Testing of New Bridge Rail and Transition Designs

Volume XIII: Appendix L

32-in (813-mm) Thrie-Beam Transition

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Research and Development
Turner-Fairbank Highway Research Center
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FOREWORD

This report presents the results of a State Planning and Research (SP&R) pooled-fund study to develop safer bridge rail and transition designs. This pooled-fund study was sponsored by the Federal Highway Administration, 23 States, and the District of Columbia. A panel of representatives from those agencies selected the designs to be studied. Ten bridge rails and two transitions were designed and crash tested in accordance with the recommendations for the various Performance Levels in the *1989 AASHTO Guide Specifications for Bridge Railings*. Acceptable performance was demonstrated for all of the crash tested designs.

Detailed drawings are presented for documentation and to facilitate implementation.

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

NOTICE

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16. Abstract

A transition proposed for use between a standard W-beam approach guardrail and a performance level two bridge railing was designed and tested to performance level two of the 1989 *Guide Specifications for Bridge Railings*. Thrie-beam rail elements were used in the transition. The prototype test installation was connected to a 32-in (813-mm) vertical faced concrete parapet bridge railing. Acceptable performance of the final design was demonstrated.

This volume is the thirteenth in a series. The other volumes in the series are: Volume I: Technical Report; Volume II: Appendix A, Oregon Side Mounted Bridge Railing; Volume III: Appendix B, BR27D Bridge Railing; Volume IV: Appendix C, Illinois 2399-1 Bridge Railing; Volume V: Appendix D, 32-in (813-mm) Concrete Parapet Bridge Railing; Volume VI: Appendix E, 32-in (813-mm) New Jersey Safety Shape; Volume VII: Appendix F, 32-in (813-mm) F-Shape Bridge Railing; Volume VIII: Appendix G, BR27C Bridge Railing; Volume IX: Appendix H, Illinois Side Mount Bridge Rail; Volume X: Appendix I, 42-in (1.07-m) Concrete Parapet Bridge Railing; Volume XI: Appendix J, 42-in (1.07-m) F-Shape Bridge Railing; Volume XII: Appendix K, Oregon Transition; and Volume XIV: Appendix M, Axial Tensile Strength of Thrie and W-Beam Terminal Connectors.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

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

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

(Revised September 1993)

TABLE OF CONTENTS

Chapter		Page
1.	**DESIGN OF TRANSITION**	1
2.	**CRASH TEST PROCEDURES**	5
3.	**FULL-SCALE CRASH TESTS**	9
	TEST 7069-19	9
	Test Description	9
	Test Results	9
	Conclusions	10
	TEST 7069-20	28
	Test Description	28
	Test Results	28
	Conclusions	29
	TEST 7069-21	51
	Test Description	51
	Test Results	52
	Conclusions	52
	TEST 7069-29	75
	Test Description	75
	Test Results	75
	Conclusions	76
	REFERENCES	99

LIST OF FIGURES

Figure No.		Page
1.	32-in (813-mm) thrie-beam transition	2
2.	Details for modified terminal connector for test 7069-21 AND 7069-29	3
3.	Vehicle prior to impact with thrie-beam transition, test 7069-19	11
4.	Vehicle/transition geometrics for test 7069-19	12
5.	Thrie-beam transition before test 7069-19	13
6.	Vehicle properties for test 7069-19	14
7.	Thrie-beam transition after test 7069-19	15
8.	Vehicle after test 7069-19	16
9.	Summary of results for test 7069-19	17
10.	Sequential photographs for test 7069-19 (frontal and overhead views)	21
11.	Sequential photographs for test 7069-19 (rear of transition view)	23
12.	Vehicle angular displacements for test 7069-19	24
13.	Vehicle longitudinal accelerometer trace for test 7069-19 (accelerometer located at center-of-gravity)	25
14.	Vehicle lateral accelerometer trace for test 7069-19 (accelerometer located at center-of-gravity)	26
15.	Vehicle vertical accelerometer trace for test 7069-19 (accelerometer located at center-of-gravity)	27
16.	Vehicle before test 7069-20	30
17.	Vehicle/transition geometrics for test 7069-20	31
18.	Thrie-beam transition before test 7069-20	32
19.	Vehicle properties for test 7069-20	33
20.	Thrie-beam transition after test 7069-20	34
21.	Vehicle after test 7069-20	35
22.	Damage to vehicle after test 7069-20	36
23.	Summary of results for test 7069-20	37
24.	Sequential photographs for test 7069-20 (frontal and overhead views)	39
25.	Sequential photographs for test 7069-20 (rear of transition and interior views)	41
26.	Vehicle angular displacements for test 7069-20	43
27.	Vehicle longitudinal accelerometer trace for test 7069-20 (accelerometer located at center-of-gravity)	44
28.	Vehicle lateral accelerometer trace for test 7069-20 (accelerometer located at center-of-gravity)	45
29.	Vehicle vertical accelerometer trace for test 7069-20 (accelerometer located at center-of-gravity)	46
30.	Vehicle longitudinal accelerometer trace for test 7069-20 (accelerometer located at front of vehicle)	47

LIST OF FIGURES (Continued)

Figure No.		Page
31.	Vehicle lateral accelerometer trace for test 7069-20 (accelerometer located at front of vehicle)	48
32.	Vehicle longitudinal accelerometer trace for test 7069-20 (accelerometer located at rear of vehicle)	49
33.	Vehicle lateral accelerometer trace for test 7069-20 (accelerometer located at rear of vehicle)	50
34.	Vehicle before test 7069-21	53
35.	Vehicle/transition geometrics for test 7069-21	54
36.	Vehicle properties for test 7069-21	55
37.	32-in (813-mm) thrie-beam transition before test 7069-21	56
38.	Modified terminal connector similar to those used in tests 7069-21 and 29	57
39.	Modified end shoe attachment for test 7069-21	58
40.	32-in (813-mm) thrie-beam transition after test 7069-21	59
41.	Vehicle after test 7069-21	60
42.	Summary of results for test 7069-21	61
43.	Sequential photographs for test 7069-21 (overhead and frontal views)	63
44.	Sequential photographs for test 7069-21 (interior and rear of transition views)	65
45.	Vehicle angular displacements for test 7069-21	67
46.	Vehicle longitudinal accelerometer trace for test 7069-21 (accelerometer located at center-of-gravity)	68
47.	Vehicle lateral accelerometer trace for test 7069-21 (accelerometer located at center-of-gravity)	69
48.	Vehicle vertical accelerometer trace for test 7069-21 (accelerometer located at center-of-gravity)	70
49.	Vehicle longitudinal accelerometer trace for test 7069-21 (accelerometer located at front of vehicle)	71
50.	Vehicle lateral accelerometer trace for test 7069-21 (accelerometer located at front of vehicle)	72
51.	Vehicle longitudinal accelerometer trace for test 7069-21 (accelerometer located at rear of vehicle)	73
52.	Vehicle lateral accelerometer trace for test 7069-21 (accelerometer located at rear of vehicle)	74
53.	Vehicle before test 7069-29	77
54.	Vehicle/transition geometrics for test 7069-29	78
55.	Vehicle properties for test 7069-29	79
56.	32-in (813-mm) thrie-beam transition before test 7069-29	80
57.	32-in (813-mm) thrie-beam transition after test 7069-29	81
58.	Damage at terminal connection to concrete parapet after test 7069-29	82

LIST OF FIGURES (Continued)

Figure No.		Page
59.	Damage to terminal connector (after removal from concrete parapet) after test 7069-29	83
60.	Vehicle after test 7069-29	84
61.	Summary of results for test 7069-29	85
62.	Sequential photographs for test 7069-29 (overhead and frontal views)	87
63.	Sequential photographs for test 7069-29 (rear of transition view)	89
64.	Vehicle angular displacements for test 7069-29	90
65.	Vehicle longitudinal accelerometer trace for test 7069-29 (accelerometer located at center-of-gravity)	91
66.	Vehicle lateral accelerometer trace for test 7069-29 (accelerometer located at center-of-gravity)	92
67.	Vehicle vertical accelerometer trace for test 7069-29 (accelerometer located at center-of-gravity)	93
68.	Vehicle longitudinal accelerometer trace for test 7069-29 (accelerometer located at front of vehicle)	94
69.	Vehicle lateral accelerometer trace for test 7069-29 (accelerometer located at front of vehicle)	95
70.	Vehicle longitudinal accelerometer trace for test 7069-29 (accelerometer located at rear of vehicle)	96
71.	Vehicle lateral accelerometer trace for test 7069-29 (accelerometer located at rear of vehicle)	97

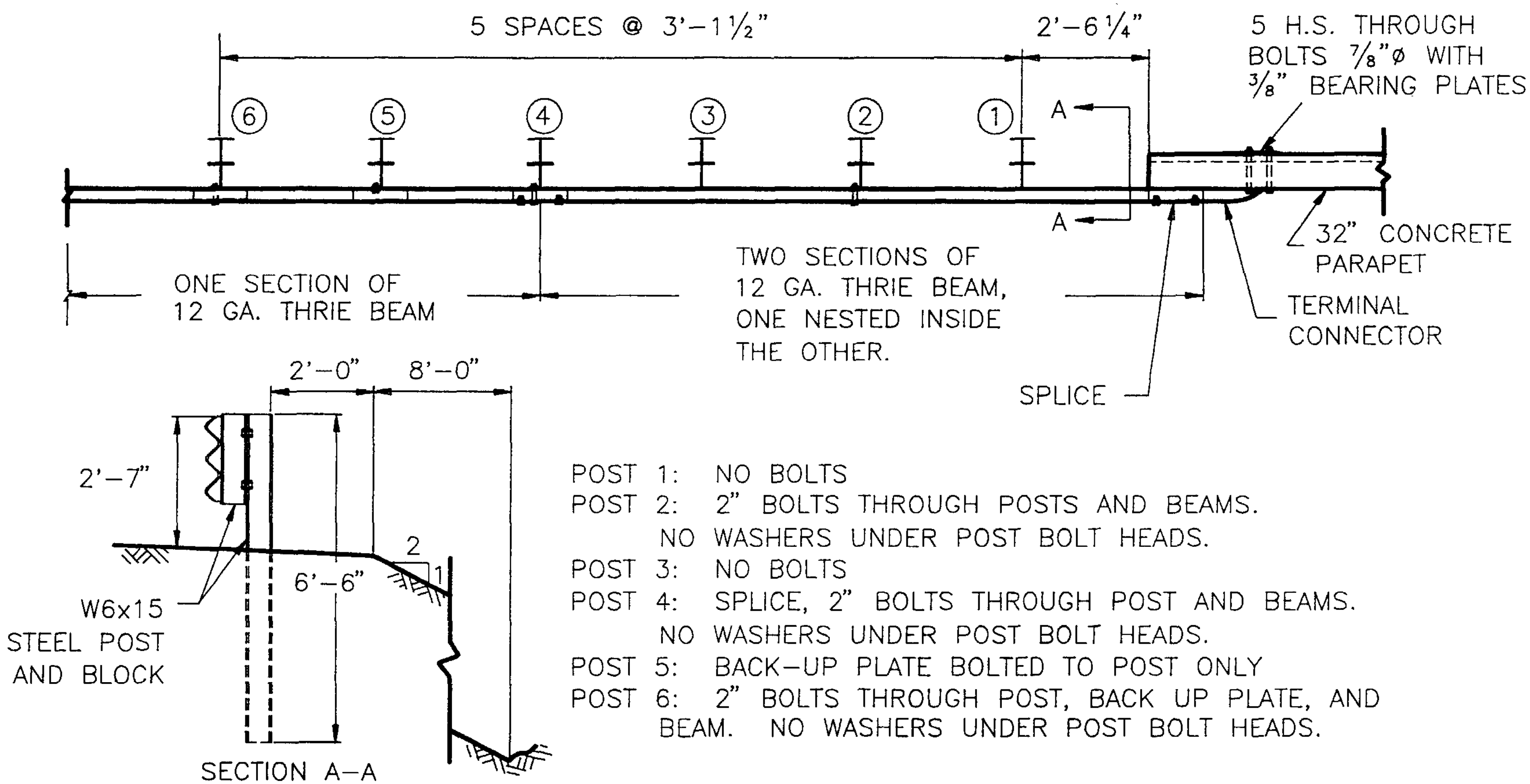
LIST OF TABLES

Table No.		Page
1.	Evaluation of crash test no. 7069-19	18
2.	Bridge railing performance levels and crash test criteria	19
3.	Evaluation of crash test no. 7069-20	38
4.	Evaluation of crash test no. 7069-21	62
5.	Evaluation of crash test no. 7069-29	86

CHAPTER 1. DESIGN OF TRANSITION

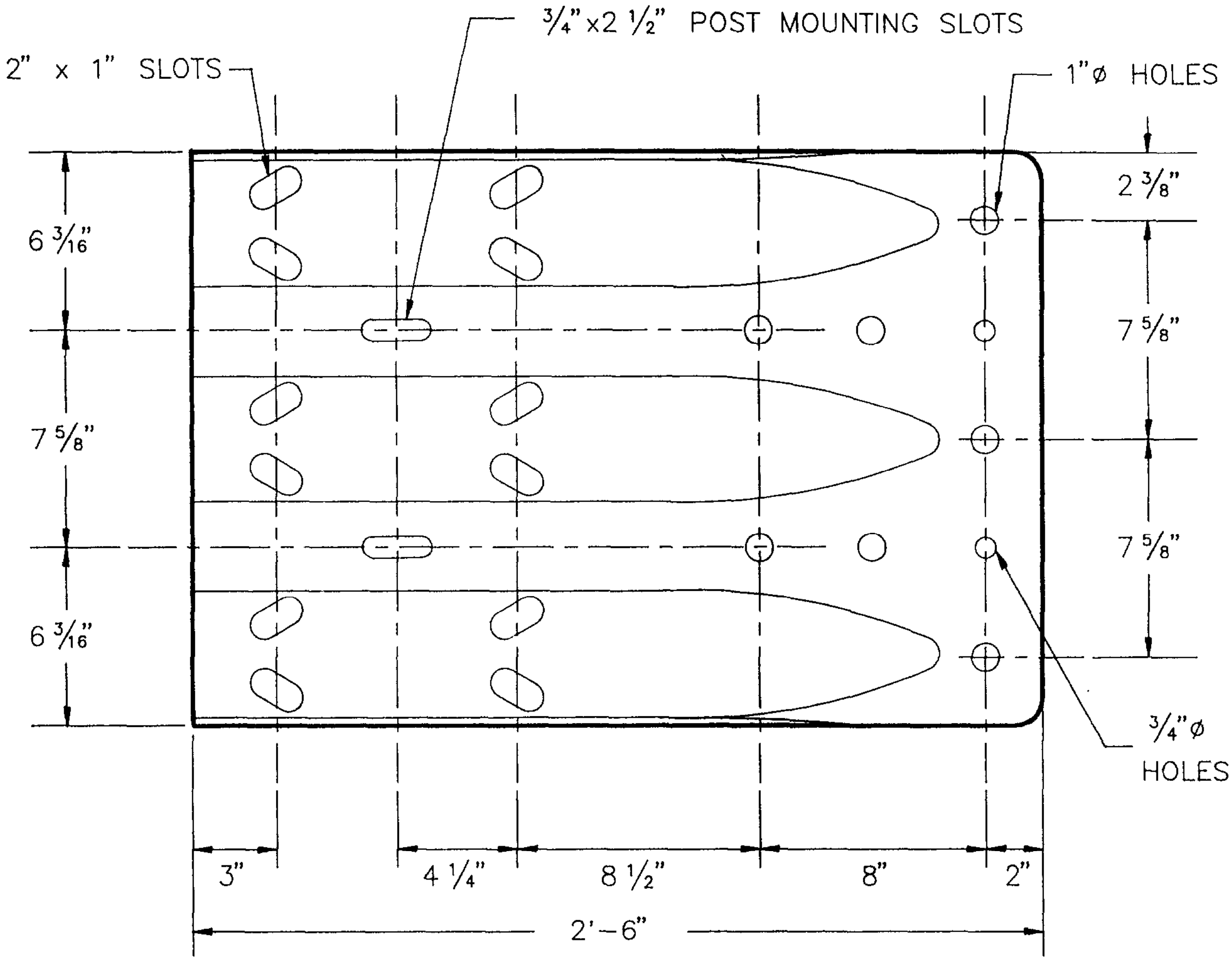
An elevation view and cross section of the transition are shown in figure 1. Height to the top of the transition rail element from ground level is 31 in (790 mm). The transition is composed of one section of 12-gauge thrie-beam spliced into two sections of 12-gauge thrie-beam, one nested inside the other. The nested thrie-beams are bolted to a 32-in (813-mm) concrete parapet using the terminal connector shown in figure 2. In tests 7069-19 and 20, a standard thrie-beam terminal connector was used. In test 7069-21, a 12-gauge terminal connector with slanted splice slots was used. In test 7069-29, a 10-gauge terminal connector with slanted splice slots was used. The transition is supported by W6x15 posts and blocks spaced at 3-ft 1-1/2-in (1 m) center-to-center with a 2-ft 6-1/4-in (768 mm) space adjacent to the end of the concrete parapet.

Because transition rails are flexible and most bridge rails are either rigid or semi-rigid, guardrail-to-bridge rail transitions must be designed to prevent impacting vehicles from deflecting the guardrail sufficiently enough to allow vehicle snagging on the end of the rigid barrier. By gradually increasing the stiffness of the guardrail as it approaches the parapet, a smooth transition from the lower stiffness of the thrie-beam guardrail to the higher stiffness of the concrete parapet is provided. Consequently, an impacting vehicle is prevented from snagging along the transition and sustaining high levels of damage or injury.



1 in = 25.4 mm

Figure 1. 32-in (813-mm) thrie-beam transition.



1 in = 25.4 mm

Figure 2. Details for modified terminal connector for test 7069-21 and test 7069-29.

CHAPTER 2. CRASH TEST PROCEDURES

The 32-in (813-mm) thrie-beam transition was tested to performance level two requirements.[1] Nominal test conditions for this performance level were as follows:

1,800-lb (817-kg) passenger car | 60 mi/h (96.6 km/h) | 20 degrees (test 7069-19)
5,400-lb (2 452-kg) pickup | 60 mi/h (96.6 km/h) | 20 degrees (tests 7069-20 and 7069-21)
18,000-lb (8 172-kg) truck | 50 mi/h (80.5 km/h) | 15 degrees (test 7069-29)

In test 7069-20 a standard thrie-beam terminal connector was used to connect the transition to the concrete parapet. The terminal was lapped on top of the two thicknesses of thrie-beam and there was difficulty in assembly of the splice. It was necessary to enlarge some holes to assemble the splice. In the crash test, the end of the connector engaged the door of the test vehicle and separated the door from the vehicle. For the subsequent test (7069-21), a modified terminal connector was used. It has slanted slotted holes to facilitate assembly of the splice. The terminal connector was sandwiched between the two layers of rail element.

Each of the test vehicles was instrumented with three solid-state angular rate transducers to measure roll, pitch, and yaw rates and a triaxial accelerometer at the vehicle center-of-gravity to measure longitudinal, lateral, and vertical acceleration levels. In addition, the pickups and the 18,000-lb (8 172-kg) truck had two sets of biaxial accelerometers--one set mounted forward of the center-of-gravity and the other set in the rear of each 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 band width 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 transition.

The multiplex of data channels transmitted on one radio frequency was received at a 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 an SAE J211 filter, and digitized using a microcomputer for analysis and evaluation of impact performance. The digitized data were then processed using two computer programs: DIGITIZE and PLOTANGLE. Brief descriptions on 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 50-ms 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 (QUATTRO PRO). For each graph, a 0.050-s average window was calculated at the center of each 0.050-s interval and plotted with the first 0.050-s average plotted at 0.026 s.

The PLOTANGLE program uses the digitized data from the yaw, pitch, and roll rate charts to compute angular displacement in degrees at 0.00067-s intervals and then instructs a plotter to draw a reproducible plot: yaw, pitch, and roll versus time. It should be noted that these angular displacements are sequence dependent with the sequence being yaw-pitch-roll for the data presented herein. 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.

The passenger car and the pickups were equipped with one Alderson Research Laboratories Hybrid II, 50th percentile anthropomorphic dummy placed in the driver position. The uninstrumented dummy was restrained with standard restraint equipment. No dummy was carried in the 18,000-lb (8 172-kg) truck.

Photographic coverage of the test included three high-speed cameras: one over head with a field of view perpendicular to the ground and directly over the impact point, one placed to have a field of view parallel to and aligned with the transition system at the downstream end, and a third placed perpendicular to the front of the transition. In addition, a high-speed camera was also placed onboard the passenger car and pickups to record the motions of the dummy placed in the driver position during the test sequence. A flash bulb 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 professional video camera, and a 3/4-in (19-mm) video recorder along with 35-mm still cameras were used for documentary purposes and to record conditions of the test vehicle and transition system before and after the test.

The test vehicles were towed into the test installation 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. A 2-to-1 speed ratio between the test and tow vehicle existed with this system. Immediately prior to impact with the transition, the test vehicle was released to be free-wheeling and unrestrained. The vehicle remained free-wheeling, i.e., no steering of braking inputs, until it cleared the immediate area of the test site, at which time brakes on the vehicle were activated to bring it to a safe and controlled stop.

CHAPTER 3. FULL-SCALE CRASH TESTS

TEST 7069-19

Test Description

The 1983 Honda Civic (figures 3 and 4) was directed into the 32-in (813-mm) thrie-beam transition (figure 5) using a cable reverse tow and guidance system. Test inertia mass of the vehicle was 1,800 lb (817 kg) and its gross static mass was 1,970 lb (894 kg). The height to the lower edge of the vehicle bumper was 14.0 in (356 mm) and it was 20.0 in (508 mm) to the top of the bumper. Other dimensions and information on the test vehicle are given in figure 6. The vehicle was free-wheeling and unrestrained just prior to impact.

The speed of the vehicle was 60.5 mi/h (97.3 km/h) and the angle of impact was 19.9 degrees. The vehicle impacted the transition approximately 0.4 ft (122 mm) down from post 2. The vehicle began to redirect at 0.030 s after impact. At approximately 0.050 s the vehicle began to deform at the A-pillar, and at 0.088 s the door glass shattered. By 0.137 s the vehicle was traveling parallel to the transition at a speed of 51.0 mi/h (82.1 km/h), and at the same time the rear of the vehicle impacted the transition. The vehicle lost contact with the transition at 0.219 s traveling at 47.7 mi/h (76.7 km/h) and 6.9 degrees. The brakes were applied, the vehicle yawed clockwise, and it subsequently came to rest 240 ft (73 m) down and 100 ft (30 m) in front of the point of impact.

As can be seen in figure 7, the transition received minor damage, most of which was cosmetic in nature. Maximum lateral deformation was 0.5 in (13 mm) at the post 2. The vehicle was in contact with the transition for 8.5 ft (2.6 m).

The vehicle sustained damage to the left side as shown in figure 8. Maximum crush at the left front corner at bumper height was 11.0 in (279 mm). The strut and c.v. joint on the left side were damaged and the roof was bent. The left front wheel was canted inward at the bottom and pushed back into the fender well. The left side window was broken out by the head of the dummy. Also, damage was done to the front bumper, hood, grill, radiator and fan, the left front quarter panel, the left door, left rear quarter panel, and left rear tire and rim.

Test Results

Impact speed was 60.5 mi/h (97.3 km/h) and the angle of impact was 19.9 degrees. The speed of the vehicle at time of parallel was 51.0 mi/h (82.1 km/h). The vehicle lost contact with the transition traveling at 47.7 mi/h (76.7 km/h). The exit angle between the vehicle path and the transition was 6.9 degrees. Occupant impact velocity was 19.3 ft/s (5.9 m/s) in the longitudinal direction and 25.9 ft/s (7.9 m/s) in the lateral direction. The highest 0.010-s occupant ridedown accelerations were -2.3 g (longitudinal) and -11.5 g (lateral). These data were further analyzed to obtain 0.050-s average accelerations versus time. The maximum 0.050-s averages calculated at the center-of-gravity were -8.5 g (longitudinal) and -14.3 g (lateral). A summary of these data and other pertinent information from the test are presented in figure 9 and tables 1 and 2. Sequential photographs are shown in figures 10 and

11. Vehicular angular displacements are displayed in figure 12. Vehicular accelerations near the center-of-gravity (front accelerometers) versus time traces filtered with SAE J211 filters are presented in figures 13 through 15.

Conclusions

The 32-in (813-mm) thrie-beam transition contained the test vehicle with minimal lateral movement of the transition. There was no intrusion into the occupant compartment with minimal (but acceptable) deformation of the passenger compartment. The vehicle remained upright and relatively stable during the collision. The transition smoothly redirected the vehicle and the effective coefficient of friction was considered fair.

The 1989 American Association of State Highway and Transportation Officials (AASHTO) *Guide Specifications For Bride Railings* sets forth limits for occupant risk factors for tests with the 1,800-lb (817-kg) vehicle.[1] The AASHTO specifications recommend a limit of 30 ft/s (9.1 m/s) for longitudinal occupant impact velocity and 25 ft/s (7.6 m/s) for the lateral occupant impact velocity. The lateral occupant impact velocity of 25.9 ft/s (7.9 m/s) in this test did not meet with the AASHTO Specifications. The longitudinal occupant impact velocity and the occupant ridedown accelerations were within the limits. The vehicle trajectory at loss of contact indicated minimum intrusion into adjacent traffic lanes. For more details on the test, see figure 9 and table 1.

Figure 3. Vehicle prior to impact with thrie-beam transition, test 7069-19.

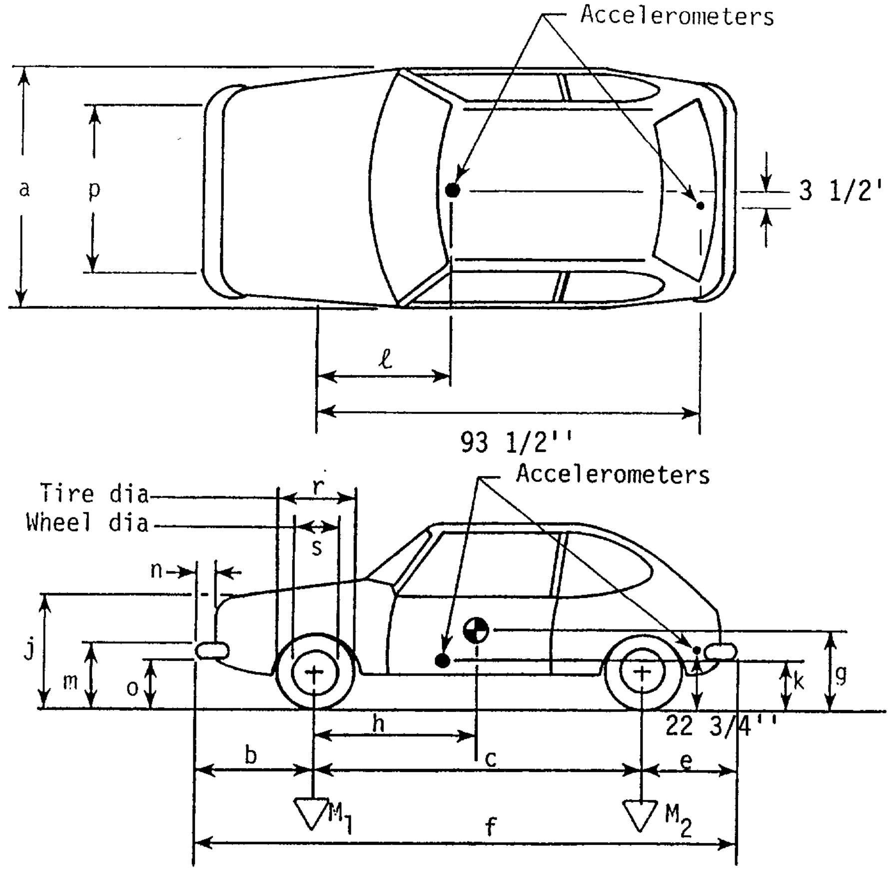
Figure 4. Vehicle/transition geometrics for test 7069-19.

Figure 5. Thrie-beam transition before test 7069-19.

Date: ________ Test No.: 7069-19 VIN: JHMSL5323DS000609

Make: Honda Model: Civic Year: 1983 Odometer: 116923

Tire Size: P-155/8012-13 Ply Rating: ________ Bias Ply: ___ Belted: ___ Radial: x



Tire Condition: good ___
fair x
badly worn ___

Vehicle Geometry - inches

a	62 1/4''	b	30 3/4''
c	88''	d*	52 3/4''
e	29''	f	
g		h	32.95''
i	----	j	29''
k	16''	ℓ	28''
m	20''	n	3 3/4''
o	14''	p	53 1/2''
r	22 1/2''	s	14 1/4''

Engine Type: ________

Engine CID: ________

Transmission Type:

~~Automatic~~ Manual

FWD ~~RWD~~ ~~4WD~~

Body Type: Hatch

Steering Column Collapse Mechanism:

- __Behind wheel units
- __Convoluted tube
- __Cylindrical mesh units
- __Embedded ball
- __NOT collapsible
- __Other energy absorption
- __Unknown

Brakes:

Front: disc x drum___

Rear: disc___ drum x

4-wheel weight for c.g. det. ℓf 596 rf 530 ℓr 335 rr 339

Mass - pounds	Curb	Test Inertial	Gross Static
M_1	1163	1126	1207
M_2	628	674	763
M_T	1791	1800	1970

Note any damage to vehicle prior to test:

____

____

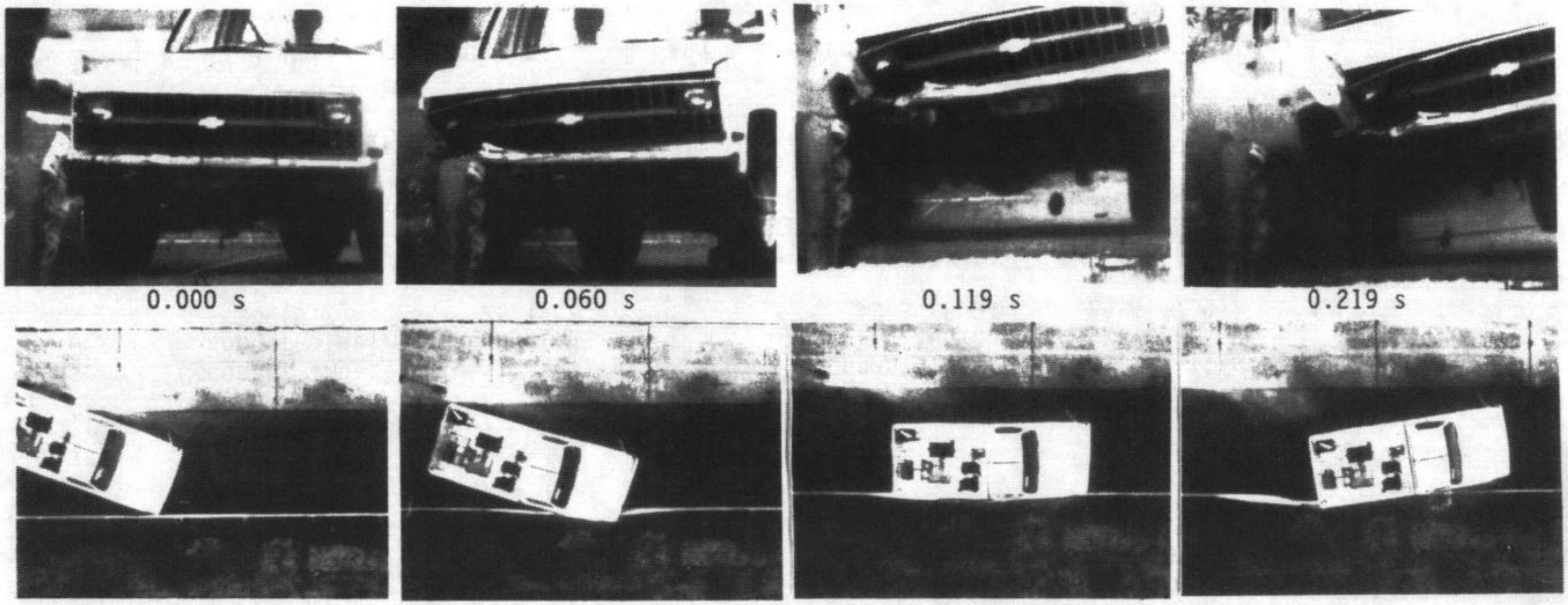
*d = overall height of vehicle

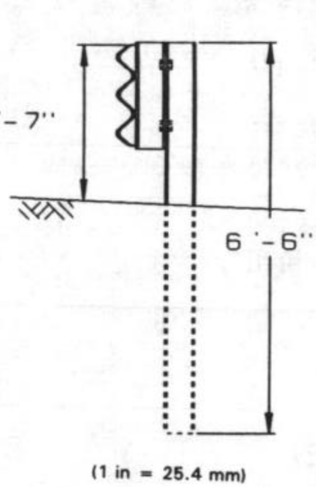
1 in = 25.4 mm
1 lb = 0.454 kg

Figure 6. Vehicle properties for test 7069-19.

Figure 7. Thrie-beam transition after test 7069-19.

Figure 8. Vehicle after test 7069-19.





Test No.	7069-19
Date	10/02/90
Test Installation . . .	32-in (813-mm) Thrie-Beam Transition
Installation Length . .	85 ft (26 m)
Test Vehicle	1983 Honda Civic
Vehicle Weight	
Test Inertia	1,800 lb (817 kg)
Gross Static	1,970 lb (894 kg)
Vehicle Damage Classification	
TAD	11FL4 & 11LD6
CDC	11FLEK2 & 11LDEW3
Maximum Vehicle Crush .	11.0 in (279 mm)

Impact Speed. . . .	60.5 mi/h (97.3 km/h)
Impact Angle. . . .	19.9 deg
Speed at Parallel .	51.0 mi/h (82.1 km/h)
Exit Speed	47.7 mi/h (76.7 km/h)
Exit Trajectory . .	6.9 deg
Vehicle Accelerations (Max. 0.050-sec Avg) at true c.g.	
Longitudinal. . .	-8.5 g
Lateral	-14.3 g
Occupant Impact Velocity (at true c.g.)	
Longitudinal. . .	19.3 ft/s (5.9 m/s)
Lateral	25.9 ft/s (7.9 m/s)
Occupant Ridedown Accelerations	
Longitudinal. . .	-2.3 g
Lateral	-12.5 g

Figure 9. Summary of results for test 7069-19.

Table 1. Evaluation of crash test no. 7069-19.
{32-in (813-mm) thrie-beam transition (1,800 lb (817 kg)|60.5 mi/h (97.3 km/h)|19.9 degrees]}

	CRITERIA		TEST RESULTS		PASS/FAIL*
A.	Must contain vehicle		Vehicle was contained		Pass
B.	Debris shall not penetrate passenger compartment		No debris penetrated passenger compartment		Pass
C.	Passenger compartment must have essentially no deformation		Acceptable deformation		Pass
D.	Vehicle must remain upright		Vehicle did remain upright		Pass
E.	Must smoothly redirect the vehicle		Vehicle was smoothly redirected		Pass
F.	Effective coefficient of friction				
	μ	Assessment	μ	Assessment	
	0 - .25	Good	.29	Fair	Pass
	.26 - .35	Fair			
	> .35	Marginal			
G.	Shall be less than				
	Occupant Impact Velocity - ft/s (m/s)		Occupant Impact Velocity - ft/s (m/s)		Fail
	Longitudinal	Lateral	Longitudinal	Lateral	
	30 (9.2)	25 (7.6)	19.3 (5.9)	25.9 (7.9)	
	Occupant Ridedown Accelerations - g's		Occupant Ridedown Accelerations - g's		Pass
	Longitudinal	Lateral	Longitudinal	Lateral	
	15	15	-2.3	-11.5	
H.	Exit angle shall be less than 12 degrees		Exit angle was 6.9 degrees		Pass

* A, B, C, D and G are required. E, F, and H are desired. (See table 2)

Table 2. Bridge railing performance levels and crash test criteria.
(Excerpt from 1989 AASHTO *Guide Specifications for Bridge Railings*)[(1)]

PERFORMANCE LEVELS		TEST SPEEDS—mph[1,2] TEST VEHICLE DESCRIPTIONS AND IMPACT ANGLES: Small Automobile $W = 1.8$ Kips $A = 5.4' \pm 0.1'$ $B = 5.5'$ $H_{cg} = 20'' \pm 1''$ $\theta = 20$ deg.	Pickup Truck $W = 5.4$ Kips $A = 8.5' \pm 0.1'$ $B = 6.5'$ $H_{cg} = 27'' \pm 1''$ $\theta = 20$ deg.	Medium Single-Unit Truck $W = 18.0$ Kips $A = 12.8' \pm 0.2'$ $B = 7.5'$ $H_{cg} = 49'' \pm 1''$ $\theta = 15$ deg.	Van-Type Tractor-Trailer[4] $W = 50.0$ Kips $A = 12.5' \pm 0.5'$ $B = 8.0'$ H_{cg} = See Note 4 $R = 0.61 \pm 0.01$ $\theta = 15$ deg.
PL-1		50	45		
PL-2		60	60	50	
PL-3		60	60		50
CRASH TEST EVALUATION CRITERIA[3]	Required	a, b, c, d, g	a, b, c, d	a, b, c	a, b, c
	Desirable[5]	e, f, h	e, f, g, h	d, e, f, h	d, e, f, h

Notes:
1. Except as noted, all full-scale tests shall be conducted and reported in accordance with the requirements in NCHRP Report No. 230. In addition, the maximum loads that can be transmitted from the bridge railing to the bridge deck are to be determined from static force measurements or ultimate strength analysis and reported.
2. Permissible tolerances on the test speeds and angles are as follows:

Speed	−1.0 mph	+2.5 mph
Angle	−1.0 deg.	+2.5 deg.

Tests that indicate acceptable railing performance but that exceed the allowable upper tolerances will be accepted.
3. Criteria for evaluating bridge railing crash test results are as follows:
   a. The test article shall contain the vehicle; neither the vehicle nor its cargo shall penetrate or go over the installation. Controlled lateral deflection of the test article is acceptable.
   b. 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.
   c. Integrity of the passenger compartment must be maintained with no intrusion and essentially no deformation.
   d. The vehicle shall remain upright during and after collision.
   e. The test article shall smoothly redirect the vehicle. A redirection is deemed smooth if the rear of the vehicle or, in the case of a combination vehicle, the rear of the tractor or trailer does not yaw more than 5 degrees away from the railing from time of impact until the vehicle separates from the railing.
   f. The smoothness of the vehicle-railing interaction is further assessed by the effective coefficient of friction, μ:

μ	Assessment
0–0.25	Good
0.26–0.35	Fair
>0.35	Marginal

where $\mu = (\cos\theta - V_p/V)/\sin\theta$

Table 2. Bridge railing performance levels and crash test criteria.
(Excerpt from 1989 AASHTO *Guide Specifications for Bridge Railings*)[1]
(continued)

g. The impact velocity of a hypothetical front-seat passenger against the vehicle interior, calculated from vehicle accelerations and 2.0-ft. longitudinal and 1.0-ft. lateral diplacements, shall be less than:

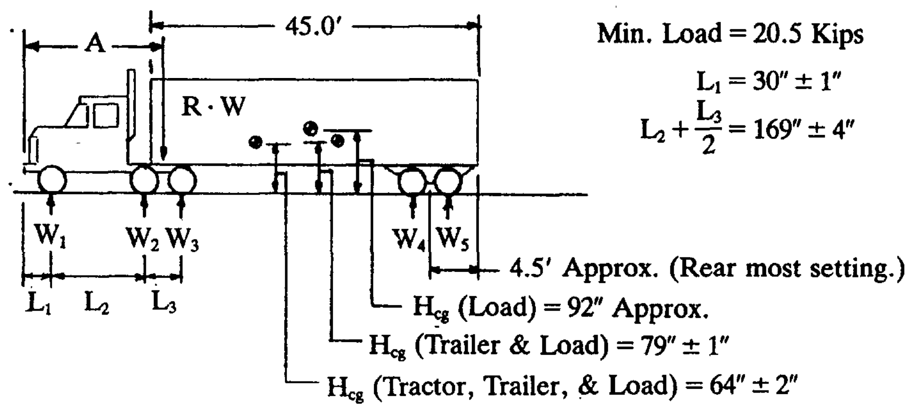
Occupant Impact Velocity–fps	
Longitudinal	Lateral
30	25

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

Occupant Ridedown Acceleration—g's	
Longitudinal	Lateral
15	15

h. Vehicle exit angle from the barrier shall not be more than 12 degrees. Within 100 ft. plus the length of the test vehicle from the point of initial impact with the railing, the railing side of the vehicle shall move no more than 20-ft. from the line of the traffic face of the railing. The brakes shall not be applied until the vehicle has traveled at least 100-ft. plus the length of the test vehicle from the point of initial impact.

4. Values A and R are estimated values describing the test vehicle and its loading. Values of A and R are described in the figure below and calculated as follows:



Min. Load = 20.5 Kips

$L_1 = 30'' \pm 1''$

$L_2 + \frac{L_3}{2} = 169'' \pm 4''$

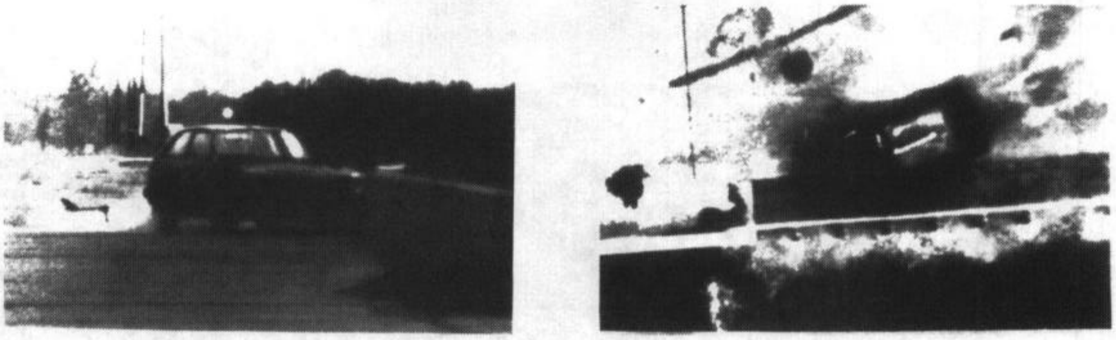
$$A = L_1 + \frac{W_2L_2 + W_3(L_2 + L_3)}{W_1 + W_2 + W_3}$$

$$R = \frac{W_1 + W_2 + W_3}{W}$$

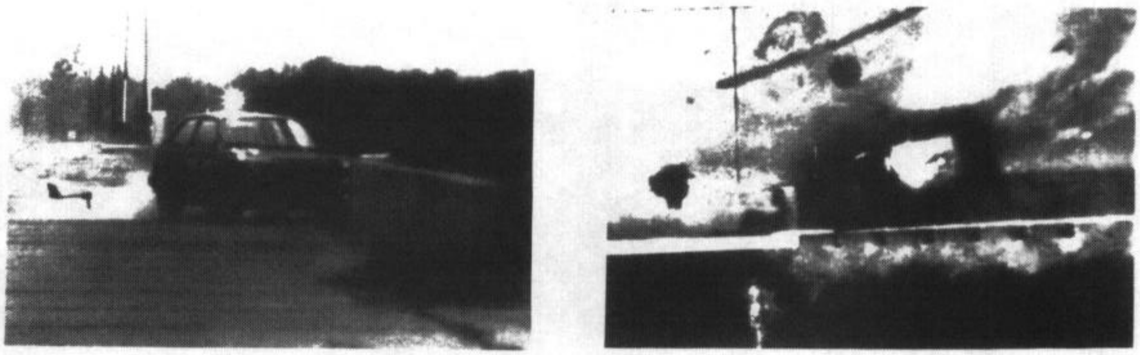
$W = W_1 + W_2 + W_3 + W_4 + W_5$
= total vehicle weight.

5. Test articles that do not meet the desirable evaluation criteria shall have their performance evaluated by a designated authority that will decide whether the test article is likely to meet its intended use requirements.

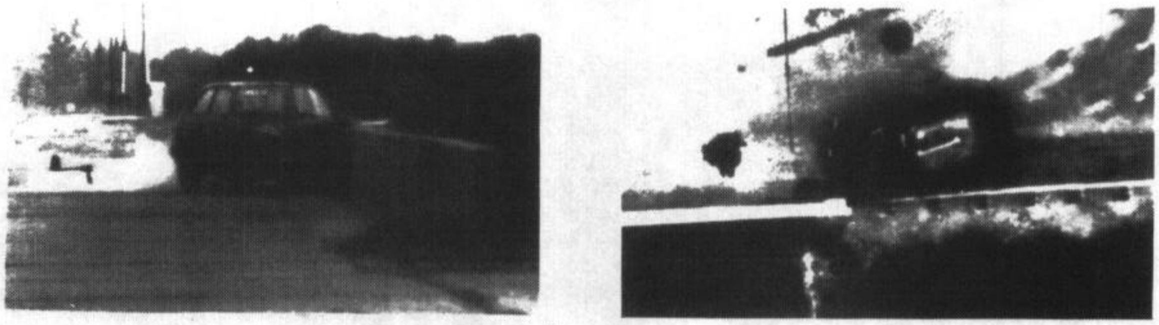
1 mi	= 1.61 km
1 kip	= 4.45 kN
1 in	= 25.4 mm



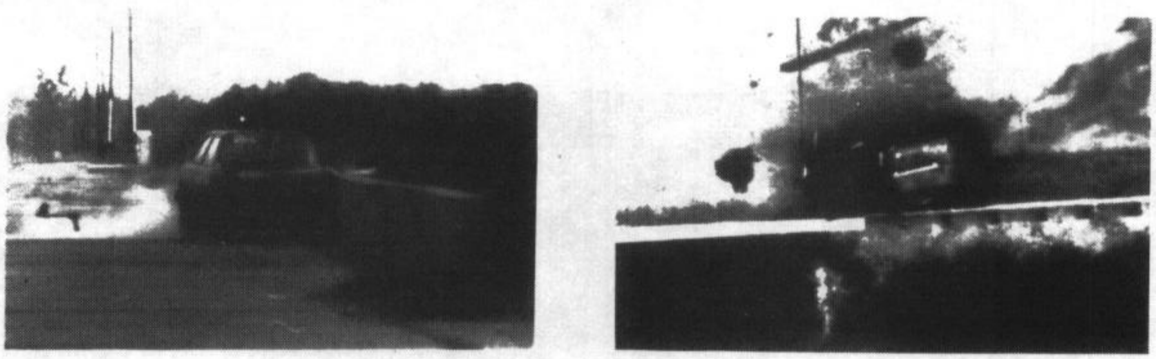
000 msec



030 msec

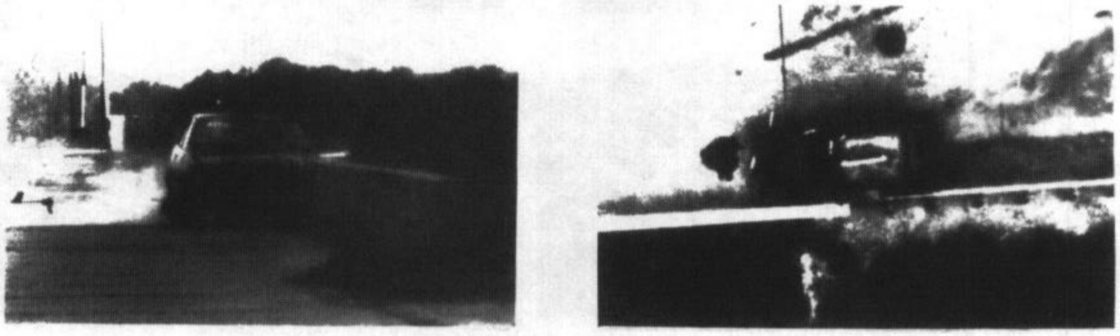


060 msec

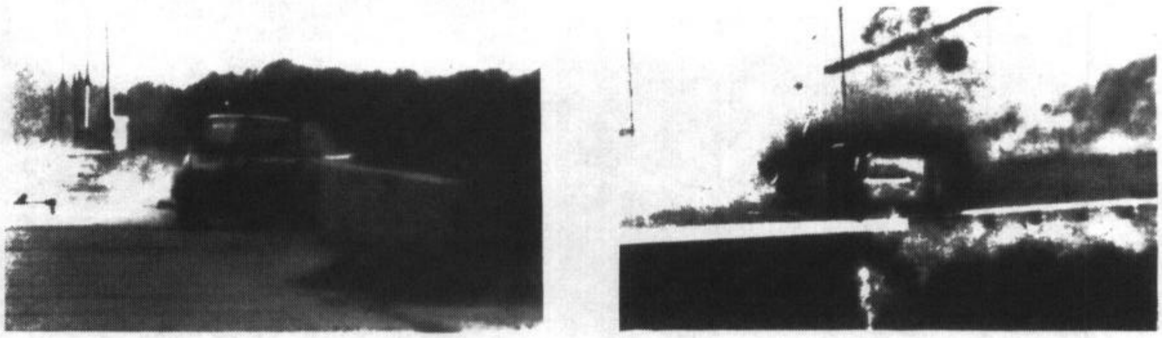


089 msec

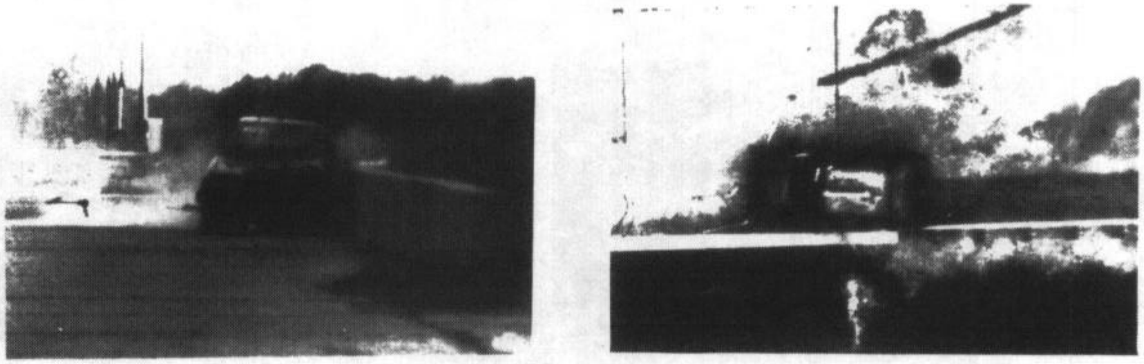
Figure 10. Sequential photographs for test 7069-19 (frontal and overhead views).



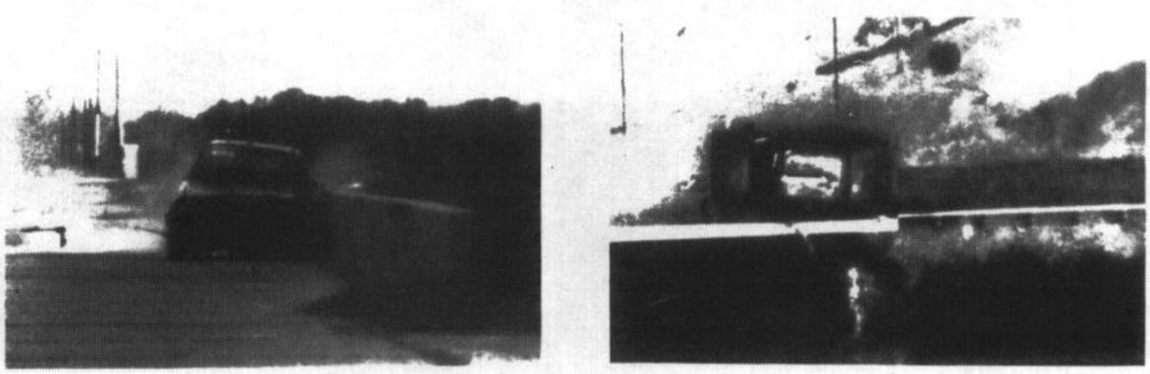
119 msec



149 msec



179 msec



219 msec

Figure 10. Sequential photographs for test 7069-19
(frontal and overhead views continued).

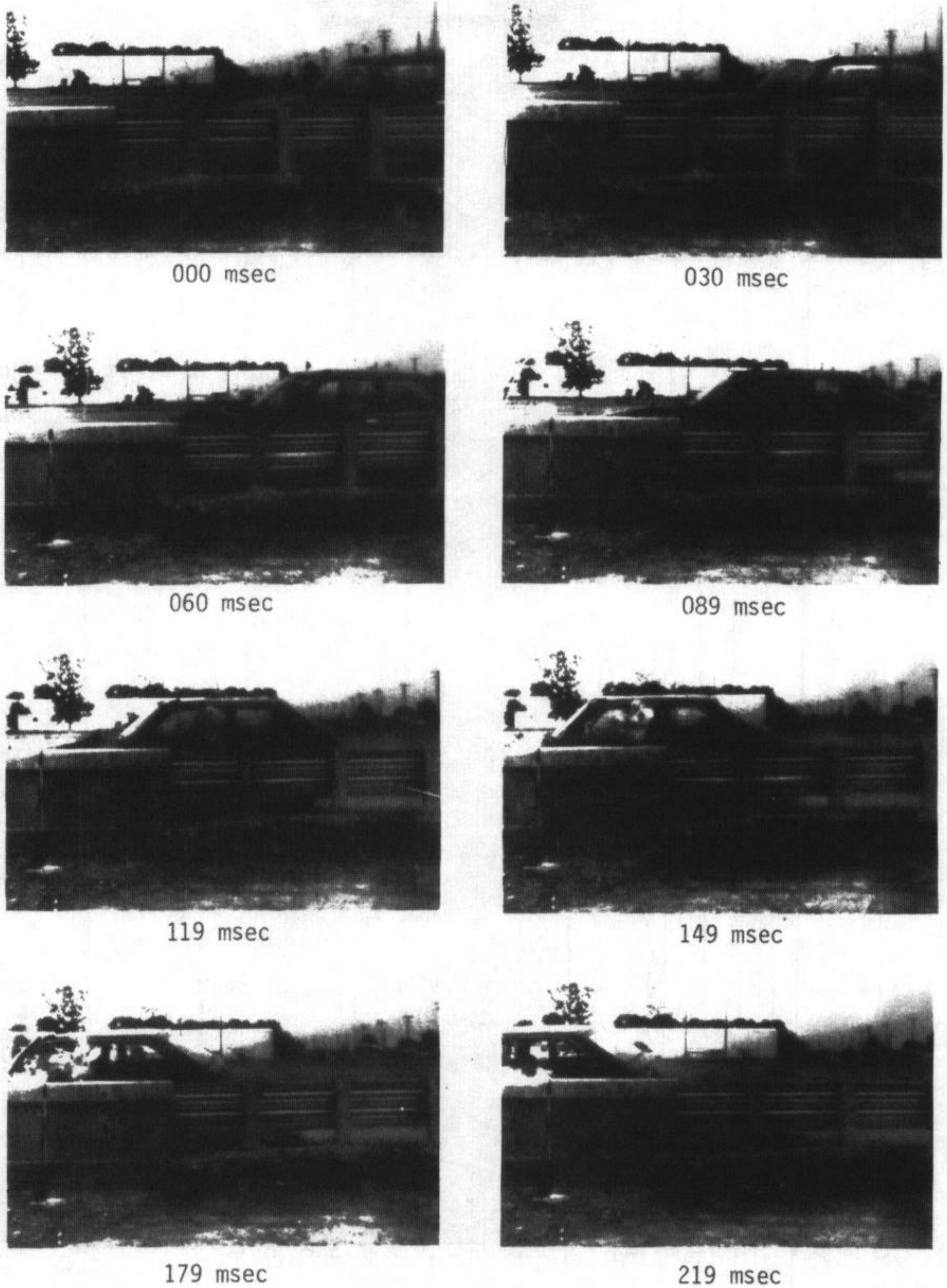
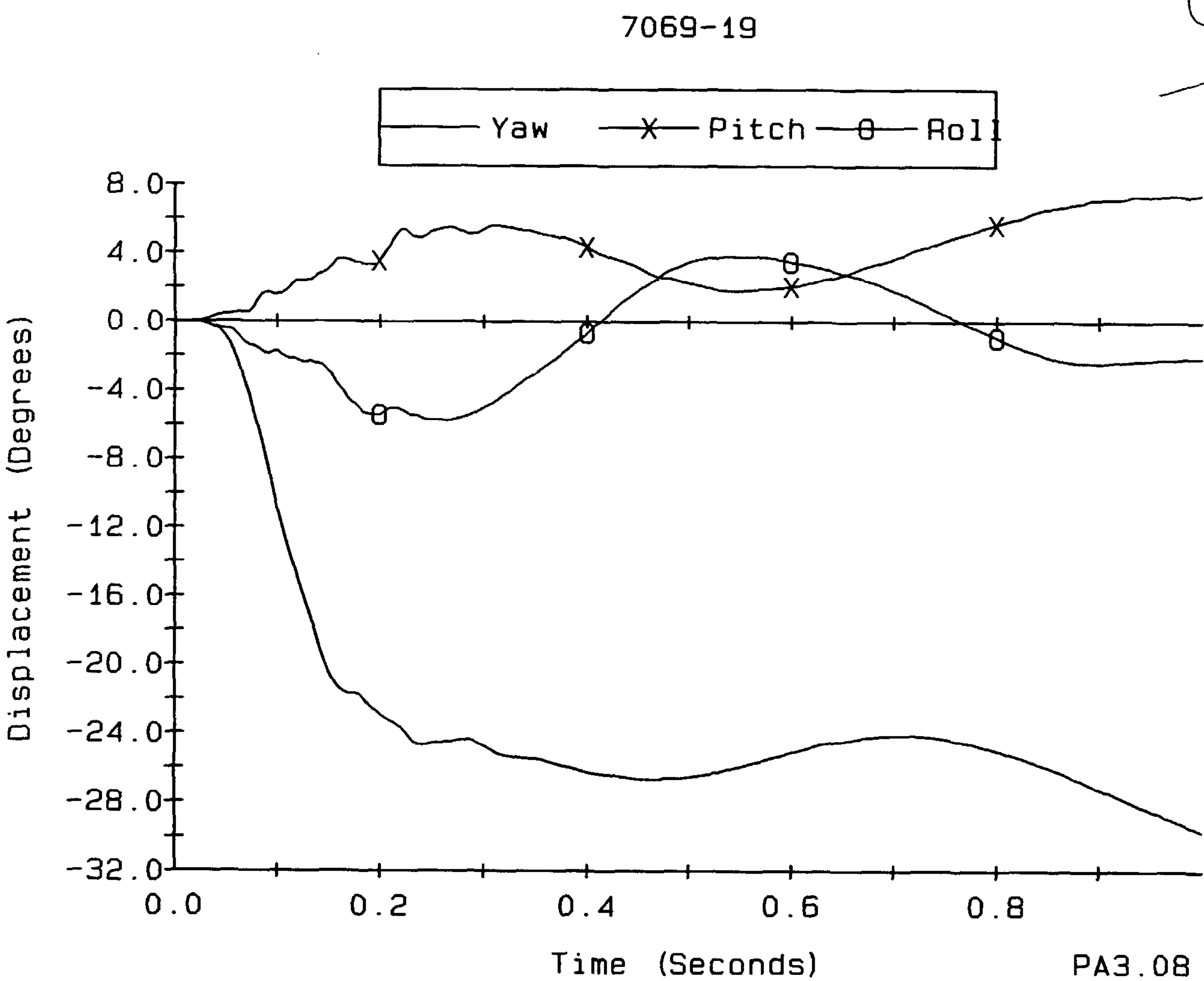
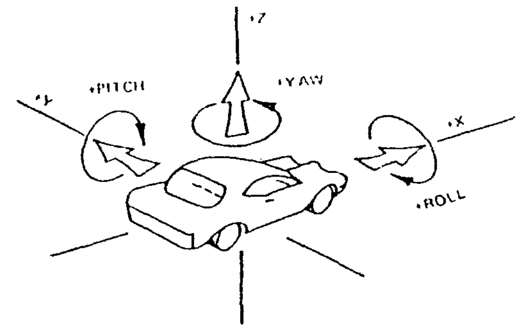


Figure 11. Sequential photographs for test 7069-19
(rear of transition view).





Axes are vehicle fixed.
Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 12. Vehicle angular displacements for test 7069-19.

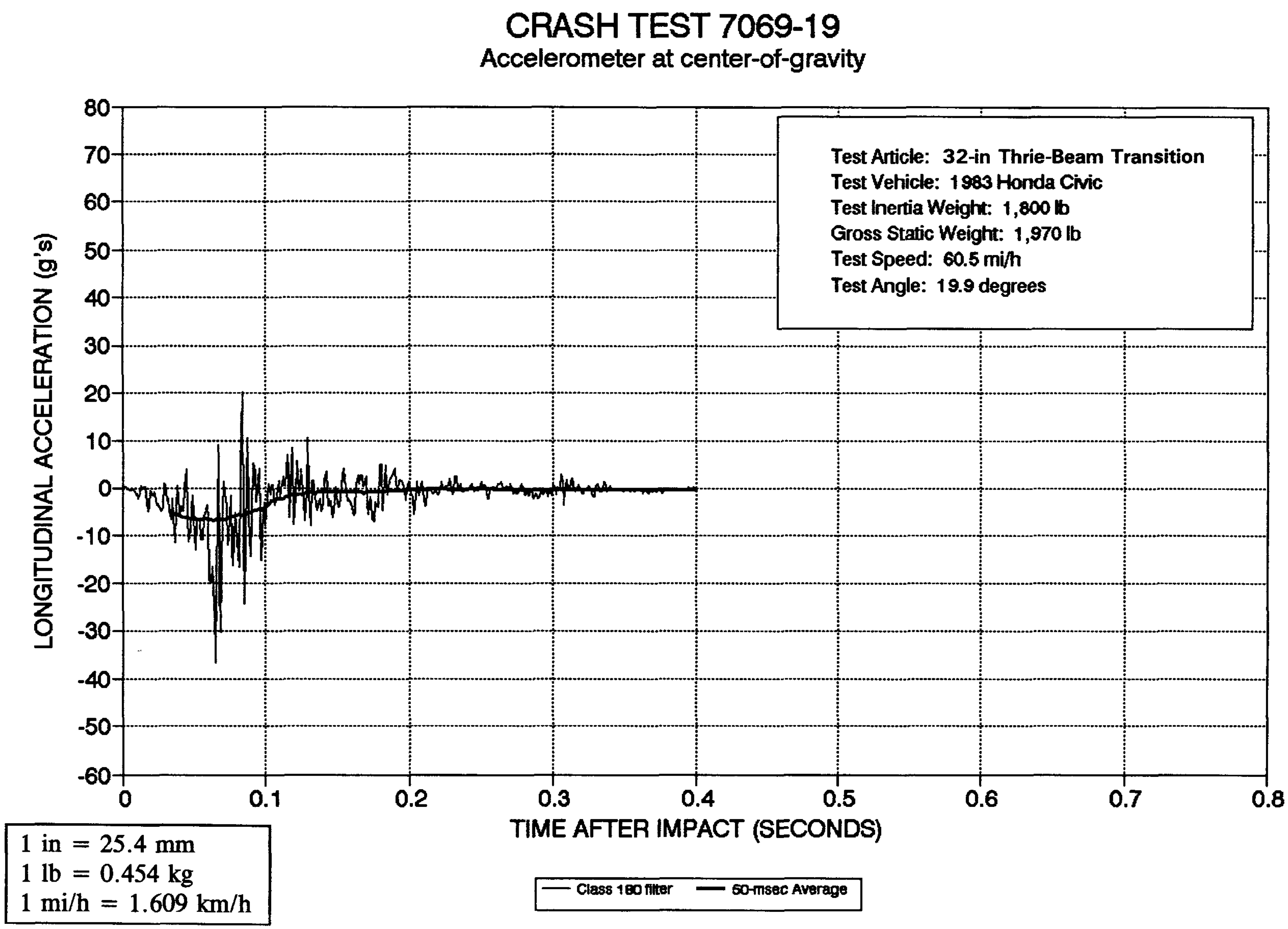
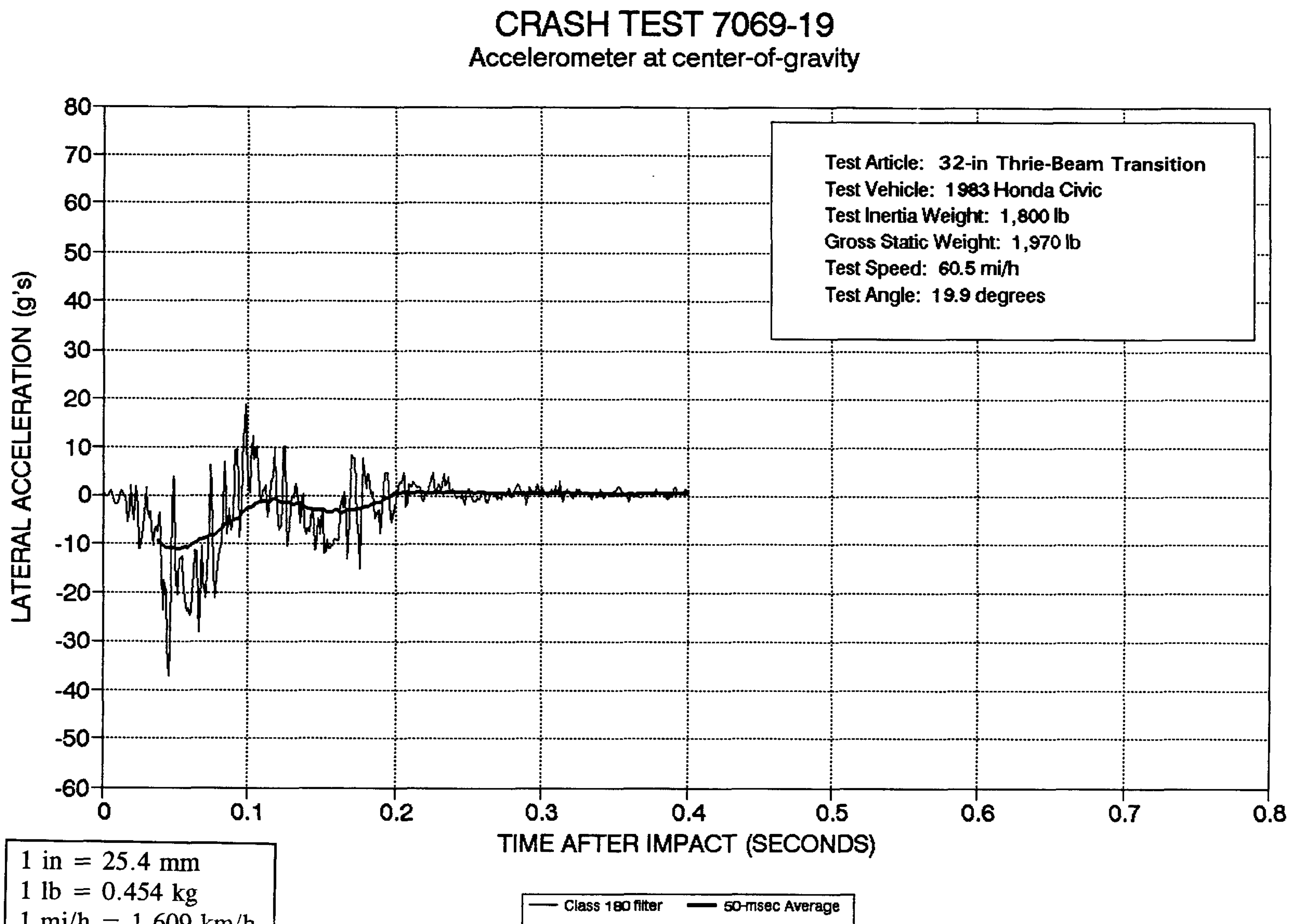


Figure 13. Vehicle longitudinal accelerometer trace for test 7069-19 (accelerometer located at center-of-gravity).



1 in = 25.4 mm
1 lb = 0.454 kg
1 mi/h = 1.609 km/h

Figure 14. Vehicle lateral accelerometer trace for test 7069-19 (accelerometer located at center-of-gravity).

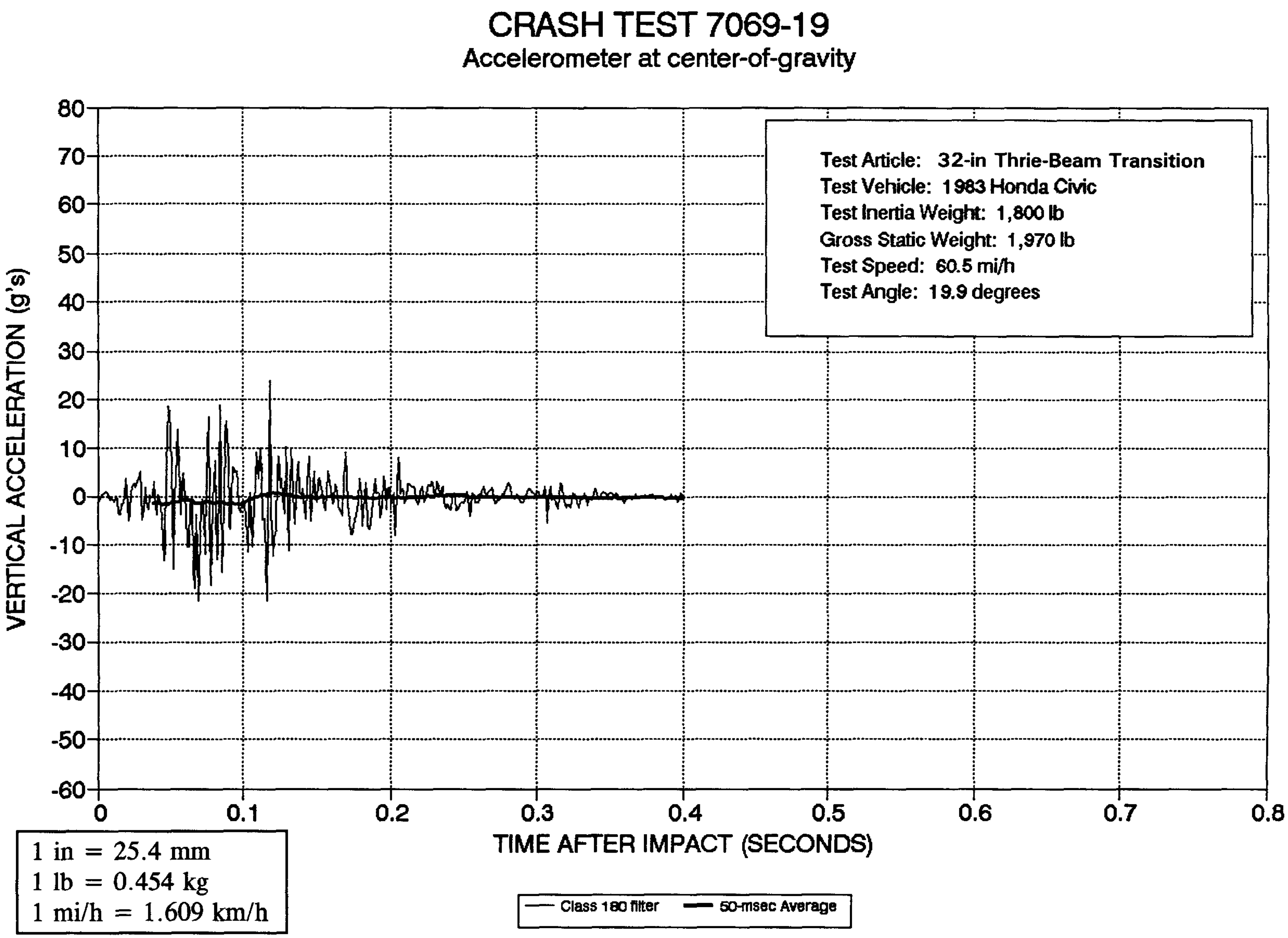


Figure 15. Vehicle vertical accelerometer trace for test 7069-19 (accelerometer located at center-of-gravity).

TEST 7069-20

Test Description

The 1981 Chevrolet C-20 pickup (figures 16 and 17) was directed into the 32-in (813-mm) thrie-beam transition (figure 18) using a cable reverse tow and guidance system. Test inertia mass of the vehicle was 5,400 lb (2 452 kg) and its gross static mass was 5,570 lb (2 529 kg). The height to the lower edge of the vehicle bumper was 17.5 in (445 mm) and it was 26.75 in (679 mm) to the top of the bumper. Other dimensions and information on the test vehicle are given in figure 19. The vehicle was free-wheeling and unrestrained just prior to impact.

The speed of the vehicle at impact was 62.7 mi/h (100.9 km/h) and the angle of impact was 19.0 degrees. The vehicle impacted the transition approximately 7 ft (2.1 m) down from the end of the concrete parapet. The vehicle began to redirect at 0.022 s after impact. At approximately 0.103 s the left door began to come open, and at 0.135 s the front edge of the door began to peel away from the hinges. By 0.204 s the vehicle was traveling parallel to the transition at a speed of 46.8 mi/h (75.3 km/h), and at the same time the rear of the vehicle impacted the transition. Maximum lateral deflection of 0.9 ft (274 mm) occurred at 0.231 s. The vehicle lost contact with the transition at 0.308 s traveling at 41.9 mi/h (67.4 km/h) and 9.0 degrees. The brakes were applied, the vehicle yawed counter-clockwise, and it subsequently came to rest 135 ft (41 m) down from the point of impact.

As can be seen in figure 20, the transition received moderate damage. Maximum lateral deformation was 6.5 in (165 mm). The vehicle was in contact with the transition for 8.5 ft (2.6 m).

The vehicle sustained damage to the left side as shown in figures 21 and 22. Maximum crush at the left front corner at bumper height was 22.0 in (559 mm). The sway bar and upper and lower control arm, the left side were damaged and the roof was bent. The left front wheel was canted inward at the bottom and pushed back into the fender well. The left side window was broken out and the door was off. Also, damage was done to the front bumper, hood, grill, radiator and fan, left front quarter panel, left rear quarter panel, and left rear tire and rim.

Test Results

Impact speed was 62.7 mi/h (100.9 km/h) and the angle of impact was 19.0 degrees. The speed of the vehicle at time of parallel was 46.8 mi/h (75.3 km/h). The vehicle lost contact with the transition traveling at 41.9 mi/h (67.4 km/h). Although the vehicle exited the barrier yawing counterclockwise, the exit angle between the vehicle path and the transition was 9.0 degrees. Occupant impact velocity was 19.3 ft/s (5.3 m/s) in the lateral direction. The highest 0.010-s occupant ridedown accelerations were -5.4 g (longitudinal) and -13.0 g (lateral). These data were further analyzed to obtain 0.050-s average accelerations versus time. The maximum 0.050-s averages calculated at the center-of-gravity were -6.4 g (longitudinal) and -7.7 g (lateral). These data and other pertinent information from the test are summarized in figure 23 and table 3. Sequential photographs are shown in figures 24 and 25. Vehicular angular displacements are displayed in figure 26. Vehicular accelerations versus time traces filtered with SAE J211 filters are presented in figures 27 through 33.

Conclusions

The 32-in (813-mm) thrie-beam transition contained the test vehicle with minimal lateral movement of the transition. There was no intrusion of railing components into the occupant compartment; however, the door was detached from the vehicle and remained lodged on the railing. The vehicle remained upright and relatively stable during the collision. The transition redirected the vehicle but the effective coefficient of friction was quite high. Velocity change of the vehicle during the collision was 20.8 mi/h (33.5 km/h).

The 1989 AASHTO guide specifications sets forth desired (but not required) limits for occupant risk factors for tests with the 5,400-lb (2 452-kg) vehicle.[1] The AASHTO specifications recommend a limit of 30 ft/s (9.1 m/s) longitudinal occupant impact velocity and 25 ft/s (7.6 m/s) for the lateral occupant impact velocity. The occupant impact velocities and the occupant ridedown accelerations were within the limits. The vehicle trajectory at loss of contact indicated minimum intrusion into adjacent traffic lanes. See figure 23 and table 3 for more details.

Figure 16. Vehicle before test 7069-20.

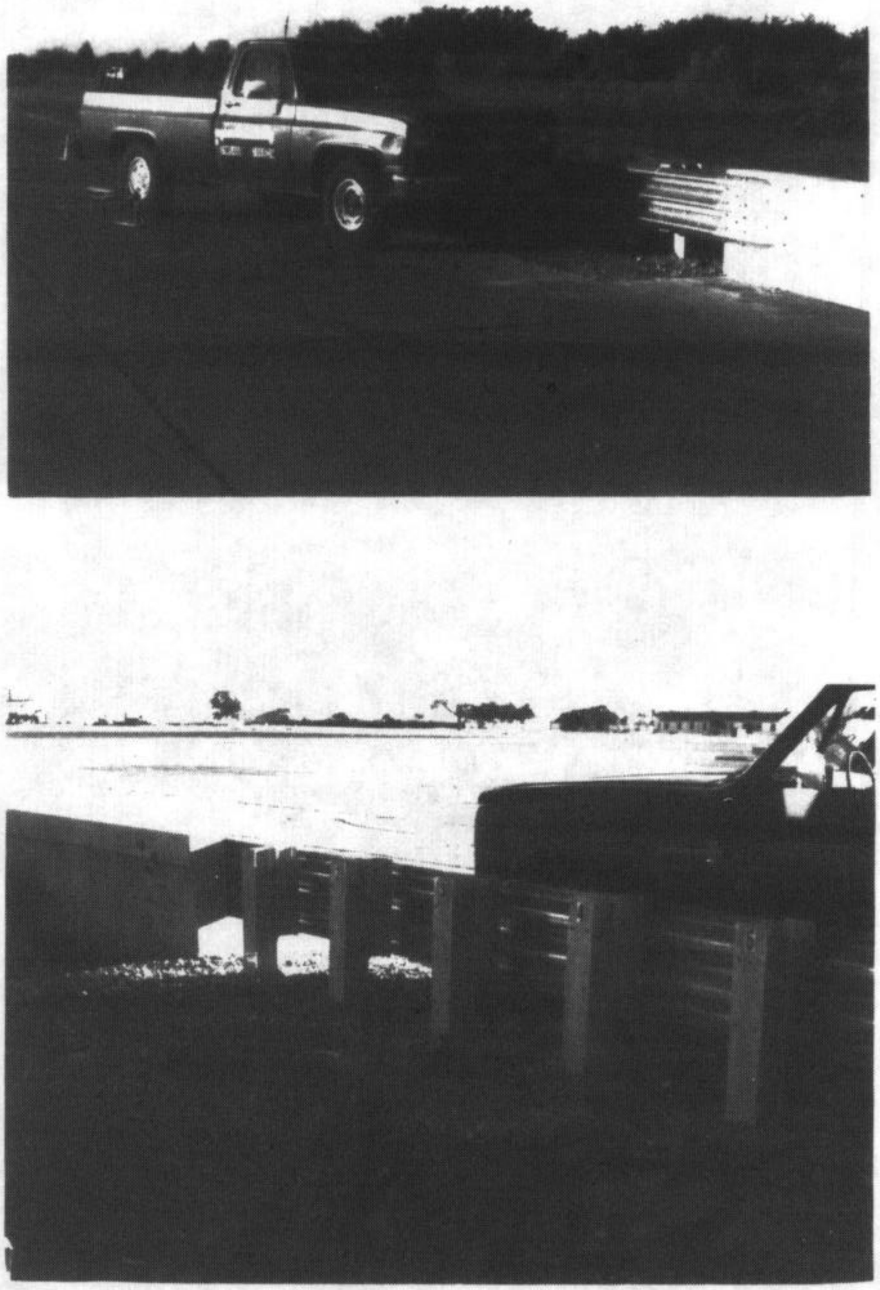


Figure 17. Vehicle/transition geometrics for test 7069-20.

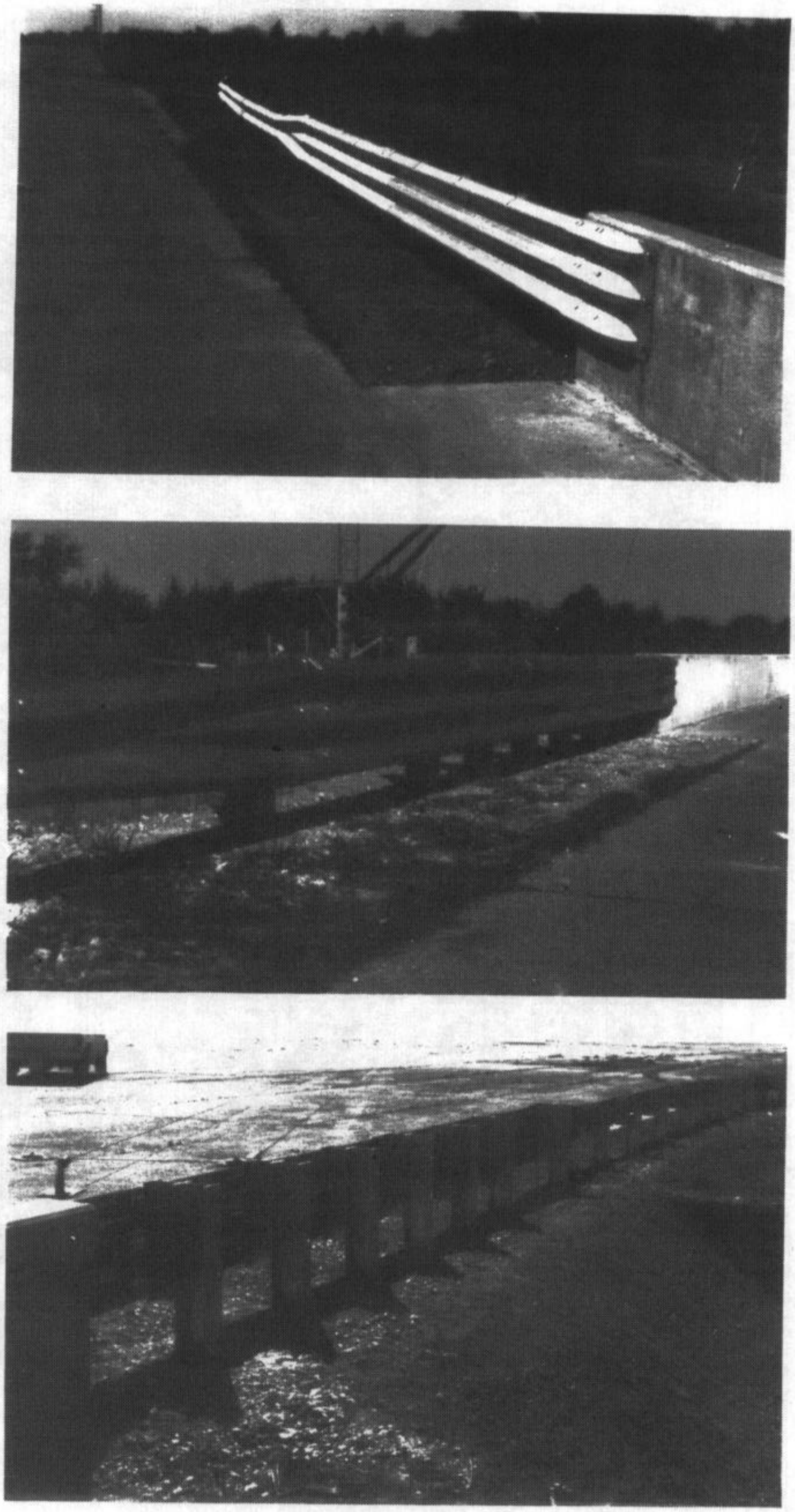


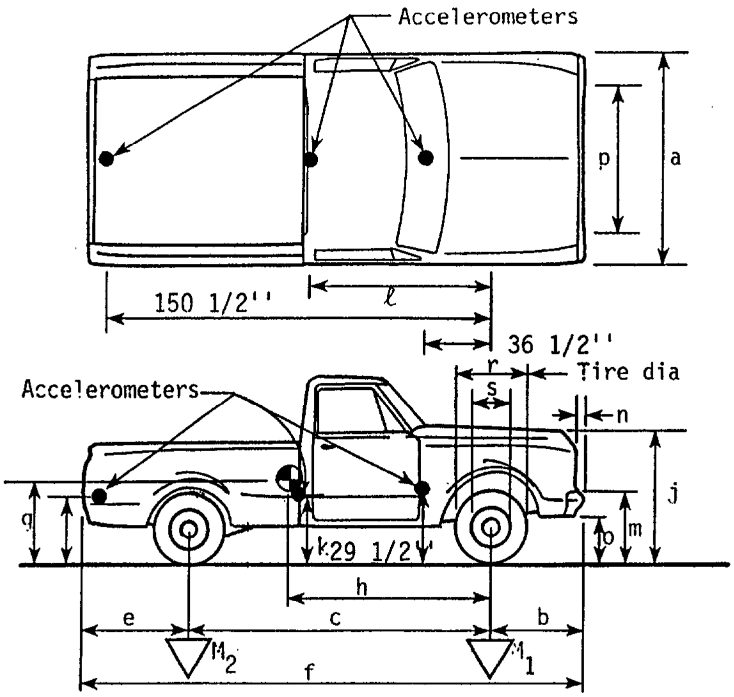
Figure 18. Thrie-beam transition before test 7069-20.

Date: 10/19/90 Test No.: 7069-20 VIN: 1GCGC24M2CF314233

Make: Chevy Model: C20 Custom Deluxe Year: 1981 Odometer: 104788

Tire Size: 750R16 Ply Rating: 5 Bias Ply: ___ Belted: ___ Radial: x

Tire Condition: good ___
fair x
badly worn ___



Vehicle Geometry - inches

a	79 1/4''	b	32 1/4''
c	131 1/2''	d*	71 1/2''
e	49 1/2''	f	
g		h	69.2''
i	----	j	45''
k	31''	ℓ	73 1/2''
m	26 3/4''	n	4''
o	17 1/2''	p	66 1/4''
r	31 1/4''	s	17 1/2''

Engine Type: V-8

Engine CID: 454

Transmission Type:

Automatic or Manual

FWD or RWD or 4WD

Body Type: PU

Steering Column Collapse Mechanism:

__Behind wheel units
__Convoluted tube
__Cylindrical mesh units
__Embedded ball
__NOT collapsible
__Other energy absorption
__Unknown

Brakes:

Front: disc x drum___

Rear: disc___ drum x

4-wheel weight for c.g. det. ℓf 1390 rf 1168 ℓr 1484 rr 1358

Mass - pounds	Curb	Test Inertial	Gross Static
M_1	2753	2558	2659
M_2	1918	2842	2911
M_T	4671	5400	5570

Note any damage to vehicle prior to test:

Cracked Windshield

*d = overall height of vehicle

1 in = 25.4 mm
1 lb = 0.454 kg

Figure 19. Vehicle properties for test 7069-20.

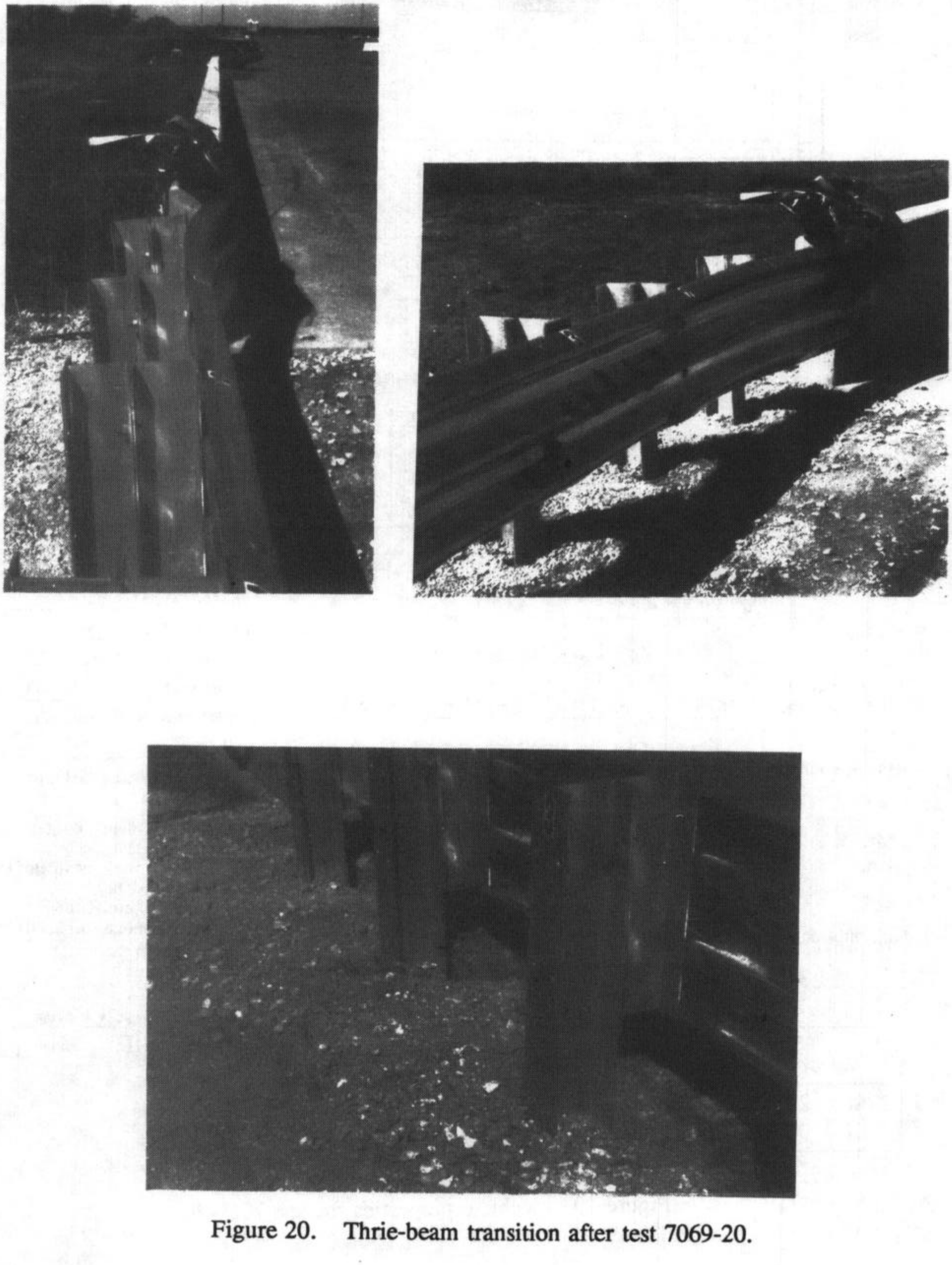


Figure 20. Thrie-beam transition after test 7069-20.

Figure 21. Vehicle after test 7069-20.

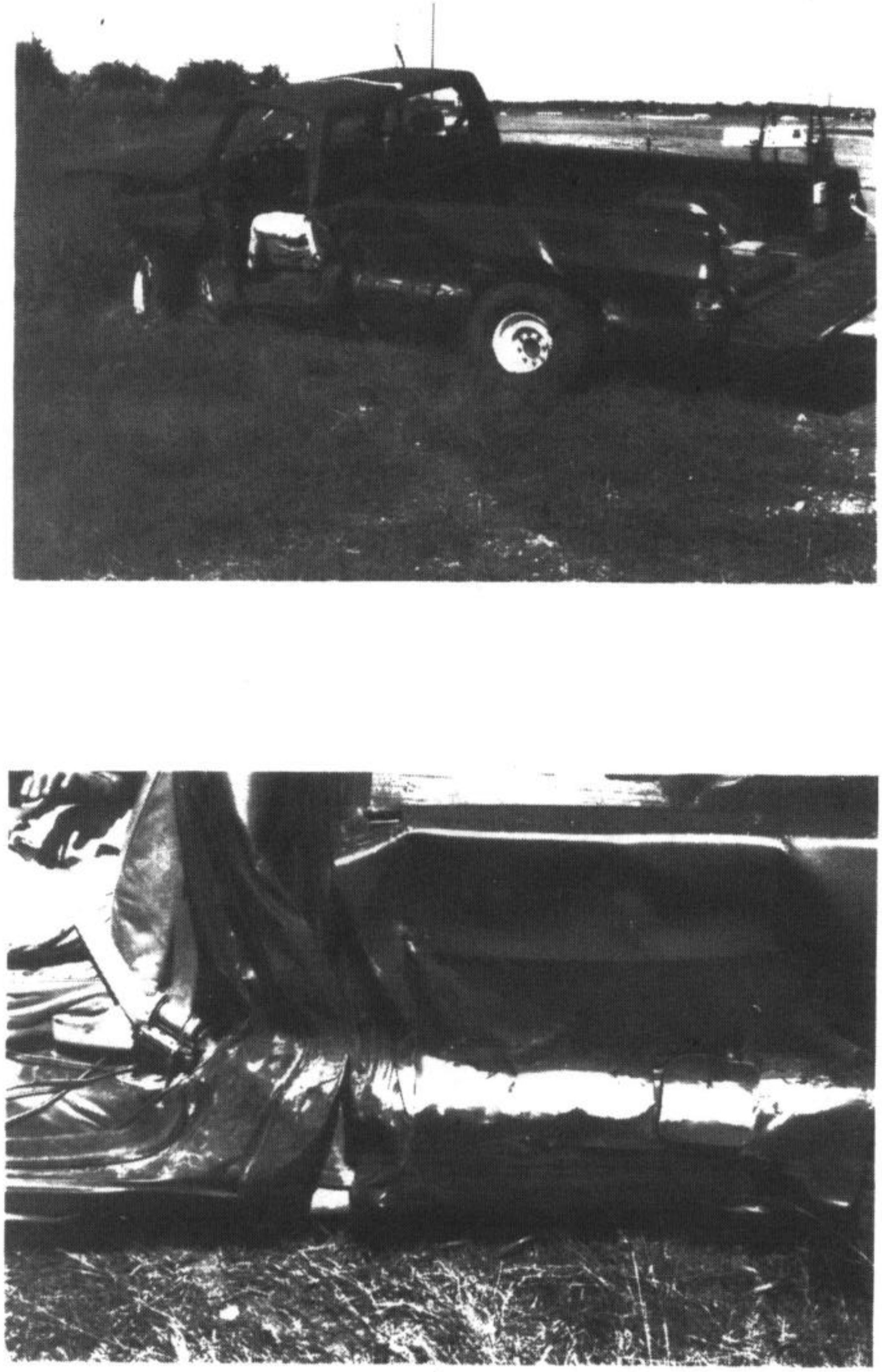
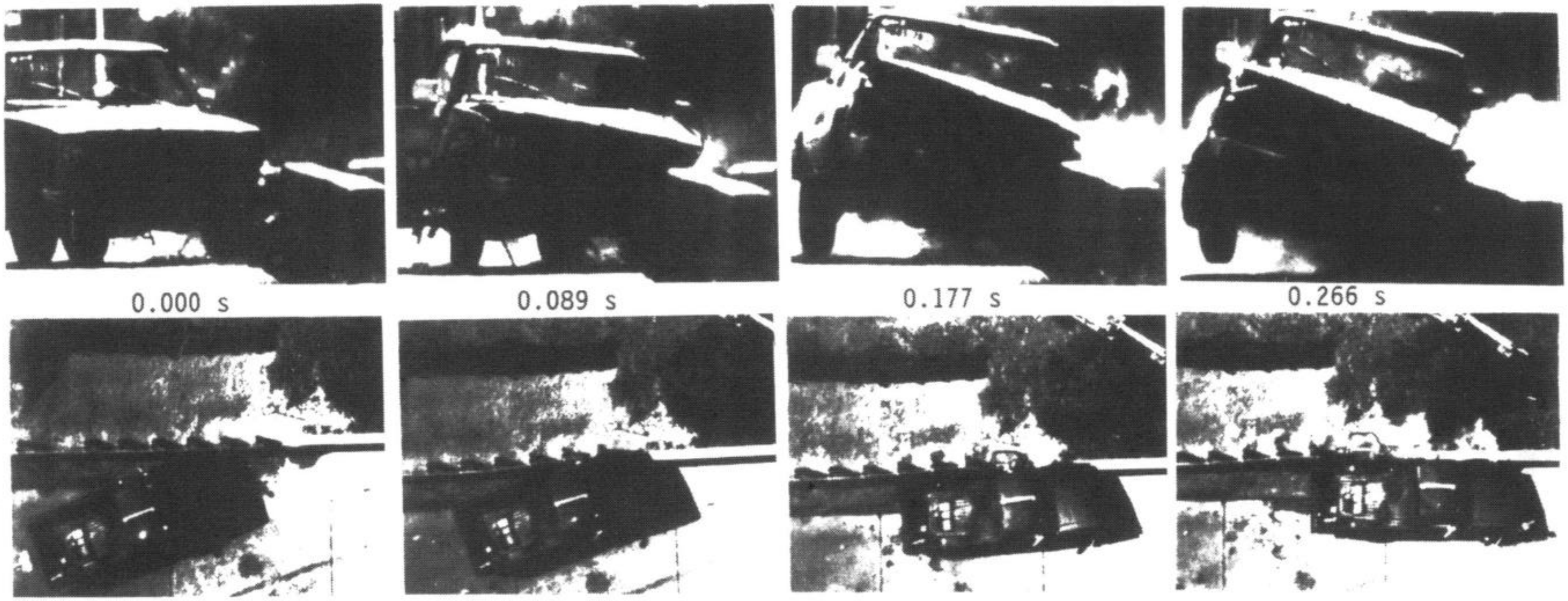
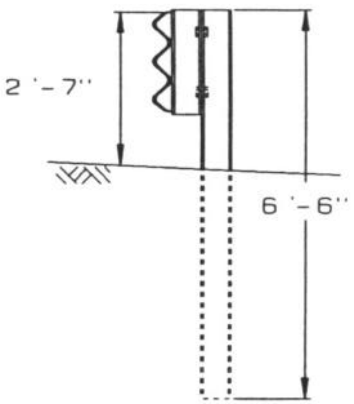


Figure 22. Damage to vehicle after test 7069-20.





(1 in = 25.4 mm)

Test No. 7069-20
Date 10/19/90

Test Installation . . . 32-in (813-mm) Thrie-Beam Transition
Installation Length . . 85 ft (26 m)

Test Vehicle . . . . . . 1981 Chevrolet C-20 Pickup

Vehicle Weight
  Test Inertia . . . . . 5,400 lb (2,452 kg)
  Gross Static . . . . . 5,570 lb (2,529 kg)
Vehicle Damage Classification
  TAD . . . . 11FL5 & 11LD7
  CDC . . . . 11FLEK3 & 11LDEW3
Maximum Vehicle Crush . 22.0 in (559 mm)

Impact Speed. . . . 62.7 mi/h (100.9 km/h)
Impact Angle. . . . 19.0 deg
Speed at Parallel . 46.8 mi/h (75.3 km/h)
Exit Speed . . . . 41.9 mi/h (67.4 km/h)
Exit Trajectory . . 9.0 deg
Vehicle Accelerations
  (Max. 0.050-sec Avg) at true c.g.
  Longitudinal. . . -6.4 g
  Lateral . . . . . -7.7 g
Occupant Impact Velocity
  Longitudinal. . . 19.3 ft/s (5.9 m/s)
  Lateral . . . . . 17.3 ft/s (5.3 m/s)
Occupant Ridedown Accelerations
  Longitudinal. . . -5.4 g
  Lateral . . . . .-13.0 g

Figure 23. Summary of results for test 7069-20.

Table 3. Evaluation of crash test no. 7069-20.
{32-in (813-mm) thrie-beam transition (5,400 lb (2 452 kg)|62.7 mi/h (100.9 km/h)|19.0 degrees]}

	CRITERIA	TEST RESULTS	PASS/FAIL*
A.	Must contain vehicle	Vehicle was contained	Pass
B.	Debris shall not penetrate passenger compartment	No debris penetrated passenger compartment	Pass
C.	Passenger compartment must have essentially no deformation	Moderate deformation Door detached	Fail
D.	Vehicle must remain upright	Vehicle did remain upright	Pass
E.	Must smoothly redirect the vehicle	Vehicle was smoothly redirected	Pass
F.	Effective coefficient of friction μ — Assessment 0 - .25 — Good .26 - .35 — Fair > .35 — Marginal	μ — Assessment .61 — Marginal	Fail
G.	Shall be less than Occupant Impact Velocity - ft/s (m/s) Longitudinal 30 (9.2); Lateral 25 (7.6)	Occupant Impact Velocity - ft/s (m/s) Longitudinal 19.3 (5.9); Lateral 17.3 (5.3)	Pass
	Occupant Ridedown Accelerations - g's Longitudinal 15; Lateral 15	Occupant Ridedown Accelerations - g's Longitudinal -5.4; Lateral -13.0	Pass
H.	Exit angle shall be less than 12 degrees	Exit angle was 6.9 degrees	Pass

* A, B, C, and D are required. E, F, G, and H are desired. (See table 2)

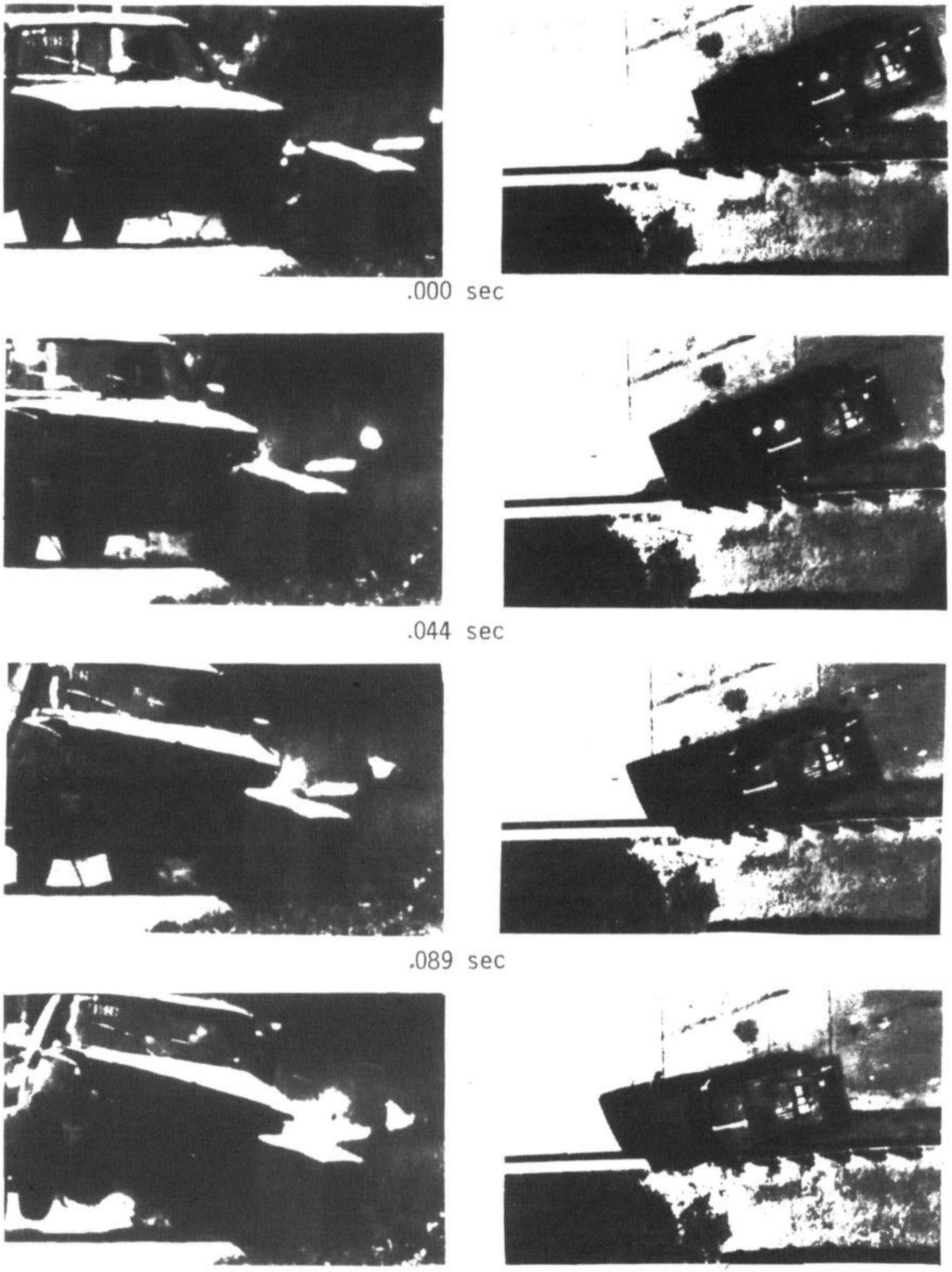
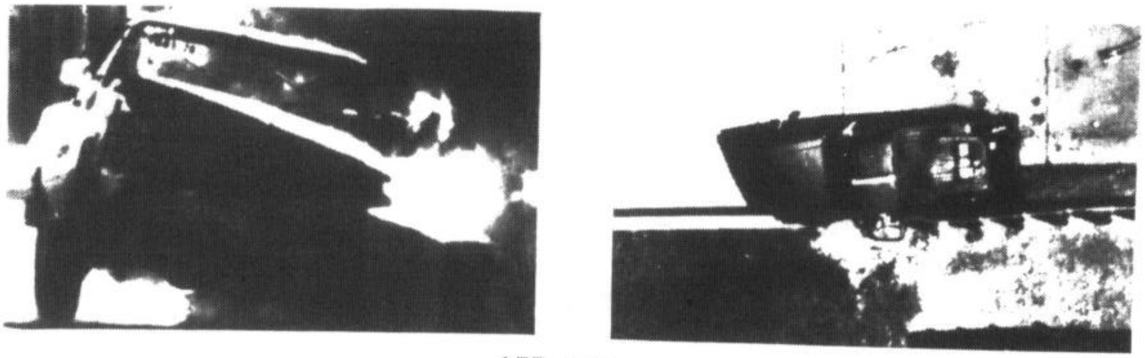
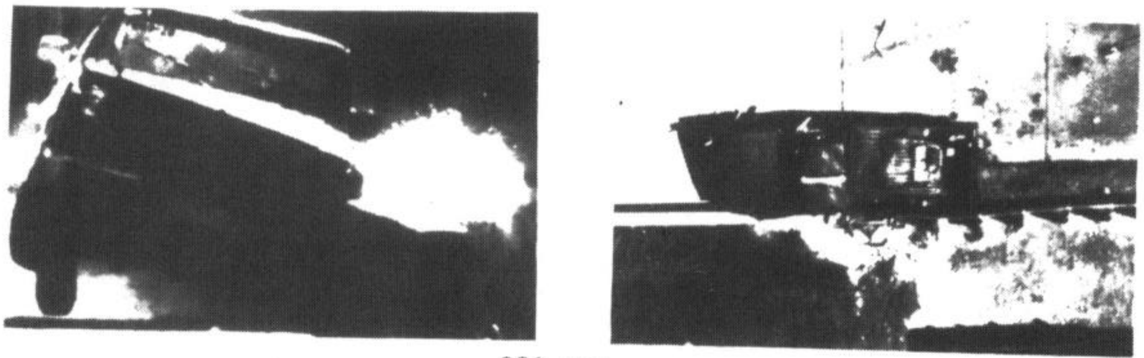


Figure 24. Sequential photographs for test 7069-20
(frontal and overhead views).



.177 sec



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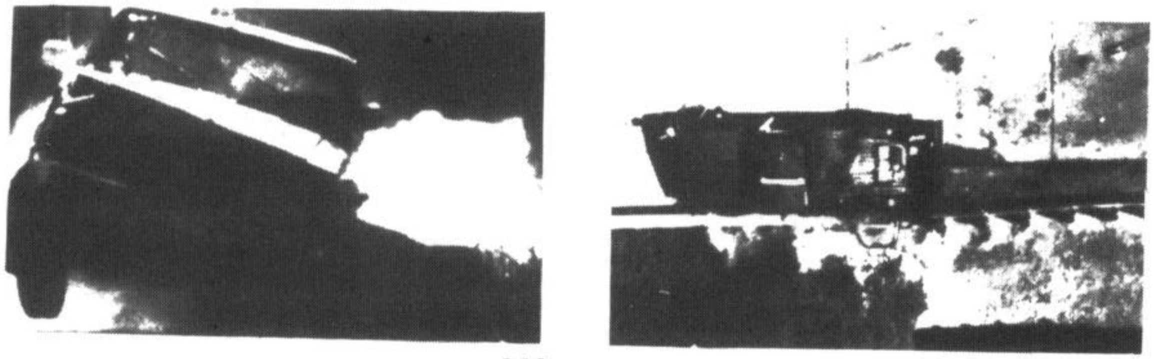
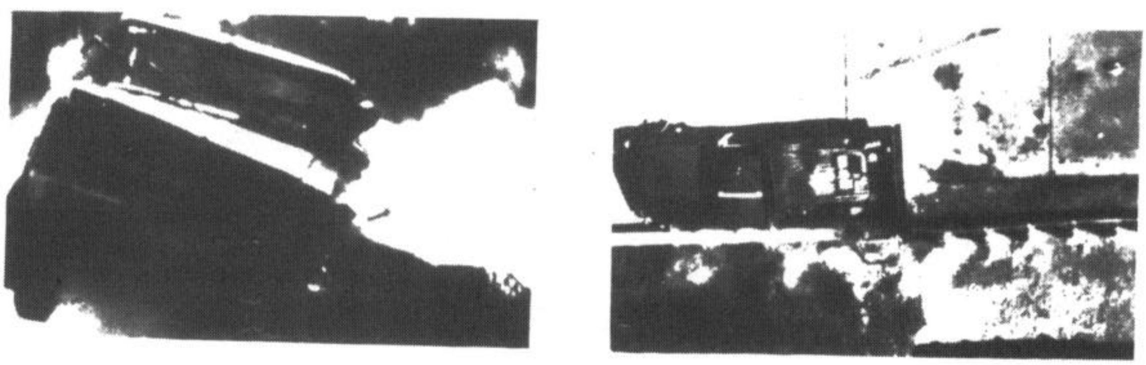
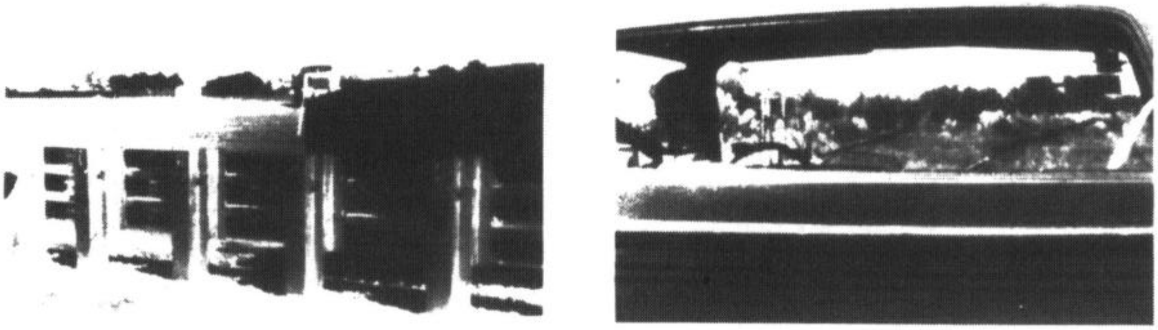


.266 sec

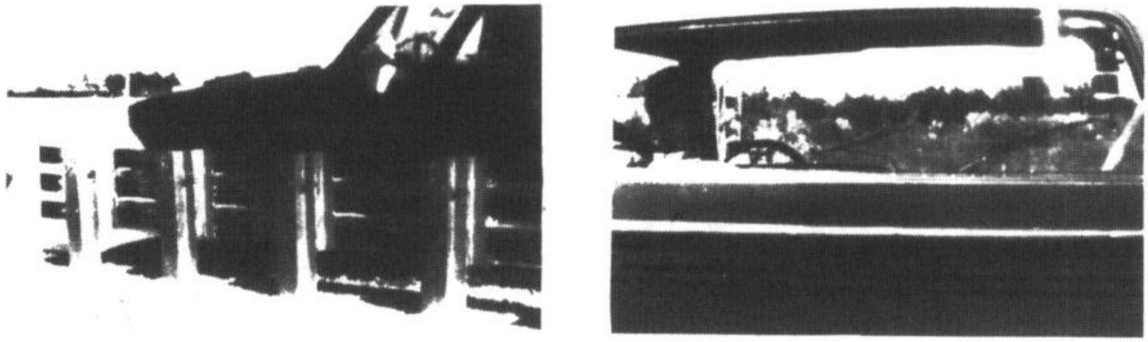


.308 sec

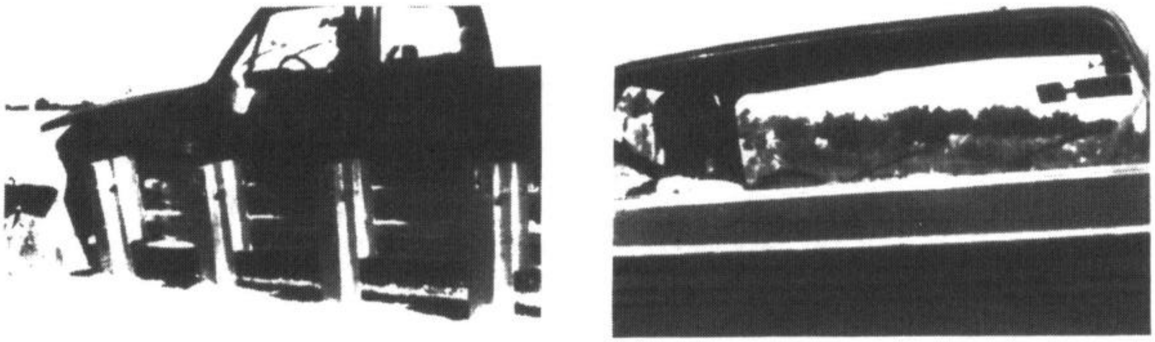
Figure 24. Sequential photographs for test 7069-20
(frontal and overhead views continued).



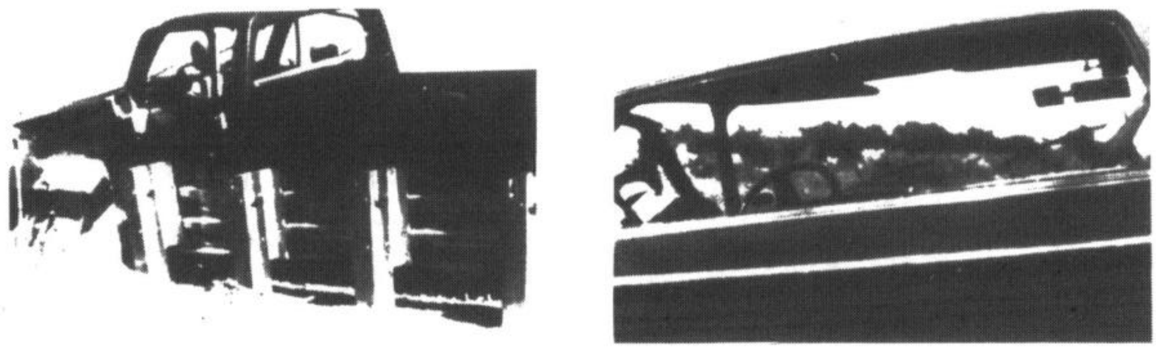
.000 sec



.044 sec

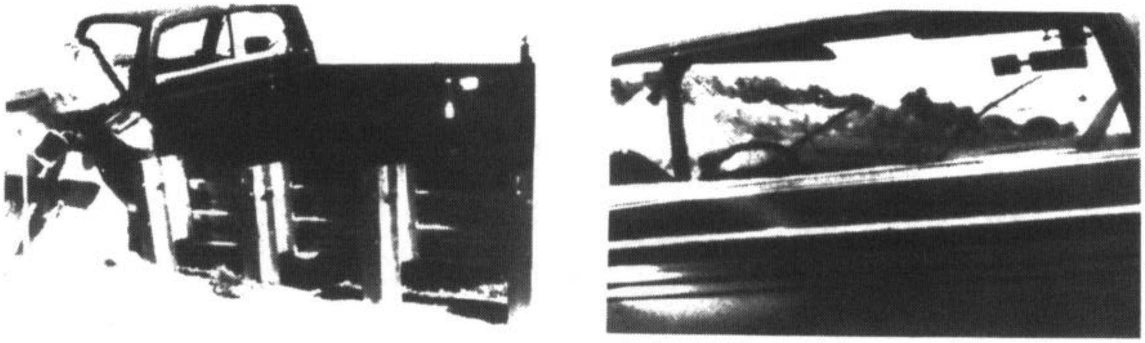


.089 sec

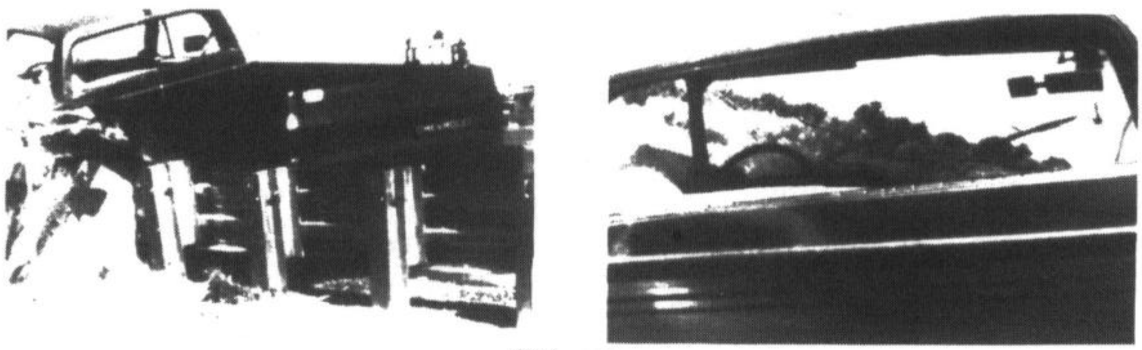


.133 sec

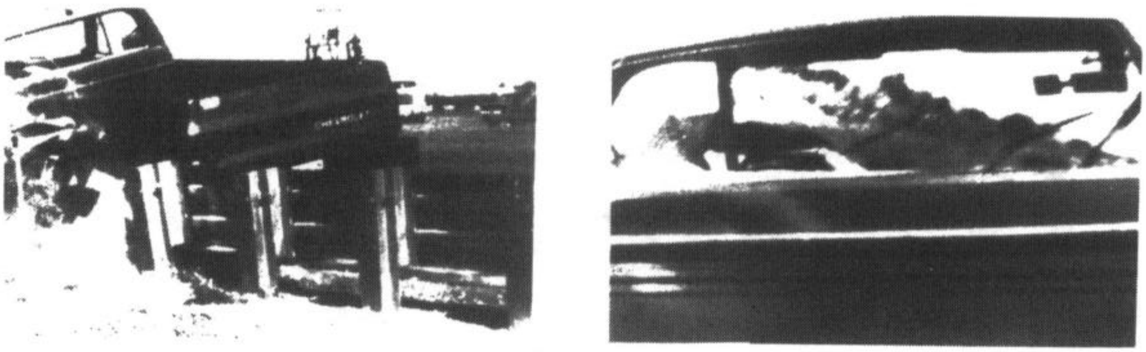
Figure 25. Sequential photographs for test 7069-20 (rear of transition and interior views).



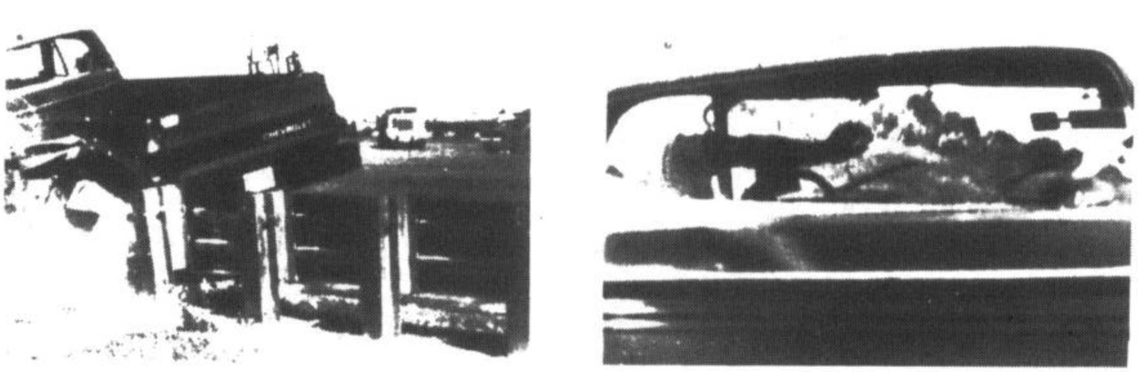
.177 sec



.221 sec



.266 sec



.308 sec

Figure 25. Sequential photographs for test 7069-20
(rear of transition and interior views continued).

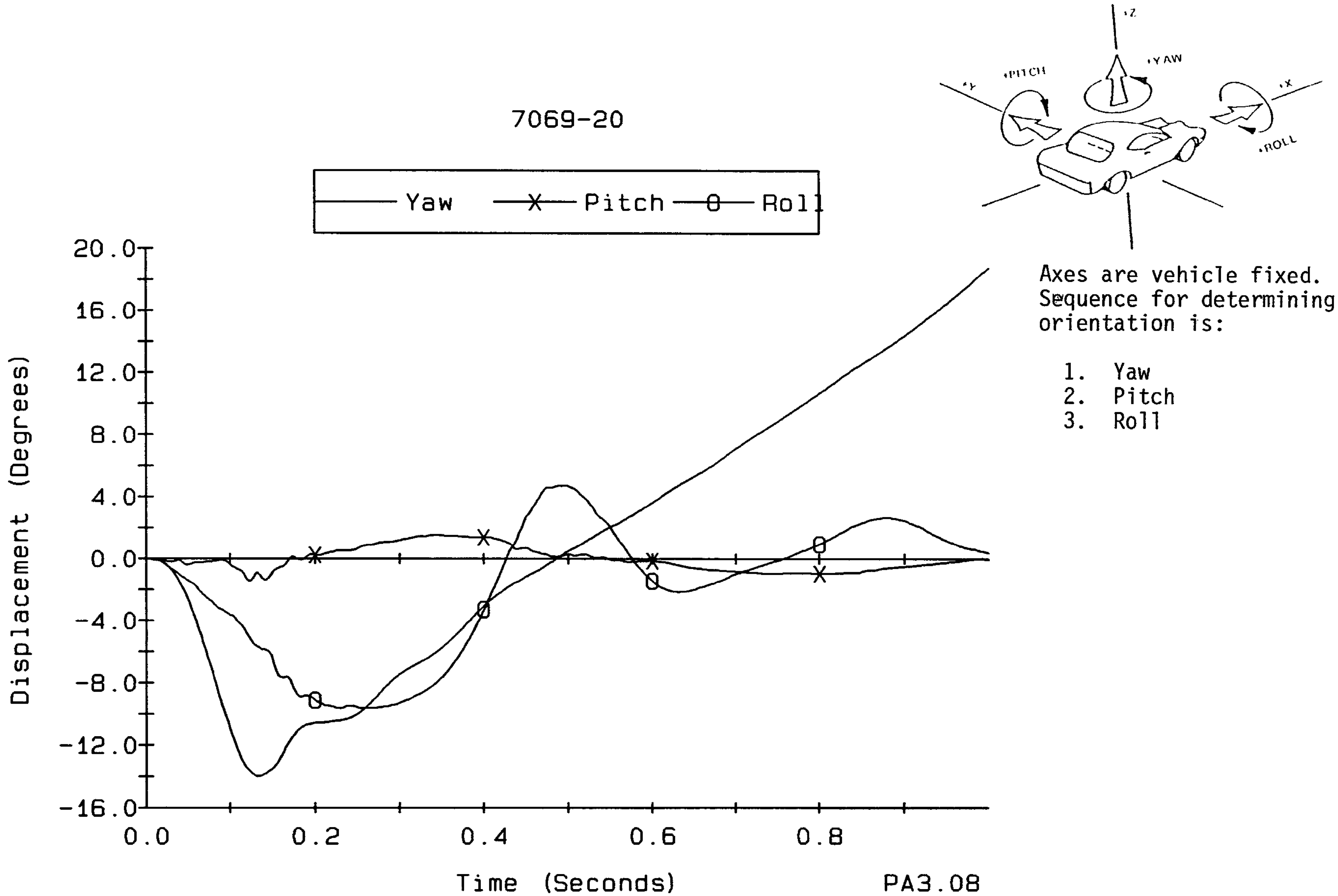
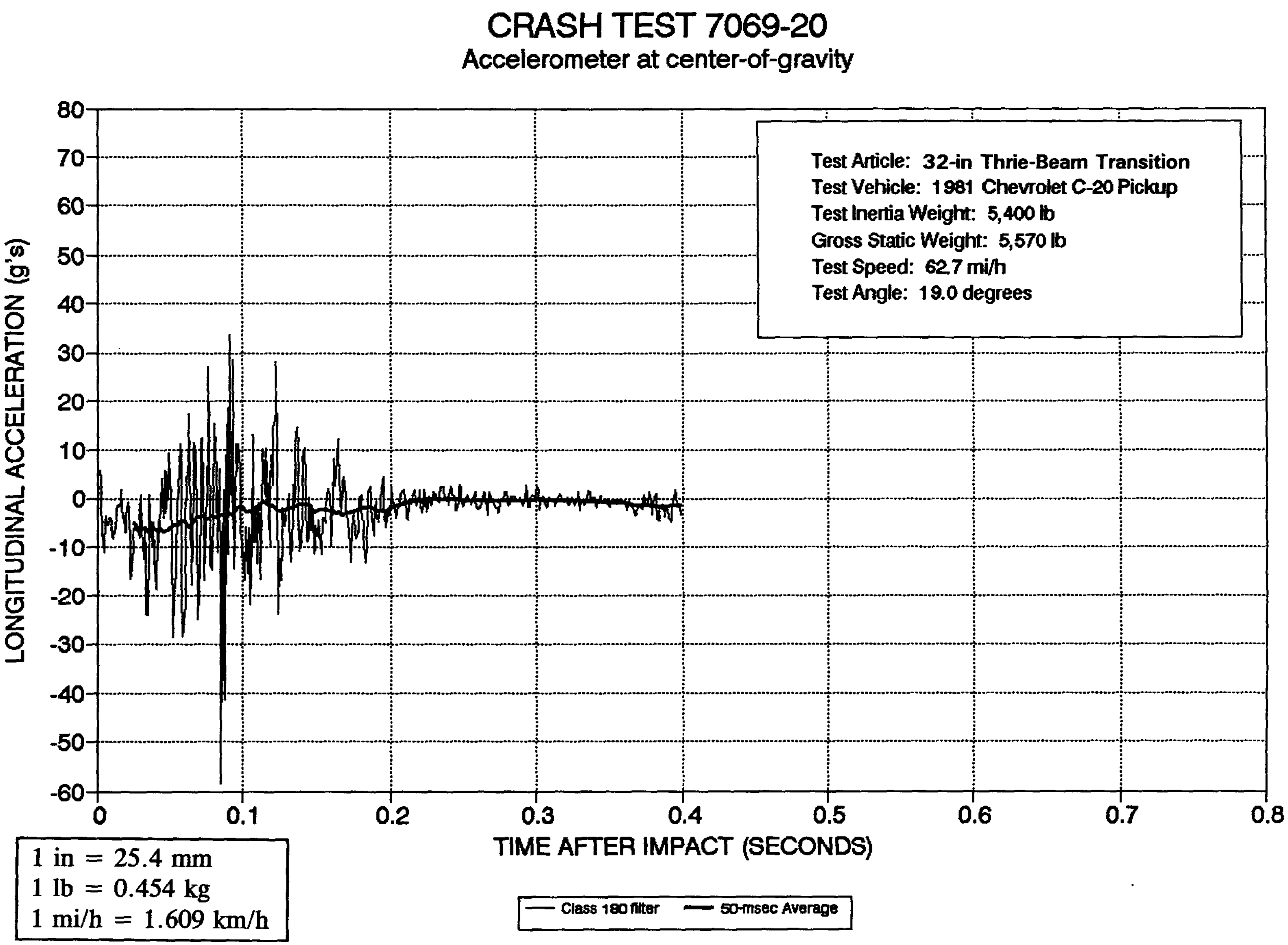
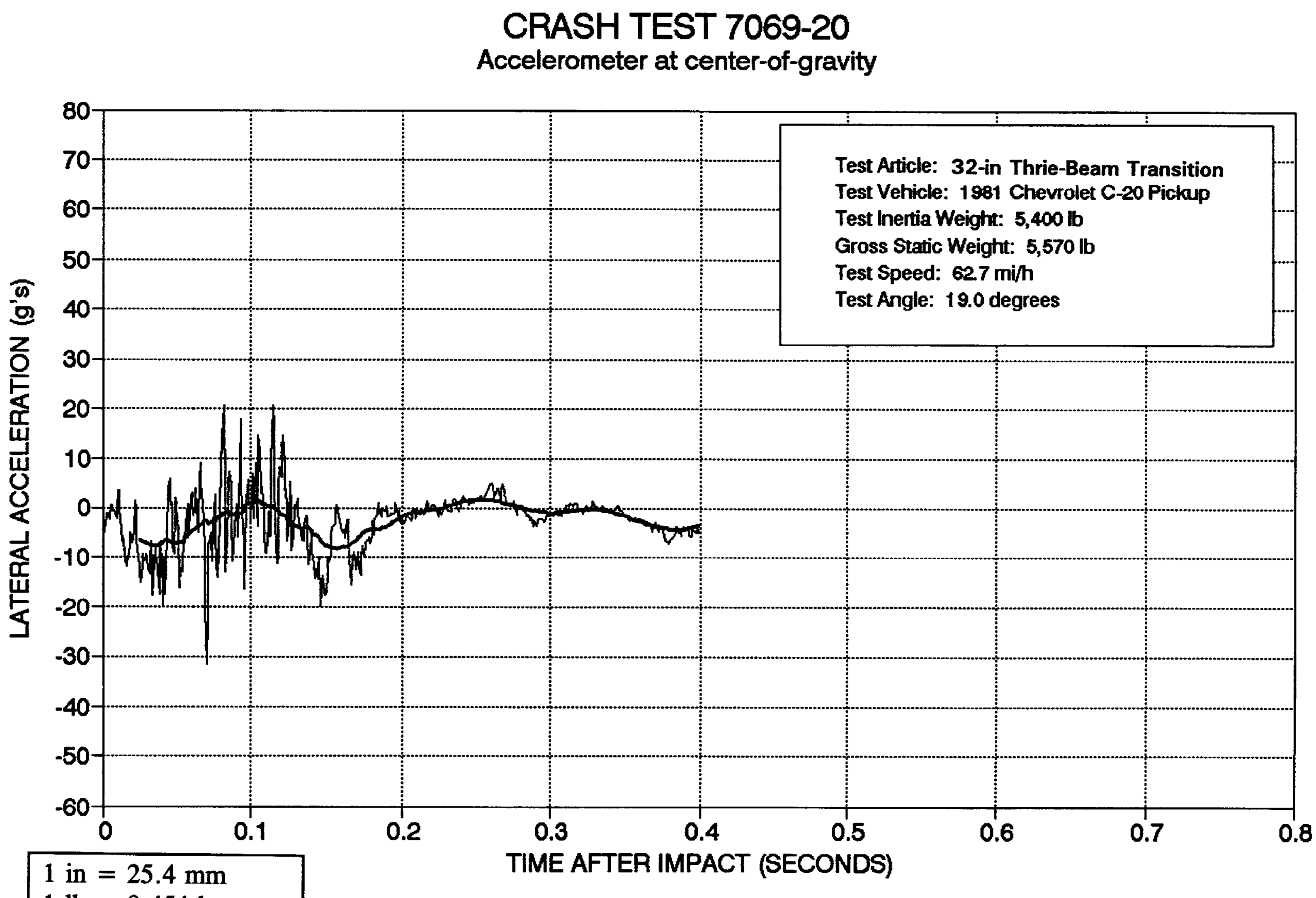


Figure 26. Vehicle angular displacements for test 7069-20.



1 in = 25.4 mm
1 lb = 0.454 kg
1 mi/h = 1.609 km/h

Figure 27. Vehicle longitudinal accelerometer trace for test 7069-20 (accelerometer located at center-of-gravity).



1 in = 25.4 mm
1 lb = 0.454 kg
1 mi/h = 1.609 km/h

Figure 28. Vehicle lateral accelerometer trace for test 7069-20 (accelerometer located at center-of-gravity).

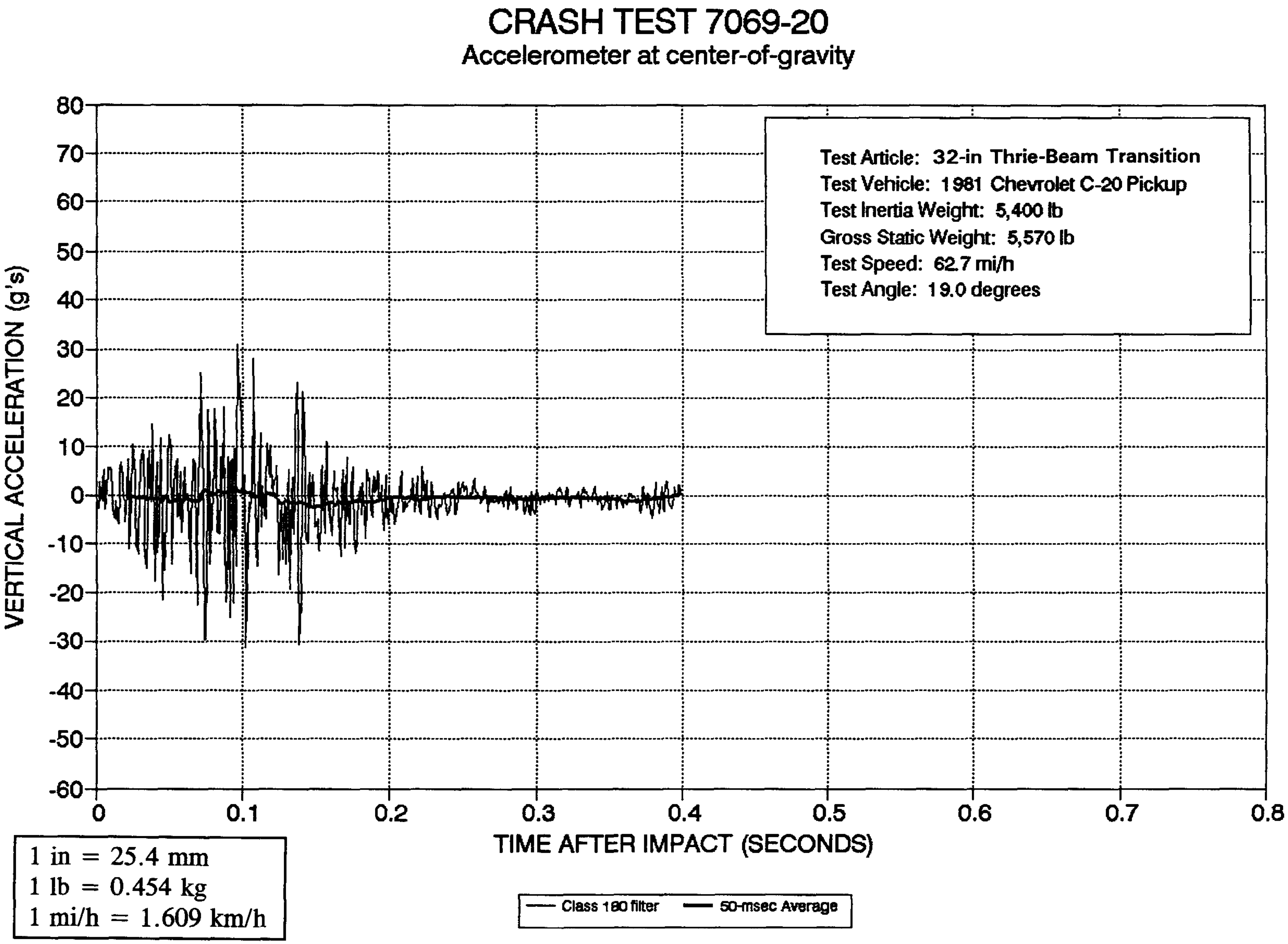
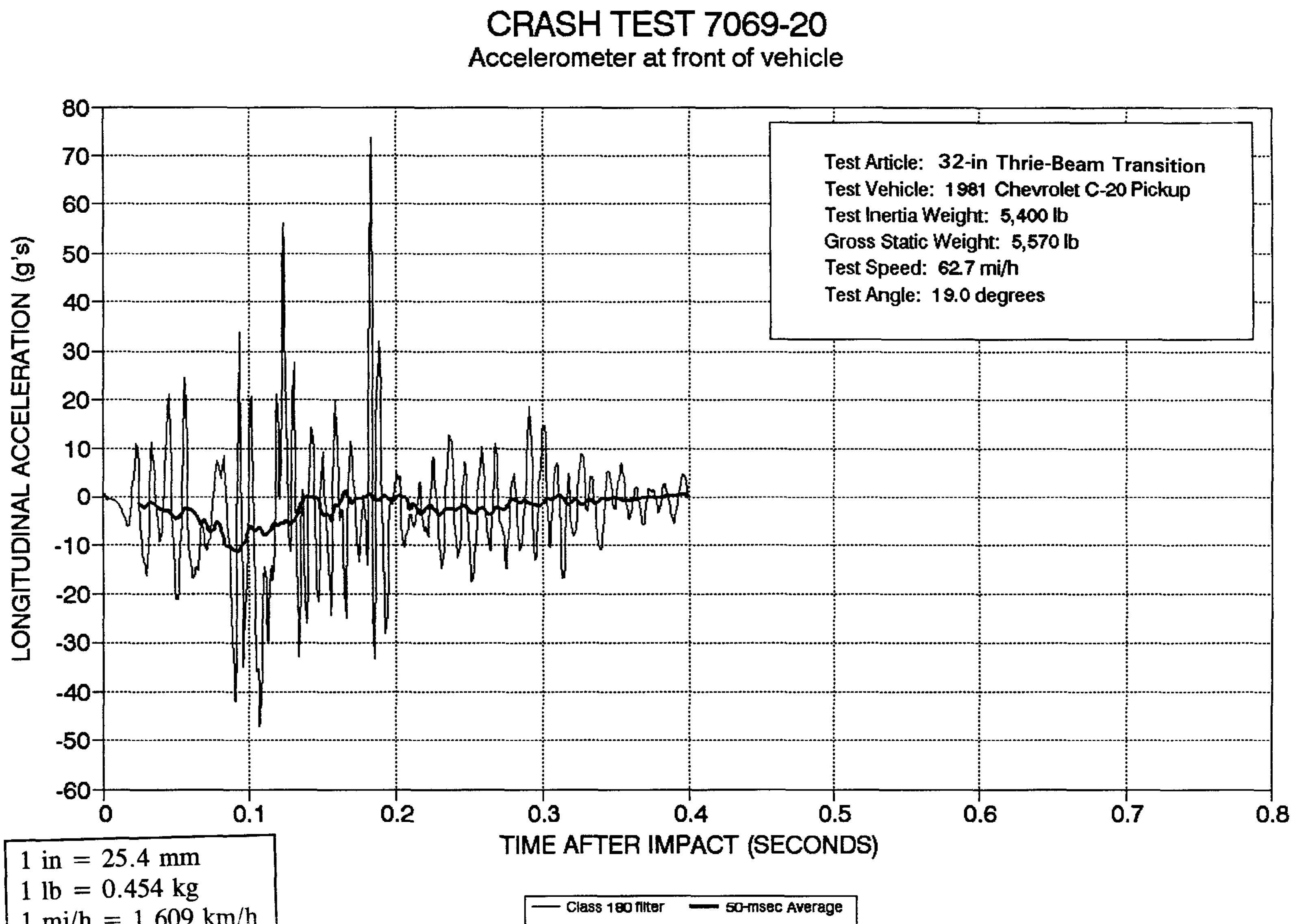
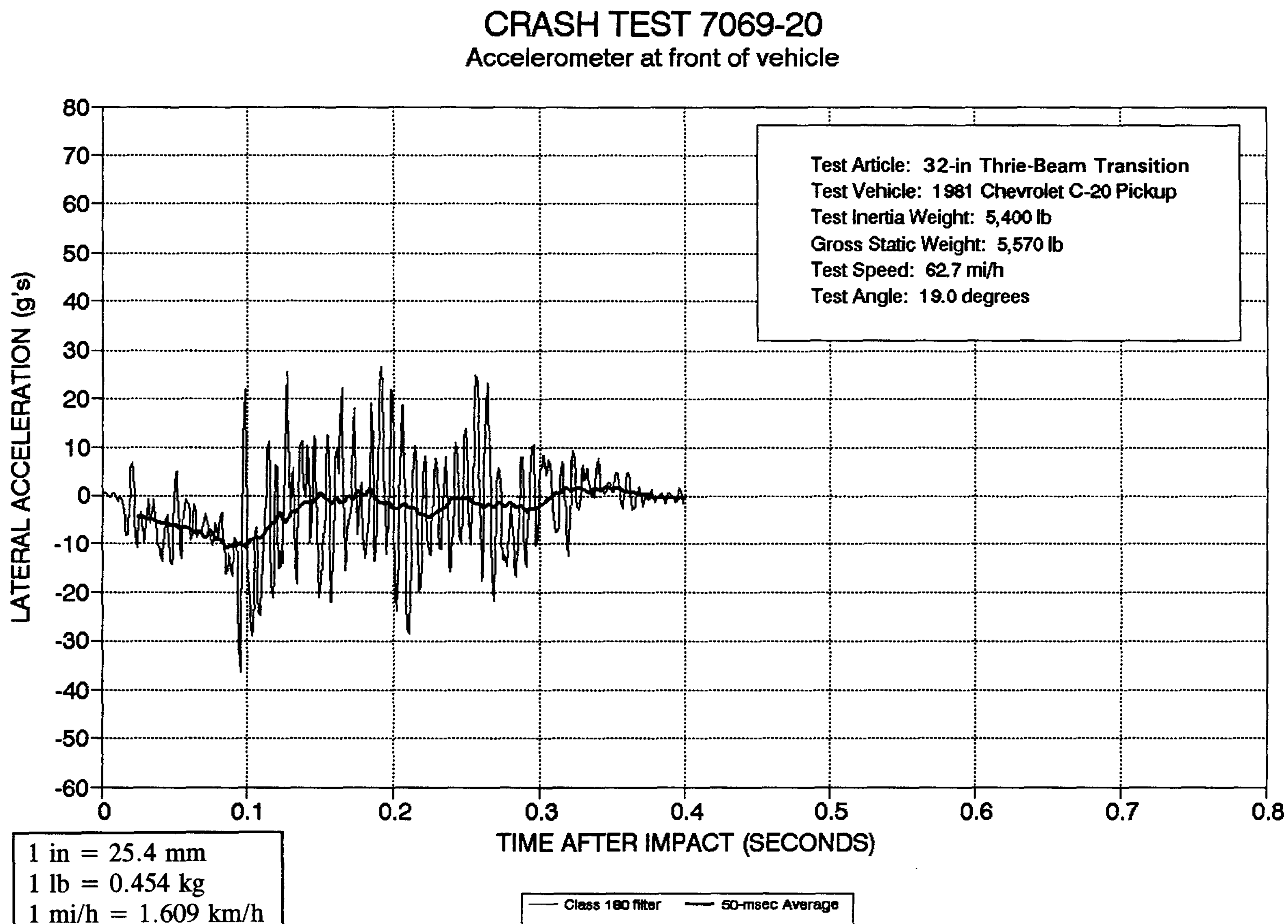


Figure 29. Vehicle vertical accelerometer trace for test 7069-20 (accelerometer located at center-of-gravity).



1 in = 25.4 mm
1 lb = 0.454 kg
1 mi/h = 1.609 km/h

Figure 30. Vehicle longitudinal accelerometer trace for test 7069-20 (accelerometer located at front of vehicle).

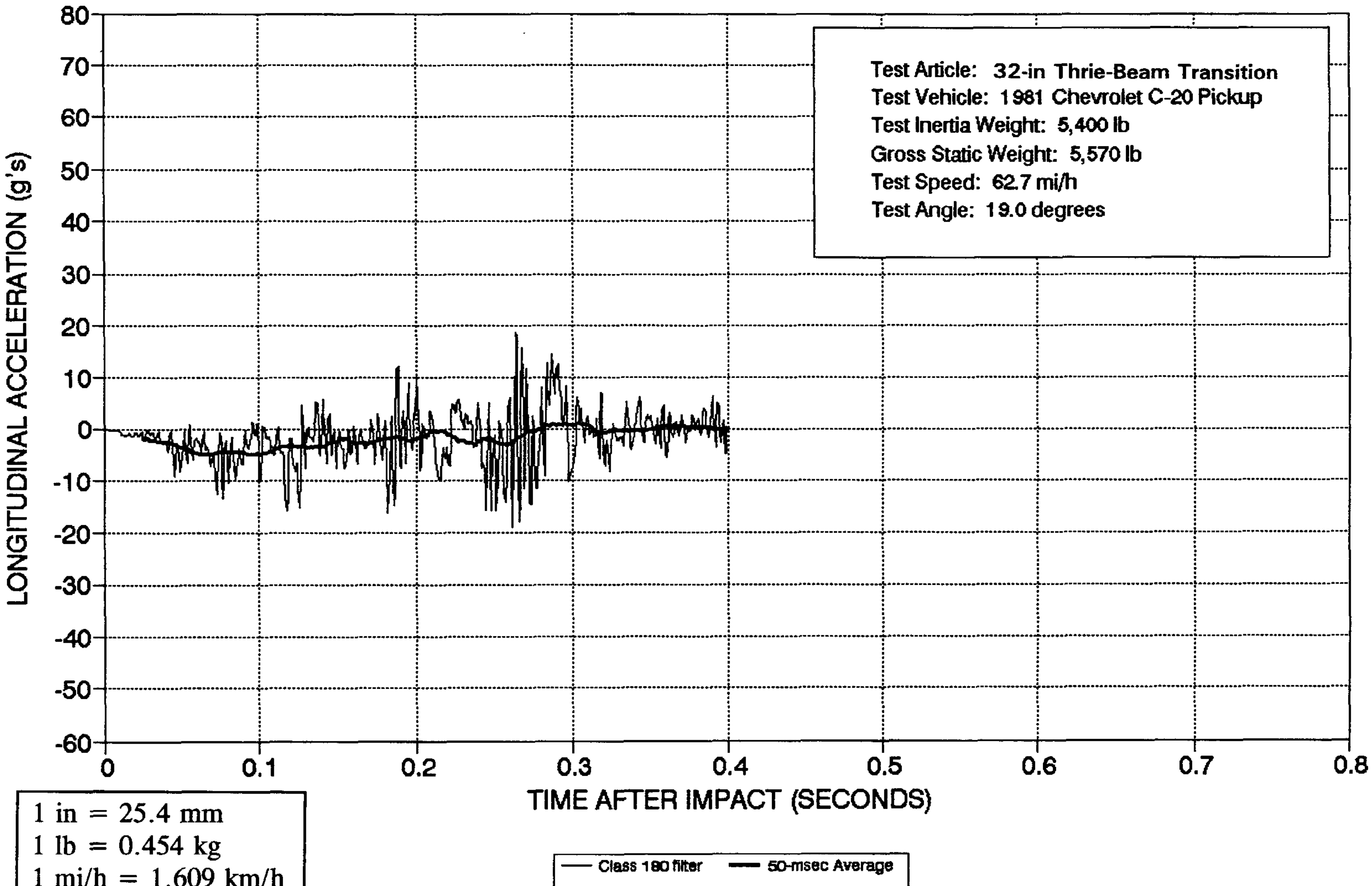


1 in = 25.4 mm
1 lb = 0.454 kg
1 mi/h = 1.609 km/h

Figure 31. Vehicle lateral accelerometer trace for test 7069-20 (accelerometer located at front of vehicle).

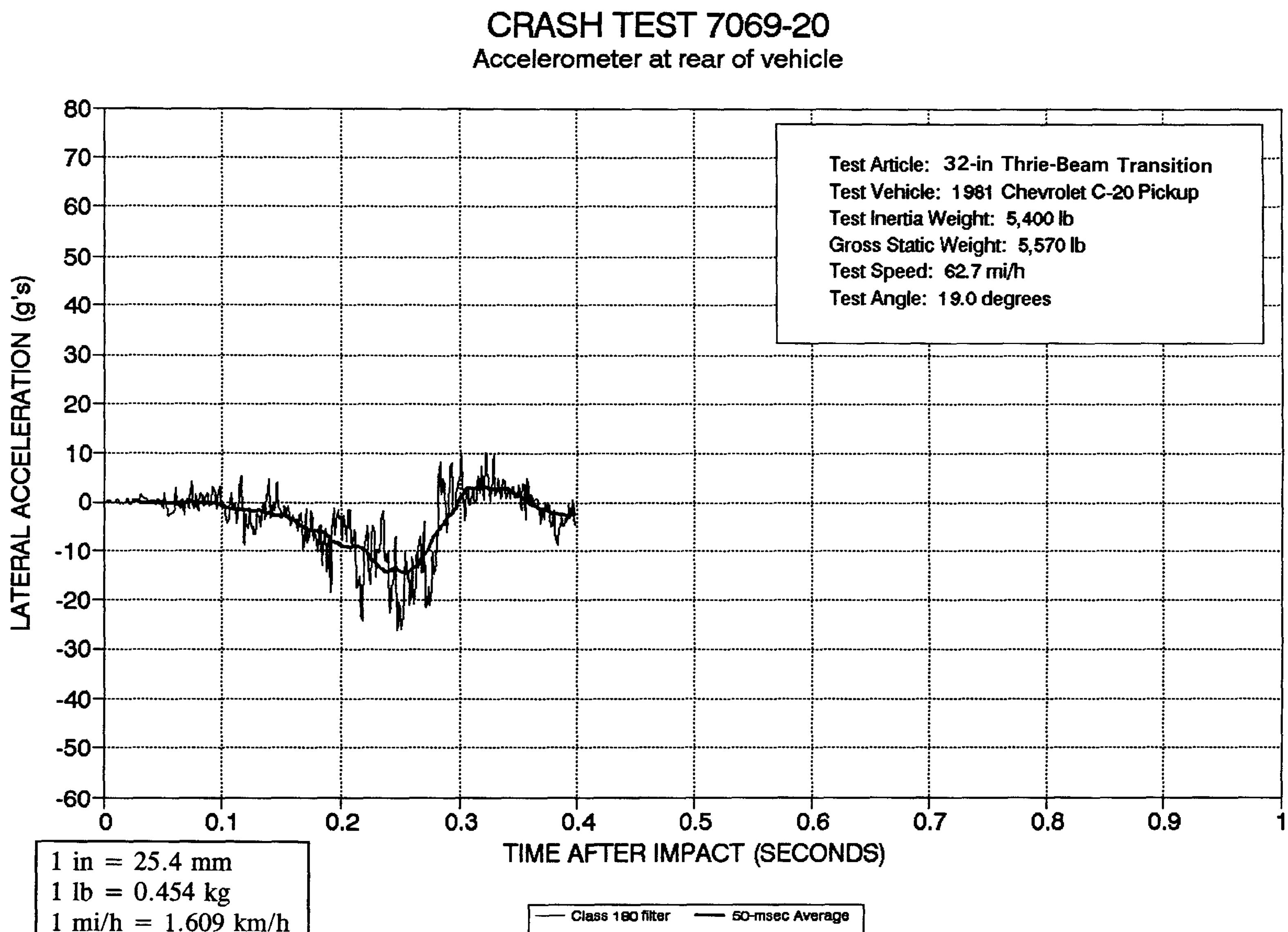
CRASH TEST 7069-20

Accelerometer at rear of vehicle



1 in = 25.4 mm
1 lb = 0.454 kg
1 mi/h = 1.609 km/h

Figure 32. Vehicle longitudinal accelerometer trace for test 7069-20 (accelerometer located at rear of vehicle).



1 in = 25.4 mm
1 lb = 0.454 kg
1 mi/h = 1.609 km/h

Figure 33. Vehicle lateral accelerometer trace for test 7069-20 (accelerometer located at rear of vehicle).

TEST 7069-21

Test Description

A 1984 Chevrolet Custom pickup (figures 34 and 35) was used for the crash test. Test inertia mass of the vehicle was 5,400 lb (2 452 kg) and its gross static mass was 5,565 lb (2 526 kg). The height to the lower edge of the vehicle bumper was 17.25 in (438 mm) and it was 26.5 in (673 mm) to the top of the bumper. Additional dimensions and information on the test vehicle are given in figure 36. The vehicle was directed into the 32-in (813-mm) thrie-beam transition (figures 37 through 39) using the cable reverse tow and guidance system and was released to be free-wheeling and unrestrained just prior to impact. The vehicle impacted the transition 25 in (635 mm) upstream of post 2 at a speed of 61.4 mi/h (98.8 km/h) and the angle of impact was 18.3 degrees.

The vehicle began to redirect at 0.026 s after impact, and at 0.042 s the vehicle contacted post 1. Maximum lateral deflection of 0.8 ft (244 mm) occurred at 0.060 s. At approximately 0.070 s the vehicle impacted the end of the concrete parapet. The left front wheel snagged on the end of the parapet at 0.099 s causing a severe steering input to the vehicle and the passenger side of the vehicle became airborne. At approximately 0.110 s the windshield shattered, and at 0.140 s the door glass on the driver side was broken by the head of the dummy. By 0.178 s the vehicle was traveling parallel to the transition at a speed of 50.3 mi/h (80.9 km/h), and at 0.188 s the rear of the vehicle impacted the transition. At 0.210 s the head of the dummy was at its maximum distance outside the vehicle (approximately 16 in [406 mm]). The tailgate of the vehicle came loose at 0.267 s; and as the vehicle continued forward, the tailgate came off and traveled with the vehicle. The vehicle lost contact with the transition at 0.314 s traveling at 50.0 mi/h (80.5 km/h) and 8.2 degrees. The dummy impacted its head against the outside of the door of the vehicle as it was re-entering the vehicle at 0.440 s. The brakes were applied as the vehicle left the installation and subsequently came to rest 195 ft (41 m) from the point of impact.

As can be seen in figure 40, the transition received moderate damage. Maximum lateral permanent deformation was 5.0 in (127 mm). The vehicle was in contact with the transition for 14.0 ft (4.2 m).

The vehicle sustained damage to the left side as shown in figure 41. Maximum crush at the left front corner at bumper height was 15.0 in (381 mm) and the right front corner was deformed outward approximately 4.75 in (121 mm). The sway bar, A-arms on the left side and gas tank were damaged and the drive shaft, frame, and roof was bent. The floorpan was pushed into the occupant compartment approximately 5 to 7 in (130 to 180 mm) and the dash moved inward approximately 3 in (80 mm). The left front wheel was canted inward at the bottom and pushed back into the fender well reducing the wheelbase on the driver side by 14.0 in (356 mm). The driver side window was broken out and the door was jammed. Also, damage was done to the front bumper, hood, grill, radiator and fan, left front quarter panel, left rear quarter panel, and left rear tire and rim. The tailgate came off the vehicle during the test.

Test Results

Impact speed was 61.4 mi/h (98.8 km/h) and the angle of impact was 18.3 degrees. The speed of the vehicle at time of parallel was 50.3 mi/h (80.9 km/h) and the coefficient of friction was 0.41. The vehicle lost contact with the transition traveling at 50.0 mi/h (80.5 km/h) and the exit angle between the vehicle path and the transition was 8.2 degrees. Data from the accelerometer located at the center-of-gravity were digitized for evaluation and occupant risk factors were computed as follows. In the longitudinal direction, occupant impact velocity was 19.3 ft/s (5.9 m/s) at 0.194 s, the highest 0.010-s average ridedown acceleration was -3.7 g between 0.200 and 0.210 s, and the maximum 0.050-s average acceleration was -6.9 g between 0.059 and 0.109 s. Lateral occupant impact velocity was 24.8 ft/s (7.6 m/s) at 0.130 s, the highest 0.010-s occupant ridedown acceleration was 12.5 g between 0.182 and 0.192 s, and the maximum 0.050-s average acceleration was -10.3 g between 0.076 and 0.126 s. The change in vehicle velocity at loss of contact was 11.1 mi/h (17.9 km/h) and the change in momentum was 1,861 lb-sec (8,280 N-s). These data and other pertinent information from the test are summarized in figure 42 and table 4. Sequential photographs are shown in figures 43 and 44. Vehicular angular displacements are displayed in figure 45. Vehicular accelerations versus time traces filtered with SAE J211 filters are presented in figures 46 through 52.

Conclusions

The 32-in (813-mm) thrie-beam transition contained the test vehicle with minimal lateral movement of the transition. There was no intrusion of railing components into the occupant compartment; however, the floorpan was deformed into the vehicle approximately 5 to 7 in (130 to 180 mm) and the instrument panel was pushed inward approximately 3 in (80 mm). The vehicle remained upright and relatively stable during the collision. The transition redirected the vehicle but the effective coefficient of friction was quite high. Velocity change of the vehicle during the collision was 11.1 mi/h (17.9 km/h).

The 1989 AASHTO guide specifications sets forth desired (but not required) limits for occupant risk factors for tests with the 5,400-lb (2 452-kg) vehicle.[1] The AASHTO specifications recommend a limit of 30 ft/s (9.1 m/s) for longitudinal occupant impact velocity and 25 ft/s (7.6 m/s) for the lateral occupant impact velocity. The occupant impact velocities and the occupant ridedown accelerations were within the limits. The vehicle trajectory at loss of contact indicates minimum intrusion into adjacent traffic lanes.

Figure 34. Vehicle before test 7069-21.

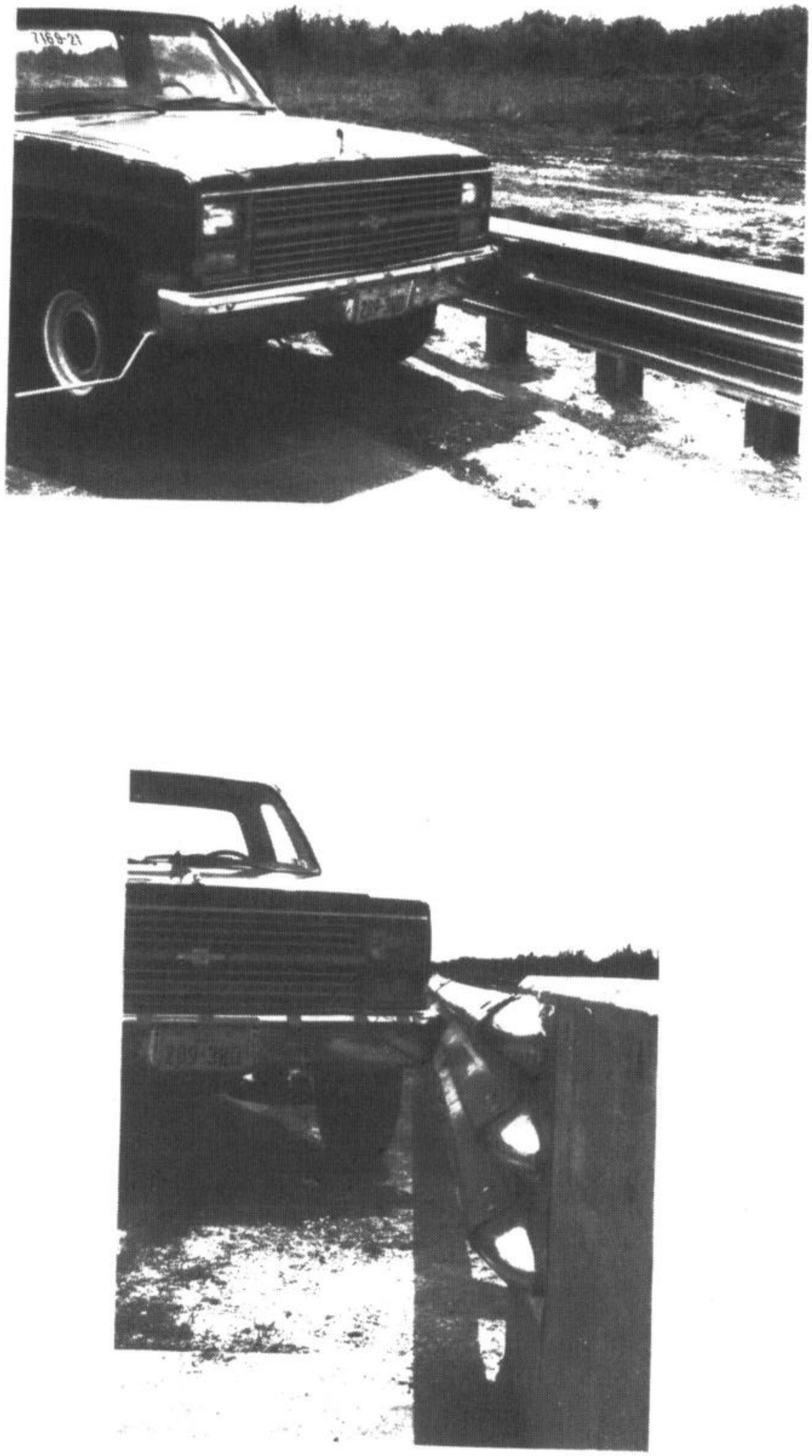


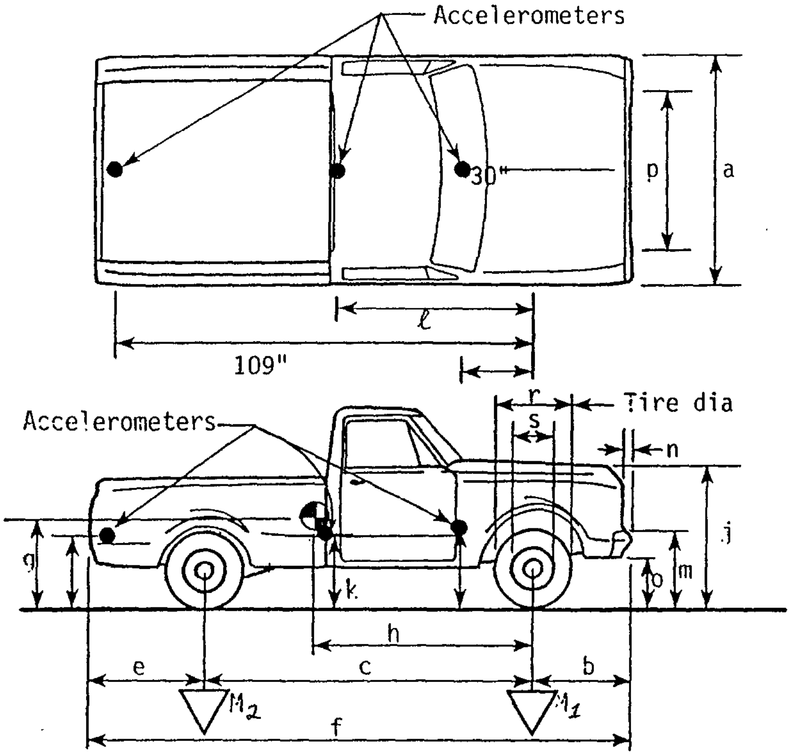
Figure 35. Vehicle/transition geometrics for test 7069-21.

Date: 03-16-92 Test No.: 7069-21 VIN: 1CCGC24J3FS129186

Make: Chevrolet Model: Custom Deluxe Year: 1984 Odometer: 68751

Tire Size: LT 235/85R16 Ply Rating: ____ Bias Ply: ___ Belted: ___ Radial: X

Tire Condition: good ___
fair X
badly worn ___



Vehicle Geometry - inches

a	79 1/4"	b	33 1/2"
c	131 3/4"	d*	71 3/4"
e	50 "	f	215.25
g		h	67.8"
i	----	j	45"
k	32"	ℓ	72 1/2"
m	26 1/2"	n	3 1/4"
o	17 1/4"	p	65 1/2"
r	31 1/4"	s	17 1/2"

Engine Type: V-8

Engine CID: 454

Transmission Type:

~~Automatic~~ or Manual

~~FWD~~ or RWD or ~~4WD~~

Body Type: pu

Steering Column Collapse Mechanism:

- ___ Behind wheel units
- ___ Convoluted tube
- ___ Cylindrical mesh units
- ___ Embedded ball
- ___ NOT collapsible
- ___ Other energy absorptio
- ___ Unknown

Brakes:

Front: disc X drum ___

Rear: disc ___ drum X

4-wheel weight for c.g. det. ℓf 1329 rf 1294 ℓr 1357 rr 1420

Mass - pounds	Curb	Test Inertial	Gross Static
M_1	2812	2623	2724
M_2	1989	2777	2841
M_T	4801	5400	5565

Note any damage to vehicle prior to test:

___

___

*d = overall height of vehicle

1 in = 25.4 mm
1 lb = 0.454 kg

Figure 36. Vehicle properties for test 7069-21

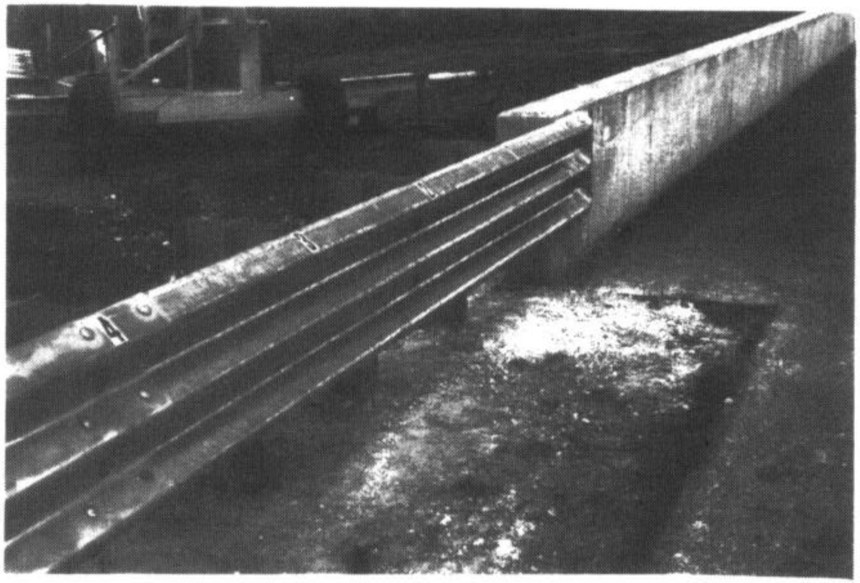


Figure 37. 32-in (813-mm) thrie-beam transition before test 7069-21.

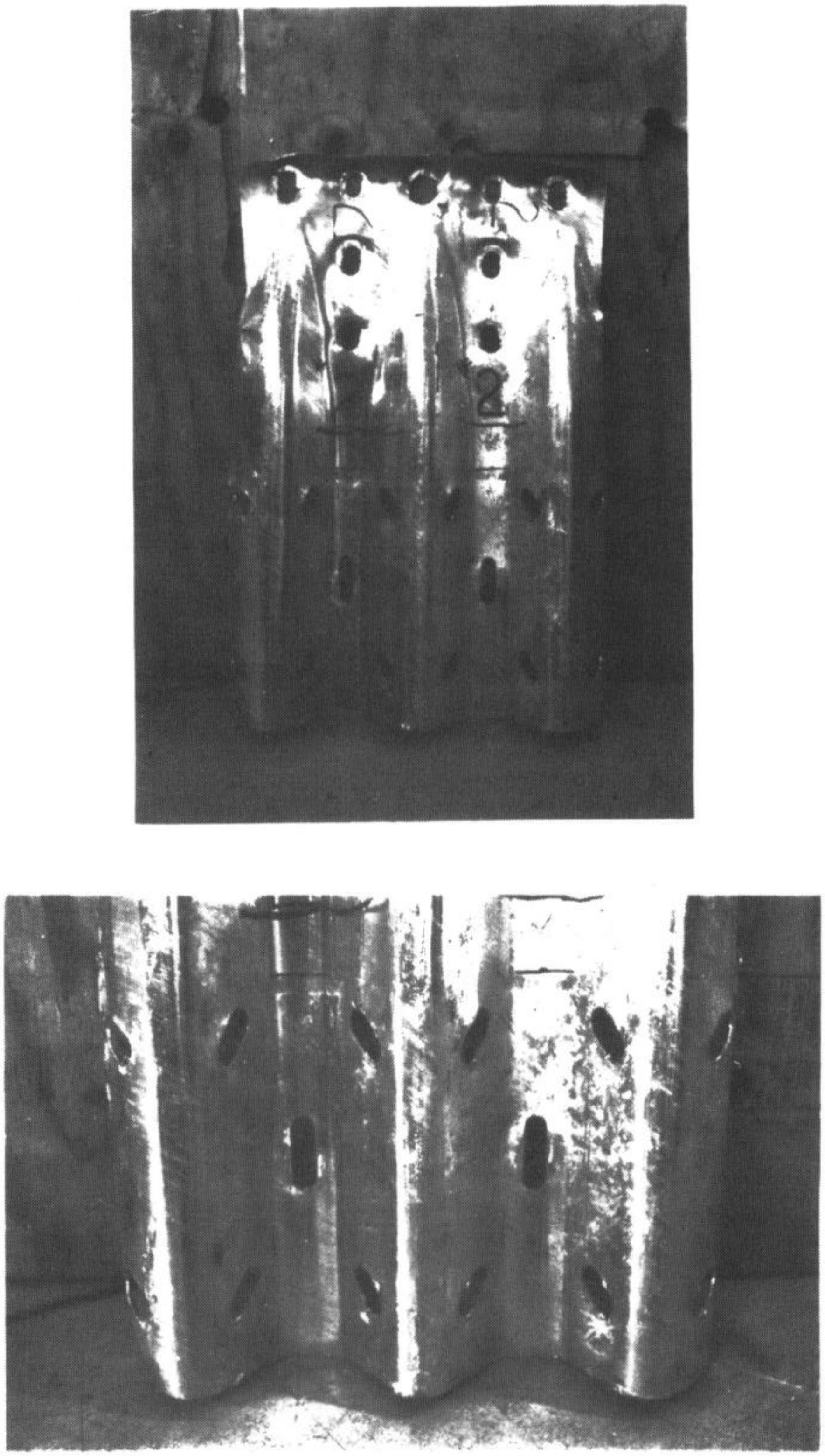


Figure 38. Modified terminal connector similar to those used in tests 7069-21 and 29.

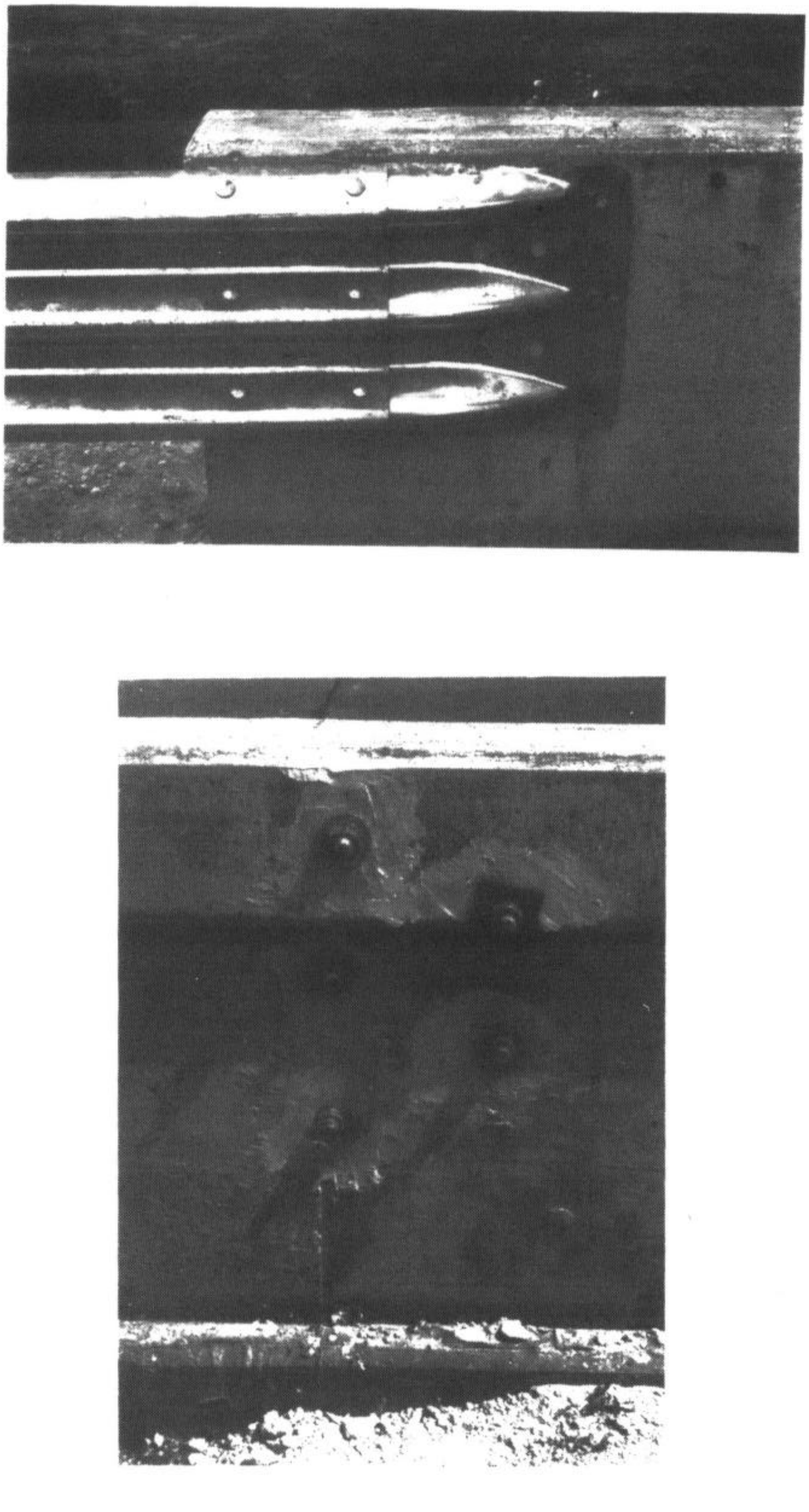
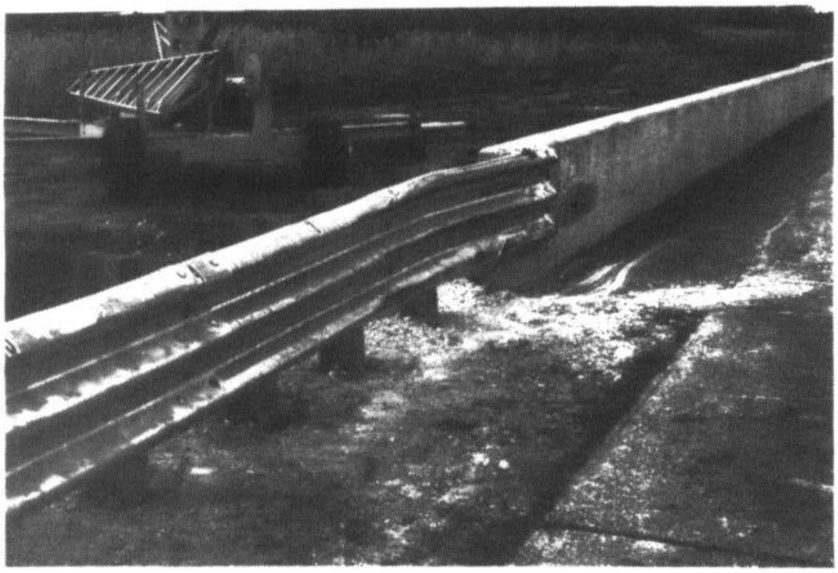


Figure 39. Modified end shoe attachment for test 7069-21.



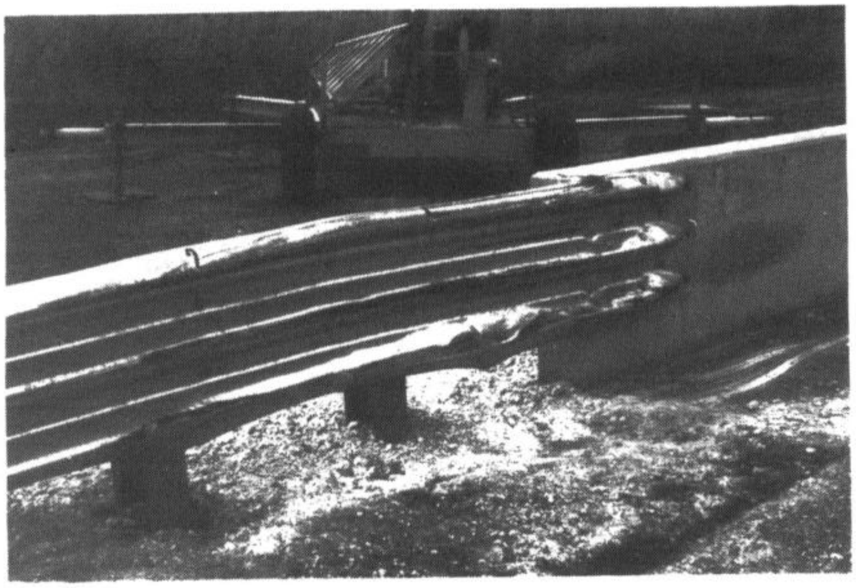


Figure 40. 32-in (813-mm) thrie-beam transition after test 7069-21.

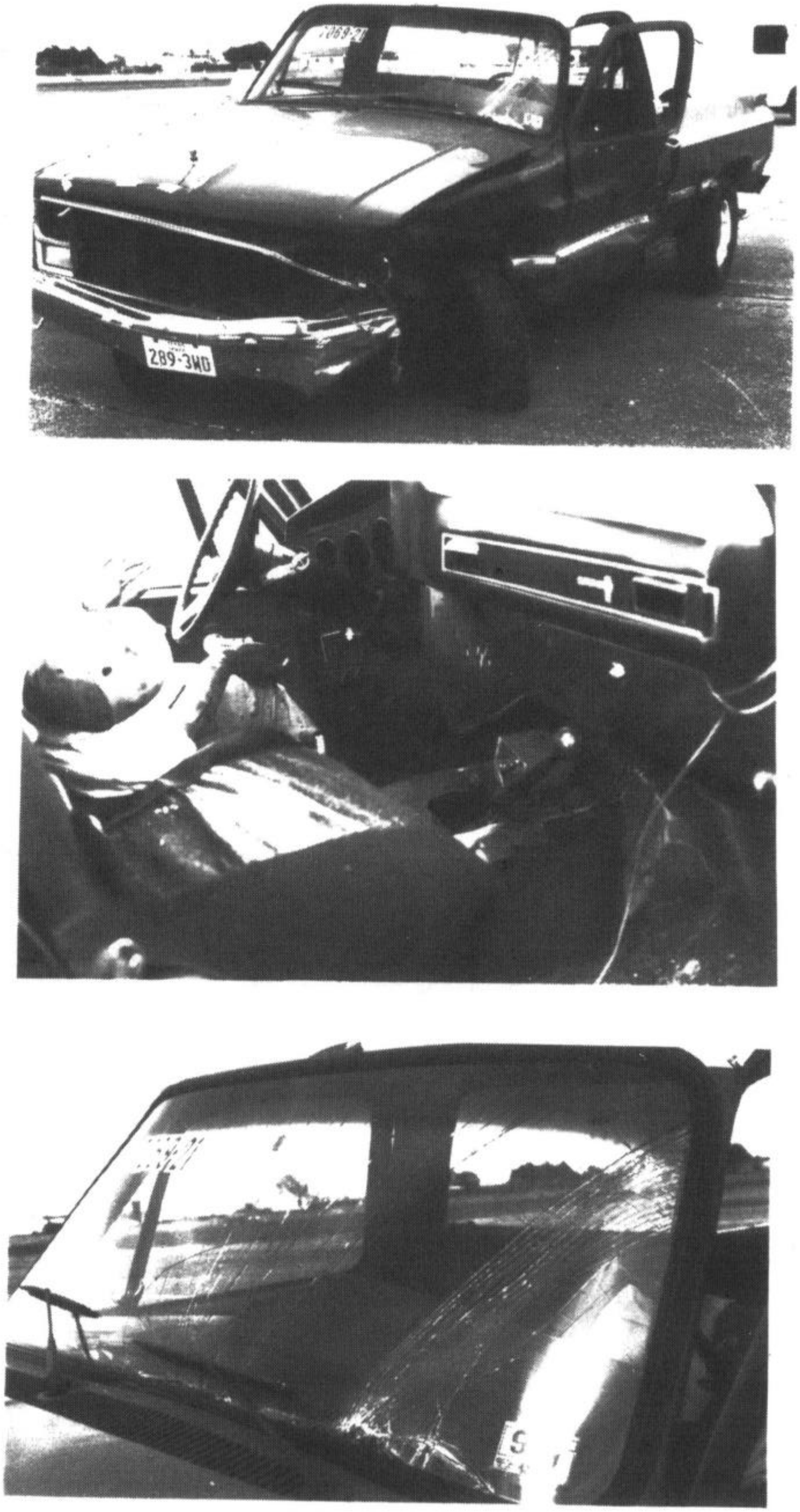
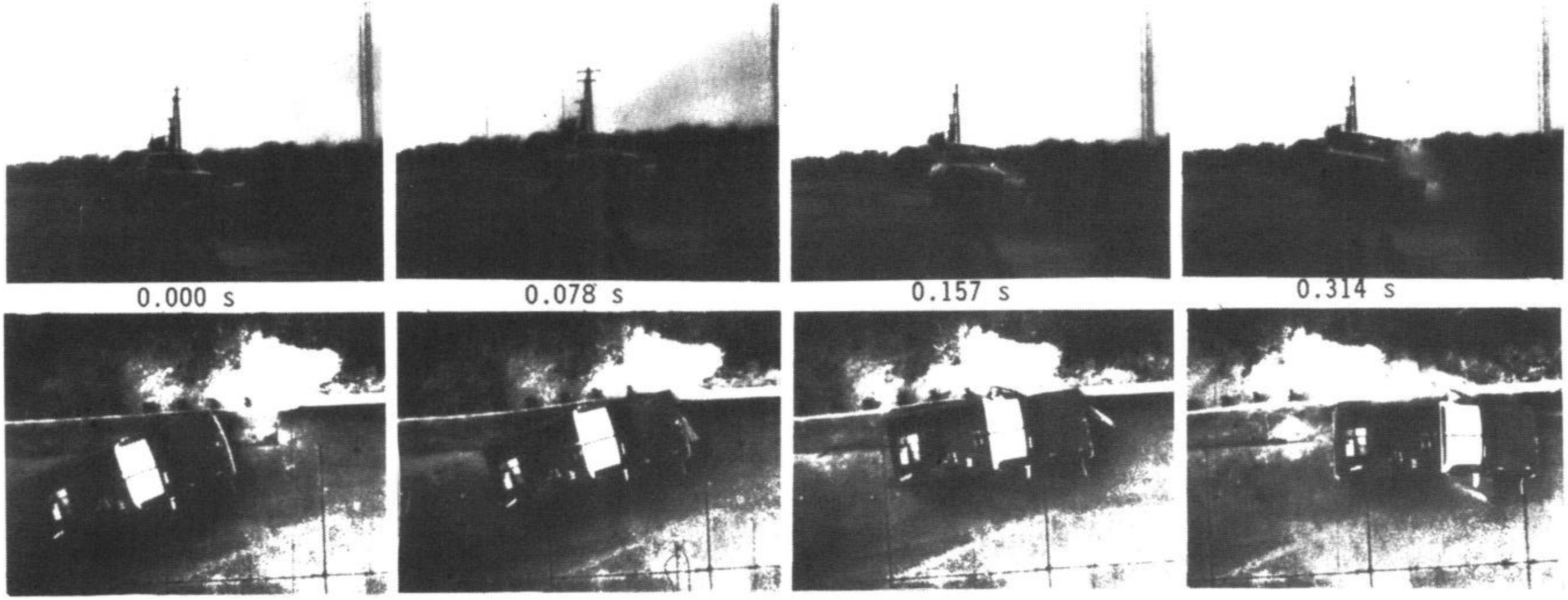
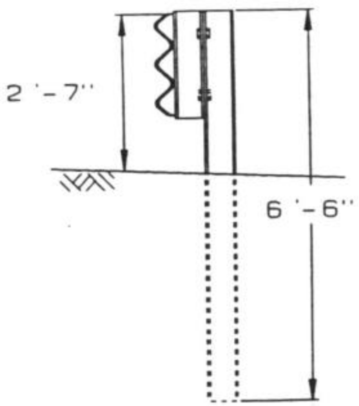


Figure 41. Vehicle after test 7069-21.





(1 in = 25.4 mm)

Test No.	7069-21
Date	03/17/92
Test Installation . . .	32-in (813-mm) Thrie-Beam Transition
Installation Length . .	85 ft (26 m)
Test Vehicle	1984 Chevrolet Custom Pickup
Vehicle Weight	
Test Inertia	5,400 lb (2,452 kg)
Gross Static	5,565 lb (2,527 kg)
Vehicle Damage Classification	
TAD	11FL5 & 11LD6
CDC	11FLEK3 & 11LDEW4
Maximum Vehicle Crush .	15.0 in (381 mm)

Impact Speed. . . .	61.4 mi/h (98.8 km/h)
Impact Angle. . . .	18.3 deg
Speed at Parallel .	50.3 mi/h (80.9 km/h)
Exit Speed	50.0 mi/h (80.5 km/h)
Exit Trajectory . .	8.2 deg
Vehicle Accelerations (Max. 0.050-sec Avg) at true c.g.	
Longitudinal. . .	-6.9 g
Lateral	-10.3 g
Occupant Impact Velocity at true c.g.	
Longitudinal. . .	19.3 ft/s (5.9 m/s)
Lateral	24.8 ft/s (7.6 m/s)
Occupant Ridedown Accelerations	
Longitudinal. . .	-3.7 g
Lateral	12.5 g

Figure 42. Summary of results for test 7069-21.

Table 4. Evaluation of crash test no. 7069-21.
{32-in (813-mm) thrie-beam transition (5,400 lb (2 452 kg)|61.4 mi/h (98.8 km/h)|18.3 degrees]}

	CRITERIA	TEST RESULTS	PASS/FAIL*
A.	Must contain vehicle	Vehicle was contained	Pass
B.	Debris shall not penetrate passenger compartment	No debris penetrated passenger compartment	Pass
C.	Passenger compartment must have essentially no deformation	Moderate deformation (approx. 5-7 in at floorpan)	Fail
D.	Vehicle must remain upright	Vehicle did remain upright	Pass
E.	Must smoothly redirect the vehicle	Vehicle was smoothly redirected	Pass
F.	Effective coefficient of friction μ — Assessment 0 - .25 — Good .26 - .35 — Fair > .35 — Marginal	μ — Assessment .41 — Marginal	Pass
G.	Shall be less than Occupant Impact Velocity - ft/s (m/s) Longitudinal 30 (9.2) — Lateral 25 (7.6)	Occupant Impact Velocity - ft/s (m/s) Longitudinal 19.3 (5.9) — Lateral 24.8 (7.6)	Pass
	Occupant Ridedown Accelerations - g's Longitudinal 15 — Lateral 15	Occupant Ridedown Accelerations - g's Longitudinal -3.7 — Lateral 12.5	Pass
H.	Exit angle shall be less than 12 degrees	Exit angle was 8.2 degrees	Pass

* A, B, C, and D are required. E, F, G, and H are desired. (See table 2)

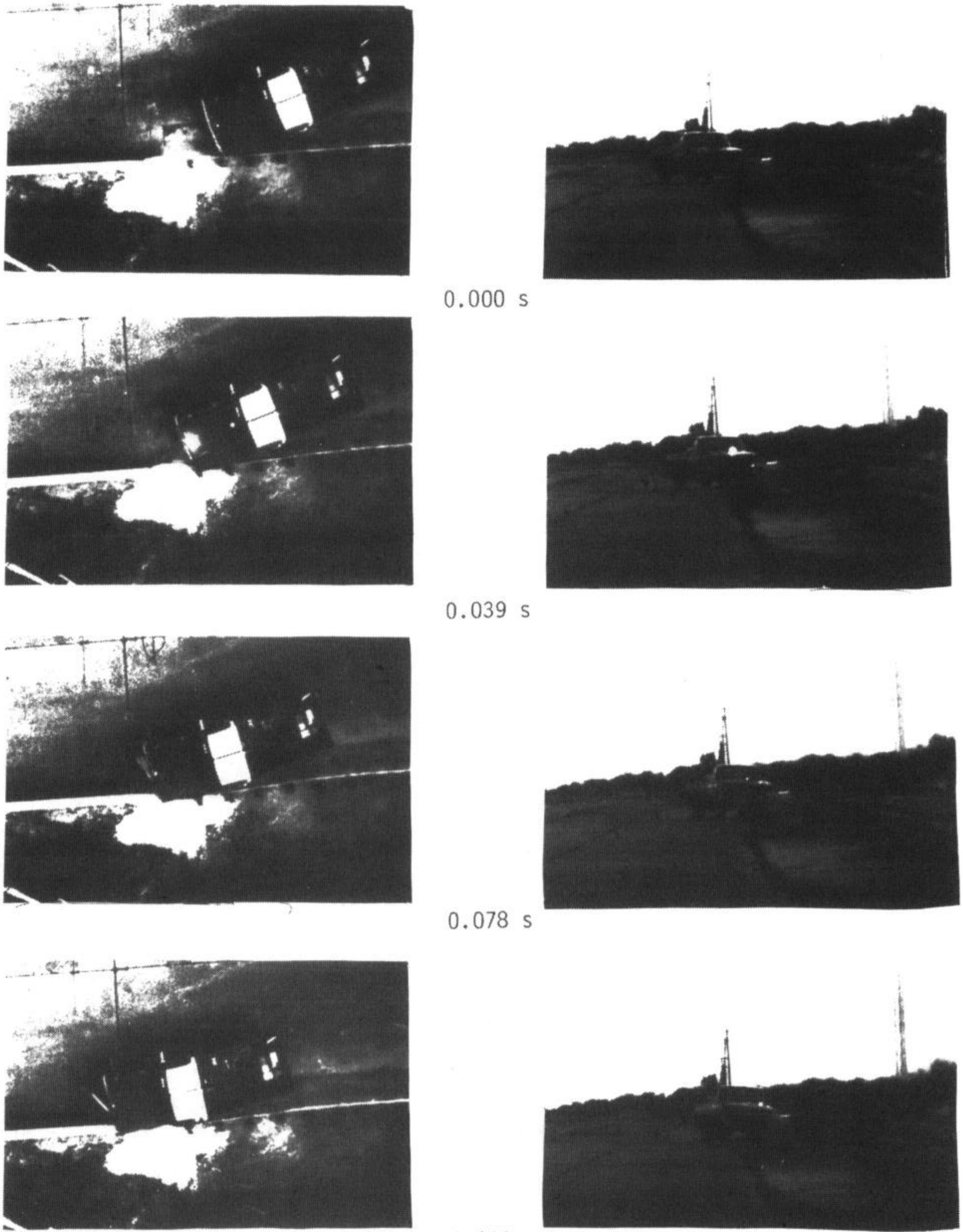
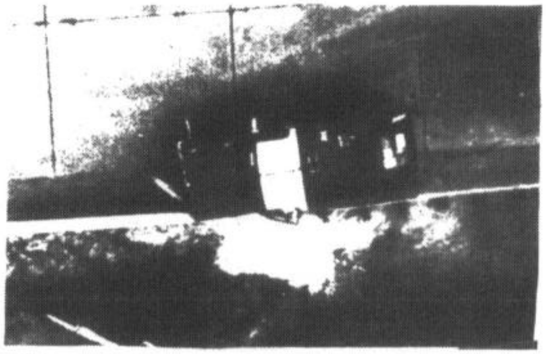
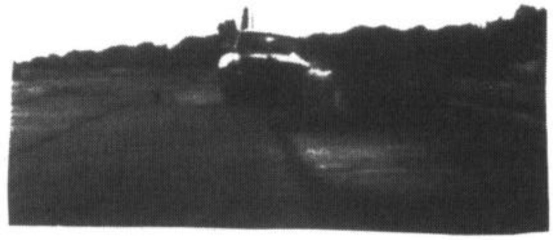
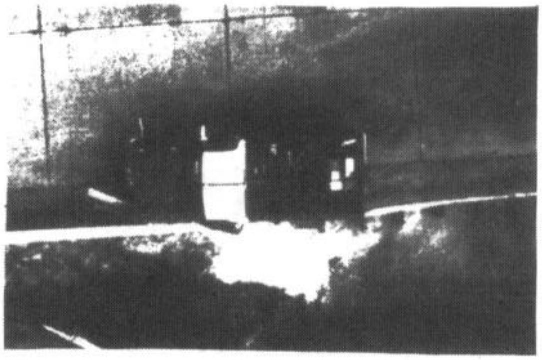


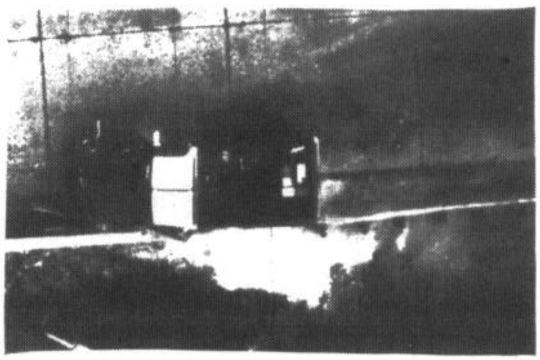
Figure 43. Sequential photographs for test 7069-21 (overhead and frontal views).

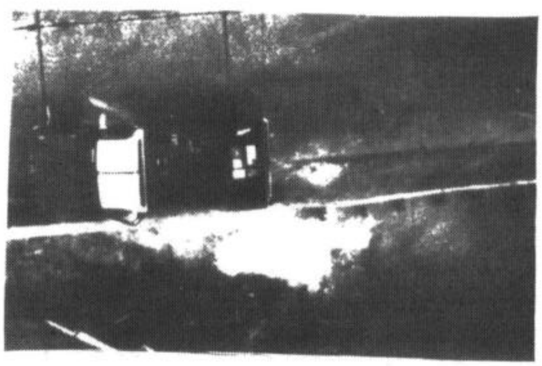
0.157 s




0.209 s




0.261 s




0.314 s

Figure 43. Sequential photographs for test 7069-21 (overhead and frontal views continued).

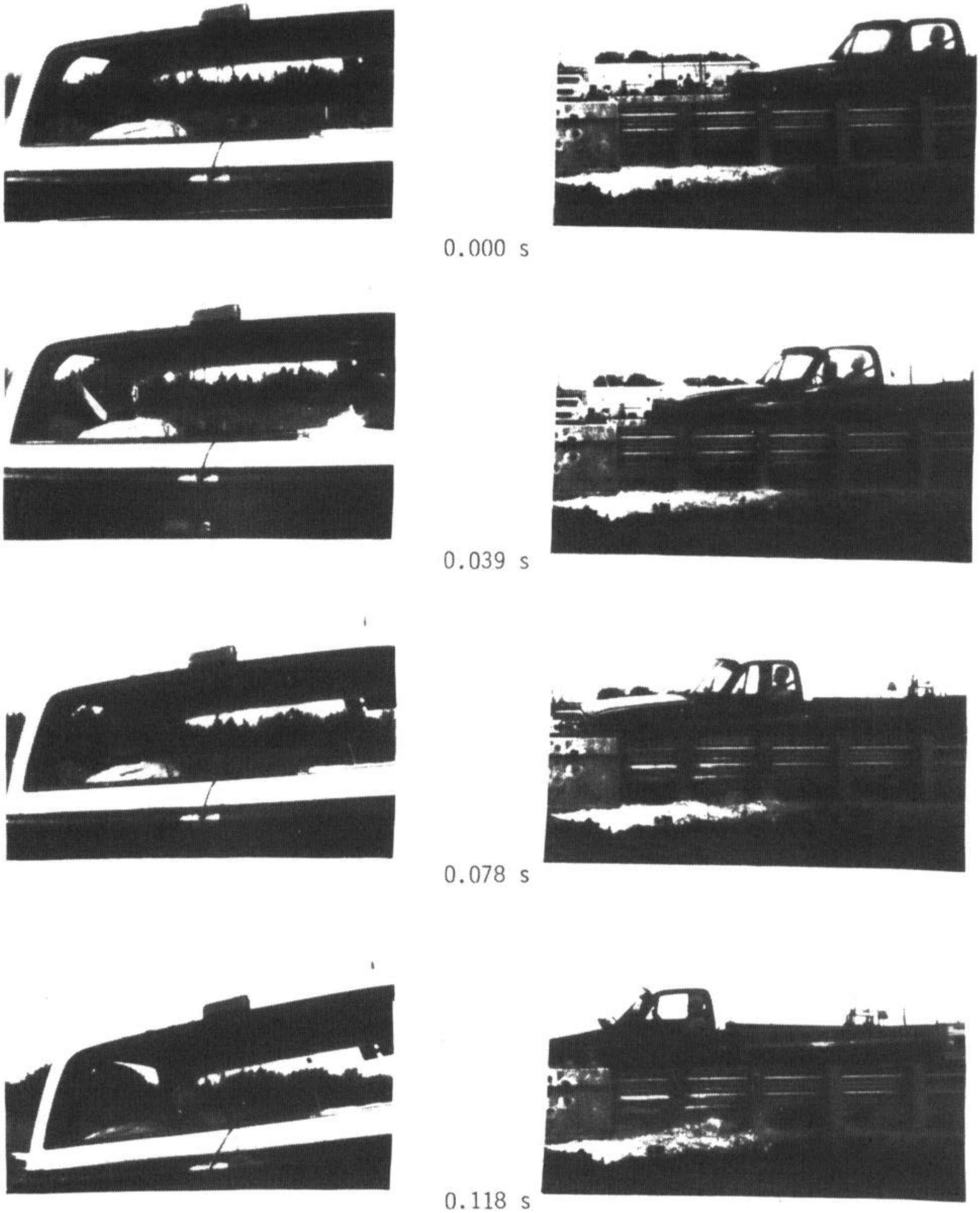
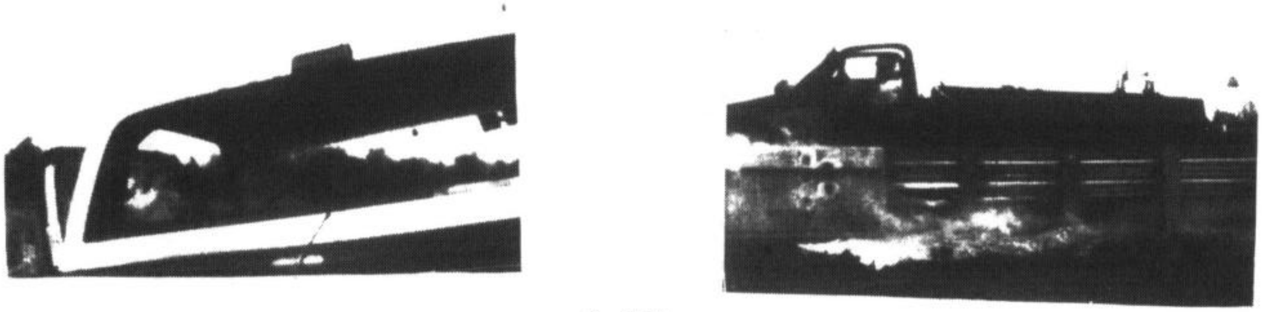
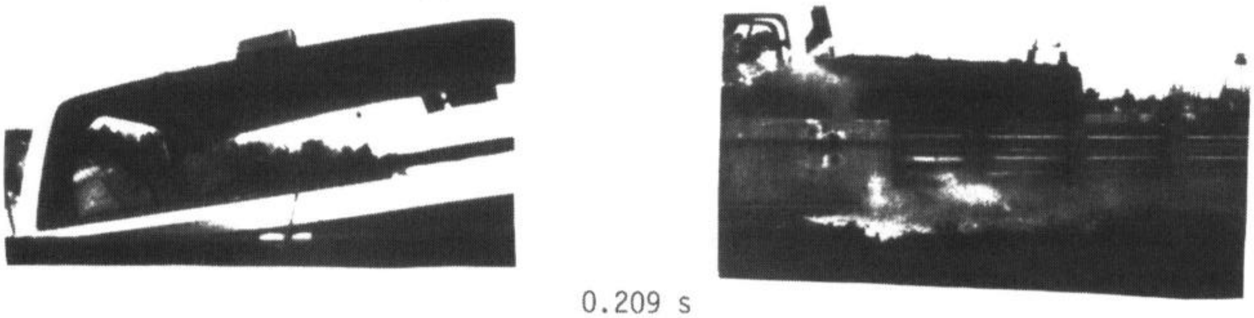


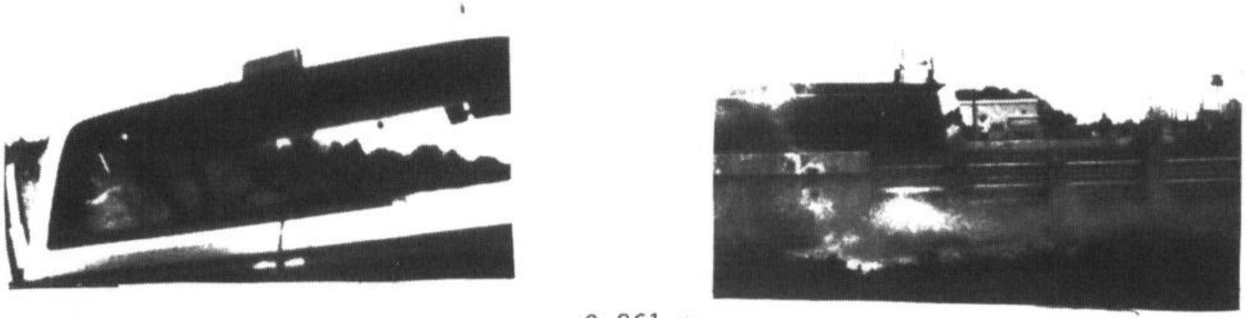
Figure 44. Sequential photographs for test 7069-21
(interior and rear of transition views).



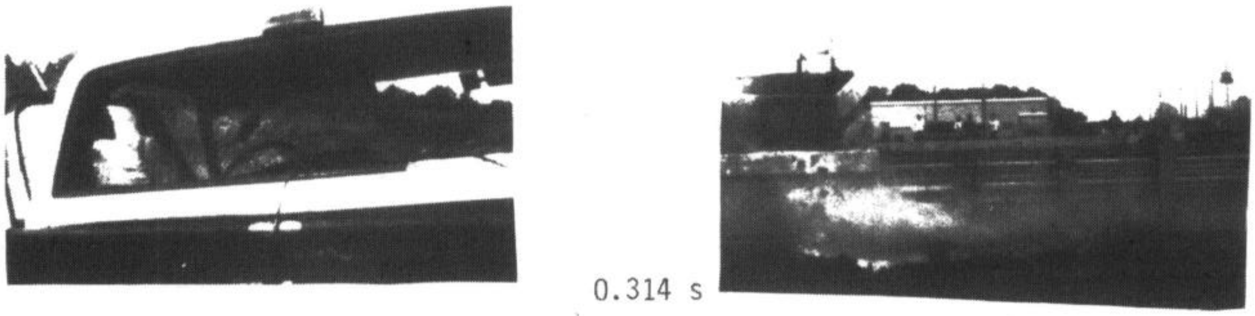
0.157 s



0.209 s

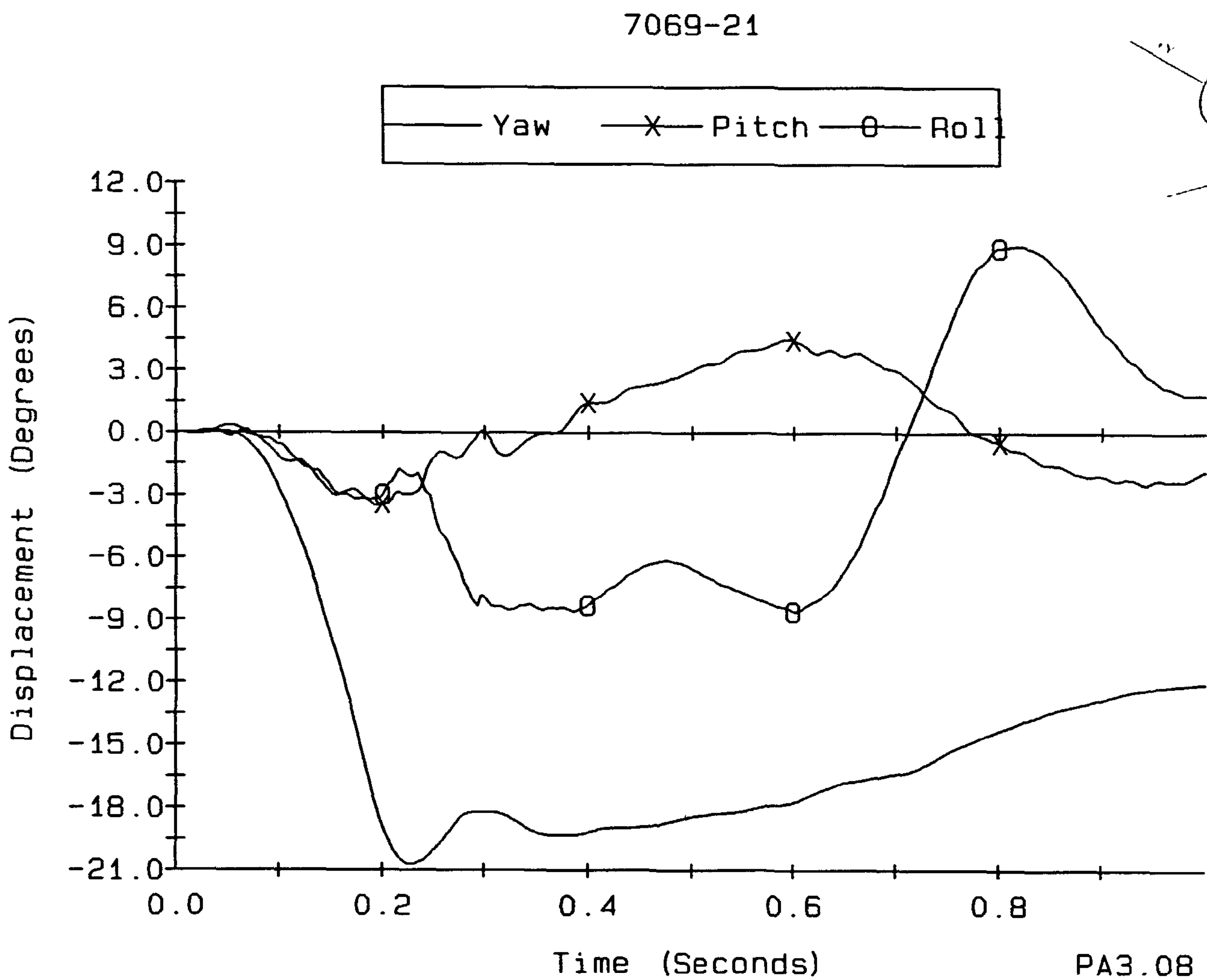


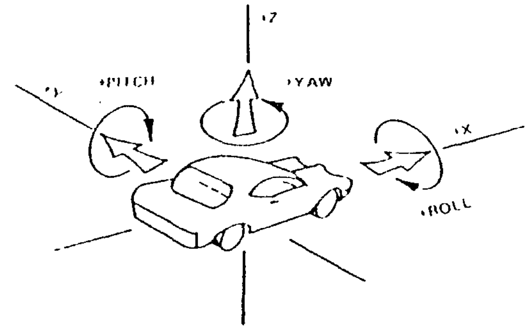
0.261 s



0.314 s

Figure 44. Sequential photographs for test 7069-21
(interior and rear of transition views continued).





Axes are vehicle fixed.
Sequence for determining
orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 45. Vehicle angular displacements for test 7069-21.

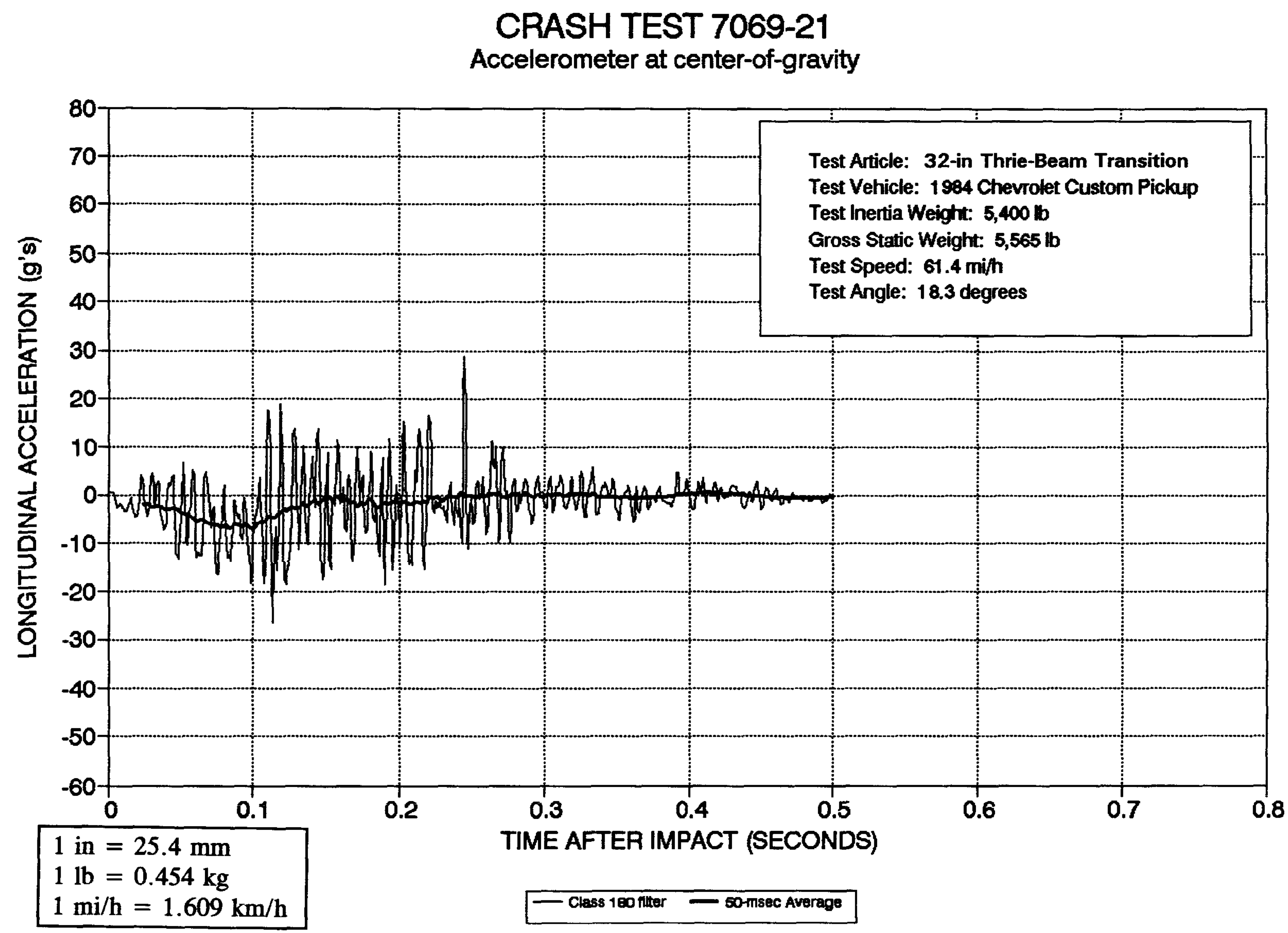


Figure 46. Vehicle longitudinal accelerometer trace for test 7069-21 (accelerometer located at center-of-gravity).

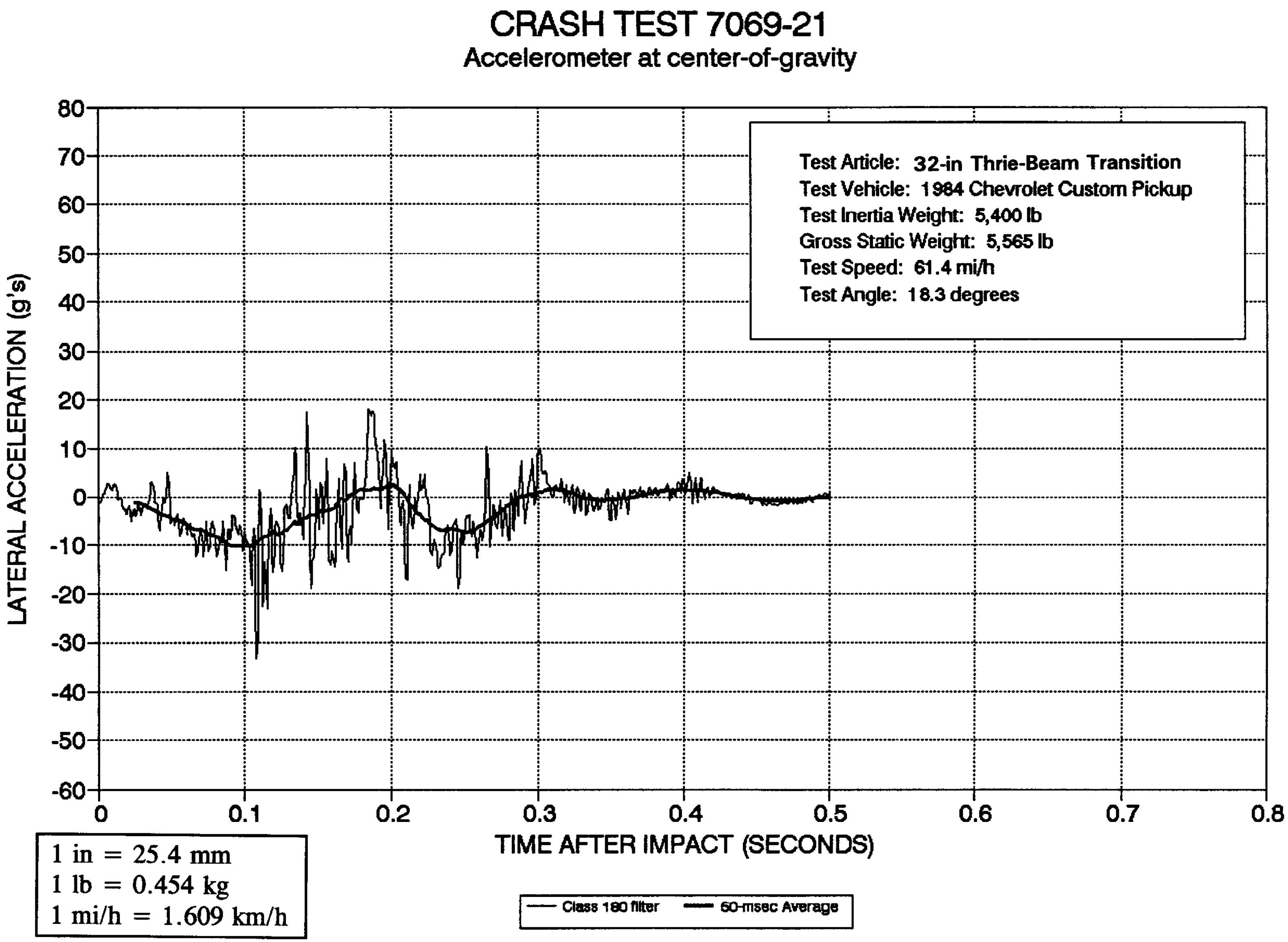
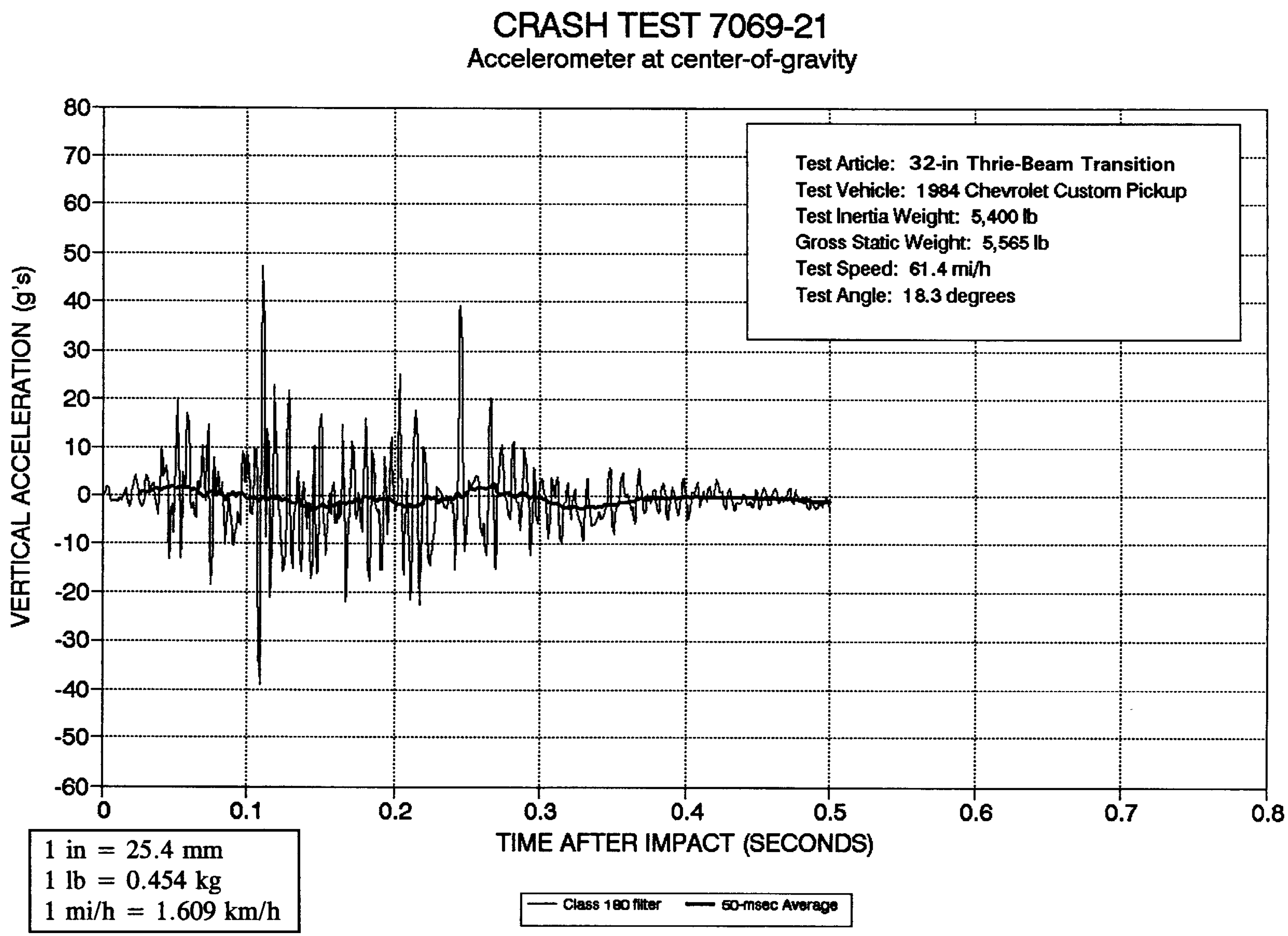


Figure 47. Vehicle lateral accelerometer trace for test 7069-21 (accelerometer located at center-of-gravity).



1 in = 25.4 mm
1 lb = 0.454 kg
1 mi/h = 1.609 km/h

Figure 48. Vehicle vertical accelerometer trace for test 7069-21 (accelerometer located at center-of-gravity).

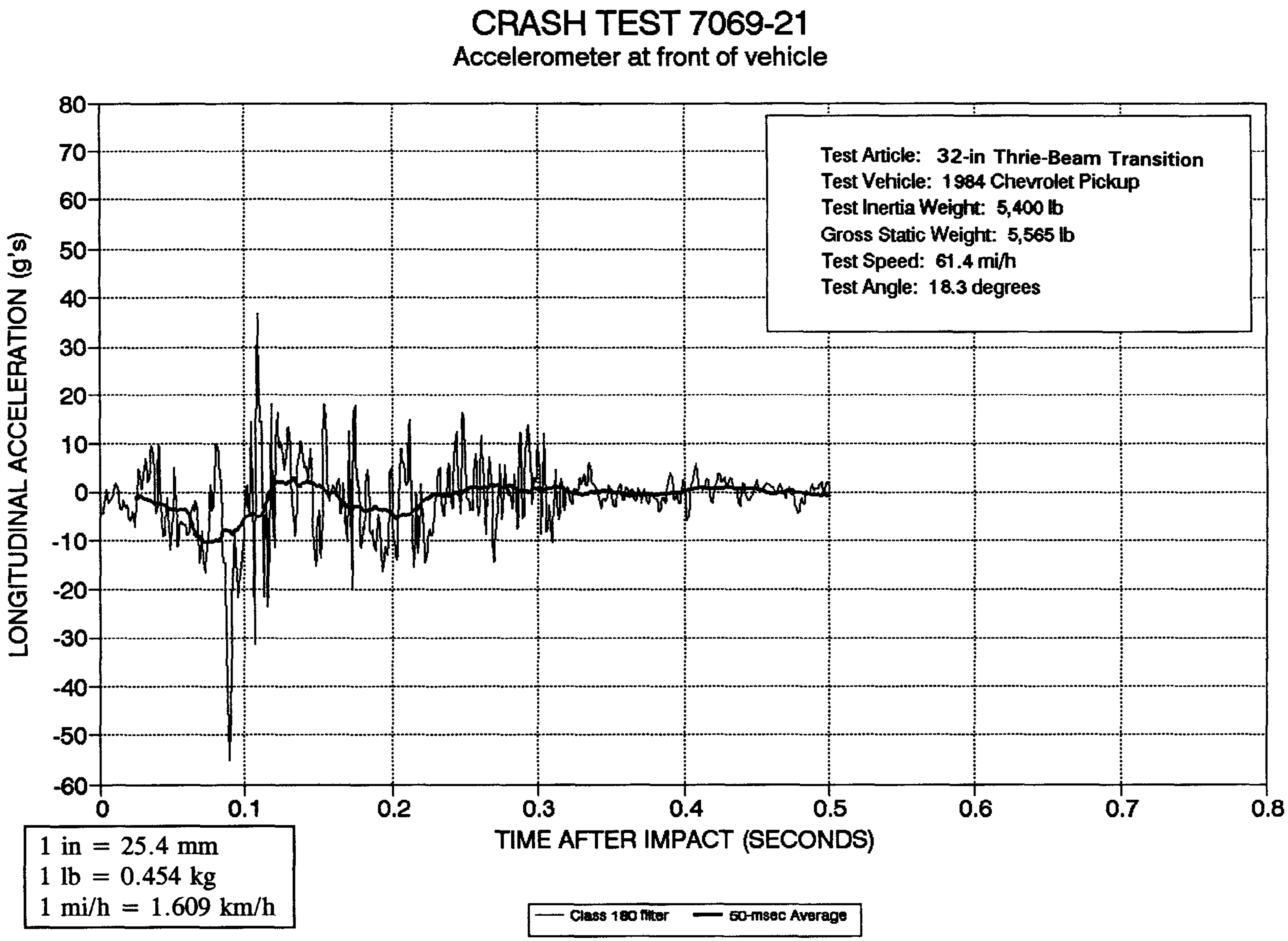


Figure 49. Vehicle longitudinal accelerometer trace for test 7069-21 (accelerometer located at front of vehicle).

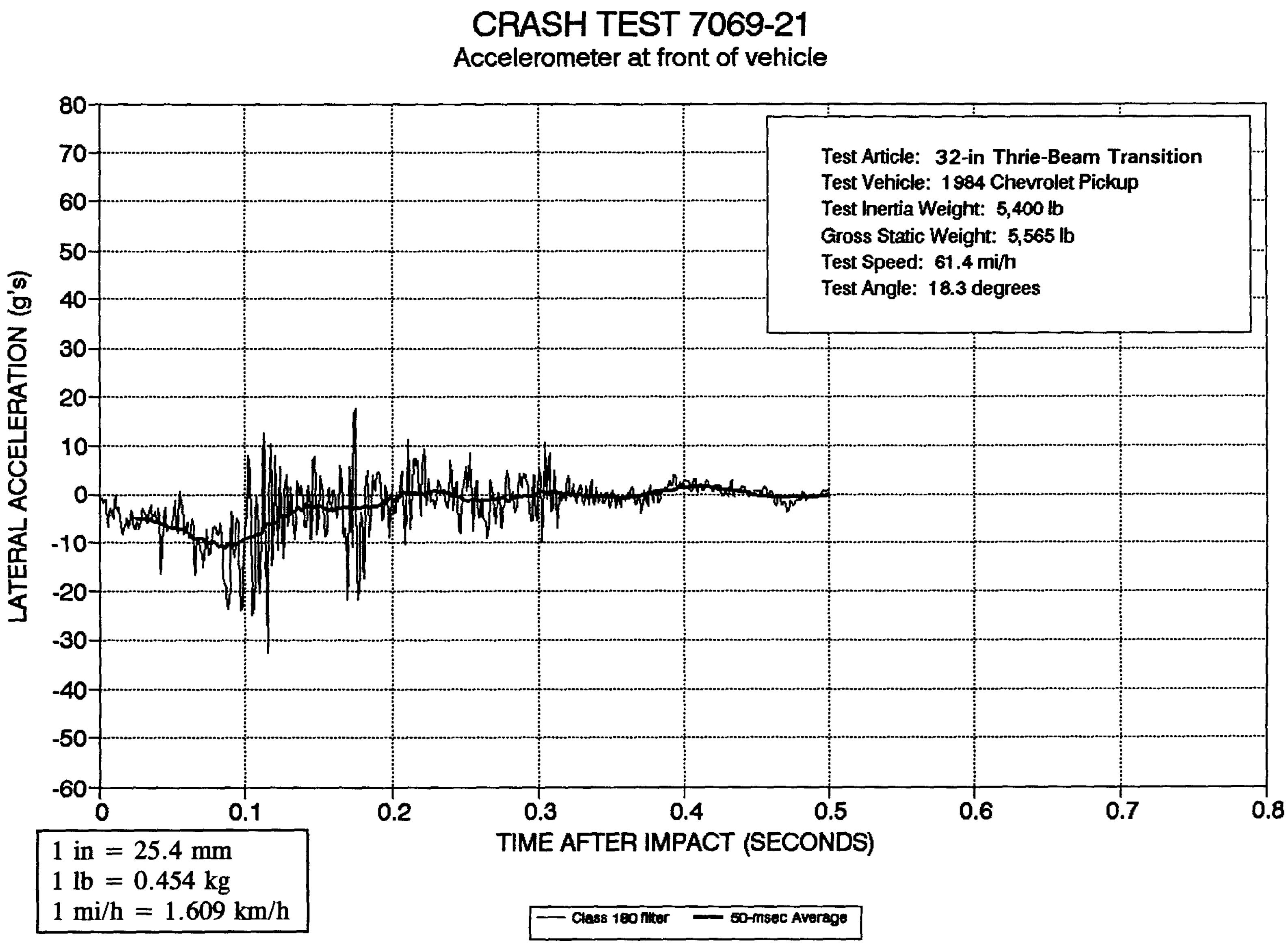


Figure 50. Vehicle lateral accelerometer trace for test 7069-21 (accelerometer located at front of vehicle).

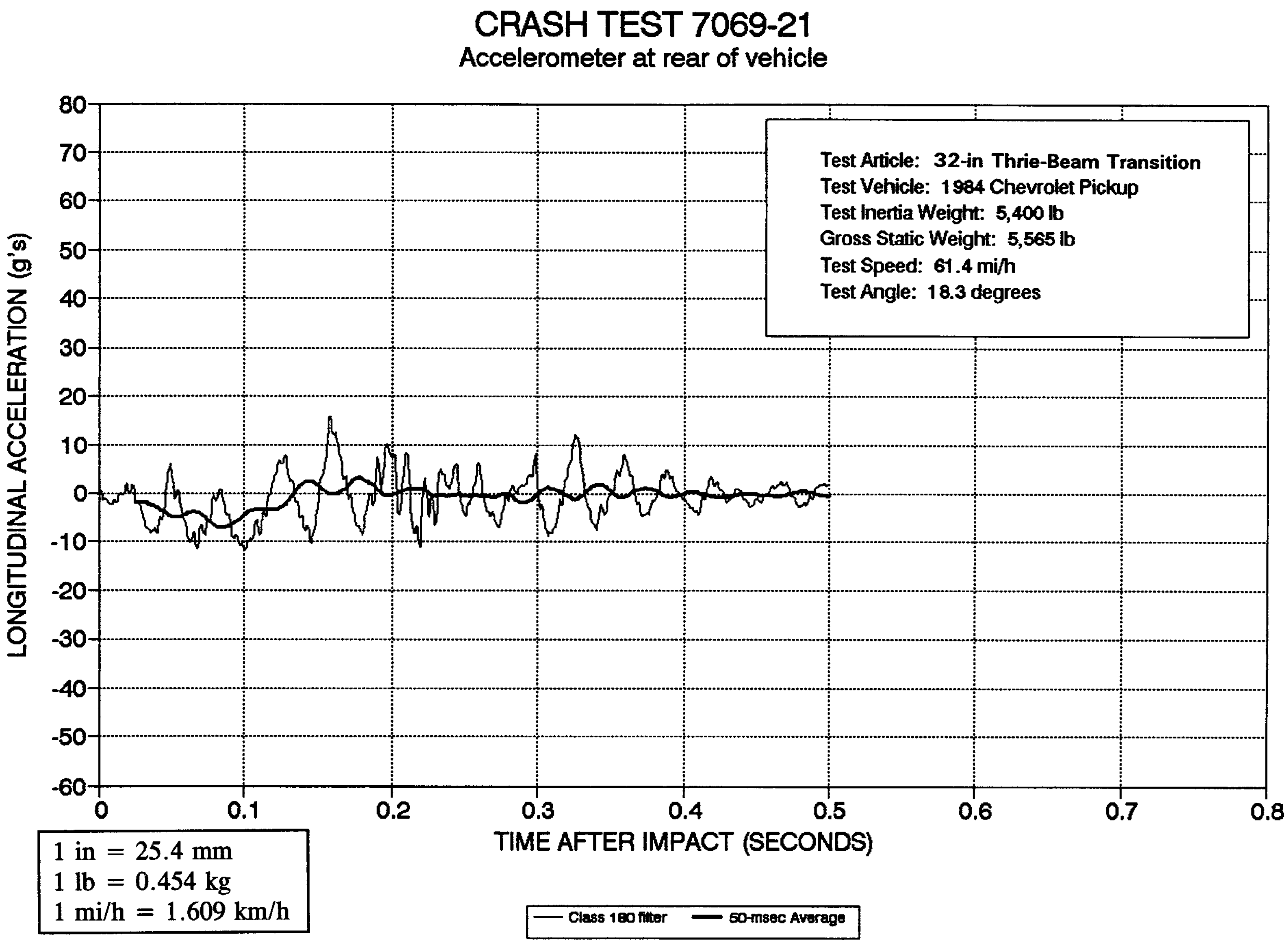


Figure 51. Vehicle longitudinal accelerometer trace for test 7069-21 (accelerometer located at rear of vehicle).

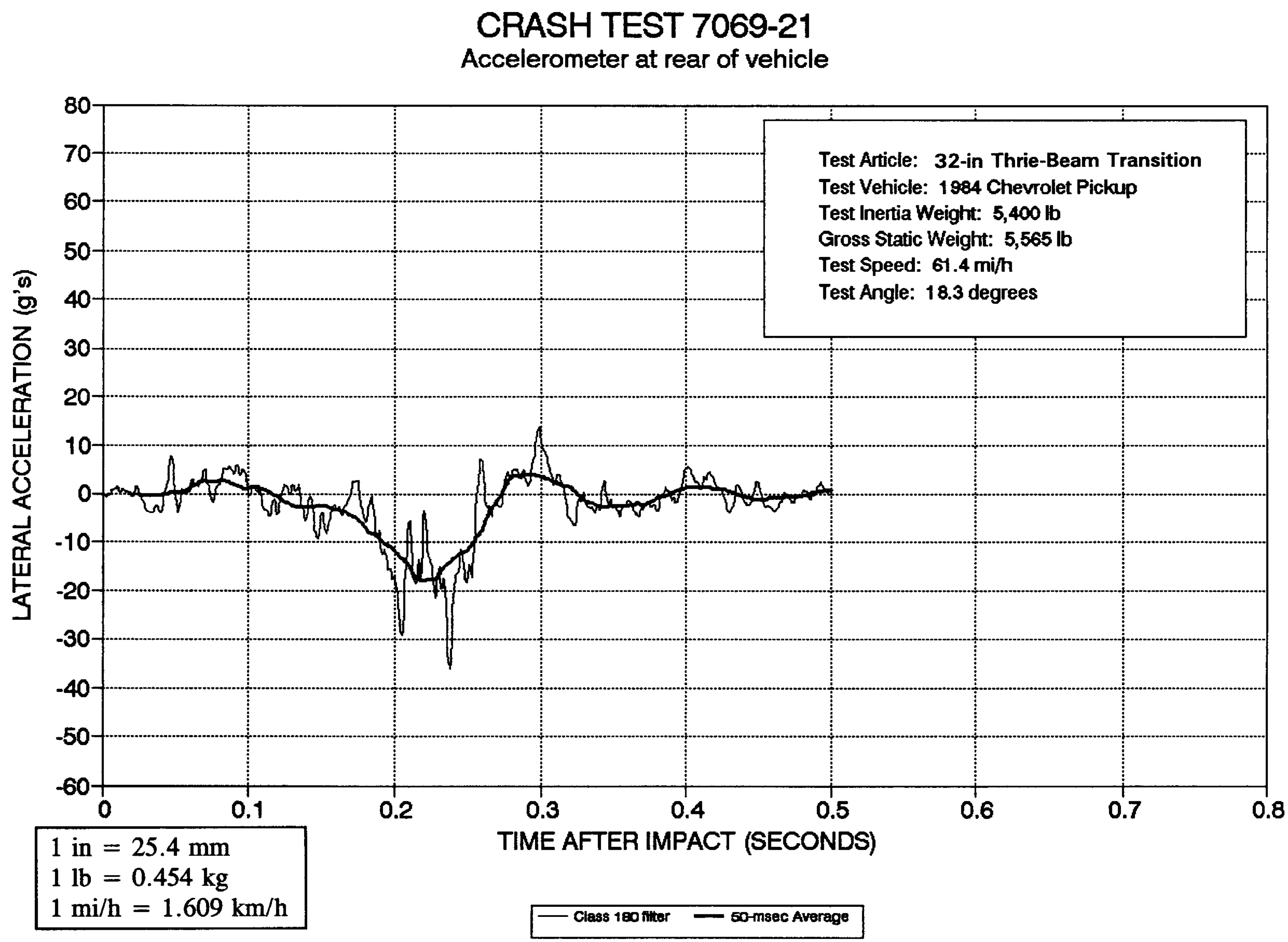


Figure 52. Vehicle lateral accelerometer trace for test 7069-21 (accelerometer located at rear of vehicle).

TEST 7069-29

Test Description

A 1981 Ford single-unit truck (figures 53 and 54) was used for the crash test. The empty weight of the vehicle was 10,790 lb (4 899 kg) and its test inertia weight was 18,000 lb (8 172 kg). The height to the lower edge of the vehicle bumper was 18.5 in (470 mm) and it was 30.5 in (775 mm) to the top of the bumper. Additional dimensions and information on the test vehicle are given in figure 55. The vehicle was directed into the 32-in (813-mm) thrie-beam transition (figure 56) using the cable reverse tow and guidance system and was released to be free-wheeling and unrestrained just prior to impact. The vehicle impacted the transition 11 ft (3.4 m) from the end of the concrete parapet at a speed of 51.6 mi/h (83.0 km/h) and the angle of impact was 14.6 degrees.

At 0.071 s after impact the front wheels received a steer input to the left and the vehicle began to redirect at 0.118 s after impact. At 0.155 s the vehicle contacted the end of the concrete parapet, and at 0.226 s a severe steer input to the vehicle occurred. By 0.262 s the vehicle was traveling parallel to the transition at a speed of 48.9 mi/h (78.7 km/h), and at 0.341 s the rear of the vehicle impacted the transition. The vehicle lost contact with the terminal connector at 0.585 s. However, the van-box remained in contact with the top of the concrete parapet until 1.718 s after impact. As the vehicle continued forward, it began to yaw clockwise and roll counterclockwise. The brakes were applied at 2.5 s after impact and the vehicle subsequently came to rest on its left side 165 ft (50 m) down and 45 ft (14 m) in front of the point of impact.

As can be seen in figure 57, the transition received moderate damage. Maximum lateral permanent deformation to the transition was 10.0 in (254 mm). The end of the concrete parapet where the terminal connector attached was cracked as shown in figure 58. Damage to the terminal connector is shown in figure 59. The vehicle was in contact with the transition installation for 18.5 ft (5.6 m).

The vehicle sustained damage to the left side as shown in figure 60. Maximum crush at the left front corner at bumper height was 13.0 in (330 mm). The floorpan was pushed inward and the cab was bent and twisted. The windshield and rear glass were broken. The frame at the rear axle was bent and the van-box was twisted and torn. The driver side window was broken out and the door was jammed. Also, damage was done to the front bumper, hood, left front quarter panel, and outer left rear tire and rim. The right door was also jammed.

Test Results

Impact speed was 51.6 mi/h (83.0 km/h) and the angle of impact was 14.6 degrees. The speed of the vehicle at time of parallel was 48.9 mi/h (78.7 km/h) and the coefficient of friction was 0.08. Data from the accelerometer located at the center-of-gravity were digitized for evaluation and occupant risk factors were computed as follows. In the longitudinal direction, occupant impact velocity was 9.4 ft/s (2.9 m/s) at 0.396 s, the highest 0.010-s average ridedown acceleration was -4.1 g between 0.449 and 0.459 s, and the maximum 0.050-s average acceleration was -2.3 g between 0.416 and 0.466 s. Lateral occupant impact velocity was 11.9 ft/s (3.6 m/s) at 0.253 s, the highest 0.010-s occupant ridedown acceleration was 9.0 g between 0.423 and 0.433 s, and the maximum 0.050-s average acceleration was 6.3 g between 0.404 and 0.454 s. These data and other pertinent information from the test are summarized in figure 61 and table 5. Sequential photographs are shown in figures 62 and 63. Vehicular angular displacements are displayed in figure 64. Vehicular accelerations versus time traces filtered with SAE J211 filters are presented in figures 65 through 71.

Conclusions

The 32-in (813-mm) thrie-beam transition contained the test vehicle with minimal lateral movement of the transition. There was no intrusion of railing components into the occupant compartment; however, the floorpan was slightly deformed into the vehicle. The vehicle remained upright and relatively stable during the collision. However, after exiting the test installation, the vehicle rolled onto its left side 45 ft (14 m) forward of the transition. The transition redirected the vehicle with the effective coefficient of friction rated as good.

The 1989 AASHTO guide specifications sets forth limits for occupant risk factors for tests with 1,800-lb (817-kg) and 5,400-lb (2 452-kg) vehicles but does not require the 18,000-lb (8 172-kg) vehicles to meet these limits.[1] The risk factors were computed for this test and reported for information only. The vehicle trajectory at loss of contact indicated some intrusion into adjacent traffic lanes. For more details, see figure 61 and table 5.

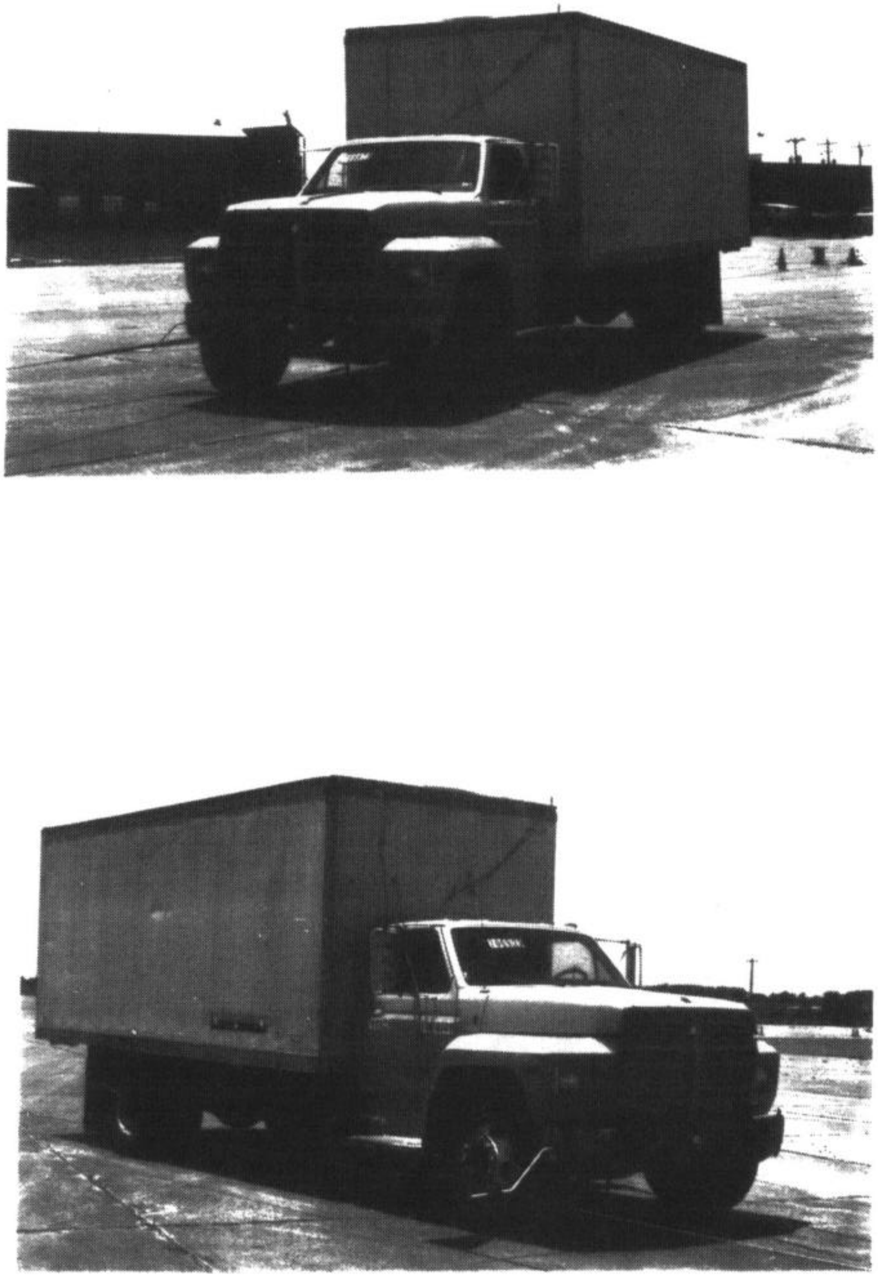
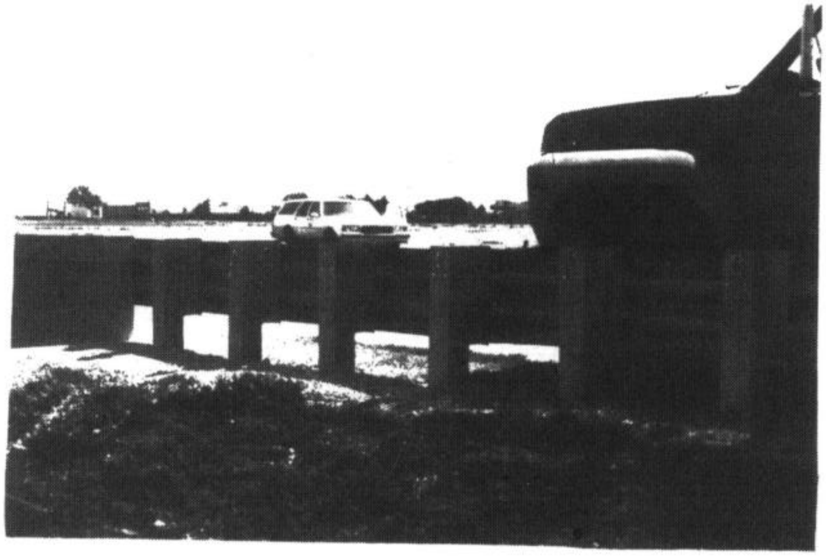


Figure 53. Vehicle before test 7069-29.



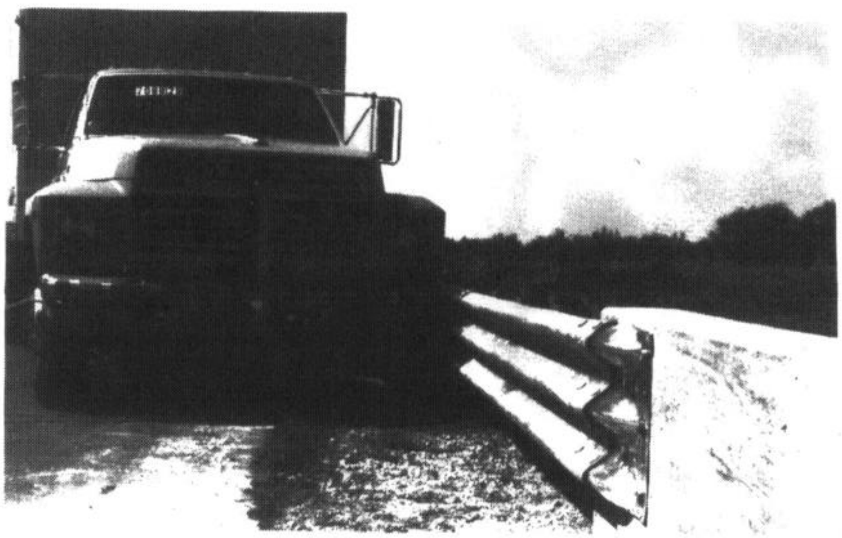
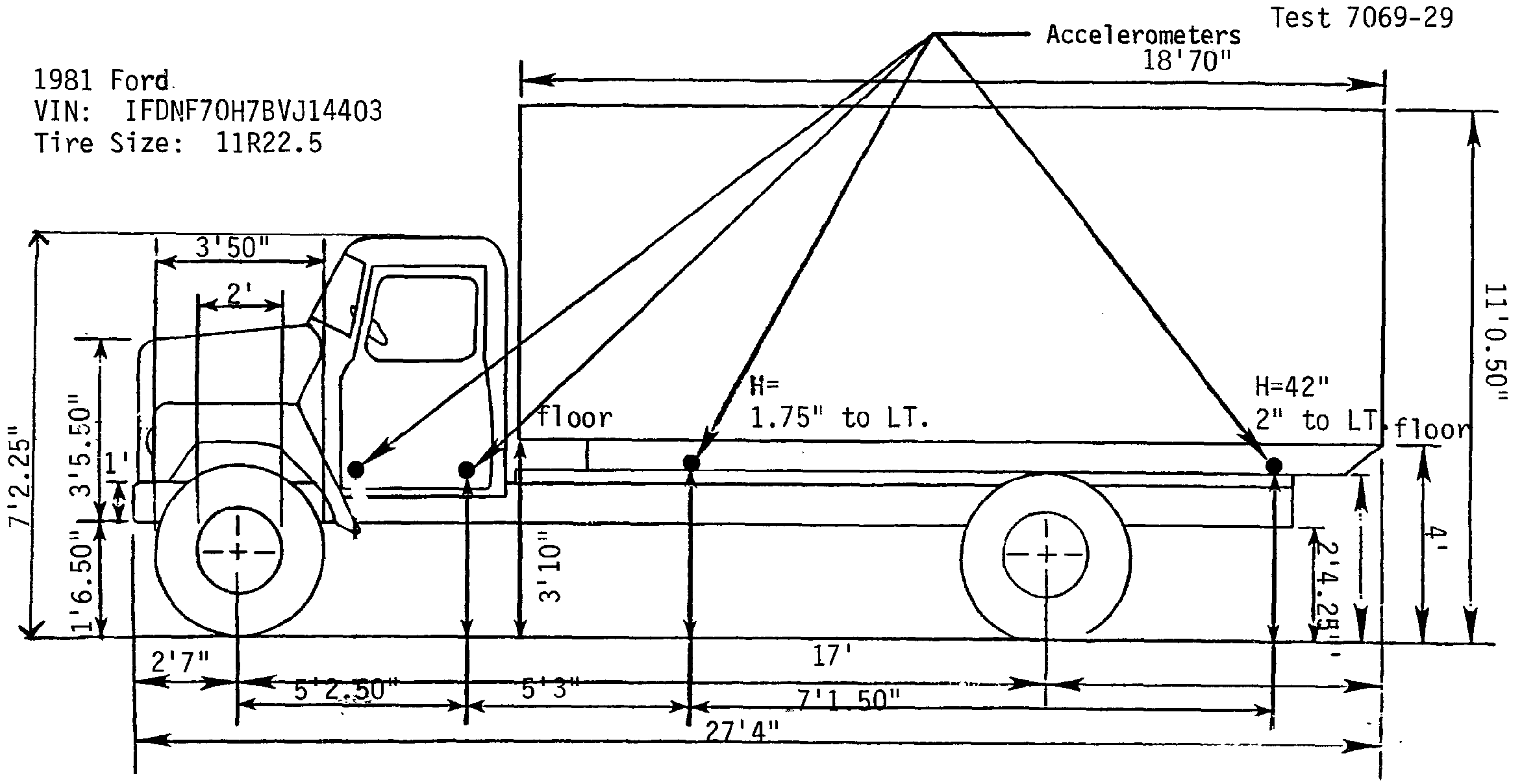


Figure 54. Vehicle/transition geometrics for test 7069-29.



EMPTY WEIGHTS

Weight on Front Axle : LF 2270 RF 2540
Weight on Rear Axle : LR 2880 RR 3100

TOTAL EMPTY WEIGHT : 10790

LOADED WEIGHTS

Weight on Front Axle : LF 3580 RF 3440
Weight on Rear Axle : RF 5350 RR 5630

TOTAL LOADED WEIGHT : 18000

1 in = 25.4 mm
1 lb = 0.454 kg

Figure 55. Vehicle properties for test 7069-29.

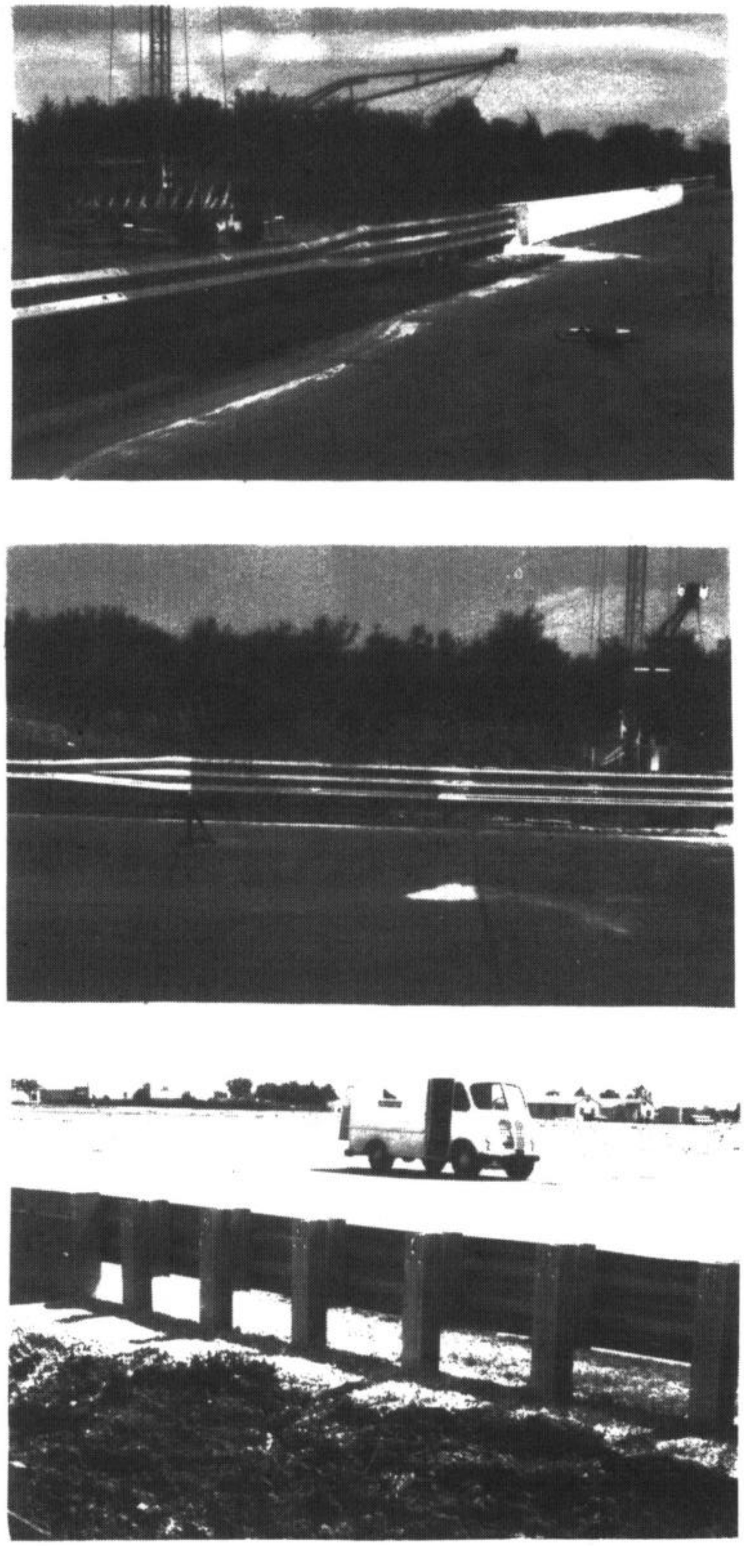


Figure 56. 32-in (813-mm) thrie-beam transition before test 7069-29.

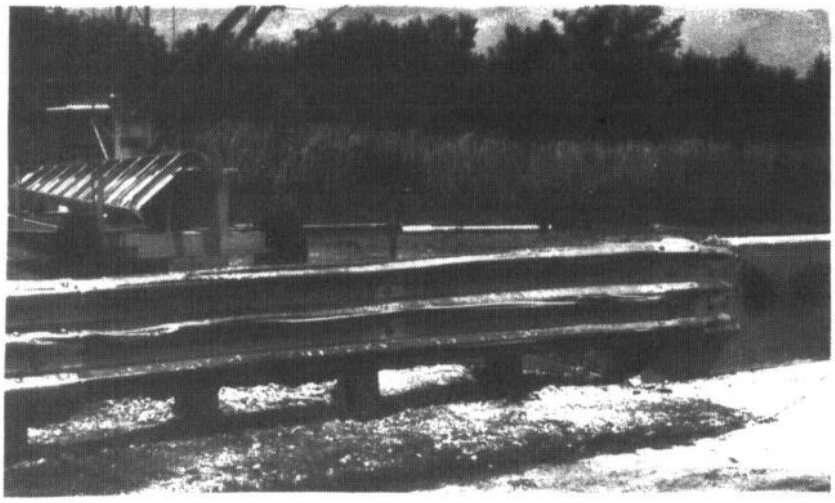
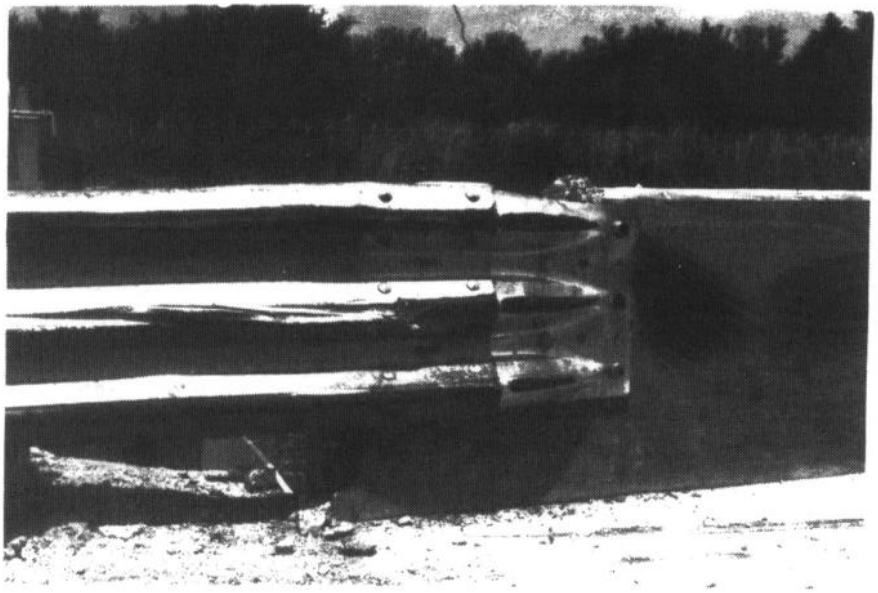


Figure 57. 32-in (813-mm) thrie beam transition after test 7069-29.



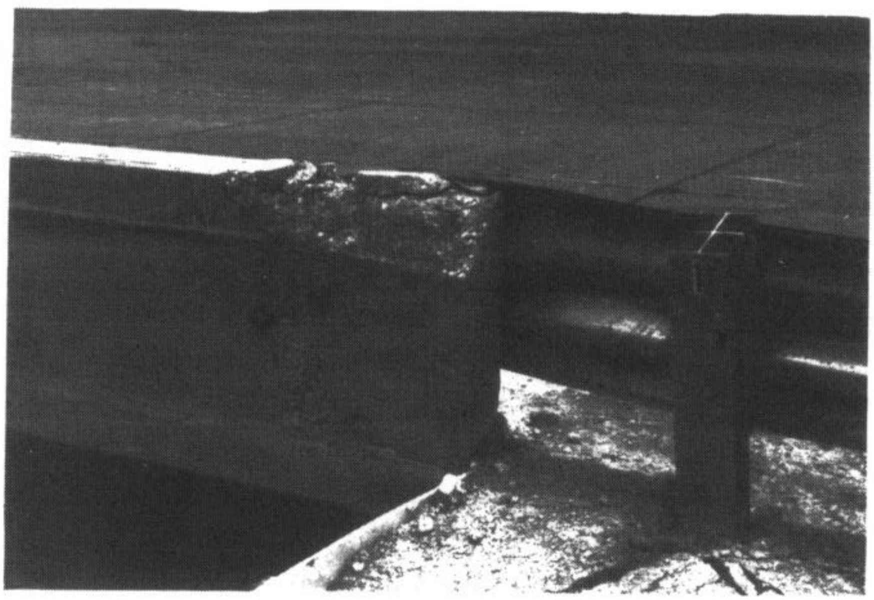


Figure 58. Damage at terminal connection to concrete parapet after test 7069-29.

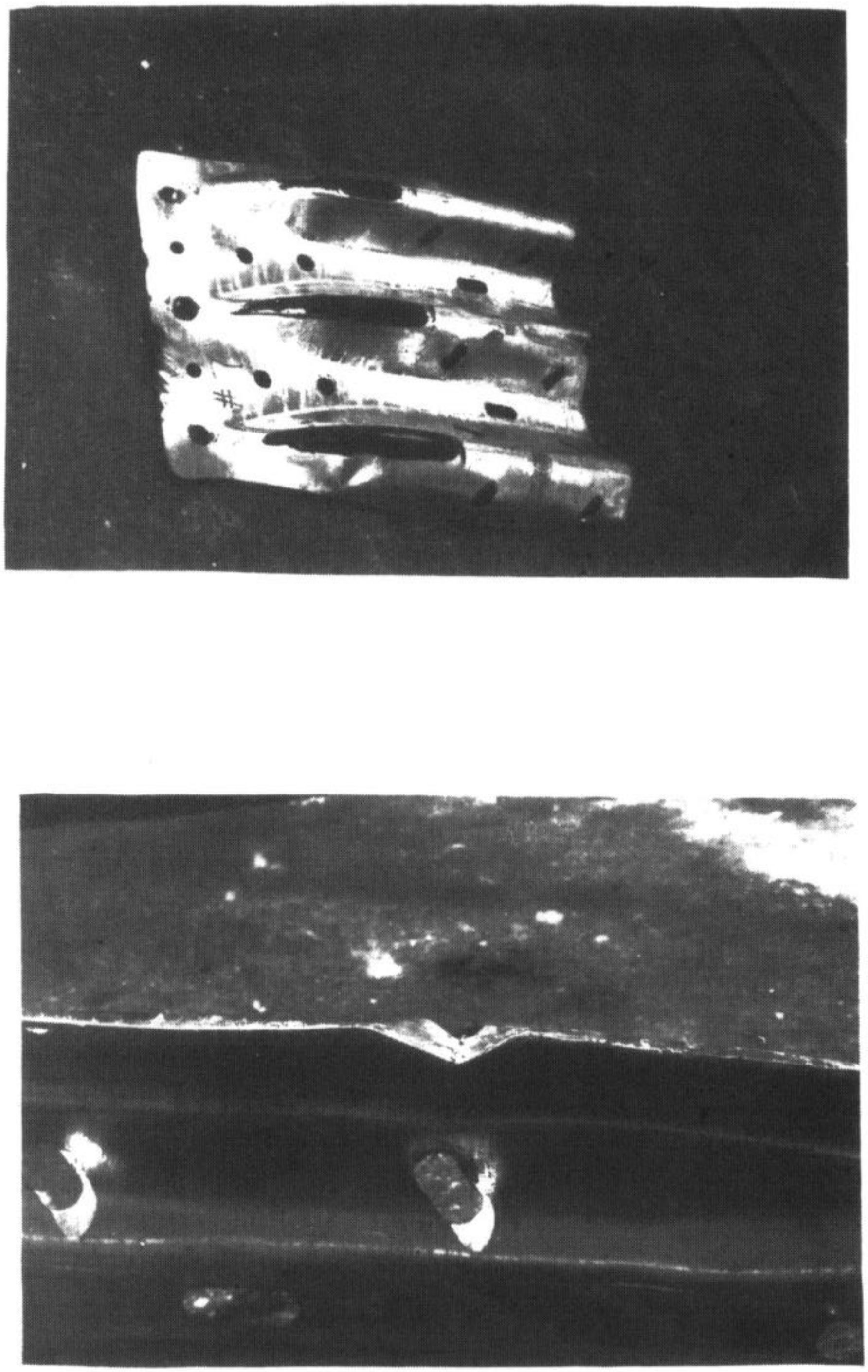


Figure 59. Damage to terminal connector
(after removal from concrete parapet) after test 7069-29.

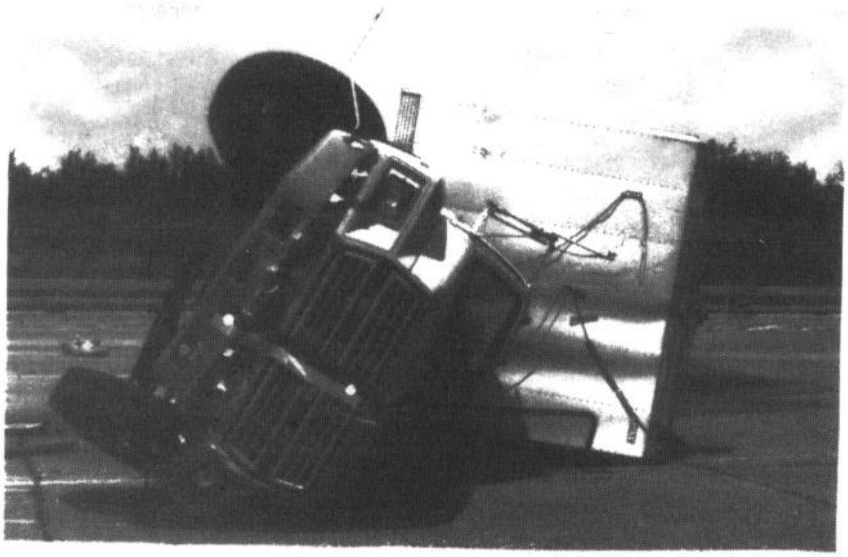
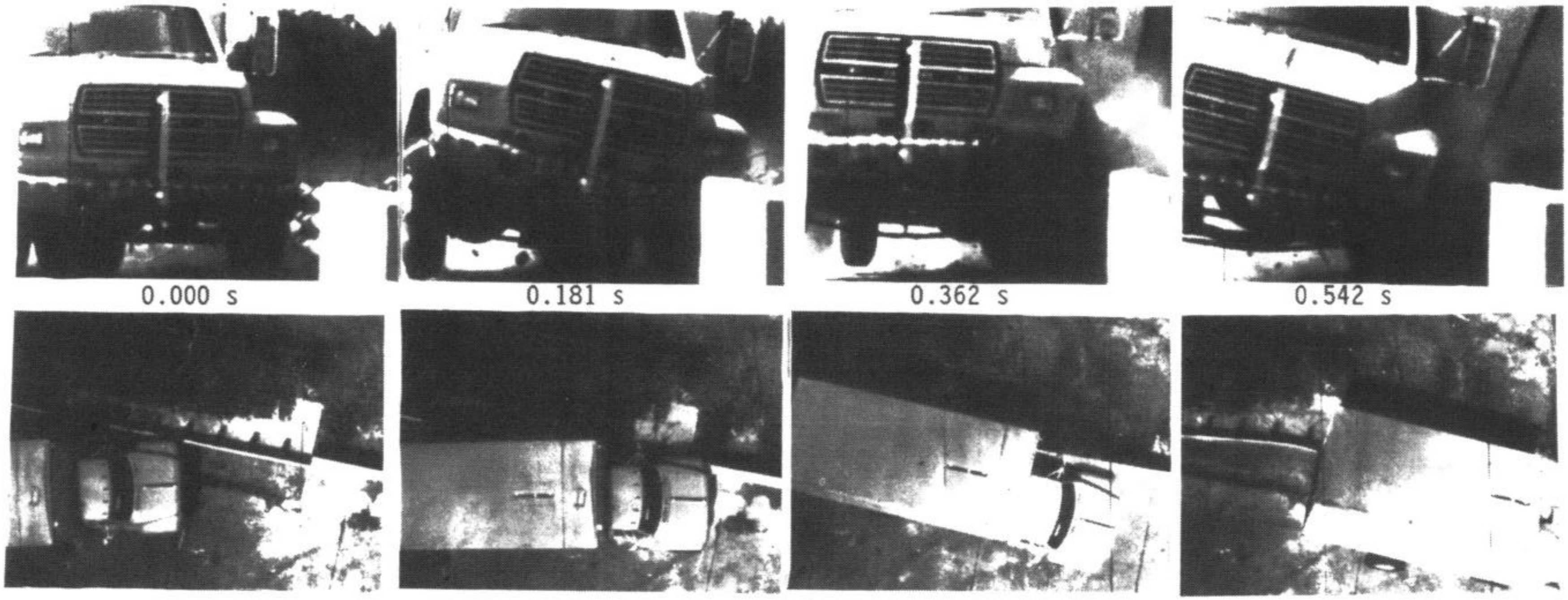
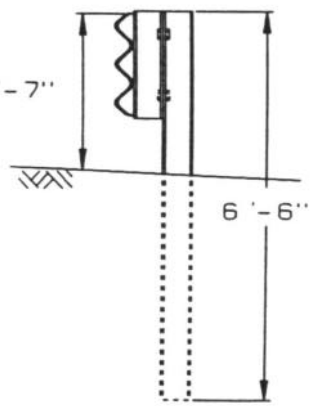


Figure 60. Vehicle after test 7069-29.





(1 in = 25.4 mm)

Test No.	7069-29
Date	06/05/92
Test Installation . . .	32-in (813-mm) Thrie-Beam Transition
Installation Length . .	85 ft (26 m)
Test Vehicle	1981 Ford Single-Unit Truck
Vehicle Weight	
Empty Weight	10,790 lb (4,899 kg)
Test Inertia	18,000 lb (8,172 kg)
Maximum Vehicle Crush	13.0 in (330-mm)
Max. Perm. Deform. . . .	10.0 in (254 mm)

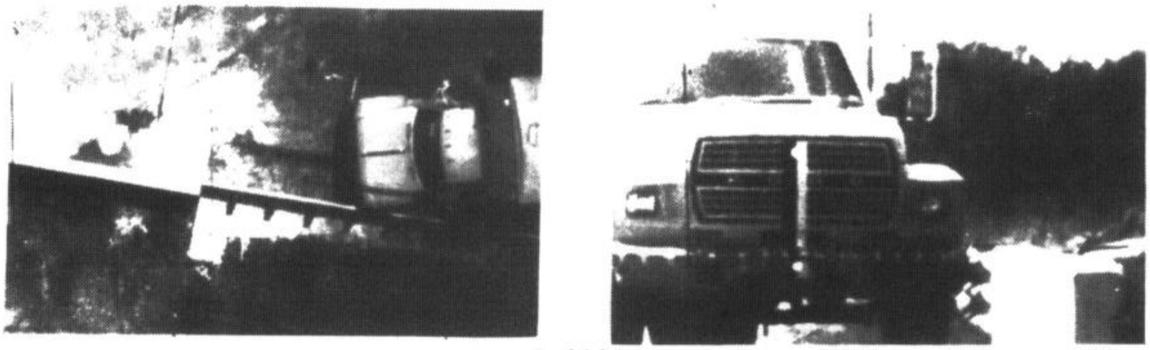
Impact Speed. . . .	51.6 mi/h (83.0 km/h)
Impact Angle. . . .	14.6 deg
Speed at Parallel .	48.9 mi/h (78.7 km/h)
Exit Speed	N/A
Exit Trajectory . .	11 deg
Vehicle Accelerations (Max. 0.050-sec Avg) at c.g.	
Longitudinal. . .	-2.3 g
Lateral	6.3 g
Occupant Impact Velocity at true c.g.	
Longitudinal. . .	9.4 ft/s (2.9 m/s)
Lateral	11.9 ft/s (3.6 m/s)
Occupant Ridedown Accelerations	
Longitudinal. . .	-4.1 g
Lateral	9.0 g

Figure 61. Summary of results for test 7069-29.

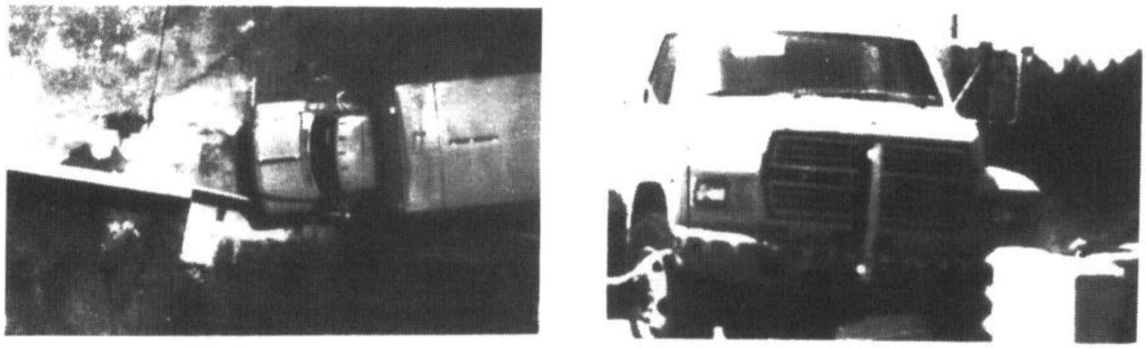
Table 5. Evaluaiton of crash test no. 7069-29.
{32-in (813-mm) thrie-beam transition (18,000 lb (8 172 kg)|51.6 mi/h (83.0 km/h)|14.6 degrees]}

	CRITERIA		TEST RESULTS		PASS/FAIL*
A.	Must contain vehicle		Vehicle was contained		Pass
B.	Debris shall not penetrate passenger compartment		No debris penetrated passenger compartment		Pass
C.	Passenger compartment must have essentially no deformation		Minimal deformation		Pass
D.	Vehicle must remain upright		Vehicle remained upright during test. Rolled after exiting test site.		N/A
E.	Must smoothly redirect the vehicle		Vehicle was smoothly redirected		N/A
F.	Effective coefficient of friction				
	μ	Assessment	μ	Assessment	
	0 - .25	Good	.08	Good	N/A
	.26 - .35	Fair			
	> .35	Marginal			
G.	Shall be less than				
	Occupant Impact Velocity - ft/s (m/s)		Occupant Impact Velocity - ft/s (m/s)		N/A
	Longitudinal	Lateral	Longitudinal	Lateral	
	30 (9.2)	25 (7.6)	9.4 (2.9)	11.9 (3.6)	
	Occupant Ridedown Accelerations - g's		Occupant Ridedown Accelerations - g's		N/A
	Longitudinal	Lateral	Longitudinal	Lateral	
	15	15	-2.3	9.0	
H.	Exit angle shall be less than 12 degrees		Exit angle was 11 degrees		N/A

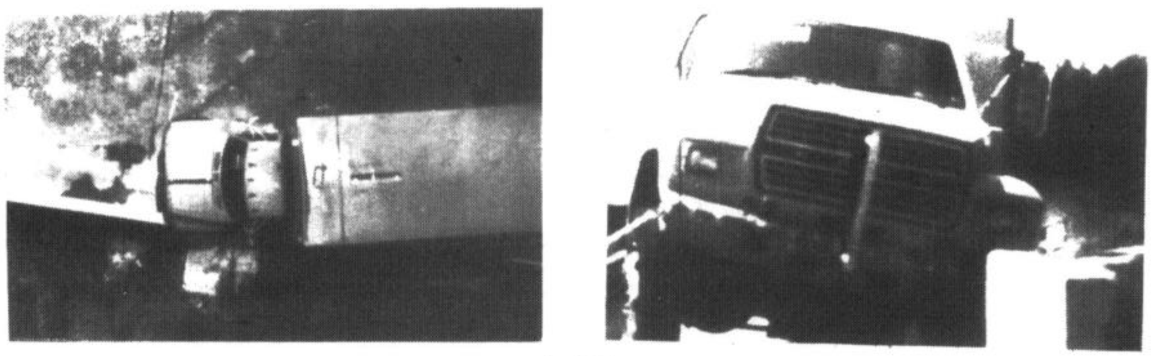
* A, B, and C are required. D, E, F, and H are desired. (See table 2)



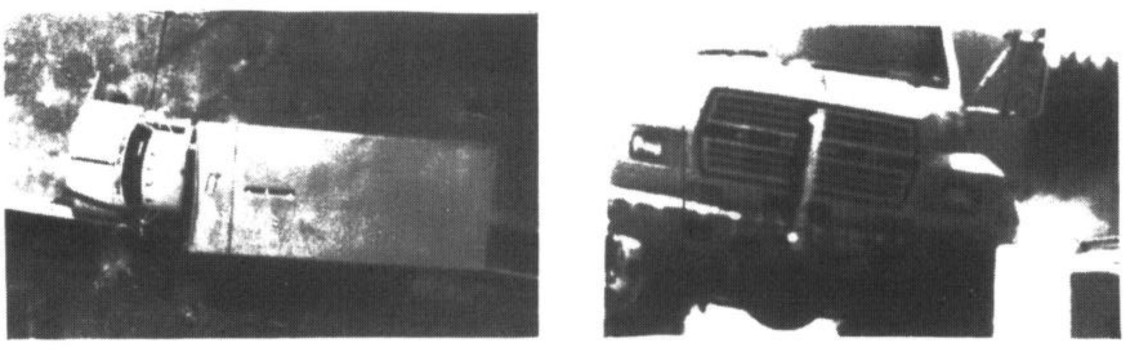
0.000 s



0.090 s

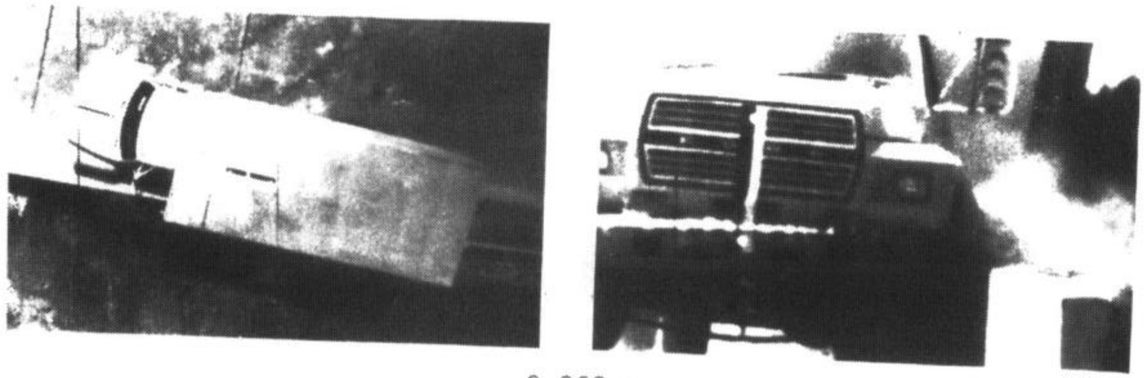


0.181 s

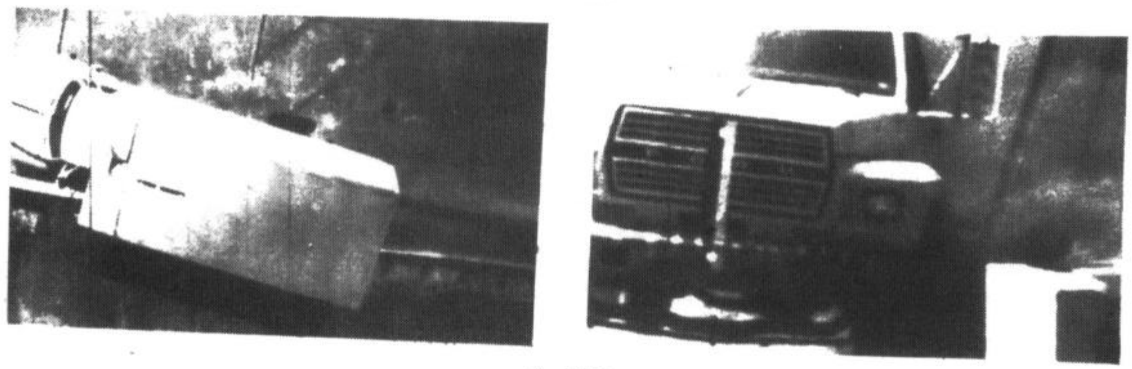


0.271 s

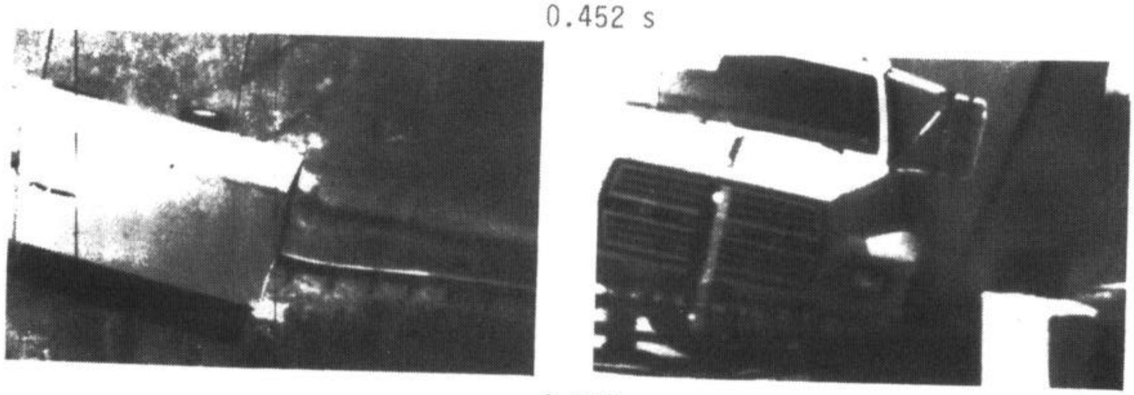
Figure 62. Sequential photographs for test 7069-29 (overhead and frontal views).



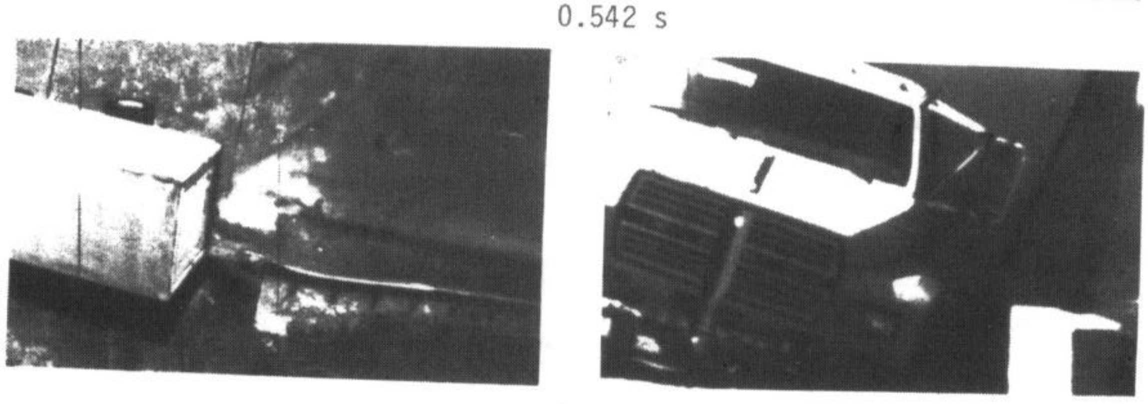
0.362 s



0.452 s



0.542 s



0.633 s

Figure 62. Sequential photographs for test 7069-29 (overhead and frontal views continued).

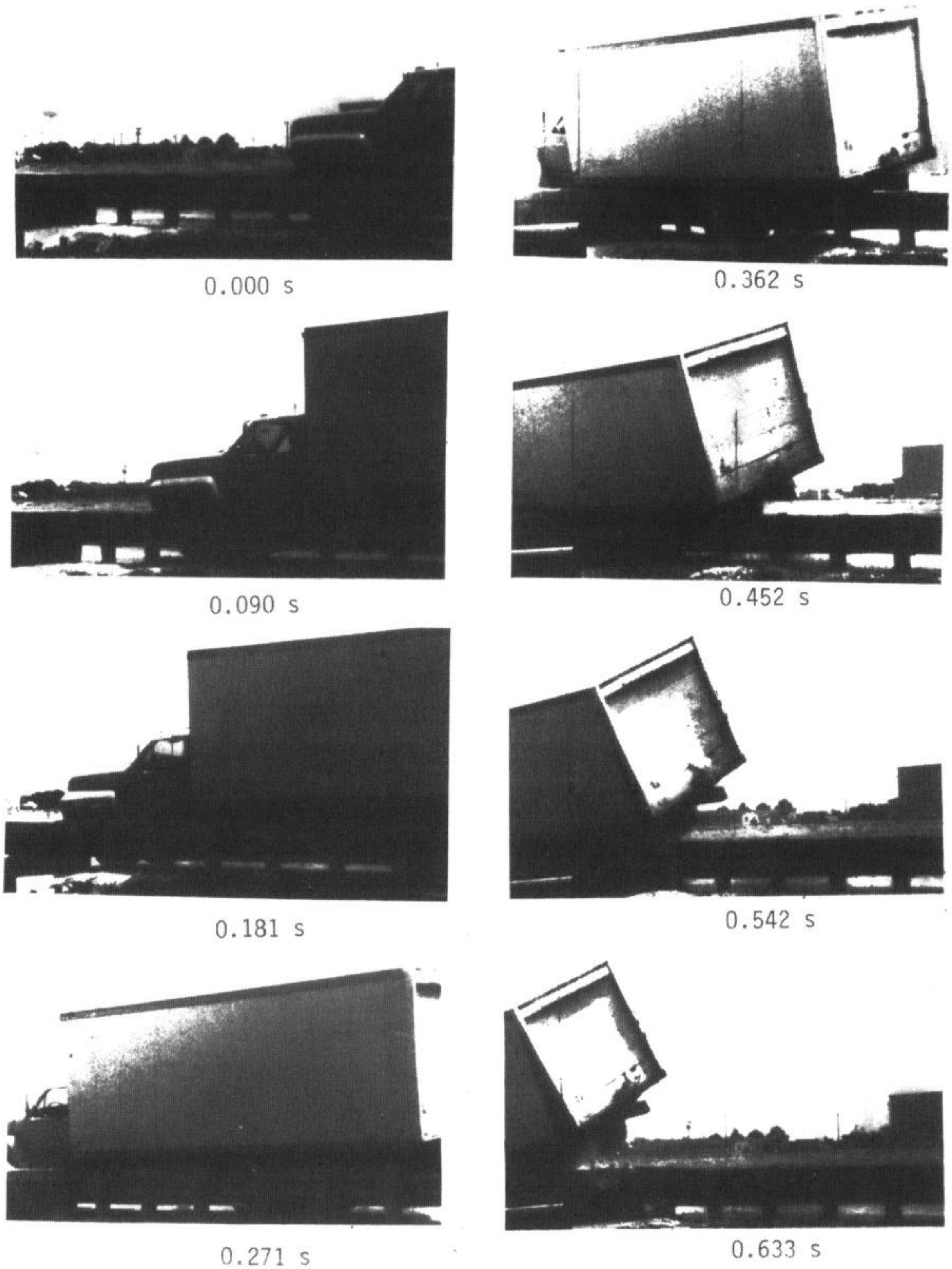


Figure 63. Sequential photographs for test 7069-29
(rear of transition view).

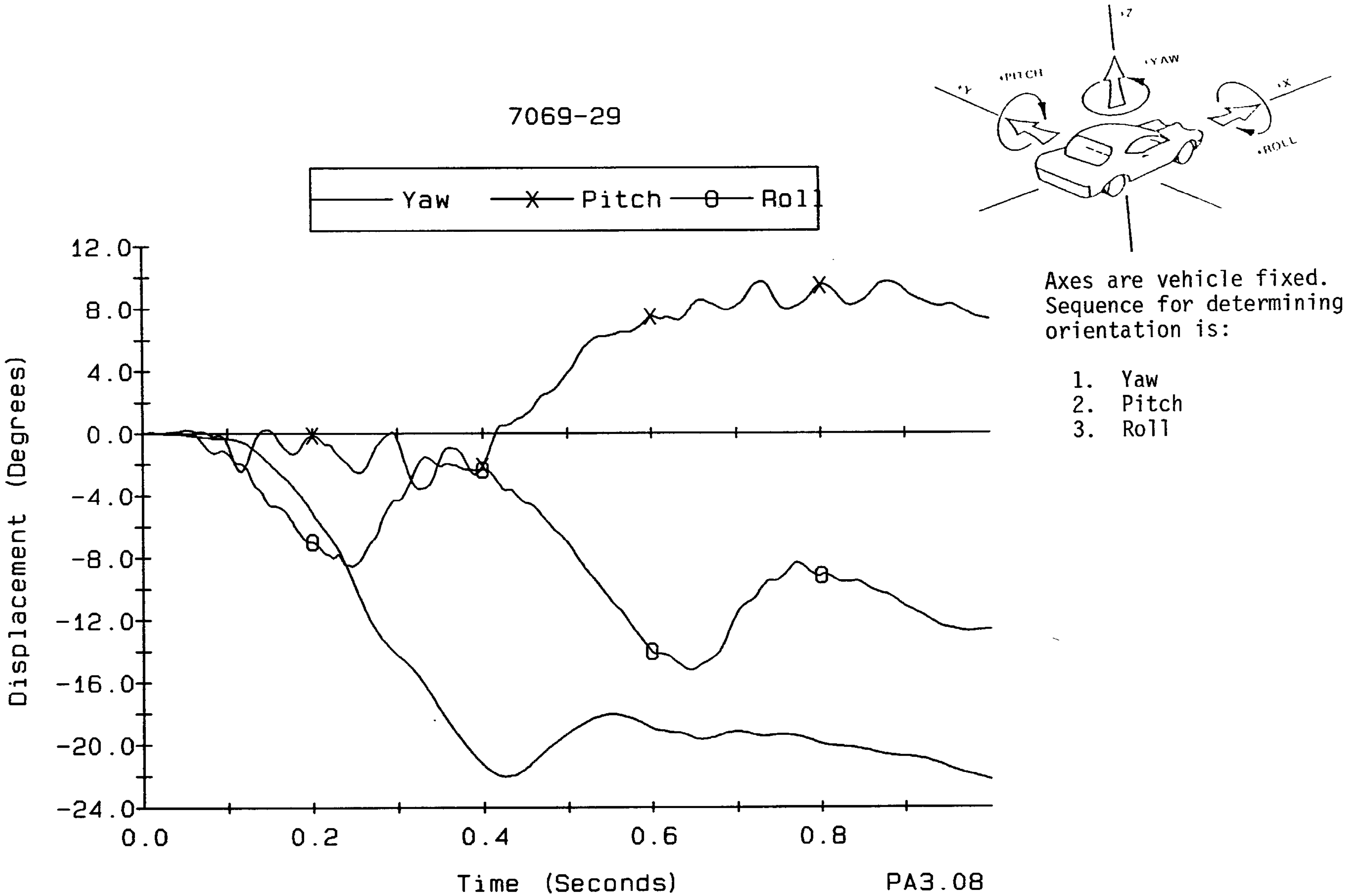


Figure 64. Vehicle angular displacements for test 7069-29.

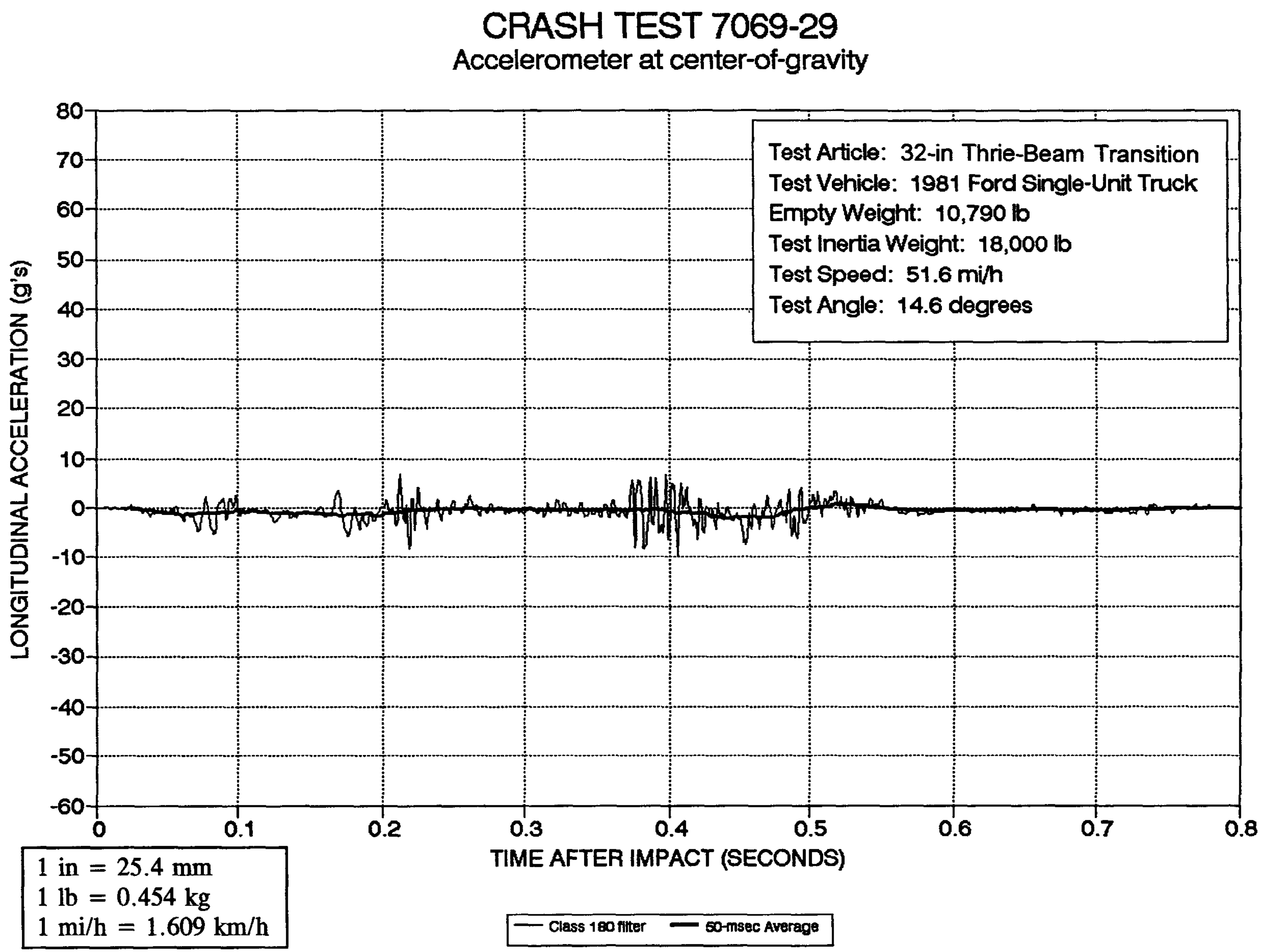


Figure 65. Vehicle longitudinal accelerometer trace for test 7069-29 (accelerometer located at center-of-gravity).

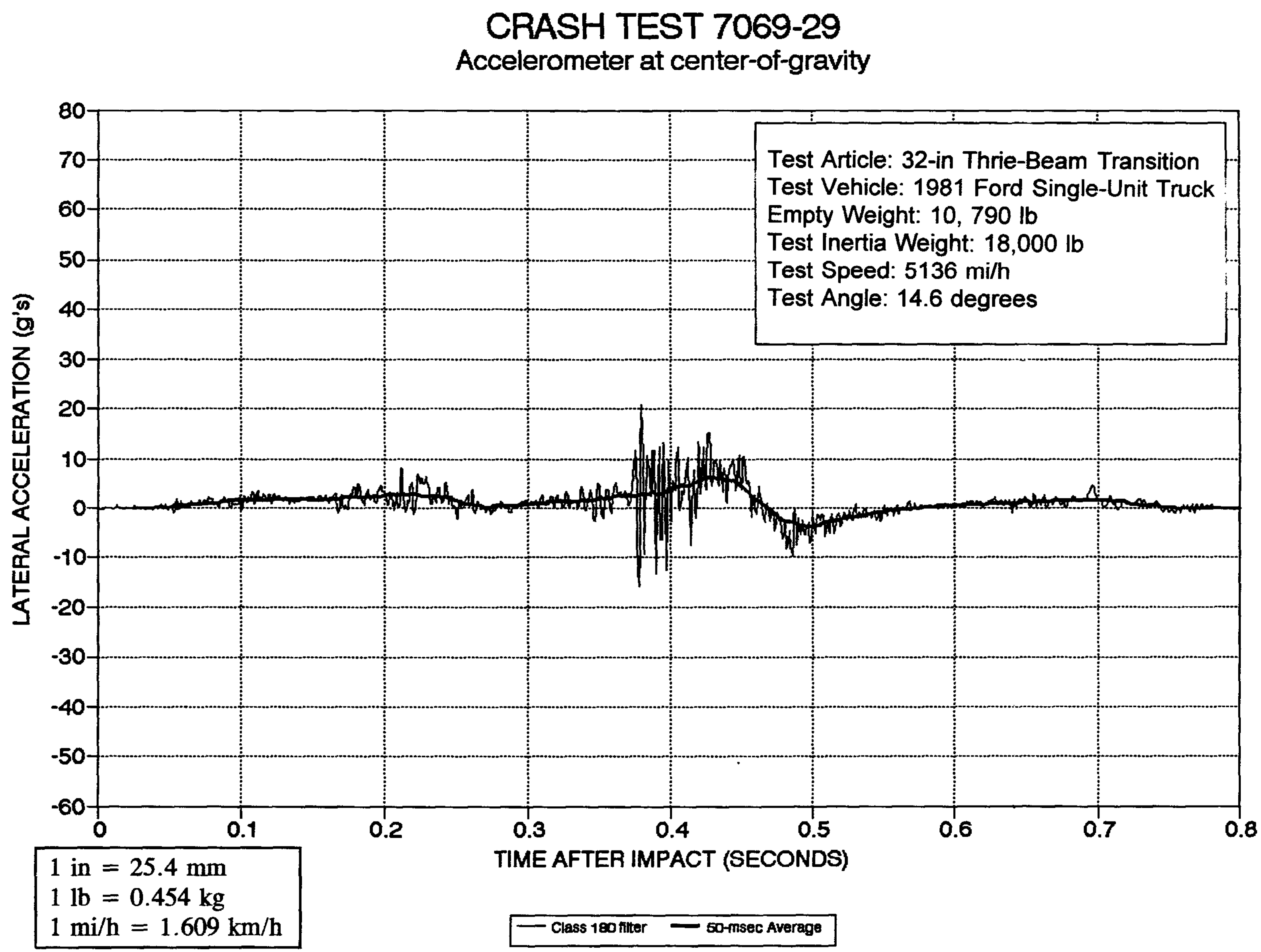
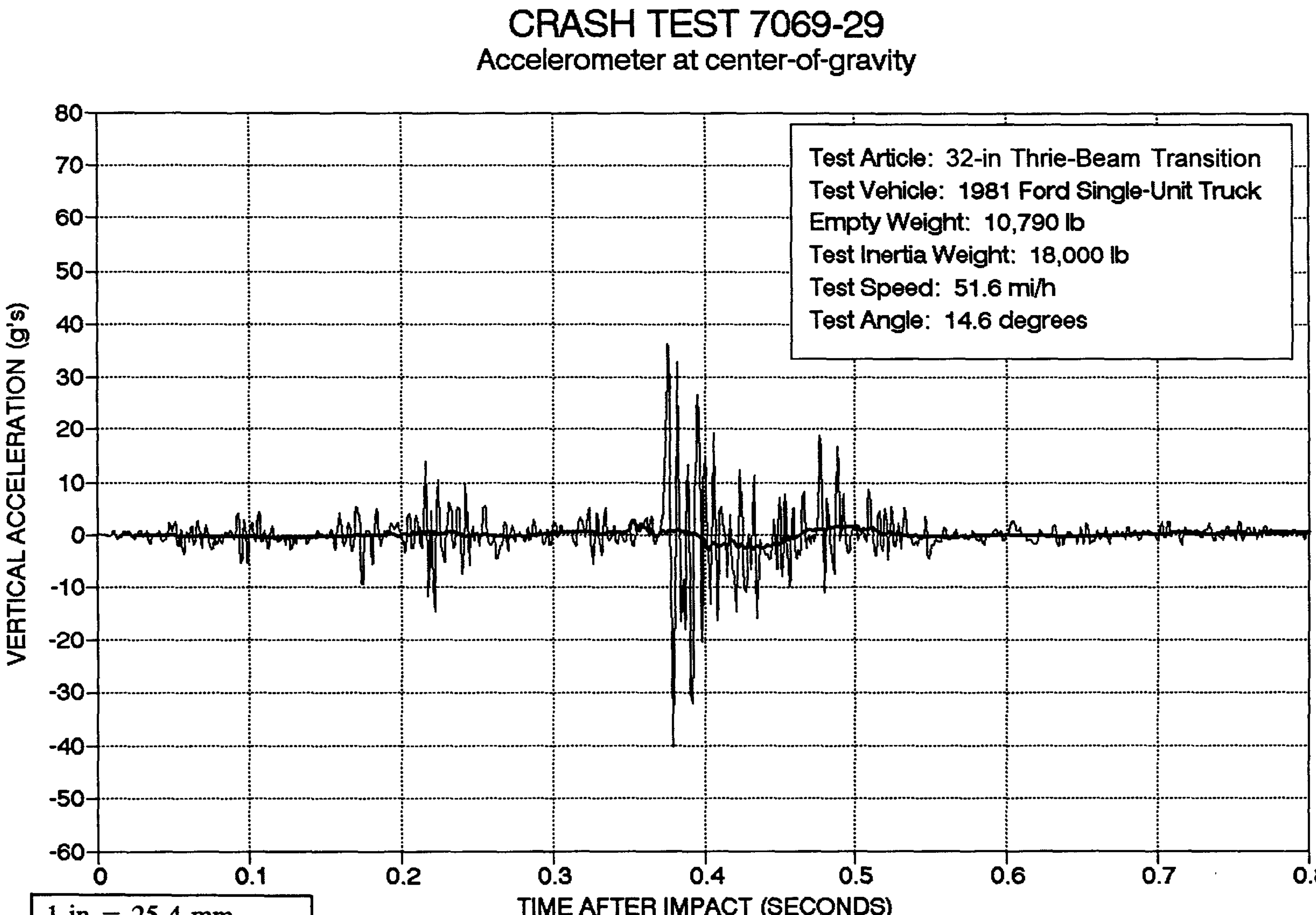


Figure 66. Vehicle lateral accelerometer trace for test 7069-29 (accelerometer located at center-of-gravity).



1 in = 25.4 mm
1 lb = 0.454 kg
1 mi/h = 1.609 km/h

Figure 67. Vehicle vertical accelerometer trace for test 7069-29 (accelerometer located at center-of-gravity).

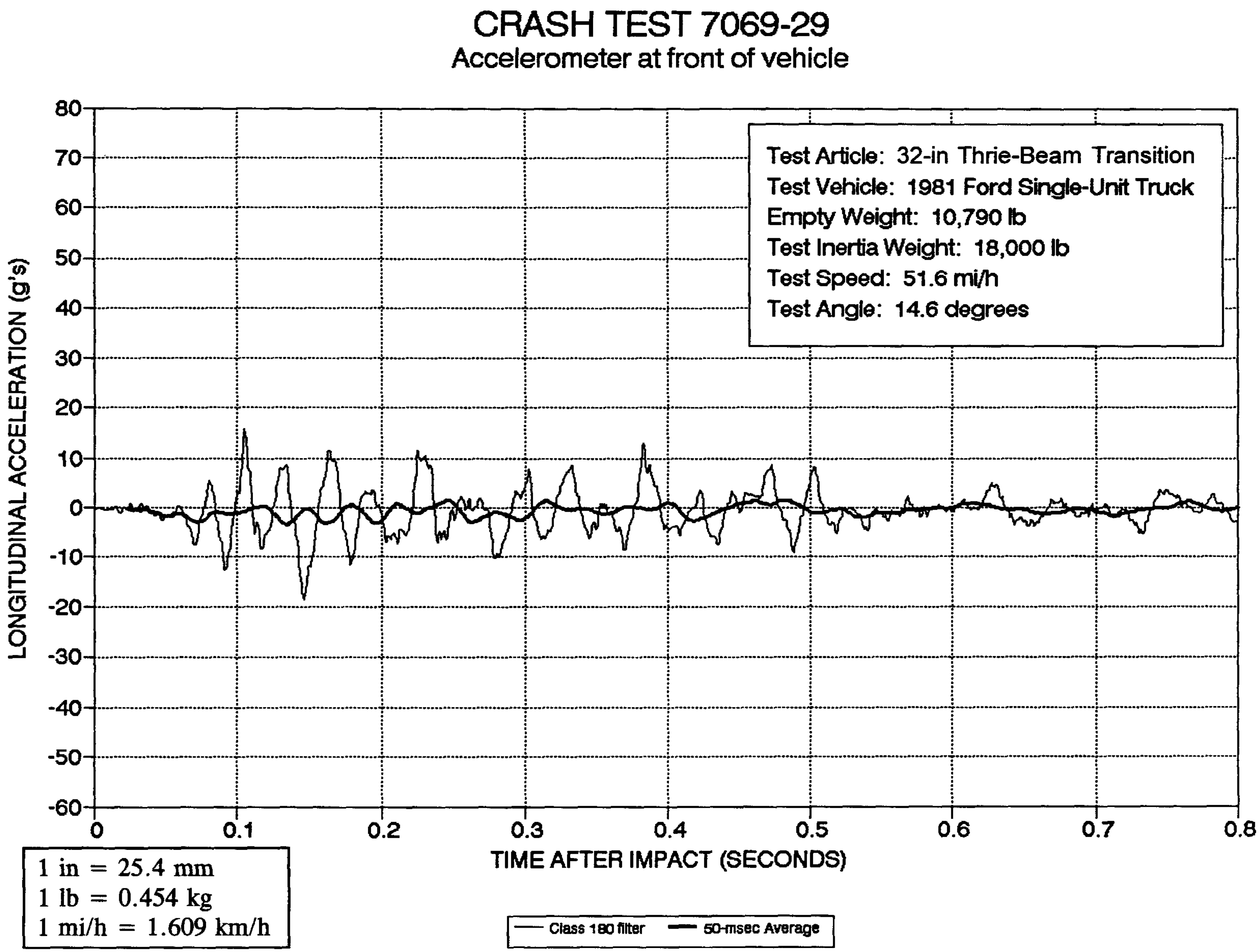


Figure 68. Vehicle longitudinal accelerometer trace for test 7069-29 (accelerometer located at front of vehicle).

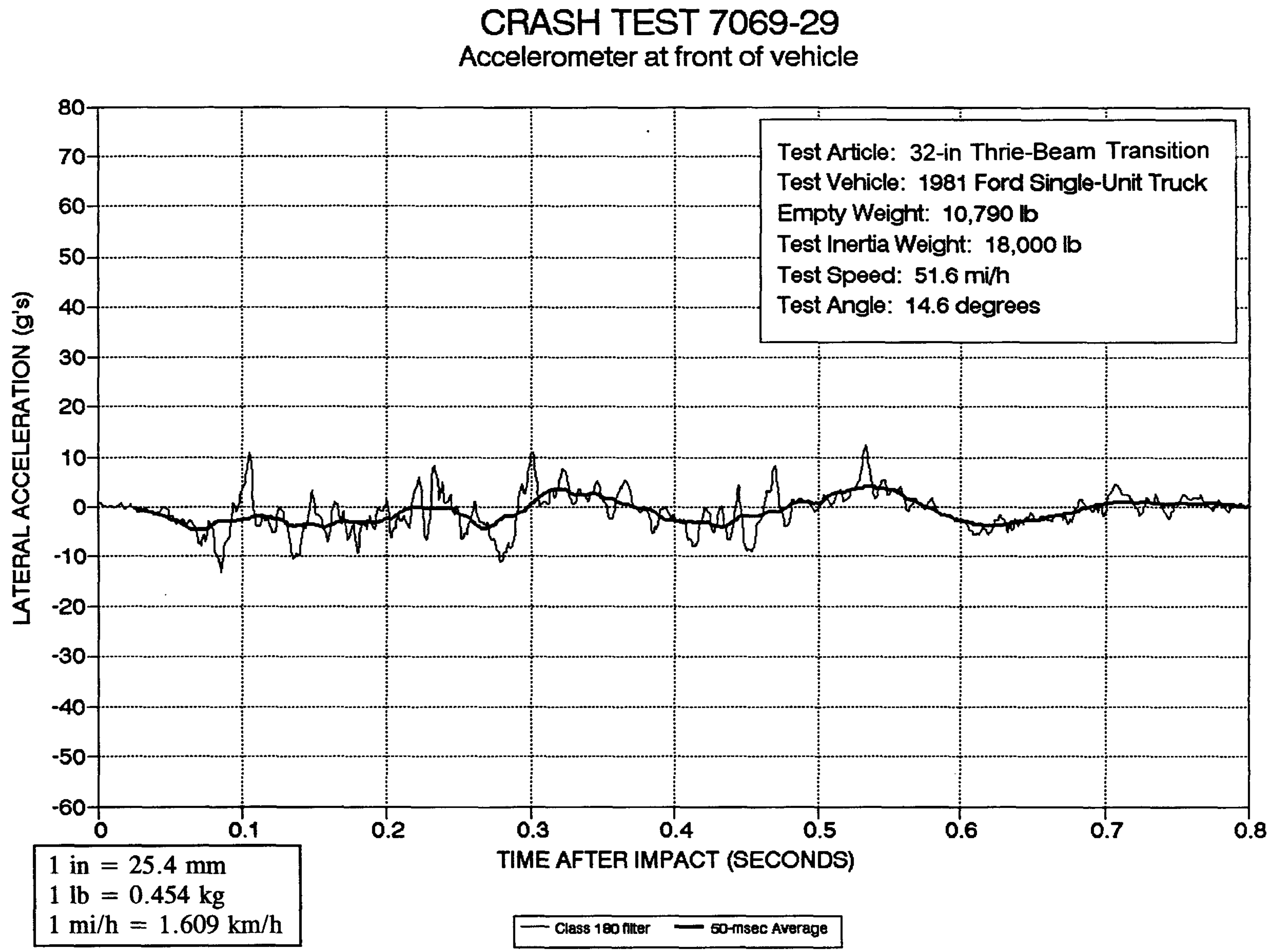
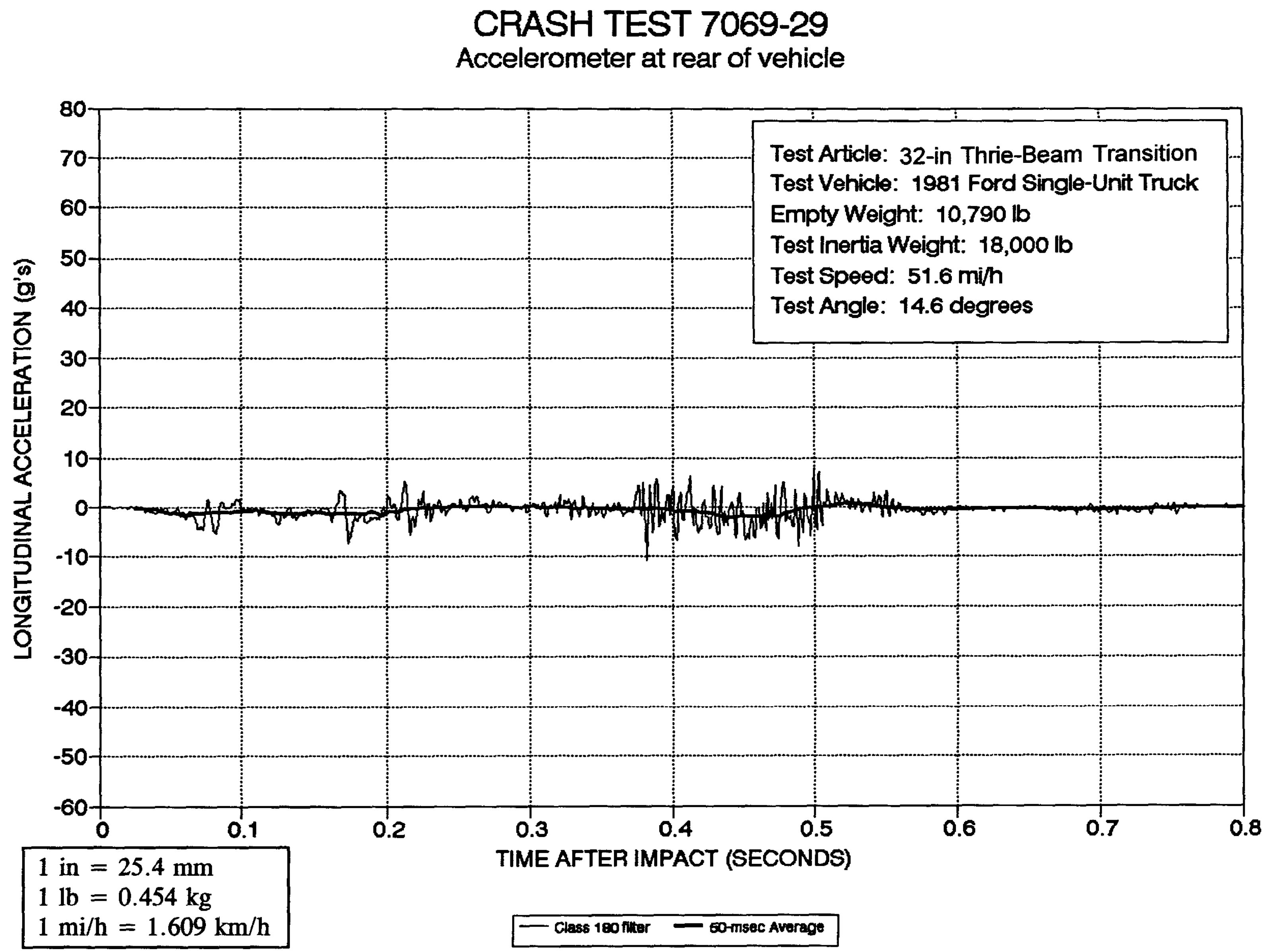


Figure 69. Vehicle lateral accelerometer trace for test 7069-29 (accelerometer located at front of vehicle).



1 in = 25.4 mm
1 lb = 0.454 kg
1 mi/h = 1.609 km/h

Figure 70. Vehicle longitudinal accelerometer trace for test 7069-29 (accelerometer located at rear of vehicle).

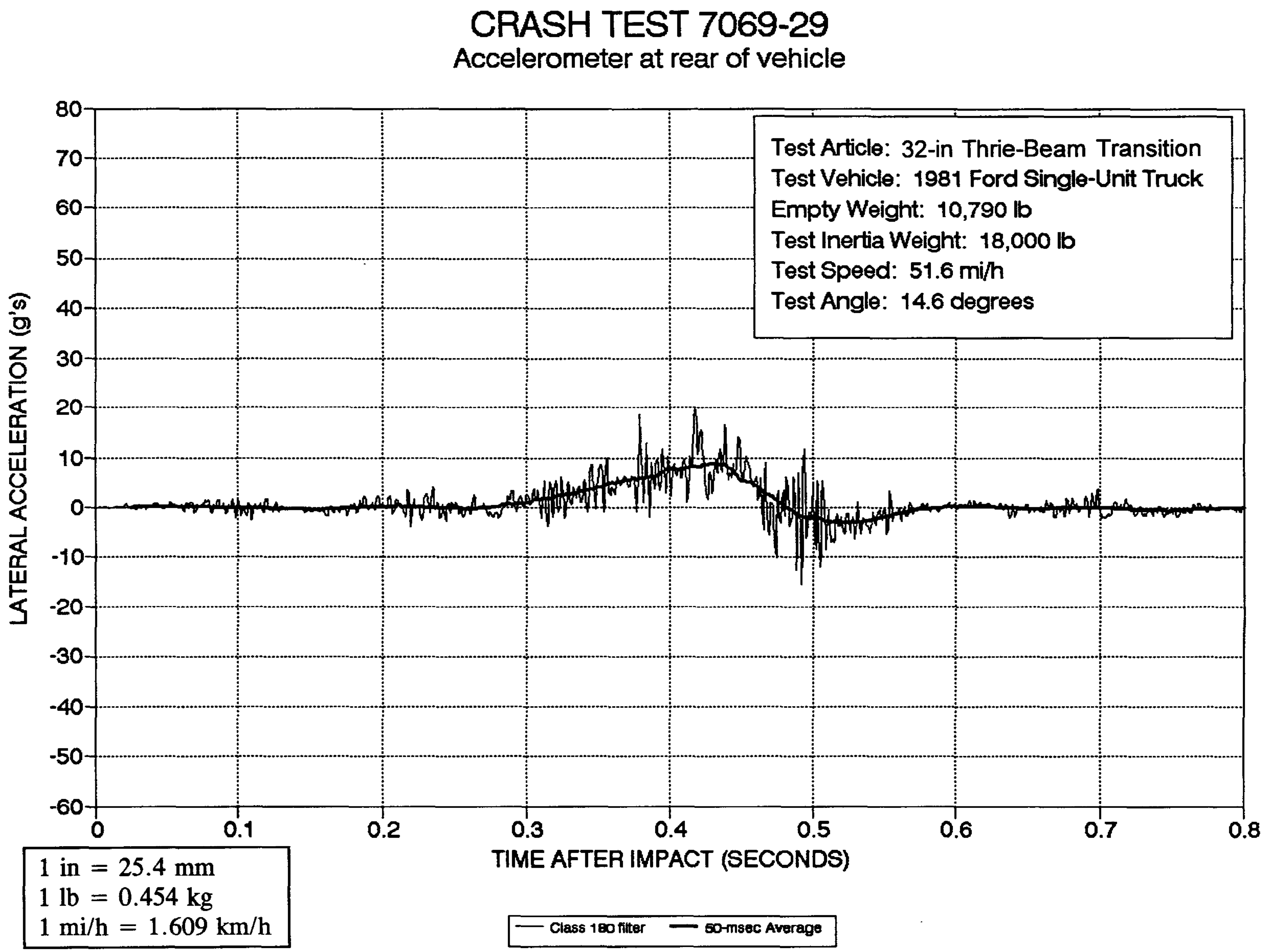


Figure 71. Vehicle lateral accelerometer trace for test 7069-29
(accelerometer located at rear of vehicle).

REFERENCES

1. *Guide Specifications For Bridge Railings*, American Association of State Highway and Transportation Officials (AASHTO), Washington, DC, 1989.