Testing of New Bridge Rail and Transition Designs

Volume XII: Appendix K

Oregon Transition

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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

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16. Abstract

A transition for the Oregon side-mounted thrie-beam bridge railing was developed and tested to performance level one of the 1989 *Guide Specifications for Bridge Railings*. Acceptable performance of the transition was demonstrated. Post spacing in the transition area is 3 ft-1 1/2 in (953 mm). A 12 ft-6 in (3.81 m) length of thrie-beam which curves behind the guardrail post on the approach end is used in the transition.

This volume is the twelfth 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 XIII: Appendix L, "32-in (813-mm) Thrie-Beam Transition;" and Volume XIV: Appendix M, "Axial Tensile Strength of Thrie and W-Beam Terminal Connectors."

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Form DOT F 1700.7 (8-69)

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)

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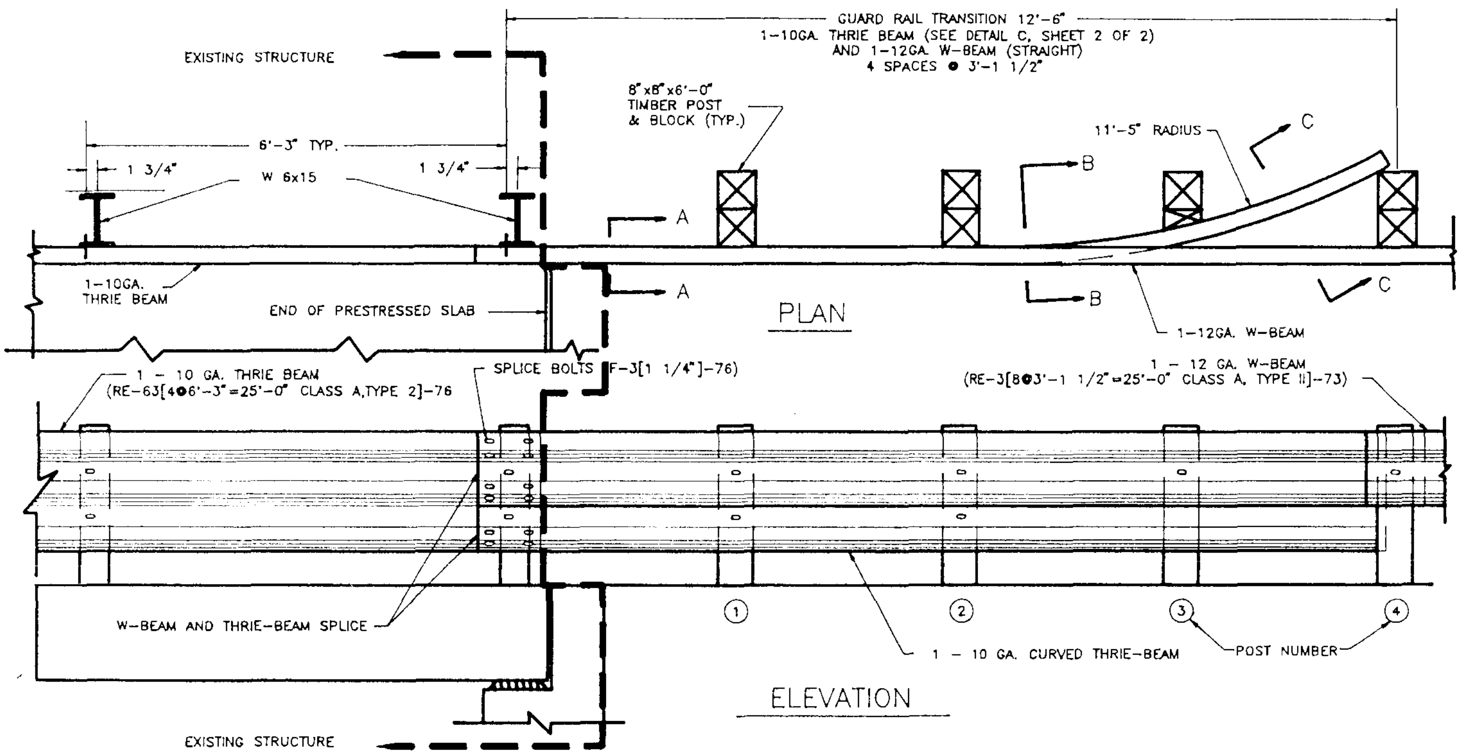
CHAPTER 1. DESIGN OF TRANSITION

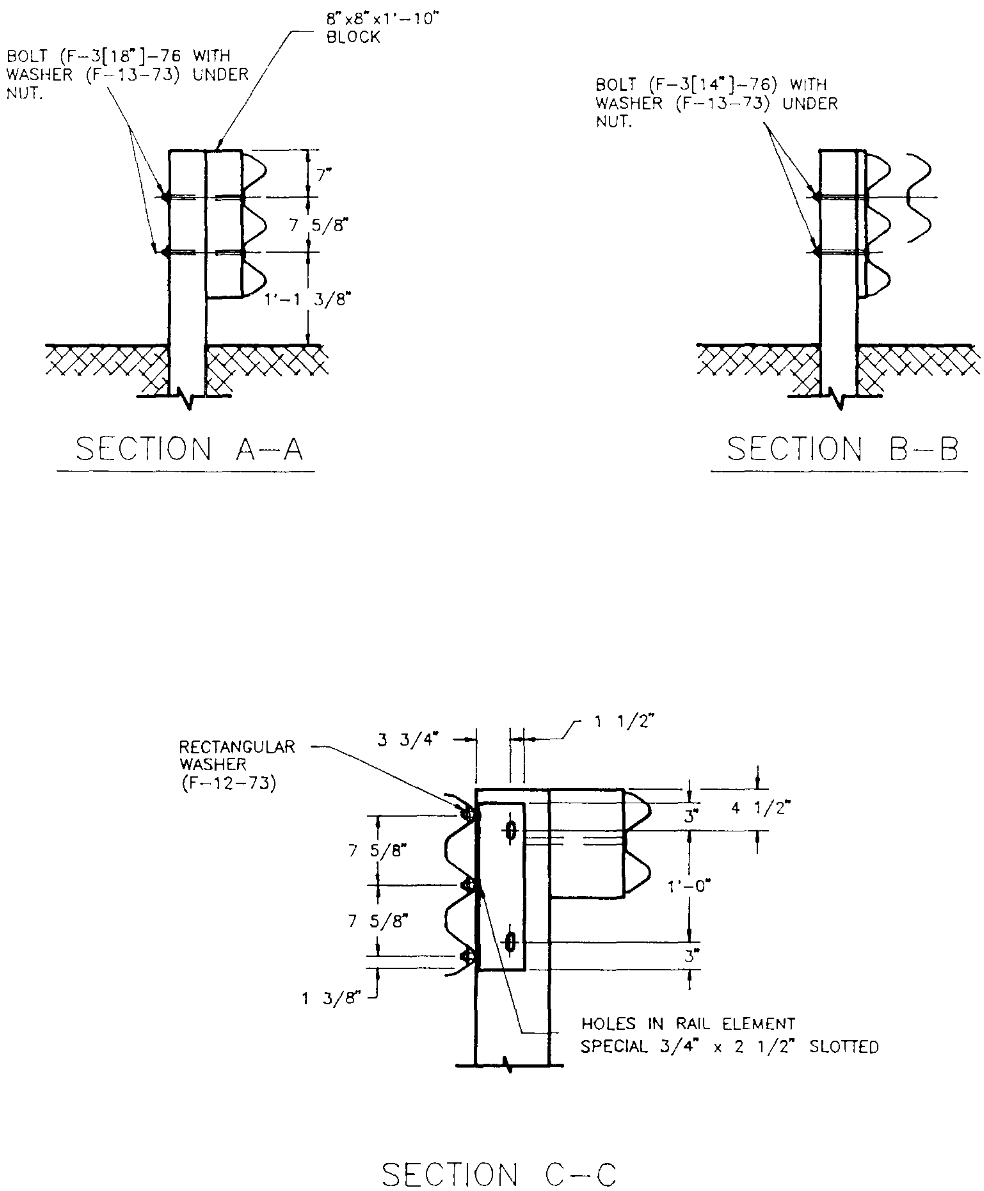
An elevation view and cross-sections of the Oregon transition are shown in figures 1 and 2. Total height of the transition is 28 in (710 mm). The bridge rail element is a 10-gauge thrie-beam which terminates at the end of the bridge. A 12-gauge W-beam connects at this point and continues straight through the transition. An additional 10-gauge thrie-beam element is connected behind the W-beam at the end of the bridge and extends straight for 6 ft-3 in (1.9 m), then curves to the field side on an 11 1/2 ft (3.5 m) radius for a distance of 6 ft-3 in (1.9 m). Timber posts 8 in by 8 in by 6 ft 0 in (203 mm by 203 mm by 1.83 m) timber posts and blockouts spaced at 3 ft-1 1/2 in (1 m) are used in the transition.

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 to allow vehicle snagging on the end of the rigid bridge railing. Curving the thrie-beam away from the traffic face creates an area that provides smooth transition from lower stiffness of the W-beam guardrail to higher stiffness of the thrie-beam bridge rail. Consequently, an impacting vehicle is prevented from snagging along the transition and sustaining high levels of damage or injury. In addition, curving the thrie-beam prevents the vehicle from snagging on the end of the thrie-beam itself.



1 in = 25.4 mm

Figure 1. Oregon Transition (elevation).



1 in = 25.4 mm

Figure 2. Oregon Transition (cross section).

CHAPTER 2. CRASH TEST PROCEDURES

This transition was tested to performance level one requirements.[1] The following nominal test conditions were used:

1,800-lb (817-kg) passenger car | 50 mi/h (80.5 km/h)) | 20 degrees (test 7069-27)
5,400-lb (2 452-kg) pickup | 45 mi/h (72.5 km/h) | 20 degrees (test 7069-28)

The test vehicles were instrumented with three solid-state angular rate transducers to measure yaw, pitch and roll rates; a triaxial accelerometer at the vehicle center-of-gravity to measure longitudinal, lateral, and vertical acceleration levels, and a back-up biaxial 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 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 Class 180 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 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 (QUATTRO PRO). For each of these graphs, a 0.050-s average window was calculated at the center of the 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.

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

Photographic coverage of the tests included four 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 at the downstream end, and a third placed perpendicular to the front of the transition. A high-speed camera was also placed onboard the vehicles to record the motions of the dummy placed in the driver position during the test sequences. 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) videotape recorder along with 35-mm still cameras were used for documentary purposes and to record conditions of the test vehicle and transition before and after the tests.

The test vehicles were towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding each 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 vehicles were released to be free-wheeling and unrestrained. The vehicles remained free-wheeling, i.e., no steering or braking inputs, until they cleared the immediate area of the test site, at which time brakes on them were activated to bring them to safe and controlled stops.

CHAPTER 3. FULL-SCALE CRASH TESTS

TEST 7069-27

Test Description

A 1983 Honda Civic (figure 3) was used for the crash test. 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 13.0 in (330 mm) and it was 18.75 in (476 mm) to the top of the bumper. Additional dimensions and information on the test vehicle are given in figure 4. The vehicle was directed into the Oregon transition (figures 5 and 6) 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 5 ft (1.5 m) from the end of the bridge deck at a speed of 51.6 mi/h (83.0 km/h) and the angle of impact was 19.9 degrees.

At 0.017 s after impact, the bumper of the vehicle began to shift to the right and at 0.029 s the front of the vehicle began to deform to the right. The vehicle began to redirect at 0.050 s after impact and at the same time the vehicle contacted post 1. By 0.133 s the vehicle was traveling parallel to the transition at a speed of 44.9 mi/h (72.2 km/h), and at 0.150 s the rear of the vehicle impacted the transition at the post 2 location. At 0.176 s the shoulder of the dummy shattered the window glass on the driver side. The vehicle lost contact with the transition at 0.245 s traveling at 44.3 mi/h (71.3 km/h) and 9.1 degrees. The brakes were applied at 1.4 s after impact and subsequently came to rest 105 ft (32 m) from the point of impact, resting against another barrier.

As can be seen in figure 7, the transition received minimal damage. Maximum lateral permanent deformation was 0.5 in (13 mm). The vehicle was in contact with the transition for 9.0 ft (2.7 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 8.0 in (203 mm) and the driver door was deformed outward approximately 8.0 in (203 mm). The driver side window was broken out and the door was jammed. Also, damage was done to the front bumper, hood, grill, left front quarter panel, left rear quarter panel, and left front tire and rim.

Test Results

Impact speed was 51.6 mi/h (83.0 km/h) and the angle of impact was 19.9 degrees. The speed of the vehicle at time of parallel was 44.9 mi/h (72.2 km/h) and the coefficient of friction was 0.21. The vehicle lost contact with the transition traveling at 44.3 mi/h (71.3 km/h) and the exit angle between the vehicle path and the transition was 9.1 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 13.1 ft/s (4.0 m/s) at 0.221 s, the highest 0.010-s average ridedown acceleration was 1.0 g between 0.224 and 0.234 s, and the maximum 0.050-s average acceleration was -5.3 g between 0.039 and 0.089 s. Lateral occupant impact velocity was

23.7 ft/s (7.2 m/s) at 0.103 s, the highest 0.010-s occupant ridedown acceleration was -9.6 g between 0.161 and 0.171 s, and the maximum 0.050-s average acceleration was -10.9 g between 0.041 and 0.091 s. The change in vehicle velocity at loss of contact was 7.3 mi/h (11.7 km/h) and the change in momentum was 598 lb-s (2,662 N-s). These data and other pertinent information from the test are summarized 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 versus time traces filtered at SAE J211 (Class 180) are presented in figures 13 through 15.

Conclusions

The transition contained the test vehicle with minimal lateral movement of the transition. There was no intrusion of transition components into the occupant compartment. The vehicle remained upright and relatively stable during the collision. The transition redirected the vehicle and the effective coefficient of friction was considered good. Velocity change of the vehicle during the collision was 7.3 mi/h (11.7 km/h).

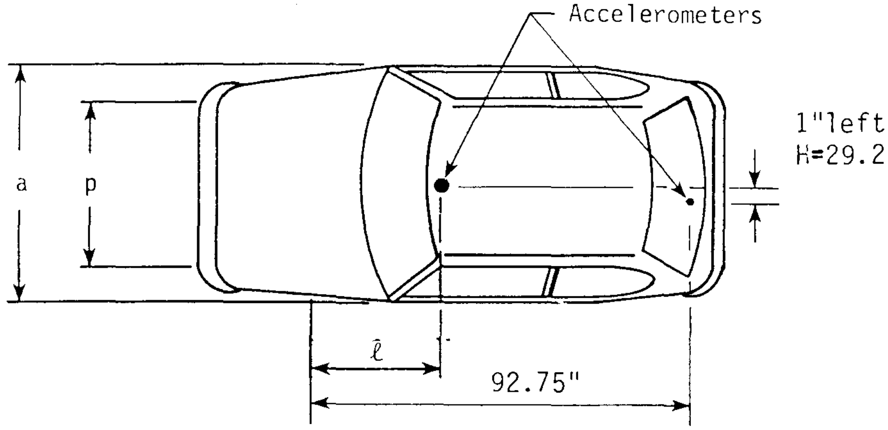
The 1989 American Association of State Highway and Transportation Officials (AASHTO) *Guide Specifications For Bridge Railings* sets forth required limits for occupant risk factors for tests with the 1,800-lb vehicle.[1] The AASHTO specifications recommend a limit of 30 ft/s (9.2 m/s) for longitudinal 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. See figure 9 and table 1 for more details.

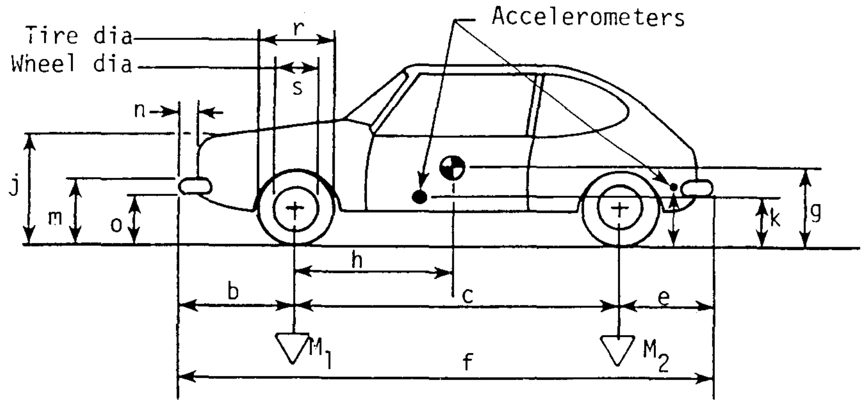
Figure 3. Vehicle before test 7069-27.

Date: 6-16-92 Test No.: 7069-27 VIN: JHMSL 4316DSQ11122

Make: Honda Model: Civic 1300 Year: 1983 Odometer: 132048

Tire Size: 155R12 Ply Rating: ___ Bias Ply: ___ Belted: ___ Radial: X





Tire Condition: good ___ fair X badly worn ___

Vehicle Geometry - inches

a	62.25"	b	29.50"
c	88.25"	d*	52.50"
e	29.00"	f	146.75"
g		h	32.36"
i	----	j	27.00"
k	16.00"	ℓ	35.00"
m	18.75"	n	3.25"
o	13.00"	p	53.75"
r	21.75"	s	13.18"

Engine Type: V-4 Gas

Engine CID: 91CID

Transmission Type:

Automatic or Manual

FWD or RWD or 4WD

Body Type: 3 door

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 586 rf 554 ℓr 332 rr 328

Mass - pounds	Curb	Test Inertial	Gross Static
M_1	1157	1140	1222
M_2	628	660	748
M_T	1785	1800	1970

Note any damage to vehicle prior to test:

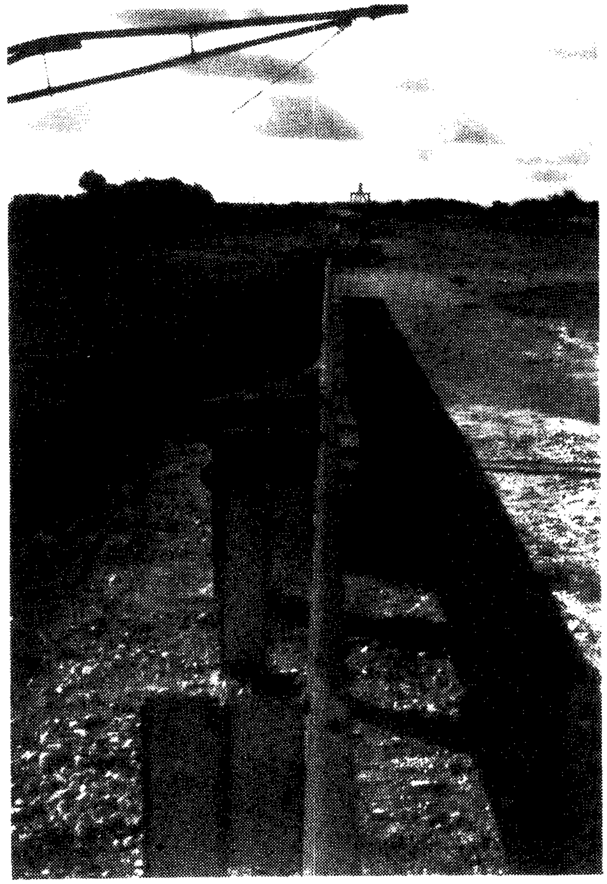
___

___

*d = overall height of vehicle

1 in = 25.4 mm
1 lb = .454 kg

Figure 4. Vehicle properties for test 7069-27.



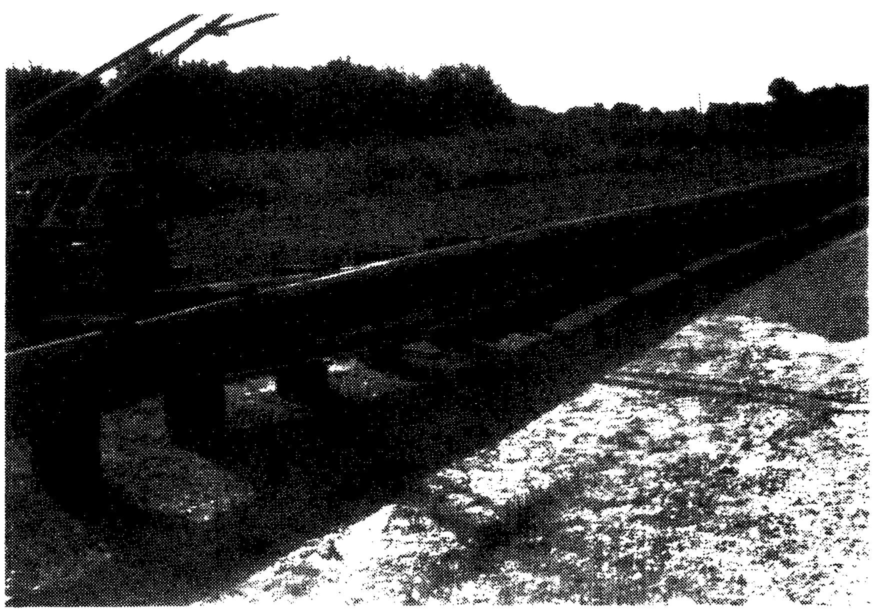


Figure 5. Oregon transition before test 7069-27.

Figure 6. Oregon transition before test 7069-27 (rear view).

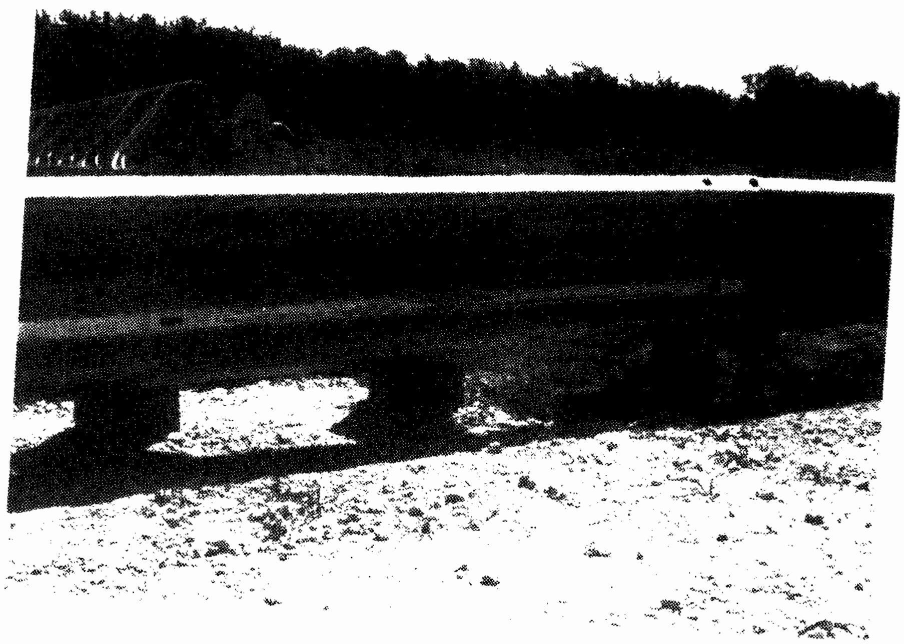


Figure 7. Oregon transition after test 7069-27.

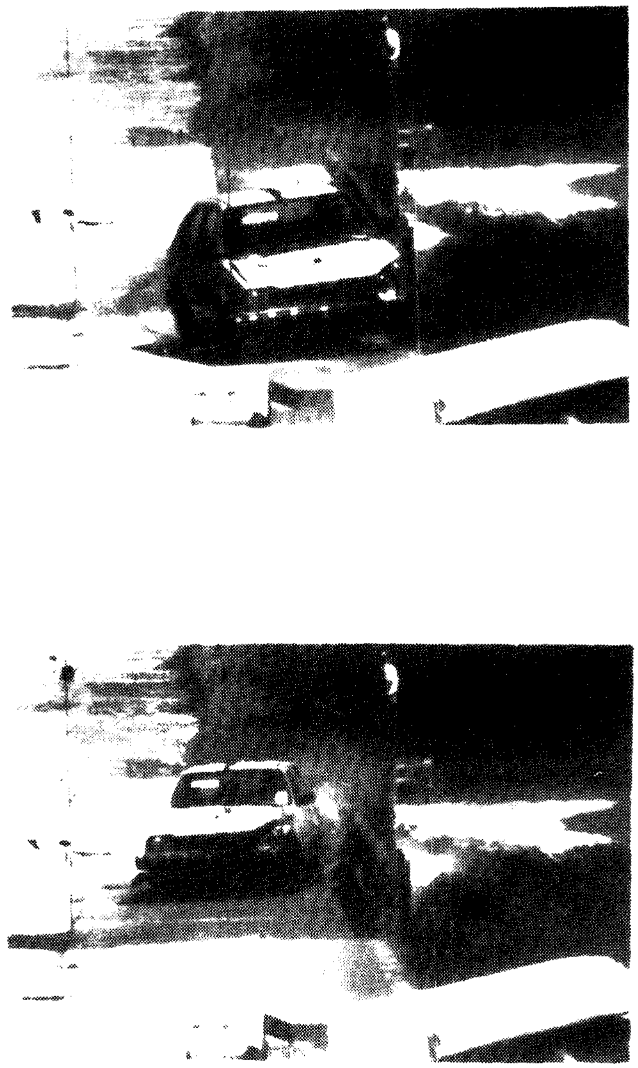
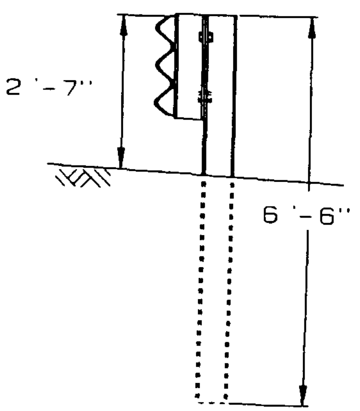


Figure 8. Vehicle after test 7069-27.



(1 in = 25.4 mm)

Test No.	7069-27
Date	06/16/92
Test Installation . . .	Oregon 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	11LFQ4 & 11LD1
CDC	11FLEK2 & 11LDEW3
Maximum Vehicle Crush .	8.0 in (203 mm)

Impact Speed. . . .	51.6 mi/h (83.0 km/h)
Impact Angle. . . .	19.9 deg
Speed at Parallel .	44.9 mi/h (72.2 km/h)
Exit Speed	44.3 mi/h (71.3 km/h)
Exit Trajectory . .	9.1 deg
Vehicle Accelerations (Max. 0.050-sec Avg) at true c.g.	
Longitudinal. . .	-5.3 g
Lateral	-10.9 g
Occupant Impact Velocity at true c.g.	
Longitudinal. . .	13.1 ft/s (4.0 m/s)
Lateral	23.7 ft/s (7.2 m/s)
Occupant Ridedown Accelerations	
Longitudinal . .	1.0 g
Lateral	-9.6 g

Figure 9. Summary of results for test 7069-27.

Table 1. Evaluation of crash test no. 7069-27.
{Oregon transition [1,800 lb (817 kg)|51.6 mi/h (83.0 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	No 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 0 - .25 — Good .26 - .35 — Fair > .35 — Marginal	μ — Assessment .21 — Good	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 13.1 (4.0) — Lateral 23.7 (7.2)	Pass
	Occupant Ridedown Accelerations - g's Longitudinal 15 — Lateral 15	Occupant Ridedown Accelerations - g's Longitudinal 1.0 — Lateral -9.6	Pass
H.	Exit angle shall be less than 12 degrees	Exit angle was 9.1 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)]

		TEST SPEEDS—mph[1,2]			
		TEST VEHICLE DESCRIPTIONS AND IMPACT ANGLES			
		Small Automobile	Pickup Truck	Medium Single-Unit Truck	Van-Type Tractor-Trailer[4]
PERFORMANCE LEVELS		W = 1.8 Kips A = 5.4′ ± 0.1′ B = 5.5′ H_{cg} = 20″ ± 1″ θ = 20 deg.	W = 5.4 Kips A = 8.5′ ± 0.1′ B = 6.5′ H_{cg} = 27″ ± 1″ θ = 20 deg.	W = 18.0 Kips A = 12.8′ ± 0.2′ B = 7.5′ H_{cg} = 49″ ± 1″ θ = 15 deg.	W = 50.0 Kips A = 12.5′ ± 0.5′ B = 8.0′ H_{cg} = See Note 4 R = 0.61 ± 0.01 θ = 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:

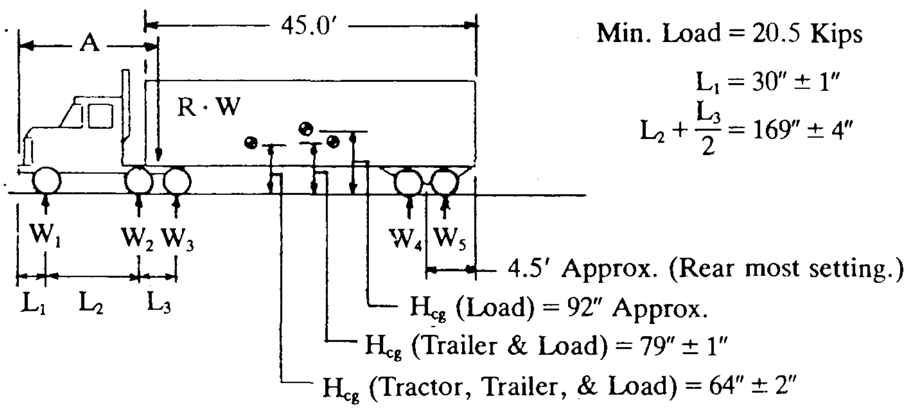
Occupant Impact Velocity–fps	
Longitudinal	Lateral
30	25

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

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

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

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

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

$$W = W_1 + W_2 + W_3 + W_4 + W_5$$

= 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

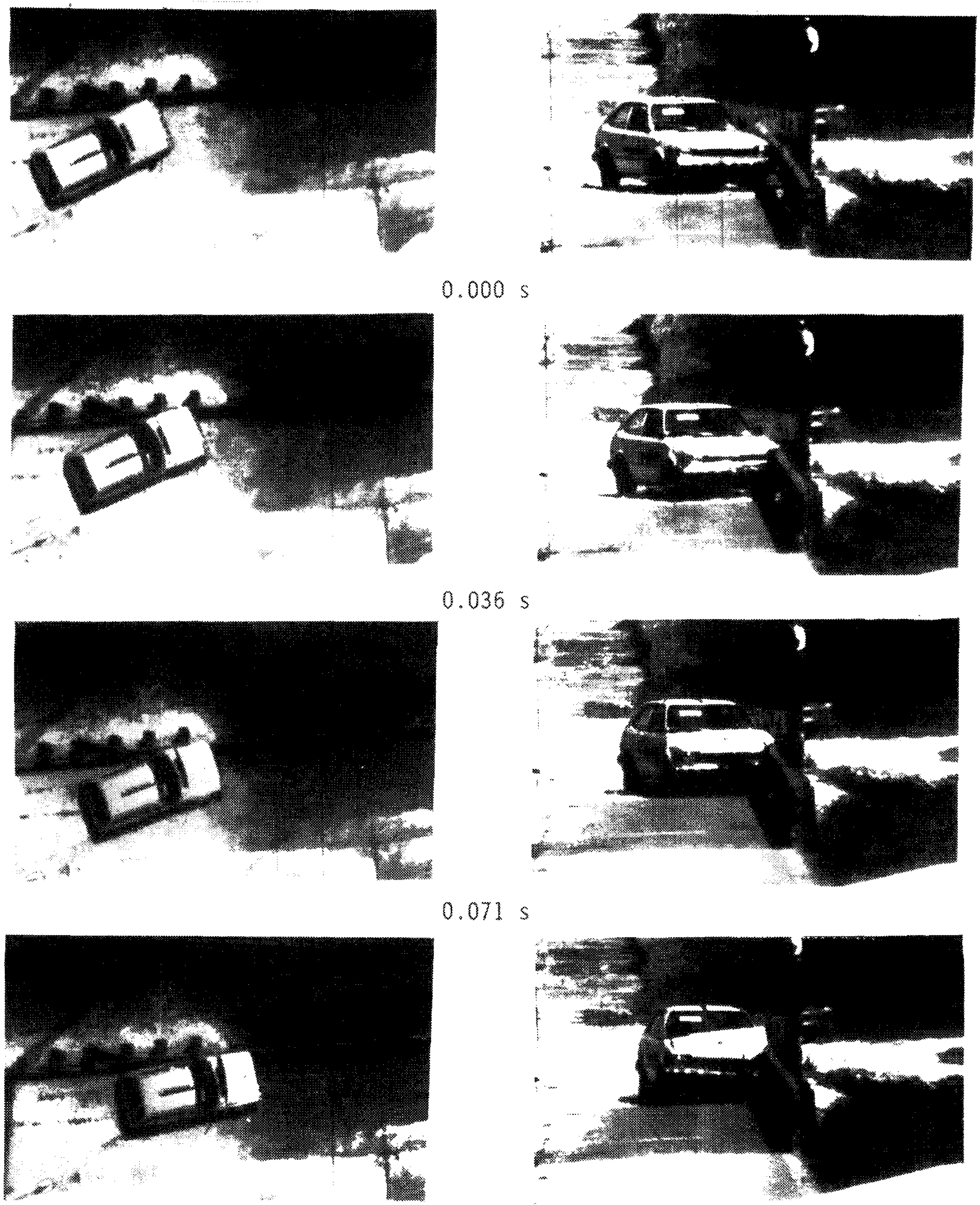
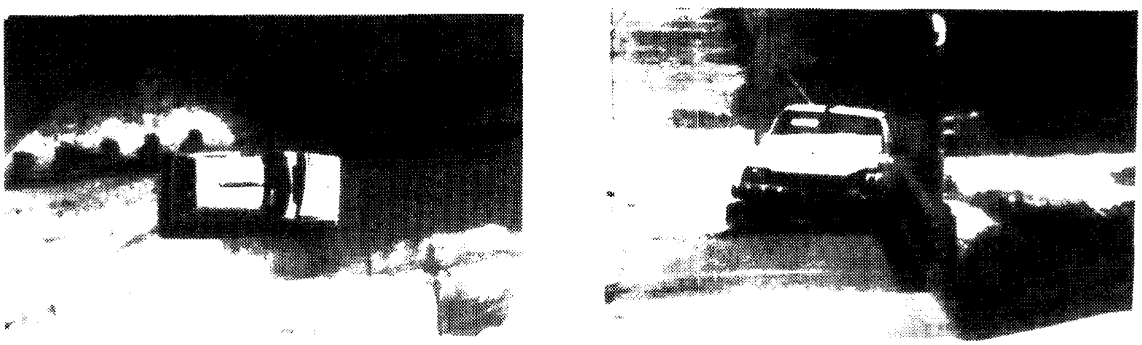


Figure 10. Sequential photographs for test 7069-27
(overhead and front views).

0.143 s



0.179 s

0.214 s

0.250 s

Figure 10. Sequential photographs for test 7069-27
(overhead and front views continued).

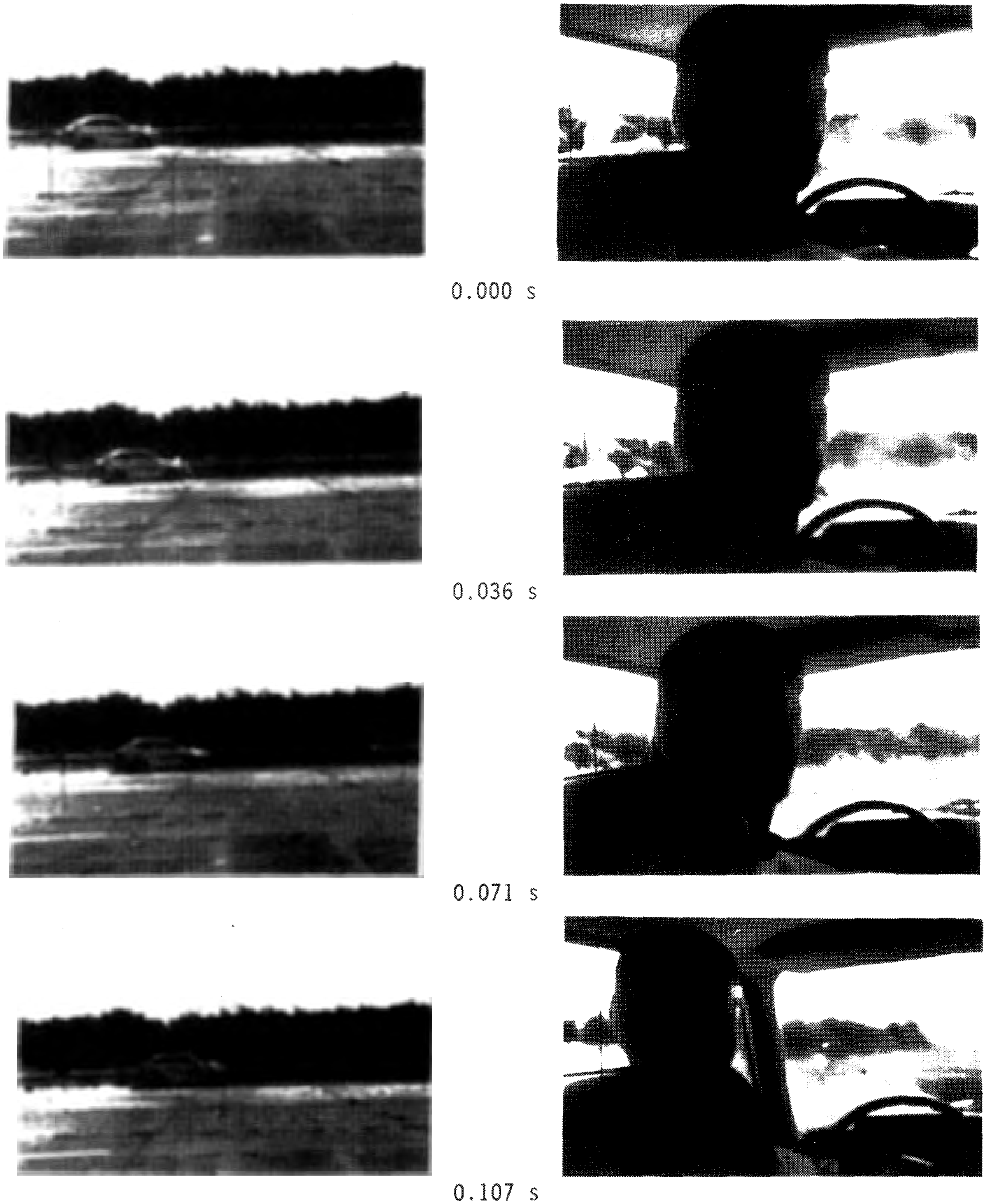
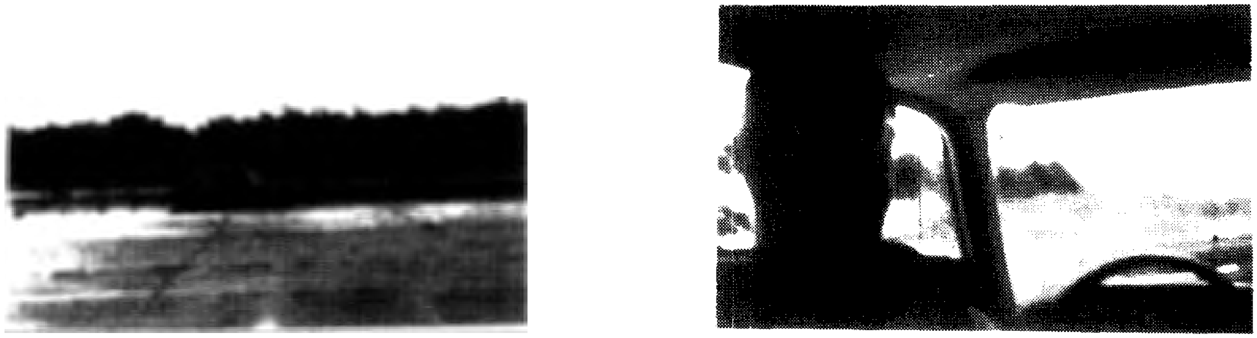


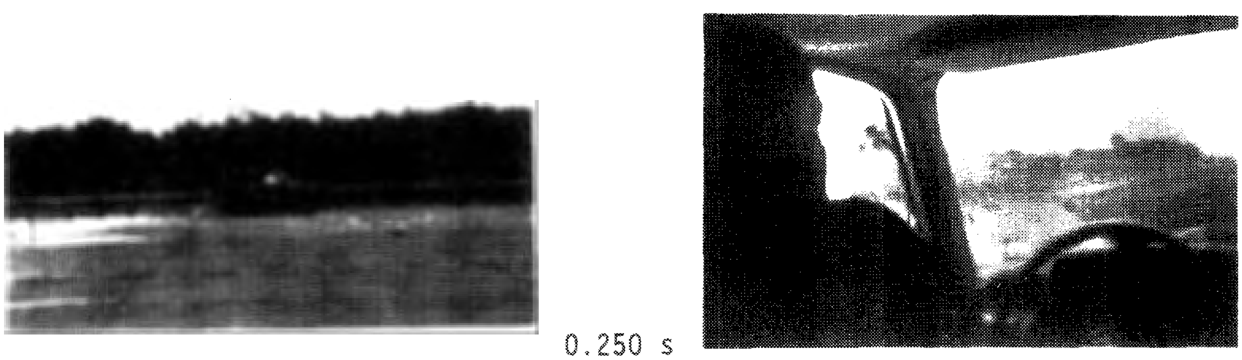
Figure 11. Sequential photographs for test 7069-27
(perpendicular and interior view).



0.143 s

0.179 s

0.214 s



0.250 s

Figure 11. Sequential photographs for test 7069-27 (perpendicular and interior view continued).

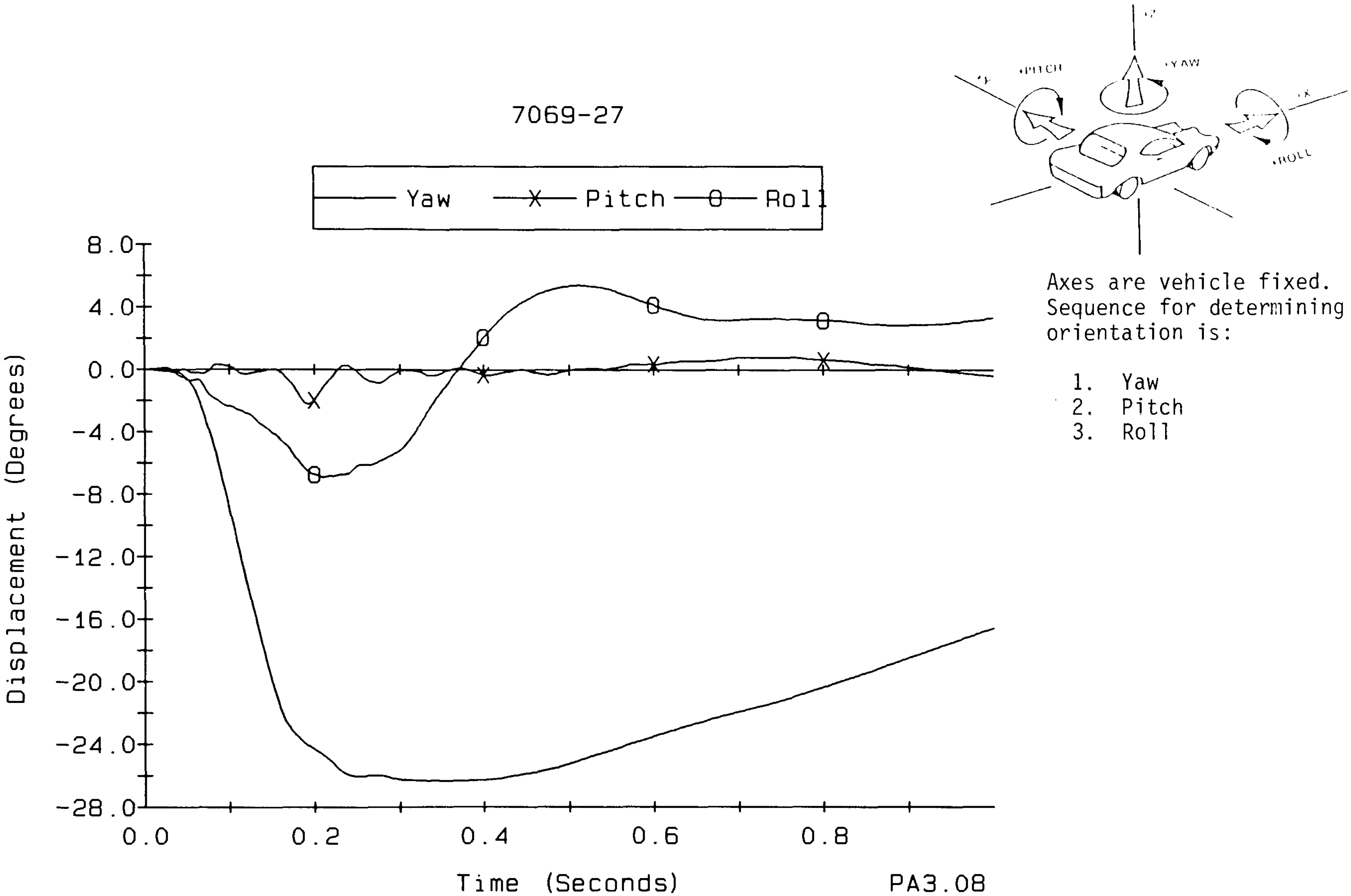


Figure 12. Vehicle angular displacements for test 7069-27.

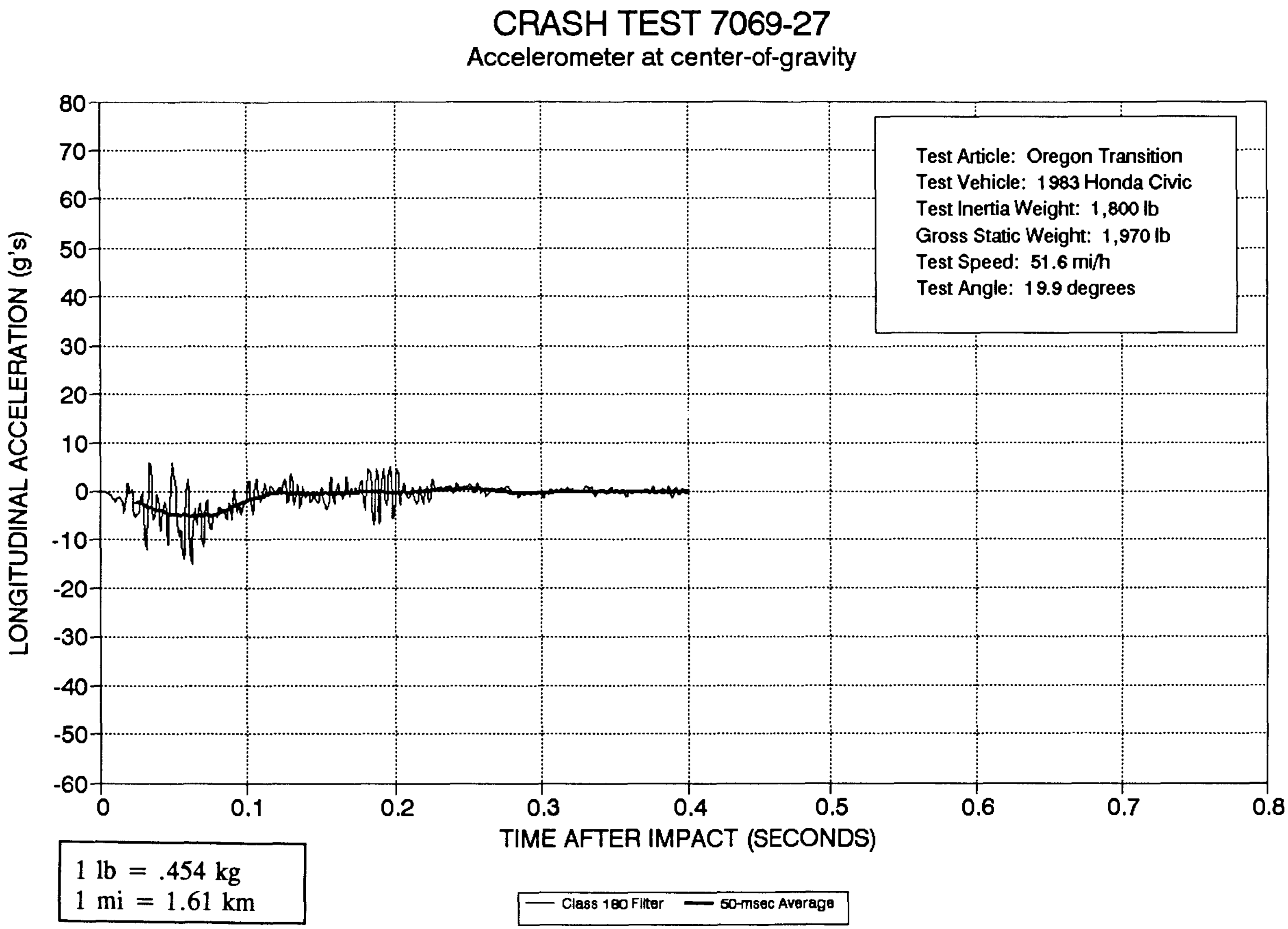


Figure 13. Vehicle longitudinal accelerometer trace for test 7069-27 (accelerometer located at center-of-gravity).

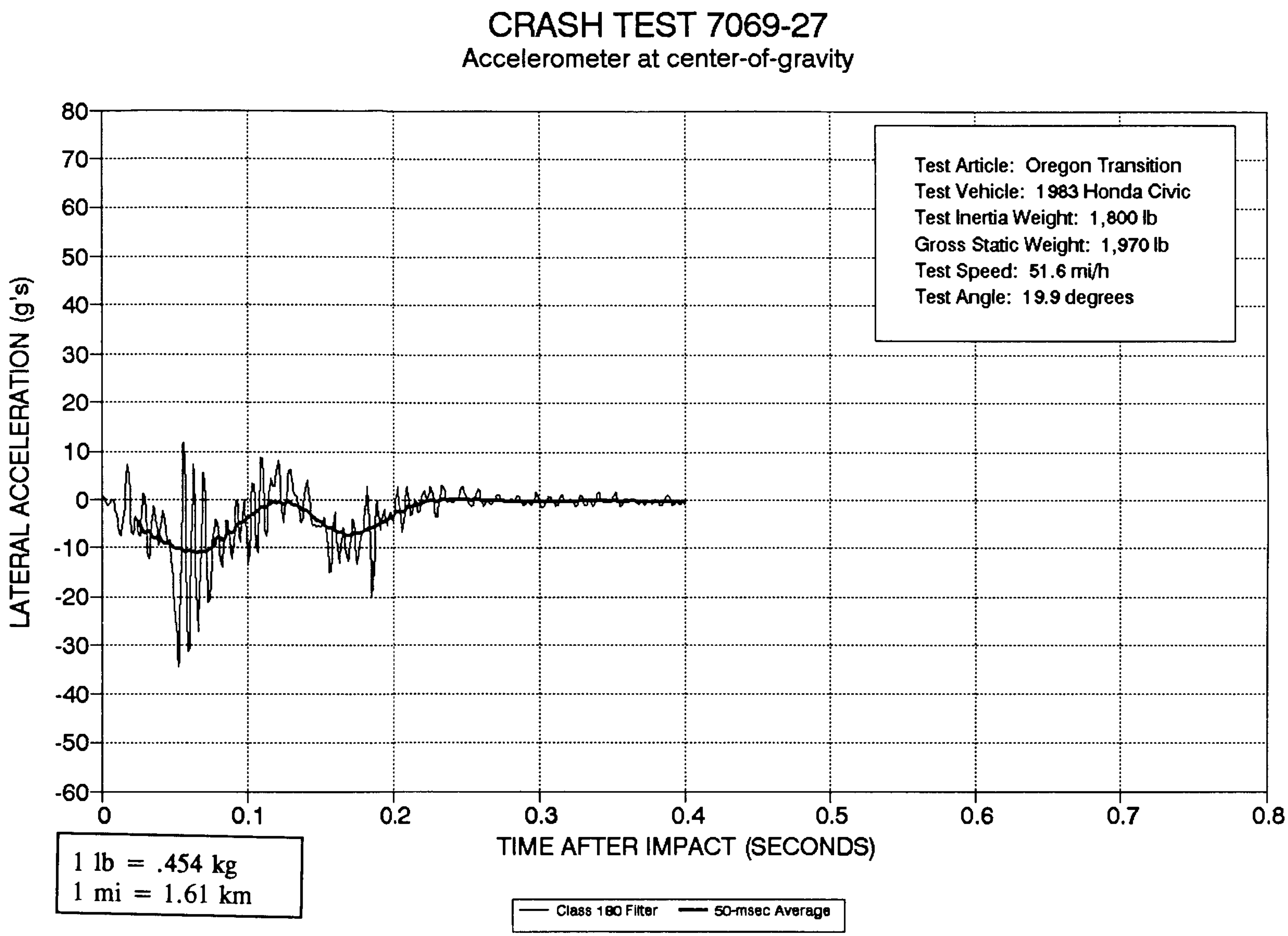


Figure 14. Vehicle lateral accelerometer trace for test 7069-27 (accelerometer located at center-of-gravity).

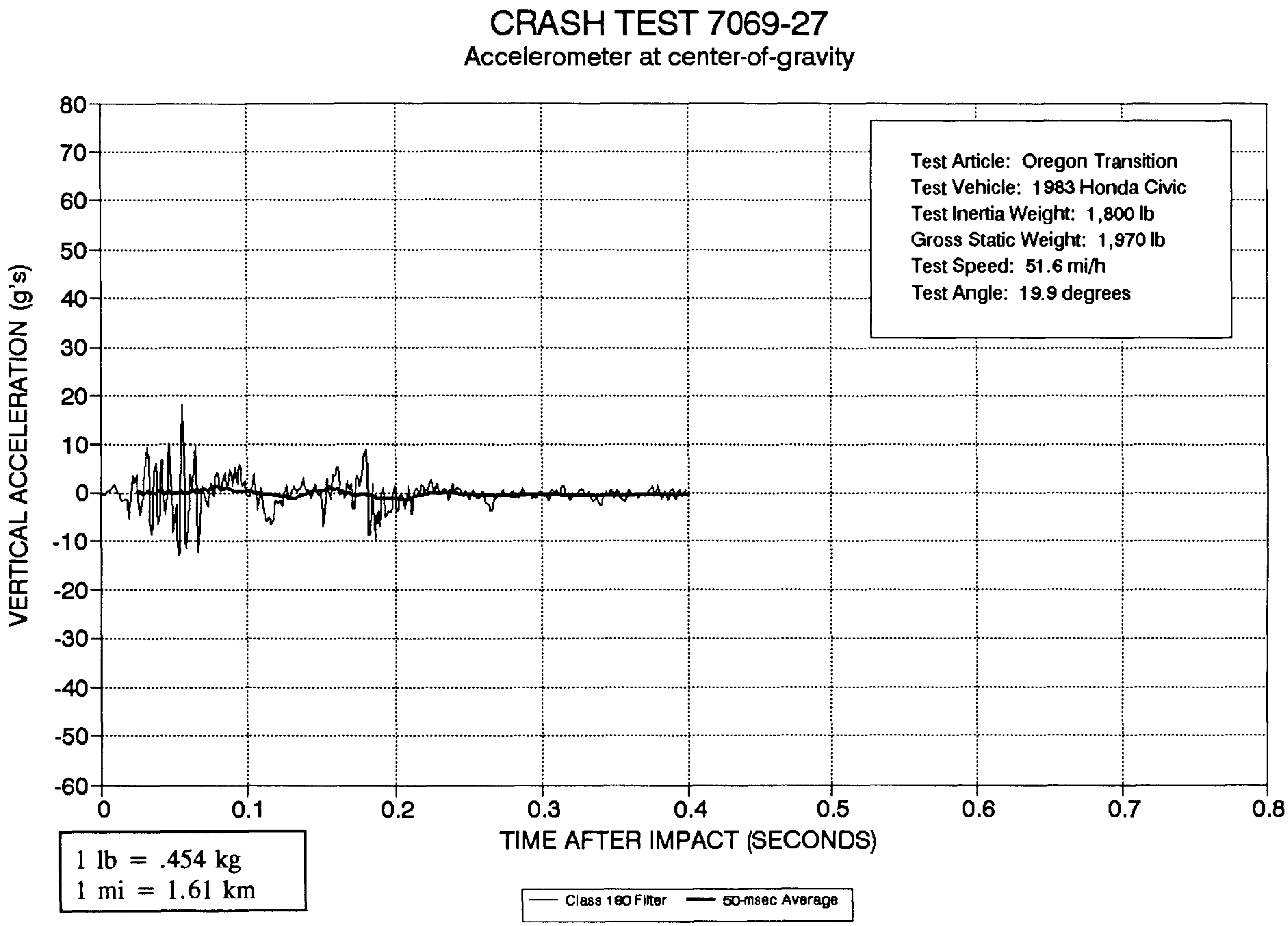


Figure 15. Vehicle vertical accelerometer trace for test 7069-27 (accelerometer located at center-of-gravity).

TEST 7069-28

Test Description

A 1985 Chevrolet C-20 pickup (figures 16 and 17) 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 (2 527 kg). The height to the lower edge of the vehicle bumper was 17.75 in (451 mm) and it was 26.75 in (679 mm) to the top of the bumper. Additional dimensions and information on the test vehicle are given in figure 18. The vehicle was directed into the Oregon transition (figure 19) 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 7 ft (2.1 m) from the end of the bridge deck at a speed of 47.7 mi/h (76.7 km/h) and the angle of impact was 19.0 degrees.

The vehicle began to redirect at 0.062 s after impact, and at 0.129 the right front tire left the roadway. By 0.192 s the vehicle was traveling parallel to the transition at a speed of 45.5 mi/h (73.2 km/h), and at 0.205 s the rear of the vehicle impacted the transition. The transition reached a maximum deflection of 0.9 ft at 0.271 s after impact and the right rear wheel lost contact with the roadway at 0.298 s. The vehicle lost contact with the transition at 0.370 s traveling at 42.8 mi/h (68.9 km/h) and 8.9 degrees. The right side of the vehicle regained contact with the roadway at 0.576 s. The brakes were applied at 1.5 s after impact and subsequently came to rest 285 ft (87 m) down from and 98 ft (30 m) in front of the point of impact.

As can be seen in figure 20, the transition received minimal damage. Maximum lateral permanent deformation was 3.5 in (89 mm). The vehicle was in contact with the transition for 14.0 ft (4.3 m).

The vehicle sustained damage to the left side as shown in figure 21. Maximum crush at the left front corner at bumper height was 8.0 in (203 mm) and the driver door was deformed outward approximately 1.0 in (25 mm). The frame was bent and the cab was deformed. The driver side window was broken out and the door was jammed. Also, damage was done to the front bumper, hood, grill, left front quarter panel, left rear quarter panel, rear bumper and left front tire and rim.

Test Results

Impact speed was 47.7 mi/h (76.7 km/h) and the angle of impact was 19.0 degrees. The speed of the vehicle at time of parallel was 45.5 mi/h (73.2 km/h) and the coefficient of friction was 0.02. The vehicle lost contact with the transition traveling at 42.8 mi/h (68.9 km/h), and the exit angle between the vehicle path and the transition was 8.9 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 7.2 ft/s (2.2 m/s) at 0.373 s, the highest 0.010-s average ridedown acceleration was 1.1 g between 0.389 and 0.399 s, and the maximum 0.050-s average acceleration was -2.2 g between 0.069 and 0.119 s. Lateral occupant impact velocity was

16.2 ft/s (4.9 m/s) at 0.161 s, the highest 0.010-s occupant ridedown acceleration was -9.6 g between 0.257 and 0.267 s, and the maximum 0.050-s average acceleration was -7.3 g between 0.076 and 0.126 s. The change in vehicle velocity at loss of contact was 4.9 mi/h (7.8 km/h), and the change in momentum was 231 lb-s (1,029 N-s). These data and other pertinent information from the test are summarized in figure 22 and table 3. Sequential photographs are shown in figures 23 and 24. Vehicular angular displacements are displayed in figure 25. Vehicular accelerations versus time traces filtered at SAE J211 (Class 180) are presented in figures 26 through 32.

Conclusions

The transition contained the test vehicle with minimal lateral movement of the transition. There was no intrusion of railing components into the occupant compartment. The vehicle remained upright and relatively stable during the collision. The transition redirected the vehicle and the effective coefficient of friction was considered good. Velocity change of the vehicle during the collision was 4.9 mi/h (7.9 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 (9.2 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 indicated minimum intrusion into adjacent traffic lanes. See figure 22 and table 3 for more details.

Figure 16. Vehicle/transition geometrics before test 7069-28.

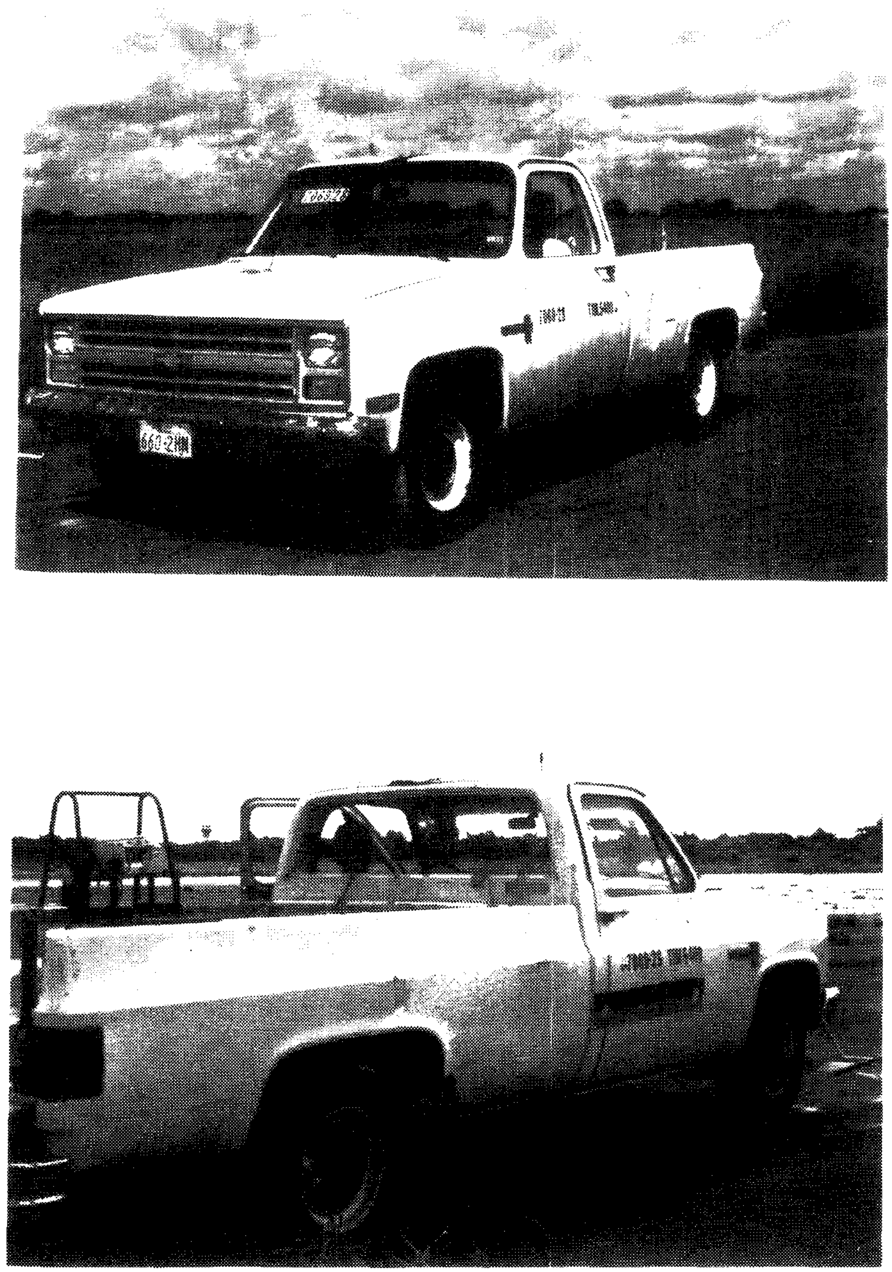


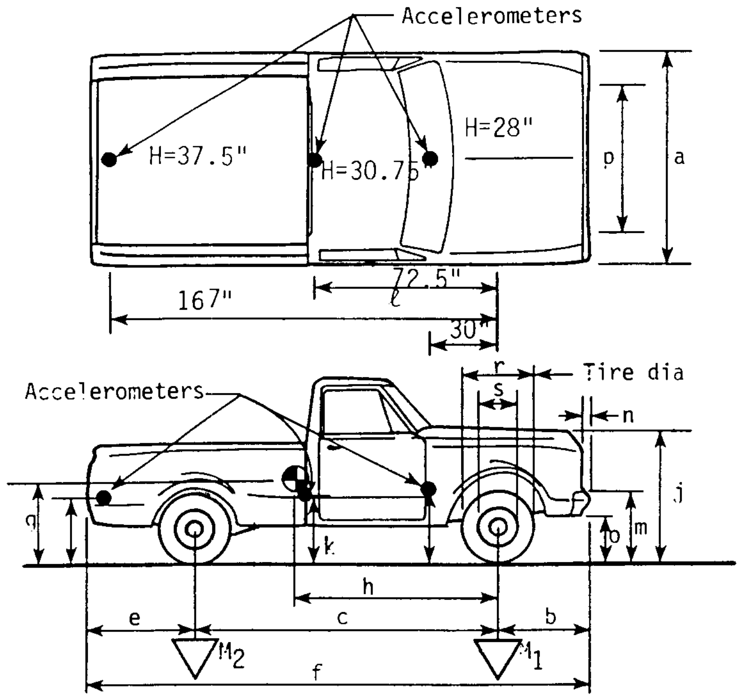
Figure 17. Vehicle before test 7069-28.

Date: 6-18-92 Test No.: 7069-28 VIN: 1GCGC24M2FF406382

Make: Chevy Model: Custom Deluxe 20 Year: 1985 Odometer: 71956

Tire Size: LT 215/85R16 Ply Rating: ______ Bias Ply: ___ Belted: ___ Radial: X

Tire Condition: good ___
fair X
badly worn ___



Vehicle Geometry - inches

a	70.75"	b	32"
c	131"	d*	71.25"
e	52"	f	
g		h	70.9"
i	----	j	45.75"
k	30.75"	ℓ	72.5"
m	26.75"	n	3.5"
o	17.75"	p	66"
r	30.5"	s	17.5"

Engine Type: 8 Cyl Gasoline

Engine CID: 5.7 liter

Transmission Type:
Automatic or Manual
~~FWD~~ or RWD or ~~4WD~~

Body Type: Pick-up

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 1248 rf 1231 ℓr 1411 rr 1510

Mass - pounds	Curb	Test Inertial	Gross Static
M_1	2531	2479	2575
M_2	1899	2921	2990
M_T	4430	5400	5565

Note any damage to vehicle prior to test:

____

____

*d = overall height of vehicle

1 in = 25.4 mm
1 lb = .454 kg

Figure 18. Vehicle properties for test 7069-28.

Figure 19. Oregon transition before test 7069-28.

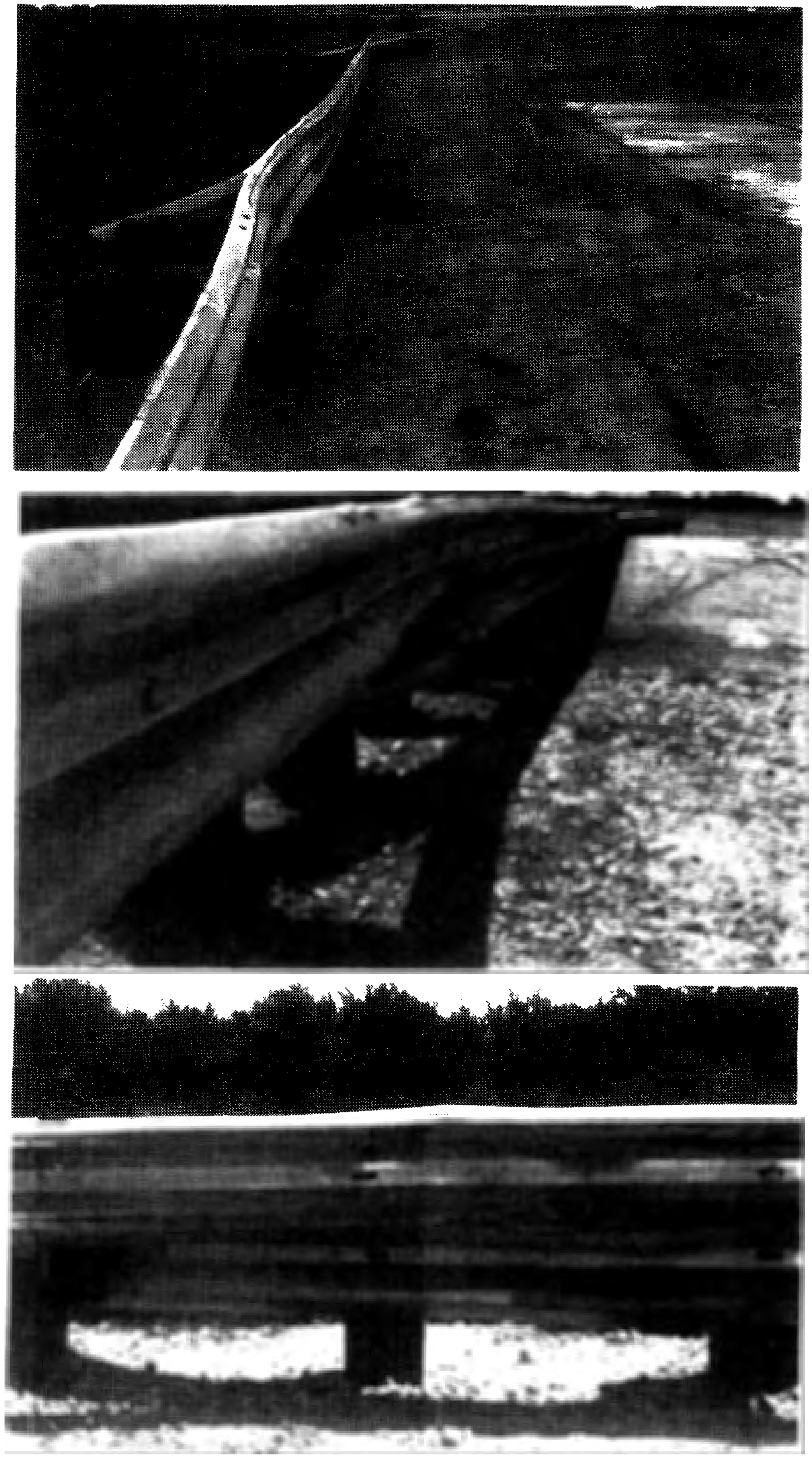
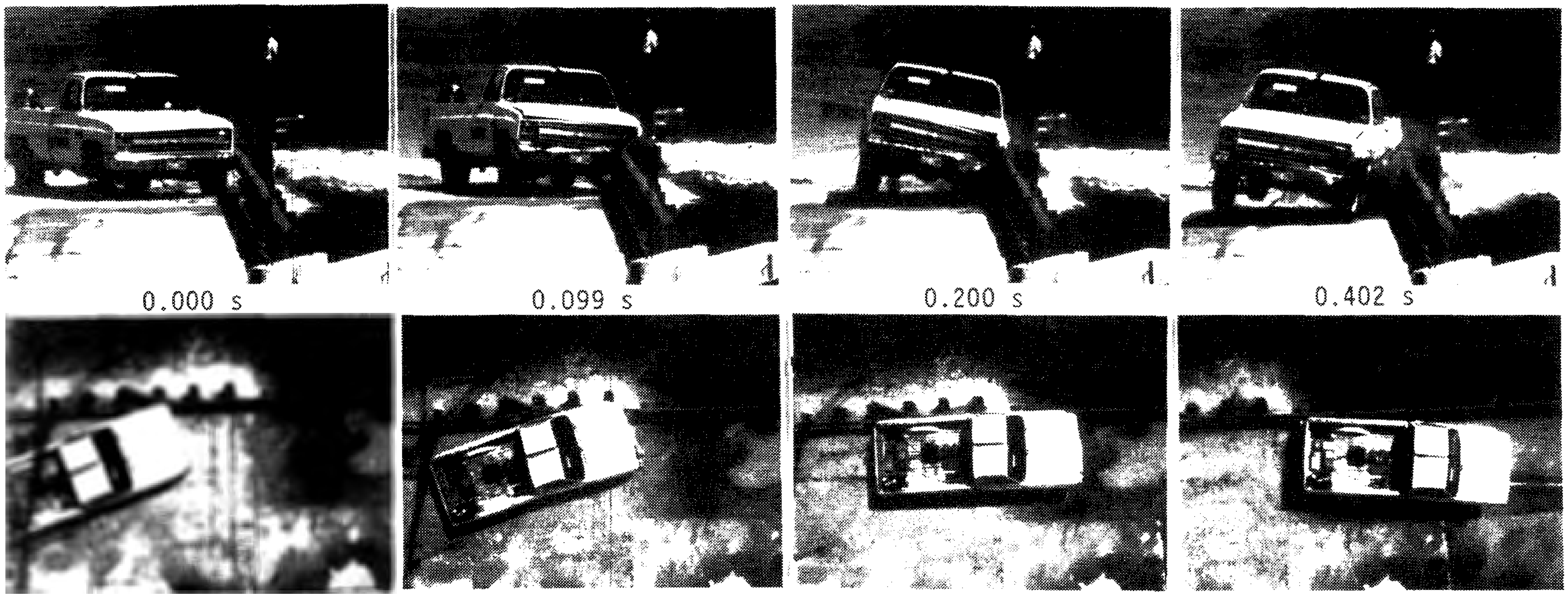
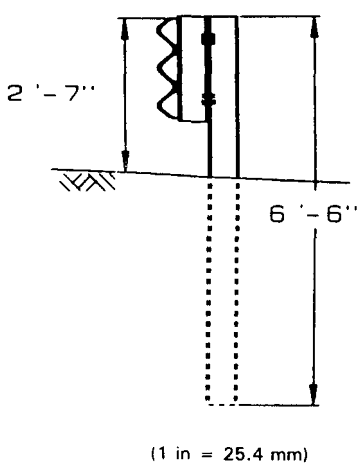


Figure 20. Oregon transition after test 7069-28.

Figure 21. Vehicle after test 7069-28.





Test No. 7069-28
Date 06/18/92

Test Installation . . . Oregon Thrie-beam Transition
Installation Length . . 85 ft (26 m)

Test Vehicle . . . . 1985 Chevrolet C-20 Pickup
Vehicle Weight
  Test Inertia . . . . . 5,400 lb (2,452 kg)
  Gross Static . . . . . 5,565 lb (2,527 kg)
Vehicle Damage Classification
  TAD . . . . 11LFQ2 & 11LD2
  CDC . . . . 11FLEK2 & 11LDEW3
Maximum Vehicle Crush . 8.0 in (203 mm)

Impact Speed. . . . 47.7 mi/h (76.7 km/h)
Impact Angle. . . . 19.0 deg
Speed at Parallel . 45.5 mi/h (73.2 km/h)
Exit Speed . . . . 42.8 mi/h (68.9 km/h)
Exit Trajectory . . 8.9 deg
Vehicle Accelerations
  (Max. 0.050-sec Avg) at true c.g.
  Longitudinal. . . -2.2 g
  Lateral . . . . . -7.3 g
Occupant Impact Velocity at true c.g.
  Longitudinal. . . 7.2 ft/s (2.2 m/s)
  Lateral . . . . . 16.2 ft/s (4.9 m/s)
Occupant Ridedown Accelerations
  Longitudinal . . 1.1 g
  Lateral . . . . . -9.6 g

Figure 22. Summary of results for test 7069-28.

Table 3. Evaluation of crash test no. 7069-28.
{Oregon transition [5,400 lb (2 452 kg)|47.7 mi/h (76.7 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	No 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 0 - .25 — Good .26 - .35 — Fair > .35 — Marginal	μ — Assessment .02 — Good	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 7.2 (2.2); Lateral 16.2 (4.9)	Pass
	Occupant Ridedown Accelerations - g's Longitudinal 15; Lateral 15	Occupant Ridedown Accelerations - g's Longitudinal 1.1; Lateral -9.6	Pass
H.	Exit angle shall be less than 12 degrees	Exit angle was 8.9 degrees	Pass

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

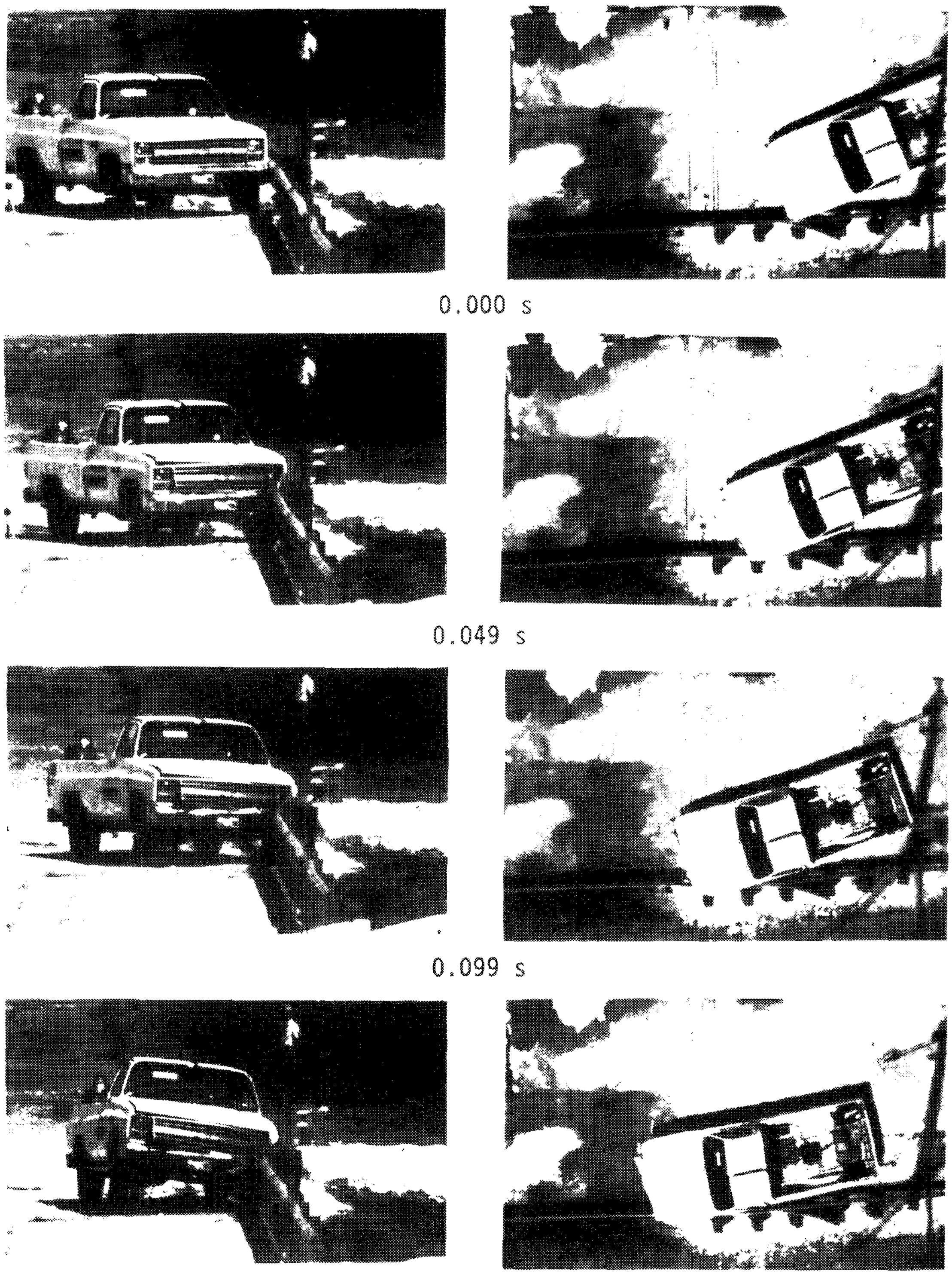
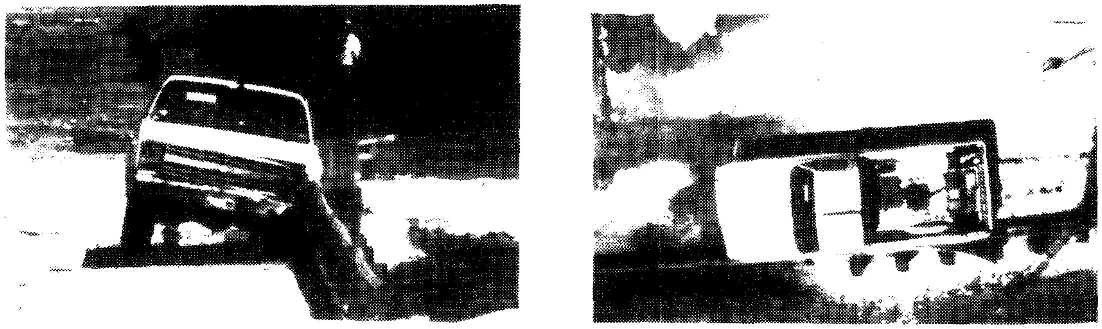
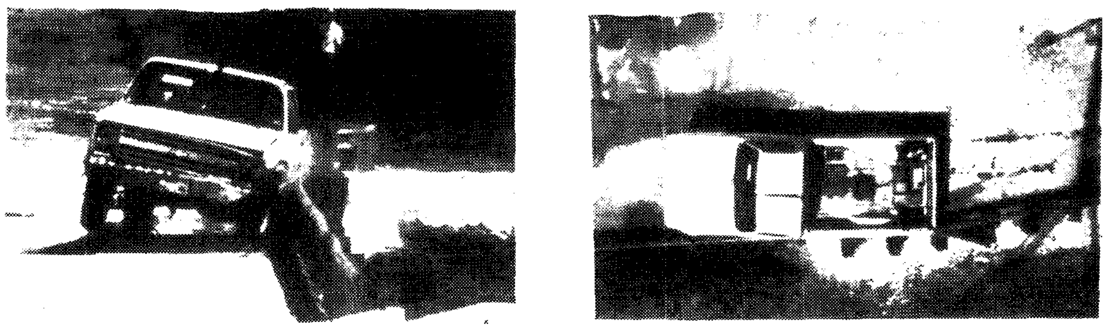


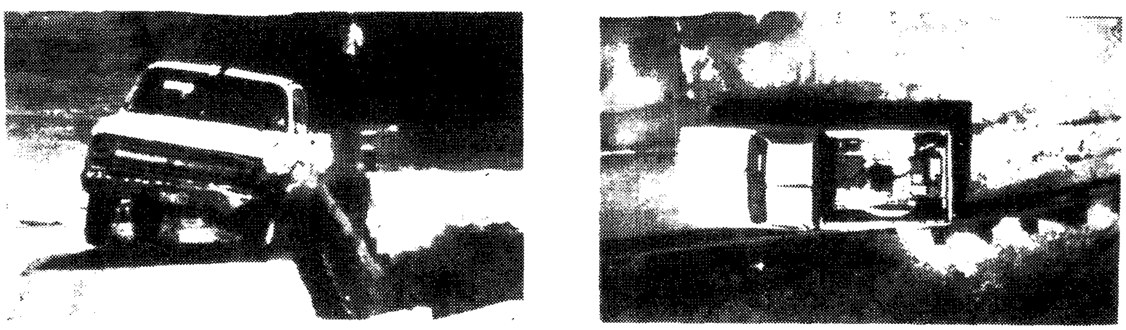
Figure 23. Sequential photographs for test 7069-28 (frontal and overhead views).



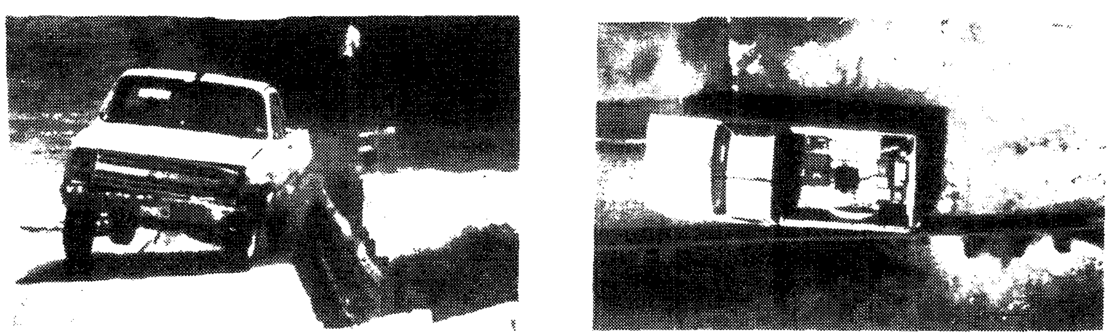
0.200 s



0.249 s



0.325 s



0.402 s

Figure 23. Sequential photographs for test 7069-28 (frontal and overhead views continued).

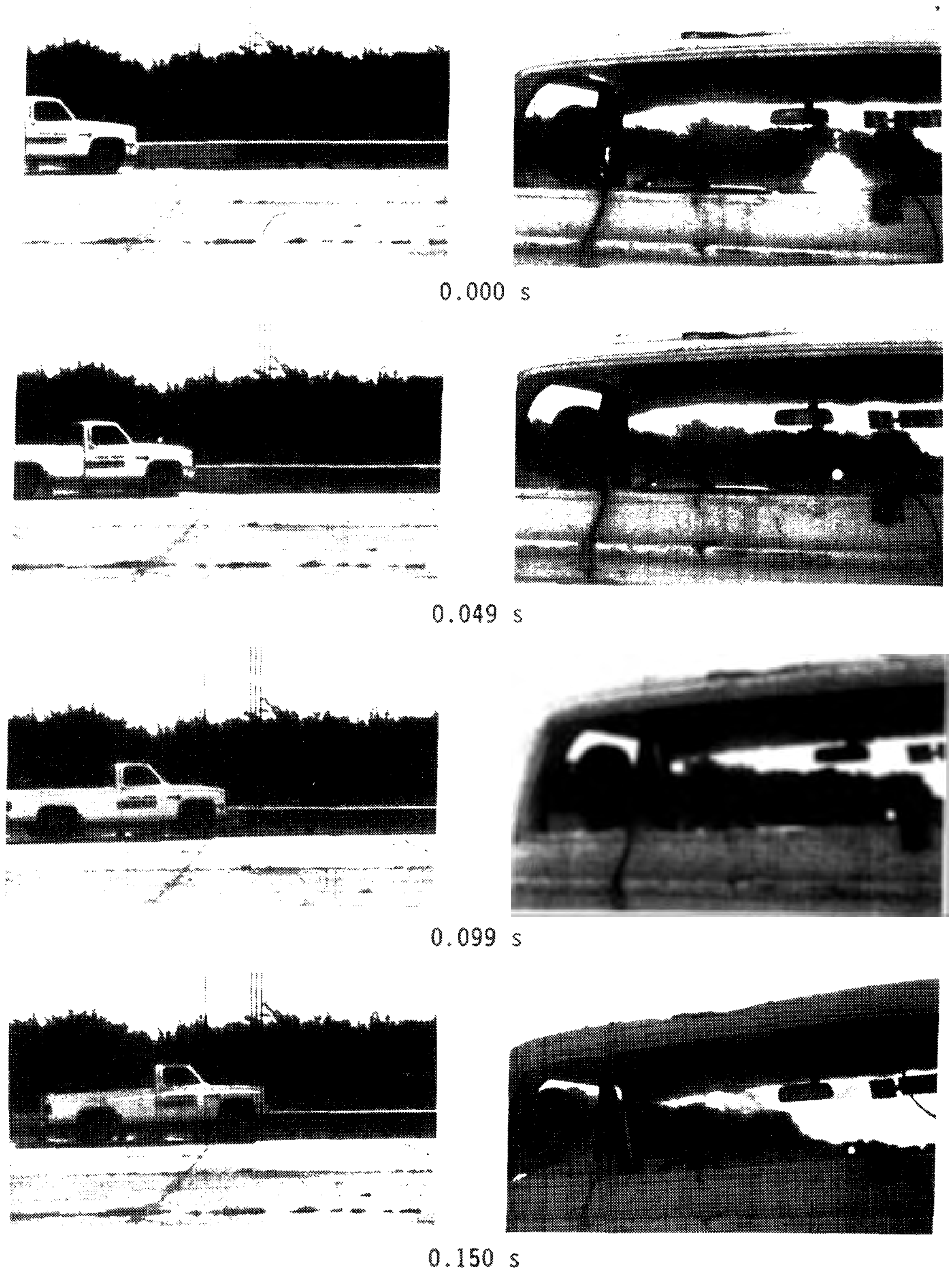
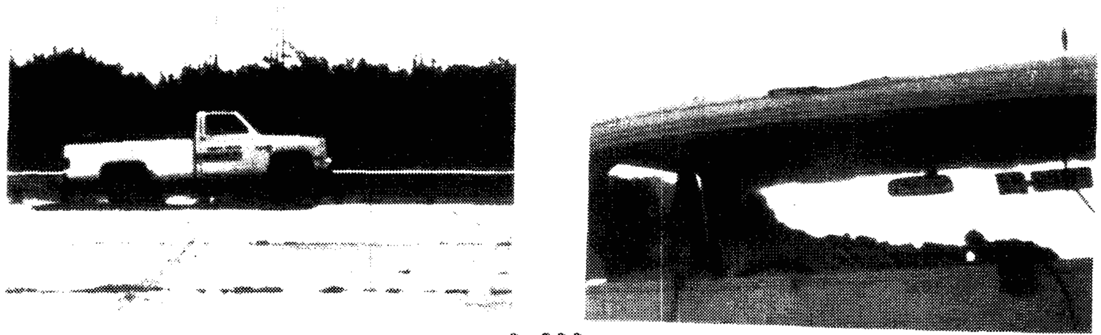
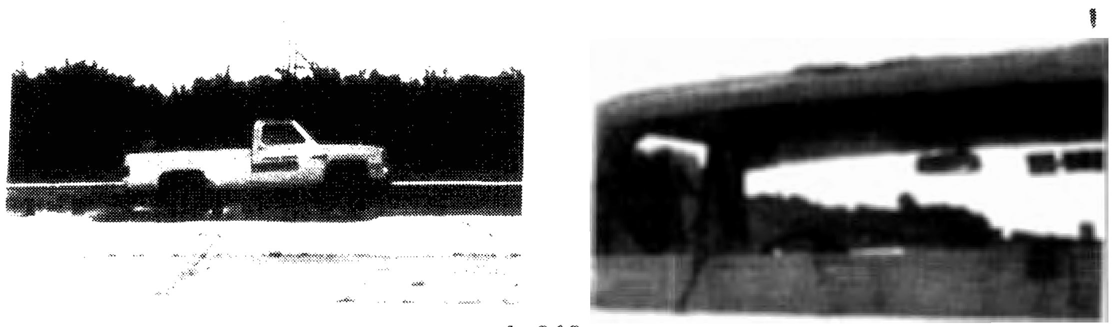


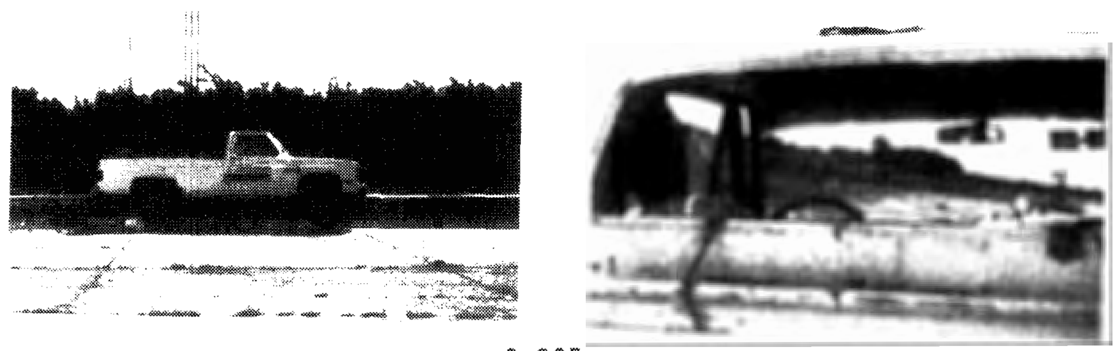
Figure 24. Sequential photographs for test 7069-28
(perpendicular and interior views).



0.200 s



0.249 s



0.325 s

0.402 s

Figure 24. Sequential photographs for test 7069-28
(perpendicular and interior views continued).

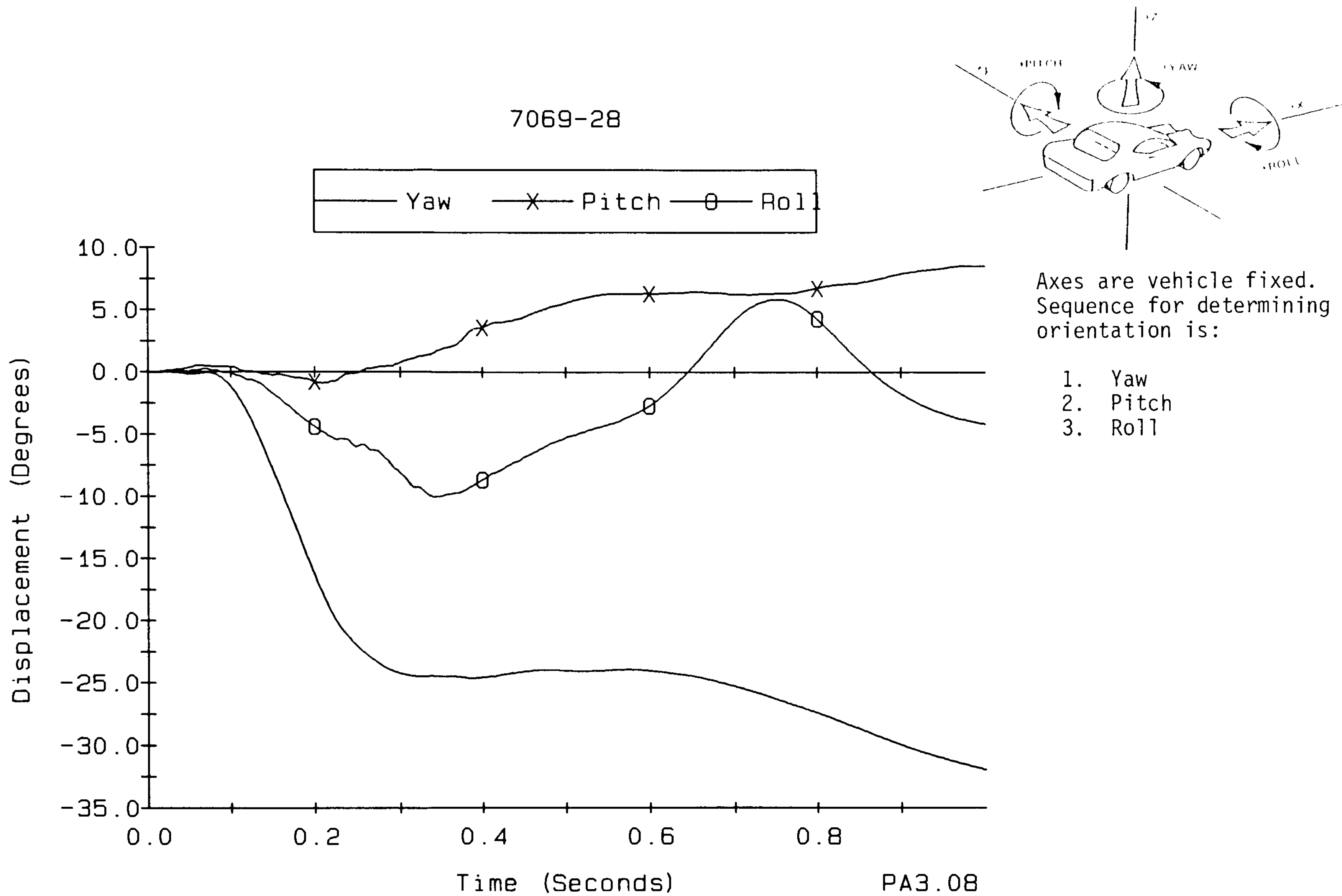


Figure 25. Vehicle angular displacements for test 7069-28.

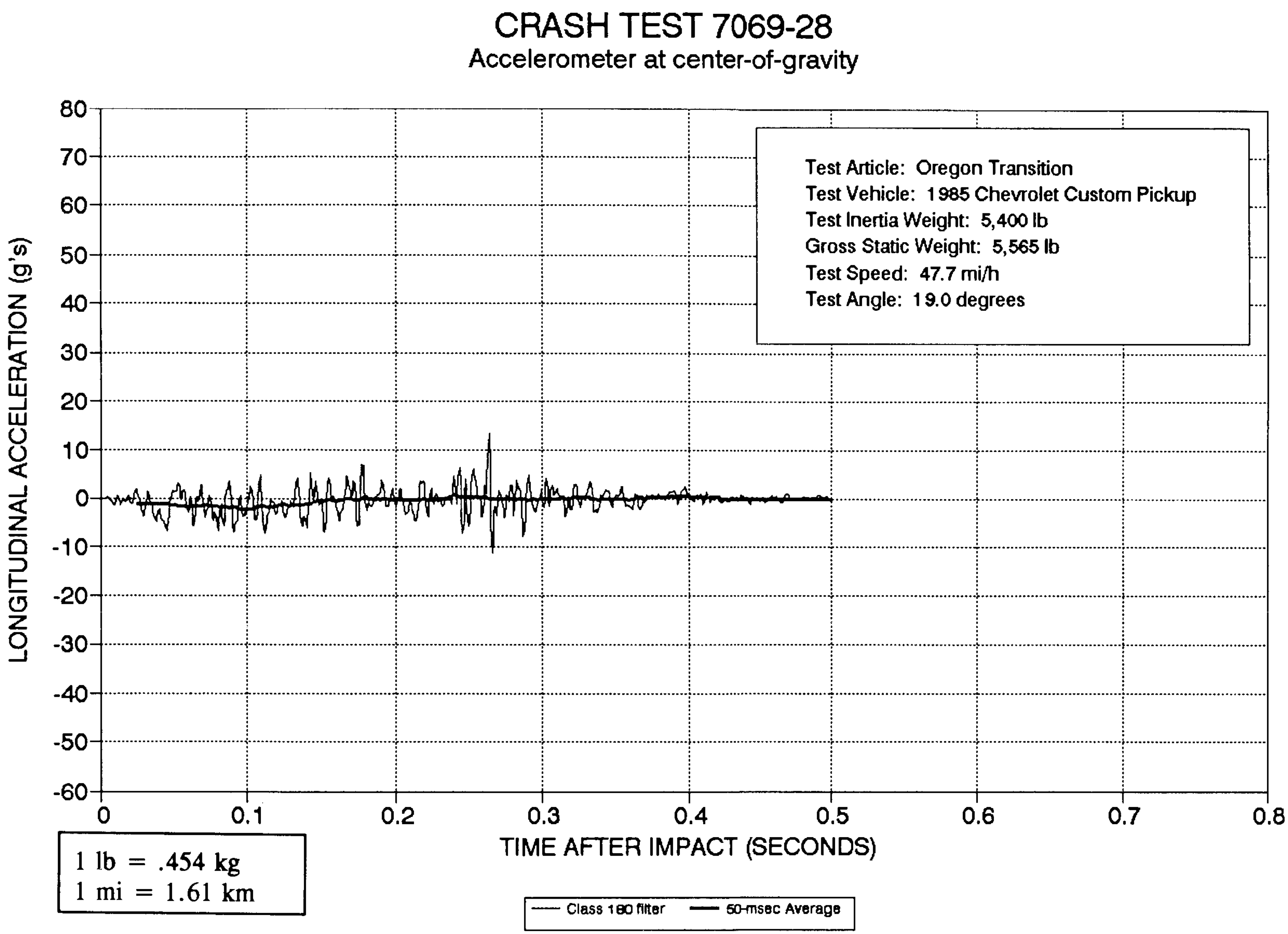


Figure 26. Vehicle longitudinal accelerometer trace for test 7069-28 (accelerometer located at center-of-gravity).

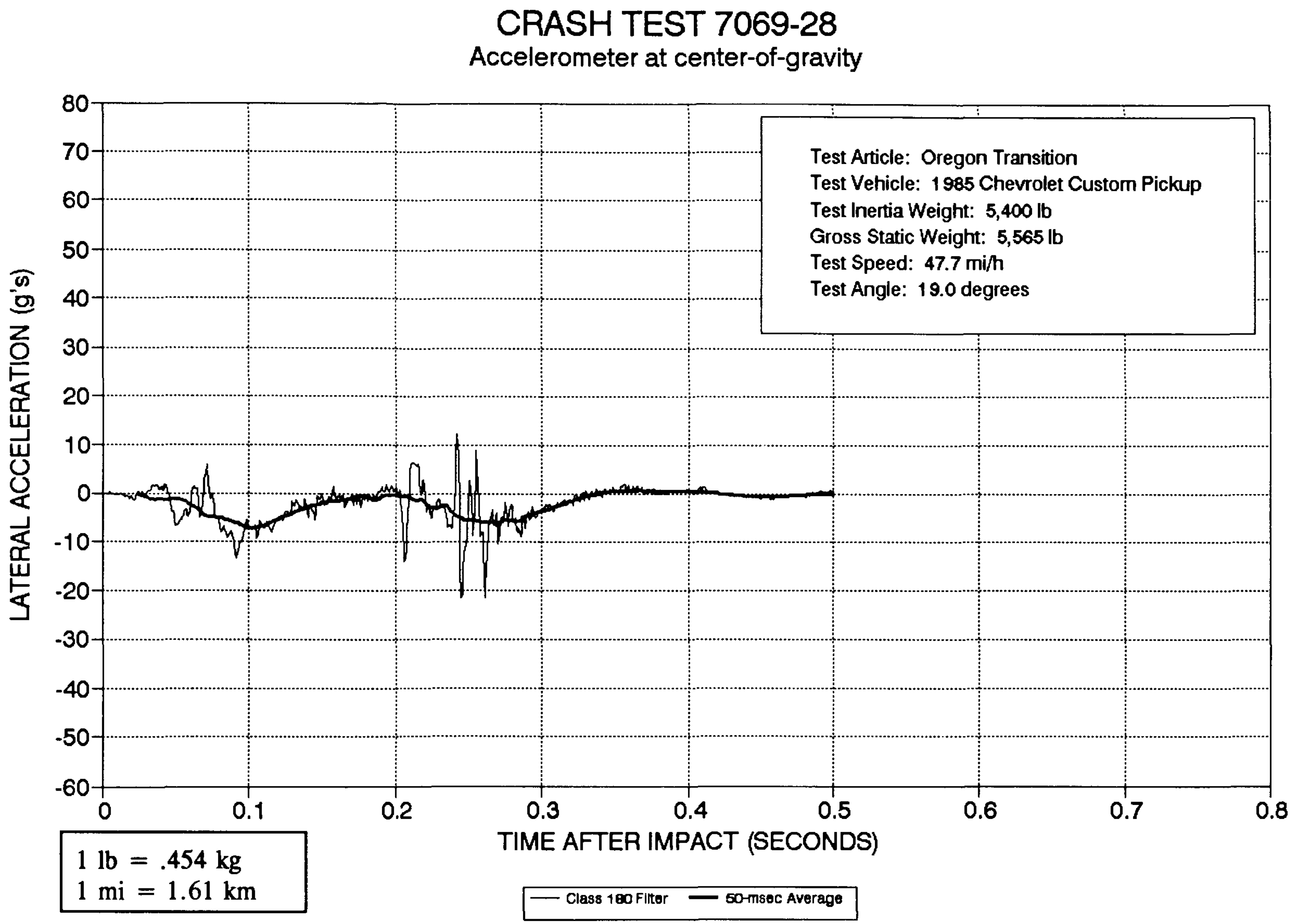


Figure 27. Vehicle lateral accelerometer trace for test 7069-28 (accelerometer located at center-of-gravity).

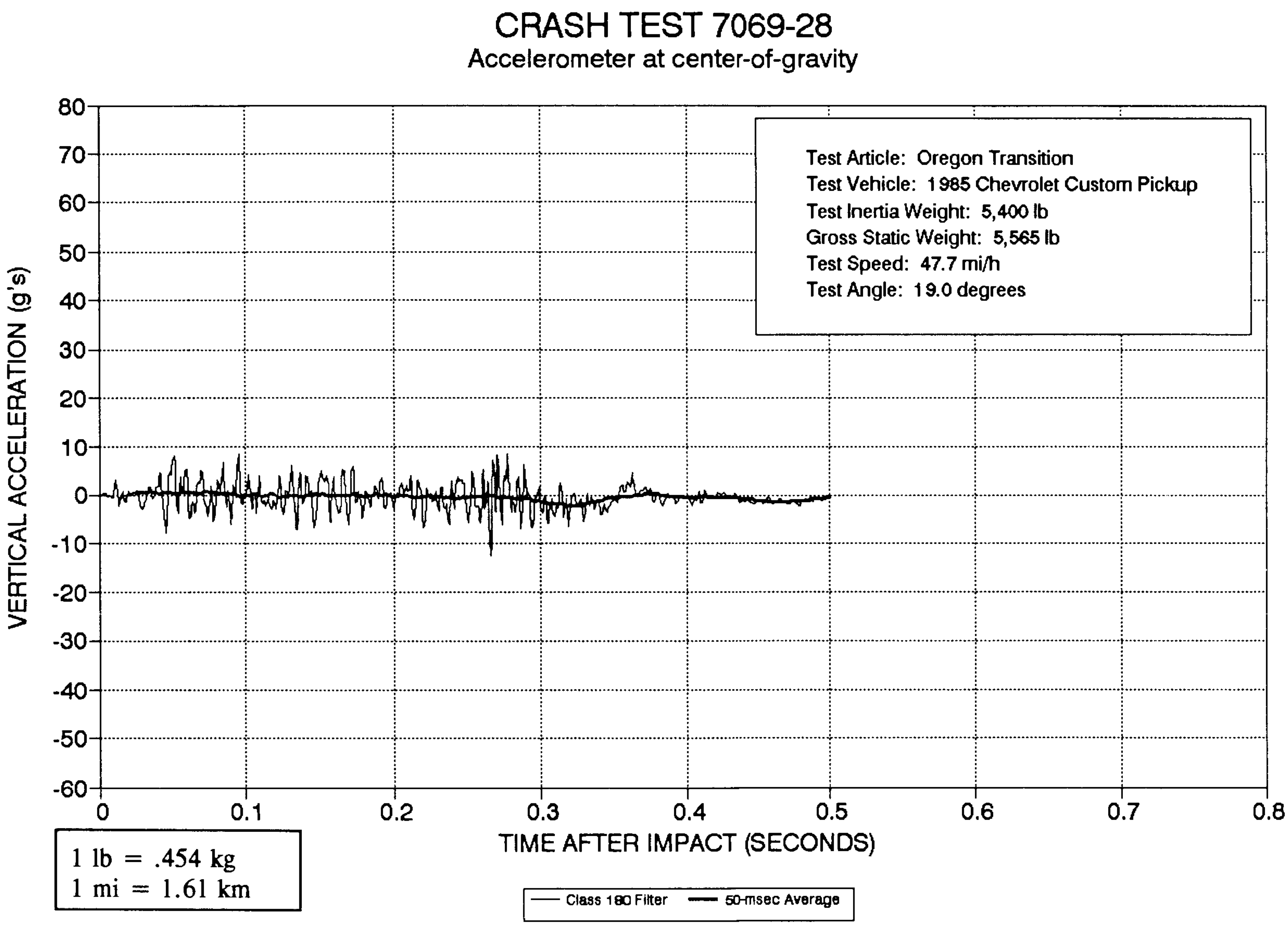


Figure 28. Vehicle vertical accelerometer trace for test 7069-28 (accelerometer located at center-of-gravity).

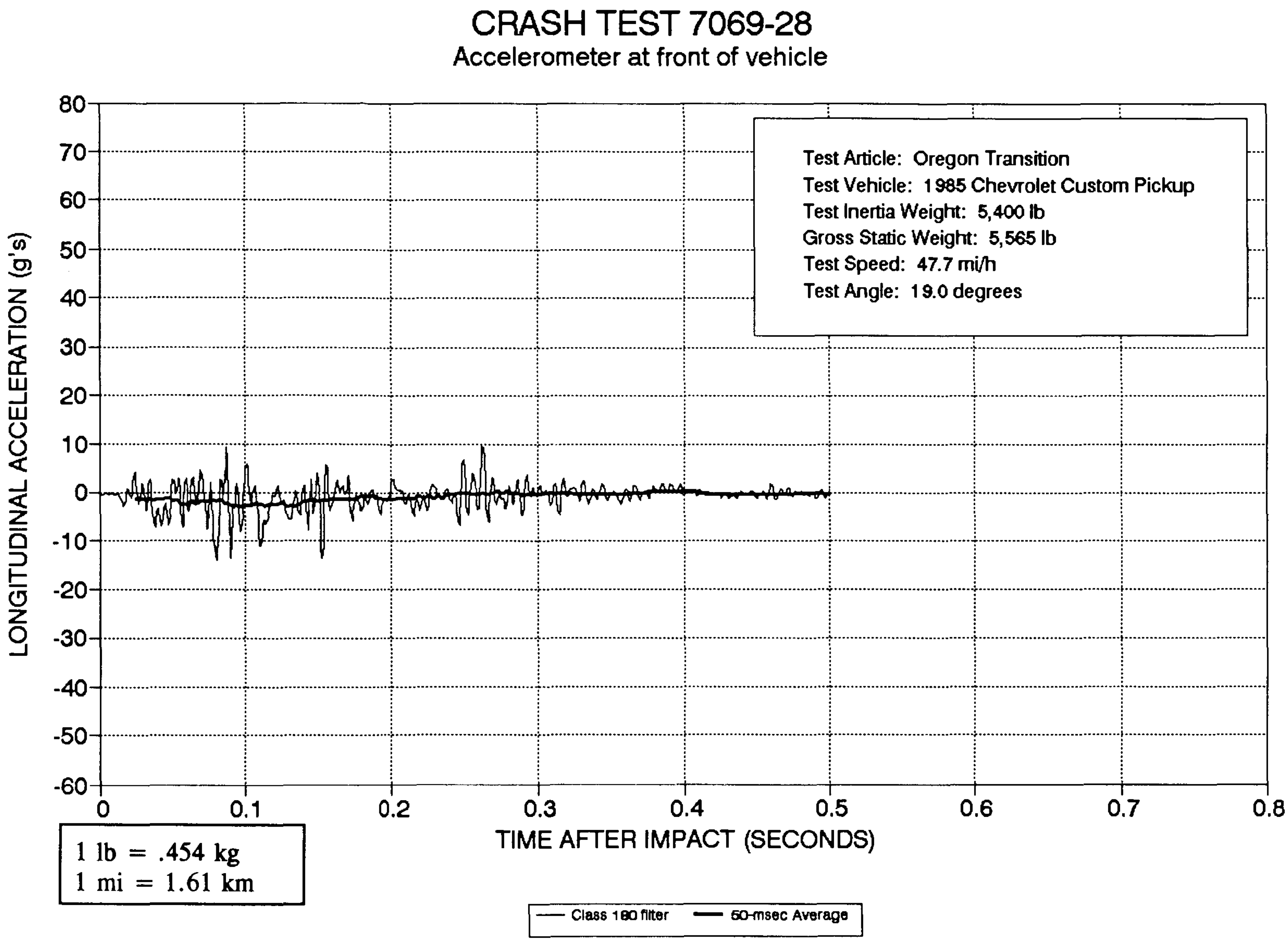


Figure 29. Vehicle longitudinal accelerometer trace for test 7069-28 (accelerometer located at front of vehicle).

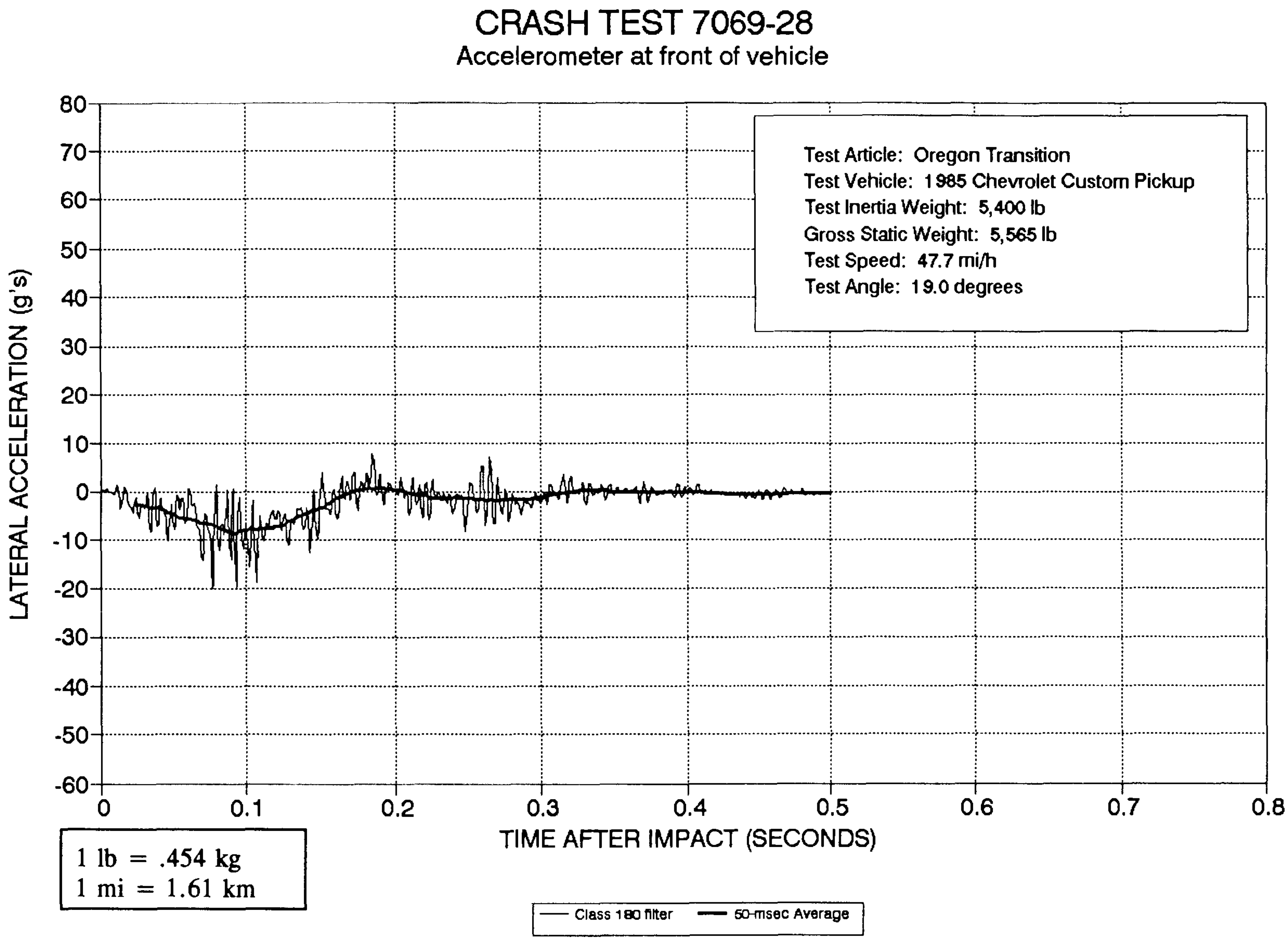


Figure 30. Vehicle lateral accelerometer trace for test 7069-28 (accelerometer located at front of vehicle).

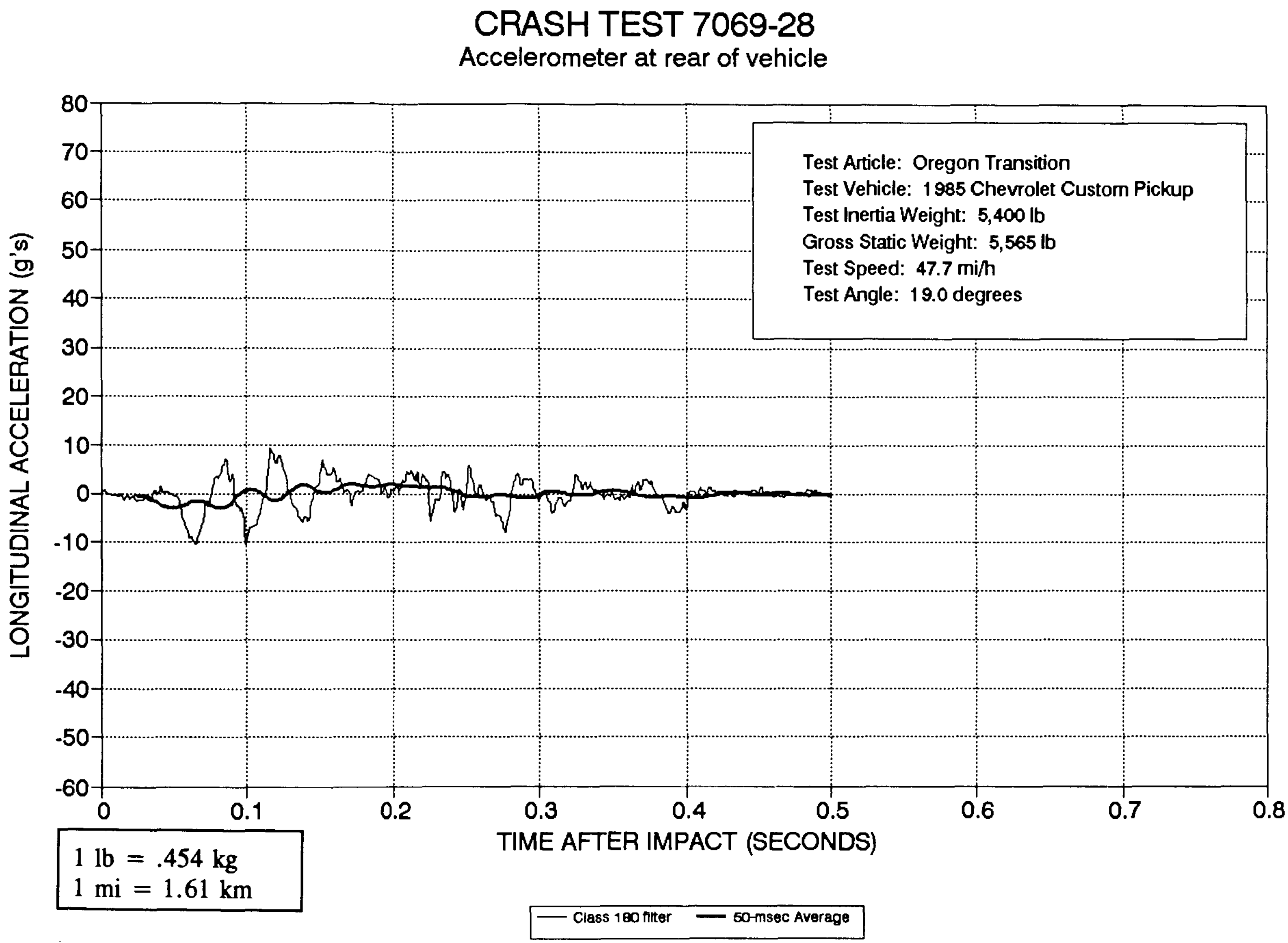


Figure 31. Vehicle longitudinal accelerometer trace for test 7069-28 (accelerometer located at rear of vehicle).

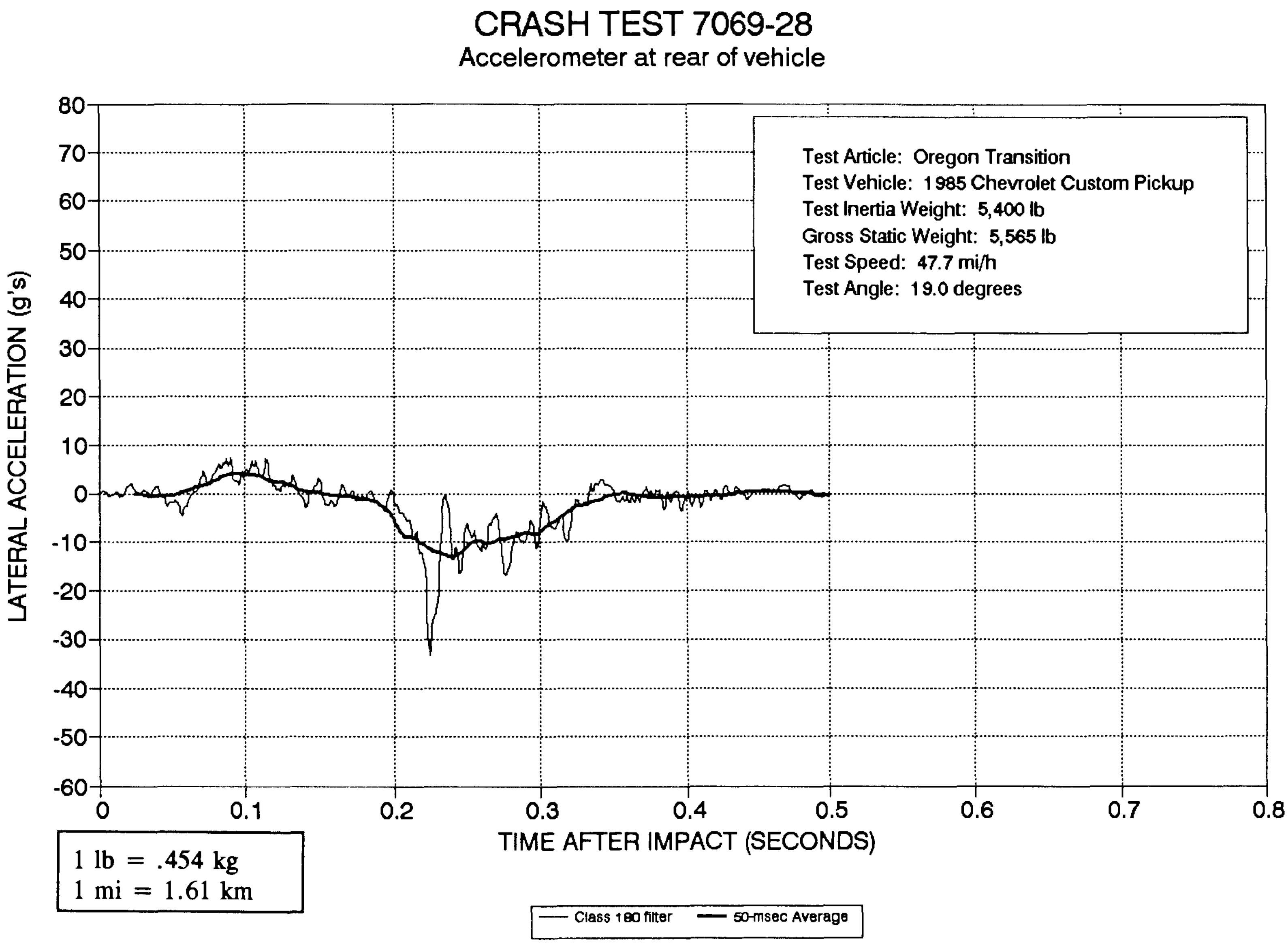


Figure 32. Vehicle lateral accelerometer trace for test 7069-28 (accelerometer located at rear of vehicle).

REFERENCES

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