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16. Abstract <p>In June of 1989, the Texas Department of Transportation (TxDOT) contracted with the Texas Transportation Institute (TTI) to develop a set of performance specifications for truck mounted attenuators (TMA's). The objectives of this project were to (1) assess the performance of several truck mounted attenuators and then (2) develop and propose the criteria that define an "acceptable" TMA. These criteria will be used by the Equipment and Procurement Division (D-4) of the Texas Department of Transportation in setting minimum performance requirements for TMA's purchased by the Department.</p> <p>This report is the second of three volumes. In this volume, the procedures and protocols employed in the 21 crash tests conducted during the course of this project are presented, along with the ways and means by which test data were collected and analyzed. Results of the tests are presented photographically (before-and-after photographs of the TMA's and impacting vehicles; sequential photographs of the crashes) and graphically (vehicle deceleration by time plots; angular displacements by time plots). Performance measures based upon NCHRP Report 230 (occupant impact velocity and occupant ridedown acceleration) and TRB Circular 191 (maximum 50-msec average longitudinal acceleration) criteria are provided.</p>					
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**COMPARATIVE CRASH TESTS CONDUCTED ON
SEVEN DIFFERENT MAKES AND MODELS OF
TRUCK MOUNTED ATTENUATORS (TMA's)**

by

Wanda L. Campise

August 1991

Safety Division
Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
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LENGTH

in	inches	2.54	centimetres	cm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km

AREA

in ²	square inches	645.2	centimetres squared	cm ²
ft ²	square feet	0.0929	metres squared	m ²
yd ²	square yards	0.836	metres squared	m ²
mi ²	square miles	2.59	kilometres squared	km ²
ac	acres	0.395	hectares	ha

MASS (weight)

oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

VOLUME

fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft ³	cubic feet	0.0328	metres cubed	m ³
yd ³	cubic yards	0.0765	metres cubed	m ³

NOTE: Volumes greater than 1000 L shall be shown in m³.

TEMPERATURE (exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C
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APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
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LENGTH

mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi

AREA

mm ²	millimetres squared	0.0016	square inches	in ²
m ²	metres squared	10.764	square feet	ft ²
km ²	kilometres squared	0.39	square miles	mi ²
ha	hectares (10 000 m ²)	2.53	acres	ac

MASS (weight)

g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T

VOLUME

mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m ³	metres cubed	35.315	cubic feet	ft ³
m ³	metres cubed	1.308	cubic yards	yd ³

TEMPERATURE (exact)

°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

These factors conform to the requirement of FHWA Order 5190.1A.



* SI is the symbol for the International System of Measurements

NOTICE

This report was prepared for the Texas State Department of Highways and Public Transportation (SDHPT) under the provisions of a contract to the Texas Transportation Institute (TTI) of the Texas A&M University System entitled "Development of Performance Specifications for Truck Mounted Attenuators" (Study Number 2-4-89-991). SDHPT assumes no liability for its contents or use thereof.

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This report does not constitute a standard, specification or regulation.

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INTRODUCTION

In June of 1989, the Texas State Department of Highways and Public Transportation (SDHPT) contracted with the Texas Transportation Institute (TTI) to develop a set of performance specifications for truck mounted attenuators (TMA's). The objective of this project, as stated in the contract, is:

To develop an objective practical performance specification for TMA's that will result in the acquisition of the most cost-effective of these devices for use in Texas construction and maintenance work zones.

This report is the second of three volumes that have been drafted to detail the work conducted during the course of this study, and to document the study findings, conclusions and recommendations. It is intended to document the procedures and results of the crash tests conducted during the course of this study.

The first volume (An Evaluation of Selected Truck Mounted Attenuators with Recommended Performance Specifications by L.I. Griffin, R. Zimmer, W.L. Campise and K.K. Mak) provides an overview of the study, along with the results obtained during crash, vibration and moisture tests on seven different makes and models of TMA's. Comparisons are drawn between the different attenuators, and a set of performance specifications for TMA certification is proposed.

In the third volume of this study [Procedures and Equipment for Conducting Vibration and Moisture Tests on Truck Mounted Attenuators (TMA's) by Richard Zimmer], the procedures for conducting vibration and moisture tests on TMA's are discussed. Detailed plans for the construction of the necessary apparatus to conduct these tests is also provided. Test procedures and protocols are documented. The results of individual vibration and moisture tests are provided.

CRASH TEST PROGRAM

The objective of the crash tests conducted during this study was to determine the impact characteristics of seven makes and models of TMA (described below) when mounted on a 24,000-lb (GVWR) dump truck that had been ballasted to 14,000 pounds prior to the attachment of the TMA. Twenty-one crash tests were conducted during the project in accordance with standards established in NCHRP Report 230¹. These 21 tests were divided into four series as outlined below:

Test Series 1: Eight tests were conducted using a 4,500-lb passenger car impacting the TMA head-on at 45 mph with the dump truck in a free-standing position, parked in second gear with the parking brake on. For purposes of comparison, an additional (ninth) test was

¹Michie, J.D. Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances, National Cooperative Highway Research Program Report 230, Transportation Research Board, National Research Council, Washington, D.C., March 1981.

conducted under the same impact conditions in the absence of a TMA.

Test Series 2: Seven tests were conducted using an 1,800-lb passenger car impacting the TMA head-on at 45 mph with the dump truck in a fixed position (parked with nose against a rigid wall). For purposes of comparison, an additional (eighth) test was conducted under the same impact conditions in the absence of a TMA.

Test Series 3: Three tests were conducted using a 3,500-lb passenger car impacting the TMA head-on at 55 mph with the dump truck in a free-standing position, parked in second gear with the parking brake on. All three of the TMA's used in these tests had previously passed the vibration and moisture tests discussed in volumes 1 and 3 of this report.

Test Series 4: One test was conducted in this series. The conditions for this test were equivalent to the conditions in Test Series 1, except the striking vehicle was a 4,500 pound pickup truck instead of a 4,500-lb passenger car.

TRUCK MOUNTED ATTENUATORS TESTED

Brief descriptions of the seven truck mounted attenuators that were tested and evaluated in this study follow:

1. Energy Absorption Alpha Model

The Alpha Model TMA manufactured by Energy Absorption is shown in Figure 1. Dimensions of the cartridge were 81.75 inches long by 93.00 inches wide by 22.50 inches high. As mounted, the TMA road clearance is nominally 12 inches.

2. Energy Absorption Hexfoam Model

The Hexfoam Model TMA manufactured by Energy Absorption is shown in Figure 2. The TMA consists of an energy absorbing cartridge mounted in a frame encased in a fiberglass shell. The cartridges are hexagon-shaped paper honeycomb cells filled with polyurethane foam. Maximum collapse distance is approximately six feet; maximum weight is approximately 1200 lb. Dimensions of the cartridge were 85.75 inches long by 96.00 inches wide by 24.00 inches high. As mounted, the TMA road clearance is nominally 12 inches.

3. Hexcel 3000

The Hexcel Model 3000 (a model currently marketed by Hexcel Corporation) is shown in Figure 3. The TMA absorbs energy by the use of aluminum honeycomb sections. Maximum collapse distance is approximately 6 feet; maximum weight is approximately 400 pounds. Dimensions of the cartridge were 84.50 inches long by 92.25 inches wide by 24.25 inches high. As mounted, the TMA road clearance is nominally 12 inches.

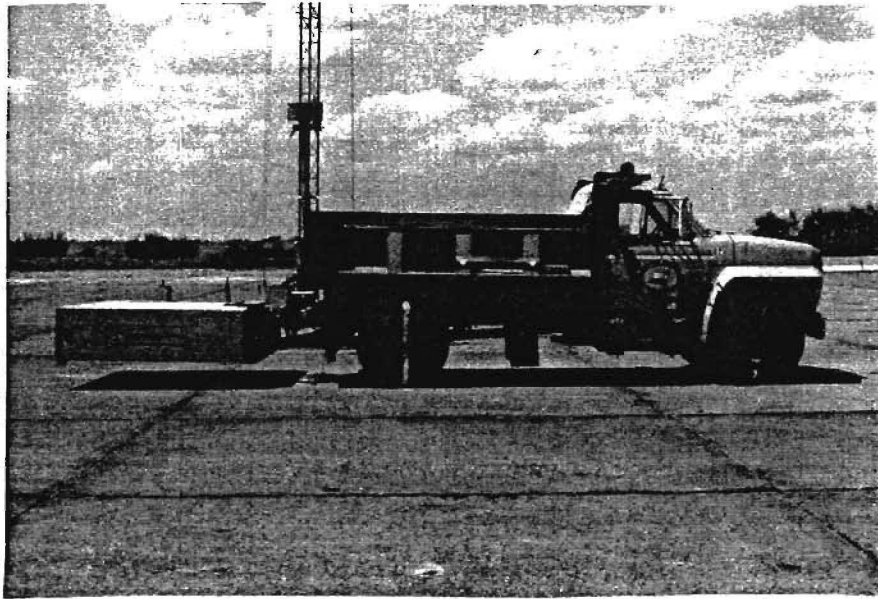
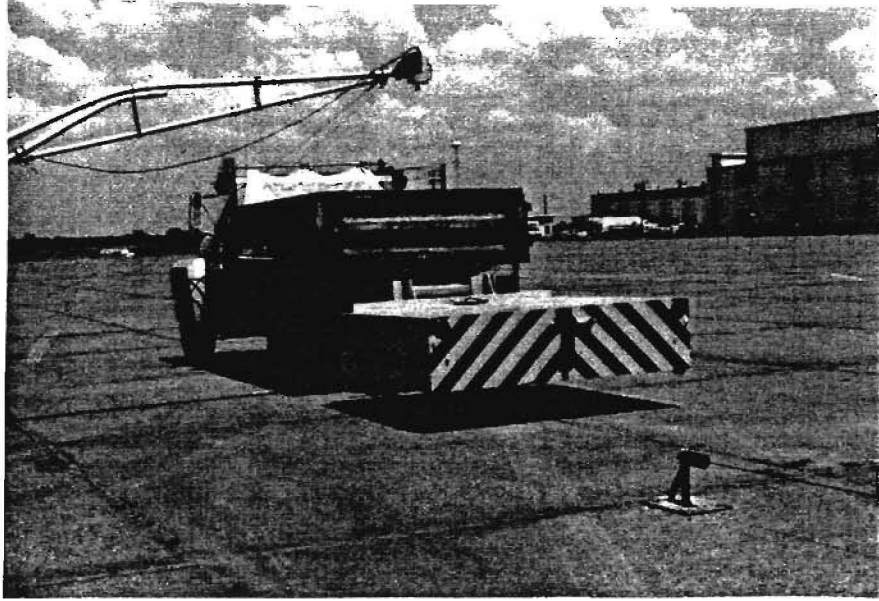


Figure 1. Energy Absorption Alpha TMA

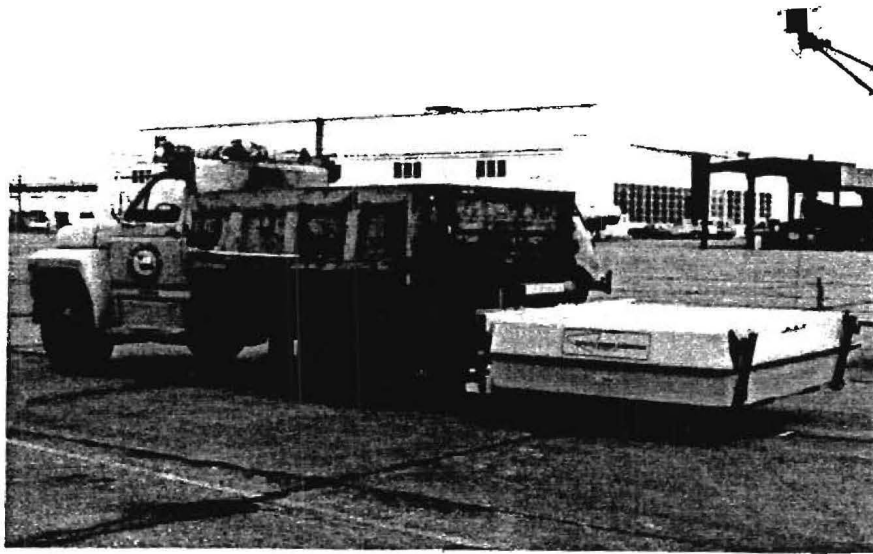


Figure 2. Energy Absorption Hex-foam TMA

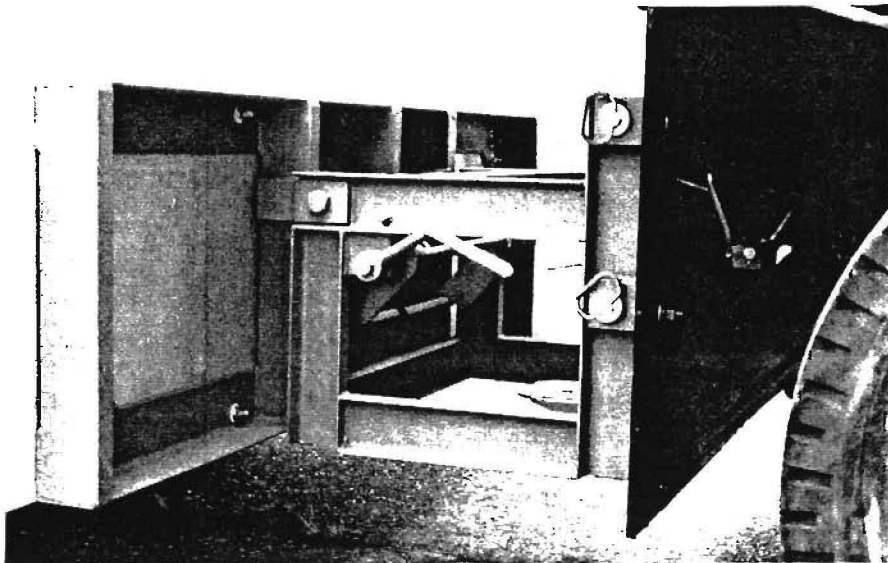
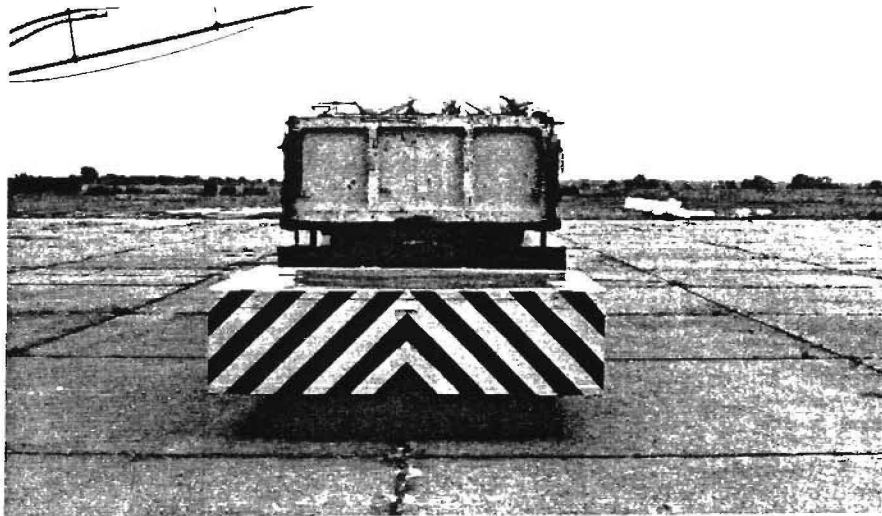


Figure 3. Hexcel Tx-3000 TMA mounted on Truck No. 1.

4. Hexcel 4000

The Hexcel Model 4000 (a model being developed by Hexcel) is shown in Figure 4. Dimensions of the cartridge were 82.25 inches long by 92.25 inches wide by 24.5 inches high. As mounted, the TMA road clearance is nominally 12 inches.

5. Renco

The Renco TMA used during the testing is shown in Figure 5. Dimensions of the cartridge were 81.50 inches long by 95.50 inches wide by 24.00 inches high. As mounted, the TMA road clearance is nominally 11 to 12 inches.

6. Markings and Equipment Corporation

The TMA manufactured by Markings and Equipment Corporation is shown in Figure 6. Dimensions of the cartridge were 83.00 inches long by 93.25 inches wide by 24.75 inches high. As mounted, the TMA road clearance is nominally 12 inches.

7. Connecticut DOT

The Connecticut TMA, shown in Figure 7, was developed by the University of Connecticut in a Highway Planning and Research Study for the Connecticut Department of Transportation. The TMA is composed of vertical steel pipe sections mounted on a sliding support frame and is cantilevered from the rear of a maintenance truck. When struck by a vehicle, the frame slides forward and energy is absorbed by crushing the pipe sections. Maximum collapse distance is approximately eight feet; maximum weight is approximately 1500 lb. Dimensions of the cartridge were 105.13 inches long by 72.00 inches wide by 34.50 inches high. As mounted, the TMA road clearance is nominally 6 to 8 inches.

CRASH TESTS PROCEDURES, DATA COLLECTION AND DATA ANALYSIS

Test Vehicle Propulsion and Guidance

The test vehicles (i.e., the impacting vehicles) were towed into the TMA's using a wire rope guidance and tow system. A wire rope 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. It was connected to the test vehicle, passed around a pulley near the impact point, then through a pulley on the tow vehicle, and was 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.

Electronic Instrumentation and Data Processing

The crash test procedures used were in accordance with guidelines presented in NCHRP Report 230. The test vehicle was instrumented with three solid-state angular rate transducers to measure roll, pitch and yaw rates; a triaxial accelerometer near the center-of-gravity to measure longitudinal, lateral, and vertical acceleration levels, and a biaxial accelerometer in the rear to measure

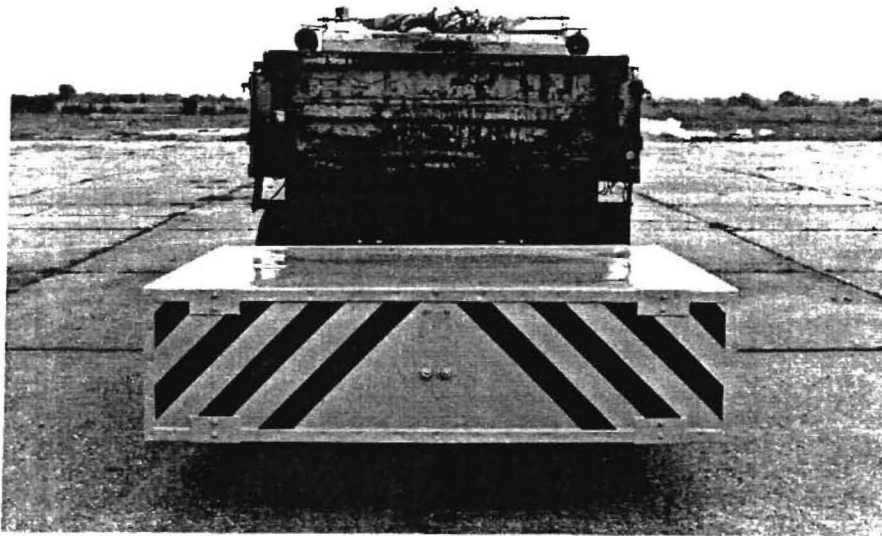
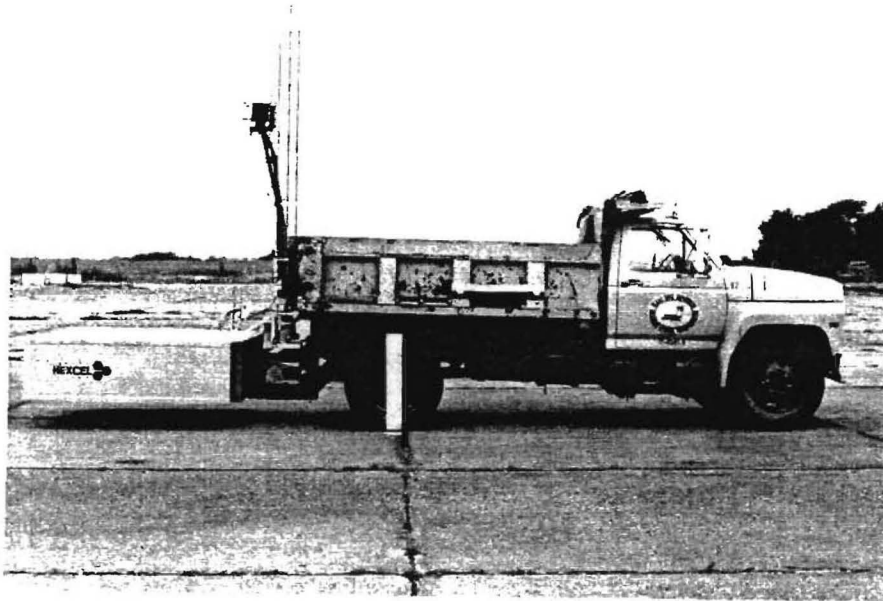


Figure 4 . Hexcel Tx-4000 TMA mounted on Truck No. 2.

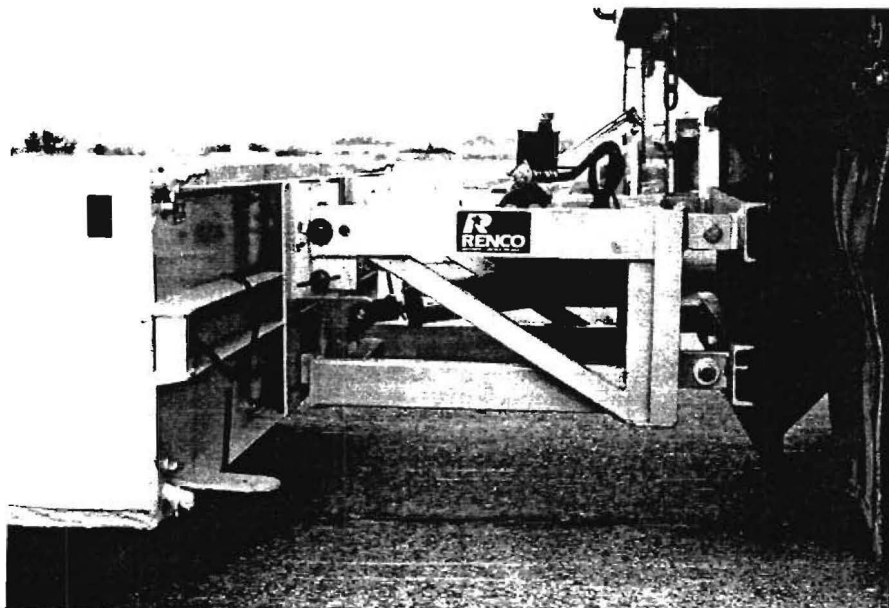
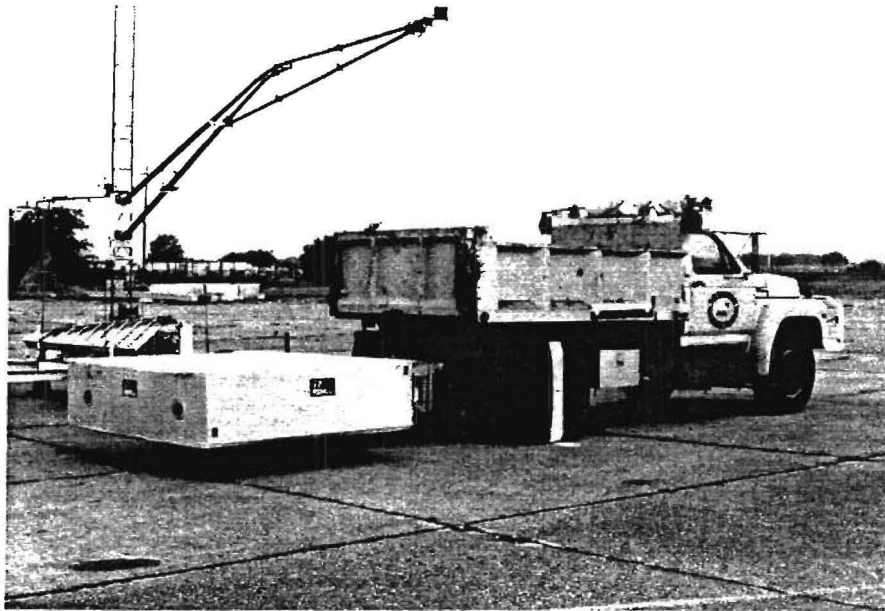


Figure 5 . Renco TMA mounted on Truck No. 1.

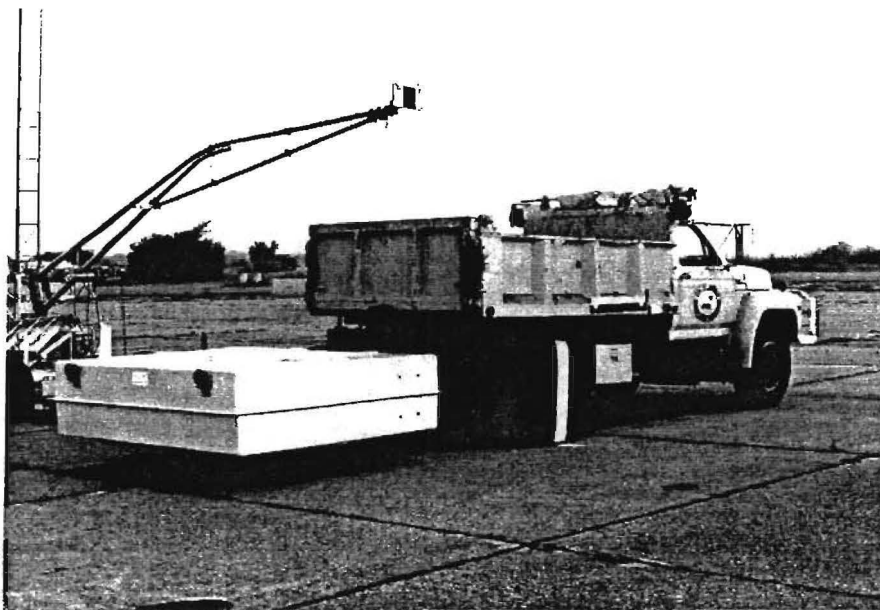
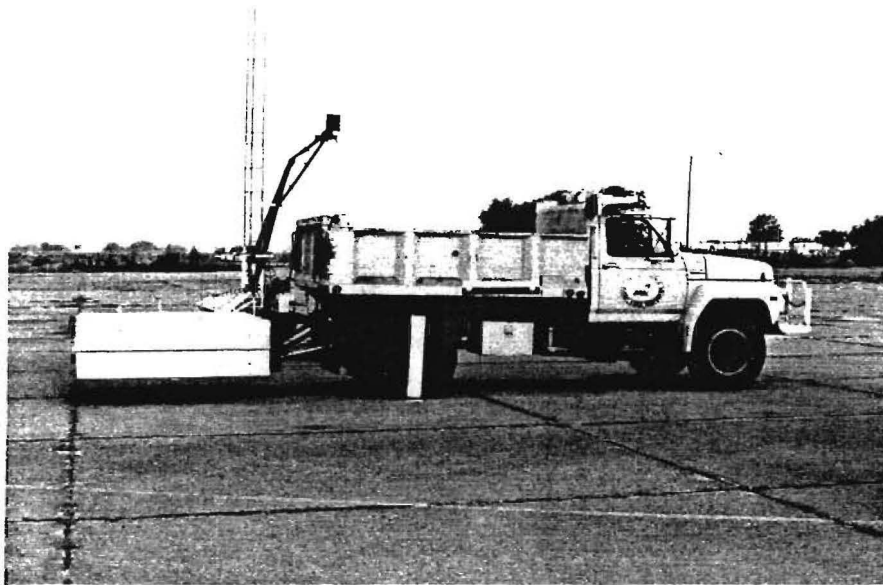


Figure 6. Marking and Equipment TMA mounted on Truck No. 1.

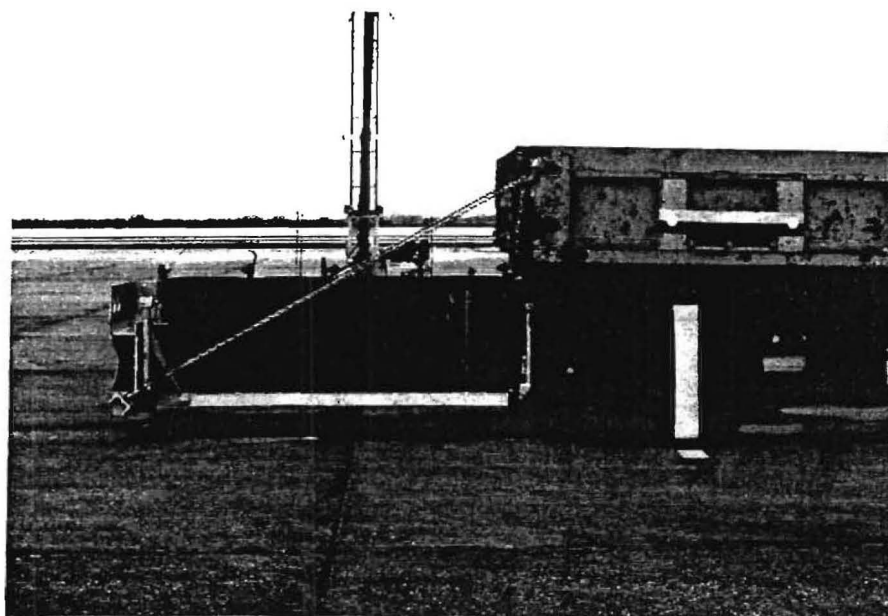


Figure 7. Connecticut TMA
mounted on Truck No. 2.

longitudinal and lateral acceleration levels. The accelerometers were strain gauge type with a linear millivolt output proportional to acceleration.

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

The multiplex of data channels, transmitted on one radio frequency, was received at the data acquisition station, and demultiplexed into separate tracks of Intermediate Range Instrumentation Group (IRIG) tape recorders. After the test, the data were played back from the tape machines, filtered with a Class 180 filter, and digitized using a microcomputer, for analysis and evaluation of performance. The digitized data were then processed using two computer programs: DIGITIZE and PLOTANGLE. Brief descriptions of the functions of these two computer programs are provided as follows.

The DIGITIZE program uses digitized data from vehicle-mounted linear accelerometers to compute occupant/compartiment impact velocities, time of occupant/compartiment impact after vehicle impact, and the highest 10-msec 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-msec 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 (LOTUS 123).

The PLOTANGLE program uses the digitized data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.001-second intervals and then instructs a plotter to draw a reproducible plot: yaw, pitch, and roll versus time. 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 Instrumentation and Data Processing

Photographic coverage of the test included two high-speed cameras, one perpendicular to the TMA/vehicle path and another overhead with a field of view perpendicular to the ground and directly over the TMA. A flash bulb activated by pressure sensitive strip switches was positioned on the impacting vehicle to indicate the instant of contact with the TMA 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 3/4-in videotape and still cameras were used for documentary purposes and to record conditions of the test vehicles and TMA before and after the test.

CRASH TEST RESULTS

The results of the four test series are summarized in Table I. Additional detail on these results is provided in the individual test reports that follow.

<p>Test Series 1: Free-Standing Truck Tests with 4500-lb Passenger Cars Traveling at 45 Miles per Hour</p>

All tests in this series were conducted using 4500-lb Cadillacs or Oldsmobiles impacting TMA's mounted on one of two 24,000-lb (GVWR) dump trucks. The trucks were virtually identical: Truck No. 1 was a 1981 Ford with a test inertia weight of 14,020 lb, and Truck No. 2 was a 1980 Ford with a test inertia weight of 14,010 lb. The trucks were placed in a free-standing position, parked in second gear with the parking brake on. The impacting vehicles were towed into the TMA's using the reverse tow and cable guidance system described earlier and were free-wheeling and unrestrained just prior to impact. The point of impact was head-on with the centerline of the vehicle aligned with the centerline of the TMA.

Energy Absorption Alpha Model (9919-05)

The Energy Absorption Alpha Model used in this test is shown in Figures 1 and 8. The TMA was mounted on Truck No. 2 which had a gross static weight of 14,830 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 12.00 inches at the front and 13.00 inches at the rear. The height to the upper rear surface of the cartridge was 35.50 inches above ground.

The 1981 Cadillac Coupe deVille (pictured in Figures 8 and 9) was towed into the Energy Absorption TMA. The height to the lower edge of the vehicle bumper was 12.25 inches and 20.50 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 10.

The vehicle was travelling at a speed of 45.9 mi/h. Upon impact, the TMA began to crush and, at 0.047 second, the rear truck tires began to rotate. At approximately 0.201 second, the truck tire had rotated 39 degrees and began to skid and rotate backwards. The front of the impacting vehicle bottomed-out at 0.206 second. The truck tire skid ended at 0.311 seconds with the tire at 9 degrees and then began to roll forward again. The truck tire continued to roll forward during the remainder of the test period. At 0.475 second, the truck reached a maximum speed of 12.0 ft/s (8.2 mi/h) and had moved approximately 5.7 ft. By this time, the impacting vehicle had slowed to 25.1 ft/s (17.1 mi/h). The rear truck tire rotated one full revolution plus 49 degrees. Sequential photographs of the test are shown in Figure 11.

The Energy Absorption TMA cartridge crushed a total of 61.25 inches during the test. The frame attachment to the cartridge was bent 1.25 inches at the lower left connection. The truck had moved forward a total of 14.8 feet, and although the parking brake was still on, second gear had become disengaged. The impacting vehicle received damage to the bumper, hood, grill, radiator, right and

Table 1: Results of 21, Full-Scale Crash Tests on Selected TMA's

Test Series (1): 4500 Pound Passenger Cars Traveling at Nominal Speeds of 45 mph

<u>TMA</u>	<u>Test Number</u>	<u>Impact Speed (mph)</u>	<u>Occupant Impact Velocity (ft/s)</u>	<u>Occupant Ridedown Acceleration (g)</u>	<u>Maximum 50 msec Average Long. Acceleration (g)</u>
EA (Alpha Model)	9919-05	45.9	32.7 (146)	-16.4 (191-201)	-12.6 (151-201)
EA (Hex-Foam Model)	9910-04	44.5	34.2 (133)	-12.4 (136-146)	- 9.8 (78-128)
Hexcel (Current Model)	9919-02	46.3	34.4 (129)	-12.8 (139-149)	-12.1 (111-161)
Hexcel (Prototype) [1]	9919-01	47.3	30.6 (120)	- 8.1 (128-138)	- 9.4 (9- 59)
Hexcel (Prototype) [2]	9910-06	44.5	27.0 (132)	-19.6 (234-244)	-13.4 (203-253)
Renco	9919-04	45.7	33.5 (146)	-15.1 (167-177)	-12.8 (146-196)
Markings and Equipment	9919-03	47.8	30.9 (148)	-18.6 (177-187)	-14.0 (146-196)
Connecticut DOT	9910-10	45.6	28.1 (140)	-19.2 (164-174)	-13.7 (155-205)
None	9910-16	46.8	46.7 (96)	- 9.2 (102-112)	-20.4 (37- 87)

Test Series (2): 1800 Pound Passenger Cars Traveling at Nominal Speeds of 45 mph

<u>TMA</u>	<u>Test Number</u>	<u>Impact Speed (mph)</u>	<u>Occupant Impact Velocity (ft/s)</u>	<u>Occupant Ridedown Acceleration (g)</u>	<u>Maximum 50 msec Average Long. Acceleration (g)</u>
EA (Alpha Model)	9910-03	43.9	45.0 (111)	-16.0 (136-146)	-16.0 (76-126)
EA (Hex-Foam Model)	9910-08	44.4	46.5 (93)	-17.8 (126-136)	-16.9 (41- 91)
Hexcel (Current Model)	9910-05	45.2	38.8 (101)	-11.5 (124-134)	-13.2 (31- 81)
Hexcel (Prototype)	9910-07	46.4	38.4 (99)	- 9.3 (142-152)	-14.7 (18- 68)
Renco	9910-02	46.3	34.4 (127)	-28.1 (142-152)	-23.9 (118-168)
Markings and Equipment	9910-01	44.9	30.1 (126)	-24.0 (185-195)	-19.7 (154-204)
Connecticut DOT	9910-09	45.3	37.3 (96)	-13.8 (100-110)	-14.0 (3- 53)
None	9910-15	45.9	58.9 (73)	-11.9 (90-100)	-30.8 (22- 72)

Notes: 1. All tests were at 0 degrees, no offset (i.e., head on).

(notes continue on next page)

Table 1: Results of 21, Full-Scale Crash Tests on Selected TMA's (Continued)

Test Series (3): 3500 Pound Passenger Cars Traveling at Nominal Speeds of 55 mph

<u>TMA</u>	<u>Test Number</u>	<u>Impact Speed (mph)</u>	<u>Occupant Impact Velocity (ft/s)</u>	<u>Occupant Ridedown Acceleration (g)</u>	<u>Maximum 50 msec Average Long. Acceleration (g)</u>
EA (Alpha Model)	9910-13	55.5	38.6 (140)	-38.6 (148-158)	-23.8 (112-162)
Hexcel (Current Model)	9910-14	58.0	34.1 (123)	-31.5 (123-133)	-20.5 (110-160)
Connecticut DOT	9910-11	55.8	34.3 (111)	-52.5 (154-164)	-23.7 (119-169)

Test Series (4): 4500 Pound Pickup Traveling at a Nominal Speed of 45 mph

<u>TMA</u>	<u>Test Number</u>	<u>Impact Speed (mph)</u>	<u>Occupant Impact Velocity (ft/s)</u>	<u>Occupant Ridedown Acceleration (g)</u>	<u>Maximum 50 msec Average Long. Acceleration (g)</u>
EA (Alpha Model)	9910-12	45.1	35.0 (152)	-14.2 (158-168)	-13.4 (124-174)

- Notes:
- Numbers in parentheses represent the times and durations (in msec after initial impact) from which velocities and accelerations were calculated.
 - The tabulated occupant impact velocities, ridedown accelerations and 50 msec average accelerations have all been adjusted to account for slight differences between impact speed (S) and the nominal, desired test speeds of 45 or 55 mph. This adjustment was made by multiplying the raw occupant impact velocities, ridedown accelerations and 50 msec average accelerations by $(45/S)^2$ or $(55/S)^2$.
 - TMA's were attached to dump trucks ballasted to 14,000 pounds prior to TMA attachment.
 - In Test Series 2, the dump trucks were pulled up to a rigid, immovable wall. In Series 1, 3 and 4, the dump trucks were "free standing," with the parking brake set and the transmission in second gear.

left front quarter panels, and the left front door. Maximum vehicle crush was 11.0 inches at bumper height. Figures 12 through 14 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 15. The maximum longitudinal 50-msec average acceleration experienced by the impacting vehicle was -13.1 g between 151 and 201 msec. Longitudinal occupant impact velocity was 34.0 ft/s at 146 msec and the maximum longitudinal ridedown acceleration was -17.1 g between 191 and 201 msec. The maximum longitudinal 50-msec average acceleration for the truck was 3.6 g between 146 and 196 msec. The truck reached a maximum speed of 12.0 ft/s (8.2 mi/h) and moved forward a total of 14.8 ft. The truck continued to roll forward after the first skid ended which may indicate second gear disengaged sometime around 0.311 second after impact. Vehicle angular displacements are plotted in Figure 16, accelerometer traces are displayed in Figures 17 through 19, and the longitudinal accelerometer trace for the truck cab is shown in Figure 20.

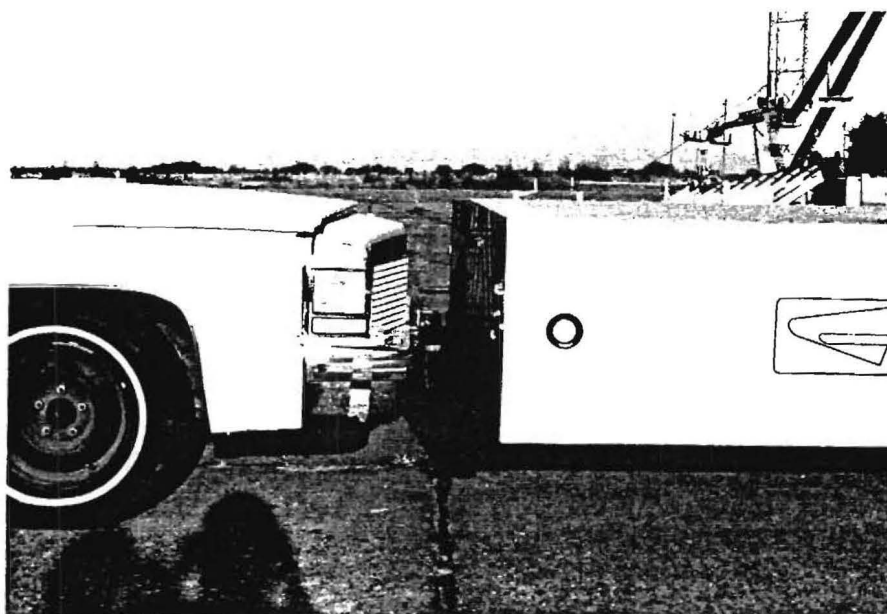
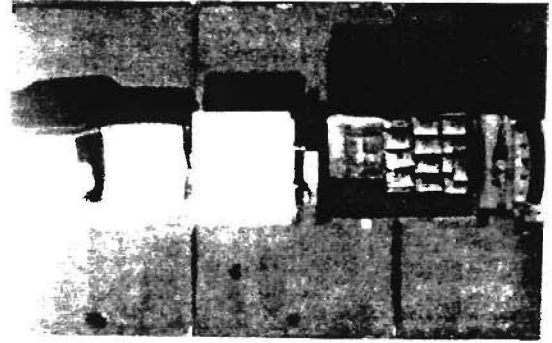
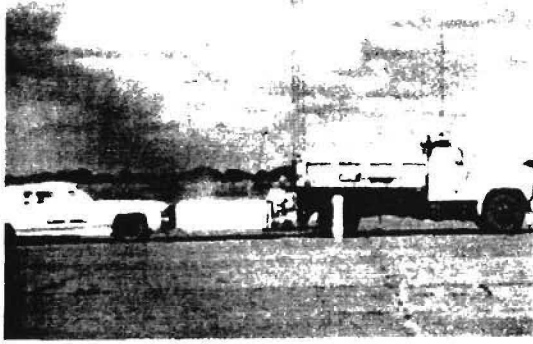


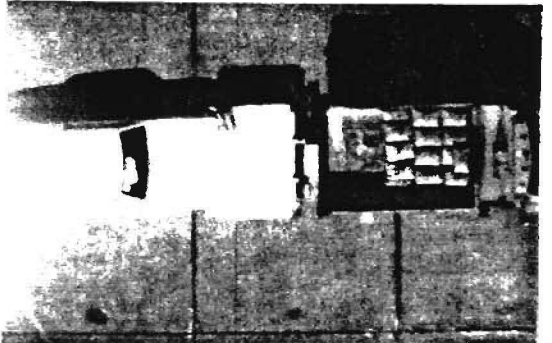
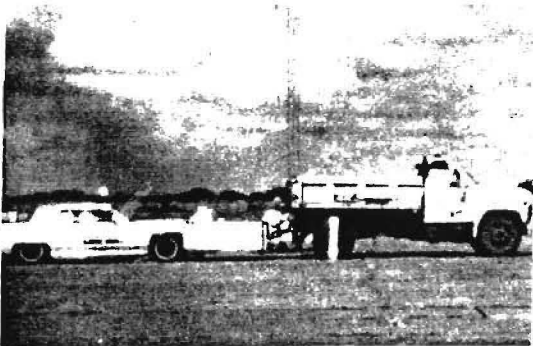
Figure 8. Configuration for test with Energy Absorption TMA.



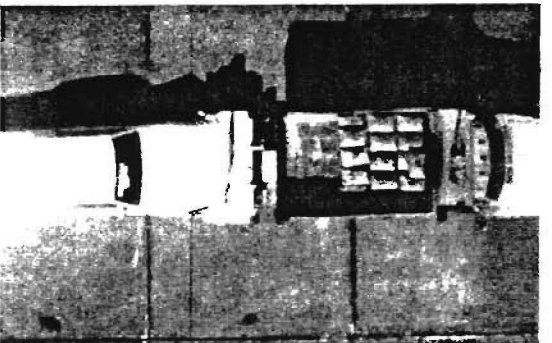
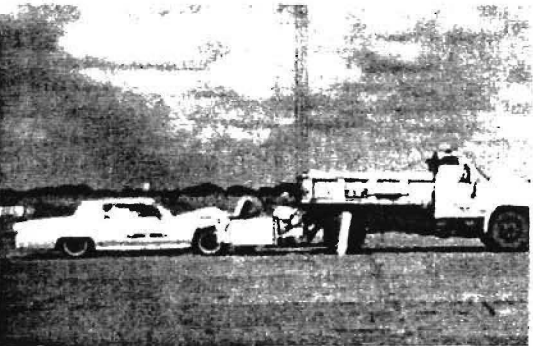
Figure 9. Vehicle before impact with Energy Absorption TMA.



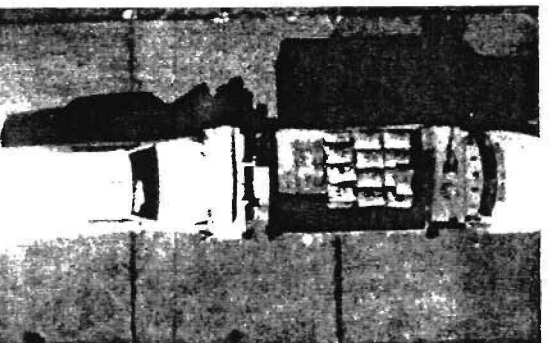
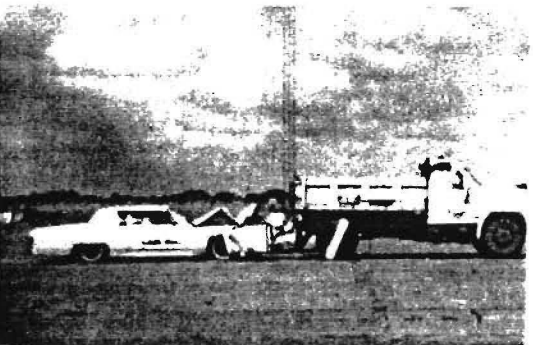
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0.050 s

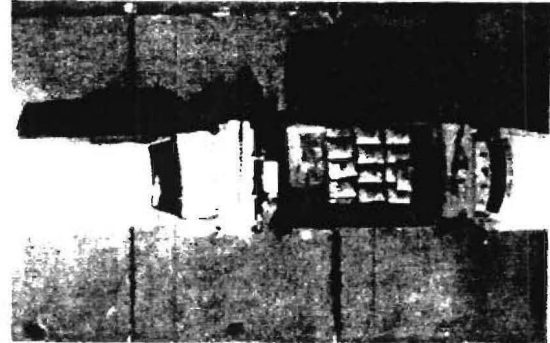
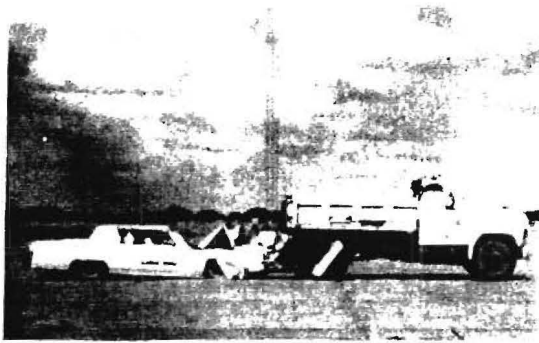


0.100 s

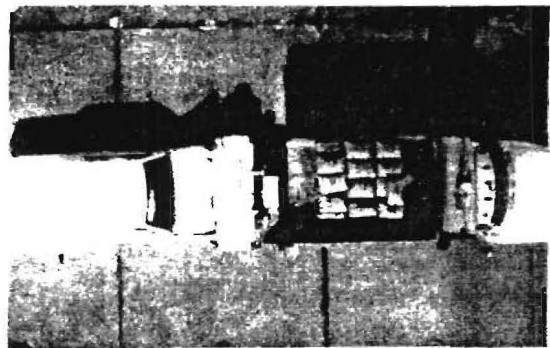
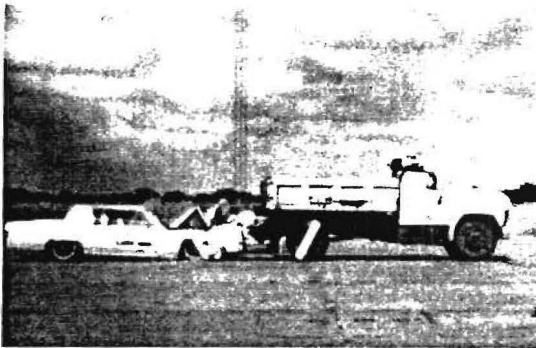


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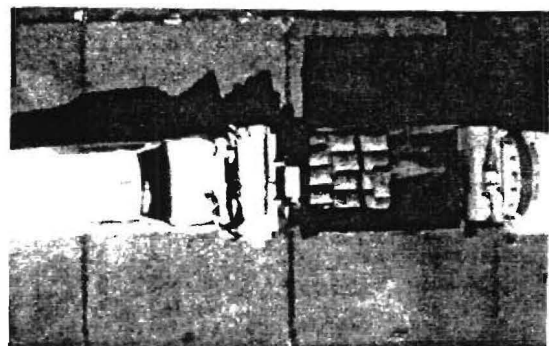
Figure 11. Sequential photographs for test 9919-5.



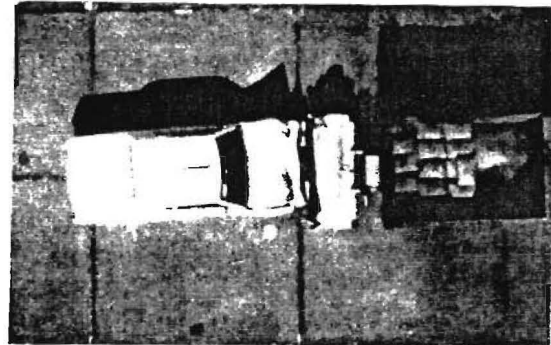
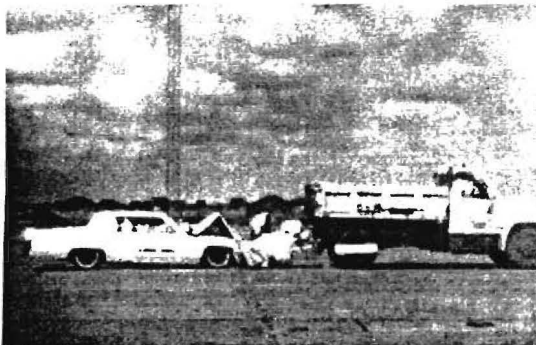
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0.250 s



0.500 s



1.000 s

Figure 11. Sequential photographs for test 9919-5.
(Continued)

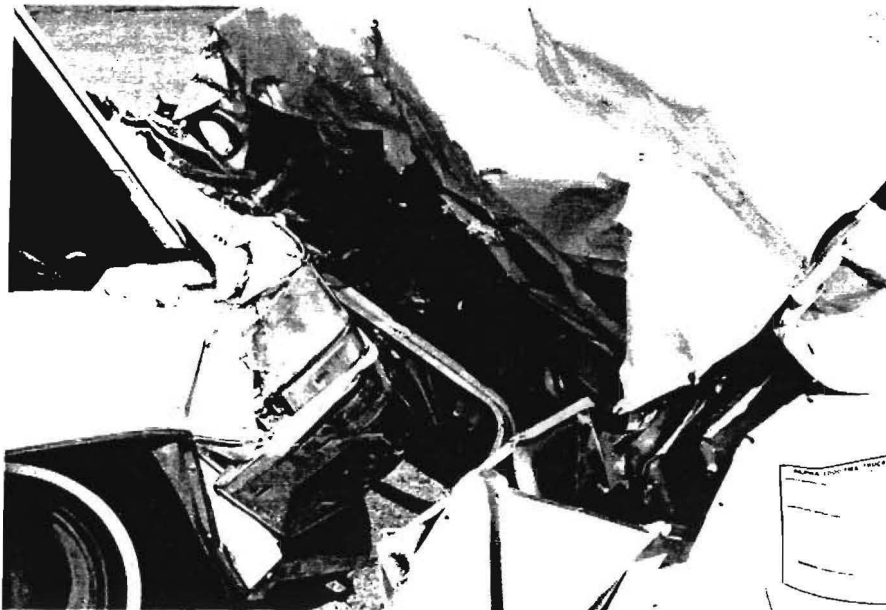
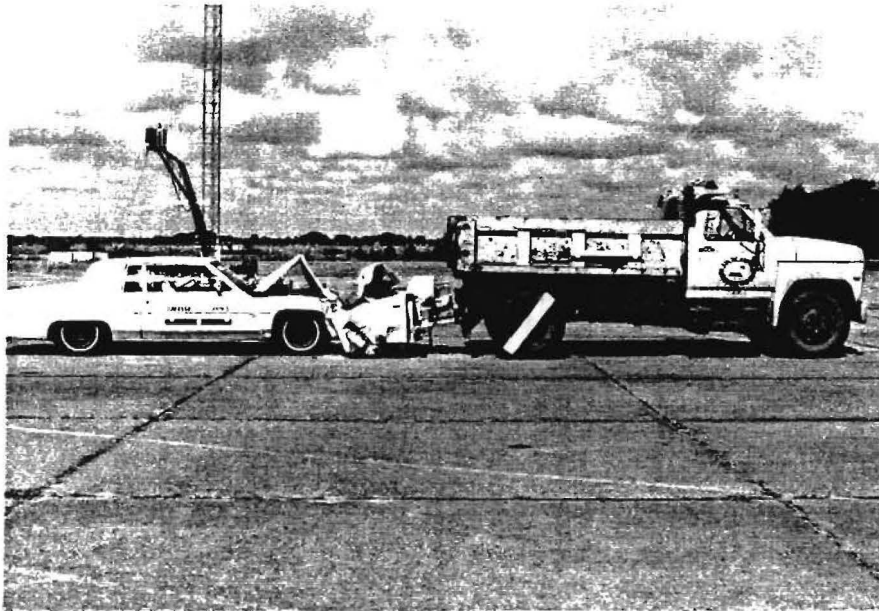


Figure 12. Damage to Energy Absorption TMA (right side).

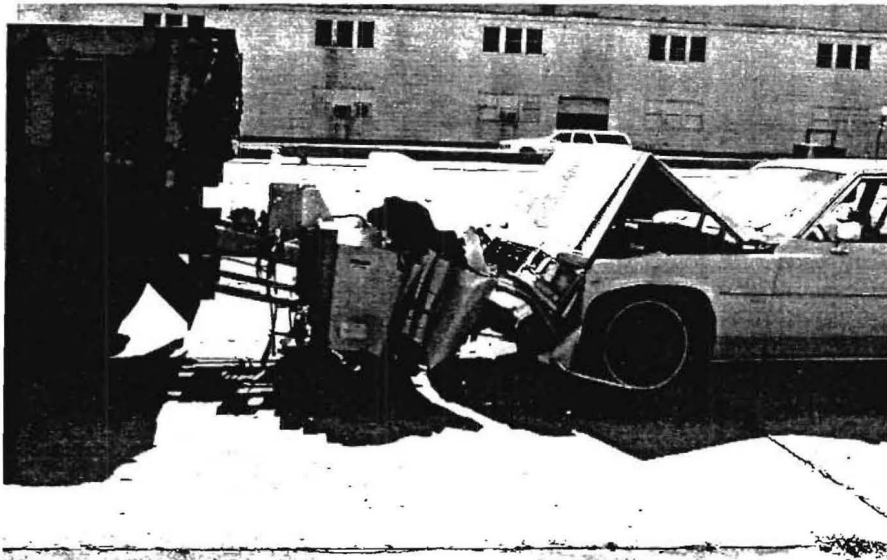
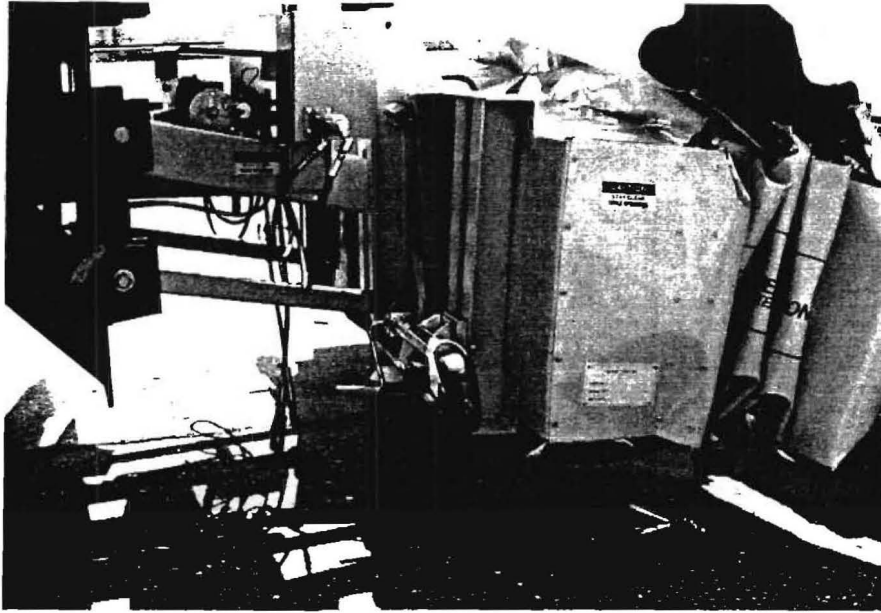
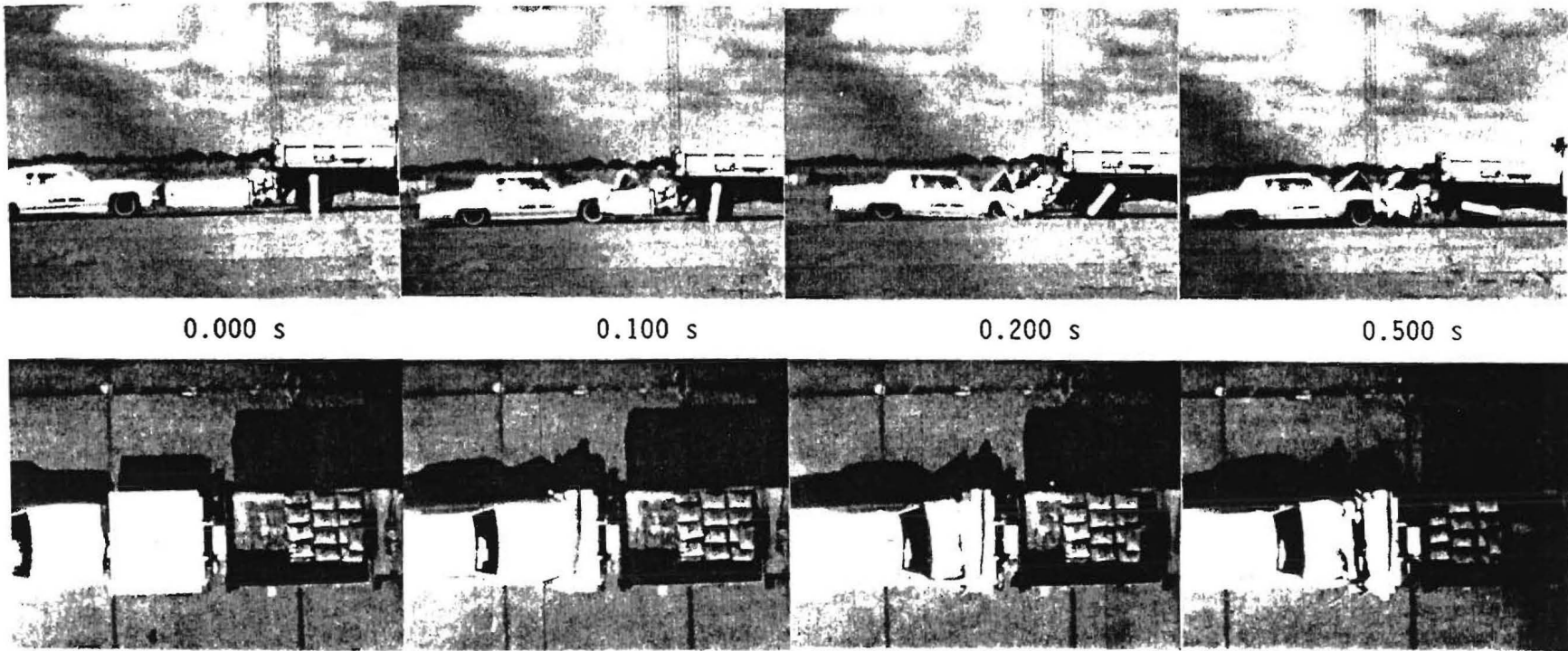


Figure 13. Damage to Energy Absorption TMA (left side).

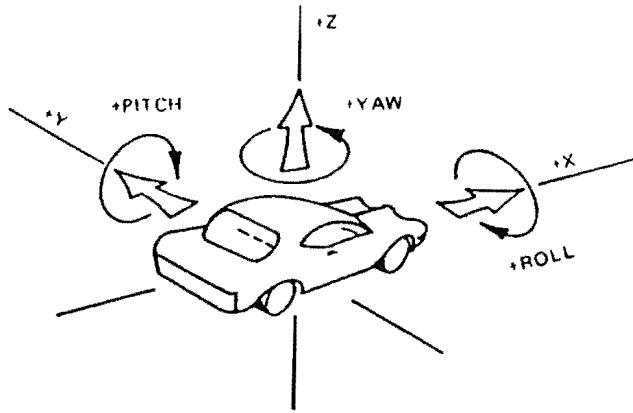


Figure 14. Vehicle after impact with Energy Absorption TMA.



Test No.	09919-5	Maximum Truck Displacement .	14.8 ft (4.5 m)
Date	08/17/89	Maximum TMA Crush	61.25 in (1.6 m)
Test Article	Truck Mounted Attenuator	Vehicle Accelerations	
Manufacturer	Energy Absorption	(Maximum 50 ms Average at c.g.)	
TMA Truck	1980 Ford Dump Truck (#2)	Vehicle Longitudinal	-13.1 g
Weight without TMA	14,010 lb (6,361 kg)	Vehicle Lateral	-1.0 g
Weight with TMA	14,830 lb (6,733 kg)	Truck Cab Longitudinal	3.6 g
Test Vehicle	1981 Cadillac Coupe deVille	Occupant Impact Velocity	
Weight	4,500 lb (2,043 kg)	Longitudinal	34.0 ft/s (10.4 m/s)
Impact Speed	45.9 mi/h (73.9 km/h)	Lateral	6.0 ft/s (1.8 m/s)
Maximum Vehicle Crush	11.0 in (27.9 cm)	Occupant Ridedown Accelerations	
Vehicle Damage Classification		Longitudinal	-17.1 g
TAD	12FD3	Lateral	-1.0 g
CDC	12FDEW2		

Figure 15. Summary of results for test 9919-5.



Axes are vehicle fixed.
Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

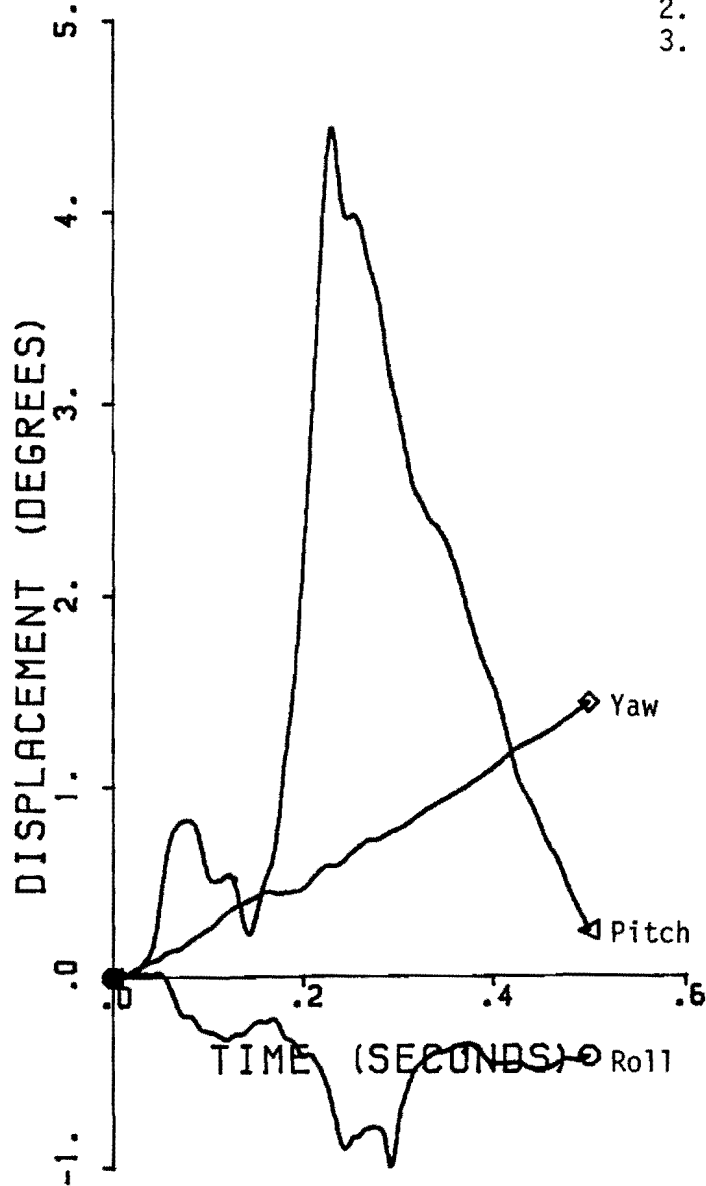


Figure 16. Vehicle angular displacements for test 9919-5.

TEST 9919-5

Class 180 Filter - Near C.G. of Car

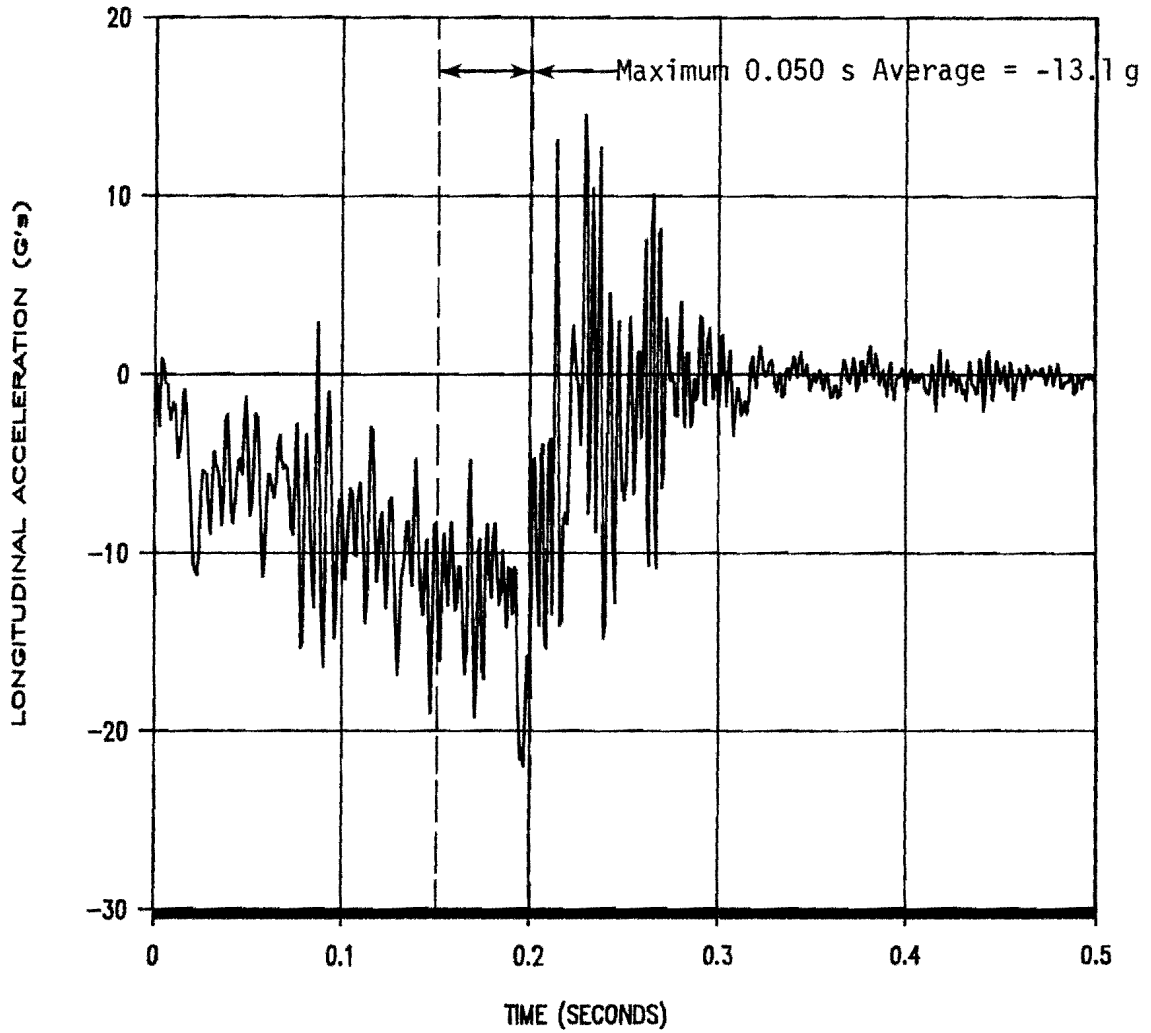


Figure 17. Vehicle longitudinal accelerometer trace for test 9919-5 (near c.g. of vehicle).

TEST 9919-5

Class 180 Filter - Near C.G. of Car

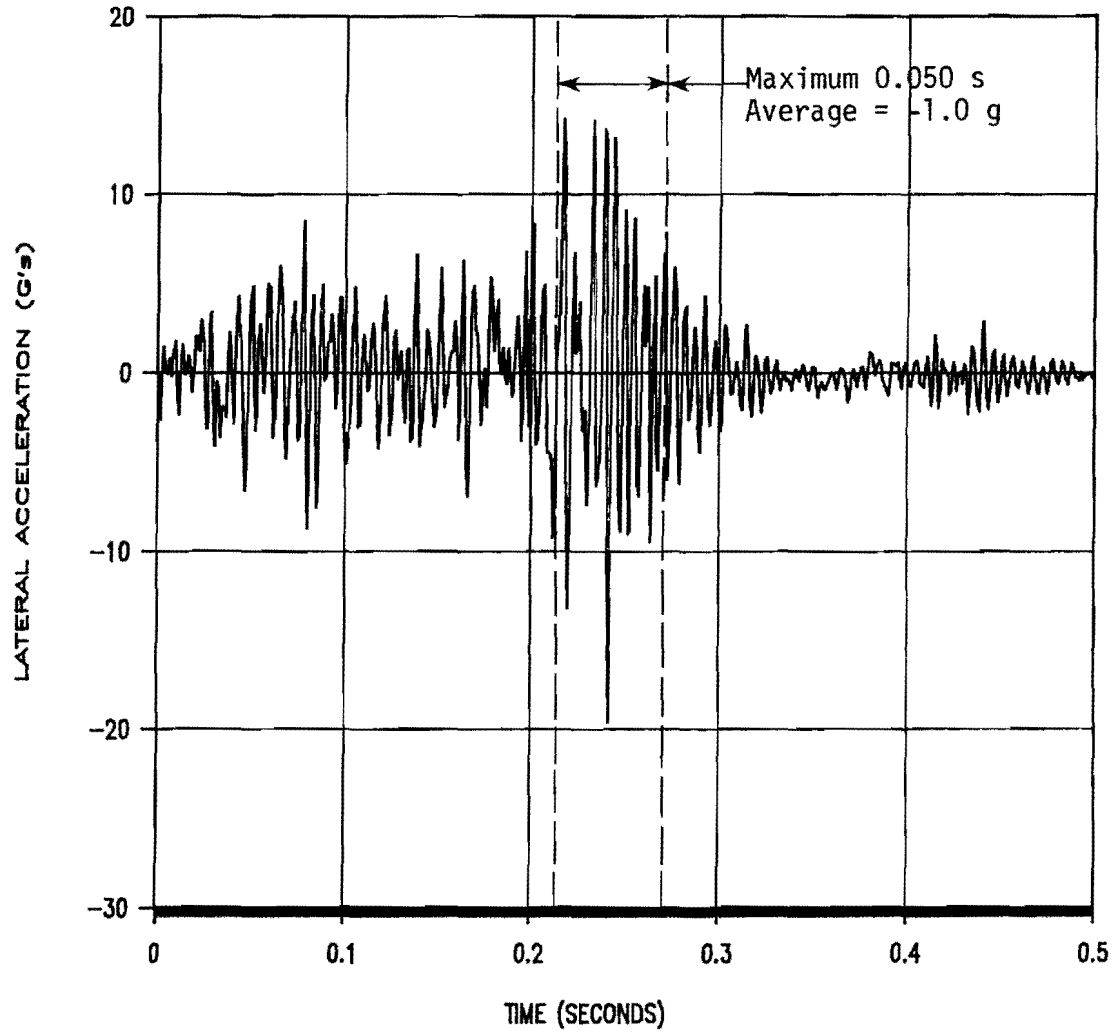


Figure 18. Vehicle lateral accelerometer trace for test 9919-5 (near c.g. of vehicle).

TEST 9919-5

Class 180 Filter - Near C.G. of Car

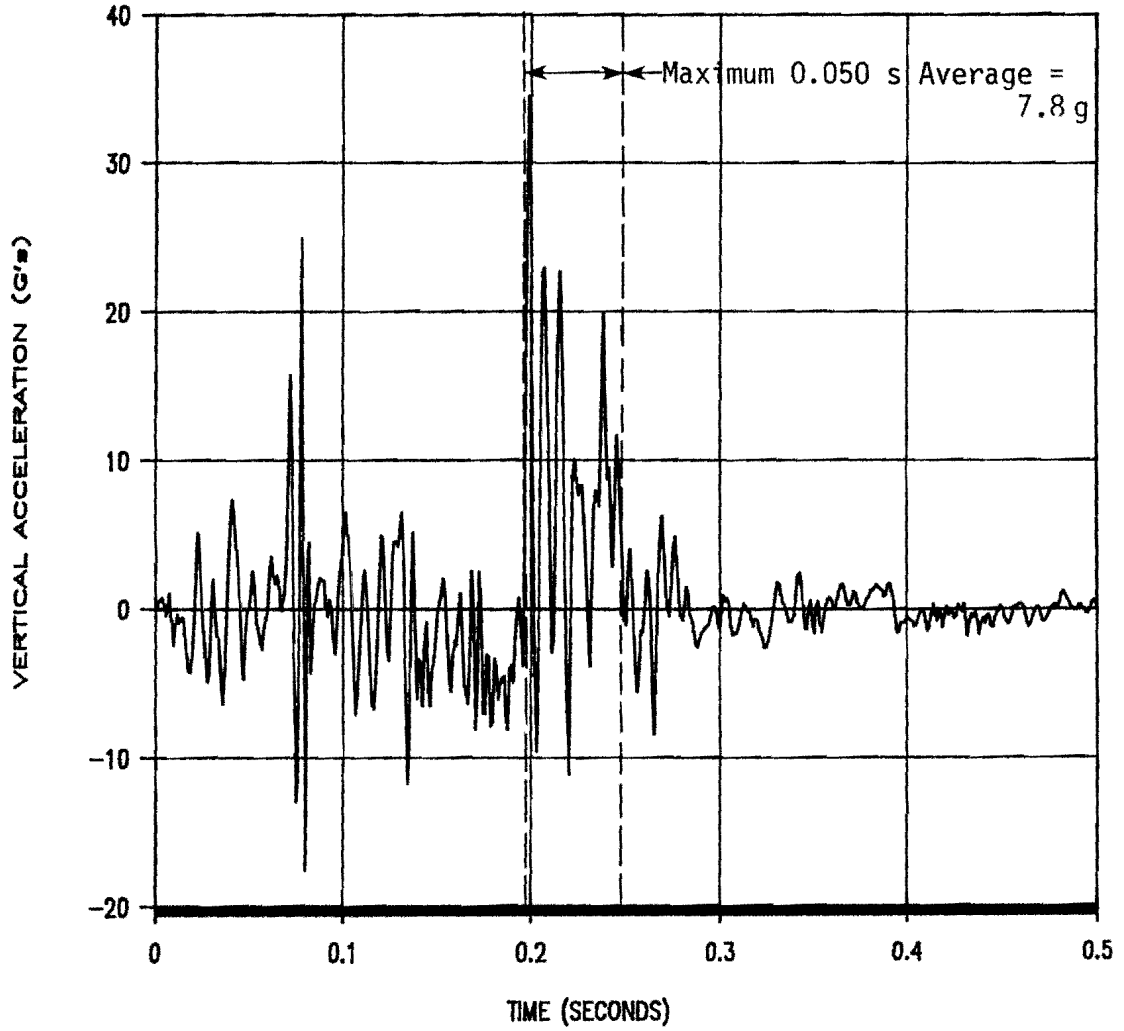


Figure 19. Vehicle vertical accelerometer trace for test 9919-5 (near c.g. of vehicle).

TEST 9919-5

Class 180 Filter - Cab of Truck

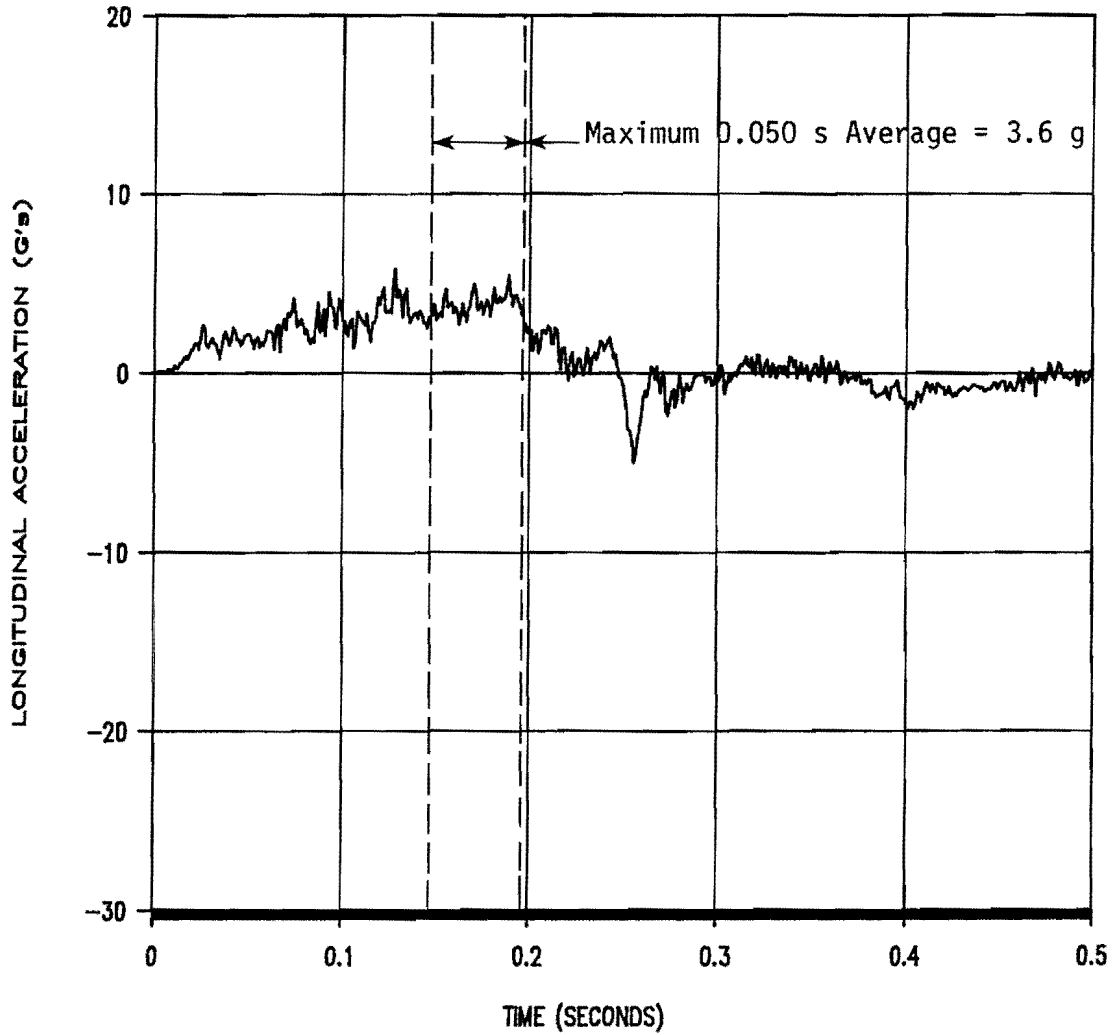


Figure 20. Truck longitudinal accelerometer trace for test 9919-5.

Energy Absorption Hexfoam (9910-04)

The Hexfoam Model TMA used during this test was manufactured by Energy Absorption and is shown in Figure 2. The TMA was mounted on Truck No. 2 which had a gross static weight of 15,350 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 12.25 inches at the front and 12.75 inches at the rear. The height to the upper rear surface of the cartridge was 36.75 inches above ground.

The 1981 Cadillac Sedan deVille (pictured in Figure 21) was directed into the Energy Absorption Hex-foam TMA. The height to the lower edge of the vehicle bumper was 12.50 inches and 20.50 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 22.

The vehicle was travelling at a speed of 44.5 mi/h. Upon impact, the TMA began to crush and, at 0.032 second, the rear truck tires began to rotate. The front of the impacting vehicle began to dive down at 0.110 second and the contents of the cartridge began to displace upward splitting the cartridge open. The impacting vehicle bottomed-out at 0.164 second. At 0.196 second, the truck reached a maximum speed of 12.3 ft/s (8.4 mi/h) and had moved approximately 1.9 ft. By this time, the impacting vehicle had slowed to 23.8 ft/s (15.7 mi/h). At approximately 0.203 second, the truck tire had rotated 34 degrees and began to skid and rotate backwards. The tire skid ended at 0.323 second with the tire at -3 degrees from perpendicular and then began to roll forward again. The truck tire continued rolling and skidding during the remainder of the test period. Sequential photographs of the test are shown in Figure 23.

The Energy Absorption Hexfoam TMA cartridge crushed a total of 57.00 inches during the test (and had split open). The truck had moved forward a total of 8.25 feet, the parking brake was still on, and second gear remained engaged. The impacting vehicle received damage to the bumper, hood, grill, radiator, right and left front quarter panels, and the windshield. Maximum vehicle crush was 20.0 inches just above bumper height. Figures 24 and 25 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 26. The maximum longitudinal 50-msec average acceleration experienced by the impacting vehicle was -9.6 g between 078 and 128 msec. Longitudinal occupant impact velocity was 33.4 ft/s at 133 msec and the maximum longitudinal ridedown acceleration was -12.1 g between 136 and 146 msec. The accelerometer in the truck cab malfunctioned, therefore the 50-msec average longitudinal acceleration for the truck was not computed. The truck reached a maximum speed of 12.3 ft/s (8.4 mi/h) and moved forward a total of 8.25 ft. Vehicle angular displacements are plotted in Figure 27, accelerometer traces are displayed in Figures 28 through 31.



Figure 21. Vehicle before impact with Energy Absorption Hex-foam TMA (9910-4).

Date: _____ Test No.: 9910-4 VIN: 1G6AD4798B9175926
 Make: Cadillac Model: Sedan deVille Year: 1981 Odometer: 39697
 Tire Size: P21575R15 Ply Rating: _____ Bias Ply: _____ Belted: _____ Radial: x

Tire Condition: good _____
 fair x
 badly worn _____

Vehicle Geometry - inches

a 76.75 b 39.50
 c 122.00 d* 55.50
 e 57.00 f 218.50
 g _____ h 55.30
 i _____ j 33.75
 k 18.50 l 37.50
 m 20.50 n 4.75
 o 12.50 p 61.75
 r 27.50 s 16.25

Engine Type: 8 cylinder
 Engine CID: 6.0 liter

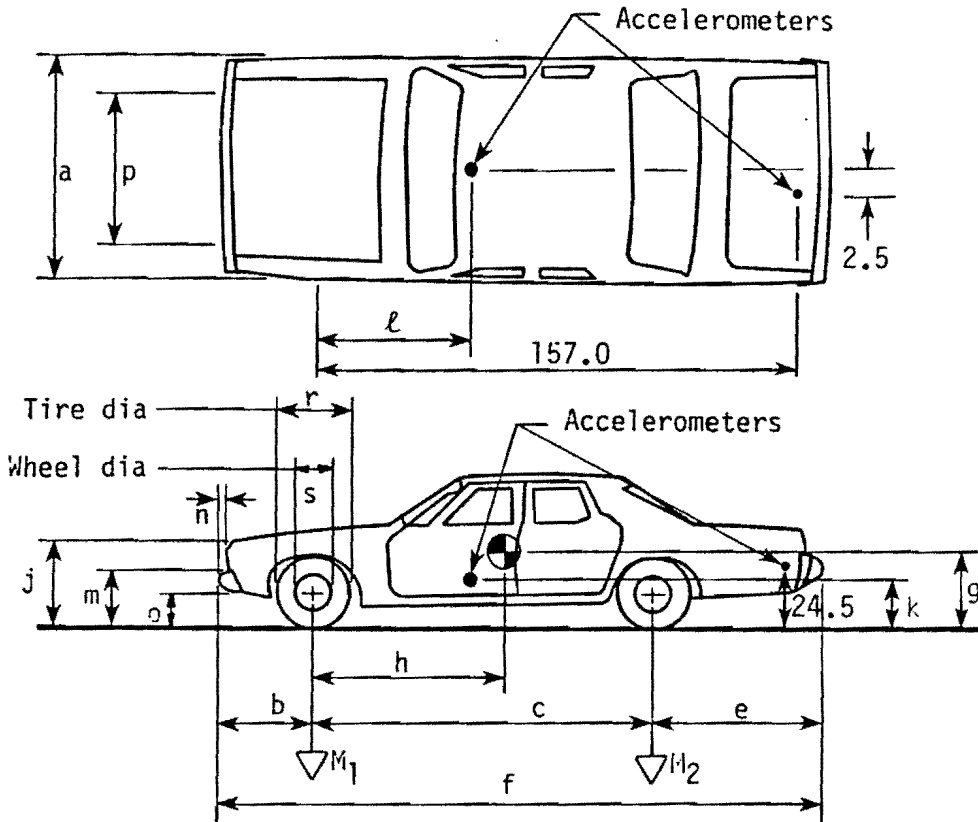
Transmission Type:
 Automatic or Manual
 FWD or RWD or 4WD

Body Type: 2 door coupe

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



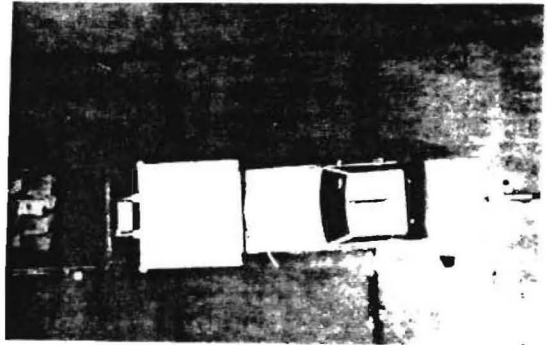
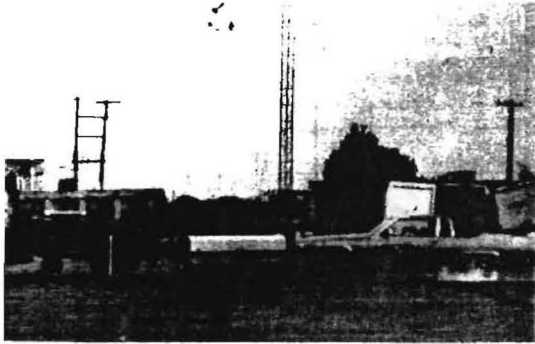
4-wheel weight for c.g. det. lf 1238 rf 1221 lr 1021 rr 1020

Mass - pounds	Curb	Test Inertial	Gross Static
M_1	<u>2376</u>	<u>2459</u>	_____
M_2	<u>1666</u>	<u>2041</u>	_____
M_T	<u>4042</u>	<u>4500</u>	_____

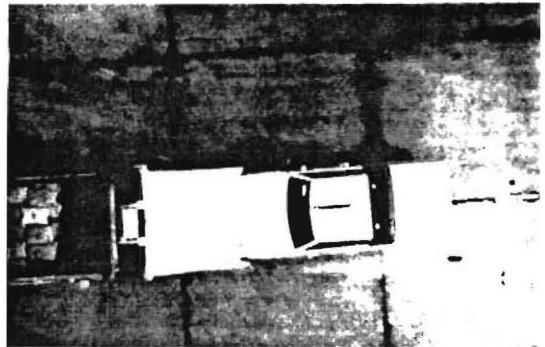
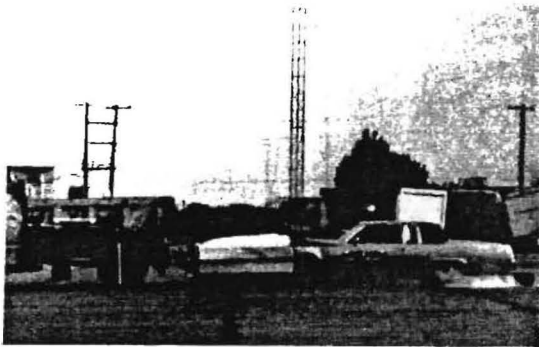
Note any damage to vehicle prior to test:
Cracked windshield marked

*d = overall height of vehicle

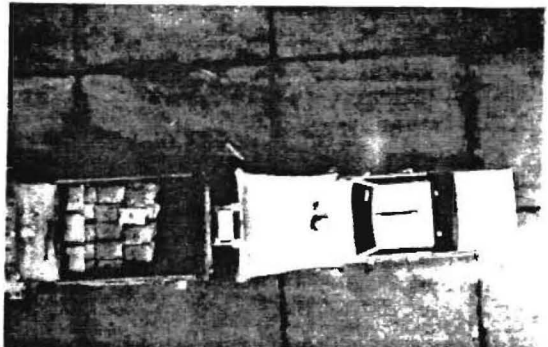
Figure 22. Test vehicle properties for test 9910-4.



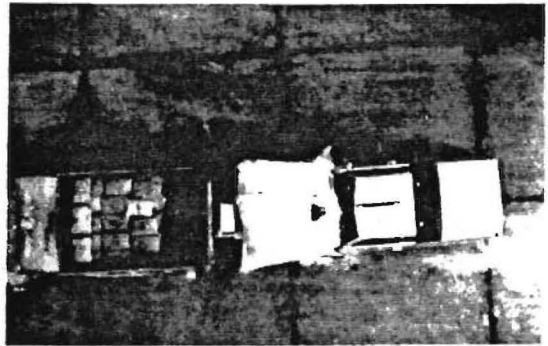
0.000 s



0.050 s

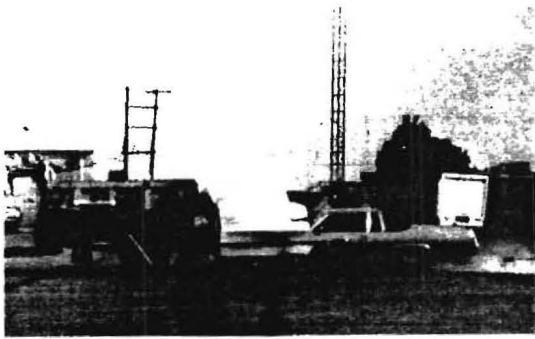


0.100 s

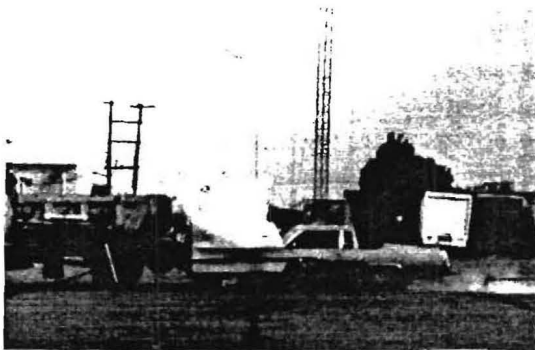
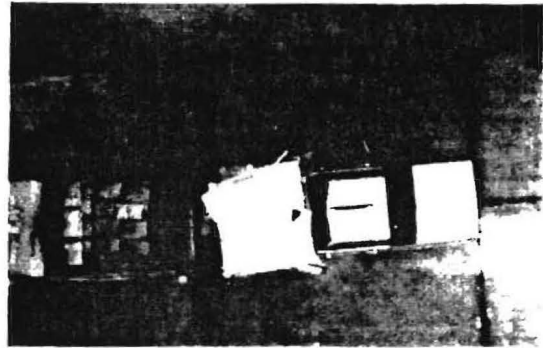


0.151 s

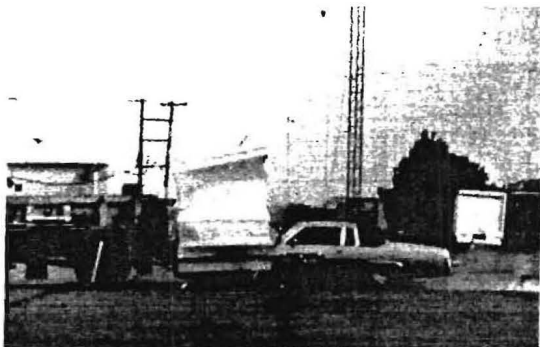
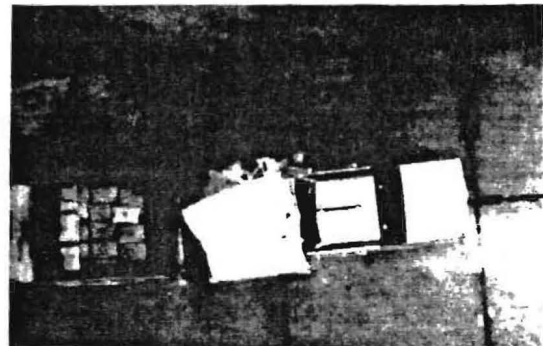
Figure 23. Sequential photographs for test 9910-4.



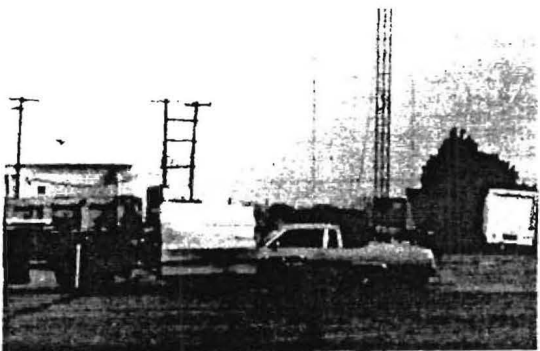
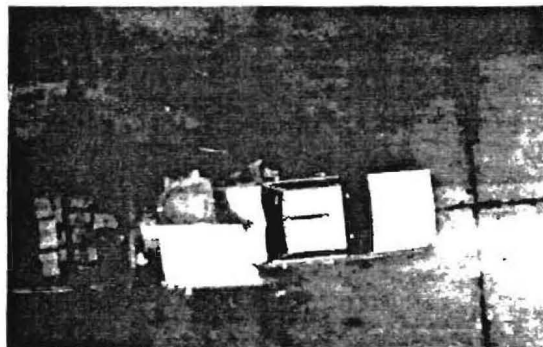
0.201 s



0.251 s



0.500 s



1.000 s

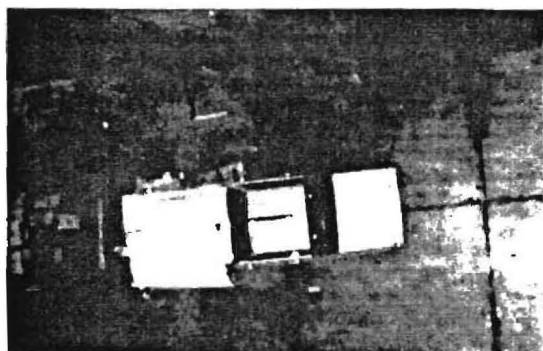


Figure 23. Sequential photographs for test 9910-4. (Continued)

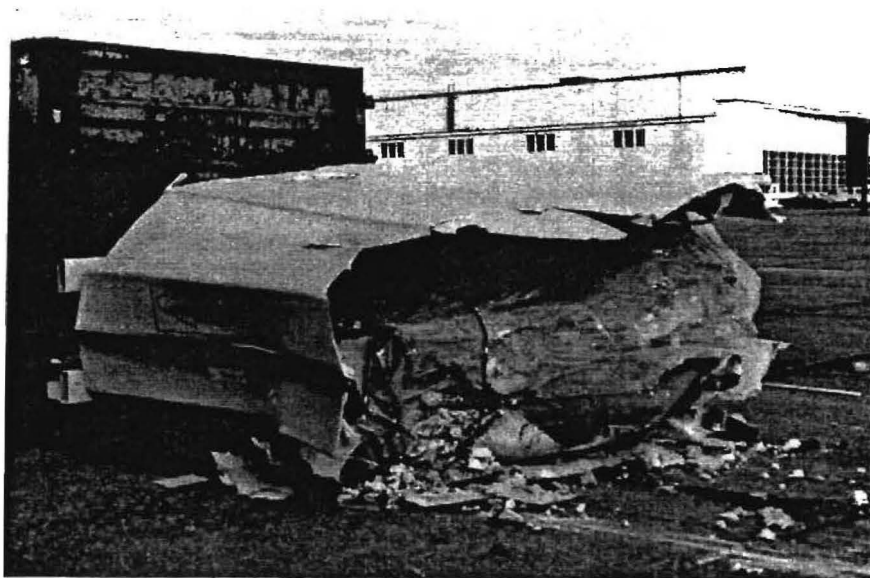


Figure 24. Energy Absorption Hex-foam TMA after test 9910-4.

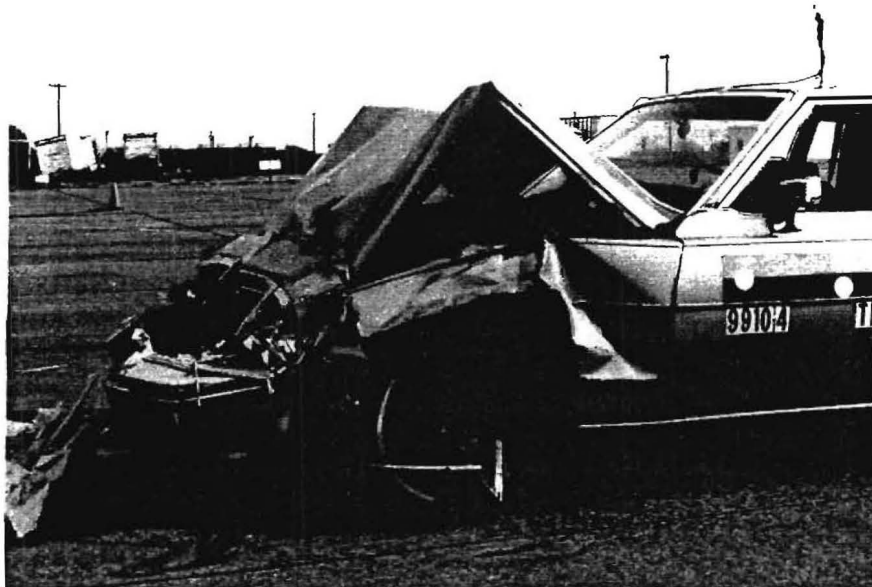
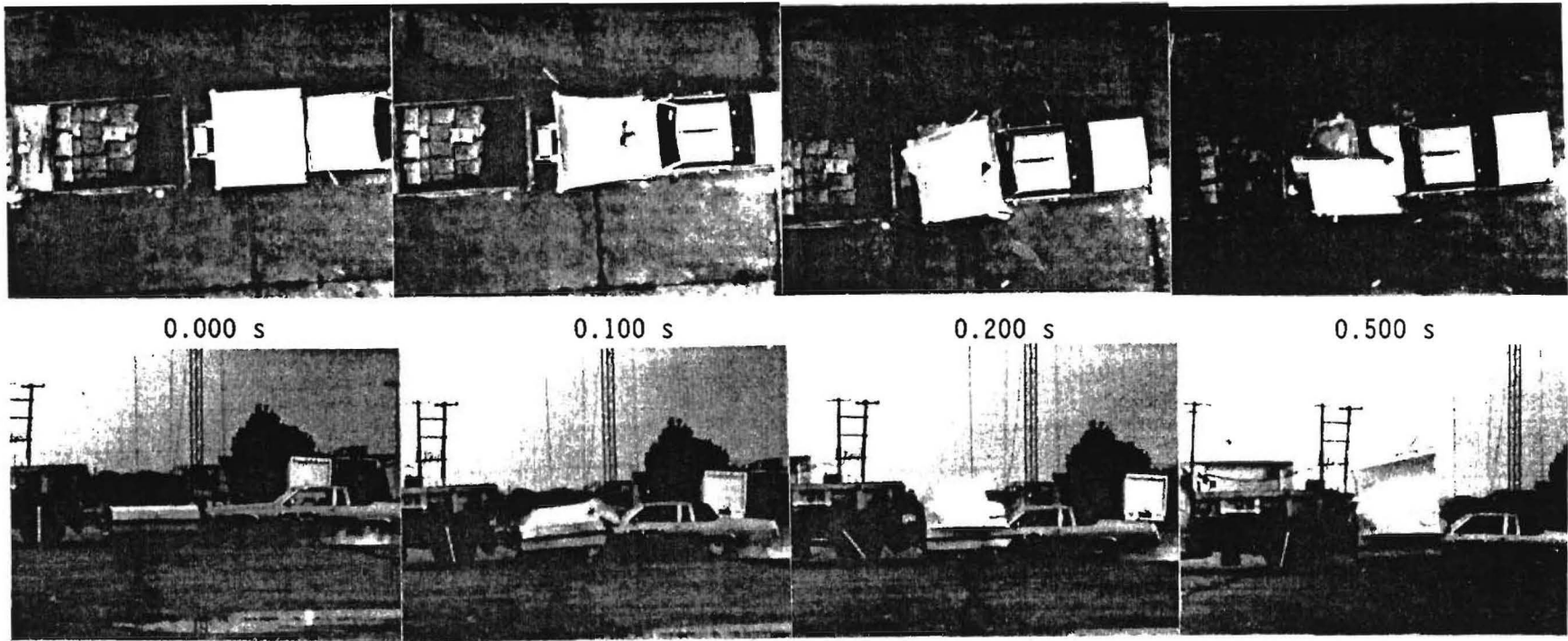
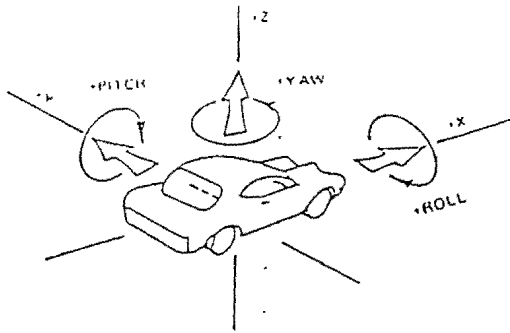


Figure 25. Vehicle after impact with Energy Absorption Hex-foam TMA (9910-4).



Test No.	09910-4	Maximum Truck Displacement .	8.25 ft (2.5 m)
Date	01/04/90	Maximum TMA Crush	57.00 in (1.4 m)
Test Article	Truck Mounted Attenuator	Vehicle Accelerations	
Manufacturer	Energy Absorption Hex-foam	(Maximum 50 ms Average at c.g.)	
TMA Truck	1980 Ford Dump Truck (#2)	Vehicle Longitudinal	-9.6 g
Weight without TMA	14,010 lb (6,361 kg)	Vehicle Lateral	-1.4 g
Weight with TMA	15,350 lb (6,969 kg)	Truck Cab Longitudinal	N/A
Test Vehicle	1981 Cadillac Sedan deVille	Occupant Impact Velocity	
Weight	4,500 lb (2,043 kg)	Longitudinal	33.4 ft/s (10.2 m/s)
Impact Speed	44.5 mi/h (71.6 km/h)	Lateral	5.6 ft/s (1.7 m/s)
Maximum Vehicle Crush	20.0 in (50.8 cm)	Occupant Ridedown Accelerations	
Vehicle Damage Classification		Longitudinal	-12.1 g
TAD	12FD4	Lateral	-1.1 g
CDC	12FDEW3		

Figure 26. Summary of results for test 9910-4.



Axes are vehicle fixed.
 Sequence for determining
 orientation is:

1. Yaw
2. Pitch
3. Roll

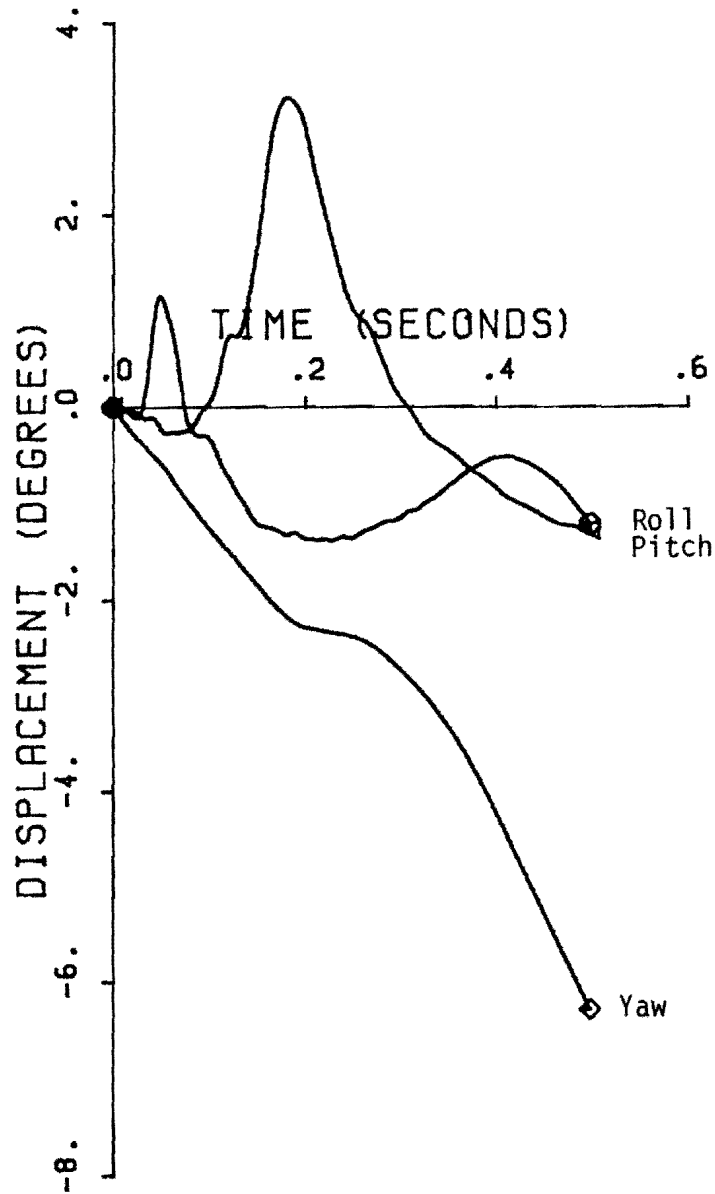


Figure 27. Vehicle angular displacements for test 9910-4.

TEST 9910-4

Class 180 Filter

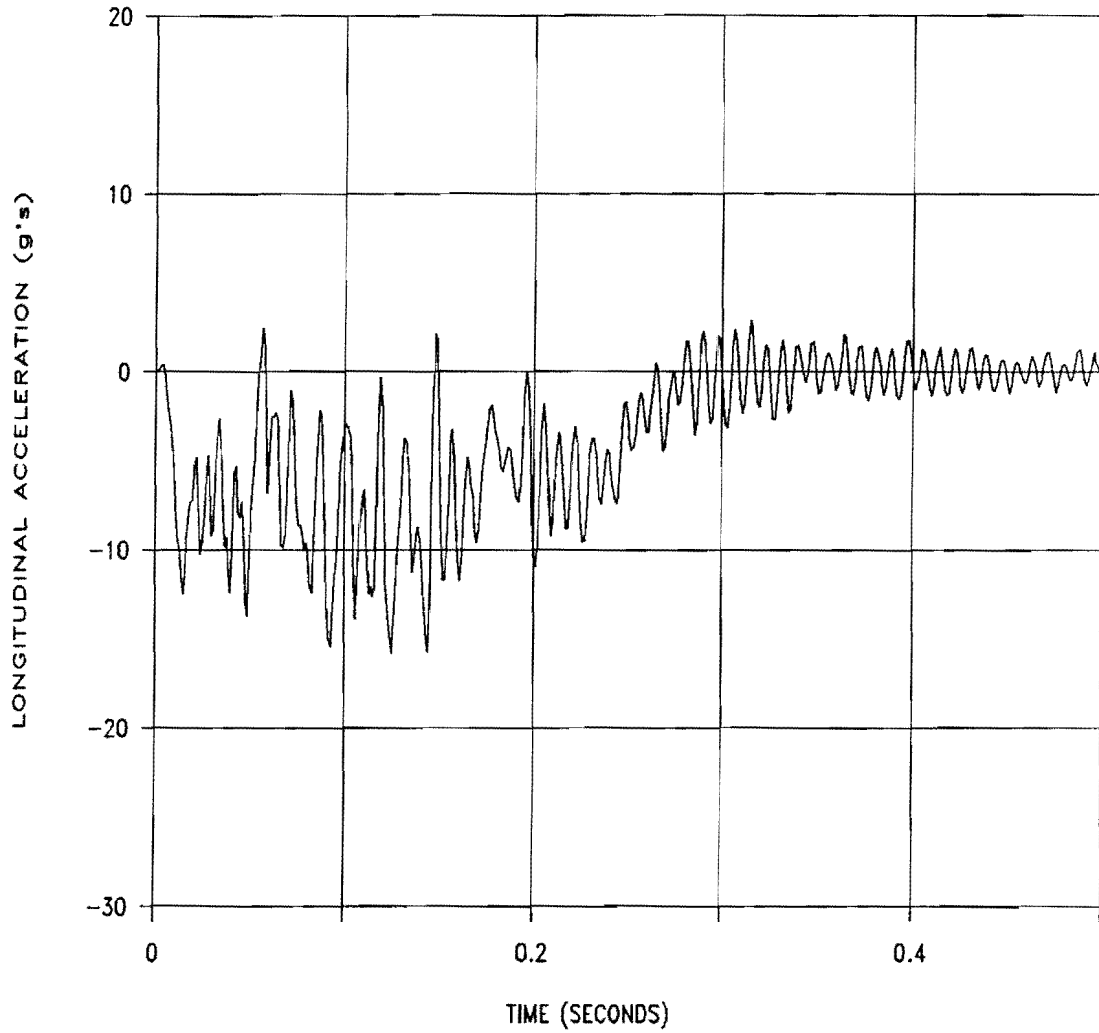


Figure 28. Vehicle longitudinal accelerometer trace for test 9910-4.

TEST 9910-4

Class 180 Filter

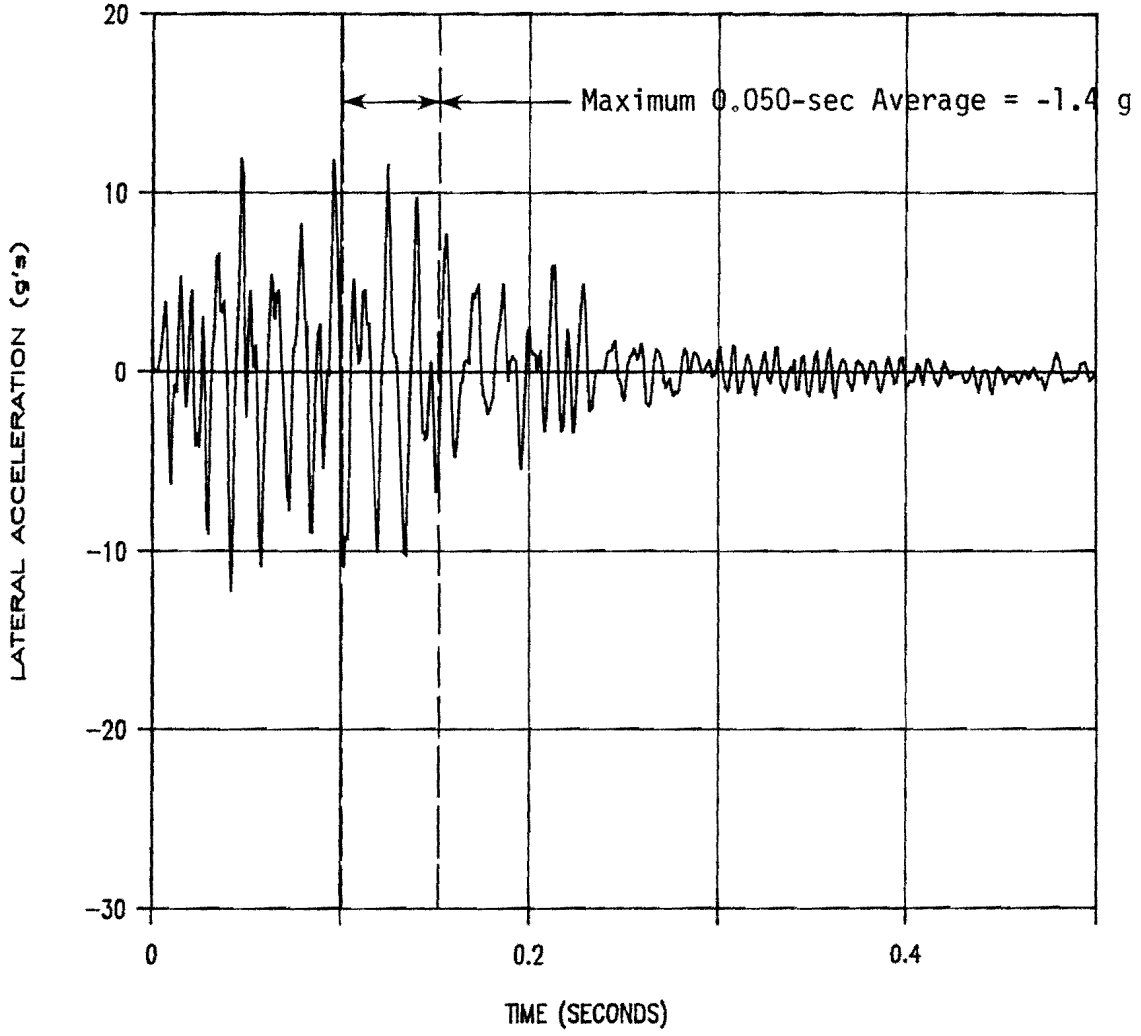


Figure 29. Vehicle lateral accelerometer trace for test 9910-4.

TEST 9910-4

Class 180 Filter

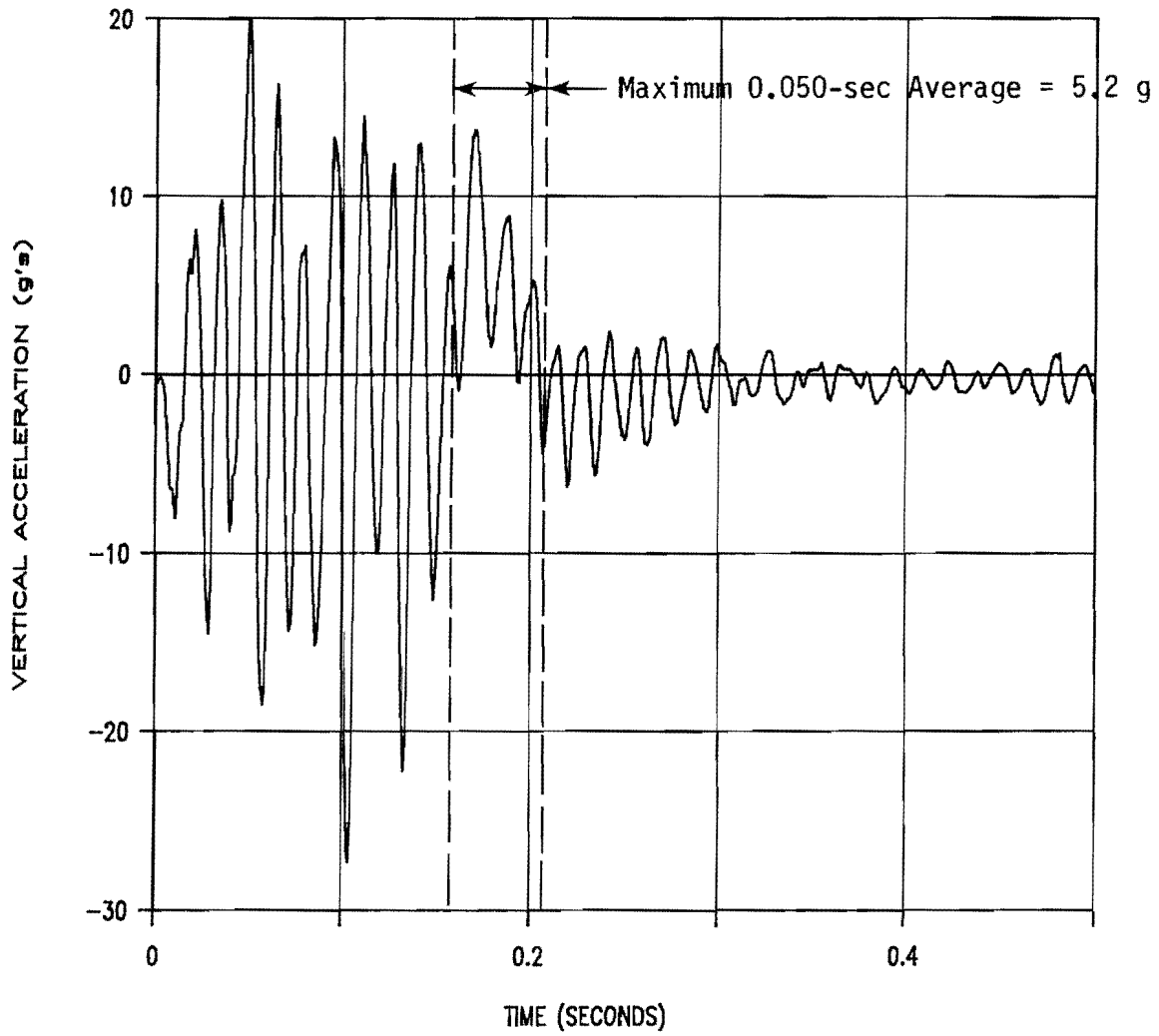


Figure 30. Vehicle vertical accelerometer trace for test 9910-4.

TEST 9910-4

Class 180 Filter - Rear of Vehicle

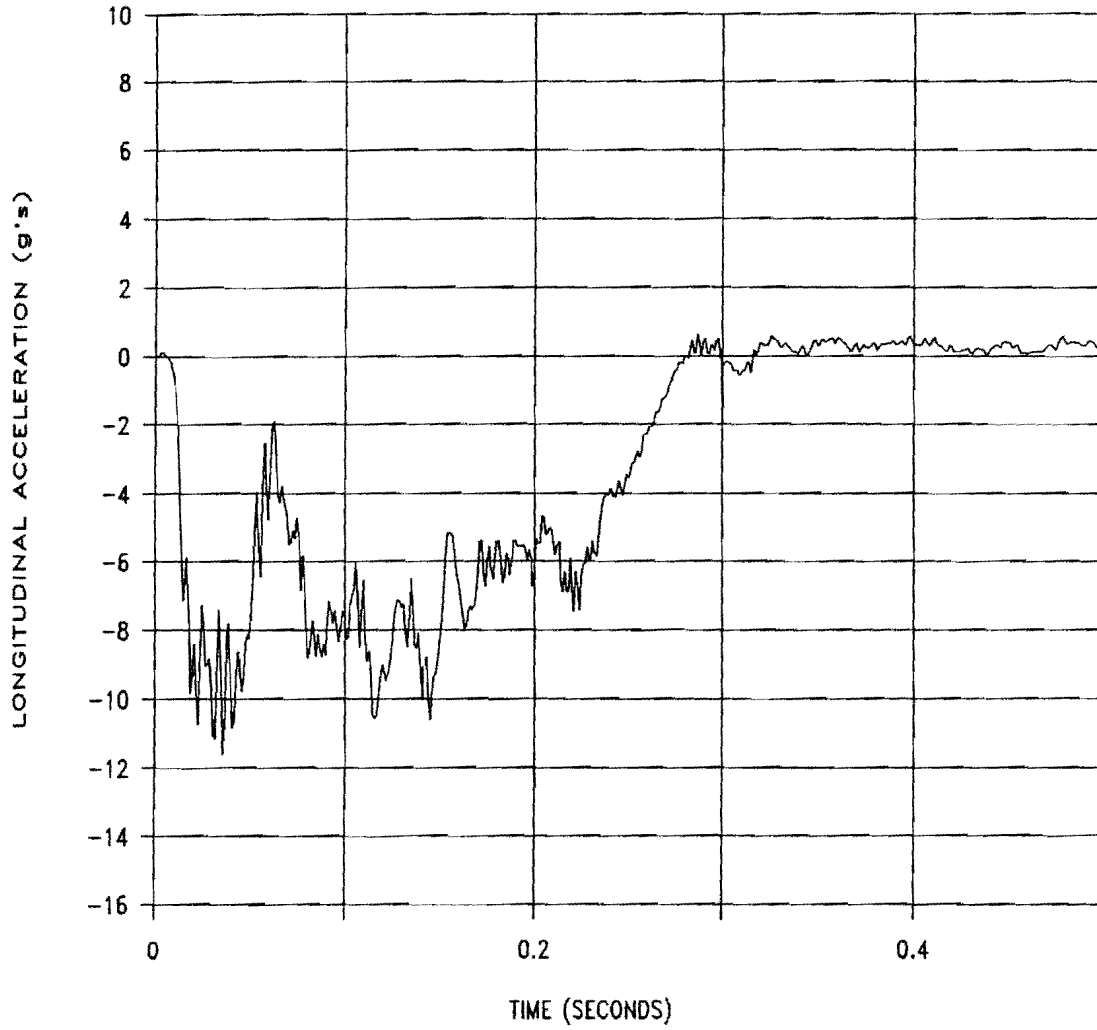


Figure 31. Vehicle longitudinal accelerometer trace for test 9910-4 (rear of vehicle).

Hexcel 3000 (9919-02)

The Hexcel Model 3000 used in this test was mounted on Truck No. 1 which had a gross static weight of 14,720 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 12.0 inches at the front and 12.0 inches at the rear. The height to the upper rear surface of the cartridge was 36.25 inches above ground.

The 1979 Cadillac Coupe deville pictured in Figures 32 and 33 was directed into the Hexcel Model 3000 TMA. The height to the lower edge of the vehicle bumper was 12.50 inches and 22.25 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 34.

The vehicle was travelling at a speed of 46.3 mi/h. Upon impact, the TMA began to crush and, at 0.038 second, the rear truck tires began to rotate. By approximately 0.290 second, the truck tire had rotated 90 degrees and at 0.370 second the tire had reached 110 degrees and began to skid. At 0.438 seconds, the truck reached a maximum speed of 12.2 ft/s (8.3 mi/h) and had moved approximately 5.3 ft. By this time, the impacting vehicle had slowed to 24.0 ft/s (16.3 mi/h). At 0.473 second, the rear truck tire ended the initial skid and began to roll. During the remainder of the test, the rear truck tires alternated between skidding and rolling. The maximum rotation angle achieved by the rear truck tires during the test was 175 degrees at 1.401 second; however, at the end of the test the tire was sitting at 162 degrees. Sequential photographs of the test are shown in Figure 35.

The Hexcel 3000 TMA cartridge crushed a total of 66.50 inches during the test. The frame attachment to the cartridge was bent forward on both sides. On the right side, it was bent forward 4 inches at the upper corner and 2 inches at the lower corner. The left side was bent forward 8 inches at the upper corner and 5 inches at the lower corner. The truck had moved forward a total of 9.8 feet and was still in second gear with the parking brake set. The impacting vehicle received damage to the bumper, hood, right and left front quarter panels and the right and left front doors. Maximum vehicle crush was 6.0 inches at bumper height. Figures 36 through 38 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 39. The maximum longitudinal 50-msec average acceleration experienced by the impacting vehicle was -12.8 g between 111 and 161 msec. Longitudinal occupant impact velocity was 36.4 ft/s at 129 msec and the maximum longitudinal ridedown acceleration was -13.6 g between 139 and 149 msec. The maximum longitudinal 50-msec average acceleration for the truck was 3.7 g between 115 and 165 msec. The truck reached a maximum speed of 12.2 ft/s (8.3 mph) and moved forward a total of 9.8 ft. The rear truck tires alternated between rolling and skidding during the test. Vehicle angular displacements are plotted in Figure 40, accelerometer traces are displayed in Figures 41 through 43, and the longitudinal accelerometer trace for the truck is shown in Figure 44.

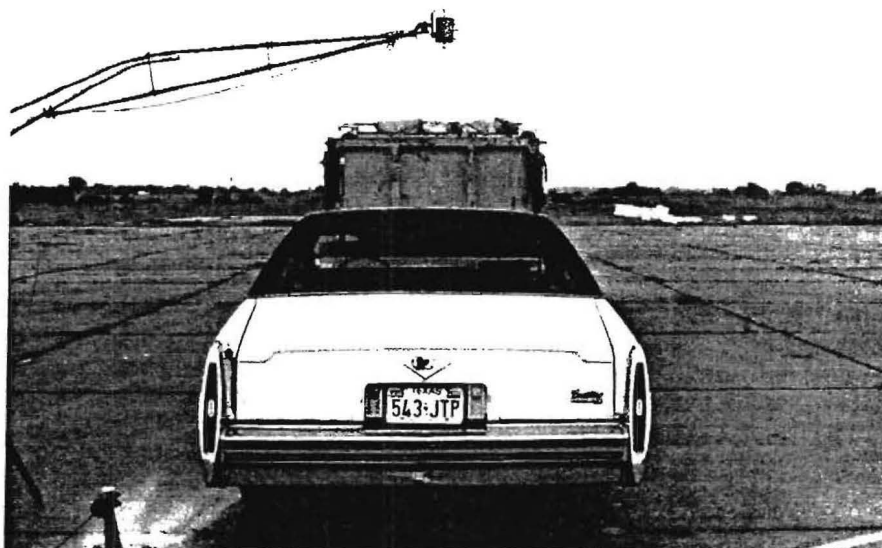
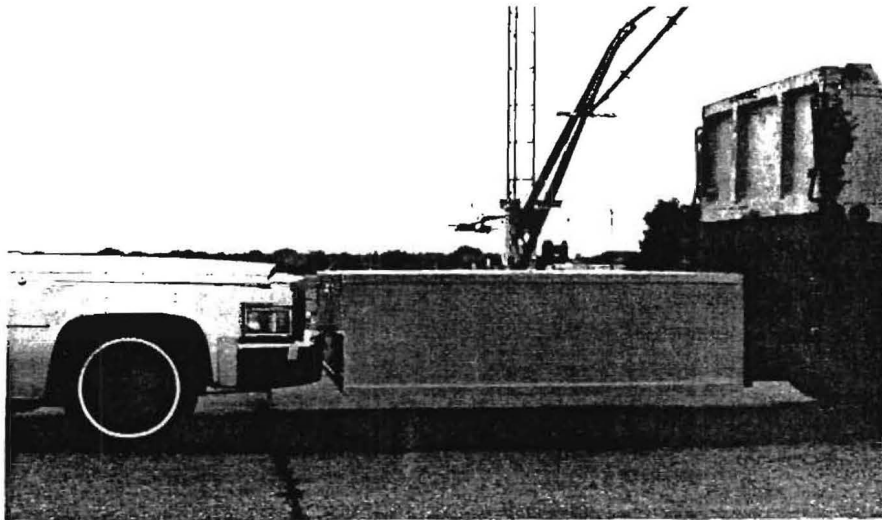


Figure 32. Configuration for test with Hexcel Tx-3000 TMA.



Figure 33. Vehicle before impact with Hexcel Tx-3000 TMA.

Date: _____ Test No.: 9919-2 VIN: 6D47T99266044
 Make: Cadillac Model: Coupe DeVille Year: 1979 Odometer: 43804
 Tire Size: P235/75R15 Ply Rating: 4 Bias Ply: Belted: Radial: X

Tire Condition: good
 fair X
 badly worn

Vehicle Geometry - inches

a 76 1/4 b 42 1/2
 c 122 d* 56
 e 56 f 220 1/2
 g h 54.5
 i j 35
 k 19 1/2 l 39 1/2
 m 22 1/4 n 4 1/2
 o 12 1/2 p 62 1/2
 r 27 1/4 s 16 1/4

Engine Type: V-8

Engine CID:

Transmission Type:

Automatic or Manual

FWD or RWD or 4WD

Body Type: 2-Door

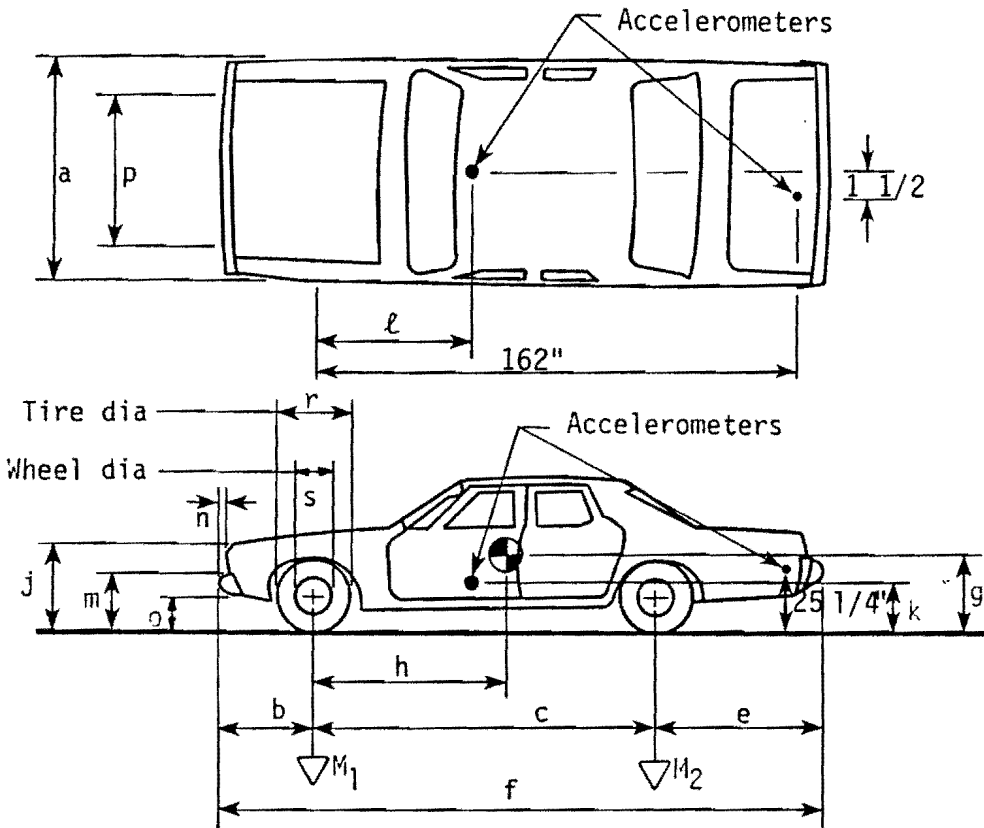
Steering Column Collapse Mechanism:

- 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



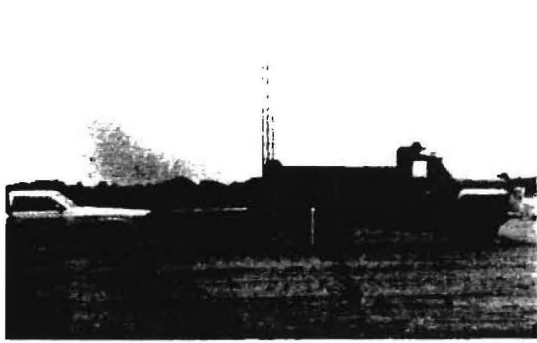
4-wheel weight for c.g. det. lf 1208 rf 1281 lr 995 rr 1016

Mass - pounds	Curb	Test Inertial	Gross Static
M ₁	<u>2465</u>	<u>2489</u>	<u> </u>
M ₂	<u>1640</u>	<u>2011</u>	<u> </u>
M _T	<u>4105</u>	<u>4500</u>	<u> </u>

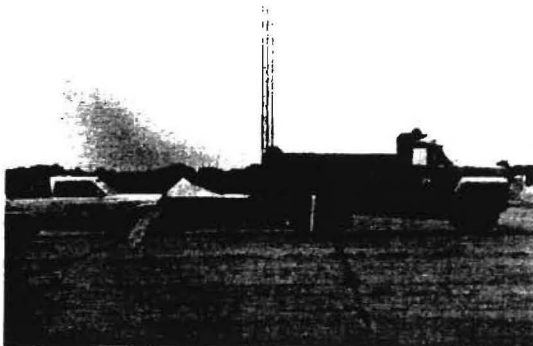
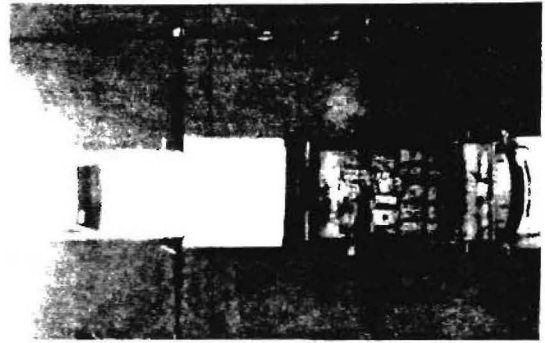
Note any damage to vehicle prior to test:

*d = overall height of vehicle

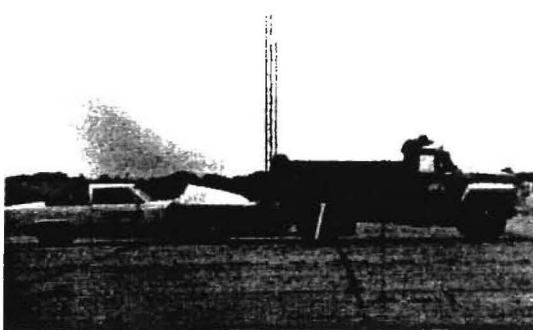
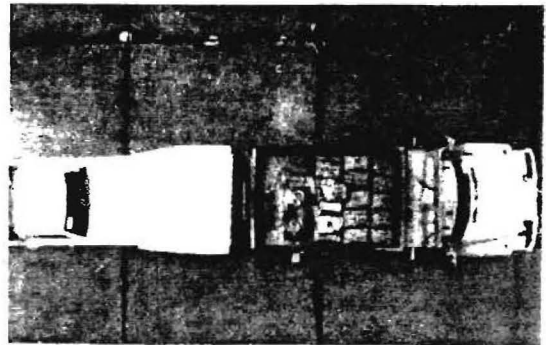
Figure 34. Test vehicle properties (9919-2).



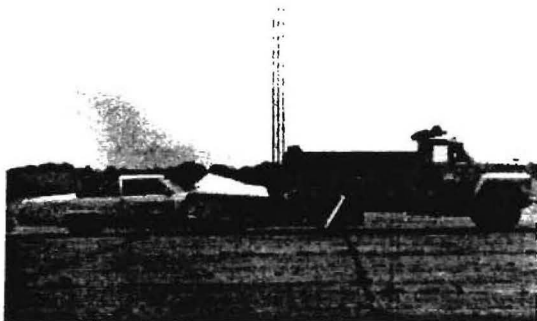
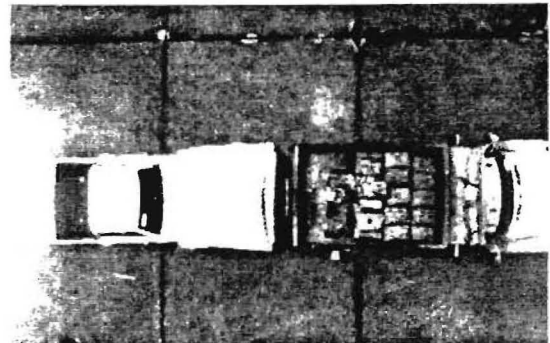
0.000 s



0.050 s



0.100 s



0.150 s

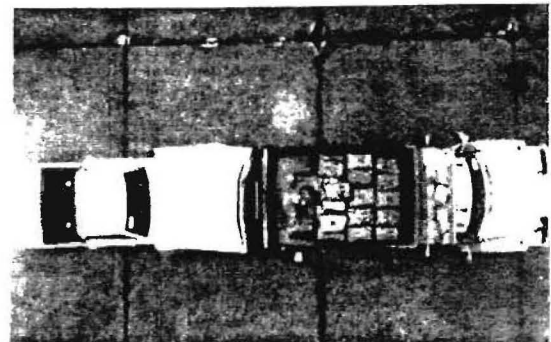
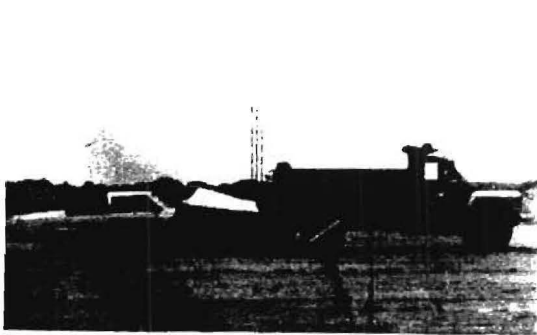
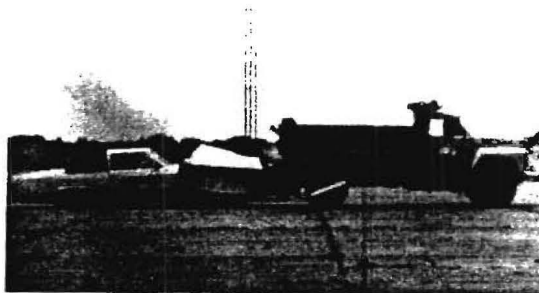
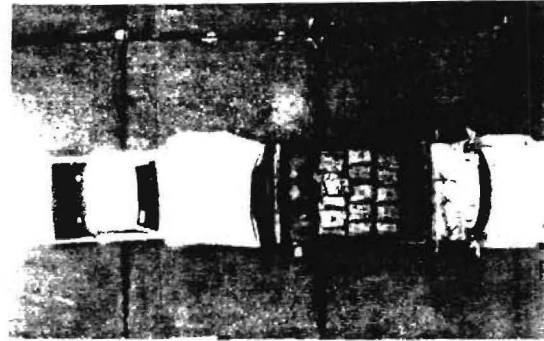


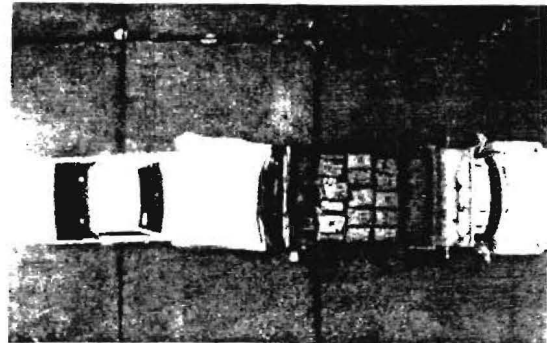
Figure 35. Sequential photographs for test 9919-2.



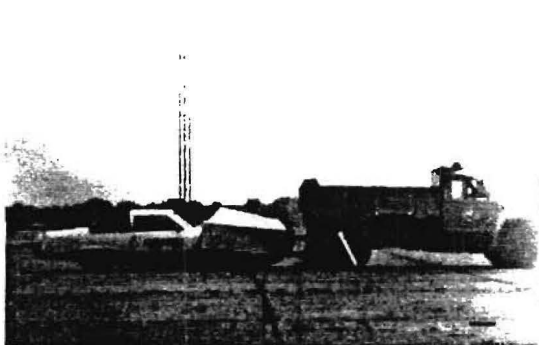
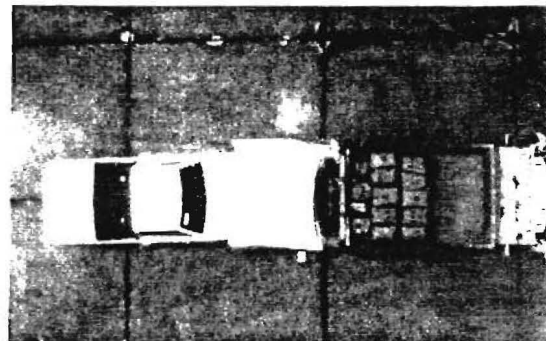
0.200 s



0.250 s



0.500 s



1.000 s

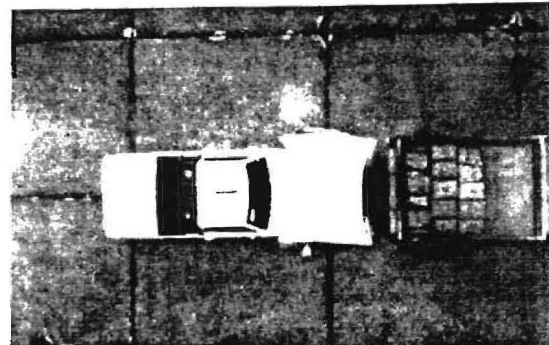


Figure 35. Sequential photographs for test 9919-2.
(Continued)

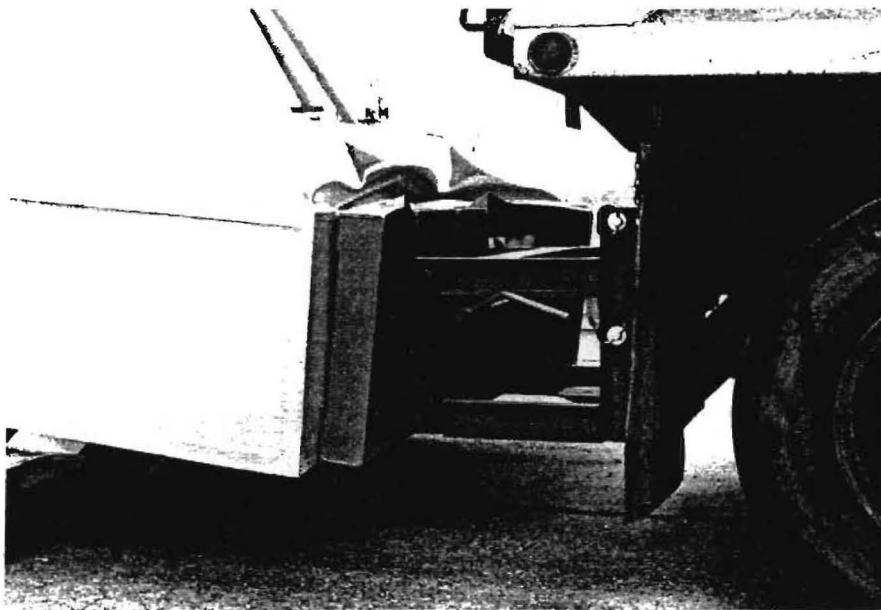


Figure 36. Damage to Hexcel Tx-3000 TMA (right side).

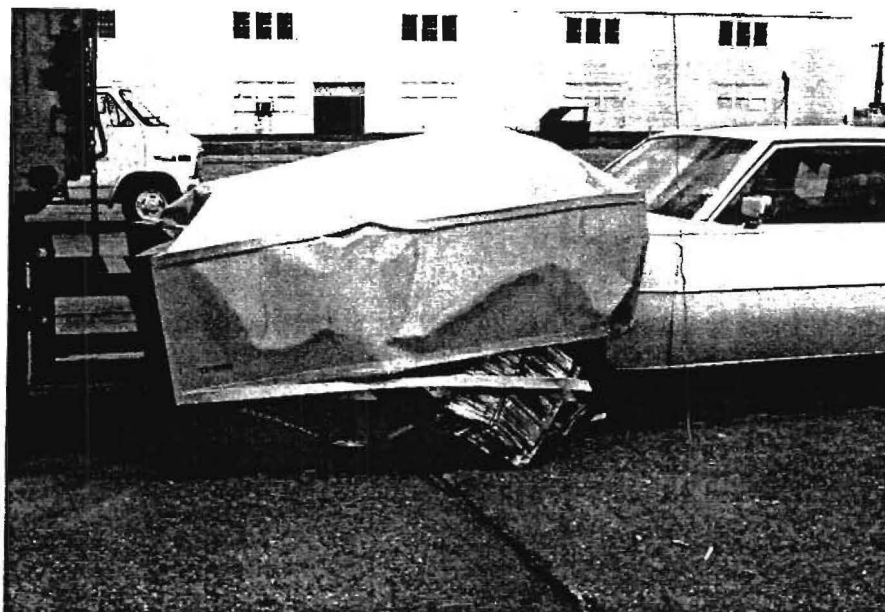
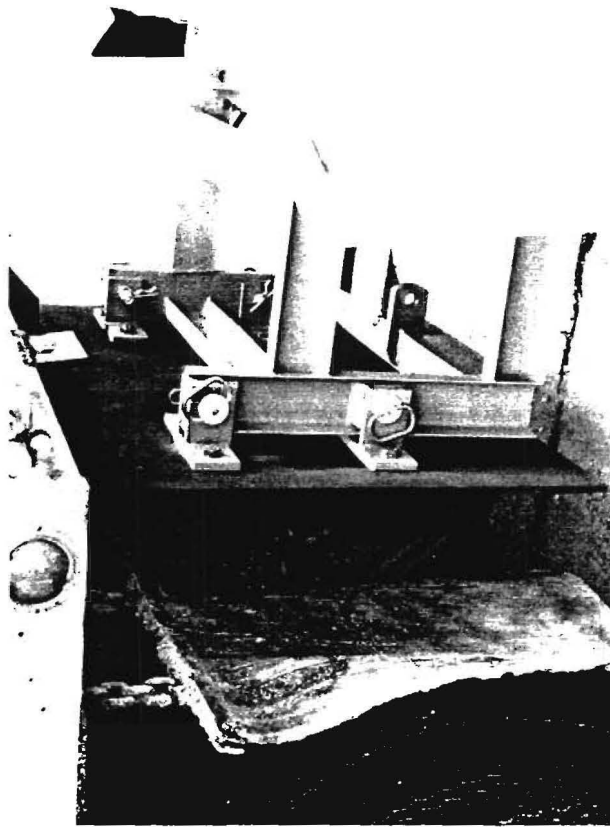
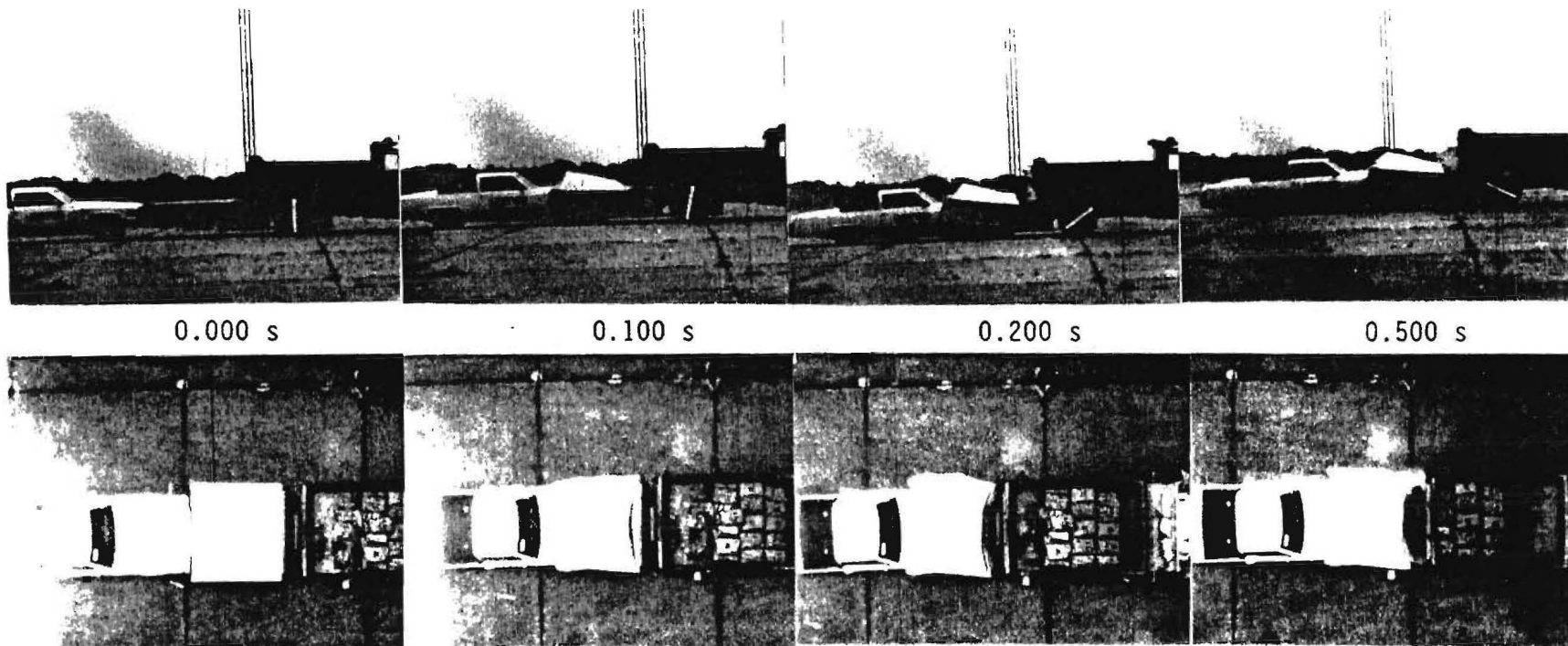


Figure 37. Damage to Hexcel Tx-3000 TMA (left side).



Figure 38. Damage to vehicle after impact with Hexcel Tx-3000 TMA.



52

Test No.	09919-2	Maximum Truck Displacement .	9.8 ft (3.0 m)
Date	08/08/89	Maximum TMA Crush	66.50 in (1.7 m)
Test Article	Truck Mounted Attenuator	Vehicle Accelerations	
Manufacturer	Hexcel Corp. (Model 3000)	(Maximum 50 ms Average at c.g.)	
TMA Truck	1981 Ford Dump Truck (#1)	Vehicle Longitudinal	-12.8 g
Weight without TMA .	14,020 lb (6,365 kg)	Vehicle Lateral	-2.0 g
Weight with TMA . . .	14,720 lb (6,683 kg)	Truck Cab Longitudinal . . .	3.7 g
Test Vehicle	1979 Cadillac Coupe deVille	Occupant Impact Velocity	
Weight	4,500 lb (2,043 kg)	Longitudinal	36.4 ft/s (11.1 m/s)
Impact Speed	46.3 mi/h (74.5 km/h)	Lateral	7.7 ft/s (2.3 m/s)
Maximum Vehicle Crush .	6.0 in (15.2 cm)	Occupant Ridedown Accelerations	
Vehicle Damage Classification		Longitudinal	-13.6 g
TAD	12FD2	Lateral	-2.2 g
CDC	12FDEW1		

Figure 39. Summary of results for test 9919-2.

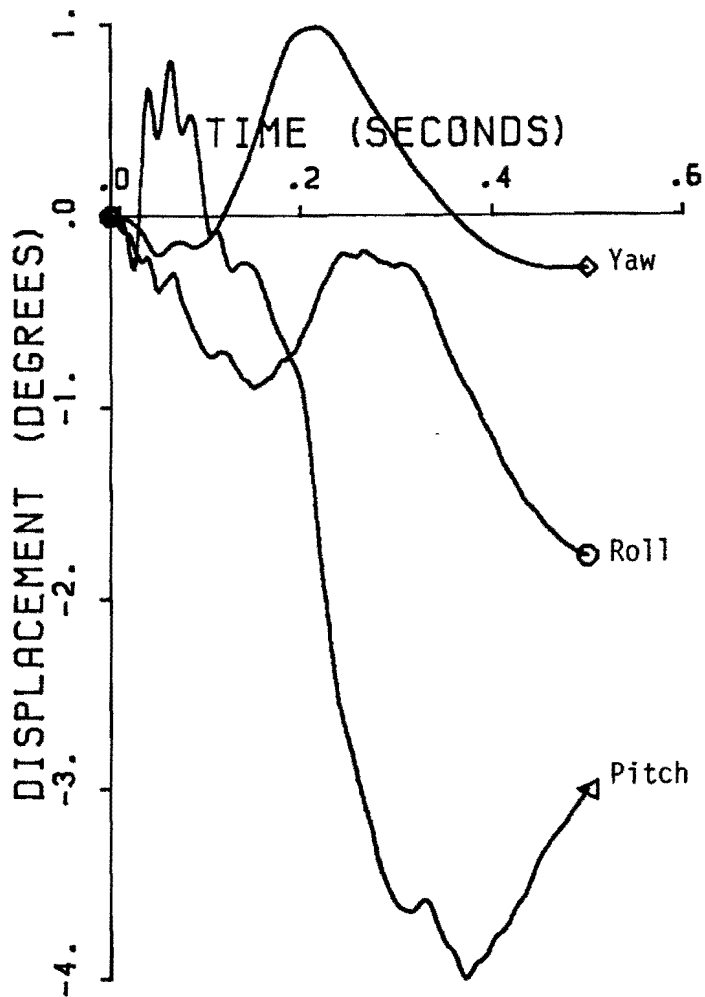
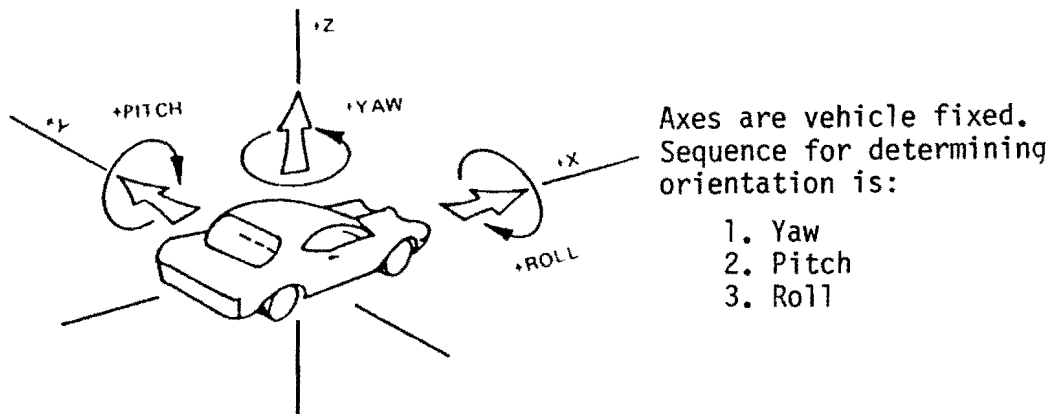


Figure 40. Vehicle angular displacement for test 9919-2.

TEST 9919-2

Class 180 Filter - Near C.G. of Car

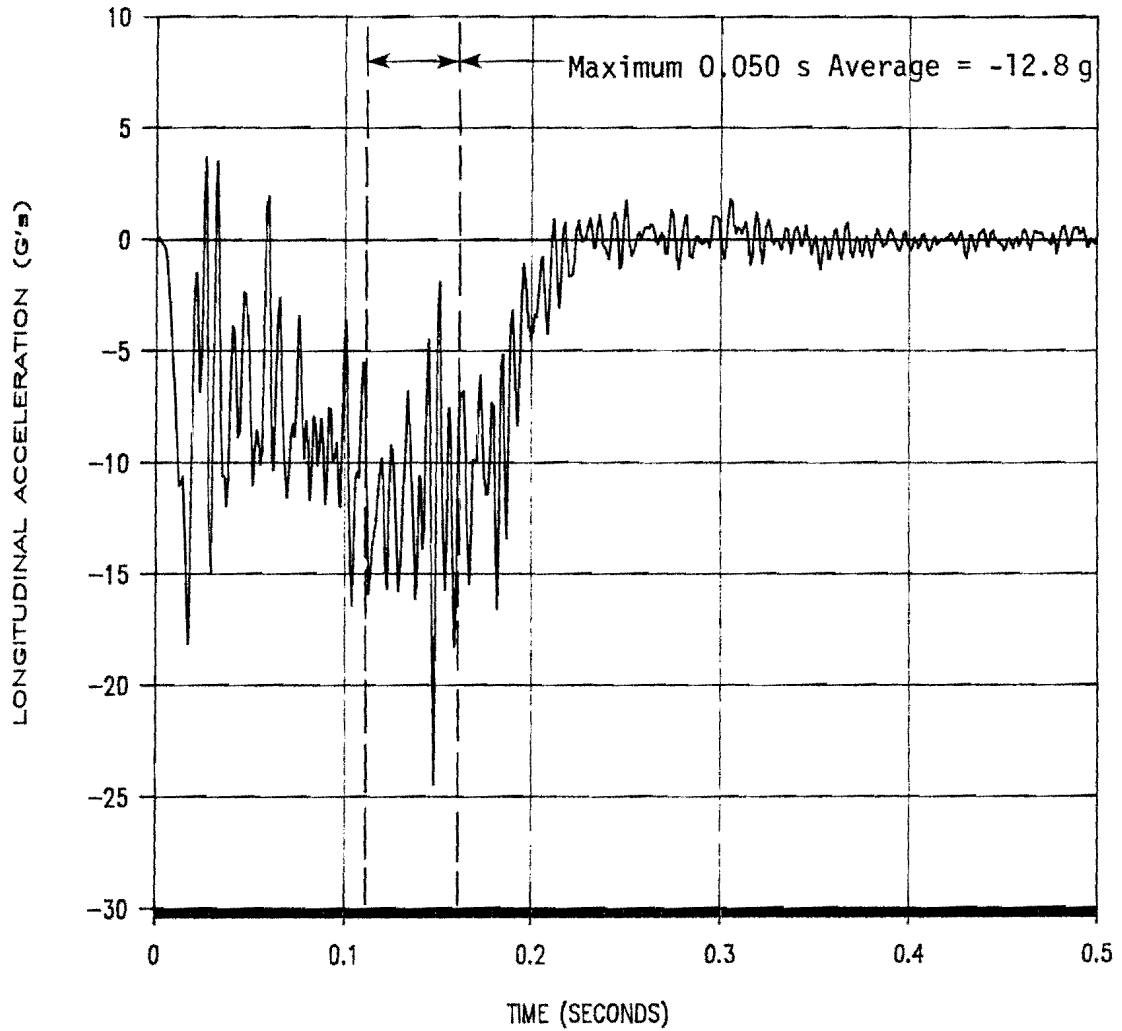


Figure 41. Vehicle longitudinal accelerometer trace for test 9919-2 (near c.g. of vehicle).

TEST 9919-2

Class 180 Filter - Near C.G. of Car

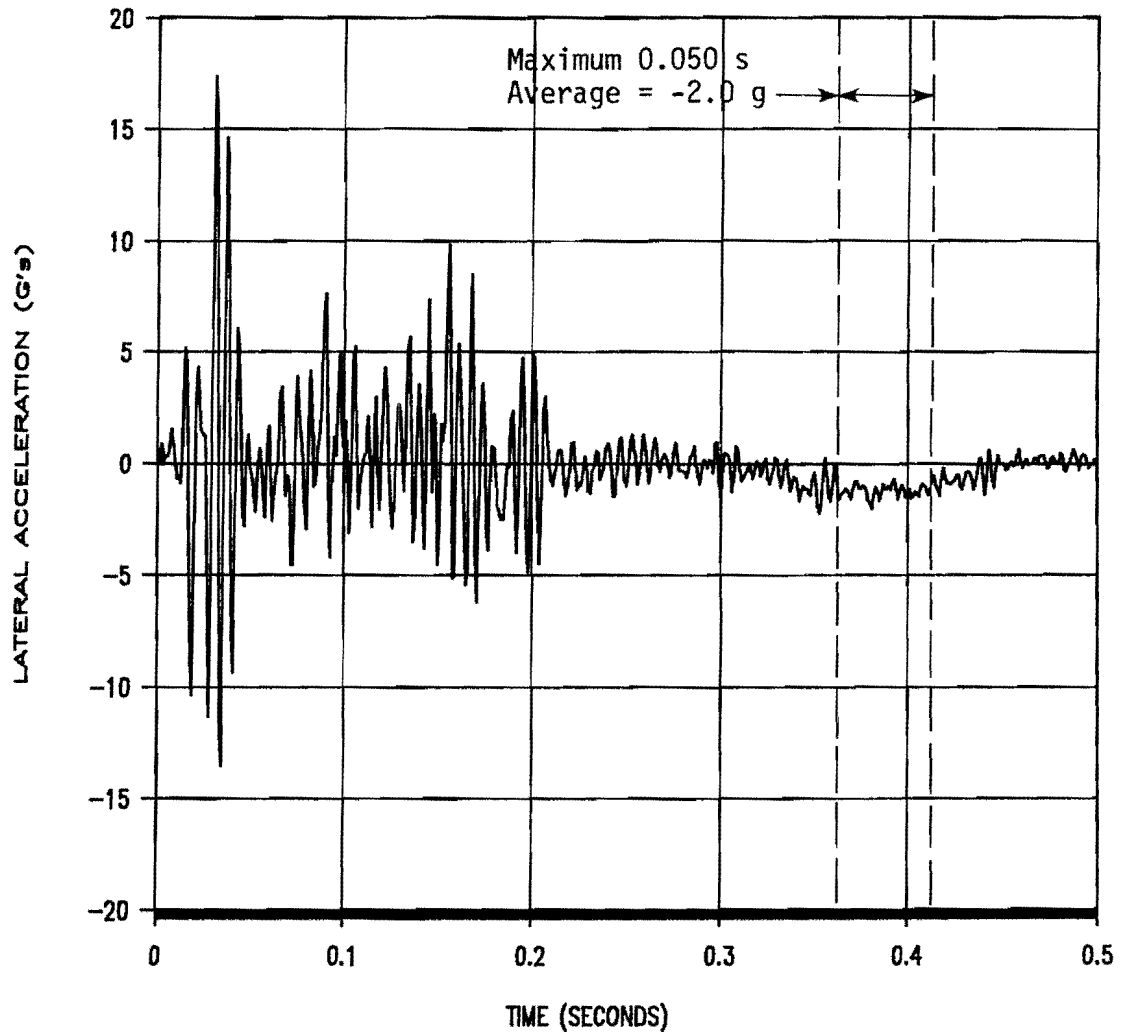


Figure 42. Vehicle lateral accelerometer trace for test 9919-2 (near c.g. of vehicle).

TEST 9919-2

Class 180 Filter - Near C.G. of Car

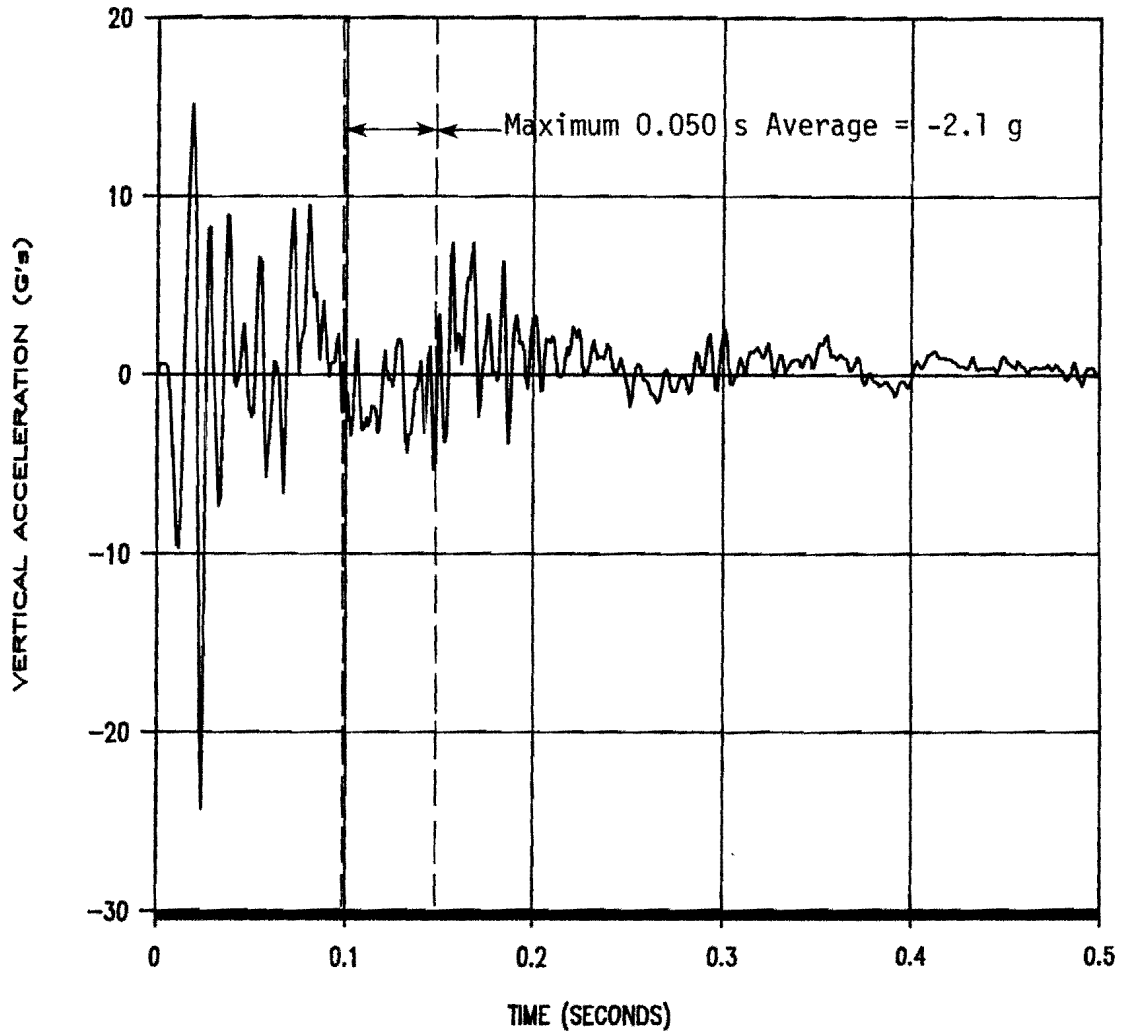


Figure 43. Vehicle vertical accelerometer trace for test 9919-2 (near c.g. of vehicle).

TEST 9919-2

Class 180 Filter - Cab of Truck

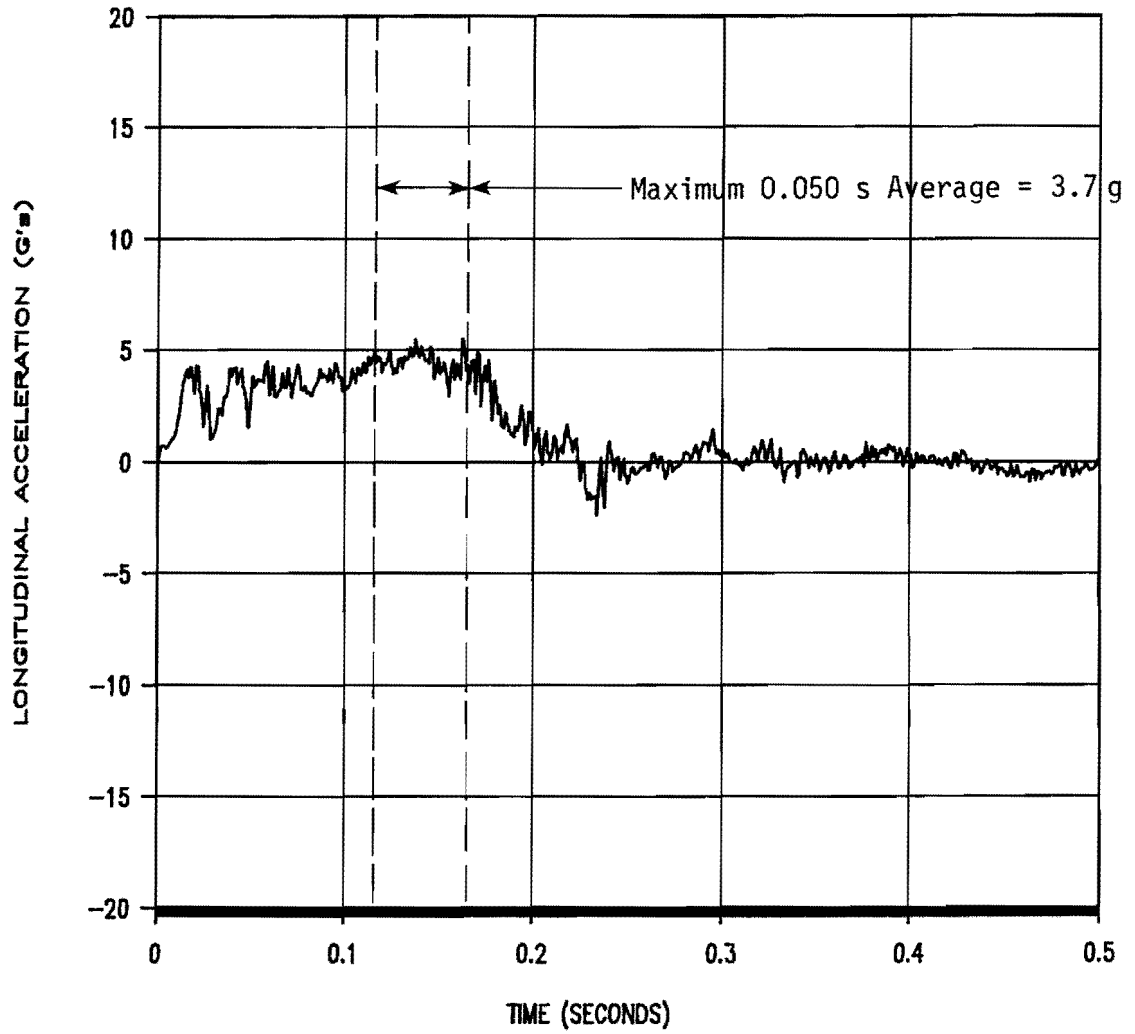


Figure 44. Truck longitudinal accelerometer trace for test 9919-2.

Hexcel 4000 (9919-01)

The Hexcel Model 4000 used in this test is shown in Figures 4 and 45. The TMA was mounted on Truck No. 2 which had a gross static weight of 14,800 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 11.25 inches at the front and 12.25 inches at the rear. The height to the upper rear surface of the cartridge was 36.75 inches above ground.

The 1979 Cadillac Coupe deVille (pictured in Figures 45 and 46) was directed into the Hexcel Model 4000 TMA. The height to the lower edge of the vehicle bumper was 11.0 inches and 21.0 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 47.

The vehicle was travelling at a speed of 47.3 mi/h. Upon impact, the TMA began to crush and, at 0.040 second, the rear truck tires began to rotate. At approximately 0.220 second, the front tires of the impacting vehicle were airborne and, at 0.225 second, the rear suspension of the vehicle bottomed out. The rear truck tire had rotated 90 degrees by 0.260 second, 180 degrees by 0.440 second, and at 0.475 second, the truck reached a maximum speed of 12.1 ft/s (8.3 mi/h) and had moved 5.76 ft. By this time, the impacting vehicle had slowed to 26.3 ft/s (17.9 mi/h) and, at 0.503 second, the vehicle became completely airborne. The rear tires of the vehicle contacted ground again at 0.608 second and the rear suspension of the vehicle bottomed out again at 0.875 second. The truck tire reached one full rotation at 0.928 second and had rotated another 270 degrees before going out of view of the high-speed camera. Sequential photographs of the test are shown in Figure 48.

The Hexcel 4000 TMA cartridge crushed a total of 63.25 inches during the test. The frame attachment to the cartridge on the right side was bent forward 5 inches and the locking mechanism was broken. The truck had moved forward a total of 22.8 feet and was still in second gear with the parking brake on. The front of the impacting vehicle was pushed upward and the hood, bumper, grill, radiator, and the right and left front quarter panels and doors were damaged. Also the roof was bent, the left side window was broken and the windshield was cracked. Maximum vehicle crush was 10.0 inches. Figures 49 through 51 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 52. The maximum longitudinal 50-msec average acceleration experienced by the impacting vehicle was -10.4 g between 9 and 59 msec. Longitudinal occupant impact velocity was 33.8 ft/s at 120 msec and the maximum longitudinal ridedown acceleration was -9.0 g between 128 and 138 msec. The maximum longitudinal 50-msec average acceleration for the truck was 3.3 g between 13 and 63 msec. The truck reached a maximum speed of 12.1 ft/s (8.3 mph) and moved forward a total of 22.8 ft. The rear truck tires rotated two full revolutions plus approximately 60 degrees. Vehicle angular displacements are plotted in Figure 53, accelerometer traces are displayed in Figures 54 through 56, and the longitudinal accelerometer trace from the cab of the truck is shown in Figure 57.

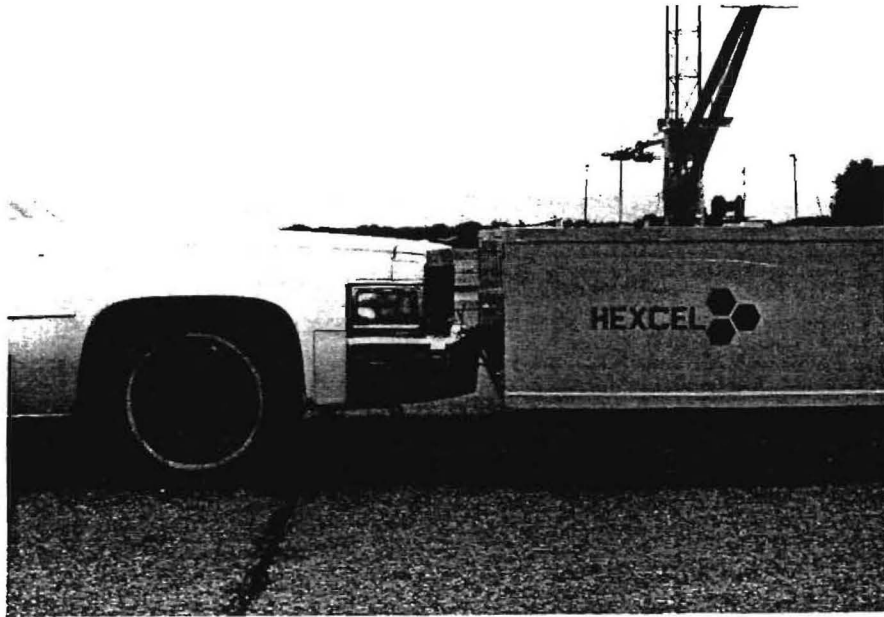


Figure 45. Configuration for test with Hexcel Tx-4000 TMA.



Figure 46. Vehicle before impact with Hexcel Tx-4000 TMA.

Date: _____ Test No.: 9919-1 VIN: 6D4759C350765
 Make: Cadillac Model: Coupe DeVille Year: 1979 Odometer: 31024
 Tire Size: P215/75R15 Ply Rating: 2 Bias Ply: Belted: Radial: X

Tire Condition: good
 fair X
 badly worn

Vehicle Geometry - inches

a 76 1/4 b 42 1/2
 c 121 1/4 d* 55 1/4
 e 55 f 218 3/4
 g h 54.78
 i ---- j 34
 k 18 1/2 l 34 1/2
 m 21 n 5
 o 11 p 61 3/4
 r 26 1/2 s 16 1/4

Engine Type: V-8

Engine CID:

Transmission Type:

Automatic or Manual
 FWD or RWD or 4WD

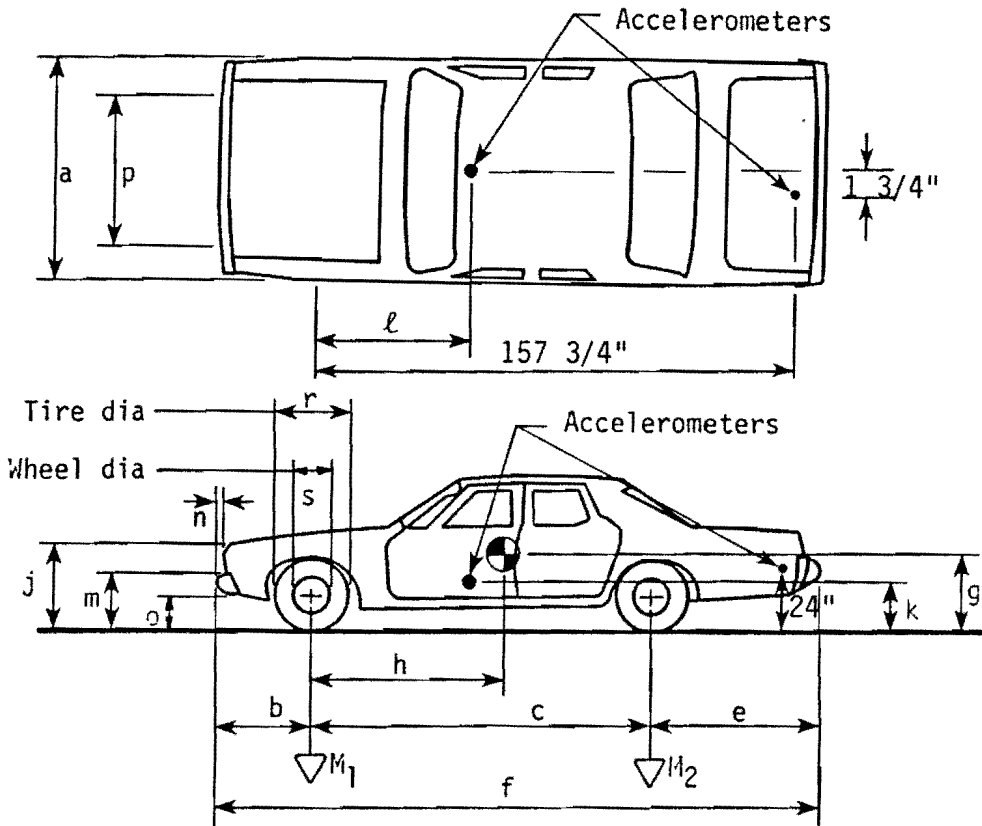
Body Type: 2-Door

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



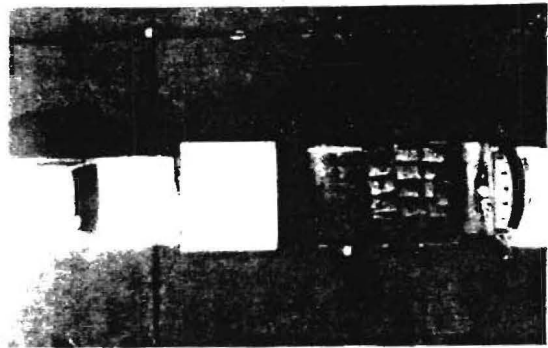
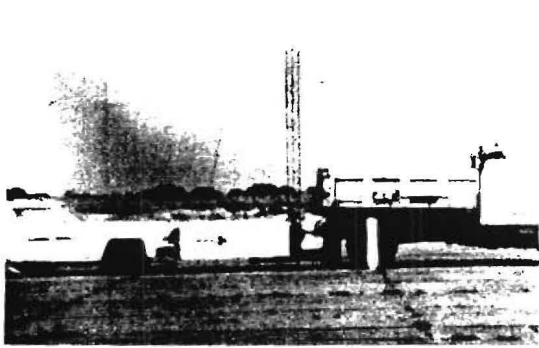
4-wheel weight for c.g. det. lf 1211 rf 1279 lr 1011 rr 1022

Mass - pounds	Curb	Test Inertial	Gross Static
M_1	<u>2440</u>	<u>2467</u>	<u> </u>
M_2	<u>1663</u>	<u>2033</u>	<u> </u>
M_T	<u>4103</u>	<u>4500</u>	<u> </u>

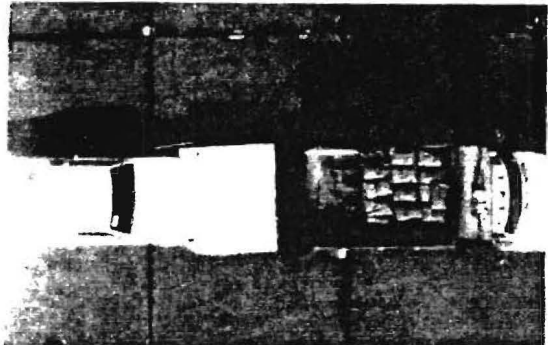
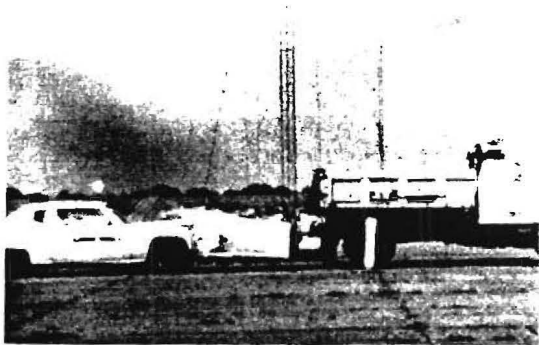
Note any damage to vehicle prior to test:

*d = overall height of vehicle

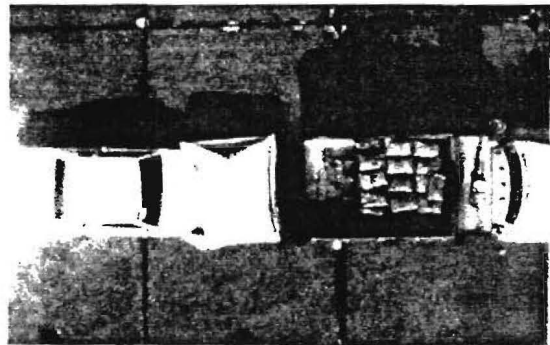
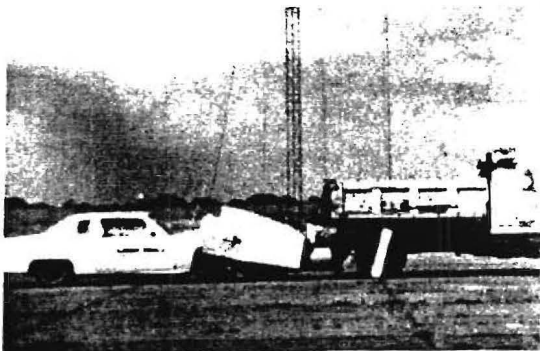
Figure 47. Test vehicle properties (9919-1).



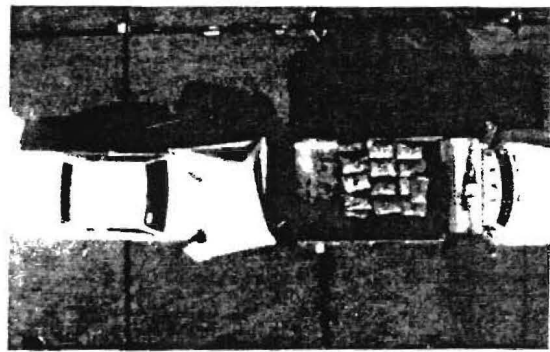
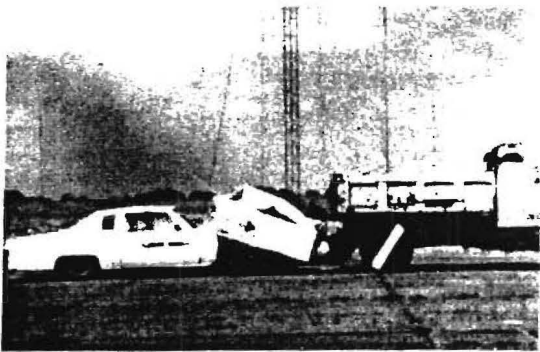
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0.050 s

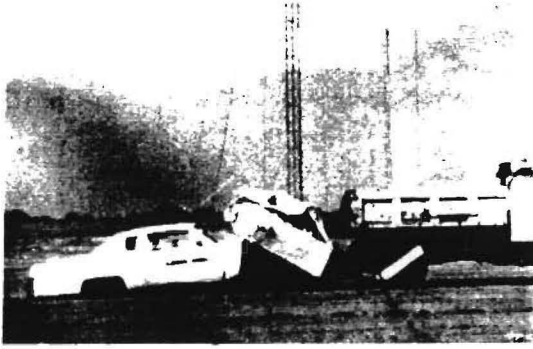


0.100 s

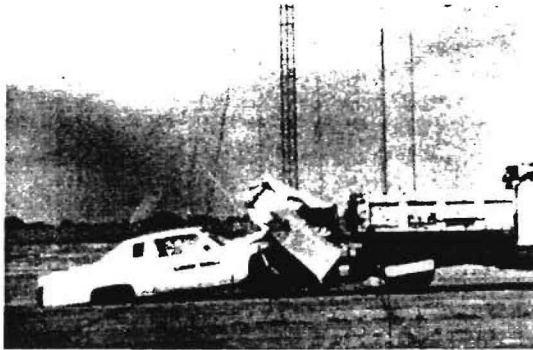


0.150 s

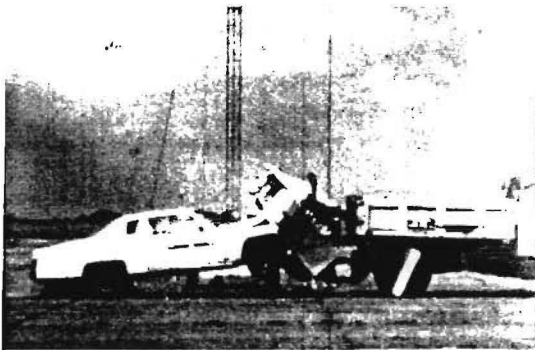
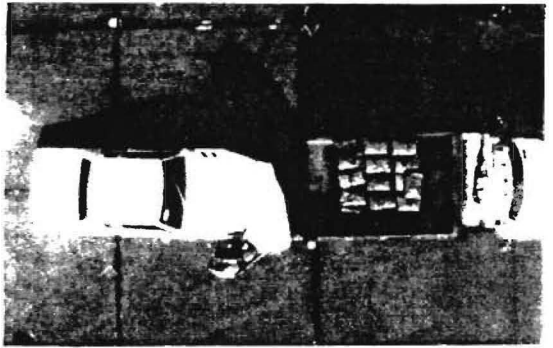
Figure 48. Sequential photographs for test 9919-1.



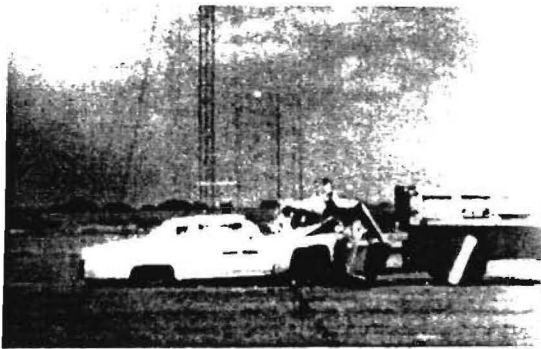
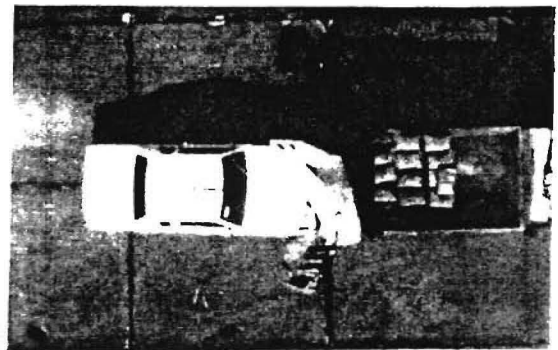
0.200 s



0.250 s



0.500 s



1.000 s

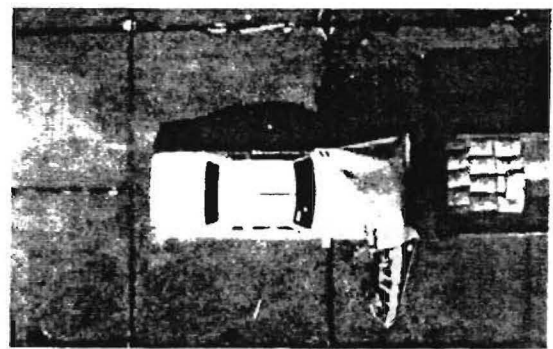


Figure 48. Sequential photographs for test 9919-1.
(Continued)

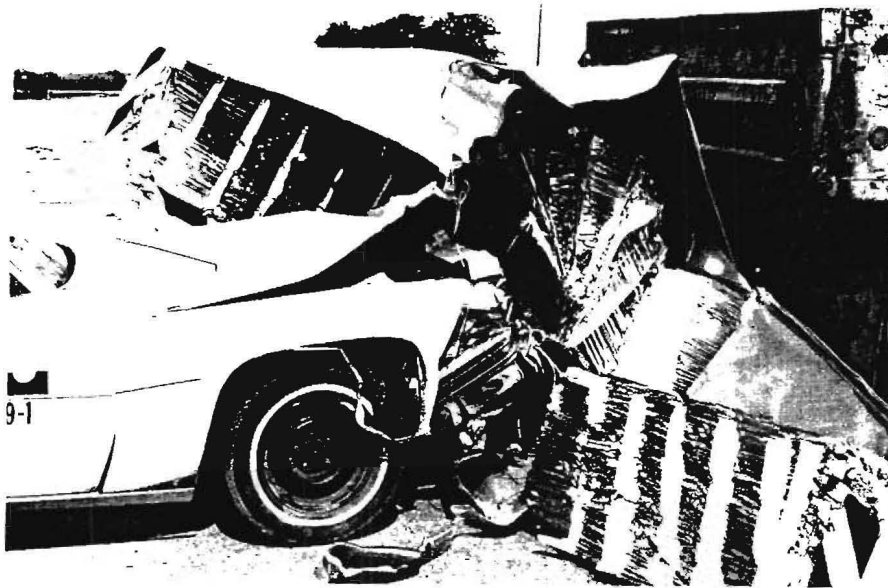


Figure 49. Damage to Hexcel Tx-4000 TMA (right side).

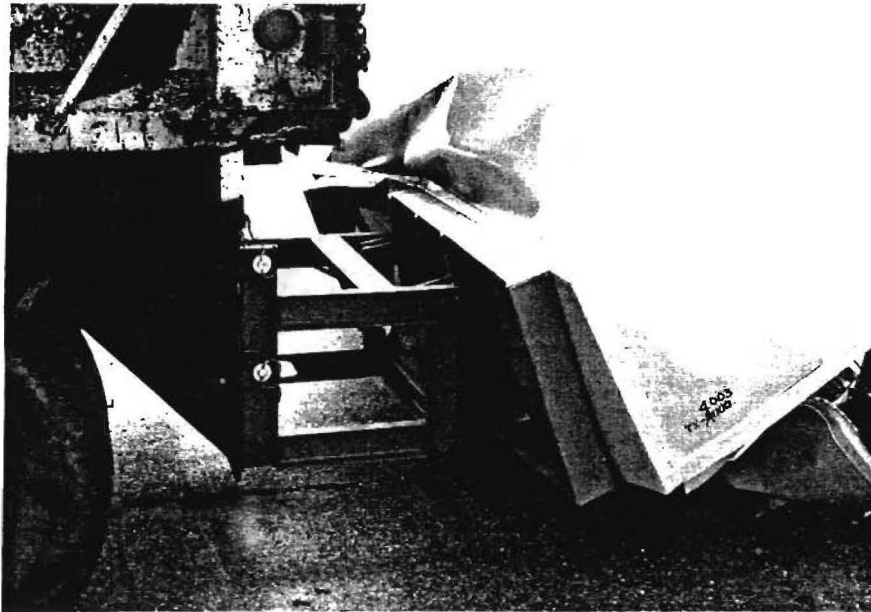
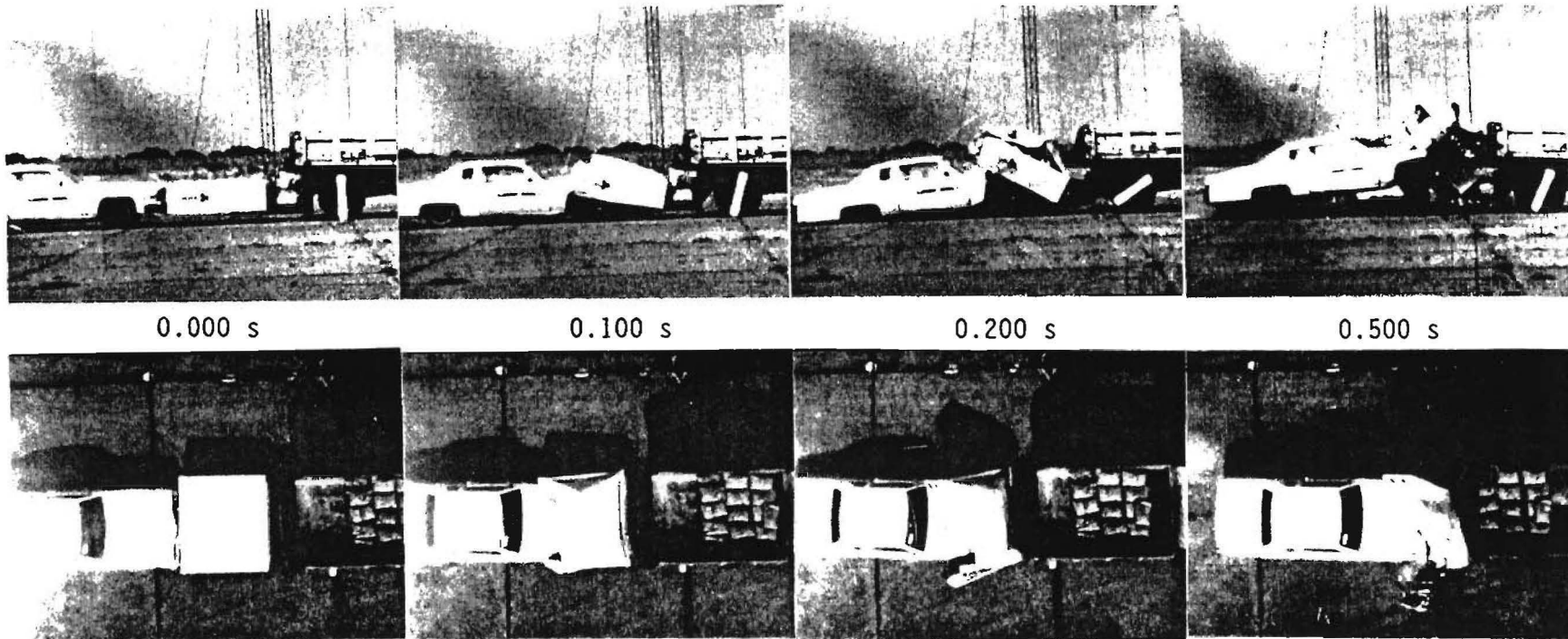


Figure 50. Damage to Hexcel Tx-4000 TMA (left side).



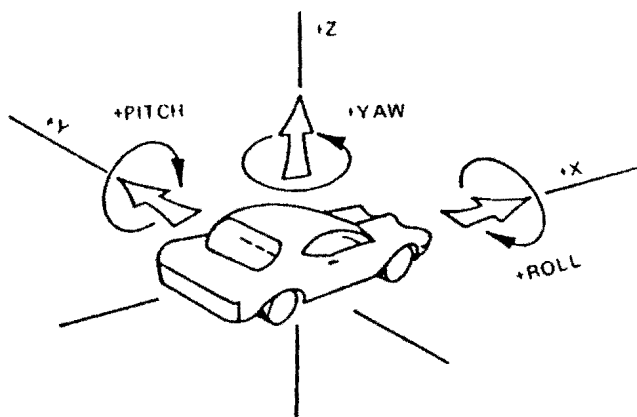
Figure 51. Test vehicle after impact with Hexcel Tx-4000 TMA.



67

Test No.	09919-1	Maximum Truck Displacement . . .	22.8 ft (6.9 m)
Date	08/08/89	Maximum TMA Crush	63.25 in (1.6 m)
Test Article	Truck Mounted Attenuator	Vehicle Accelerations	
Manufacturer	Hexcel Corp. (Model 4000)	(Maximum 50 ms Average at c.g.)	
TMA Truck	1980 Ford Dump Truck (#2)	Vehicle Longitudinal	-10.4 g
Weight without TMA . . .	14,010 lb (6,361 kg)	Vehicle Lateral	-1.7 g
Weight with TMA	14,800 lb (6,719 kg)	Truck Cab Longitudinal	3.3 g
Test Vehicle	1979 Cadillac Coupe deVille	Occupant Impact Velocity	
Weight	4,500 lb (2,043 kg)	Longitudinal	33.8 ft/s (10.3 m/s)
Impact Speed	47.3 mi/h (76.1 km/h)	Lateral	6.3 ft/s (1.9 m/s)
Maximum Vehicle Crush .	10.0 in (25.4 cm)	Occupant Ridedown Accelerations	
Vehicle Damage Classification		Longitudinal	-9.0 g
TAD	12FD4	Lateral	-1.5 g
CDC	12FDEW2		

Figure 52. Summary of results for test 9919-1.



Axes are vehicle fixed.
Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

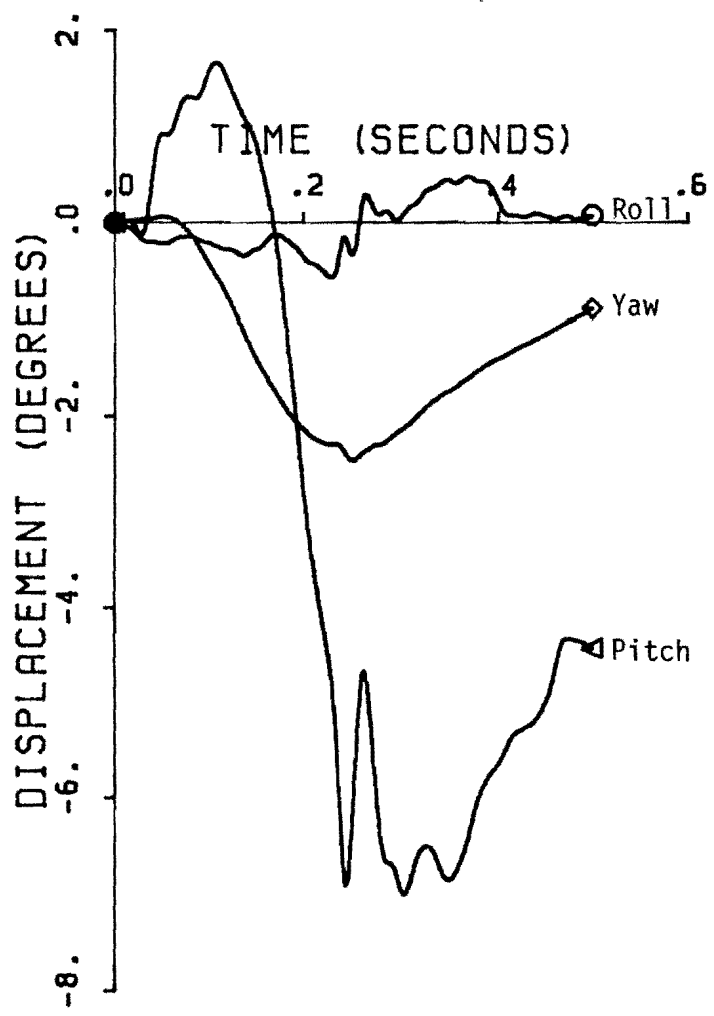


Figure 53. Vehicle angular displacement for test 9919-1.

TEST 9919-1

Class 180 Filter - Near C.G. of Car

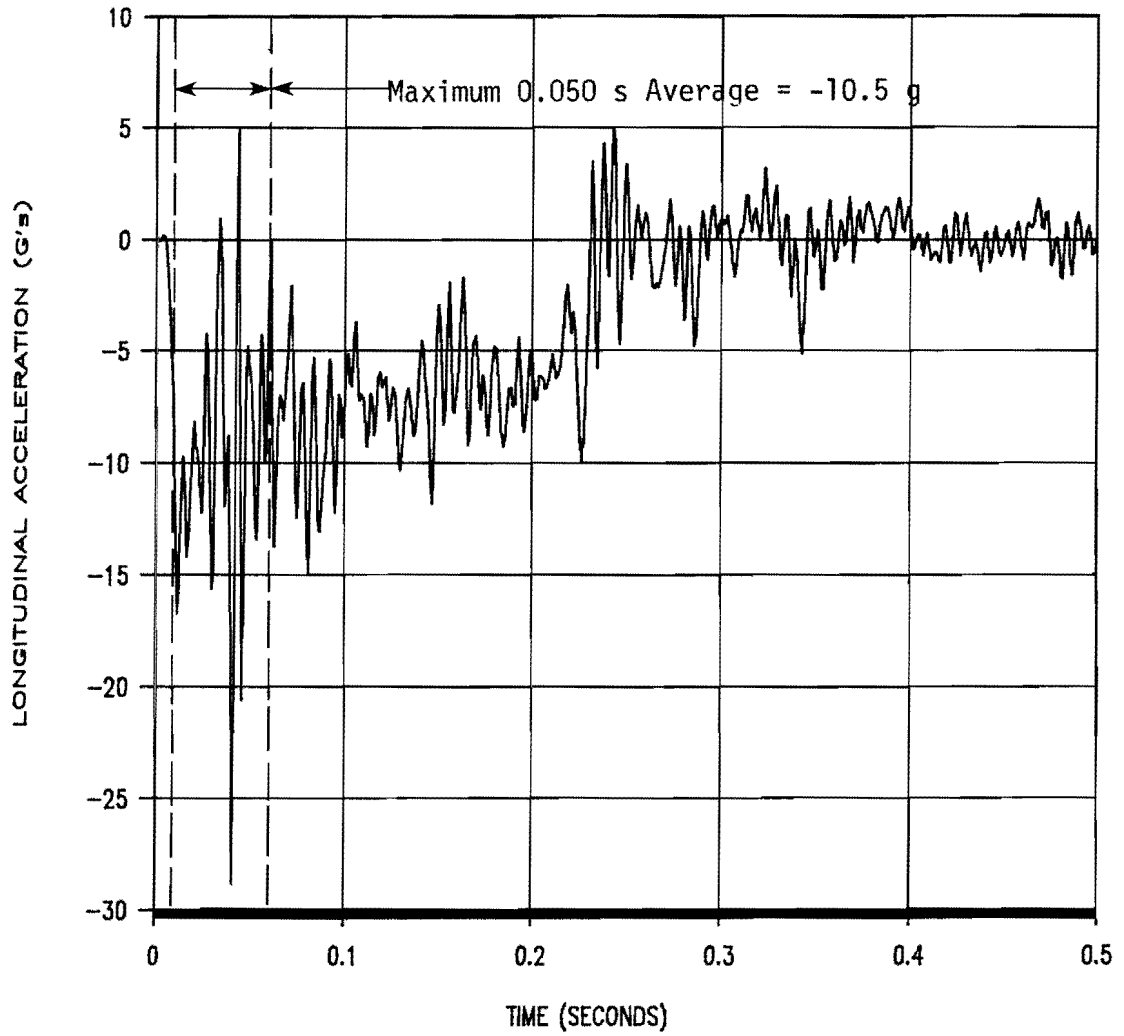


Figure 54. Vehicle longitudinal accelerometer trace for test 9919-1 (near c.g. of vehicle).

TEST 9919-1

Class 180 Filter - Near C.G. of Car

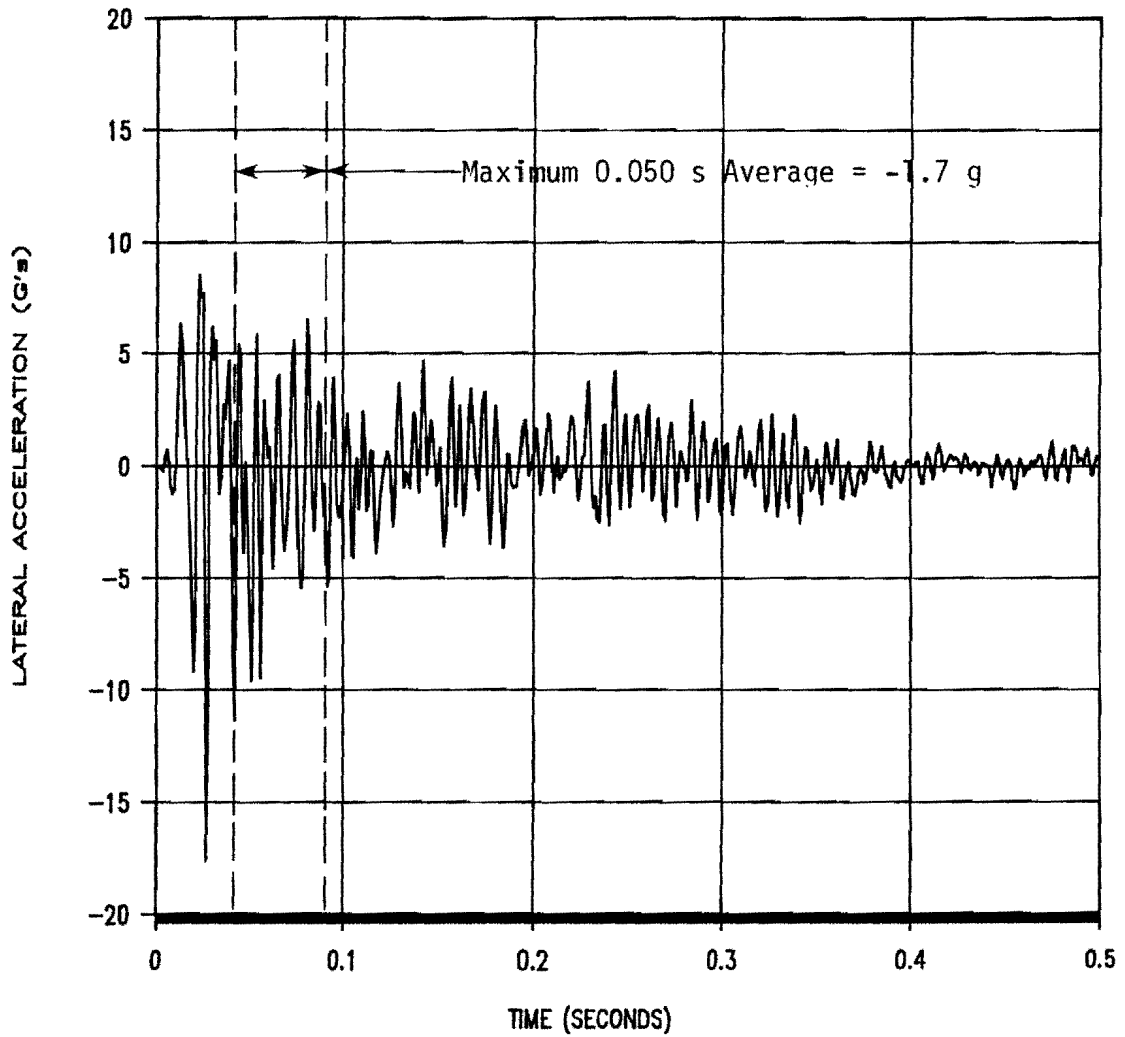


Figure 55 . Vehicle lateral accelerometer trace for test 9919-1 (near c.g. of vehicle).

TEST 9919-1

Class 180 Filter - Near C.G. of Car

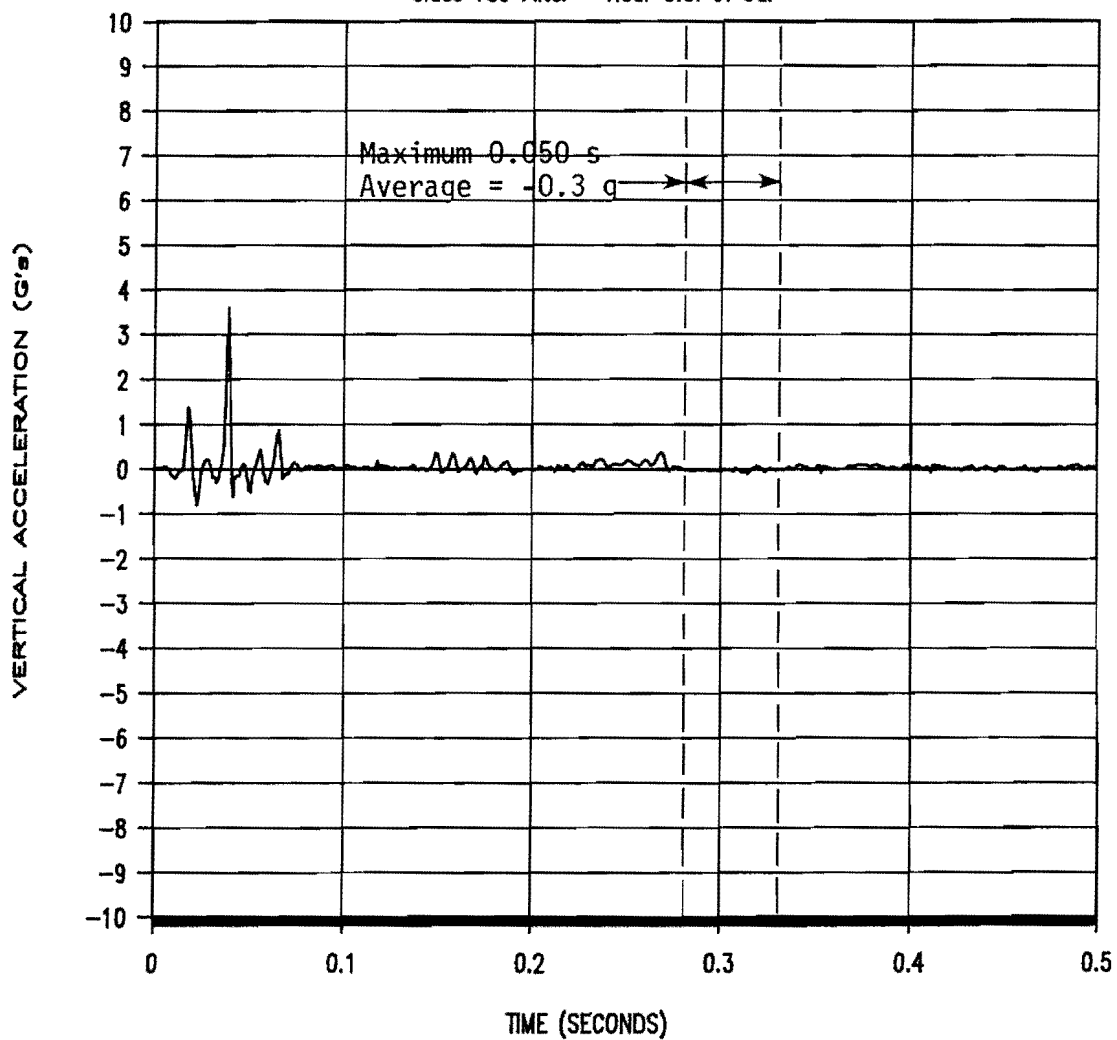


Figure 56 . Vehicle vertical accelerometer trace for test 9919-1 (near c.g. of vehicle).

TEST 9919-1

Class 180 Filter - Cab of Truck

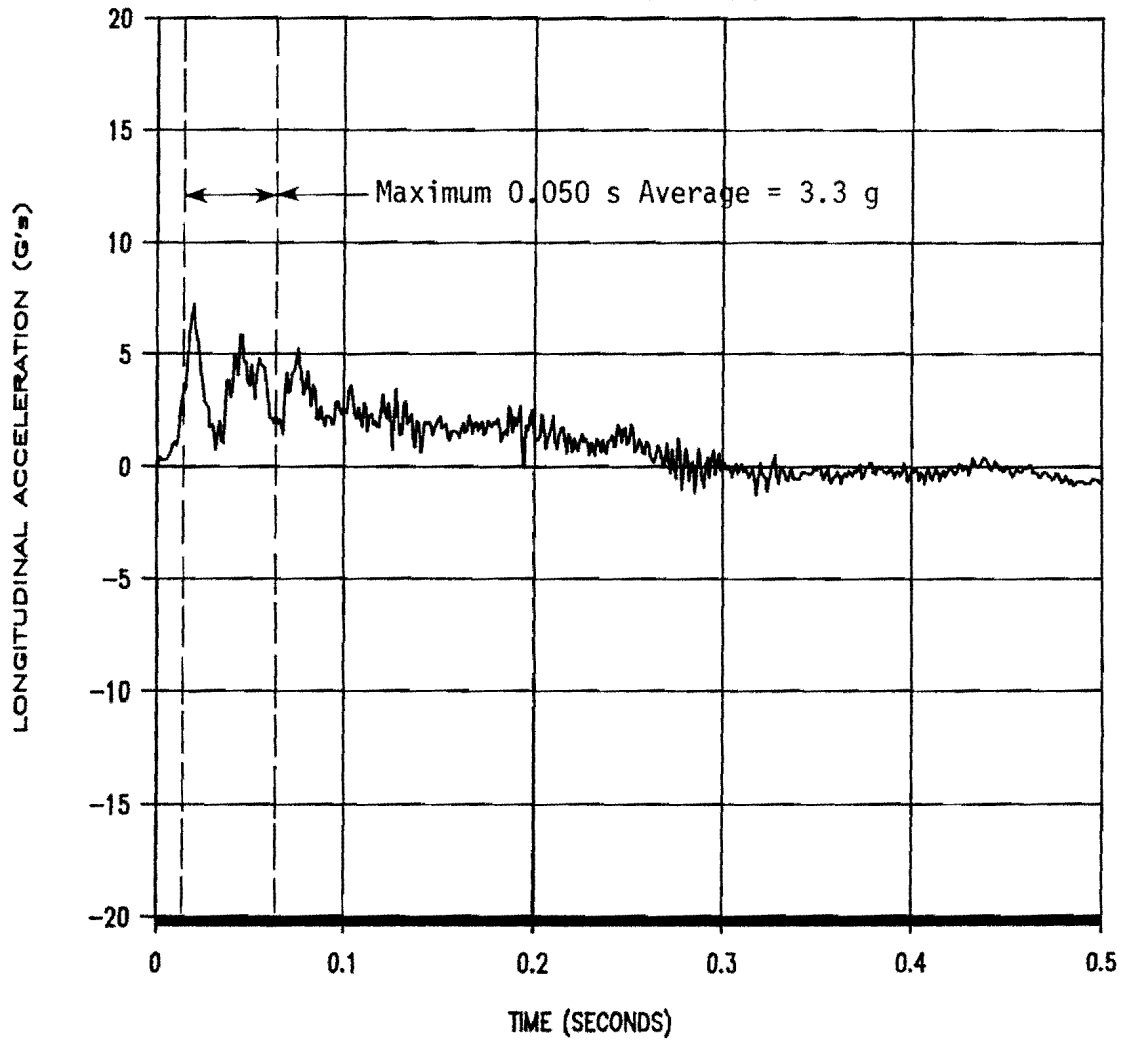


Figure 57. Truck longitudinal accelerometer trace for test 9919-1.

Hexcel 4000 (9910-06)

The TMA used during this test was the Hexcel Model 4000 and is shown in Figures 4 and 58. The TMA was mounted on Truck No. 2 which had a gross static weight of 14,890 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 11.00 inches at the front and 11.75 inches at the rear. The height to the upper rear surface of the cartridge was 36.25 inches above ground.

The 1981 Cadillac Sedan deVille (pictured in Figure 58) was directed into the Hexcel Model 4000 TMA. The height to the lower edge of the vehicle bumper was 11.75 inches and 20.00 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 59.

The vehicle was travelling at a speed of 44.5 mi/h. Upon impact, the TMA began to crush and displace upward. The rear truck tire began to rotate forward at 0.036 second. The impacting vehicle began to dive under the TMA at 0.072 second and bottomed-out at 0.179 second. The rear of the truck began to rise at 0.179 second and, at the same time, the rear tire had rotated 26 degrees forward and began to rotate backwards. As the impacting vehicle continued forward, the front bumper went under the cartridge attachment frame. The bumper extended a maximum of 1.3 ft forward of the front of the cartridge at 0.239 second. By 0.286 second, the rear truck tire had rotated back -15 degrees from perpendicular and continued to rotate forward and backward during the remainder of the test. Forward motion of the impacting vehicle stopped at 1.671 second. The vehicle subsequently came to rest under the TMA. Sequential photographs of the test are shown in Figure 60.

The Hexcel Model 4000 TMA cartridge crushed a total of 82.25 inches longitudinally and displaced upward during the test. The frame attachment to the cartridge was bent 0.38 inch on both sides. The truck had moved forward a total of 13.1 ft, and the parking brake was still on and second gear still engaged. The impacting vehicle received damage to the front bumper, hood, grill, radiator, the right and left front quarter panels, and left and right front doors. The hood of the vehicle was pushed back during the test and had crushed the windshield and bent the roof above the windshield. Maximum vehicle crush was 14.0 inches just above bumper height. The front of the vehicle was also crushed downward. Figures 61 and 62 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 63. The maximum longitudinal 50-msec average acceleration experienced by the impacting vehicle was -13.1 g between 203 and 253 msec. Longitudinal occupant impact velocity was 26.4 ft/s at 132 msec and the maximum longitudinal ridedown acceleration was -19.2 g between 234 and 244 msec. Vehicle angular displacements are plotted in Figure 64 and accelerometer traces are displayed in Figures 65 through 68.

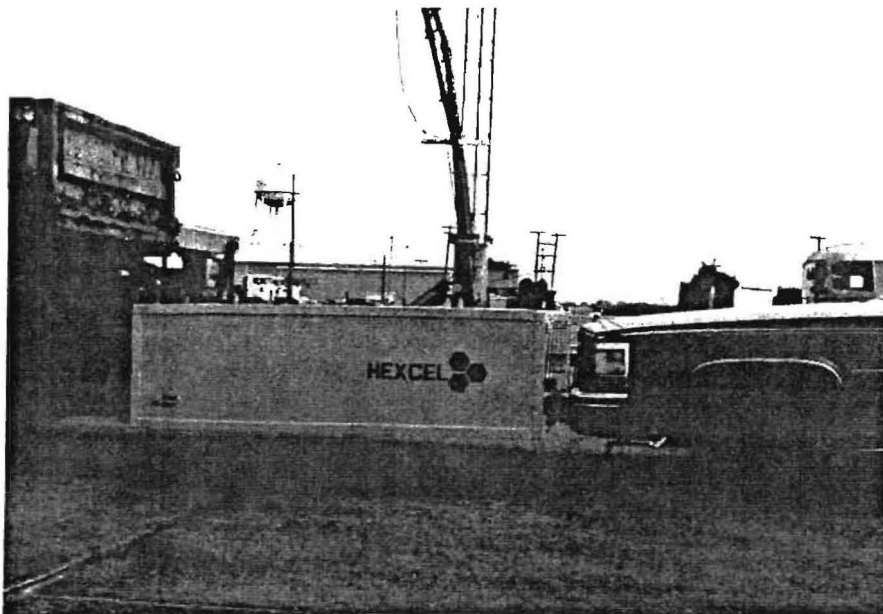


Figure 58. Vehicle before impact with Hexcel Model 4000 TMA (9910-6).

Date: 2/13/90 Test No.: 9910-6 VIN: 106AD69NXB9176498
 Make: Cadillac Model: Sedan DeVille Year: 1981 Odometer: 61525
 Tire Size: P215/75R15 Ply Rating: _____ Bias Ply: _____ Belted: _____ Radial: X

Tire Condition: good _____
 fair X
 badly worn _____

Vehicle Geometry - inches

a 77 1/4 b 42
 c 121 1/2 d* 58 1/4
 e 56 1/2 f 220
 g _____ h 55
 i _____ j 33 1/2
 k 20 1/4 l 36 1/2
 m 20 n 4
 o 11 3/4 p 61 1/4
 r 27 1/2 s 16 1/4

Engine Type: V-8

Engine CID: 350 Diesel

Transmission Type:

Automatic or Manual
 FWD or RWD or 4WD

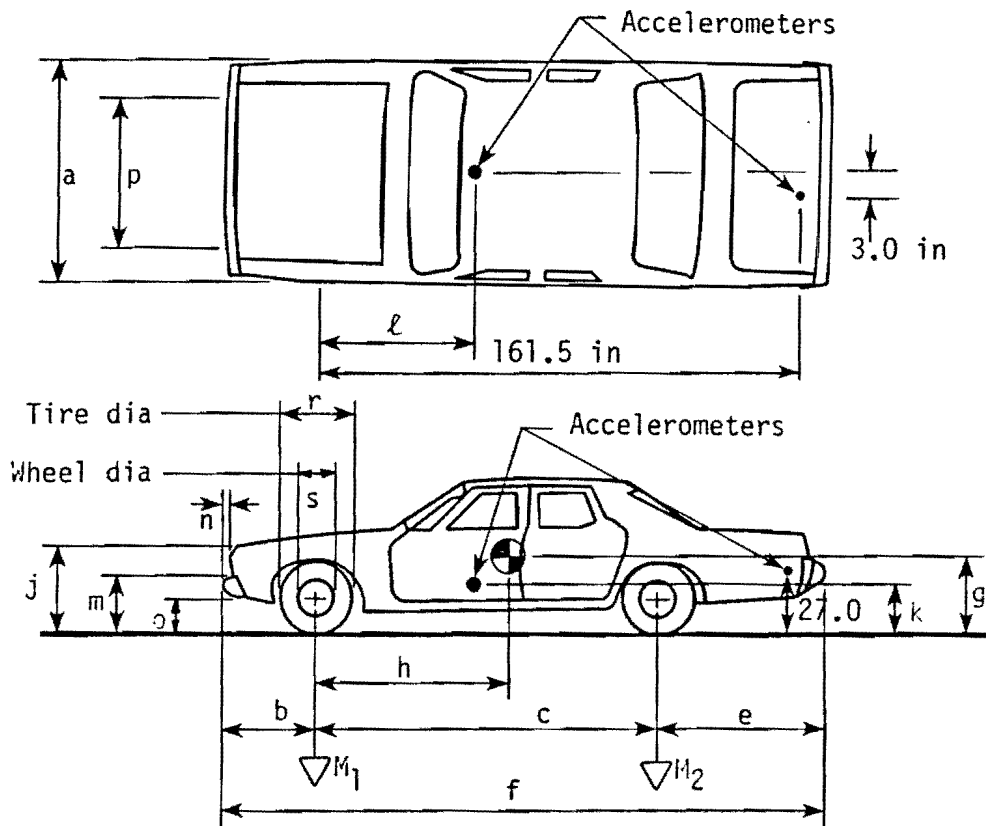
Body Type: 4-Door

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



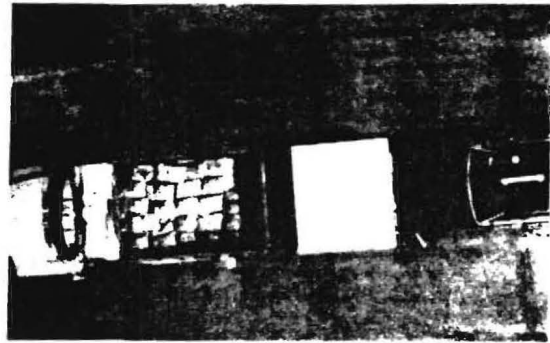
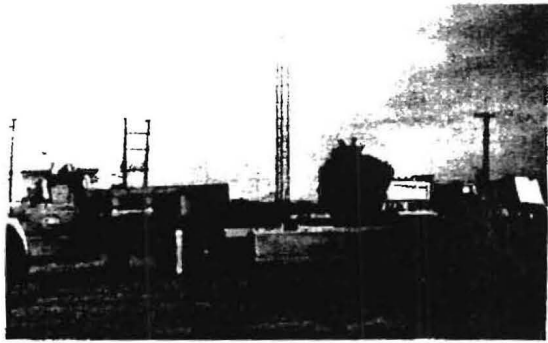
4-wheel weight for c.g. det. lf 1236 rf 1226 lr 1008 rr 1030

Mass - pounds	Curb	Test Inertial	Gross Static
M_1	<u>2484</u>	<u>2462</u>	_____
M_2	<u>1860</u>	<u>2038</u>	_____
M_T	<u>4344</u>	<u>4500</u>	_____

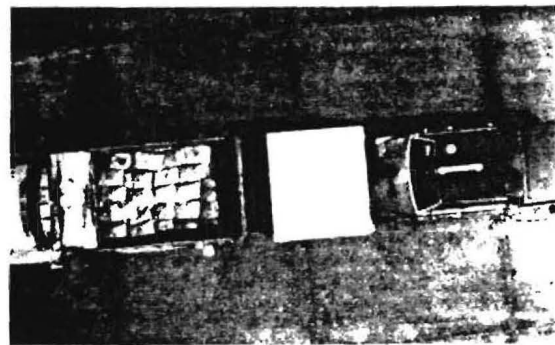
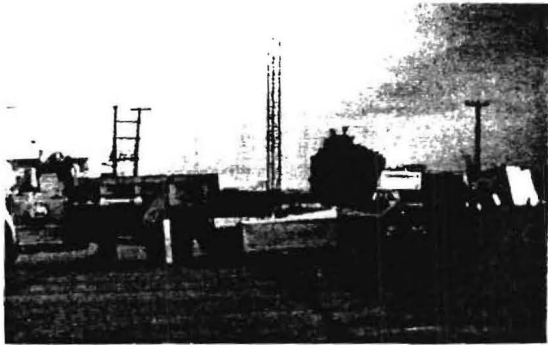
Note any damage to vehicle prior to test:

*d = overall height of vehicle

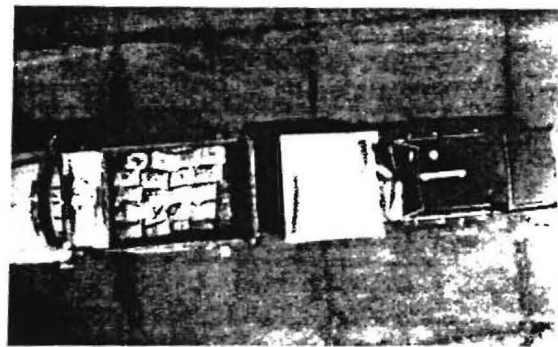
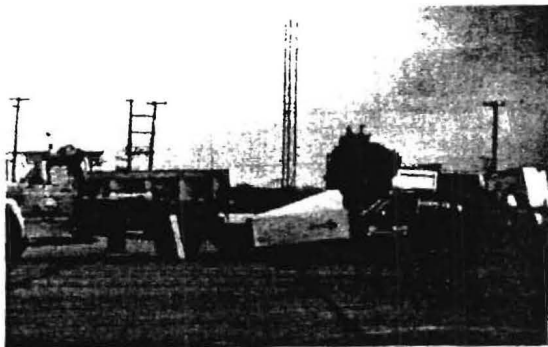
Figure 59. Test vehicle properties (test 9910-6).



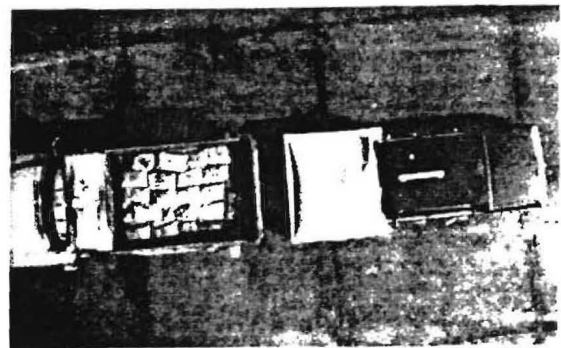
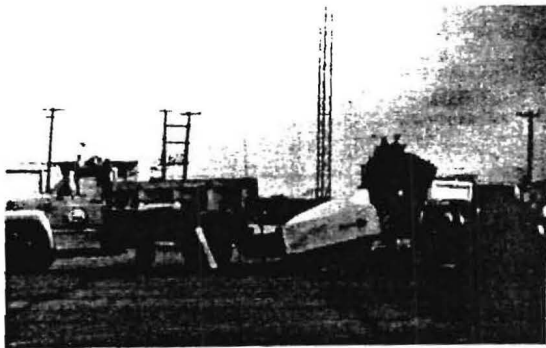
0.000 s



0.050 s

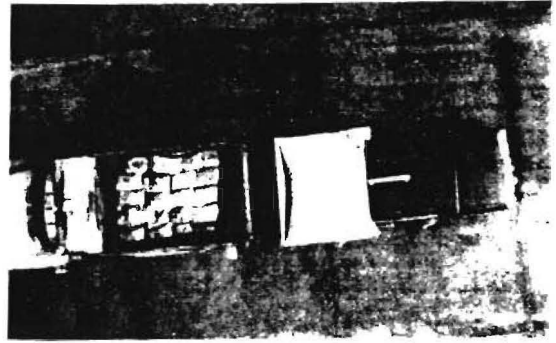
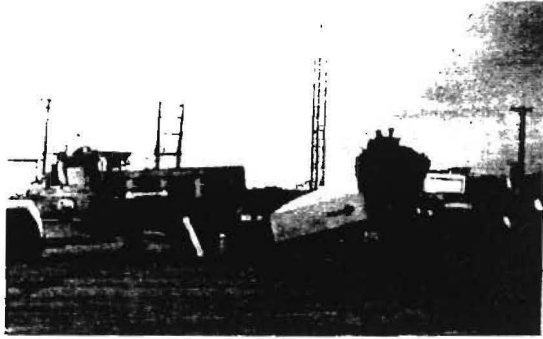


0.100 s

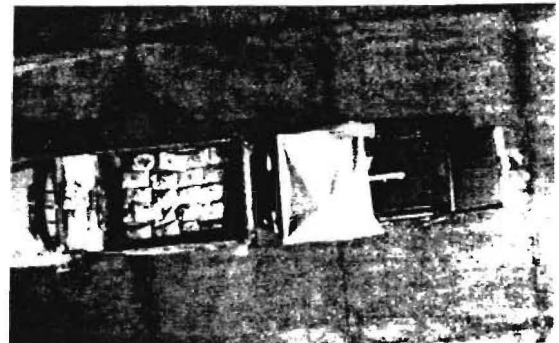


0.150 s

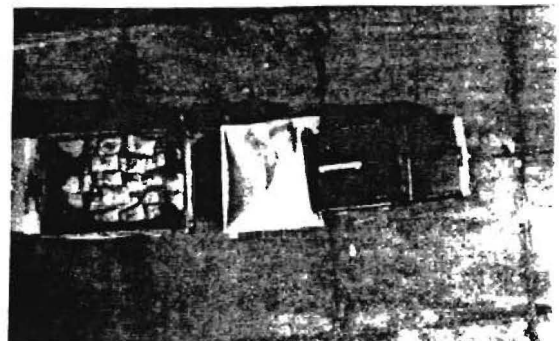
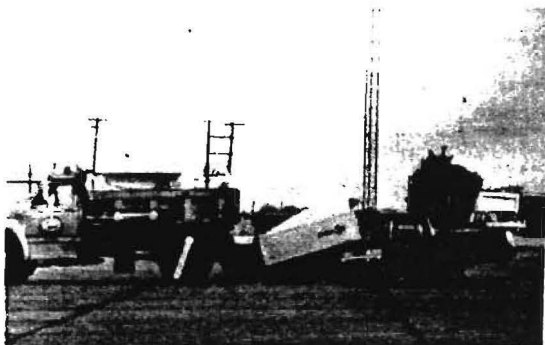
Figure 60. Sequential photographs for test 9910-6.



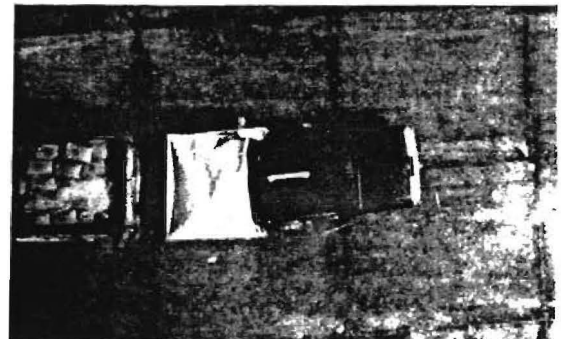
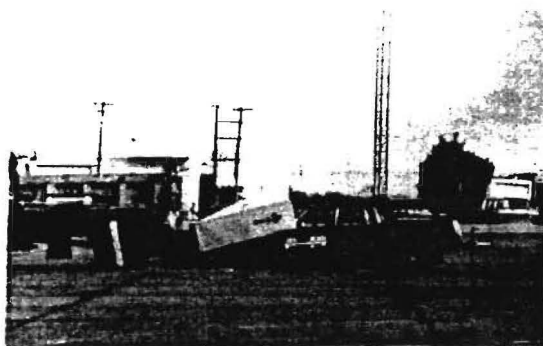
0.201 s



0.251 s



0.499 s



1.000

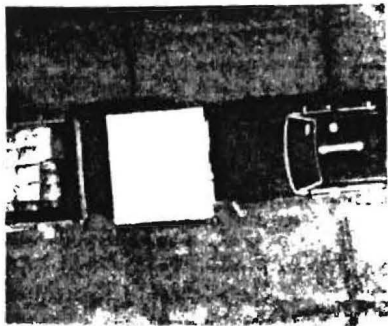
Figure 60. Sequential photographs for test 9910-6.
(Continued)



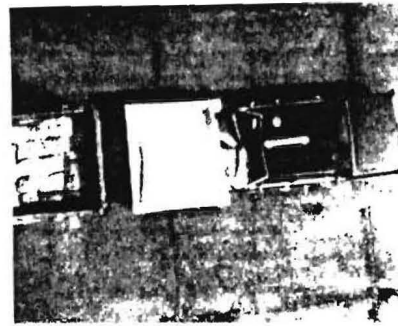
Figure 61. Hexcel Model 4000 TMA
after test 9910-6.



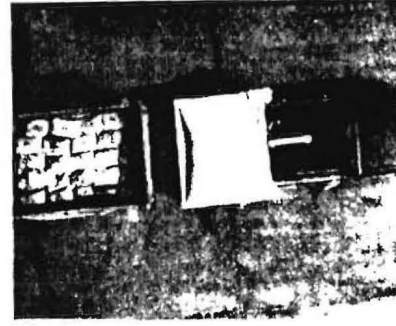
Figure 62 Vehicle after impact with Hecel Model 4000 TMA (9910-6).



0.000 s



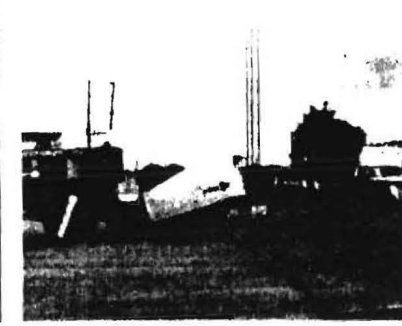
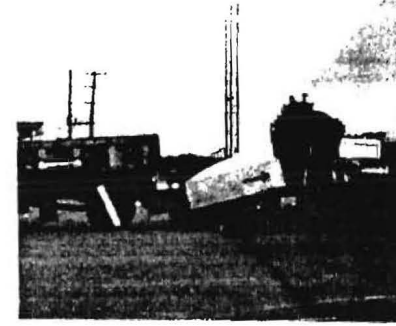
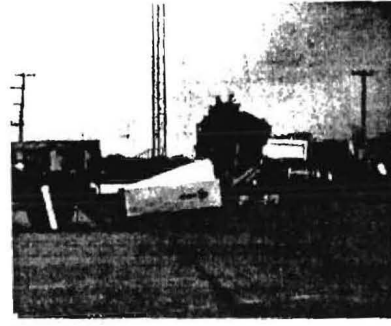
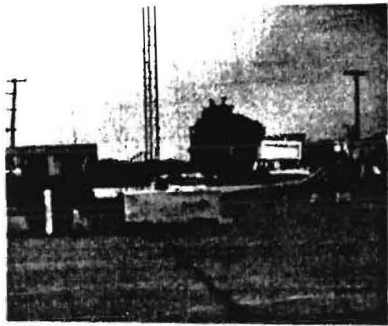
0.100 s



0.201 s



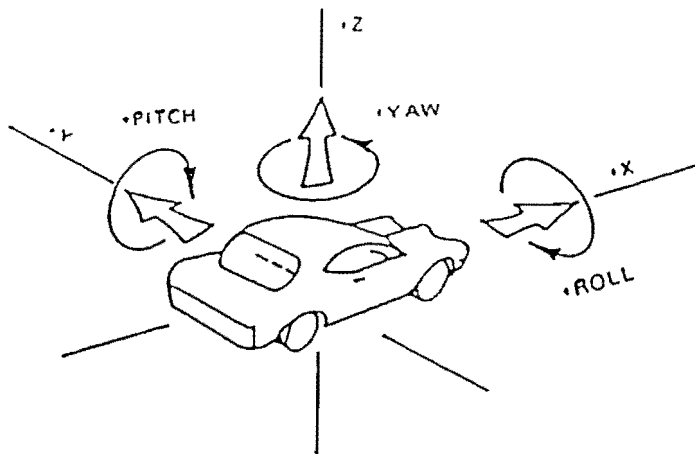
0.499 s



08

Test No.	09910-6	Maximum Truck Displacement .	13.1 ft (4.0 m)
Date	02/13/90	Maximum TMA Crush	82.25 in (2.1 m)
Test Article	Truck Mounted Attenuator	Vehicle Accelerations	
Manufacturer	Hexcel Model 4000	(Maximum 50 ms Average at c.g.)	
TMA Truck	1980 Ford Dump Truck (#2)	Vehicle Longitudinal	-12.1 g
Weight without TMA .	14,010 lb (6,361 kg)	Vehicle Lateral	-1.1 g
Weight with TMA . . .	14,890 lb (6,760 kg)	Truck Cab Longitudinal . . .	11.5 g
Test Vehicle	1981 Cadillac Sedan deVille	Occupant Impact Velocity	
Weight	4,500 lb (2,043 kg)	Longitudinal	26.4 ft/s (8.0 m/s)
Impact Speed	44.5 mi/h (71.6 km/h)	Lateral	5.5 ft/s (1.7 m/s)
Maximum Vehicle Crush .	14.0 in (35.6 cm)	Occupant Ridedown Accelerations	
Vehicle Damage Classification		Longitudinal	-19.2 g
TAD	12FD5	Lateral	-1.5 g
CDC	12FDEW4		

Figure 63. Summary of results for test 9910-6.



Axes are vehicle fixed.
 Sequence for determining
 orientation is:

1. Yaw
2. Pitch
3. Roll

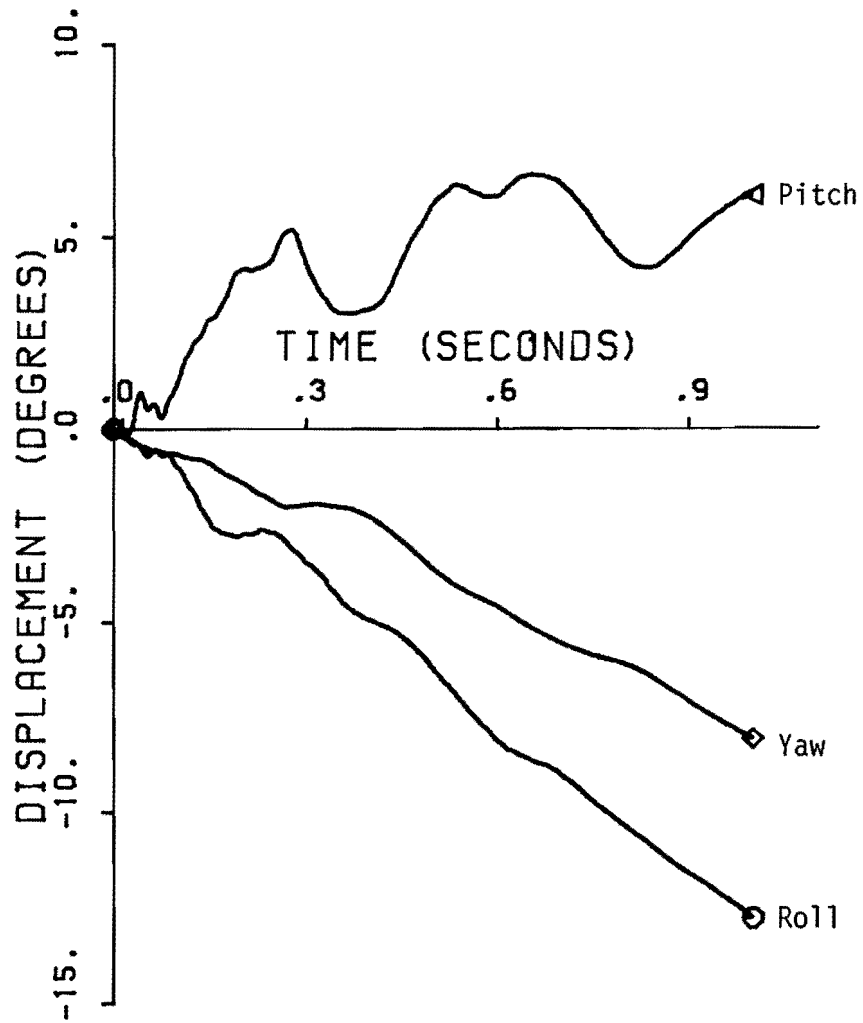


Figure 64. Vehicle angular displacements for test 9910-6.

TEST 9910-6

Class 180 Filter

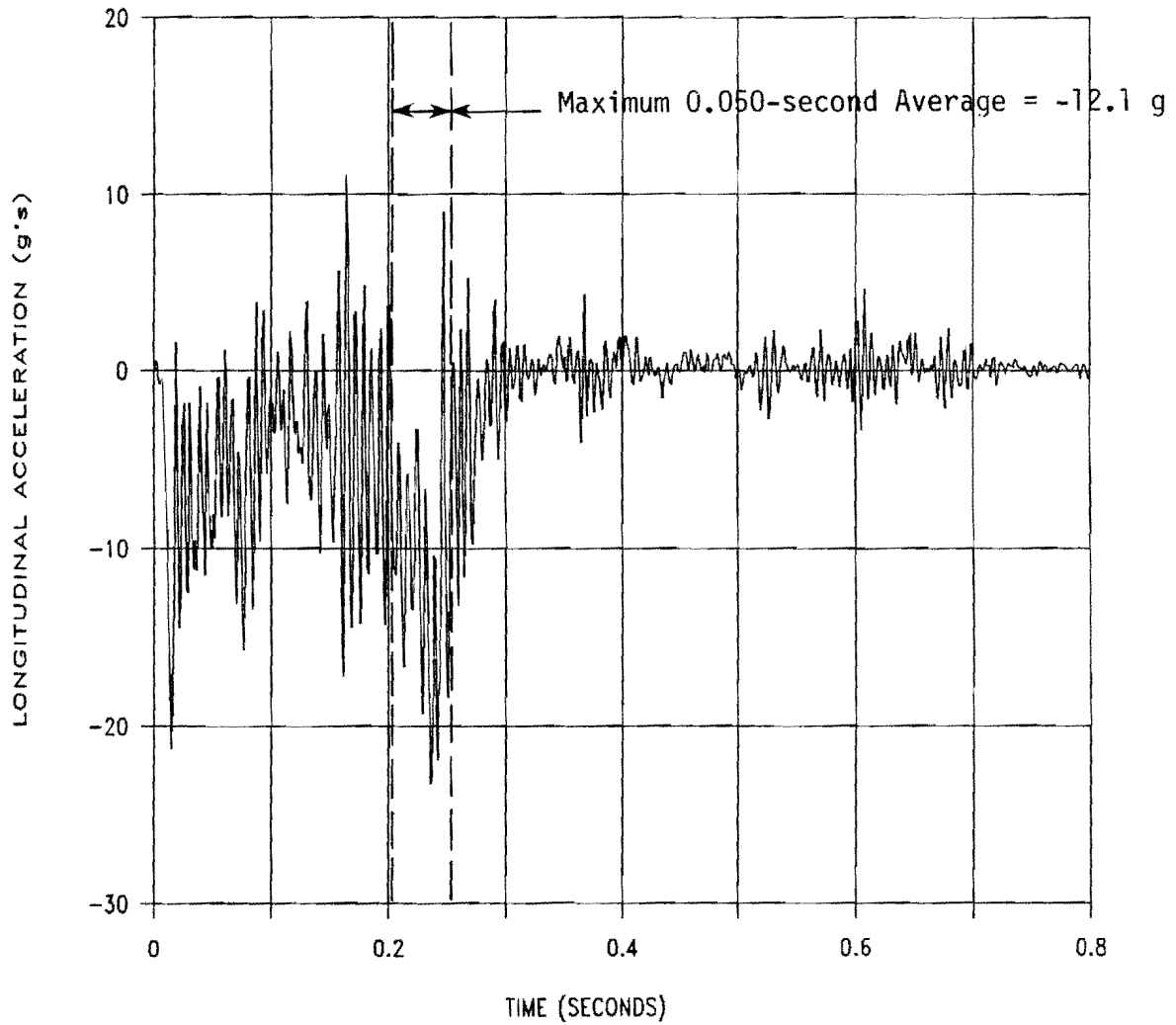


Figure 65. Longitudinal accelerometer trace for test 9910-6.

TEST 9910-6

Class 180 Filter

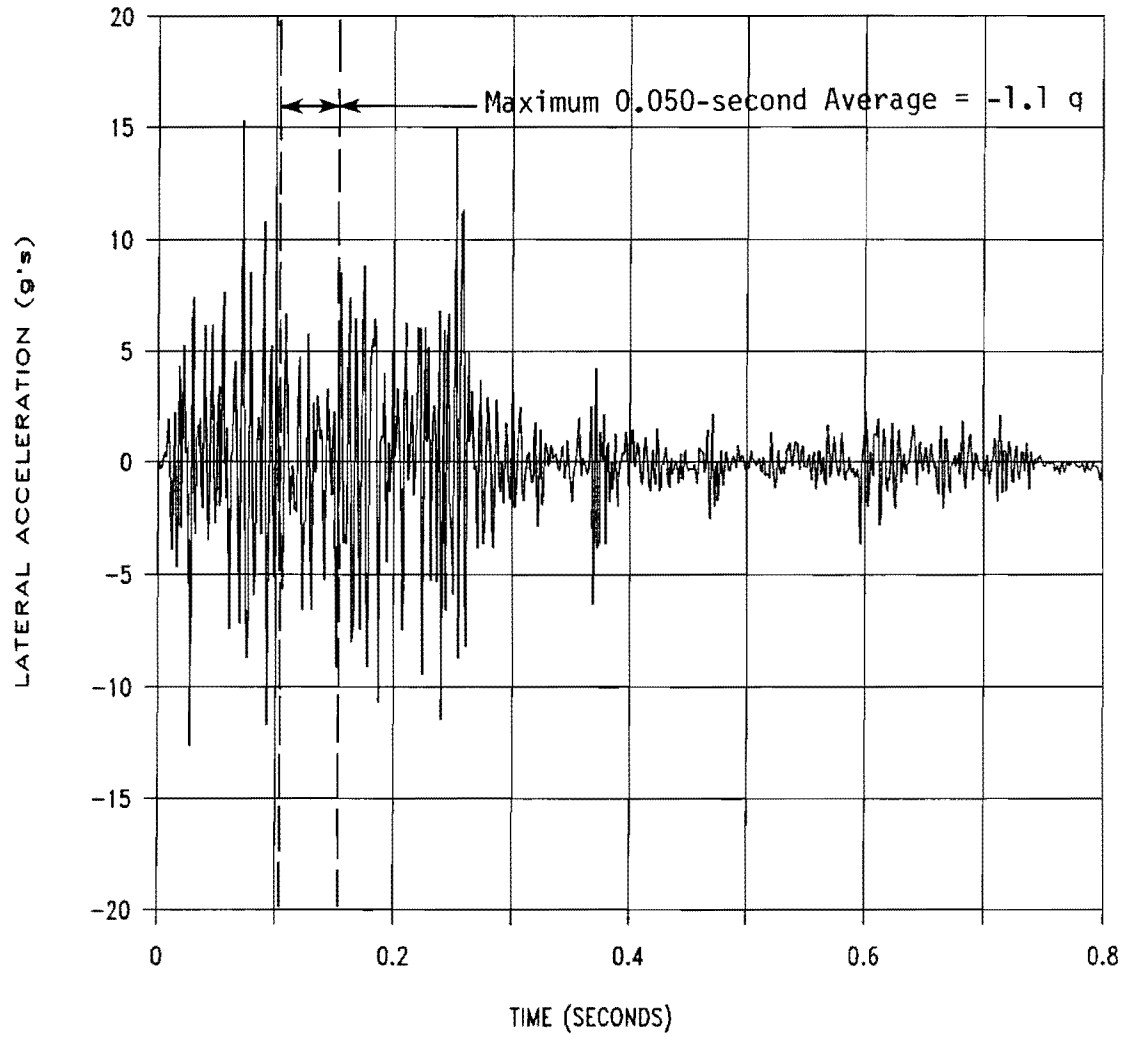


Figure 66. Lateral accelerometer trace for test 9910-6.

TEST 9910-6

Class 180 Filter

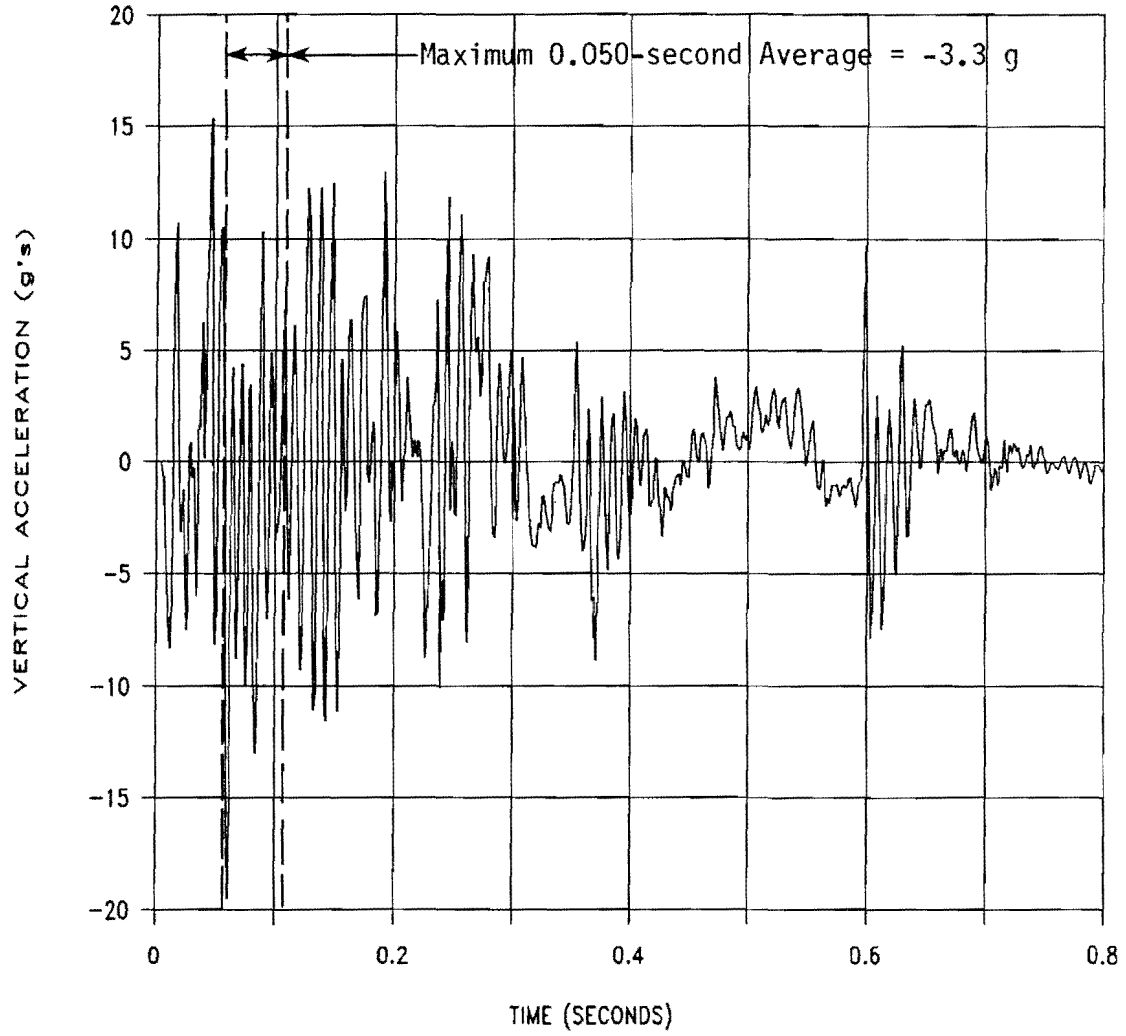


Figure 67. Vertical accelerometer trace for test 9910-6.

TEST 9910-6

Class 180 Filter - Dump Truck Cab

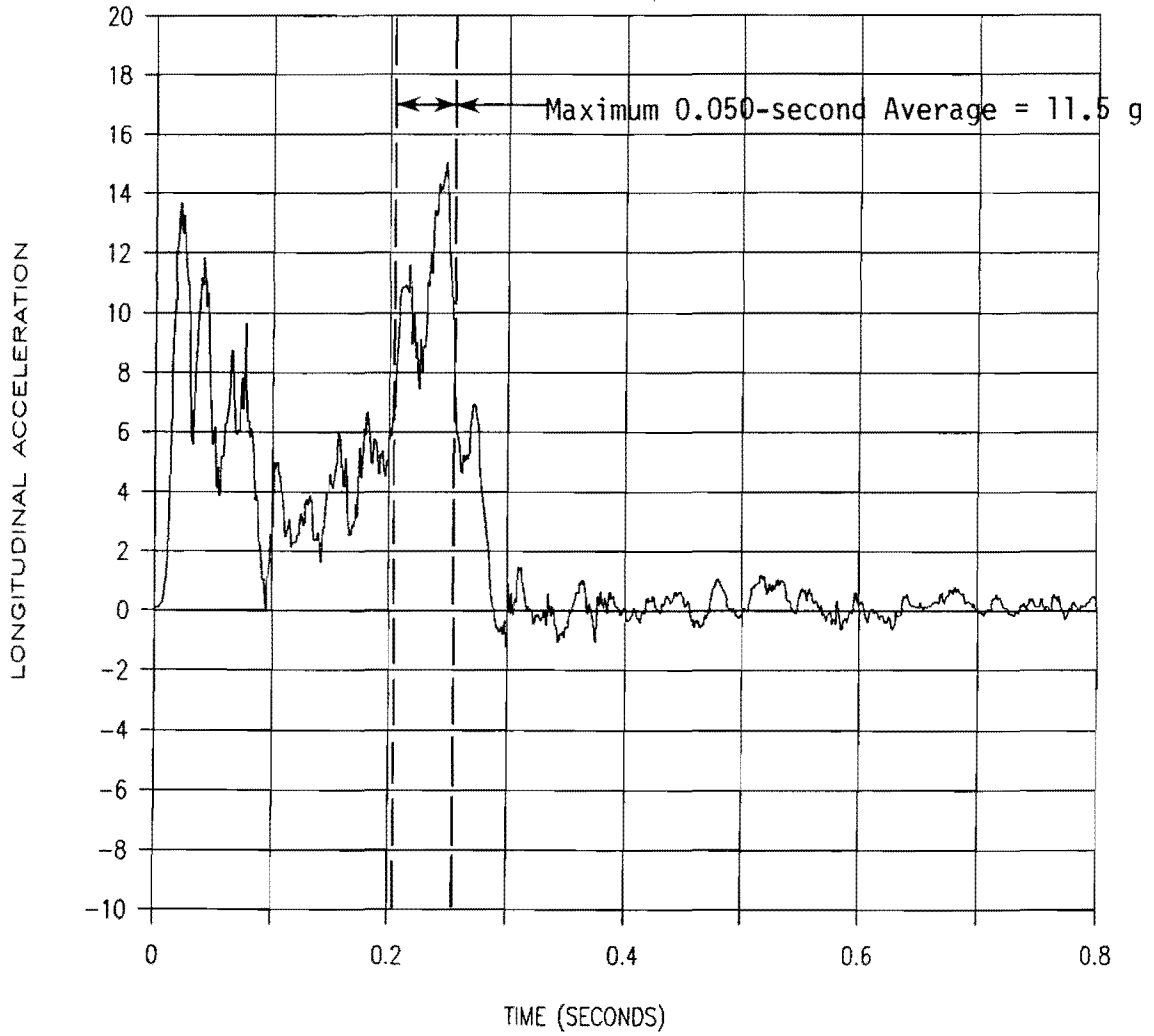


Figure 68. Longitudinal accelerometer trace for test 9910-6 (dump truck cab).

Renco (9919-04)

The TMA used during this test was manufactured by Renco and is shown in Figures 5 and 69. The TMA was mounted on Truck No. 1 which had a gross static weight of 15,260 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 11.25 inches at the front and 11.50 inches at the rear. The height to the upper rear surface of the cartridge was 35.50 inches above ground.

The 1981 Oldsmobile 98 Regency (pictured in Figures 69 and 70) was towed into the Renco TMA. The height to the lower edge of the vehicle bumper was 10.50 inches and 19.00 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 71.

The vehicle was travelling at a speed of 45.7 mi/h. Upon impact, the TMA began to crush and, at 0.070 second, the rear truck tires began to rotate. At approximately 0.162 second, the impacting vehicle began to nose down, however it did not contact the ground. The truck tire had rotated 32 degrees by 0.194 second and began to skid and rotate backwards. The tire skid ended at 0.277 second with the tire at -9 degrees from perpendicular and then began to roll forward again. The truck tire continued to alternate between rolling and skidding during the remainder of the test period. At 0.438 second, the truck reached a maximum speed of 11.3 ft/s (7.7 mi/h) and had moved approximately 4.9 ft. By this time, the impacting vehicle had slowed to 25.0 ft/s (17.1 mi/h). The maximum rotation angle achieved by the rear truck tires during the test was 36 degrees at 0.907 second; however, at the end of the test the tire was sitting at 3 degrees. Sequential photographs of the test are shown in Figure 72.

The Renco TMA cartridge crushed a total of 54.00 inches during the test. The frame attachment to the cartridge was not damaged. The truck had moved forward a total of 7.9 feet and was still in second gear with the parking brake on. The impacting vehicle received damage to the bumper, hood, grill, radiator, right and left front quarter panels, right and left front doors, and the windshield was cracked in the lower corners. Maximum vehicle crush was 10.0 inches at bumper height. Figures 73 through 75 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 76. The maximum longitudinal 50-msec average acceleration experienced by the impacting vehicle was -13.2 g between 146 and 196 msec. Longitudinal occupant impact velocity was 34.6 ft/s at 146 msec and the maximum longitudinal ridedown acceleration was -15.6 g between 167 and 177 msec. The maximum longitudinal 50-msec average acceleration for the truck was 3.6 g between 130 and 180 msec. The truck reached a maximum speed of 11.3 ft/s (7.7 mi/h) and moved forward a total of 7.9 ft. The rear truck tires alternated between rolling and skidding during the test. Vehicle angular displacements are plotted in Figure 77 and accelerometer traces are displayed in Figures 78 through 81.

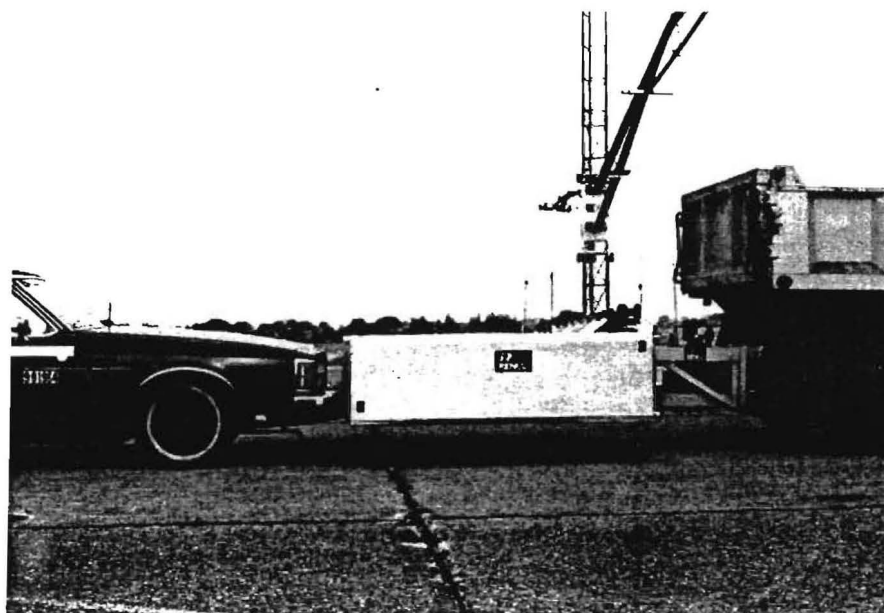
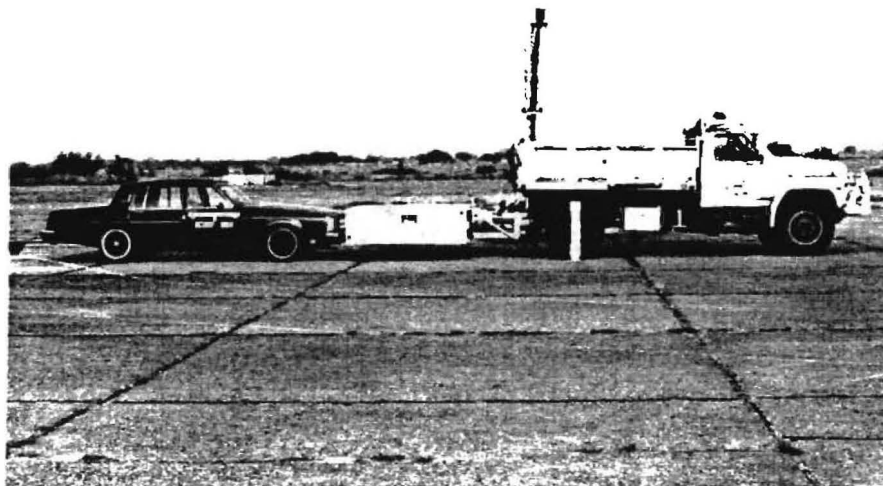
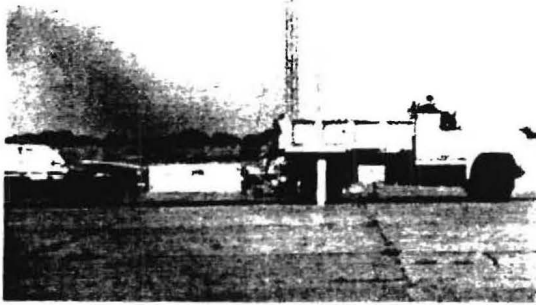


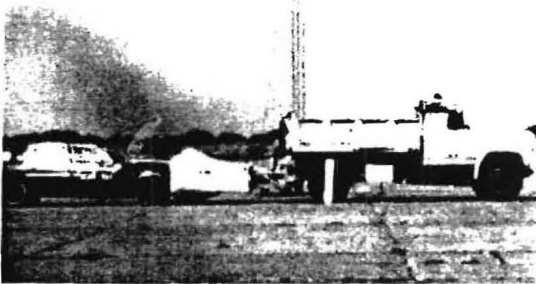
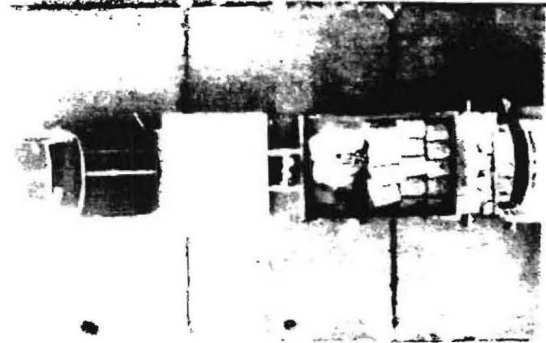
Figure 69. Configuration for test with RENCO TMA.



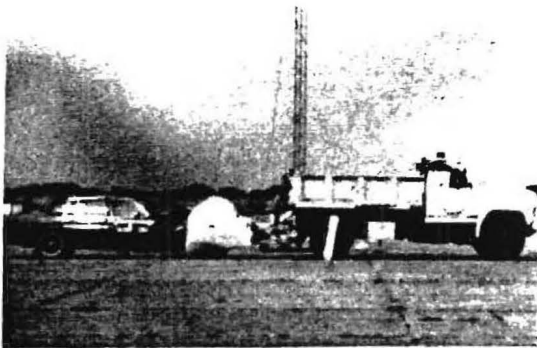
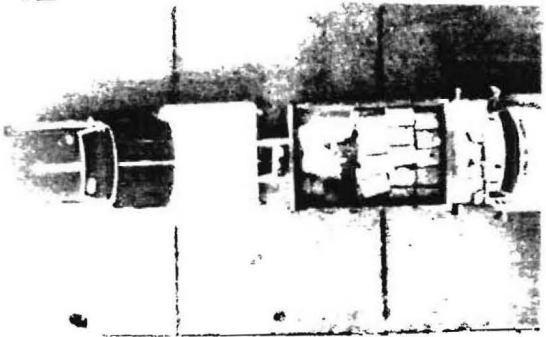
Figure 70. Vehicle before impact with RENCO TMA.



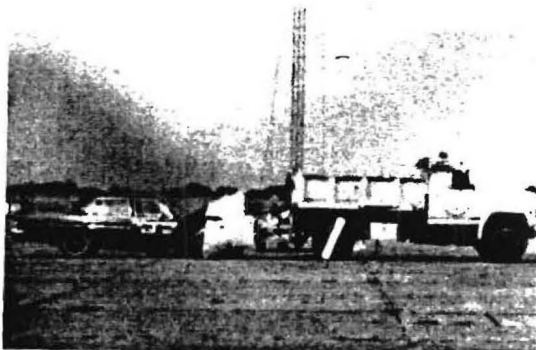
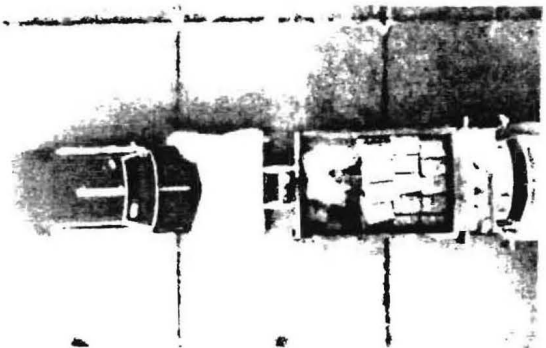
0.000 s



0.050 s



0.100 s



0.150 s

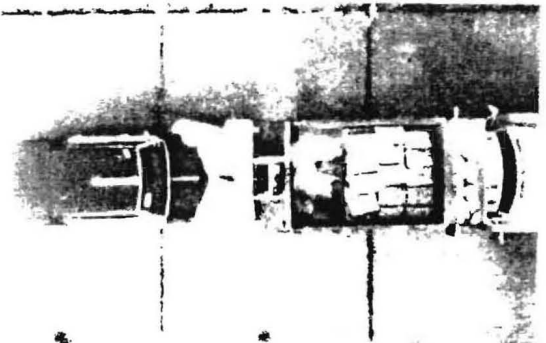
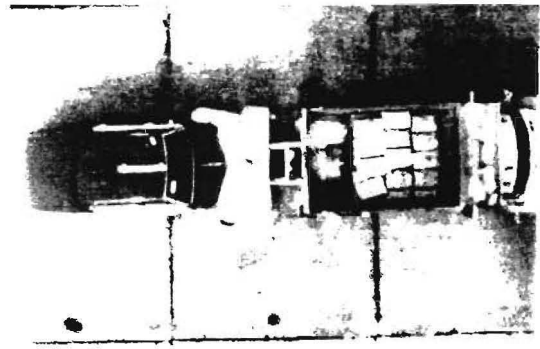
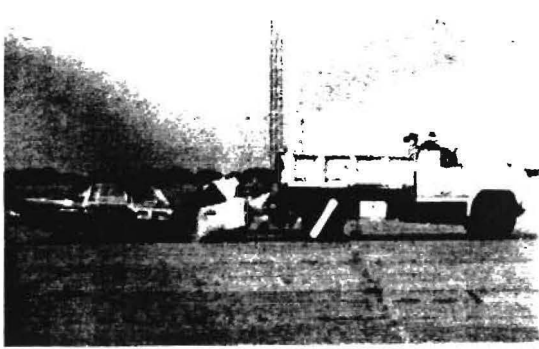
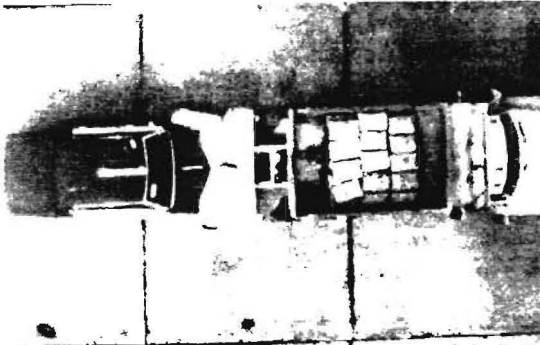
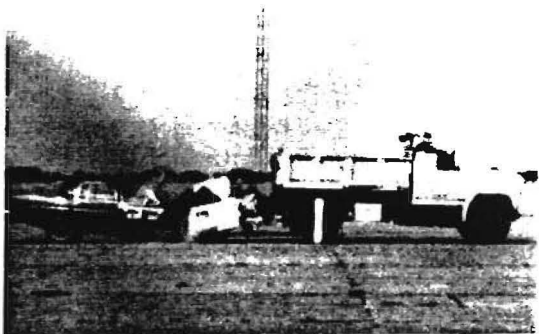


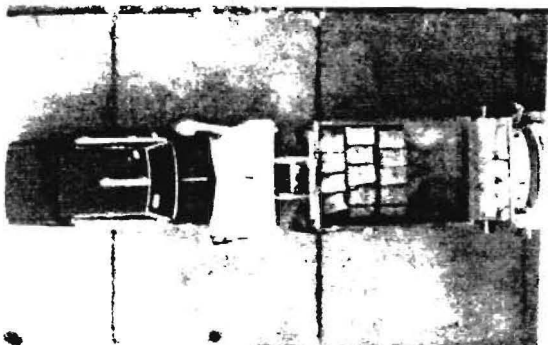
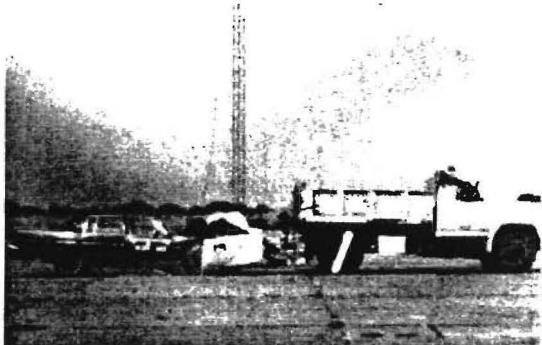
Figure 72. Sequential photographs for test 9919-4.



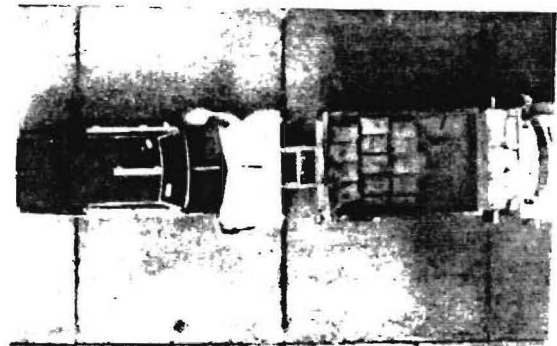
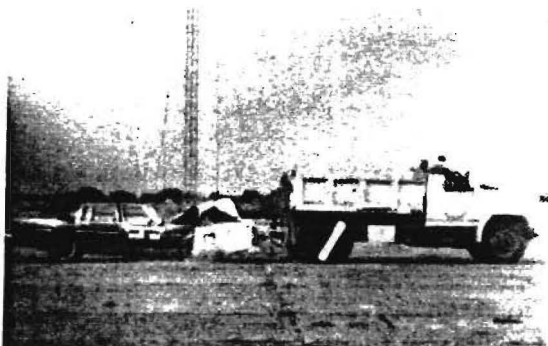
0.200 s



0.250 s



0.500 s



1.000 s

Figure 72. Sequential photographs for test 9919-4.
(Continued)

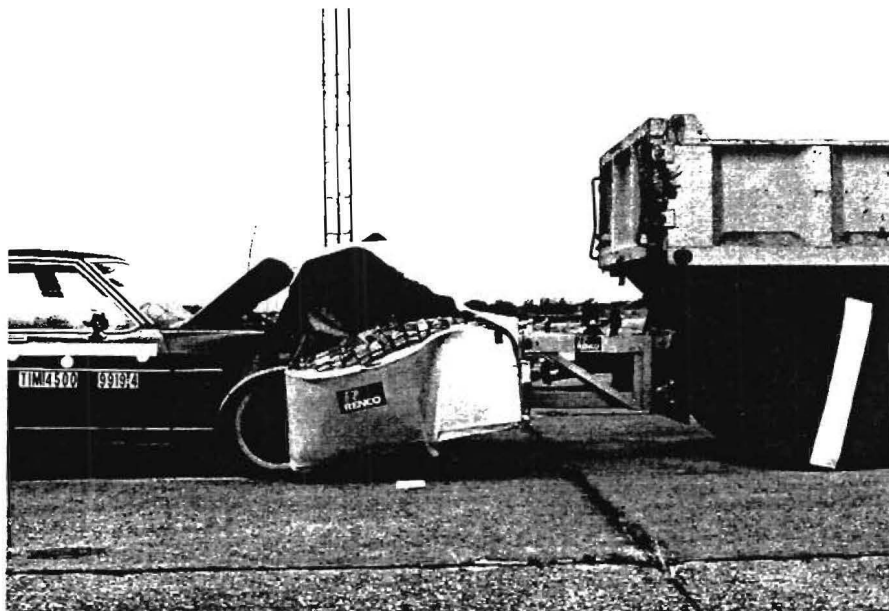
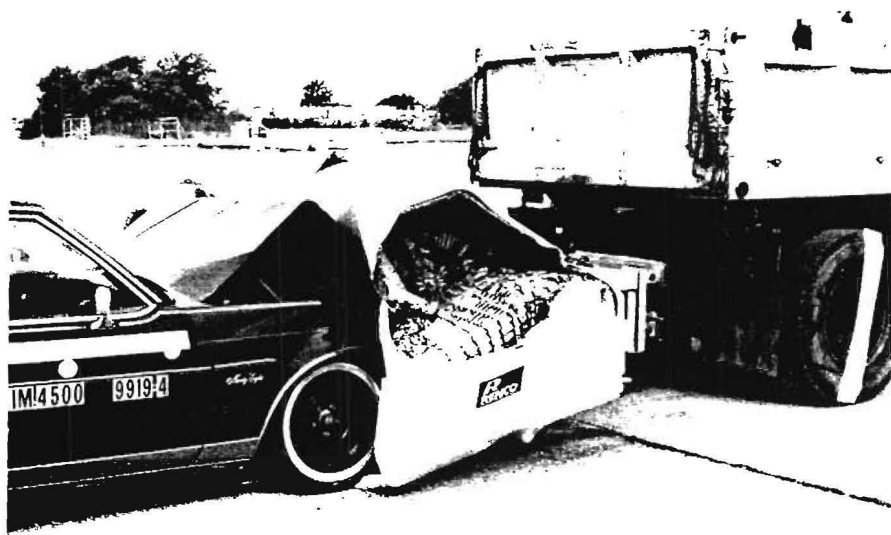


Figure 73. Damage to Renco TMA (right side).

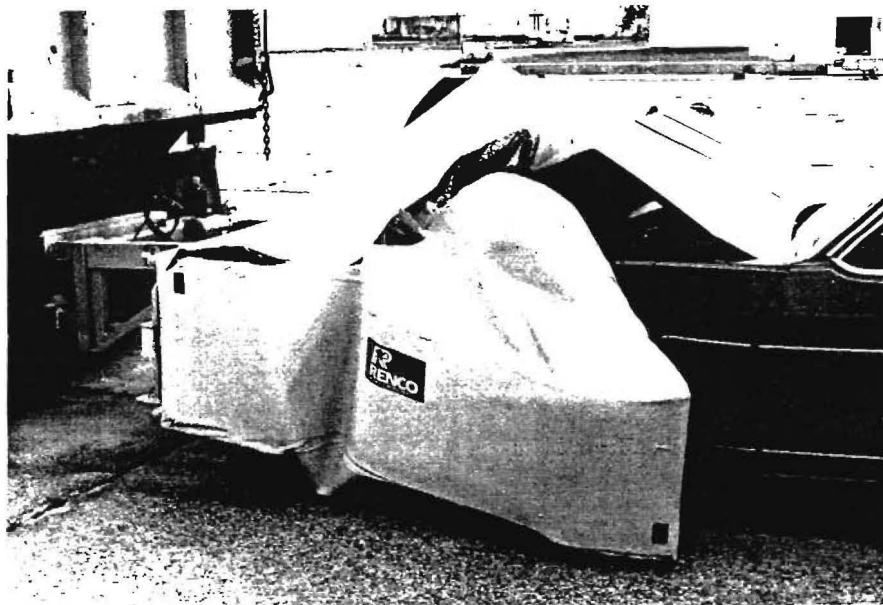
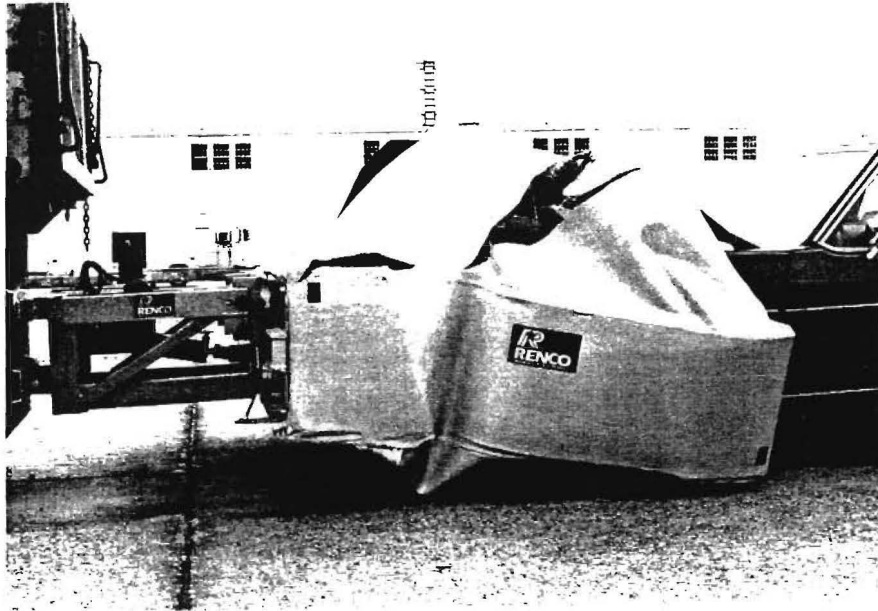


Figure 74. Damage to RENCO TMA (left side).

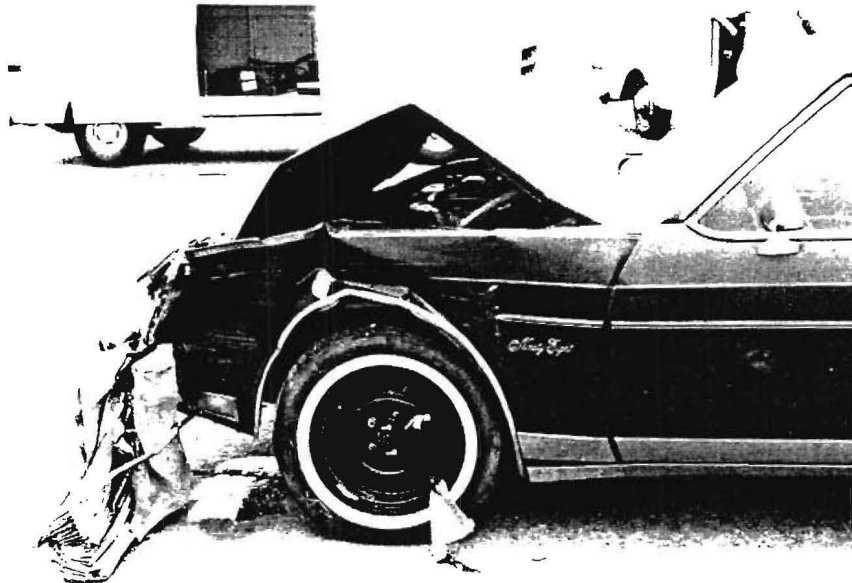
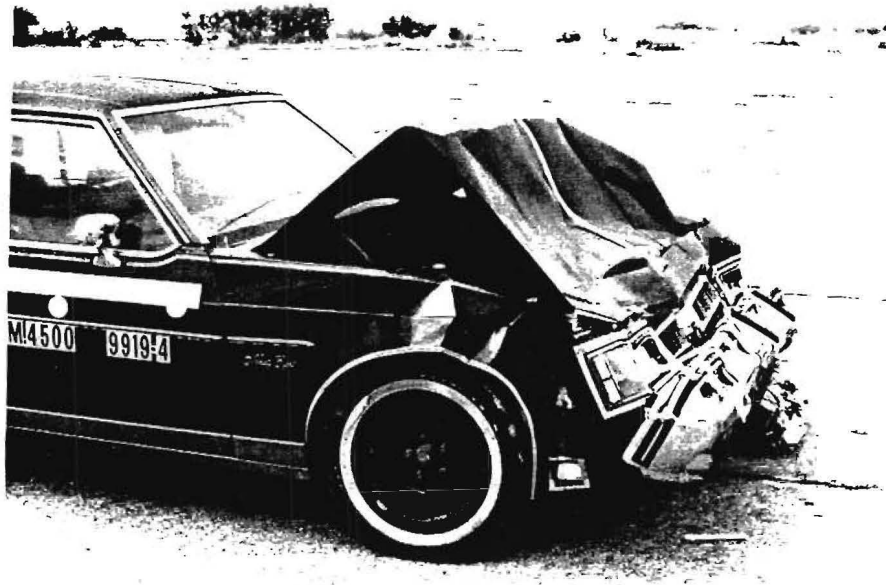
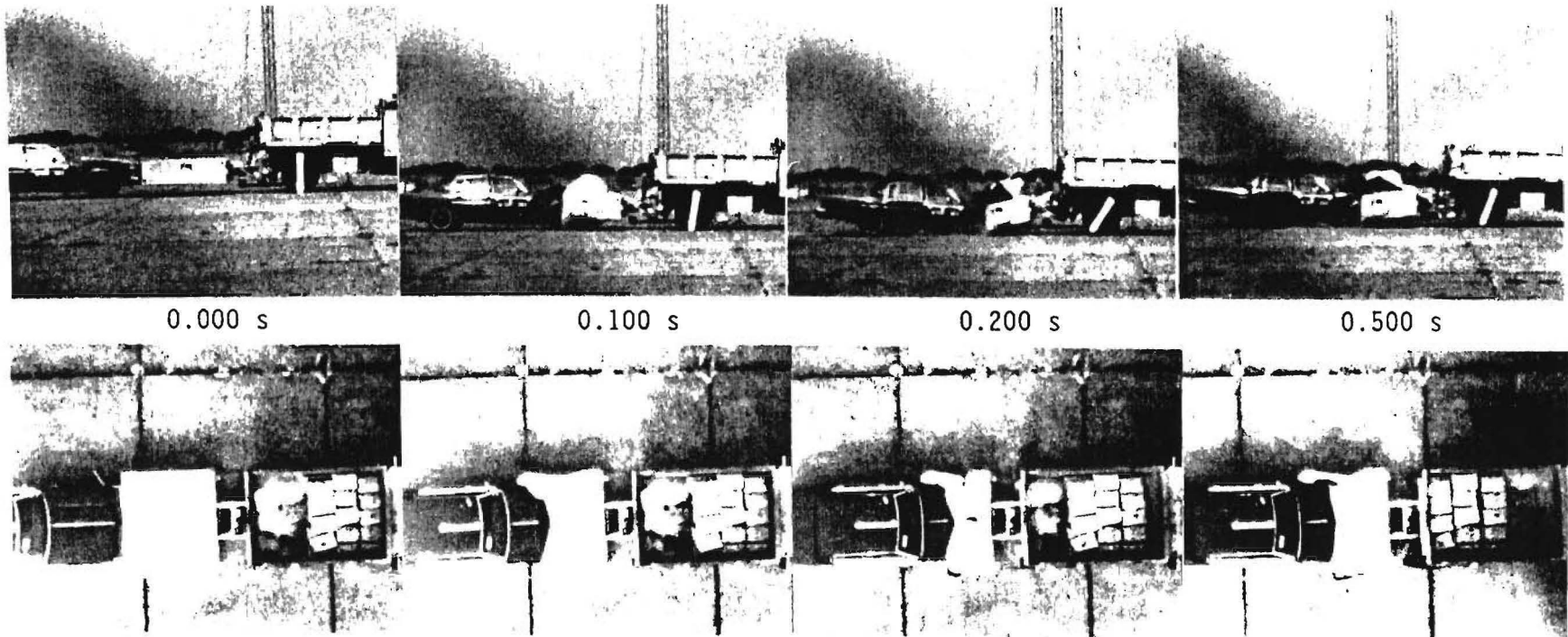


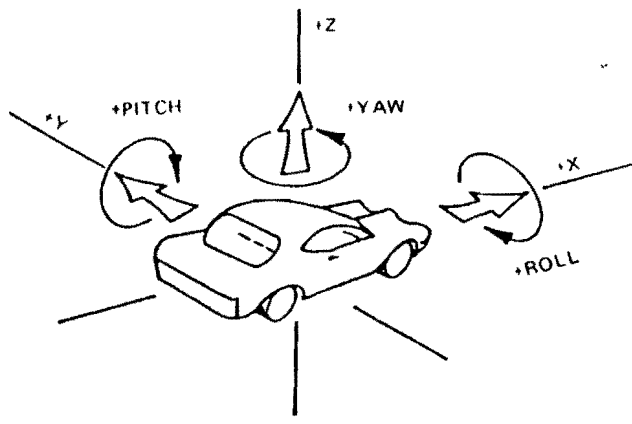
Figure 75. Vehicle after impact with RENCO TMA.



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Test No.	09919-4	Maximum Truck Displacement	7.9 ft (2.4 m)
Date	08/15/89	Maximum TMA Crush	54.00 in (1.4 m)
Test Article	Truck Mounted Attenuator	Vehicle Accelerations	
Manufacturer	RENCO	(Maximum 50 ms Average at c.g.)	
TMA Truck	1981 Ford Dump Truck (#1)	Vehicle Longitudinal	-13.2 g
Weight without TMA	14,010 lb (6,361 kg)	Vehicle Lateral	-1.2 g
Weight with TMA	15,260 lb (6,928 kg)	Truck Cab Longitudinal	3.6 g
Test Vehicle	1981 Oldsmobile 98 Regency	Occupant Impact Velocity	
Weight	4,500 lb (2,043 kg)	Longitudinal	34.6 ft/s (10.5 m/s)
Impact Speed	45.7 mi/h (73.5 km/h)	Lateral	7.1 ft/s (2.2 m/s)
Maximum Vehicle Crush	10.0 in (25.4 cm)	Occupant Ridedown Accelerations	
Vehicle Damage Classification		Longitudinal	-15.6 g
TAD	12FD3	Lateral	-1.9 g
CDC	12FDEW2		

Figure 76. Summary of results for test 9919-4.



Axes are vehicle fixed.
 Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

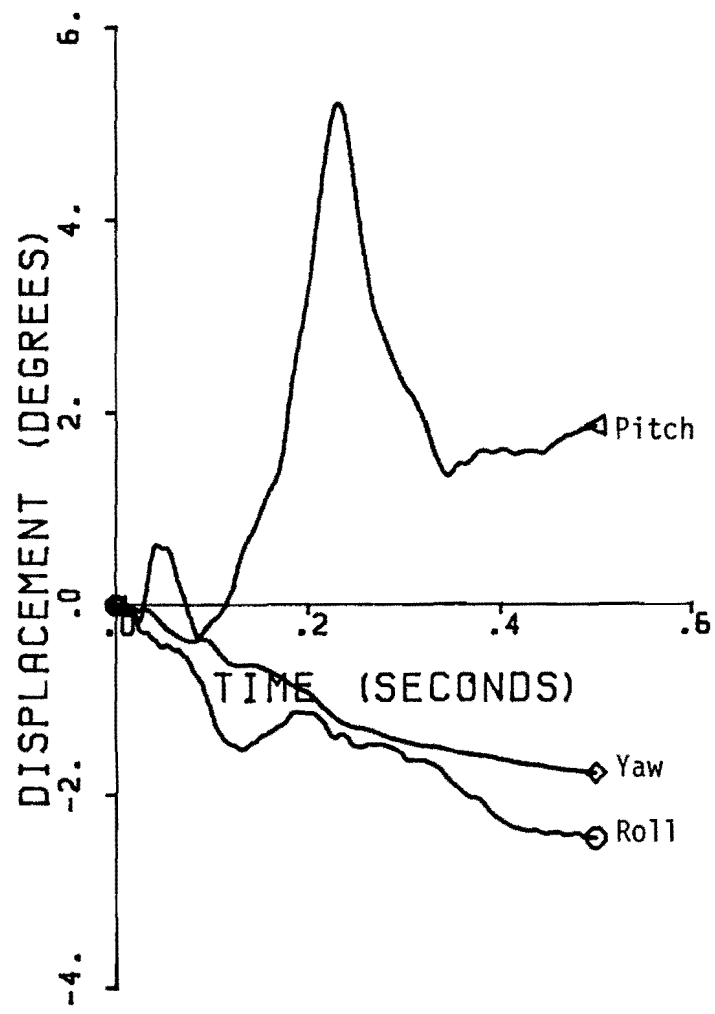


Figure 77. Vehicle angular displacements for test 9919-4.

TEST 9919-4

Class 180 Filter - Near C.G. of Car

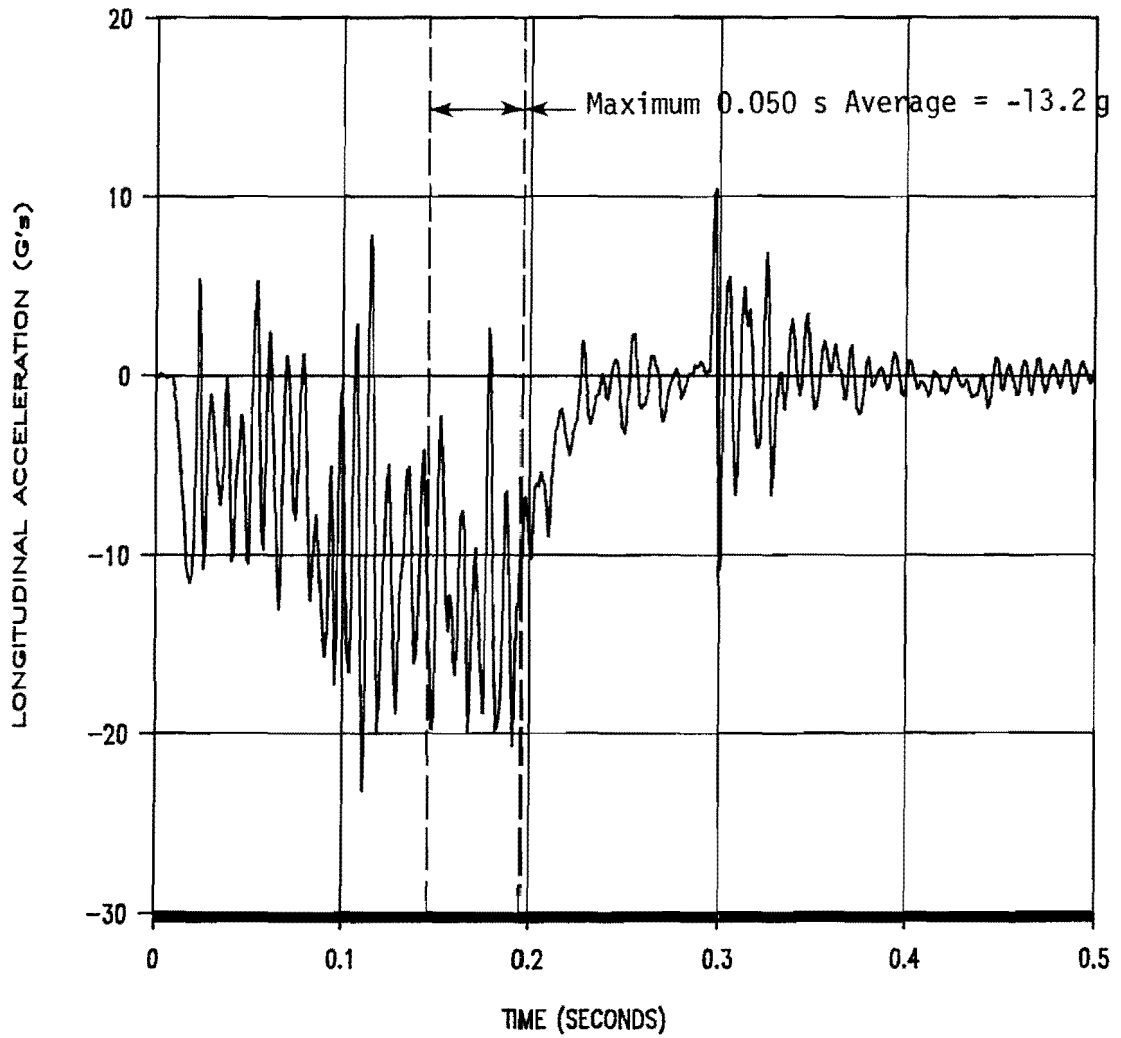


Figure 78 . Vehicle longitudinal accelerometer trace for test 9919-4 (near c.g. of vehicle).

TEST 9919-4

Class 180 Filter - Near C.G. of Car

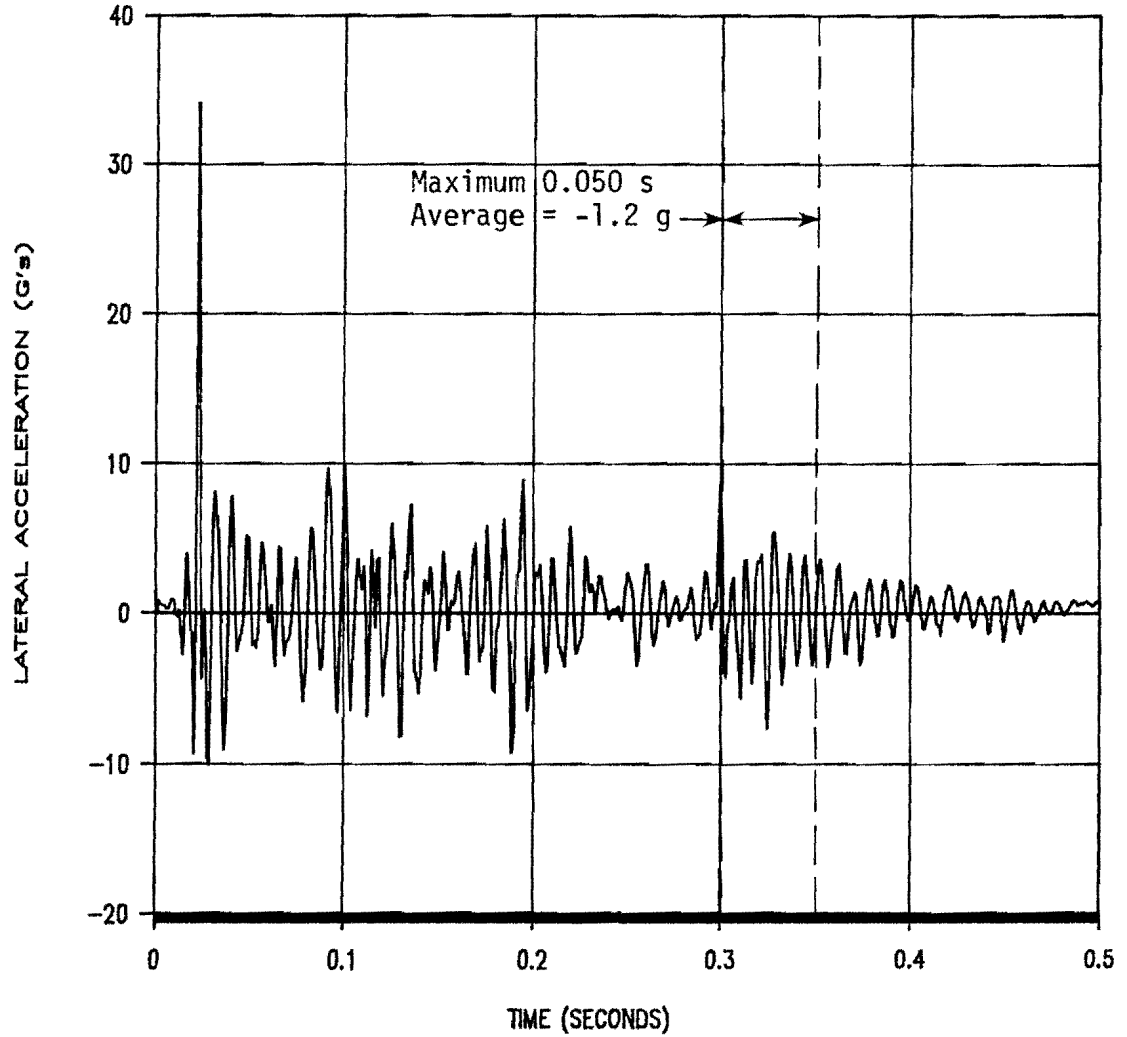


Figure 79 . Vehicle lateral accelerometer trace for test 9919-4 (near c.g. of vehicle).

TEST 9919-4

Class 180 Filter - Near C.G. of Car

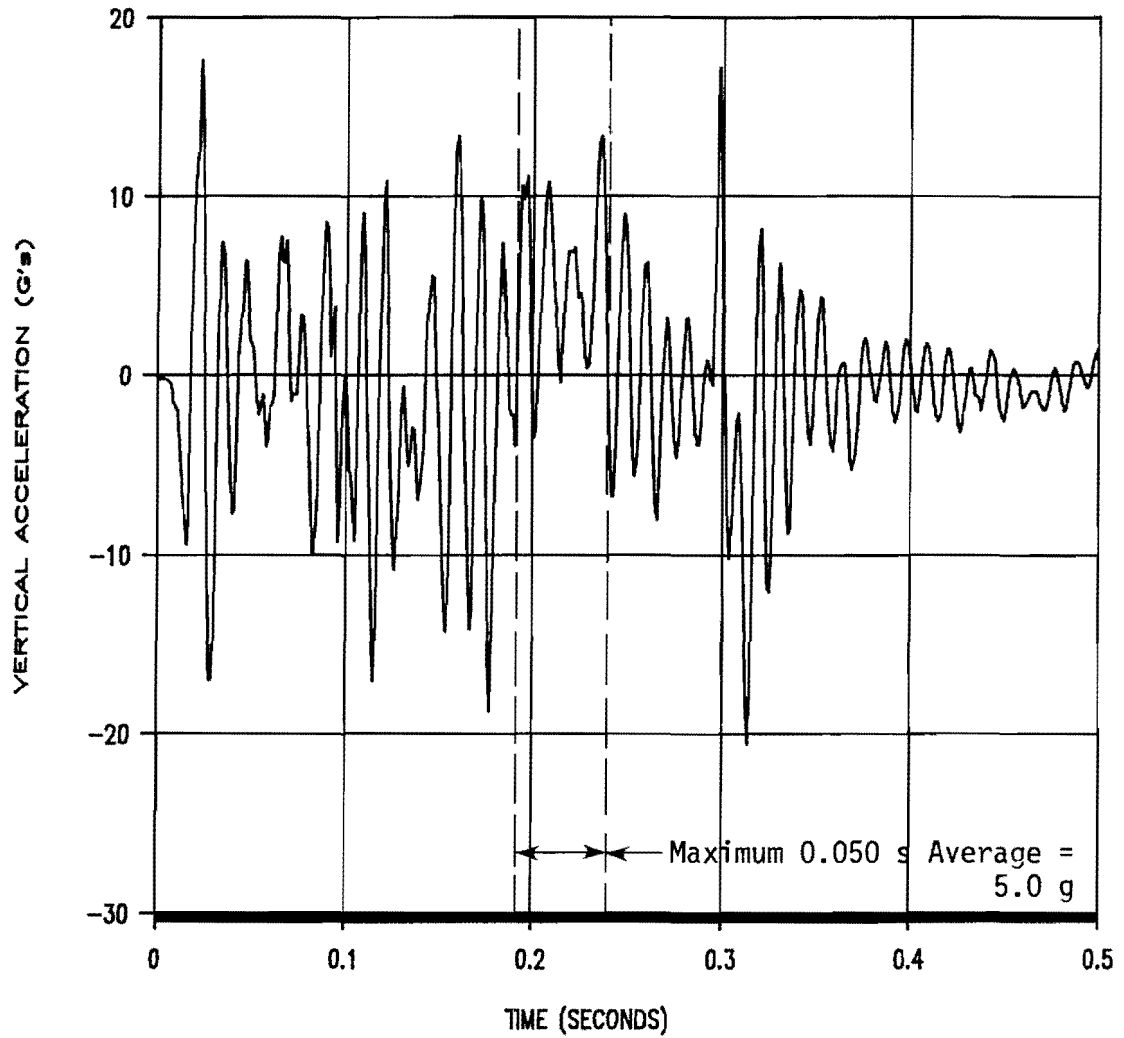


Figure 80. Vehicle vertical accelerometer trace for test 9919-4 (near c.g. of vehicle).

TEST 9919-4

Class 180 Filter - Cab of Truck

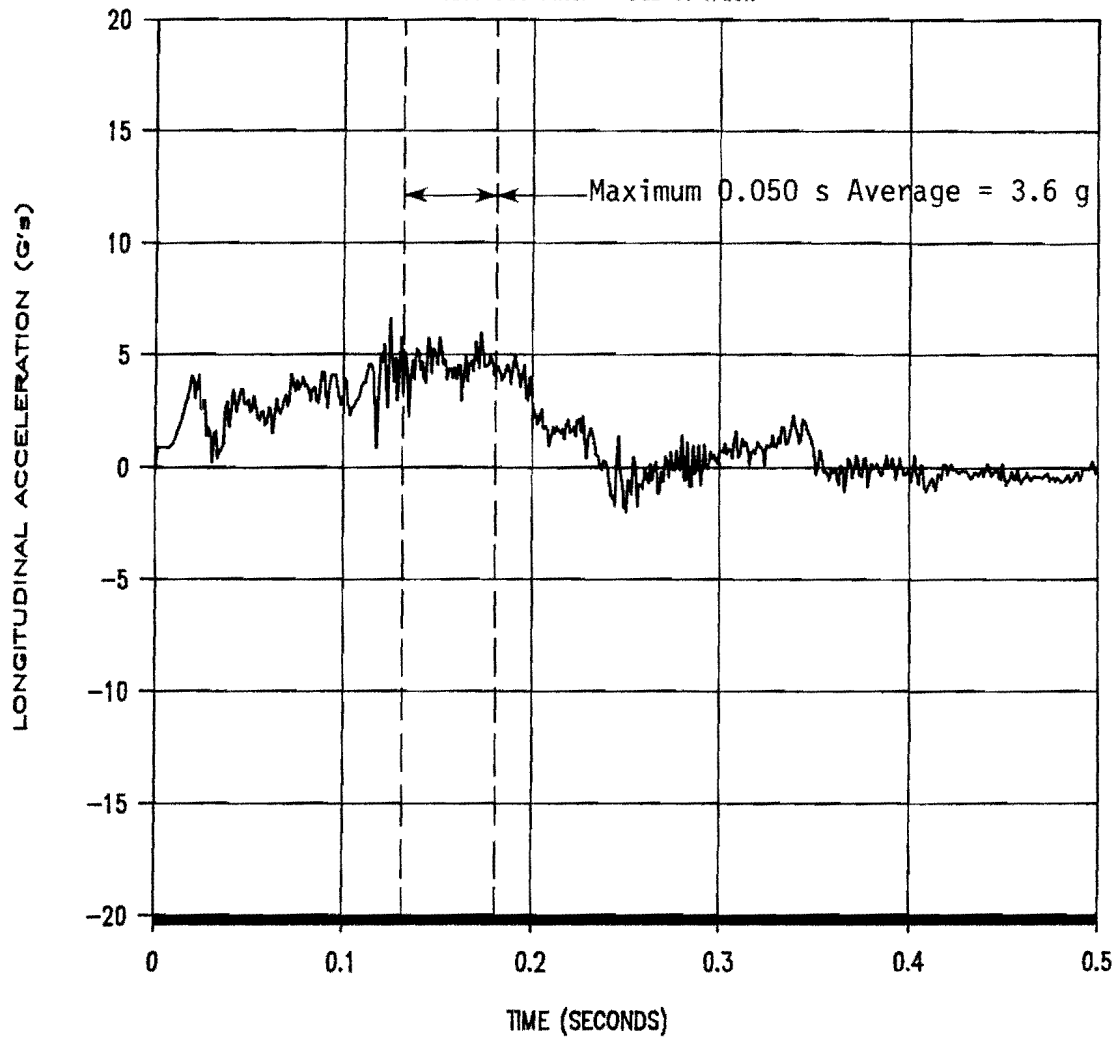


Figure 81. Truck longitudinal accelerometer trace for test 9919-4.

Markings and Equipment Corporation (9919-03)

The TMA used during this test was manufactured by Markings and Equipment Corporation and is shown in Figures 6 and 82. The TMA was mounted on Truck No. 1 which had a gross static weight of 14,910 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 12.0 inches at the front and 12.0 inches at the rear. The height to the upper rear surface of the cartridge was 36.75 inches above ground.

The 1982 Oldsmobile 98 Regency (pictured in Figures 82 and 83) was directed into the Markings and Equipment Corporation TMA. The height to the lower edge of the vehicle bumper was 12.00 inches and 20.50 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 84.

The vehicle was travelling at a speed of 47.8 mi/h. Upon impact, the TMA began to crush and, at 0.047 second, the rear truck tires began to rotate. At approximately 0.162 second, the truck tire had rotated 19 degrees and began to skid. The front of the impacting vehicle began to nose down at 0.172 second and then bottomed-out at 0.244 second. The rear truck tires stopped skidding at 0.314 second after rotating backwards to -11 degrees from perpendicular and then began to roll forward. The truck tire continued to alternate between rolling and skidding during the remainder of the test period. At 0.488 seconds, the truck reached a maximum speed of 14.0 ft/s (9.6 mi/h) and had moved approximately 6.8 ft. By this time, the impacting vehicle had slowed to 24.2 ft/s (16.5 mi/h). The maximum rotation angle achieved by the rear truck tires during the test was 79 degrees at 1.047 second; however, at the end of the test the tire was sitting at 68 degrees. Sequential photographs of the test are shown in Figure 85.

The Markings and Equipment Corporation TMA cartridge crushed a total of 53.00 inches during the test. The frame attachment to the cartridge was bent forward 1.5 inches on the left side. The truck had moved forward a total of 13.8 feet and was still in second gear with the parking brake on. The impacting vehicle received damage to the bumper, hood, grill, radiator, right and left front quarter panels and the right and left front doors. The floor pan and subframe of the vehicle was bent and the windshield was cracked in the lower corners. Maximum vehicle crush was 16.0 inches at bumper height. Figures 86 through 88 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 89. The maximum longitudinal 50-msec average acceleration experienced by the impacting vehicle was -15.8 g between 146 and 196 msec. Longitudinal occupant impact velocity was 34.9 ft/s at 148 msec and the maximum longitudinal ridedown acceleration was -21.0 g between 177 and 187 msec. The maximum longitudinal 50-msec average acceleration for the truck was 5.2 g between 133 and 183 msec. The truck reached a maximum speed of 14.0 ft/s (9.6 mph) and moved forward a total of 13.8 ft. The truck tire alternated between rolling and skidding during the test. Vehicle angular displacements are plotted in Figure 90 and accelerometer traces are displayed in Figures 91 through 94.

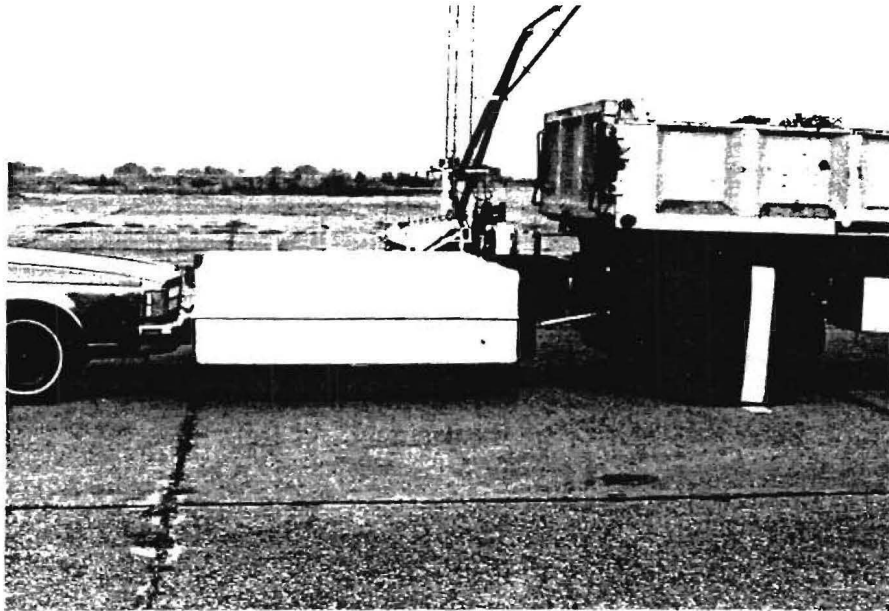
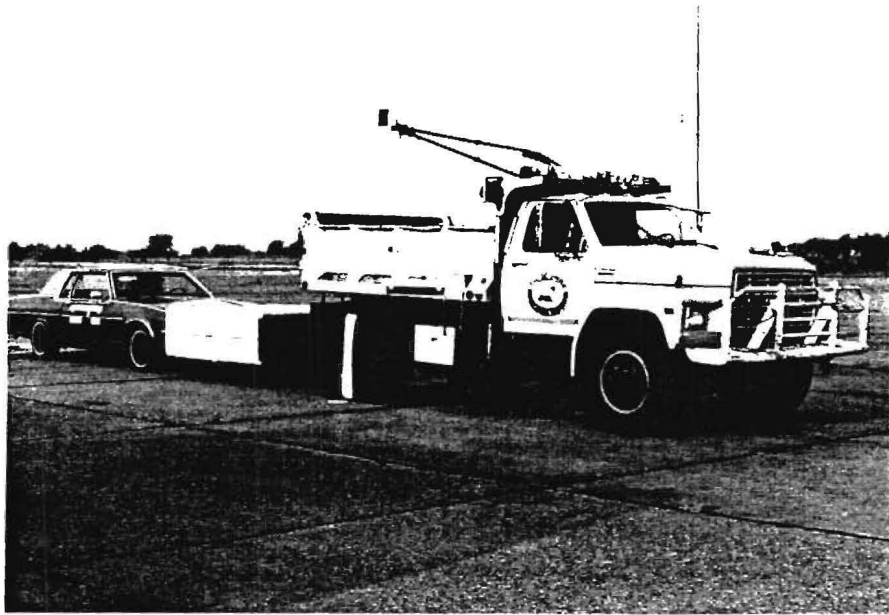
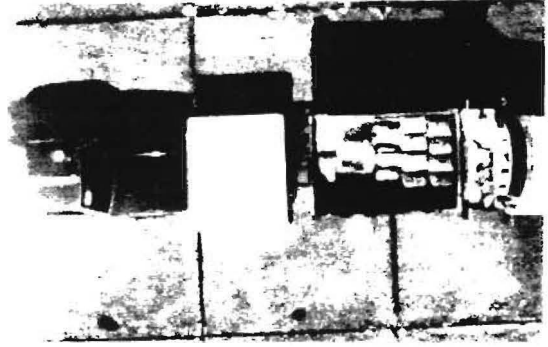
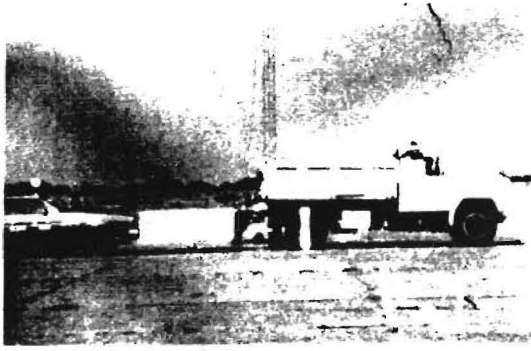


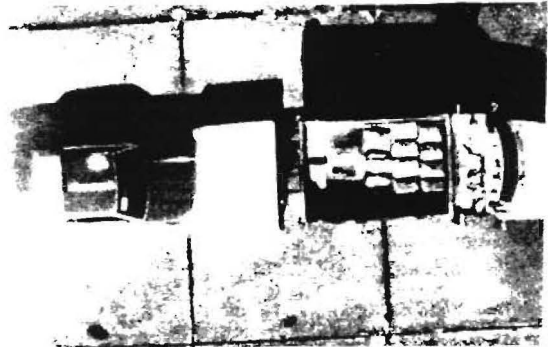
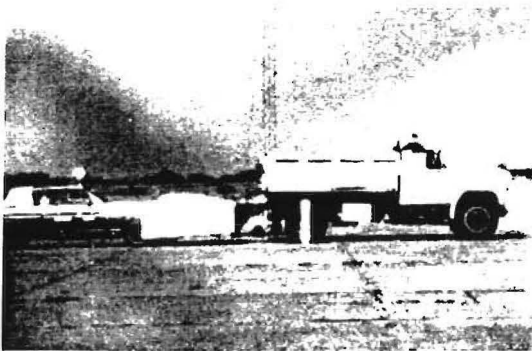
Figure 82. Configuration for test with Marking and Equipment TMA.



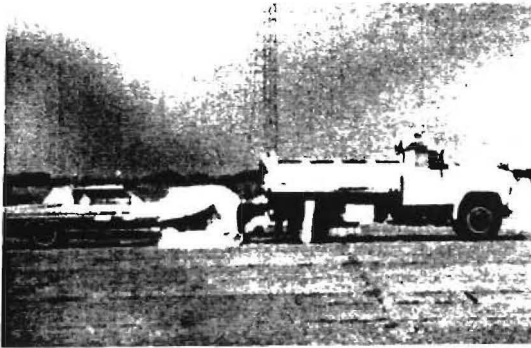
Figure 83. Vehicle before impact with Marking and Equipment TMA.



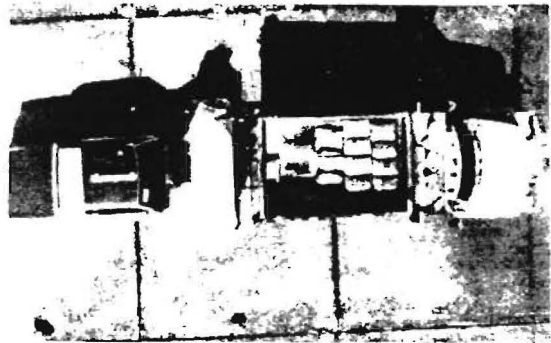
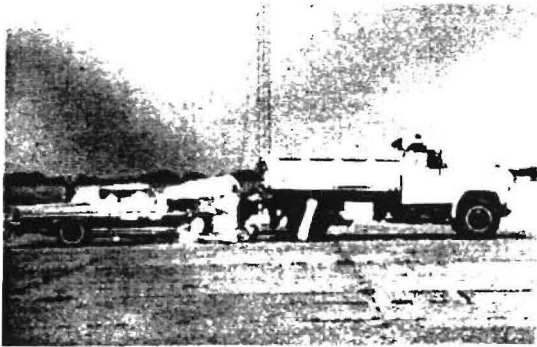
0.000 s



0.050 s



0.100 s

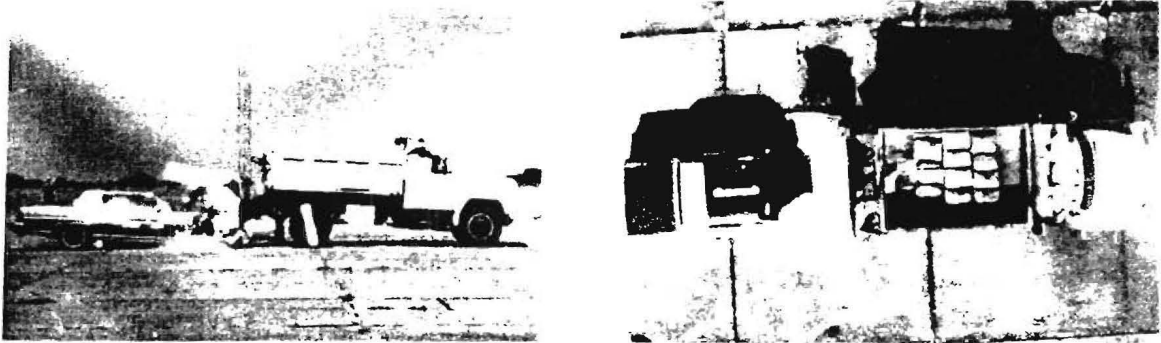


0.150 s

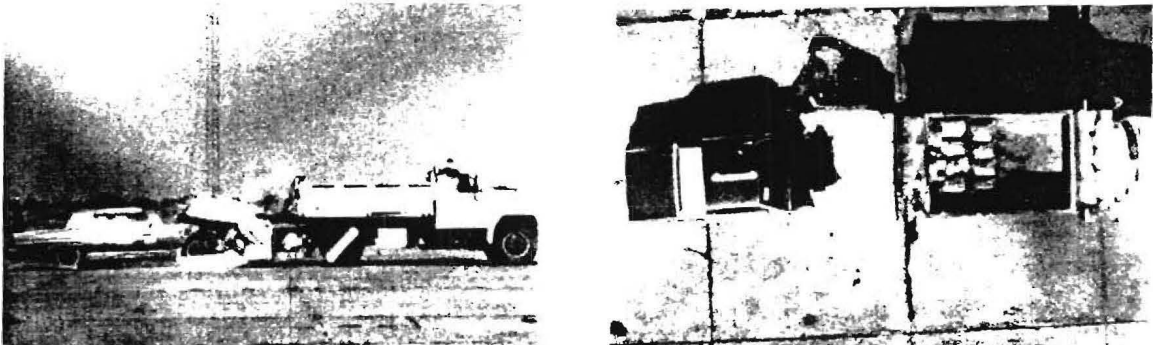
Figure 85. Sequential photographs for test 9919-3.



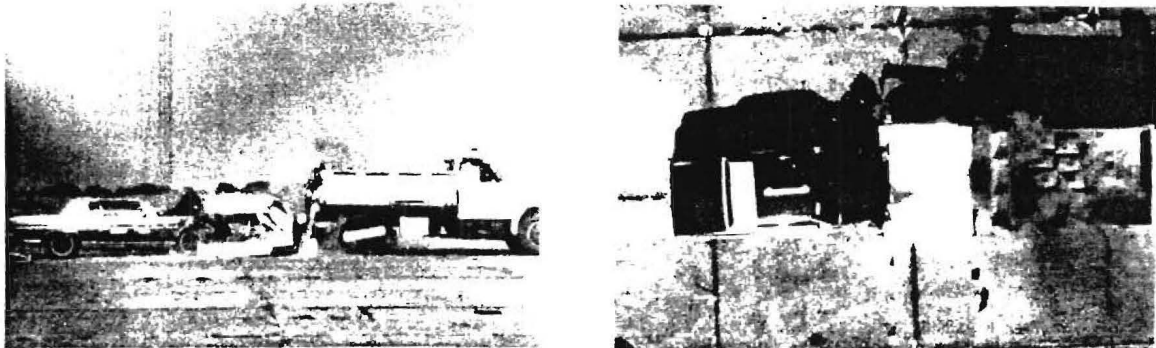
0.200 s



0.250 s



0.500 s



1.000 s

Figure 85. Sequential photographs for test 9919-3.
(Continued)

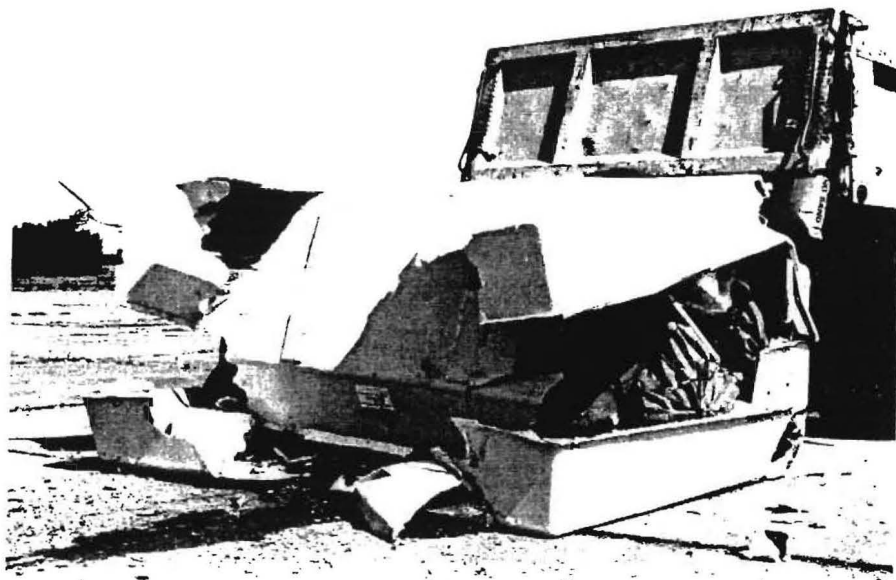


Figure 86. Damage to Marking and Equipment TMA (right side).

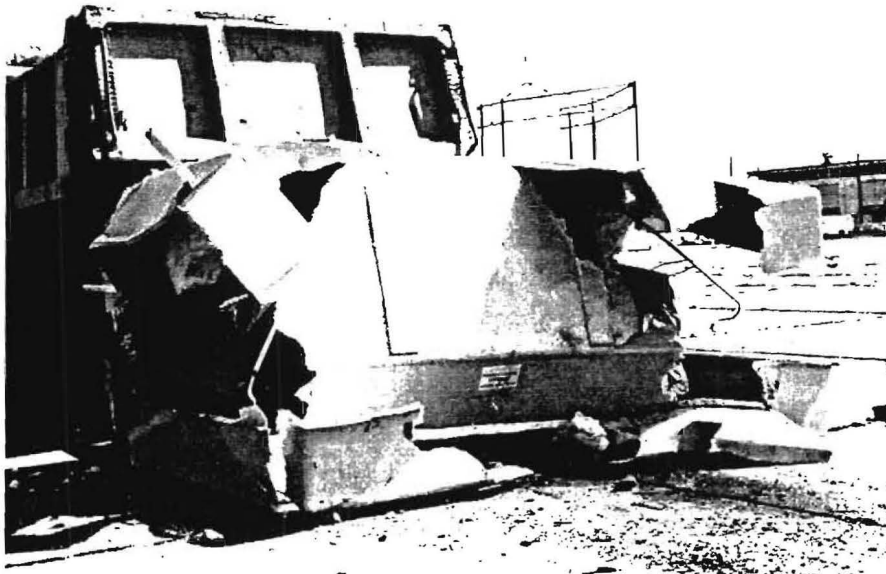
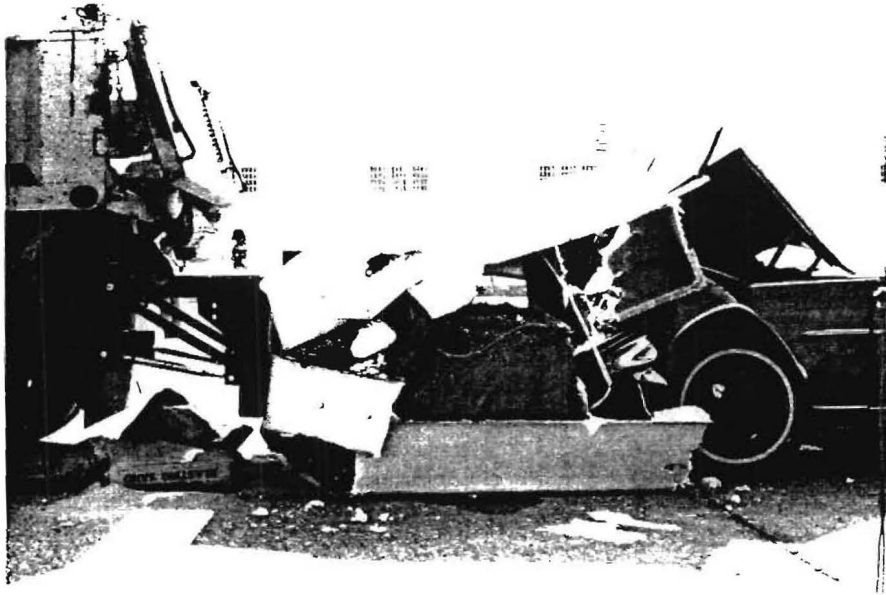
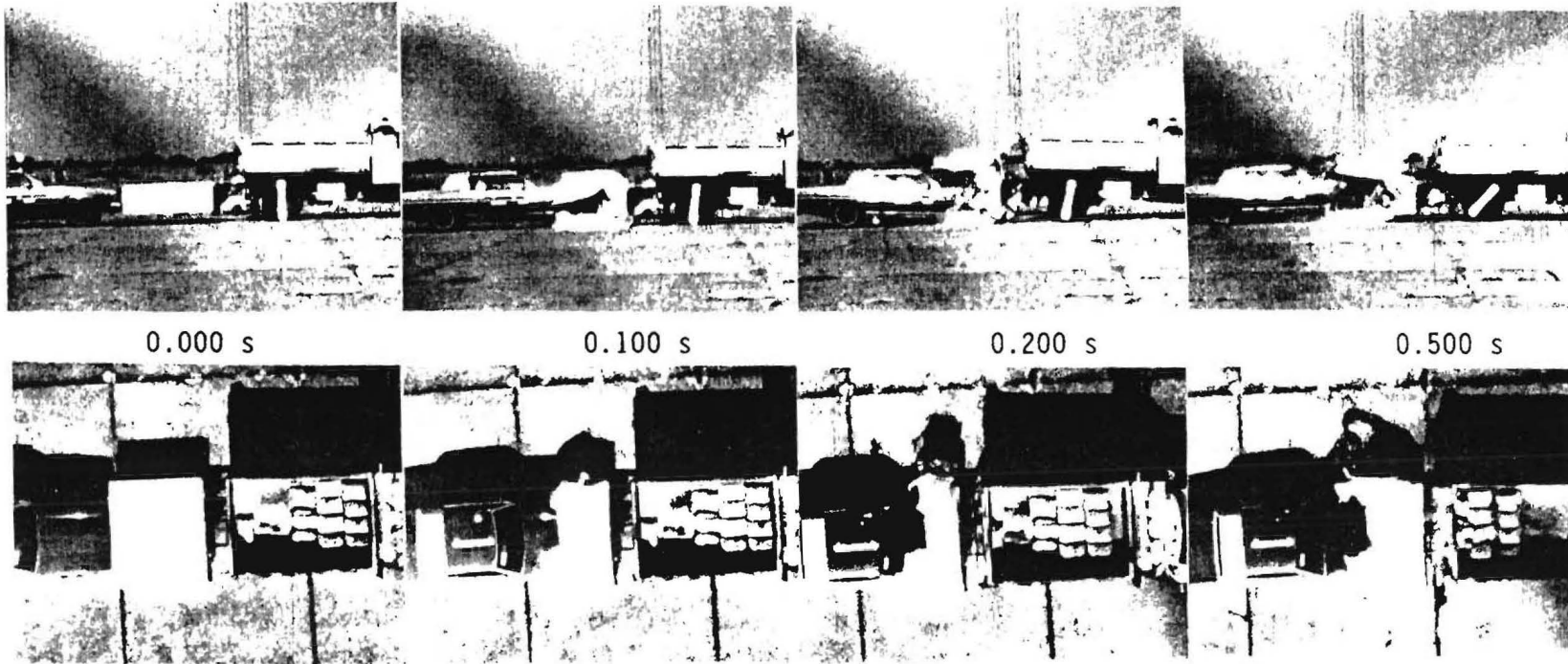


Figure 87. Damage to Marking and Equipment TMA (left side).

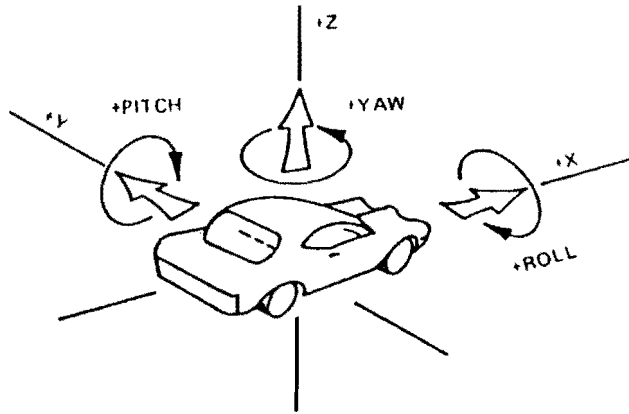


Figure 88. Vehicle after impact with
Marking and Equipment TMA.



Test No.	09919-3	Maximum Truck Displacement .	13.8 ft (4.2 m)
Date	08/10/89	Maximum TMA Crush	53.00 in (1.3 m)
Test Article	Truck Mounted Attenuator	Vehicle Accelerations	
Manufacturer	Markings & Equipment	(Maximum 50 ms Average at c.g.)	
TMA Truck	1981 Ford Dump Truck (#1)	Vehicle Longitudinal	-15.8 g
Weight without TMA .	14,020 lb (6,365 kg)	Vehicle Lateral	-1.6 g
Weight with TMA . . .	14,910 lb (6,769 kg)	Truck Cab Longitudinal . . .	5.2 g
Test Vehicle	1982 Oldsmobile 98 Regency	Occupant Impact Velocity	
Weight	4,500 lb (2,043 kg)	Longitudinal	34.9 ft/s (10.6 m/s)
Impact Speed	47.8 mi/h (76.9 km/h)	Lateral	5.9 ft/s (1.8 m/s)
Maximum Vehicle Crush .	16.0 in (40.6 cm)	Occupant Ridedown Accelerations	
Vehicle Damage Classification		Longitudinal	-21.0 g
TAD	12FD4	Lateral	-1.1 g
CDC	12FDEW3		

Figure 89. Summary of results for test 9919-3.



Axes are vehicle fixed.
Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

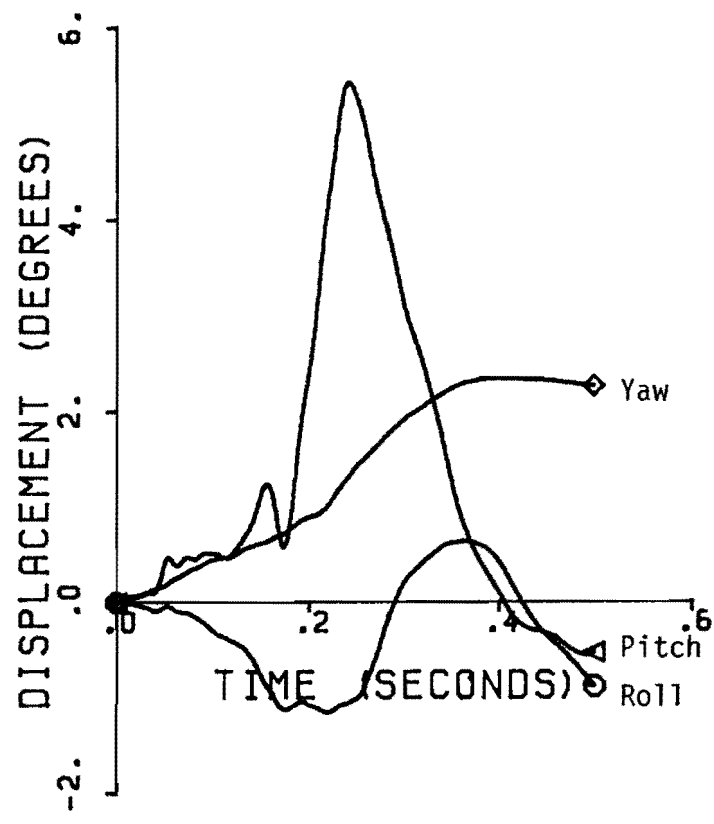


Figure 90 . Vehicle angular displacements for test 9919-3.

TEST 9919-3

Class 180 Filter - Near C.G. of Car

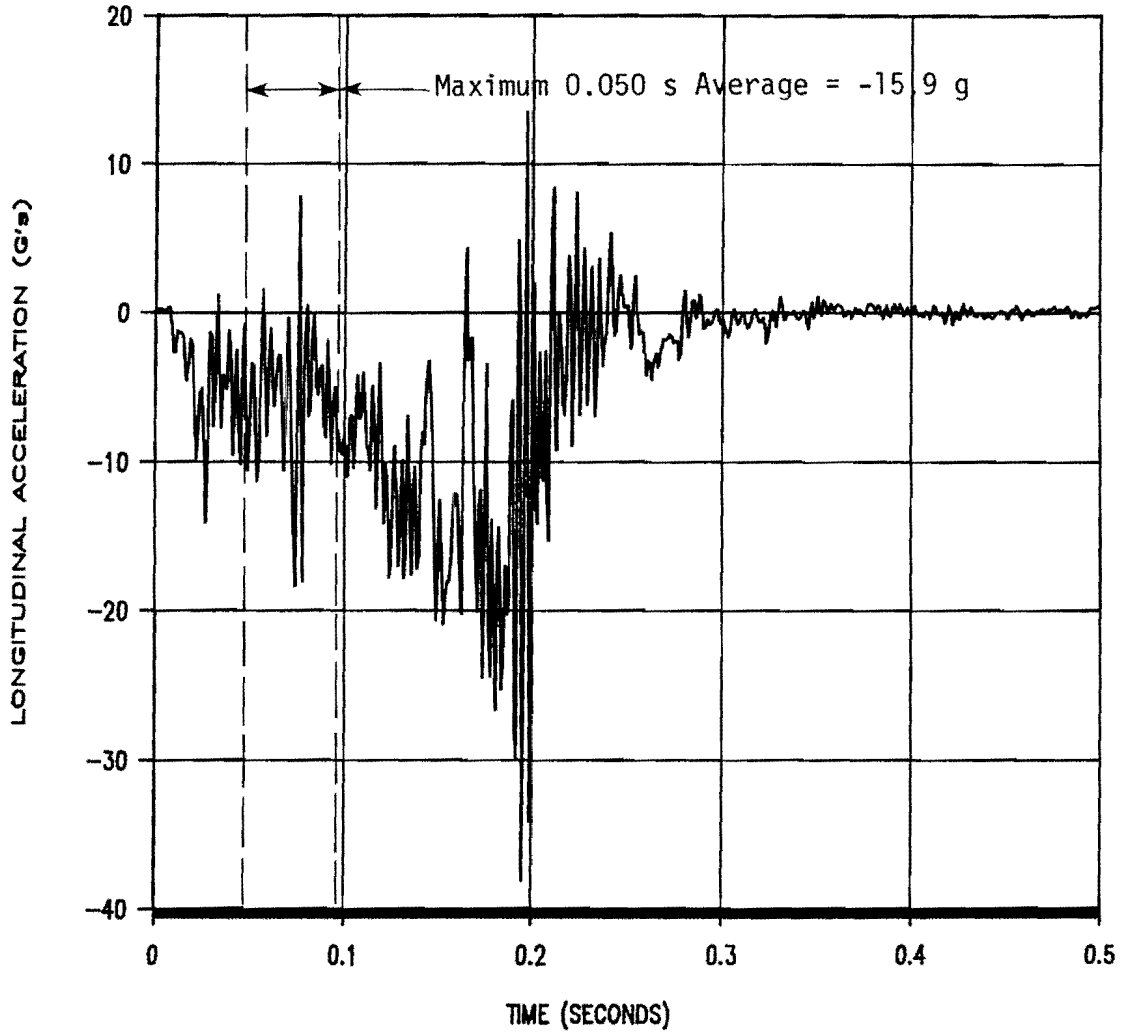


Figure 91. Vehicle longitudinal accelerometer trace for test 9919-3 (near c.g. of vehicle).

TEST 9919-3

Class 180 Filter - Near C.G. of Car

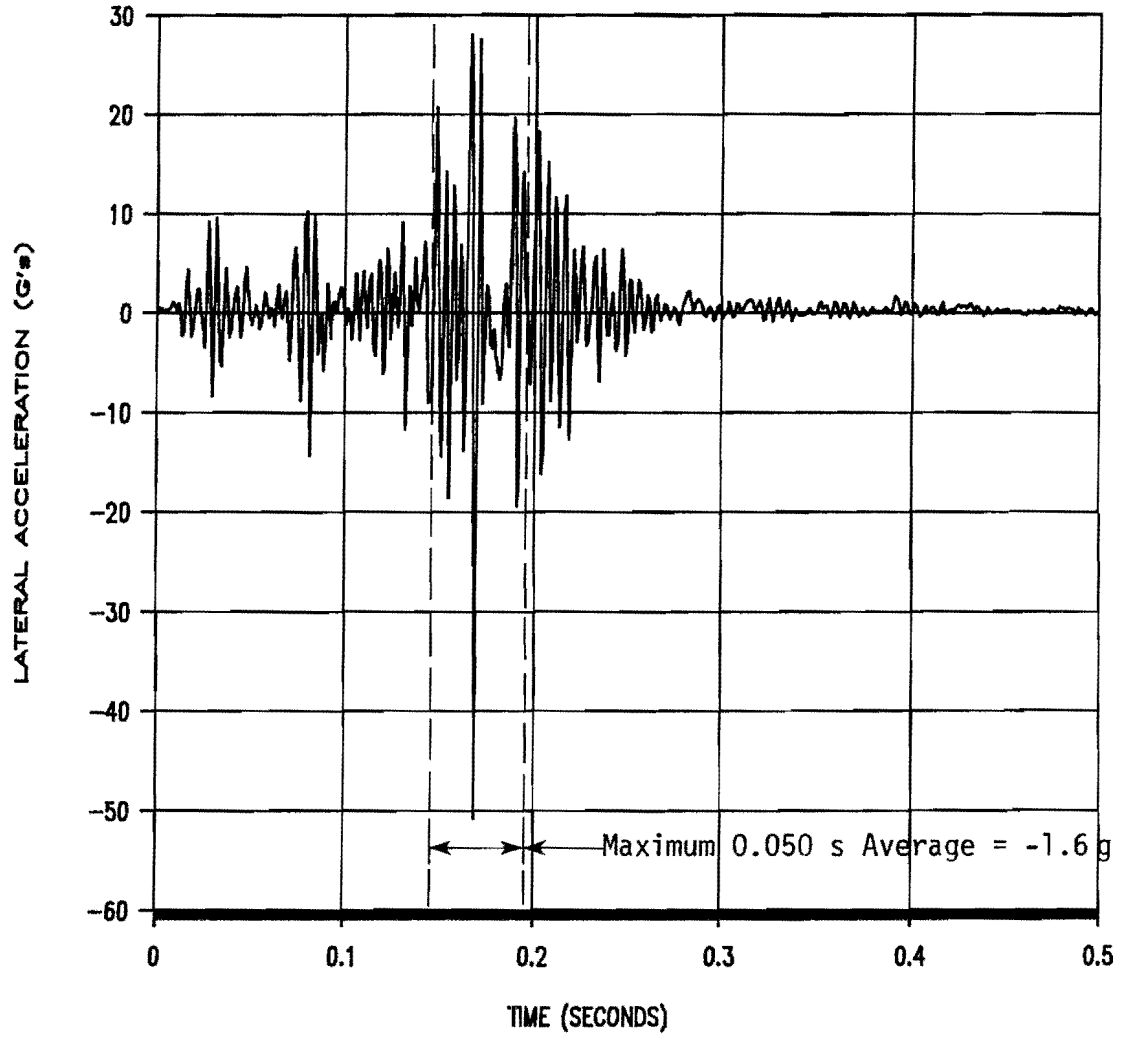


Figure 92. Vehicle lateral accelerometer trace for test 9919-3 (near c.g. of vehicle).

TEST 9919-3

Class 180 Filter - Near C.G. of Car

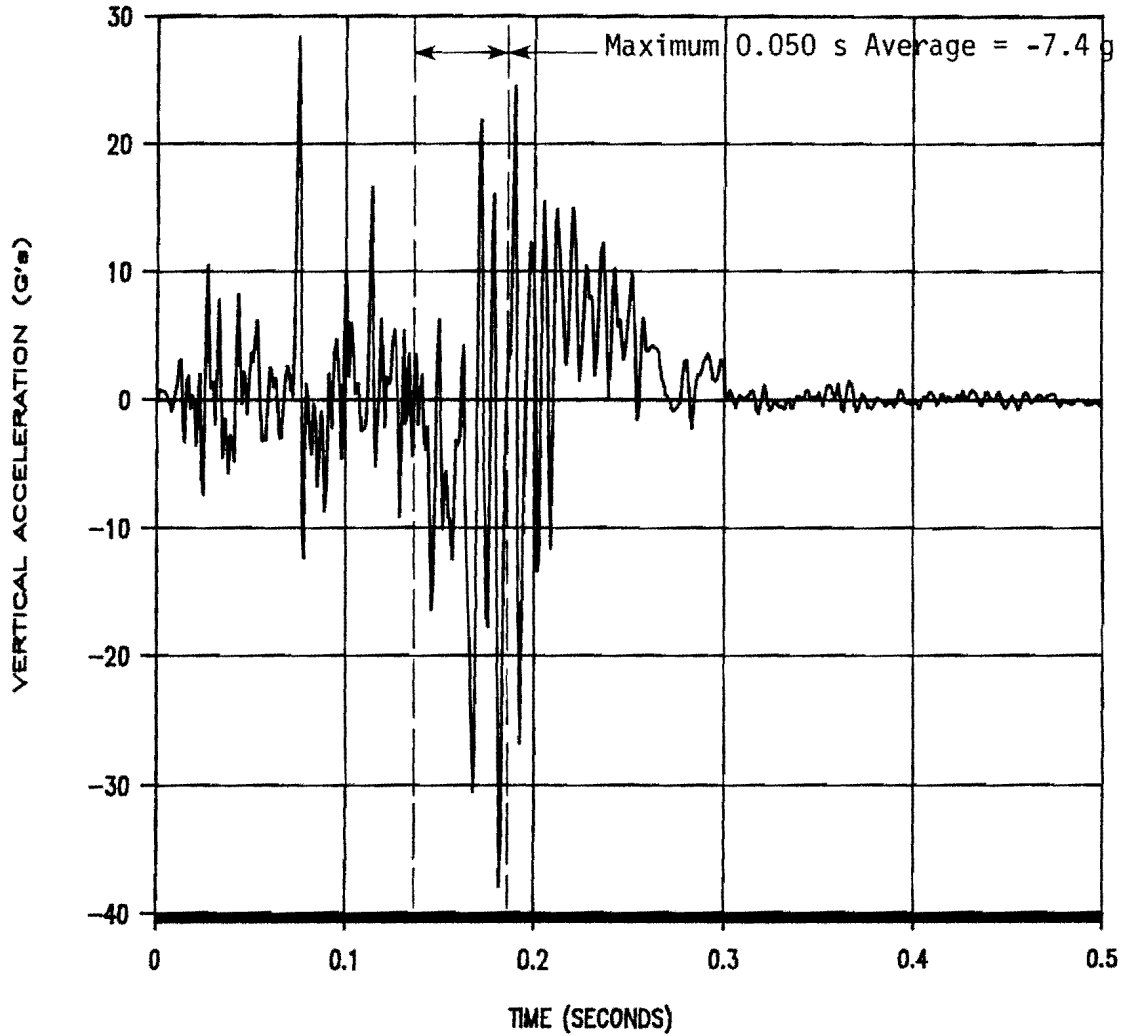


Figure 93 . Vehicle vertical accelerometer trace for test 9919-3 (near c.g. of vehicle).

TEST 9919-3

Class 180 Filter - Cab of Truck

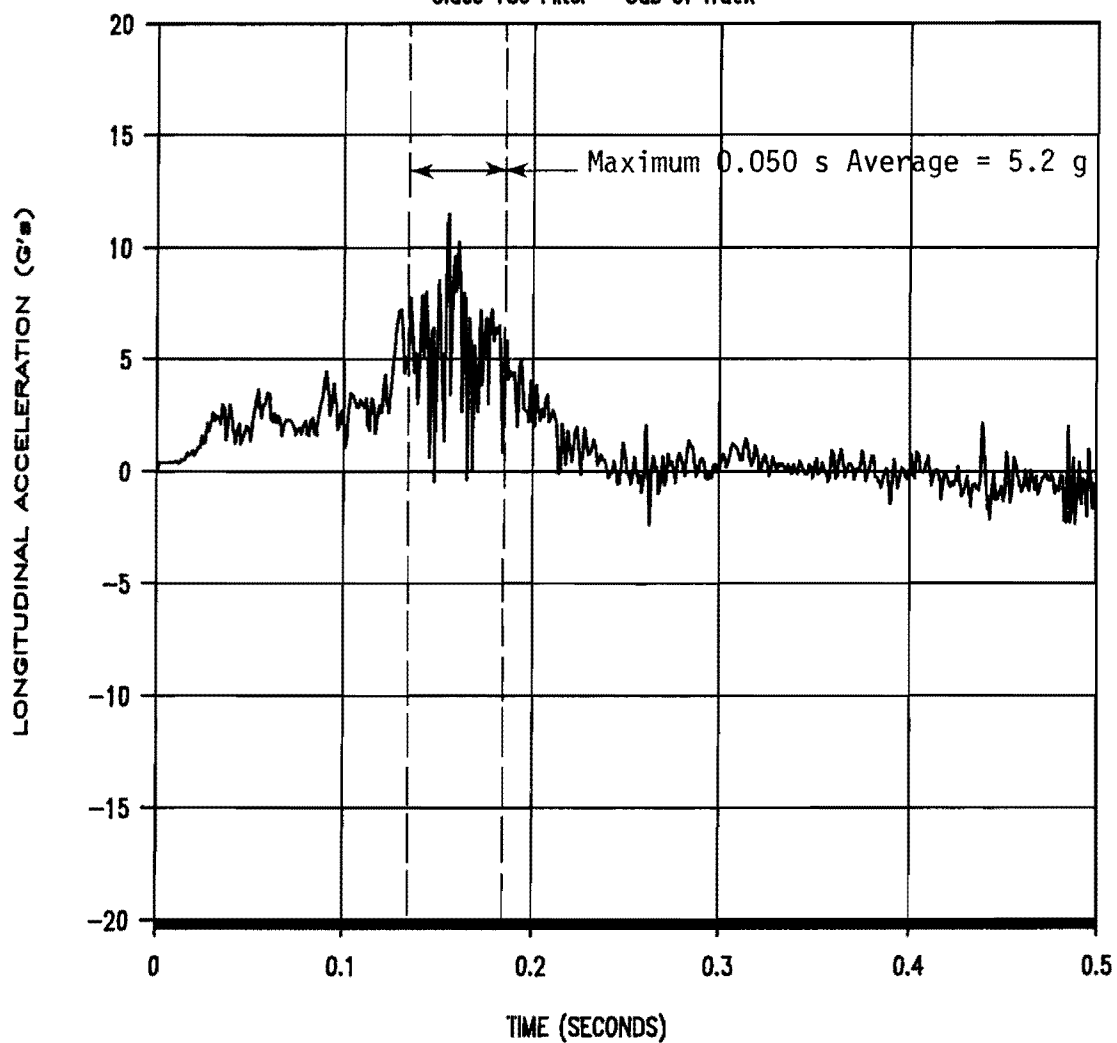


Figure 94 . Truck longitudinal accelerometer trace for test 9919-3.

Connecticut DOT (9910-10)

The TMA used during this test was provided by Connecticut DOT and is shown in Figures 7 and 95. The TMA was mounted on Truck No. 2 which had a gross static weight of 16,090 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 8.00 inches at the front and 6.00 inches at the rear. The height to the upper rear surface of the cartridge was 40.63 inches above ground.

The 1980 Cadillac Sedan deVille (pictured in Figure 95) was towed into the Connecticut TMA. The height to the lower edge of the vehicle bumper was 14.00 inches and 21.75 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 96.

The vehicle was travelling at a speed of 45.6 mi/h. Upon impact, the first pipe in the TMA began to crush. Approximately 0.039 second after impact the second pipe began to crush and third pipe at 0.073 second. At 0.078 second, the rear truck tire began to rotate forward. The fourth pipe began to crush at 0.116 second. Maximum crush of the TMA of 71.0 inches occurred at 0.188 second. The rear truck tire rotated 90 degrees by 0.307 second and at approximately the same time the truck was moving at its maximum speed of 12.0 mi/h. The truck had moved 3.3 ft at this time and the impacting vehicle was travelling at 6.4 mi/h. Forward motion of the impacting vehicle stopped at 1.491 second. The vehicle subsequently came to rest directly against the rear of the TMA. Sequential photographs of the test are shown in Figure 97.

The Connecticut TMA crushed a total of 71.0 inches during the test. The attachment frame on the cartridge was not damaged. The truck had moved 12.6 ft and was still in second gear with the parking brake on. The impacting vehicle received damage to the front bumper, hood, grill, radiator, the right and left front quarter panels, and the right and left doors. The windshield was cracked in each corner. Maximum vehicle crush was 16.0 inches at bumper height. Figures 98 and 99 show damage to the TMA and test vehicle.

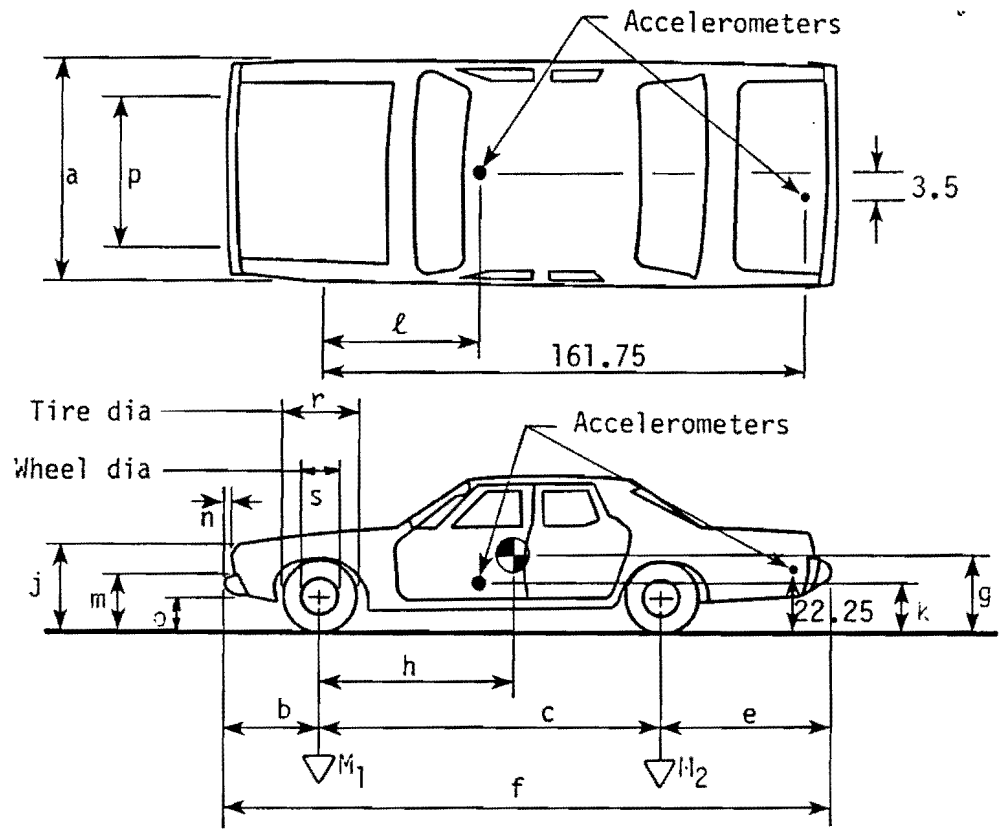
A summary of the test results and other information pertinent to this test are given in Figure 100. The maximum longitudinal 50-msec average acceleration experienced by the impacting vehicle was -14.1 g between 155 and 205 msec. Longitudinal occupant impact velocity was 28.9 ft/s at 140 msec and the maximum longitudinal ridedown acceleration was -19.7 g between 164 and 174 msec. Vehicle angular displacements are plotted in Figure 101 and accelerometer traces are displayed in Figures 102 through 105.



Figure95. Vehicle before impact with Connecticut TMA (9910-10).

Date: _____ Test No.: 9910-10 VIN: 6D47NA9116045
 Make: Cadillac Model: Sedan DeVille Year: 1980 Odometer: 85610
 Tire Size: P215/75R15 Ply Rating: _____ Bias Ply: _____ Belted: _____ Radial: _____

Tire Condition: good _____
 fair X
 badly worn _____



Vehicle Geometry - inches

a	<u>26 3/4</u>	b	<u>42 1/2</u>
c	<u>121 1/4</u>	d*	<u>55</u>
e	<u>57</u>	f	<u>220 3/4</u>
g	_____	h	<u>56.4</u>
i	<u>----</u>	j	<u>35</u>
k	<u>18 3/4</u>	l	<u>41 1/2</u>
m	<u>21 3/4</u>	n	<u>4</u>
o	<u>14</u>	p	<u>61 1/2</u>
r	<u>27 1/4</u>	s	<u>16 1/4</u>

Engine Type: V-8
 Engine CID: 350
 Transmission Type: _____

Automatic or Manual _____
 FWD or RWD or 4WD _____

Body Type: 2-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

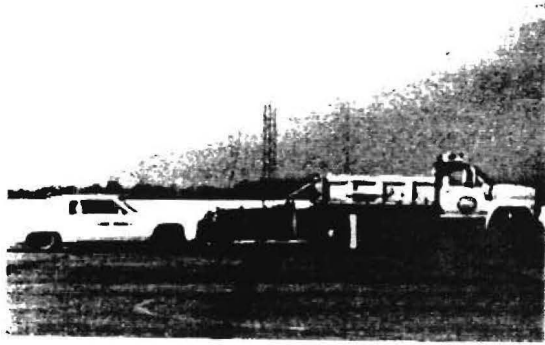
4-wheel weight for c.g. det. lf 1199 rf 1206 lr 1044 rr 1051

Mass - pounds	Curb	Test Inertial	Gross Static
M_1	<u>2378</u>	<u>2405</u>	_____
M_2	<u>1734</u>	<u>2095</u>	_____
M_T	<u>4112</u>	<u>4500</u>	_____

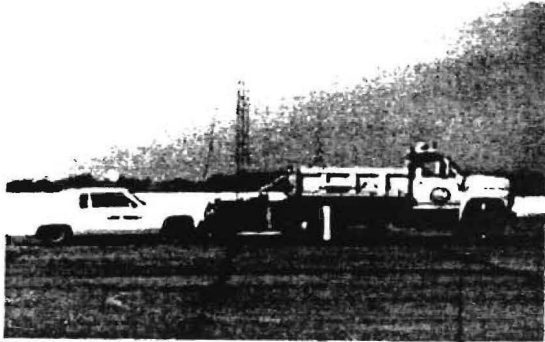
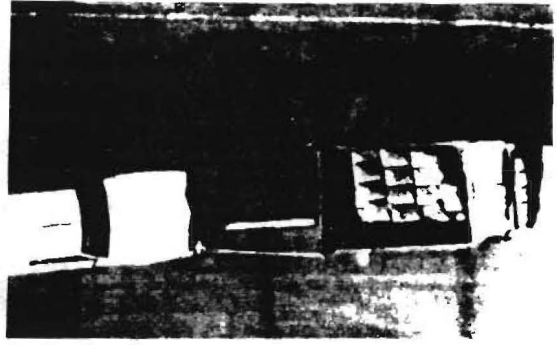
Note any damage to vehicle prior to test:

*d = overall height of vehicle

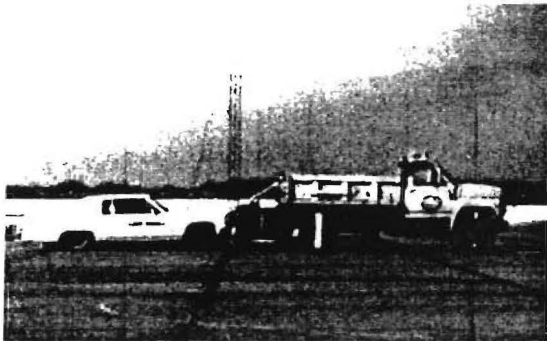
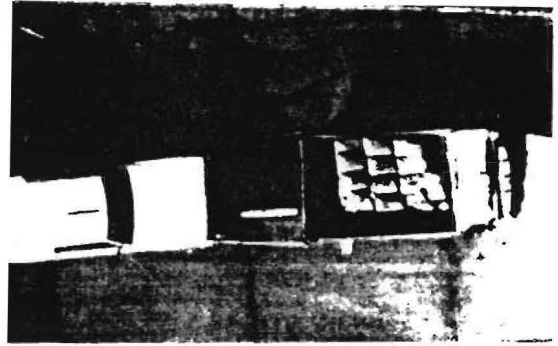
Figure 96. Test vehicle properties (test 9910-10).



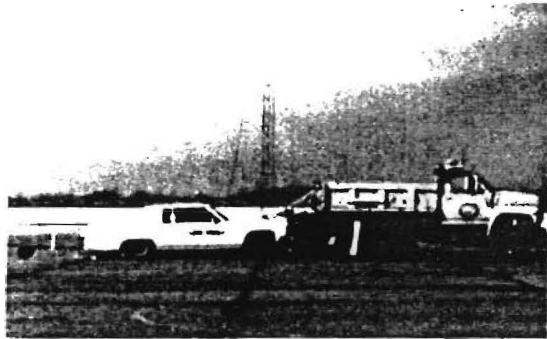
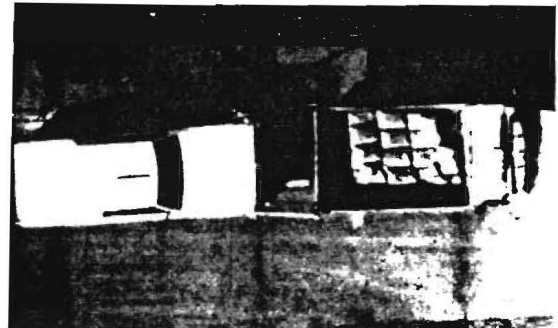
0.000 s



0.049 s



0.100 s



0.149 s

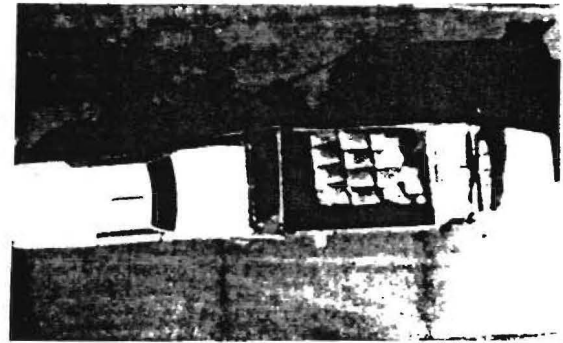
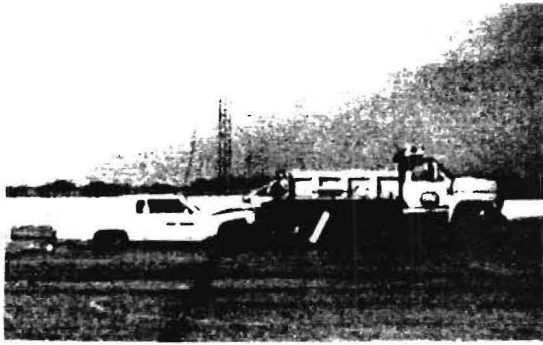
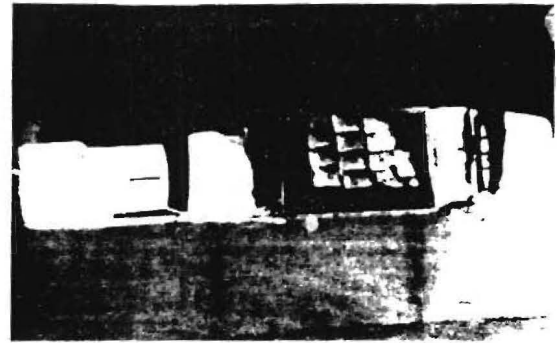


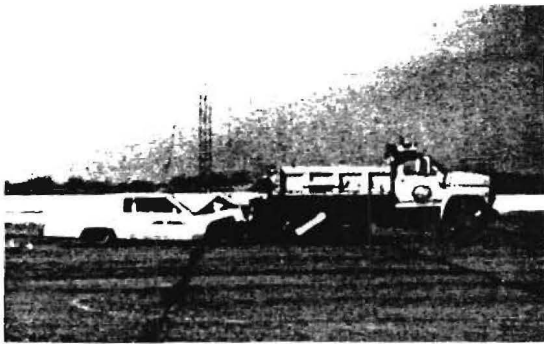
Figure 97. Sequential photographs for test 9910-10.



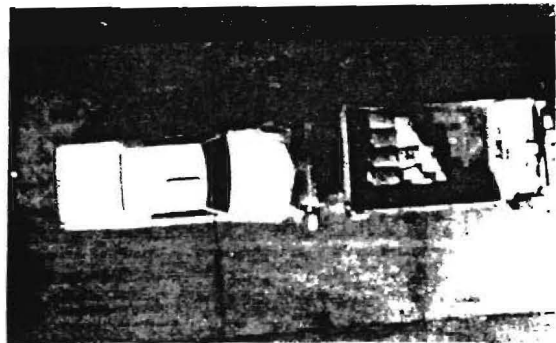
0.201 s



0.250 s



0.500 s



1.000

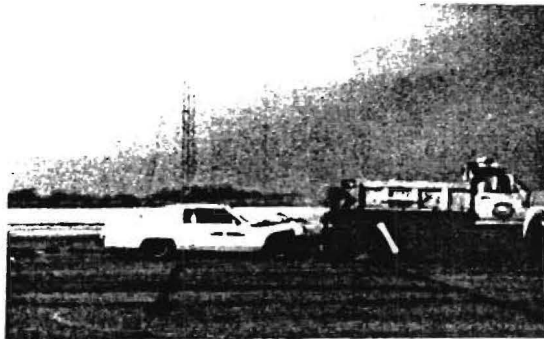


Figure 97. Sequential photographs for test 9910-10.
(Continued)

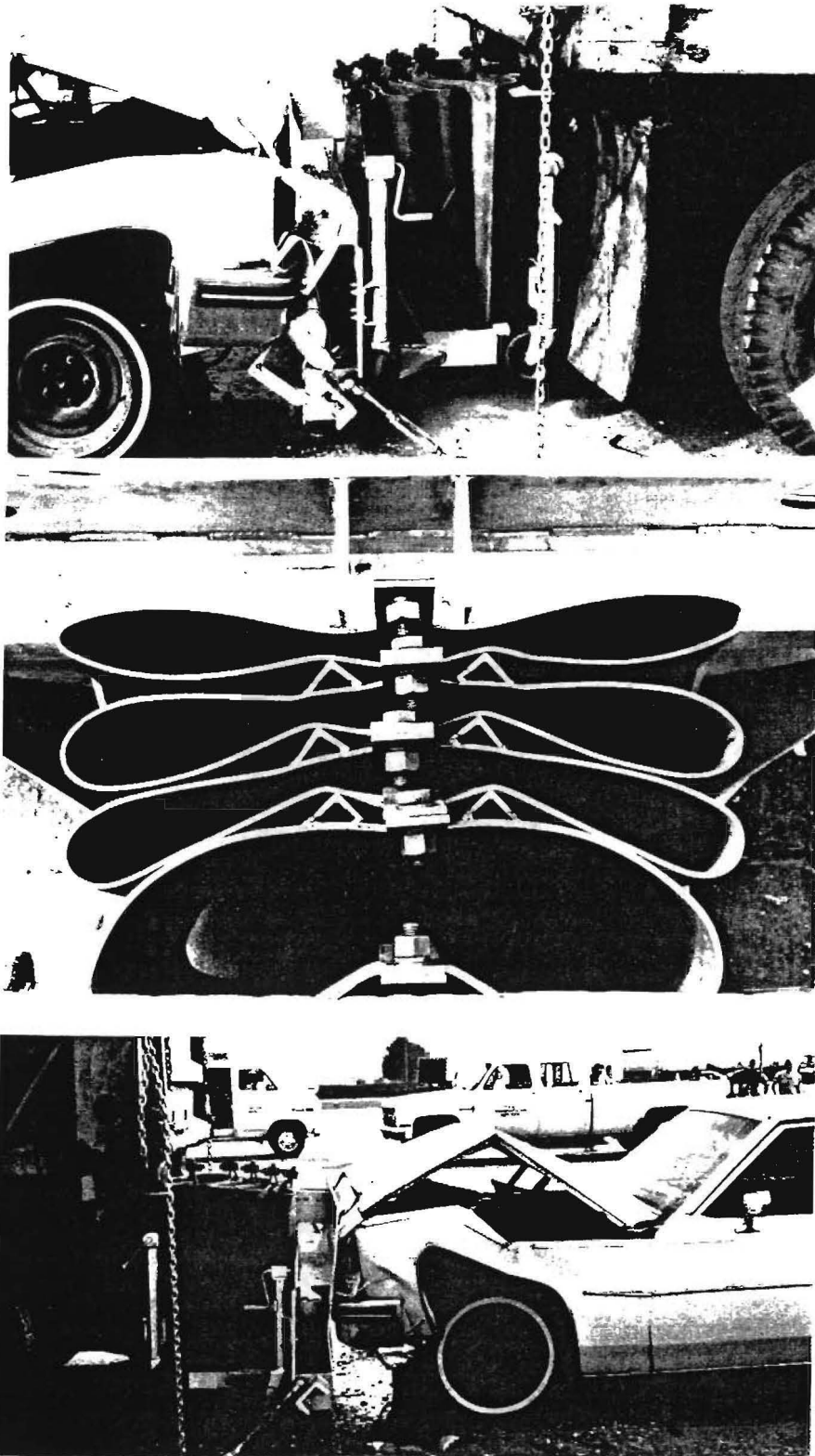
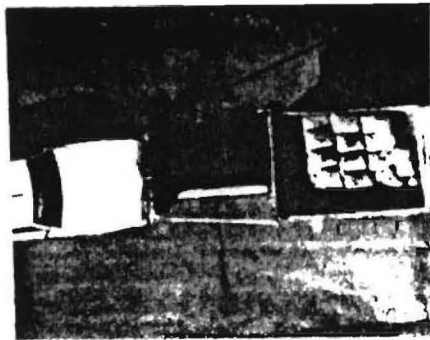


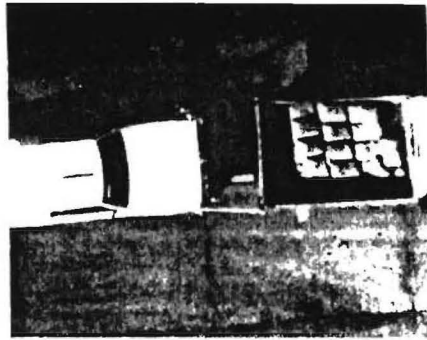
Figure 98 Connecticut TMA
after test 9910-10.



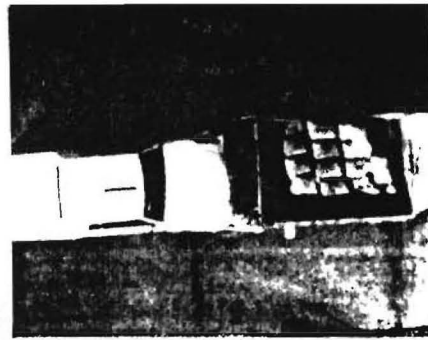
Figure 99 Vehicle after impact with Connecticut TMA (9910-10).



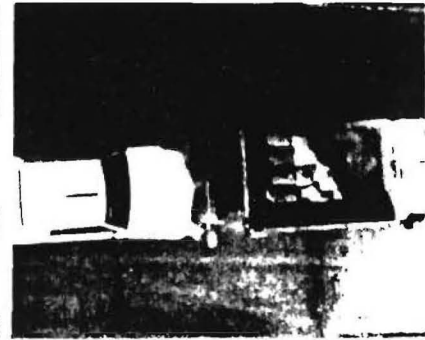
0.000 s



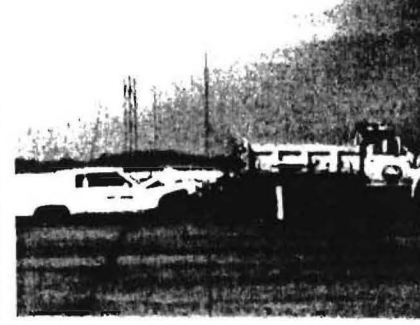
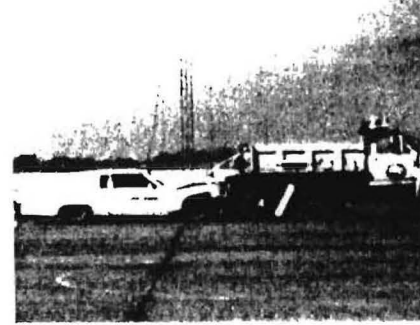
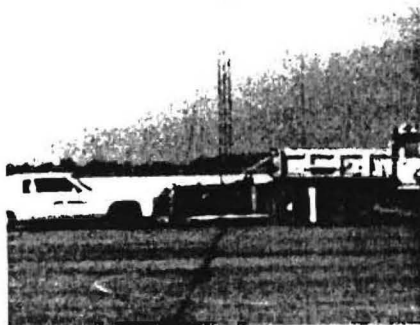
0.100 s



0.201 s



0.500 s

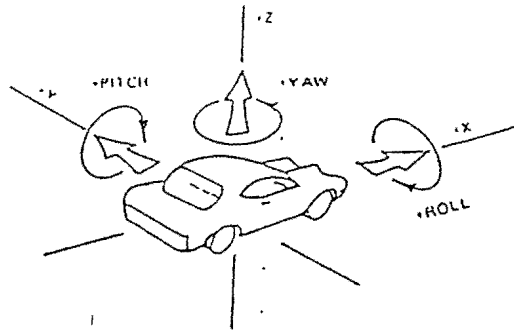


123

Test No. 09910-10
 Date 02/07/90
 Test Article Truck Mounted Attenuator
 Manufacturer Connecticut
 TMA Truck 1980 Ford Dump Truck (#2)
 Weight without TMA . . . 14,010 lb (6,361 kg)
 Weight with TMA 16,090 lb (7,305 kg)
 Test Vehicle 1980 Cadillac Sedan DeVille
 Weight 4,500 lb (2,043 kg)
 Impact Speed 45.6 mi/h (73.4 km/h)
 Maximum Vehicle Crush . 16.0 in (40.6 cm)
 Vehicle Damage Classification
 TAD 12FD4
 CDC 12FDEW3

Maximum Truck Displacement . 12.6 ft (3.8 m)
 Maximum TMA Crush 71.0 in (1.8 m)
 Vehicle Accelerations
 (Maximum 50 ms Average at c.g.)
 Vehicle Longitudinal . . . -14.1 g
 Vehicle Lateral -1.6 g
 Truck Cab Longitudinal . . 5.4
 Occupant Impact Velocity
 Longitudinal 28.9 ft/s (8.8 m/s)
 Lateral 6.9 ft/s (2.1 m/s)
 Occupant Ridedown Accelerations
 Longitudinal -19.7 g
 Lateral -1.6 g

Figure 100 Summary of results for test 9910-10.



Axes are vehicle fixed.
Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

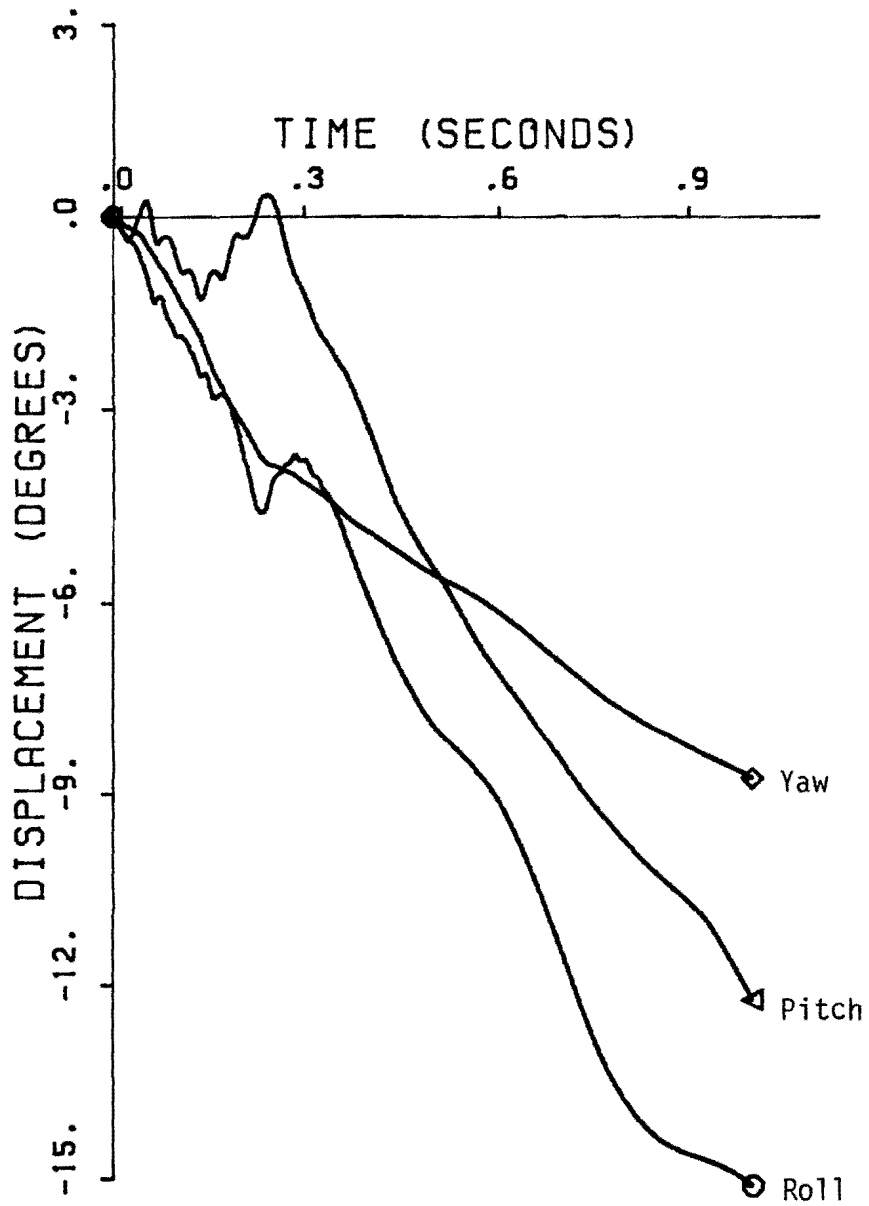


Figure 101 Vehicle angular displacements for test 9910-10.

TEST 9910-10

Class 180 Filter

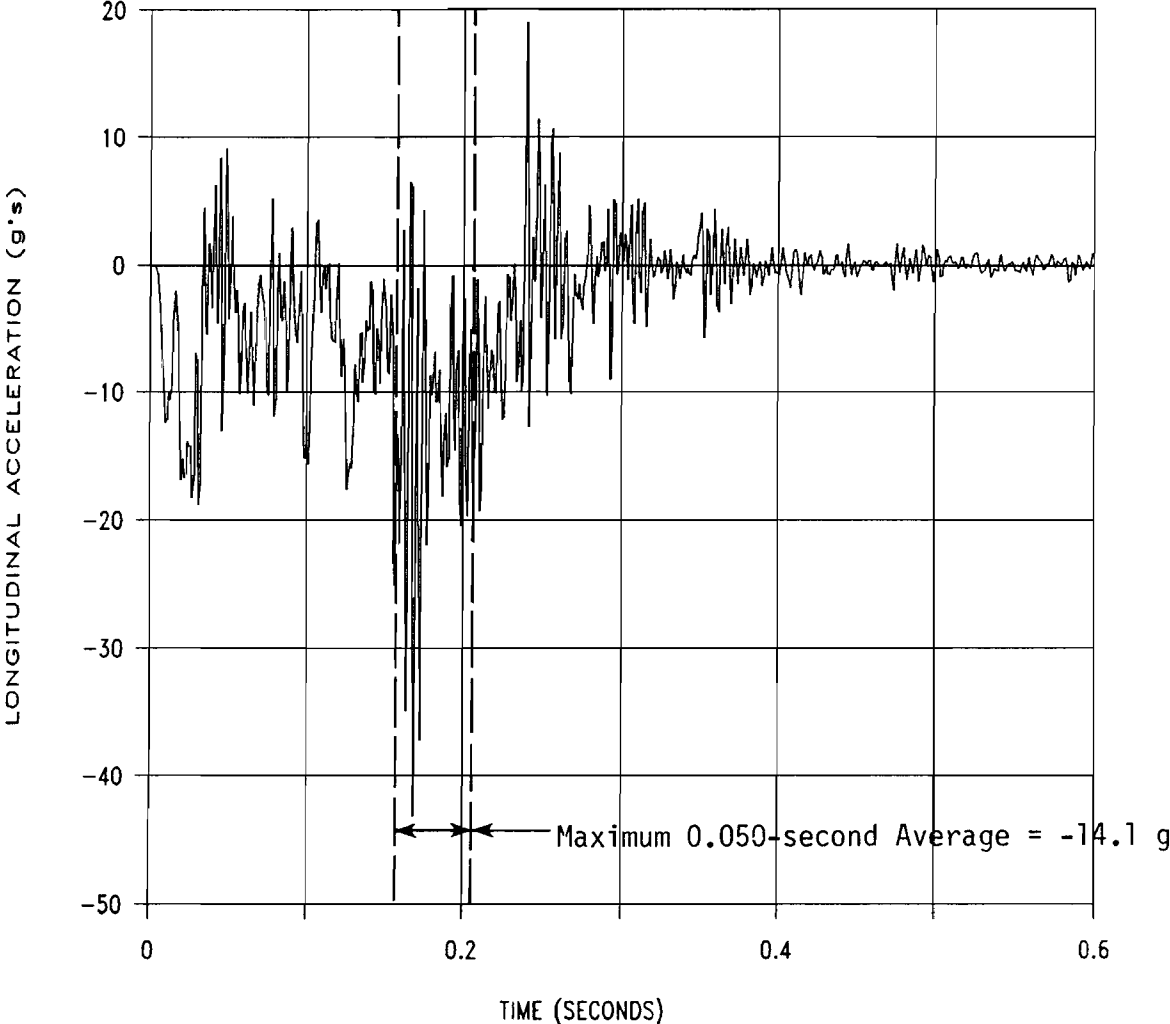


Figure 102 Longitudinal accelerometer trace for test 9910-10.

TEST 9910-10

Class 180 Filter

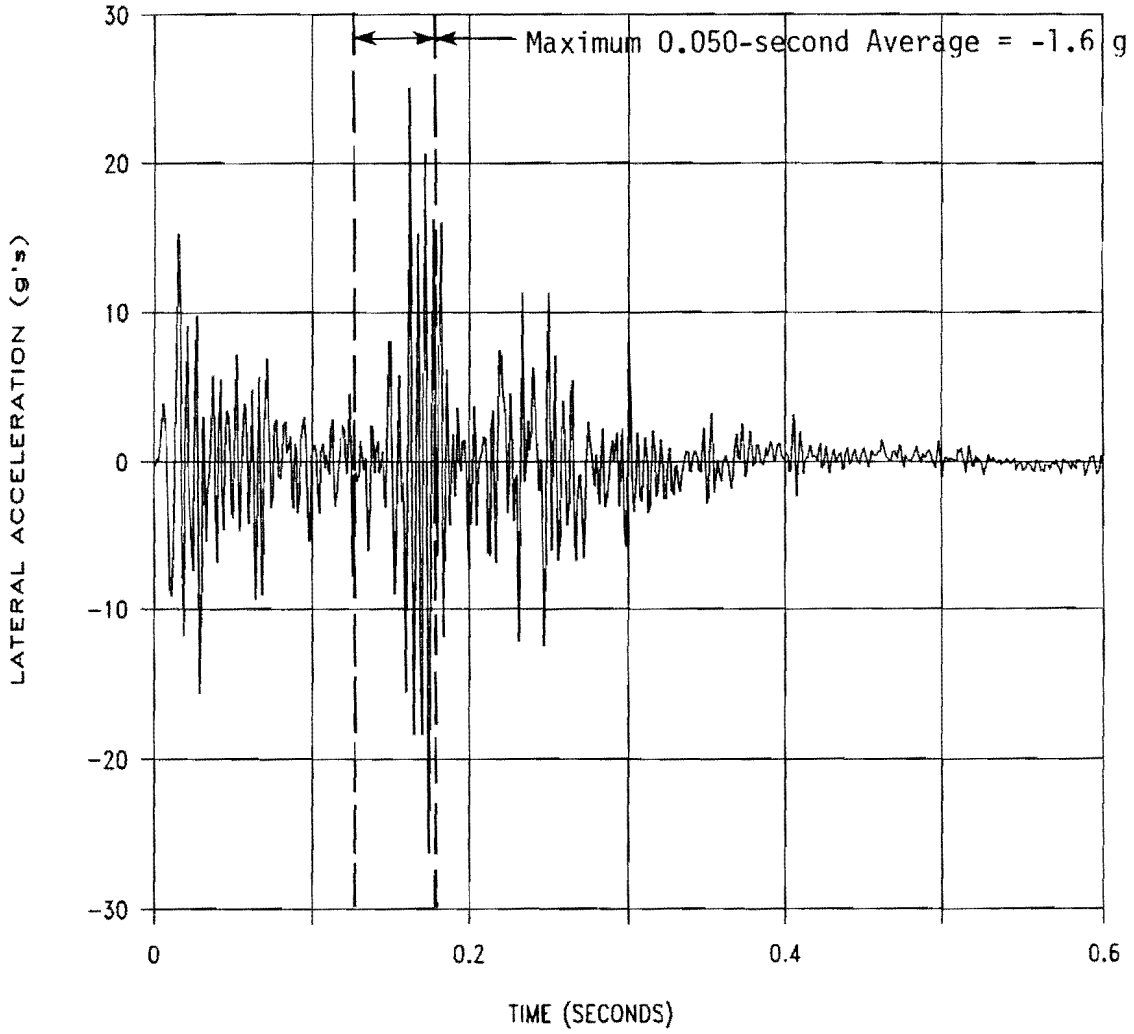


Figure 103 Lateral accelerometer trace for test 9910-10.

TEST 9910-10

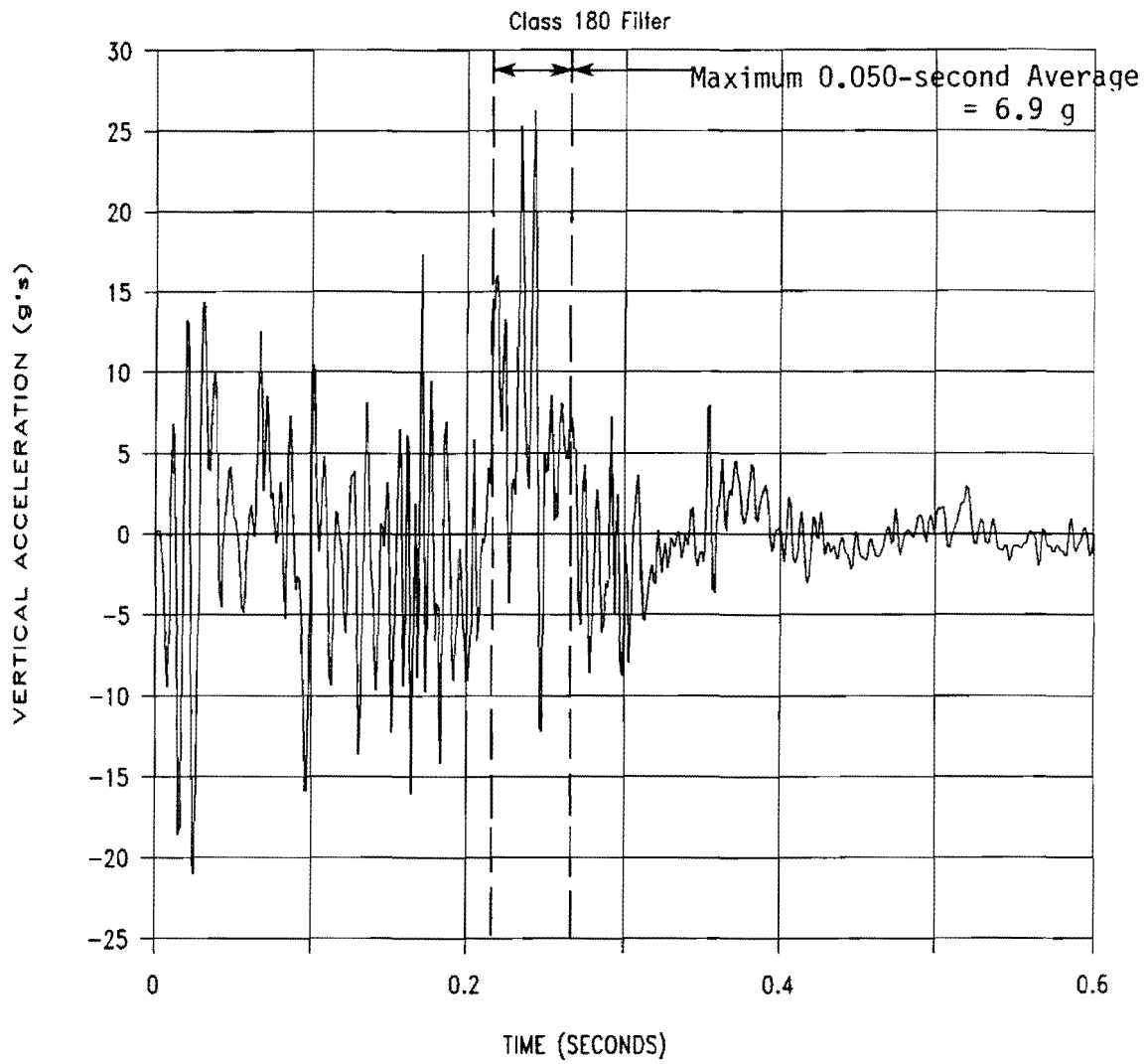


Figure 104 Vertical accelerometer trace for test 9910-10.

TEST 9910-10

Class 180 Filter - Dump Truck Cab

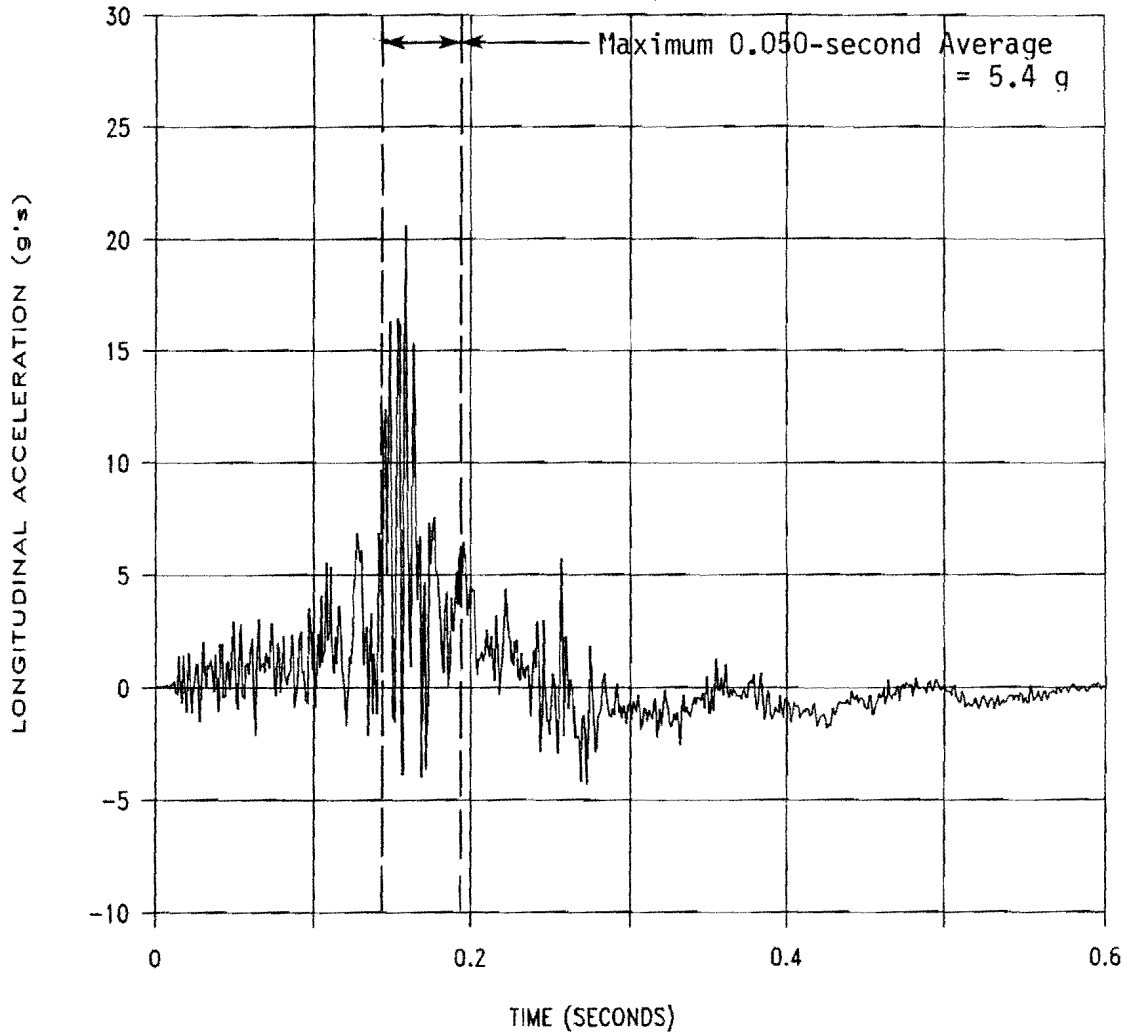


Figure 105 Longitudinal accelerometer trace for test 9910-10 (dump truck cab).

No TMA (9910-16)

The 1982 Cadillac Fleetwood (pictured in Figure 106) was directed into the rear of Truck No. 2 with no TMA. The height to the lower edge of the impacting vehicle's bumper was 11.25 inches and 20.00 inches to the top of the bumper. Other dimensions and information on the impacting vehicle are given in Figure 107.

The vehicle was travelling at a speed of 46.8 mi/h. Upon impact, the impacting vehicle began to crush. The rear truck tire began to rotate forward at 0.022 second. The impacting vehicle began to dive down and bottomed-out at 0.074 second. The dump truck reached a maximum speed of 12.4 mi/hr at 0.133 second and had moved forward 1.5 ft. By 0.169 second, the rear truck tire had rotated 30 degrees from the vertical and continued to rotate forward and backward during the remainder of the test. Forward motion of the impacting vehicle stopped at 0.732 second. Sequential photographs of the test are shown in Figure 108.

The impacting vehicle received damage to the front bumper, hood, grill, radiator, the right and left front quarter panels, and all four doors. The roof and floorpan were bent and the windshield was broken. The drive shaft and rear axle were also damaged. Maximum vehicle crush was 35.0 inches just above bumper height. The only damage sustained by the dump truck was to the TMA attachment panel. Figures 109 and 110 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 111. The maximum longitudinal 50-ms average acceleration experienced by the impacting vehicle was -22.1 g between 037 and 087 ms. Longitudinal occupant impact velocity was 50.5 ft/s at 096 ms and the maximum longitudinal ridedown acceleration was -10.0 g between 102 and 112 ms. Vehicle angular displacements are plotted in Figure 112 and accelerometer traces are displayed in Figures 113 through 116.

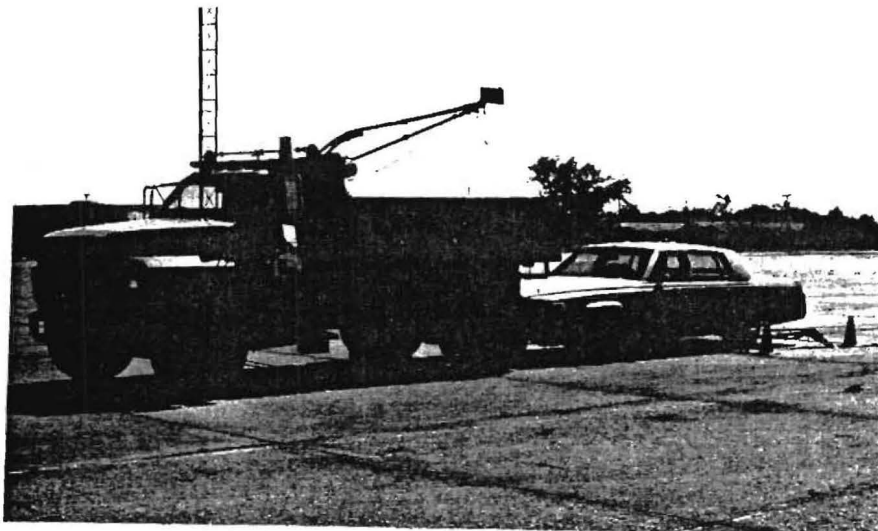
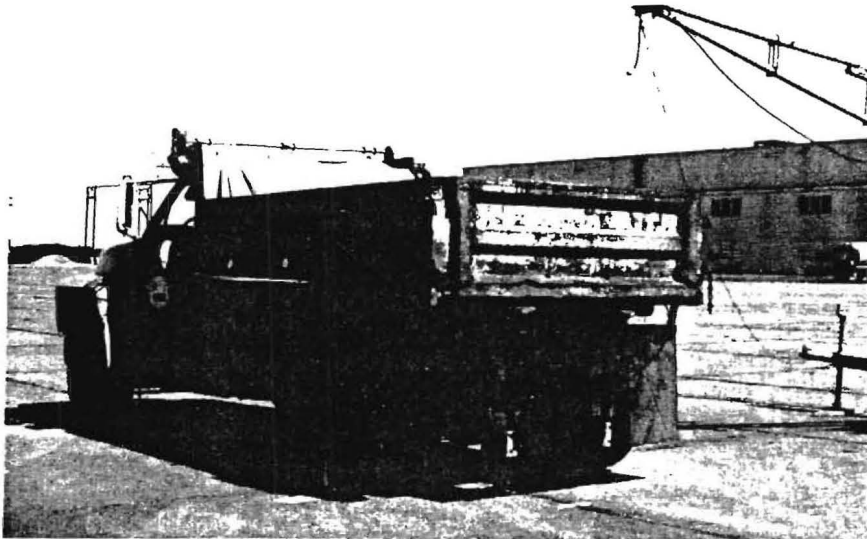
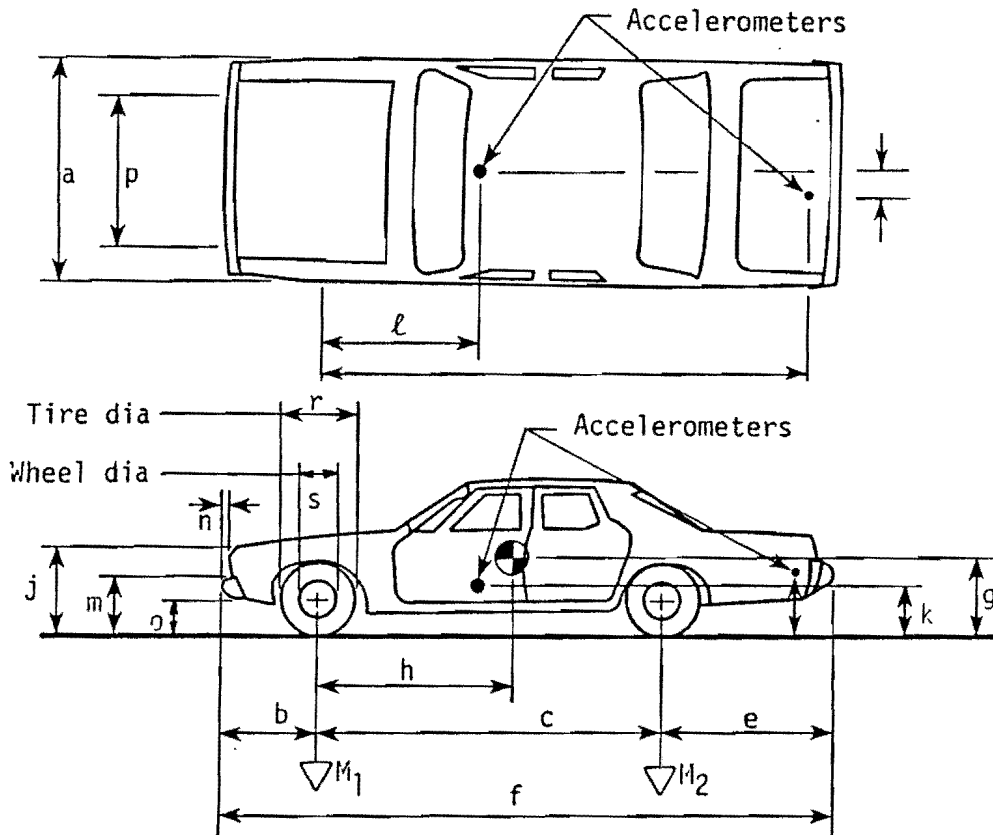


Figure 106. Vehicles prior to test 9910-16.

Date: 10/25/90 Test No.: 9910-16 VIN: 1G6AB6988C9112896
 Make: Cadillac Model: Fleet Wood Year: 1982 Odometer: 47777
 Tire Size: D225/75R15 Ply Rating: _____ Bias Ply: Belted: Radial:

Tire Condition: good x
 fair
 badly worn



Vehicle Geometry - inches
 a 78'' b 42 1/2''
 c 121 3/4'' d* 56 1/2''
 e 56'' f _____
 g _____ h _____
 i ----- j 32 1/2''
 k 19 1/2'' l 35 1/2''
 m 20'' n 4''
 o 11 1/4'' p _____
 r 28 1/2'' s 16 1/4''

Engine Type: 8 Gasoline
 Engine CID: 4.1

Transmission Type:
 Automatic ~~xxxx~~ Manual
~~xxxx~~ RWD ~~xxxx~~ 4WD

Body Type: 4 Door

Steering Column Collapse Mechanism:
 Behind wheel units
 Convoluted tube
 Cylindrical mesh units
 Embedded ball
 NOT collapsible
 Other energy absorption
 Unknown

4-wheel weight for c.g. det. lf 1172 rf 1140 lr 1093 rr 1095

Mass - pounds	Curb	Test Inertial	Gross Static
M_1	<u>2185</u>	<u>2312</u>	_____
M_2	<u>1866</u>	<u>2188</u>	_____
M_T	<u>4051</u>	<u>4500</u>	_____

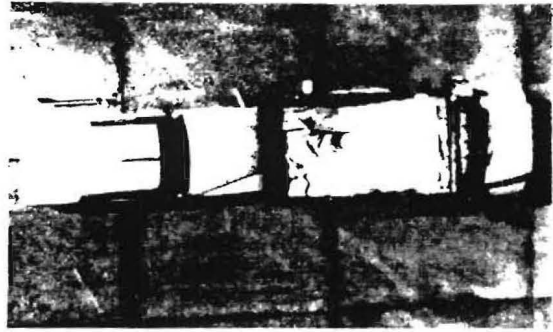
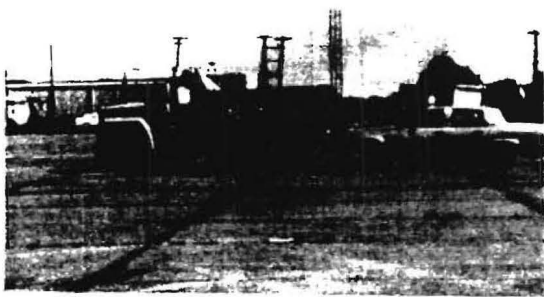
Note any damage to vehicle prior to test:

Crack in Windshield-passenger side

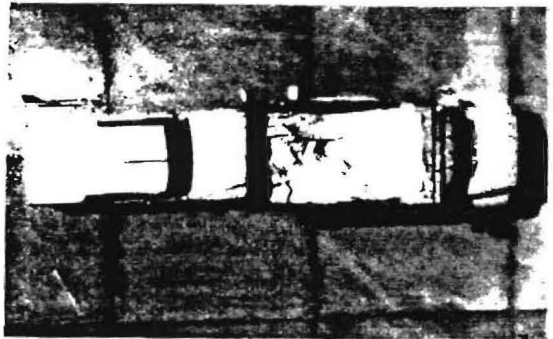
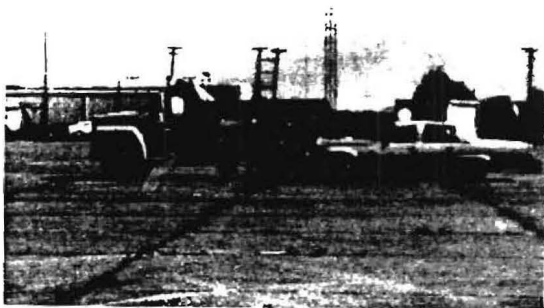
Brakes:
 Front: disc x drum _____
 Rear: disc _____ drum x

*d = overall height of vehicle

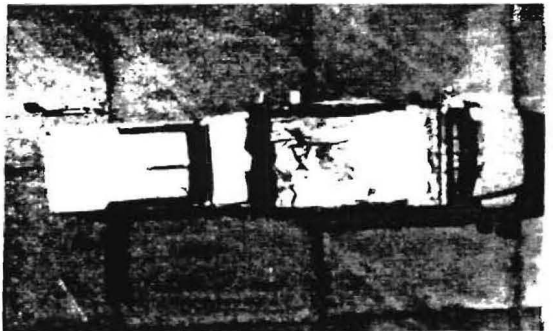
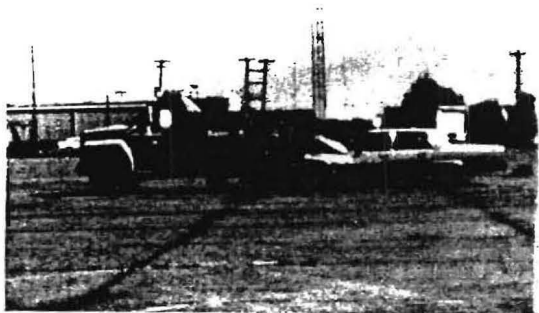
Figure 107. Test vehicle properties (9910-16).



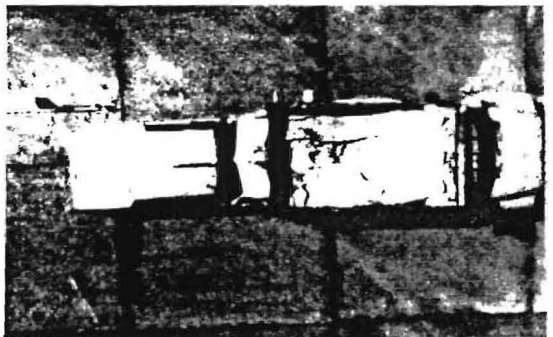
.000 sec



.024 sec

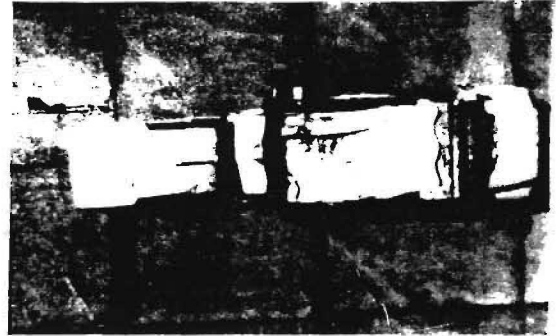
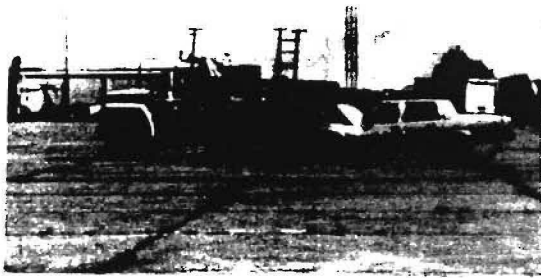


.048 sec

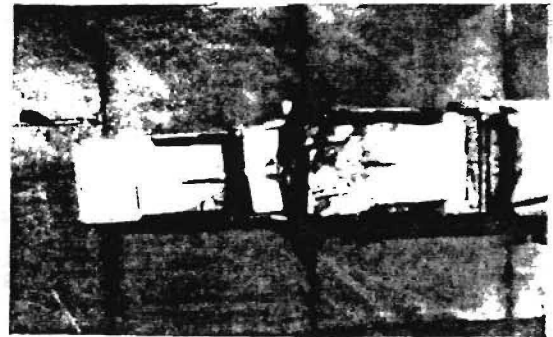


.073 sec

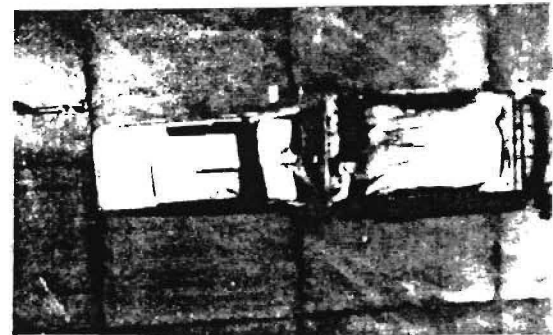
Figure 108. Sequential photographs for test 9910-16.



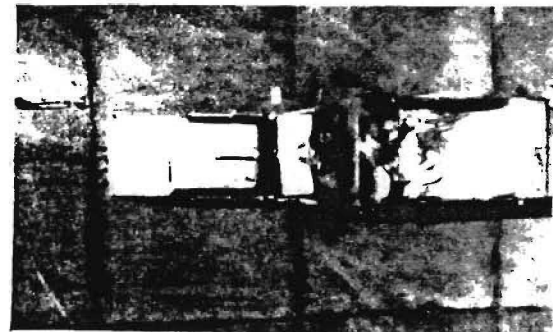
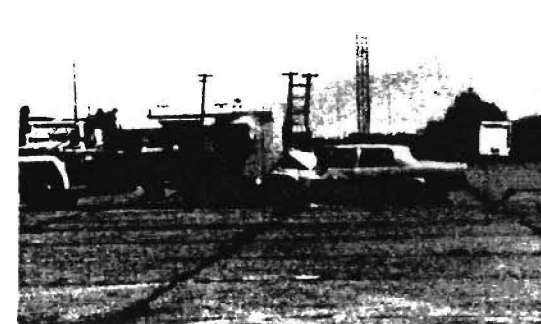
.097 sec



.242 sec



.483 sec



.732 sec

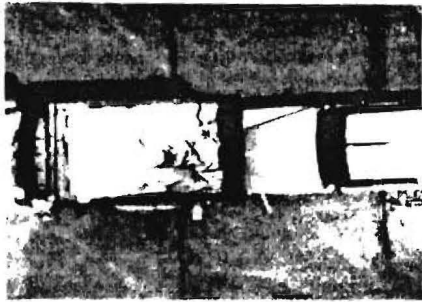
Figure 108. Sequential photographs for test 9910-16.
(Continued)



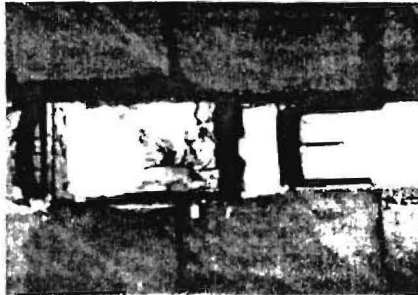
Figure 109. Damage to truck after test 9910-16.



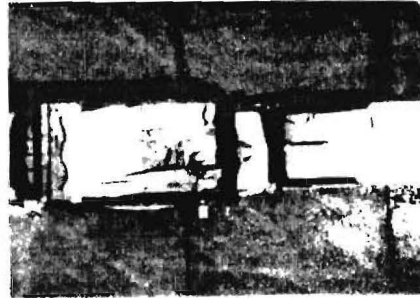
Figure 110. Damage to passenger car after test 9910-16.



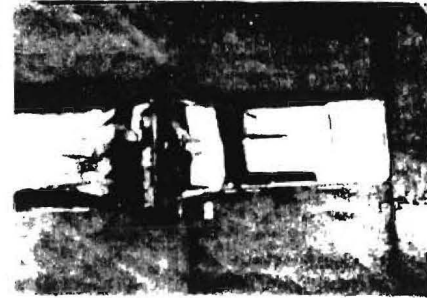
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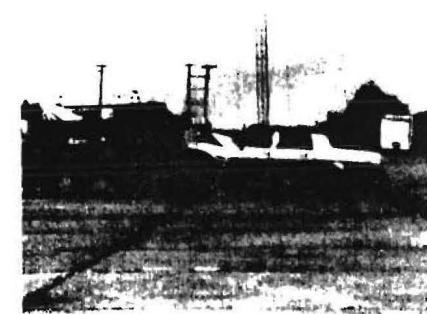
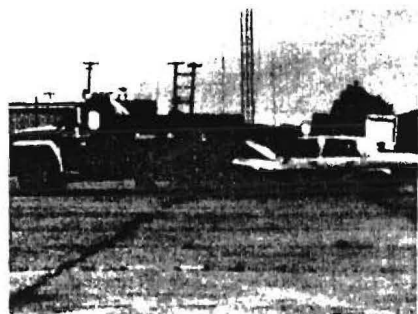
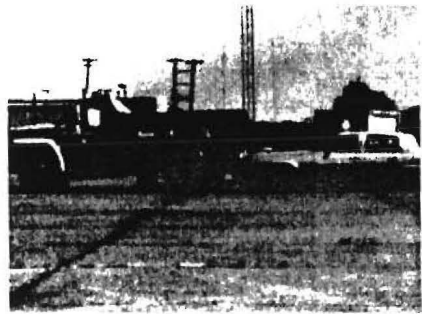
0.048 s



0.097 s



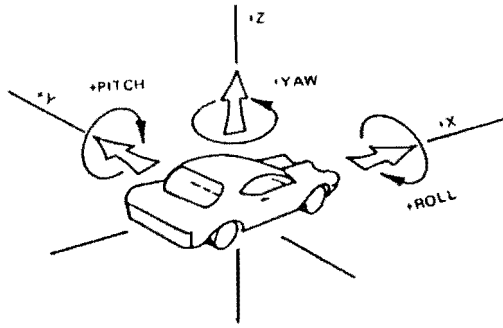
0.483 s



Test No. 09910-16
 Date 10/25/90
 Test Article Truck Mounted Attenuator
 Manufacturer No TMA (baseline test)
 TMA Truck 1980 Ford Dump Truck (#2)
 Weight without TMA 14,010 lb (6,361 kg)
 Weight with TMA No TMA
 Test Vehicle 1982 Cadillac Fleetwood
 Weight 4,500 lb (2,043 kg)
 Impact Speed 46.8 mi/h (75.3 km/h)
 Maximum Vehicle Crush 35.0 in (88.9 cm)
 Vehicle Damage Classification
 TAD 12FD7
 CDC 12FDEW4

Maximum Truck Displacement 10.8 ft (3.3m)
 Maximum TMA Crush N/A (No TMA)
 Vehicle Accelerations
 (Maximum 50 ms Average at c.g.)
 Vehicle Longitudinal -22.1 g
 Vehicle Lateral -2.9 g
 Truck Cab Longitudinal 6.9 g
 Occupant Impact Velocity
 Longitudinal 50.5 ft/s (15.4 m/s)
 Lateral No contact
 Occupant Ridedown Accelerations
 Longitudinal -10.0 g
 Lateral N/A

Figure 111 Summary of results for test 9910-16.



Axes are vehicle fixed.
Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

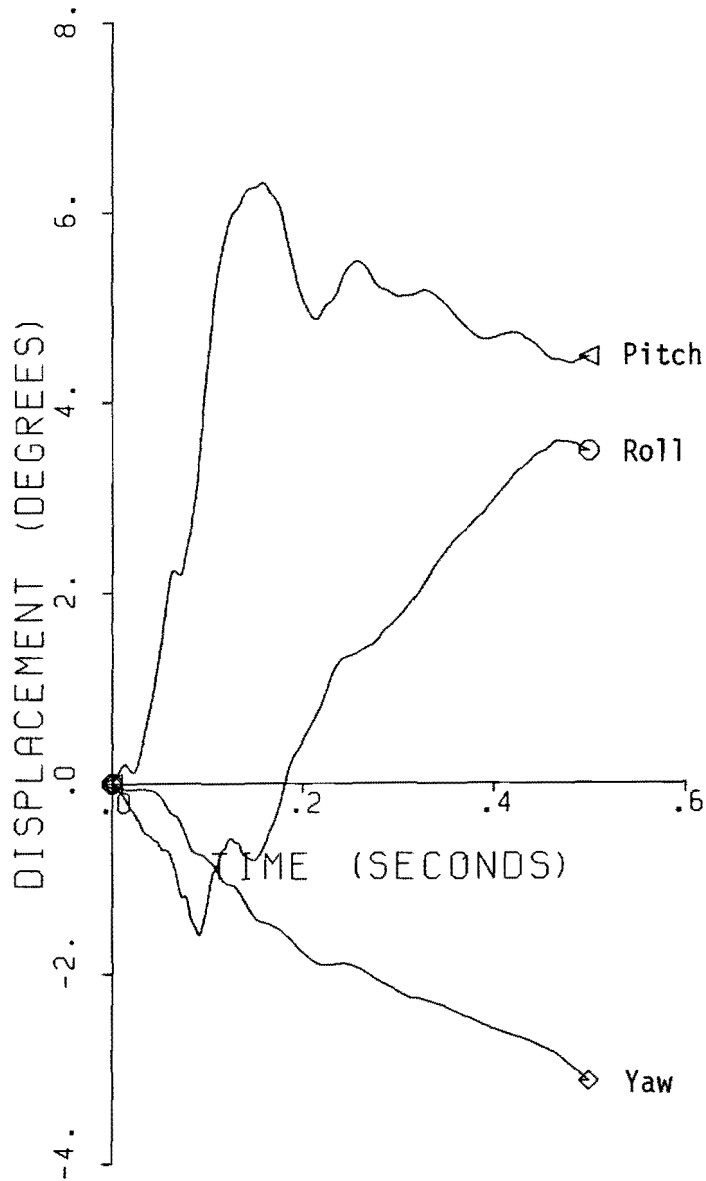


Figure 112. Vehicle angular displacements for test 9910-16.

TEST 9910-16

Class 180 Filter

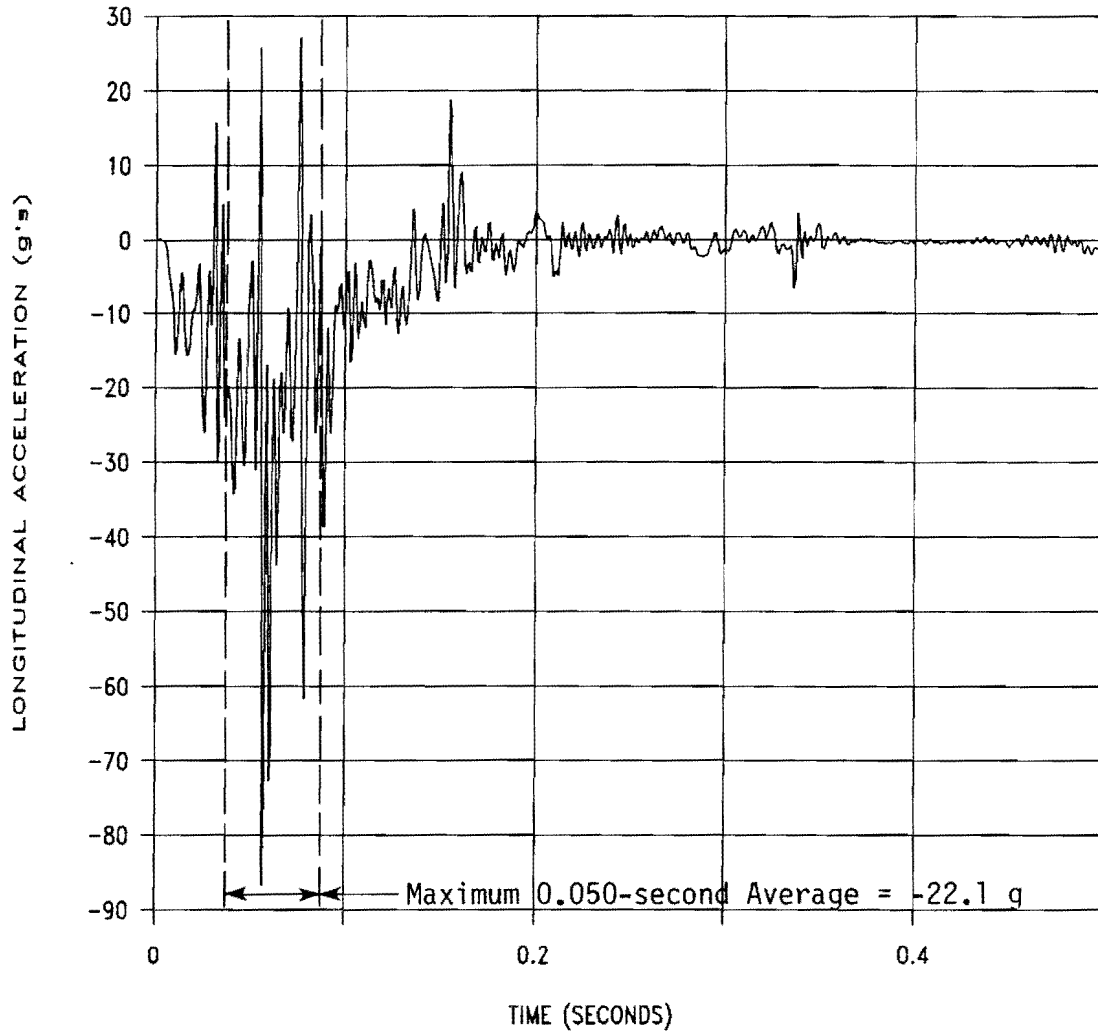


Figure 113. Vehicle longitudinal accelerometer trace for test 9910-16.

TEST 9910-16

Class 180 Filter

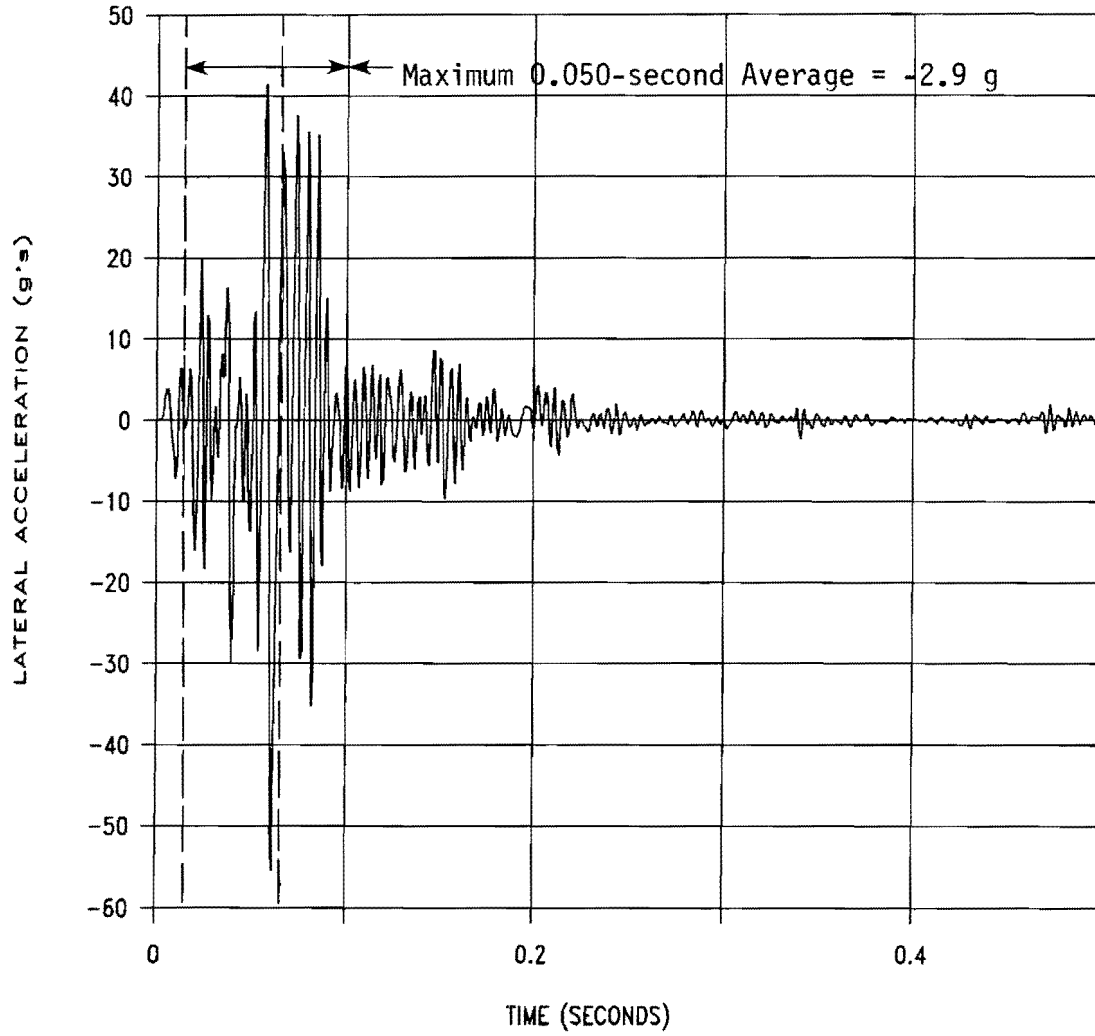


Figure 114. Vehicle lateral accelerometer trace for test 9910-16.

TEST 9910-16

Class 180 Filter

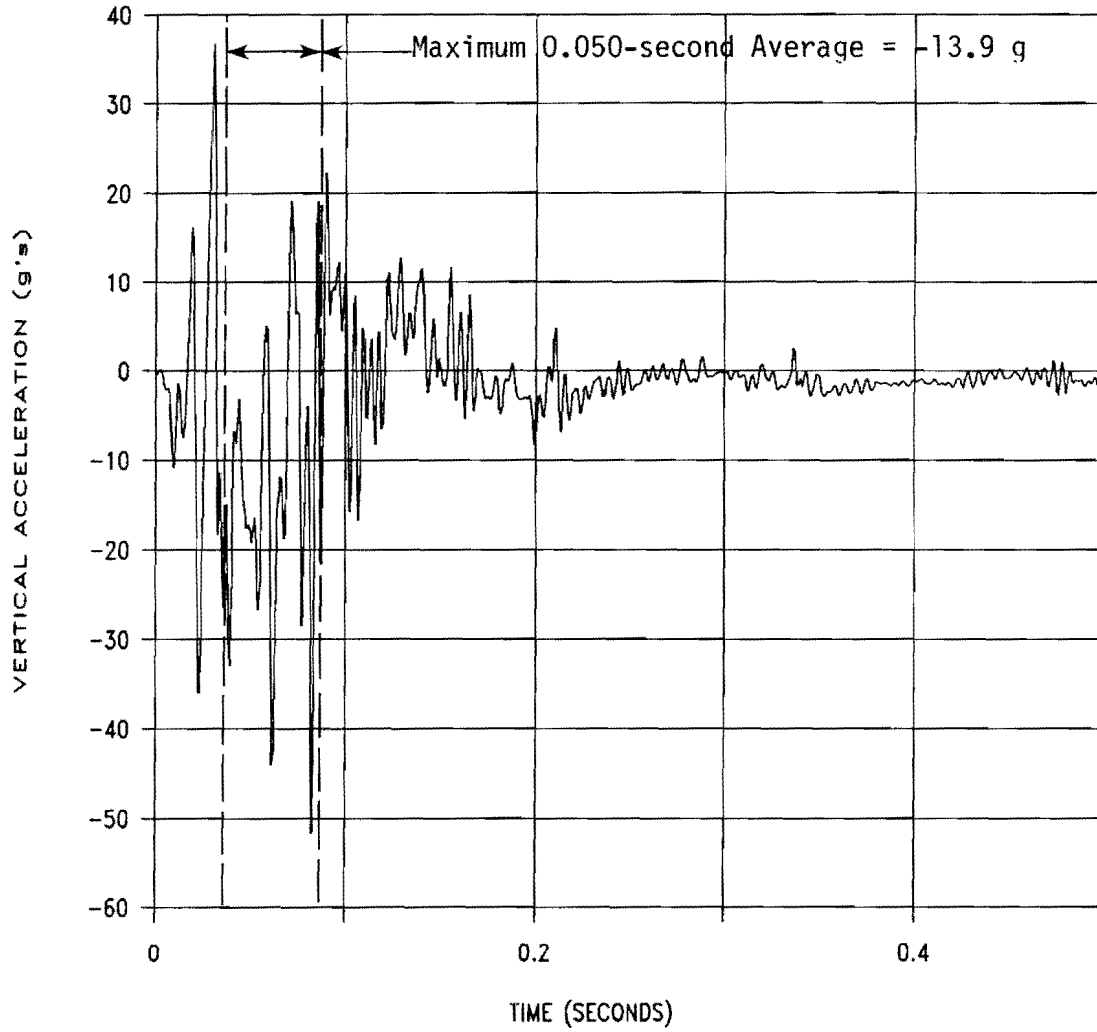


Figure 115. Vehicle vertical accelerometer trace for test 9910-16.

TEST 9910-16

Class 180 Filter - Dump Truck

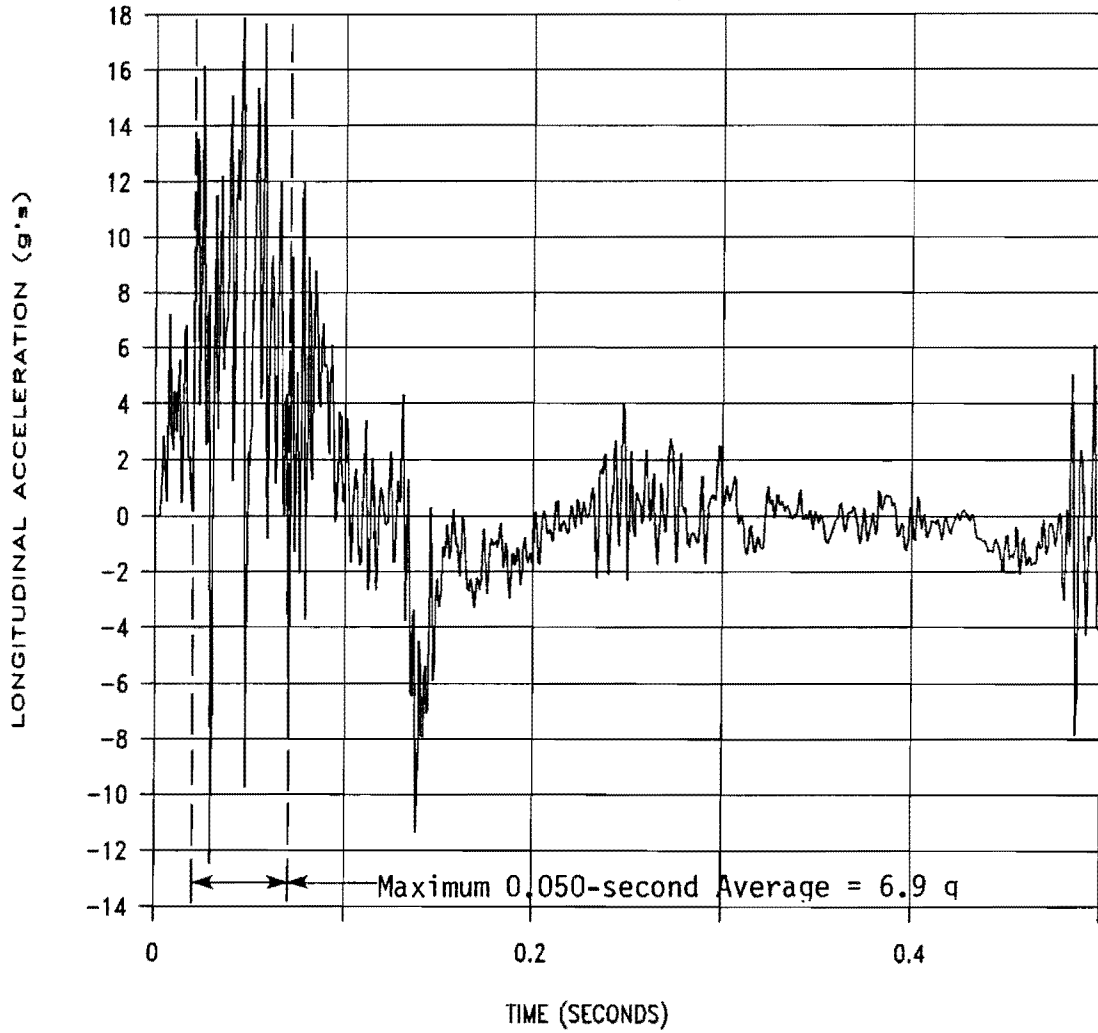


Figure 116. Dump truck longitudinal accelerometer trace for test 9910-16.

**Test Series 2: Fixed-Position Truck Tests with 1800-lb Passenger Cars
Traveling at 45 Miles per Hour**

The tests performed in this series used 1800-lb Hondas impacting the TMA's mounted on the same two trucks used in the first series. The trucks were parked in second gear with the parking brake on, against a rigid barrier to prevent forward motion of the truck. The Hondas were directed into the TMA's using the reverse tow and cable guidance system and were free-wheeling and unrestrained just prior to impact. The point of impact was head-on with the centerline of the vehicle aligned with the centerline of the TMA.

Energy Absorption Alpha Model (9910-03)

The TMA used during this test was manufactured by Energy Absorption (Alpha model) and is shown in Figures 1 and 117. The TMA was mounted on Truck No. 2 which had a gross static weight of 14,980 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 12.00 inches at the front and 13.00 inches at the rear. The height to the upper rear surface of the cartridge was 33.50 inches above ground.

The 1980 Honda Civic (pictured in Figure 117) was directed into the Energy Absorption Alpha TMA. The height to the lower edge of the vehicle bumper was 13.75 inches and 18.75 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 118.

The vehicle was travelling at a speed of 43.9 mi/h. Upon impact, the TMA began to crush smoothly and steadily. The impacting vehicle remained at a constant height without diving under the TMA. Forward motion of the impacting vehicle stopped at 0.161 second. The vehicle subsequently came to rest 2 ft behind the TMA. Sequential photographs of the test are shown in Figure 119.

The Energy Absorption Alpha TMA cartridge crushed a total of 57.40 inches during the test. The frame attachment to the cartridge was bent 1.00 inch on both sides. The impacting vehicle received damage to the front bumper, hood, grill, radiator, and the right and left front quarter panels. Maximum vehicle crush was 4.0 inches at bumper height. Figures 120 and 121 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 122. The maximum longitudinal 50-msec average acceleration experienced by the impacting vehicle was -15.2 g between 076 and 126 msec. Longitudinal occupant impact velocity was 42.8 ft/s at 111 msec and the maximum longitudinal ridedown acceleration was -15.2 g between 136 and 146 msec. Vehicle angular displacements are plotted in Figure 123 and accelerometer traces are displayed in Figures 124 through 126.

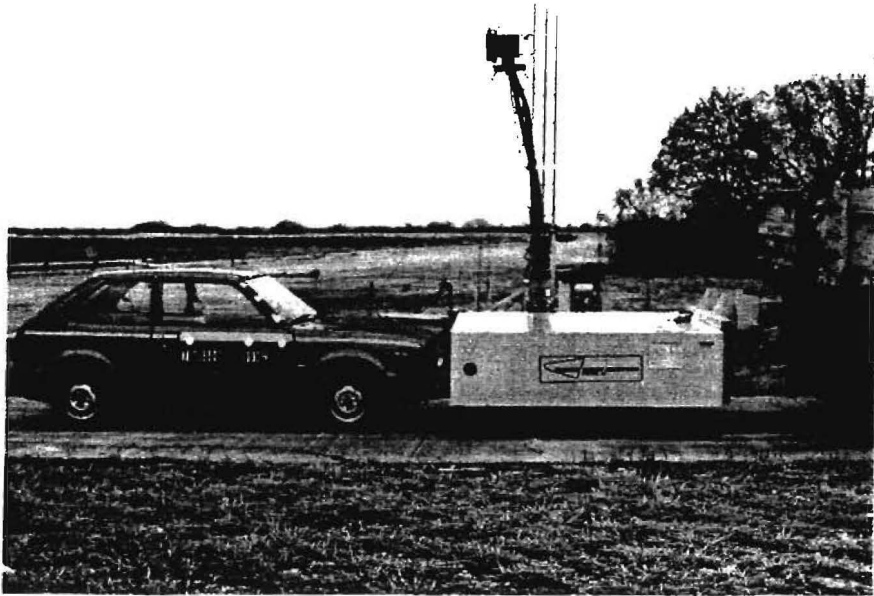
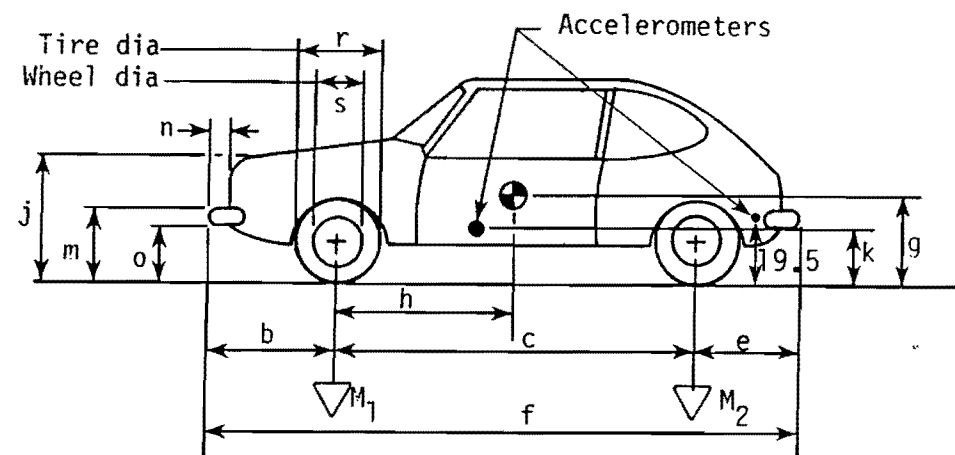
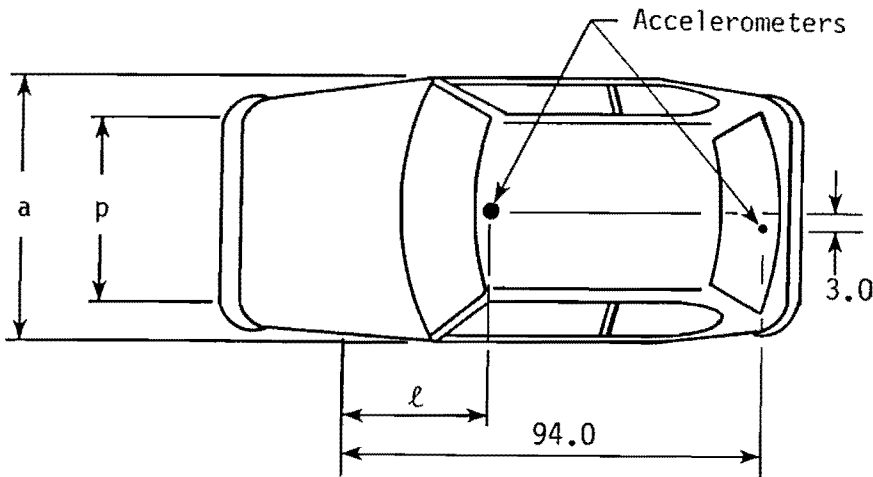


Figure 117. Vehicle before test with Energy Absorption Alpha TMA.

Date: _____ Test No.: 9910-3 VIN: SLC1039593
 Make: Honda Model: Civic Year: 1980 Odometer: 125286
 Tire Size: 155SR12 Ply Rating: _____ Bias Ply: _____ Belted: _____ Radial: x



Tire Condition: good _____
 fair x _____
 badly worn _____

Vehicle Geometry - inches

a	62.5	b	29.0
c	88.25	d*	52.0
e	28.5	f	145.75
g	_____	h	33.3
i	----	j	29.0
k	14.5	l	29.0
m	18.75	n	2.75
o	13.75	p	53.5
r	21.5	s	13.5

Engine Type: 4 cylinder
 Engine CID: 91 CID
 Transmission Type: _____

Automatic or Manual _____
FWD or RWD or 4WD

Body Type: 3 door

Steering Column Collapse Mechanism: _____

- _____ Behind wheel units
- _____ Convoluted tube
- _____ Cylindrical mesh units
- _____ Embedded ball
- _____ NOT collapsible
- _____ Other energy absorption
- _____ Unknown

Brakes:
 Front: disc x drum _____
 Rear: disc _____ drum x _____

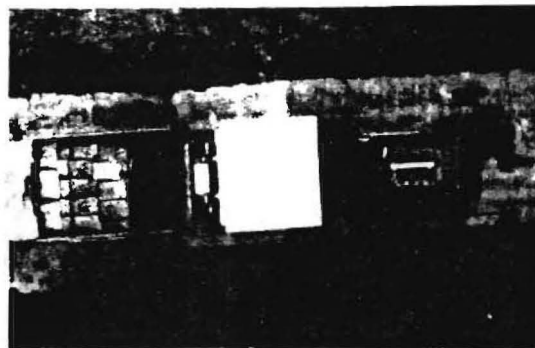
4-wheel weight for c.g. det. lf 590 rf 530 lr 340 rr 340

Mass - pounds	Curb	Test Inertial	Gross Static
M ₁	<u>1124</u>	<u>1120</u>	_____
M ₂	<u>635</u>	<u>680</u>	_____
M _T	<u>1759</u>	<u>1800</u>	_____

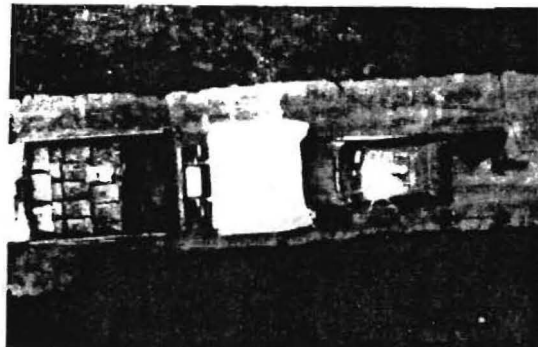
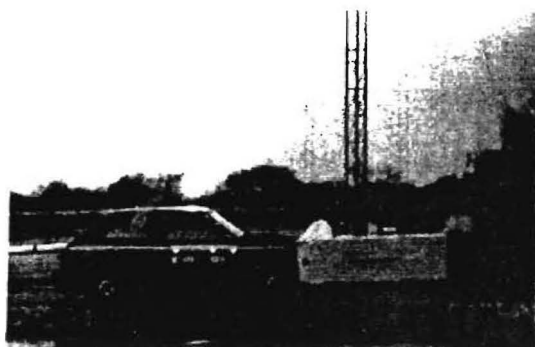
Note any damage to vehicle prior to test:
Cracked windshield marked

*d = overall height of vehicle

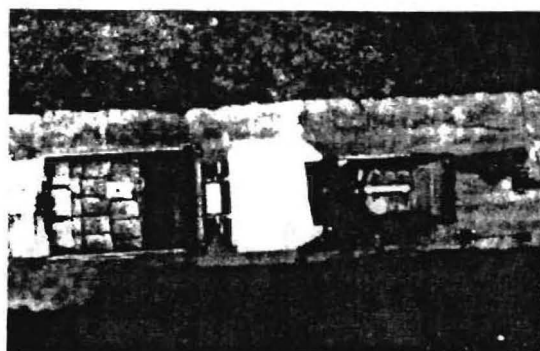
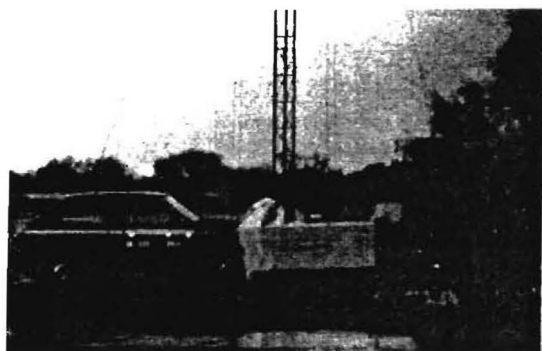
Figure 118. Test vehicle properties for test 9910-3.



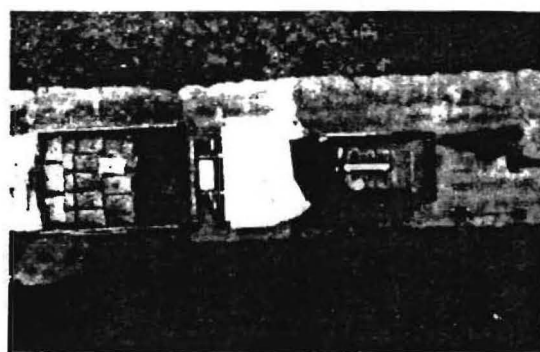
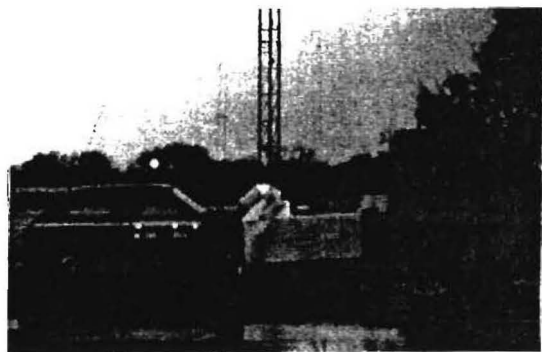
0.000 s



0.024 s

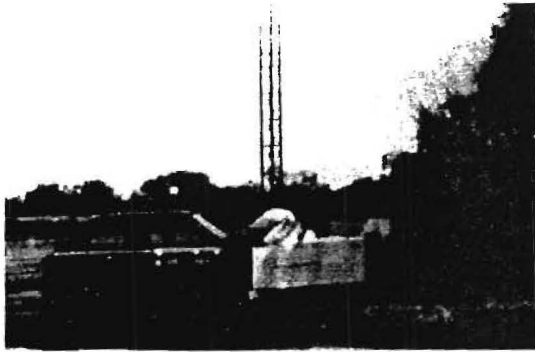


0.048 s

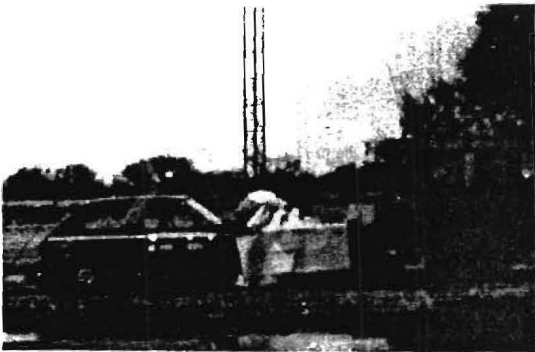
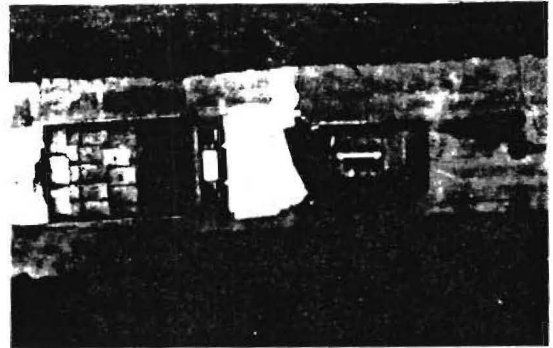


0.072 s

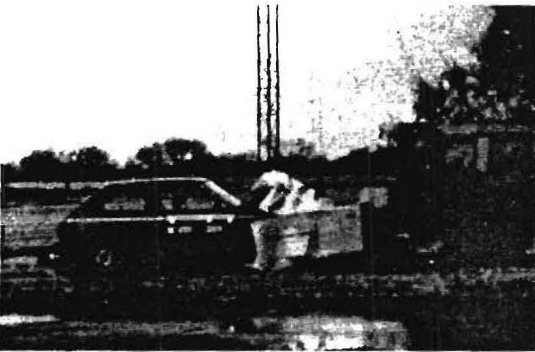
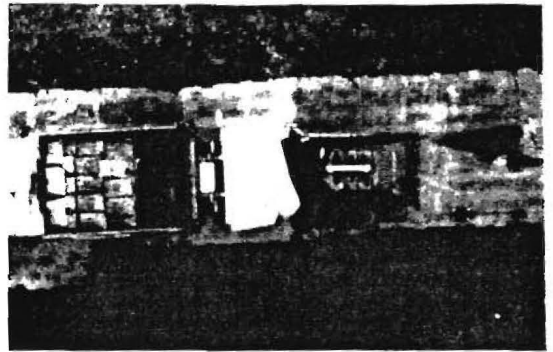
Figure 119. Sequential photographs for test 9910-3.



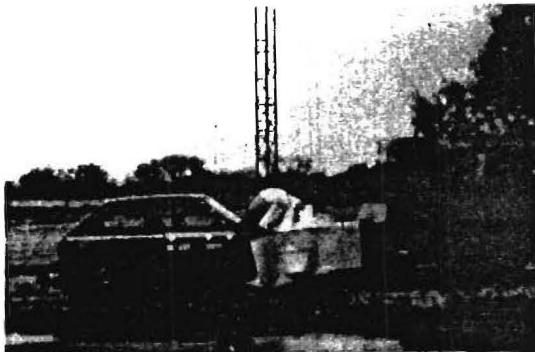
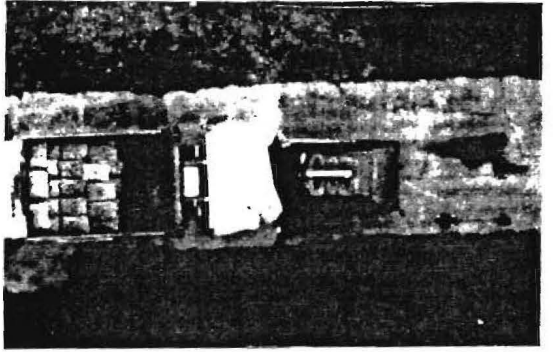
0.096 s



0.120 s



0.144 s



0.167 s



Figure 119. Sequential photographs for test 9910-3. (Continued)

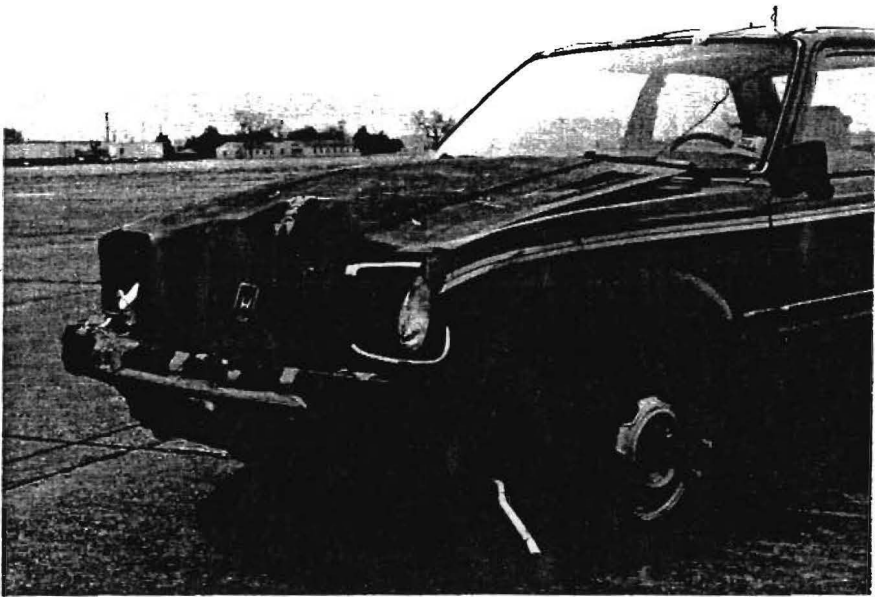


Figure 120. Vehicle after impact with Energy Absorption Alpha TMA (9910-3).

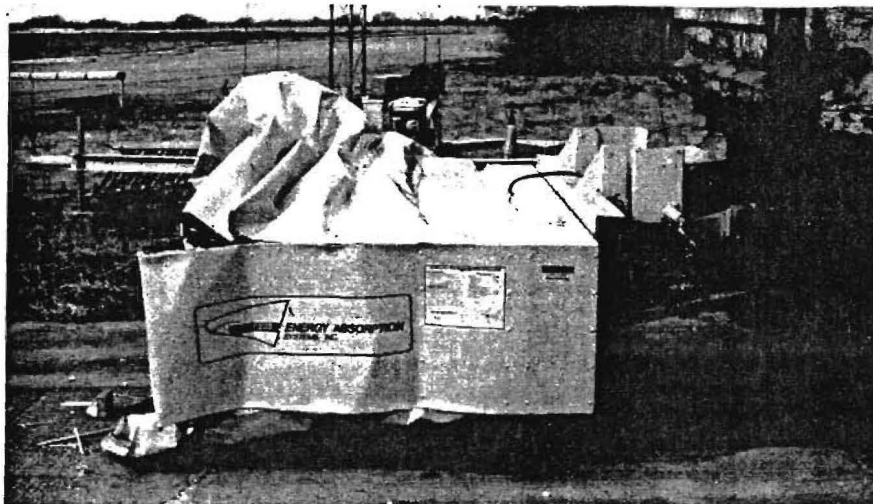
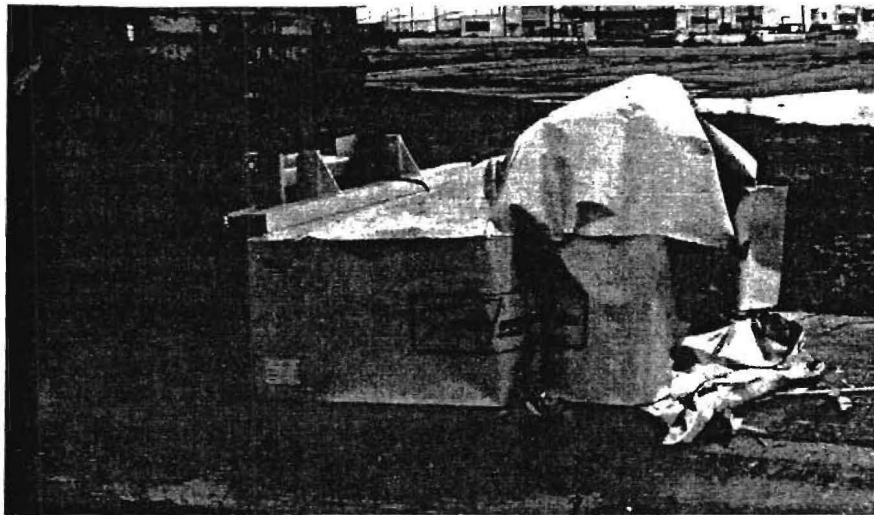
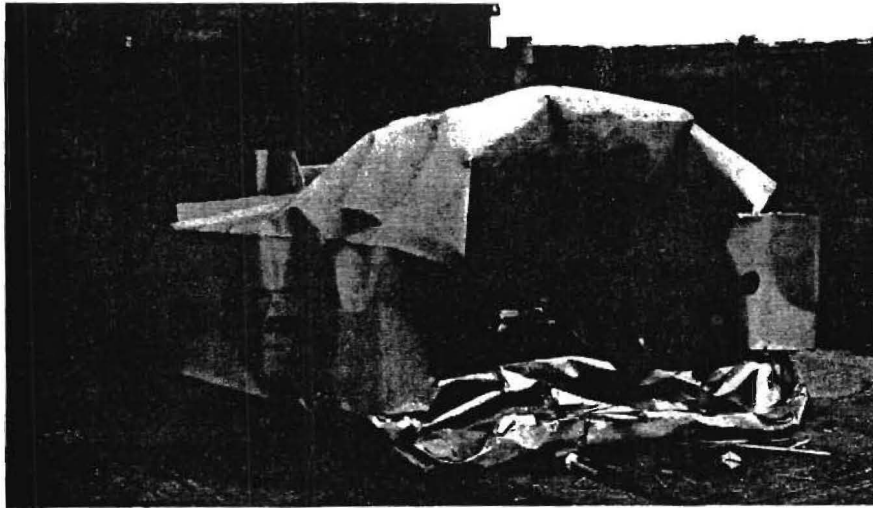
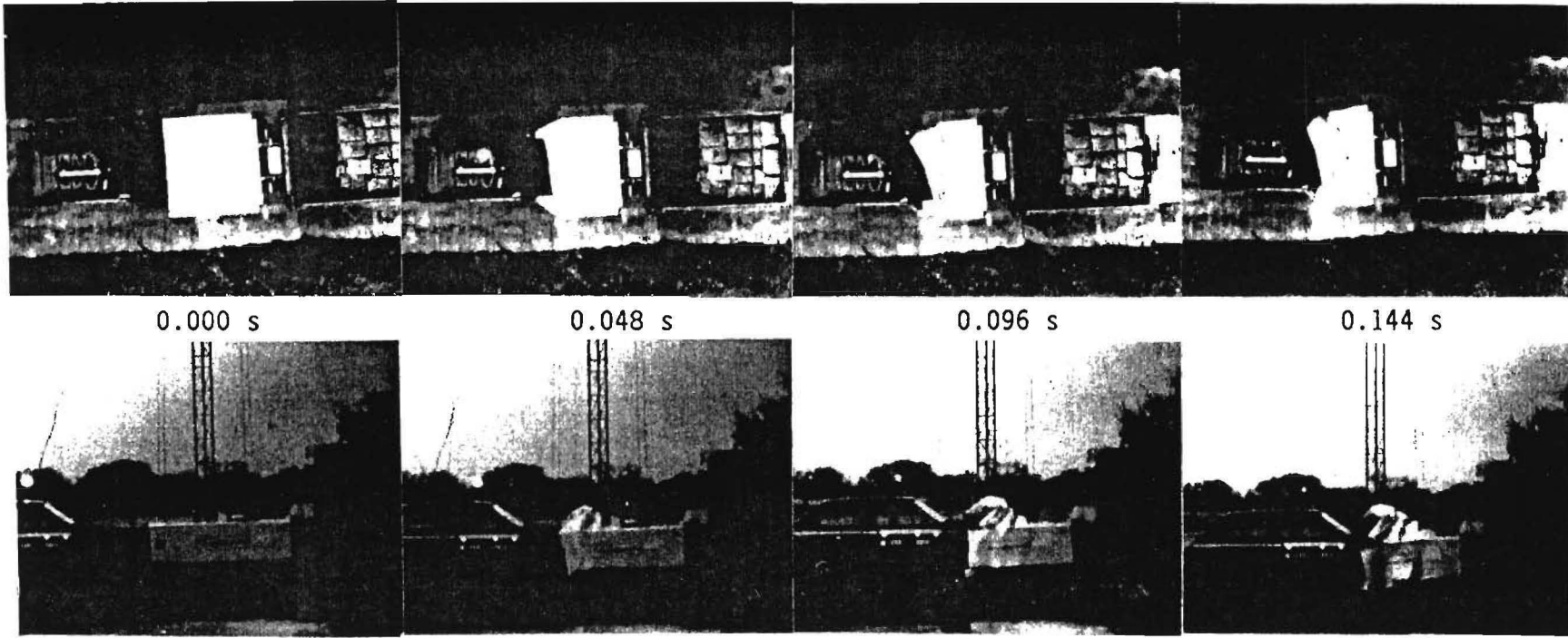


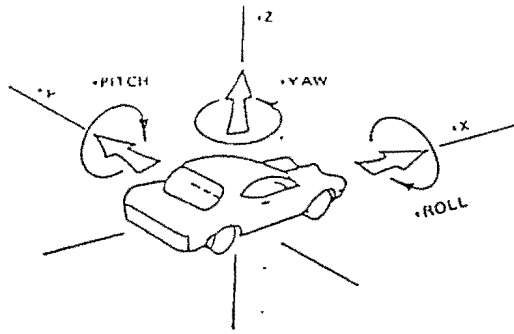
Figure 121. Energy Absorption Alpha TMA after test 9910-3.



149

Test No.	09910-3	Maximum Truck Displacement .	N/A (fixed position)
Date	01/04/90	Maximum TMA Crush	57.4 in (1.5 m)
Test Article	Truck Mounted Attenuator	Vehicle Accelerations	
Manufacturer	Energy Absorption Alpha	(Maximum 50 ms Average at c.g.)	
TMA Truck	1980 Ford Dump Truck (#2)	Vehicle Longitudinal	-15.2 g
Weight without TMA	14,010 lb (6,361 kg)	Vehicle Lateral	-1.5 g
Weight with TMA	14,980 lb (6,801 kg)	Truck Cab Longitudinal	N/A
Test Vehicle	1980 Honda Civic	Occupant Impact Velocity	
Weight	1,800 lb (817 kg)	Longitudinal	42.8 ft/s (13.0 m/s)
Impact Speed	43.9 mi/h (70.6 km/h)	Lateral	5.8 ft/s (1.8 m/s)
Maximum Vehicle Crush	4.0 in (10.2 cm)	Occupant Ridedown Accelerations	
Vehicle Damage Classification		Longitudinal	-14.8 g
TAD	12FD2	Lateral	-1.0 g
CDC	12FDEW2		

Figure 122 Summary of results for test 9910-3.



Axes are vehicle fixed.
Sequences for determining orientation is:

1. Yaw
2. Pitch
3. Roll

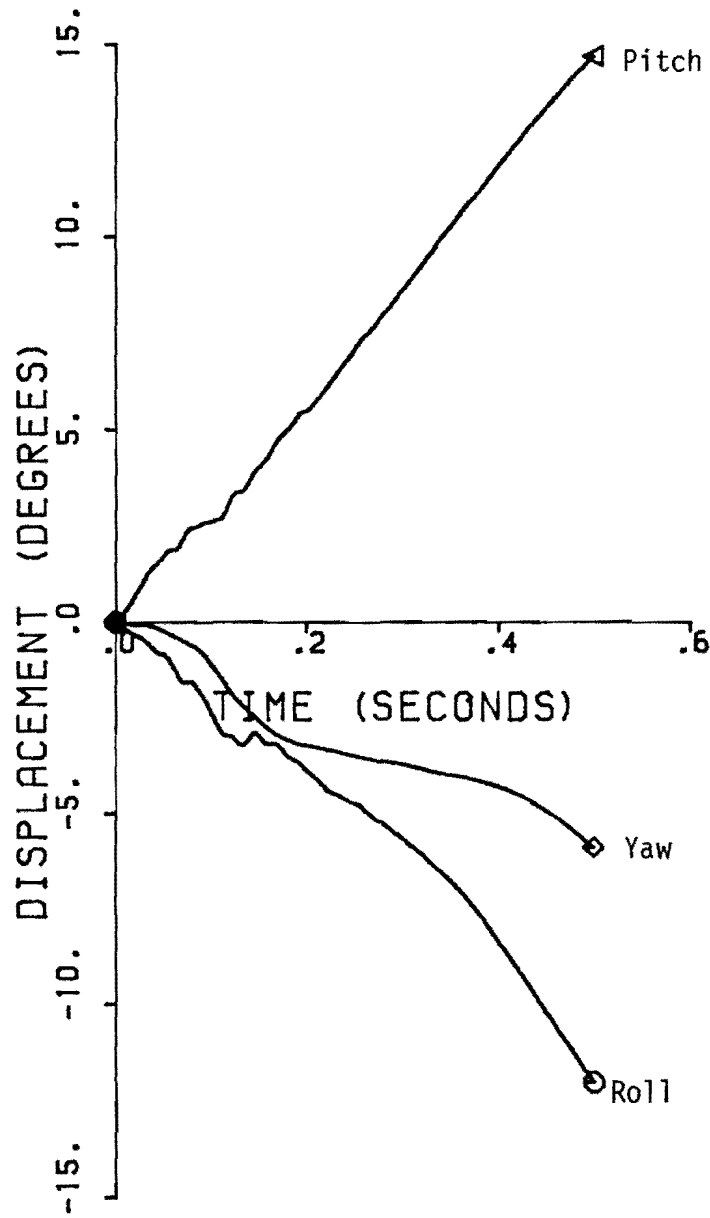


Figure 123. Vehicle angular displacements for test 9910-3.

TEST 9910-3

Class 180 Filter

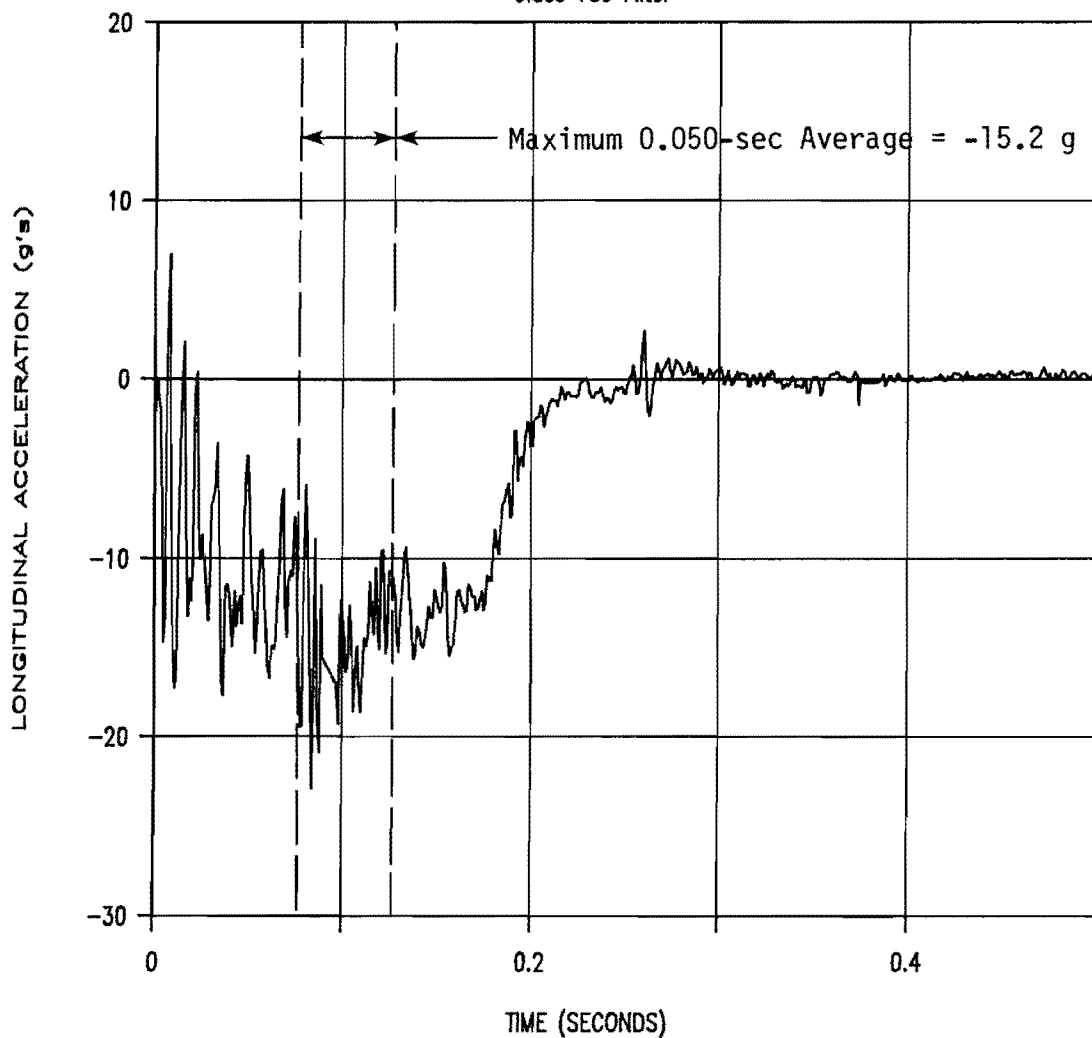


Figure 124. Vehicle longitudinal accelerometer trace for test 9910-3.

TEST 9910-3

Class 180 Filter

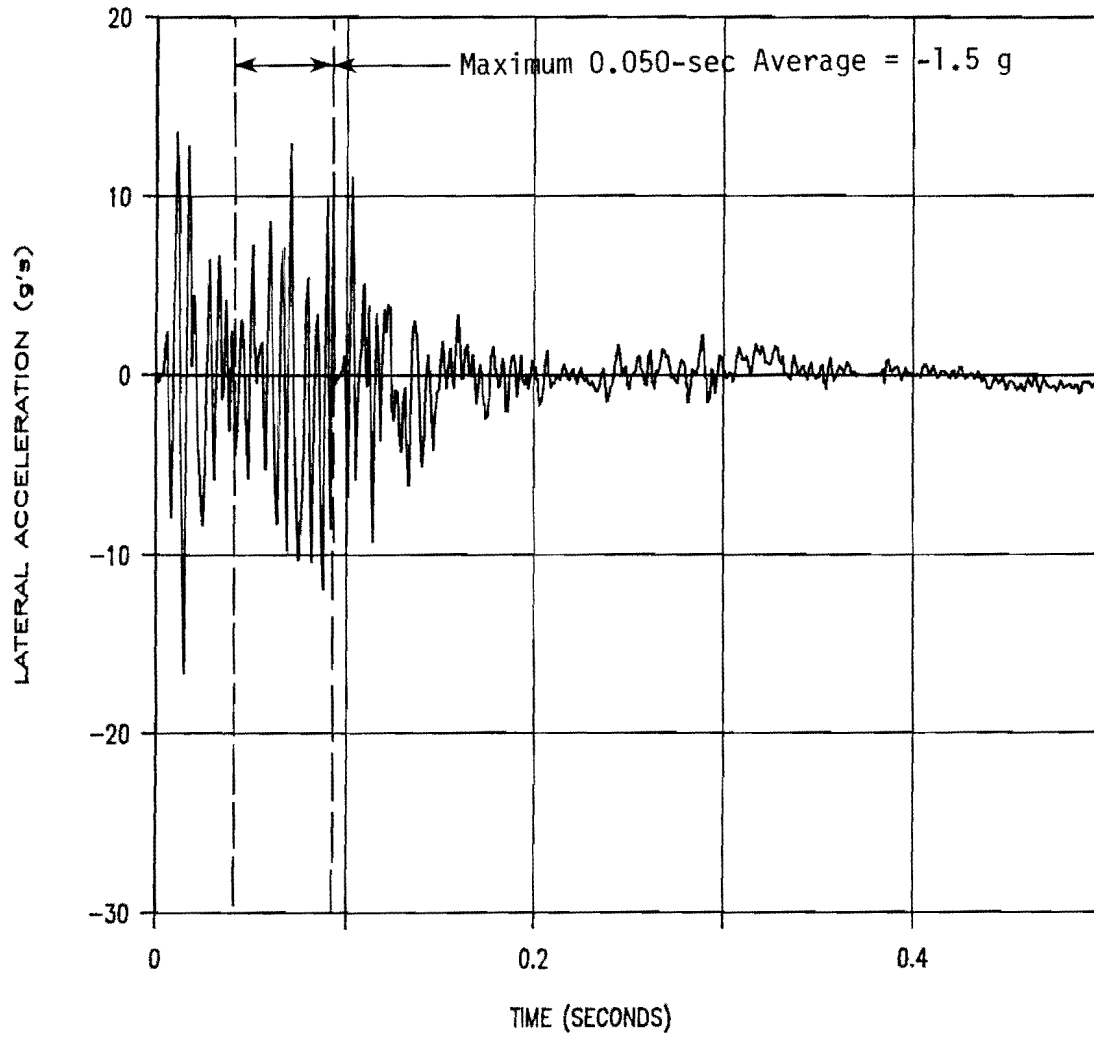


Figure 125. Vehicle lateral accelerometer trace for test 9910-3.

TEST 9910-3

Class 180 Filter

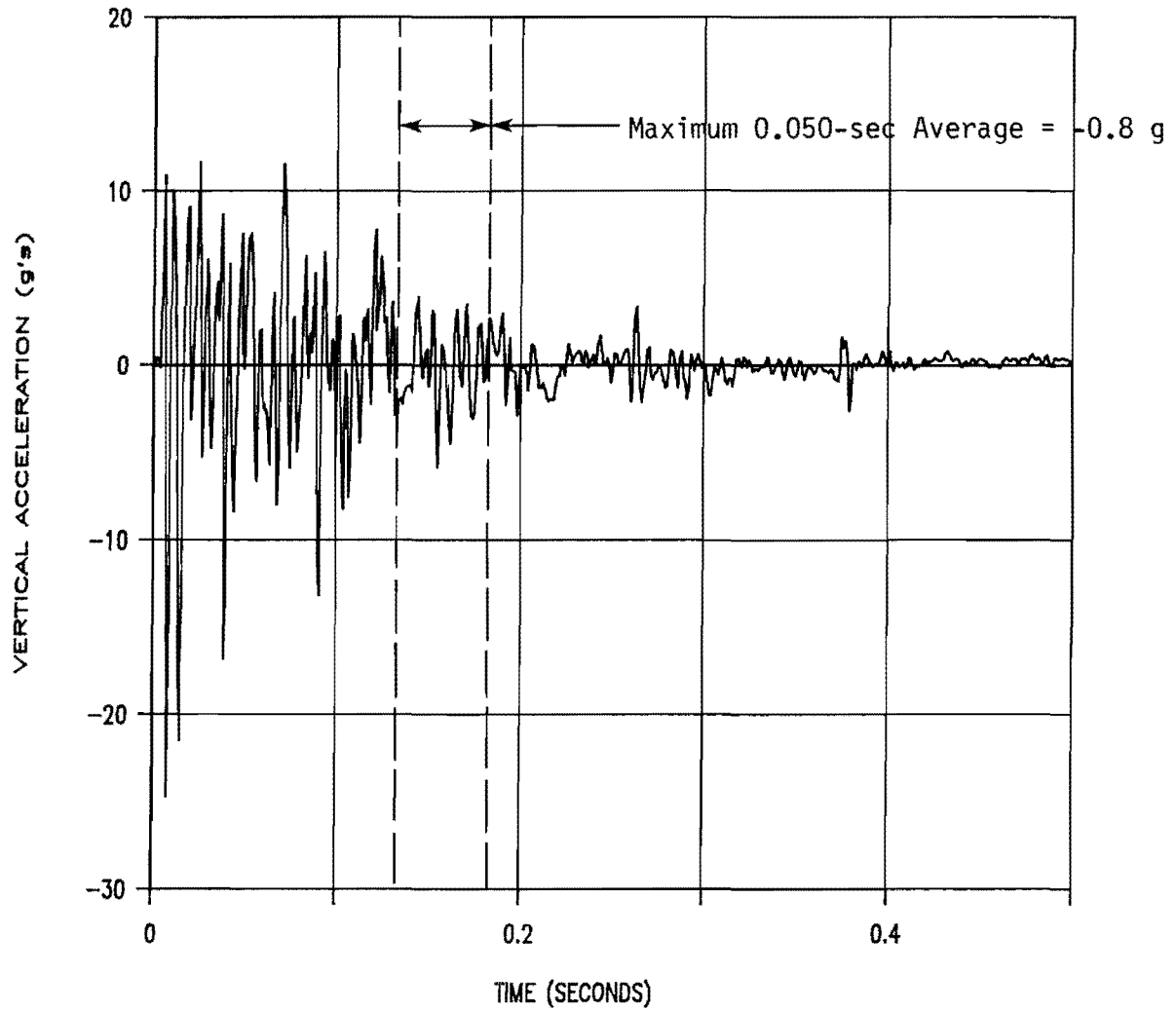


Figure 126. Vehicle vertical accelerometer trace for test 9910-3.

Energy Absorption Hexfoam (9910-08)

The TMA used during this test was manufactured by Energy Absorption (Hex-foam model) and is shown in Figures 2 and 127. The TMA was mounted on Truck No. 2 which had a gross static weight of 15,250 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 11.50 inches at the front and 12.00 inches at the rear. The height to the upper rear surface of the cartridge was 36.00 inches above ground.

The 1982 Honda Civic (pictured in Figure 127) was directed into the Energy Absorption Hex-foam TMA. The height to the lower edge of the vehicle bumper was 14.00 inches and 19.50 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 128.

The vehicle was travelling at a speed of 44.4 mi/h. Upon impact, the TMA began to crush and the impacting vehicle began to dive under the TMA. By 0.147 second the impacting vehicle bottomed-out and forward motion stopped at 0.182 second. The vehicle subsequently came to rest 5.5 ft behind the TMA. Sequential photographs of the test are shown in Figure 129.

The Energy Absorption Hex-foam TMA cartridge crushed a total of 58.80 inches during the test. The attachment frame on the cartridge was not damaged. The impacting vehicle received damage to the front bumper, hood, grill, radiator, the right and left front quarter panels and the right door. Maximum vehicle crush was 6.0 inches at bumper height. Figures 130 and 131 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 132. The maximum longitudinal 50-msec average acceleration experienced by the impacting vehicle was -16.5 g between 041 and 091 msec. Longitudinal occupant impact velocity was 45.3 ft/s at 093 msec and the maximum longitudinal ridedown acceleration was -17.3 g between 126 and 136 msec. Vehicle angular displacements are plotted in Figure 133 and accelerometer traces are displayed in Figures 134 through 136.



Figure 127. Vehicle before impact with Energy Absorption Hex-foam TMA (9910-8).

Date: _____ Test No.: 9910-8 VIN: JHMSR532XCS033250
 Make: Honda Model: Civic Year: 1982 Odometer: 135725
 Tire Size: P155/80R13 Ply Rating: _____ Bias Ply: _____ Belted: _____ Radial: x

Tire Condition: good x
 fair _____
 badly worn _____

Vehicle Geometry - inches

a 63.0 b 29.5
 c 88.5 d* 52.75
 e 29.0 f 147.0
 g _____ h 32.5
 i ----- j 29.0
 k 16.0 l 25.0
 m 19.5 n 3.5
 o 14.0 p 53.5
 r 22.75 s 14.25

Engine Type: 4 cylinder

Engine CID: _____

Transmission Type:

Automatic or Manual

FWD or RWD or 4WD

Body Type: _____

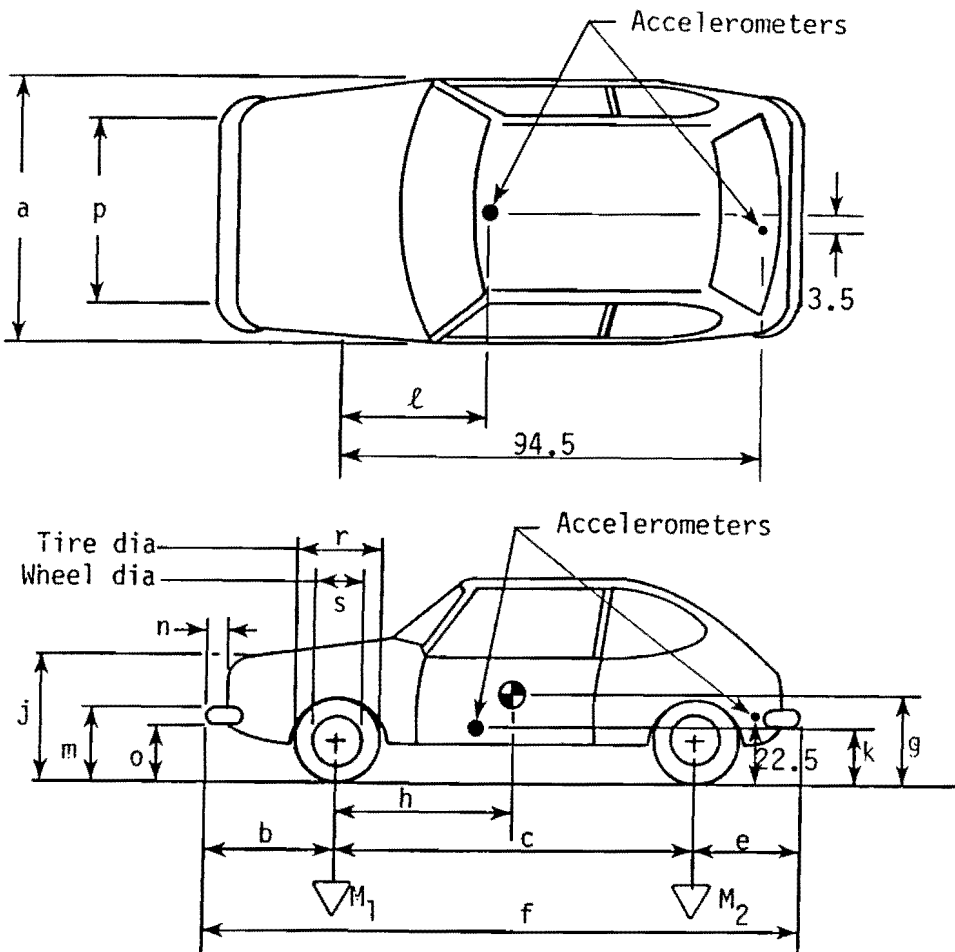
Steering Column Collapse Mechanism:

- Behind wheel units
- Convolute tube
- Cylindrical mesh units
- Embedded ball
- NOT collapsible
- Other energy absorption
- Unknown

Brakes:

Front: disc x drum _____

Rear: disc _____ drum x



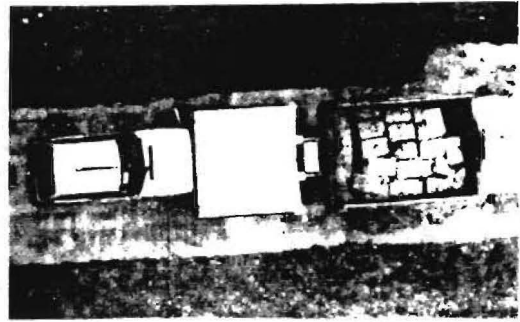
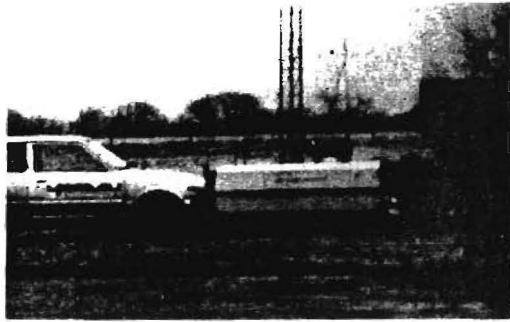
4-wheel weight for c.g. det. ℓf 560 rf 578 ℓr 343 rr 319

Mass - pounds	Curb	Test Inertial	Gross Static
M_1	<u>1207</u>	<u>1138</u>	_____
M_2	<u>652</u>	<u>662</u>	_____
M_T	<u>1859</u>	<u>1800</u>	_____

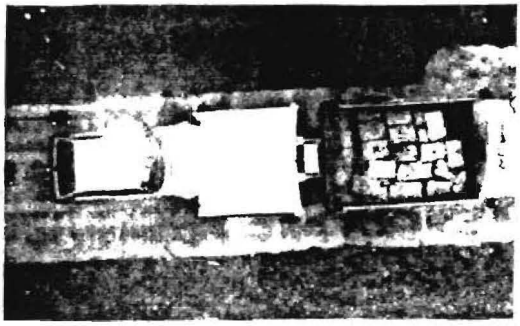
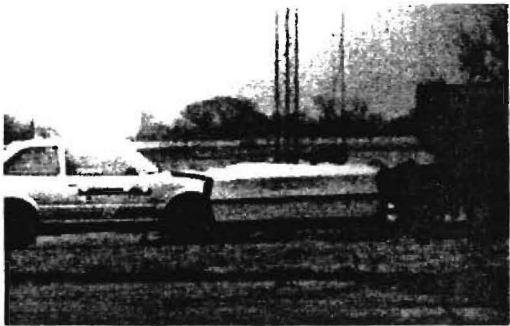
Note any damage to vehicle prior to test:

*d = overall height of vehicle

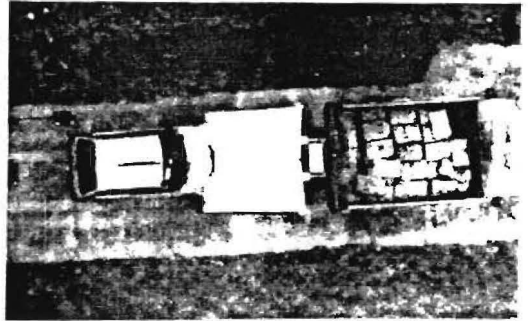
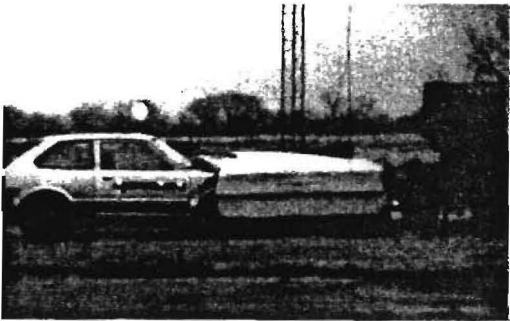
Figure 128. Vehicle properties for test 9910-8.



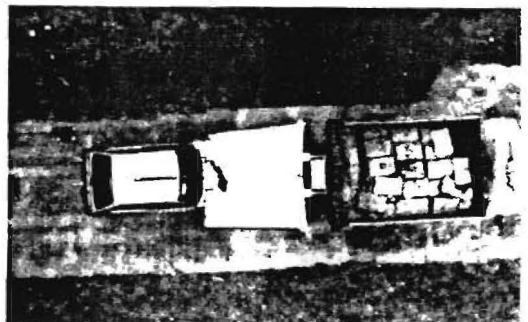
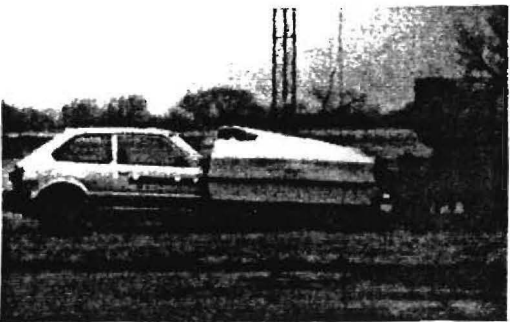
0.000 s



0.024 s



0.049 s

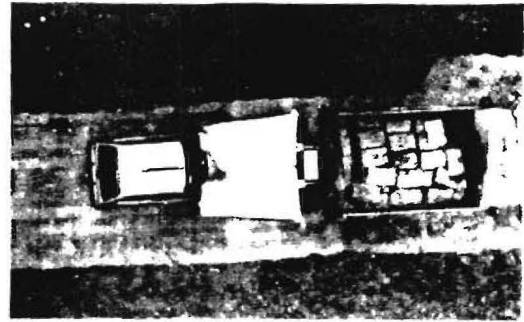


0.075 s

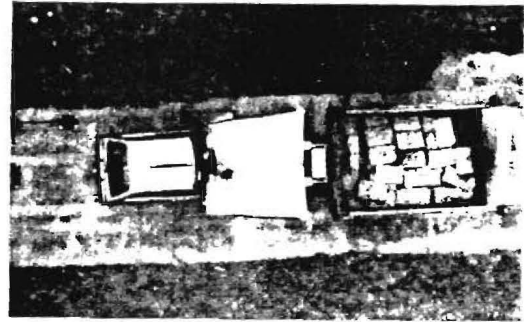
Figure 129 Sequential photographs for test 9910-8.



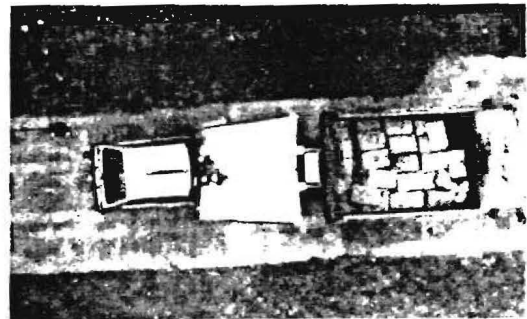
0.102 s



0.129 s



0.155 s



0.182 s

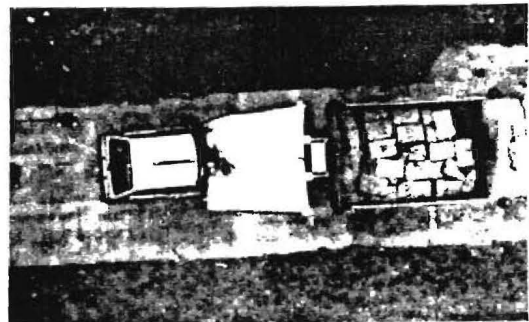


Figure 129 Sequential photographs
for test 9910-8.
(Continued)

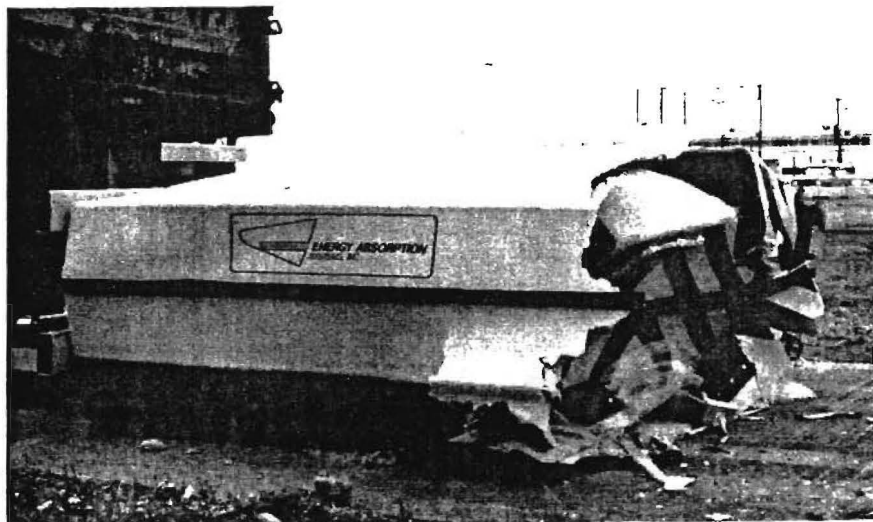
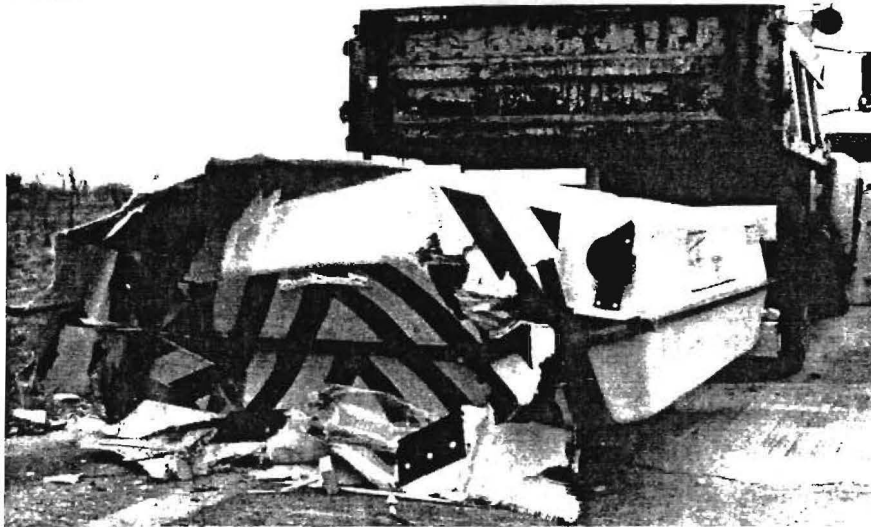
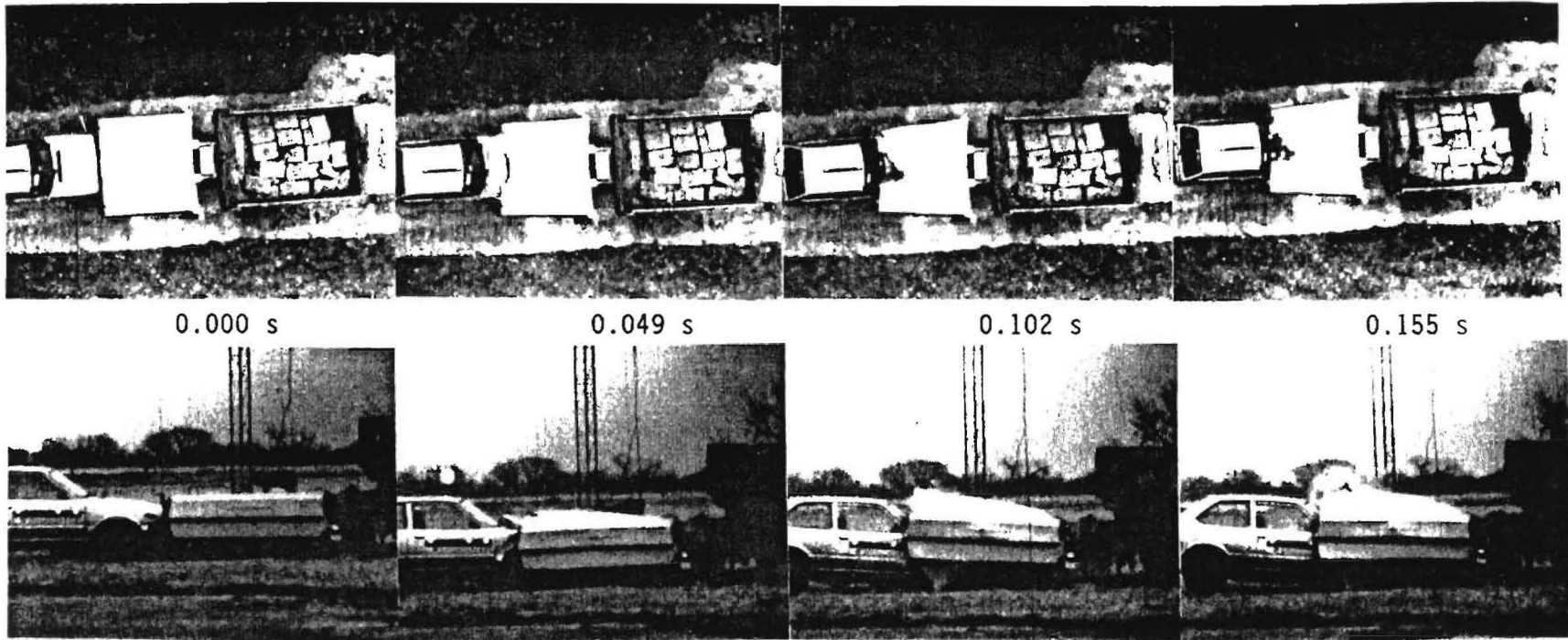


Figure 130. Energy Absorption Hex-foam TMA after test 9910-8.

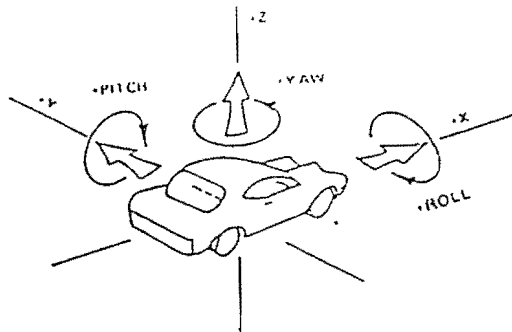


Figure 131. Vehicle after impact with Energy Absorption Hex-foam TMA (9910-8).



Test No.	09910-8	Maximum Truck Displacement .	N/A (fixed position)
Date	01/16/90	Maximum TMA Crush	58.8 in (1.5 m)
Test Article	Truck Mounted Attenuator	Vehicle Accelerations	
Manufacturer	Energy Absorption Hex-foam	(Maximum 50 ms Average at c.g.)	
TMA Truck	1980 Ford Dump Truck (#2)	Vehicle Longitudinal	-16.5 g
Weight without TMA	14,010 lb (6,361 kg)	Vehicle Lateral	-1.4 g
Weight with TMA	15,250 lb (6,924 kg)	Truck Cab Longitudinal	N/A
Test Vehicle	1982 Honda Civic	Occupant Impact Velocity	
Weight	1,800 lb (817 kg)	Longitudinal	45.3 ft/s (13.8 m/s)
Impact Speed	44.4 mi/h (71.4 km/h)	Lateral	7.4 ft/s (2.3 m/s)
Maximum Vehicle Crush	6.0 in (15.2 cm)	Occupant Ridedown Accelerations	
Vehicle Damage Classification		Longitudinal	-17.3 g
TAD	12FD2	Lateral	-1.7 g
CDC	12FDEW2		

Figure 132 Summary of results for test 9910-8.



Axes are vehicle fixed.
 Sequence for determining
 orientation is:

1. Yaw
2. Pitch
3. Roll

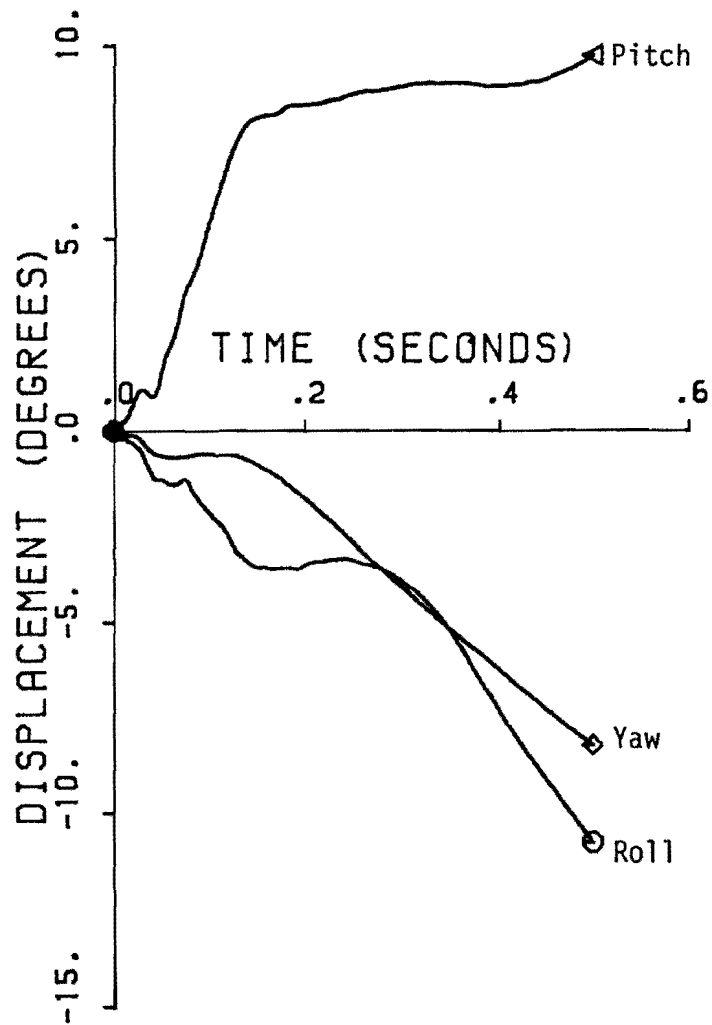


Figure 133. Vehicle angular displacement for test 9910-8.

TEST 9910-8

Class 180 Filter

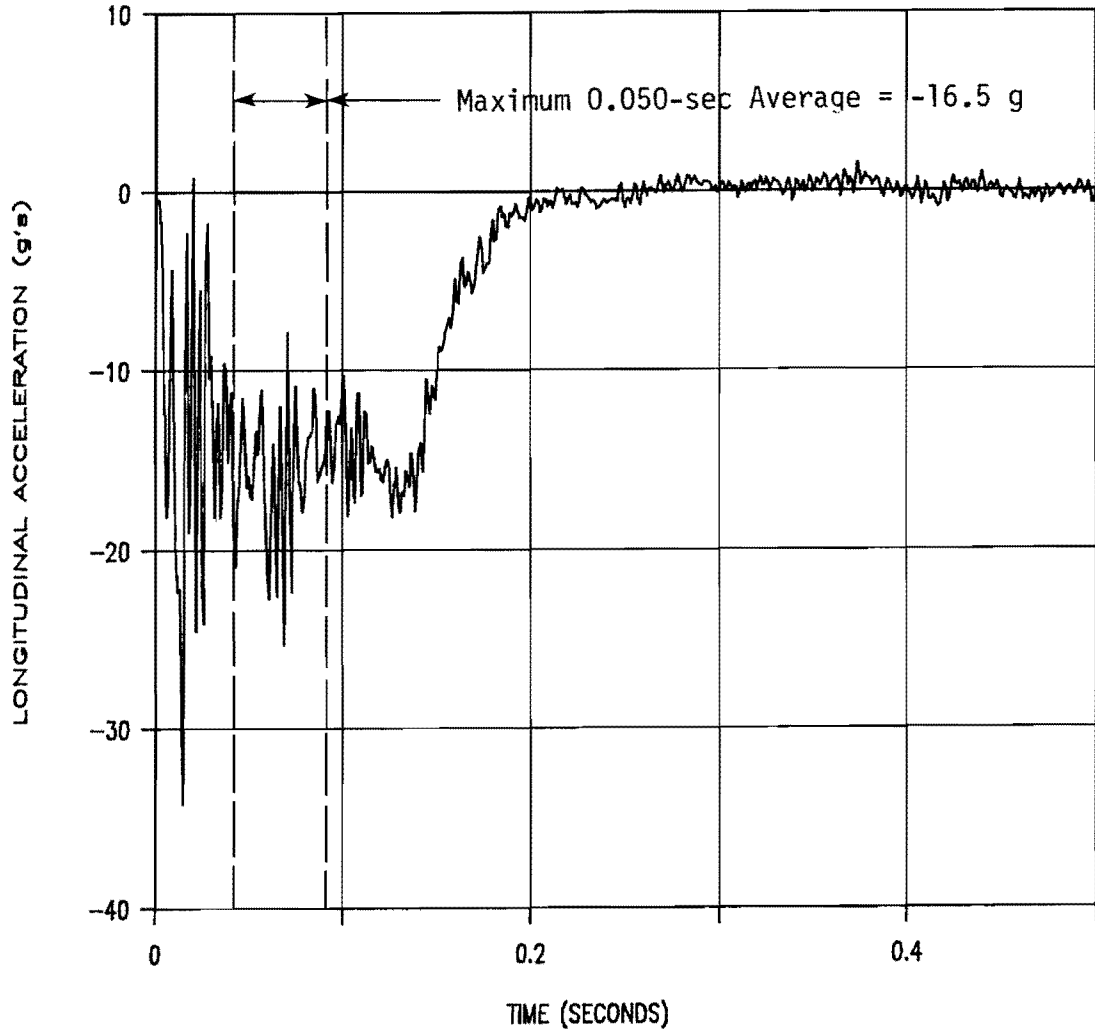


Figure 134. Vehicle longitudinal accelerometer trace for test 9910-8.

TEST 9910-8

Class 180 Filter

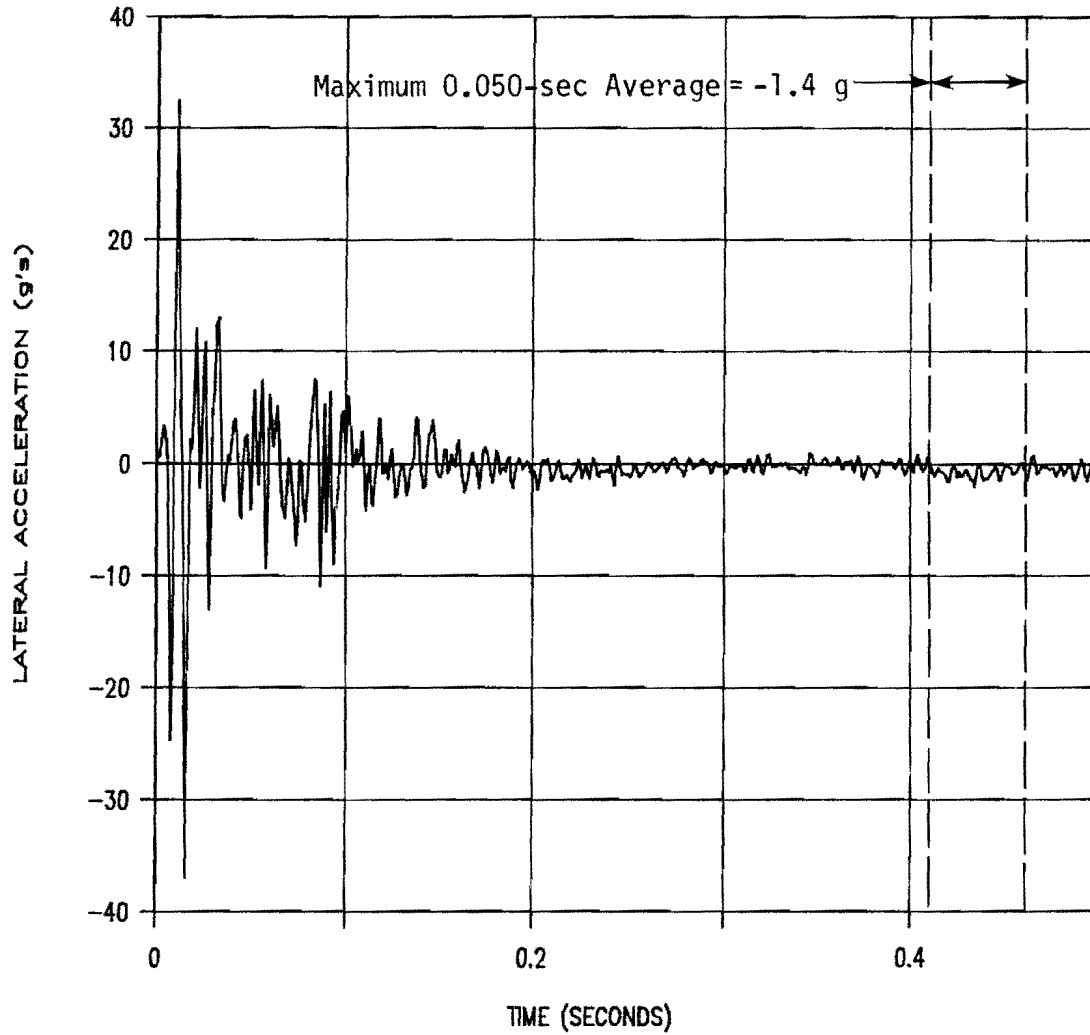


Figure 135. Vehicle lateral accelerometer trace for test 9910-8.

TEST 9910-8

Class 180 Filter

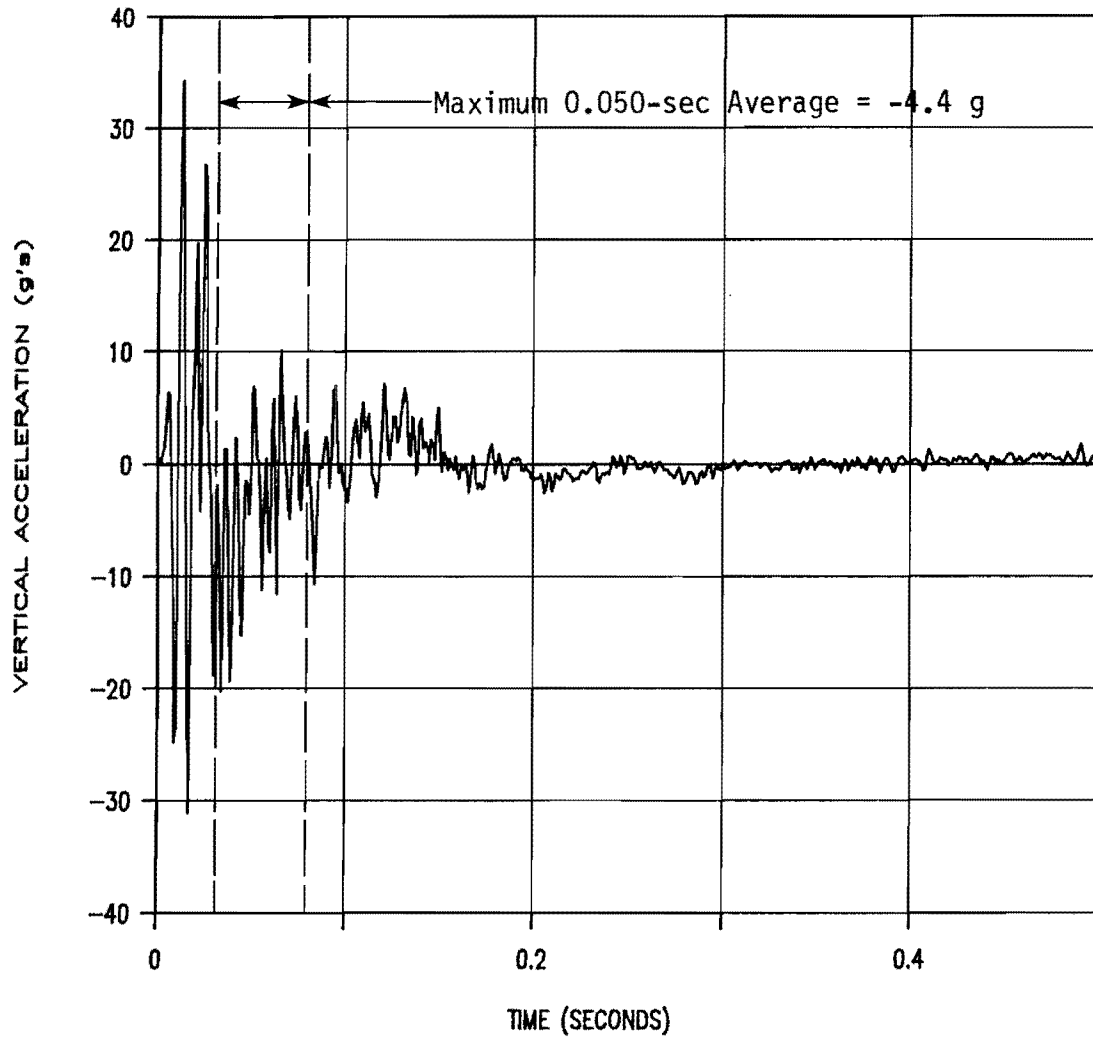


Figure 136. Vehicle vertical accelerometer trace for test 9910-8.

Hexcel 3000 (9910-05)

The Hexcel Model 3000 TMA used during this test is shown in Figure 3. The TMA was mounted on Truck No. 1 which had a gross static weight of 14,860 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 11.50 inches at the front and 12.00 inches at the rear. The height to the upper rear surface of the cartridge was 36.25 inches above ground.

The 1980 Honda Civic (pictured in Figure 137) was directed into the Hexcel Model 3000 TMA. The height to the lower edge of the vehicle bumper was 14.25 inches and 19.50 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 138.

The vehicle was travelling at a speed of 45.2 mi/h. Upon impact, the TMA began to crush and displace upward. The impacting vehicle began to dive under the TMA at 0.044 second and the rear of the truck began to rise at 0.109 second. Forward motion of the impacting vehicle stopped at 0.193 second. The vehicle subsequently came to rest under the TMA. Sequential photographs of the test are shown in Figure 139.

The Hexcel Model 3000 TMA cartridge crushed a total of 65.50 inches longitudinally and displaced upward during the test. The frame attachment to the cartridge was bent 0.25 inch on both sides. The impacting vehicle received damage to the front bumper, hood, grill, radiator, and the right and left front quarter panels. Maximum vehicle crush was 10.0 inches just above bumper height. Figures 140 and 141 show damage to the TMA and test vehicle.

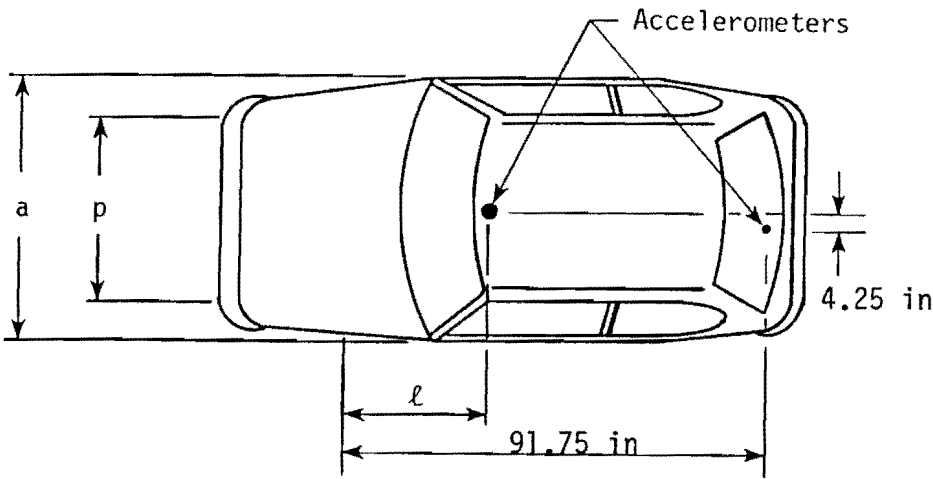
A summary of the test results and other information pertinent to this test are given in Figure 142. The maximum longitudinal 50-msec average acceleration experienced by the impacting vehicle was -13.3 g between 031 and 081 msec. Longitudinal occupant impact velocity was 39.1 ft/s at 101 msec and the maximum longitudinal ridedown acceleration was -11.6 g between 124 and 134 msec. Vehicle angular displacements are plotted in Figure 143 and accelerometer traces are displayed in Figures 144 and 145.



Figure 137 Vehicle before impact with
Hexcel Model 3000 TMA (9910-5).

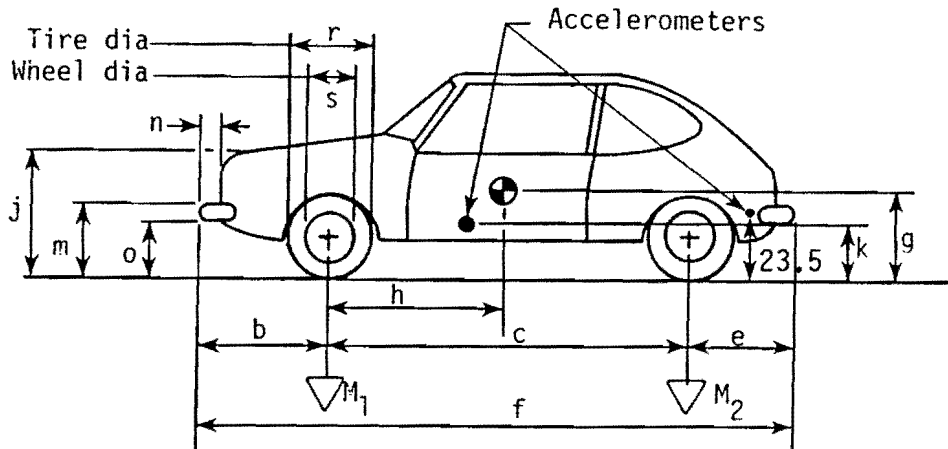
Date: _____ Test No.: 9910-5 VIN: JHMSL5322BS005720
 Make: Honda Model: Civic Year: 1980 Odometer: 214755
 Tire Size: 155 SR12 Ply Rating: _____ Bias Ply: _____ Belted: _____ Radial: X

Tire Condition: good _____
 fair X
 badly worn _____



Vehicle Geometry - inches

a	62 1/4	b	27 3/4
c	88 1/2	d*	52 3/4
e	29	f	145 1/4
g		h	33.3
i	----	j	30
k	16 1/2	l	29 1/2
m	19 1/2	n	5
o	14 1/4	p	53
r	21 1/2	s	13 1/4



Engine Type: 4 cyl
 Engine CID: _____
 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 578 rf 545 lr 342 rr 335

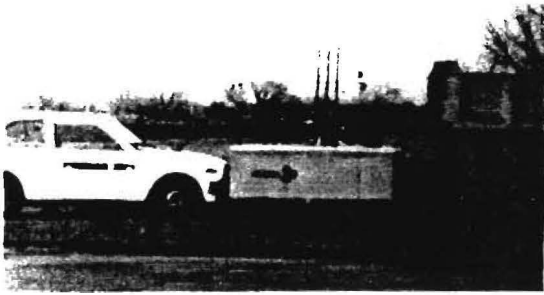
Mass - pounds	Curb	Test Inertial	Gross Static
M ₁	<u>1122</u>	<u>1123</u>	_____
M ₂	<u>667</u>	<u>677</u>	_____
M _T	<u>1789</u>	<u>1800</u>	_____

Note any damage to vehicle prior to test:

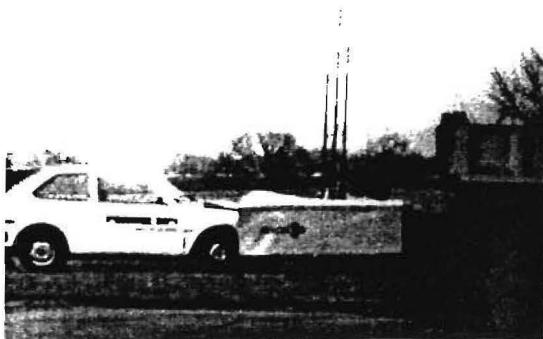
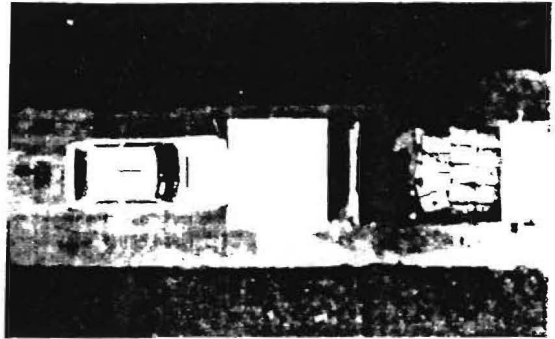
Crack in windshield

*d = overall height of vehicle

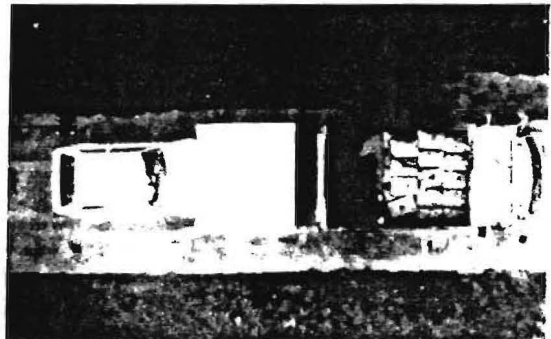
Figure 138 Test vehicle properties (test 9910-5).



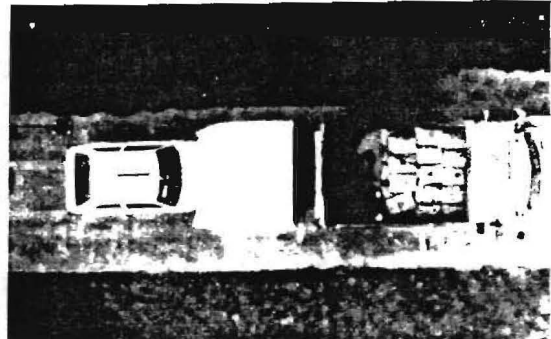
0.000 s



0.024 s



0.048 s



0.073 s

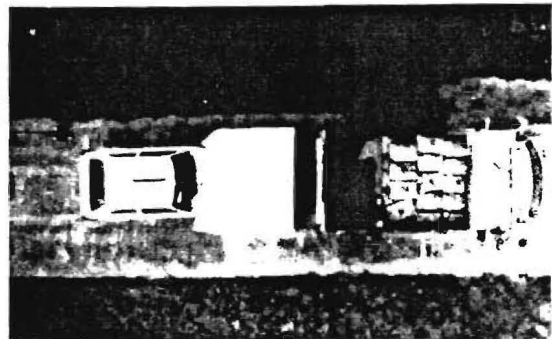
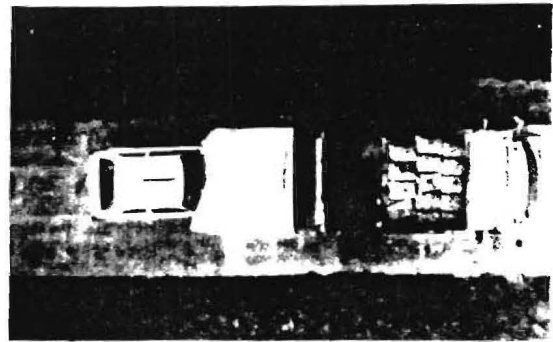
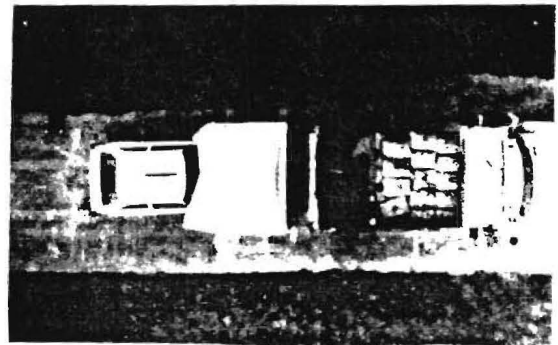
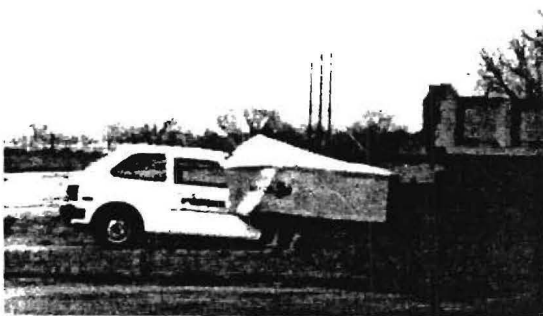


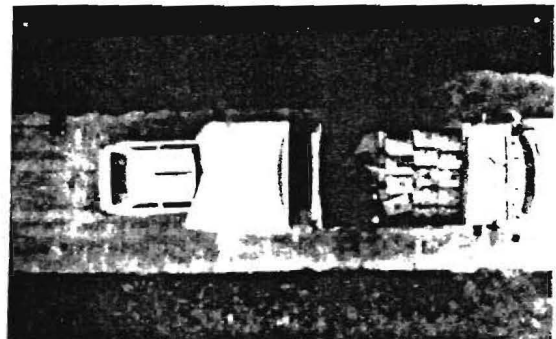
Figure 139 Sequential photographs for test 9910-5.



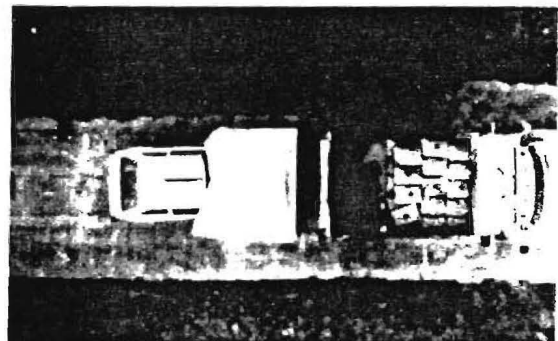
0.097 s



0.121 s



0.157 s



0.193 s

Figure 139. Sequential photographs for test 9910-5.
(Continued)

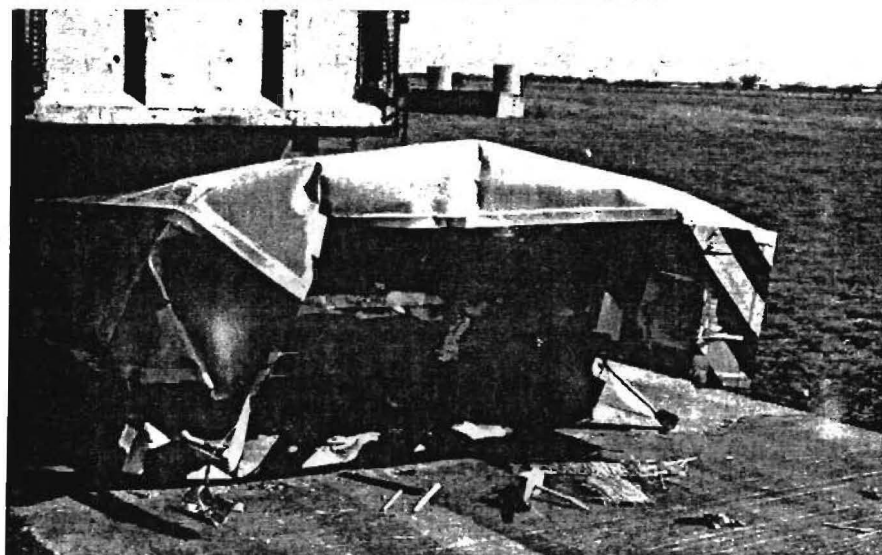
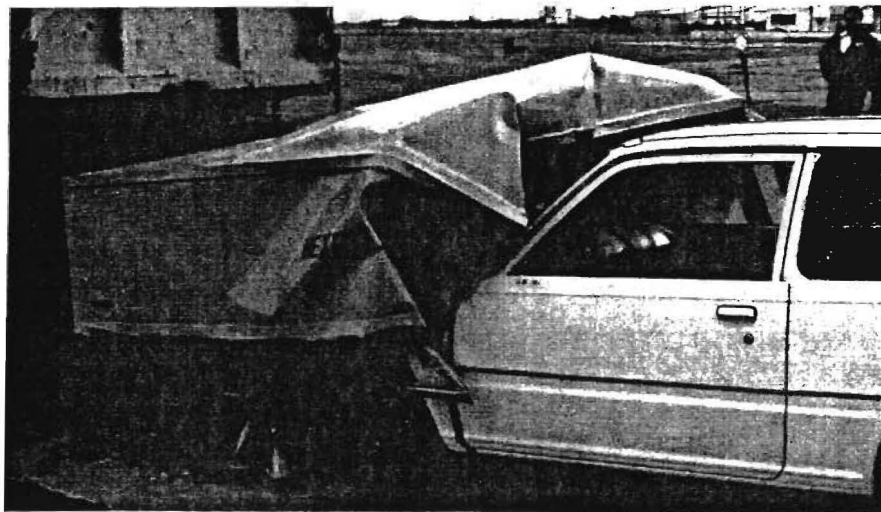
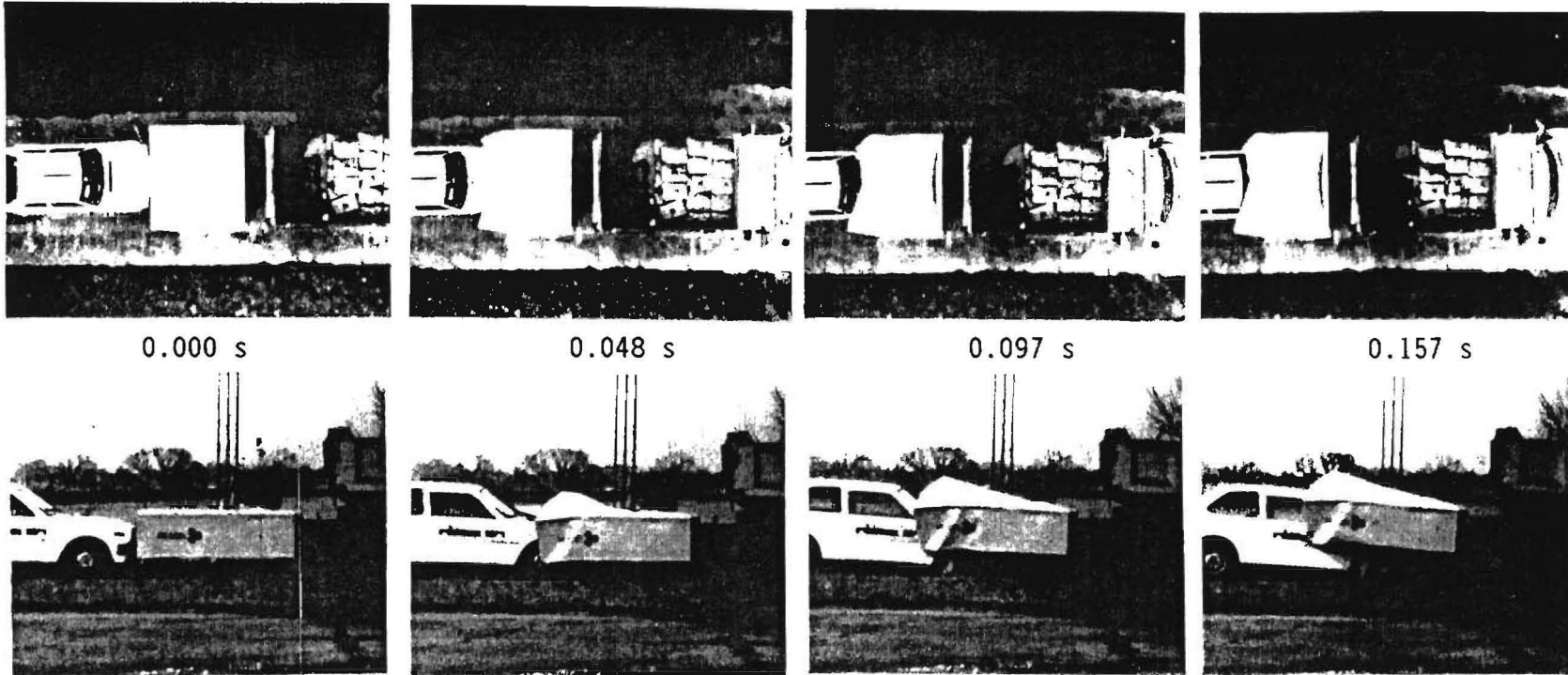


Figure 140 Hexcel Model 3000 TMA
after test 9910-5.



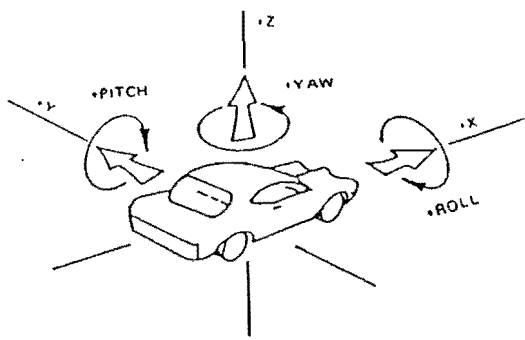
Figure 141 Vehicle after impact with
Hexcel Model 3000 TMA (9910-5).



173

Test No.	09910-5	Maximum Truck Displacement .	N/A (fixed position)
Date	02/13/90	Maximum TMA Crush	65.5 in (1.7 m)
Test Article	Truck Mounted Attenuator	Vehicle Accelerations	
Manufacturer	Hexcel Model 3000	(Maximum 50 ms Average at c.g.)	
TMA Truck	1981 Ford Dump Truck (#1)	Vehicle Longitudinal . . .	-13.3 g
Weight without TMA .	14,010 lb (6,361 kg)	Vehicle Lateral	-1.2 g
Weight with TMA . . .	14,860 lb (6,746 kg)	Truck Cab Longitudinal . .	N/A
Test Vehicle	1980 Honda Civic	Occupant Impact Velocity	
Weight	1,800 lb (817 kg)	Longitudinal	39.1 ft/s (11.9 m/s)
Impact Speed	45.2 mi/h (72.7 km/h)	Lateral	2.6 ft/s (0.8 m/s)
Maximum Vehicle Crush .	10.0 in (25.4 cm)	Occupant Ridedown Accelerations	
Vehicle Damage Classification		Longitudinal	-11.6 g
TAD	12FD4	Lateral	-1.2 g
CDC	12FDEW4		

Figure 142 Summary of results for test 9910-5.



Axes are vehicle fixed.
 Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

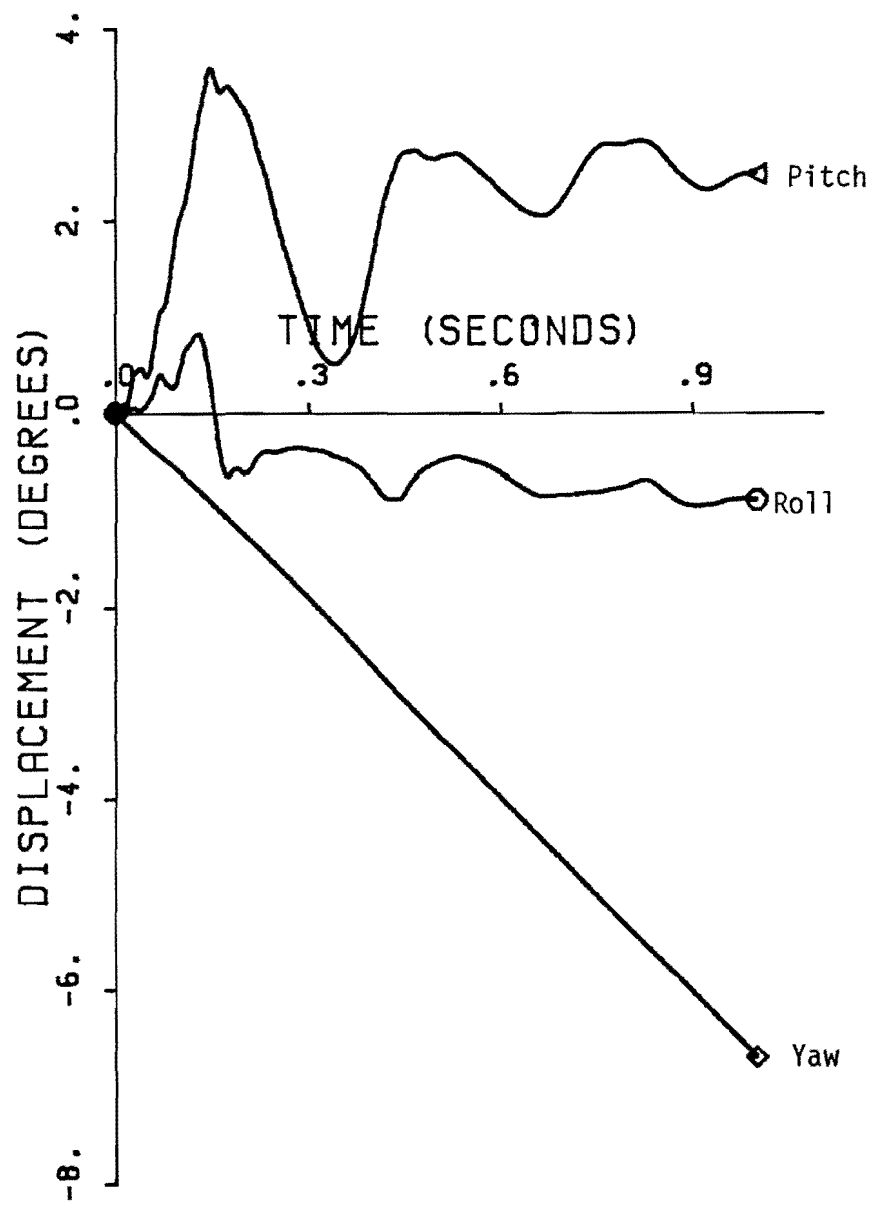


Figure 143. Vehicle angular displacements for test 9910-5.

TEST 9910-5

Class 180 Filter

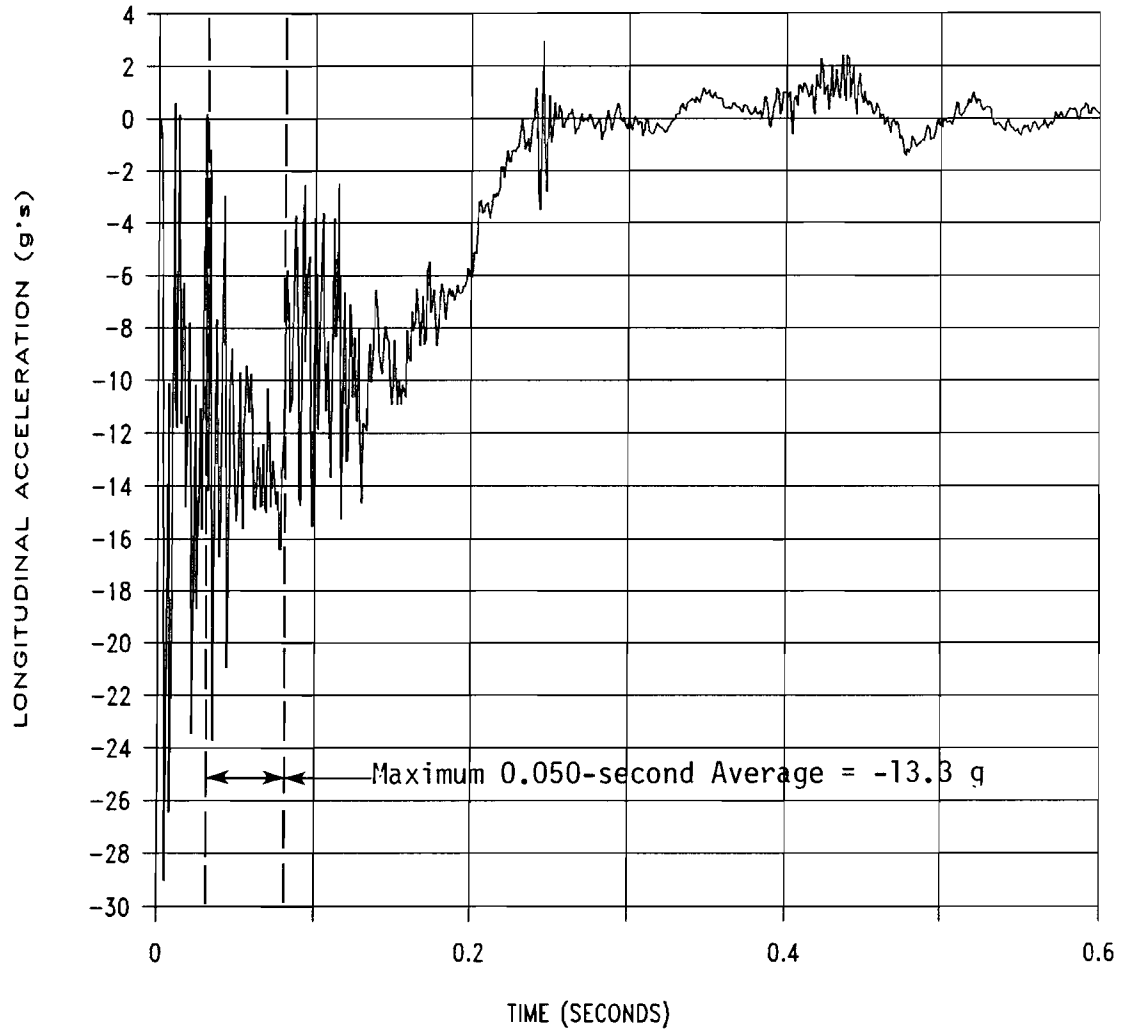


Figure 144 Longitudinal accelerometer trace for test 9910-5.

TEST 9910-5

Class 180 Filter

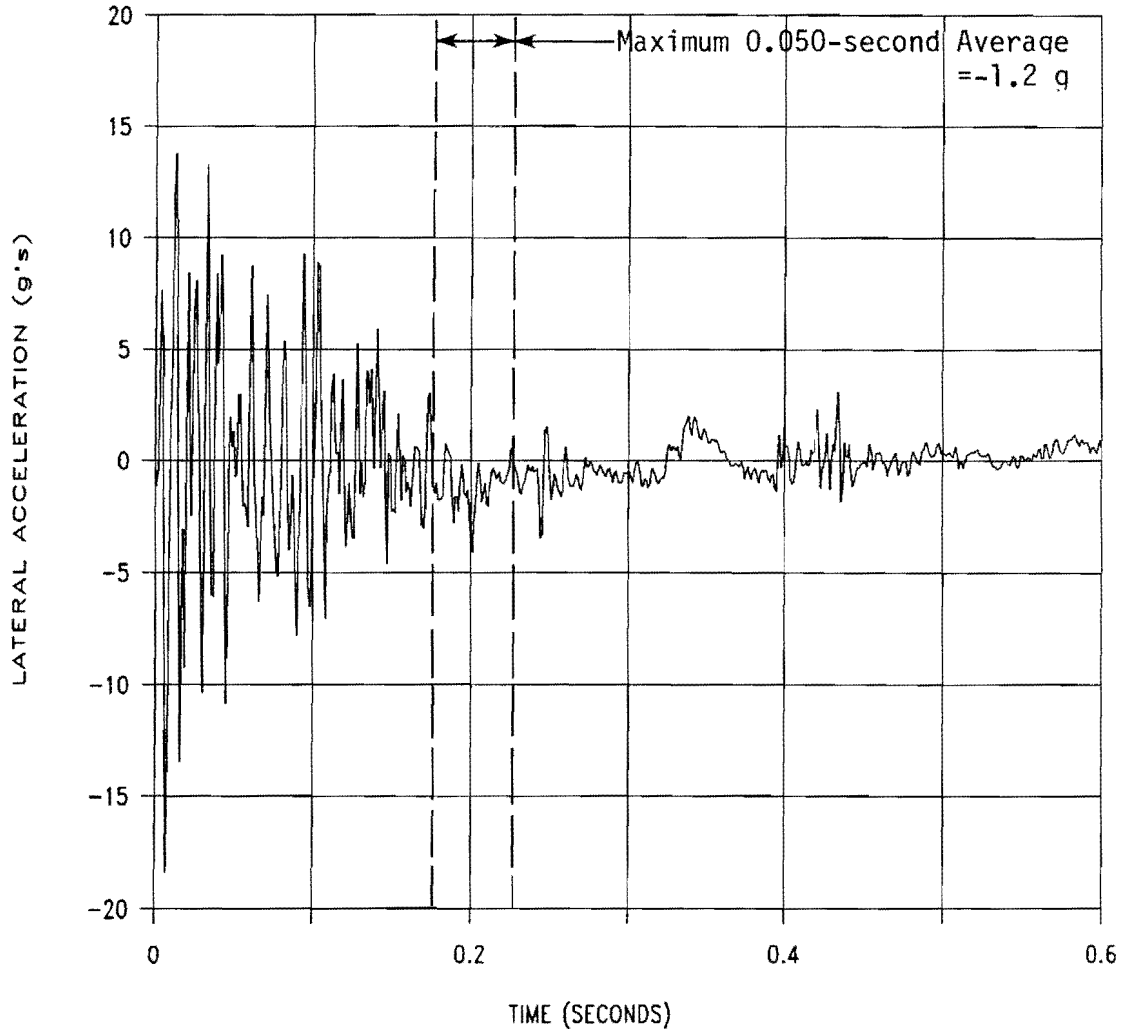


Figure 145 Lateral accelerometer trace for test 9910-5.

Hexcel 4000 (9910-07)

The Hexcel Model 4000 TMA was used during this test and is shown in Figure 4. The TMA was mounted Truck No. 1 which had a gross static weight of 14,820 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 11.75 inches at the front and 12.50 inches at the rear. The height to the upper rear surface of the cartridge was 37.00 inches above ground.

The 1980 Honda Civic (pictured in Figure 146) was directed into the Hexcel Model 4000 TMA. The height to the lower edge of the vehicle bumper was 14.50 inches and 20.25 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 147.

The vehicle was travelling at a speed of 46.4 mi/h. Upon impact, the TMA began to crush and displace upward. The impacting vehicle began to dive under the TMA at 0.029 second and the front of the vehicle bottomed-out at 0.094 second. The rear of the truck also began to rise at 0.094 second. At 0.266 second the rear of the impacting vehicle bottomed-out. Forward motion of the impacting vehicle stopped at 0.213 second. The vehicle subsequently came to rest under the TMA. Sequential photographs of the test are shown in Figure 148.

The Hexcel Model 4000 TMA cartridge crushed a total of 69.50 inches longitudinally and displaced upward during the test. The frame attachment to the cartridge was bent 0.25 inch on both sides. The impacting vehicle received damage to the front bumper, hood, grill, radiator, and the right and left front quarter panels. The hood of the vehicle had been pushed back during the test and had crushed the windshield and bent the roof above the windshield. Maximum vehicle crush was 16.0 inches at bumper height on the right side. Figures 149 and 150 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 151. The maximum longitudinal 50-msec average acceleration experienced by the impacting vehicle was -15.6 g between 018 and 068 msec. Longitudinal occupant impact velocity was 40.8 ft/s at 099 msec and the maximum longitudinal ridedown acceleration was -9.9 g between 142 and 152 msec. Vehicle angular displacements are plotted in Figure 152 and accelerometer traces are displayed in Figures 153 through 155.

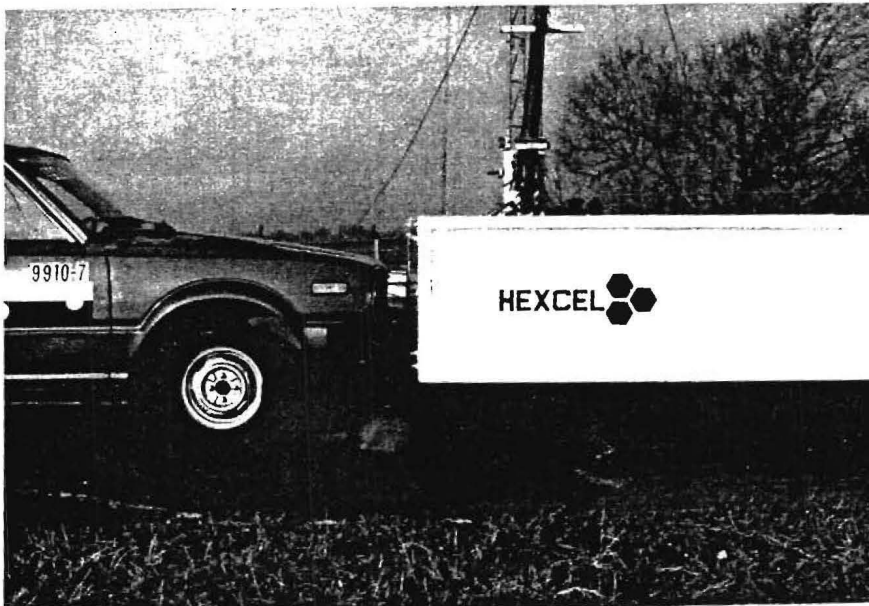
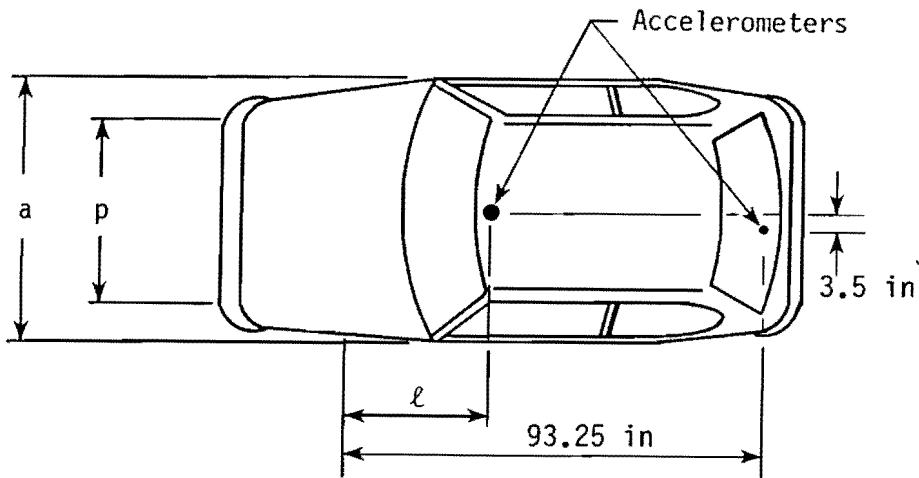


Figure 146. Vehicle before impact with Hexcel Model 4000 TMA (9910-7).

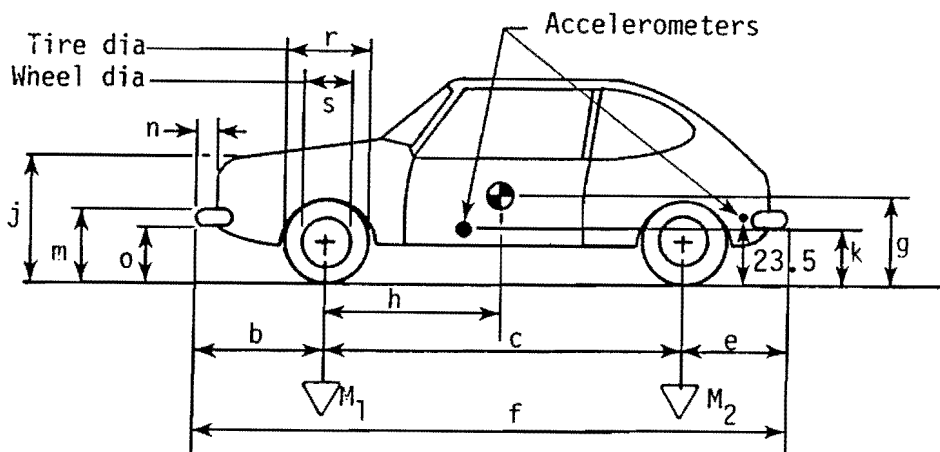
Date: _____ Test No.: 9910-7 VIN: SLA1038383
 Make: Honda Model: Civic Year: 1980 Odometer: 457177
 Tire Size: P155/80R12 Ply Rating: _____ Bias Ply: _____ Belted: _____ Radial: X

Tire Condition: good _____
 fair X
 badly worn _____



Vehicle Geometry - inches

a	<u>62 1/4</u>	b	<u>29 1/2</u>
c	<u>88 1/4</u>	d*	<u>52</u>
e	<u>28 1/2</u>	f	<u>146 1/4</u>
g	_____	h	<u>36</u>
i	_____	j	<u>30</u>
k	<u>16</u>	l	<u>27 1/2</u>
m	<u>20 1/4</u>	n	<u>4</u>
o	<u>14 1/2</u>	p	<u>54</u>
r	<u>21</u>	s	<u>13 1/4</u>



Engine Type: 4 cyl

Engine CID: _____

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

4-wheel weight for c.g. det. lf 566 rf 500 lr 346 rr 388

Mass - pounds	Curb	Test Inertial	Gross Static
M ₁	<u>1059</u>	<u>1066</u>	_____
M ₂	<u>659</u>	<u>734</u>	_____
M _T	<u>1718</u>	<u>1800</u>	_____

Note any damage to vehicle prior to test:

Crack in windshield

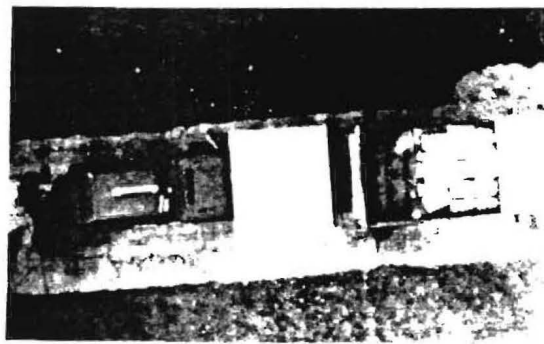
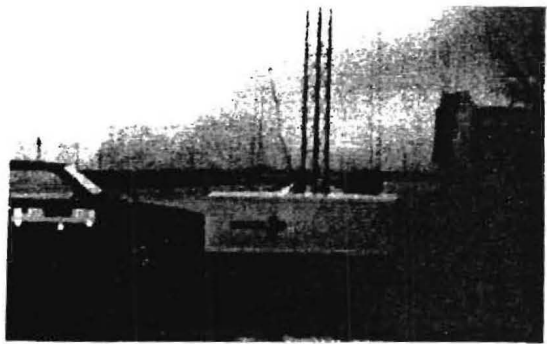
Brakes:

Front: disc X drum _____

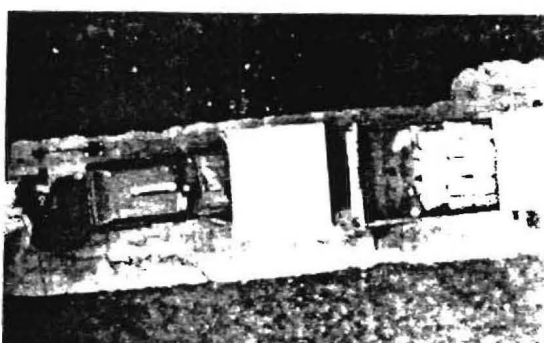
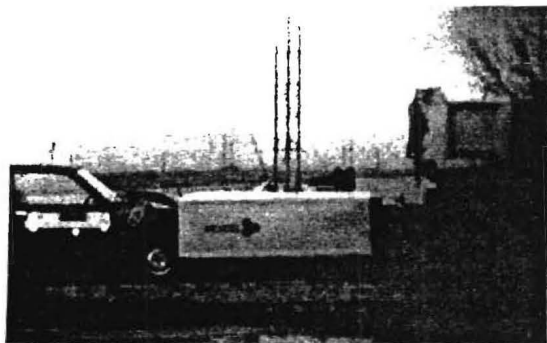
Rear: disc _____ drum X

*d = overall height of vehicle

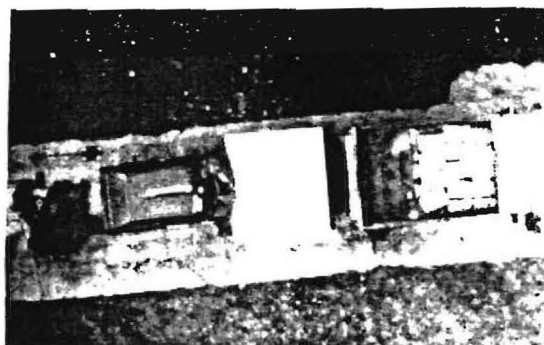
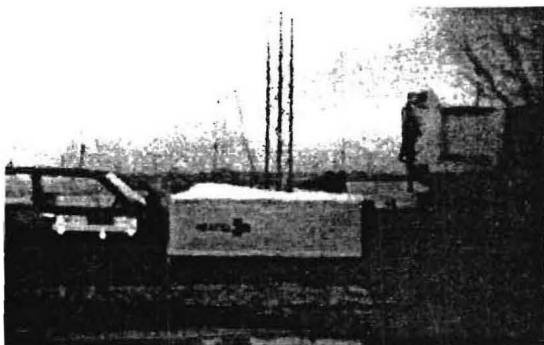
Figure 147 Test vehicle properties (test 9910-7).



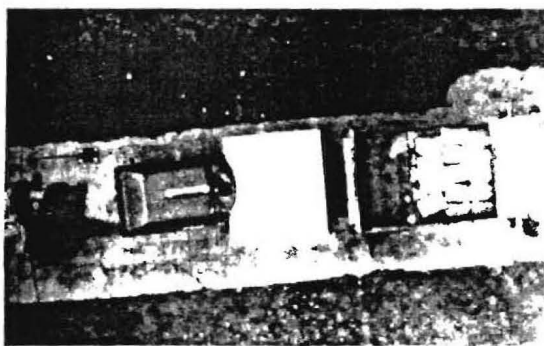
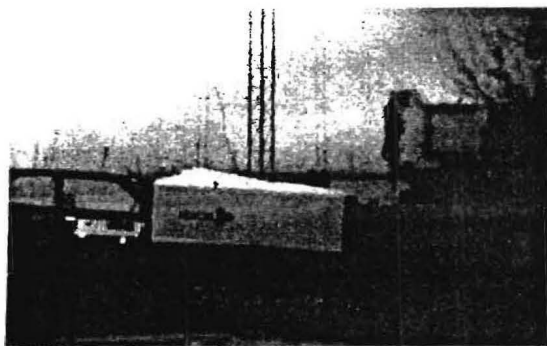
0.000 s



0.024 s

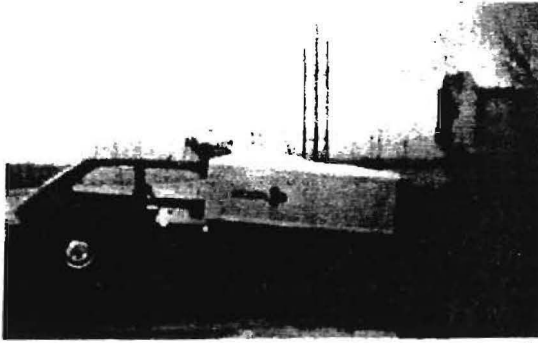


0.048 s

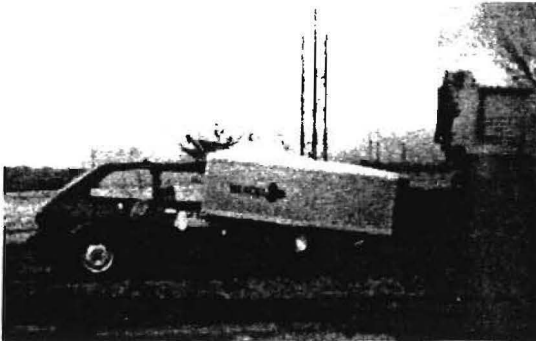
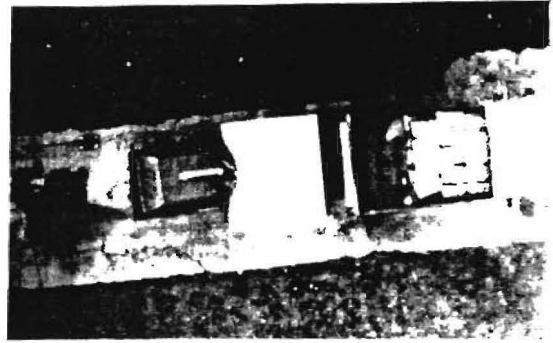


0.085 s

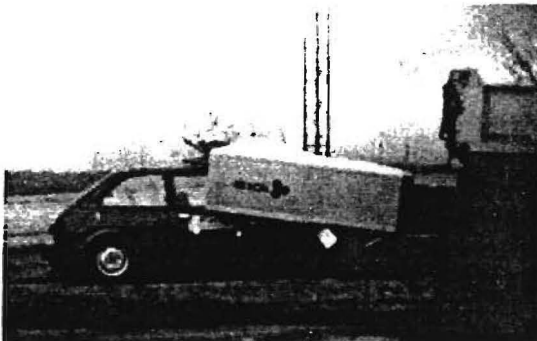
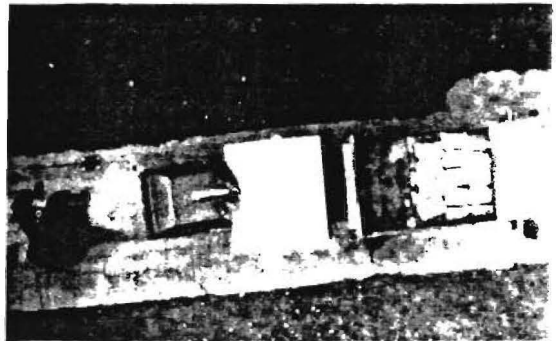
Figure 148. Sequential photographs for test 9910-7.



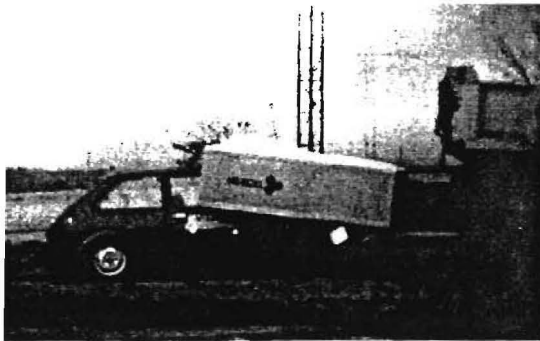
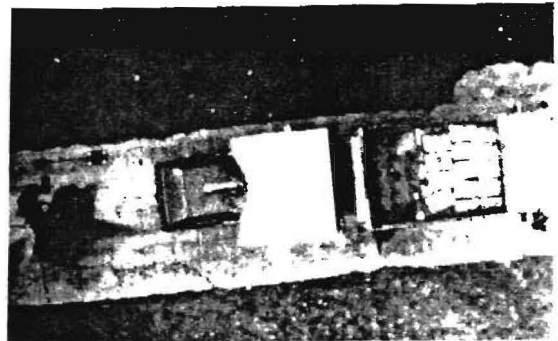
0.121 s



0.157 s



0.194 s



0.230 s

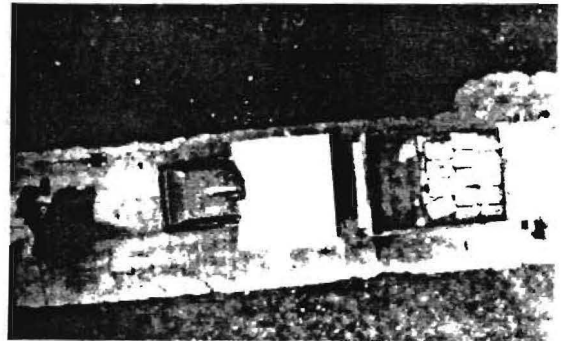


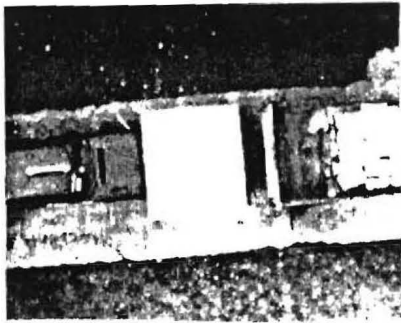
Figure 148 Sequential photographs for test 9910-7.
(Continued)



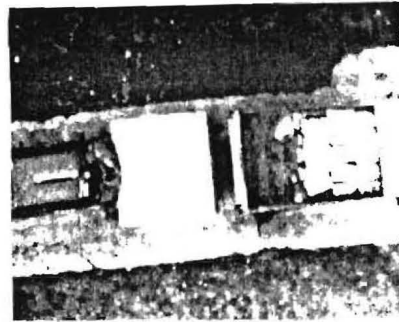
Figure 149. Hexcel Model 4000 TMA after test 9910-7.



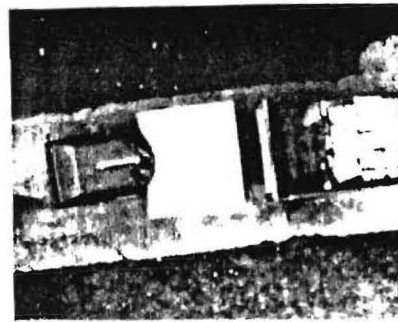
Figure 150. Vehicle after impact with Hexcel Model 4000 TMA (9910-7).



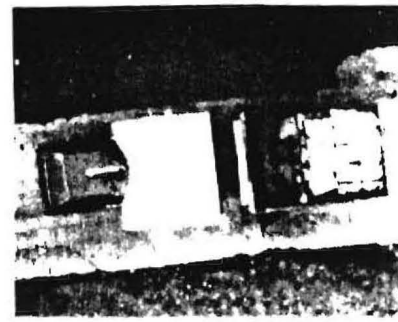
0.000 s



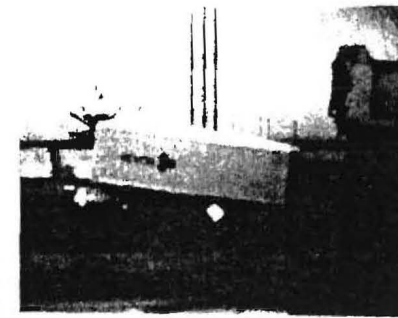
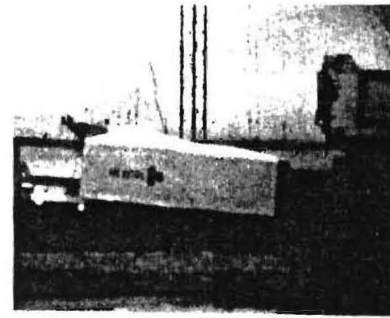
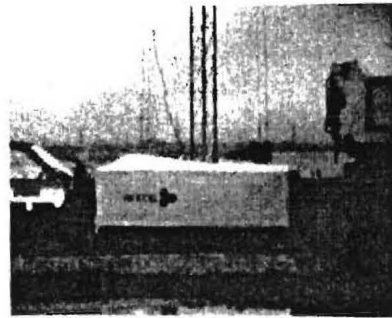
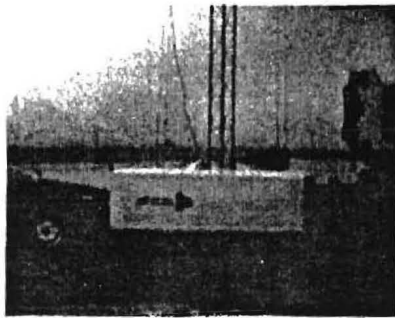
0.048 s



0.121 s



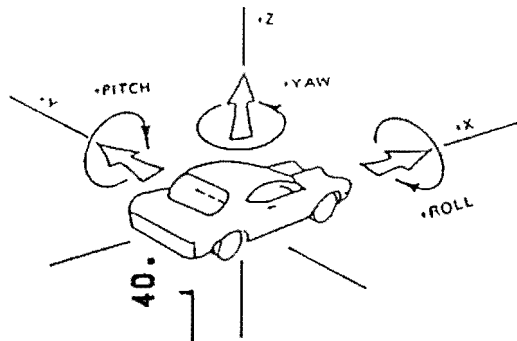
0.194 s



Test No. 09910-7
 Date 02/15/90
 Test Article Truck Mounted Attenuator
 Manufacturer Hexcel Model 4000
 TMA Truck 1981 Ford Dump Truck (#1)
 Weight without TMA 14,010 lb (6,361 kg)
 Weight with TMA 14,820 lb (6,728 kg)
 Test Vehicle 1980 Honda Civic
 Weight 1,800 lb (817 kg)
 Impact Speed 46.4 mi/h (74.7 km/h)
 Maximum Vehicle Crush 13.0 in (33.0 cm)
 Vehicle Damage Classification
 TAD 12FD6
 CDC 12FDEW4

Maximum Truck Displacement N/A (fixed position)
 Maximum TMA Crush 69.5 in (1.8 m)
 Vehicle Accelerations
 (Maximum 50 ms Average at c.g.)
 Vehicle Longitudinal -15.6 g
 Vehicle Lateral -2.8 g
 Truck Cab Longitudinal N/A
 Occupant Impact Velocity
 Longitudinal 40.8 ft/s (12.4 m/s)
 Lateral 8.2 ft/s (2.5 m/s)
 Occupant Ridedown Accelerations
 Longitudinal -9.9 g
 Lateral 1.4 g

Figure 151 Summary of results for test 9910-7.



Axes are vehicle fixed.
 Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

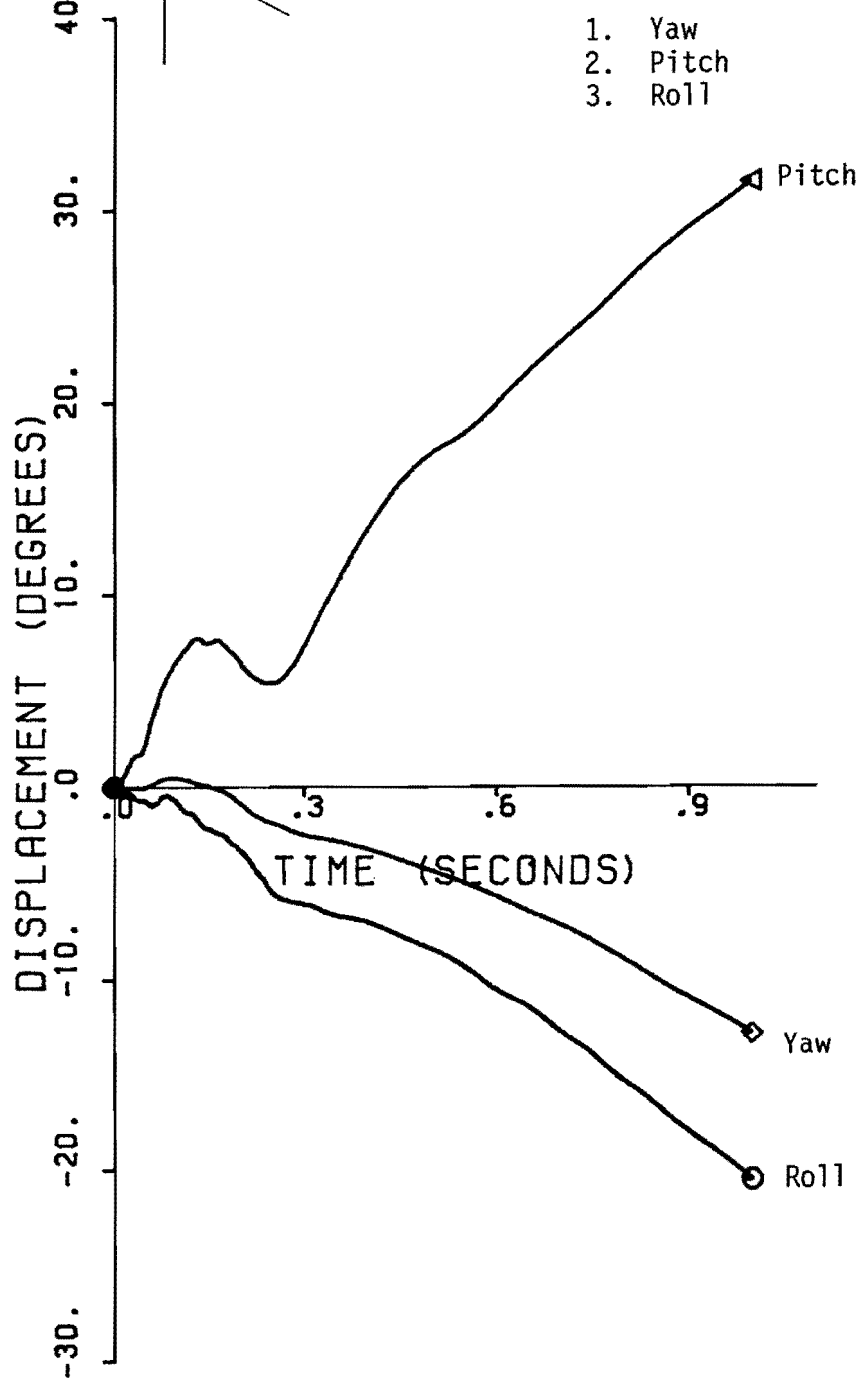


Figure152. Vehicle angular displacements for test 9910-7.

TEST 9910-7

Class 180 Filter

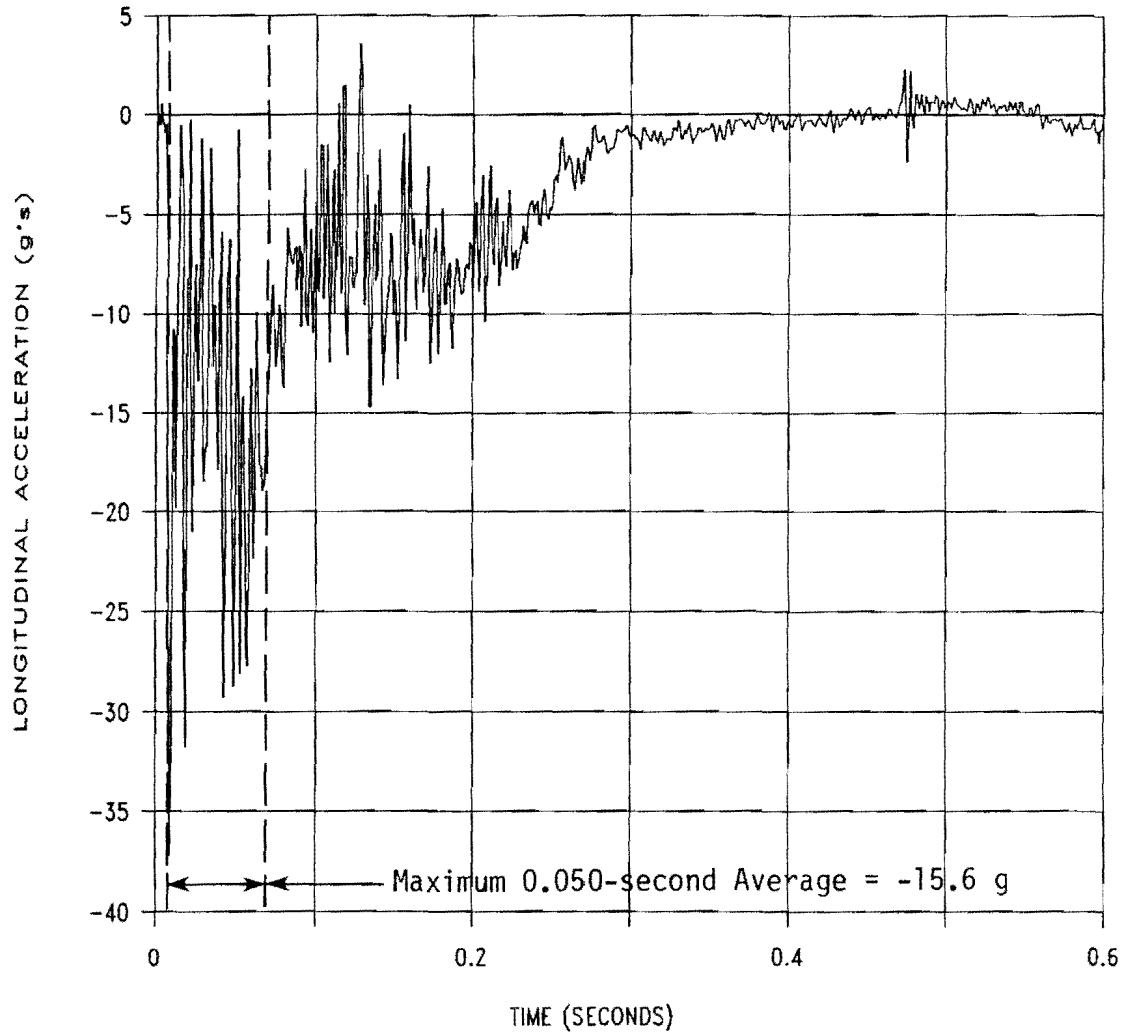


Figure 153. Longitudinal accelerometer trace for test 9910-7.

TEST 9910-7

Class 180 Filter

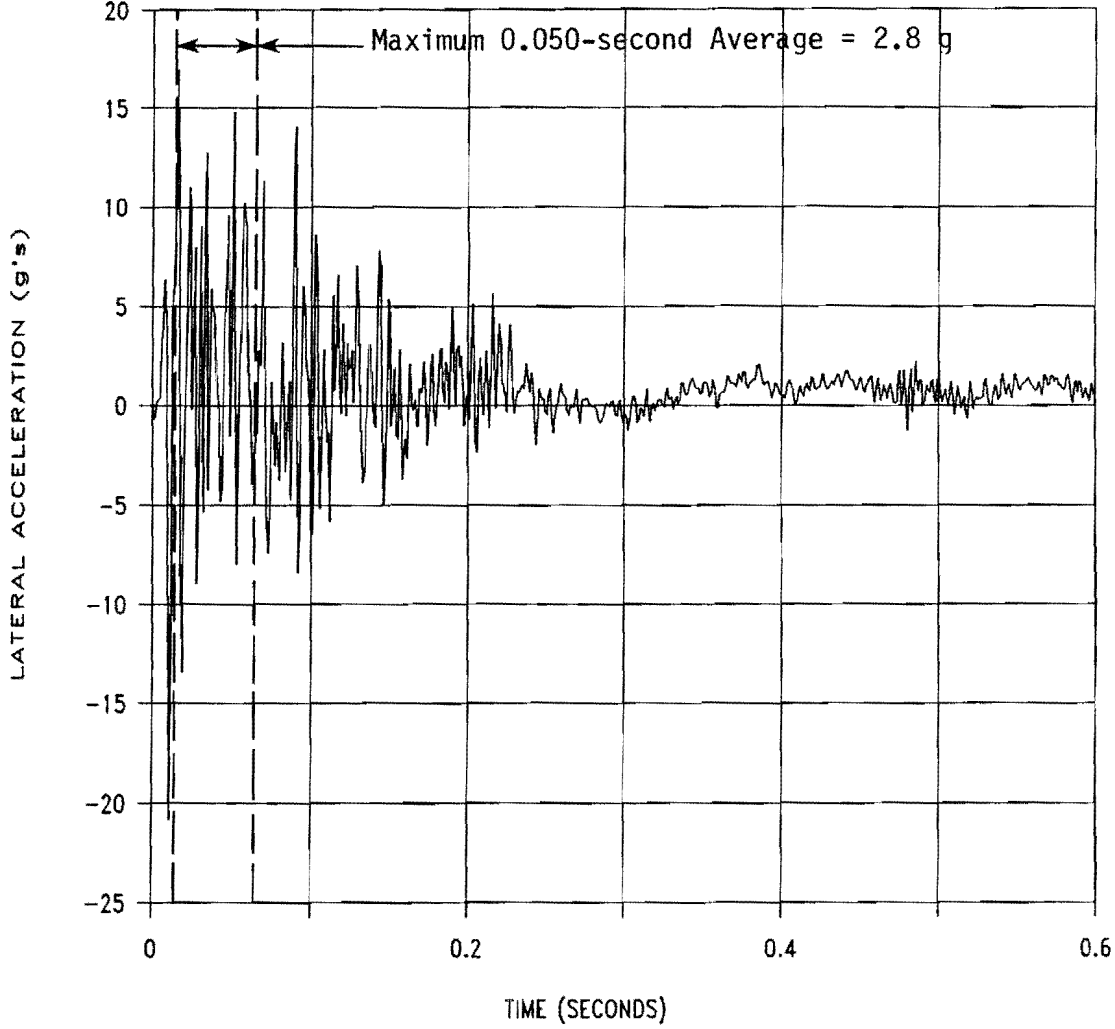


Figure 154 Lateral accelerometer trace for test 9910-7.

TEST 9910-7

Class 180 Filter

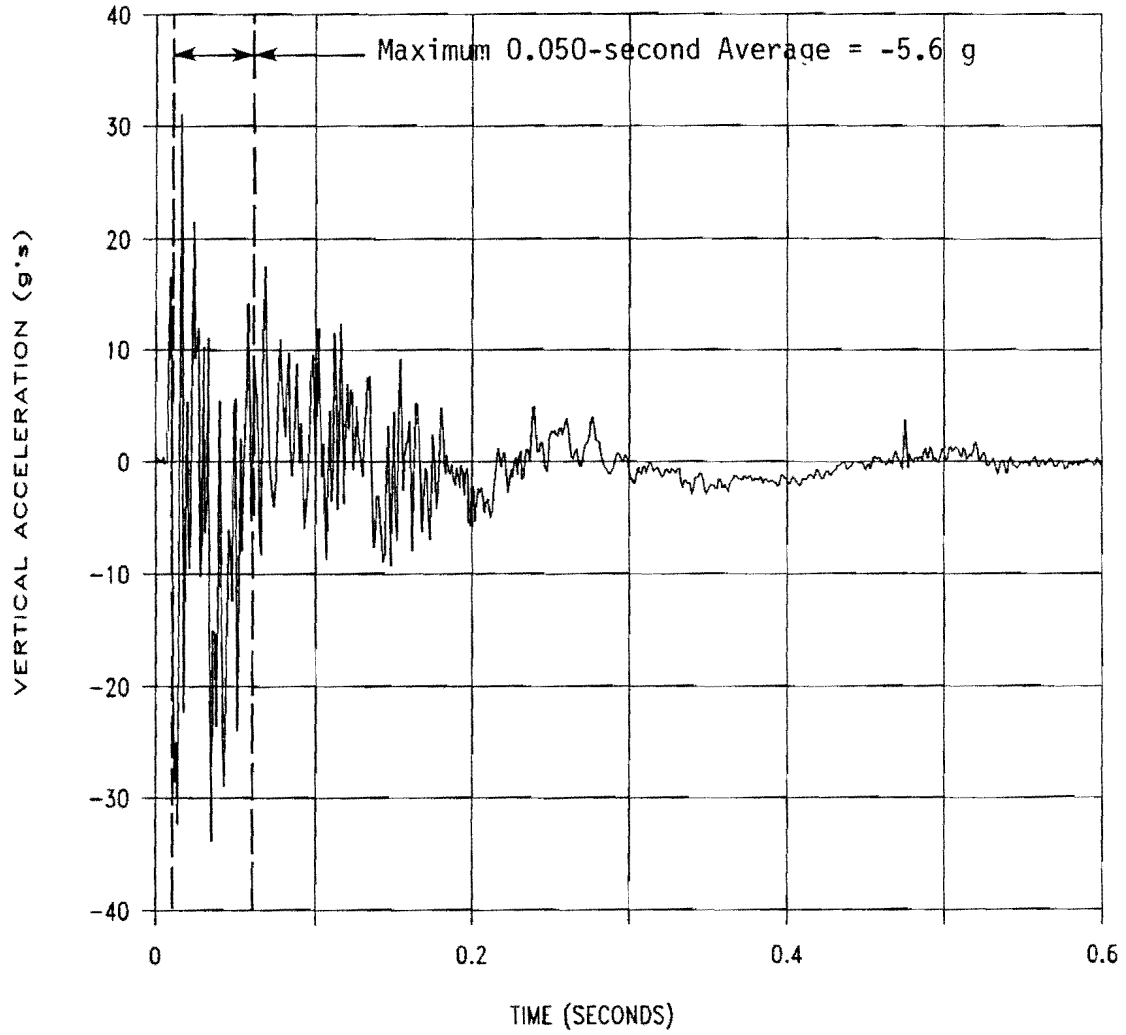


Figure 155. Vertical accelerometer trace for test 9910-7.

Renco (9910-02)

The TMA used during this test was manufactured by Renco and is shown in Figures 5 and 156. The TMA was mounted on Truck No. 1 which had a gross static weight of 15,260 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 11.00 inches at the front and 12.00 inches at the rear. The height to the upper rear surface of the cartridge was 36.00 inches above ground.

The 1981 Honda Civic (pictured in Figure 156) was directed into the Renco TMA. The height to the lower edge of the vehicle bumper was 13.25 inches and 18.25 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 157.

The vehicle was travelling at a speed of 46.3 mi/h. Upon impact, the TMA began to crush and, at 0.090 second, the rear of the truck began to rise as the impacting vehicle rode under the TMA cartridge. As the vehicle continued forward, the TMA cartridge displaced upward and allowed the vehicle to underride the cartridge sufficiently to ride under the attachment frame. Forward motion of the impacting vehicle stopped at approximately 0.155 second after impact. The vehicle subsequently came to rest under the TMA. Sequential photographs of the test are shown in Figure 158.

The Renco TMA cartridge crushed approximately 40 inches longitudinally with the remainder displaced upward as shown in Figures 5 and 6. The bumper of the impacting vehicle underrode the attachment frame approximately 2-3 inches. The attachment frame of the cartridge was bent 0.50 inch on the right side, 0.25 inch on the left and was displaced upward. The impacting vehicle received damage to the front bumper, hood, grill, radiator, right and left front quarter panels, and the roof. The windshield was shattered. Maximum vehicle was crushed down 6.25 inches just above bumper height. Figures 159 through 161 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 162. The maximum longitudinal 50-msec average acceleration experienced by the impacting vehicle was -25.3 g between 118 and 168 msec. Longitudinal occupant impact velocity was 36.4 ft/s at 127 msec and the maximum longitudinal ridedown acceleration was -29.7 g between 142 and 152 msec. Vehicle angular displacements are plotted in Figure 163 and accelerometer traces are displayed in Figures 164 through 166.

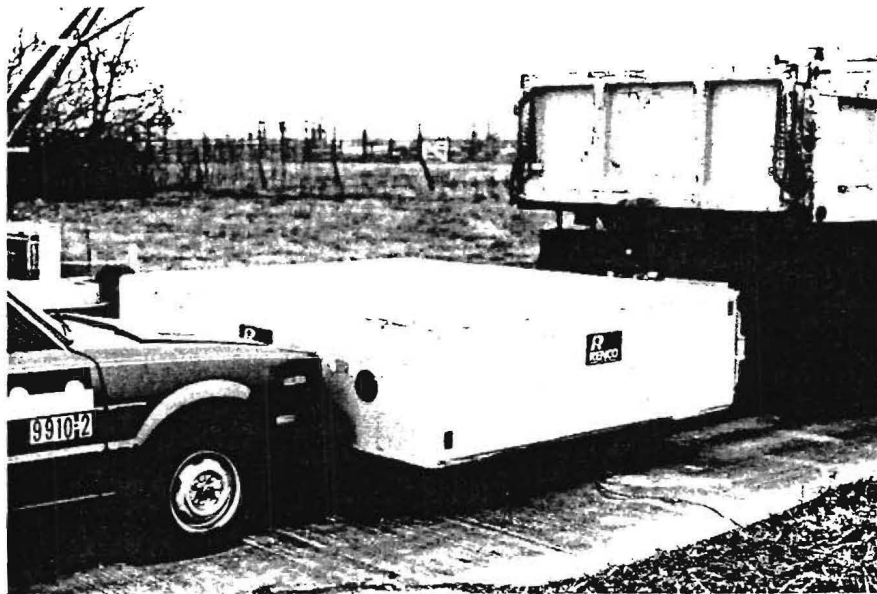
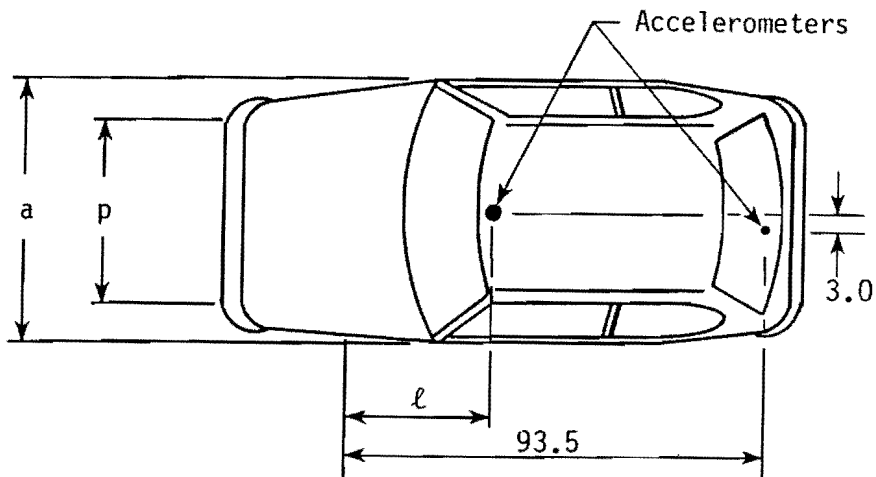


Figure 156. Vehicle before impact with RENCO TMA (9910-2).

Date: _____ Test No.: 9910-2 VIN: SRD1043852

Make: Honda Model: Civic Year: 1980 Odometer: 83279

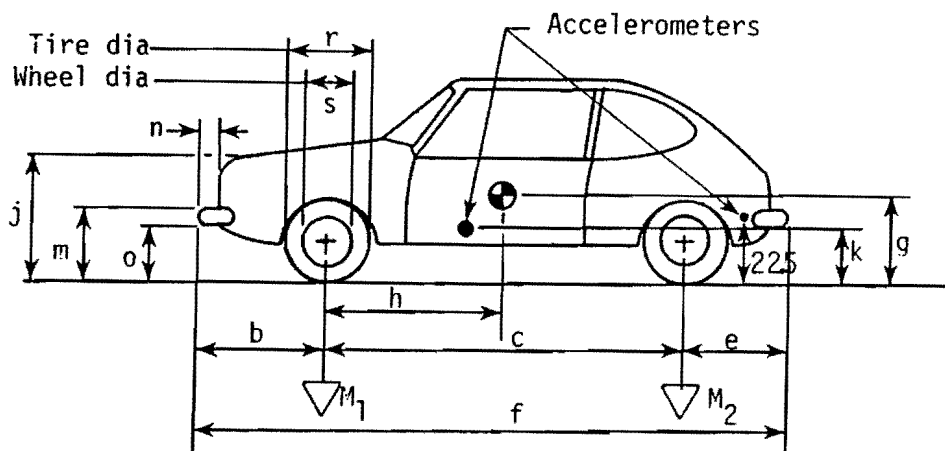
Tire Size: 155R12 Ply Rating: _____ Bias Ply: _____ Belted: _____ Radial: x



Tire Condition: good _____
 fair x
 badly worn _____

Vehicle Geometry - inches

a	<u>52.0</u>	b	<u>30.0</u>
c	<u>88.0</u>	d*	<u>52.25</u>
e	<u>28.5</u>	f	<u>146.5</u>
g	_____	h	<u>31.6</u>
i	<u>----</u>	j	<u>28.75</u>
k	<u>15.5</u>	l	<u>26.0</u>
m	<u>18.75</u>	n	<u>2.75</u>
o	<u>13.25</u>	p	<u>53.75</u>
r	<u>21.0</u>	s	<u>13.25</u>



Engine Type: 4 cylinder

Engine CID: _____

Transmission Type:

Automatic or Manual

FWD or RWD or 4WD

Body Type: 3 door

Steering Column Collapse Mechanism:

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

4-wheel weight for c.g. det. lf 623 rf 530 lr 302 rr 345

Mass - pounds	Curb	Test Inertial	Gross Static
M ₁	<u>1283</u>	<u>1153</u>	_____
M ₂	<u>647</u>	<u>647</u>	_____
M _T	<u>1930</u>	<u>1800</u>	_____

Note any damage to vehicle prior to test:

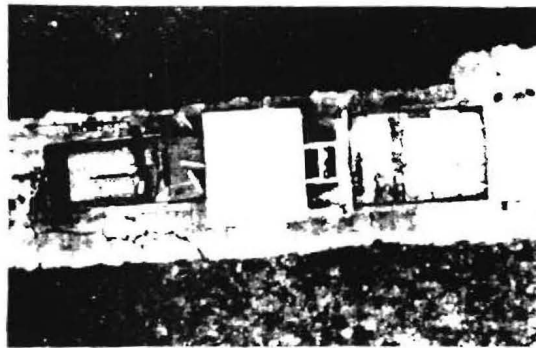
Brakes:

Front: disc x drum _____

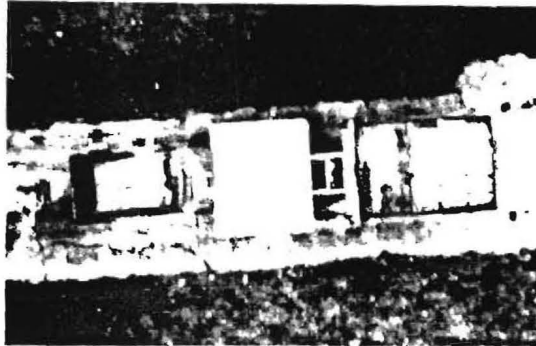
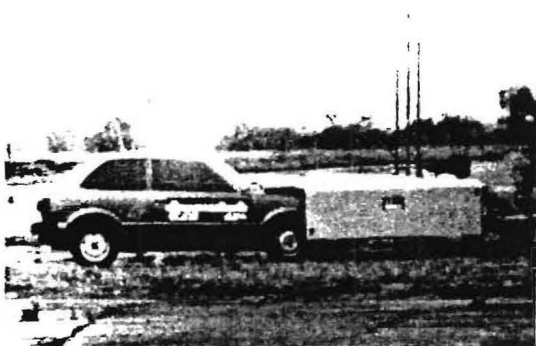
Rear: disc _____ drum x

*d = overall height of vehicle

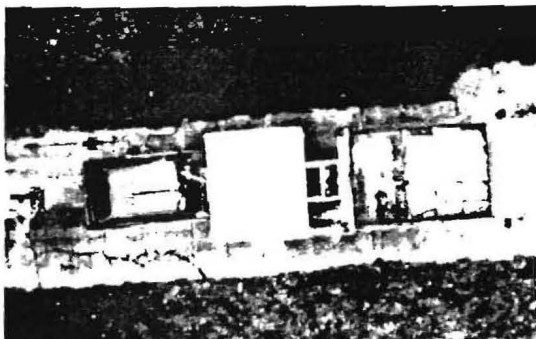
Figure 157. Test vehicle properties for test 9910-2.



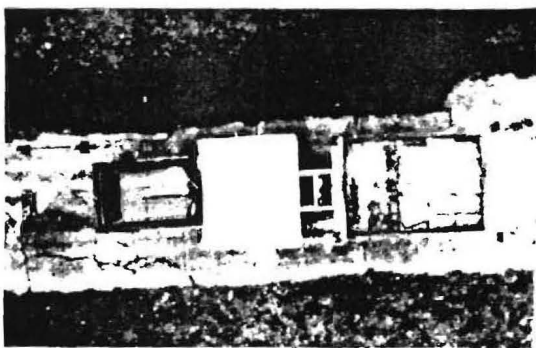
0.000 s



0.024 s



0.048 s

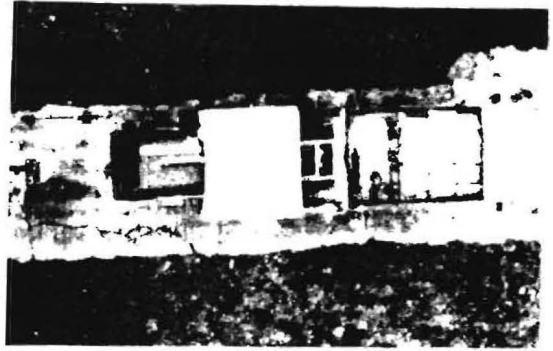


0.073 s

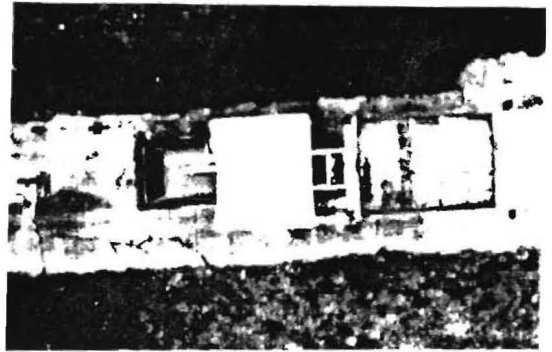
Figure 158 Sequential photographs for test 9910-2.



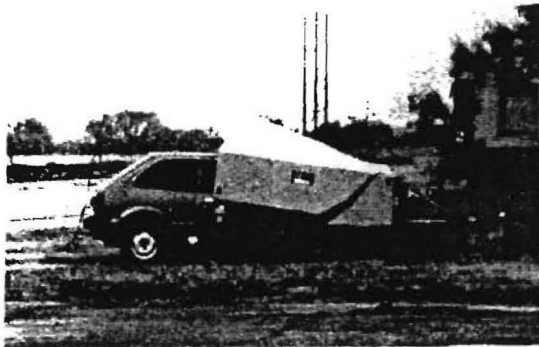
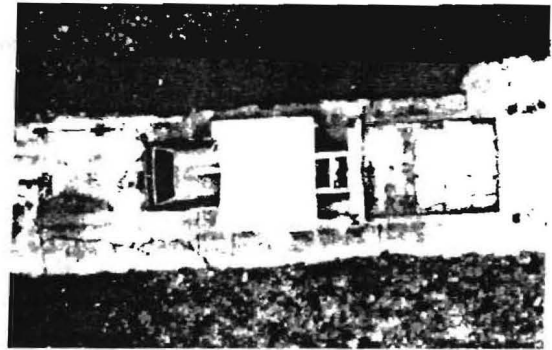
0.097 s



0.121 s



0.145 s



0.170 s

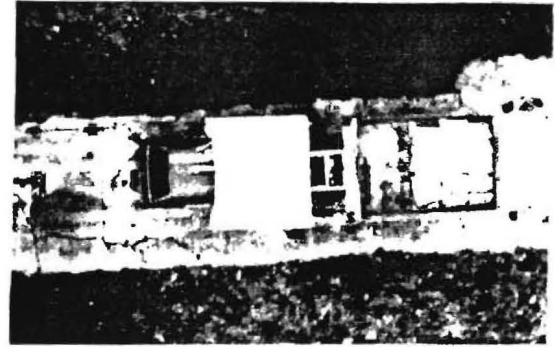


Figure 158 Sequential photographs
for test 9910-2.
(Continued)

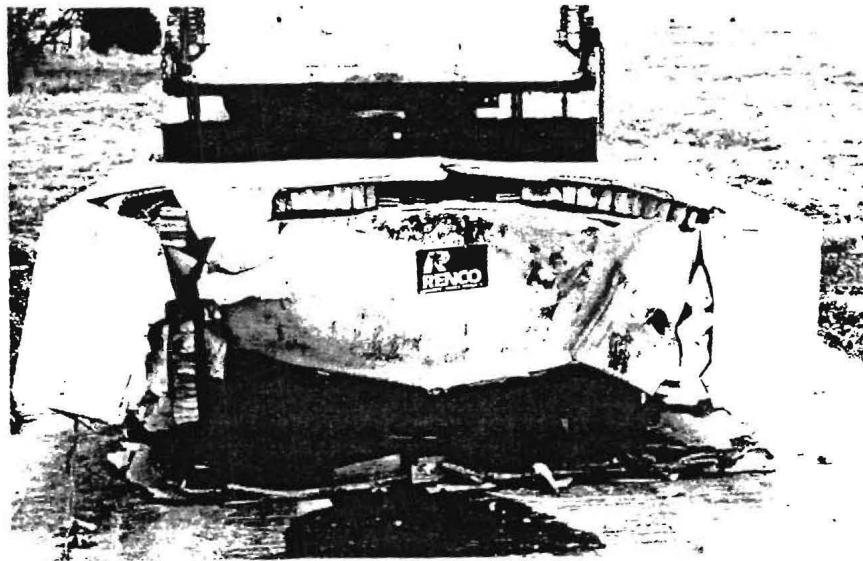
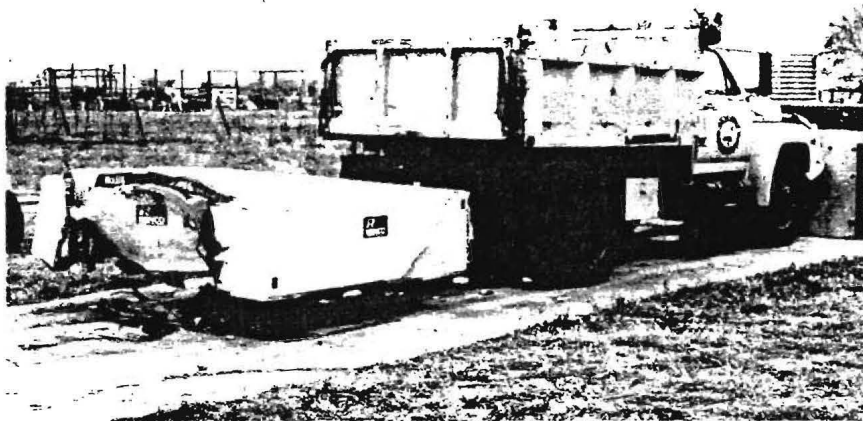


Figure 159. Renco TMA after test 9910-2.

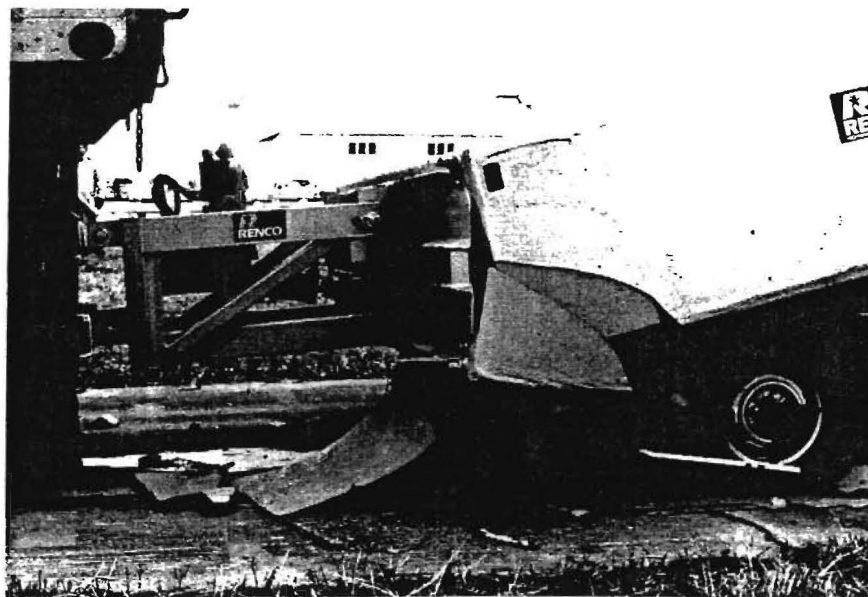
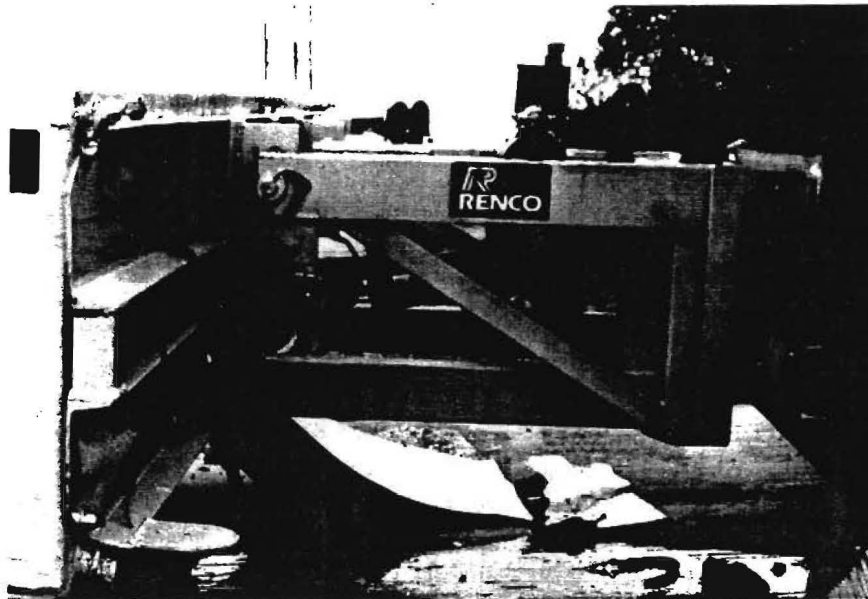
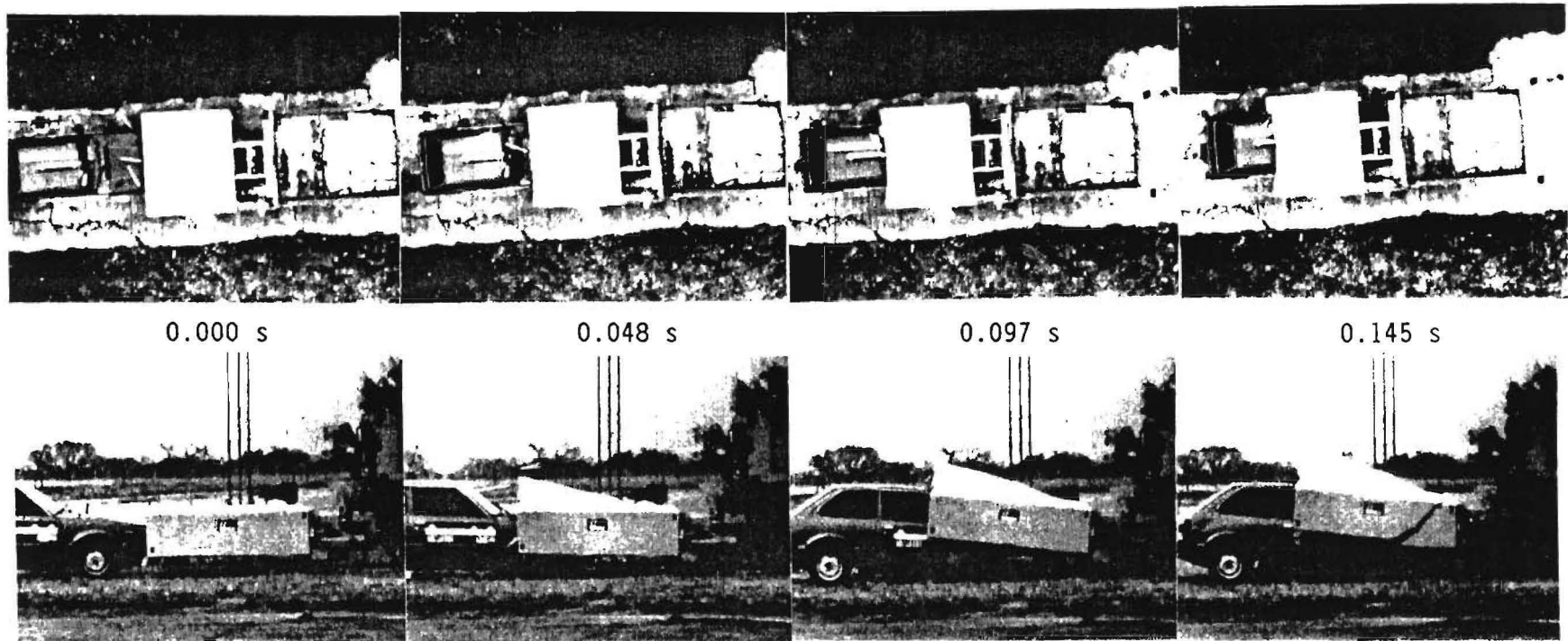


Figure 160. Damage to RENCO TMA mounting hardware (9910-2)



Figure 161. Vehicle after impact with Renco TMA (9910-2).

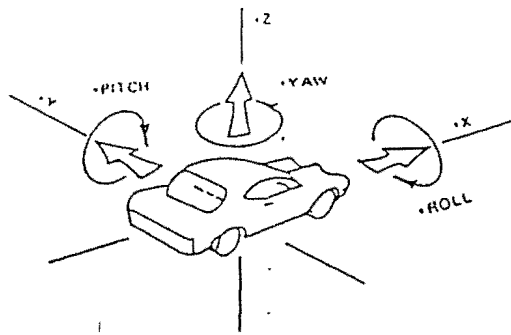


197

Test No.	09910-2	Maximum Truck Displacement .	N/A (fixed position)
Date	12/19/89	Maximum TMA Crush	N/A*
Test Article	Truck Mounted Attenuator	Vehicle Accelerations	
Manufacturer	RENCO	(Maximum 50 ms Average at c.g.)	
TMA Truck	1981 Ford Dump Truck (#1)	Vehicle Longitudinal	-25.3 g
Weight without TMA	14,010 lb (6,361 kg)	Vehicle Lateral	-1.8 g
Weight with TMA	15,260 lb (6,928 kg)	Truck Cab Longitudinal	N/A
Test Vehicle	1980 Honda Civic	Occupant Impact Velocity	
Weight	1,800 lb (817 kg)	Longitudinal	36.4 ft/s (11.1 m/s)
Impact Speed	46.3 mi/h (74.5 km/h)	Lateral	None
Maximum Vehicle Crush	6.25 in (15.9 cm)	Occupant Ridedown Accelerations	
Vehicle Damage Classification		Longitudinal	-29.7 g
TAD	12FD4	Lateral	N/A
CDC	12FDHW1 & 12TYHA6		

*Vehicle underrode TMA cartridge.

Figure 162 Summary of results for test 9910-2.



Axes are vehicle fixed.
 Sequence for determining
 orientation is:

1. Yaw
2. Pitch
3. Roll

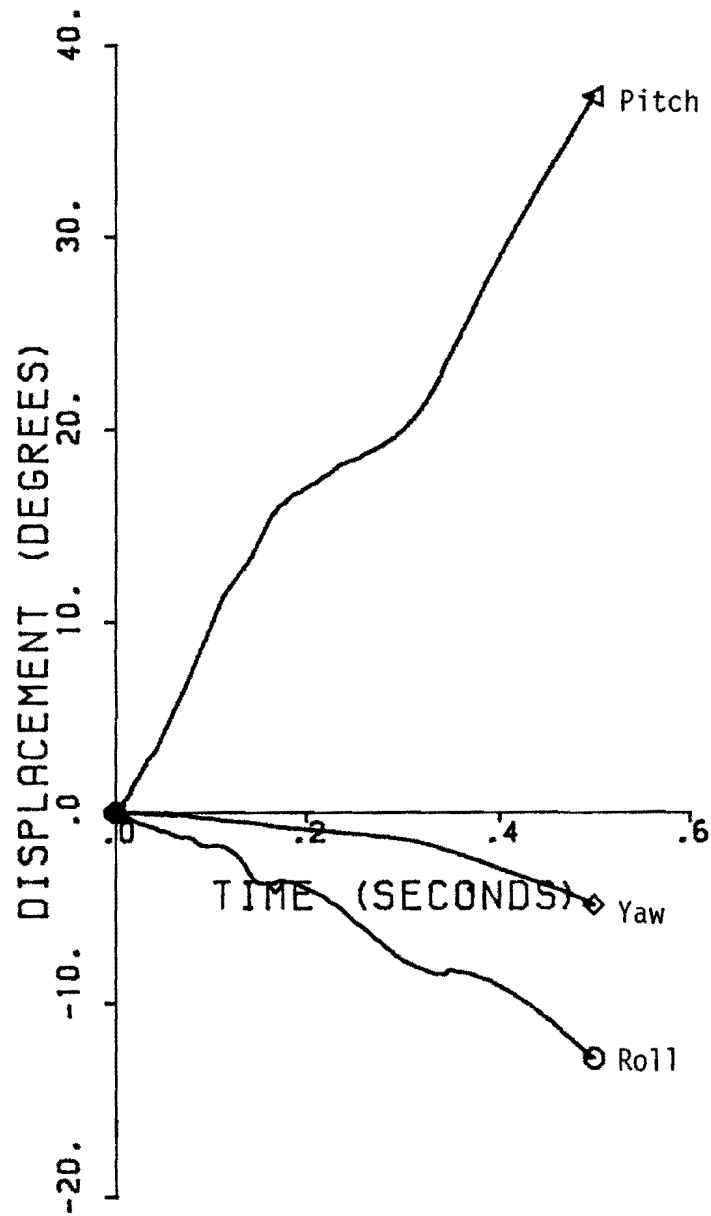


Figure 163 Vehicle angular displacements for test 9910-2.

TEST 9910-2

Class 180 Filter

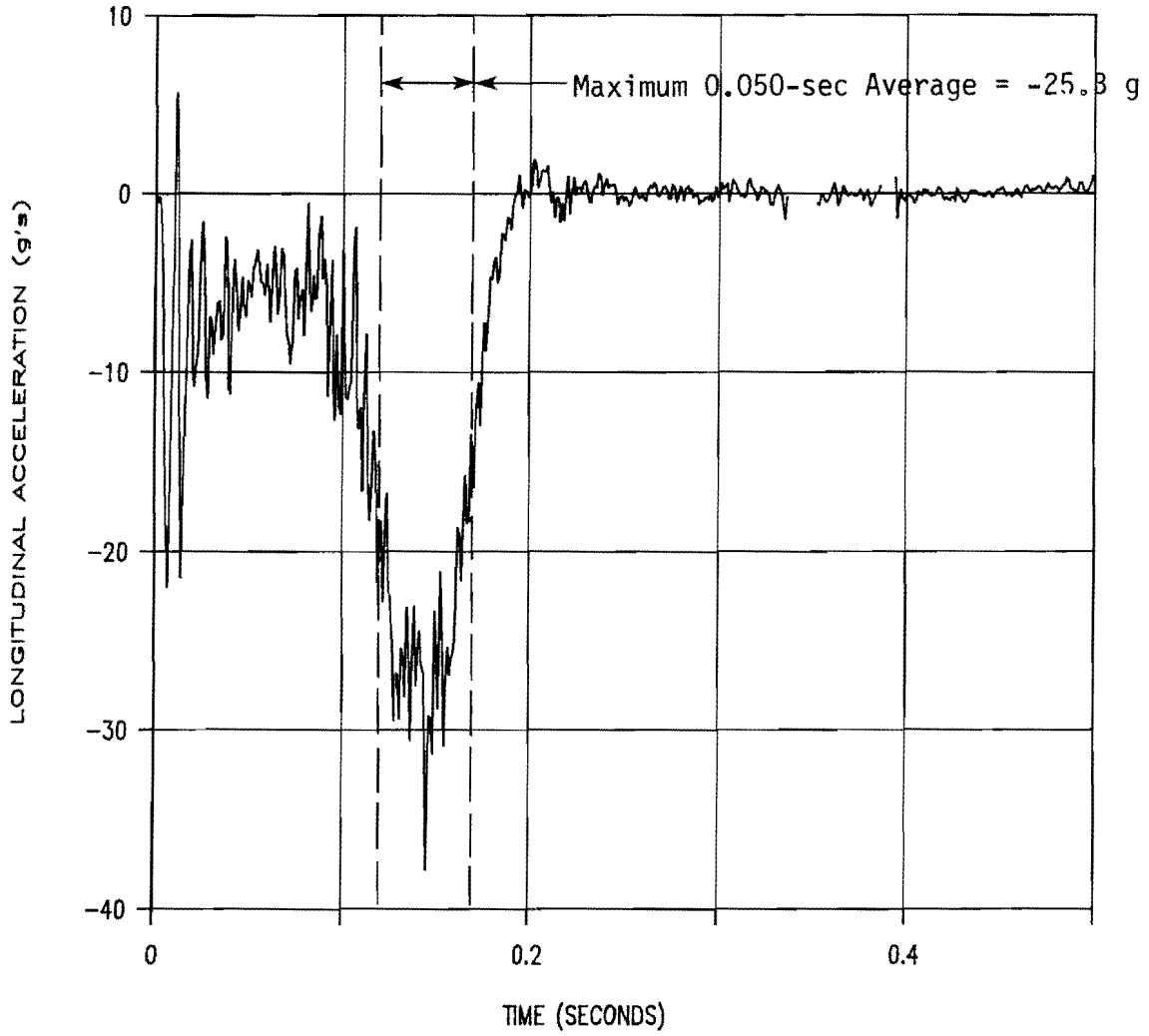


Figure 164. Vehicle longitudinal accelerometer trace for test 9910-2.

TEST 9910-2

Class 180 Filter

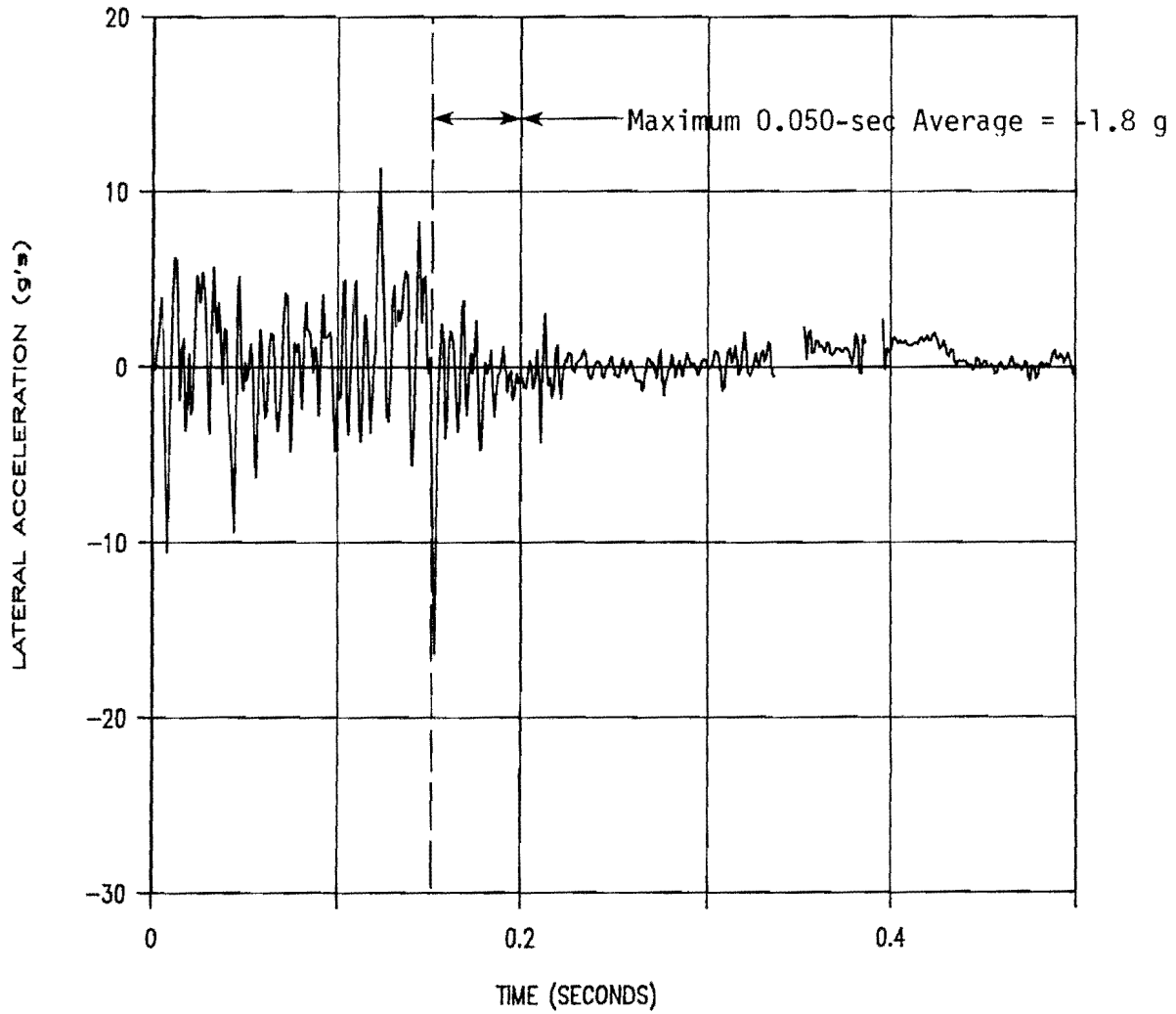


Figure 165. Vehicle lateral accelerometer trace for test 9910-2.

TEST 9910-2

Class 180 Filter

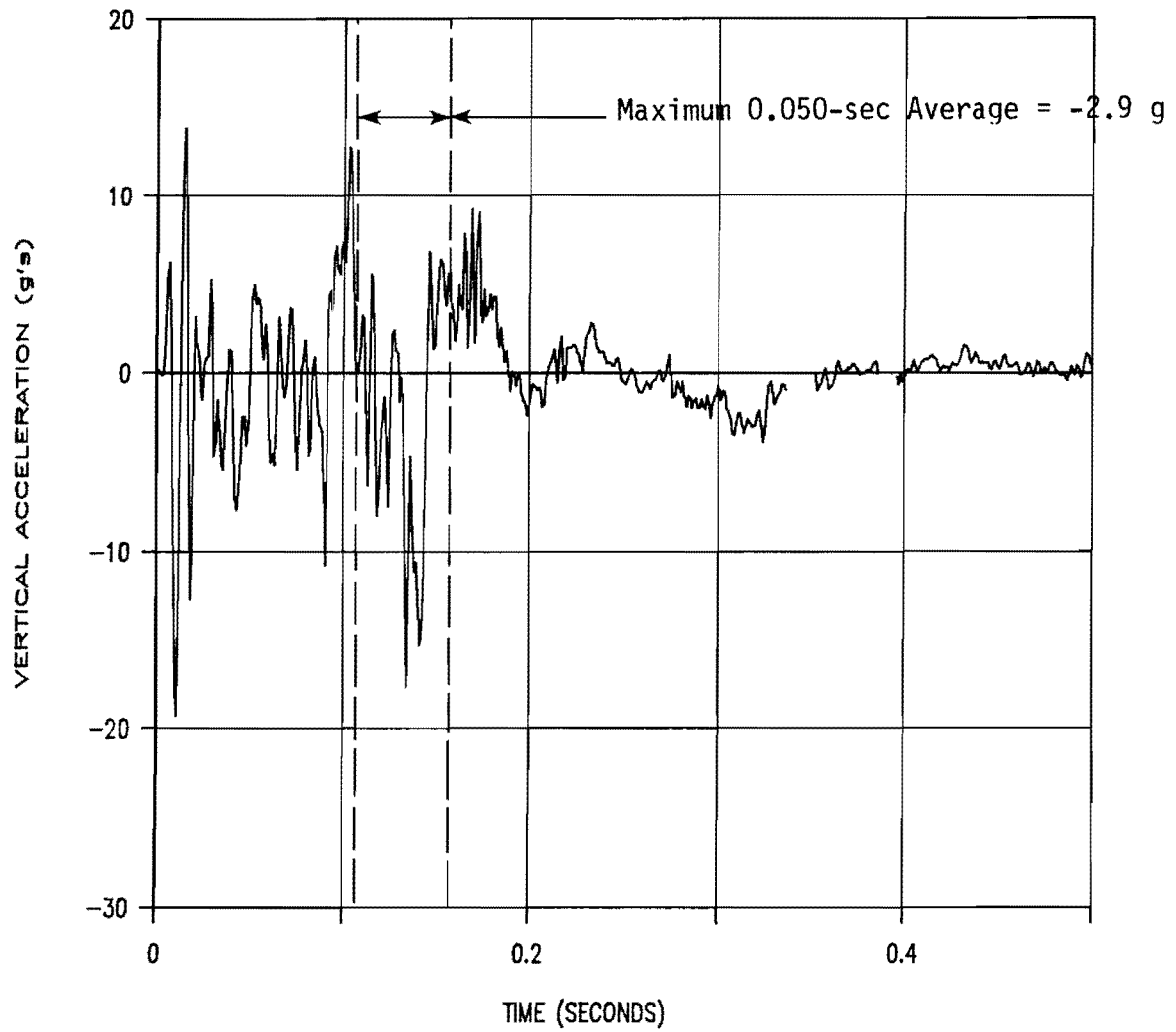


Figure 166. Vehicle vertical accelerometer trace for test 9910-2.

Markings and Equipment Corporation (9910-01)

The TMA used during this test was manufactured by Markings and Equipment and is shown in Figures 6 and 167. The TMA was mounted on Truck No. 2 which had a gross static weight of 14,930 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 11.00 inches at the front and 12.00 inches at the rear. The height to the upper rear surface of the cartridge was 36.75 inches above ground.

The 1981 Honda Civic (pictured in Figures 167) into the Markings & Equipment TMA. The height to the lower edge of the vehicle bumper was 11.25 inches and 19.25 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 168.

The vehicle was travelling at a speed of 44.9 mi/h. Upon impact, the TMA began to crush and, at 0.142 second, the rear of the truck began to rise as the impacting vehicle dove under the TMA. The impacting vehicle stopped forward motion at approximately 0.203 second, and began to roll back. The vehicle subsequently came to rest 37 ft behind the TMA. Sequential photographs of the test are shown in Figure 169.

The Markings & Equipment TMA cartridge crushed a total of 84.0 inches during the test. The frame attachment to the cartridge was bent 0.25 inches at the lower right connection. The impacting vehicle received damage to the front bumper, hood, grill, radiator, right and left front quarter panels, and the left front door. The rear bumper was also damaged on the left side indicating subframe damage to the vehicle. Maximum vehicle crush was 12.0 inches at bumper height. Figures 170 and 171 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 172. The maximum longitudinal 50-msec average acceleration experienced by the impacting vehicle was -19.6 g between 154 and 204 msec. Longitudinal occupant impact velocity was 30.0 ft/s at 126 msec and the maximum longitudinal ridedown acceleration was -23.9 g between 185 and 195 msec. Vehicle angular displacements are plotted in Figure 173 and accelerometer traces are displayed in Figures 174 through 176.

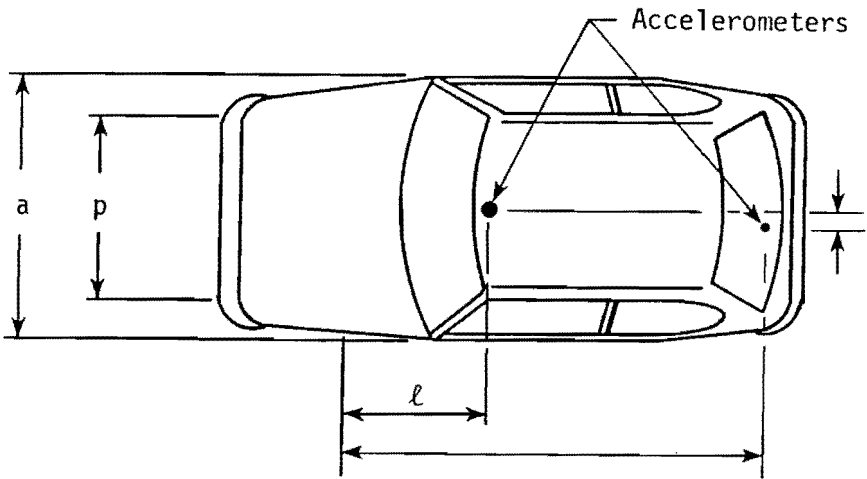


Figure 167. Vehicle before impact with Markings & Equipment TMA (9910-1)

Date: _____ Test No.: 9910-1 VIN: JHMSL5322BS024235

Make: Honda Model: Civic Year: 1981 Odometer: 663824

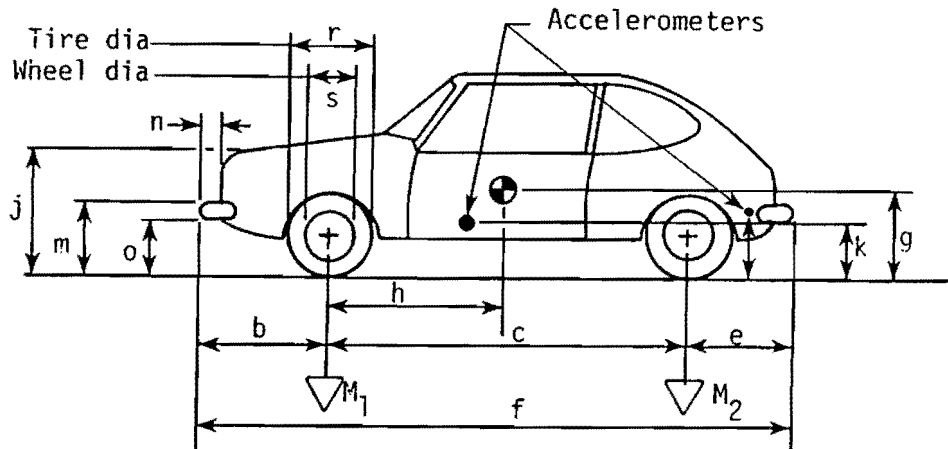
Tire Size: P155 80R12 Ply Rating: 4 Bias Ply: Belted: Radial: x



Tire Condition: good
 fair x
 badly worn

Vehicle Geometry - inches

a	<u>62.25</u>	b	<u>30.0</u>
c	<u>88.25</u>	d*	<u>52.0</u>
e	<u>29.0</u>	f	<u>147.25</u>
g	<u> </u>	h	<u> </u>
i	<u>----</u>	j	<u>27.75</u>
k	<u>15.5</u>	l	<u>27.5</u>
m	<u>19.25</u>	n	<u>3.0</u>
o	<u>11.25</u>	p	<u>54.13</u>
r	<u>21.0</u>	s	<u>13.25</u>



Engine Type: 4 cylinder

Engine CID:

Transmission Type:

Automatic or Manual
FWD or RWD or 4WD

Body Type: 3 door

Steering Column Collapse Mechanism:

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

4-wheel weight for c.g. det. lf 604 rf 550 lr 336 rr 310

Mass - pounds	Curb	Test Inertial	Gross Static
M ₁	<u>1197</u>	<u>1154</u>	<u> </u>
M ₂	<u>668</u>	<u>646</u>	<u> </u>
M _T	<u>1865</u>	<u>1800</u>	<u> </u>

Note any damage to vehicle prior to test:

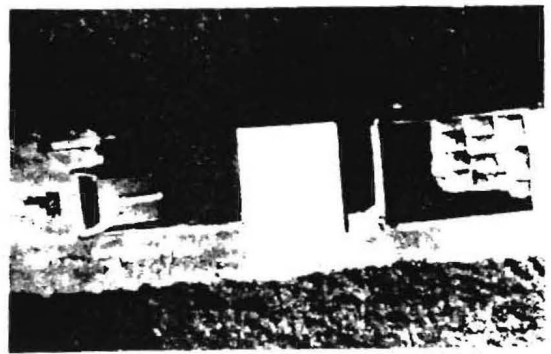
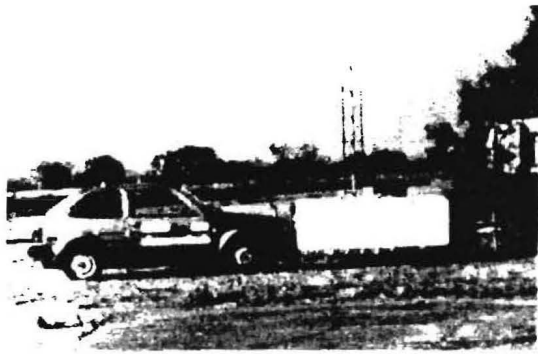
Crack in windshield marked

Brakes:

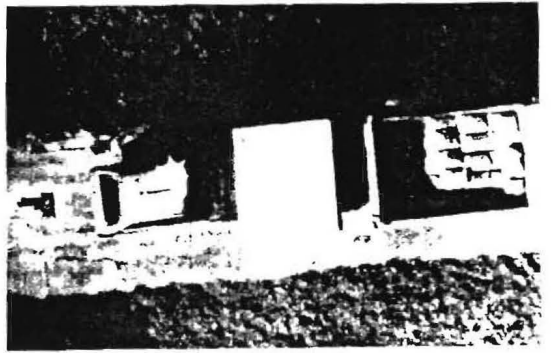
Front: disc x drum
 Rear: disc drum x

*d = overall height of vehicle

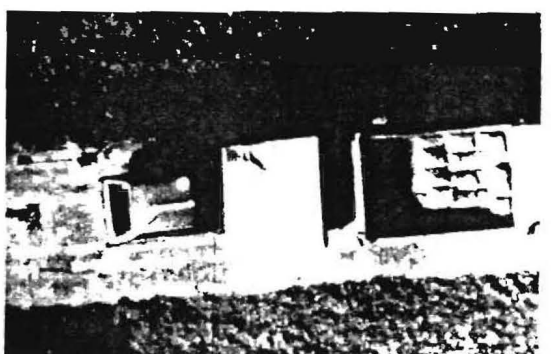
Figure 168. Test vehicle properties for test 9910-1.



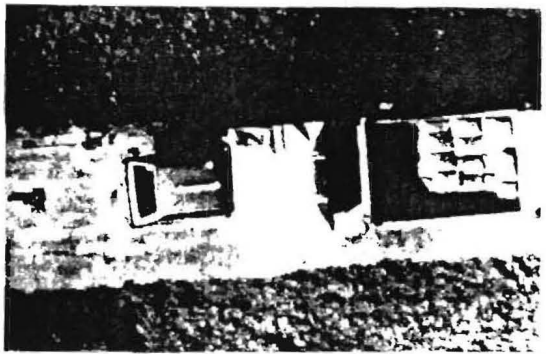
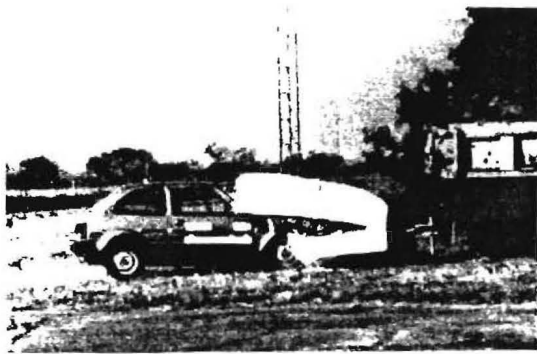
0.000 s



0.030 s

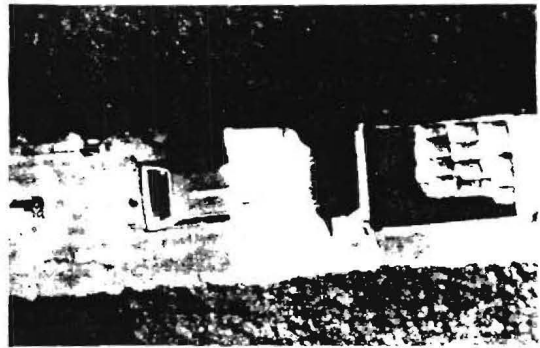
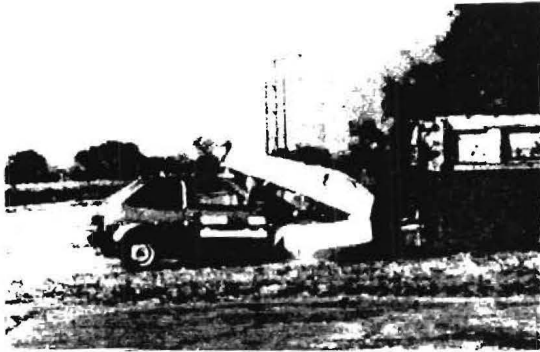


0.059 s

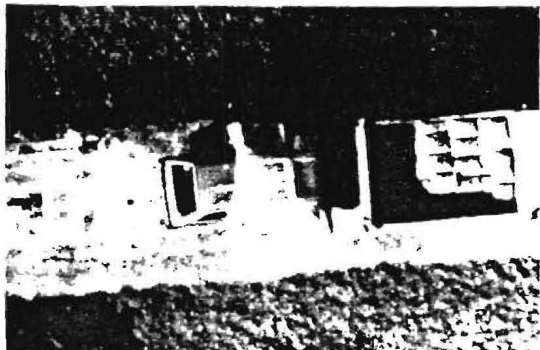


0.089 s

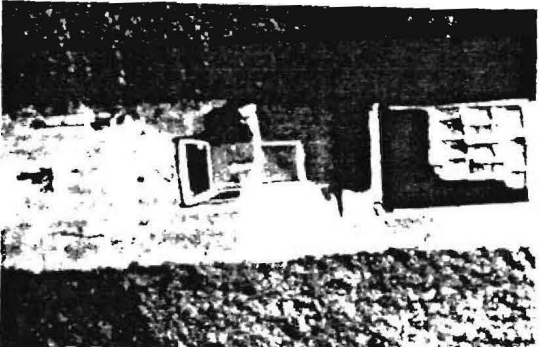
Figure 169 Sequential photographs for test 9910-1.



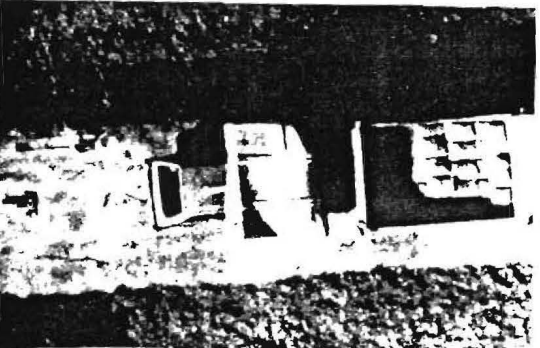
0.119 s



0.148 s



0.178 s



0.208 s

Figure 169. Sequential photographs for test 9910-1. (Continued)

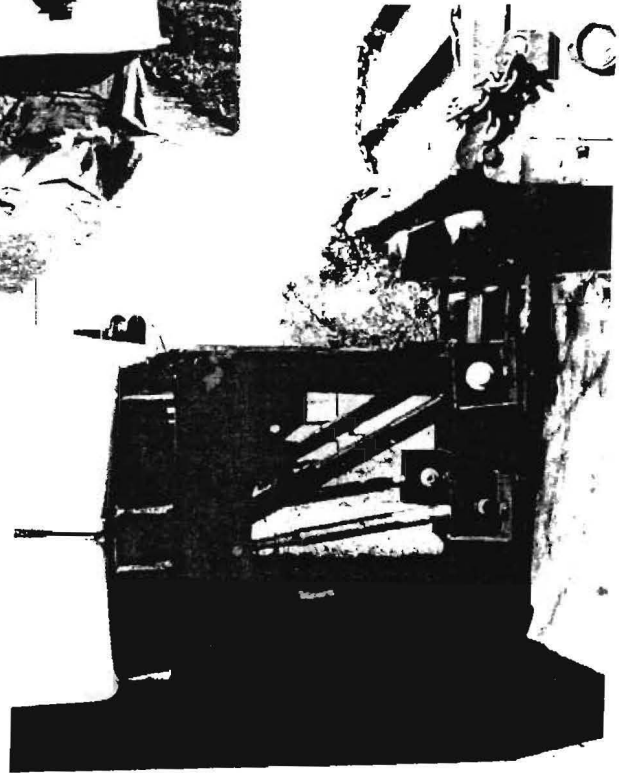
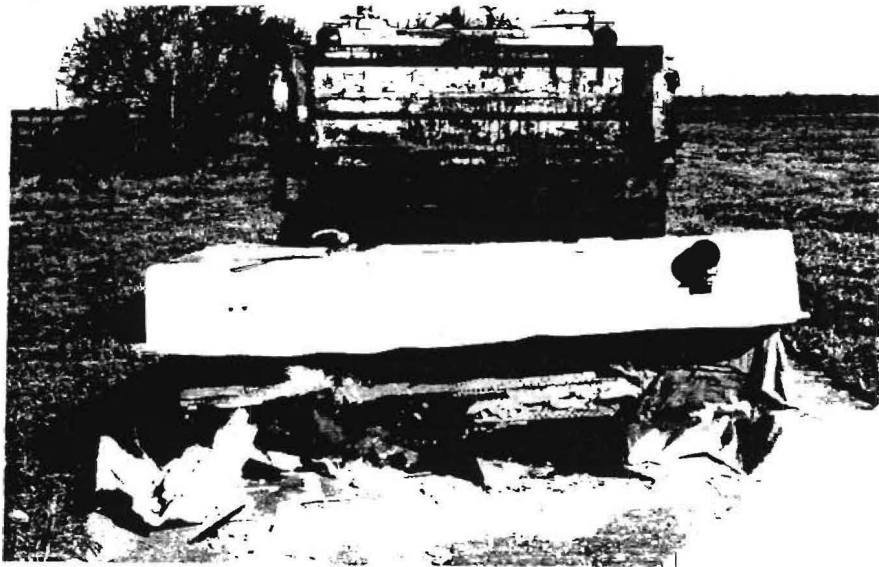


Figure 170. Markings & Equipment TMA after test 9910-1.

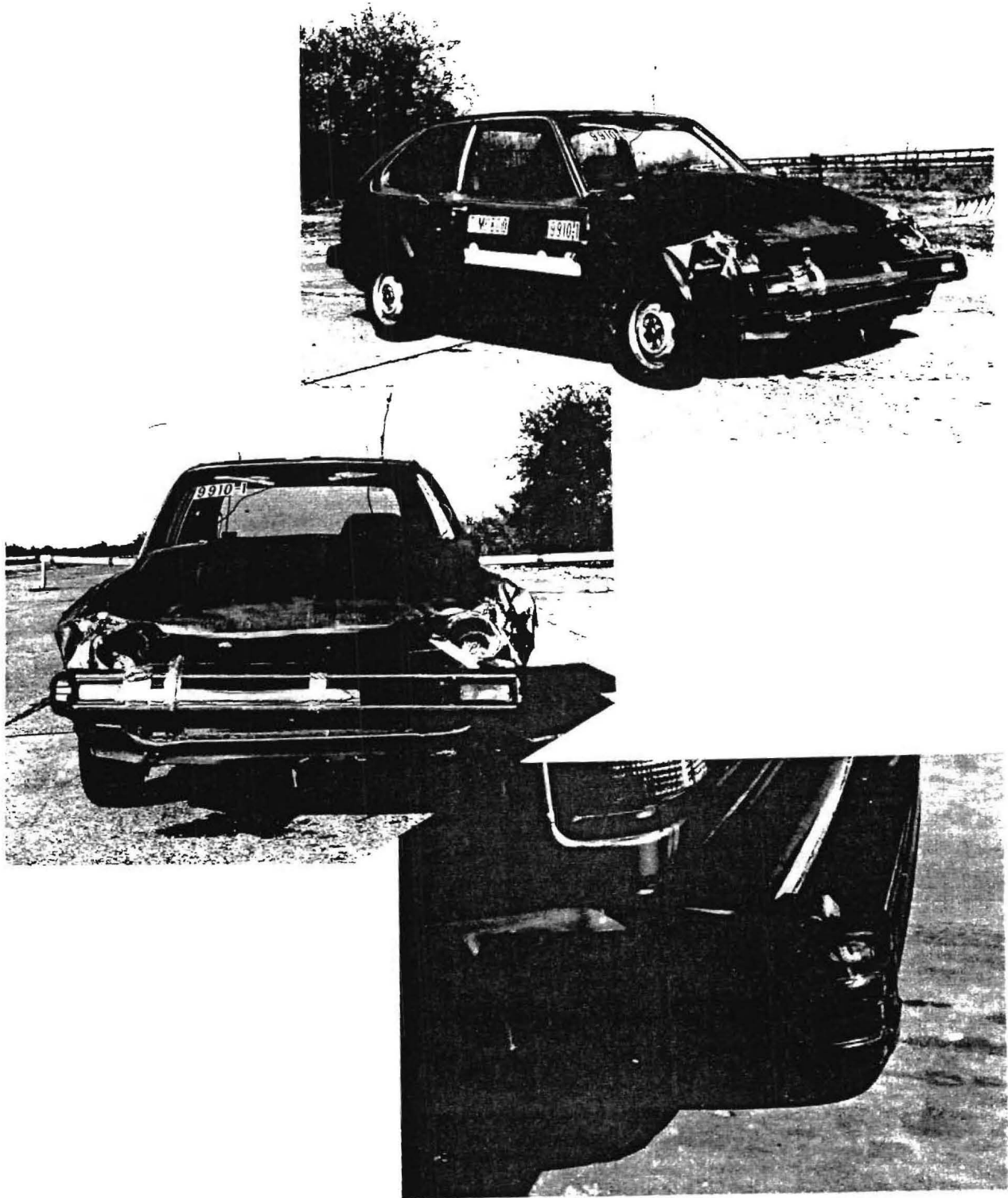
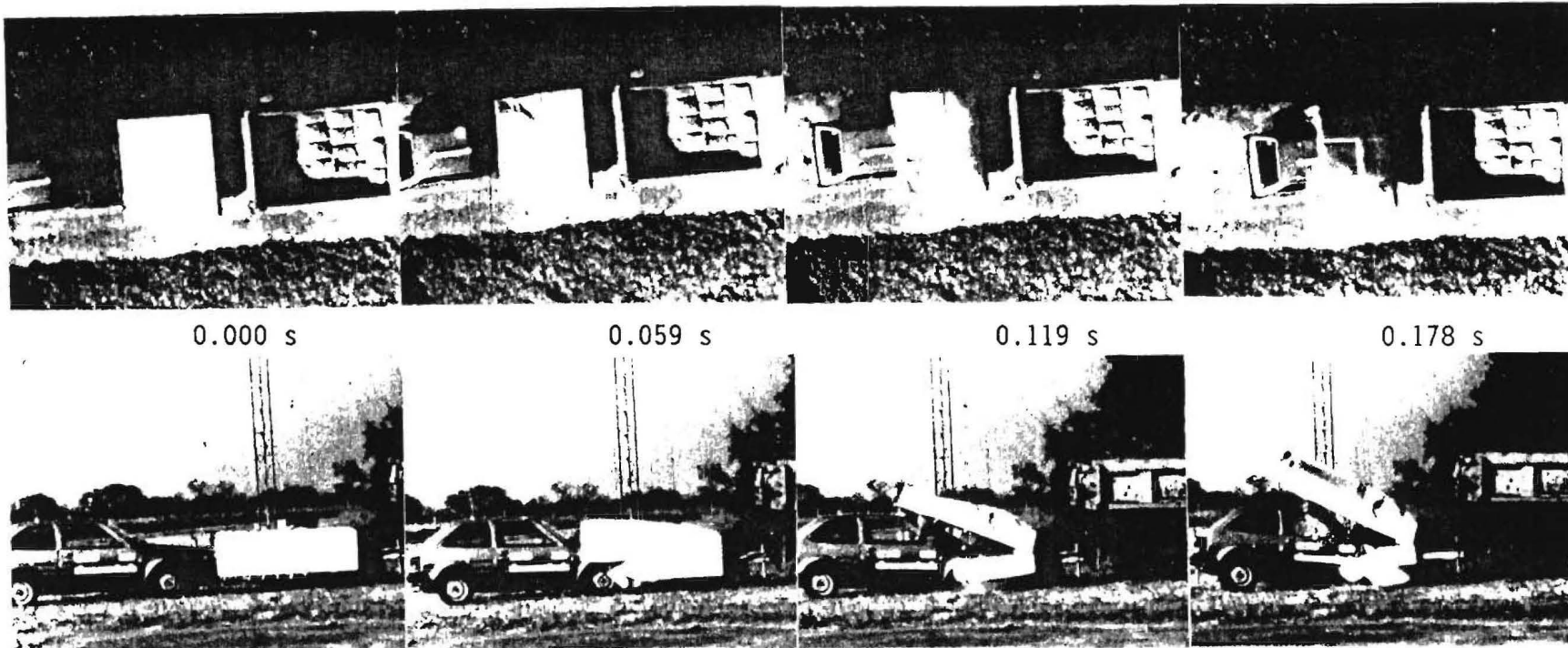


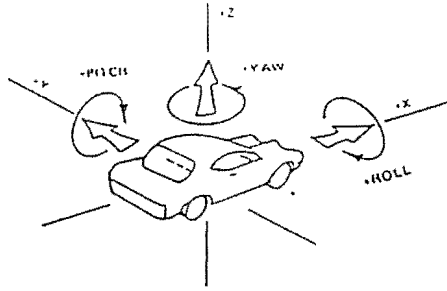
Figure 171. Vehicle after impact with
Markings & Equipment TMA (9910-1)



Test No. 09910-1
 Date 12/15/89
 Test Article Truck Mounted Attenuator
 Manufacturer Markings & Equipment
 TMA Truck 1980 Ford Dump Truck (#2)
 Weight without TMA . . . 14,010 lb (6,361 kg)
 Weight with TMA 14,930 lb (6,778 kg)
 Test Vehicle 1981 Honda Civic
 Weight 1,800 lb (817 kg)
 Impact Speed 44.9 mi/h (72.2 km/h)
 Maximum Vehicle Crush . 12.0 in (30.5 cm)
 Vehicle Damage Classification
 TAD 12FD4
 CDC 12FDEW3

Maximum Truck Displacement . N/A (fixed position)
 Maximum TMA Crush 84.0 in (2.1 m)
 Vehicle Accelerations
 (Maximum 50 ms Average at c.g.)
 Vehicle Longitudinal . . . -19.6 g
 Vehicle Lateral -1.5 g
 Truck Cab Longitudinal . . N/A
 Occupant Impact Velocity
 Longitudinal 30.0 ft/s (9.1 m/s)
 Lateral 6.9 ft/s (2.1 m/s)
 Occupant Ridedown Accelerations
 Longitudinal -23.9 g
 Lateral -1.2 g

Figure 172 Summary of results for test 9910-1.



Axes are vehicle fixed.
 Sequence for determining
 orientation is:

1. Yaw
2. Pitch
3. Roll

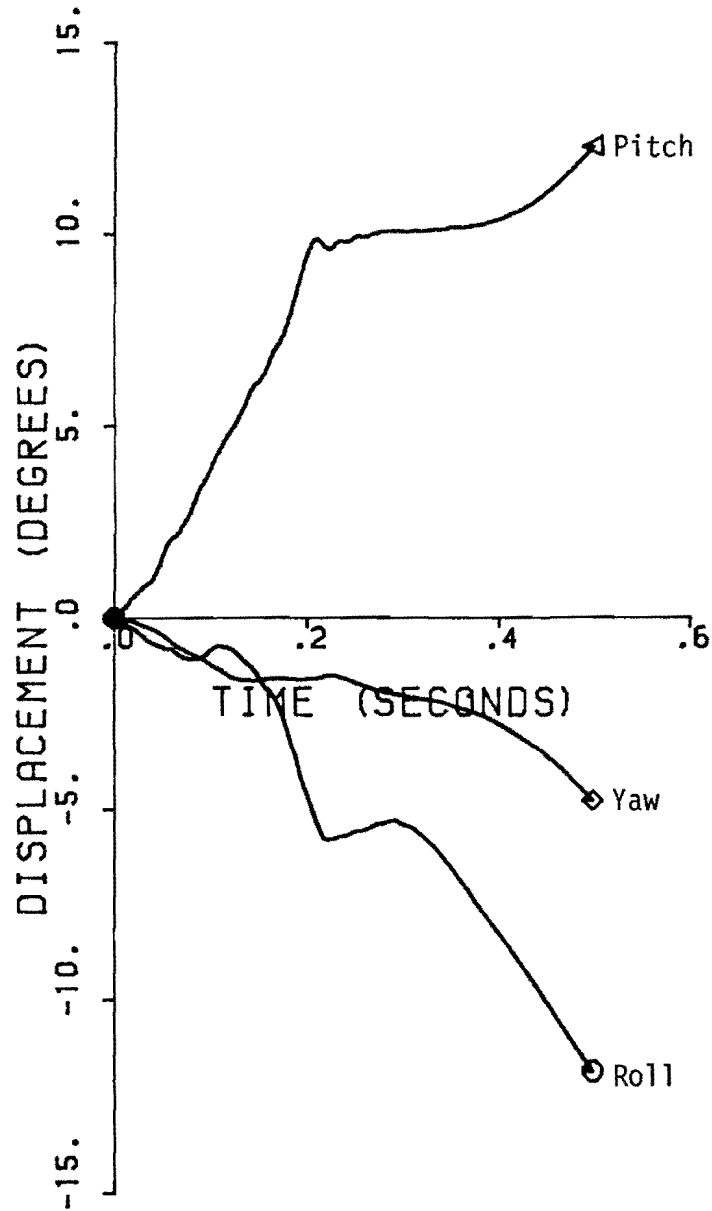


Figure 173. Vehicle angular displacements for test 9910-1.

TEST 9910-1

Class 180 Filter

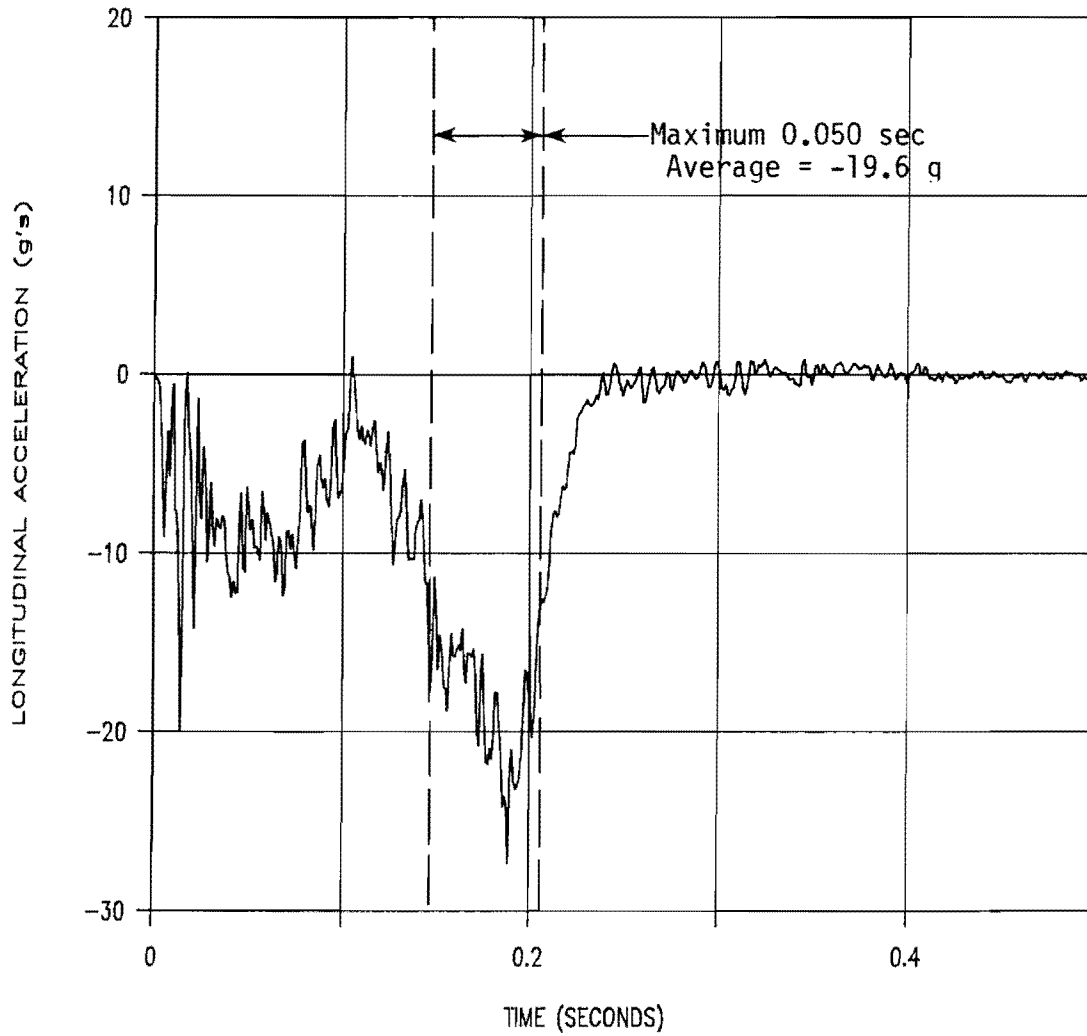


Figure 174. Vehicle longitudinal accelerometer trace for test 9910-1.

TEST 9910-1

Class 180 Filter

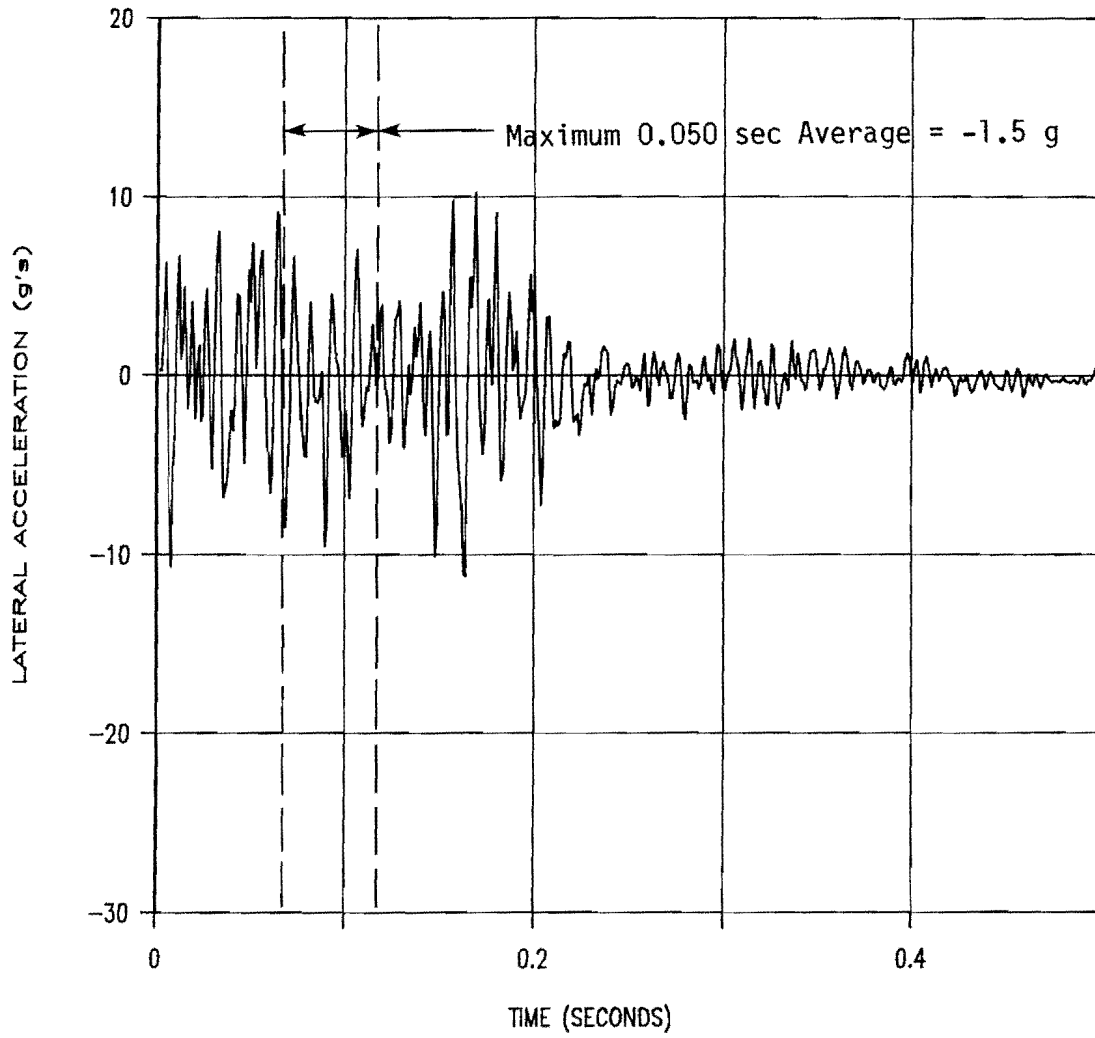


Figure 175. Vehicle lateral accelerometer trace for test 9910-1.

TEST 9910-1

Class 180 Filter

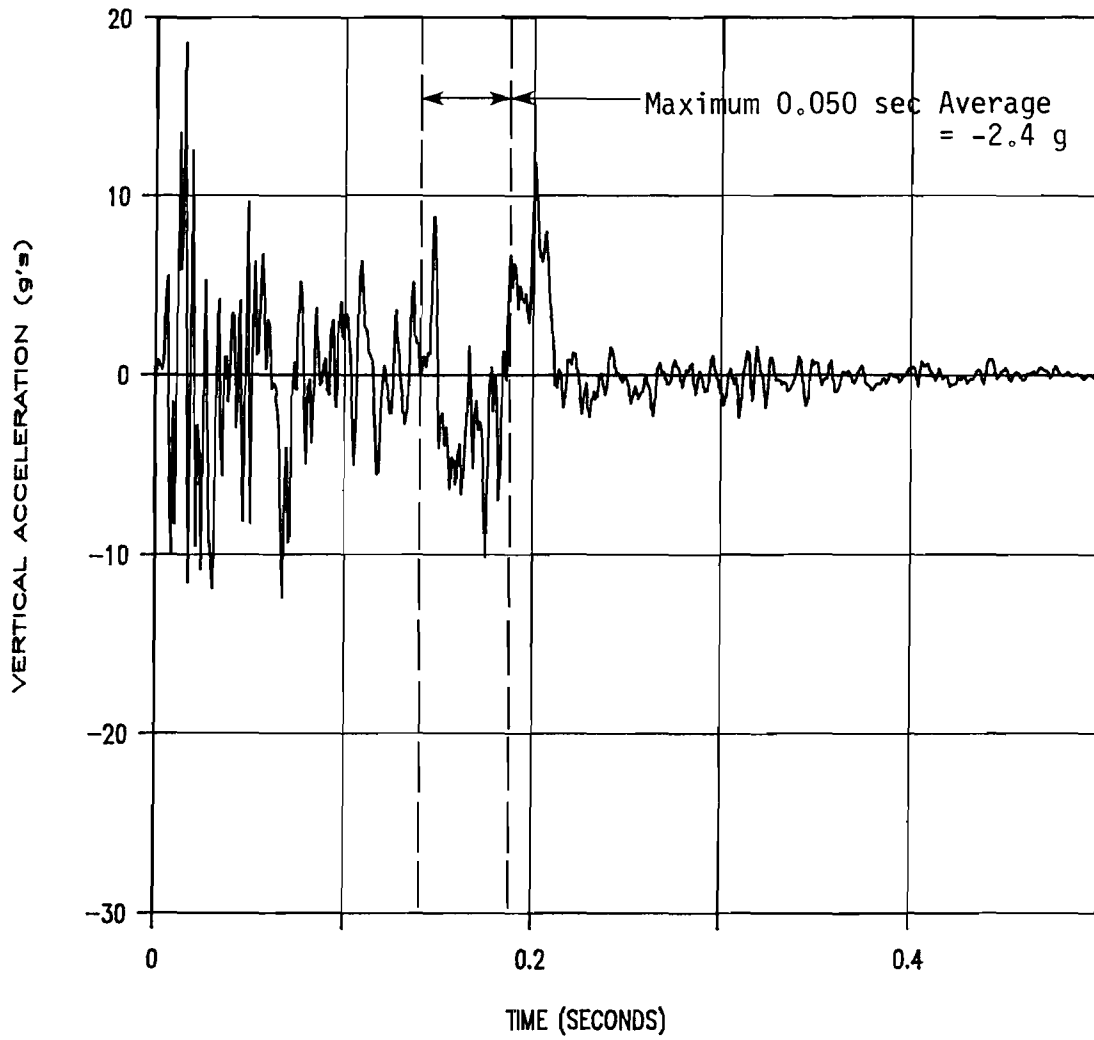


Figure 176. Vehicle vertical accelerometer trace for test 9910-1.

Connecticut DOT (9910-09)

The Connecticut DOT TMA used during this test is shown in Figures 7 and 177. The TMA was mounted on Truck No. 2 which had gross static weight of 16,130 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 8.00 inches at the front and 7.00 inches at the rear. The height to the upper rear surface of the cartridge was 41.00 inches above ground.

The 1982 Honda Civic (pictured in Figure 177) into the Connecticut TMA. The height to the lower edge of the vehicle bumper was 14.25 inches and 20.00 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 178.

The vehicle was travelling at a speed of 45.3 mi/h. Upon impact, the first pipe in the TMA began to crush. Approximately 0.052 second after impact the second and third pipe began to crush. At 0.079 second, the rear of the impacting vehicle began to rise and, at 0.133 second, the rear tires lost contact with the ground. Forward motion of the impacting vehicle stopped at 0.185 second and it began to rebound at 0.212 second. The rear of the impacting vehicle reached its highest elevation at 0.248 second. The vehicle subsequently came to rest 25 ft behind the TMA. Sequential photographs of the test are shown in Figure 179.

The Connecticut TMA crushed a total of 44.13 inches during the test. The attachment frame on the cartridge was not damaged. The impacting vehicle received damage to the front bumper, hood, grill, radiator, and the right and left front quarter panels. The right and left doors were also jammed. Maximum vehicle crush was 7.0 inches at bumper height. Figures 180 through 182 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 183. The maximum longitudinal 50-msec average acceleration experienced by the impacting vehicle was -14.2 g between 003 and 053 msec. Longitudinal occupant impact velocity was 37.8 ft/s at 096 msec and the maximum longitudinal ridedown acceleration was -14.0 g between 100 and 110 msec. Vehicle angular displacements are plotted in Figure 184 and accelerometer traces are displayed in Figures 185 through 187.

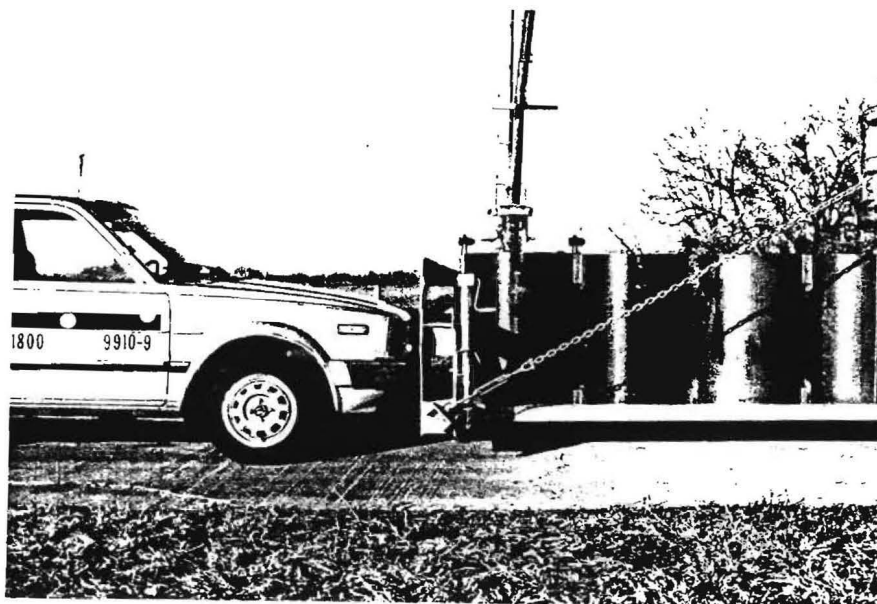
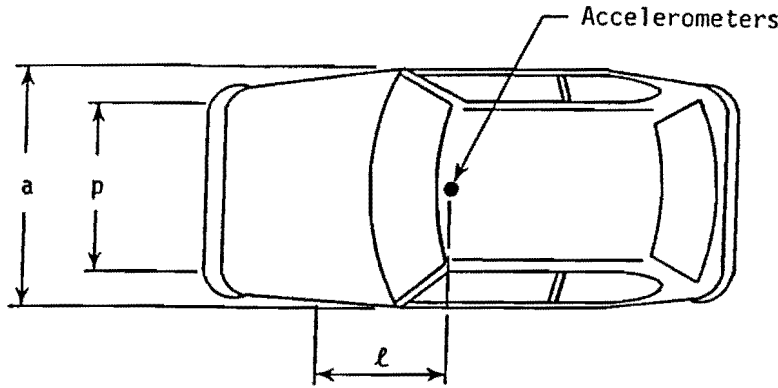


Figure 177. Vehicle before impact with Connecticut TMA (9910-9).

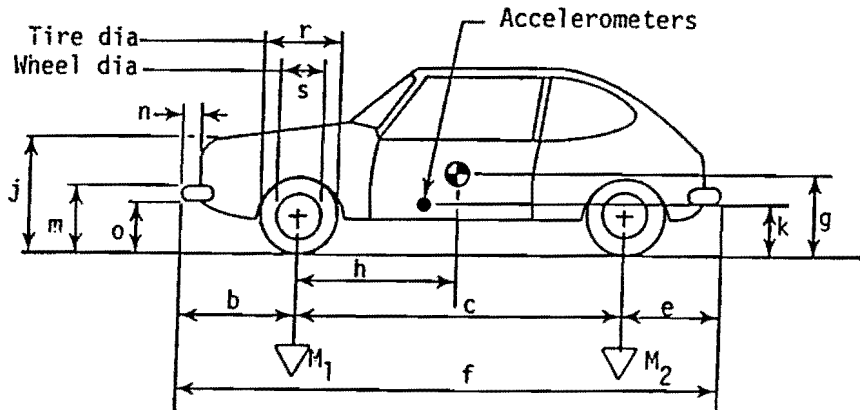
Date: _____ Test No.: 9910-9 VIN: JHMSL5321CS010702
 Make: Honda Model: Civic Year: 1982 Odometer: 1484666
 Tire Size: 155/SR13 Ply Rating: 3 Bias Ply: Belted: Radial:



Tire Condition: good
 fair
 badly worn

Vehicle Geometry - inches

a	<u>62 1/2</u>	b	<u>30</u>
c	<u>88</u>	d*	<u>53 1/2</u>
e	<u>29</u>	f	<u>147</u>
g	<u> </u>	h	<u>32.66</u>
i	<u>----</u>	j	<u>28 3/4</u>
k	<u>16 3/4</u>	l	<u>29</u>
m	<u>20</u>	n	<u>4</u>
o	<u>14 1/4</u>	p	<u>53 1/2</u>
r	<u>22 1/2</u>	s	<u>14 1/4</u>



Engine Type: 4 cyl

Engine CID:

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

4-wheel weight for c.g. det. lf 586 rf 546 lr 348 rr 320

Mass - pounds	Curb	Test Inertial	Gross Static
M ₁	<u>1100</u>	<u>1132</u>	<u> </u>
M ₂	<u>671</u>	<u>668</u>	<u> </u>
M _T	<u>1771</u>	<u>1800</u>	<u> </u>

Note any damage to vehicle prior to test:

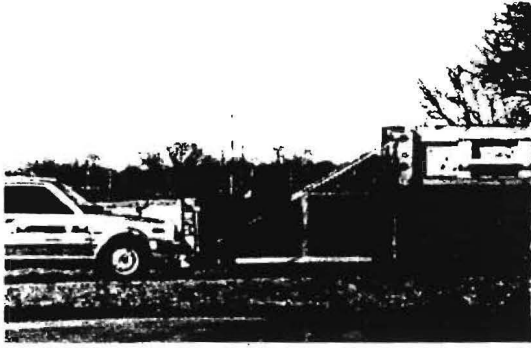
Brakes:

Front: disc X drum

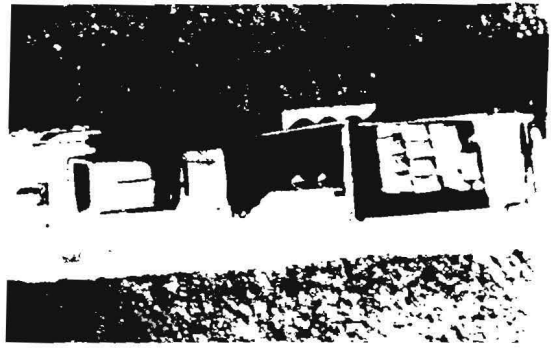
Rear: disc drum X

*d = overall height of vehicle

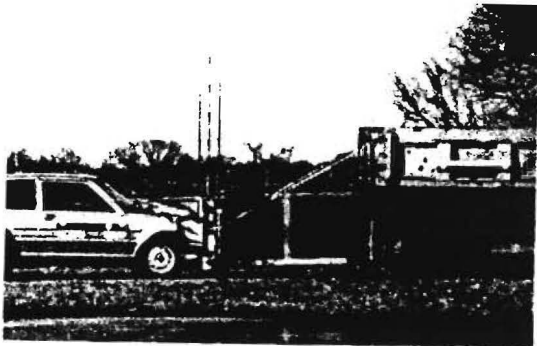
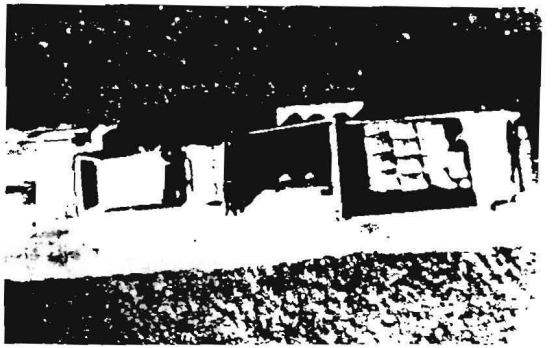
Figure 178. Test vehicle properties (test 9910-9).



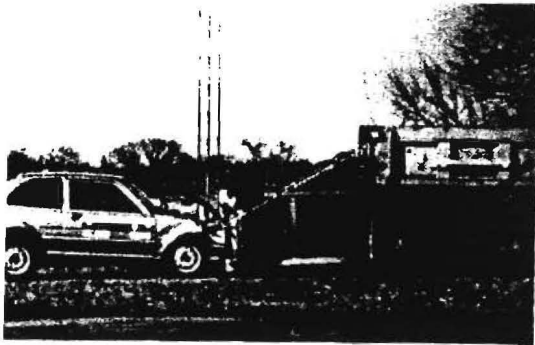
0.000 s



0.026 s



0.052 s



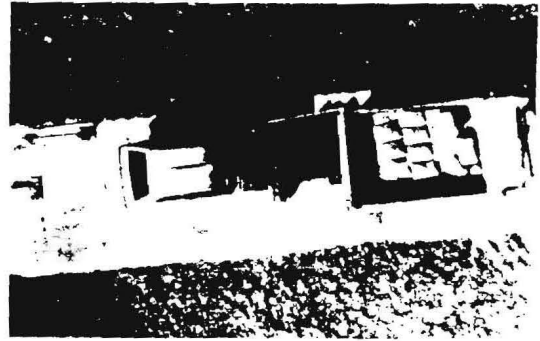
0.078 s



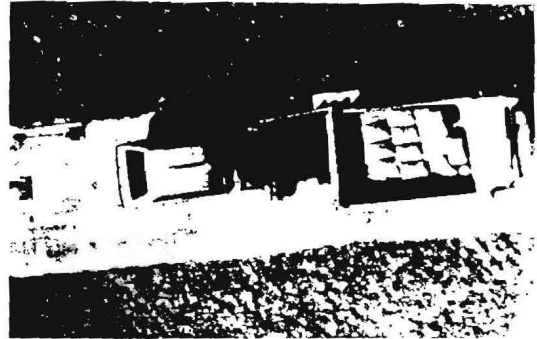
Figure 179. Sequential photographs for test 9910-9.



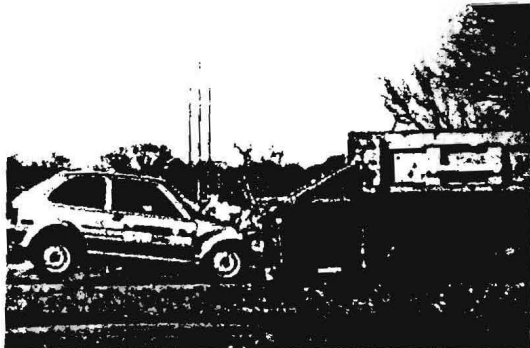
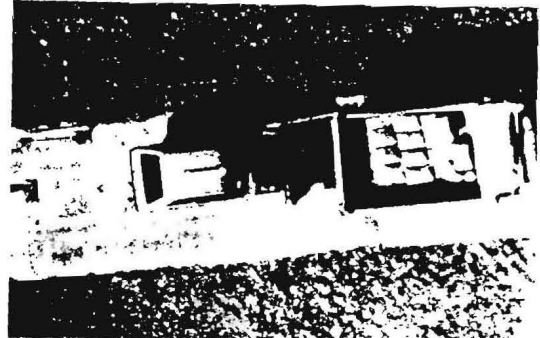
0.104 s



0.130 s



0.156 s



0.185 s



Figure 179 Sequential photographs
for test 9910-9.
(Continued)

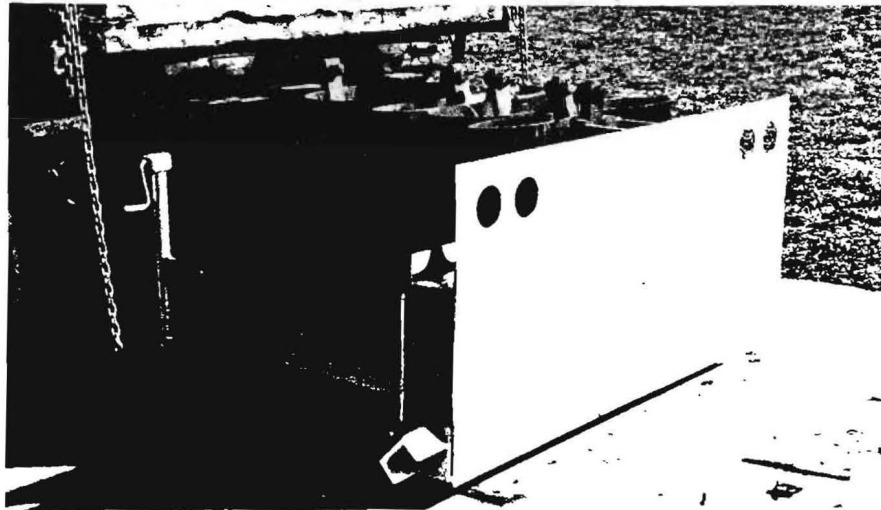
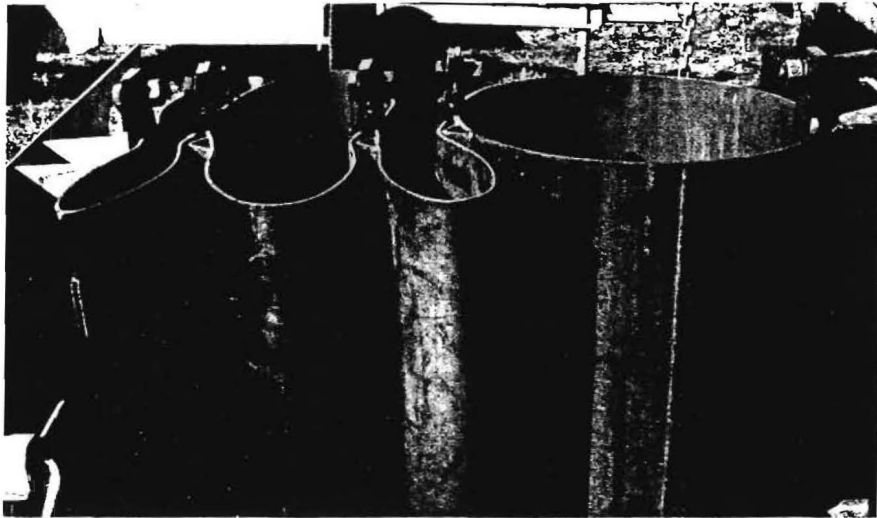
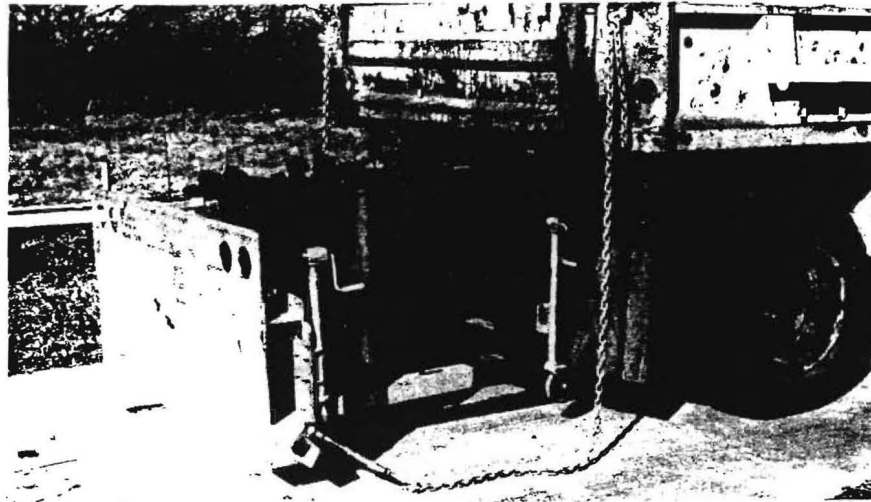


Figure 180. Connecticut TMA
after test 9910-9 .

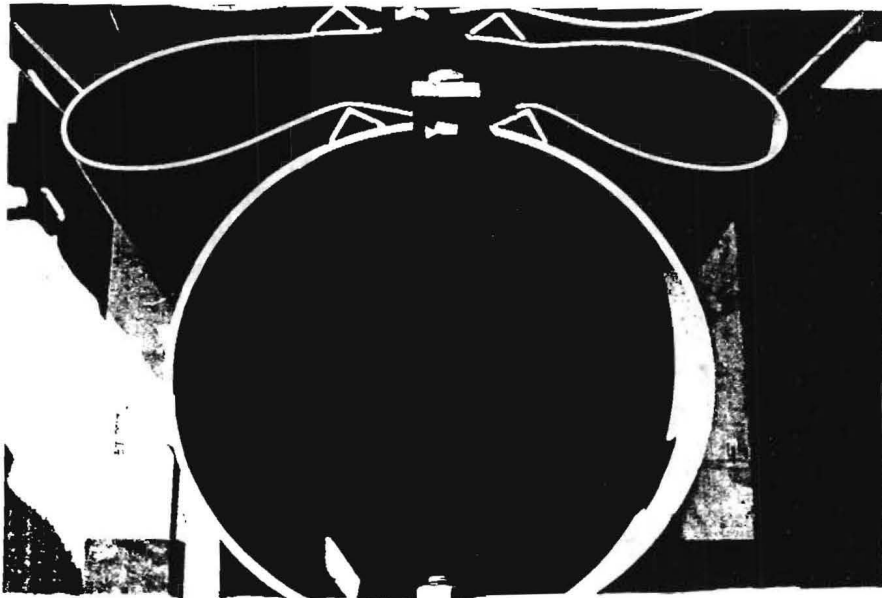
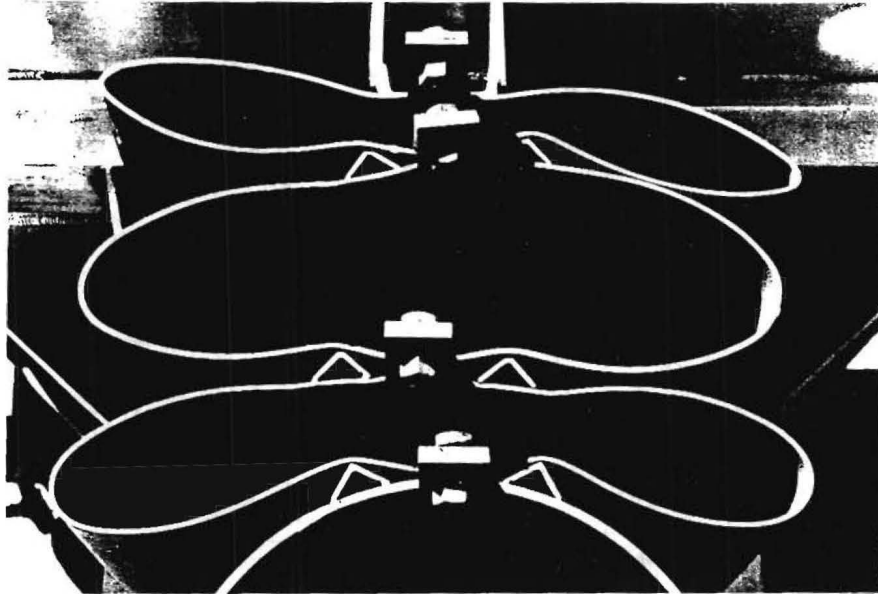


Figure 181. Pipes of Connecticut TMA
after test 9910-9 .

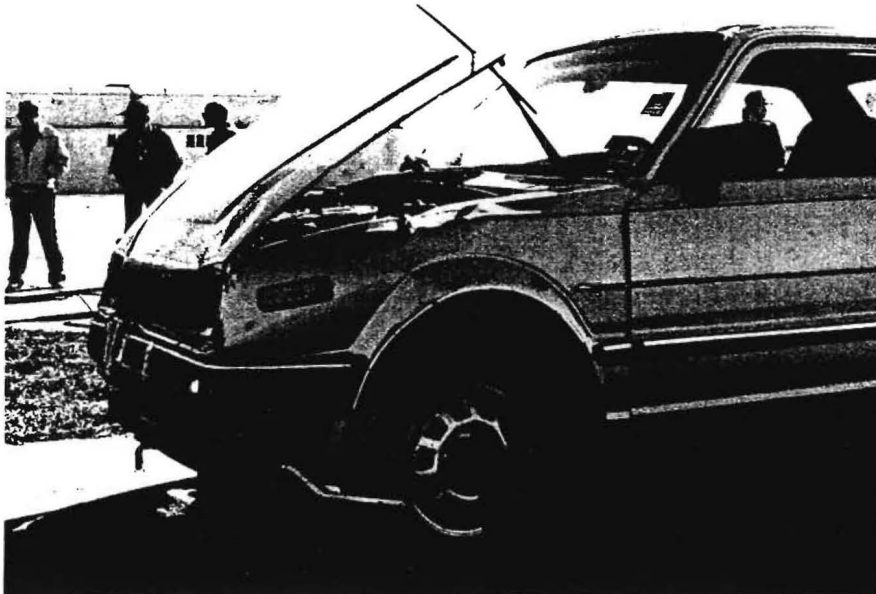
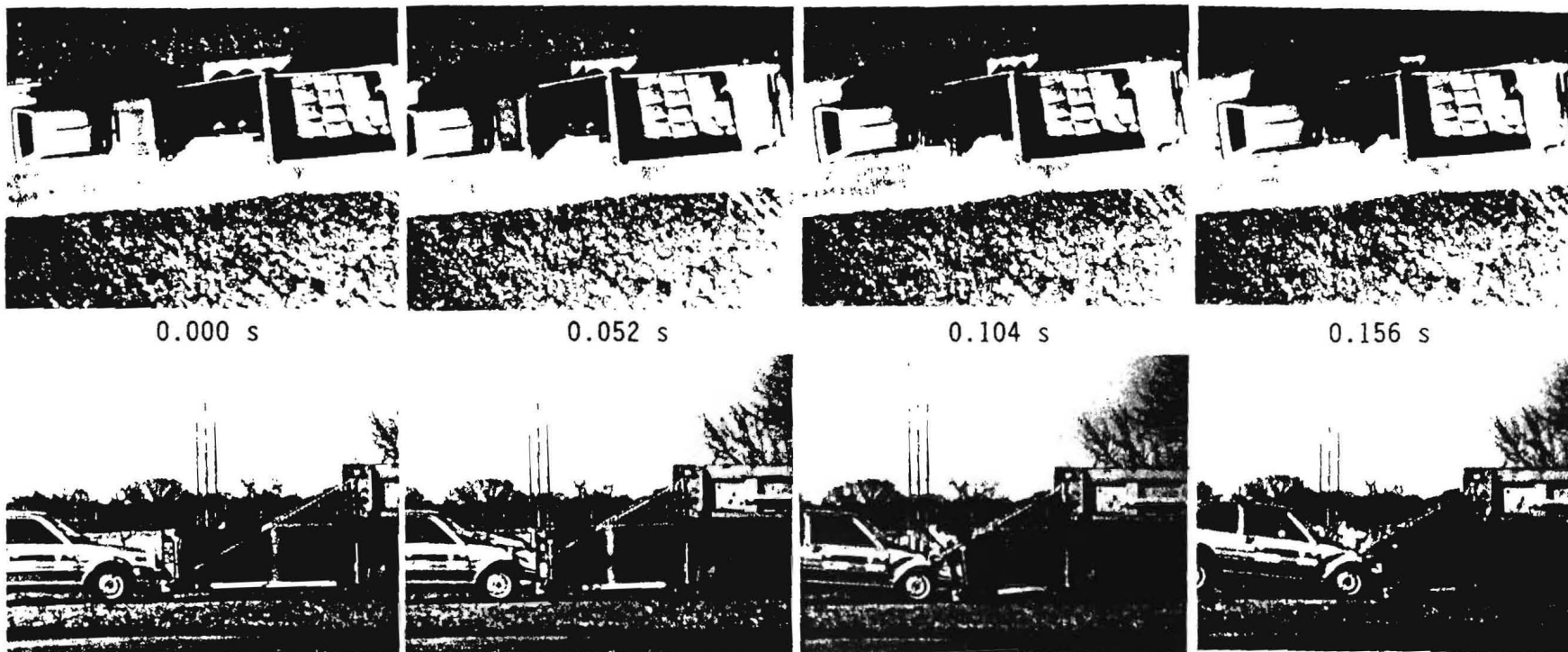


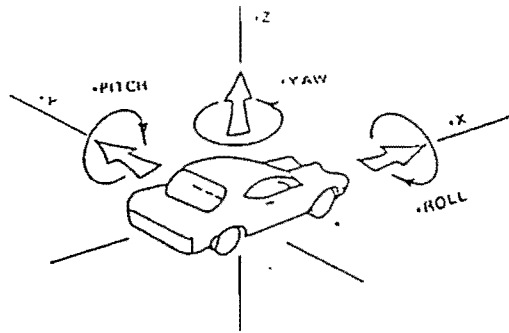
Figure 182. Vehicle after impact with Connecticut TMA (9910-9).



Test No. 09910-9
 Date 01/25/90
 Test Article Truck Mounted Attenuator
 Manufacturer Connecticut
 TMA Truck 1980 Ford Dump Truck (#2)
 Weight without TMA . . . 14,010 lb (6,361 kg)
 Weight with TMA 16,130 lb (7,323 kg)
 Test Vehicle 1982 Honda Civic
 Weight 1,800 lb (817 kg)
 Impact Speed 45.3 mi/h (72.9 km/h)
 Maximum Vehicle Crush . 7.0 in (17.7 cm)
 Vehicle Damage Classification
 TAD 12FD3
 CDC 12FDEW3

Maximum Truck Displacement . N/A (fixed position)
 Maximum TMA Crush 44.1 in (1.1 m)
 Vehicle Accelerations
 (Maximum 50 ms Average at c.g.)
 Vehicle Longitudinal . . . -14.2 g
 Vehicle Lateral -1.5 g
 Truck Cab Longitudinal . . N/A
 Occupant Impact Velocity
 Longitudinal 37.8 ft/s (11.5 m/s)
 Lateral 4.8 ft/s (1.5 m/s)
 Occupant Ridedown Accelerations
 Longitudinal -14.0 g
 Lateral -0.9 g

Figure 183 Summary of results for test 9910-9.



Axes are vehicle fixed.
Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

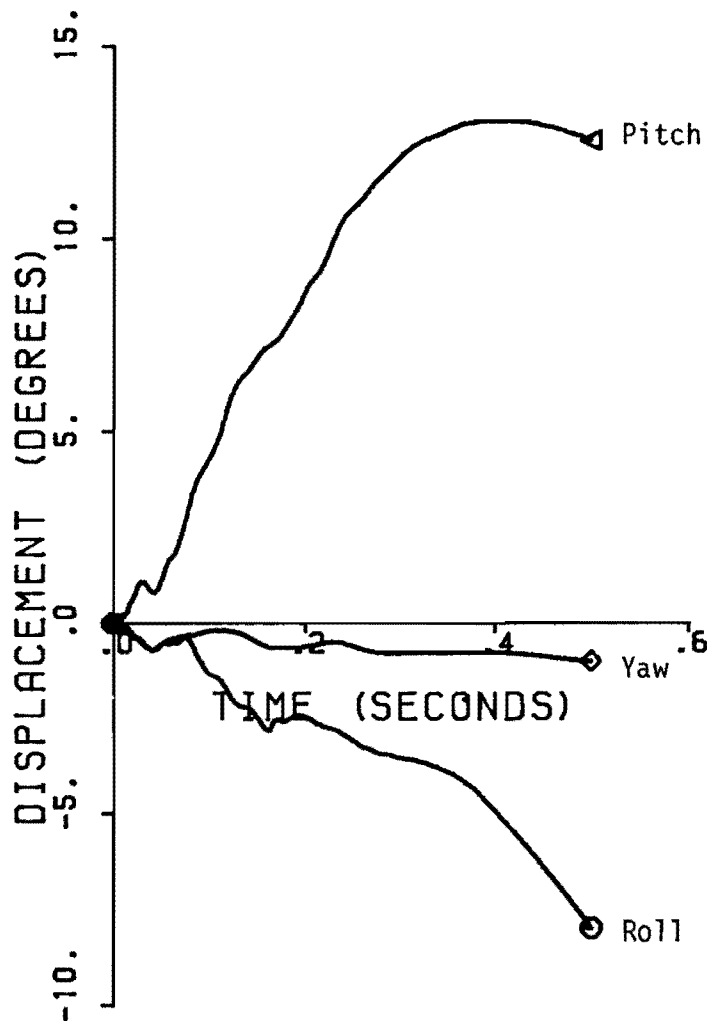


Figure 184. Vehicle angular displacements for test 9910-9.

TEST 9910-9

Class 180 Filter

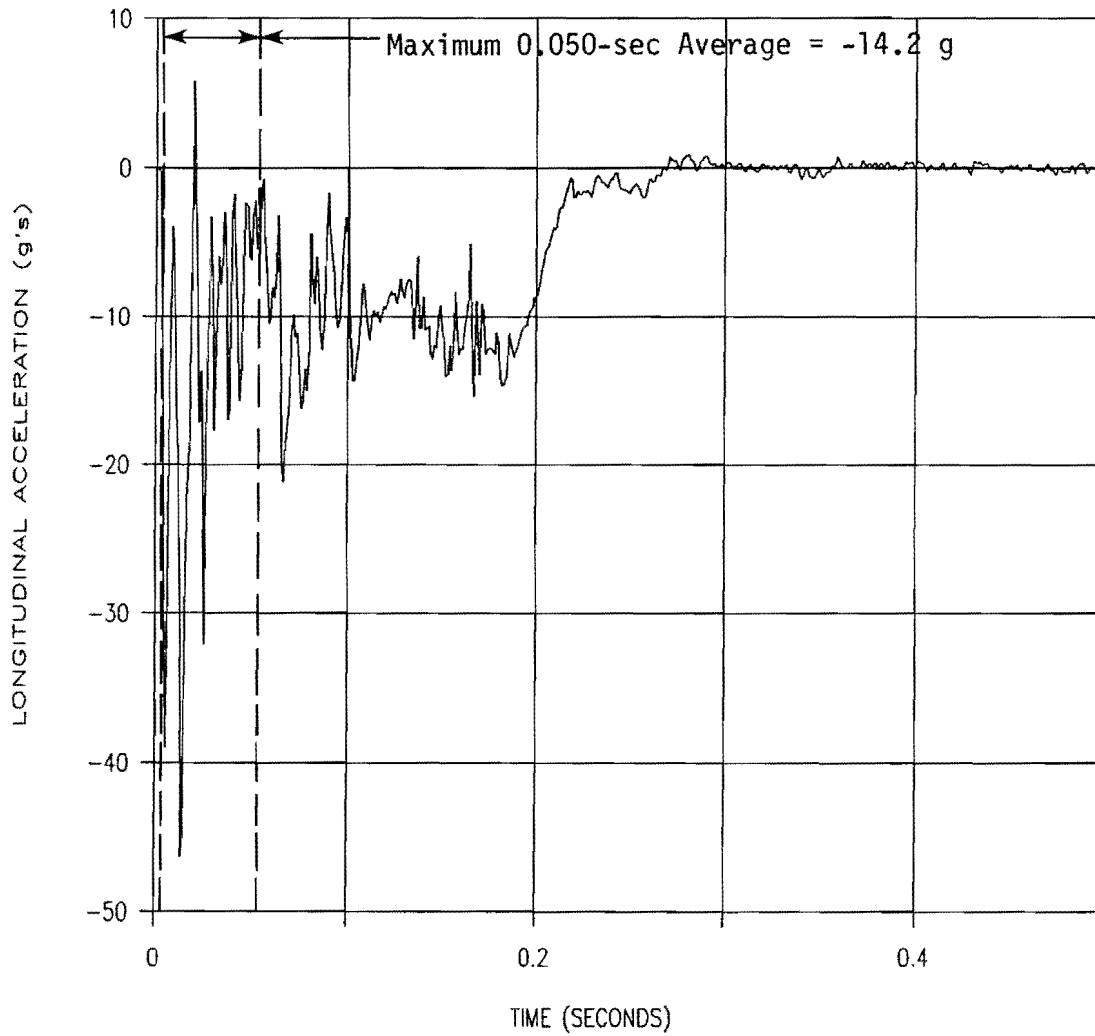


Figure 185. Vehicle longitudinal accelerometer trace for test 9910-9.

TEST 9910-9

Class 180 Filter

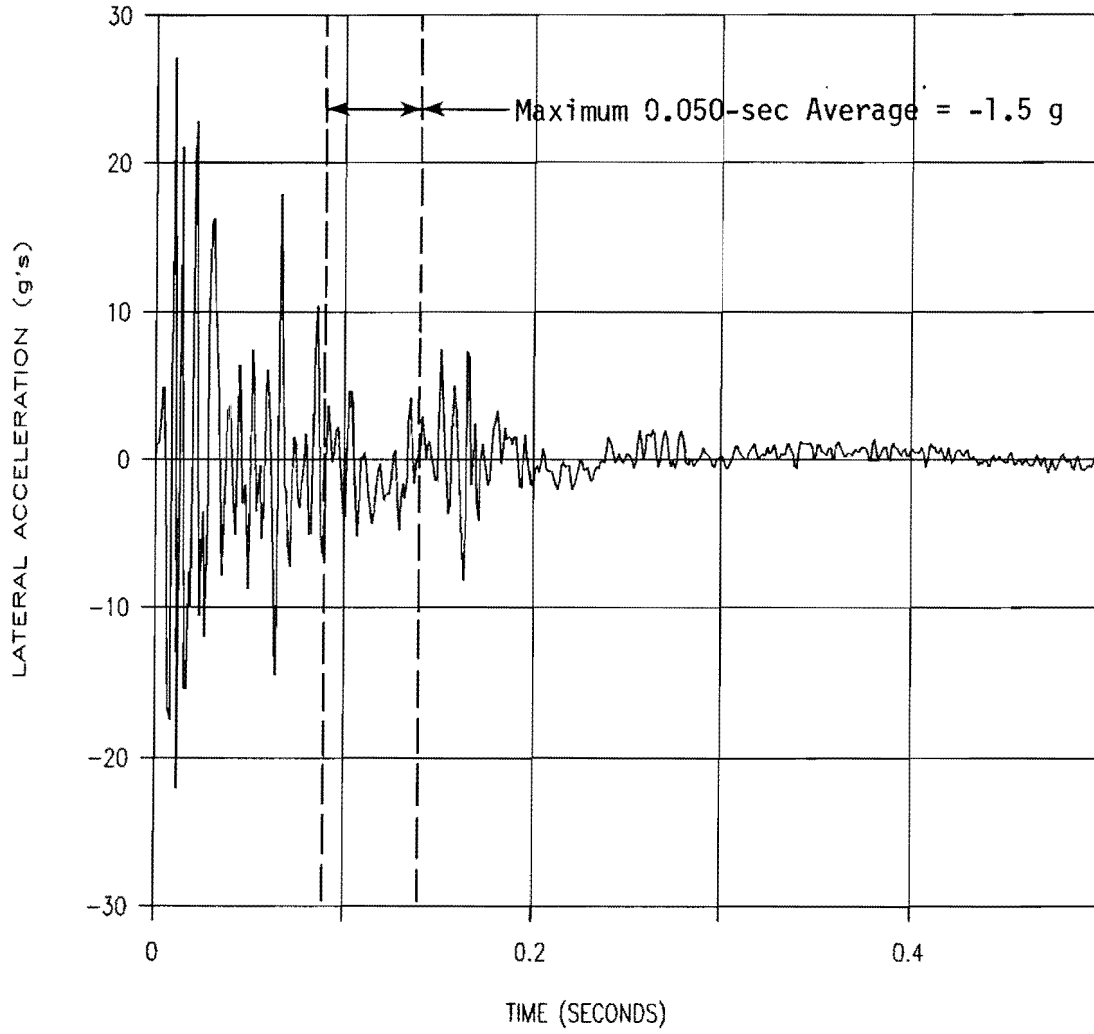


Figure 186. Vehicle lateral accelerometer trace for test 9910-9.

TEST 9910-9

Class 180 Filter

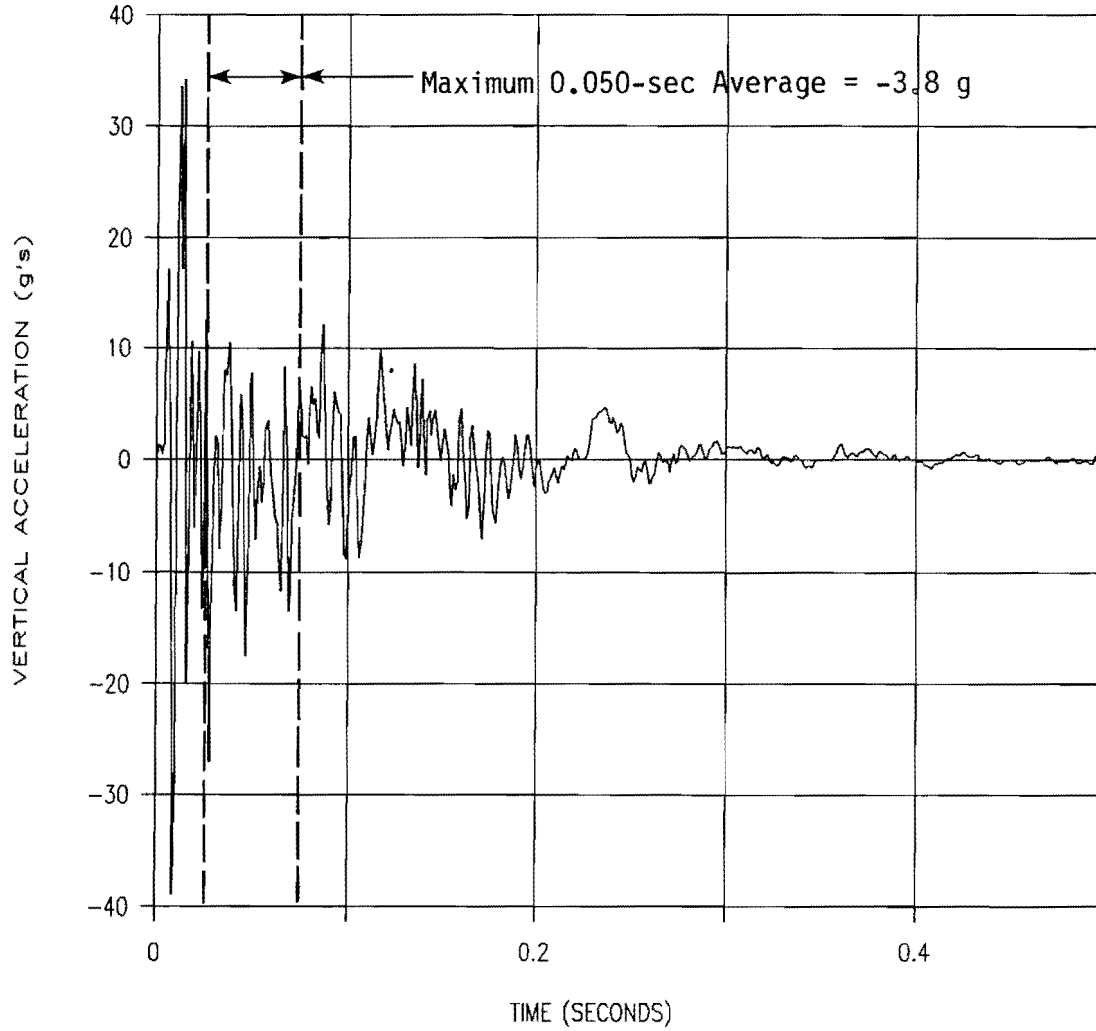


Figure 187. Vehicle vertical accelerometer trace for test 9910-9.

No TMA (9910-15)

The 1980 Honda Civic (pictured in Figure 188) was directed into the rear of Truck No. 1 with no TMA. The height to the lower edge of the impacting vehicle's bumper was 13.5 inches and 18.75 inches to the top of the bumper. Other dimensions and information on the impacting vehicle are given in Figure 189.

The vehicle was travelling at a speed of 45.9 mi/h. Upon impact, the impacting vehicle began to crush. Forward motion of the impacting vehicle stopped at 0.322 second. The vehicle subsequently came to rest 9.5 ft behind the truck. Sequential photographs of the test are shown in Figure 190.

The impacting vehicle received damage to the front bumper, hood, grill, radiator, the right and left front quarter panels, the right and left doors, and the right and left rear quarter panels. The roof and floorpan were bent and the windshield was broken. The instrument panel was also damaged. Maximum vehicle crush was 29.0 inches at bumper height. The truck received damage to the mounting bracket only. Figures 191 and 192 show damage to the truck and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 193. The maximum longitudinal 50-ms average acceleration experienced by the impacting vehicle was -32.0 g between 021 and 071 ms. Longitudinal occupant impact velocity was 61.3 ft/s at 073 ms and the maximum longitudinal ridedown acceleration was -12.4 g between 090 and 110 ms. Vehicle angular displacements are plotted in Figure 194 and accelerometer traces are displayed in Figures 195 through 197.

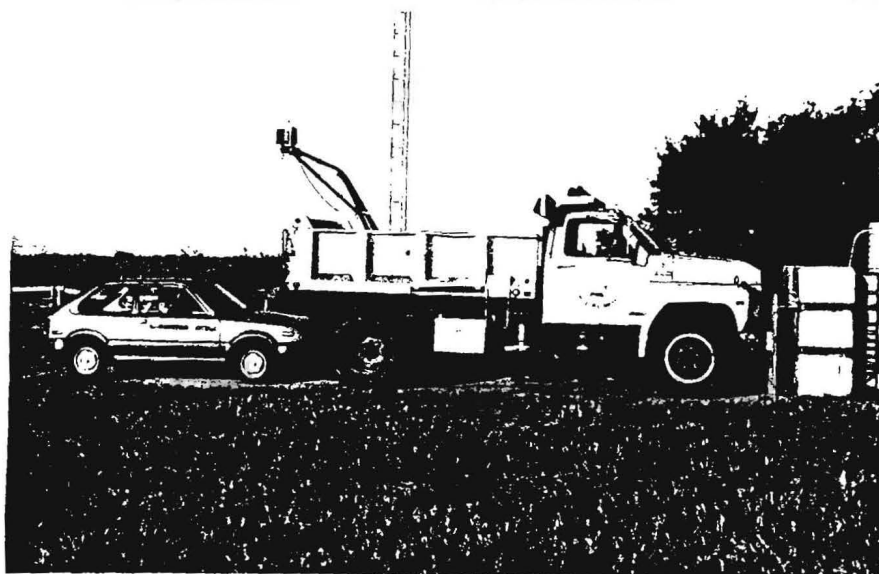
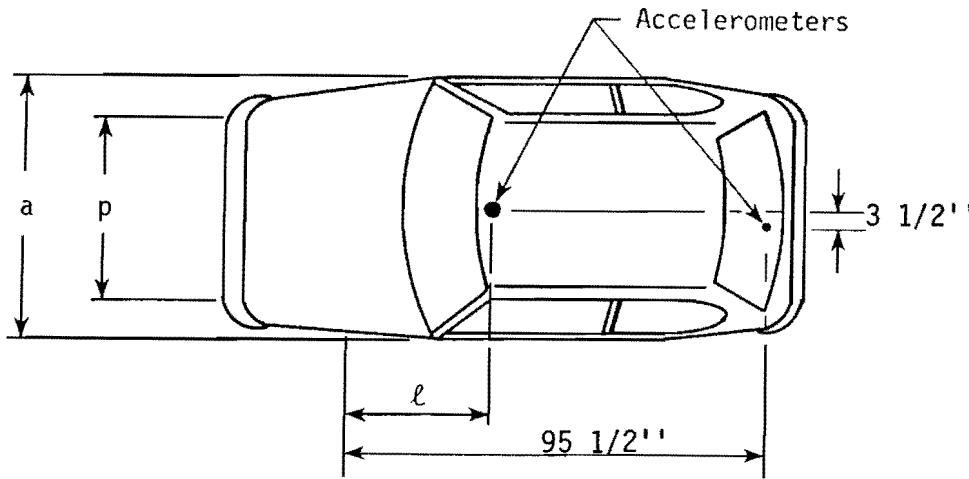


Figure 188 Vehicles prior to test 9910-15.

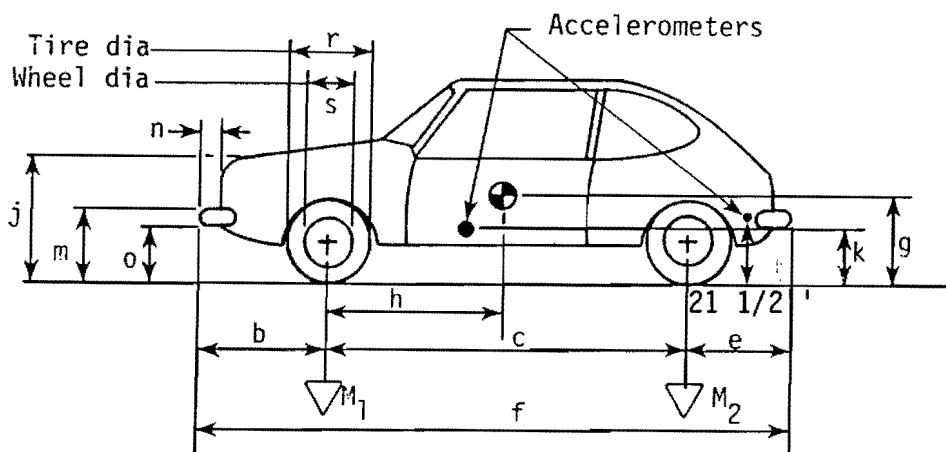
Date: 10/25/90 Test No.: 9910-15 VIN: SEA1022665
 Make: Honda Model: Civic Year: _____ Odometer: 12077.5
 Tire Size: 155SR12 Ply Rating: _____ Bias Ply: _____ Belted: _____ Radial: x

Tire Condition: good _____
 fair x
 badly worn _____



Vehicle Geometry - inches

a 62'' b 29''
 c 88 1/2'' d* 51 1/2''
 e 29'' f 146 1/2''
 g _____ h 33.3
 i _____ j 28 1/2''
 k 15'' l 29''
 m 18 3/4'' n 3''
 o 13 1/2'' p 54''
 r 21 1/2'' s 13 1/4''



Engine Type: 4 cylinder

Engine CID: _____

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

4-wheel weight for c.g. det. lf 632 rf 490 lr 311 rr 367

Mass - pounds	Curb	Test Inertial	Gross Static
M ₁	<u>1096</u>	<u>1122</u>	_____
M ₂	<u>647</u>	<u>678</u>	_____
M _T	<u>1743</u>	<u>1800</u>	_____

Note any damage to vehicle prior to test:

Crack in windshield

Brakes:

Front: disc x drum _____

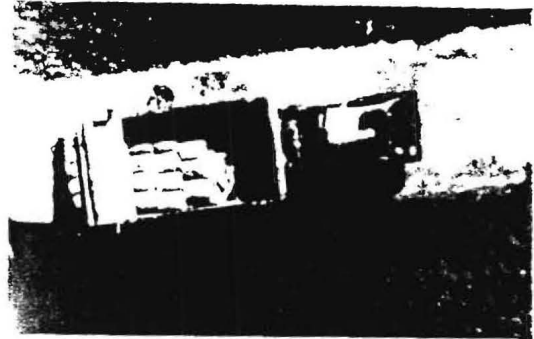
Rear: disc _____ drum x

*d = overall height of vehicle

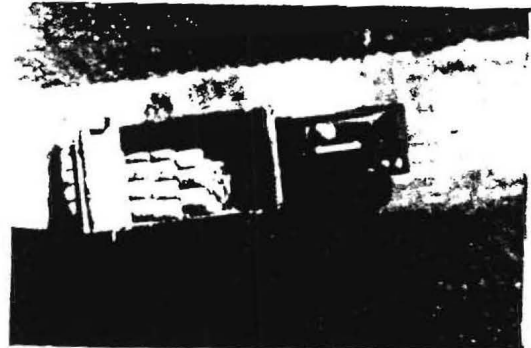
Figure 189. Test vehicle properties (test 9910-15).



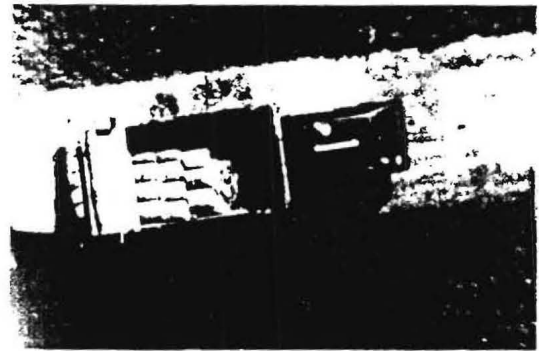
000 sec



014 sec

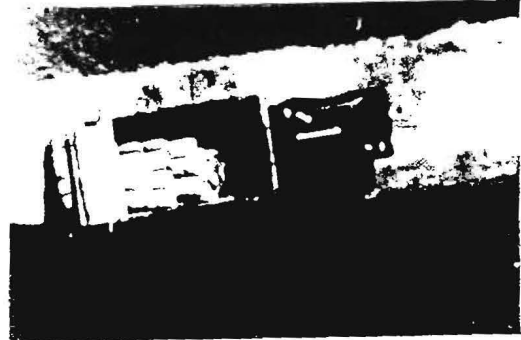
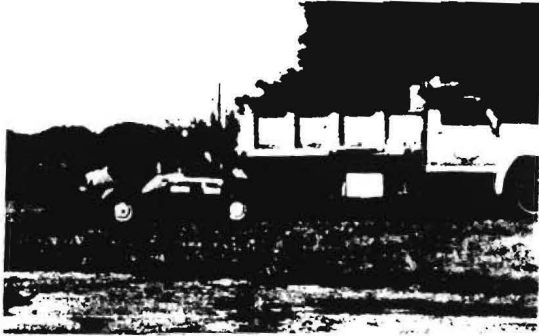


029 sec



043 sec

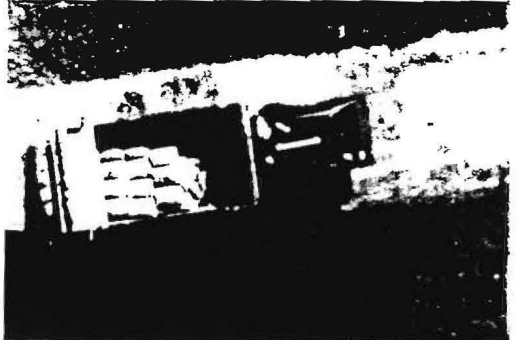
Figure 190 Sequential photographs for test 9910-15.



.057 sec



.076 sec



.091 sec



.322 sec

Figure 190 Sequential photographs for test 9910-15.
(Continued)

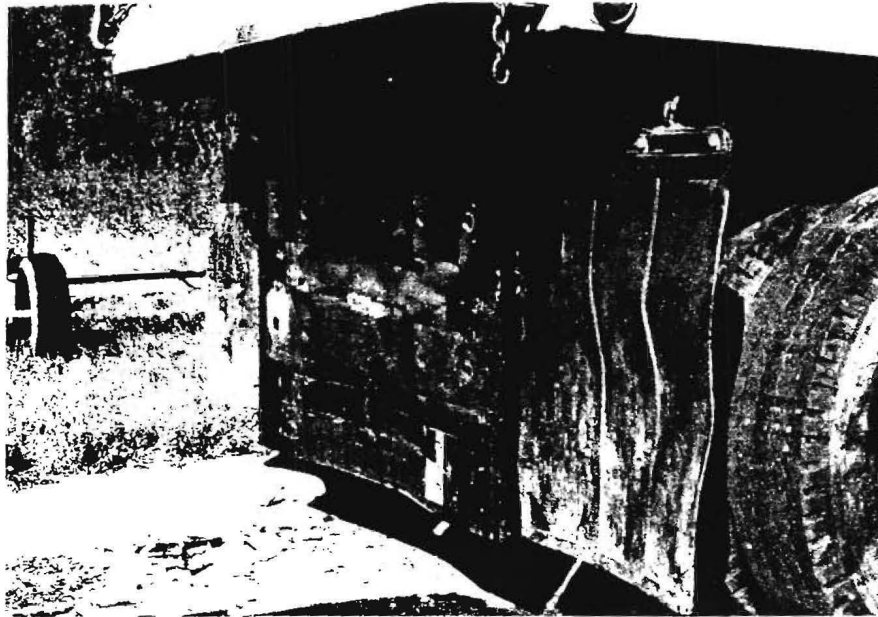


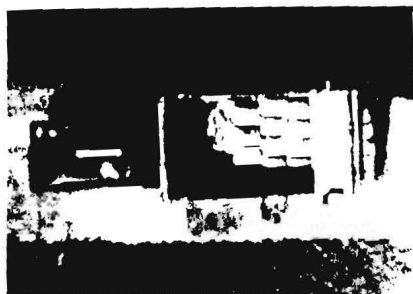
Figure 191 Damage to truck after test 9910-15.



Figure 192 Damage to passenger car after test 9910-15.



0.000 s



0.029 s



0.057 s



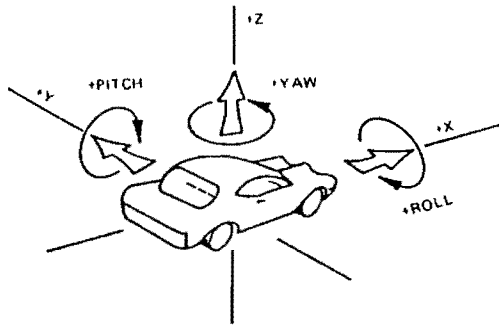
0.091 s



Test No. 09910-15
 Date 10/25/90
 Test Article Truck Mounted Attenuator
 Manufacturer No TMA (baseline test)
 TMA Truck 1981 Ford Dump Truck (#1)
 Weight without TMA 14,020 lb (6,365 kg)
 Weight with TMA No TMA
 Test Vehicle 1980 Honda Civic
 Weight 1,800 lb (817 kg)
 Impact Speed 45.9 mi/h (73.8 km/h)
 Maximum Vehicle Crush 29.0 in (73.7 cm)
 Vehicle Damage Classification
 TAD 12FD7
 CDC 12FDEW4

Maximum Truck Displacement . N/A (fixed position)
 Maximum TMA Crush N/A (No TMA)
 Vehicle Accelerations
 (Maximum 50 ms Average at c.g.)
 Vehicle Longitudinal . . . -32.0 g
 Vehicle Lateral -4.3 g
 Truck Cab Longitudinal . . . N/A
 Occupant Impact Velocity
 Longitudinal 61.3 ft/s (18.7 m/s)
 Lateral No contact
 Occupant Ridedown Accelerations
 Longitudinal -12.4 g
 LateralN/A

Figure 193 Summary of results for test 9910-15.



Axes are vehicle fixed.
Sequence for determining
orientation is:

1. Yaw
2. Pitch
3. Roll

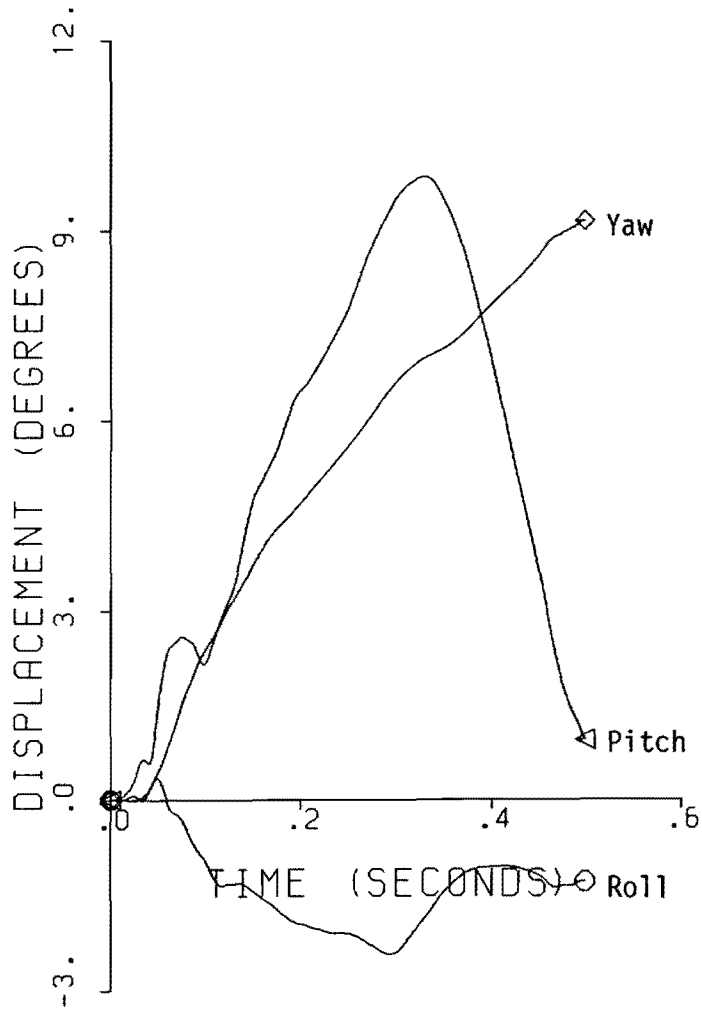


Figure 194. Vehicle angular displacements for test 9910-15.

TEST 9910-15

Class 180 Filter

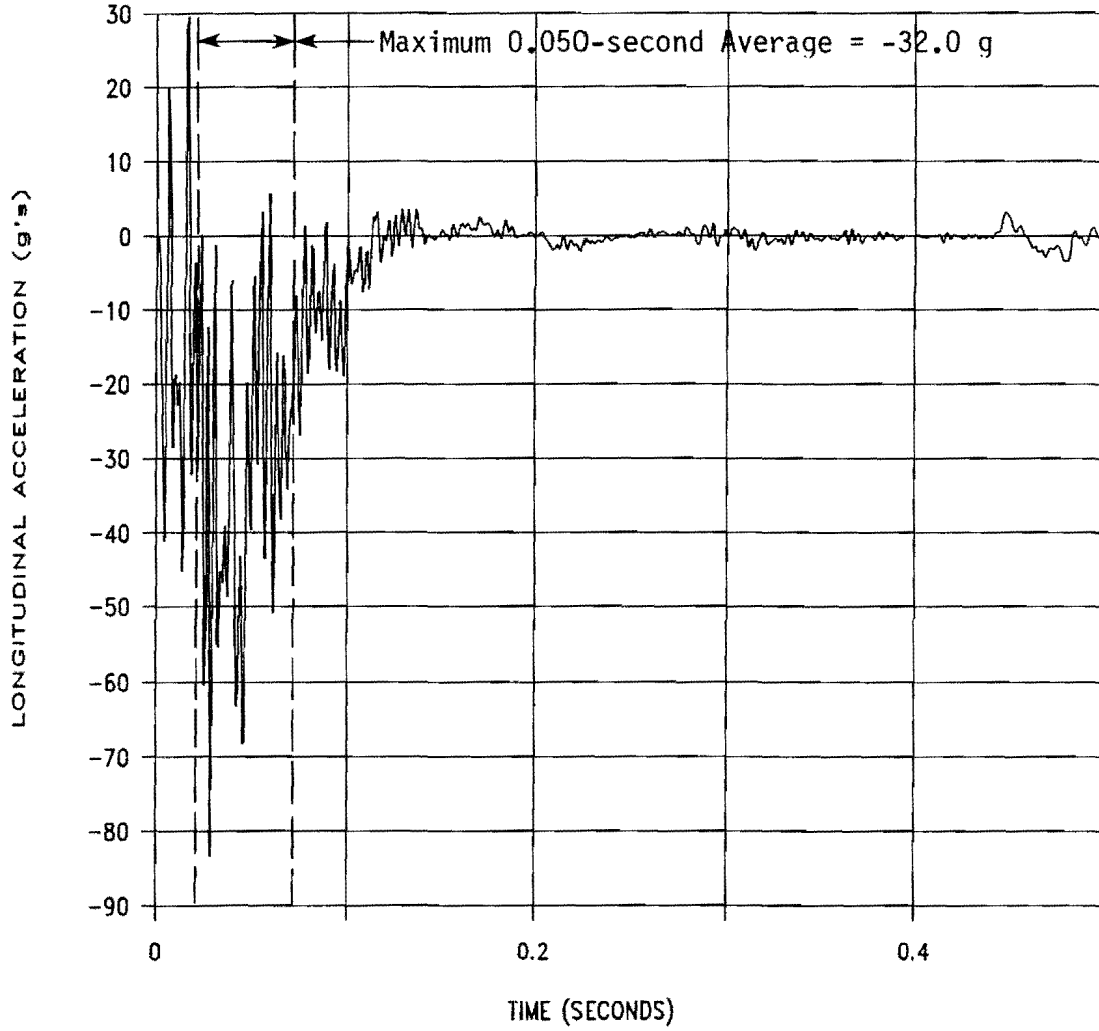


Figure 195. Vehicle longitudinal accelerometer trace for test 9910-15.

TEST 9910-15

Class 180 Filter

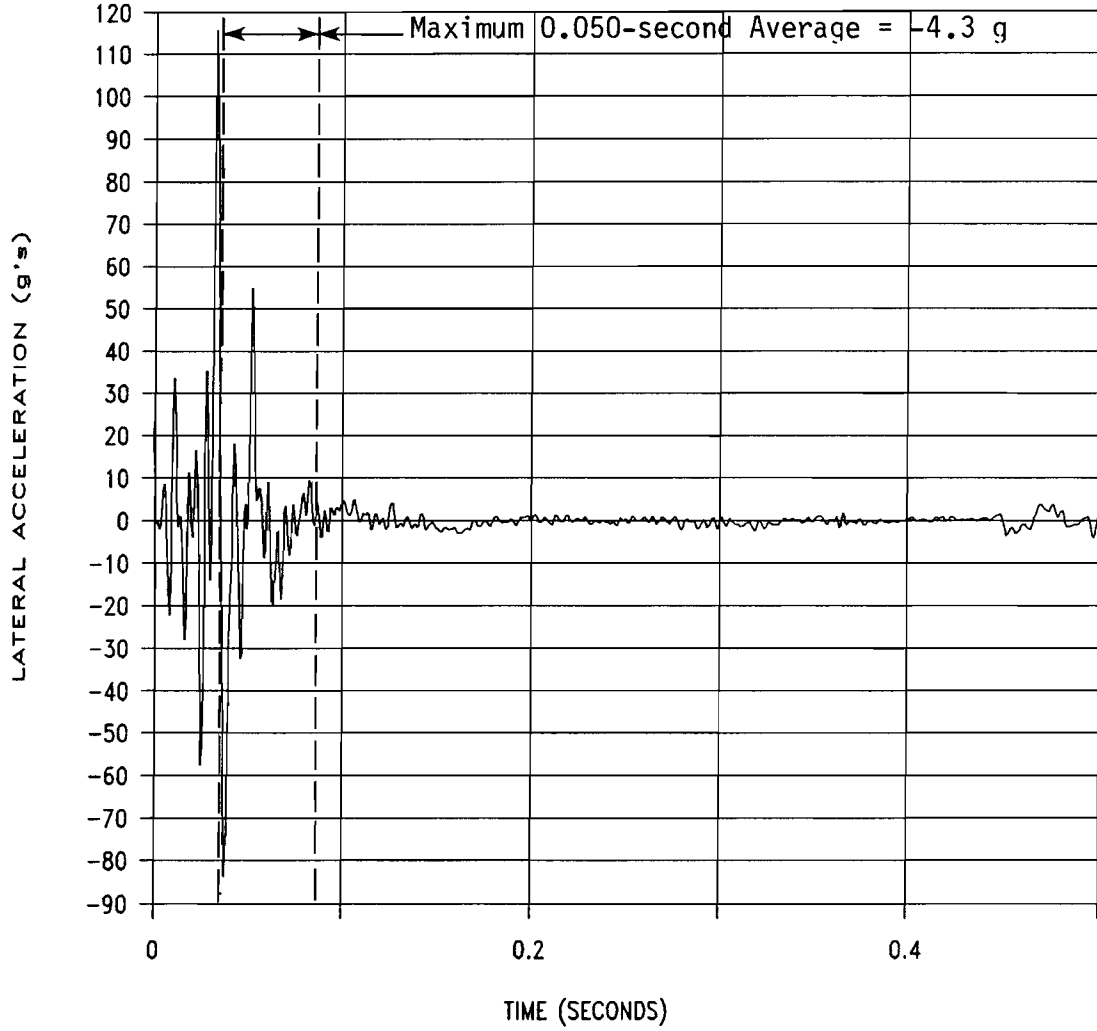


Figure 196. Vehicle lateral accelerometer trace for test 9910-15.

TEST 9910-15

Class 180 Filter

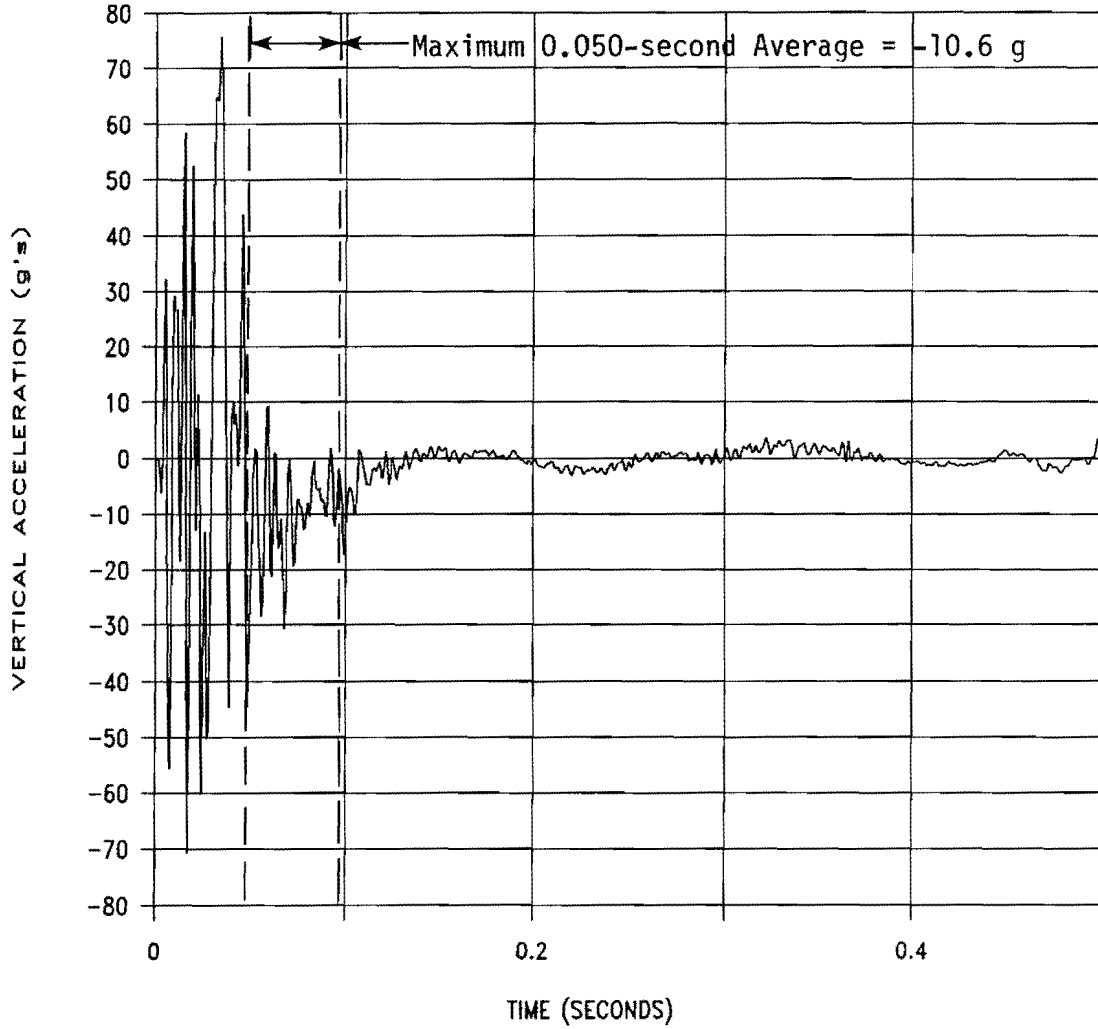


Figure 197. Vehicle vertical accelerometer trace for test 9910-15.

**Test Series 3: Free-Standing Truck Tests with 3500-lb Passenger Cars
Traveling at 55 Miles per Hour**

Before this series of tests, the TMA's were subjected to vibration and moisture tests to determine environmental effects on performance. The TMA's that passed these tests were then crash tested with a 3500-lb vehicle travelling at 55 mph. The TMA's were mounted on the trucks in a free-standing position, parked in second gear with the parking brake on. The test vehicles were directed into the TMA's using the reverse tow and cable guidance system and the point of impact being head-on with the centerline of the vehicle aligned with the centerline of the TMA. The test vehicles were free-wheeling and unrestrained just prior to impact.

Energy Absorption Alpha Model (9910-13)

The TMA used during this test was manufactured by Energy Absorption (Alpha model) and is shown in Figures 1 and 198. The TMA was mounted on Truck No. 2 a gross static weight of 15,030 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 11.5 inches at the front and 12.75 inches at the rear. The height to the upper rear surface of the cartridge was 35.25 inches above ground.

The 1982 Chevrolet Malibu (pictured in Figure 198) was towed into the Energy Absorption Alpha TMA. The height to the lower edge of the vehicle bumper was 12.75 inches and 20.75 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 199.

The vehicle was travelling at a speed of 55.5 mi/h. Upon impact, the TMA began to crush smoothly and steadily. The rear tire of the dump truck began to rotate at 0.063 second after impact. The impacting vehicle began to dive at 0.111 second and bottomed out at 0.163 second. By 0.183 second the rear tire of the dump truck had rotated 30 degrees, began to skid forward and rotate backwards, and continued to do so for the remainder of the test. The dump truck reached a maximum speed of 12.6 mi/h at 0.201 second and had moved forward 2.7 ft. Forward motion of the impacting vehicle stopped at 1.131 second at which time it had travelled forward 17.1 ft and then rolled backwards. Sequential photographs of the test are shown in Figure 200.

The Energy Absorption Alpha TMA cartridge crushed a total of 68.0 inches during the test. The frame attachment to the cartridge was bent 1.75 inches on the left side and 0.75 inch on the right. The impacting vehicle received damage to the front bumper, hood, grill, radiator, and the right and left front quarter panels. The subframe and floorpan were bent and the windshield was cracked. Maximum vehicle crush was 22.0 inches at bumper height. Figures 201 and 202 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 203. The maximum longitudinal 50-ms average acceleration experienced by the impacting vehicle was -24.2 g between 112 and 162 ms. Longitudinal occupant impact velocity was 39.3 ft/s at 140 ms and the maximum

longitudinal ridedown acceleration was -39.3 g between 148 and 158 ms. Vehicle angular displacements are plotted in Figure 204 and accelerometer traces are displayed in Figures 205 through 208.

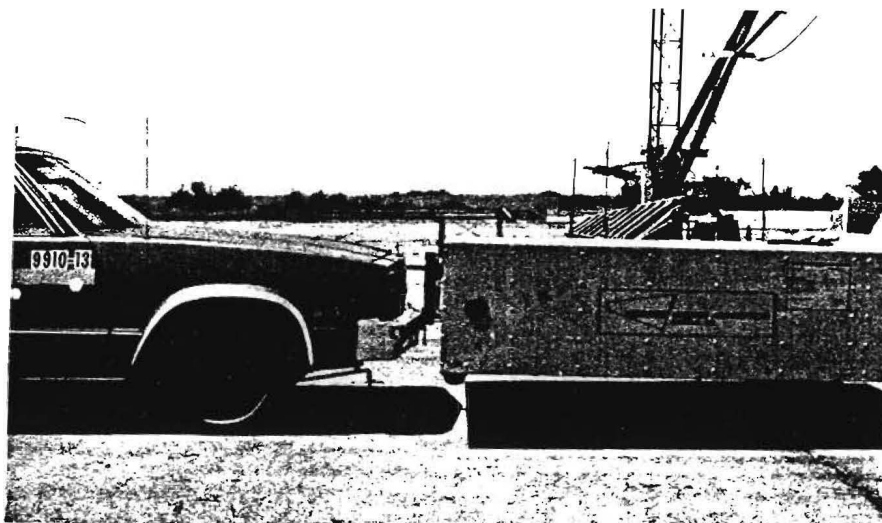
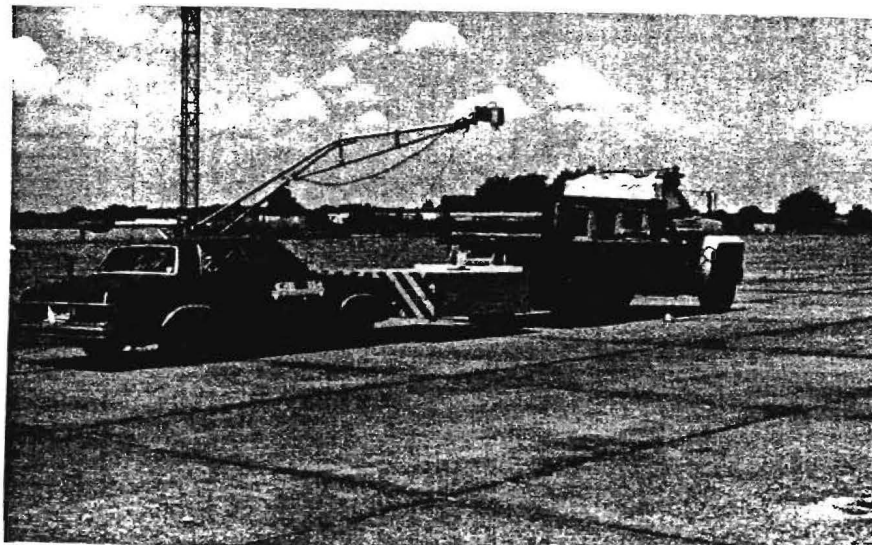
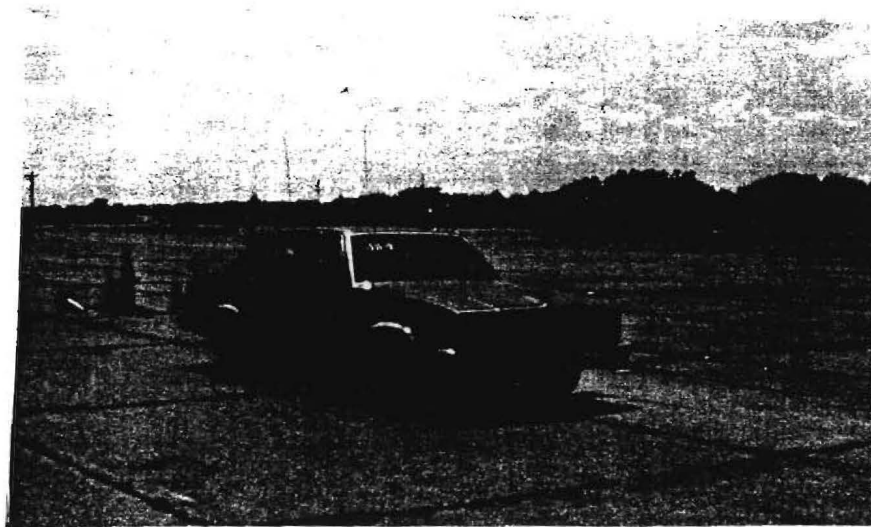
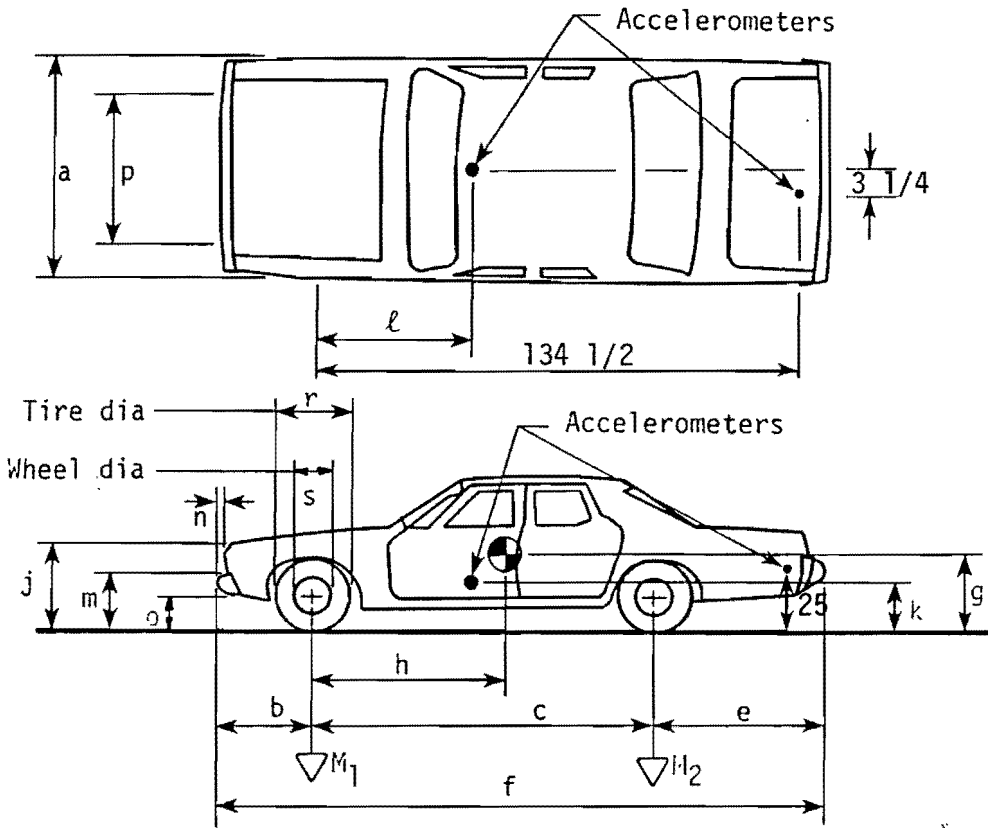


Figure 198 Vehicle before impact with Energy Absorption Alpha TMA (9910-13).

Date: _____ Test No.: 9910-13 VIN: 1G1AW69K8CR119885
 Make: Chevrolet Model: Malibu Year: 1982 Odometer: 286395
 Tire Size: P185 75R14 Ply Rating: _____ Bias Ply: _____ Belted: _____ Radial: _____

Tire Condition: good _____
 fair x
 badly worn _____



Vehicle Geometry - inches

a	<u>71 1/4</u>	b	<u>35</u>
c	<u>107 1/2</u>	d*	<u>54 1/2</u>
e	<u>48</u>	f	<u>190 1/2</u>
g	_____	h	<u>49.73</u>
i	<u>----</u>	j	<u>32 1/2</u>
k	<u>19</u>	l	<u>31 1/4</u>
m	<u>20 3/4</u>	n	<u>4</u>
o	<u>12 3/4</u>	p	<u>58 1/4</u>
r	<u>24 1/2</u>	s	<u>15 1/4</u>

Engine Type: V8
 Engine CID: 305
 Transmission Type: _____

Automatic or Manual
 FWD or RWD or 4WD

Body Type: 4 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 992 rf 889 lr 820 rr 799

Mass - pounds	Curb	Test Inertial	Gross Static
M_1	<u>1885</u>	<u>1881</u>	_____
M_2	<u>1324</u>	<u>1619</u>	_____
M_T	<u>3209</u>	<u>3500</u>	_____

Note any damage to vehicle prior to test:

*d = overall height of vehicle

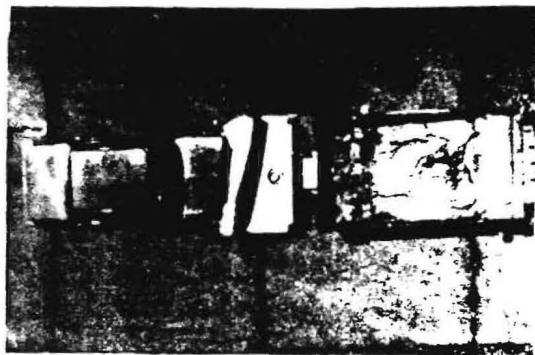
Figure 199. Test vehicle properties (test 9910-13)



0.000 s



0.063 s



0.126 s



0.189 s

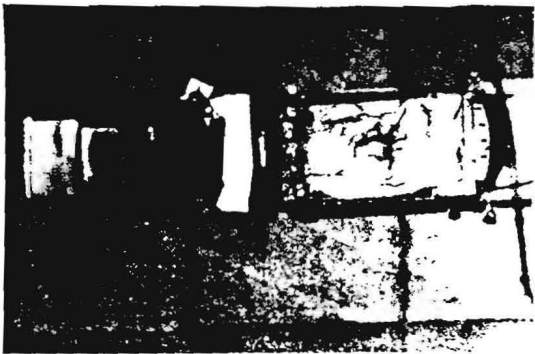


Figure 200 Sequential photographs for test 9910-13.



0.377 s



0.628 s



0.880 s



1.131 s

Figure 200 Sequential photographs for test 9910-13.
(Continued)

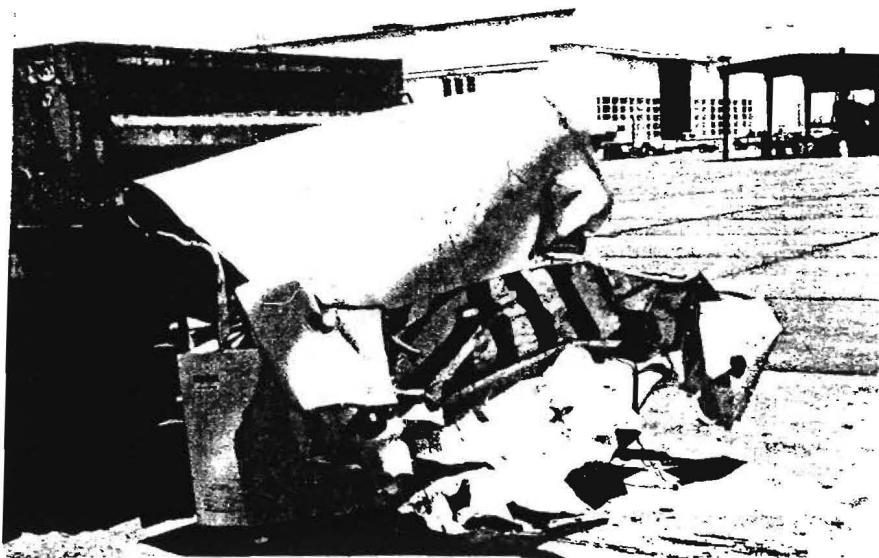
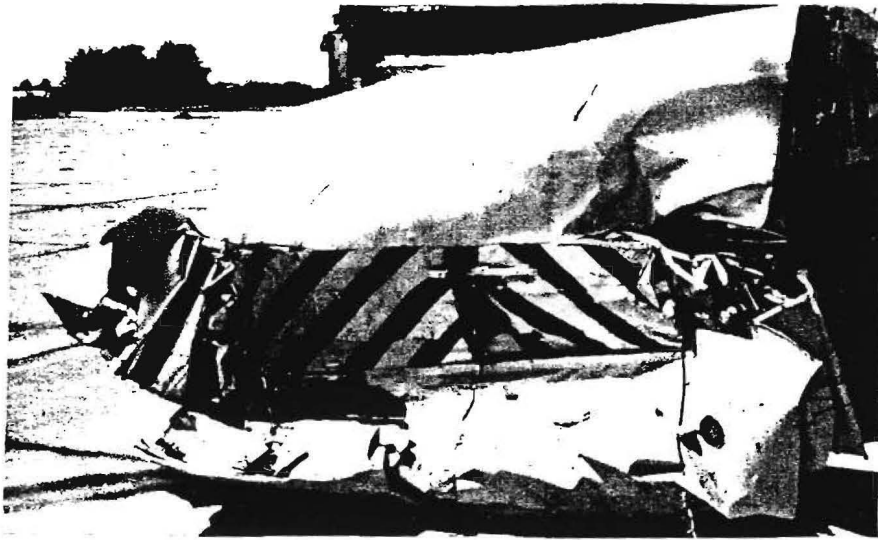
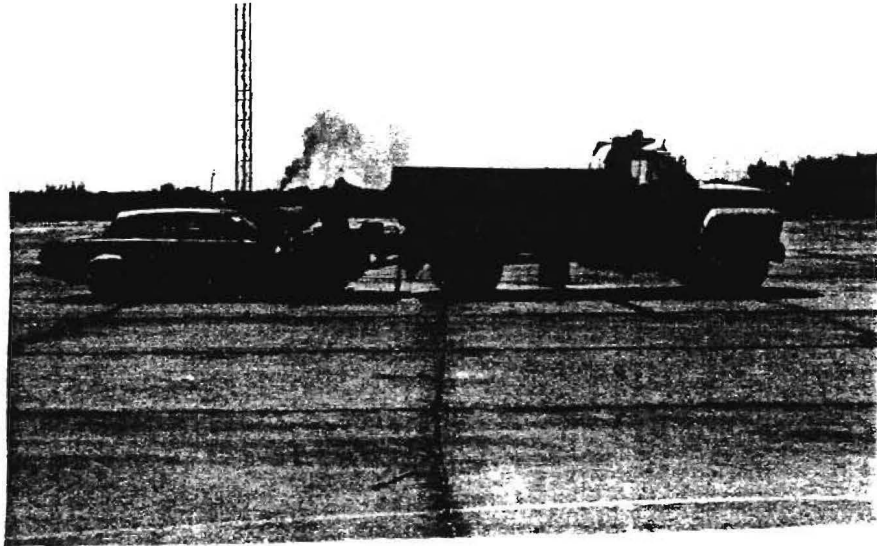
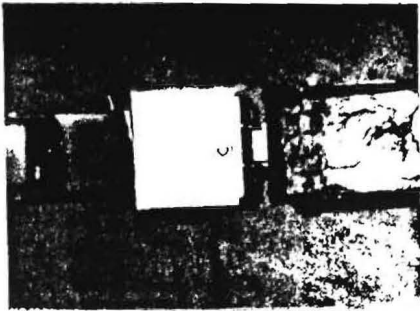


Figure 201 Energy Absorption Alpha TMA after test (9910-13).



Figure 202 Vehicle after impact with Energy Absorption Alpha TMA (9910-13).



0.000 s



0.126 s



0.189 s



0.628 s

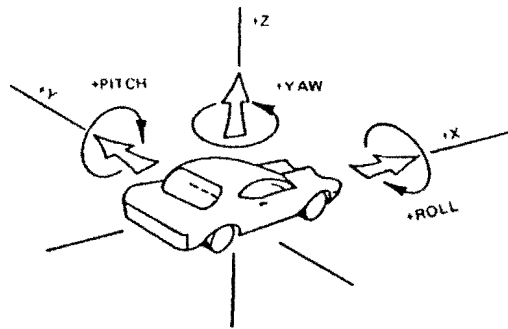


247

Test No. 09910-13
 Date 08/31/90
 Test Article Truck Mounted Attenuator
 Manufacturer Energy Absorption (Alpha)
 TMA Truck 1980 Ford Dump Truck (#2)
 Weight without TMA 14,010 lb (6,361 kg)
 Weight with TMA 15,030 lb (6,824 kg)
 Test Vehicle 1982 Chevrolet Malibu
 Weight 3,500 lb (1,589 kg)
 Impact Speed 55.5 mi/h (89.3 km/h)
 Maximum Vehicle Crush 22.0 in (55.9 cm)
 Vehicle Damage Classification
 TAD 12FD6
 CDC 12FDEW3

Maximum Truck Displacement 8.5 ft (2.6 m)
 Maximum TMA Crush 68.0 in (1.7 m)
 Vehicle Accelerations
 (Maximum 50 ms Average at c.g.)
 Vehicle Longitudinal -24.2 g
 Vehicle Lateral 2.2 g
 Truck Cab Longitudinal 5.8
 Occupant Impact Velocity
 Longitudinal 39.3 ft/s (12.0 m/s)
 Lateral None
 Occupant Ridedown Accelerations
 Longitudinal -39.3 g
 Lateral N/A

Figure 203. Summary of results for test 9910-13.



Axes are vehicle fixed.
 Sequence for determining
 orientation is:

1. Yaw
2. Pitch
3. Roll

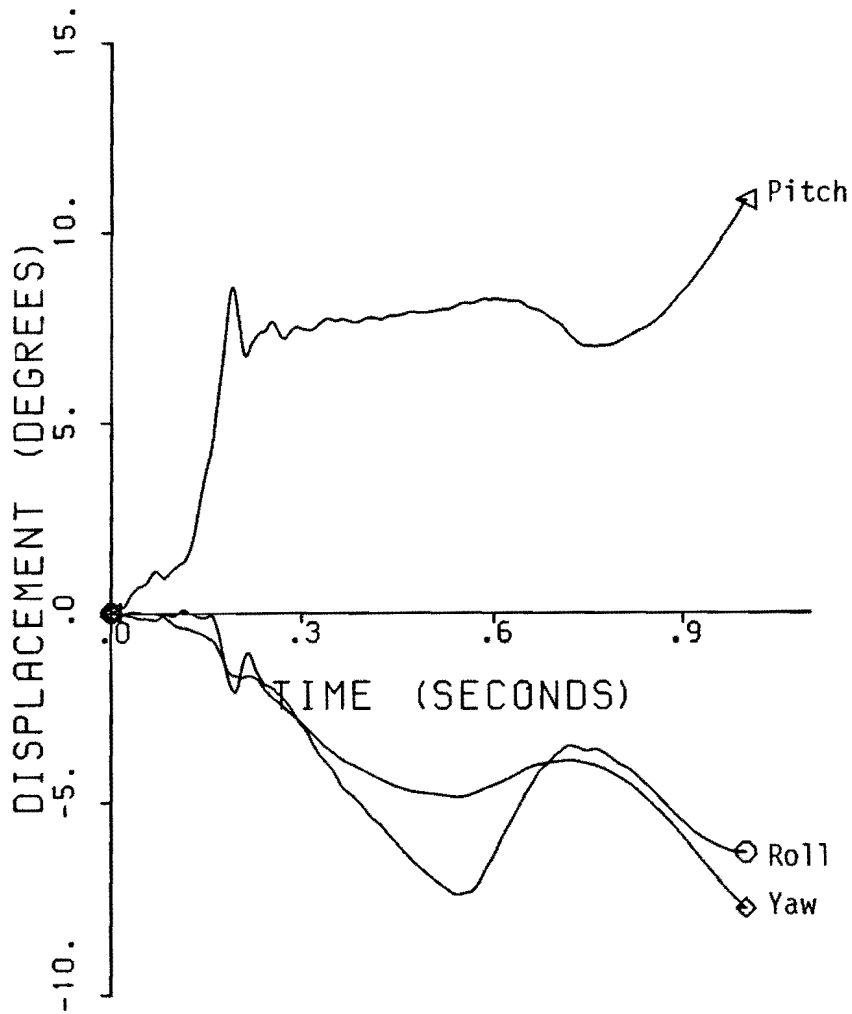


Figure 204. Vehicle angular displacements for test 9910-13.

TEST 9910-13

Class 180 Filter

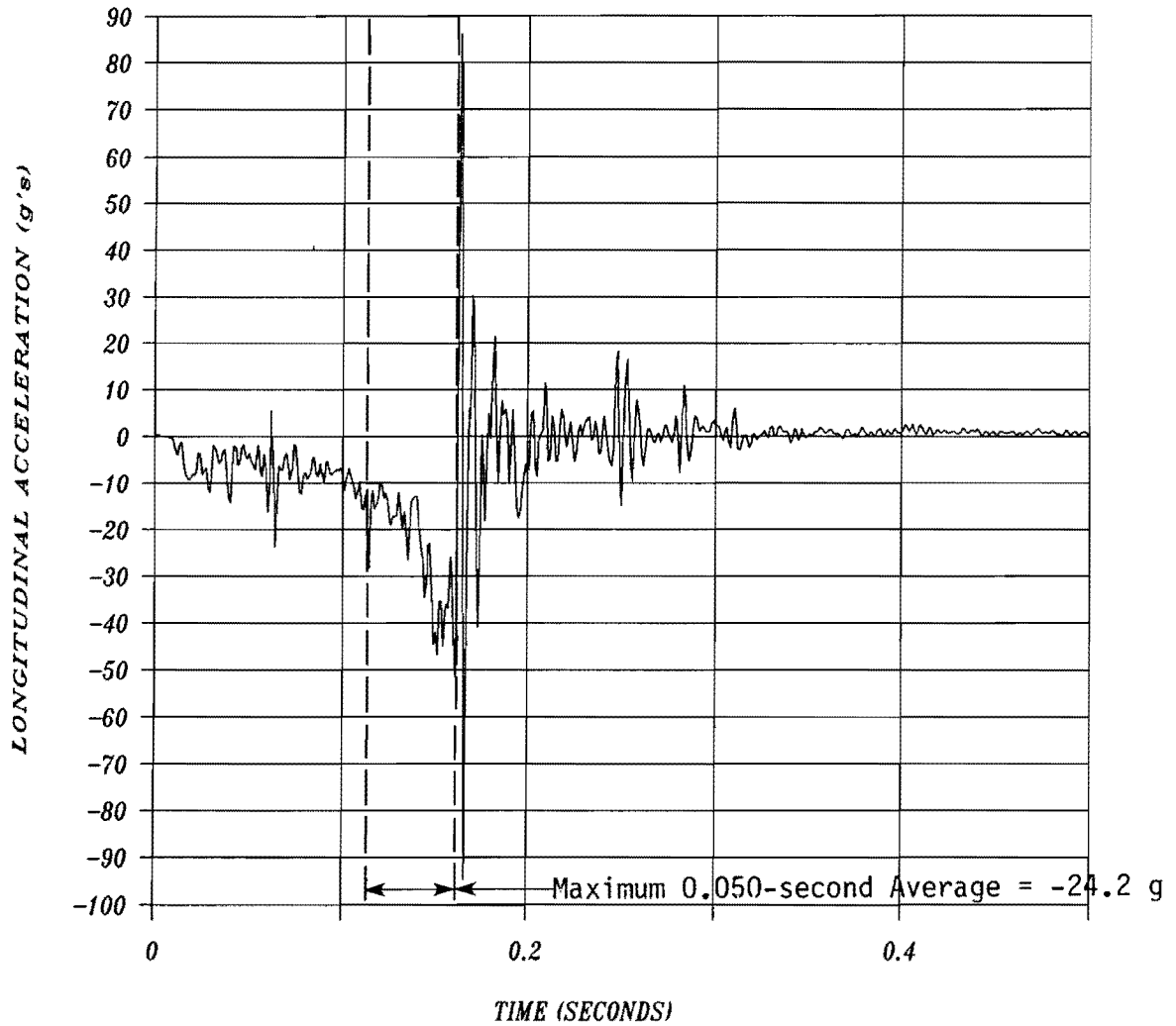


Figure 205. Vehicle longitudinal accelerometer trace for test 9910-13.

TEST 9910-13

Class 180 Filter

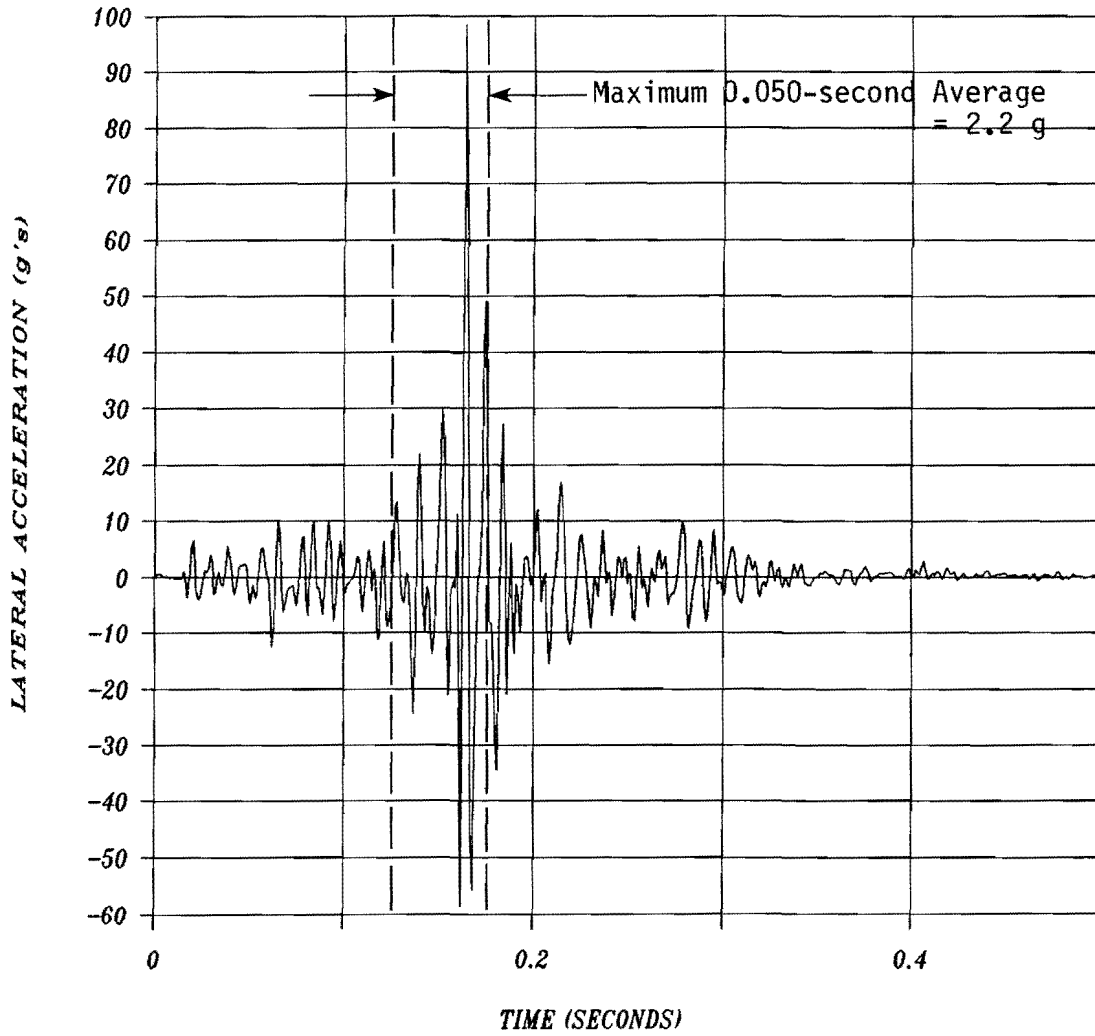


Figure 206. Vehicle lateral accelerometer trace for test 9910-13.

TEST 9910-13

Class 180 Filter

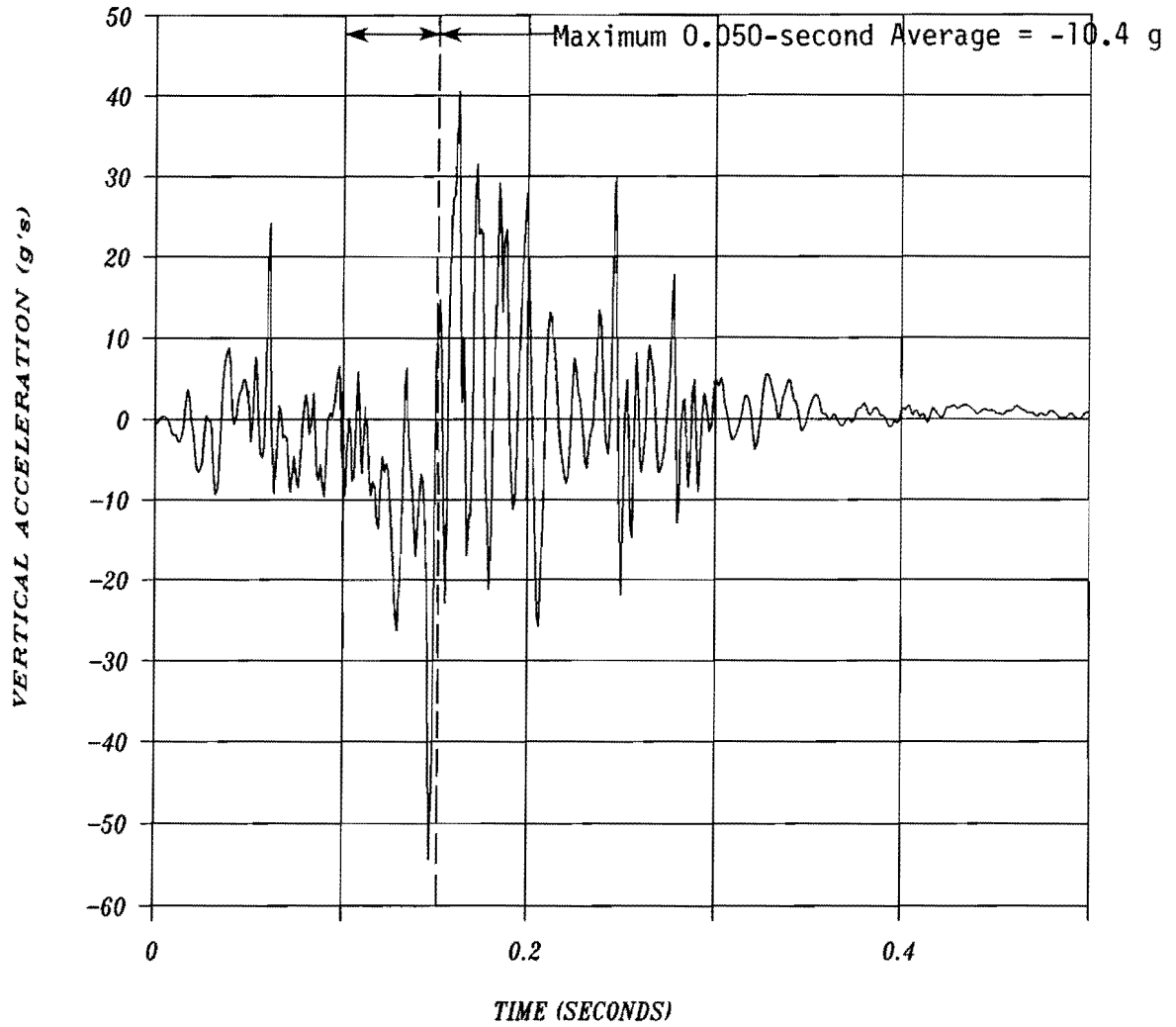


Figure 207. Vehicle vertical accelerometer trace for test 9910-13.

TEST 9910-13

Class 180 Filter - Dump Truck

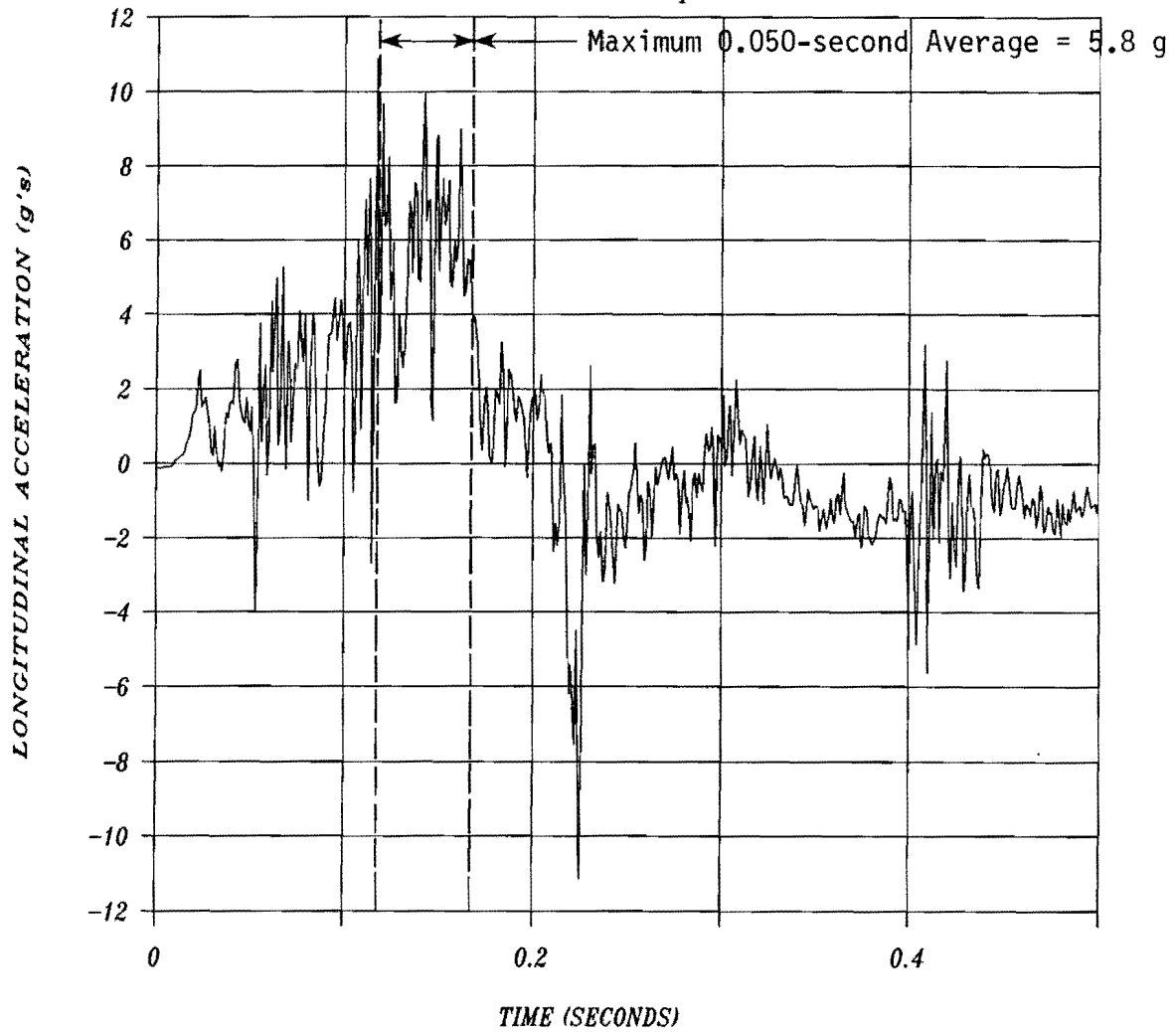


Figure 208. Dump truck longitudinal accelerometer trace for test 9910-13.

Hexcel 3000 (9910-14)

The TMA used during this test was manufactured by Hexcel (Model 3000) and is shown in Figures 3 and 209. The TMA was mounted on Truck No. 2 which had a gross static weight of 14,920 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 10.5 inches at the front and 11.5 inches at the rear. The height to the upper rear surface of the cartridge was 35.75 inches above ground.

The 1979 Chevrolet Malibu (pictured in Figure 209) was towed into the Hexcel Model 3000 TMA. The height to the lower edge of the vehicle bumper was 12.5 inches and 20.0 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 210.

The vehicle was travelling at a speed of 58.0 mi/h. Upon impact, the TMA began to crush smoothly and steadily. The rear tire of the dump truck began to rotate at 0.032 second after impact. The impacting vehicle began to dive at 0.062 second and bottomed out at 0.149 second. The dump truck reached at maximum speed of 8.9 mi/h at 0.161 second and had moved forward 1.1 ft. By 0.181 second the rear tire of the dump truck had rotated 14 degrees, began to skid forward and rotate backwards, and continued to do so for the remainder of the test. Forward motion of the impacting vehicle stopped at 0.985 second at which time it had travelled forward 18.0 ft and then rolled backwards. Sequential photographs of the test are shown in Figure 211.

The Hexcel Model 3000 TMA cartridge crushed a total of 75.0 inches during the test. The frame attachment to the cartridge was bent 0.5 inches on the left side and 0.69 inch on the right. The impacting vehicle received damage to the front bumper, hood, grill, radiator, the right and left front quarter panels, and right and left doors. The roof, subframe and floorpan were bent and the windshield was cracked. Maximum vehicle crush was 22.0 inches at bumper height. Figures 212 and 213 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 214. The maximum longitudinal 50-ms average acceleration experienced by the impacting vehicle was -22.8 g between 120 and 170 ms. Longitudinal occupant impact velocity was 37.9 ft/s at 132 ms and the maximum longitudinal ridedown acceleration was -35.1 g between 139 and 149 ms. Vehicle angular displacements are plotted in Figure 215 and accelerometer traces are displayed in Figures 216 through 219.

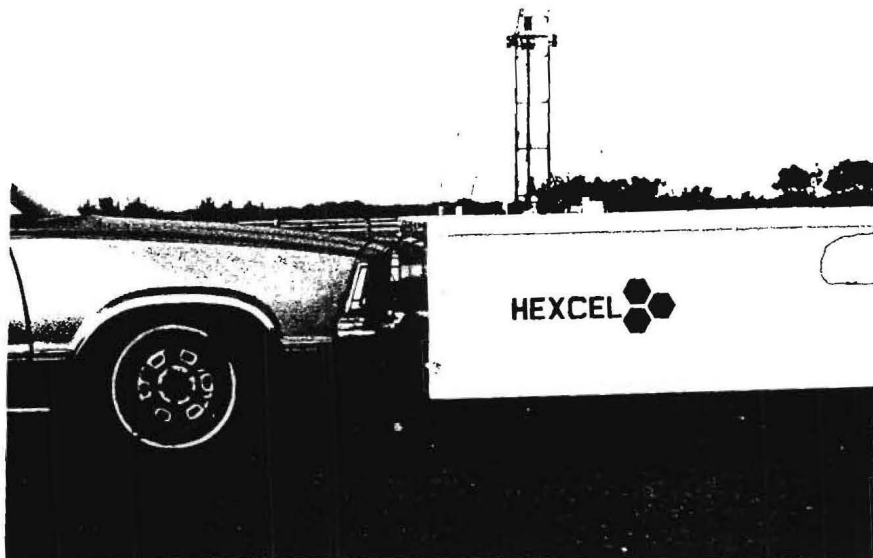
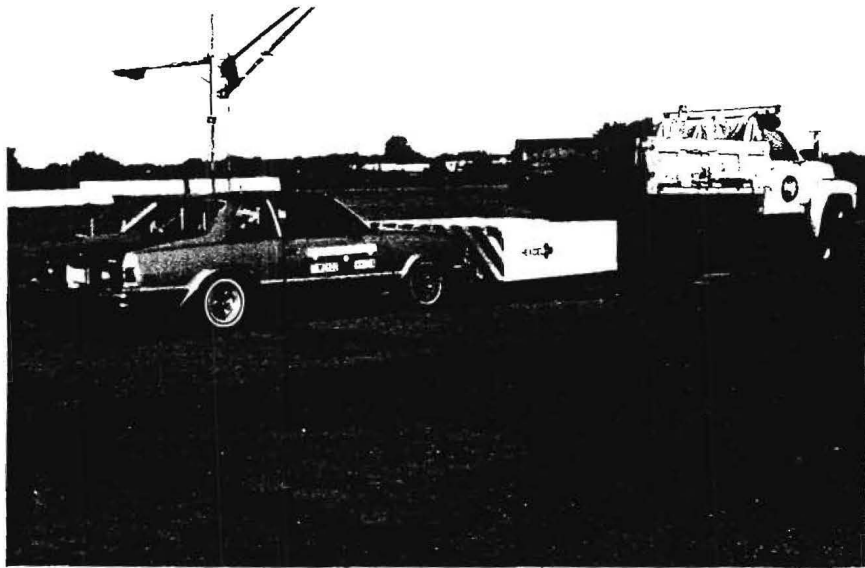


Figure 209 Vehicle before impact with Hexcel TMA (9910-14).

Date: 10/23/90 Test No.: 9910-14 VIN: 1W27J9D483393
 Make: Chevy Model: Malibu Year: 1979 Odometer: 29314.6
 Tire Size: 19575R-15 Ply Rating: _____ Bias Ply: ___ Belted: x Radial: ___

Tire Condition: good x
 fair ___
 badly worn ___

Vehicle Geometry - inches

a 71 1/2'' b 36 1/2''
 c 108'' d* 53 3/4''
 e _____ f _____
 g _____ h 48.4
 i ---- j 32 1/4''
 k 18 3/4'' l 28''
 m 20'' n 3''
 o 12 1/2'' p 57 7/8''
 r 26'' s 15 1/4''

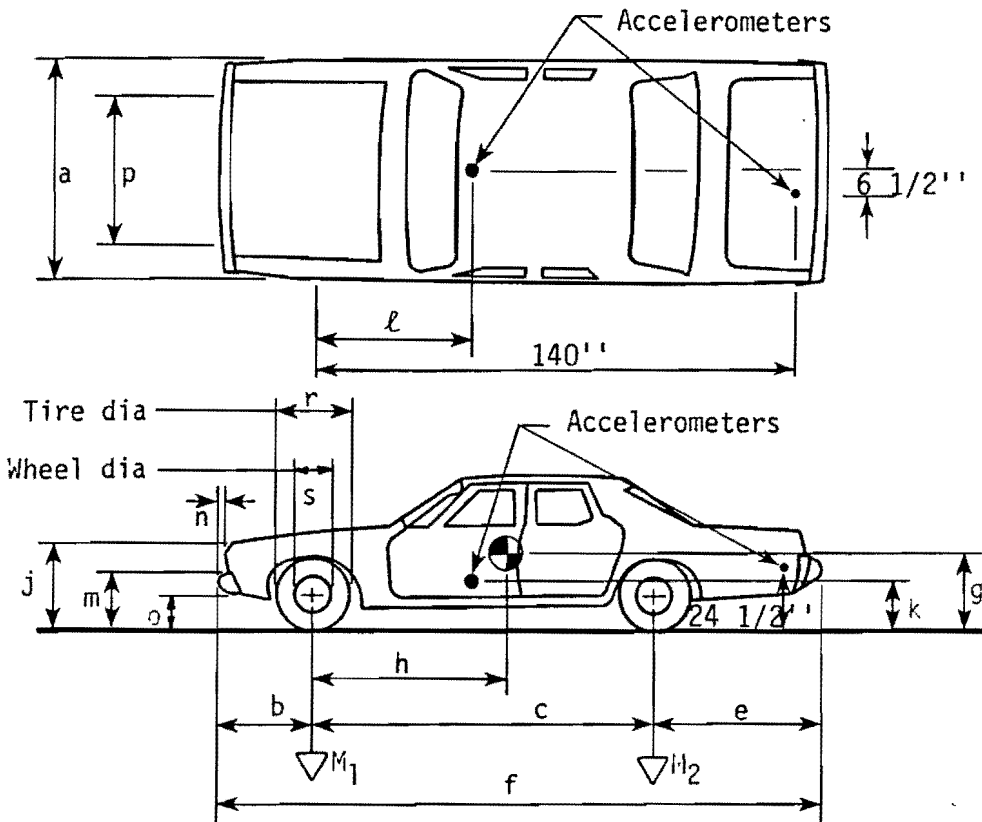
Engine Type: 8 cylinder
 Engine CID: _____

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

Body Type: 2 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



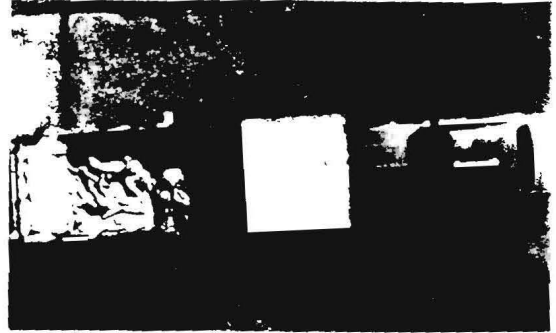
4-wheel weight for c.g. det. lf 990 rf 942 lr 783 rr 785

Mass - pounds	Curb	Test Inertial	Gross Static
M ₁	<u>1978</u>	<u>1932</u>	_____
M ₂	<u>1326</u>	<u>1568</u>	_____
M _T	<u>3304</u>	<u>3500</u>	_____

Note any damage to vehicle prior to test:

*d = overall height of vehicle

Figure 210. Test vehicle properties (test 9910-14).



.000 sec



.037 sec

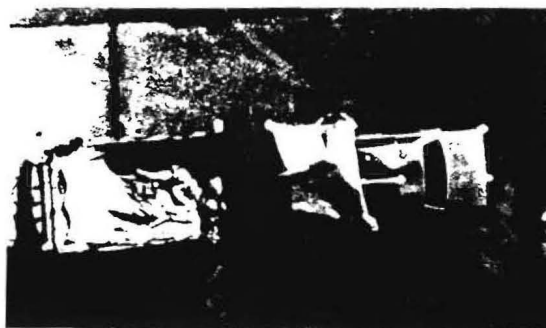


.074 sec

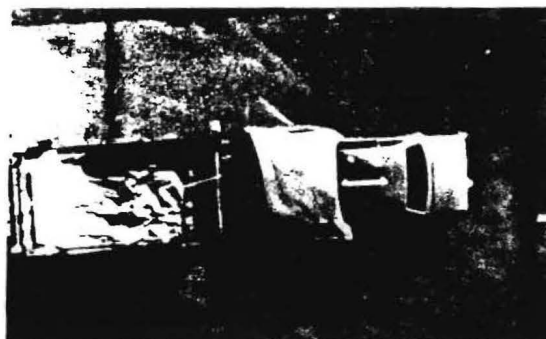
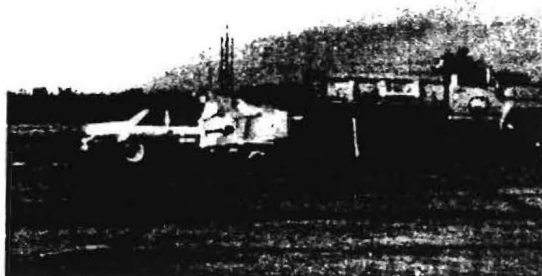


.110 sec

Figure 211 Sequential photographs for test 9910-14.



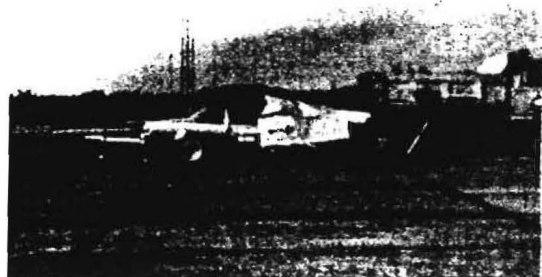
.147 sec



.245 sec



.613 sec



.985 sec

Figure 211 Sequential photographs for test 9910-14.
(Continued)

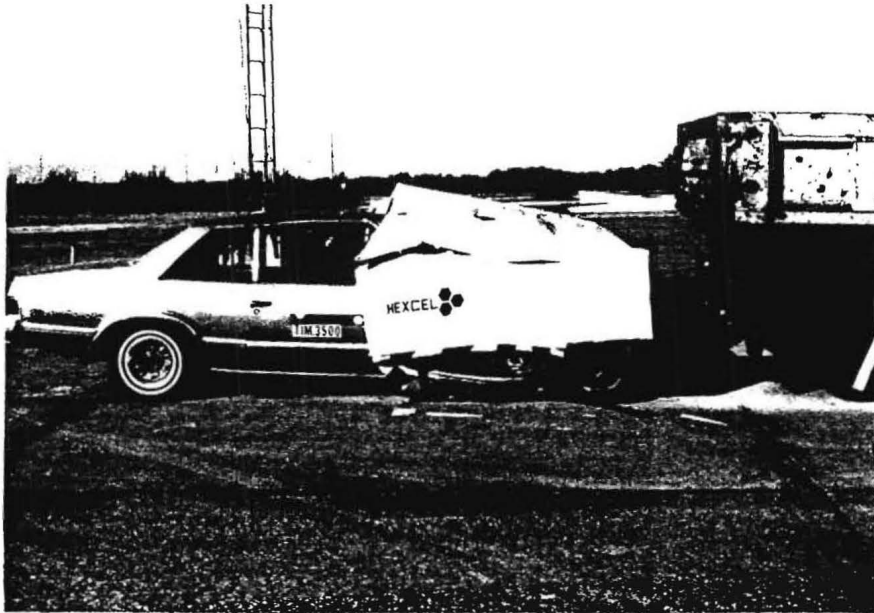


Figure 212 Hexcel TMA after test 9910-14.

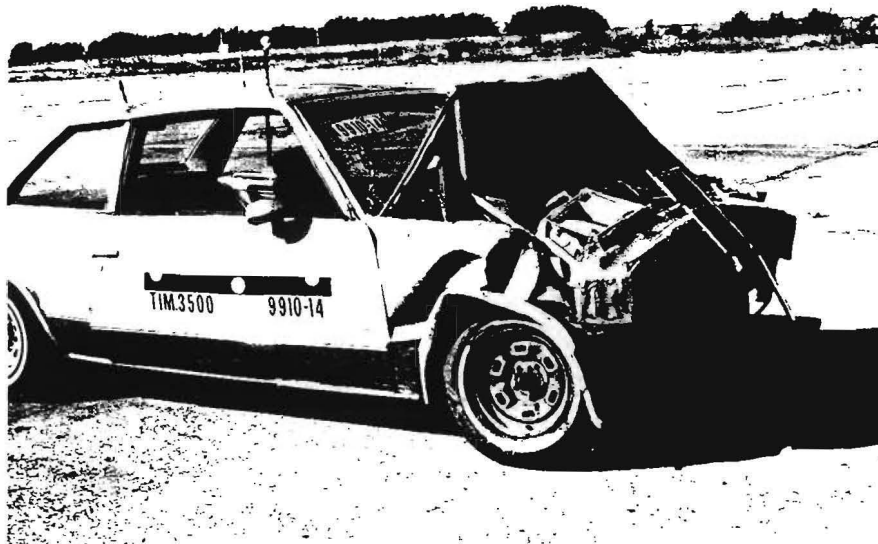
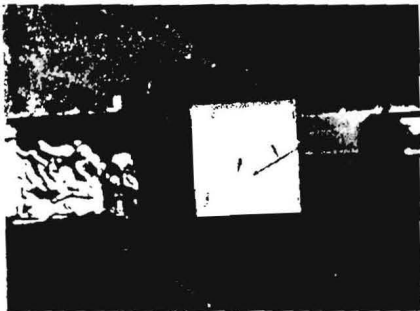


Figure 213 Vehicle after impact with Hexcel TMA (9910-14).



0.000 s



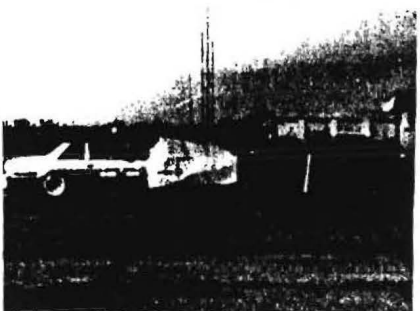
0.074 s



0.147 s



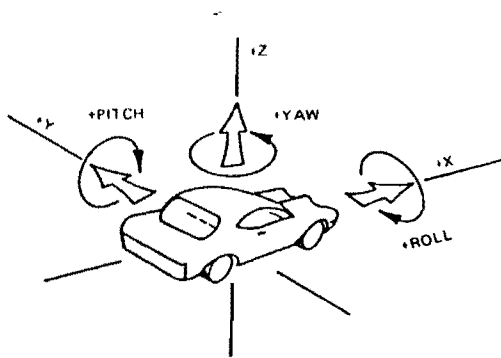
0.613 s



Test No. 09910-14
 Date 10/23/90
 Test Article Truck Mounted Attenuator
 Manufacturer Hexcel Model 3000
 TMA Truck 1980 Ford Dump Truck (#2)
 Weight without TMA . . . 14,040 lb (6,374 kg)
 Weight with TMA 14,920 lb (6,774 kg)
 Test Vehicle 1979 Chevrolet Malibu
 Weight 3,500 lb (1,589 kg)
 Impact Speed 58.0 mi/h (93.3 km/h)
 Maximum Vehicle Crush . . 22.0 in (55.9 cm)
 Vehicle Damage Classification
 TAD 12FD6
 CDC 12FDEW3

Maximum Truck Displacement . 10.6 ft (3.2 m)
 Maximum TMA Crush 75.0 in (1.9 m)
 Vehicle Accelerations
 (Maximum 50 ms Average at c.g.)
 Vehicle Longitudinal . . . -22.8 g
 Vehicle Lateral 1.9 g
 Truck Cab Longitudinal . . . 4.7
 Occupant Impact Velocity
 Longitudinal 37.9 ft/s (11.6 m/s)
 Lateral None
 Occupant Ridedown Accelerations
 Longitudinal -35.1 g
 Lateral N/A

Figure 214 Summary of results for test 9910-14.



Axes are vehicle fixed.
Sequence for determining
orientation is:

1. Yaw
2. Pitch
3. Roll

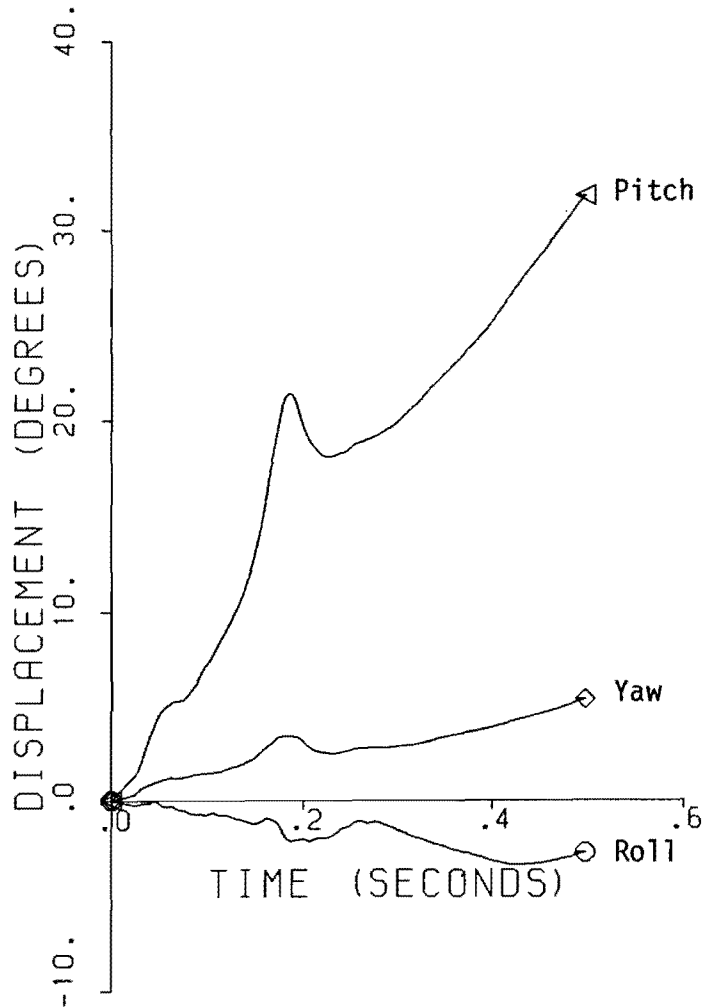


Figure 215 Vehicle angular displacements for test 9910-14

TEST 9910-14

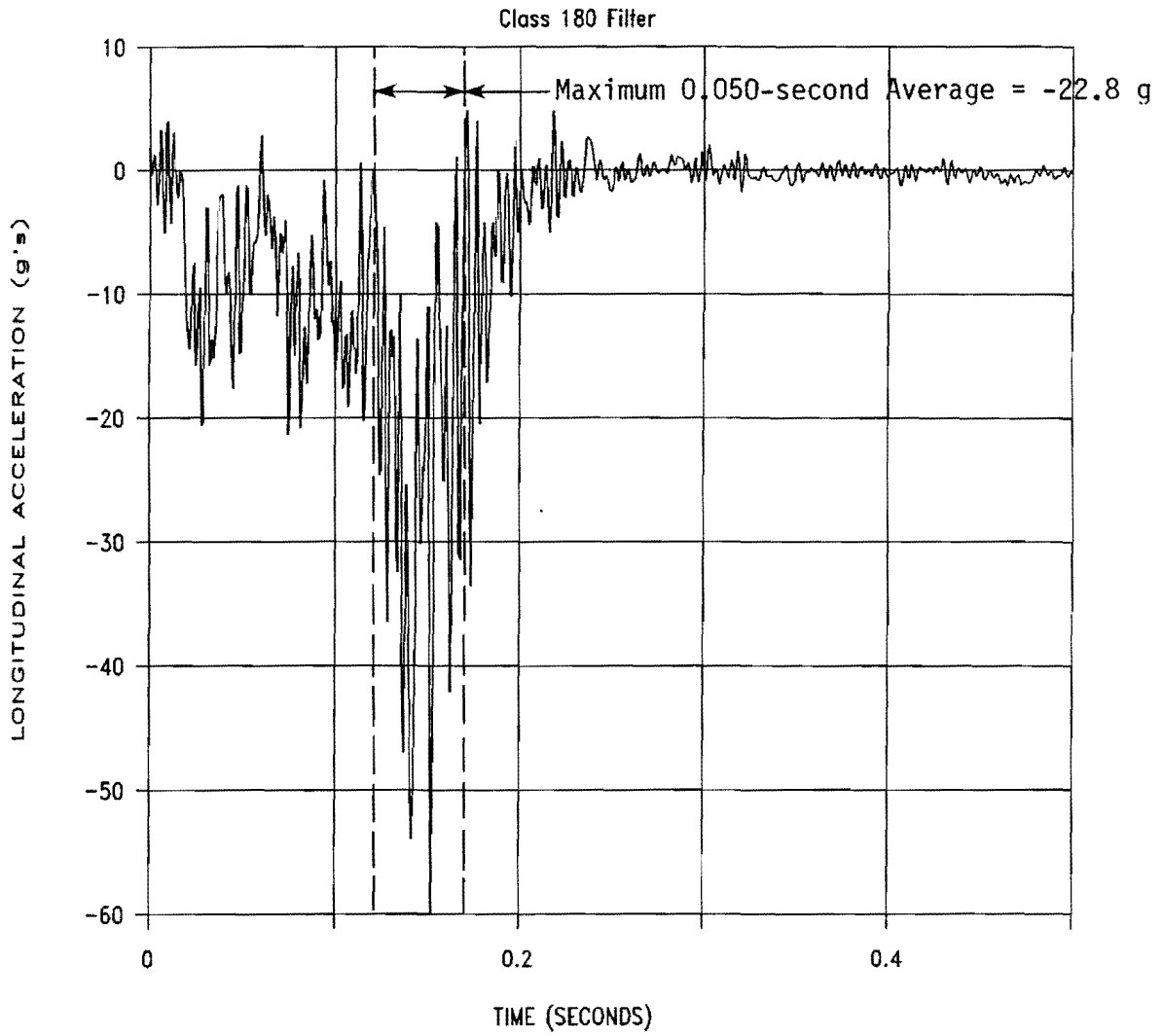


Figure 216. Vehicle longitudinal accelerometer trace for test 9910-14.

TEST 9910-14

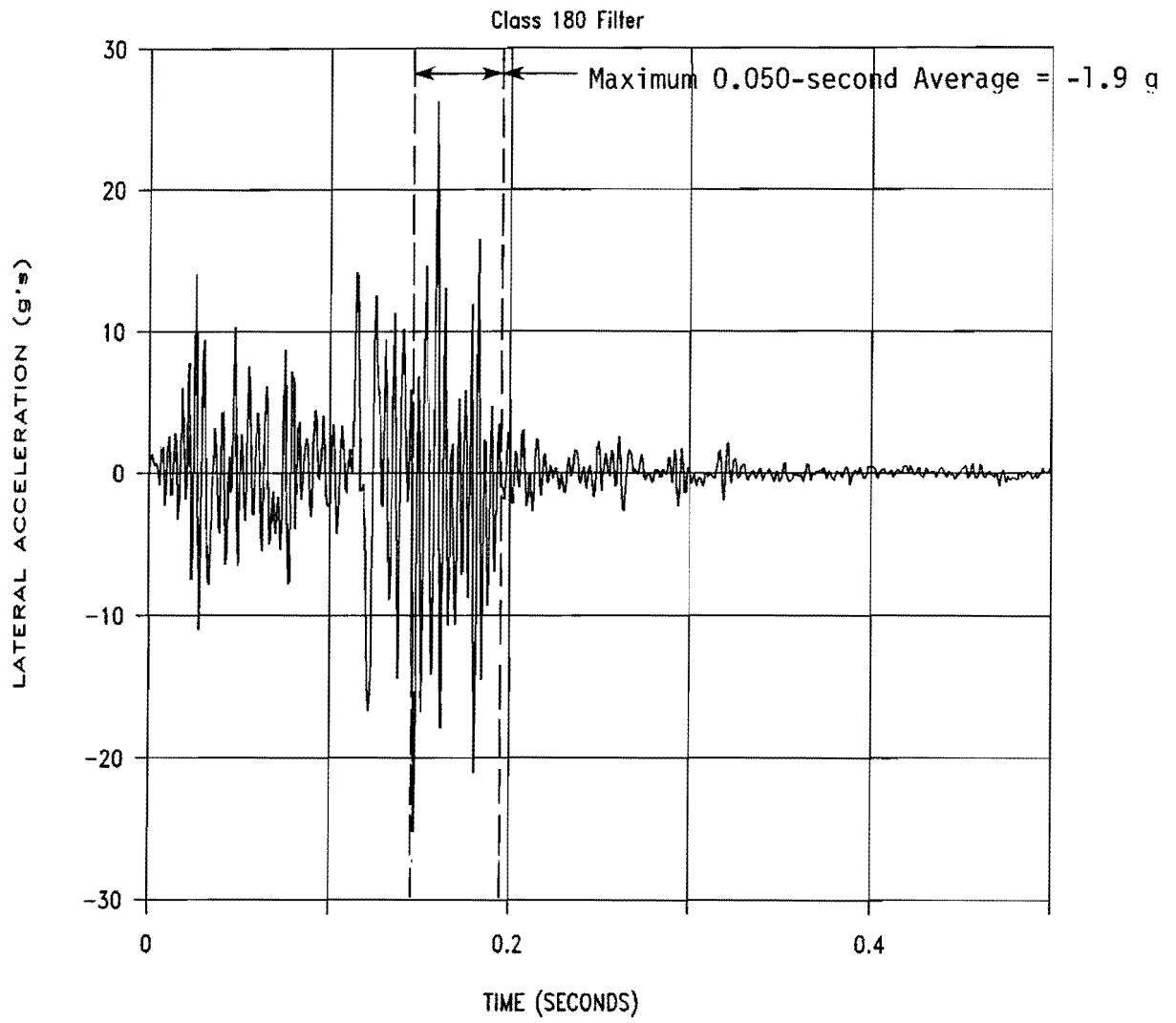


Figure 217. Vehicle lateral accelerometer trace for test 9910-14.

TEST 9910-14

Class 180 Filter

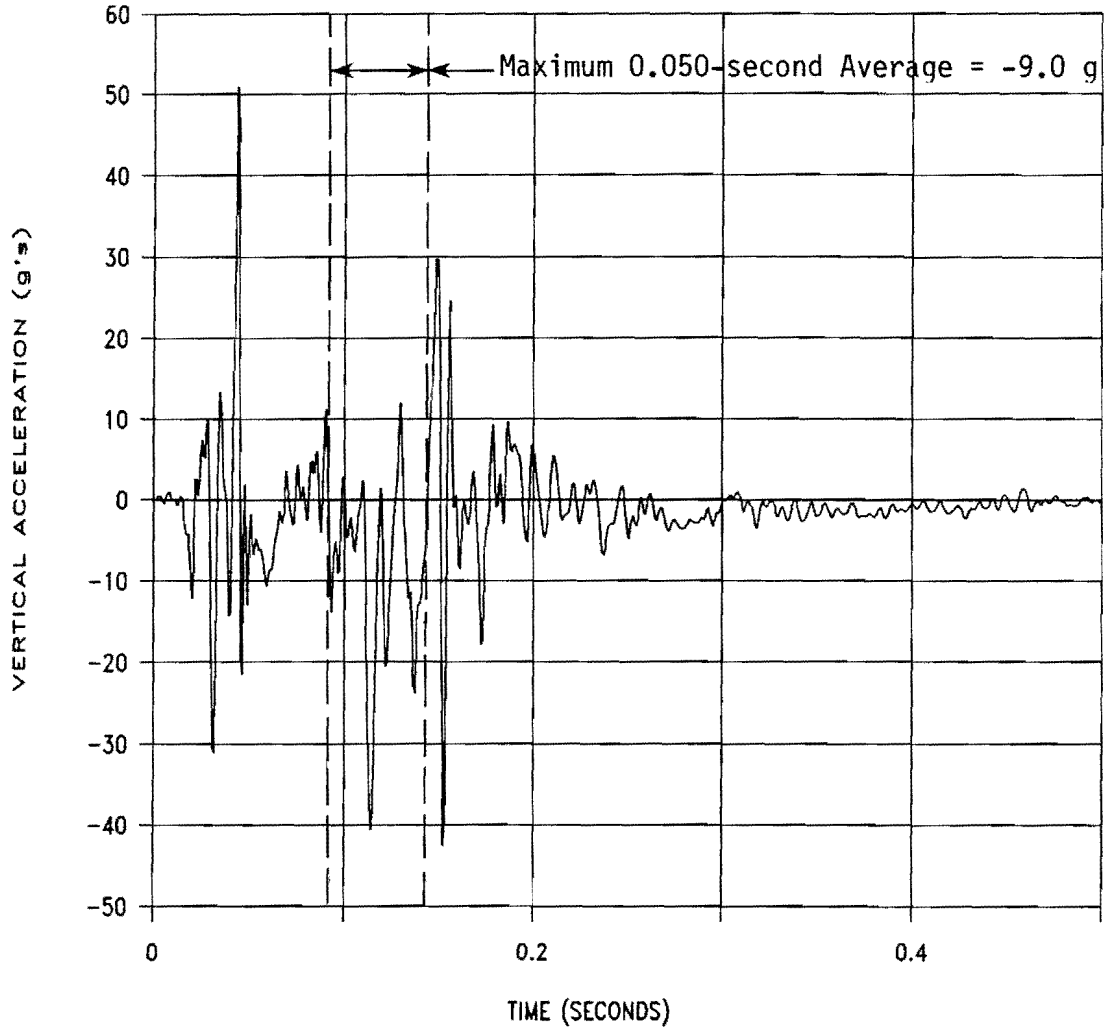


Figure 218. Vehicle vertical accelerometer trace for test 9910-14.

TEST 9910-14

Class 180 Filter - Dump Truck

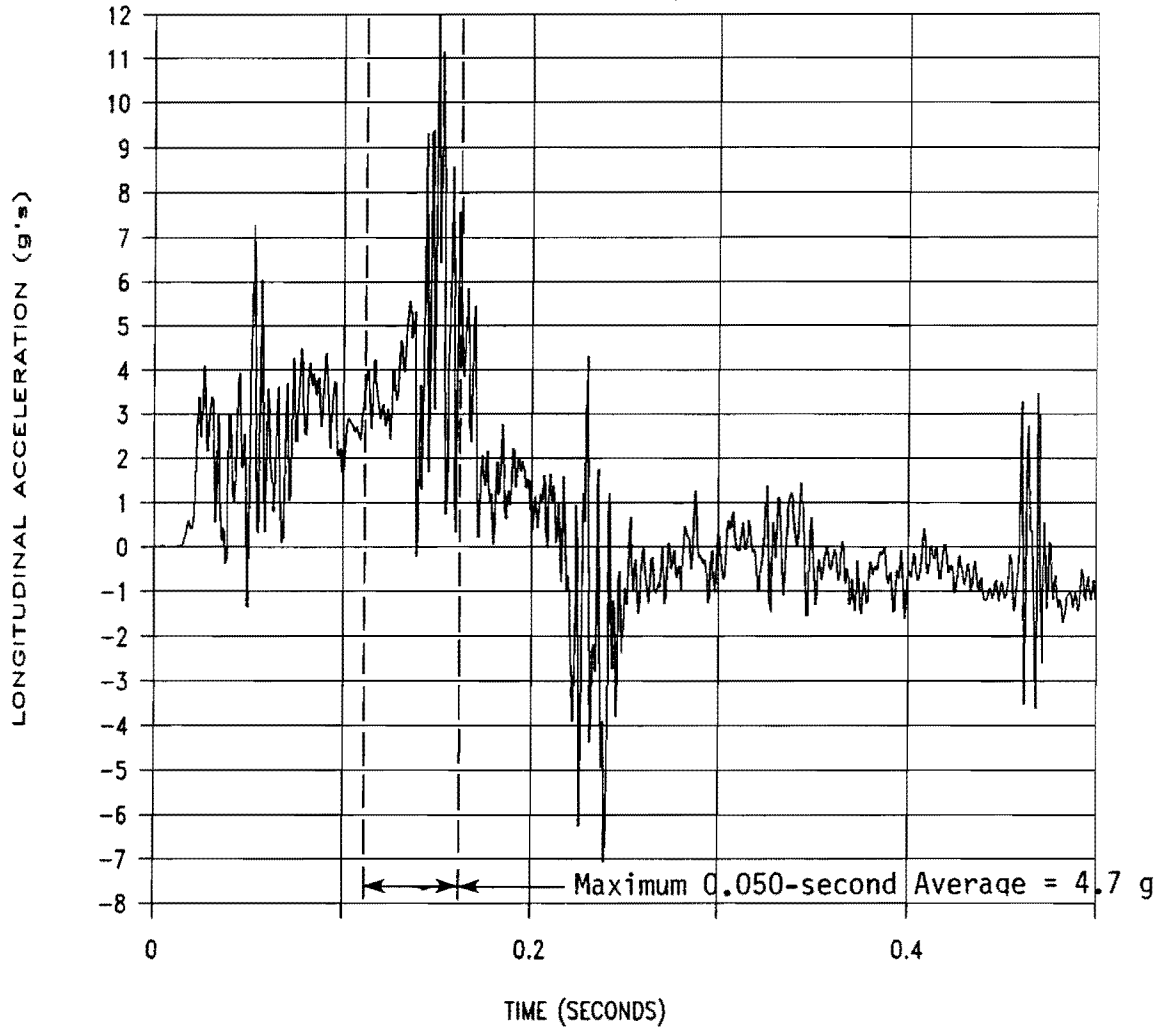


Figure 219. Dump truck longitudinal accelerometer trace for test 9910-14.

Connecticut DOT (9910-11)

The Connecticut DOT TMA used during this test is shown in Figures 7 and 220. The TMA was mounted on Truck No. 2 which had a gross static weight of 16,130 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 7.00 inches at the front and 7.75 inches at the rear. The height to the upper rear surface of the cartridge was 41.00 inches above ground.

The 1980 Chevrolet Malibu (pictured in Figure 220) was directed into the Connecticut TMA. The height to the lower edge of the vehicle bumper was 12.25 inches and 20.00 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 221.

The vehicle was travelling at a speed of 55.8 mi/h. Upon impact, the first pipe in the TMA began to crush. Approximately 0.027 second after impact the second pipe began to crush and the third pipe at 0.036 second. The rear tires of the truck began to rotate 0.077 second after impact. At 0.097 second the fourth pipe began to crush, the impacting vehicle began to dive at 0.099 second and the front of the vehicle bottomed-out at 0.155 second. At 0.185 second, the rear tires of the impacting vehicle left the ground. The rear truck tire had rotated 23 degrees by 0.217 second, and began to rotate backwards reaching -5 degrees from perpendicular by 0.365 second. The rear of the impacting vehicle reached its highest elevation at 0.488 second, the tires touched down again at 0.750 second and the rear of the vehicle bottomed-out at 0.878 second. Forward motion of the impacting vehicle stopped at 0.787 second, then began to move forward again shortly thereafter, and stopped completely at 1.524 second. The vehicle subsequently came to rest 21 behind the TMA. Sequential photographs of the test are shown in Figure 222.

The Connecticut TMA crushed a total of 78.0 inches during the test. The attachment frame on the cartridge was not damaged. The impacting vehicle received damage to the front bumper, hood, grill, radiator, the right and left front quarter panels, the right and left doors, and the windshield was broken. The subframe was bent and the floor pan around the transmission tunnel was also bent and twisted. Maximum vehicle crush was 21.0 inches at bumper height. Figures 223 and 224 show damage to the TMA and test vehicle.

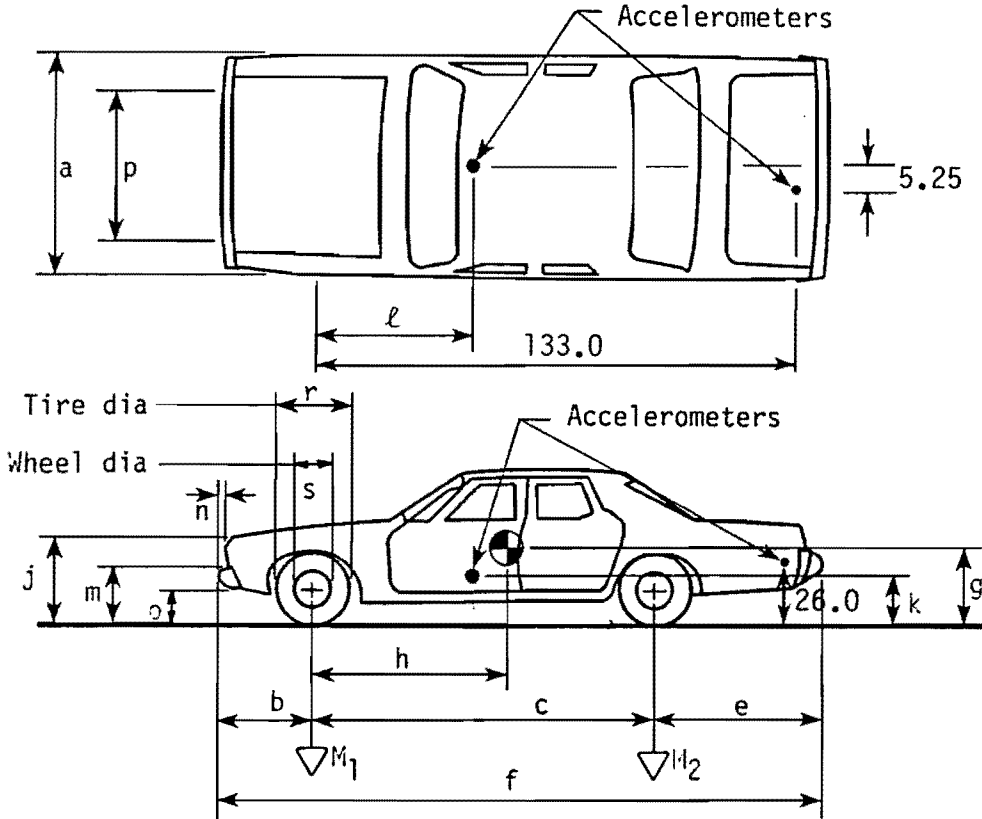
A summary of the test results and other information pertinent to this test are given in Figure 225. As noted in the damage to the vehicle, the floor pan around the transmission tunnel was damaged and the accelerometer block was mounted in this area. Although this bending and twisting of the tunnel may have some affect on the accelerations measured during the test period, it is felt that this influence was minimal. The following values are reported as recorded with no adjustments made. The maximum longitudinal 50-msec average acceleration experienced by the impacting vehicle was -24.4 g between 119 and 169 msec. Longitudinal occupant impact velocity was 35.3 ft/s at 111 msec and the maximum longitudinal ridedown acceleration was -54.0 g between 154 and 164 msec. Vehicle angular displacements are plotted in Figure 226 and accelerometer traces are displayed in Figures 227 through 230.



Figure 220 Vehicle before impact with Connecticut TMA (9910-11).

Date: 2/8/90 Test No.: 9910-11 VIN: 1T19HAR459851
 Make: Chevrolet Model: Malibu Year: 1980 Odometer: 121866
 Tire Size: P195/75R14 Ply Rating: _____ Bias Ply: _____ Belted: _____ Radial: _____

Tire Condition: good _____
 fair X
 badly worn _____



Vehicle Geometry - inches

a 70 1/2 b 36
 c 107 d* 55 3/4
 e 47 f 190
 g _____ h 46.2
 i ---- j 32
 k 18 3/4 l 34
 m 20 n 4
 o 12 1/4 p 58 1/4
 r 25 s 15 1/4

Engine Type: V-8

Engine CID: 305

Transmission Type:

Automatic or Manual
 FWD or RWD or 4WD

Body Type: 4-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

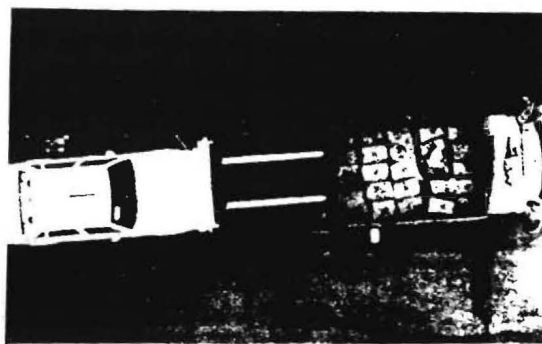
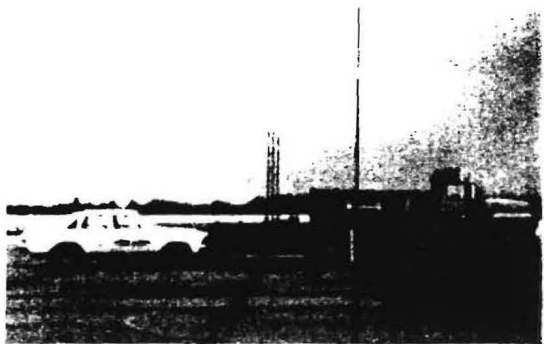
4-wheel weight for c.g. det. lf 990 rf 999 lr 788 rr 723

Mass - pounds	Curb	Test Inertial	Gross Static
M ₁	<u>1949</u>	<u>1989</u>	_____
M ₂	<u>1284</u>	<u>1511</u>	_____
M _T	<u>3233</u>	<u>3500</u>	_____

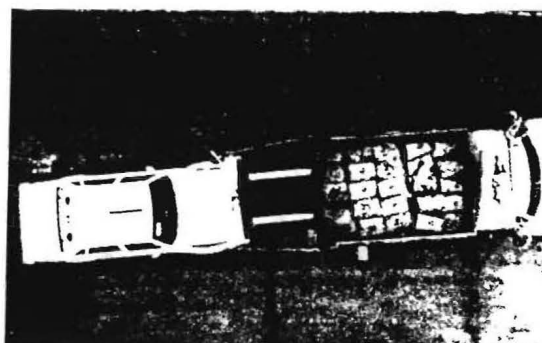
Note any damage to vehicle prior to test:

*d = overall height of vehicle

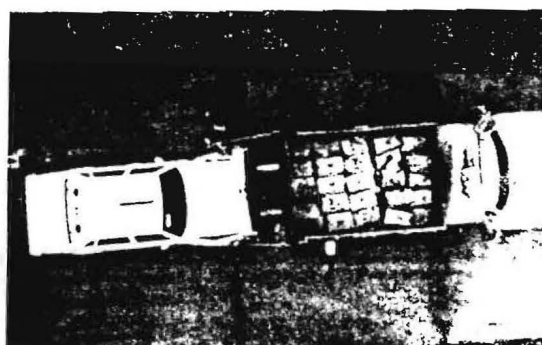
Figure 221 Test vehicle properties (test 9910-11).



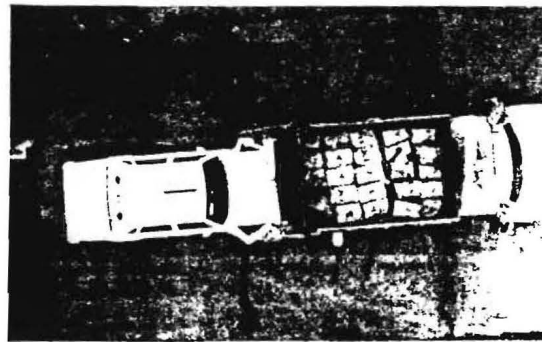
0.000 s



0.057 s

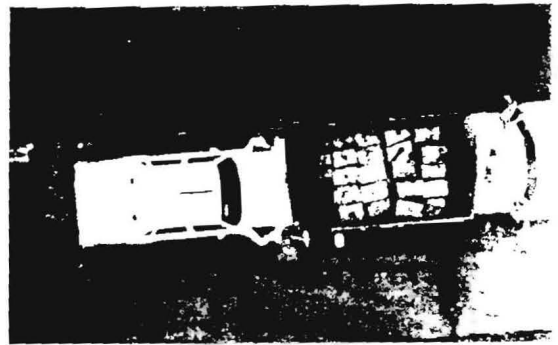


0.099 s

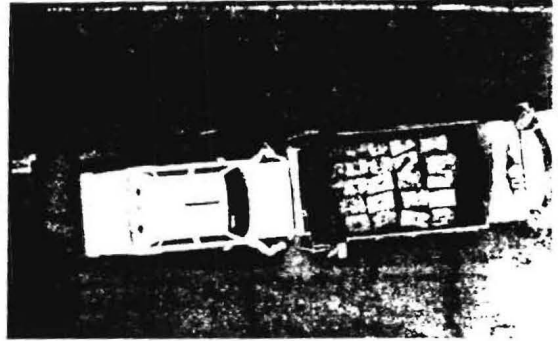


0.150 s

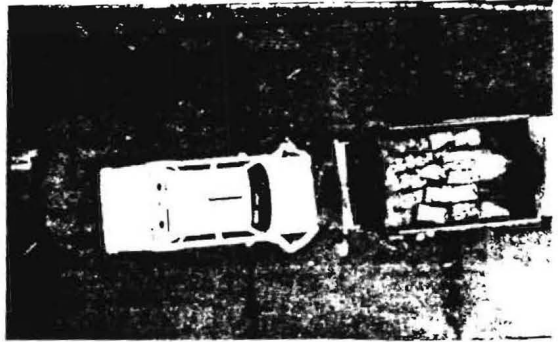
Figure 222. Sequential photographs for test 9910-11.



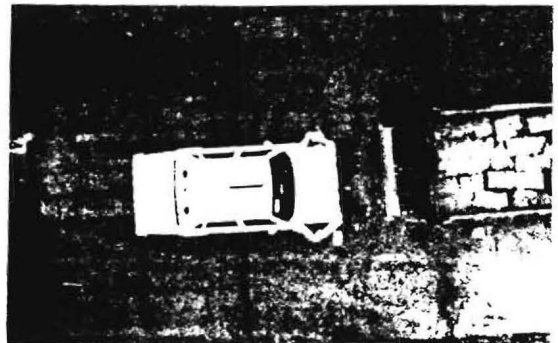
0.201 s



0.249 s



0.501 s



1.000 s

Figure 222 Sequential photographs for test 9910-11.
(Continued)

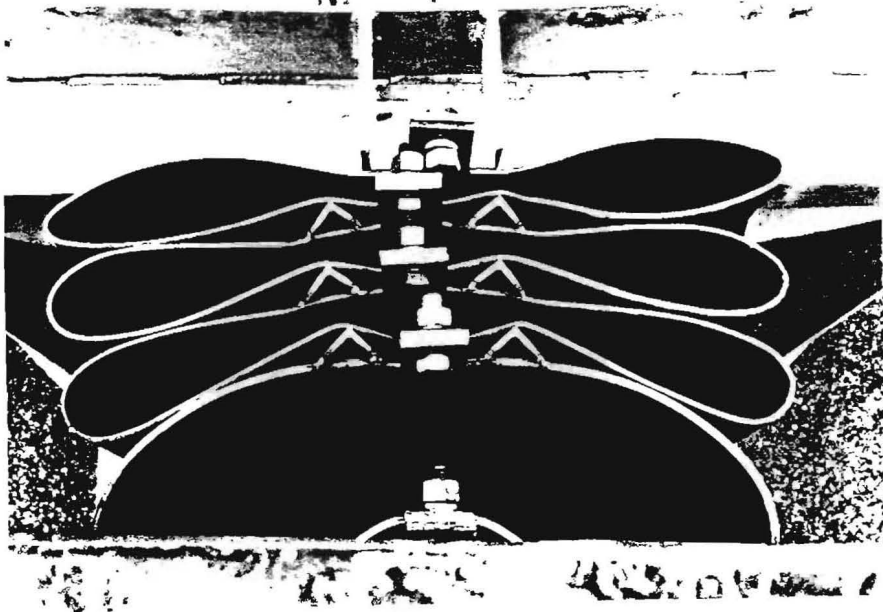


Figure 223 Connecticut TMA
after test 9910-11.

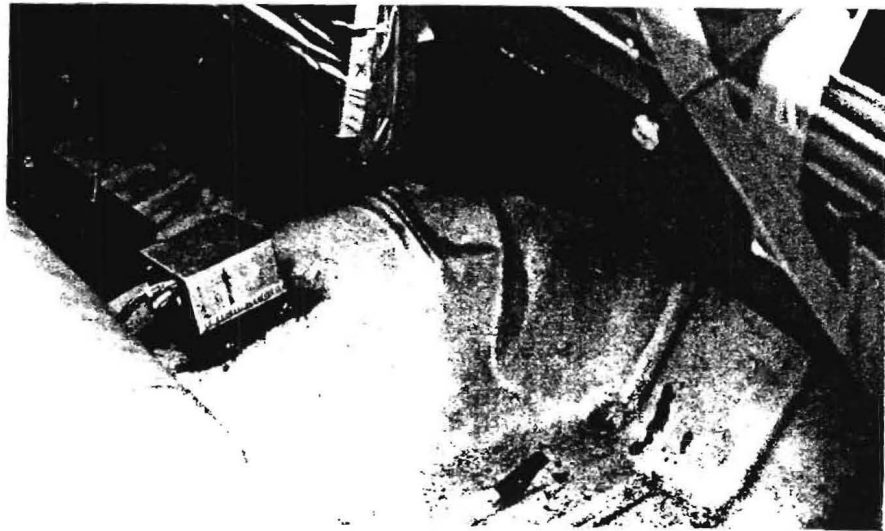
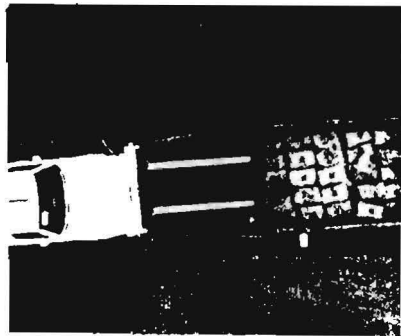
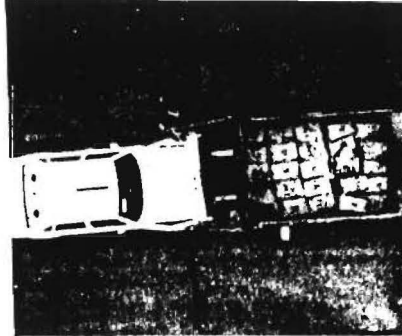


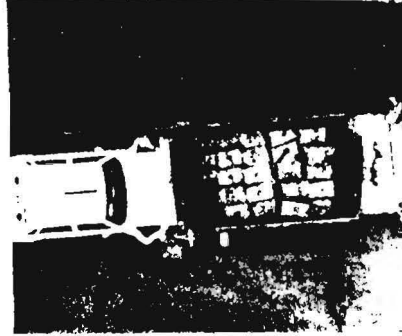
Figure 224 Vehicle after impact with Connecticut TMA (9910-11).



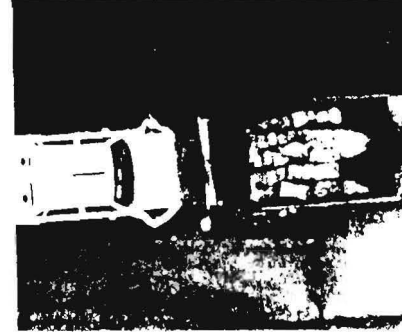
0.000 s



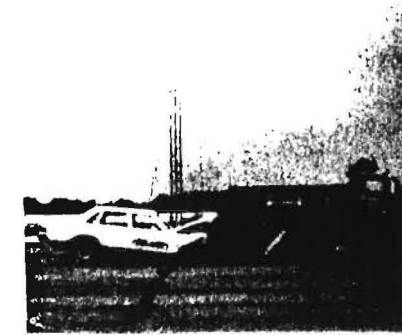
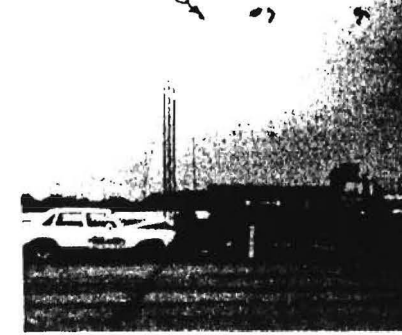
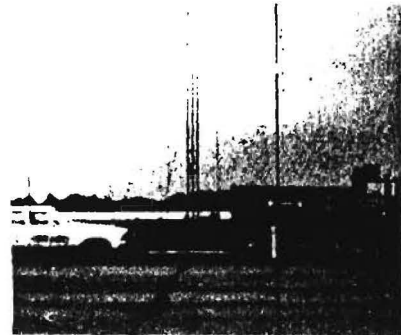
0.099 s



0.201 s



0.501 s

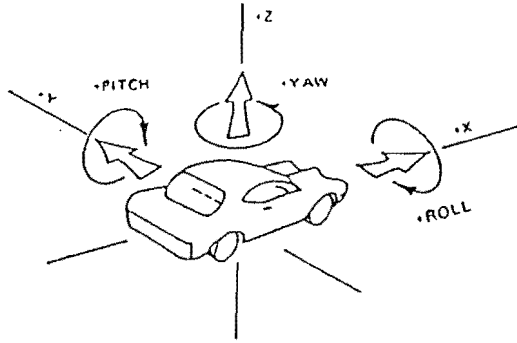


273

Test No. 09910-11
 Date 02/08/90
 Test Article Truck Mounted Attenuator
 Manufacturer Connecticut
 TMA Truck 1980 Ford Dump Truck (#2)
 Weight without TMA . . . 14,010 lb (6,361 kg)
 Weight with TMA 16,100 lb (7,309 kg)
 Test Vehicle 1980 Chevrolet Malibu
 Weight 3,500 lb (1,589 kg)
 Impact Speed 55.8 mi/h (89.8 km/h)
 Maximum Vehicle Crush . . 21.0 in (53.3 cm)
 Vehicle Damage Classification
 TAD 12FD5
 CDC 12FDEW3

Maximum Truck Displacement . 9.0 ft (2.7 m)
 Maximum TMA Crush 78.0 in (2.0 m)
 Vehicle Accelerations
 (Maximum 50 ms Average at c.g.)
 Vehicle Longitudinal . . . -24.4 g
 Vehicle Lateral -7.1 g
 Truck Cab Longitudinal . . . 7.0
 Occupant Impact Velocity
 Longitudinal 35.3 ft/s (10.8 m/s)
 Lateral 12.4 ft/s (3.8 m/s)
 Occupant Ridedown Accelerations
 Longitudinal -54.0 g
 Lateral -2.6 g

Figure 225 Summary of results for test 9910-11.



Axes are vehicle fixed.
Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

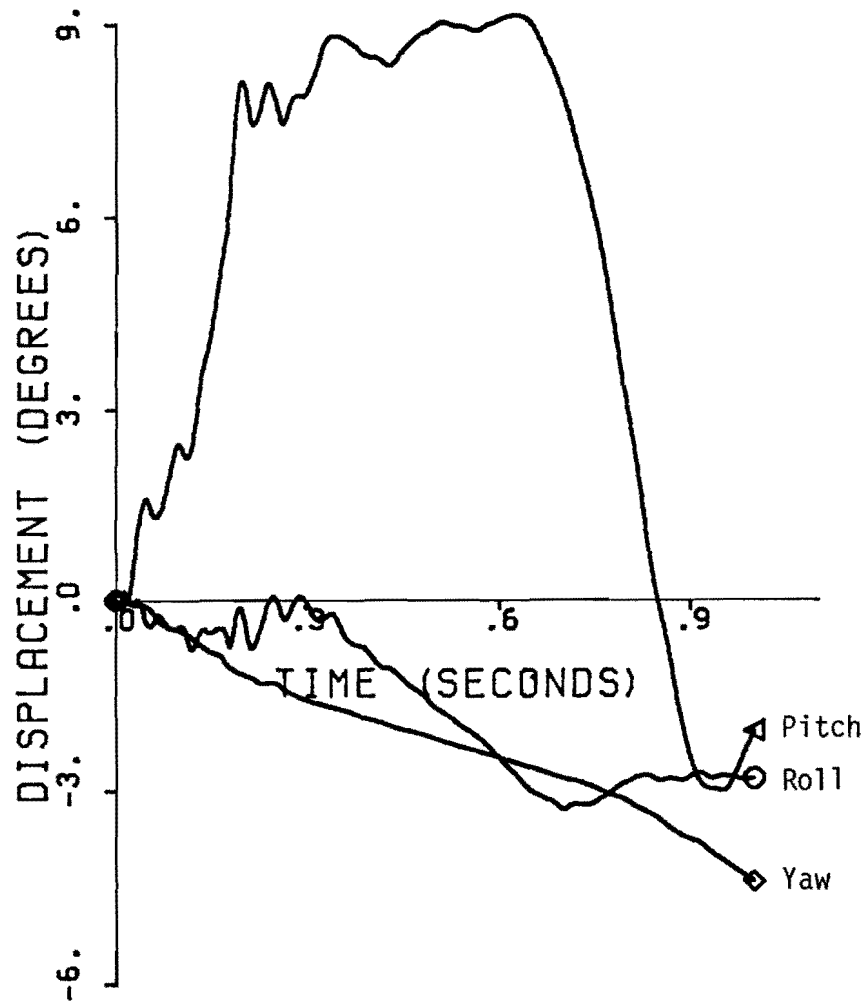


Figure 226 Vehicle angular displacements for test 9910-11.

TEST 9910-11

Class 180 Filter

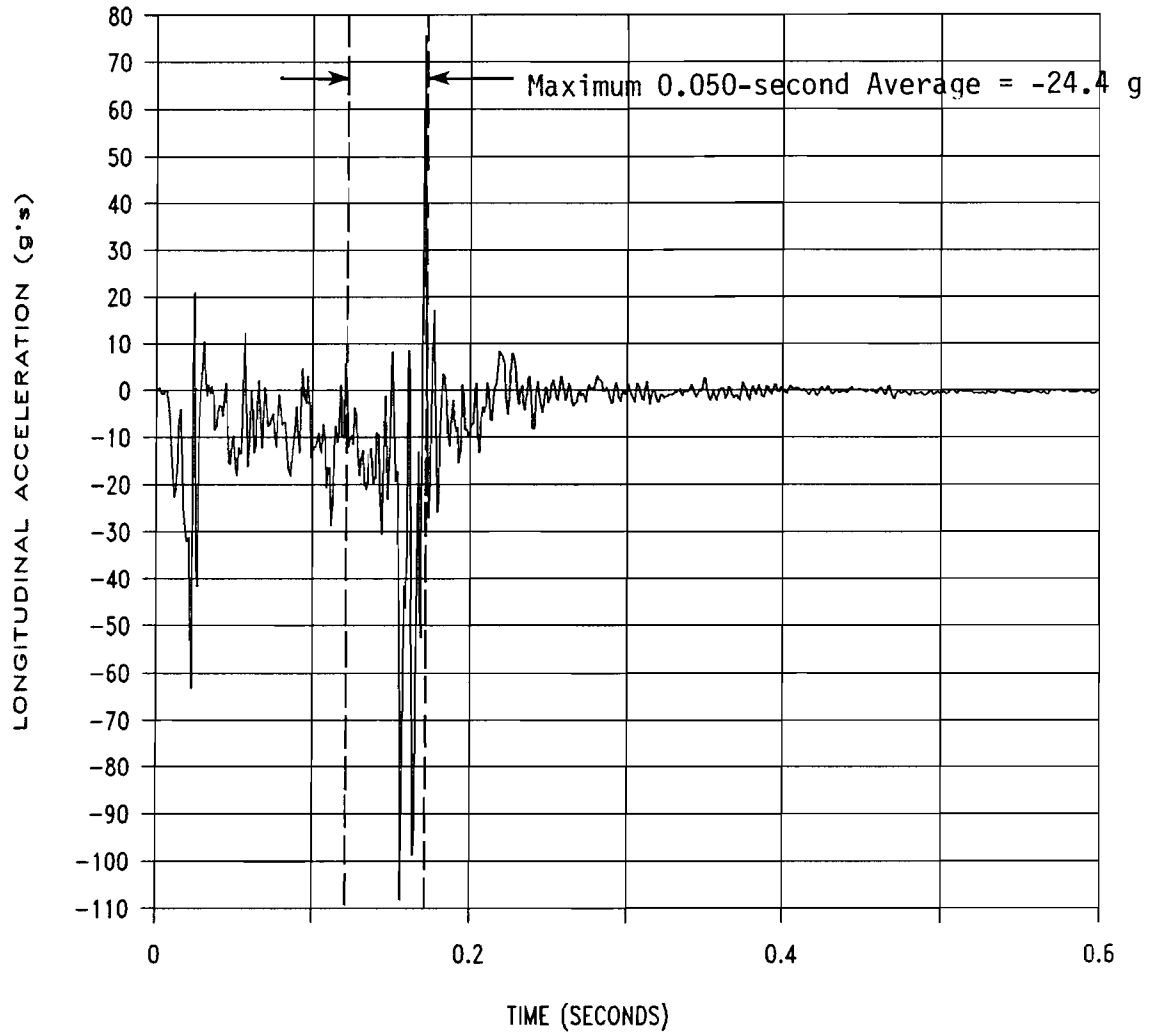


Figure 227 Longitudinal accelerometer trace for test 9910-11.

TEST 9910-11

Class 180 Filter

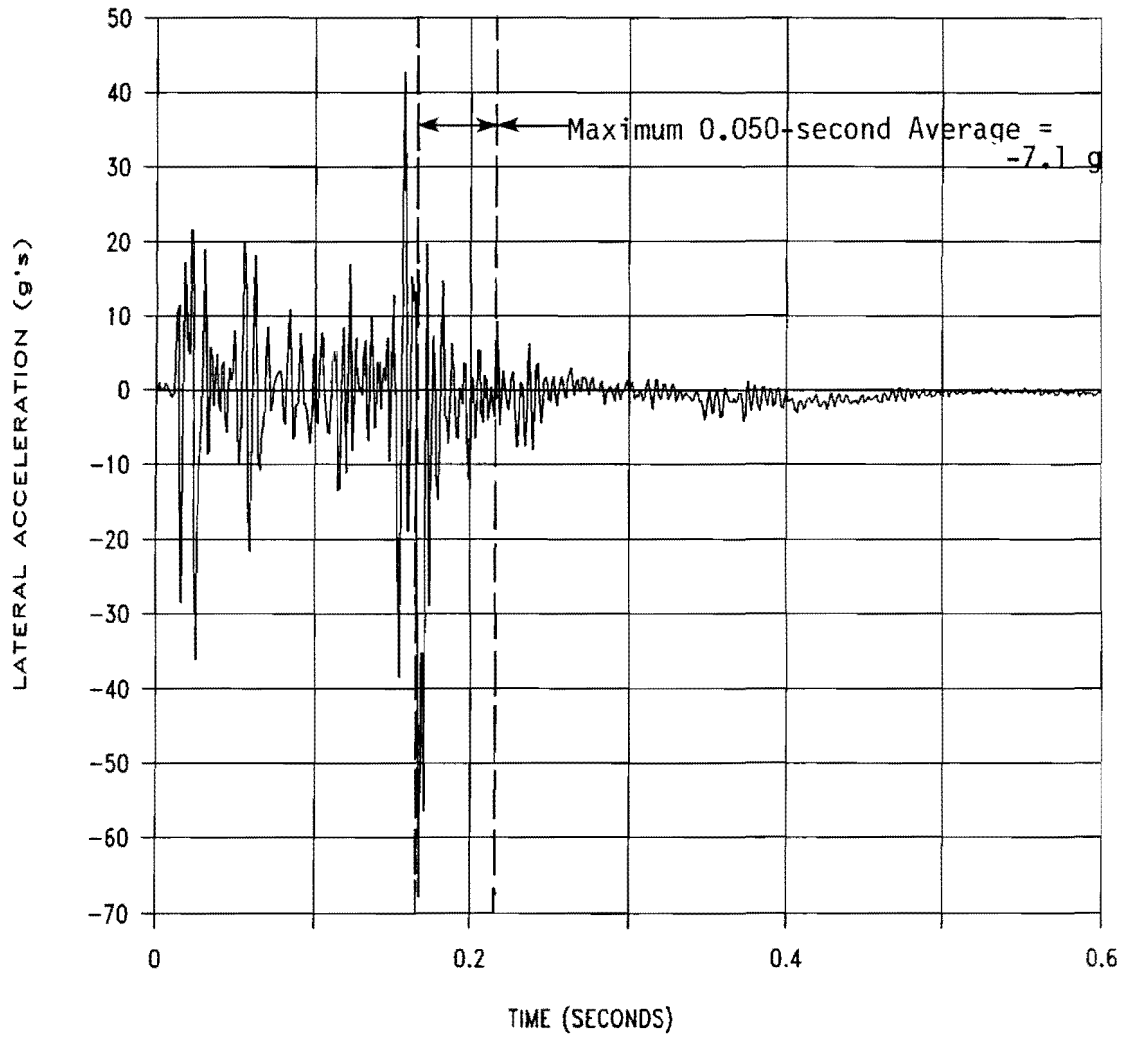


Figure 228 Lateral accelerometer trace for test 9910-11.

TEST 9910-11

Class 180 Filter

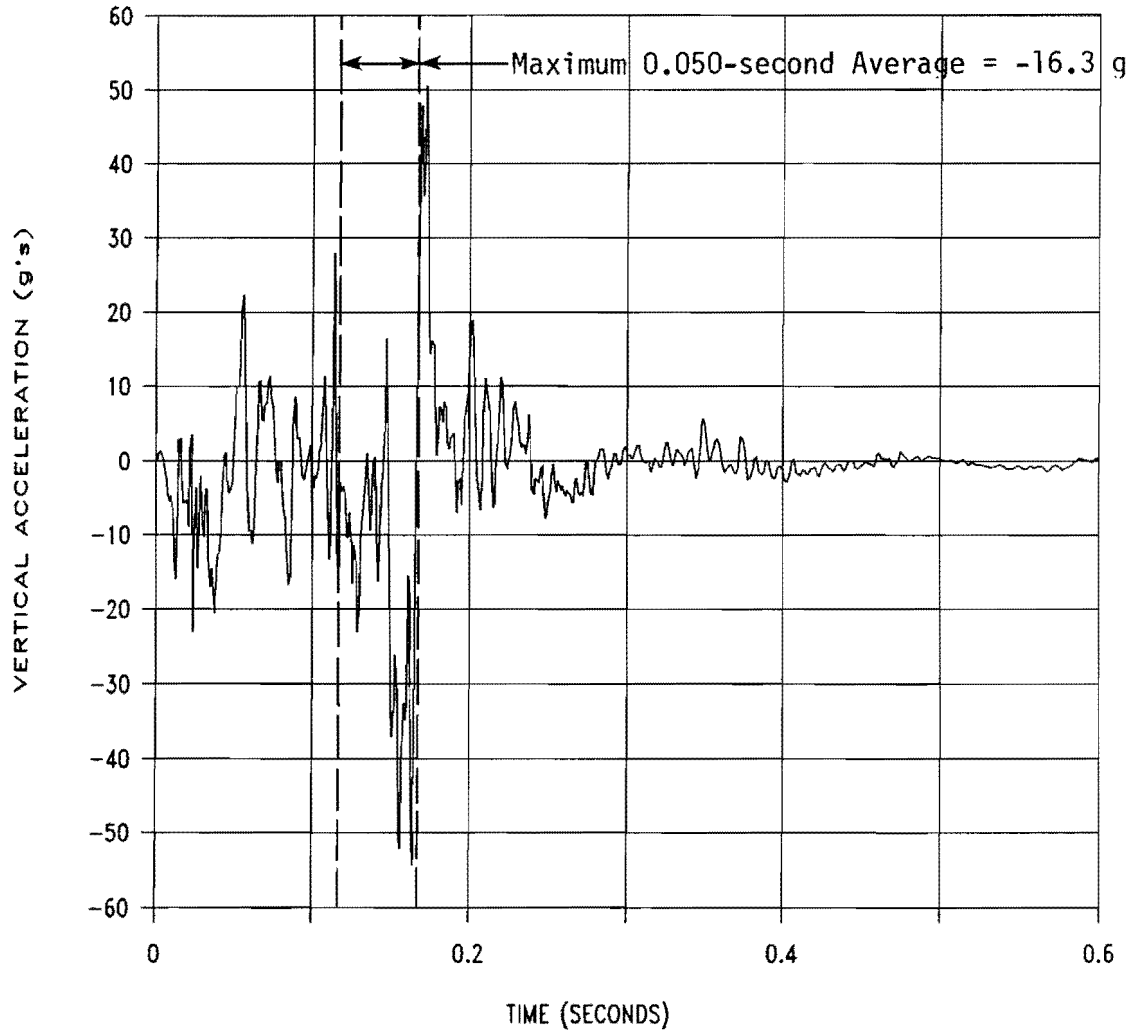


Figure 229 Vertical accelerometer trace for test 9910-11.

TEST 9910-11

Class 180 Filter - Dump Truck Cab

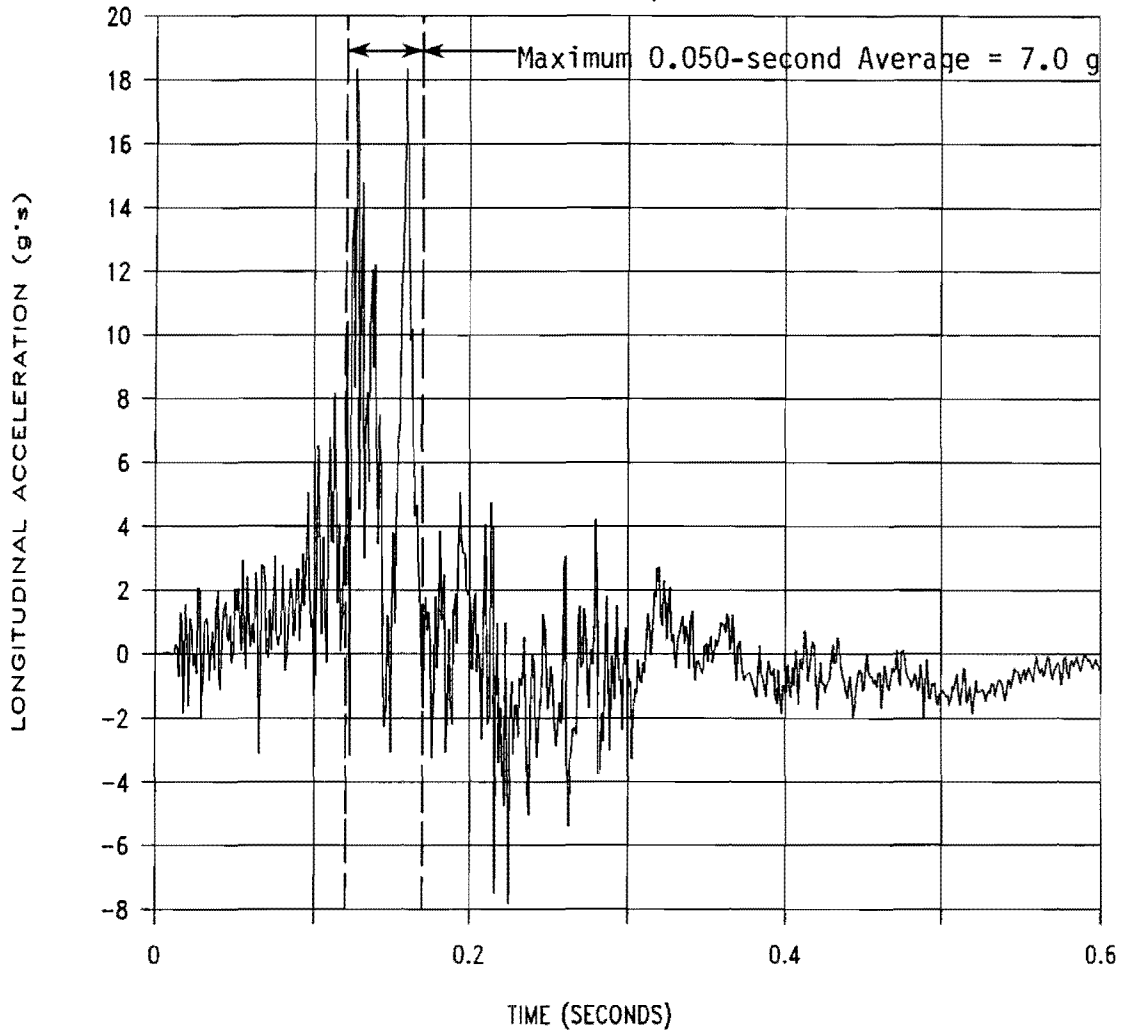


Figure 230 Longitudinal accelerometer trace for test 9910-11. (dump truck cab).

**Test Series 4: Free-Standing Truck Test with 4500-lb Pickup Truck
Traveling at 45 Miles per Hour**

The one crash test in this series was run under the same conditions reported in Test Series 1, except that in this test a 4,500-lb pickup truck was used in place of a 4,500-lb passenger car.

Energy Absorption Alpha Model (9910-12)

The TMA used during this test was manufactured by Energy Absorption (Alpha Model) and is shown in Figures 1 and 231. The TMA was mounted on Truck No. 2 and had a gross static weight of 14,990 lb, including the TMA cartridge and mounting structure. As mounted, the TMA cartridge clearance above the ground was 12.00 inches at the front and 12.00 inches at the rear. The height to the upper rear surface of the cartridge was 34.50 inches above ground.

The 1981 Chevrolet Scottsdale Pick-up (pictured in Figure 231) was towed into the Energy Absorption Alpha TMA. The height to the lower edge of the vehicle bumper was 15.0 inches and 25.0 inches to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 232.

The vehicle was travelling at a speed of 45.1 mi/h. Upon impact, the TMA began to crush smoothly and steadily. The rear tire of the dump truck began to rotate at 0.063 second after impact. The front of the pick-up began to dive downward at 0.113 second and the rear wheels began to rise. Maximum crush of the TMA occurred at 0.162 second. By 0.270 second the rear tire of the dump truck had rotated forward to an angle of 55 degrees and then began to skid forward and rotate backward. The tire continued in this manner during the remainder of the test. The dump truck reached a maximum speed of 8.3 mi/h at 0.398 second and had moved forward 4.1 ft. Forward motion of the impacting vehicle stopped at 1.094 second at which time it had travelled 15.6 ft and began to roll backwards. The vehicle subsequently came to rest 2 ft behind the TMA. Sequential photographs of the test are shown in Figure 233.

The Energy Absorption Alpha TMA cartridge crushed a total of 66.5 inches during the test. The frame attachment to the cartridge was bent 3.5 inches on the left side and 0.6 inch on the right. The impacting vehicle received damage to the front bumper, hood, grill, radiator, and the right front quarter panels. Maximum vehicle crush was 8.0 inches at bumper height. Figures 234 and 235 show damage to the TMA and test vehicle.

A summary of the test results and other information pertinent to this test are given in Figure 236. The maximum longitudinal 50-ms average acceleration experienced by the impacting vehicle was -13.5 g between 124 and 174 ms. Longitudinal occupant impact velocity was 35.2 ft/s at 152 ms and the maximum longitudinal ridedown acceleration was -14.3 g between 158 and 168 ms. Vehicle angular displacements are plotted in Figure 237 and accelerometer traces are displayed in Figures 238 through 241.

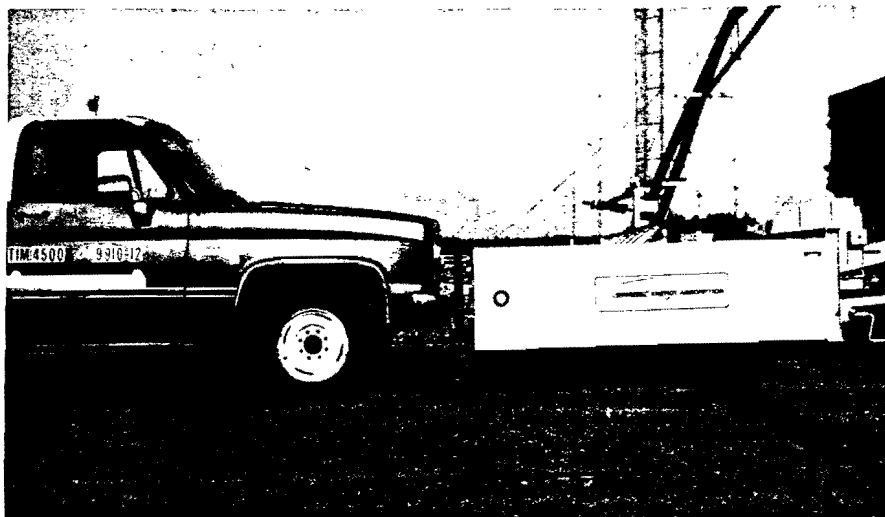
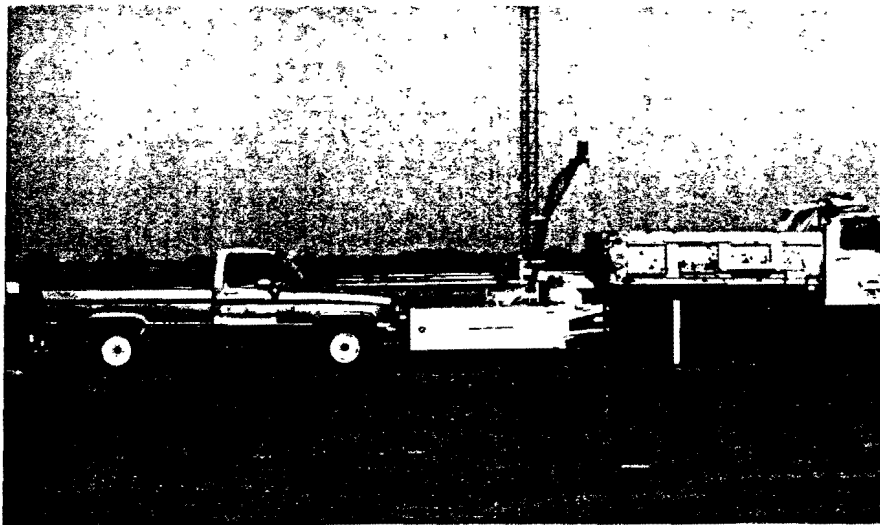
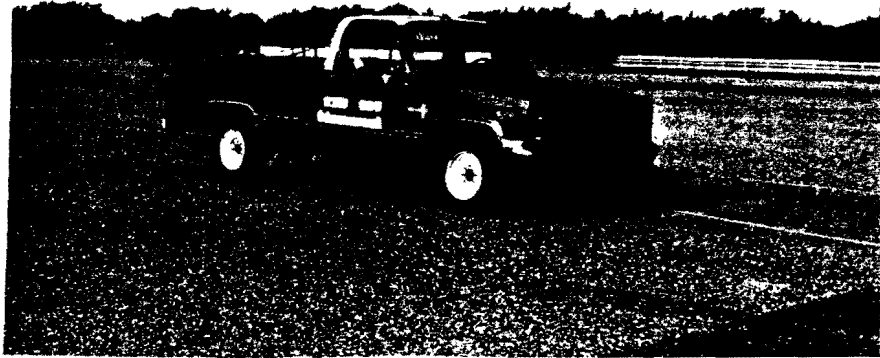
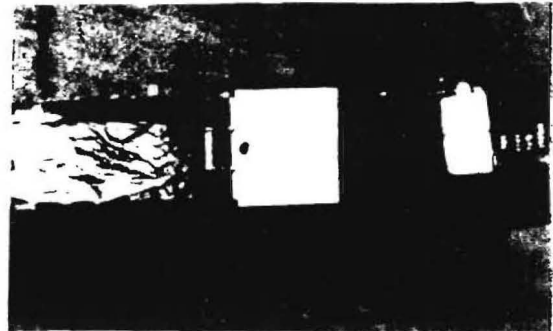
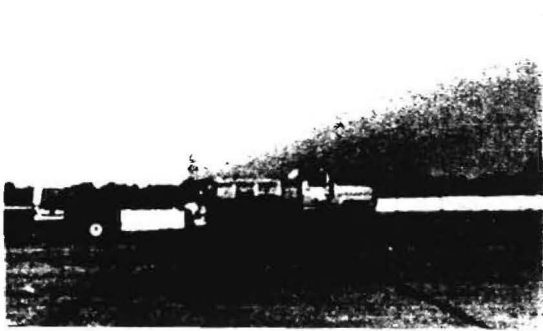


Figure 231 Vehicle before impact with Energy Absorption Alpha TMA (9910-12).



0.000 s



0.099 s



0.199 s

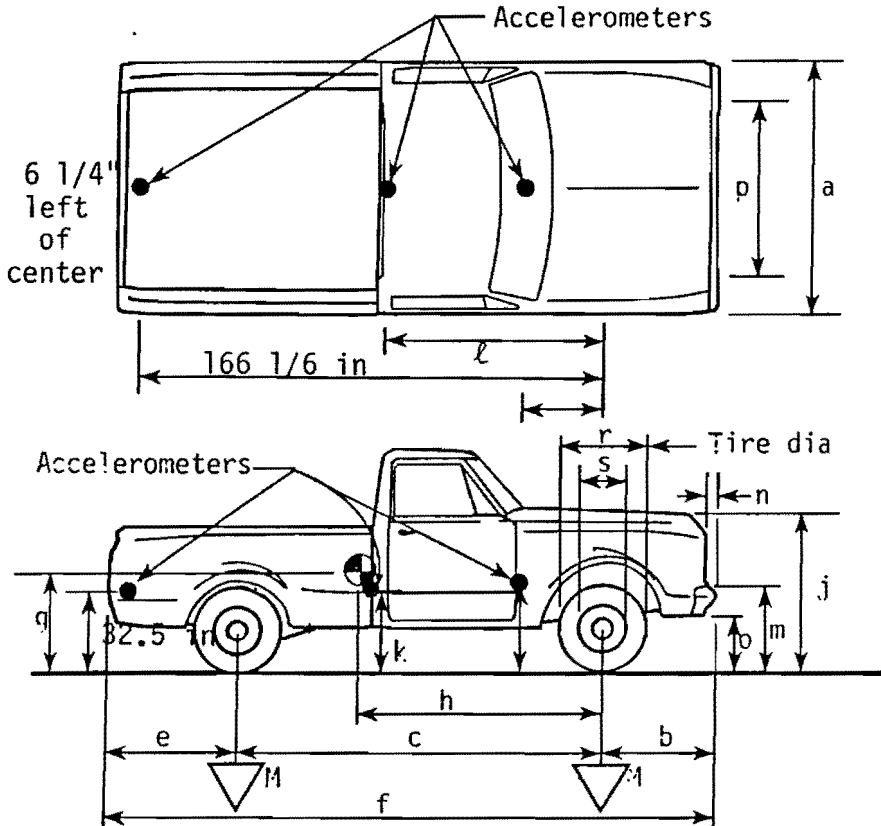


0.298 s

Figure 233 Sequential photographs for test 9910-12.

Date: _____ Test No.: 9910-12 VIN: 1GCGC24M189142573
 Make: Chevrolet Model: Scottsdale Year: 1981 Odometer: 63949
 Tire Size: 9.50 16.5 Ply Rating: _____ Bias Ply: x Belted: _____ Radial: _____

Tire Condition: good _____
 fair x
 badly worn _____



Vehicle Geometry - inches

a	<u>79 1/4</u>	b	<u>33 1/2</u>
c	<u>131 1/2</u>	d*	<u>70 1/2</u>
e	<u>50</u>	f	<u>215</u>
g	_____	h	<u>59.5</u>
i	<u>----</u>	j	<u>43 1/2</u>
k	<u>30 1/4</u>	l	<u>73</u>
m	<u>25</u>	n	<u>4</u>
o	<u>15</u>	p	<u>66</u>
r	<u>29</u>	s	<u>17 1/4</u>

Engine Type: V8
 Engine CID: 305
 Transmission Type:

Automatic or Manual
 FWD or RWD or 4WD
 Body Type: Pick-up

Steering Column Collapse Mechanism:
 Behind wheel units
 Convoluted tube
 Cylindrical mesh units
 Embedded ball
 NOT collapsible
 Other energy absorption
 Unknown

4-wheel weight for c.g. det. lf 1283 rf 1181 lr 983 rr 1053

Mass - pounds	Curb	Test Inertial	Gross Static
M ₁	<u>2508</u>	<u>2464</u>	_____
M ₂	<u>2196</u>	<u>2036</u>	_____
M _T	<u>4704</u>	<u>4500</u>	_____

Note any damage to vehicle prior to test:
Crack in windshield

Brakes:
 Front: disc x drum _____
 Rear: disc _____ drum x

*d = overall height of vehicle

Figure 232. Test vehicle properties (test 9910-12)



0.398 s



0.497 s



0.796 s



1.094 s

Figure 233 Sequential photographs for test 9910-12.
(Continued)

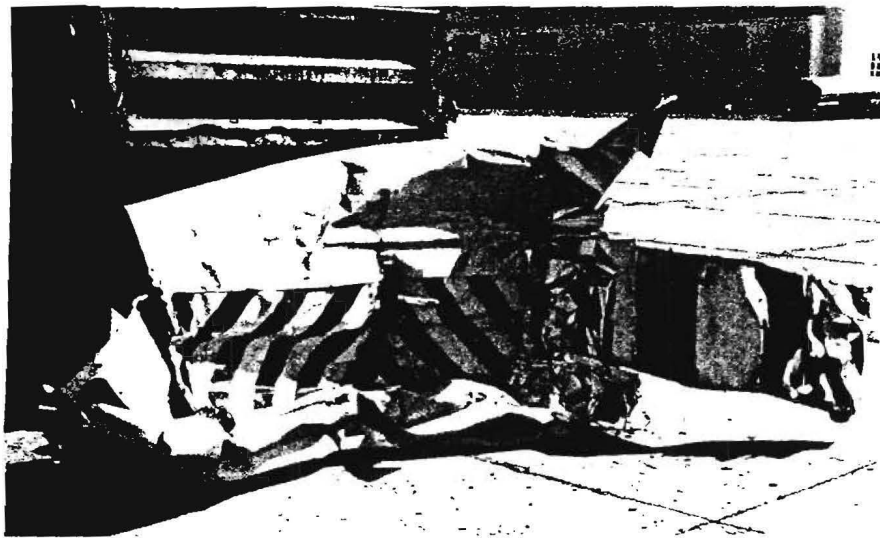
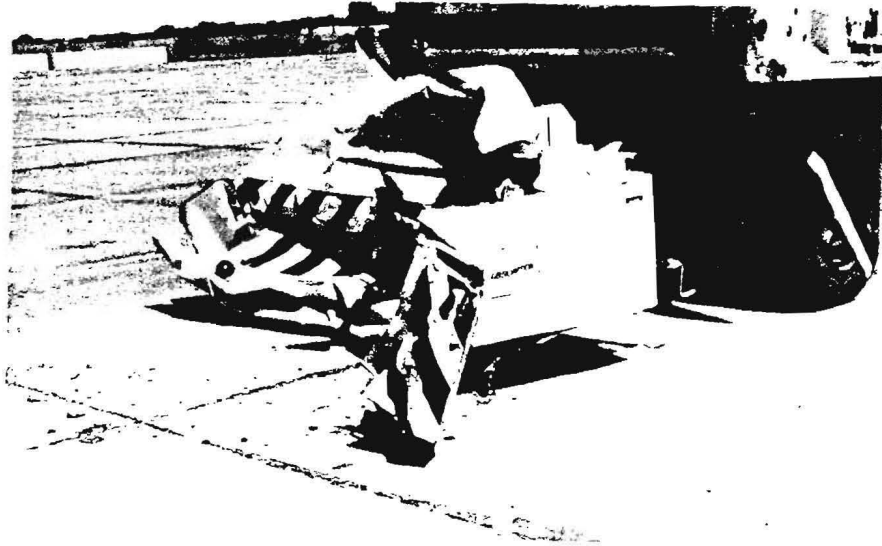
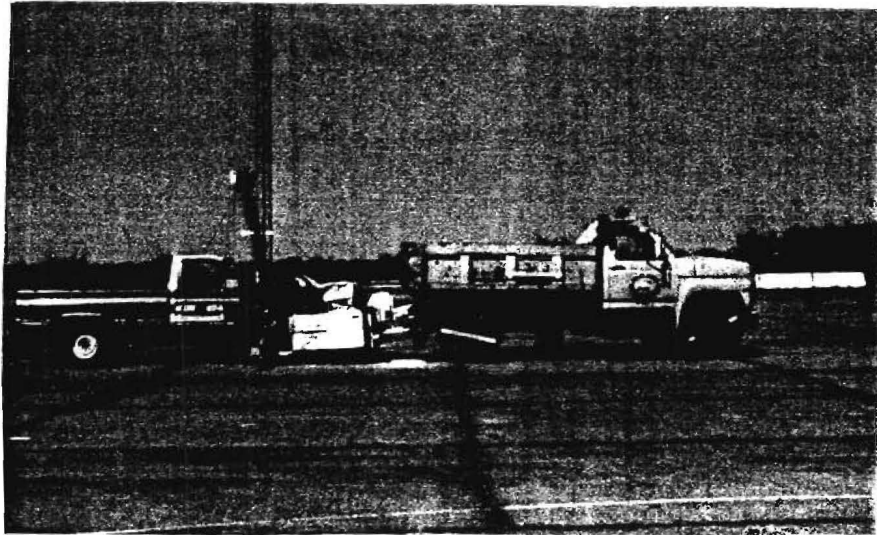


Figure 234. Energy Absorption Alpha TMA after test (9910-12).

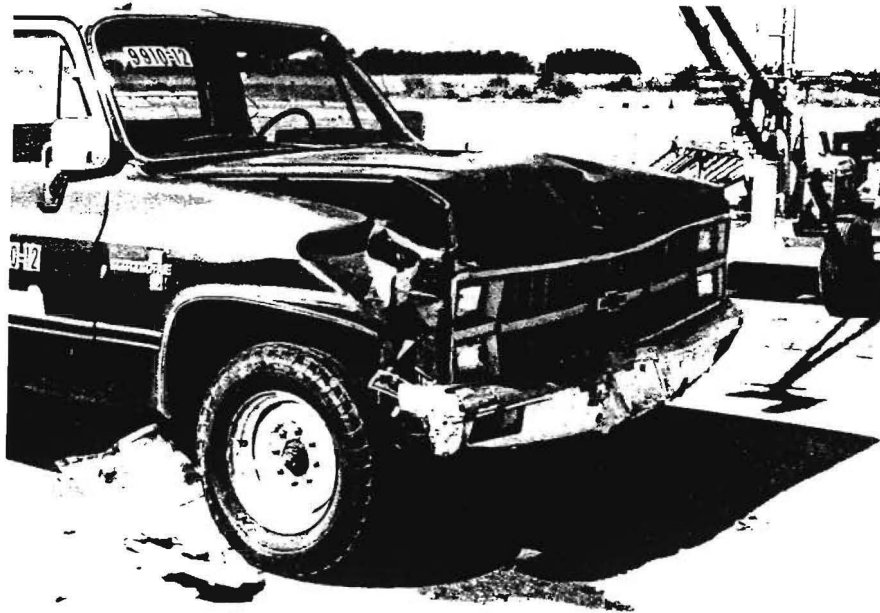
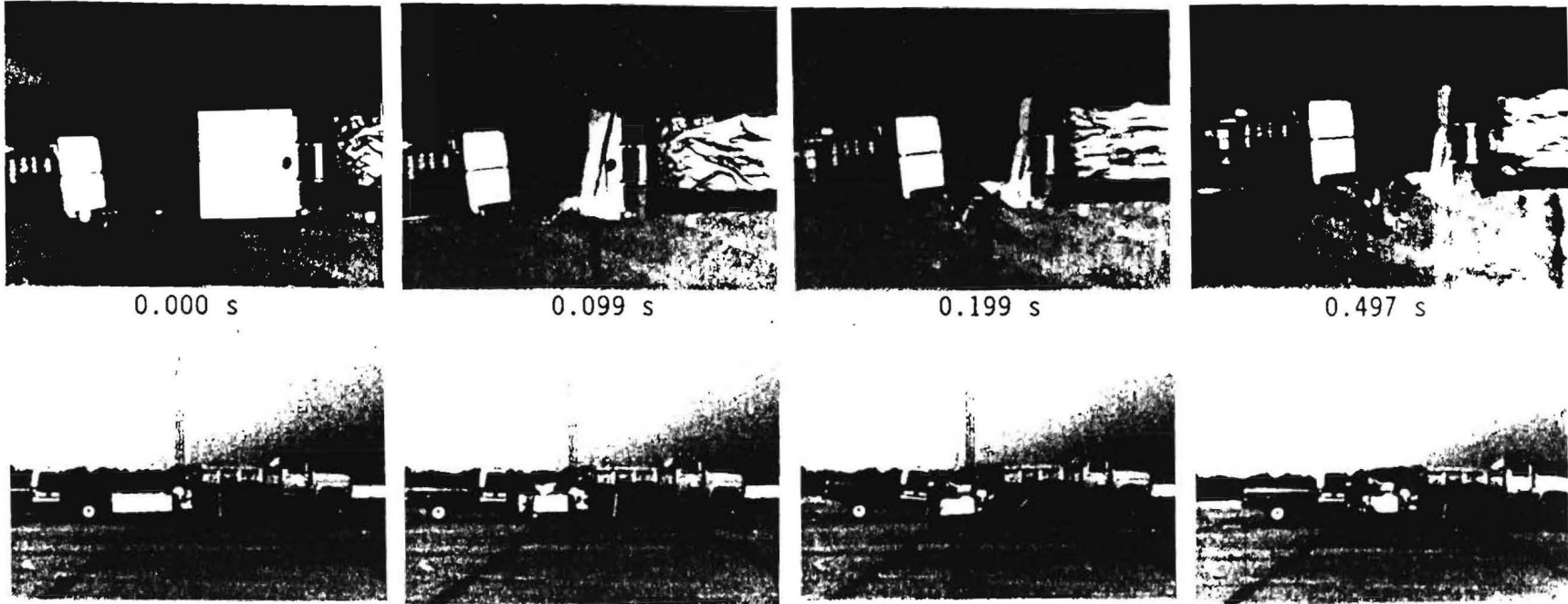
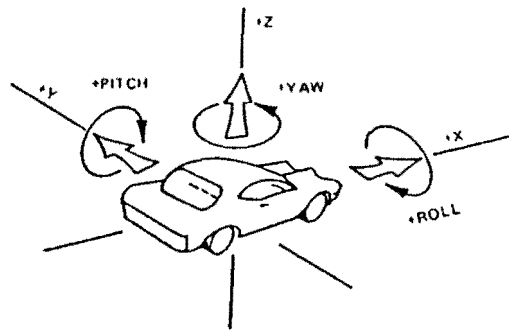


Figure 235 Vehicle after impact with Energy Absorption Alpha TMA (9910-12).



Test No.	09910-12	Maximum Truck Displacement	8.4 ft (2.6 m)
Date	08/31/90	Maximum TMA Crush	66.5 in (1.7 m)
Test Article	Truck Mounted Attenuator	Vehicle Accelerations	
Manufacturer	Energy Absorption (Alpha)	(Maximum 50 ms Average at c.g.)	
TMA Truck	1980 Ford Dump Truck (#2)	Vehicle Longitudinal	-13.5 g
Weight without TMA	14,010 lb (6,361 kg)	Vehicle Lateral	-1.5 g
Weight with TMA	14,990 lb (6,805 kg)	Truck Cab Longitudinal	4.8
Test Vehicle	1981 Chevrolet Scottsdale	Occupant Impact Velocity	
Weight	4,500 lb (2,043 kg)	Longitudinal	35.2 ft/s (10.7 m/s)
Impact Speed	45.1 mi/h (72.6 km/h)	Lateral	None
Maximum Vehicle Crush	8.0 in (20.0 cm)	Occupant Ridedown Accelerations	
Vehicle Damage Classification		Longitudinal	-14.3 g
TAD	12FD2	Lateral	N/A
CDC	12FDEW2		

Figure 236. Summary of results for test 9910-12.



Axes are vehicle fixed.
Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

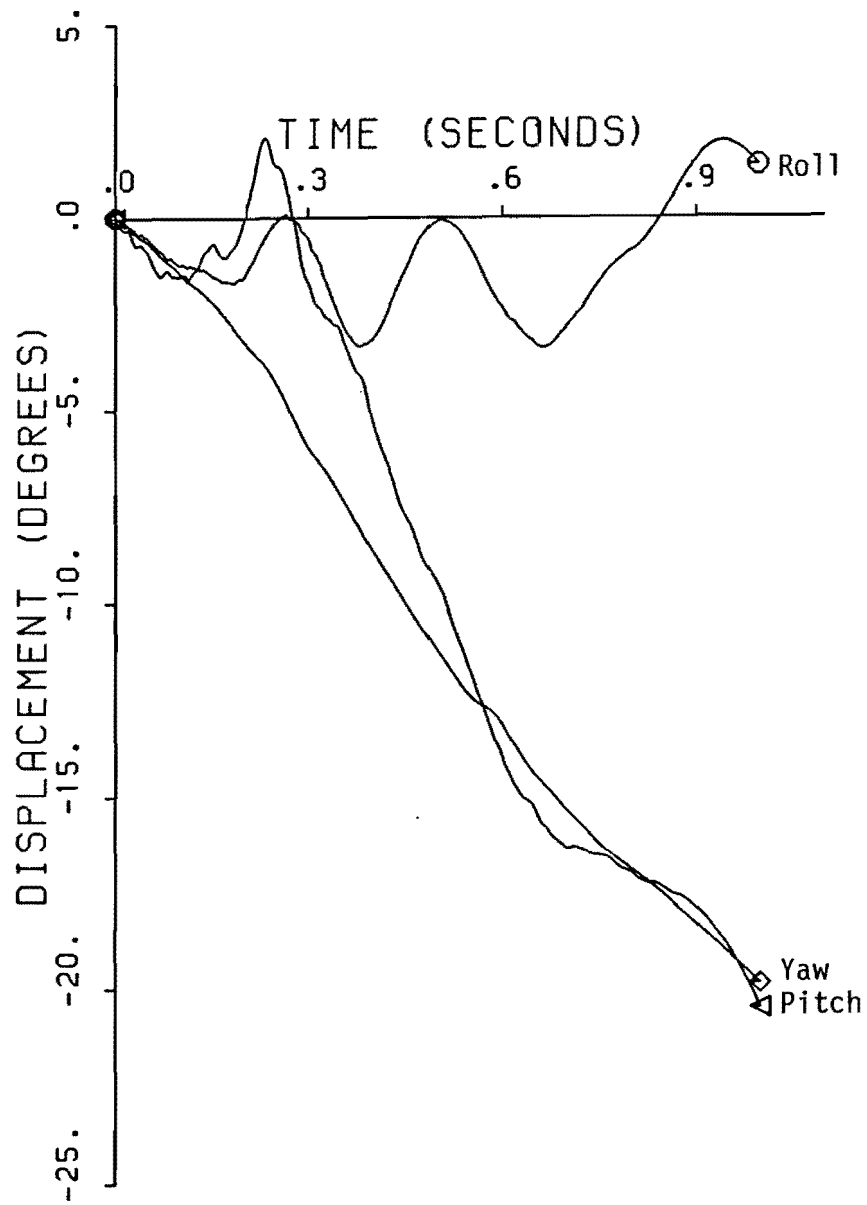


Figure 237. Vehicle angular displacements for test 9910-12.

TEST 9910-12

Class 180 Filter

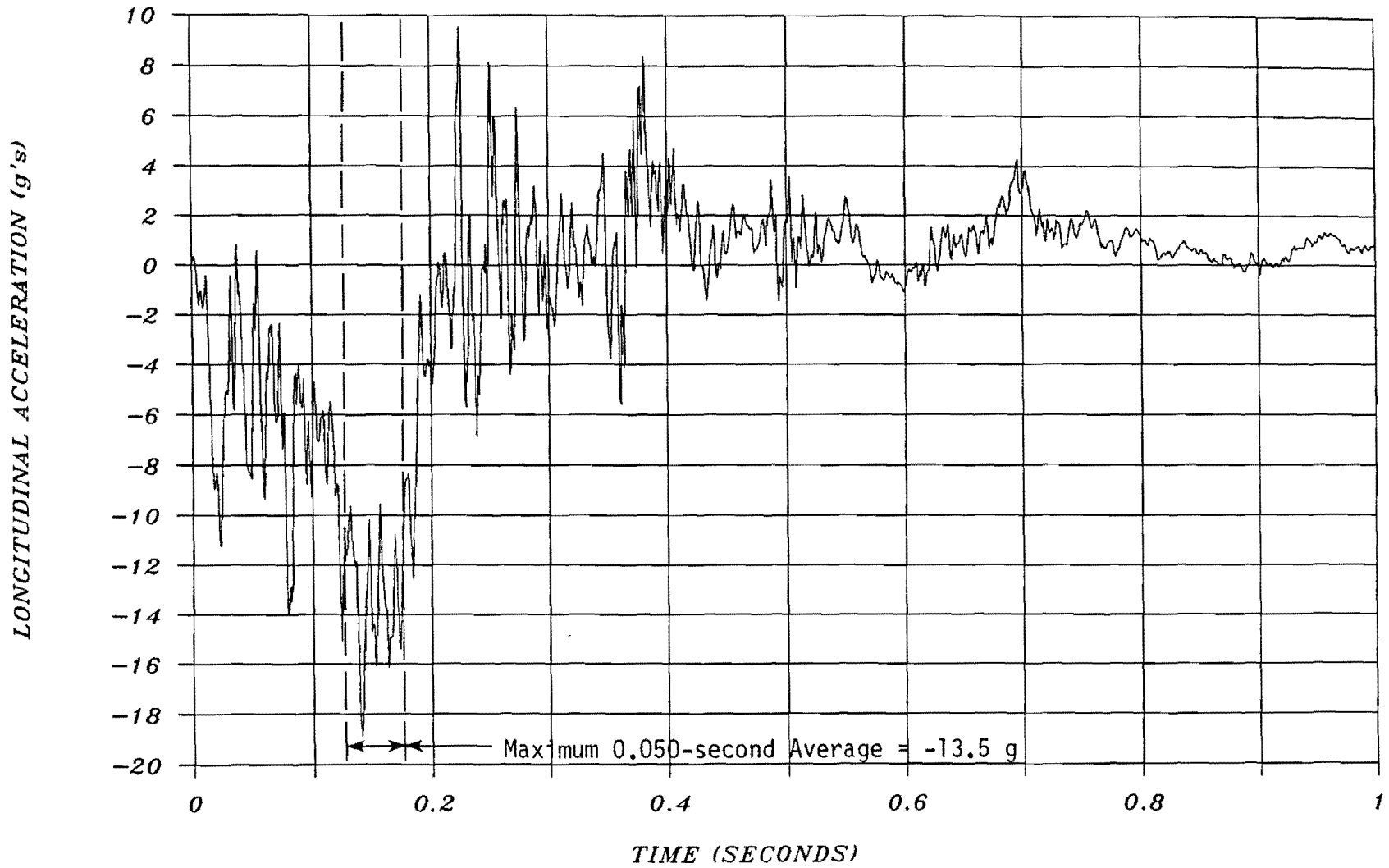


Figure 238. Vehicle longitudinal accelerometer trace for test 9910-12.

TEST 9910-12

Class 180 Filter

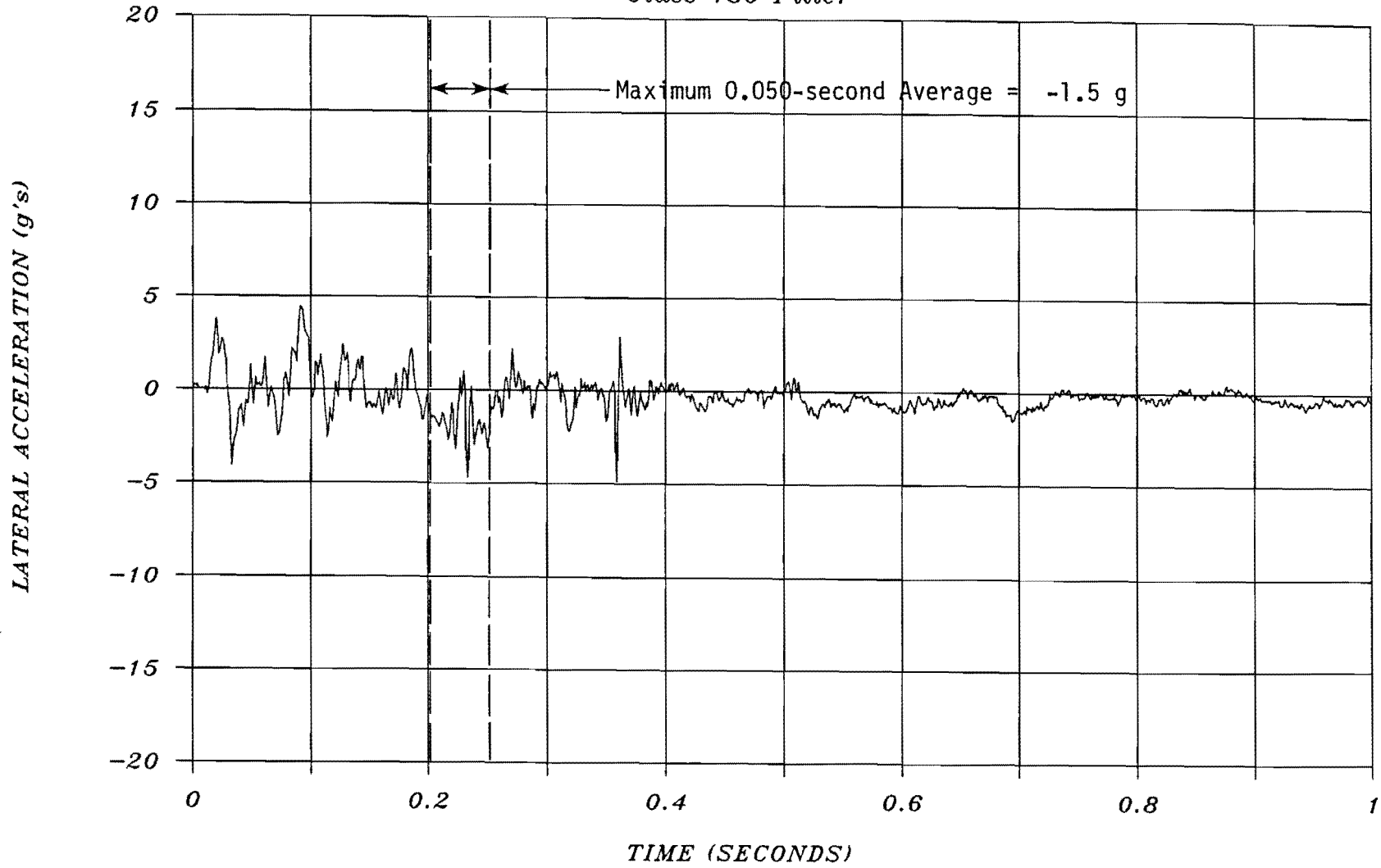


Figure 239. Vehicle lateral accelerometer trace for test 9910-12.

TEST 9910-12

Class 180 Filter

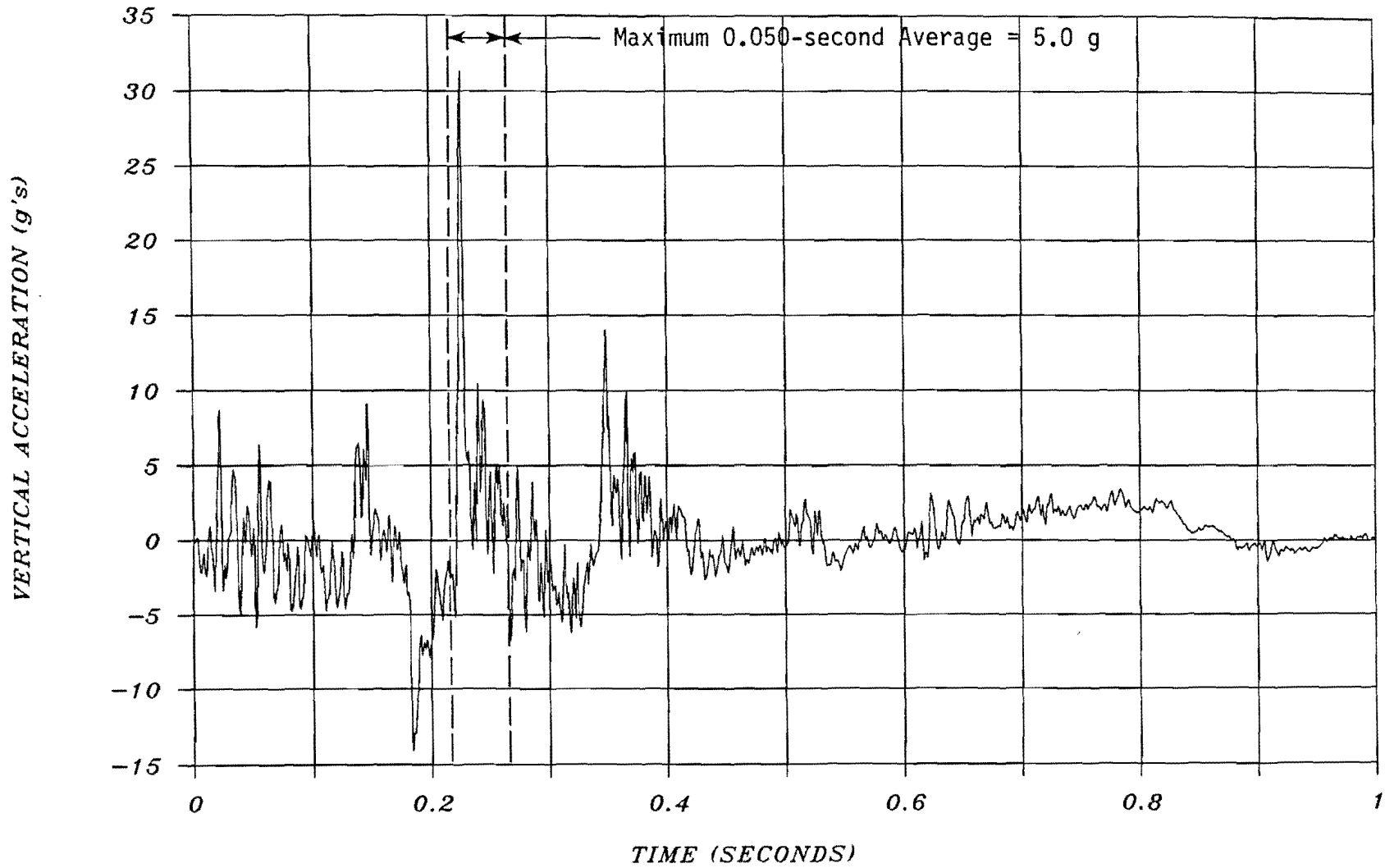
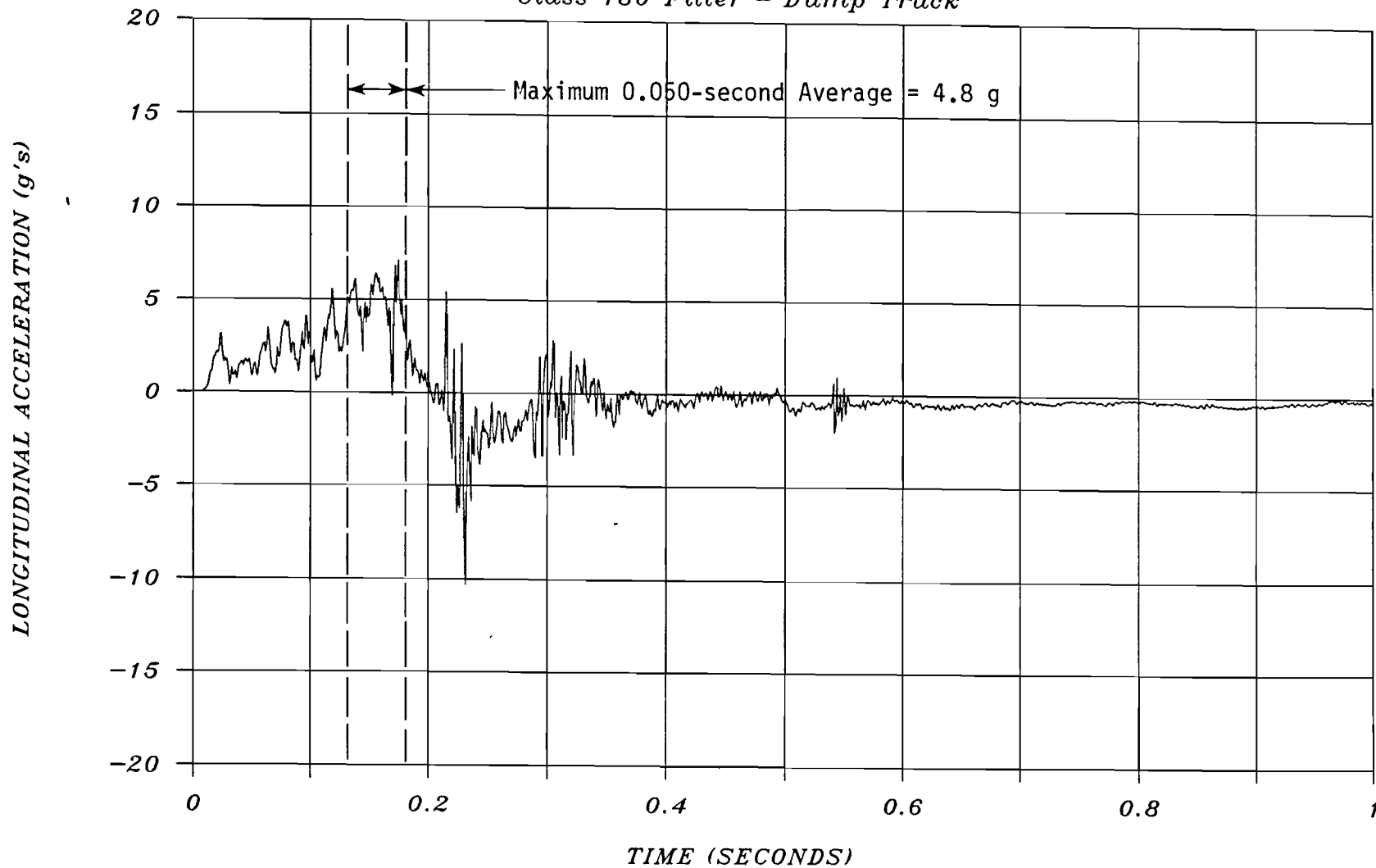


Figure 240. Vehicle vertical accelerometer trace for test 9910-12.

TEST 9910-12

Class 180 Filter - Dump Truck



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Figure 241. Dump Truck longitudinal accelerometer trace for test 9910-12.

