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DISCLAIMER STATEMENT

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1 INTRODUCTION

1.1 Background

The Coordinated Federal Lands Highways Technology Improvement Program (CTIP) was developed with the purpose of serving the immediate needs of those who design and construct Federal Lands Highways, including Indian Reservation roads, National Park roads and parkways, and forest highways. A wide assortment of guardrails, bridge rails and transitions are being used on roads under the jurisdiction of the National Park Service and other Federal agencies. These guardrails, bridge rails and transitions are intended to blend in with the roadside in order to preserve the visual integrity of the parks and parkways. However, many of them have never been crash tested (1,2). A testing program was developed in order to ensure that the safety hardware used in these areas are safe for the traveling public. The Steel Backed Log Rail was included in the second Federal Highway Administration (FHWA) testing program - Guardrail Testing Program II.

1.2 Test Installation

The Steel-Backed Log Rail was constructed from 10-in. diameter logs backed by 6-in. x ⅜-in. x 9-ft 9-in. ASTM A588 steel plates. Backup plates were attached to the log rails with ⅝-in. x 4-in. lag screws and the 10 ft long rail elements were connected with 6 in. x ⅜ in. x 2-ft. 6-in. ASTM A588 steel splice plates. The railing was mounted on 12 in. diameter round posts with cast steel blockouts placed at each splice joint. The center of the rail elements was placed at a height of 1 ft - 9 in.

Both the posts and rail elements of this 80 ft long system consisted of ponderosa pine. All fastener hardware was manufactured from steel conforming to ASTM A588. Photographs of the Steel-Backed Log Rail are shown in Figures 1 and 2. Design details are shown in Figures 3 and 4.

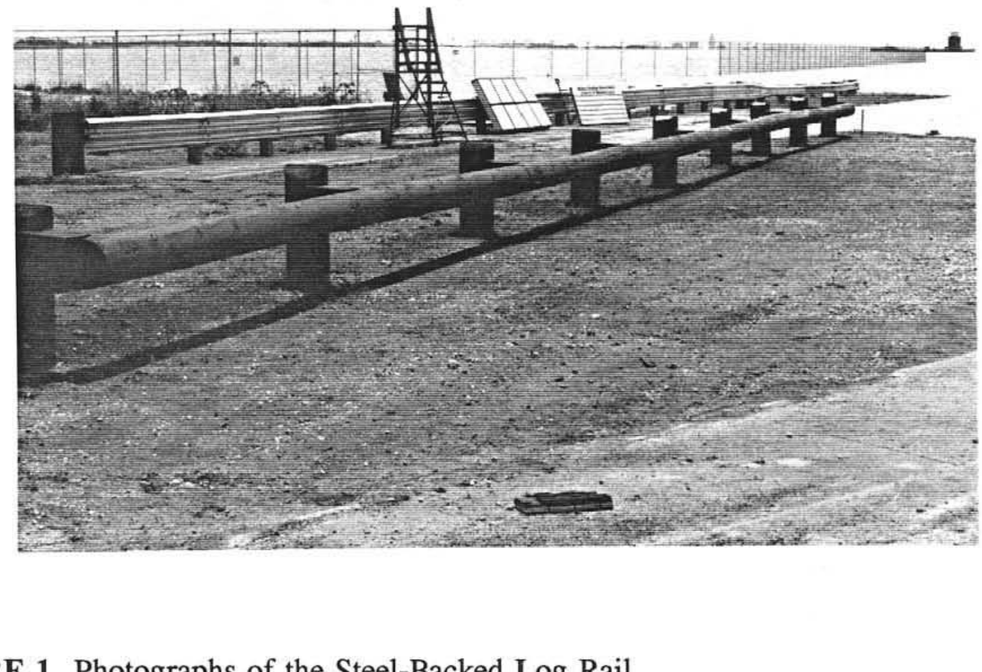


FIGURE 1. Photographs of the Steel-Backed Log Rail

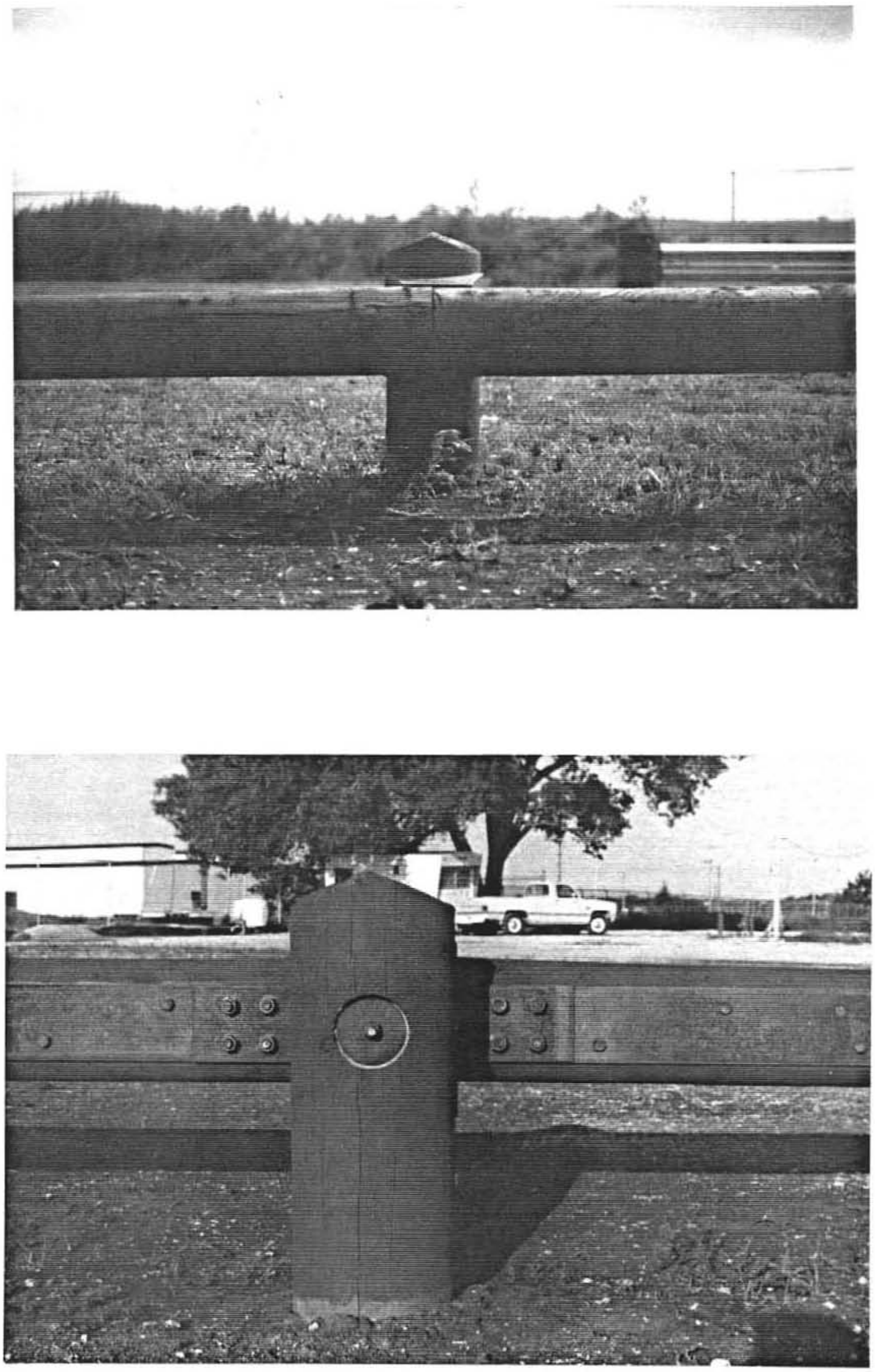


FIGURE 2. Photographs of the Steel-Backed Log Rail (continued)

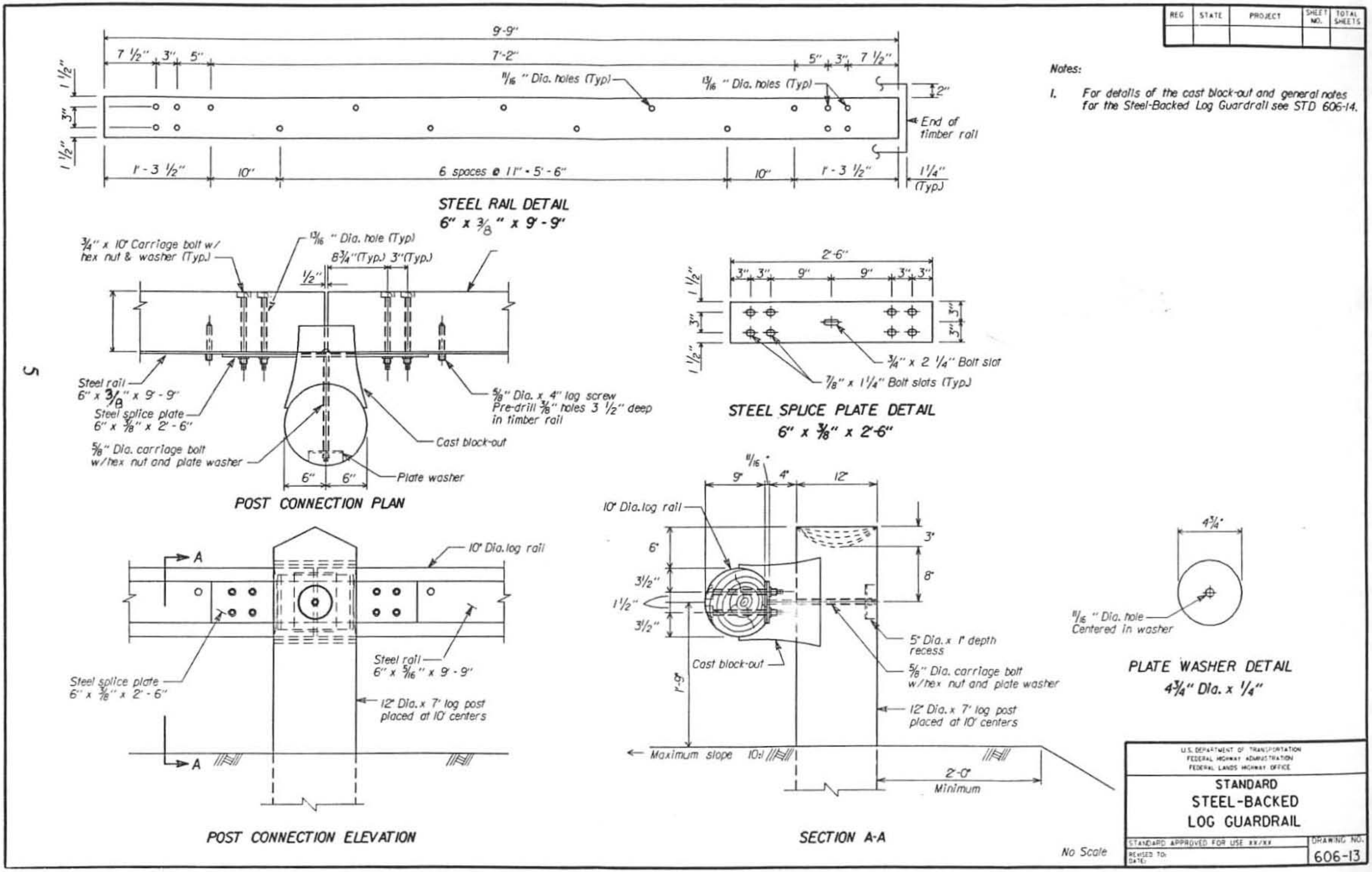


FIGURE 3. Details of the Steel-Backed Log Rail System

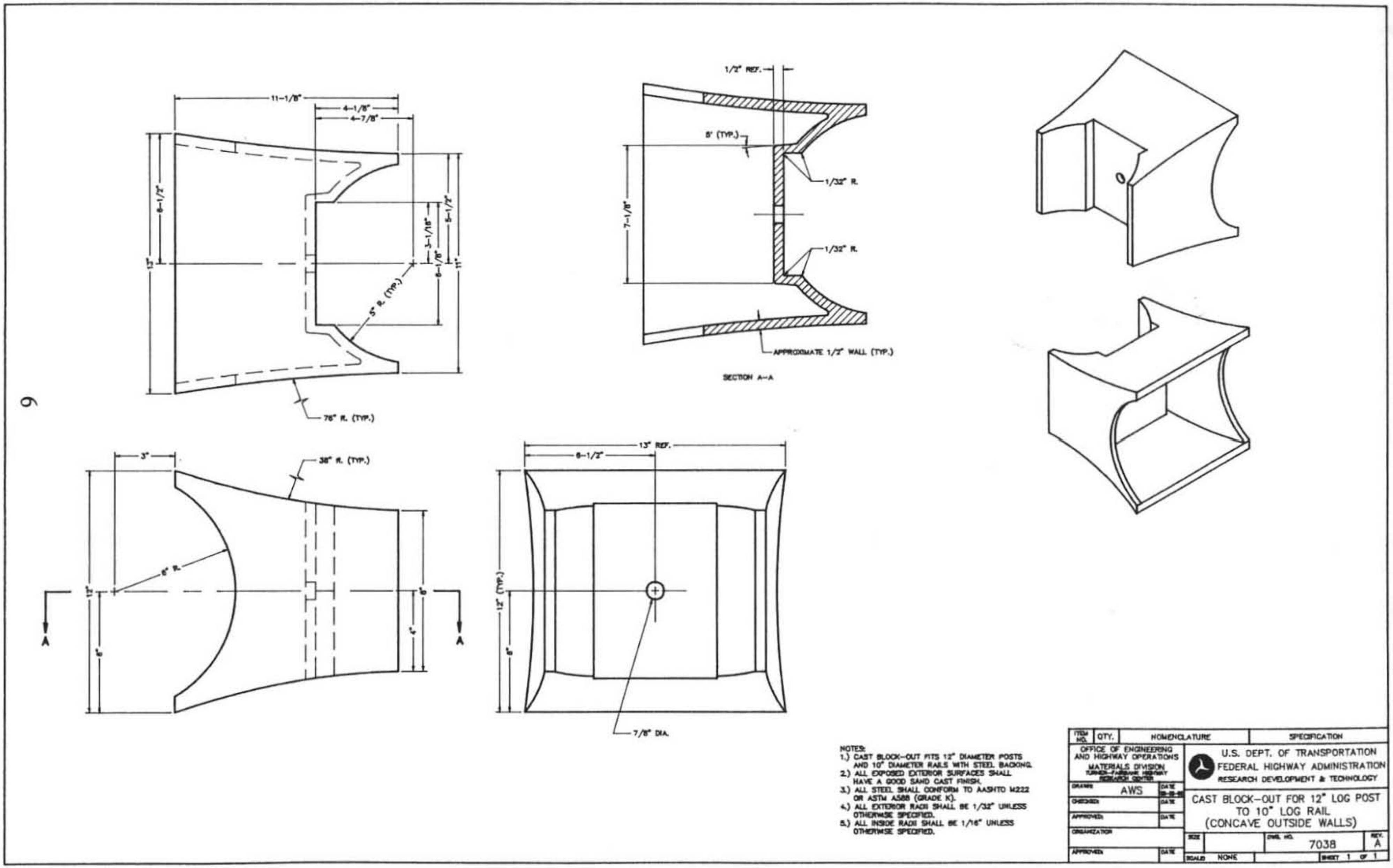


FIGURE 4. Details of the Cast Steel Blockout used in the Steel-Backed Log Rail System

2 TEST CONDITIONS

2.1 Test Vehicles

A 1984 Dodge Colt, shown in Figure 5, was used as a test vehicle in Test SBLR-1. As shown in Figure 6, the vehicle had a test inertial and a gross static weight of 1850 lbs and 2015 lbs, respectively.

A 1986 3/4 ton Chevrolet pickup, shown in Figure 7, was used as a test vehicle in Test SBLR-2. This vehicle had test inertial and gross static weights of 5400 lbs and 5565 lbs, respectively. Vehicle weights and dimensions are shown in Figure 8.

Center of gravity heights for both vehicles were determined using the suspension method (3). This method is based on the principle that the center of gravity of any freely suspended body is in the vertical plane through the point of suspension. Each vehicle was suspended in three positions, and the respective planes containing the center of gravity were established. The intersection of these planes pinpointed the location of the center of gravity. The longitudinal location of the center of gravity was confirmed by using the axle weights of the vehicles.

Black and white-checkered targets were placed on the vehicle for high-speed film analysis. Two targets were located on the center of gravity, one on the top and one on the driver's side of the test vehicle. Additional targets, visible from all three high speed cameras, were located for reference. The front wheels of the test vehicle were aligned for camber, caster, and toe-in values of zero so that the vehicle would track properly along the guide cable. Two 5B flash bulbs, fired by a pressure tape switch on the front bumper, were mounted on the roof of each vehicle to establish the time of impact on the high-speed film.

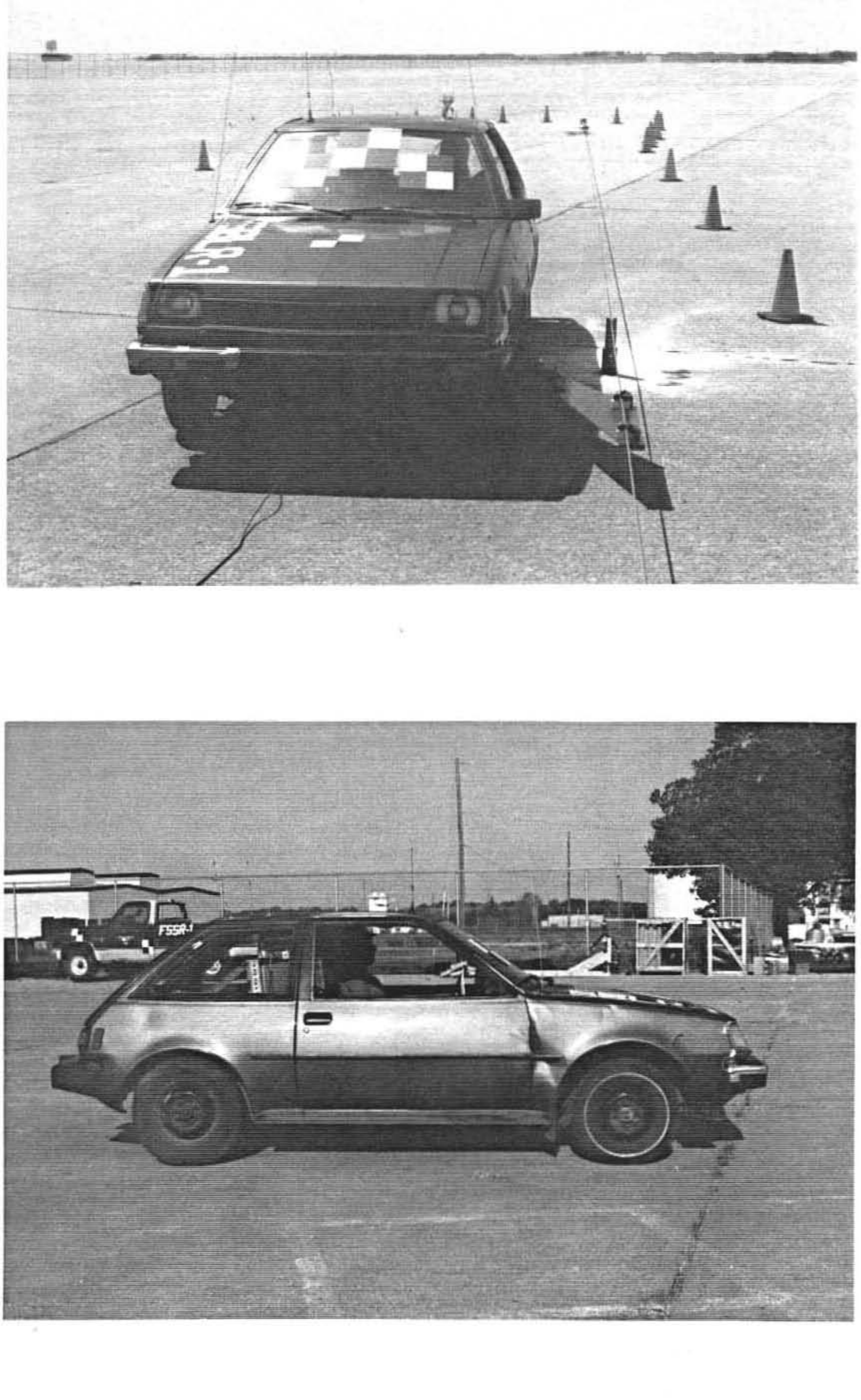
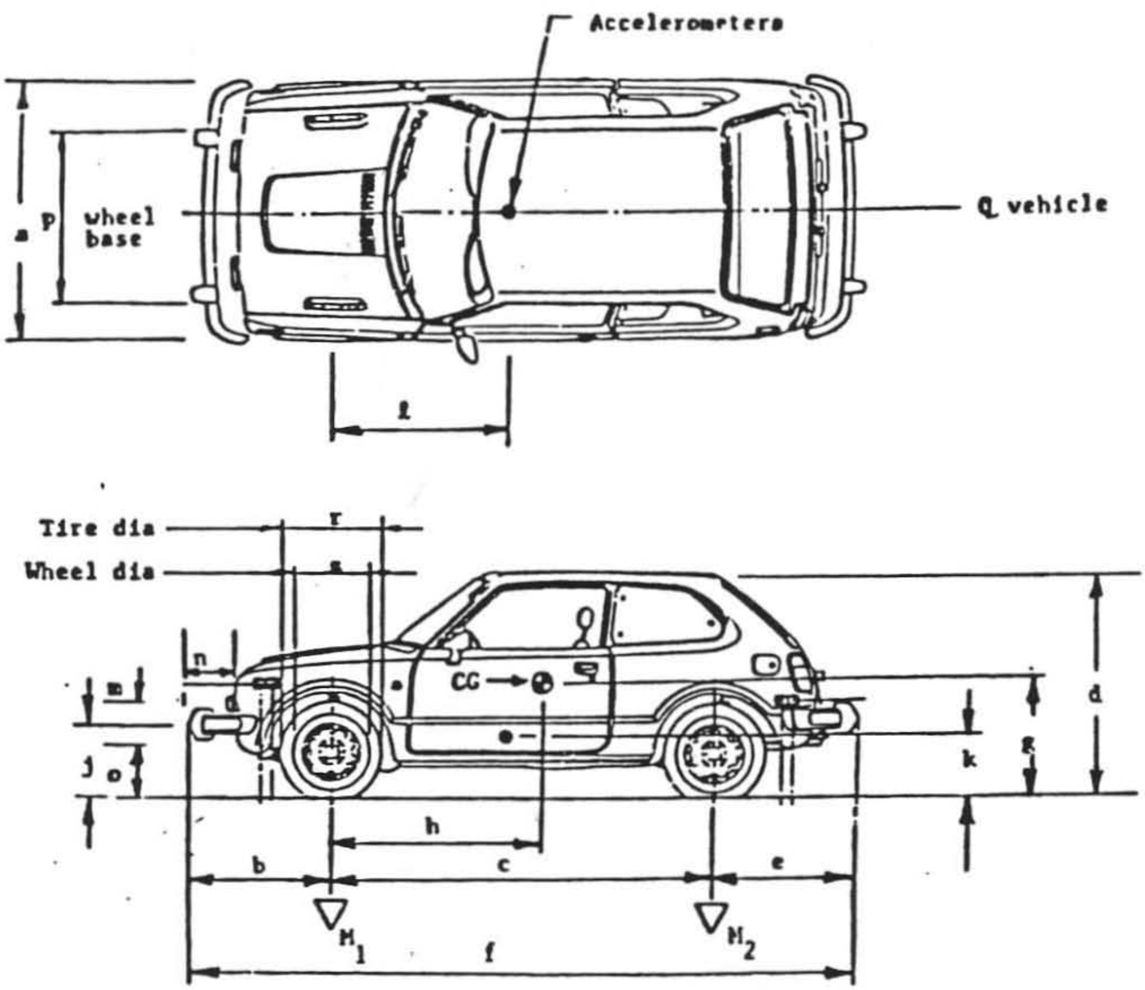


FIGURE 5. Test Vehicle, Test SBLR-1



Geometry - in.

a 62.0	d 52.0	j 18.0	m 5.0	p 54.0
b 33.5	e 32.0	k 17.0	n 6.25	r 22.5
c 90.0	f 155.5	ℓ 46.5	o 15.5	s 14.0

Mass - lb	Curb	Test Inertial*	Gross Static**
M_1	1107	1205	1290
M_2	552	645	725
M_T	1659	1850	2015
h - in. (m)	31.75	31.75	31.75
g - in. (m)	21.0	21.0	21.0

Vehicle Type
1984 Dodge Colt

* Ready for test but excludes passenger/cargo payload
** Gross ready for test including passenger/cargo payload

FIGURE 6. Vehicle Dimensions, Test SBLR-1

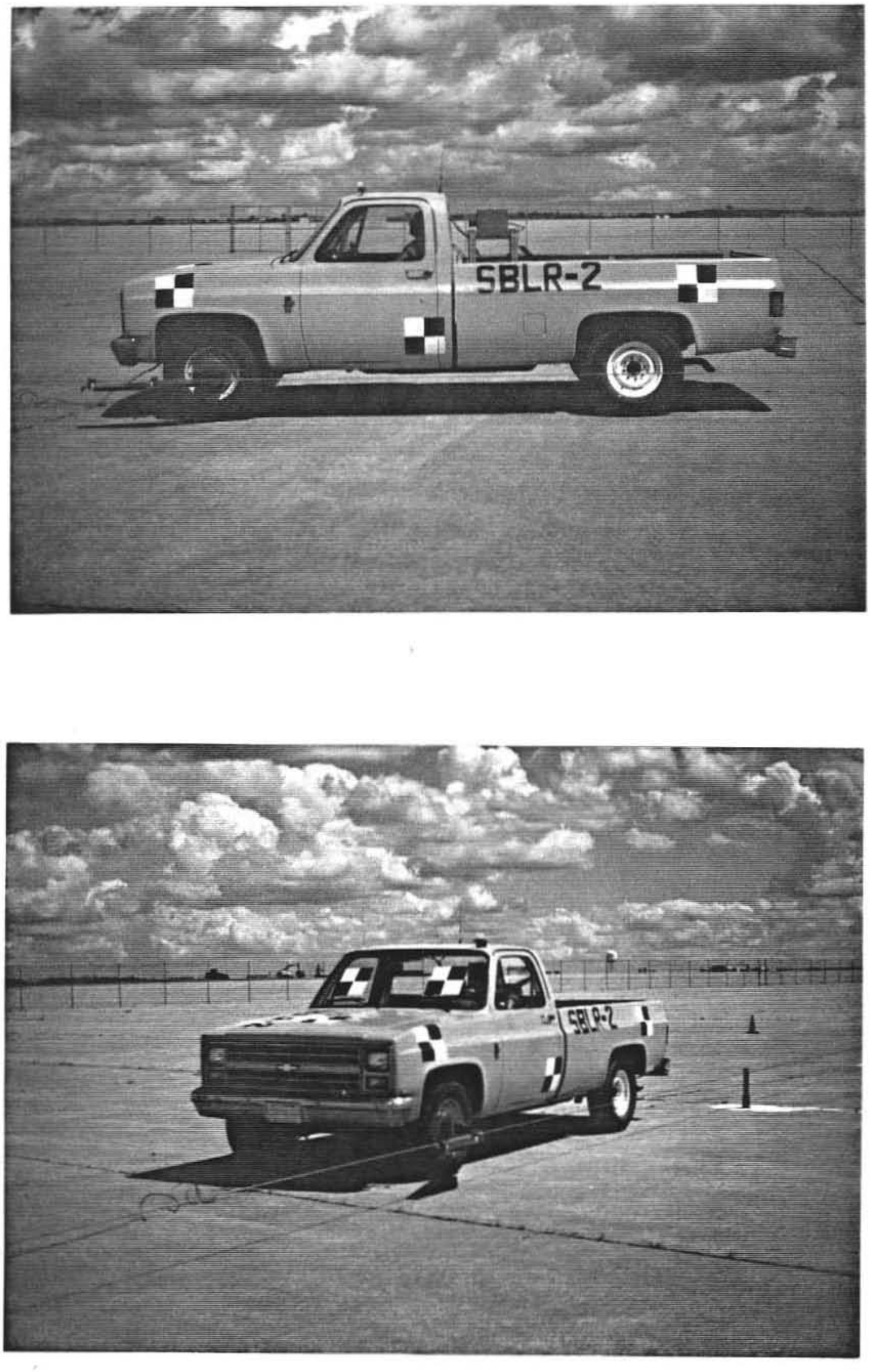
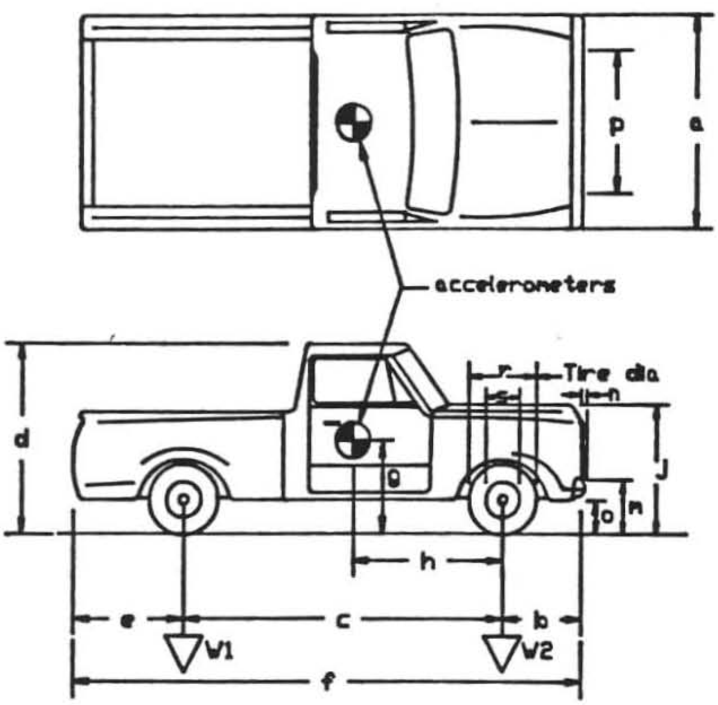


FIGURE 7. Test Vehicle, Test SBLR-2

Date: 7/29/92 Test No.: SBLR-2 Vehicle I.D. #: 1GC6C24M31116120

Make: Chevrolet Model: Custom Deluxe 20 Year: 1986 Odometer: ______

Tire Size: 7.5 16LT



Vehicle Geometry - inches

a	78	b	31.5
c	132	d	72
e	52	f	215.5
g	27	h	67
i	--	j	45
k	--	l	--
m	27	n	3
o	18.5	p	66
r	30.5	s	17

Engine Type: V8

Engine Size: 350 cu. in.

4 - wheel weight: lf____ rf____ lr____ rr____

Transmission Type:

Automatic or Manual

FWD or [RWD] or 4WD

Weight - pounds	Curb	Test Inertial	Gross Static
W1	2600	2760	2840
W2	2000	2640	2725
Wtotal	4600	5400	5565

Note any damage prior to test: None

FIGURE 8. Vehicle Dimensions, Test SBLR-2

2.2 Data Acquisition Systems

2.2.1 Accelerometers

Two triaxial piezoresistive accelerometer systems with a range of ± 200 g's (Endevco Model 7264) were used to measure vehicle accelerations. The accelerometers were rigidly attached to a metal block mounted near the vehicle's center of gravity. Accelerometer signals were received and conditioned by an onboard Series 300 Multiplexed FM Data System built by Metraplex Corporation. The multiplexed signal was then transmitted to a Honeywell 101 Analog Tape Recorder. "Computerscope" computer software was used to digitize accelerometer data and transfer it to a Cyclone 386/16 Mhz computer with a high-speed data acquisition board. "DSP" computer software was then used to analyze and plot the data on a PC Brand 486/33 Mhz computer.

2.2.2 High Speed Photography

Four high-speed 16-mm cameras, with operating speeds of approximately 500 frames/sec were used to film the crash tests. A Red Lake Locam with a 12.5 mm lens was placed above the test installation to provide a field of view perpendicular to the ground. A Photec IV, with an 80-mm lens, was placed downstream from the impact point and had a field of view parallel to the barrier. A second Photec IV, with a 55-mm lens, was placed on the traffic side of the bridge rail and had a field of view perpendicular to the barrier. Another Red Lake Locam with a 5.7-mm lens was placed onboard the vehicle to record dummy motions during the test. A schematic of the camera locations for each test is shown in Figure 9. A white-colored backboard with a 2-ft by 2-ft grid was placed behind the rail in view of the overhead camera. This backboard provided a visible reference system to use in the analysis of the overhead high-speed film. The film was analyzed using a Vanguard Motion Analyzer.

2.2.3 Speed Trap

Eight tape pressure switches spaced at 5-ft intervals were used to determine the speed of the vehicle before and after impact. Each tape switch fired a strobe light and sent an electronic timing mark to the data acquisition system as the left front tire of the test vehicle passed over it. Test vehicle speeds were determined from electronic timing mark data recorded on the analog tape. Strobe lights and high speed film analysis are used only as a backup in the event that vehicle speeds cannot be determined from the electronic data.

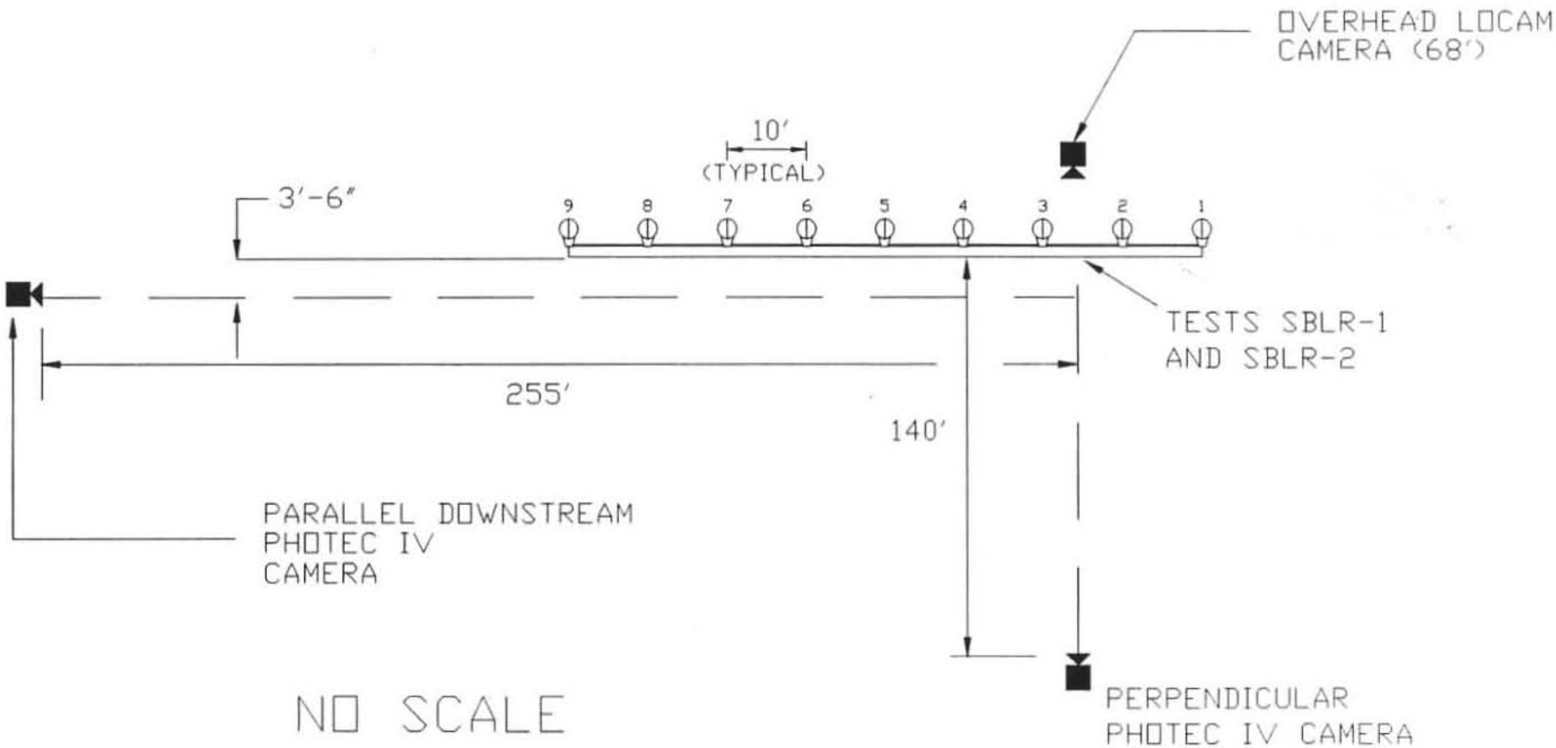


FIGURE 9. Layout of High-Speed Cameras

3 TEST RESULTS

3.1 Test SBLR-1 (1850 lbs, 50.6 mph, 19.2 deg)

The 1984 Dodge Colt was directed into the Steel-Backed Log Rail using a reverse tow and cable guidance system (4). The vehicle was released from the tow cable and guidance system and was free wheeling at impact. The speed of the vehicle at impact was 50.6 mph and the angle of impact was 19.2 degrees. The impact point, shown in Figure 10, was located midspan between Post Nos. 2 and 3, or 15 ft from the upstream end of the installation. A summary of the test results and sequential photographs is shown in Figure 11. Additional sequential photographs are shown in Figures 12 through 14.

Upon impact with the log rail, the front bumper slipped under the rail, and the front right corner of the vehicle began to crush inward. The vehicle slid along the log rail and reached Post No. 3 approximately 64 ms after impact. 216 ms after impact the vehicle reached Post No. 4 and became parallel to the rail at approximately 352 ms. The vehicle exited the rail at an angle of 2 degrees approximately 503 ms after impact. After exiting the rail, the vehicle continued to travel downstream and to the left, coming to a rest 240 ft downstream from impact and 153 ft to the left of a line parallel to the railing face. This vehicle trajectory is shown in Figure 15.

Test vehicle damage was relatively minor and was largely limited to the right-front quarter panel and passenger door, as shown in Figure 16. There was no intrusion or deformation of the occupant compartment. Vehicle crush measurements are shown in Figure 17.

Damage to the Log Rail consisted of minor scrapes on the surface of the rail and a maximum permanent deflection of 2 $^{15}/_{16}$ in. at the first post after impact. This damage can be seen in Figure 18. The effective coefficient of friction was found to be 1.02 and would be classified as "marginal" according to the AASHTO Guide Specifications for Bridge Railings (5).

The longitudinal and lateral occupant impact velocities as determined from accelerometer data were 24.3 fps and 21.1 fps, respectively. The highest 10-ms average occupant ridedown decelerations were 3.9 g's (longitudinal) and 4.8 g's (lateral). Accelerometer traces from Test SBLR-1 are shown in Appendix A.

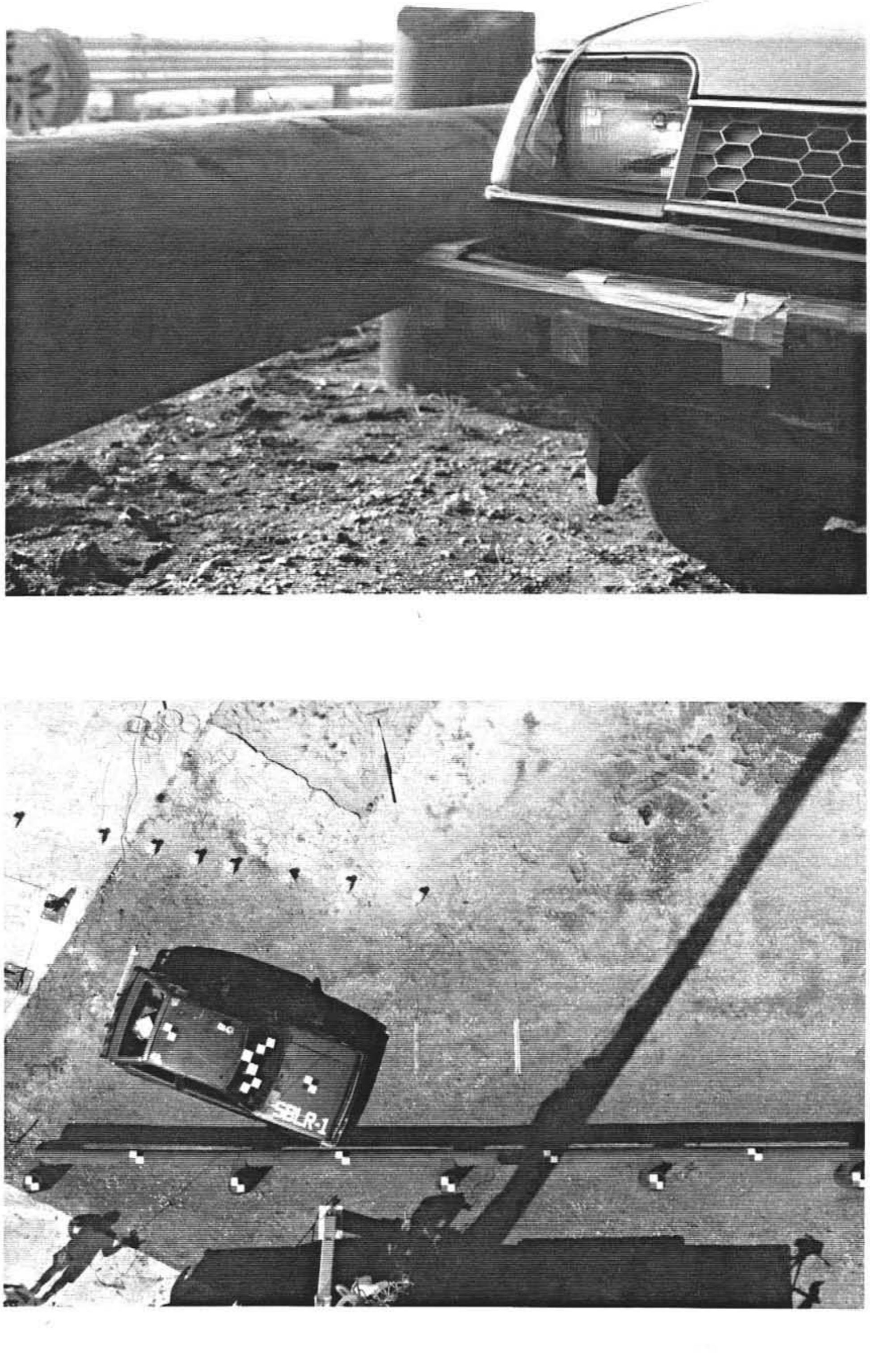
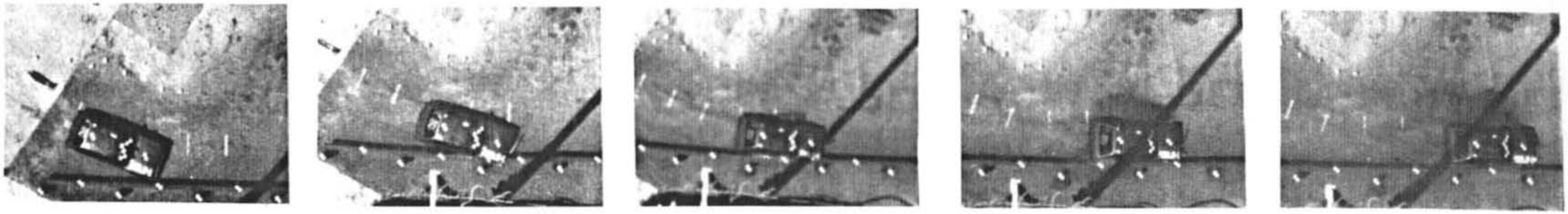
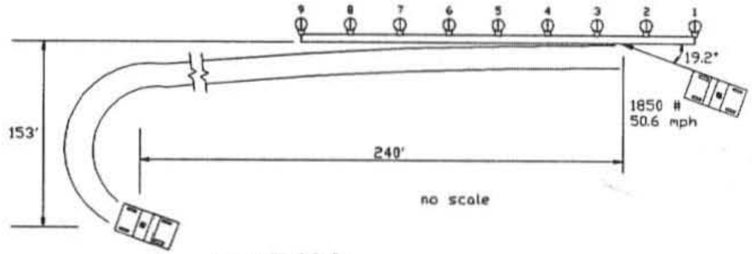


FIGURE 10. Vehicle Impact Location, Test SBLR-1



Impact | 105 ms | 209 ms | 314 ms | 418 ms



Test Number	SBLR-1
Date	6/18/92
Installation	Steel Backed Log Guardrail
Installation Length	80 ft
Post	
Material	Ponderosa Pine
Diameter	12 in.
Length	7 ft
Rail Sections	
Material	Ponderosa Pine
Diameter	10 in.
Length	10 ft
Backup Plate	
Material	ASTM A588 Steel
Dimensions	6 in. x 3/8 in. x 9 ft-9 in.
Splice Plate	
Material	ASTM A 588 Steel
Dimensions	6 in. x 3/8 in. x 30 in.
Cast Blockout	
Material	ASTM A588 Steel

Test Vehicle	1984 Dodge Colt
Weight	
Test Inertial	1850 lbs
Gross Static	2015 lbs
Impact Speed	50.6 mph
Impact Angle	19.2 deg
Exit Speed	28.2 mph
Exit Angle	2 deg
Occupant Impact Velocity	
Longitudinal	24.3 fps
Lateral	21.1 fps
Occupant Ridedown Deceleration	
Longitudinal	3.9 g's
Lateral	4.8 g's
Vehicle Damage	
TAD	1-RFQ-4
VDI	01RYES2
Vehicle Rebound Distance	6 ft-11 in. @ 113 ft
Coefficient of Friction	1.02

FIGURE 11. Test SBLR-1 Summary

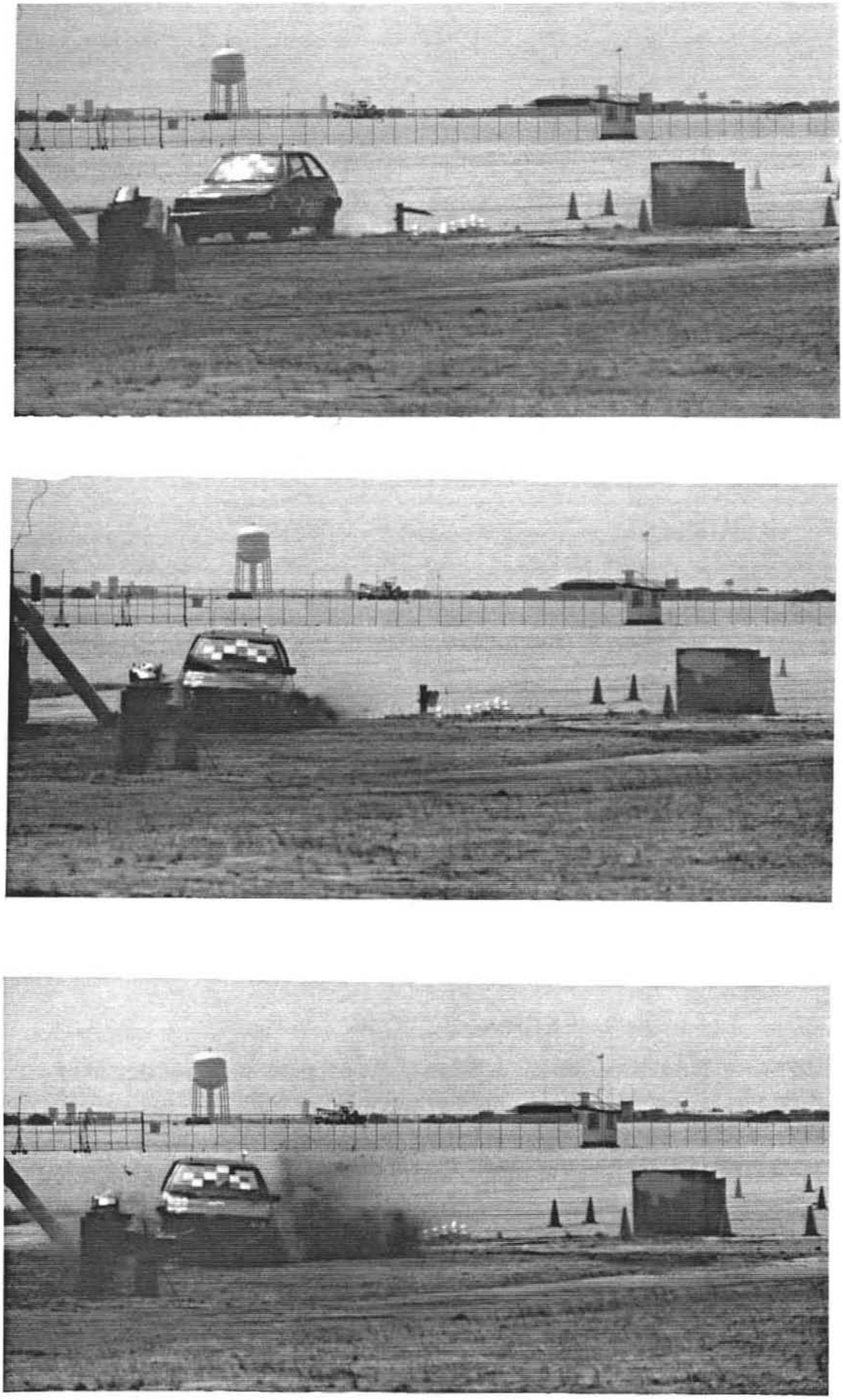


FIGURE 12. Downstream Sequential Photographs, Test SBLR-1

FIGURE 13. Downstream Sequential Photographs, Test SBLR-1 (continued)

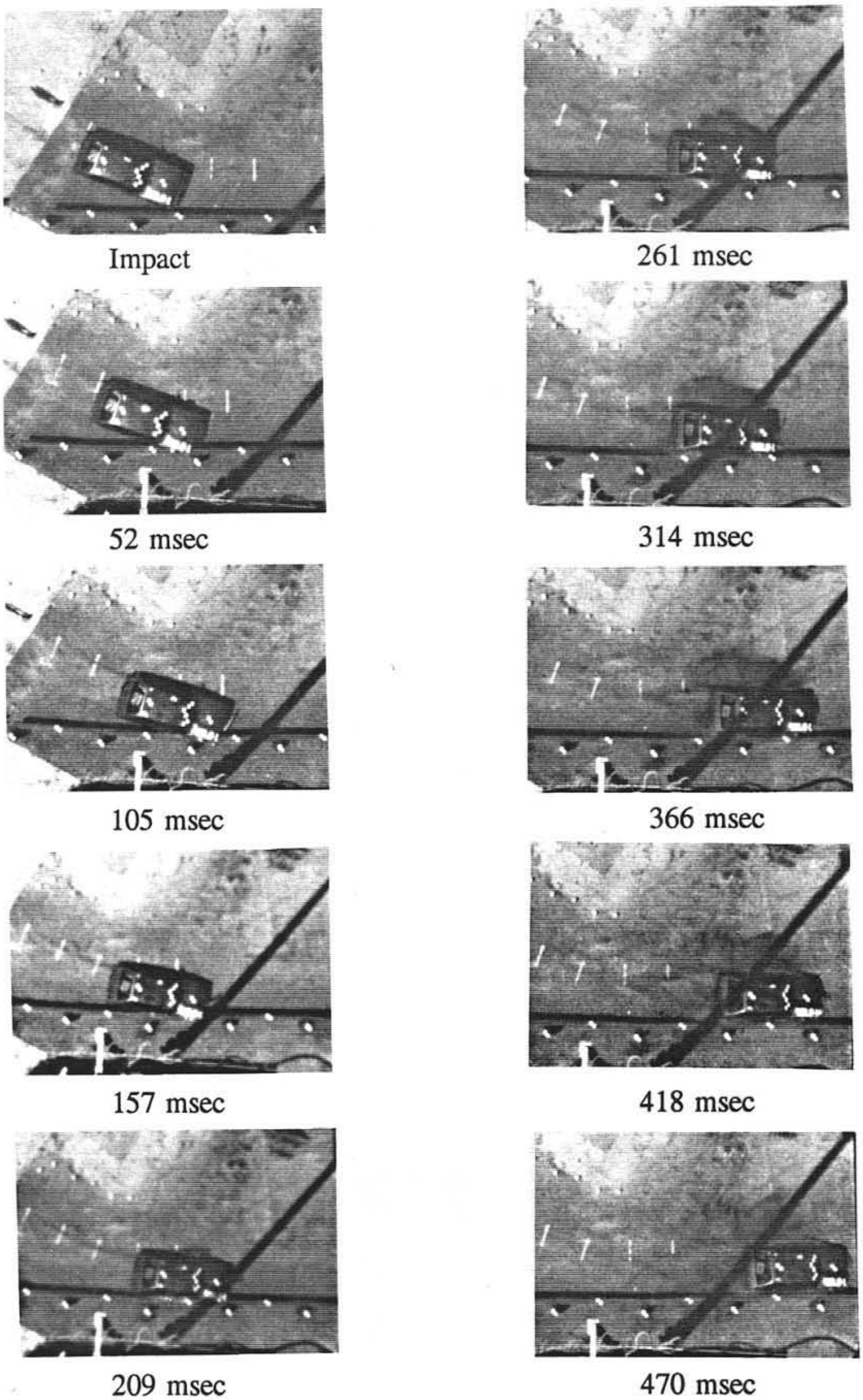


FIGURE 14. Overhead Sequential Photographs, Test SBLR-1

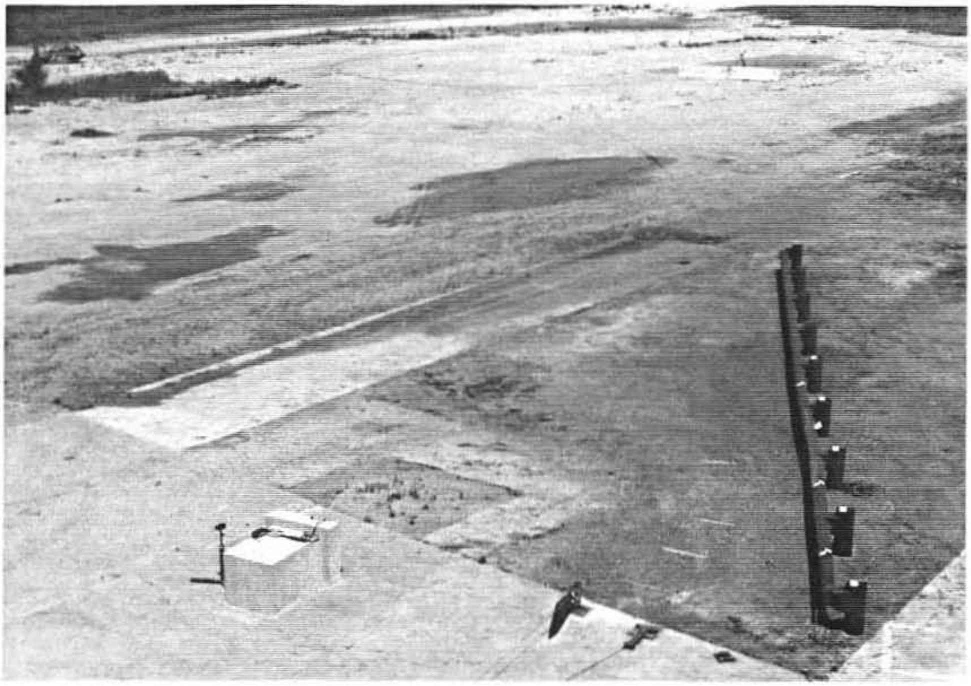


FIGURE 15. Vehicle Trajectory, Test SBLR-1

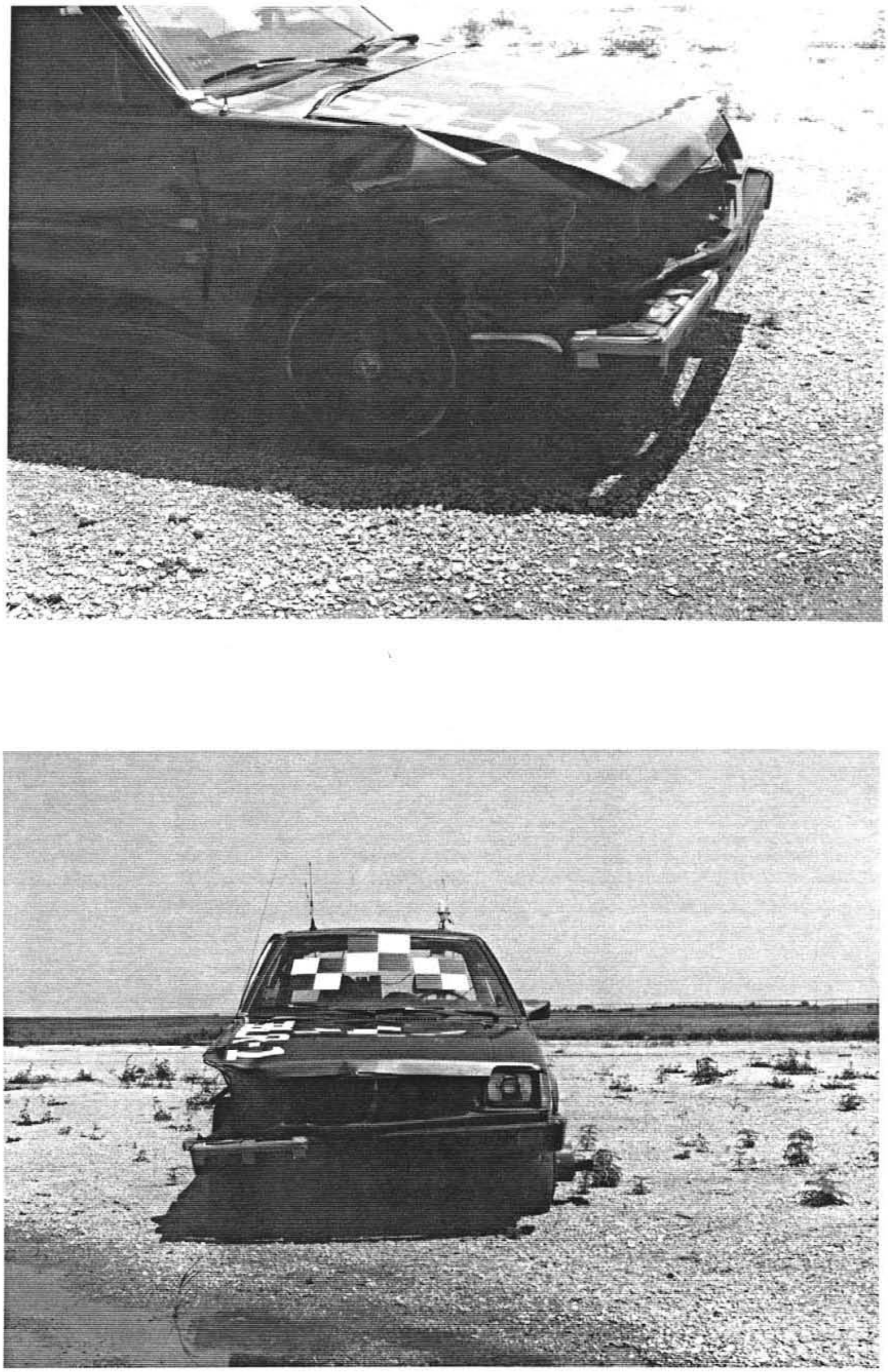


FIGURE 16. Vehicle Damage, Test SBLR-1

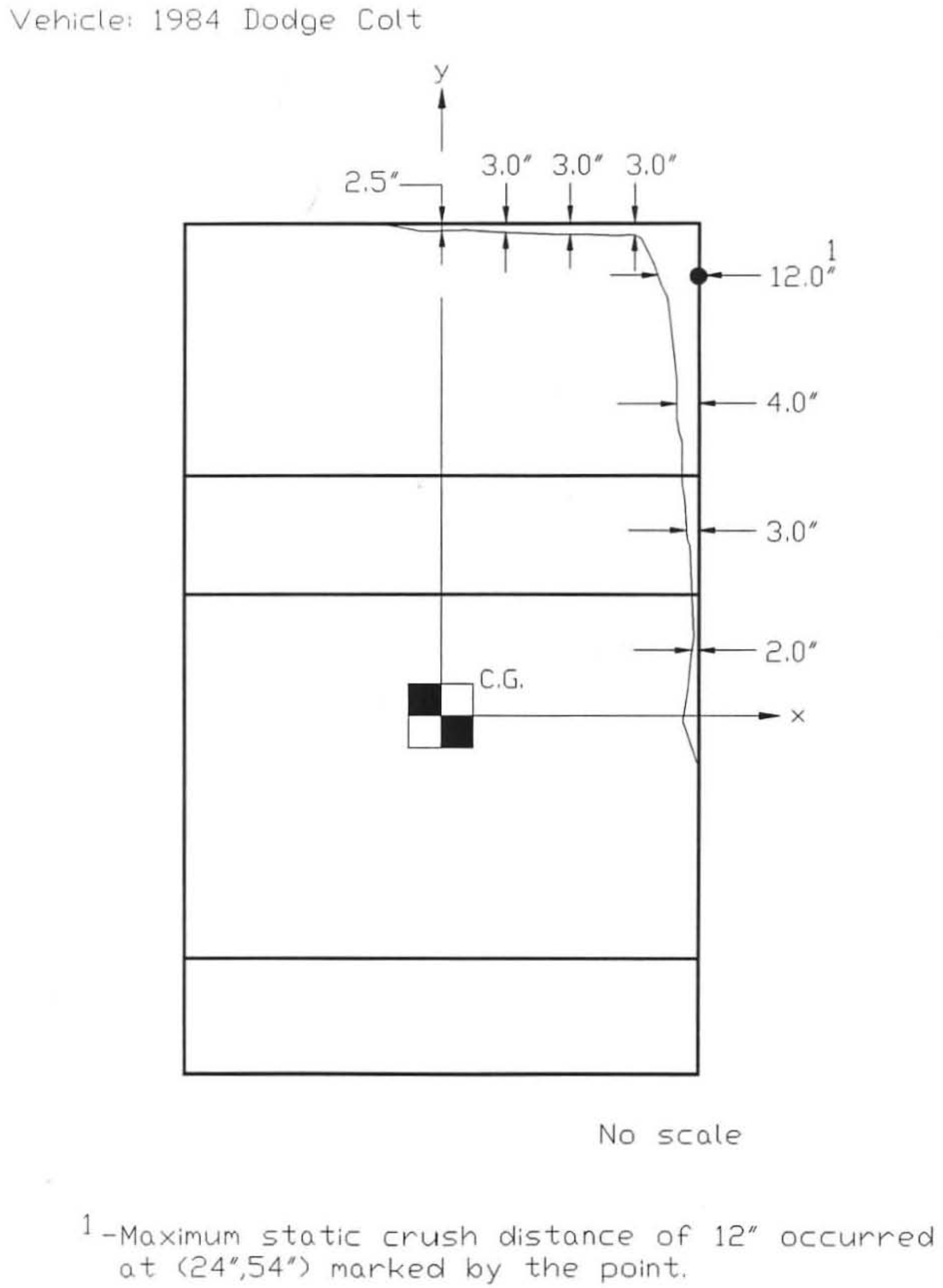


FIGURE 17. Vehicle Crush Measurements, Test SBLR-1

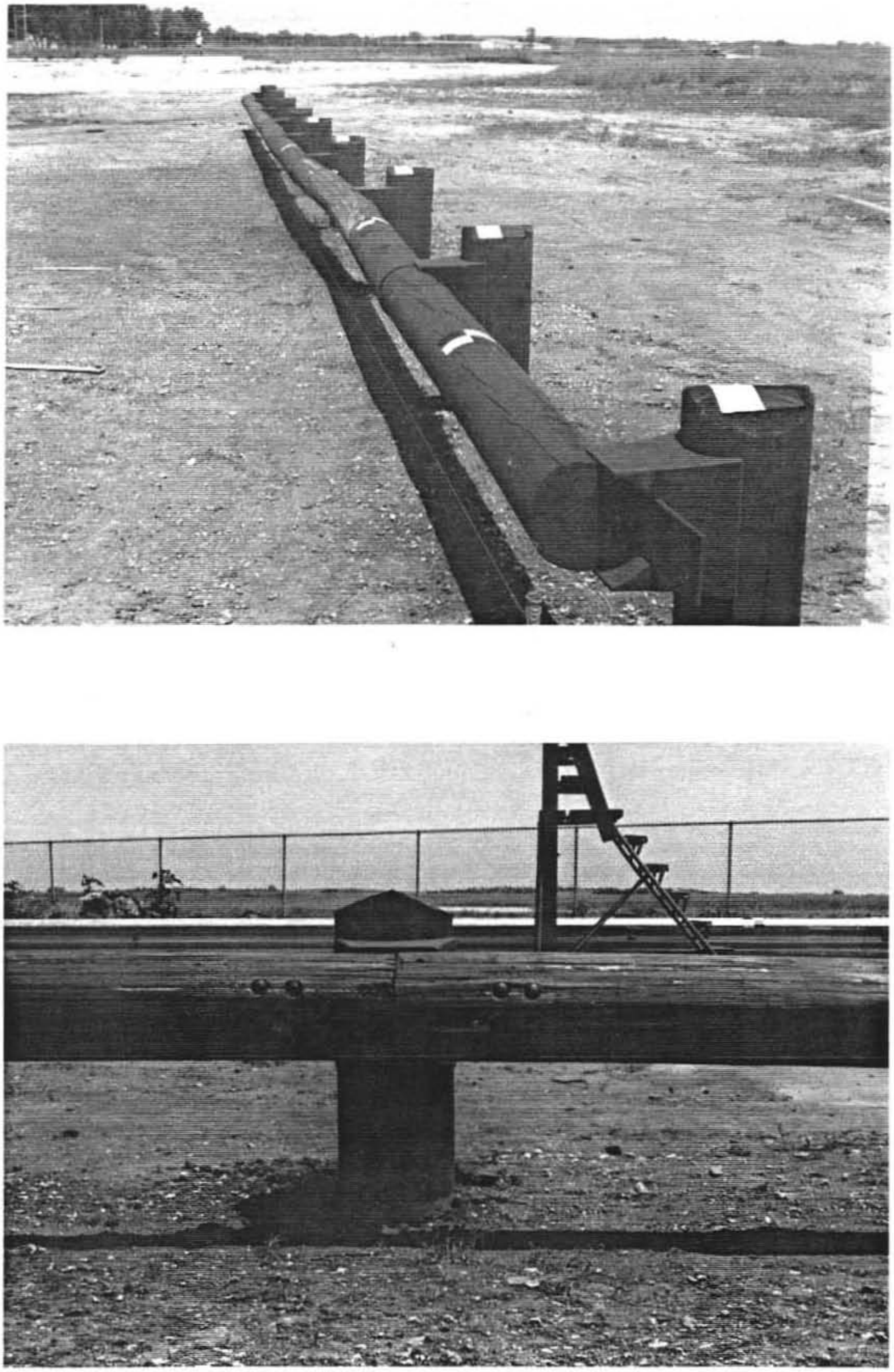


FIGURE 18. Log Rail Damage, Test SBLR-1

3.2 Test SBLR-2 (5400 lbs, 46.1 mph, 20.9 deg)

A 1986 3/4 ton Chevrolet Pickup was directed into the steel-backed log rail using a reverse tow and cable guidance system (4). The vehicle was released from the tow cable and guidance system and was free wheeling at impact. The speed of the vehicle at impact was 46.1 mph and the angle of impact was 20.9 degrees. The impact point, shown in Figure 19, was located midspan between Post Nos. 2 and 3, or 15 ft from the upstream end of the rail. A summary of the test results and sequential photographs is shown in Figure 20. Additional sequential photographs are shown in Figures 21 and 22.

Upon impact, the bumper of the test vehicle began to ride up onto the log rail. The vehicle traveled along the top of the log rail until it reached Post No. 5 approximately 448 ms after impact. After impacting Post No. 5, the vehicle began to rotate clockwise, coming to rest perpendicular to the rail, 45 ft downstream from impact. The vehicle trajectory is shown in Figure 23.

Test vehicle damage, shown in Figure 24, was limited to the undercarriage on the right-front corner and along the right side. Vehicle crush measurements are shown in Figure 25. The vehicle remained upright both during and after the test, and there was no intrusion of the occupant compartment.

Damage to the log rail consisted of scrapes and gouges along the traffic face and at some of the posts. A maximum permanent deflection of 9 ⅛ in. was measured at Post No. 3. The damaged barrier is shown in Figure 26.

As a result of technical problems incurred during this test, the accelerometer data was not available. Therefore, the high speed film was analyzed to obtain longitudinal and lateral occupant impact velocities of 14.8 fps and 12.8 fps, respectively. The highest occupant ridedown decelerations in the longitudinal and lateral directions were 13.1 g's and -13.4 g's, respectively.

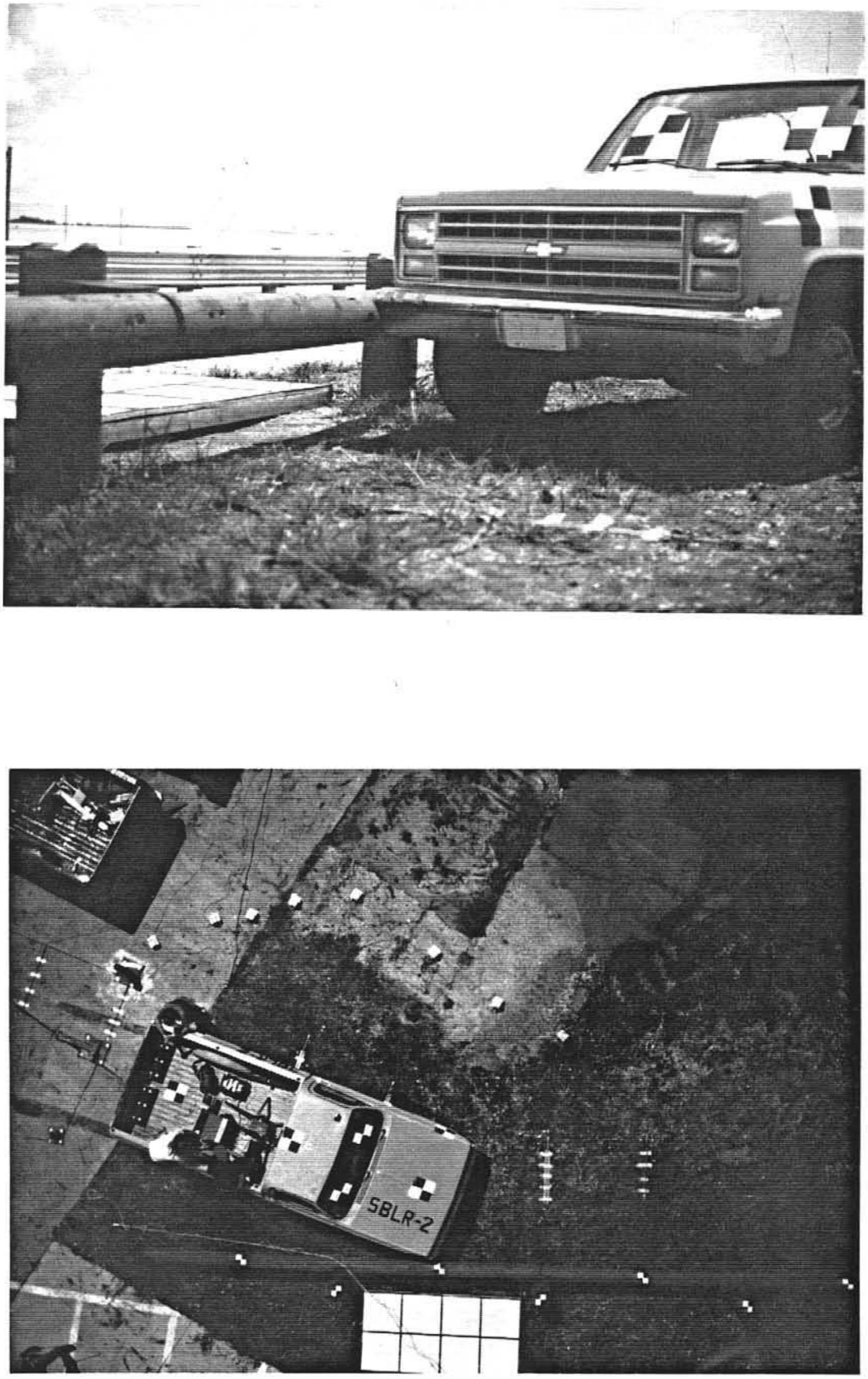


FIGURE 19. Vehicle Impact Location, Test SBLR-2

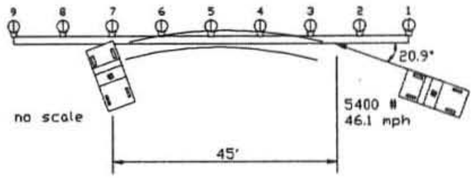
Impact

183 ms

396 ms

711 ms

1137 ms



Test Number	SBLR-2
Date	7/29/92
Installation	Steel Backed Log Guardrail
Installation Length	80 ft
Post	
Material	Ponderosa Pine
Diameter	12 in.
Length	7 ft
Rail Sections	
Material	Ponderosa Pine
Diameter	10 in.
Length	10 ft
Backup Plate	
Material	ASTM A588 Steel
Dimensions	6 in. x 3/8 in. x 9 ft-9 in.
Splice Plate	
Material	ASTM A 588 Steel
Dimensions	6 in. x 3/8 in. x 30 in.
Cast Blockout	
Material	ASTM A588 Steel

Test Vehicle	1986 Chevy 3/4 ton pickup
Weight	
Test Inertial	5,400 lbs
Gross Static	5,565 lbs
Impact Speed	46.1 mph
Impact Angle	20.9 deg
Exit Speed	NA
Exit Angle	NA
Occupant Impact Velocity	
Longitudinal	14.8 fps
Lateral	12.8 fps
Occupant Ridedown Deceleration	
Longitudinal	13.1 g's
Lateral	-13.4 g's
Vehicle Damage	
TAD	1-RD-5
VDI	01RDES2
Vehicle Rebound Distance	0 ft
Coefficient of Friction	NA

FIGURE 20. Test SBLR-2 Summary

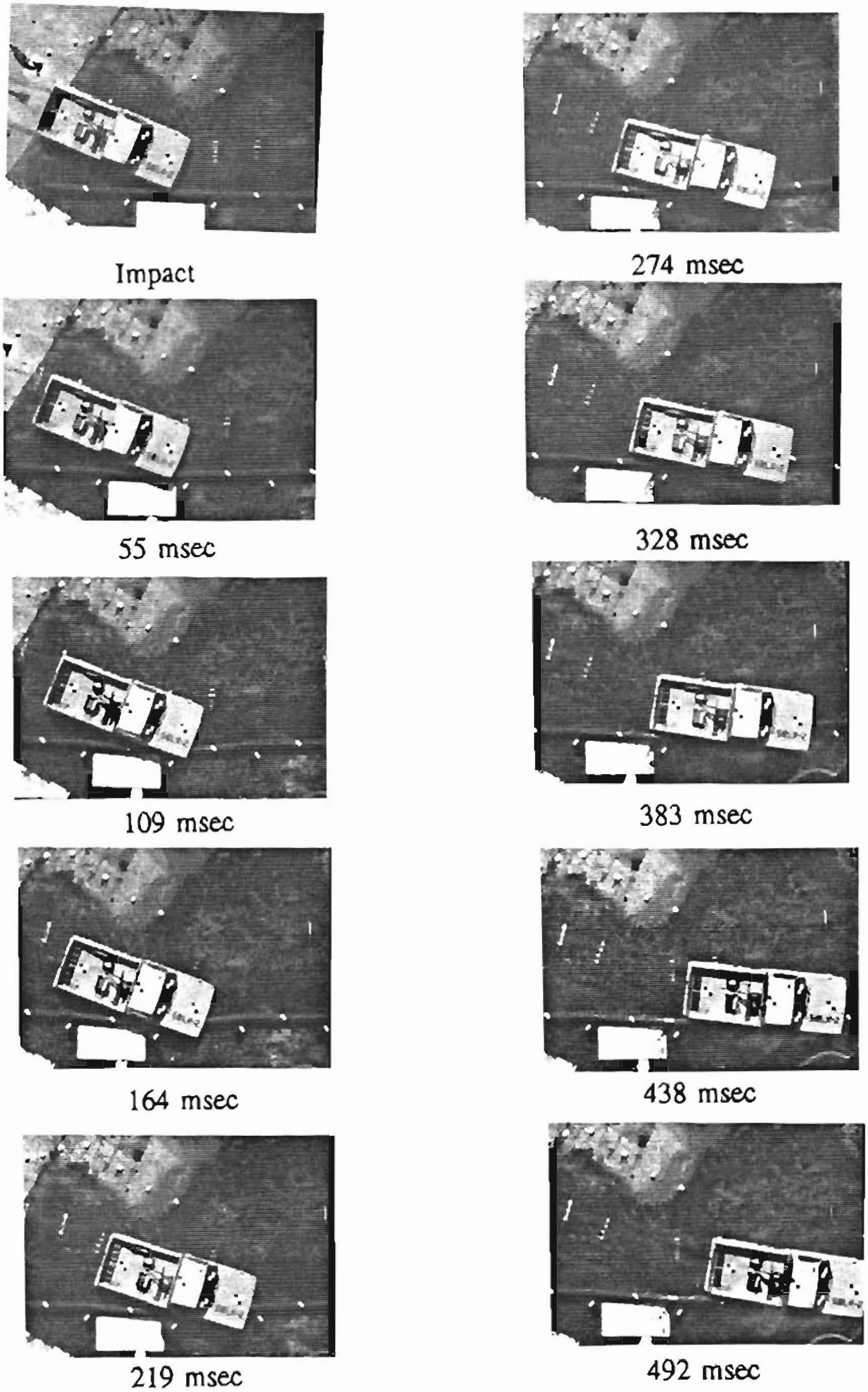
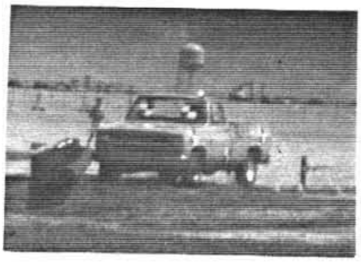
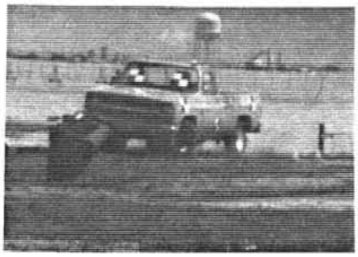


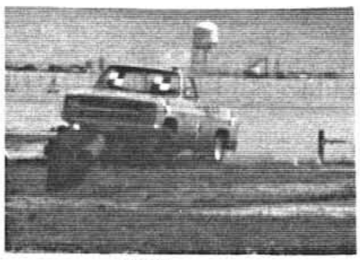
FIGURE 21. Overhead Sequential Photographs, Test SBLR-2



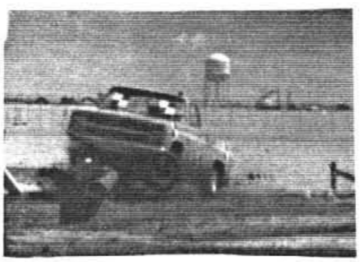
Impact



91 msec

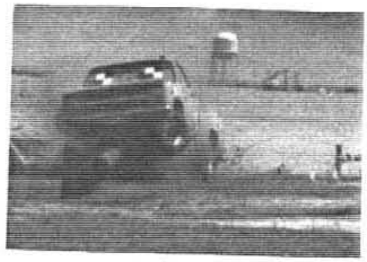


183 msec

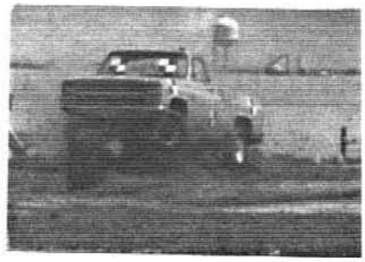


284 msec

396 msec



548 msec



711 msec

914 msec

1137 msec

1625 msec

FIGURE 22. Downstream Sequential Photographs, Test SBLR-2

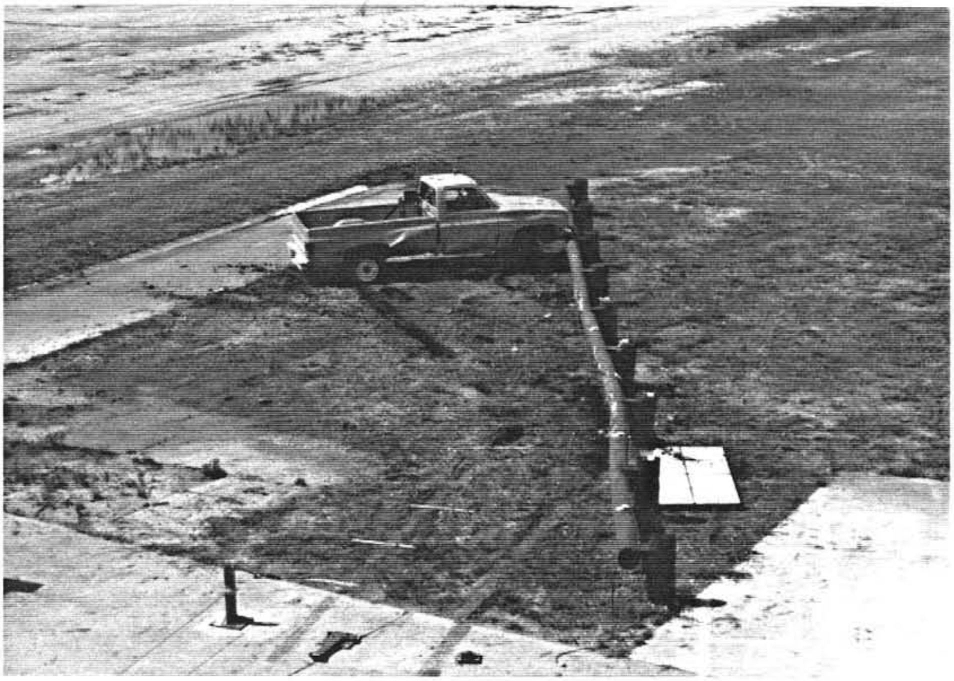


FIGURE 23. Vehicle Trajectory, Test SBLR-2

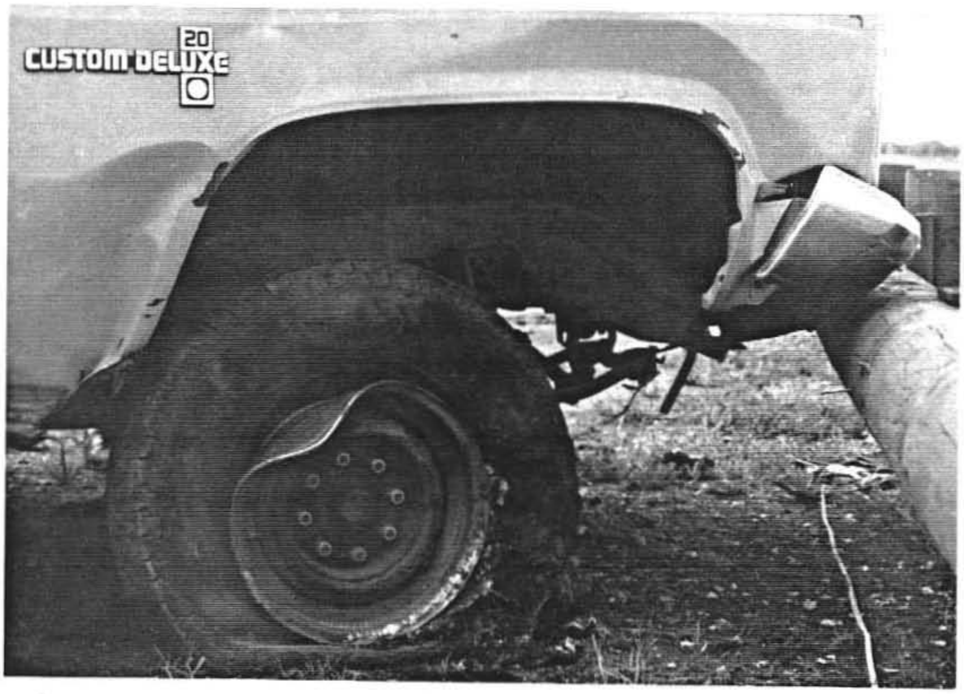
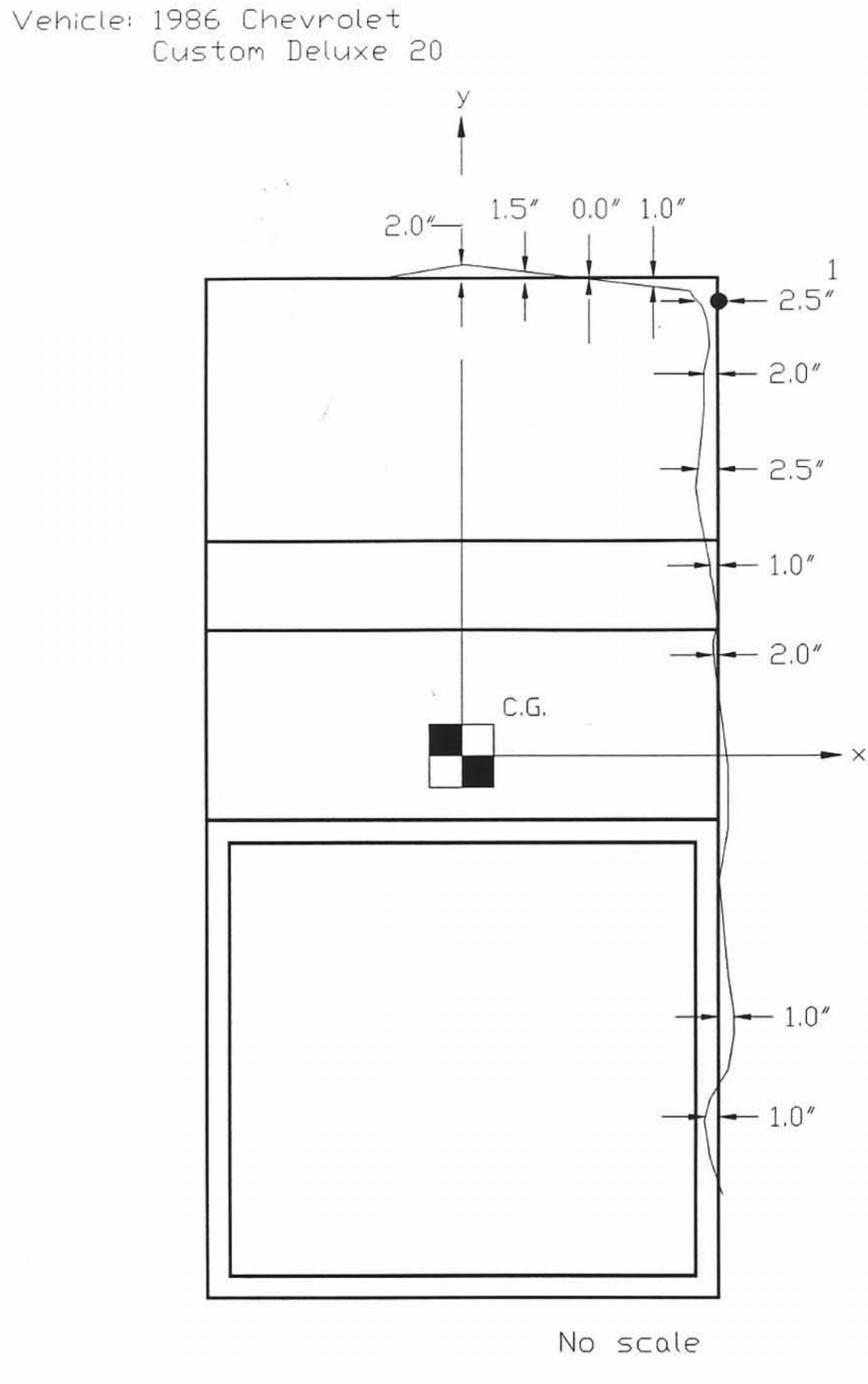


FIGURE 24. Vehicle Damage, Test SBLR-2



[1]-Maximum static crush distance of 2.5" occurred at (36",96") marked by the point.

FIGURE 25. Vehicle Crush Measurements, Test SBLR-2

FIGURE 26. Log Rail Damage, Test SBLR-2

4 CONCLUSIONS

Both the AASHTO Guide Specifications for Bridge Rails (5) and NCHRP Report 230 (6) provide specific criteria for evaluating the performance of PL-1 bridge rails. Table 3 summarizes all of the relevant evaluation criteria from these two reports, as well as the findings from the two tests reported herein. As shown in this table, the Steel-Backed Log Rail successfully passed all requirements for performance level 1 bridge rails.

Table 3. Summary of Safety Performance Results

Evaluation Criteria	Results	
	SBLR-1	SBLR-2
3.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.	S	S
3.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.	S	S
3.c. Integrity of the passenger compartment must be maintained with no intrusion and essentially no deformation.	S	S
3.d. The vehicle shall remain upright during and after collision.	S	S
3.e. The test article shall smoothly redirect the vehicle. A redirection is deemed smooth if the rear of the vehicle does not yaw more than 5 degrees away from the railing from time of impact until the vehicle separates from the railing.	S	S
3.f. The smoothness of the vehicle-railing interaction is further assessed by the effective coefficient of friction μ, where $\mu = (\cos\theta - V_p/V)/\sin\theta$. μ — Assessment 0.0 - 0.25 — Good 0.26 - 0.35 — Fair > 0.35 — Marginal	M (μ=1.02)	NA

Table 3. Summary of Safety Performance Results (continued)

Evaluation Criteria	Results			
	SBLR-1		SBLR-2	
3.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 displacements, shall be less than:	Occupant Impact Velocity (fps)			
	Longitudinal	Lateral	Longitudinal	Lateral
<u>Occupant Impact Velocity - fps</u> <u>Longitudinal</u> <u>Lateral</u> 30 25	S (24.3)	S (21.1)	S (14.8)	S (12.8)
and for the vehicle highest 10-ms average accelerations subsequent to the instant of hypothetical passenger impact should be less than:	Occupant Ridedown Accelerations (g's)			
	Longitudinal	Lateral	Longitudinal	Lateral
<u>Occupant ridedown Accelerations - g's</u> <u>Longitudinal</u> <u>Lateral</u> 15 15	S (3.9)	S (4.8)	S (13.1)	S (-13.4)
3.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.	S (2.0 deg)		NA	
	U		S	

S - Satisfactory
M - Marginal
U - Unsatisfactory
NA - Not Available

5 REFERENCES

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2. Stout, D., Hinch, J., Sawyer, D., *Guardrail Testing Program*, Federal Highway Administration, Report No. FHWA-RD-90-087, June 1990.

3. *Center of Gravity Test Code - SAE J874 March 1981*, SAE Handbook Vol. 4, Society of Automotive Engineers, Inc., Warrendale, Penn., 1986

4. Hinch, J., Yang, T-L, and Owings, R., *Guidance Systems for Vehicle Testing*, ENSCO, Inc., Springfield, VA, 1986.

5. *Guide Specifications for Bridge Railings*, American Association of State Highway and Transportation Officials, Washington, D.C., 1989.

6. *Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances*, National Cooperative Highway Research Program Report No. 230, Transportation Research Board, Washington, D.C., March 1981.

APPENDIX A.

ACCELEROMETER DATA, TEST SBLR-1

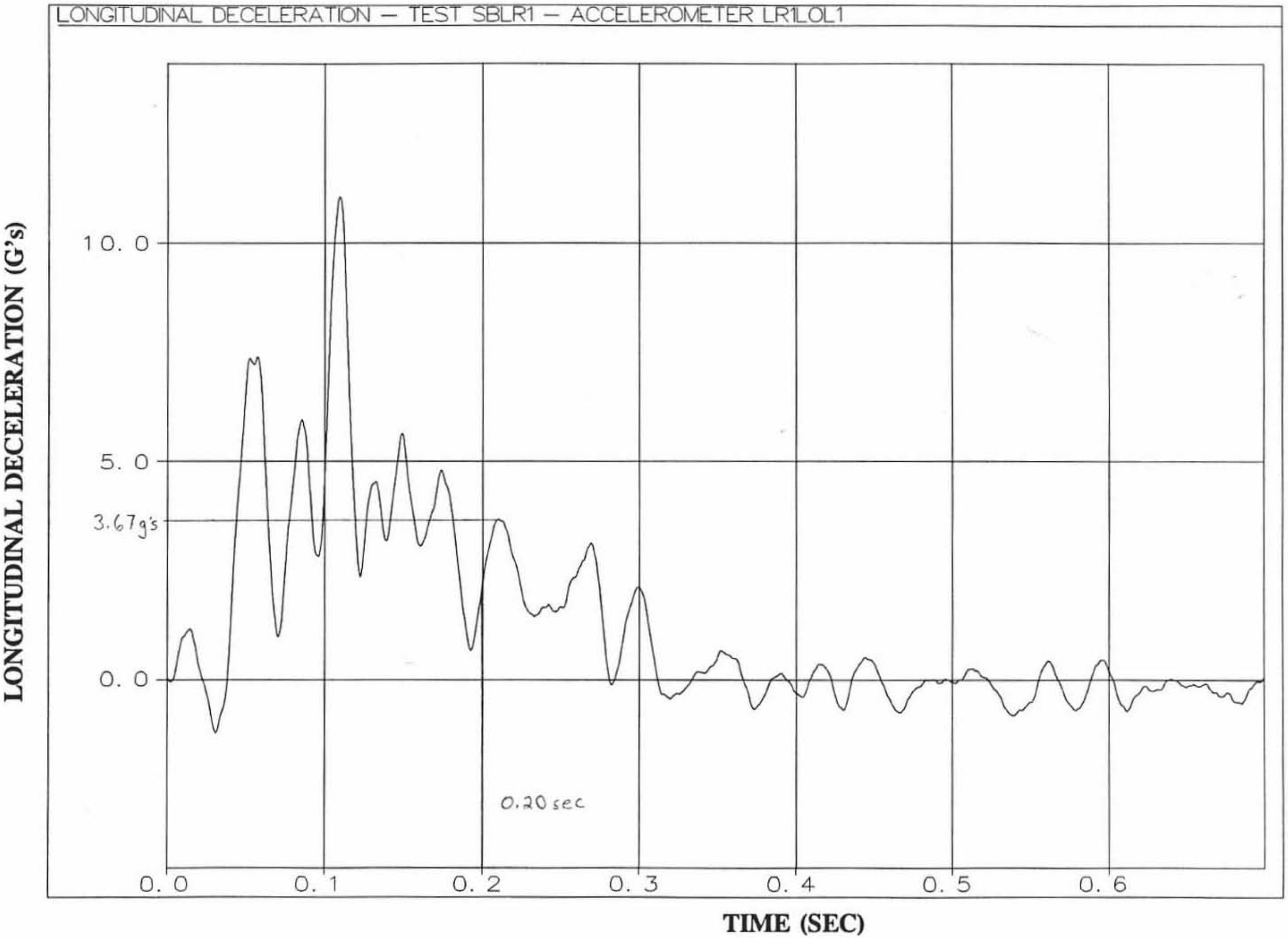

Figure A-1 Graph of Longitudinal Deceleration, Acc. #1

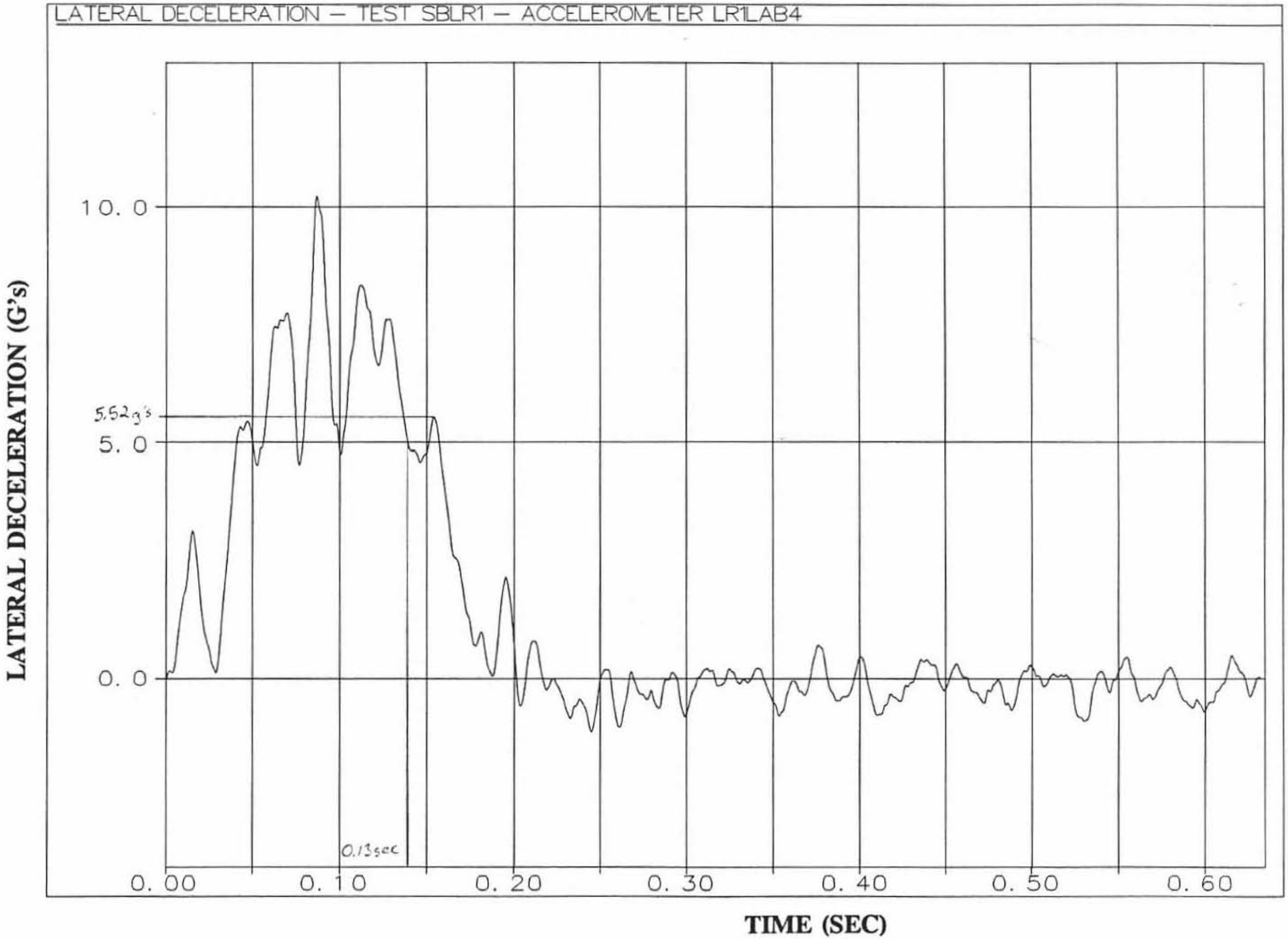

Figure A-2 Graph of Lateral Deceleration, Acc. #3