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16. Abstract

Seven full-scale crash tests were conducted to evaluate the impact behavior of thin-wall steel tube signposts and delineator posts. Tests were conducted in accordance with current guidelines, and the results were evaluated in terms of AASHTO safety performance specifications for sign supports. All tests involved single-post installations. In terms of AASHTO specifications, the following was found:

1. A 3.50 in. (8.89 cm) O.D. by 0.083 in. (0.17 cm) and a 2.875 in. (7.30 cm) O.D. by 0.120 in. (0.30 cm) signpost in a concrete footing do not satisfy specifications.
2. A 2.875 in. (7.30 cm) O.D. by 0.120 in. (0.30 cm) signpost with sleeve and base in concrete is marginally acceptable.
3. A 2.875 in. (7.30 cm) O.D. by 0.065 in. (0.17 cm) and a 2.375 in. (6.03 cm) O.D. by 0.109 in. (0.28 cm) signpost in a concrete footing satisfy specifications.
4. A 1.66 in. (4.22 cm) O.D. by 0.047 in. (0.12 cm) delineator post and a 1.90 in. (4.83 cm) O.D. by 0.065 in. (0.17 cm) mile marker post satisfy specifications.

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IMPACT BEHAVIOR OF THIN-WALL STEEL
TUBE SIGNPOSTS AND DELINEATOR POST

by

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Research Report 264-1F

on

Research Study No. 2-5-78-264
CRASH TESTING SIGN AND DELINEATOR POSTS

Sponsored by

Texas State Department of Highways and Public Transportation

in cooperation with

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Federal Highway Administration

November 1978
Revised April 1979

TEXAS TRANSPORTATION INSTITUTE
Texas A&M University
College Station, Texas

ABSTRACT

Initial and maintenance costs of small, single-post sign installations to the Texas State Department of Highways and Public Transportation (SDHPT) are substantial. A recent survey found that costs of routine sign maintenance exceeded 11 million dollars in 1976. Also, the hazard potential of small roadside sign installations can no longer be disregarded, especially in light of the increasing use of small vehicles. The SDHPT has over 900,000 such installations.

With a view toward reduced costs and improved safety, the SDHPT undertook a study to evaluate the economics and safety of thin-wall steel tube signposts and delineator posts. This report describes a full-scale crash test program conducted to evaluate the impact behavior of several sizes of thin-wall steel tube signposts and delineator posts. All installations were the single-post type. Tests were conducted in accordance with nationally recognized test procedures, and the results were evaluated in terms of American Association of State Highway and Transportation Officials (AASHTO) impact performance specifications. In terms of AASHTO specifications, the following was found:

1. A 3.50 in. (8.89 cm) O.D. by 0.083 in. (0.17 cm) and a 2.875 in. (7.30 cm) O.D. by 0.120 in. (0.30 cm) signpost in a concrete footing do not satisfy specifications.
2. A 2.875 in. (7.30 cm) O.D. by 0.120 in. (0.30 cm) signpost with sleeve and base in concrete is marginally acceptable.
3. A 2.875 in. (7.30 cm) O.D. by 0.065 in. (0.17 cm) and a 2.375 in. (6.03 cm) O.D. by 0.109 in. (0.28 cm) signpost in a concrete footing satisfy specifications.
4. A 1.66 in. (4.22 cm) O.D. by 0.047 in. (0.12 cm) delineator post and a 1.90 in. (4.83 cm) O.D. by 0.065 in. (0.17 cm) mile marker post satisfy specifications.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

KEY WORDS

Sign Support(s), Signpost(s), Delineator Post(s), Crash Test(s), Impact(s), Safety

ACKNOWLEDGMENTS

This research study was conducted under a cooperative program between the Texas Transportation Institute (TTI), the State Department of Highways and Public Transportation (SDHPT), and the Federal Highway Administration (FHWA). Mr. John F. Nixon (Engineer of Research, SDHPT), Mr. Ernest W. Kanak (Supervising Traffic Engineer, SDHPT), and Mr. Devidas B. Tulsiani (Traffic Design Engineer) worked closely with the researchers and their guidance was appreciated.

IMPLEMENTATION STATEMENT

As of the writing of this report, the SDHPT was evaluating the findings presented herein. The SDHPT has elected to install some of the thin-wall steel tubes for small sign supports on an experimental basis. Field performance and impact behavior will be closely monitored for a period of time.

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INTRODUCTION

Texas has approximately 900,000 single-post sign installations in place along state-maintained roadways. In addition to the initial cost, Texas spends about 8 percent of its annual routine maintenance budget to maintain signs, the vast majority of which are small single-post installations. This, quite obviously, represents a considerable investment and a significant annual maintenance expenditure.

To reduce costs and possibly enhance roadside safety, an evaluation of thin-wall steel pipe or tube as a potential sign support and a delineator post was undertaken. A full-scale crash test program was conducted to determine the impact behavior of the thin-wall tube. Tests were conducted according to current guidelines (1), and results were evaluated in terms of American Association of State Highway and Transportation Officials (AASHTO) Specifications (2). This report describes the tests and results obtained therefrom. Analysis of costs of the thin-wall tube as a sign support and as a delineator post was not within the scope of this study. Persons interested in the economics of this system should contact Texas State Department of Highways and Public Transportation (SDHPT) officials.

CRASH TEST DETAILS

A total of seven full-scale crash tests were conducted. General details of the test program are given in Table 1. Complete details of each test are given in subsequent sections. Each test was conducted in accordance with recommended guidelines (1).

TEST VEHICLES

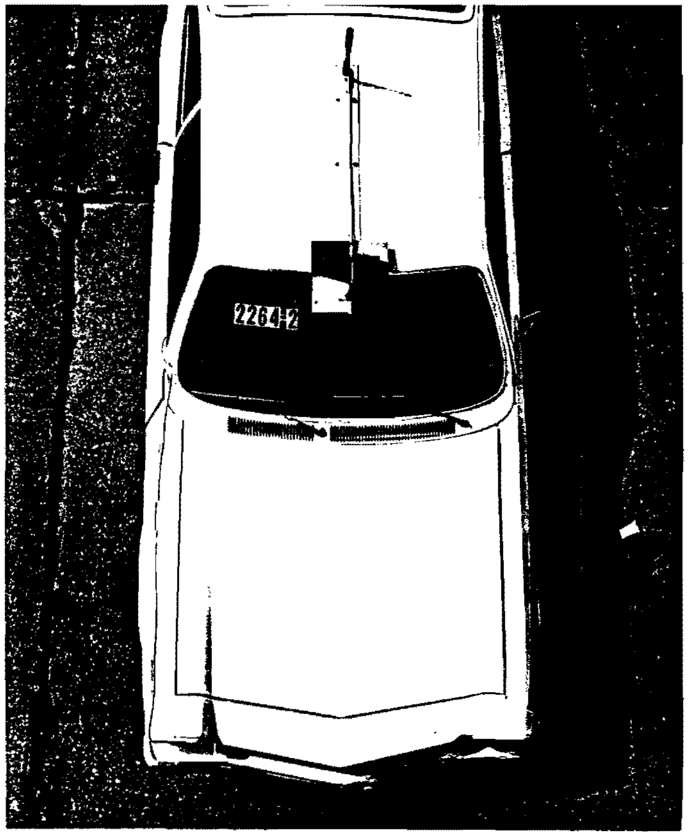
The test vehicles were 1973 Chevrolet Vegas, one of which is shown in Figure 1. Dimensions of the vehicle are given in Figure 2. The vehicle was accelerated to test speed with a reverse tow system, and was kept on line with the test article by a cable guidance system.

ELECTRONIC INSTRUMENTATION

A strain gage accelerometer was placed on both frame members to measure accelerations in the longitudinal direction. Signals from accelerometers were telemetered to a base receiver station and recorded on magnetic tape for permanent record. The signals were passed through a 100 Hz max flat filter to produce analog traces for analysis. Figure 3 shows the on-board vehicle instrumentation.

PHOTOGRAPHIC INSTRUMENTATION

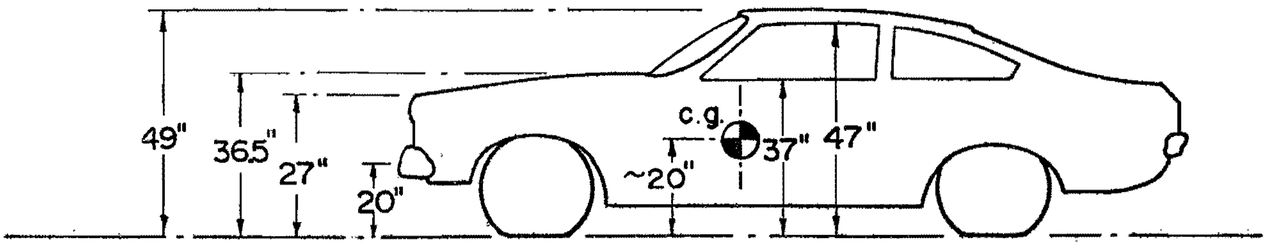
Four cameras were used to record each test; three of these were high-speed cameras. The first camera was positioned perpendicular to the direction of impact, and had a field of view 15 ft (4.58 m) on each side of the signpost. The second camera was also perpendicular to the direction of travel, and had a field of view 10 ft (3.05 m) before impact and 40 ft (12.2 m) after impact. These high-speed cameras are shown in Figure 3. The third high-speed camera was positioned 45 degrees to the rear of the signpost, and was fitted with a long focal lens to take a closeup view. The fourth camera was used to make a documentary film.



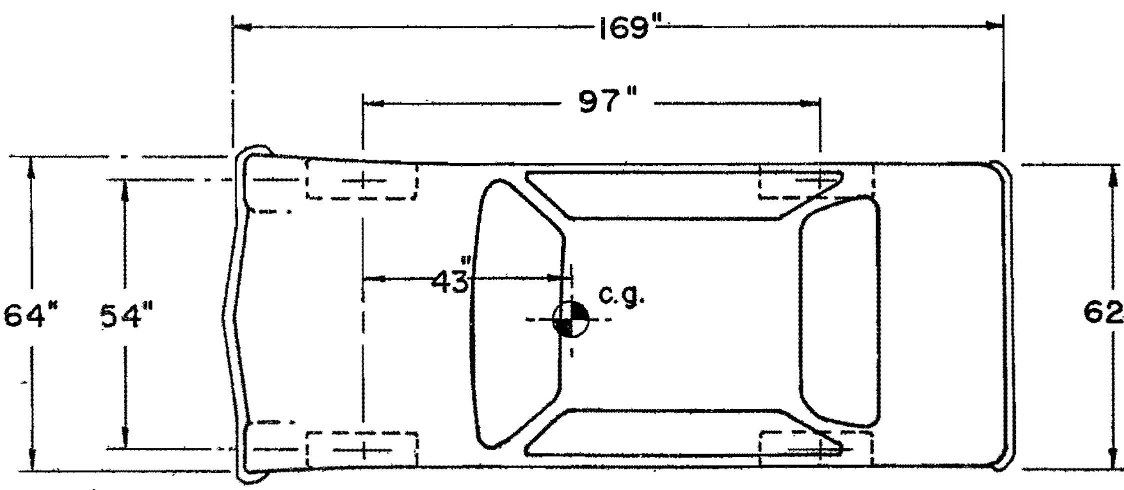
a) Top View

b) Front View

FIGURE 1. 1973 CHEVROLET VEGA.



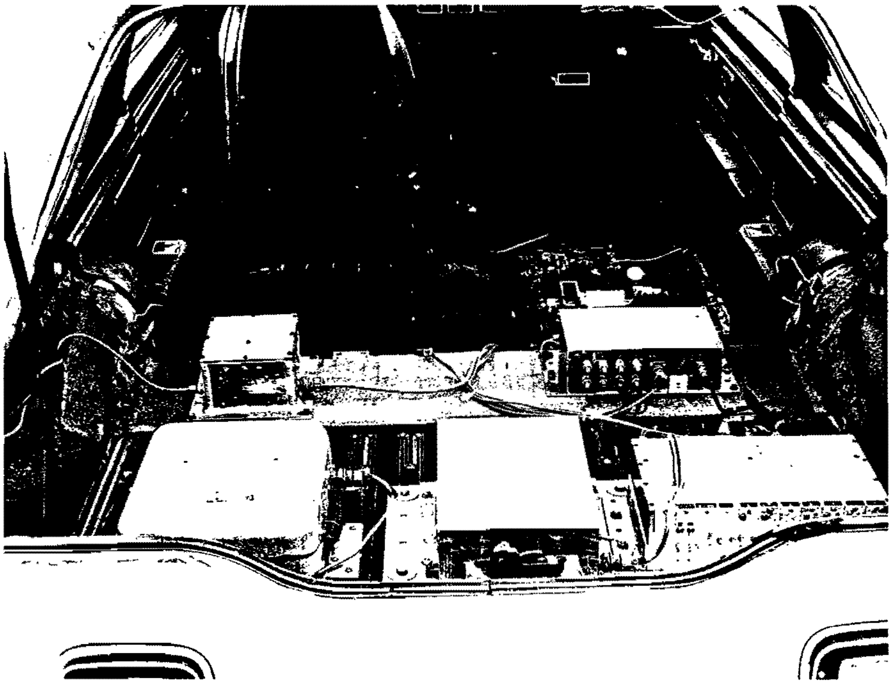
ELEVATION



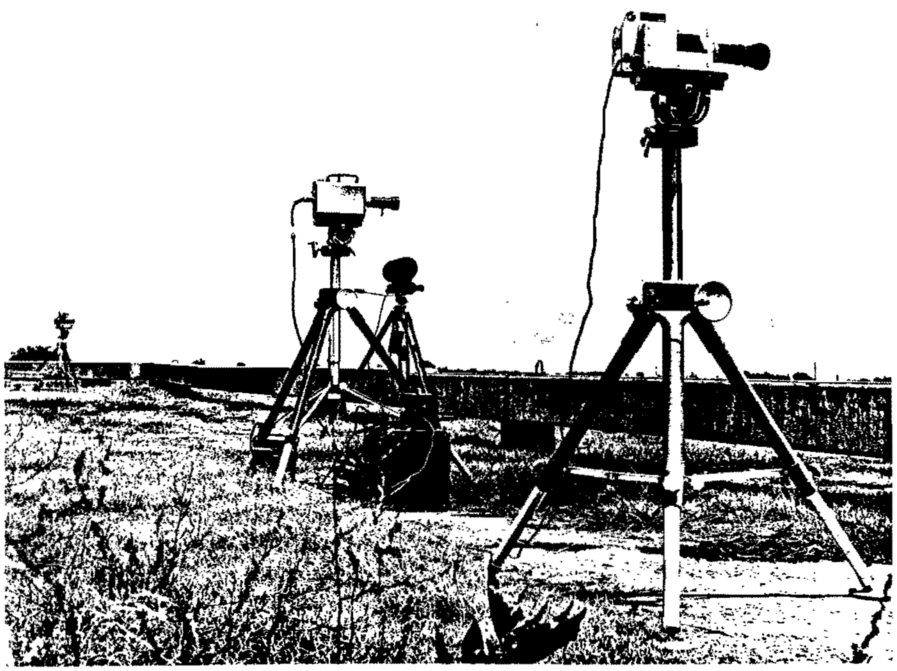
PLAN

Metric Conversion: 1 in. = 2.54 cm

FIGURE 2 . TYPICAL DIMENSIONS OF 1971-1973 CHEVROLET VEGA.



a) Vehicle Instrumentation



b) High-Speed Cameras

FIGURE 3. DATA ACQUISITION SYSTEMS.

TEST ARTICLES

As given in Table 1, four different sizes of thin-wall tubing were tested as signposts. A thin-wall tube delineator post and a milepost marker were also tested.

In tests 1 and 2, a 2.875 in. (7.30 cm) outside diameter by 0.120 in. (0.30 cm) thick tube was tested in the type "F" configuration, shown in Figure 4. The post was embedded 2 ft (0.61 m) in an unreinforced concrete footing.

Test 3 configuration and tube size was the same as tests 1 and 2 except the post was inserted in an anchor sleeve as shown in Figure 4. The post was inserted 2 ft (0.61 m) into the sleeve and held with a single fastener to prevent twisting from wind loads. In tests 1, 2, and 3, three U-bolts and mounting clamps were used to fasten the 36 in. (91.4 cm) by 48 in. (121.9 cm) aluminum sign panel to the post. Details of the clamp are given in Figure 5. Photos of these installations can be seen in Figures 6 and 7.

Tests 4 and 5 involved a type "A" configuration as shown in Figure 8. A 2.875 in. (7.30 cm) outside diameter by 0.065 in. (0.17 cm) thick tube was used in test 4, and a 2.375 in. (6.03 cm) outside diameter by 0.109 in. (0.28 cm) thick post was used in test 5. Two U-bolts and mounting clamps were used to fasten the 24 in. (61.0 cm) by 30 in. (76.2 cm) aluminum sign panel to the post. A photo of the installation for tests 4 and 5 is shown in Figure 9.

A milepost marker and delineator post were tested together in test 6. Installation details are given in Figure 8. The milepost marker was a 1.90 in. (4.83 cm) outside diameter by 0.065 in. (0.17 cm) thick post. A 12 in. (30.5 cm) by 48 in. (121.9 cm) aluminum panel was attached with three U-bolts and mounting clamps. A 1.66 in. (4.22 cm) outside diameter by 0.047 in. (0.12 cm) thick tube was used as a delineator post. A 3 in. (7.62 cm) outside diameter clear delineator was mounted with a 0.25 in. (0.64 cm) by 2.5 in. (6.35 cm) bolt and nut. The delineator post was mounted 15 in. (38.1 cm) to the right and 15 in. (38.1 cm) behind the milepost. The milepost installation and the delineator post are shown in Figure 10.

TABLE 1. TEST DETAILS.

VEHICLE				SIGNPOST			PANEL	
TEST NO.	WEIGHT (lb)	SPEED (mph)	ANGLE (deg.)	SIZE	METHOD OF EMBEDMENT	DEPTH OF EMBEDMENT (ft)	SIZE	MOUNTING HEIGHT (ft)
1	2270	18.2	0	2.875 in. O.D. x 0.120 in.	12 in. Dia. Concrete Footing	2.0	36 in. x 48 in.	6
2	2270	60.4	0	2.875 in. O.D. x 0.120 in.	12 in. Dia. Concrete Footing	2.0	36 in. x 48 in.	6
3	2270	62.7	0	2.875 in. O.D. x 0.120 in.	Inserted in Sleeve[a]	2.0	36 in. x 48 in.	6
4	2270	59.0	0	2.875 in. O.D. x 0.065 in.	12 in. Dia. Concrete Footing	2.0	24 in. x 30 in.	6
5	2270	59.6	0	2.375 in. O.D. x 0.109 in.	12 in. Dia. Concrete Footing	2.0	24 in. x 30 in.	6
6A	2270	63.0	0	1.90 in. O.D. x 0.065 in.	Driven	2.5	12 in. x 48 in.	4
6B				1.66 in. O.D. x 0.047 in.	Driven	2.0	(b)	4
7	2270	60.5	0	3.50 in. O.D. x 0.083 in.	12 in. Dia. Concrete Footing	2.0	36 in. x 48 in.	6

[a] A 3.5 in. standard steel pipe was used as sleeve. Sleeve was embedded in 12 in. diameter concrete footing.

[b] A 3 in. diameter clear delineator was used.

Metric Conversions:
1 ft = 0.305 m
1 in. = 2.54 cm
1 lb_f = 4.448 N
1 mph = 0.447 m/s

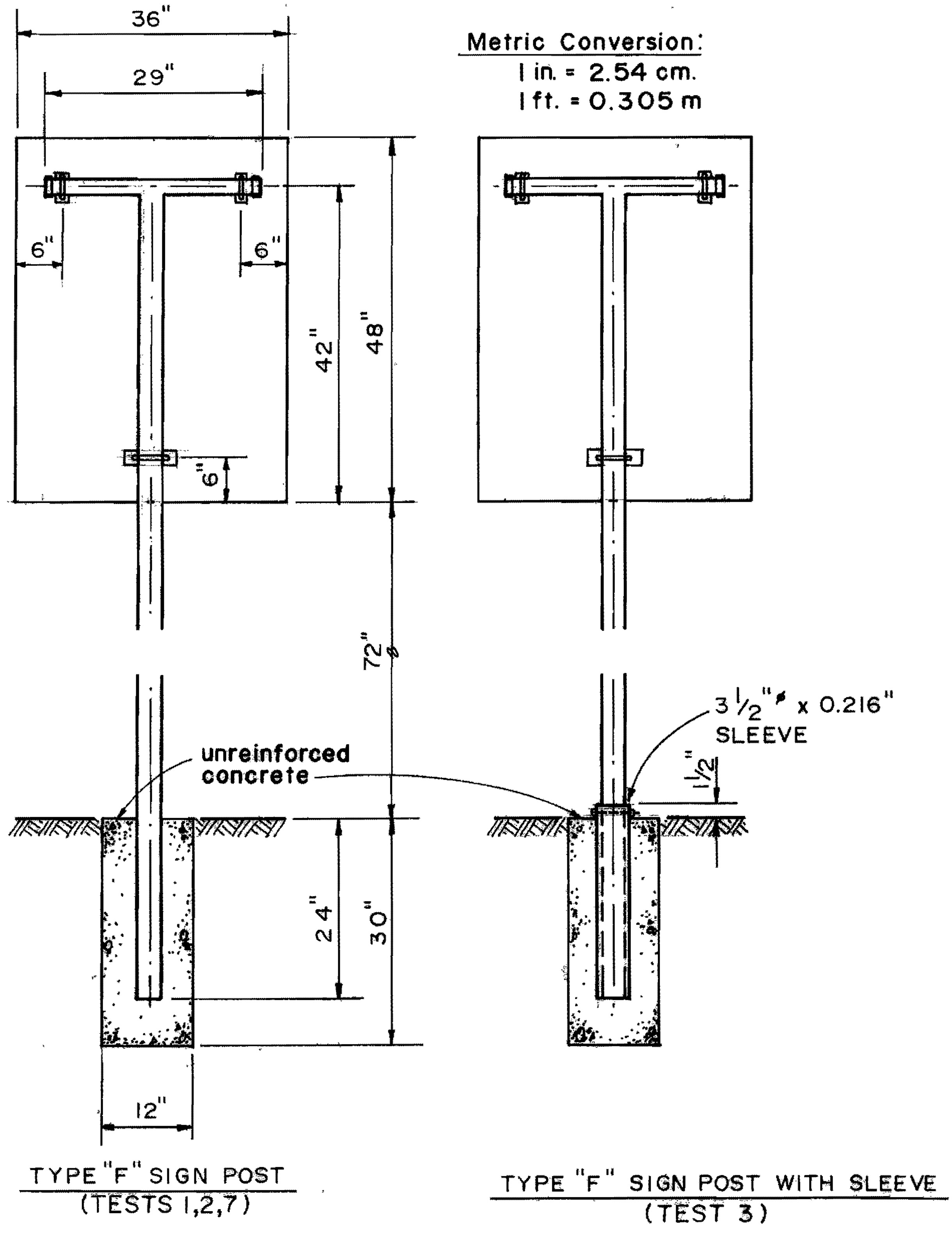
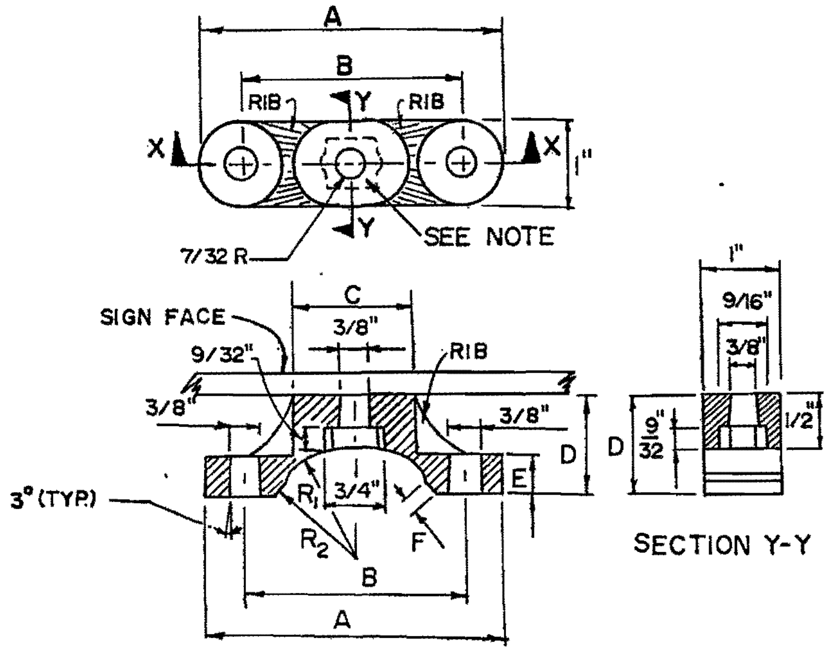


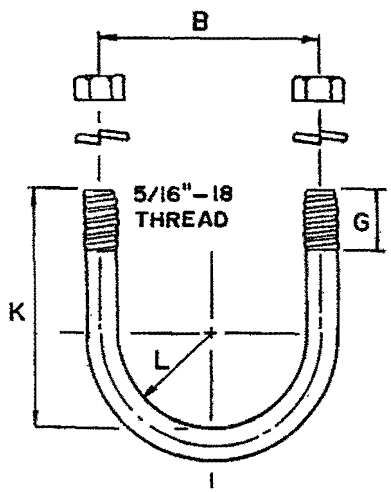
Figure 4. Installation Details, Tests 1, 2, 3 and 7.

NOTE: SLOT TO HOLD HEAD OF 5/16" SQ. HEAD BOLT. THE BOLT SHALL BE 1" LONG FOR METAL SIGNS AND 1 1/2" LONG FOR PLYWOOD SIGNS, WITH FULL THREAD AND A MEDIUM WASHER. THE HEAD MUST NOT TURN IN SLOT.



SECTION Y-Y

SECTION X-X



U-BOLT

U-BOLT TO BE MADE IN ACCORDANCE WITH STANDARD MANUFACTURING PROCEDURE, 9/32" DIA. STOCK IS PERMISSIBLE. AMERICAN STANDARD REGULAR SEMI-FINISHED HEX. NUTS & SPRING LOCKWASHERS.

PIPE CLAMP CASTING

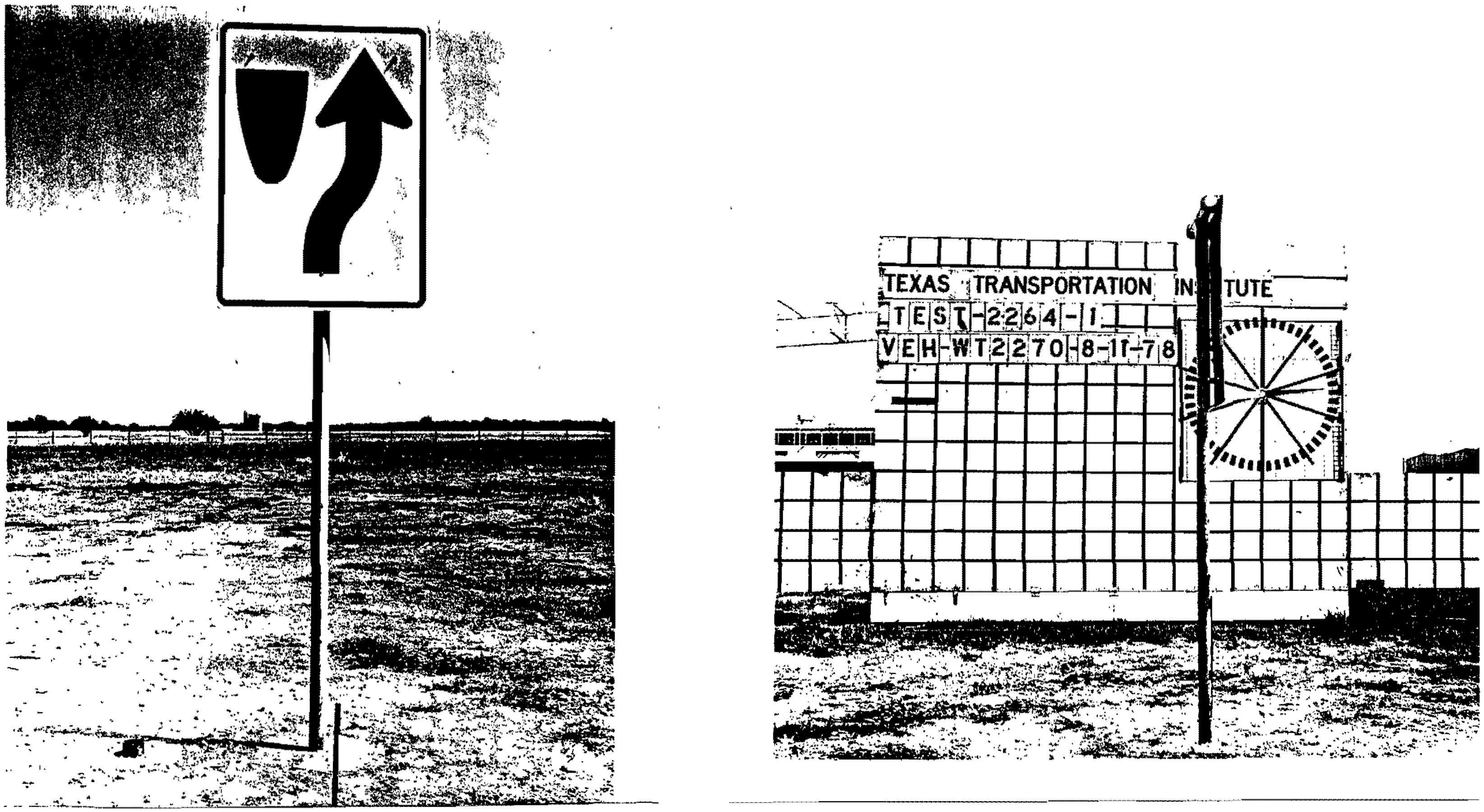
PIPE CLAMP CASTING SHALL BE ALUMINUM ALLOY A344-T4 OR 356-F.
ALL SIGN MOUNTING CLAMP PARTS NOT MADE FROM ALUMINUM SHALL BE STAINLESS STEEL OR GALVANIZED STEEL IN CONFORMANCE WITH ITEM 422 OF THE STANDARD SPECIFICATIONS.

Metric Conversion: 1 in. = 2.54 cm.

DIMENSIONS FOR MOUNTING CLAMP

STANDARD PIPE SIZE	A	B	C	D	E	F	G	K	L	R_1	R_2
2"	3 3/4"	2 3/4"	1 1/2	1 1/8"	1/2"	3/16	1"	2 11/16"	1 7/32	1 1/4"	1 3/16"
2 1/2"	4 1/4"	3 1/4"	2"	1 1/4"	1/2"	1/4"	1"	3 3/16"	1 15/32"	1 1/2"	1 7/16"

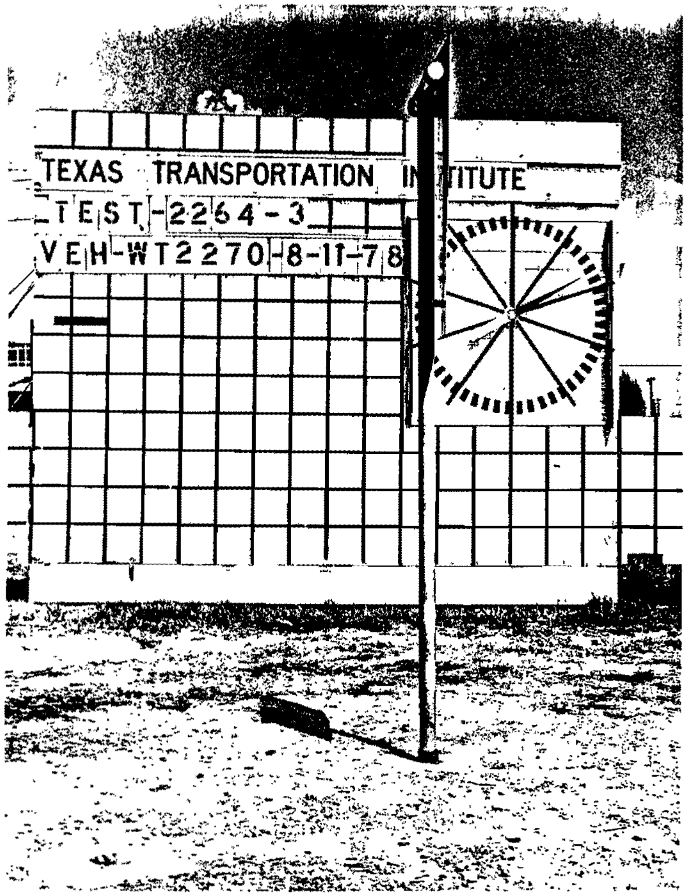
FIGURE 5. MOUNTING CLAMP DETAILS



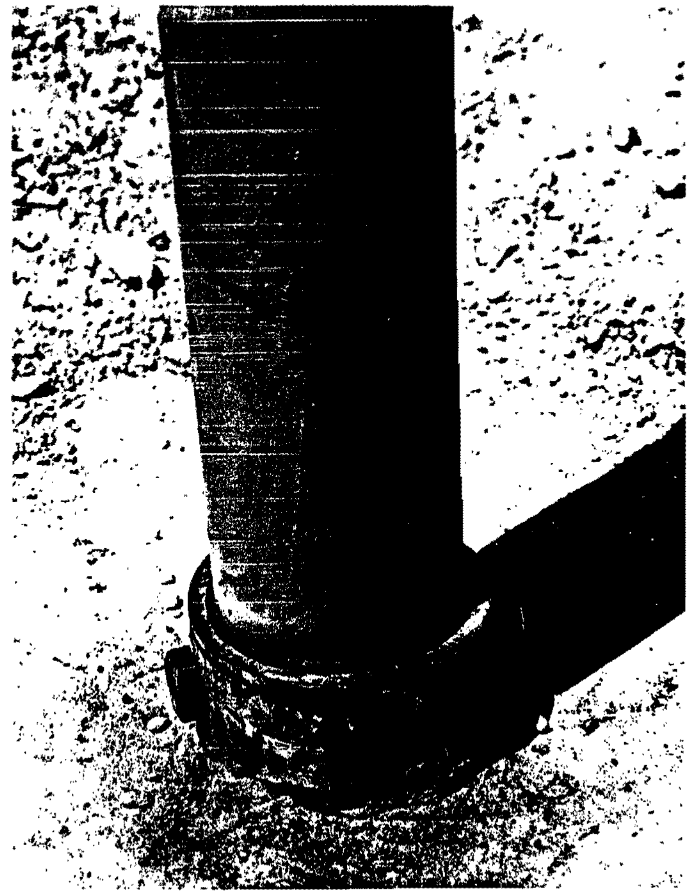
a) Front View

b) Side View

FIGURE 6. SIGN SYSTEM, TESTS 1 AND 2.



a) Side View



b) Closeup of Base

FIGURE 7. SIGN SYSTEM AND BASE, TEST 3.

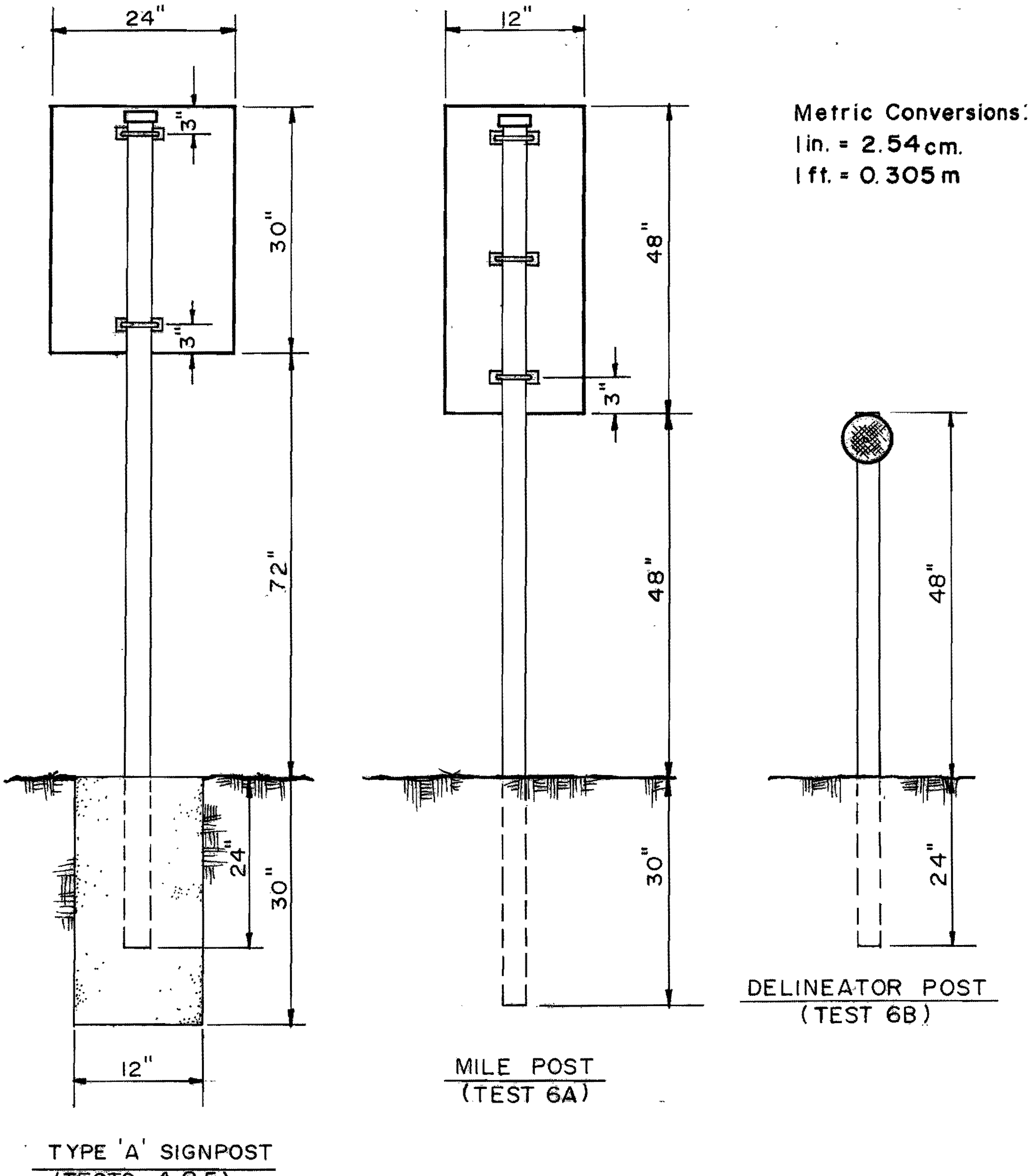
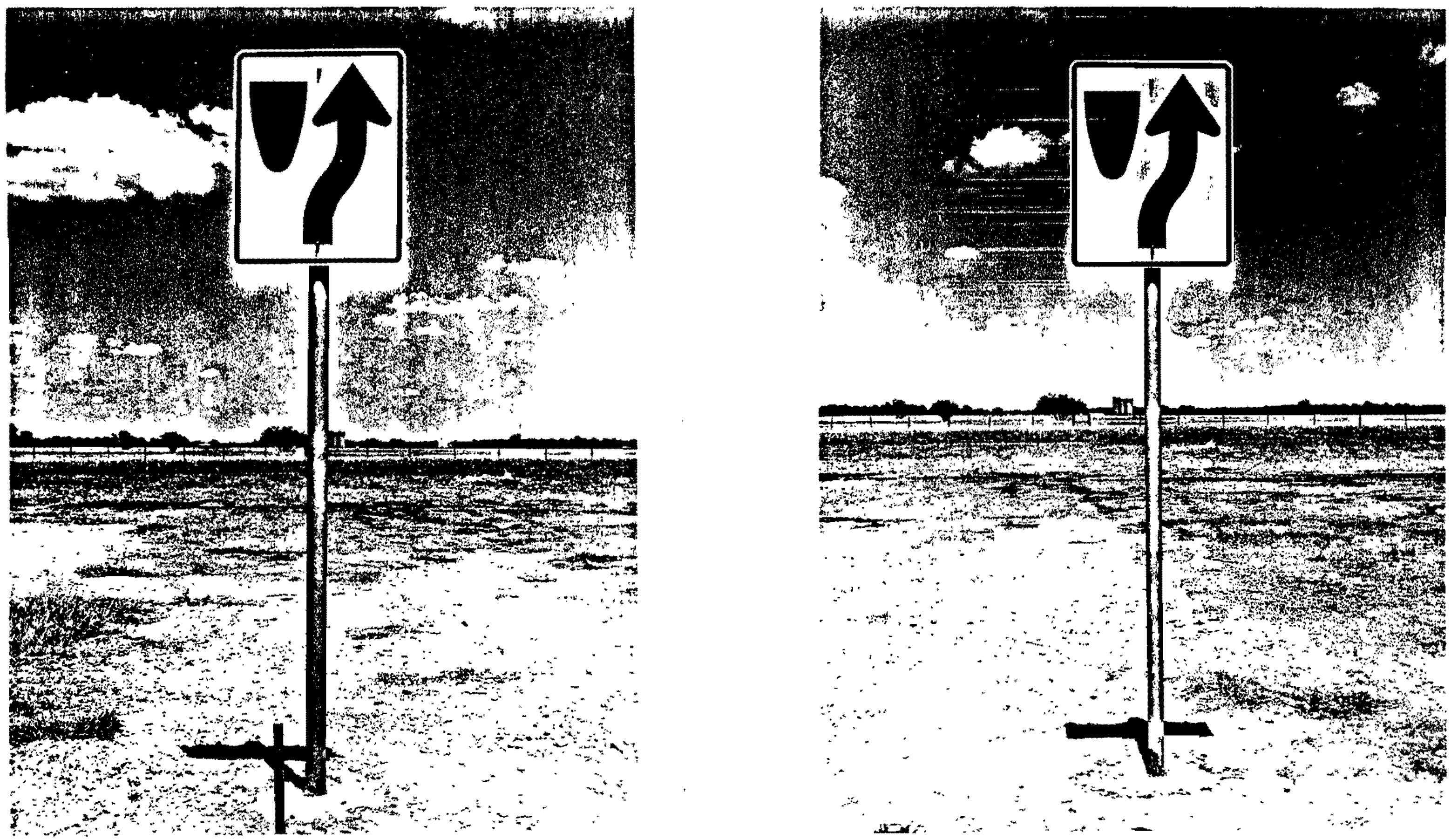


Figure 8. Installation Details, Tests 4,5 and 6.



a) Test 4 b) Test 5

FIGURE 9. SIGN SYSTEM, TESTS 4 AND 5.

a) Test 6

b) Test 7

FIGURE 10. SIGN SYSTEM, TESTS 6 AND 7.

Test 7 involved a 3.5 in. (8.89 cm) outside diameter by 0.083 in. (0.17 cm) thick signpost in the type "F" configuration of Figure 4. Three U-bolts and mounting clamps were used to fasten a 36 in. (91.4 cm) by 48 in. (121.9 cm) aluminum sign panel. Figure 10 shows the installation for test 7.

Physical and chemical properties of the posts, as provided by the manufacturer of the posts (3), are given in Table 2. The posts are cold formed, electric resistance welded, steel tubes conforming to ASTM A525 specifications, except as noted in Table 2.

TABLE 2. POST PROPERTIES[a].

OD (in.)	WALL (in.)	YIELD ST. (psi)	TENSILE ST. (psi)	ELONG. % in 2"	CARBON %	MN %
1.660	.047	50,200	54,800	40	.14	.38
1.900	.065	52,400	60,200	40	.15	.42
2.375	.109	61,000	66,900	20	.15	.40
2.875	.065	37,100	46,100	54	.08	.31
2.875	.120	57,800	64,400	26	.16	.39
3.500	.083	54,000	67,500	26	.14	.41

Chem Notes: All analyses are ladle analyses. In each case sulfur & Phos. were less than .04%.

All items were made from AISI 1015 steel except 2.875 OD x .065 wall which was AISI 1010. Manufacturer does not have the 2.875 x .065 in 1015.

All tubing except 2.875 x .065 meets the requirements of ASTM A-500 Gr. B structural tubing.

[a]Provided by manufacturer (3).

PERFORMANCE SPECIFICATIONS AND TEST RESULTS

According to AASHTO (2), "Satisfactory dynamic performance is indicated when the maximum change in momentum for a standard 2250 lb (1020 kg) vehicle, or its equivalent, striking a breakaway support at speeds from 20 mph to 60 mph (32 kmph to 97 kmph) does not exceed 1100 pound-seconds (4893 N-sec), but desirably does not exceed 750 pound-seconds (336 N-sec)."

As used in the Specification, "breakaway supports" is a generic term meant to include all types of sign supports whether the release mechanism is a slip plane, plastic hinges, fracture elements, or a combination of these. The Specification states that "Breakaway structures should also be designed to prevent the structure or its parts from penetrating the vehicle occupant compartment." The Specification also alludes to the unacceptability of vehicle rollover following impact with the signpost.

Data acquisition and data reduction procedures were in accordance with recognized guidelines (1,2). Test results consist of data derived from accelerometer readings, photos of the impact phase, and photos of damage to the sign installation and the vehicle. Three plots are presented for each test, namely vehicle deceleration versus time, change in vehicle momentum versus time, and "free missile travel" versus time. Free missile travel is the distance an unconstrained occupant (with no seat friction) would travel after impact with respect to the moving vehicle. The deceleration-versus-time plot is obtained from the filtered accelerometer signals. Change in momentum is obtained by first integrating the deceleration over a given time interval, which gives the change in vehicle velocity during the interval. Change in vehicle velocity is then multiplied by the vehicle's mass to obtain the change in momentum. Free missile travel for a given period of time is obtained by double integration of the deceleration over that period of time.

Since change in momentum is time dependent, a time duration must be specified for its computation. Current guidelines for determining this duration are as follows (1):

"For yielding supports (such as base-bending signs) change in vehicle momentum to be used in the acceptance criteria of this section shall be computed on the basis of time integration of the vehicle deceleration signal over a 'duration of the event'. This duration shall be defined as the lesser of the following: (1) time between incipient contact and loss of contact between the vehicle and the yielding support, or (2) the time for a free missile to travel a distance of 24 in. starting from rest with the same magnitude of vehicle deceleration."

Free missile travel is explicitly determined from measured accelerometer data. "Time between incipient contact and loss of contact between the vehicle and the yielding support" is not so explicit. High-speed film would seem to be the logical means with which this time duration could be determined. However, it is often difficult to ascertain the time that "loss of contact" occurs with precision. In a low-speed impact, the vehicle may bend the post down and travel over it. "Apparent contact" can occur over a relatively large time period, although there may be no appreciable contact forces. In a high-speed impact, the post may wrap around and remain with the vehicle after it has fractured or pulled from the ground. Again, "apparent contact" is still being made with no appreciable contact forces. Compounding the problem is the fact that filtering accelerometer output causes slight phase shifts in the filtered data.

To overcome these difficulties with computation of "contact time", a simple procedure was adopted in which only accelerometer data were used. In effect, contact time was defined as the duration between initial contact and the time at which the deceleration essentially returned to and remained at zero. Obviously, deceleration does not remain at zero unless the vehicle reaches a constant velocity or comes to a stop. However, in most tests contact was followed by a period where wind drag and rolling resistance were the only forces on the vehicle. These forces decelerate the vehicle at a level which is small in comparison with that caused by contact forces. Subsequent to that period the brakes were applied. Film data were used as a check or backup to insure there were no gross discrepancies in the contact time derived from accelerometer data.

Damage to the vehicle was assessed in terms of two nationally recognized rating scales. These were the Vehicle Damage Scale published by the Traffic Accident Data Project (TAD) (4) and the Collision Deformation Classification recommended by the Society of Automotive Engineers (SAE) (5).

All tests were conducted with the vehicle impacting the sign installation in a head-on orientation. With the exception of test 6, impact point on the vehicle was approximately 15 in. (38.1 cm) either to the left or right of the center of the front bumper. In test 6 a milepost marker was hit 15 in. (38.1 cm) to the left of center, and a delineator post was hit at the midpoint of the bumper.

TEST NO. 1

Results of test 1 are summarized in Table 3. Sequential photos from high-speed film of the impact are shown in Figure 11, and Table 4 contains the time-displacement event summary. The post first started bending at the base and then at bumper height. As the interaction continued, the post fell away and the vehicle rolled over the installation.

Deceleration, change in momentum, and free missile travel versus time data are given in Figures 12, 13, and 14. Installation damage is shown in Figure 15. The sign panel and mounting hardware sustained little damage and could be reused. The remainder of the installation would require replacement.

Figure 16 pictures the damage to the vehicle. Damage was light, and only the bumper and grille header panel were involved. TAD and SAE damage ratings are given in Table 3.

TABLE 3. SUMMARY OF RESULTS, TEST 1.

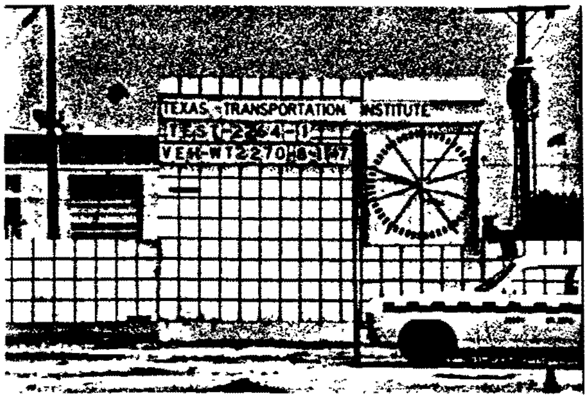
Impact Velocity = 18.2 mph

POST DATA			
Type	Thin Wall Tubing		
Size	2.875"ϕ x 0.120"		
Embedment Method	12"ϕ Concrete Footing		
Embedment Depth (ft)	2		
VEHICLE DATA			
Make	Chevrolet		
Model	Vega		
Year	1973		
Weight (lb)	2270		
Impact Point	15 in. to right of center		
ACCELEROMETER DATA		Left	Right
Change in Momentum (lb-sec)		901	905
Duration of Event (sec)*		0.182	0.182
Peak Deceleration (G's)		7.08	6.78
Maximum 0.050 Sec Average Deceleration (G's)		3.68	3.74
VEHICLE DAMAGE CLASSIFICATION			
TAD	FR-1		
SAE	12FREN1		
Did test article penetrate the passenger compartment?	No		
Was windshield broken?	No		

*Time of contact

Metric Conversions:

1 in. = 2.54 cm
1 ft = 0.305 m
1 lb_m = 0.454 kg
1 lb_m-sec = 0.454 kg-s
1 mph = 0.447 m/s



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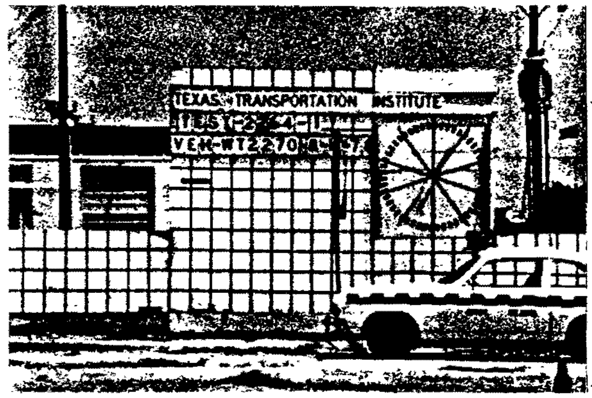

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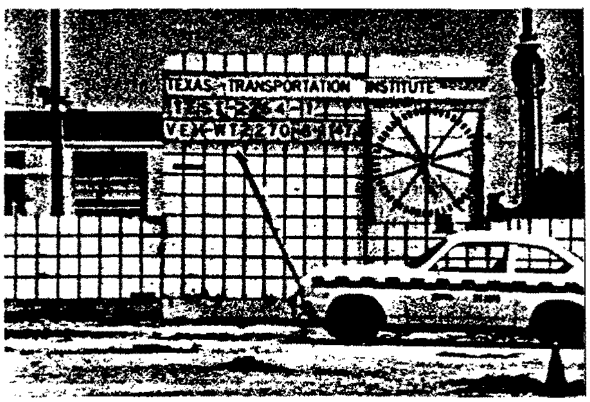

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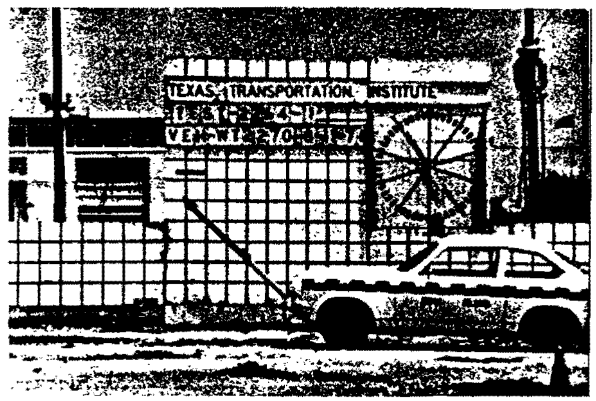

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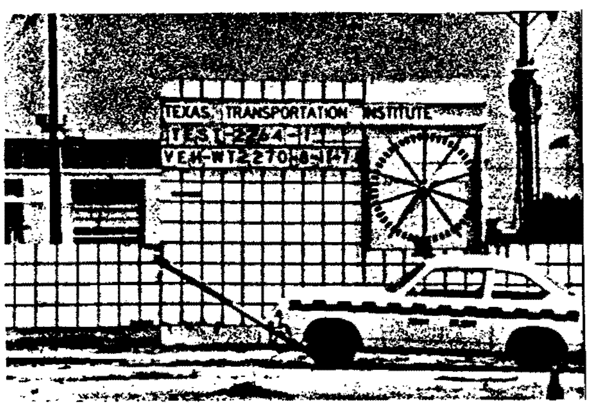

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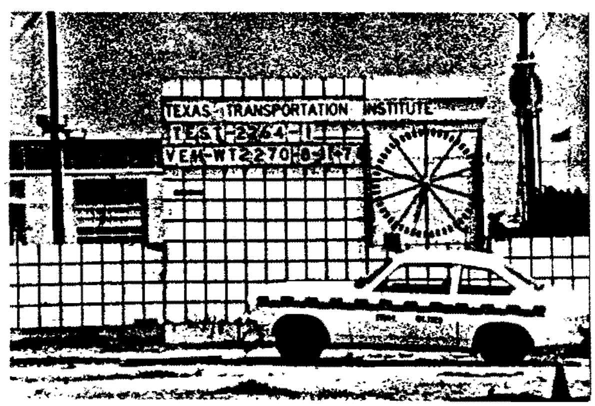


0.310 sec

FIGURE 11. SEQUENTIAL PHOTOS, TEST 1.

TABLE 4. TIME DISPLACEMENT EVENT SUMMARY FOR TEST 1.

TIME (sec)	NOMINAL VEHICLE DISPLACEMENT (ft)	EVENT
0.000	0.00	Impact
0.081	1.94	Post bending at bumper
0.146	3.03	Right front tire lifts off
0.181	3.55	Signpost falling away
0.206	3.89	Loss of contact
0.310	5.39	Post and panel hit ground

Metric Conversion:

1 ft = 0.305 m

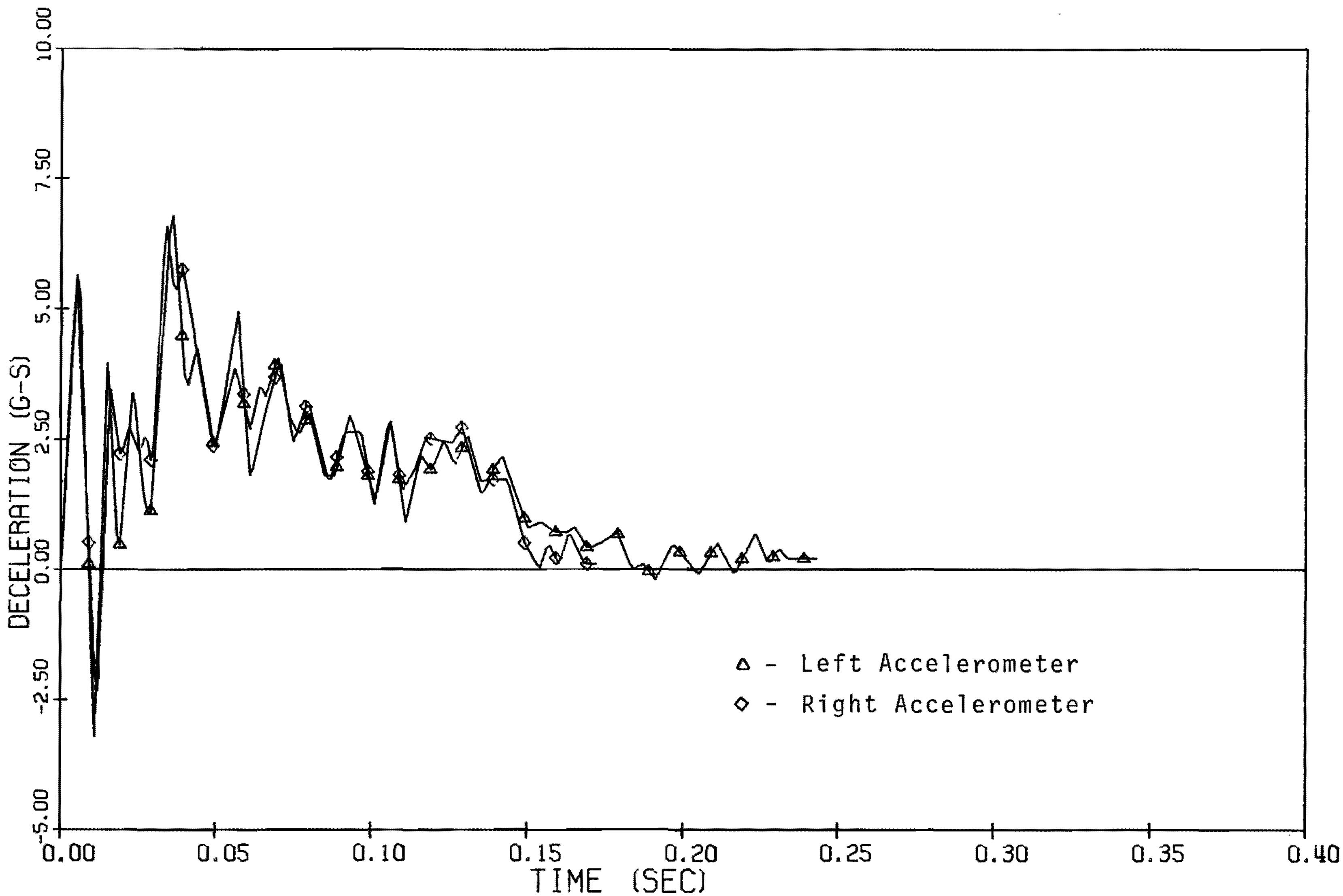


FIGURE 12. DECELERATION VERSUS TIME, TEST 1

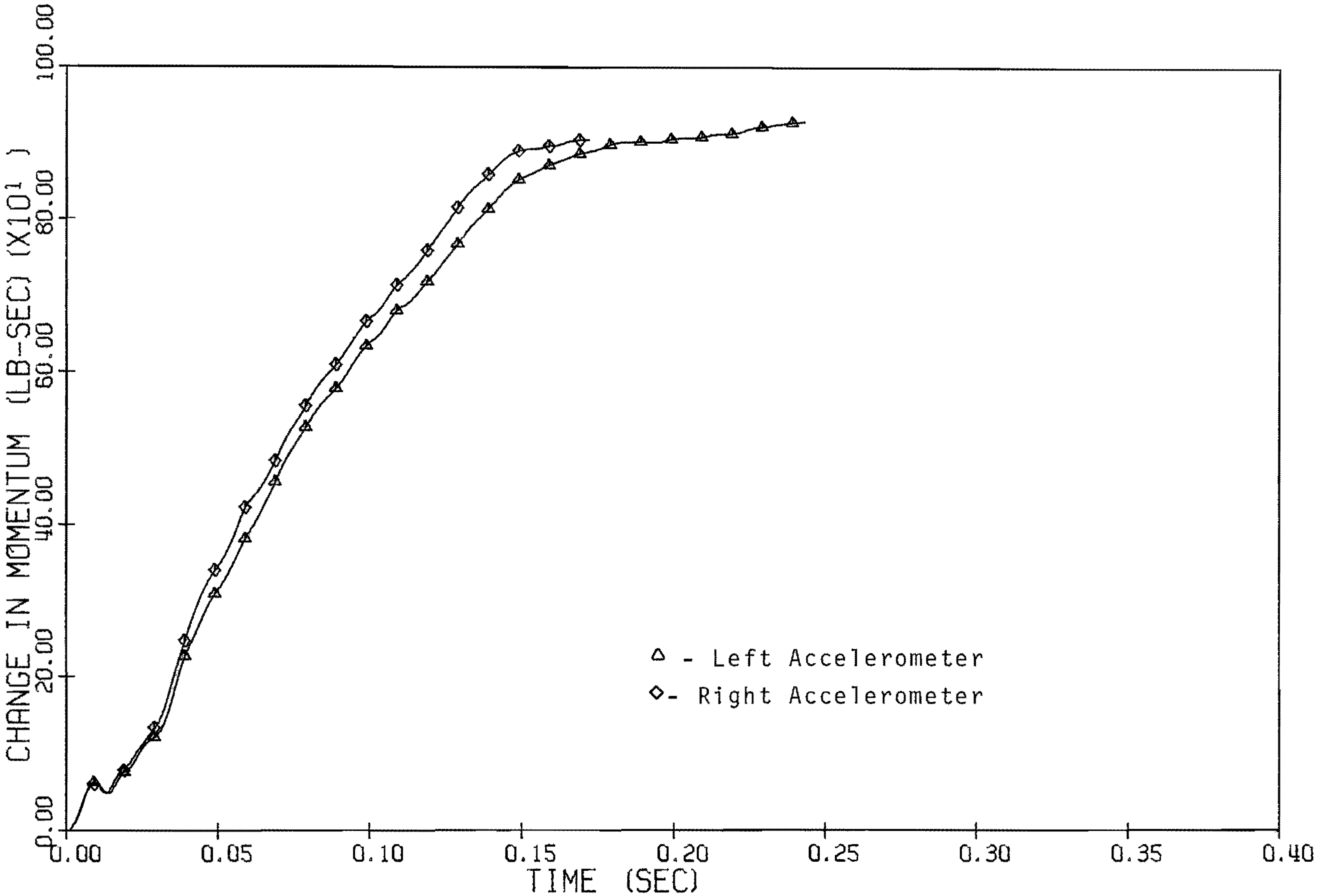


FIGURE 13. CHANGE IN MOMENTUM VERSUS TIME, TEST 1.

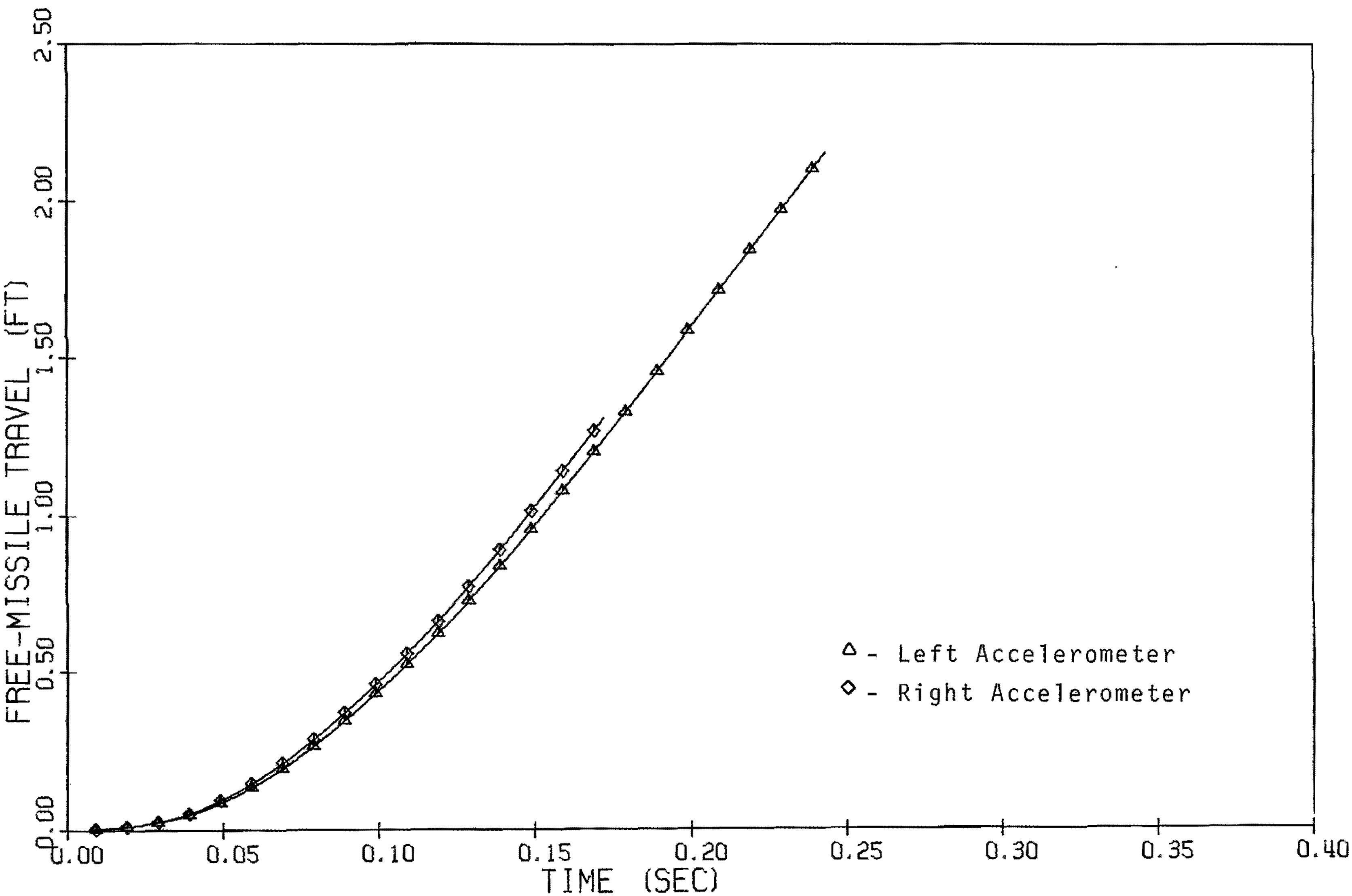
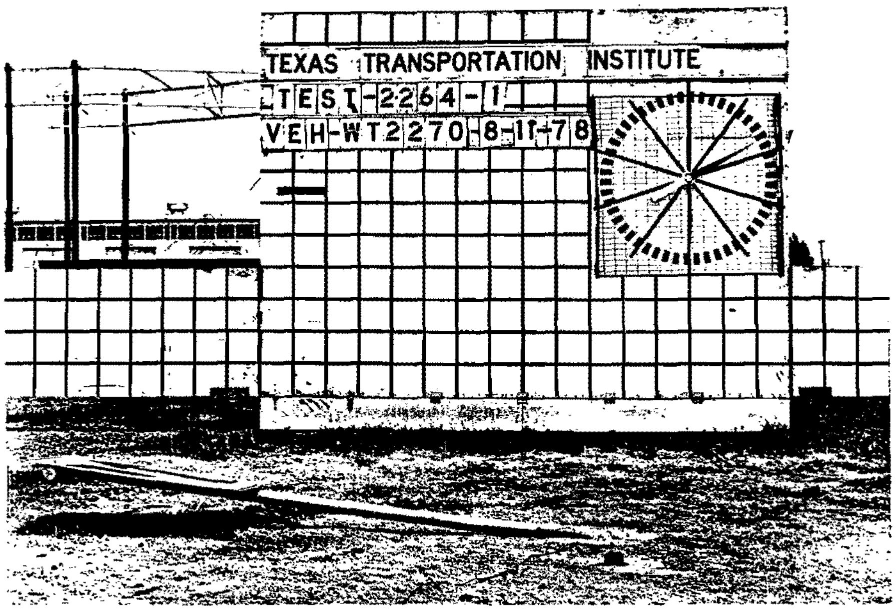


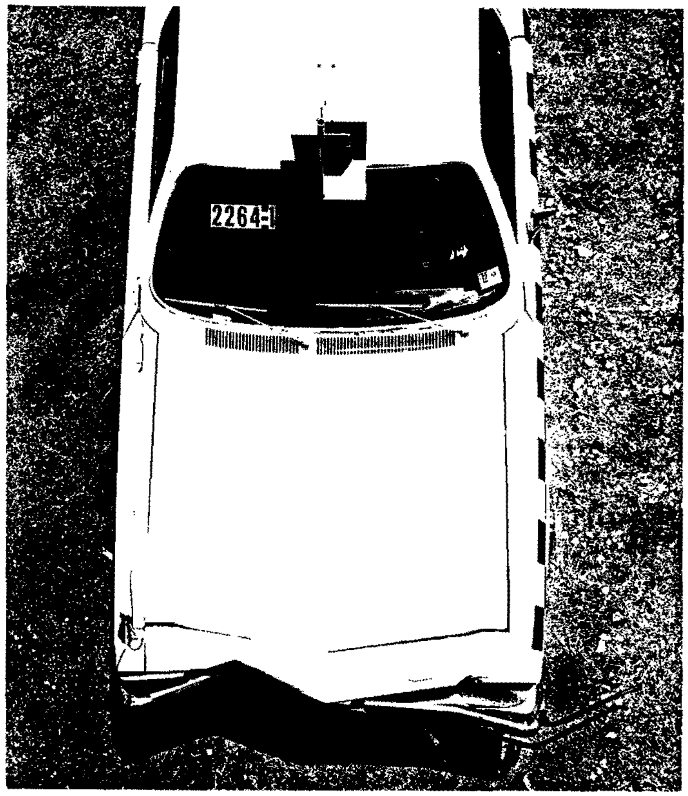
FIGURE 14. FREE MISSILE TRAVEL VERSUS TIME, TEST 1.



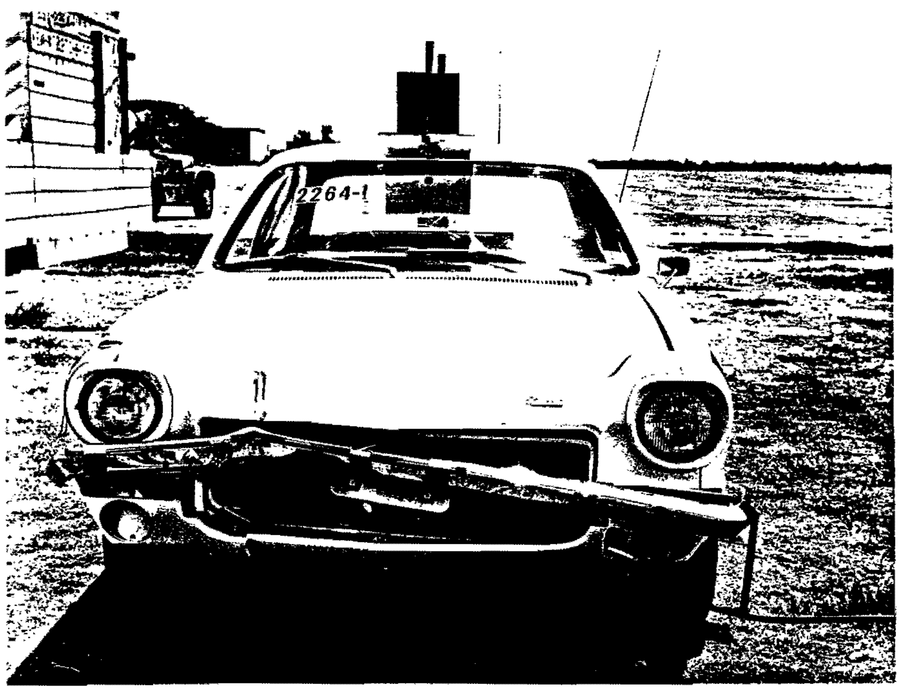
a) Side View

b) Front View

FIGURE 15. INSTALLATION DAMAGE, TEST 1.



a) Top View



b) Front View

FIGURE 16. VEHICLE DAMAGE, TEST 1.

TEST NO. 2

The configuration tested was identical to that in test 1. In this case the impact speed was increased to 60.4 mph (27 m/s). Table 5 contains a summary of results for test 2. The high-speed film sequential photos are given in Figure 17, and the time-displacement event summary is in Table 6. Upon impact the post flattened and then began wrapping around the front of the vehicle. As impact continued, the post was straightened out, and the tee at the top hooked the bumper. Larger change in momentum values in this test compared to those for test 1 show that a high-speed impact is more hazardous than a low-speed impact for this signpost type.

Figure 18, 19, and 20 show deceleration, change in momentum, and free missile travel versus time data. Damage to the signpost is shown in Figure 21. The sign panel came off the mounting during impact, and was practically undamaged. The remainder of the installation would require replacement.

Vehicle damage is shown in Figure 22. Damage was assessed according to TAD and SAE damage scales and is given in Table 5.

TABLE 5. SUMMARY OF RESULTS, TEST 2.

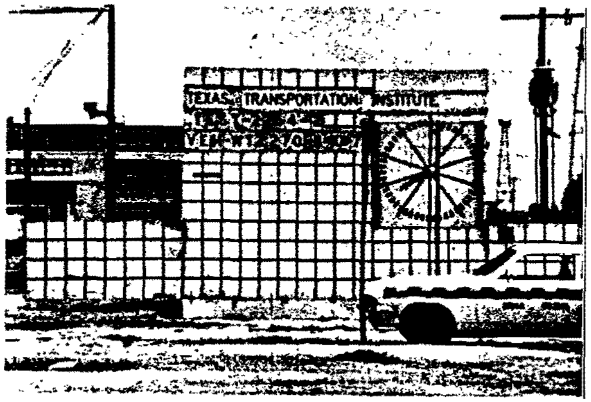
Impact Velocity = 60.4 mph

POST DATA		
Type	Thin Wall Tubing	
Size	2.875"φ x 0.120"	
Embedment Method	12"φ Concrete Footing	
Embedment Depth (ft)	2	
VEHICLE DATA		
Make	Chevrolet	
Model	Vega	
Year	1973	
Weight (lb)	2270	
Impact Point	15 in. to right of center	
ACCELEROMETER DATA	Left	Right
Change in Momentum (lb-sec)	1054	1192
Duration of Event (sec)*	0.173	
Peak Deceleration (G's)	13.85	13.23
Maximum 0.050 Sec Average Deceleration (G's)	4.86	5.06
VEHICLE DAMAGE CLASSIFICATION		
TAD	FR-2	
SAE	12FREN1	
Did test article penetrate the passenger compartment?	No	
Was windshield broken?	No	

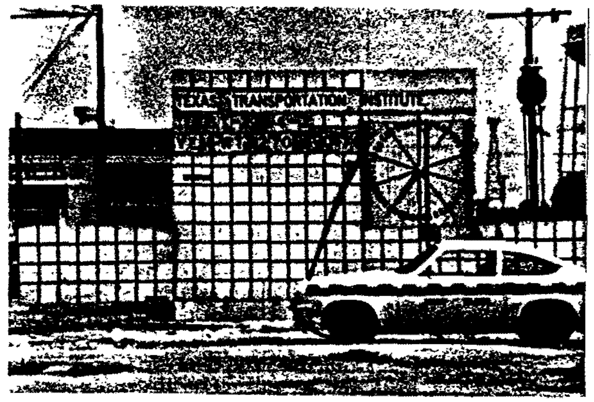
Metric Conversions:

1 in. = 2.54 cm
1 ft = 0.305 m
1 lb_m = 0.454 kg
1 lb_m-sec = 0.454 kg-s
1 mph = 0.447 m/s

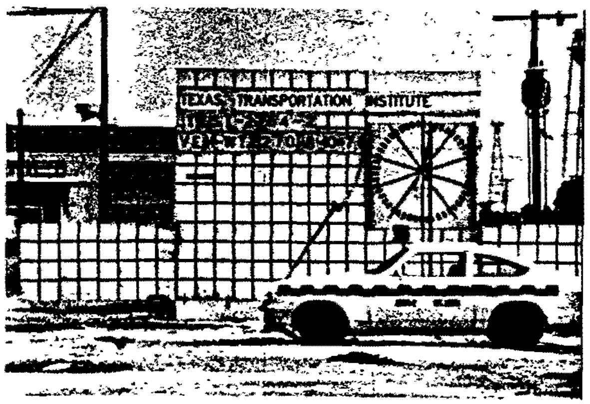
*Time of contact



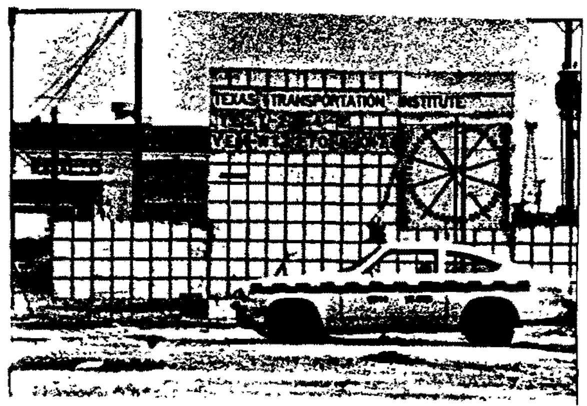
0.000 sec



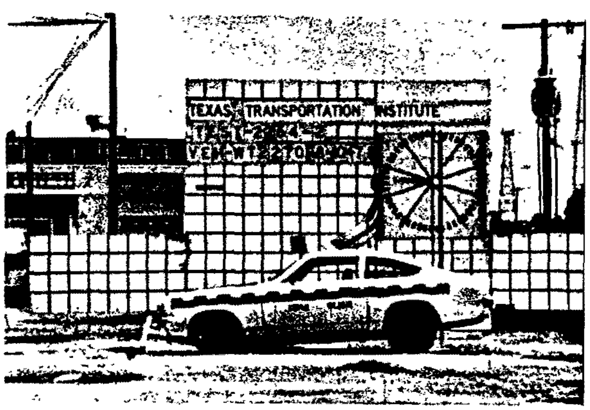
0.033 sec



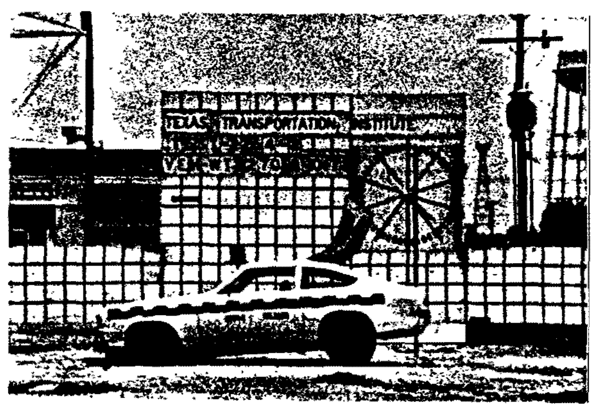
0.048 sec



0.079 sec



0.110 sec



0.131 sec

FIGURE 17. SEQUENTIAL PHOTOS, TEST 2.

TABLE 6. TIME DISPLACEMENT EVENT SUMMARY FOR TEST 2.

TIME (sec)	NOMINAL VEHICLE DISPLACEMENT (ft)	EVENT
0.000	0.00	Impact
0.033	2.83	Post begins to flatten
0.048	4.11	Sign flies from post
0.079	6.58	Maximum hood deformation
0.110	8.94	First loss of contact
0.131	10.55	Bumper strikes post "tee"

Metric Conversions:

1 ft = 0.305 m

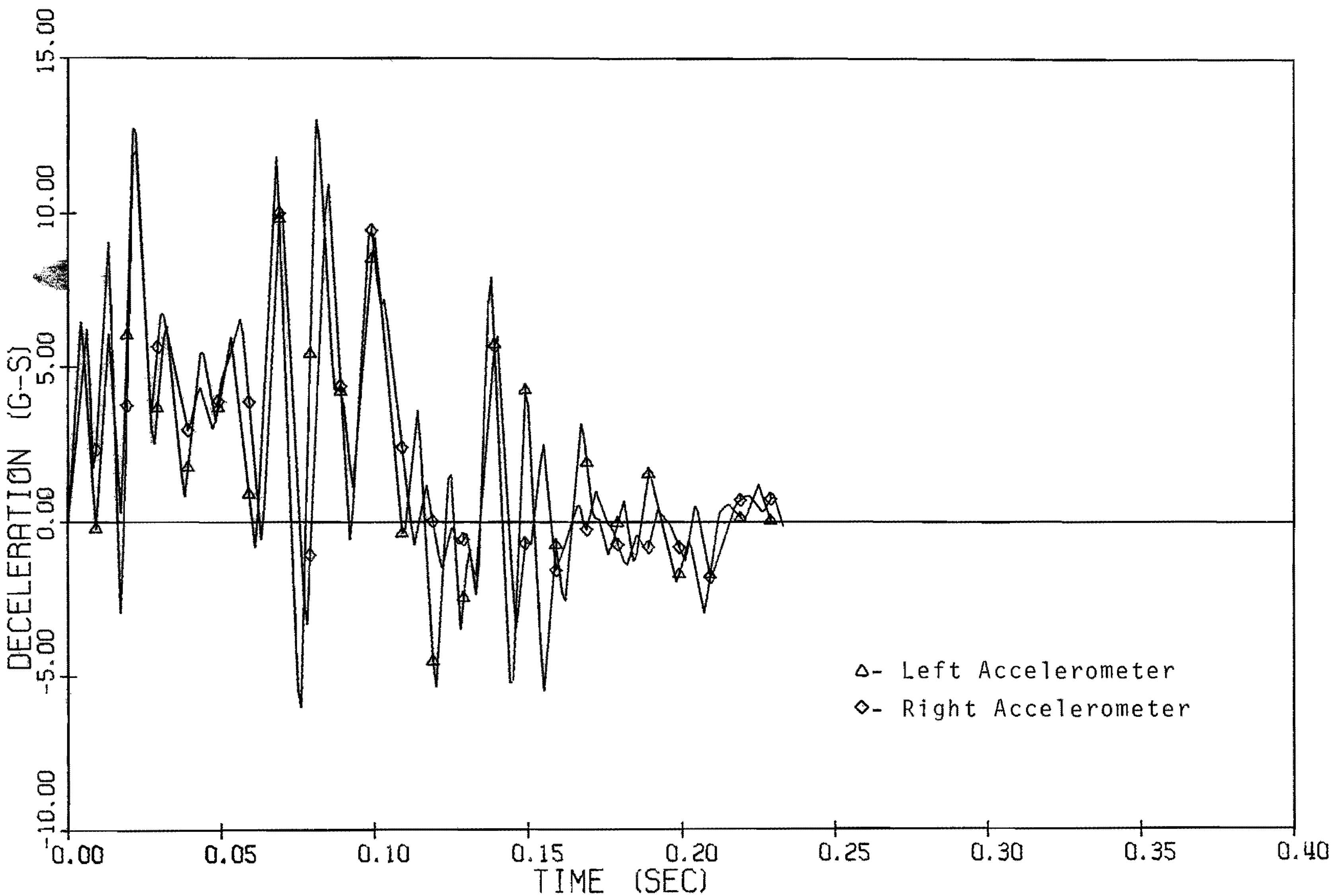


FIGURE 18. DECELERATION VERSUS TIME, TEST 2.

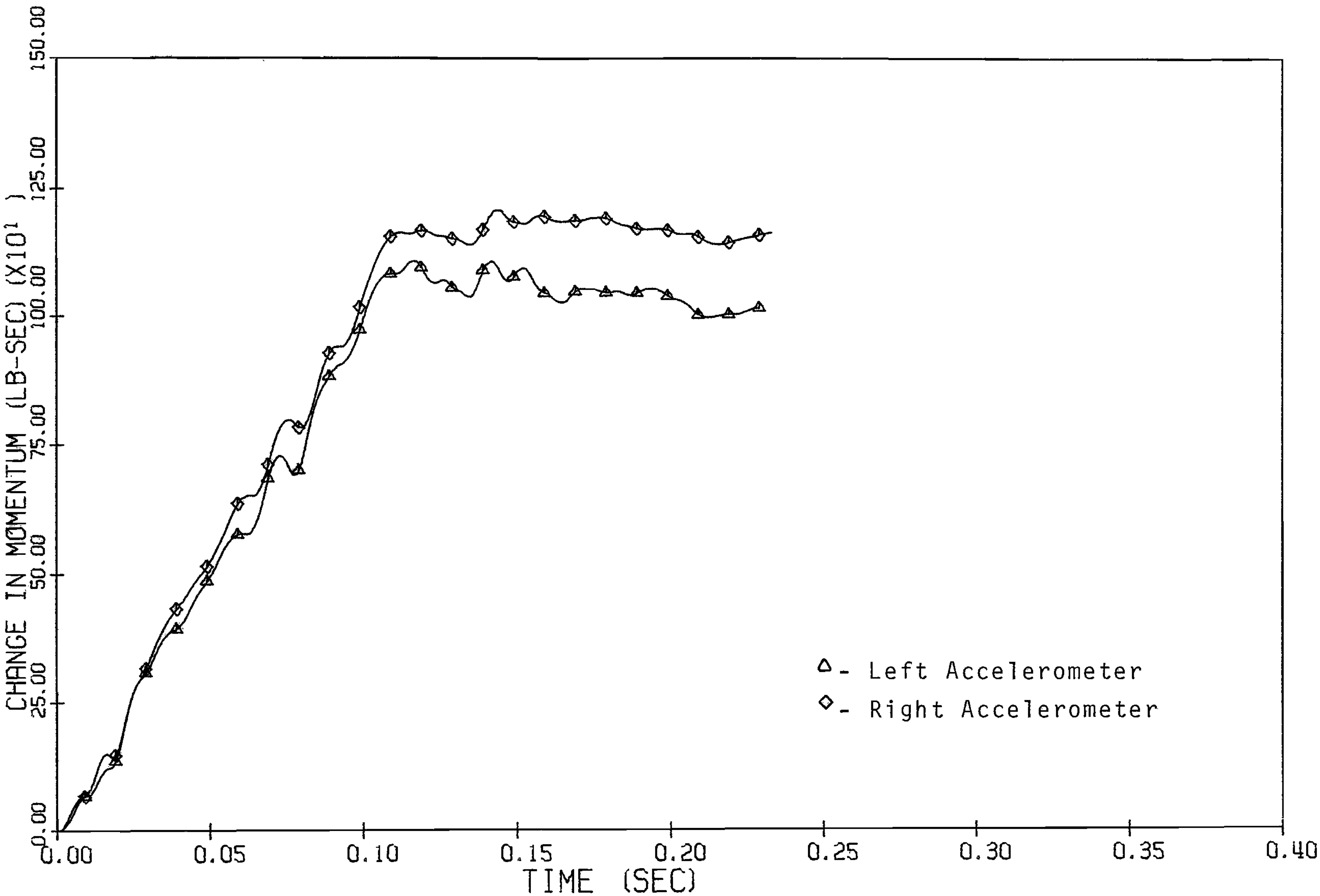


FIGURE 19. CHANGE IN MOMENTUM VERSUS TIME, TEST 2.

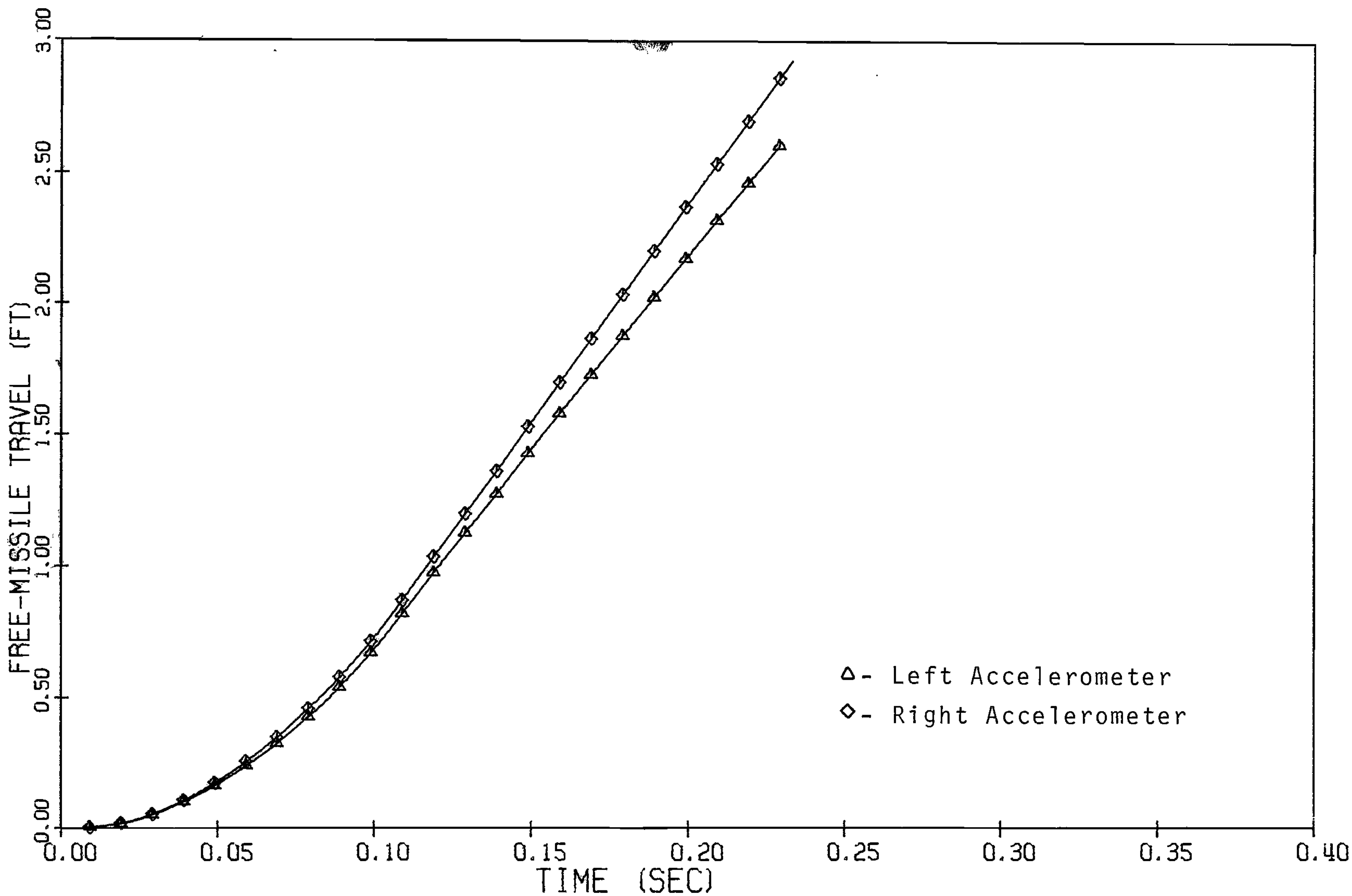
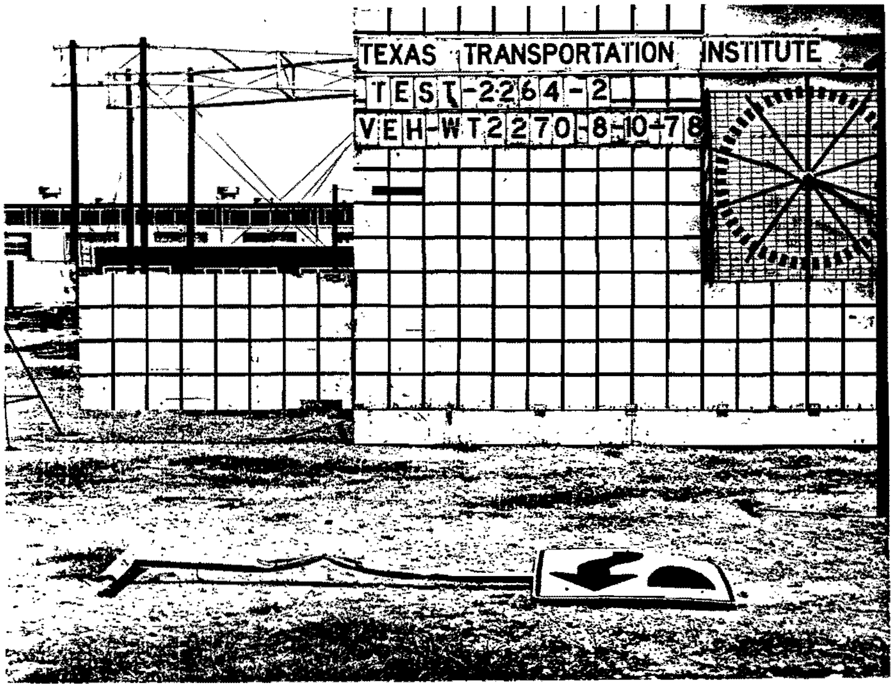
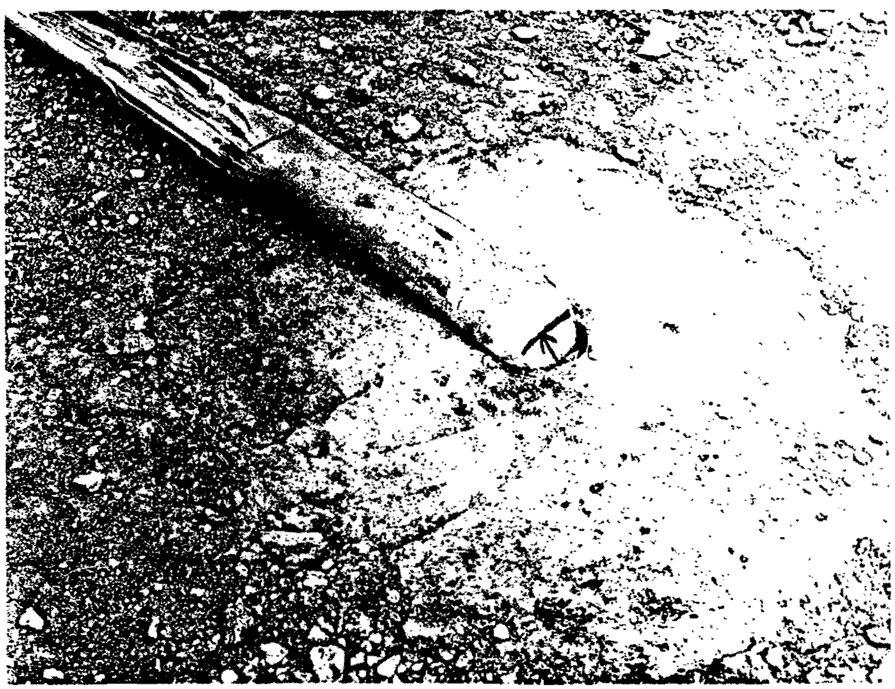


FIGURE 20. FREE MISSILE TRAVEL VERSUS TIME, TEST 2.

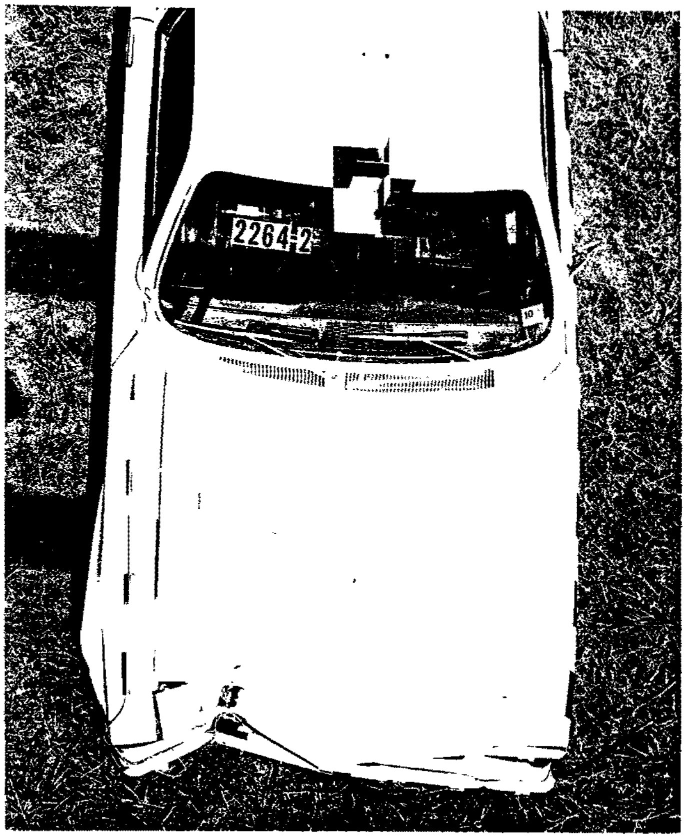


a) Post and Panel



b) Closeup of Footing

FIGURE 21. INSTALLATION DAMAGE, TEST 2.



a) Top View

b) Front View

FIGURE 22. VEHICLE DAMAGE, TEST 2.

TEST NO. 3

The design used in tests 1 and 2 was modified to include a sleeve in the footing in which the signpost was inserted. Test results for this configuration are given in Table 7. Figure 23 shows the sequential photos, and the time-displacement event summary is listed in Table 8. At impact the signpost began to bend away from the vehicle, and then wrapped around the bumper and hood. The sign panel also warped away from the signpost and hit the windshield. As the impact continued, the post broke away at the base, and then rotated down into windshield and roof.

Figures 24, 25, and 26 show deceleration, change in momentum, and free missile travel versus time data. The anchor sleeve and concrete footing were undamaged but the post and panel were damaged beyond repair. The installation after impact can be seen in Figure 27. Damage to the vehicle was extensive. The bumper, grille header panel, hood, and fender were all crushed to some degree. The windshield was also broken. This can be seen in Figure 28.

The TAD and SAE damage rating scales were used as a measure of impact severity. These values are tabulated in the summary of results, Table 7.

TABLE 7. SUMMARY OF RESULTS, TEST 3.

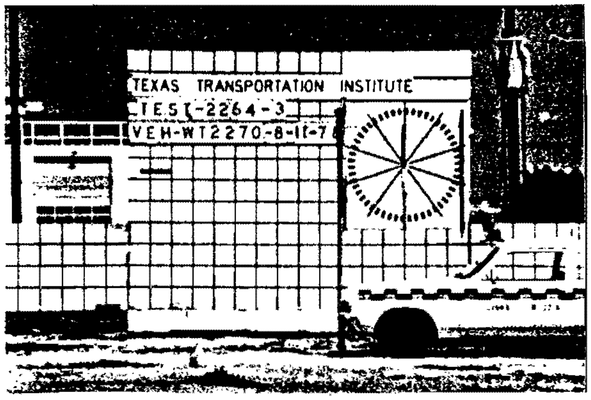
Impact Velocity = 62.7 mph

POST DATA		
Type	Thin Wall Tube w/Sleeve	
Size	2.875"ϕ x 0.120"ϕ -Post	
Embedment Method	3.5"ϕ x 0.216"ϕ -Sleeve	
Embedment Depth (ft)	12"ϕ Concrete Footing	
VEHICLE DATA		
Make	Chevrolet	
Model	Vega	
Year	1973	
Weight (lb)	2270	
Impact Point	15 in. to left of center	
ACCELEROMETER DATA	Left	Right
Change in Momentum (lb-sec)	841	757
Duration of Event (sec)*	0.138	
Peak Deceleration (G's)	13.59	12.83
Maximum 0.050 Sec Average Deceleration (G's)	4.53	3.93
VEHICLE DAMAGE CLASSIFICATION		
TAD	FL-4	
SAE	12FLEN2	
Did test article penetrate the passenger compartment?	No	
Was windshield broken?	Yes, by sign panel	

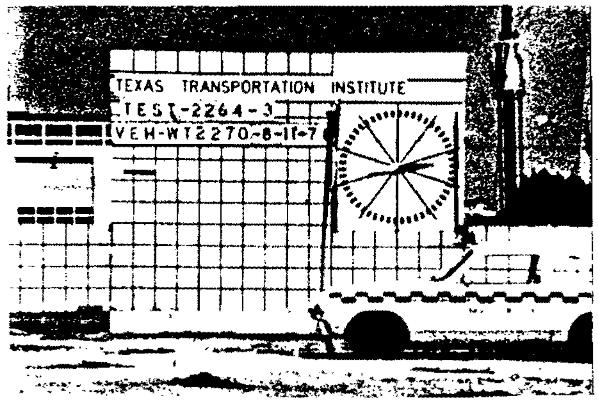
Metric Conversions:

1 in.	= 2.54 cm
1 ft	= 0.305 m
1 lb_m	= 0.454 kg
1 lb_m-sec	= 0.454 kg-s
1 mph	= 0.447 m/s

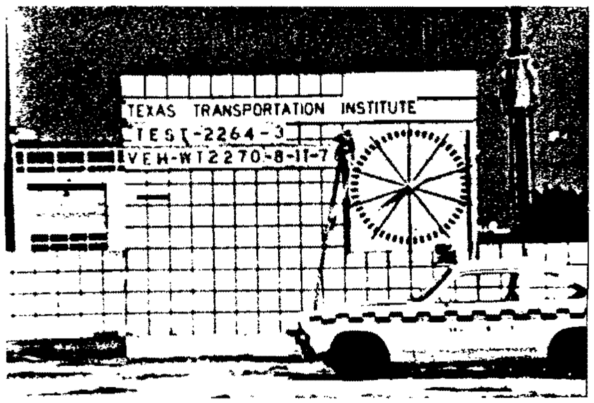
*Time of contact



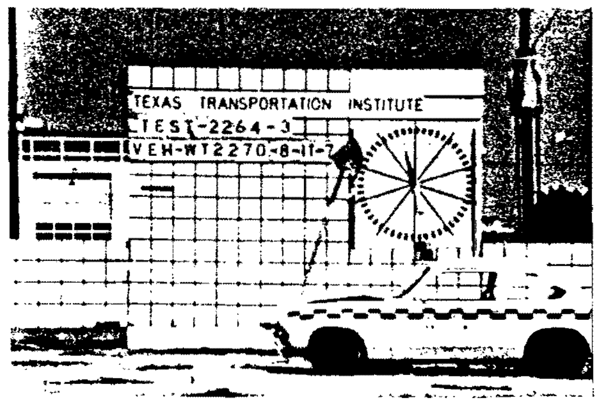
0.000 sec



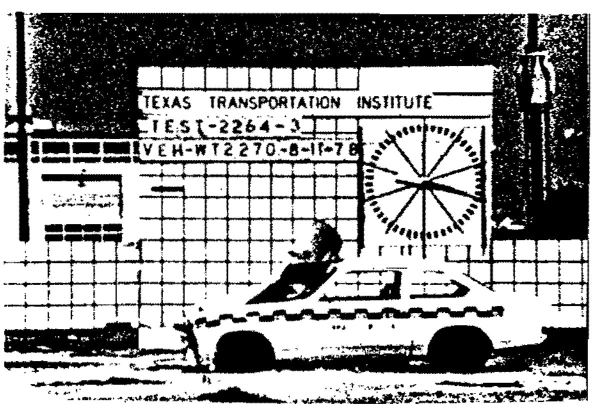
0.009 sec



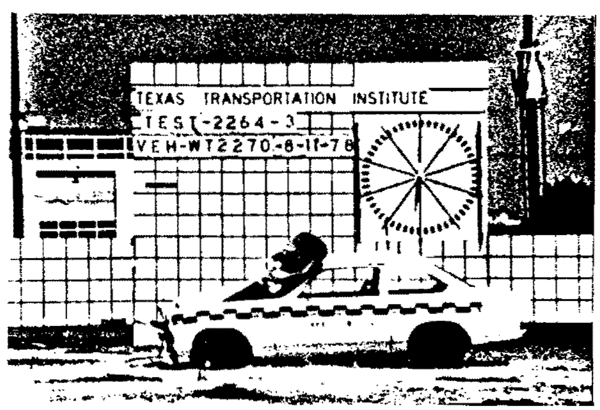
0.023 sec



0.034 sec



0.081 sec



0.089 sec

FIGURE 23. SEQUENTIAL PHOTOS, TEST 3.

TABLE 8. TIME DISPLACEMENT EVENT SUMMARY FOR TEST 3.

TIME (sec)	NOMINAL VEHICLE DISPLACEMENT (ft)	EVENT
0.000	0.00	Impact
0.009	0.76	Signpost begins to bend
0.023	2.02	Panel moving away from post
0.034	2.93	Hood buckles
0.081	6.81	Post breaks at base
0.089	7.48	Panel strikes roof

Metric Conversion:

1 ft = 0.305 m

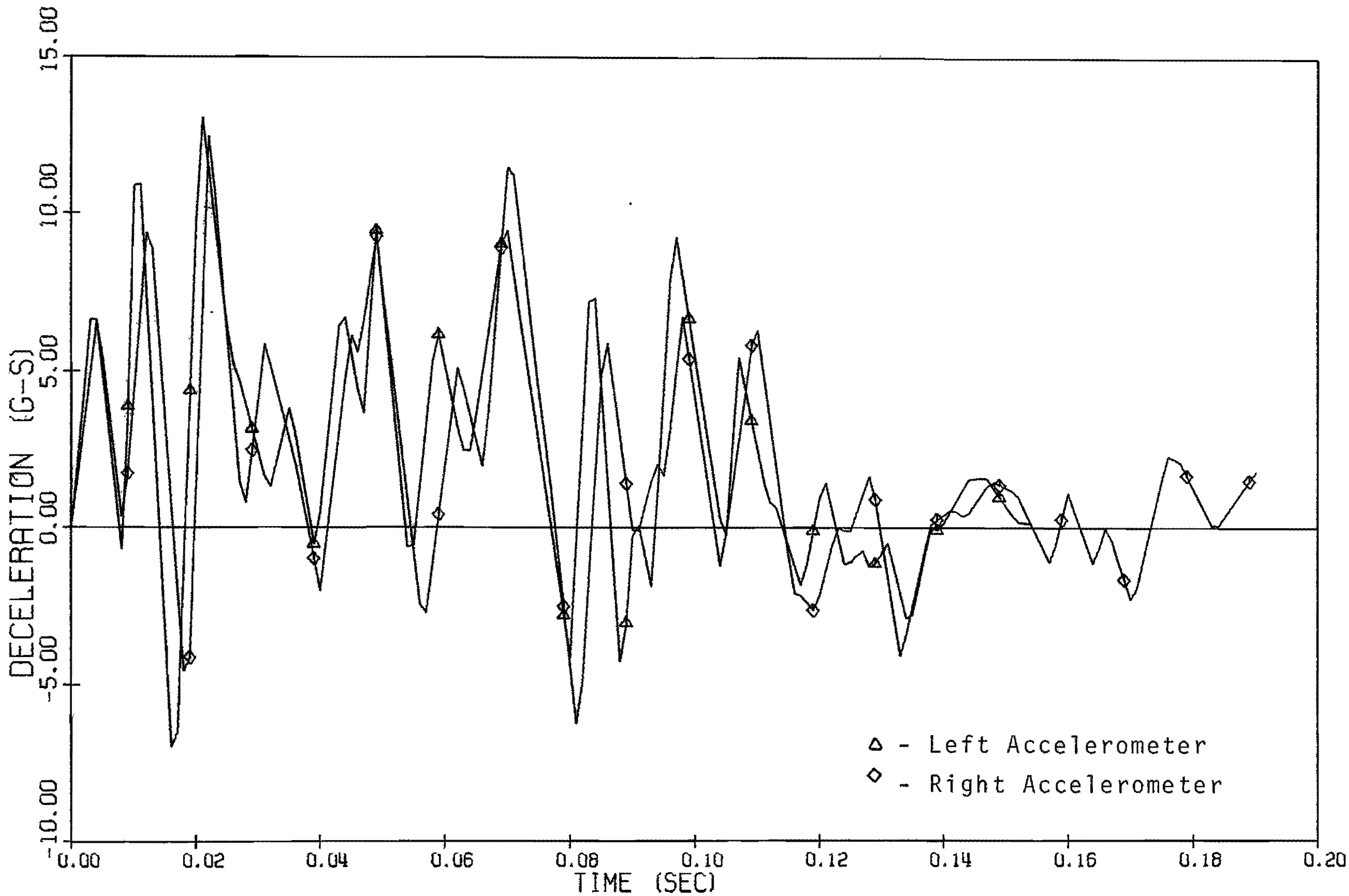


FIGURE 24. DECELERATION VERSUS TIME, TEST 3.

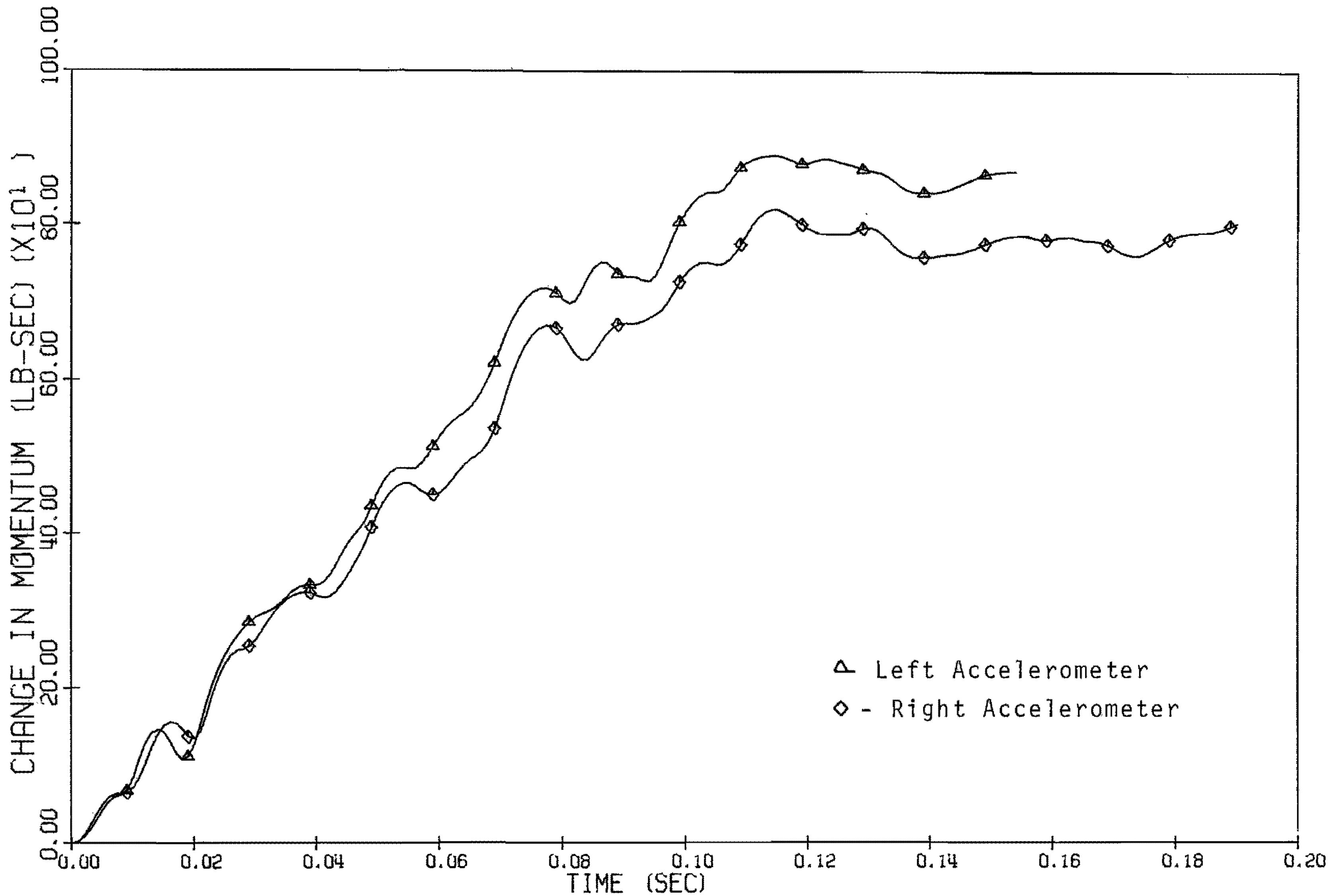


FIGURE 25. CHANGE IN MOMENTUM VERSUS TIME, TEST 3.

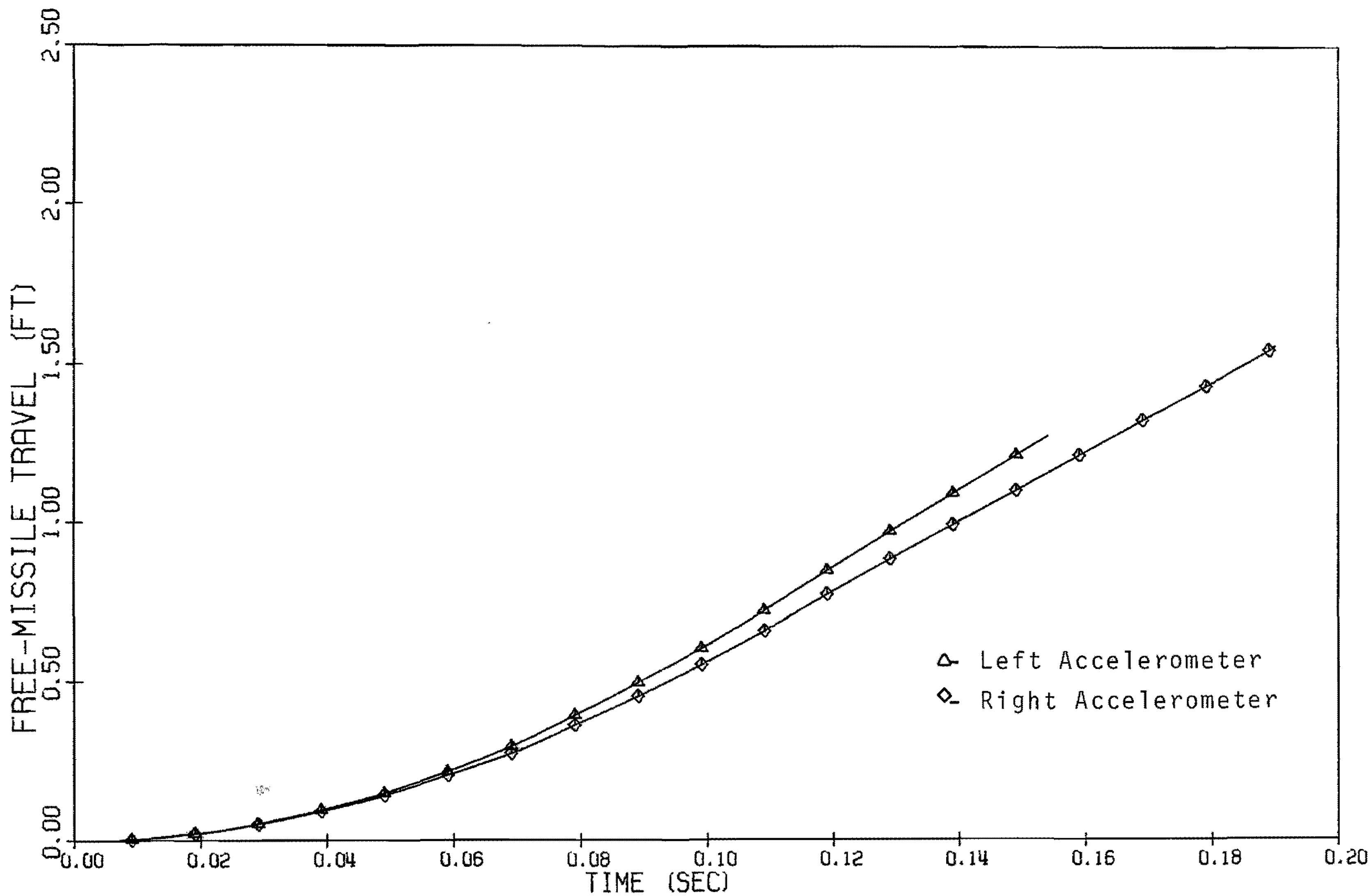
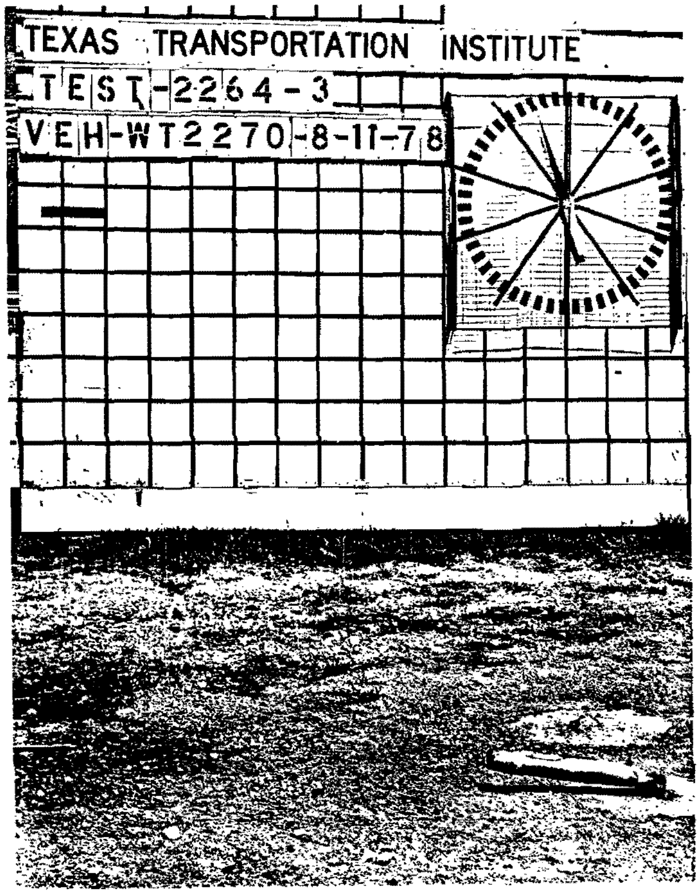
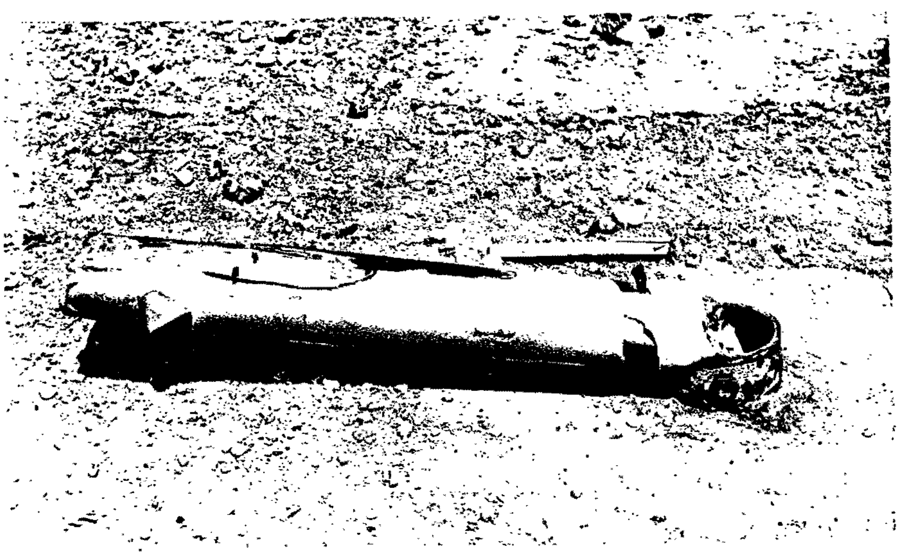


FIGURE 26. FREE MISSILE TRAVEL VERSUS TIME, TEST 3.

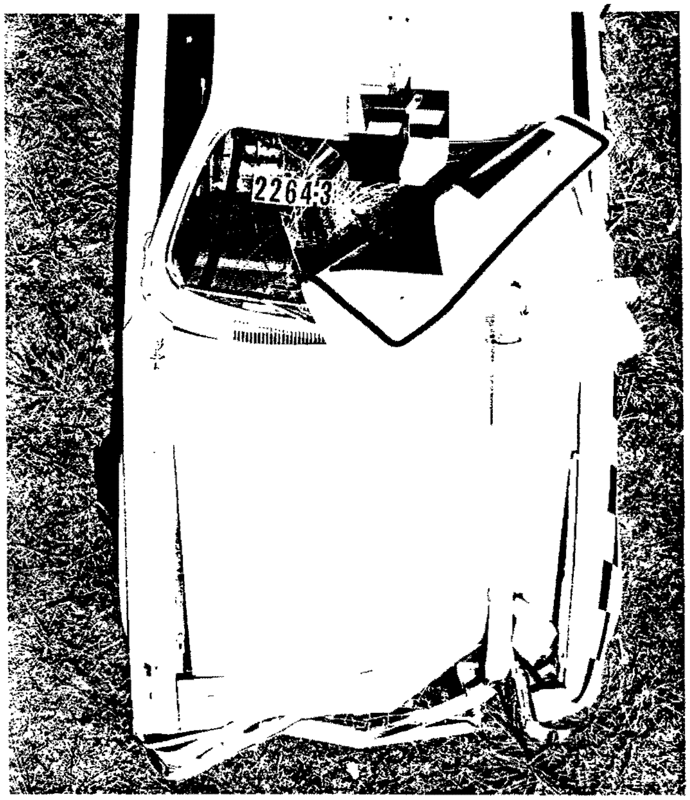


a) Side View

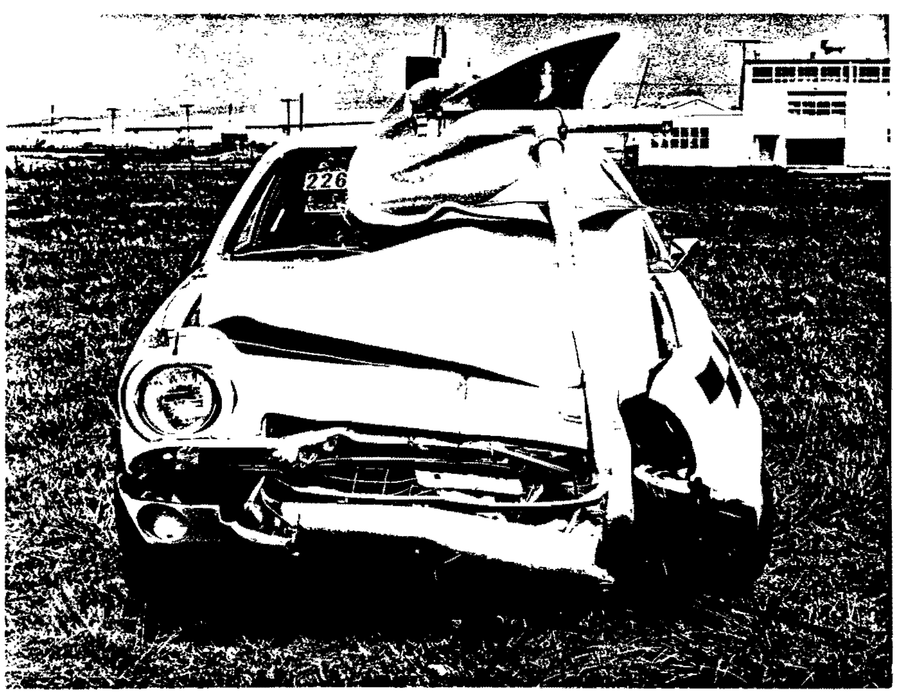


b) Closeup of Footing

FIGURE 27. INSTALLATION DAMAGE, TEST 3.



a) Top View



b) Front View

FIGURE 28. VEHICLE DAMAGE, TEST 3.

TEST NO. 4

The fourth test involved a post with the same diameter as the first three tests, but a smaller wall thickness. Table 9 summarizes the results of test 4. Figure 29 shows the sequential photos during impact, and the time-displacement event summary is contained in Table 10. The results of this test were far less severe than in previous tests, as can be seen in the vehicle's response. As the post began to bend away, the sign panel and mounting hardware slid off the post. The post started to wrap around the vehicle and was then restraightened as the car passed over it. The sign panel hit the roof and slid off after leaving the signpost.

Figures 30, 31, and 32 show deceleration, change in momentum, and free missile travel versus time data. Damage to the post and footing is given in Figure 33. Restoration would require replacement of both the footing and signpost. However, the panel and mounting hardware could be reused.

Damage to the vehicle was minimal, and it was operable after the test. Figure 34 shows the damage to the vehicle. Table 9 contains the TAD and SAE damage classifications for this test.

TABLE 9. SUMMARY OF RESULTS, TEST 4.

Impact Velocity = 59.0

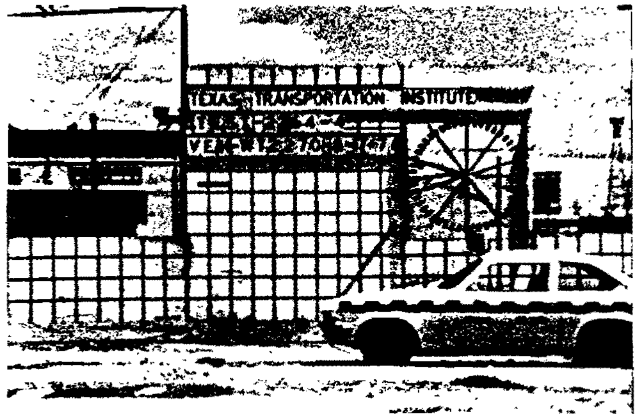
POST DATA			
Type	Thin Wall Tube		
Size	2.875"ϕ x 0.065"		
Embedment Method	12"ϕ Concrete Footing		
Embedment Depth (ft)	2		
VEHICLE DATA			
Make	Chevrolet		
Model	Vega		
Year	1973		
Weight (lb)	2270		
Impact Point	15 in. to right of center		
ACCELEROMETER DATA		Left	Right
Change in Momentum (lb-sec)		359	206
Duration of Event (sec)*		0.245	
Peak Deceleration (G's)		4.17	5.46
Maximum 0.050 Sec Average Deceleration (G's)		1.92	1.71
VEHICLE DAMAGE CLASSIFICATION			
TAD	FR-0		
SAE	12FREN1		
Did test article penetrate the passenger compartment?	No		
Was windshield broken?	No		

Metric Conversions:

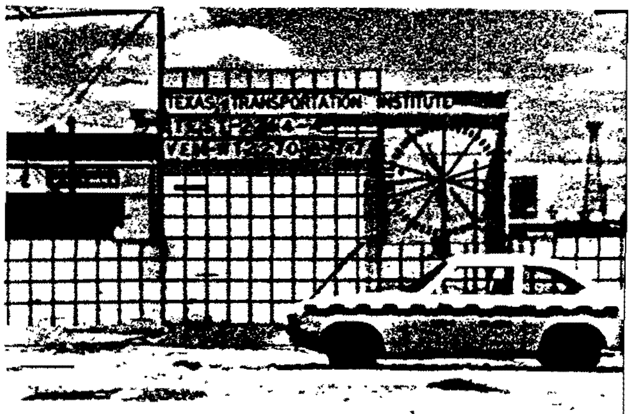
1 in.	= 2.54 cm
1 ft	= 0.305 m
1 lb_m	= 0.454 kg
1 lb_m-sec	= 0.454 kg-s
1 mph	= 0.447 m/s

*Time of contact

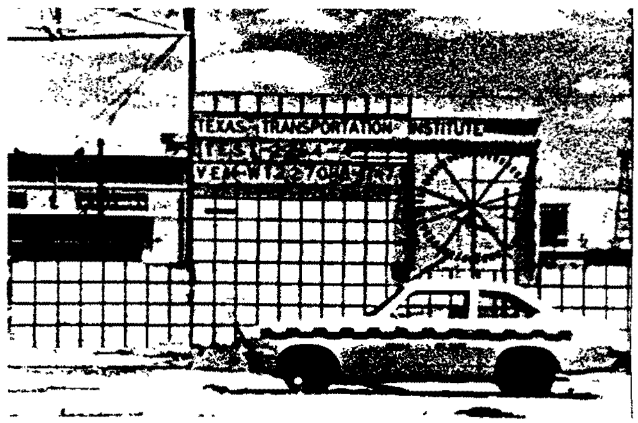
0.000 sec



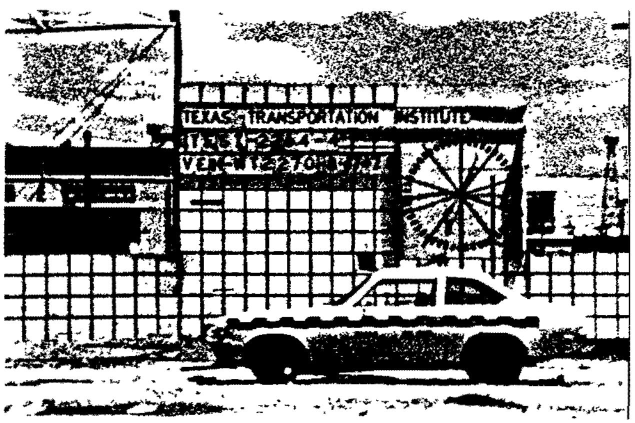
0.035 sec



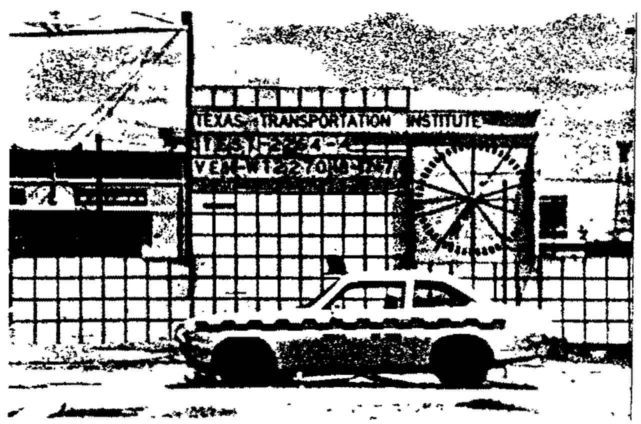
0.041 sec



0.072 sec



0.081 sec



0.101 sec

FIGURE 29. SEQUENTIAL PHOTOS, TEST 4.

TABLE 10. TIME DISPLACEMENT EVENT SUMMARY FOR TEST 4.

TIME (sec)	NOMINAL VEHICLE DISPLACEMENT (ft)	EVENT
0.000	0.00	Impact
0.035	3.16	Panel slides off post
0.041	3.57	Maximum hood deformation
0.072	6.21	Panel contacts roof
0.081	7.01	Loss of contact
0.101	8.63	Car rolling over post

Metric Conversion:

1 ft = 0.305 m

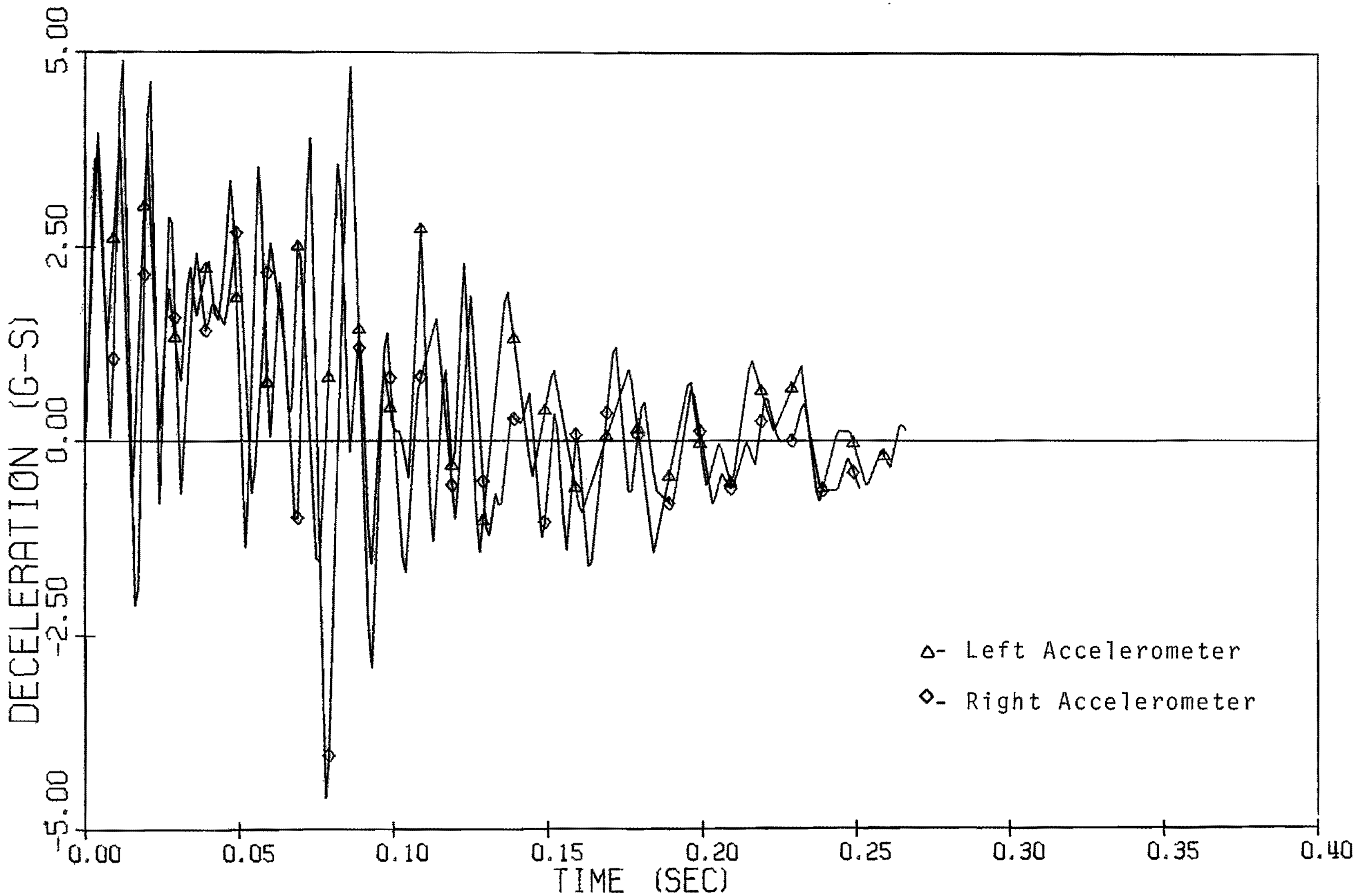


FIGURE 30. DECELERATION VERSUS TIME, TEST 4.

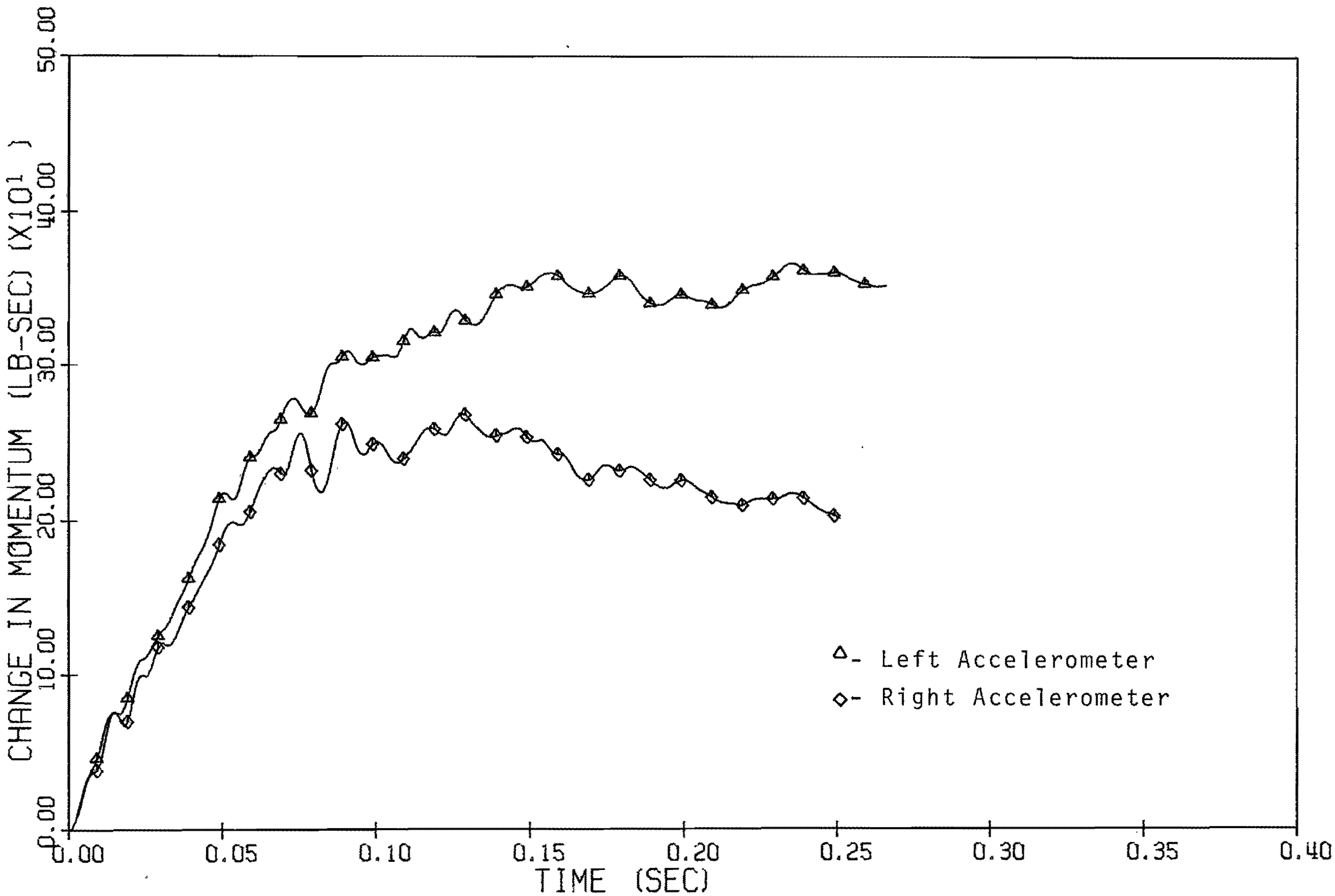


FIGURE 31. CHANGE IN MOMENTUM VERSUS TIME, TEST 4.

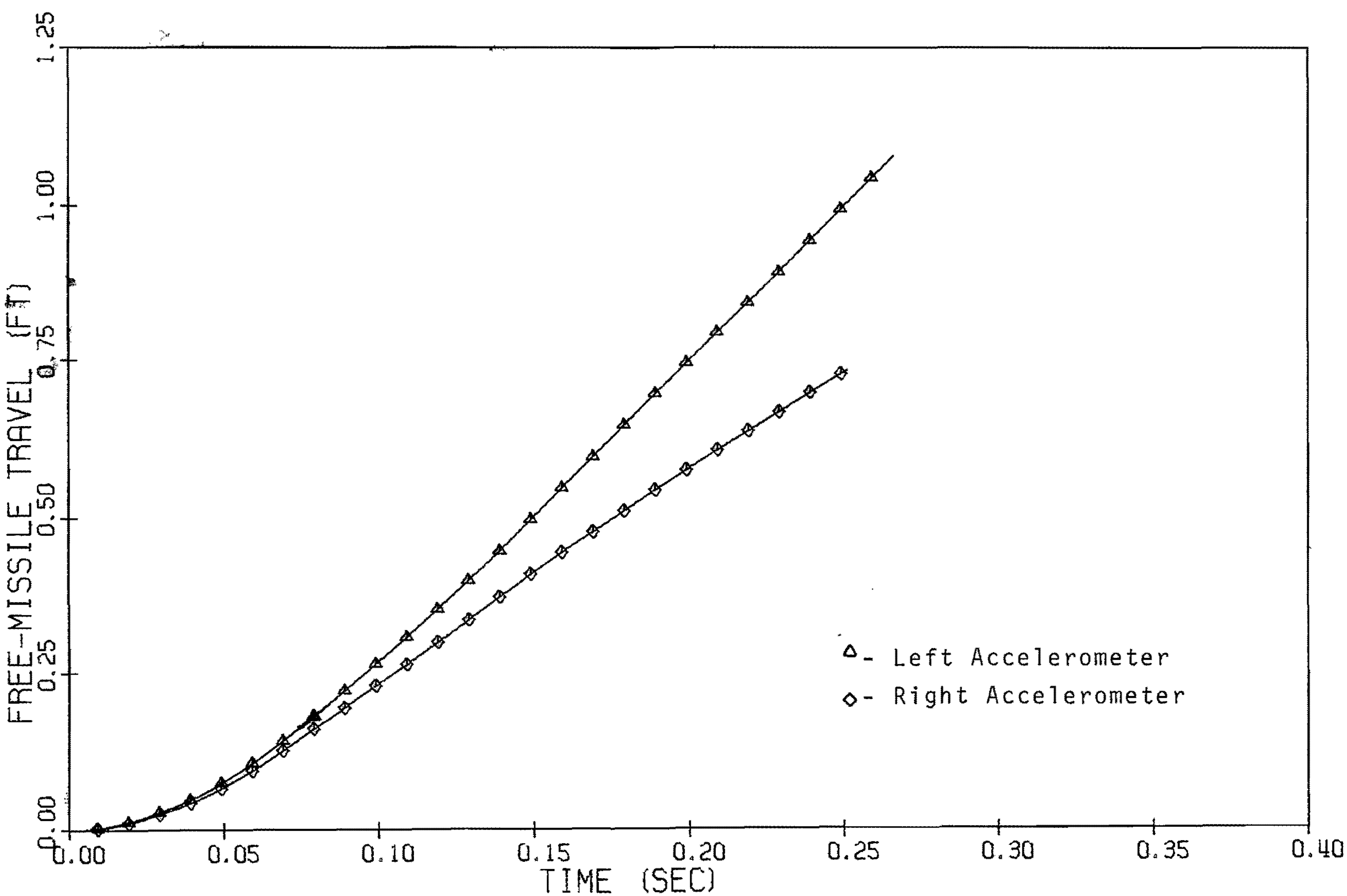
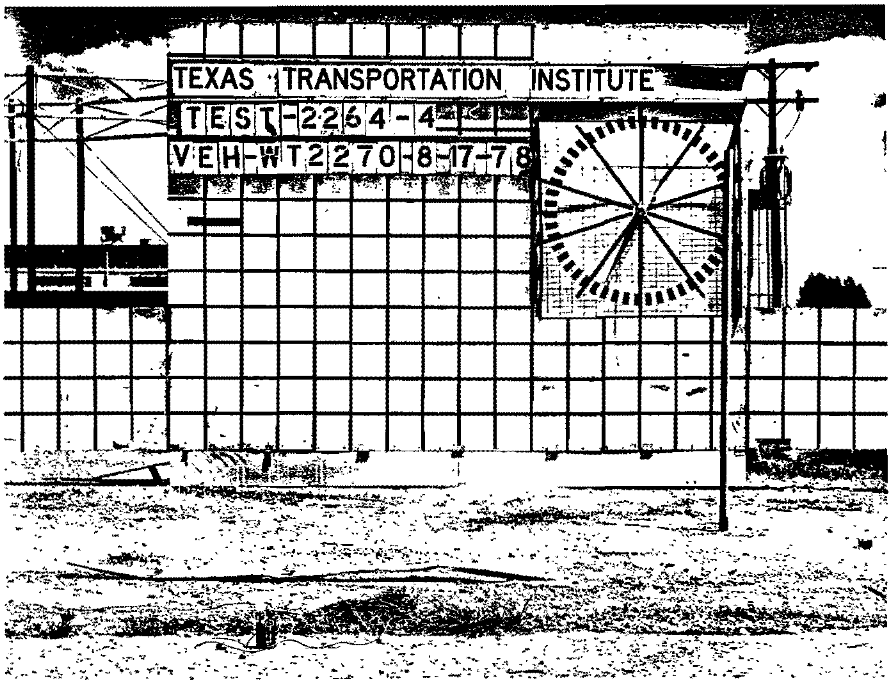
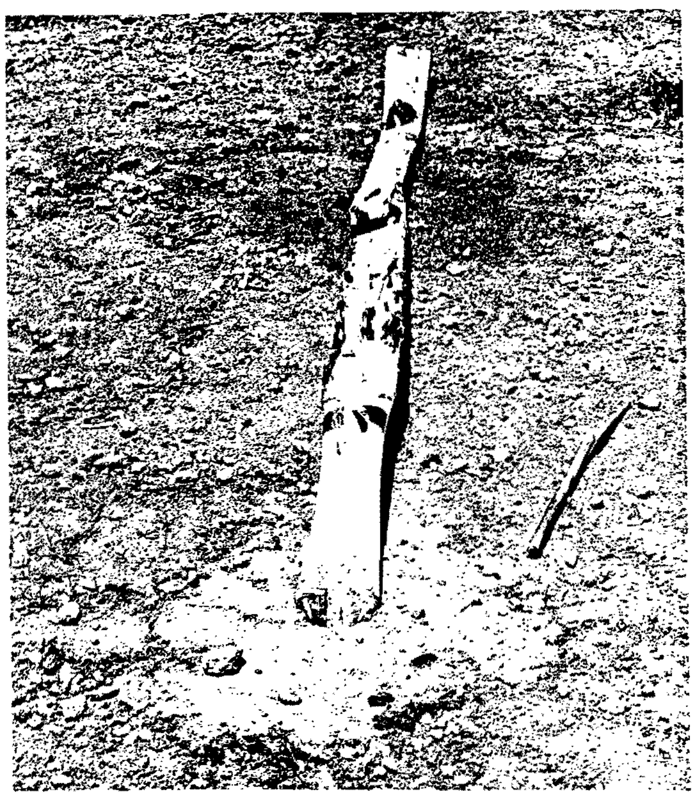


FIGURE 32. FREE MISSILE TRAVEL VERSUS TIME, TEST 4.

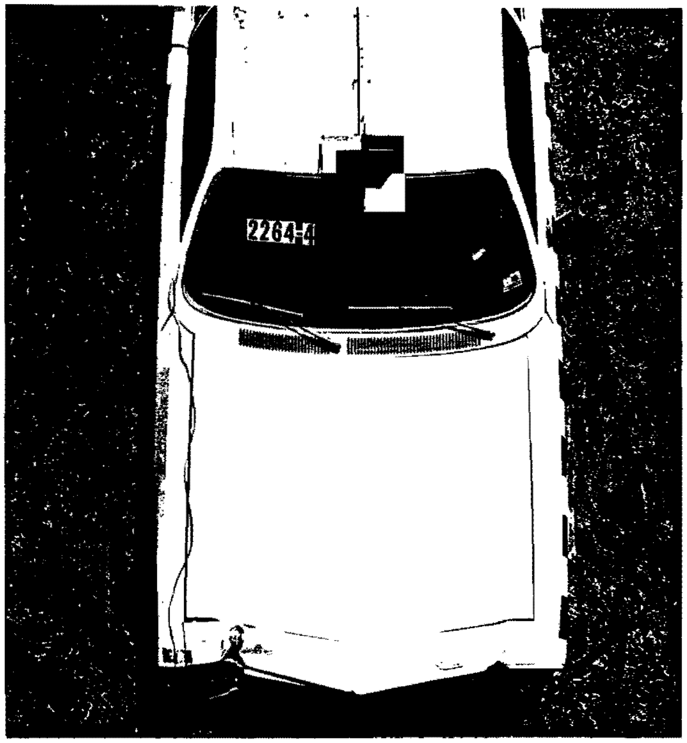


a) Side View

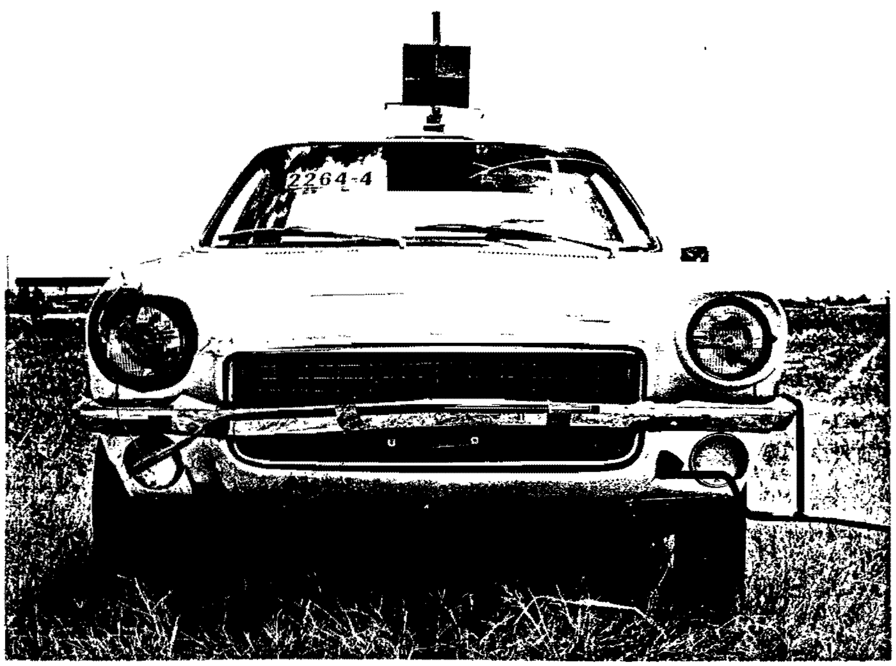


b) Closeup of Footing

FIGURE 33. INSTALLATION DAMAGE, TEST 4.



a) Top View



b) Front View

FIGURE 34. VEHICLE DAMAGE, TEST 4.

TEST NO. 5

This test involved a signpost with a smaller diameter but larger wall thickness than that of test 4. Results were similar to those in test 4. Table 11 has the summary of results for test 5; sequential photos are in Figure 35; and Table 12 gives the time-displacement event summary. As the vehicle impacted the installation, the signpost began to bend away at the base and then wrapped around the hood. At the same time, the panel slid off the signpost and hit the roof of the vehicle. The post then broke away and fell under the vehicle as it moved through the crash.

Data for the deceleration, change in momentum, and free missile travel versus time results are in Figures 36, 37, and 38. Damage to the installation would require replacement of the footing and signpost but the sign panel and hardware could be reused. This damage is shown in Figure 39. Damage to the vehicle was relatively minor. The bumper and grille header panel would require repair, but the fender and hood were not impacted. Photos of the vehicle after testing are in Figure 40. Damage to the vehicle was rated according to TAD and SAE rating scales and is given in Table 11.

TABLE 11. SUMMARY OF RESULTS, TEST 5.

Impact Velocity = 59.6 mph

POST DATA

Type	Thin Wall Tube
Size	2.375"ϕ x 0.109"
Embedment Method	12"ϕ Concrete Footing
Embedment Depth (ft)	2

VEHICLE DATA

Make	Chevrolet
Model	Vega
Year	1973
Weight (lb)	2270
Impact Point	15 in. to right of center

ACCELEROMETER DATA	Left		Right
Change in Momentum (lb-sec)	343		360
Duration of Event (sec)*		0.210	
Peak Deceleration (G's)	5.78		10.80
Maximum 0.050 Sec Average Deceleration (G's)	2.11		2.65

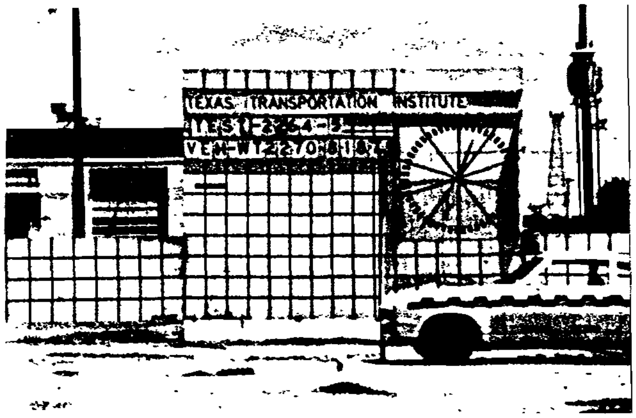
VEHICLE DAMAGE CLASSIFICATION

TAD	FR-1
SAE	12FREN1
Did test article penetrate the passenger compartment?	No
Was windshield broken?	No

*Time of contact

Metric Conversions:

1 in.	= 2.54 cm
1 ft	= 0.305 m
1 lb_m	= 0.454 kg
1 lb_m-sec	= 0.454 kg-s
1 mph	= 0.447 m/s



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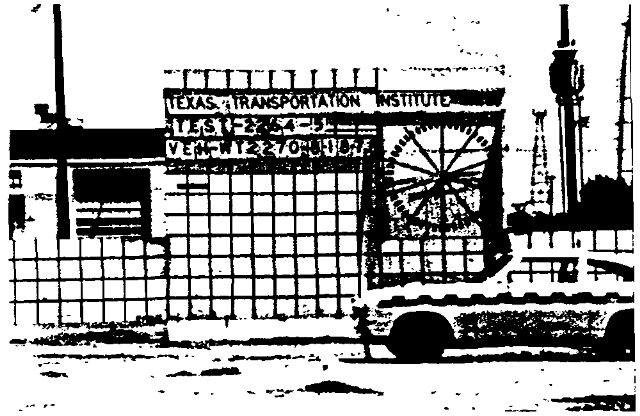

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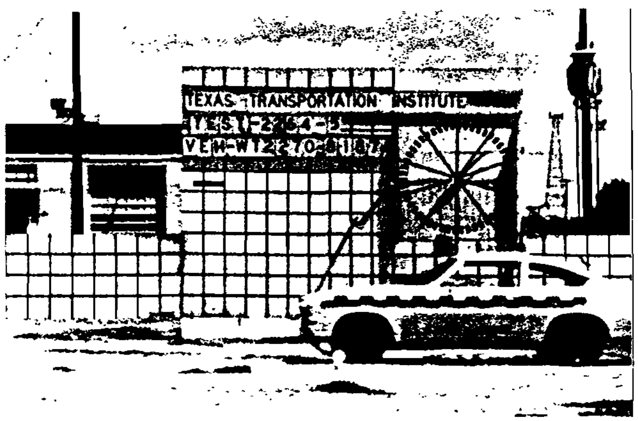
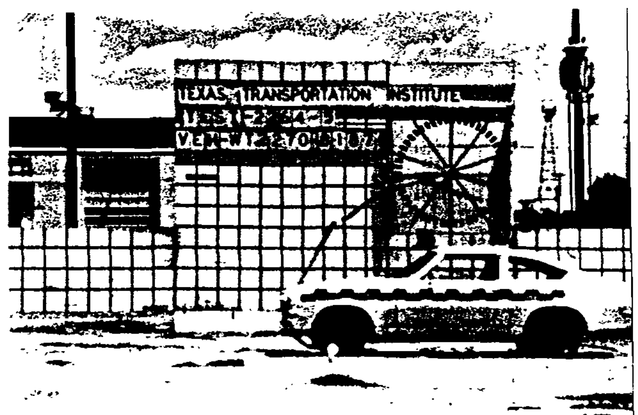
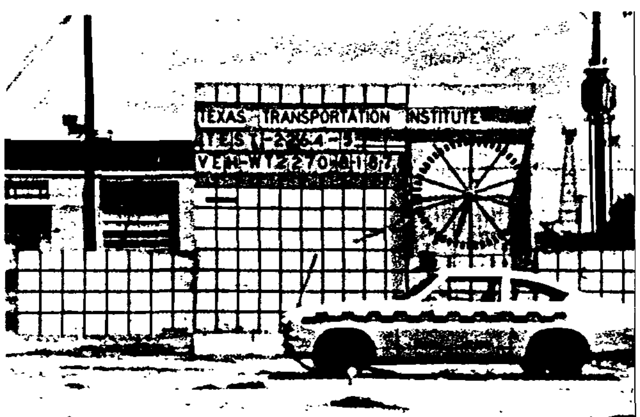


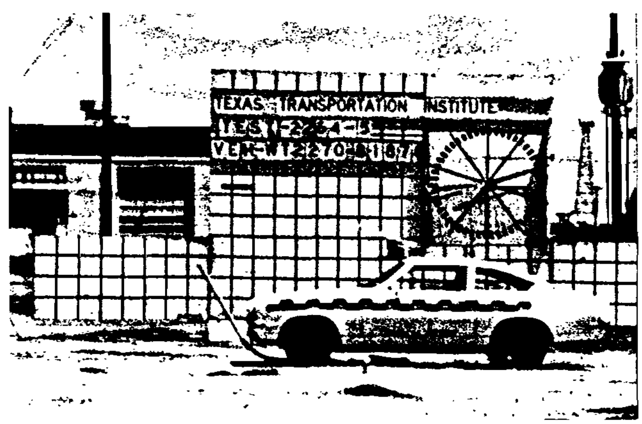
0.039 sec



0.044 sec



0.053 sec



0.076 sec

FIGURE 35. SEQUENTIAL PHOTOS, TEST 5.

TABLE 12. TIME DISPLACEMENT EVENT SUMMARY FOR TEST 5.

TIME (sec)	NOMINAL VEHICLE DISPLACEMENT (ft)	EVENT
0.000	0.00	Impact
0.007	0.53	Post begins bending
0.039	3.17	Maximum hood deformation
0.044	3.70	Panel free from post
0.053	4.41	Post breaks
0.076	6.30	Post falling away from vehicle

Metric Conversion:

1 ft = 0.305 m

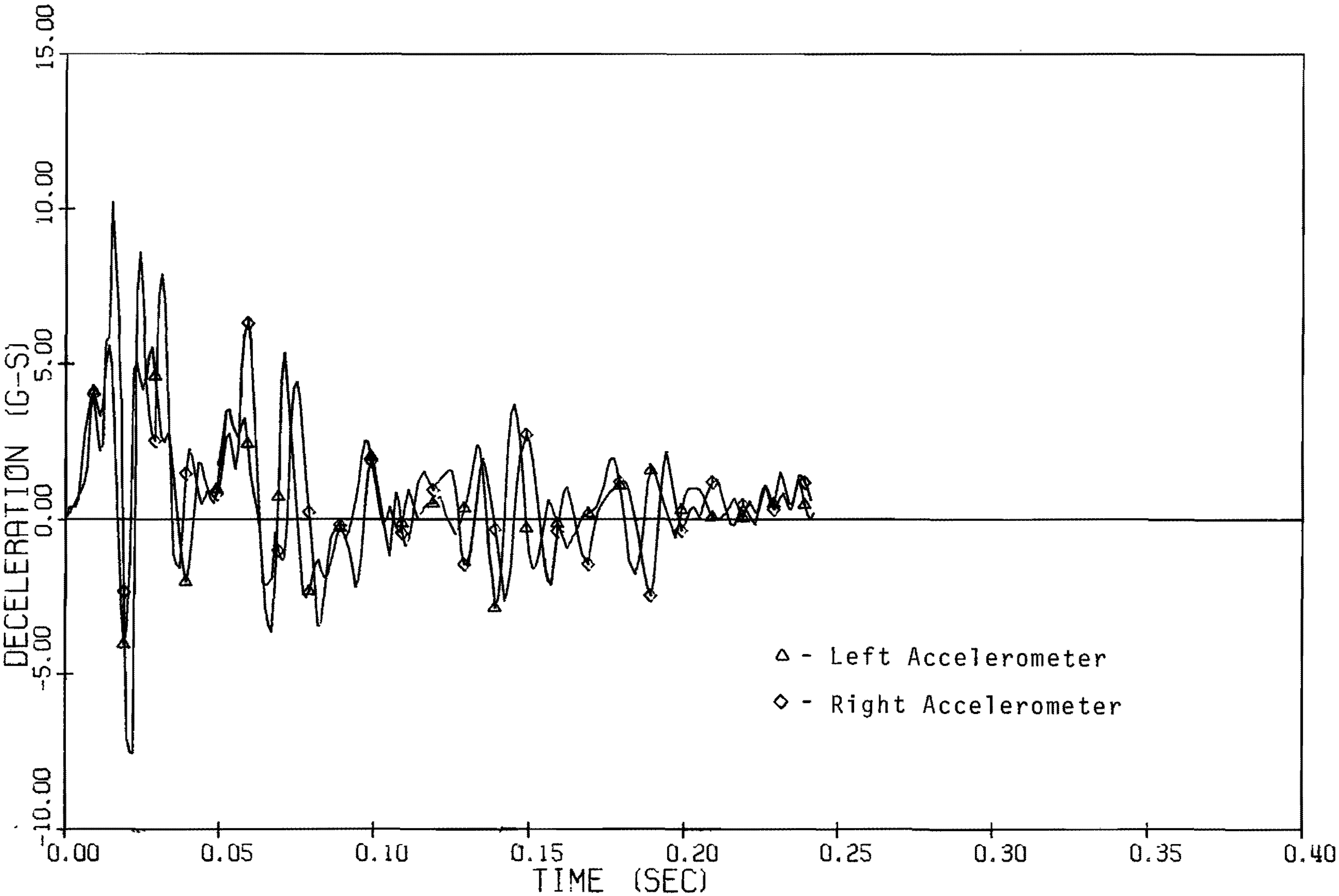


FIGURE 36. DECELERATION VERSUS TIME, TEST 5.

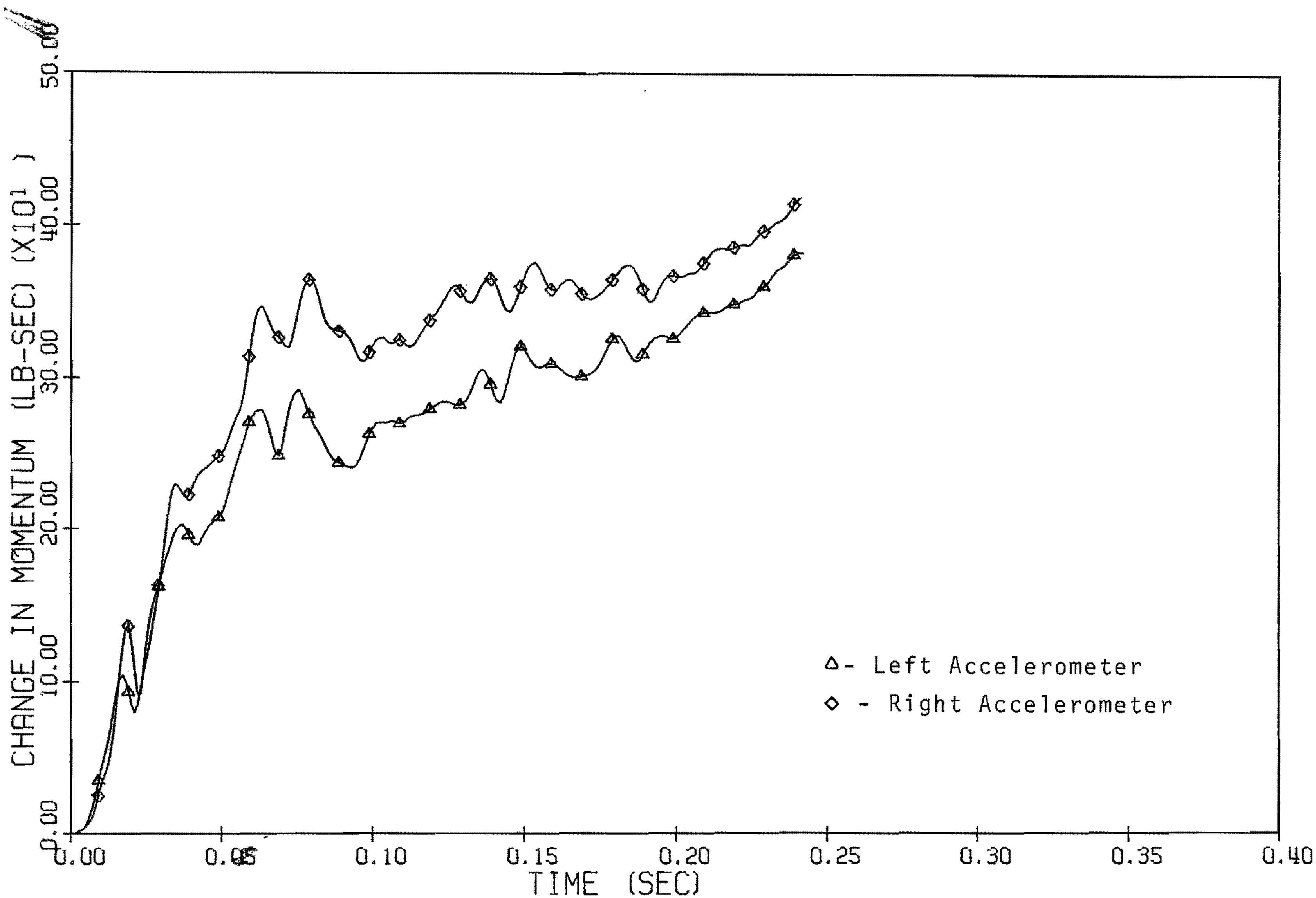


FIGURE 37. CHANGE IN MOMENTUM VERSUS TIME, TEST 5.

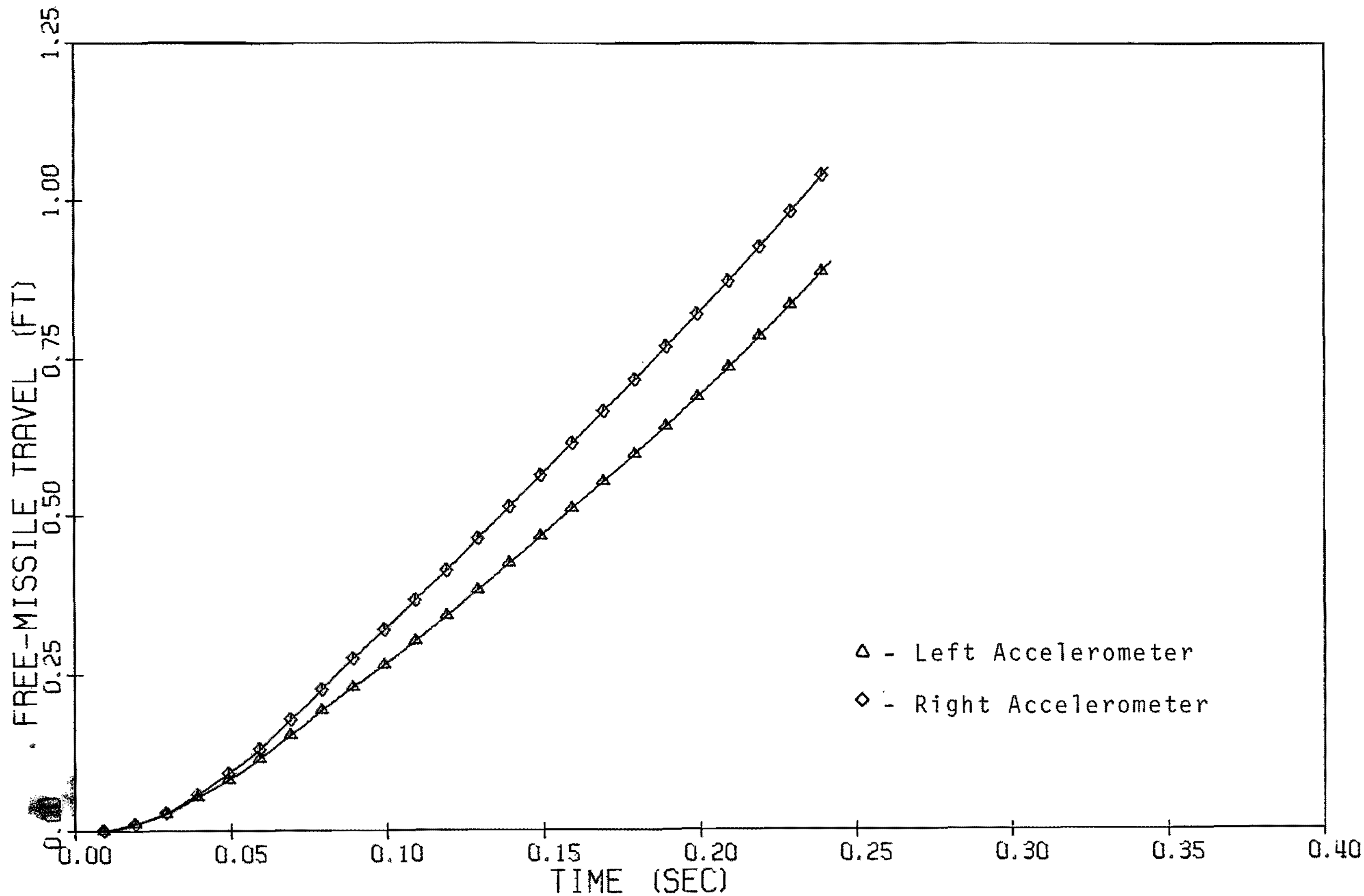
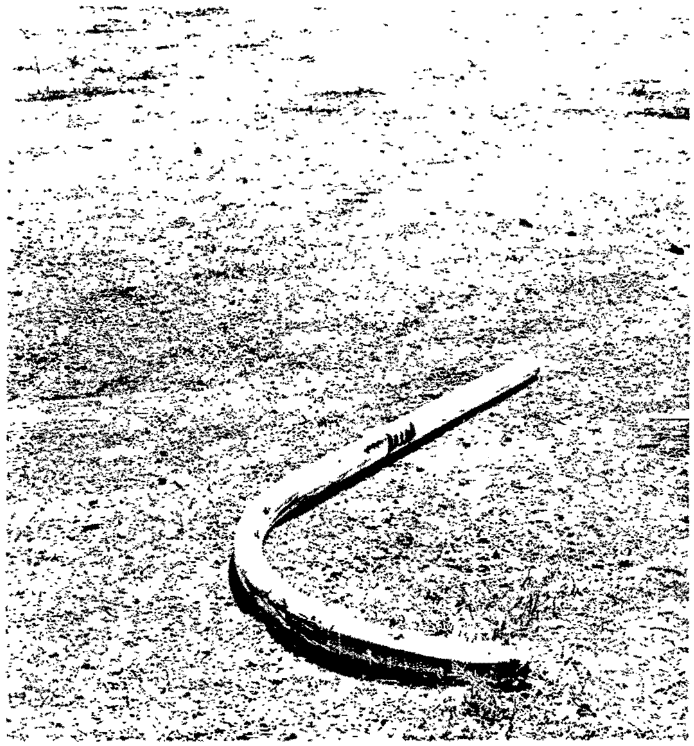
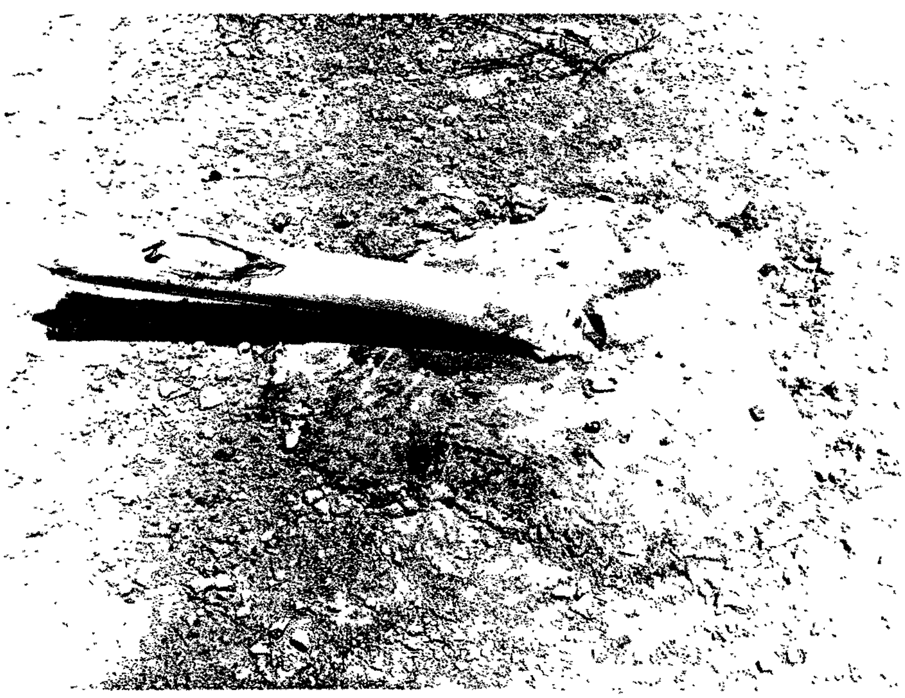


FIGURE 38. FREE MISSILE TRAVEL VERSUS TIME, TEST 5.

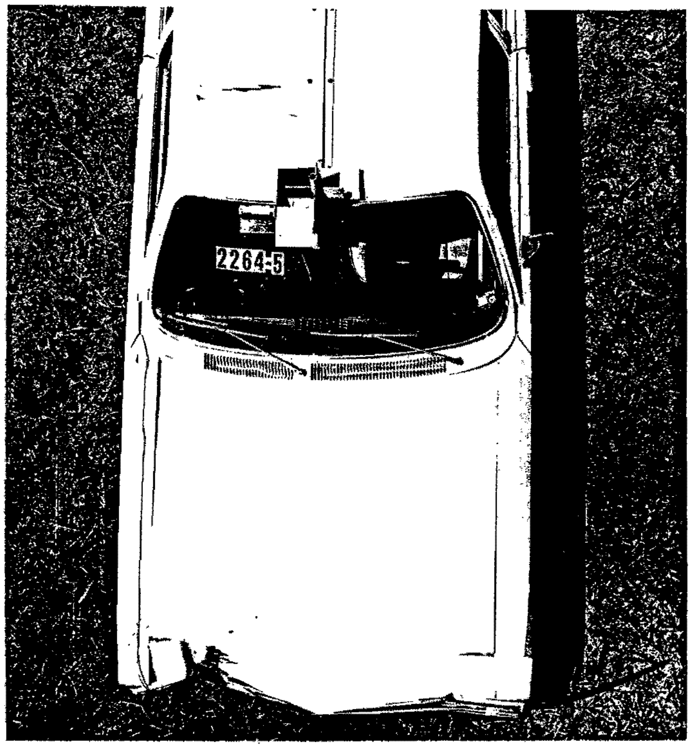


a) Signpost Damage



b) Closeup of Base

FIGURE 39. INSTALLATION DAMAGE, TEST 5.



a) Top View

b) Front View

FIGURE 40. VEHICLE DAMAGE, TEST 5.

TEST NO. 6

A milepost marker and delineator post were tested together in test 6. Deceleration and change in momentum values reported here are combined values for both posts. Results are summarized in Table 13; Figure 41 has the sequential photos; and Table 14 contains the time-displacement event summary. The vehicle first impacted the milepost and began to bend it away. The milepost wrapped around the hood as the vehicle struck the delineator post. The milepost was then pulled out of the ground and traveled with the vehicle. The vehicle knocked the delineator post down and rolled over it.

Figures 42, 43, and 44 show deceleration, change in momentum, and free missile travel versus time data. Damage to both posts was total, and each installation would require complete replacement. This damage is shown in Figures 45 and 46.

Minor vehicle damage occurred during this test, as can be seen in Figure 47. The milepost caused slight damage to the bumper, hood, and grille header panel. Table 13 contains the TAD and SAE damage ratings.

Some difficulty was encountered in driving the milepost support and delineator post. This was due to the combined effects of the very stiff soil conditions and the relatively thin wall of the tubes. Local buckling and wrinkling at the top of each post occurred, as shown in Figure 48.

TABLE 13. SUMMARY OF RESULTS, TEST 6.

Impact Velocity = 63.0 mph

POST DATA

Type	Thin Wall Tube-2
Size	a) 1.90"ϕ x 0.065" b) 1.66"ϕ x 0.047"
Embedment Method	Driven
Embedment Depth (ft)	a) 2.5 b) 2.0

VEHICLE DATA

Make	Chevrolet
Model	Vega
Year	1973
Weight (lb)	2270
Impact Point	a) 15" to left of center b) Center of vehicle

ACCELEROMETER DATA	Left	Right
Change in Momentum (lb-sec)	324	261
Duration of Event (sec)*	0.130	
Peak Deceleration (G's)	5.66	5.70
Maximum 0.050 Sec Average Deceleration (G's)	2.23	1.97

VEHICLE DAMAGE CLASSIFICATION

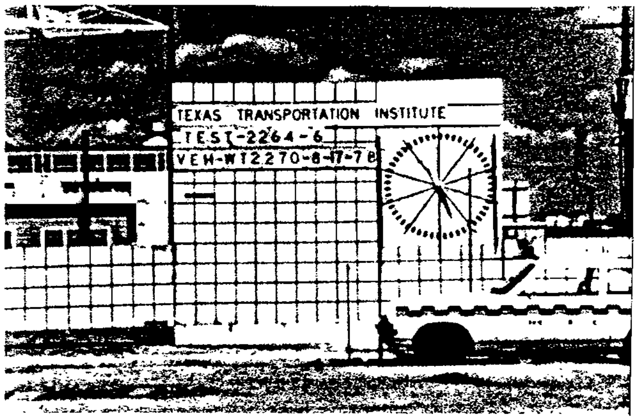
TAD	a) FL-1	b) FC-0
SAE	a) 12FLEN1	b) 12FCEN1

Did test article penetrate the passenger compartment?	No
Was windshield broken?	No

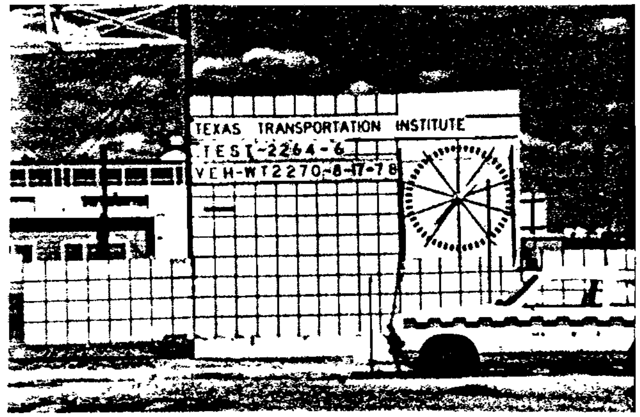
Metric Conversions:

1 in.	= 2.54 cm
1 ft	= 0.305 m
1 lb_m	= 0.454 kg
1 lb_m-sec	= 0.454 kg-s
1 mph	= 0.447 m/s

*Time of contact



0.000 sec



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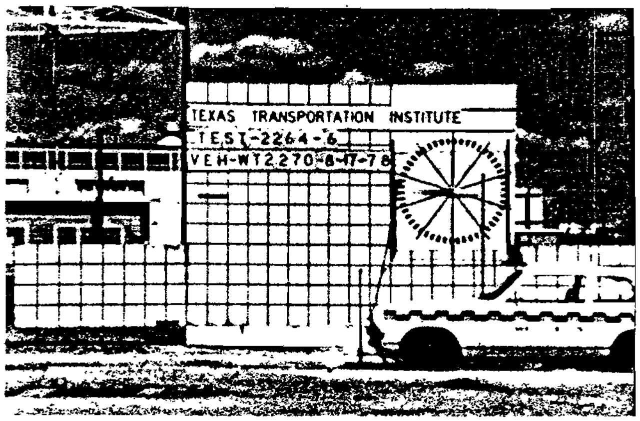
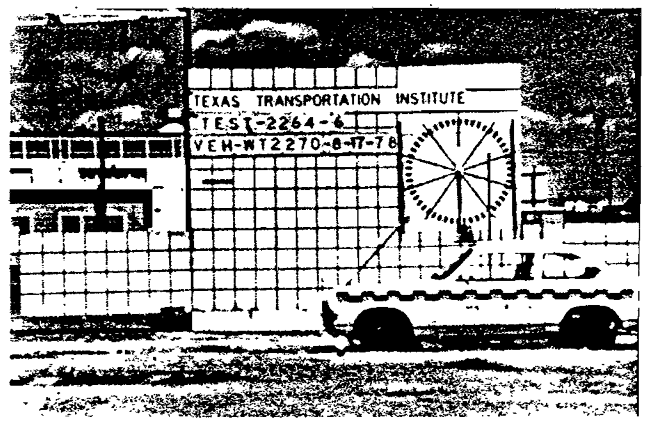
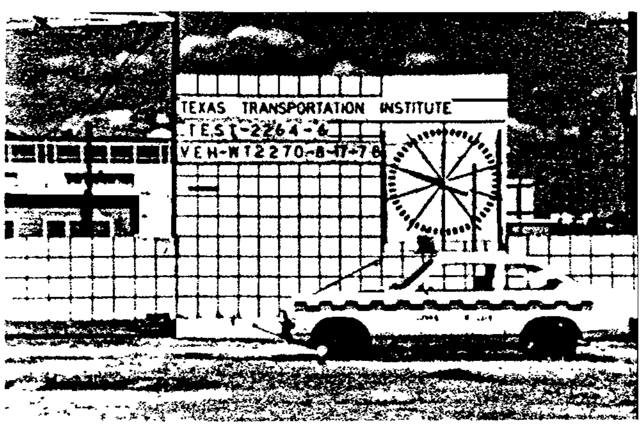


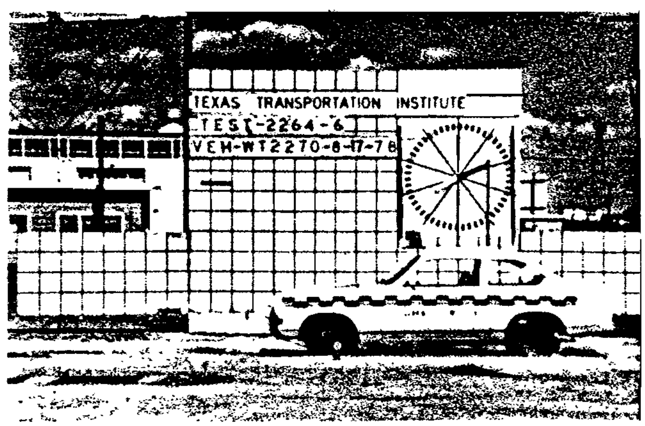
0.011 sec



0.037 sec



0.048 sec



0.062 sec

FIGURE 41. SEQUENTIAL PHOTOS, TEST 6.

TABLE 14. TIME DISPLACEMENT EVENT SUMMARY FOR TEST 6.

TIME (sec)	NOMINAL VEHICLE DISPLACEMENT (ft)	EVENT
0.000	0.00	Impact with milepost
0.007	0.59	Milepost begins bending
0.011	0.95	Impact with delineator
0.037	3.15	Milepost breaks
0.048	4.06	Delineator falls away
0.062	5.14	Milepost traveling with car

Metric Conversion:

1 ft = 0.305 m

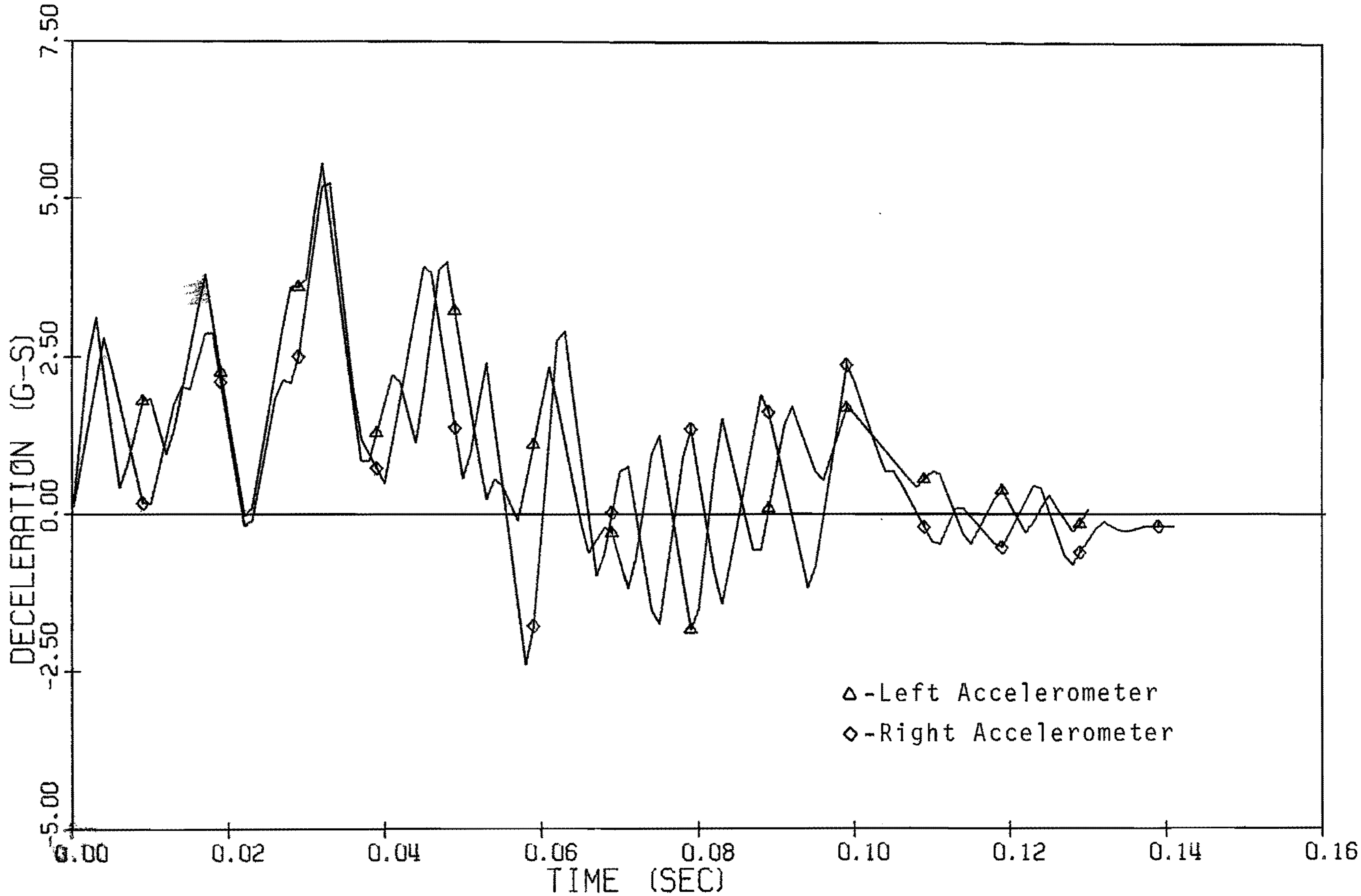


FIGURE 42. DECELERATION VERSUS TIME, TEST 6.

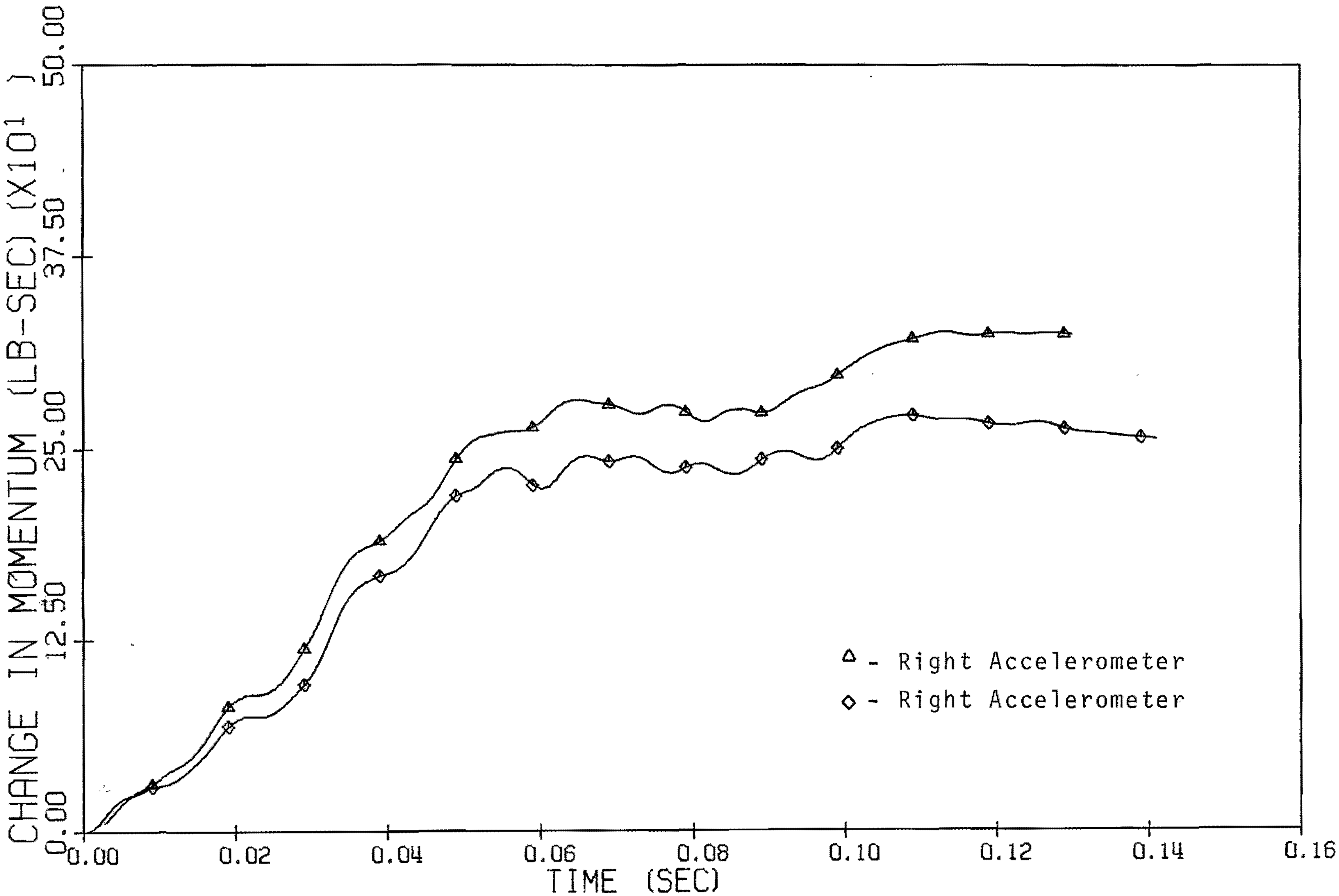


FIGURE 43. CHANGE IN MOMENTUM VERSUS TIME, TEST 6.

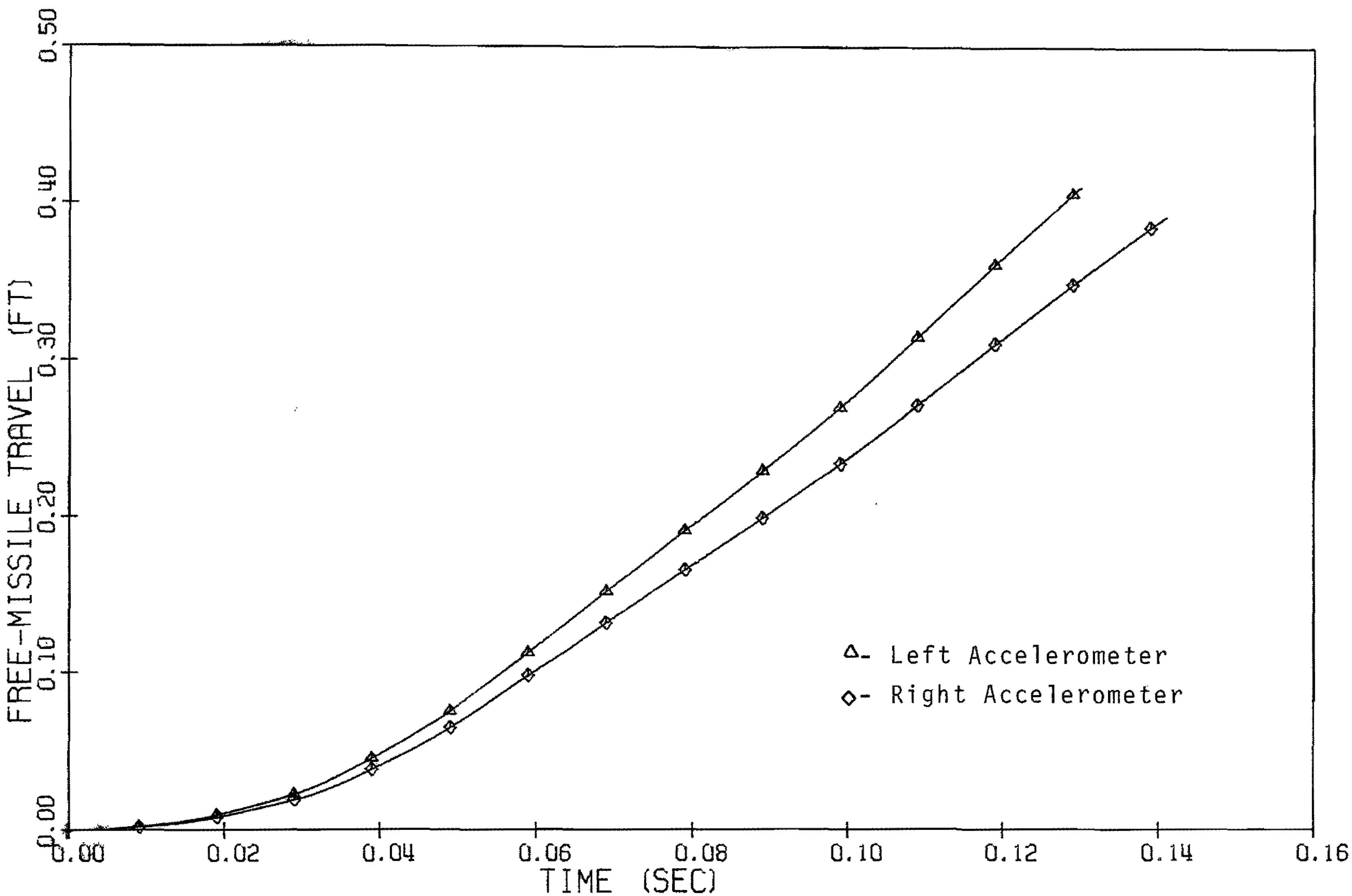
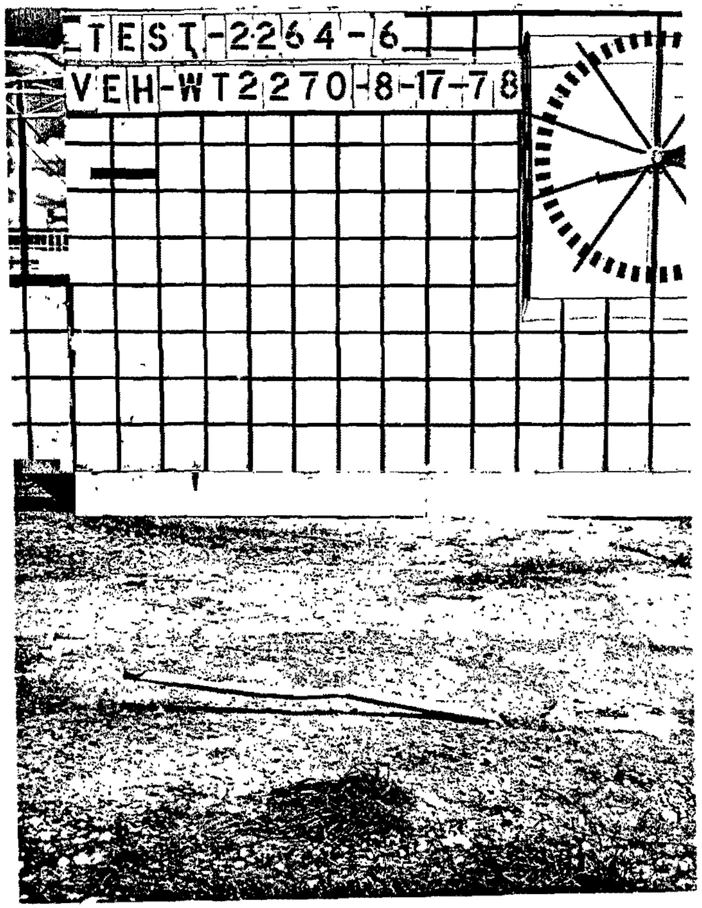


FIGURE 44. FREE MISSILE TRAVEL VERSUS TIME, TEST 6.



a) Side View

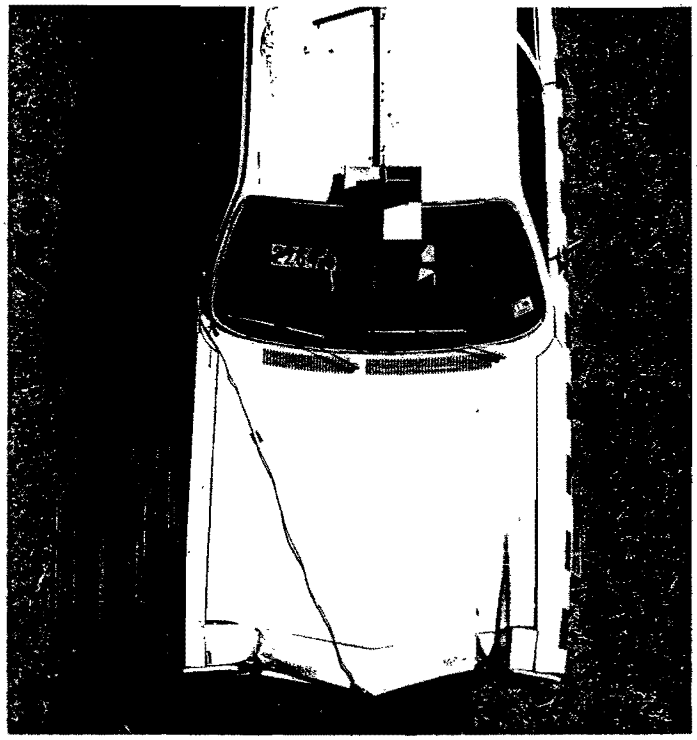
b) Front View

FIGURE 45. DELINEATOR DAMAGE, TEST 6.

a) Milepost Damage

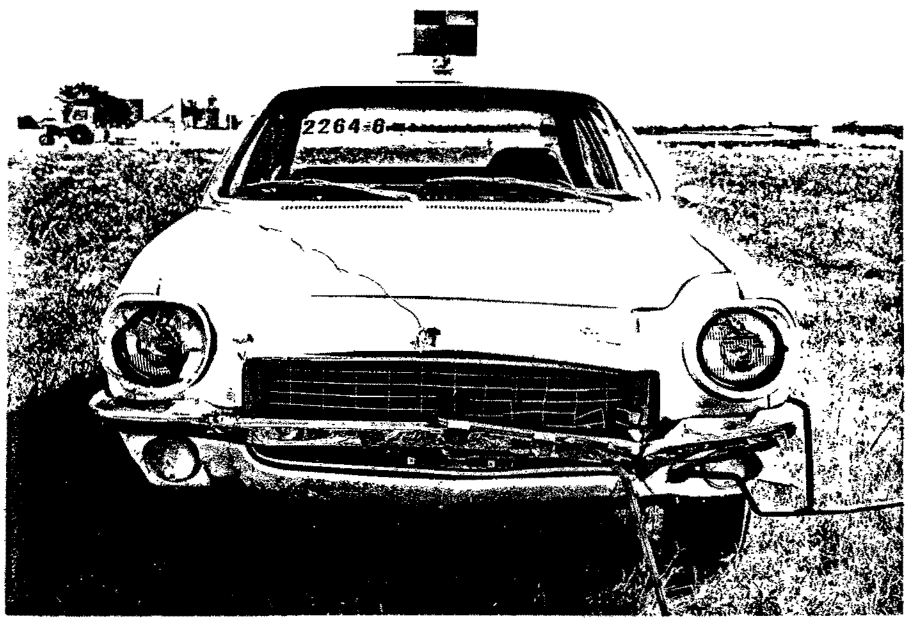
b) Closeup of Soil

FIGURE 46. MILEPOST DAMAGE, TEST 6.



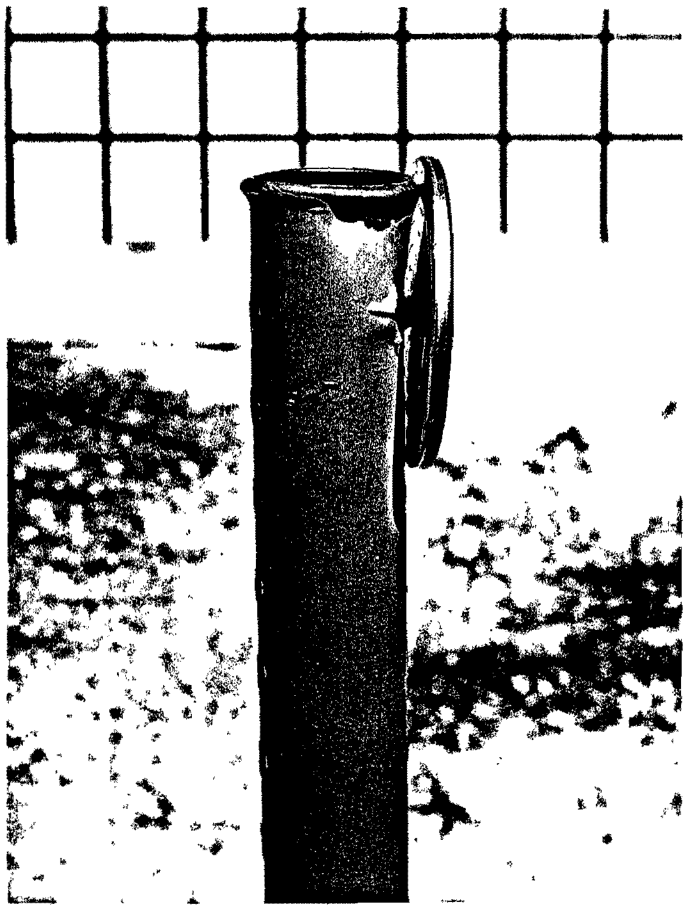
a) Top View

NOTE: Damage at center due to delineator post; damage at left due to milepost.



b) Front View

FIGURE 47. VEHICLE DAMAGE, TEST 6.



a) Delineator Post

b) Milepost

FIGURE 48. BUCKLING AT TOP OF MILEPOST AND DELINEATOR SUPPORTS.

TEST NO. 7

Based on the marginal results of tests 1 and 2 (relatively high change in momentum values), involving the 2.875 in. (7.30 cm) by 0.120 in. (0.30 cm) thick tube, it was conjectured that a 3.5 in. (8.89 cm) by 0.083 in. (0.17 cm) tube may be a better alternative. It was surmised that a post with a thinner wall would collapse more readily than a smaller post with a thicker wall and thus offer less impact resistance. However, this was not found to be the case.

The results of test 7 are summarized in Table 15; the sequential photos are given in Figure 49; and the time-displacement event summary is given in Table 16.

At impact, the post began to flatten at bumper height and wrap around the hood. The panel hit the windshield as the deformed post hooked and pitched the vehicle downward, causing the rear wheels to lift off momentarily. The post was then straightened as the vehicle continued to move through the impact.

Figures 50, 51, and 52 show deceleration, change in momentum, and free missile travel versus time data. Damage to the installation is shown in Figure 53.

Vehicle damage is shown in Figure 54. The entire front of the car was damaged, including the windshield, fender, hood, bumper, and grille header panel. The TAD and SAE damage ratings are given in Table 15.

TABLE 15. SUMMARY OF RESULTS, TEST 7.

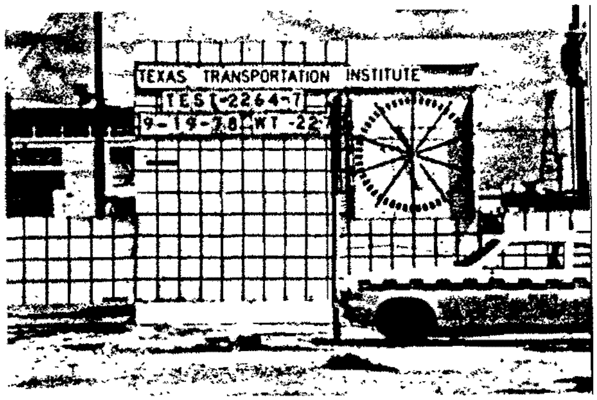
Impact Velocity = 60.5 mph

POST DATA		
Type	Thin Wall Tube	
Size	3.50"ϕ x 0.083"	
Embedment Method	12"ϕ Concrete Footing	
Embedment Depth (ft)	2	
VEHICLE DATA		
Make	Chevrolet	
Model	Vega	
Year	1973	
Weight (lb)	2270	
Impact Point	15 in. to right of center	
ACCELEROMETER DATA	**Left**	**Right**
Change in Momentum (lb-sec)	1513	1592
Duration of Event (sec)*	0.165	
Peak Deceleration (G's)	10.81	11.08
Maximum 0.050 Sec Average Deceleration (G's)	6.31	6.79
VEHICLE DAMAGE CLASSIFICATION		
TAD	FR-4	
SAE	12FREN2	
Did test article penetrate the passenger compartment?	No	
Was windshield broken?	Yes, by sign panel	

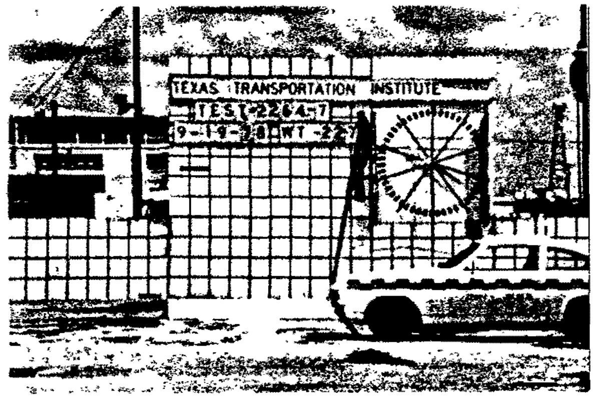
*Free missile travel time

Metric Conversions:

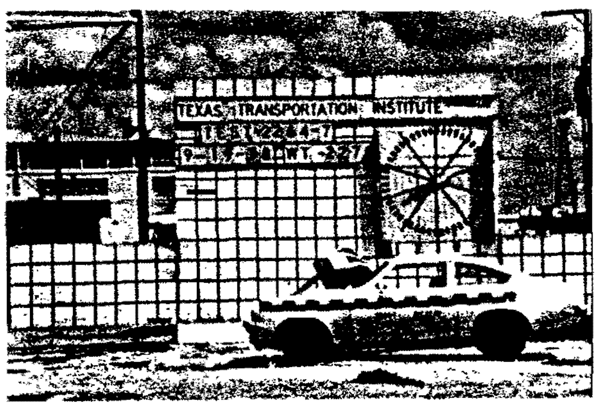
1 in. = 2.54 cm
1 ft = 0.305 m
1 lb_m = 0.454 kg
1 lb_m-sec = 0.454 kg-s
1 mph = 0.447 m/s



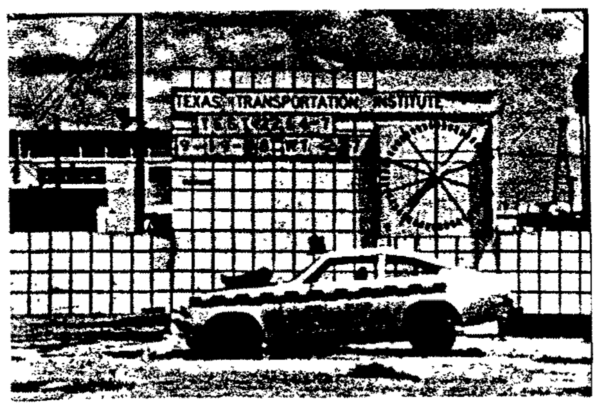
0.000 sec



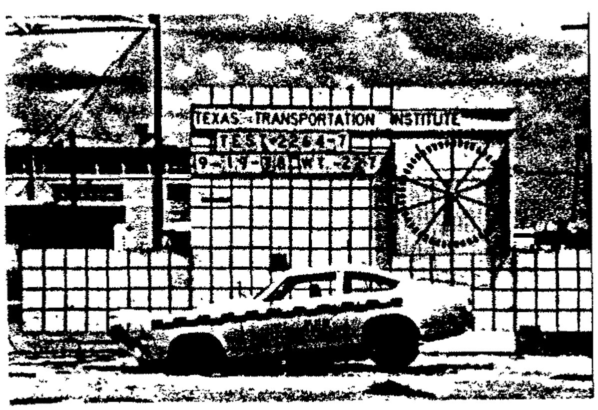
0.014 sec



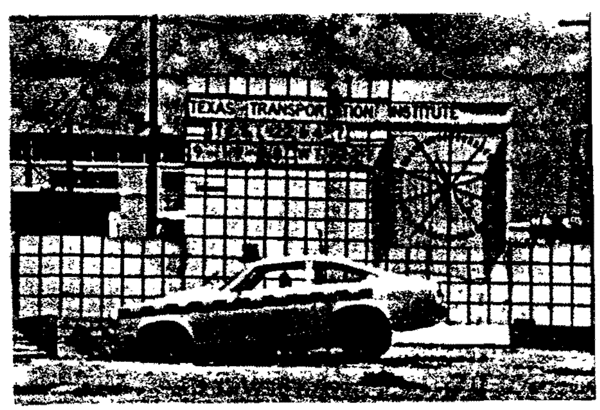
0.062 sec



0.096 sec



0.126 sec



0.142 sec

FIGURE 49. SEQUENTIAL PHOTOS, TEST 7.

TABLE 16. TIME DISPLACEMENT EVENT SUMMARY FOR TEST 7.

TIME (sec)	NOMINAL VEHICLE DISPLACEMENT (ft)	EVENT
0.000	0.00	Impact
0.014	1.26	Post flattening at bumper
0.062	5.08	Panel hits windshield
0.096	7.67	Post wrapped around vehicle
0.126	9.73	Top of post strikes ground
0.142	10.87	Loss of contact

Metric Conversion:

1 ft = 0.305 m

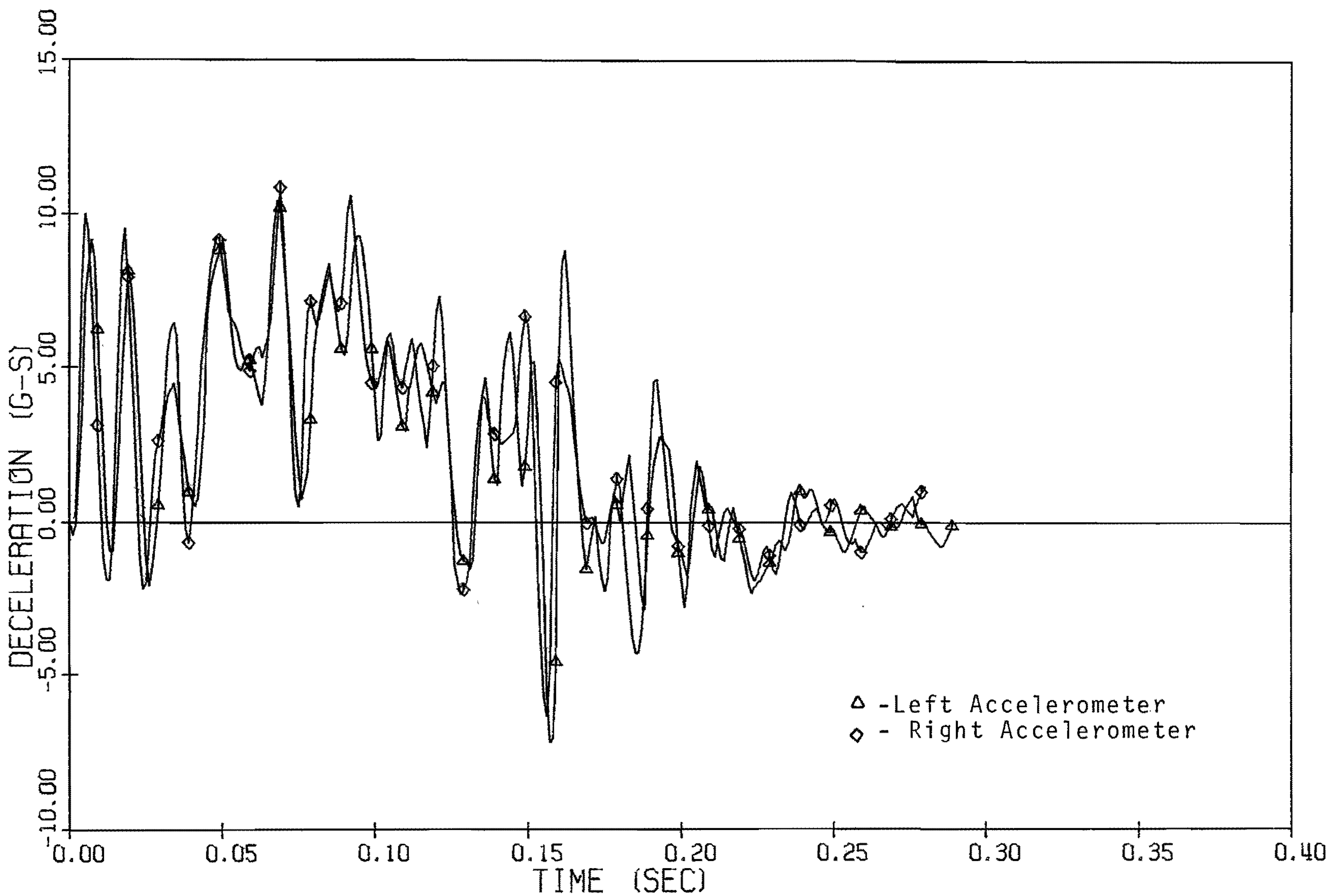


FIGURE 50. DECELERATION VERSUS TIME, TEST 7.

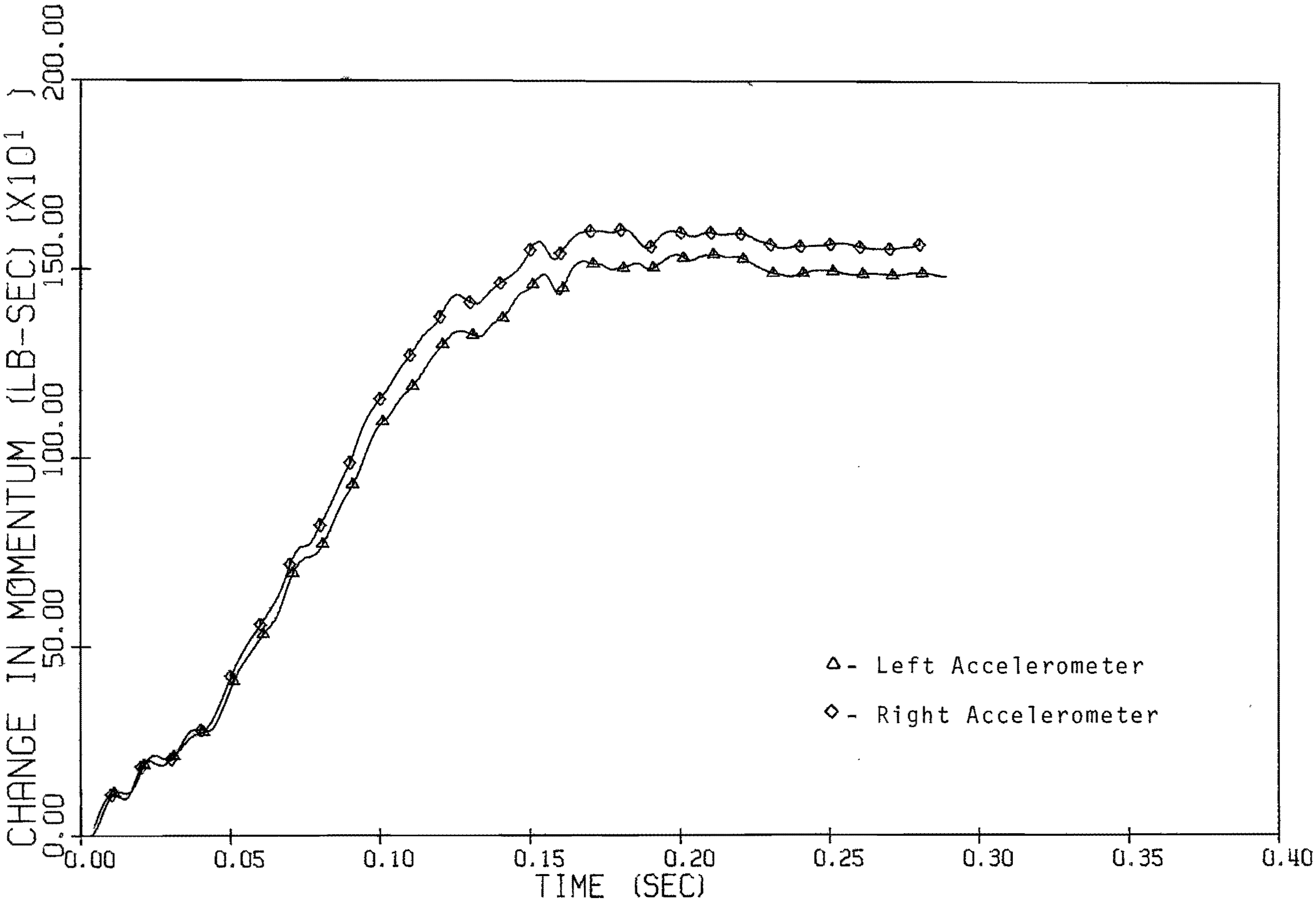


FIGURE 51. CHANGE IN MOMENTUM VERSUS TIME, TEST 7.

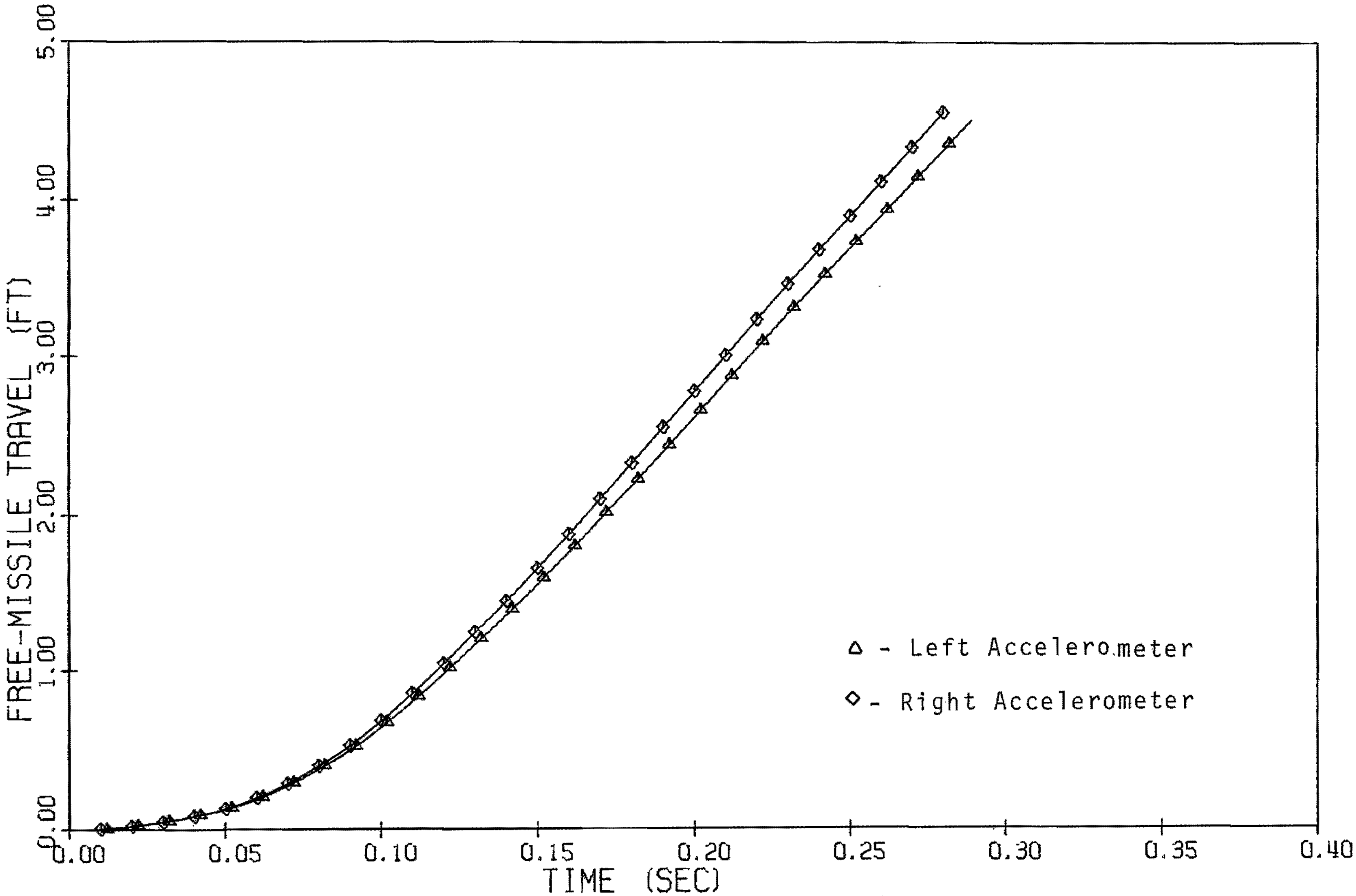
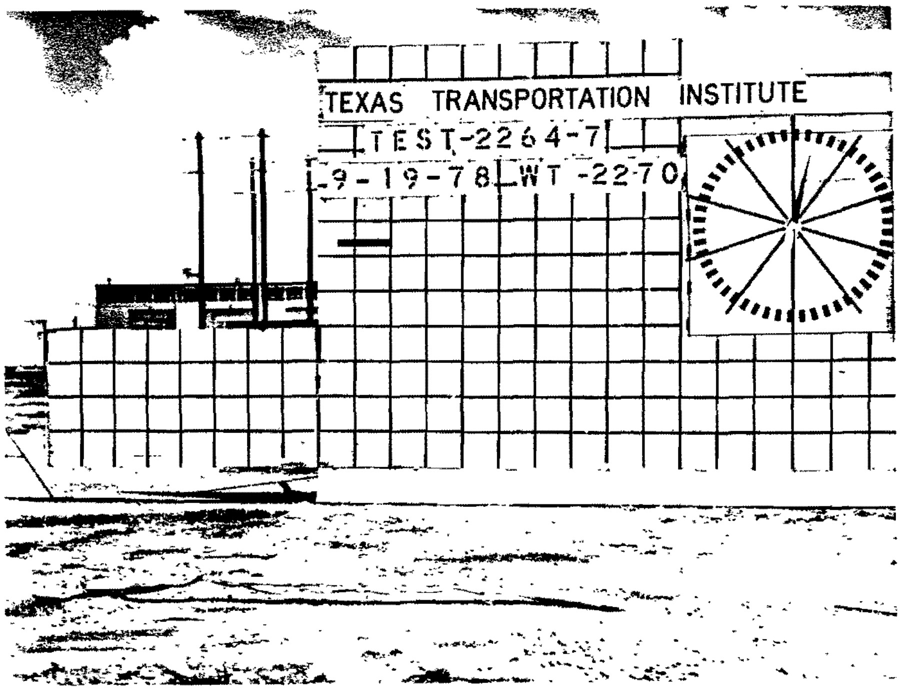
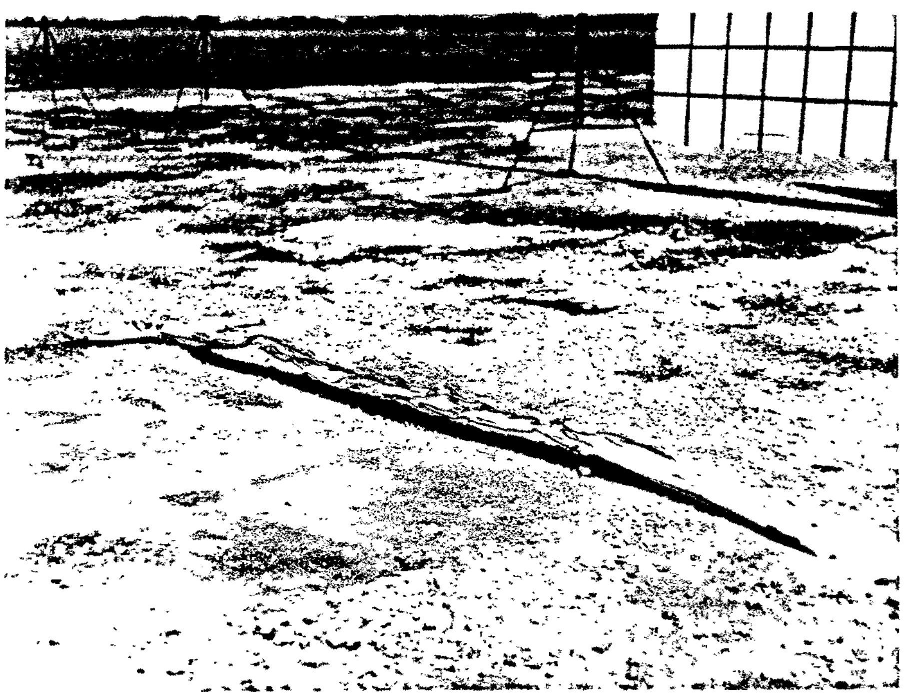


FIGURE 52. FREE MISSILE TRAVEL VERSUS TIME, TEST 7.

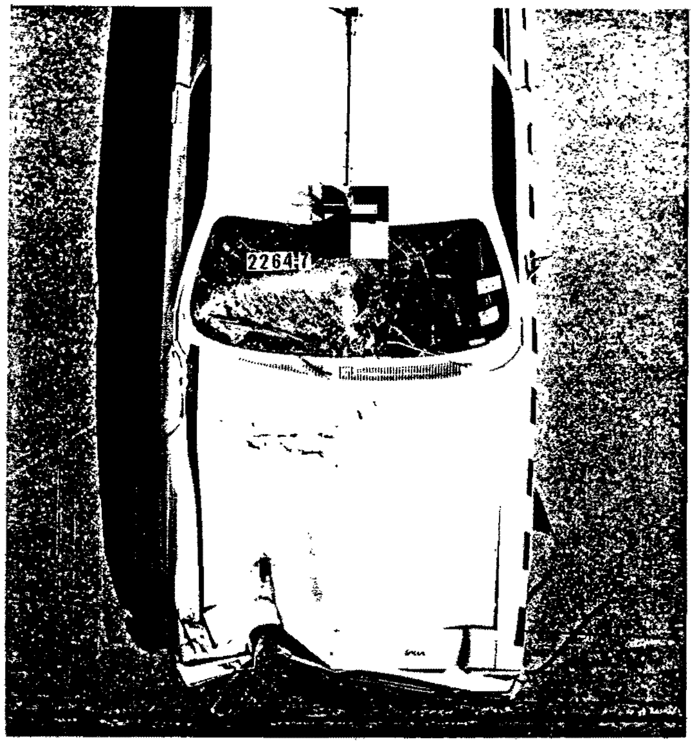


a) Side View

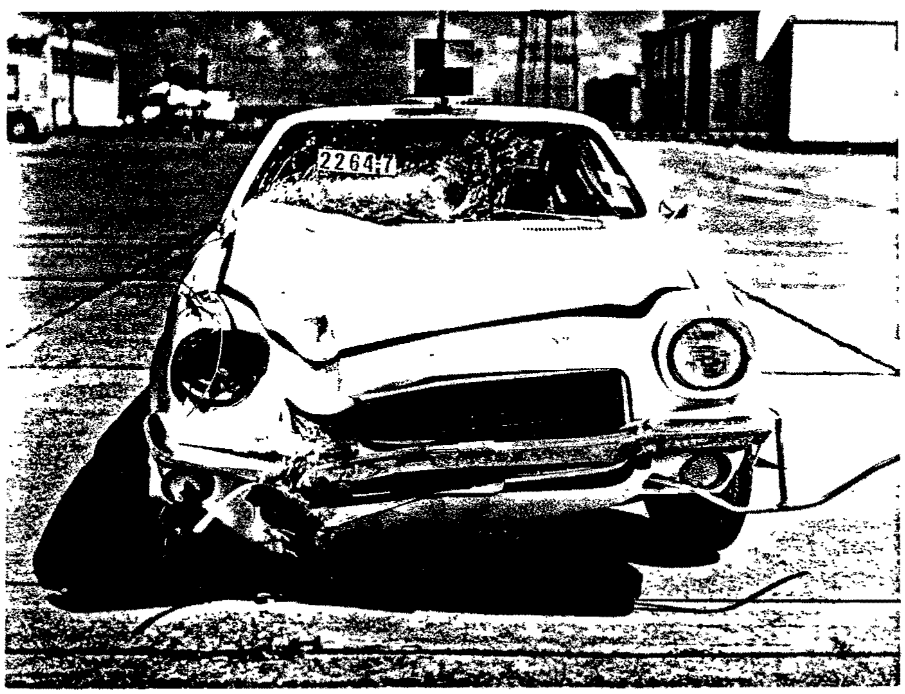


b) Closeup

FIGURE 53. INSTALLATION DAMAGE, TEST 7.



a) Top View



b) Front View

FIGURE 54. VEHICLE DAMAGE, TEST 7.

SUMMARY AND CONCLUSIONS

Table 17 contains a summary of the results of seven crash tests of various thin-wall steel tube posts. These tests were conducted in accordance with nationally recognized guidelines (1), and the results were evaluated in terms of AASHTO impact performance specifications for sign supports (2). In terms of the AASHTO specifications, the following was found:

1. A 3.50 in. (8.89 cm) O.D. by 0.083 in. (0.17 cm) and a 2.875 in. (7.30 cm) O.D. by 0.120 in. (0.30 cm) signpost in a concrete footing do not satisfy specifications.
2. A 2.875 in. (7.30 cm) O.D. by 0.120 in. (0.30 cm) signpost with sleeve and base in concrete is marginally acceptable.
3. A 2.875 in. (7.30 cm) O.D. by 0.065 in. (0.17 cm) and a 2.375 in. (6.03 cm) O.D. by 0.109 in. (0.28 cm) signpost in a concrete footing satisfy specifications.
4. A 1.66 in. (4.22 cm) O.D. by 0.047 in. (0.12 cm) delineator post and a 1.90 in. (4.83 cm) O.D. by 0.065 in. (0.17 cm) mile marker post satisfy specifications.

The posts tested were produced from relatively mild, low carbon steel having considerable toughness or ductility. For a given size post produced from this type steel, high-speed impacts generally result in higher vehicle momentum changes than do low-speed impacts. When impacted at a high speed the post undergoes large deformations, momentarily wraps around the hood of the vehicle, and is then flattened or straightened out as the vehicle rides over it. This produces large impact forces on the vehicle, especially on a small or compact vehicle. Similar impact behavior was observed in numerous tests of other types of yielding steel signposts in a Federal Highway Administration study (6).

Tests have shown that improved impact behavior of ductile steel can be obtained by reducing the toughness or ductility of the material (6).

This is usually accomplished by increasing the carbon content of the material, which also increases the strength of the material. Increased strength has an added benefit since smaller posts can be used to satisfy wind load requirements. However, the ability of manufacturers to produce thin-wall tubes from such a material, and to do so economically, has not been established.

TABLE 17. SUMMARY OF RESULTS

	TEST 1[a] IMPACT VELOCITY = 18.2 mph			TEST 2[a] IMPACT VELOCITY = 60.4 mph			TEST 3[a] IMPACT VELOCITY = 62.7 mph		
SIGNPOST DATA									
Signpost Type (SDHPT Spec.)	Type "F"			Type "F"			Type "F" with Sleeve		
Signpost Size	2.875"ϕ x 0.120"			2.875"ϕ x 0.120"			2.875"ϕ x 0.120" - Post 3.5"ϕ x 0.216" - Sleeve		
Embedment Depth (ft)	2			2			2		
Embedment Method	Concrete Footing[b]			Concrete Footing[b]			Concrete Footing[b]		
Panel Size	36" x 48"			36" x 48"			36" x 48"		
ACCELEROMETER DATA	Left	Right	Average	Left	Right	Average	Left	Right	Average
Change in Momentum (lb-sec)	901	905	903	1054	1192	1123	841	757	799
Duration of Event (sec)[c]	0.182			0.173			0.138		
Peak Deceleration (g's)	7.08	6.78		13.85	13.23		13.59	12.83	
Maximum 50 msec Average Deceleration (g's)	3.68	3.74		4.86	5.06		4.53	3.93	
VEHICLE DAMAGE CLASSIFICATION									
TAD	FR-1			FR-2			FL-4		
SAE	12FREN1			12FREN1			12FLEN2		
Did test article penetrate passenger compartment?	No			No			No		
Was windshield broken?	No			No			Yes, by Sign Panel		

[a]All test vehicles were 1973 Chevrolet Vegas, 2270 lbs.

[b]Footing is 12" diameter x 30" depth.

[c]For tests 1-6, time of contact used; in test 7, free missile travel time used.

Metric Conversions:
1 in. = 2.54 cm
1 ft = 0.305 m
1 lb_m = 0.454 kg
1 lb_m-sec = 0.454 kg-sec
1 mph = 0.447 m/s

TABLE 17. SUMMARY OF RESULTS (continued)

	TEST 4[a] IMPACT VELOCITY = 59.0 mph			TEST 5[a] IMPACT VELOCITY = 59.6 mph			TEST 6[a] IMPACT VELOCITY = 63.0 mph		
SIGNPOST DATA									
Signpost Type (SDHPT Spec.)	Type "A"			Type "A"			A) Mile Marker Post and B) Delineator Post		
Signpost Size	2.875"ϕ x 0.065"			2.375"ϕ x 0.109"			A) 1.90"ϕ x 0.065" B) 1.66"ϕ x 0.047"		
Embedment Depth (ft)	2			2					
Embedment Method	Concrete Footing[b]			Concrete Footing[b]			A) 2.5 B) 2.0; both driven		
Panel Size	24" x 30"			24" x 30"			Delineator - N/A Mile Marker - 12" x 48"		
ACCELEROMETER DATA	Left	Right	Average	Left	Right	Average	Left	Right	Average
Change in Momentum (lb-sec)	359	206	283	343	360	352	324	261	293
Duration of Event (sec)[c]	0.245			0.210			0.130		
Peak Deceleration (g's)	4.17	5.46		5.78	10.80		5.66	5.70	
Maximum 50 msec Average Deceleration (g's)	1.92	1.71		2.11	2.65		2.23	1.97	
VEHICLE DAMAGE CLASSIFICATION									
TAD	FR-0			FR-1			A) FL-1		B) FC-0
SAE	12FREN1			12FREN1			A) 12FLEN1		B) 12FCEN1
Did test article penetrate passenger compartment?	No			No			No		
Was windshield broken?	No			No			No		

[a]All test vehicles were 1973 Chevrolet Vegas, 2270 lbs.

[b]Footing is 12" diameter x 30" depth.

[c]For tests 1-6, time of contact used; in test 7, free missile travel time used.

Metric Conversions:
1 in. = 2.54 cm
1 ft = 0.305 m
1 lb_m = 0.454 kg
1 lb_m-sec = 0.454 kg-sec
1 mph = 0.447 m/s

TABLE 17. SUMMARY OF RESULTS (continued)

	TEST 7[a] IMPACT VELOCITY = 60.5 mph				
SIGNPOST DATA					
Signpost Type (SDHPT Spec.)	Type "F"				
Signpost Size	3.50"φ x 0.083"				
Embedment Depth (ft)	2				
Embedment Method	Concrete Footing[b]				
Panel Size	36" x 48"				
ACCELEROMETER DATA	Left	Right	Average		
Change in Momentum (lb-sec)	1513	1592	1553		
Duration of Event (sec)[c]	0.165				
Peak Deceleration (g's)	10.81	11.08			
Maximum 50 msec Average Deceleration (g's)	6.31	6.79			
VEHICLE DAMAGE CLASSIFICATION					
TAD	FR-4				
SAE	12FREN2				
Did test article penetrate passenger compartment?	No				
Was windshield broken?	Yes, by Sign Panel				

[a]All test vehicles were 1973 Chevrolet Vegas, 2270 lbs.

[b]Footing is 12" diameter x 30" depth.

[c]For tests 1-6, time of contact used; in test 7, free missile travel time used.

Metric Conversions:
1 in. = 2.54 cm
1 ft = 0.305 m
1 lb_m = 0.454 kg
1 lb_m-sec = 0.454 kg-sec
1 mph = 0.447 m/s

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