Testing of State Roadside Safety Systems Volume II: Appendix A–Crash Testing and Evaluation of a Michigan Thrie-Beam Transition Design

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FOREWORD

Because of specific needs or constraints of individual States, new or modified roadside safety hardware are being designed and developed on a continuing basis. To ensure that these new or modified designs perform according to established guidelines, full-scale crash testing and evaluation were deemed necessary. The objective of this study is to crash test and evaluate these roadside safety hardware and where necessary redesign the devices to improve their impact performance. The three major areas addressed in this study are the impact performance of bridge railings, transitions from guardrails to bridge railings, and end treatments for guardrails and median barriers.

Detailed drawings are presented for documentation as well as a summary of findings and conclusions for each of the devices tested, and where necessary recommendations for improvement.

It should be noted that this research did not produce a version of the MELT—Modified Eccentric Loader Terminal—that was acceptable to FHWA for use on the National Highway System.

Michael F. Trentacoste, Director
Office of Safety Research and
Development

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16. Abstract

The purpose of this study is to crash test and evaluate new or modified roadside safety hardware and, where necessary, redesign the devices to improve their impact performance. The three major areas addressed in this study are the impact performance of bridge railings, transitions from guardrails to bridge railings, and end treatments for guardrails and median barriers.

This report presents the results of a crash test conducted on a Michigan thrie-beam transition design in accordance with guidelines set forth in National Cooperative Highway Research Program (NCHRP) Report 230. The crash test (test no. 471470-1) involved a 2043-kg (4500-lb) passenger car traveling at a nominal speed and angle of 96.5 km/h (60 mi/h) and 25 degrees. The transition design was judged to have satisfactorily met all evaluation criteria set forth in NCHRP Report 230.

This volume is the second in a series of 14 volumes for the final report. The other volumes in the series are: Volume I - Technical Report; Volume III, Appendix B - Crash Testing and Evaluation of a Guardrail System for Low-Fill Culvert; Volume IV, Appendix C - Crash Testing and Evaluation of a Pennsylvania Transition Design; Volume V, Appendix D - Crash Testing and Evaluation of a Washington, DC, PL-1 Bridge Rail; Volume VI, Appendix E - Crash Testing and Evaluation of a Modified Breakaway Cable Terminal (BCT) Design; Volume VII, Appendix F - Crash Testing and Evaluation of the Minnesota Swing-Away Mailbox Support; Volume VIII, Appendix G - Crash Testing and Evaluation of the Single Slope Bridge Rail; Volume IX, Appendix H - Crash Testing and Evaluation of the NETC PL-2 Bridge Rail Design; Volume X, Appendix I - Crash Testing and Evaluation of a Mini-MELT for a W-Beam, Weak-Post (G2) Guardrail System; Volume XI, Appendix J - Crash Testing and Evaluation of Existing Guardrail Systems; Volume XII, Appendix K - Crash Testing and Evaluation of the MELT; Volume XIII, Appendix L - Crash Testing and Evaluation of the Modified MELT; and Volume XIV, Appendix M - Laboratory and Pendulum Testing of Modified Breakaway Wooden Posts.

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PREFACE

Because of specific needs or constraints of individual states, new or modified roadside safety hardware are being designed and developed on a continuing basis. To assure that these new or modified designs perform according to established guidelines, full-scale crash testing and evaluation were deemed necessary. The objective of this study is to crash test and evaluate this roadside safety hardware and, where necessary, redesign the devices to improve their impact performance. The three major areas addressed in this study are the impact performance of bridge railings, transitions from guardrails to bridge railings, and end treatments for guardrails and median barriers.

This is Volume II of a 14-volume series of final reports for this study. The 14 volumes are as follows:

Volume	Appendix	Title
I		Technical Report.
II	A	Crash Testing and Evaluation of a Michigan Thrie-Beam Transition Design.
III	B	Crash Testing and Evaluation of a Guardrail System for Low-Fill Culvert.
IV	C	Crash Testing and Evaluation of a Pennsylvania Transition Design.
V	D	Crash Testing and Evaluation of a Washington, DC, PL-1 Bridge Rail.
VI	E	Crash Testing and Evaluation of a Modified Breakaway Cable Terminal (BCT) Design.
VII	F	Crash Testing and Evaluation of the Minnesota Swing-Away Mailbox Support.
VIII	G	Crash Testing and Evaluation of the Single Slope Bridge Rail.
IX	H	Crash Testing and Evaluation of the NETC PL-2 Bridge Rail Design.
X	I	Crash Testing and Evaluation of a Mini-MELT for a W-Beam, Weak-Post (G2) Guardrail System.
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XII	K	Crash Testing and Evaluation of the MELT.
XIII	L	Crash Testing and Evaluation of the Modified MELT.
XIV	M	Laboratory and Pendulum Testing of Modified Breakaway Wooden Posts.

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in²	square inches	645.2	square millimeters	mm²
ft²	square feet	0.093	square meters	m²
yd²	square yards	0.836	square meters	m²
ac	acres	0.405	hectares	ha
mi²	square miles	2.59	square kilometers	km²
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft³	cubic feet	0.028	cubic meters	m³
yd³	cubic yards	0.765	cubic meters	m³
NOTE: Volumes greater than 1000 l shall be shown in m³.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m²	cd/m²
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in²	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm²	square millimeters	0.0016	square inches	in²
m²	square meters	10.764	square feet	ft²
m²	square meters	1.195	square yards	yd²
ha	hectares	2.47	acres	ac
km²	square kilometers	0.386	square miles	mi²
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m³	cubic meters	35.71	cubic feet	ft³
m³	cubic meters	1.307	cubic yards	yd³
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m²	candela/m²	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in²

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

(Revised September 1993)

TABLE OF CONTENTS

Section Page

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

Because of specific needs or constraints of individual states, new or modified roadside safety hardware have been designed and developed recently. To ensure that these new or modified designs perform according to established performance guidelines, full-scale crash testing and evaluation were deemed necessary. The objective of this study is to develop and test this roadside safety hardware and, where necessary, redesign the tested devices to improve their performance. The three major areas addressed in this study are the performance of bridge rails, transitions from guardrails to bridge rails, and end treatments for guardrails and median barriers.

The Michigan Department of Transportation has designed a thrie-beam transition for use in transitioning from a standard W-beam guardrail to a safety-shaped concrete parapet bridge rail. This report presents the details of a full-scale crash test and the performance of this transition design when impacted by a 2043-kg (4500-lb) passenger car traveling at a nominal speed and angle of 96.5 km/h (60 mi/h) and 25 degrees. Testing and evaluation was performed according to guidelines outlined in National Cooperative Highway Research Program (NCHRP) Report 230.[1]

II. STUDY APPROACH

2.1 TEST ARTICLE

A 2.44 m (8-ft) section of Michigan Type 5 (concrete safety-shaped) bridge railing was constructed and tied into an existing 864-mm- (34-in-) high concrete safety-shaped median barrier, as shown in figure 1. Approximately 22.9 m (75 ft) of approach guardrail was constructed, including a Detail T-4 guardrail to bridge rail transition section, one 3.81-m (12-ft, 6-in) section of standard Type T (thrie-beam) guardrail, one 1.91-m (6-ft, 3-in) transition section from thrie-beam to W-beam guardrail, and a 11.4-m (37-ft, 6-in) section of a Breakaway Cable Terminal (BCT) guardrail anchorage. The Detail T-4 guardrail to bridge rail transition consisted of one 3.81-m (12-ft, 6-in) section of thrie beam, one 1.91-m (6-ft, 3-in) transition from thrie-beam to W-beam, and a W-beam end section anchored to the concrete bridge rail. There was also a 5.18-m- (17-ft-) long curb and gutter section with backfill to the top of the curb in the transition area.

Foundation and steel reinforcement details for the simulated bridge railing end section are shown in figure 2. Details of the transition section are shown in figure 3, and figure 4 illustrates the details of the approach curb and gutter section. Photographs of the completed Michigan thrie-beam transition system prior to the full-scale crash test are shown in figures 5 and 6.

2.2 CRASH TEST CONDITIONS

The crash test reported herein corresponded to test designation 30 of the crash test matrix set forth in NCHRP Report 230 for a transition test. The test involved a 4500-lb (2043-kg) passenger car impacting the transition at a nominal speed and angle of 96.5 km/h (60 mi/h) and 25 degrees. The primary purpose of this test is to evaluate the structural adequacy of the transition system.

2.3 CRASH TEST AND DATA ANALYSIS PROCEDURES

The crash test and data analysis procedures were in accordance with guidelines presented in NCHRP Report 230.[1] Brief descriptions of these procedures are presented as follows.

2.3.1 Electronic Instrumentation and Data Processing

The crash test procedures were in accordance with guidelines presented in NCHRP Report 230. The test vehicle was instrumented with three solid-state angular rate transducers to measure roll, pitch, and yaw rates; a triaxial accelerometer near the vehicle center of gravity to measure longitudinal, lateral, and vertical acceleration levels; and a backup biaxial

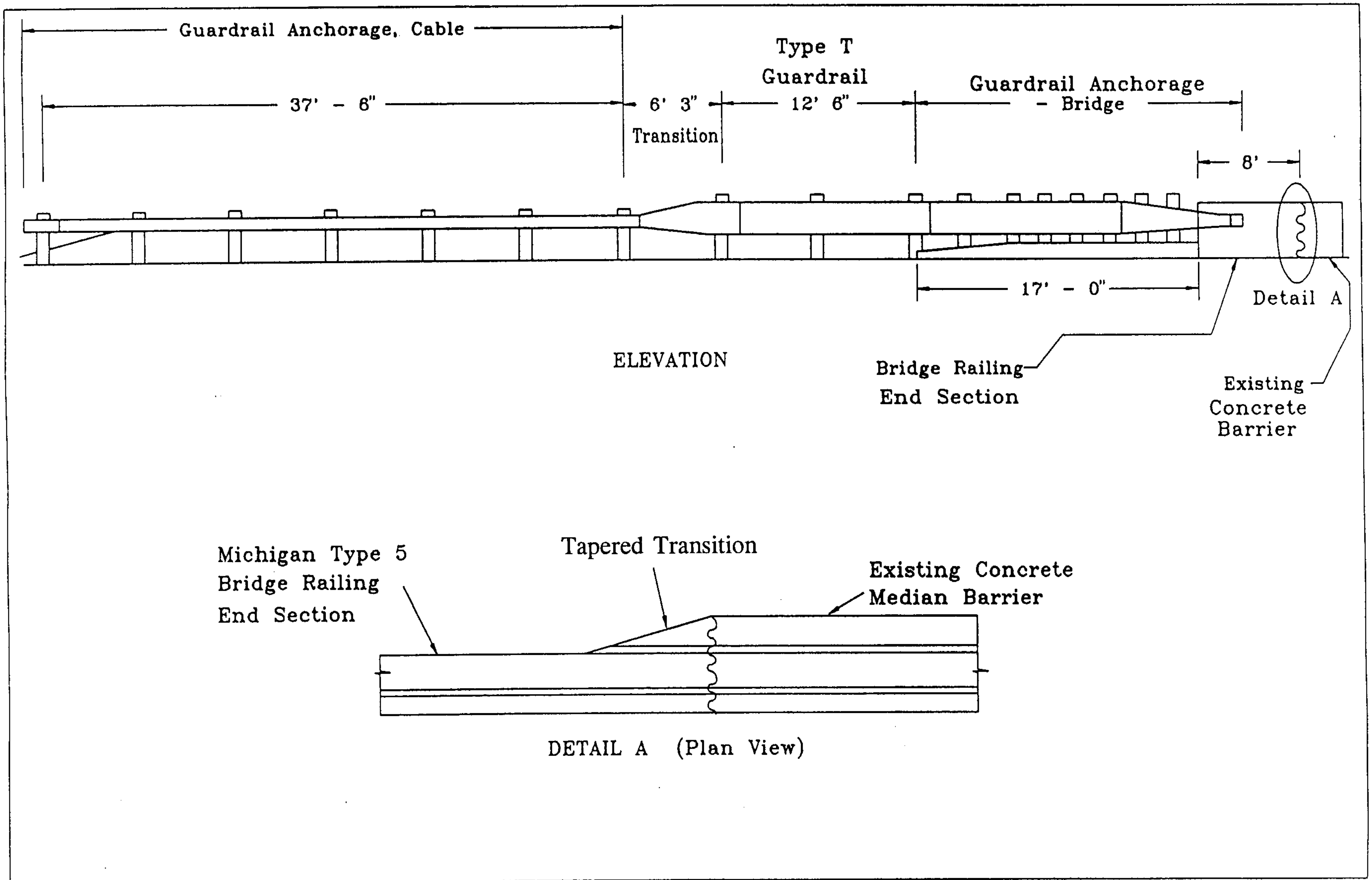


Figure 1. Details of Michigan transition.

1 in = 25.4 mm
1 ft = 0.305 mm

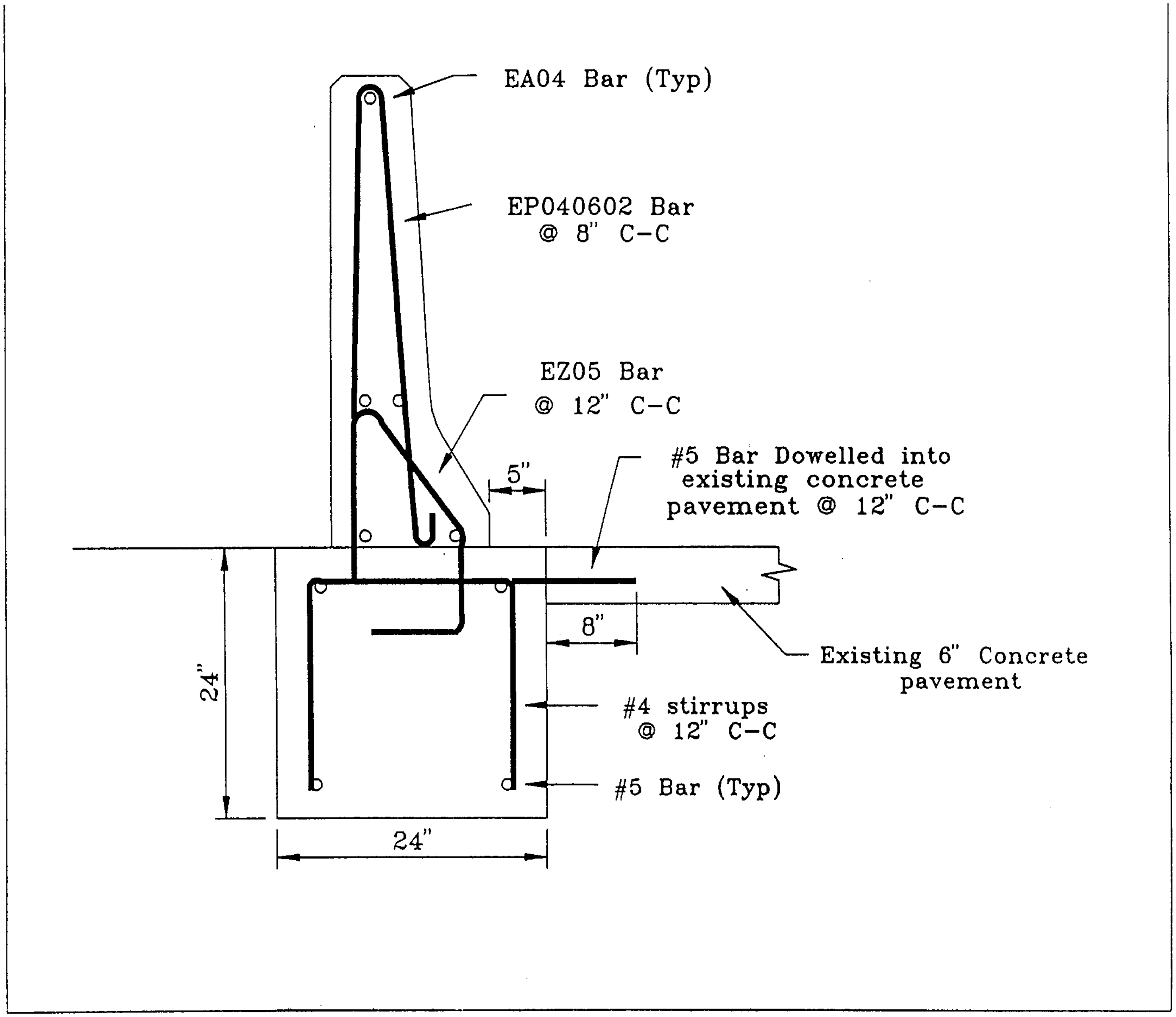


Figure 2. Foundation and reinforcement details.

1 in = 25.4 mm
1 ft = 0.305 mm

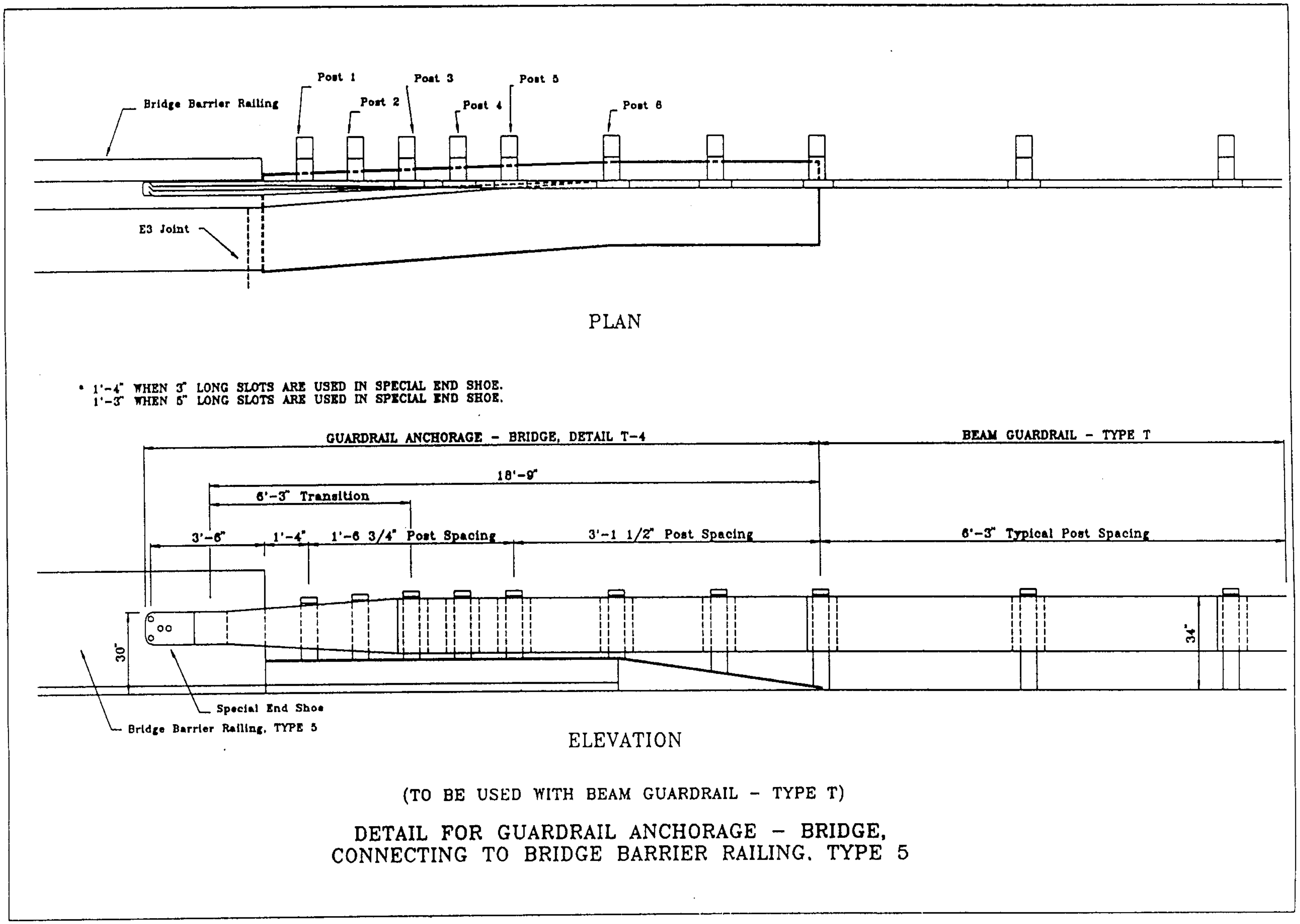


Figure 3. Details of transition section.

1 in = 25.4 mm
1 ft = 0.305 mm

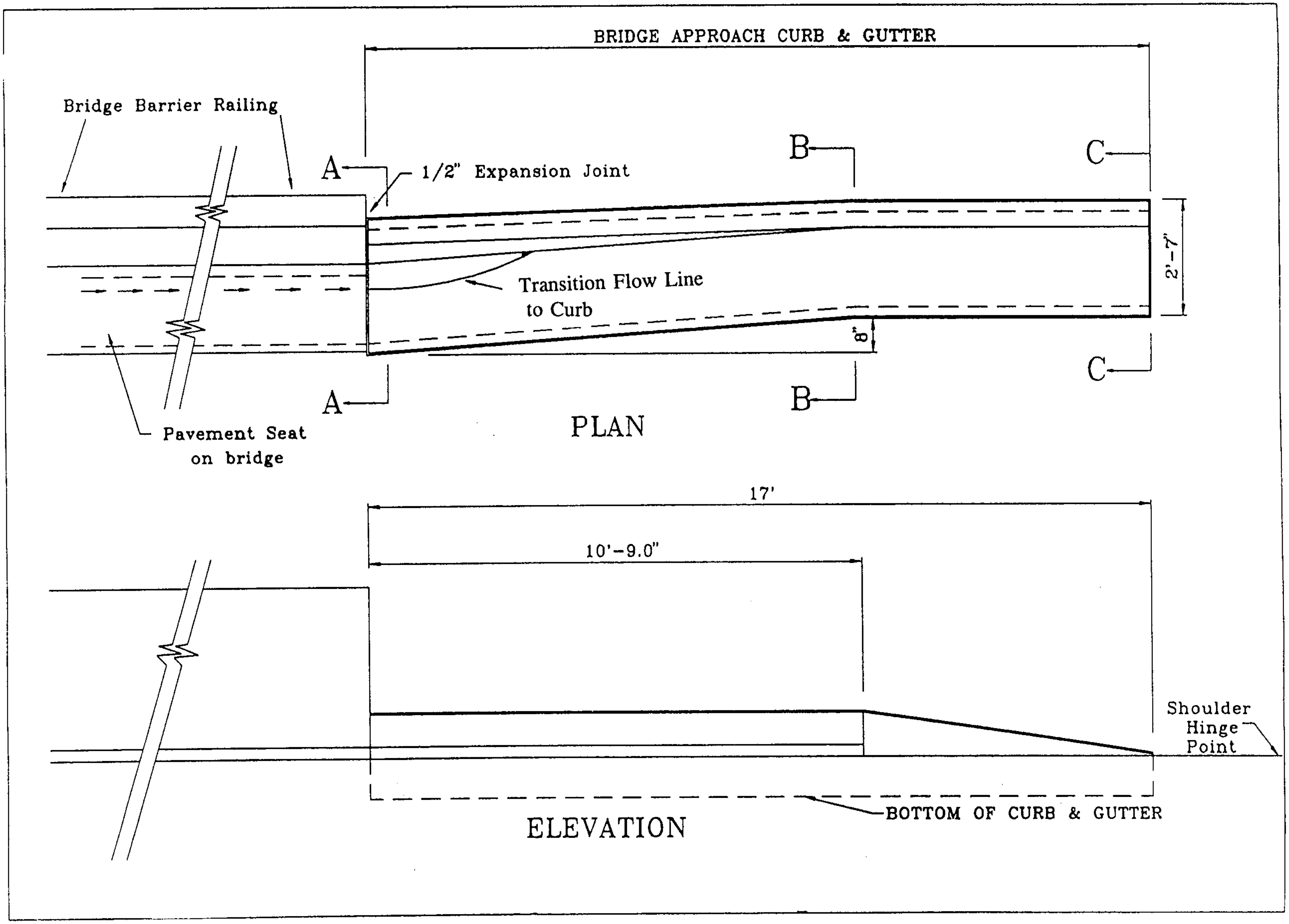
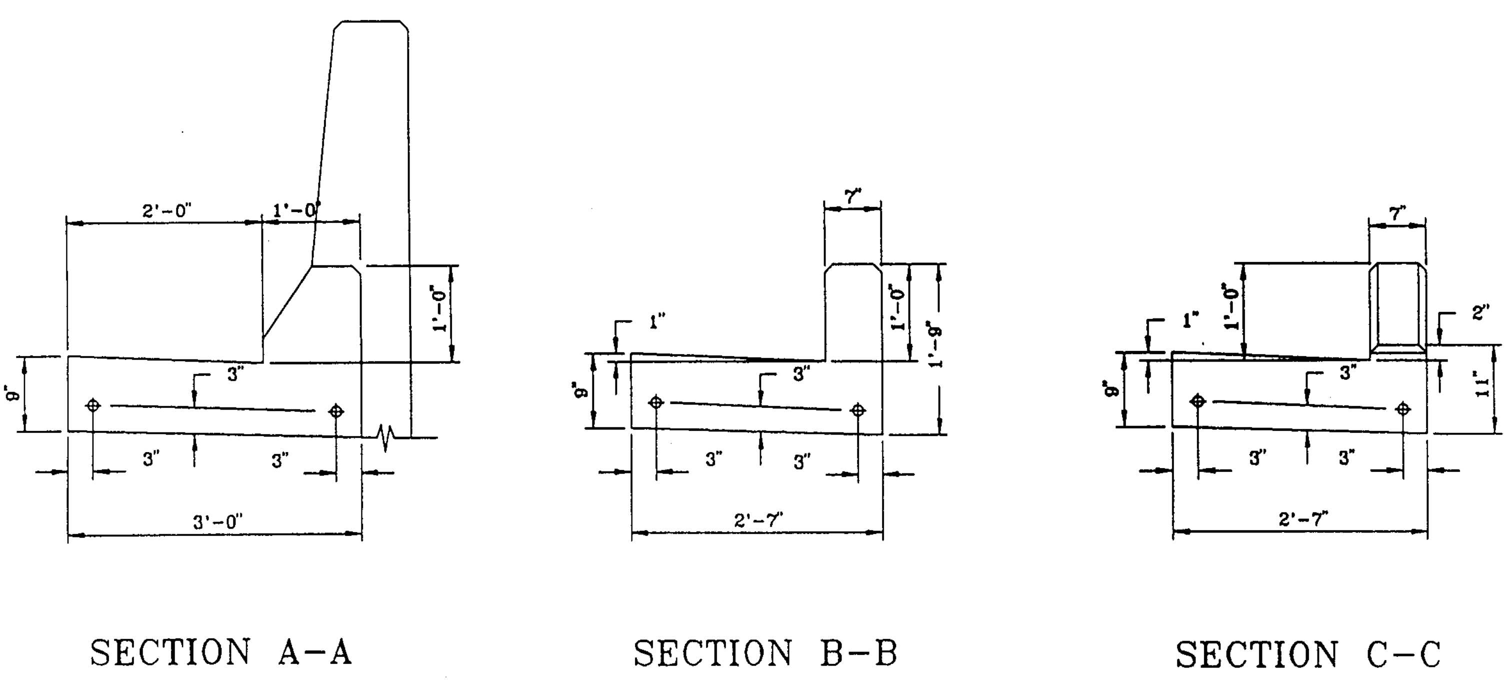


Figure 4. Details of approach curb and gutter section.



1 in = 25.4 mm
1 ft = 0.305 mm

Figure 4. Details of approach curb and gutter section (continued).

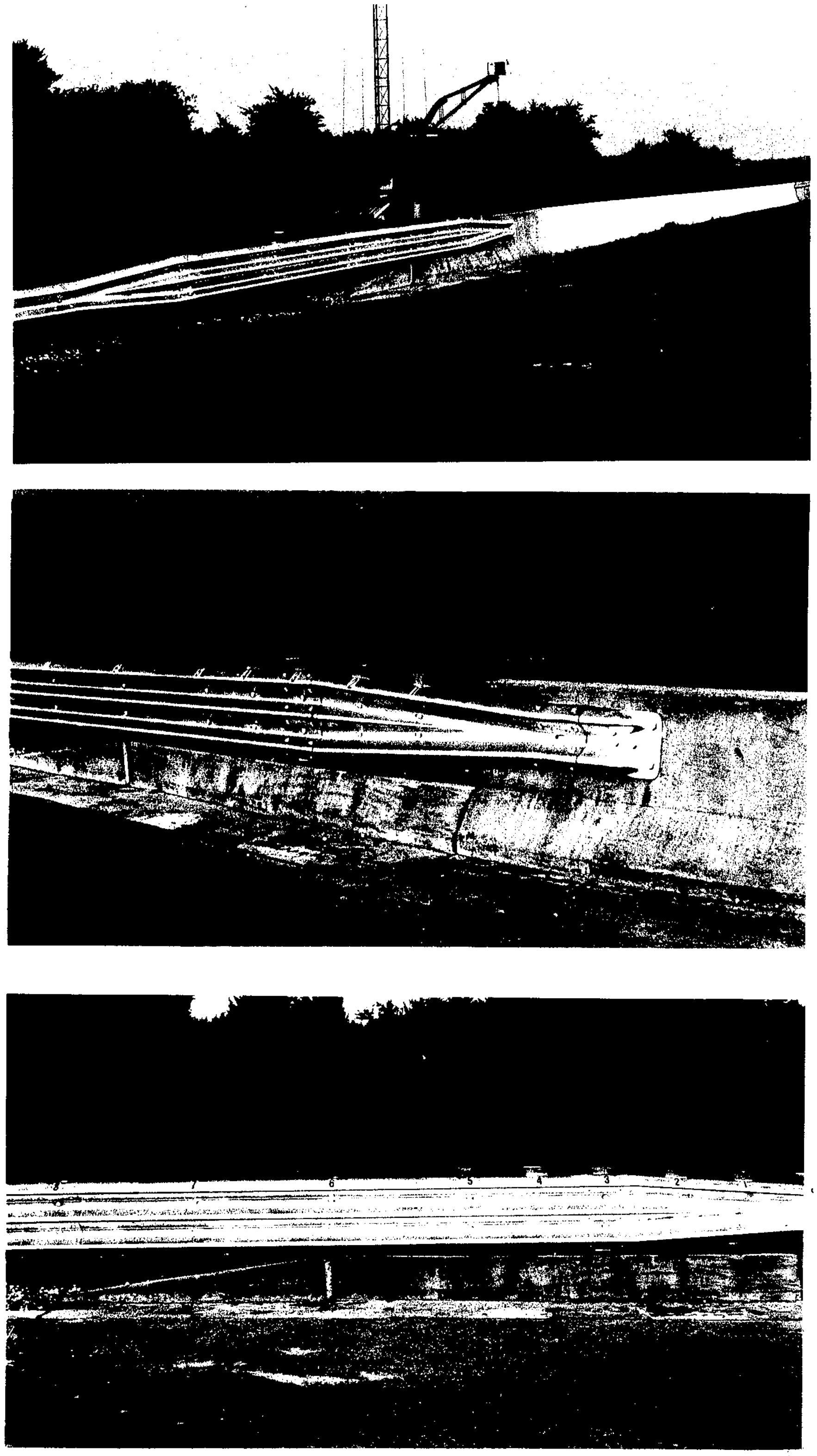


Figure 5. Michigan transition with 12-gauge, thrie beam prior to test 7147-1.

Figure 6. View of rear of Michigan transition with 12-gauge thrie beam.

accelerometer in the rear of the vehicle to measure longitudinal and lateral acceleration levels. The accelerometers were strain-gauge type with a linear millivolt output proportional to acceleration.

The electronic signals from the accelerometers and transducers were transmitted to a base station by means of constant bandwidth FM/FM telemetry link for recording on magnetic tape and for display on a real-time strip chart. Provision was made for the transmission of calibration signals before and after the test, and an accurate time reference signal was simultaneously recorded with the data. Pressure-sensitive contact switches on the bumper were actuated just prior to impact by wooden dowels to indicate the elapsed time over a known distance to provide a measurement of impact velocity. The initial contact also produced an "event" mark on the data record to establish the exact instant of contact with the guardrail transition.

The multiplex of data channels, transmitted on one radio frequency, was received at the data acquisition station, and demultiplexed into separate tracks of Intermediate Range Instrumentation Group (I.R.I.G.) tape recorders. After the test, the data were played back from the tape machines, filtered with a Class 180 filter, and digitized using a microcomputer, for analysis and evaluation of performance. The digitized data were then processed using two computer programs: DIGITIZE and PLOTANGLE. Brief descriptions of the functions of these two computer programs are as follows.

The DIGITIZE program uses digitized data from vehicle-mounted linear accelerometers to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 0.010-s average ridedown acceleration. The DIGITIZE program also calculates a vehicle impact velocity and the change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 0.050-s intervals in each of the three directions are computed. Acceleration versus time curves for the longitudinal, lateral, and vertical directions are then plotted from the digitized data of the vehicle-mounted linear accelerometers using a commercially available software package (LOTUS 123).

The PLOTANGLE program uses the digitized data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.001-s intervals and then instructs a plotter to draw a reproducible plot: yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation of the vehicle-fixed coordinate system being that which existed at initial impact.

2.3.2 Anthropomorphic Dummy Instrumentation

An Alderson Research Laboratories Hybrid II, 50th-percentile male anthropomorphic dummy, restrained with lap and shoulder belts, was placed in the driver's position of the vehicle. The dummy was uninstrumented; however, a high-speed onboard camera recorded the motions of the dummy during the test.

2.3.3 Photographic Instrumentation and Data Processing

Photographic coverage of the test included four high-speed cameras: one perpendicular to the point of impact; another overhead with a field of view perpendicular to the ground and directly over the impact point; and a third placed to have a field of view parallel to and aligned with the transition at the downstream end. A high-speed camera was also placed onboard the vehicle to record the motions of the dummy driver. A flashbulb activated by pressure-sensitive tape switches was positioned on the impacting vehicle to indicate the instant of contact with the transition and was visible from each camera. The films from these high-speed cameras were analyzed on a computer-linked Motion Analyzer to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A 16-mm movie cine, a 3/4-in videotape camcorder, and still cameras were used for documentary purposes and to record conditions of the test vehicle and transition before and after the test.

2.3.4 Test Vehicle Propulsion and Guidance

The automobile was towed into the guardrail transition using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was stretched along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. Another steel cable was connected to the test vehicle, passed around a pulley near the impact point, through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. The system had a 2 to 1 speed ratio between the test and tow vehicle.

III. CRASH TEST RESULTS

A 1979 Cadillac Coupe de Ville, shown in figures 7 and 8, was directed into the Michigan thrie-beam transition system. Test inertia weight of the vehicle was 2043 kg (4500 lb) and its gross static weight was 2118 kg (4666 lb). The height to the lower edge of the vehicle bumper was 343 mm (13.5 in) and it was 584 mm (23.0 in) to the upper edge. Additional dimensions and information on the vehicle are given in figure 9. The vehicle was directed into the transition using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

3.1 TEST DESCRIPTION

The vehicle was traveling at a speed of 100.1 km/h (62.2 mi/h) when it impacted the transition approximately 2.9 m (9.4 ft) from the end of the concrete bridge railing. The impact angle was 26.0 degrees. At 0.041 s after impact, the vehicle slowly began to redirect. As the vehicle continued forward, it began to deform at the A-pillar at 0.075 s and then began to redirect significantly at 0.082 s. The dummy hit the side window and shattered it at 0.143 s. At 0.167 s, the vehicle was traveling parallel to the transition at a speed of 81.4 km/h (50.6 mi/h) and, almost immediately afterwards, the rear of the vehicle impacted the transition. The vehicle exited the transition at 0.324 s, traveling at a speed of 77.7 km/h (48.3 mi/h), with an exit trajectory of 14.1 degrees. The brakes were applied after the vehicle cleared the test installation and the vehicle came to rest 66 m (218 ft) down and 27 m (88 ft) in front of the point of impact. Sequential photographs of the test sequence are presented in figures 10 and 11.

3.2 DAMAGE TO TEST INSTALLATION

The transition received moderate damage to the thrie beam, as shown in figures 12 through 14. As also can be seen in the photographs, the curb was chipped and there were tire marks along the contact area. There was also some slight movement in the curb and gutter section. Total length of contact with the transition was 4.3 m (14 ft) and the maximum permanent deformation was 102 mm (4.0 in) at post 4.

3.3 VEHICLE DAMAGE

The vehicle (shown in figure 15) sustained severe damage to the left side. The tie rod was bent and the windshield and left door glass were broken. There was damage to the front bumper, hood, grill, radiator and fan, left front quarter panel, left door, left rear quarter panel, and rear bumper. The left front wheel rim was split, the welds were broken, and the tire was cut. The left rear rim and tire were also damaged. Maximum crush to the vehicle was 432 mm (17.0 in) at the left front corner at bumper height.

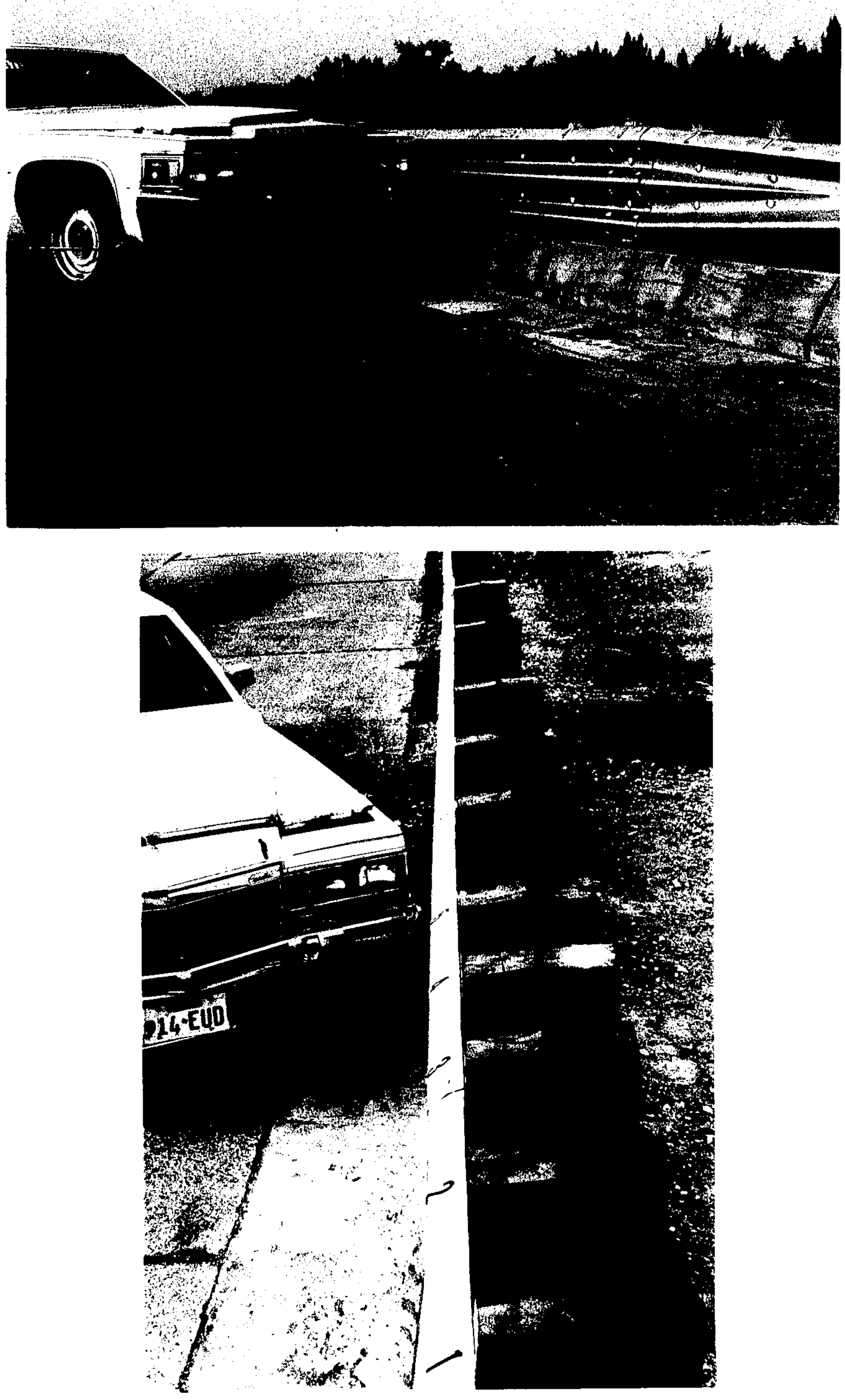


Figure 7. Vehicle/transition geometry for test 7147-1.

Figure 8. Vehicle prior to test 7147-1.

DATE: 07/31/90 TEST NO.: 471470-1 VIN NO.: 6D4759C362215

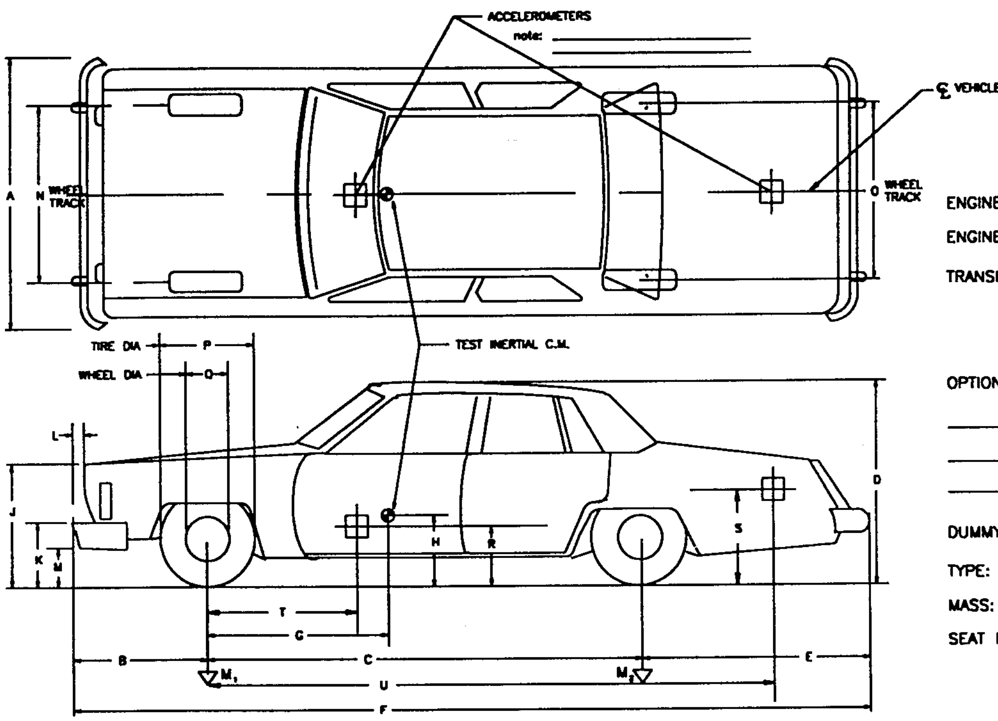
YEAR: 1979 MAKE: Cadillac MODEL: Coupe deVille

TIRE INFLATION PRESSURE: ______ ODOMETER: 97812 TIRE SIZE: ______

MASS DISTRIBUTION (kg) LF 549 RF 558 LR 465 RR 471

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:

Crack in windshield



ENGINE TYPE: V8

ENGINE CID: 7 L

TRANSMISSION TYPE:

X AUTO

__ MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: 50th male

MASS: 75 kg

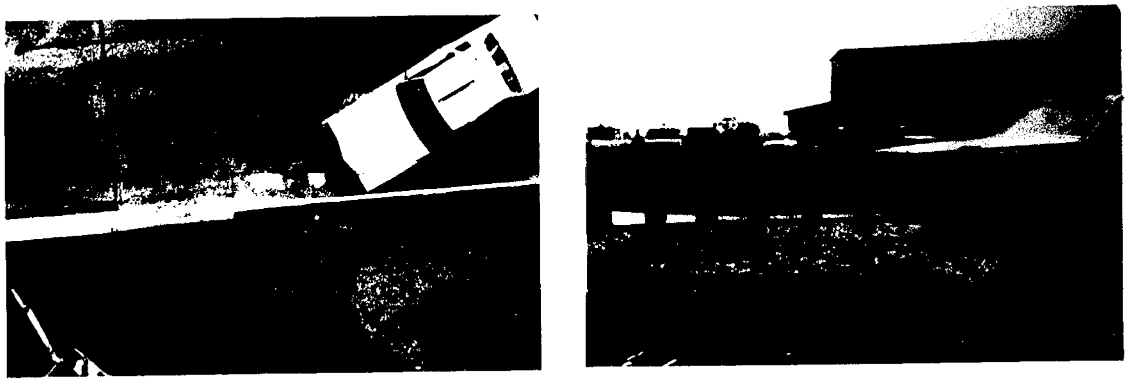
SEAT POSITION: Driver's

GEOMETRY – (mm)

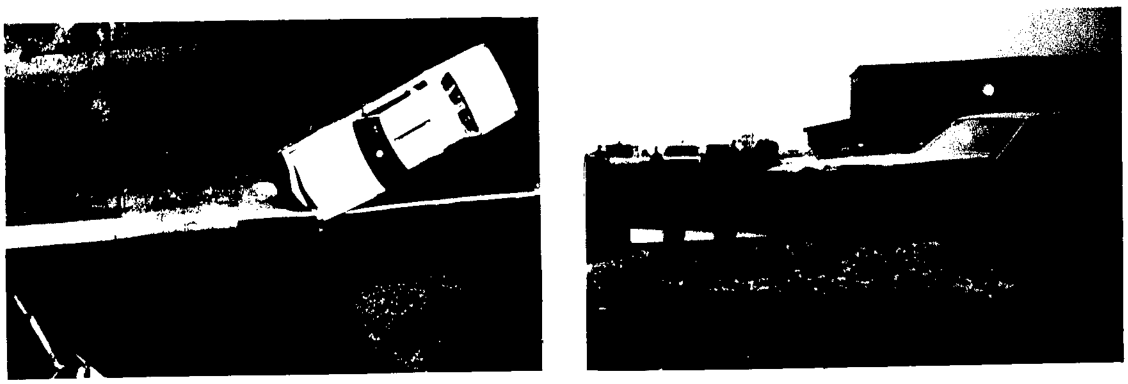
A 1937	E 1397	J 914	N 1575	R 495
B 1080	F 5550	K 584	O	S 597
C 3073	G 1407	L 121	P 686	T 978
D 1403	H	M 343	Q 413	U 4039

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	1092	1107	1145
M_2	763	936	973
M_T	1856	2043	2118

Figure 9. Vehicle properties (test 7147-1).



0.000 s



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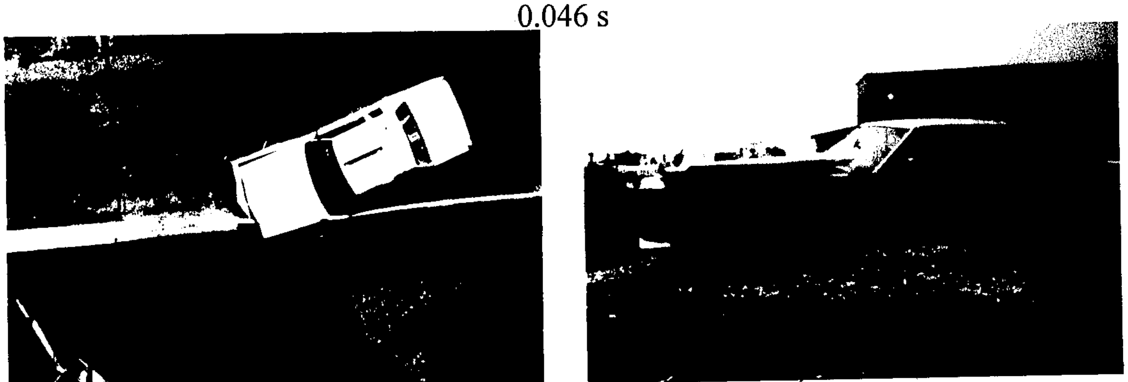
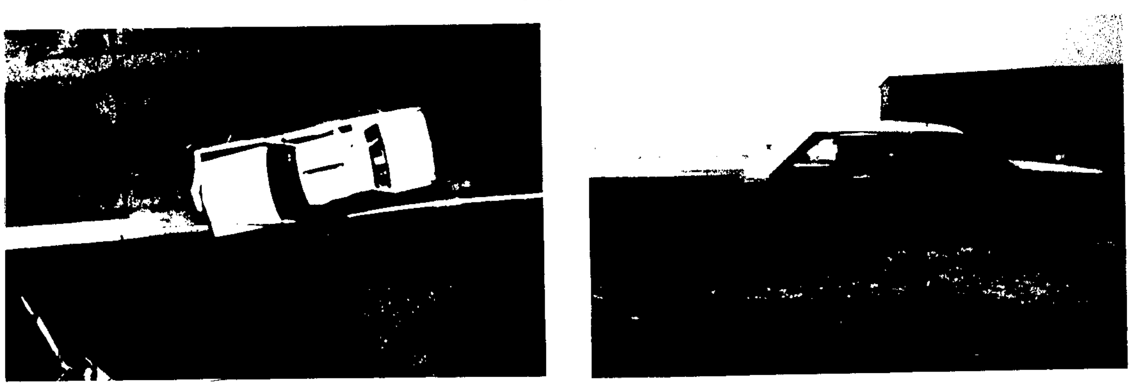


0.092 s



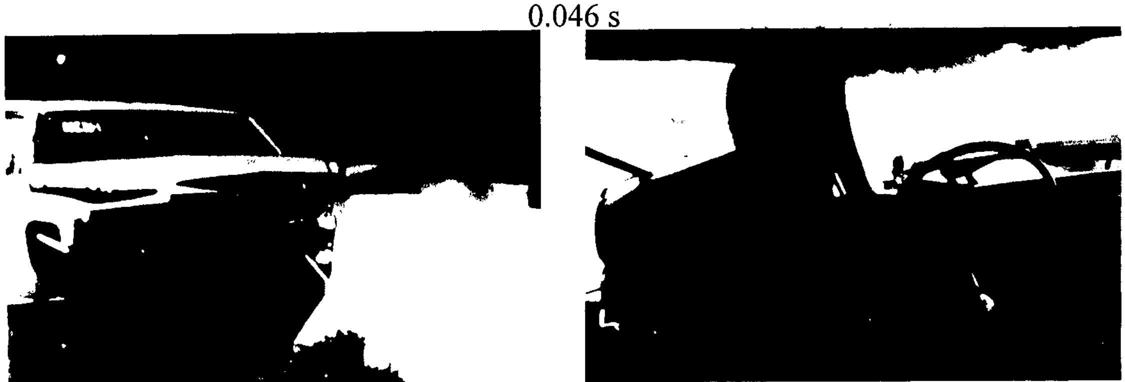
0.139 s

Figure 10. Sequential photographs for test 7147-1
(overhead and behind the rail views).

Figure 10. Sequential photographs for test 7147-1 (overhead and behind the rail views) (continued).

0.000 s

0.046 s



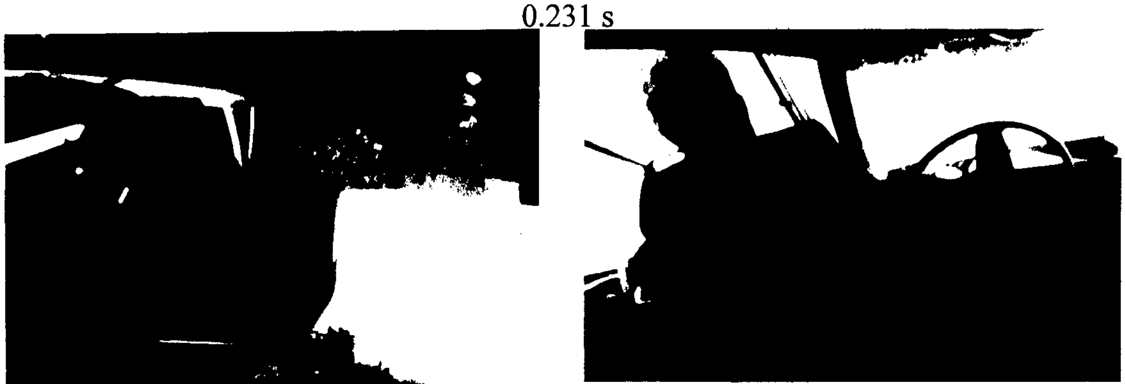
0.092 s

0.139 s

Figure 11. Sequential photographs for test 7147-1
(frontal and interior views).

0.185 s

0.231 s



0.277 s

0.324 s

Figure 11. Sequential photographs for test 7147-1 (frontal and interior views) (continued).

Figure 12. Michigan transition after test 7147-1.

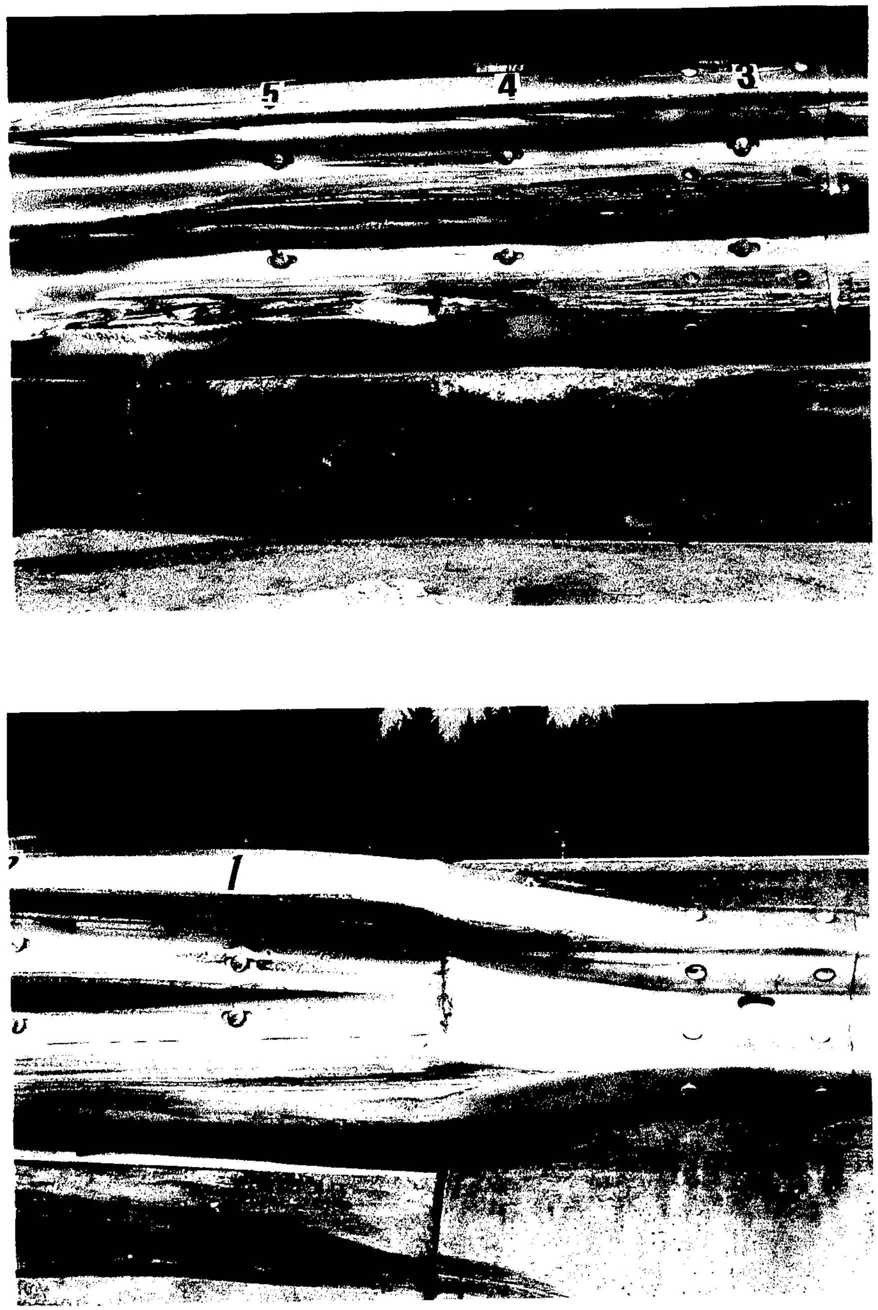
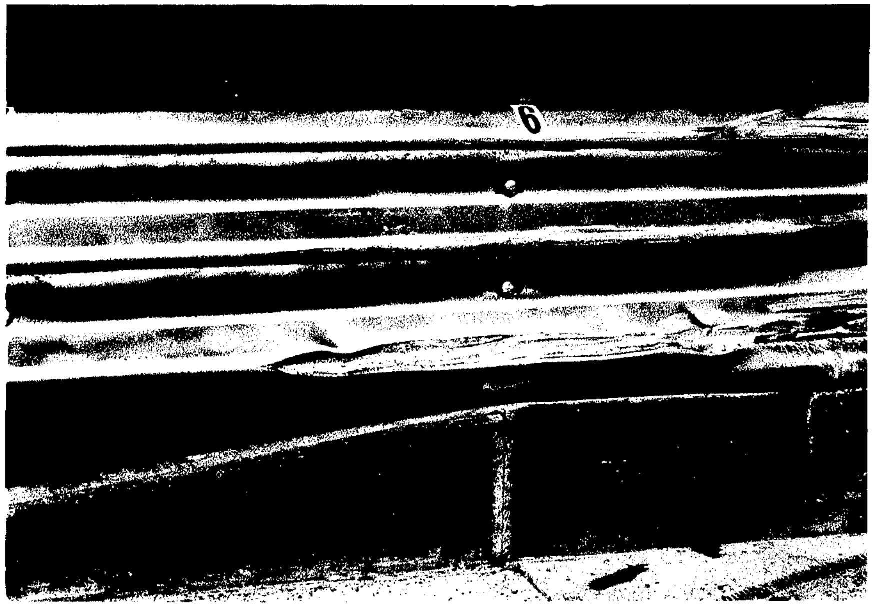


Figure 13. Damage to rail at posts 1-5, test 7147-1.



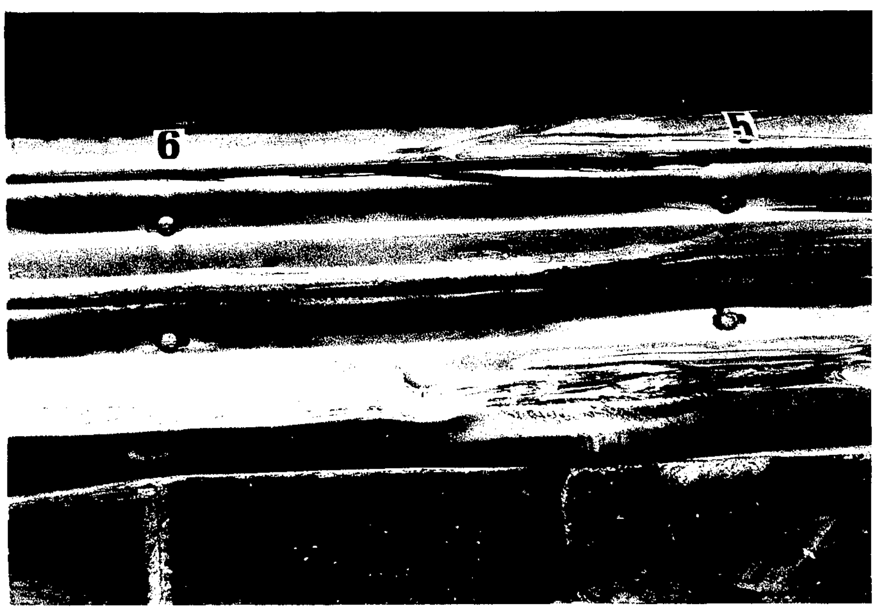


Figure 14. Damage to rail at posts 5-7, test 7147-1.

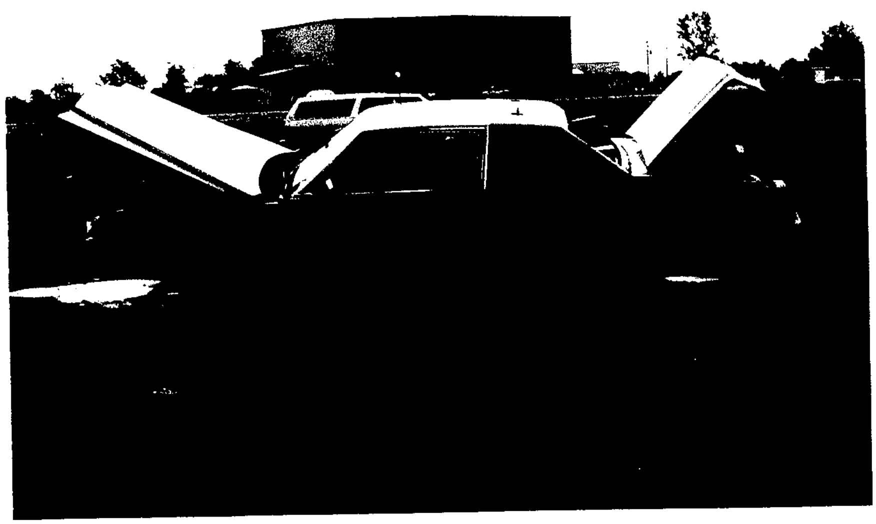
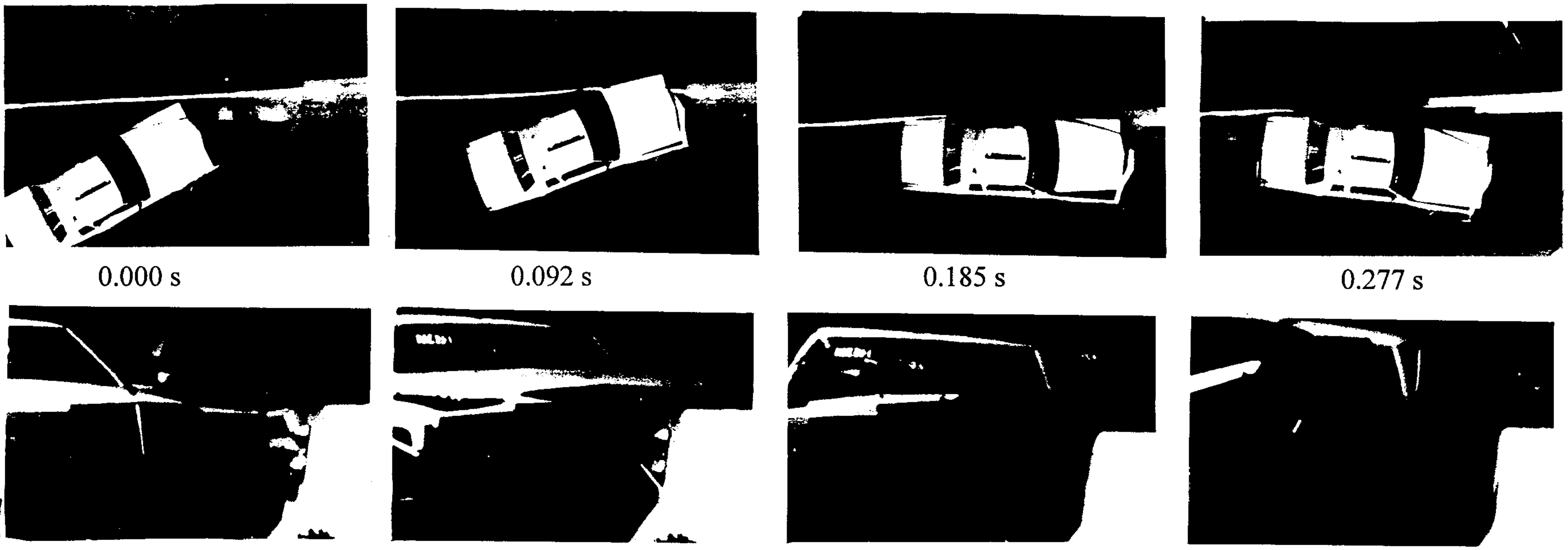


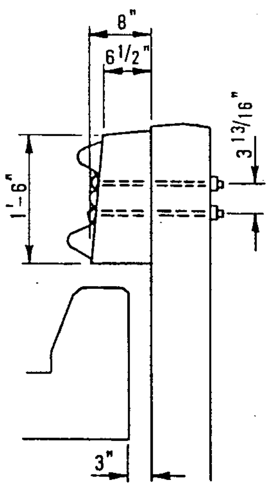
Figure 15. Damage to vehicle, test 7147-1.

3.4 OCCUPANT RISK VALUES

Data from the electronic instrumentation were digitized for evaluation, and occupant risk factors were computed as follows. In the longitudinal direction, occupant impact velocity was 7.2 m/s (23.6 ft/s) at 0.176 s; the highest 0.010-s average ridedown acceleration was -7.9 g's from 0.221 to 0.231 s; and the maximum 0.050-s average acceleration was -7.5 g's between 0.068 and 0.118 s. Lateral occupant impact velocity was 8.7 m/s (28.7 ft/s) at 0.106 s, the highest 0.010-s average ridedown acceleration was -12.2 g's from 0.106 to 0.116 s; and the maximum 0.050-s average acceleration was -13.7 g's between 0.067 and 0.117 s. The change in vehicle velocity at loss of contact was 22.4 km/h (13.9 mi/h) and the change in momentum was 12 672 N-s (2849 lb-s).

A summary of pertinent data from the electronic instrumentation, high-speed film, and field measurements is given in figure 16. Vehicle angular displacements are displayed in figure 17, and vehicular accelerations versus time traces filtered at 300 Hz are presented in figures 18 through 20.





Post 1

Test No.	7147-1
Date	07/31/90
Test Installation	Michigan Transition with 12-Gauge Thrie Beam
Installation Length	23 m (75 ft)
Max. Dynamic Deflection	Not Attainable
Max. Perm. Deformation	0.1 m (0.3 ft)
Test Vehicle	1979 Cadillac Coupe deVille
Vehicle Weight	
Test Inertia	2043 kg (4500 lb)
Gross Static	2118 kg (4666 lb)
Vehicle Damage Classification	
TAD	11FL6 & 11LD6
CDC	11FLEK2 & 11LDES3
Maximum Vehicle Crush	432 mm (17.0 in)

Impact Speed	100.1 km/h (62.2 mi/h)
Impact Angle	26.0 deg
Speed at Parallel	81.4 km/h (50.6 mi/h)
Exit Speed	77.7 km/h (48.3 mi/h)
Exit Trajectory	14.1 deg
Vehicle Accelerations (Max. 0.050-s avg)	
Longitudinal	-7.5 g's
Lateral	-13.7 g's
Occupant Impact Velocity	
Longitudinal	7.2 m/s (23.6 ft/s)
Lateral	8.7 m/s (28.7 ft/s)
Occupant Ridedown Accelerations	
Longitudinal	-7.9 g's
Lateral	-12.2 g's

Figure 16. Summary of results for test 7147-1.

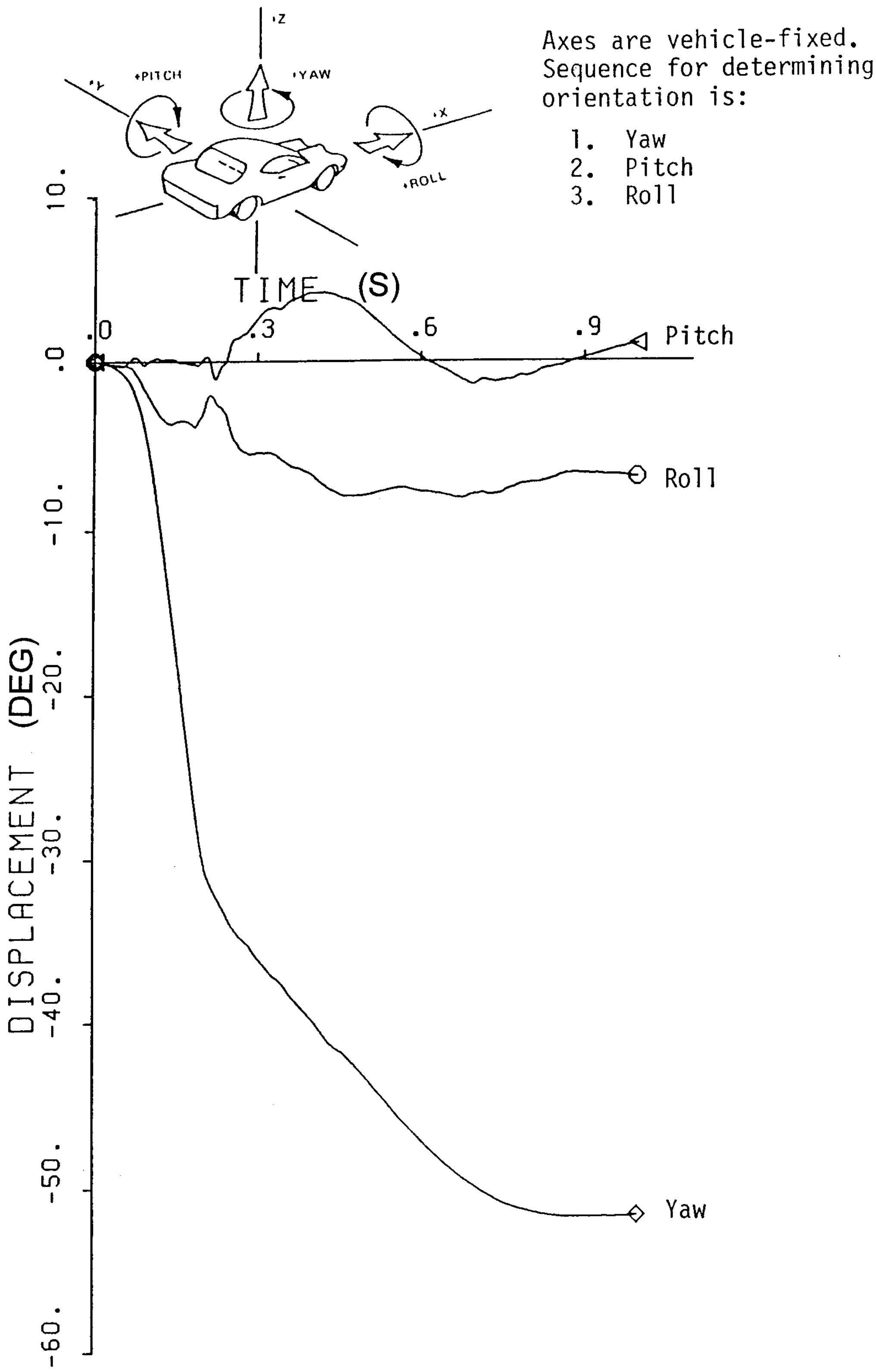


Figure 17. Vehicle angular displacement for test 7147-1.

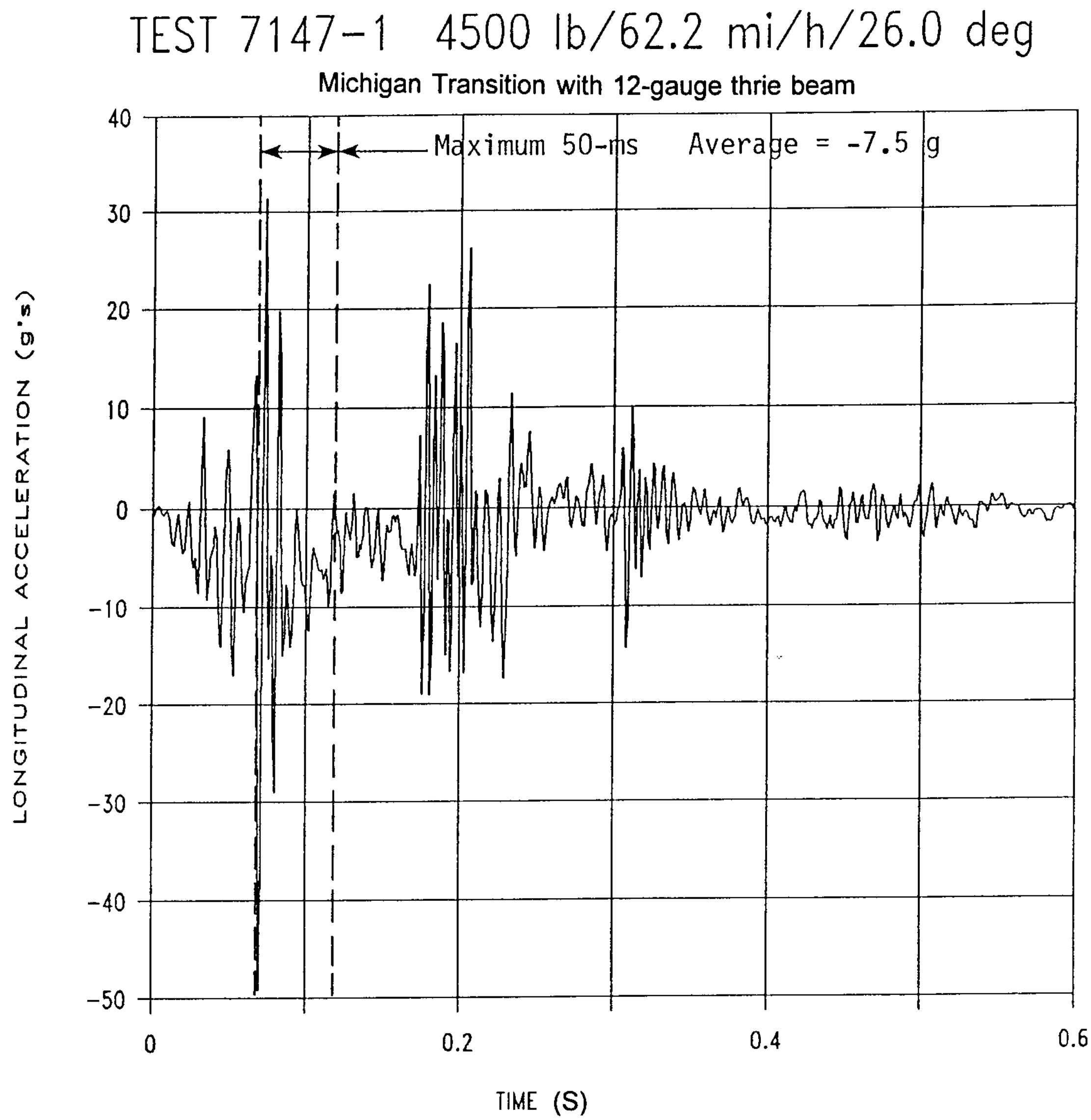


Figure 18. Longitudinal vehicle accelerometer trace for test 7147-1 .

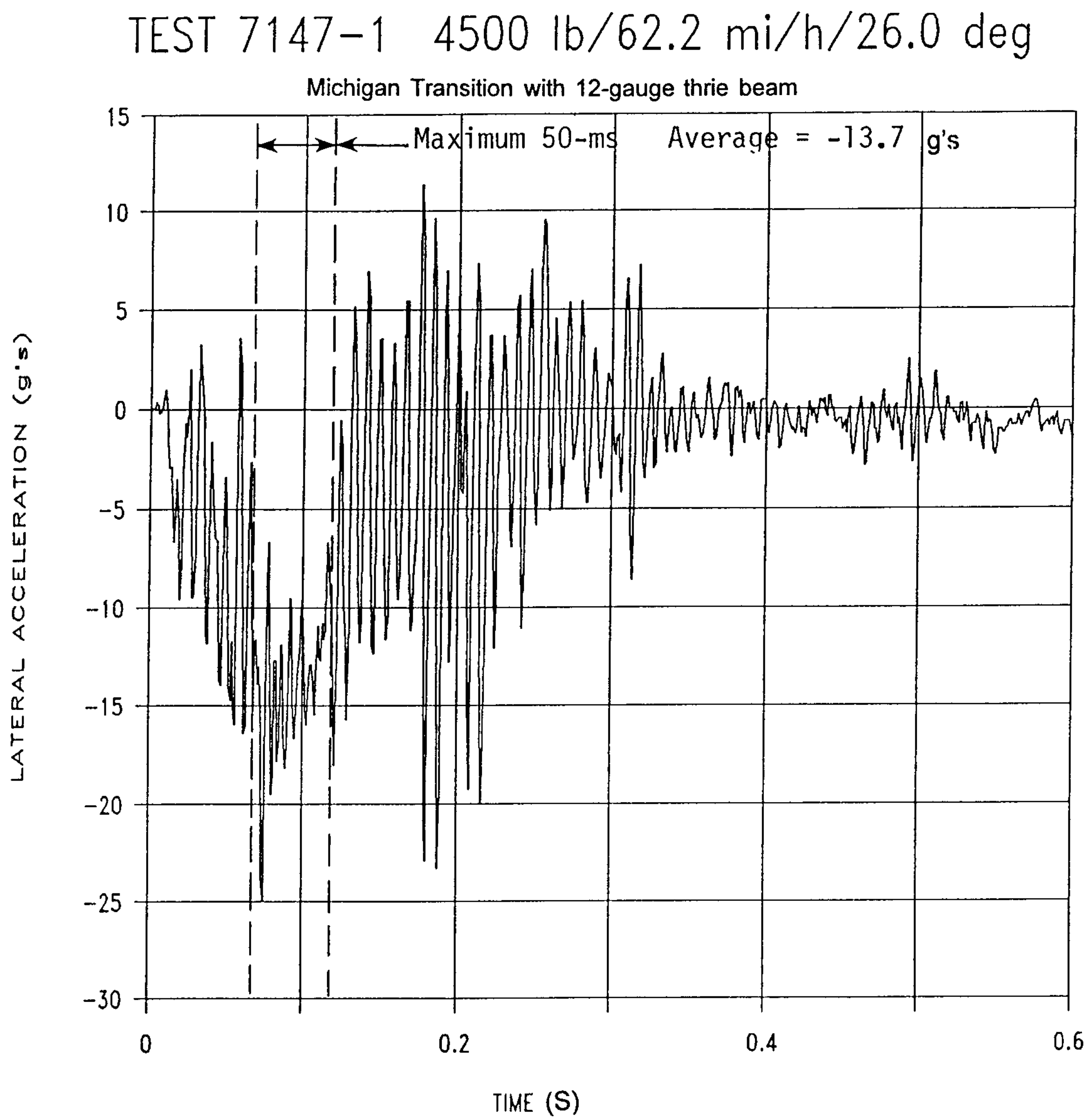


Figure 19. Lateral vehicle accelerometer trace for test 7147-1.

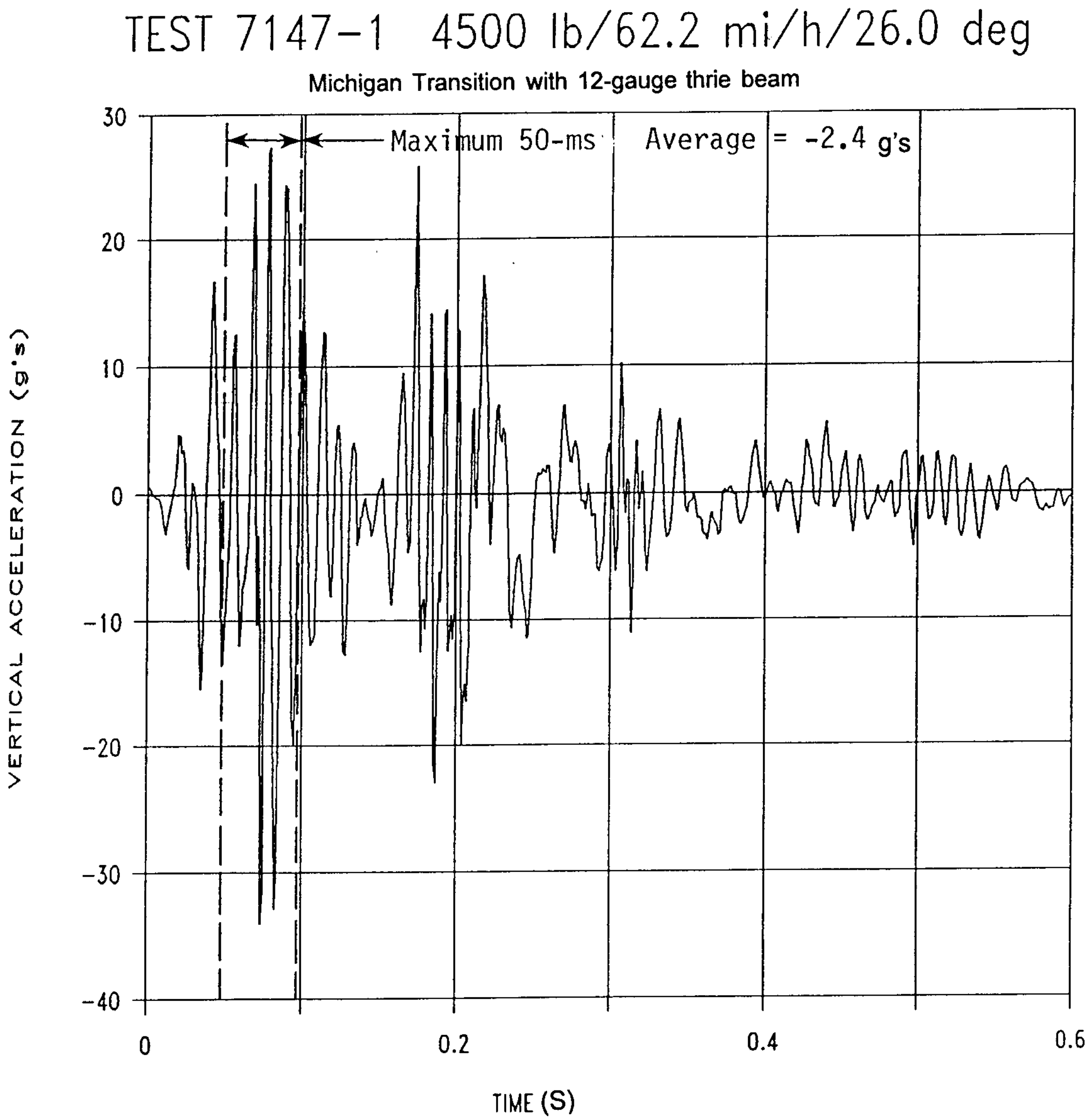


Figure 20. Vertical vehicle accelerometer trace for test 7147-1.

IV. SUMMARY OF FINDINGS AND CONCLUSIONS

The Michigan thrie-beam transition system performed satisfactorily in the crash test, as shown in table 1. The vehicle was smoothly redirected and did not penetrate or go over the transition. There were no detached elements or debris to show potential for penetration of the occupant compartment or to present undue hazard to other traffic. The vehicle remained upright and stable during the impact with the transition and after exiting the test installation. Some intrusion into the occupant compartment occurred with moderate deformation of the compartment. Vehicle trajectory at loss of contact indicates minimal intrusion into adjacent traffic lanes.

The lateral occupant impact velocity of 8.7 m/s (28.7 ft/s) was below the limit of 9.1 m/s (30.0 ft/s), but higher than the design value of 6.1 m/s (20 ft/s), as outlined in NCHRP Report 230. Otherwise, the longitudinal occupant impact velocity and the highest 0.010-s average ridedown accelerations for both the longitudinal and lateral directions are below the design values. The velocity change of 22.4 km/h (13.9 mi/h) was less than the recommended velocity change of 24.1 km/h (15 mi/h) and the exit angle of 14.1 degrees was less than 60 percent of the impact angle.

In summary, the Michigan thrie-beam transition system is judged to have met all evaluation criteria set forth in NCHRP Report 230.

Table 1. Assessment of results of test 471470-1 (according to NCHRP 230).

Test Agency: Texas Transportation Institute | Test No.: 7147-1 | Test Date: 07/31/90

Evaluation Criteria	Test Results	Assessment
Structural Adequacy		
A. Test article shall contain and redirect the vehicle; the vehicle should not penetrate or go over the installation although controlled lateral deflection of the test article is acceptable.	The vehicle did not penetrate or go over the barrier and was smoothly redirected.	Pass
D. 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.	No debris showed potential for penetrating passenger compartment or presenting undue hazard to other traffic.	Pass
Occupant Risk		
E. 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.	Vehicle remained upright and stable during collision. There was no deformation or intrusion into the passenger compartment.	Pass
F. Impact velocity of hypothetical front seat passenger against the vehicle interior shall be less than Occupant Impact Velocity Limits (m/s): Longitudinal 12.2 (40 ft/s); Lateral 9.1 (30 ft/s)	Longitudinal Impact Velocity = 7.2 m/s (23.6 ft/s) Lateral Impact Velocity = 8.7 m/s (28.7 ft/s)	N/A
and vehicle highest 10 ms average accelerations subsequent to instant of hypothetical passenger contact should be less than: Occupant Ridedown Acceleration Limits (g's): Longitudinal 20; Lateral 20	Longitudinal Occupant Ridedown = -7.9 g's Lateral Occupant Ridedown = -12.2 g's	N/A
Vehicle Trajectory		
H. After collision, the vehicle trajectory and final stopping position shall intrude a minimum distance, if at all, into adjacent traffic lanes.	Vehicle came to rest 66 m (218 ft) downstream and 27 m (88 ft) in front of the point of impact, indicating minimal intrusion.	Pass
I. In tests where the vehicle is judged to be redirected into or stopped while in adjacent traffic lanes, vehicle speed change during test article collision should be less than 24.1 km/h (15 mi/h) and the exit angle from the test article should be less than 60 percent of test impact angle, both measured at time of vehicle loss of contact with test device.	Velocity change 22.4 km/h (13.9 mi/h) (<24.1 km/h (15 mi/h); exit angle 14.1 degrees (<15.6 degrees or 60 percent of 26.0 degrees)	Pass

REFERENCE

1. Michie, J. D., *Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances*, NCHRP Report 230, Transportation Research Board, Washington, DC, 1980.