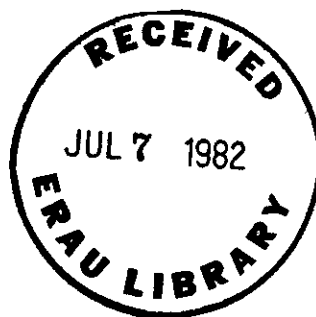


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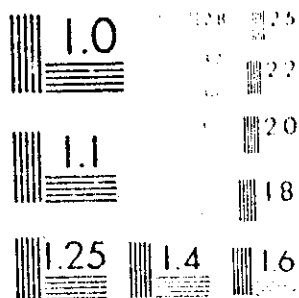
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EVALUATION OF SEATING AND RESTRAINT SYSTEMS  
CONDUCTED DURING FISCAL YEAR 1978

Richard F. Chandler  
and  
Edwin M. Trout

FAA Civil Aeromedical Institute  
Oklahoma City, Oklahoma

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June 1979

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EVALUATION OF SEATING AND RESTRAINT SYSTEMS  
CONDUCTED DURING FISCAL YEAR 1978

INTRODUCTION

This report summarizes the results of test programs conducted by the Protection and Survival Laboratory to investigate the performance of prototype or operational seating and restraint systems relative to their ability to provide protection against crash injury and to validate the performance of the Seat Occupant Model: Light Aircraft (SOMLA).

METHOD

The system evaluations were conducted on the Civil Aeromedical Institute (CAMI) test track. This is an impact test device capable of producing a controlled deceleration pulse that can be programed to produce decelerations between 2 and 50 g, as required for a specific test. The device consists of a test sled that carries the test item along two 150-ft-long (46-m) horizontal rails, an accelerating device that brings the sled up to the desired impact velocity, and a sled braking device that produces the desired impact pulse. Modifications to the facility completed in FY-78 increased the maximum energy that can be imparted to the sled by about 68 percent, from 108,000 ft-lb to 182,400 ft-lb (153 kJ to 250 kJ).

The sled is a flat-topped steel truss on which the test item is mounted. By the use of adapters, a variety of test items can be attached to the sled so that the impact vector, which lies in a horizontal plane, can act on the test item in the desired direction. The sled is equipped with low-friction rollers that guide it along the rails of the track with minimal energy loss.

Velocity is imparted to the sled by an accelerating device that includes a 6,500-lb (2,900-kg) weight, a cable system with a 4-to-1 mechanical advantage attached between the sled and the weight, and a winch cart that can be positioned and locked at any point along the track. The winch cart retracts the sled and locks it into the "ready" position just prior to the test and, simultaneously, it lifts the weight. As the weight is lifted, potential energy is stored in the system and is subsequently used to accelerate the sled and test item to the desired impact velocity. A maximum of 182,000 ft-lb (250 kJ) of energy can be stored that can accelerate the sled and payload to velocities of up to 50 mi/h (80 km/h), depending on the payload weight. To accomplish the test, the sled is released from its locked position, is accelerated along the track by the falling weight, is allowed to coast without acceleration for a predetermined distance after the weight is stopped, and then contacts the braking device which produces the desired impact pulse.

The braking device is a "metal bender" form of energy absorber. This device uses two layers of No. 3 gage wires that are plastically deformed as



they are pulled over rollers by the sled and thus absorb energy to provide the required braking force. The wires are cut to length with sufficient allowance to provide a safety factor above displacement required by the sled during the impact. The wire size and the diameter of the rollers over which it passes were selected to generate a nominally required force of 2,500 lb (11 k N) to pull the wire through the rollers. The braking device holds two layers of 43 wires and is thus capable of generating a maximum braking force of 215,000 lb (940 k N). The deceleration-time history of the sled can be precisely controlled by selecting the number of wires placed in the braking device and adjusting the position at which they are contacted by the sled. The total deceleration distance is not limited by this braking device.

Component evaluations were conducted on specially built equipment that met the provisions of the specifications describing those tests.

#### ELECTRONICS INSTRUMENTATION

The electronics instrumentation system used by the Protection and Survival Laboratory for dynamic testing was designed for maximum versatility and reliability. Special provisions have been made for using strain gage bridge-type transducers. This type of transducer is available in many models and has proved to be reliable for measuring strain, acceleration, pressure, forces, and low frequency vibrations.

Signals are transmitted from transducers on the sled or test item to signal conditioners through a loose, flexible cable that is attached at one end to the sled. The signal conditioners (Endevco model 4470/4476.2) provide excitation to the transducers (3 to 10 V dc), amplify the signal, provide low-pass filtering if required, and provide resistance shunt calibration for each transducer through the entire data-recording system.

Outputs from the signal conditioners modulate subcarrier oscillators of a constant-bandwidth high frequency multiplexer system. The composite output from the multiplexer system is recorded on wideband analog tape that serves as primary data storage. The magnetic tape data are then reproduced through appropriate discriminators for recording on an oscillographic recorder (for quick-look analysis) or digitized and recorded on high-density digital tape for automatic data processing. Final data are processed in accordance with the requirements of Society of Automotive Engineers (SAE) Recommended Practice J211b, Instrumentation for Impact Tests, unless a specialized requirement exists.

#### PHOTOGRAPHIC INSTRUMENTATION

All dynamic tests are photographically recorded for technical documentation and for data collection. Instrumentation-quality 16-mm cameras of various types are operated with film speeds of 500 pictures/s (pps) or 1,000 pps to provide the necessary coverage with the required fields of view.

Color film is used in all cameras and processed at CAMI for maximum picture quality. Synchronization of all cameras with the electronics instrumentation system and timing of all film is provided; both serial-coded pulses (IRIG-A or IRIG-B\*) and numerical display are available on the film edge. Cameras and lighting are controlled by a 42-channel programing system that enables obtaining optimum frame rates during the impact event and prevents damage to the test specimen by the high-intensity lighting necessary for proper exposure. Film data are extracted and analyzed by using a Hewlett-Packard 9820 data system to digitize, store, analyze, and plot data as required.

\*Inter-Range Instrumentation Group

STATIC AND DYNAMIC TESTS FOR VALIDATION OF THE  
FAA SEAT OCCUPANT MODEL: LIGHT AIRCRAFT

The second series of tests to validate the Seat Occupant Model: Light Aircraft (SOMLA) program was accomplished using a rigid seat with deformable tubular legs. The purpose of this test series was to evaluate the ability of the model to predict seat structural response in the presence of localized deformation that changed the cross section of critical structural elements. To achieve this goal, the rigid test seat was constructed so that the tubular legs were fixed in place with a clamping system that provided a high "end fixity." The foot end of the legs was pin-joined to the floor structure to provide low "end fixity" in the x-z plane of the tests. Because the technique of clamping the legs in place used precision draw collets, it was not possible to control the length of the leg to a predrilled pinhole. Consequently the pinholes were located and drilled after the legs were clamped in place, using special tooling and the pin fittings on the sled for control. In this manner it was possible to achieve a seat structure that was not prestressed by the installation on the sled.

Eight static tests and 58 dynamic tests were completed in the forward-facing (-Gx) orientations and with the floor angled at  $60^{\circ}$  to provide a downward and forward occupant reaction. Deceleration levels of 5.4 g and 9.5 g provided minimal plastic deformation (without significant cross section change) and marked plastic deformation (with localized buckling and cross section change at the fixed end), respectively, in the -Gx orientation. In the tests with the floor angled, deceleration levels of 13.5 g and 22 g were required to produce similar results. Each test was repeated 10 times so that the results could be combined to yield a mean and standard deviation time history. Measurements of head, chest, and pelvis acceleration; seatbelt and shoulder belt loads; floor loads; and seat displacement were obtained. The results are presented in Appendix A, Figures A-1 through A-8.

## PERFORMANCE OF AN AFTERMARKET SHOULDER HARNESS

Owners of general aviation aircraft are sometimes reluctant to install a shoulder harness (upper torso restraint) in their aircraft because of the cost and complexity associated with modifying the airframe to provide an attachment point for the shoulder harness. Thus they do not benefit from the well-documented advantages of upper torso restraint during a crash. This problem could be alleviated if a proper shoulder harness could be installed without modifying the aircraft. One approach to this solution consists of a V-type shoulder harness with sewn loops at the apex and tips of the V. The rear seatbelt is passed through the loop at the apex of the V to secure the shoulder harness in the aircraft. The front (occupant) seatbelt is passed through the loops at the tips of the V and is then latched and adjusted in the normal manner. Adjusters are provided in each strap of the shoulder harness system so that it may be adjusted independently of the front or rear seatbelts.

Two aspects of this system warranted study. As in all systems in which the shoulder belts are attached near the center of the seatbelt (without negative "g" strap), the possibility exists that the seatbelt may be pulled from the pelvic skeleton into the abdominal area (submarining) with resultant soft tissue and spinal column injury. Also, if the downward angle of the shoulder harness causes compressive loads that act on the spinal column, vertebral fracture may occur. The importance of these two aspects depends on several factors of system installation and usage and on the events of the crash. In general, the potential for submarining may be influenced by seatbelt angles, softness or deformation of the seat structure or cushion under load, the lengths of belt webbing that stretch under load and can alter the geometry of the installation, and the positioning and adjustment of the restraint system by the user. In addition to the angle of the shoulder belt, vertebral column loading can be influenced by the above factors as well as the ability of the seat back to absorb the vertical component of the shoulder belt load, the tendency of the body to flex under the restraint, and the magnitude of the vertical component of loading that exists in the crash. Human tolerance to vertebral injury is influenced by age and spinal abnormalities that may exist.

To evaluate the performance and potential problems that might exist with this restraint, a brief series of controlled impact tests were completed. The tests were accomplished in a forward-facing (-Gx) orientation, using a general aviation (Piper) seat mounted on a rigid framework that not only supported the seat but provided attachment points for an aft seatbelt. A 50th-percentile anthropomorphic dummy weighing approximately 170 lb was used in all tests. The feet of the dummy rested on a flat plywood floor and were unrestrained. Instrumentation included accelerometers in the dummy and on the test sled and webbing load cells on the webbing of the restraint system. The general arrangement for these tests is shown in Figure 1. Three conditions of the restraint were evaluated in this series. Tests 059, 060, and 061 considered

the condition where the front seatbelt was short and attached to the seat frame. This created a seatbelt loop length of about 39 in when the webbing was snugly adjusted against the dummy.

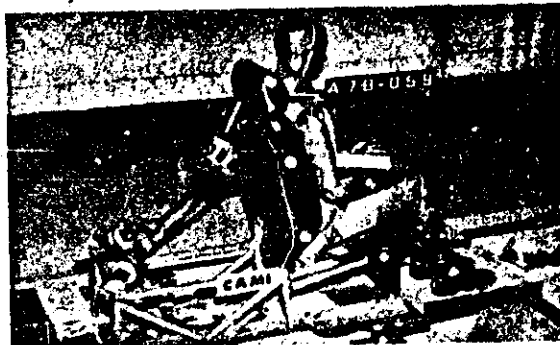


Figure 1. General test arrangement.

Tests 062 and 063 maintained the same general configuration but attached the seatbelt to the floor so as to provide a seatbelt loop length of about 70 in. The rear seatbelt attachment was unchanged. These tests were included to evaluate the effect of the longer seatbelt used in some aircraft. Finally, Tests 064, 065, and 066 evaluated this same configuration but with a somewhat loose restraint system (76-in seatbelt loop length). These tests were included to evaluate the effect of a slack restraint system, often encountered in the field even though it is generally considered to increase the potential of injury in a crash.

The seat pan membrane was found to be torn after Test 060. This membrane consisted of a thin moulded rubber sheet attached to the seat frame by hooks fitted into reinforced holes in the sheet. The membrane was replaced by a web of nylon seatbelt webbing attached to the hoods via anchor fittings and tensioned by a webbing adjuster mechanism. The webbing was brought sufficiently tight so that no subject difference was noted when compared to the moulded membrane (Figure 2).

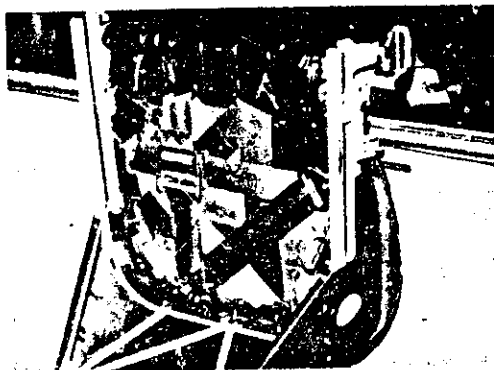


Figure 2. View of seat pan showing webbing which replaced seat pan membrane after Test 060.

The results of these tests are shown in Table 1.

TABLE 1. Test Results

Test No.	G	Lapbelt Load (lb)	Shoulder Belt Load (lb)	Head Forward (in)
059	6	950	700	18
060	10	1,750	1,450	18
061	14	2,200	1,800	21
062	10	1,800	1,400	21
063	14	2,200	1,900	21
064	6	1,100	900	24
065	10	1,850	1,550	28
066	14	2,700	2,050	25

The results of these tests indicate that 18 to 28 in of forward head motion could be expected when the restraint is used under the conditions of the test. During this movement the head bowed forward and down. The motion was most severe with the loose restraint system. Submarining also appeared imminent at the higher impact loads when the restraint was loose.

The spinal column load generated by the downward angle of the shoulder belt attachment to the lapbelt was estimated using the high-speed motion picture coverage of the tests. The angle between the shoulder belt and the estimated position of the spinal column was measured and used to calculate the component of belt load which would be generated along the axis of the spinal column. Since the seat back folded forward in the tests, it did not carry significant loading from the shoulder belt and was ignored for these computations. The results of these computations are shown in Figure 3. The open symbols in this figure refer to the component of spinal compressive load resulting from the aft portion of the shoulder belt; the closed symbols indicate the maximum total spinal compressive load that would exist if the shoulder belt load were carried, without frictional loss, over the shoulder to the lapbelt, and if that load were parallel to the spinal column. This condition was approximated during the tests. The actual spinal compressive load should fall between these extremes.

The ability of the spinal column to carry compressive load is dependent on several factors influenced by both human and crash conditions. A complete discussion of these conditions can be found in the references, but for the purpose of this report it is sufficient to note that the compressive strength varies from about 300 to 2,800 lb if normal spinal curvature is maintained. This is a severe limiting condition and was not attained in these tests. If the spinal column is flexed, the ability to carry load is greatly reduced. Although quantitative data are not generally available, best estimates indicate that the ability of the spinal column to carry compressive loading will be reduced by a factor of 3 to 5 if the column is flexed (1). Thus,

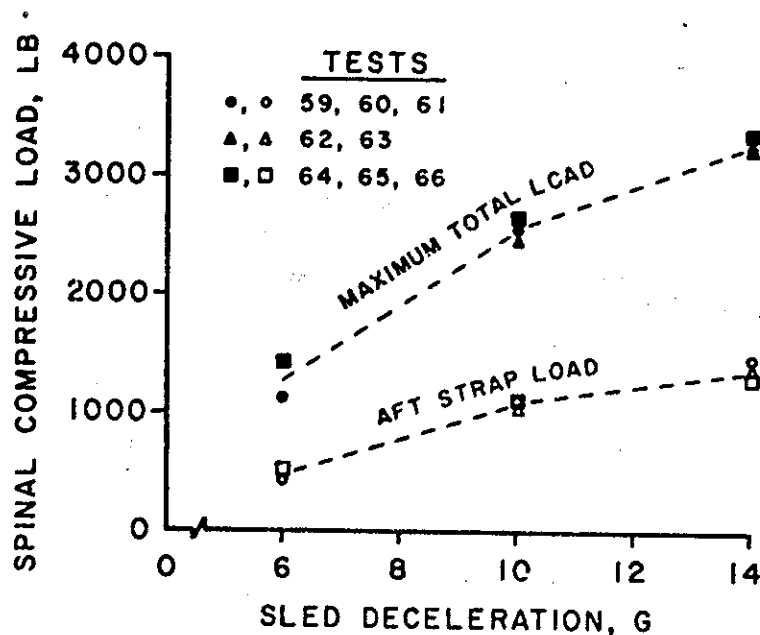


Figure 3. Results of computations of test results.

under the conditions of the tests, the spinal column could be expected to carry a compressive load, without fracture, which varies from a low tolerance of 60 lb to a maximum tolerance of 930 lb. It would be expected that elderly users of the restraint system would be most subject to injury (2,3). It should be noted that a vertical component of direct crash loading, not present in our tests but commonly present in aircraft crashes, would make injury even more likely.

Use of this restraint system should be judged on the availability of sufficient clearance in front of the body for head motion and on the option of possibly reducing head and facial injury at the expense of increasing the probability of vertebral fracture. Both of these injuries could be life-threatening or, if survivable, may cause lasting impairment.

The results of these tests are presented graphically in Appendix B, Figures B-1 through B-8.

## EVALUATION OF THE PERFORMANCE OF LOW-ELONGATION WEBBING

Samples of 2-in-wide Kevlar webbing and low-elongation polyester webbing were used to construct a four-point restraint system. This system was then tested in a rigid seat with 90° seat back angle (4). Both static webbing and dynamic restraint system tests were conducted. Although these stiffer webbing systems performed well in the dynamic tests, an unusually severe cyclic pattern was noted in the restraint webbing load data with two pronounced load peaks of almost equal magnitude. This was confirmed by high-speed photoinstrumentation, which showed two obvious displacement cycles of the upper torso relative to the seat. The reason for this unusual performance is not yet known but may be related to the high spring constant provided by the webbing, especially when coupled to a rigid seat.

Fabrication and use problems were noted with the Kevlar webbing. This material was found to be relatively difficult to cut as it was being fabricated and slippage was noted in the webbing adjuster mechanism. This last problem may be rectified by the use of adjusters designed specifically for the Kevlar material, rather than the standard assemblies used for these tests. Inasmuch as there is no significant difference in performance between the low-elongation polyester webbing and the Kevlar webbing, the polyester webbing, which permits the use of conventional hardware and can be fabricated by conventional methods, holds greater potential for further development.

The results of these tests are presented in Appendix C, Figures C-1 through C-3.



#### USAARL ENERGY-ABSORBING HELICOPTER SEAT TESTS

Two tests were conducted on the fourth evaluation of a prototype two-passenger helicopter seat in cooperation with the U.S. Army Aeromedical Research Laboratory (USAARL) (3). Tests were conducted in the lateral orientation at 16 g and in the 30° yaw orientation at 24 g. Failures occurred under both conditions, the most serious of which was the failure of the stock floor anchorage fittings on the seats. These fittings use a ring of "fingers" which grasp a "button head" mounted on the floor. The fingers are locked in place by a spring-loaded collar, arranged so that lifting the collar releases the fingers so that the seat can be removed. The fingers failed while under load. These failures may have been aggravated by slack in the stainless steel cable system that goes between the seat back and the floor and is designed to absorb the lateral component of the seat load. One of these cables also failed during the 30° yaw test.

#### REFERENCES

1. Kazarian, L., and G. A. Graves, Jr.: Compressive Strength Characteristics of the Human Vertebral Column, SPINE, Vol. 2, No. 1, March 1977.
2. Henzel, J. H.: The Human Spinal Column and Upward Ejection Acceleration: An Appraisal of Biodynamic Implications. AMRL-TR-66-233, Wright-Patterson AFB, Ohio, September 1967.
3. Perey, Olaf: Fracture of the Vertebral End Plate in the Lumbar Spine, ACTA ORTHOP. SCAND., Supplement No. SSV, 1957.
4. Chandler, R. F., and E. M. Trout: Evaluation of Seating and Restraint Systems and Anthropomorphic Dummies Conducted During Fiscal Year 1977. FAA Office of Aviation Medicine Report No. FAA-AM-78-24, June 1978.

APPENDIX A.

RESULTS OF STATIC AND DYNAMIC TESTS FOR VALIDATION  
OF THE FAA SEAT OCCUPANT MODEL: LIGHT AIRCRAFT  
(SOMLA) - SERIES I AND II.

Figure No.

		<u>page</u>
	Series I	
A-1	Forward-facing, low-deceleration tests.	13
A-2	Forward-facing, higher deceleration tests.	24
A-3	Combined loading, low-deceleration tests.	35
A-4	Combined loading, higher deceleration tests.	46
	Series II	
A-5	Forward-facing, low-deceleration tests.	57
A-6	Forward-facing, higher deceleration tests.	68
A-7	Combined loading, low-deceleration tests.	79
A-8	Combined loading, higher deceleration tests.	90

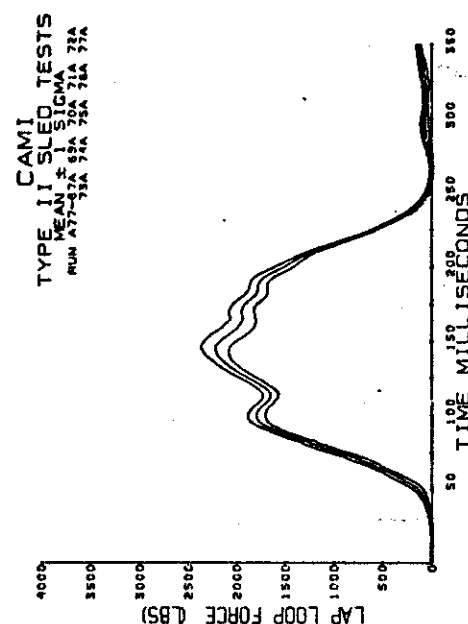
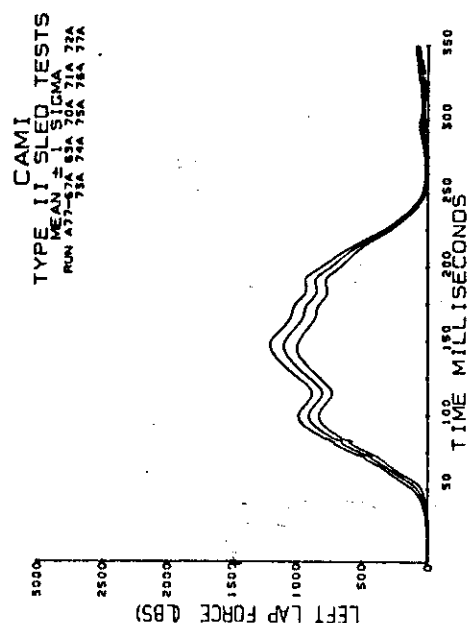
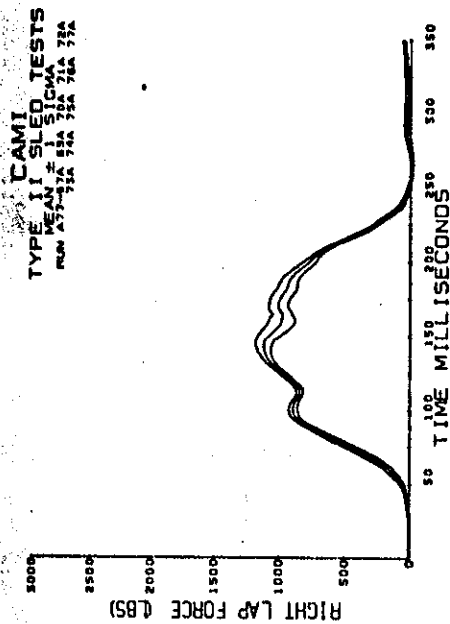
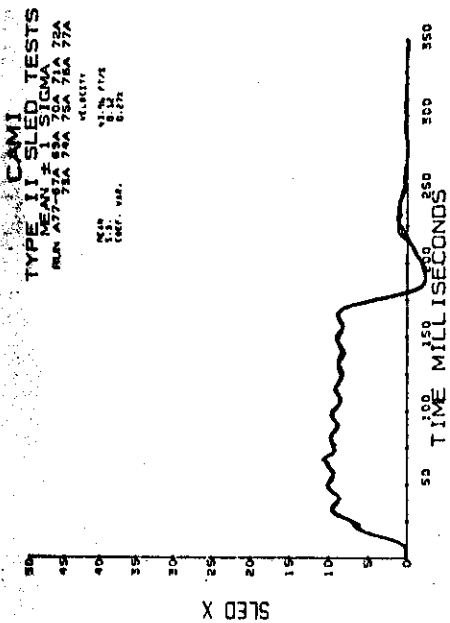
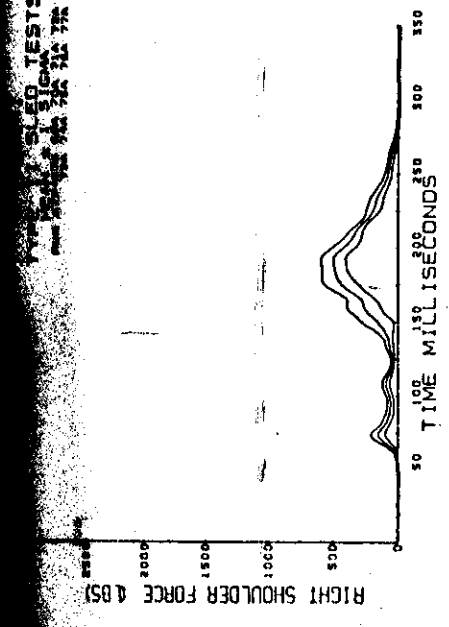
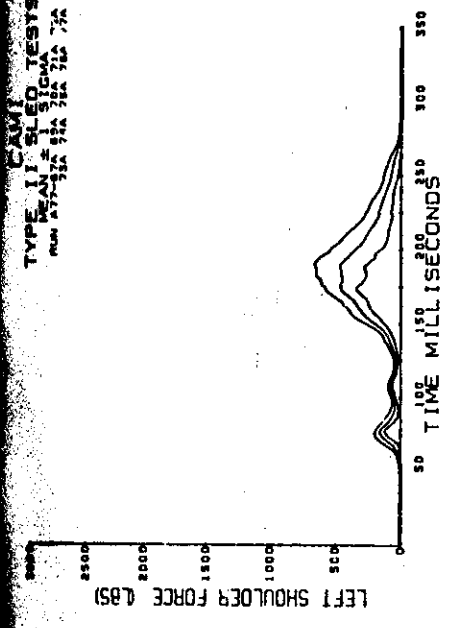


Figure A-1. Forward-facing, low deceleration tests.  
 Sled deceleration and lapbelt loads.

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RUN A77-57A 75A 76A 77A 78A 79A

CAMI  
TYPE II SLED TESTS  
MEAN  $\pm$  1 SIGMA  
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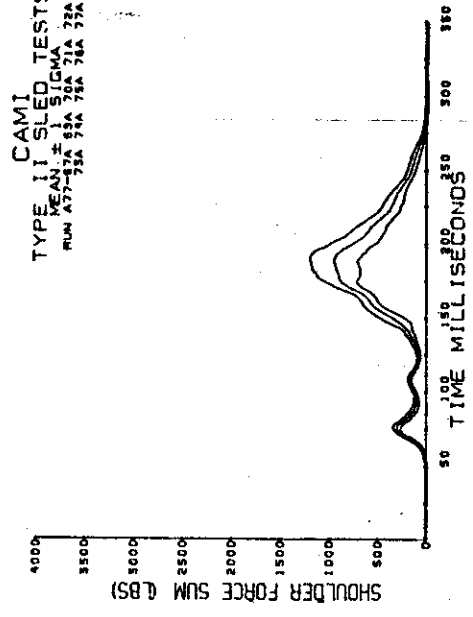


Figure A-1 (continued). Shoulder belt loads.

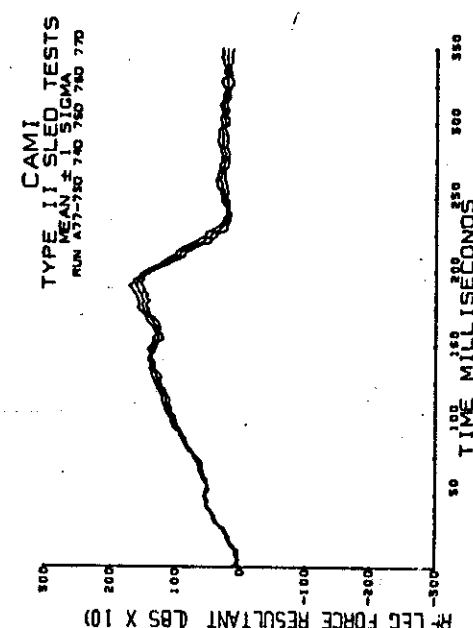
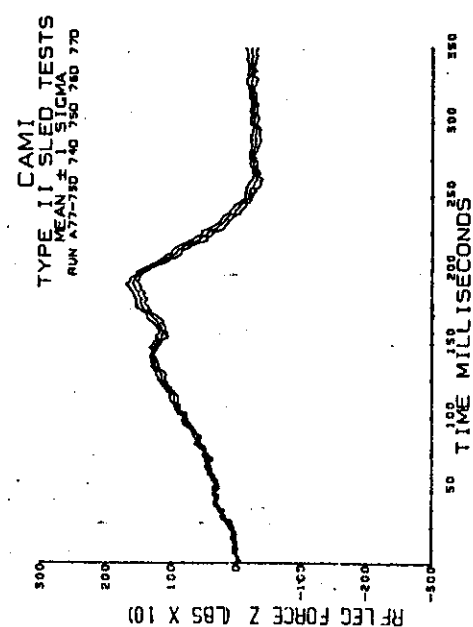
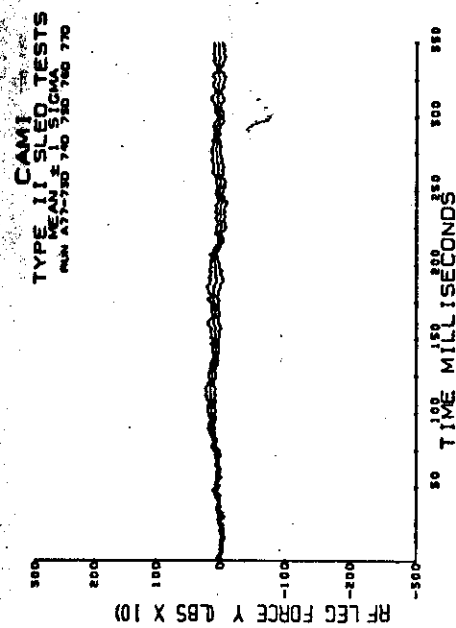
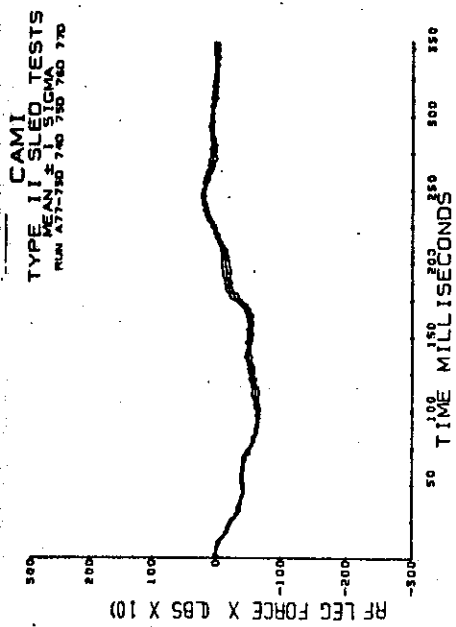


Figure A-1 (continued). Right front seat leg loads.

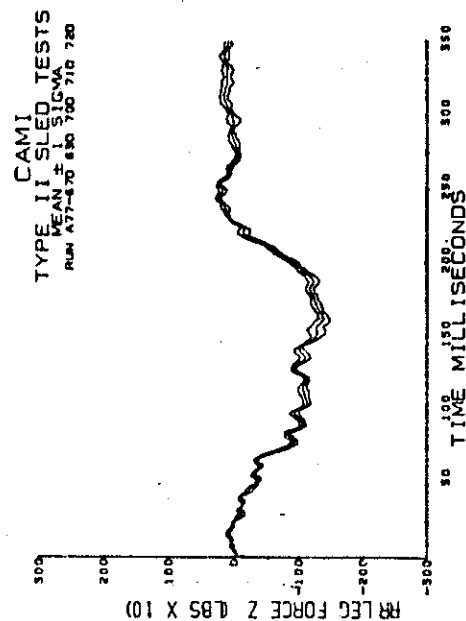
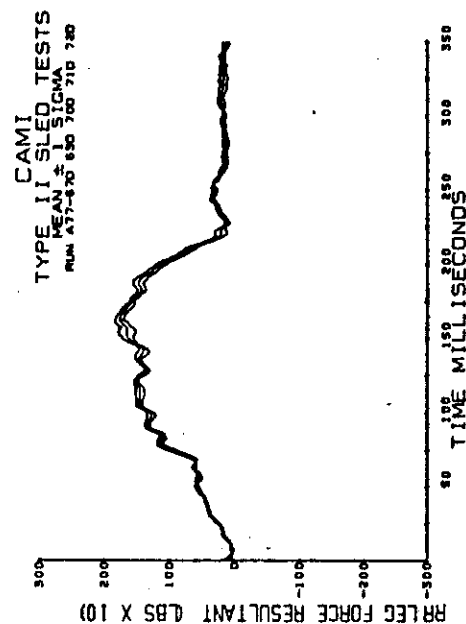
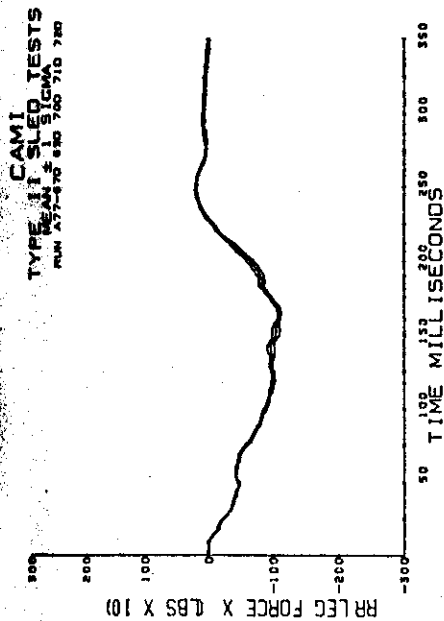
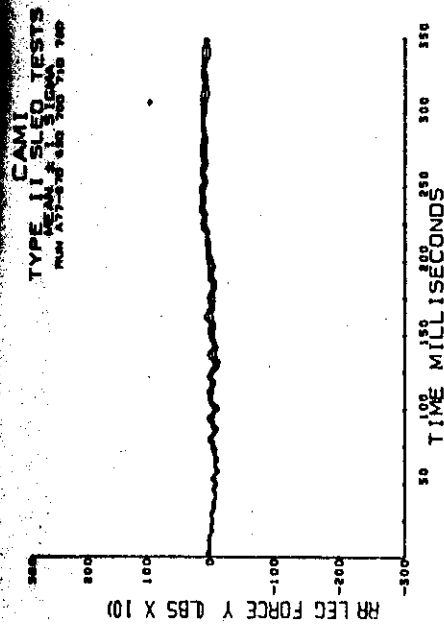


Figure A-1 (continued). Right rear  
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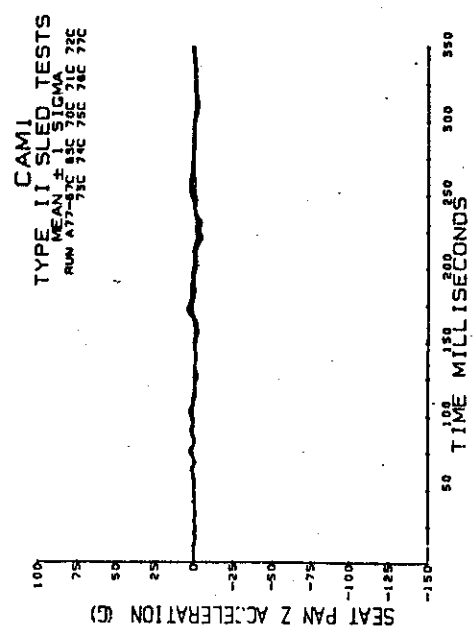
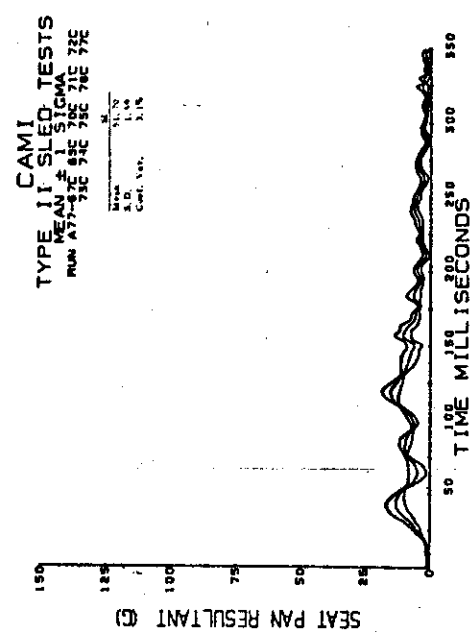
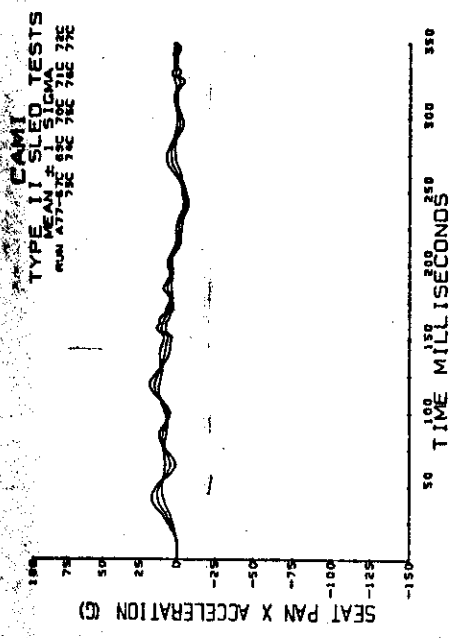
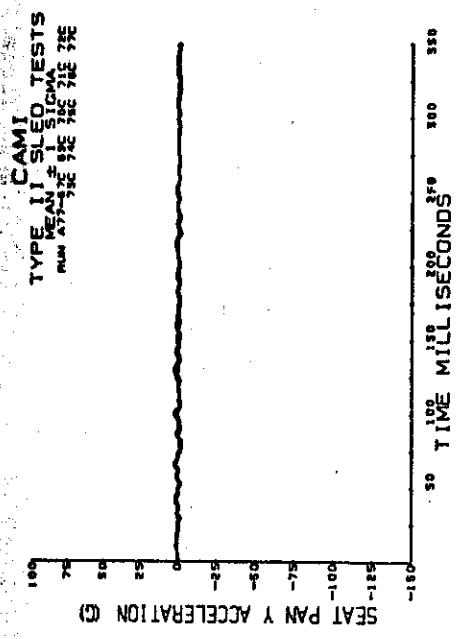
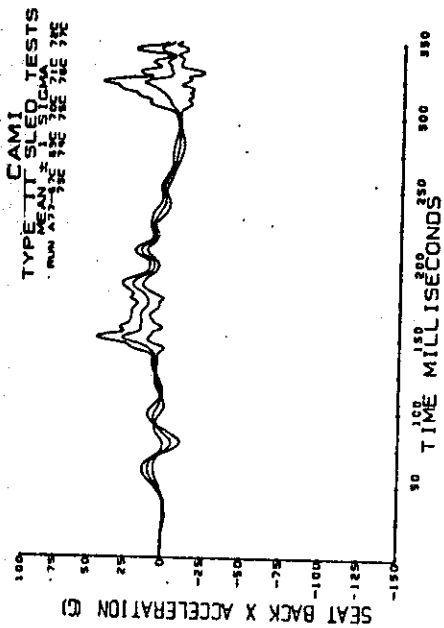


Figure A-1 (continued). Seat pan acceleration.





81

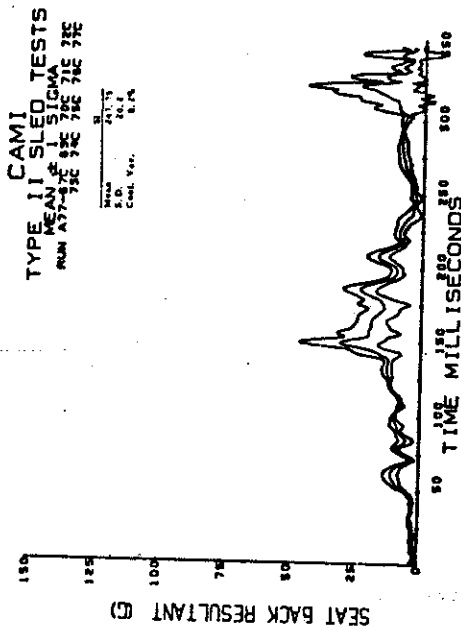
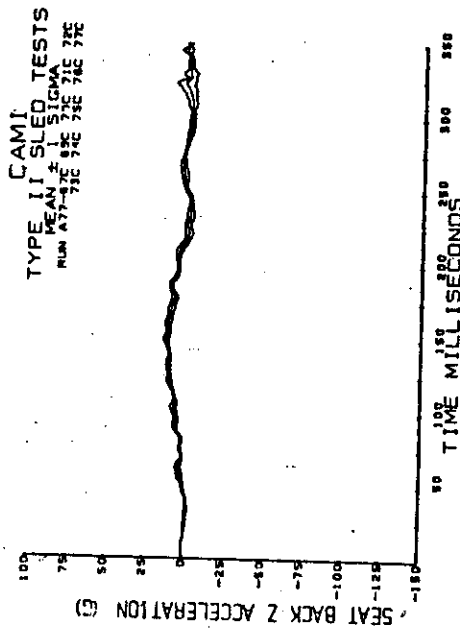
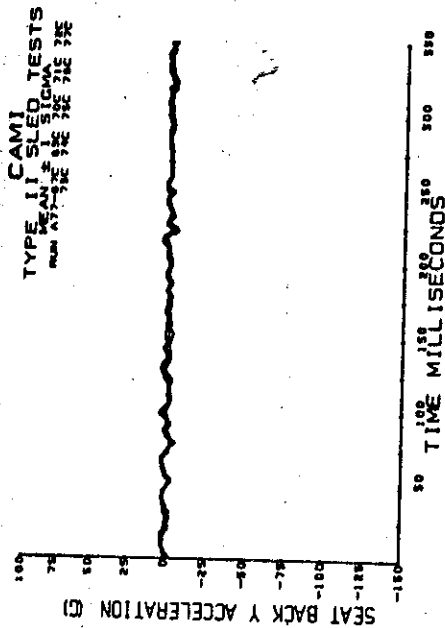


Figure A-1 (continued). Seat back acceleration.

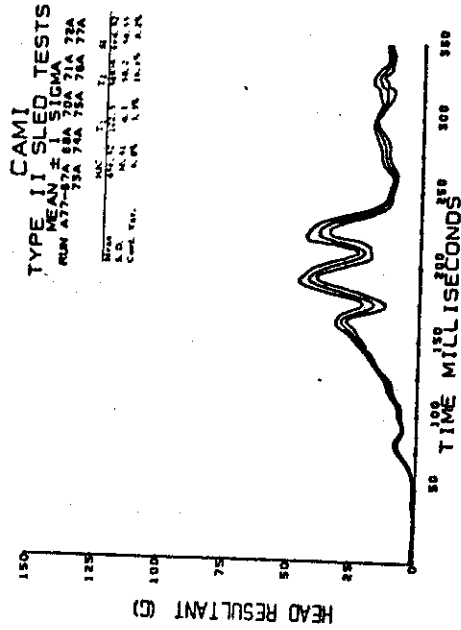
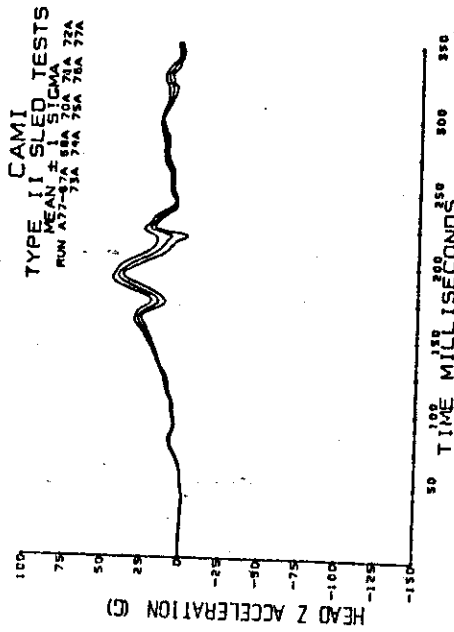
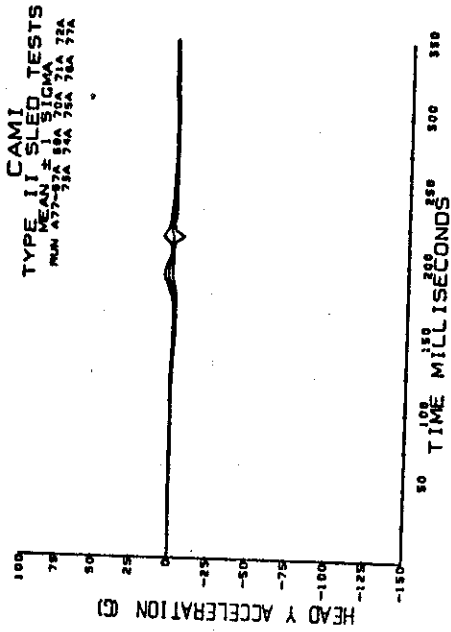
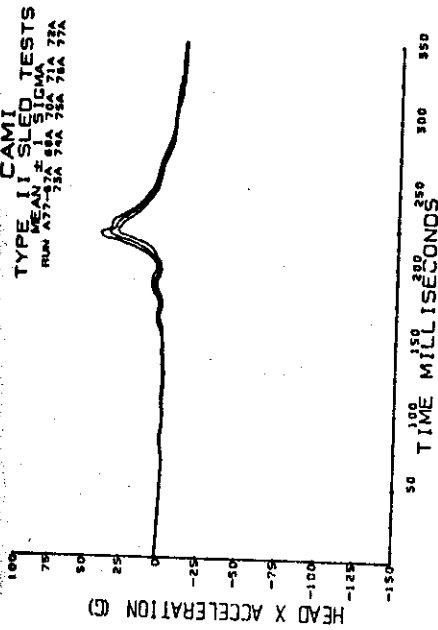
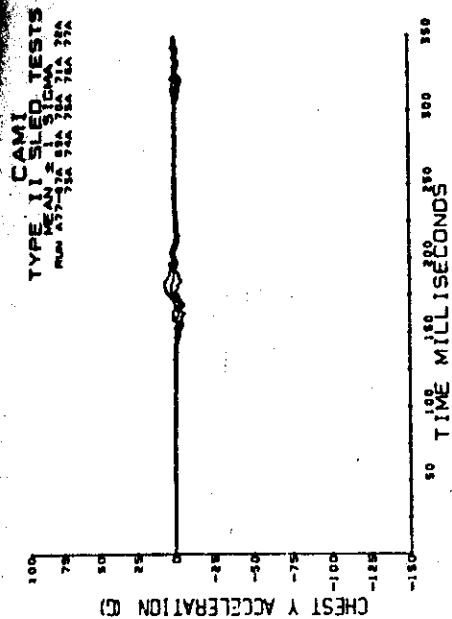


Figure A-1 (continued). Head acceleration.



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RUN A77-87A 93A 76A 71A 72A

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S.D.	11.11
CONF. YEA	94.96

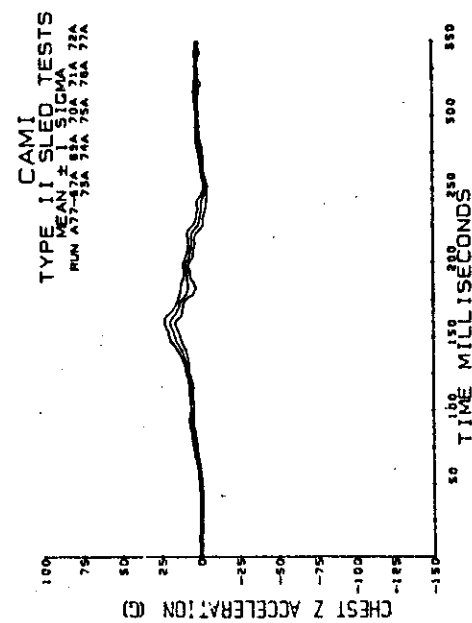


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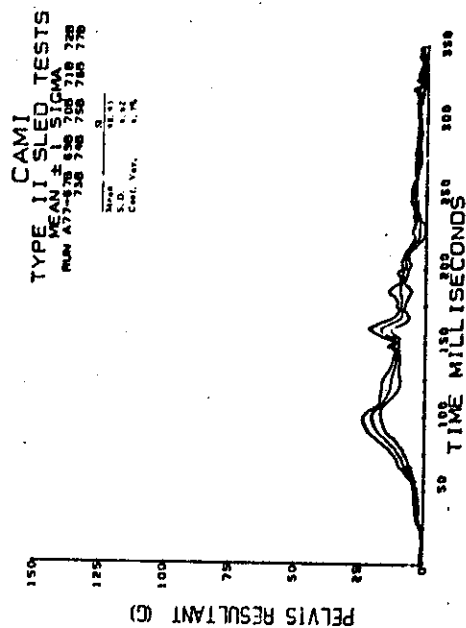
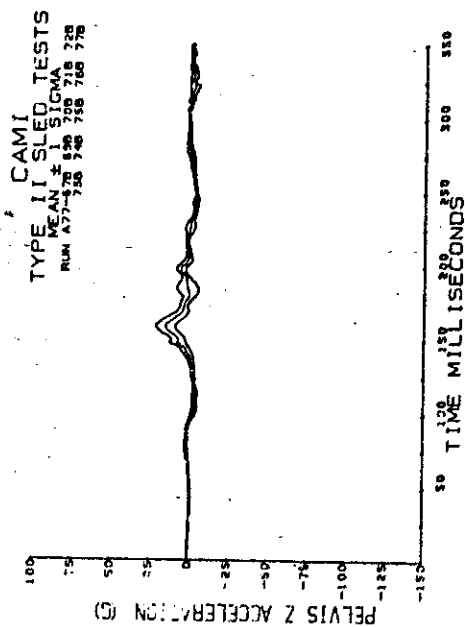
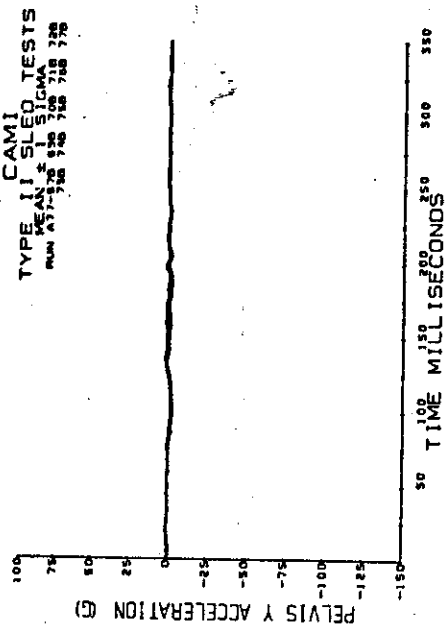
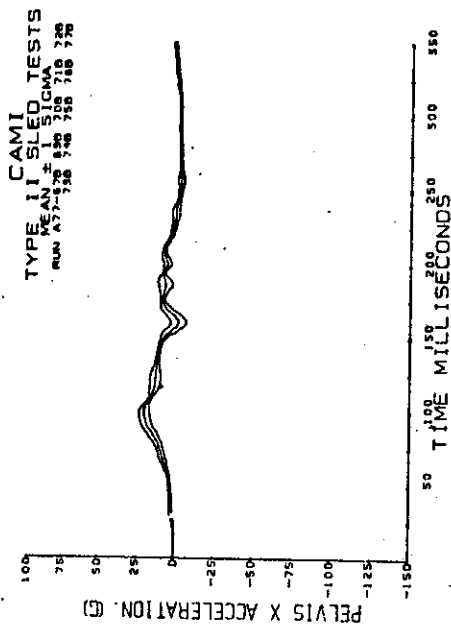


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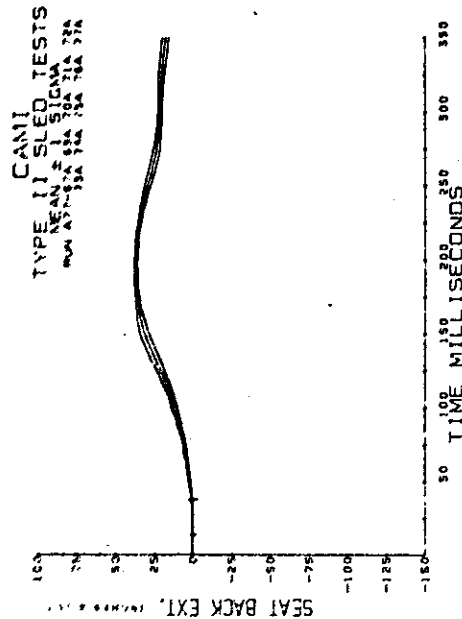
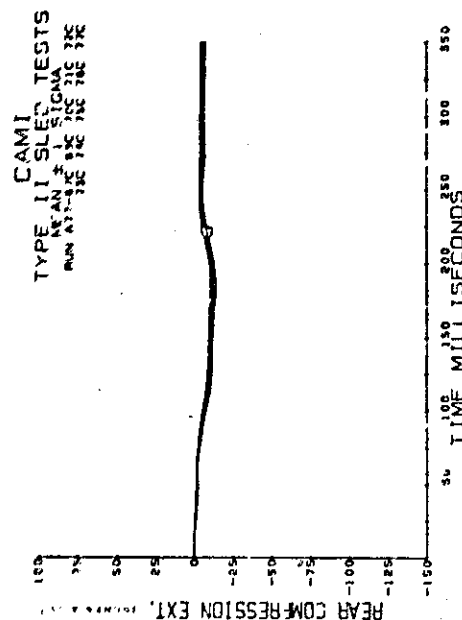
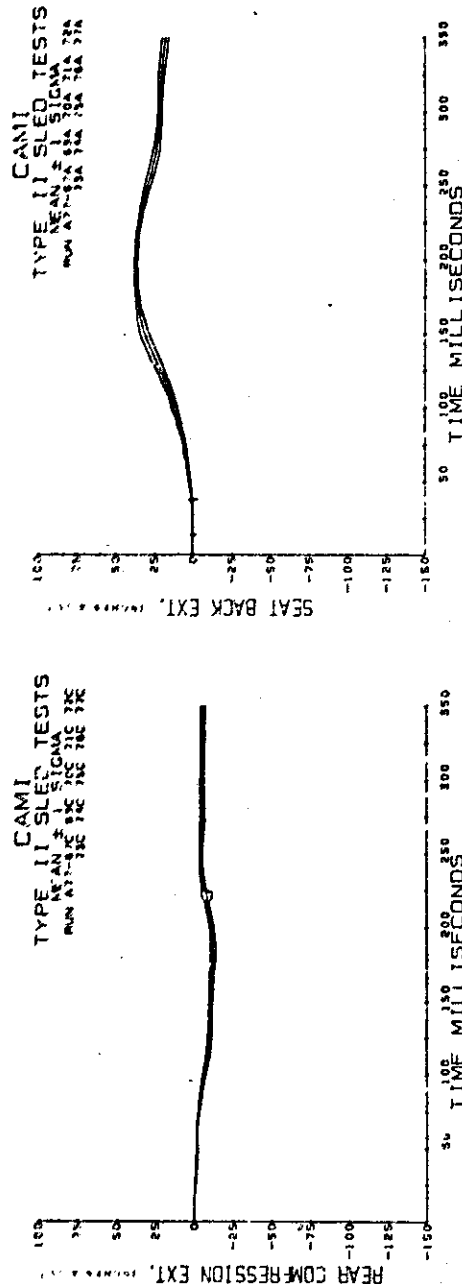
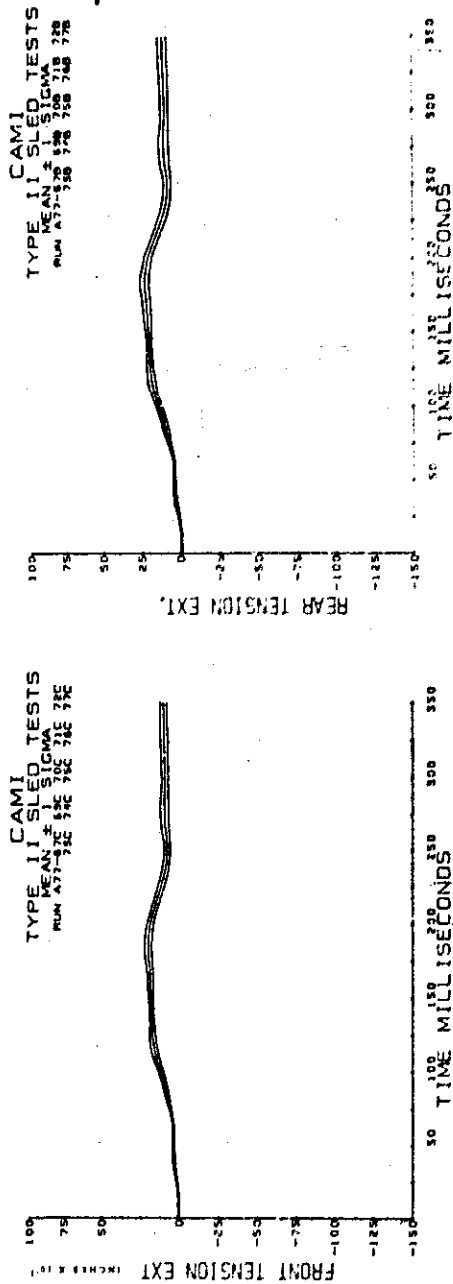


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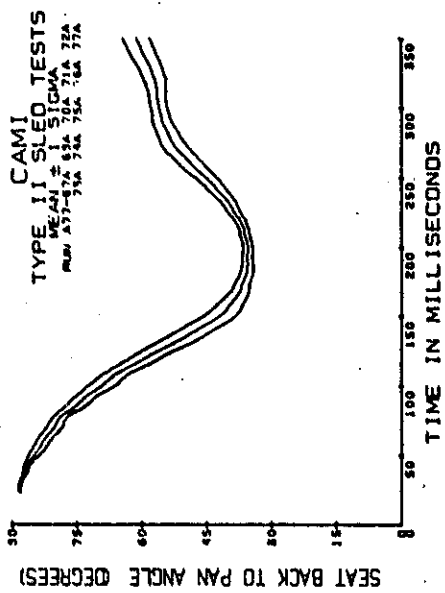
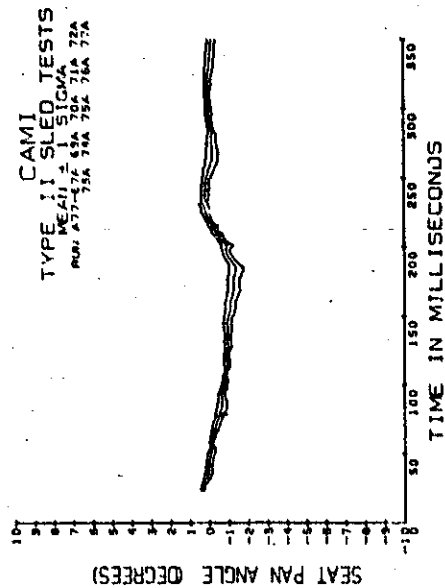
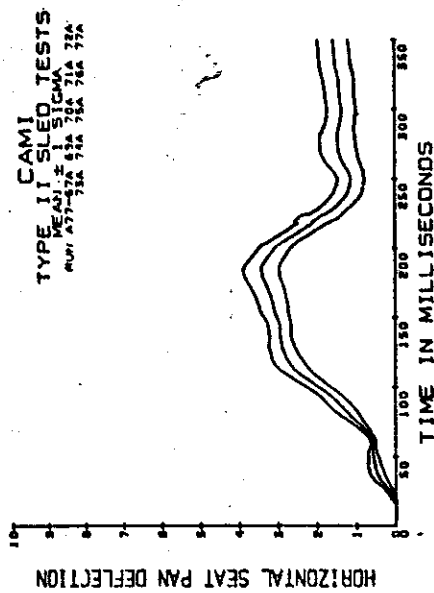
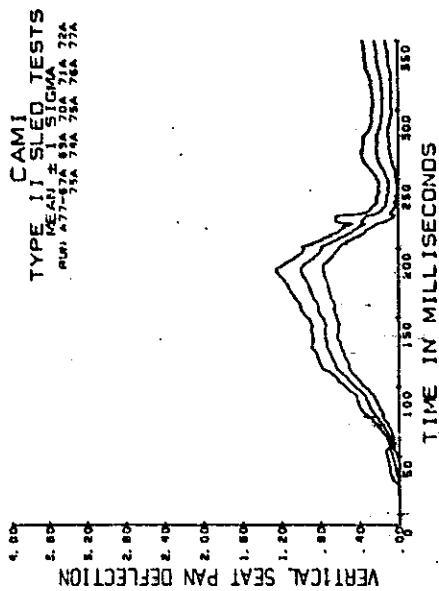


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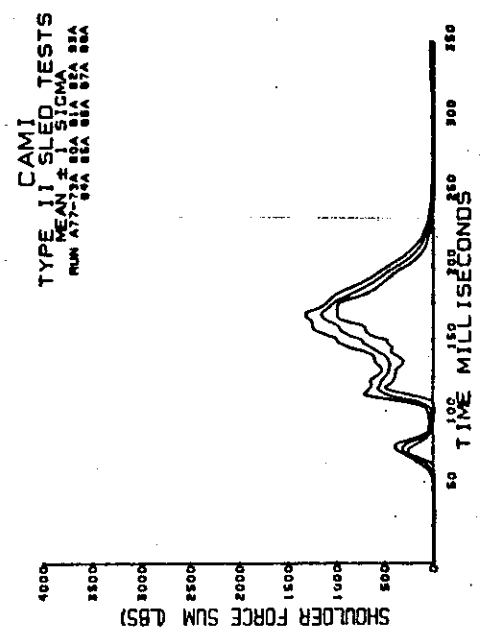
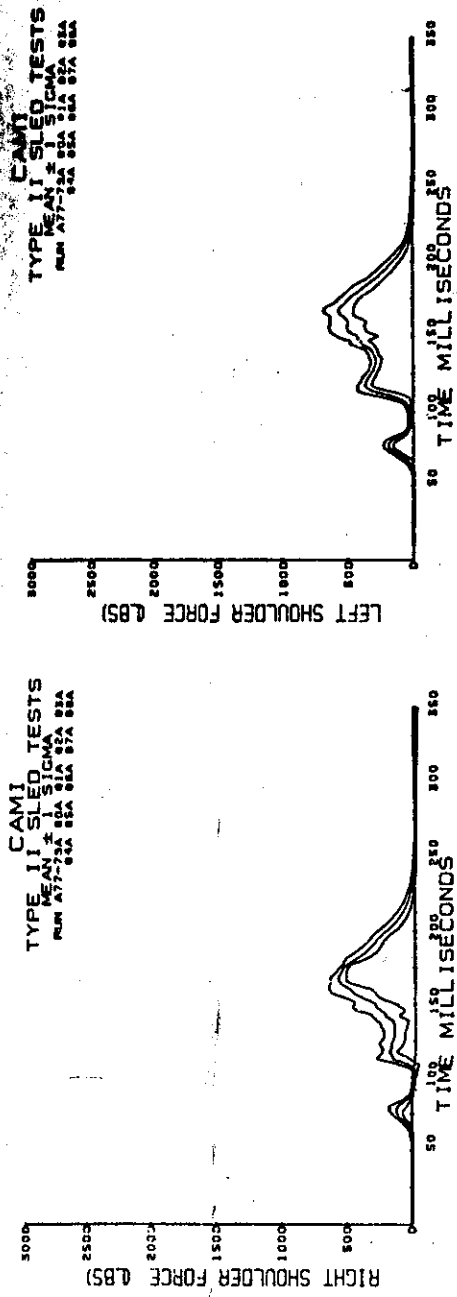


Figure A-2 (continued). Shoulder belt loads.

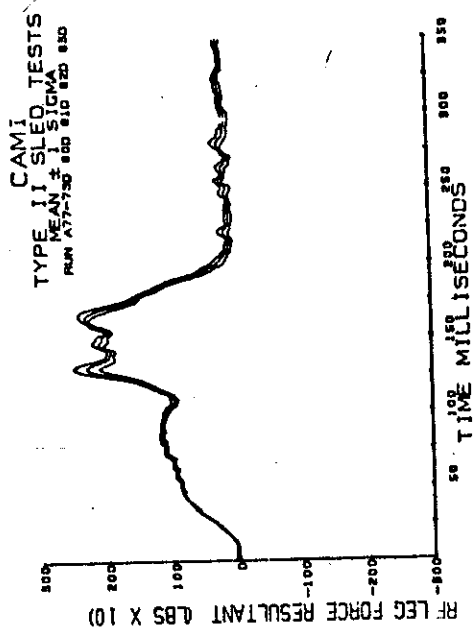
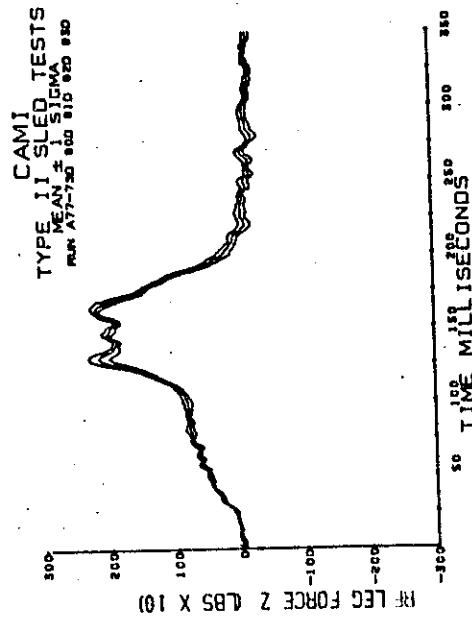
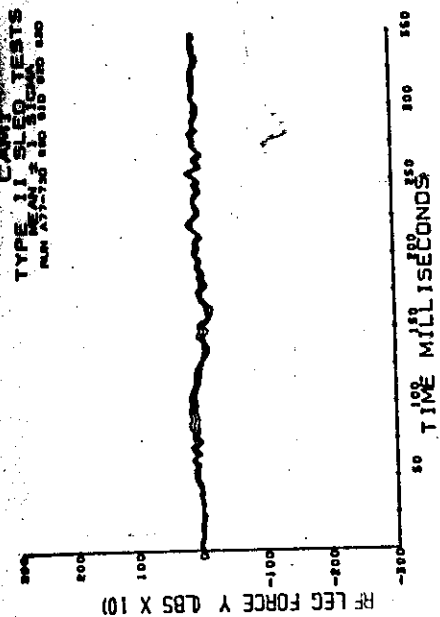
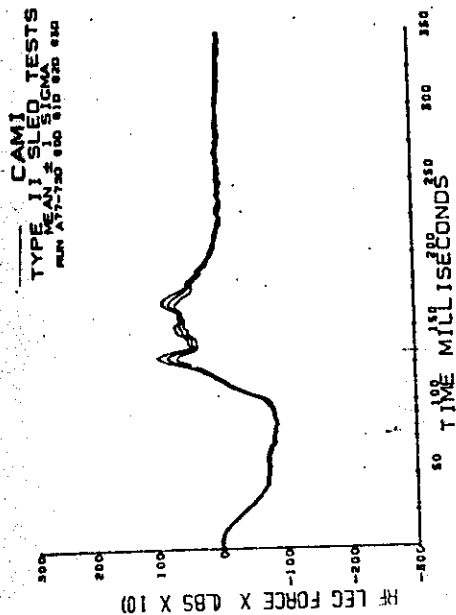


Figure A-2 (continued). Right front  
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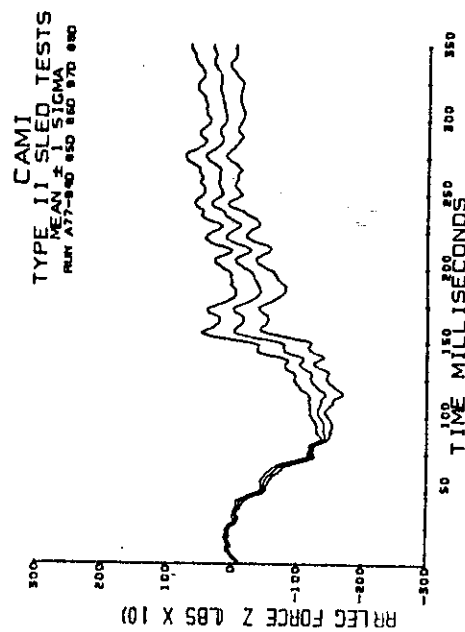
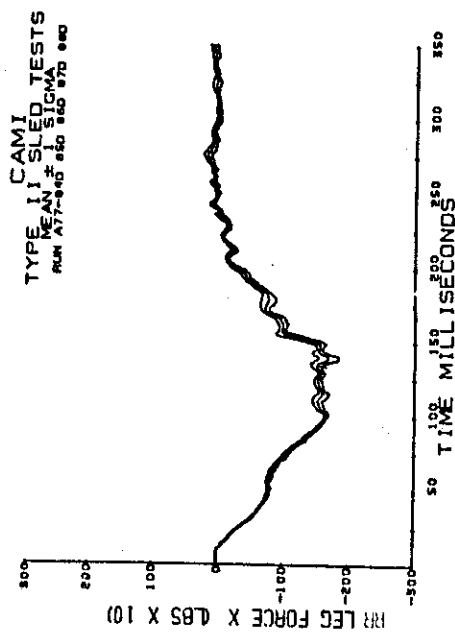
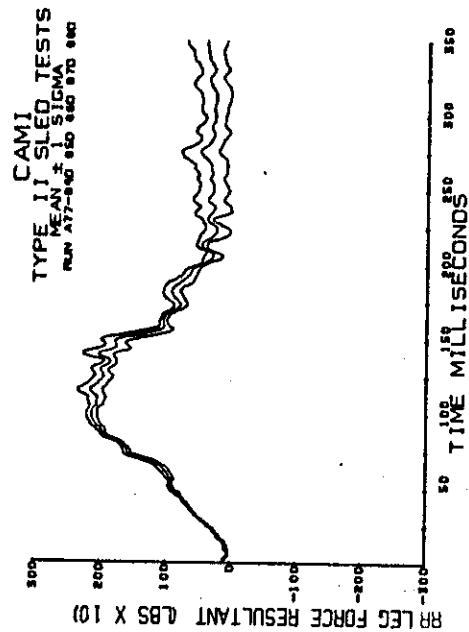
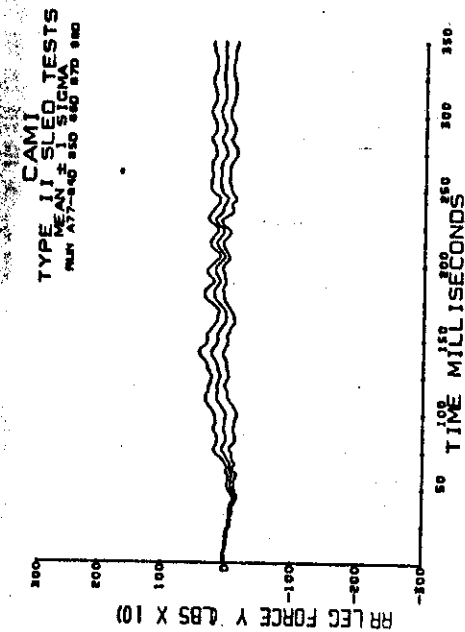
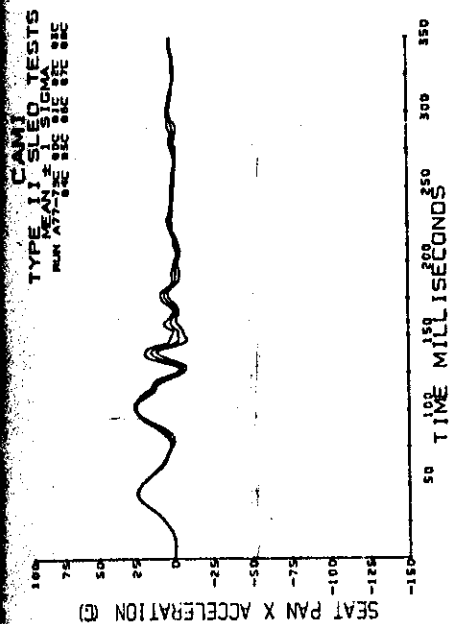
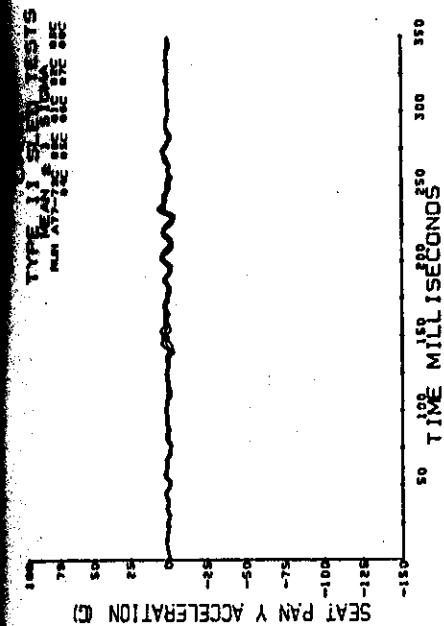


Figure A-2 (continued). Right rear  
seat leg loads.



CAMI  
TYPE 11 SLED TESTS  
MEAN  $\pm$  1 SIGMA  
RUN AT 100 SEC 0.10 SEC 0.10 SEC

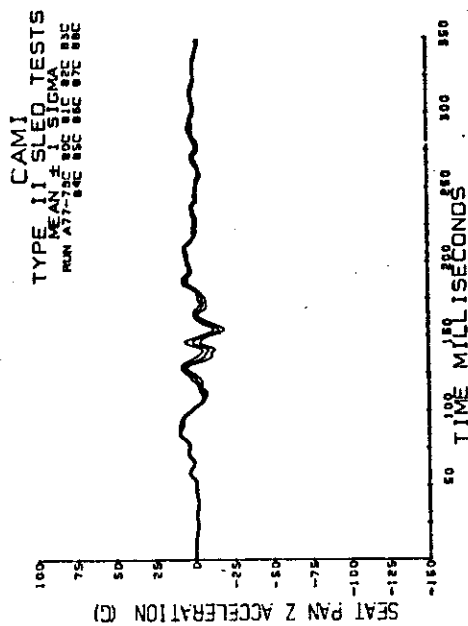
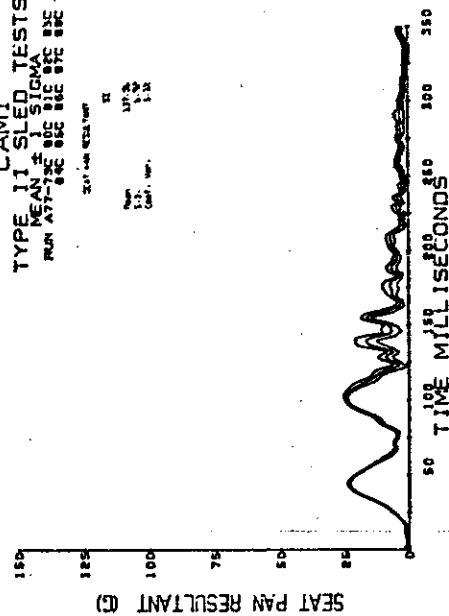


Figure A-2 (continued). Seat pan acceleration.

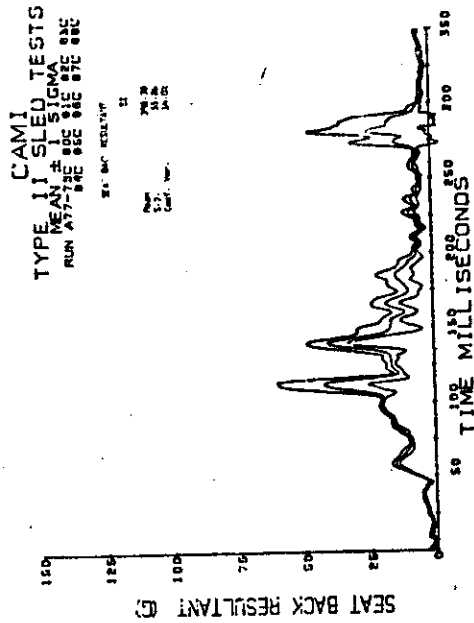
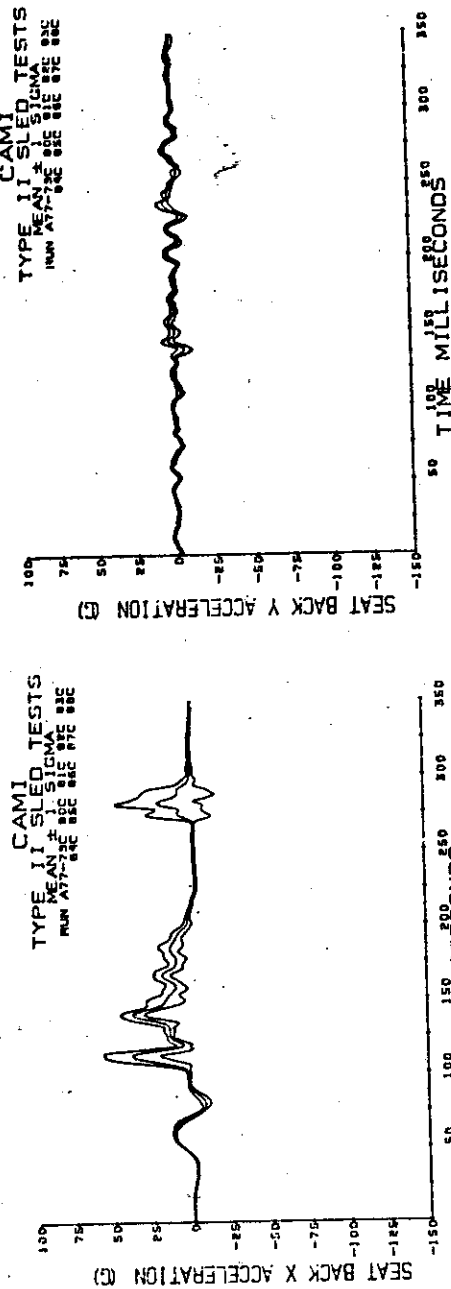


Figure A-2 (continued). Seat back acceleration.

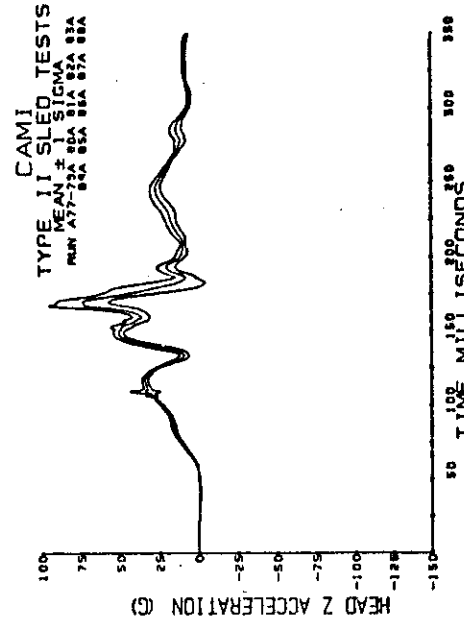
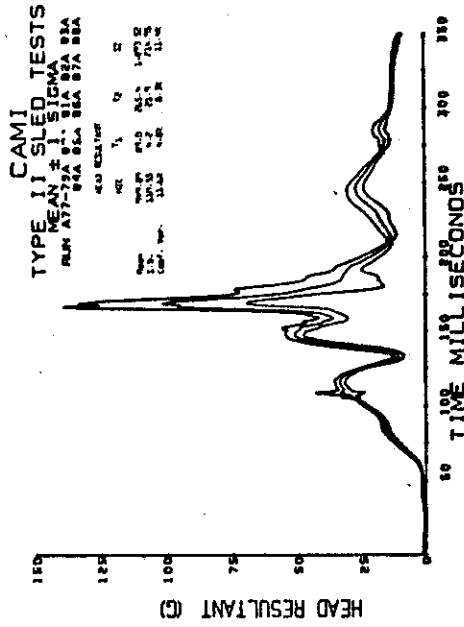
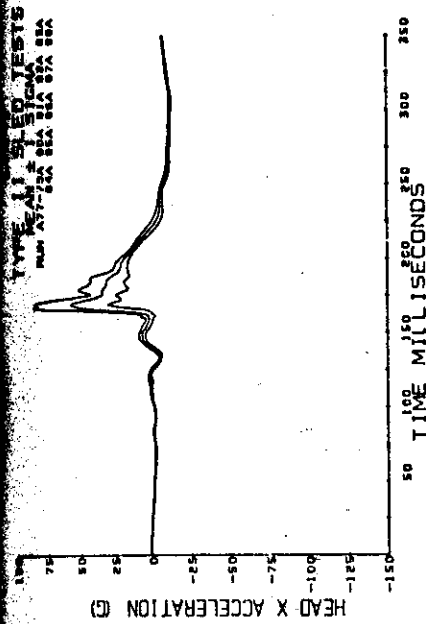
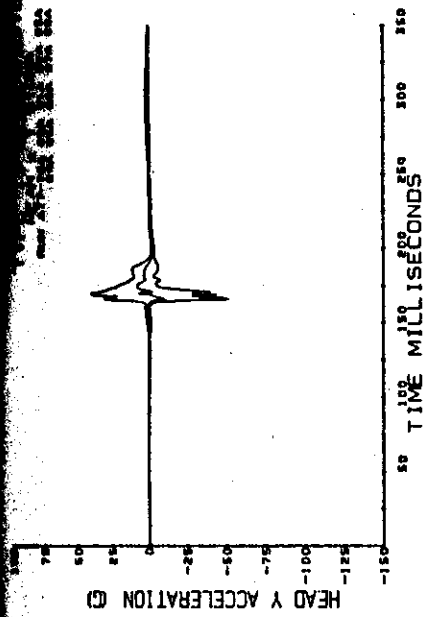


Figure A-2 (continued). Head acceleration.

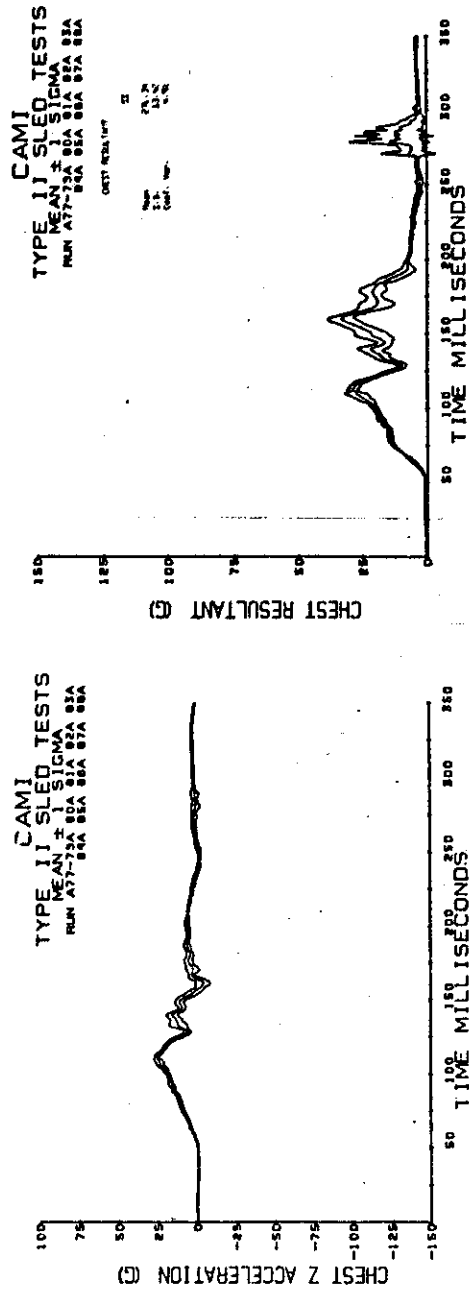
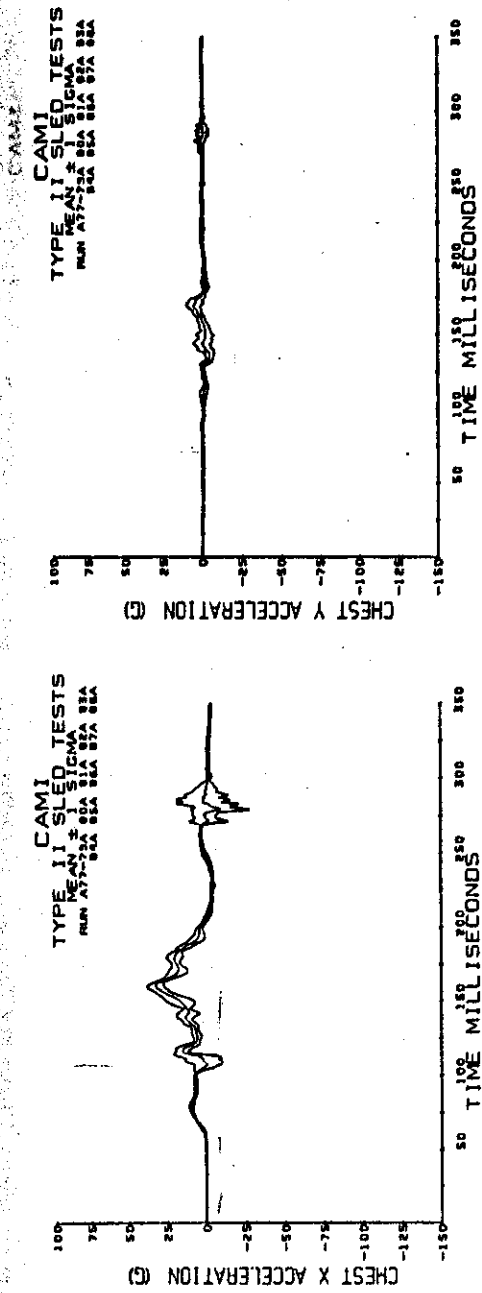


Figure A-2 (continued). Chest acceleration.

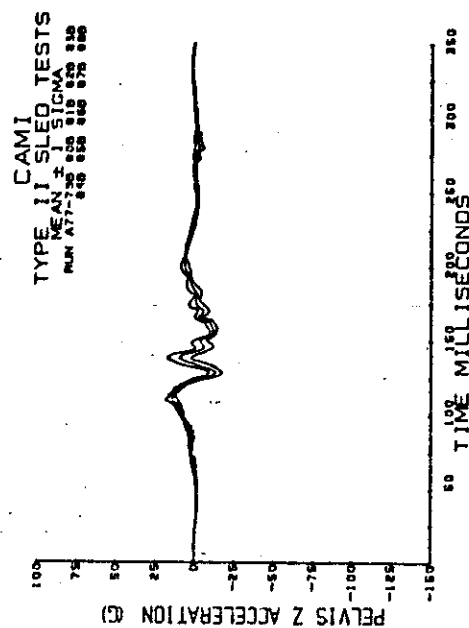
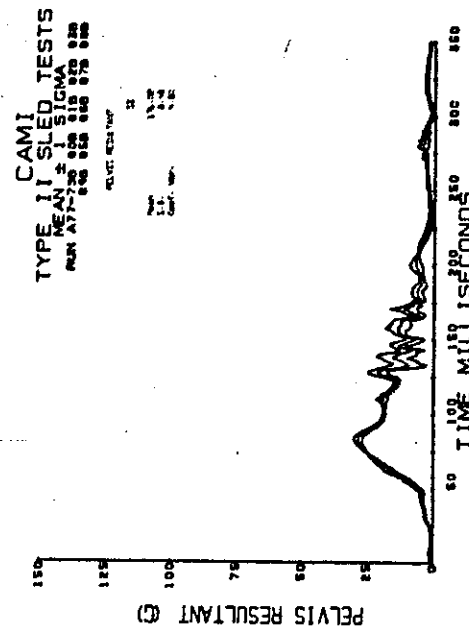
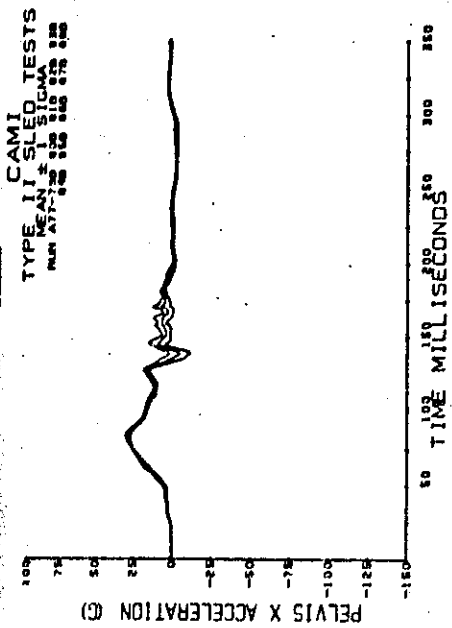
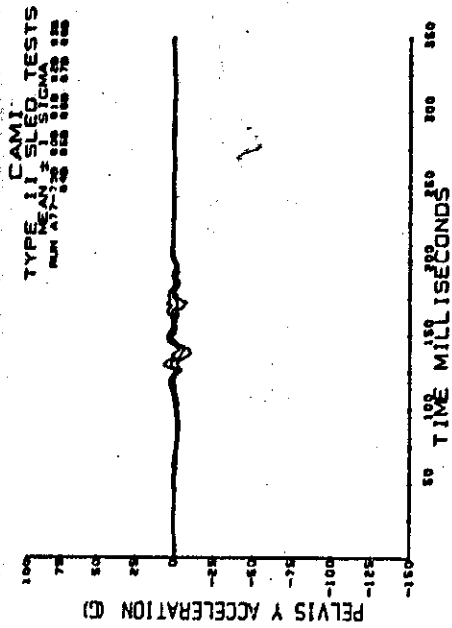


Figure A-2 (continued). Pelvis acceleration.

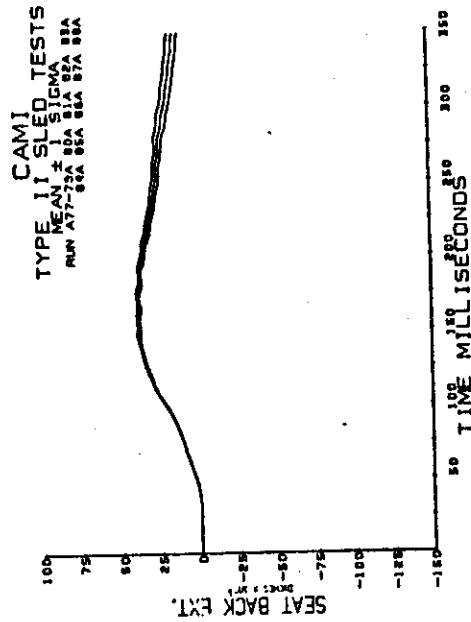
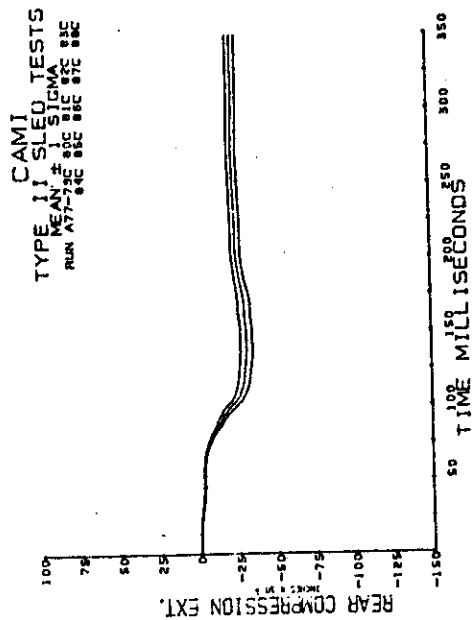
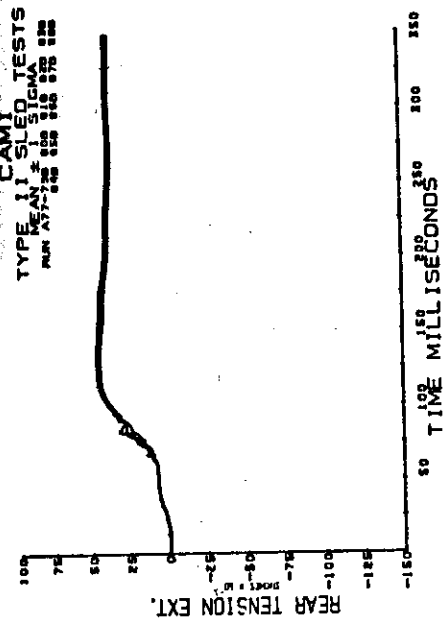
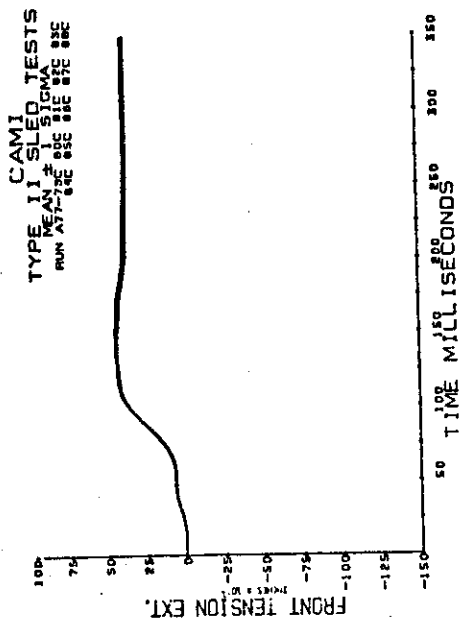


Figure A-2 (continued). Seat  
extensometer data.

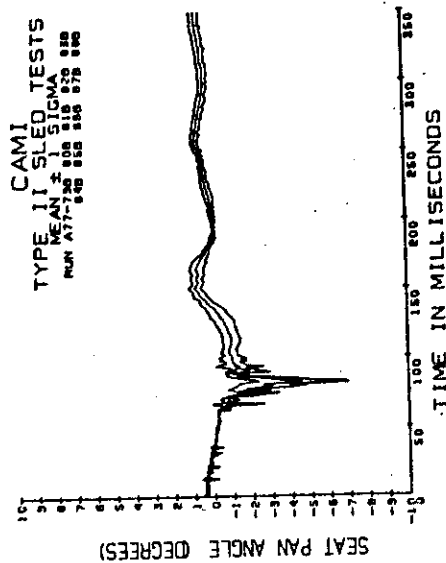
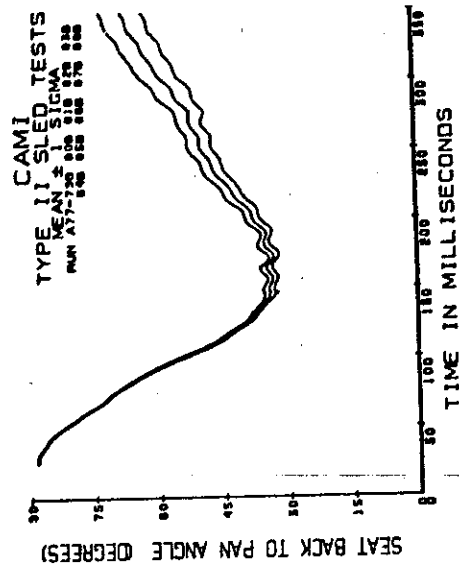
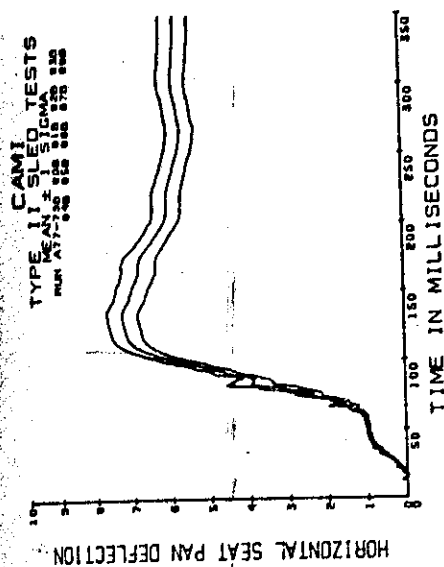
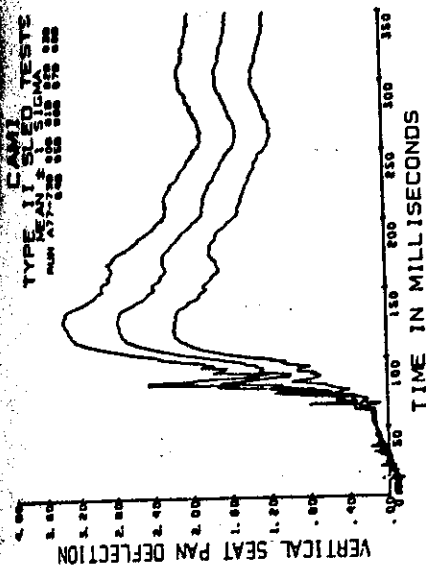
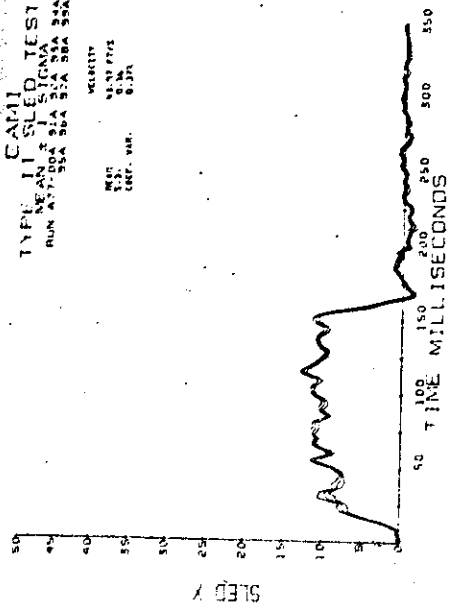


Figure A-2 (continued). Deflection data.

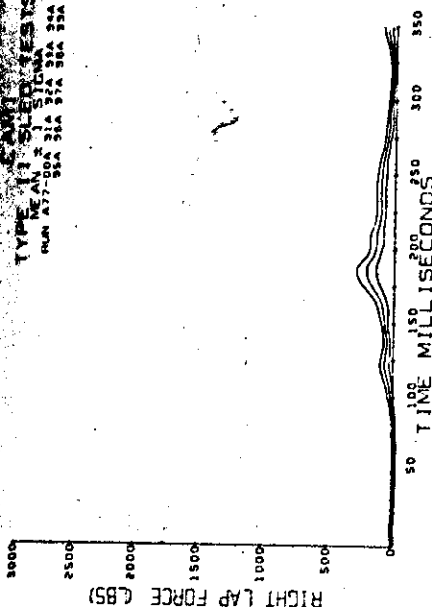


CAMI  
TYPE II SLED TESTS  
MEAN ± 1 SIGMA  
RUN A77-00A 31A 32A 33A 34A  
35A 36A 37A 38A 39A

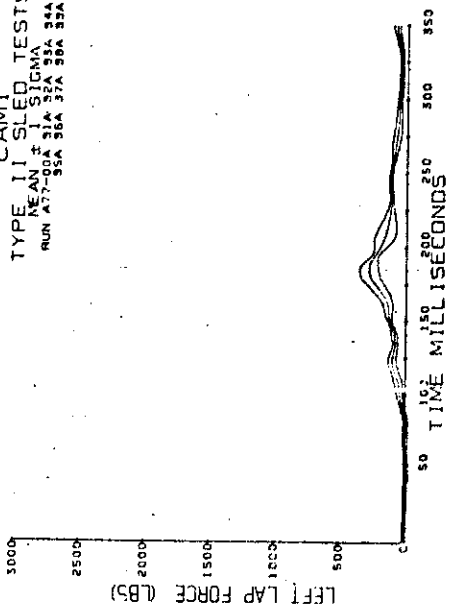
VELOCITY  
1.5  
0.5  
0.5



CAMI  
TYPE II SLED TESTS  
MEAN ± 1 SIGMA  
RUN A77-00A 31A 32A 33A 34A  
35A 36A 37A 38A 39A



CAMI  
TYPE II SLED TESTS  
MEAN ± 1 SIGMA  
RUN A77-00A 31A 32A 33A 34A  
35A 36A 37A 38A 39A



CAMI  
TYPE II SLED TESTS  
MEAN ± 1 SIGMA  
RUN A77-00A 31A 32A 33A 34A  
35A 36A 37A 38A 39A

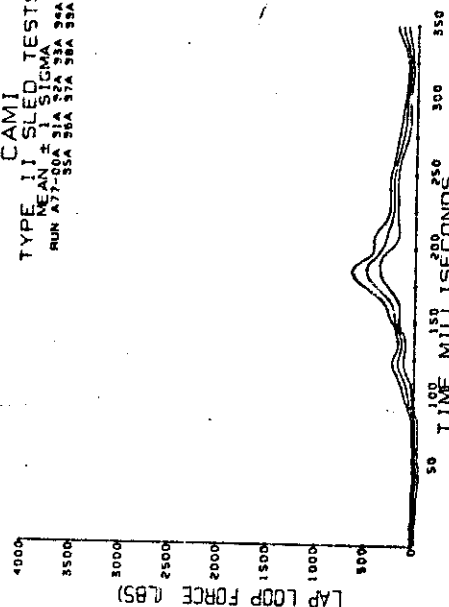


Figure A-3. Combined loading, low-deceleration tests.  
Sled deceleration and lapbelt loads.

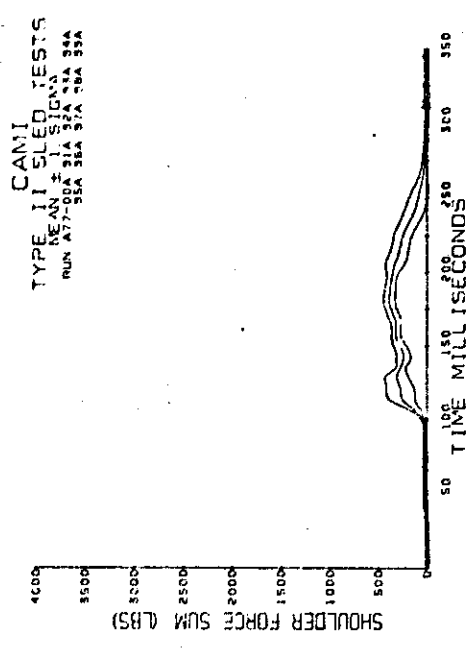
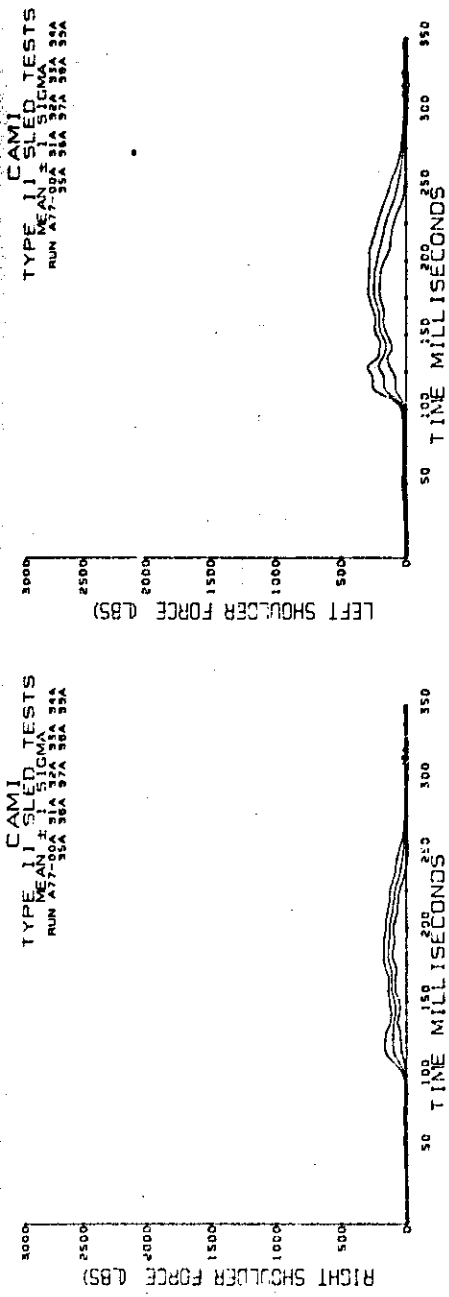


Figure A-3 (continued). Shoulder  
telt loads.

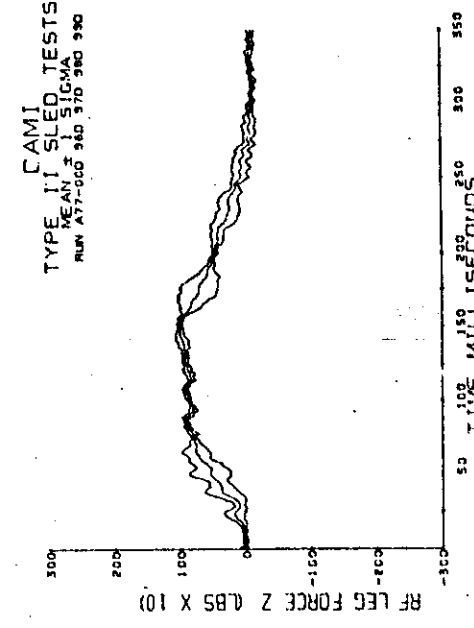
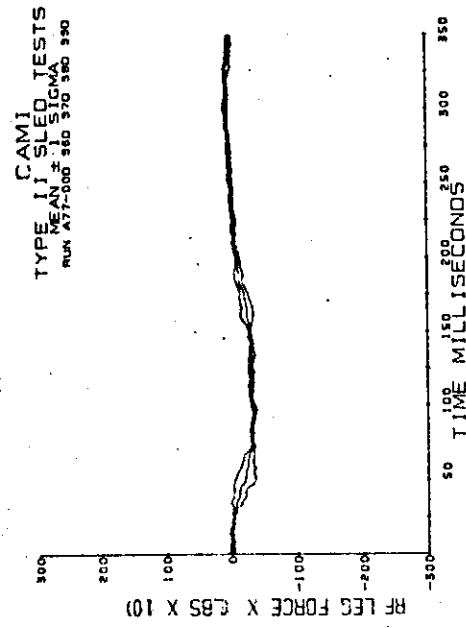
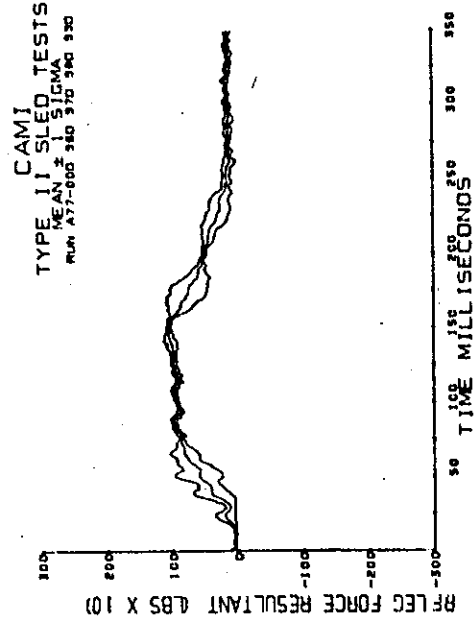
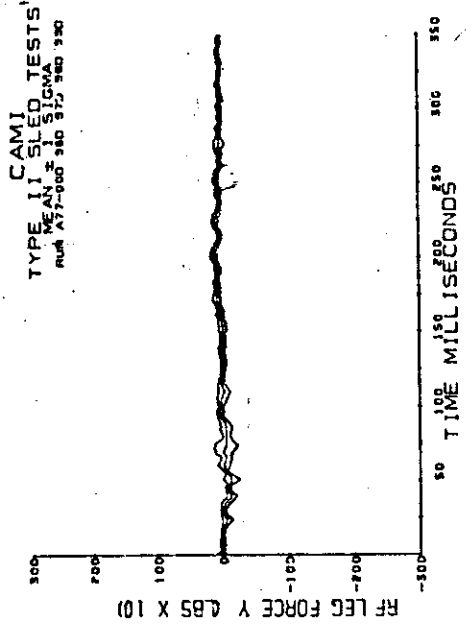


Figure A-3 (continued). Right front  
seat leg loads.

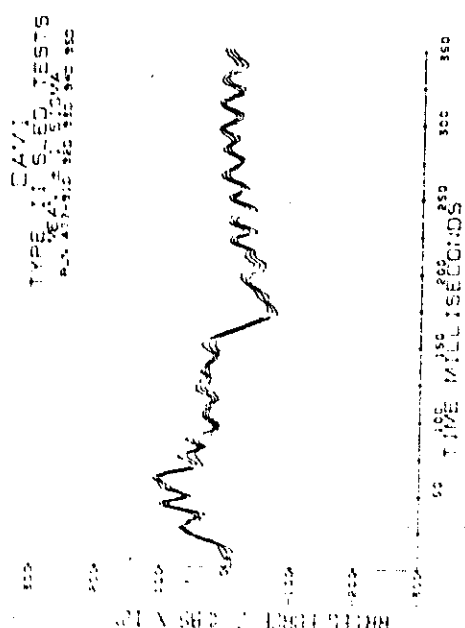
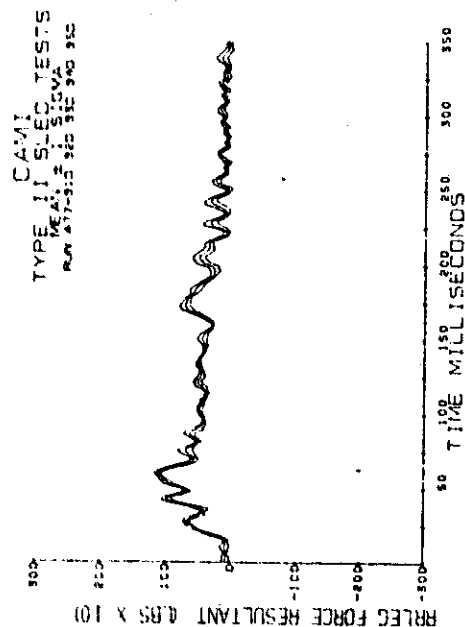
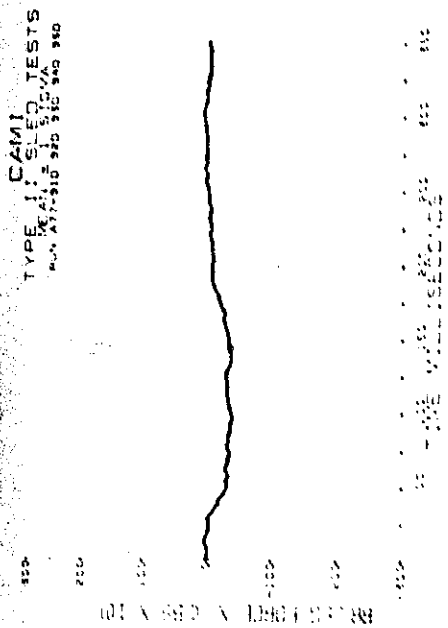
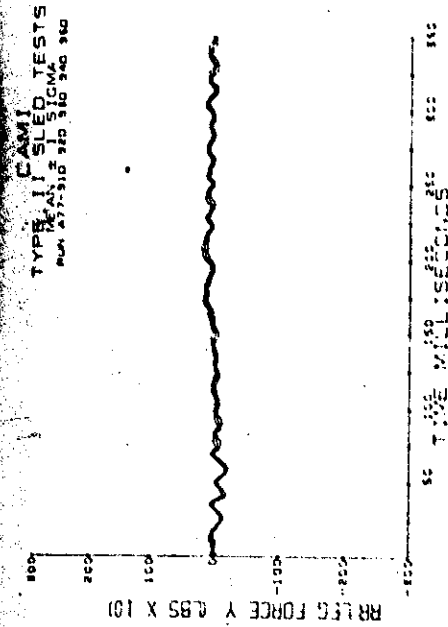


Figure A-3 (continued). Right rear seat leg loads.

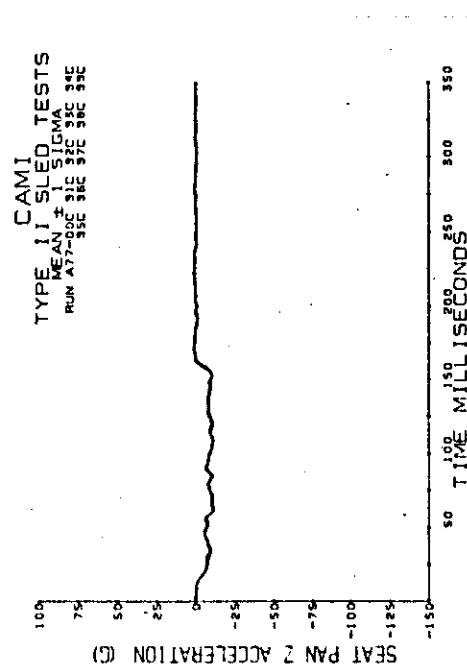
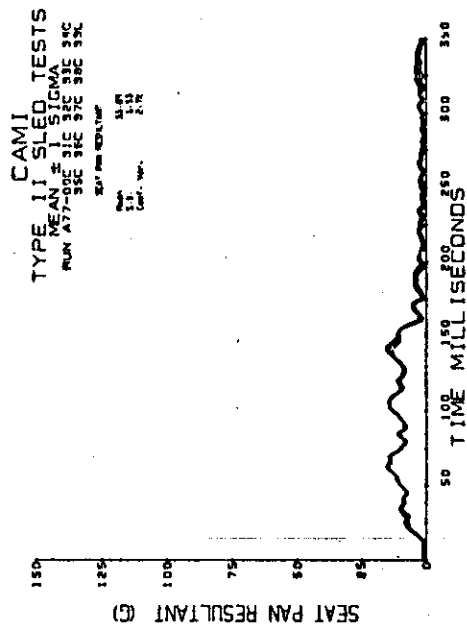
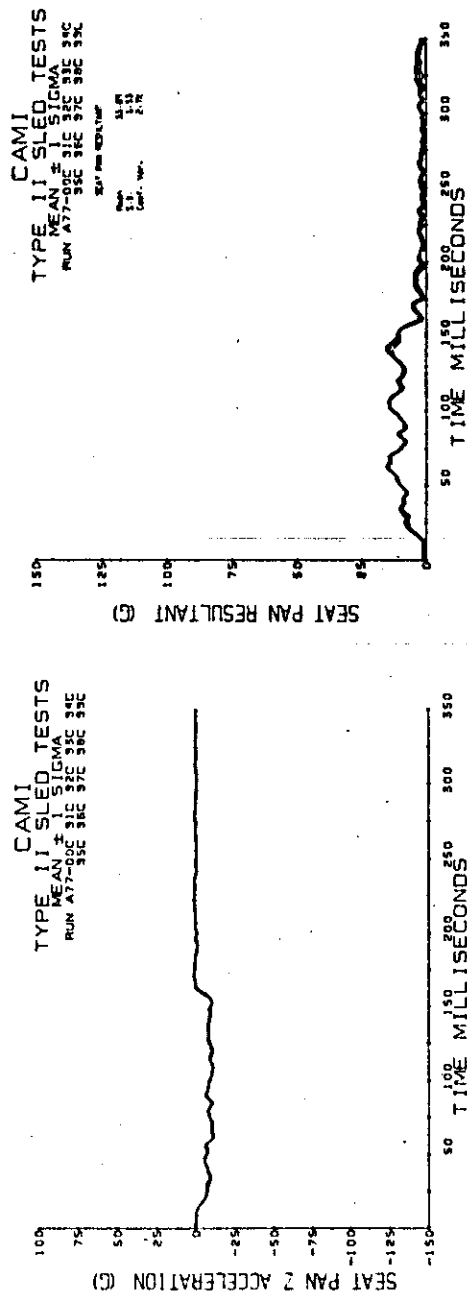
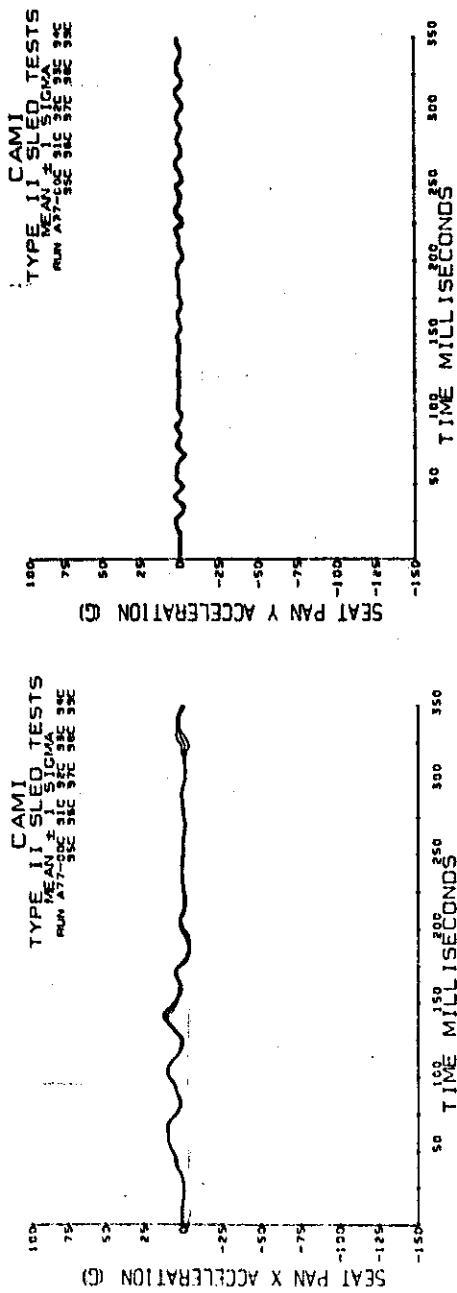


Figure A-3 (continued). Seat pan acceleration.

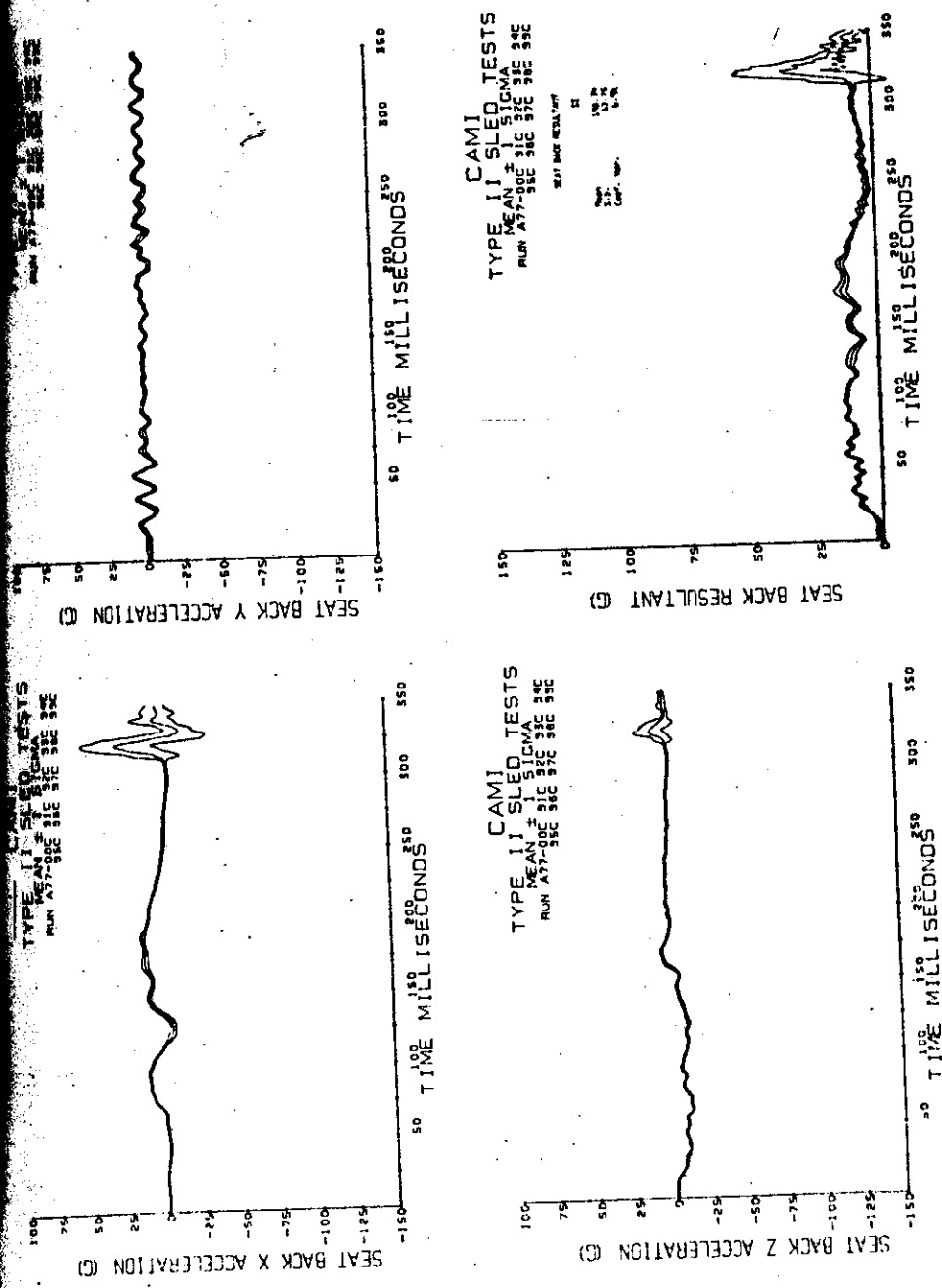


Figure A-3 (continued). Seat back acceleration.

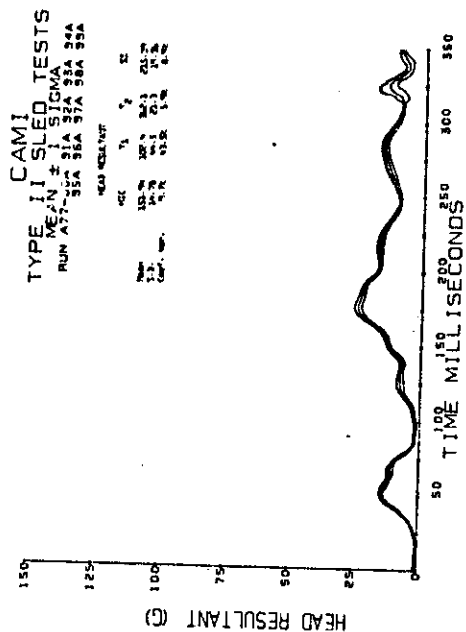
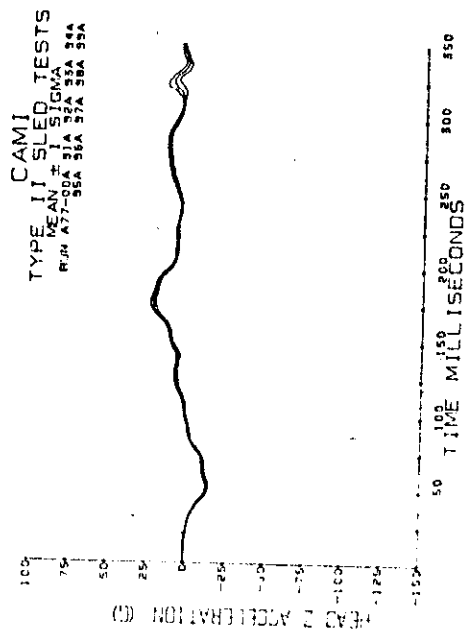
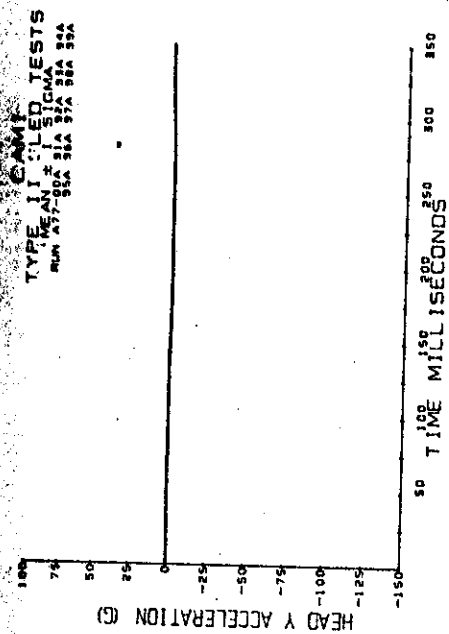
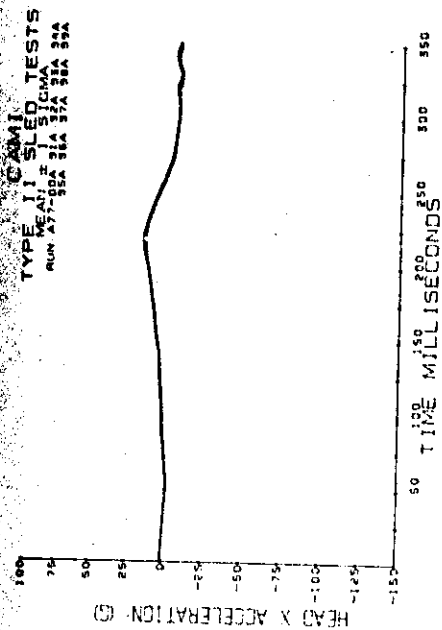


Figure A-3 (continued). Head acceleration.

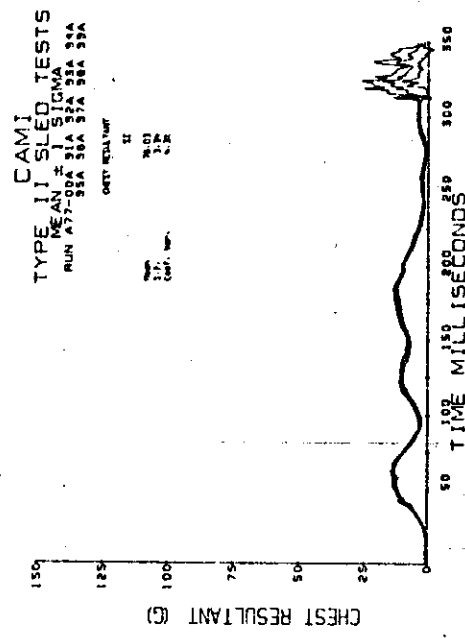
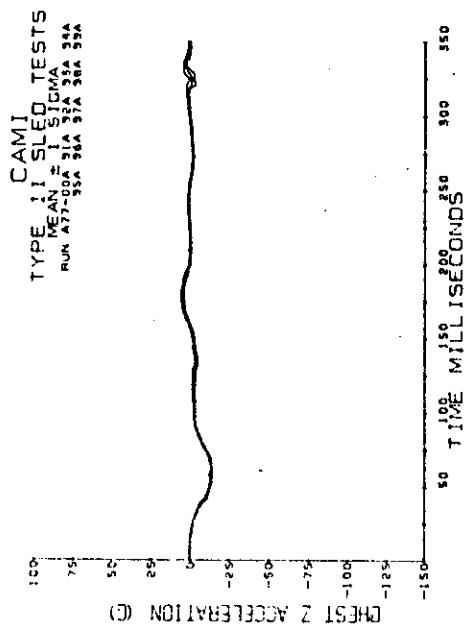
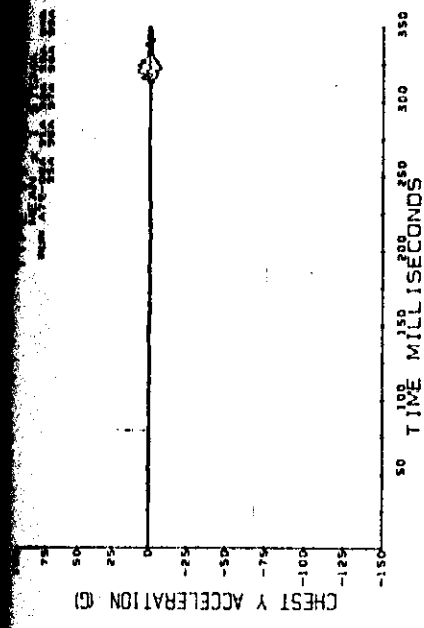
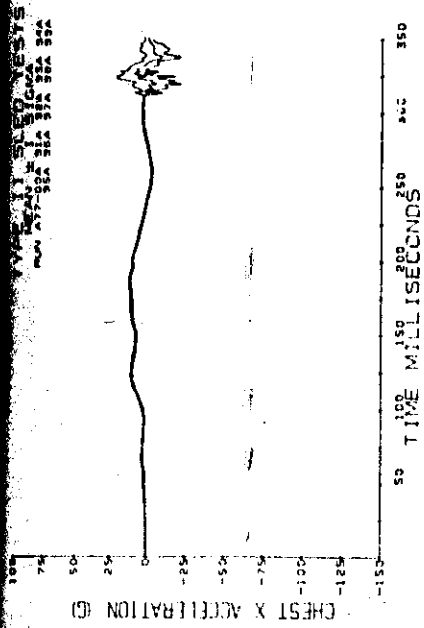


Figure A-3 (continued). Chest acceleration.



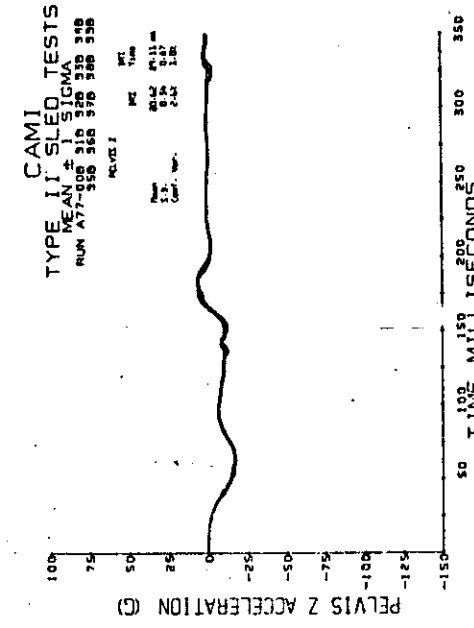
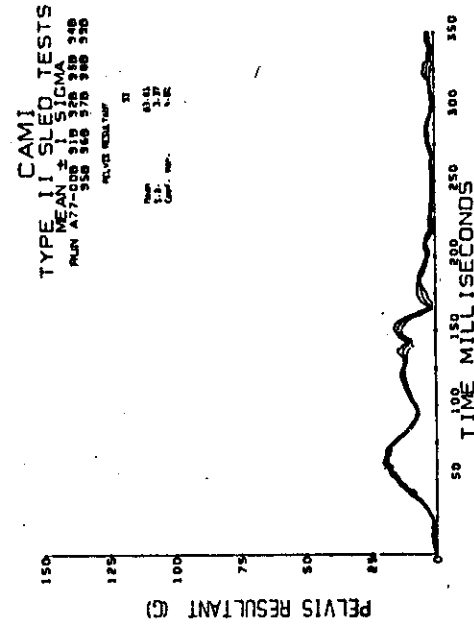
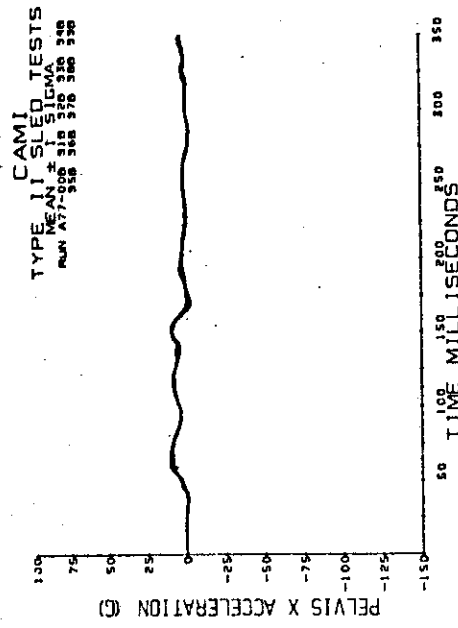
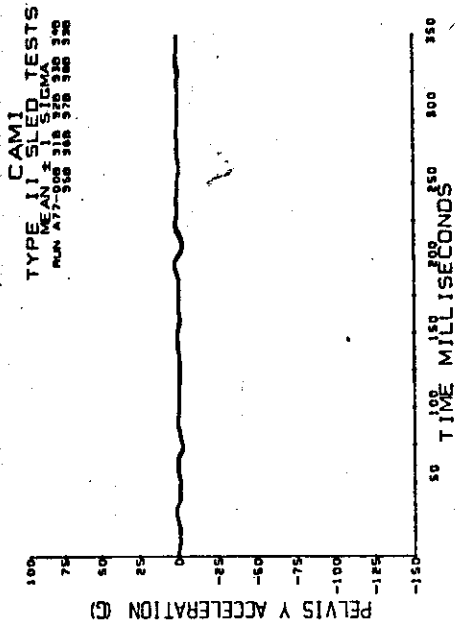


Figure A-3 (continued): Pelvis acceleration.

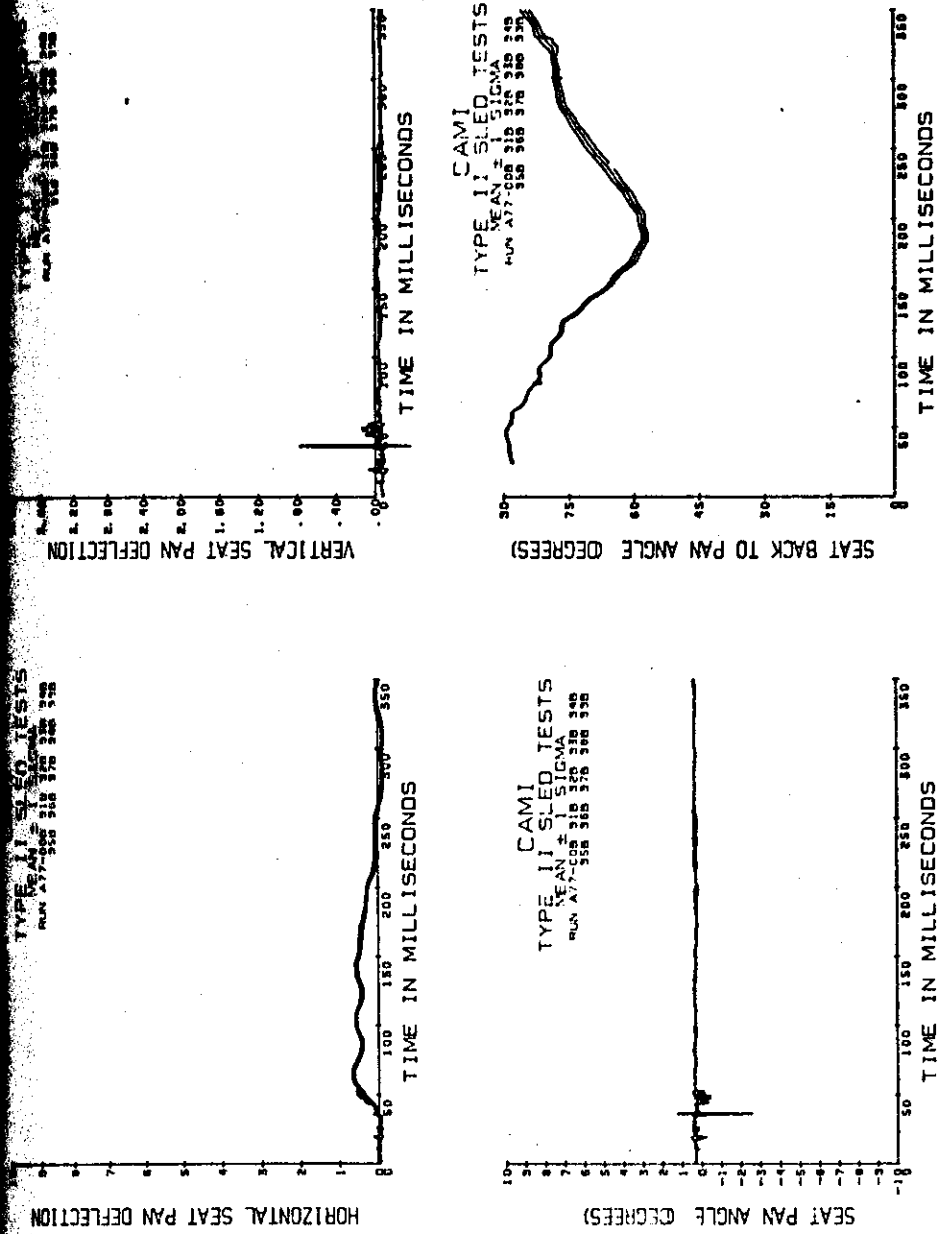


Figure A-3 (continued). Seat extensometer data.

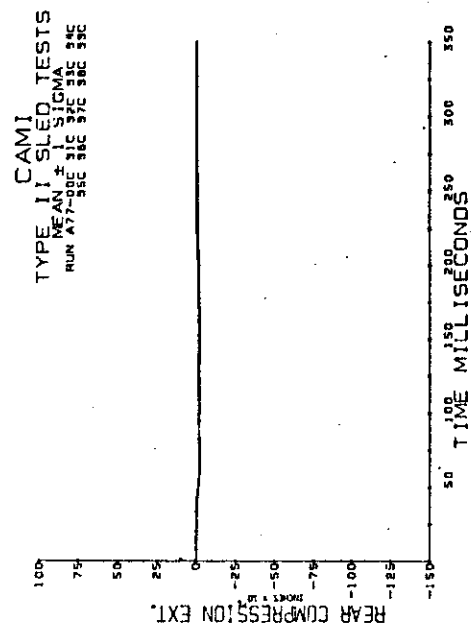
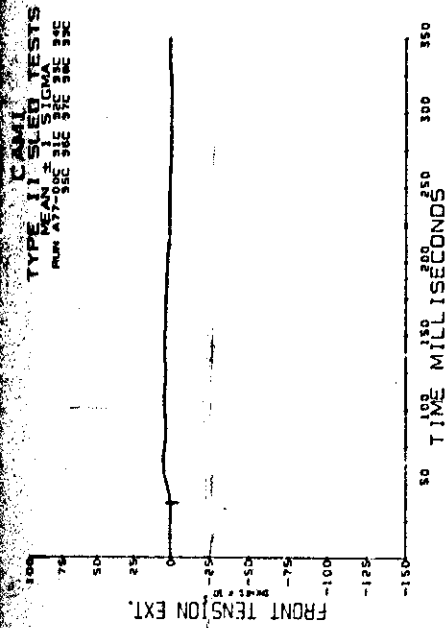
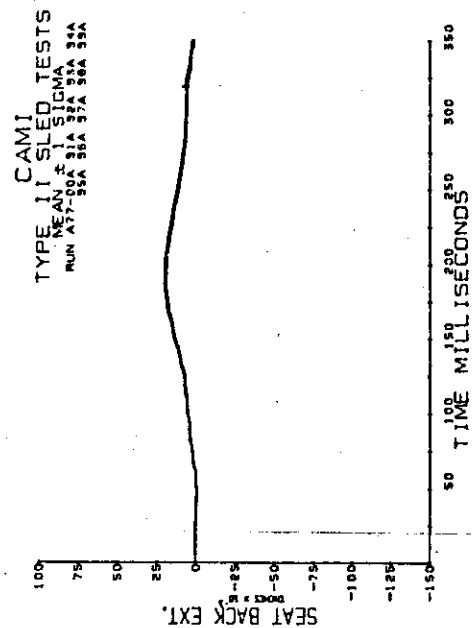
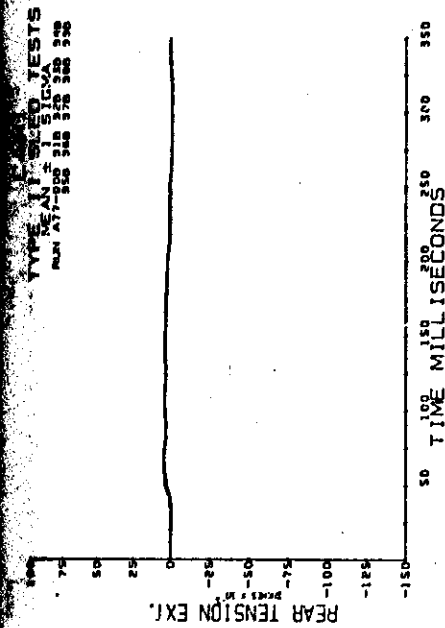


Figure A-3 (continued). Deflection data.

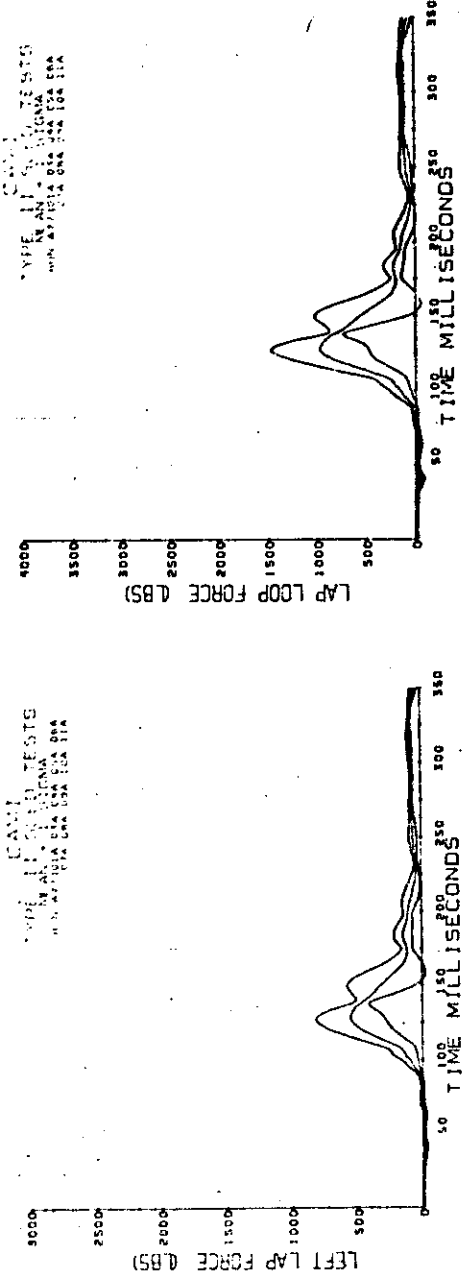
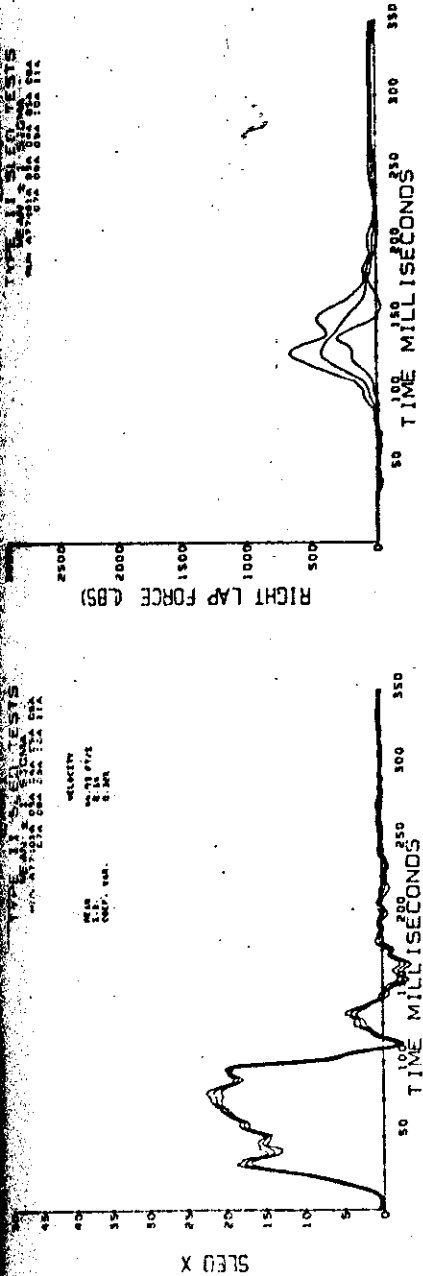


Figure A-4. Combined loading, higher deceleration tests.  
 Sled deceleration and lapbelt loads.

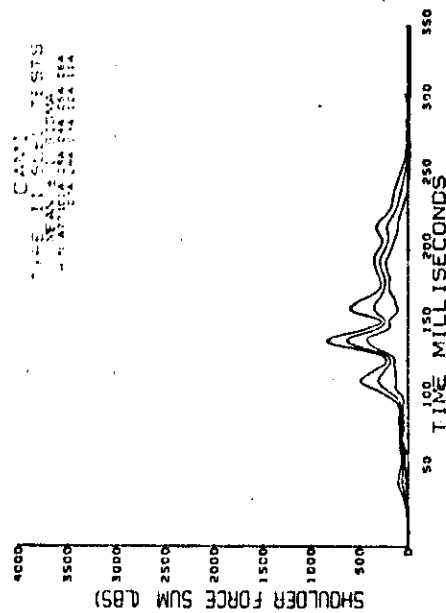
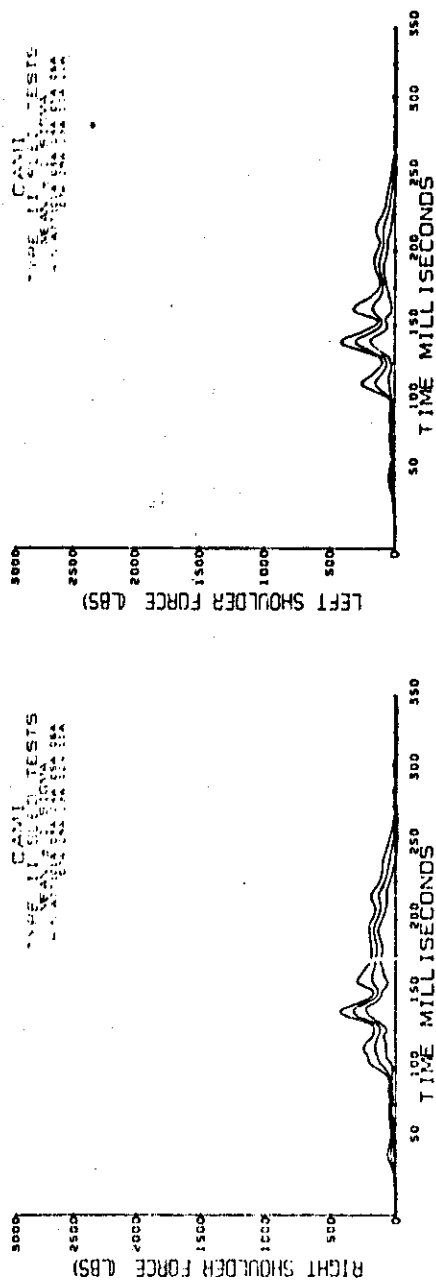


Figure A-4 (continued). Shoulder belt loads.



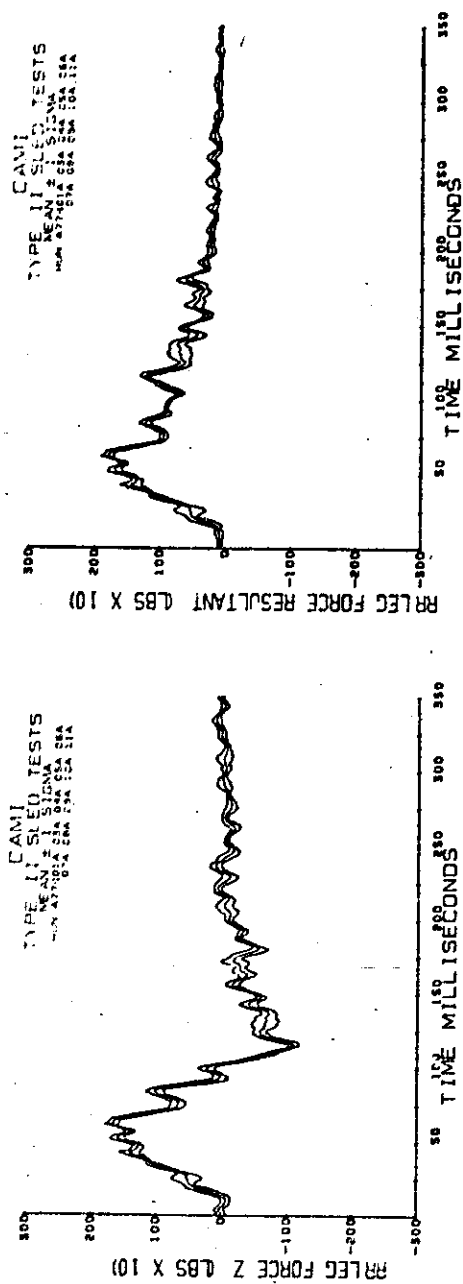


Figure A-4 (continued). Right rear seat leg loads.

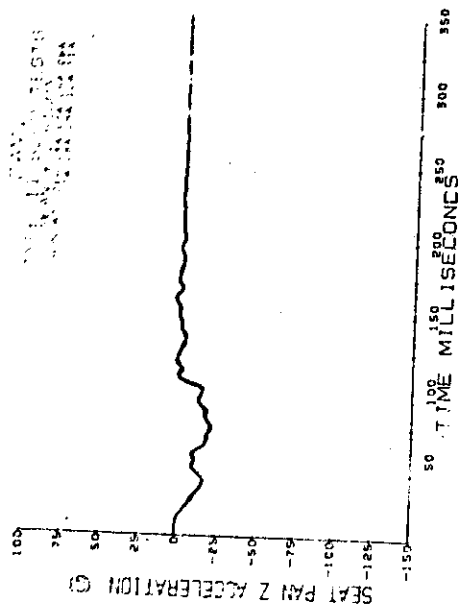
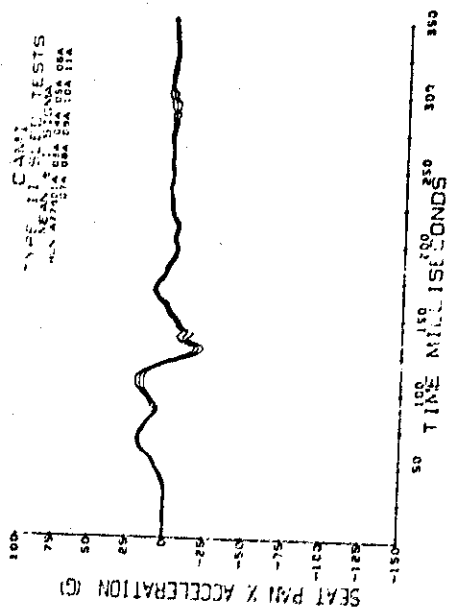


Figure A-4 (continued). Seat pan acceleration.



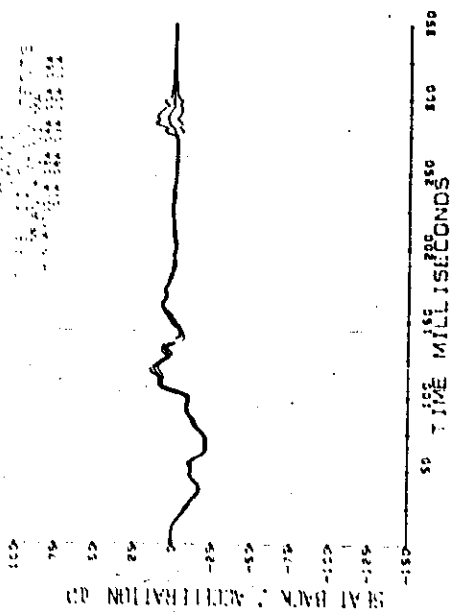
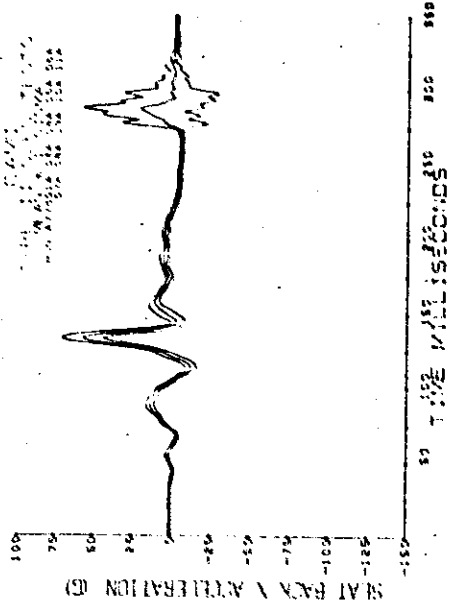
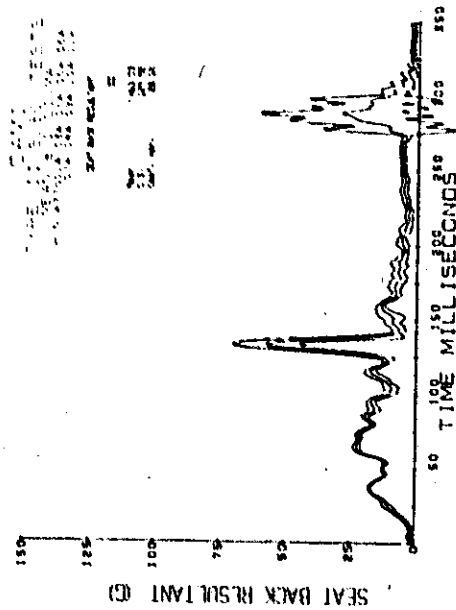
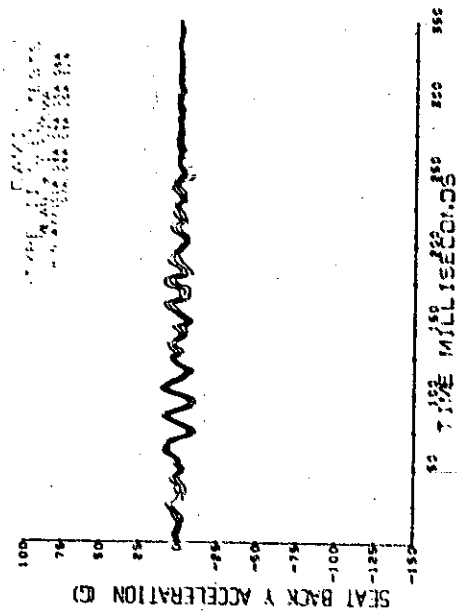


Figure A-4 (continued). Seat back acceleration.

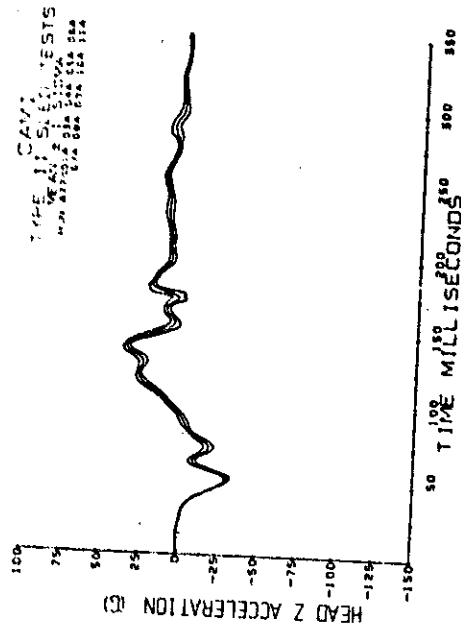
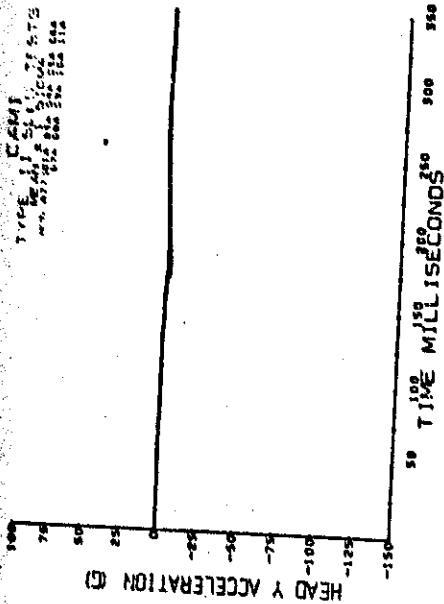
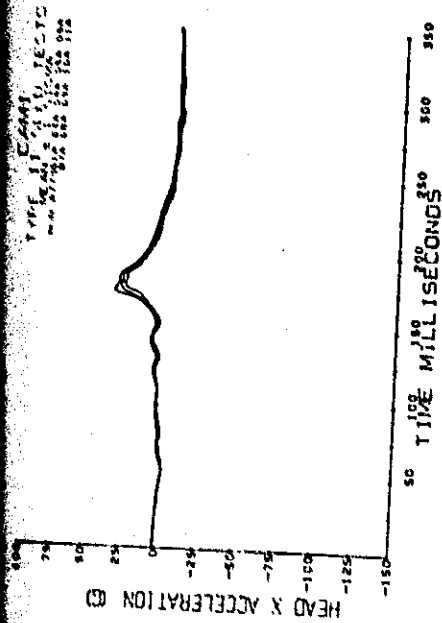


Figure A-4 (continued). Head acceleration.

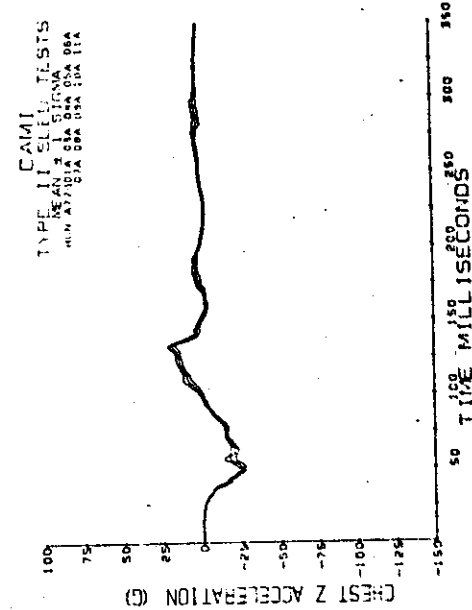
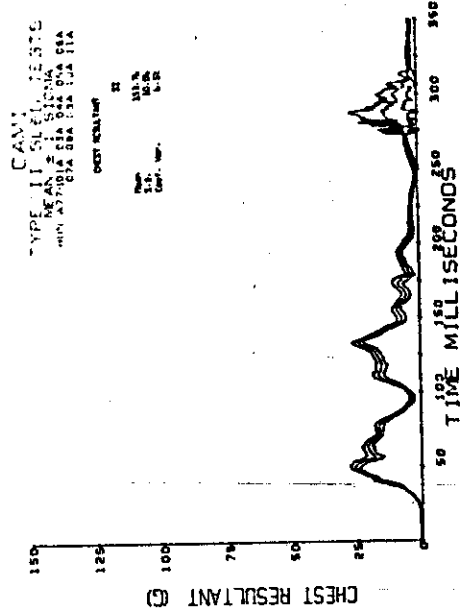
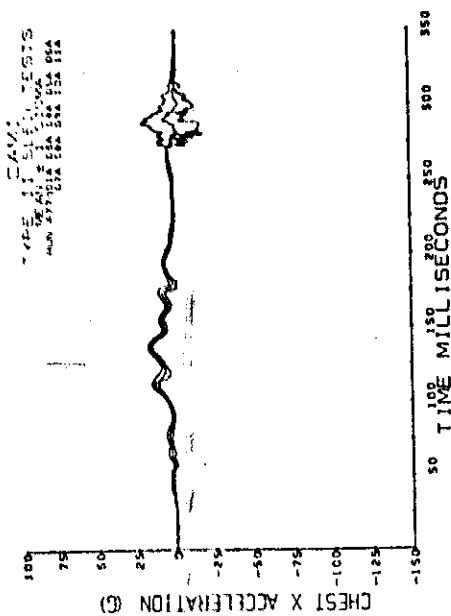
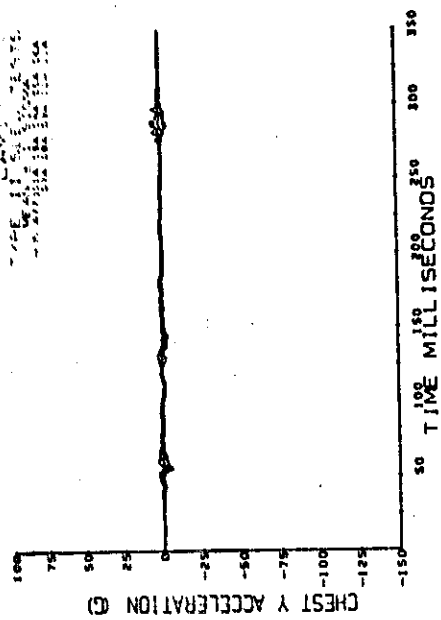


Figure A-4 (continued). Chest acceleration.

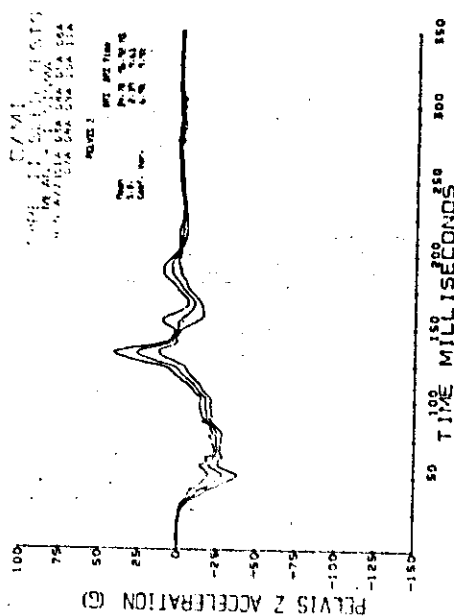
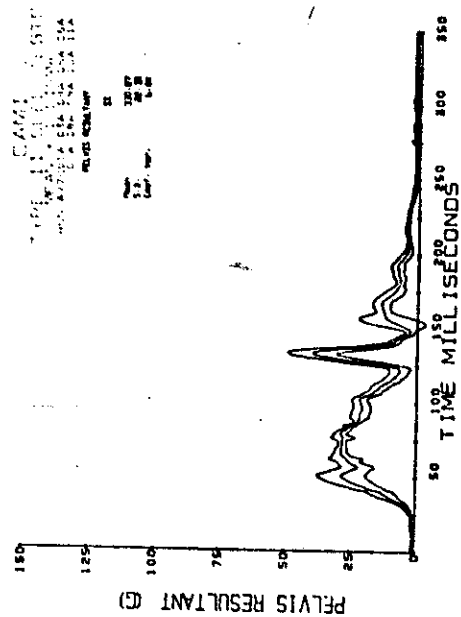
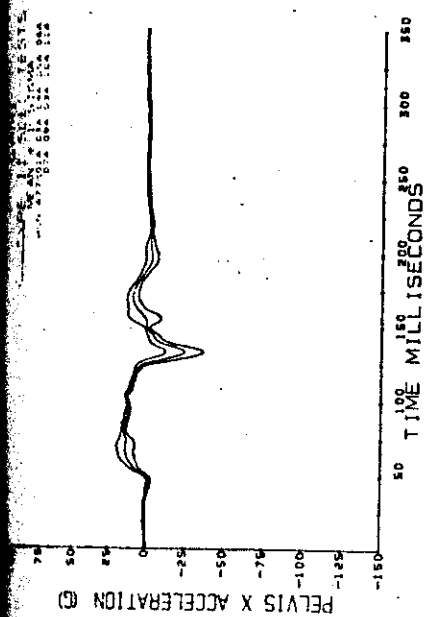
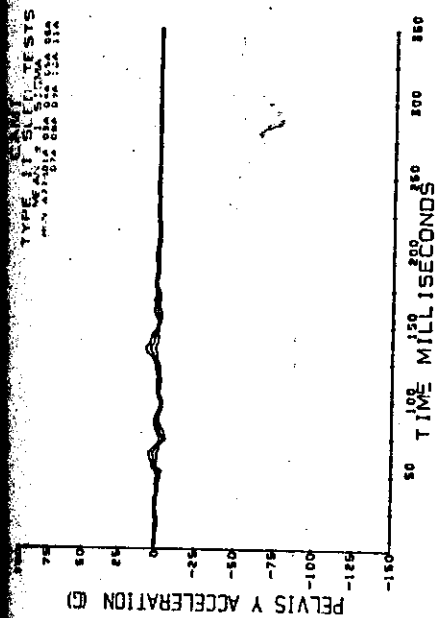


Figure A-4 (continued). Pelvis acceleration.

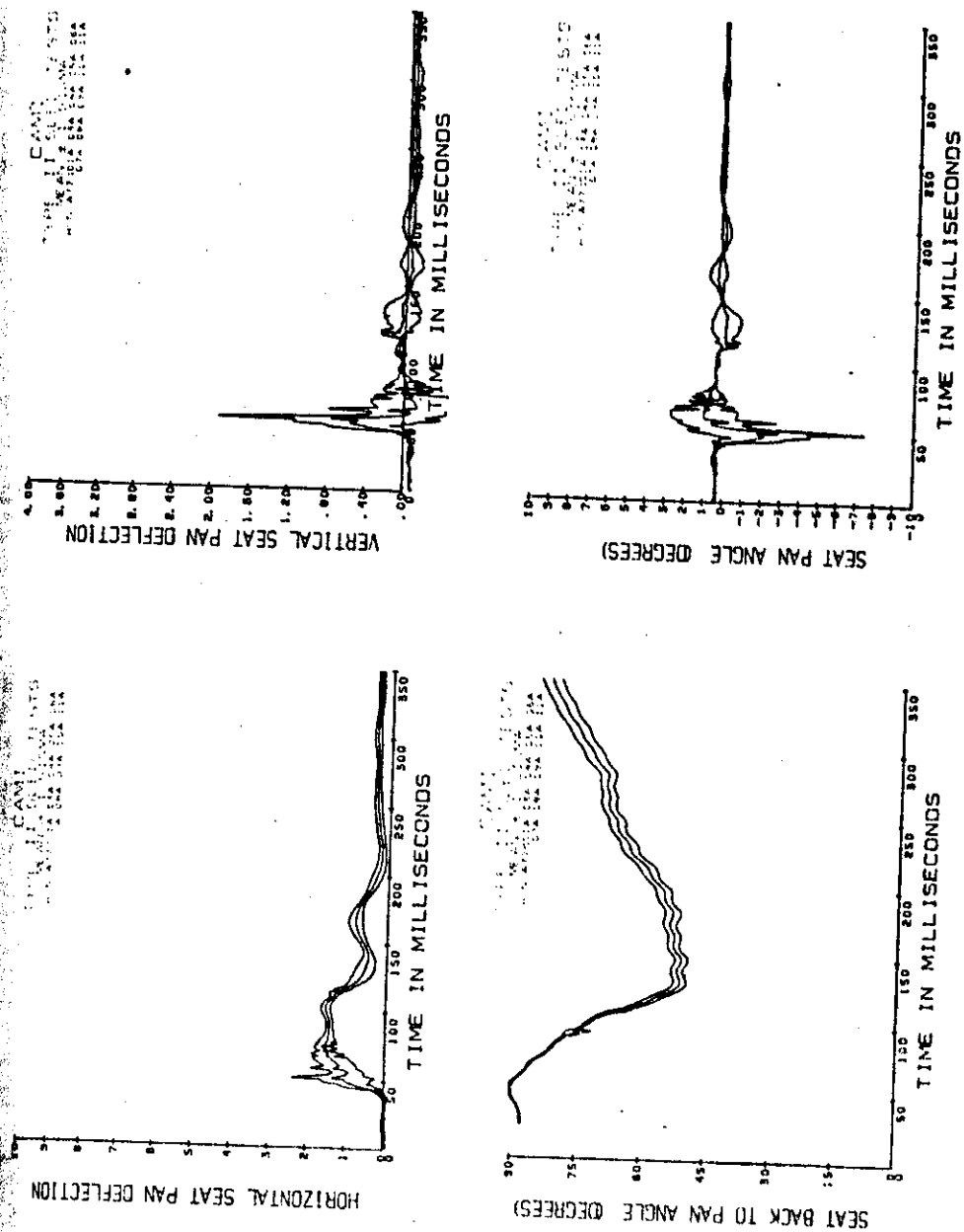


Figure A-4 (continued). Seat extensometer data.



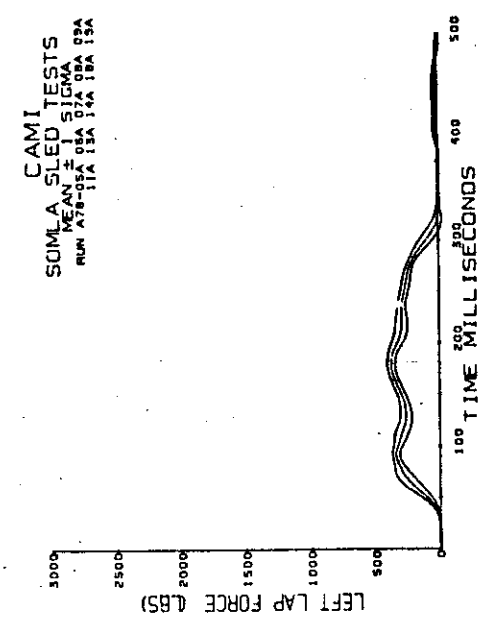
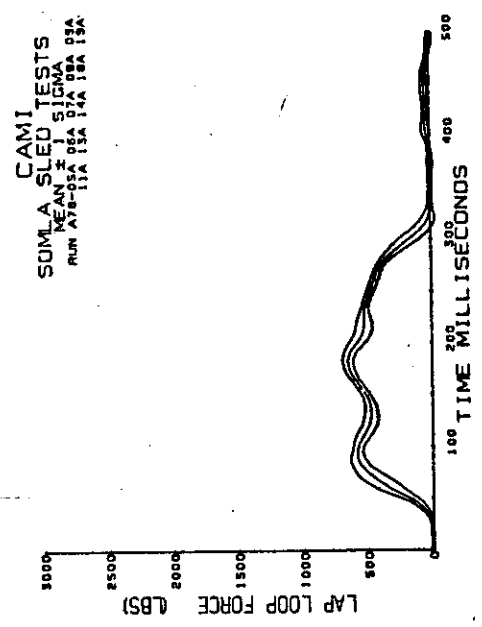
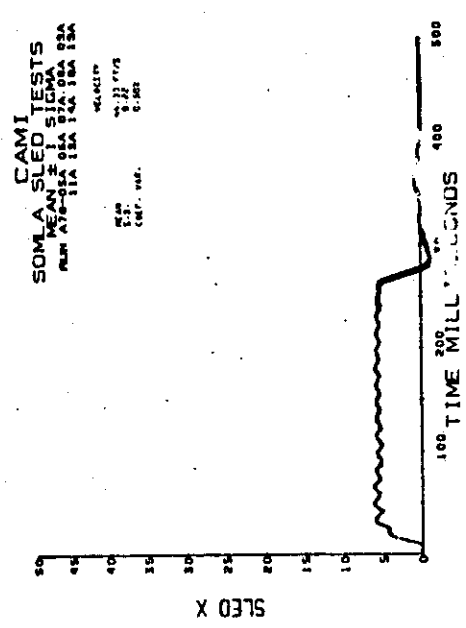
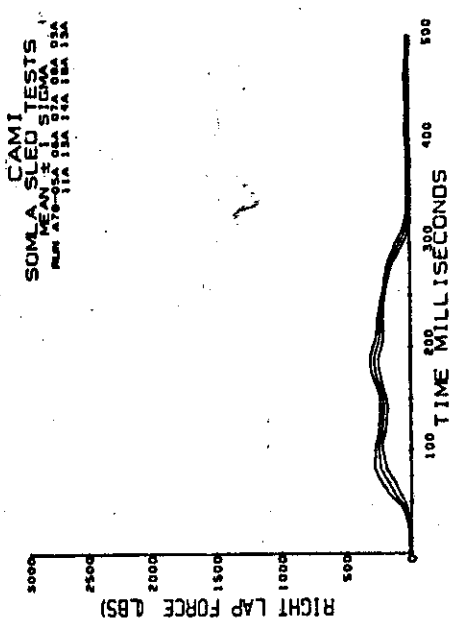
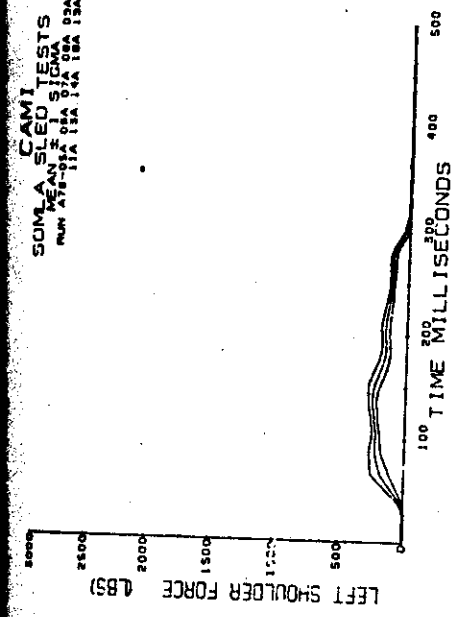
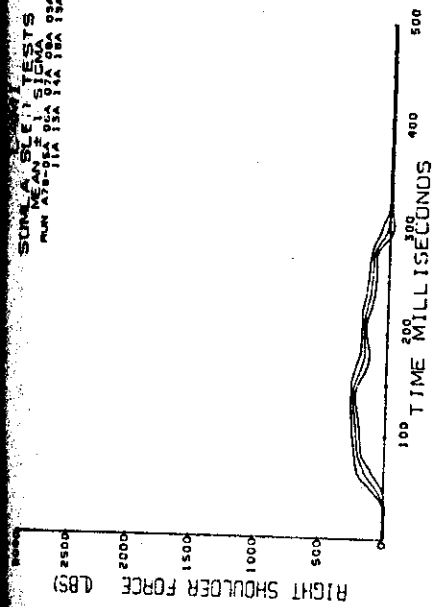


Figure A-5. Forward-facing, low-deceleration tests.  
Sled deceleration and lapbelt loads.

SOMLA SLED TESTS  
 MEAN  $\pm$  1 SIGMA  
 RUN A76-02A 06A 07A 08A 09A  
 11A 12A 13A 14A 15A 16A

CAMI  
 SOMLA SLED TESTS  
 MEAN  $\pm$  1 SIGMA  
 RUN A76-02A 06A 07A 08A 09A  
 11A 12A 13A 14A 15A 16A



CAMI  
 SOMLA SLED TESTS  
 MEAN  $\pm$  1 SIGMA  
 RUN A76-02A 06A 07A 08A 09A  
 11A 12A 13A 14A 15A 16A

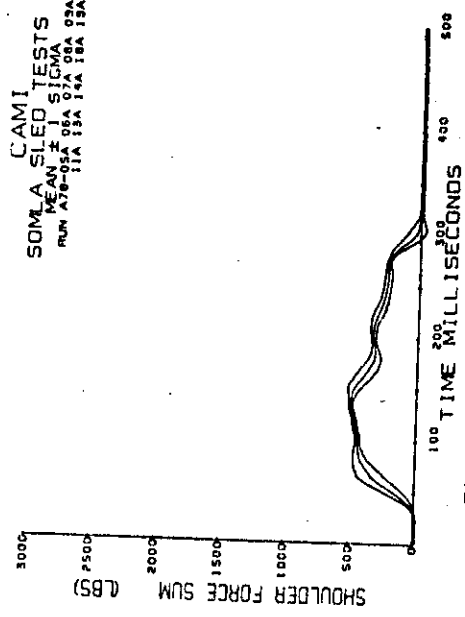


Figure A-5 (continued). Shoulder belt loads.



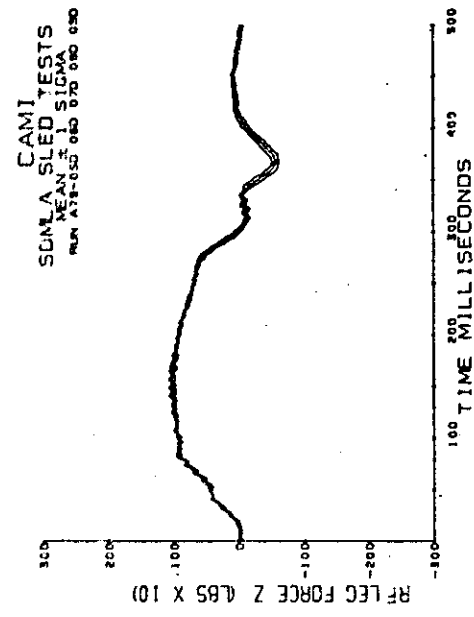
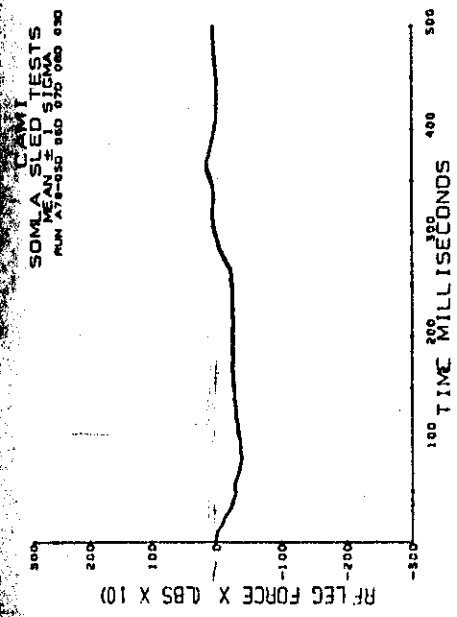
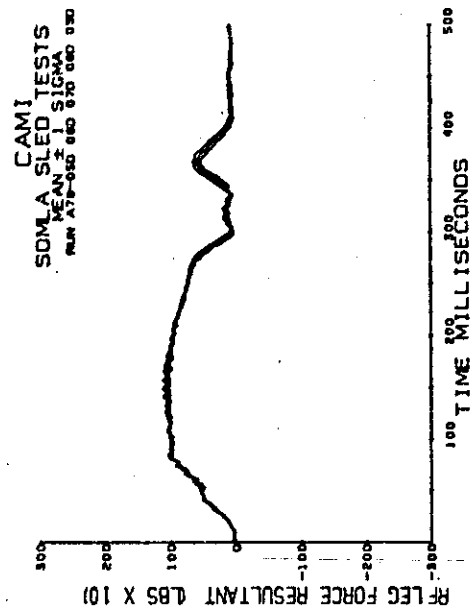
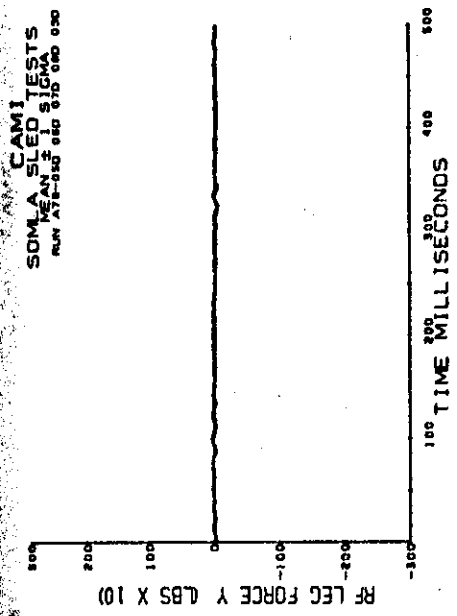
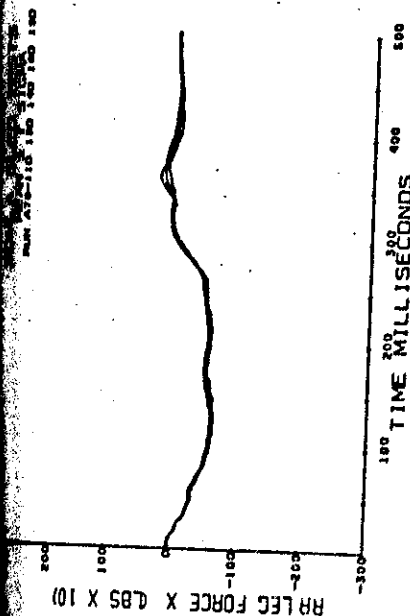
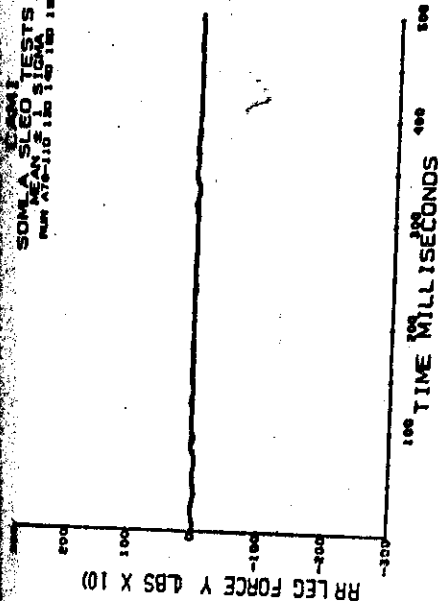
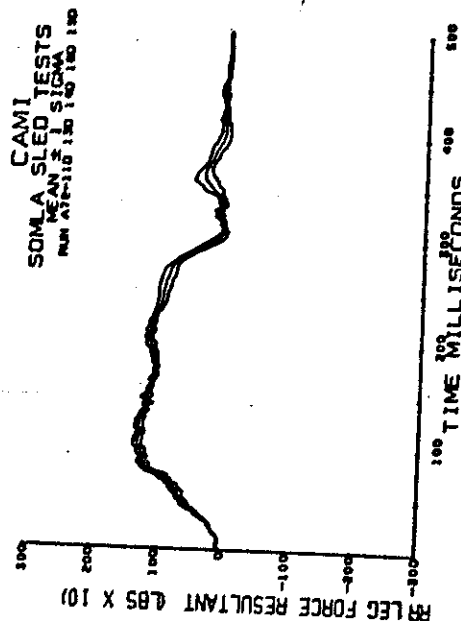


Figure A-5 (continued). Right front  
seat leg loads.

CAMI  
SOMLA SLED TESTS  
MEAN ± 1 SIGMA  
RUN AT 110 120 130 140 150



CAMI  
SOMLA SLED TESTS  
MEAN ± 1 SIGMA  
RUN AT 110 120 130 140 150



CAMI  
SOMLA SLED TESTS  
MEAN ± 1 SIGMA  
RUN AT 110 120 130 140 150

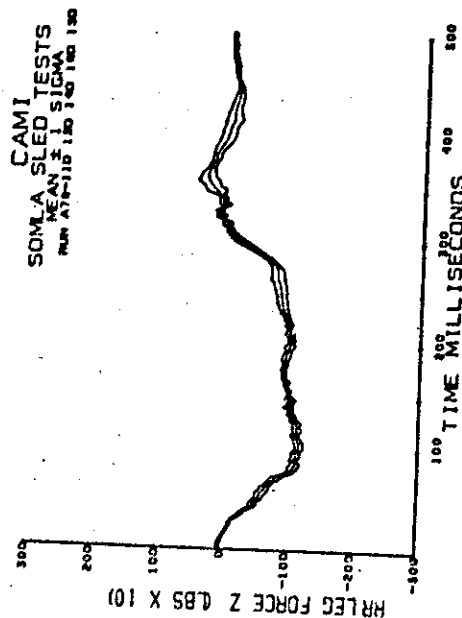


Figure A-5 (continued). Right rear seat leg loads.

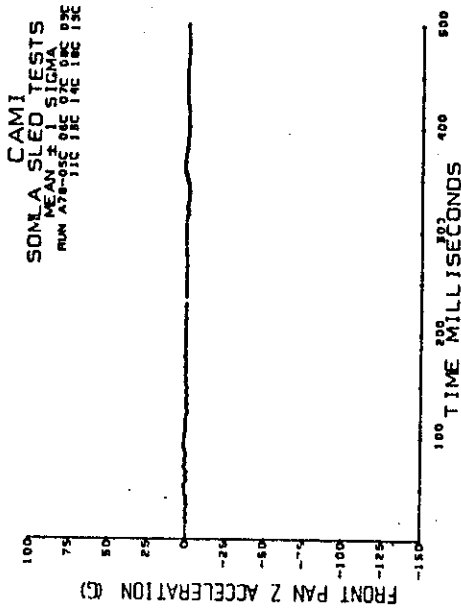
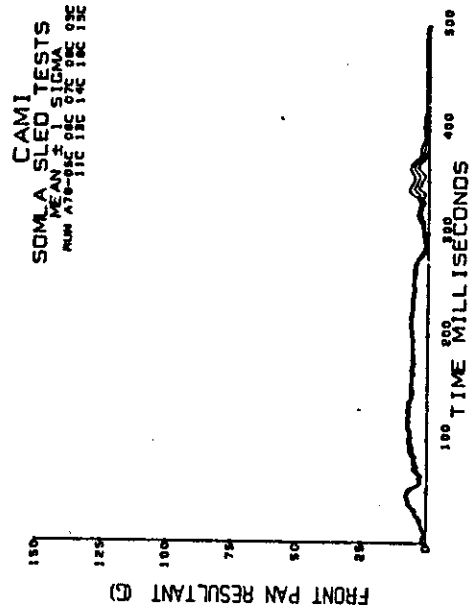
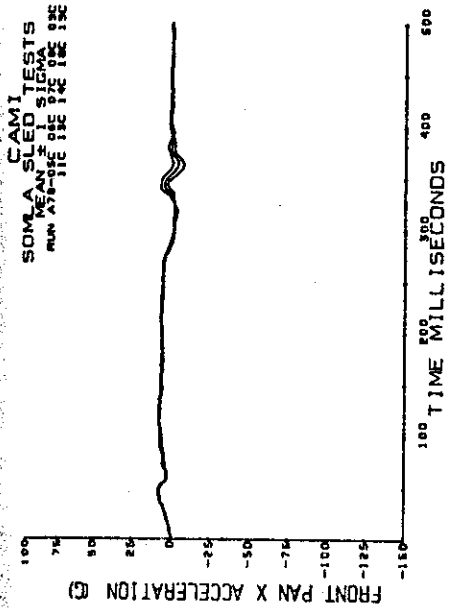
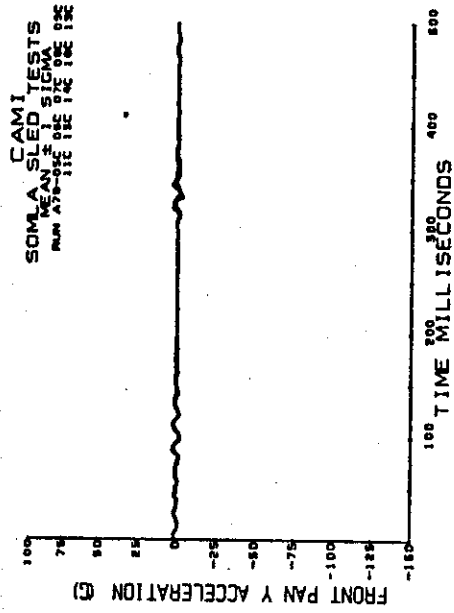


Figure A-5 (continued). Front seat pan acceleration.

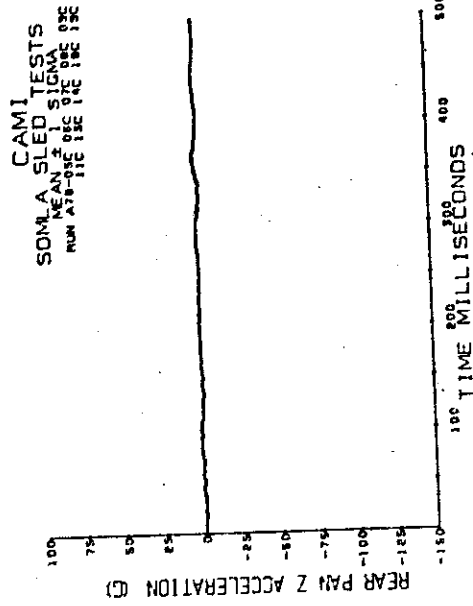
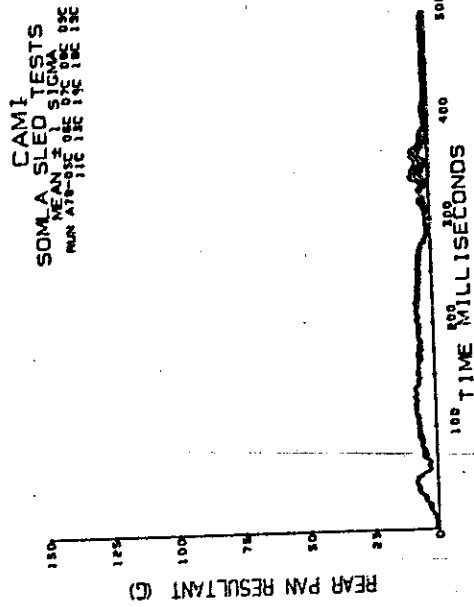
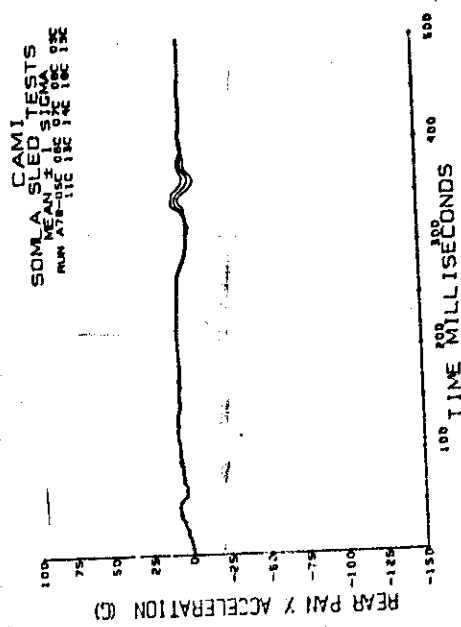
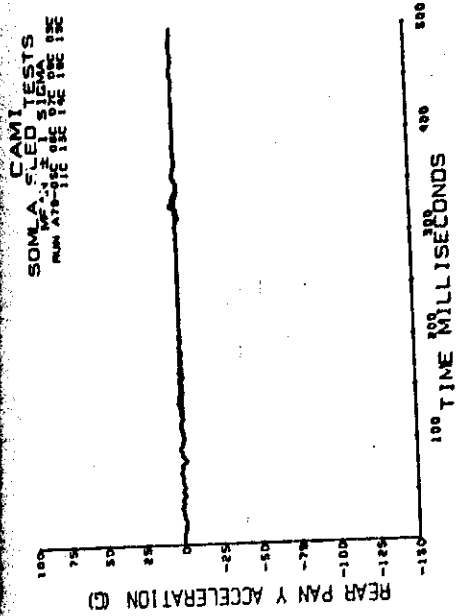


Figure A-5 (continued). Rear seat pan acceleration.

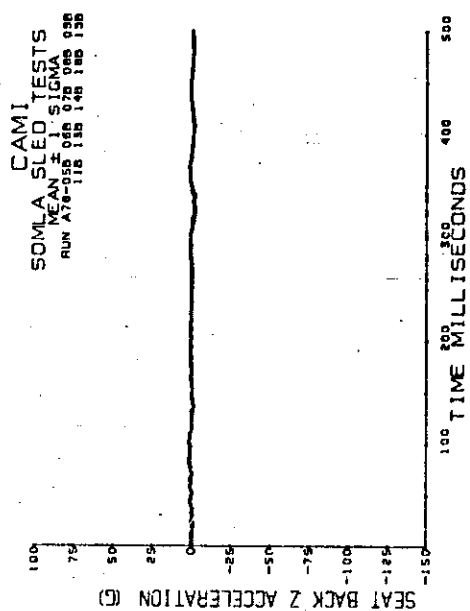
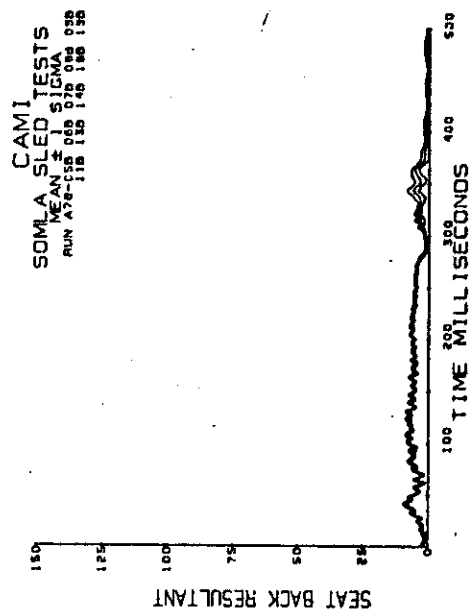
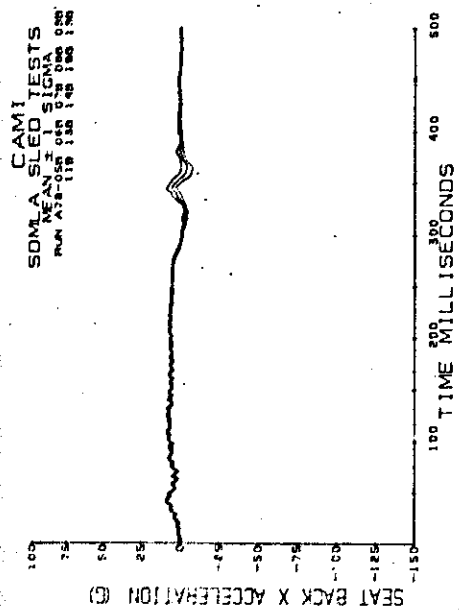
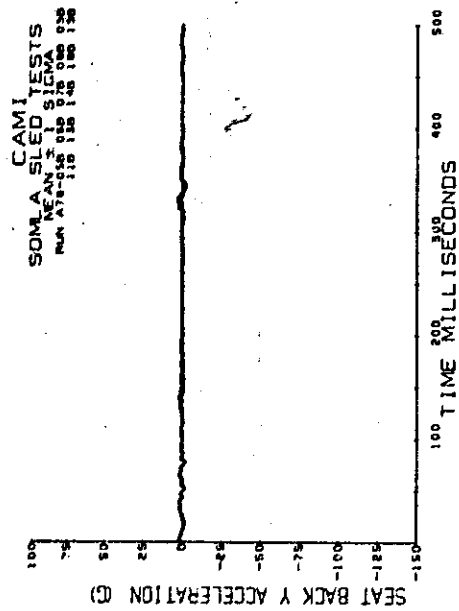


Figure A-5 (continued). Seat back acceleration.

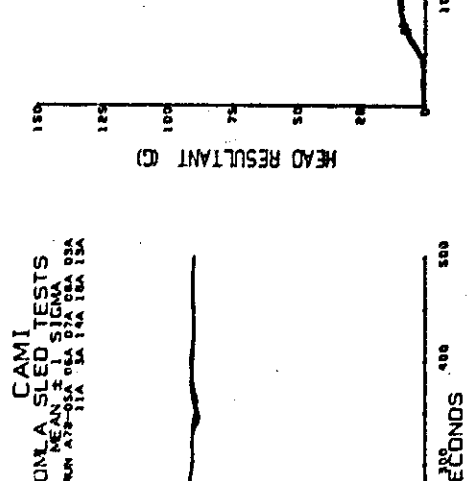
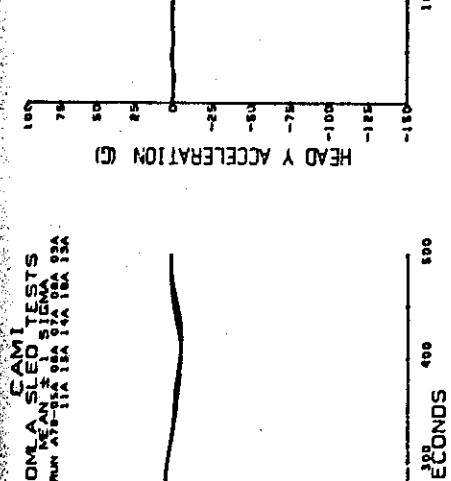
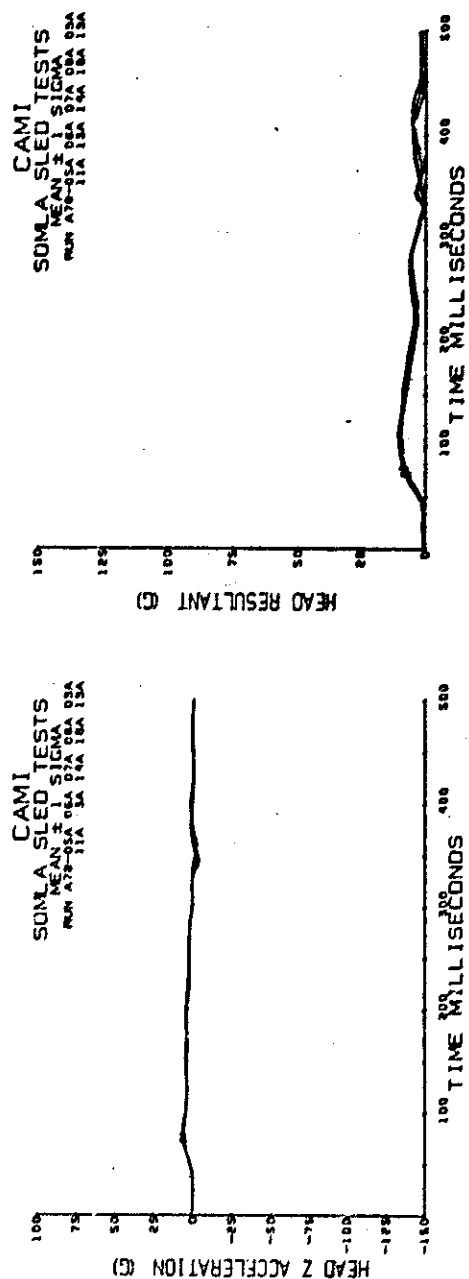
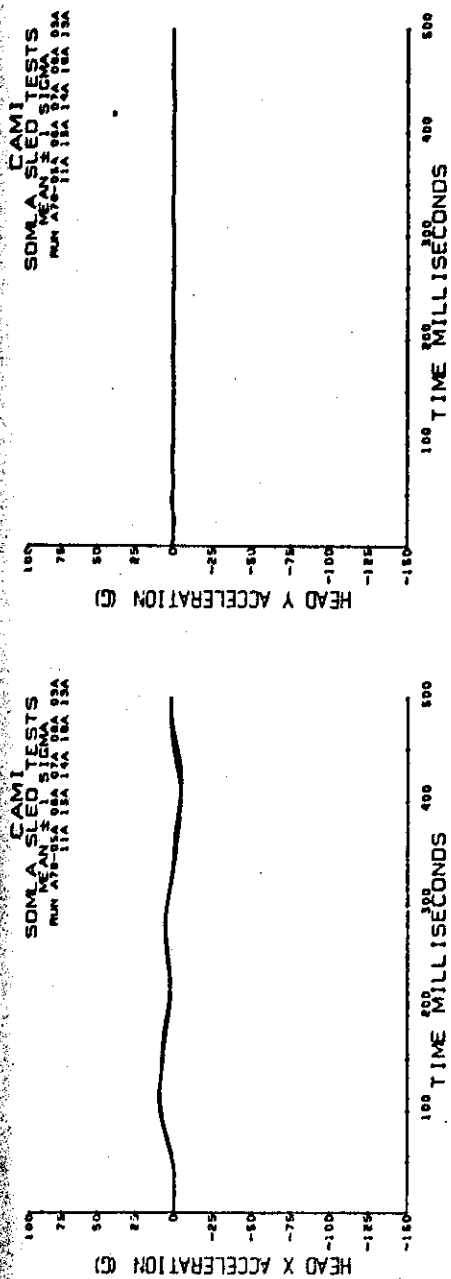


Figure A-5 (continued). Head acceleration.

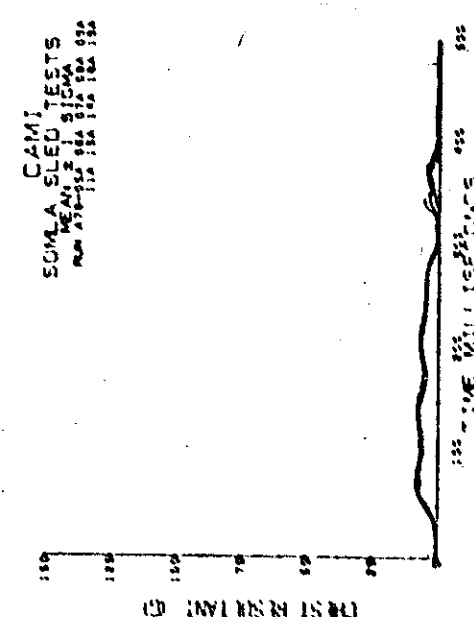
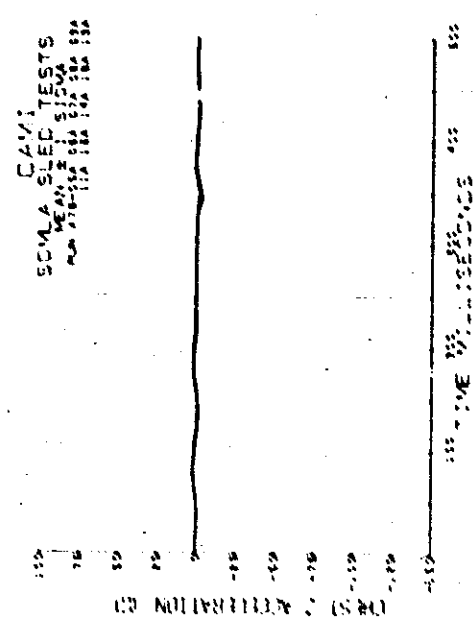
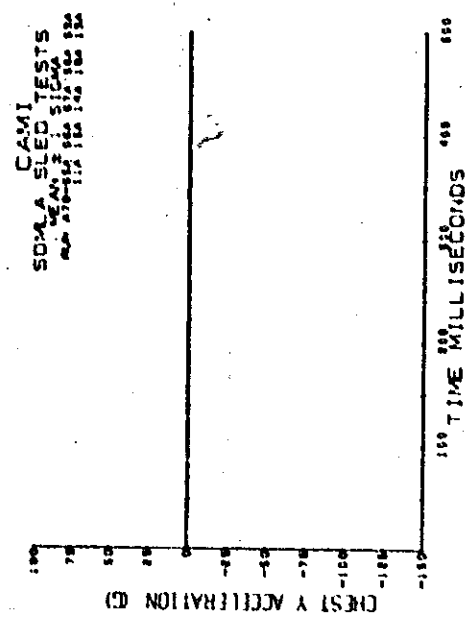
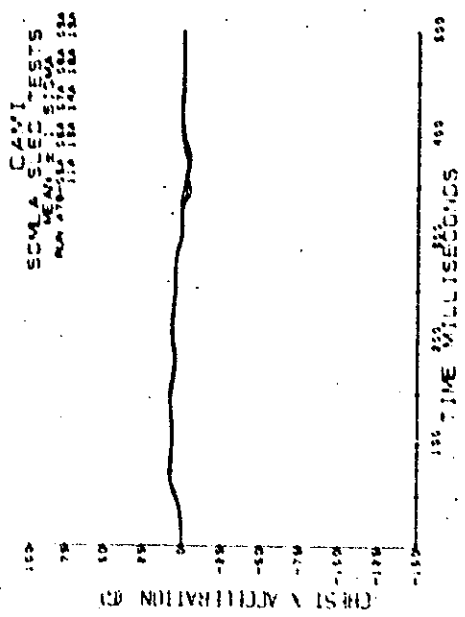


Figure 4-5 (continued) CAVI  
acceleration

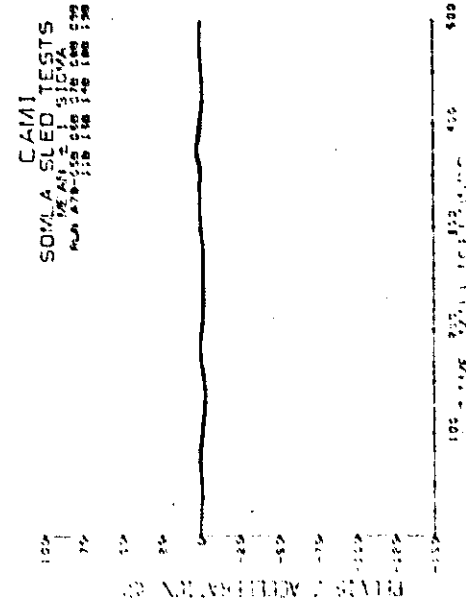
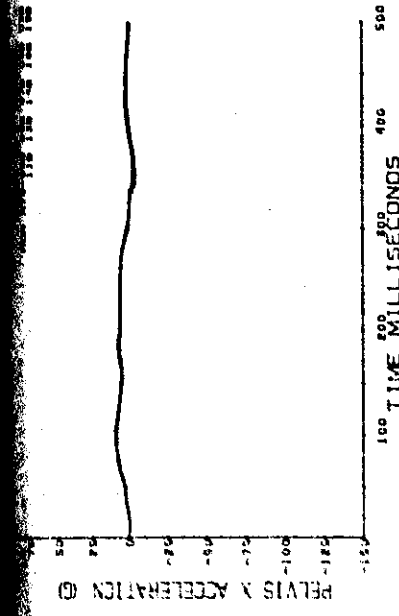
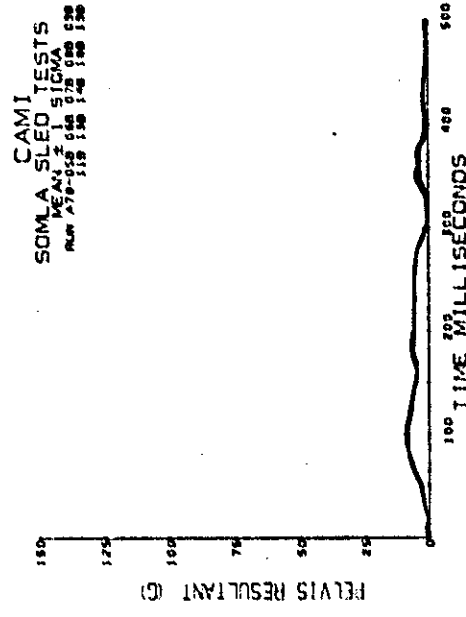
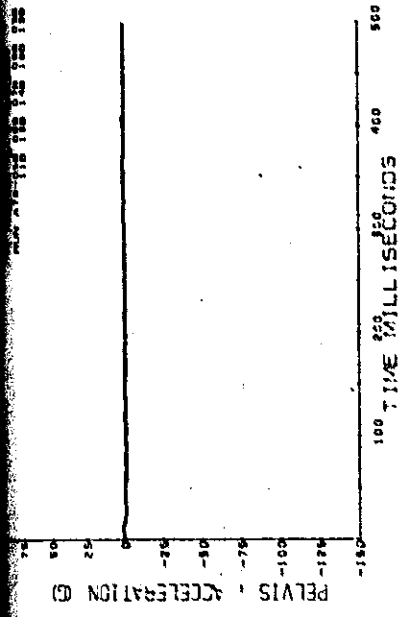


Figure A-5 (continued). Pelvis acceleration.



CAMI  
 SOMA SLED TEST  
 MEAN 21 SIC  
 RUN AT 110 120 130 140 150

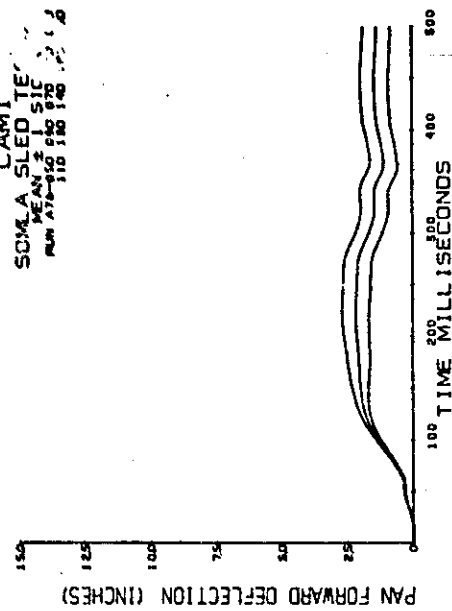
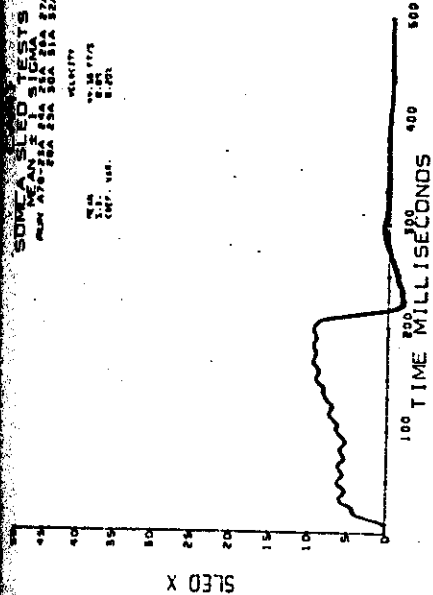


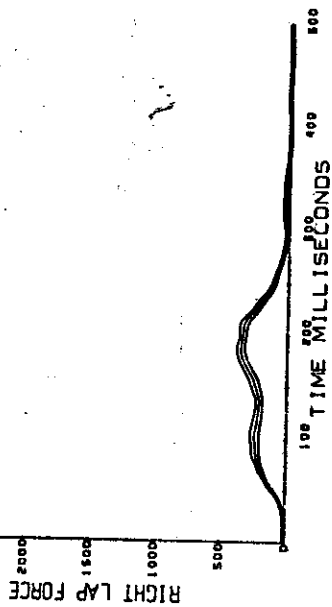
Figure A-5 (continued). Deflection data.

SOMLA SLED TESTS  
MEAN  $\pm$  1 SIGMA  
RUN A78-23A 23A 23A 23A 23A 23A

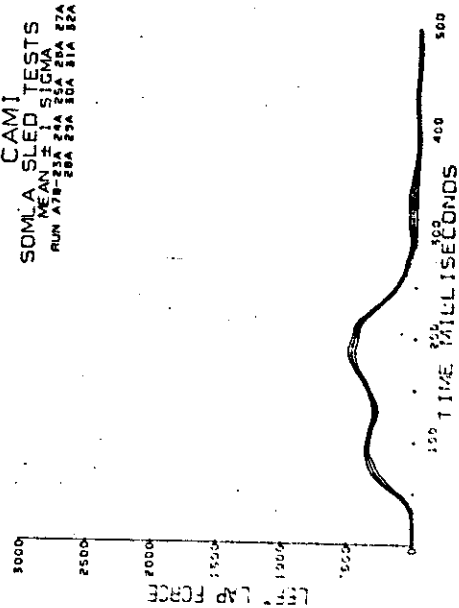
VELOCITY  
1000 1000  
1000 1000  
1000 1000



SOMLA SLED TESTS  
MEAN  $\pm$  1 SIGMA  
RUN A78-23A 23A 23A 23A 23A 23A



SOMLA SLED TESTS  
MEAN  $\pm$  1 SIGMA  
RUN A78-23A 23A 23A 23A 23A 23A



SOMLA SLED TESTS  
MEAN  $\pm$  1 SIGMA  
RUN A78-23A 23A 23A 23A 23A 23A

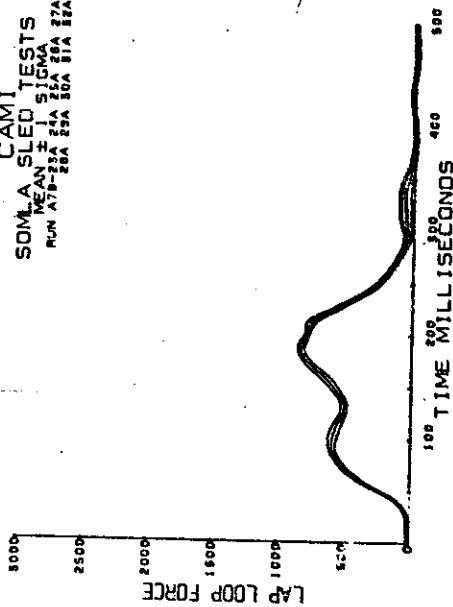


Figure A-6. Forward-facing, higher deceleration tests.  
Sled deceleration and lapbelt loads.

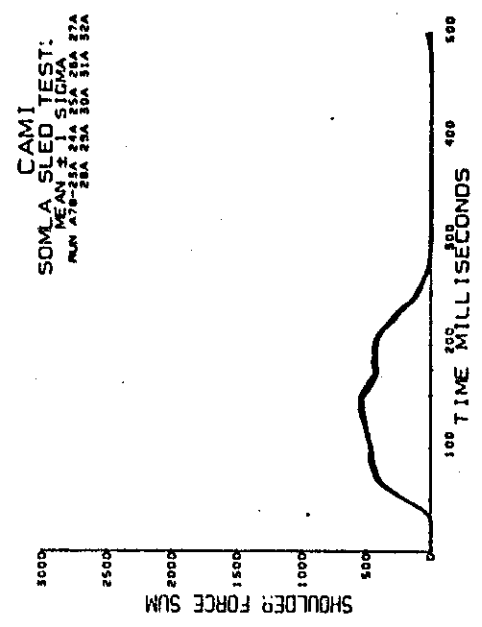
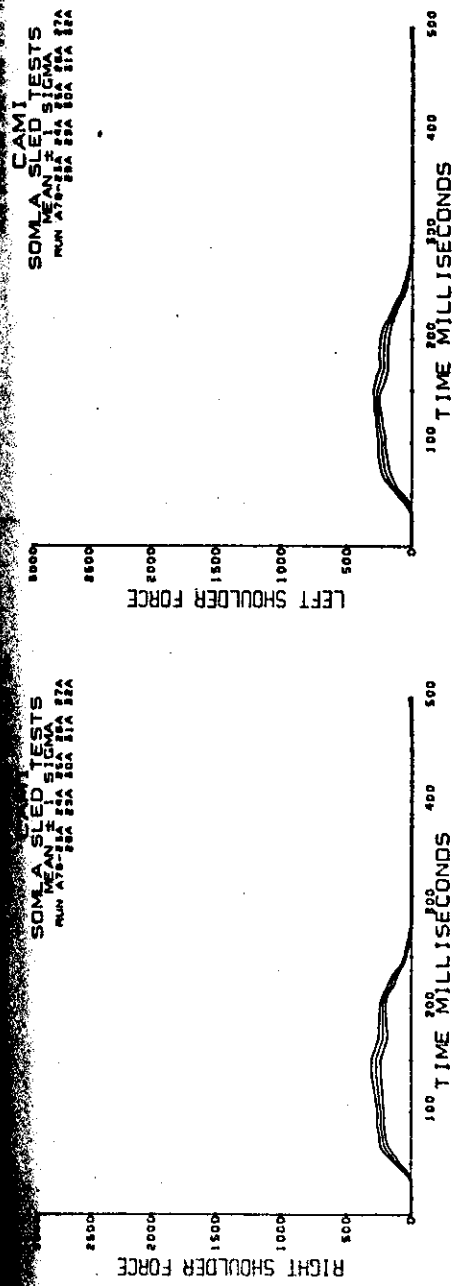


Figure A-6 (continued). Shoulder belt loads.

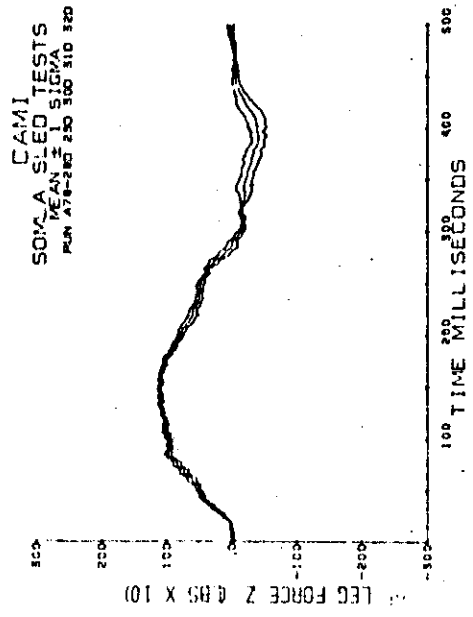
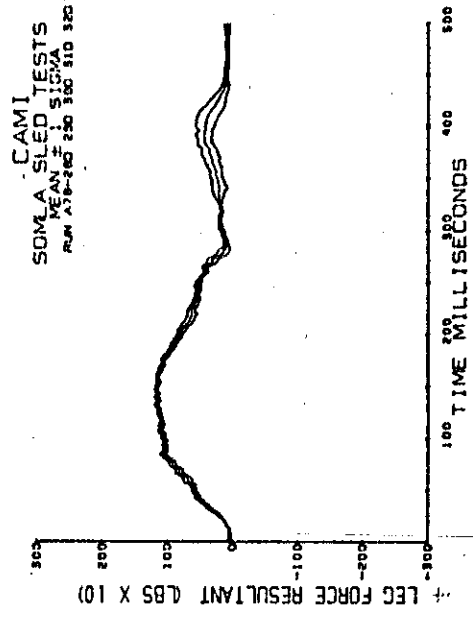
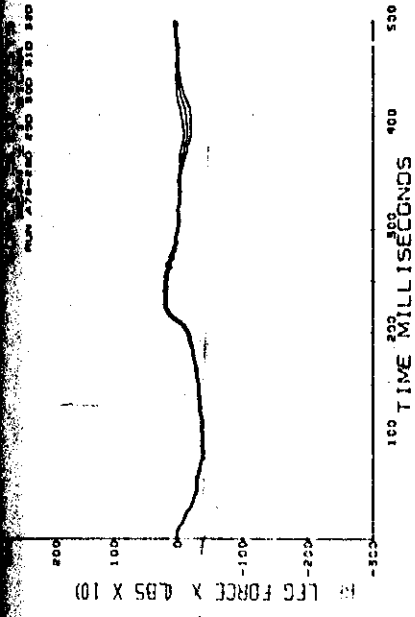
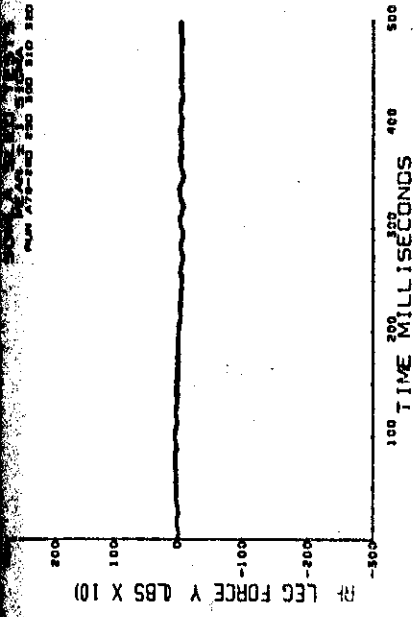


Figure A-6 (continued). Right front seat leg loads.

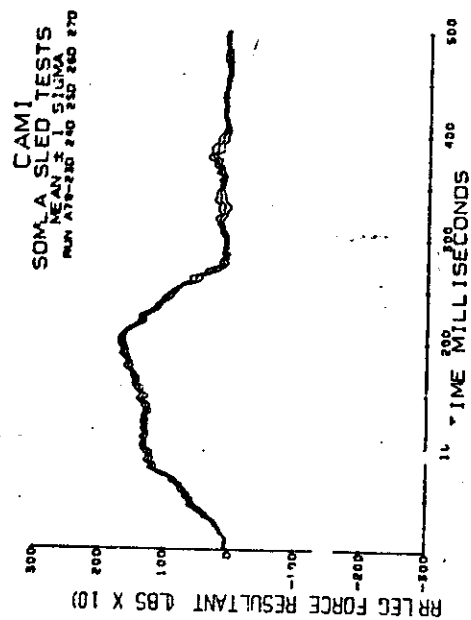
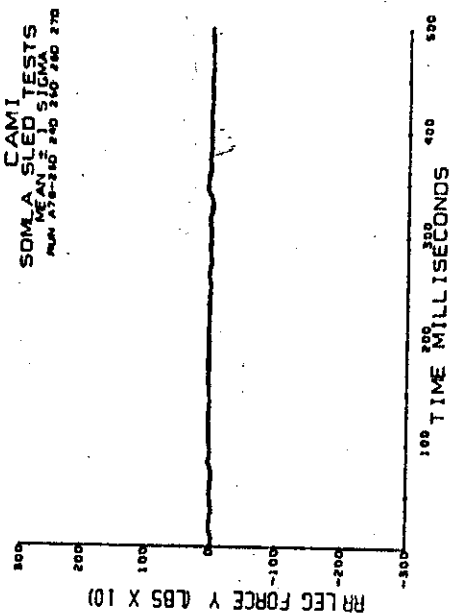
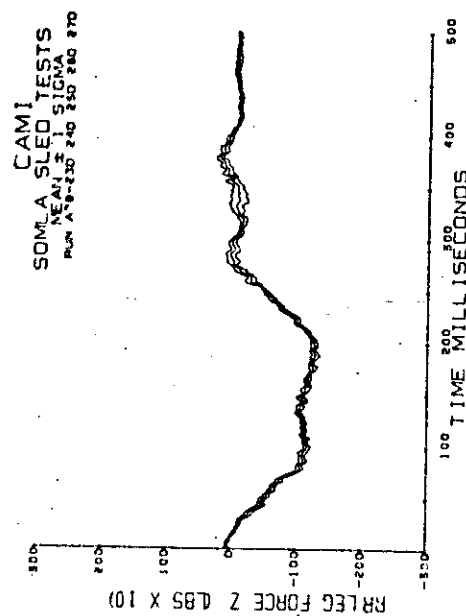
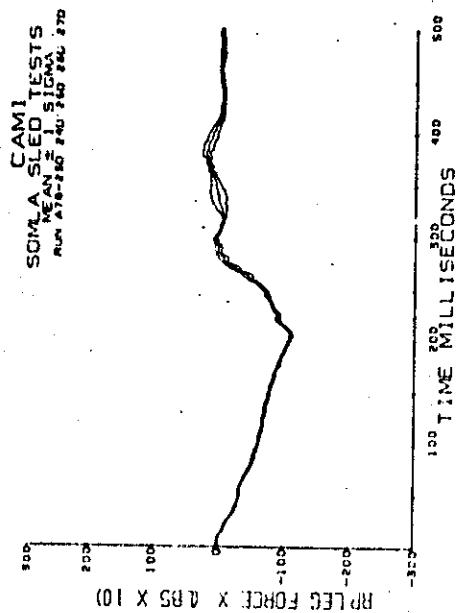


Figure A-6 (continued). Right rear  
seat leg loads.

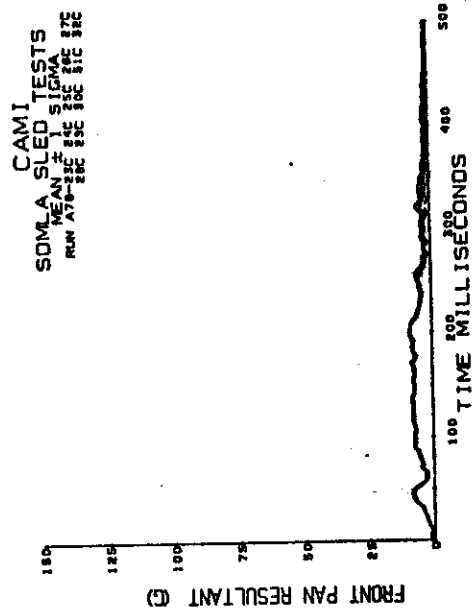
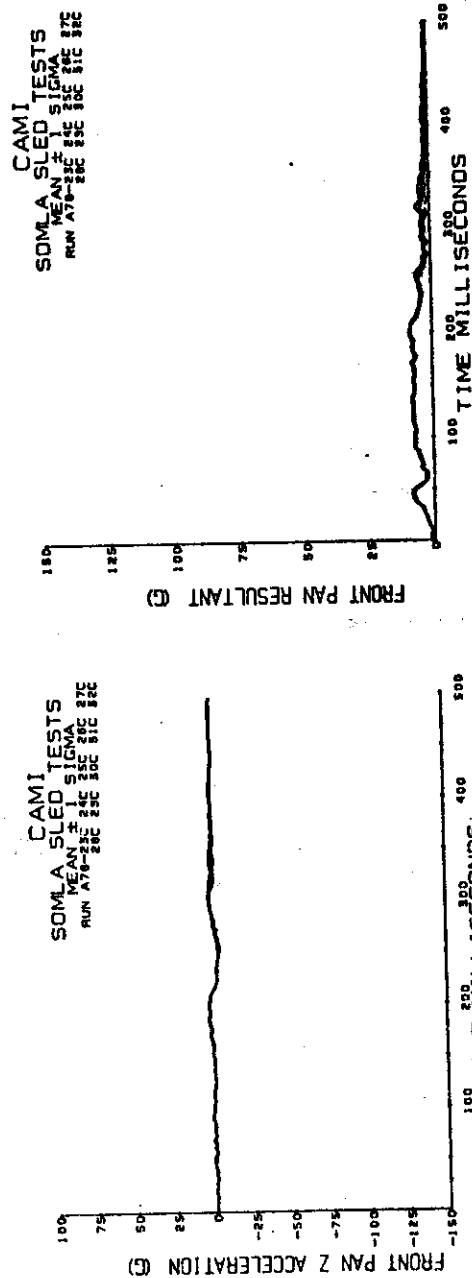
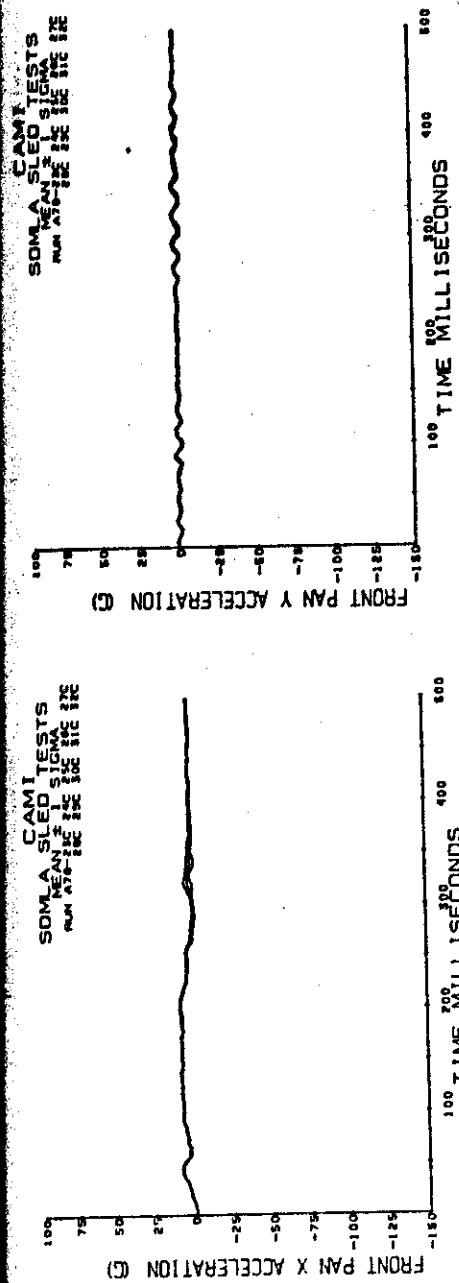


Figure A-6 (continued). Front seat pan acceleration.

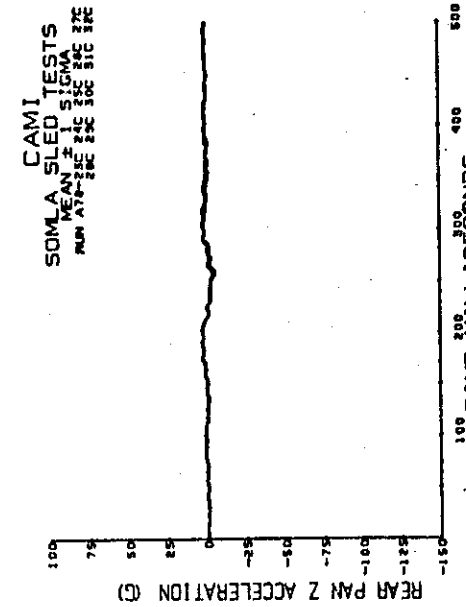
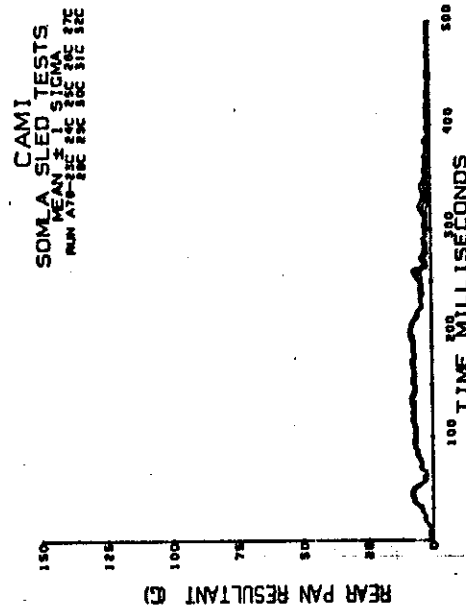
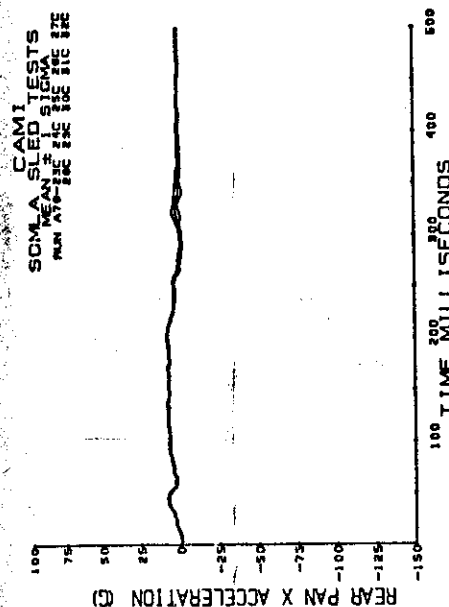
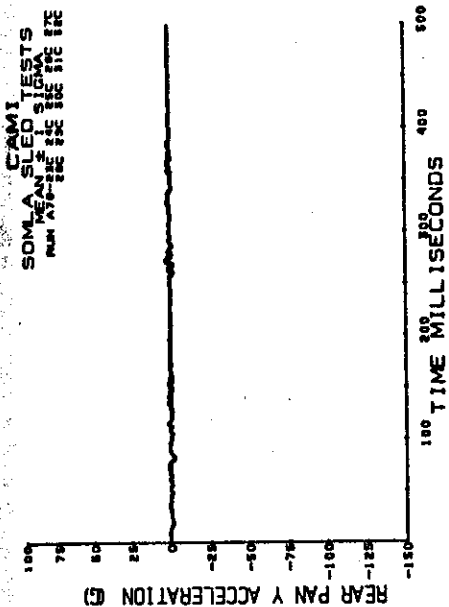


Figure A-6 (continued). Rear seat pan acceleration.

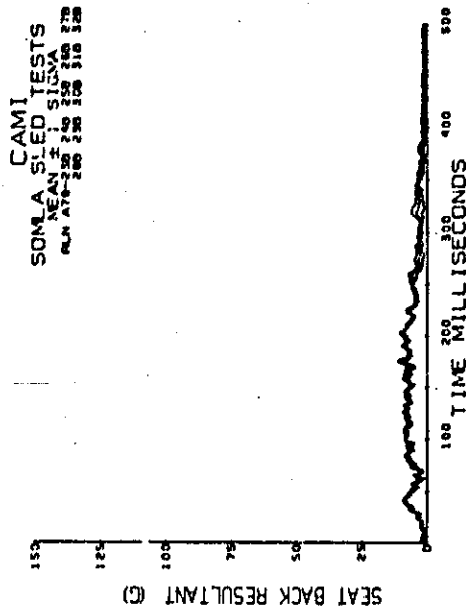
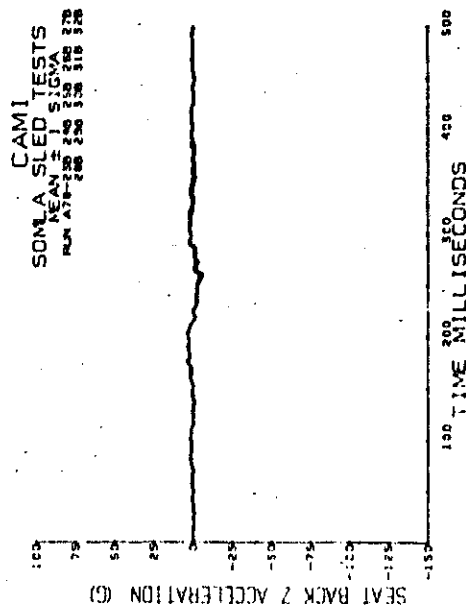
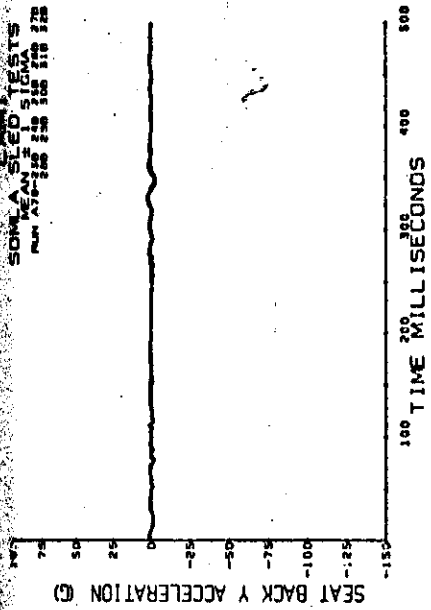
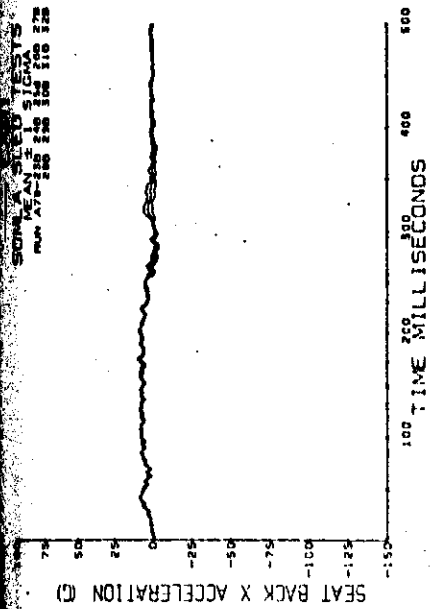


Figure A-6 (continued). Seat back acceleration.



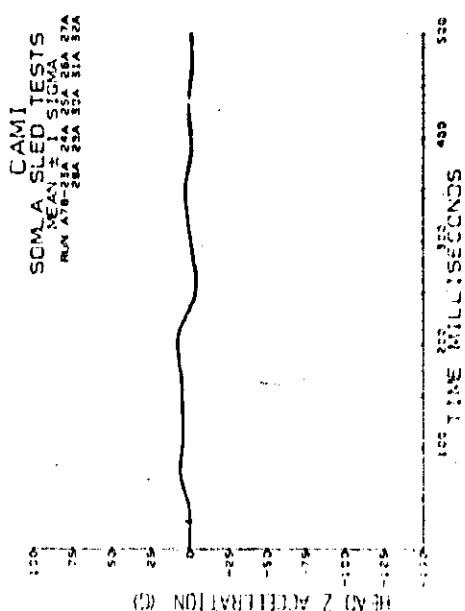
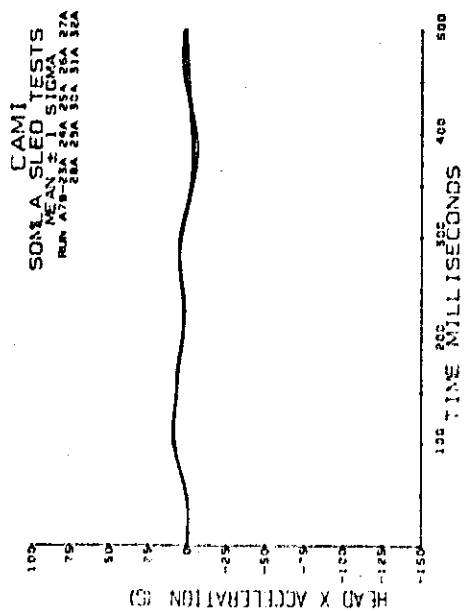
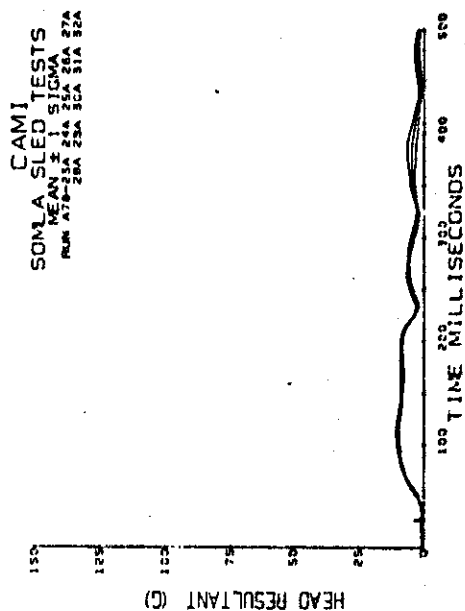
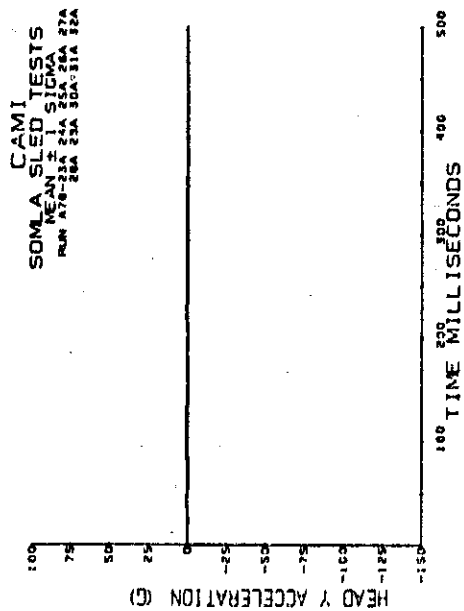


Figure A-6 (continued). Head acceleration.

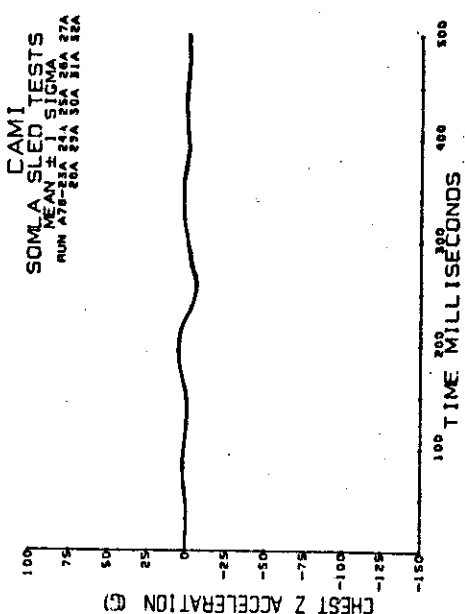
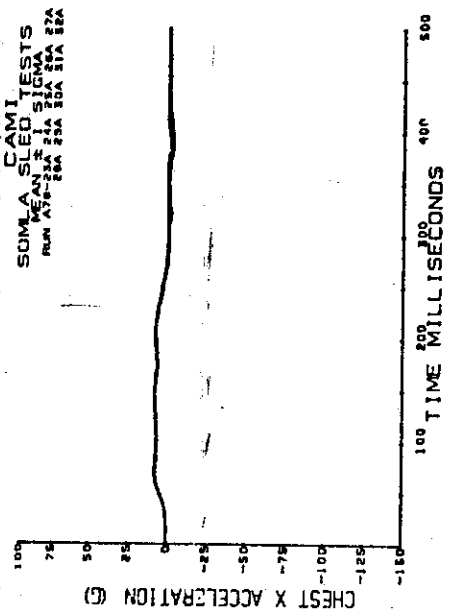
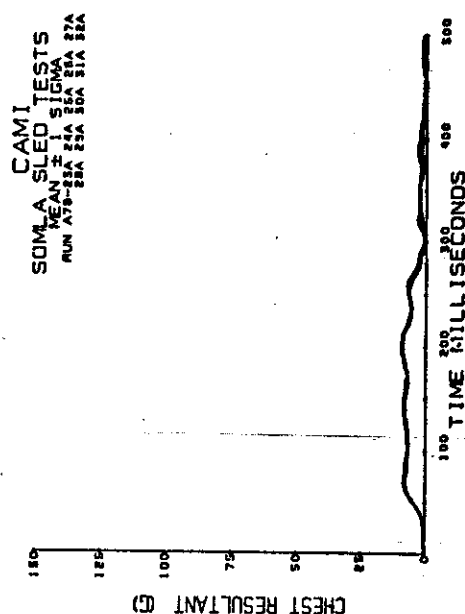
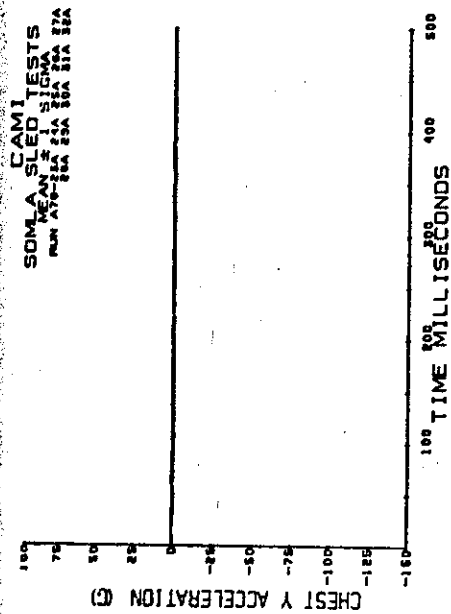


Figure A-6 (continued). Chest acceleration.

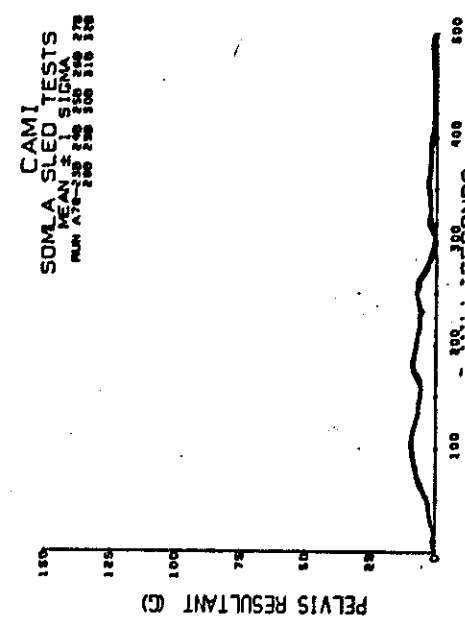
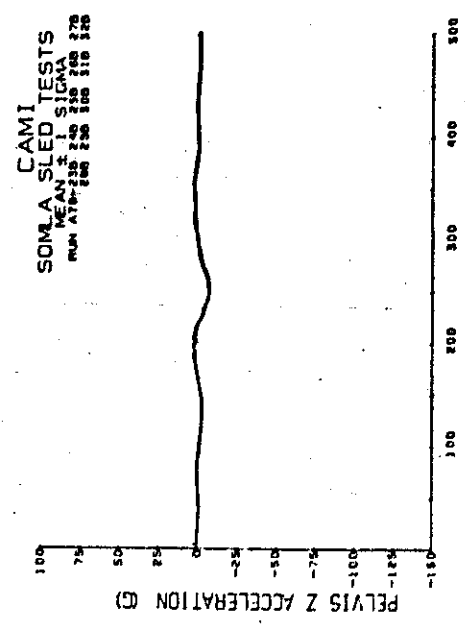
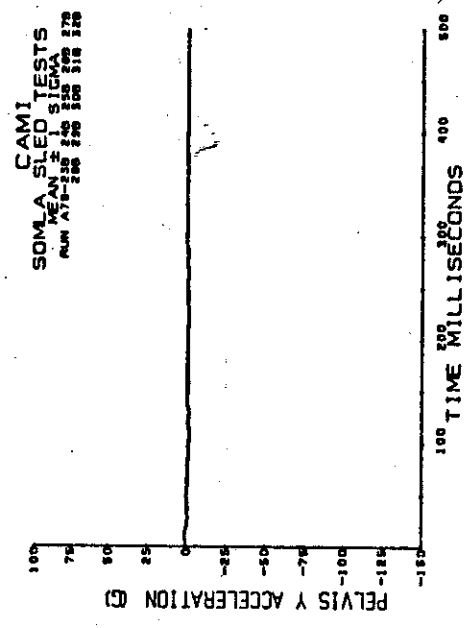
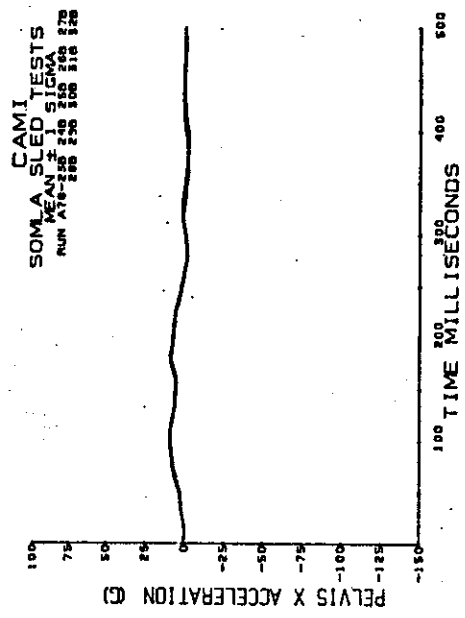


Figure A-6 (continued). Pelvis acceleration.

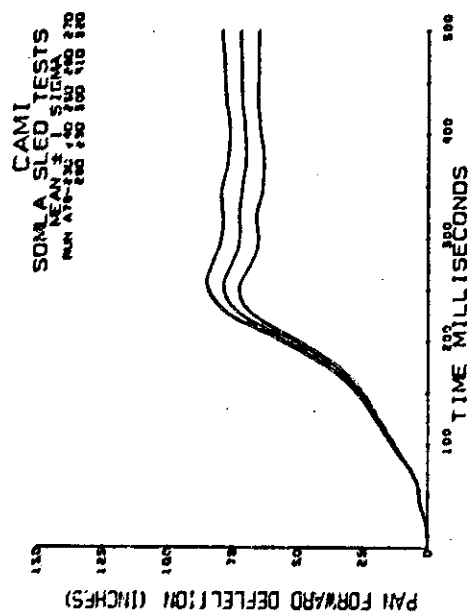


Figure A-6 (continued). Deflection data.

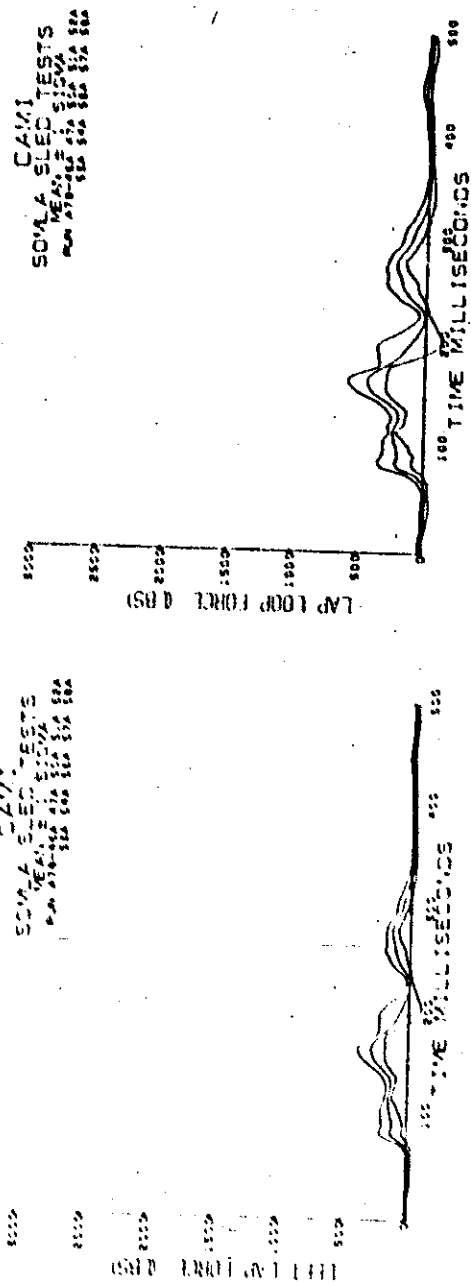


Figure A-7. Combined loading, low-deceleration tests.  
Sled deceleration and lapbelt loads.

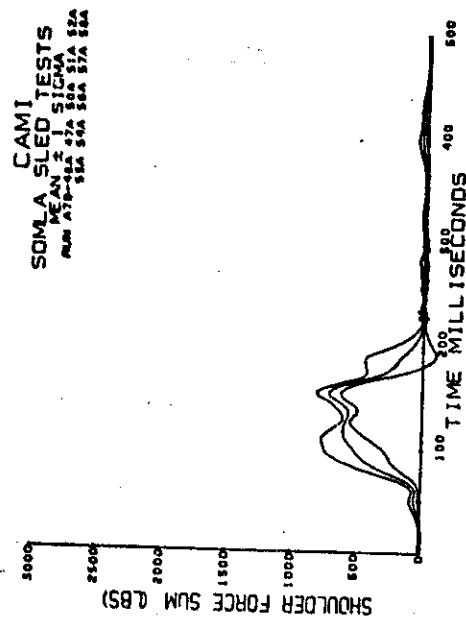
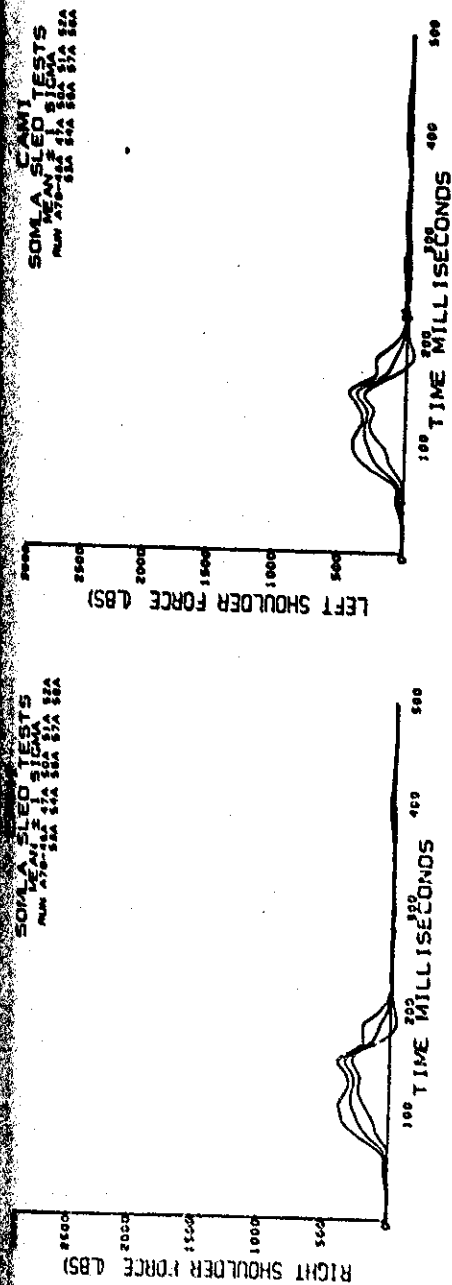


Figure A-7 (continued). Shoulder belt loads.

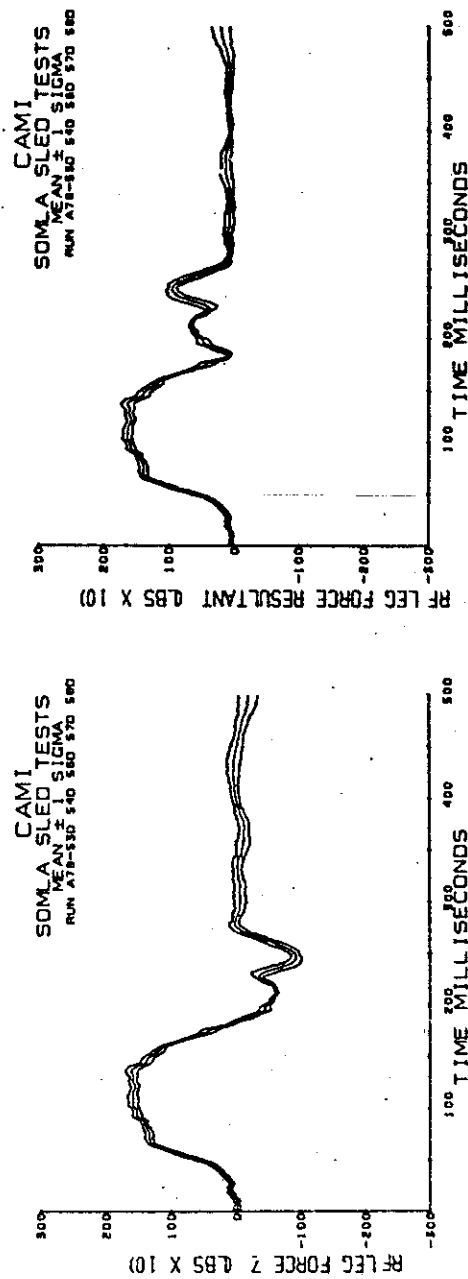
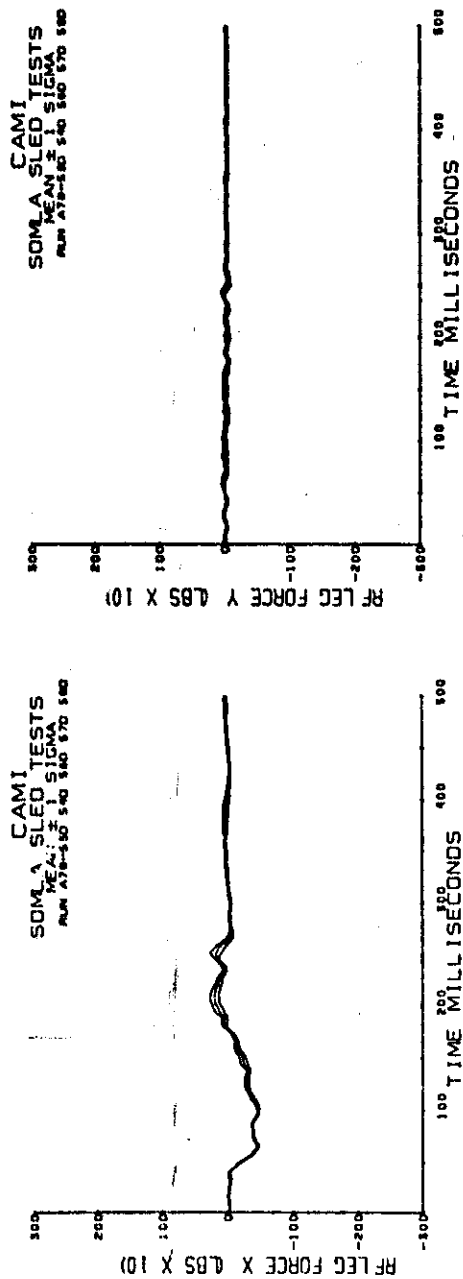


Figure A-7 (continued). Right front  
seat leg loads.

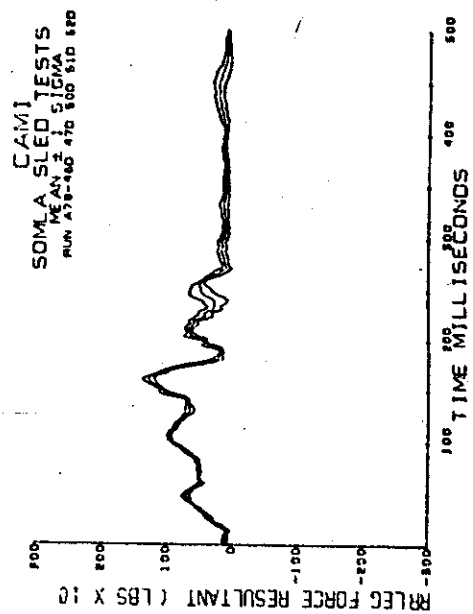
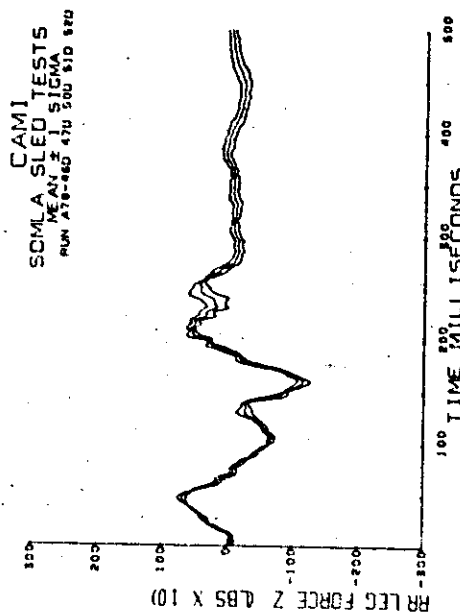
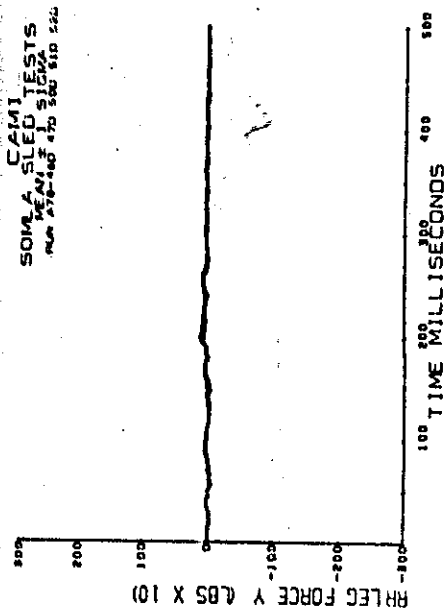
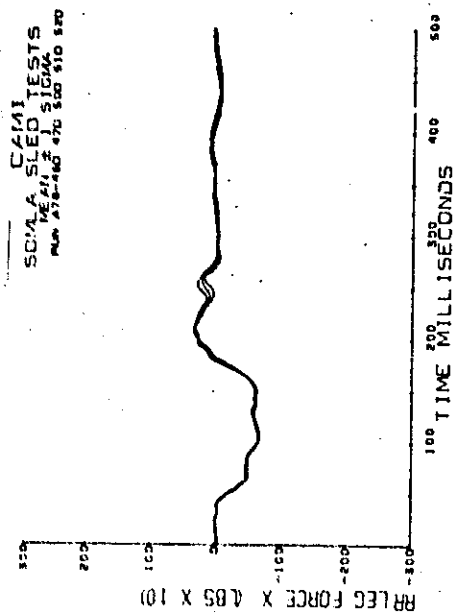


Figure A-7 (continued). Right rear  
seat leg loads.



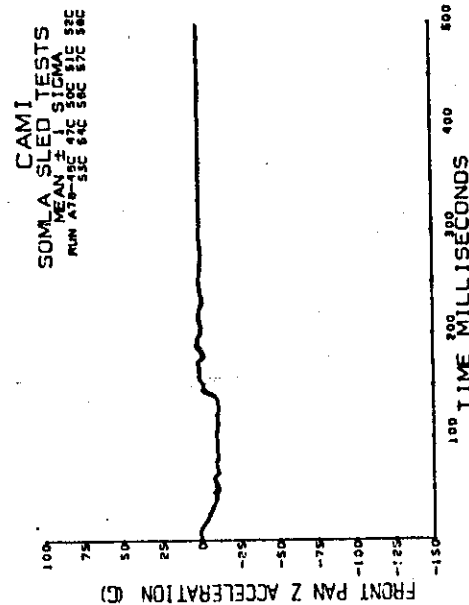
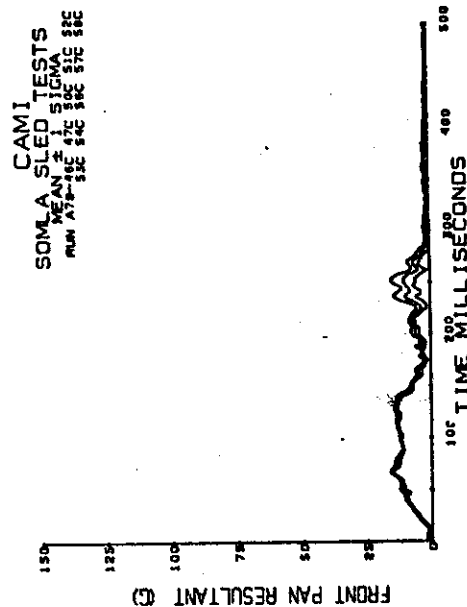
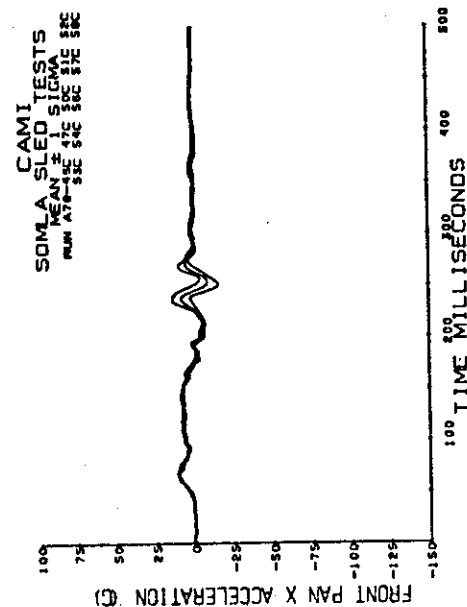
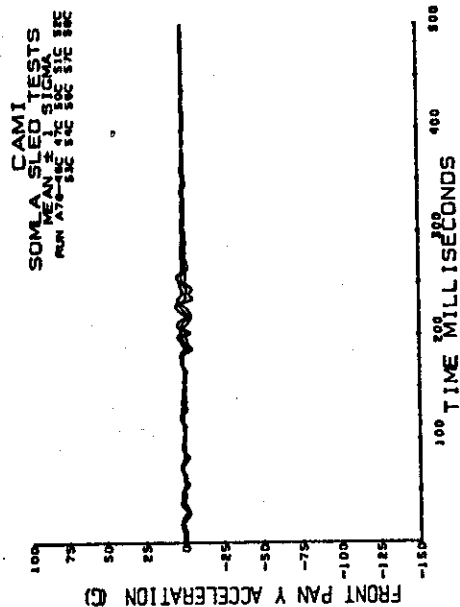


Figure A-7 (continued). Front seat pan acceleration.

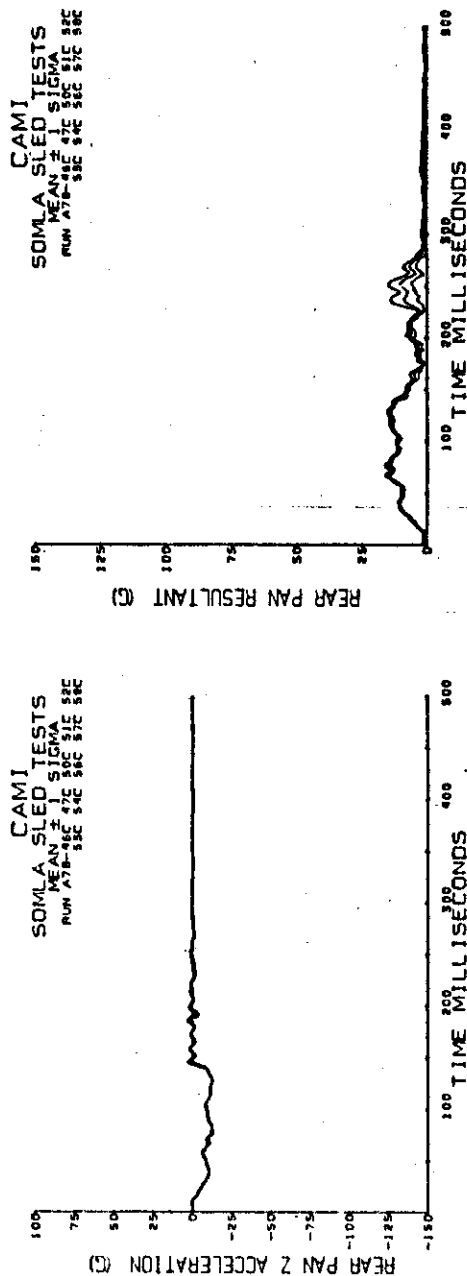
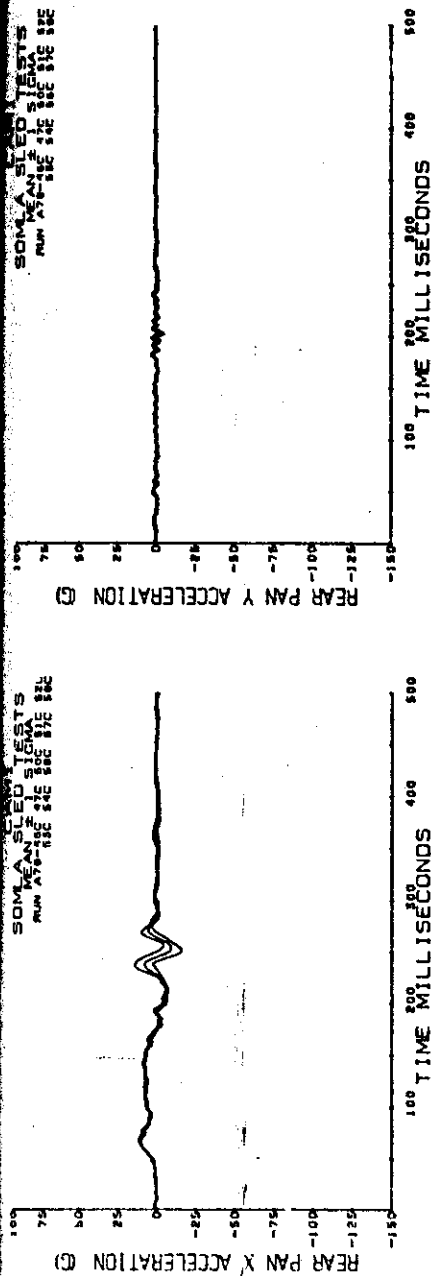


Figure A-7 (continued). Rear seat pan acceleration.

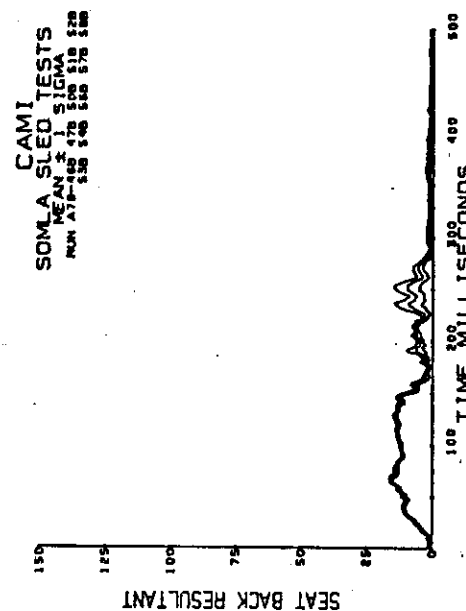
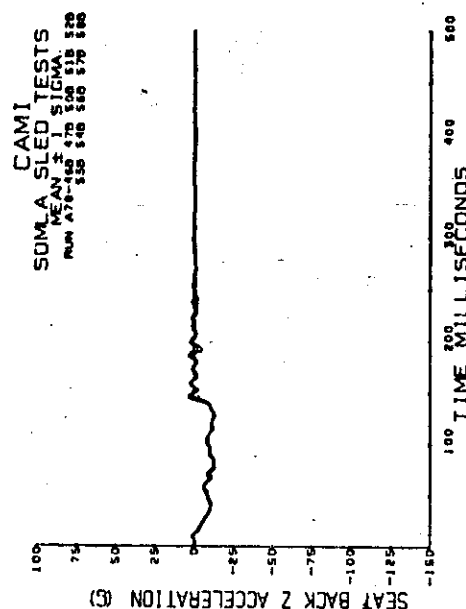
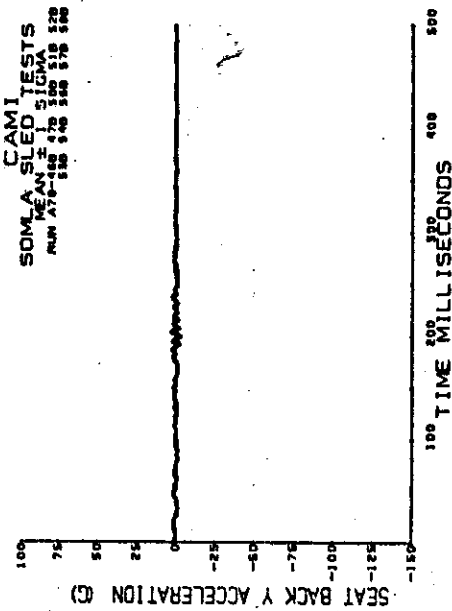
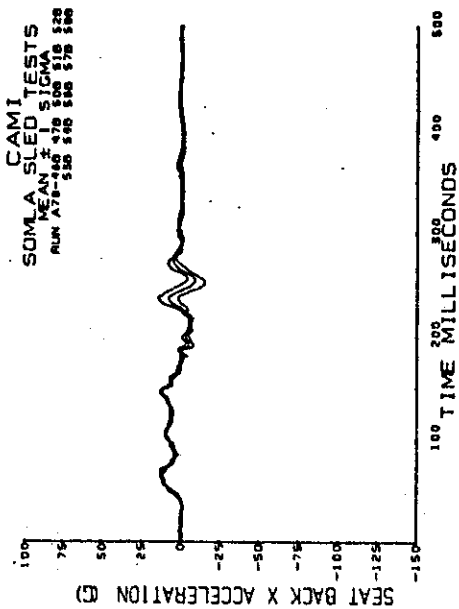


Figure A-7 (continued). Seat back acceleration.

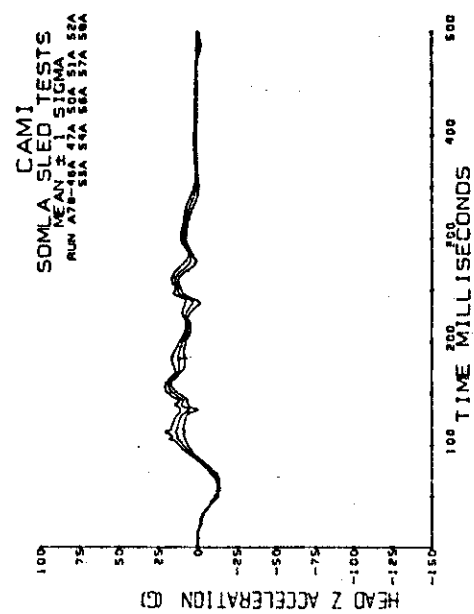
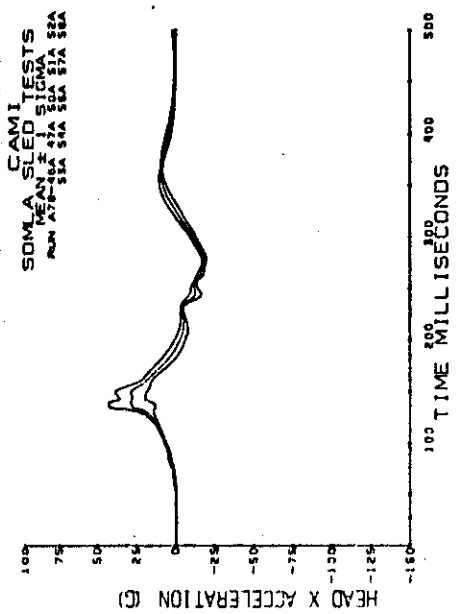
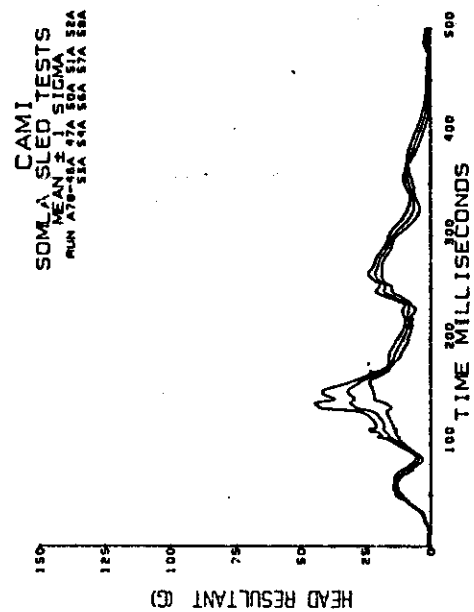
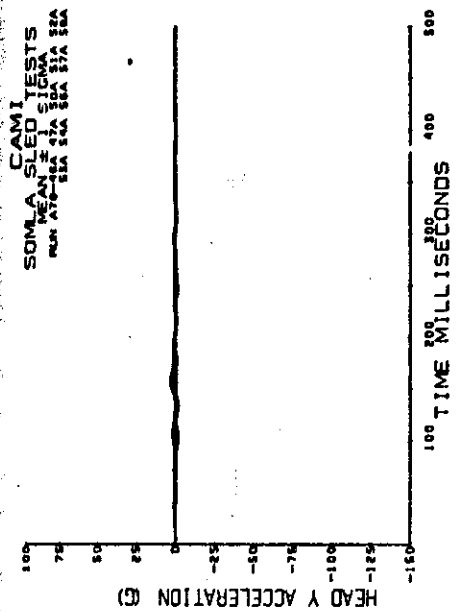


Figure A-7 (continued). Head acceleration.

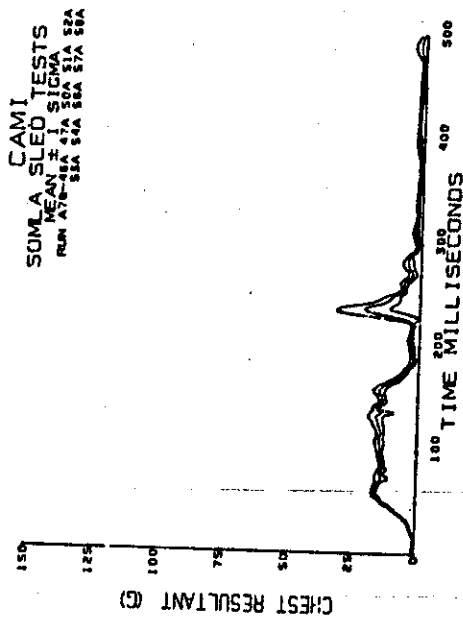
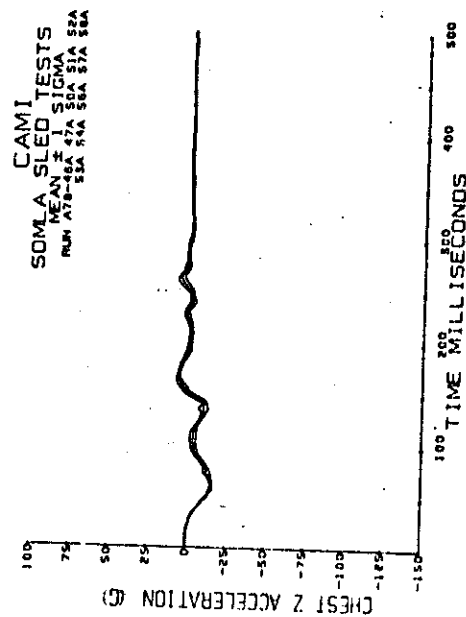
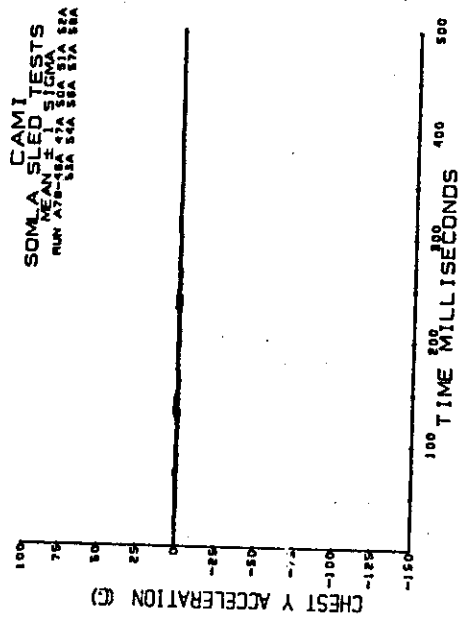
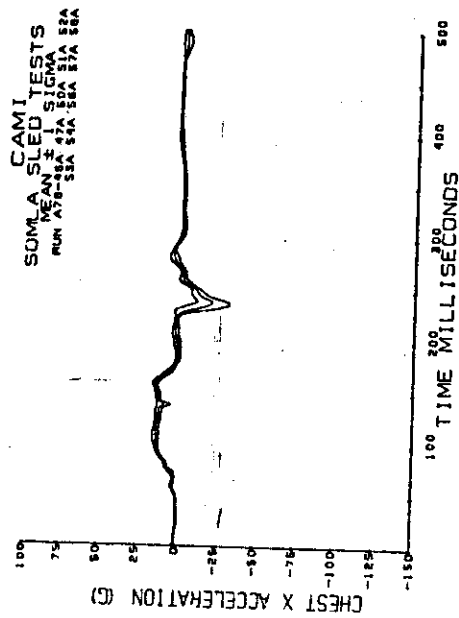


Figure A-7 (continued). Chest acceleration.

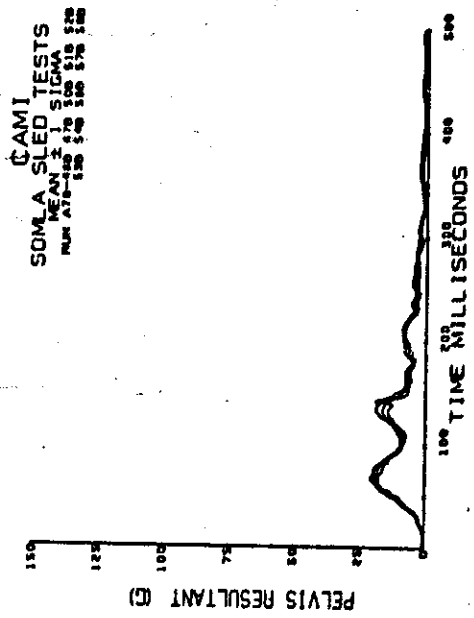
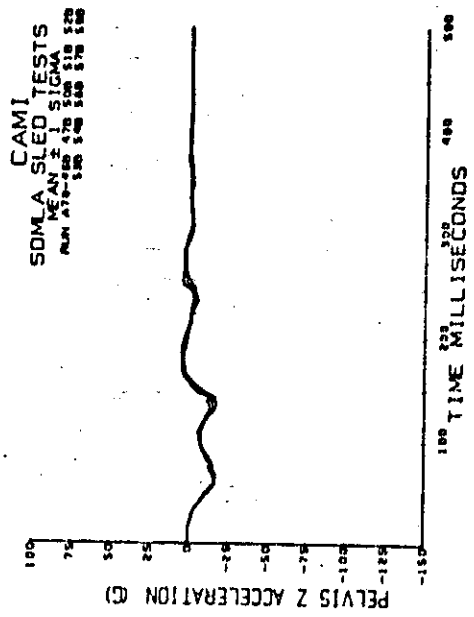
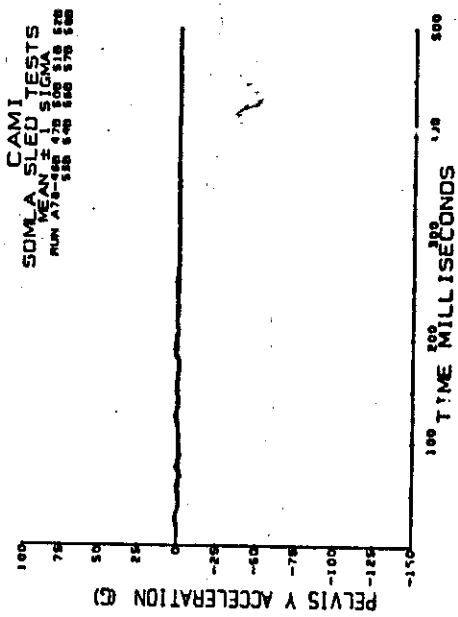
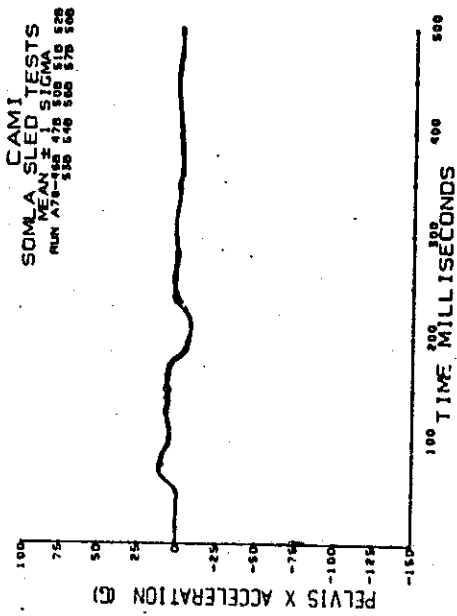


Figure A-7 (continued). Pelvis acceleration.

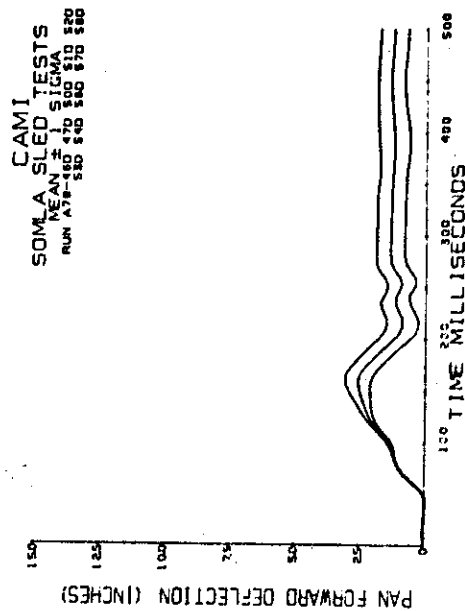


Figure A-7 (continued). Deflection data.

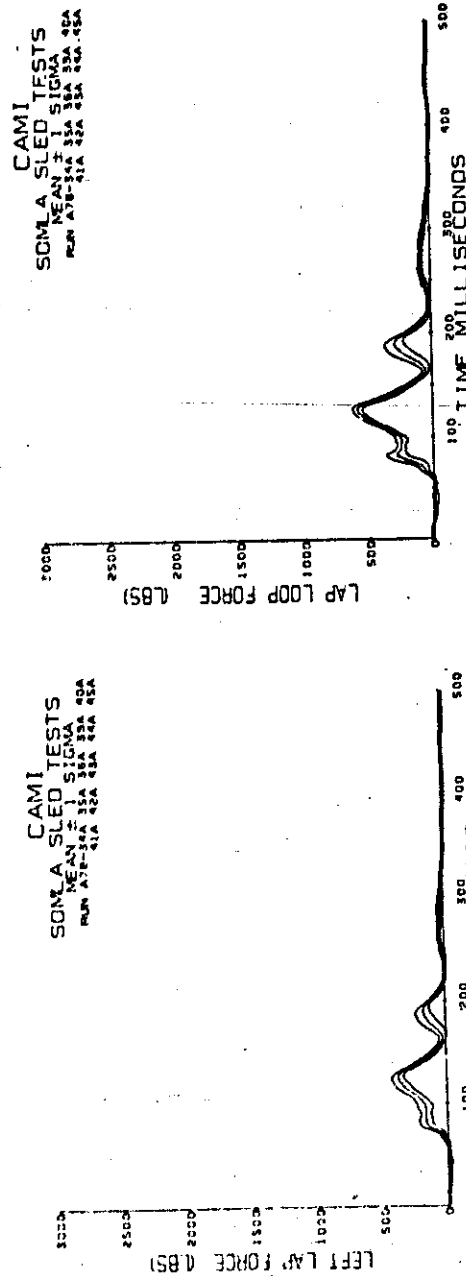
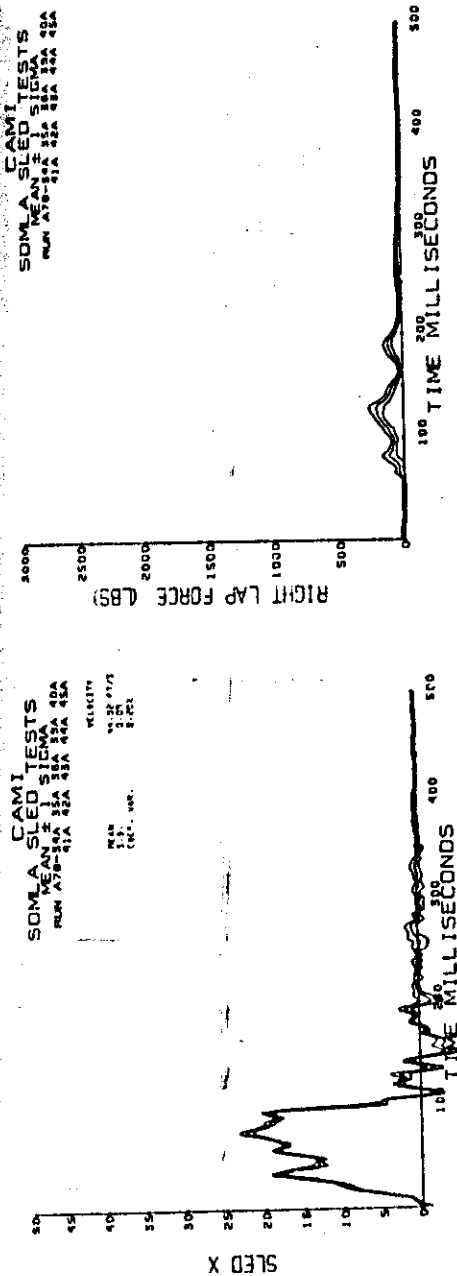


Figure A-8. Combined loading higher deceleration tests.  
Sled deceleration and lapbelt loads.



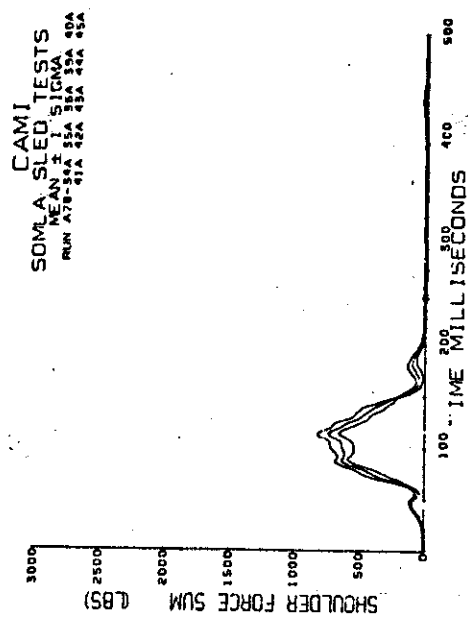
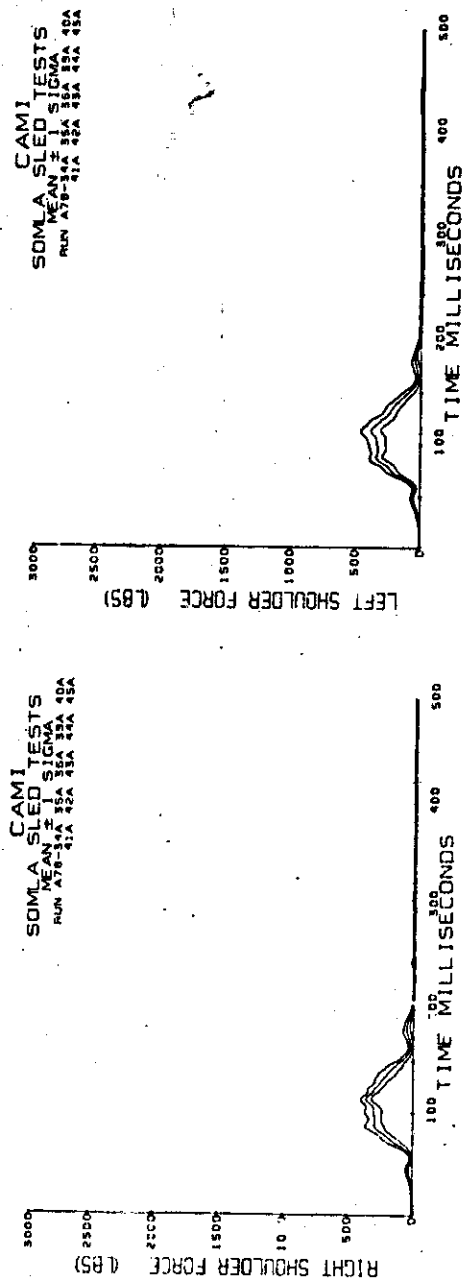


Figure A-8 (continued). Shoulder  
belt loads.

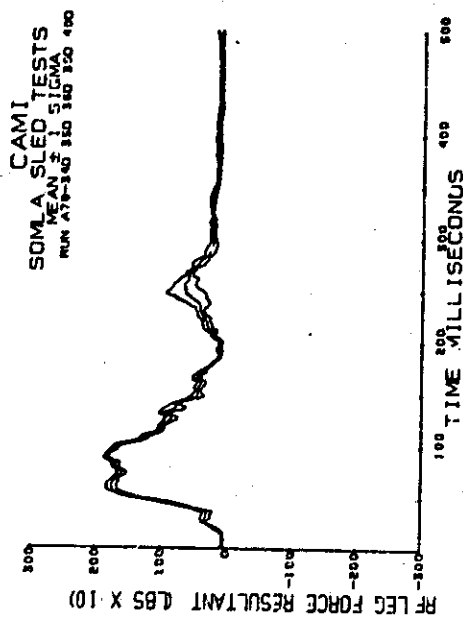
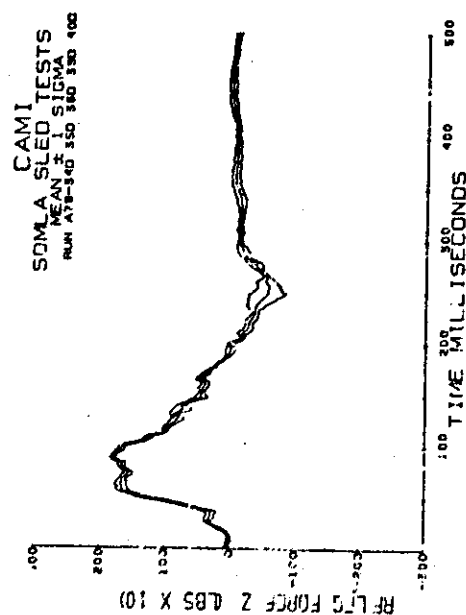
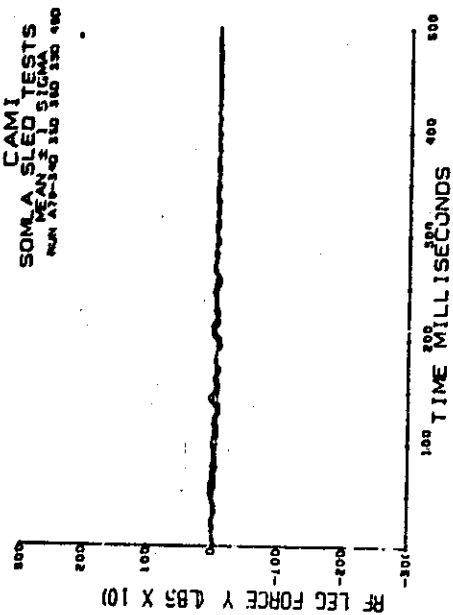
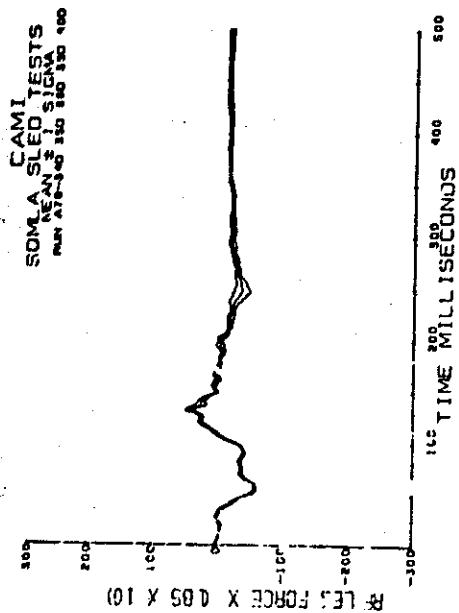


Figure A-8 (continued). Right: front  
seat leg loads.

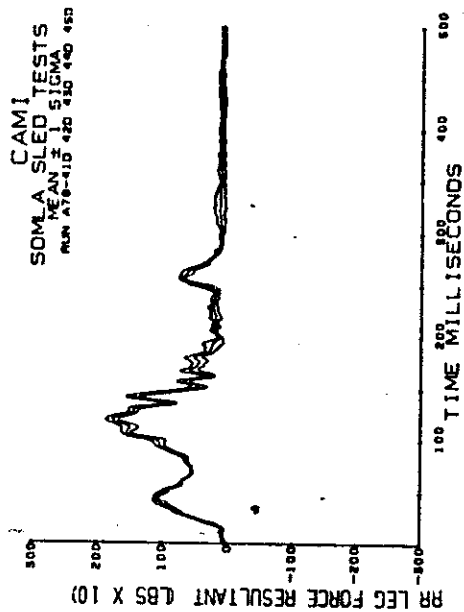
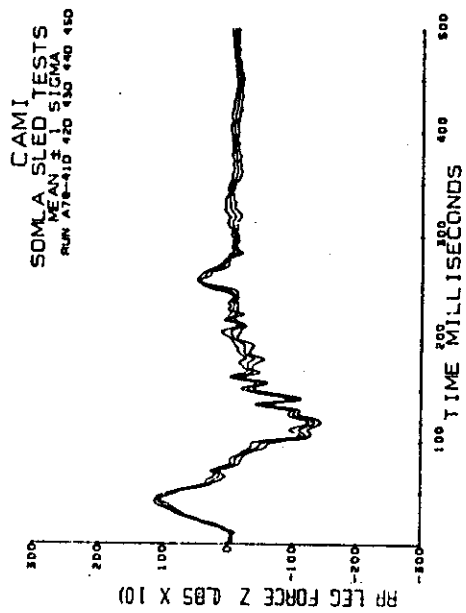
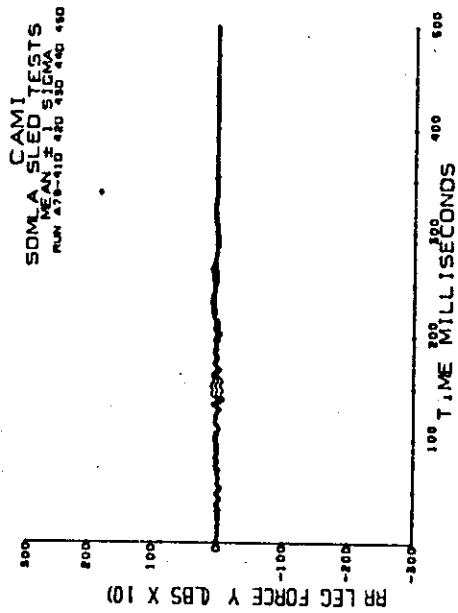
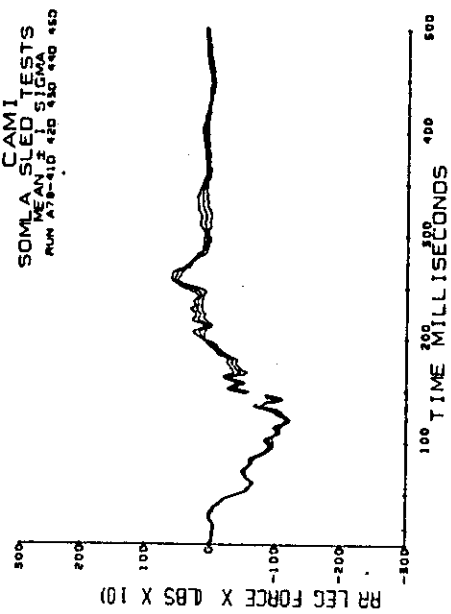
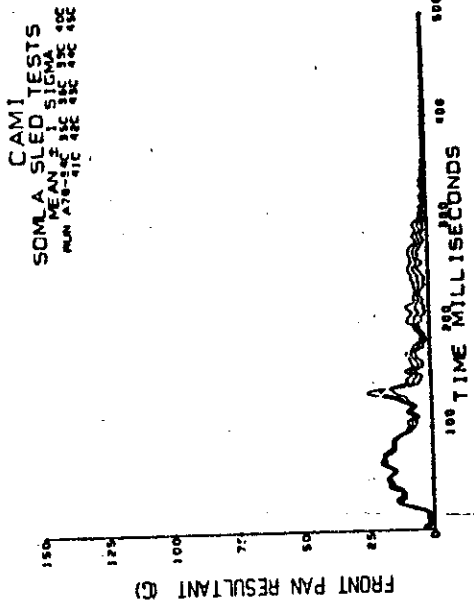
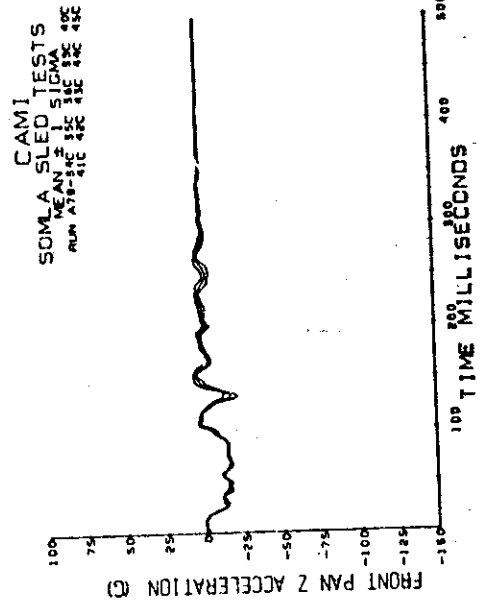
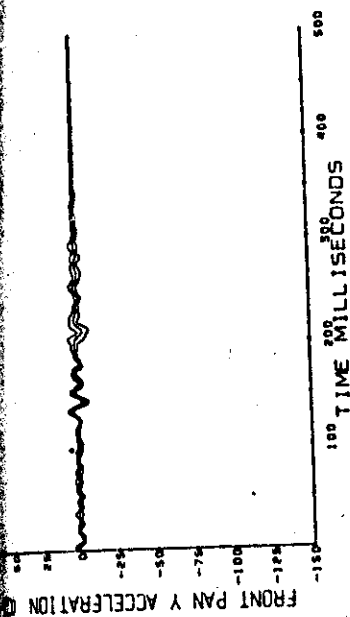
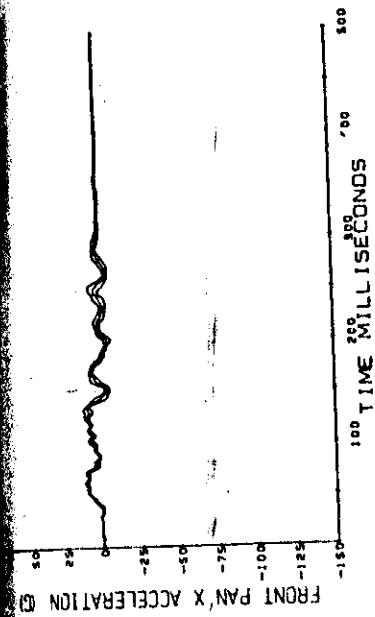


Figure A-8 (continued). Right rear  
seat leg loads.



CAMI  
SOMLA SLED TESTS  
MEAN 2.1 SIGMA  
RUN 478-54C 35C 35C 40C  
41C 42C 43C 44C 45C

CAMI  
SOMLA SLED TESTS  
MEAN 2.1 SIGMA  
RUN 478-54C 35C 35C 40C  
41C 42C 43C 44C 45C

Figure A-8 (continued). Front seat pan acceleration.

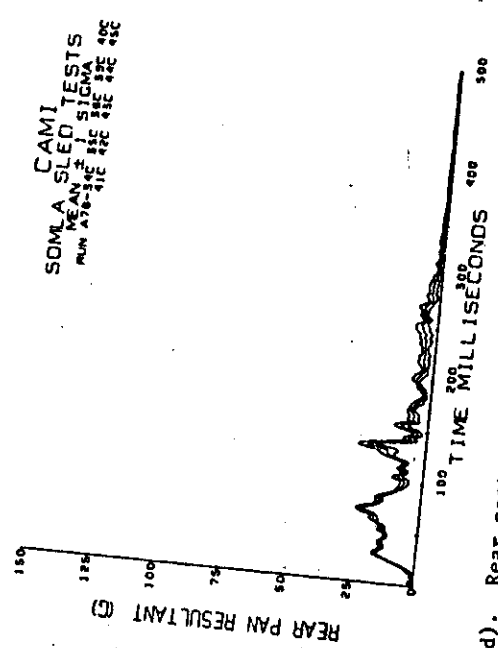
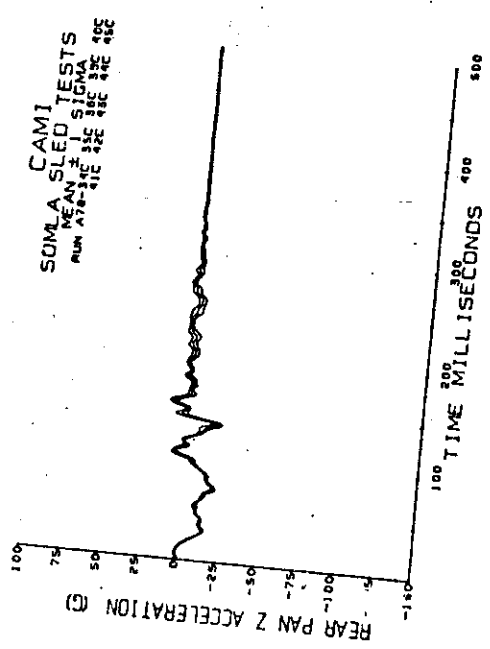
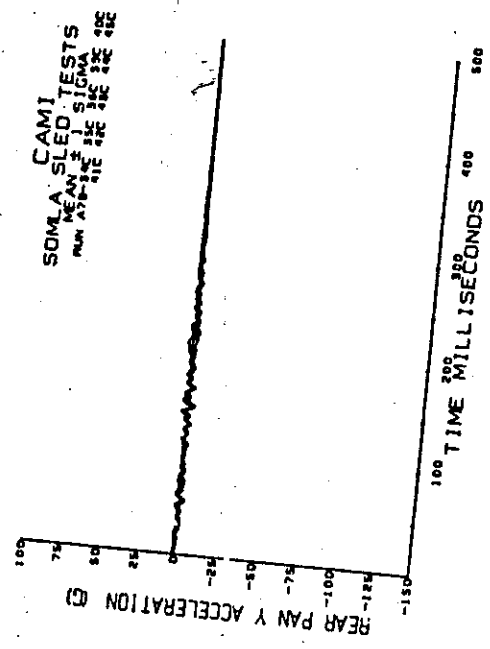
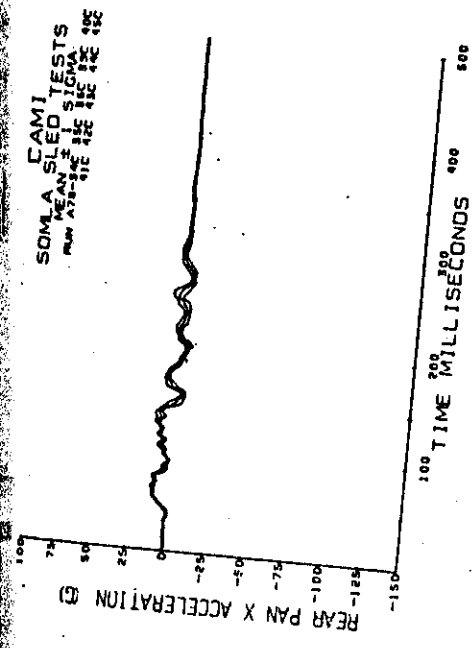
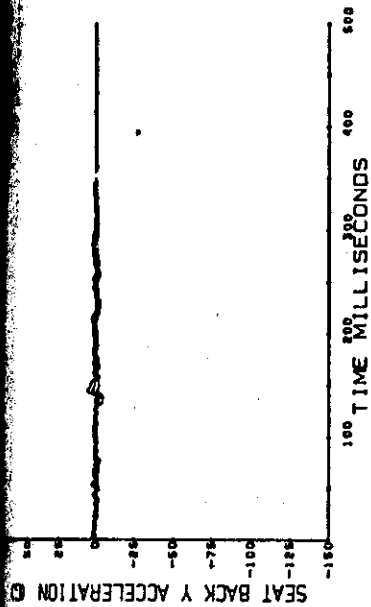
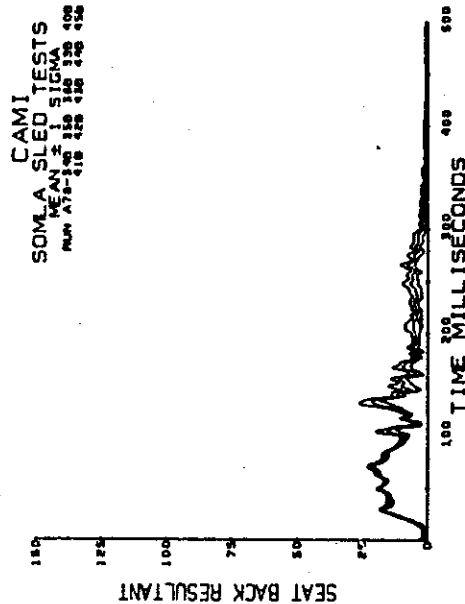
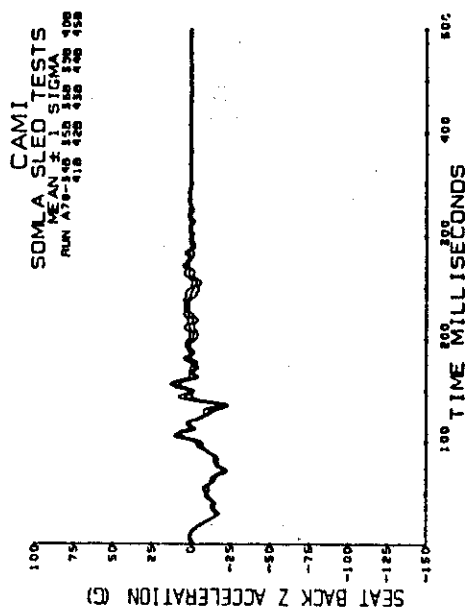
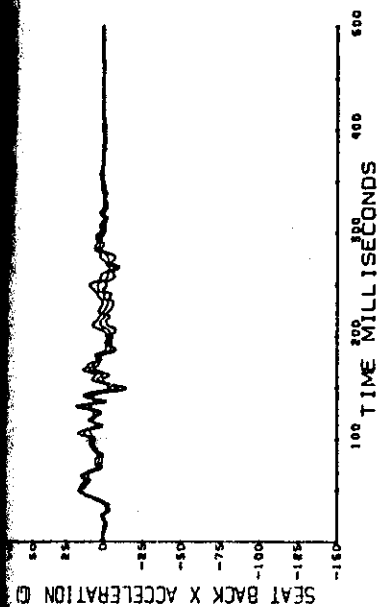


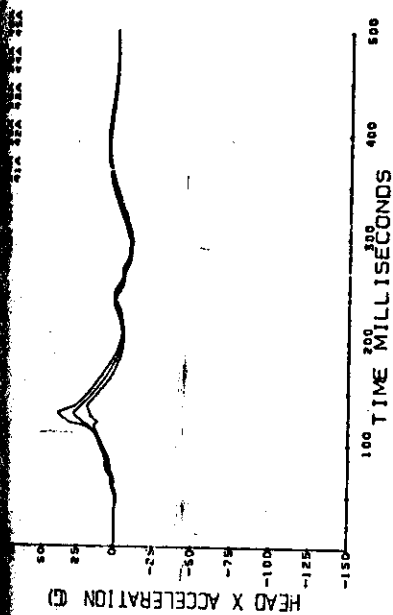
Figure A-8 (continued). Rear seat pan acceleration.



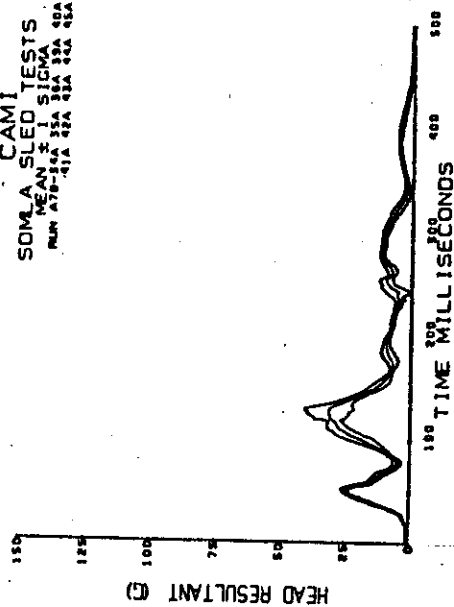
CAMI  
SOMLA SLED TESTS  
MEAN  $\pm$  1 SIGMA  
RUN A78-148 150 150 150 150 150  
418 418 418 418 418

CAMI  
SOMLA SLED TESTS  
MEAN  $\pm$  1 SIGMA  
RUN A78-148 150 150 150 150 150  
418 418 418 418 418

Figure A-8 (continued). Seat back acceleration.



**CAMI**  
**SOMLA SLED TESTS**  
MEAN  $\pm$  I SIGMA  
RUN A78-84A 35A 36A 39A 40A  
41A 42A 43A 44A 45A



CAMI  
SOMLA SLED TESTS  
MEAN  $\pm$  1 SIGMA  
RUN A78-34A 35A 36A 37A 40A  
41A 42A 43A 44A 45A

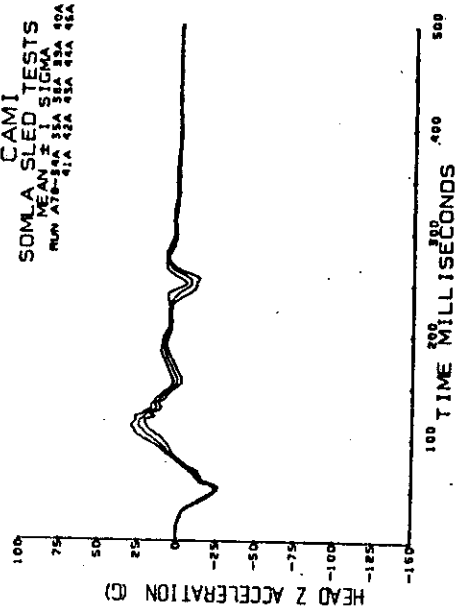
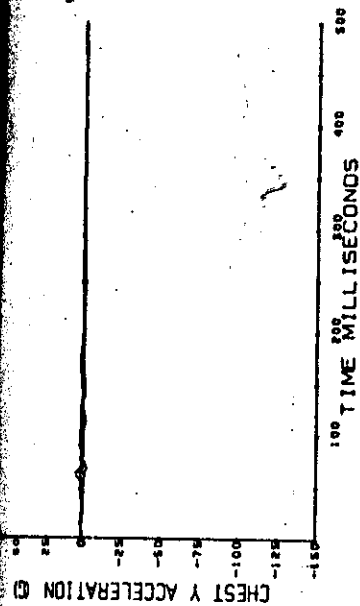
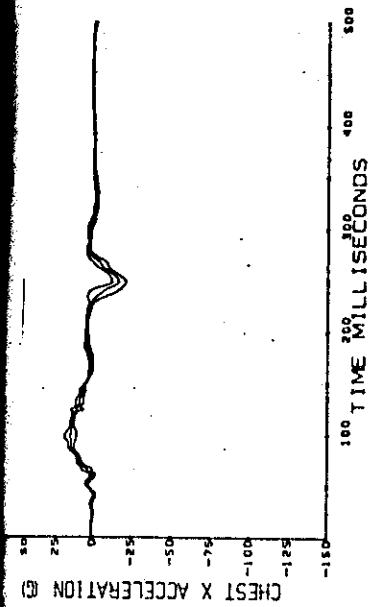


Figure A-8 (continued). Head acceleration.



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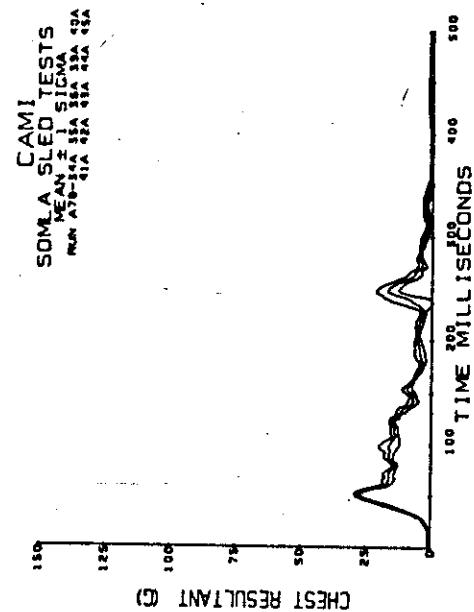
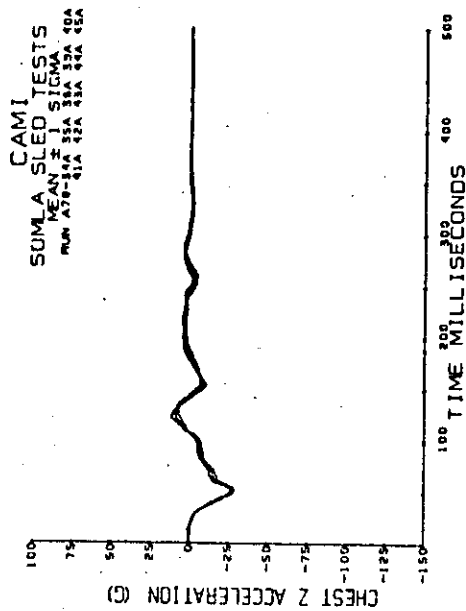


Figure A-8 (continued). Chest acceleration.



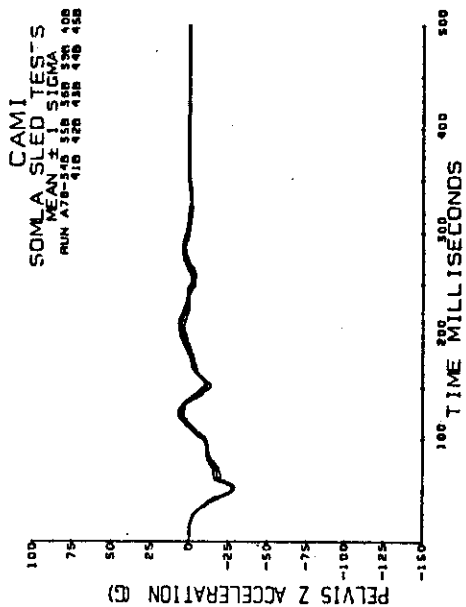
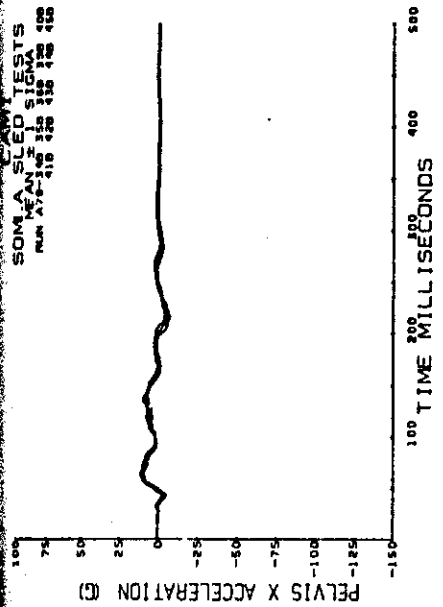
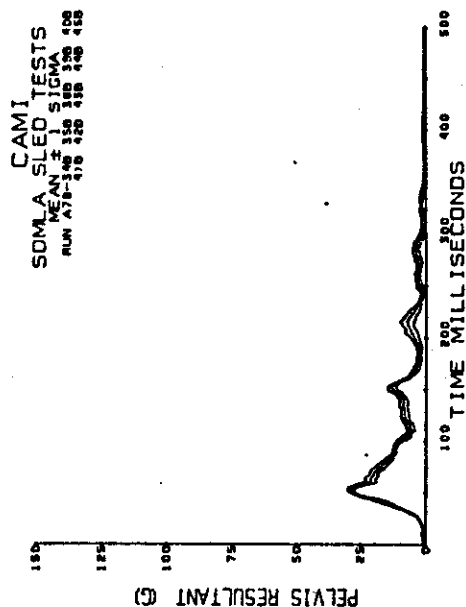
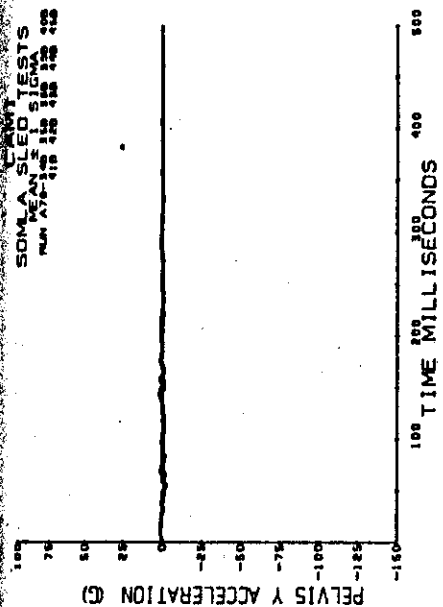


Figure A-8 (continued). Pelvis acceleration.

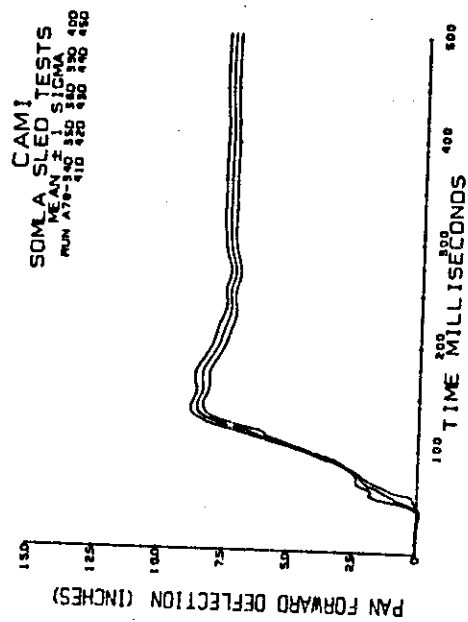


Figure A-8 (continued). Deflection data.

## APPENDIX B

### RESULTS OF DYNAMIC TESTS OF AN AFTERMARKET SHOULDER HARNESS

Figure No.

page

Tests 059, 060, and 061.  
Front seatbelt short and attached to the seat frame.  
Seatbelt loop length about 39 in with belt adjusted  
snugly against dummy.

B-1	6-g tests.	102
B-2	10-g tests.	108
B-3	14-g tests.	114

Tests 062 and 063.  
Conditions same as for Tests 059-061  
but with 70-in seatbelt loop length.

B-4	10-g tests.	120
B-5	14-g tests.	126

Tests 064, 065, and 066.  
Conditions same as for Tests 059-063  
but with 76-in seatbelt loop length  
(slack restraint system).

B-6	6-g tests.	132
B-7	10-g tests.	138
B-8	14-g tests.	144

RESULTS OF DYNAMIC TESTS OF AN AFTERMARKET SHOULDER HARNESS

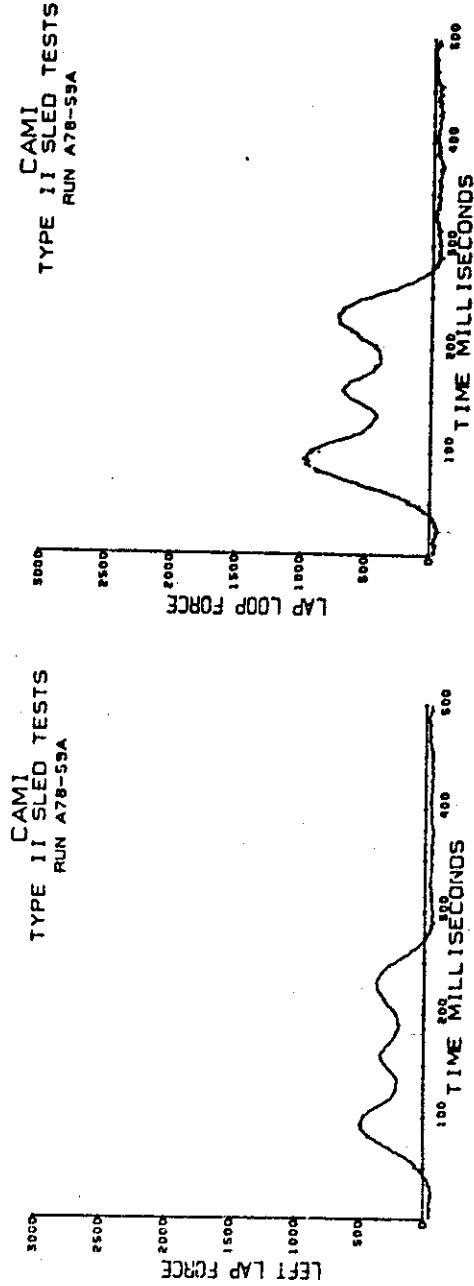
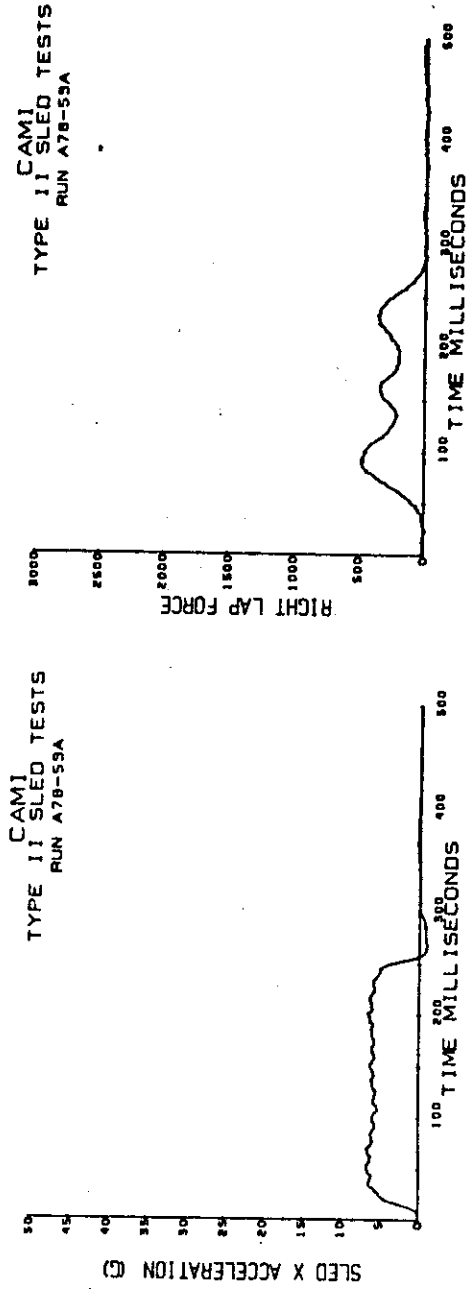
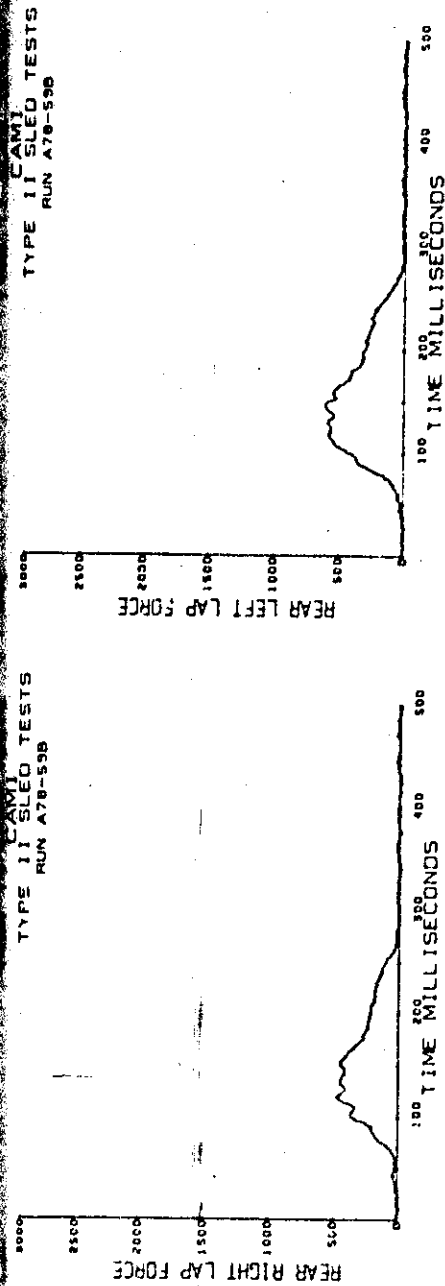


Figure B-1. 6-g tests.  
Sled deceleration and lapbelt loads.



CAMI  
TYPE II SLED TESTS  
RUN A78-598

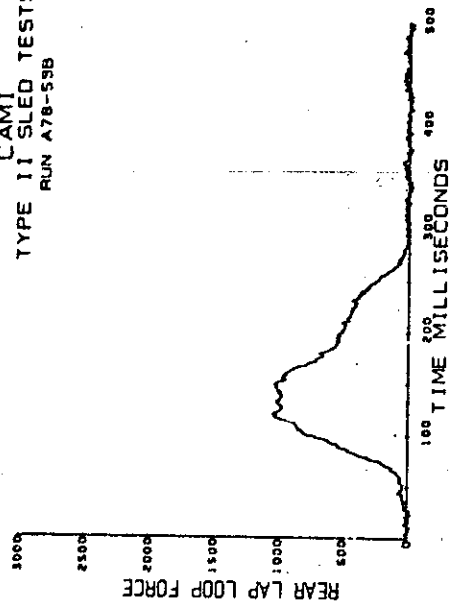
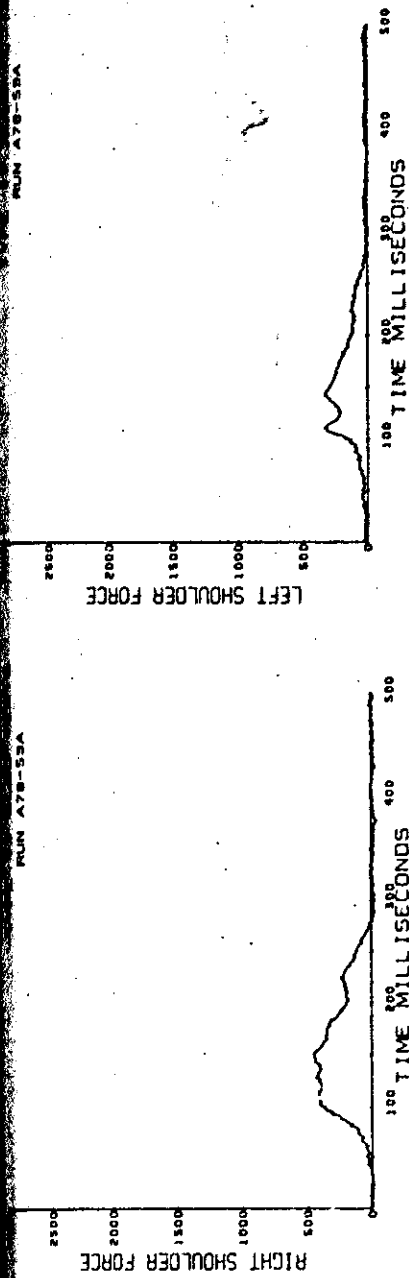


Figure B-1 (continued). Rear lapbelt loads.



CAMI  
TYPE II SLED TESTS  
RUN A78-55A

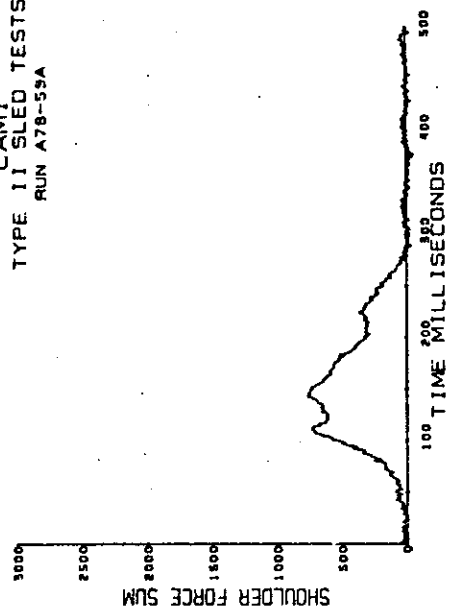


Figure B-1 (continued). Shoulder belt loads.

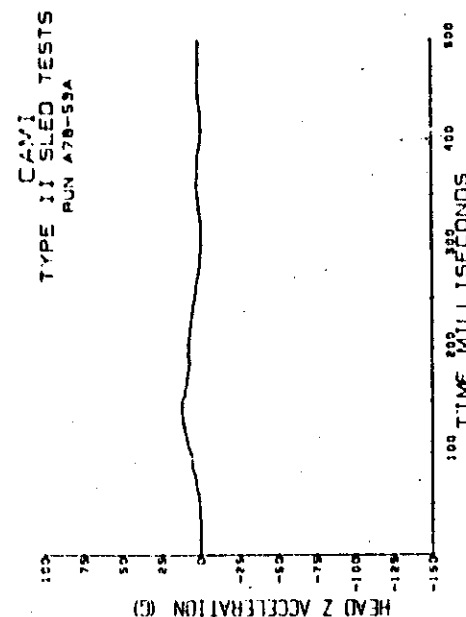
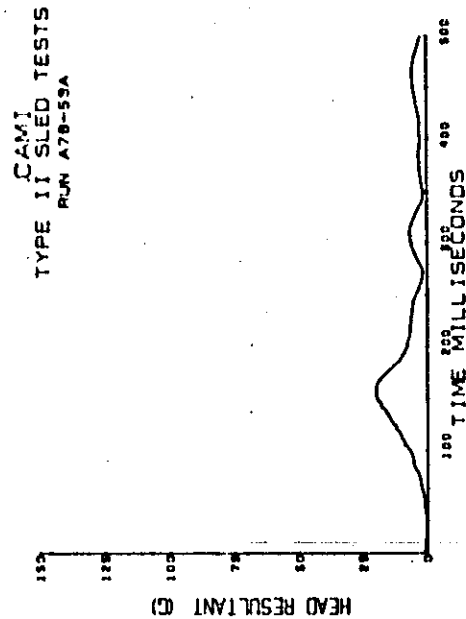
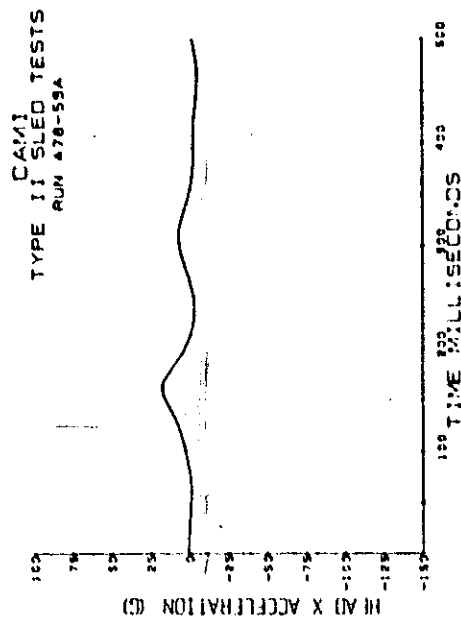
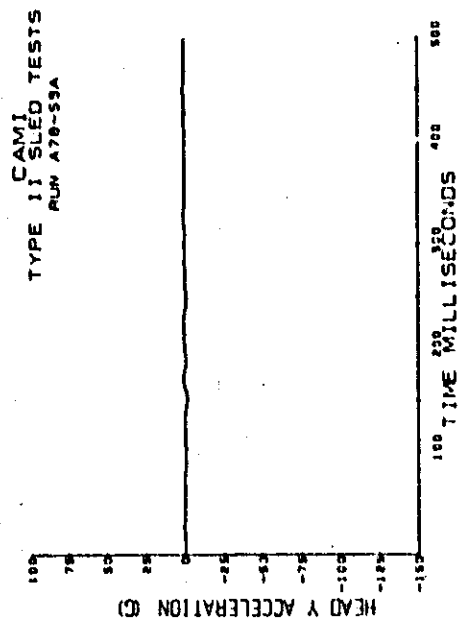


Figure B-1 (continued). Head acceleration.

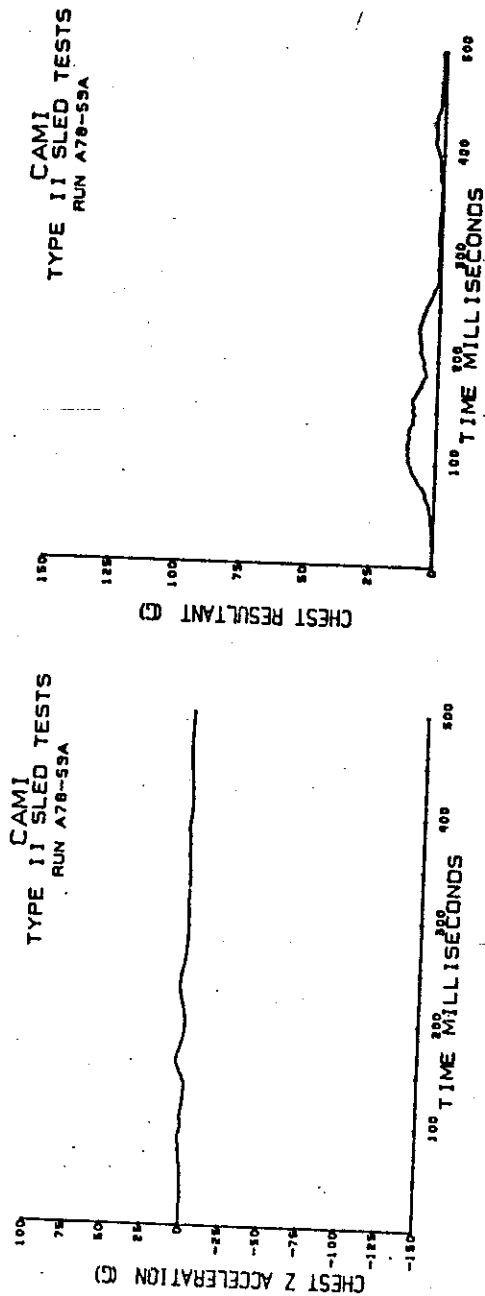
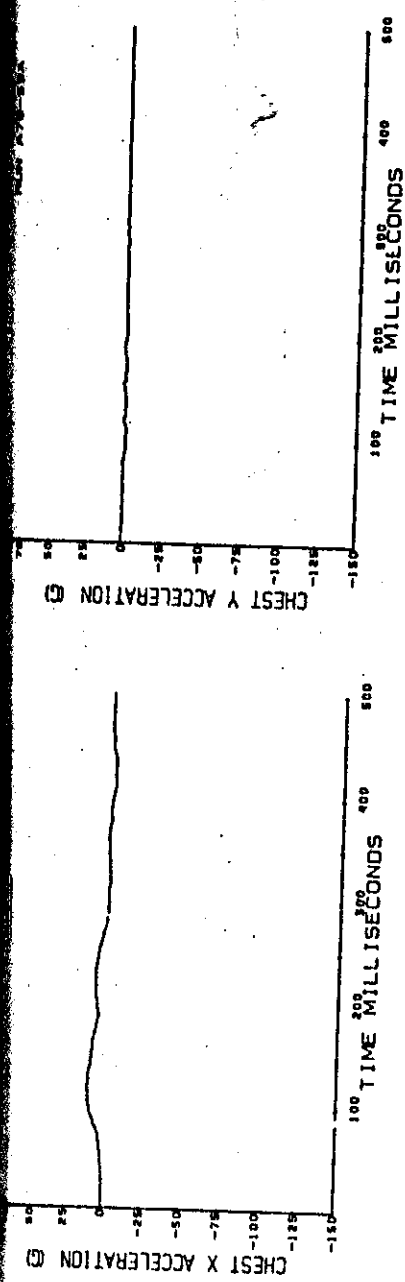
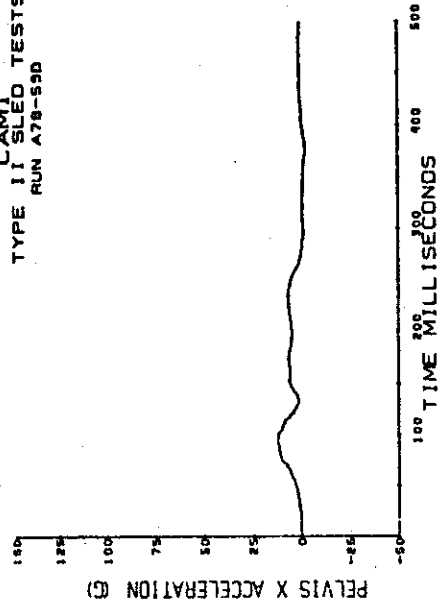


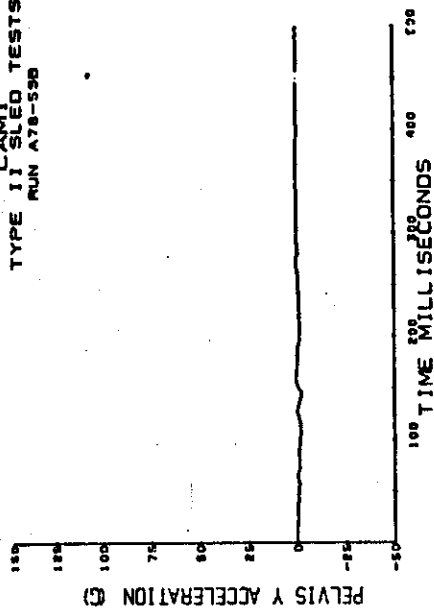
Figure B-1 (continued). Chest acceleration.



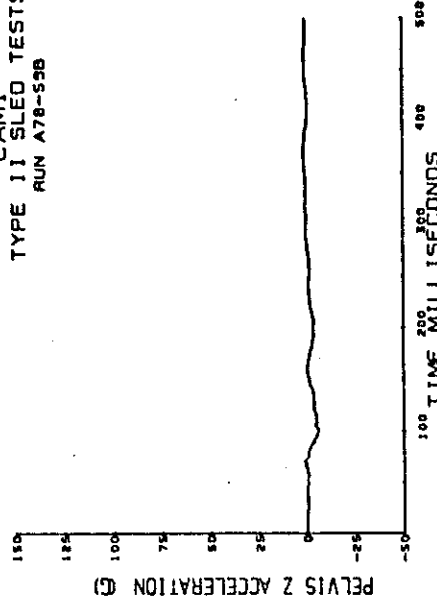
CAMI  
TYPE II SLED TESTS  
RUN A78-520



CAMI  
TYPE II SLED TESTS  
RUN A78-520



CAMI  
TYPE II SLED TESTS  
RUN A78-520



CAMI  
SOMLA SLED TESTS  
RUN A78-520

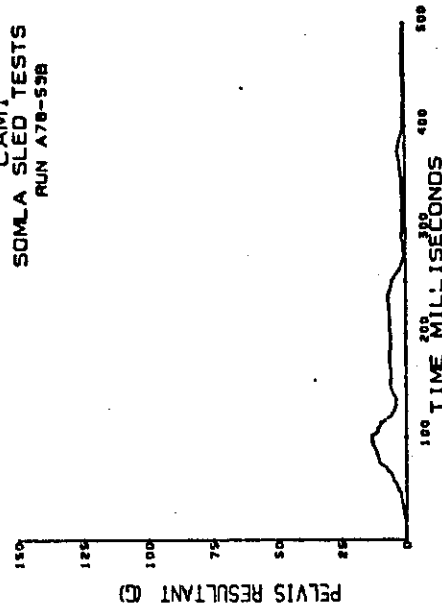
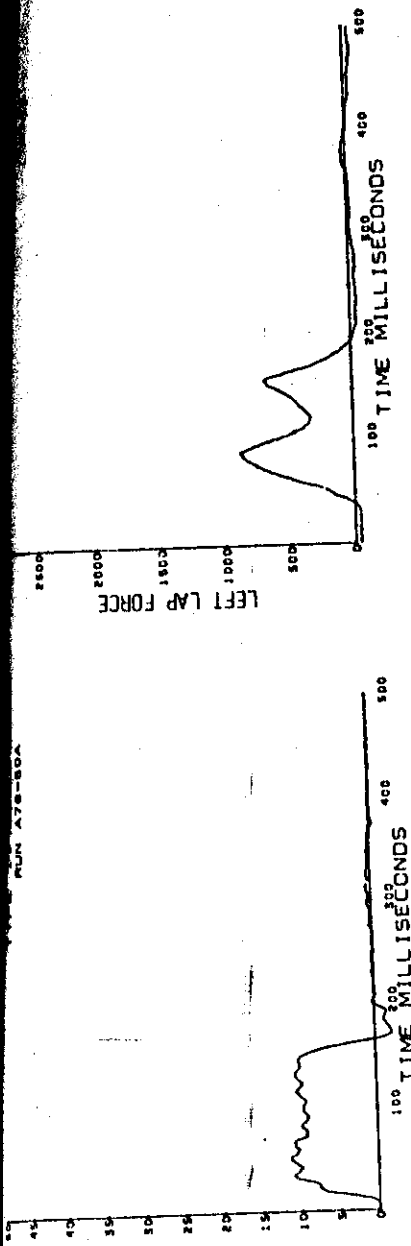


Figure B-1 (continued). Pelvis acceleration.

RUN A78-60A

SLED X ACCELERATION (G)

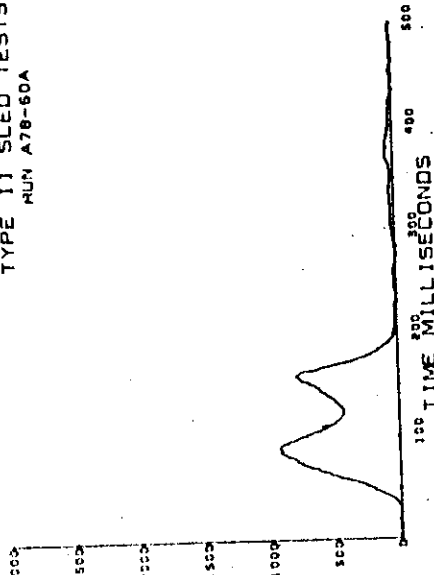


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CAMI  
TYPE II SLED TESTS  
RUN A78-60A

CAMI  
TYPE II SLED TESTS  
RUN A78-60A

RIGHT LAP FORCE



LAP LOOP FORCE

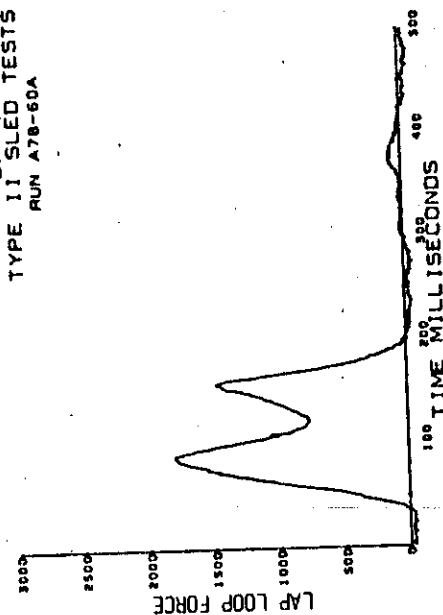
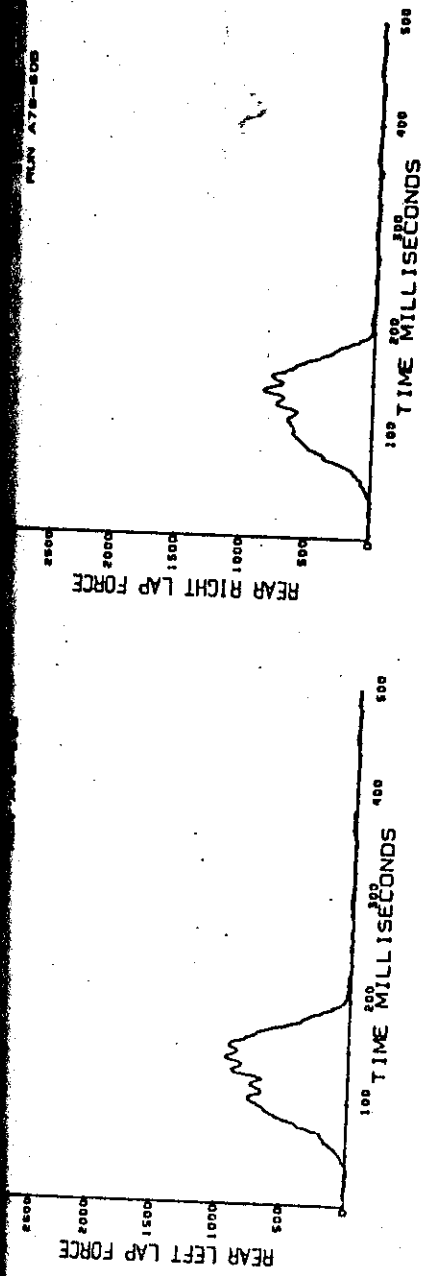


Figure B-2. 10-g tests.  
Sled acceleration and lapbelt forces.



CAMI  
TYPE II SLED TESTS  
RUN A78-608

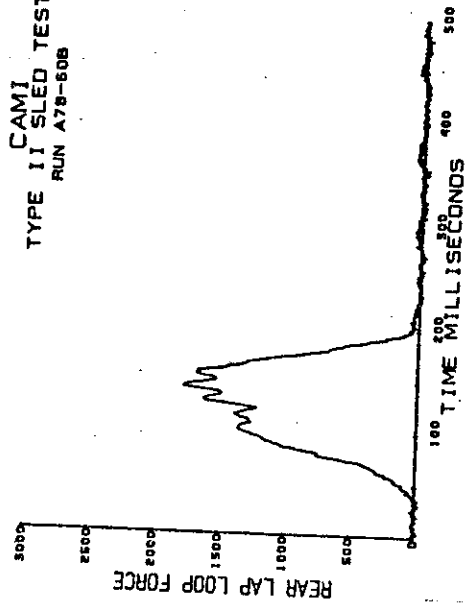
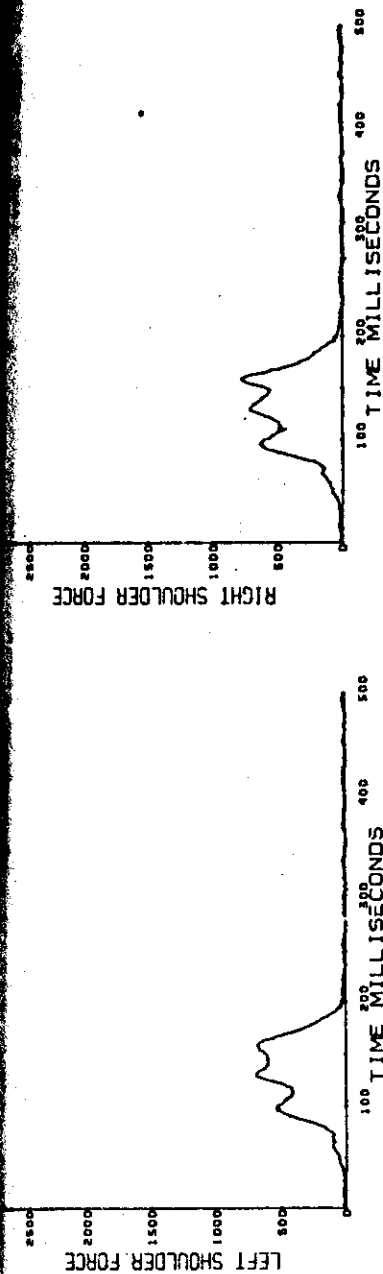


Figure B-2 (continued). Rear lapbelt loads.



CAMI  
TYPE II SLED TESTS  
RUN A78-60A

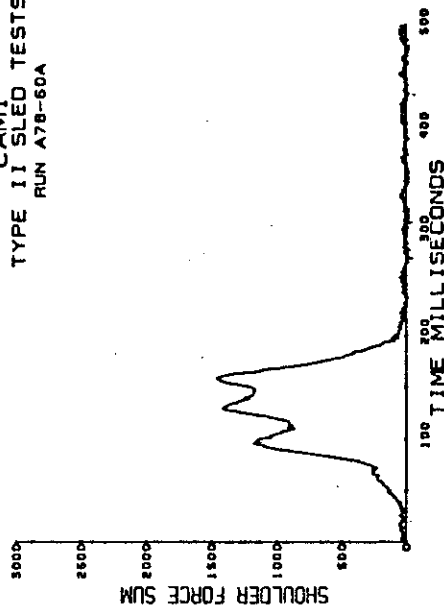
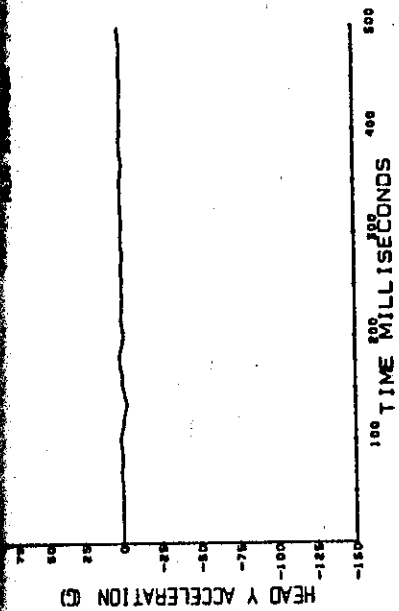
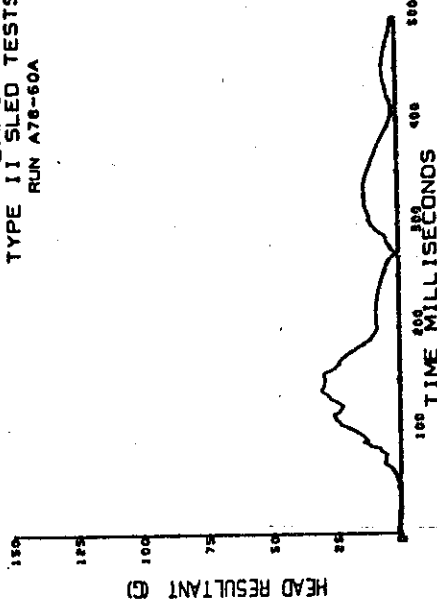


Figure B-2 (continued). Shoulder belt loads.



CAMI  
TYPE II SLED TESTS  
RUN A78-60A



CAMI  
TYPE II SLED TESTS  
RUN A78-60A

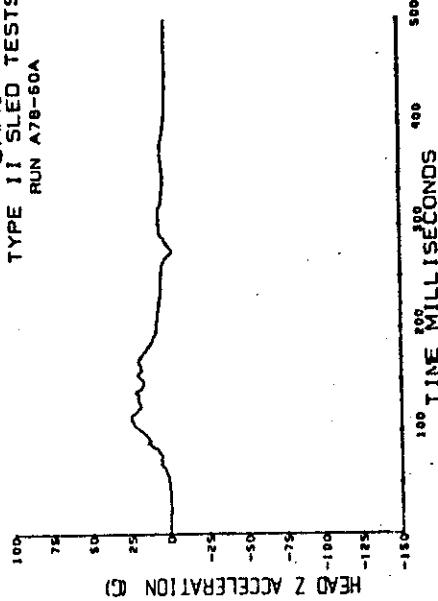
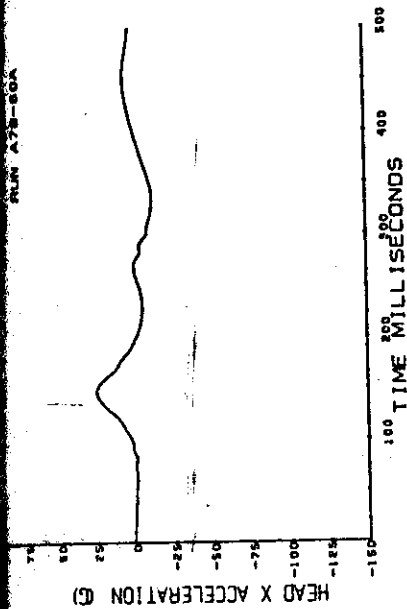


Figure B-2 (continued). Head  
acceleration.

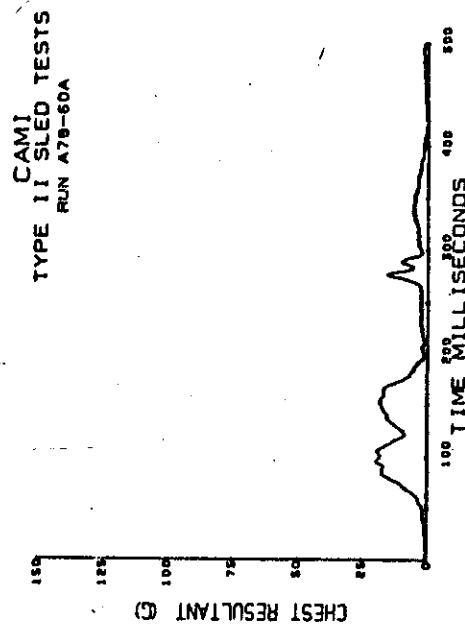
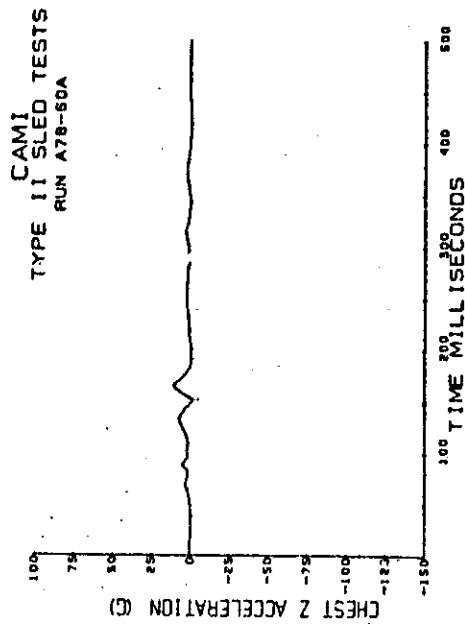
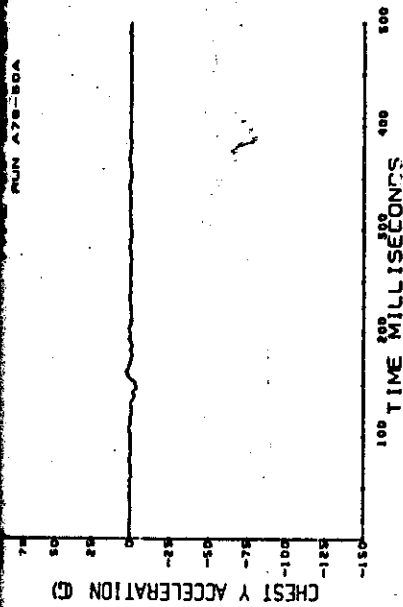
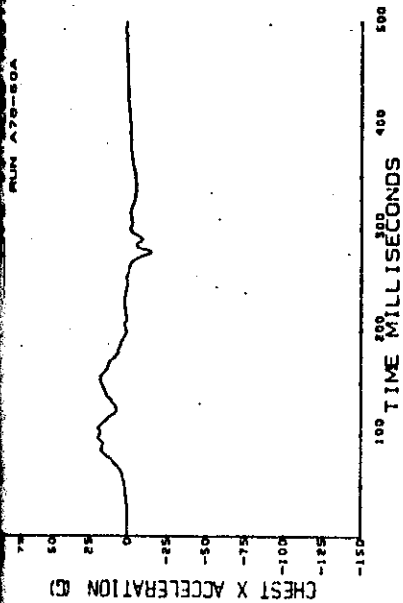
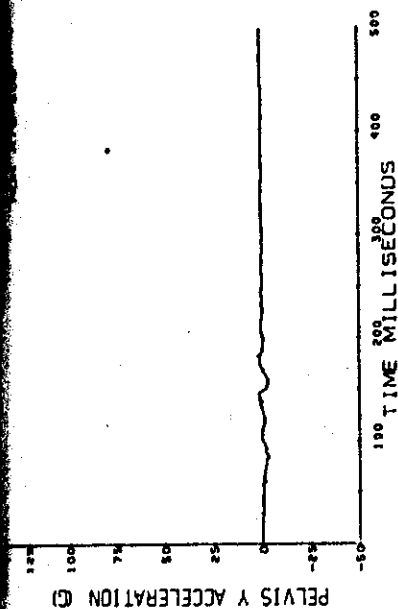
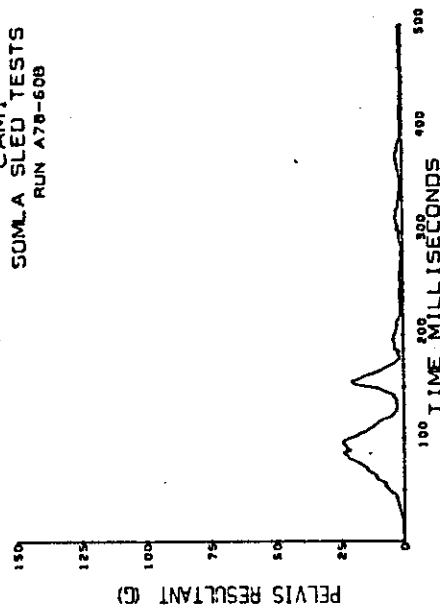


Figure B-2 (continued). Chest acceleration.



CAMI  
SUMMA SLED TESTS  
RUN A78-608



CAMI  
TYPE II SLED TESTS  
RUN A78-608

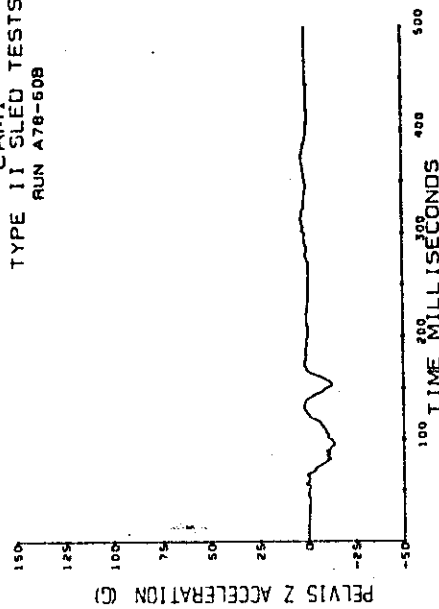
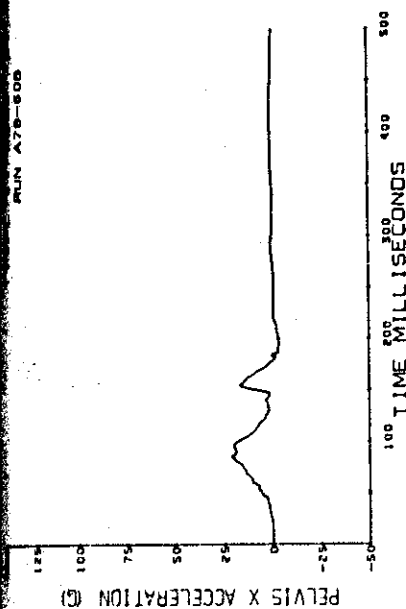
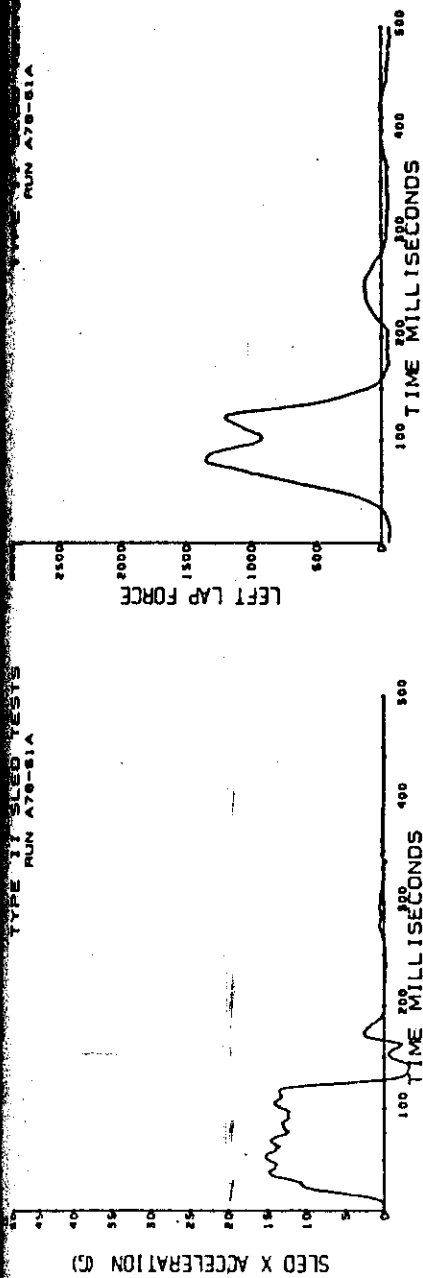


Figure B-2 (continued). Pelvis acceleration.



CAMI  
TYPE 17 SLED TESTS  
RUN A78-61A

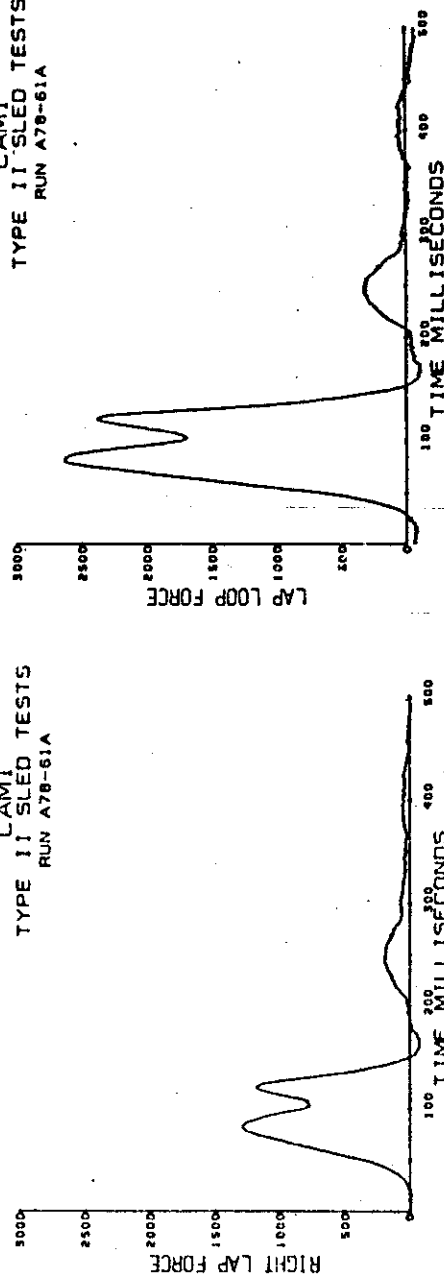


Figure B-3. 14-g tests.  
Sled acceleration and lapbelt loads.



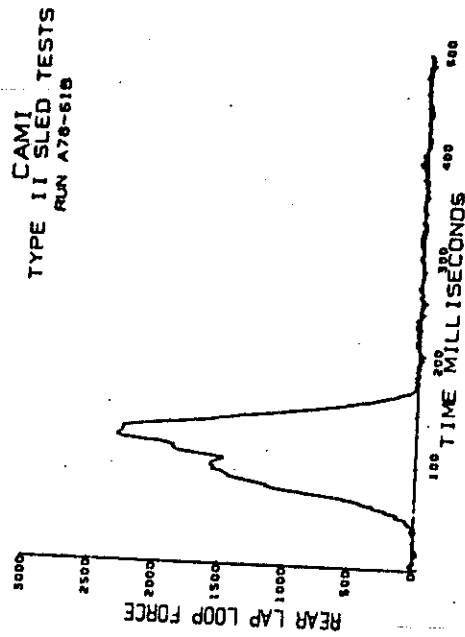
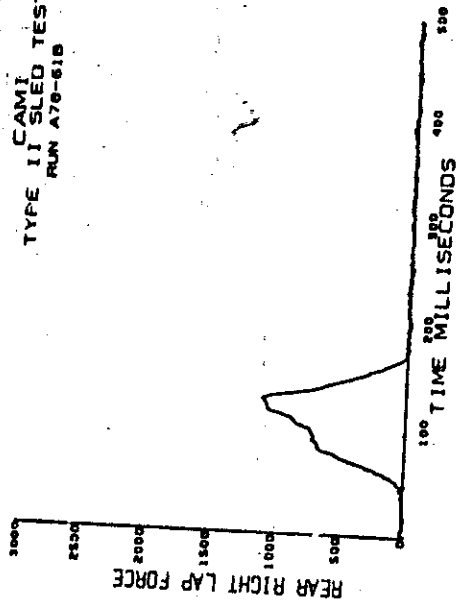
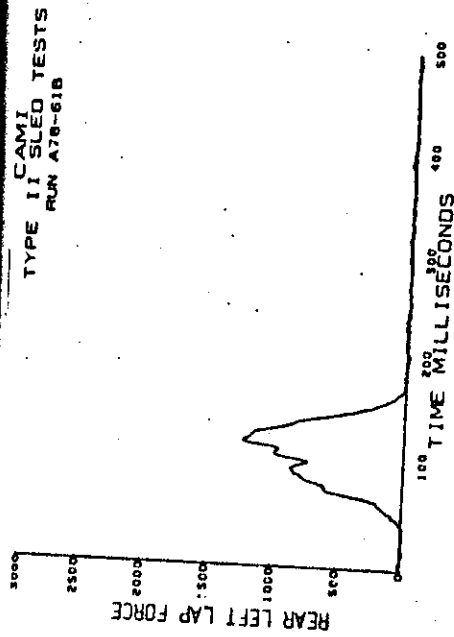
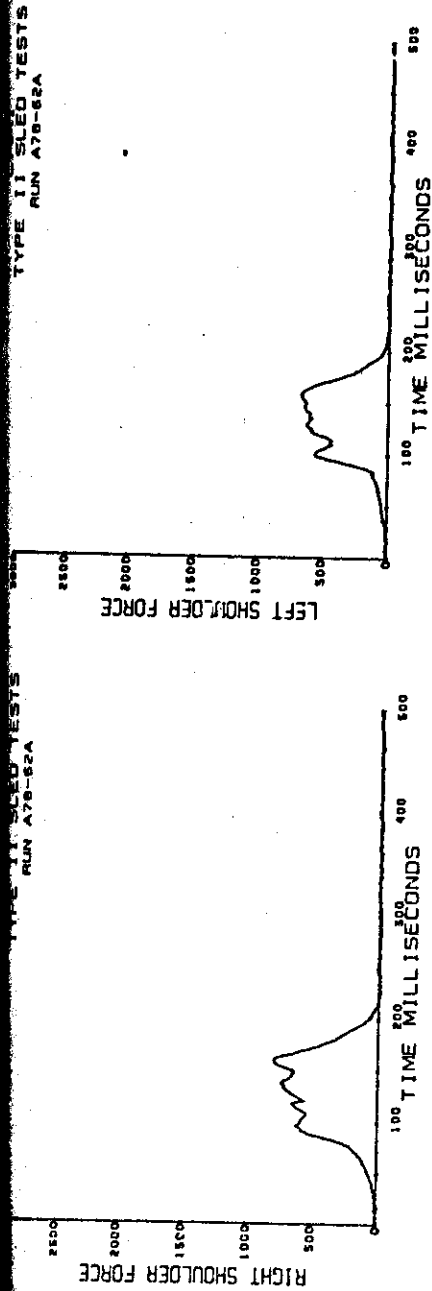


Figure B-3 (continued). Rear  
lapbelt loads.



CAMI  
TYPE II SLED TESTS  
RUN A78-62A

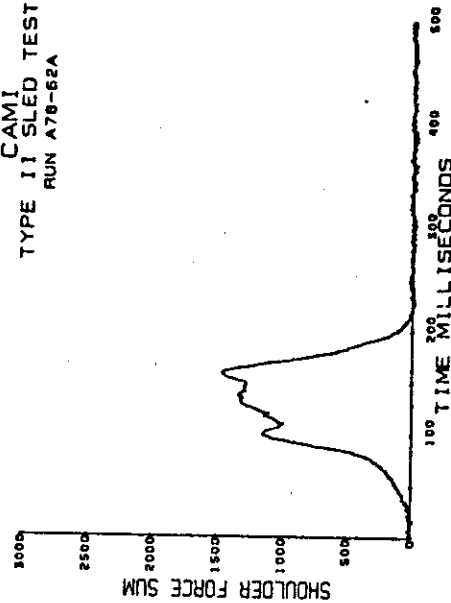


Figure B-3 (continued). Shoulder  
belt loads.

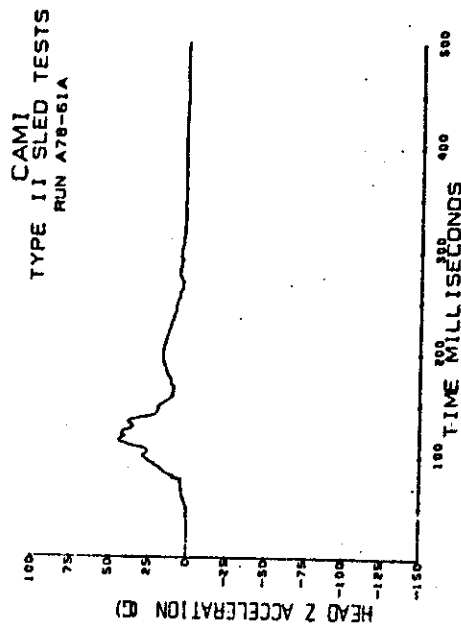
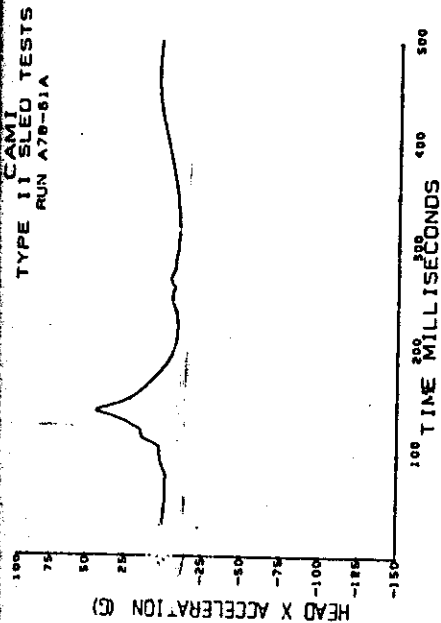
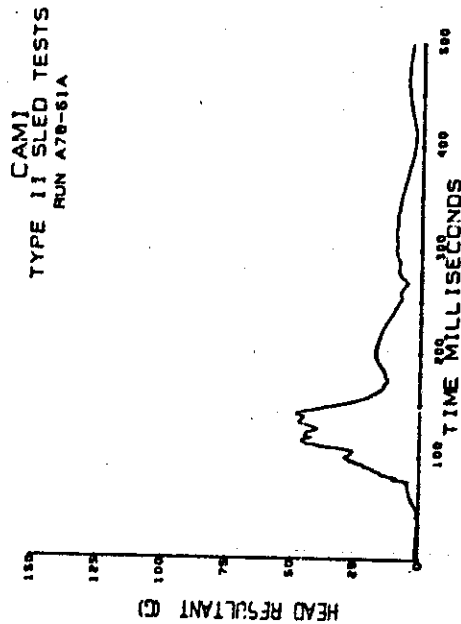
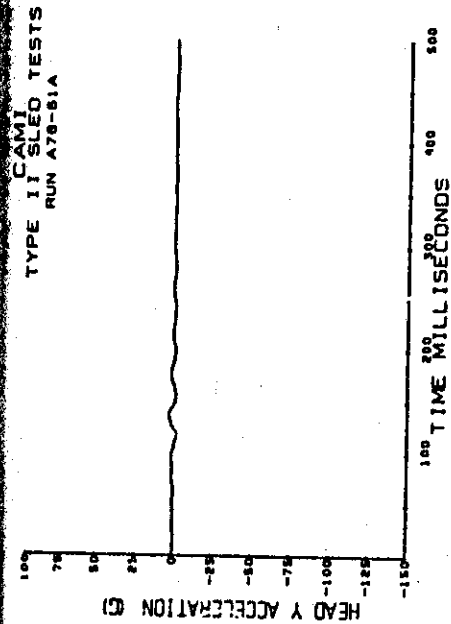
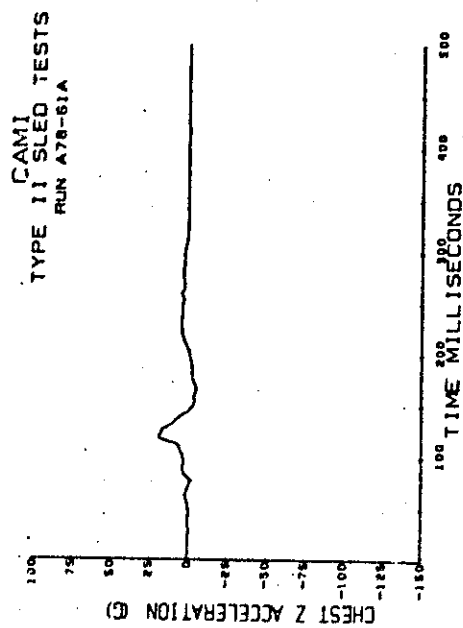
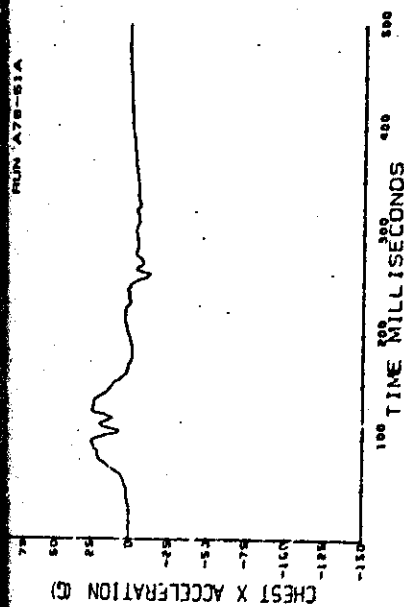
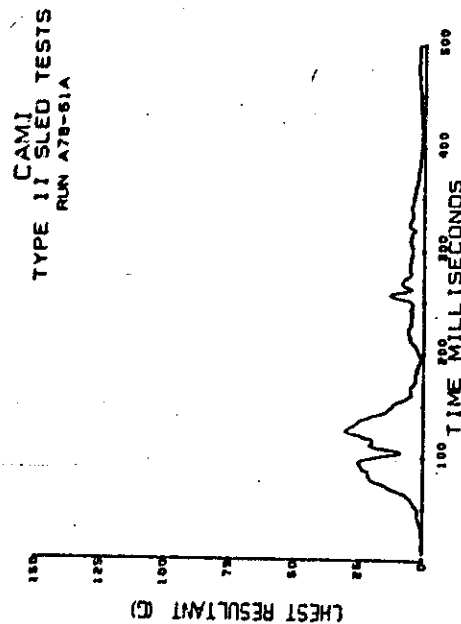
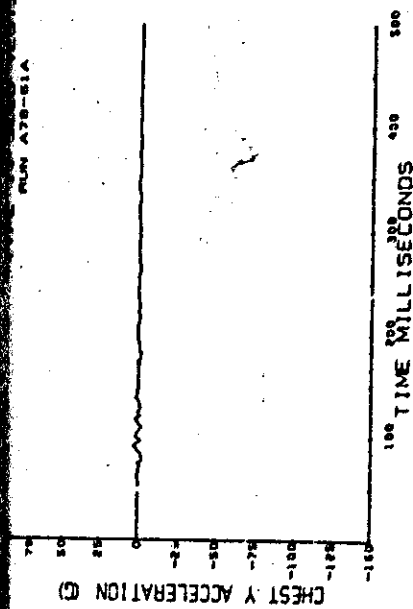


Figure B-3 (continued). Head acceleration.



-gure B-3 (continued). Chest acceleration.

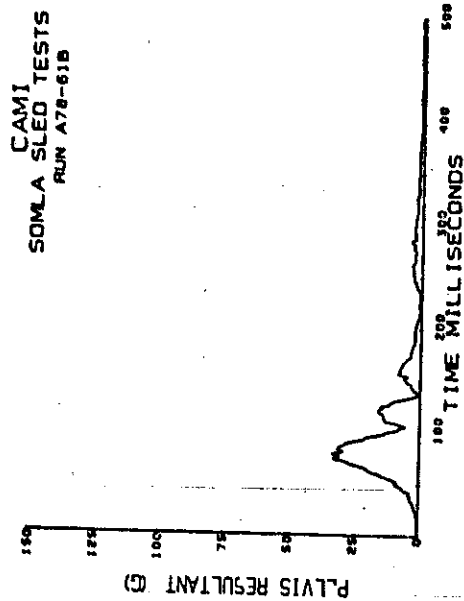
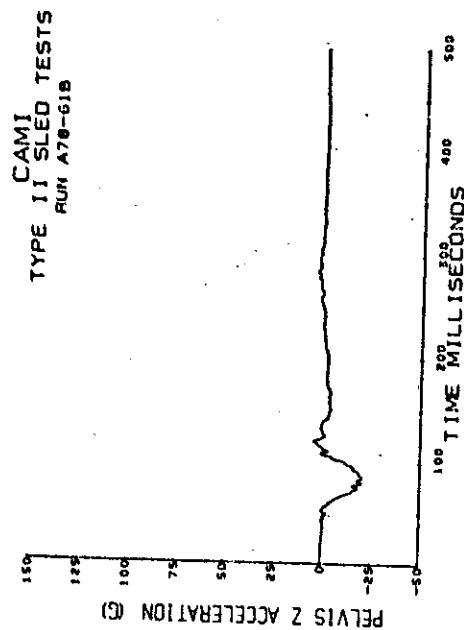
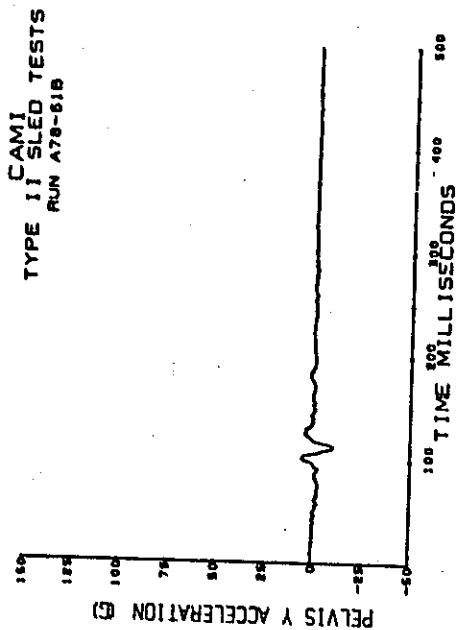
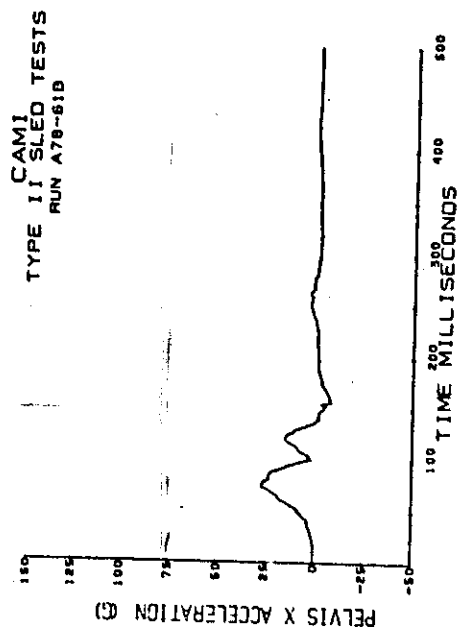
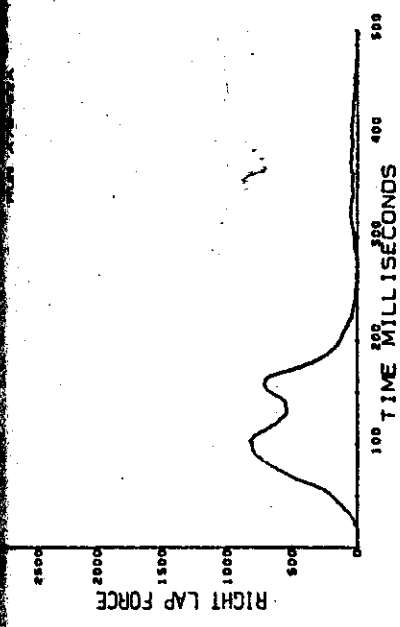
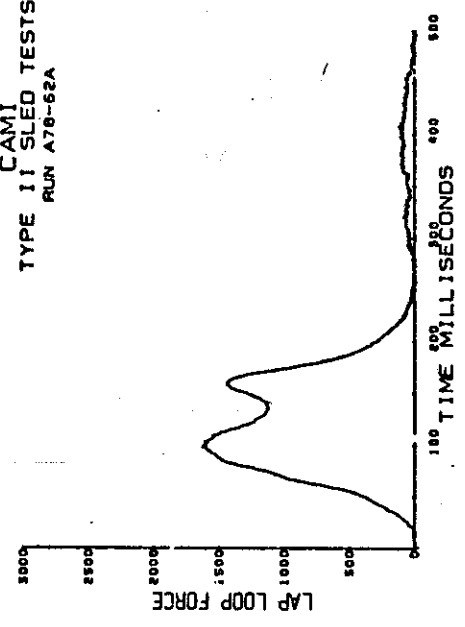


Figure B-3 (continued). Pelvis acceleration.



CAMI  
TYPE II SLED TESTS  
RUN A78-62A



CAMI  
TYPE II SLED TESTS  
RUN A78-62A

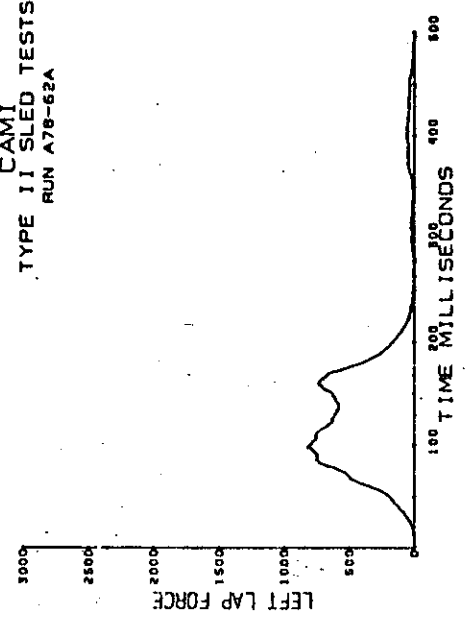
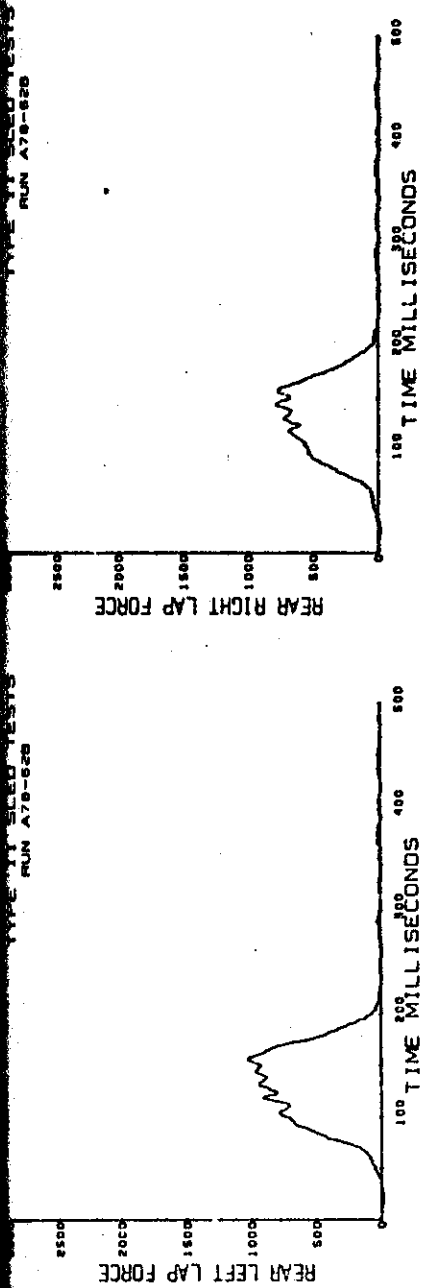


Figure B-4. 10-g tests.  
Sled acceleration and lapbelt loads.



CAMI  
TYPE II SLED TESTS  
RUN A78-629

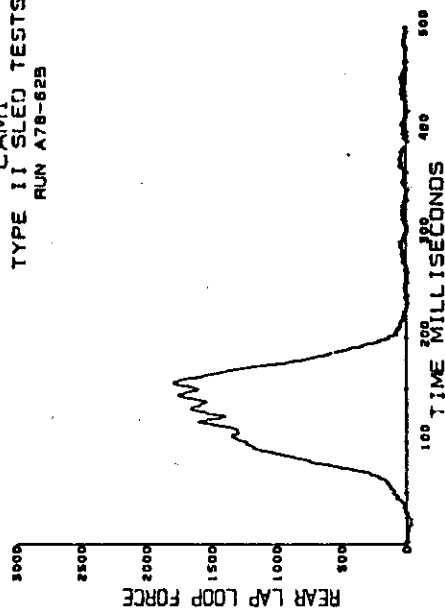
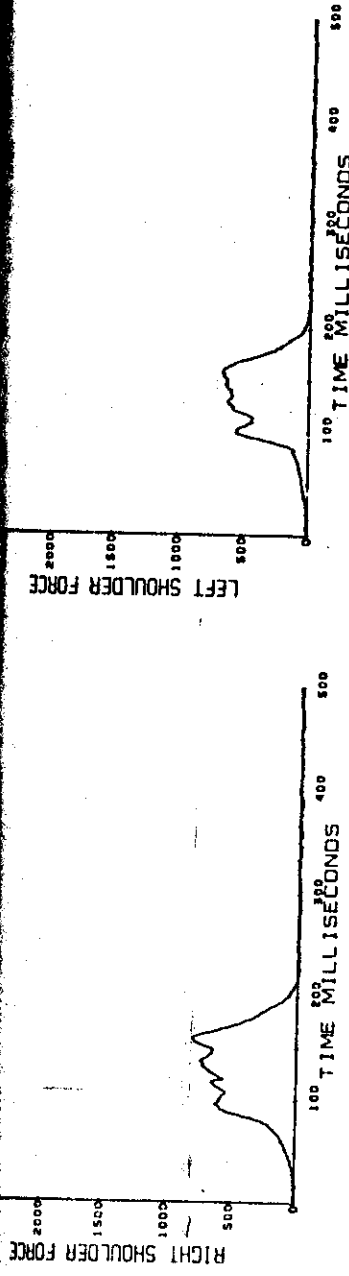


Figure B-4 (continued). Rear  
lapbelt loads.



CAMI  
TYPE II SLED TESTS  
RUN A78-62A

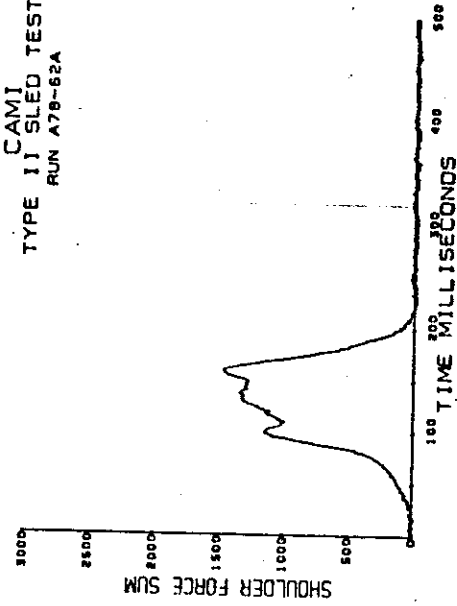


Figure B-4 (continued). Shoulder belt loads.



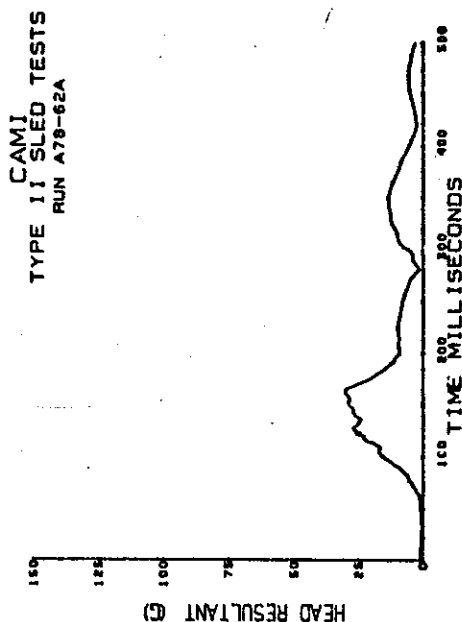
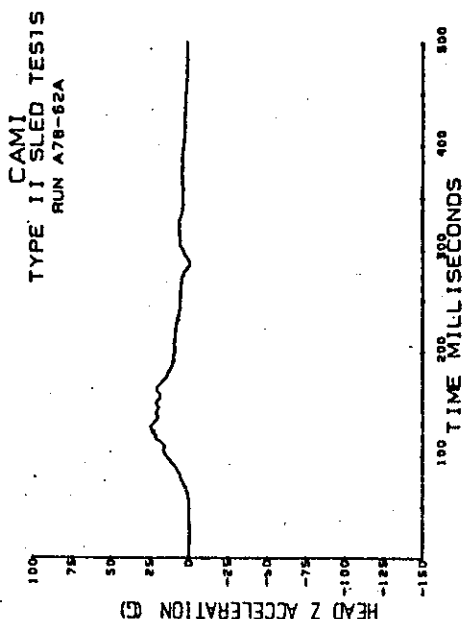
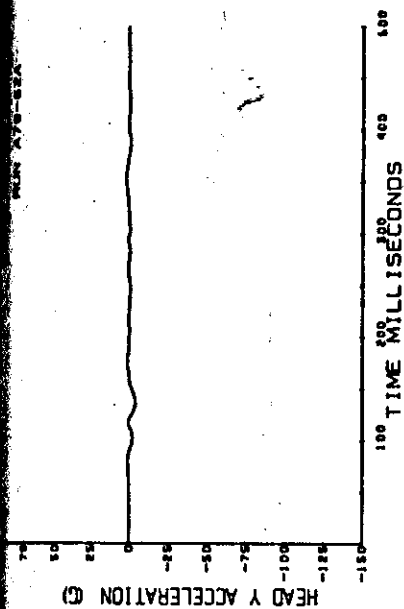
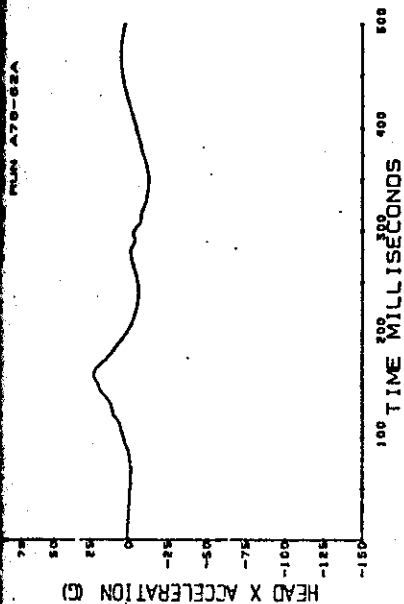
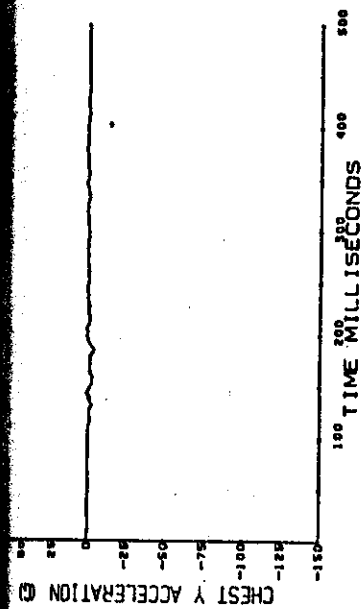
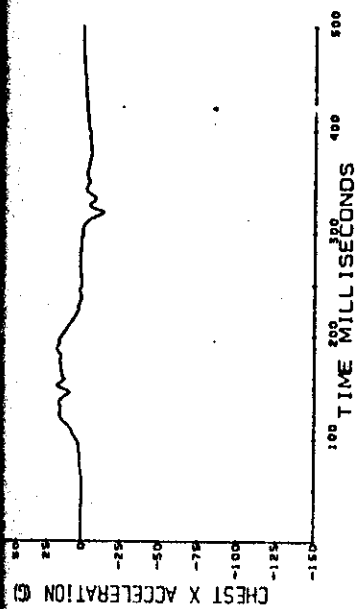
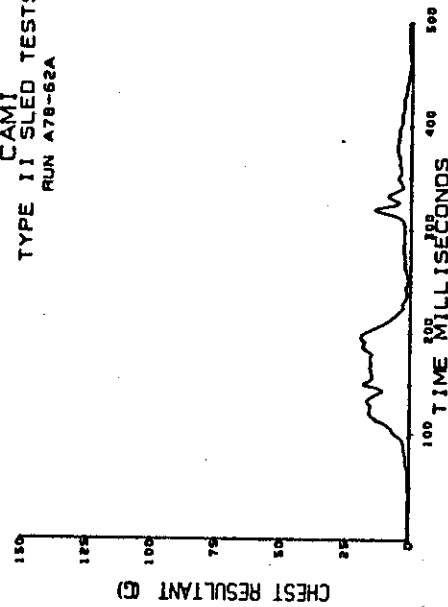


Figure B-4 (continued). Head acceleration.



CAMI  
TYPE II SLED TESTS  
RUN A78-52A



CAMI  
TYPE II SLED TESTS  
RUN A78-52A

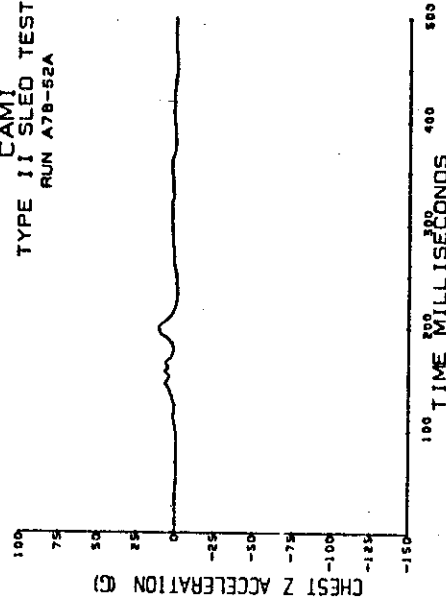


Figure B-4 (continued). Chest acceleration.

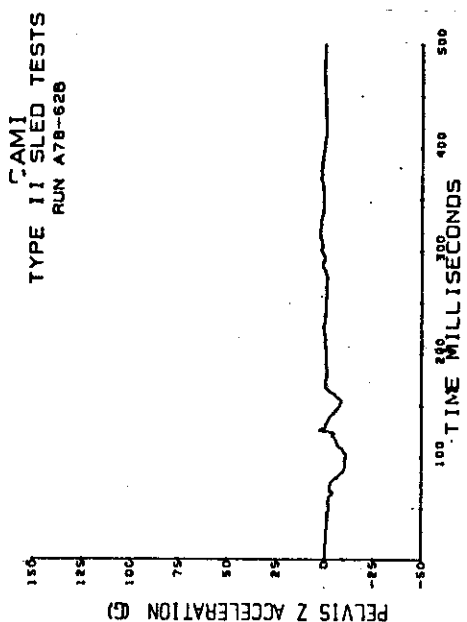
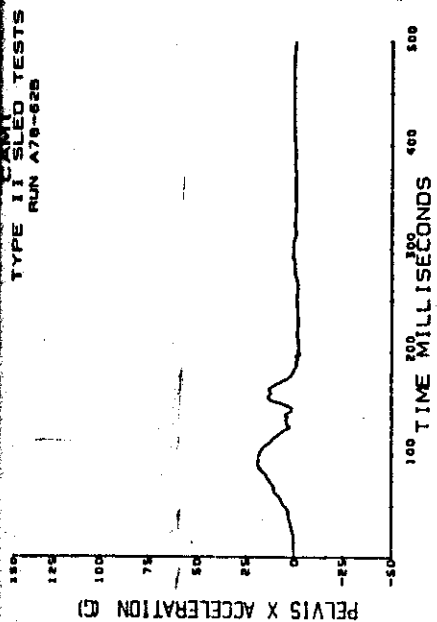
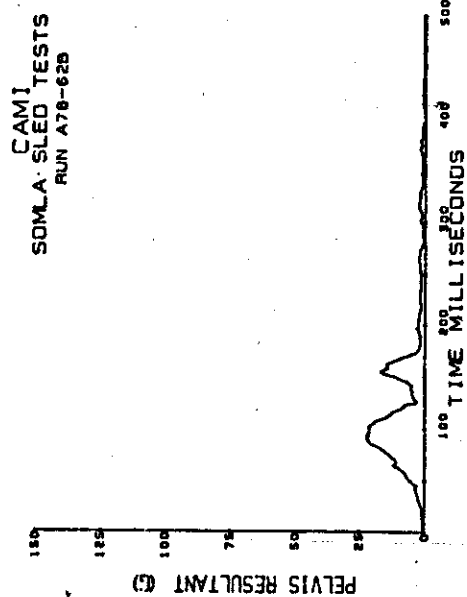
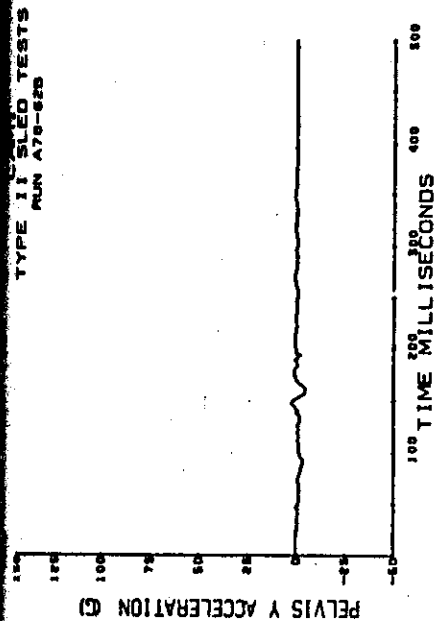
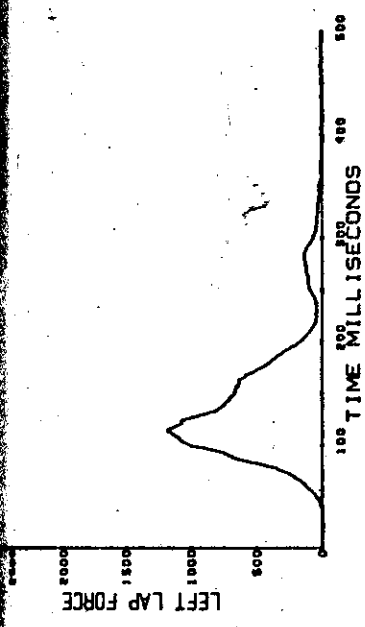
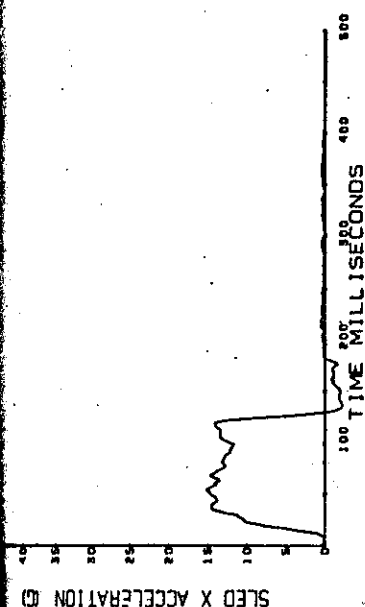


Figure B-4 (continued). Pelvis acceleration.



CAMI  
TYPE II SLED TESTS  
RUN A78-63A

CAMI  
TYPE II SLED TESTS  
RUN A78-63A

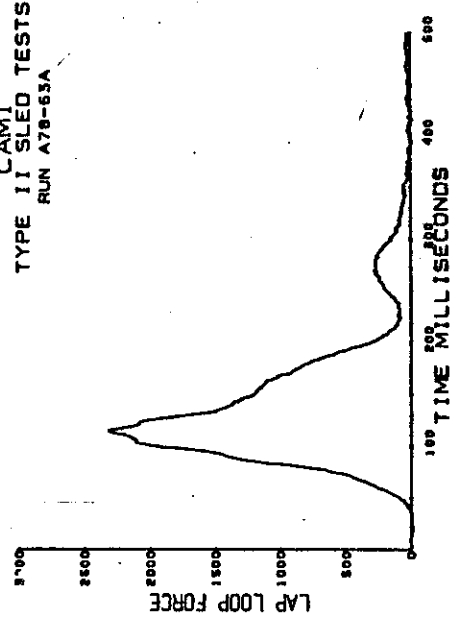
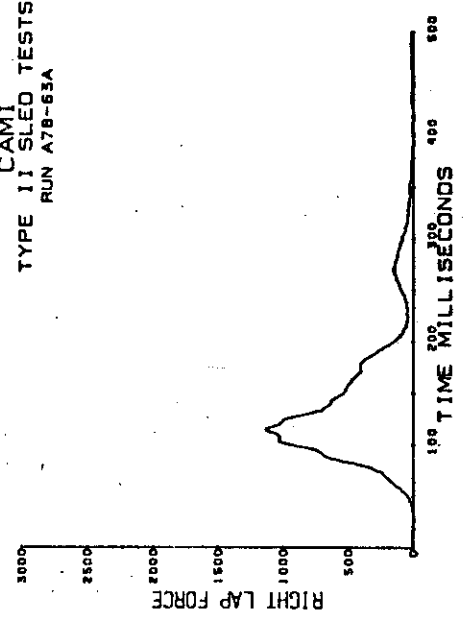
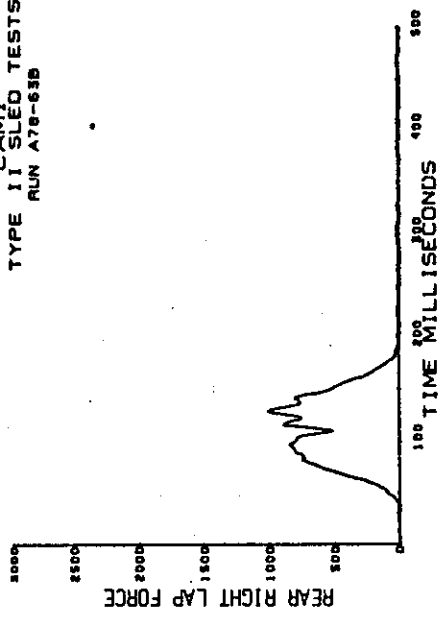
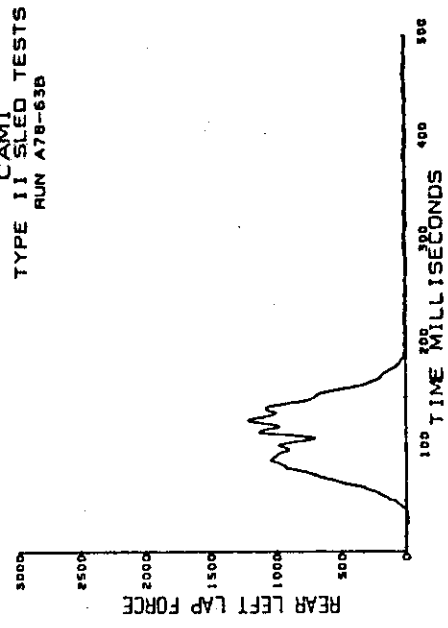


Figure B-5. 14-g tests.  
Sled acceleration and lapbelt loads.

CAMI  
TYPE II SLED TESTS  
RUN A78-63B



CAMI  
TYPE II SLED TESTS  
RUN A78-63B



CAMI  
TYPE II SLED TESTS  
RUN A78-63B

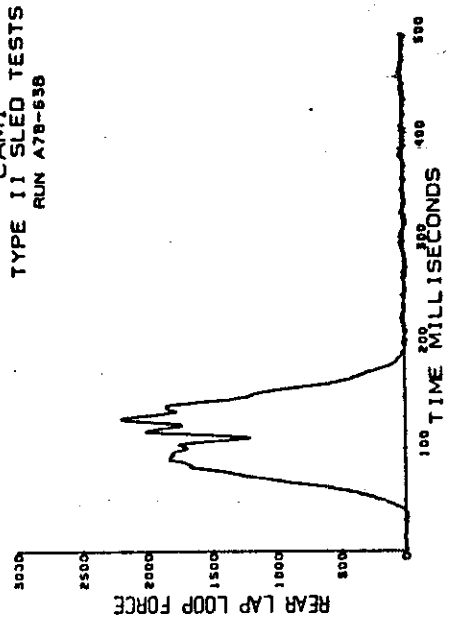
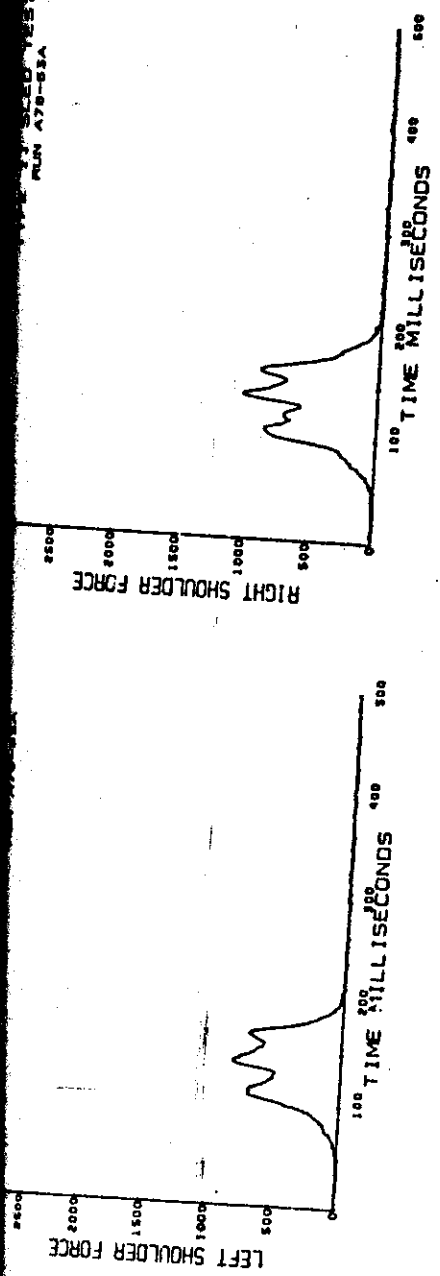


Figure B-5 (continued). Rear lapbelt loads.

TYPE II SLED TESTS  
RUN A78-63A



CAMI  
TYPE II SLED TESTS  
RUN A78-63A

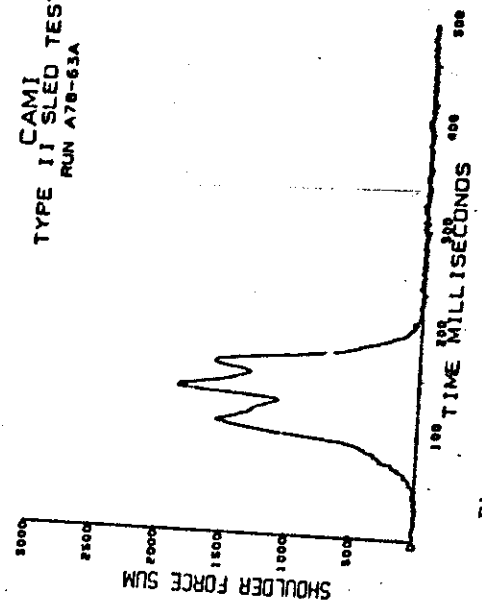
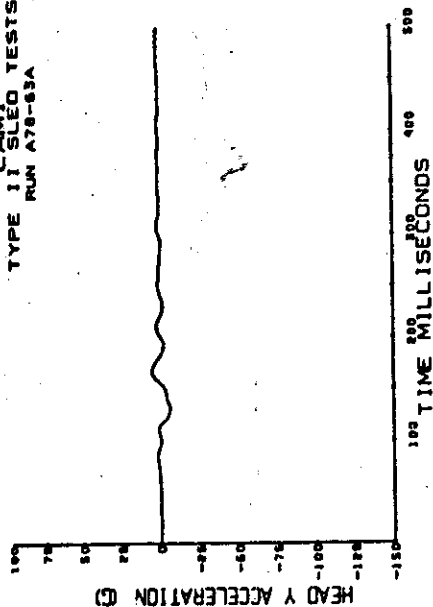
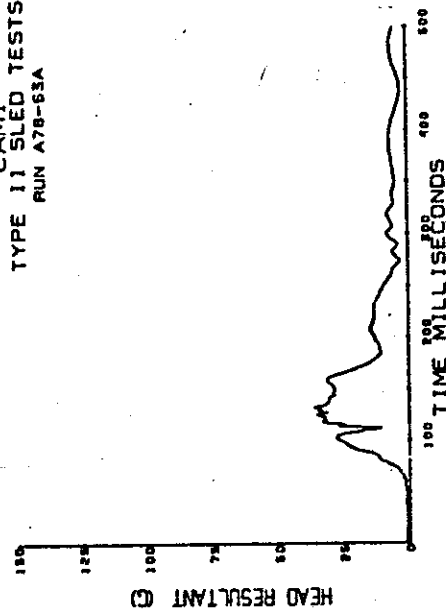


Figure B-5 (continued). Shoulder belt loads.

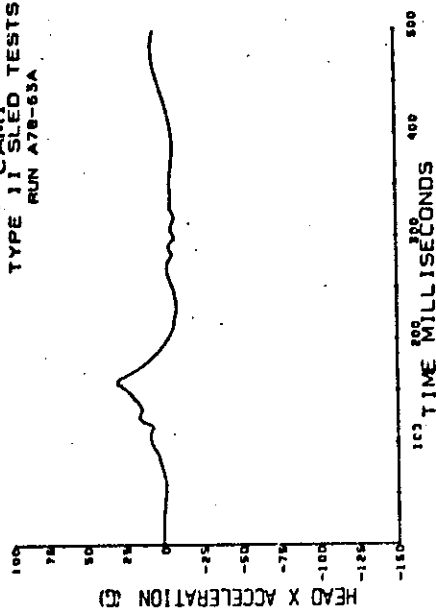
CAMI  
TYPE II SLED TESTS  
RUN A78-63A



CAMI  
TYPE II SLED TESTS  
RUN A78-63A



CAMI  
TYPE II SLED TESTS  
RUN A78-63A



CAMI  
TYPE II SLED TESTS  
RUN A78-63A

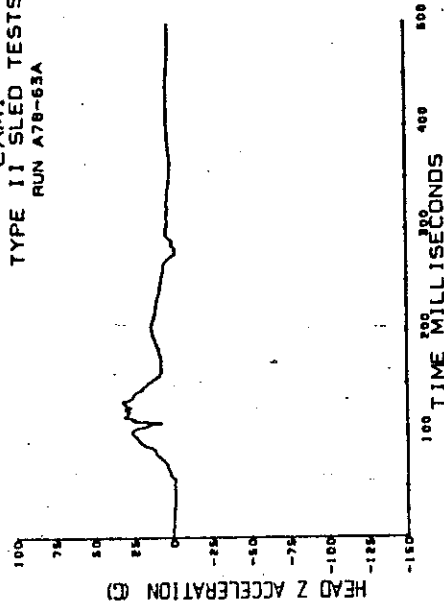
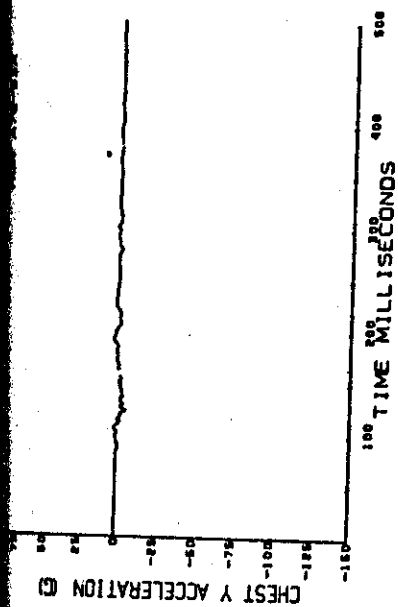


Figure B-5 (continued). Head acceleration.



CAMI  
TYPE 11 SLED TESTS  
RUN A78-63A

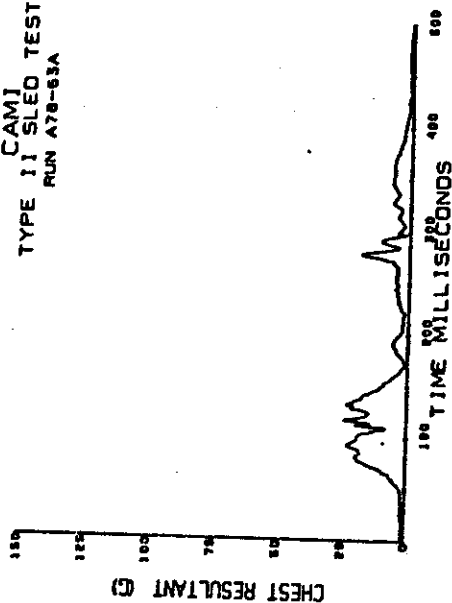
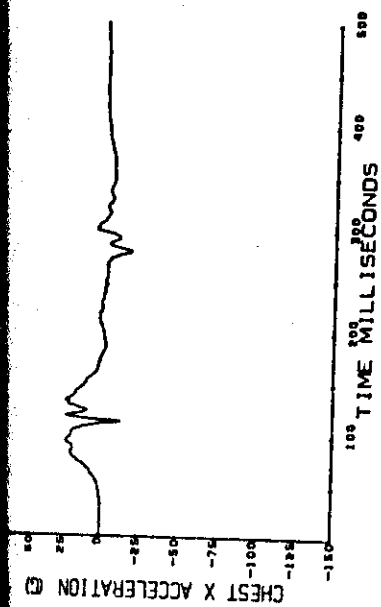
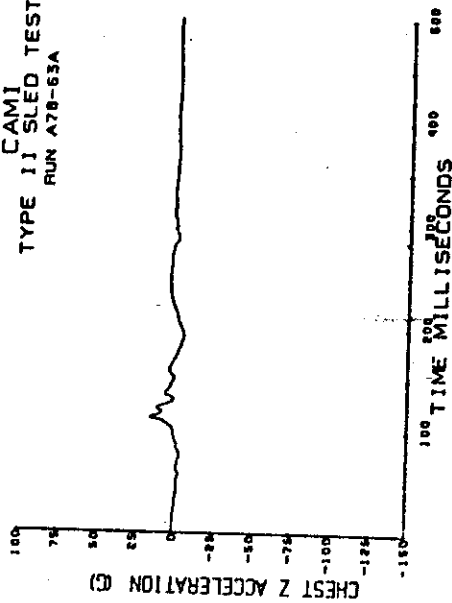


Figure B-5 (continued). Chest acceleration.



CAMI  
TYPE 11 SLED TESTS  
RUN A78-63A





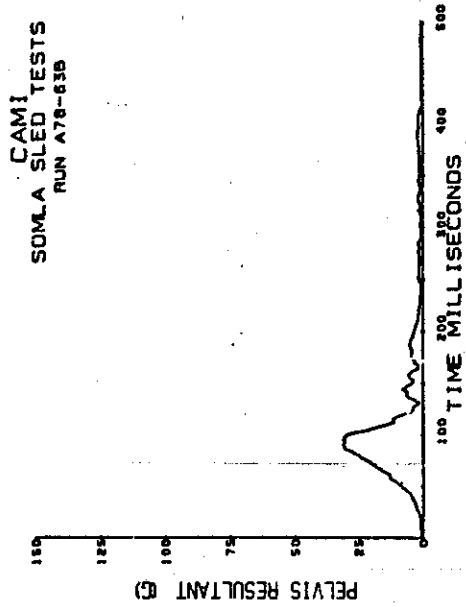
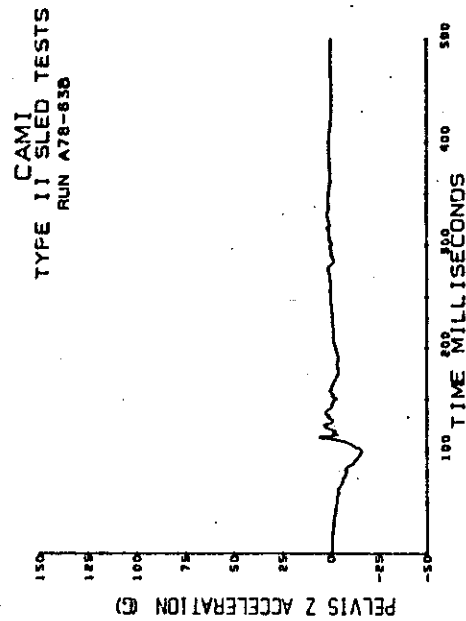
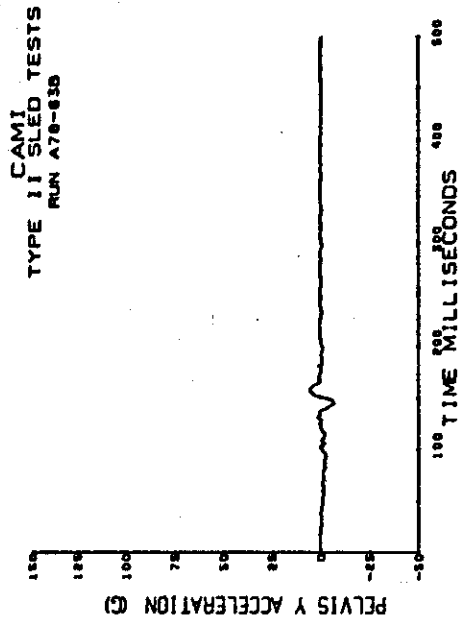
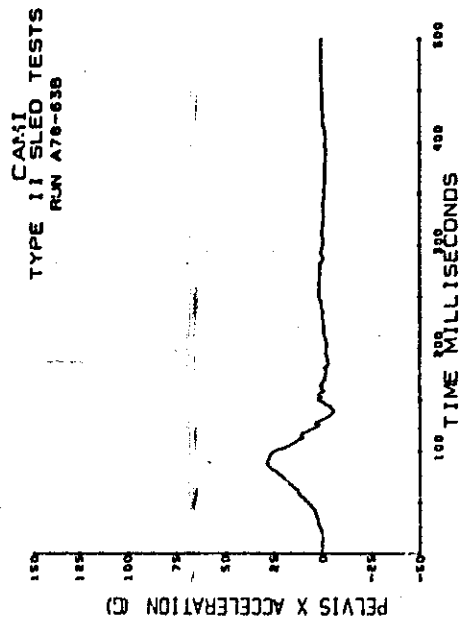
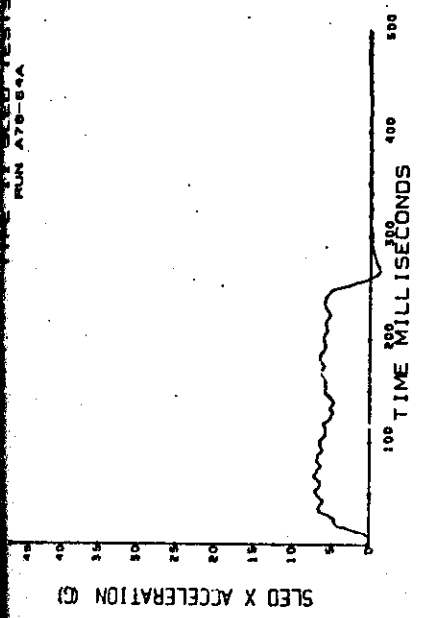
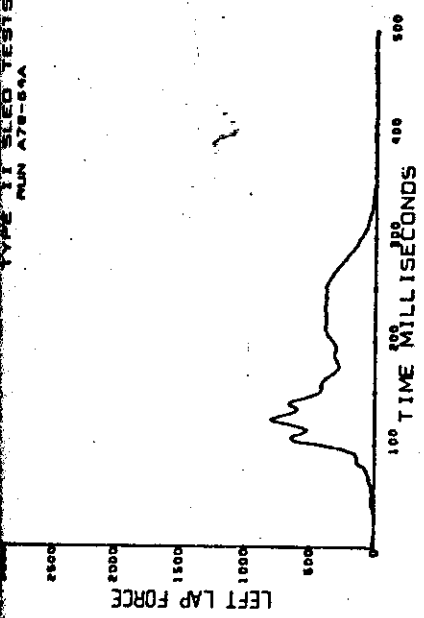


Figure B-5 (continued). Pelvis acceleration.

TYPE II SLED TESTS  
RUN A78-64A

TYPE II SLED TESTS  
RUN A78-64A



CAMI  
TYPE II SLED TESTS  
RUN A78-64A

CAMI  
TYPE II SLED TESTS  
RUN A78-64A

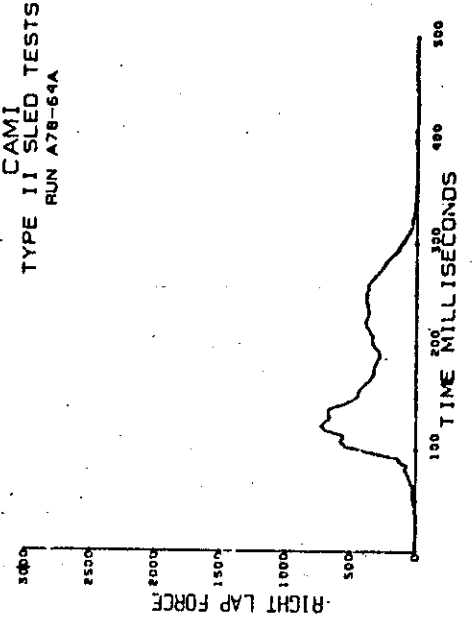
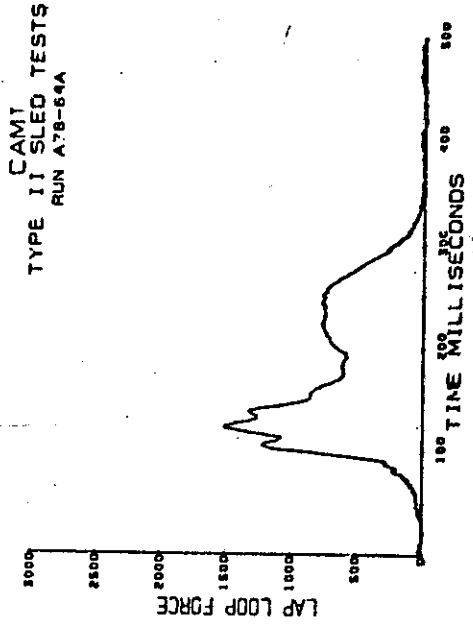
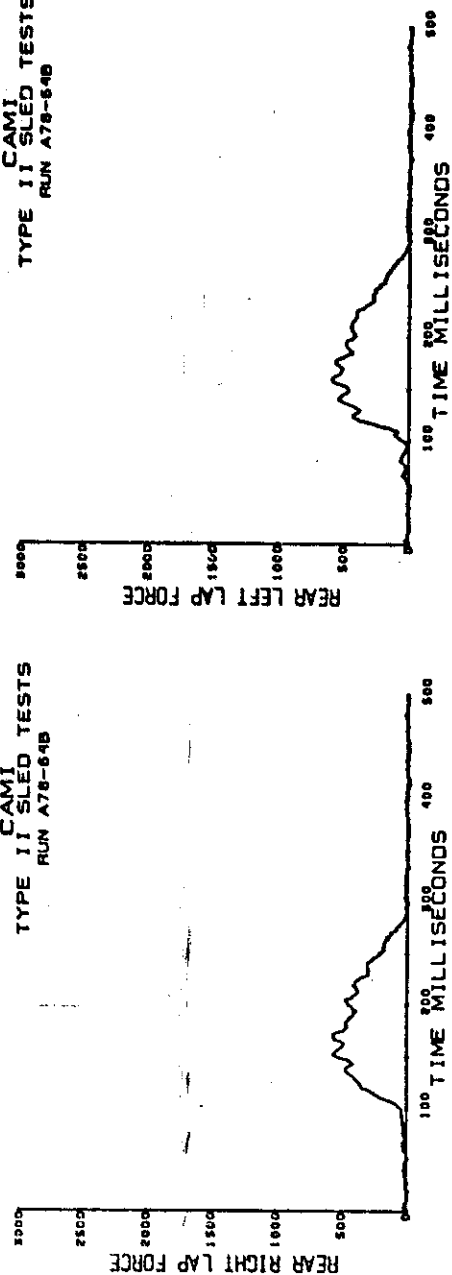


Figure B-6. 6-8 tests.  
Sled acceleration and lapbelt loads.

CAMI  
TYPE II SLED TESTS  
RUN A78-64B



CAMI  
TYPE II SLED TESTS  
RUN A78-64B

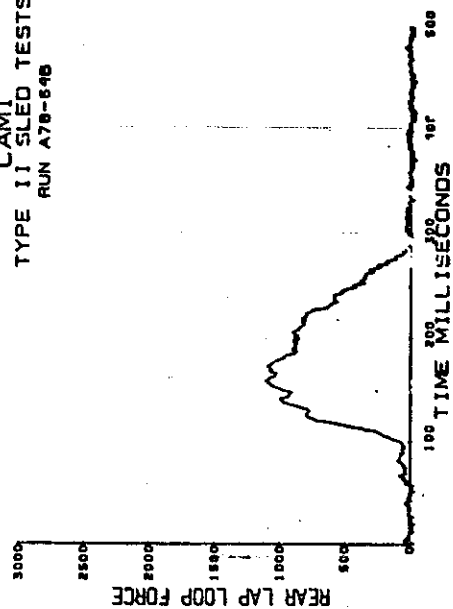
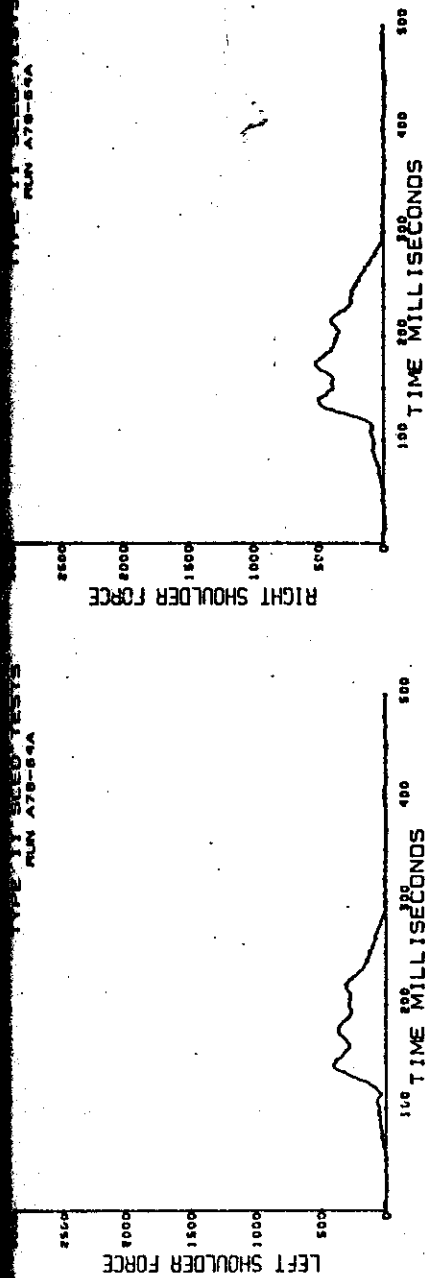


Figure B-6 (continued). Rear  
lapbelt loads.

TYPE II SLED TESTS  
RUN A78-84A

TYPE II SLED TESTS  
RUN A78-84A



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CAMI  
TYPE II SLED TESTS  
RUN A78-84A

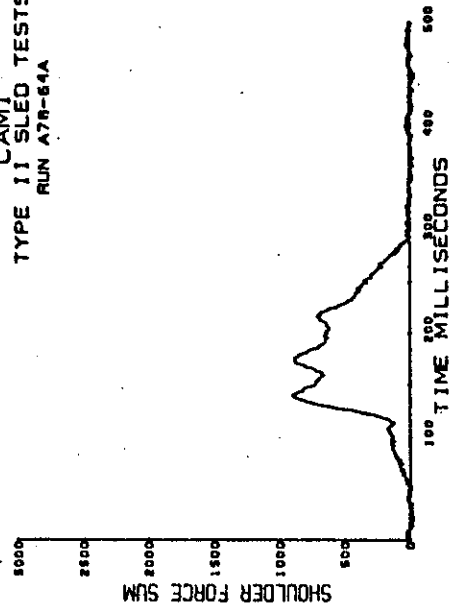


Figure B-6 (continued). - Shoulder belt loads.

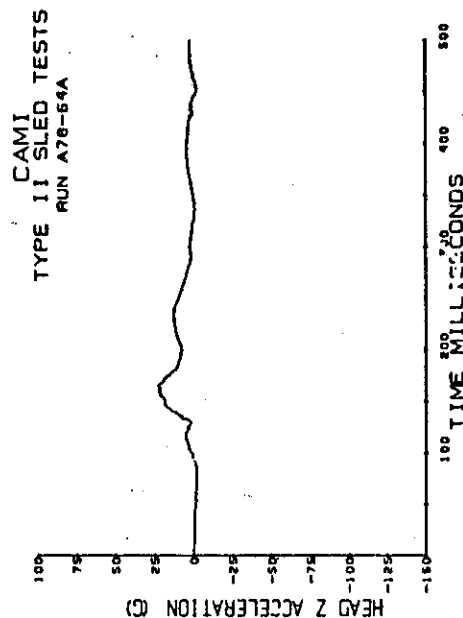
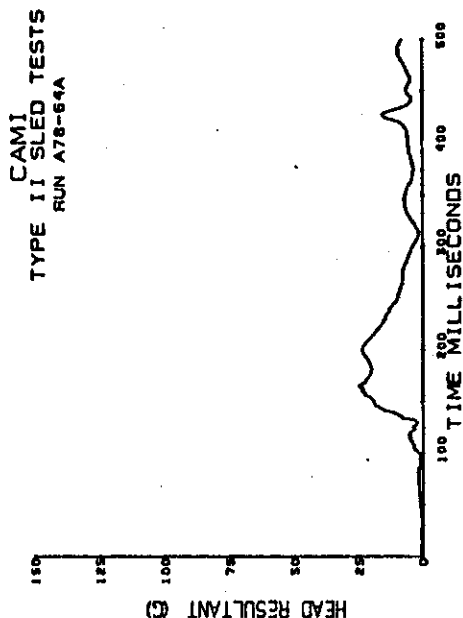
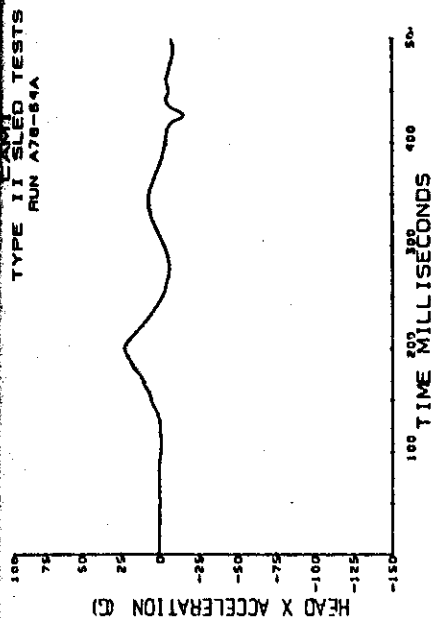
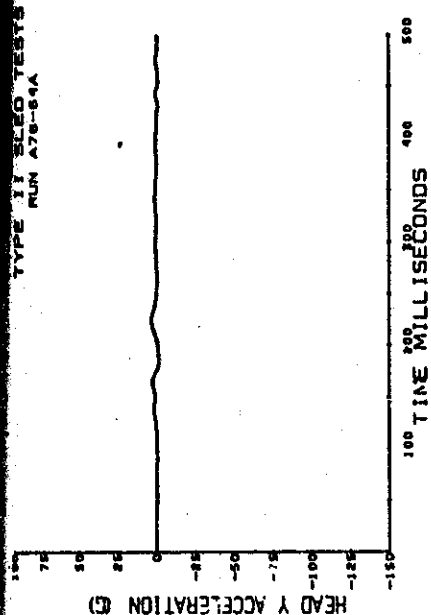
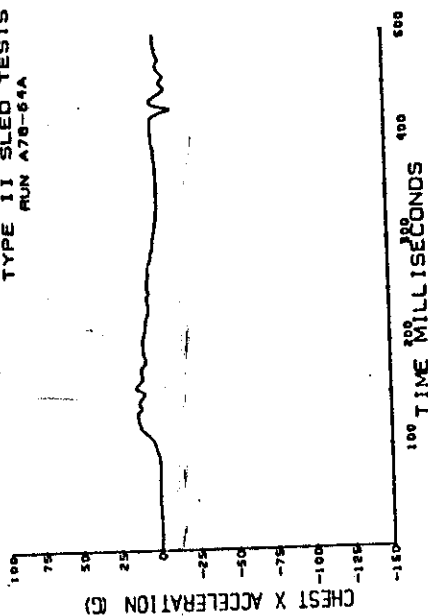
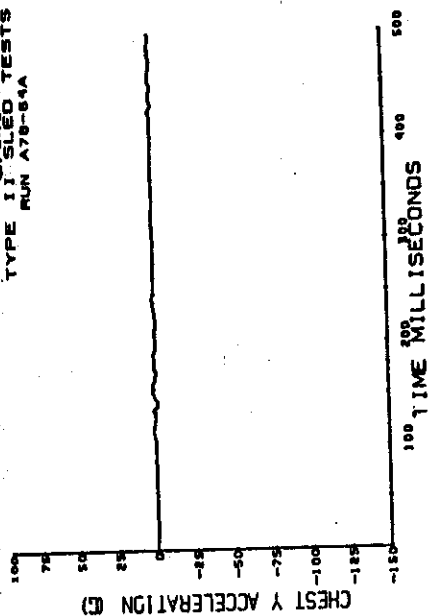


Figure B-6 (continued). Head acceleration.

CAMI  
TYPE II SLED TESTS  
RUN A78-64A

CAMI  
TYPE II SLED TESTS  
RUN A78-64A



CAMI  
TYPE II SLED TESTS  
RUN A78-64A

CAMI  
TYPE II SLED TESTS  
RUN A78-64A

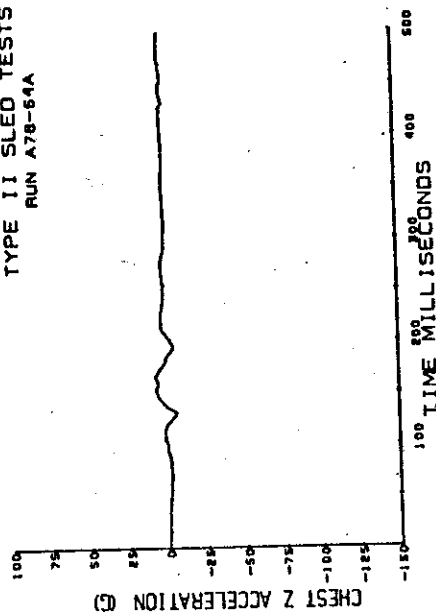
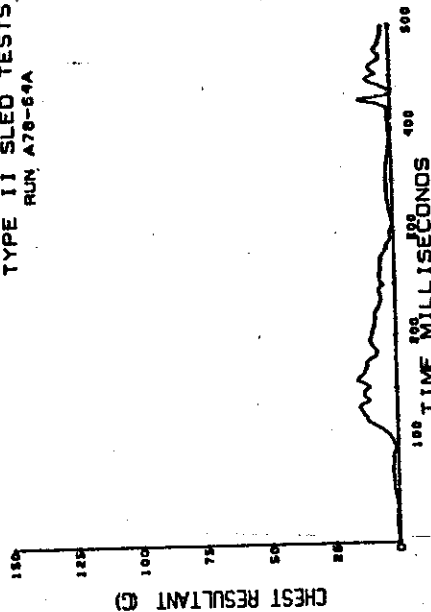
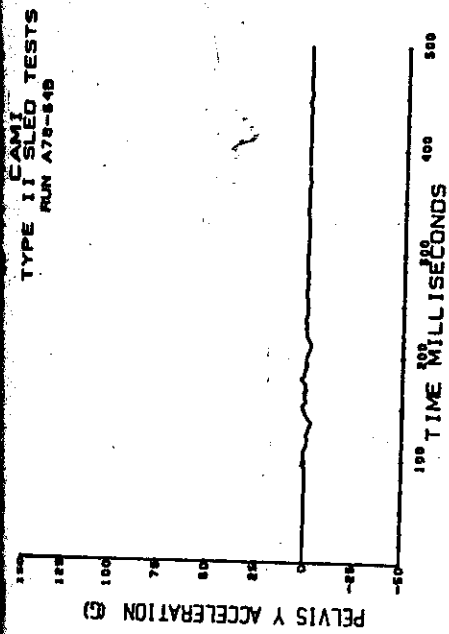
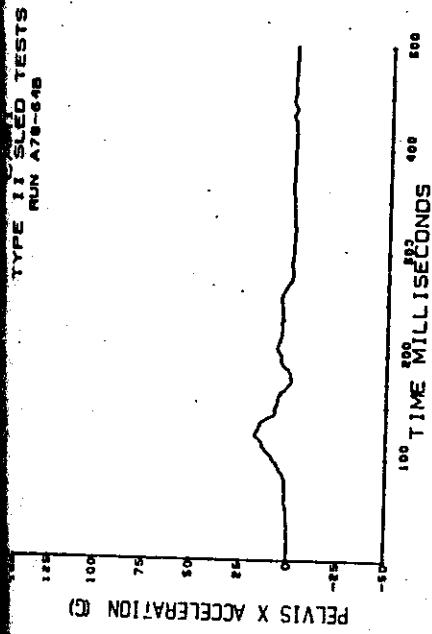


Figure B-6 (continued). Chest acceleration.



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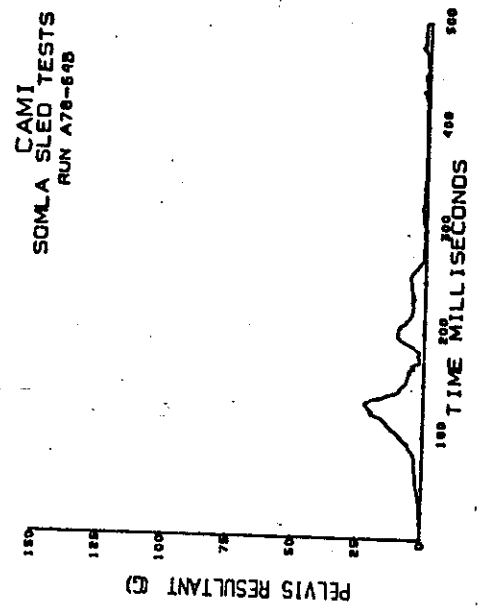
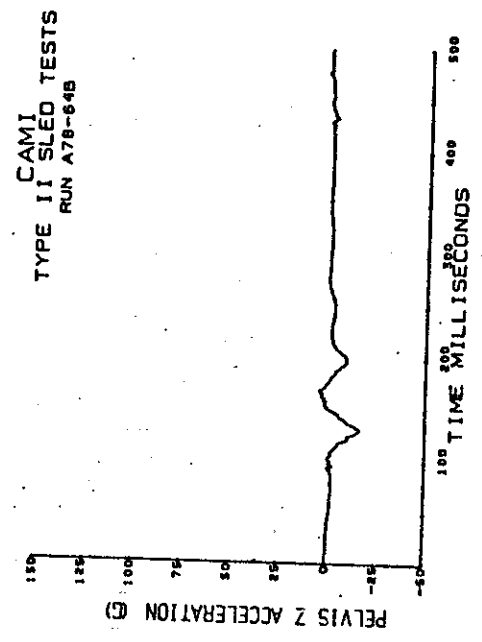


Figure B-6 (continued). Pelvis acceleration.

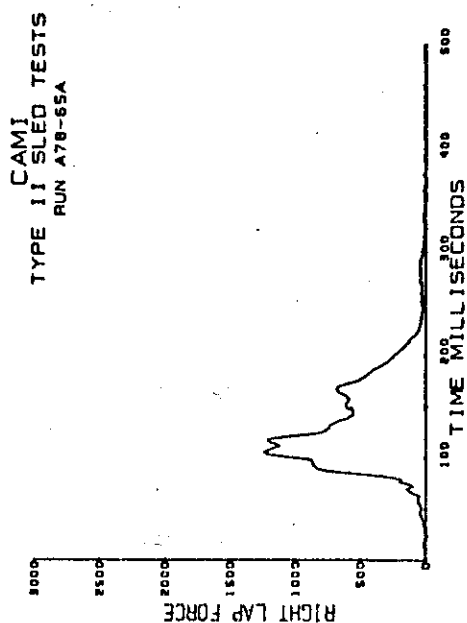
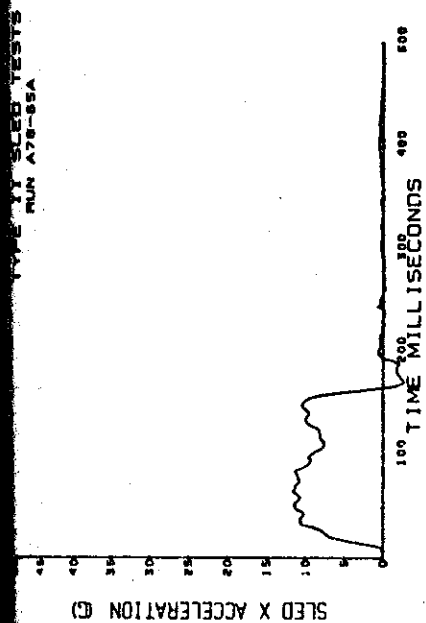
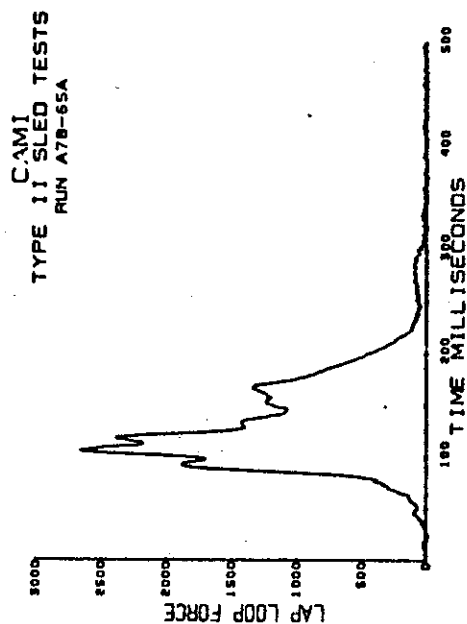
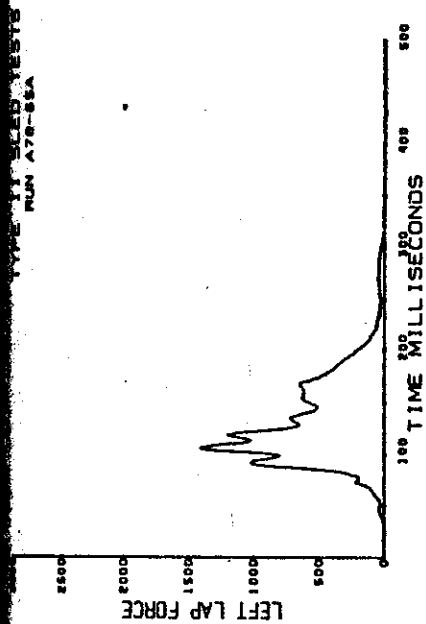
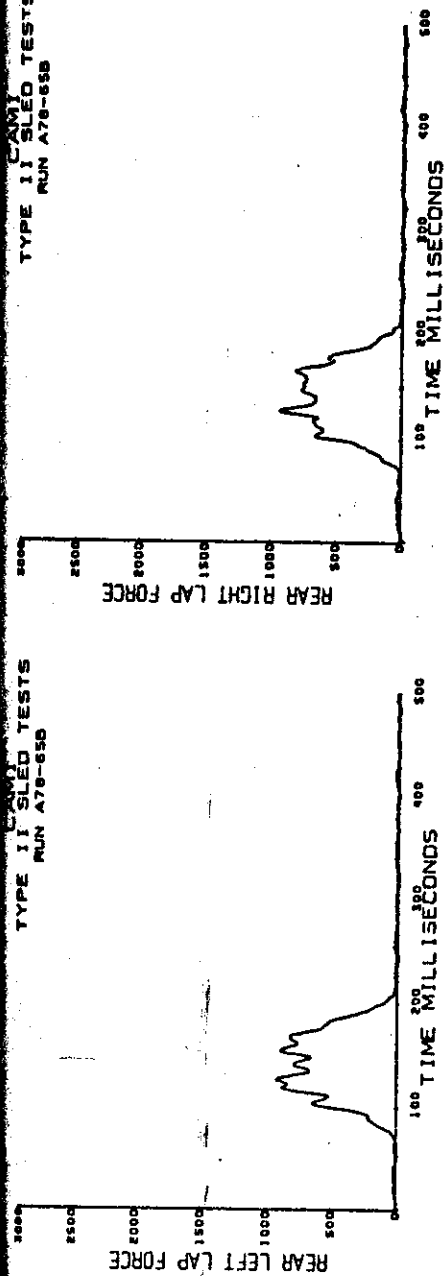


Figure B-7. 10-g tests.  
Sled acceleration and lapbelt loads.



CAMI  
TYPE II SLED TESTS  
RUN A78-558

CAMI  
TYPE II SLED TESTS  
RUN A78-558



CAMI  
TYPE II SLED TESTS  
RUN A78-558

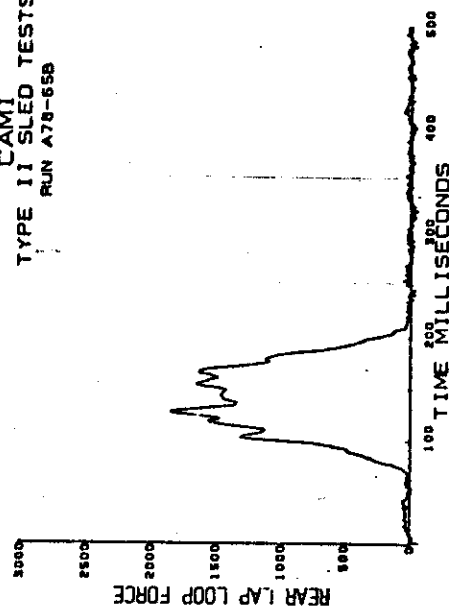
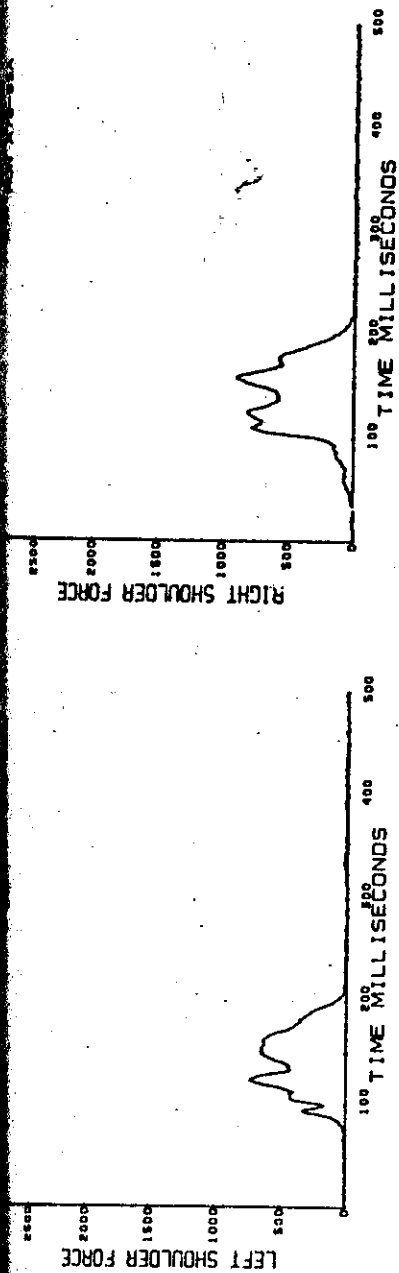


Figure B-7 (continued). Rear lapbelt loads.



CAMI  
TYPE II SLED TESTS  
RUN A78-65A

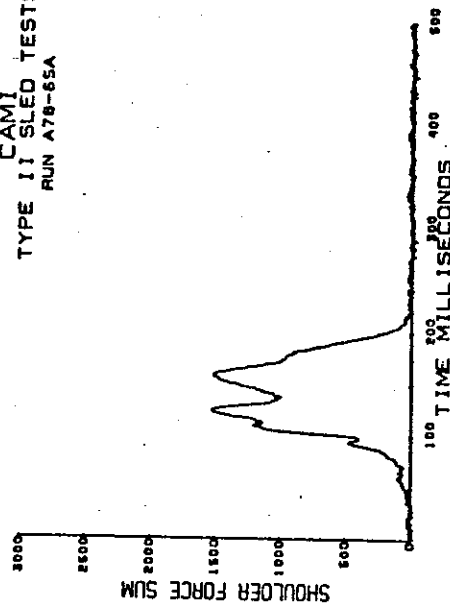


Figure B-7 (continued). Shoulder belt loads.

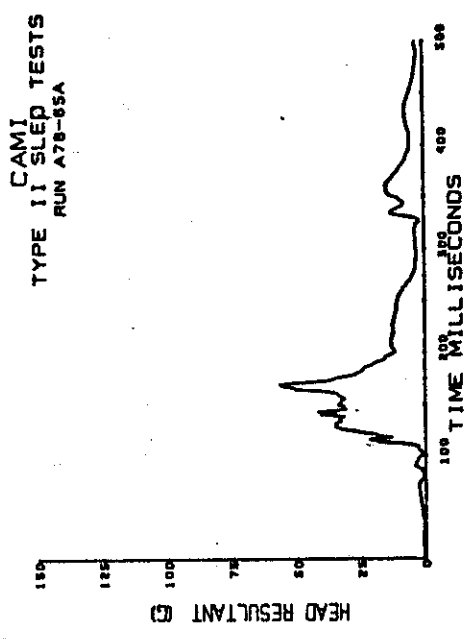
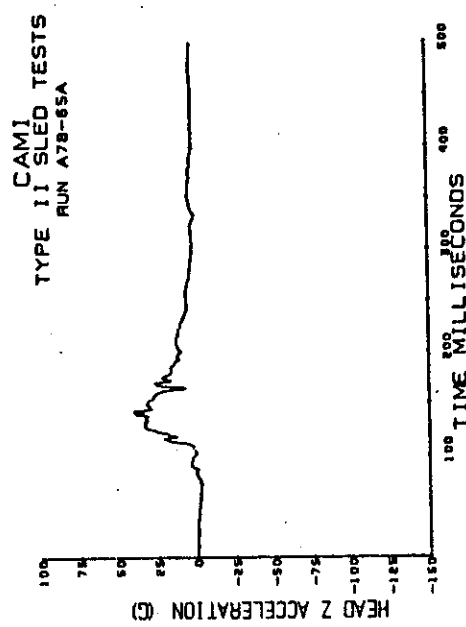
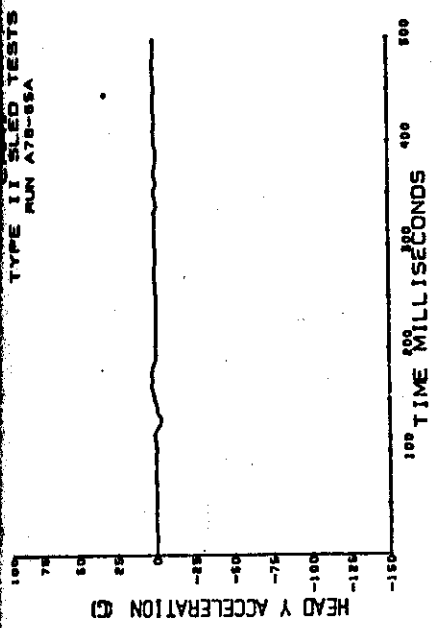
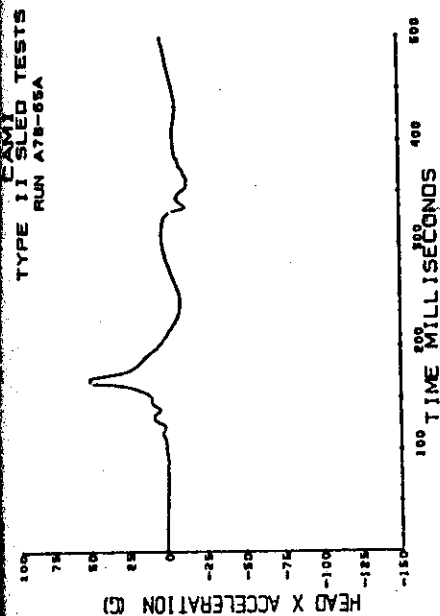
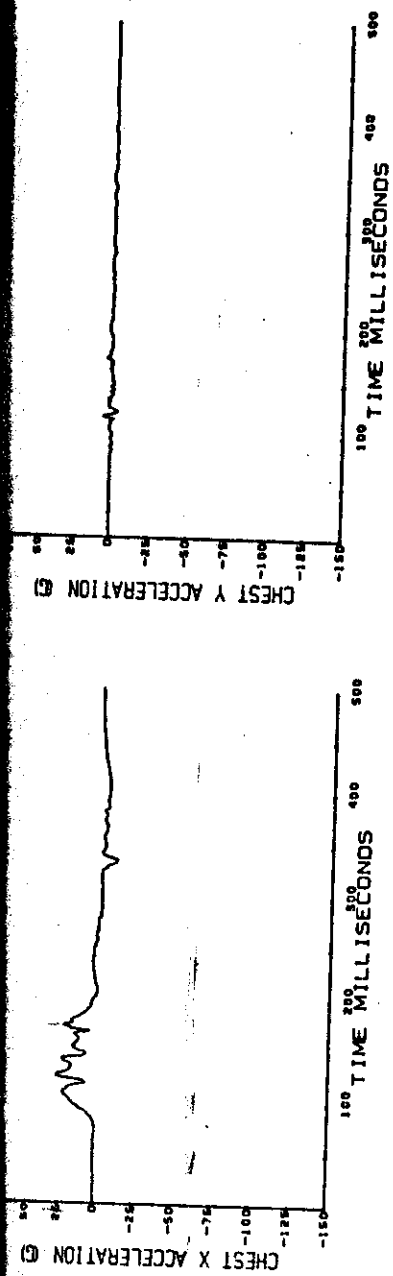


Figure B-7 (continued). Head acceleration.



CAMI  
TYPE II SLED TESTS  
RUN A78-65A

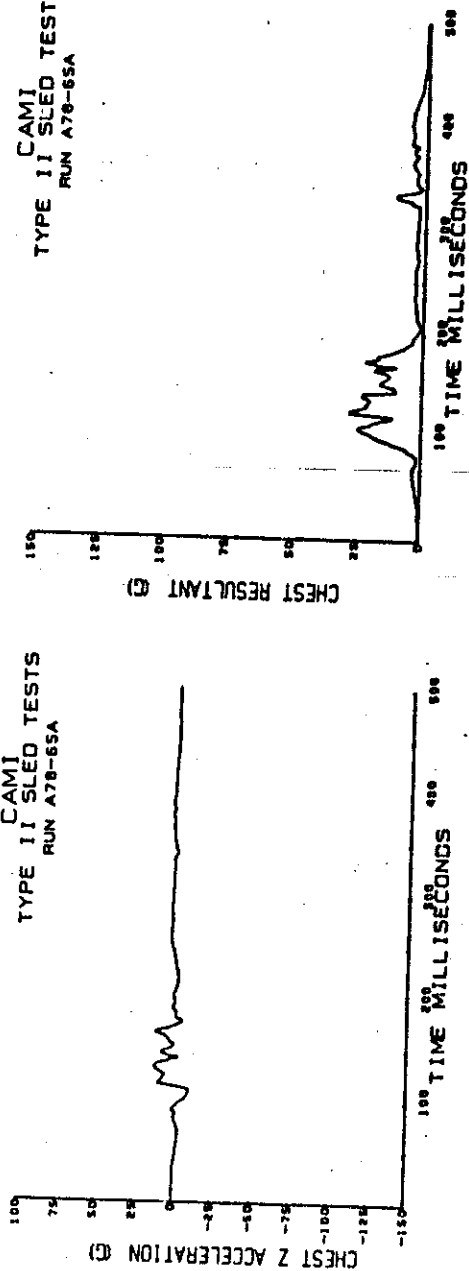
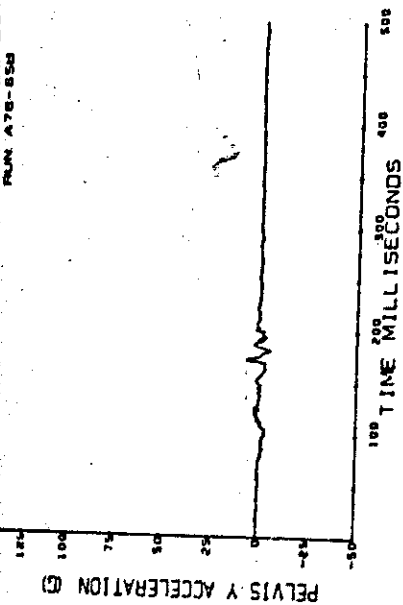
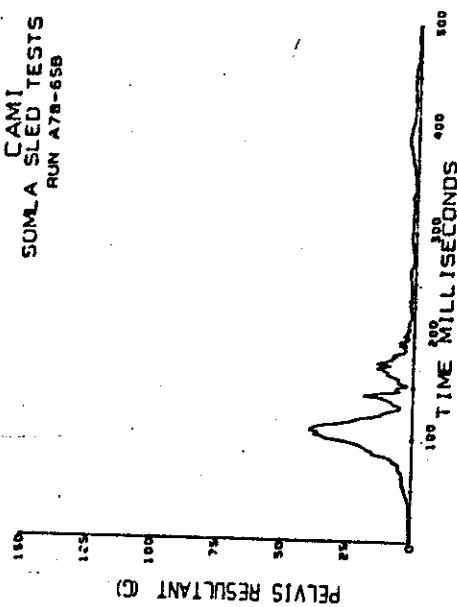


Figure B-7 (continued). Chest acceleration.

TYPE II SLED TESTS  
RUN A78-65B



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SOMLA SLED TESTS  
RUN A78-65B



CAMI  
TYPE II SLED TESTS  
RUN A78-65B

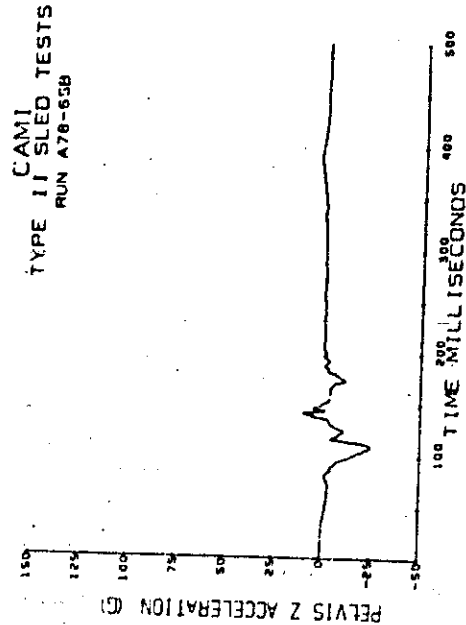
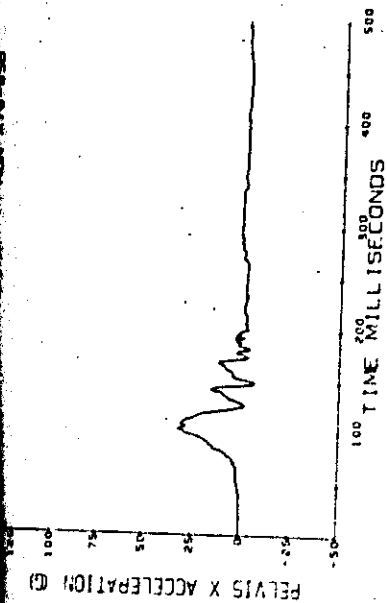


Figure B-7 (continued). Pelvis acceleration.

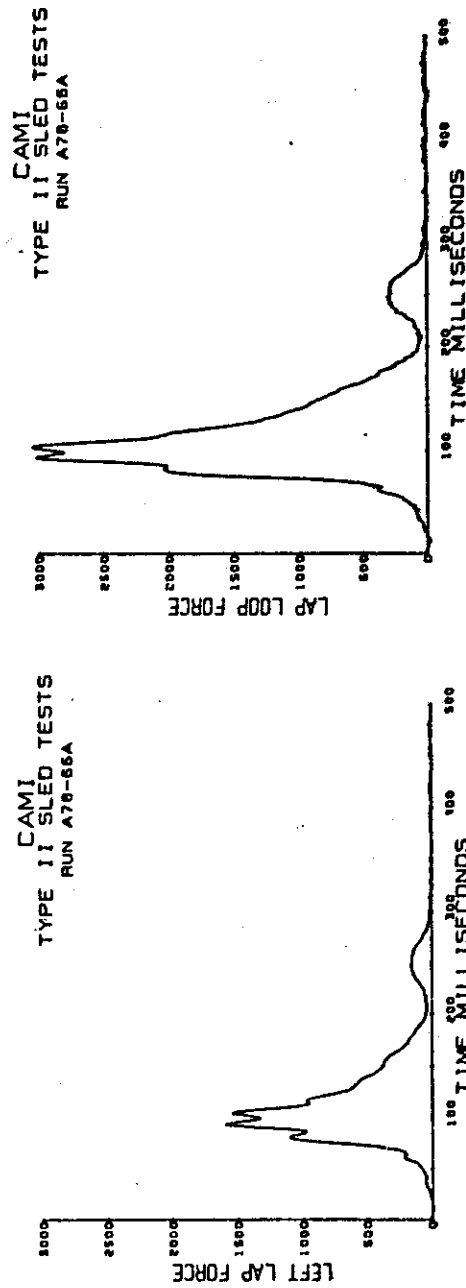
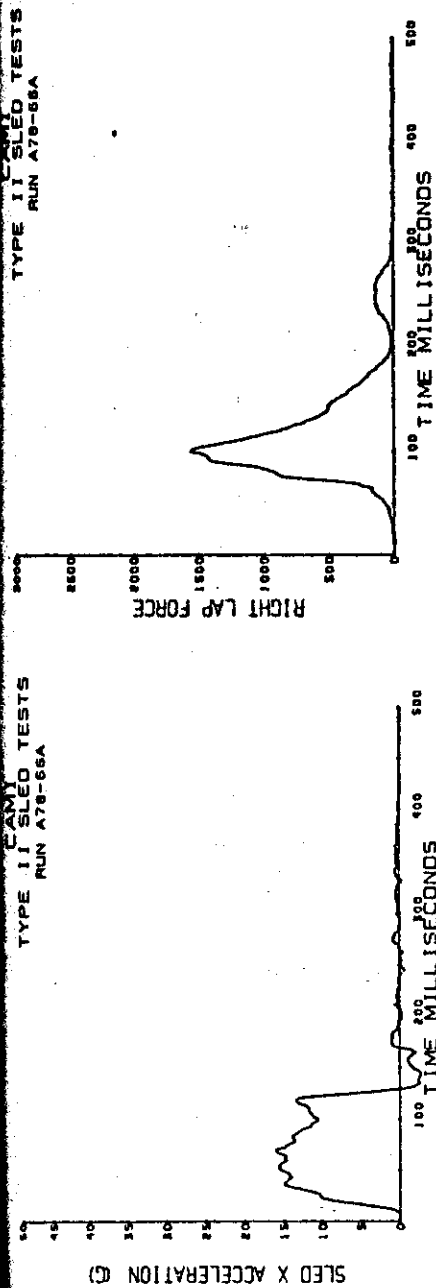


Figure B-8. 14-g tests.  
Sled acceleration and lapbelt tests.

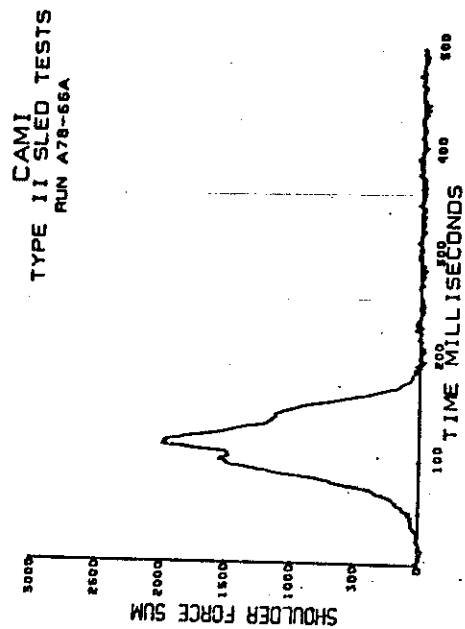
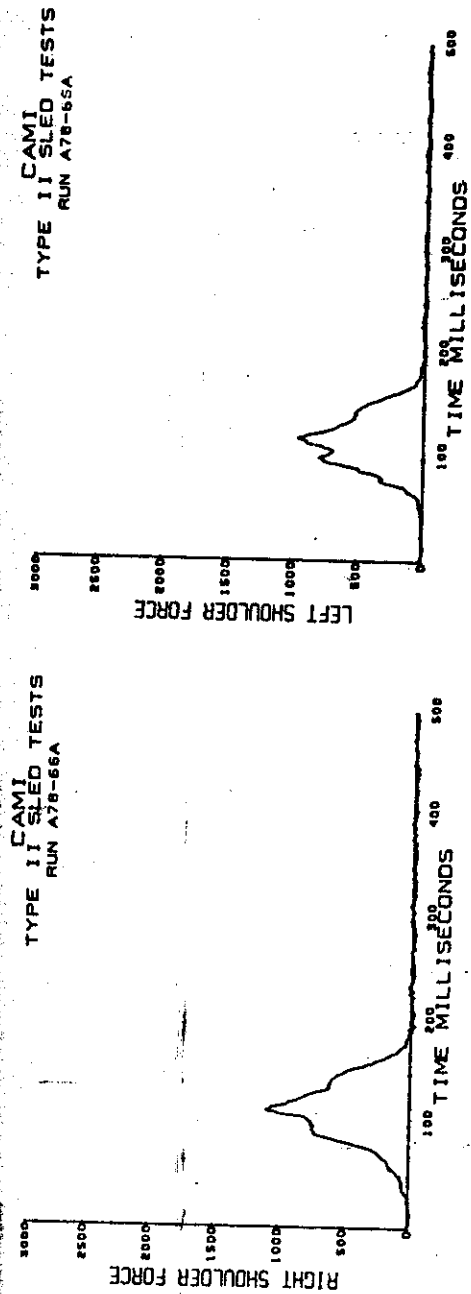
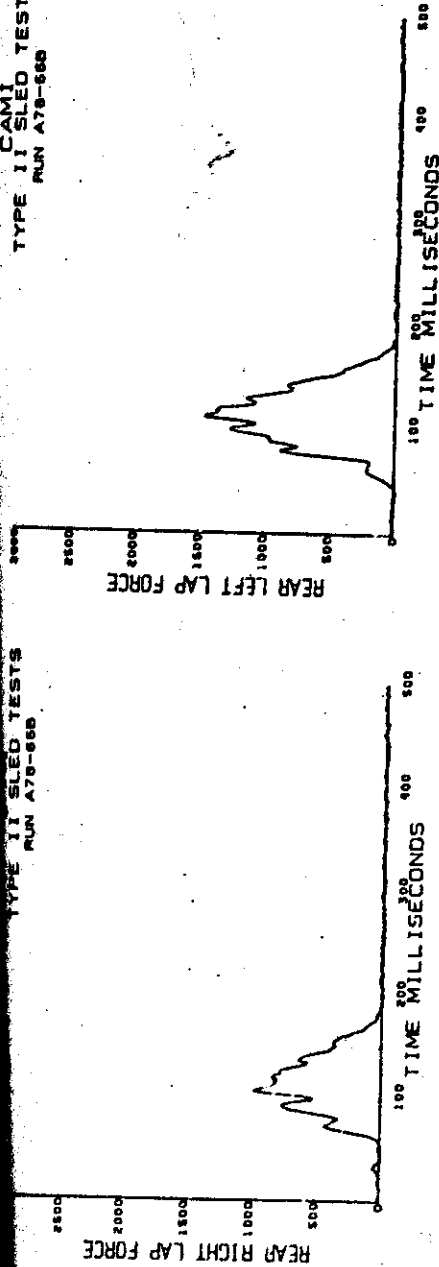


Figure B-8 (continued). Shoulder belt loads.

TYPE II SLED TESTS  
RUN A78-868

CAMI  
TYPE II SLED TESTS  
RUN A78-868



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CAMI  
TYPE II SLED TESTS  
RUN A78-868

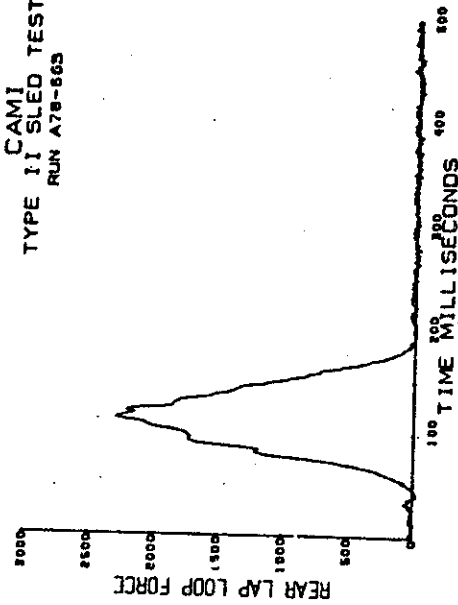


Figure B-8 (continued). Rear  
lapbelt loads.



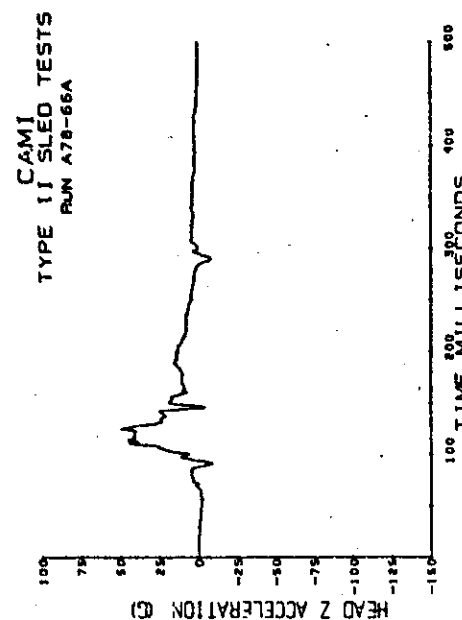
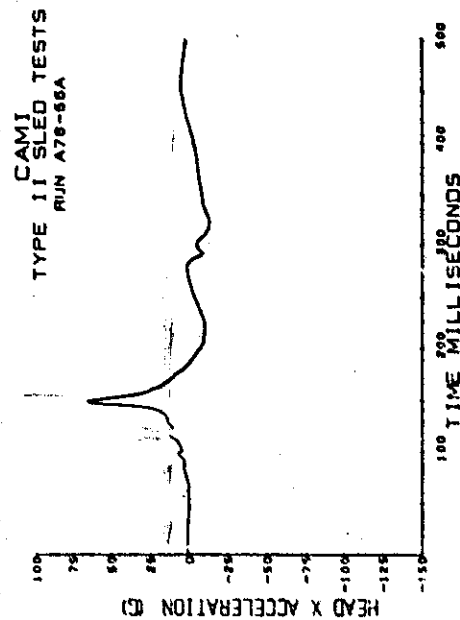
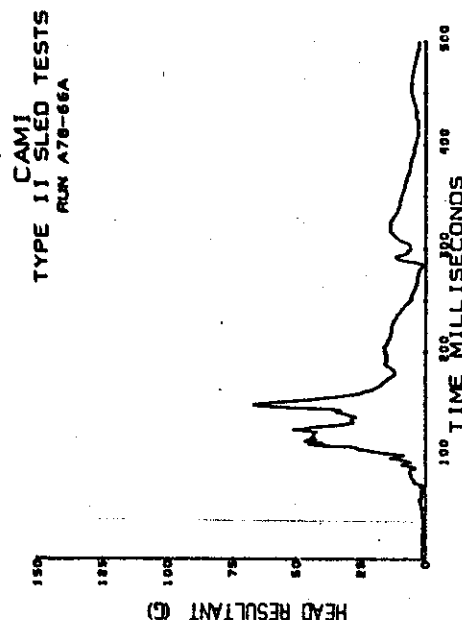
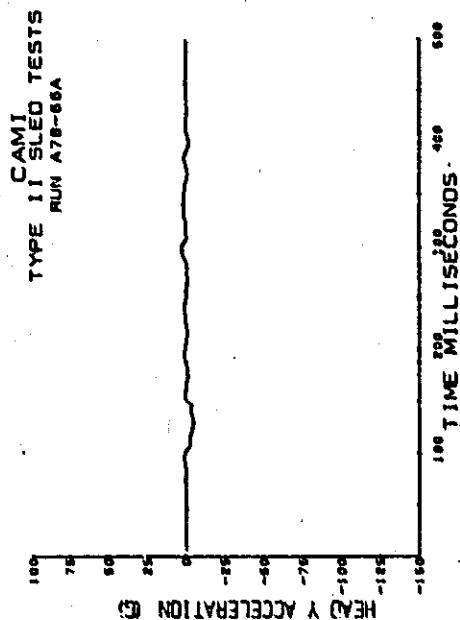
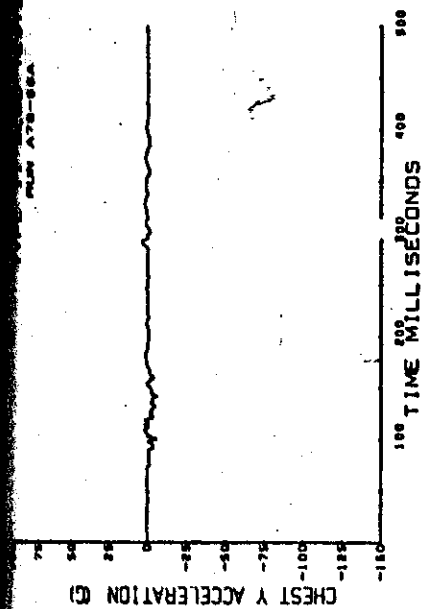
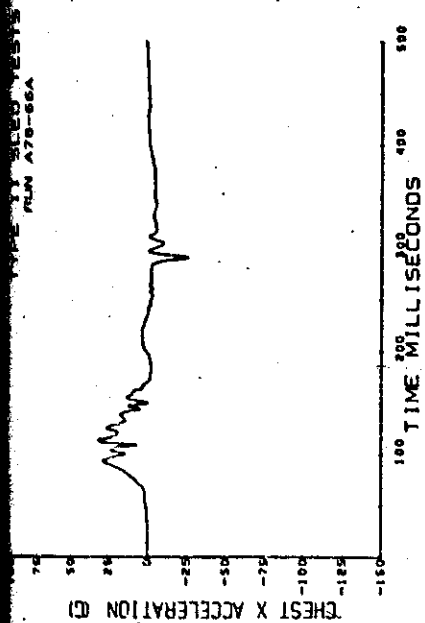


Figure B-8 (continued). Head acceleration.



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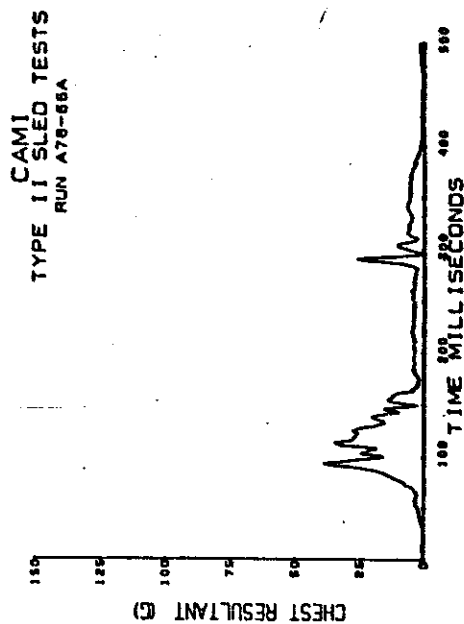
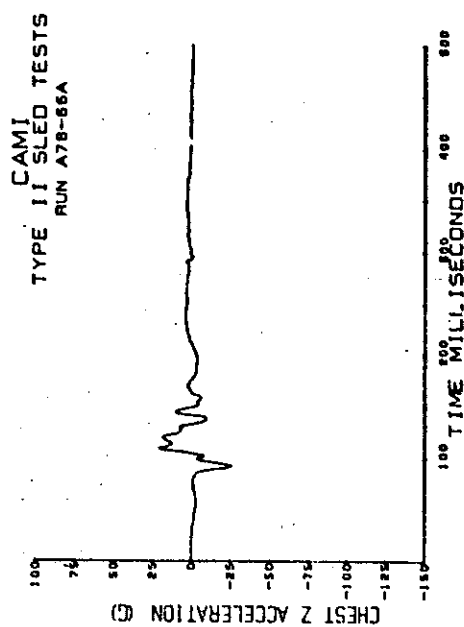


Figure B-8 (continued). Chest acceleration.

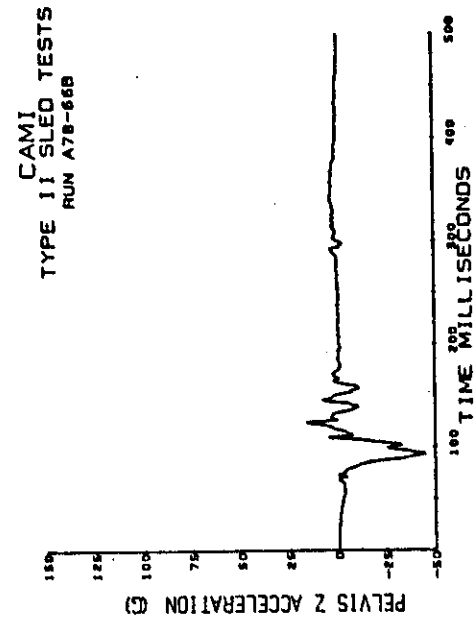
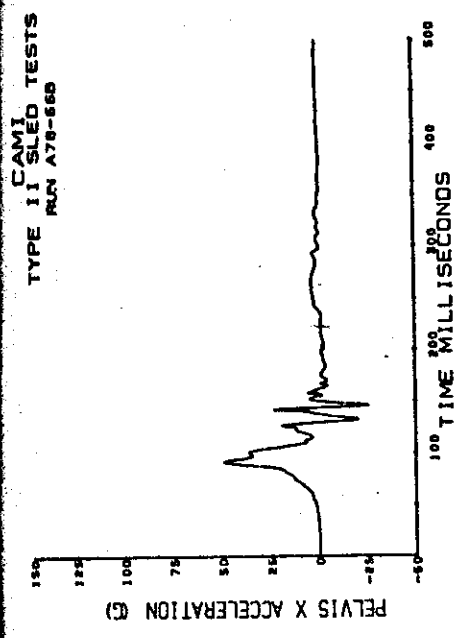
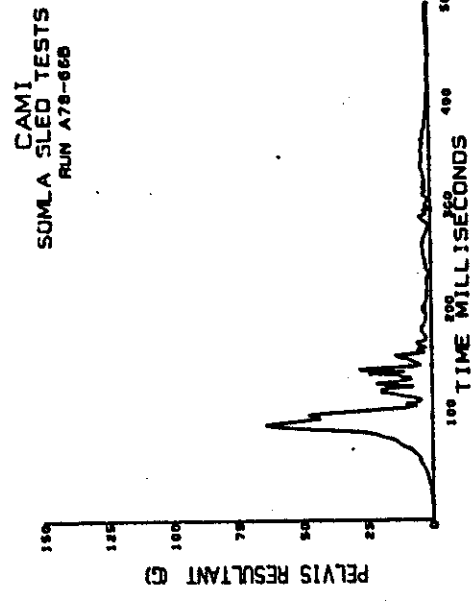
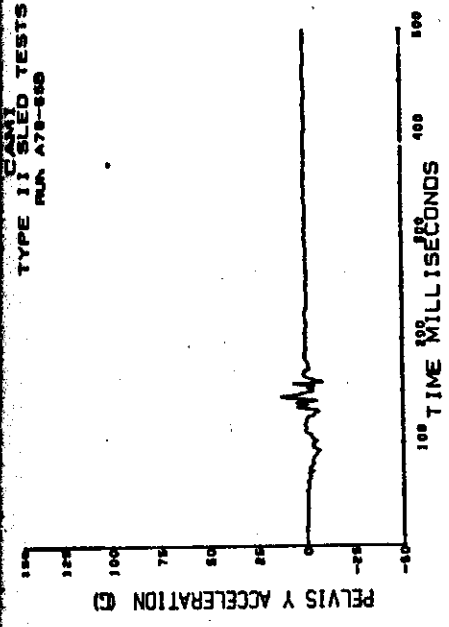


Figure B-8 (continued). Pelvis acceleration.

# APPENDIX C

## RESULTS OF LOW-ELONGATION WEBBING EVALUATIONS

Figure No.

page

### C-1 Standard webbing.

9-g tests.	151
12-g tests.	156
16-g tests.	161
18-g tests.	166
21-g tests.	171

### C-2 Kevlar webbing.

9-g tests.	176
12-g tests.	181
16-g tests.	186
18-g tests.	191
22-g tests.	196

### C-3 Polyester webbing.

9-g tests.	201
12-g tests.	206
16-g tests.	211
18-g tests.	216
21-g tests.	221

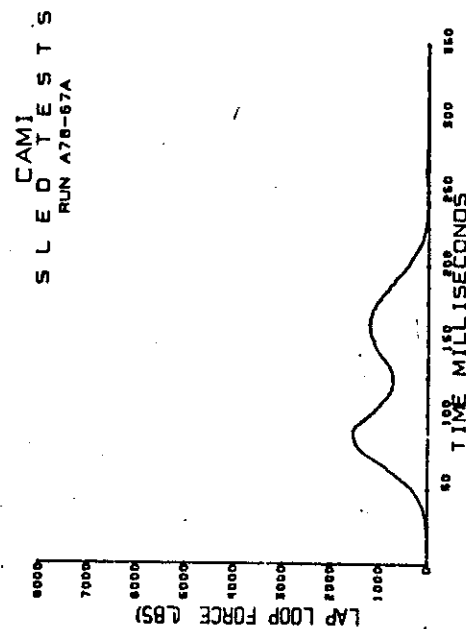
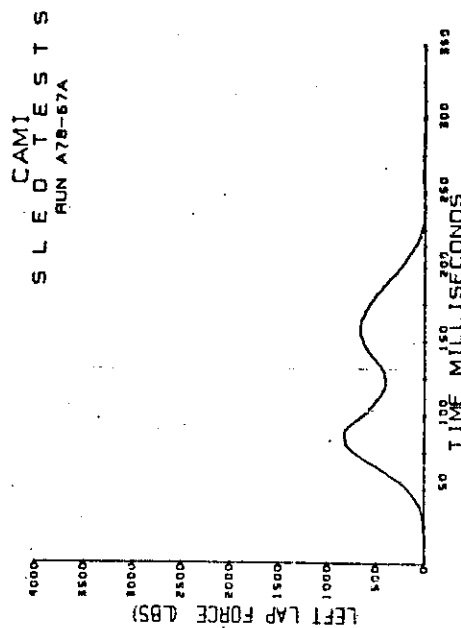
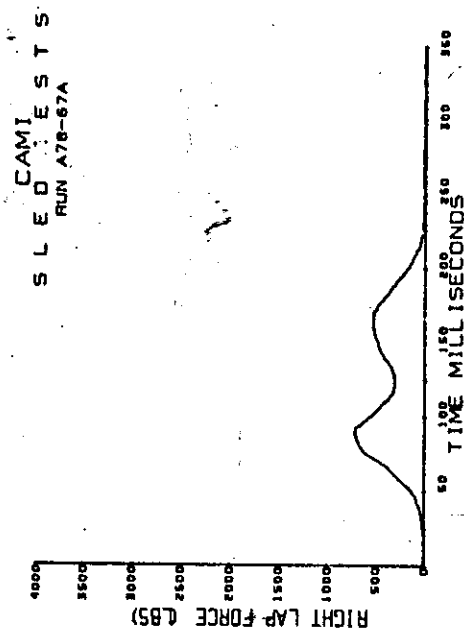
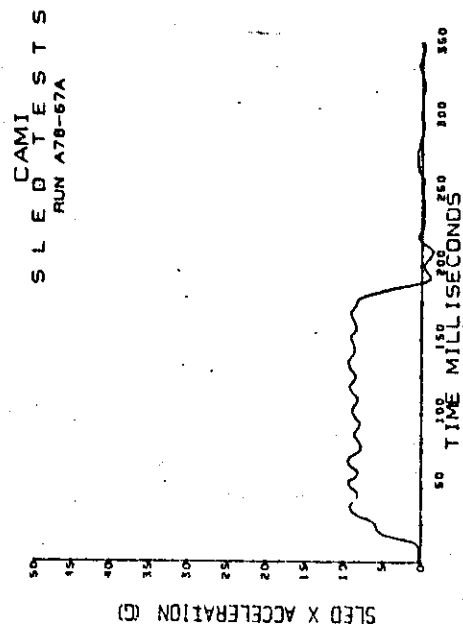
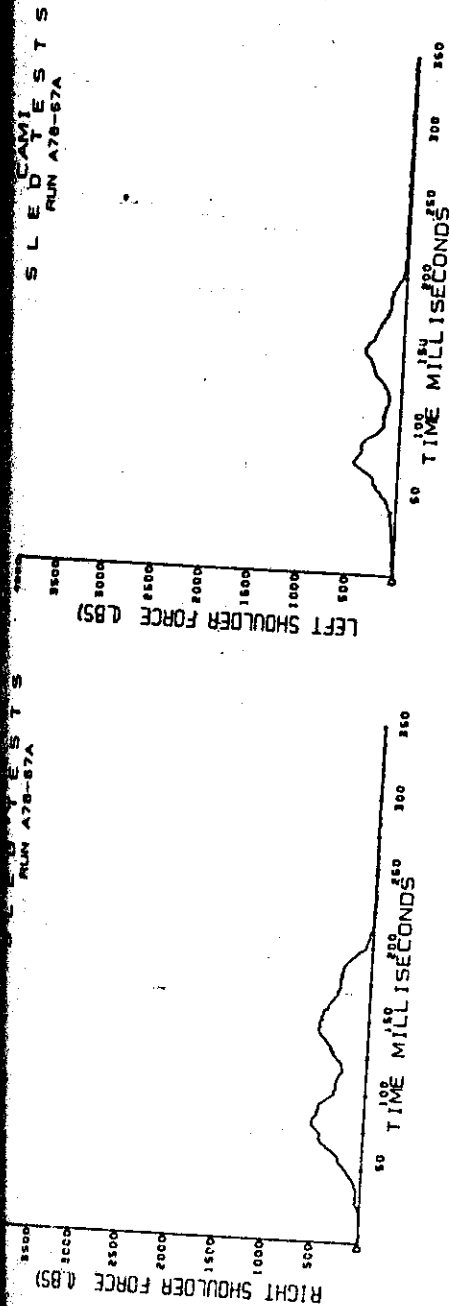


Figure C-1. Standard webbing, 9-g tests.  
Sled deceleration and lapbelt loads.



S L E D C A M I  
E S T S  
RUN A78-57A

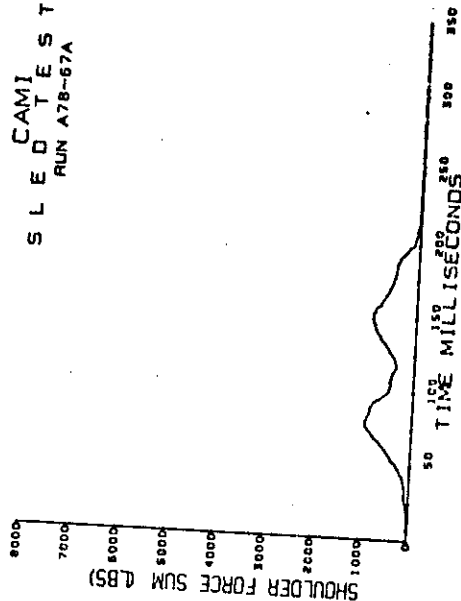


Figure C-1 (continued). 9-8 tests.  
Shoulder belt loads.

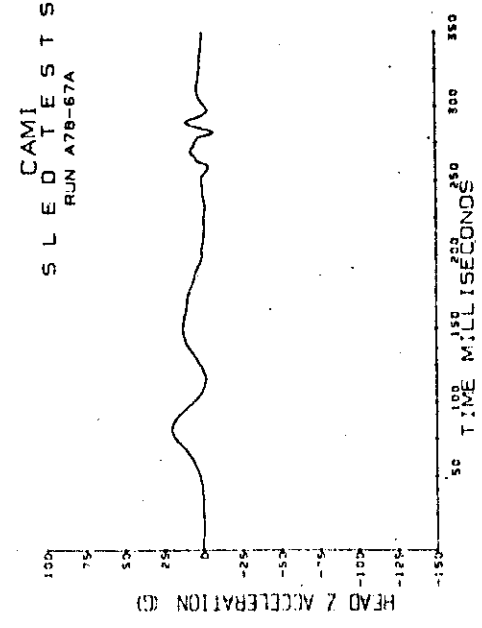
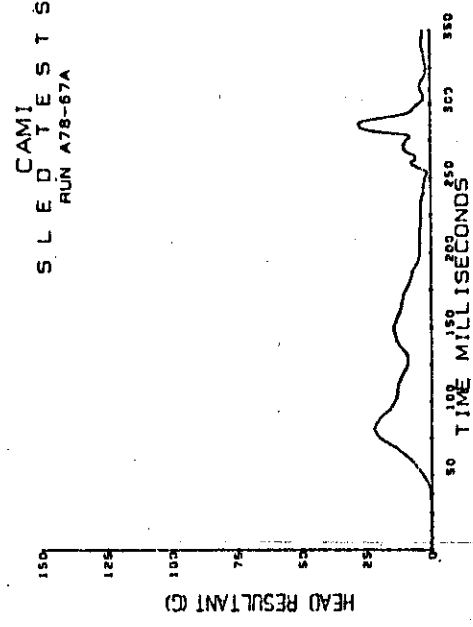
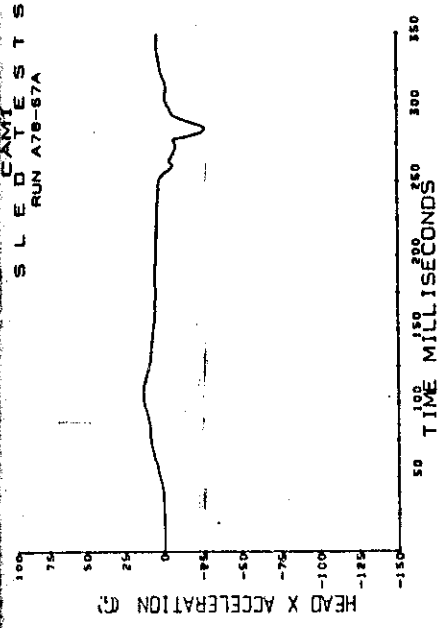
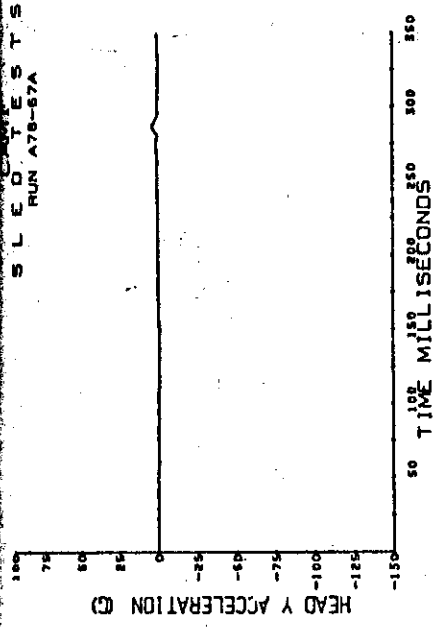
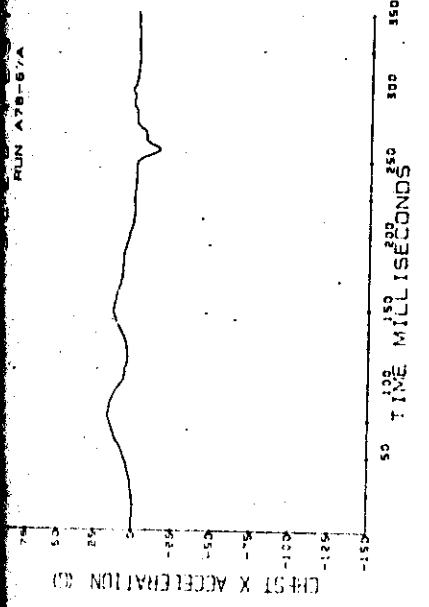
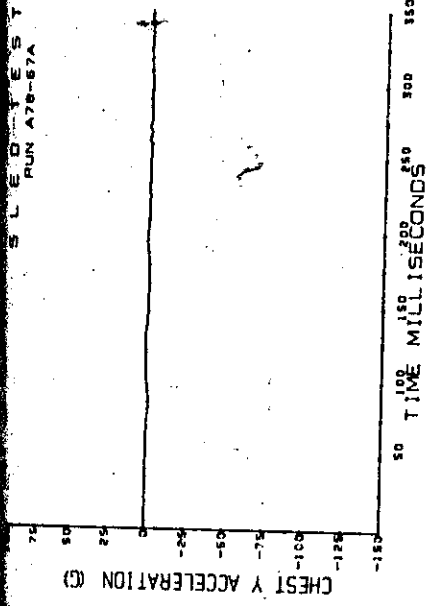


Figure C-1 (continued). 9-8 tests.  
Head acceleration.

S L E D T E S T S  
RUN A78-67A



CAMI  
S L E D T E S T S  
RUN A78-67A

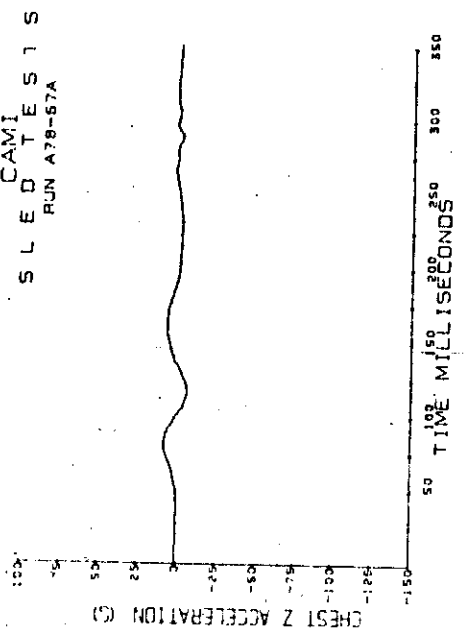
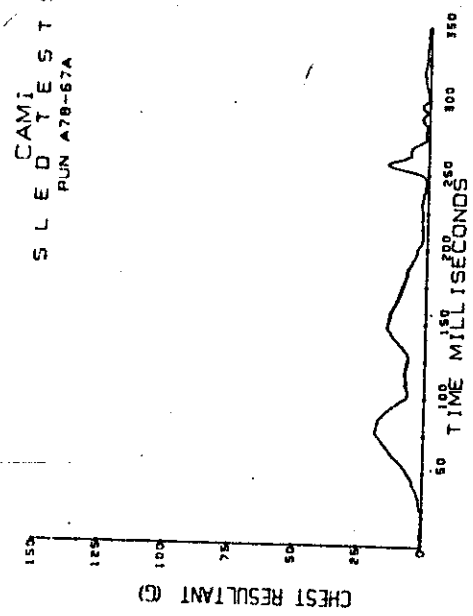
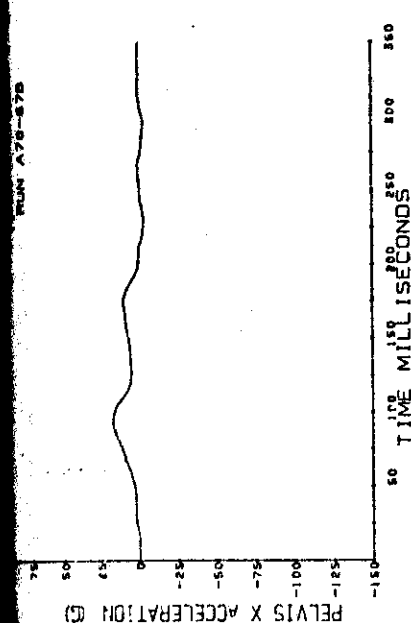
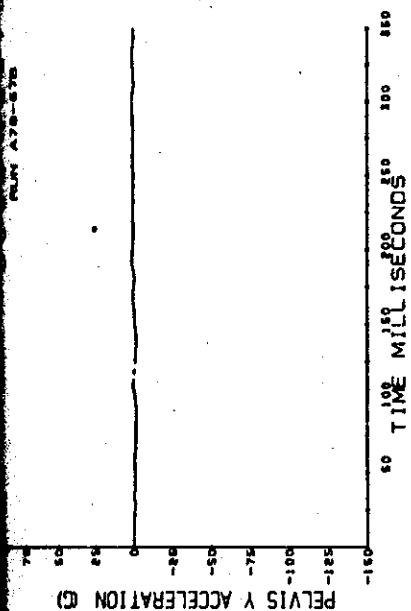
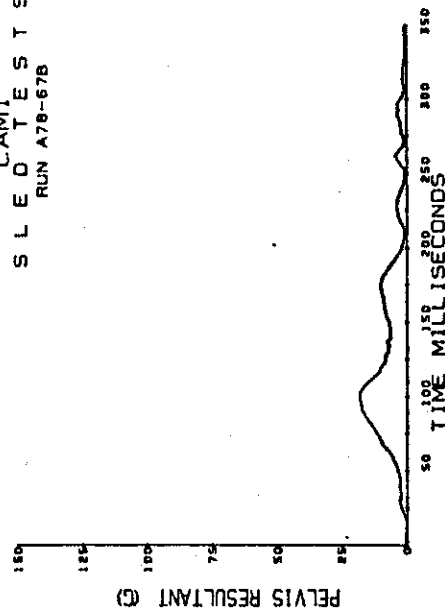


Figure C-1 (continued). 9-g tests.  
Chest acceleration.





CAMI  
SLED TESTS  
RUN A78-67B



CAMI  
SLED TESTS  
RUN A78-67B

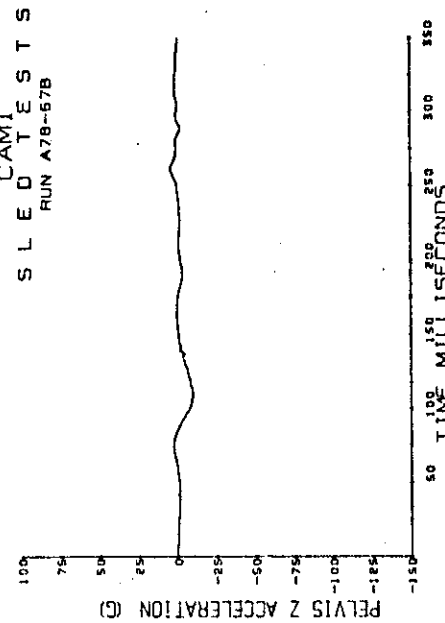
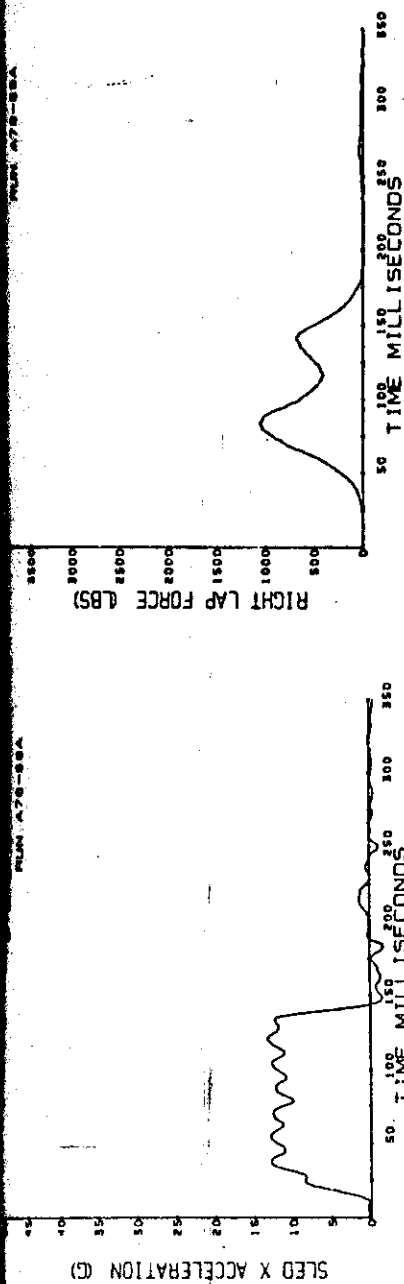


Figure C-1 (continued). 9-g tests.  
Pelvis acceleration.



CAMI  
SLED TESTS  
RUN A78-68A

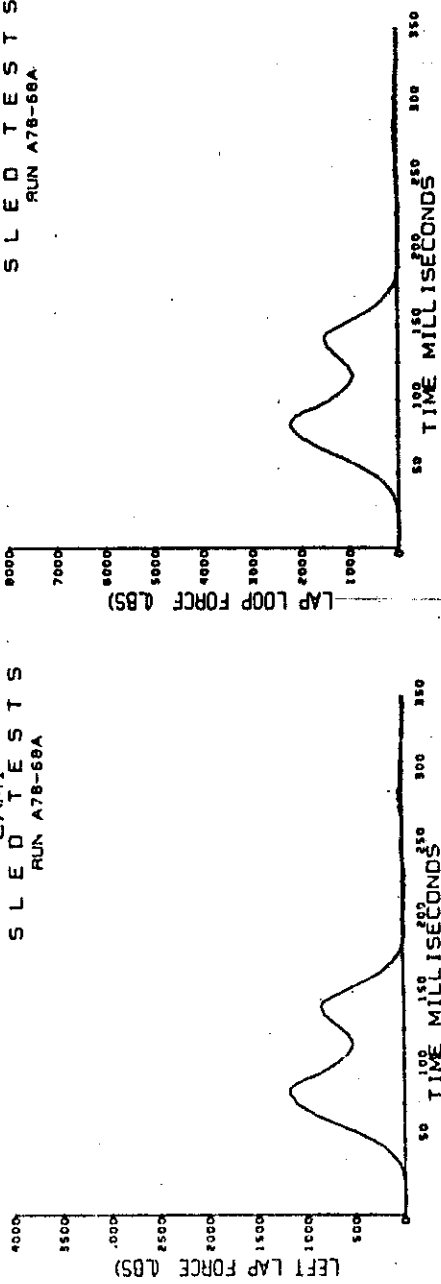
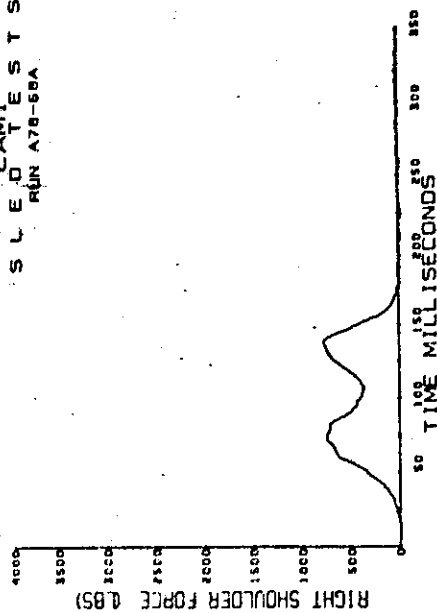
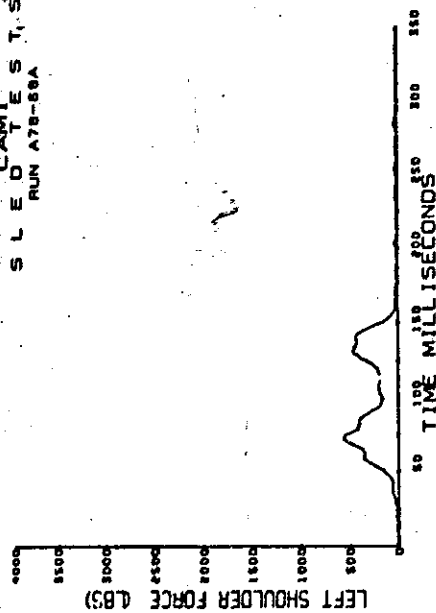


Figure C-1 (continued). 12-g tests.  
Sled deceleration and lapbelt loads.

SLED CAMI TESTS  
RUN A78-58A



SLED CAMI TESTS  
RUN A78-58A



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CAMI  
SLED TESTS  
RUN A78-58A

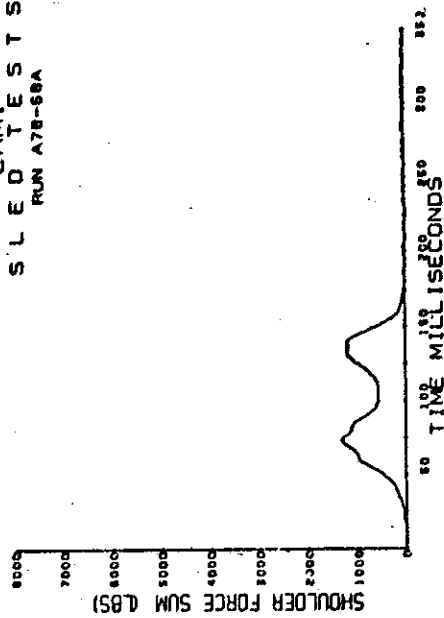


Figure C-1 (continued). 12-8 tests.  
Shoulder belt loads.

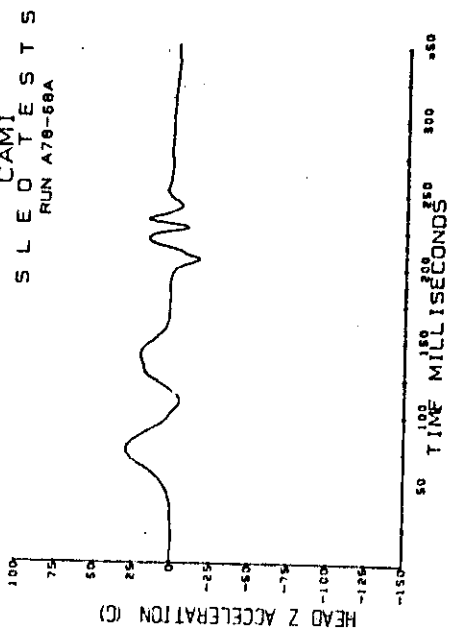
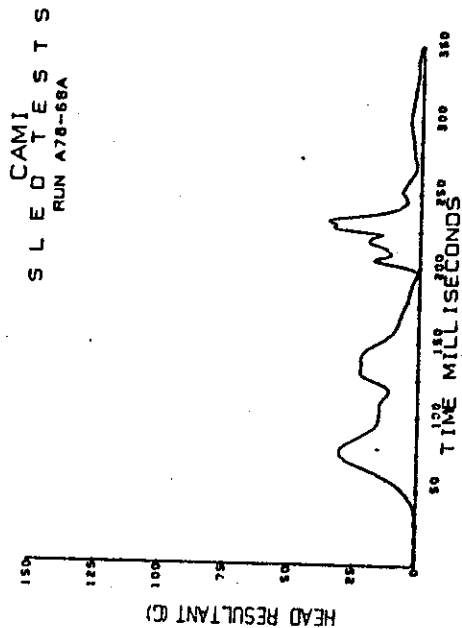
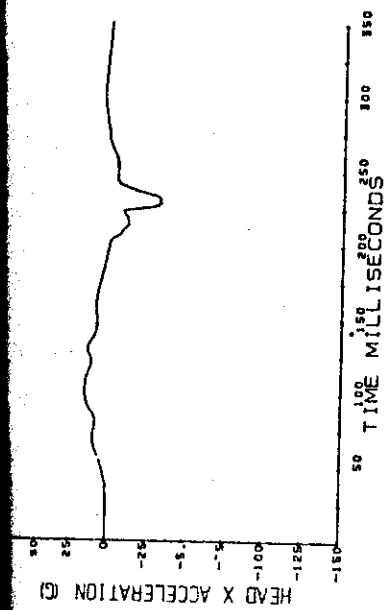
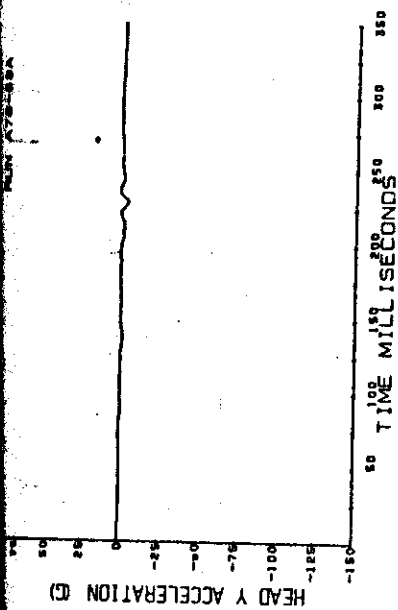
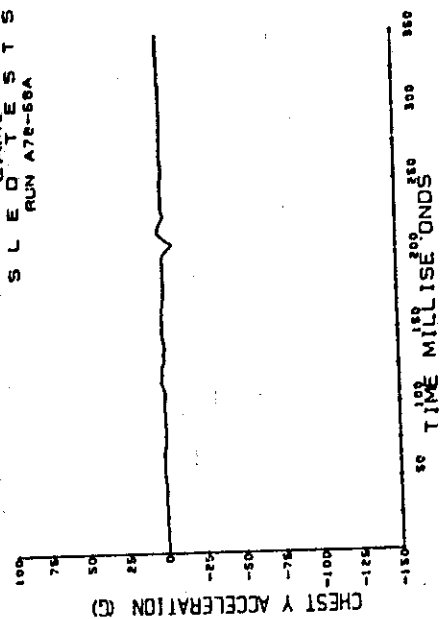
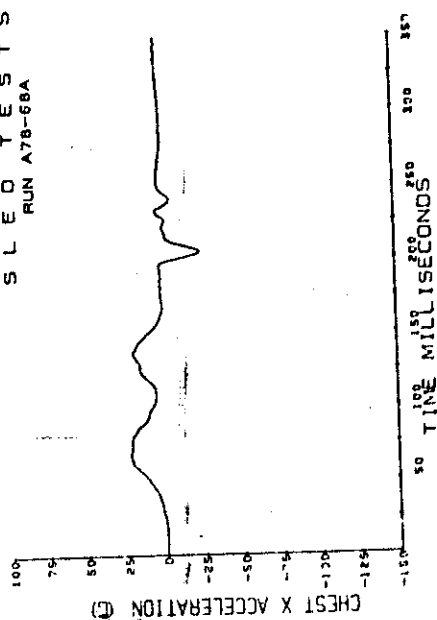


Figure C-1 (continued). 12-g tests.  
Head acceleration.

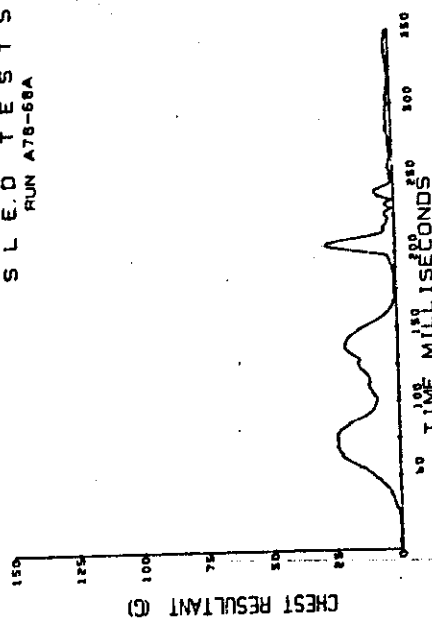
CAMI  
SLED TESTS  
RUN A78-68A



CAMI  
SLED TESTS  
RUN A78-68A



CAMI  
SLED TESTS  
RUN A78-68A



CAMI  
SLED TESTS  
RUN A78-68A

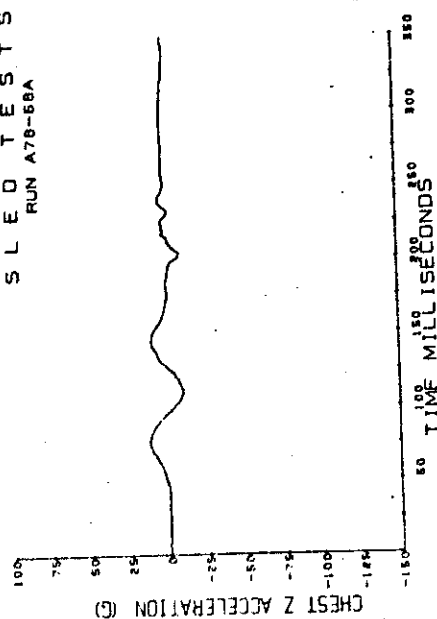


Figure C-1 (continued). 12-g tests.  
Chest acceleration.

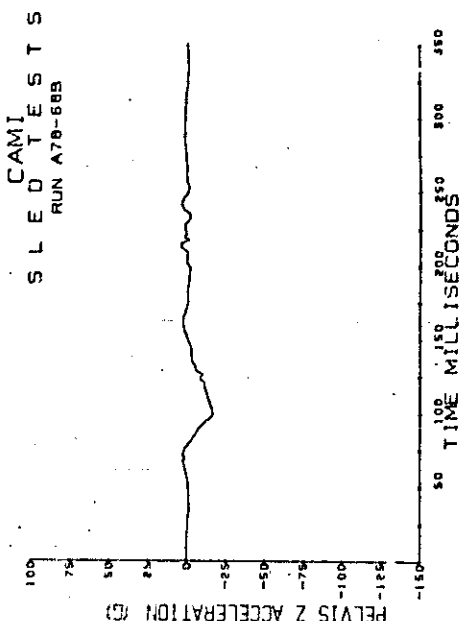
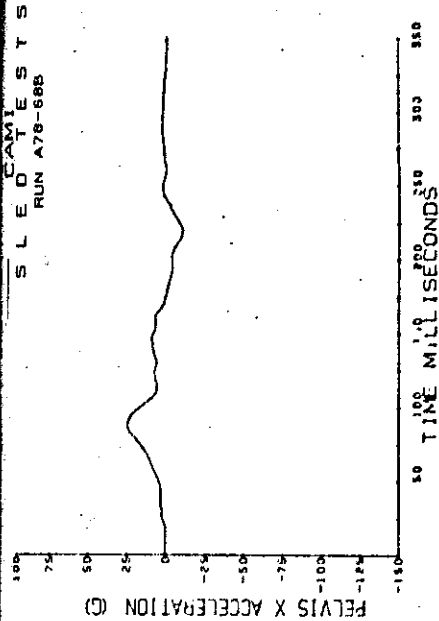
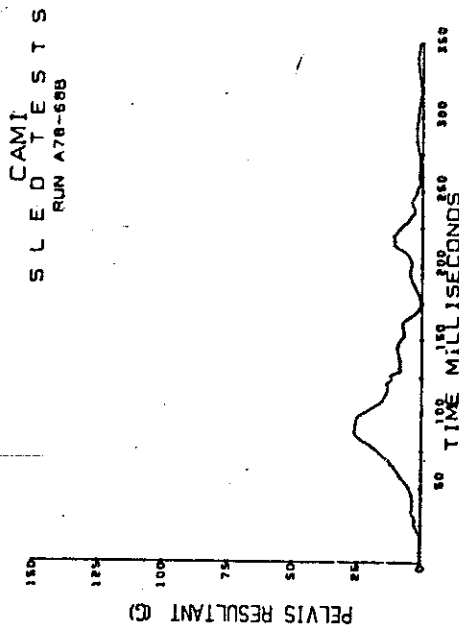
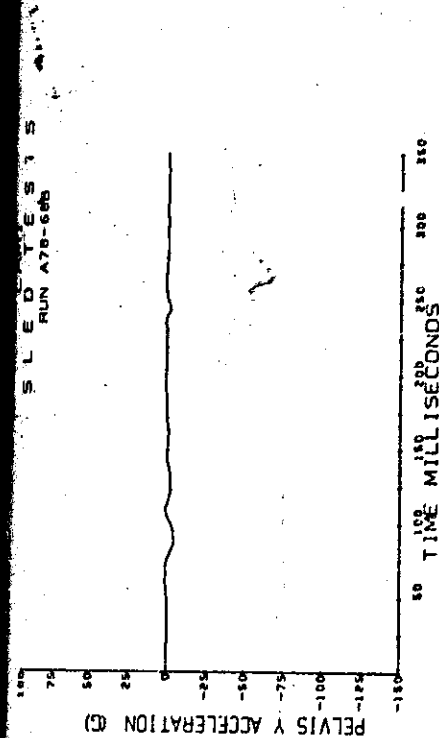


Figure C-1 (continued). 12-8 tests.  
Pelvis acceleration.

CAMI  
SLED TESTS  
PJA 478-53A

RIGHT LAP FORCE (LBS)

TIME (MILLISECONDS)

CAMI  
SLED TESTS  
PJA 478-53A

SLED ACCELERATION (G)

TIME (MILLISECONDS)

CAMI  
SLED TESTS  
PJA 478-53A

LEFT LAP FORCE (LBS)

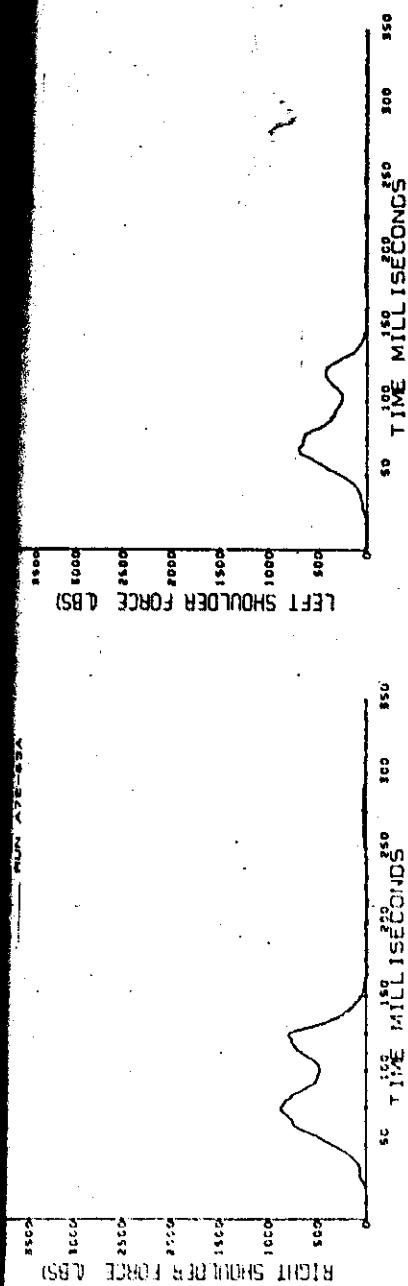
TIME (MILLISECONDS)

CAMI  
SLED TESTS  
PJA 478-53A

SLED ACCELERATION (G)

TIME (MILLISECONDS)

Figure C-1 (continued). 16-g tests.  
Sled deceleration and lapbelt loads.



CAMI  
SLED TESTS  
RUN A78-63A

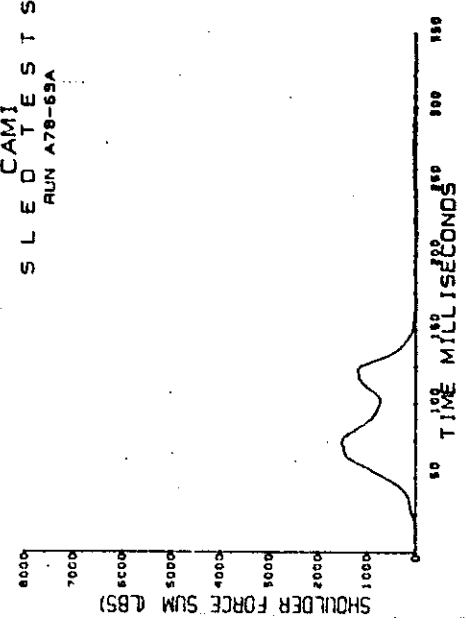


Figure C-1 (continued). 16-g tests.  
Shoulder belt loads.



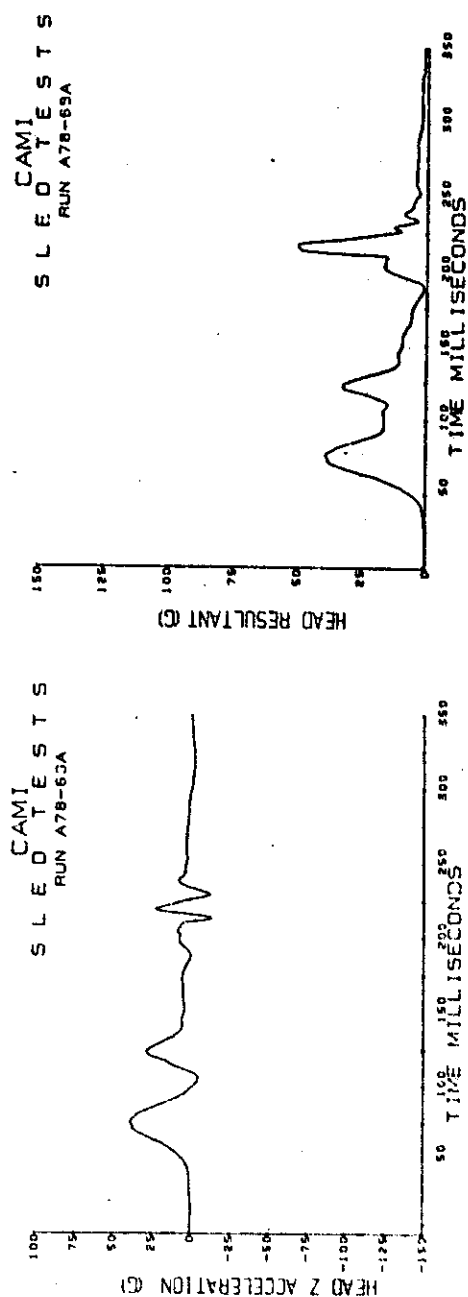
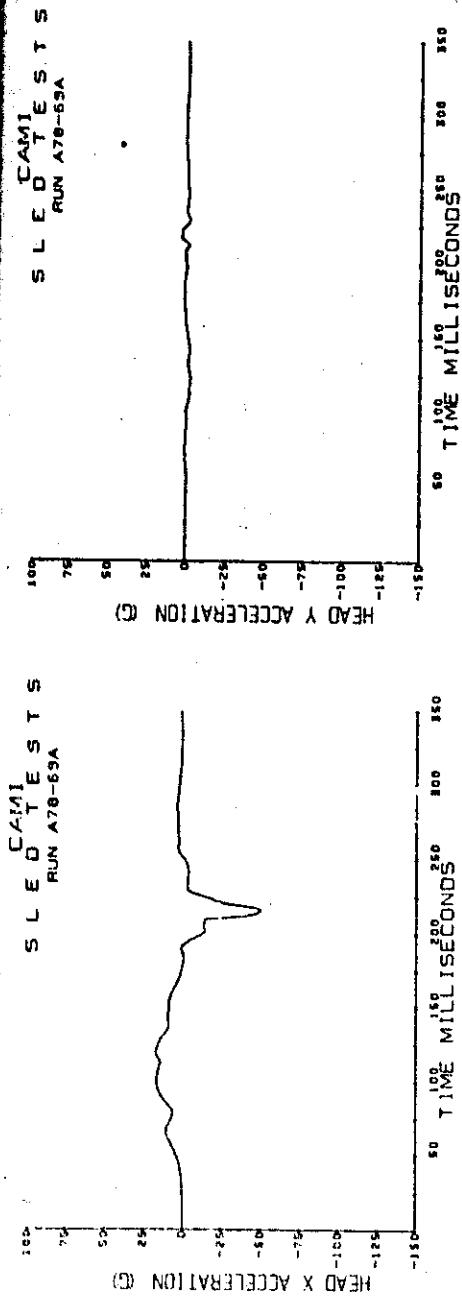
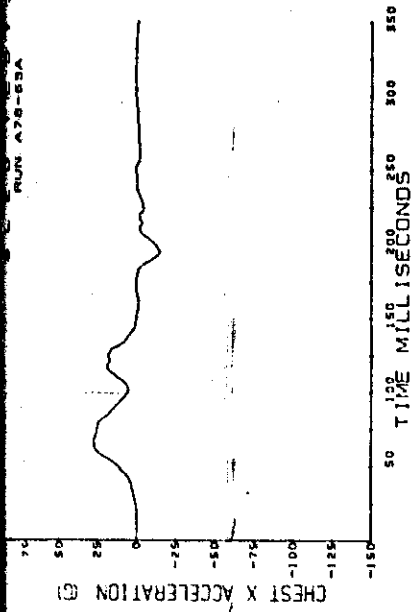
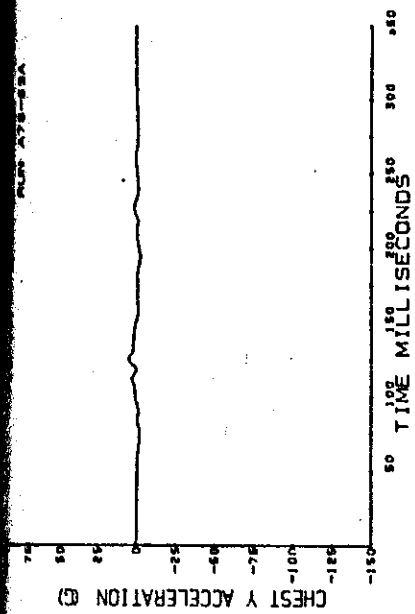


Figure C-1 (continued). 16-g tests.  
Head acceleration.



CAMI  
S L E D T E S T S  
RUN A78-63A

CAMI  
S L E D T E S T S  
RUN A78-63A

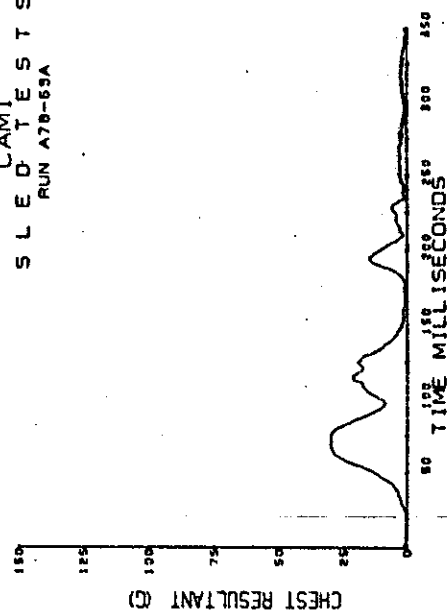
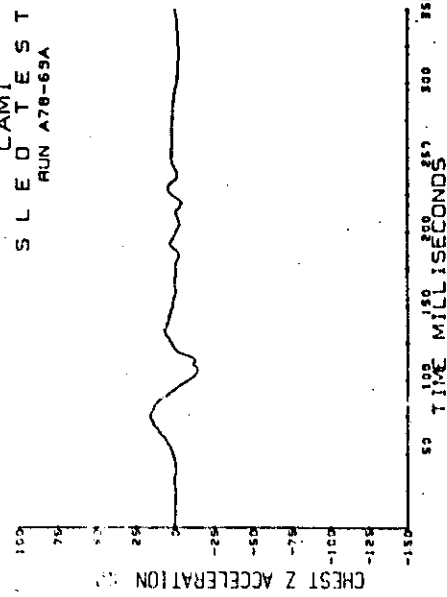
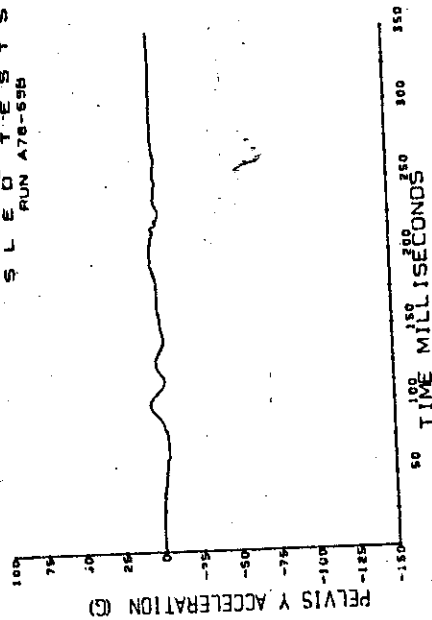
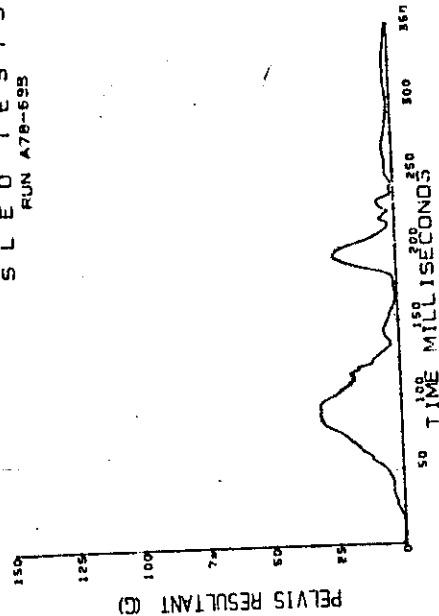


Figure C-1 (continued). 16-g tests.  
Chest acceleration.

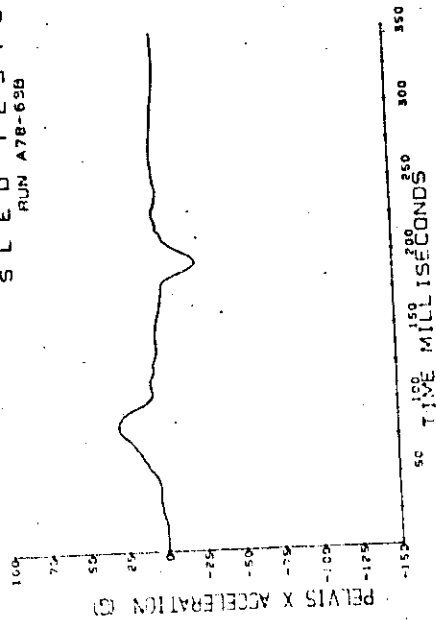
CAMI  
S L E D T E S T S  
RUN A78-69B



CAMI  
S L E D T E S T S  
RUN A78-69B



CAMI  
S L E D T E S T S  
RUN A78-69B



CAMI  
S L E D T E S T S  
RUN A78-69B

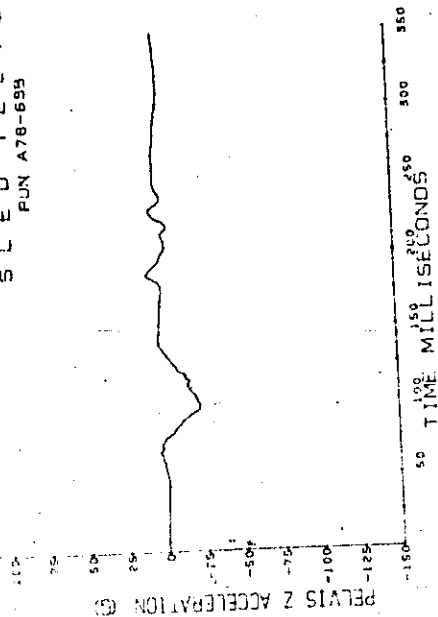


Figure C-1 (continued). 16-g tests.  
pelvis acceleration.



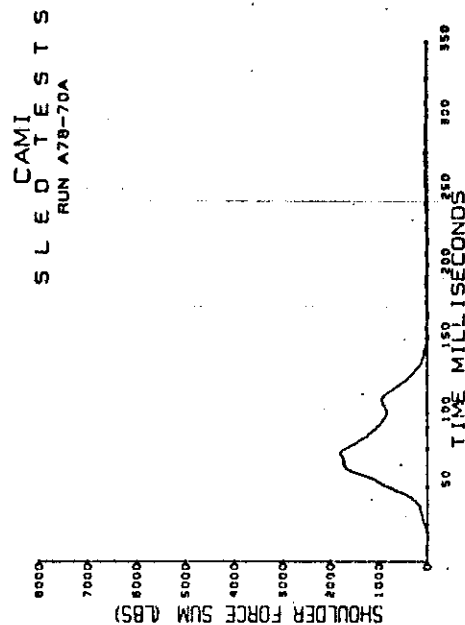
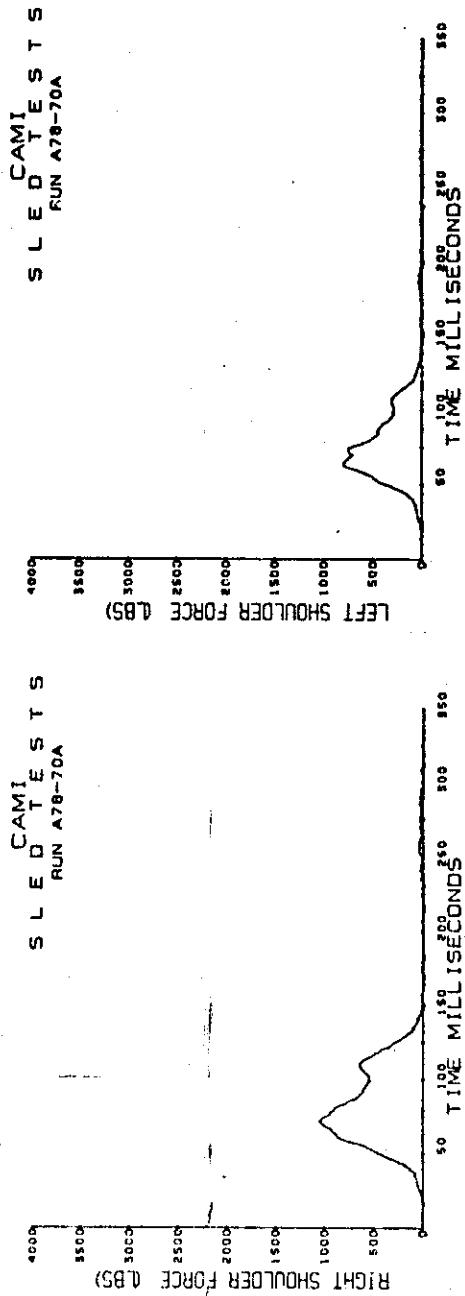


Figure C-1 (continued). 18-g tests.  
Shoulder belt loads.

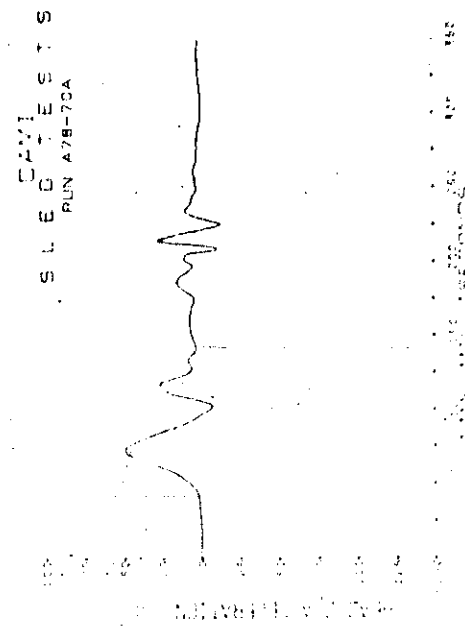
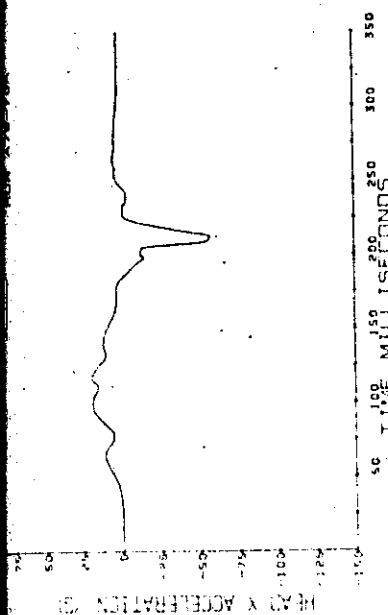
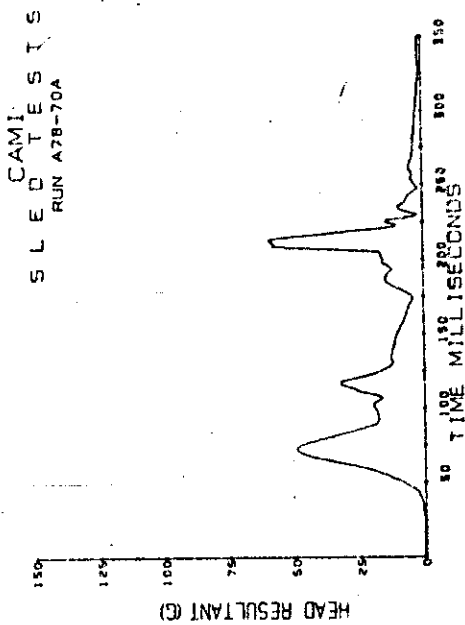
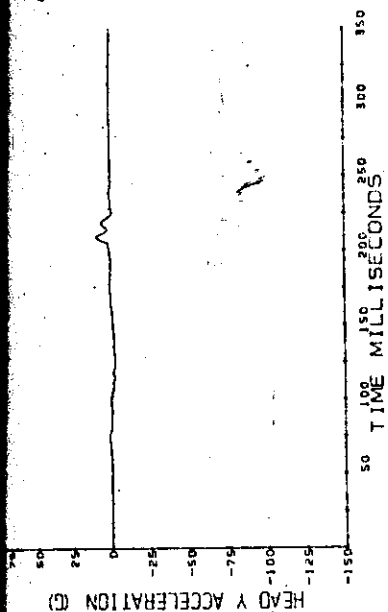


Figure C-1 (continued). 18-g tests.  
Head acceleration.

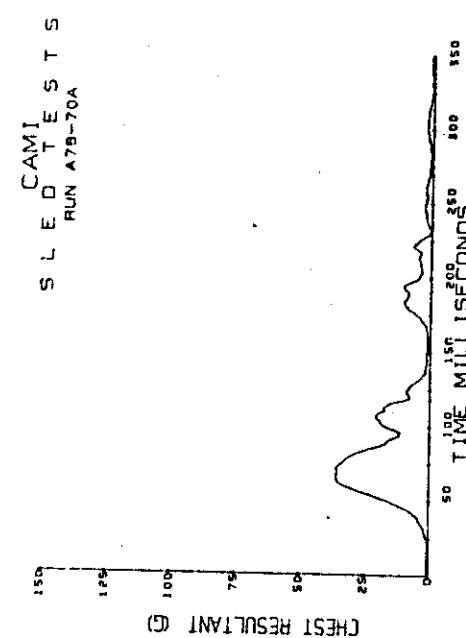
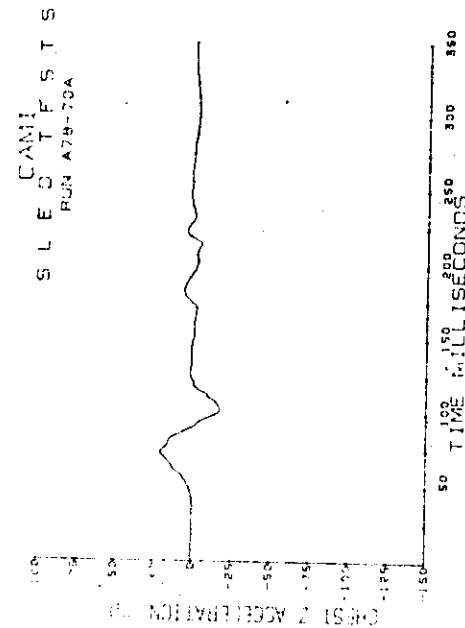
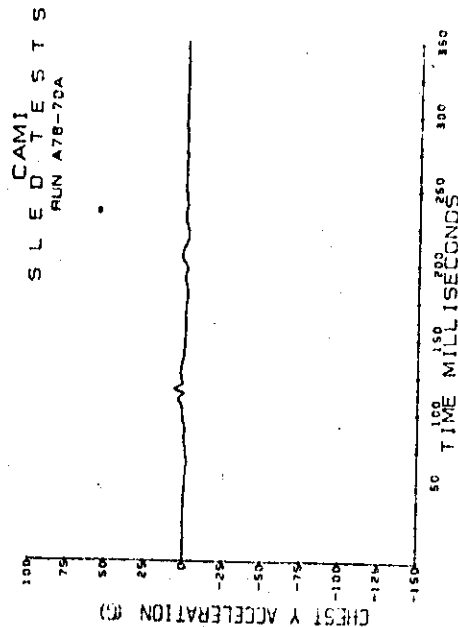
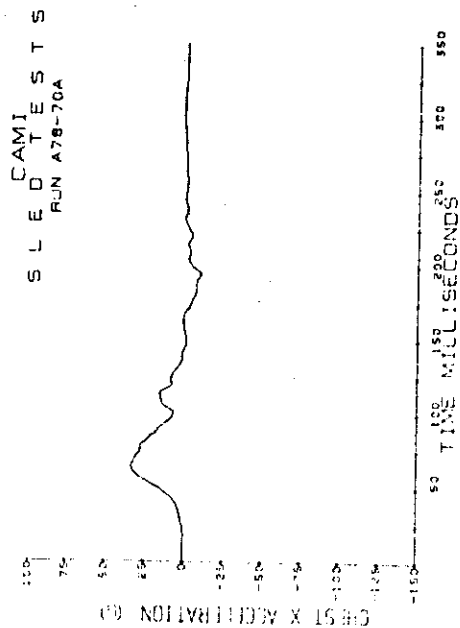
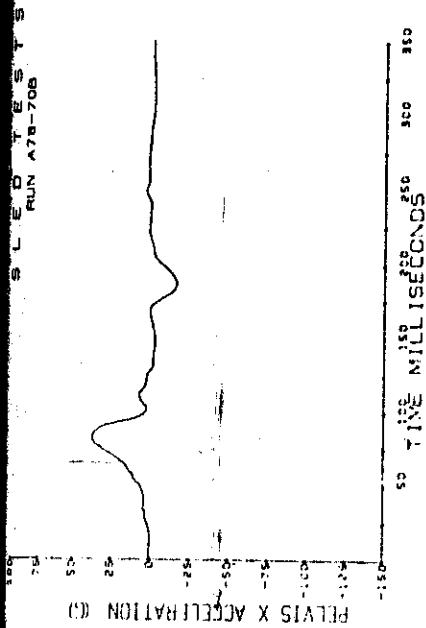


Figure C-1 (continued). 18-g tests.  
Chest acceleration.



170

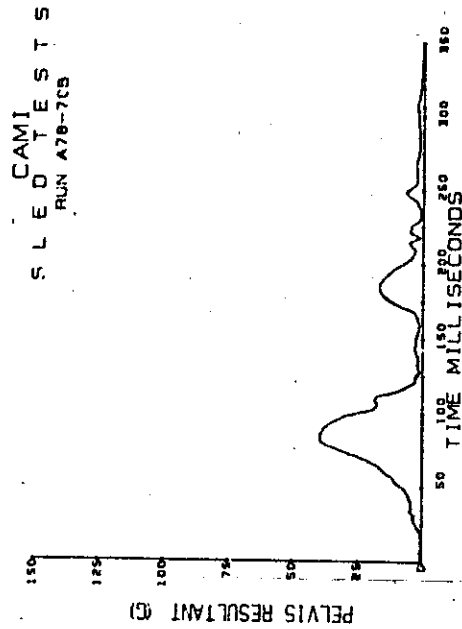
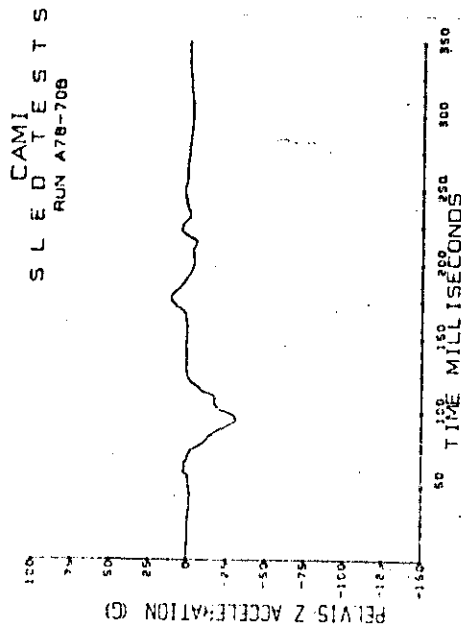
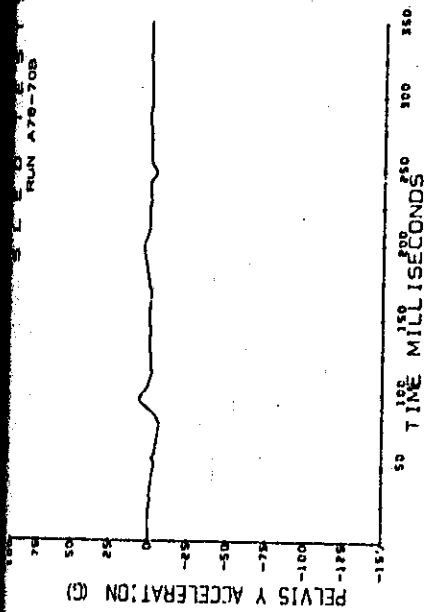
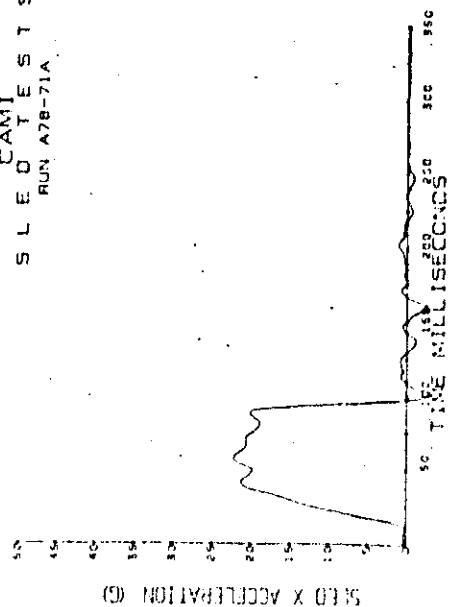


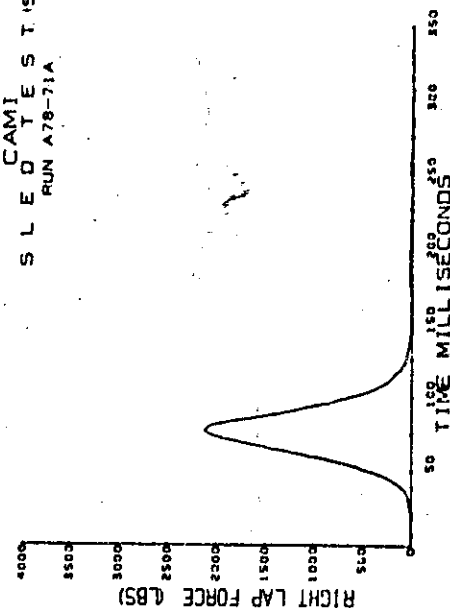
Figure C-1 (continued). 18-g tests.  
Pelvis acceleration.



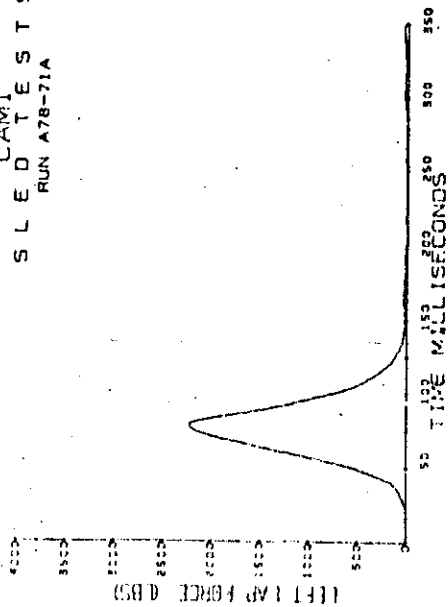
CAMI  
SLED TESTS  
RUN A78-71A



CAMI  
SLED TESTS  
RUN A78-71A



CAMI  
SLED TESTS  
RUN A78-71A



CAMI  
SLED TESTS  
RUN A78-71A

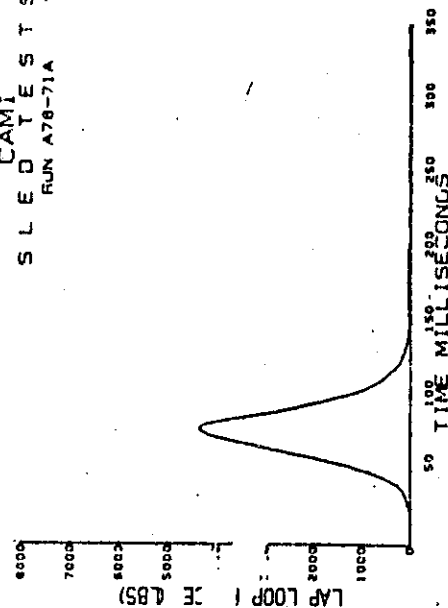
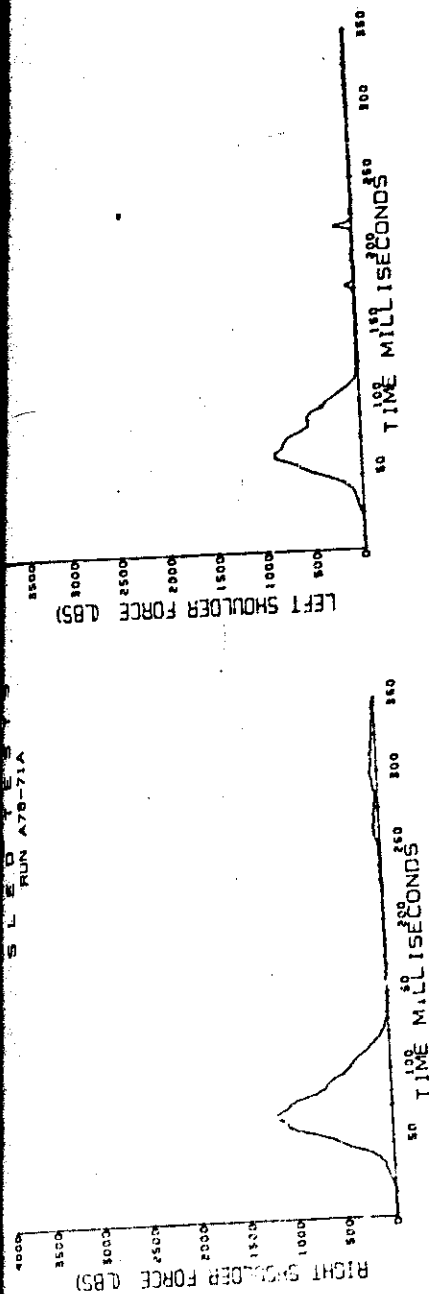


Figure C-1 (continued). 21-g tests.  
Sled deceleration and lapbelt loads.



CAMI  
S L E D T E S T S  
RUN A78-71A

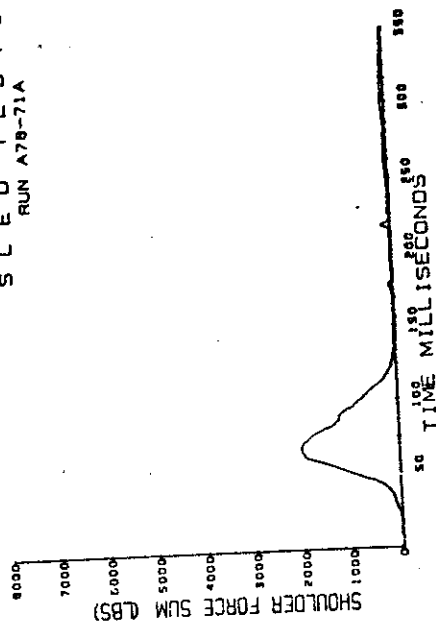


Figure C-1 (continued). 21-g tests.  
Shoulder belt loads.

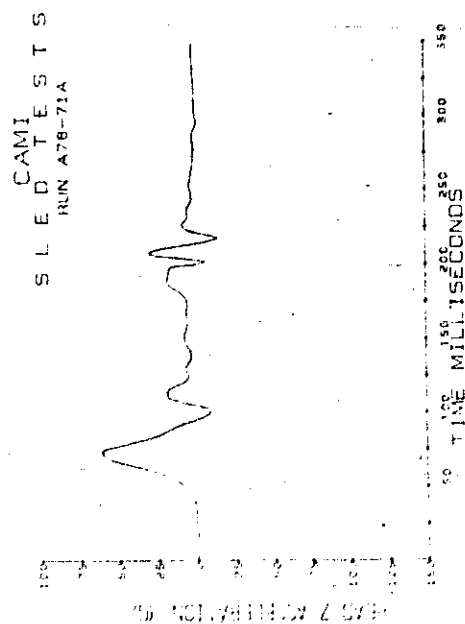
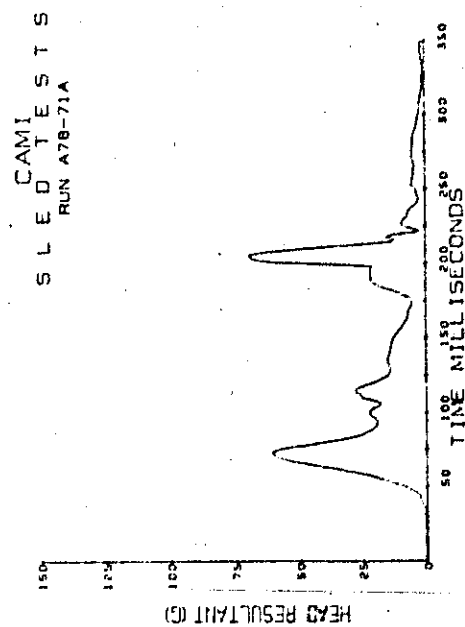
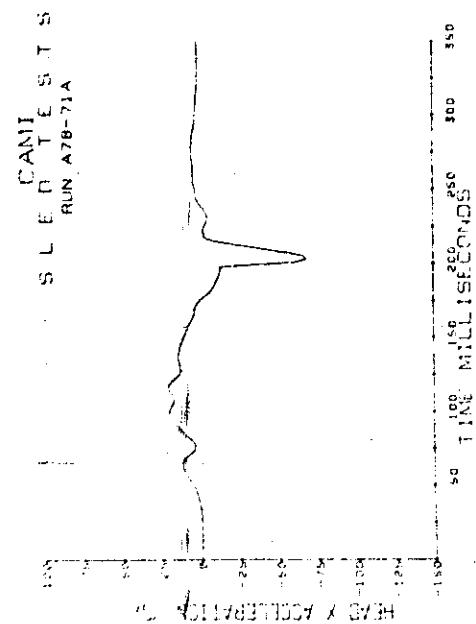
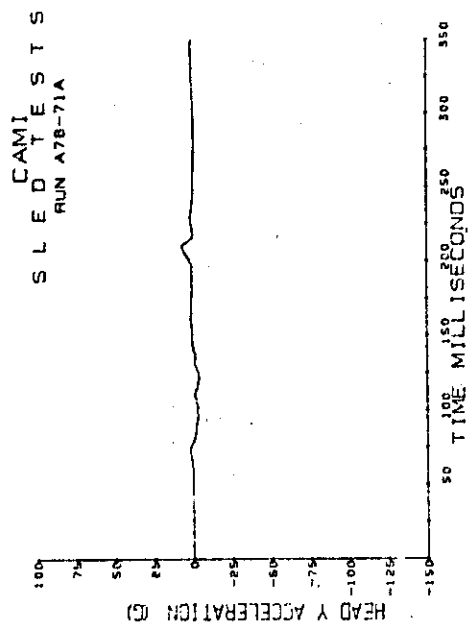


Figure C-1 (continued). 21-g tests.  
Head acceleration.

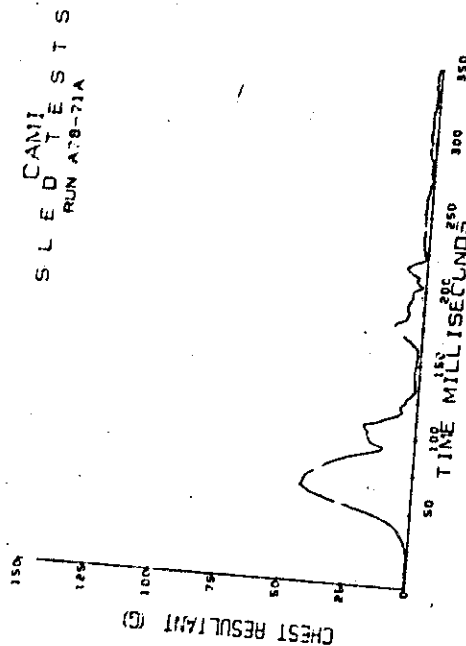
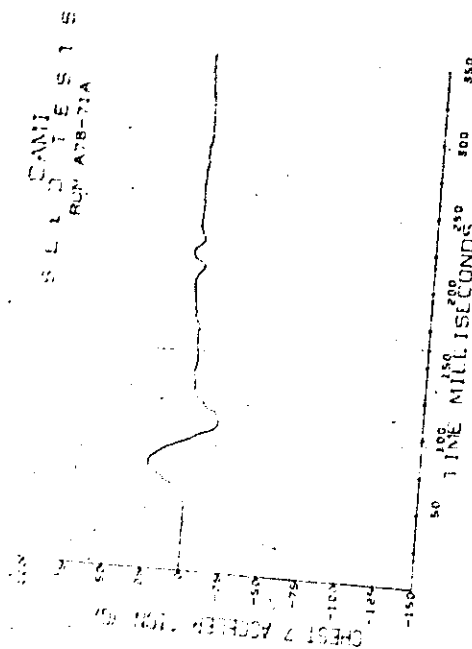
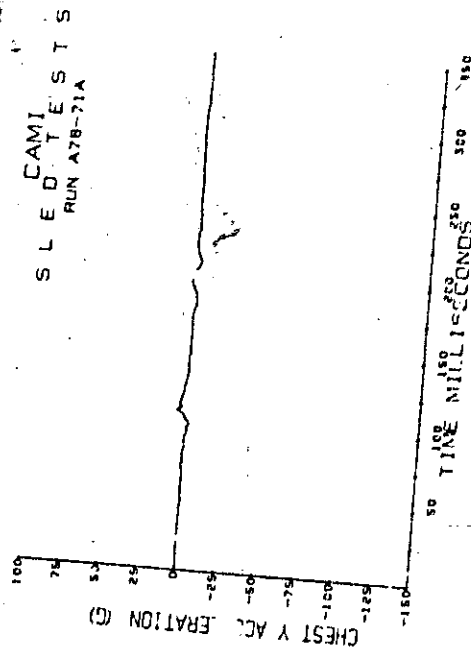
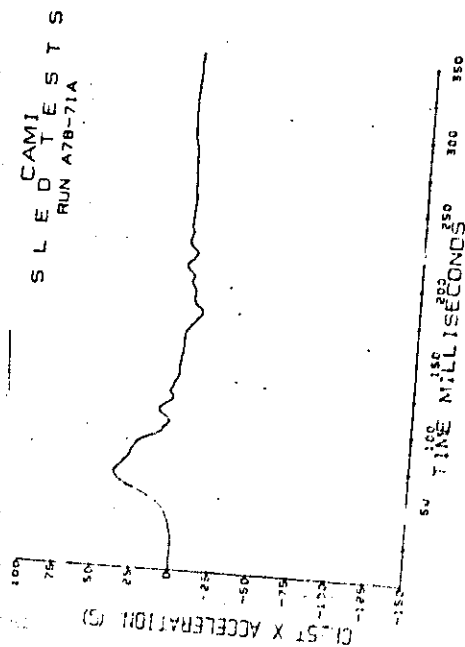
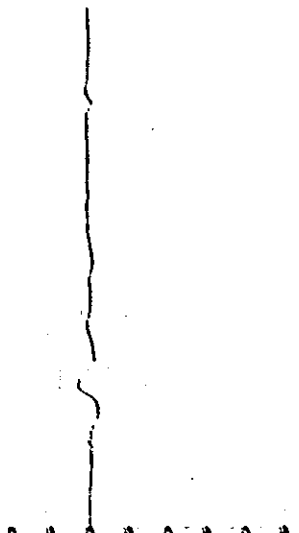


Figure C-1 (continued). 21-g tests.  
Chest acceleration.

S - E C  
 CAV.  
 0.1% A78-71.9

100

CD INTRINSIC STATE



S - E C  
 CAV.  
 0.1% A78-71.9

S - E C  
 CAV.  
 0.1% A78-71.9

100

CD INTRINSIC STATE

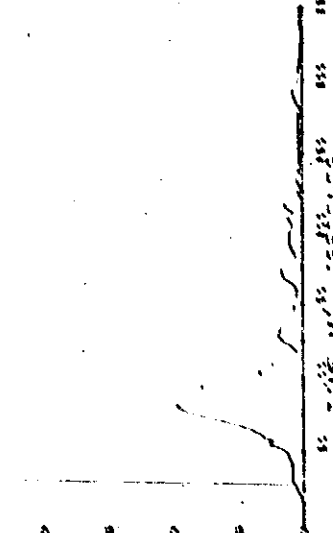


Figure 2 (continued). 21-g test.  
 0.1% A78-71.9

SLED TESTS  
RUN A78-72A

RIGHT LAP FORCE (LBS)

50 TIME MILLISECONDS 100 150 200

CAMI  
SLED TESTS  
RUN A78-72A

LAP LOOP FORCE (LBS)

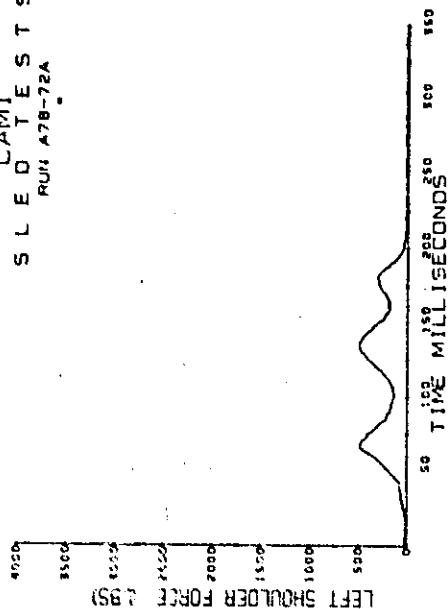
50 TIME MILLISECONDS 100 150 200

CAMI  
SLED TESTS  
RUN A78-72A

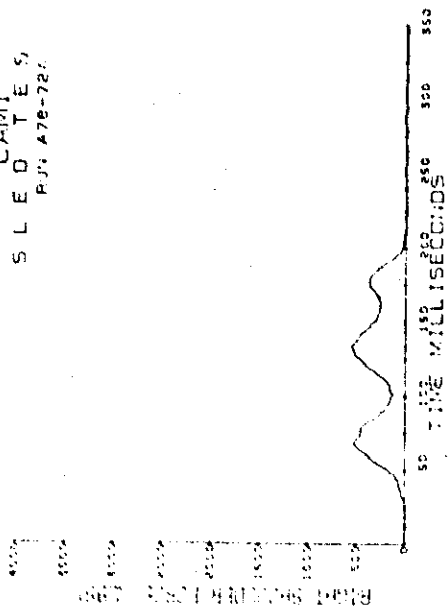
50 TIME MILLISECONDS 100 150

Figure C-2 Kevlar webbing. 9-2 tests.  
Sled deceleration and lapbelt loads.

# CAMI SLED TESTS RUN A78-72A



# CAMI SLED TESTS RUN A78-72A



# CAMI SLED TESTS RUN A78-72A

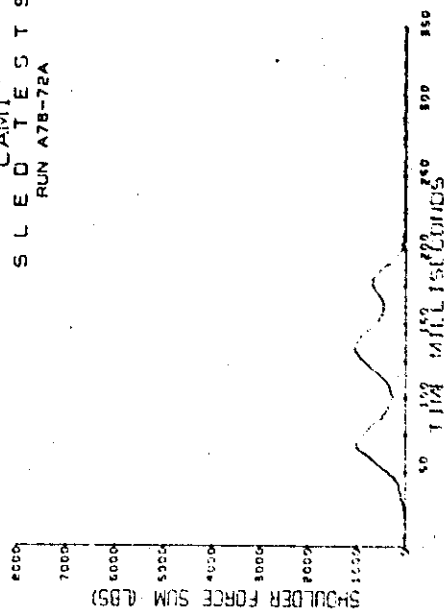


Figure C-2 (continued). 9-g test.  
Shoulder belt loads.

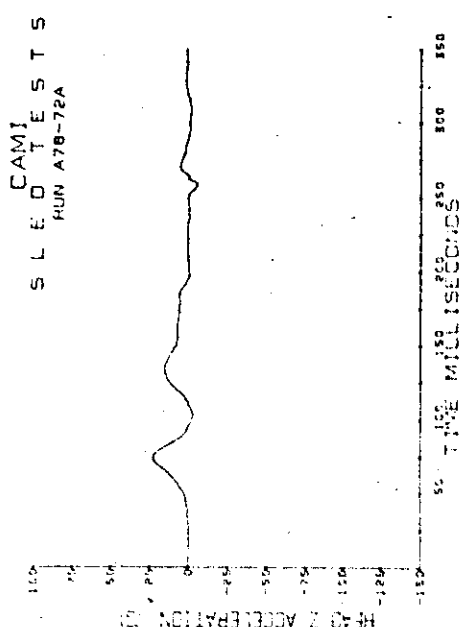
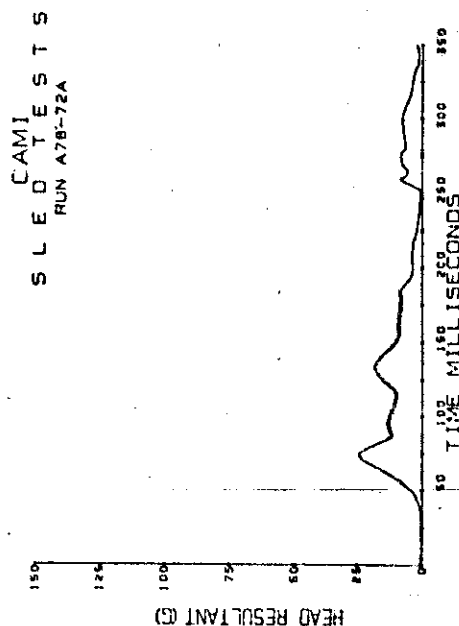
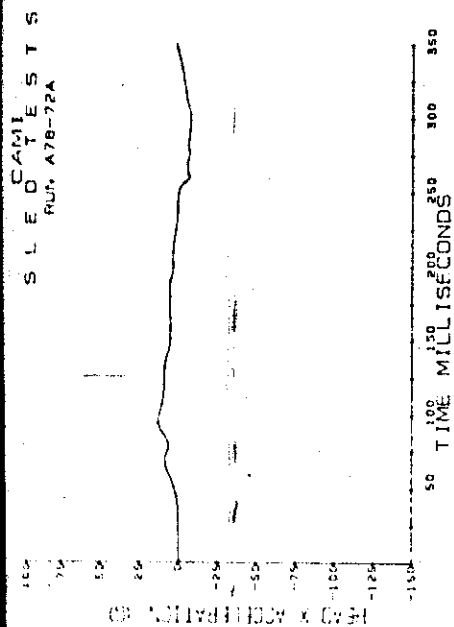
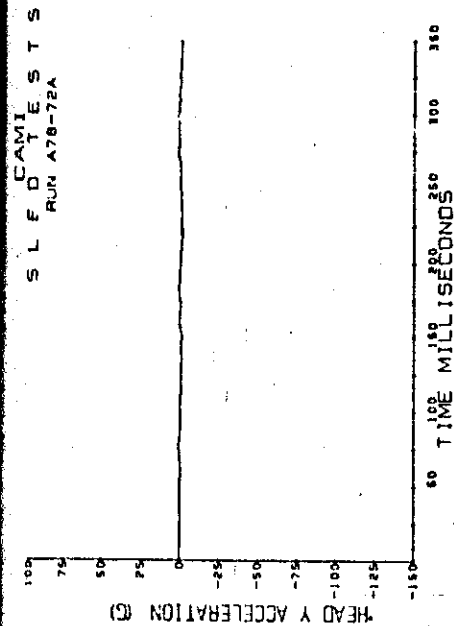


Figure C-2 (continued). 9-8 tests.  
Head acceleration.



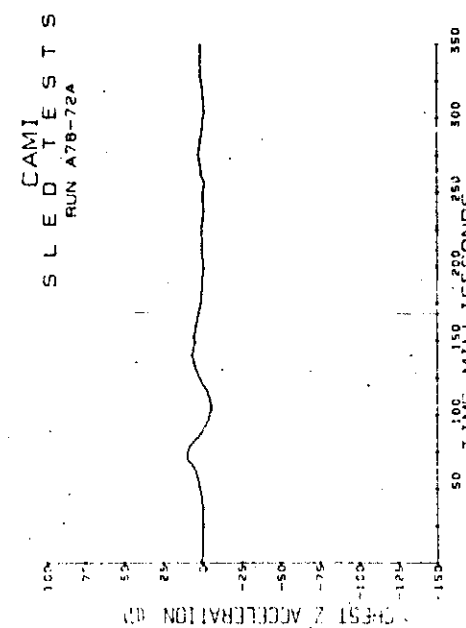
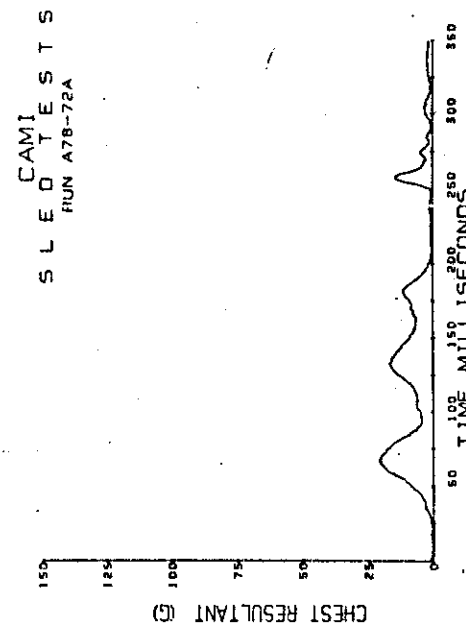
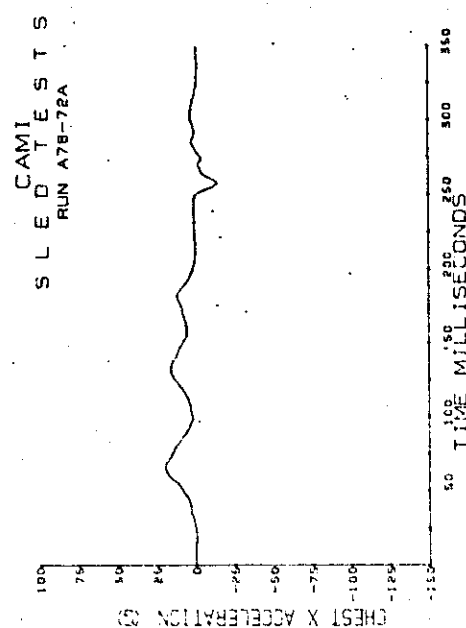
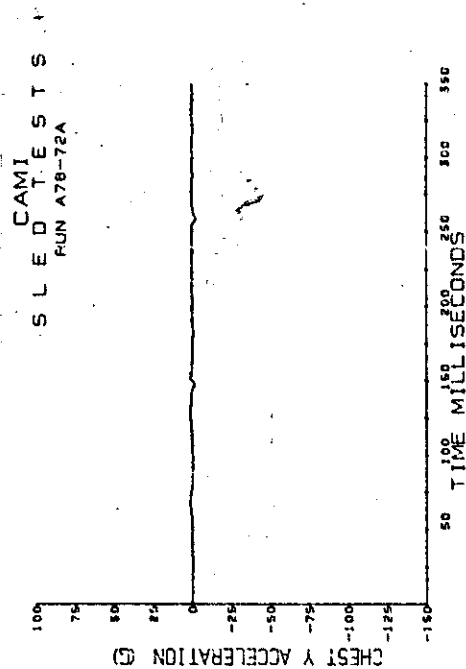


Figure C-2 (continued). 9-g tests.  
Chest acceleration.

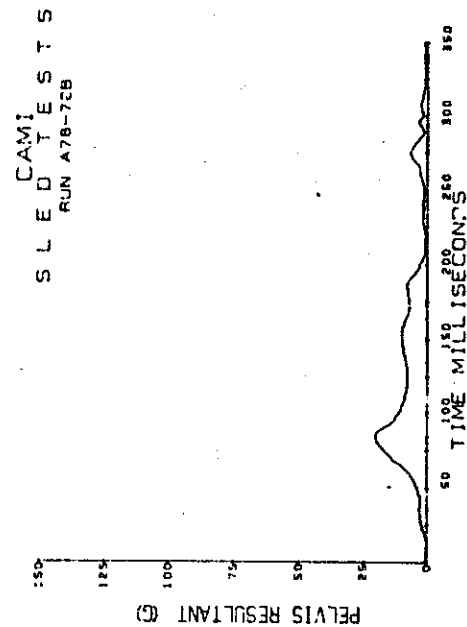
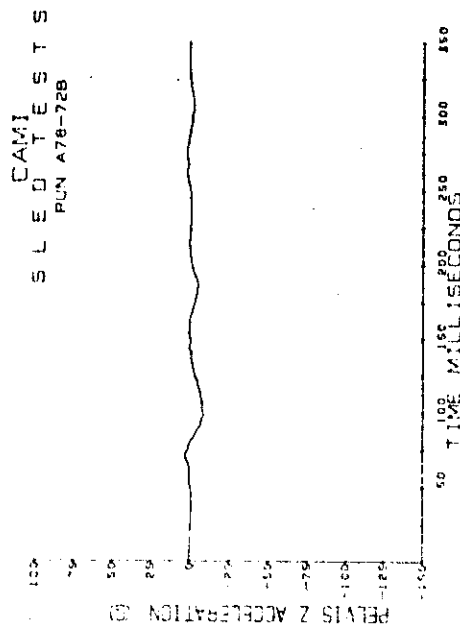
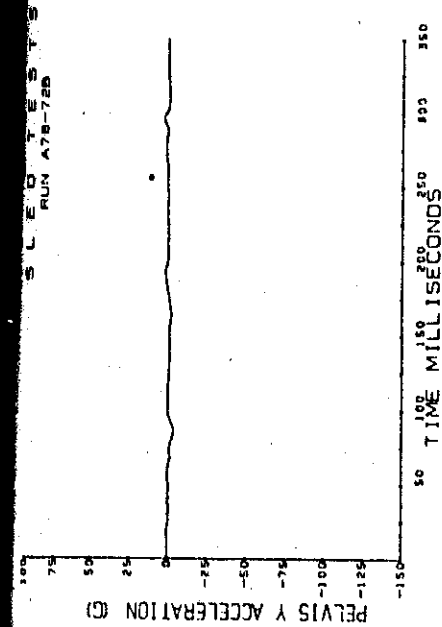
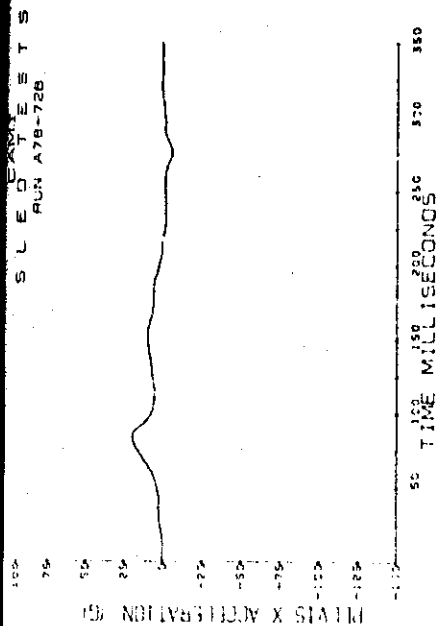


Figure C-2 (continued). 9-8 tests.  
Pelvis acceleration.

CAMI  
SLED TESTS  
RUN A78-73A

RIGHT LAP FORCE (LBS)

50 100 150 200 250 300 350  
TIME MILLISECONDS

CAMI  
SLED TESTS  
RUN A78-73A

SLED X ACCELERATION (G)

50 100 150 200 250 300 350  
TIME MILLISECONDS

CAMI  
SLED TESTS  
RUN A78-73A

LAP LOOP FORCE (LBS)

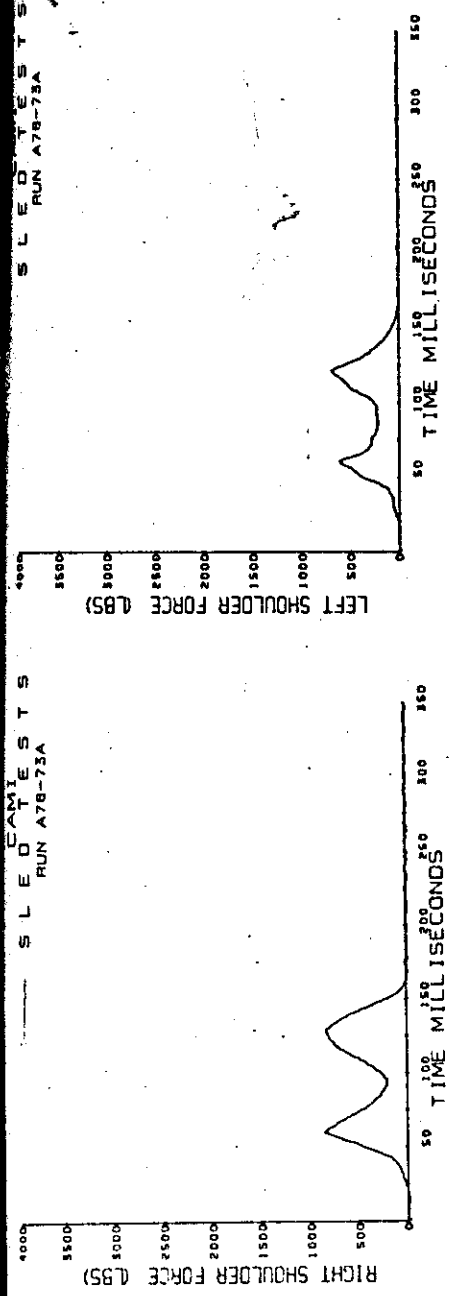
50 100 150 200 250 300 350  
TIME MILLISECONDS

CAMI  
SLED TESTS  
RUN A78-73A

LEFT LAP FORCE (LBS)

50 100 150 200 250 300 350  
TIME MILLISECONDS

Figure C-2 (continued). 12-g tests.  
Sled deceleration and lapbelt loads.



CAMI  
 S L E D T E S T S  
 RUN A78-73A

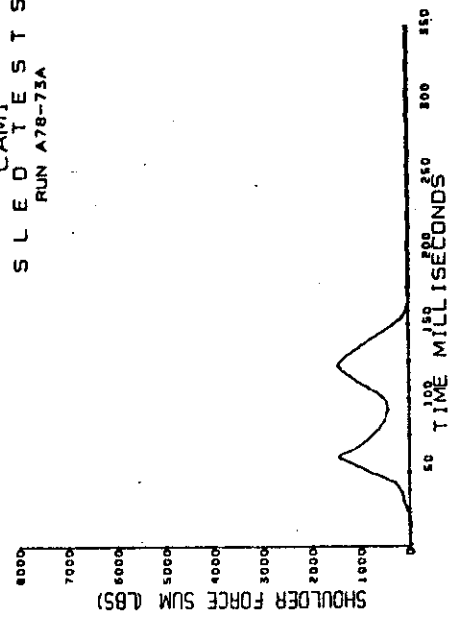


Figure C-2 (continued). 12-g tests.  
 Shoulder belt loads.

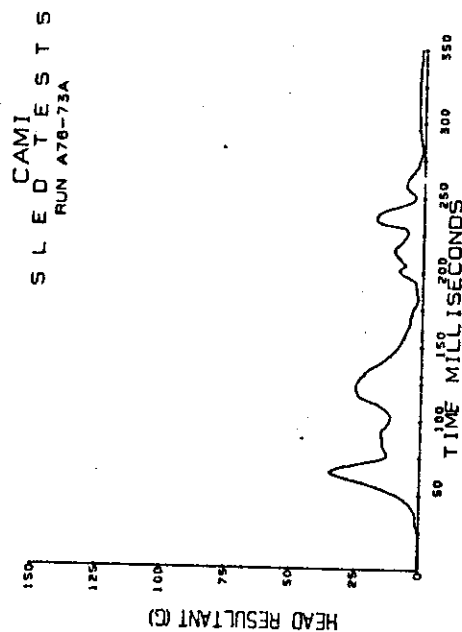
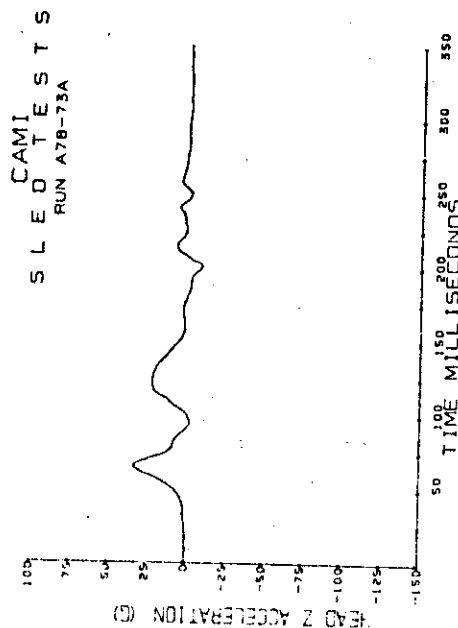
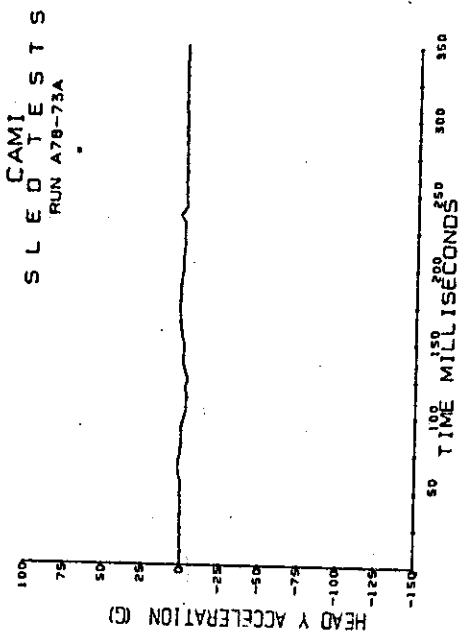
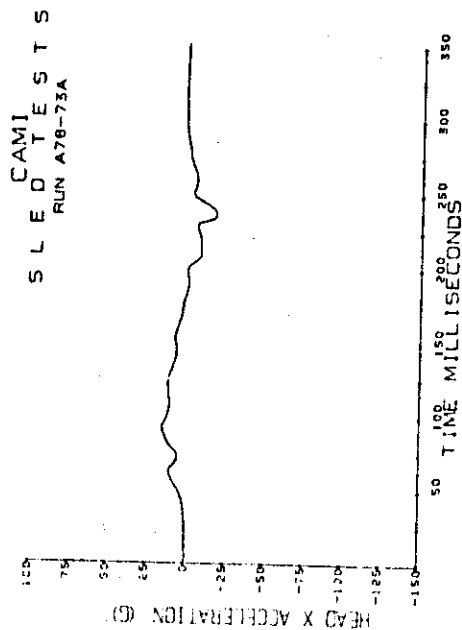


Figure C-2 (continued), 12-g tests.  
Head acceleration.

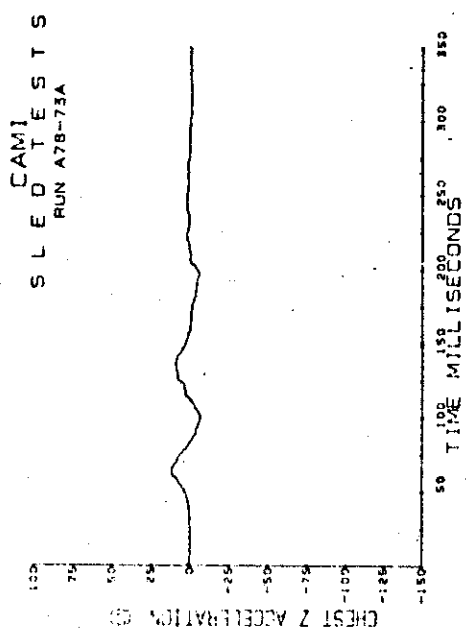
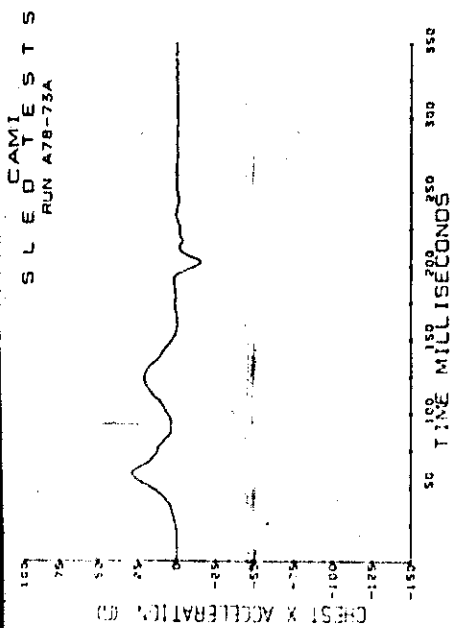
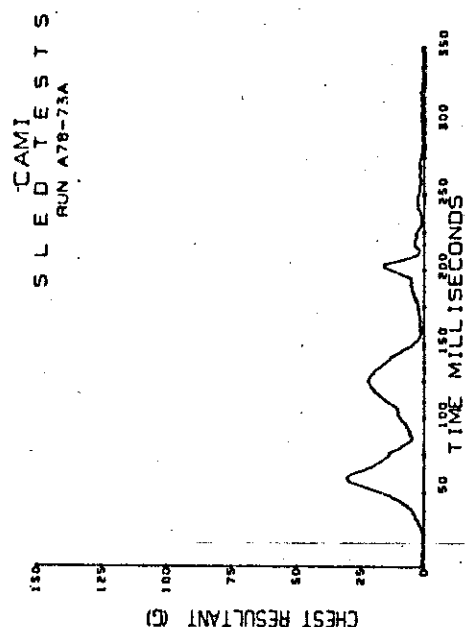
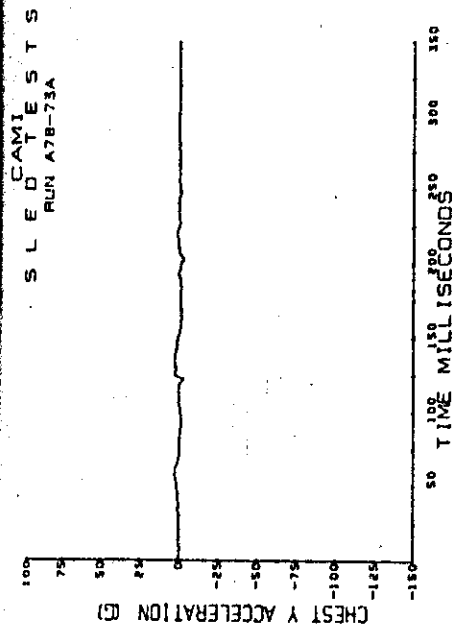


Figure C-2 (continued). 12-8 tests.  
Chest acceleration.

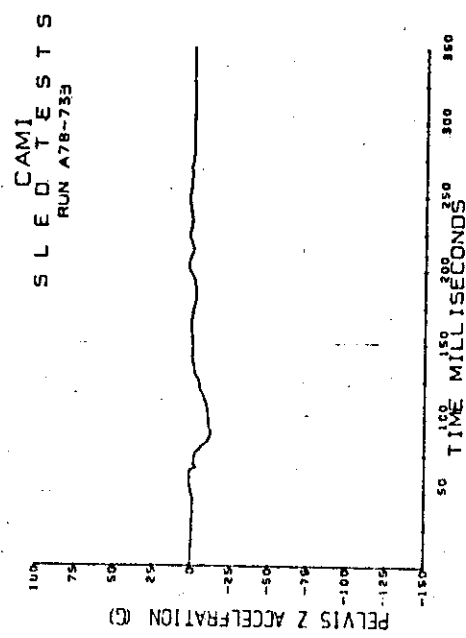
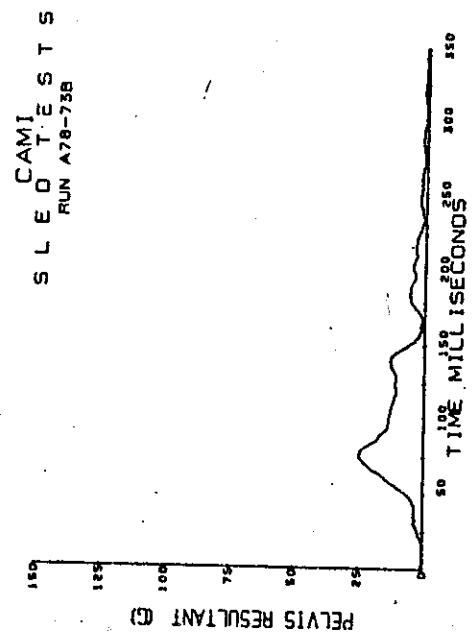
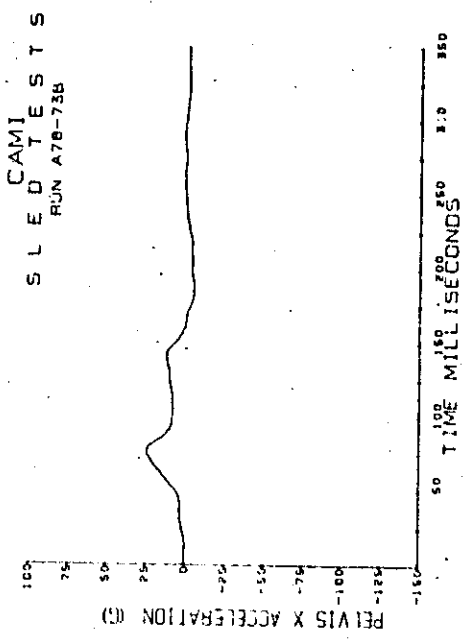
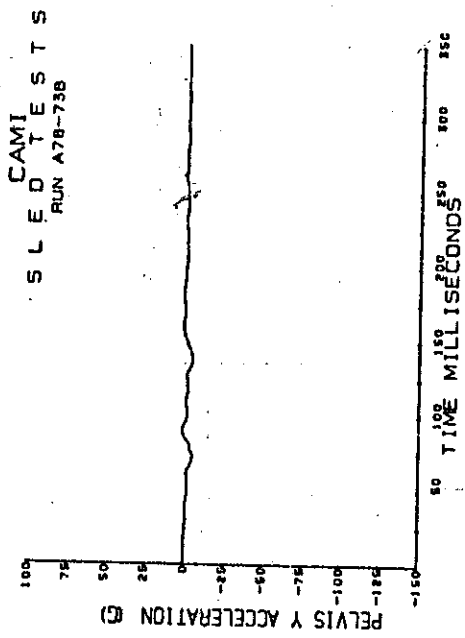


Figure C-2 (continued). 12-g tests.  
Pelvis acceleration.

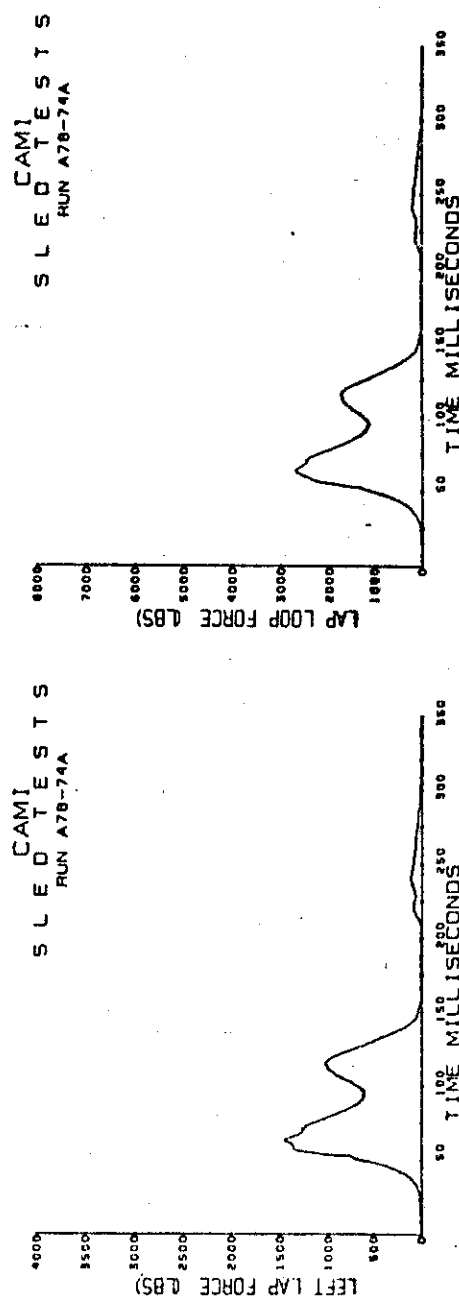
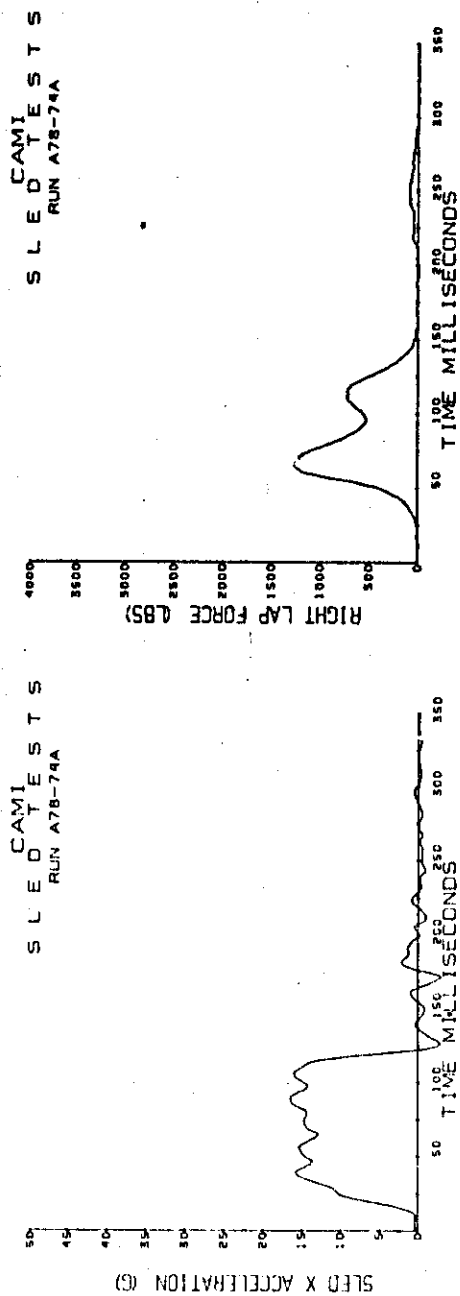
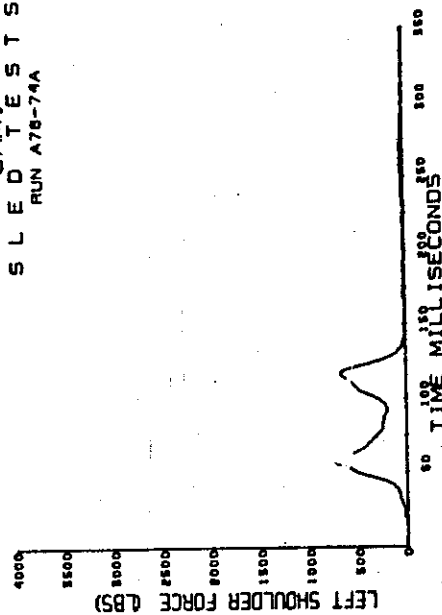


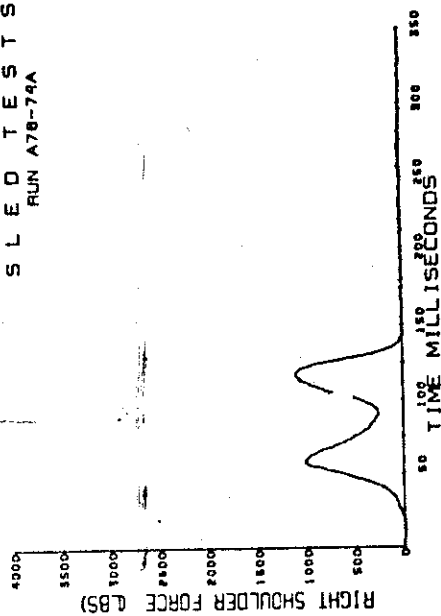
Figure C-2 (continued). 16-g tests.  
Sled deceleration and lapbelt loads.



CAMI  
S L E D T E S T S  
RUN A76-74A



CAMI  
S L E D T E S T S  
RUN A76-74A



CAMI  
S L E D T E S T S  
RUN A76-74A

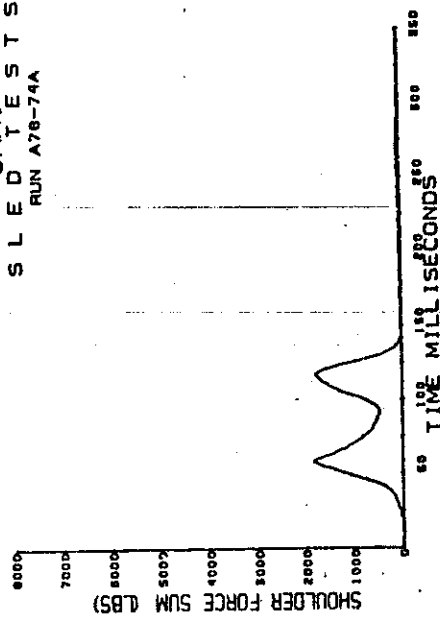


Figure C-2 (continued). 16-8 tests.  
Shoulder belt loads.

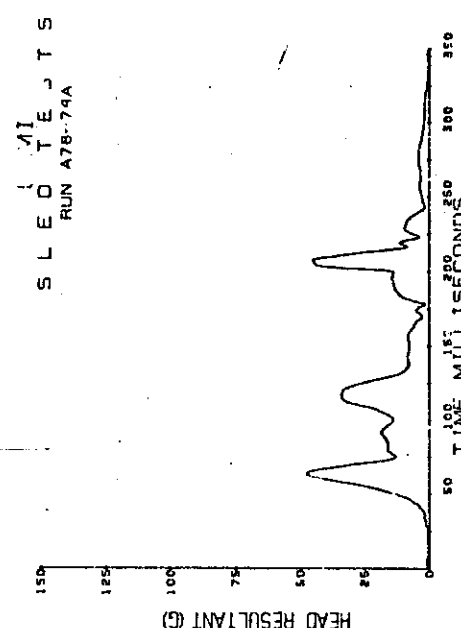
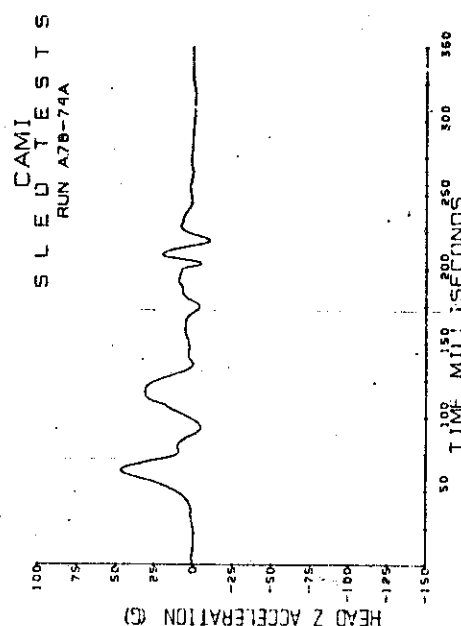
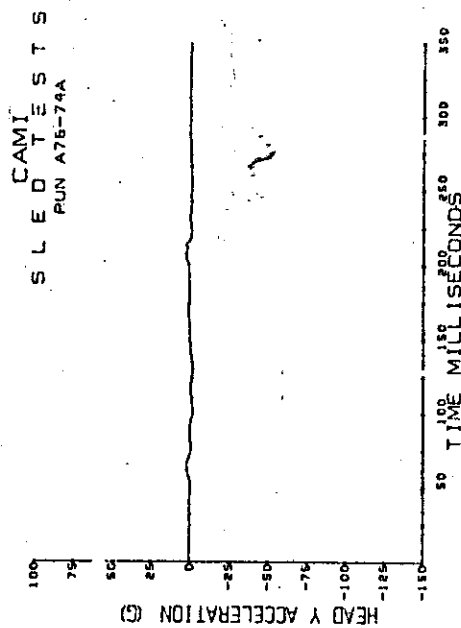
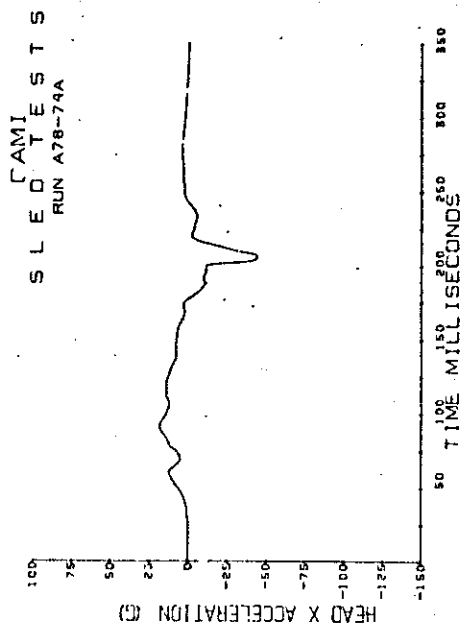


Figure C-2 (continued). 16-g tests.  
Head acceleration.

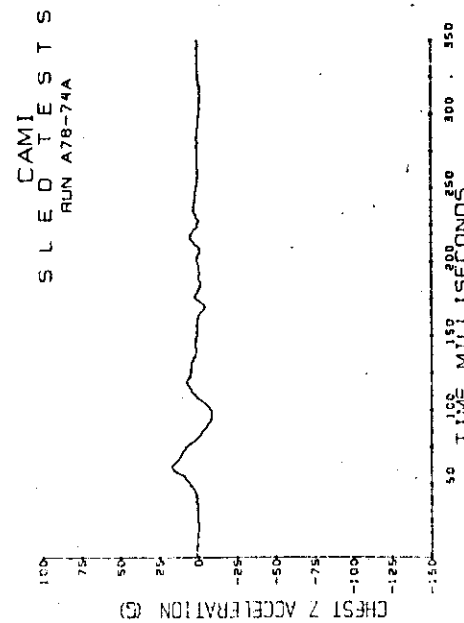
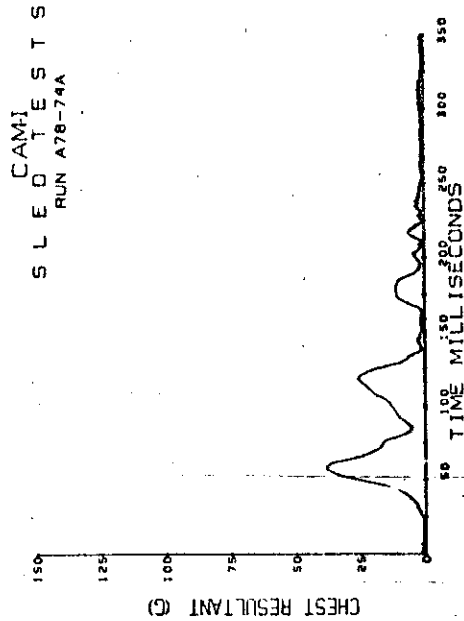
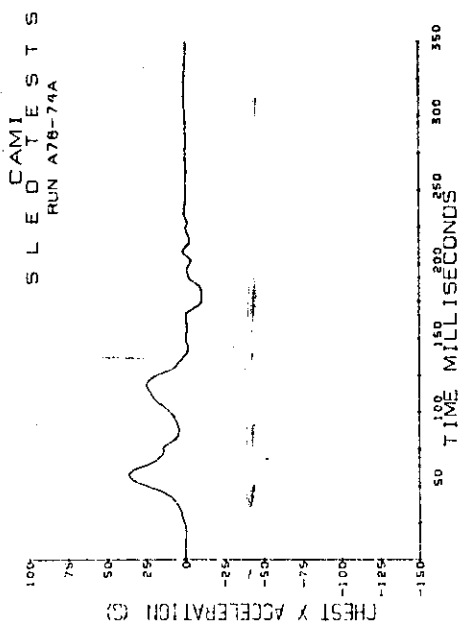
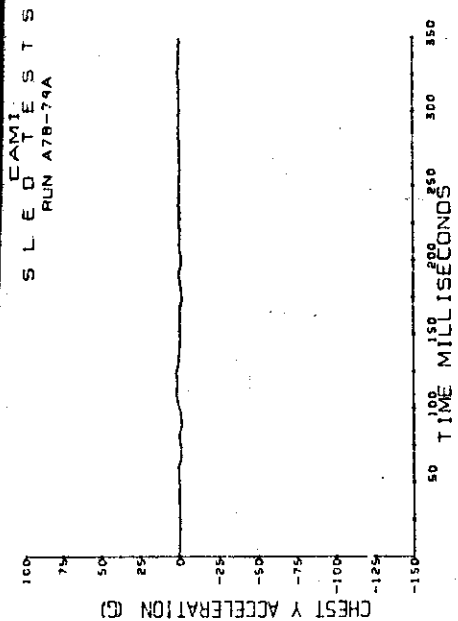


Figure C-2 (continued). 16-g tests.  
Chest acceleration.

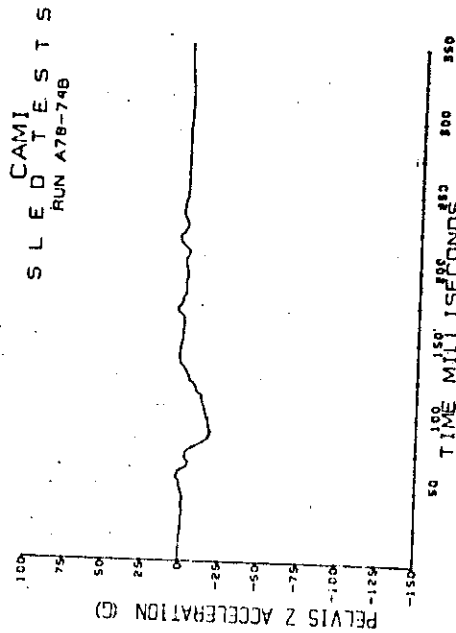
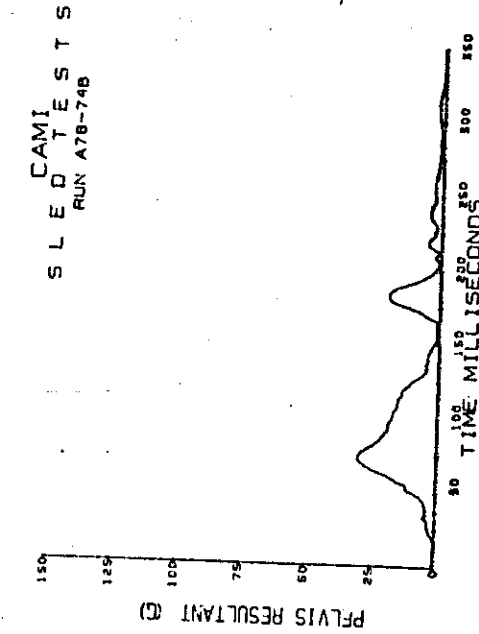
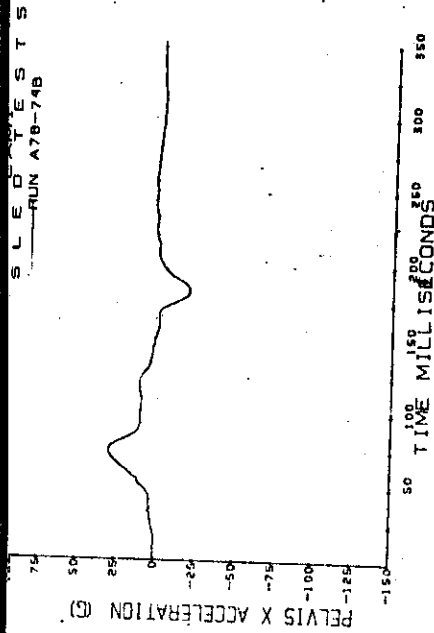
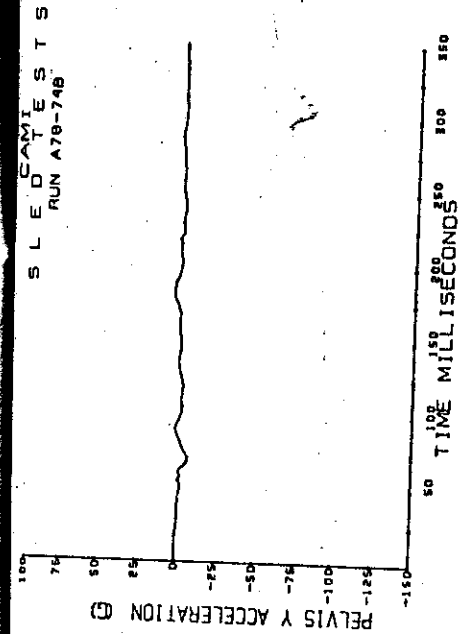
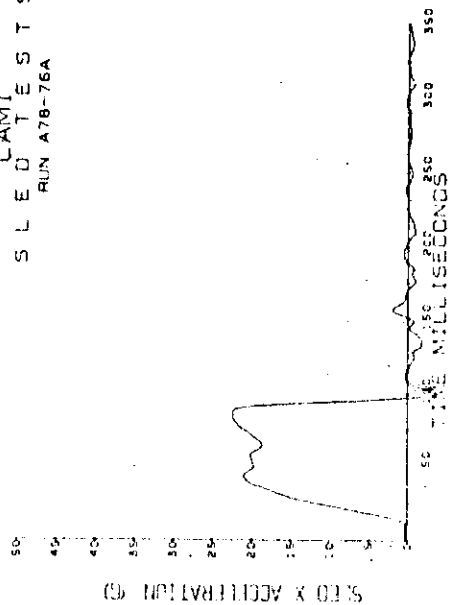
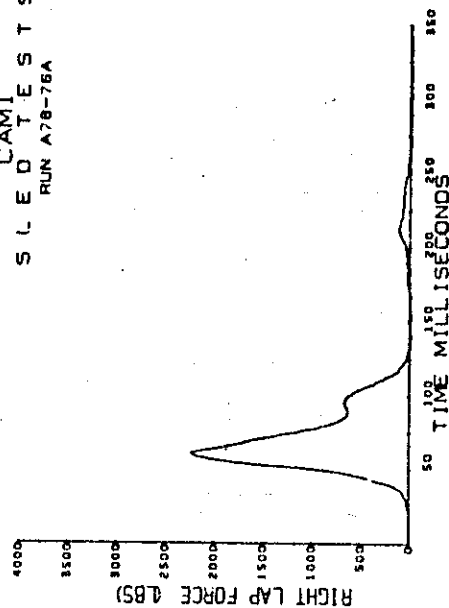


Figure C-2 (continued). 16-g tests.  
Pelvis acceleration.

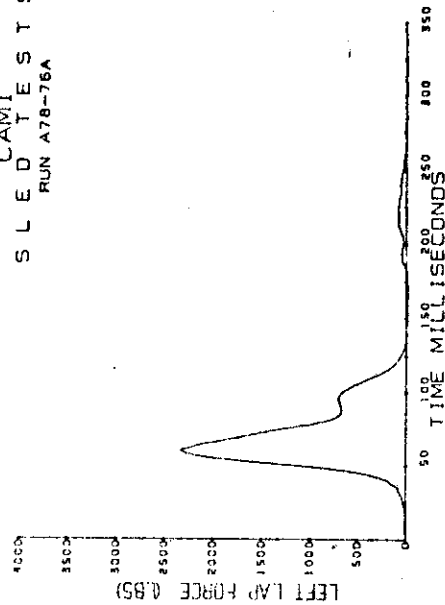
CAMI  
S L E D T E S T S  
RUN A78-76A



CAMI  
S L E D T E S T S  
RUN A78-76A



CAMI  
S L E D T E S T S  
RUN A78-76A



CAMI  
S L E D T E S T S  
RUN A78-76A

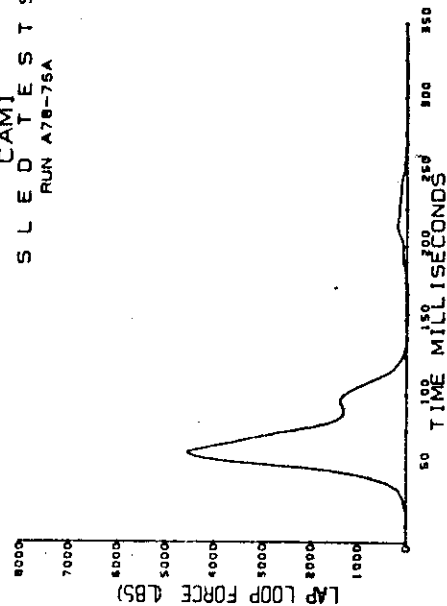
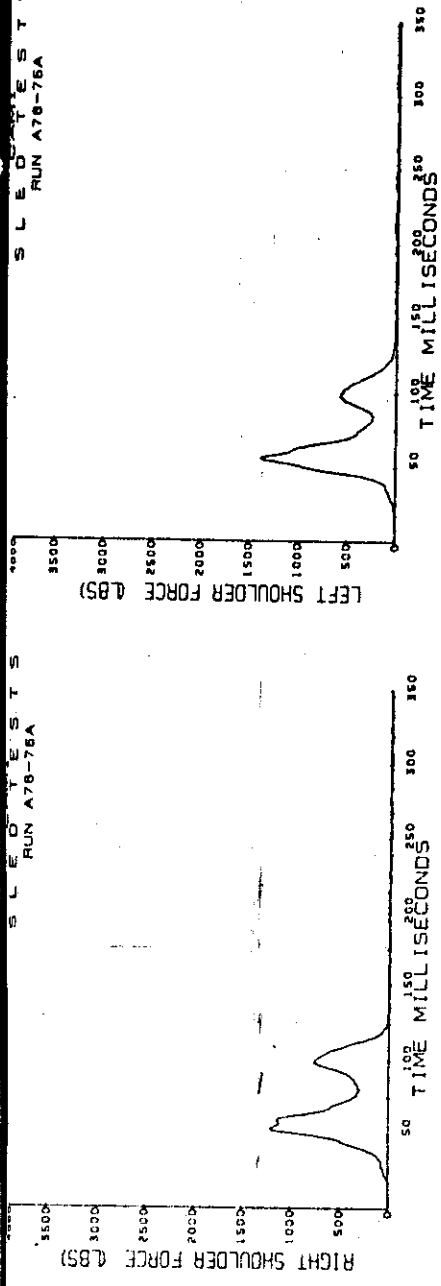


Figure C-2 (continued). 18-g tests.  
Sled deceleration and lapbelt loads.

S L E D T E S T S  
RUN A78-76A

S L E D T E S T S  
RUN A78-76A



CAMI  
S L E D T E S T S  
RUN A78-76A

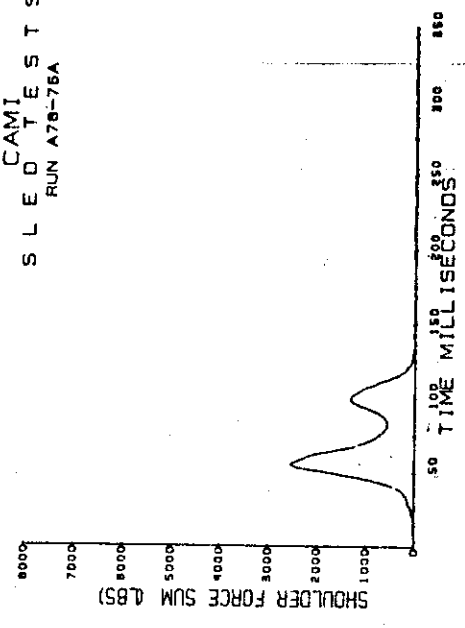


Figure C-2 (continued). 18-g tests.  
Shoulder belt loads.

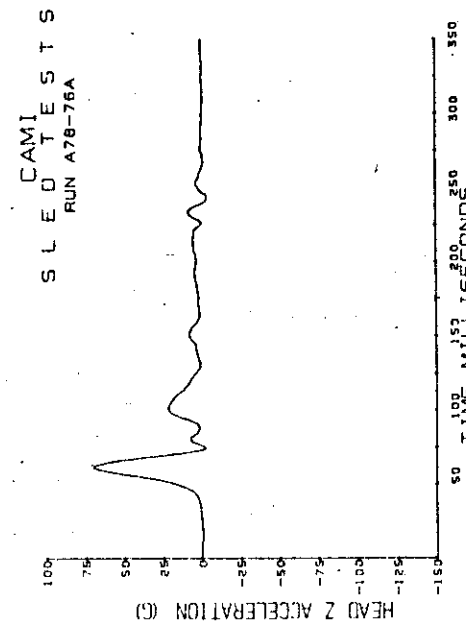
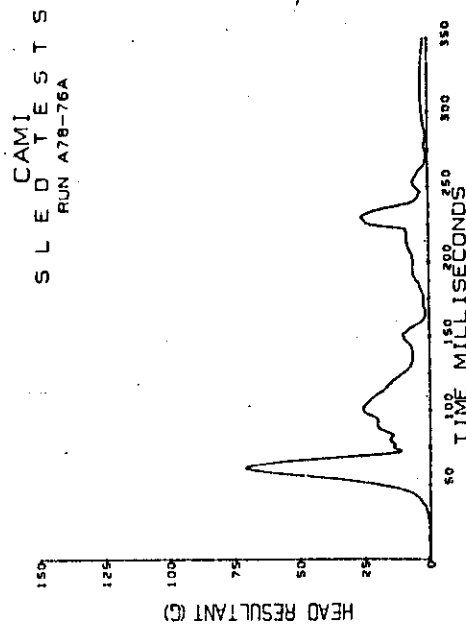
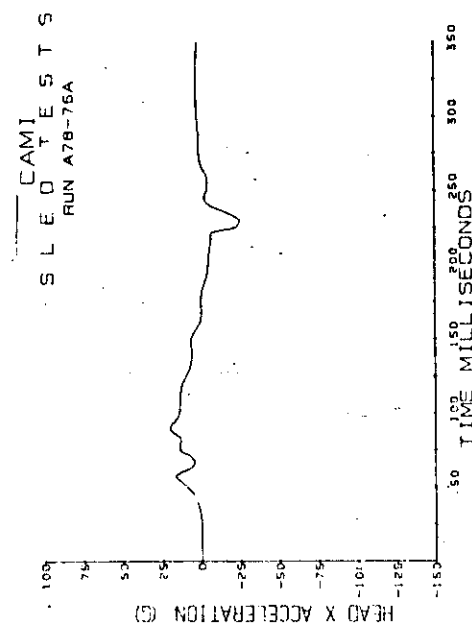
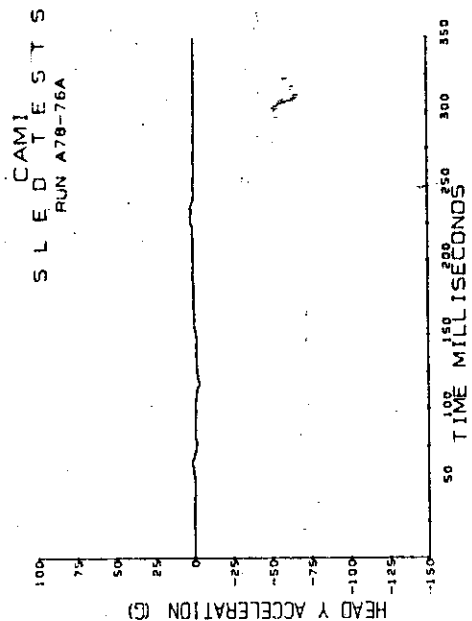


Figure C-2 (continued). 18-g tests.  
Head acceleration.

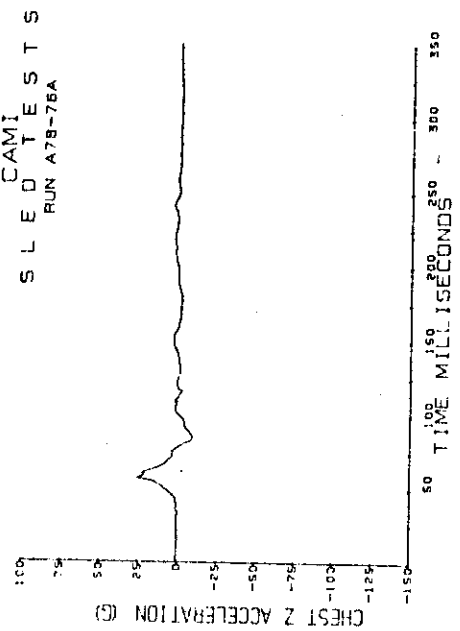
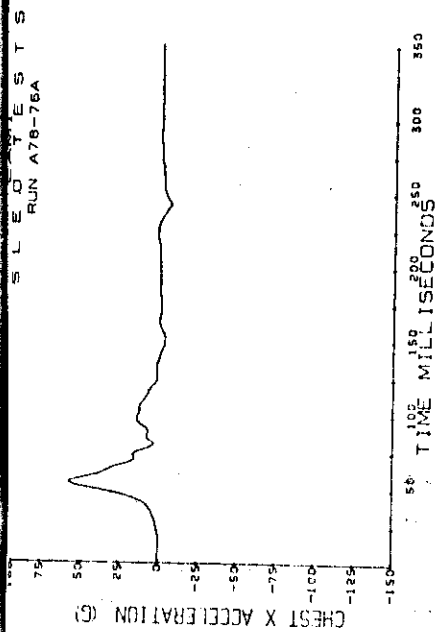
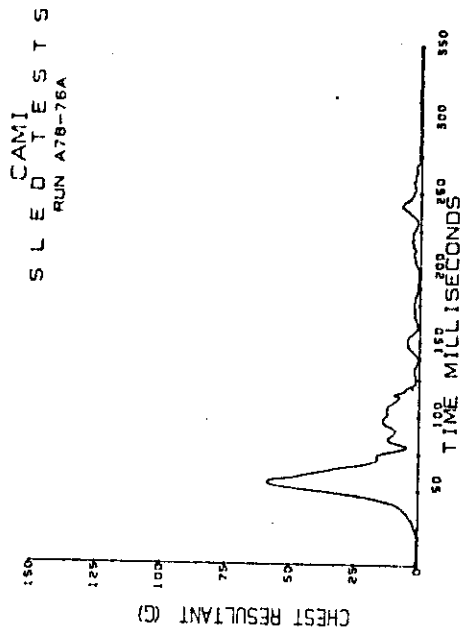
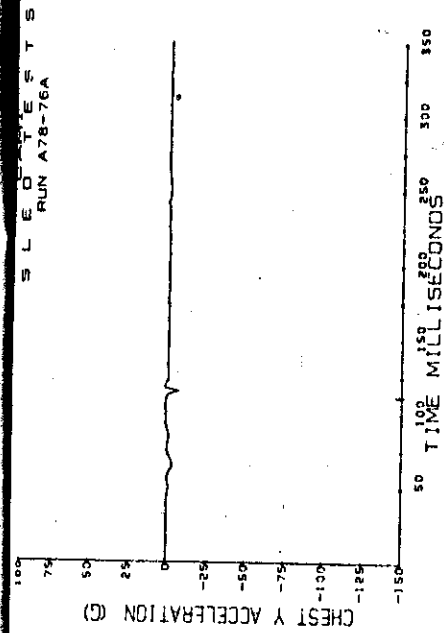
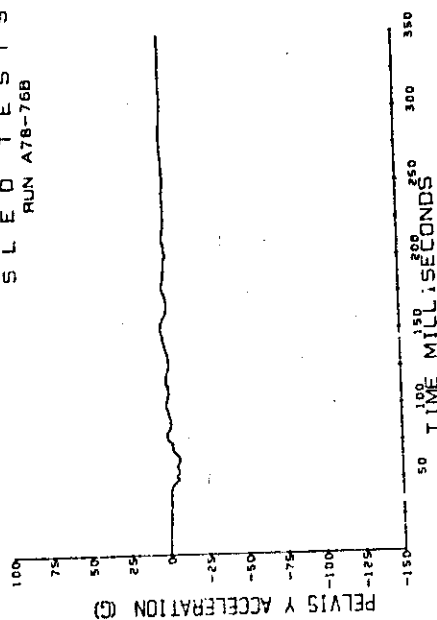


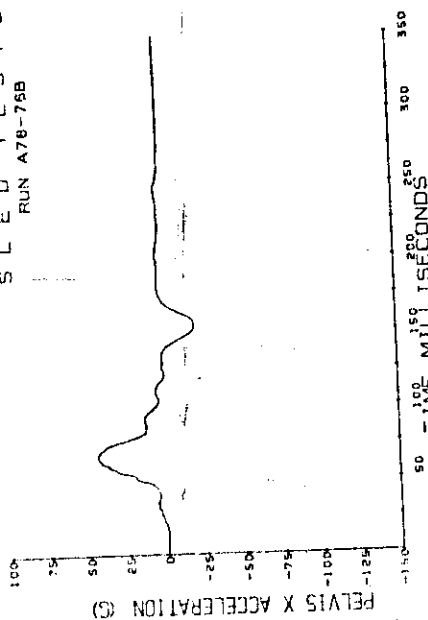
Figure C-2 (continued). 18-g tests.  
Chest acceleration.



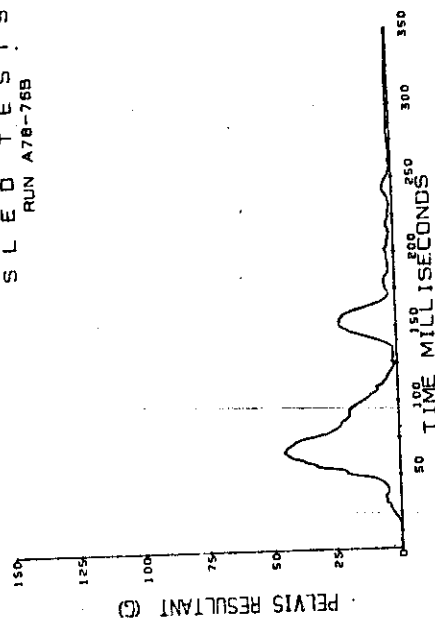
CAMI  
S L E D T E S T S  
RUN A78-76B



CAMI  
S L E D T E S T S  
RUN A78-76B



CAMI  
S L E D T E S T S  
RUN A78-76B



CAMI  
S L E D T E S T S  
RUN A78-76B

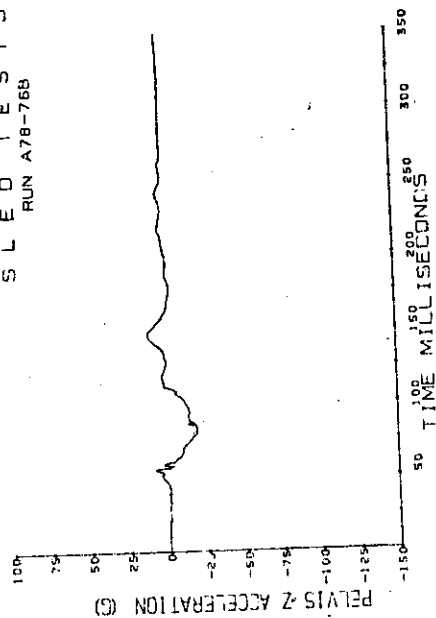


Figure C-2 (continued). 18-g tests.  
Pelvis acceleration.

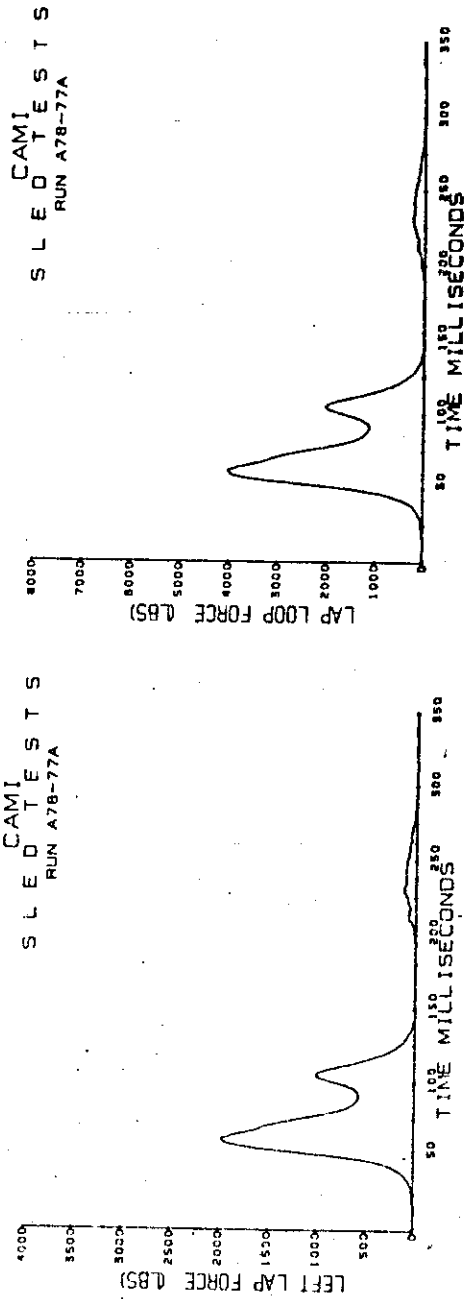
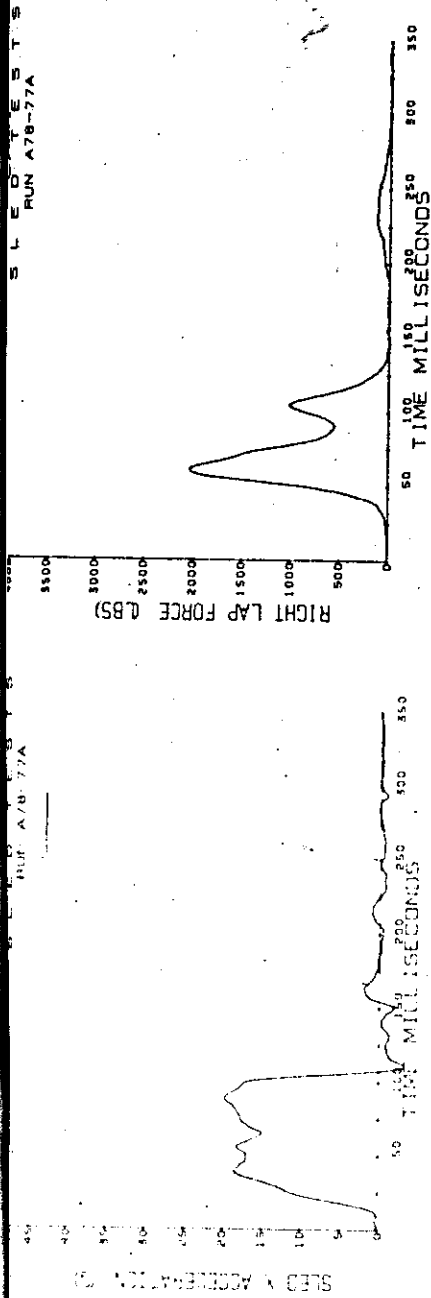


Figure C-2 (continued). 22-g tests.  
Sled deceleration and lapbelt loads.

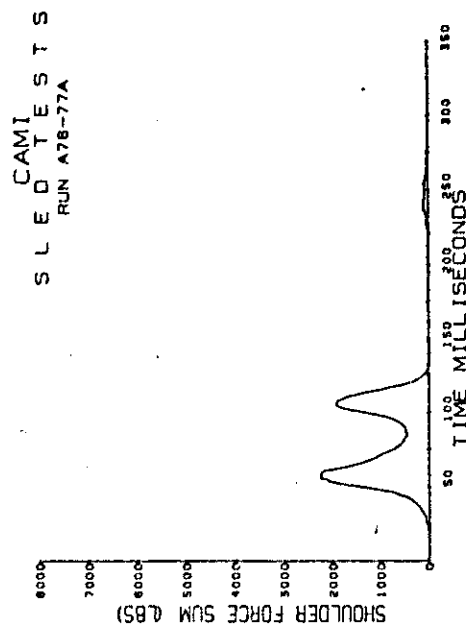
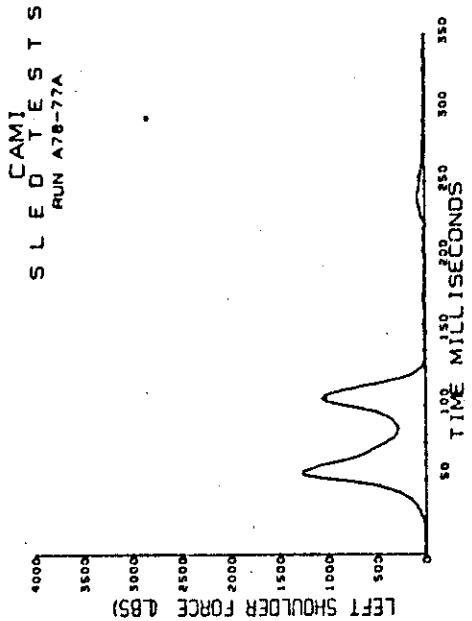
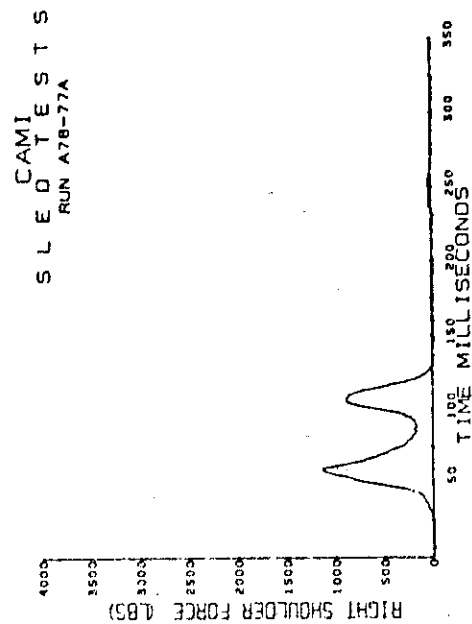
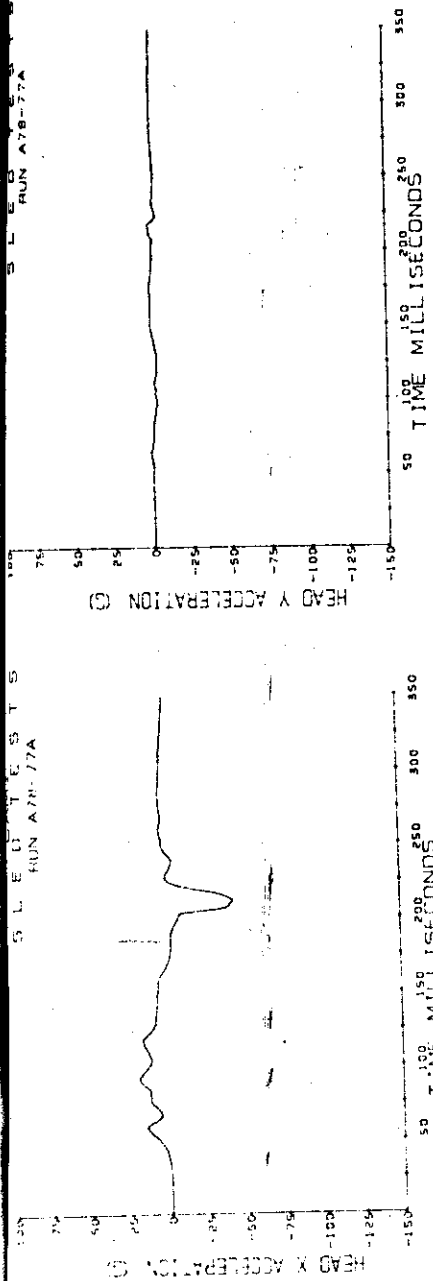
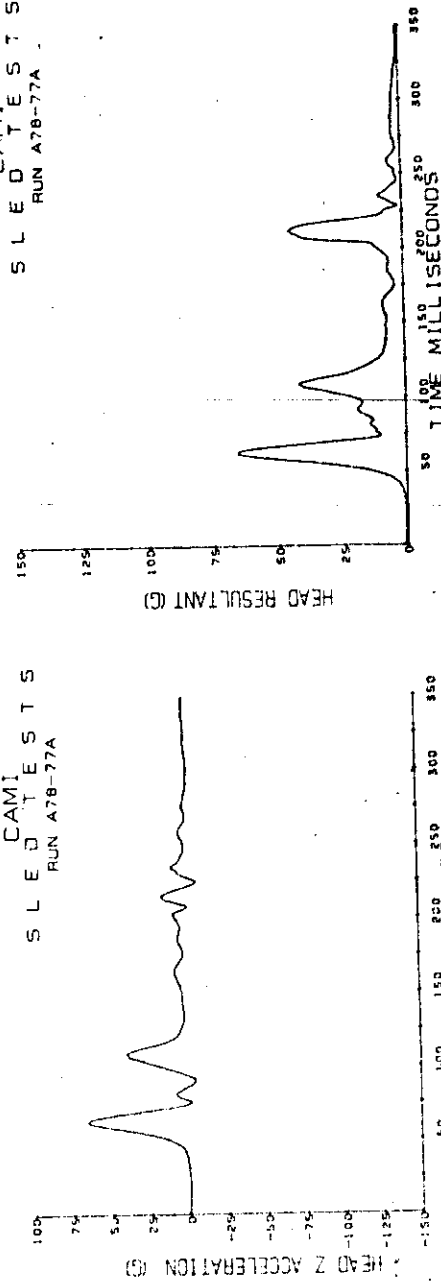


Figure C-2 (continued). 22-g tests.  
Shoulder belt loads.



CAMI  
SLID TESTS  
RUN A78-77A



CAMI  
SLID TESTS  
RUN A78-77A

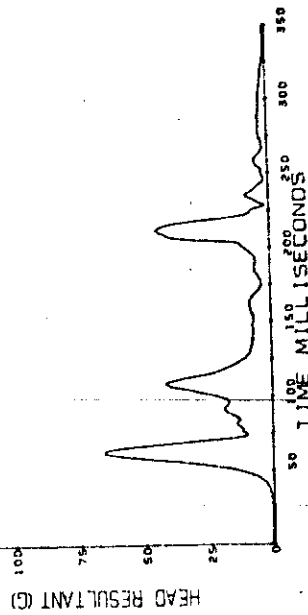


Figure C-2 (continued). 22-g tests.  
Head acceleration.

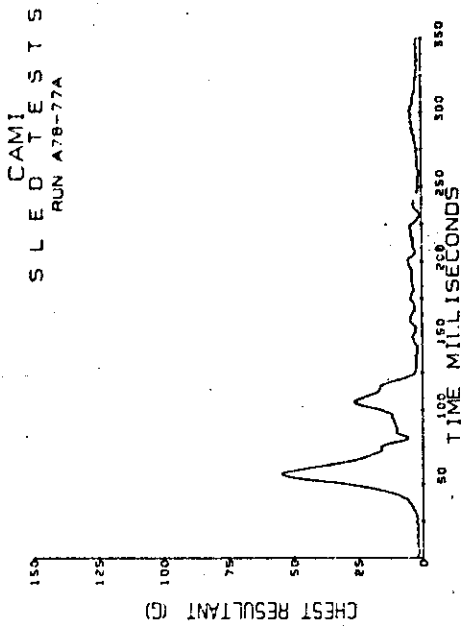
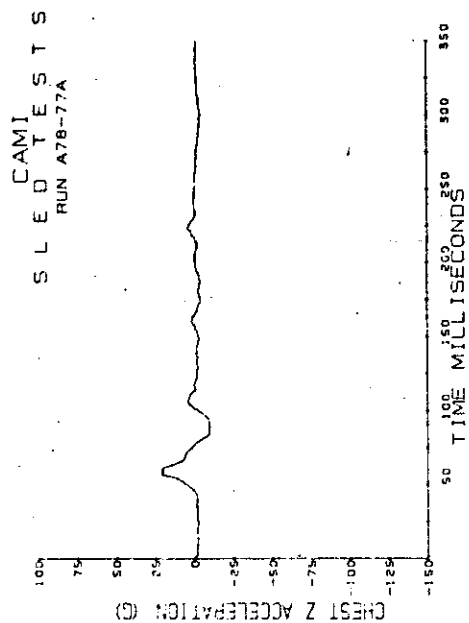
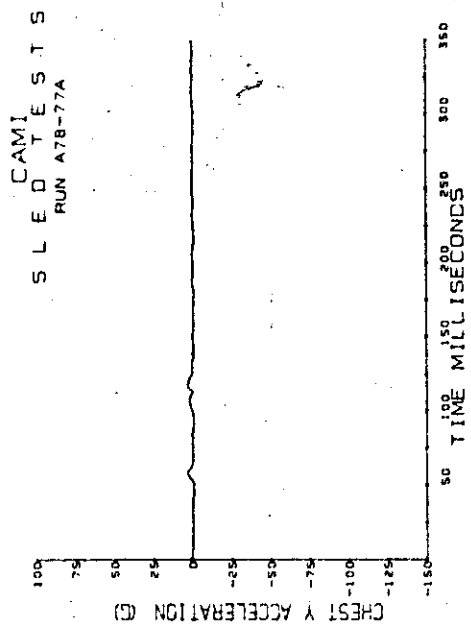
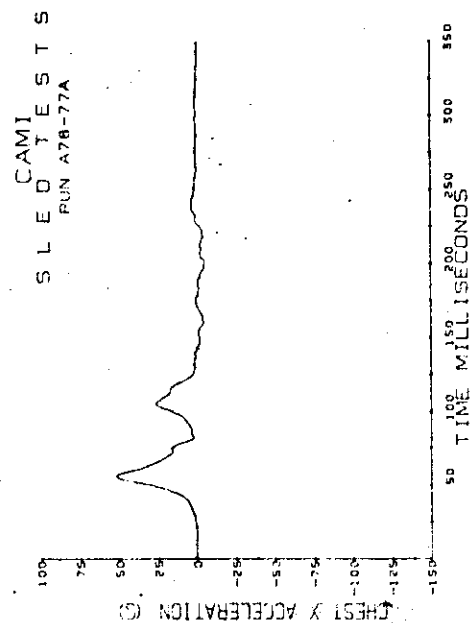
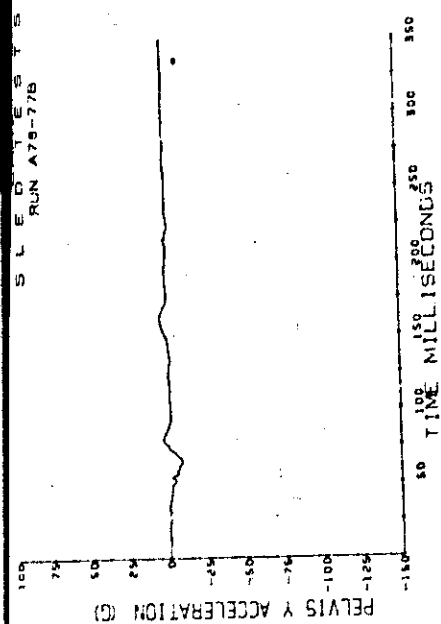
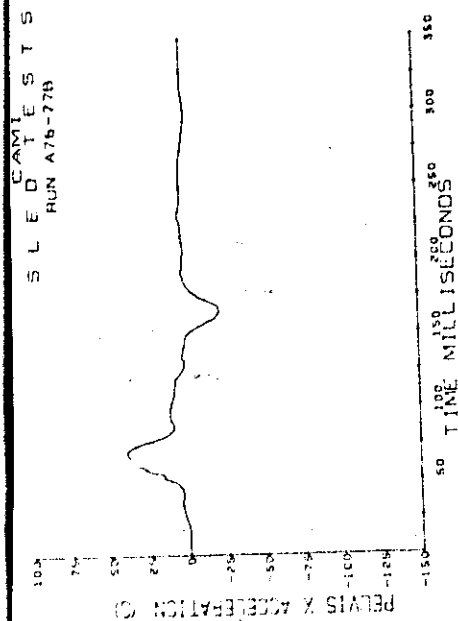
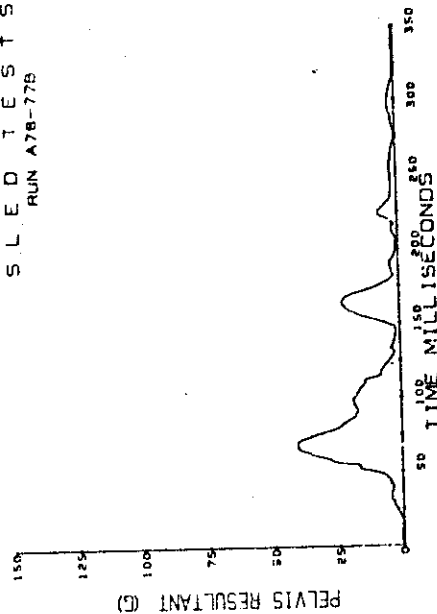


Figure C-2 (continued). 22-g tests.  
Chest acceleration.



CAMI  
S L E D T E S T S  
RUN A78-77B



CAMI  
S L E D T E S T S  
RUN A78-77B

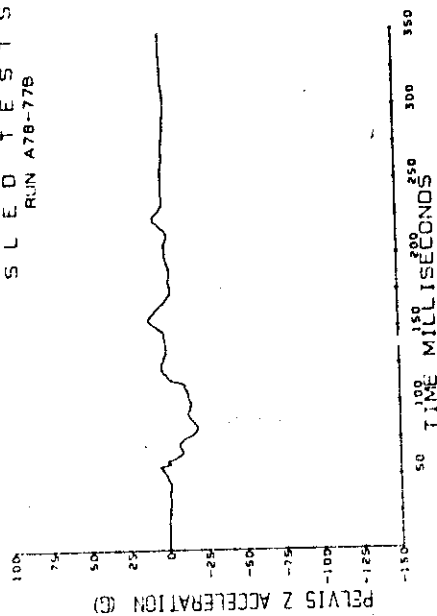


Figure C-2 (continued). 22-g tests.  
Pelvis acceleration.

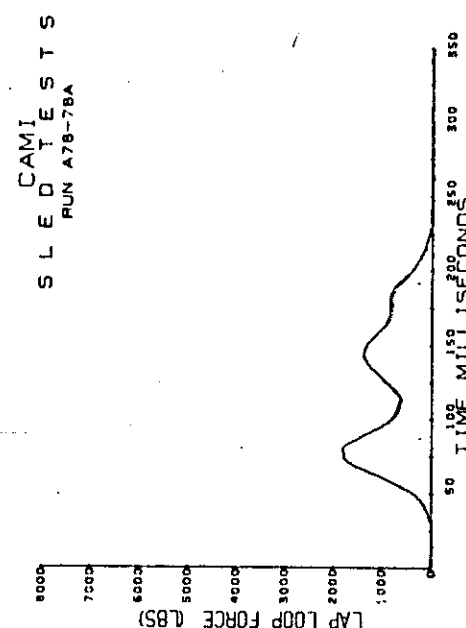
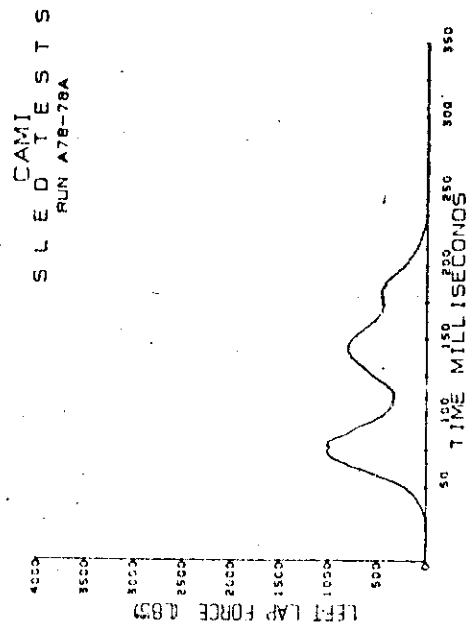
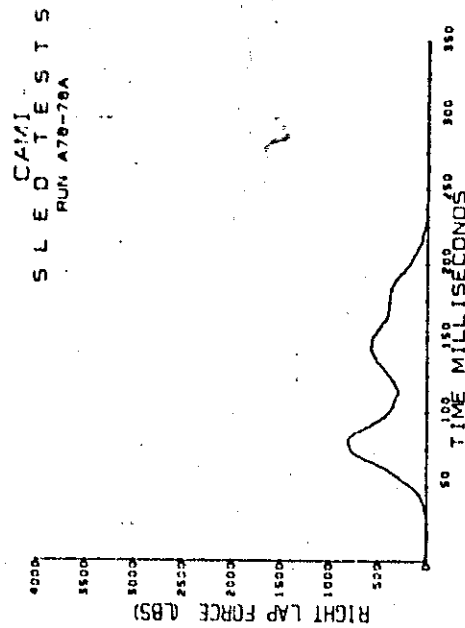
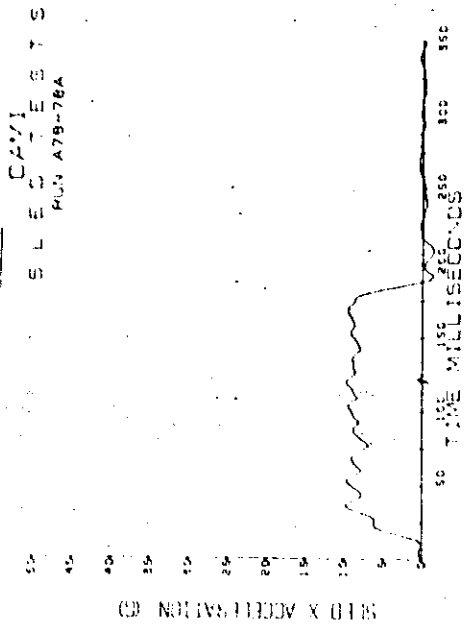
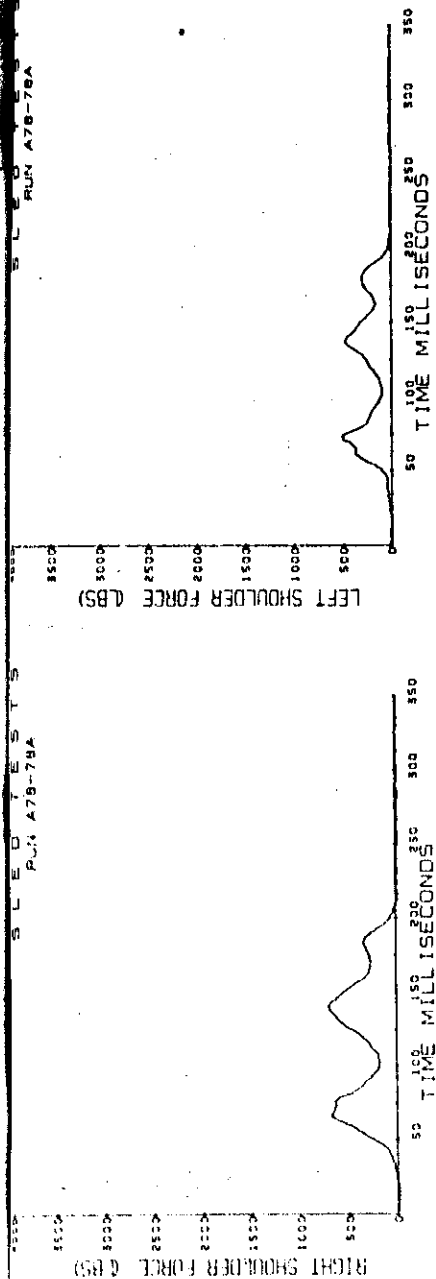


Figure C-3 Polyester webbing. 9-g tests.  
Sled deceleration and lapbelt loads.



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# SLED TESTS CAMI RUN A78-78A

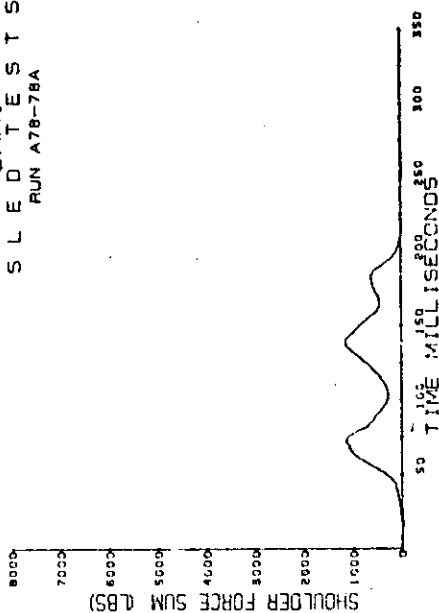


Figure C-3 (continued). 9-g tests.  
Shoulder belt loads.



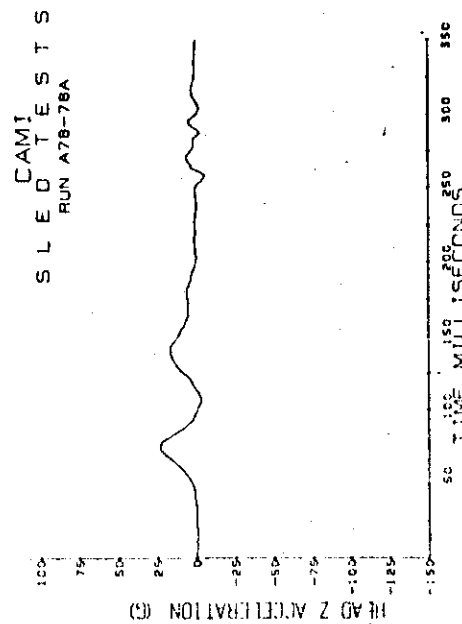
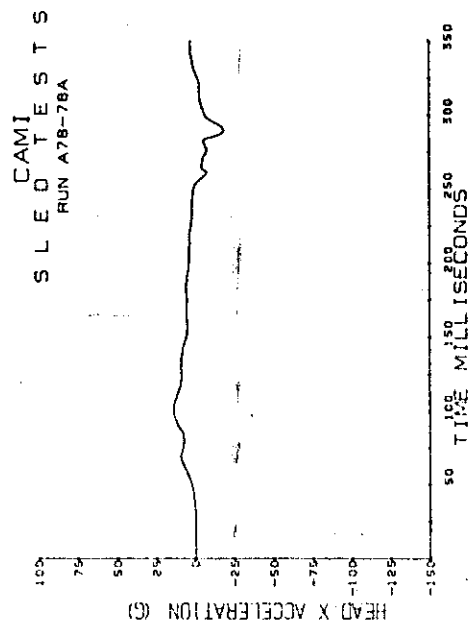
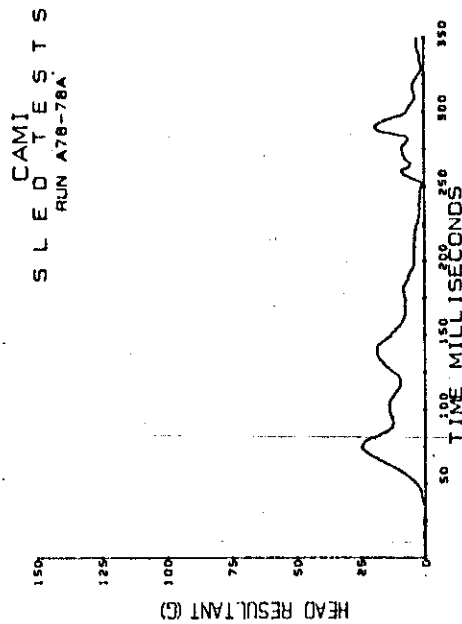
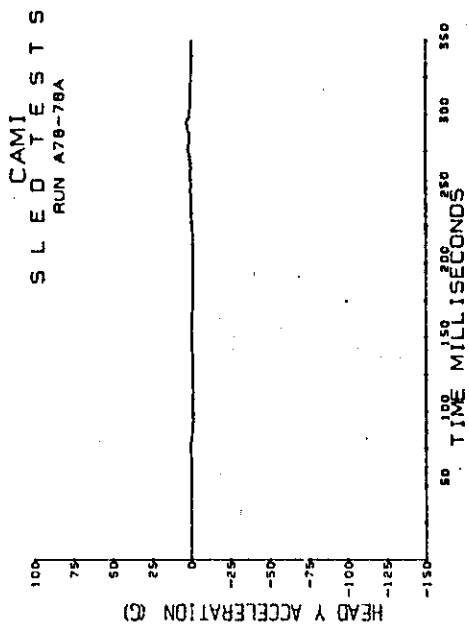


Figure C-3 (continued). 9-8 tests.  
Head acceleration.

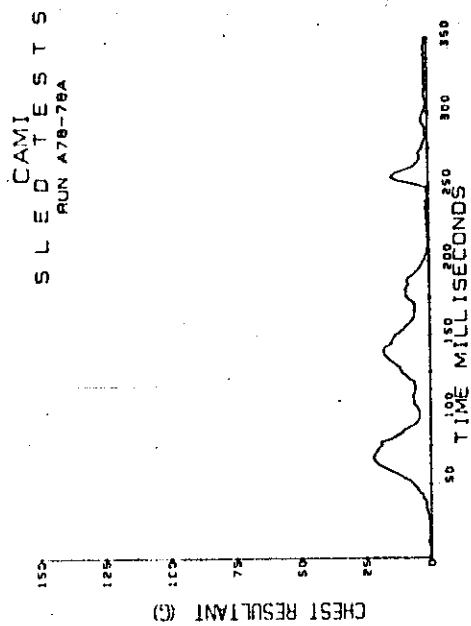
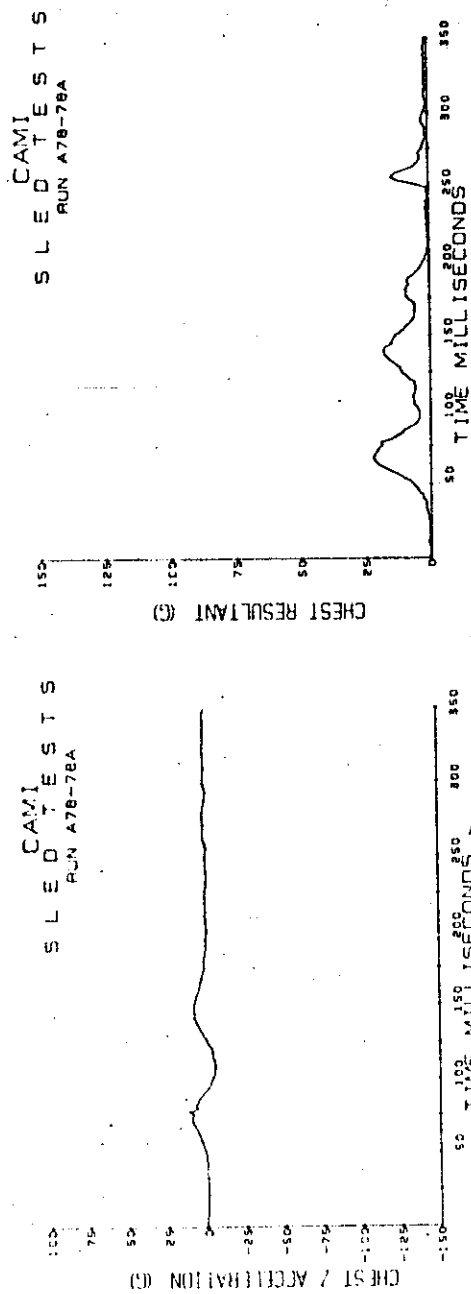
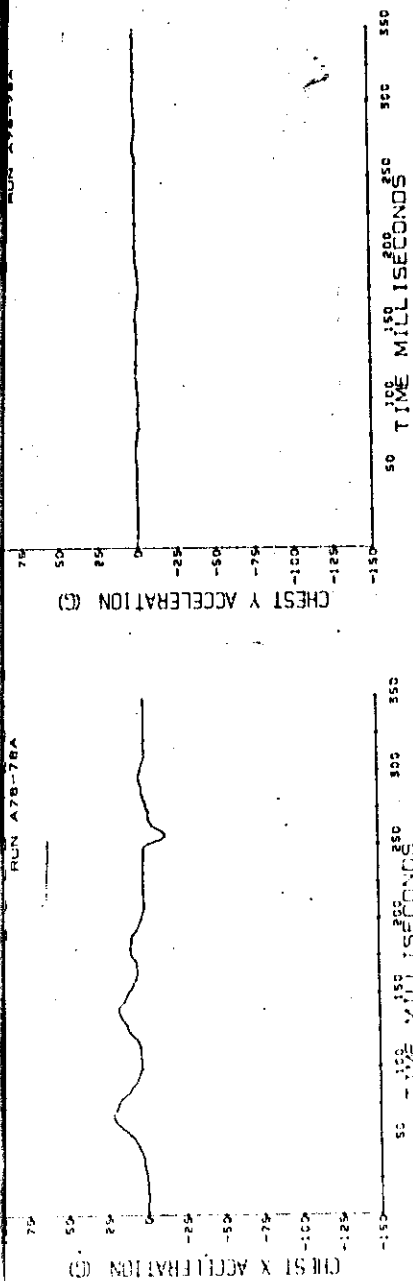


Figure C-3 (continued). 9-g tests.  
Chest acceleration.

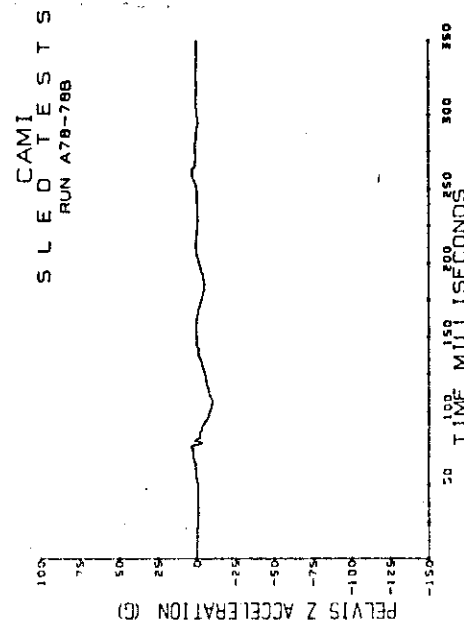
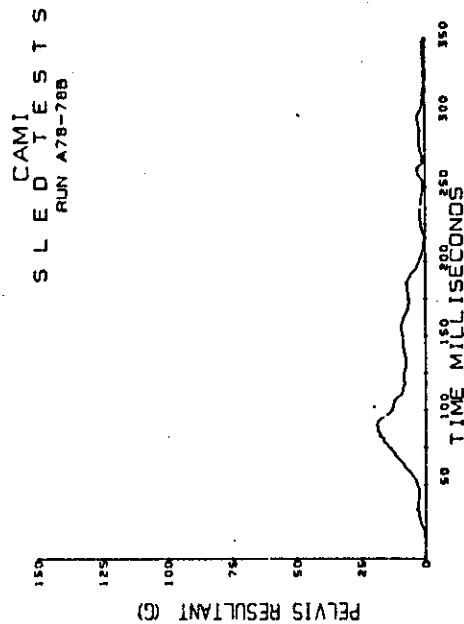
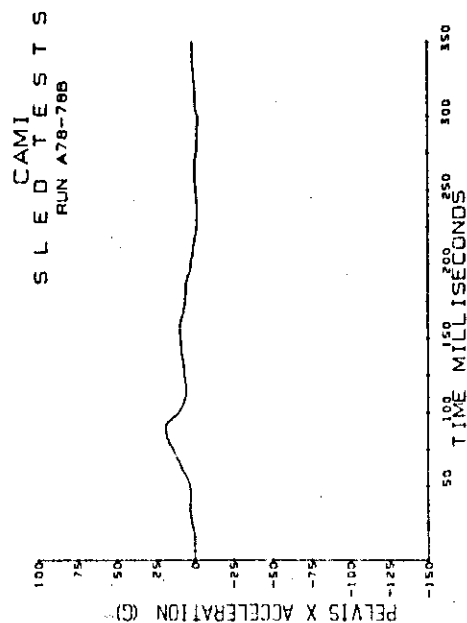
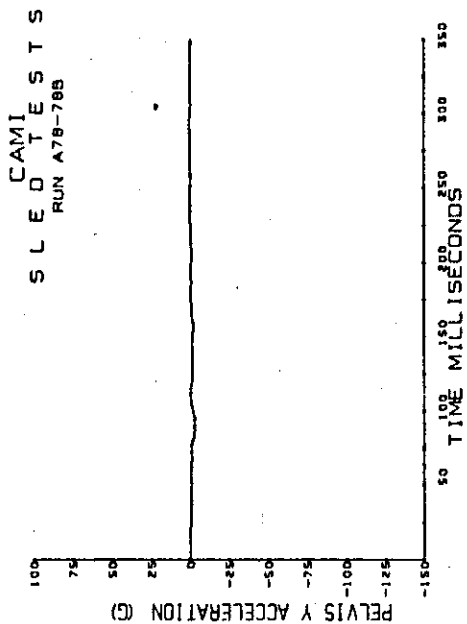


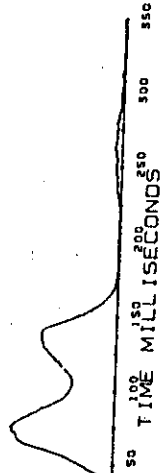
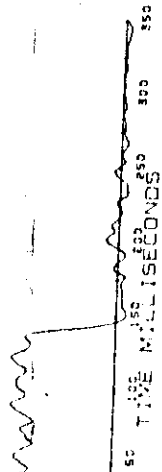
Figure C-3 (continued). 9-8 tests.  
Pelvis acceleration.

SLED TESTS  
RUN A78-79A

SLED TESTS  
RUN A78-79A

SLED X ACCELERATION (G)

RIGHT LAP FORCE (LBS)



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CAMI  
SLED TESTS  
RUN A78-79A

LEFT LAP FORCE (LBS)

LAP LOOP FORCE (LBS)

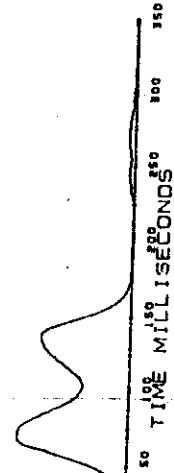
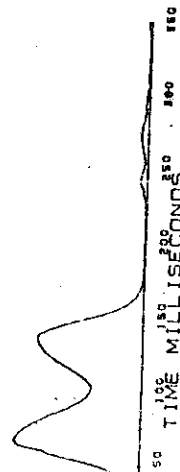
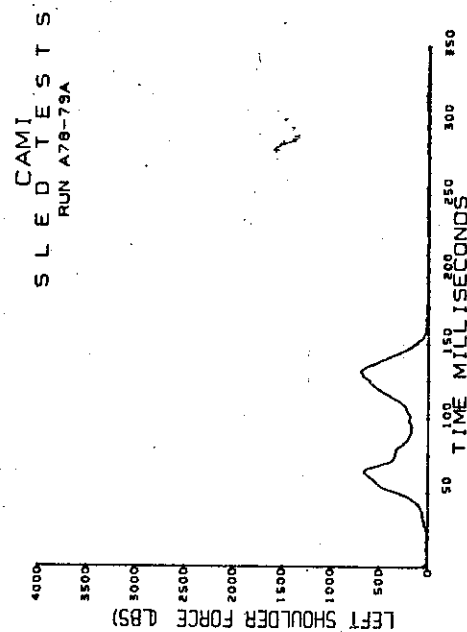
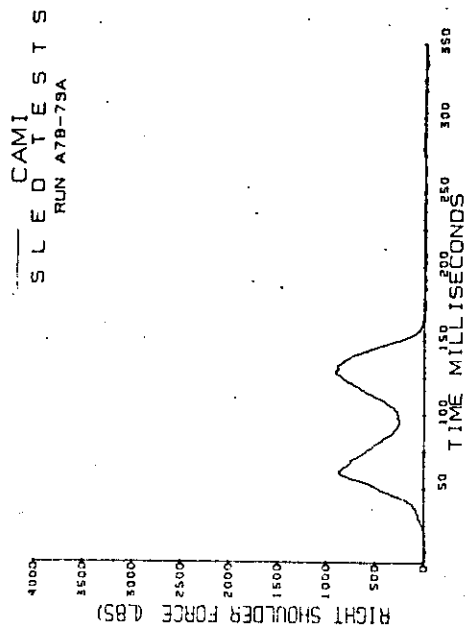


Figure C-3 (continued). 12-g tests.  
Sled deceleration and lapbelt loads.



CAMI  
S L E D T E S T S  
RUN A78-79A

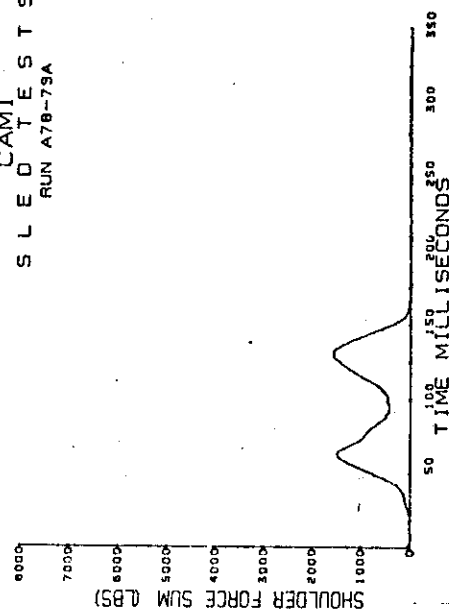


Figure C-3 (continued). 12-g tests.  
Shoulder belt loads.

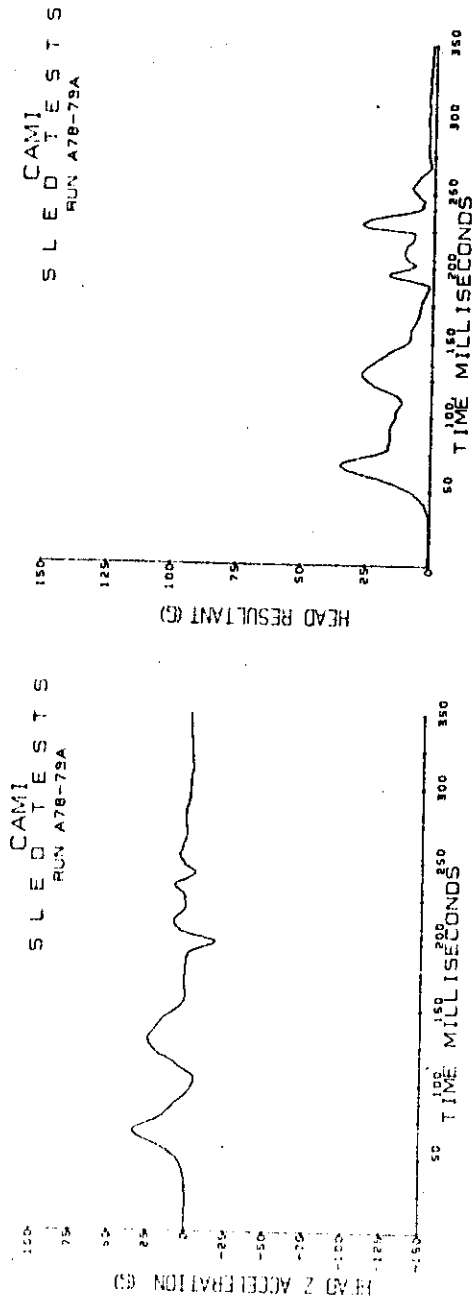
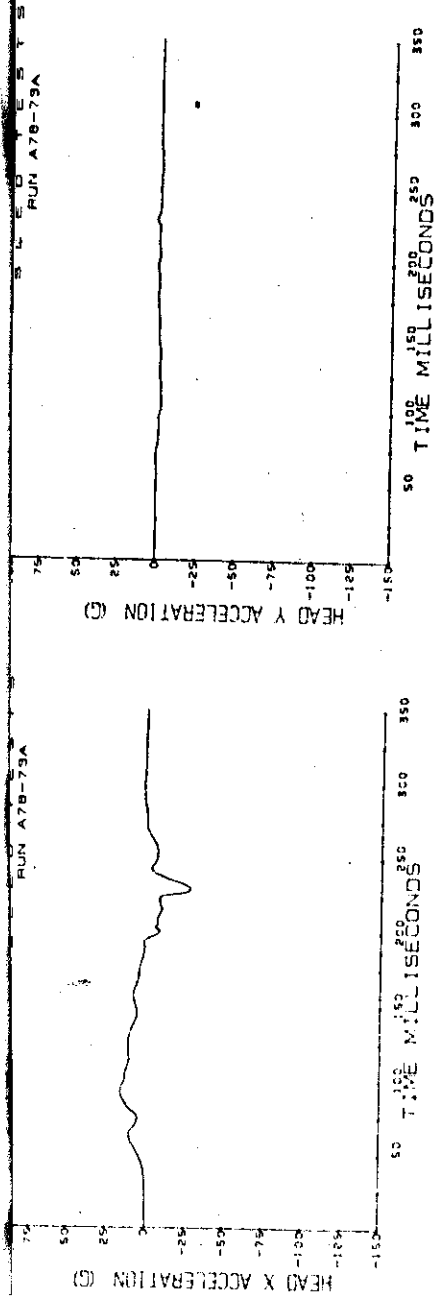


Figure C-3 (continued). 12-g tests.  
Head acceleration.

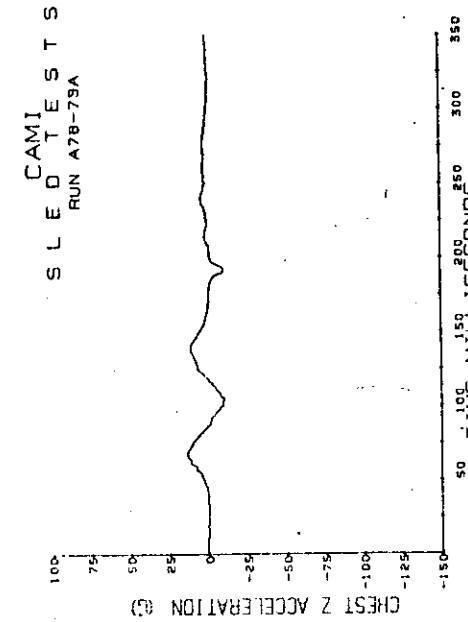
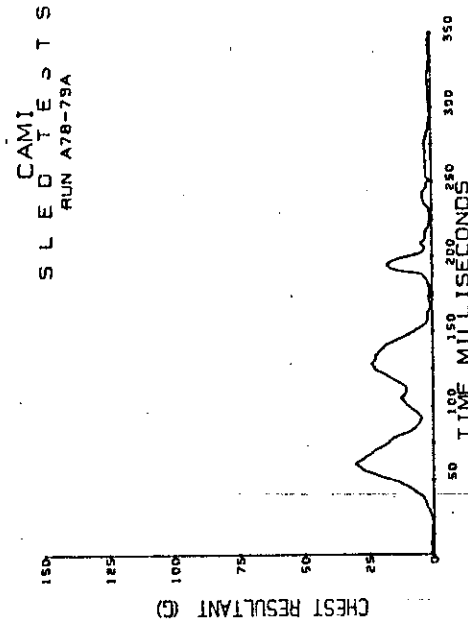
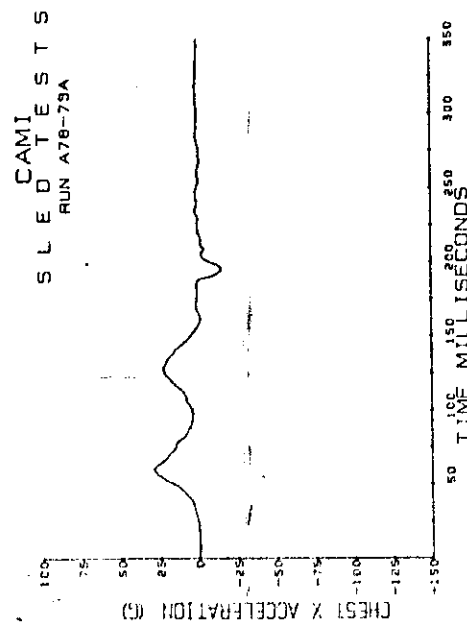
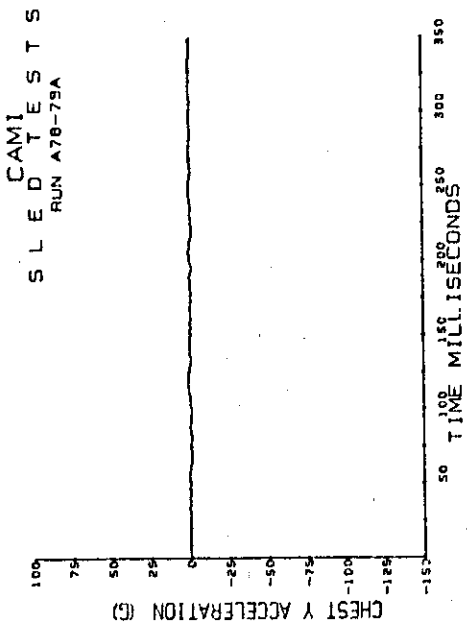


Figure C-3 (continued). 12-g tests.  
Chest acceleration.

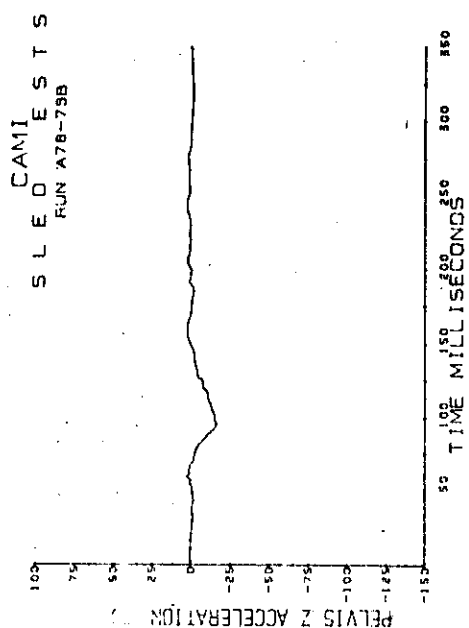
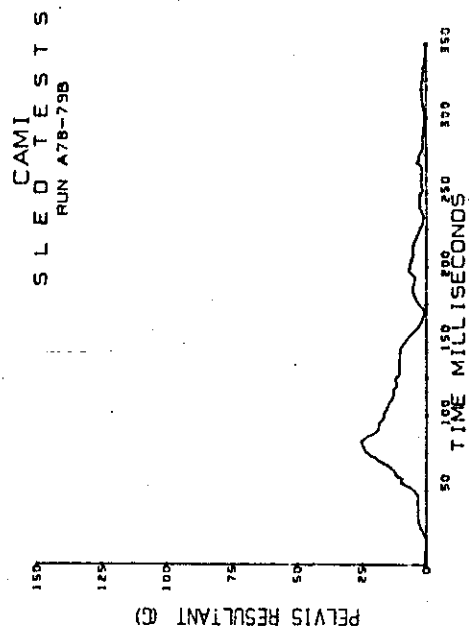
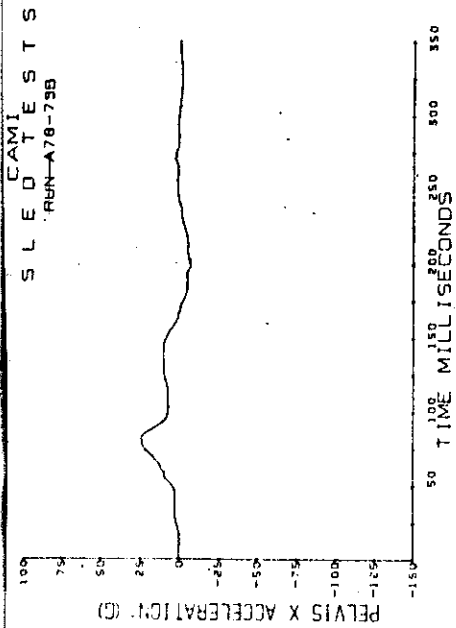
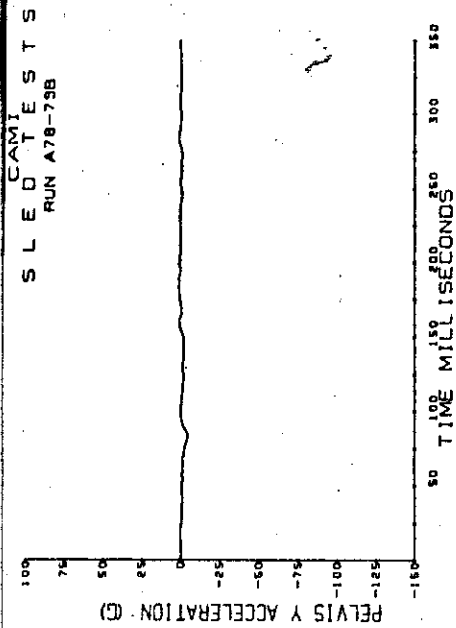


Figure C-3 (continued). 12-g tests.  
Pelvis acceleration.



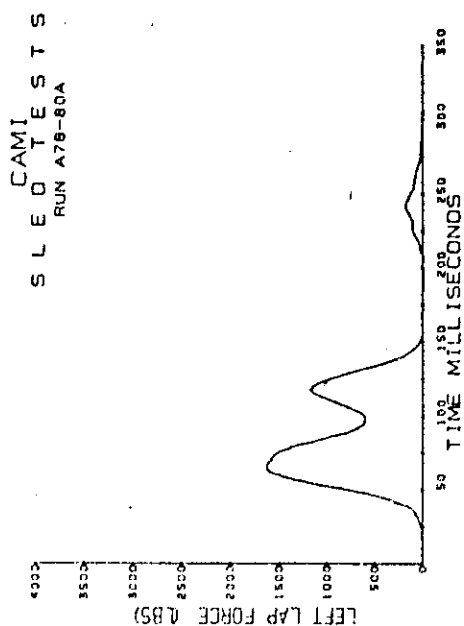
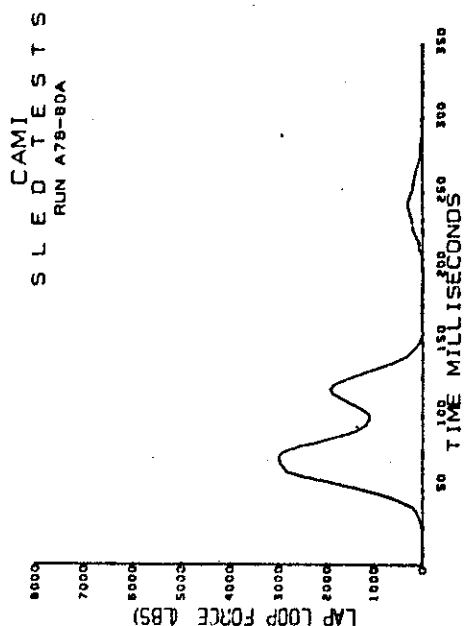
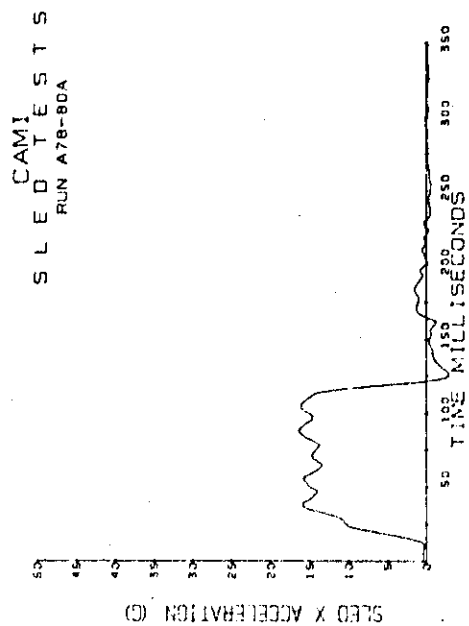
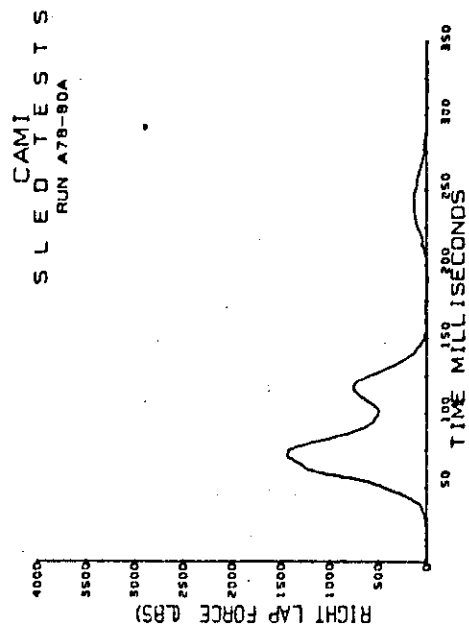
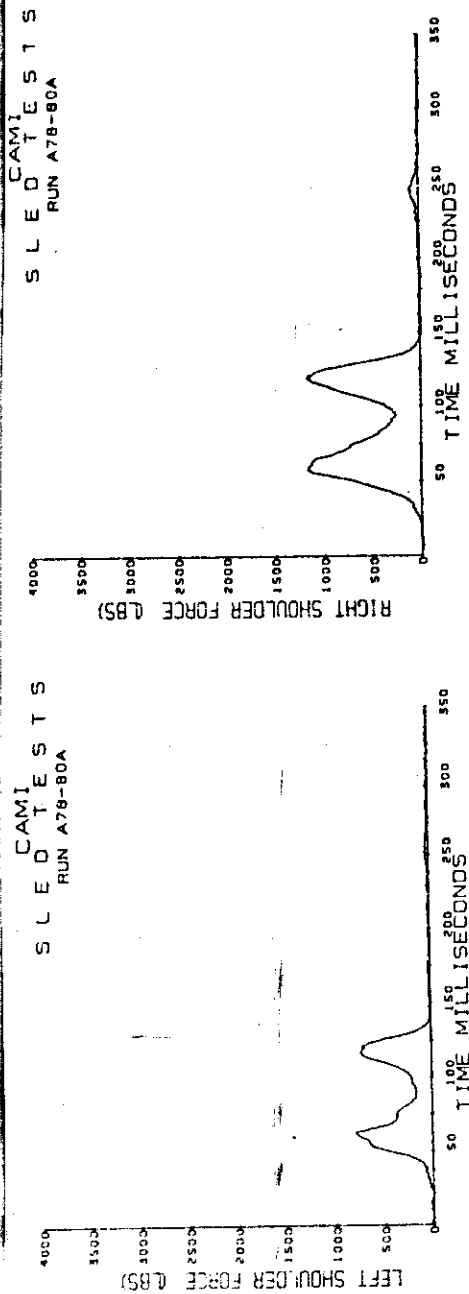


Figure C-3 (continued). 16-g tests.  
Sled deceleration and lapbelt loads.



CAMI  
SLED TESTS  
RUN A78-80A

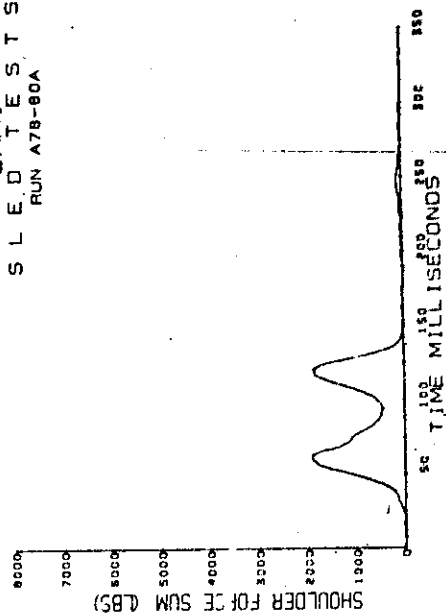
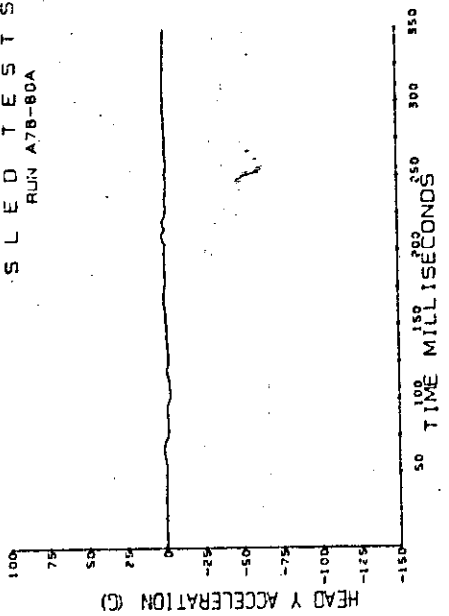
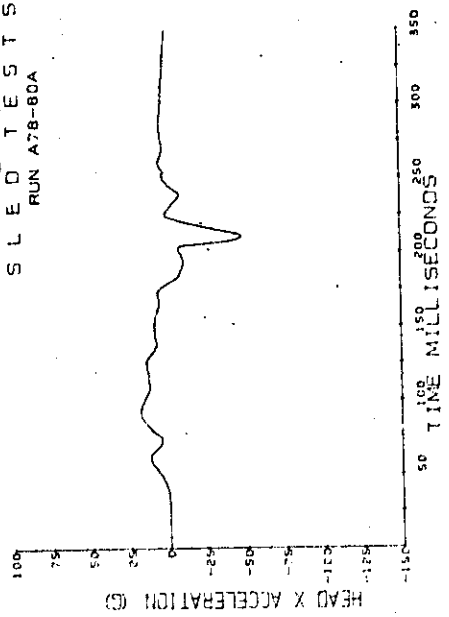


Figure C-3 (continued). 16-8 tests.  
Shoulder belt loads.

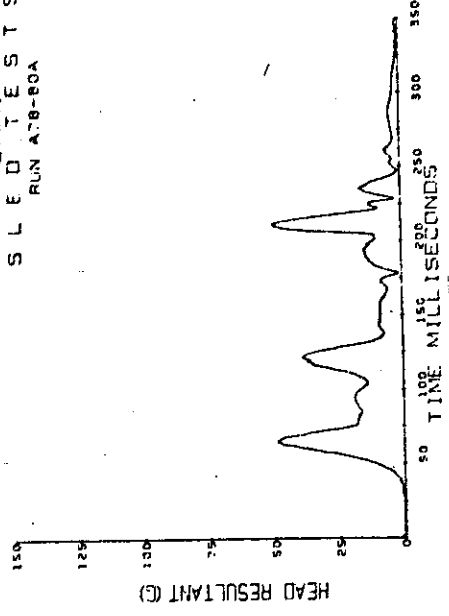
CAMI  
SLED TESTS  
RUN A78-80A



CAMI  
SLED TESTS  
RUN A78-80A



CAMI  
SLED TESTS  
RUN A78-80A



CAMI  
SLED TESTS  
RUN A78-80A

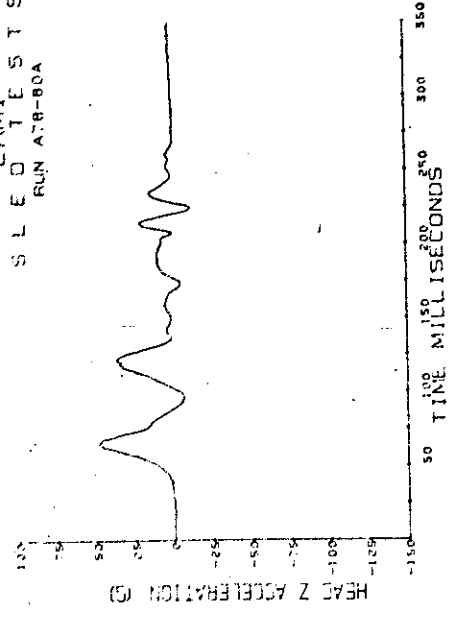


Figure C-3 (continued). 16-g tests.  
Head acceleration.

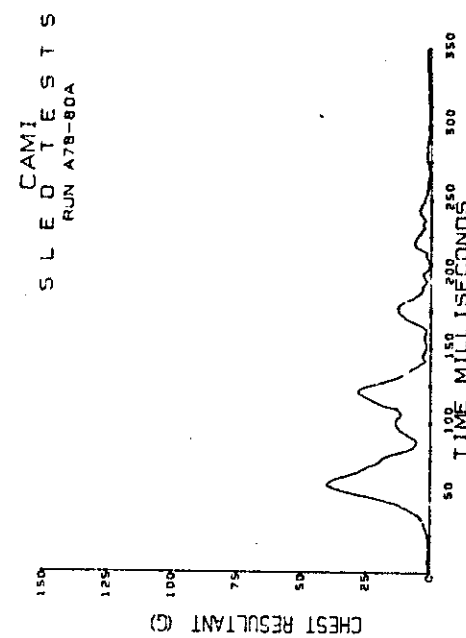
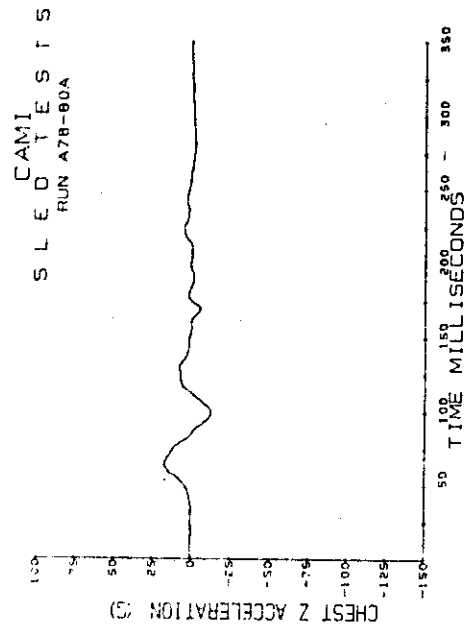
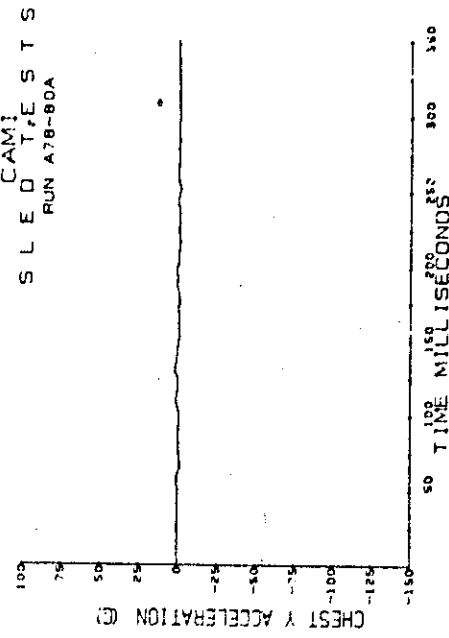
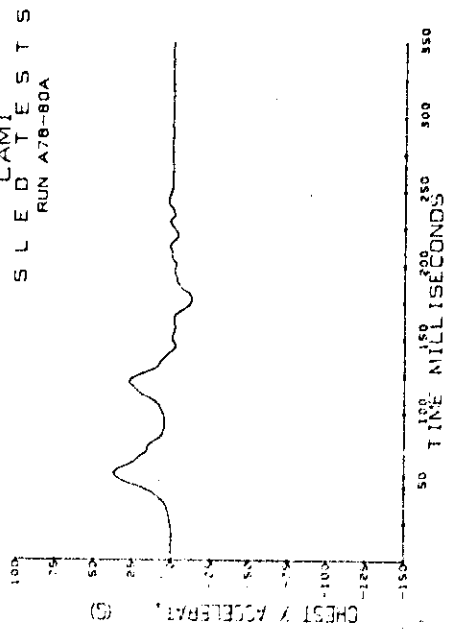


Figure C-3 (continued). 16-g tests.  
Chest acceleration.

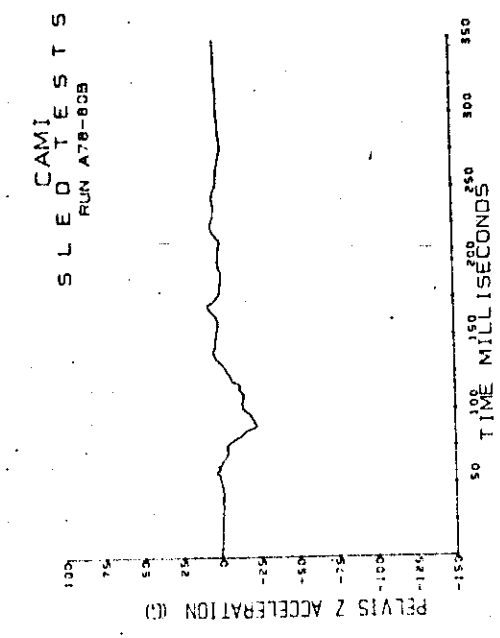
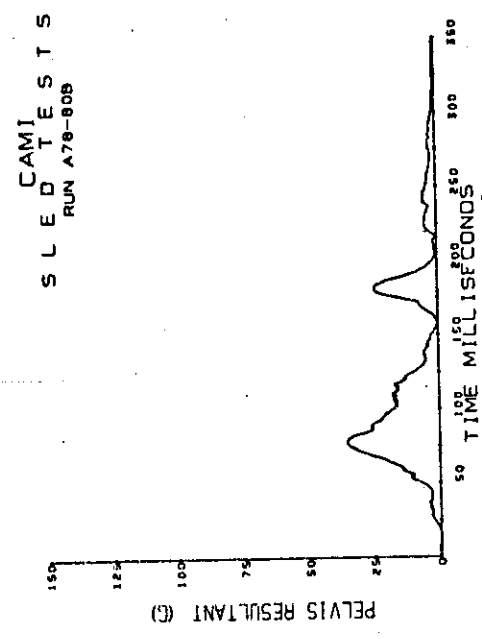
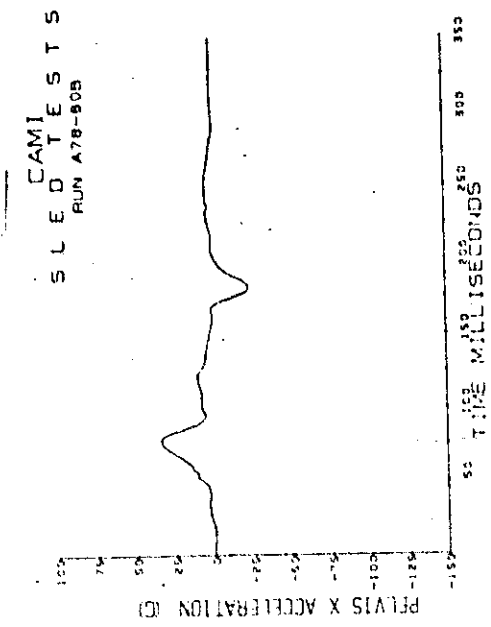
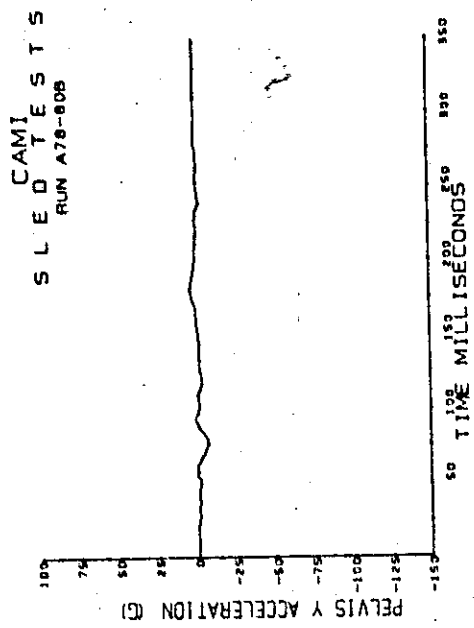
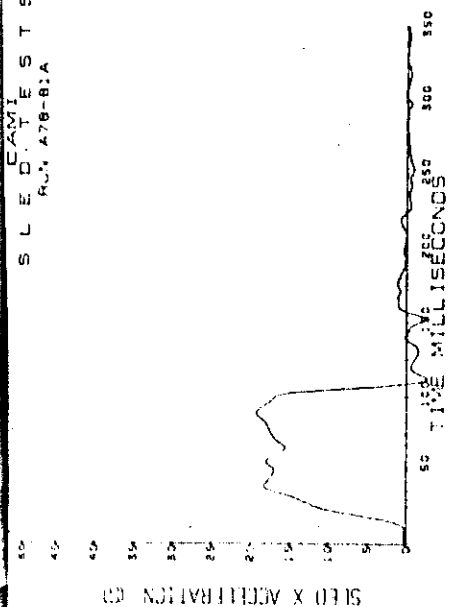
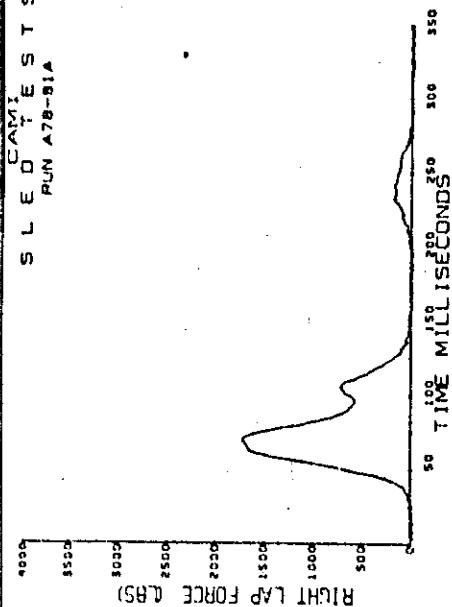


Figure C-3 (continued). 16-8 tests.  
Pelvis acceleration.

CAMI  
SLED TESTS  
RUN A78-B1A

CAMI  
SLED TESTS  
RUN A78-B1A



CAMI  
SLED TESTS  
RUN A78-B1A

CAMI  
SLED TESTS  
RUN A78-B1A

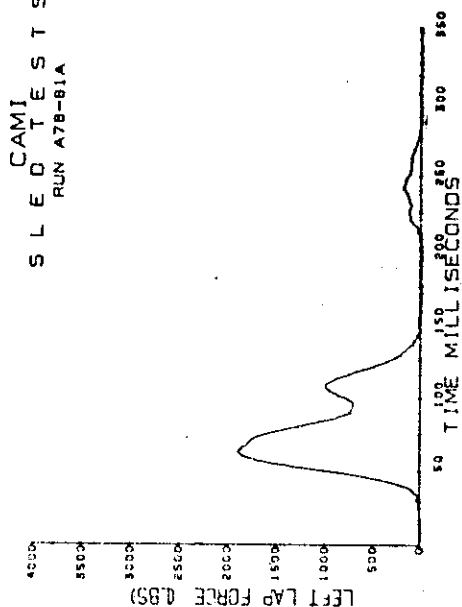
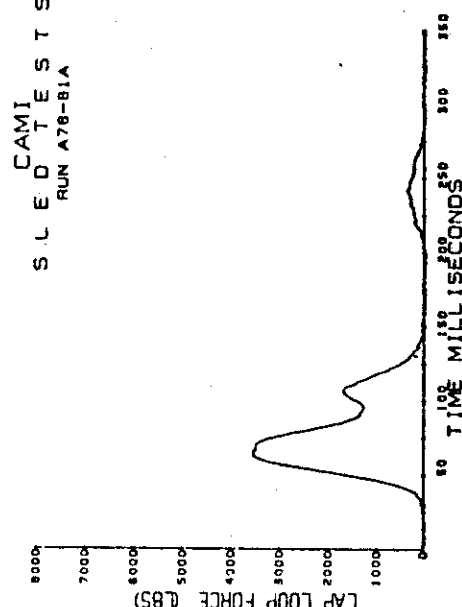
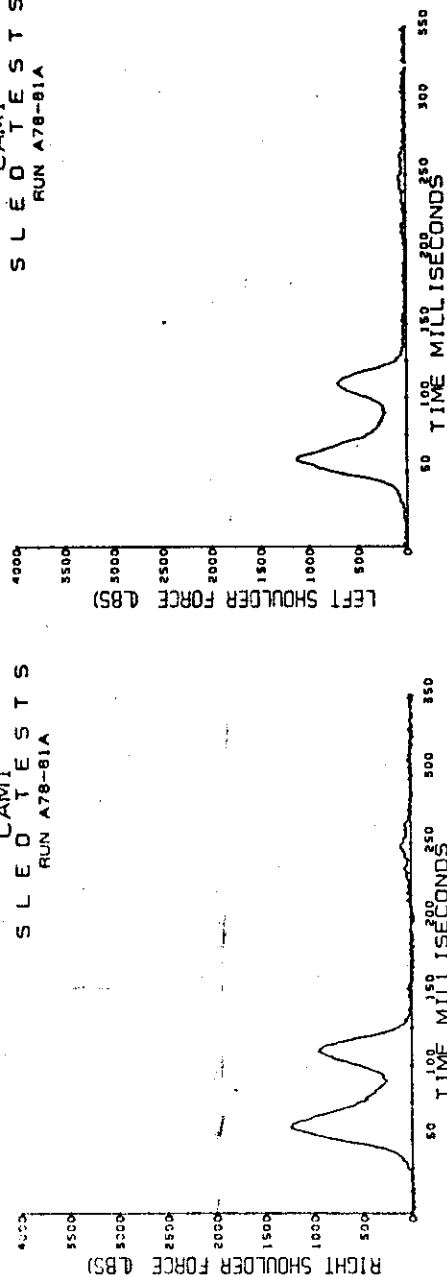


Figure C-3 (continued). 18-g tests.  
Sled deceleration and lapbelt loads.

CAMI  
S L E D T E S T S  
RUN A78-81A

CAMI  
S L E D T E S T S  
RUN A78-81A



CAMI  
S L E D T E S T S  
RUN A78-81A

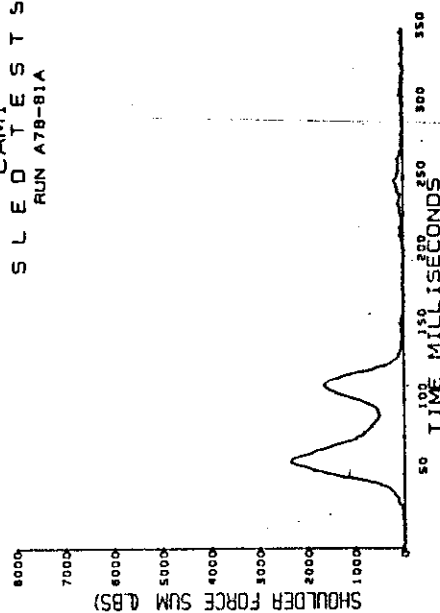


Figure C-3 (continued). 18-g tests.  
Shoulder belt loads.

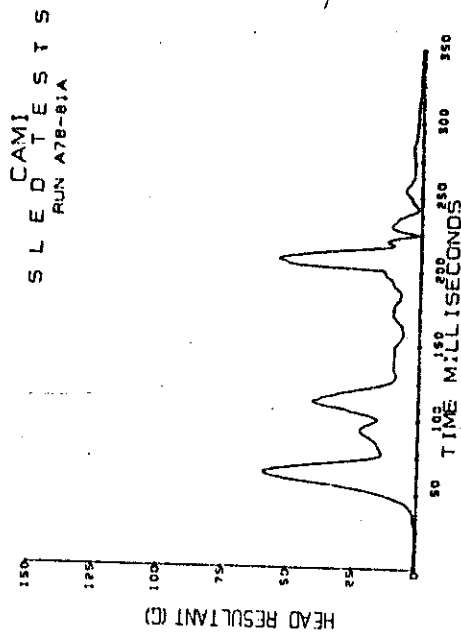
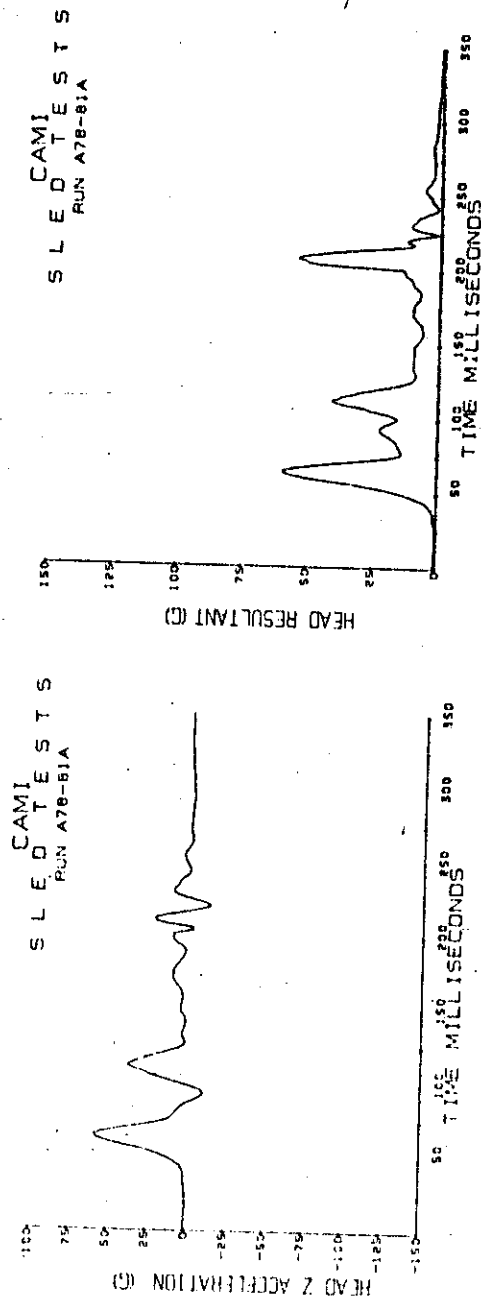
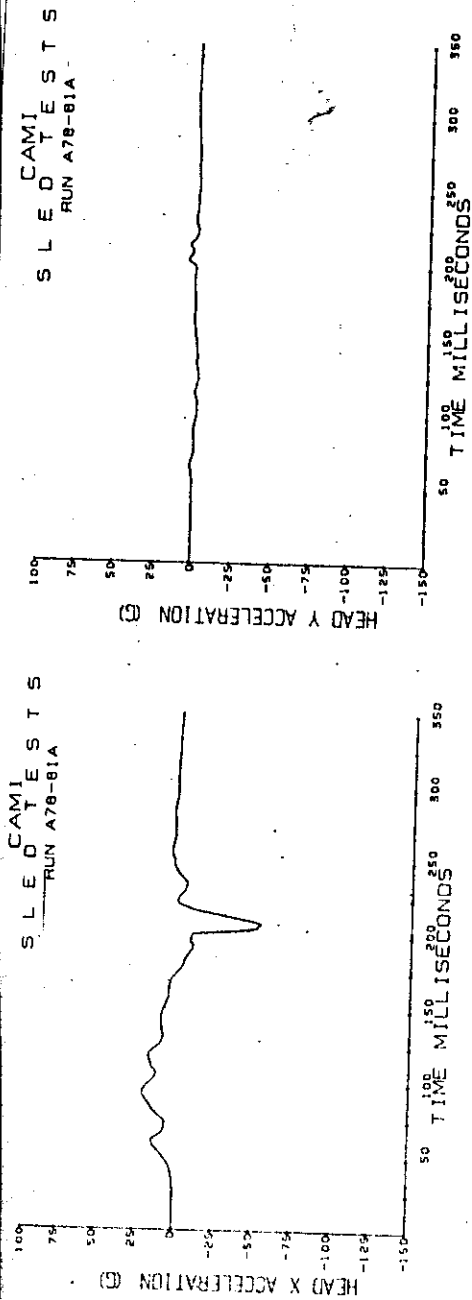


Figure C-3 (continued). 18-g tests.  
Head acceleration.



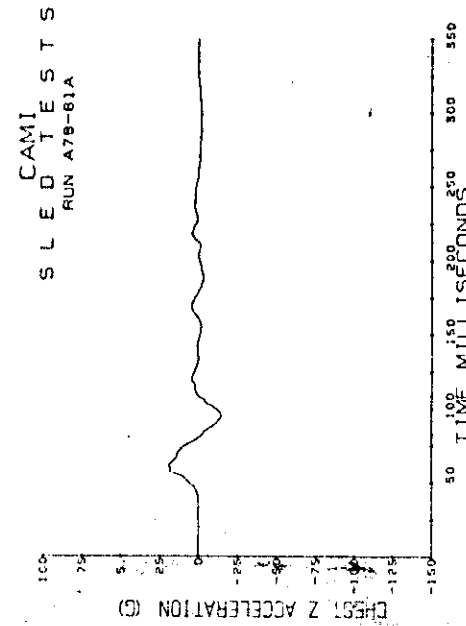
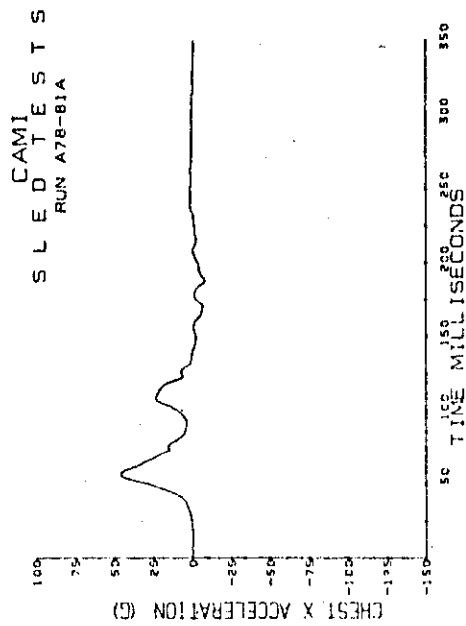
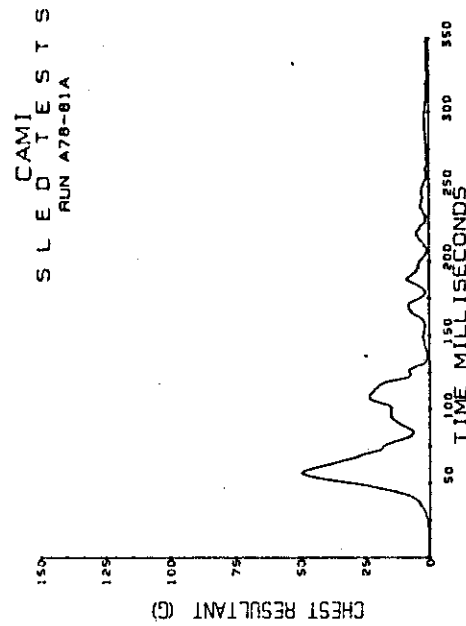
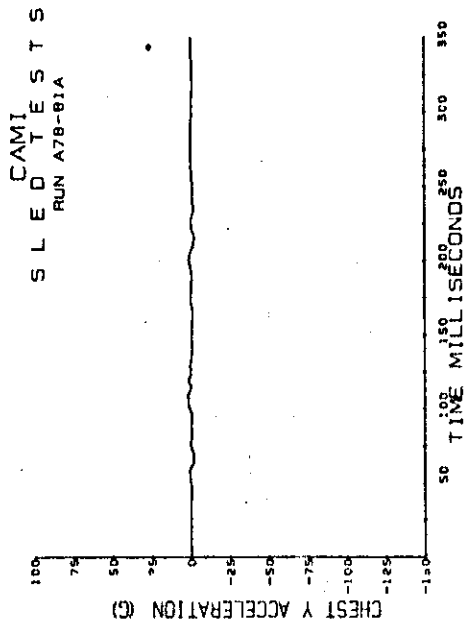


Figure C-3 (continued). 18-g tests.  
Chest acceleration.

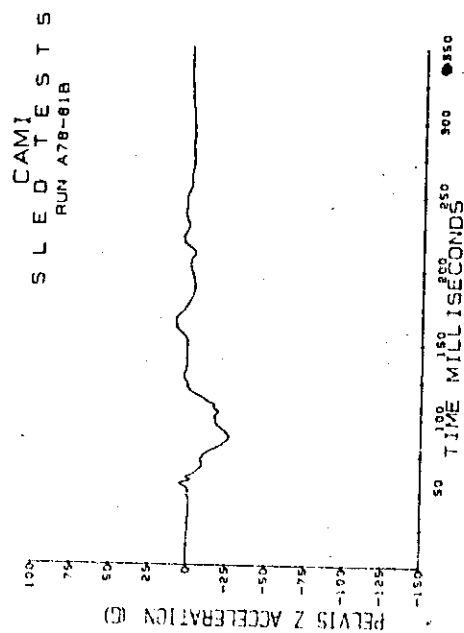
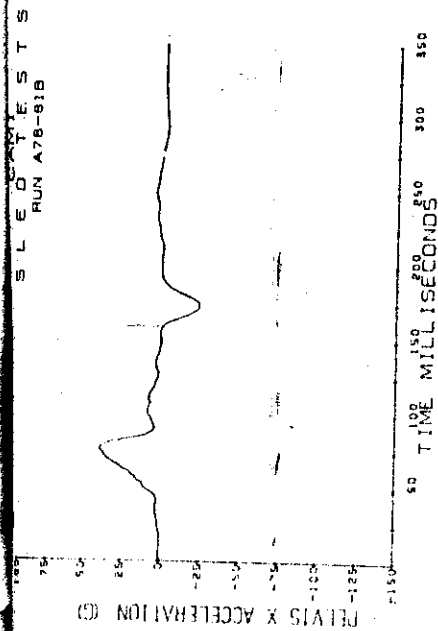
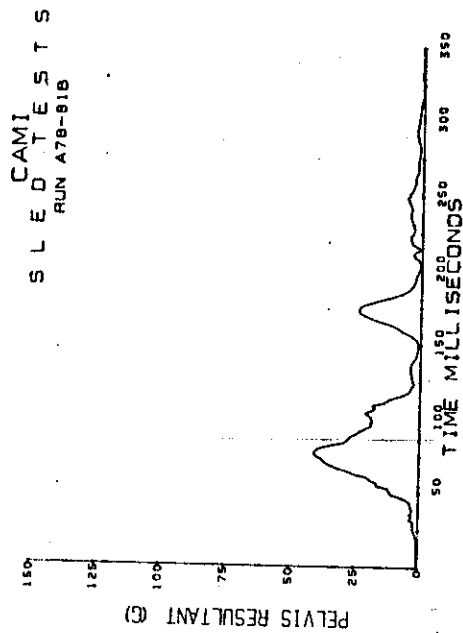
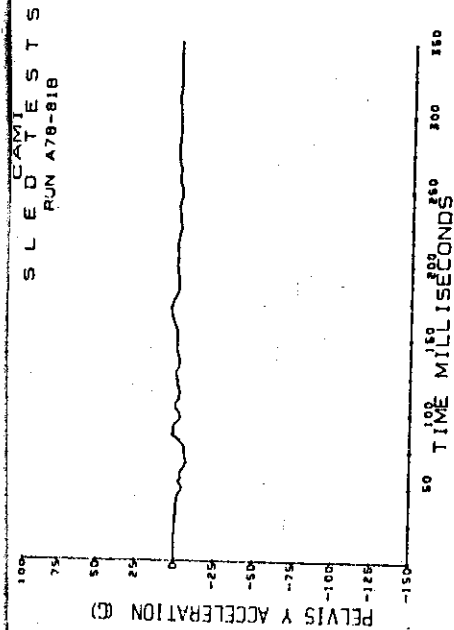
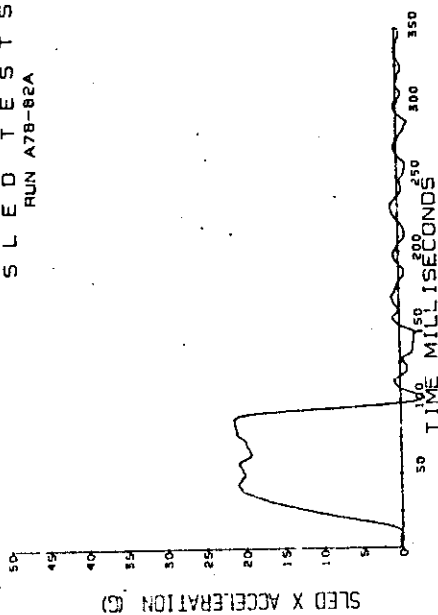
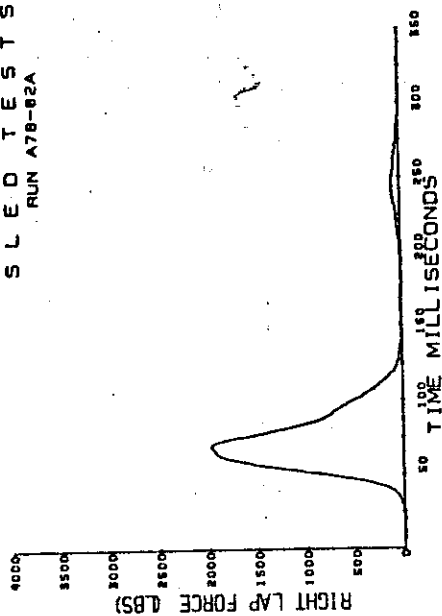


Figure C-3 (continued). 18-g tests.  
Pelvis acceleration.

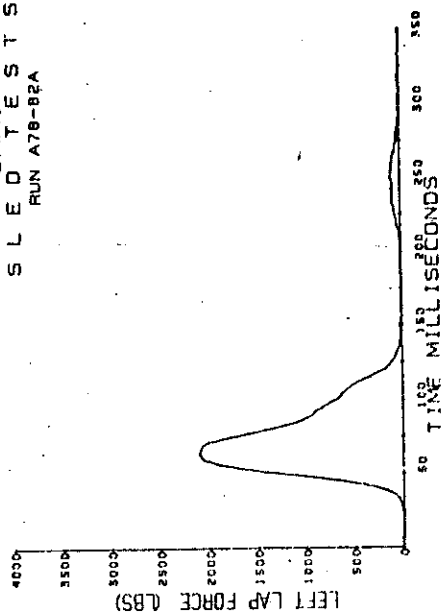
CAMI  
SLED TESTS  
RUN A78-82A



CAMI  
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RUN A78-82A



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RUN A78-82A



CAMI  
SLED TESTS  
RUN A78-82A

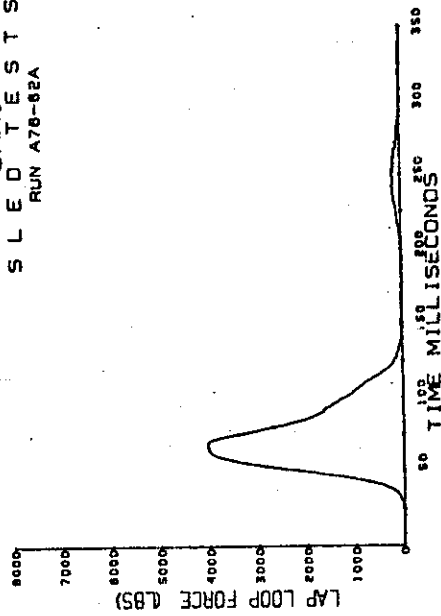
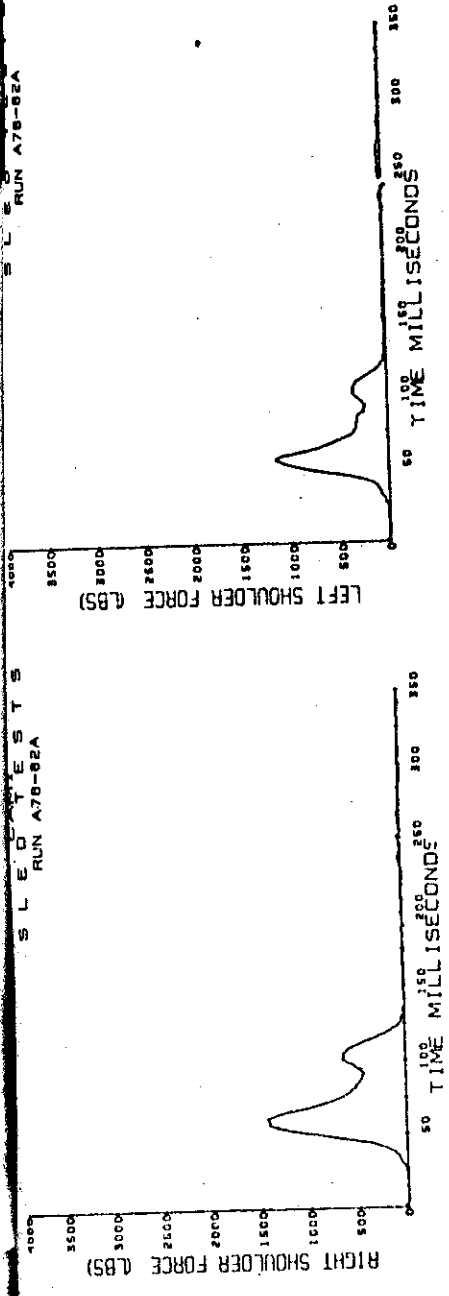


Figure C-3 (continued). 21-g tests.  
Sled deceleration and lapbelt loads.



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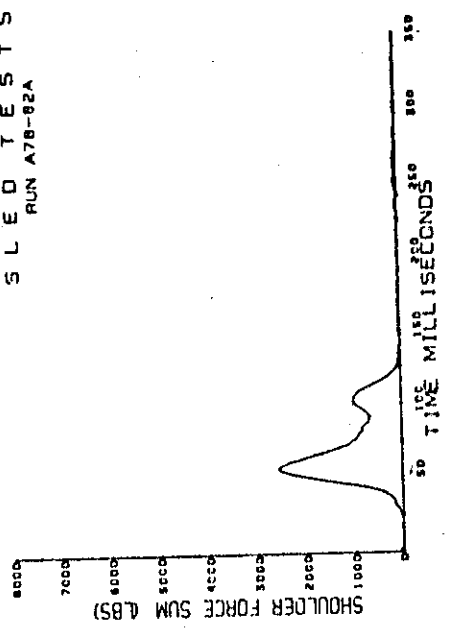


Figure C-3 (continued). 21-g tests.  
Shoulder belt loads.

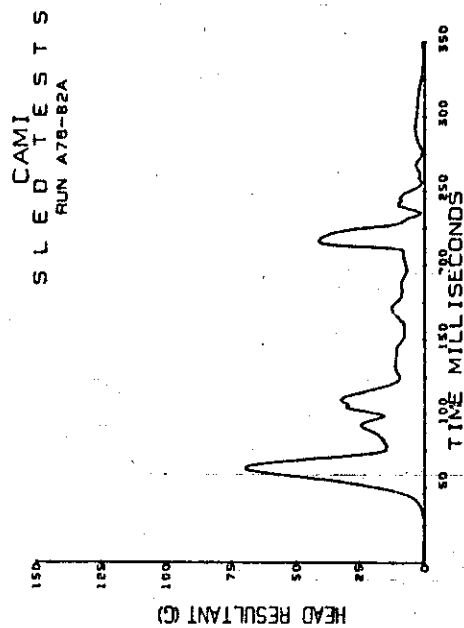
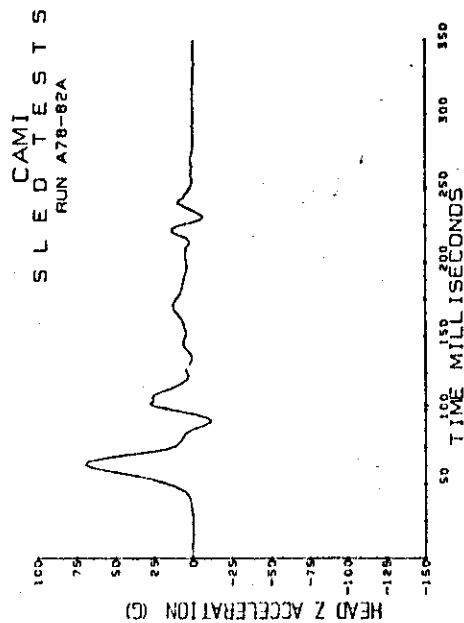
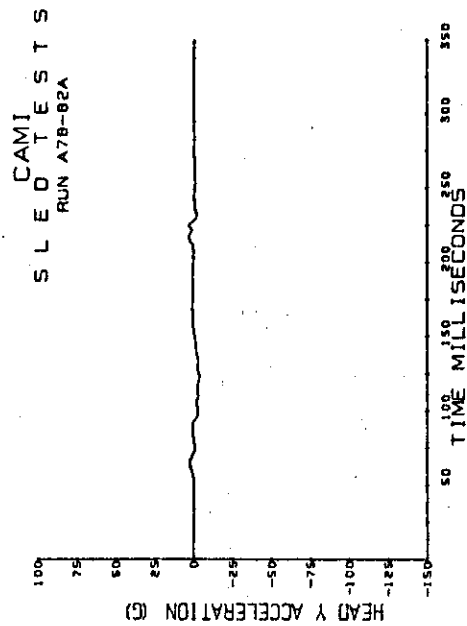
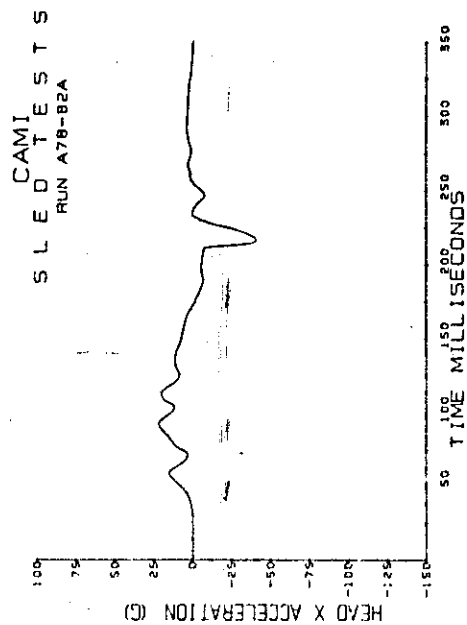


Figure C-3 (continued). 21-g tests.  
Head acceleration.

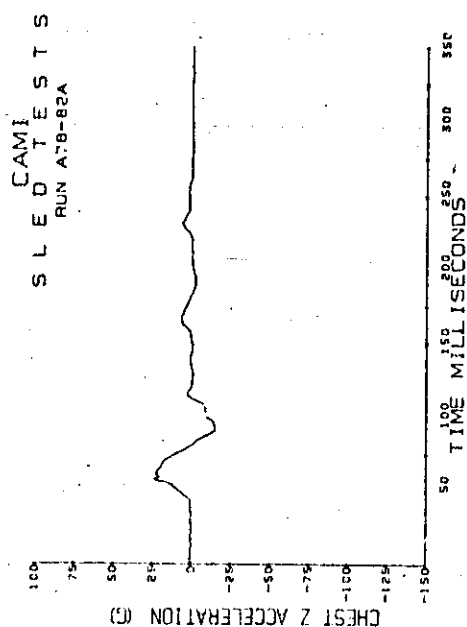
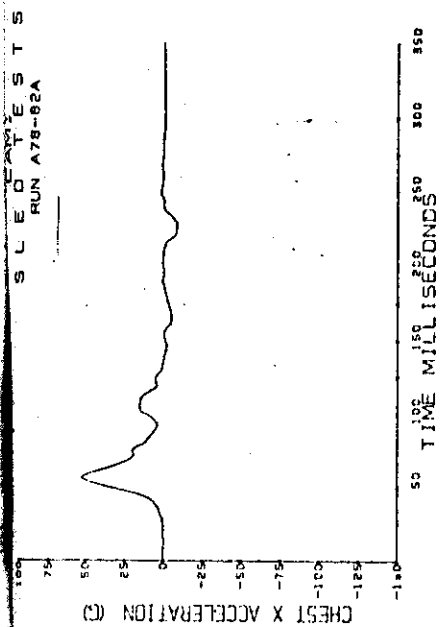
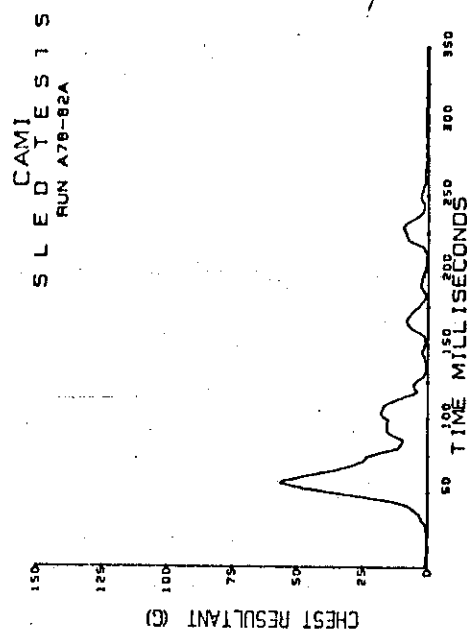
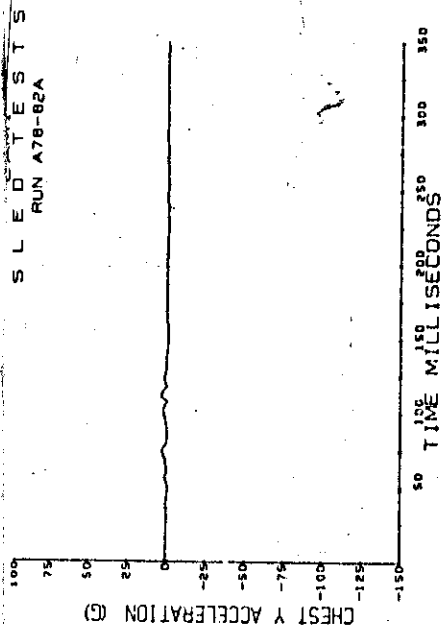


Figure C-3 (continued). 21-g tests.  
Chest acceleration.

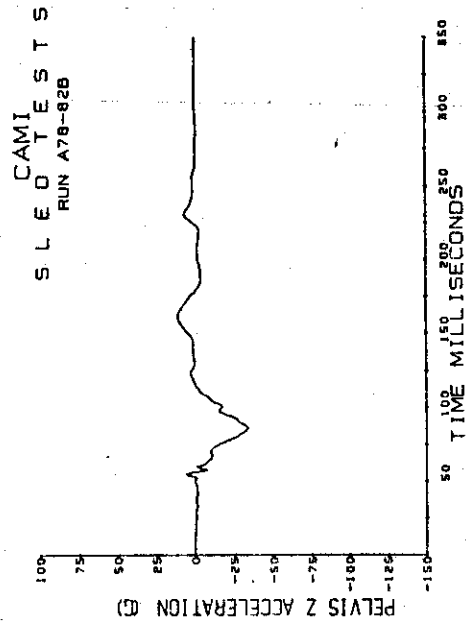
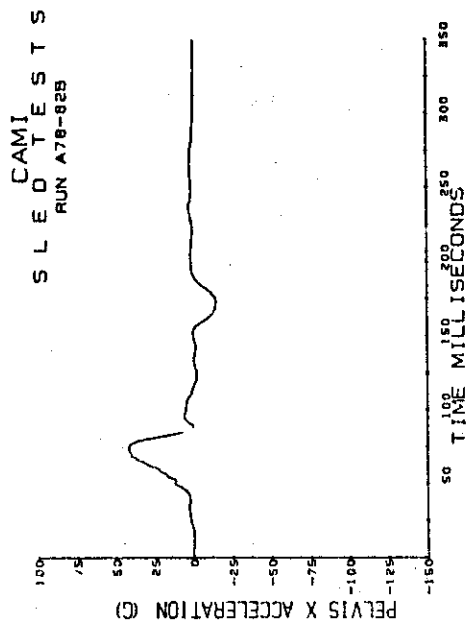
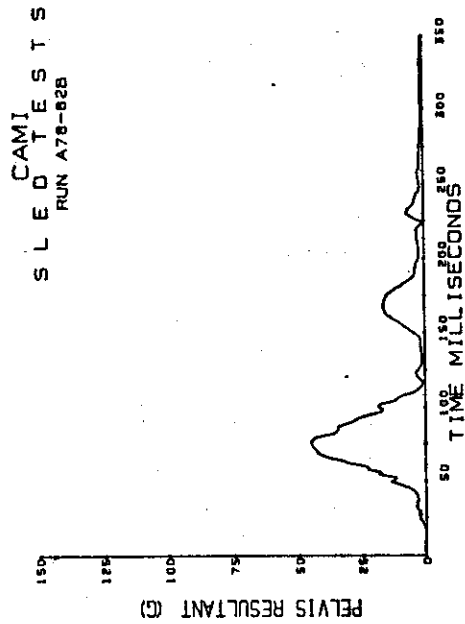
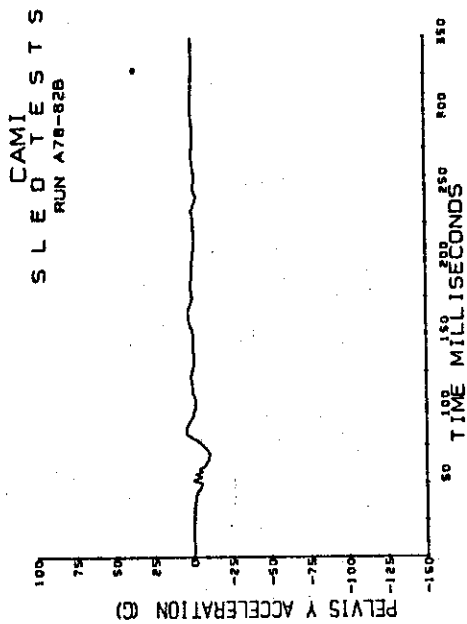


Figure C-3 (continued). 21-g tests.  
Pelvis acceleration.