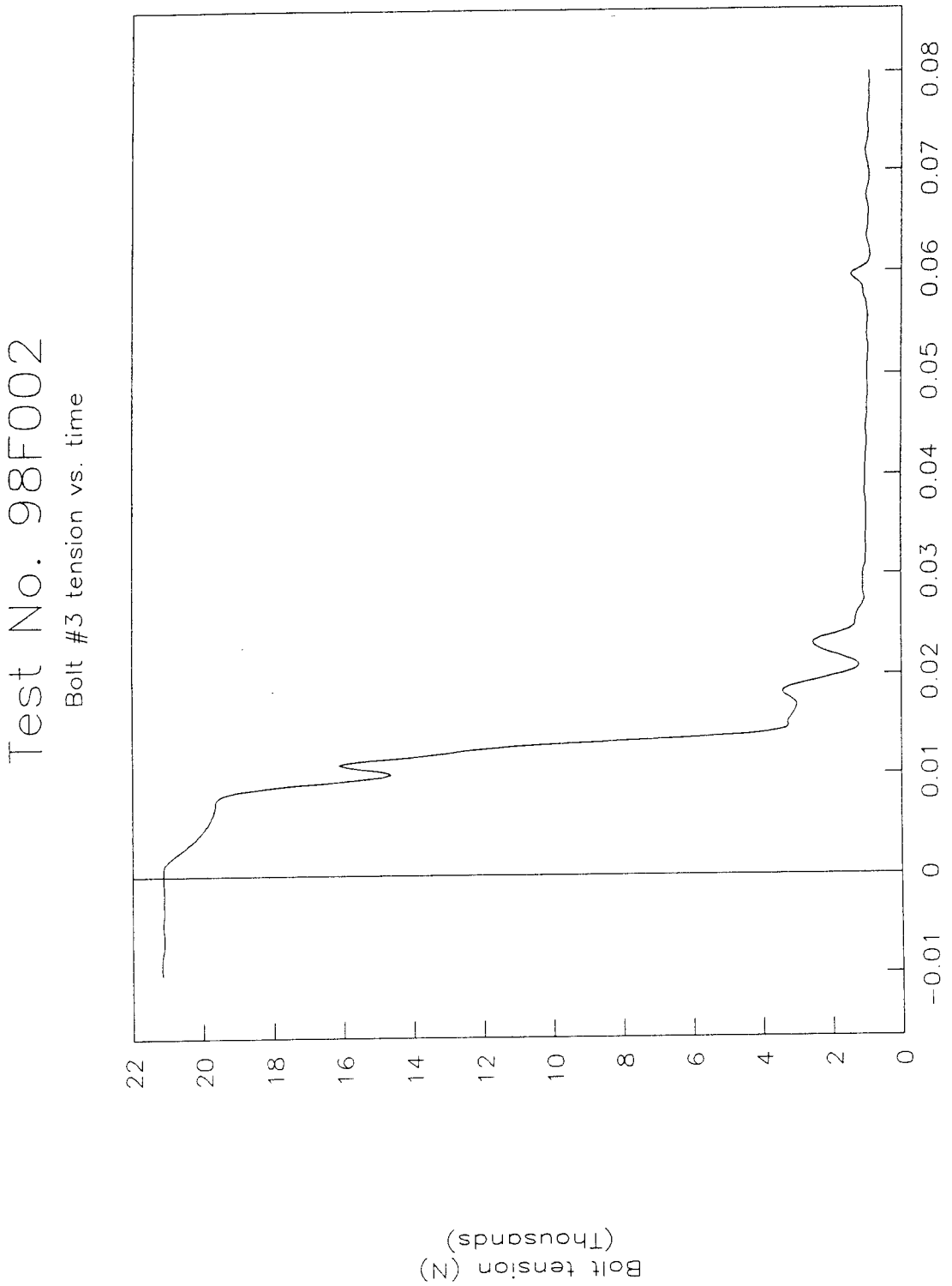


Figure 14. Bolt tension vs. time, bolt #3, test 98F002.

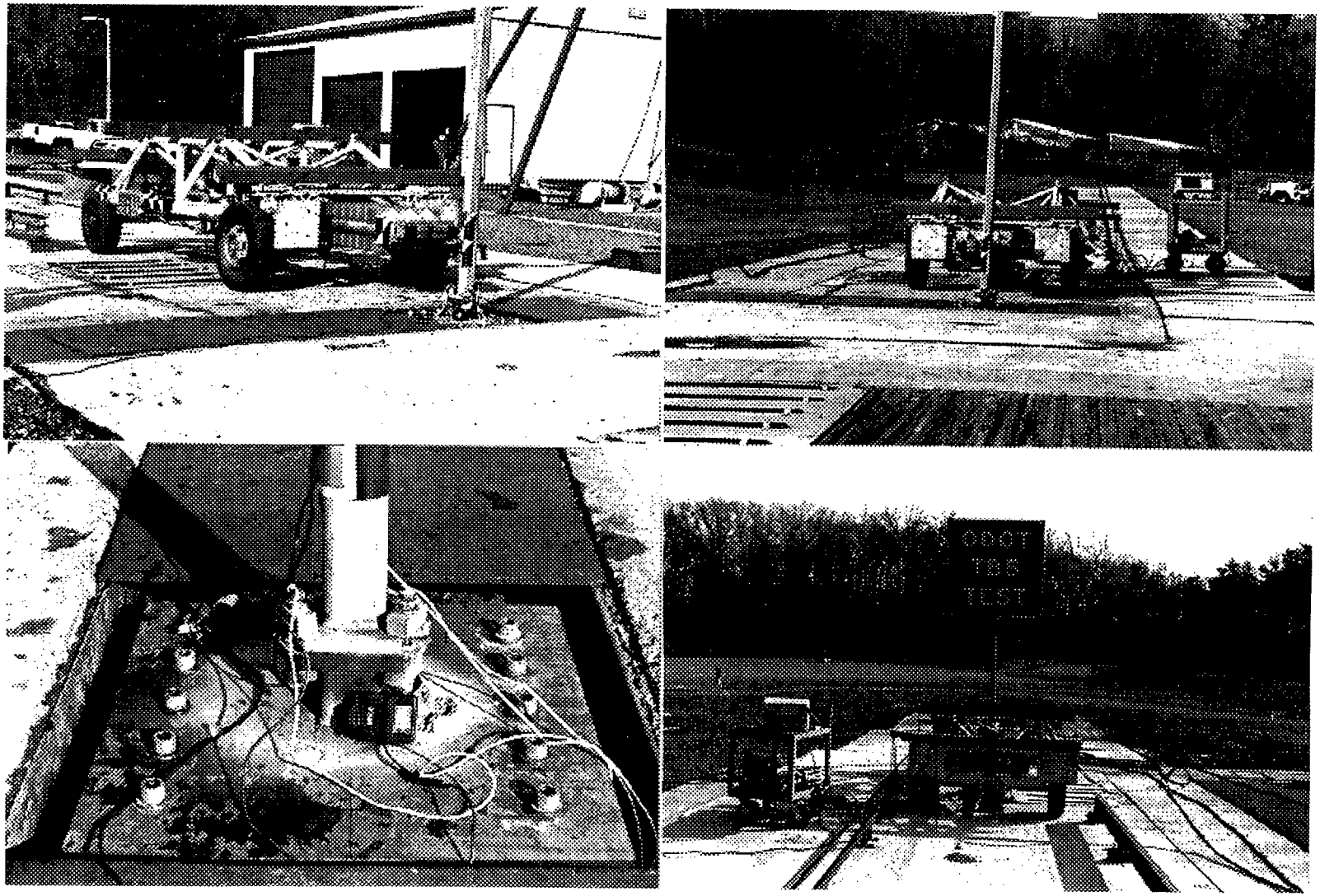


Figure 15. Pretest photographs, test 98F002.

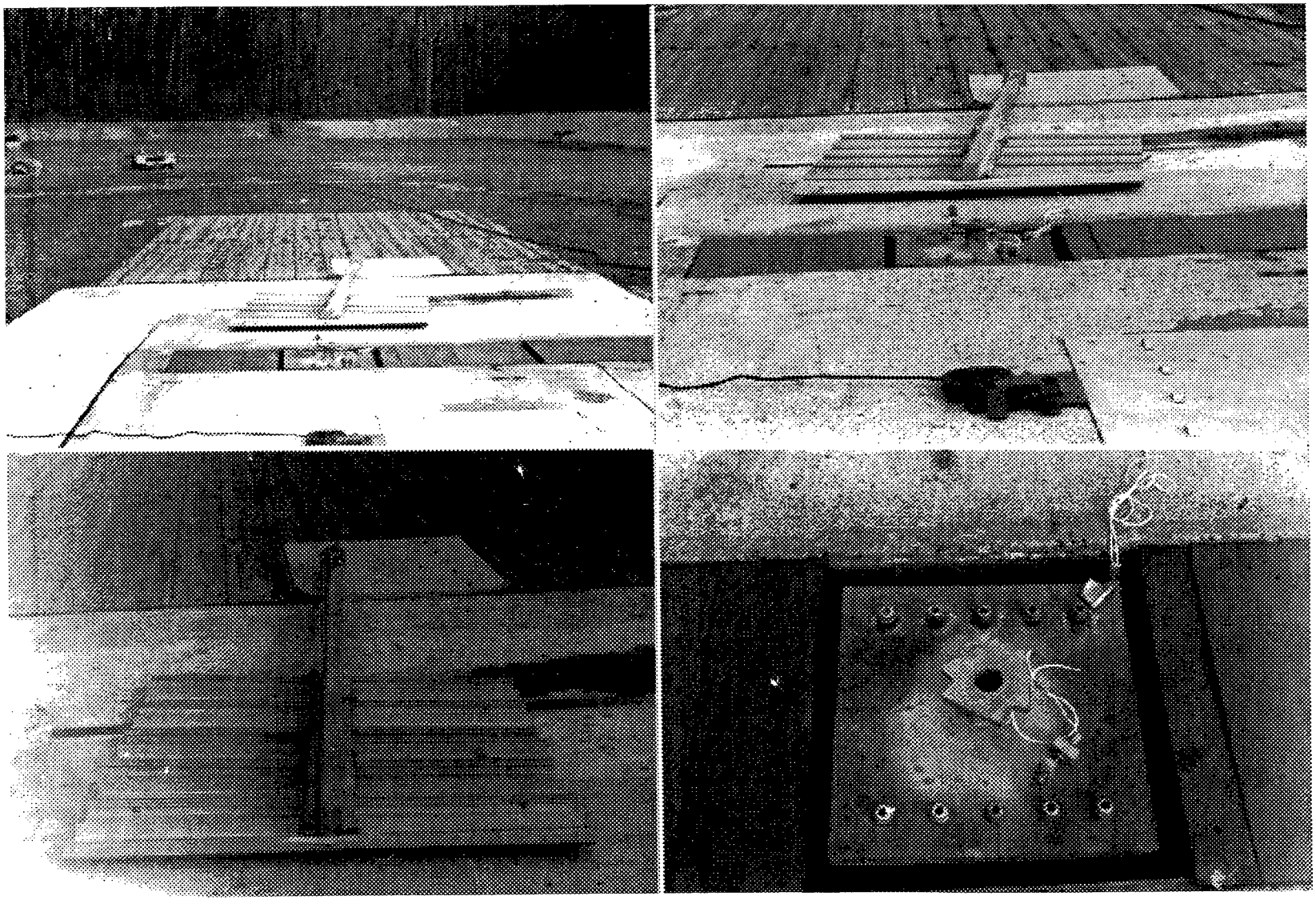


Figure 16. Post-test photographs, test 98F002.

TEST RESULTS, TEST 98F004

a. Performance: The bogie vehicle was accelerated to 99.9 km/h prior to striking the Oregon 3X3 TBB sign support's centerline. The honeycomb material crushed as the bogie continued forward. The slip-base began to activate 0.010 s after initial contact. The sign post base was clear of the foundation base plate by 0.016 s. The peak acceleration determined from the vehicle center-of-gravity data was 17.8 g's. Multiplying the peak acceleration by the mass of the bogie, the peak force required to activate the slip-base was 146 kN. The bogie vehicle continued to push on the sign post, rotating the sign post upward. The bogie vehicle passed underneath the sign support without further contact. As the sign post rotated, the sign panel slipped off the post. The clamping load of the sign panel clips could not hold the panel to the stub. The sign panel fell on top of the foundation base plate. The sign post rotated around approximately 540°, striking the ground top first. The brakes were applied 105 m downrange. The lack of a suspension system in the bogie prevented the brakes from stopping the vehicle. The bogie was eventually stopped by the catch fence.

Figure 17 contains photographs of the sign support during the crash test. Figure 18 presents a summary of the test data and the location of the test vehicle and sign system after impact. Figures 19 through figure 26 present data plots from data obtained from accelerometers and strain gage bolts. Figure 27 is photographs of the bogie and sign support taken before the test, and figure 28 shows photographs of the bogie and sign support after the test.

The longitudinal vehicle change in velocity was determined to be 1.4 m/s. The triaxial rate transducer measured no significant pitch, roll, or yaw rates during the test.

b. Occupant Responses: The longitudinal occupant impact velocity for the test was determined to be 1.4 m/s and occurred at 0.519 s after initial contact. The longitudinal 10-ms average ridedown acceleration was determined to be 0.3 g's. There was no lateral occupant impact during the bogie/sign interaction.

c. Vehicle Damage: The bogie vehicle damage consisted of crushed honeycomb. The measured honeycomb crush was 330 mm. Due to the nature of crush there is no figure depicting vehicle crush included in this report. This amount of crush would denote that a minimum of 92 kN of force was reached during the test.

d. Test Article Damage: There was no significant damage to the sign support system. The post disconnected from the base and tore the keeper plate. Although the sign panel slipped off the sign post, the sign support system could be reused after reattachment of the sign panel and installation of a new bolt keeper plate.

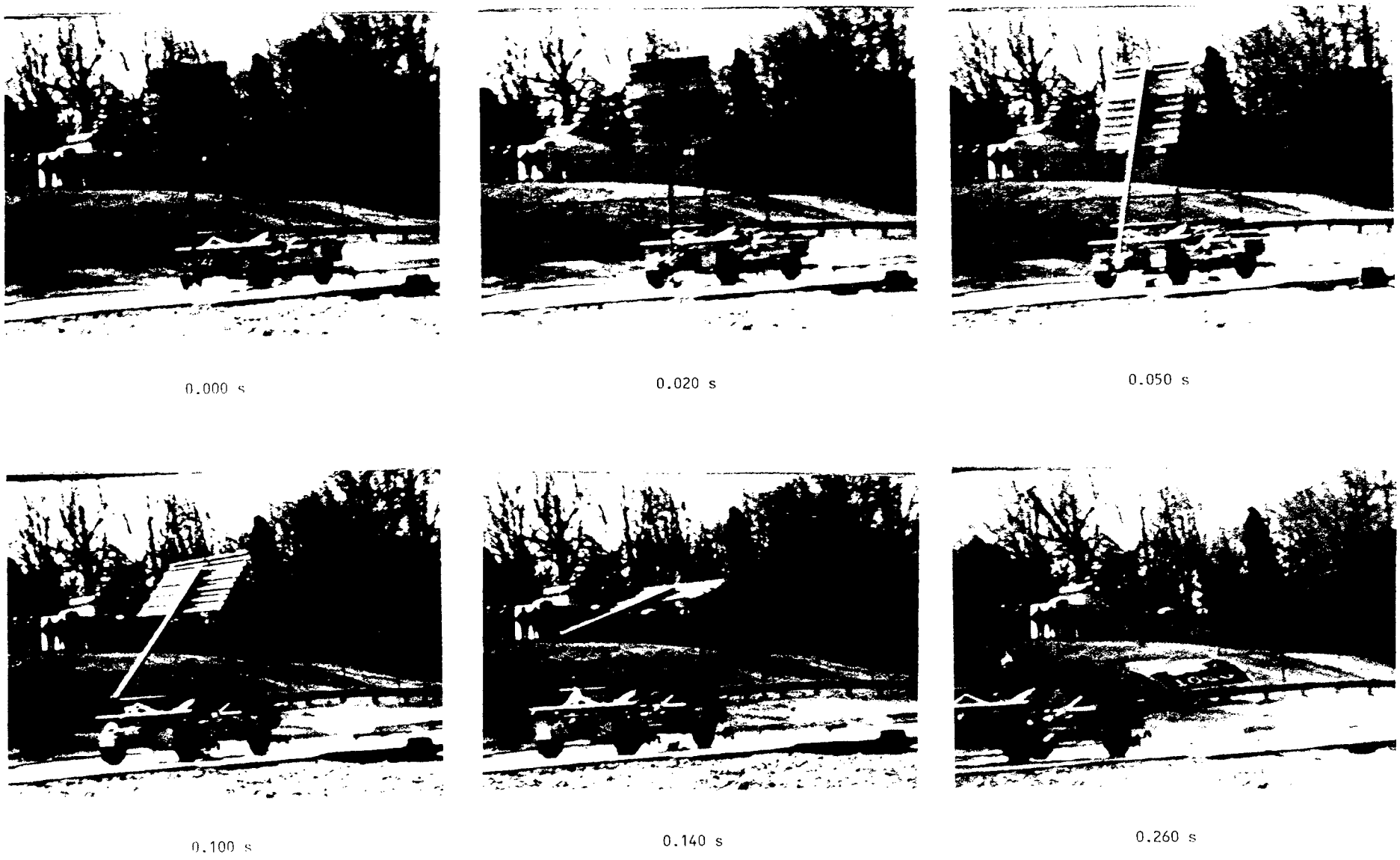
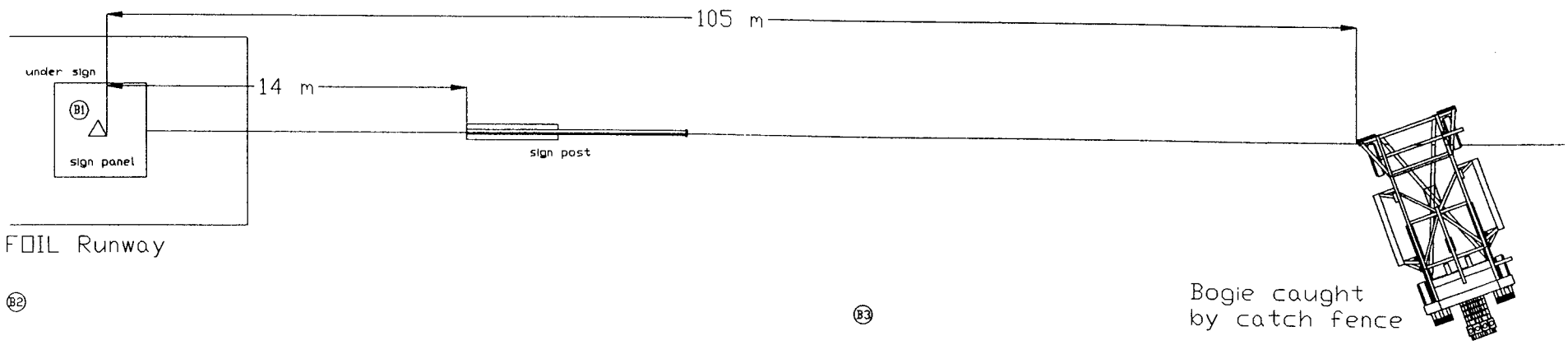


Figure 17. Test photographs during impact, test 98F004.



Test number.....98F004

Date.....February 5, 1998

Test article.....Single-leg sign support

Support.....3X3 TB on a triangular slip-base

Total clamp load.....62.5 kN

Sign panel.....Aluminum 1.5 m by 1.5 m

Foundation.....FOIL Universal Foundation

Vehicle.....FOIL Bogie

Weight: Inertial.....839 kg
Gross.....839 kg

Impact speed.....99.9 km/h

Impact location.....Single-leg center

Impact angle.....0 degrees

Vehicle front-end crush (honeycomb).....330 mm

Vehicle damage.....N/A

Vehicle analysis
Longitudinal:
Vehicle Delta-V.....1.4 m/s
Occupant Delta-V at 0.6 m
(acceptable 5.0 m/s).....1.4 m/s
Ridedown Acceleration
(acceptable 15 g's).....0.3 g's
Lateral:
Occupant Delta-V at 0.3 m.....No contact
Ridedown Acceleration.....No contact

Vertical stub height (100-mm limit).... .....95 mm

Figure 18. Summary of results, test 98F004.

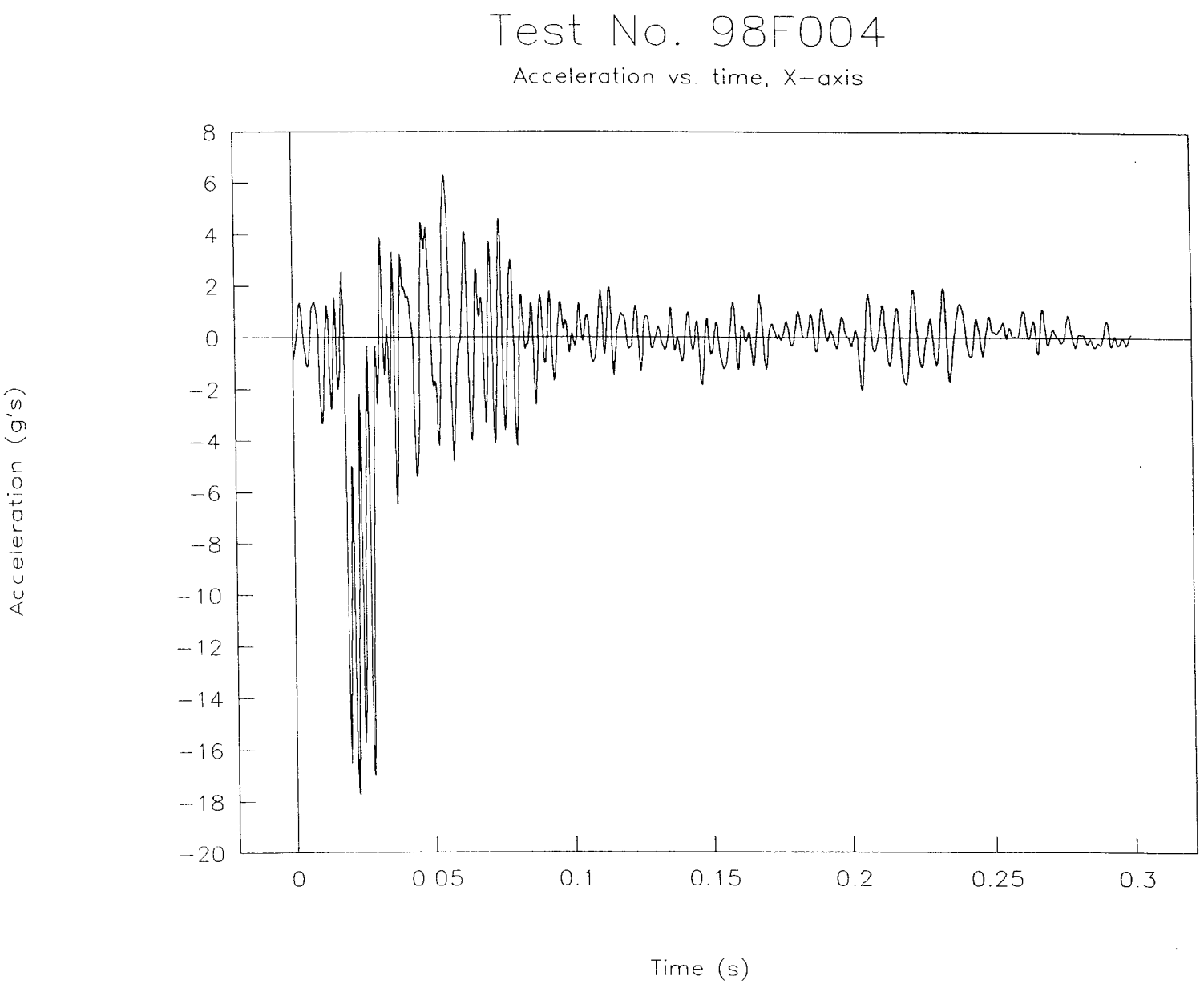


Figure 19. Acceleration vs. time, X-axis, test 98F004.

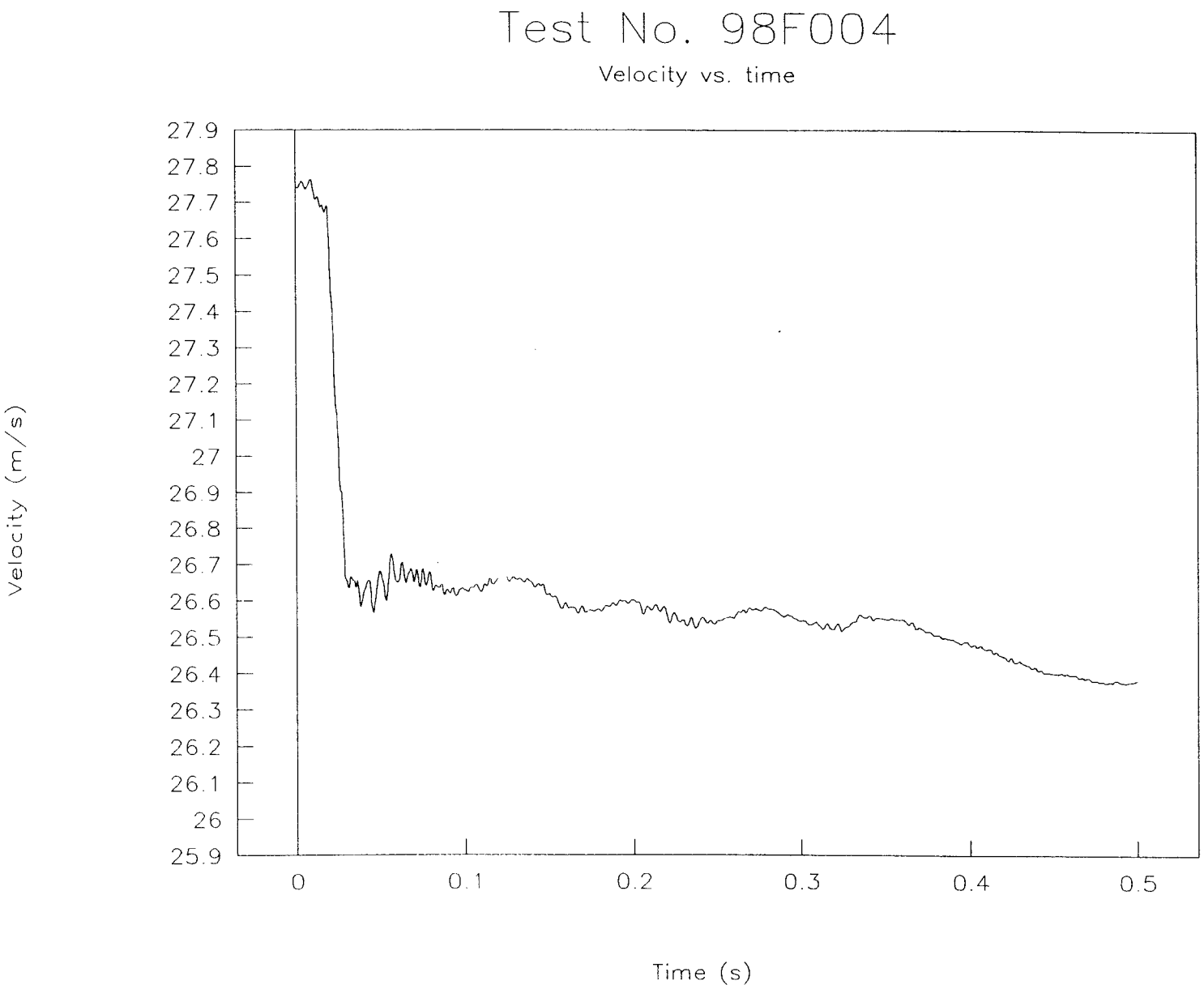


Figure 20. Velocity vs. time, test 98F004.

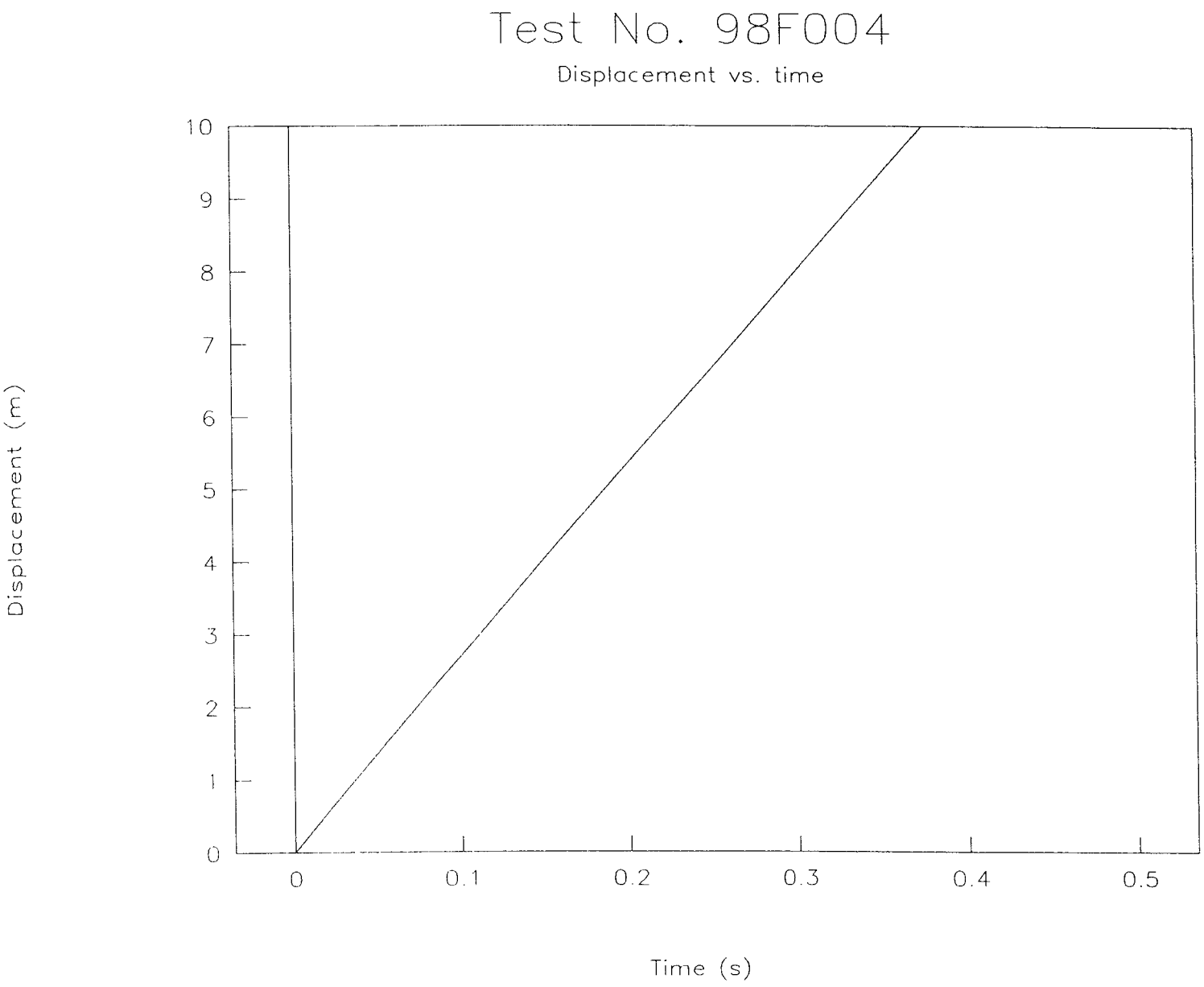


Figure 21. Displacement vs. time, test 98F004.

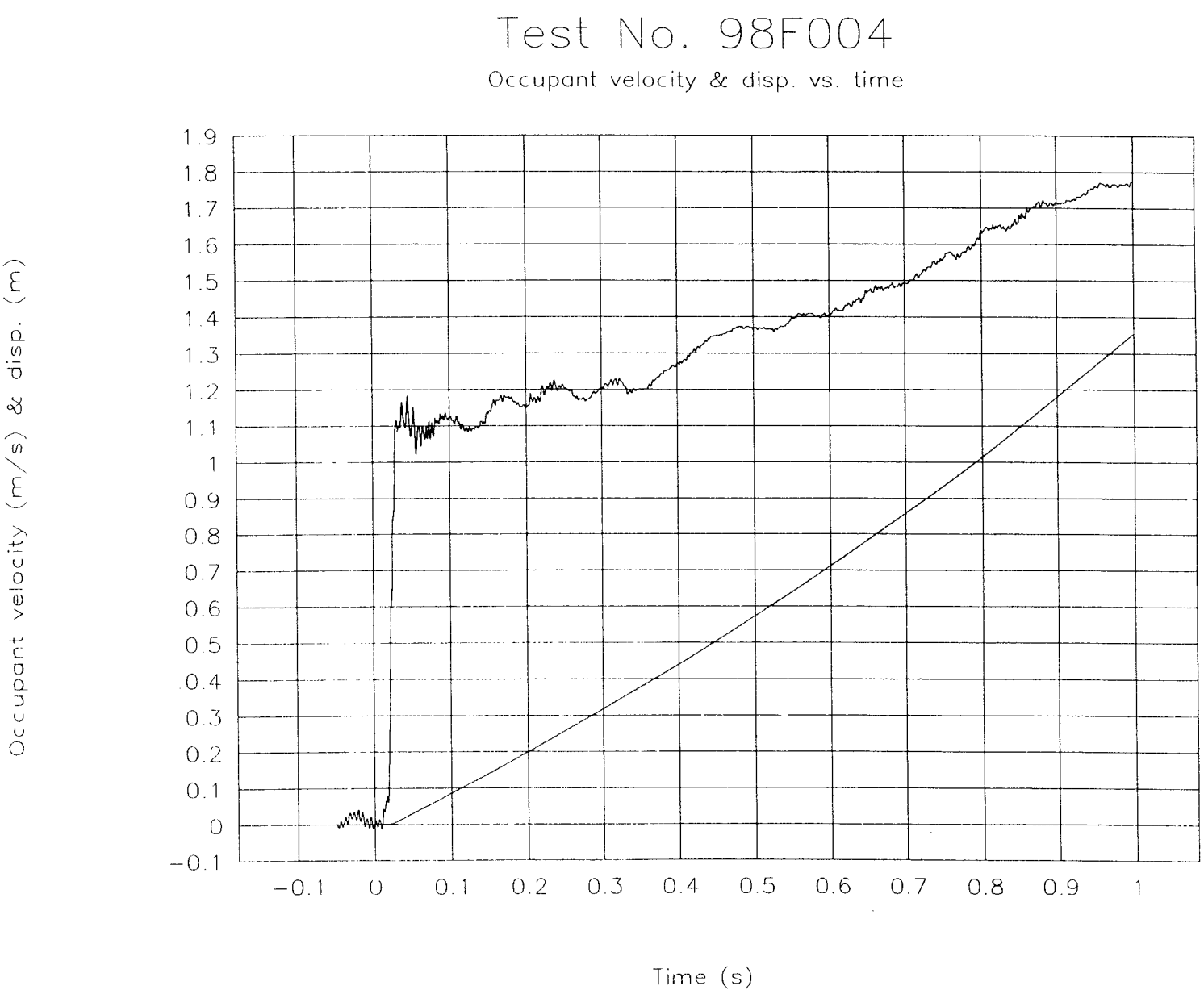


Figure 22. Occupant velocity and displacement vs. time, test 98F004.

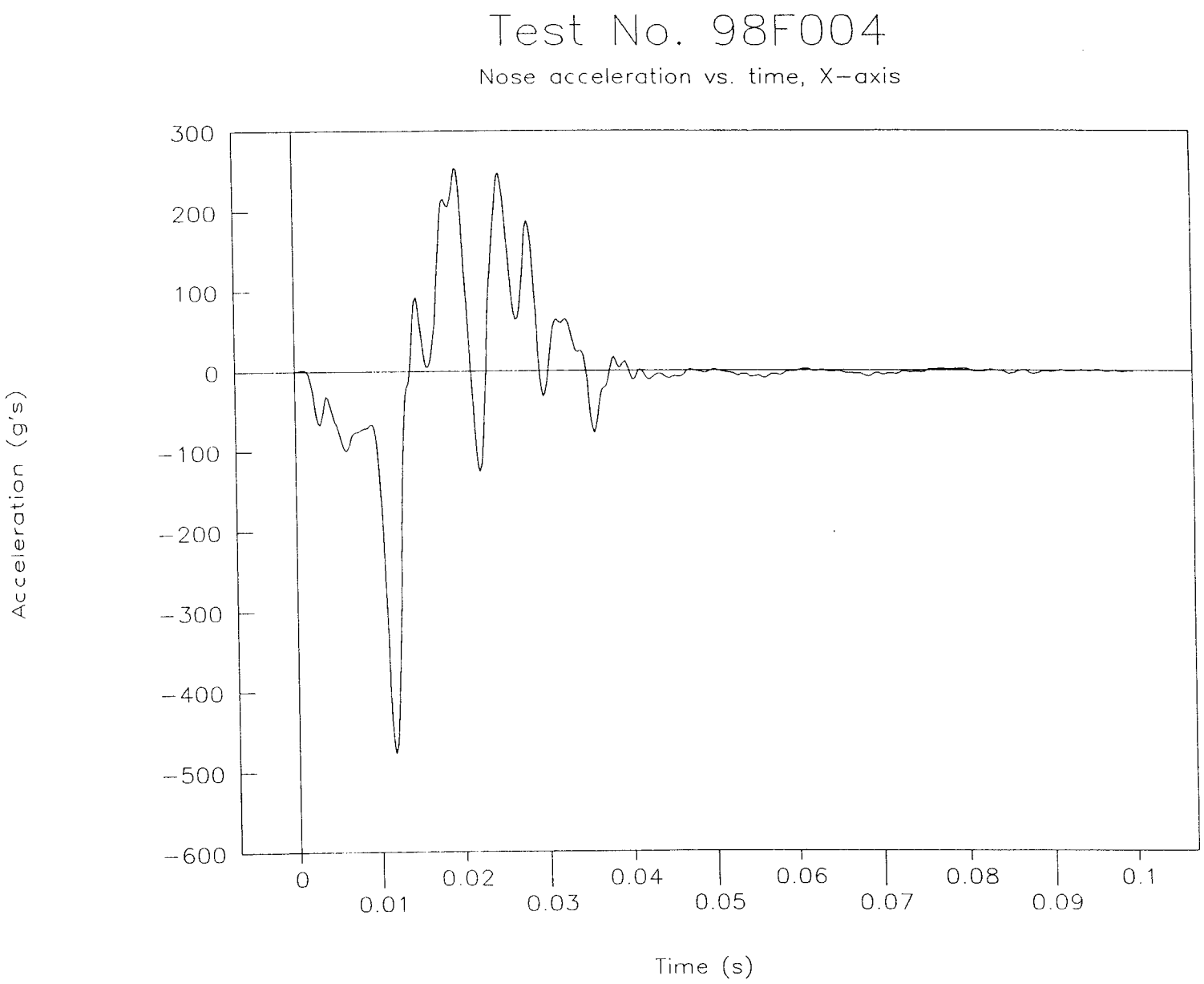


Figure 23. Acceleration vs. time, nose X-axis, test 98F004.

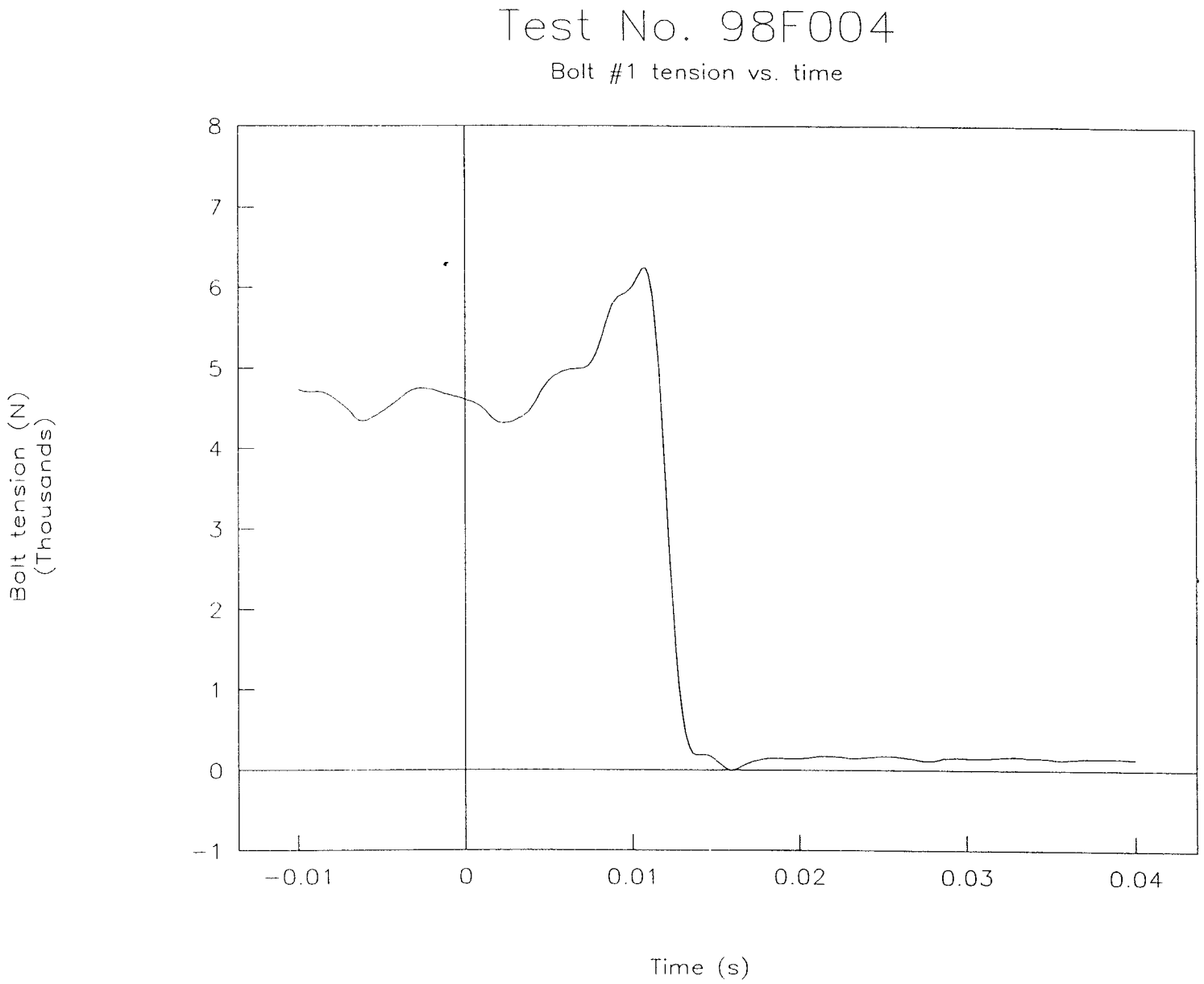


Figure 24. Bolt tension vs. time, bolt #1, test 98F004.

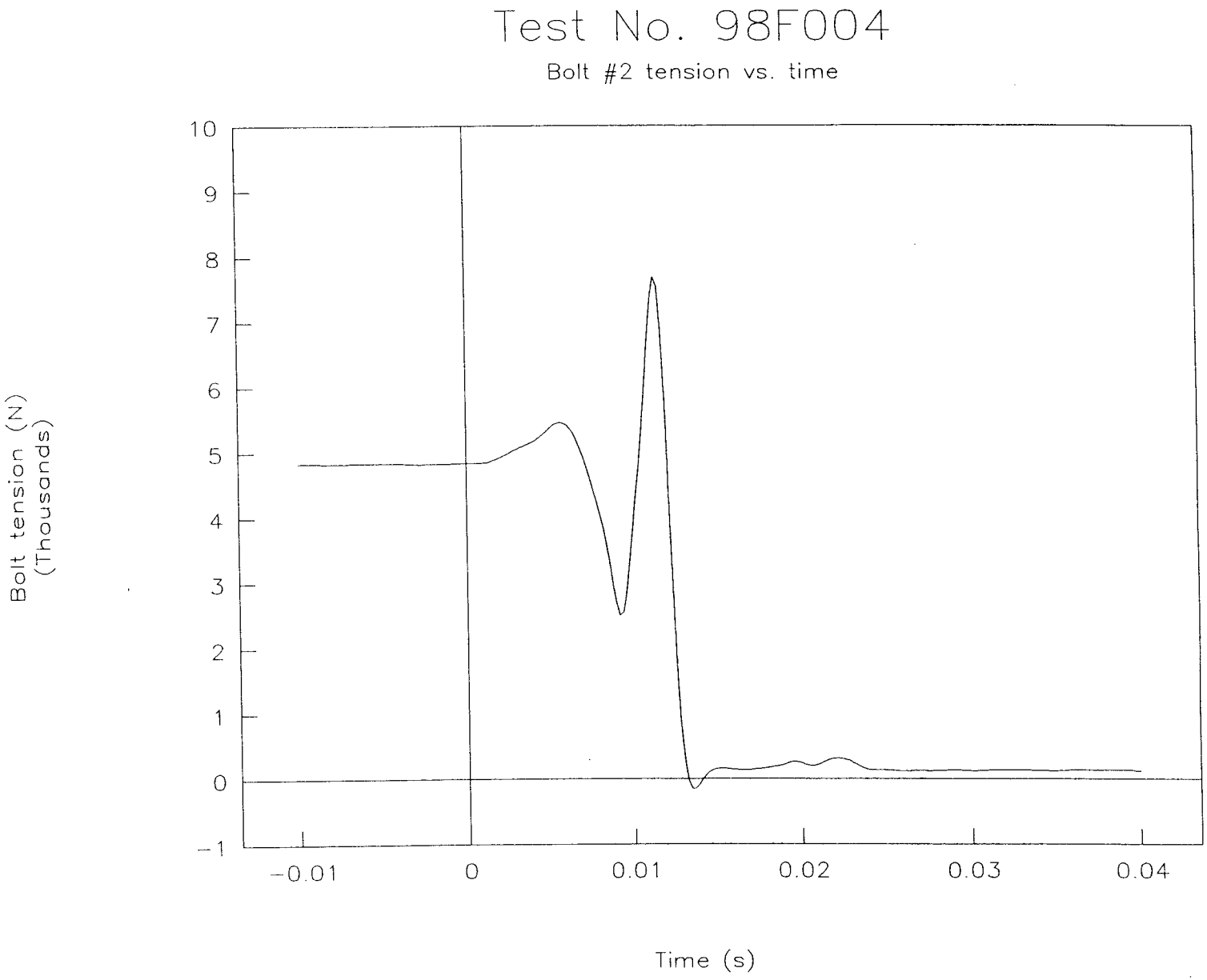


Figure 25. Bolt tension vs. time, bolt #2, test 98F004.

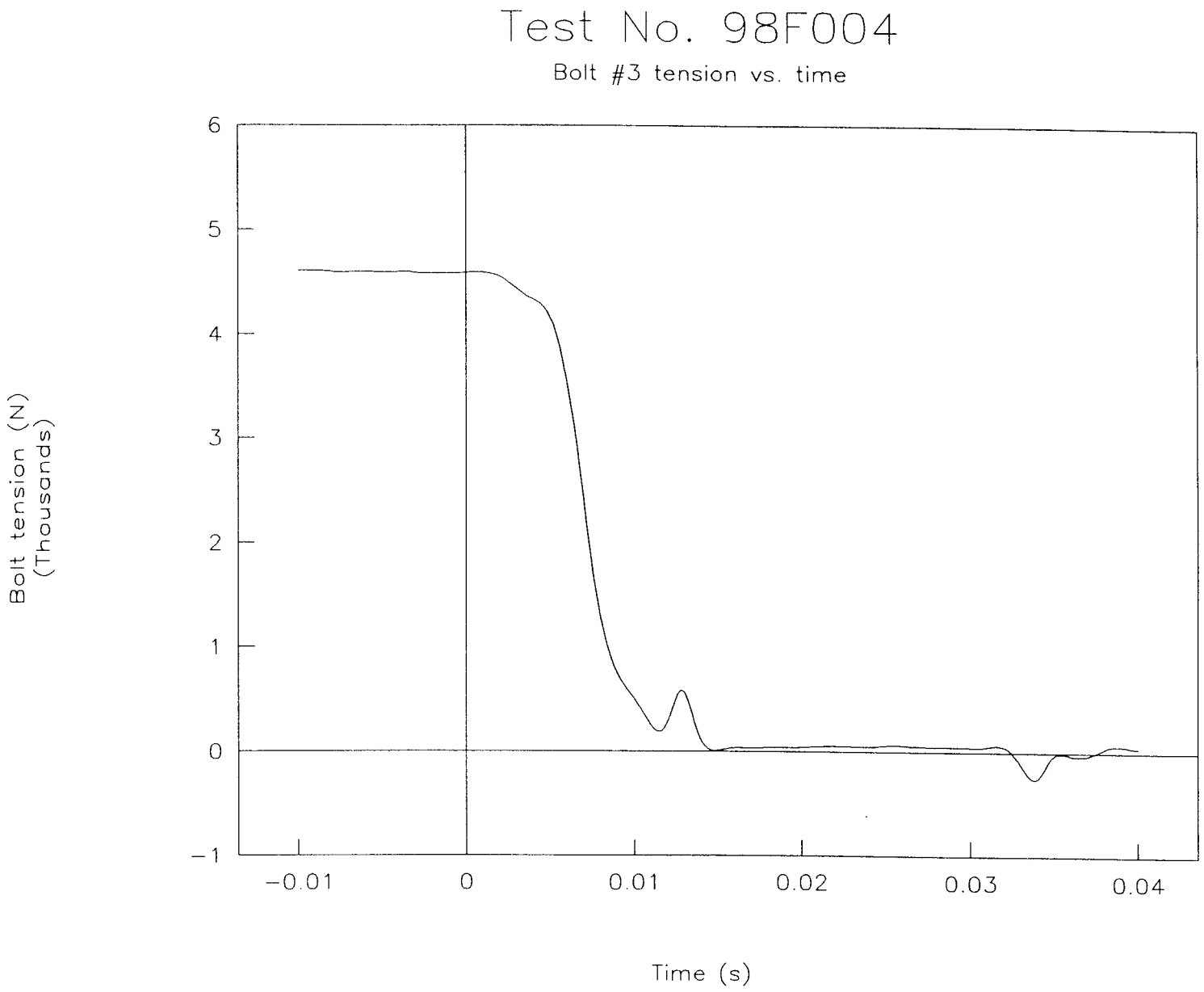


Figure 26. Bolt tension vs. time, bolt #3, test 98F004.

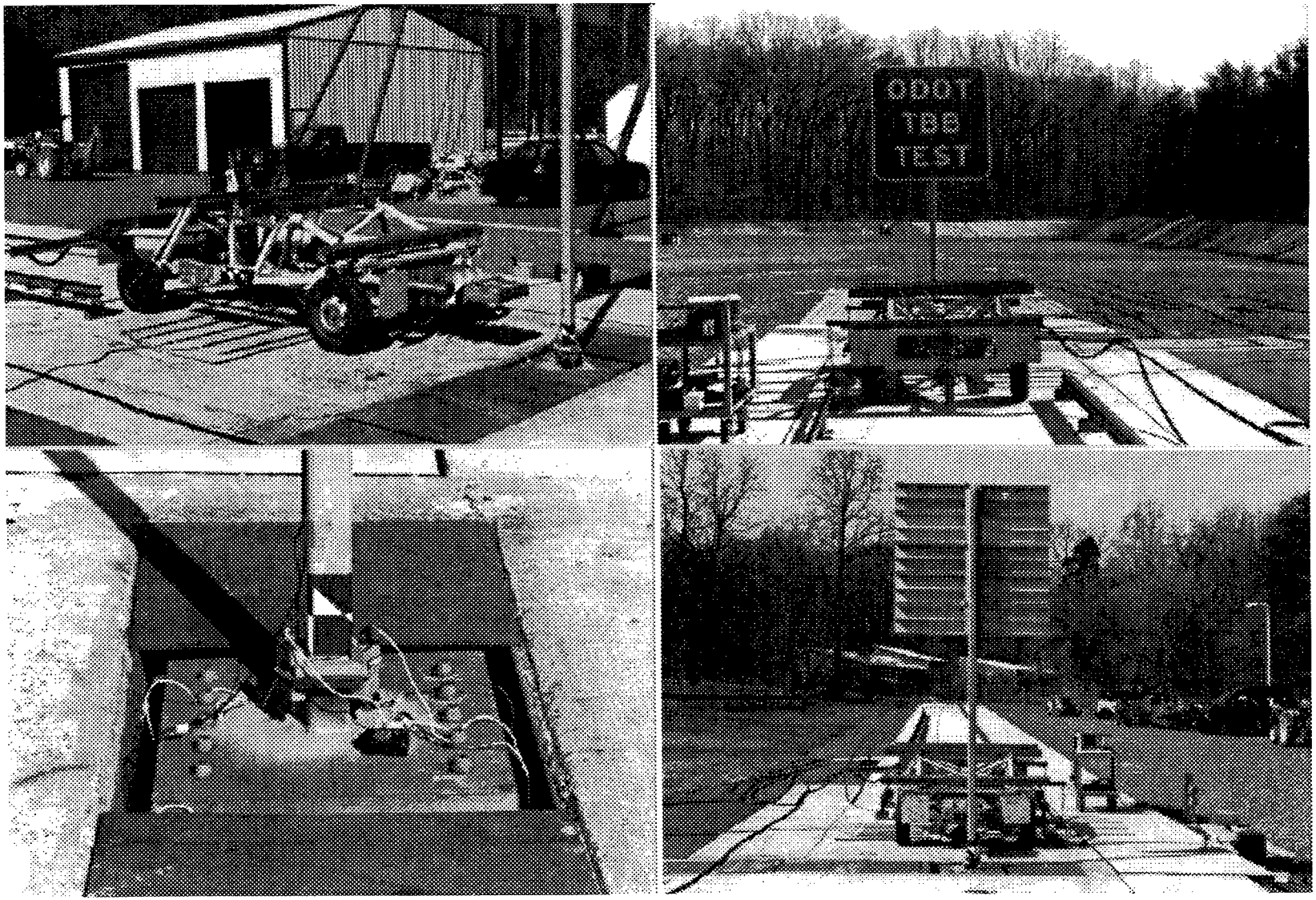


Figure 27. Pretest photographs, test 98F004.

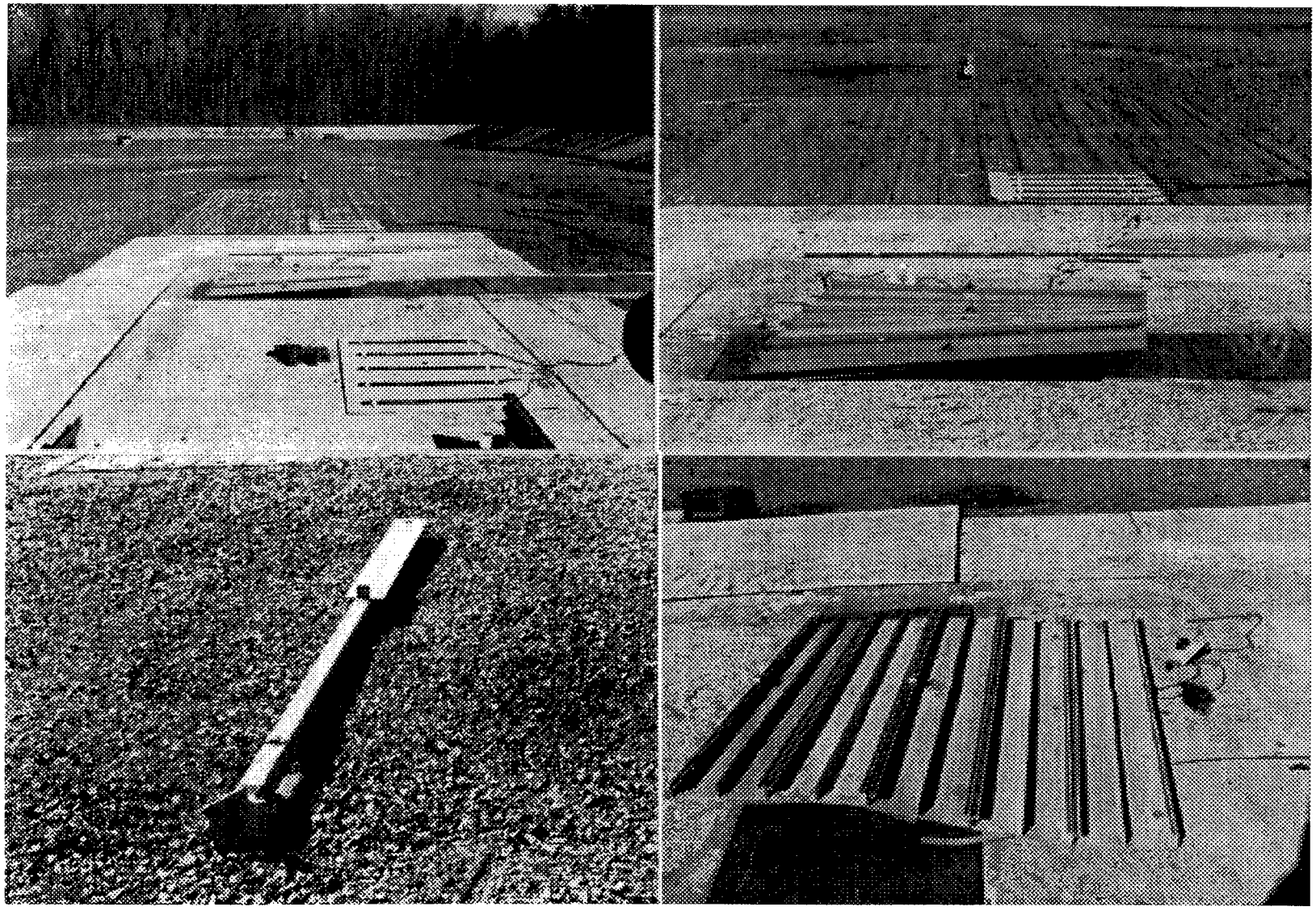


Figure 28. Post-test photographs, test 98F004.

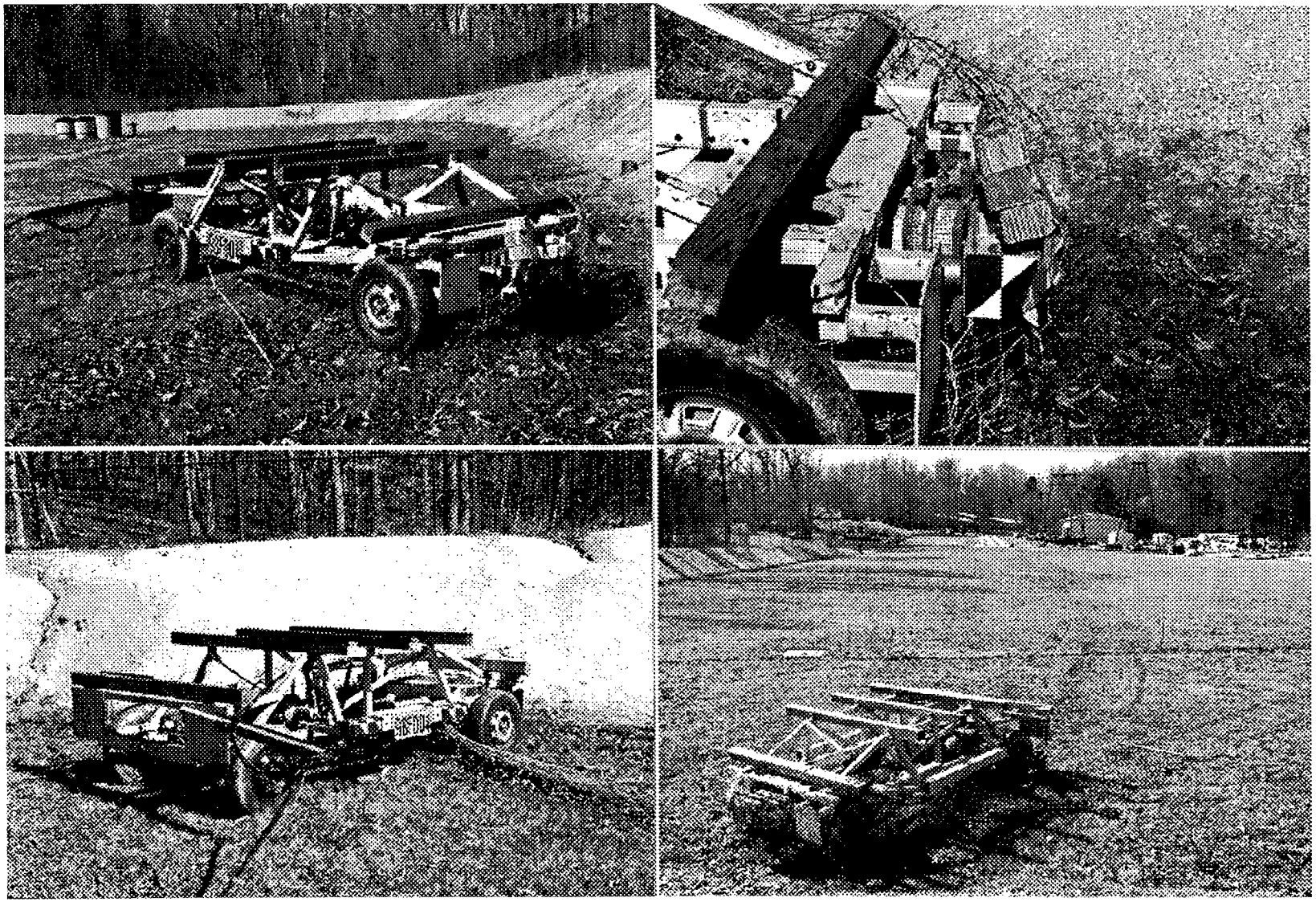


Figure 28. Post-test photographs, test 98F004 (continued).

CONCLUSION

The test results indicate that the Oregon 3X3 TBB multidirectional triangular slip-base sign support with the 90° notches meets the safety performance criteria outlined in NCHRP Report 350. The 3X3 TBB met the safety performance criteria for both the low-speed and high-speed tests. Refer to table 5 for a summary of the results from the two Oregon slip-base sign support tests. The table shows acceptable limits for the occupant impact velocity, ridedown acceleration, and stub height. In addition to these three criterion, the bogie remained upright after the collision and the slip-base mechanism performed in a predictable manner.

Table 5. Summary of Oregon slip-base sign support testing.

Test Number	Test Article	Impact Speed (km/h)	Occupant Impact Velocity (m/s)	Ridedown Acceleration 10 msec (g's)	Stub Height (mm)
98F002	3X3 TBB	35.3	0.84	0.3	95
98F004	3X3 TBB	99.9	1.4	0.3	95
FHWA Specifications			≤ 5	≤ 15	≤ 100

REFERENCES

(1) Christopher M. Brown, *Testing of the Oregon Multidirectional Slip-Base Sign Support Systems, FOIL Test Numbers: 93F014, 93F015, and 93F019*, Report No. FHWA-RD-94-091, Federal Highway Administration, Washington, DC, August 1994.

(2) H. E. Ross, Jr., D. L. Sicking, R. A. Zimmer, and J. D. Michie, *Recommended Procedures for the Safety Performance Evaluation of Highway Features, NCHRP Report 350*, National Cooperative Highway Research Program, Transportation Research Board, Washington, DC, 1993.

(3) Maher K. Ghanoudi, Christopher M. Brown, *Testing of a Modified Oregon Multidirectional Slip-Base Sign Support, FOIL Test Numbers: 95F007 and 95F009*, Report No. FHWA-RD-97-048, Federal Highway Administration, Washington, DC, July 1995.

(4) Charles R. Hott, Christopher M. Brown, Nick Totani and Allen G. Hansen, *Crush Characteristics of the 'Breakaway' Bogie*, Report No. FHWA-RD-89-107, Federal Highway Administration, Washington, DC, July 1990.

(5) Charles R. Hott, Christopher M. Brown, Nick Totani, *Slip Base Clamping Force Tests*, Report No. FHWA-RD-89-197, Federal Highway Administration, Washington, DC, July 1989.