CRASH TESTING AND EVALUATION OF A LOW-SPEED W-BEAM GUARDRAIL SYSTEM

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CRASH TESTING AND EVALUATION OF A LOW-SPEED W-BEAM GUARDRAIL SYSTEM

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3

NOTE: Volumes greater than 1000 l shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	l
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
psi	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	ac
ha	hectares	2.47	acres	mi^2
km^2	square kilometers	0.386	square miles	
		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	megagrams	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	psi

(Revised August 1992)

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

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I. INTRODUCTION

1.1 BACKGROUND

The design, development, crash testing and evaluation of roadside safety appurtenances have traditionally been aimed at high-speed applications, i.e., 60 mi/h (96.6 km/h), and little attention has been given to lower-speed applications, e.g., 45 mi/h (72.5 km/h) or less. Currently, the same roadside safety appurtenances designed for high-speed applications are used for lower-speed applications since roadside safety appurtenances specifically designed for lower-speed applications are not available.

It is evident that the impact conditions for roadside safety appurtenances vary as a function of site and traffic characteristics. For example, the impact conditions for collisions with longitudinal barriers on a rural roadway with low traffic volume and low operating speed are expected to be much less severe than those on an intestate highway. It is, therefore, logical to reason that roadside safety appurtenances intended for use on low-volume, low-speed roadways do not need to be designed to the same standards as those intended for use on high-volume, high-speed roadways. By designing roadside safety appurtenances to lower performance levels, some cost savings may be effected. The cost savings could be substantial when one considers the number of miles of roadways with low traffic volumes and low operating speeds, such as local county roads and city streets.

The concept of multiple performance levels, i.e., different performance levels for different applications as a function of site and traffic conditions, is gaining popularity in recent years. The 1989 American Association of State Highway and Transportation Officials (AASHTO) *Guide Specifications for Bridge Railings* defines multiple performance levels and their applications for bridge railings.[1] The revised procedures and guidelines for the safety performance evaluation of highway features presented in the new National Cooperative Highway Research Program (NCHRP) Report 350 also embraced this multiple performance level concept and defined different test levels for different intended applications.[2]

The current standard G4 guardrail systems with blockouts and post spacing of 6 ft-3 in (1.91 m) were developed through an evolutionary, trial-and-error process. The design has been shown to perform well in crash testing and field applications. However, this does not necessarily mean that the design is optimal or it cannot be modified for different applications. For example, one recently completed study shows that a post spacing of 8 ft-4 in (2.54 m) would be adequate and some cost savings would be effected by eliminating one-third of the required posts.[3] For lower-speed applications, there is good reason to believe that a post spacing of 12 ft-6 in (3.81 m) may be sufficient for the intended applications and this would allow for considerable cost savings by eliminating one-half of the required posts.

In fact, the earlier W-beam guardrail design used a post spacing of 12 ft-6 in (3.81 m) and a rail height of 24 inches (61.0 cm). It was later found in a full-scale crash testing with a 4,500-lb (2,041-kg) vehicle impacting the barrier at 60 mi/h (96.6 km/h) and 25 degrees that the vehicle could ride on top and over the rail element due to excessive deflection of the system.[4] The post spacing was thus reduced to 6 ft-3 in (1.91 m) and the rail height raised to 27 inches (68.6 cm). However, for an impact speed of 45 mi/h (72.5 km/h), the kinetic energy of the impacting vehicle would be only 56 percent of that at 60 mi/h (96.6 km/h). There is good reason to believe that the guardrail system would work with the increased post spacing of 12 ft-6 in (3.81 m).

1.2 STUDY OBJECTIVE AND SCOPE

The objective of this project is to crash test and evaluate the impact performance of a W-beam guardrail system with 12 ft-6 in (3.81-m) post spacing, intended for lower-speed applications, in accordance with criteria outlined in the new NCHRP Report 350. the proposed guardrail system will be tested at test level 2, i.e., at a nominal impact speed of 70 km/h (43.5 mi/h). The following two crash tests are required for a guardrail length-of-need (LON) in accordance with requirement under NCHRP Report 350:

1. Test Designation 2-10. A 820-kg (1,800-lb) passenger car impacting the test installation at 70 km/h (43.5 mi/h) and at an angle of 20 degrees. The purpose of this small car test is to evaluate the overall performance of the LON section in general, and occupant risks in particular.
2. Test Designation 2-11. A 2,000-kg (4,409-lb) pickup truck impacting the test installation at 70 km/h (43.5 mph) and at an angle of 25 degrees. The purpose

of this test is to evaluate the strength of the LON section in containing and redirecting the test vehicle.

For the purpose of evaluating this proposed guardrail design, test 2-11 is considered the more critical test. While the proposed W-beam guardrail design with blockouts and post spacing of 12 ft-6 in (3.81 m) has not been tested with an 820-kg (1,800-lb) passenger car at the specific nominal impact speed and angle of 70 km/h (43.5 mi/h) and 20 degrees, there is no reason to believe that the design would not perform satisfactorily under these conditions. The concern with the increased post spacing is the excessive deflection of the system which could allow the impacting vehicle to ride up on top and eventually over the guardrail. Such conditions are not expected with the small car test. The pickup truck test was therefore conducted first, the results of which are presented in this report.

Prior to the full-scale crash test, computer simulation was used to evaluate the impact performance of the 12 ft-6 in (3.81 m) post spacing W-beam guardrail system. A standard G4(2W) strong-post blocked-out W-beam guardrail system with post spacing of 12 ft-6 in (3.81 m) was used with the simulation effort.

II. STUDY APPROACH

Evaluation of the 12 ft-6 in (3.81 m) post spacing W-beam guardrail system consisted of first conducting a series of computer simulation runs, followed by a full-scale crash test. Brief descriptions of the simulation effort and the full-scale crash tests are presented as follows.

2.1 COMPUTER SIMULATION

The BARRIER VII simulation program was the primary tool used in the evaluation of the guardrail system.[5] It is a two-dimensional simulation program that models vehicular impacts with deformable barriers. The program employs a sophisticated barrier model that is idealized as an assemblage of discrete structural members possessing geometric and material nonlinearities. The available structural members include beams, cables, posts, springs, columns, links, and damping devices. The vehicle is idealized as a plain rigid body surrounded by a series of discrete inelastic springs. The BARRIER VII program has been shown to be capable of accurately predicting barrier deflections for a wide variety of flexible barrier designs, even under severe impact conditions. Although it cannot be used to evaluate the effect of wheel/post interaction and rail rupture, it can predict the occurrence of these events. The amount of wheel snag can be inferred from the position of the vehicle tire and the deflected position of a post. Rail failure can be predicted by evaluating the maximum strain in the rail and comparing the computed values to the rated ductility of the rail element. These and other methods which will be described later were used to evaluate to performance of the guardrail system reported herein.

The following impact conditions were used in the simulation runs to evaluate the impact performance of the 12 ft-6 in (3.81 m) post spacing W-beam guardrail system:

1. An 1,800-lb (817-kg) passenger car impacting the guardrail at a nominal speed of 45 mi/h (72.5 km/h) and 20 degrees.
2. A 4,500-lb (2,041-kg) pickup truck impacting the guardrail at a nominal speed of 45 mi/h (72.5 km/h) and 25 degrees.

2a. A 4,500-lb (2,041-kg) passenger car impacting the guardrail at a nominal speed of 45 mi/h (72.5 km/h) and 25 degrees.

3. An 1,800-lb (817-kg) passenger car impacting midway between the nose of the end terminal and beginning of length-of-need at a nominal speed of 45 mi/h (72.5 km/h) and 20 degrees.

4. A 4,500-lb (2,041-kg) pickup truck impacting the guardrail at the beginning of length-of-need at a nominal speed of 45 mi/h (72.5 km/h) and 25 degrees.

4a. A 4,500-lb (2,041-kg) passenger car impacting the guardrail at the beginning of length-of-need at a nominal speed of 45 mi/h (72.5 km/h) and 25 degrees.

5. For comparison purposes, a simulation run with a 4,500-lb (2,041-kg) passenger car impacting a standard guardrail system with post spacing of 6 ft-3 in (1.91 m) at the beginning of length-of-need at a nominal speed of 45 mi/h (72.5 km/h) and 25 degrees was also conducted.

2.2 DESCRIPTION OF TEST INSTALLATION

A schematic of the test installation is shown in figure 1 and photographs of the test installation are shown in figure 2. The test installation consisted of 100 ft (30.5 m) of length-of-need and two 25-ft (7.62-m) end terminals for a total length of 150 ft (45.7 m). The guardrail length-of-need section was similar to that of a standard G4(2W) guardrail system, except for the 12 ft-6 in (3.81 m) post spacing. The wooden posts were 6 in x 8 in (152.4 mm x 203 mm) in cross section and 6 ft (1.83 m) in length with 6 in x 8 in x 14 in (152.4 mm x 203 mm x 356 mm) wooden blockouts. The W-beam rail element was attached to the posts and blockouts with 5/8-in (15.9-mm) diameter, 20-in (0.51-m) long dome headed bolts. Post washers were not used so that the W-beam rail element could readily disengage from the posts. This minimizes the potential for the W-beam rail element to rotate with the posts, thus reducing the effective height of the rail element. The height of the guardrail to the top of the rail element was 27 in (0.69 m).

Two slotted rail end terminals were used to anchor the guardrail installation. The slotted rail end terminal is a new end terminal design developed at TTI for the Tennessee Department of Transportation for use on roadways with speed limits of 45 mi/h (72.5 km/h) or lower.[6] This new slotted rail end terminal has been successfully crash tested and found to have met all evaluation requirements set forth in NCHRP Report 230.[7] Since the guardrail

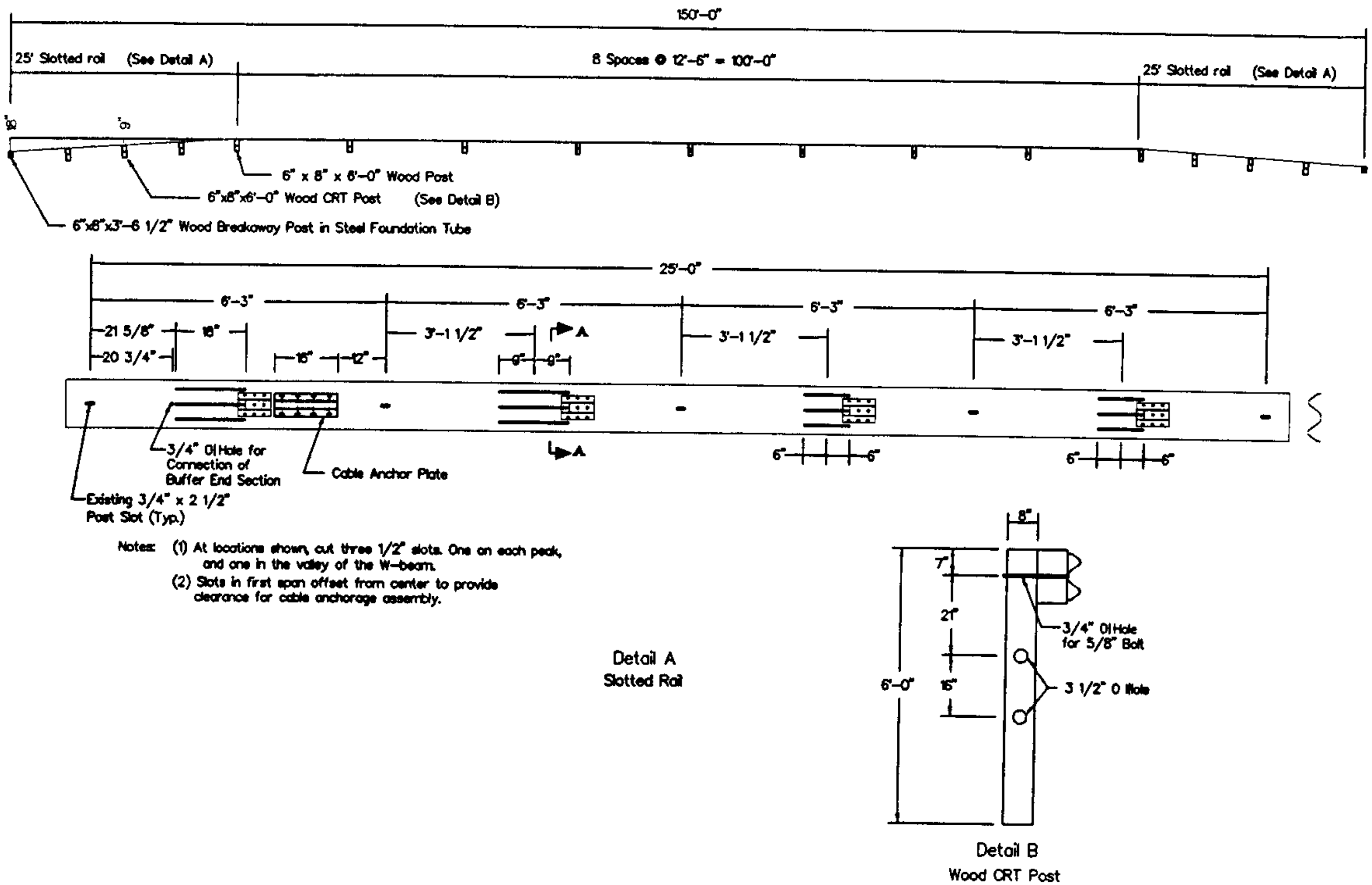
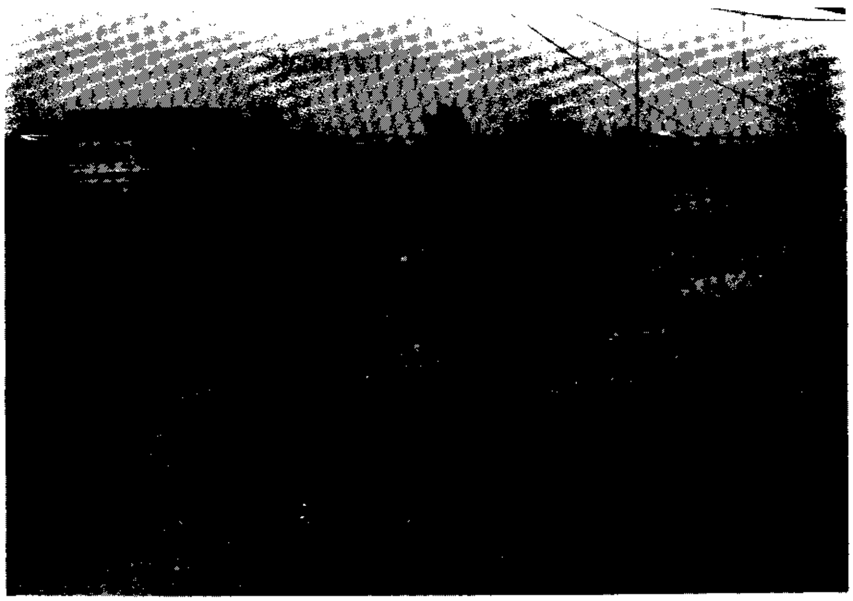


Figure 1. Schematic drawing of test installation 04820-1.



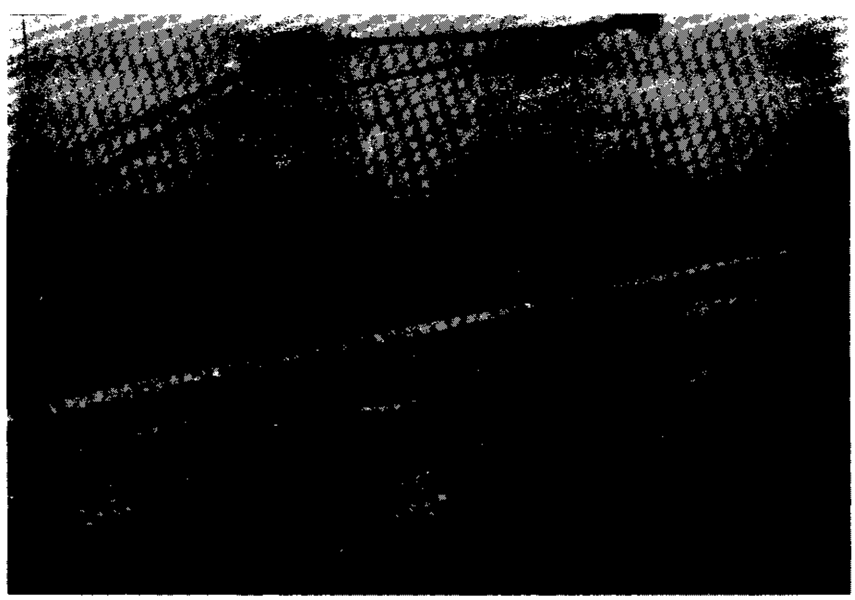


Figure 2 . W-Beam rail installation before test 0482-1.

system under evaluation is also intended for use on roadways with speed limits of 45 mi/h (72.5 km/h) or lower, it seemed appropriate to use the new slotted end terminal with the test installation instead of the higher performance end terminals.

2.3 DESCRIPTION OF CRASH TEST PROCEDURES

All crash test and data analysis procedures were conducted in accordance with guidelines set forth in NCHRP Report 350. Brief descriptions of the crash test and data analysis procedures are presented as follows.

2.3.1 Electronic Instrumentation and Data Processing

The test vehicle was instrumented with three solid-state angular rate transducers to measure yaw, pitch and roll rates; a triaxial accelerometer at the vehicle center-of-gravity to measure longitudinal, lateral, and vertical acceleration levels, and a back-up biaxial accelerometer in the rear of the vehicle to measure longitudinal and lateral acceleration levels. The accelerometers were strain gauge type with a linear millivolt output proportional to acceleration.

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

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 a SAE J211 Class 180 filter, and were digitized using a microcomputer, for analysis and evaluation of impact performance. The digitized data were then processed using two computer programs: DIGITIZE and PLOTANGLE. Brief descriptions on the functions of these two computer programs are as follows.

The DIGITIZE program uses digitized data from vehicle-mounted linear accelerometers to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-millisecond average ridedown acceleration. The DIGITIZE program also calculates a vehicle impact velocity and the change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-millisecond 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).

The PLOTANGLE program uses the digitized data from the yaw, pitch, and roll rate charts to compute angular displacement in degrees at 0.00067-second 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.

2.3.2 Photographic Instrumentation and Data Processing

Photographic coverage of the test included three high-speed cameras; one overhead with a field of view perpendicular to the ground and directly over the impact point; one placed behind the rail with the field of view at approximately a 45 degree angle; and a third aligned parallel with the face of the rail and downstream from impact. A flash bulb activated by pressure sensitive tape switch was positioned on the impacting vehicle to indicate the instant of contact with the barrier 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 professional video camera, 3/4-in video recorder and 35-mm cameras were used for documentary purposes to record conditions of the test vehicle and rail installation before and after the test.

2.3.3 Test Vehicle Propulsion and Guidance

The test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the vehicle travel path. The guide cable was threaded through a guide rod attached to the front spindle of the test vehicle. An additional steel cable was attached to the front of the test vehicle, passed to and around a pulley near the impact point, and to and around an additional pulley mounted to the tow vehicle, and then anchored to the ground. This configuration allowed the tow vehicle to move away from the test site with a 2 to 1 speed ratio existing between the test vehicle and tow vehicle. Immediately prior to impact with the rail, 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.

III. SIMULATION AND CRASH TEST RESULTS

Results of the computer simulation and the 2,000-kg (4,409-lb) pickup truck full-scale crash test are presented in this chapter.

3.1 COMPUTER SIMULATION RESULTS

Results of the computer simulation effort using the BARRIER VII program are summarized as follows:

1. An 1,800-lb (817-kg) passenger car impacting the guardrail at a nominal speed of 45 mi/h (72.5 km/h) and 20 degrees.
   Critical point of impact: 6 ft (1.83 m) upstream of post.
   Maximum deflection: 12.4 in (315 mm).
   Rail yielding in tension: No.
   Maximum wheel contact at post: 3.6 in (91 mm).
   Maximum post rotation: 12 degrees.
2. A 4,500-lb (2,041-kg) pickup truck impacting the guardrail at a nominal speed of 45 mi/h (72.5 km/h) and 25 degrees.
   Critical point of impact: 8.5 ft (2.59 m) upstream of post.
   Maximum deflection: 24.0 in (610 mm).
   Rail yielding in tension: No.
   Maximum wheel contact at post: 8.0 in (203 mm).
   Maximum post rotation: 26 degrees.

2a. A 4,500-lb (2,041-kg) passenger car impacting the guardrail at a nominal speed of 45 mi/h (72.5 km/h) and 25 degrees.
   Critical point of impact: 8.5 ft (2.59 m) upstream of post.
   Maximum deflection: 23.0 in (584 mm).
   Rail yielding in tension: No.
   Maximum wheel contact at post: 3.2 in (81 mm).
   Maximum post rotation: 26 degrees.

Note that the difference in wheel contact at post is result of wheel/tire position in relation to fender. The pickup truck has less offset for the tire from the fender and thus more wheel contact.

3. An 1,800-lb (817-kg) passenger car impacting midway between the nose of the end terminal and beginning of length-of-need at a nominal speed of 45 mi/h (72.5 km/h) and 20 degrees.

   Point of impact: 6.25 ft (1.91 m) downstream of nose of terminal, i.e., 6.25 ft (1.91 m) upstream of post 2 which is selected as the beginning of length-of-need.

   Maximum deflection: 15 in (381 mm).

   Rail yielding in tension: No.

   Maximum wheel contact at post 2: 4.7 in (119 mm).

   Maximum rotation at post 2: 16 degrees.

   The simulation did not predict failure of post 2. However, it is believed that post 2 will likely fail upon contact by the vehicle wheel.

4. A 4,500-lb (2,041-kg) pickup truck impacting the guardrail at the beginning of length-of-need at a nominal speed of 45 mi/h (72.5 km/h) and 25 degrees.

   Point of impact: 12.5 ft (3.81 m) downstream of nose of terminal, i.e., at post 2 which is selected as the beginning of length-of-need.

   Maximum deflection: 29.0 in (727 mm).

   Rail yielding in tension: No.

   Maximum wheel contact at post 3: 9.7 in (246 mm).

   Maximum rotation at post 3: 29 degrees.

   Post 3 is predicted to fail.

   Maximum force on anchor: 82 kips (37.2 kN).

4a. A 4,500-lb (2,041-kg) passenger car impacting the guardrail at the beginning of length-of-need at a nominal speed of 45 mi/h (72.5 km/h) and 25 degrees.

   Point of impact: 12.5 ft (3.81 m) downstream of nose of terminal, i.e., at post 2 which is selected as the beginning of length-of-need.

   Maximum deflection: 28.5 in (724 mm).

Rail yielding in tension: No.

Maximum wheel contact at post 3: 4.5 in (114 mm).

Maximum rotation at post 3: 25 degrees.

Post 3 is predicted to fail.

Maximum force on anchor: 84.5 kips (38.3 kN).

Again, note that the difference in wheel contact at post is result of wheel/tire position in relation to fender.

5. A 4,500-lb (2,041-kg) passenger car impacting a standard G4(2W) guardrail with 6 ft-3 in (1.91-m) post spacing at the beginning of length-of-need at a nominal speed of 45 mi/h (72.5 km/h) and 25 degrees.

   Point of impact: 12.5 ft (3.81 m) downstream of nose of terminal, i.e., at post 2 which is selected as the beginning of length-of-need.

   Maximum deflection: 27.0 in (686 mm).

   Rail yielding in tension: Yes, 99.7 kips (45.2 kN), 2% strain.

   Maximum wheel contact at post 3: 2.0 in (51 mm).

   Maximum rotation at post 3: 19 degrees.

   Post 3 is predicted to fail.

   Maximum force on anchor: 98 kips (44.45 kN).

   There appeared to be some pocketing around post 3, which accounted for the increased forces on the rail element and anchor. However, there was less snagging and post rotation at post 3.

The computer simulation results indicate that the guardrail system should perform satisfactorily for the 45 mi/h (72.5 km/h) impact conditions. From a structural adequacy standpoint, there does not appear to be any problem. The amount of deflection is not excessive and there is no yielding of the rail. The forces acting on the anchor are well within the capacity of the anchor. There is some wheel contact at the downstream post, but not considered a problem since the post is predicted to either fail or rotate a significant amount.

From an occupant risk standpoint, the lateral deceleration experienced by the impacting vehicle is expected to be lower with the 12 ft-6 in (3.81-m) post spacing since the guardrail system is "softer" than the standard 6 ft-3 in (1.91-m) post spacing guardrail system. There appears to be some wheel contact with the downstream post, but the extent of overlap between the wheel and the post is relatively small and should not be of any major concern.

From the vehicle trajectory standpoint, the increased post spacing should not have any effect on the small car. The concern is mainly with the pickup truck overriding and vaulting over the guardrail. The BARRIER VII computer simulation program is a two-dimensional model and cannot assess the potential for overriding or vaulting. Thus, the vehicle trajectory criteria will have to be evaluated from full-scale crash testing.

In summary, the computer simulation results are pretty much as expected. There is no anticipated problem with either the structural adequacy or occupant risk criteria. The concern is with the vehicle trajectory or, more specifically, the overriding and vaulting of the pickup truck over the guardrail. This will be addressed with the 2,000-kg (4,409-lb) pickup truck test.

3.2 FULL-SCALE CRASH TEST RESULTS (Test No. 0482-1)

A 1985 Chevrolet C-20 pickup truck (Figures 3 and 4) was used for the crash test. Test inertia mass of the vehicle was 2,000 kg (4,409 lb). The height to the lower edge of the vehicle bumper was 0.47 m (18.3 in) and 0.69 m (27.2 in) 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 rail 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 rail 2.6 m (8.5 ft) upstream of post 8 at a speed of 69.5 km/h (43.2 mi/h) and at an angle of 24.5 degrees.

Upon impact, the W-beam rail element began to twist and deform as the left front corner of the vehicle bumper climbed atop the rail. At 0.052 second, the left front tire of the vehicle impacted the rail element and began to climb. By 0.089 second, the left front tire was airborne. Thereafter, the left front tire pocketed at the post and blockout connection at post 8, which was the post immediately downstream of the initial point of impact. The post, blockout and rail element at post 8 served as a ramp and the vehicle began to vault over the rail installation. At 0.123 second, the rail element pulled away from the post. The right front tire was airborne by 0.199 second. By 0.303 second, the left rear tire was in contact with the rail element and struck the blockout at post 8 at 0.333 second. The right front tire struck the rail element between posts 8 and 9 at 0.308 second. The vehicle was essentially not redirected

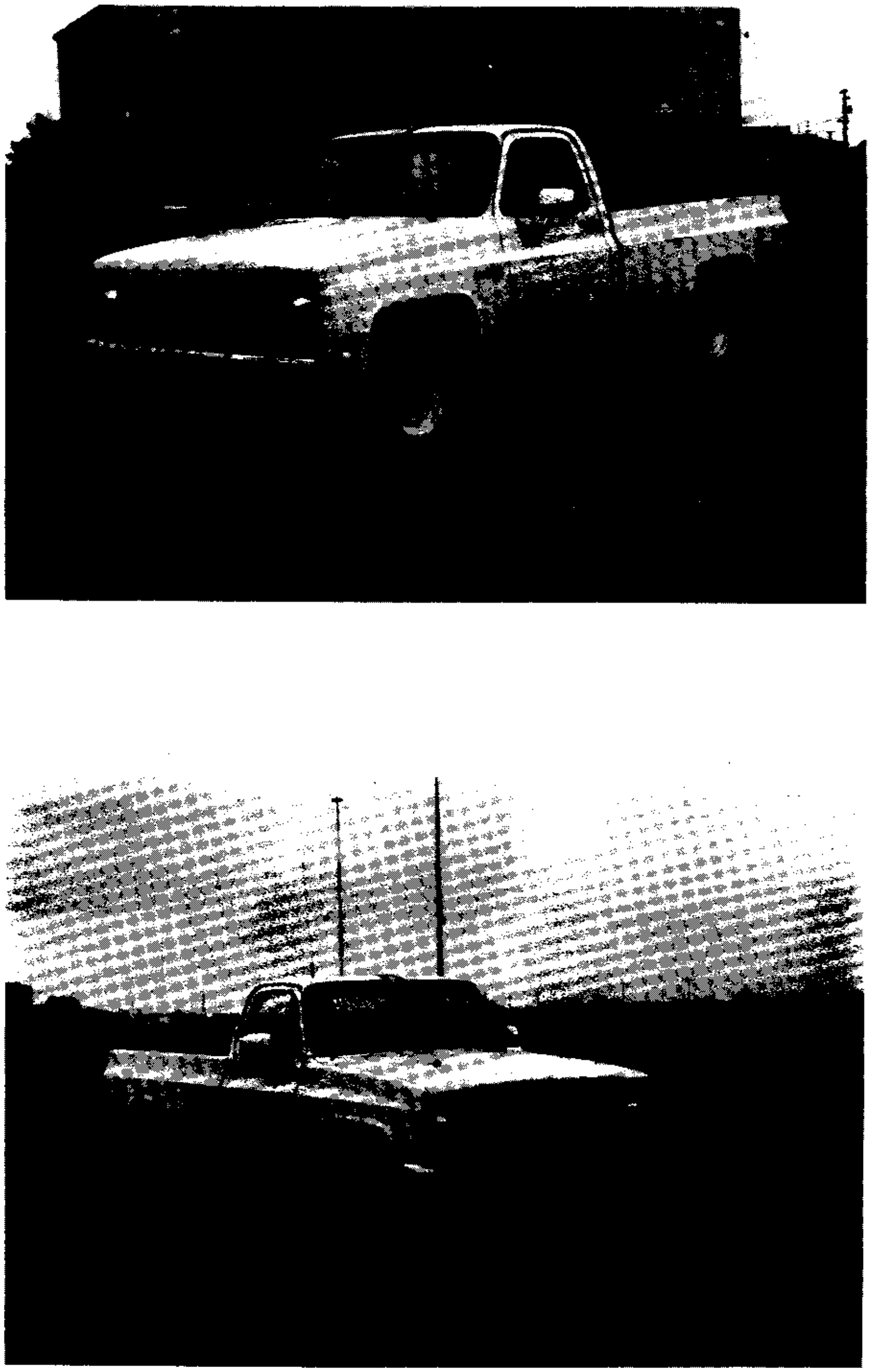


Figure 3 . Vehicle before test 0482-1.

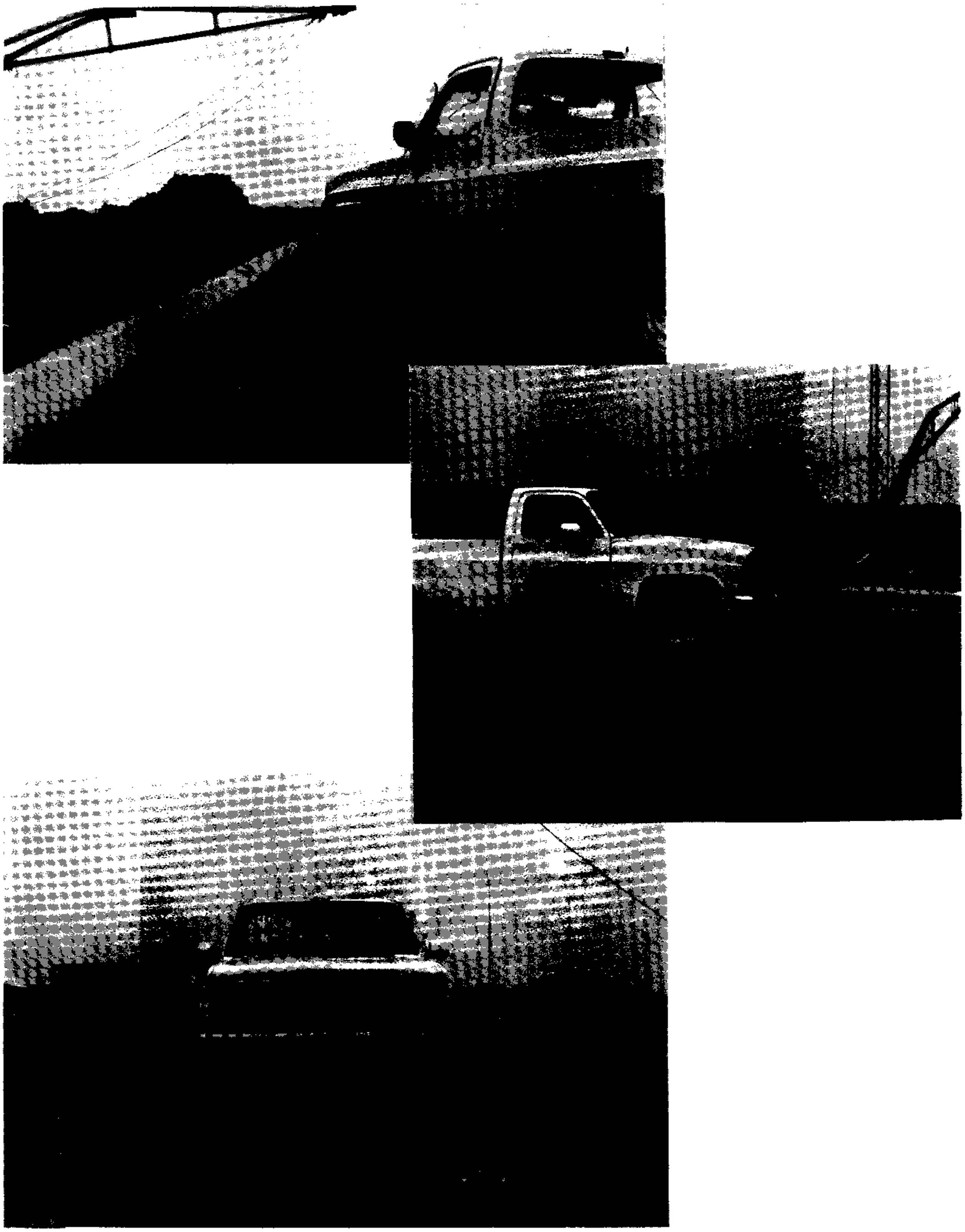


Figure 4 . Vehicle/rail geometrics for test 0482-1.

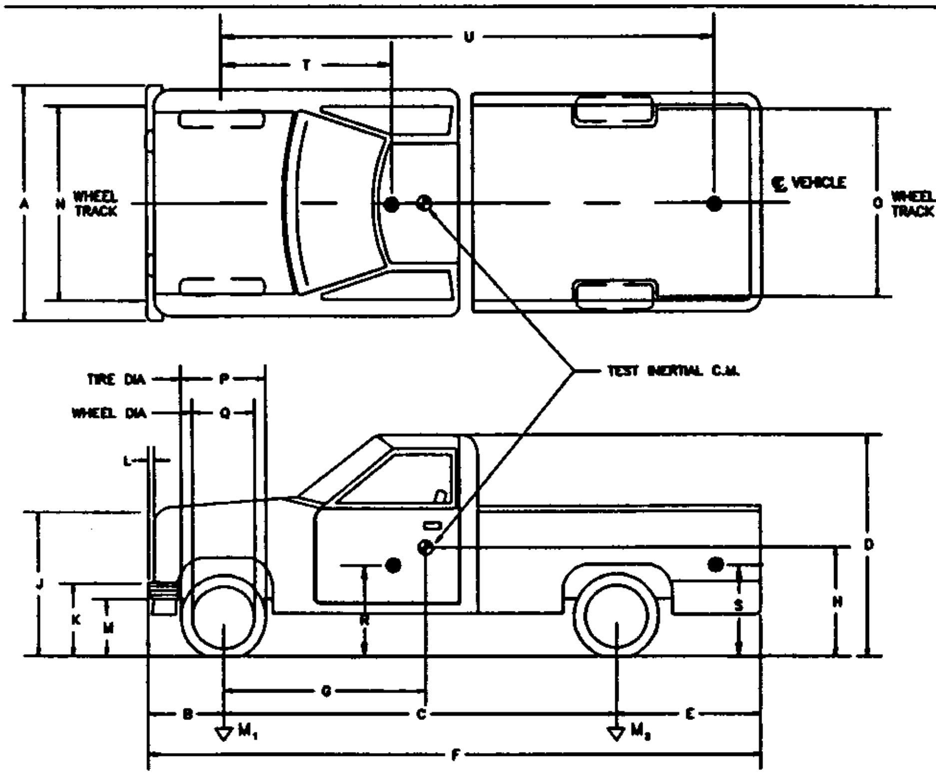
DATE: 5-18-93 | TEST NO.: 04820-1 | VIN NO.: 1GTGC24M7GF71204 | MAKE: GMC

MODEL: Sierra | YEAR: 1986 | ODOMETER: 94524 | GVW: ______

TIRE SIZE: LT235/85R16 | TIRE INFLATION PRESSURE: ______ | TREAD TYPE: Hwy

MASS DISTRIBUTION (kg) LF 547 RF 559 LR 446 RR 448

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



● Denotes accelerometer location.

NOTES: Rear- 2 cm to right

ENGINE TYPE: V-8 Gasoline

ENGINE CID: 350

TRANSMISSION TYPE:

X AUTO

— MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: ______

MASS: ______

SEAT POSITION: ______

GEOMETRY – (cm)

A	200	E	135	J	115.5	N	166.5	R	66.5
B	82	F	550	K	69	O	167	S	100.5
C	333	G	148.9	L	7	P	81	T	154
D	185	H		M	46.5	Q	45	U	417

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	1195	1106	
M_2	902	894	
M_T	2097	2000	

Figure 5. Vehicle properties for test 0482-1.

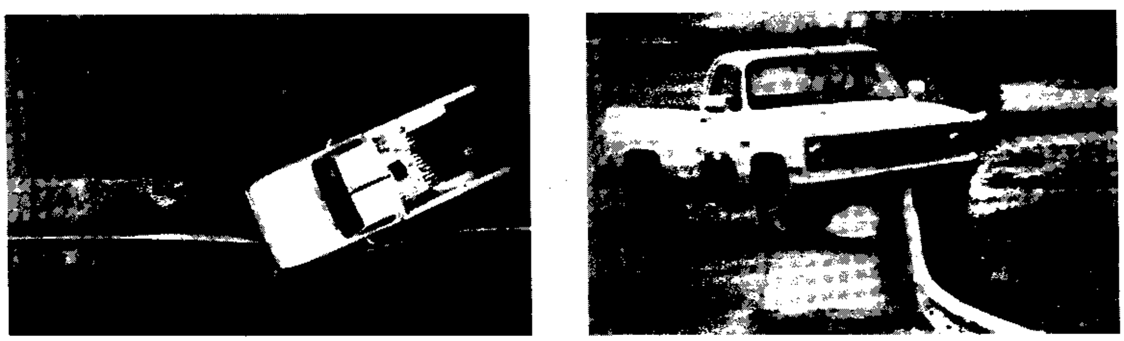
and continued to vault over the rail installation. By 0.425 second, the right rear tire also became airborne and cleared the rail installation with the exception of the bottom of the tire contacting the top of post 10 at 0.846 second. The vehicle lost contact with the barrier travelling at 58.5 km/h (36.4 mi/h) and at an angle of 14.0 degrees. By 1.191 second, all tires on the vehicle had contacted the ground behind the installation. The brakes were applied and the vehicle came to rest upright 29.3 m (96.0 ft) downstream from the point of impact and 27.4 m (90.0 ft) behind the test installation. Sequential photographs are shown in Figures 6 and 7.

As can be seen in figure 8, the guardrail received only minimal damage. The damage was confined to only one 3.81-m (12 ft-6 in) section of the W-beam rail element and two posts (posts 8 and 9). The maximum dynamic deflection of the guardrail was 0.5 m (1.7 ft) and maximum permanent deflection was 0.3 m (1.0 ft).

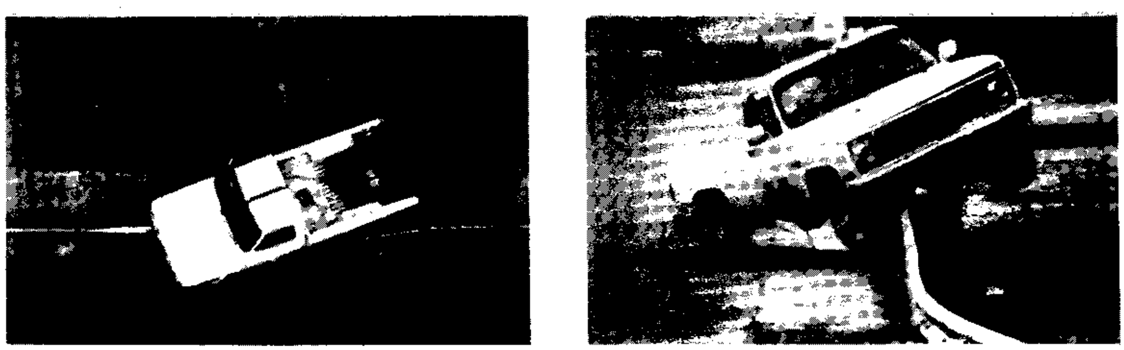
The vehicle sustained little damage as shown in Figure 9. Maximum crush at the right front fender of the vehicle was only 5 mm (0.2 in) due to the bumper being pushed into the fender. The left front wheel was pushed rearward 40 mm (1.6 in), the left side of the frame was bent slightly and the left inner tie-rod was bent.

Data from the accelerometer located at the center-of-gravity were digitized for evaluation of occupant risk factor and were computed as follows. In the longitudinal direction, occupant impact velocity was 3.3 m/s (10.7 ft/s) at 0.314 second, the highest 0.010-second average ridedown acceleration was 3.4 g between 0.442 and 0.452 second, and the maximum 0.050-second average acceleration was -3.7 g between 0.075 and 0.125 second. Lateral occupant impact velocity was -1.9 m/s (6.1 ft/s) at 0.272 second, the highest 0.010-second occupant ridedown acceleration was 2.9 g between 0.325 and 0.335 second and the maximum 0.050-second average acceleration was 2.1 g between 0.299 and 0.349 second. These data and other pertinent information from the test are summarized in Figure 10. Vehicular angular displacements are displayed in Figure 11. Vehicular accelerations versus time traces filtered at SAE J211 (Class 180) are presented in Figures 12 through 14.

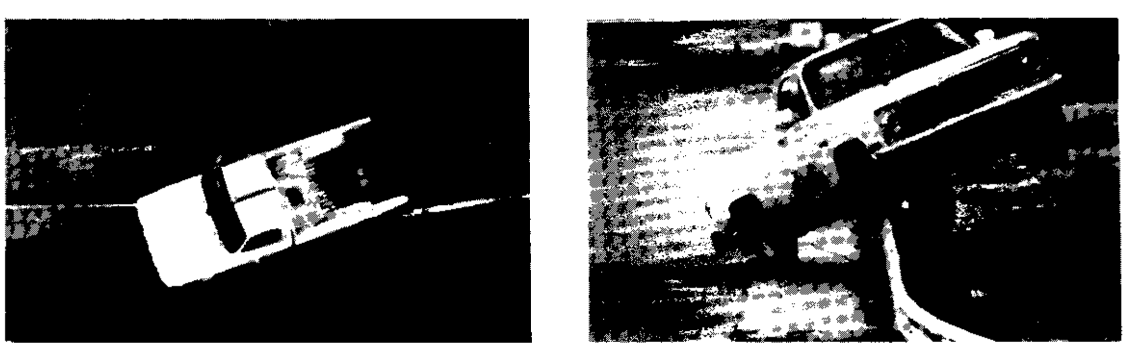
0.000 s



0.121 s

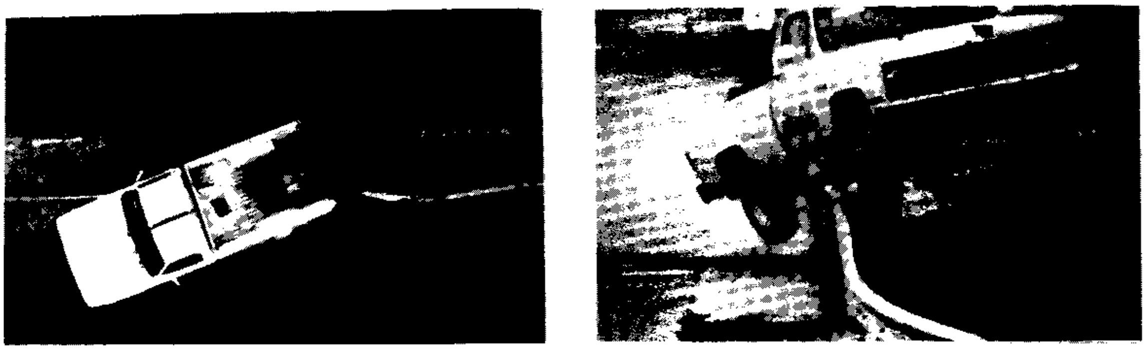


0.243 s

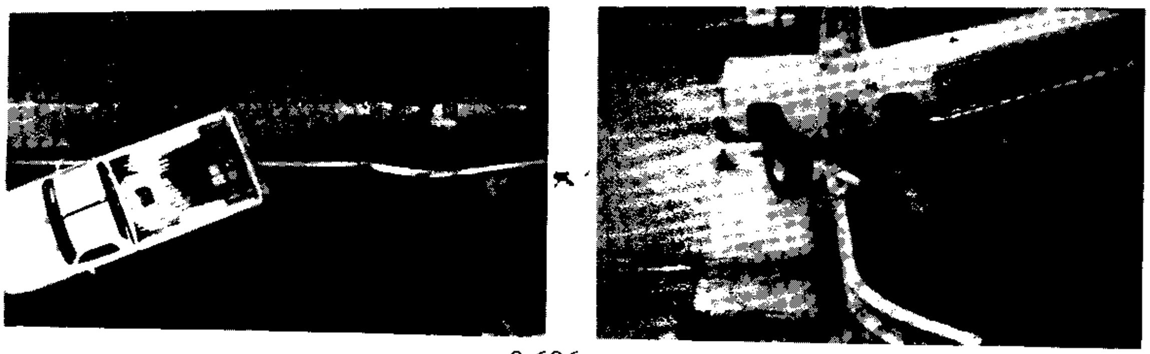


0.364 s

Figure 6 . Sequential photographs for test 0482-1.
(overhead and frontal views).

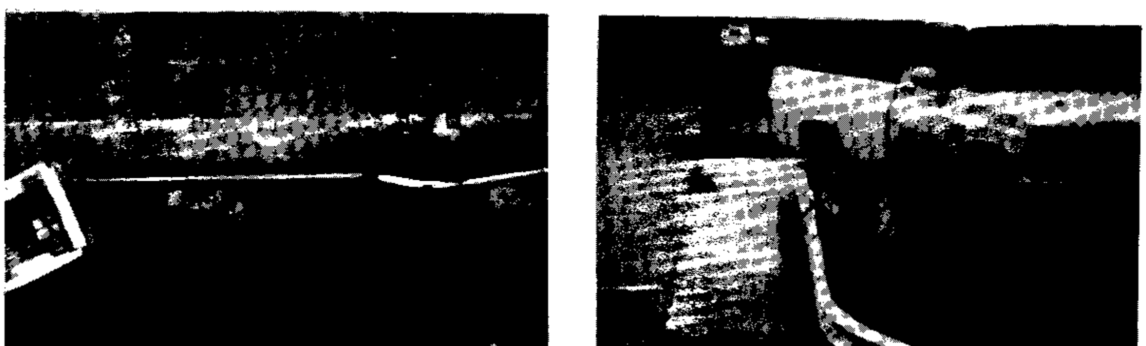


0.485 s



0.606 s

0.728 s

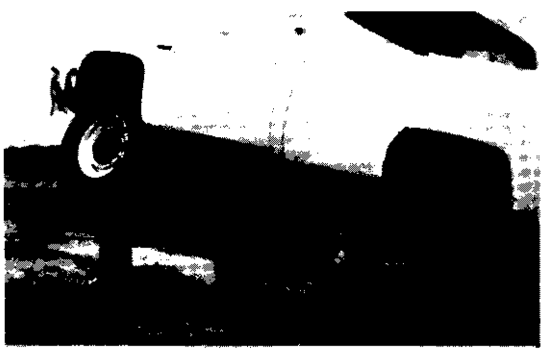


0.849 s

Figure 6. Sequential photographs for test 0482-1 (continued) (overhead and frontal views).

0.000 s

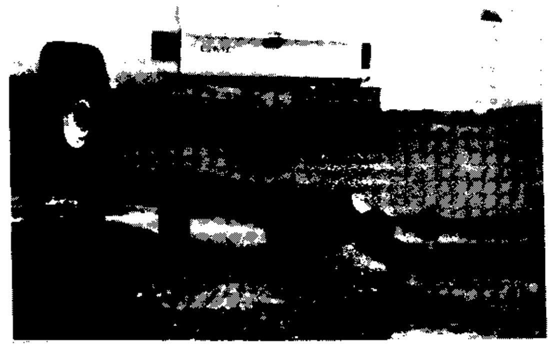
0.121 s



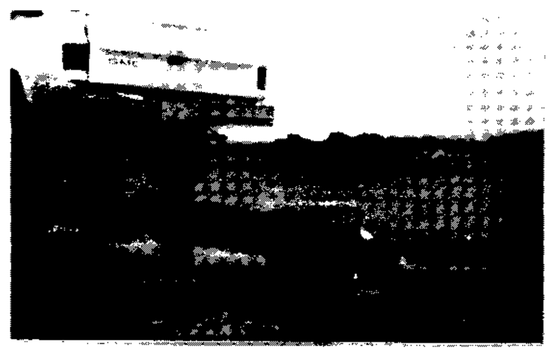
0.243 s

0.364 s

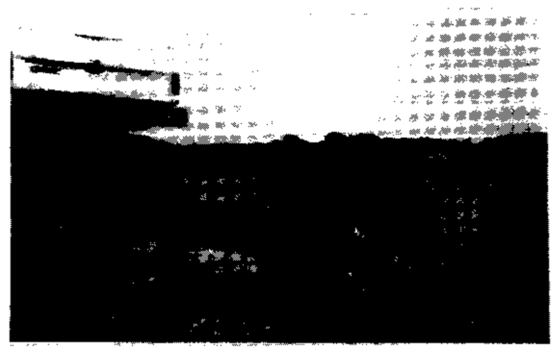
0.485 s



0.606 s



0.728 s



0.849 s

Figure 7 . Sequential photographs for test 0482-1.
(behind the rail view)

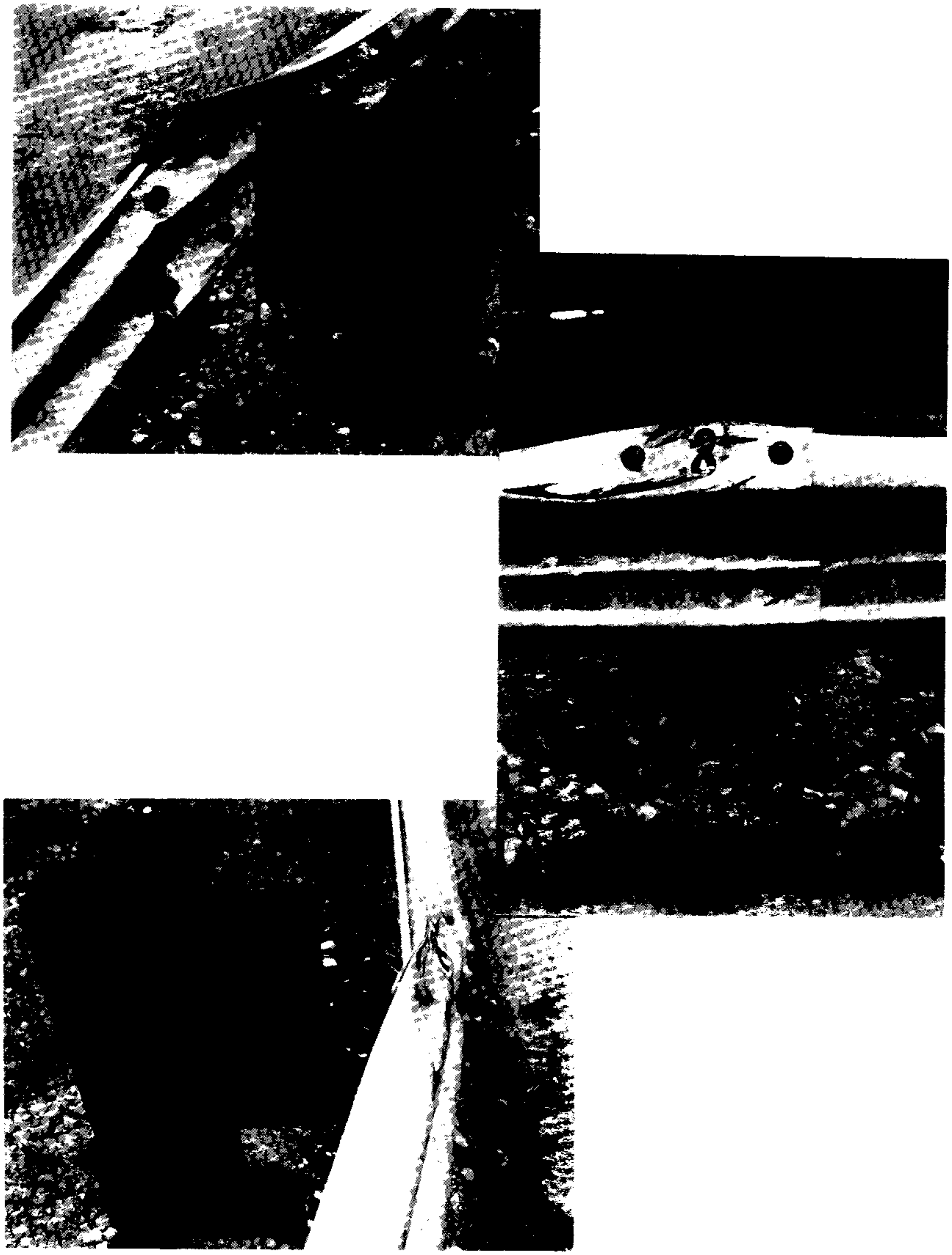
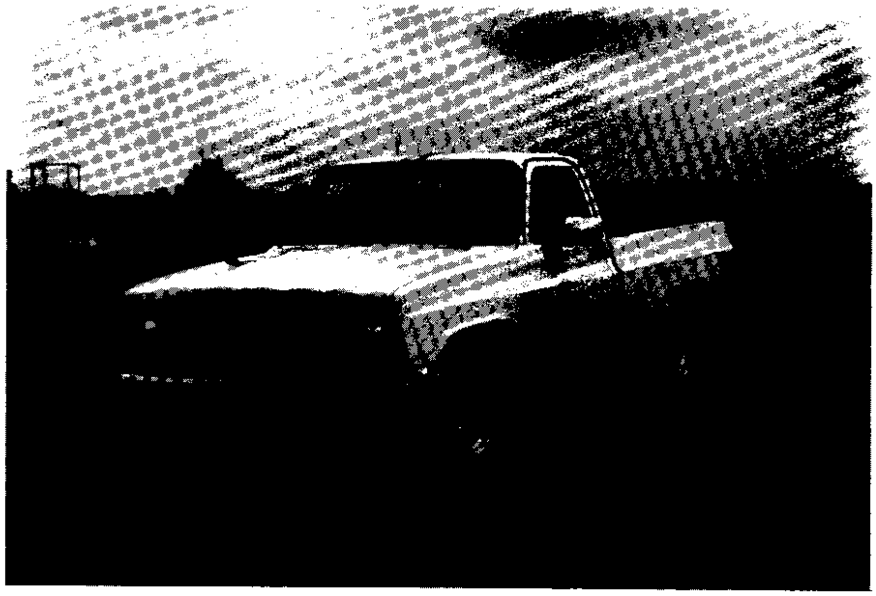


Figure 8 . W-Beam rail installation after test 0482-1.

Figure 8. W-Beam rail installation after test 0482-1 (continued).



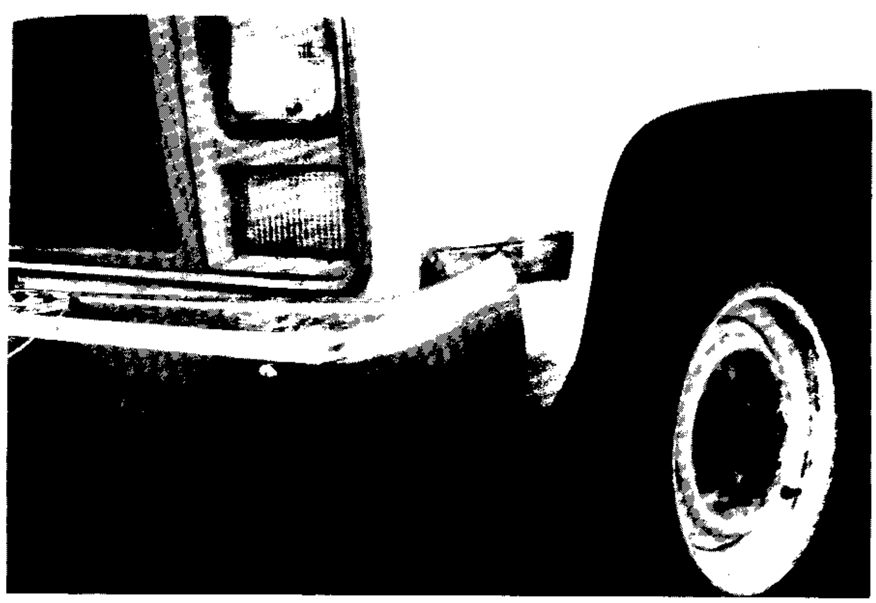
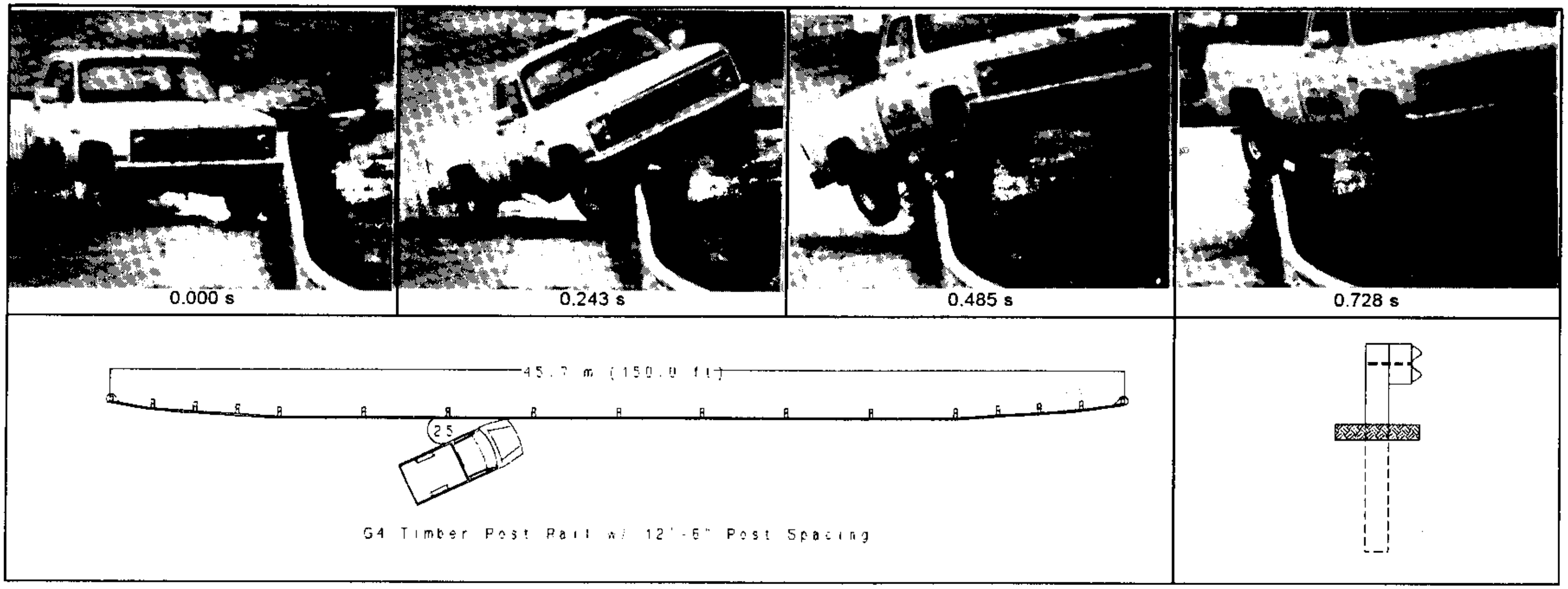


Figure 9 . Vehicle after test 0482-1.



General Information	
Test Agency	Texas Transportation Institute
Test No.	04820-1
Date	05/18/93
Test Article	
Type	W-Beam Guardrail
Installation Length (m)	30.5 (100.0 ft)
Size and/or dimension and material of key elements	12'-6" Post Spacing
Soil Type and Condition	Strong soil
Test Vehicle	
Type	1985 Chevrolet Truck
Designation	2000P
Model	C-20
Mass (kg) Curb	2097 (4,623 lb)
Test Inertial	2000 (4,409 lb)
Dummy	
Gross Static	

Impact Conditions	
Speed (km/h)	69.5 (43.2 mi/h)
Angle (deg)	24.5
Exit Conditions	
Speed (km/h)	58.5 (36.4 mi/h)
Angle (deg)	14.0
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	3.3 (10.7 ft/s)
y-direction	1.9 (6.1 ft/s)
THIV (optional)	
Ridedown Accelerations (g's)	
x-direction	3.4
y-direction	2.9
PHD (optional)	
ASI (optional)	

Test Article Deflections (m)	
Dyanmic	0.5 (1.7 ft)
Permanent	0.3 (1.0 ft)
Vehicle Damage	
Exterior	
VDS	11LFQ-1
CDC	11LFLW3
Interior	
OCDI	
Post-Impact Behavior	
Max. Roll Angle (deg)	20.1
Max. Pitch Angle (deg)	12.3
Max. Yaw Angle (deg)	5.8

Figure 10. Summary of results for test 0482-1.

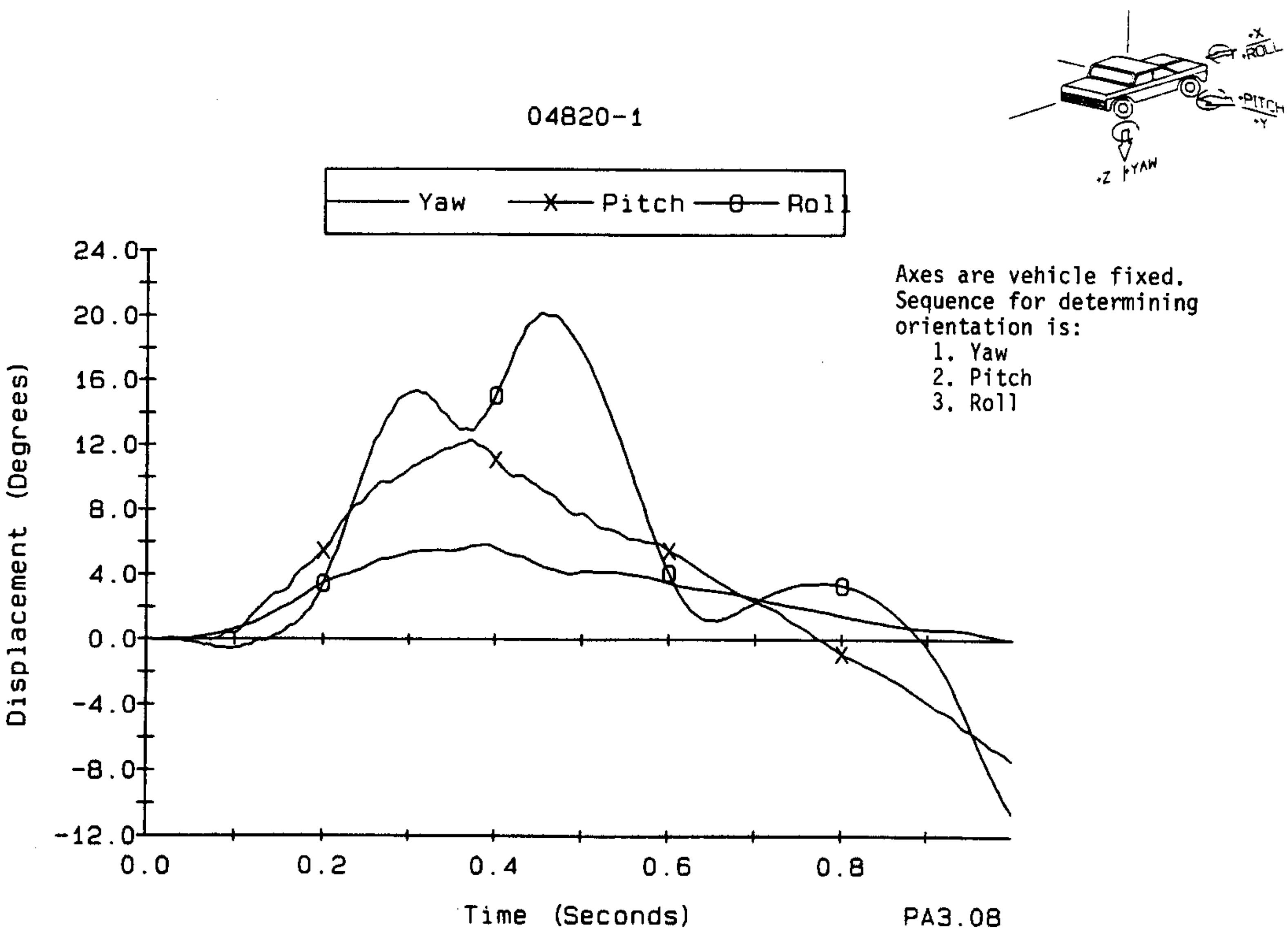


Figure 11. Vehicle angular displacements for test 0482-1.

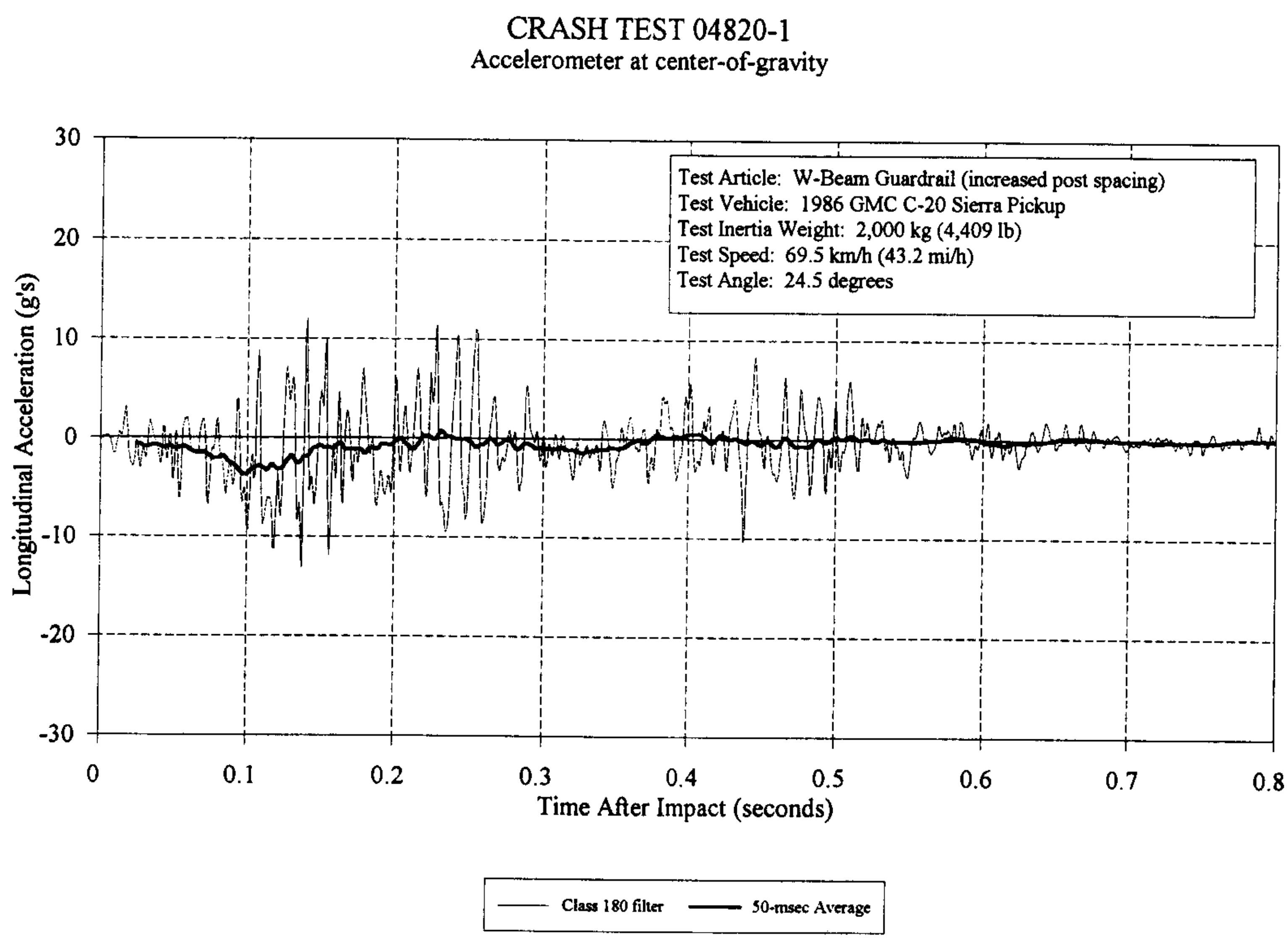


Figure 12 . Vehicle longitudinal accelerometer trace for test 04820-1.

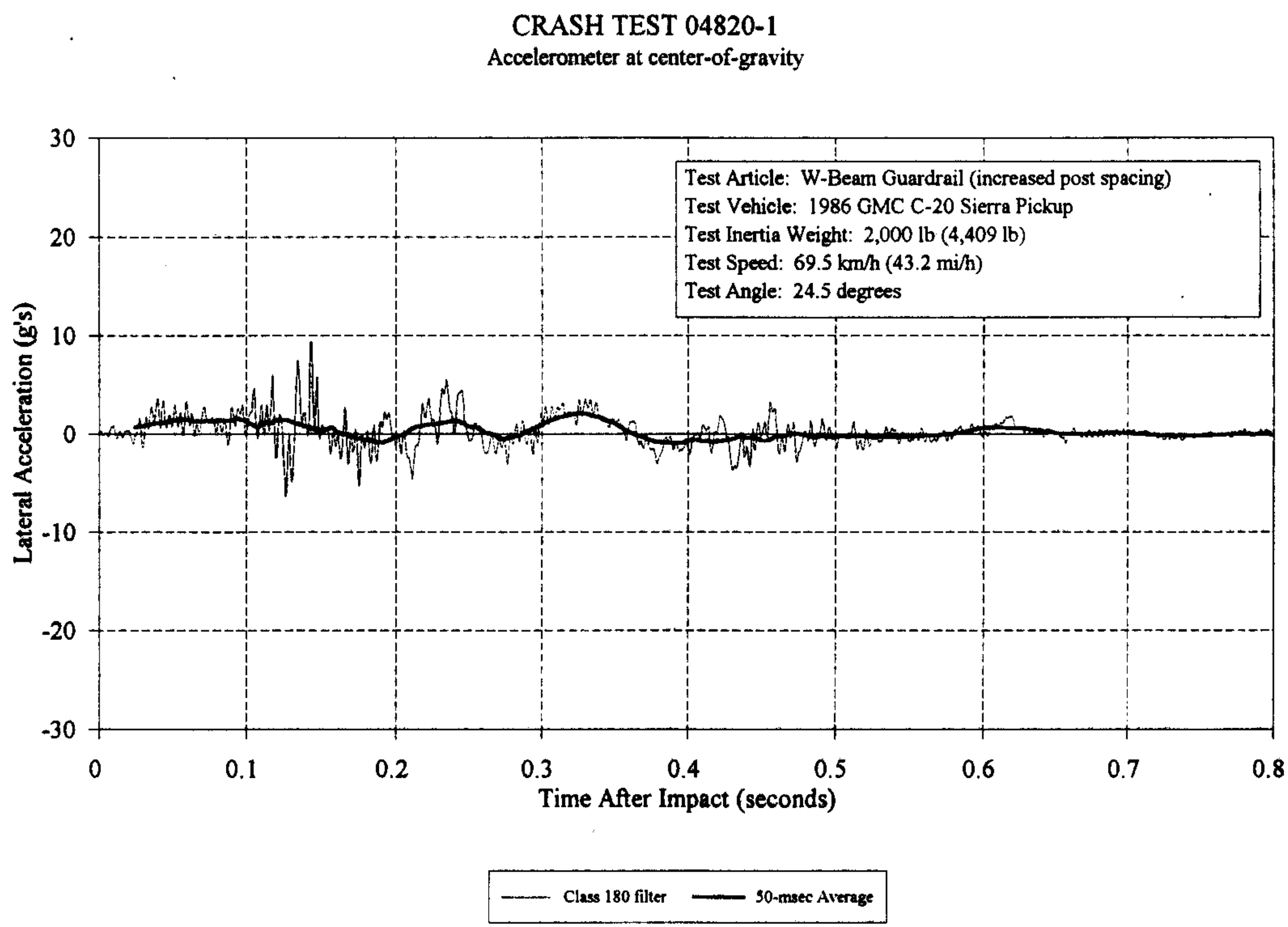


Figure 13. Vehicle lateral accelerometer trace for test 04820-1.

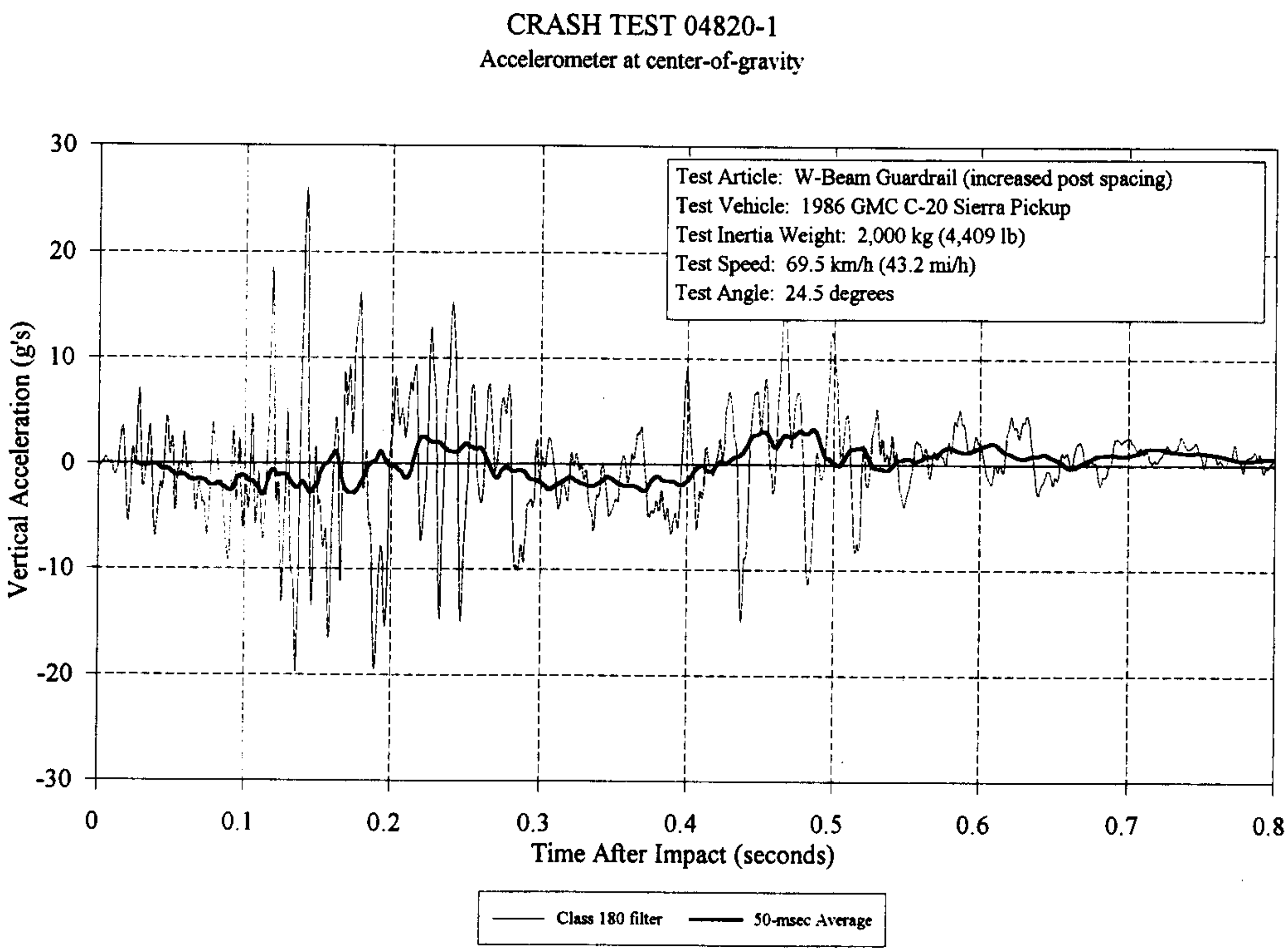


Figure 14 . Vehicle vertical accelerometer trace for test 04820-1.

IV. CONCLUSIONS AND RECOMMENDATIONS

The 12 ft-6 in (3.81-m) post spacing guardrail system failed to meet the evaluation criteria set forth in NCHRP Report 350, a summary of which is shown in Table 1. The vehicle vaulted over the guardrail system with surprising ease. The unsatisfactory performance can be partially attributed to the lack of torsional rigidity of the W-beam rail element and the increased post spacing. However, there is also some concern regarding the pickup truck as the standard test vehicle because of its higher center-of-gravity than a passenger car, which was the standard test vehicle under NCHRP Report 230. As mentioned previously, a crash test with a 4,500-lb (2,041-kg) passenger car on a W-beam guardrail system with a post spacing of 12 ft-6 in (3.81 m) and a rail height of 24 in (0.61 m) at a nominal speed and angle of 60 mi/h (96.6 km/h) and 25 degrees also resulted in failure as the vehicle rode on top of the rail element and eventually went over the guardrail due to excessive deflection of the system. In comparison, the pickup truck in this crash test began to vault over the guardrail prior to any substantive deflection.

Given the ease with which the test vehicle vaulted over the 12 ft-6 in (3.81-m) post spacing W-beam guardrail system, further crash testing with the 820-kg (1,800-lb) passenger car was not recommended. Also, it does not appear that the impact performance of the guardrail system can be improved without major modifications to the design, which would greatly increase the cost of the system and defeats the purpose of developing a lower cost guardrail system for use on lower-speed roadways. Thus, further developmental effort is also not recommended.

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3. Sicking, D. L., and Ross, H. E., Jr., "Structural Optimization of Strong Post W-Beam Guardrail," Transportation Research Record No. 1133, Transportation Research Board, Washington, D. C., 1987.

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7. Michie, J. D., "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances," NCHRP Report 230, National Cooperative Highway Research Program, Transportation Research Board, Washington, D. C., March 1981.