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16. Abstract

A combination concrete parapet and metal railing was designed for performance level one of the 1989 *Guide Specifications for Bridge Railings*. Computed strength of the railing is 18 kips (80 kN) at 40 in (1.02 m) above the deck (sidewalk) or 91 kips (405 kN) at 27 in (686 mm) above the deck (sidewalk). The railing was tested to performance level two and acceptable results were obtained.

This volume is the eighth 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 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;" 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." 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		
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)

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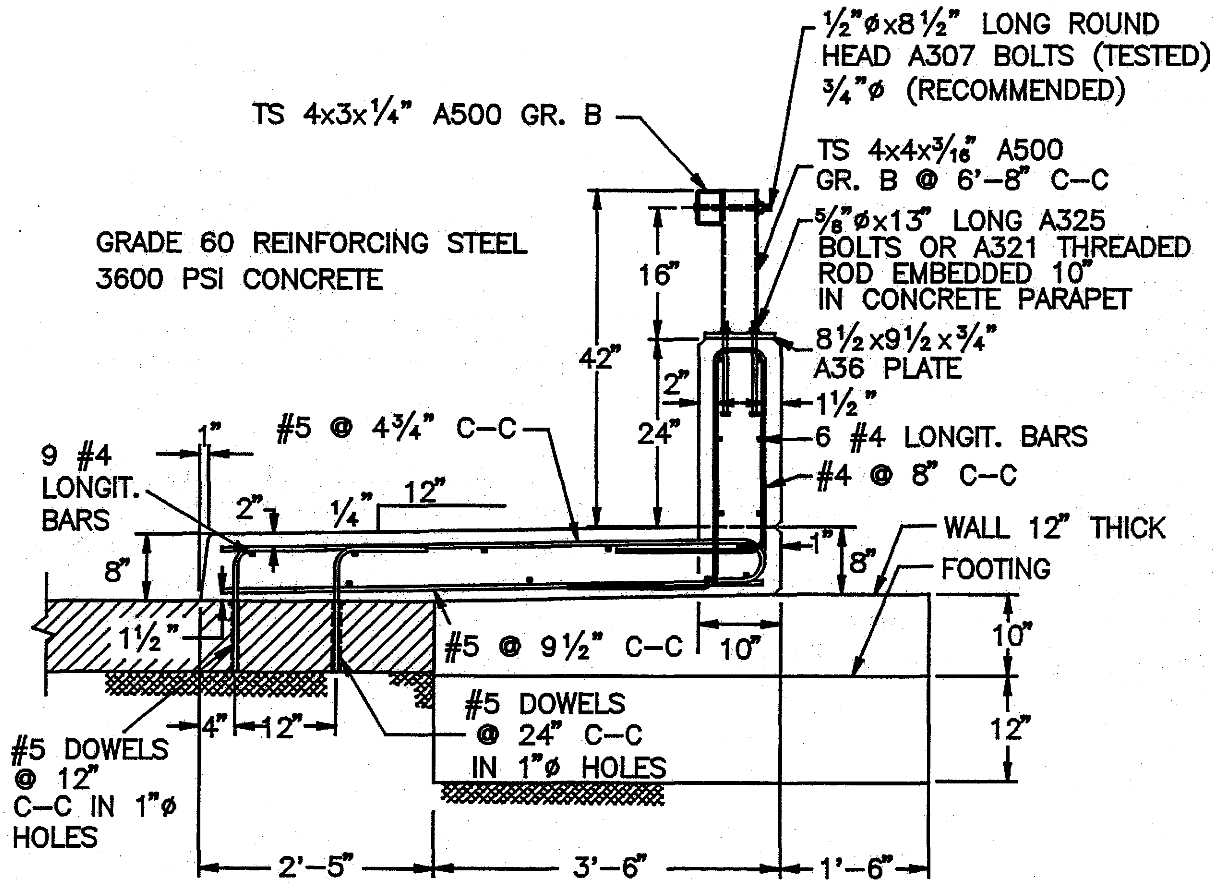
CHAPTER 1. DESIGN OF RAILING

The BR27C railing was originally designed to meet performance level one (1989 *Guide Specifications for Bridge Railings* when mounted on a 5-ft (1.5-m) wide sidewalk with an 8-in (200-mm) high curb at the face of the sidewalk (figure 1).[1] The design force for this situation was 30 kips (133 kN) of uniformly distributed line force 42-in (1.07-m) long located at least 35 in (890 mm) above the top surface of the sidewalk. An analysis of strength of this railing for force applied at various heights is presented in Chapter 4.

The railing was eventually tested to performance level two conditions both on the sidewalk and on the deck.

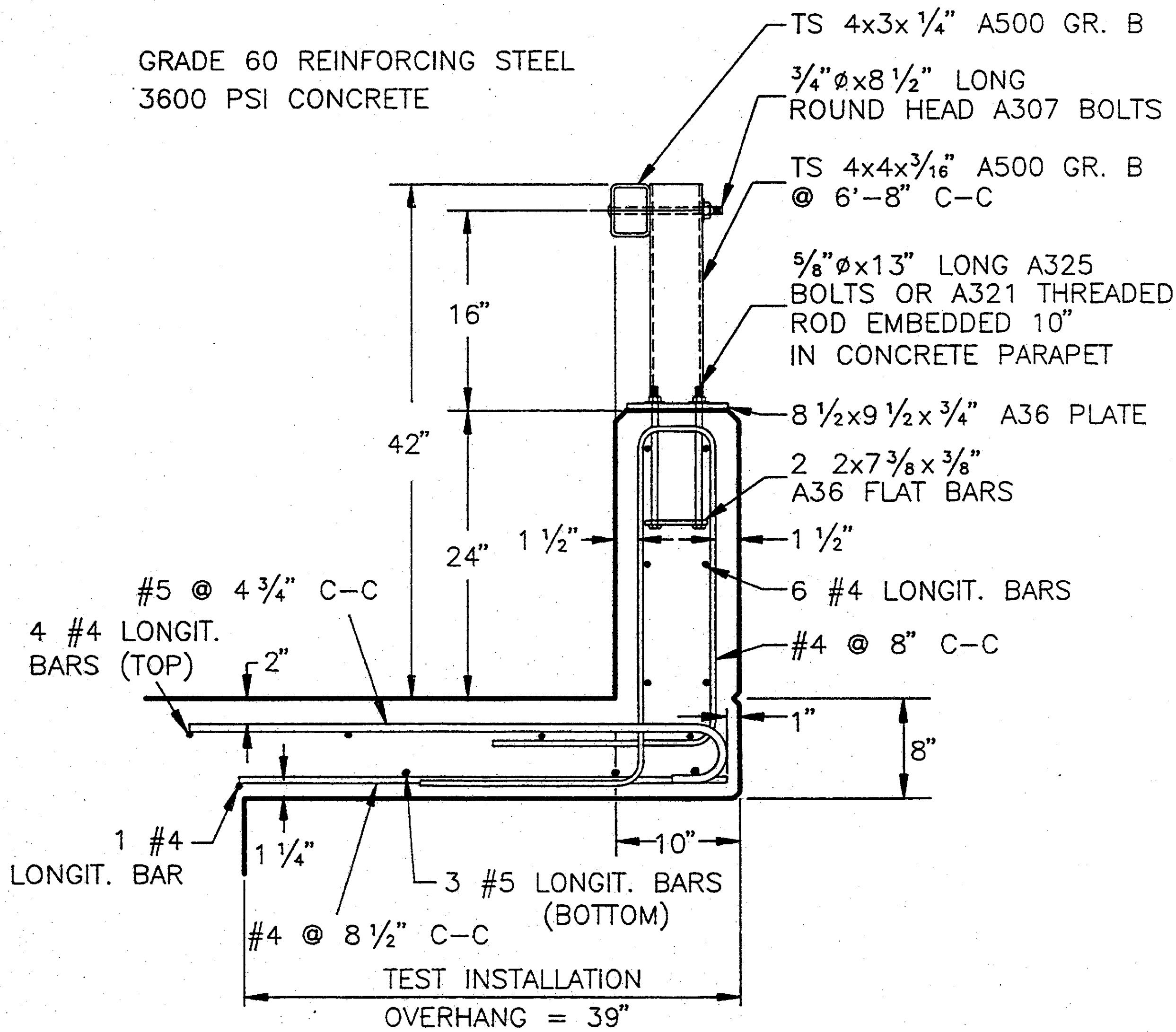
Cross-sections of both the curbed and flush-mounted railings are shown in figures 1 and 2. Total height of the railing is 42 in (1.067 mm). The lower portion of the railing consists of a 24-in (610-mm) high concrete parapet that is a constant 10-in (250-mm) thick. The upper portion of the railing consists of TS 4 by 4 by 3/16 in (102 by 102 by 2 mm) A500 grade B structural tubing utilized as vertical posts spaced at 6 ft-8 in (2 m) on center. One TS 4 by 3 by 1/4 in (102 by 76 by 6 mm) structural tube is utilized as a horizontal rail element mounted to each post with splices at low moment regions.

There are six #4 longitudinal bars and #4 vertical bent bars spaced at 8 in (200 mm) on center. The specified concrete strength was 3,600 psi (24 804 kPa) at 28 days, and the specified steel yield for the reinforcement was 60,000 psi (413 400 kPa). The sidewalk of the BR27C was cantilevered over the existing concrete pavement and supported by 12-in (305-mm) thick vertical concrete walls spaced at 25 ft (7.6 m) on center. The deck of the flush mounted BR27C was cantilevered without any vertical supports.



1 in = 25.4 mm
1 psi = 6.89 kPa

Figure 1. Cross section of BR27C bridge railing on sidewalk.



1 in = 25.4 mm
1 psi = 6.89 kPa

Figure 2. Cross section of BR27C bridge railing on deck.

CHAPTER 2. CRASH TEST PROCEDURES

The BR27C bridge railing on sidewalk was tested to performance level two requirements.[1] The following nominal test conditions were used:

1,800-lb (817-kg) passenger car | 60 mi/h (96.6 km/h) | 20 degrees (test 7069-24)
5,400-lb (2 452-kg) pickup | 60 mi/h (96.6 km/h) | 20 degrees (test 7069-25)
18,000-lb (8 172-kg) truck | 50 mi/h (80.5 km/h) | 15 degrees (test 7069-26)

The BR27C bridge railing on deck was also tested to performance level two requirements.[1] The following nominal test conditions were used:

1,800-lb (817-kg) passenger car | 60 mi/h (96.6 km/h) | 20 degrees (test 7069-32)
5,400-lb (2 452-kg) pickup | 60 mi/h (96.6 km/h) | 20 degrees (test 7069-33)
18,000-lb (8 172-kg) truck | 50 mi/h (80.5 km/h) | 15 degrees (test 7069-34)

Each vehicle was instrumented with three solid-state angular rate transducers to measure roll, pitch, and yaw rates; a triaxial accelerometer mounted at the vehicle center-of-gravity to measure longitudinal, lateral, and vertical acceleration levels, and a biaxial accelerometer in the rear of the vehicle to measure longitudinal and lateral acceleration levels. In addition, another biaxial accelerometer was mounted forward of the center-of-gravity in the pickup and truck tests. 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 of each vehicle 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 curb of the sidewalk.

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

The digitized data from the electronic transducers 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 0.001-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.

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 bridge railing system at the downstream end, and a third placed perpendicular to the front of the bridge railing. A high-speed camera was also placed onboard the passenger car and the pickup to record the motions of the dummy placed in the driver seat 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 curb of the sidewalk 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 bridge railing 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 bridge railing, the test vehicle was released to be free-wheeling and unrestrained. The vehicle remained free-wheeling, i.e., no steering or braking inputs, until the vehicle cleared the immediate area of the test site, at which time brakes on the vehicle were activated to bring the vehicle to a safe and controlled stop.

CHAPTER 3. FULL-SCALE CRASH TESTS

BR27C BRIDGE RAILING ON SIDEWALK

Test 7069-24

Test Description

A 1982 Honda Civic (figures 3 and 4) was used for the crash test. Test inertia mass of the vehicle was 1,800 lb (817 kg) and its gross static mass was 1,965 lb (892 kg). The height to the lower edge of the vehicle bumper was 15.0 in (381 mm) and it was 20.5 in (521 mm) to the top of the bumper. Additional dimensions and information on the test vehicle are given in figure 5. The vehicle was directed into the BR27C bridge railing on sidewalk (figures 6 and 7) 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 curb of the sidewalk approximately 20 ft (6 m) upstream of post 5 at a speed of 61.7 mi/h (99.3 km/h) and the angle of impact was 18.7 degrees.

At approximately 0.025 s after impact, the left front corner of the vehicle began to deform and at 0.185 s the right front tire impacted the curb. The vehicle impacted the concrete parapet at 0.219 s traveling at a speed of 55.5 mi/h (89.3 km/h) and an angle of 18.1 degrees. At 0.267 s the vehicle began to redirect significantly and at 0.302 s the right rear tire impacted the curb. The vehicle briefly lost contact with the parapet at 0.397 s. It became totally airborne and remained as such as it began to travel parallel with the bridge railing at a speed of 50.9 mi/h (81.9 km/h). The rear of the vehicle contacted the parapet at 0.440 s and then exited the bridge railing at 0.521 s traveling at a speed of 50.3 (80.9 km/h) and an exit angle of 1.0 degrees. As the vehicle exited the bridge railing installation, the brakes were applied. The vehicle yawed clockwise and subsequently came to rest 187 ft (57 m) down and 50 ft (15 m) in front of the point of impact.

As can be seen in figure 8, the bridge railing system received minimal damage. There was no measurable permanent deformation to the metal railing elements; however, the left corner of the bumper had snagged post 6 (leaving plastic trim). Also, posts 5 and 6 were pulled up such that the washers rotated freely under the nuts on the front side of the railing (see figure 9). There was only cosmetic damage to the concrete parapet, i.e., tire marks on the concrete parapet from post 5 on past post 6 and then again between posts 8 and 9 where the vehicle contacted the parapet the s time. The vehicle was in contact with the bridge railing system for 12.25 ft (3.7 m).

The vehicle sustained damage to the left side as shown in figure 10. Maximum crush at the left front corner at bumper height was 7.5 in (191 mm). The left front strut was bent and the left front wheel was pushed back reducing the wheelbase on the driver side by 3 in (76 mm). Also, damage was done to the front bumper, hood, left front quarter panel, left rear quarter panel, rear bumper, left front and rear tires and rims, and right front tire.

Test Results

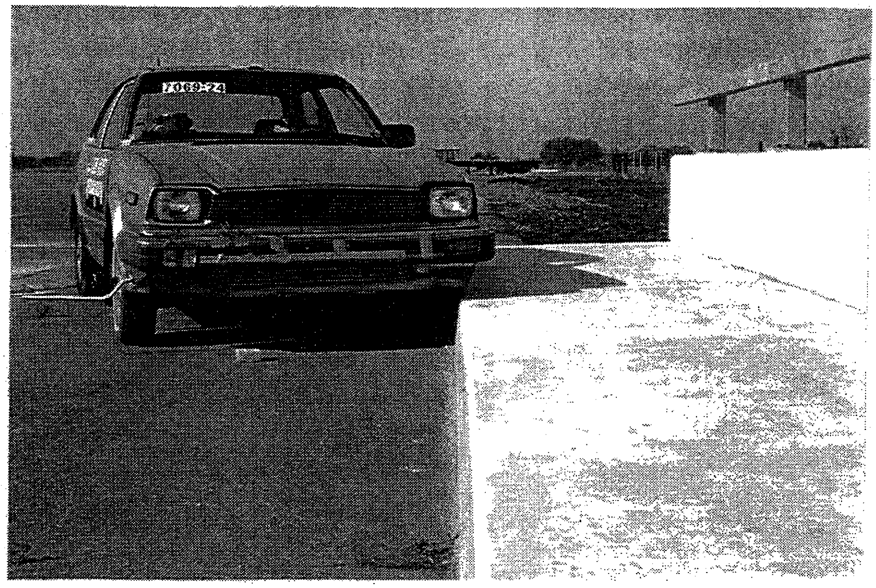
The vehicle impacted the curb of the sidewalk at 61.7 mi/h (99.3 km/h) and the angle of impact was 18.7 degrees. As the vehicle impacted the concrete parapet, it was traveling at a speed of 55.5 mi/h (89.3 km/h) and an angle of 18.1 degrees. The speed of the vehicle at the time of parallel was 50.9 mi/h (81.9 km/h). In determining the effective coefficient of friction which is an assessment of the smoothness of the "vehicle-railing" interaction, it should be noted that vehicle impact speed and angle is used in the calculation. If "vehicle-railing" interaction is interpreted literally, impact at the time of contact with the concrete parapet would be used. However, the curb could be considered to be part of this "vehicle-railing" interaction. Therefore, two assessments could be made: (1) interpreting "vehicle-railing" interaction literally disregarding the impact at the curb and using the speed and angle at which the vehicle impacted the concrete parapet or (2) considering the curb as an element of the "railing" system and using the speed and angle at which the vehicle impacted the curb. The coefficient of friction was calculated both ways for this test. Considering the curb as part of the vehicle-railing interaction the coefficient of friction was 0.38, while it was 0.11 using impact with the concrete parapet in the calculation. The vehicle lost contact with the bridge railing traveling at 50.3 mi/h (80.9 km/h) and the exit angle between the vehicle path and the bridge railing was 1.0 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 15.3 ft/s (4.7 m/s) at 0.307 s, the highest 0.010-s average ridedown acceleration was -3.8 g between 0.660 and 0.670 s, and the maximum 0.050-s average acceleration was -5.6 g between 0.260 and 0.310 s. Lateral occupant impact velocity was 6.5 ft/s (2.0 m/s) at 0.214 s, the highest 0.010-s occupant ridedown acceleration was -17.2 g between 0.276 and 0.286 s, and the maximum 0.050-s average acceleration was -9.3 g between 0.255 and 0.305 s. The change in vehicle velocity at loss of contact using impact with the curb was 11.4 mi/h (18.3 km/h) and the change in momentum was 935 lb-sec (4,157 N-s). These data and other pertinent information from the test are summarized in figure 11 and table 1. Sequential photographs are shown in figures 12 and 13. Vehicular angular displacements are displayed in figure 14. Vehicular accelerations versus time traces filtered with SAE J211 filters are presented in figures 15 through 17.

Conclusions

The BR27C bridge railing on sidewalk contained the test vehicle with no lateral movement of the bridge railing. There was no intrusion of railing components into the occupant compartment and no debris to present undue hazard to other traffic. The integrity of the occupant compartment was maintained with no intrusion and no deformation. The vehicle remained upright and relatively stable during the collision. The bridge railing system smoothly redirected the vehicle. The effective coefficient of friction using the curb impact conditions was considered marginal, while using impact conditions with the railing itself was good.

The 1989 AASHTO (American Association of State Highway and Transportation Officials) guide specifications sets forth desired 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 and a limit of 15 g's for occupant ridedown accelerations in both longitudinal and lateral directions. Although the lateral ridedown acceleration of 17.2 g's was slightly above the recommended limit, the test was judged acceptable for this category as it was well within the limits of the other three occupant risk factors. The vehicle trajectory at loss of contact indicated minimum intrusion into adjacent traffic lanes. See figure 11 and table 1 for more details.



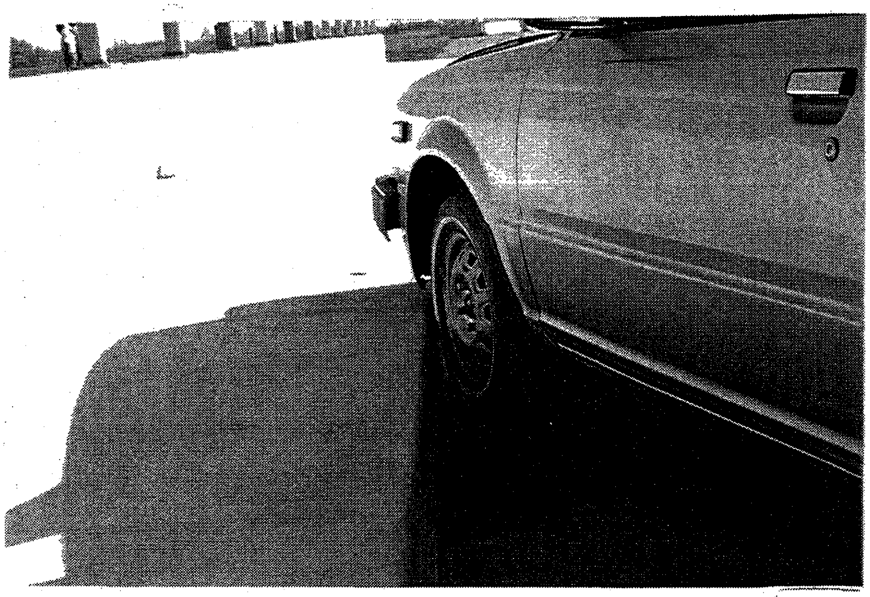


Figure 3. Vehicle/bridge railing geometrics for test 7069-24.

Figure 4. Vehicle prior to test 7069-24.

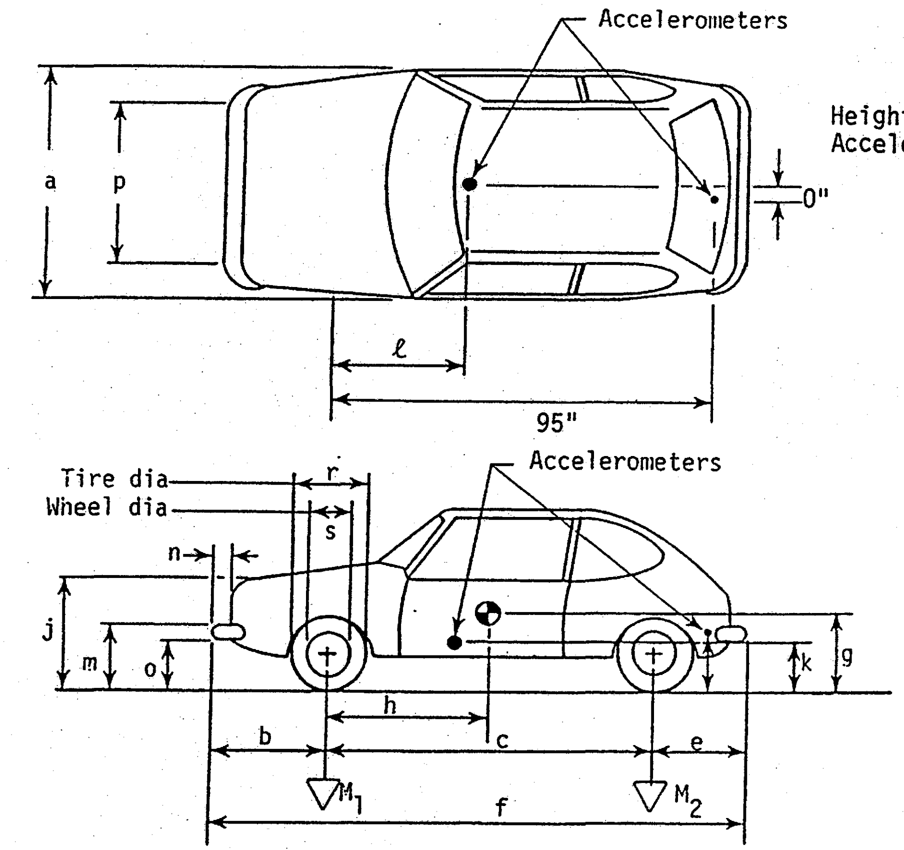
Date: 3-31-92 Test No.: 7069-24 VIN: JHMSR5328CS006791

Make: Honda Model: Civic Year: 1982 Odometer: 138404

Tire Size: P155/80R13 Ply Rating: ____ Bias Ply: ___ Belted: ___ Radial: X

Tire Condition: good ___ fair X badly worn ___

Height of Rear Accelerometer 29 1/2"



Vehicle Geometry - inches

a	63"	b	30"
c	89"	d*	53 1/4"
e	28 1/2"	f	147.5
g		h	34.4
i	----	j	29"
k	18"	ℓ	34 1/2"
m	20 1/2"	n	3"
o	15"	p	53 1/2"
r	22 3/4"	s	14 1/4"

Engine Type: 4 cyl

Engine CID: 91

Transmission Type:

~~Automatic~~ or Manual

FWD or ~~RWD~~ or ~~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 575 rf 530 ℓr 350 rr 345

Mass - pounds	Curb	Test Inertial	Gross Static
M_1	614 1186 572	1105	1180
M_2	351 696 345	695	785
M_T	1882	1800	1965

Note any damage to vehicle prior to test:

Crack in windshield (marked)

*d = overall height of vehicle

1 in = 25.4 mm
1 lb = 0.454 kg

Figure 5. Vehicle properties for test 7069-24.

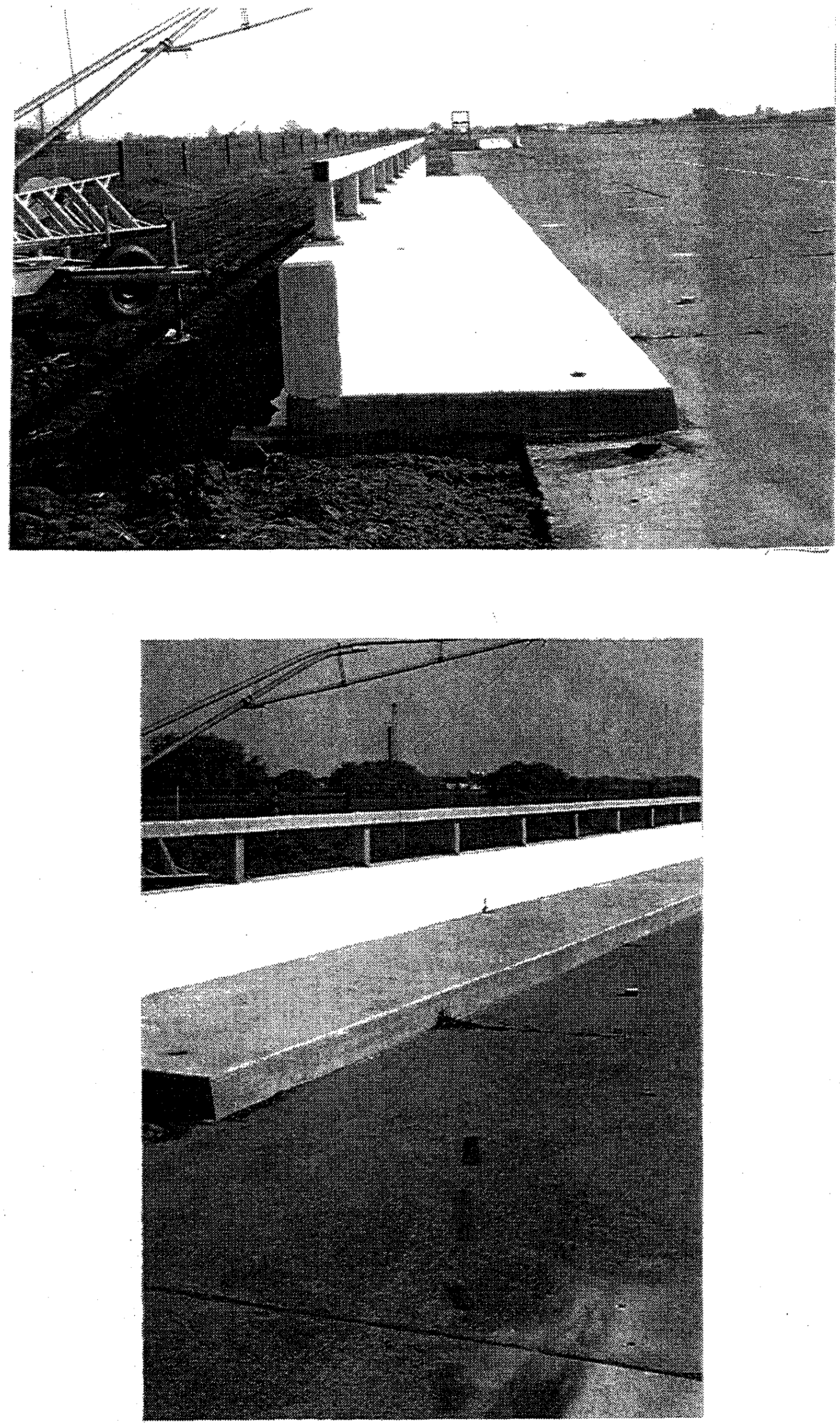


Figure 6.   BR27C bridge railing on sidewalk before test 7069-24.

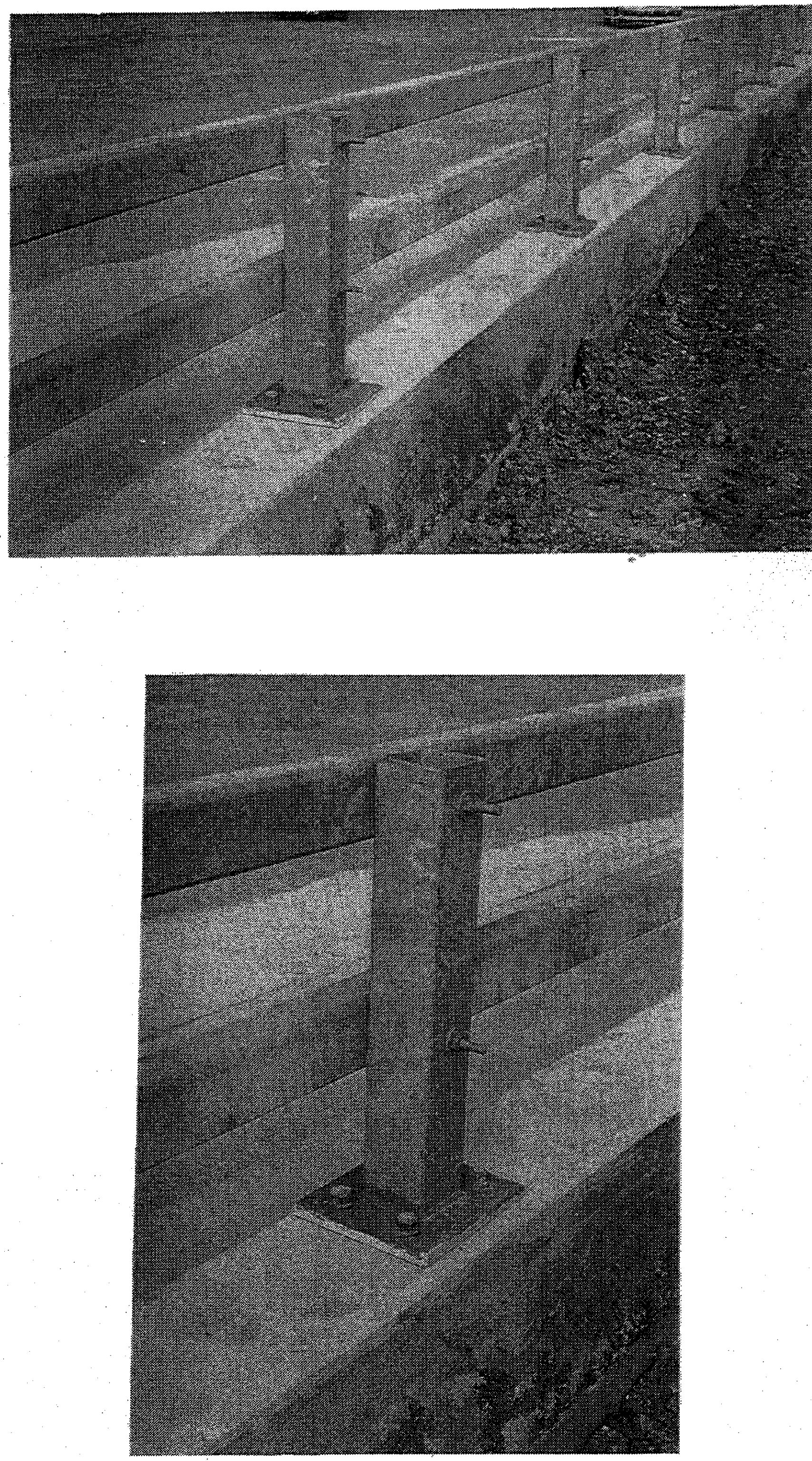


Figure 7. Rear view of BR27C bridge railing on sidewalk.

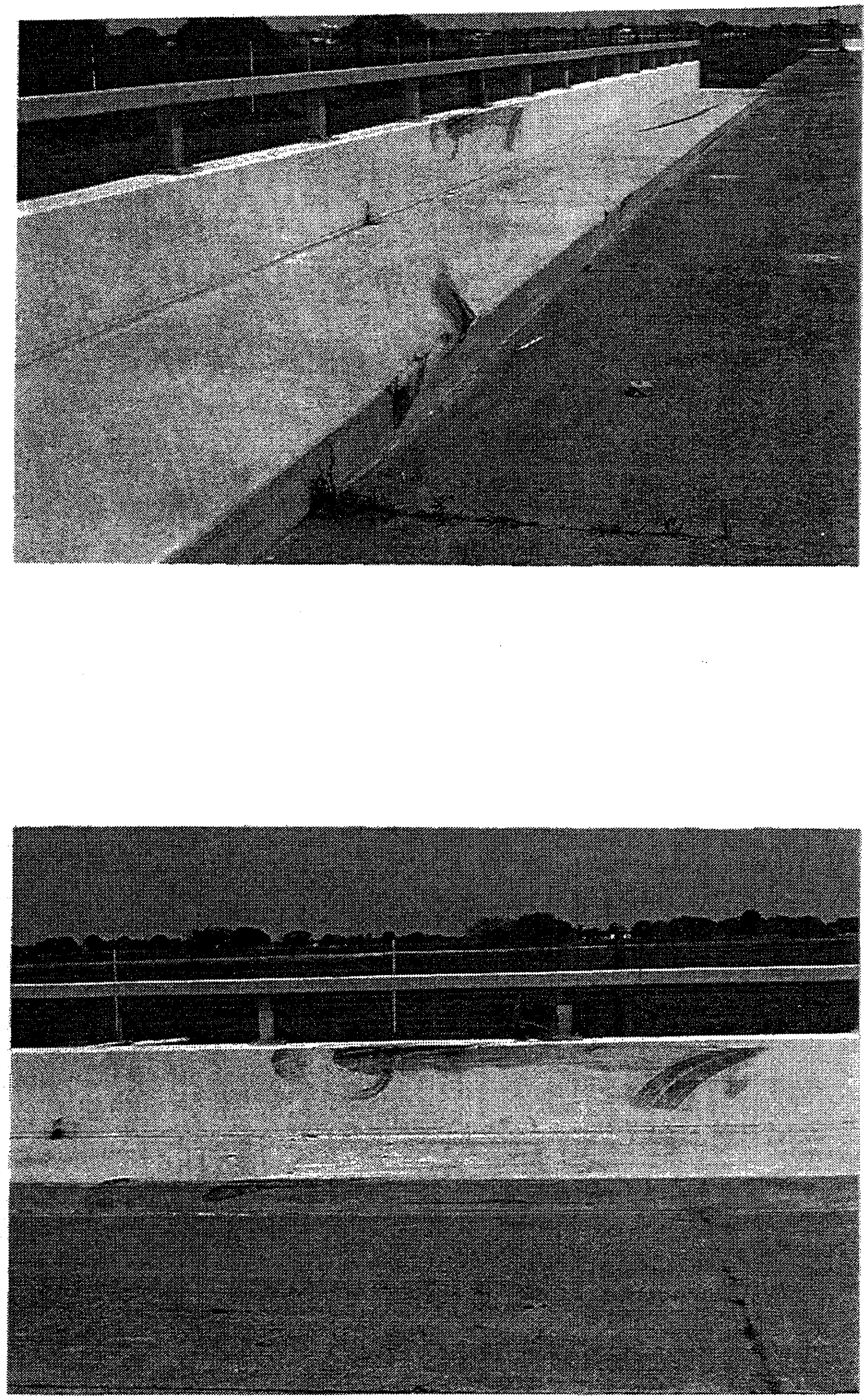
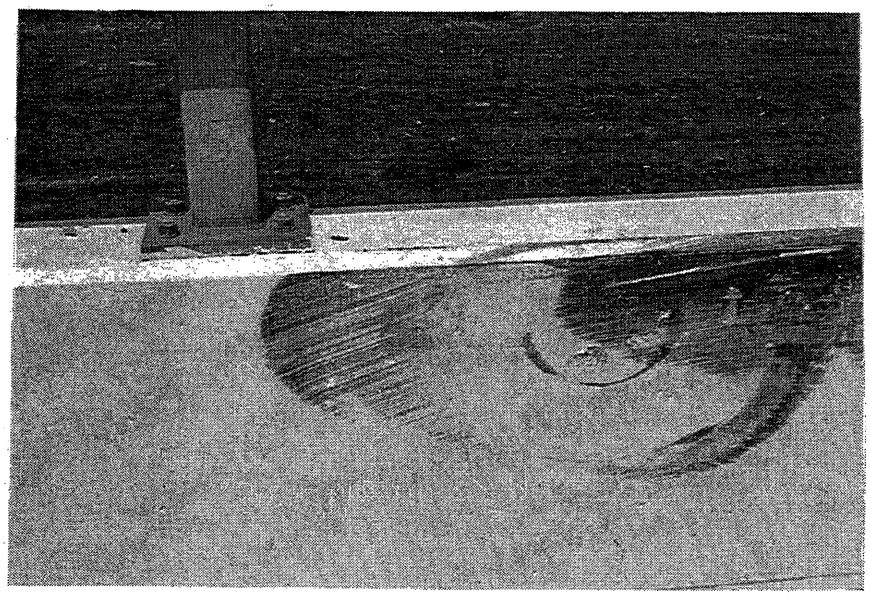


Figure 8. BR27C bridge railing on sidewalk after test 7069-24.



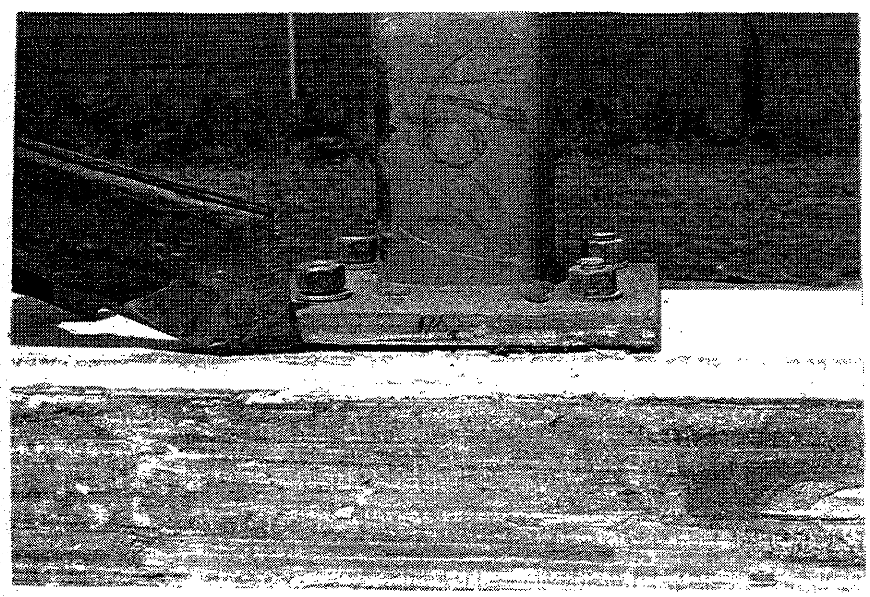
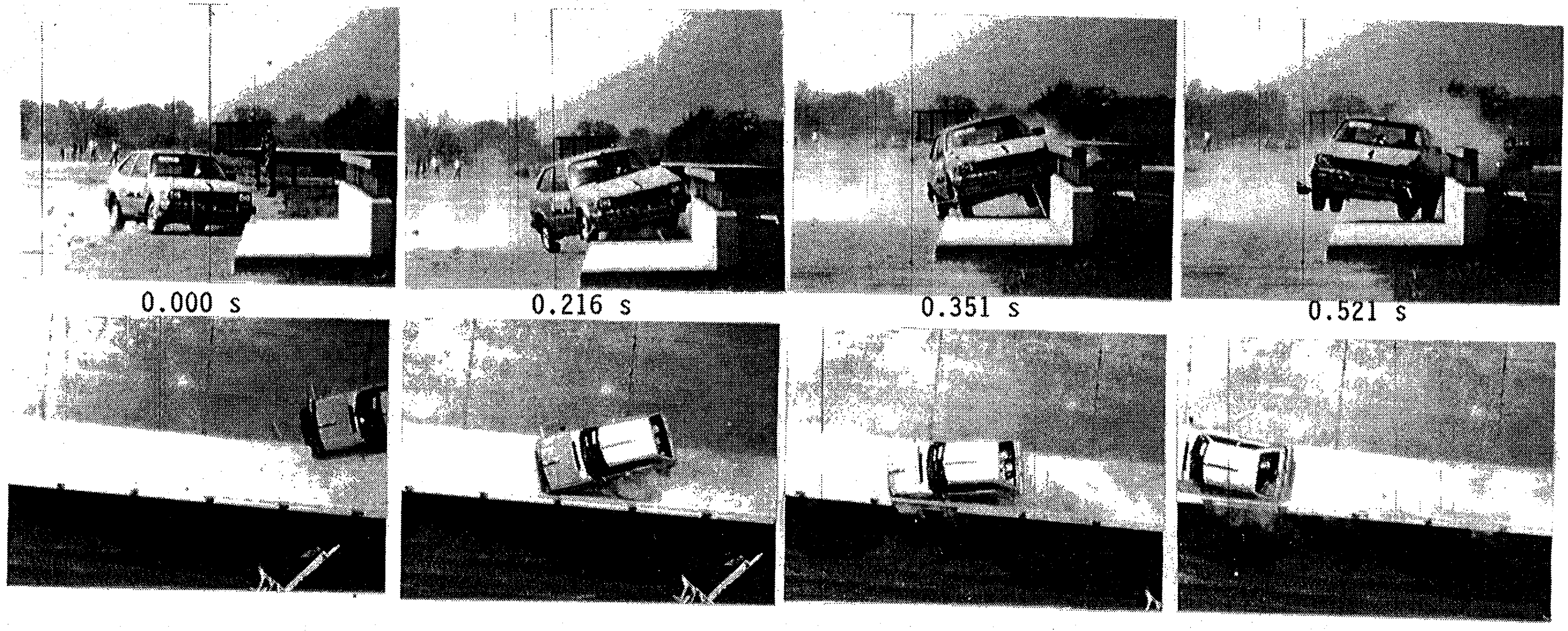
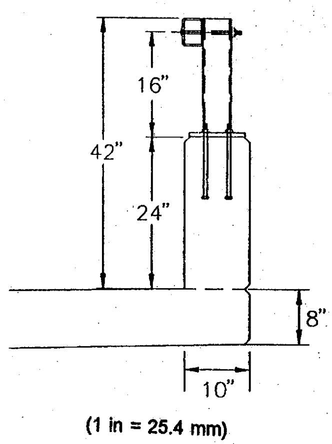


Figure 9. Damage at posts 5 and 6, test 7069-24.

Figure 10. Vehicle after test 7069-24.





Test No.	7069-24
Date	03/31/92
Test Installation . . .	BR27C Bridge Railing on sidewalk
Installation Length . .	100 ft (30 m)
Test Vehicle	1982 Honda Civic
Vehicle Weight	
Test Inertia	1,800 lb (817 kg)
Gross Static	1,965 lb (892 kg)
Vehicle Damage Classification	
TAD	11LFQ3
CDC	11FLEK2 & 11LFES2
Maximum Vehicle Crush .	7.5 in (191 mm)

Impact Speed. . . .	61.7 mi/h (99.3 km/h)
Impact Angle. . . .	18.7 deg
Speed at Parallel .	50.9 mi/h (81.9 km/h)
Exit Speed	50.3 mi/h (80.9 km/h)
Exit Trajectory . .	1.0 deg
Vehicle Accelerations (Max. 0.050-sec Avg) at true c.g.	
Longitudinal. . .	-5.6 g
Lateral	-9.3 g
Occupant Impact Velocity at true c.g.	
Longitudinal. . .	15.3 ft/s (4.7 m/s)
Lateral	6.5 ft/s (2.0 m/s)
Occupant Ridedown Accelerations	
Longitudinal. . .	-3.8 g
Lateral	-17.2 g

Figure 11. Summary of results for test 7069-24.

Table 1. Evaluation of crash test no. 7069-24.
{BR27C bridge railing on sidewalk [1,800 lb (817 kg)|61.7 mi/h (99.3 km/h)|18.7 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		
	<u>μ</u> / <u>Assessment</u> 0 - .25 / Good .26 - .35 / Fair > .35 / Marginal	<u>μ</u> / <u>Assessment</u> .38 (Impact @ curb) / Marginal .11 (Impact @ rail) / Good	Pass
G.	Shall be less than		
	<u>Occupant Impact Velocity - ft/s (m/s)</u> Longitudinal: 30 (9.2) Lateral: 25 (7.6)	<u>Occupant Impact Velocity - ft/s (m/s)</u> Longitudinal: 15.3 (4.7) Lateral: 6.5 (2.0)	Pass
	<u>Occupant Ridedown Accelerations - g's</u> Longitudinal: 15 Lateral: 15	<u>Occupant Ridedown Accelerations - g's</u> Longitudinal: -3.8 Lateral: -17.2	Pass
H.	Exit angle shall be less than 12 degrees	Exit angle was 1.0 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′ ± 0.1′ B = 5.5′ H_{cg} = 20″ ± 1″ θ = 20 deg.	Pickup Truck W = 5.4 Kips A = 8.5′ ± 0.1′ B = 6.5′ H_{cg} = 27″ ± 1″ θ = 20 deg.	Medium Single-Unit Truck W = 18.0 Kips A = 12.8′ ± 0.2′ B = 7.5′ H_{cg} = 49″ ± 1″ θ = 15 deg.	Van-Type Tractor-Trailer[4] 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:

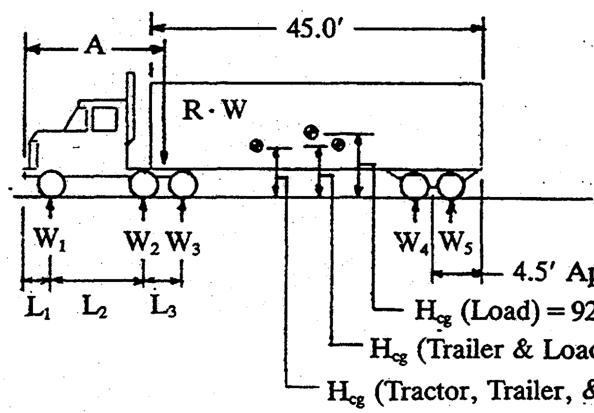
Occupant Impact Velocity–fps	
Longitudinal	Lateral
30	25

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

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

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

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

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

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

= 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

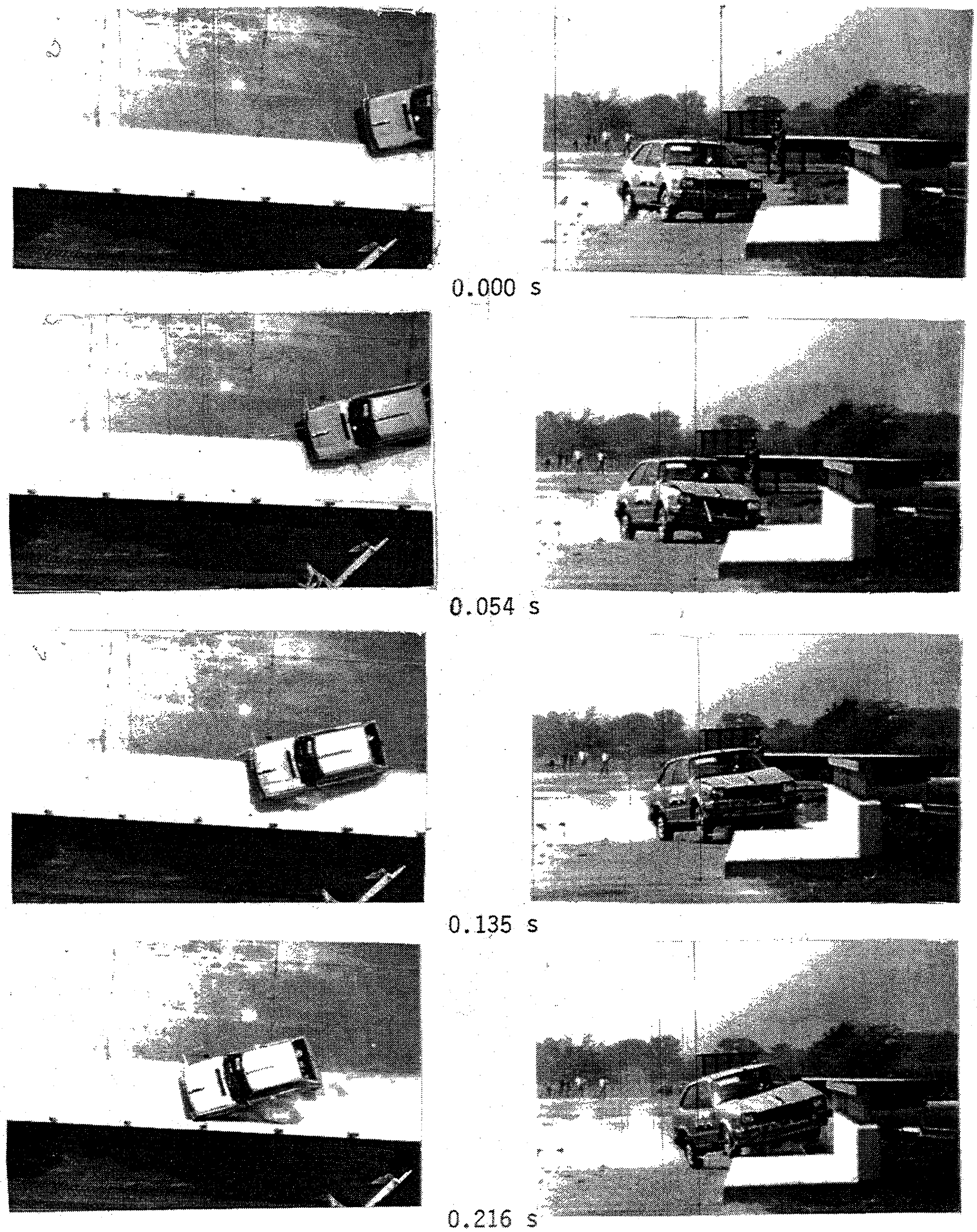


Figure 12. Sequential photographs for test 7069-24 (overhead and front views).

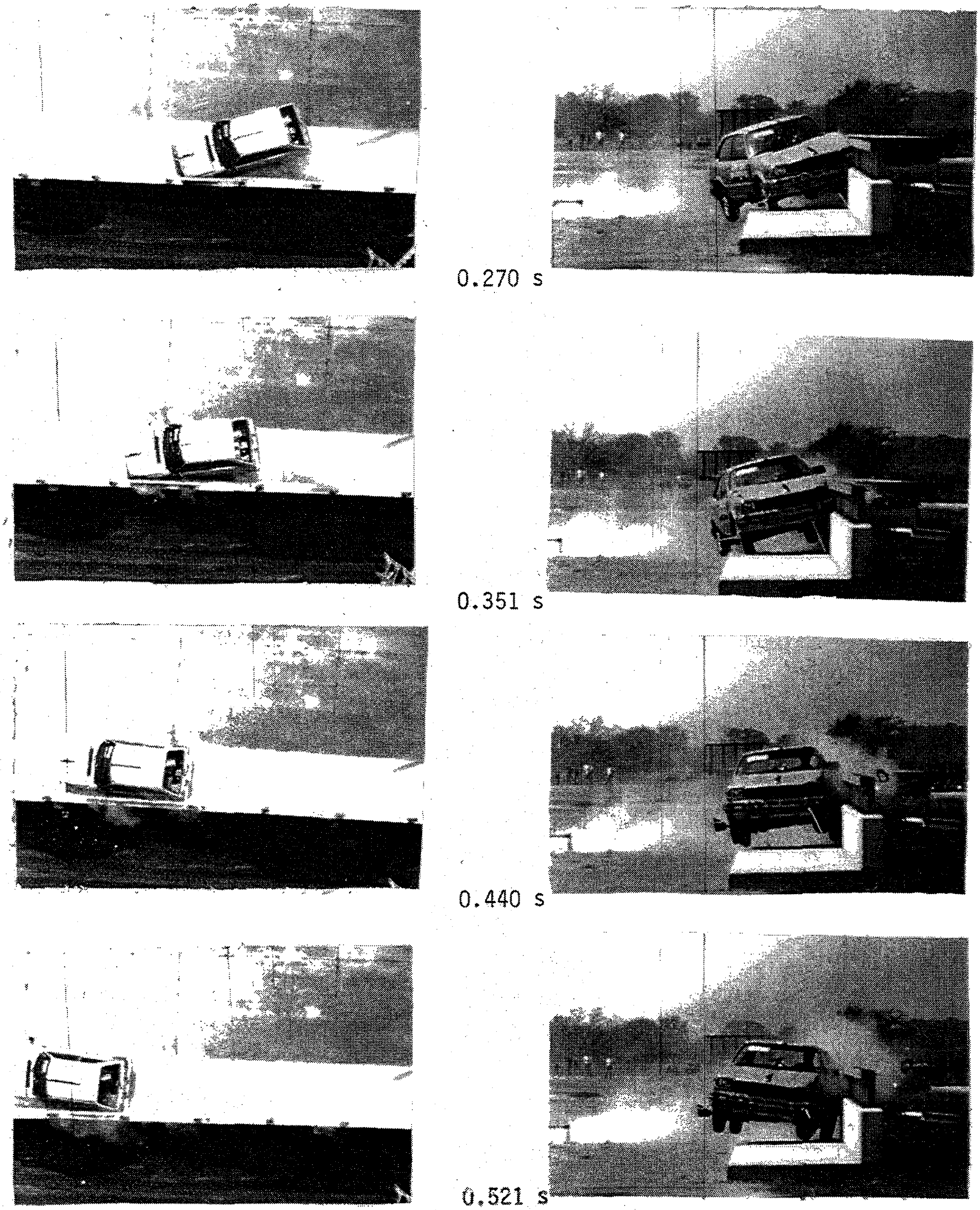


Figure 12. Sequential photographs for test 7069-24 (overhead and front views continued).

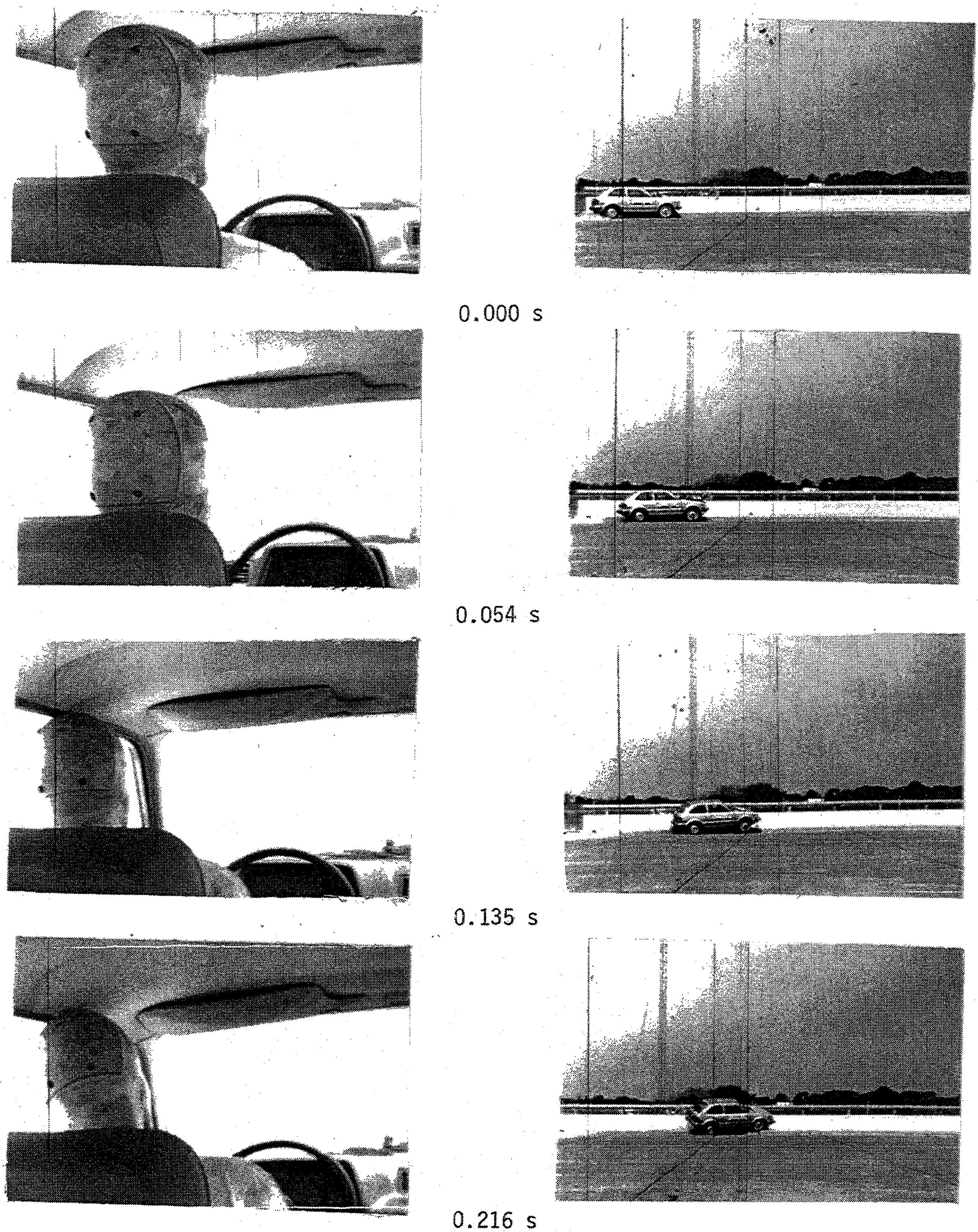
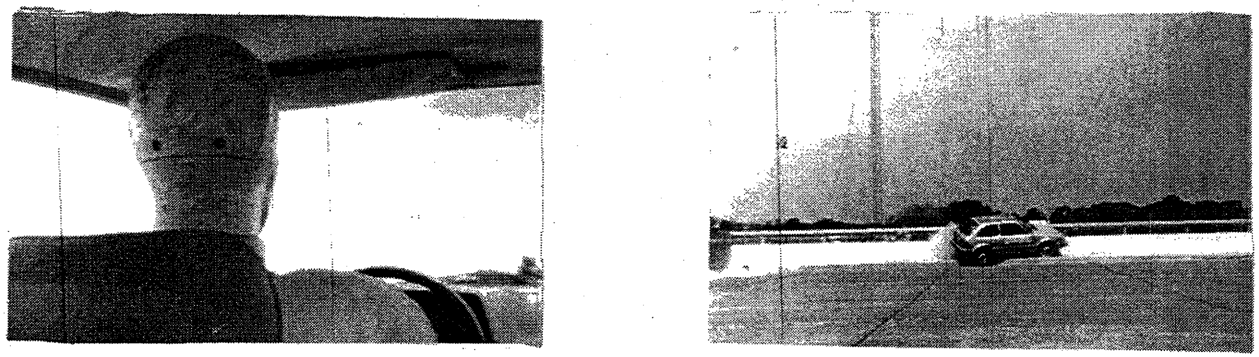
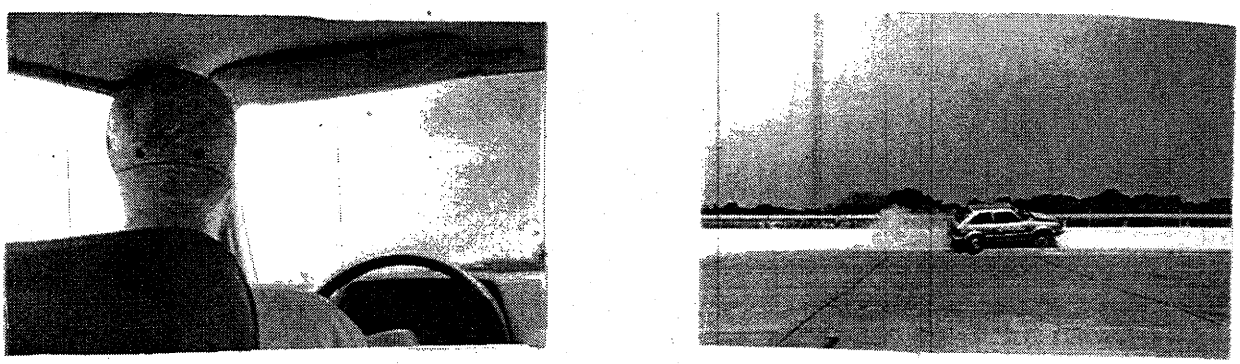


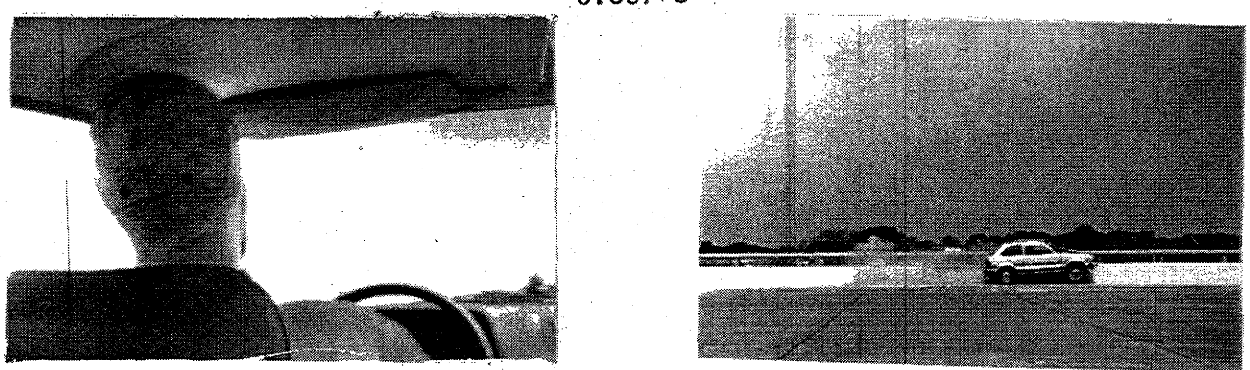
Figure 13. Sequential photographs for test 7069-24
(interior and perpendicular views).



0.270 s



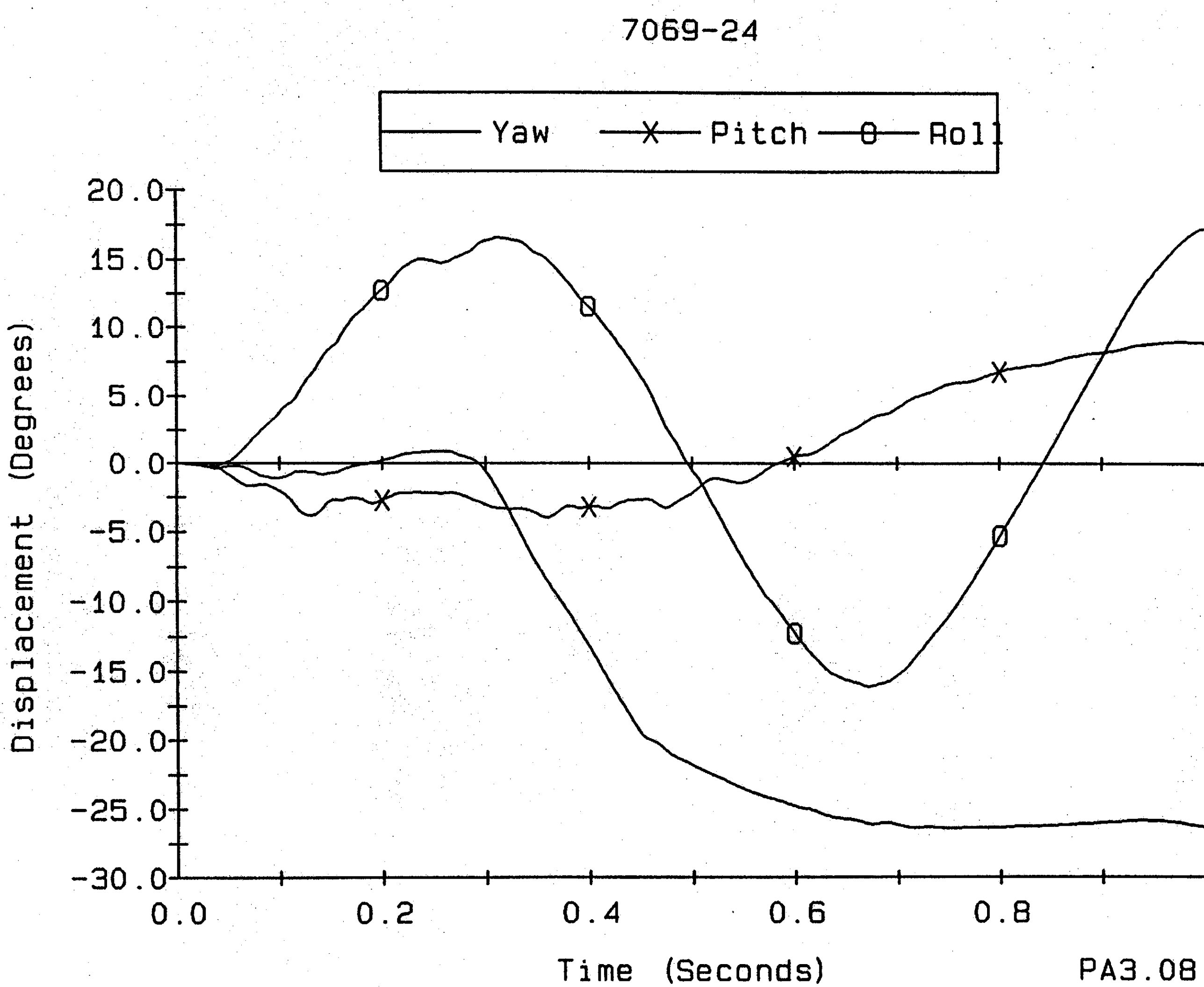
0.357 s

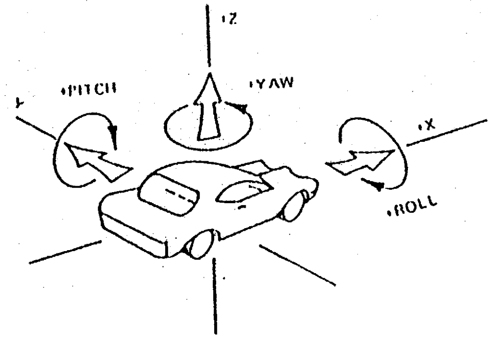


0.440 s

0.521 s

Figure 13. Sequential photographs for test 7069-24 (interior and perpendicular views continued).





Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 14. Vehicle angular displacements for test 7069-24.

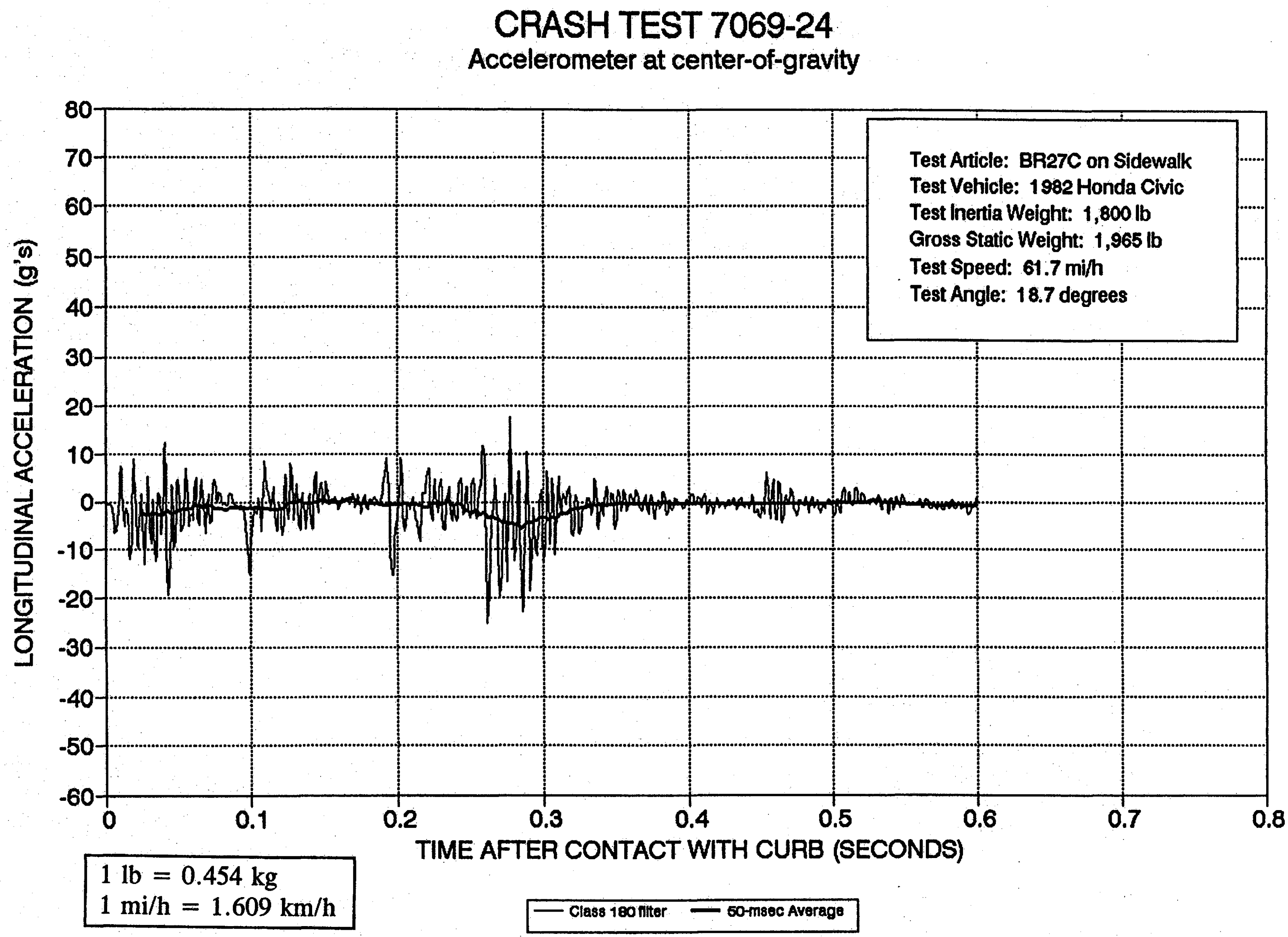


Figure 15. Vehicle longitudinal accelerometer trace for test 7069-24 (accelerometer located at center-of-gravity).

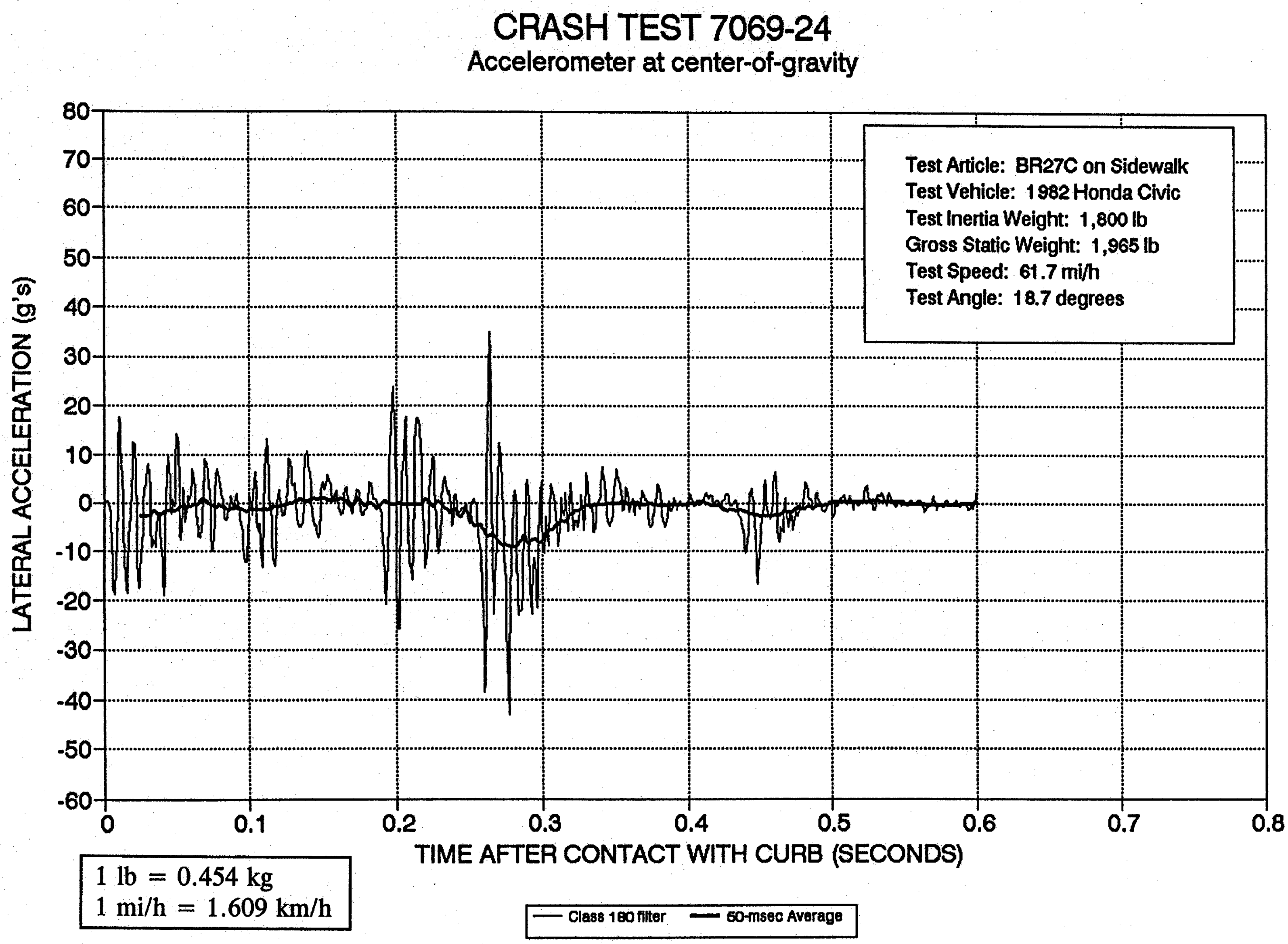


Figure 16. Vehicle lateral accelerometer trace for test 7069-24 (accelerometer located at center-of-gravity).

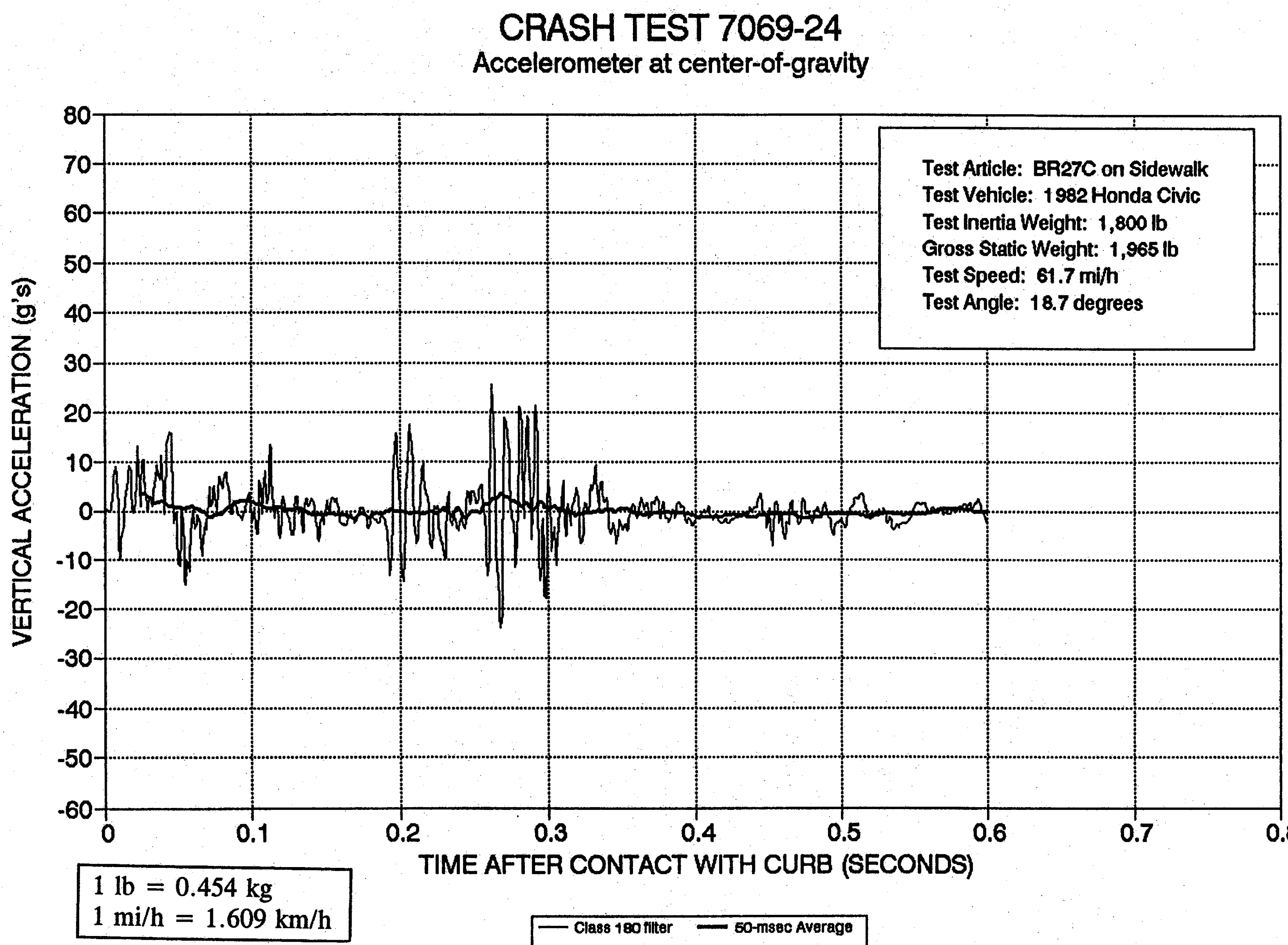


Figure 17. Vehicle vertical accelerometer trace for test 7069-24 (accelerometer located at center-of-gravity).

Test 7069-25

Test Description

A 1984 GMC Sierra 2500 pickup (figures 18 and 19) 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 5,568 lb (2 582 kg). The height to the lower edge of the vehicle bumper was 17.0 in (432 mm) and it was 26.25 in (667 mm) to the top of the bumper. Additional dimensions and information on the test vehicle are given in figure 20. The vehicle was directed into the BR27C bridge railing on sidewalk (figure 21) 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 curb of the sidewalk approximately 8.8 ft (2.7 m) downstream from the end at a speed of 62.6 mi/h (100.7 km/h) and the angle of impact was 19.4 degrees.

As the left front wheel of the vehicle mounted the curb, the tire aired out. At approximately 0.064 s after impact, the vehicle began to redirect, and at 0.118 s the left rear tire contacted the curb. The vehicle bumper impacted the concrete parapet (near post 4) at 0.150 s traveling at a speed of 59.8 mi/h (96.2 km/h) and an angle of 17.9 degrees. At 0.167 s the right front wheel contacted the curb and the vehicle impacted the metal railing element. By 0.214 s the vehicle began to redirect significantly, and by 0.329 s the vehicle was traveling parallel with the bridge railing at a speed of 56.7 mi/h (91.2 km/h). The rear of the vehicle contacted the concrete parapet at 0.348 s and then exited the bridge railing at 0.463 s traveling at a speed of 53.5 (86.1 km/h) and an exit angle of 5.4 degrees. As the vehicle exited the bridge railing installation, the brakes were applied. The vehicle yawed counter-clockwise and subsequently came to rest 210 ft (64 m) down and 6 ft (2 m) in behind of the point of impact.

As can be seen in figure 22, the bridge railing system received minimal damage. There was no measurable permanent deformation to the metal railing elements; however, the left corner of the bumper had snagged post 5 and pulled it up such that the washer rotated freely under the nut on the left front side of the railing. There was only cosmetic damage to the concrete parapet, i.e., tire marks on the concrete parapet from post 4 to post 6. The vehicle was in contact with the bridge railing system for a total of 13.0 ft (4.0 m).

The vehicle sustained damage to the left side as shown in figures 23 and 24. Maximum crush at the left front corner at bumper height was 12.0 in (305 mm) and the right front corner was deformed outward 7.0 in (178 mm). The left front wheel was pushed back reducing the wheelbase on the driver side by 2.25 in (57 mm). Also, damage was done to the front bumper, hood, grill, left front quarter panel, left door and glass, left rear quarter panel, rear bumper and tailgate, left front tire and rim, and right front tire. The welds on the left rear rim broke and the tire separated from the rim as shown in figure 24.

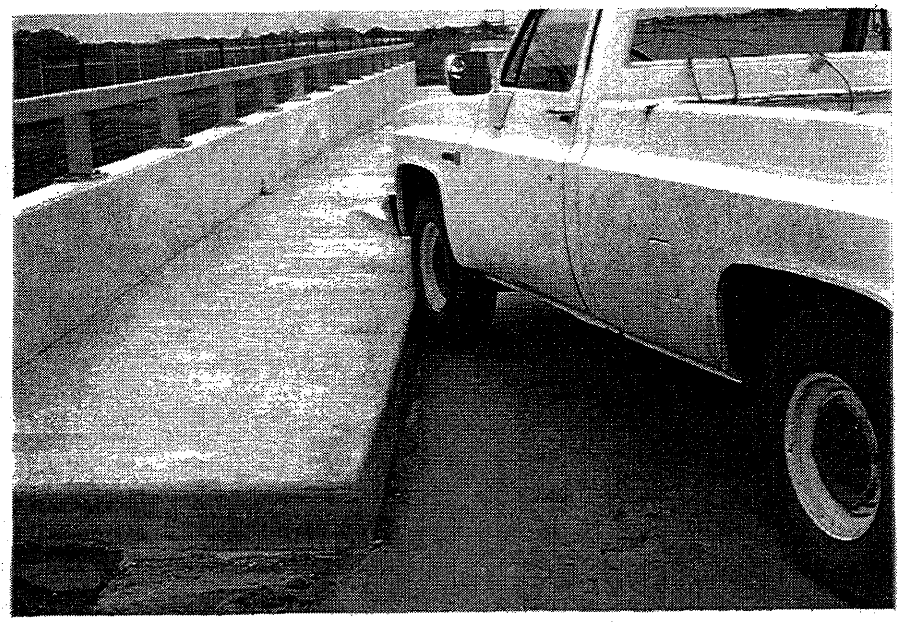
Test Results

The vehicle impacted the curb of the sidewalk at 62.6 mi/h (100.7 km/h) and the angle of impact was 19.4 degrees. As the vehicle impacted the concrete parapet, it was traveling at a speed of 59.8 mi/h (96.2 km/h) and an angle of 17.9 degrees. The speed of the vehicle at the time of parallel was 56.7 mi/h (91.2 km/h). In determining the effective coefficient of friction which is an assessment of the smoothness of the "vehicle-railing" interaction, it should be noted that vehicle impact speed and angle is used in the calculation. If "vehicle-railing" interaction is interpreted literally, impact at the time of contact with the concrete parapet would be used. However, the curb could be considered to be part of this "vehicle-railing" interaction. Therefore, two assessments could be made: (1) interpreting "vehicle-railing" interaction literally disregarding the impact at the curb and using the speed and angle at which the vehicle impacted the concrete parapet or (2) considering the curb as an element of the "railing" system and using the speed and angle at which the vehicle impacted the curb. The coefficient of friction was calculated both ways for this test. Considering the curb as part of the vehicle-railing interaction, the coefficient of friction was 0.11, while it was 0.01 using impact with the concrete parapet in the calculation. The vehicle lost contact with the bridge railing traveling at 53.5 mi/h (86.1 km/h) and the exit angle between the vehicle path and the bridge railing was 5.4 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 12.9 ft/s (3.9 m/s) at 0.344 s, the highest 0.010-s average ridedown acceleration was -4.4 g between 0.387 and 0.397 s, and the maximum 0.050-s average acceleration was -4.6 g between 0.194 and 0.244 s. Lateral occupant impact velocity was 19.9 ft/s (6.1 m/s) at 0.259 s, the highest 0.010-s occupant ridedown acceleration was -10.8 g between 0.365 and 0.375 s, and the maximum 0.050-s average acceleration was -9.3 g between 0.202 and 0.252 s. The change in vehicle velocity at loss of contact using impact with the curb was 9.1 mi/h (14.6 km/h) and the change in momentum was 2,238 lb-sec (9,956 N-s). These data and other pertinent information from the test are summarized in figure 25 and table 3. Sequential photographs of the test period are shown in figures 26 and 27. Vehicular angular displacements are displayed in figure 28. Vehicular accelerations versus time traces filtered with SAE J211 filters are presented in figures 29 through 35.

Conclusions

The BR27C bridge railing on sidewalk contained the test vehicle with no lateral movement of the bridge railing. There was no intrusion of railing components into the occupant compartment and no debris to present undue hazard to other traffic. The integrity of the occupant compartment was maintained with no intrusion and no deformation. The vehicle remained upright and relatively stable during the collision. The bridge railing system smoothly redirected the vehicle. The effective coefficient of friction was considered good.

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 and a limit of 15 g's for occupant ridedown accelerations in both longitudinal and lateral directions. The occupant risk factors were well within the specified limits. The vehicle trajectory at loss of contact indicated minimum intrusion into adjacent traffic lanes. See figure 25 and table 3 for more details.



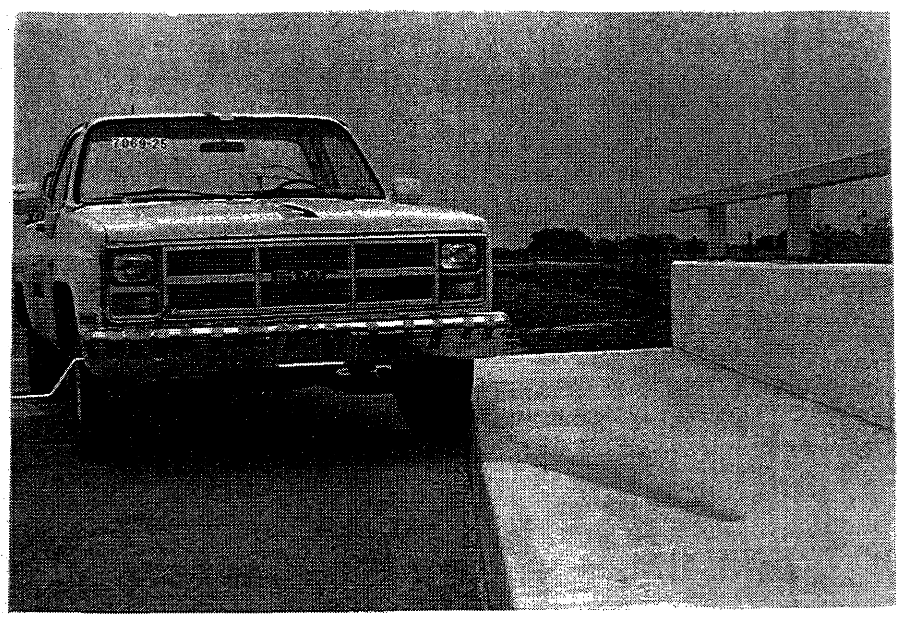


Figure 18. Vehicle/bridge railing geometrics for test 7069-25.

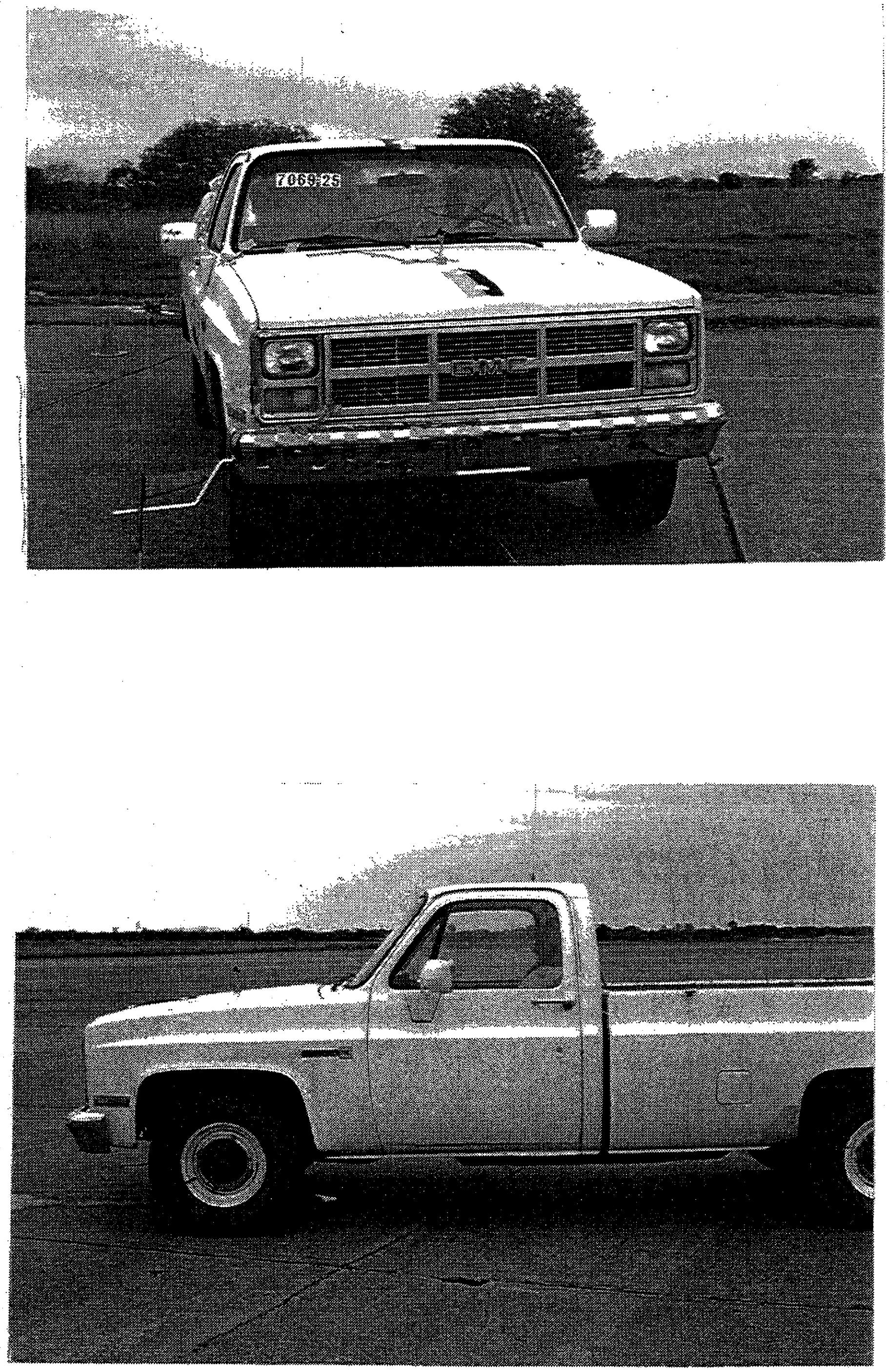


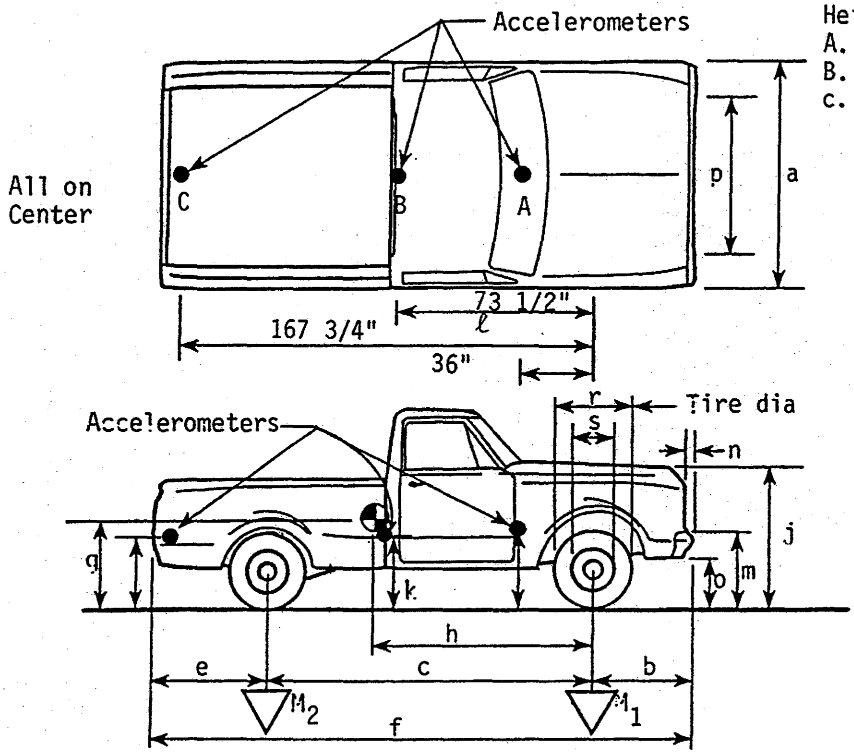
Figure 19. Vehicle prior to test 7069-25.

Date: 04-02-92 Test No.: 7069-25 VIN: 1GTGC24M0FJ526791

Make: GMC Model: Serra 2500 Year: 1984 Odometer: 95257.7

Tire Size: 750 16 LT Ply Rating: ______ Bias Ply: X Belted: ___ Radial: ___

Tire Condition: good ___ fair ___ badly worn ___



Height of
A. 29 3/4"
B. 31"
C. 37 3/4"

Vehicle Geometry - inches

a	79 1/2"	b	32"
c	131.25	d*	71 1/4"
e	52 1/2"	f	
g		h	70.8
i	----	j	44 1/2"
k		ℓ	
m	26 1/4"	n	3 1/4"
o	17"	p	
r	30 1/2"	s	17 1/2"

Engine Type: V-8

Engine CID: ______

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 1281 rf 1207 ℓr 1371 rr 1541

Mass - pounds	Curb	Test Inertial	Gross Static
M_1	2642	2488	2585
M_2	2090	2912	2983
M_T	4732	5400	5568

Note any damage to vehicle prior to test:

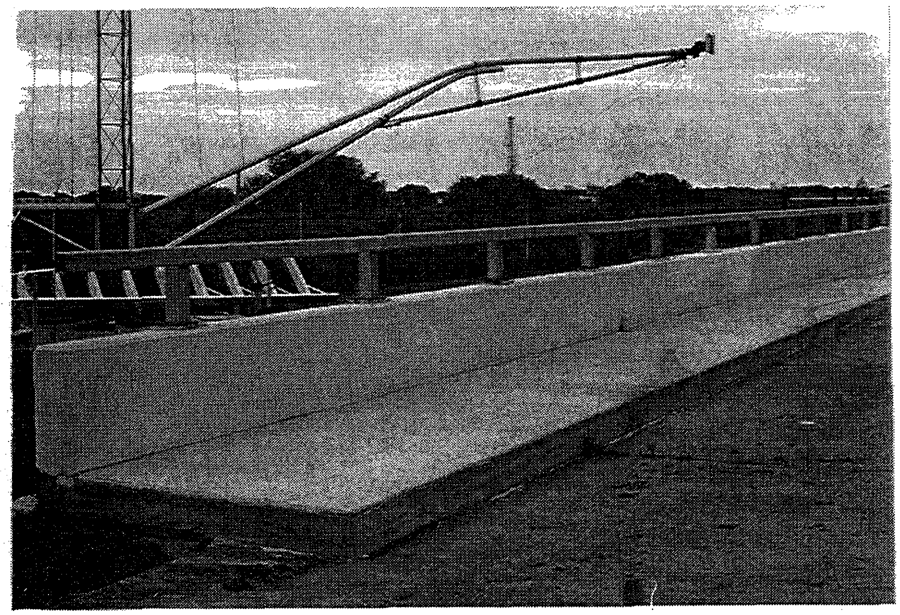
____

____

*d = overall height of vehicle

1 in = 25.4 mm
1 lb = 0.454 kg

Figure 20. Vehicle properties for test 7069-25.



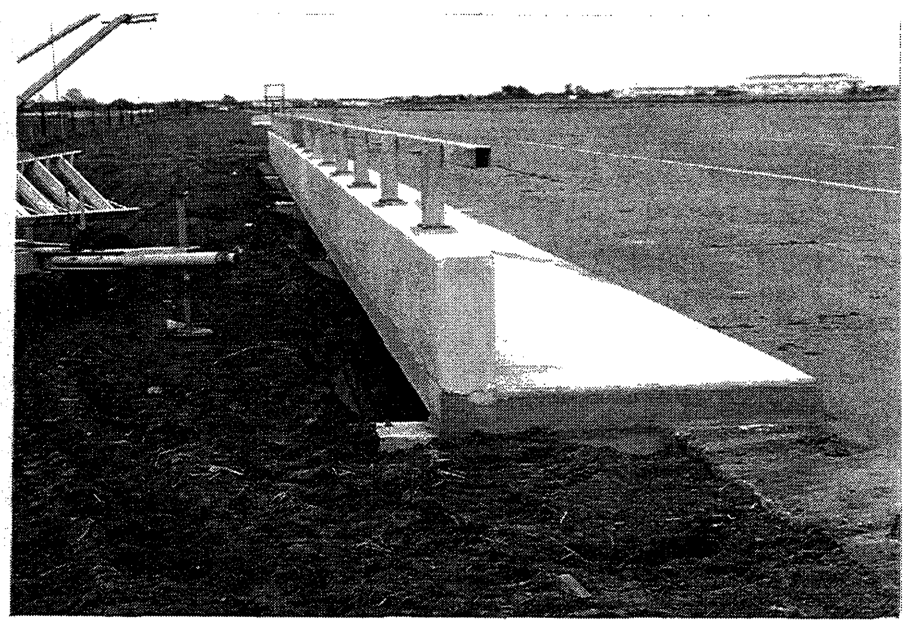


Figure 21. BR27C bridge railing on sidewalk before test 7069-25.

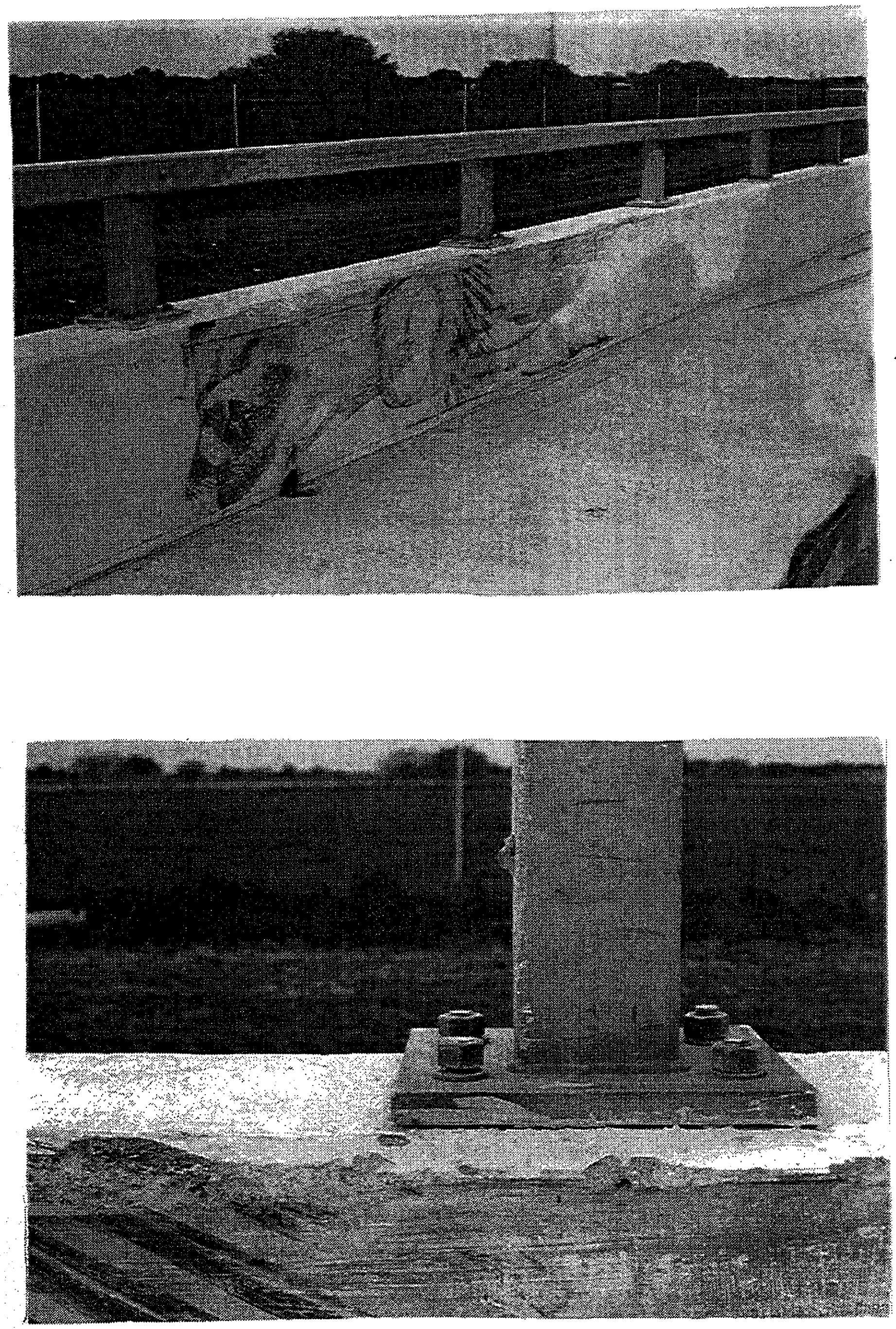


Figure 22. BR27C bridge railing on sidewalk after test 7069-25.

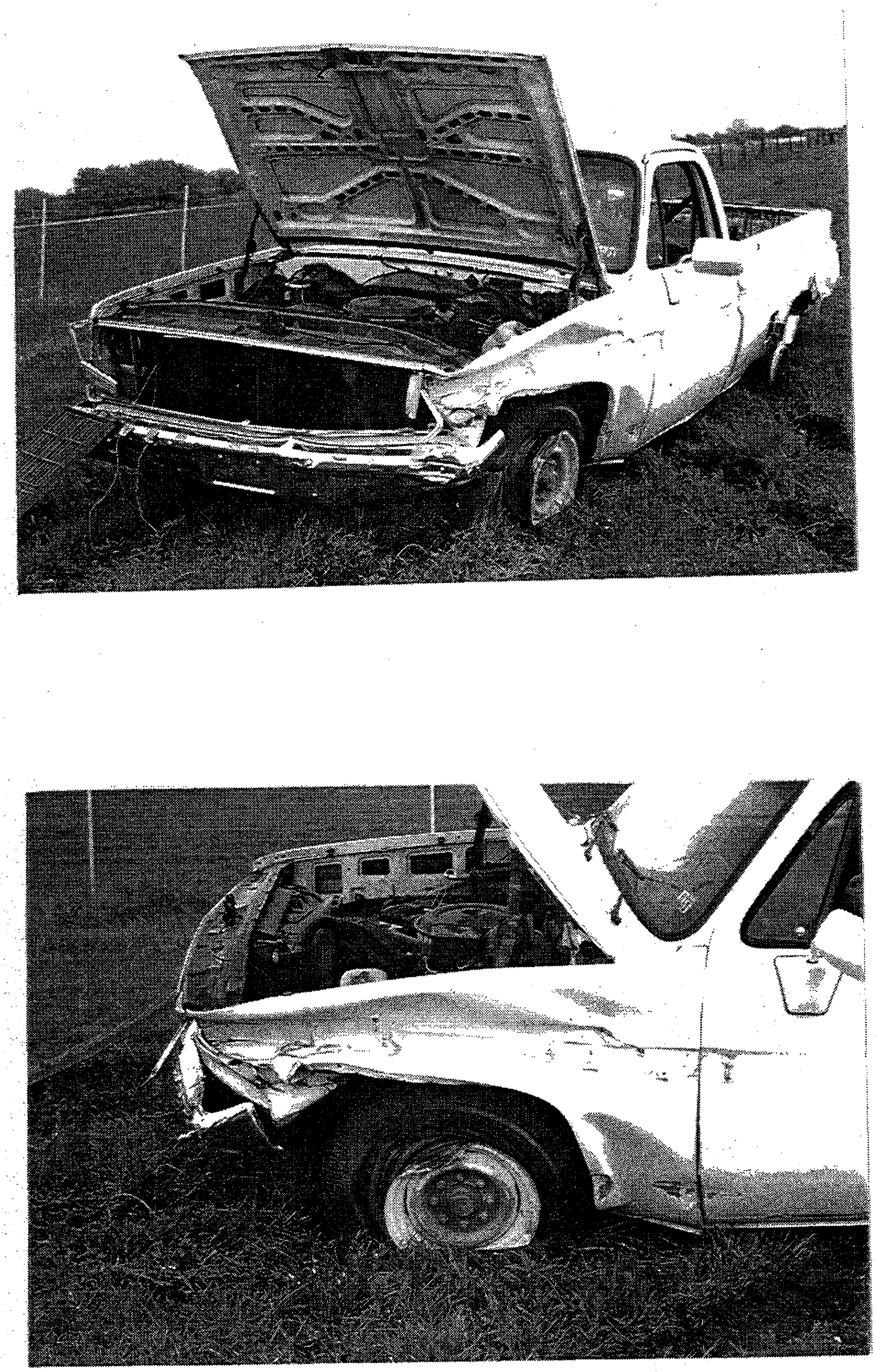
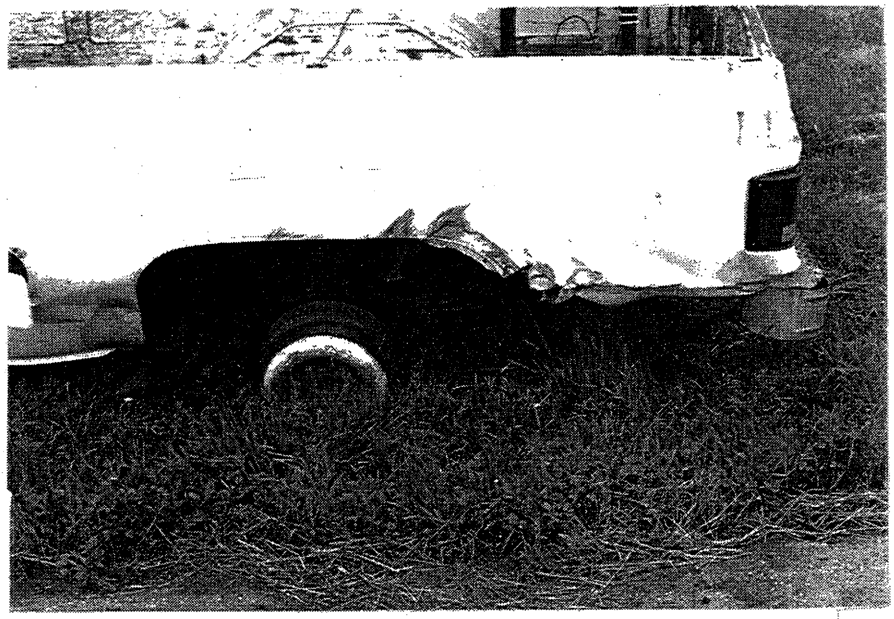


Figure 23. Vehicle after test 7069-25.



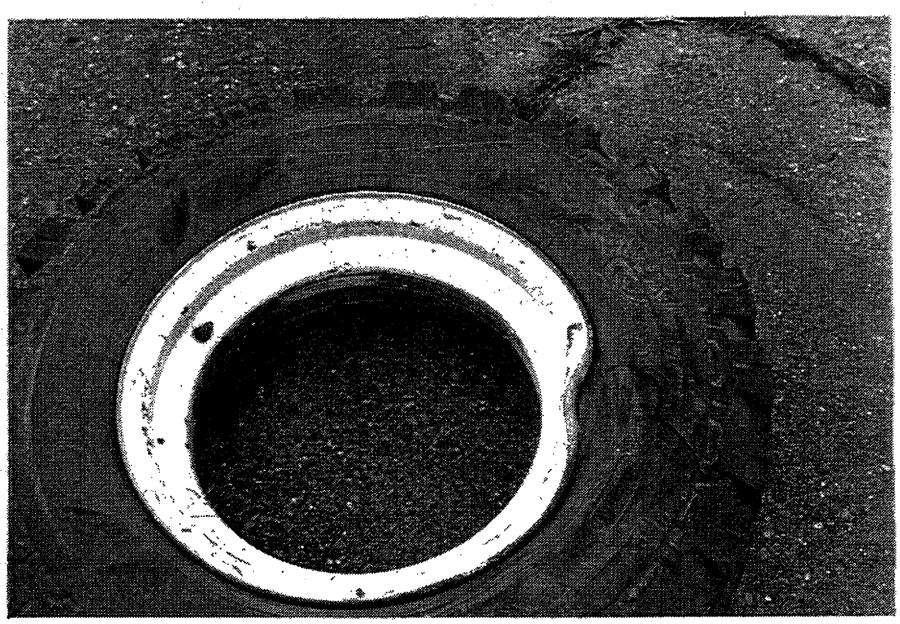
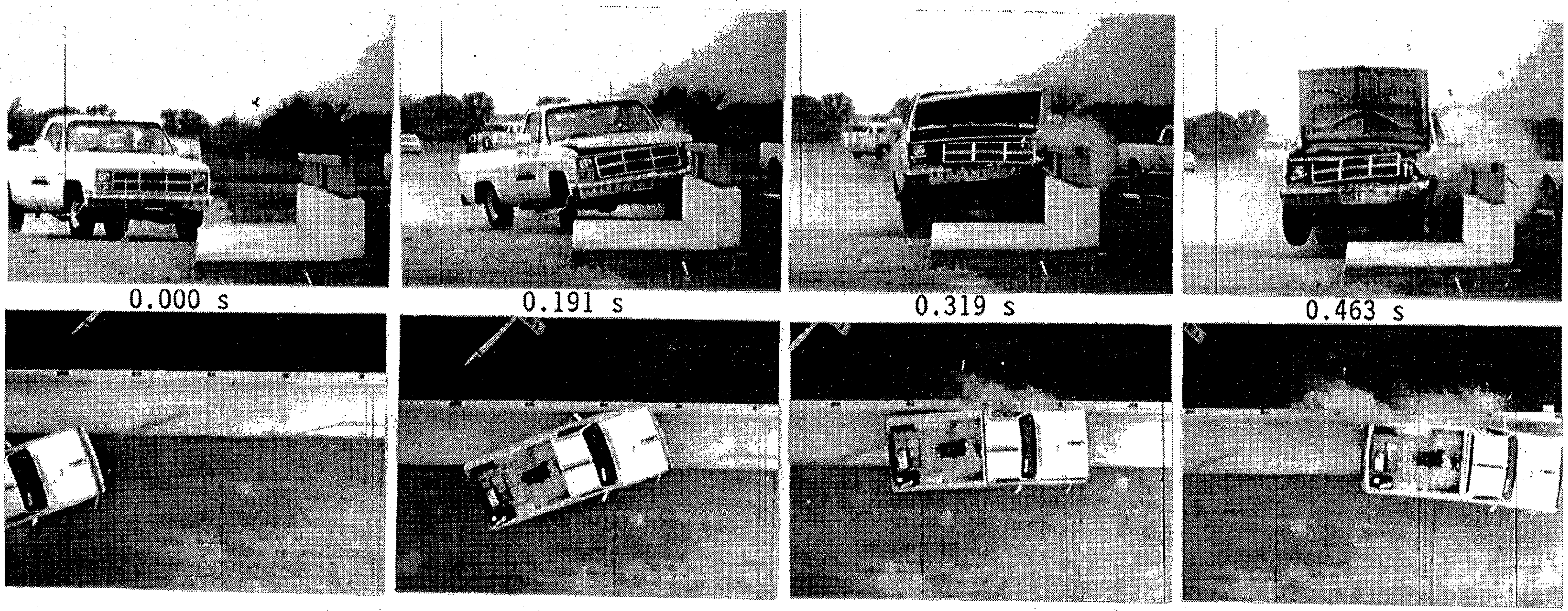
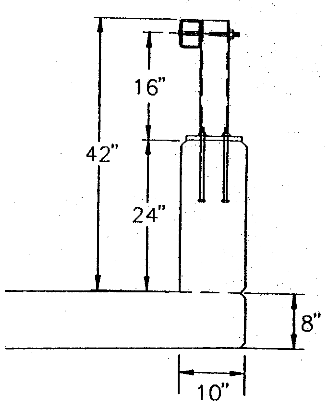


Figure 24. Damage to left rear wheel of vehicle after test 7069-25.





(1 in = 25.4 mm)

Test No. 7069-25
Date 04/02/92

Test Installation . . . BR27C Bridge Railing on sidewalk
Installation Length . . 100 ft (30 m)

Test Vehicle . . . . 1984 GMC Sierra Pickup
Vehicle Weight
  Test Inertia . . . . . 5,400 lb (2,452 kg)
  Gross Static . . . . . 5,568 lb (2,528 kg)
Vehicle Damage Classification
  TAD . . . . 11LFQ4 & 11LD4
  CDC . . . . 11FLEK2 & 11LDEW2
Maximum Vehicle Crush . 12.0 in (305 mm)

Impact Speed. . . . 62.6 mi/h (100.7 km/h)
Impact Angle. . . . 19.4 deg
Speed at Parallel . 56.7 mi/h (91.2 km/h)
Exit Speed . . . . 53.5 mi/h (86.1 km/h)
Exit Trajectory . . 5.4 deg
Vehicle Accelerations
  (Max. 0.050-sec Avg) at true c.g.
  Longitudinal. . . -4.6 g
  Lateral . . . . . -9.3 g
Occupant Impact Velocity at true c.g.
  Longitudinal. . . 12.9 ft/s (3.9 m/s)
  Lateral . . . . . 19.9 ft/s (6.1 m/s)
Occupant Ridedown Accelerations
  Longitudinal. . . -4.4 g
  Lateral . . . . .-10.8 g

Figure 25. Summary of results for test 7069-25.

Table 3. Evaluation of crash test no. 7069-25.
{BR27C bridge railing on sidewalk [5,400 lb (2 452 kg)|62.6 mi/h (100.7 km/h)|19.4 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 .11 (Impact @ curb) — Good .01 (Impact @ rail) — 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 12.9 (3.9); Lateral 19.9 (6.1)	Pass
	Occupant Ridedown Accelerations - g's Longitudinal 15; Lateral 15	Occupant Ridedown Accelerations - g's Longitudinal -4.4; Lateral -10.8	Pass
H.	Exit angle shall be less than 12 degrees	Exit angle was 5.4 degrees	Pass

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

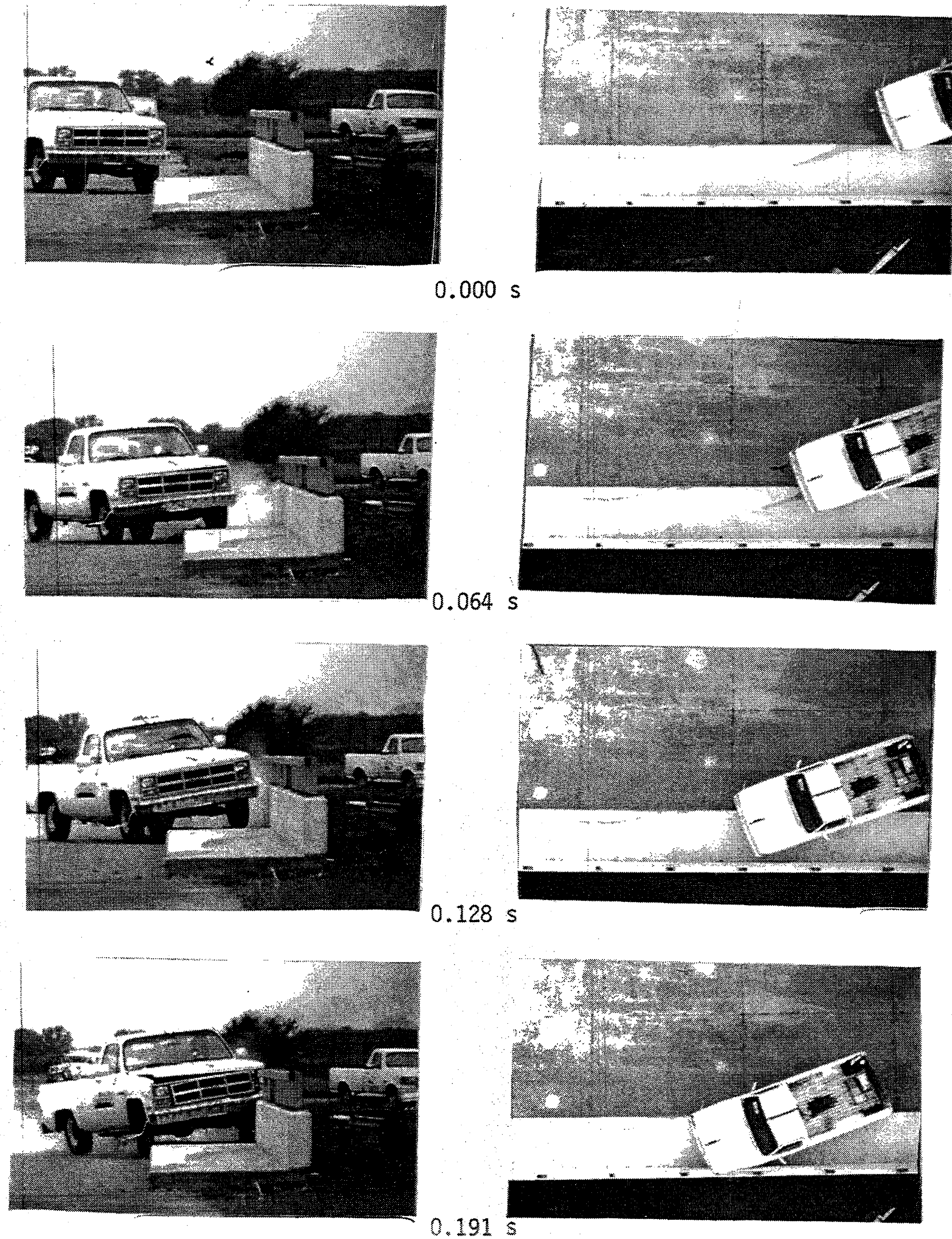
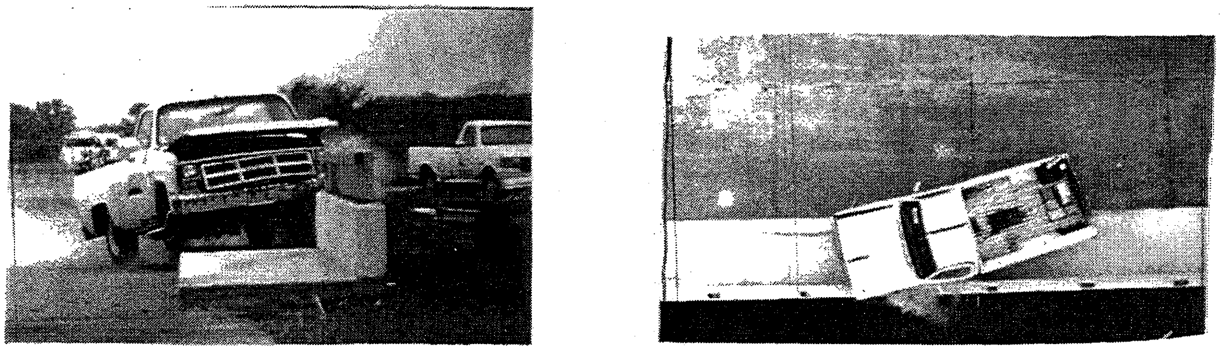
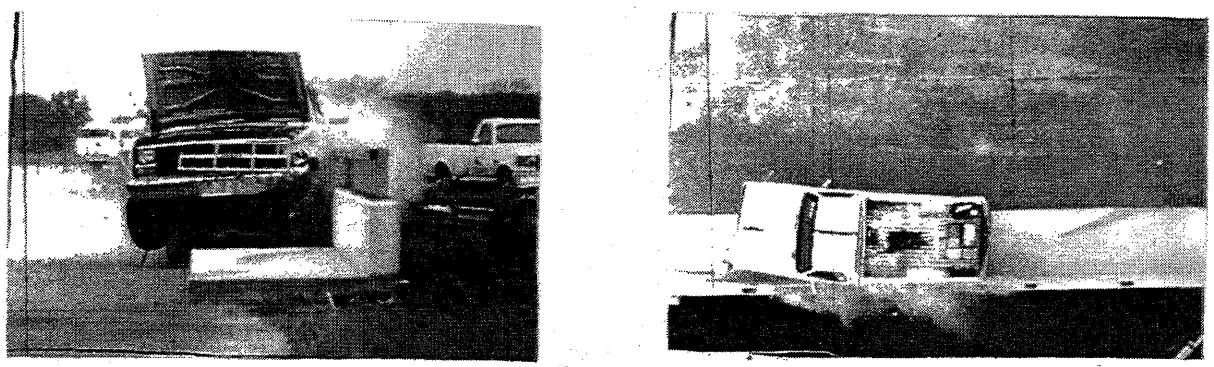


Figure 26. Sequential photographs for test 7069-25 (front and overhead views).

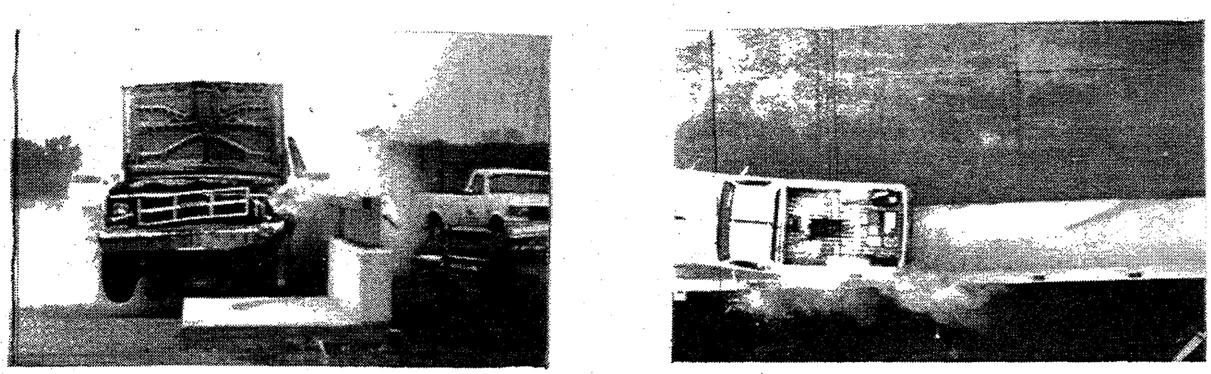


0.255 s

0.319 s



0.383 s



0.463 s

Figure 26. Sequential photographs for test 7069-25
(front and overhead views continued).

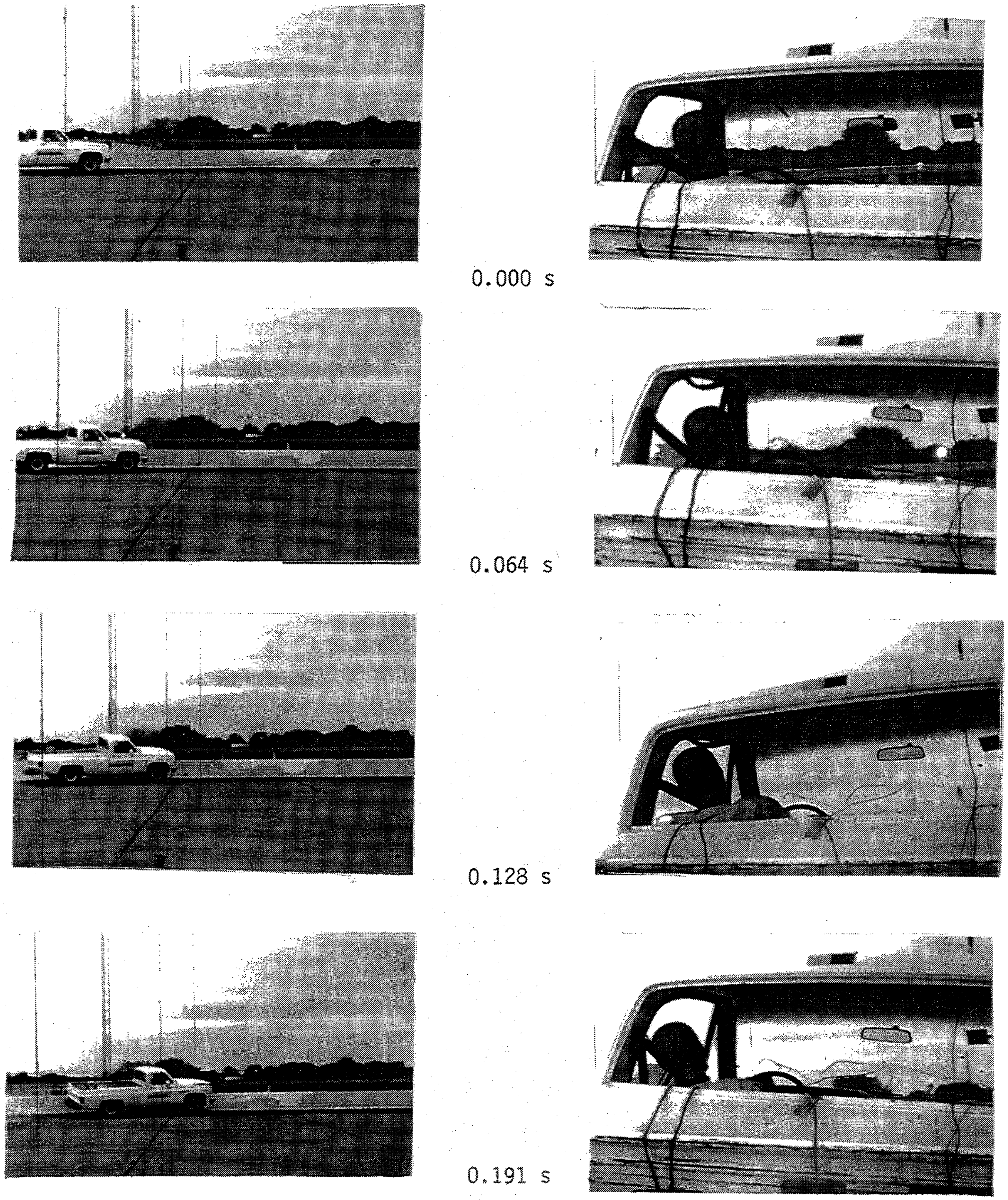
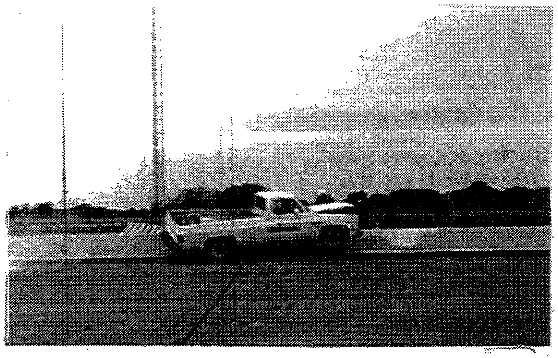
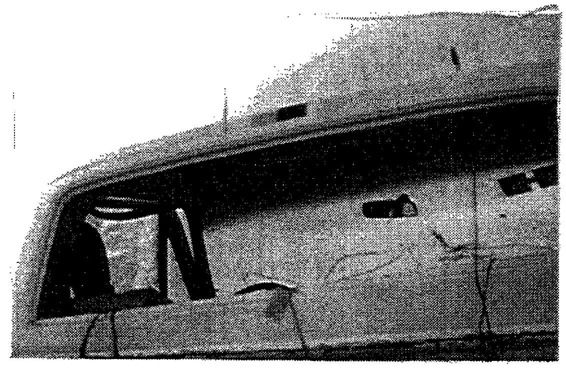
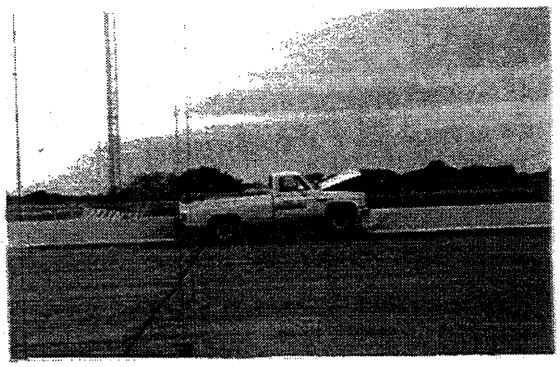
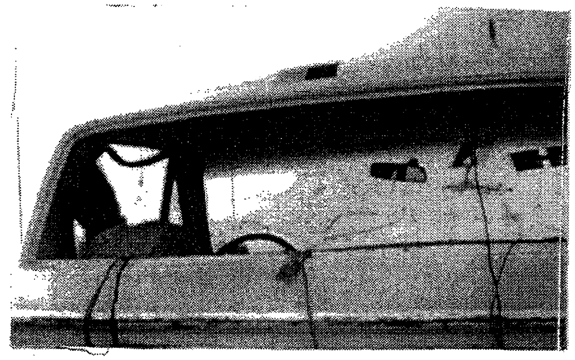


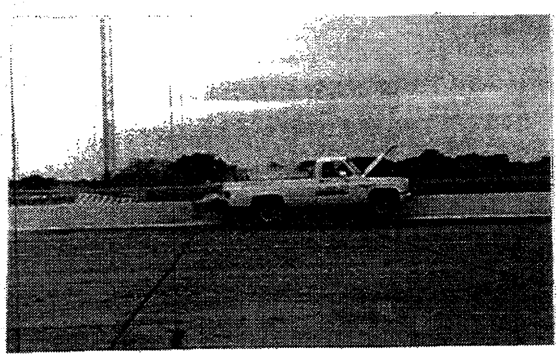
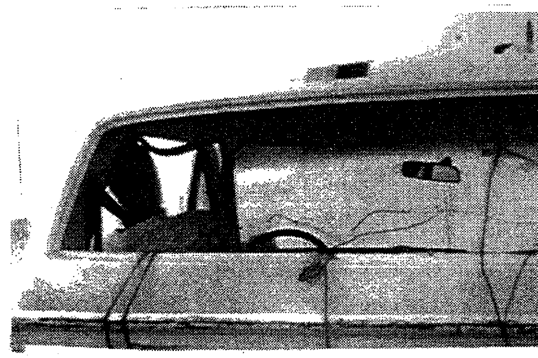
Figure 27. Sequential photographs for test 7069-25
(perpendicular and interior views).

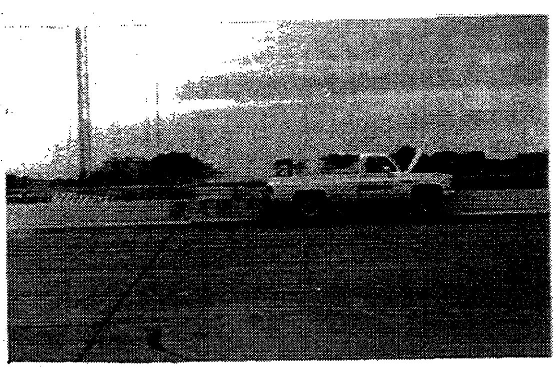
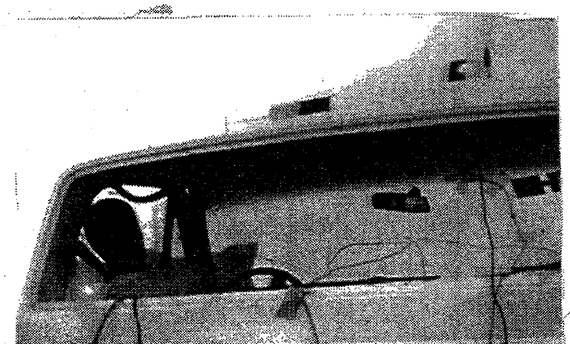
0.255 s

0.319 s

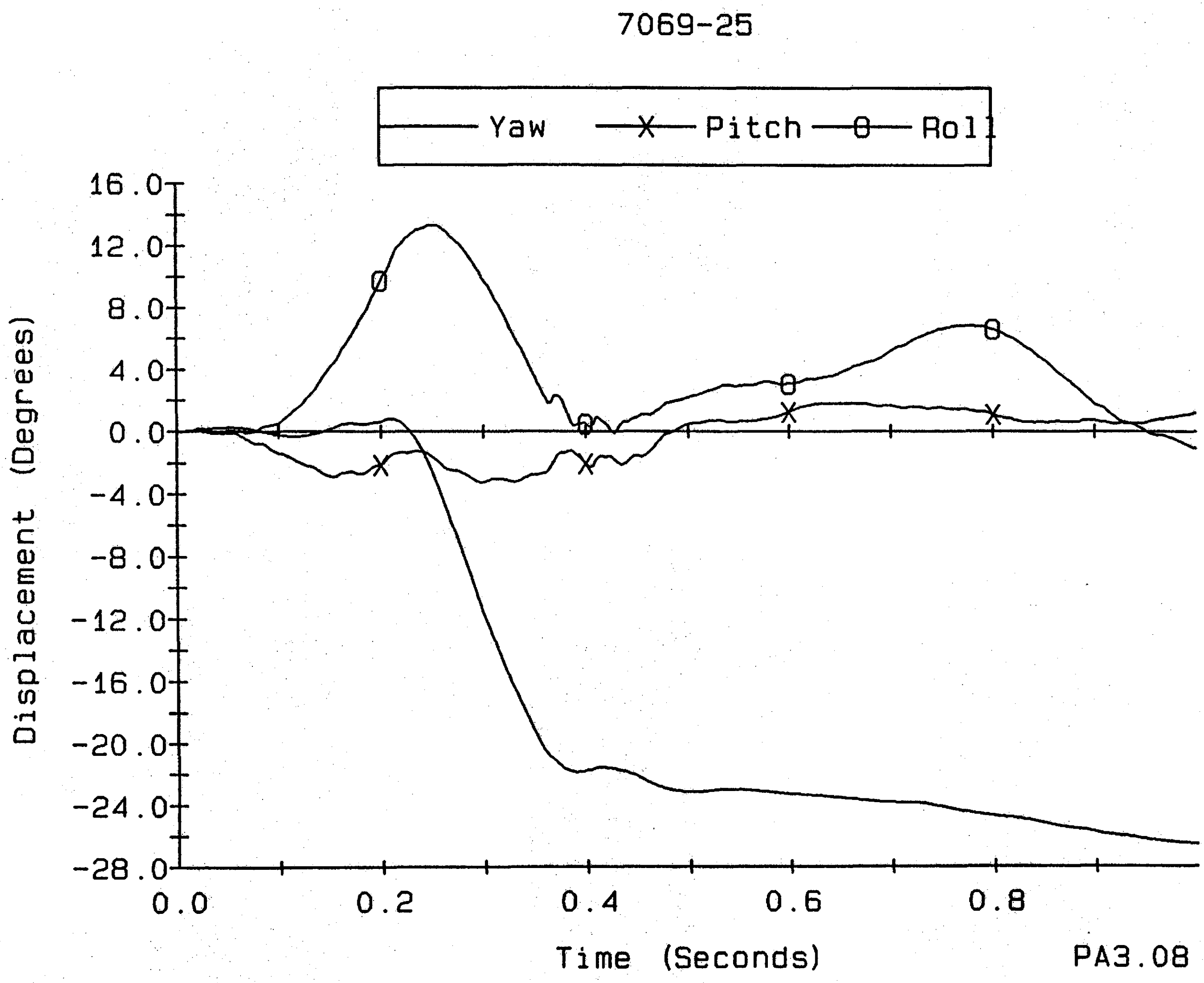



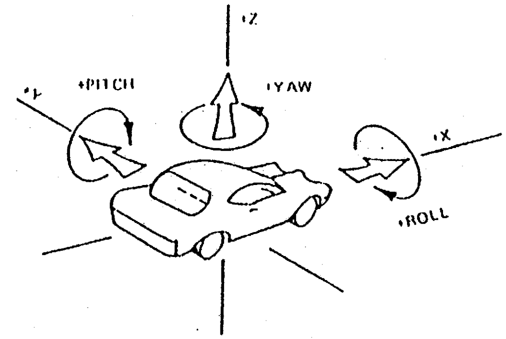
0.383 s

0.463 s

Figure 27. Sequential photographs for test 7069-25 (perpendicular and interior views continued).





Axes are vehicle fixed.
Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

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

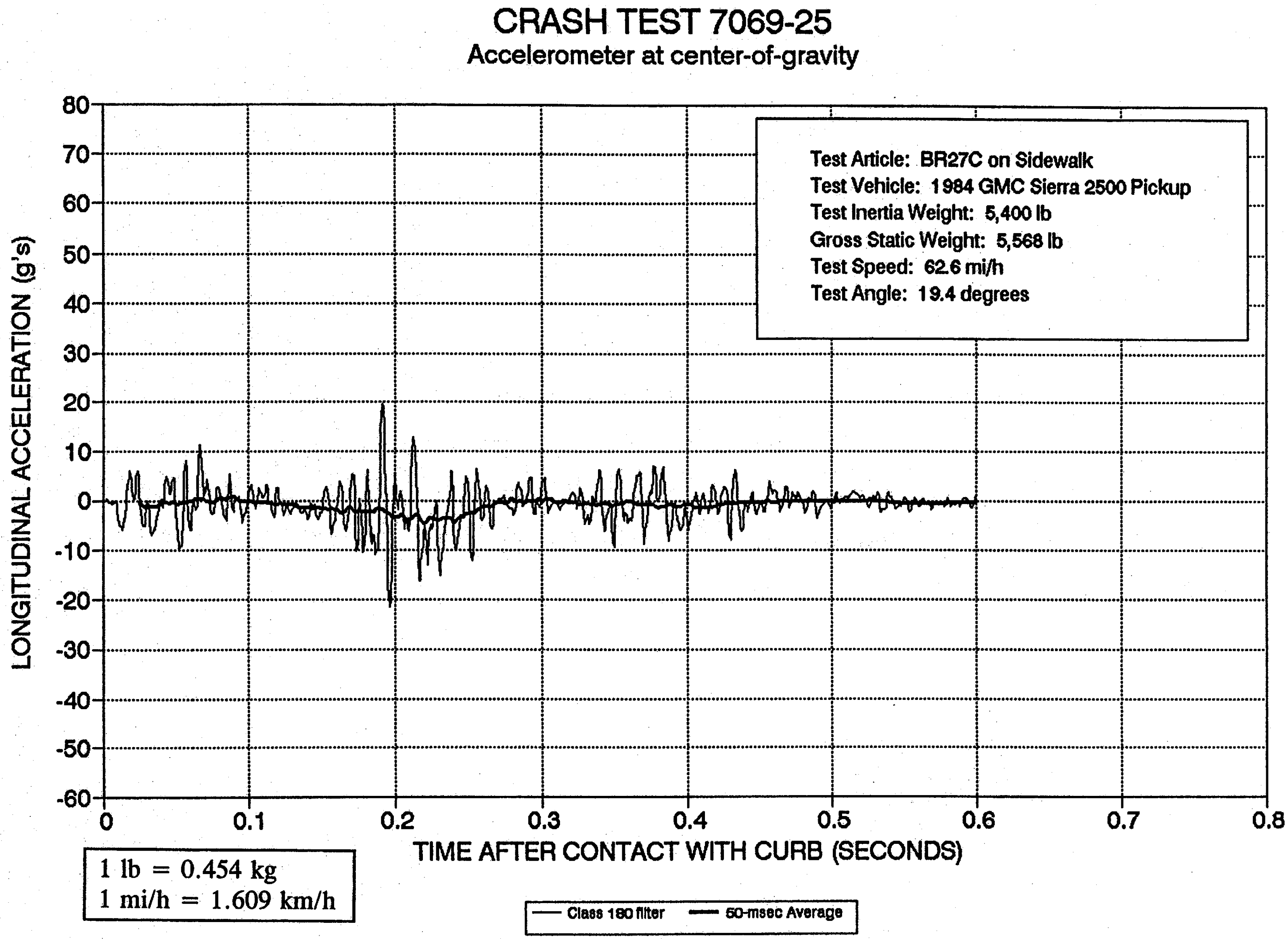


Figure 29. Vehicle longitudinal accelerometer trace for test 7069-25 (accelerometer located at center-of-gravity).

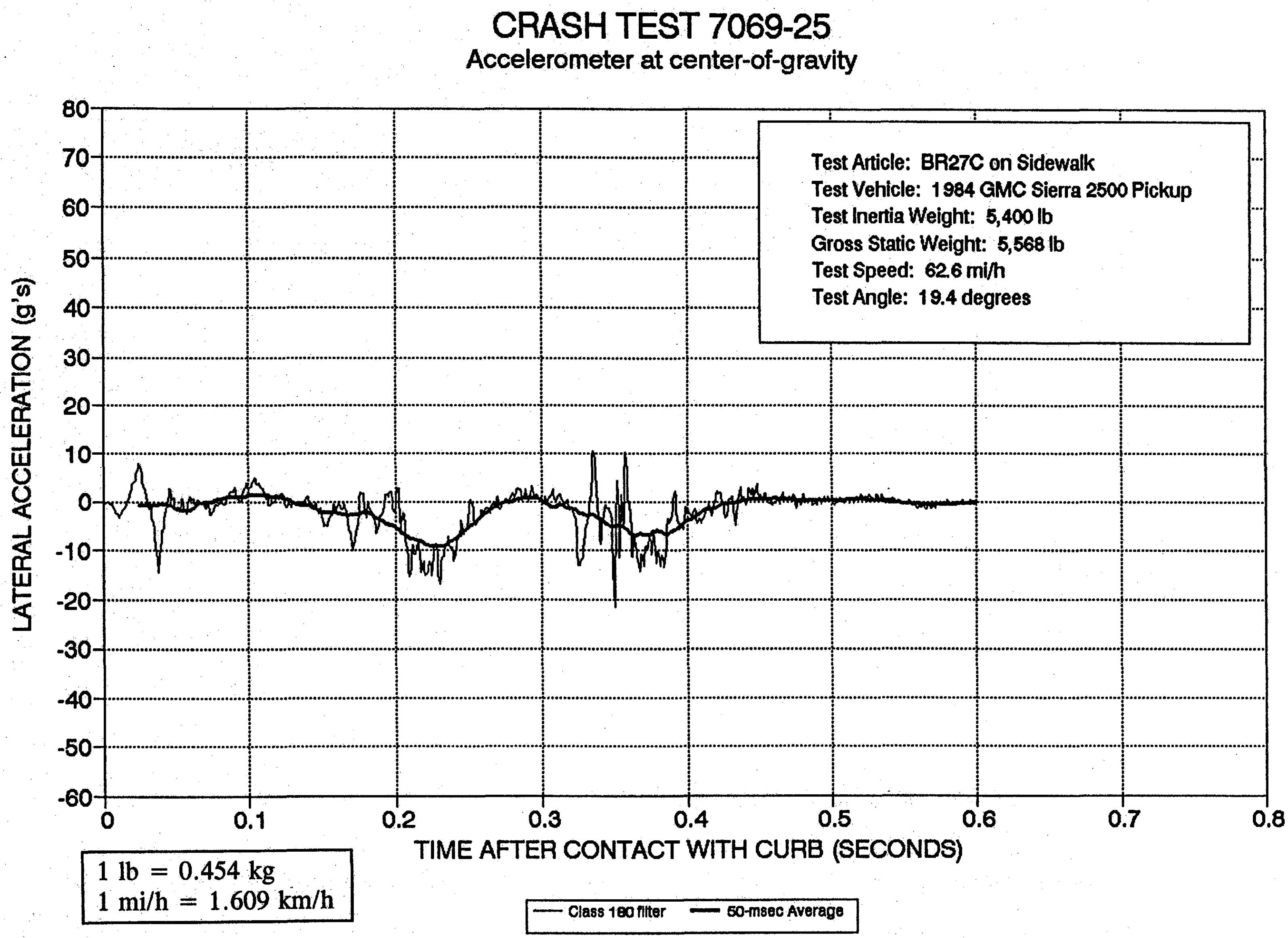


Figure 30. Vehicle lateral accelerometer trace for test 7069-25 (accelerometer located at center-of-gravity).

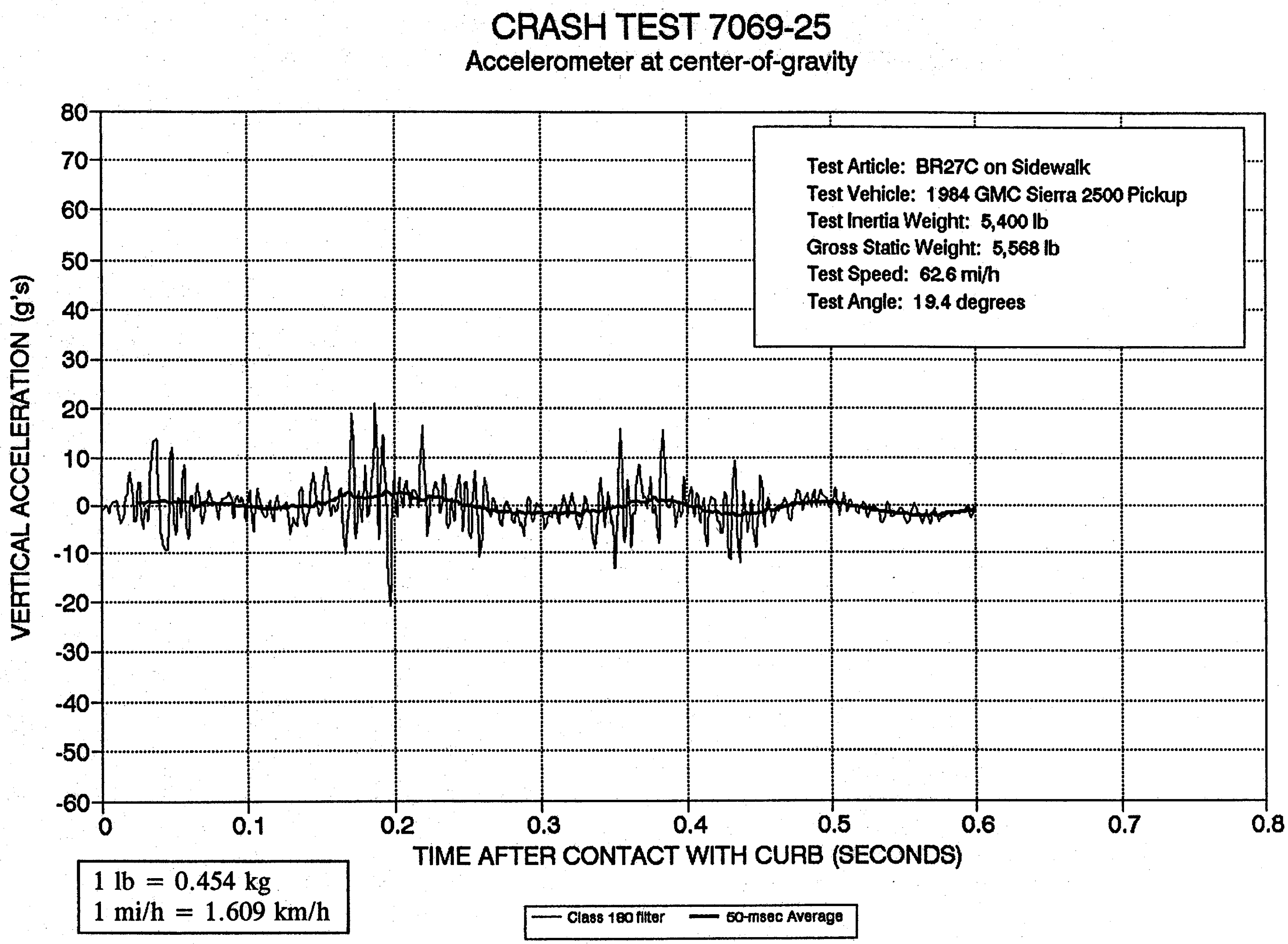


Figure 31. Vehicle vertical accelerometer trace for test 7069-25
(accelerometer located at center-of-gravity).

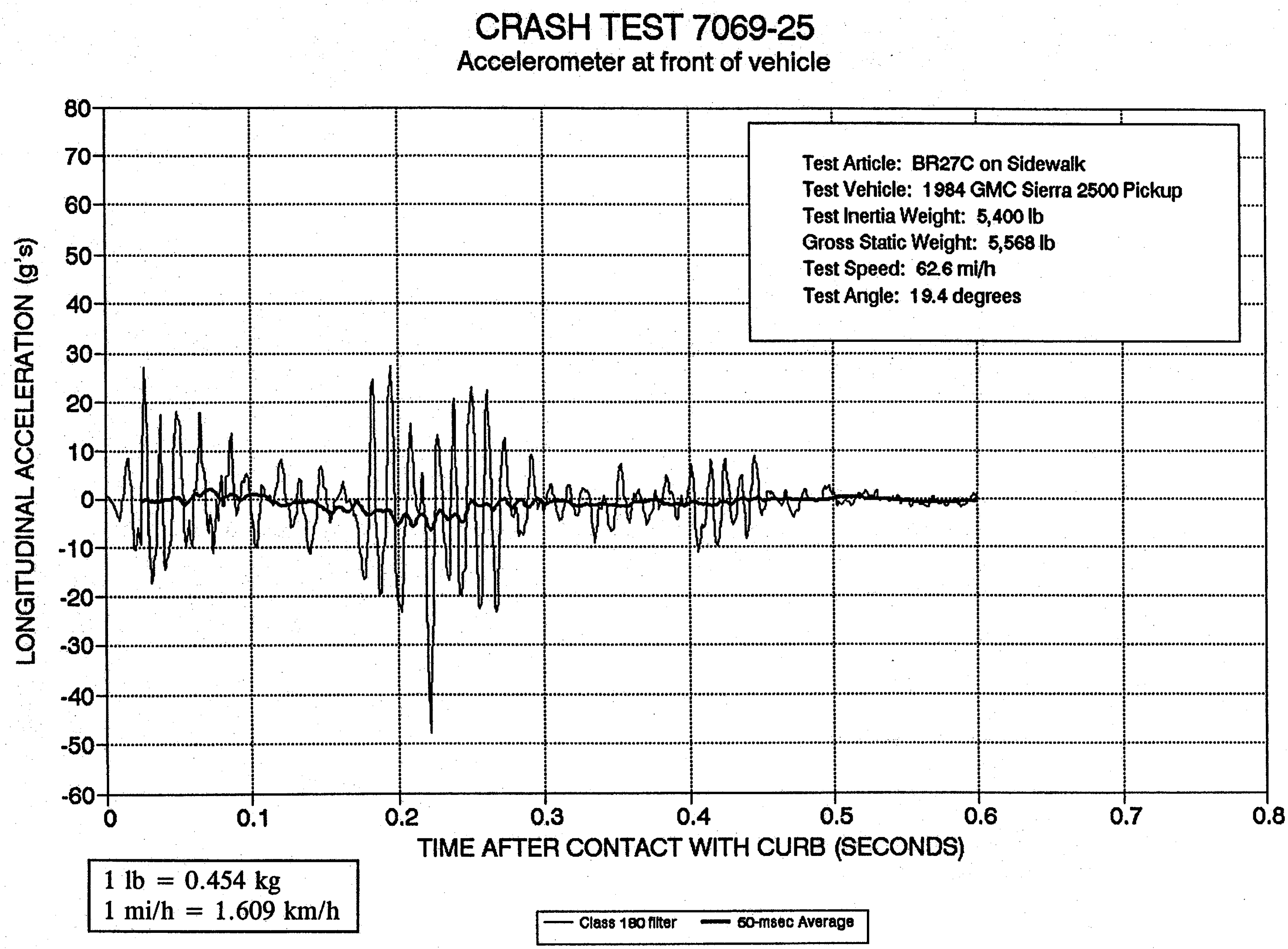


Figure 32. Vehicle longitudinal accelerometer trace for test 7069-25 (accelerometer located at front of vehicle).

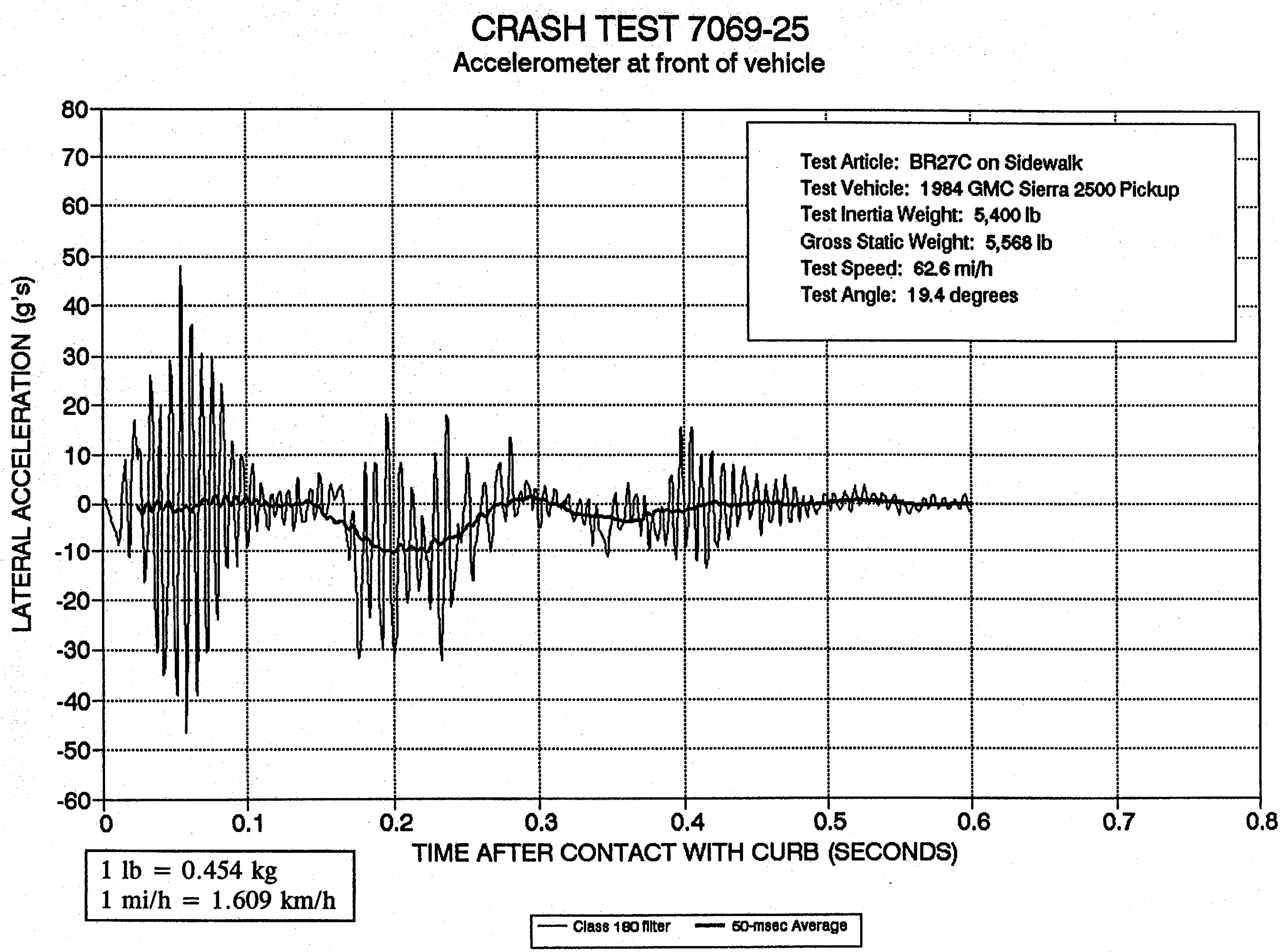


Figure 33. Vehicle lateral accelerometer trace for test 7069-25 (accelerometer located at front of vehicle).

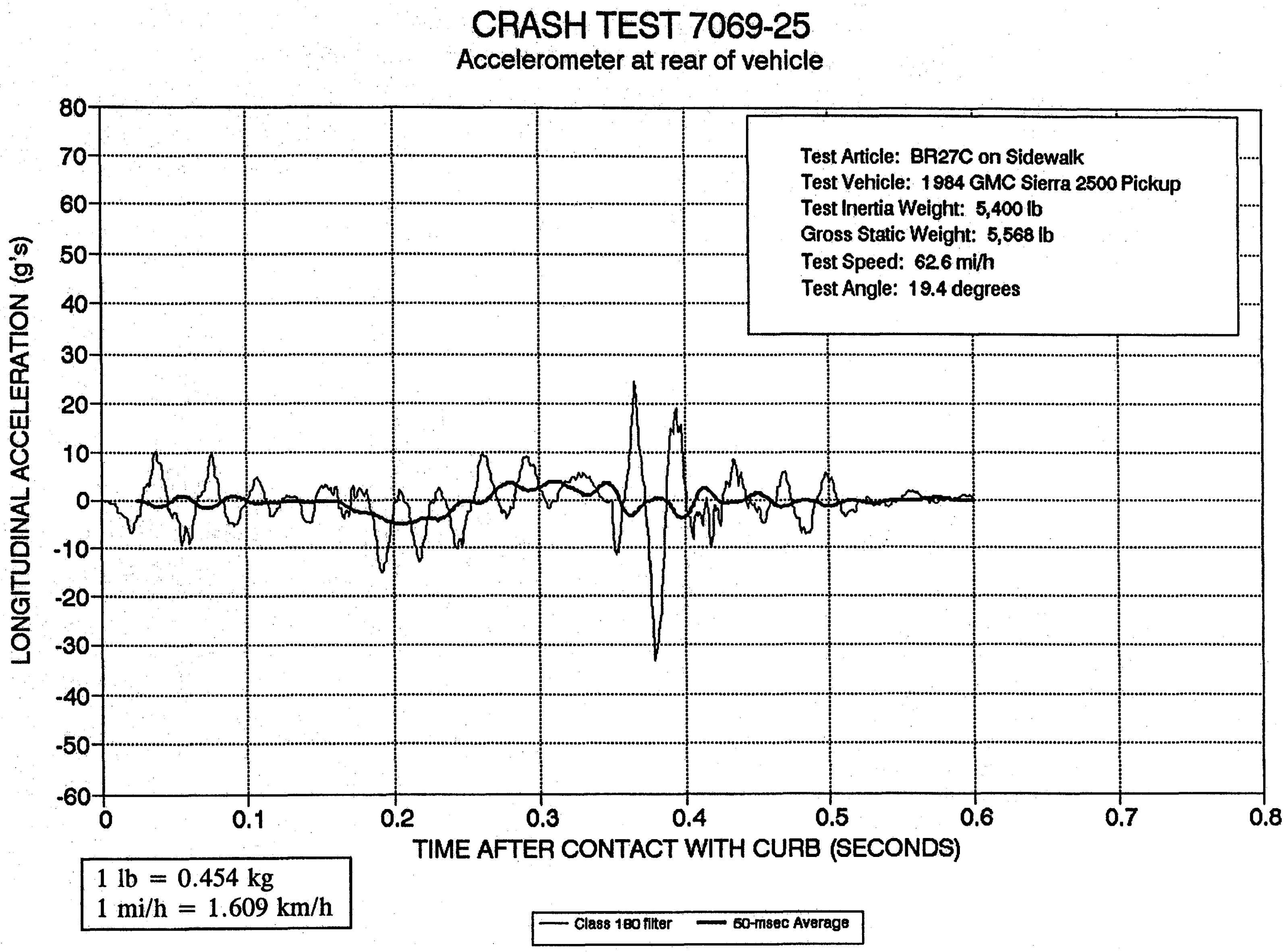


Figure 34. Vehicle longitudinal accelerometer trace for test 7069-25 (accelerometer located at rear of vehicle).

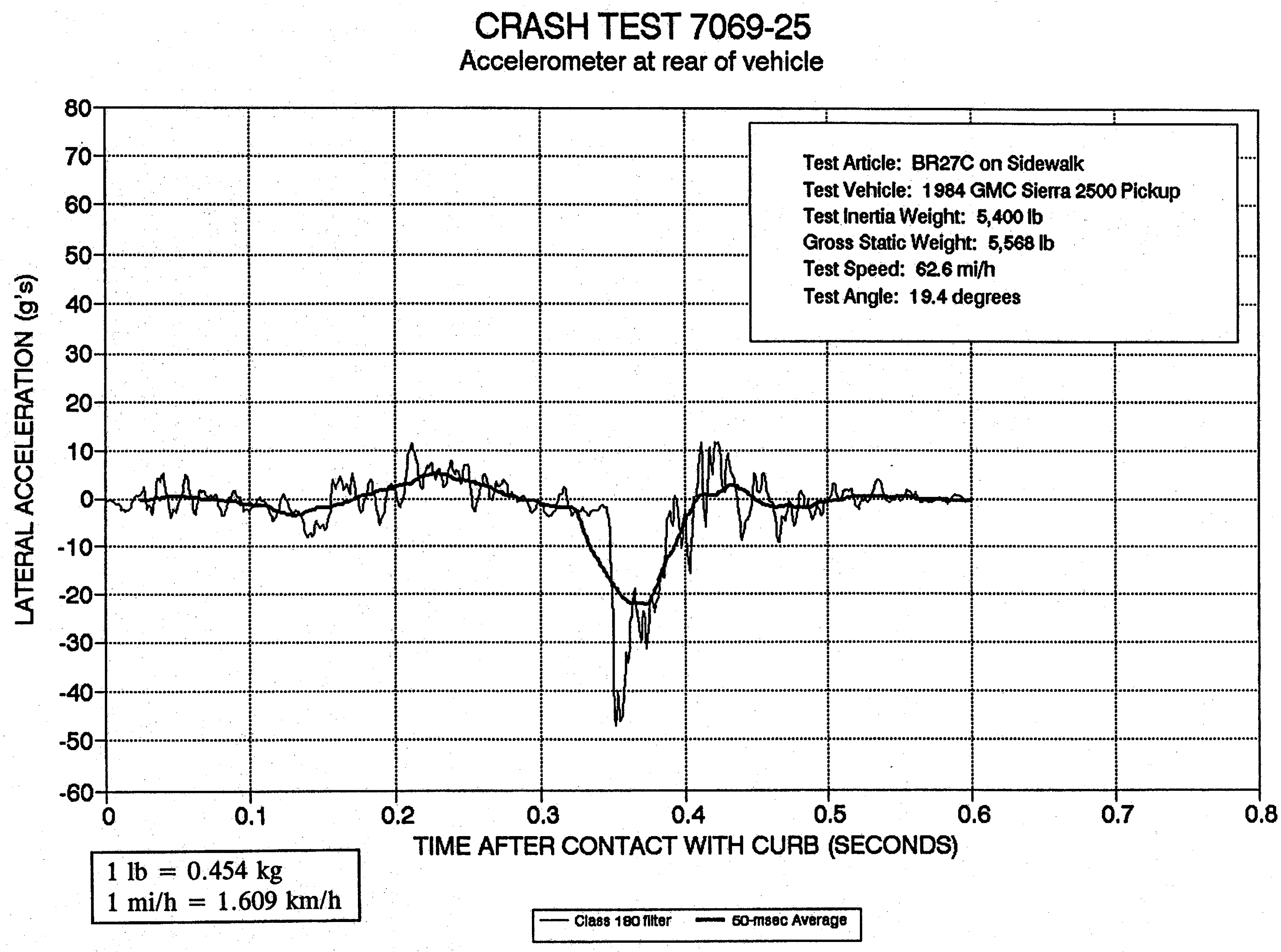


Figure 35. Vehicle lateral accelerometer trace for test 7069-25 (accelerometer located at rear of vehicle).

Test 7069-26

<u>Test Description</u>

A 1980 Ford single-unit truck (figures 36 through 38) was used for the crash test. The empty weight of the vehicle was 10,550 lb (4 790 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 39. The vehicle was directed into the BR27C bridge railing on sidewalk (figure 40) 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 curb of the sidewalk approximately 24.5 ft (7.5 m) downstream from the end at a speed of 51.0 mi/h (82.0 km/h) and the angle of impact was 13.7 degrees.

At approximately 0.084 s after impact, the vehicle began a slight counter-clockwise yaw, and at 0.220 s the left rear tire contacted the curb of the sidewalk. The vehicle bumper impacted the concrete parapet 3 ft (1 m) downstream of post 7 at 0.290 s traveling at a speed of 47.9 mi/h (77.1 km/h) and an angle of 14.4 degrees. At 0.307 s the left front wheel contacted the parapet, and at 0.368 s the right front wheel and part of the hub broke loose from the axle. By 0.431 s the vehicle began to redirect, and at 0.502 s the axle contacted the curb. The vehicle was moving parallel with the bridge railing by 0.590 s traveling at a speed of 44.8 mi/h (72.1 km/h). The rear of the vehicle contacted the concrete parapet at 0.607 s; and as the vehicle continued forward, the lower edge of the cargo box of the vehicle pulled the metal railing off posts 10 through 14. The front of the cab dropped off the end of the curb at 1.325 s; and as the vehicle exited the test site, it rode over the dislodged axle and driveshaft. The vehicle subsequently came to rest 195 ft (59 m) down from the point of impact.

As can be seen in figure 41, the bridge railing system received moderate damage. There was no measurable permanent deformation to the metal railing elements in the immediate impact area; however the bolts connecting the railing to the posts from 10 through 14 were sheared as a result of vertical load from the cargo box. There was only cosmetic damage to the concrete parapet, i.e., tire marks on the concrete parapet from post midway of posts 7 & 8 to post 11 and from posts 13 to 14. The vehicle was in contact with the bridge railing system for a total of 63 ft (19 m).

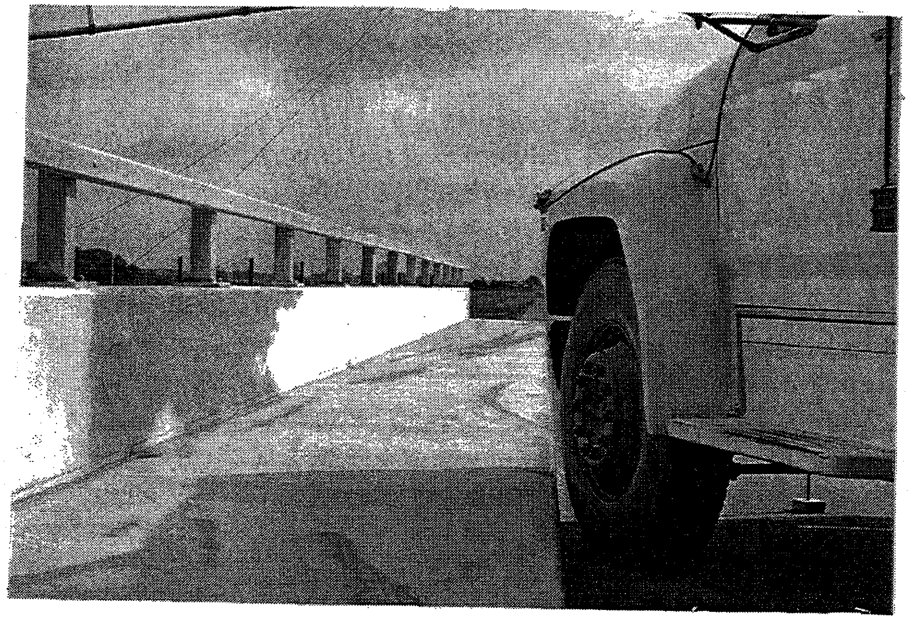
The vehicle sustained damage to the left side as shown in figure 42. Maximum crush at the left front corner at bumper height was 6.0 in (152 mm). The front axle broke loose and became separated from the vehicle as did the driveshaft (see figure 43). There was damage to the springs and shocks, steering box, front bumper, left front quarter panel, left door, and left front tire and rim. The lower edge of the left side of the cargo box was also damaged.

Test Results

The vehicle impacted the curb of the sidewalk at 51.0 mi/h (82.0 km/h) and the angle of impact was 13.7 degrees. As the vehicle impacted the concrete parapet, it was traveling at a speed of 47.9 mi/h (77.1 km/h) and an angle of 14.4 degrees. The speed of the vehicle at time of parallel was 44.8 mi/h (72.1 km/h). In determining the effective coefficient of friction which is an assessment of the smoothness of the "vehicle-railing" interaction, it should be noted that vehicle impact speed and angle is used in the calculation. If "vehicle-railing" interaction is interpreted literally, impact at the time of contact with the concrete parapet would be used. However, the curb could be considered to be part of this "vehicle-railing" interaction. Therefore, two assessments could be made: (1) interpreting "vehicle-railing" interaction literally disregarding the impact at the curb and using the speed and angle at which the vehicle impacted the concrete parapet or (2) considering the curb as an element of the "railing" system and using the speed and angle at which the vehicle impacted the curb. The coefficient of friction was calculated both ways for this test. Considering the curb as part of the vehicle-railing interaction the coefficient of friction was 0.40, while it was 0.14 using impact with the concrete parapet in the calculation. 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 8.2 ft/s (2.5 m/s) at 0.619 s, the highest 0.010-s average ridedown acceleration was -2.9 g between 0.734 and 0.744 s, and the maximum 0.050-s average acceleration was -1.9 g between 0.303 and 0.353 s. Lateral occupant impact velocity was 9.4 ft/s (2.9 m/s) at 0.442 s, the highest 0.010-s occupant ridedown acceleration was -6.9 g between 0.586 and 0.596 s, and the maximum 0.050-s average acceleration was -2.9 g between 0.388 and 0.438 s. These data and other pertinent information from the test are summarized in figure 44 and table 4. Sequential photographs are shown in figures 45 and 46. Vehicular angular displacements are displayed in figure 47. Vehicular accelerations versus time traces filtered with SAE J211 filters are presented in figures 48 through 54.

Conclusions

The BR27C bridge railing on sidewalk contained the test vehicle with minimal lateral movement of the bridge railing. There was no intrusion of railing components into the occupant compartment and no debris to present undue hazard to other traffic. The integrity of the occupant compartment was maintained with no intrusion and no deformation. The vehicle remained upright and relatively stable during the collision. The bridge railing system smoothly redirected the vehicle. The effective coefficient of friction was considered marginal to good. The vehicle trajectory at loss of contact indicated minimum intrusion into adjacent traffic lanes. See figure 44 and table 4 for more details.



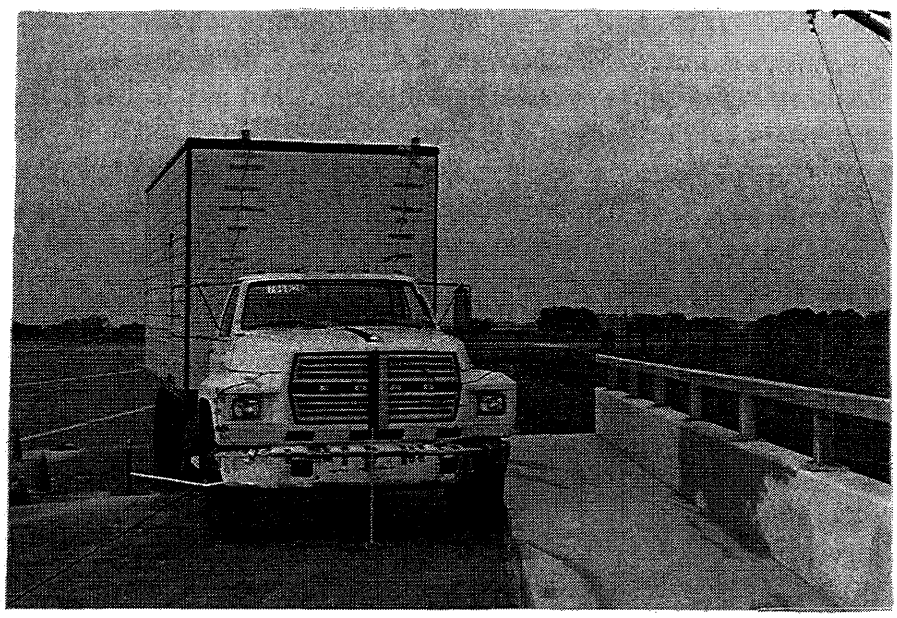
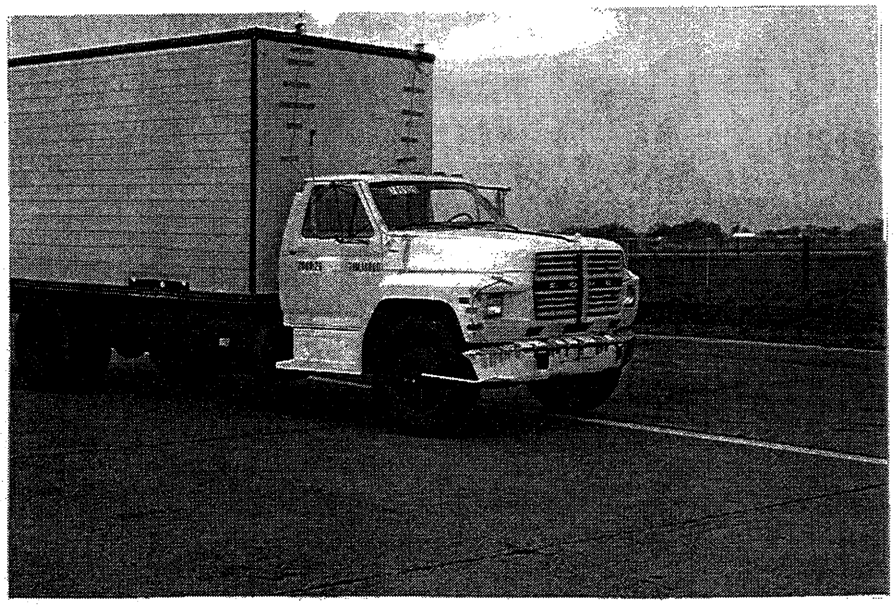


Figure 36. Vehicle/bridge railing geometrics for test 7069-26.



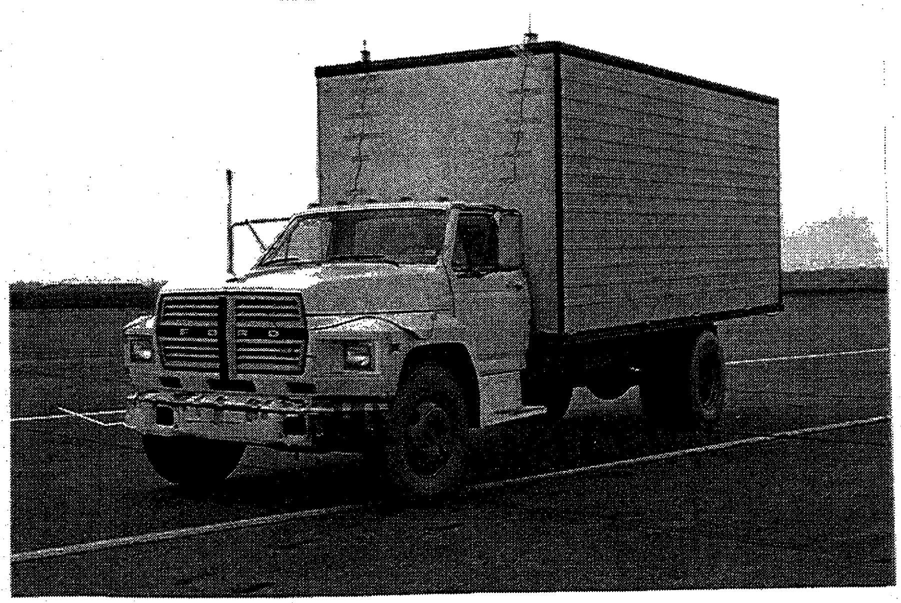
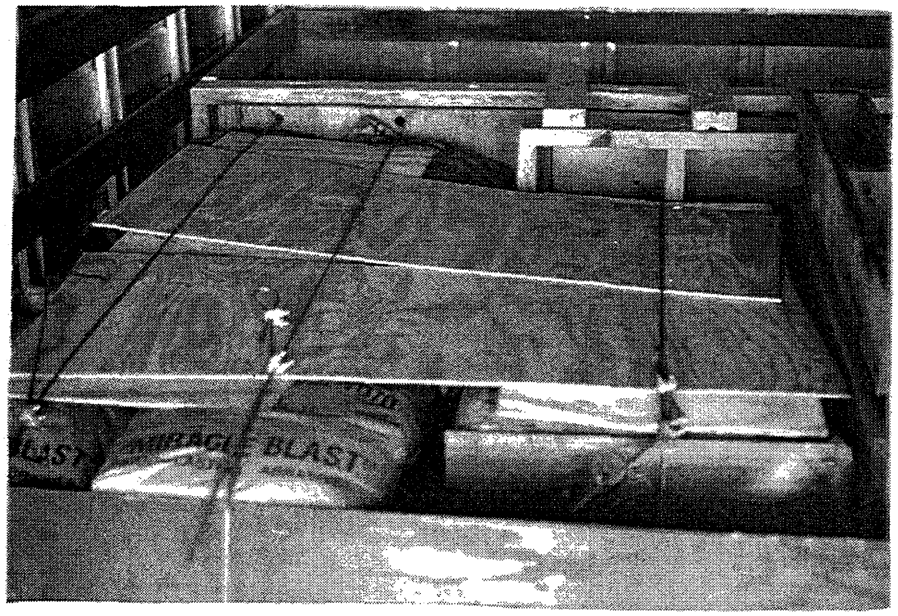


Figure 37. Vehicle prior to test 7069-26.



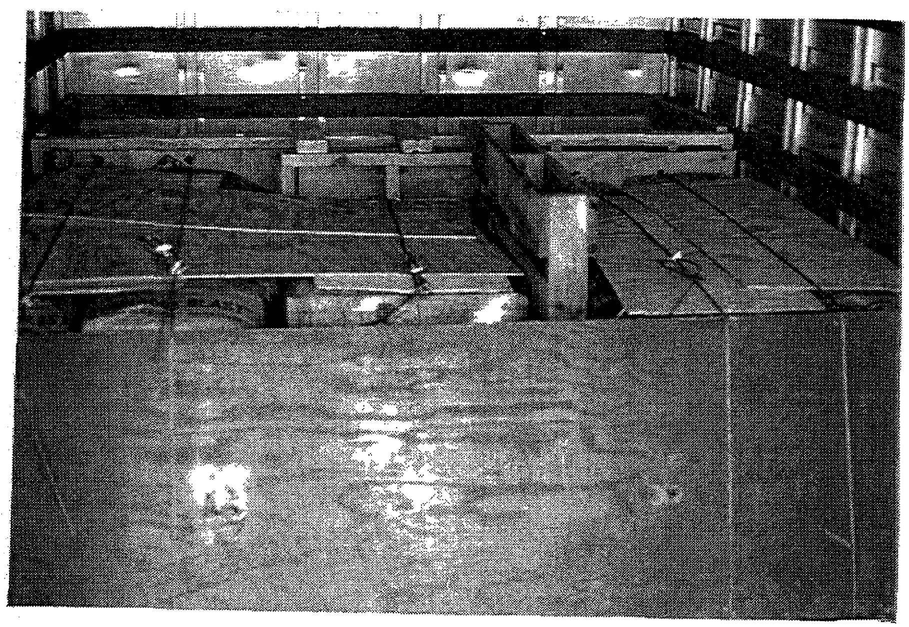
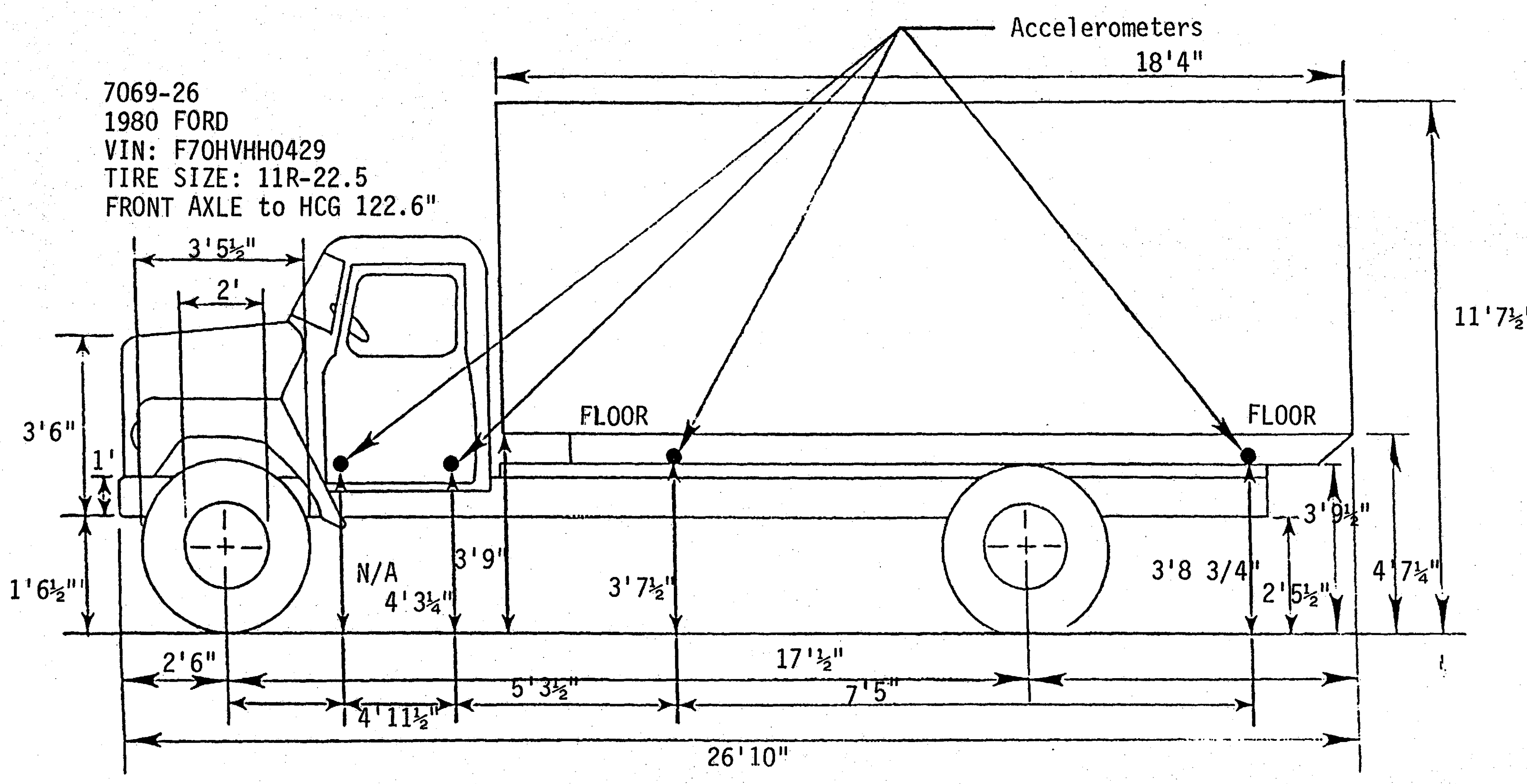


Figure 38. Cargo in vehicle for 7069-26.



EMPTY WEIGHTS

Weight on Front Axle : LF 2450 RF 2470

Weight on Rear Axle : LR 2650 RR 2980

TOTAL EMPTY WEIGHT : 10550

LOADED WEIGHTS

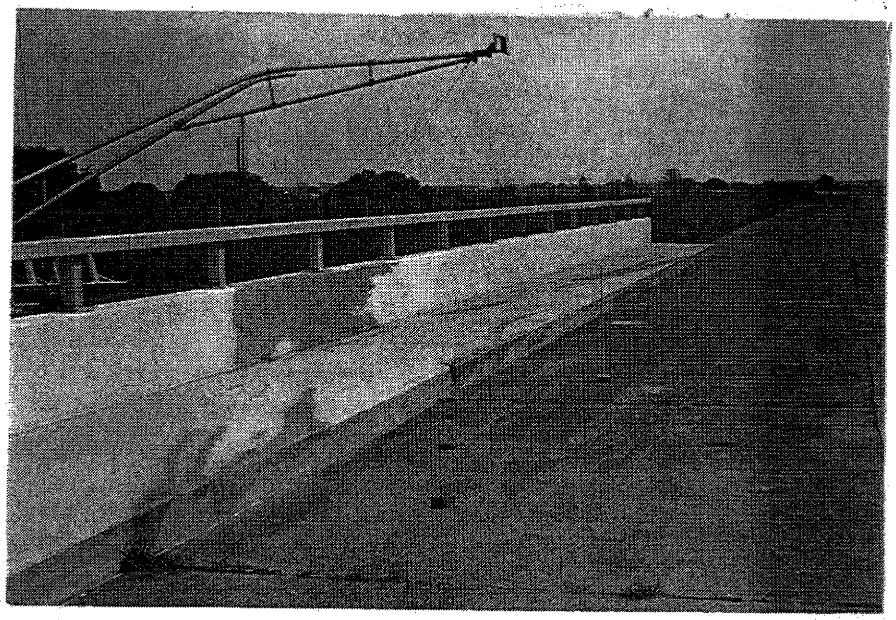
Weight on Front Axle : LF 3540 RF 3670

Weight on Rear Axle : RF 5220 RR 5570

TOTAL LOADED WEIGHT : 18000

1 in = 25.4 mm
1 lb = 0.454 kg

Figure 39. Vehicle properties for test 7069-26.



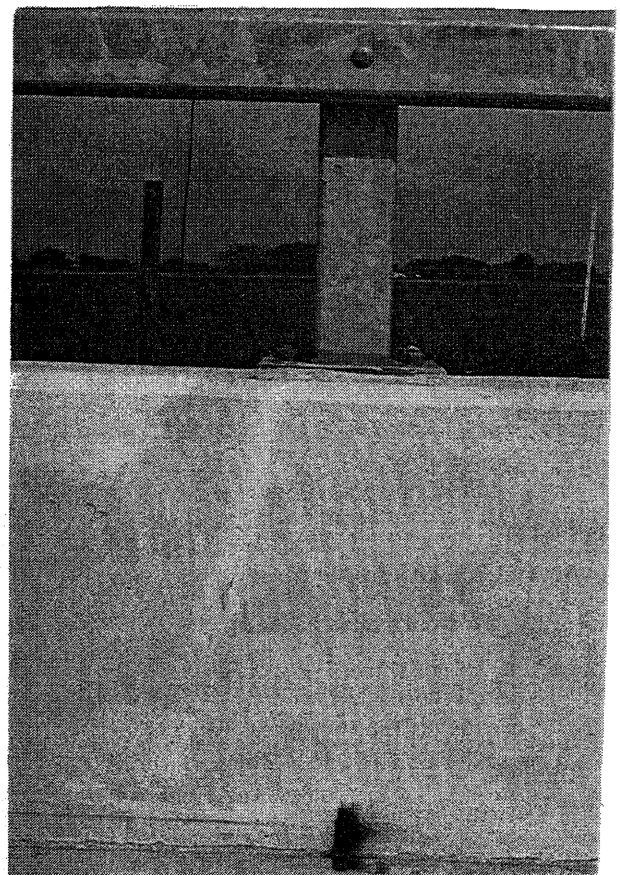


Figure 40. BR27C bridge railing on sidewalk before test 7069-26.

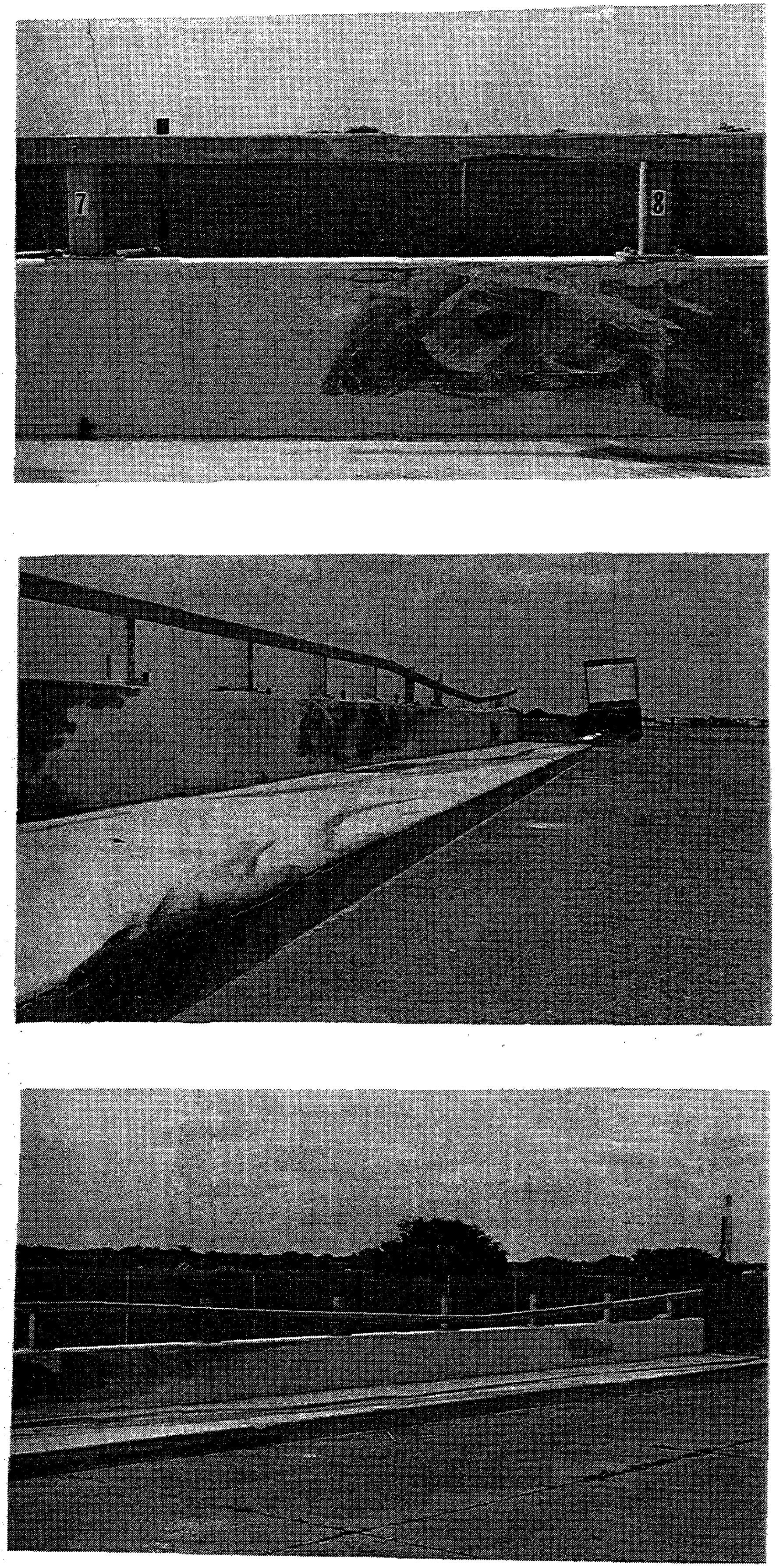


Figure 41. BR27C bridge railing on sidewalk after test 7069-26.

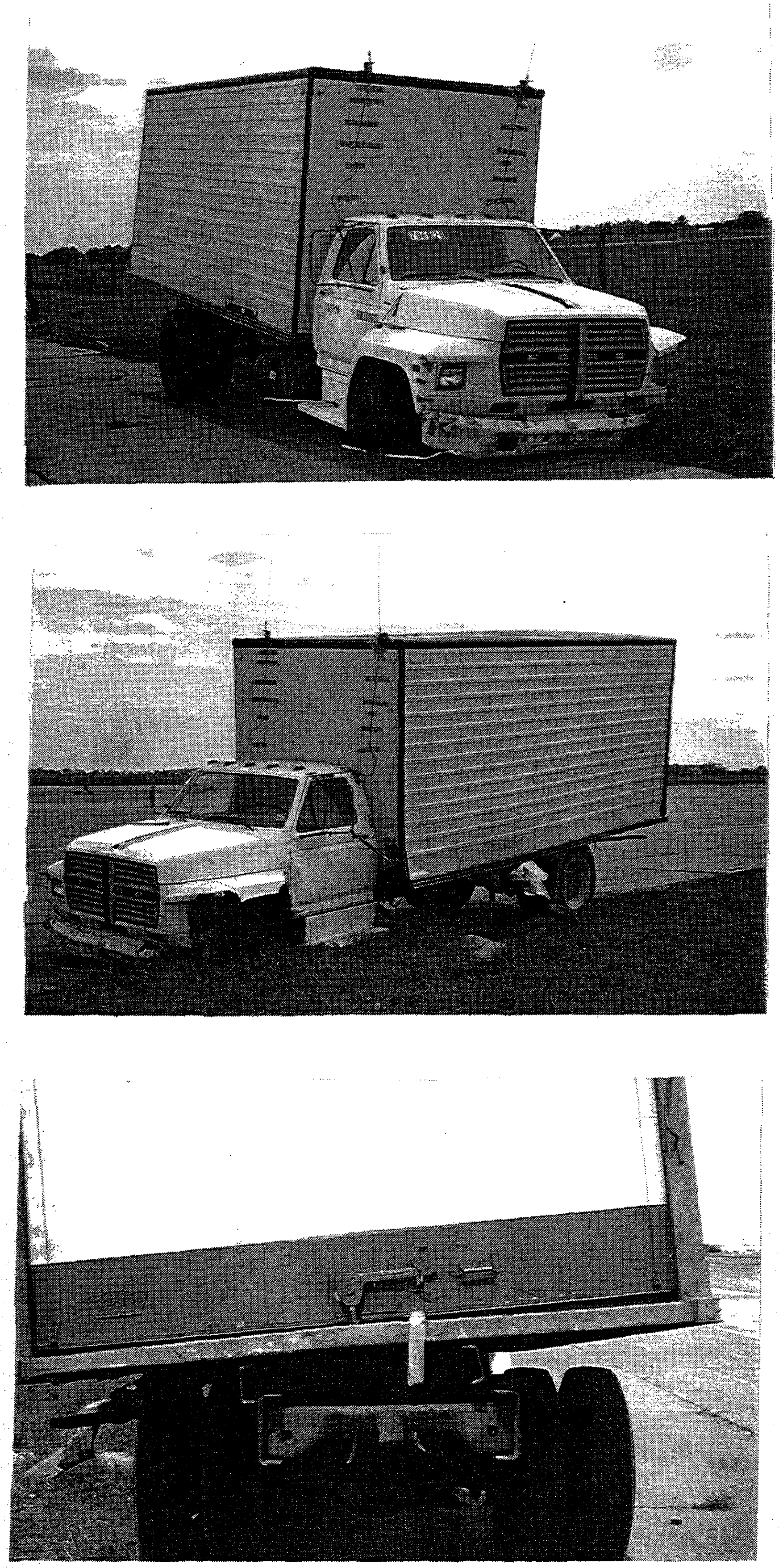


Figure 42. Vehicle after test 7069-26.

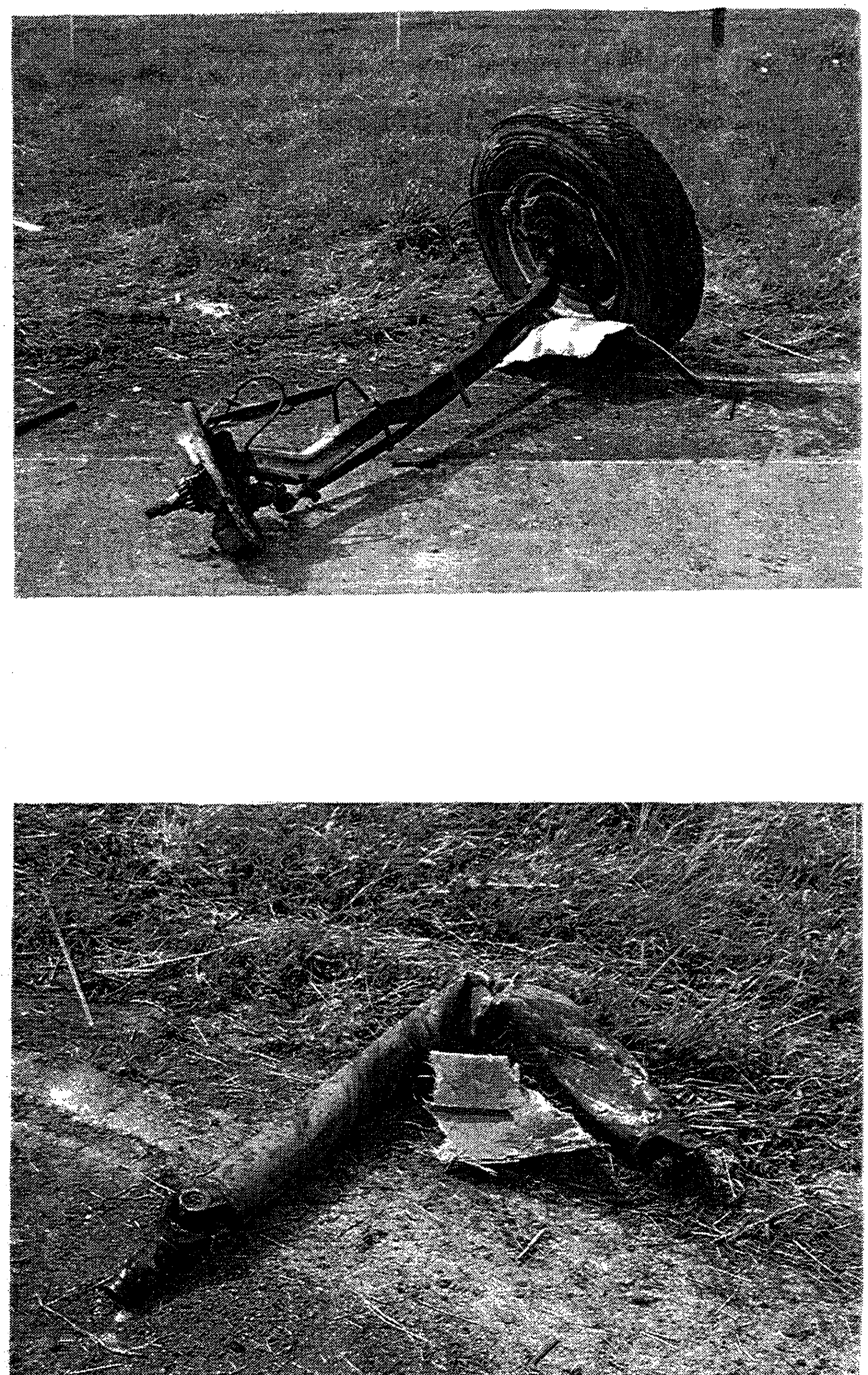
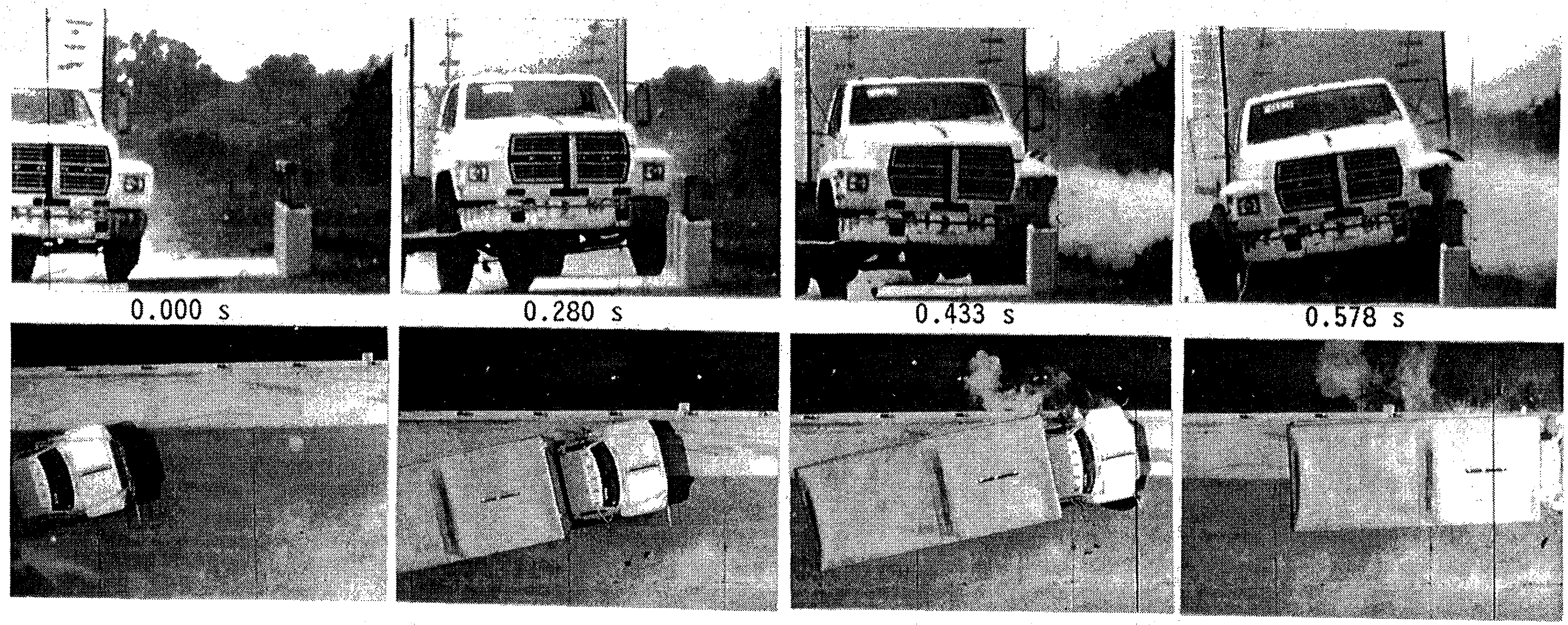
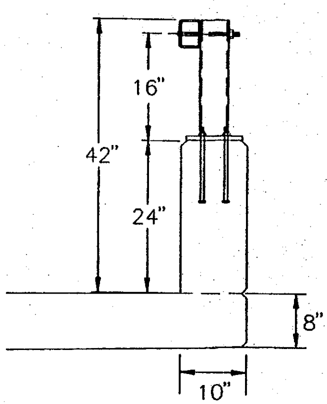


Figure 43. Debris from vehicle after test 7069-26.





(1 in = 25.4 mm)

Test No 7069-26
Date 04/08/92

Test Installation . . . . BR27C Bridge Railing on sidewalk
Installation Length . . 100 ft (30 m)

Test Vehicle . . . . . . 1980 Ford Single-Unit Truck
Vehicle Weight
  Empty Weight . . . . . 10,550 lb (4,790 kg)
  Test Inertia . . . . . 18,000 lb (8,172 kg)

Maximum Vehicle
  Crush . . . . 12.0 in (305 mm)

Impact Speed. . . . 51.0 mi/h (82.0 km/h)
Impact Angle. . . . 13.7 deg
Speed at Parallel . 44.8 mi/h (72.1 km/h)
Exit Speed . . . . N/A
Exit Trajectory . . 0 deg
Vehicle Accelerations
  (Max. 0.050-sec Avg) at true c.g.
  Longitudinal. . . -1.9 g
  Lateral . . . . . -2.9 g
Occupant Impact Velocity at true c.g.
  Longitudinal. . . 8.2 ft/s (2.5 m/s)
  Lateral . . . . . 9.4 ft/s (2.9 m/s)
Occupant Ridedown Accelerations
  Longitudinal. . . -2.9 g
  Lateral . . . . . -6.9 g

Figure 44. Summary of results for test 7069-26.

Table 4. Evaluation of crash test no. 7069-26.
{BR27C bridge railing on sidewalk (18,000 lb (8 172 kg)|51.0 mi/h (82.0 km/h)|13.7 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 .40 (Impact @ curb) — Marginal .14 (Impact @ rail) — 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: 8.2 (2.5); Lateral: 9.4 (2.9)	N/A
	Occupant Ridedown Accelerations - g's Longitudinal: 15; Lateral: 15	Occupant Ridedown Accelerations - g's Longitudinal: -2.9; Lateral: -6.9	N/A
H.	Exit angle shall be less than 12 degrees	Exit angle was 0 degrees	Pass

*A, B, and C are required. D, E, F, and H are desired. G is not applicable for this test.(See table 2)

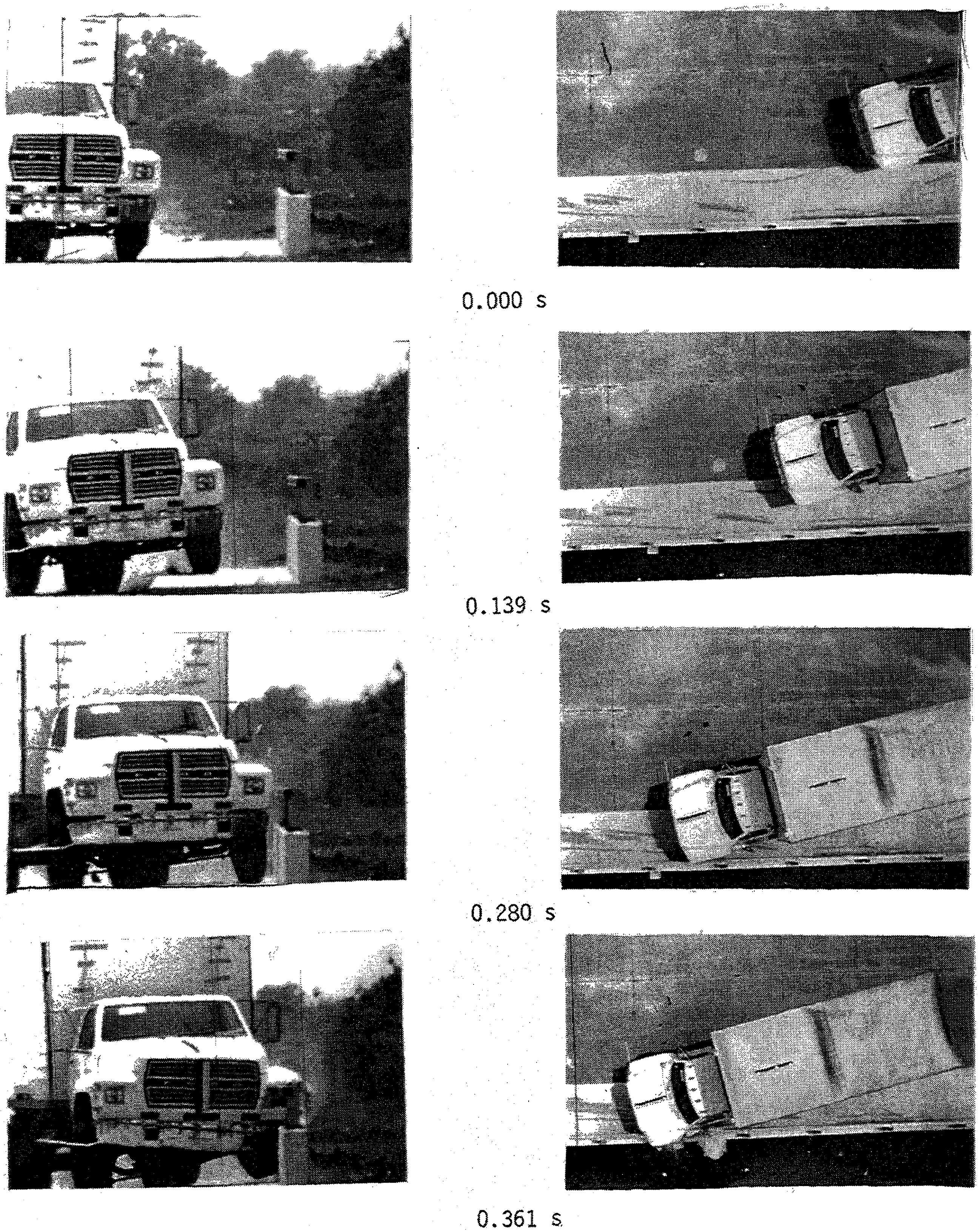


Figure 45. Sequential photographs for test 7069-26 (frontal and overhead views).

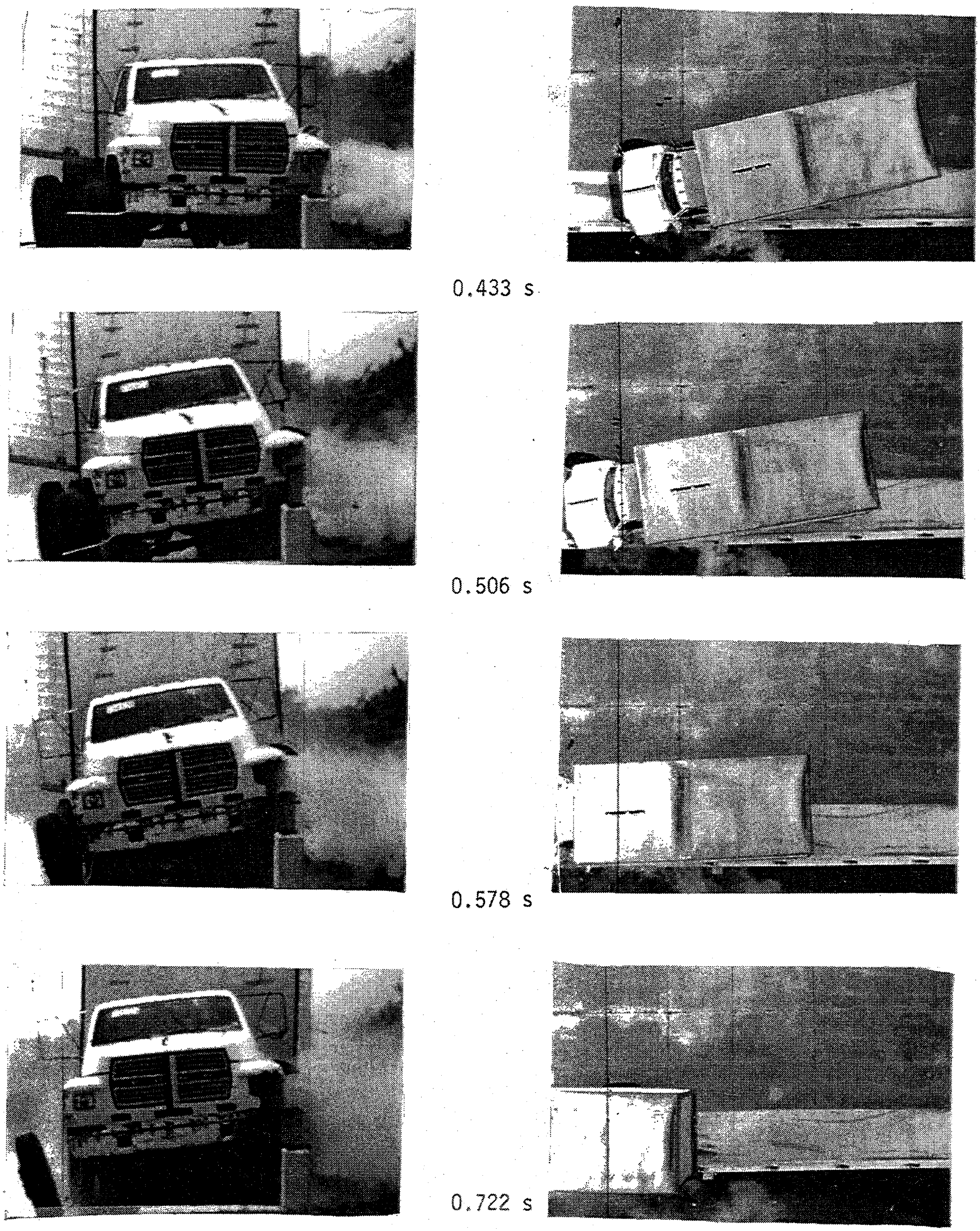
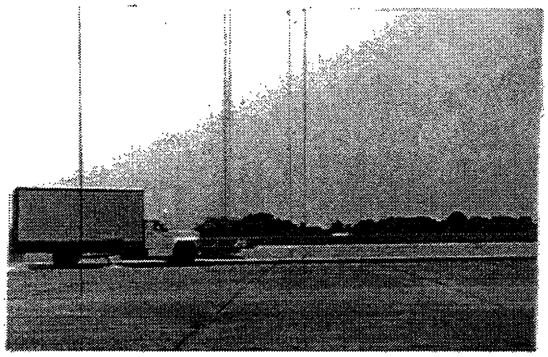
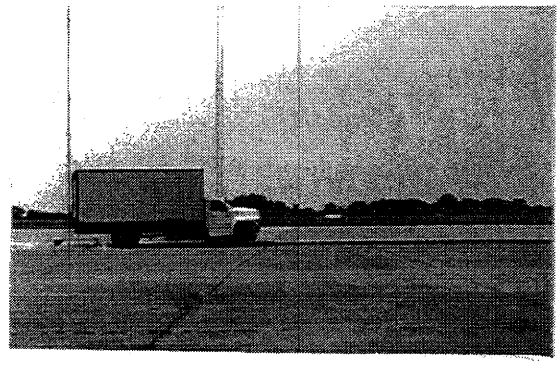


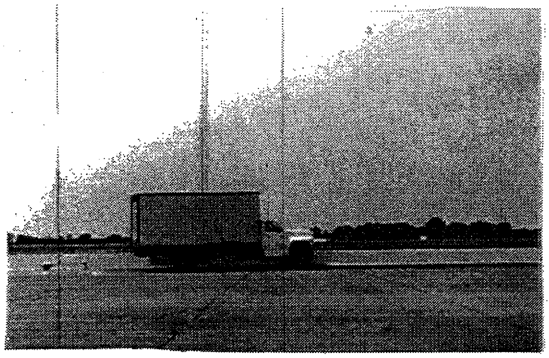
Figure 45. Sequential photographs for test 7069-26
(frontal and overhead views continued).



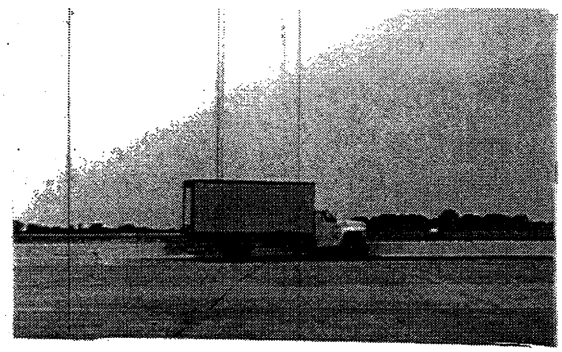
0.000 s



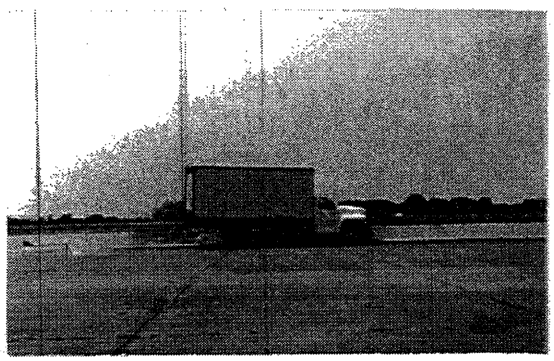
0.139 s



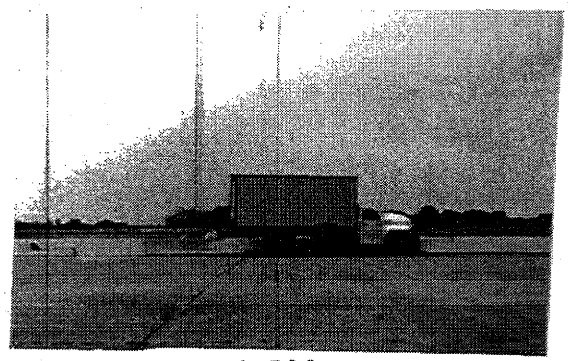
0.280 s



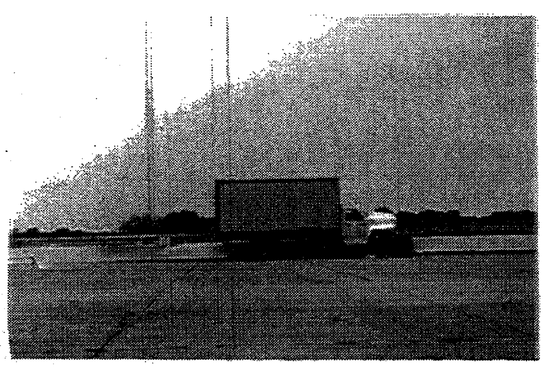
0.361 s



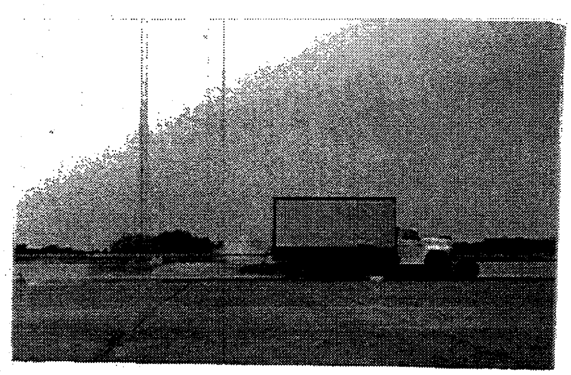
0.433 s



0.506 s



0.578 s



0.722 s

Figure 46. Sequential photographs for test 7069-26 (perpendicular view).

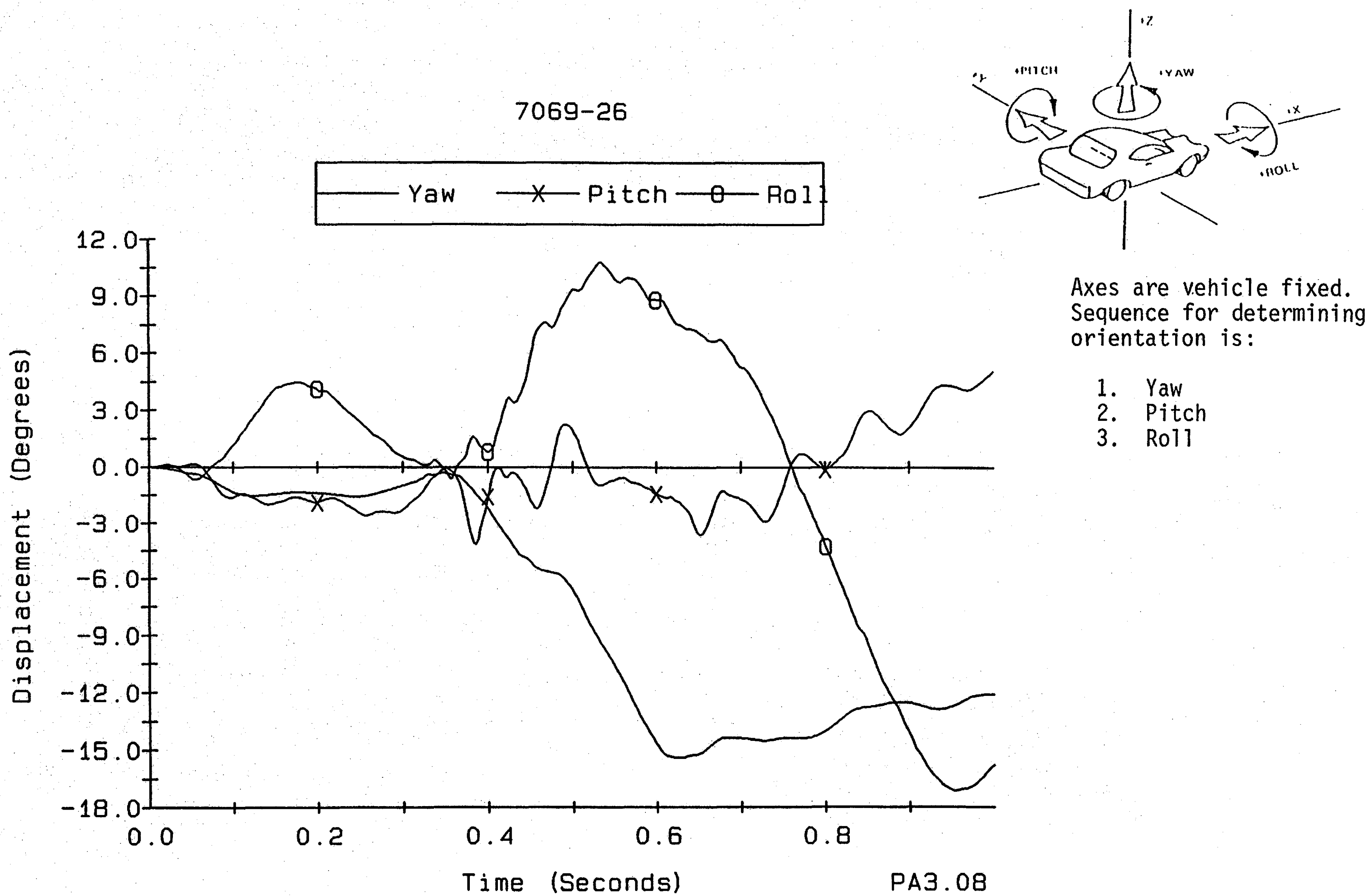


Figure 47. Vehicle angular displacements for test 7069-26.

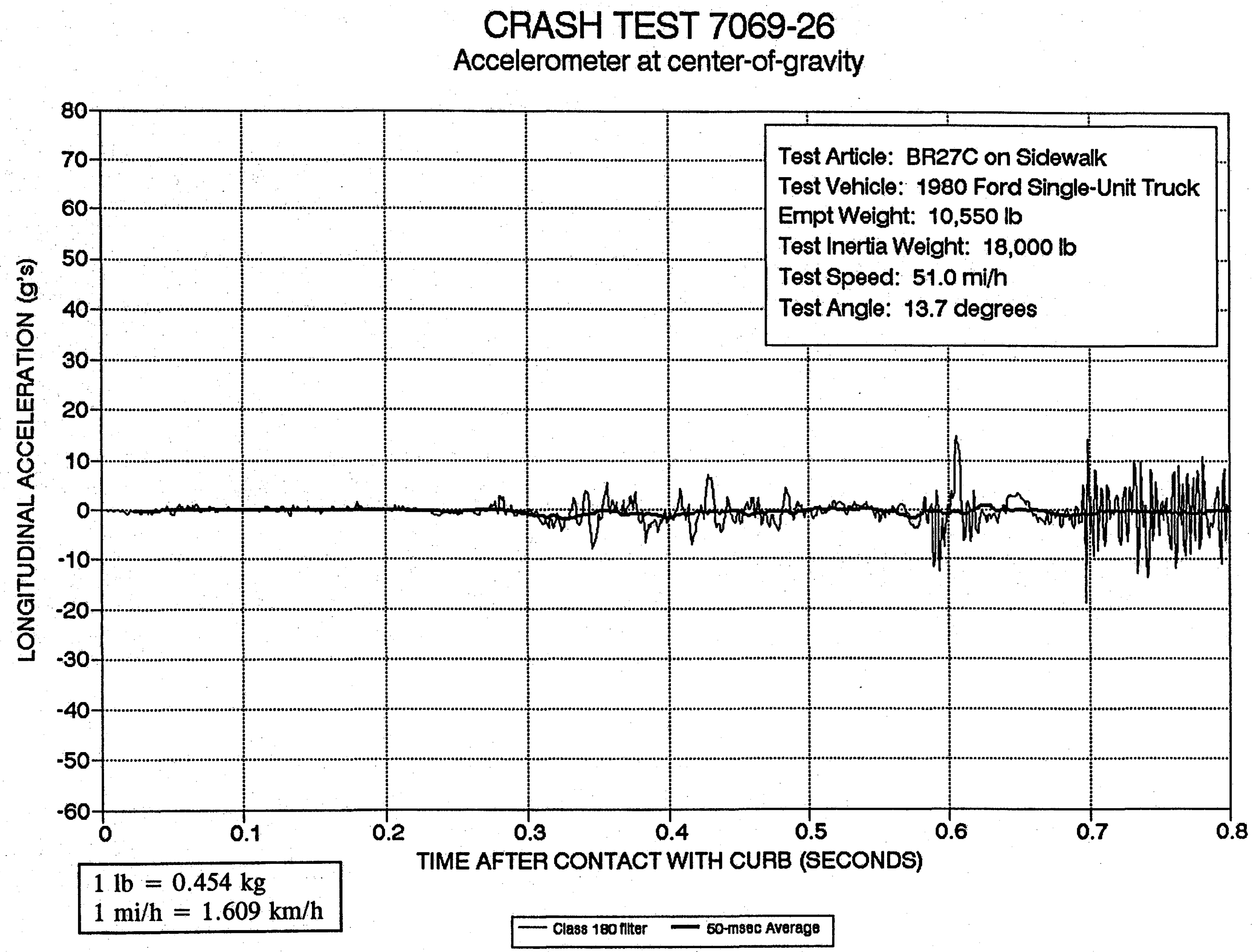


Figure 48. Vehicle longitudinal accelerometer trace for test 7069-26 (accelerometer located at center-of-gravity).

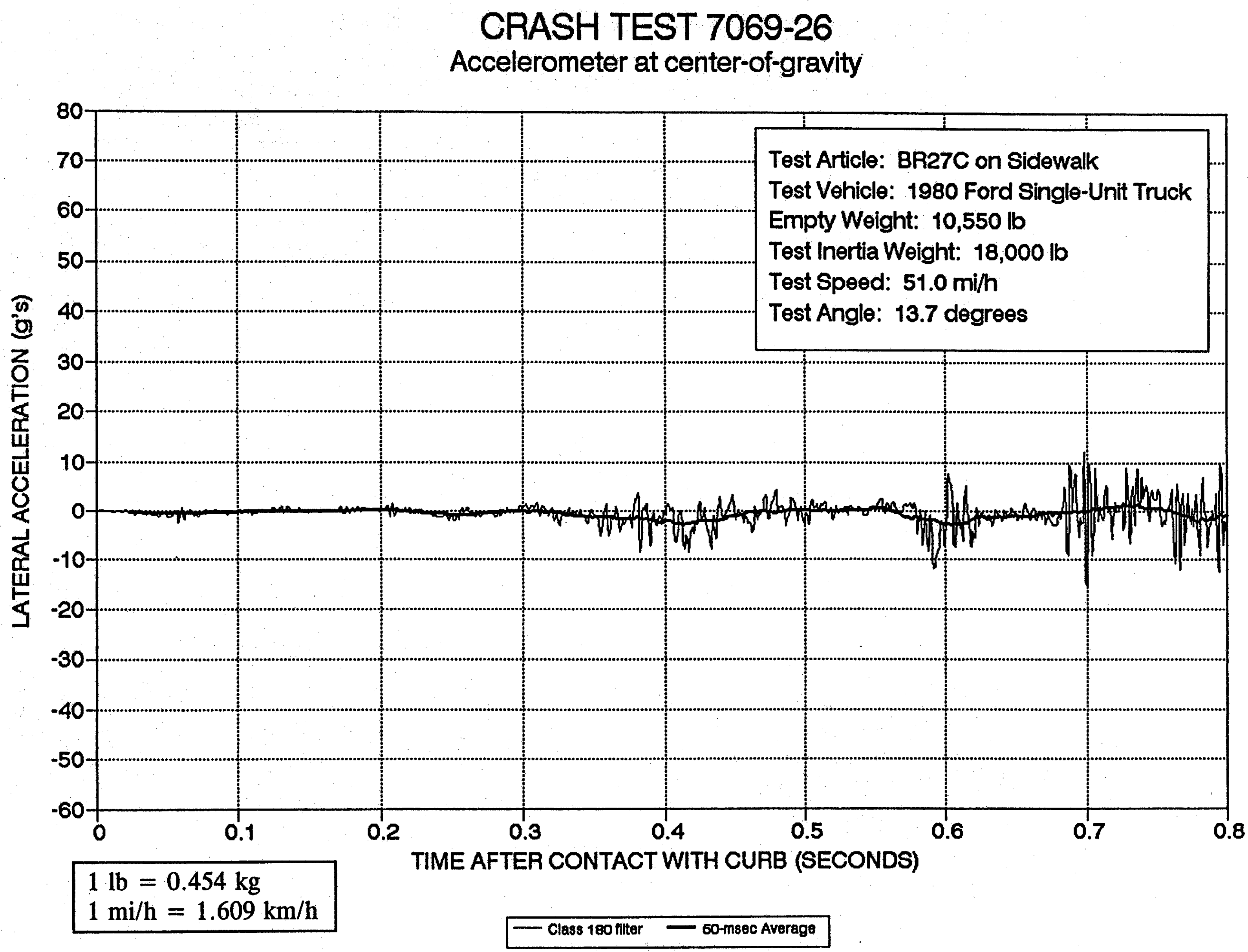


Figure 49. Vehicle lateral accelerometer trace for test 7069-26 (accelerometer located at center-of-gravity).

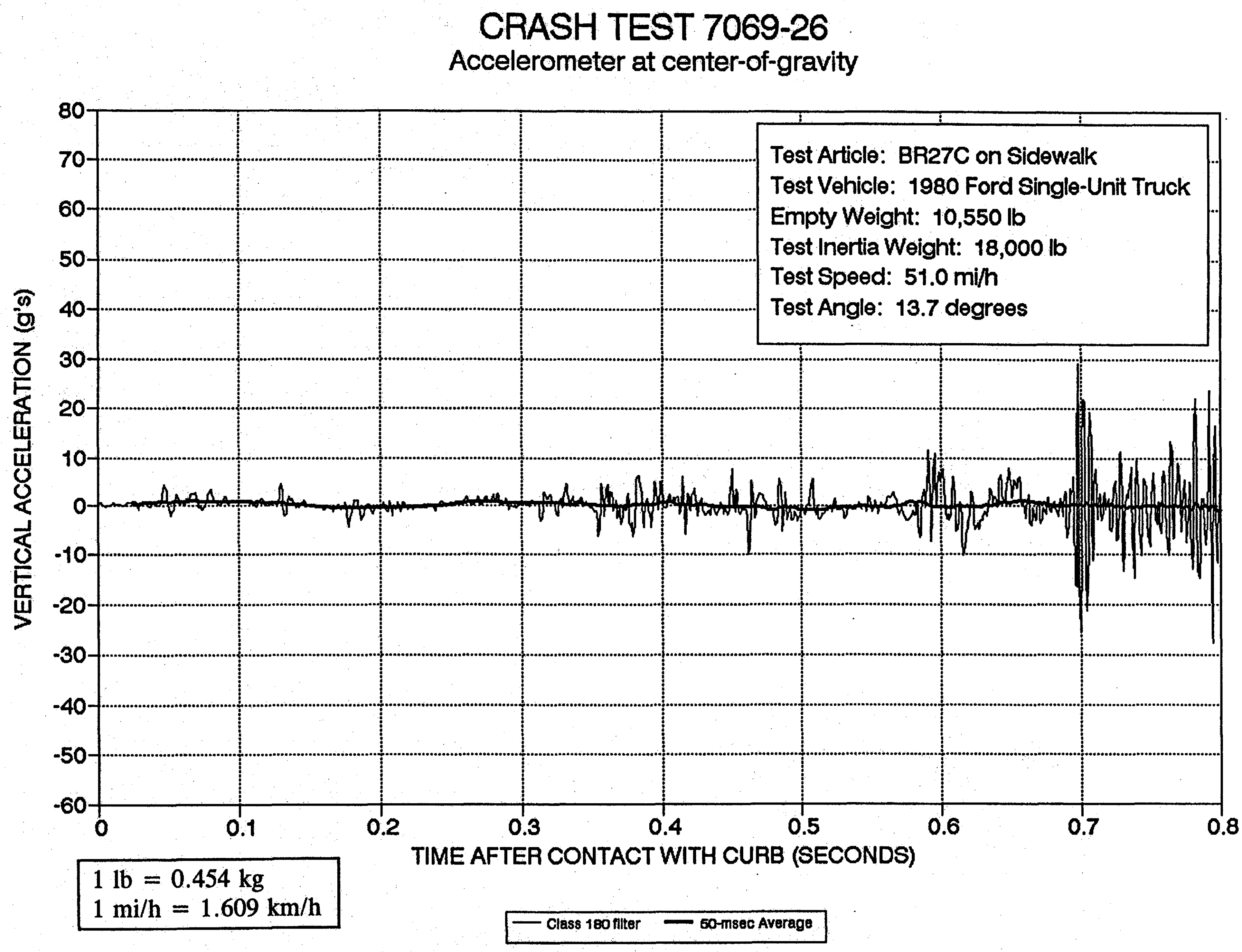


Figure 50. Vehicle vertical accelerometer trace for test 7069-26 (accelerometer located at center-of-gravity).

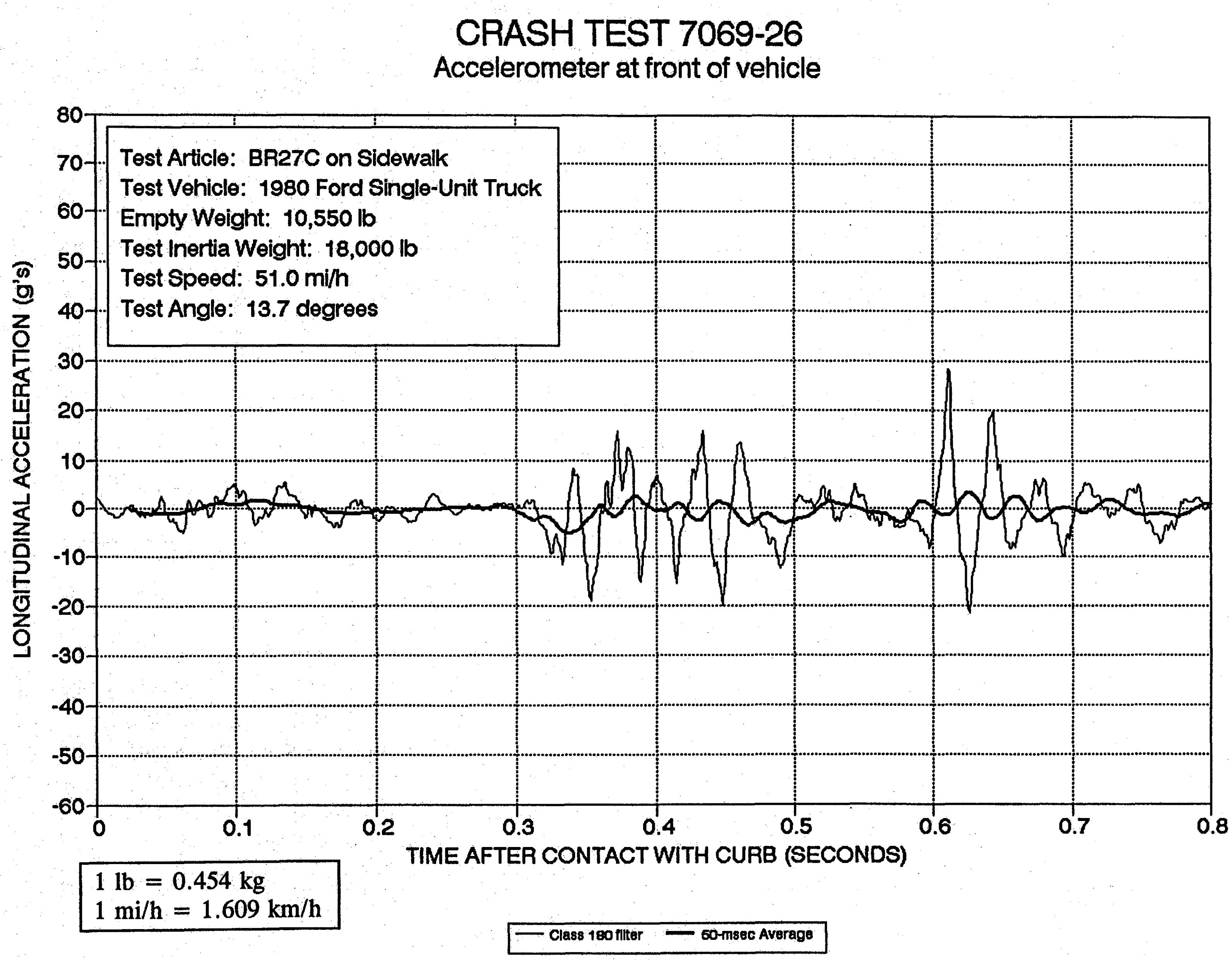


Figure 51. Vehicle longitudinal accelerometer trace for test 7069-26 (accelerometer located at front of vehicle).

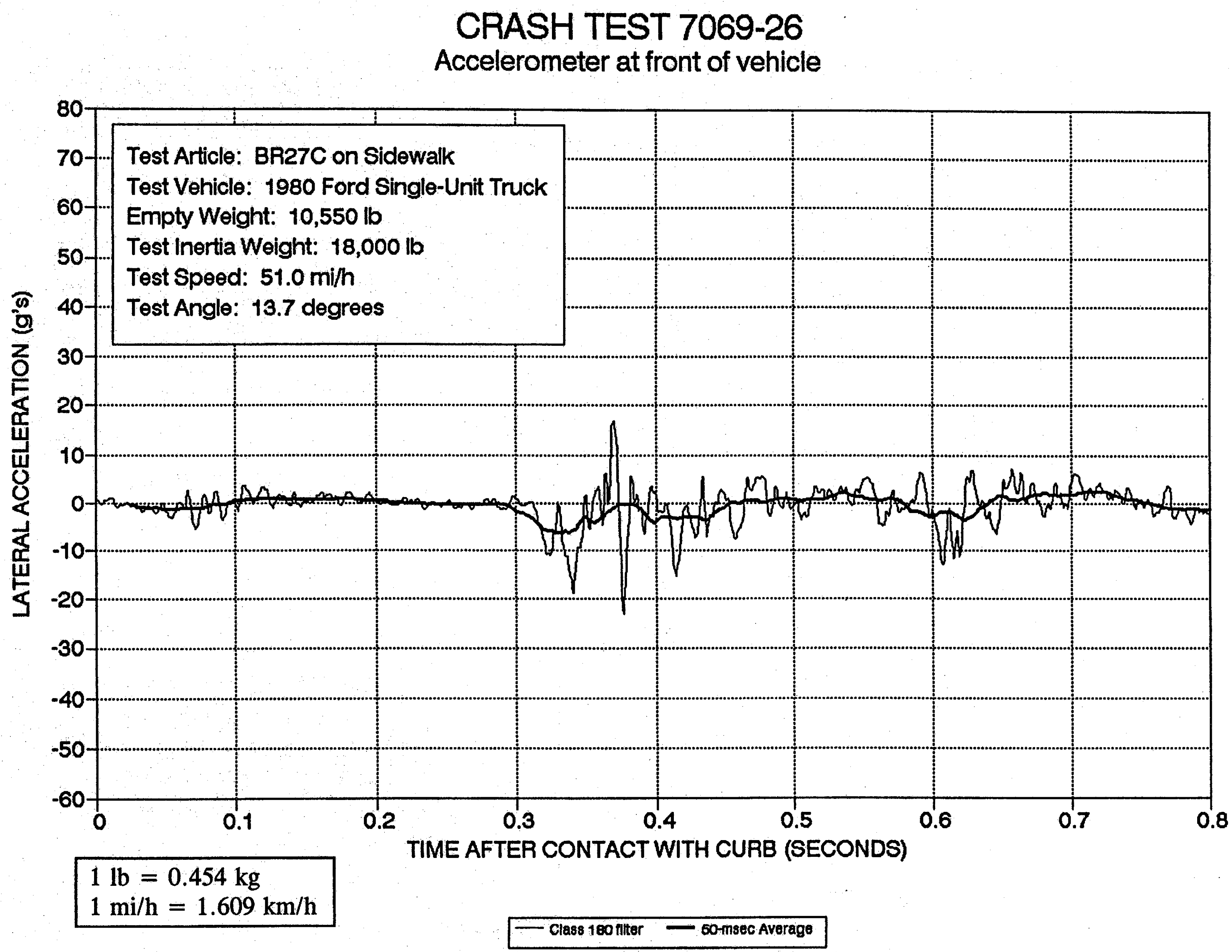


Figure 52. Vehicle lateral accelerometer trace for test 7069-26 (accelerometer located at front of vehicle).

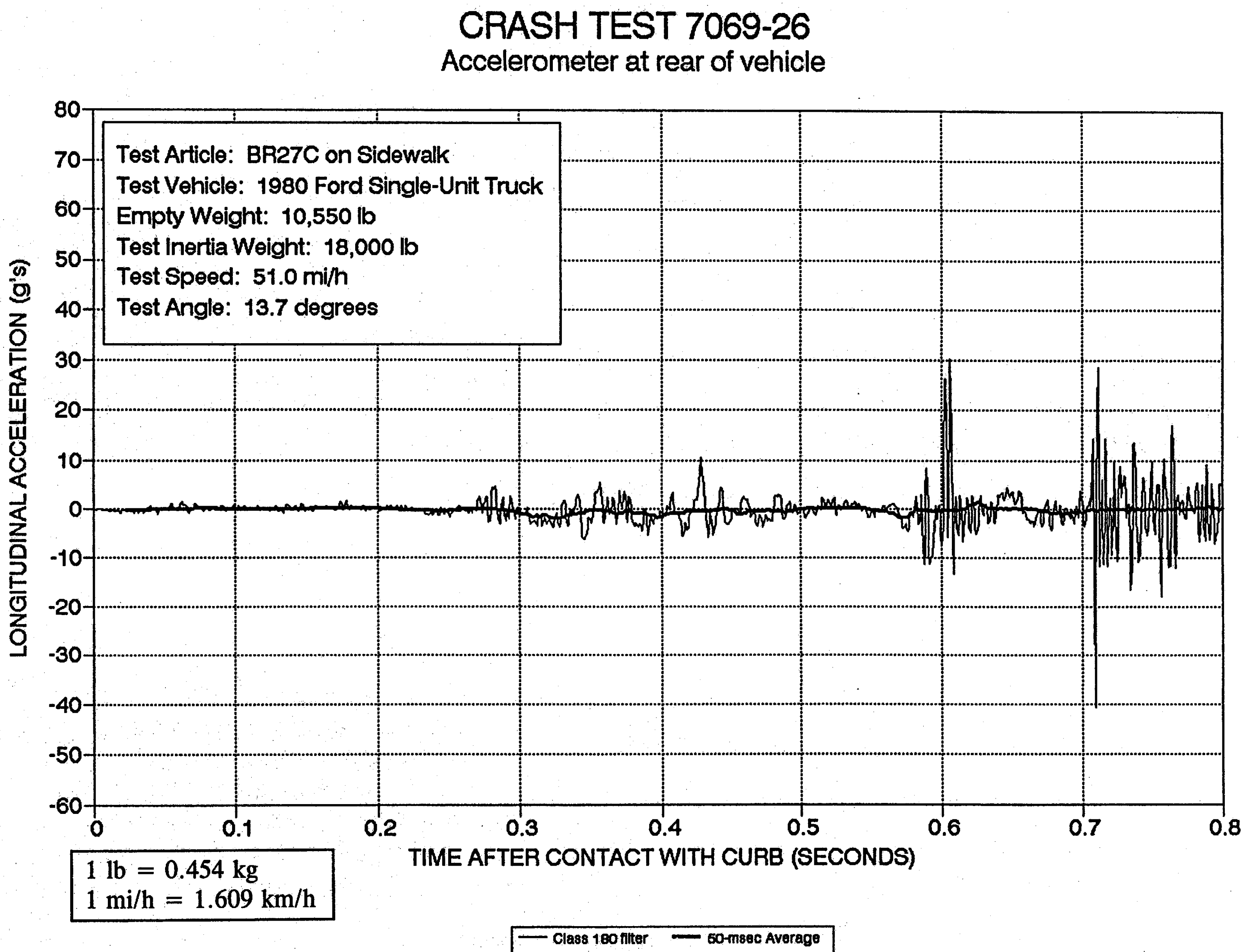


Figure 53. Vehicle longitudinal accelerometer trace for test 7069-26 (accelerometer located at rear of vehicle).

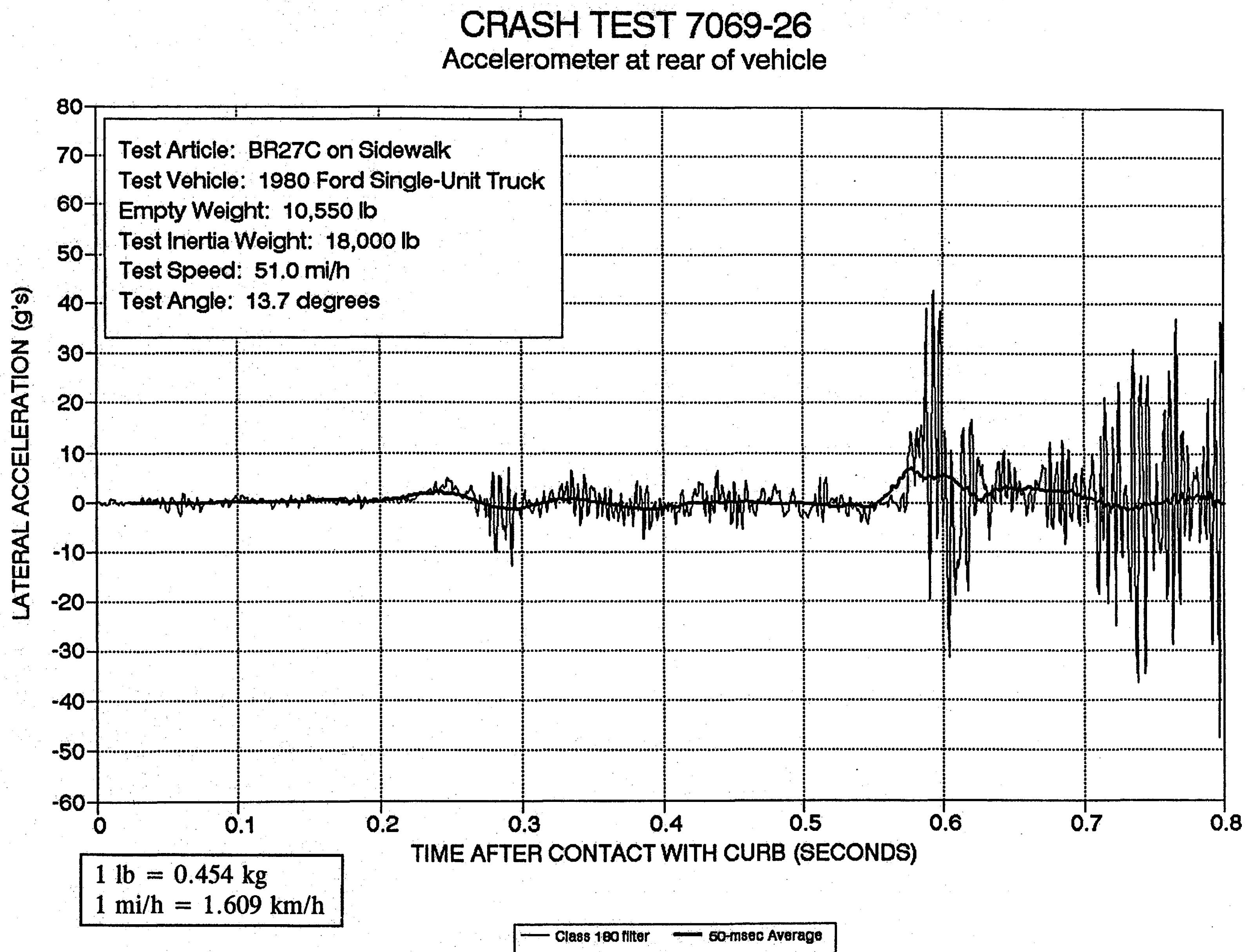


Figure 54. Vehicle lateral accelerometer trace for test 7069-26
(accelerometer located at rear of vehicle).

BR27C BRIDGE RAILING ON DECK

Test 7069-32

Test Description

A 1983 Honda Civic (figures 55 and 56) 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 14.25 in (362 mm) and it was 19.75 in (502 mm) to the top of the bumper. Additional dimensions and information on the test vehicle are given in figure 57. The vehicle was directed into the BR27C bridge railing on deck (figure 58) 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 bridge railing 1.1 ft (335 mm) downstream from post 3 (or 17.8 ft (5.4 m) from the end of the bridge railing) at a speed of 60.3 mi/h (97.0 km/h) and the angle of impact was 19.8 degrees.

At 0.040 s after impact, the front of the vehicle began to deform to the right, and at 0.049 s the vehicle began to redirect. The roof of the vehicle began to deform at 0.084 s after impact. By 0.145 s the vehicle was traveling parallel to the bridge railing at a speed of 53.6 mi/h (86.2 km/h), and at 0.155 s the rear of the vehicle impacted the bridge railing. The vehicle lost contact with the bridge railing at 0.258 s traveling at 50.6 mi/h (81.4 km/h) and 6.6 degrees. The brakes on the vehicle were applied at 1.4 s after impact and the vehicle subsequently came to rest 210 ft (64 m) down from and 120 ft (37 m) in front of the point of impact.

As can be seen in figure 59, the bridge railing received minimal damage. There was no deformation to the metal railing element. The vehicle was in contact with the bridge railing for 9.9 ft (3.0 m).

The vehicle sustained damage to the right side as shown in figure 60. Maximum crush at the right front corner at bumper height was 6.5 in (165 mm) and there was a 1.0-in (25-mm) dent into the occupant compartment at the firewall. The passenger door was deformed outward approximately 1.3 in (33 mm) and the wheelbase on the right side was reduced 3.0 in (76 mm). There was an 8-in by 14-in by 7/16-in (203-mm by 356-mm by 11-mm) deep dent in the roof just over the right rear passenger location. The right front strut and sway bar were damaged and the instrument panel was bent. Also, damage was done to the front bumper, hood, grill, radiator, fan, right front quarter panel, right front rim, right door, right rear quarter panel, and right rear rim.

Test Results

Impact speed was 60.3 mi/h (97.0 km/h) and the angle of impact was 19.8 degrees. The speed of the vehicle at time of parallel was 53.6 mi/h (86.2 km/h) and the coefficient of friction was 0.15. The vehicle lost contact with the bridge railing traveling at 50.6 mi/h (81.4 km/h) and the exit angle between the vehicle path and the bridge railing was 6.6 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 14.5 ft/s (4.4 m/s) at 0.216 s, the highest 0.010-s average ridedown acceleration was -1.2 g between 0.429 and 0.439 s, and the maximum 0.050-s average acceleration was -5.7 g between 0.044 and 0.094 s. Lateral occupant impact velocity was 24.6 ft/s (7.5 m/s) at 0.103 s, the highest 0.010-s occupant ridedown acceleration was 12.7 g between 0.141 and 0.151 s, and the maximum 0.050-s average acceleration was 12.2 g between 0.034 and 0.084 s. The change in vehicle velocity at loss of contact was 9.7 mi/h (15.6 km/h) and the change in momentum was 795 lb-sec (3,537 N-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 67.

Conclusions

The BR27C bridge railing on deck contained the test vehicle with no lateral movement of the bridge railing. There was no intrusion of railing components into the occupant compartment although there was a 1-in (25-mm) dent into the occupant compartment at the firewall. The vehicle remained upright and relatively stable during the collision. The bridge railing redirected the vehicle and the effective coefficient of friction was considered good. Velocity change of the vehicle during the collision was 9.7 mi/h (15.6 km/h).

The 1989 AASHTO guide specifications sets forth required 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 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 50 and table 4 for more details.

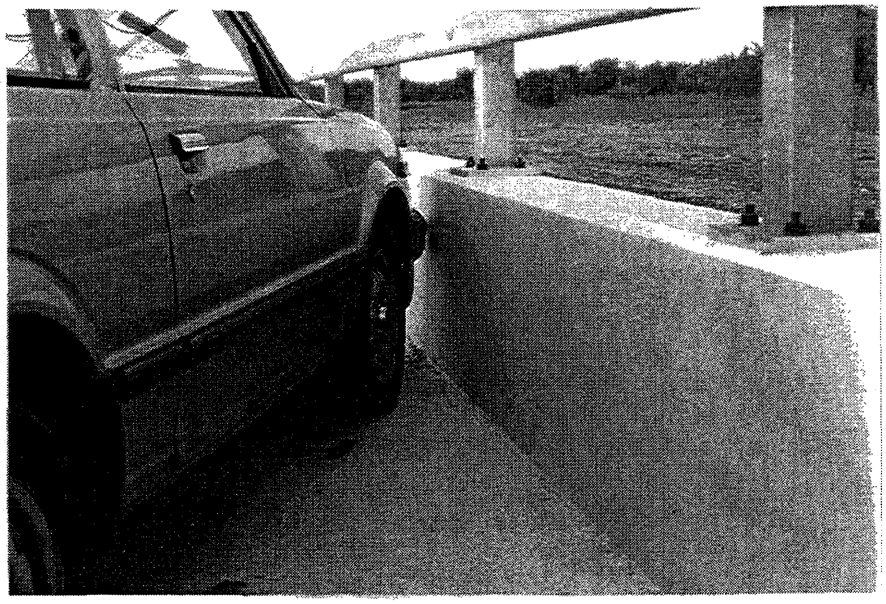


Figure 55. Vehicle/bridge railing geometrics for test 7069-32.

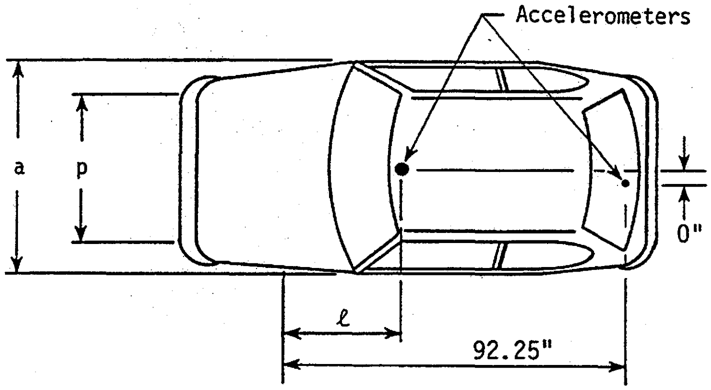
Figure 56. Vehicle prior to test 7069-32.

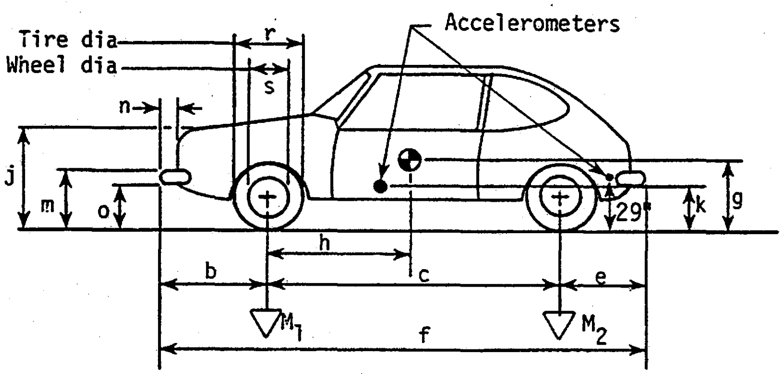
Date: 7-13-92 Test No.: 7069-32 VIN: JHMSL5326DS016898

Make: Honda Model: Civic Year: 1983 Odometer: 116812

Tire Size: 165/70SL13 Ply Rating: ____ Bias Ply: ___ Belted: ___ Radial: X

Tire Condition: good ___ fair X badly worn ___





Vehicle Geometry - inches

a	62.5"	b	29"
c	88.25"	d*	52.25"
e	28.5"	f	145.75"
g		h	32"
i	----	j	28"
k	15.75"	ℓ	38"
m	19.75"	n	3.25"
o	14.25"	p	53.5"
r	22.25"	s	14.19"

Engine Type: 4-Gas

Engine CID: 81 CID

Transmission Type:

~~Automatic~~ X Manual

FWD [illegible]

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 544 ℓr 329 rr 341

Mass - pounds	Curb	Test Inertial	Gross Static
M_1	1153	1130	1235
M_2	650	670	735
M_T	1803	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 57. Vehicle properties for test 7069-32.

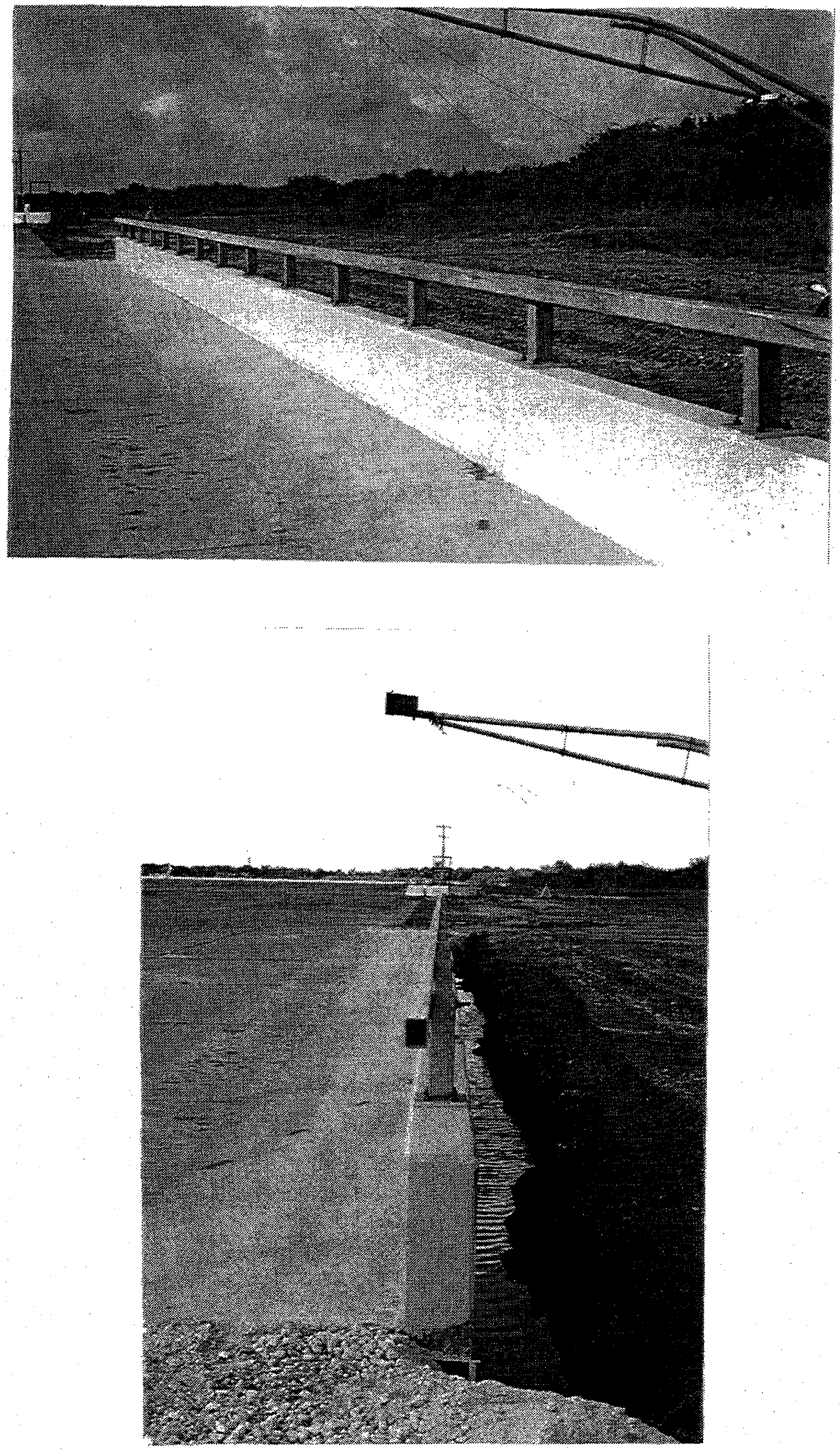


Figure 58. BR27C bridge railing on deck before test 7069-32.

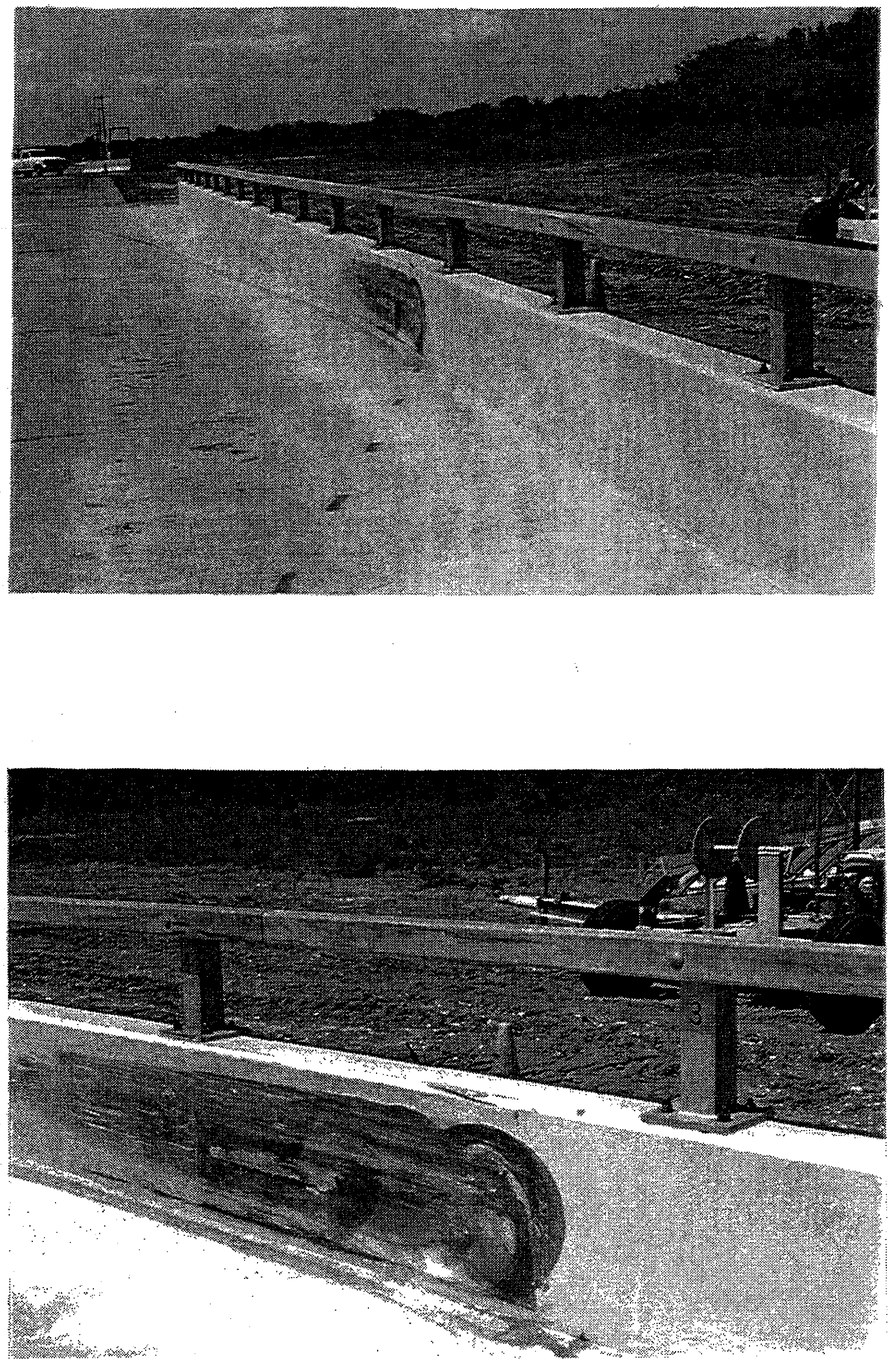
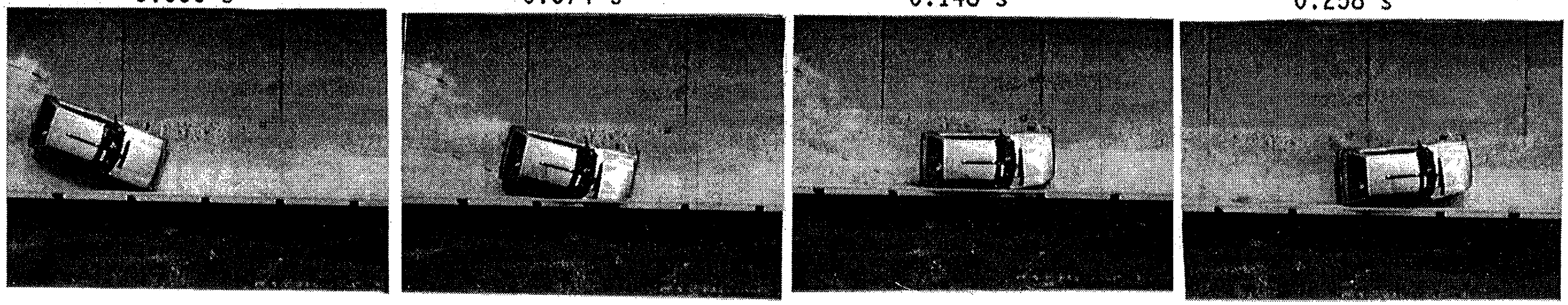
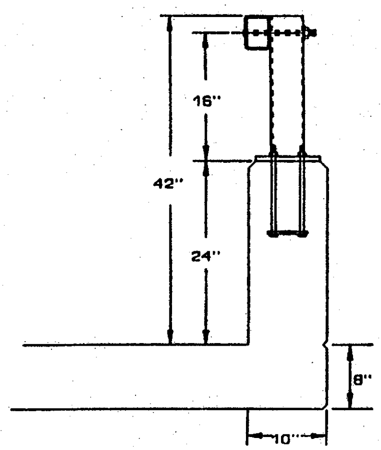


Figure 59. BR27C bridge railing on deck after test 7069-32.

Figure 60. Vehicle after test 7069-32.

0.000 s　0.074 s　0.148 s　0.258 s





(1 in = 25.4 mm)

Test No. 7069-32
Date 07/14/92

Test Installation . . . BR27C Bridge Railing on deck
Installation Length . . 100 ft (30 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 01RFQ5
  CDC . . . . 01FREK3 & 01RYEW4
Maximum Vehicle Crush . 6.5 in (165 mm)

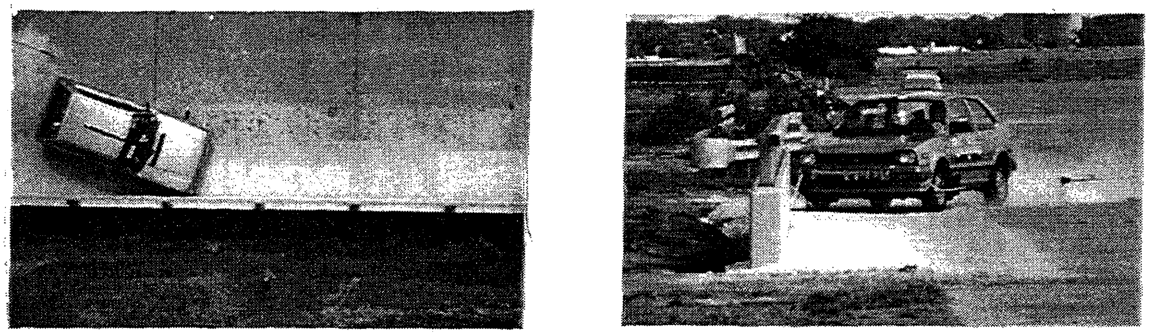
Impact Speed. . . . 60.3 mi/h (97.0 km/h)
Impact Angle. . . . 19.8 deg
Speed at Parallel . 53.6 mi/h (86.2 km/h)
Exit Speed . . . . 50.6 mi/h (81.4 km/h)
Exit Trajectory . . 6.6 deg
Vehicle Accelerations
  (Max. 0.050-sec Avg) at true c.g.
  Longitudinal. . . -5.7 g
  Lateral . . . . . 12.2 g
Occupant Impact Velocity at true c.g.
  Longitudinal. . . 14.5 ft/s (4.4 m/s)
  Lateral . . . . . 24.6 ft/s (7.5 m/s)
Occupant Ridedown Accelerations
  Longitudinal . . -1.2 g
  Lateral . . . . . 12.7 g

Figure 61. Summary of results for test 7069-32.

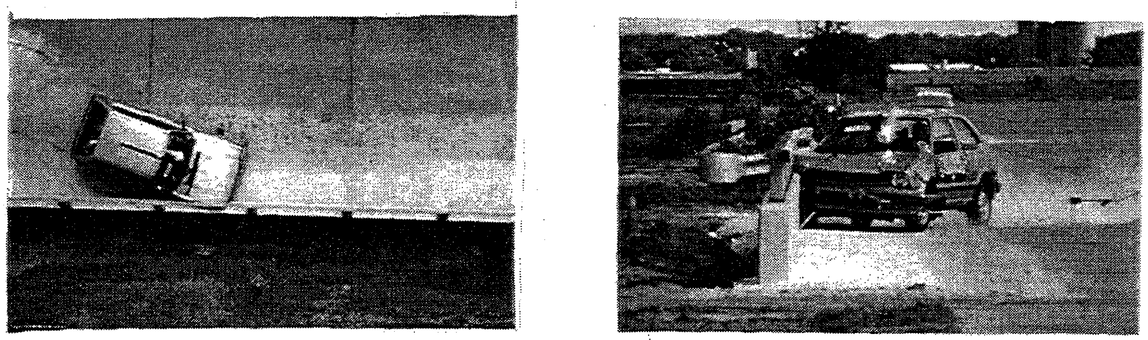
Table 5. Evaluation of crash test no. 7069-32.
{BR27C bridge railing on deck [1,800 lb (817 kg)|60.3 mi/h (97.0 km/h)|19.8 degrees]}

	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 (1 in)	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 .15 / Good	Pass
G.	Shall be less than Occupant Impact Velocity - ft/s (m/s) Longitudinal / Lateral 30 (9.2) / 25 (7.6)	Occupant Impact Velocity - ft/s (m/s) Longitudinal / Lateral 14.5 (4.4) / 24.6 (7.5)	Pass
	Occupant Ridedown Accelerations - g's Longitudinal / Lateral 15 / 15	Occupant Ridedown Accelerations - g's Longitudinal / Lateral -1.2 / 12.7	Pass
H.	Exit angle shall be less than 12 degrees	Exit angle was 6.6 degrees	Pass

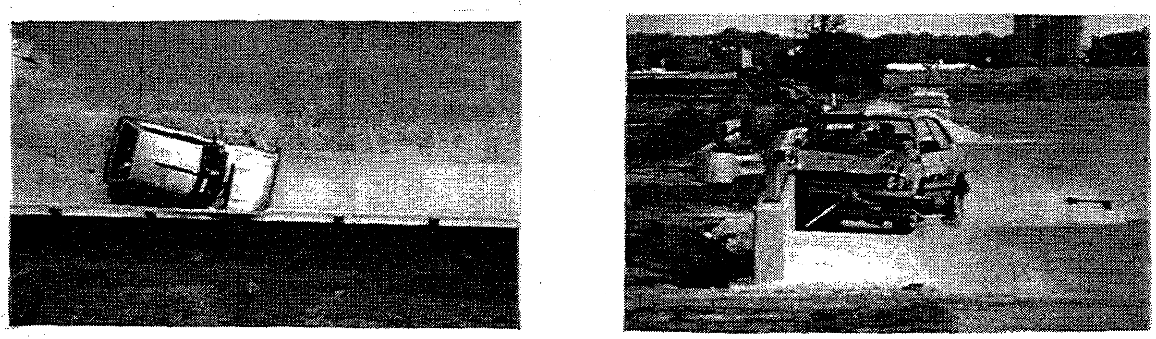
* A, B, C, D and G are required. E, F, and H are desired. (See table 2)



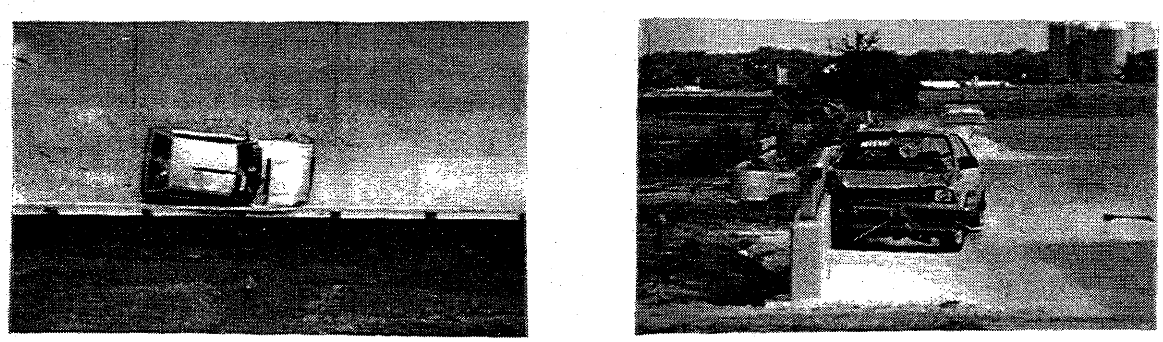
0.000 s



0.037 s

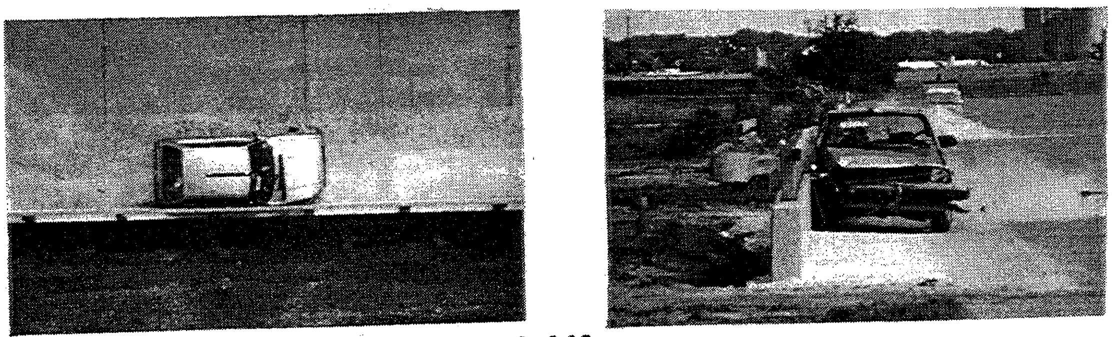


0.074 s

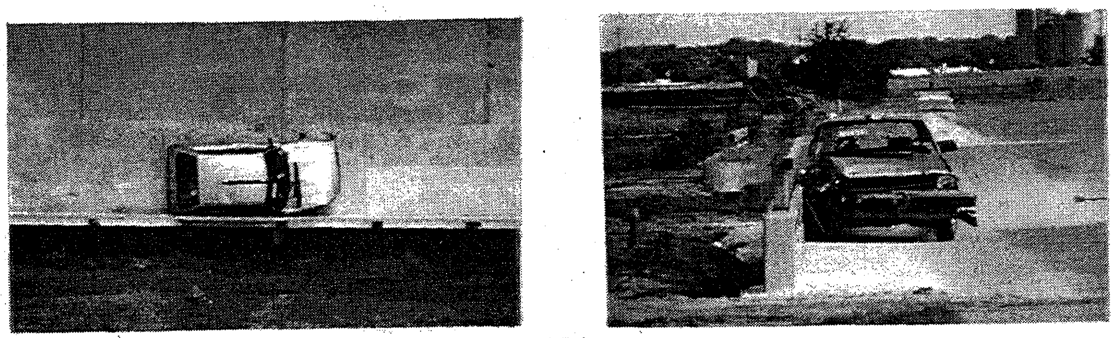


0.111 s

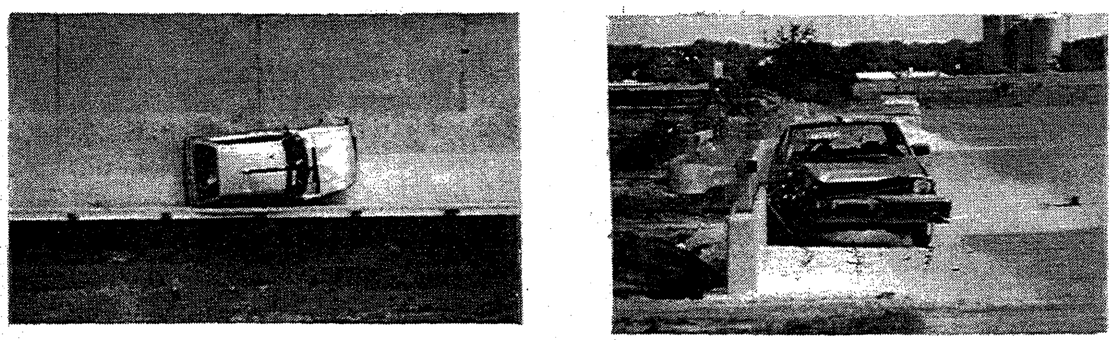
Figure 62. Sequential photographs for test 7069-32
(overhead and frontal views).



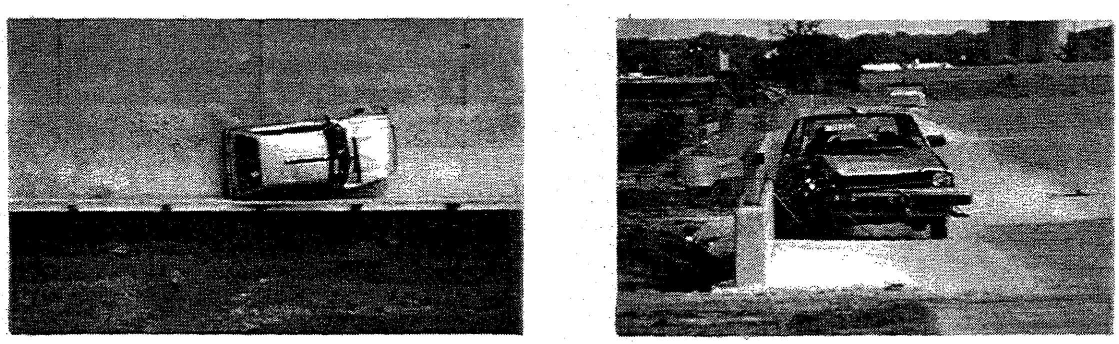
0.148 s



0.184 s

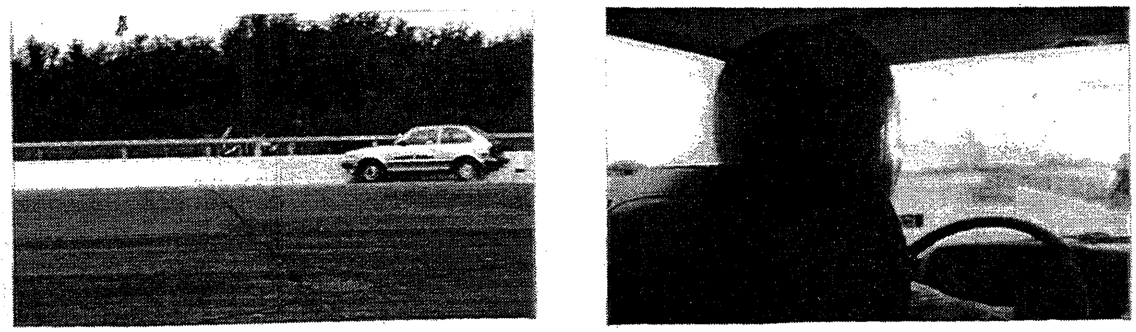


0.221 s

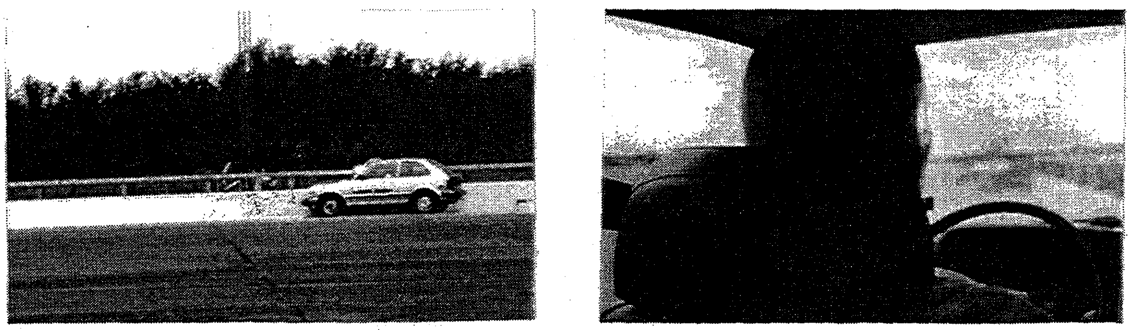


0.258 s

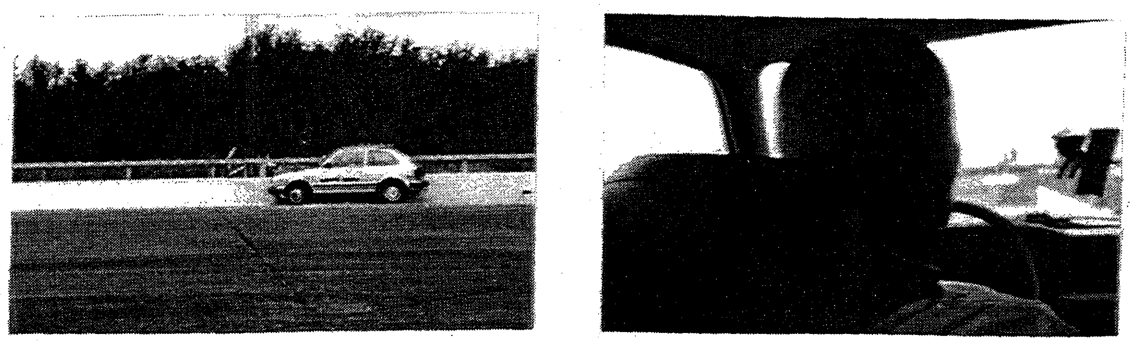
Figure 62. Sequential photographs for test 7069-32
(overhead and frontal views continued).



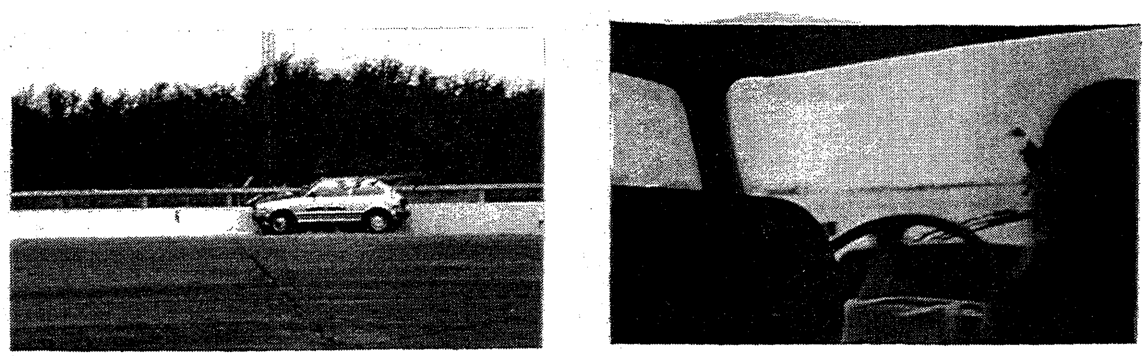
0.000 s



0.037 s

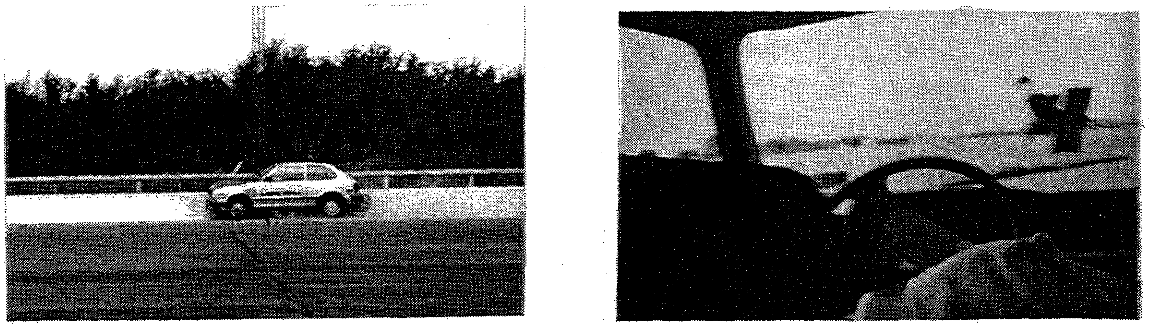


0.074 s

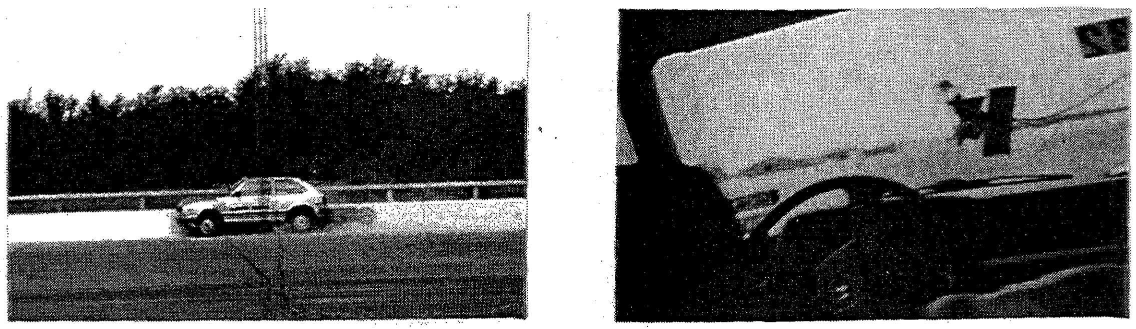


0.111 s

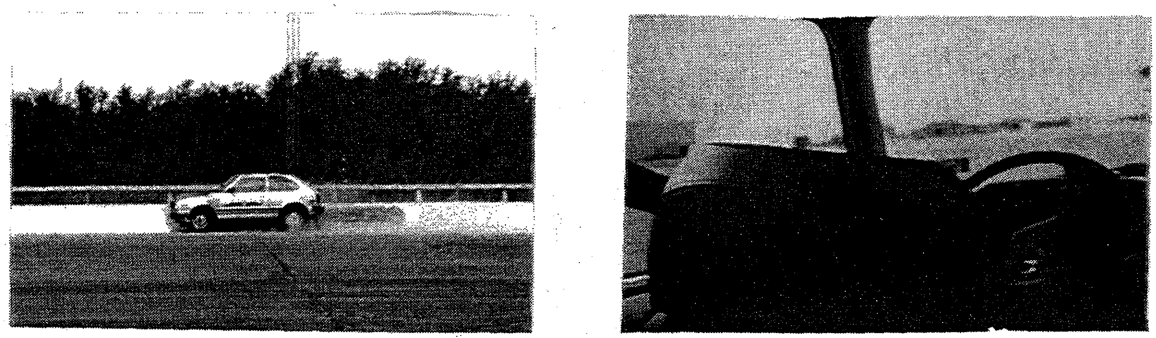
Figure 63. Sequential photographs for test 7069-32
(perpendicular and interior views).



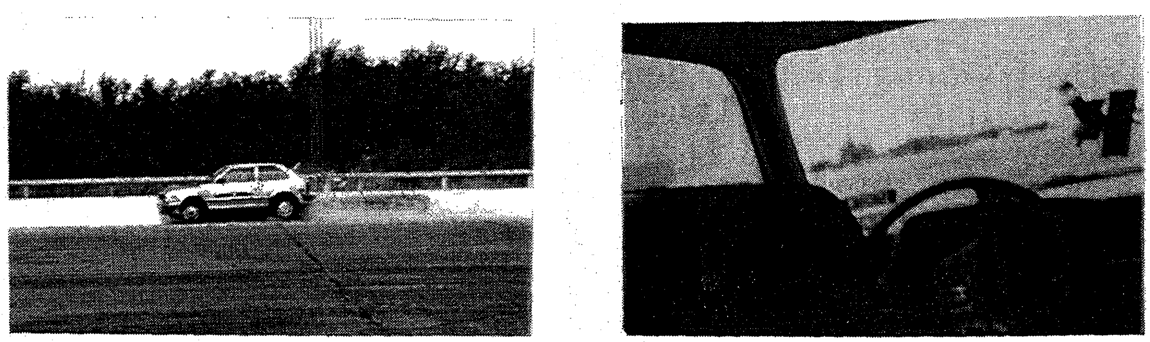
0.148 s



0.184 s



0.221 s



0.258 s

Figure 63. Sequential photographs for test 7069-32
(perpendicular and interior views continued).

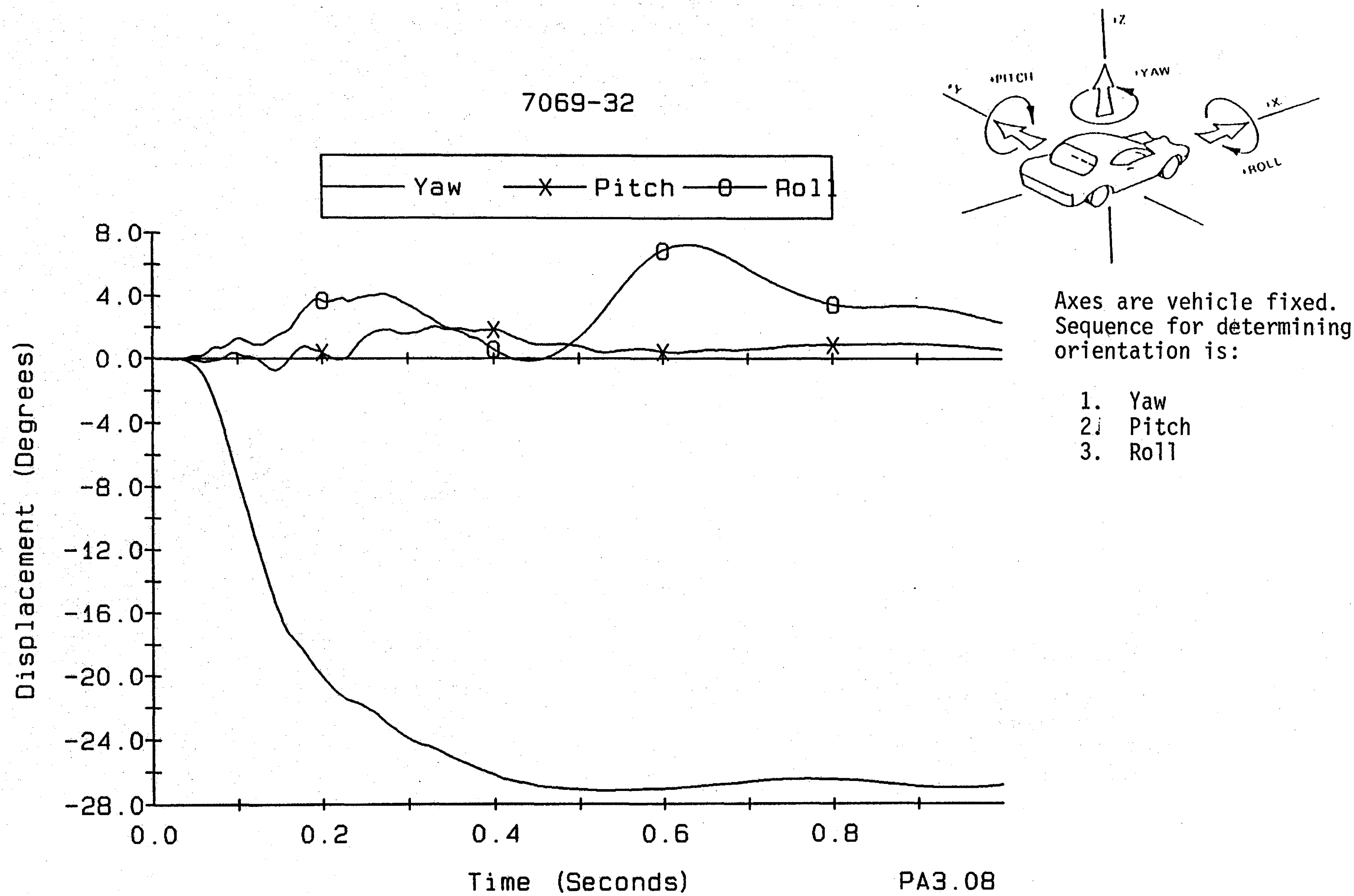
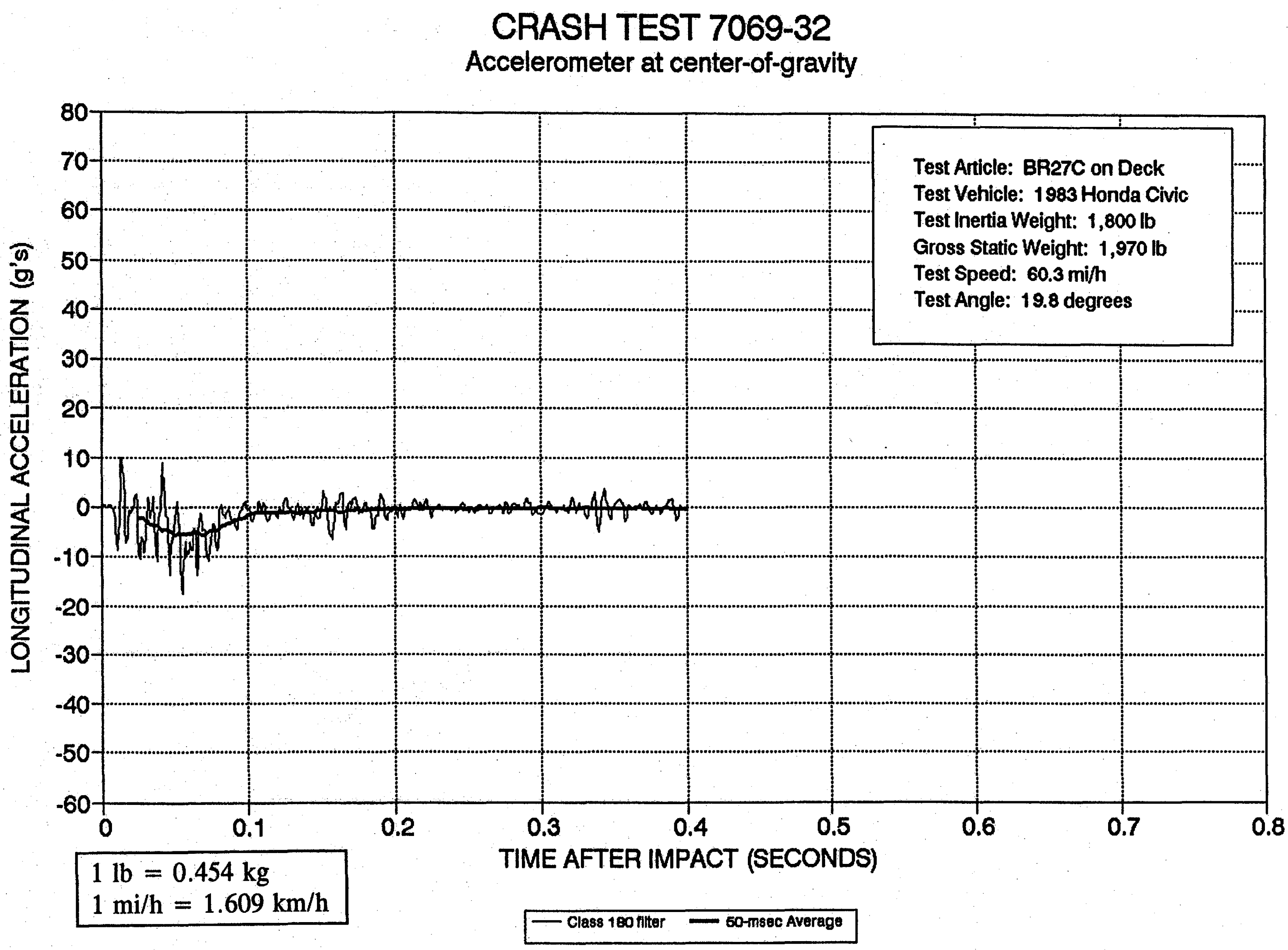


Figure 64. Vehicle angular displacements for test 7069-32.



1 lb = 0.454 kg
1 mi/h = 1.609 km/h

Figure 65. Vehicle longitudinal accelerometer trace for 7069-32 (accelerometer located at center-of-gravity).

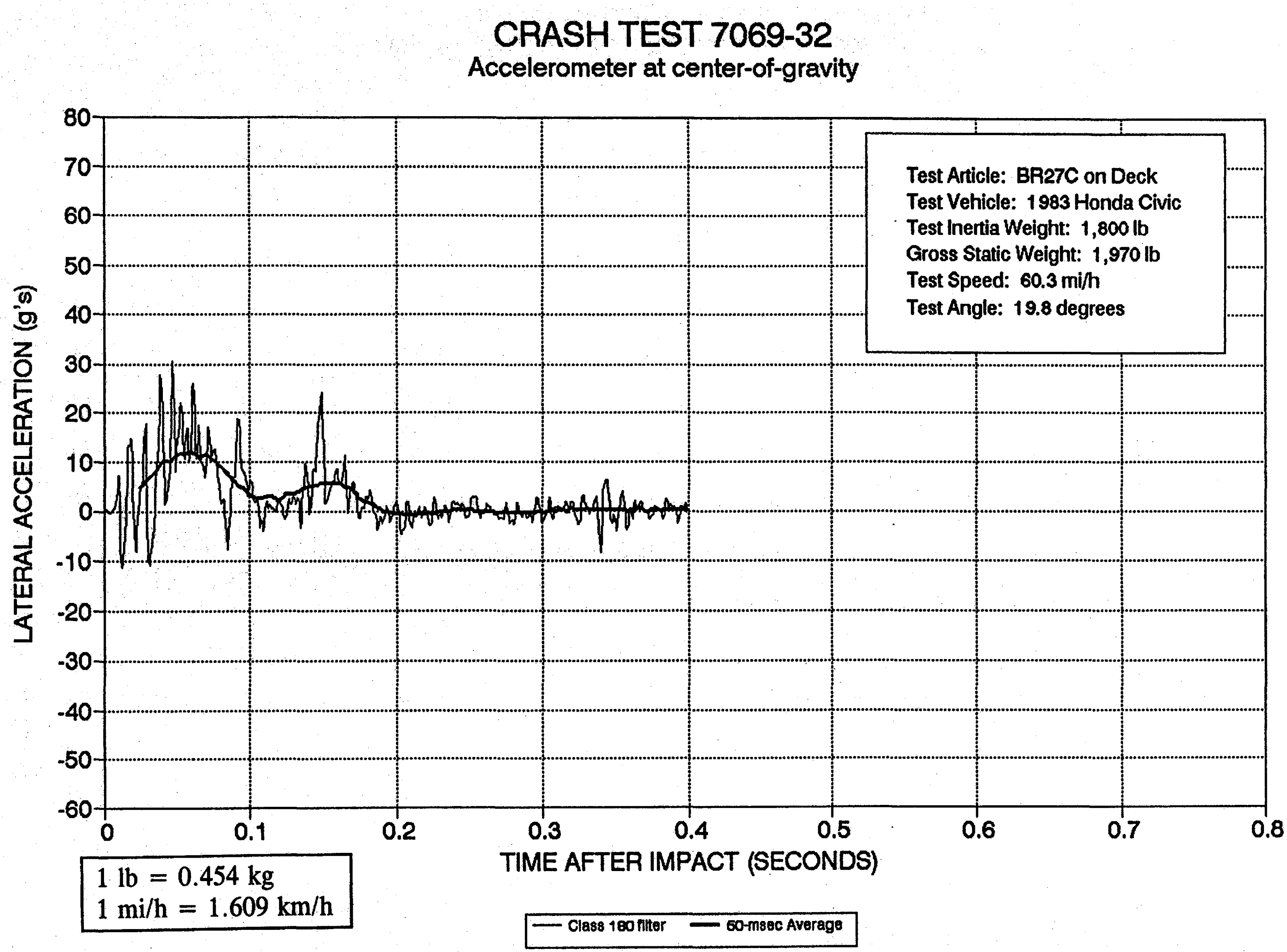


Figure 66. Vehicle lateral accelerometer trace for test 7069-32 (accelerometer located at center-of-gravity).

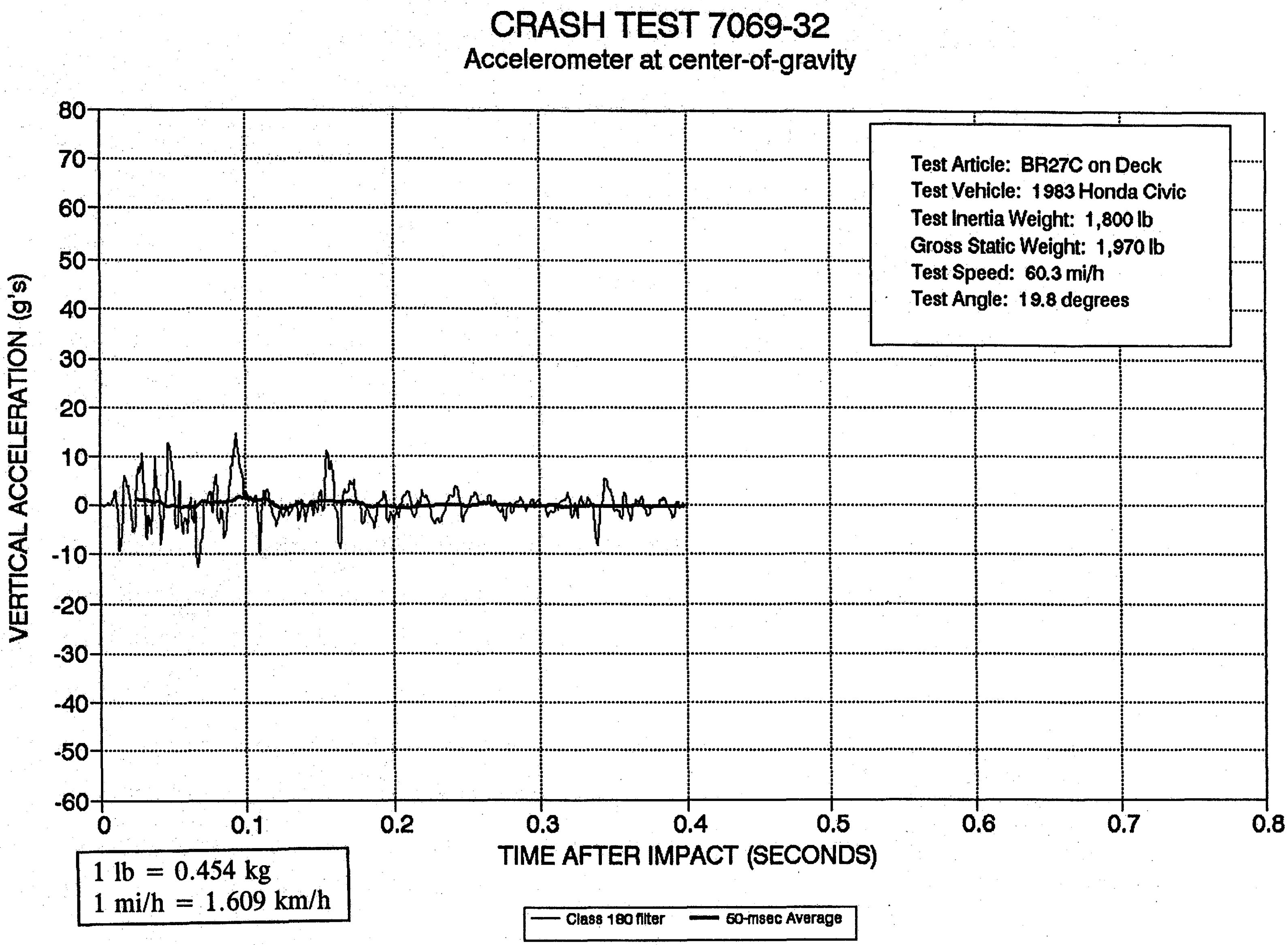


Figure 67. Vehicle vertical accelerometer trace for test 7069-32 (accelerometer located at center-of-gravity).

Test 7069-33

Test Description

A 1985 Chevrolet Custom Deluxe pickup (figures 68 and 69) 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 5,570 lb (2 529 kg). The height to the lower edge of the vehicle bumper was 18.0 in (457 mm) and it was 27.0 in (686 mm) to the top of the bumper. Additional dimensions and information on the test vehicle are given in figure 70. The vehicle was directed into the BR27C bridge railing on deck (figure 71) 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 bridge railing 1.9 ft (519 mm) downstream from post 3 (or 18.6 ft (5.7 m) from the end of the bridge railing) at a speed of 55.3 mi/h (89.0 km/h) and the angle of impact was 19.6 degrees.

At 0.022 s after impact, the vehicle bumper began to ride up the barrier, and at 0.039 s the vehicle began to redirect. The bumper went between the concrete beam and lower metal railing element at 0.054 s, and at 0.083 the vehicle made contact with post 4. By 0.195 s the vehicle was traveling parallel to the bridge railing at a speed of 47.9 mi/h (77.1 km/h), and at 0.208 s the rear of the vehicle impacted the bridge railing. The vehicle lost contact with the bridge railing at 0.315 s traveling at 44.8 mi/h (72.1 km/h) and 6.5 degrees. The brakes on the vehicle were applied at 1.7 s after impact and the vehicle subsequently came to rest 225 ft (68.6 m) down from and 5 ft (2 m) behind the point of impact.

As can be seen in figure 72, the bridge railing received minimal damage. There was 0.5-in (13-mm) deformation to the lower metal railing element and there was a hairline crack in the concrete beam 17.5 in (445 mm) down from post 3. The vehicle was in contact with the bridge railing for 11.0 ft (3.4 m).

The vehicle sustained damage to the right side as shown in figure 73. Maximum crush at the right front corner at bumper height was 9.0 in (229 mm) and there was a 0.5-in (1.3-cm) dent into the occupant compartment at the firewall. The wheelbase on the right side was reduced 2.0 in (51 mm). The sway bar was damaged and the frame was bent. Also, damage was done to the front bumper, hood, grill, radiator, fan, right front quarter panel, right front tire and rim, right door, right rear quarter panel, rear bumper, right rear rim, and left front quarter panel.

Test Results

Impact speed was 55.3 mi/h (89.0 km/h) and the angle of impact was 19.6 degrees. The speed of the vehicle at time of parallel was 47.9 mi/h (77.1 km/h) and the coefficient of friction was 0.23. The vehicle lost contact with the bridge railing traveling at 44.8 mi/h (72.1 km/h) and the exit angle between the vehicle path and the bridge railing was 6.5 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 11.6 ft/s (3.5 m/s) at 0.257 s, the highest 0.010-s average ridedown acceleration was -2.2 g between 0.259 and 0.269 s, and the maximum 0.050-s average acceleration was -4.9 g between 0.054 and 0.104 s. Lateral occupant impact velocity was 20.1 ft/s (6.1 m/s) at 0.126 s, the highest 0.010-s occupant ridedown acceleration was 8.1 g between 0.252 and 0.262 s, and the maximum 0.050-s average acceleration was 9.3 g between 0.049 and 0.099 s. The change in vehicle velocity at loss of contact was 10.5 mi/h (16.9 km/h) and the change in momentum was 2,583 lb-sec (11,487 N-s). These data and other pertinent information from the test are summarized in figure 74 and table 6. Sequential photographs are shown in figures 75 and 76. Vehicular angular displacements are displayed in figure 77. Vehicular accelerations versus time traces filtered at SAE J211 (Class 180) are presented in figures 78 through 84.

Conclusions

The BR27C bridge railing on deck contained the test vehicle with no lateral movement of the bridge railing. There was no intrusion of railing components into the occupant compartment although there was a 0.5-in (13-mm) dent into the occupant compartment at the firewall. The vehicle remained upright and relatively stable during the collision. The bridge railing redirected the vehicle and the effective coefficient of friction was considered good. Velocity change of the vehicle during the collision was 10.5 mi/h (16.9 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 indicated minimum intrusion into adjacent traffic lanes. See figure 74 and table 6 for more details.

Figure 68. Vehicle/bridge railing geometrics for test 7069-33.

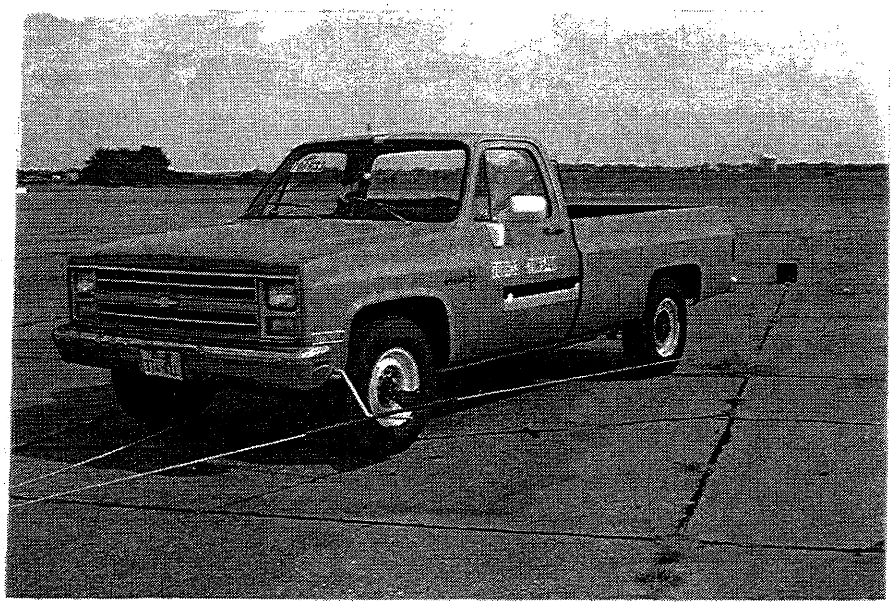


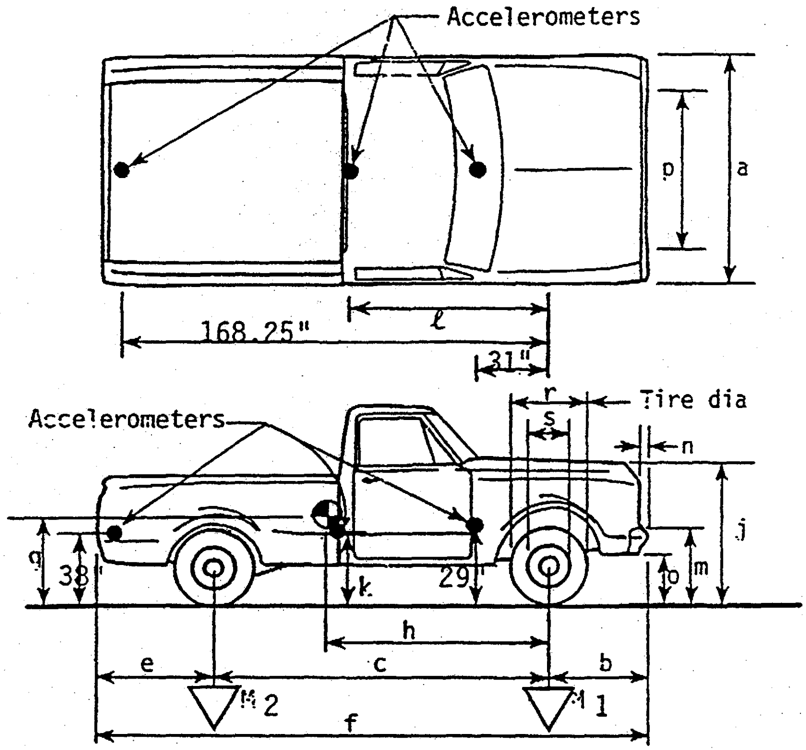
Figure 69. Vehicle prior to test 7069-33.

Date: 7-16-92 Test No.: 7069-33 VIN: 2GCGC24WGF1112038

Make: Chevrolet Model: PU Custom Deluxe Year: 1985 Odometer: 63534

Tire Size: lt 235/85 r16 Ply Rating: ______ Bias Ply: ___ Belted: ___ Radial: ___

Tire Condition: good ___
fair ___
badly worn ___



Vehicle Geometry - inches

a	79.5"	b	33"
c	132"	d*	71.5"
e	49.5"	f	
g		h	68"
i	----	j	45.5"
k	31"	ℓ	74"
m	27"	n	3"
o	18"	p	65.25"
r	31"	s	17.5"

Engine Type: V-8

Engine CID: 7.4 Liter

Transmission Type:

Automatic ~~or Manual~~

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

Body Type: P4

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 1290 rf 1330 ℓr 1340 rr 1440

Mass - pounds	Curb	Test Inertial	Gross Static
M_1	2378	2620	2718
M_2	1972	2780	2852
M_T	4710	5400	5570

Note any damage to vehicle prior to test:

____

____

d = overall height of vehicle

Figure 70. Vehicle properties for test 7069-33.

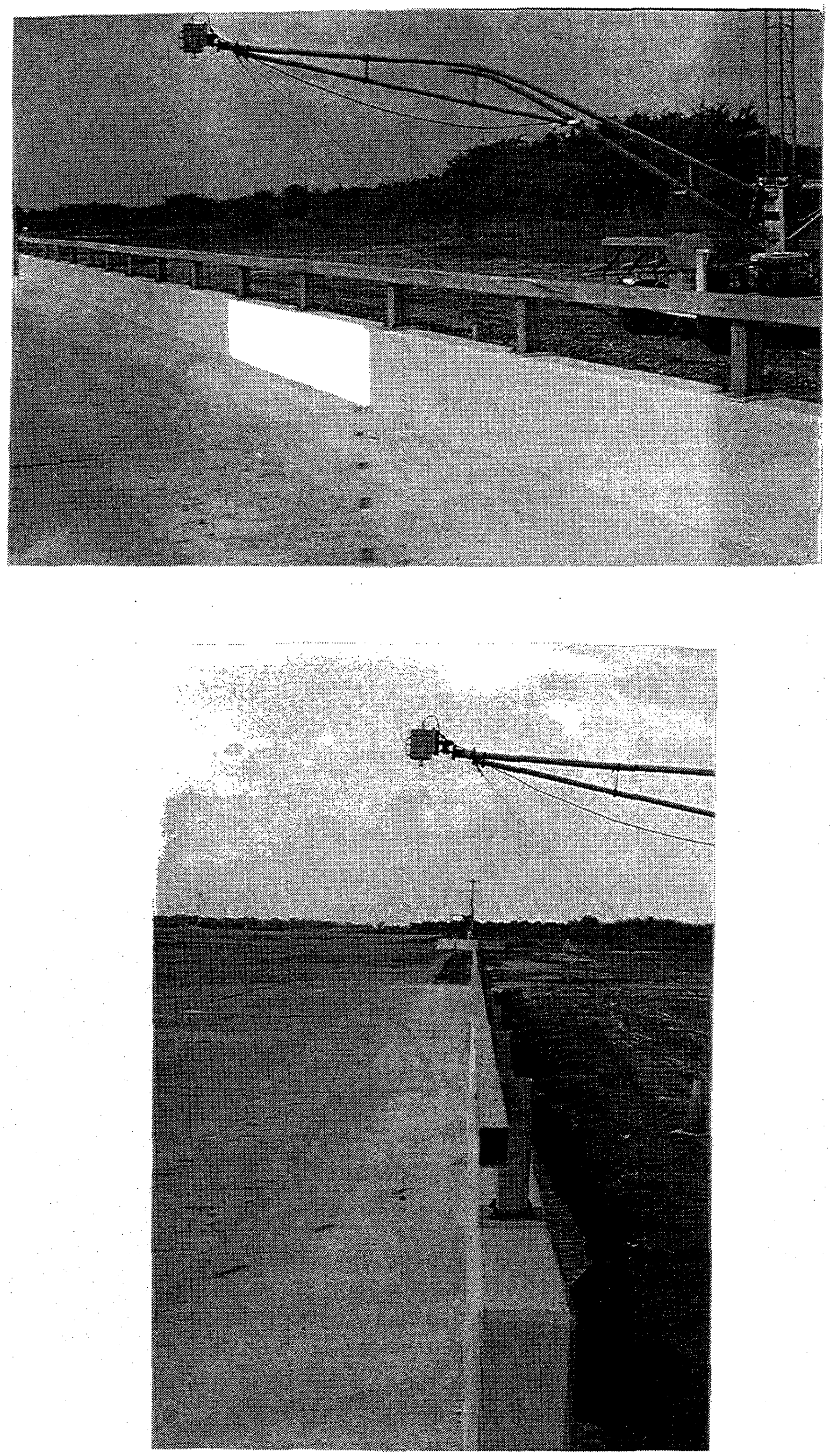
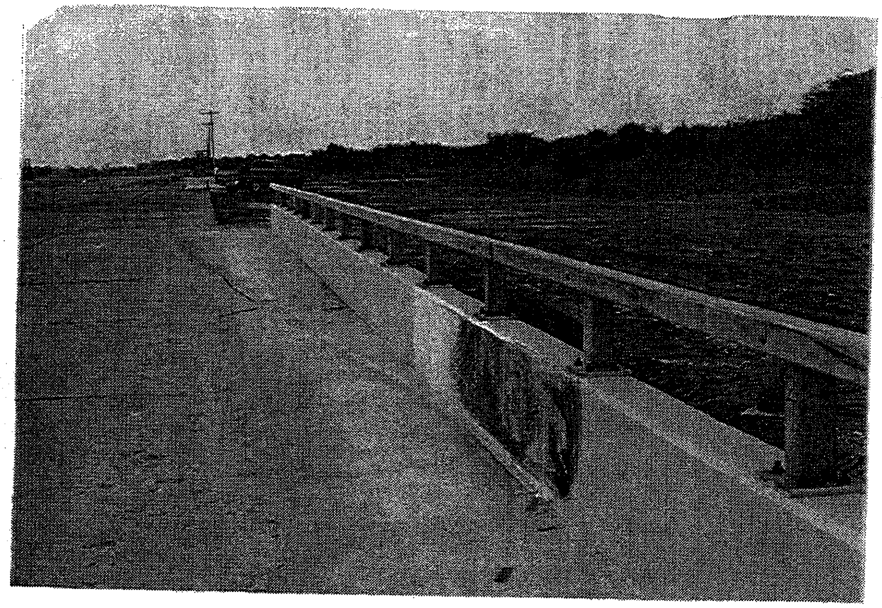


Figure 71. BR27C bridge railing on deck before test 7069-33.



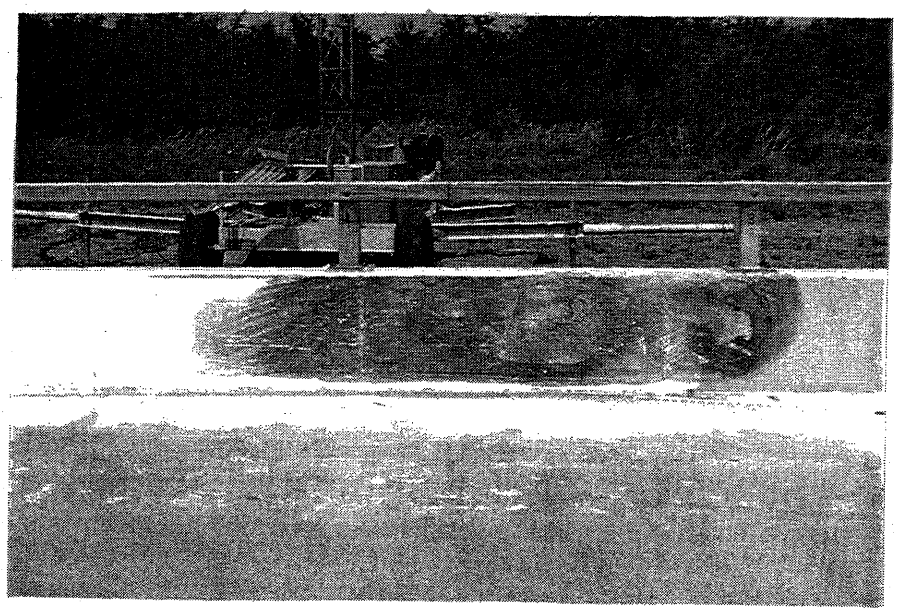


Figure 72. BR27C bridge railing on deck after test 7069-33.

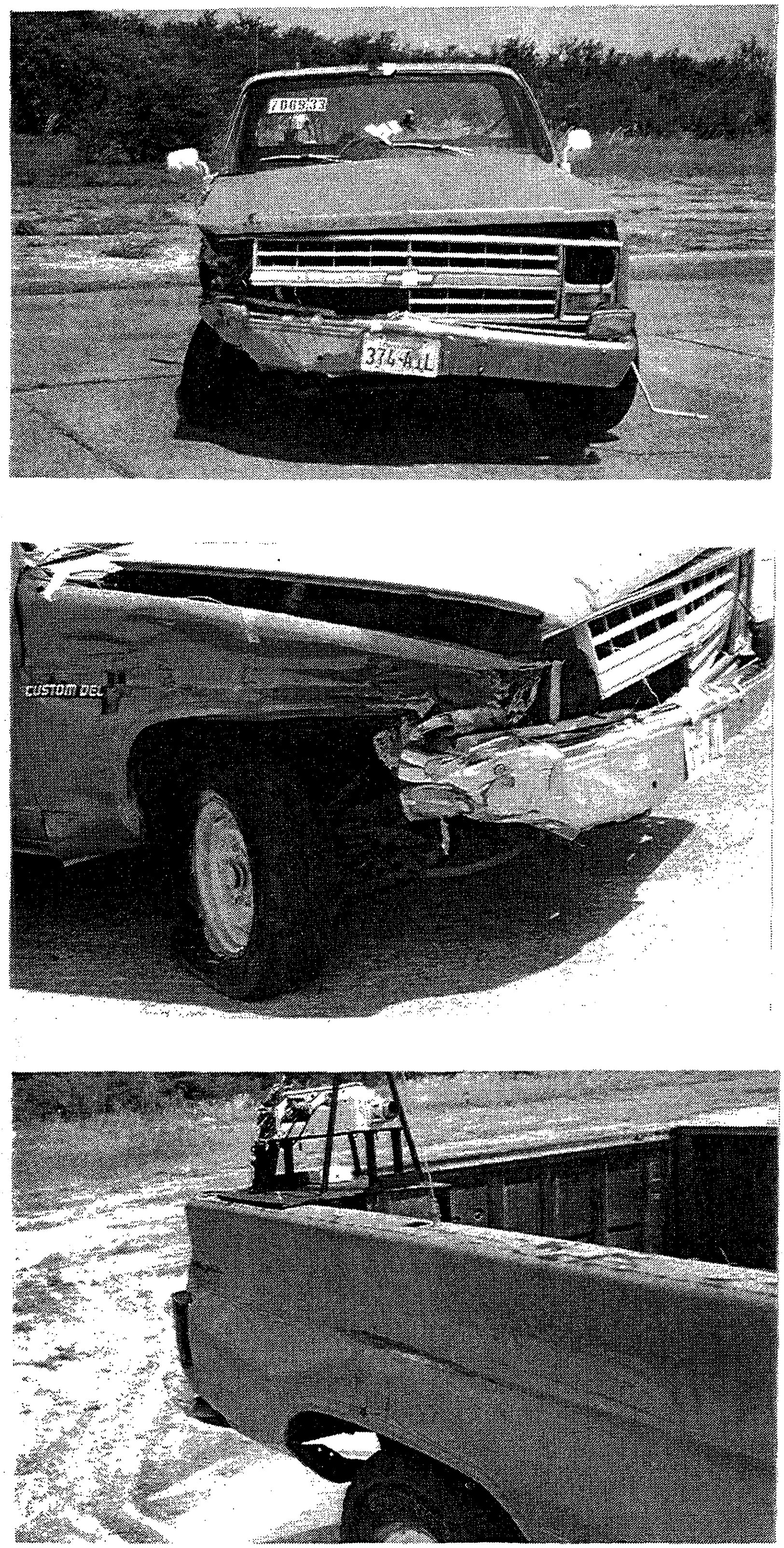
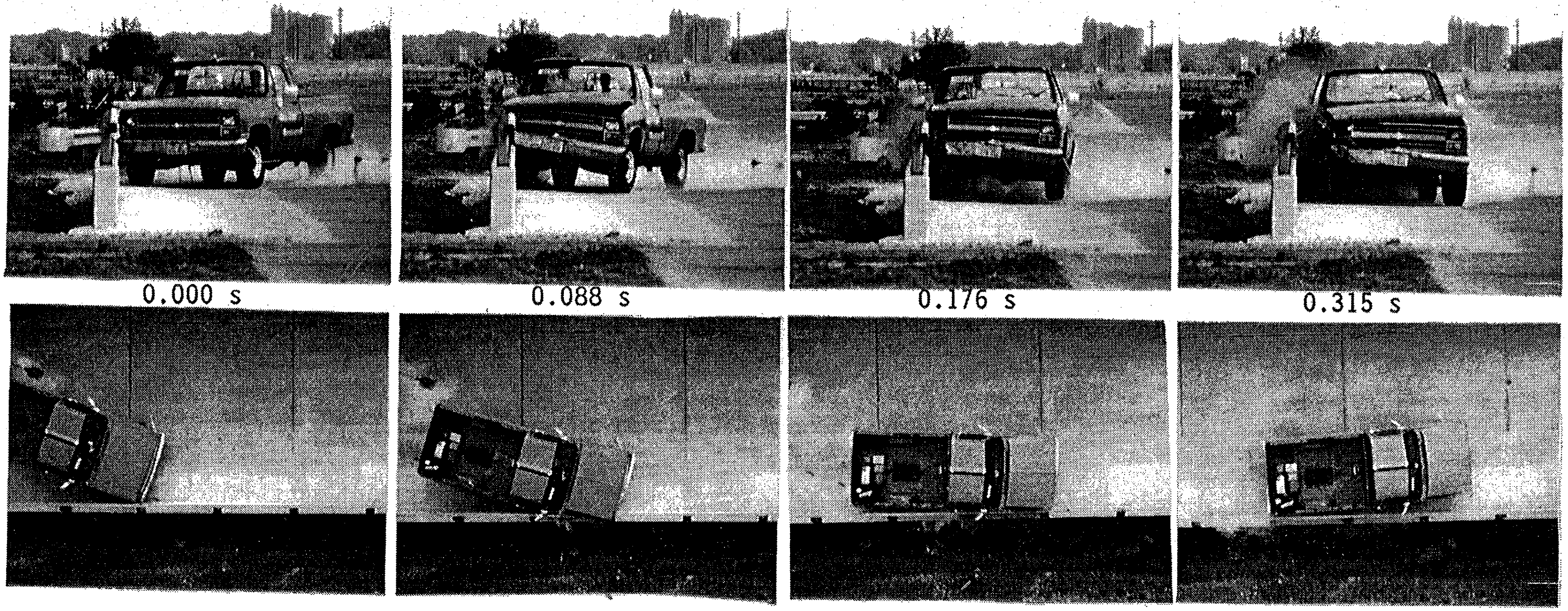
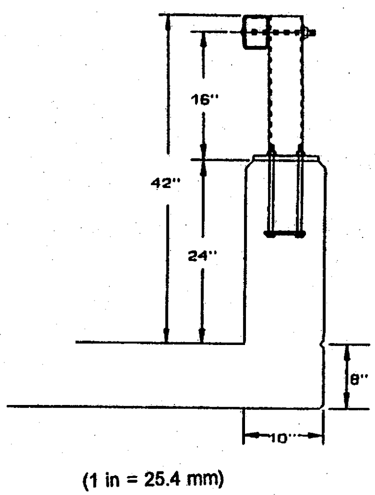


Figure 73. Vehicle after test 7069-33.





Test No. 7069-33
Date 07/16/92

Test Installation . . . BR27C Bridge Railing on deck
Installation Length . . 100 ft (30 m)

Test Vehicle . . . . . . 1985 Chevrolet Pickup
Vehicle Weight
  Test Inertia . . . . . 5,400 lb (2,452 kg)
  Gross Static . . . . . 5,570 lb (2,529 kg)
Vehicle Damage Classification
  TAD . . . . 01RFQ4 & 01RD2
  CDC . . . . 01FREK2 & 01RDEW2
Maximum Vehicle Crush . 9.0 in (229 mm)

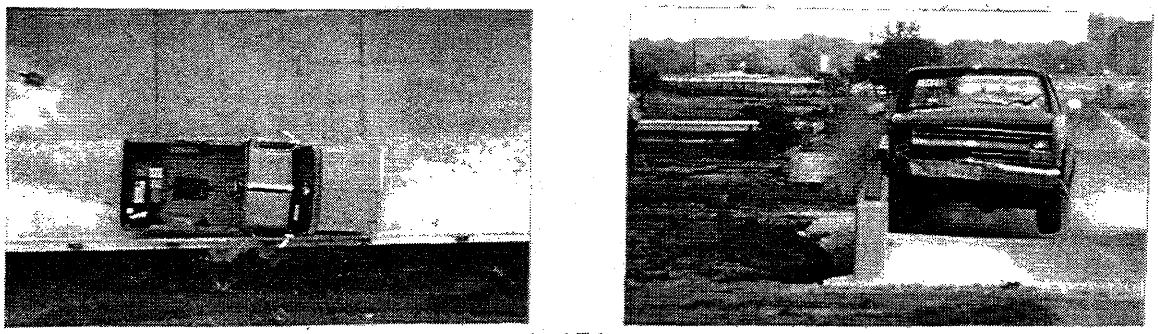
Impact Speed. . . . 55.3 mi/h (89.0 km/h)
Impact Angle. . . . 19.6 deg
Speed at Parallel . 47.9 mi/h (77.1 km/h)
Exit Speed . . . . 44.8 mi/h (72.1 km/h)
Exit Trajectory . . 6.5 deg
Vehicle Accelerations
  (Max. 0.050-sec Avg) at true c.g.
  Longitudinal. . . -4.9 g
  Lateral . . . . . 9.3 g
Occupant Impact Velocity at true c.g.
  Longitudinal. . . 11.6 ft/s (3.5 m/s)
  Lateral . . . . . 20.1 ft/s (6.1 m/s)
Occupant Ridedown Accelerations
  Longitudinal . . -2.2 g
  Lateral . . . . . 8.1 g

Figure 74. Summary of results for test 7069-33.

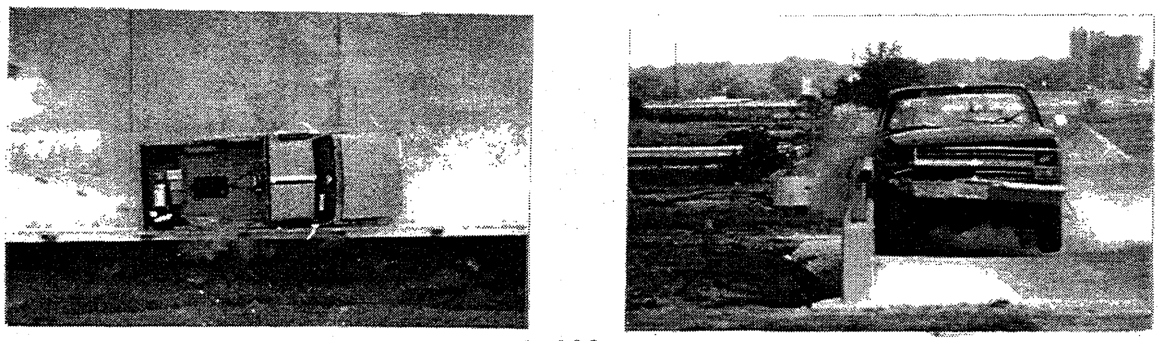
Table 6. Evaluation of crash test no. 7069-33.
{BR27C bridge railing on deck (5,400 lb (2 452 kg)|55.3 mi/h (89.0 km/h)|19.6 degrees]}

	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 of 0.5 in	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 .23 — 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: 11.6 (3.5); Lateral: 20.1 (6.1)	Pass
	Occupant Ridedown Accelerations - g's Longitudinal: 15; Lateral: 15	Occupant Ridedown Accelerations - g's Longitudinal: -2.2; Lateral: 8.1	Pass
H.	Exit angle shall be less than 12 degrees	Exit angle was 6.5 degrees	Pass

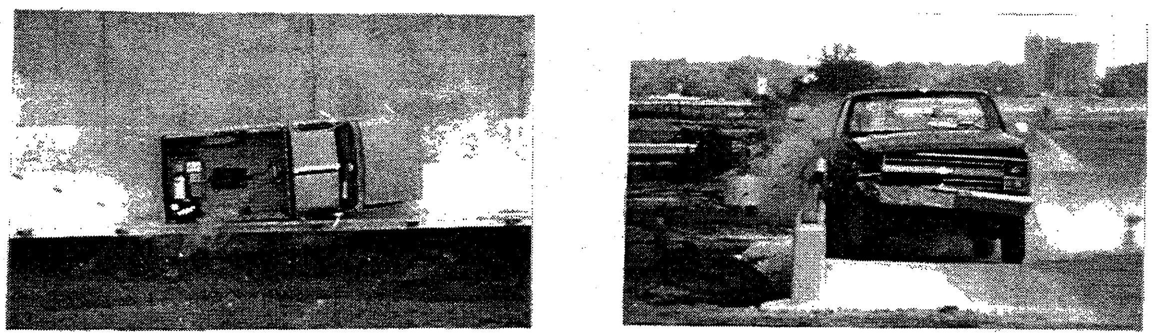
* A, B, C, and D are required. E, F, G, and H are desired. (See table 2)



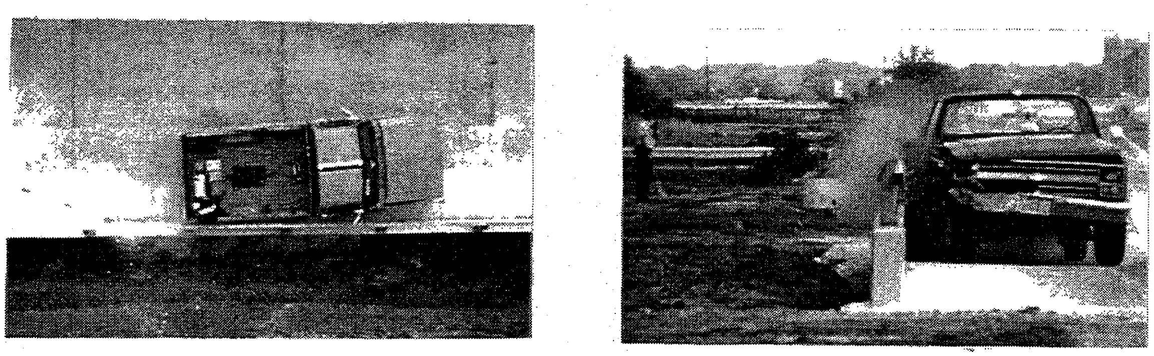
0.176 s



0.220 s

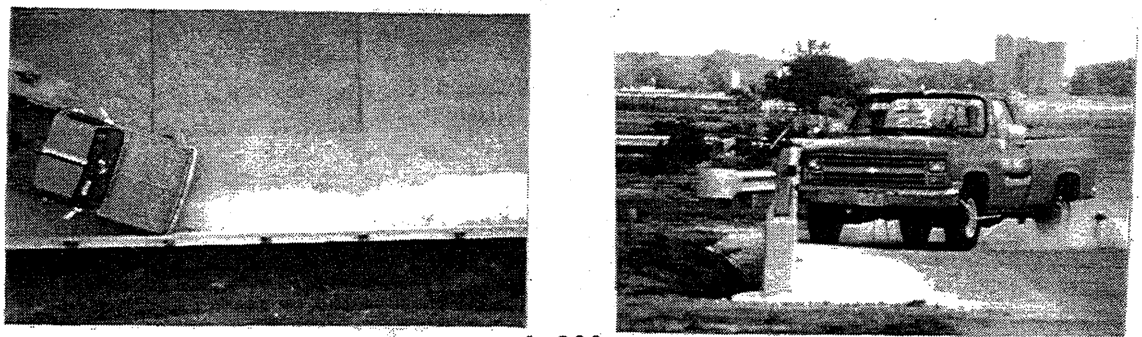


0.264 s

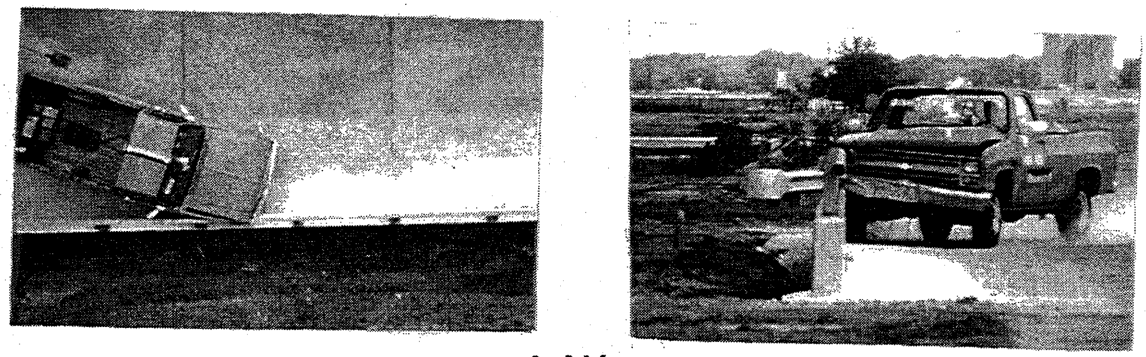


0.315 s

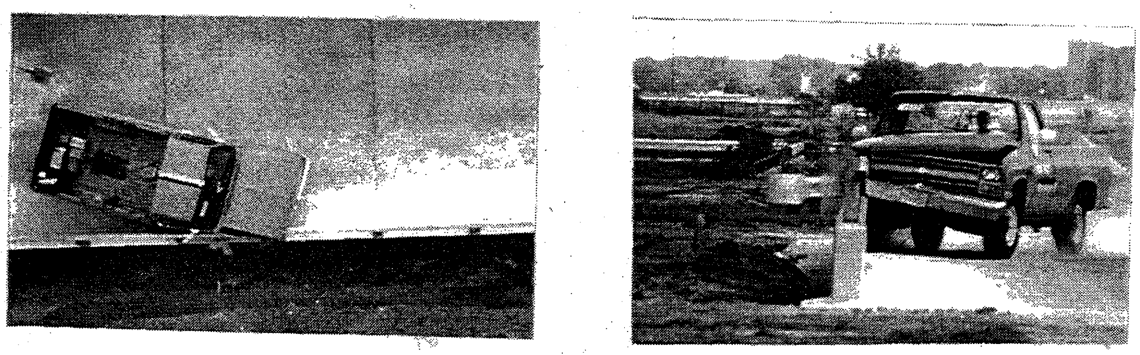
Figure 75. Sequential photographs for test 7069-33 (overhead and frontal views).



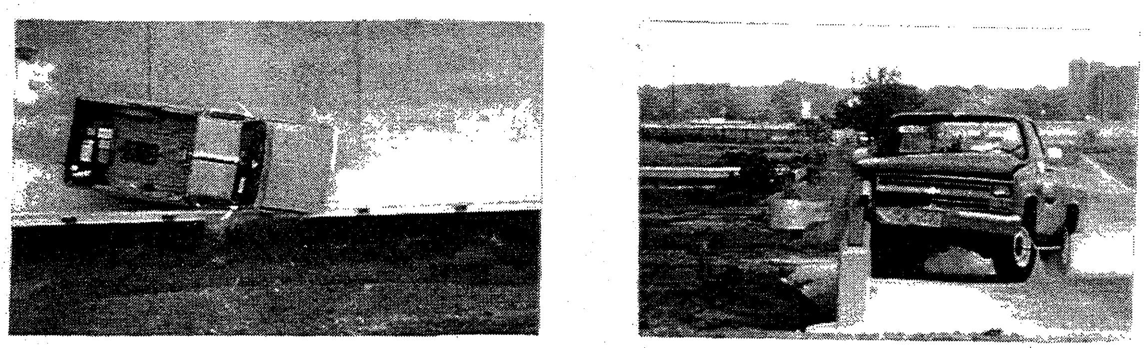
0.000 s



0.044 s



0.088 s



0.132 s

Figure 75. Sequential photographs for test 7069-33 (overhead and frontal views continued).

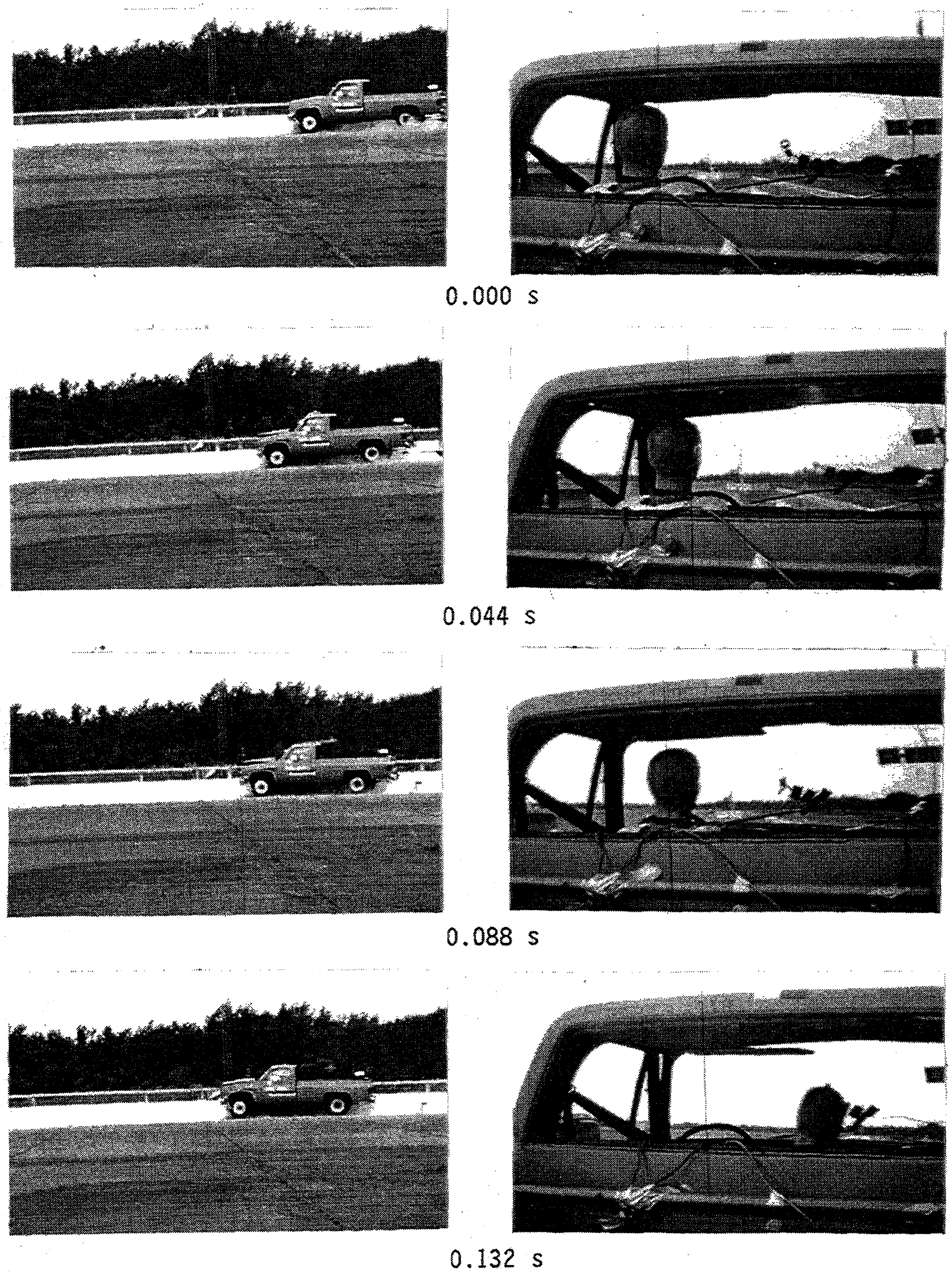
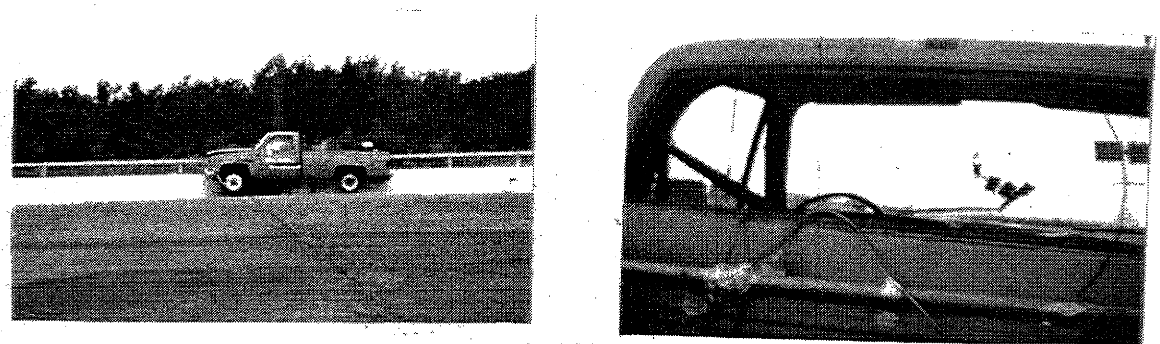
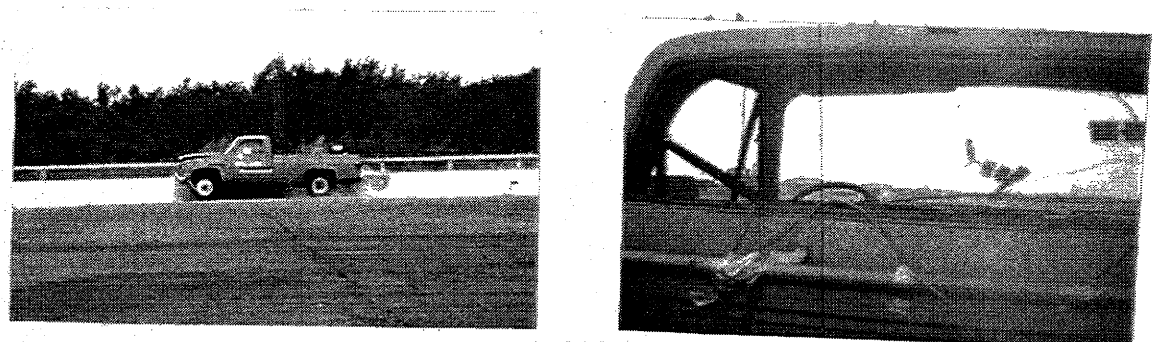


Figure 76. Sequential photographs for test 7069-33 (perpendicular and interior views).

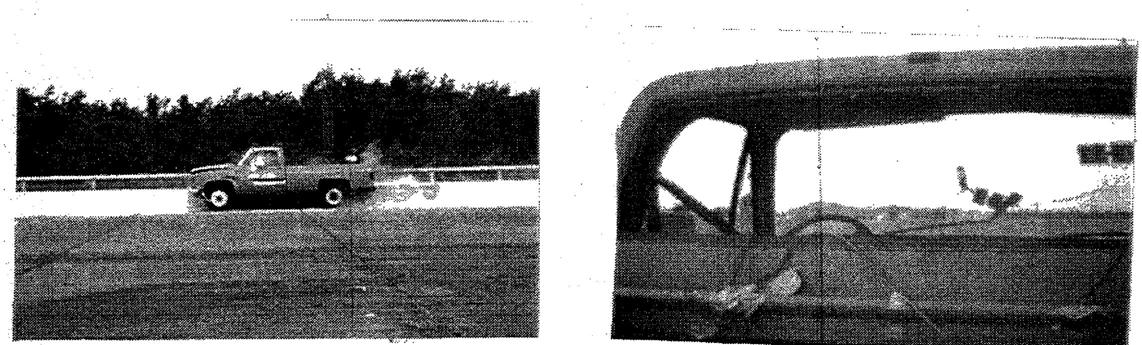
0.176 s



0.220 s



0.264 s



0.315 s

Figure 76. Sequential photographs for test 7069-33 (perpendicular and interior views continued).

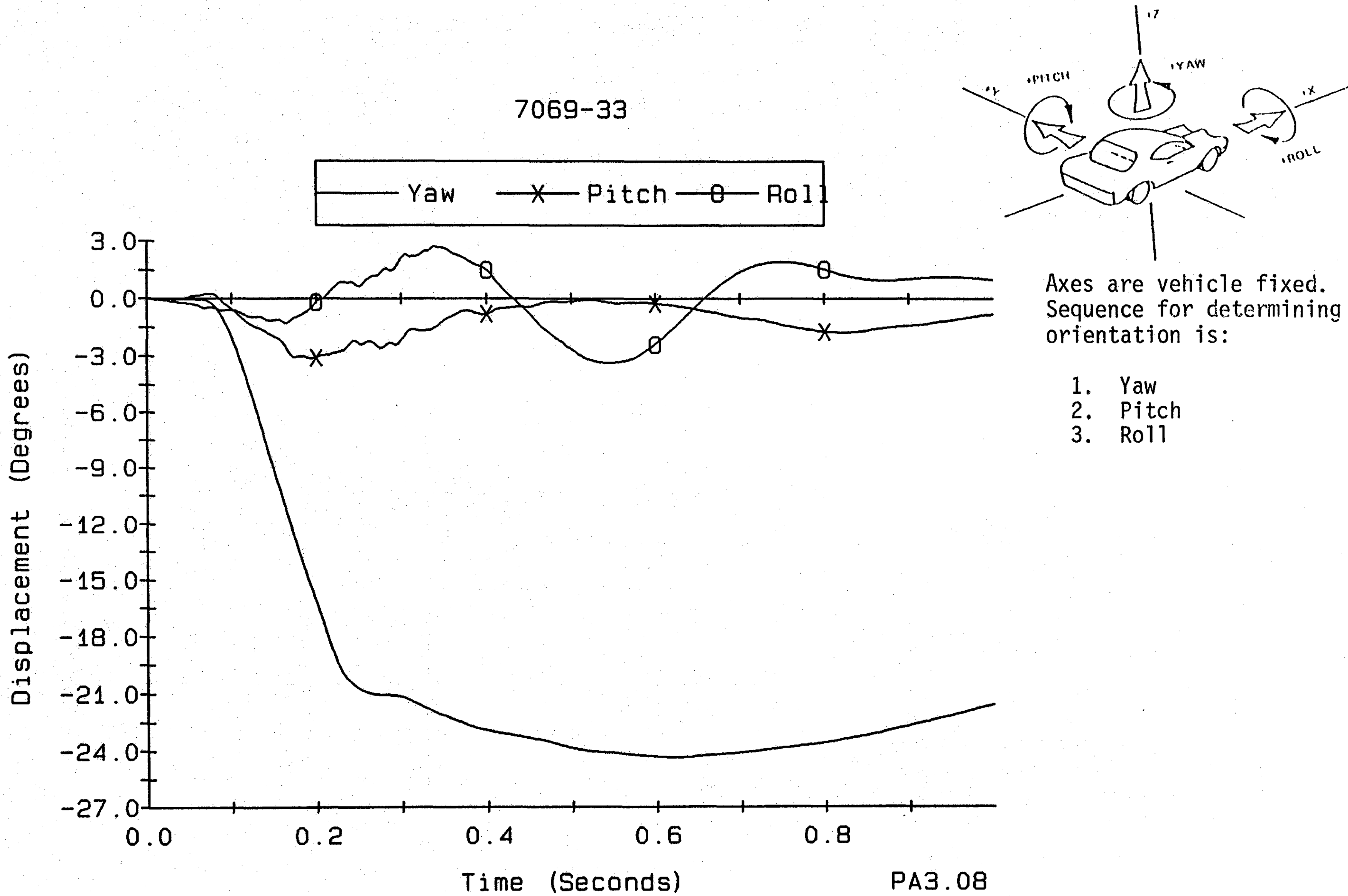


Figure 77. Vehicle angular displacements for test 7069-33.

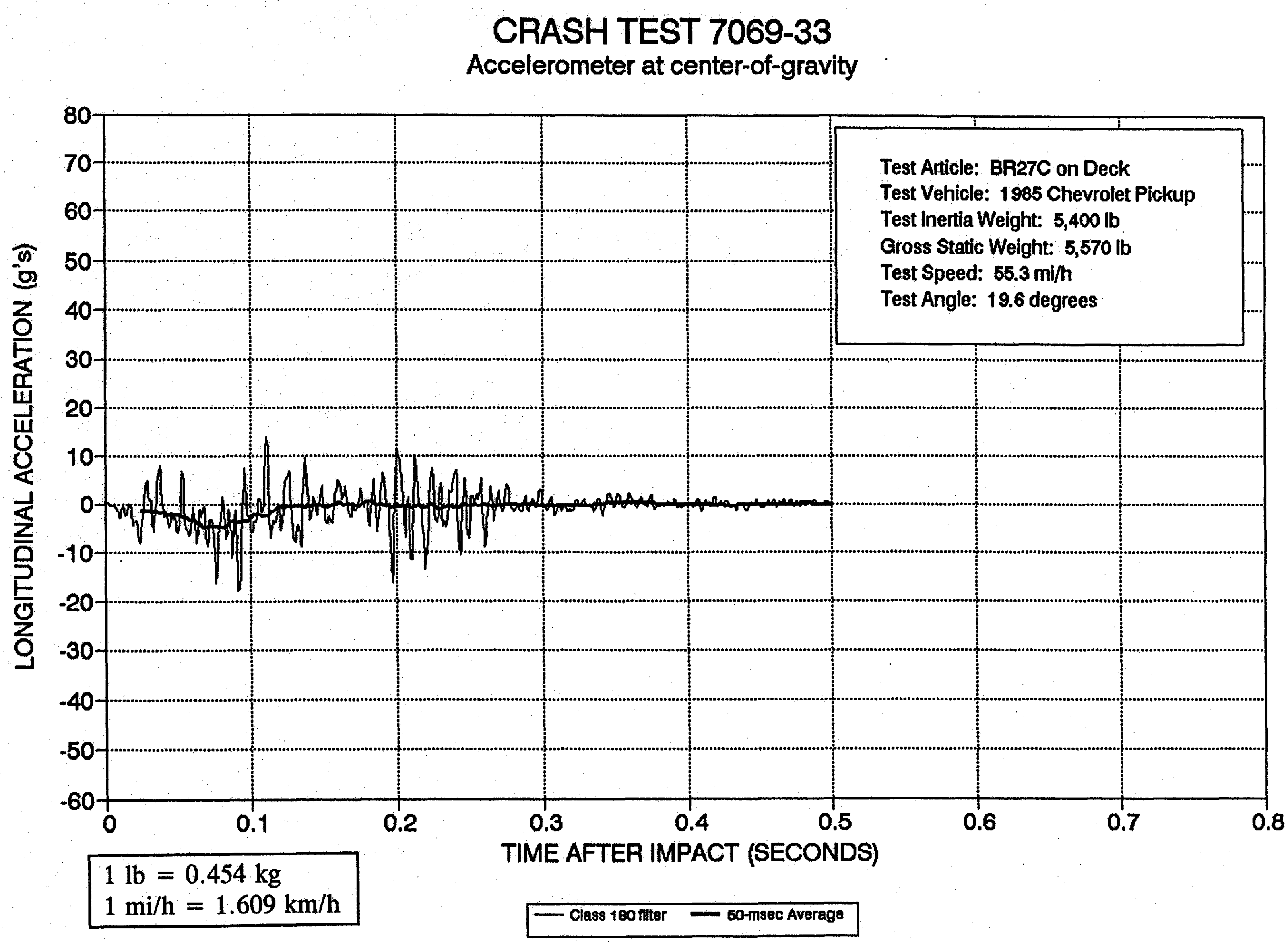


Figure 78. Vehicle longitudinal accelerometer trace for test 7069-33 (accelerometer located at center-of-gravity).

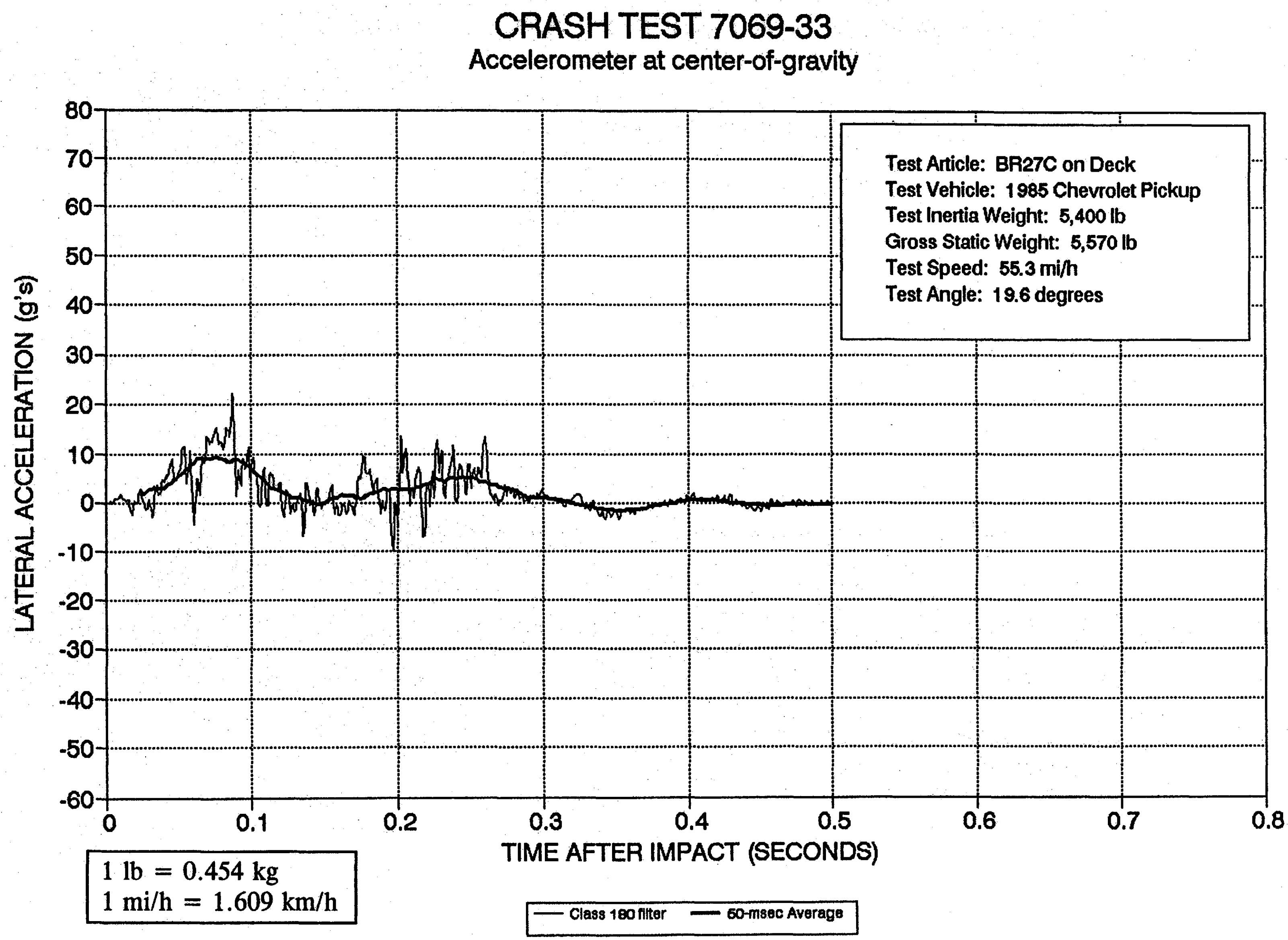


Figure 79. Vehicle lateral accelerometer trace for test 7069-33 (accelerometer located at center-of-gravity).

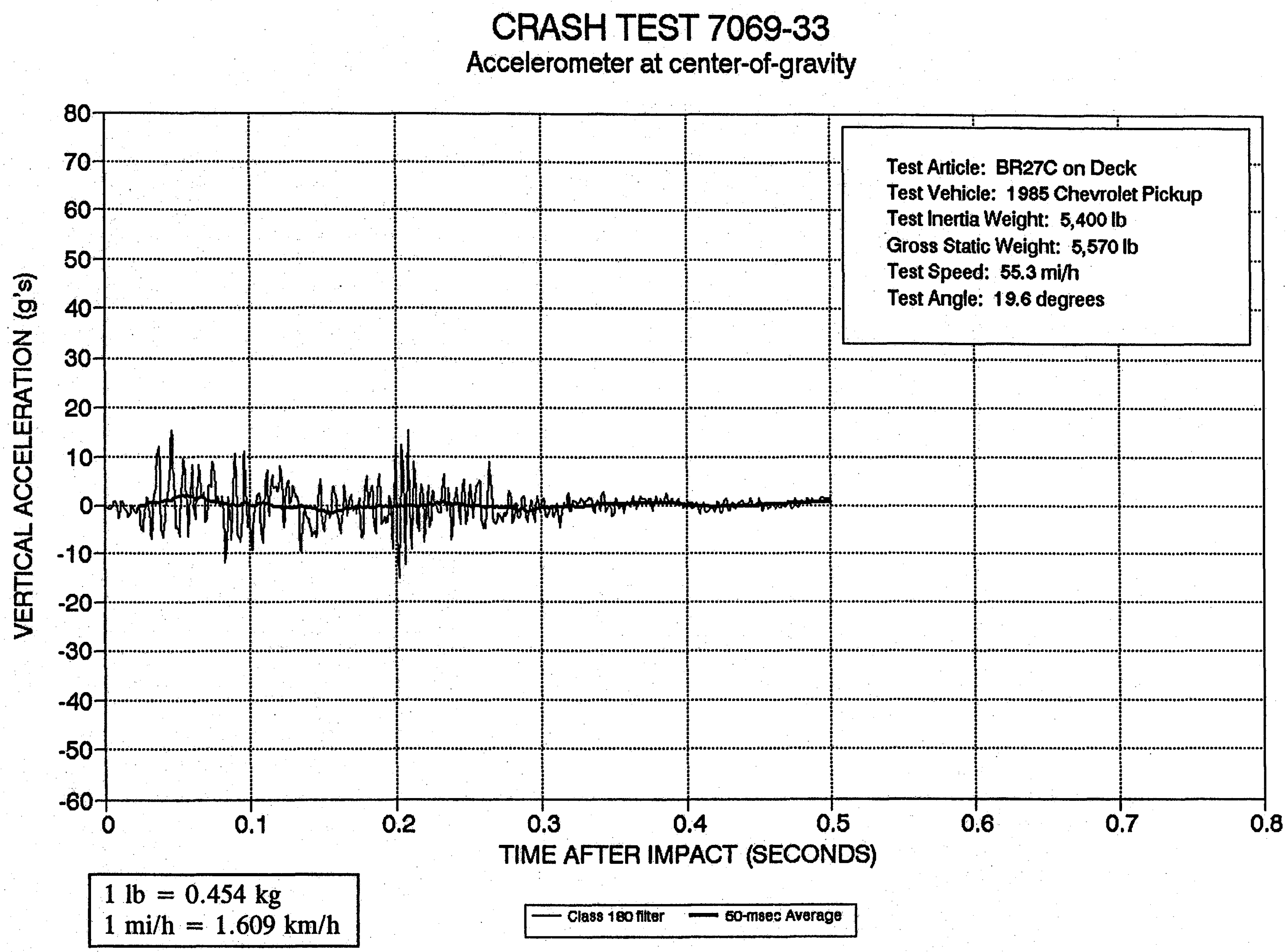


Figure 80. Vehicle vertical accelerometer trace for test 7069-33 (accelerometer located at center-of-gravity).

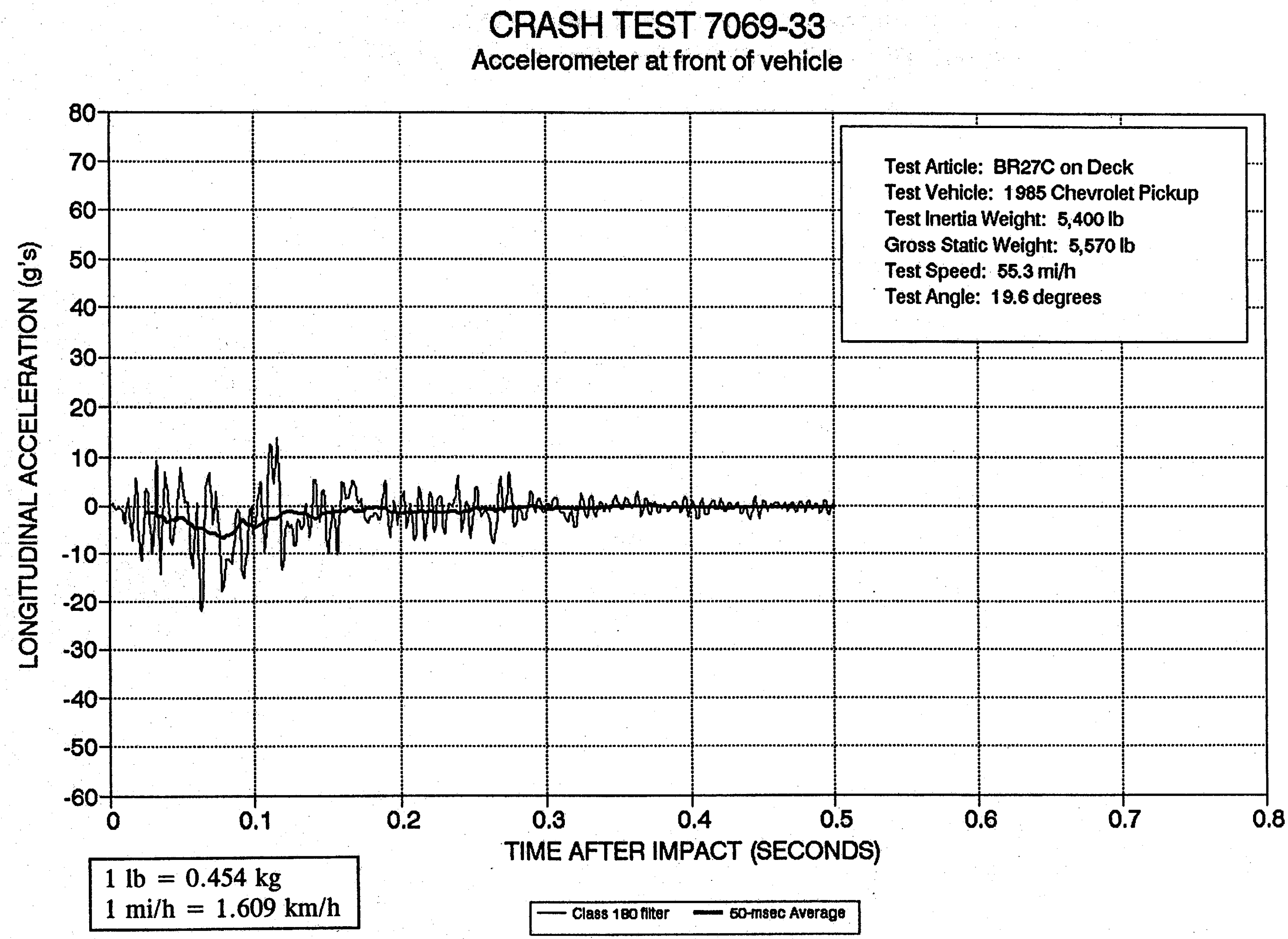


Figure 81. Vehicle longitudinal accelerometer trace for test 7069-33 (accelerometer located at front of vehicle).

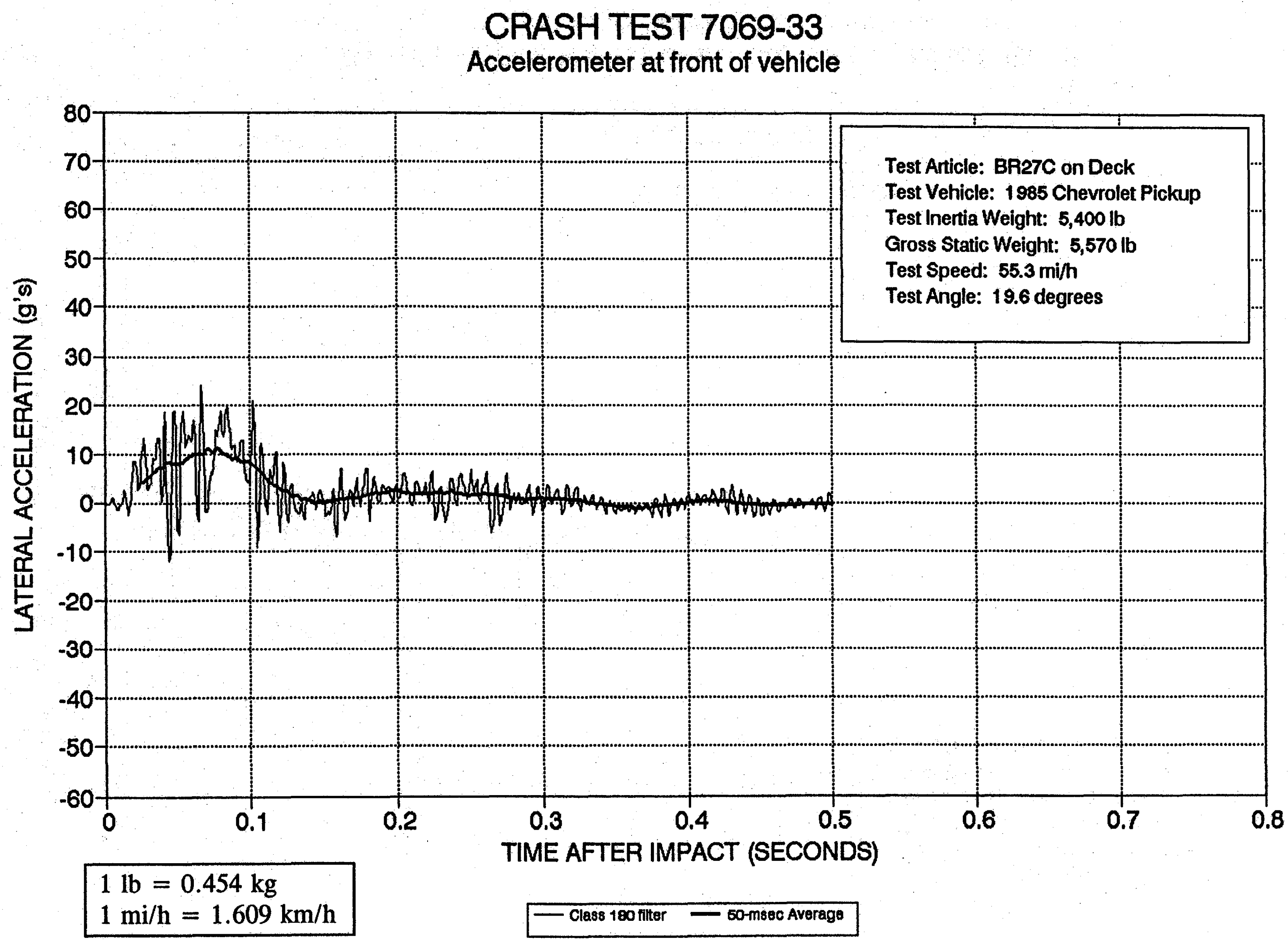


Figure 82. Vehicle lateral accelerometer trace for test 7069-33 (accelerometer located at front of vehicle).

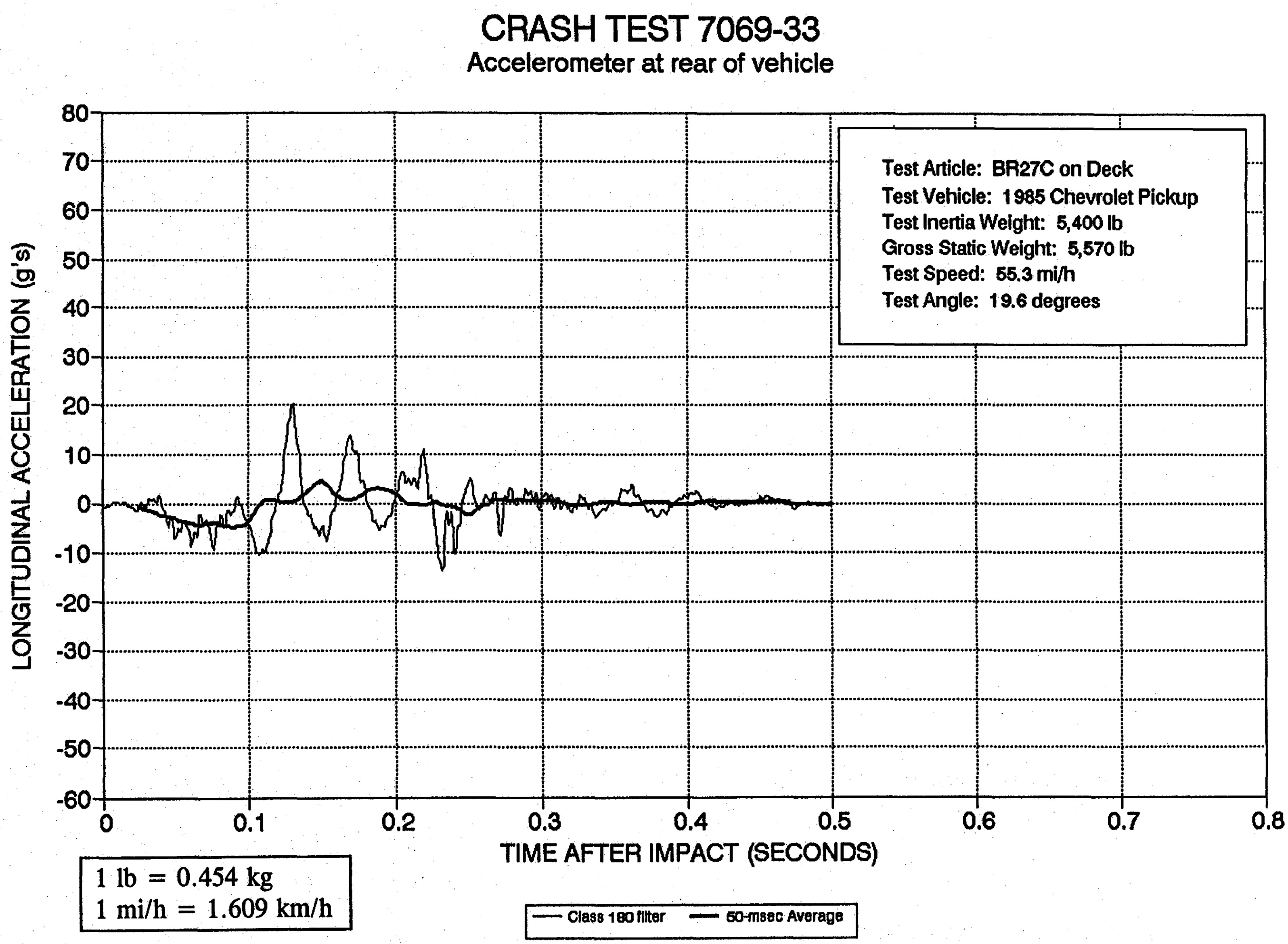


Figure 83. Vehicle longitudinal accelerometer trace for test 7069-33 (accelerometer located at rear of vehicle).

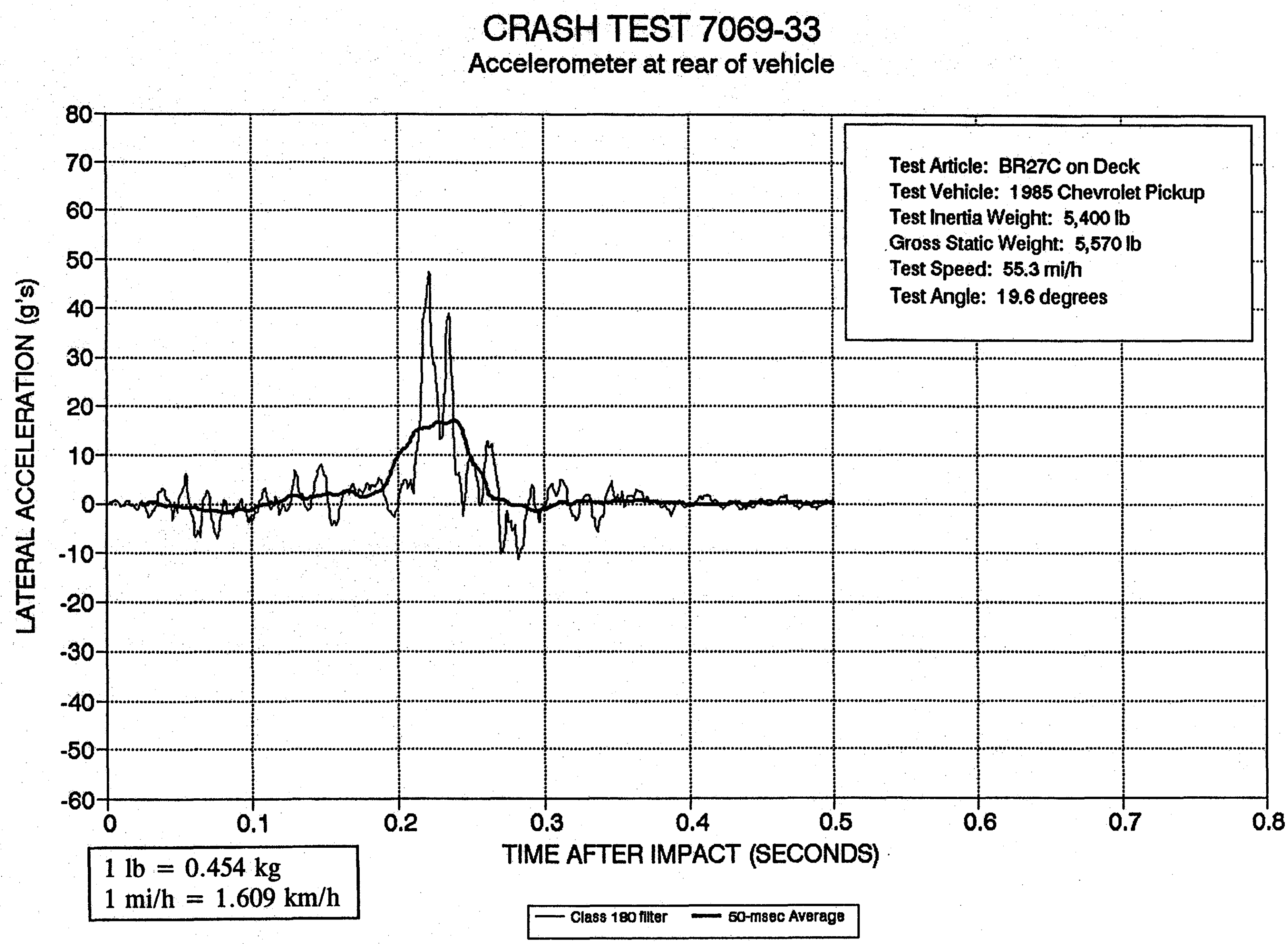


Figure 84. Vehicle lateral accelerometer trace for test 7069-33 (accelerometer located at rear of vehicle).

Test 7069-34

Test Description

A 1981 Ford single-unit truck (figures 85 and 86) was used for the crash test. The empty weight of the vehicle was 10,490 lb (4 762 kg) and its test inertia weight was 18,000 lb (8 172 kg). The height to the lower edge of the vehicle bumper was 18.25 in (464 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 87. The vehicle was directed into the BR27C bridge railing on deck (figure 88) 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 bridge railing 1.0 ft (0.3 m) downstream from post 5 at a speed of 52.5 mi/h (84.5 km/h) and the angle of impact was 12.8 degrees.

As the vehicle impacted the bridge railing, the vehicle bumper began to ride up the concrete parapet. At 0.017 s after impact the right front wheel made contact with the concrete parapet, and at 0.072 s a significant clockwise steer input occurred. The bumper went between the concrete parapet and lower metal railing element at 0.094 s, and by 0.118 s the vehicle was traveling parallel to the bridge railing at a speed of 46.8 mi/h (75.3 km/h). At 0.174 the vehicle bumper made contact with post 6 and then contacted post 7 at 0.276 s. The vehicle lost contact with the bridge railing at approximately 0.811 s traveling at 44.6 mi/h (71.8 km/h) and 3.5 degrees. The brakes on the vehicle were applied at 1.9 s after impact and the vehicle subsequently came to rest 225 ft (68.6 m) down from the point of impact.

As can be seen in figures 89 and 90, the bridge railing received minimal damage with most being contained within the area around posts 4, 5, and 6. Cracking occurred in posts 4 and 5 in the heat affected zone in the posts at the post-to-baseplate connection. The crack occurred at the corners on the traffic side of the tubular steel element (corner of maximum stress) and extended approximately 1 in in both directions. There was a hairline crack in the concrete parapet in line with the rear bolts at post 4. There was 1.5-in (38-mm) deformation to the metal railing element between posts 4 and 5. The vehicle was in contact with the bridge railing for 41.0 ft (12.5 m).

The vehicle sustained damage mostly to the right side as shown in figure 91 and 92. Maximum crush at the right front corner at bumper height was 28.0 in (711 mm). The steering arm, front springs and shackles, left front king pin, and front axle were damaged and the frame was bent. Also, damage was done to the front bumper, right front quarter panel, right front tire and rim, right door, right rear outside tire and rim, gas tank, and box-van.

Test Results

Impact speed was 52.5 mi/h (84.5 km/h) and the angle of impact was 12.8 degrees. The speed of the vehicle at time of parallel was 46.8 mi/h (75.9 km/h) and the coefficient of friction was 0.38. The vehicle lost contact with the bridge railing traveling at 44.6 mi/h

(71.8 km/h) and the exit angle between the vehicle path and the bridge railing was 3.5 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 8.2 ft/s (2.5 m/s) at 0.393 s, the highest 0.010-s average ridedown acceleration was -1.1 g between 0.606 and 0.616 s, and the maximum 0.050-s average acceleration was -1.9 g between 0.164 and 0.214 s. Lateral occupant impact velocity was 13.1 ft/s (4.0 m/s) at 0.185 s, the highest 0.010-s occupant ridedown acceleration was 5.2 g between 0.241 and 0.251 s, and the maximum 0.050-s average acceleration was 4.3 g between 0.123 and 0.173 s. The change in vehicle velocity at loss of contact was 7.9 mi/h (12.7 km/h) and the change in momentum was 6,477 lb-sec (28,810 N-s). These data and other pertinent information from the test are summarized in figure 93 and table 7. Sequential photographs are shown in figures 94 and 95. Vehicular angular displacements are displayed in figure 96. Vehicular accelerations versus time traces filtered with SAE J211 filters are presented in figures 97 through 103.

Conclusions

The BR27C bridge railing on deck contained the test vehicle with minimal lateral movement of the bridge railing. There was no intrusion of railing components into the occupant compartment. The vehicle remained upright and relatively stable during the collision. The bridge railing redirected the vehicle and the effective coefficient of friction was considered marginal. Velocity change of the vehicle during the collision was 9.7 mi/h (15.6 km/h). The vehicle trajectory at loss of contact indicated minimum intrusion into adjacent traffic lanes. See figure 93 and table 7 for more details.

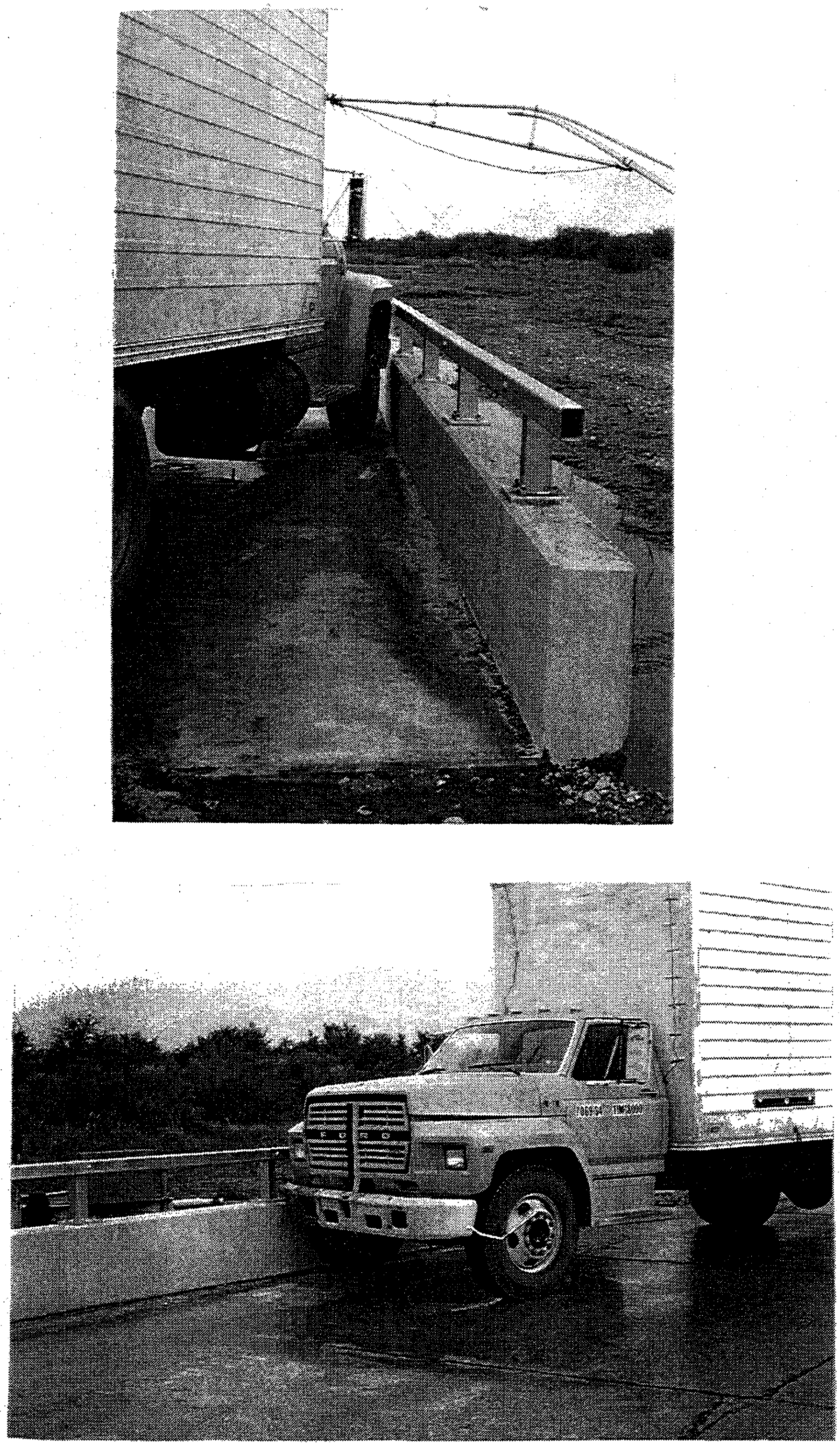
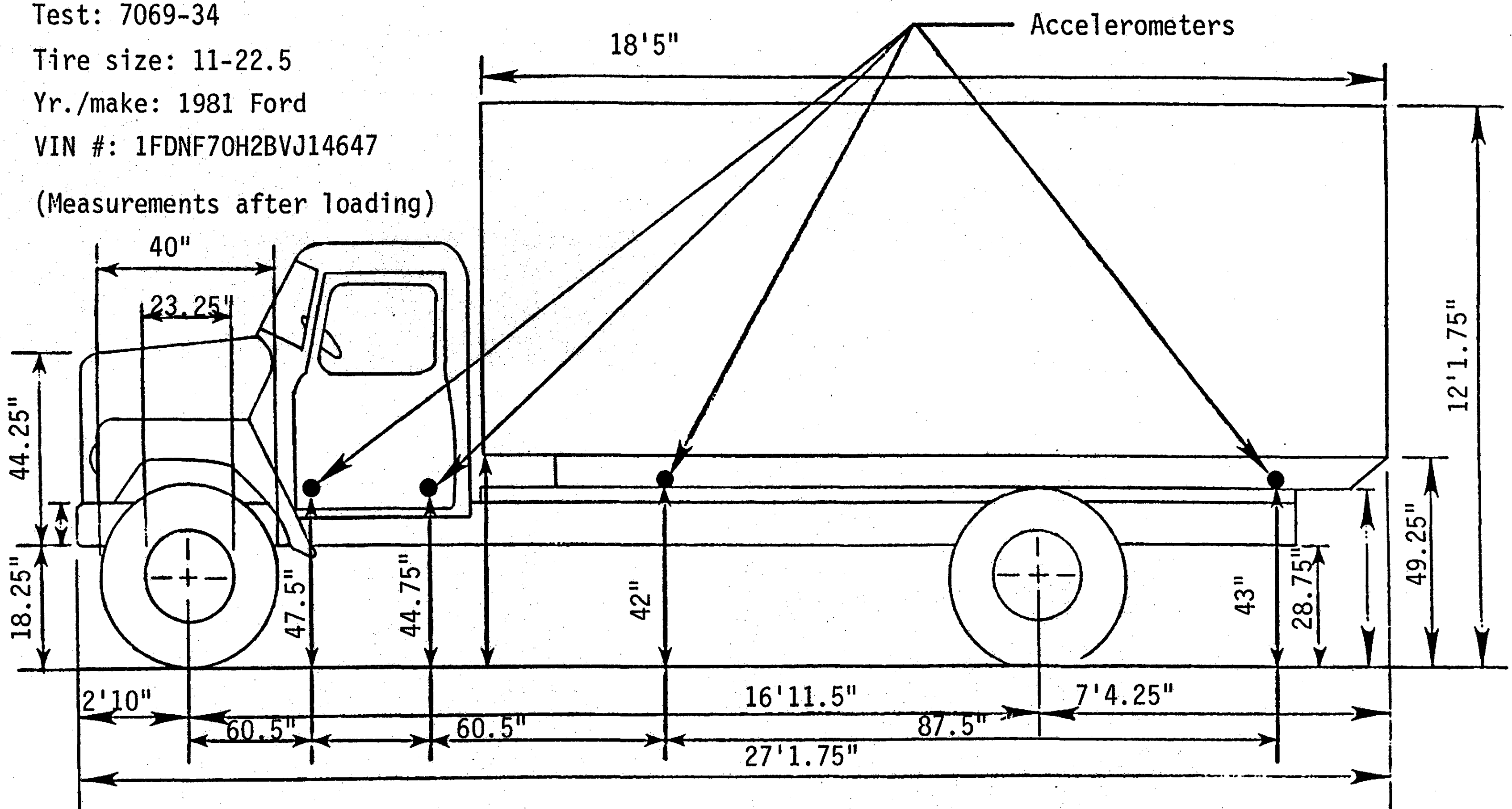


Figure 85. Vehicle prior to test 7069-34.

Figure 86. Vehicle/bridge railing geometrics for test 7069-32.

Test: 7069-34
Tire size: 11-22.5
Yr./make: 1981 Ford
VIN #: 1FDNF70H2BVJ14647

(Measurements after loading)



EMPTY WEIGHTS

Weight on Front Axle : LF 2230 RF 2440
Weight on Rear Axle : LR 2810 RR 3010

TOTAL EMPTY WEIGHT : 10490

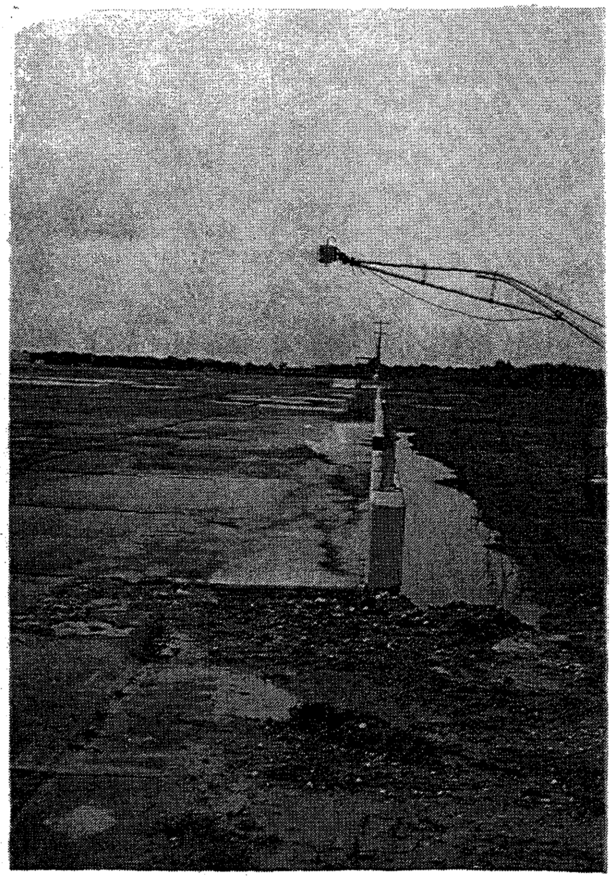
LOADED WEIGHTS

Weight on Front Axle : LF 3680 RF 3610
Weight on Rear Axle : RF 5190 RR 5520

TOTAL LOADED WEIGHT : 18000

1 in = 25.4 mm
1 lb = 0.454 kg

Figure 87. Vehicle properties for test 7069-34.



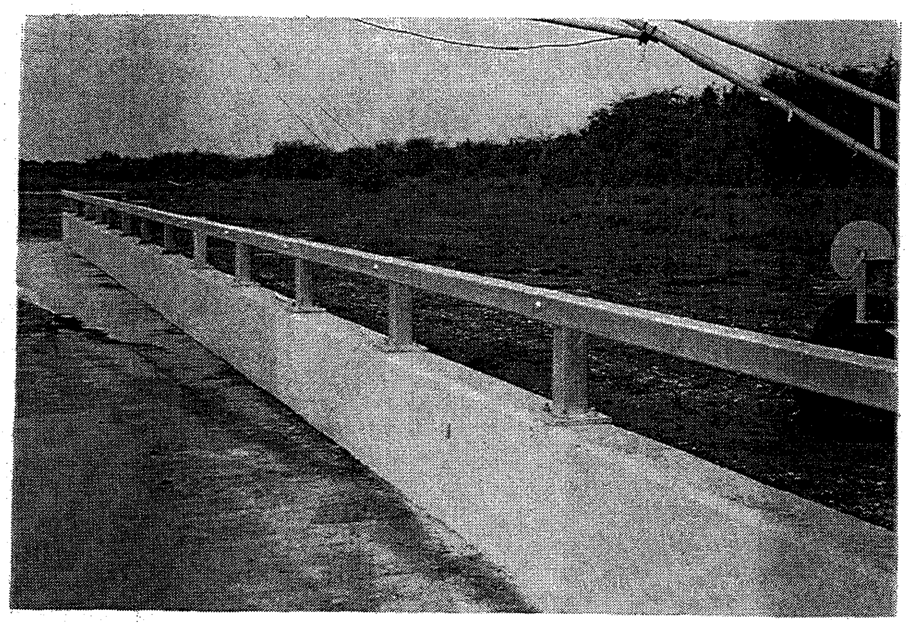
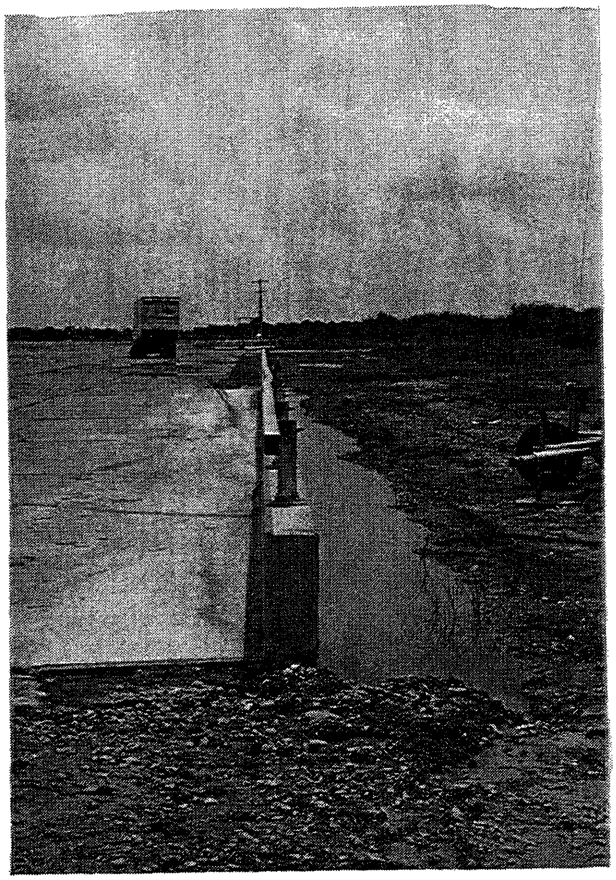


Figure 88. BR27C bridge railing on deck before test 7069-34.



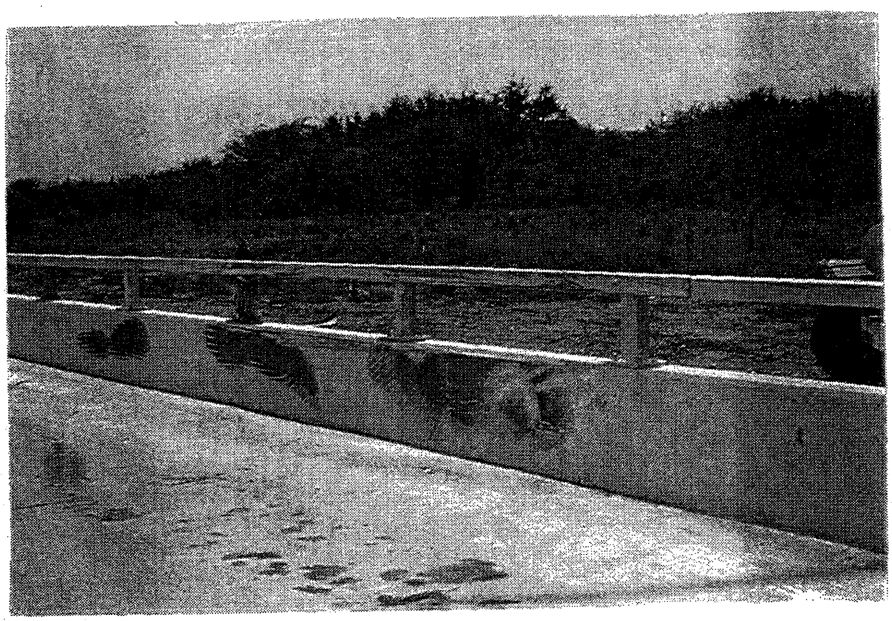


Figure 89. Test site after test 7069-34.

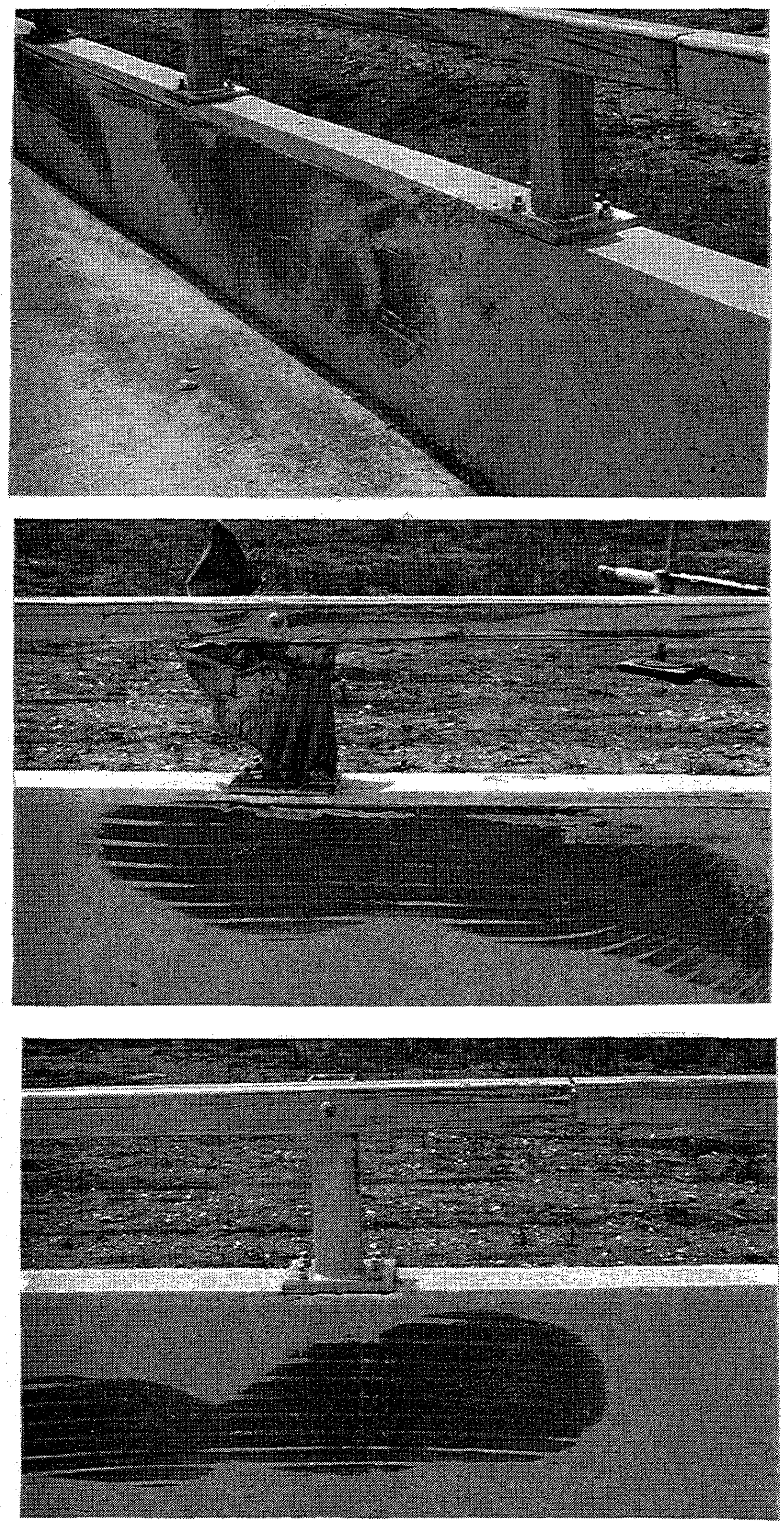
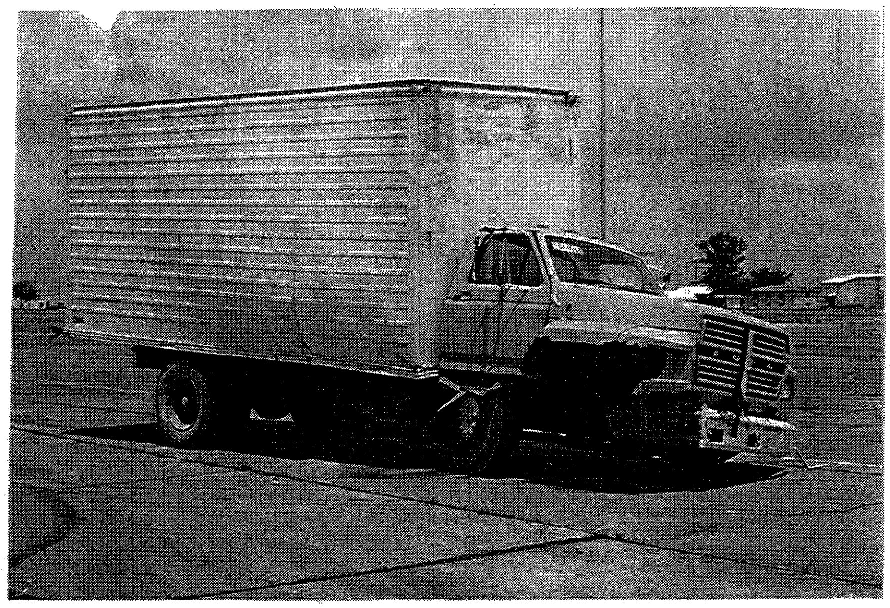


Figure 90. BR27C bridge railing on deck after test 7069-34.



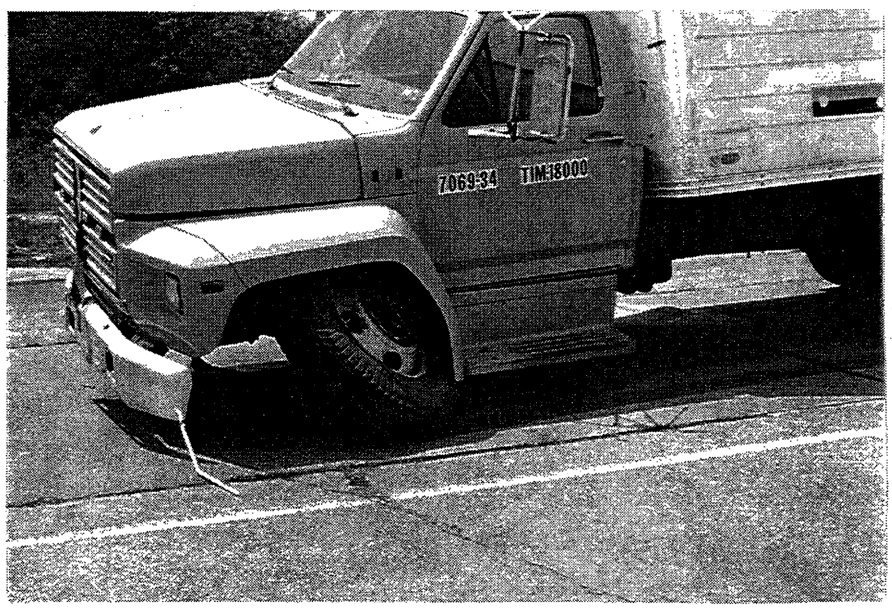


Figure 91. Vehicle after test 7069-34.

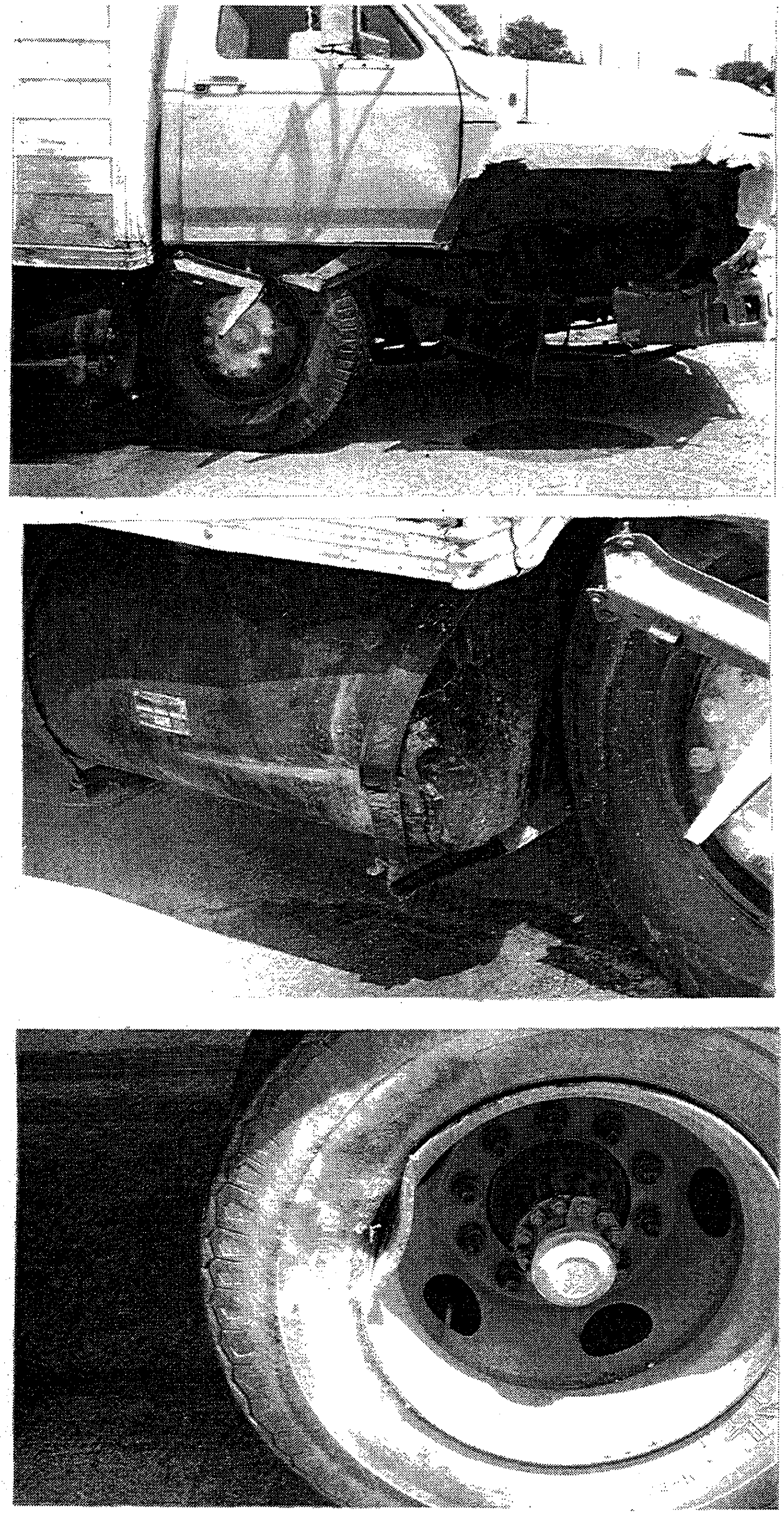
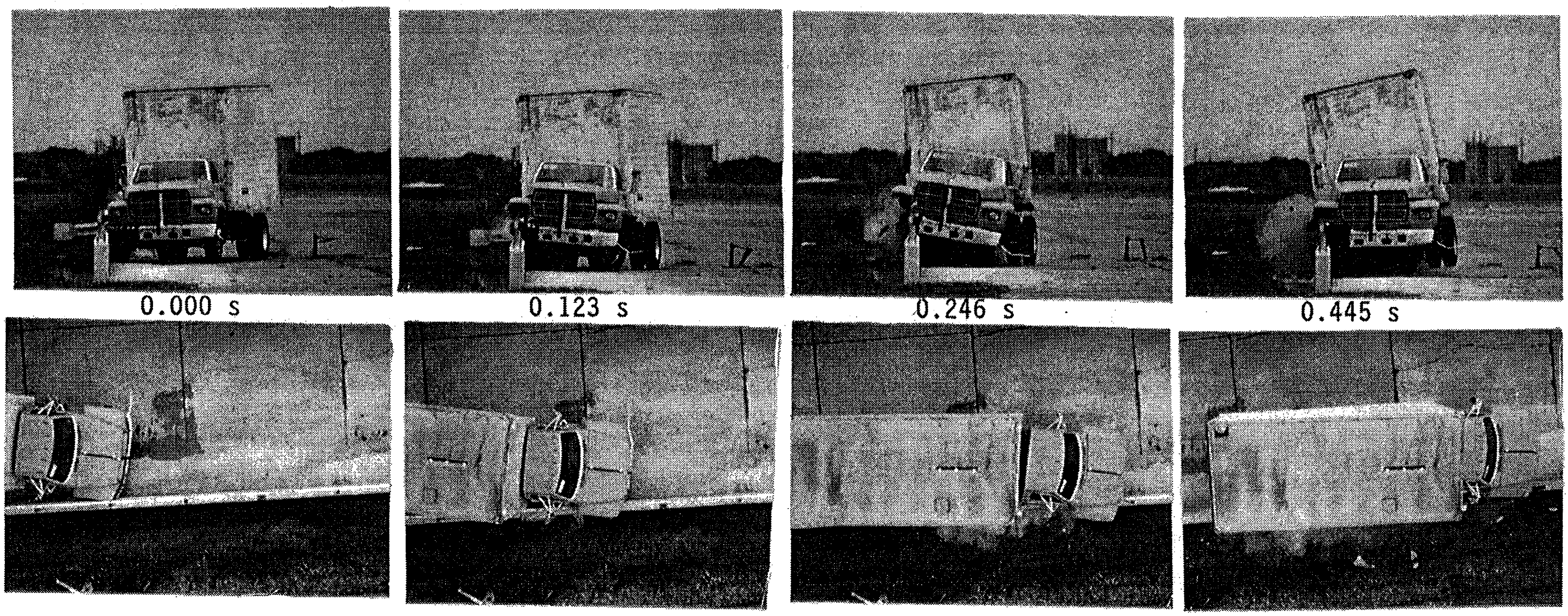
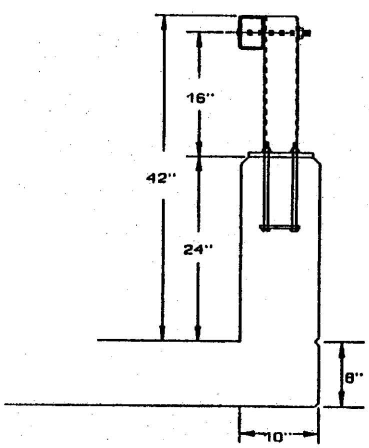


Figure 92. Damage to right side of vehicle, test 7069-34.





(1 in = 25.4 mm)

Test No.	7069-34
Date	08/12/92
Test Installation . . .	BR27C Bridge Railing on deck
Installation Length . .	100 ft (30 m)
Test Vehicle	1981 Ford Single-Unit Truck
Vehicle Weight	
Empty Weight	10,490 lb (4,762 kg)
Test Inertia	18,000 lb (8,172 kg)
Maximum Vehicle Crush .	28.0 in (711 mm)
Max. Perm. Deform.	1.5 in (38 mm)

Impact Speed. . . .	52.5 mi/h (84.5 km/h)
Impact Angle. . . .	12.8 deg
Speed at Parallel .	46.8 mi/h (75.3 km/h)
Exit Speed	44.6 mi/h (71.8 km/h)
Exit Trajectory . .	3.5
Vehicle Accelerations (Max. 0.050-sec Avg) at c.g.	
Longitudinal. . .	-1.9 g
Lateral	4.3 g
Occupant Impact Velocity at true c.g.	
Longitudinal. . .	8.2 ft/s (2.5 m/s)
Lateral	13.1 ft/s (4.0 m/s)
Occupant Ridedown Accelerations	
Longitudinal. . .	-1.1 g
Lateral	5.2 g

Figure 93. Summary of results for test 7069-34.

Table 7. Evaluation of crash test no. 7069-34.
{BR27C bridge railing on deck (18,000 lb (8 172 kg)|52.5 mi/h (84.5 km/h)|12.8 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 remained upright during test.	N/A
E.	Must smoothly redirect the vehicle	Vehicle was smoothly redirected	N/A
F.	Effective coefficient of friction μ — Assessment 0 - .25 — Good .26 - .35 — Fair > .35 — Marginal	μ — Assessment .38 — Marginal	N/A
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 8.2 (2.5) — Lateral 13.1 (4.0)	N/A
	Occupant Ridedown Accelerations - g's Longitudinal 15 — Lateral 15	Occupant Ridedown Accelerations - g's Longitudinal -1.1 — Lateral 4.3	N/A
H.	Exit angle shall be less than 12 degrees	Exit angle was 3.5 degrees	N/A

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

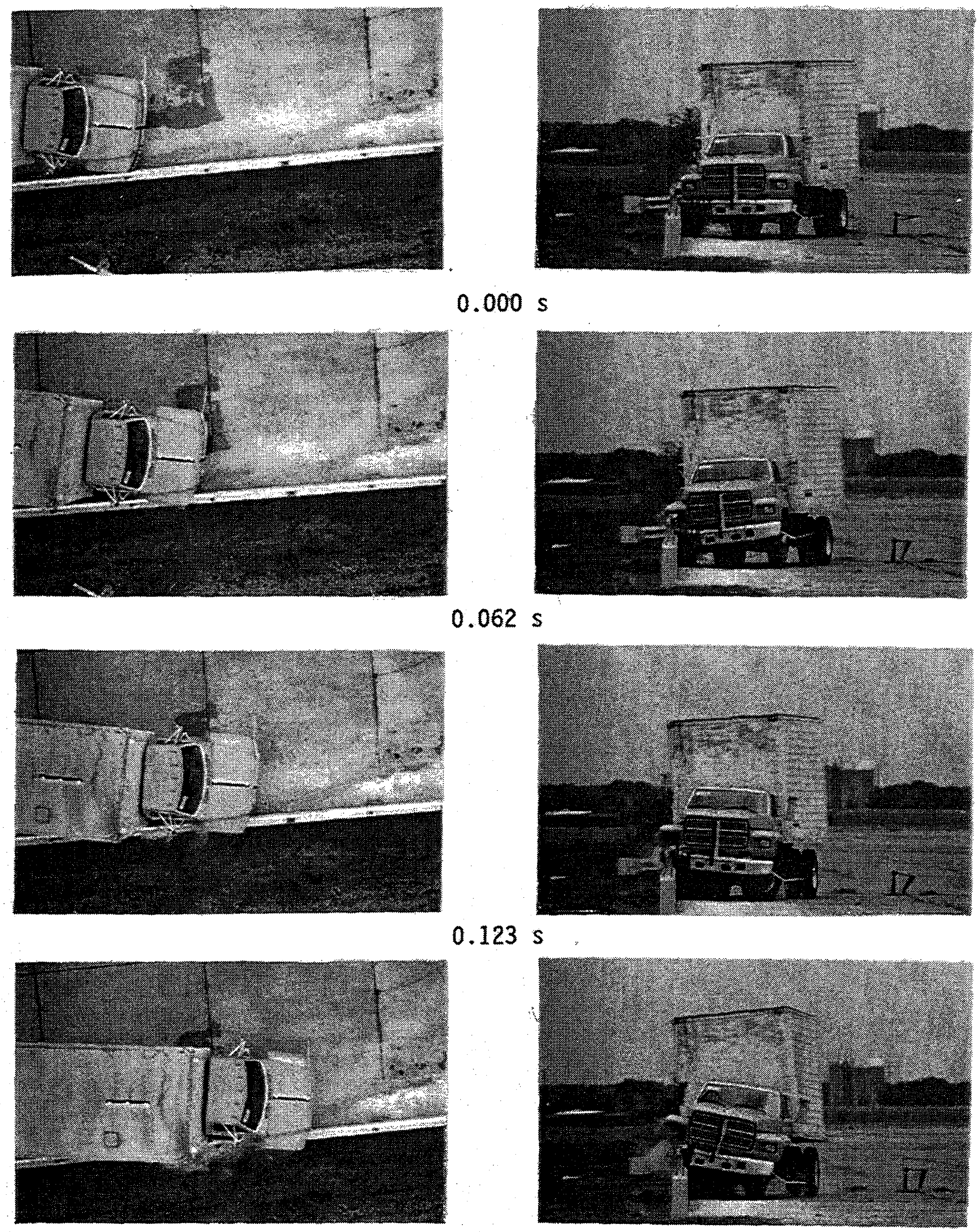
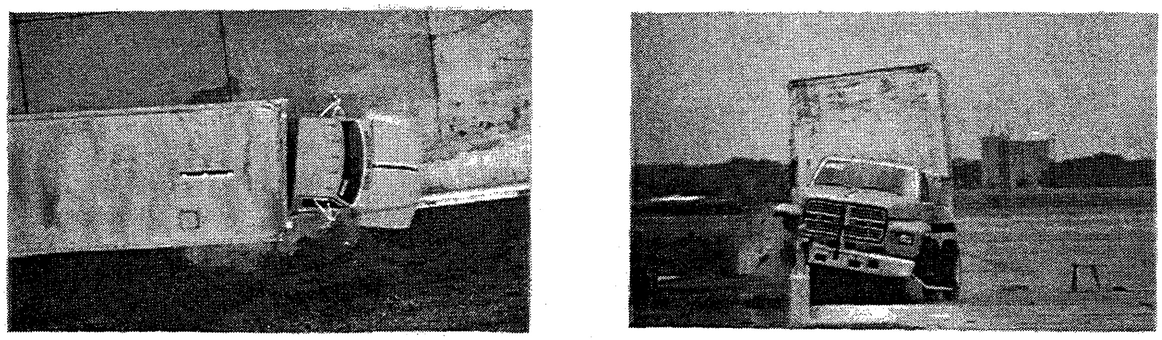
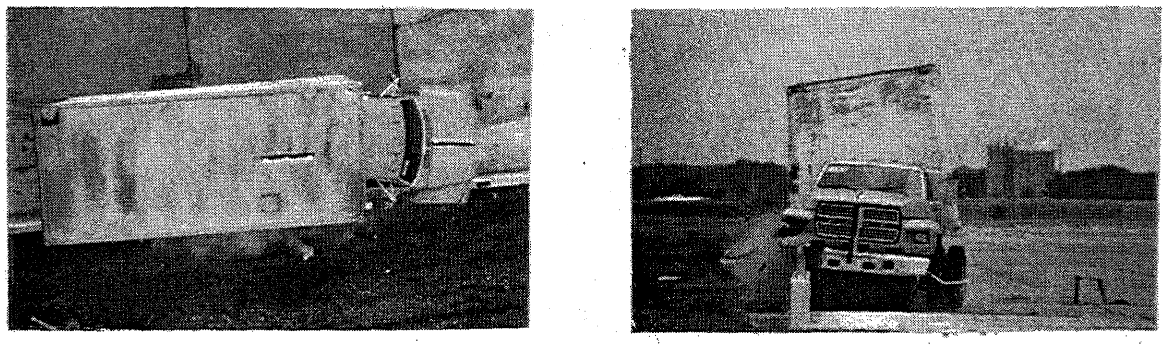


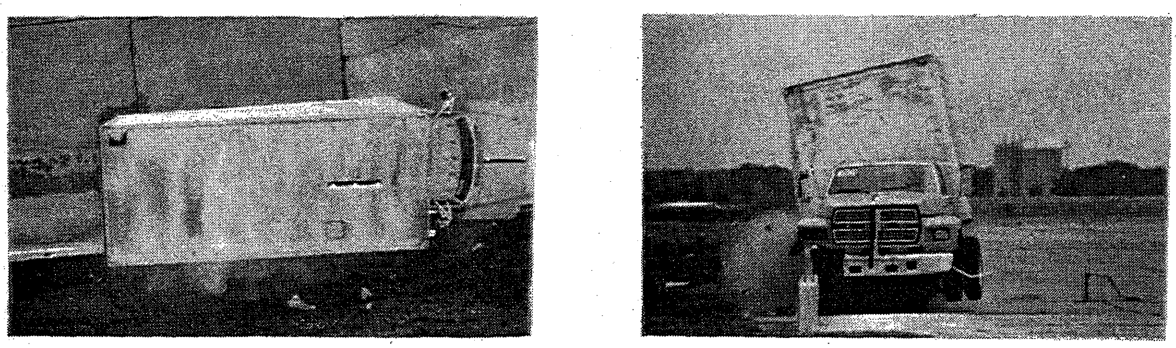
Figure 94. Sequential photographs for test 7069-34
(overhead and front views).



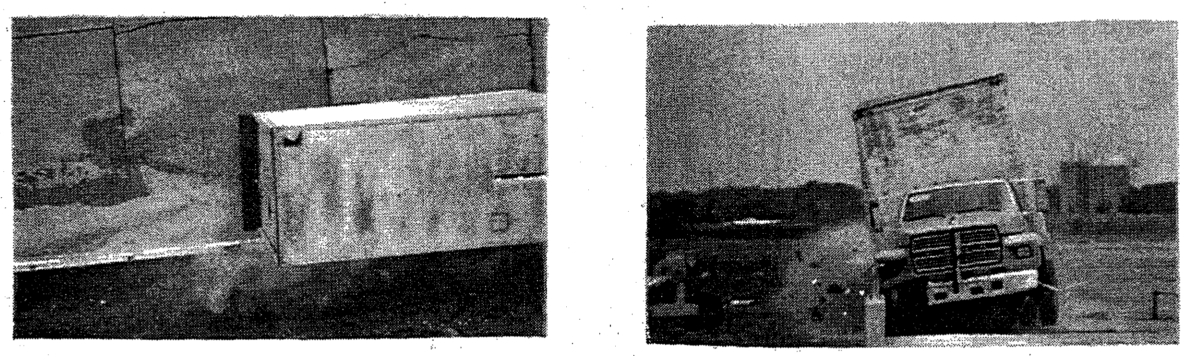
0.246 s



0.345 s

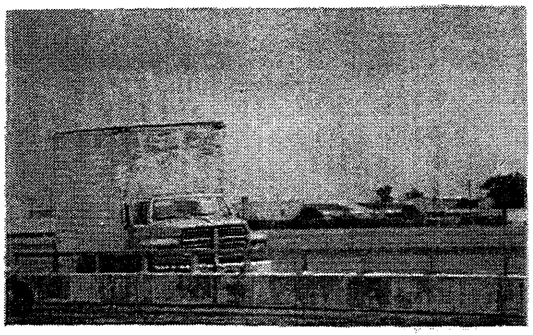


0.445 s

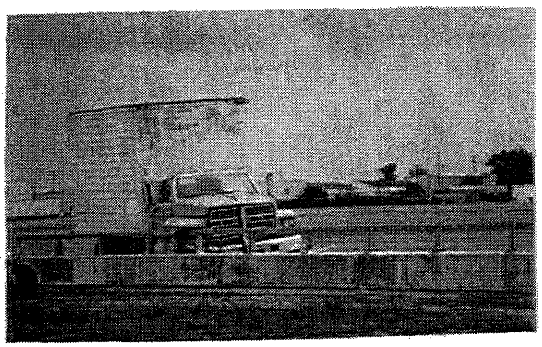


0.601 s

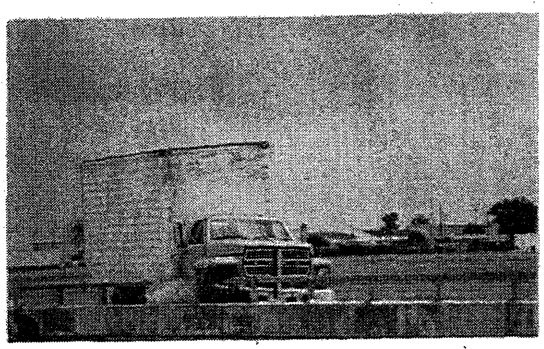
Figure 94. Sequential photographs for test 7069-34
(overhead and front views continued).



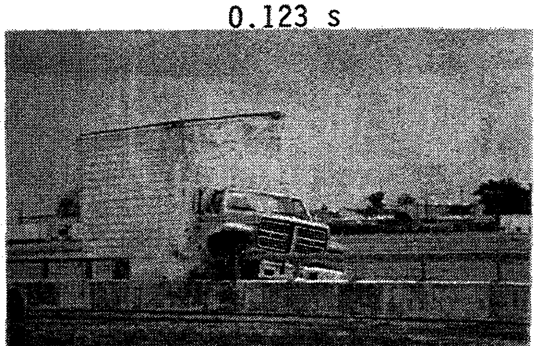
0.000 s



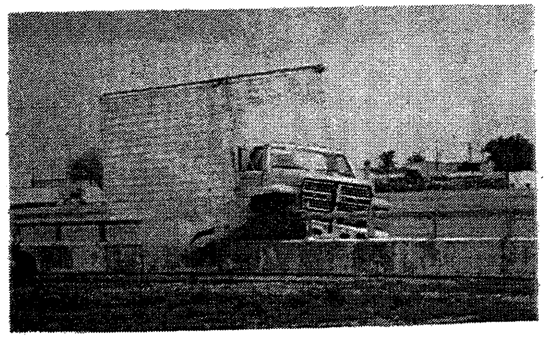
0.062 s



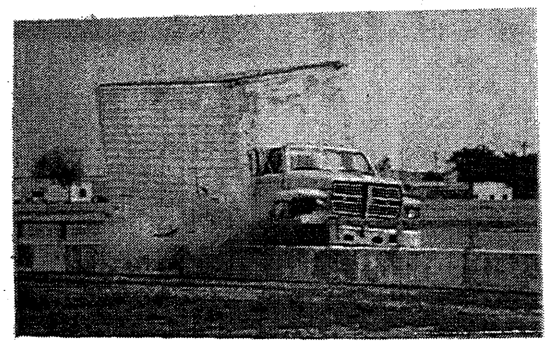
0.123 s



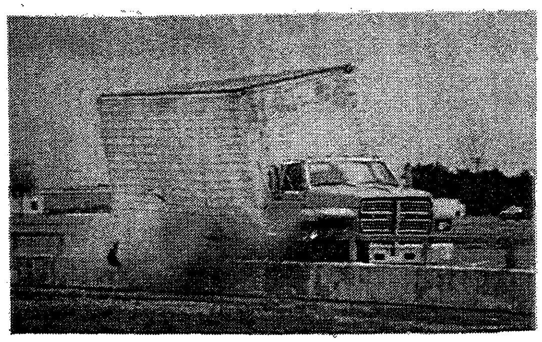
0.185 s



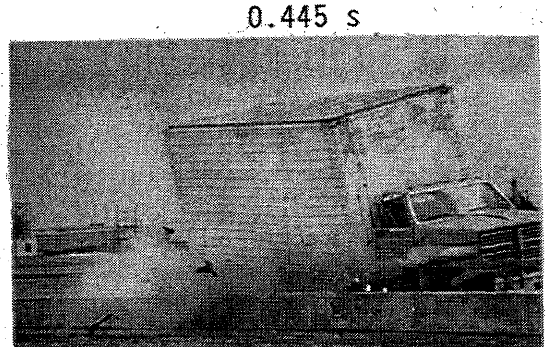
0.246 s



0.345 s



0.445 s



0.601 s

Figure 95. Sequential photographs for test 7069-34 (side view).

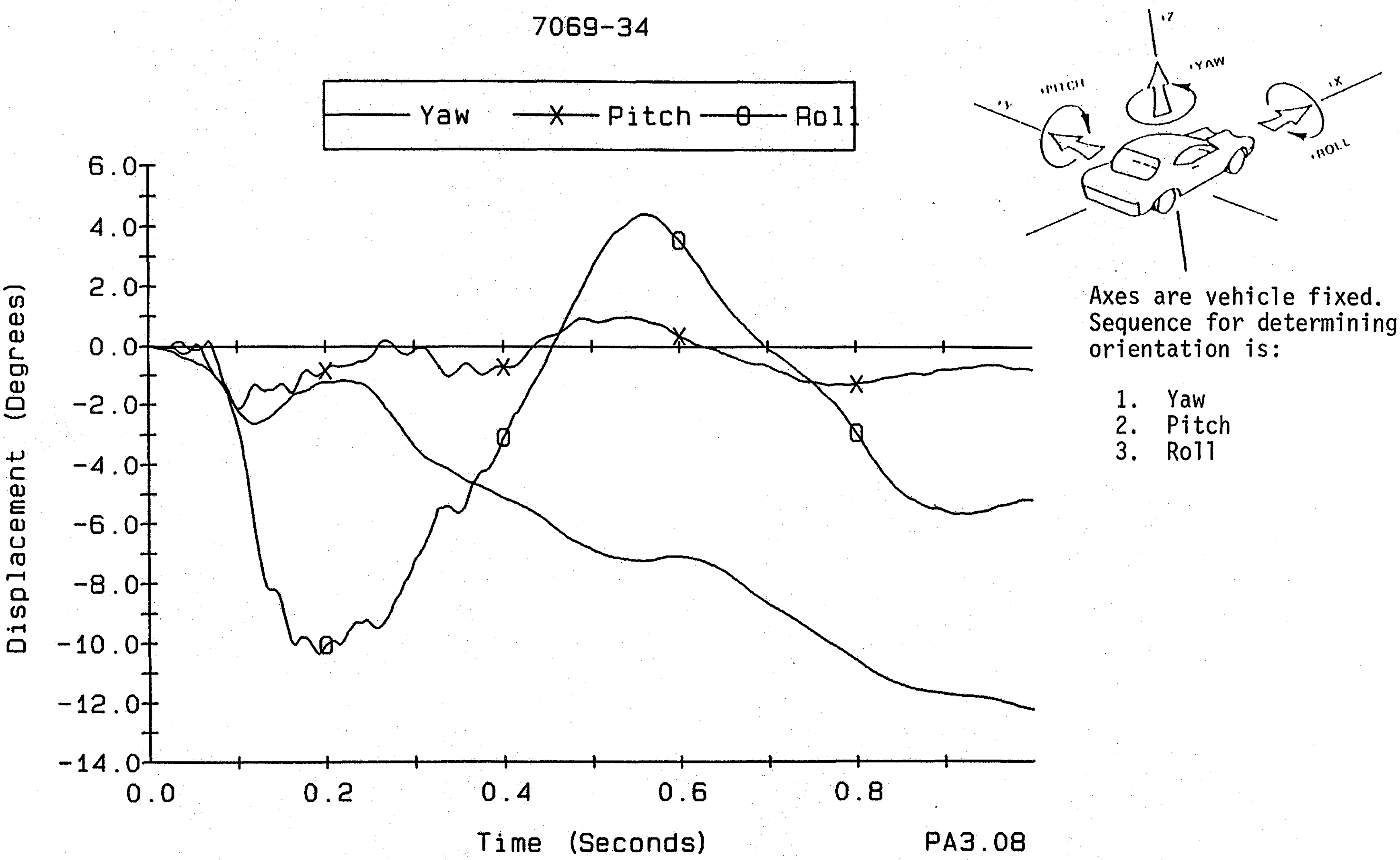


Figure 96. Vehicle angular displacements for test 7069-34.

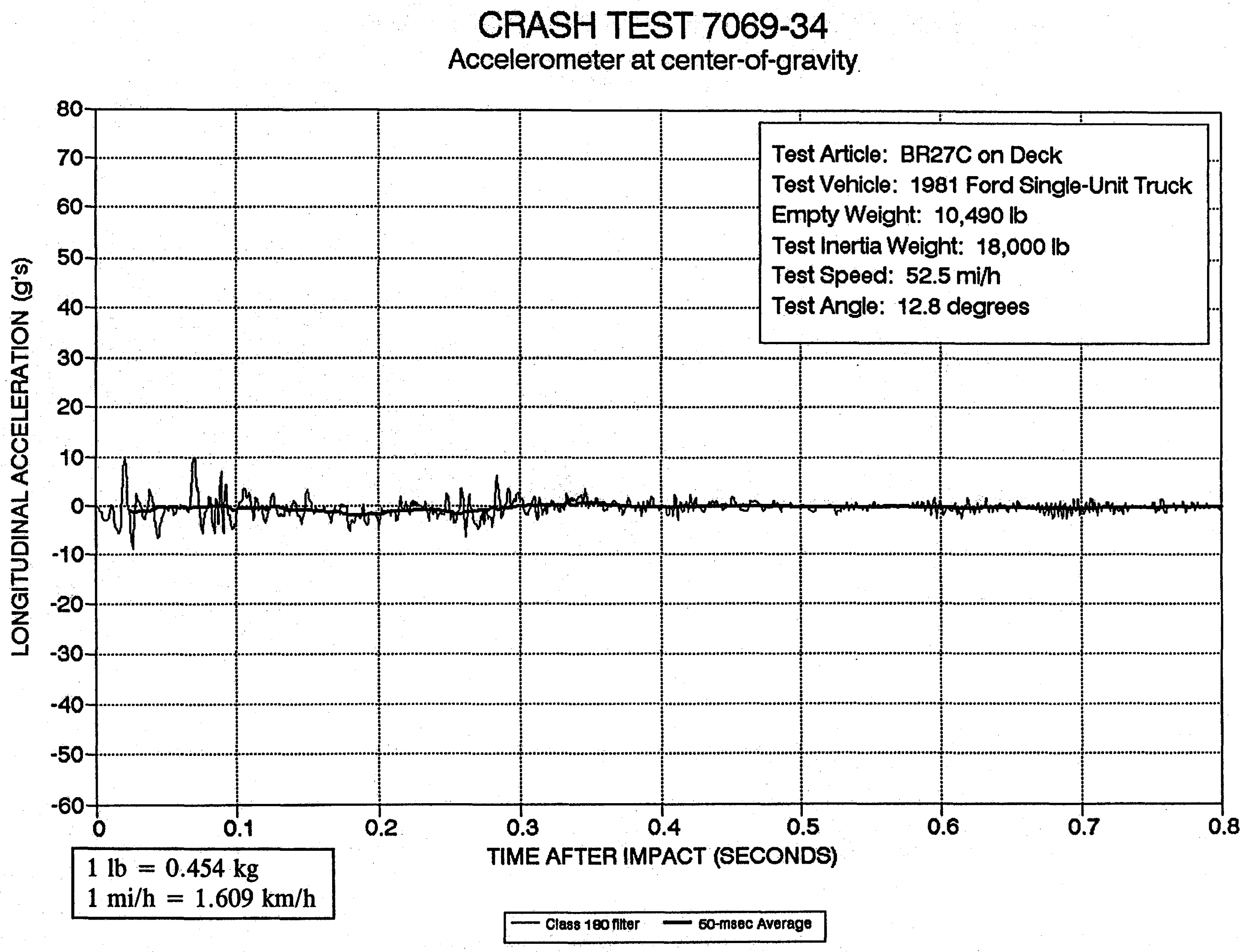


Figure 97. Vehicle longitudinal accelerometer trace for test 7069-34 (accelerometer located at center-of-gravity).

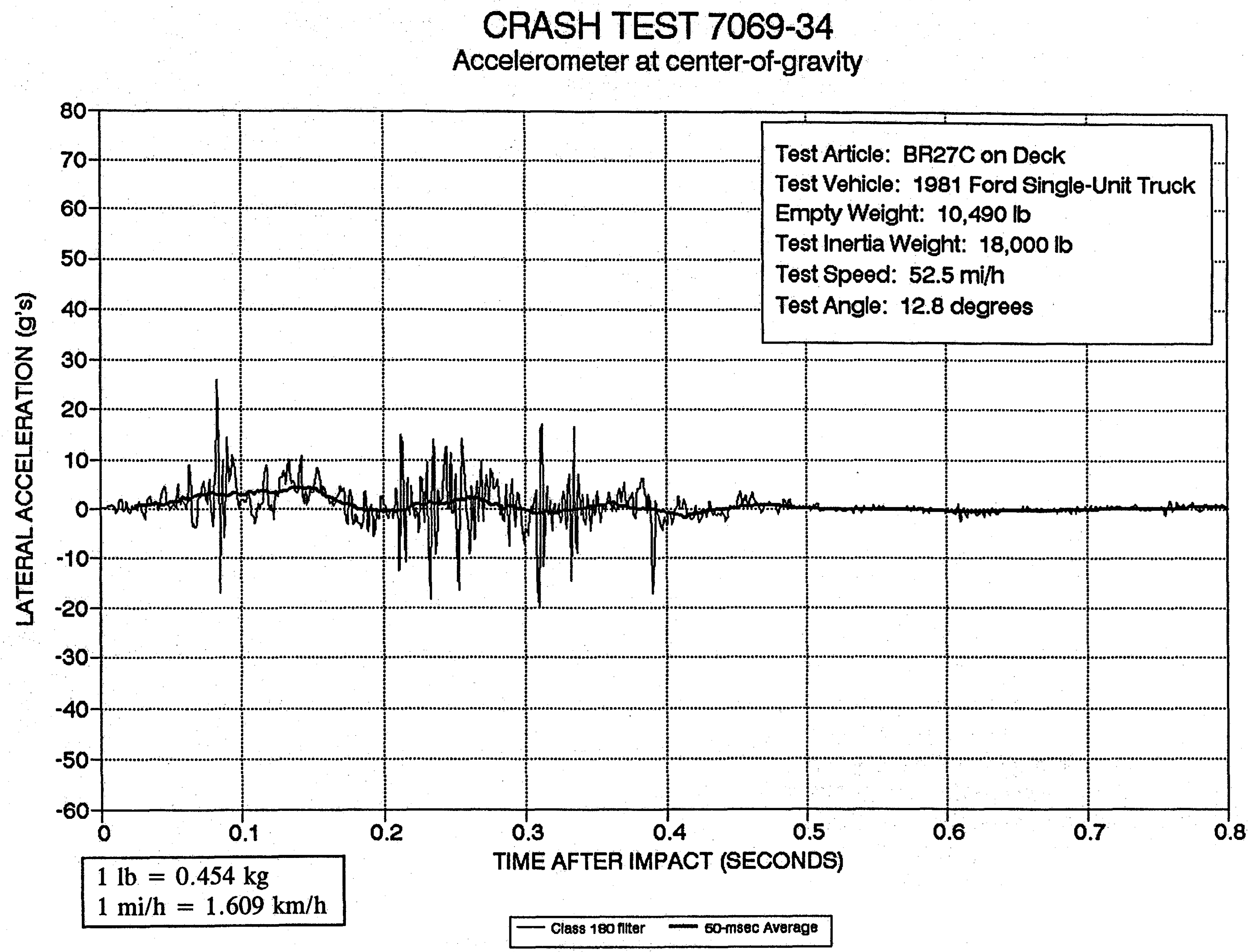


Figure 98. Vehicle lateral accelerometer trace for test 7069-34 (accelerometer located at center-of-gravity).

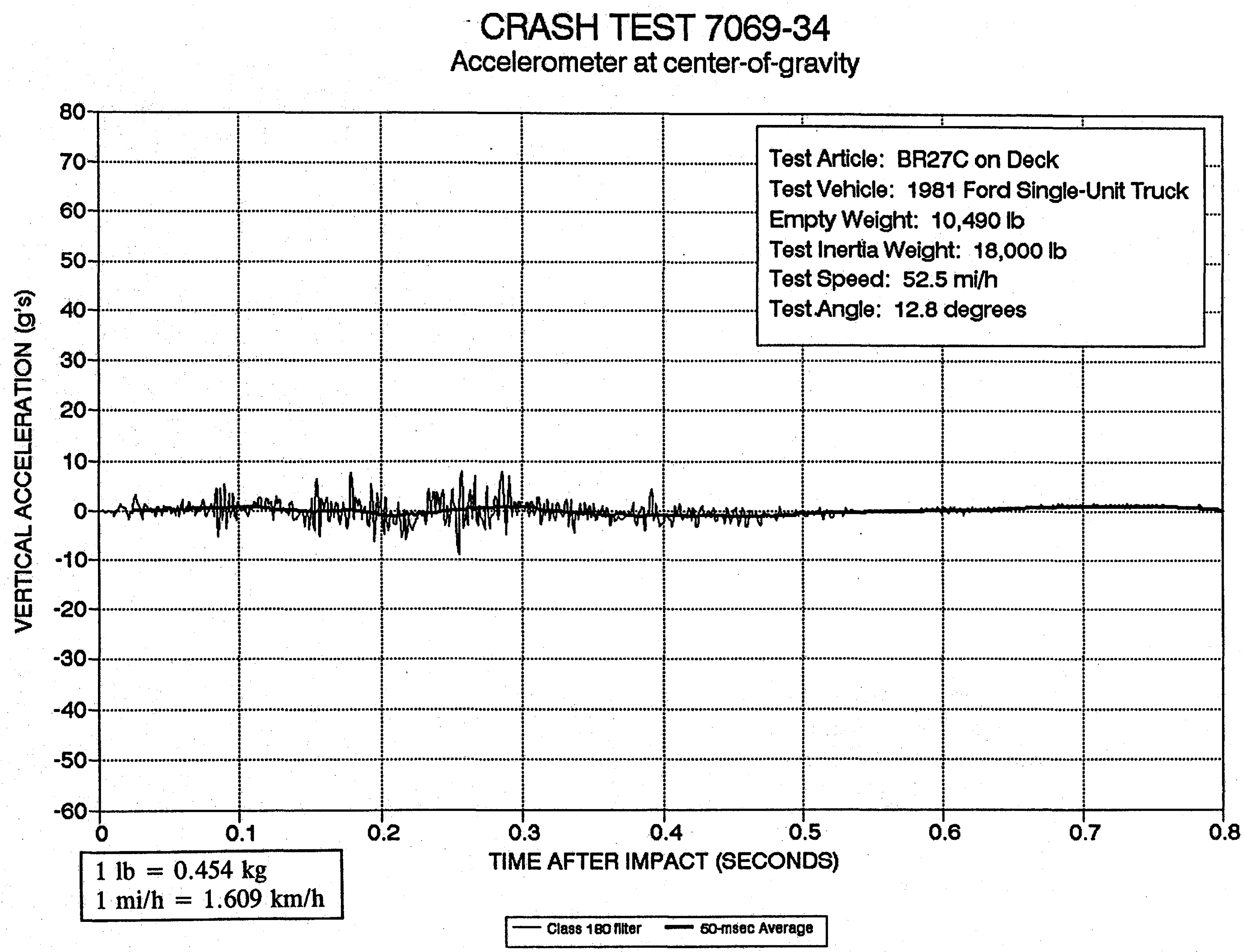


Figure 99. Vehicle vertical accelerometer trace for test 7069-34 (accelerometer located at center-of-gravity).

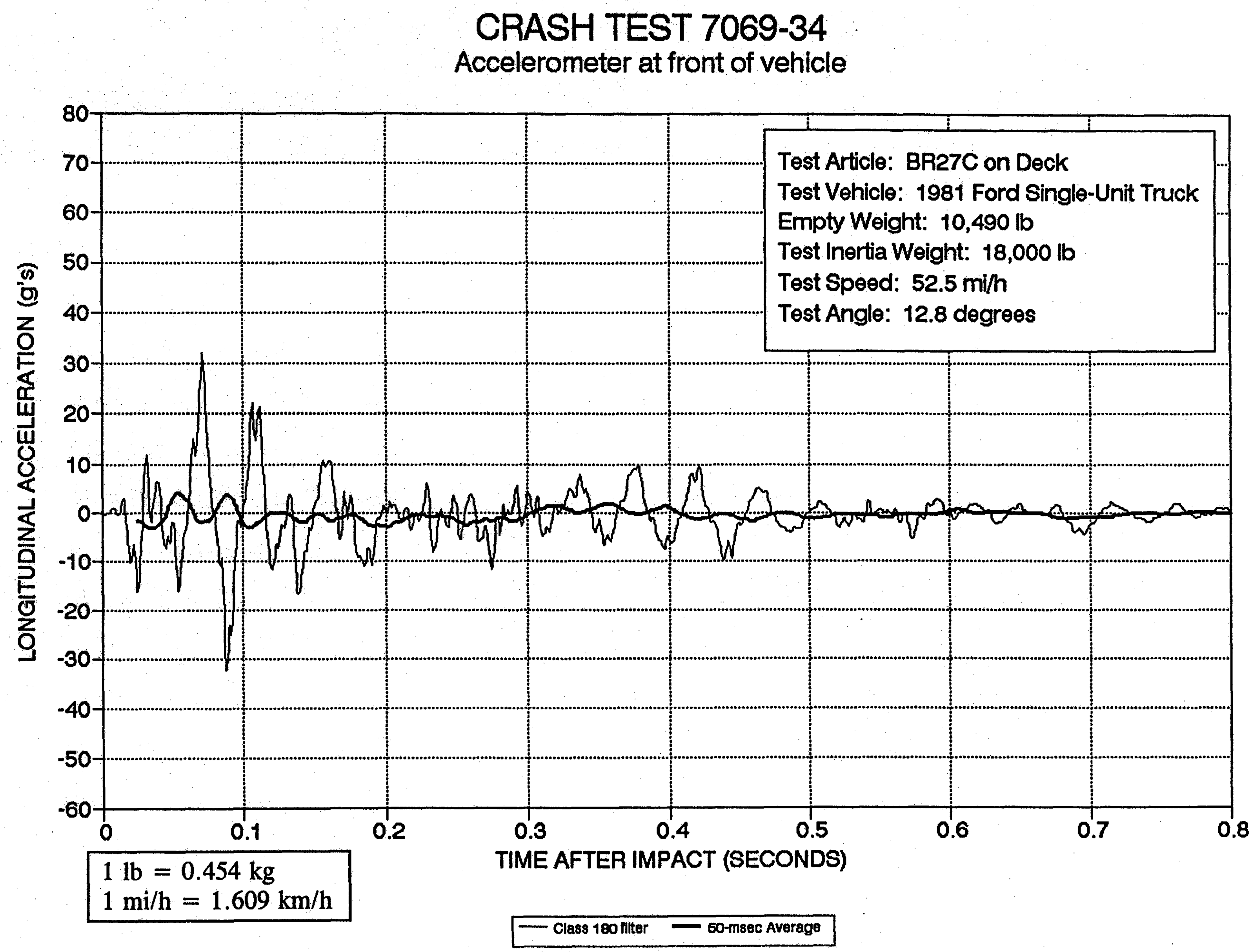


Figure 100. Vehicle longitudinal accelerometer trace for test 7069-34 (accelerometer located at front of vehicle).

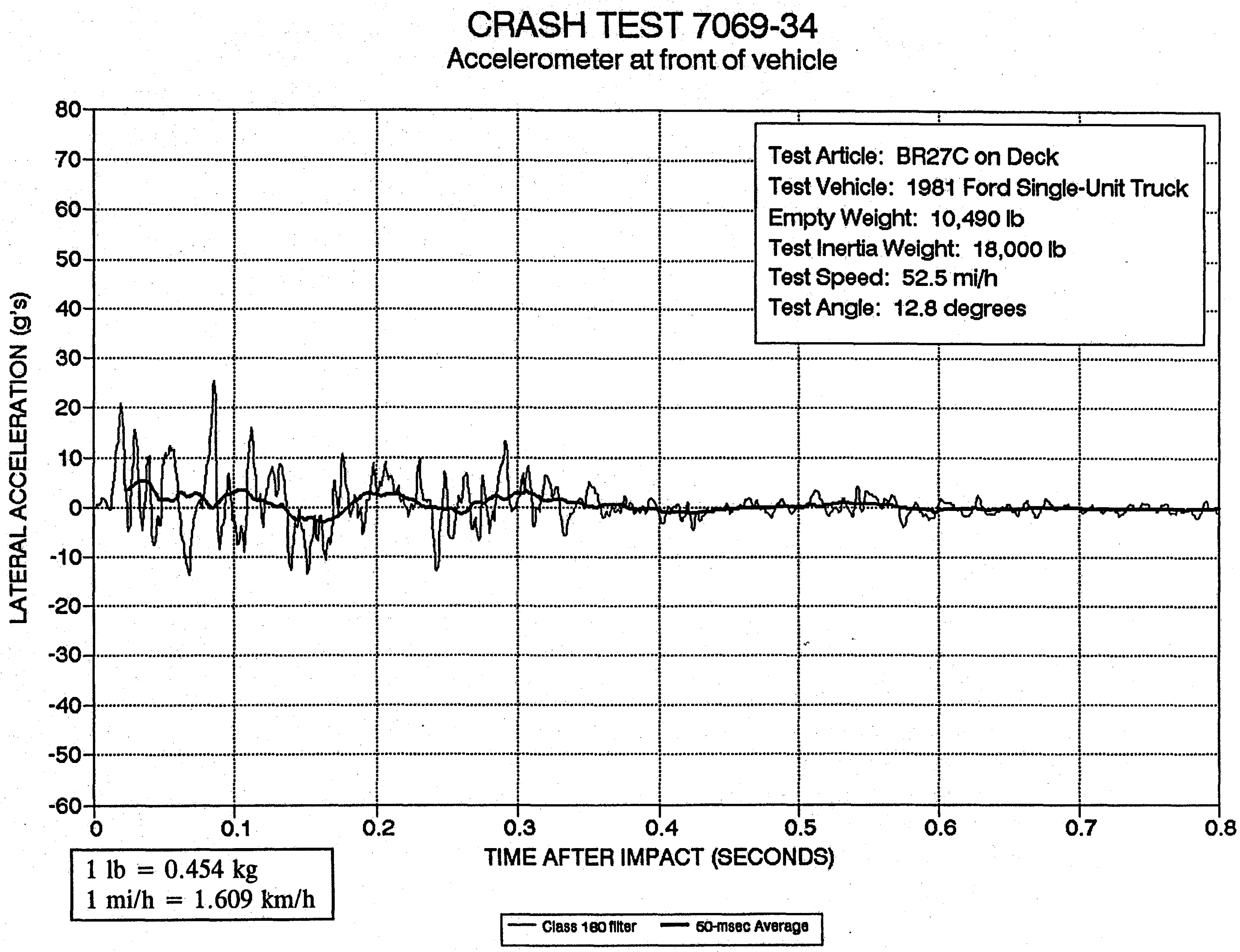


Figure 101. Vehicle lateral accelerometer trace for test 7069-34 (accelerometer located at front of vehicle).

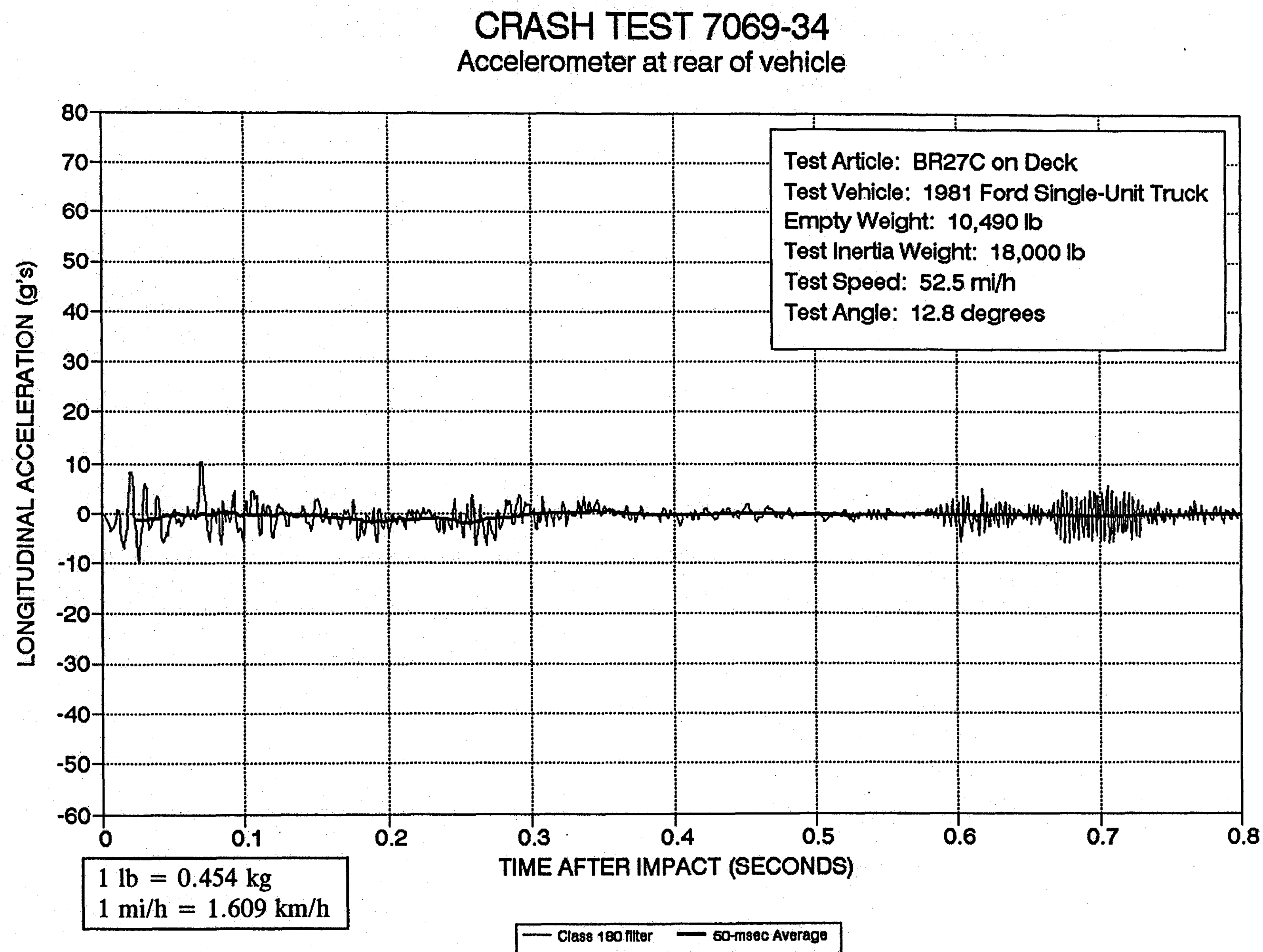
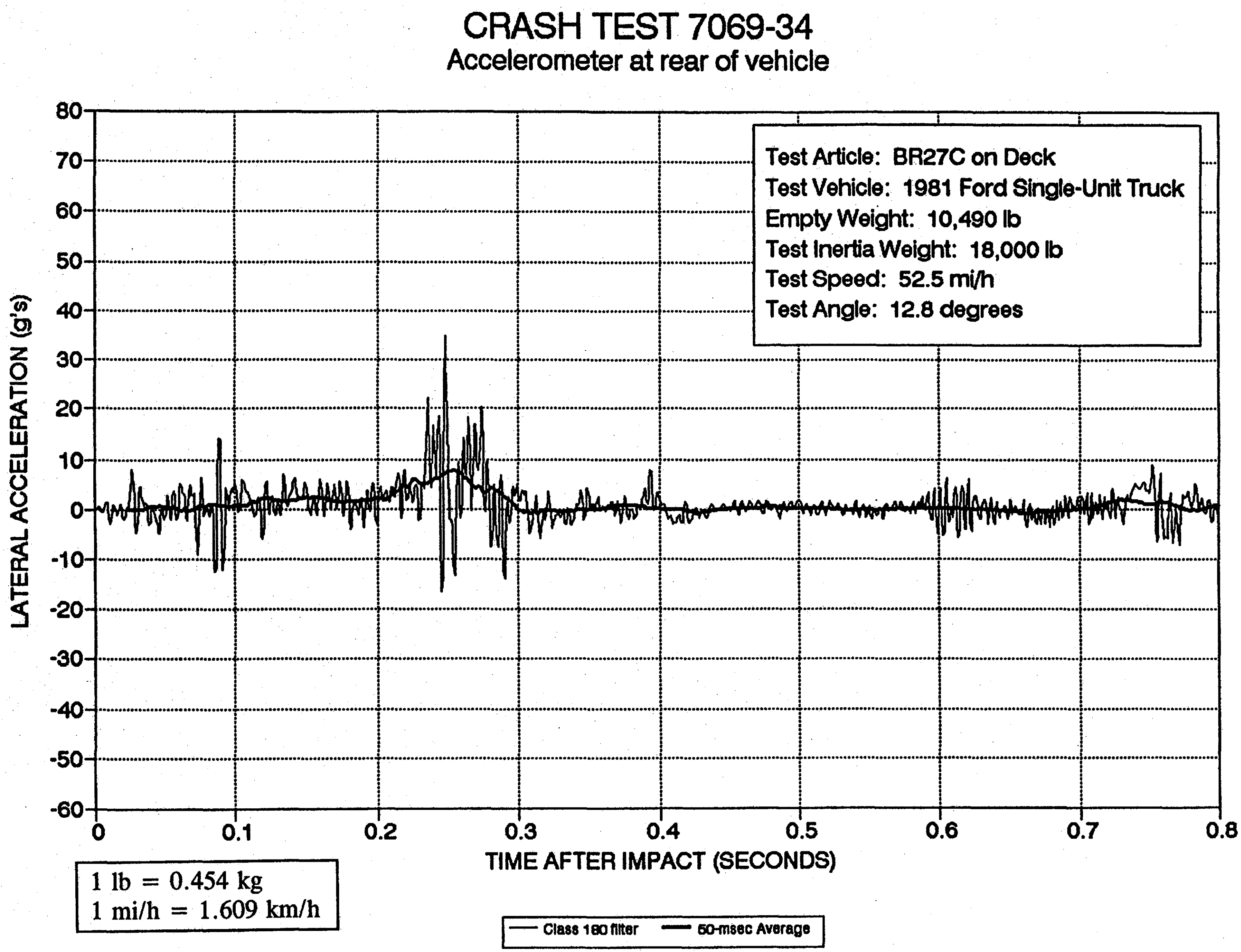


Figure 102. Vehicle longitudinal accelerometer trace for test 7069-34 (accelerometer located at rear of vehicle).



1 lb = 0.454 kg
1 mi/h = 1.609 km/h

Figure 103. Vehicle lateral accelerometer trace for test 7069-34 (accelerometer located at rear of vehicle).

CHAPTER 4. STRENGTH CALCULATIONS

The railing consists of a metal beam-and-post portion mounted on top of a concrete parapet. Strength of the metal portion is first analyzed assuming that the concrete parapet has adequate strength to support the metal railing. Equations given in figure 104 are used to compute strength of the metal railing.[2] The metal rail element is a TS 4 by 3 by 1/4-in (102 by 76 by 6-mm) ASTM A500 grade B with a plastic section modulus of 3.3 in^3 (54 077 mm^3) and a plastic moment capacity of 12.7 ft-kips (17.2 m-kN).

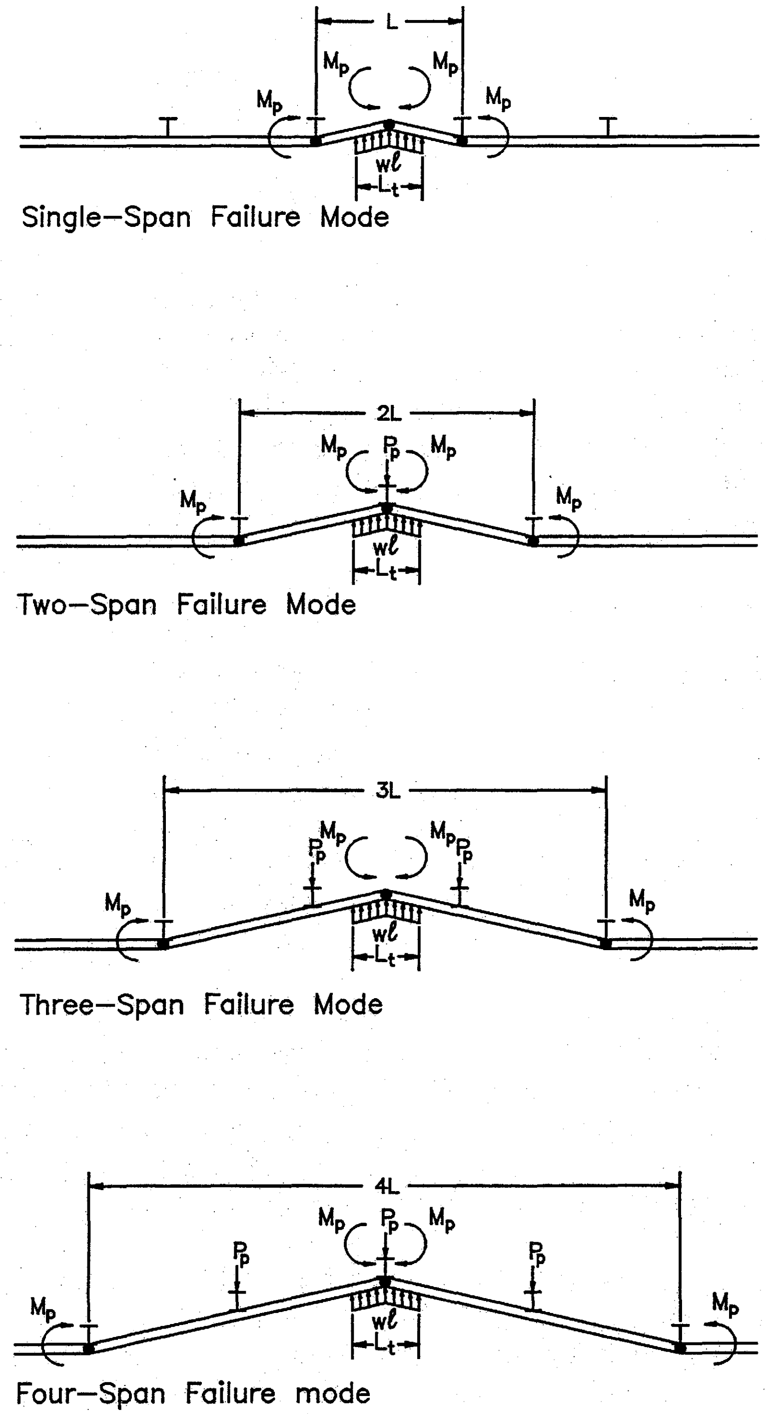
The plastic moment capacity of the post section [TS 4 by 4 by 3/16-in (102 by 102 by 5-mm) ASTM grade B] is 15.0 ft-kips (20.4 m-kN). The anchor bolts provide a computed moment capacity at the base of the post of 23.1 ft-kips (31.4 m-kN). The post-to-baseplate weld provides a moment capacity of 11.3 ft-kips (15.3 m-kN) which is the controlling failure mode. It is noted that the strength of the weld should be increased so that the moment capacity of the post section would control and the plastic hinge would be forced into the post section rather than in the welded connection.

The resistance of the post to lateral load depends on the location of the applied force.

If the force were located at the metal rail element, it would be 16 in (406 mm) above the base of the post and the strength of the post would be 8.5 kips (37.8 kN). Under this loading situation, the strength of the metal portion of the railing, computed in accordance with figure 104, would be 20.6 kips (91.7 kN) for a one-span mechanism, 18.6 kips (82.8 kN) for a two-span mechanism, 18.0 kips (80.1 kN) for a three-span mechanism, and 22.3 kips (99.2 kN) for a four-span mechanism. The three-span mechanism controls and computed capacity of the railing is 18.0 kips (80.1 kN). The force would be located at 40 in (1.02 m) above the top of the sidewalk.

The strength of the concrete parapet may be analyzed using the equations for the yieldline mechanism shown in figure 105. Computed cantilever moment capacity of the parapet, M_c, is 10.8 ft-k/ft (48.1 m-kN/m). Moment capacity of the parapet about a vertical axis, M_w, is 19.6 ft-k/ft (87.2 m-kN/m). No additional beam stiffening exists along the top of the parapet; therefore, M_b is zero. These values result in a length of failure mechanism, L, of 9.6 ft (2.9 m) and computed strength of the parapet is 73.3 kips (326.2 kN).

If it is assumed that load is applied to the metal rail element and to the parapet such that maximum resistance of the railing system is obtained, a three-span failure mechanism would be involved in the metal portion of the railing and a yieldline failure pattern in the parapet would be located at midlength of the failure mechanism in the metal railing. Total strength of the railing system would be approximately 18.0 kips (80.1 kN) plus 73 kips (324.9 kN) equals 91 kips (405 kN) located 27 in (686 mm) above the sidewalk.



$$w\ell = \frac{16M_p}{2L - L_t}$$

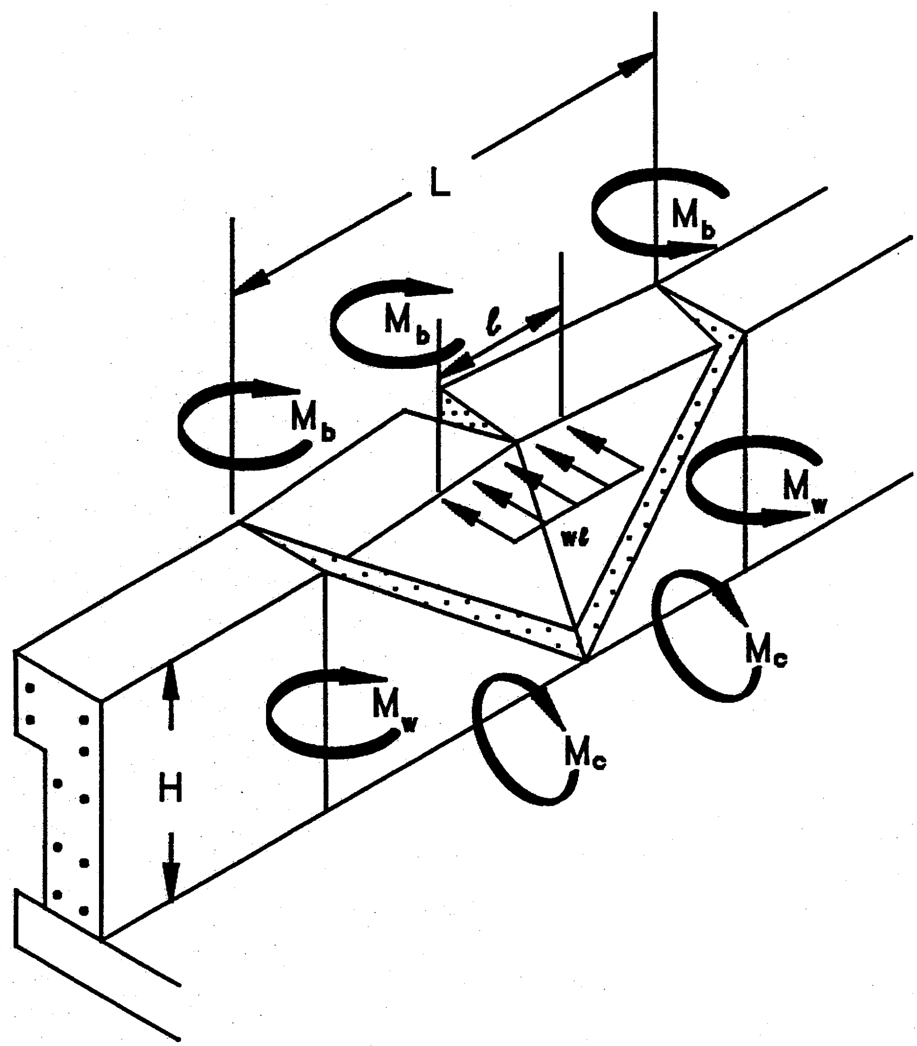
$$w\ell = \frac{16M_p + 4P_p L}{4L - L_t}$$

$$w\ell = \frac{16M_p + 8P_p L}{6L - L_t}$$

$$w\ell = \frac{16M_p + 16P_p L}{8L - L_t}$$

Longer mechanisms may also be possible.

Figure 104. Plan view illustrating some possible failure mechanisms.



$$L = \frac{\ell}{2} + \sqrt{\left(\frac{\ell}{2}\right)^2 + \frac{8H(M_b + M_w H)}{M_c}}$$

$$(w\ell)_{ult} = \frac{8M_b}{L - \frac{\ell}{2}} + \frac{8M_w H}{L - \frac{\ell}{2}} + \frac{M_c L^2}{H\left(L - \frac{\ell}{2}\right)}$$

Figure 105. Yieldline failure pattern for concrete parapet.

REFERENCES

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

2. Hirsch, T. J., "Analytical Evaluation of Texas Bridge Rails to Contain Buses and Trucks," Research Report 230-2, Texas Transportation Institute, Texas A&M University, College Station, TX, August 1978.