REPORT NO. FHWA-RD-88-225

LUMINAIRE AND SIGN SUPPORTS

SEPTEMBER 1989

LUMINAIRE AND SIGN SUPPORTS TECHNICAL VOLUME

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Prepared For:

FEDERAL HIGHWAY ADMINISTRATION
OFFICE OF RESEARCH & DEVELOPMENT
WASHINGTON, D.C. 20590

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FOREWORD

This report presents the results, test reports and findings pertaining to the project "Luminaire and Sign Supports" conducted for the Federal Highway Administration (FHWA) by the contractor under contract no. DTFH61-87-Z-00103.

Five designs of luminaire and sign supports were impacted with 1800 lb class vehicles. The test results were evaluated to determine the safety performance of the tested luminaire and sign supports against the requirements specified by the AASHTO and NCHRP No. 230 documents. This report will be of interest to highway engineers dealing with roadside safety.

R. J. Betsold, Director
Office of Safety and Traffic
Operations Research and Development

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-RD-88-225		

4. Title and Subtitle
LUNINAIRE AND SIGN SUPPORTS
Technical Volume

5. Report Date
September 1989

6. Performing Organization Code

7. Author(s)
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8. Performing Organization Report No.
R8006-Final

9. Performing Organization Name and Address
MOBILITY SYSTEMS AND EQUIPMENT COMPANY
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10. Work Unit No. (TRAIS)
31T3-282

11. Contract or Grant No.
DTFH61-87-Z-00103

12. Sponsoring Agency Name and Address
Federal Highway Administration
Office of Safety and Traffic Operations R&D
6300 Georgetown Pike
McLean, Virginia 22101-2296

13. Type of Report and Period Covered
Final Report
August 1987 to September 1989

14. Sponsoring Agency Code

15. Supplementary Notes
Mr. Marty Hargrave and Mr. Charles McDevitt, P.E., HSR-20, FHWA Contracting Officer's Technical Representatives to this project.

16. Abstract

A series of eight full-scale crash tests were conducted on five luminaire and sign supports. The test articles were embedded in S-1 soil as per NCHRP No. 230 recommendations. The test vehicles used for all eight impact tests were 1979 Volkswagen Rabbits with the test mass adjusted to be in the range of 1800 ± 50 lb. A triaxial accelerometer was placed near the vehicle center gravity (c.g.) to record the vehicle decelerations. Each test event was covered with one real-time and three to four high-speed movie cameras. The data acquired from the tests were processed as per NCHRP No. 230 procedure. The results were evaluated against the dynamic performance requirements specified in the most recent AASHTO and NCHRP No. 230 documents. The detailed test and evaluation results and the test reports are presented in this final report. This report is published in two parts. They are:

- "Luminaire and Sign Supports - Executive Summary". Report No.: FHWA-RD-88-224, and
- "Luminaire and Sign Supports - Technical Volume". Report No.: FHWA-RD-88-225.

17. Key Words	18. Distribution Statement
Luminaire and Sign Supports, Breakaway Supports, NCHRP No. 230, 1979 Volkswagen Rabbit, Crash Testing, AASHTO, 20-60 mi/h tests.	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	244	

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

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

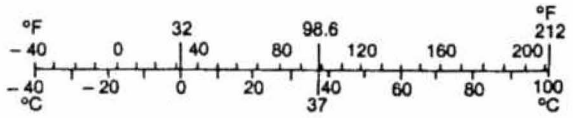
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	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	Mg
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
TEMPERATURE (exact)				
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

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INTRODUCTION

The objective of the study was to determine the breakaway properties of five designs of luminaire and sign supports. Eight crash tests were run to ascertain the performance of selected Federal Highway Administration (FHWA)-supplied luminaire and sign supports when impacted with 1800 - ± 50-lb 1979 Volkswagen Rabbits. The tests were conducted at speeds of 20 and 60 mi/h. The test articles were evaluated by comparing these performance results against the criteria outlined in the revised AASHTO specifications and NCHRP Report Number 230 for breakaway or yielding supports. [1,2]

Descriptions of the study approach and the test procedures used begin on page 2. A summary of all the test results begins on page 33.

STUDY APPROACH AND TEST PROCEDURES

The test program is comprised of eight luminaire and sign support impact tests as shown in table 1. The tests were numbered 1 through 8.

Table 1. The test matrix.

Test No.	Test Article	Test Vehicle	Target Impact Speed (mi/h)	Impact Point	Target Test Vehicle Mass lb
1	Small Sign Support (Arkansas Back Brace)	1979 VW Rabbit	60	Front, Center	1800 ± 50
2	Metal Luminaire Support (A.B. Chance Slip Base Anchoring System)	1979 VW Rabbit	60	Front, Center	1800 ± 50
3	Metal Luminaire Support (A.B. Chance Slip Base Anchoring System)	1979 VW Rabbit	20	Front, Center	1800 ± 50
4	Fiberglass Luminaire Support (Highline Products Corporation Model No. HL-228H-1)	1979 VW Rabbit	60	Front, Center	1800 ± 50
5	Freeway Stiff Leg Sign Support (Wisconsin Type B)	1979 VW Rabbit	20	Front, Center	1800 ± 50
6	Freeway Stiff Leg Sign Support (Wisconsin Type B)	1979 VW Rabbit	60	Front, Center	1800 ± 50
7	Freeway Stiff Leg Sign Support (Wisconsin Type D)	1979 VW Rabbit	20	Front, Center	1800 ± 50
8	Freeway Stiff Leg Sign Support (Wisconsin Type D)	1979 VW Rabbit	60	Front, Center	1800 ± 50

1. Test Articles

Luminaire and Sign Supports

Five designs of luminaire and sign supports were evaluated under this crash test project. The details of the five luminaire and sign supports and the impact tests are shown in figures 1 through 5 and table 2. The test articles were selected and provided by the FHWA and were delivered to the research and testing facility at Mira Loma, California.

The test article for each test was buried and embedded in the NCHRP 230, S-1 strong soil. [2] The support was installed at the end of the asphalt test track such that the vehicle was completely on a packed soil surface during the impact and run-out phase of the test. The installation was done as per the manufacturer's specification.

Sieve Analysis of S-1 Soil

After the fourth test, at the request of FHWA COTR, the S-1 strong soil pit was subjected to a reevaluation sieve analysis by a certified soil testing laboratory. The results confirmed that the S-1 strong soil still contained the proportion of soil contents generally within the margins recommended by the NCHRP 230 report, as shown in table 3. [2] Minor deviation from specification in no. 4 and no. 10 sieve size percentages was considered insignificant. The COTR reviewed the results and gave a go-ahead for the tests.

Arkansas Back Brace Small Sign Support

The Arkansas Back Brace Small Sign Support was a 12-ft, 3-lb/ft, u-shaped steel sign support pole with a rear mounted back brace. The back brace was a 9-ft steel pole of the same construction as the

Table 2. Tested luminaire and sign supports.

Test No.	Support Description	Target Test Impact Speed	Target Impact Location
1	Arkansas Back Brace Small Sign Support	60 mi/h	Front, Centerline
2	A.B. Chance Luminaire Support with Slip Base Foundation	20 mi/h 60 mi/h	Front, Centerline Front, Centerline
3	Highline Products Corporation Fiberglass Luminaire Support, Model No. HL-228H-1	60 mi/h	Front, Centerline
4	Wisconsin Stiff Leg Sign Support, Type B	20 mi/h 60 mi/h	Front, Centerline Front, Centerline
5	Wisconsin Stiff Leg Sign Support, Type D	20 mi/h 60 mi/h	Front, Centerline Front, Centerline

Table 3. Results of sieve analysis on S-1 soil.

Sieve Size	Mass Percent Passing	
	NCHRP-230 Specifications	Test Results
50 mm (2 in)	100	100
25 mm (1 in)	75-95	93
9.5 mm (318 in)	40-75	65
4.75 mm (no. 4)	30-60	64
2.00 mm (no. 10)	20-45	47
0.425 mm (no. 40)	15-30	27
0.075 mm (no. 200)	5-20	10

main pole, attached to the main pole 2 in below the bottom of the sign blank, and extending diagonally downward into the soil. The separation between the main pole and the back brace was 2 ft at ground level. A 30-in octagonal stop sign was attached to the top of the main pole with 5/16-in bolts spaced 24 in apart. The pole was oriented such that one leg of the u-shape was facing impacting vehicle.

The support was buried in NCHRP 230, S-1 strong soil to a depth of 2.5 ft. No restraint was placed on the top of the support.

Dimensional and weight data on the Arkansas Back Brace Small Support are shown in figure 1.

A.B. Chance Metal Luminaire Support with Slip Base Foundation

The metal luminaire support was a 30.1-ft long, tapered metal pole with a 13-ft mast arm attached 29.5 ft above the mounting base. The pole had a diameter of 8 in at the base and 3.75 in at the top. The mast arm had a 50-lb weight attached to its free end to simulate the weight of a lighting assembly. The pole was oriented such that the mast arm was at roughly 4 o'clock if the line of vehicle travel is given to be 12 o'clock. The pole was manufactured by Union Metal Company. The test article with dimensional and weight data is shown in figure 2.

Fiberglass Luminaire Support

The test article was an 8-in-diameter, hollow, fiberglass luminaire support pole. The pole was manufactured by Highline Products Corporation. The model number tested was HL-228H-1. The pole was buried in S-1 strong soil as defined in NCHRP 230, to a depth of 5 ft. A 50-lb weight was attached to the end of the 6-ft mast arm to simulate the weight of a lighting assembly. The pole was oriented such that the access panel was facing towards the impacting vehicle. No restraint was placed on the top of the pole. The dimensional and weight data for the pole are shown in figure 3.

Wisconsin Stiff Leg Sign Support, Type B

The test article consisted of 2 steel slip base stubs, each 5 1/2 ft in length; 2 steel slip base supports, each 18 ft in length; and 11 sign panels, each 1 ft by 15 ft. This hardware is used

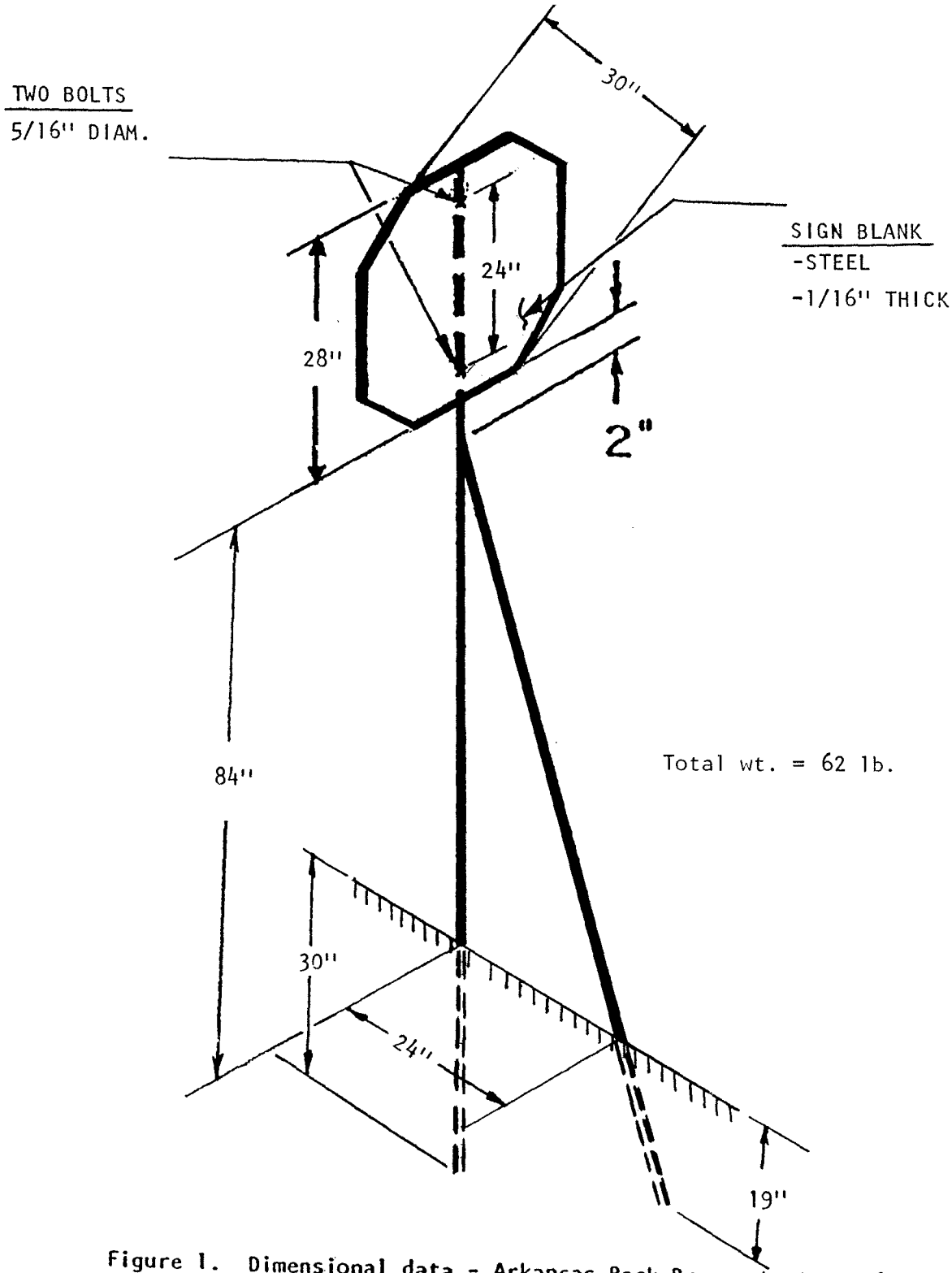
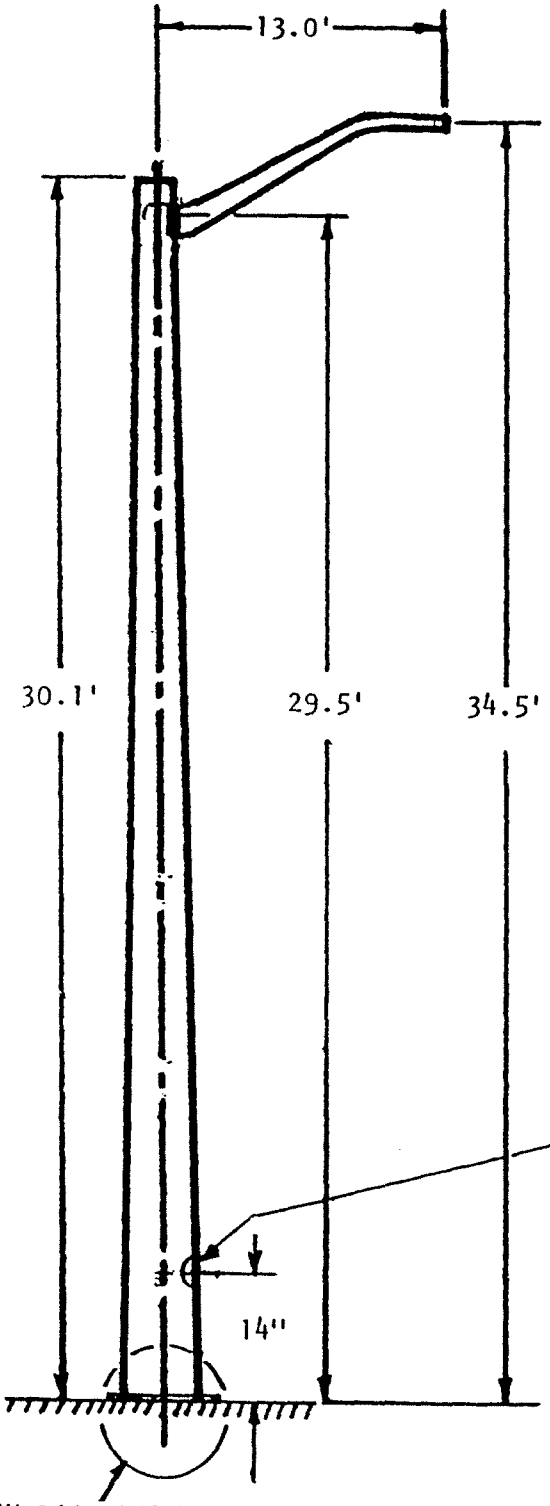


Figure 1. Dimensional data - Arkansas Back Brace, test no. 1.



POLE DATA

1. DIAMETERS — INCHES

TOP	3.75
HANDHOLE	7.9
BOTTOM	8.0

2. WALL THICKNESS — INCHES

BOTTOM	0.25

3. WEIGHT — POUNDS

POLE	320
ARM	76
WEIGHT LUMINAIRE SIMULATION	50
TOTAL	446

HANDHOLE LOCATED VERTICALLY BELOW ARM ATTACHMENT

- 3-7/8" DIAM BOLTS ON A TRIANGULAR SLIP BASE 1-1/16 IN THICK
- "KEEPER PLATES" USED, PLATED STEEL, 0.0359 IN THICK
- TORQUE SPEC. 85 ft-lb.

Figure 2. A. B. Chance metal luminaire support with slip base foundation, test nos. 2 and 3.

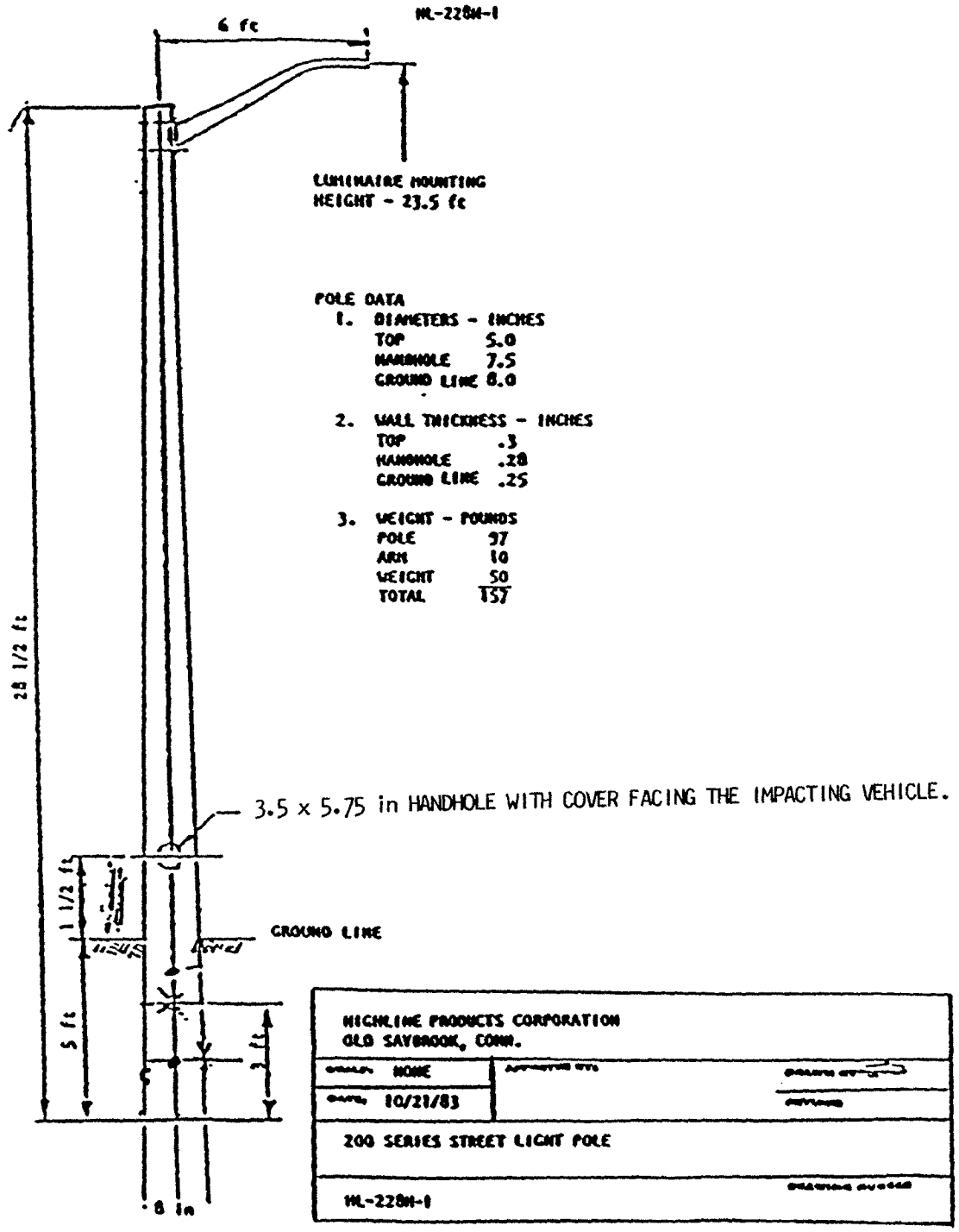


Figure 3. Fiberglass luminaire support, test no. 4.

to construct a Type B support with a 15-ft by 11-ft sign. The stubs were set in a 2-ft radius concrete form and then buried in S-1 strong soil so that there was a stub projection of 3 in above the level surface. The steel supports were bolted to the stubs using the manufacturer's recommended torque (85 ft-lb). To obtain perpendicularity, the supports were shimmed at the slip base in accordance with manufacturer's instructions. The sign boards were then clamped on to the supports one at a time to form the completed sign. Design specifications for the Wisconsin Stiff Leg Support are presented in figures 4 and 5. Each leg support weighed 288 lb, and was an I - beam with 12-in depth and 3 7/8-in flange.

Wisconsin Stiff Leg Sign Support, Type D

The test article consisted of 2 steel slip base stubs, each 6 1/2 ft in length; 2 steel slip base supports, each 21 ft in length; and 14 sign panels, each 1 ft by 22 ft. This hardware is used to construct a Type D support with a 22-ft by 14-ft sign. The stubs were set in a 2-ft radius concrete form and then buried in S-1 strong soil so that there was a stub projection of 3 in above the level surface. The steel supports were bolted to the stubs using the manufacturer's recommended torque procedure (85 ft-lb). To obtain perpendiculatity, the supports were shimmed at the slip base in accordance with the manufacturer's instructions. The sign boards were then clamped on to the supports one at a time to form the completed sign. Design specifications for the Wisconsin Stiff Leg Sign Support are presented in figures 4 and 5. Each leg support weighed 462 lb, and was an I - beam with 12-in depth and 4-in flange.

The installation of Wisconsin Stiff Leg Sign Supports in the S-1 soil was accomplished using a very rigorous compaction procedure. The procedure followed the specification provided in the NCHRP 230.

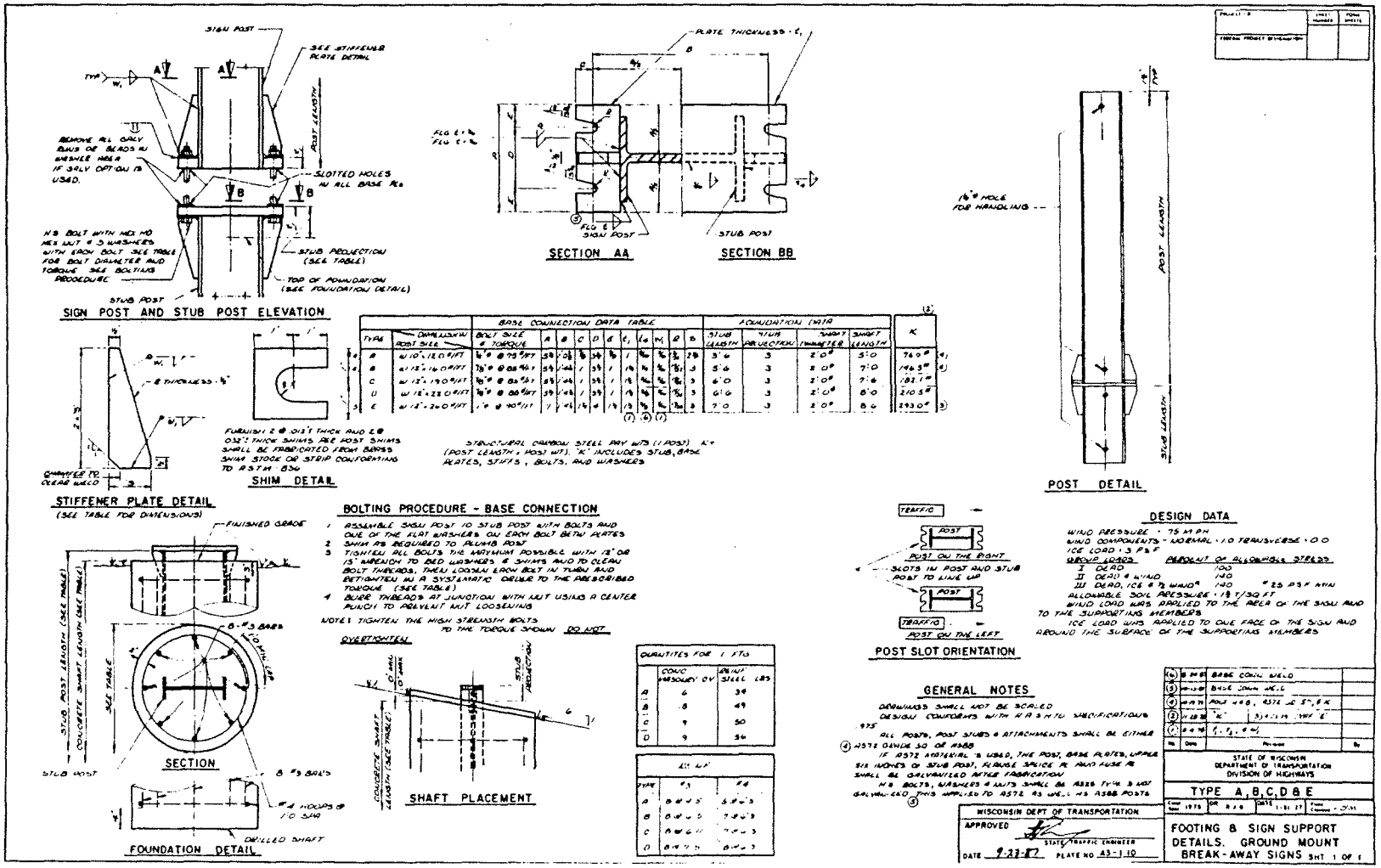


Figure 4. Sign support installation details - State design, test nos. 5 through 8.

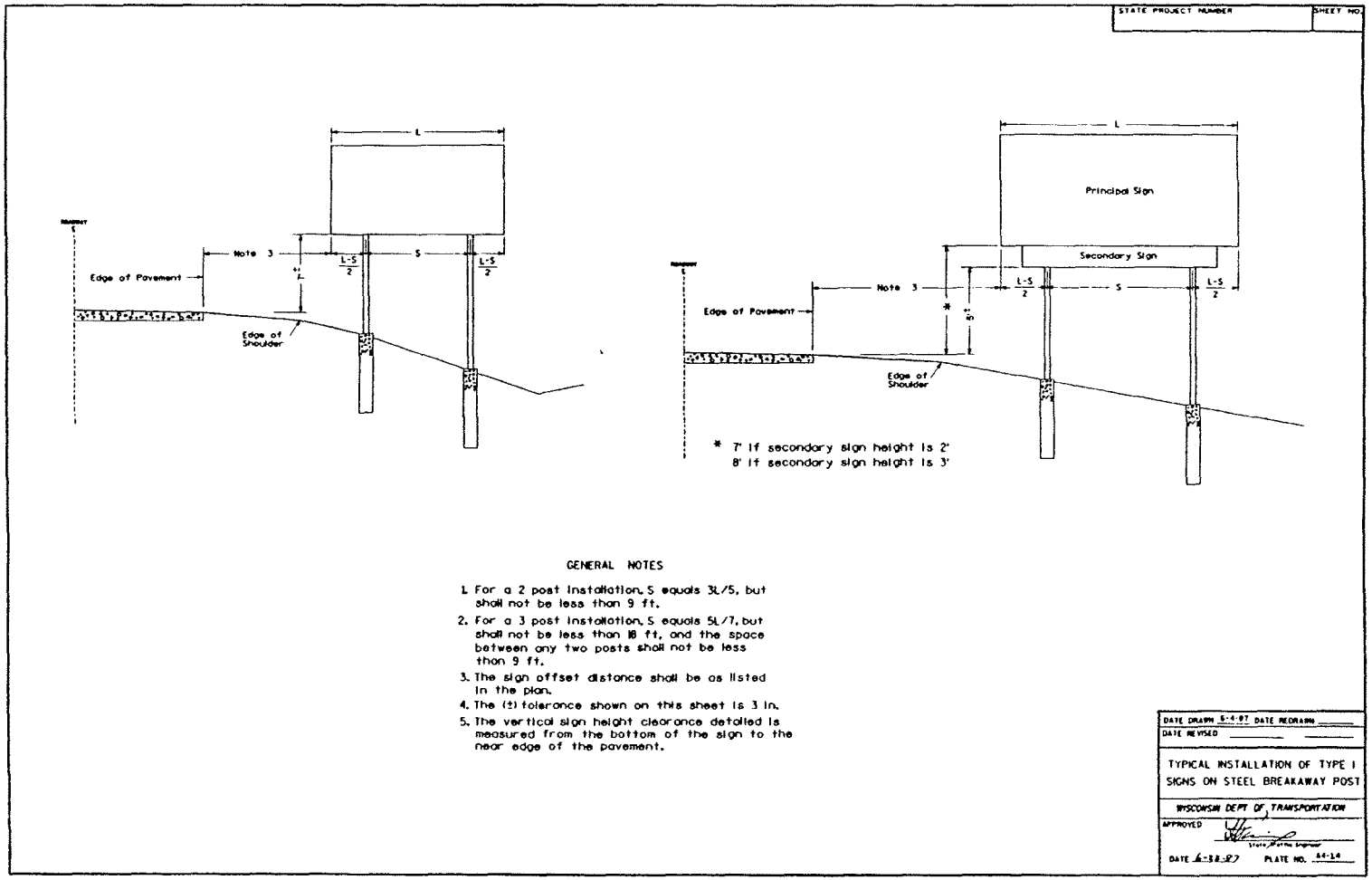


Figure 5. Typical installation, Type 1 signs on steel breakaway posts, test nos. 5 through 8.

Soil samples were tested to establish the optimum moisture content for obtaining the maximum density of the S-1 soil. The results show that a 9.5 percent moisture content provided a maximum dry density of 129.0 lb/ft^3. The compaction of the soil around the foundation was then achieved using a power compactor and by adding soil and compacting in 6-in layers. At each stage, the sand volume method (ASTM D1556) was used to determine the moisture content and the actual density achieved. The results were checked using a nuclear density gauge (ASTM 2922). The density achieved using this method at various depths was in the range of 122.9 to 126.4 lb/ft^3. This transforms into a range of 95.3 to 98 percent of the optimal density. The results are within the specifications of NCHRP 230 recommendations.

2. Test Vehicles

The test vehicles used for all eight tests were 1979 Volkswagen Rabbits. The test vehicles were carefully inspected before purchase to meet the following criteria:

- No front end structural damage.
- All components to be original equipment and correctly installed. The items under this category included wheels, brakes, transmission, engine, door, hatches, suspension components, hood, etc.
- The vehicle to be anesthetically acceptable, meaning it could not have large areas of damage, rusting or poor paint condition, even in the rear and side areas.
- Tires and wheels to be in good condition.

- Front suspension/steering geometry such that the vehicle could track accurately.

The acquired 1979 Volkswagen Rabbits were prepared for testing using the following procedure:

- Wheels were inspected (or installed, if necessary) and the vehicle's front suspension/steering were aligned to ensure desired tracking characteristics.

- The engine coolant and battery acid were drained.

- The vehicle attitude measurement at test weight were documented.

- The dry (no fluids) vehicle weight was documented.

- Components that did not contribute to the frontal structural characteristics of the vehicle were removed as necessary to achieve the 1800 $\pm$ 50-lb test weight.

- The guidance ring, accelerometers, data umbilical, abort system, labels, targets, and inch tape were installed on the vehicle.

- The final test weight was determined and documented.

- A triaxial accelerometer was mounted on each test vehicle on the longitudinal centerline. It was mounted on a flat level location on the transmission on tunnel as close to the location of the vehicle's

center of gravity as was reasonably possible at that location. Typical details of the accelerometer location are shown in table 4. These generally remained unchanged from test to test.

- A pressure sensitive contact switch was attached to either the front bumper or the pole in order to signal the instant of first contact to the data recorder and to the visual strobe.

- The vehicle length, width, track width, wheelbase, and accelerometer locations were measured and documented.

- The pre-impact front bumper contour with reference to the rear end of the vehicle was measured and documented.

3. Description of Test Facilities

Vehicle Guidance and Tow System

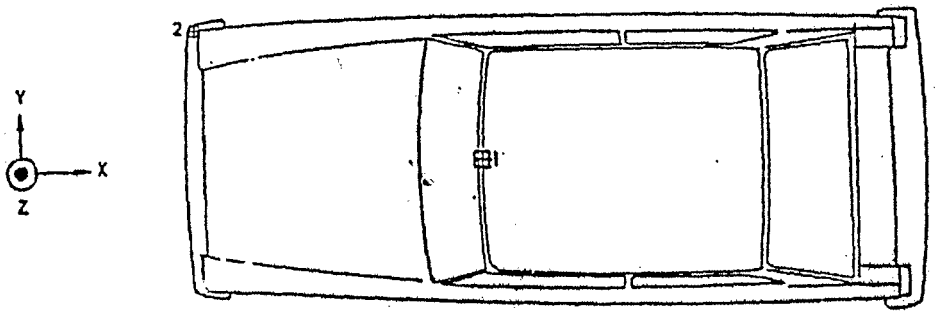
The facility has a level, 800-ft approach to the pole impact area. A steel guide cable, terminating 10 ft from the pole, is installed on the approach surface and restrained to provide positive lateral guidance to the vehicle.

The vehicle velocity is controlled using an ignition limiter that controls the speed of the tow truck. The ignition limiter is calibrated to achieve the specified velocity prior to testing and takes into consideration the two to one mechanical advantage of the reverse tow system.

Table 4. Typical accelerometer locations.

Vehicle: 1979 Volkswagen Rabbit Test Date: 04/26/88

No. Location	X Distance From Front of Bumper in	Y Distance From Centerline in	Z Distance Above Ground in
Veh. long. 1 centerline	58.2	0.0	14.25



⊕ - Single Axis

⊞ - Triaxial

Vehicle Abort System

A solenoid-actuated hydraulic accumulator is connected to the test vehicle's service-brake system. When the accumulator is electrically activated, the vehicle brakes are actuated. This abort system can be activated manually at any time necessary to abort the test. The driver of the towing vehicle is informed simultaneously and can abort the towing action.

Timing Traps (Velocity Measurements)

The impact speed of the test was measured by using two pressure sensitive strips. The two pressure sensitive strips are set across the vehicle's path just prior to the impact. Test nos. 5 through 8 also used a post impact speed trap. The strips are placed a precise distance apart. The output from the strips start and stop electronic counters such that the time to traverse the distance is known to be within 1 microsecond accuracy.

Measurement System Calibration

A calibration system and procedure is in place and functioning that satisfies the requirements of the FHWA procedure. All instruments are calibrated against a higher order standard at periodic intervals not exceeding 6 months. All calibration instruments are traceable to the National Bureau of Standards. The test equipment is labeled with the date and place of calibration, date for the next calibration, and the name of the technician and the organization who calibrated it. The calibration procedure is maintained by the contractors and was approved by FHWA prior to initiation of testing.

4. Motion Pictures

Three high-speed motion picture cameras were used during test nos. 1 through 4, to provide photographic coverage of the vehicle during the impact event. Positions of the cameras were as follows:

- Right side, close up view of impact (the view area was perpendicular to the vehicle's motion and was set to be approximately 5 ft forward and aft of the pole center).

- Right side, overall view, impact and run-out (the view area was perpendicular to the vehicle's motion and was set to be approximately 1 car length forward and 3 car lengths aft of the pole.

- Run out view (the view area was set to be 3/4 (angled) view at impact and run-out of the vehicle).

A contact switch was placed on the pole face to activate the flash units in the field of view of all the cameras.

After the fourth test, one additional high-speed camera was added to provide a right side overall view. This view was slightly "off of perpendicular" relative to the motion of impacting vehicle. Since test nos. 5 through 8 tested two-legged sign supports, this camera was deemed necessary to capture the movement of the impacted support (which was hidden behind the non-impacted support in the "field of view" of the perpendicular cameras.

A real-time documentary camera was used to take movies of all pretest, impact, and posttest views of the test vehicle and of

the luminaire and sign support. The camera position, lens sizes, camera/make/model, frame rates, etc. were documented for each test. Table 5 shows a typical camera location table.

5. Still Photo Coverage

The following still photographs and color slides were taken for each test:

Pretest

- Luminaire or Sign Support
- Right/Left Side View
- Right/Left 3/4 (angle) View with car in place
- Front View, Overhead View
- Test Area - General looking down from a high position

Posttest

- Luminaire or Sign Support Base
- Luminaire or Sign Support
- Right/Left Side View
- Right/Left 3/4 (angle) View vehicle
- Front View, Overhead View
- General view showing vehicle relative to impact area

Typical pretest photographs of a test vehicle taken for test no. 5 are shown in figures 6 through 11. The next eight sections describing the eight tests do not include the pretest photographs.

Table 5. Camera locations and descriptions.

Location Number	Field of View	Lens Size mm	Frame Rate fps	Timing Speed Hz	Mfg./Model Number	Impact Dist-X	Centerline Dist-Y	Camera Height Dist-Z	Film Quality
1	Right Side Close-up	50	600	100	Fastex 230	0 ft	-71.0 ft	+51.0 in	Good
2	Right Side Overall	16	600	100	Fastex 231	-17 ft	+56.0 ft	+50.0 in	Good
3	Post Impact Run Out	28	600	100	Fastex 228	+142 ft	+65.0 ft	+74.0 in	Good
4	Documentary Run Out	12-70	24	N/A	Arriflex NR6837	-41 ft	+83.0 ft	+56.0 in	Good
5	Right Medium	28	600	100	Fastex 232	-10 ft	+91.0 ft	+61.5 in	Good

Dist-X: + behind impact point
Dist-Y: + to the right
Dist-Z: + above ground

Figure 6. Typical full left side view, pretest.

Figure 7. Typical full right side view, pretest.

Figure 8. Typical left front 3/4 view, pretest.

Figure 9. Typical right front 3/4, view, pretest.

Figure 10. Typical full front view, pretest.

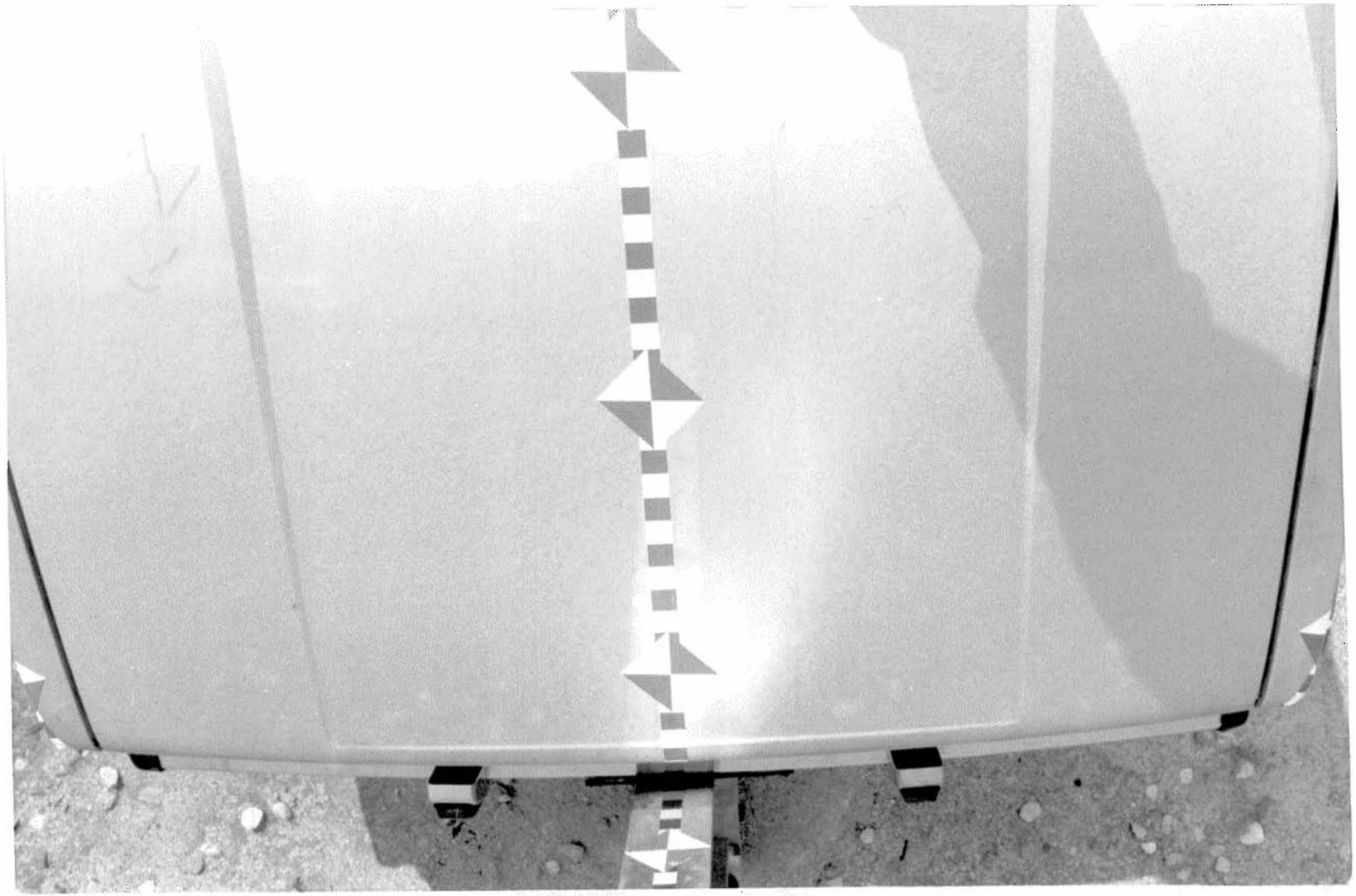


Figure 11. Typical impact location overhead view, pretest.

6. Data Collection, Processing, and Analysis

Three channels of acceleration data were recorded. The accelerometers were installed on the longitudinal centerline of the vehicle, to record the longitudinal, vertical, and lateral accelerations. The three accelerometers were mounted as a triaxial accelerometer package on the transmission tunnel.

Significant elements of the data collection, processing and analysis are described in the paragraphs that follow:

- Acceleration/time plots (X, Y, Z-axis): The data are recorded in analog form on a Kyowa RTP-602A tape recorder using an umbilical cable between the test vehicle and the instrumentation van. The data are played back through a 4-pole SAE class 1000 filter (having a cut-off frequency of 1650 Hz) and subsequently digitized at a rate of at least 5000 samples per second. The relationship between the digitizing rate (5000 samples per second) and the filter's cut off frequency (1650 Hz) is approximately 3:1. This ratio has been carefully chosen, to prevent the introduction of aliased or distorted data during the digitization process. The digitized X, Y and Z acceleration data are digitally filtered using an SAE class 60 filter (cut off frequency of 100 Hz) using a computer, and subsequently plotted to produce the acceleration/time plots shown in this report.

- 50 ms average peak accelerations: After the acceleration data from each channel (X, Y and Z) have been digitally filtered using the SAE class 60 filter, the data are further

processed using appropriate software to determine the highest average acceleration level in each channel having a time interval width of 50 ms.

10 ms average peak accelerations: After the digitization of the X-axis data channel only, the data are further digitally filtered, this time using an SAE class 180 filter (having a cut off frequency of 300 Hz), to determine the highest 10 ms average peak acceleration. Subsequent to this filtering, the data are further processed using appropriate software to determine the highest average acceleration level having a time interval width of 10 ms.

Velocity/time plot (from acceleration data): For X-axis acceleration data channel only, and after the data have been filtered using an SAE class 180 filter, the acceleration data are integrated using appropriate software to determine the velocity/time plot.

Velocity/time plot (from film data): The test impact velocity was measured in two ways. First, pressure sensitive tape switches were placed on the ground a known distance apart. The tape switches were connected to a direct readout time interval meter. The velocity was calculated from the distance traversed versus the recorded time interval. Secondly, the two high-speed side view movies were examined with the aid of a stop motion projector to compare vehicle motion relative to stationary references within the field of view. The film analysis then provided the test impact velocity. During the film analysis, a stationary ground-based reference was used to eliminate analysis error caused by lateral film movement (called "jitter") in the high-speed

camera and in the film analysis projector. Since the filming camera has accurate timing works on the edge of film at intervals of 10 ms, the accurate speed of the film can be established and the time between the frames can be determined. Therefore, a plot of vehicle displacement versus time can be determined from these data. Subsequently, the displacement data were differentiated to form a cvelocity/time plot. The differentiation was done manually. The number of points on the displacement/time plot where the slopes were calculated was based on an evaluator's judgment. It is appropriate to mention that differentiation is a "roughening" process and tends to magnify errors. A velocity/time plot from film data was derived as a cross check and a general comparison with the velocity/time plot from acceleration data.

For test nos. 1 through 4, a single pair of tape switches located prior to impact was used to document the test vehicle's impact velocity. A second pair of tape switches was added in test nos. 5 through 8 behind the test article that was impacted. The objective of this second pair of tape switches was to measure the test vehicle's velocity at a known distance after the impact with the test article.

- Occupant impact velocity (calculated per NCHRP-230): For the X-axis acceleration data channel only and after the data have been filtered using an SAE class 180 filter, the acceleration data are integrated using appropriate software to determine the velocity/time plot. Subsequently, this velocity/time plot is further integrated to determine the displacement/time plot, again, using appropriate computer software. Both of these plots can be visualized as the

velocity and displacement of a theoretical occupant relative to the moving test vehicle. At the time when the theoretical occupant has moved forward relative to the car, a distance of 24 in (determined from the displacement/time plot), the velocity of impact relative to an interior surface can be determined from the velocity/time plot. Using this method, the impact velocity of a theoretical occupant into an interior surface of the car is calculated in accordance with the procedures set forth in NCHRP Report No. 230.[2] This velocity is considered by highway safety experts to be the primary indicator of the level of occupant injury in such a collision.

10 ms average ride-down acceleration (calculated per NCHRP 230): For the X-axis acceleration data channel only and after the data have been filtered using an SAE class 180 filter, the acceleration data are again analyzed using appropriate software to determine the highest average acceleration level having a width of 10 ms. This time, however, only the portion of the acceleration trace remaining after the time of occupant impact is analyzed. Using this method, the ride-down acceleration (a measure of the force applied to the occupant after impact with an interior surface of the vehicle) is determined in accordance with the procedures set forth in NCHRP Report No. 230.[2] This acceleration is considered by highway safety experts to be the primary indicator of the level of occupant injury in such a collision after the occupant has impacted an interior surface of the car.

7. Performance Evaluation of the Tested Luminaire Sign Supports

The results of the impact tests were evaluated using two sets of recommended procedures for the breakaway or yielding supports. The two procedures were:

- AASHTO Specifications (Section 7).[1]
- NCHRP 230 Specifications.[2]

A summary of the safety performance requirements from the two documents listed above is given in the following subsections. The actual evaluations are presented in the section starting on page 23.

AASHTO Specifications

Section 7 of the AASHTO document has three major safety requirements.[1] They are listed below:

- Breakaway supports are designed to yield when struck by a vehicle, thereby minimizing injury to the occupants of the vehicle and damage to the vehicle itself.

- Satisfactory dynamic performance of a breakaway support is indicated when the maximum change in velocity for a standard 1800-lb vehicle, or its equivalent, striking a breakaway support at speeds from 20 mi/h to 60 mi/h does not exceed 15 ft/s, but preferably 10 ft/s or less.

- To avoid vehicle undercarriage snagging, any substantial remains of a support, after breaking away, should not project more than 4 in above ground. The 4-in

projection is determined by using a 60-in chord aligned radially to the centerline of the highway and connecting any point, within the length of the chord, on the ground surface on one side of the support to a point on the ground surface on the other side.

NCHRP 230 Specification

The NCHRP 230 safety performance specifications, only as they apply to breakaway supports are taken from table 6, page 13 of the NCHRP 230 document and are listed below:[2]

Structural Adequacy

- The test article shall readily activate in a predictable manner by breaking away or yielding.

- Detached elements, fragments or other debris from the test article shall not penetrate or show potential for penetrating the passenger compartment or present undue hazard to other traffic.

Occupant Risk

- The vehicle shall remain upright during and after collision although moderate roll, pitching and yawing are acceptable. Integrity of the passenger compartment must be maintained with essentially no deformation or intrusion.

- Impact velocity of a hypothetical front seat passenger against the vehicle interior, calculated from vehicle

accelerations and a 24-in forward displacement of the occupant, shall be less than:

Longitudinal Occupant Impact Velocity-ft/s

40/2.67 = 15

and vehicle highest 10 ms average accelerations subsequent to instant of hypothetical passenger impact should be less than:

Longitudinal Occupant Ridedown Accelerations-g's

20/1.33 = 15

Vehicle Trajectory

- After collision, the vehicle trajectory and final stopping position shall intrude a minimum distance, if at all, into adjacent traffic lanes.

- Vehicle trajectory behind the test article is acceptable.

TEST RESULTS AND EVALUATIONS

1. Test Matrix

The matrix of the eight tests that were undertaken under this project was presented in table 1. Table 4, in this section, shows the actual values of the test parameters that were presented as target values in tables 1 and 2. The eight tests are designated as test nos. 1 through 8.

2. Test Results

Later sections of this report contain the detailed test results for the eight tests conducted under this study project. The highlights of the test results are summarized in this section. Table 5 includes the significant results for all of the eight tests.

3. Evaluation of the Results

AASHTO Specifications

Table 6 summarizes the evaluation of the test results as compared to the AASHTO specifications for the eight luminaire and sign supports. The luminaire and sign supports that were tested are listed below for ready reference.

- Small Sign Support (Arkansas Back Brace)
  Test no. 1–60 mi/h.

- Metal Luminaire Support with A.B. Chance Slip Base Anchoring System
  Test no. 2–60 mi/h. Test no. 3–20 mi/h.

Table 6. The test results.

Test No.	Test Date	Test Article Manufacture & Model Model No.	Test Vehicle	Test Vehicle Mass lbs	Impact Velocity mi/h		Impact Point in
					Speed Trap	Film Analysis	
1	09/22/87	Small Sign Support (Arkansas Back Brace)	1979 VW Rabbit	1827	61.02	60.7	1.5 to the right of the center-line
2	10/08/87	Metal Luminaire Support (A.B. Chance Slip Base Anchoring System)	1979 VW Rabbit	1839	—	60.07	7.0 to the right of the center-line
3	10/09/87	Metal Luminaire Support (Arkansas Back Brace)	1979 VW Rabbit	1839	20.11	19.57	5.0 to the left of the center-line
4	02/12/88	Fiberglass Luminaire Support (Highline Product Corp. Model No. HL-288H-1)	1979 VW Rabbit	1846	59.66	—	3.5 to the left of the center-line
5	02/26/88	Freeway Stiff Leg Sign Support (Wisconsin Type B)	1979 VW Rabbit	1844	20.32	20.25	0.5 to the left of the center-line
6	04/15/88	Freeway Stiff Leg Sign Support (Wisconsin Type B)	1979 VW Rabbit	1838	58.40	58.19	2.0 to the left of the center-line
7	04/26/88	Freeway Stiff Leg Sign Support (Wisconsin Type D)	1979 VW Rabbit	1845	20.93	20.86	0.4 to the right of the center-line
8	05/06/88	Freeway Stiff Leg Sign Support (Wisconsin Type D)	1979 VW Rabbit	1822	59.83	59.65	5.0 to the right of the center-line

Table 7. Significant results from the eight tests.

Test Results Description Parameter	Test No. 1	Test No. 2	Test No. 3	Test No. 4*	Test No. 5	Test No. 6	Test No. 7	Test No. 8
Pre-Impact Speed – mi/h (ft/s)								
– Speed Trap	61.0 (89.5)	N/A	20.1 (29.5)	60.3 (88.5)	20.3 (29.8)	58.4 (85.7)	21.0 (30.7)	59.8 (87.7)
– Film Analysis	60.17(88.1)	60.1 (88.1)	19.5 (28.6)	59.7 (87.5)	20.3 (29.7)	58.2 (85.4)	20.9 (30.6)	59.7 (87.5)
Post-Impact Speed – mi/h ft/s								
– From Speed Trap and Acceleration Data	51.7 (75.8)	51.4 (75.4)	10.2 (15.0)	42.7 (62.6)	12.4 (18.2)	53.5 (79.0)	13.3 (19.5)	53.4 (78.3)
– Film Analysis	52.1 (76.4)	52.1 (76.4)	10.2 (15.0)	42.7 (62.6)	12.4 (18.2)	51.8 (75.9)	13.2 (19.4)	52.8 (77.5)
Vehicle Change – mi/h (ft/s) In Velocity								
– Speed from Trap and Integration of Acceleration	8.4 (12.3)	8.7 (12.7)	9.3 (13.6)	17.0 (24.9)	7.9 (11.6)	4.7 (6.3)	7.6 (11.2)	6.4 (9.4)
– Film Analysis	8.0 (11.7)	8.0 (11.7)	9.3 (13.6)	17.0 (24.9)	7.9 (11.5)	6.5 (9.5)	7.6 (11.2)	6.8 (10.0)
Peak Deceleration (at c.g.) g's	10.1	18.5	20.9	14.0	13.3	30.8	16.8	29.6
Maximum 50 Msec Average Deceleration g's								
– X – Axis	3.7	6.2	8.1	8.0	5.6	4.8	6.0	7.6
– Y – Axis	0.6	0.7	0.5	NA	0.5	0.6	1.3	1.0
– Z – Axis	0.9	1.2	1.6	NA	1.3	2.3	1.6	4.6
Maximum Crush – in	6.0	13.0	14.0	5.9	5.5	15.0	14.0	17.3
Longitudinal Occupant Impact Velocity – ft/s (NCHRP 230)	11.5	10.6	14.2	24.9	11.5	6.3	11.1	9.4
Longitudinal Occupant Ridedown Acceleration – g's (NCHRP 230)	1.0	1.5	1.6	12.7	2.3	1.0	1.8	1.2
Posttest Stub Measurement – in	0.0	3.1	3.4	38.8	3.8	3.8	3.6	3.6

* For test no. 4 only, all acceleration data were derived from differentiation of the velocity time history from film analysis.

NA Not Available

Table 8. Evaluation of tested sign and luminaire supports compared to AASHTO criteria.

AASHTO Criteria*	Test No. 1	Test No. 2	Test No. 3	Test No. 4	Test No. 5	Test No. 6	Test No. 7	Test No. 8
1. Pole must yield or break away. Did the pole completely yield or break away? Yes or No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. Dynamic Test Performance Is velocity change (ΔV) equal to or less than 15 ft/s? Yes or No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Is Velocity change (ΔV) equal to or less than 10 ft/s? Yes or No	No	No	No	No	No	Yes	No	Yes
3. Posttest Stub Measurement Does the remaining stub, if any meet the AASHTO specifications?	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes

- Fiberglass Luminaire Support, Highline Products Corporation Model No. HL-228H-1
  Test no. 4-60 mi/h.

- Freeway Stiff Leg Sign Support, Wisconsin Type B
  Test no. 5-20 mi/h. Test no. 6-60 mi/h.

- Freeway Stiff Leg Sign Support, Wisconsin Type D
  Test no. 7-20 mi/h. Test no. 8-60 mi/h.

In summary, the Arkansas Back Brace sign support met the minimum AASHTO requirements in the test at 60 mi/h.

The metal luminaire pole with A.B. Chance Shear plate met the minimum AASHTO requirements in tests carried out at 20 mi/h and 60 mi/h.

The Highline Products Corporation pole, model no. HL-228H-1, did break away but left a stub measuring more than 4 in. It also failed dynamic performance criteria as the velocity change was more than 15 ft/s.

Wisconsin Stiff Leg sign supports Type B and Type D met the minimum AASHTO requirements at the test speeds 20 mi/h and 60 mi/h.

NCHRP 230 Specifications

Table 7 summarizes the evaluation of the test results to the NCHRP 230 specifications for the eight luminaire and sign supports.

In summary, the Arkansas Back Brace sign support met the minimum NCHRP 230 requirements in the test at 60 mi/h.

Table 9. Evaluation of tested sign and luminaire supports, compared to NCHRP 230 criteria.

	AASHTO Criteria	Test No. 1	Test No. 2	Test No. 3	Test No. 4	Test No. 5	Test No. 6	Test No. 7	Test No. 8
	Structural Adequacy								
B	Did the pole break away or yield completely?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
D	Did detached elements fragments, or other debris meet the no penetration of the passesenger compartment requirement?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Occupant Risk								
E	o Did the vehicle remain upright during and after collision?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	o Was the no passenger compartment deformation requirement met?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	o Was the no passenger compartment intrusion requirement met?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F	o Is longitudinal occupant impact velocity calculated using NCHRP 230 procedure less than 15 ft/s?	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
	o Was longitudinal occupant ride-down acceleration calculated using NCHRP 230 procedure less than 15 g's?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Vehicle Trajectory								
H	After collision, did the vehicle trajectory and final stopping position intrude a minimum distance, if at all, into adjacent traffic lanes?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
I	Was the vehicle trajectory behind the test article?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The metal luminaire pole with A.B. Chance Shear Plate, met the minimum NCHRP 230 requirements in tests carried out at 20 mi/h and 60 mi/h.

The Highline Products Corporation pole, model no. HL-228H-1, when tested at 60 mi/h, failed to meet the NCHRP 230 criteria because the occupant impact velocity was more than 15 ft/s.

Wisconsin Stiff Leg Sign supports Type B and Type D performed satisfactorily and met the NCHRP 230 requirements at test speeds of 20 mi/h and 60 mi/h.

4. General Comments

1. The Arkansas Back Brace test at 60 mi/h was a repeat of a test conducted by the contractor a few years ago. In that test, the Arkansas Back Brace snagged and the test vehicle rolled over. The design of the tested sign support under this project included a different grade metal in the diagonal support. The results from this test show that the modification worked well. The test article met all NCHRP 230 and AASHTO criteria. The test vehicle did not rollover, and its trajectory after the impact was generally straight and acceptable.

2. The tested A.B. Chance metal luminaire support broke away cleanly at both 20 and 60 mi/h. It appeared to meet all AASHTO and NCHRP 230 criteria. Damage to the vehicle in the front was observed. However, passenger compartment deformation was not deemed to be significant. There was no passenger compartment intrusion.

3. The Highline Products fiberglass luminaire support was tested at an impact speed of 60 mi/h. The test article did break away. However, it broke away at a level such that a few feet of pole was still protruding from the ground. Also the change in velocity was higher than the NCHRP 230/AASHTO specification criterion of 15 ft/s. The 20 mi/h test on Highline Products fiber glass pole was conducted on an earlier contract. The results are available in Report No. FHWA/RD - 87/065.

4. The Wisconsin Stiff Leg large sign support was tested with a Type B sign in test nos. 5 and 6. The results show that the test article met all requirements of AASHTO and NCHRP 230 criteria. It is appropriate to note here that the big freeway sign (15 ft by 11 ft) came tumbling down on top of the vehicle during the 20 mi/h test. However, other than front end damage to the vehicle, there was no significant deformation or intrusion of the passenger compartment of the test vehicle.

5. Test nos. 7 and 8 were conducted with Type D freeway sign supported by Wisconsin Stiff Leg supports. The Type D sign is significantly larger than the Type B sign. It measures 22 ft by 14 ft. The steel supports for the Type D sign are longer and heavier than those for the Type B sign. Hence, even though the breakaway design performed acceptably with Type B sign, a decision was made to conduct test nos. 7 and 8 with the larger and heavier sign and supports. The results show that the sign support on the impact side broke away cleanly both at 20 mi/h and at 60 mi/h and all AASHTO

and NCHRP 230 specifications were met. Once again the sign came tumbling down on top of the test vehicle during the 20 mi/h test. However, no deformation of the passenger compartment was observed.

DETAILED TEST RESULTS

The next eight sections present the detailed test results from the eight tests conducted under this project. The tests were conducted in strict conformance of the NCHRP 230 test procedures. The test target impact speeds were either 20 or 60 mi/h. The elements of the test procedure that were common to all tests were described in earlier sections. The elements of each test that were unique to that test and all the detail data sheets and results are presented in the sections that follow.

The data for each test are generally presented as listed below:

1. Introduction
2. Test Article Description
3. Data Tables
4. Test Results
5. Photographic Coverage
6. Data Plots

LUMINAIRE AND SIGN SUPPORT TEST NO. 1, 60 MI/H

1. Introduction

Test No. 1 (sign support 01) was conducted on 22 September 1987 using a 1979 Volkswagen Rabbit with a weight of 1800 ± 50 lb which was guided to impact the test article at the vehicle's front centerline.

2. Test Article

The test article was a 12-ft, 3-lb/ft, u-shaped steel sign support pole with a rear mounted back-brace. The back-brace was a 9-ft steel pole of the same construction as the main pole, attached to the main, 2 in below the bottom of the sign blank, and extending diagonally downward into the soil. The separation between the main pole and the back-brace was 2 ft at ground level. A 30-in octagonal stop sign was attached to the top of the main pole with two 5/16-in bolts, spaced 24 in apart. The pole was oriented such that one leg of the u-shape was facing the impacting vehicle. The distance between supports at ground level was 24 in. The Length from ground line to the bottom of the sign blank was 84 in. The test article is shown in figure 13.

The pole was buried in NCHRP 230, S-1 (strong) soil to a depth of 2.5 ft. No restraint was placed on the top of the pole. Installation photographs are presented in subsection 5.

3. Data Tables

Tables 10 through 14 show the data from test no. 1. Table 10 shows crash test summary. Table 11 shows test vehicle information. Table 12 shows test vehicle crush data. Table 13 shows test vehicle moving average acceleration data and table 14 shows the results from the data analysis.

Table 10. Crash test summary, luminaire support impact, test no. 1.

Project: Luminaire and Sign Supports

Test: Sign Support 01 (Test No. 1)

Date: 09/22/87 Time: 2:20 PM

Test Articles: Sign Support (Arkansas Back Brace)
with NCHRP S-1 strong soil

Vehicle: 1979 Volkswagen Rabbit

Inertial mass:	1827 lb	Test mass:	1827 lb
Pre-Impact speed:	*89.5 ft/s	Post-Impact:	**76.4 ft/s
	**88.1 ft/s		***75.8 ft/s
Offset distance from vehicle centerline:			1.5 in (right)
Maximum crush:	6.0 in	Rebound:	None
Damage: TAD:	FC1	CDC:	12FZEN4
Maximum deceleration (at c.g.)			10.1 g
Maximum 50 ms average deceleration (at c.g.)			3.7 g
Maximum 10 ms average deceleration (at c.g.)			7.5 g

Number of Data Channels: 3 accelerometers, time zero switch.

Number of High-Speed Cameras: 3, frame rate: 600 fps

* Speed trap

** Film analysis

*** Integration of acceleration data

Table 11. Test vehicle information, test no. 1.

Vehicle Manufacturer:	Volkswagen of America		
Make/Model/Year:	Volkswagen/Rabbit/1979		
Body Style:	2 door hatchback		
VIN:	1793813259	Build Date:	03/79
Engine:	Transverse 4 cylinder		
Transmission:	Manual 4 speed		
GVWR:	2822 lb		
GAWR:	1609 lb Front	Rear:	1278 lb
Tire Size:	155SR13	Load Range:	B
Tire Pressure:	27 psi	Rear:	27 psi
Date Received:	21 Sep 1987	Color:	Blue

MASS OF VEHICLE AS RECEIVED: lb

Left Front:	608	Right Front:	586
Left Rear:	377	Right Rear:	379
Total Front Mass:	1194	(61 % of total vehicle mass)	
Total Rear Mass:	756	(39 % of total vehicle mass)	
Total Mass:	1950		

TEST MASS OF VEHICLE: lb

Left Front:	612	Right Front:	601
Left Rear:	310	Right Rear:	304
Total Front Mass:	1213	(66 % of total vehicle mass)	
Total Rear Mass:	614	(34 % of total vehicle mass)	
Total Mass:	1827		

VEHICLE ATTITUDE: in

Left Front:	24.7
Right Front:	24.5
Left Rear:	24.7
Right Rear:	25.0

Table 11. Test vehicle information, test no. 1 (continued).

VEHICLE DIMENSIONS: in			
Length:	155.0		
Width:	63.4		
Wheel-base:	95.0		
Track: Front:	55.0	Rear:	53.5

CENTER OF GRAVITY LOCATION: in	
31.9	behind the front axle
0.0	to the right of centerline
21.6	above ground

Table 12. Vehicle crush data, test no. 1.

Maximum crush of 6.0 in occurred 1.5 in
to the right of the centerline.

Vehicle Rebound: None

Vehicle Speed: (measured 20 ft from impact)

Trap No. 1: 61.02 mi/h (89.90 ft/s)
Trap No. 2: Not used.

DAMAGE DIMENSIONS, in:

		Pre-Impact	Post-Impact	Change
Left Side	C_1	154.0	152.5	-1.5
	C_2	154.5	152.2	-2.3
	C_3	155.0	151.9	-3.1
	C_4	155.0	151.0	-4.0
	C_5	154.5	149.5	-5.0
Right Side	C_6	154.0	148.0	-6.0

Width of Contact: 3.0 in

Table 13. Moving average data - vehicle accelerations, test no. 1.

Vehicle c.g. Acceleration Axis	Moving Average Time (ms)	Maximum Acceleration Value (g's)	Time of Occurance (ms)
x	10	7.52	68.75 - 78.75
x	50	3.69	64.00 - 114.00
y	50	0.62	110.50 - 160.50
z	50	0.90	84.75 - 134.75

Table 14. Data analysis summary sheet, test no. 1.

TEST NUMBER: 1 TEST DATE : 09/22/87

TEST ARTICLE: Sign Support: Arkansas Back Brace

MANUFACTURER: Not available

MODEL NUMBER: Not available

TEST VEHICLE: 1979 Volkswagen Rabbit	VEHICLE WEIGHT (lb)	
POLE LENGTH (ft): 12.0	MAST ARM LENGTH (ft)	N/A
POLE BURIED In: NCHRP S-1 STRONG SOIL		
IMPACT SPEED (ft/s):	CAMERA:	88.1
	SPEED TRAP:	89.5
EXIT SPEED (ft/s):	CAMERA:	76.4
	INTEGRAL Ax:	75.8
CHANGE IN VELOCITY FROM EACH SOURCE (ft/s)	CAMERA:	11.7
	INTEGRAL Ax:	12.3
MOMENTUM CHANGE: (lb-sec reported velocity change multiplied by vehicle mass)		663.8
MAX FORCE (kips, peak x-axis deceleration * velocity weight)		18.5
MAX ACCELERATION (g's, peak x-axis deceleration)		10.1
MAXIMUM MEASURED VEHICLE CRUSH LENGTH (in, static)		6.0
LONGITUDINAL OCCUPANT IMPACT VELOCITY (ft/s, NCHRP 230)		11.5
LONGITUDINAL OCCUPANT RIDEDOWN ACCEL. (g/s , NCHRP 230)		1.0
MAX 50 MS AVERAGE DECELERATION (g's)		
	X-AXIS	3.7
	Y-AXIS	0.6
	Z-AXIS	0.9

VEHICLE VELOCITY CHANGE: 12.0 ft/s

(Average of film and accelerometer data)

4. Test Results

The vehicle impact velocity was 60.1 mi/h. The test vehicle impacted the pole 1.5 in to the right of the vehicle centerline. The main pole and back-brace wrapped around the front end of the vehicle and were pulled out of the ground. The pole exerted a downward frictional force on the bumper which caused the right side of the bumper to be rotated downward approximately 45 degrees and pushed rearward 6 in. The right side bumper shock absorber mounting was distorted, causing the right fender to be moderately deformed. The hood was moderately deformed along its centerline. No part of the sign support or sign contacted the roof or windshield of the test vehicle. Vehicle crush data are presented in table 12.

The test article was thrown 81 ft longitudinally and 5 ft laterally from impact. The test article pieces remained attached together.

The longitudinal occupant impact velocity was 11.5 ft/s and the longitudinal occupant ridedown acceleration was 1 g based on the maximum x-axis 10 ms moving average acceleration after occupant impact at 162.0 ms. The total vehicle velocity change was 12.0 ft/s or 8.2 mi/h.

Pre-and Posttest photographs of the test vehicle and test article are presented in subsection 5. Table 13 presents the vehicle maximum moving average data. All data plots are presented in subsection 6.

5. Photographic Coverage

Figures 12 through 21 show the test area, the test article and the posttest photographs of the test vehicle and the test article.

6. Data Plots

The data plots from test no. 1 are shown in figures 22 through 26.

Figure 12. Test area elevated view, pretest, test no. 1.

Figure 13. Test article, pretest, test no. 1.

Figure 14. Test area elevated view, posttest, test no. 1.

Figure 15. Test article on the ground, posttest, test no. 1.

Figure 16. 1979 Volkswagen Rabbit, full left side view, posttest, test no. 1.

Figure 17. 1979 Volkswagen Rabbit, full right side view, posttest, test no. 1.

Figure 18. 1979 Volkswagen Rabbit, left front 3/4 view, posttest, test no. 1.

Figure 19. 1979 Volkswagen Rabbit, right front 3/4 view, posttest, test no. 1.

Figure 20. 1979 Volkswagen Rabbit, full front view, posttest, test no. 1.

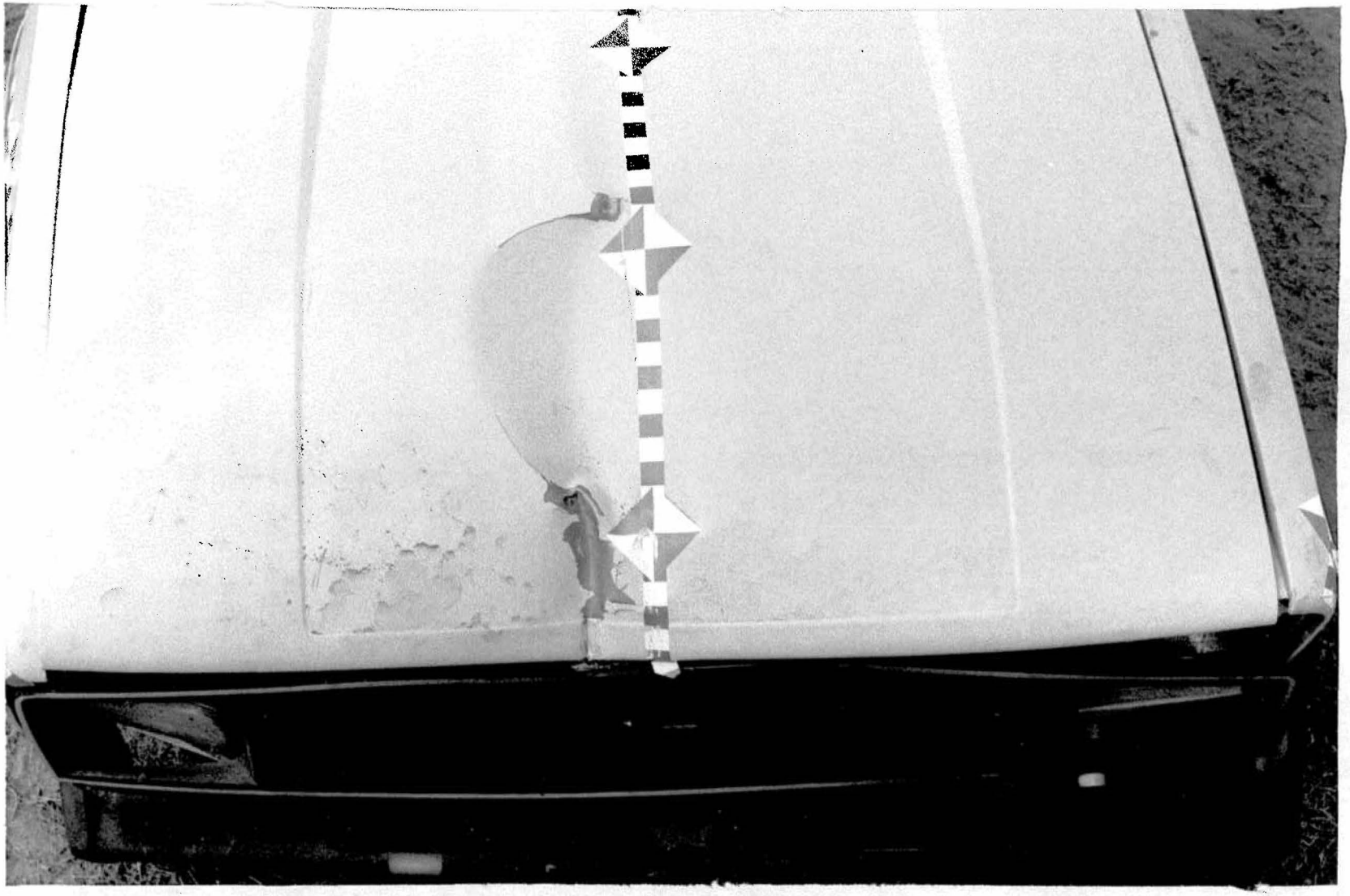


Figure 21. 1979 Volkswagen Rabbit, impact location overhead view, posttest, test no. 1.

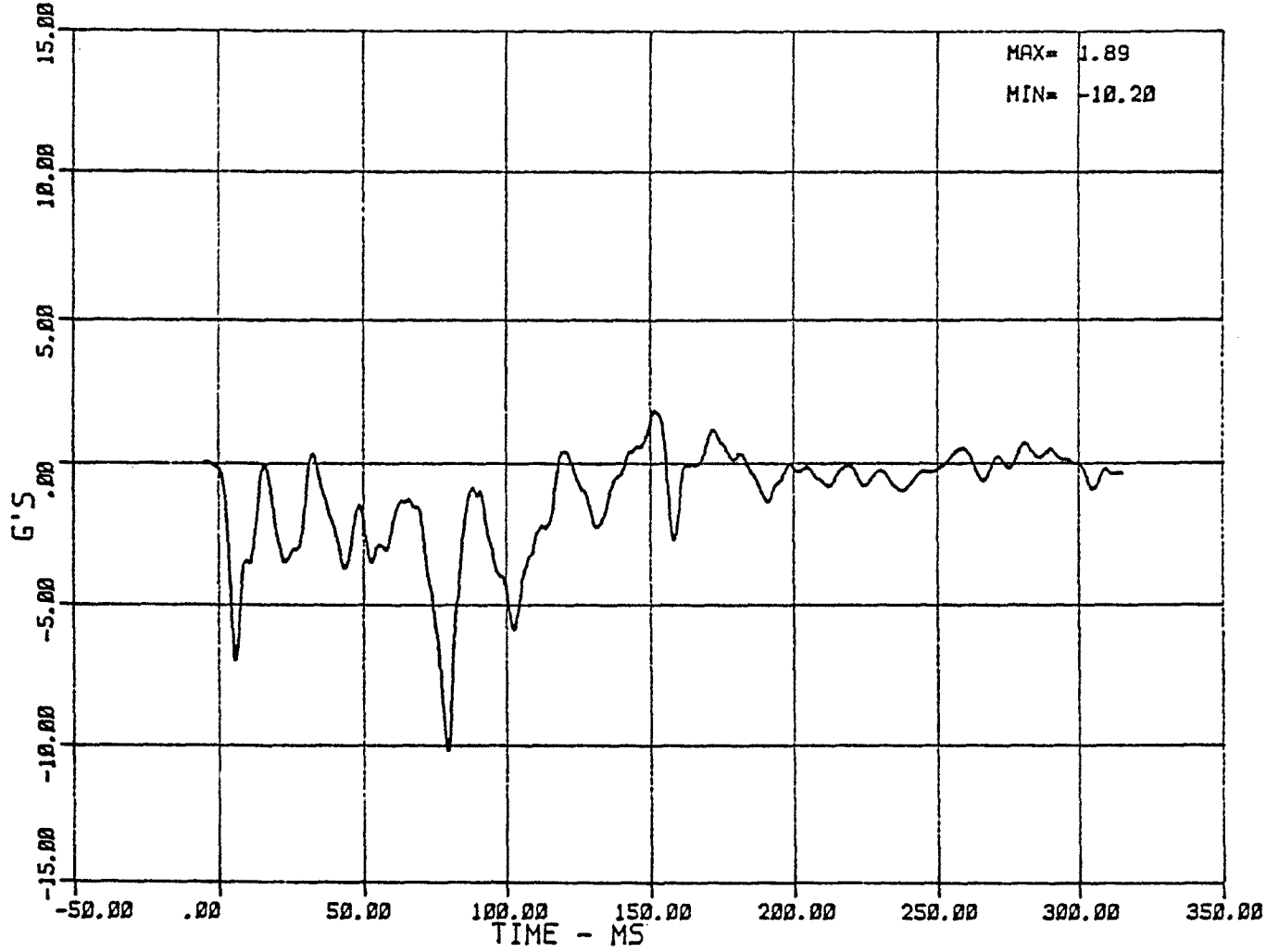


Figure 22. Deceleration time history, x-axis, test no. 1.

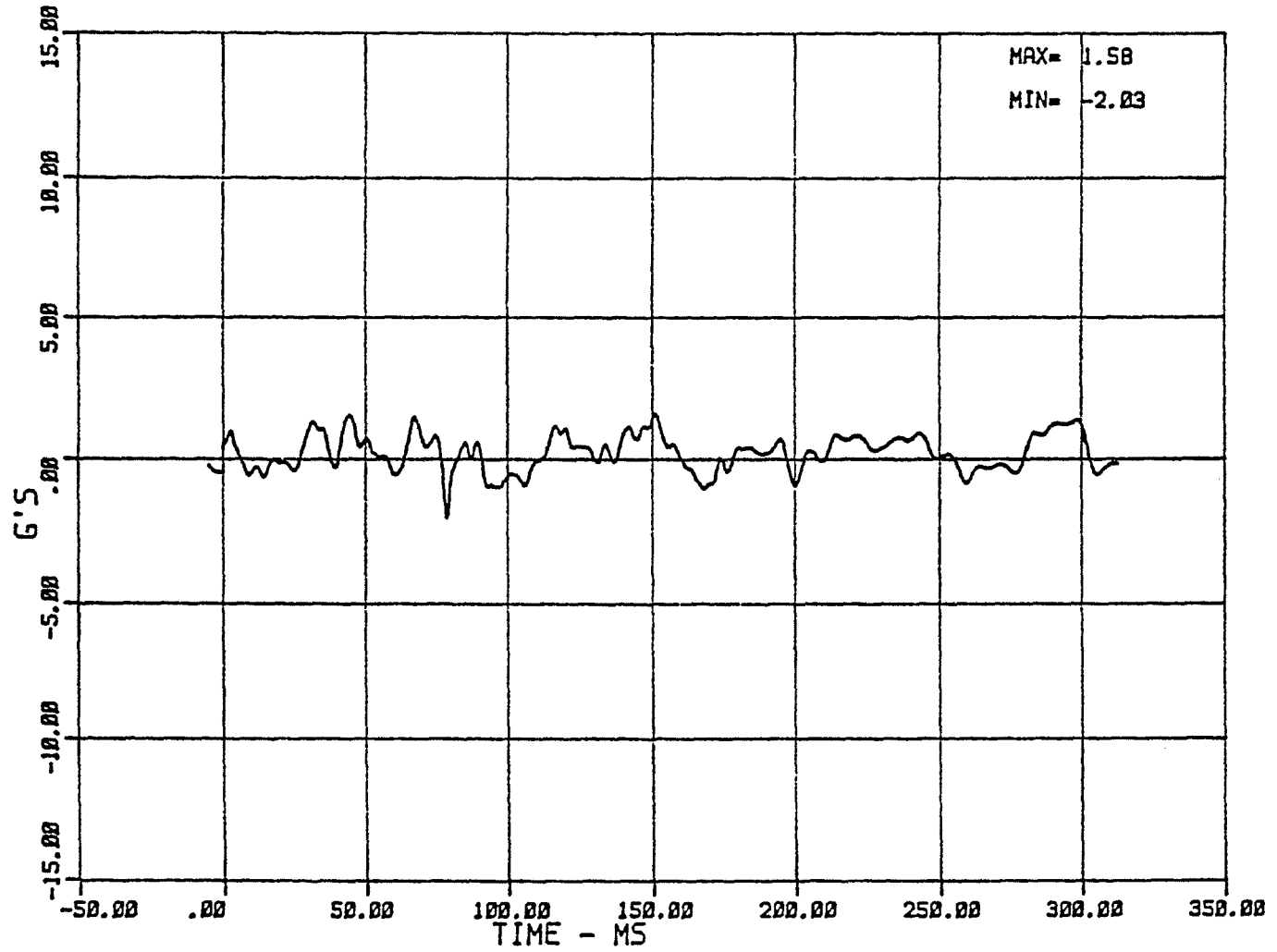


Figure 23. Deceleration time history, y-axis, test no. 1.

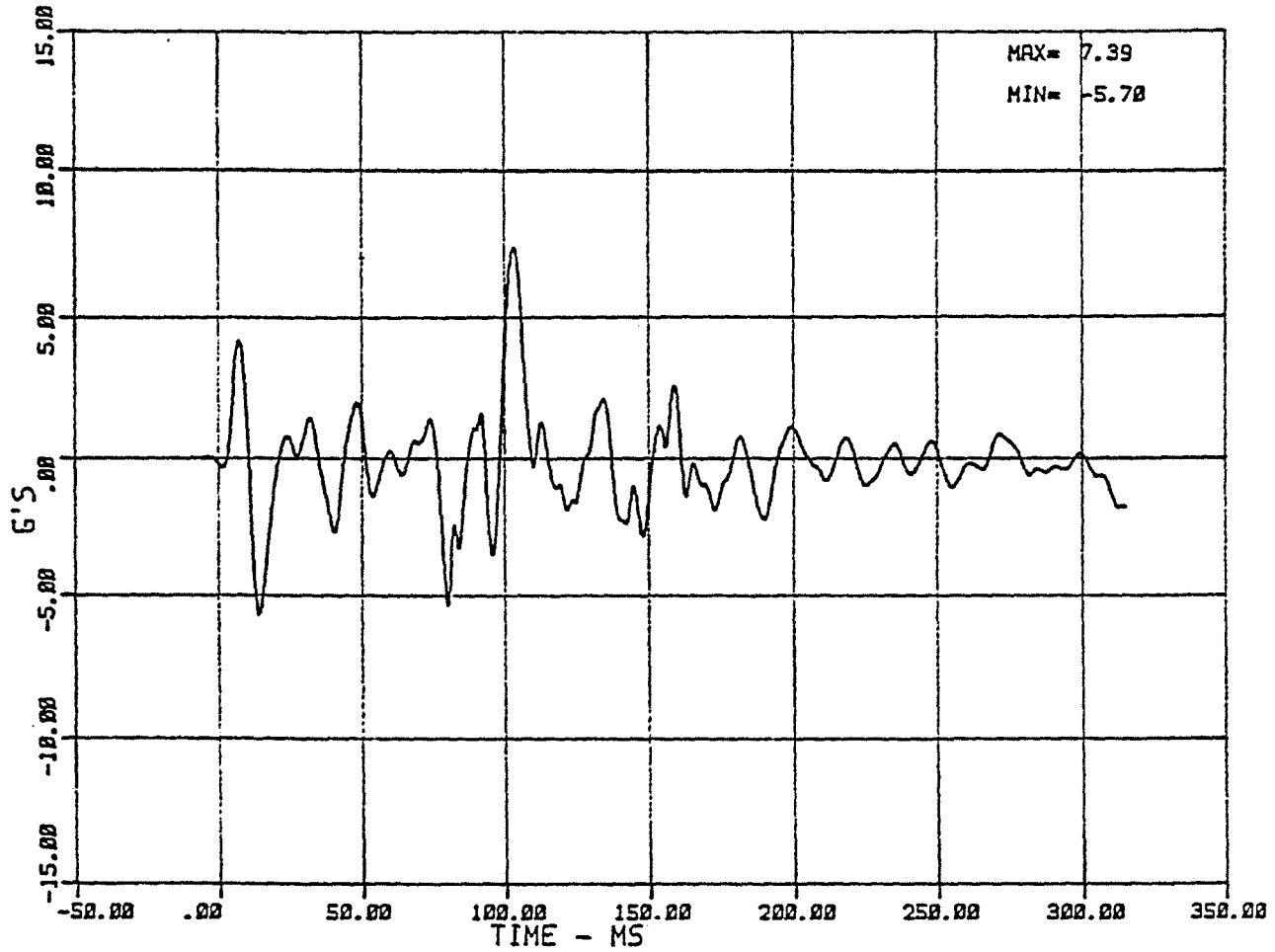
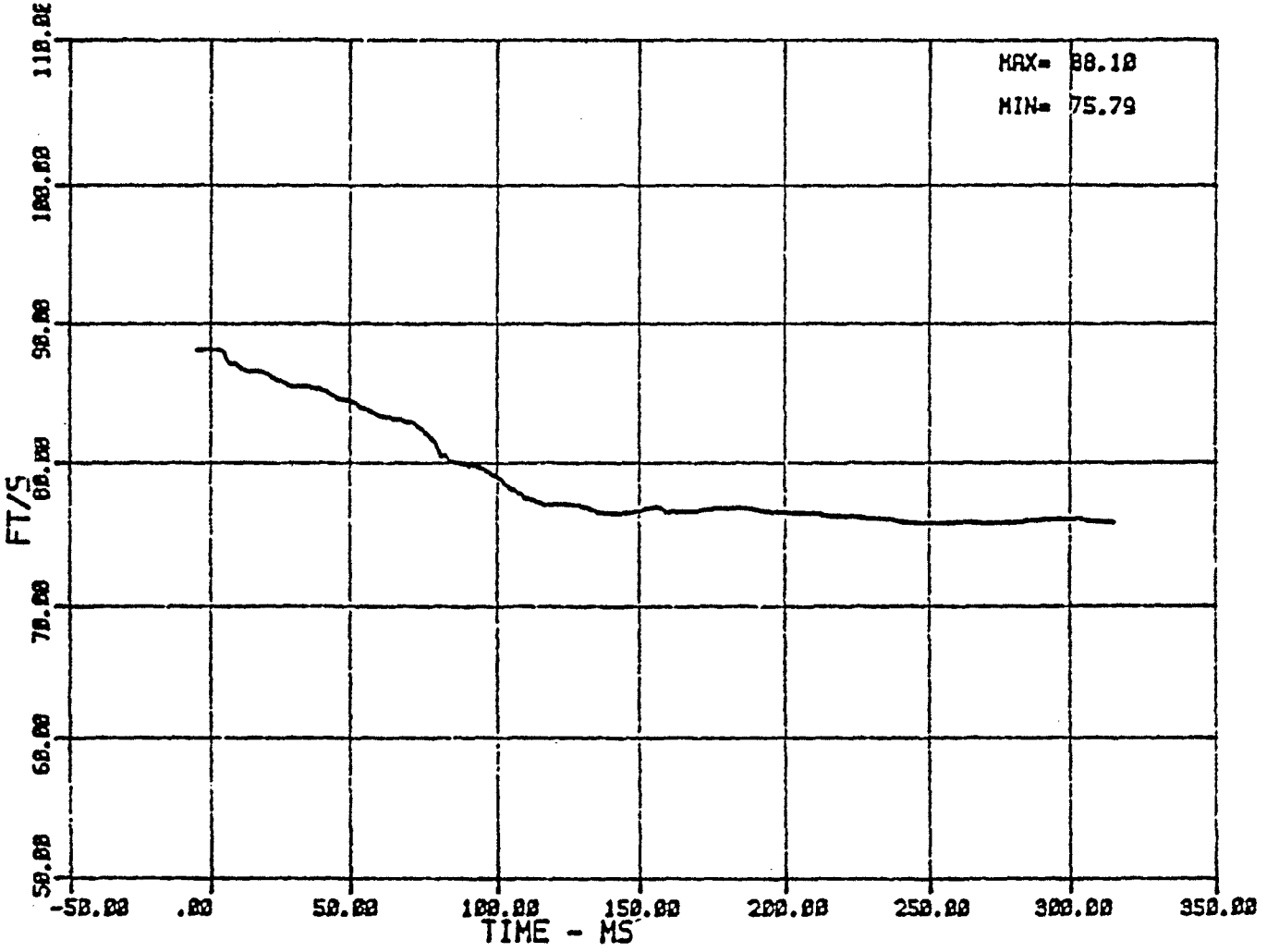


Figure 24. Deceleration time history, z-axis, test no. 1.



VEHICLE VELOCITY DERIVED FROM X ACCELERATION INTEGRATION, CLASS 180 FILTER
FSS188 1979 VOLKSWAGEN RABBIT 09/22/87

Figure 25. Longitudinal-velocity by integration, test no. 1.

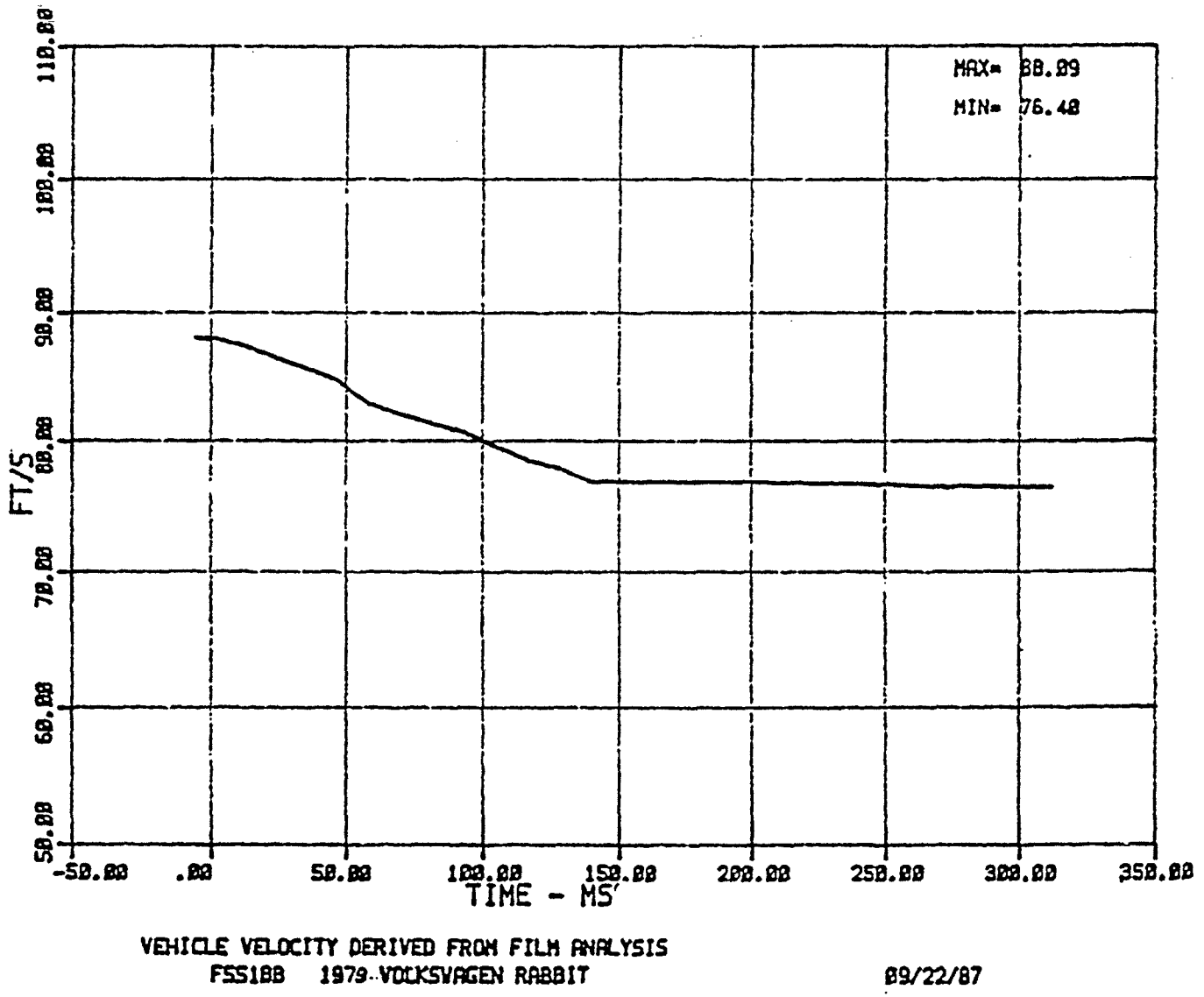


Figure 26. Longitudinal-velocity time history, by film analysis, test no. 1.

LUMINAIRE AND SIGN SUPPORT TEST NO. 2, 60 MI/H

1. Introduction

Test No. 2 (luminaire 01) was conducted on 08 October 1987 using a 1979 Volkswagen Rabbit with a weight of 1800 ± 50 lb which was guided to impact the test article at the vehicle's front centerline.

2. Test Article

The test article was a slip base luminaire support. The luminaire pole was a 30.1-ft long, tapered metal pole with a 13-ft mast arm attached 29.5 ft above the mounting base. The pole was 8 inches in diameter at the base and 3.75 inches in diameter at the top. The mast arm had a 50-lb weight attached to its free end to simulate the weight of a lighting assembly. The pole was oriented such that the mast arm was at roughly 4 o'clock, if the line of vehicle travel is given to be 12 o'clock. The pole was manufactured by Union Metal Company.

The slip base for the luminaire is a triangular plate, 1 1/16 in thick. Three 7/8-in diameter mounting bolts were used. They were torqued to 50 ft-lb as per manufacturer's specifications. "Keeper plates" were used on the mounting bolts. All installation was done by manufacturer's representative. The hand hole on the pole was directly under the mast arm. The wall thickness of the pole at the base was 0.25 in.

The anchoring system consisted of a screw-in foundation with a "Caltrans" Shear Plate assembly (slip base) on top. The anchoring system was manufactured by A.B. Chance Company.

The pole foundation was buried in NCHRP 230, S-1 strong soil to the specified depth. No restraint was placed on the top of the

pole. Installation details for slip base foundation are shown in figure 2. Installation photographs are presented in subsection 5.

3. Data Tables

Tables 15 through 19 show the data from test no. 2. Table 15 shows crash test summary. Table 16 shows test vehicle information. Table 17 shows the test vehicle crush data. Table 18 shows test vehicle moving average acceleration data, and table 19 shows the results from the data analysis.

4. Test Results

The vehicle impact velocity was 60.1 mi/h. The test vehicle impacted the pole 7 in to the right of the vehicle centerline. The base of the luminaire pole sheared away from the foundation due to the force of impact. As vehicle motion continued, the pole rotated upward, completely clearing the test vehicle. At one point, the luminaire pole was horizontal, approximately 12 ft above the ground. The vehicle bumper was pushed into an "L" shape; the grill, supporting structure and radiator were moderately deformed and the hood was badly deformed. The maximum crush depth was 13 in. Vehicle crush data are presented in table 17.

The luminaire pole came to rest nearly parallel to the direction of vehicle travel. The top of the pole was 22 ft from impact in the x-axis and 6.5 ft to the right in the y-axis. The base of the pole was 52 ft from impact in the x-axis. The base of the pole was 52 ft from impact in the x-axis and 8 ft to the right in the y-axis.

The longitudinal occupant impact velocity was 10.6 ft/s at 137 ms after time zero. The subsequent maximum 10 ms moving average ridedown acceleration was 1.5 g. The total vehicle velocity change

Table 15. Crash test summary, luminaire support impact, test no. 2.

Project: Luminaire and Sign Supports

Test: Sign Support 01 (Test No. 2)

Date: 10/08/87 Time: 4:30 PM

Test Articles: Metal luminaire pole with A. B. Chance "Cal Trans" shear plate anchoring system.

Vehicle: 1979 Volkswagen Rabbit

Inertial mass:	1839 lb	Test mass:	1839 lb
Pre-Impact speed:	* N.D. ft/s	Post-Impact:	**76.4 ft/s
	**88.1 ft/s		***75.4 ft/s
Offset distance from vehicle centerline:			7.0 in (right)
Maximum crush:	13.0 in	Rebound:	None
Damage: TAD:	FC4	CDC:	12FZEN4
Maximum deceleration (at c.g.)			18.5 g
Maximum 50 ms average deceleration (at c.g.)			6.2 g
Maximum 10 ms average deceleration (at c.g.)			14.4 g

Number of Data Channels: 3 accelerometers, time zero switch.

Number of High-Speed Cameras: 3, frame rate: 600 fps

* Speed trap (not recorded)

** Film analysis

*** Integration of acceleration data

N.D. No data

Table 16. Test vehicle information, test no. 2.

Vehicle Manufacturer:	Volkswagen of America		
Make/Model/Year:	Volkswagen/Rabbit/1979		
Body Style:	2 door hatchback		
VIN:	1793813259	Build Date:	03/79
Engine:	Transverse 4 cylinder		
Transmission:	Manual 4 speed		
GVWR:	2822 lb		
GAWR:	1609 lb Front	Rear:	1278 lb
Tire Size:	155SR13	Load Range:	B
Tire Pressure:	27 psi	Rear:	27 psi
Date Received:	29 Sep 1987	Color:	Green

MASS OF VEHICLE AS RECEIVED: lb

Left Front:	600	Right Front:	602
Left Rear:	390	Right Rear:	378
Total Front Mass:	1202	(61 % of total vehicle mass)	
Total Rear Mass:	768	(39 % of total vehicle mass)	
Total Mass:	1970		

TEST MASS OF VEHICLE: lb

Left Front:	610	Right Front:	606
Left Rear:	315	Right Rear:	308
Total Front Mass:	1216	(66 % of total vehicle mass)	
Total Rear Mass:	623	(34 % of total vehicle mass)	
Total Mass:	1839		

VEHICLE ATTITUDE: in

Left Front:	25.1
Right Front:	24.7
Left Rear:	25.5
Right Rear:	25.5

Table 16. Test vehicle information, test no. 2 (continued).

VEHICLE DIMENSIONS: in			
Length:	155.0		
Width:	63.4		
Wheel-base:	94.5		
Track: Front:	55.0	Rear:	53.5

CENTER OF GRAVITY LOCATION: in	
32.0	behind the front axle
0.0	to the right of centerline
21.6	above ground

Table 17. Vehicle crush data, test no. 2.

Maximum crush of 13.0 in occurred 7.0 in
to the right of the centerline.

Vehicle Rebound: None

Vehicle Speed: (measured 20 ft from impact)

Trap No. 1: No data.
Trap No. 2: Not used.

DAMAGE DIMENSIONS, in:

		Pre-Impact	Post-Impact	Change
Left Side	C_1	154.0	155.5	+1.5
	C_2	154.5	152.5	-2.0
	C_3	155.0	149.0	-6.0
	C_4	155.0	143.5	-11.5
	C_5	154.5	145.5	-9.0
Right Side	C_6	154.0	155.5	+1.5

Width of Contact: 8 in

Table 18. Moving average data - vehicle accelerations, test no. 2.

Vehicle c.g. Acceleration Axis	Moving Average Time (ms)	Maximum Acceleration Value (g's)	Time of Occurance (ms)
x	10	14.41	24.5 - 34.5
x	50	6.22	2.0 - 52.0
y	50	0.68	40.25 - 90.25
z	50	1.20	32.5 - 82.5

Table 19. Data analysis summary sheet, test no. 2.

TEST NUMBER: 2 TEST DATE : 10/08/87

TEST ARTICLE: Metal Luminaire Pole With Shear Plate Anchor

MANUFACTURER: Union Metal (Pole)/A.B. Chance (Anchor)

MODEL NUMBER: Not available

TEST VEHICLE: 1979 Volkswagen Rabbit	VEHICLE WEIGHT (lb)	1839
POLE LENGTH (ft): 30.1	MAST ARM LENGTH (ft)	13.0
POLE BURIED in: NCHRP S-1 STRONG SOIL		
IMPACT SPEED (ft/s):	CAMERA:	88.1
	SPEED TRAP:	No Data
EXIT SPEED (ft/s):	CAMERA:	76.4
	INTEGRAL Ax:	75.4
CHANGE IN VELOCITY FROM EACH SOURCE (ft/s)	CAMERA:	11.7
	INTEGRAL Ax:	12.7
MOMENTUM CHANGE: (lb-sec reported velocity change multiplied by vehicle mass)		696.0
MAX FORCE (kips, peak x-axis deceleration * velocity weight)		33.97
MAX ACCELERATION (g's, peak x-axis deceleration)		18.47
MAXIMUM MEASURED VEHICLE CRUSH LENGTH (in, static)		13.0
LONGITUDINAL OCCUPANT IMPACT VELOCITY (ft/s, NCHRP 230)		10.6
LONGITUDINAL OCCUPANT RIDEDOWN ACCEL. (g/s , NCHRP 230)		1.5
50 MS AVERAGE DECELERATION (g's)		
	X-AXIS	6.2
	Y-AXIS	0.7
	Z-AXIS	1.2

VEHICLE VELOCITY CHANGE: 12.2 ft/s

(Average of film and accelerometer data)

was 12.2 ft/s or 8.3 mi/h. Table 18 presents the vehicle maximum moving average data and table 19 presents a data analysis summary.

5. Photographic Coverage

Figures 27 through 37 show the test area, the test article and the posttest photographs of the test vehicle and the test article.

6. Data Plots

The data plots from test no. 2 are shown in figures 38 through 42.

Figure 27. General test area, pretest, test no. 2.

Figure 28. Test area elevated view, pretest, test no. 2.

Figure 29. Test area elevated view, posttest, test no. 2.

Figure 30. Test article on the ground, posttest, test no. 2.

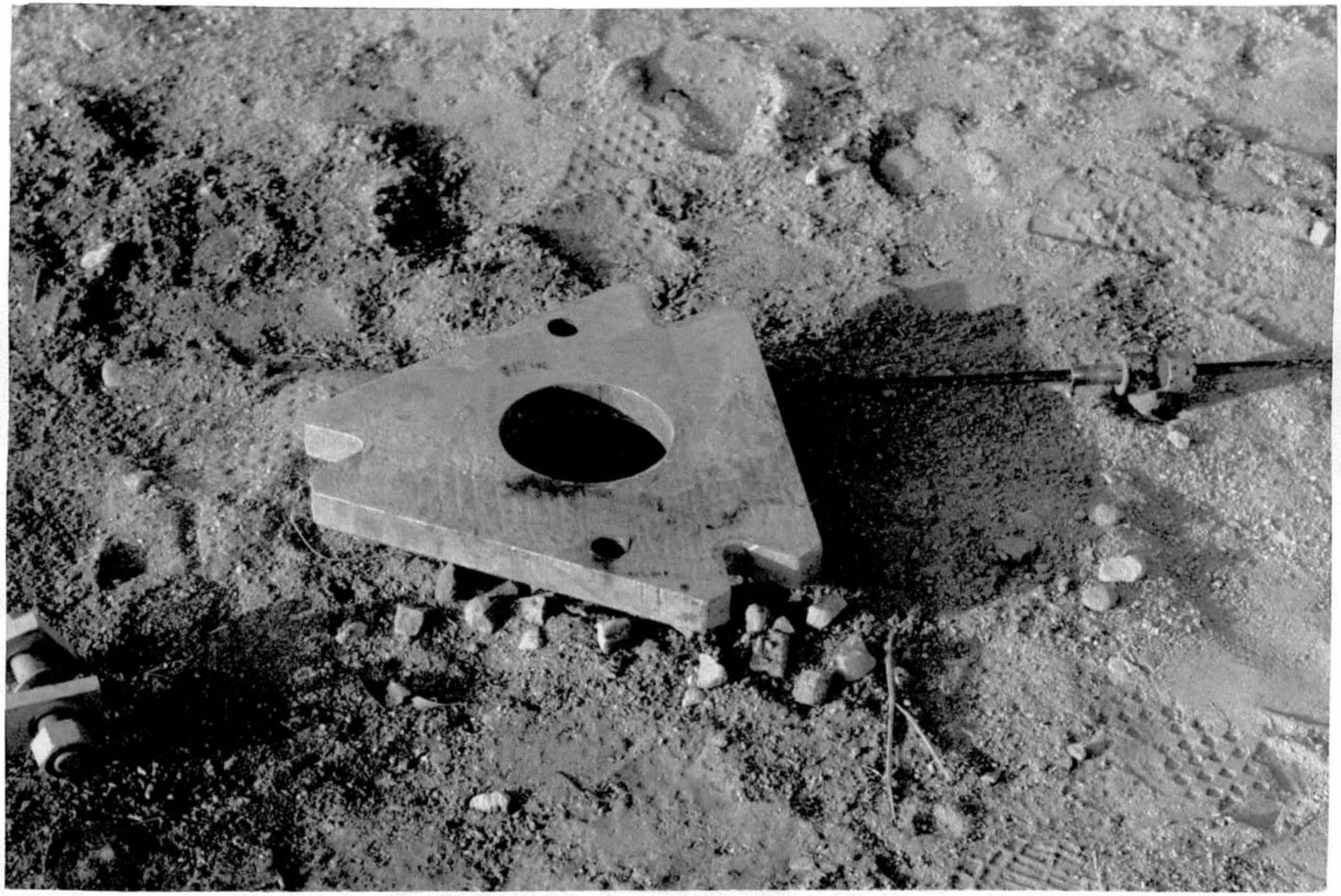


Figure 31. Closeup view of pole break away, posttest, test no. 2.

Figure 32. Full left side view, posttest, test no. 2.

Figure 33. Full right side view, posttest, test no. 2.

Figure 34. Left front 3/4 view, posttest, test no. 2.

Figure 35. Right front 3/4 view, posttest, test no. 2.

Figure 36. Full front view, posttest, test no. 2.

Figure 37. Impact location overhead view, posttest, test no. 2.

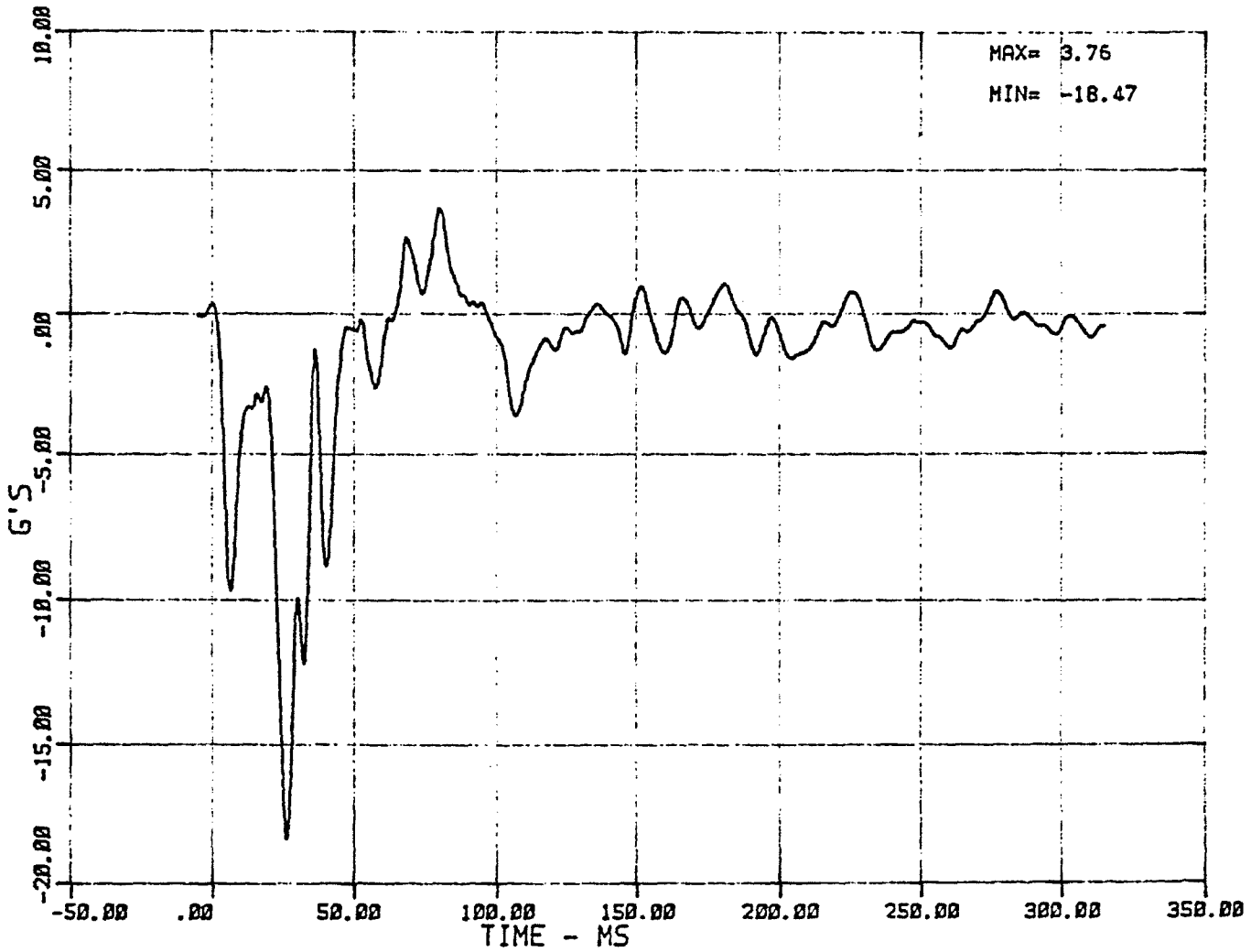


Figure 38. Deceleration time history, x-axis, test no. 2.

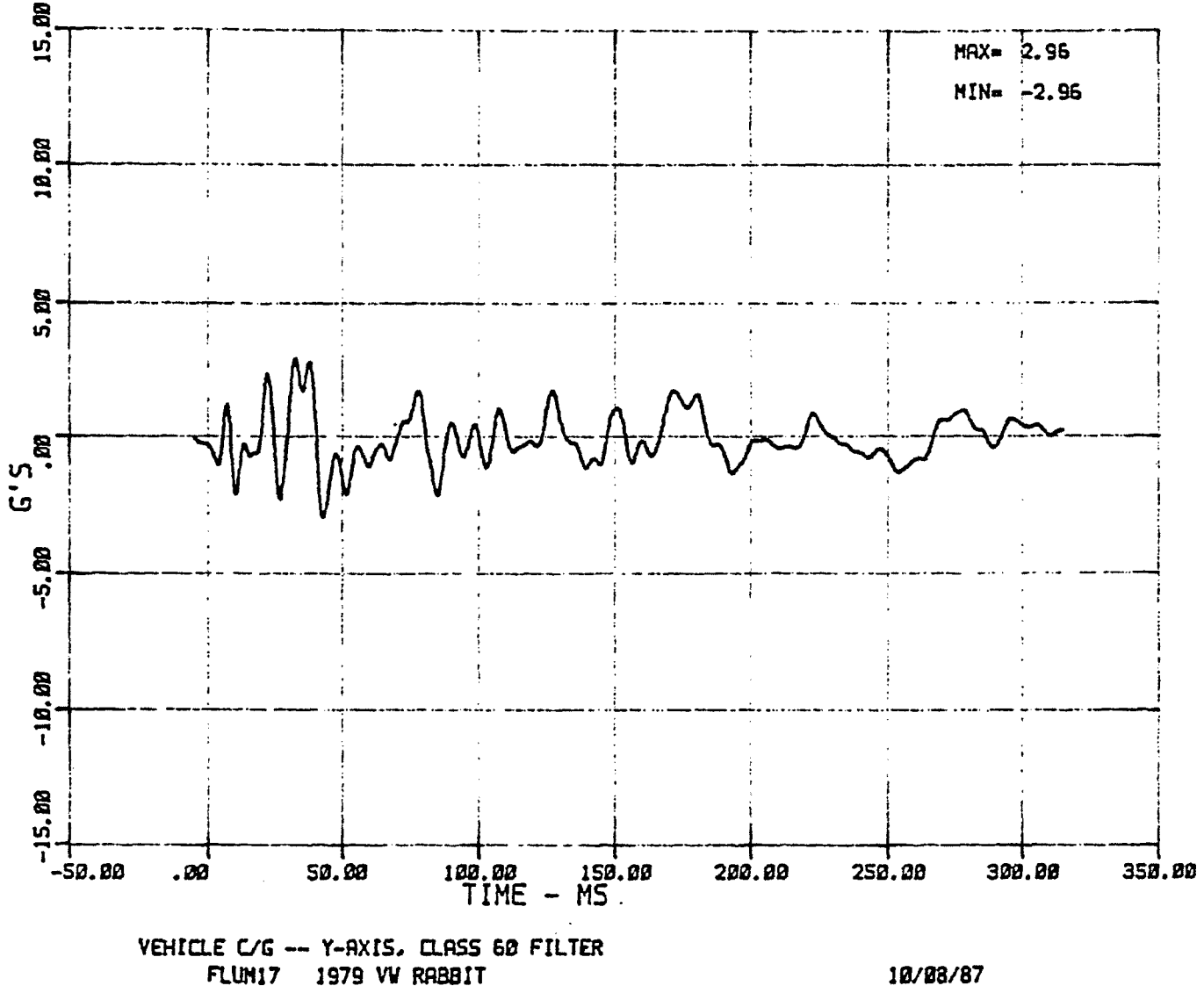


Figure 39. Deceleration time history, y-axis, test no. 2.

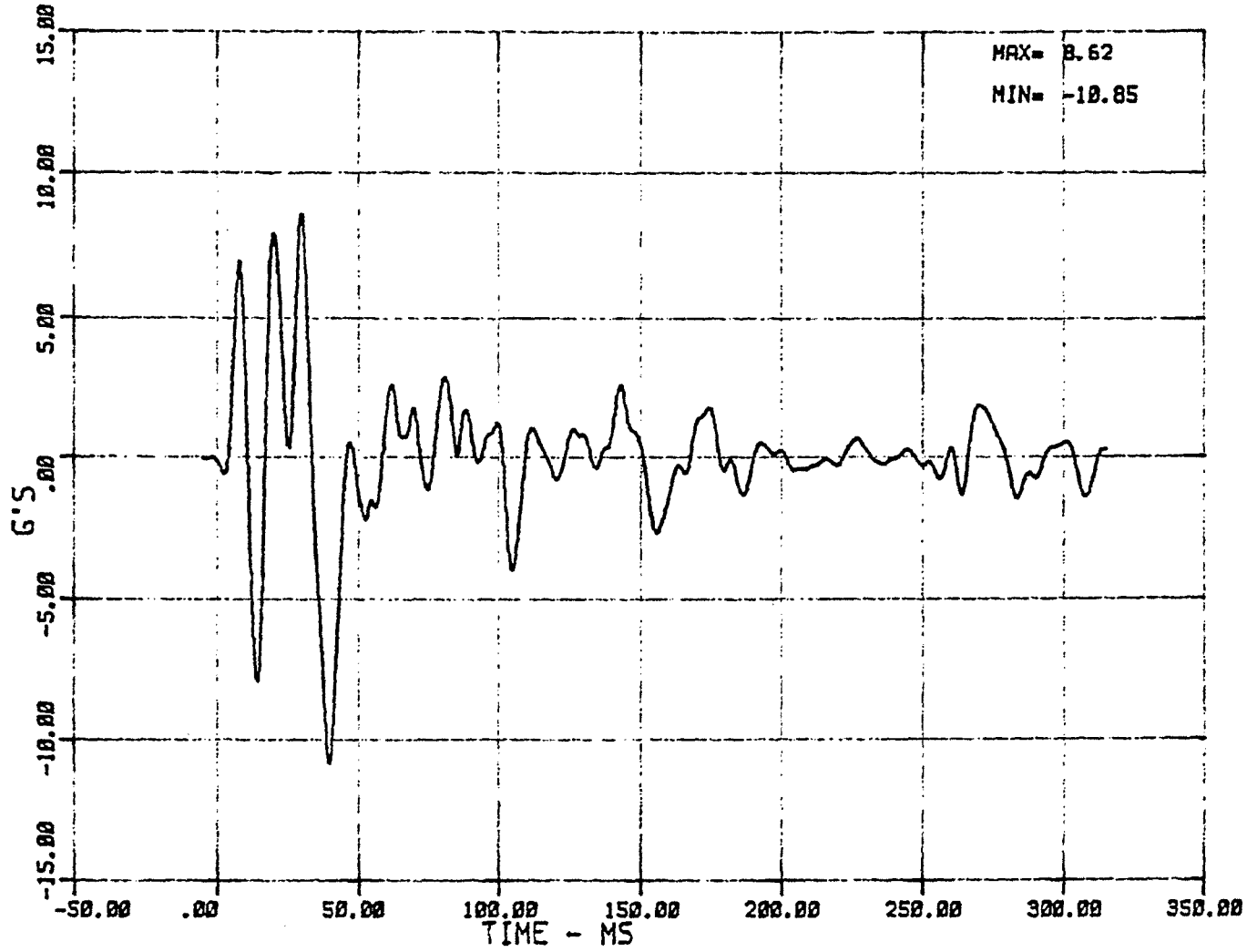
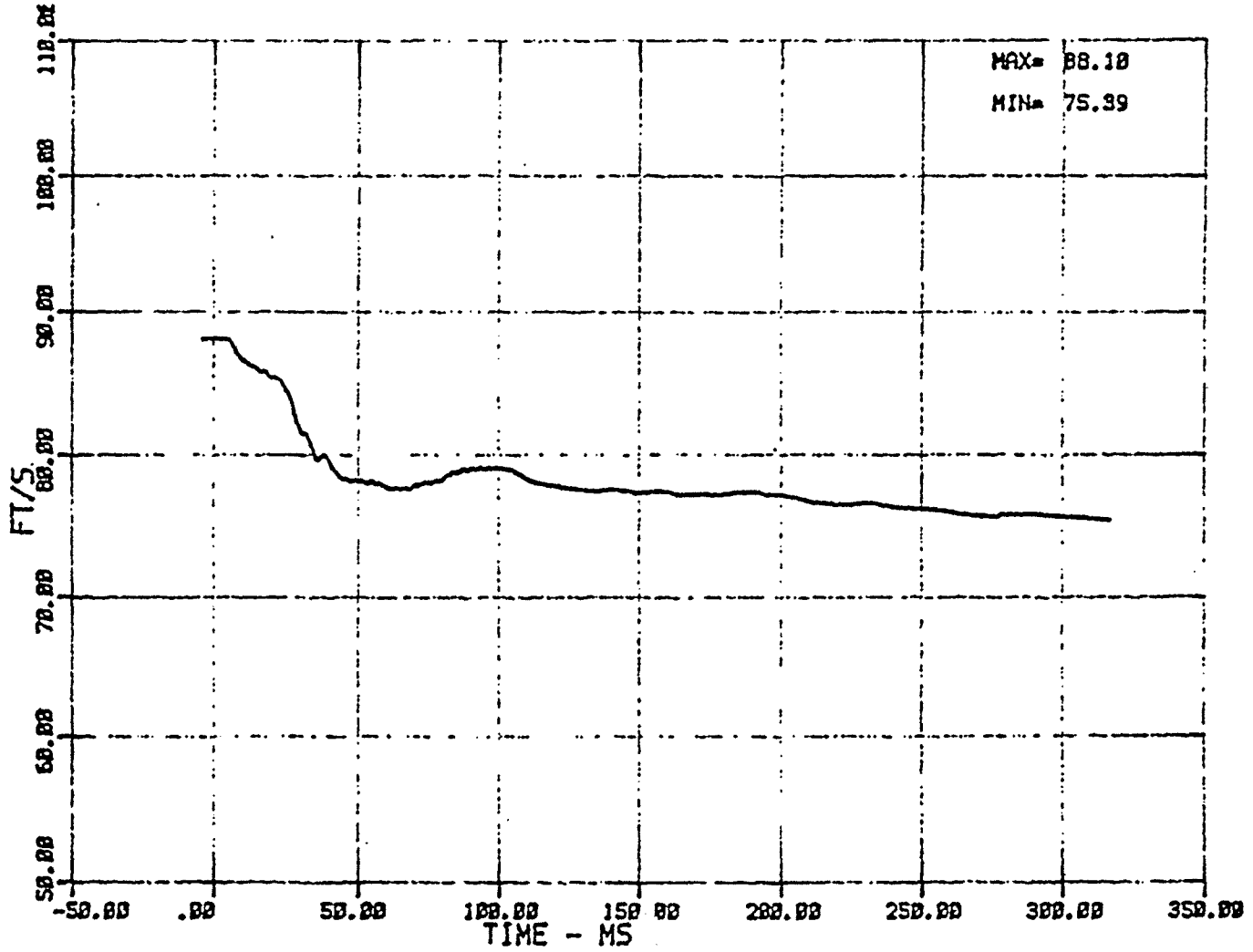


Figure 40. Deceleration time history, z-axis, test no. 2.



VEHICLE VELOCITY DERIVED FROM X ACCELERATION INTEGRATION, CLASS 180 FILTER
FLUM17 1979 VOLKSWAGEN RABBIT 10/08/87

Figure 41. Longitudinal-velocity by integration, test no. 2.

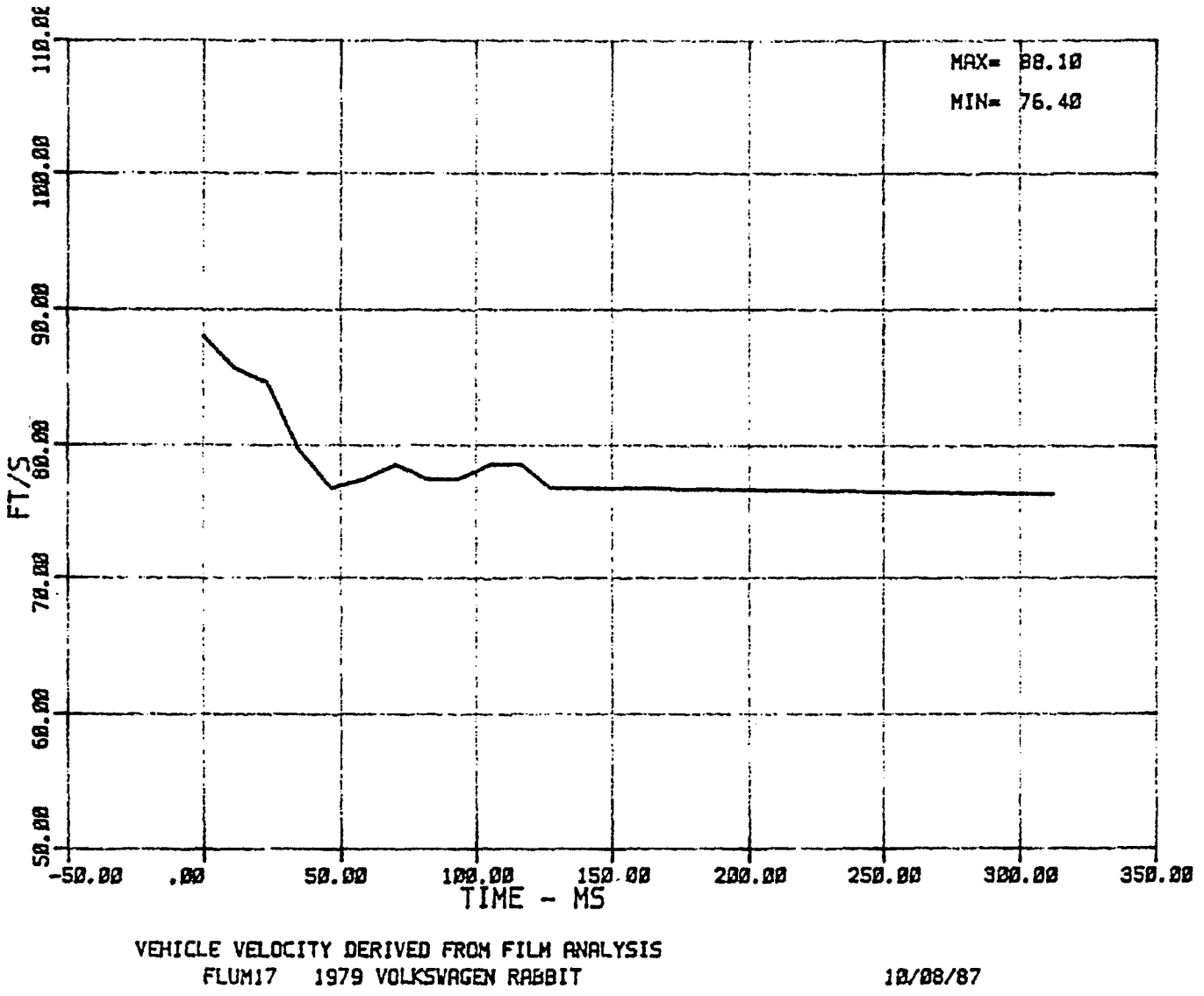


Figure 42. Longitudinal-velocity time history, by film analysis, test no. 2.

LUMINAIRE AND SIGN SUPPORT TEST NO. 3, 20 MI/H

1. Introduction

Test No. 3 (luminaire 02) was conducted on 09 October 1987 using a 1979 Volkswagen Rabbit with a weight of 1800 ± 50 lb which was guided to impact the test article at the vehicle's front centerline. The luminaire support tested was identical to that tested in test no. 2.

2. Test Article

The test article was a slip base luminaire support. The luminaire pole was a 30.1-ft long, tapered metal pole with a 13-ft mast arm attached 29.5 ft above the mounting base. The pole was 8 inches in diameter at the base and 3.75 inches in diameter at the top. The mast arm had a 50-lb weight attached to its free end to simulate the weight of a lighting assembly. The pole was oriented such that the mast arm was at roughly 4 o'clock, if the line of vehicle travel is given to be 12 o'clock. The pole was manufactured by Union Metal Company.

The slip base for the luminaire is a triangular plate, 1 1/16 in thick. Three 7/8-in diameter mounting bolts were used. They were torqued to 50 ft-lb as per manufacturer's specifications. "Keeper plates" were used on the mounting bolts. All installation was done by manufacturer's representative. The hand hole on the pole was directly under the mast arm. The wall thickness of the pole at the base was 0.25 in.

The anchoring system consisted of a screw-in foundation with a "Caltrans" Shear Plate assembly (slip base) on top. The anchoring system was manufactured by A.B. Chance Company.

The pole foundation was buried in NCHRP 230, S-1 (strong) soil to the specified depth. No restraint was placed on the top of

the pole. Installation instructions are presented in figure 2. Installation photographs are presented in subsection 5.

3. Data Tables

Tables 20 through 24 show the data from test no. 3. Table 20 shows the crash test summary. Table 21 shows test vehicle information. Table 22 shows test vehicle crush data. Table 23 shows test vehicle moving average acceleration data and table 24 shows the results from the data analysis.

4. Test Results

The vehicle impact velocity was 60.1 mi/h. The test vehicle impacted the pole 7 in to the right of the vehicle centerline. The base of the luminaire pole sheared away from the foundation due to the force of impact. As vehicle motion continued, the base of the pole rotated upward about its center of gravity. During this rotation, the pole momentarily lost contact with the front of the vehicle as it rotated ahead of the slowing vehicle. After about 10 degrees of rotation, the base of the pole struck a screw-in anchor from a previous test and stopped, thus causing the test vehicle to impact the pole a second time. The second impact halted the forward motion of the vehicle. The pole and mast then rotated 360 degrees about its z-axis (the vertical centerline of the pole) before coming to rest aside the vehicle. The vehicle bumper was pushed into an "L" shape. The grill, supporting structure, and radiator were moderately deformed, and the hood was badly deformed.

The snagging of the pole occurred after the separation of the pole from the impacting vehicle. The research question investigated in the test was whether the A. B. Chance pole can perform with the metal foundation during the low-speed, 20 mi/h impact test. Despite the snagging,

Table 20. Crash test summary, luminaire support impact, test no. 3.

Project: Luminaire and Sign Supports

Test: Luminaire 02 (Test No. 3)

Date: 10/09/87 Time: 3:30 PM

Test Articles: Metal luminaire pole with A.B. Chance "Cal Trans" shear plate anchoring system.

Vehicle: 1979 Volkswagen Rabbit

Inertial mass:	1834 lb	Test mass:	1834 lb
Pre-Impact speed:	*29.5 ft/s	Post-Impact:	**15.0 ft/s
	**28.6 ft/s		***15.0 ft/s
Offset distance from vehicle centerline:			5.0 in (left)
Maximum crush:	14.0 in	Rebound:	None
Damage: TAD:	FC4	CDC:	12FYMN5
Maximum deceleration (at c.g.)			20.9 g
Maximum 50 ms average deceleration (at c.g.)			8.1 g
Maximum 10 ms average deceleration (at c.g.)			15.6 g

Number of Data Channels: 3 accelerometers, time zero switch.

Number of High-Speed Cameras: 3, frame rate: 600 fps

* Speed trap

** Film analysis

*** Integration of acceleration data

Table 21. Test vehicle information, test no. 3.

Vehicle Manufacturer:	Volkswagen of America		
Make/Model/Year:	Volkswagen/Rabbit/1979		
Body Style:	2 door hatchback		
VIN:	1793352372	Build Date:	02/79
Engine:	Transverse 4 cylinder		
Transmission:	Manual 4 speed		
GVWR:	2822 lb		
GAWR:	1609 lb Front	Rear:	1278 lb
Tire Size:	155SR13	Load Range:	B
Tire Pressure:	27 psi	Rear:	27 psi
Date Received:	24 Jul 1986	Color:	Burgundy

MASS OF VEHICLE AS RECEIVED: lb

Left Front:	590	Right Front:	582
Left Rear:	294	Right Rear:	298
Total Front Mass:	1172	(66 % of total vehicle mass)	
Total Rear Mass:	592	(34 % of total vehicle mass)	
Total Mass:	1764		

TEST MASS OF VEHICLE: lb

Left Front:	615	Right Front:	607
Left Rear:	303	Right Rear:	309
Total Front Mass:	1222	(67 % of total vehicle mass)	
Total Rear Mass:	612	(33 % of total vehicle mass)	
Total Mass:	1834		

VEHICLE ATTITUDE: in

Left Front:	24.8
Right Front:	24.8
Left Rear:	25.4
Right Rear:	25.5

Table 21. Test vehicle information, test no. 3 (continued).

VEHICLE DIMENSIONS: in			
Length:	155.0		
Width:	61.5		
Wheel-base:	95.0		
Track: Front:	55.0	Rear:	53.5

CENTER OF GRAVITY LOCATION: in	
31.9	behind the front axle
0.0	to the right of centerline
21.6	above ground

Table 22. Vehicle crush data, test no. 3.

Maximum crush of 14.0 in occurred 5.0 in
to the left of the centerline.

Vehicle Rebound: None

Vehicle Speed: (measured 20 ft from impact)

Trap No. 1: 20.01 mi/h (29.35 ft/s)
Trap No. 2: Not used.

DAMAGE DIMENSIONS, in:

		Pre-Impact	Post-Impact	Change
Left Side	C_1	154.0	160.0	+6.0
	C_2	154.5	153.0	-1.5
	C_3	155.0	146.5	-8.5
	C_4	155.0	148.0	-7.0
	C_5	154.5	154.0	-0.5
Right Side	C_6	154.0	157.0	+3.0

Width of Contact: 8 in

Table 23. Moving average data - vehicle accelerations, test no. 3.

Vehicle c.g. Acceleration Axis	Moving Average Time (ms)	Maximum Acceleration Value (g's)	Time of Occurance (ms)
x	10	15.61	45.13 - 55.13
x	50	8.11	19.00 - 69.00
y	50	0.529	25.00 - 75.00
z	50	1.55	80.25 - 130.25

Table 24. Data analysis summary sheet, test no. 3.

TEST NUMBER: 3 TEST DATE : 10/09/87

TEST ARTICLE: Metal Luminaire Pole With Shear Plate Anchor

MANUFACTURER: Union Metal (Pole)/A.B. Chance (Anchor)

MODEL NUMBER: Not available

TEST VEHICLE: 1979 Volkswagen Rabbit	VEHICLE WEIGHT (lb)	1834
POLE LENGTH (ft): 30.1	MAST ARM LENGTH (ft)	13.0
POLE BURIED in: NCHRP S-1 STRONG SOIL		
IMPACT SPEED (ft/s):	CAMERA:	28.6
	SPEED TRAP:	29.5
EXIT SPEED (ft/s):	CAMERA:	15.0
	INTEGRAL Ax:	15.0
CHANGE IN VELOCITY FROM EACH SOURCE (ft/s)	CAMERA:	13.6
	INTEGRAL Ax:	13.6
MOMENTUM CHANGE: (lb-sec reported velocity change multiplied by vehicle mass)		774.6
MAX FORCE (kips, peak x-axis deceleration * velocity weight)		38.33
MAX ACCELERATION (g's, peak x-axis deceleration)		20.9
MAXIMUM MEASURED VEHICLE CRUSH LENGTH (in, static)		14.0
LONGITUDINAL OCCUPANT IMPACT VELOCITY (ft/), NCHRP 230)		14.2
LONGITUDINAL OCCUPANT RIDEDOWN ACCEL (g/s , NCHRP 230)		1.6
MAX 50 MS AVERAGE DECELERATION (g's)		
	X-AXIS	8.1
	Y-AXIS	0.5
	Z-AXIS	1.6

VEHICLE VELOCITY CHANGE: 13.6 ft/s

(Average of film and accelerometer data)

sufficient data were available to evaluate the breakaway and other performance of the luminaire support. The maximum crush depth was 14 in. Vehicle crush data are presented in table 22.

The longitudinal occupant impact velocity was 14.2 ft/s at 136 ms after time zero. The subsequent maximum 10 ms moving average ride-down acceleration was 1.6 g. The total vehicle velocity change was 13.6 ft/s or 9.3 mi/h. Table 23 presents the vehicle maximum moving average data and table 24 presents a data analysis summary.

5. Photographic Coverage

Figures 43 through 52 show the test area, the test article and the posttest photographs of the test vehicle and the test article.

6. Data Plots

The data plots from test no. 3 are shown in figures 53 through 57.

Figure 43. General test area, pretest, test no. 3.

Figure 44. Test area elevated view, pretest, test no. 3.

Figure 45. General test area, posttest, test no. 3.

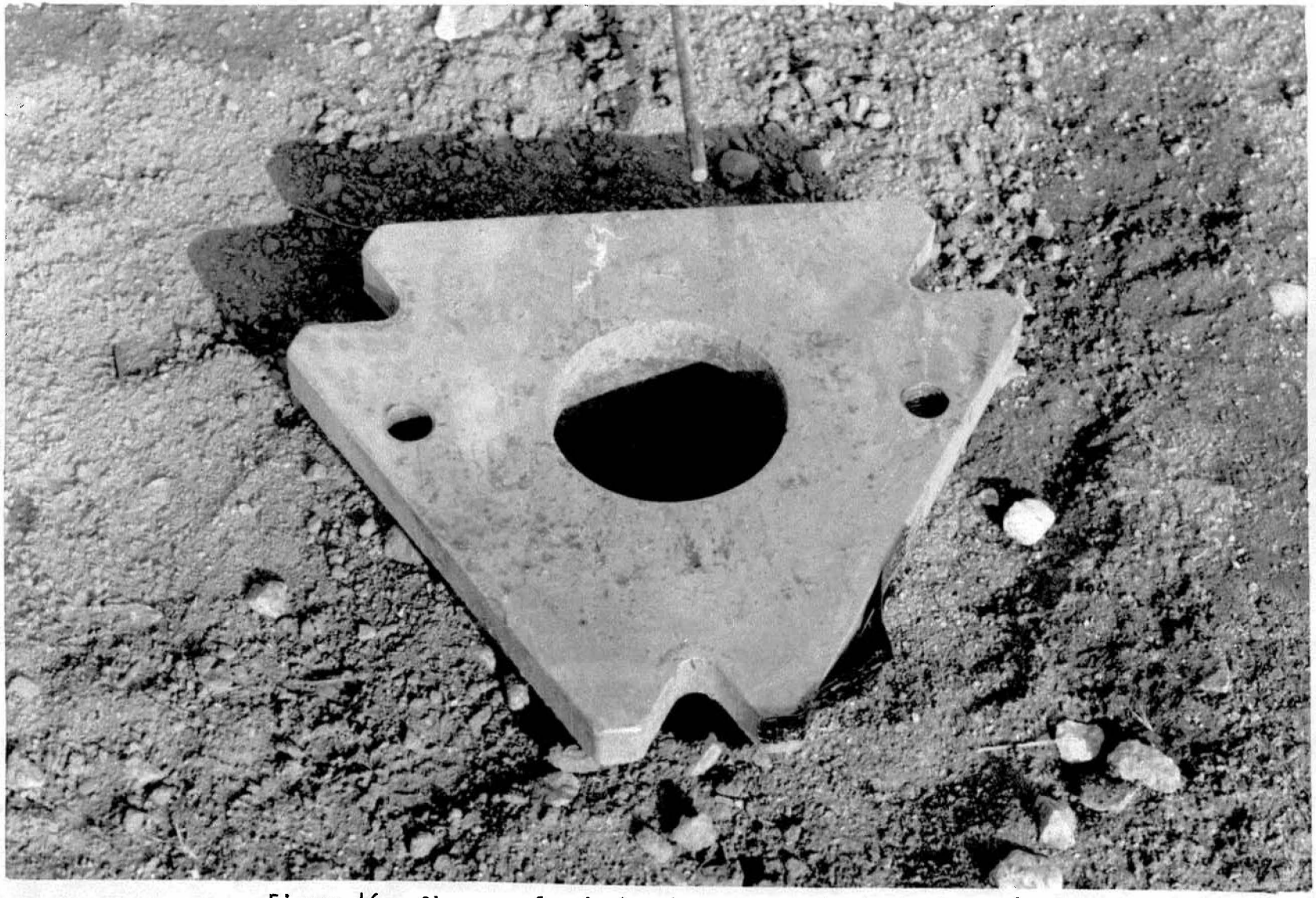


Figure 46. Closeup of pole break away, posttest, test no. 3.

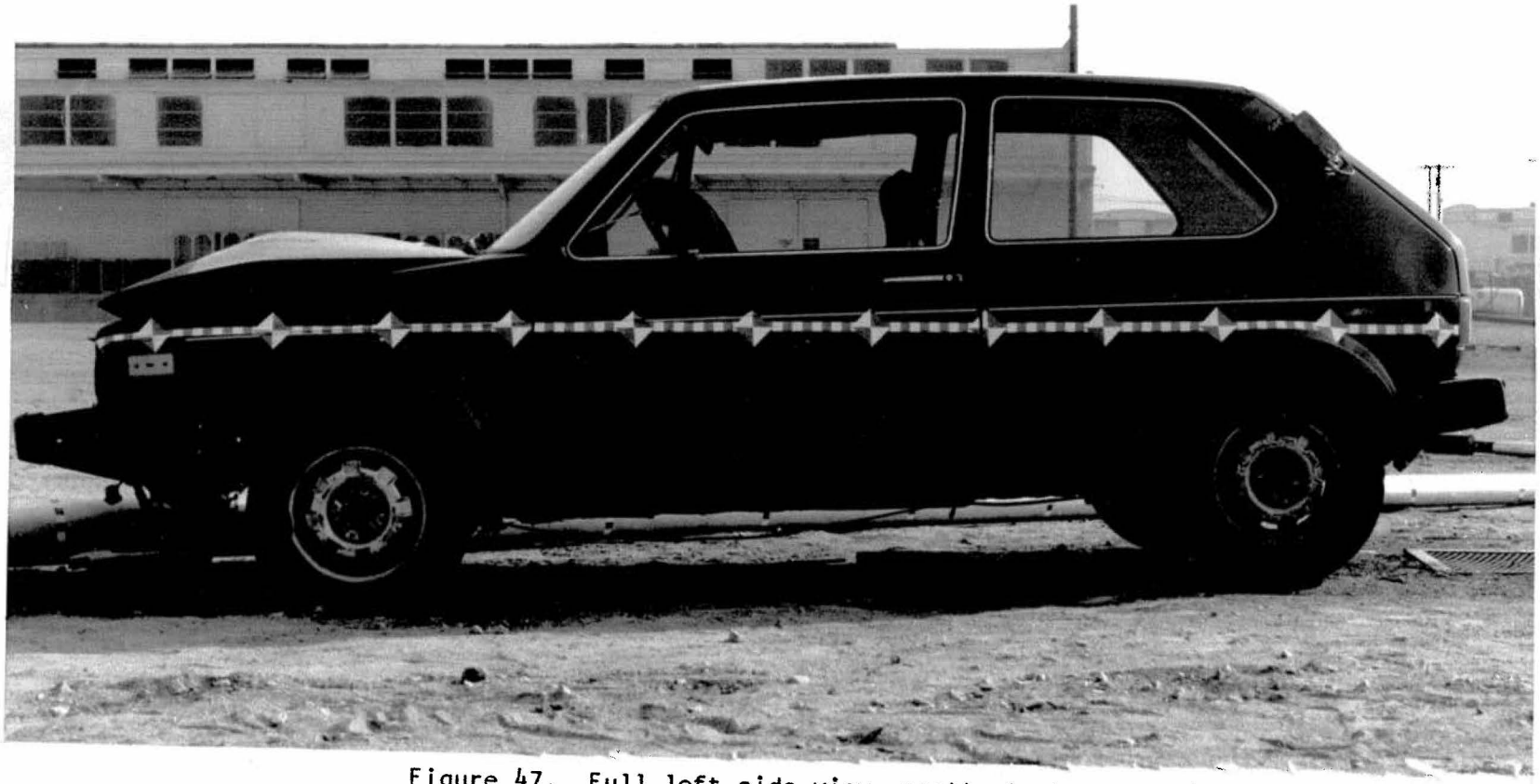


Figure 47. Full left side view, posttest, test no. 3.

Figure 48. Full right side view, posttest, test no. 3.

Figure 49. Left front 3/4 view, posttest, test no. 3.

Figure 50. Right front 3/4 view, posttest, test no. 3.

Figure 51. Front view, posttest, test no. 3.

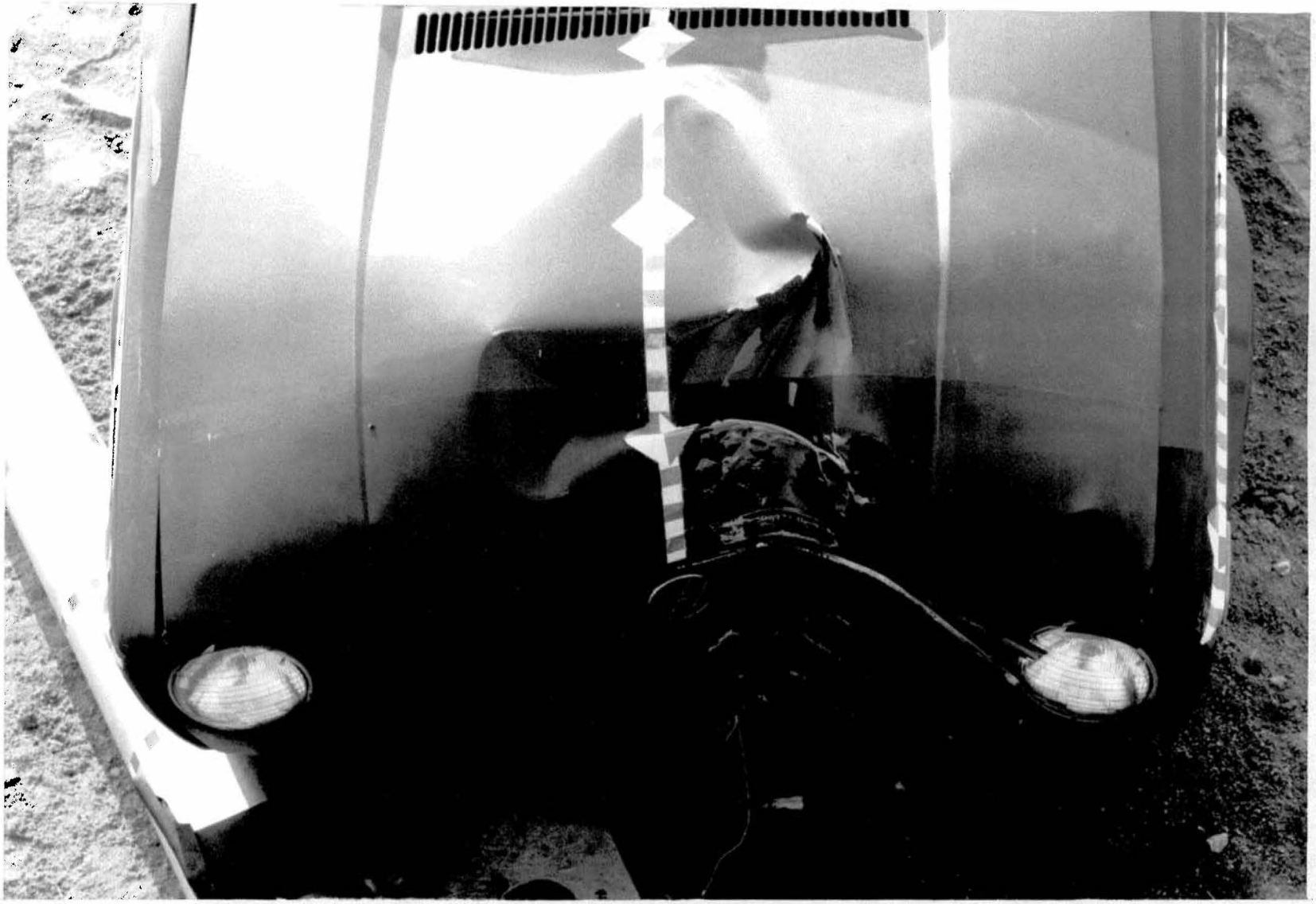


Figure 52. Impact location overhead view, posttest, test no. 3.

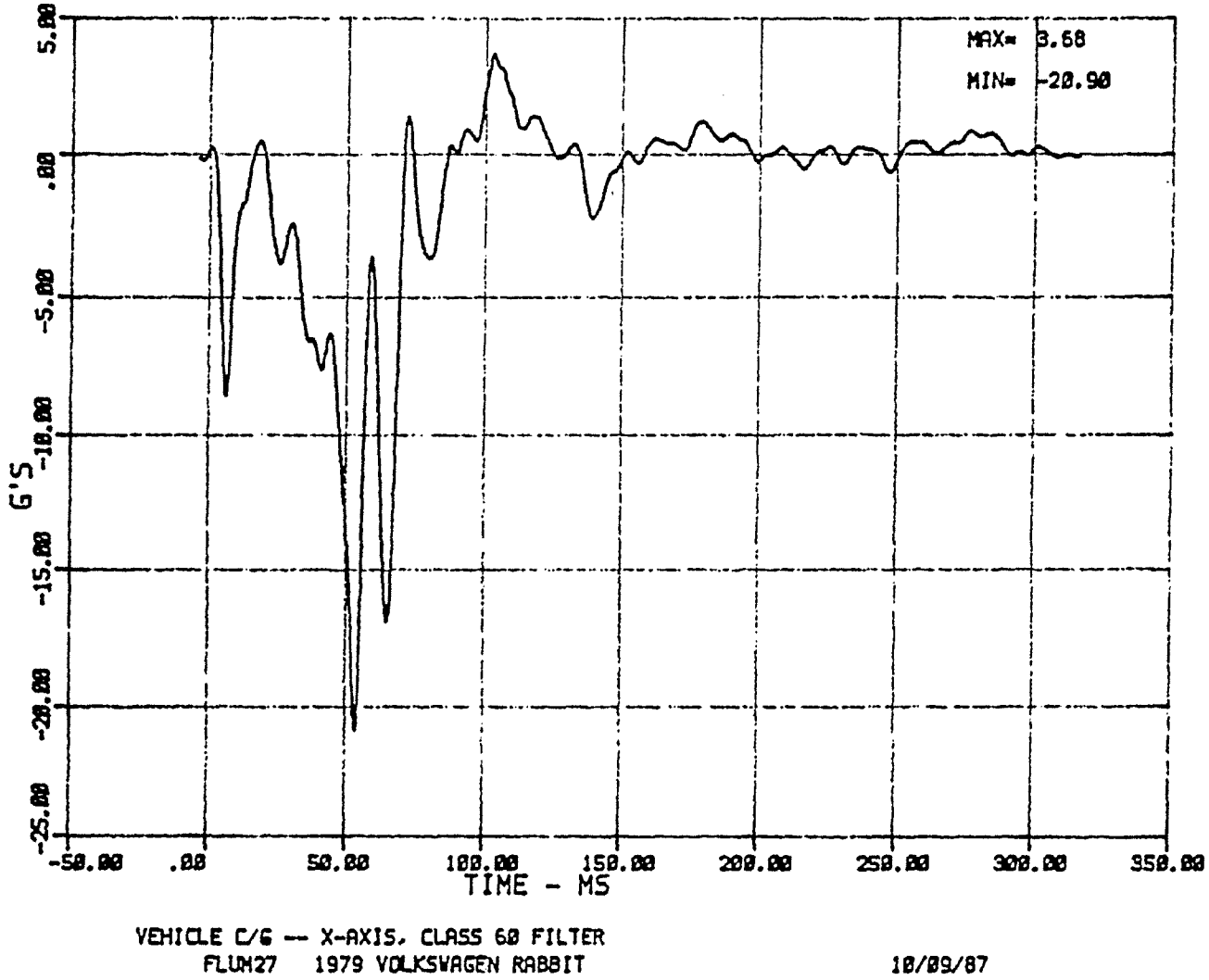


Figure 53. Deceleration time history, x-axis, test no. 3.

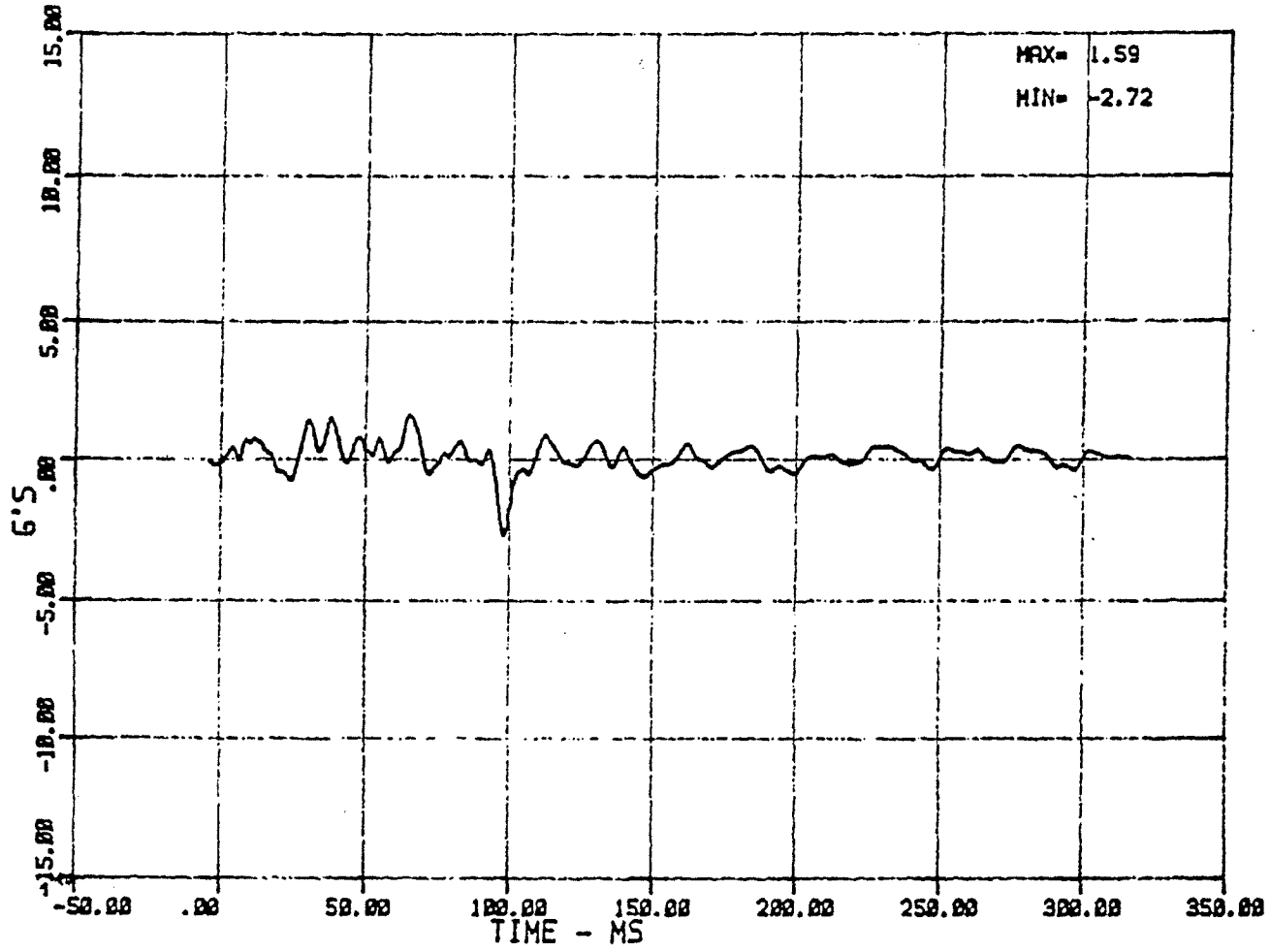


Figure 54. Deceleration time history, y-axis, test no. 3.

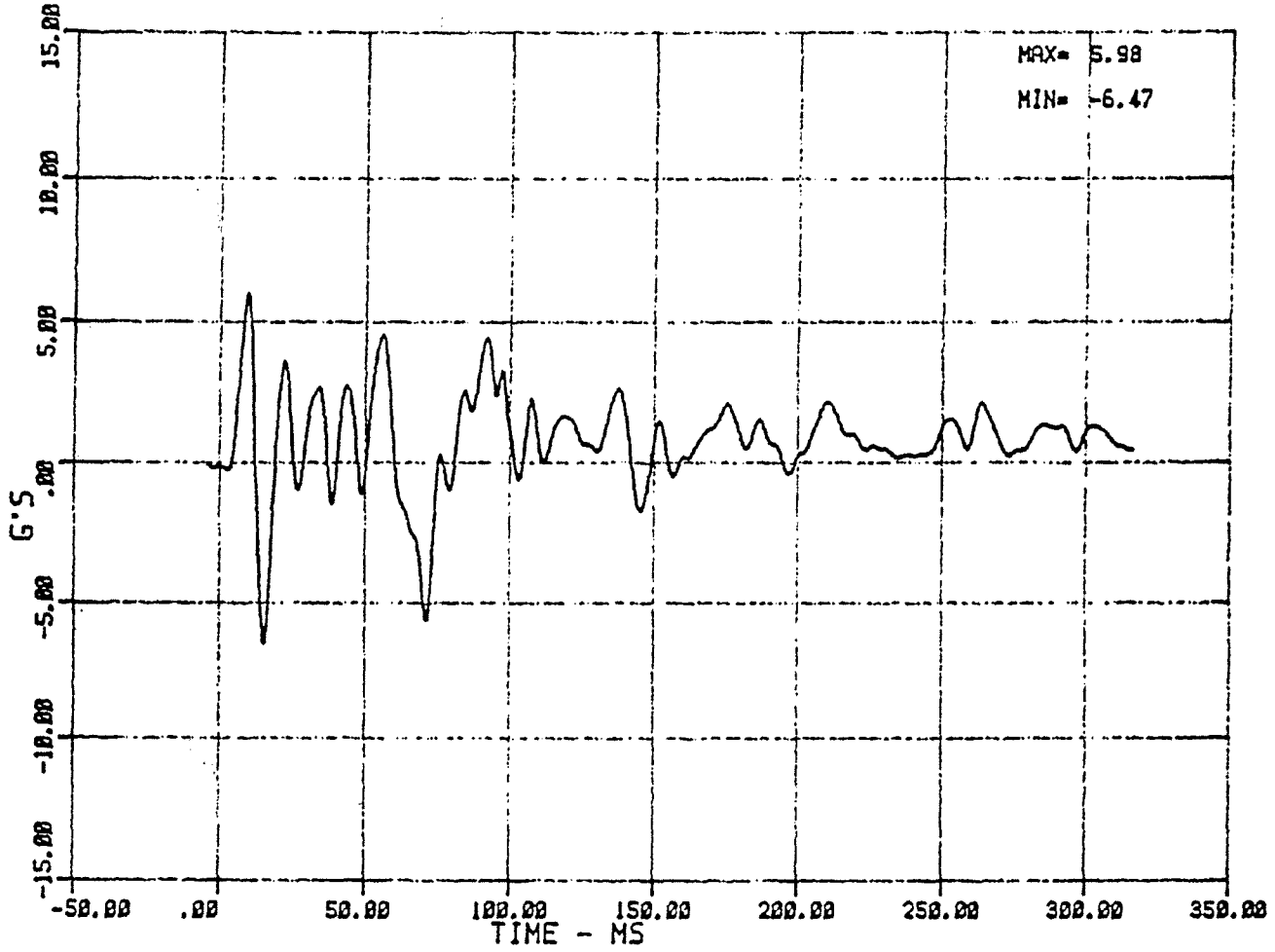
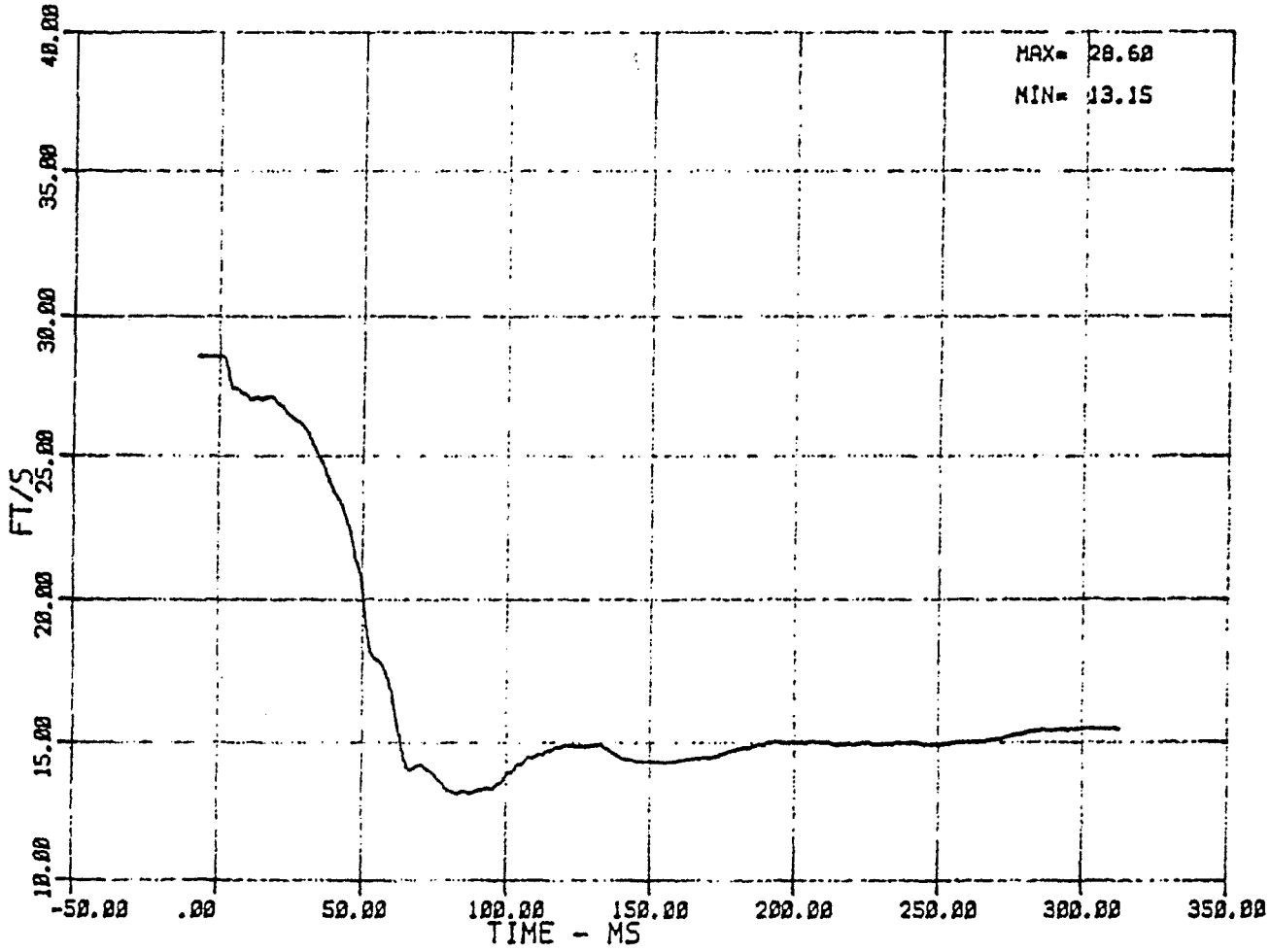


Figure 55. Deceleration time history, z-axis, test no. 3.



VEHICLE VELOCITY DERIVED FROM INTEGRATION OF X ACCELERATION, CLASS 180 FILTER
FLUM27 1979 VOLKSWAGEN RABBIT 10/09/87

Figure 56. Longitudinal-velocity by integration, test no. 3.

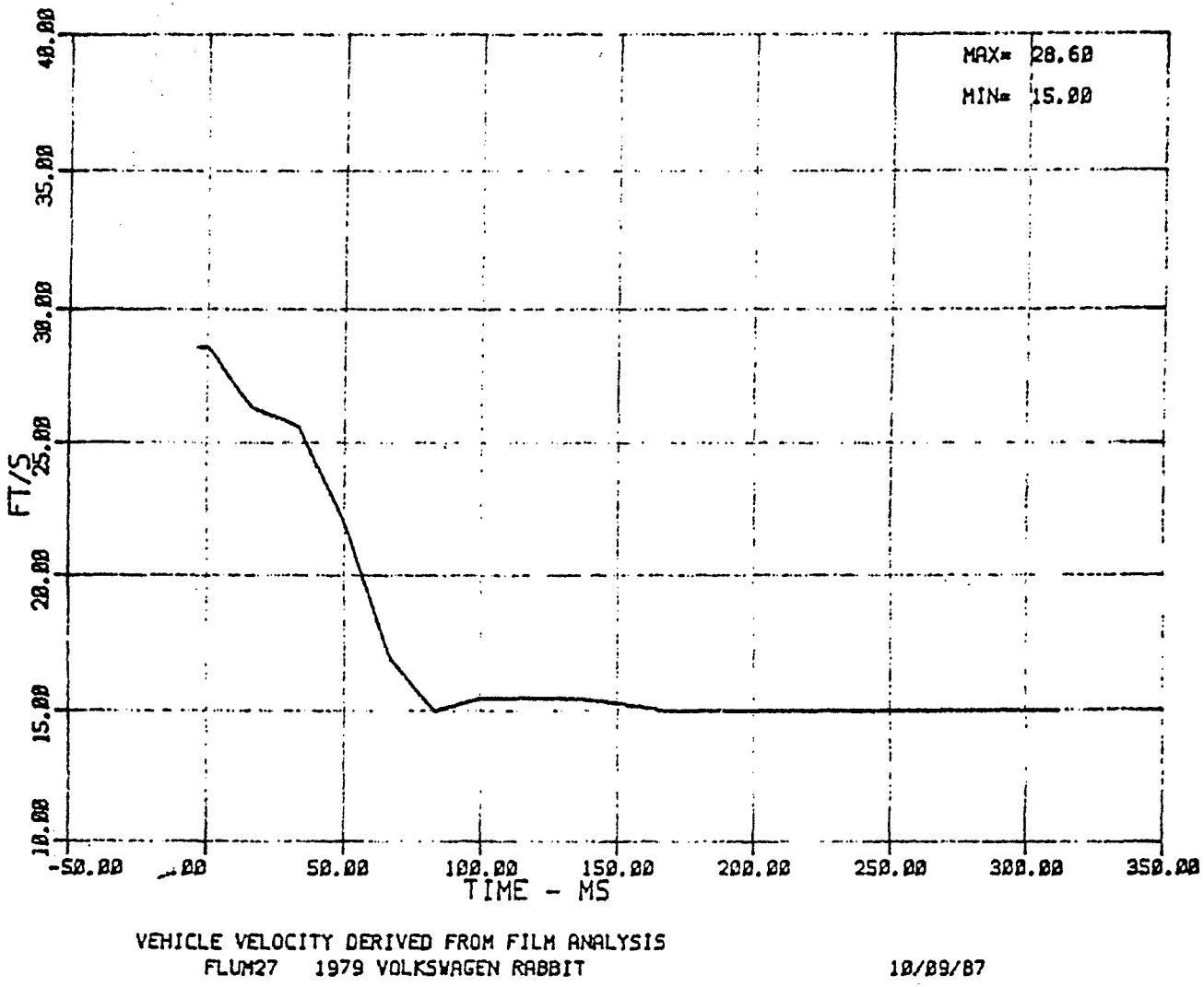


Figure 57. Longitudinal-velocity time history, by film analysis, test no. 3.

LUMINAIRE AND SIGN SUPPORT TEST NO. 4, 60 MI/H

1. Introduction

Test No. 4 (luminaire 03) was conducted on 12 February 1988 using a 1979 Volkswagen Rabbit with a weight of 1800 ± 50 lb which was guided to impact the test article at the vehicle's front centerline.

2. Test Article

The test articles was an 8-in diameter, hollow, fiberglass luminaire support pole. The pole was manufactured by Highline Products Corporation. The model number tested was HL-228H-1. The pole was buried in S-1 strong soil as defined in NCHRP 230, to a depth of 5 ft. A 50-lb weight was attached to the end of the 6-ft mast arm to simulate the weight of a lighting assembly. The pole was oriented such that the access panel was facing towards the impacting vehicle. No restraint was placed on the top of the pole. Installation photographs are presented in subsection 5. A reproduction of the manufacturer's drawing is presented in figure 3.

3. Data Tables

Tables 25 through 29 show the data from test no. 4. Table 25 shows crash test summary. Table 26 shows test vehicle information. Table 27 shows test vehicle crush data. Table 28 shows test vehicle moving average acceleration data and table 29 shows the results from the data analysis.

4. Test Results

The vehicle impact velocity was 59.7 mi/h. The test vehicle impacted the pole 3.5 in to the right of the vehicle centerline. The

Table 25. Crash test summary, luminaire support impact, test no. 4.

Project: Luminaire and Sign Supports

Test: Luminaire 03 (Test No. 4)

Date: 02/12/88 Time: 3:00 PM

Test Articles: Fiberglass Luminaire Support, Highline Products Corporation, Model No. HL-228-1, S-1 Strong Soil NCHRP 230

Vehicle: 1979 Volkswagen Rabbit

Inertial mass:	1846 lb	Test mass:	1846 lb
Pre-Impact speed:	*88.5 ft/s	Post-Impact:	**62.6 ft/s
	**87.5 ft/s		***62.6 ft/s
Offset distance from vehicle centerline:			3.5 in (right)
Maximum crush:	5.9 in	Rebound:	None
Damage: TAD:	FC1	CDC:	12FYMN5
Maximum deceleration (at c.g.)			14.0 g ***
Maximum 50 ms average deceleration (at c.g.)			8.0 g ***
Maximum 10 ms average deceleration (at c.g.)			12.7 g ***

Number of Data Channels: 3 accelerometers, time zero switch.

Number of High-Speed Cameras: 3, frame rate: 600 fps

* Speed trap

** Film analysis

*** Integration of acceleration data (for this test only, derived from differentiation of velocity time history from film analysis.)

Table 26. Test vehicle information, test no. 4.

Vehicle Manufacturer:	Volkswagen of America		
Make/Model/Year:	Volkswagen/Rabbit/1979		
Body Style:	2 door hatchback		
VIN:	1793352372	Build Date:	01/79
Engine:	Transverse 4 cylinder		
Transmission:	450 Manual		
GVWR:	2822 lb		
GAWR:	1609 lb Front	Rear:	1278 lb
Tire Size:	155SR13	Load Range:	B
Tire Pressure:	27 psi	Rear:	31 psi
Date Received:	02 Oct 1987	Color:	Yellow

MASS OF VEHICLE AS RECEIVED: lb

Left Front:	601	Right Front:	606
Left Rear:	304	Right Rear:	306
Total Front Mass:	1207	(66 % of total vehicle mass)	
Total Rear Mass:	610	(34 % of total vehicle mass)	
Total Mass:	1817		

TEST MASS OF VEHICLE: lb

Left Front:	608	Right Front:	612
Left Rear:	314	Right Rear:	312
Total Front Mass:	1220	(66 % of total vehicle mass)	
Total Rear Mass:	626	(34 % of total vehicle mass)	
Total Mass:	1846		

VEHICLE ATTITUDE: in

Left Front:	25.1
Right Front:	25.0
Left Rear:	25.4
Right Rear:	25.5

Table 26. Test vehicle information, test no. 4 (continued).

VEHICLE DIMENSIONS: in			
Length:	155.0		
Width:	61.5		
Wheel-base:	95.5		
Track: Front:	55.0	Rear:	53.5

CENTER OF GRAVITY LOCATION: in	
31.9	behind the front axle
0.0	to the right of centerline
21.6	above ground

Table 27. Vehicle crush data, test no. 4.

Maximum crush of 5.9 in occurred 3.5 in
to the right of the centerline.

Vehicle Rebound: None

Vehicle Speed: (measured Not Available from impact)

Trap No. 1: 60.3 mi/h (88.5 ft/s)
Trap No. 2: Not used.

DAMAGE DIMENSIONS, in:

		Pre-Impact	Post-Impact	Change
Left Side	C_1	154.0	153.7	-0.34
	C_2	154.5	152.5	-2.0
	C_3	155.5	151.5	-3.5
	C_4	155.0	149.1	-5.9
	C_5	154.5	150.5	-4.0
Right Side	C_6	154.5	154.9	+0.40

Width of Contact: 12 in

Table 28. Moving average data - vehicle accelerations, test no. 4.

Vehicle c.g. Acceleration Axis	Moving Average Time (ms)	Maximum Acceleration Value (g's)	Time of Occurance (ms)
x	10	* 7.97	*47.4 - 97.4
x	50		-
y	50		-
z	50		-

*Derived from differentiation of velocity time history from film analysis.

Table 29. Data analysis summary sheet, test no. 4.

TEST NUMBER: 4 (Luminaire 03) TEST DATE : 02/12/88

TEST ARTICLE: Fiberglass Luminaire Support

MANUFACTURER: Highline Products Corporation

MODEL NUMBER: HL-228H-1

TEST VEHICLE: 1979 Volkswagen Rabbit	VEHICLE WEIGHT (lb)	1846
POLE LENGTH (ft): 28.5	MAST ARM LENGTH (ft)	8.0
POLE BURIED in: NCHRP S-1 STRONG SOIL		
IMPACT SPEED (ft/s):	CAMERA:	87.5
	SPEED TRAP:	88.5
EXIT SPEED (ft/s):	CAMERA:	62.6
	INTEGRAL Ax:	62.6 *
CHANGE IN VELOCITY FROM EACH SOURCE (ft/s)	CAMERA:	24.9
	INTEGRAL Ax:	24.9
MOMENTUM CHANGE: (lb-sec reported velocity change multiplied by vehicle mass)		1427.0
MAX FORCE (kips, peak x-axis deceleration * velocity weight)		26.1 *
MAX ACCELERATION (g's, peak x-axis deceleration)		14.0 *
MAXIMUM MEASURED VEHICLE CRUSH LENGTH (in, static)		5.9
LONGITUDINAL OCCUPANT IMPACT VELOCITY (ft/s, NCHRP 230)		24.9 *
LONGITUDINAL OCCUPANT RIDEDOWN ACCEL' (g/s , NCHRP 230)		12.7 *
MAX 50 MS AVERAGE DECELERATION (g's)		
	X-AXIS	8.0 *
	Y-AXIS	No Data
	Z-AXIS	No Data

VEHICLE VELOCITY CHANGE: 24.9 ft/s

(Average of film and accelerometer data)

* Derived from differentiation of velocity time history from film.

pole did not shear upon impact, but deformed around the front of the automobile while remaining implanted in the soil. As motion continued, the pole mast rotated counter-clockwise to the right of the vehicle, the Volkswagen continued forward, and the pole base remained planted in the soil. After approximately 160 ms, the fiberglass pole sheared both at the vehicle bumper and at the mast arm attachment as well. At this point, the pole's stub still mounted in soil, continued to contact the underside of the vehicle while the pole and mast arm were thrown free. The vehicle bumper was pushed into an "L" shape. The grill, supporting structure, and radiator were moderately deformed; and the hood was badly deformed. Vehicle crush data are presented in table 27.

The longitudinal occupant impact velocity was 24.9 ft/s at 138.5 ms after time zero. The subsequent maximum 10 ms moving average ridedown acceleration was 12.7 g. The total vehicle velocity change was 24.9 ft/s or 17.0 mi/h. All accelerometer values for this test were derived from differentiation of the velocity time history from film analysis.

5. Photographic Coverage

Figures 58 through 68 show the test area, the test article and the posttest photographs of the test vehicle and the test article.

6. Data Plots

The data plots from test no. 4 are shown in figures 69 through 71.

Figure 58. Test area elevated view, pretest, test no. 4.

Figure 59. Test article, pretest, test no. 4.

Figure 60. Test area elevated view, posttest, test no. 4.

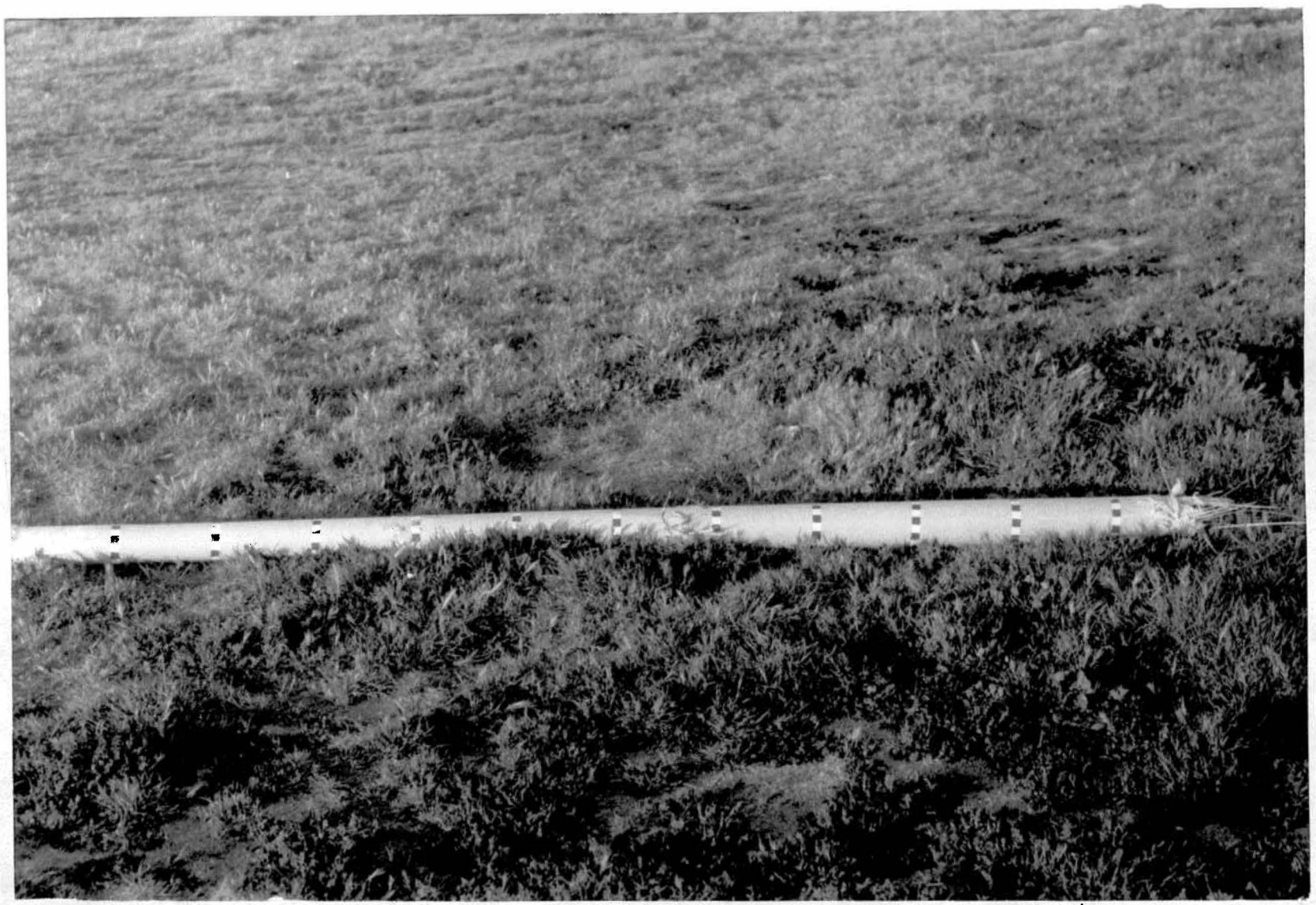


Figure 61. Test article on the ground, posttest, test no. 4.

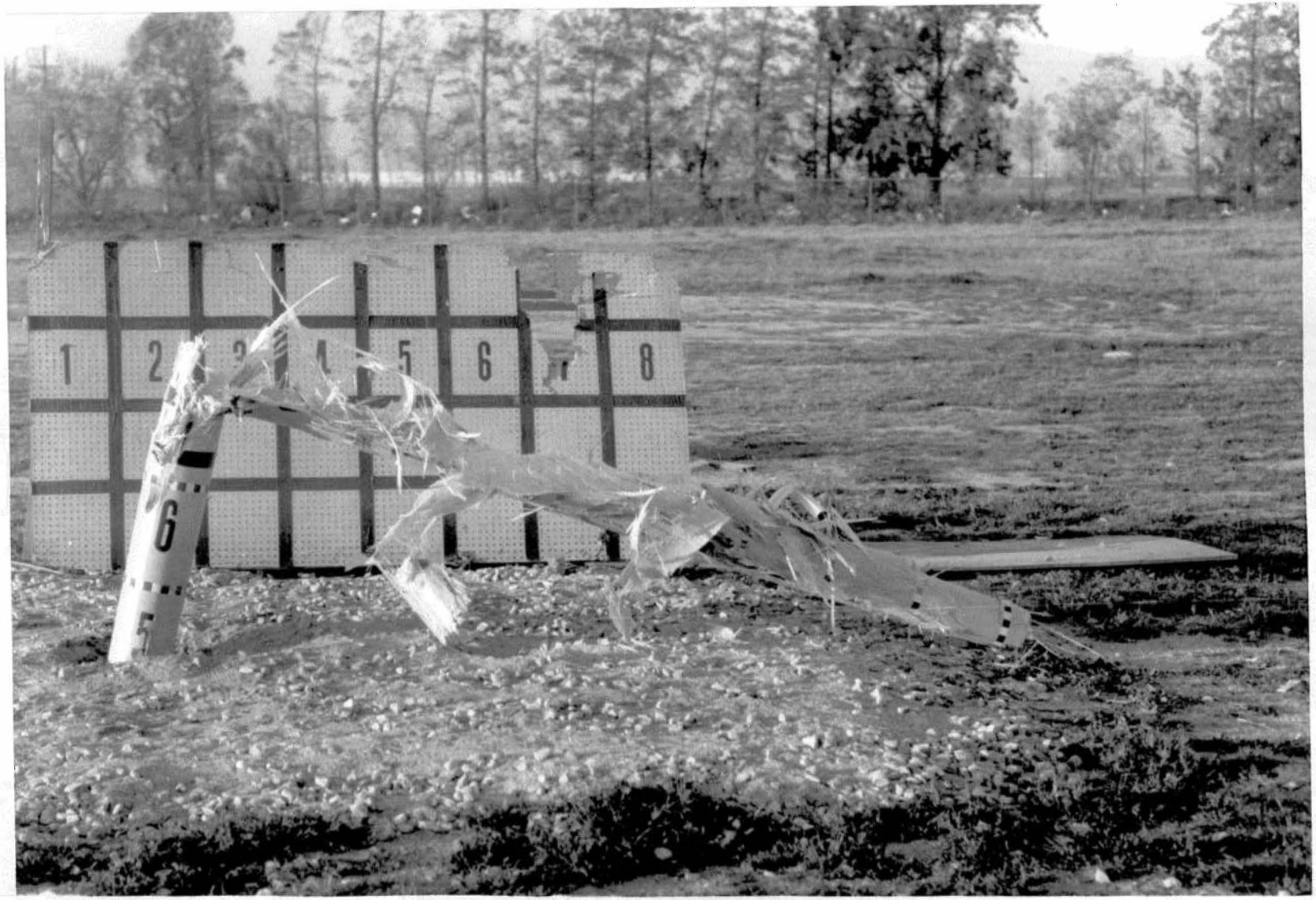


Figure 62. Closeup of pole break away, posttest, test no. 4.

Figure 63. Full left side view, posttest, test no. 4.

Figure 64. Full right side view, posttest, test no. 4.

Figure 65. Left front 3/4 view, posttest, test no. 4.

Figure 66. Right front 3/4 view, posttest, test no. 4.

Figure 67. Front view, posttest, test no. 4

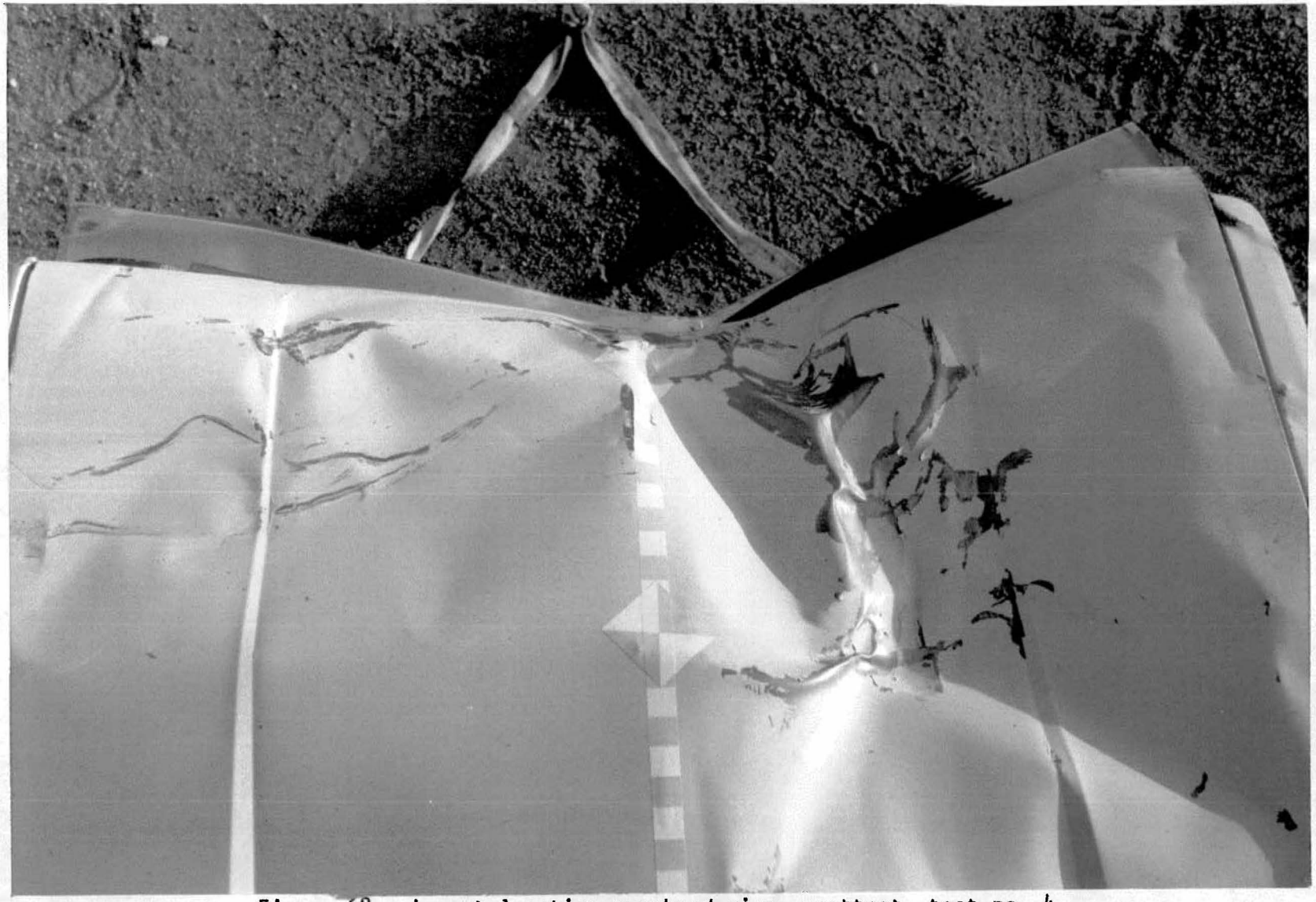


Figure 68. Impact location overhead view, posttest, test no. 4.

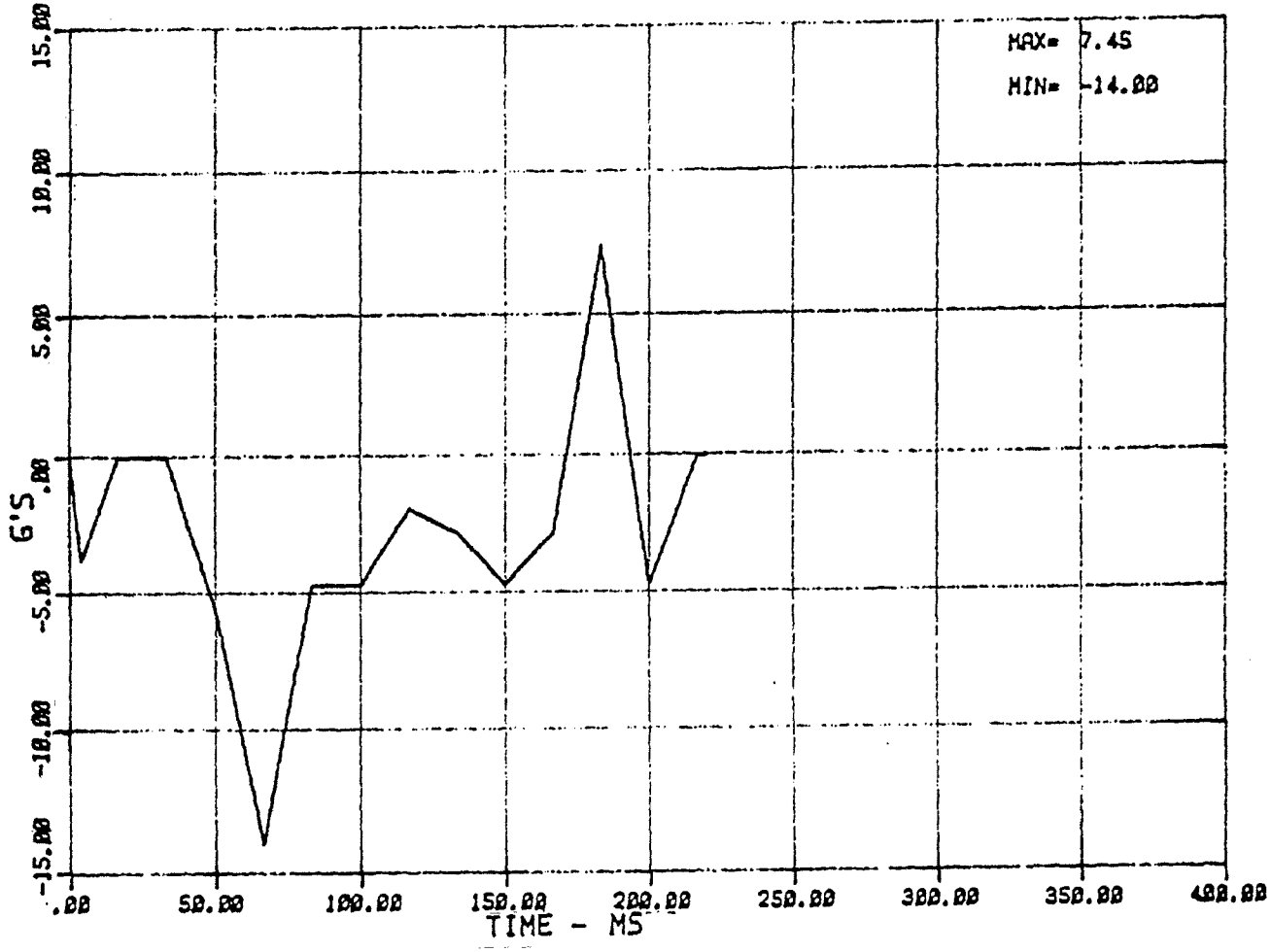


Figure 69. Deceleration time history, x-axis, test no. 4.

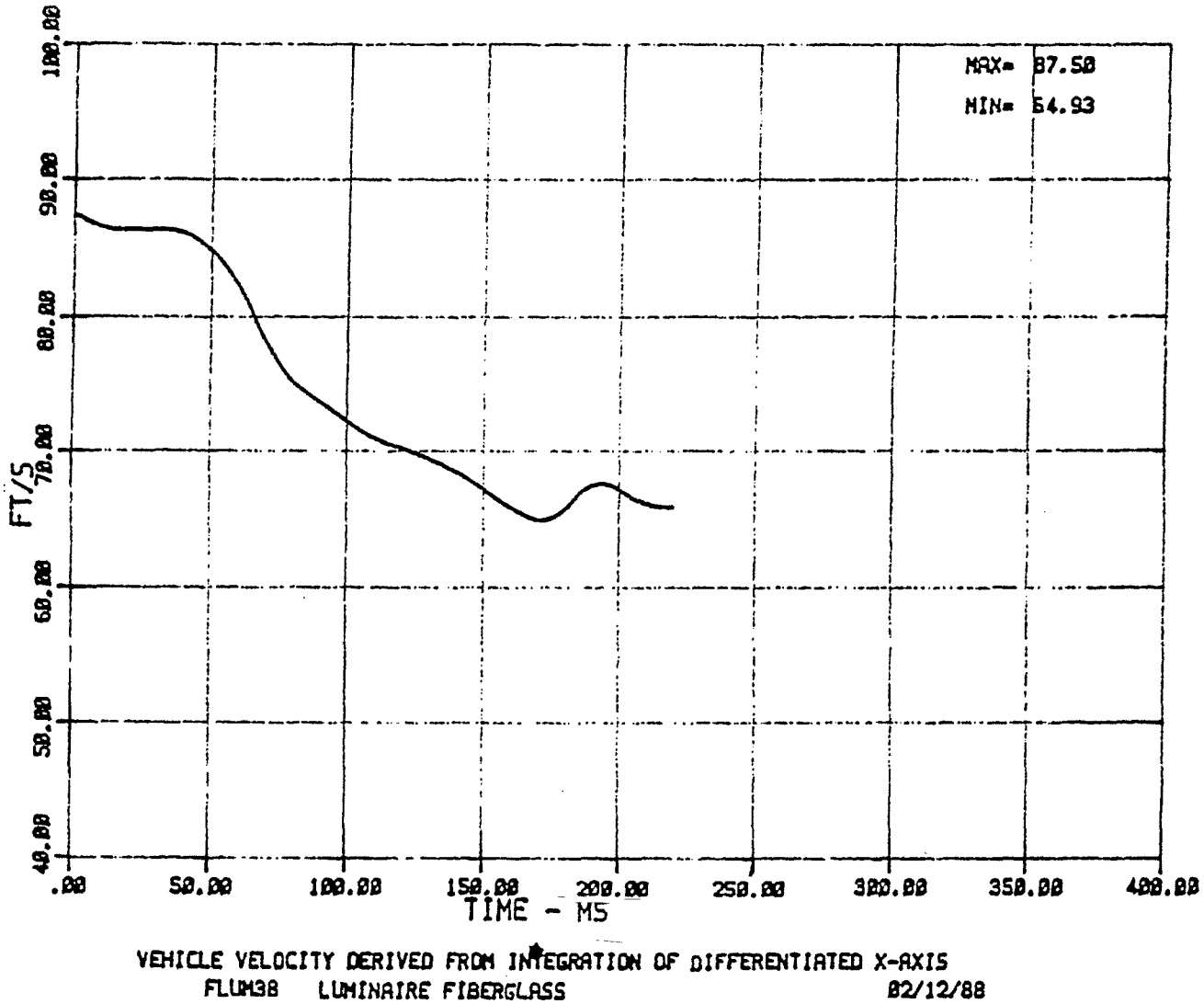


Figure 70. Longitudinal-velocity time history, by integration, test no. 4.

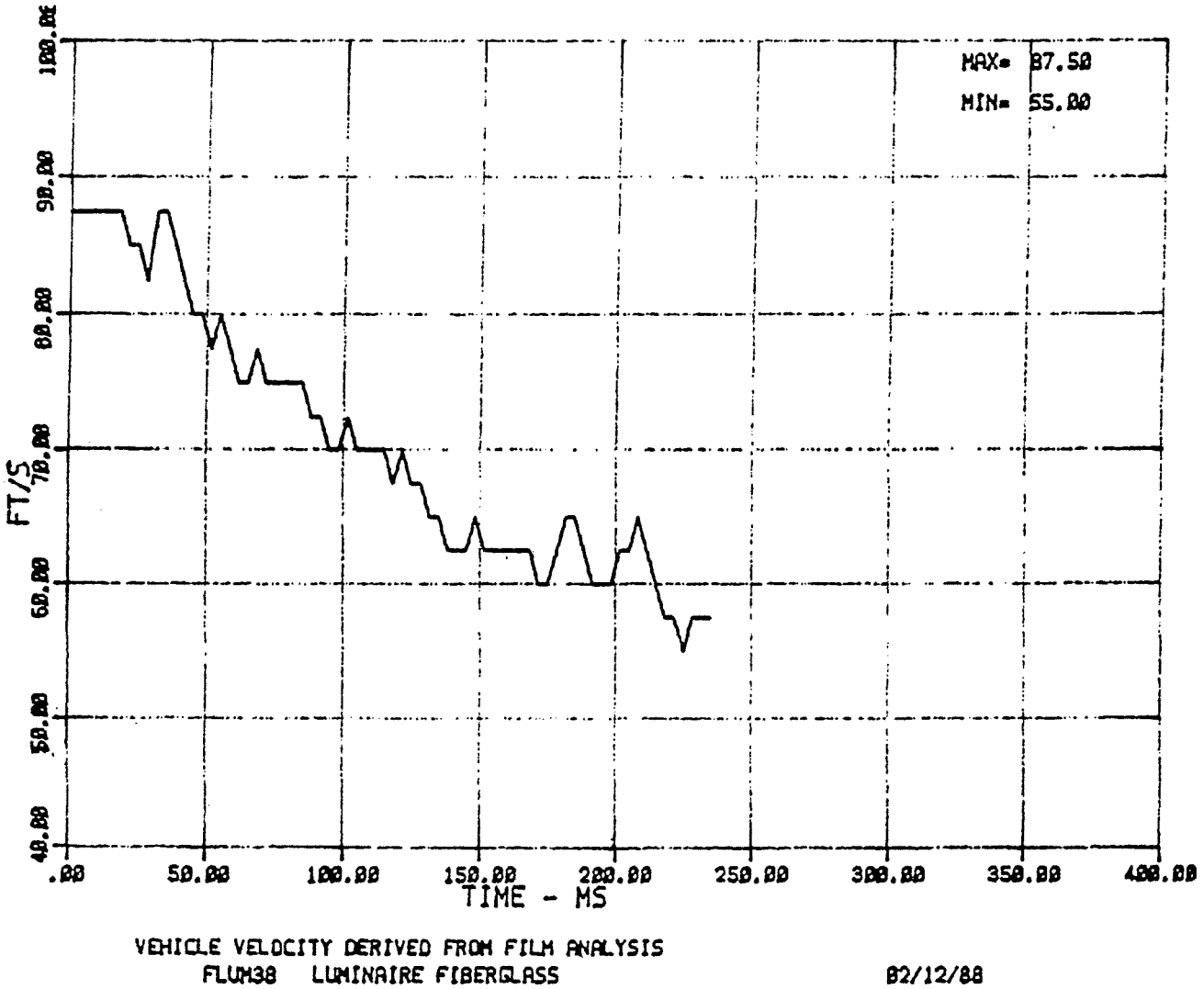


Figure 71. Longitudinal-velocity time history, by film analysis, test no. 4.

LUMINAIRE AND SIGN SUPPORT TEST NO. 5, 20 MI/H

1. Introduction

Test No. 5 (Wisconsin Stiff Leg Sign Support 01) was conducted on 26 February 1988 using a 1979 Volkswagen Rabbit with a weight of 1800 ± 50 lb which was guided to impact the test article at the vehicle's front centerline.

2. Test Article

The test article consisted of 2 steel stubs, each 5 1/2-ft in length; 2 steel supports each 18 ft in length; and 11 sign panels, each 1 ft by 15 ft. This hardware is used to construct a Type B support with a 15-ft by 11-ft sign area. The stubs were set in a 2-ft radius concrete form and then buried in S-1 strong soil so that there was a stub projection of 3 in above the level surface. The steel supports were bolted to the stubs using the manufacturer's recommended torque procedure (85 ft-lb). To obtain perpendicularity the supports were shimmed at the slip base in accordance with manufacturer's instructions. The sign boards were then clamped on to the supports one at a time to form the complete sign. Design specifications for the Wisconsin Stiff Leg Support are presented in figures 4 and 5.

The stubs used are steel slip base stubs, each weighing 88 lb. The I - beam support that was impacted had depth of 12 in, flange of 3 7/8 in, flange thickness of 0.275 in and web thickness of 0.225 in. The 18-ft I - beam weighed 288 lb. The slip base was rectangular in shape. Dimensions were 24 in by 5.5 by 1.5 in (thick). Four 7/8-in diameter mounting bolts were used. No "keeper plates" were used on the mounting bolts.

3. Data Tables

Tables 30 through 34 show the data from test no. 5. Table 30 shows crash test summary. Table 31 shows test vehicle information.

Table 30. Crash test summary, luminaire support impact, test no. 5.

Project: Wisconsin Stiff Leg Sign Supports

Test: Wisconsin Stiff Leg Sign Support Test 1

Date: 02/26/88 Time: 3:45 PM

Test Articles: Freeway Stiff Leg Sign Support Type B with 15-ft by 11-ft sign.

Vehicle: 1979 Volkswagen Rabbit

Inertial mass:	1844 lb	Test mass:	1844 lb
Pre-Impact speed:	* 29.8 ft/s	Post-Impact:	**18.2 ft/s
	**29.7 ft/s		***18.2 ft/s
Offset distance from vehicle centerline:			0.5 in (left)
Maximum crush:	5.5 in	Rebound:	None
Damage: TAD:	FC1	CDC:	12FCEN4
Maximum deceleration (at c.g.)			13.3 g
Maximum 50 ms average deceleration (at c.g.)			5.6 g
Maximum 10 ms average deceleration (at c.g.)			11.5 g

Number of Data Channels: 3 accelerometers, time zero switch.

Number of High-Speed Cameras: 3, frame rate: 600 fps

* Speed trap

** Film analysis

*** Integration of acceleration data

Table 31. Test vehicle information, test no. 5.

Vehicle Manufacturer:	Volkswagen of America		
Make/Model/Year:	Volkswagen/Rabbit/1979		
Body Style:	2 door hatchback		
VIN:	1793519413	Build Date:	04/79
Engine:	4 cyl. gasoline		
Transmission:	Manual 4 speed		
GVWR:	2822 lb		
GAWR:	1609 lb Front	Rear:	1278 lb
Tire Size:	155SR13	Load Range:	B
Tire Pressure:	27 psi	Rear:	31 psi
Date Received:	15 Feb 1988	Color:	White

MASS OF VEHICLE AS RECEIVED: lb

Left Front:	673	Right Front:	690
Left Rear:	323	Right Rear:	310
Total Front Mass:	1363	(68.3% of total vehicle mass)	
Total Rear Mass:	633	(31.7% of total vehicle mass)	
Total Mass:	1996		

TEST MASS OF VEHICLE: lb

Left Front:	609	Right Front:	623
Left Rear:	323	Right Rear:	310
Total Front Mass:	1232	(66.8% of total vehicle mass)	
Total Rear Mass:	612	(33.2% of total vehicle mass)	
Total Mass:	1844		

VEHICLE ATTITUDE: in

Left Front:	24.5
Right Front:	24.7
Left Rear:	25.1
Right Rear:	25.5

Table 31. Test vehicle information, test no. 5 (continued).

VEHICLE DIMENSIONS: in

Length:	155.3		
Width:	68.4		
Wheel-base:	94.4		
Track: Front:	54.7	Rear:	53.5

CENTER OF GRAVITY LOCATION: in

32.30	behind the front axle
1.78	to the right of centerline
21.60	above ground

Table 32. Vehicle crush data, test no. 5.

Maximum crush of 5.5 in occurred 0.5 in
to the left of the centerline.

Vehicle Rebound: None

Vehicle Speed: (measured Approximate 6 ft forward and from impact)
6 ft aft

Trap No. 1: 20.30 mi/h (29.8 ft/s)
Trap No. 2: 12.41 mi/h (18.2 ft/s)

DAMAGE DIMENSIONS, in:

		Pre-Impact	Post-Impact	Change
Left Side	C_1	152.6	152.4	0.2
	C_2	152.8	151.5	1.3
	C_3	153.5	149.2	4.3
	C_4	153.5	149.7	3.8
	C_5	152.5	151.3	1.2
Right Side	C_6	152.1	151.8	0.3

Width of Contact: 3.8 in

Table 33. Moving average data - vehicle accelerations, test no. 5.

Vehicle c.g. Acceleration Axis	Moving Average Time (ms)	Maximum Acceleration Value (g's)	Time of Occurance (ms)
x	10	11.50	38.45 - 48.45
x	50	5.60	0.60 - 50.60
y	50	0.45	272.20 - 322.20
z	50	1.20	51.00 - 101.00

Table 34. Data analysis summary sheet, test no. 5.

TEST NUMBER: 5 TEST DATE : 02/26/88

TEST ARTICLE: Wisconsin Stiff Leg Sign Support

MANUFACTURER: Not Available

MODEL NUMBER: Type B with 15-ft by 11-ft sign.

TEST VEHICLE: 1979 Volkswagen Rabbit	VEHICLE WEIGHT (lb)	1844
POLE LENGTH (ft): 18.0	MAST ARM LENGTH (ft)	None
POLE BURIED in: NCHRP 5-1 STRONG SOIL		
IMPACT SPEED (ft/s):	CAMERA:	29.7
	SPEED TRAP:	29.8
EXIT SPEED (ft/s):	CAMERA:	18.2
	SPEED TRAP:	18.2
	INTEGRAL Ax:	18.2
CHANGE IN VELOCITY FROM EACH SOURCE (ft/s)	CAMERA:	11.5
	SPEED TRAP:	11.6
	INTEGRAL Ax:	11.6
MOMENTUM CHANGE: (lb-sec reported velocity change multiplied by vehicle mass)		664.8
MAX FORCE (kips, peak x-axis deceleration * velocity weight)		24.5
MAX ACCELERATION (g's, peak x-axis deceleration)		13.3
MAXIMUM MEASURED VEHICLE CRUSH LENGTH (in, static)		5.5
LONGITUDINAL OCCUPANT IMPACT VELOCITY (ft/s, NCHRP 230)		11.5
LONGITUDINAL OCCUPANT RIDEDOWN ACCEL. (g/s, NCHRP 230)		2.3
MAX 50 MS AVERAGE DECELERATION (g's)		
	X-AXIS	5.6
	Y-AXIS	0.5
	Z-AXIS	1.3
VEHICLE VELOCITY CHANGE: (Weighted average of three values)		11.6 ft/s

Table 32 shows test vehicle crush data. Table 33 shows test vehicle moving average acceleration data and table 34 shows the results from the data analysis.

4. Test Results

The vehicle impacted the pole 0.5 in to the left of the lateral centerline. The impact velocity was 20.3 mi/h. The bumper was displaced rearward 5.5 in at the impact location and the undercarriage was also pushed in along with the bumper. The car impacted the support a second time when the support base hit the ground in front of the vehicle. This second impact produced very minor damage to the hood to the right of the initial impact area. There was no windshield or roof damage to the vehicle. The test vehicle damage was contained to the bumper and front undercarriage sections, resulting in minor hood buckling only. Vehicle crush data are presented in table 32.

The impacted support broke away cleanly at impact and was pushed forward and away from the vehicle. As previously indicated, the support base struck the ground in front of the oncoming vehicle and a second impact occurred. The base of the impacted support came to rest 38 ft aft of the impact point and 4 ft towards the second support. The second support was left standing vertical with no sign boards remaining attached to it.

The sign boards came tumbling down on the test vehicle, but the vehicle escaped from under them. Vehicle trajectory did not appear to be affected. Also there was no reportable damage to the vehicle roof.

Table 33 shows the maximum vehicle acceleration data in the form of 50 ms moving average for the x, y, and z axes.

Summary of Compliance with AASHTO and NCHRP Specifications

AASHTO Specifications

This test of a Wisconsin Stiff Leg sign support Type B with a 15-ft by 11-ft sign appears to meet all AASHTO specifications. The pole completely broke away in the desired fashion leaving less than the maximum 4 in of stub height allowed. The velocity change of the test vehicle was less than the 15-ft/s maximum.

NCHRP Specifications

The dynamics of this test seem to adhere to the NCHRP specifications except for a slight deviation in trajectory after impact. The support broke completely away, and no elements of the supports or sign penetrated the passenger compartment. The vehicle remained upright with no passenger compartment deformation or intrusion. The occupant impact velocity was less than the maximum allowed value of 15 ft/s. The longitudinal ridedown acceleration was less than the maximum allowed value of 15 g's. The vehicle did pull slightly to the right off of a straight line trajectory due to the continued contact with the support, however, this deviation is not considered significant.

5. Photographic Coverage

Figures 72 through 82 show the test area, the test article and the posttest photographs of the test vehicle and the test article.

6. Data Plots

The data plots from test no. 5 are shown in figures 83 through 87.

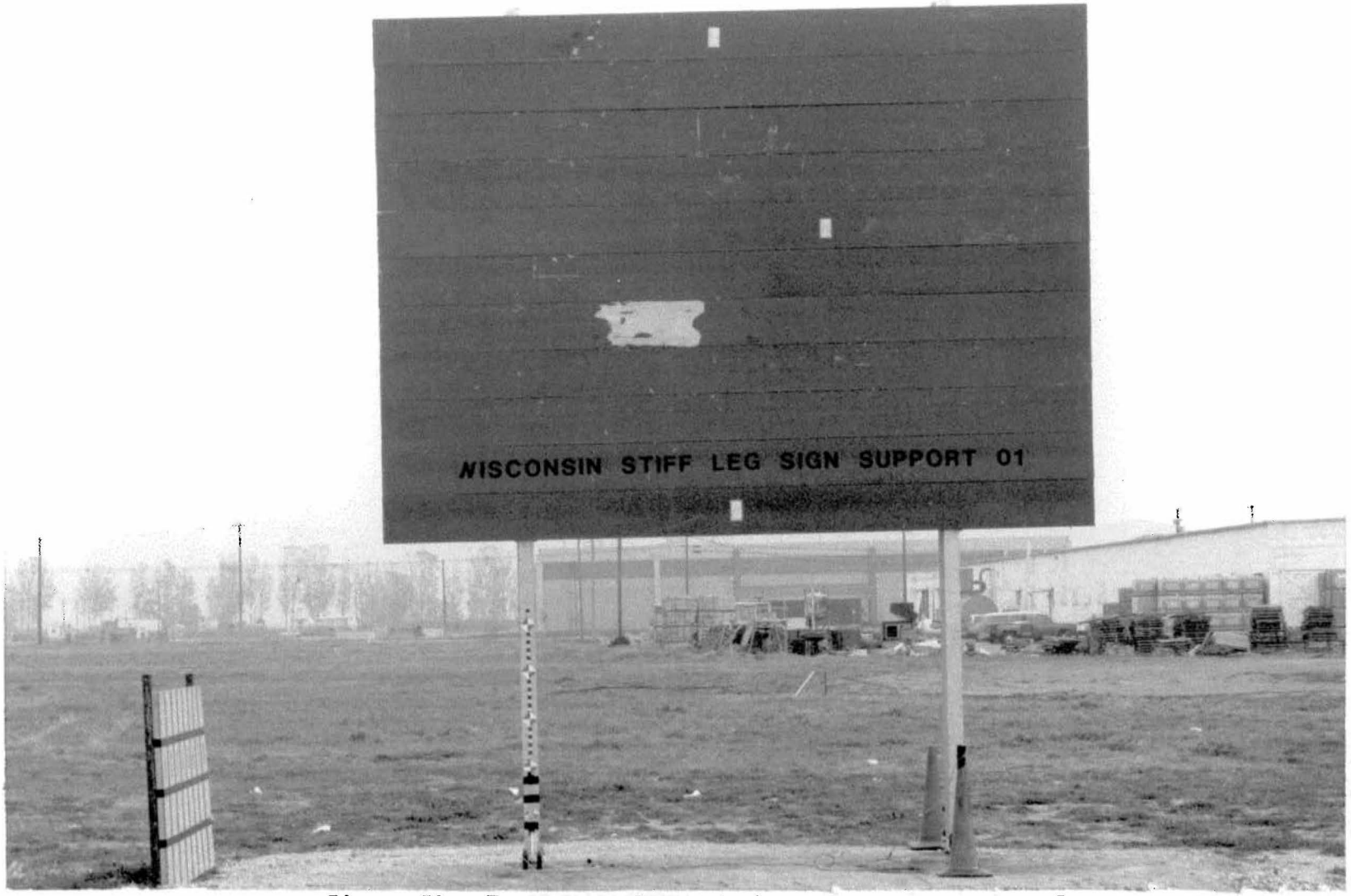


Figure 72. Test area elevated view, pretest, test no. 5.

Figure 73. Test article, pretest, test no. 5.

Figure 74. Test area elevated view, posttest, test no. 5.

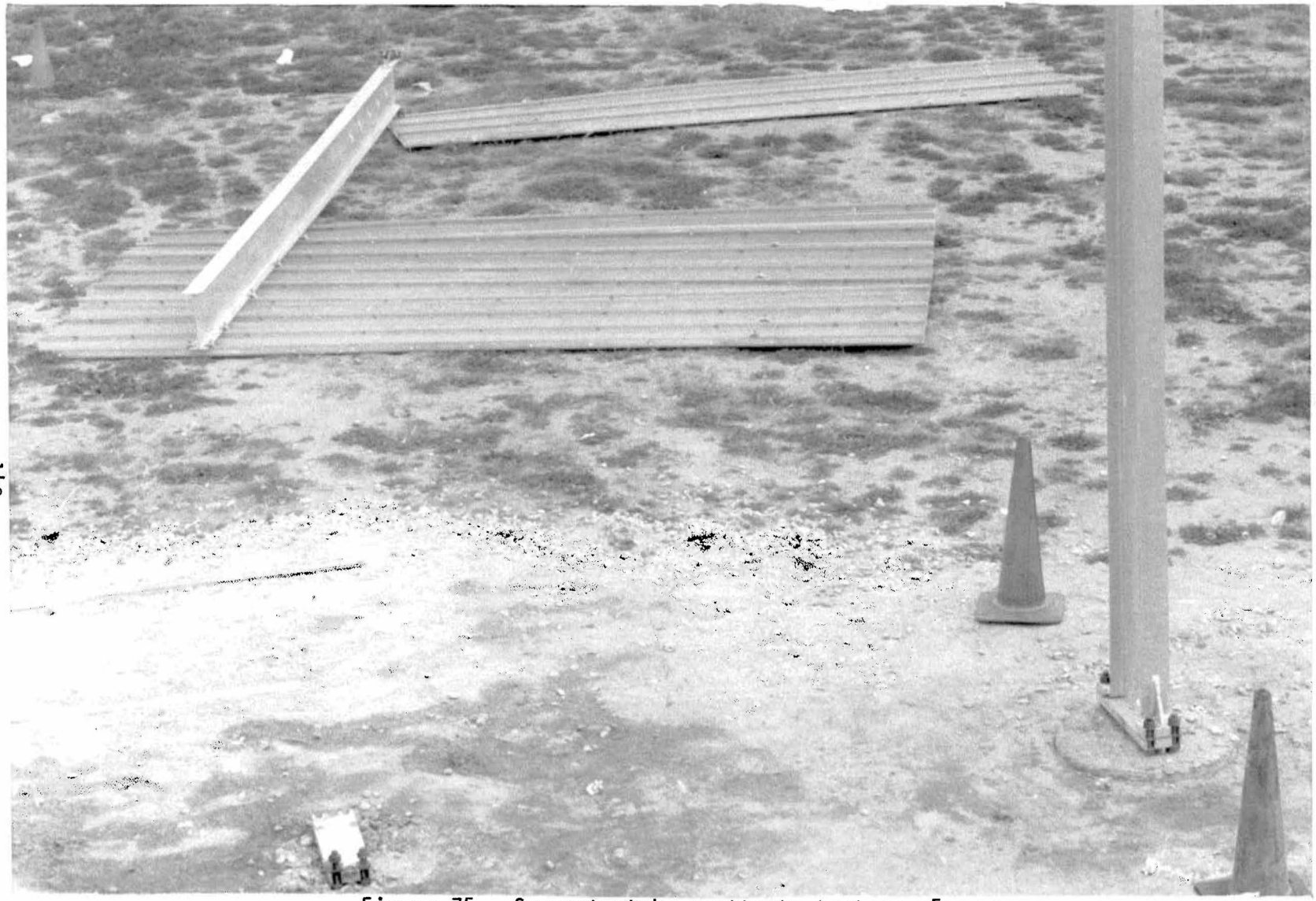


Figure 75. Support stub, posttest, test no. 5.

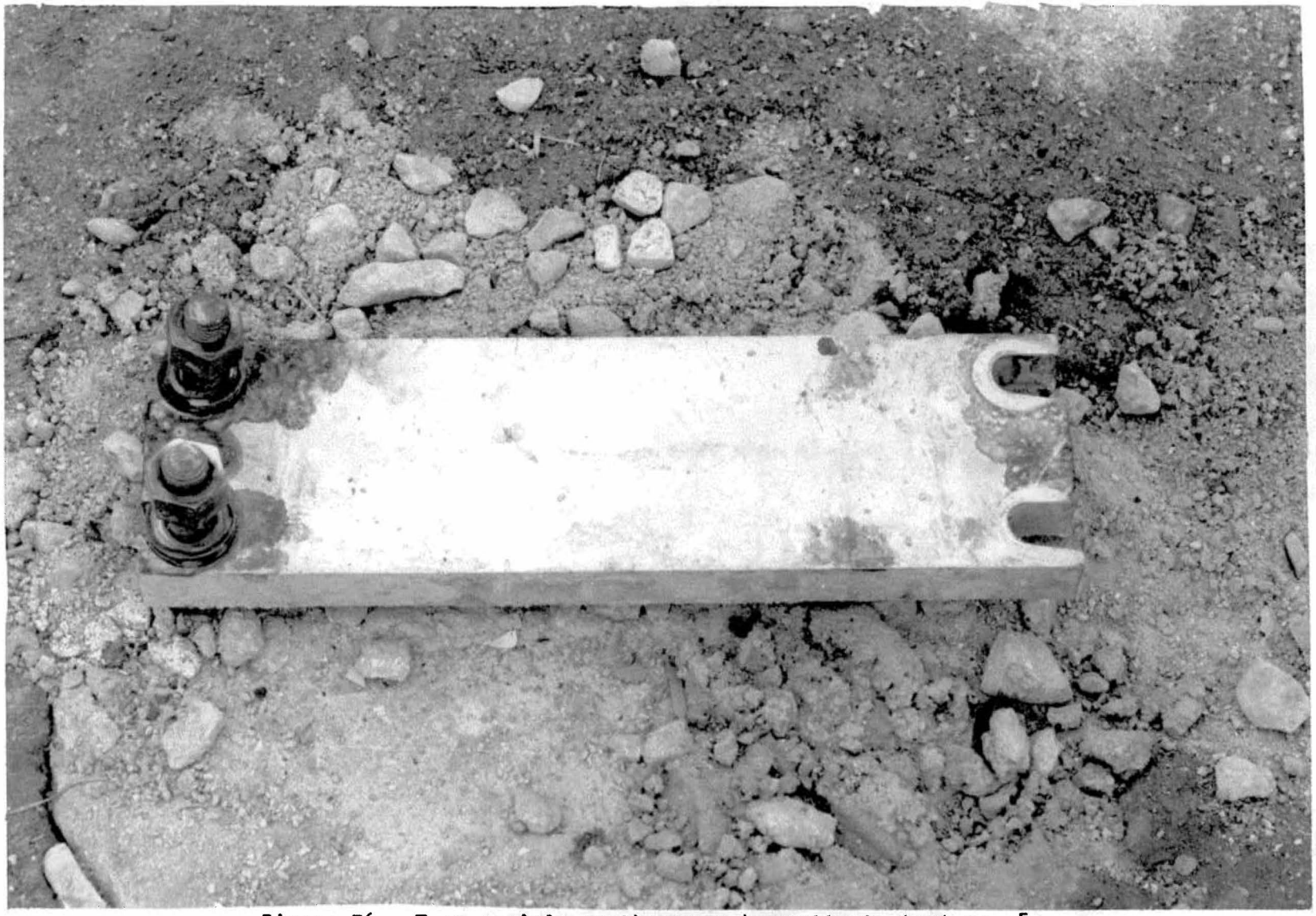


Figure 76. Test article on the ground, posttest, test no. 5.

Figure 77. Full left side view, posttest, test no. 5.

Figure 78. Full right side view, posttest, test no. 5.

Figure 79. Left front 3/4 view, posttest, test no. 5.

Figure 80. Right front 3/4 view, posttest, test no. 5.

Figure 81. Full front view, posttest, test no. 5.

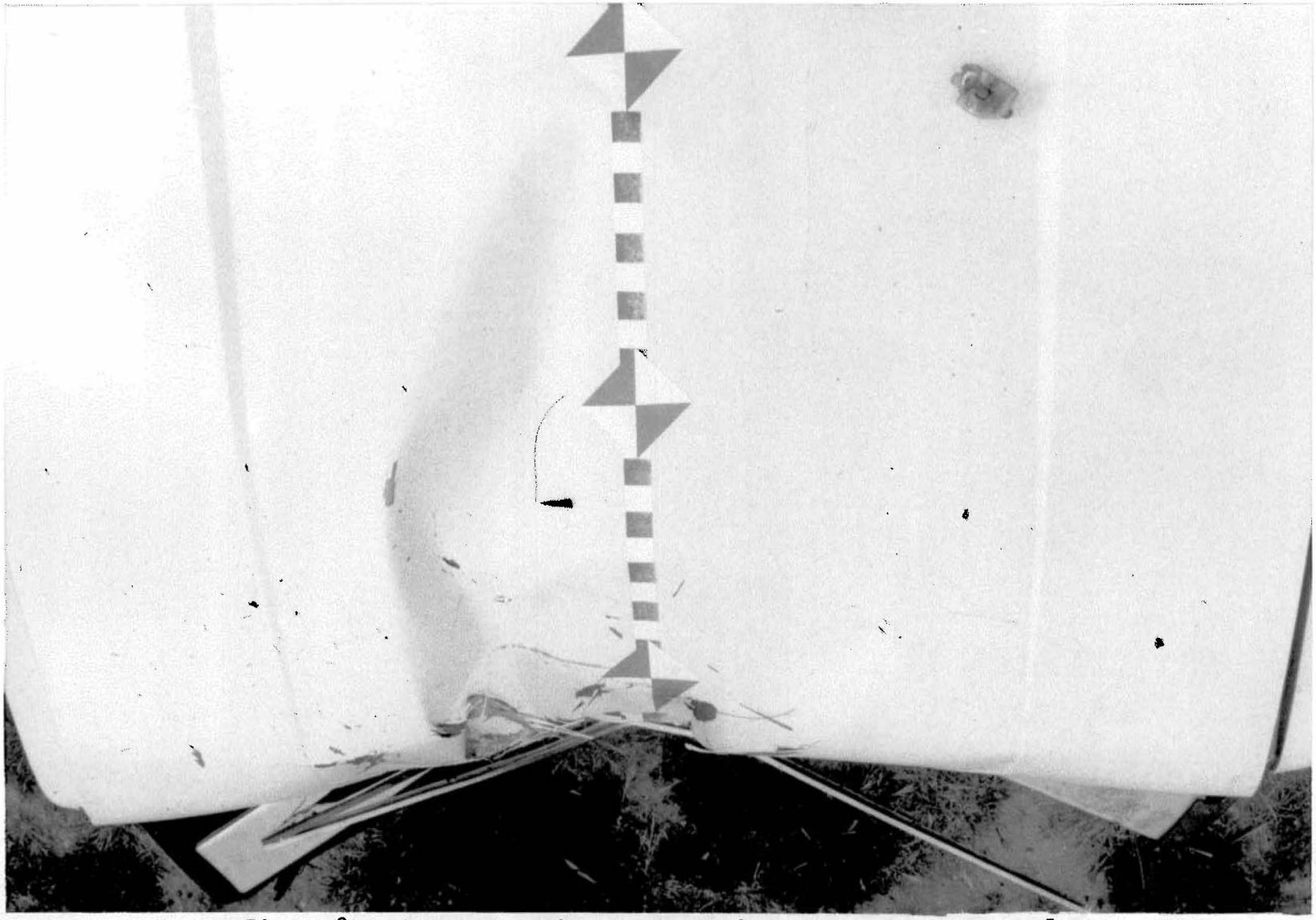


Figure 82. Impact location overhead view, posttest, test no. 5.

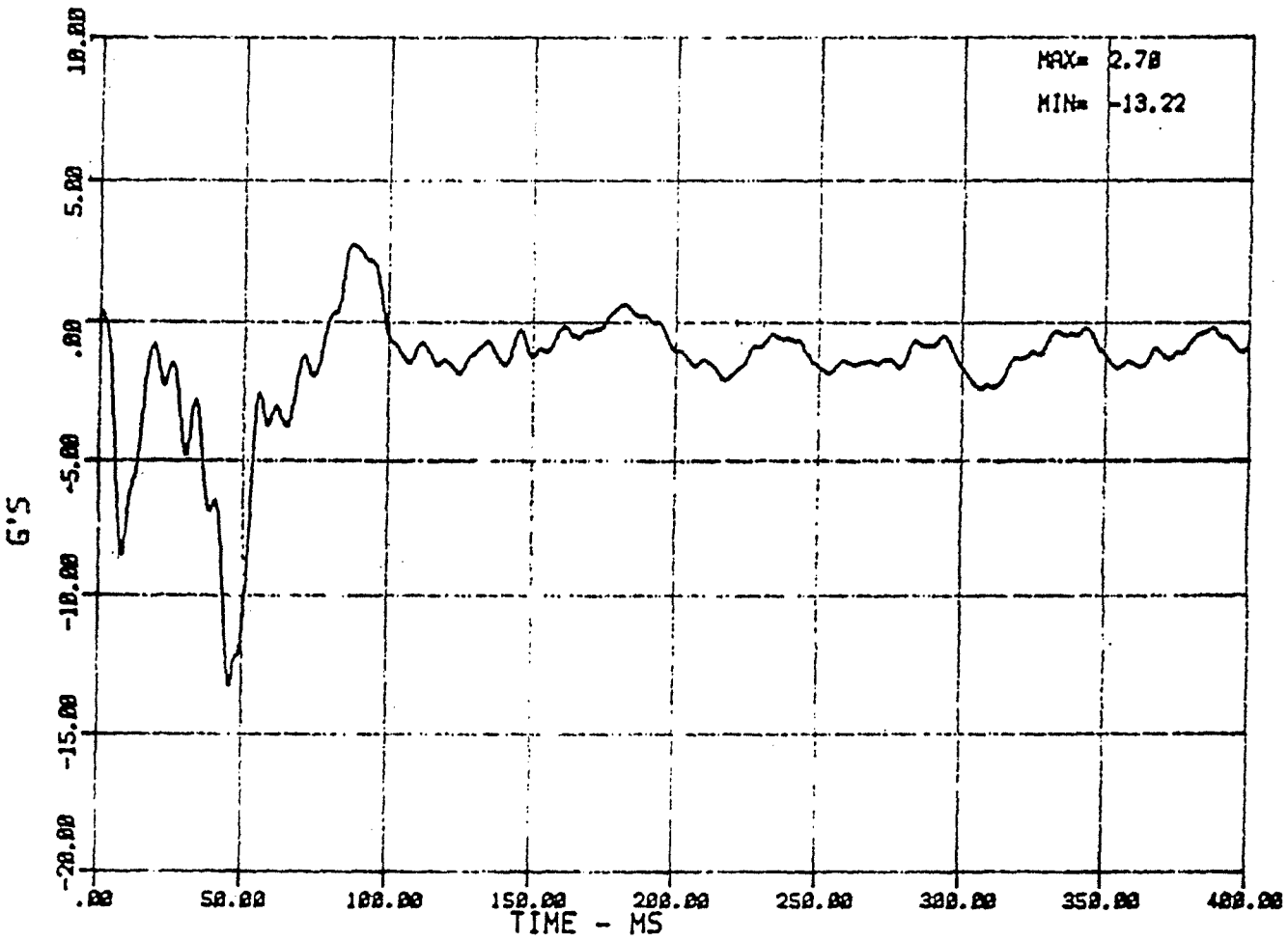


Figure 83. Deceleration time history, x-axis, test no. 5.

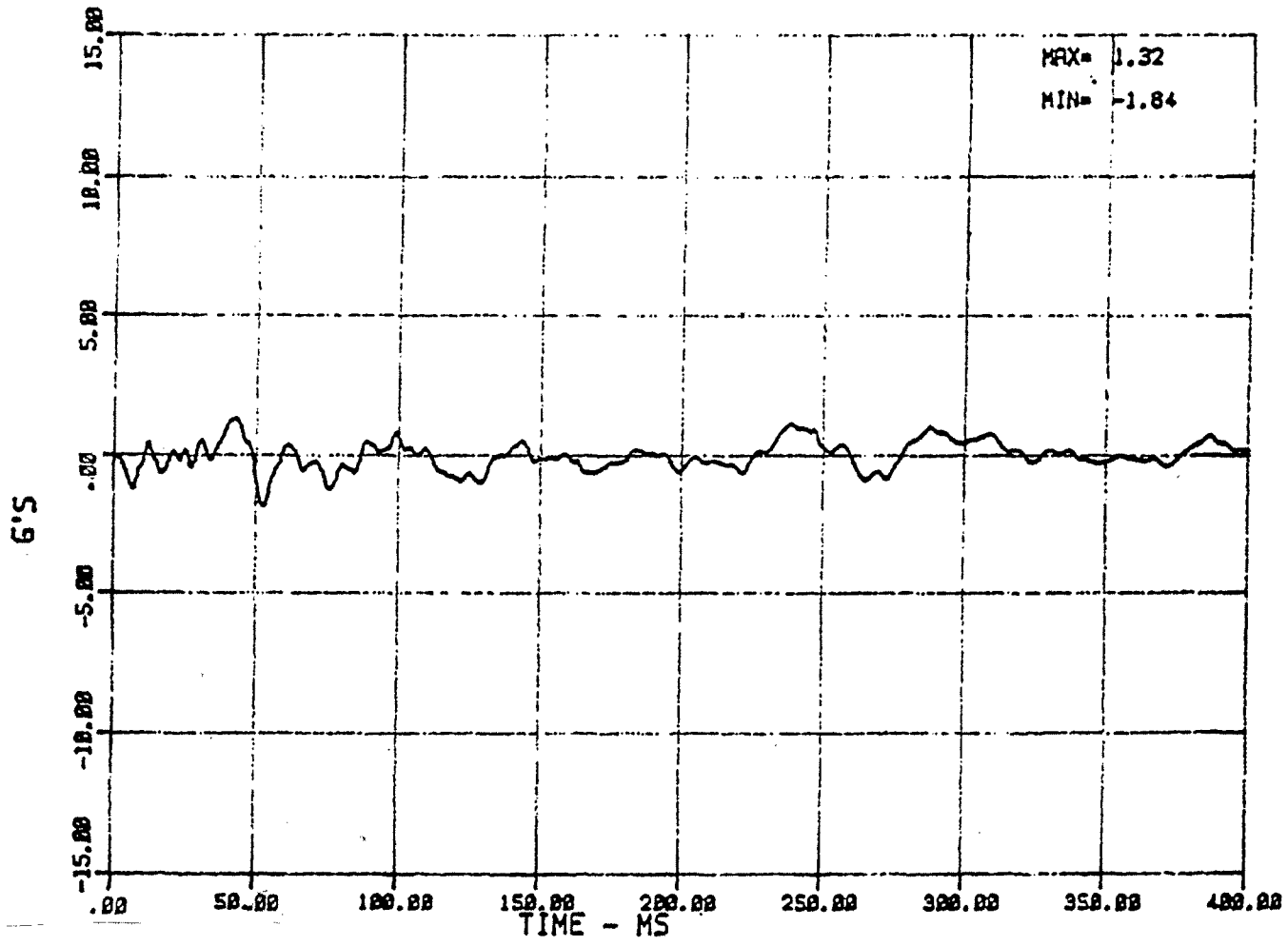


Figure 84. Deceleration time history, y-axis, test no. 5.

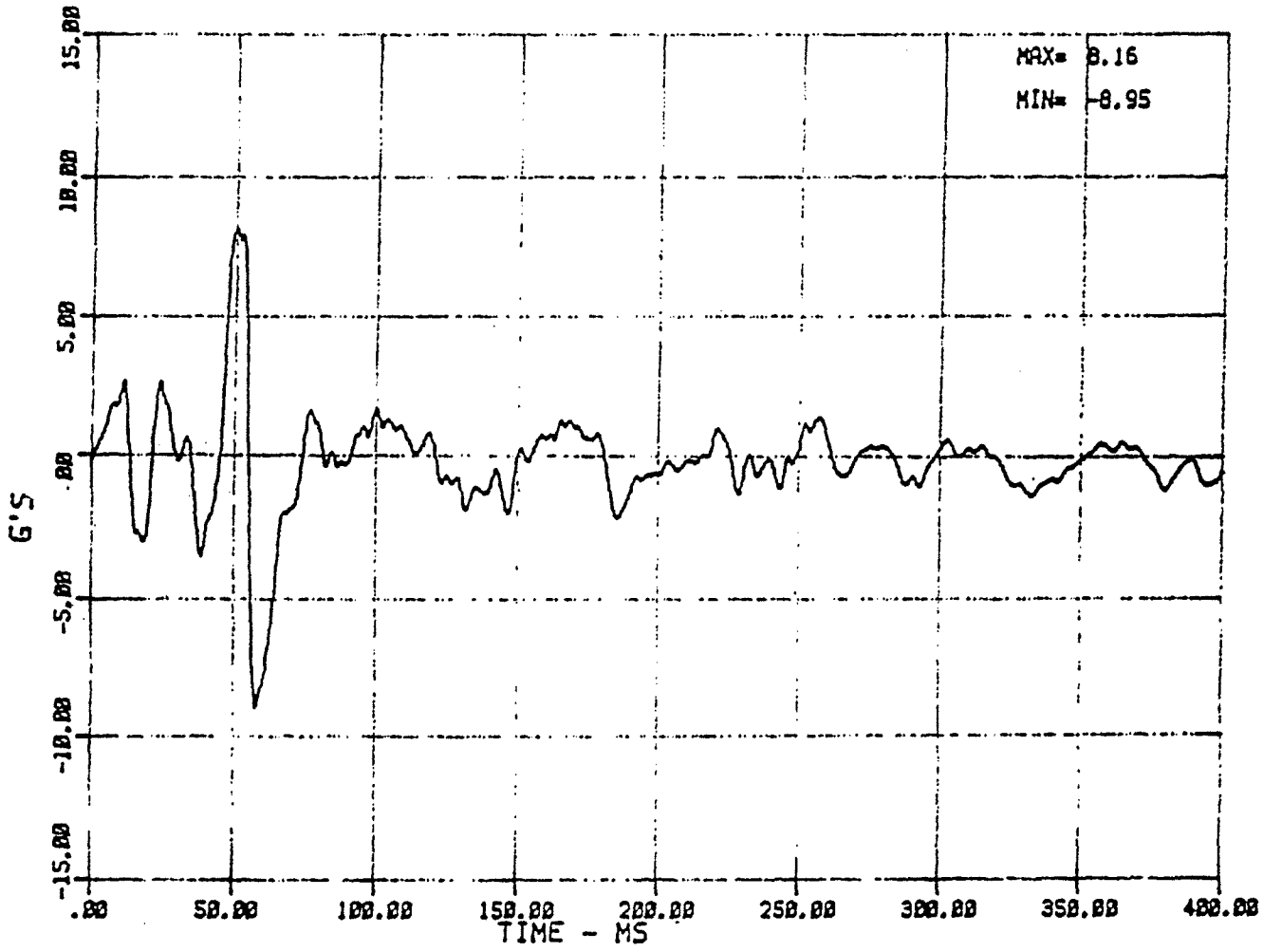
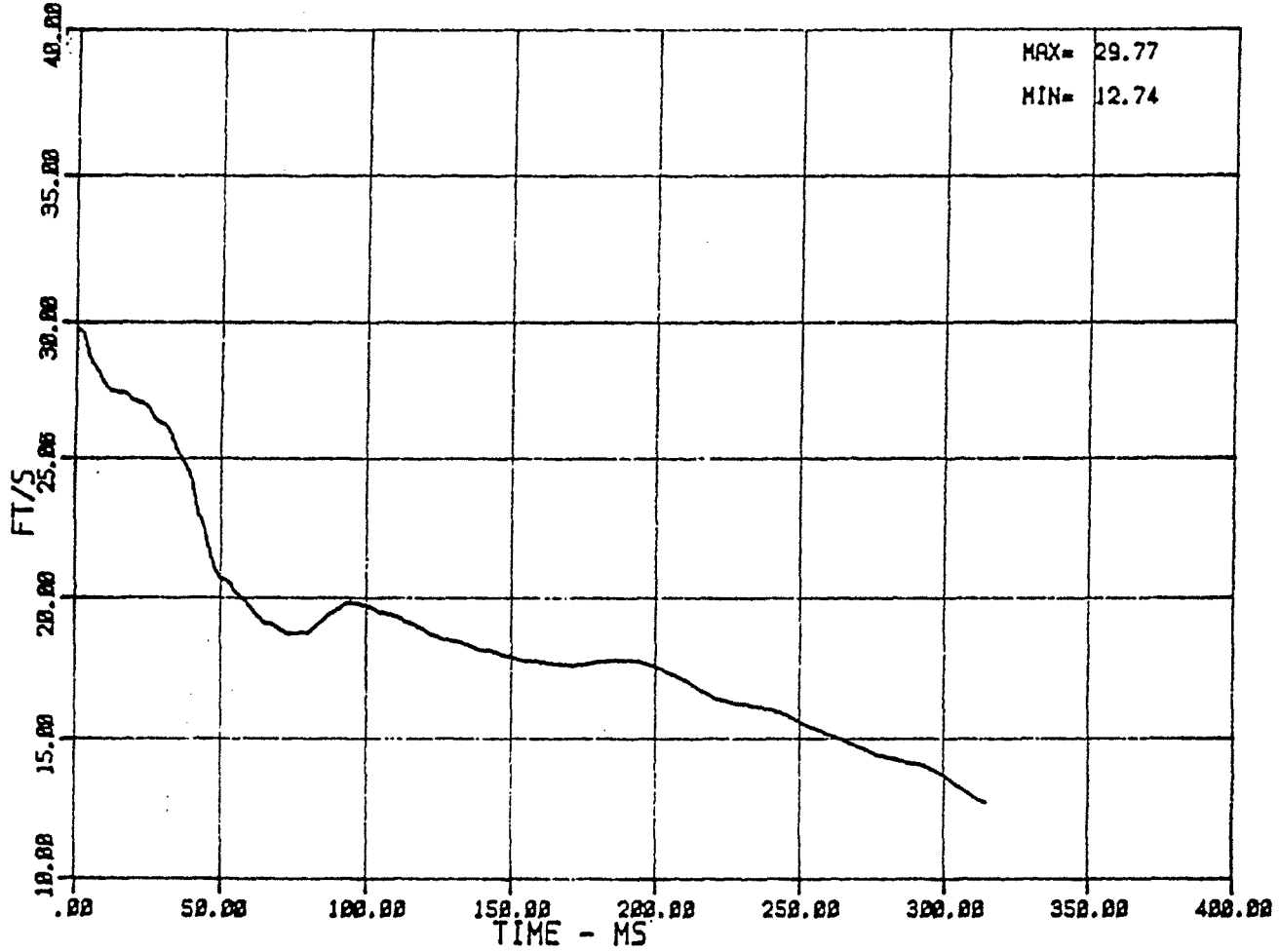


Figure 85. Deceleration time history, z-axis, test no. 5.



VEHICLE VELOCITY DERIVED FROM INTEGRATION OF X-AXIS ACCEL, CLASS 180 FILTER
FWIS18 WISCONSIN STIFF LEG -- 20 mi/h 02/26/88

Figure 86. Longitudinal-velocity by integration, test no. 5.

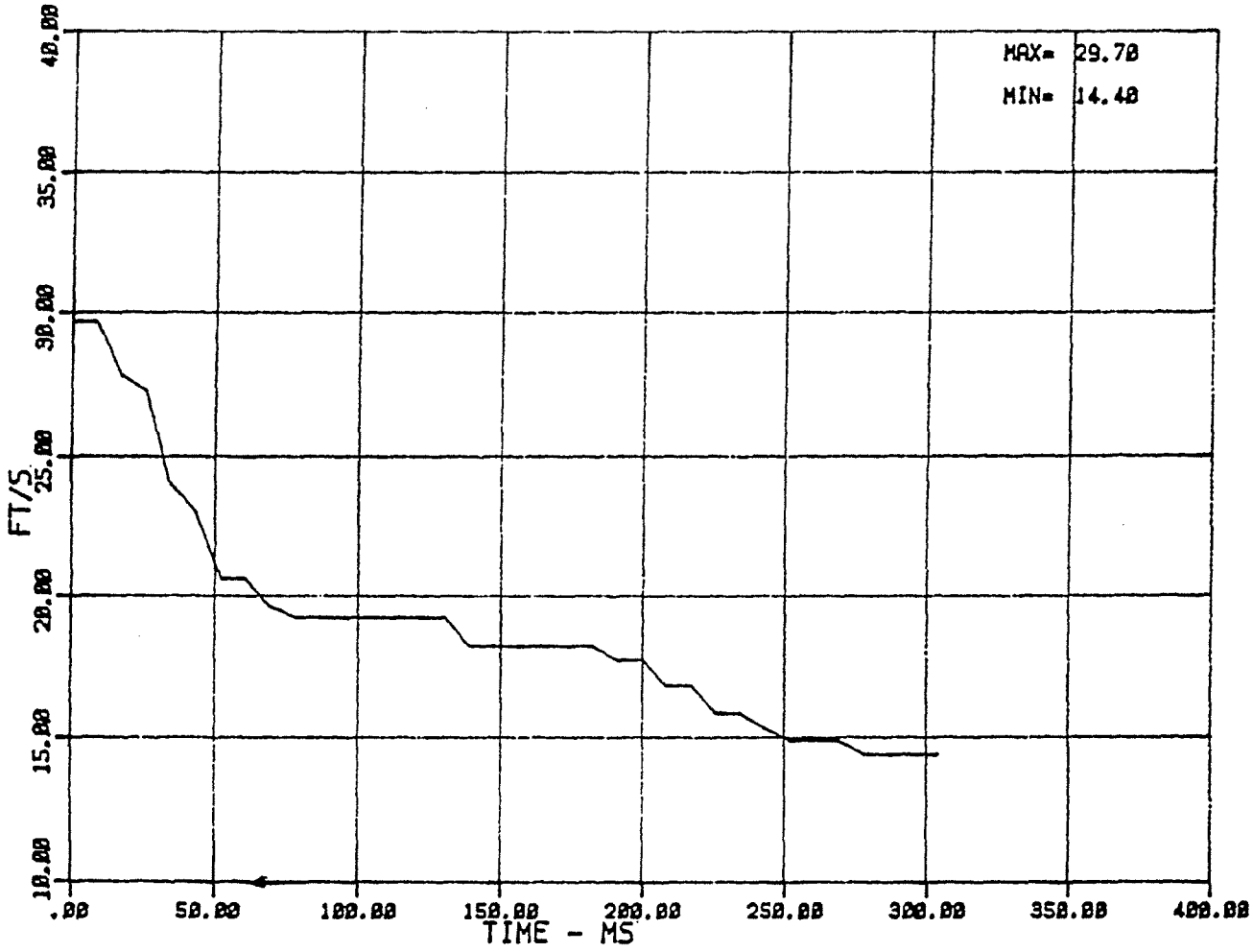


Figure 87. Longitudinal-velocity time history, by film analysis, test no. 5.

LUMINAIRE AND SIGN SUPPORT TEST NO. 6, 60 MI/H

1. Introduction

Test No. 6 (Wisconsin Stiff Leg Sign Support 02) was conducted on 15 April 1988 using a 1979 Volkswagen Rabbit with a weight of 1800 ± 50 lb which was guided to impact the test article at the vehicle's front centerline. This is the high-speed companion test to the low-speed test, test no. 5.

2. Test Article

The test article consisted of two steel stubs, each 5 1/2 ft in length; two steel supports, each 18 ft in length; and 11 sign panels, each 1 ft by 15 ft. This hardware is used to construct a Type B support with a 15-ft by 11-ft sign. The stubs were set in a 2-ft radius concrete form and then buried in S-1 strong soil so that there was stub projection of 3 in above the track level surface. The steel supports were bolted to the stubs using the manufacturer's recommended torque procedure (85 ft-lb). To obtain perpendicularity the supports were shimmed at the slip base in accordance with manufacturer's instructions. The sign boards were then clamped on to the supports one at a time to form the complete sign. Design specifications for the Wisconsin Stiff Leg Support are presented in figures 4 and 5.

The stubs used are steel slip base stubs, each weighing 88 lb. The I - beam support that was impacted had depth of 12 in, flange of 3 7/8 in, flange thickness of 0.275 in and web thickness of 0.225 in. The 18-ft I - beam weighed 288 lb. The slip base was rectangular in shape. Dimensions were 24 in by 5.5 by 1.5 in (thick). Four 7/8-in diameter mounting bolts were used. No "keeper plates" were used on the mounting bolts.

3. Data Tables

Tables 35 through 39 show the data from test no. 6. Table 35 shows crash test summary. Table 36 shows test vehicle information. Table 37 shows test vehicle crush data. Table 38 shows test vehicle moving average acceleration data and table 39 shows the results from the data analysis.

4. Test Results

The vehicle impacted the pole 2.0 in to the left of the lateral centerline. The impact velocity was 58.2 mi/h. The bumper was displaced rearward 15.0 in at the impact location. The undercarriage was also pushed in along with the bumper. The hood was creased downward a maximum of 5.5 in. No damage was done to the windshield, roof, or front quarter panels of the vehicle. The vehicle came to rest in a straight line relative to the initial pre-impact trajectory with a slight initial movement to the right following impact. Vehicle crush data are presented in table 37.

The test article seemed to perform in the desired breakaway fashion. The impact support was knocked cleanly away from the stub and was thrown up and over the vehicle which passed easily underneath the support. The impacted support landed with its base 36 ft rearward and from the impact point. The second support stayed upright and vertical. The sign panels separated cleanly from both supports and landed approximately 8 ft rearward from the impact point. The sign came apart in two pieces, the bottom six panels landing on top of the upper five panels. The sign panels did not cause any damage to the roof of the test vehicle.

Table 38 shows the maximum vehicle acceleration data in the form of 50 ms moving average for the x, y, and z axes.

Table 35. Crash test summary, sign support impact, test no. 6.

Project: Wisconsin Stiff Leg Sign Supports

Test: Wisconsin Stiff Leg Sign Support Test 2

Date: 04/15/88 Time: 4:30 PM

Test Articles: Freeway Stiff Leg Sign Support Type B with 15-ft by 11-ft sign.

Vehicle: 1979 Volkswagen Rabbit

Inertial mass:	1838 lb	Test mass:	1838 lb
Pre-Impact speed:	* 85.7 ft/s	Post-Impact:	**75.9 ft/s
	**85.4 ft/s		***79.0 ft/s
Offset distance from vehicle centerline:			2.0 in (left)
Maximum crush:	15.0 in	Rebound:	None
Damage: TAD:	FC1	CDC:	12FCEN5
Maximum deceleration (at c.g.)			30.8 g
Maximum 50 ms average deceleration (at c.g.)			4.8 g
Maximum 10 ms average deceleration (at c.g.)			17.4 g

Number of Data Channels: 3 accelerometers, time zero switch.

Number of High-Speed Cameras: 3, frame rate: 600 fps

* Speed trap

** Film analysis

*** Integration of acceleration data

Table 36. Test vehicle information, test no. 6.

Vehicle Manufacturer:	Volkswagen of America		
Make/Model/Year:	Volkswagen/Rabbit/1979		
Body Style:	2 door hatchback		
VIN:	1793519413	Build Date:	04/79
Engine:	4 cyl. gasoline		
Transmission:	Manual 4 speed		
GVWR:	2822 lb		
GAWR:	1609 lb Front	Rear:	1278 lb
Tire Size:	155SR13	Load Range:	B
Tire Pressure:	27 psi	Rear:	31 psi
Date Received:	15 Feb 1988	Color:	White

MASS OF VEHICLE AS RECEIVED: lb

Left Front:	615	Right Front:	622
Left Rear:	314	Right Rear:	305
Total Front Mass:	1237	(66.6% of total vehicle mass)	
Total Rear Mass:	619	(33.4% of total vehicle mass)	
Total Mass:	1856		

TEST MASS OF VEHICLE: lb

Left Front:	592	Right Front:	614
Left Rear:	325	Right Rear:	303
Total Front Mass:	1206	(66.6% of total vehicle mass)	
Total Rear Mass:	628	(33.4% of total vehicle mass)	
Total Mass:	1835		

VEHICLE ATTITUDE: in

Left Front:	24.5
Right Front:	25.7
Left Rear:	25.8
Right Rear:	25.8

Table 36. Test vehicle information, test no. 6 (continued).

VEHICLE DIMENSIONS: in

Length:	155.3		
Width:	68.4		
Wheel-base:	94.4		
Track: Front:	54.7	Rear:	53.5

CENTER OF GRAVITY LOCATION: in

32.30	behind the front axle
1.78	to the right of centerline
21.60	above ground

Table 37. Vehicle crush data, test no. 6.

Maximum crush of 15.0 in occurred 2.0 in
to the left of the centerline.

Vehicle Rebound: None

Vehicle Speed: (measured Approximate 6 ft forward and 6 ft aft from impact)

Trap No. 1: 58.4 mi/h (85.7 ft/s)
Trap No. 2: 53.5 mi/h (79.0 ft/s)

DAMAGE DIMENSIONS, in:

		Pre-Impact	Post-Impact	Change
Left Side	C_1	152.6	152.5	0.1
	C_2	153.0	153.3	-0.3
	C_3	153.1	138.6	14.5
	C_4	153.1	144.8	8.3
	C_5	152.9	153.7	-0.8
Right Side	C_6	152.5	152.5	0.0

Width of Contact: 3.8 in

Table 38. Moving average data - vehicle accelerations, test no. 6.

Vehicle c.g. Acceleration Axis	Moving Average Time (ms)	Maximum Acceleration Value (g's)	Time of Occurance (ms)
x	10	17.4	19.875 - 29.875
x	50	4.8	0.000 - 50.000
y	50	0.6	22.125 - 72.125
z	50	2.3	30.125 - 80.125

Table 39. Data analysis summary sheet, test no. 6.

TEST NUMBER: 6 TEST DATE : 04/15/88

TEST ARTICLE: Wisconsin Stiff Leg Sign Support

MANUFACTURER: Not Available

MODEL NUMBER: Type B with 15-ft by 11-ft sign.

TEST VEHICLE: 1979 Volkswagen Rabbit	VEHICLE WEIGHT (lb)	1838
POLE LENGTH (ft): 18.0	MAST ARM LENGTH (ft)	None
POLE BURIED in: NCHRP S-1 STRONG SOIL		
IMPACT SPEED (ft/s):	CAMERA:	85.4
	SPEED TRAP:	85.7
EXIT SPEED (ft/s):	CAMERA:	75.9
	SPEED TRAP:	78.5
	INTEGRAL Ax:	79.1
CHANGE IN VELOCITY FROM EACH SOURCE (ft/s)	CAMERA:	9.5
	SPEED TRAP:	6.9
	INTEGRAL Ax:	6.3
MOMENTUM CHANGE: (lb-sec reported velocity change multiplied by vehicle mass)		416.7
MAX FORCE (kips, peak x-axis deceleration * velocity weight)		56.6
MAX ACCELERATION (g's, peak x-axis deceleration)		30.8
MAXIMUM MEASURED VEHICLE CRUSH LENGTH (in, static)		15.0
LONGITUDINAL OCCUPANT IMPACT VELOCITY (ft/s, NCHRP 230)		6.3
LONGITUDINAL OCCUPANT RIDEDOWN ACCEL. (g's, NCHRP 230)		1.0
MAX 50 MS AVERAGE DECELERATION (g's)		
	X-AXIS	4.8
	Y-AXIS	0.6
	Z-AXIS	2.3
VEHICLE VELOCITY CHANGE: (Weighted average of three values)		7.3 ft/s

Summary of Compliance with AASHTO and NCHRP Specifications

AASHTO Specifications

This test of a Wisconsin Stiff Leg sign support Type B with a 15-ft by 11-ft sign appears to meet all AASHTO specifications. The pole completely broke away in the desired fashion leaving less than the maximum 4 in of stub height allowed. The velocity change of the test vehicle was less than the 15-ft/s maximum and also less than 10 ft/s.

NCHRP Specifications

The dynamics of this test seem to adhere to the NCHRP specifications except for a slight deviation in trajectory after impact. The support broke completely away and no elements of the supports or sign penetrated the passenger compartment. The vehicle remained upright with no passenger compartment deformation or intrusion. The occupant impact velocity was less than the maximum allowed value of 15 ft/s. The longitudinal ridedown acceleration was less than the maximum allowed value of 15 g's. The vehicle did pull slightly to the right off of trajectory line due to the continued contact with the support after impact.

5. Photographic Coverage

Figures 88 through 97 show the test area, the test article and the posttest photographs of the test vehicle and the test article.

6. Data Plots

The data plots from test no. 6 are shown in figures 98 through 102.

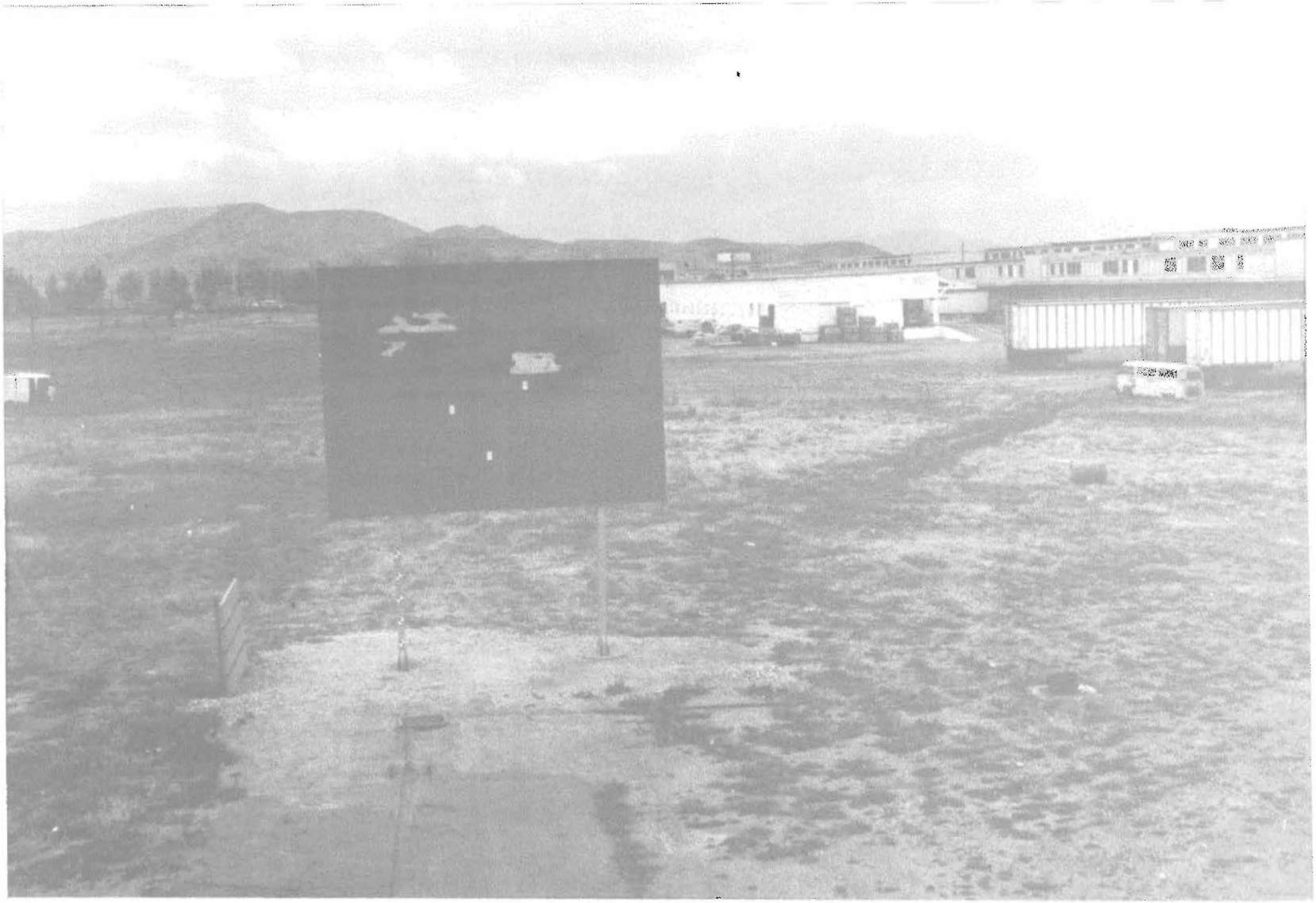


Figure 88. Test area elevated view, pretest, test no. 6.

Figure 89. Test article, pretest, test no. 6.

Figure 90. Test area elevated view, posttest, test no. 6.

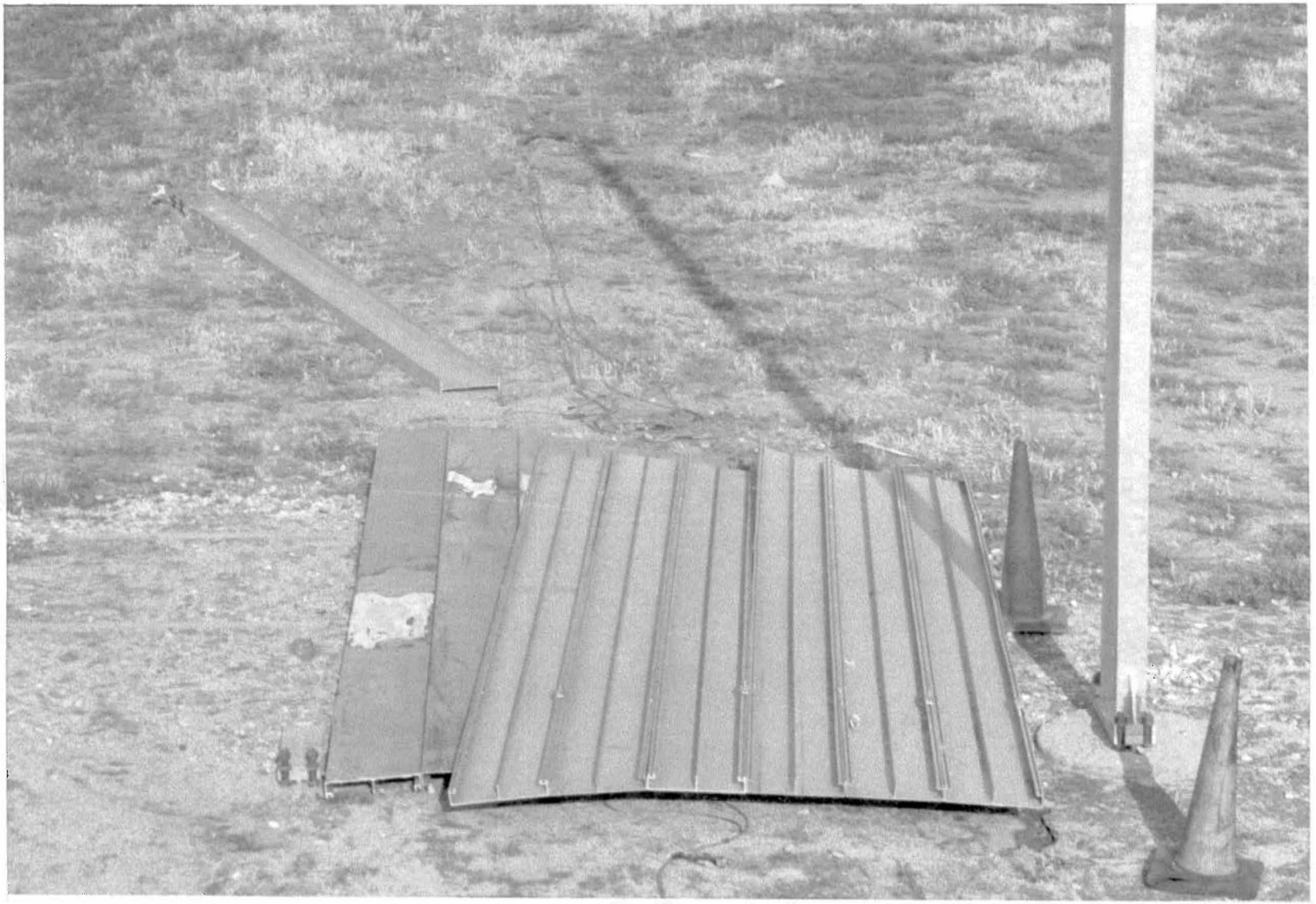


Figure 91. Test article on the ground, posttest, test no. 6.

Figure 92. Full left side view, posttest, test no. 6.

Figure 93. Full right side view, posttest, test no. 6.

Figure 94. Left front 3/4 view, posttest, test no. 6.

Figure 95. Right front 3/4 view, posttest, test no. 6.

Figure 96. Full front view, posttest, test no. 6.

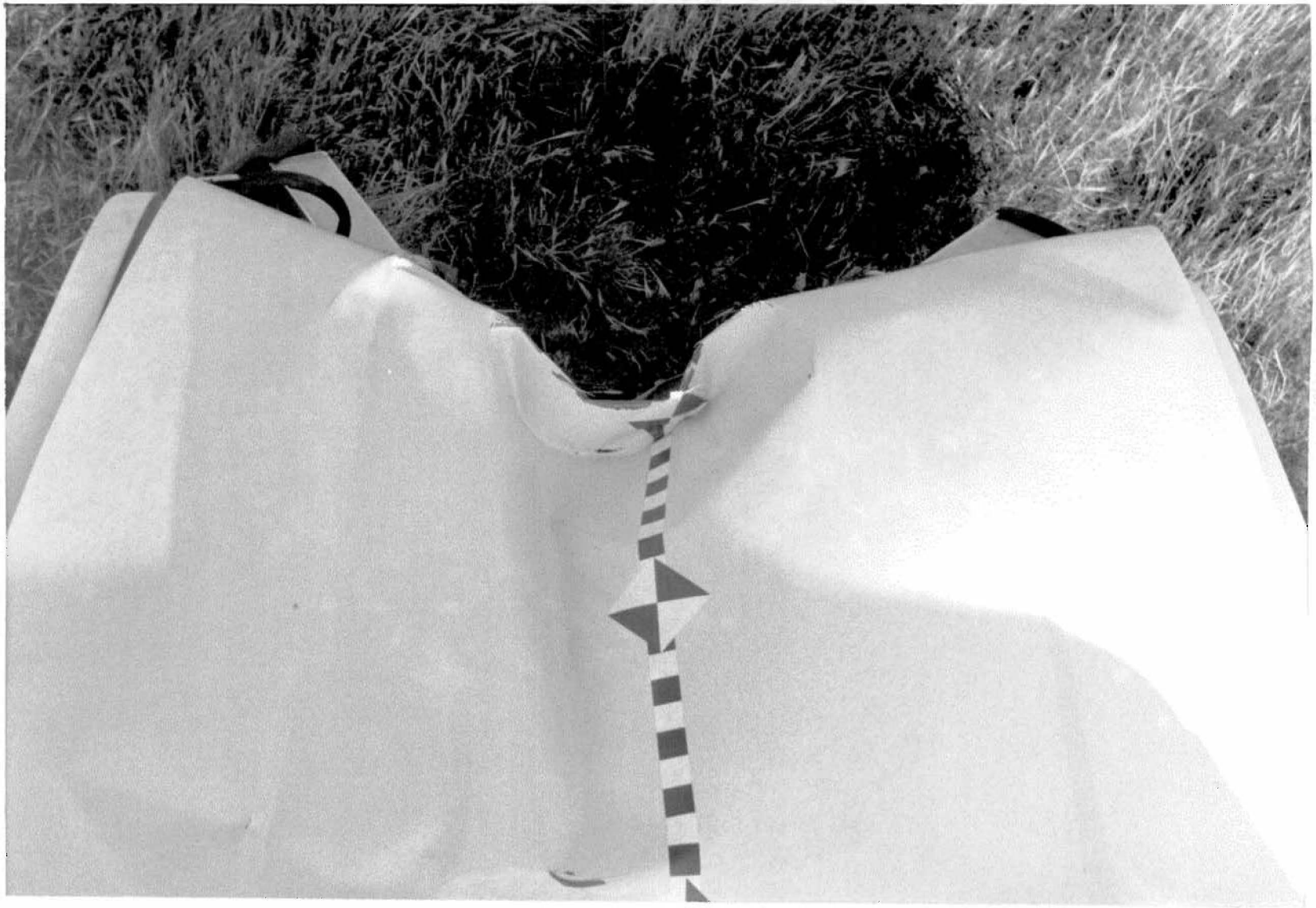


Figure 97. Impact location overhead view, posttest, test no. 6.

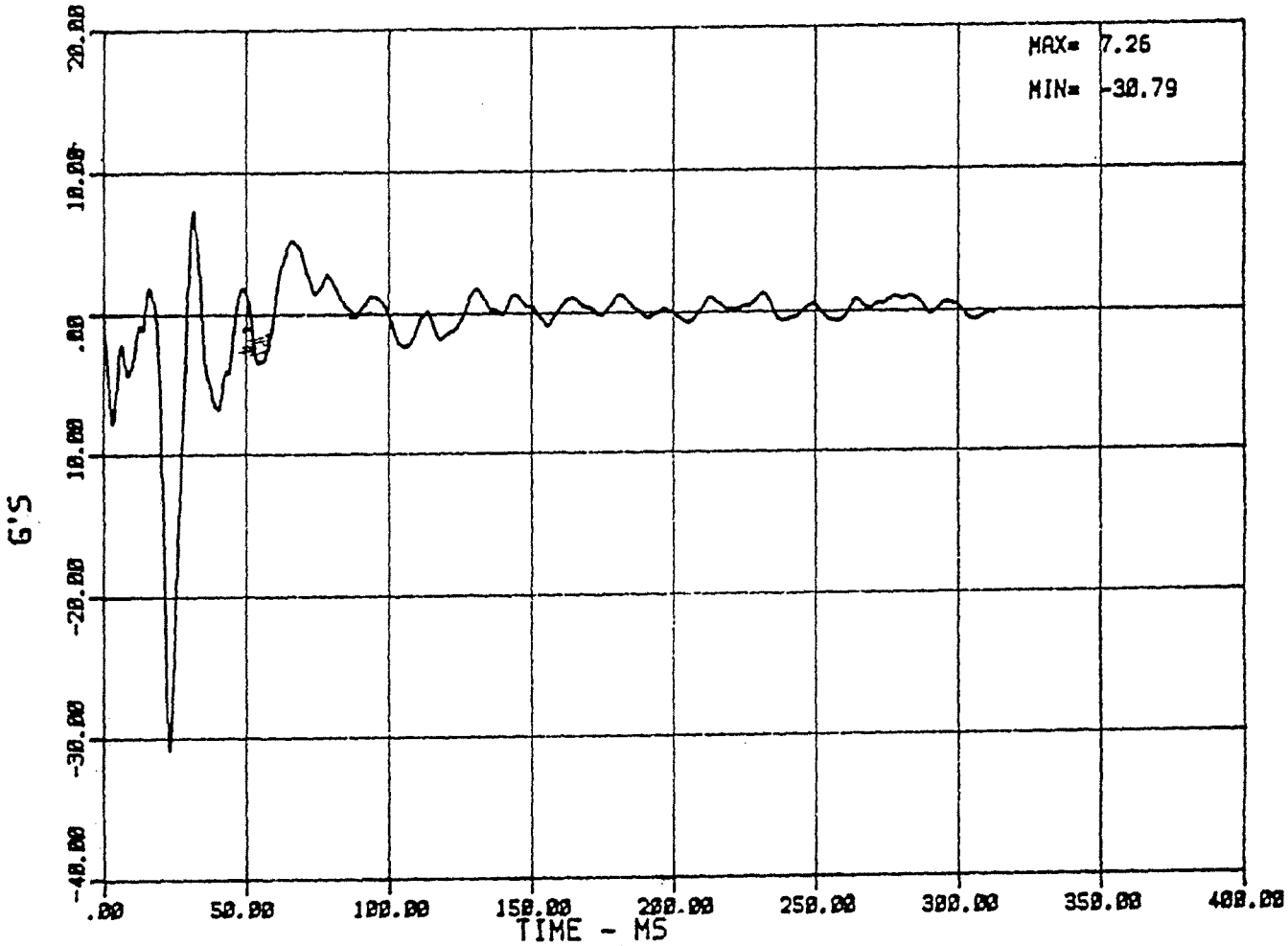


Figure 98. Deceleration time history, x-axis, test no. 6.

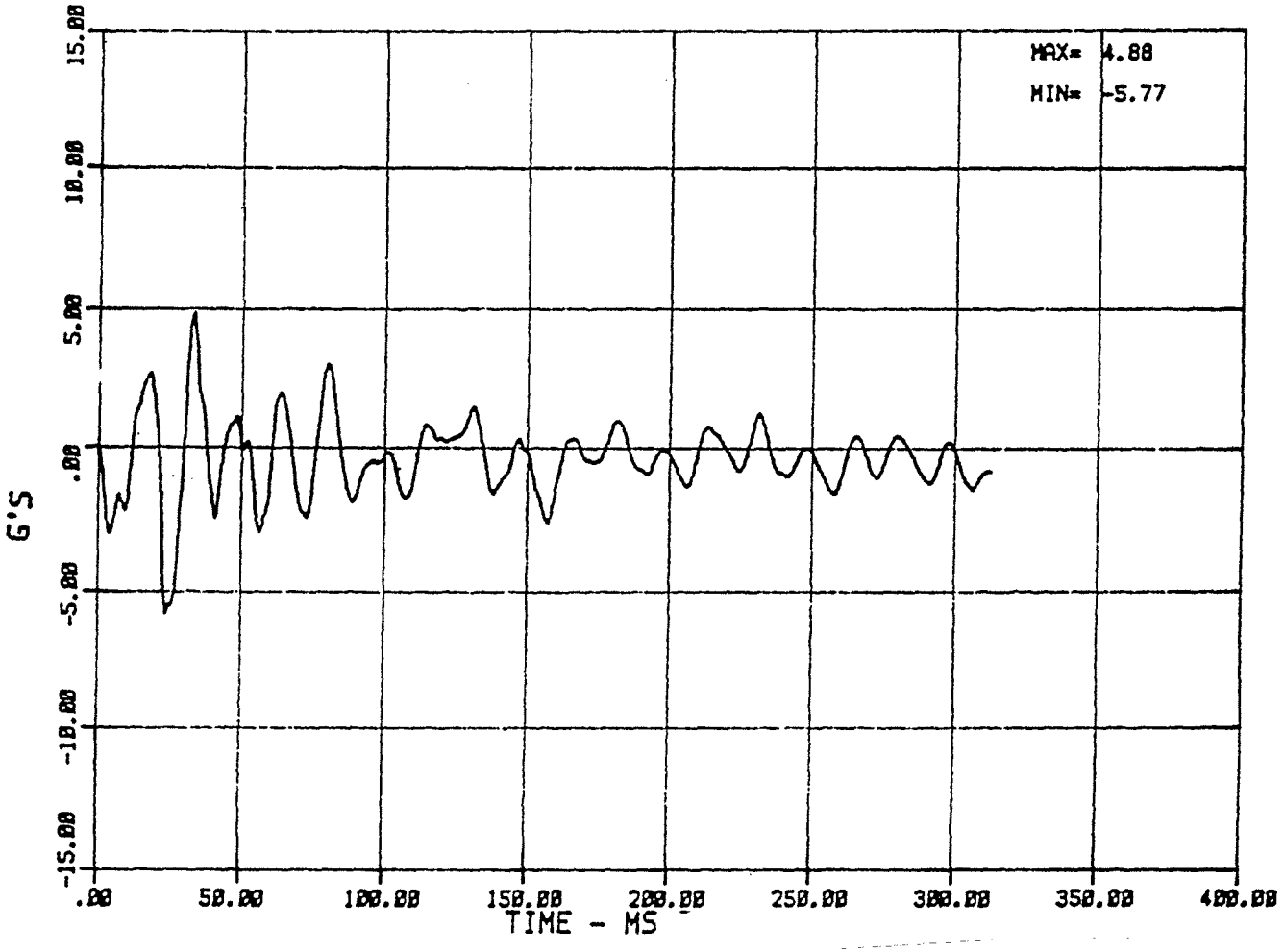


Figure 99. Deceleration time history, y-axis, test no. 6.

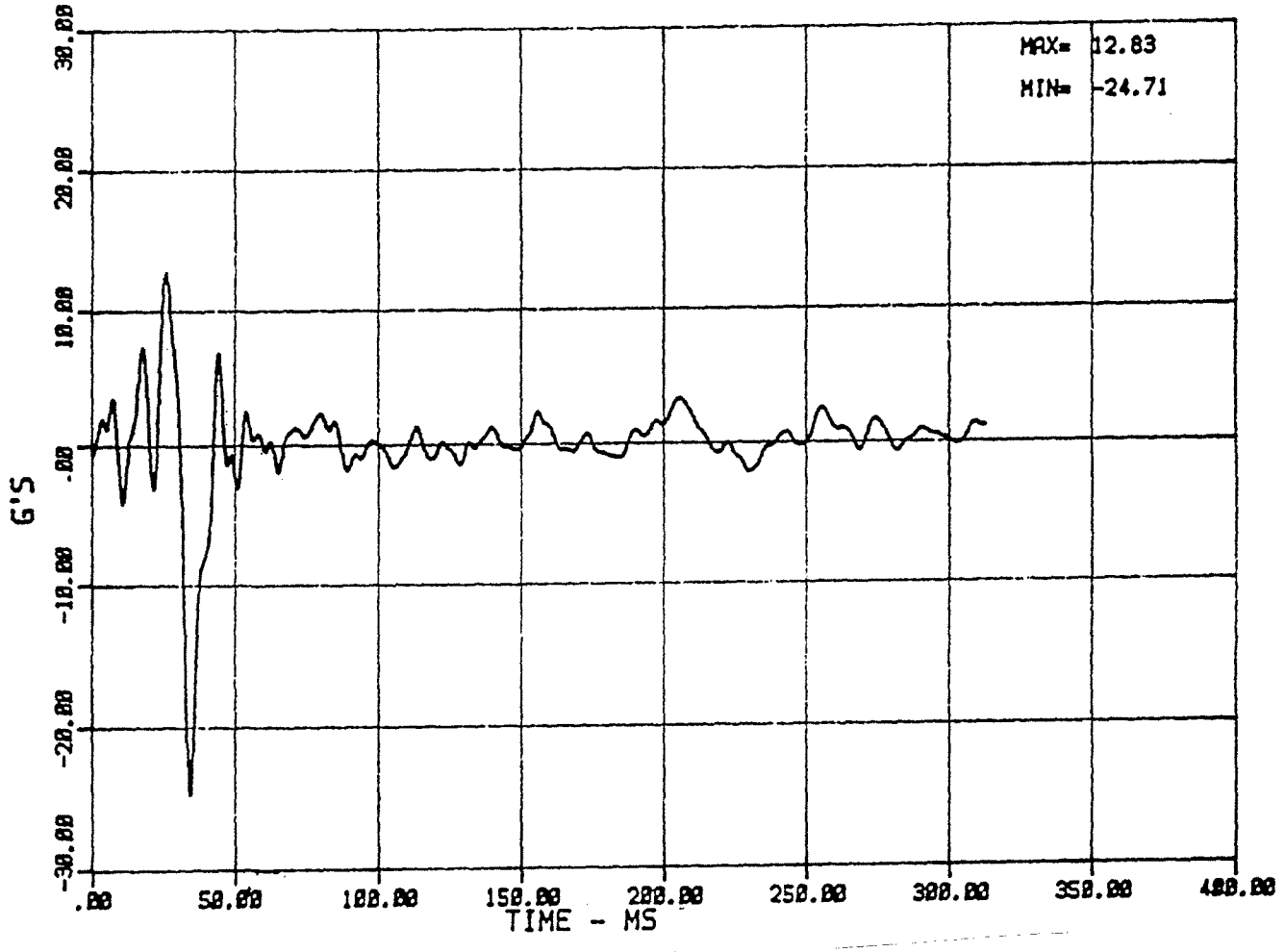
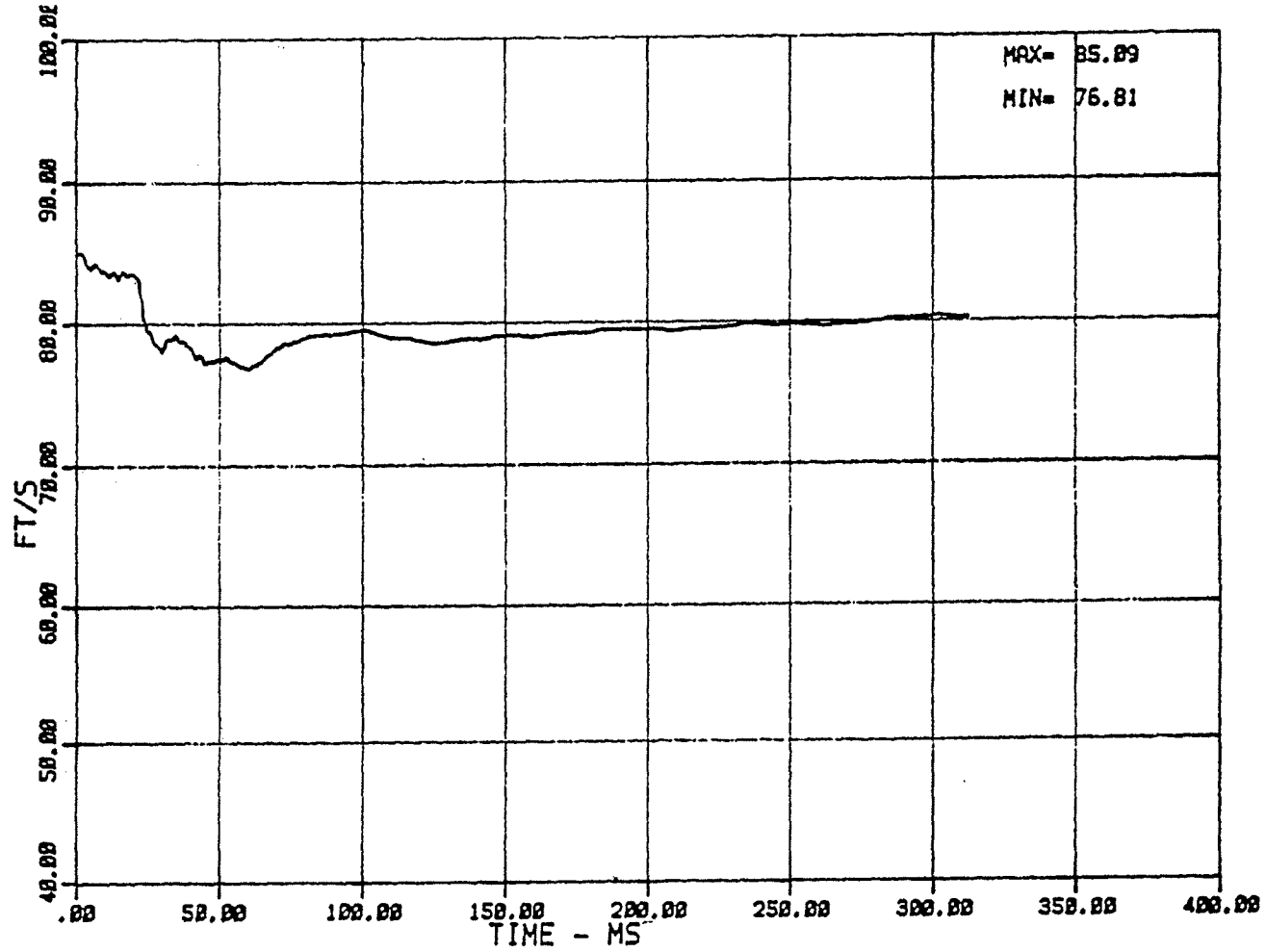
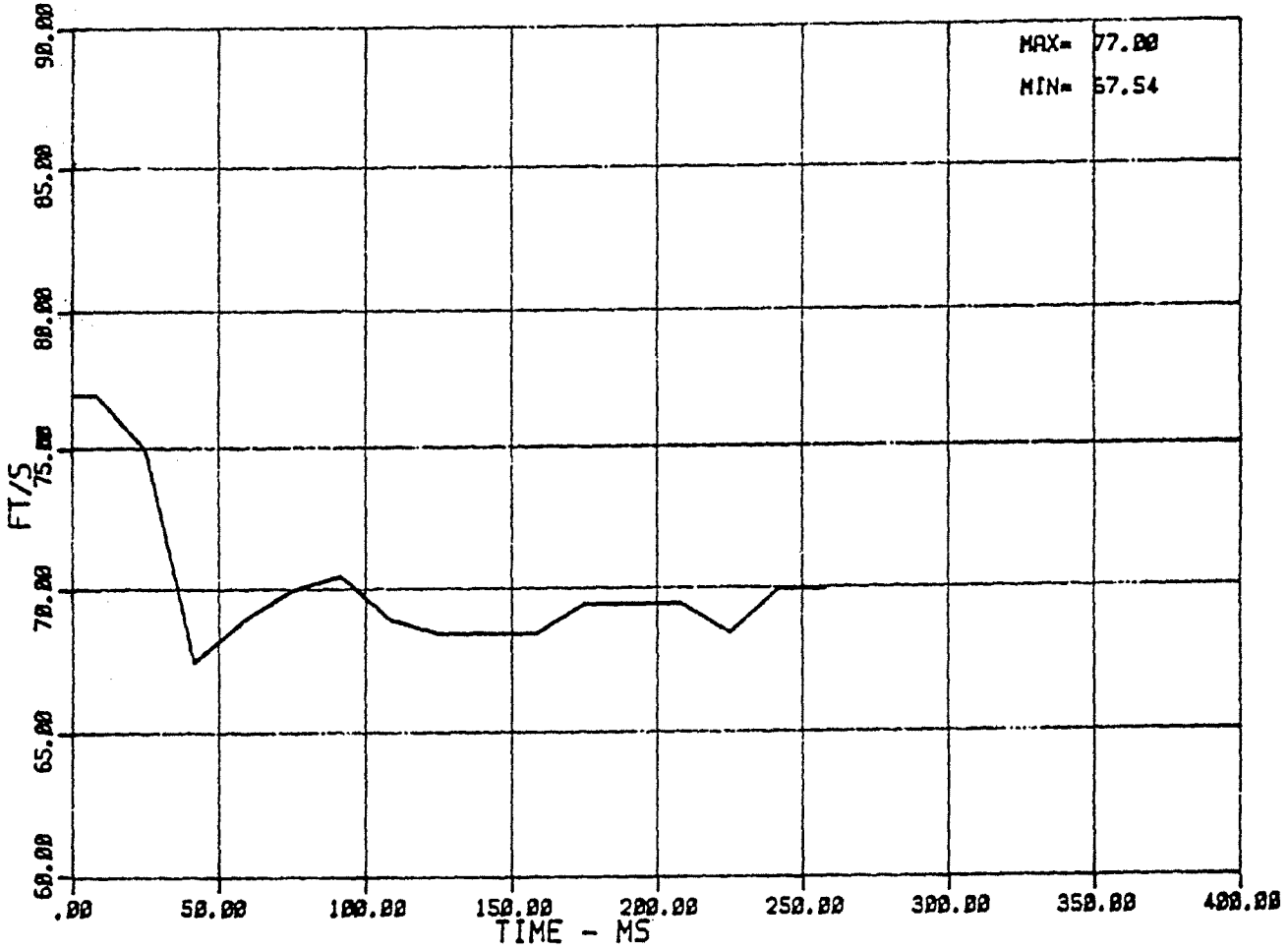


Figure 100. Deceleration time history, z-axis, test no. 6.



VEHICLE VELOCITY DERIVED FROM FIRST INTEGRAL OF X-AXIS ACCEL., CLASS 180 FILTER
FWIS28 VISCONSIN STIFF LEG -- 60 mi/h 04/15/88

Figure 101. Longitudinal-velocity by integration, test no. 6.



VEHICLE VELOCITY DERIVED FROM FILM ANALYSIS
FWIS28 WISCONSIN STIFF NO. 6 - 60 mi/h 04/15/88

Figure 102. Longitudinal-velocity time history, by film analysis, test no. 6.

LUMINAIRE AND SIGN SUPPORT TEST NO. 7, 20 MI/H

1. Introduction

Test No. 7 (Wisconsin Stiff Leg Sign Support 03) was conducted on 26 April 1988 using a 1979 Volkswagen Rabbit with a weight of 1800 ± 50 lb which was guided to impact the test article at the vehicle's front centerline.

2. Test Article

The test article consisted of 2 steel stubs, each 6 1/2 ft in length; 2 steel supports, each 21 ft in length; and 14 sign panels, each 1 ft by 22 ft. This hardware is used to construct a Type D support with a 22-ft by 14-ft sign area. The stubs were set in a 2-ft radius concrete form and then buried in S-1 strong soil so that there was stub projection of 3 in above the level surface. The steel supports were bolted to the stubs using the manufacturer's recommended torque procedure (85 ft-lb). To obtain perpendicularity the supports were shimmed at the slip base in accordance with manufacturer's instructions. The sign boards were then clamped on to the supports one at a time to form the completed sign. Design specifications for the Wisconsin Stiff Leg sign support are presented in figures 4 and 5.

The stubs used are steel slip base stubs, each weighing 144 lb. The I - beam support that was impacted had depth of 12 in, flange width of 4 in, flange thickness of 0.438 in, and web thickness of 0.25 in. The 21-ft I - beam weighted 462 lb. The slip base was rectangular in shape. Dimensions were 24 by 5.5 in by 1.5 in (thick). Four 7/8-in diameter mounting bolts were used. No "keeper plates" were used on the mounting bolts.

3. Data Tables

Tables 40 through 44 show the data from test no. 7. Table 40 shows crash test summary. Table 41 shows test vehicle information. Table

Table 40. Crash test summary, sign support impact, test no. 7

Project: Wisconsin Stiff Leg: Sign Supports

Test: Wisconsin Stiff Leg Sign Support Test 3

Date: 04/26/88 Time: 3:30 PM

Test Articles: Freeway Stiff Leg Sign Support Type D with 22-ft by 14-ft sign.

Vehicle: 1979 Volkswagen Rabbit

Inertial mass:	1845 lb	Test mass:	1845 lb
Pre-Impact speed:	* 30.7 ft/s	Post-Impact:	**19.4 ft/s
	**30.6 ft/s		***19.5 ft/s
Offset distance from vehicle centerline:			0.4 in (right)
Maximum crush:	14.0 in	Rebound:	None
Damage: TAD:	FC1	CDC:	12FCEN6
Maximum deceleration (at c.g.)			16.8 g
Maximum 50 ms average deceleration (at c.g.)			6.0 g
Maximum 10 ms average deceleration (at c.g.)			12.8 g

Number of Data Channels: 3 accelerometers, time zero switch.

Number of High-Speed Cameras: 3, frame rate: 600 fps

* Speed trap

** Film analysis

*** Integration of acceleration data

Table 41. Test vehicle information, test no. 7.

Vehicle Manufacturer:	Volkswagen of America		
Make/Model/Year:	Volkswagen/Rabbit/1979		
Body Style:	2 door hatchback		
VIN:	17930222882	Build Date:	08/78
Engine:	Diesel 90 CID		
Transmission:	Manual 4 speed		
GVWR:	2822 lb		
GAWR:	1609 lb Front	Rear:	1278 lb
Tire Size:	155SR13	Load Range:	B
Tire Pressure:	27 psi	Rear:	31 psi
Date Received:	23 Apr 1988	Color:	Silver

MASS OF VEHICLE AS RECEIVED: lb

Left Front:	662	Right Front:	685
Left Rear:	313	Right Rear:	318
Total Front Mass:	1347	(68.1% of total vehicle mass)	
Total Rear Mass:	631	(31.9% of total vehicle mass)	
Total Mass:	1978		

TEST MASS OF VEHICLE: lb

Left Front:	611	Right Front:	618
Left Rear:	303	Right Rear:	313
Total Front Mass:	1229	(66.6% of total vehicle mass)	
Total Rear Mass:	616	(33.4% of total vehicle mass)	
Total Mass:	1845		

VEHICLE ATTITUDE: in

Left Front:	25.2
Right Front:	25.3
Left Rear:	25.4
Right Rear:	25.7

Table 41. Test vehicle information, test no. 7 (continued).

VEHICLE DIMENSIONS: in			
Length:	155.3		
Width:	68.4		
Wheel-base:	94.4		
Track: Front:	54.7	Rear:	53.5

CENTER OF GRAVITY LOCATION: in	
32.30	behind the front axle
1.78	to the right of centerline
21.60	above ground

Table 42. Vehicle crush data, test no. 7.

Maximum crush of 14.0 in occurred 0.4 in
to the right of the centerline.

Vehicle Rebound: None

Vehicle Speed: (measured Approximate 6 ft forward and from impact)
6 ft aft

Trap No. 1: 20.94 mi/h (30.7 ft/s)
Trap No. 2: 10.77 mi/h (15.8 ft/s)

DAMAGE DIMENSIONS, in:

		Pre-Impact	Post-Impact	Change
Left Side	C_1	151.9	151.3	0.6
	C_2	152.9	149.8	3.1
	C_3	154.0	144.5	9.5
	C_4	154.0	143.0	11.0
	C_5	152.9	149.2	3.7
Right Side	C_6	152.5	153.8	-1.3

Width of Contact: 3.8 in

Table 43. Moving average data - vehicle accelerations, test no. 7.

Vehicle c.g. Acceleration Axis	Moving Average Time (ms)	Maximum Acceleration Value (g's)	Time of Occurance (ms)
x	10	12.8	42.2 - 52.2
x	50	6.0	2.2 - 52.2
y	50	1.3	257.6 - 307.6
z	50	1.6	34.6 - 84.6

Table 44. Data analysis summary sheet, test no. 7.

TEST NUMBER: 7 TEST DATE : 04/26/88

TEST ARTICLE: Wisconsin Stiff Leg Sign Support

MANUFACTURER: Not Available

MODEL NUMBER: Type D with 22-ft by 14-ft sign.

TEST VEHICLE: 1979 Volkswagen Rabbit	VEHICLE WEIGHT (lb)	1845
POLE LENGTH (ft): 21.0	MAST ARM LENGTH (ft)	None
POLE BURIED in: NCHRP S-1 STRONG SOIL		
IMPACT SPEED (ft/s):	CAMERA:	30.6
	SPEED TRAP:	30.7
EXIT SPEED (ft/s):	CAMERA:	19.4
	SPEED TRAP:	15.8
	INTEGRAL Ax:	19.5
CHANGE IN VELOCITY FROM EACH SOURCE (ft/s)	CAMERA:	11.2
	SPEED TRAP:	14.9
	INTEGRAL Ax:	11.2
MOMENTUM CHANGE: (lb-sec reported velocity change multiplied by vehicle mass)		682.3
MAX FORCE (kips, peak x-axis deceleration * velocity weight)		31.0
MAX ACCELERATION (g's, peak x-axis deceleration)		16.8
MAXIMUM MEASURED VEHICLE CRUSH LENGTH (in, static)		14.0
LONGITUDINAL OCCUPANT IMPACT VELOCITY (ft/s, NCHRP 230)		11.1
LONGITUDINAL OCCUPANT RIDEDOWN ACCEL. (g's , NCHRP 230)		1.8
MAX 50 MS AVERAGE DECELERATION (g's)		
	X-AXIS	6.0
	Y-AXIS	1.3
	Z-AXIS	1.6
VEHICLE VELOCITY CHANGE: (Weighted average of three values)		11.9 ft/s

42 shows test vehicle crush data. Table 43 shows test vehicle moving average acceleration data and table 44 shows the results from the data analysis.

4. Test Results

The vehicle impacted the pole 0.4 in to the right of the lateral centerline. The impact velocity was 20.88 mi/h. The bumper was displaced rearward 14 in at the impact location. The undercarriage was also pushed in along with the bumper. Two areas of slight scratches and denting of the hood indicate secondary impacts of the support with the vehicle. This occurred as the support bounced or slid its way across the right side of the hood and out of the way of the moving vehicle. These secondary impacts occurred approximately 12 in and 26 in to the right of vehicle centerline. There was no damage to the windshield or roof of the vehicle. Vehicle crush data are presented in table 42.

The impact support broke away cleanly from the stub foundation. The support was knocked ahead of the car but was impacted again with much less force as the support bounced or slid its way along to the right and out of the way of the vehicle. The base of the impact support came to rest 17 ft aft of the impact and 5 ft towards the second support. The bottom 9 sign panels were still attached to the second support. The sign itself stayed basically together and remained attached to the impacted support. The impacted support did fall to the ground - it remained standing at an awkward angle.

The sign boards appeared to touch the top of the vehicle, but there was no noticeable damage to the test vehicle as a result of the sign board contact.

Summary of Compliance with AASHTO and NCHRP Specifications

AASHTO Specifications

The Wisconsin Stiff Leg sign support Type D with 22-ft by 14-ft sign appears to meet all AASHTO specifications. The pole completely broke away in the desired fashion leaving less than the maximum 4 in of stub height allowed. The velocity change of the test vehicle was less than the 15-ft/s maximum.

NCHRP Specifications

The dynamics of this test seem to adhere to the NCHRP specifications except for a slight deviation in trajectory after impact. The support broke completely away and no elements of the supports or sign penetrated the passenger compartment. The vehicle remained upright with no passenger compartment deformation or intrusion. The longitudinal impact velocity was less than maximum allowed value of 15 ft/s. The longitudinal ridedown acceleration was less than the maximum allowed value of 15 g's. The vehicle did pull slightly to the right off of trajectory line due to the continued contact with support.

5. Photographic Coverage

Figures 103 through 112 show the test area, the test article and the posttest photographs of the test vehicle and the test article.

6. Data Plots

The data plots from test no. 7 are shown in figures 113 through 117.

Figure 103. Test area elevated view, pretest, test no. 7.

Figure 104. Test article, pretest, test no. 7.

Figure 105. Test area elevated view, posttest, test no. 7.

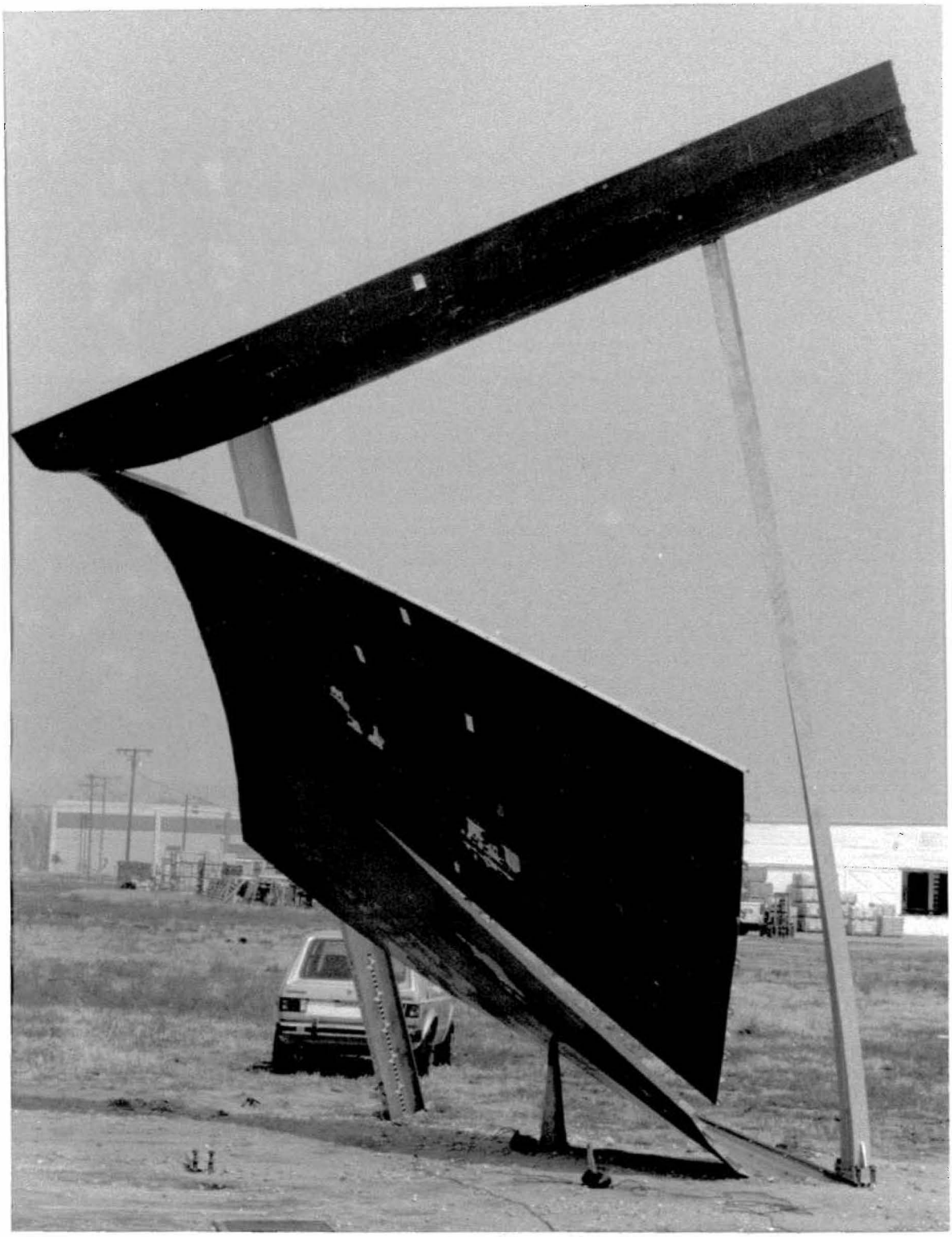


Figure 106. Test article on the ground, posttest, test no. 7.

Figure 107. Full left side view, posttest, test no. 7.

Figure 108. Full right side view, posttest, test no. 7.

Figure 109. Left front 3/4 view, posttest, test no. 7.

Figure 110. Right front 3/4 view, posttest, test no. 7.

Figure 111. Full front view, posttest, test no. 7.

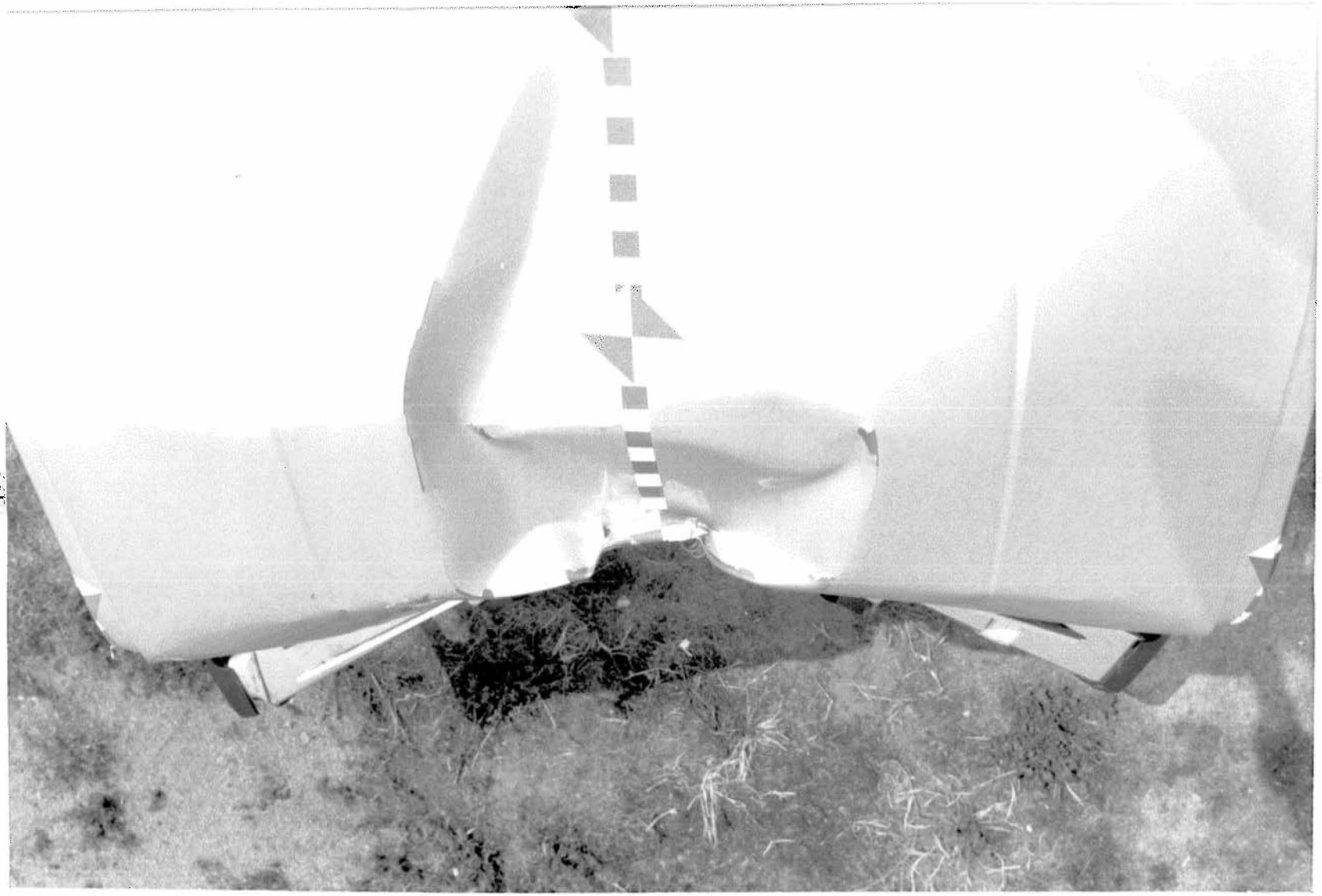


Figure 112. Impact location overhead view, posttest, test no. 7.

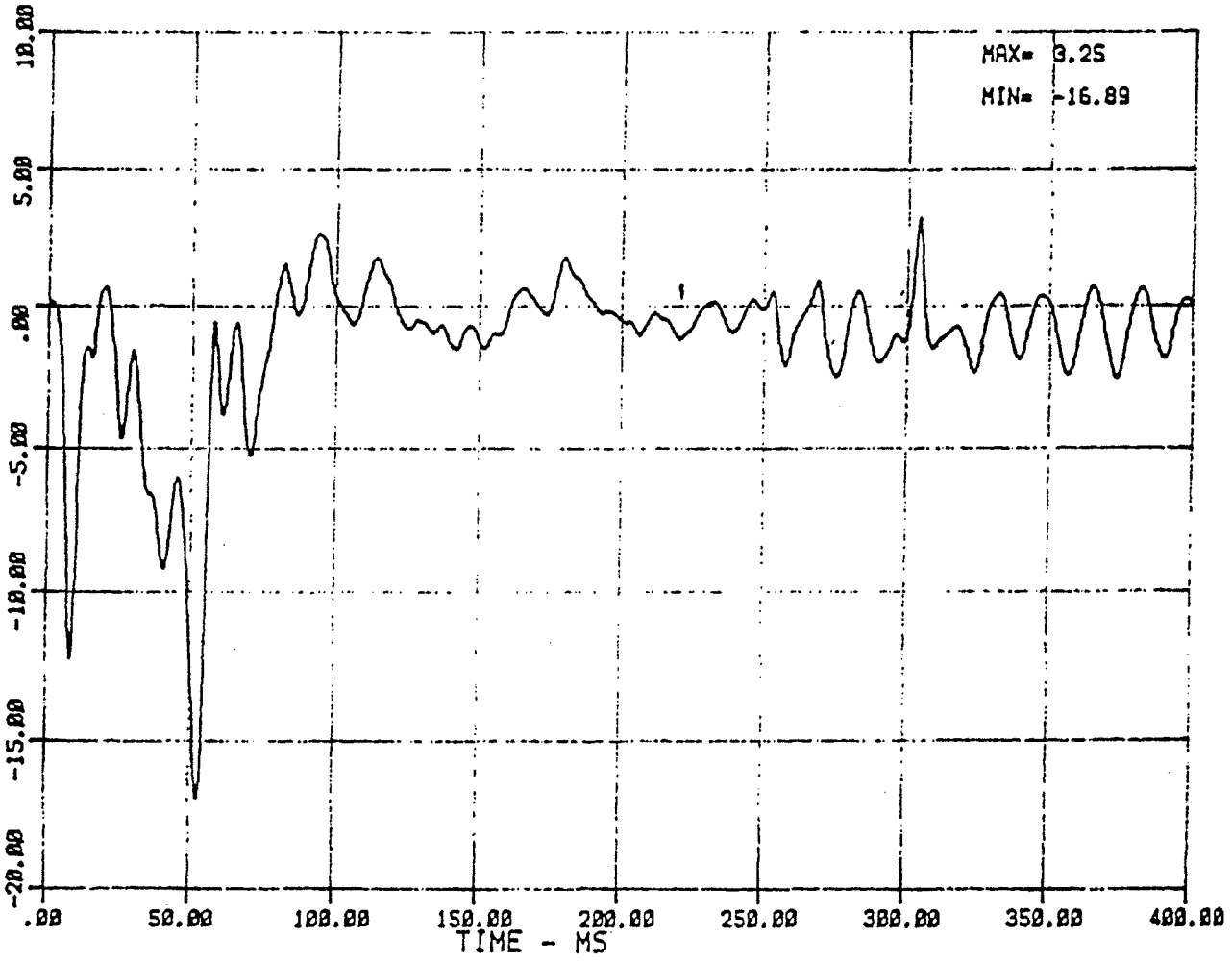


Figure 113. Deceleration time history, x-axis, test no. 7.

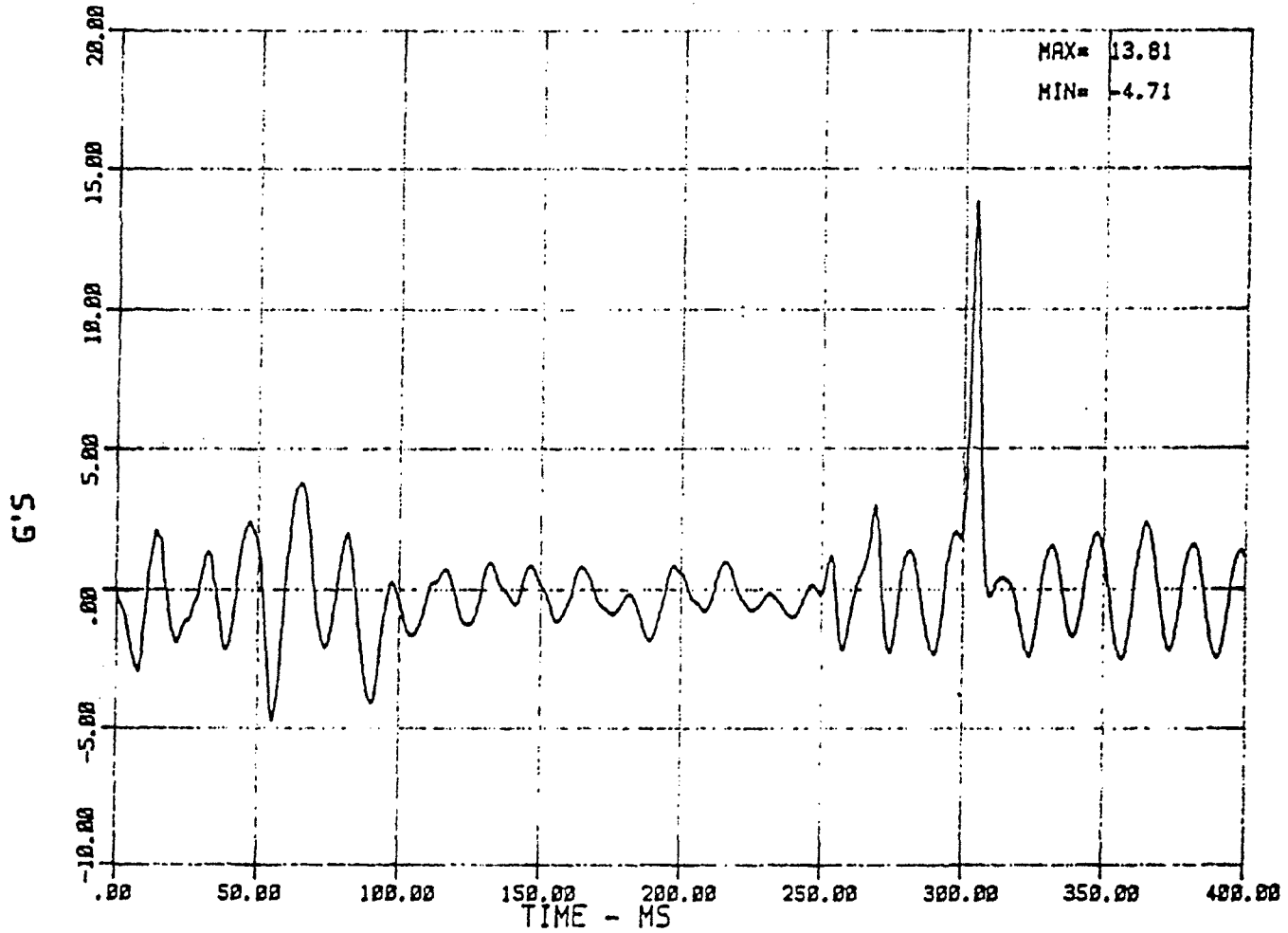


Figure 114. Deceleration time history, y-axis, test no. 7.

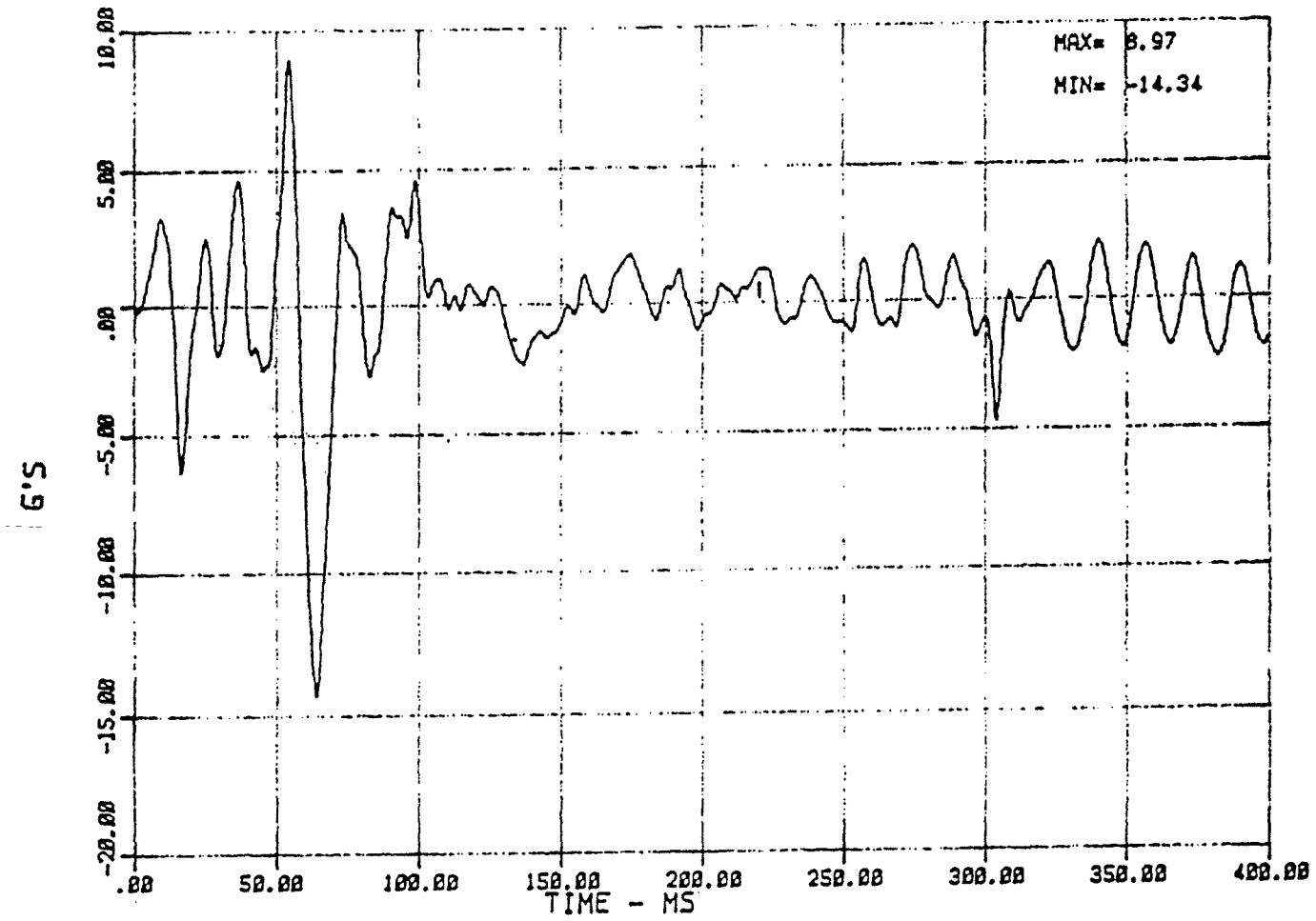


Figure 115. Deceleration time history, z-axis, test no. 7.

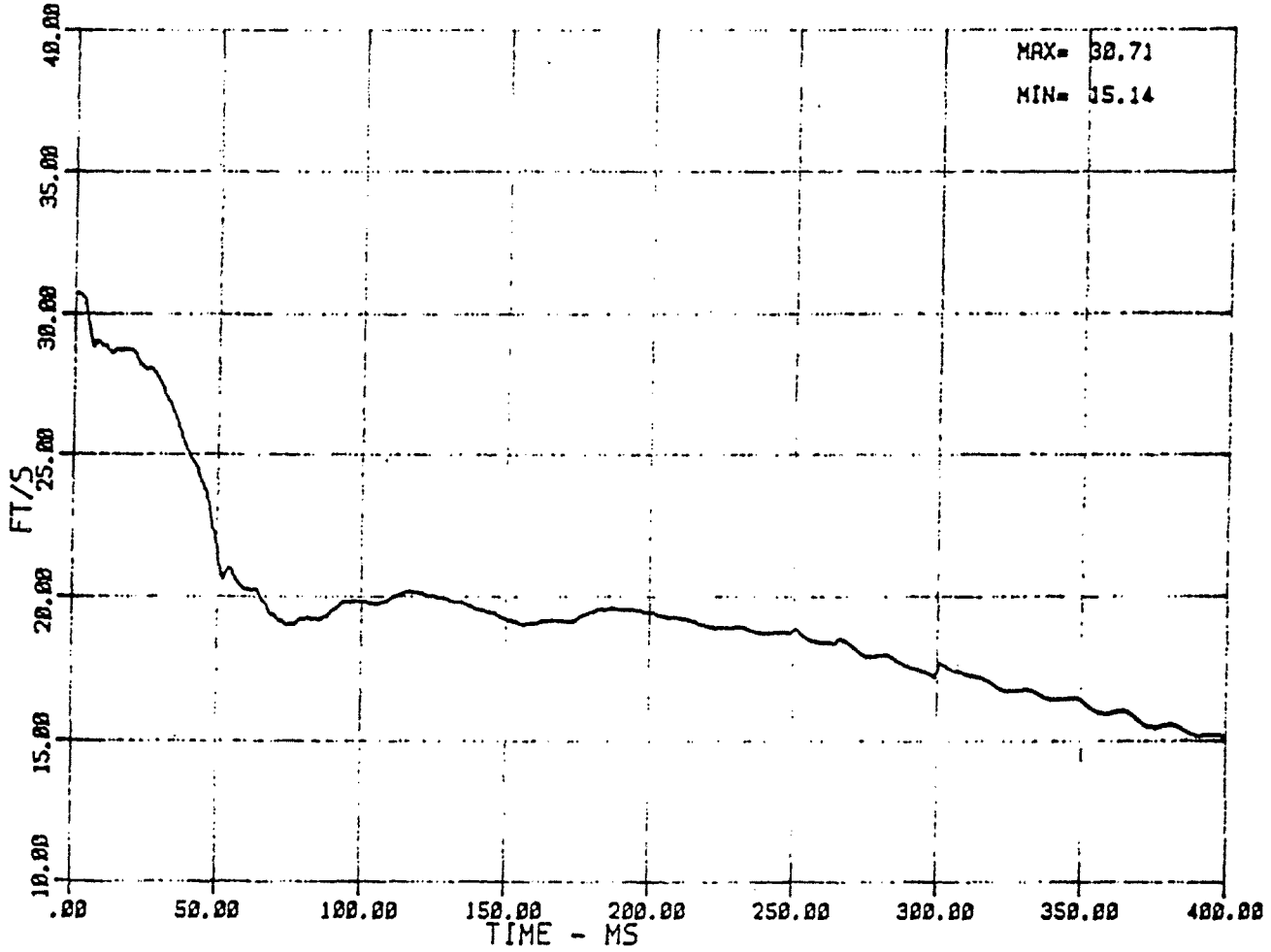


Figure 116. Longitudinal-velocity time history by integration, test no. 7

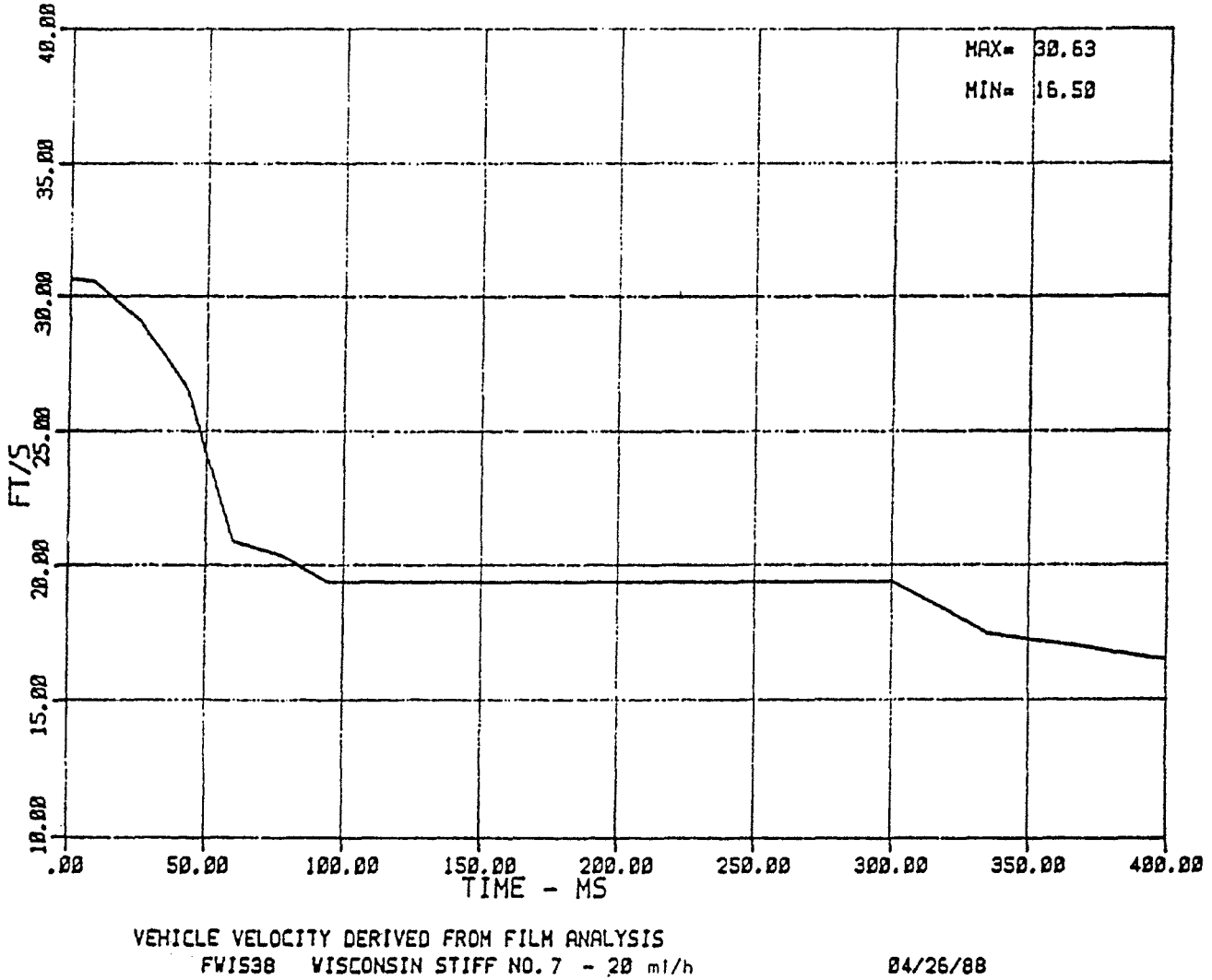


Figure 117. Longitudinal-velocity time history, by film analysis, test no. 7.

LUMINAIRE AND SIGN SUPPORT TEST NO. 8, 60 MI/H

1. Introduction

Test no. 8 (Wisconsin Stiff Leg Sign Support 04) was conducted on 06 May 1988 using a 1979 Volkswagen Rabbit with a weight of 1800 ± 50 lb which was guided to impact the test article at the vehicle's front centerline. This is the high-speed companion test to the low-speed test, test no. 7.

2. Test Article

The test article consisted of 2 steel stubs, each 6 1/2 ft in length; 2 steel supports, each 21 ft in length, and 14 sign panels each 1 ft by 22 ft. This hardware is used to construct a Type D support with a 22-ft by 14-ft sign. The stubs were set in a 2-ft radius concrete form and then buried in S-1 strong soil so that there was stub projection of 3 in above the track level surface. The steel supports were bolted to the stubs using the manufacturer's recommended torque procedure (85 ft-lb). To obtain perpendicularity the supports were shimmed at the slip base in accordance with manufacturer's instructions. The sign boards were then clamped on to the supports one at a time to form the completed sign. Design specifications for the Wisconsin Stiff Leg sign support are presented in figures 4 and 5.

The stubs used are steel slip base stubs, each weighing 144 lb. The I - beam support that was impacted had depth of 12 in, flange width of 4 in, flange thickness of 0.438 in, and web thickness of 0.25 in. The 21-ft I - beam weighted 462 lb. The slip base was rectangular in shape. Dimensions were 24 by 5.5 in by 1.5 in (thick). Four 7/8-in diameter mounting bolts were used. No "keeper plates" were used on the mounting bolts.

3. Data Tables

Tables 45 through 49 show the data from test no. 8. Table 45 shows crash test summary. Table 46 shows test vehicle information. Table 47 shows test vehicle crush data. Table 48 shows test vehicle moving average acceleration data and table 49 shows the results from the data analysis.

4. Test Results

The vehicle impacted the pole 5.0 in to the left of the lateral centerline. The impact velocity was 59.8 mi/h. The bumper was displaced rearward 17.25 in at the impact location. The undercarriage was also pushed in along with the bumper. The vehicle's radiator was pushed into the engine and major damage was done to the hood. The front quarter panels were bent slightly inward towards the vehicle front. No damage was done to the windshield or roof of the vehicle. The vehicle came to rest in a straight line with the initial pre-impact trajectory. Vehicle crush data are presented in table 47.

The test article seemed to perform in the desired breakaway fashion. The impact support was knocked cleanly away from the stub and was thrown up and over the vehicle which passed easily underneath the support. The impact support landed with its base 30 ft back of the impact point and the second support stayed upright and vertical. The sign panels separated cleanly from both supports and landed approximately 2 ft back from the impact point. The sign came apart in 2 pieces, the bottom 10 panels landing on top of the upper 4 panels. The sign panels did not cause any damage to the roof of the test vehicle.

Table 48 shows the vehicle acceleration data in the form of 50 ms moving average for the x, y, and z axes.

Table 45. Crash test summary, sign support impact, test no. 8

Project: Wisconsin Stiff Leg Sign Supports

Test: Wisconsin Stiff Leg Sign Support Test 4

Date: 05/06/88 Time: 1:30 PM

Test Articles: Freeway Stiff Leg Sign Support Type D with 22-ft by 14-ft sign.

Vehicle: 1979 Volkswagen Rabbit

Inertial mass:	1822 lb	Test mass:	1822 lb
Pre-Impact speed:	*87.7 ft/s	Post-Impact:	**77.5 ft/s
	**87 5 ft/s		***78.3 ft/s
Offset distance from vehicle centerline:			5.0 in (left)
Maximum crush:	17.25in	Rebound:	None
Damage: TAD:	FC1	CDC:	12FCEN5
Maximum deceleration (at c.g.)			29.6 g
Maximum 50 ms average deceleration (at c.g.)			7.6 g
Maximum 10 ms average deceleration (at c.g.)			19.4 g

Number of Data Channels: 3 accelerometers, time zero switch.

Number of High-Speed Cameras: 3, frame rate: 600 fps

* Speed trap

** Film analysis

*** Integration of acceleration data

Table 46. Test vehicle information, test no. 8.

Vehicle Manufacturer:	Volkswagen of America		
Make/Model/Year:	Volkswagen/Rabbit/1979		
Body Style:	2 door hatchback		
VIN:	1793317269	Build Date:	01/79
Engine:	4 cyl. gasoline		
Transmission:	Manual 4 speed		
GVWR:	2822 lb		
GAWR:	1609 lb Front	Rear:	1278 lb
Tire Size:	155SR13	Load Range:	B
Tire Pressure:	27 psi	Rear:	31 psi
Date Received:	14 Apr 1988	Color:	Green

MASS OF VEHICLE AS RECEIVED: lb

Left Front:	666	Right Front:	686
Left Rear:	314	Right Rear:	316
Total Front Mass:	1352	(68.2% of total vehicle mass)	
Total Rear Mass:	630	(31.8% of total vehicle mass)	
Total Mass:	1982		

TEST MASS OF VEHICLE: lb

Left Front:	593	Right Front:	615
Left Rear:	301	Right Rear:	313
Total Front Mass:	1208	(66.3% of total vehicle mass)	
Total Rear Mass:	614	(33.7% of total vehicle mass)	
Total Mass:	1822		

VEHICLE ATTITUDE: in

Left Front:	24.0
Right Front:	24.2
Left Rear:	25.1
Right Rear:	25.4

Table 46. Test vehicle information, test no. 8 (continued).

VEHICLE DIMENSIONS: in

Length:	155.3		
Width:	68.4		
Wheel-base:	94.4		
Track: Front:	54.7	Rear:	53.5

CENTER OF GRAVITY LOCATION: in

32.30	behind the front axle
1.78	to the right of centerline
21.60	above ground

Table 47. Vehicle crush data, test no. 8.

Maximum crush of 17.25 in occurred 5.0 in
to the left of the centerline.

Vehicle Rebound: None

Vehicle Speed: (measured Approximate 6 ft forward and 6 ft aft from impact)

Trap No. 1: 59.8 mi/h (87.7 ft/s)
Trap No. 2: 50.5 mi/h (74.1 ft/s)

DAMAGE DIMENSIONS, in:

		Pre-Impact	Post-Impact	Change
Left Side	C_1	152.1	145.5	6.6
	C_2	153.0	153.75	-0.75
	C_3	153.3	136.1	17.25
	C_4	153.2	145.0	8.2
	C_5	153.0	154.0	-1.0
Right Side	C_6	151.8	145.1	6.7

Width of Contact: 3.8 in

Table 48. Moving average data - vehicle accelerations, test no. 8.

Vehicle c.g. Acceleration Axis	Moving Average Time (ms)	Maximum Acceleration Value (g's)	Time of Occurance (ms)
x	10	19.4	15.25 - 25.25
x	50	7.6	.625 - 50.625
y	50	1.0	27.25 - 77.25
z	50	4.6	28.875 - 78.875

Table 49. Data analysis summary sheet, test no. 8.

TEST NUMBER: 8 TEST DATE : 05/06/88

TEST ARTICLE: Wisconsin Stiff Leg Sign Support

MANUFACTURER: Not Available

MODEL NUMBER: Type D with 22-ft by 14-ft sign.

TEST VEHICLE: 1979 Volkswagen Rabbit VEHICLE WEIGHT (lb) 1822

POLE LENGTH (ft): 21.0 MAST ARM LENGTH (ft) None

POLE BURIED in: NCHRP S-1 STRONG SOIL

IMPACT SPEED (ft/s):	CAMERA:	87.5
	SPEED TRAP:	87.7
EXIT SPEED ft/s):	CAMERA:	77.5
	SPEED TRAP:	74.1
	INTEGRAL Ax:	78.3
CHANGE IN VELOCITY FROM EACH SOURCE (ft/s)	CAMERA:	10.0
	SPEED TRAP:	13.6
	INTEGRAL Ax:	9.4
MOMENTUM CHANGE: (lb-sec reported velocity change multiplied by vehicle mass)		594.6
MAX FORCE (kips, peak x-axis deceleration * velocity weight)		53.9
MAX ACCELERATION (g's, peak x-axis deceleration)		29.6
MAXIMUM MEASURED VEHICLE CRUSH LENGTH (in, static)		17.25
LONGITUDINAL OCCUPANT IMPACT VELOCITY (ft/s, NCHRP 230)		9.4
LONGITUDINAL OCCUPANT RIDEDOWN ACCEL. (g's , NCHRP 230)		1.2
MAX 50 MS AVERAGE DECELERATION (g's)		
	X-AXIS	7.6
	Y-AXIS	1.0
	Z-AXIS	4.6
VEHICLE VELOCITY CHANGE: (Weighted average of three values)		10.5 ft/s

Summary of Compliance with AASHTO and NCHRP Specifications

AASHTO Specifications

This test of a Wisconsin Stiff Leg sign support Type D with a 22-ft by 14-ft sign appears to meet all AASHTO specifications. The pole completely broke away in the desired fashion leaving less than the maximum 4 in of stub height allowed. The velocity change of the test vehicle was less than the 15-ft/s maximum.

NCHRP Specifications

The dynamics of this test seem to adhere to the NCHRP specifications except for a slight deviation in trajectory after impact. The support broke completely away, and no elements of the supports or sign penetrated the passenger compartment. The vehicle remained upright with no passenger compartment deformation or intrusion. The longitudinal impact velocity was less than maximum allowed value of 15 ft/s. The longitudinal ridedown acceleration was less than the maximum allowed value of 15 g's. The vehicle did pull slightly to the right off of a straight line trajectory due to the continued contact with support; however, this deviation was not considered significant.

5. Photographic Coverage

Figures 118 through 127 show the test area, the test article and the posttest photographs of the test vehicle and the test article.

6. Data Plots

The data plots from test no. 8 are shown in figures 128 through 132.

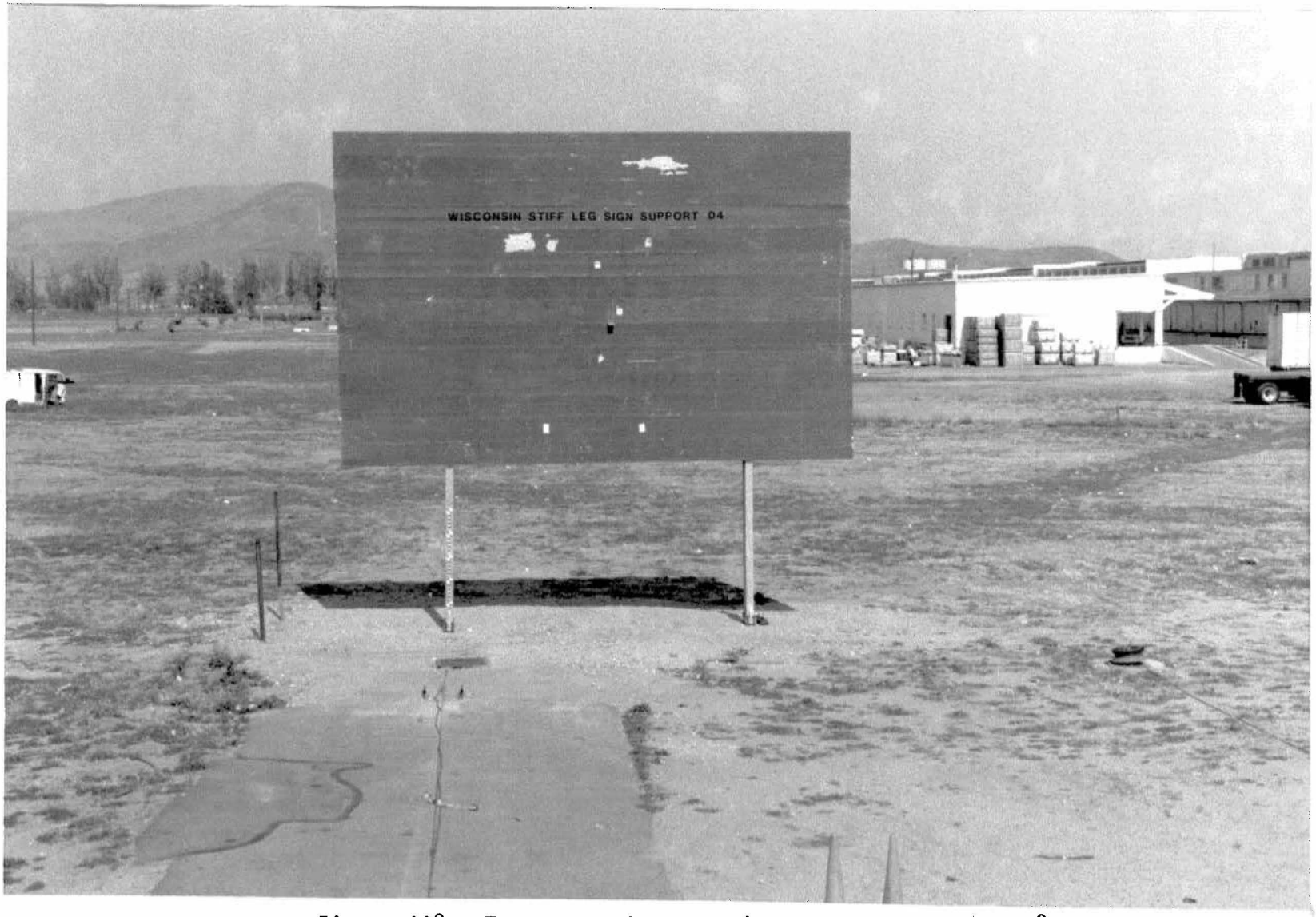


Figure 118. Test area elevated view, pretest, test no. 8.

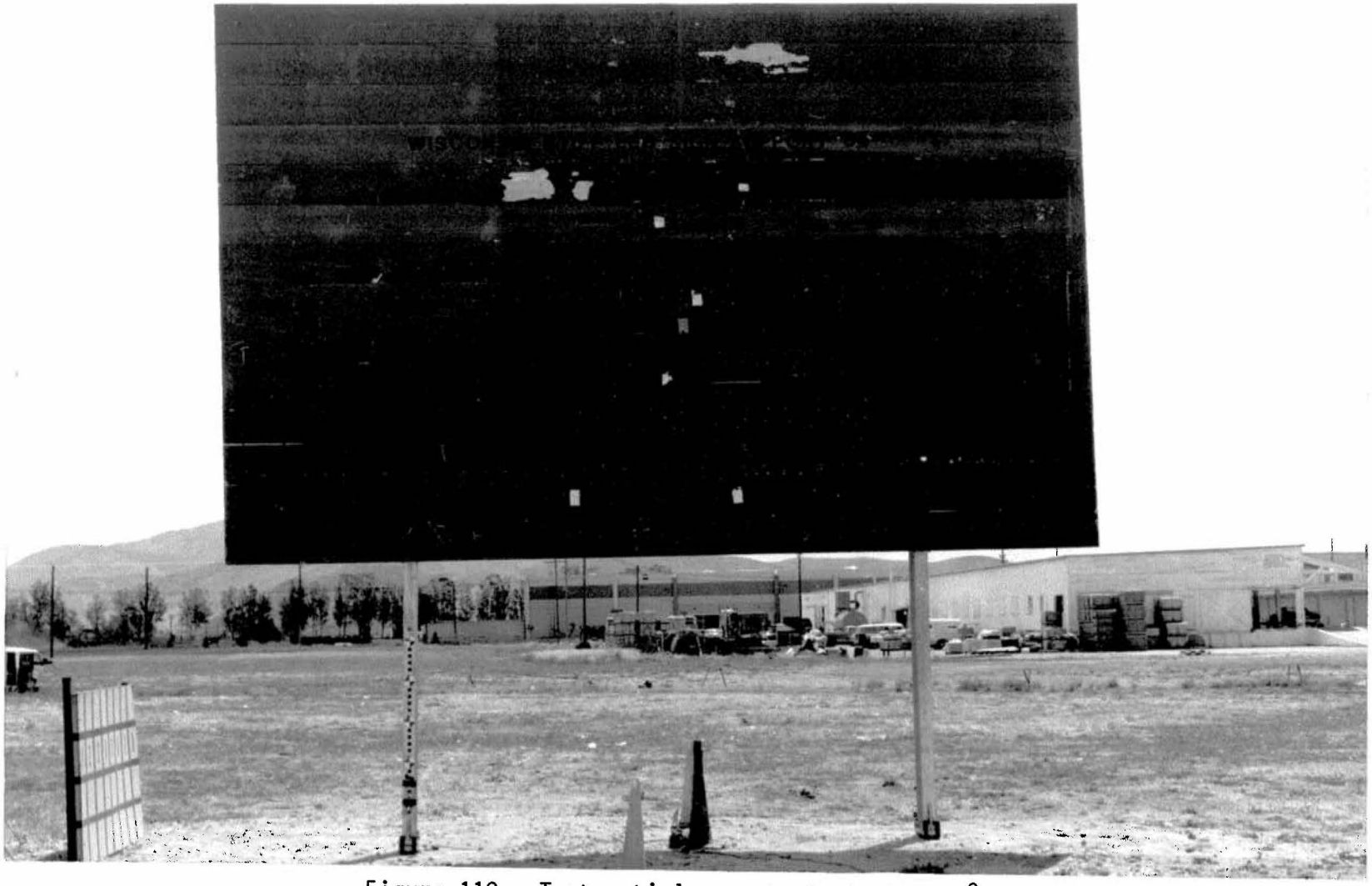


Figure 119. Test article, pretest, test no. 8.

Figure 120. Test area elevated view, posttest, test no. 8.

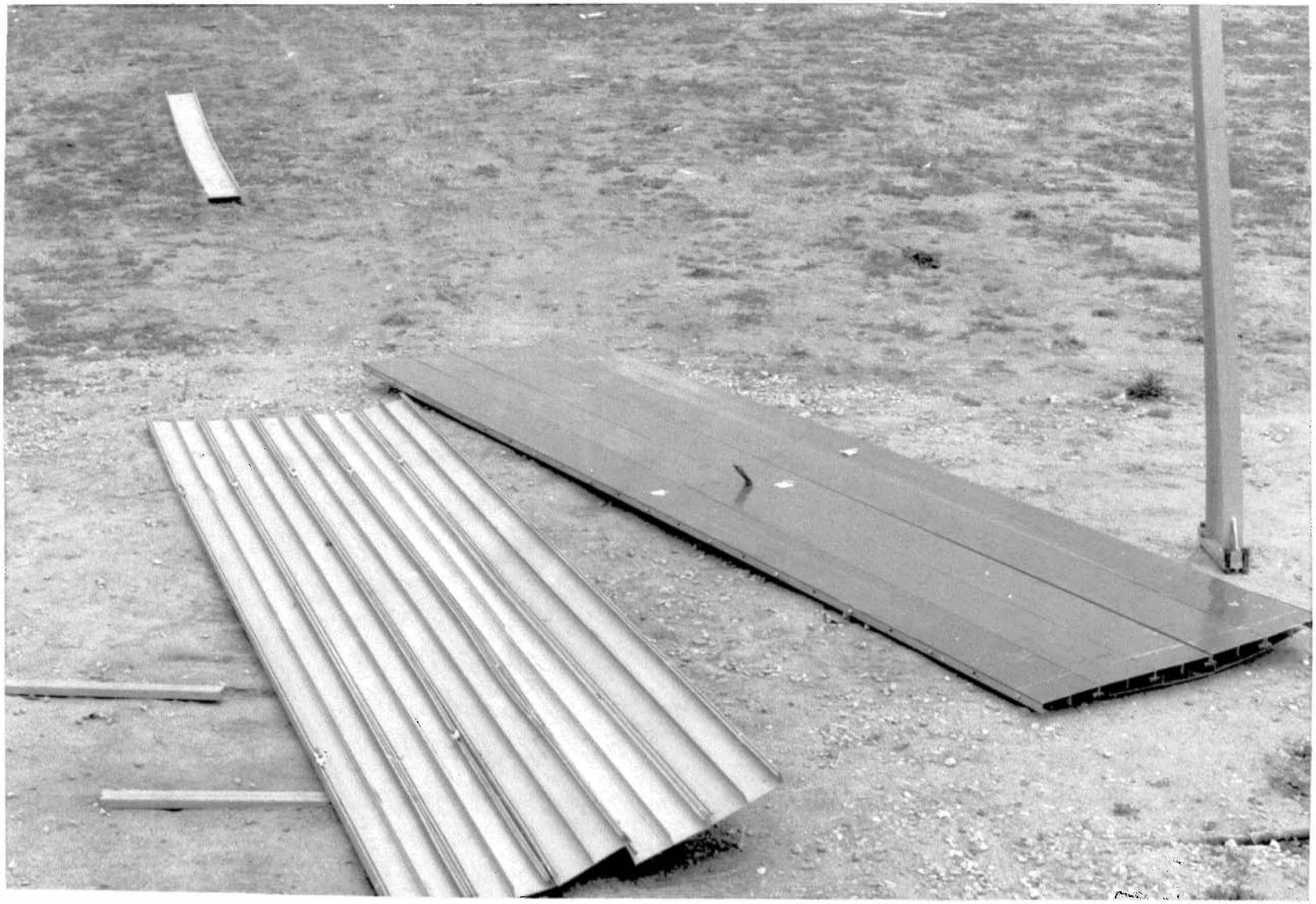


Figure 121. Test article on the ground, posttest, test no. 8.

Figure 122. Full left side view, posttest, test no. 8.

Figure 123. Full right side view, posttest, test no. 8.

Figure 124. Left front 3/4 view, posttest, test no. 8.

Figure 125. Right front 3/4 view, posttest, test no. 8.

Figure 126. Full front view, posttest, test no. 8.

Figure 127. Impact location overhead view, posttest, test no. 8.

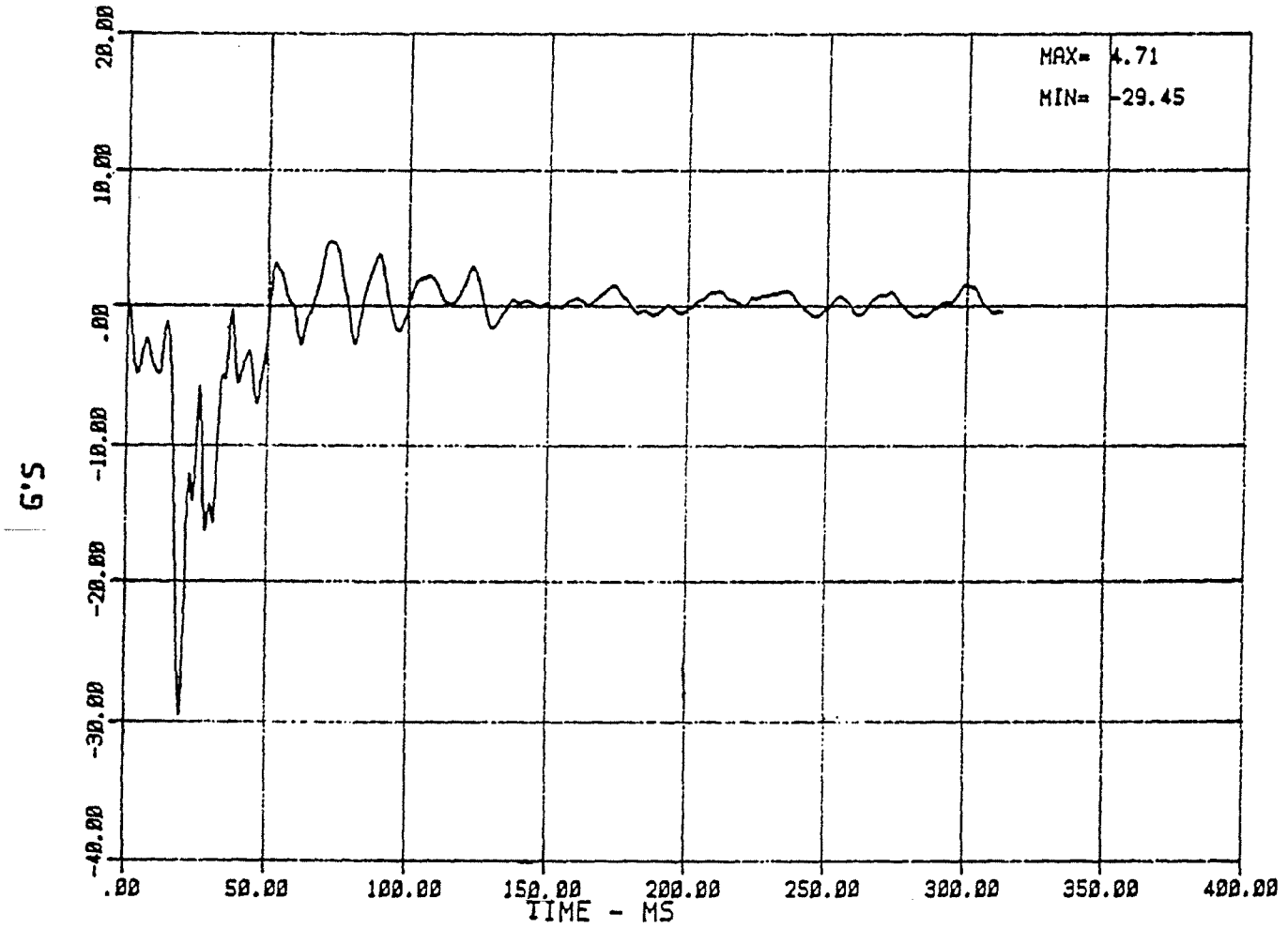


Figure 128. Deceleration time history, x-axis, test no. 8.

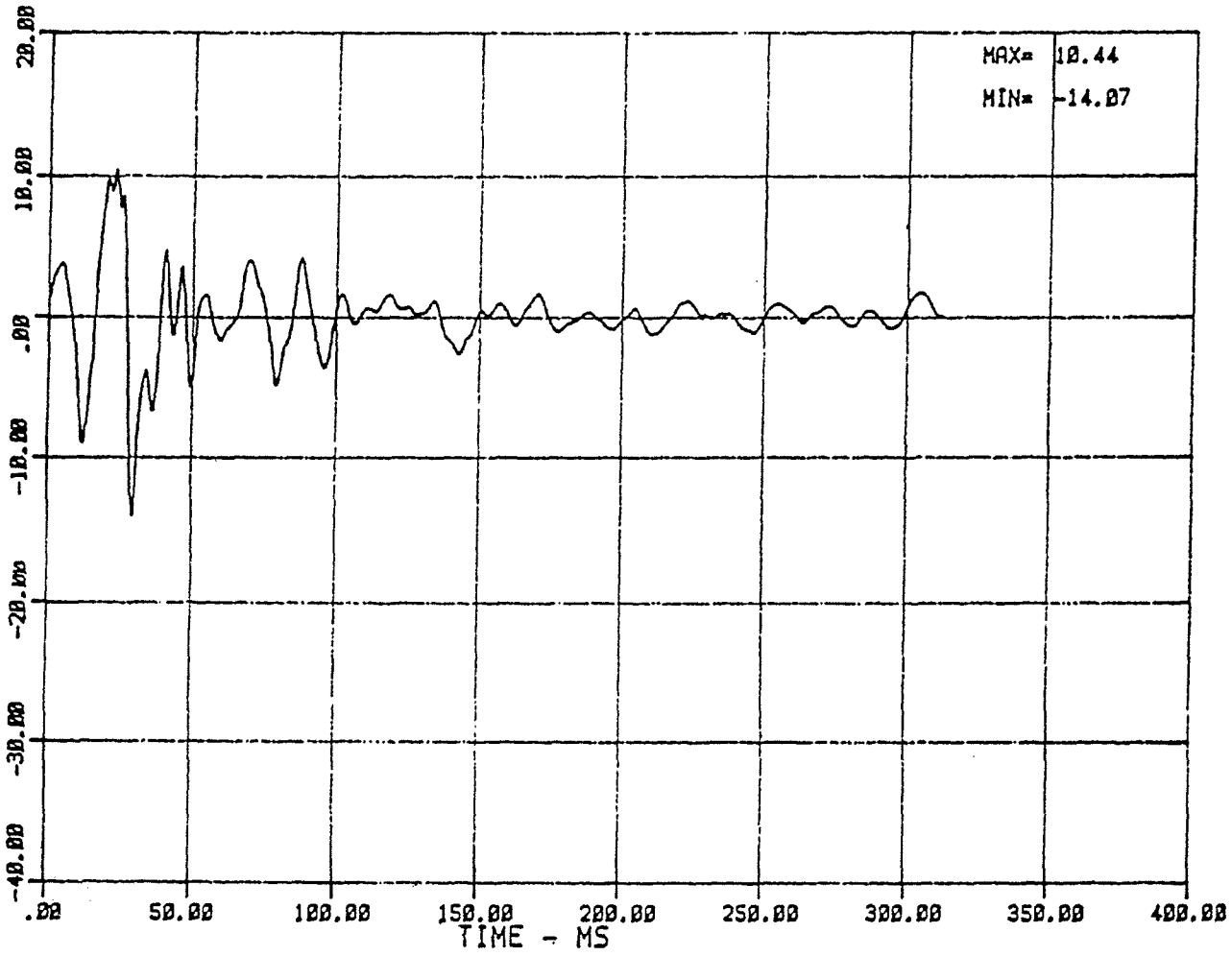


Figure 129. Deceleration time history, y-axis, test no. 8.

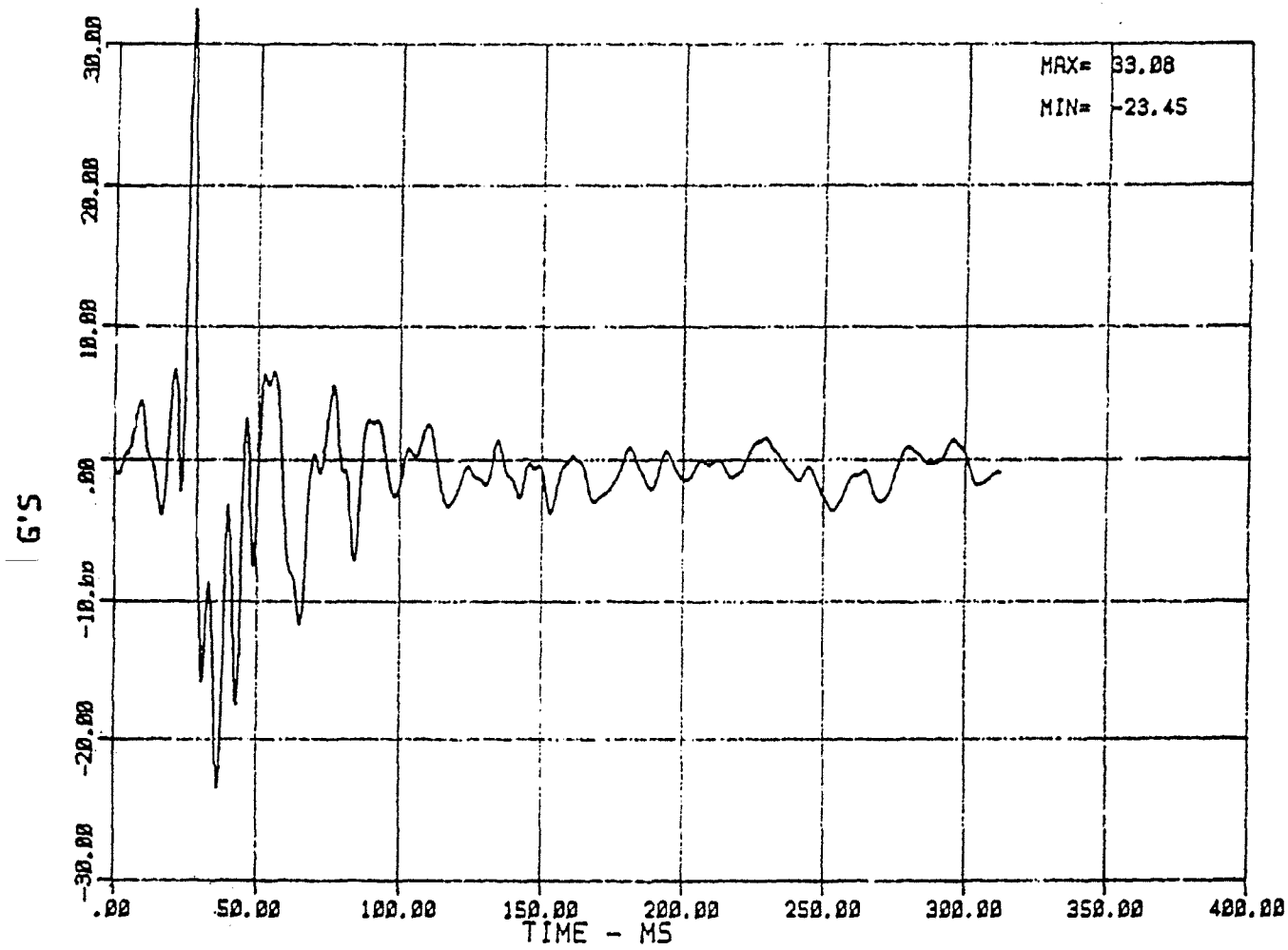
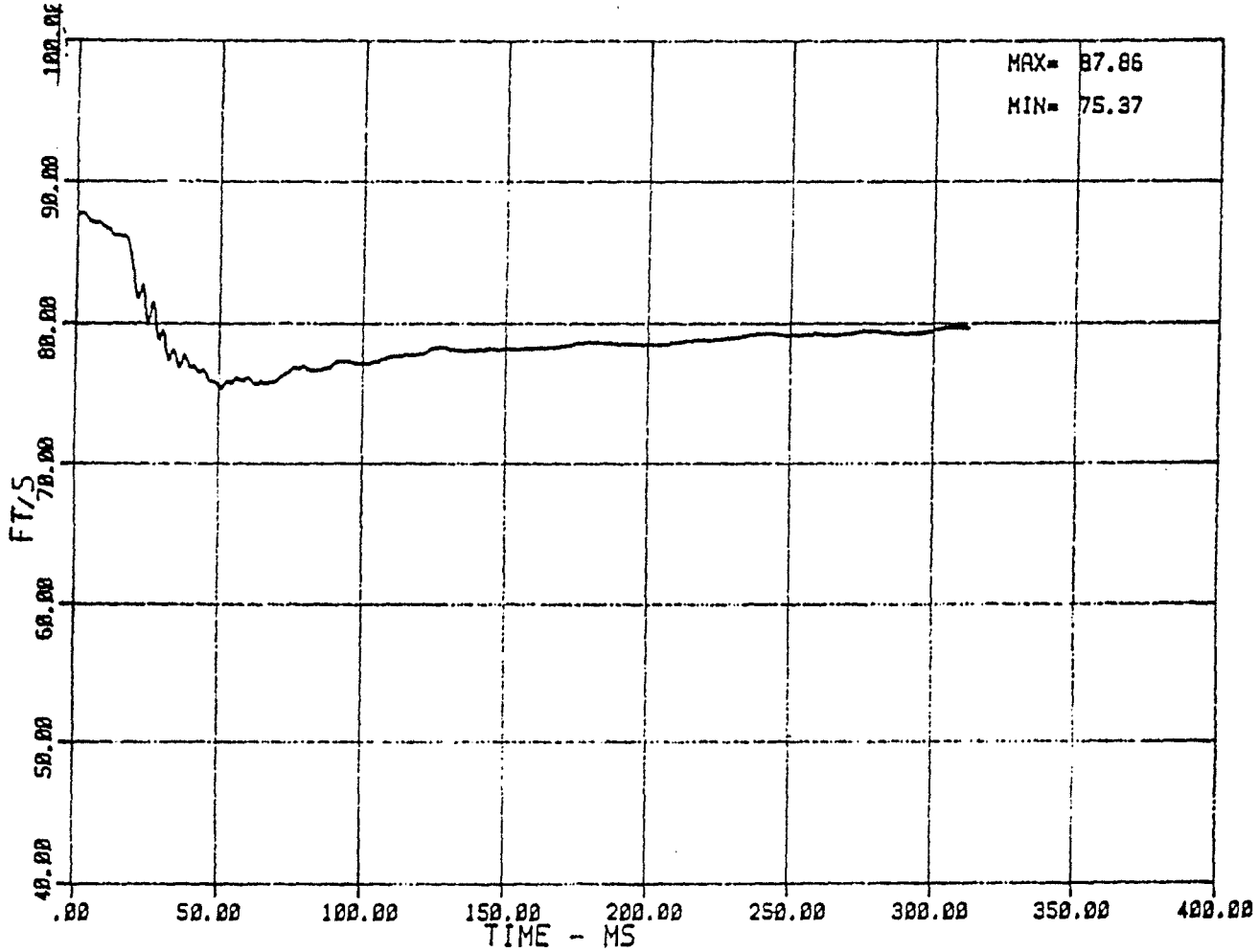


Figure 130. Deceleration time history, z-axis, test no. 8.



VEHICLE VELOCITY DERIVED FROM INTEGRATION OF X-AXIS ACCELERATION, CLASS 180 FILTER
FWIS48 WISCONSIN STIFF NO. 8 - 60 mi/h 05/06/88

Figure 131. Longitudinal-velocity time history by integration, test no. 8.

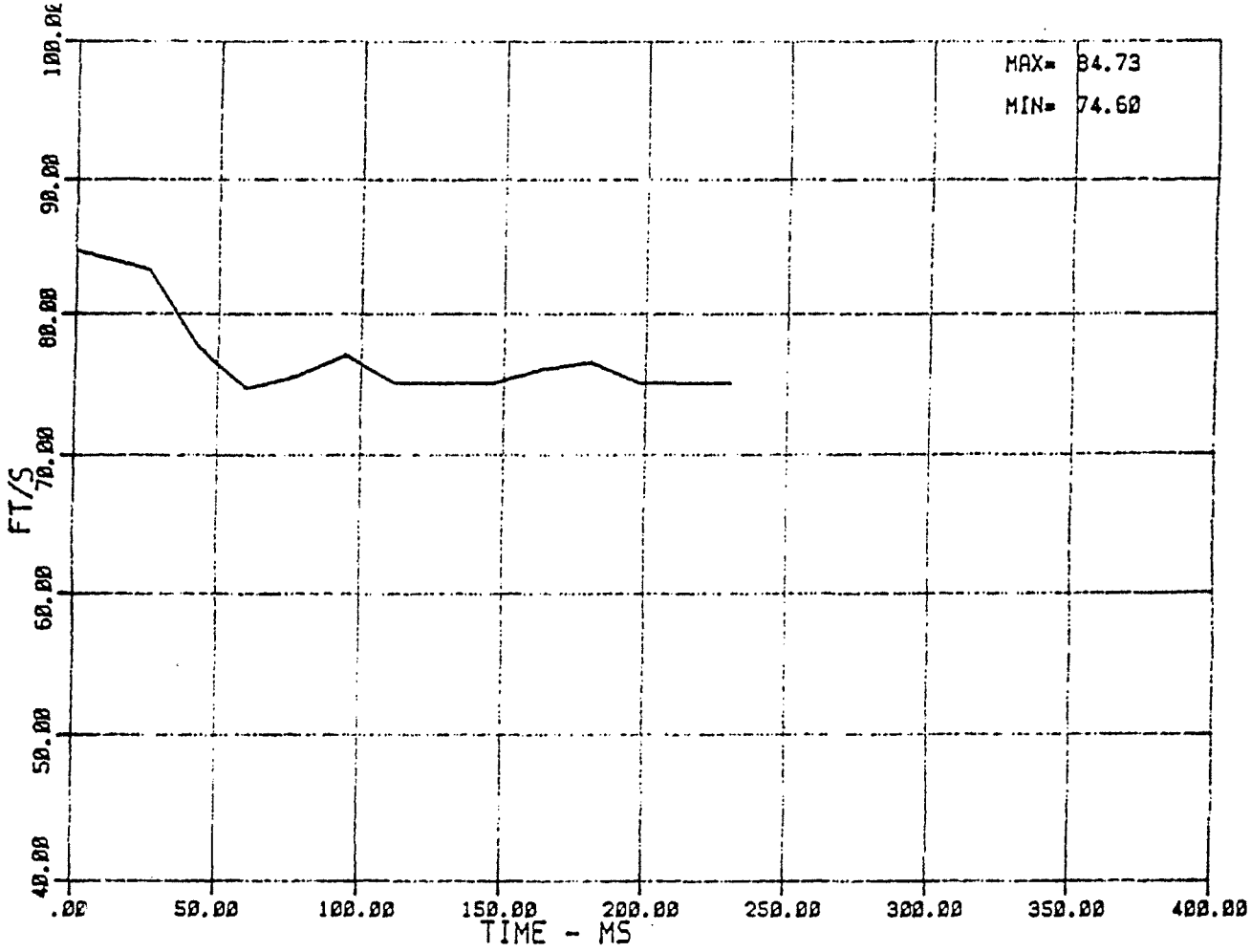


Figure 132. Longitudinal-velocity time history, by film analysis, test no. 8.

REFERENCES

(1) American Association of the State Highway and Transportation Officials, Standard Specification for structural Supports for Highway Signs, Luminaires and Traffic Signals-1985. (Washington, D.C. 1985).

(2) Transportation Research Board of the National Research Council, Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances, National Cooperative Highway Research Program Report 230 (Washington, D.C., March 1981).

(3) Society of Automotive Engineers, Inc., Instrumentation for Impact Tests - SAE J211b, SAE Recommended Practice, (SAE Handbook 1987), (Warrendale, PA 1987).