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16. Abstract

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 investigate the performance of anthropomorphic dummies in the dynamic environment are reported.

The data in this report were previously presented in a memorandum report and are subject to additional evaluation or change upon review, conduct of additional testing, or receipt of additional facts.

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# EVALUATION OF SEATING AND RESTRAINT SYSTEMS AND ANTHROPOMORPHIC DUMMIES CONDUCTED DURING FISCAL YEAR 1976

## 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 investigate the performance of anthropomorphic dummies in the dynamic environment.

## 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 programmed 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 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.

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 6,400-lb 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 110,000 ft-lb of energy can be stored that can accelerate the sled and payload to velocities of up to 50 mi/hr, 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 ¼-in-diameter 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 the 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 to pull the wire through the rollers. The braking device holds two layers of

10 wires and is thus capable of generating a braking force of 50,000 lb. 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 electronic 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-band-width high frequency multiplexer system. The composite output from the multiplexer system is recorded on wide-band 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 electronic 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 programming 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.

# EVALUATION OF VEST-TYPE CHILD AND INFANT RESTRAINT SYSTEM

A prototype child restraint system fabricated of webbing straps held in position by a cloth vest (Figure 1) was subjected to tests designed to evaluate its performance in crash and turbulence conditions. The system was fitted to a 17.4-lb dummy simulating a 6-mo-old infant or a 32.6-lb dummy simulating a 3-yr-old child and installed, by a conventional seatbelt, in a test fixture simulating the dynamic properties of an air carrier passenger seat. Adjustment for size was accomplished by means of adjusters located on the belt and shoulder straps. No adjustment was provided on the vest.

Turbulence was simulated by inverting the passenger seat carrying the restraint system. The dummy was restrained in the vicinity of the seat, but slack inherent in the seatbelt and child restraint straps allowed considerable movement from the original position. This was most critical in the lateral direction, where the dummy was allowed to move into the armrest or cabin wall area, where injury could occur (Figure 2).

Crash conditions were simulated on the test track under the criteria outlined in Table 1. The restraint system allowed the dummy to move to the far edge of the seat, even under the least severe test conditions (Figure 3). Under slightly more severe conditions (Figure 4), the restraint system failed through tears in stitching and material and allowed the dummy to move off the seat onto the floor. More severe tests, even with the lighter weight dummy, caused the restraint system to fail. An additional problem inherent in this type of restraint system is that no protection was provided to prevent the seat back from compressing the child against the seat bottom.

Figure 1.

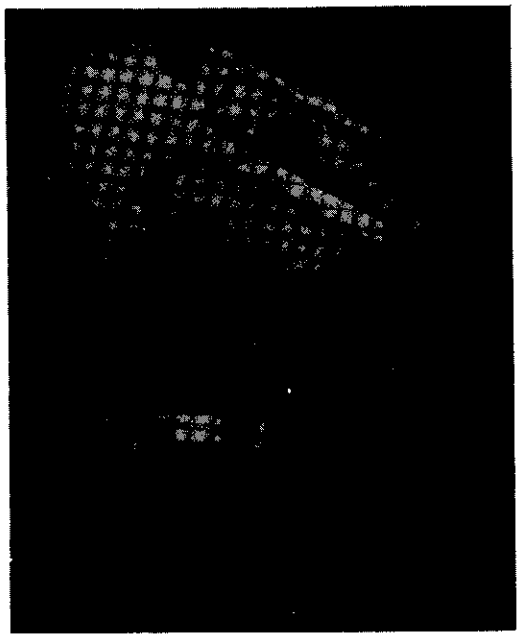


Figure 2.

TABLE 1. Child Restraint Vest

| Test No. | Sled Deceleration (g) | Impact Velocity (ft/s) | Dummy Weight (lb) | System Failure |
|---|---|---|---|---|
| A76-015 | 11 | 44.6 | 17.4 | Yes |
| A76-016 | 11 | 44.3 | 32.6 | Yes |
| A76-017 | 25 | 44.3 | 17.4 | Yes |
| A76-018 | 22 | 44.5 | 32.6 | Yes |

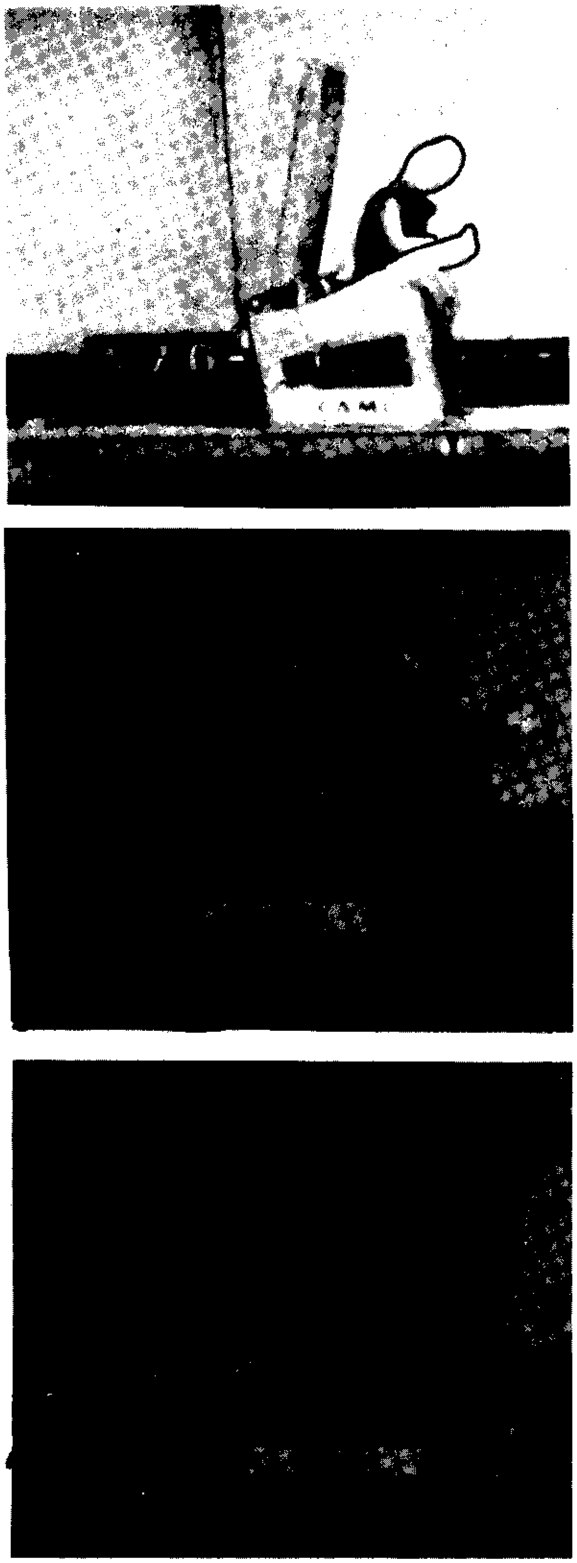



Figure 3. Dynamic Crash Test.
Sequence taken from high-speed film.

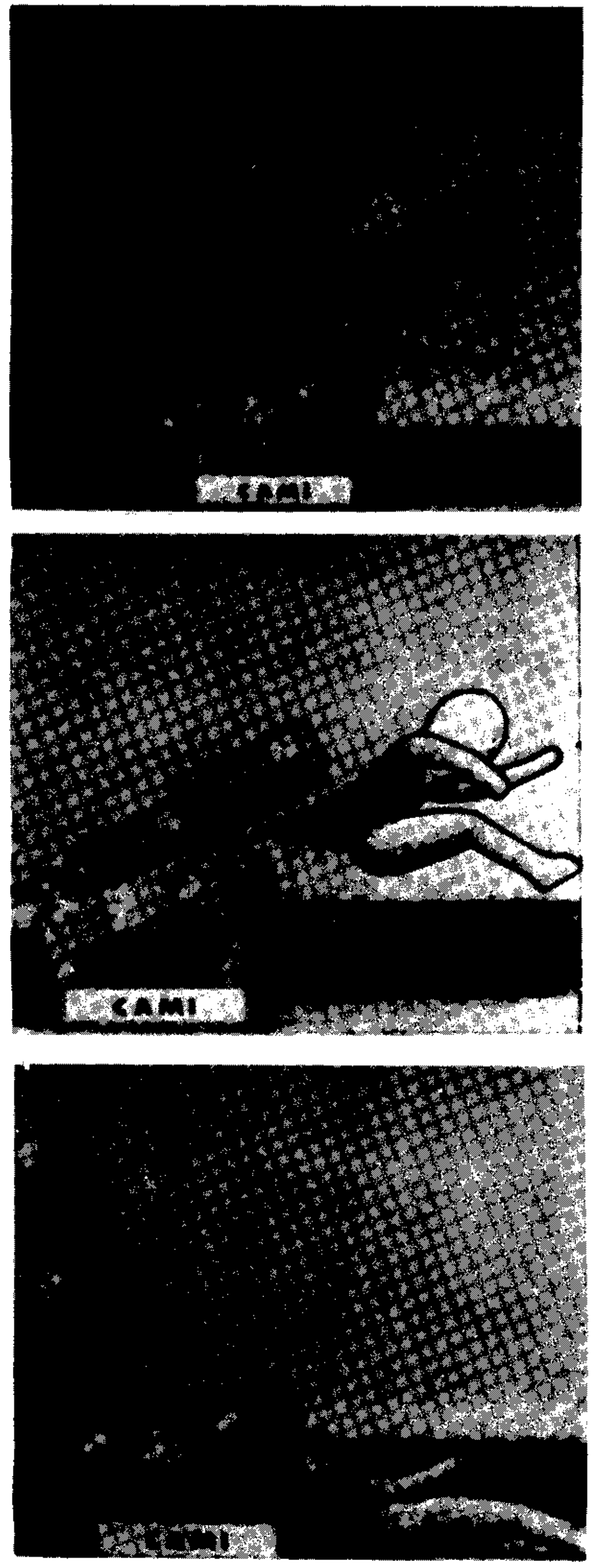
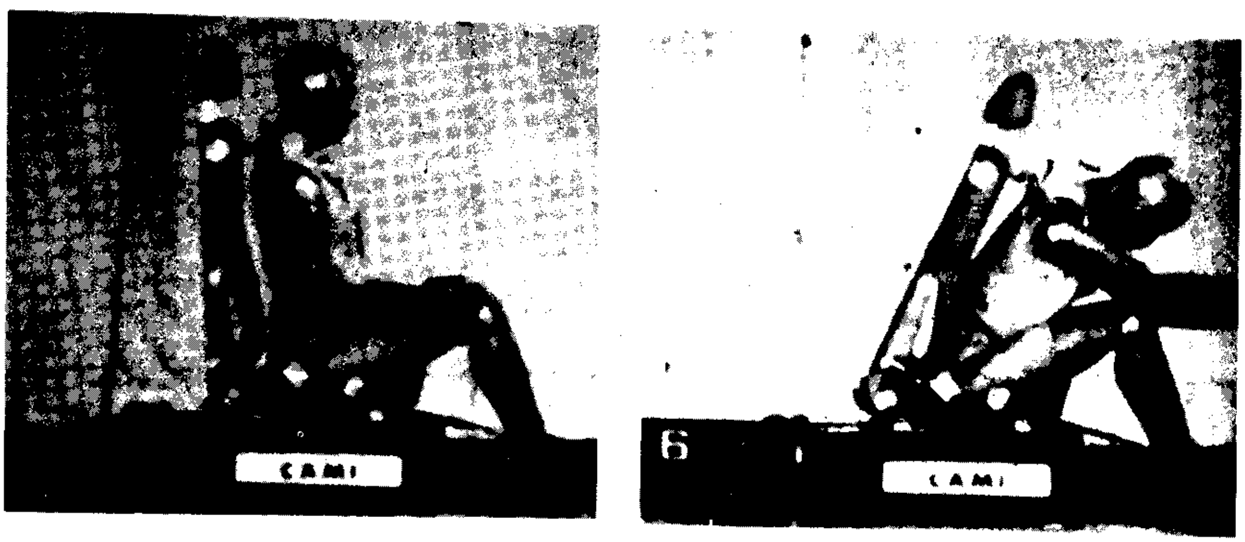



Figure 4. Dynamic Crash Test.
Sequence taken from high-speed film.

## DYNAMIC TEST OF INTEGRATED SEAT/RESTRAINT SYSTEM FOR GENERAL AVIATION AIRCRAFT

A certificated general aviation seat that incorporates an upper torso restraint in the seat back was obtained for testing. This concept uses an inertia reel located in the seat with the back latched in the upright position. The single diagonal upper torso belt passes through the seat back at shoulder height, passes over the shoulder, and then attaches to the lapbelt via a keyhole slot in the lapbelt buckle. The lapbelt is attached to the airframe. Although this system is certificated, and thus should comply with the 9-g static equivalent load requirement in the forward direction, it failed in the 6.5-g dynamic test (Figure 5). The failure occurred in the seat pan frame, a simple planar rectangle of steel tubing, as it attempted to resist the bending moment introduced by the upper torso restraint through the seat back. An attempt to reinforce the seat pan frame did not improve system performance but only transferred the failure location to the latch mechanism. In analyzing the results of these tests, we noted that the current regulatory requirements do not provide guidance relative to the loads that must be carried through the upper torso restraint into the supporting structure. Certification of the system can be accomplished by using only the lapbelt, which in this system is attached to the airframe and avoids major loading of the seat.




a. During the impact, the torso restraint system (arrow) loads the seat back.

b. The frame of the seat pan fails as a result of the seat back load.

Figure 5. Events during impact. Sequence taken from high-speed film.

EVALUATION OF A GENERAL AVIATION
CABIN/SEAT/RESTRAINT SYSTEM

A series of oblique impact tests was conducted with a four-place general aviation cabin to evaluate problems that could be encountered in increasing the crash injury protection offered by the seat and restraint system. The cabin was positioned so that the impact vector was oriented from 10° to the left and 10° below the aircraft longitudinal centerline. The restraint system being evaluated in these tests included a diagonal upper torso restraint that passed through a guide attached to overhead structure and then to an inertia reel mounted low in the cabin. The long belt length that results from such an installation could allow significant total elongation under elastic load and thus reduce the effectiveness of the system. The seat used in these tests was a conventional four-legged seat that had been reinforced by the manufacturer in the slipper area, apparently as a result of earlier crash investigation. The lapbelts were anchored to the airframe and the general aircraft cabin interior was in accordance with the manufacturer's standard practice. Selected data from the tests are shown in Table 2.

After the second test, the attachment for the upper torso restraint guide was reinforced. On the third test, rotation of the dummy torso from under the diagonal belt was noted (Figure 6). This rotation was corrected by shortening the length of webbing that carried loads from both the shoulder belt and the lapbelt. Further improvement was obtained by relocating the inboard lapbelt anchorage 5 in to the rear. Tests were then completed to a 28-g level without further changes (Figure 7). The changes made in the restraint system are shown in Figure 8. Data collected on the final test indicated that survival without irreversible injury would have been accomplished from an equivalent crash. However, the energy stored in the long upper torso restraint strap aggravated the potential for injury during rebound and the elongation of that strap allowed the head to move into the vicinity of the instrument panel, a potential injury source.

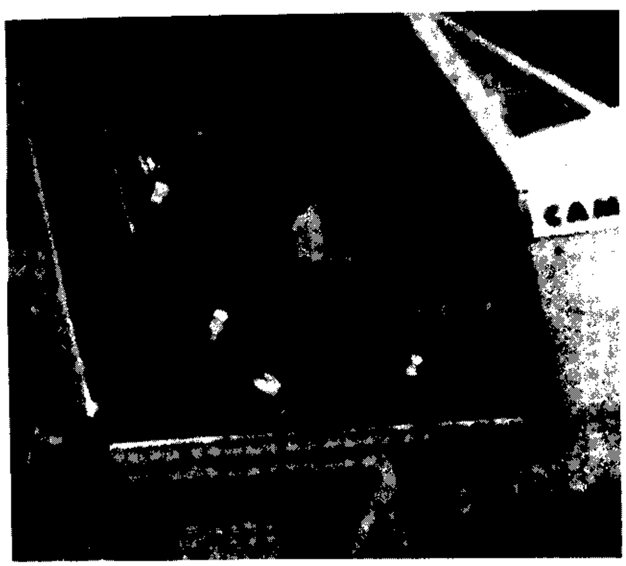


Figure 6. Rotation of dummy from upper torso restraint at 13 g.

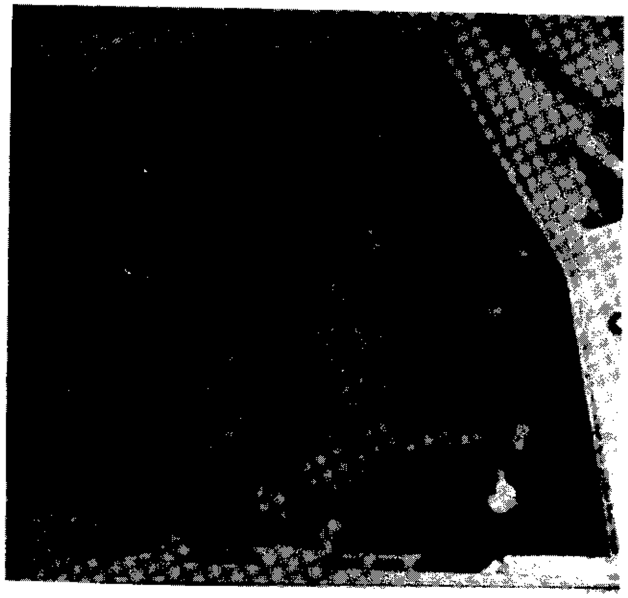


Figure 7. Modified restraint retains dummy torso even at 28 g.

Figure 8. Modifications to restraint included relocation of buckle to the side of the hip and movement of inboard anchorage point to the rear. Initial locations are shown by circles.

TABLE 2. General Aviation Cabin/Seat/Restraint System Evaluation

| Test No. | Sled Deceleration (g) | Sled Velocity (ft/s) | Left Dummy Belt Loads (lb) | | | Right Dummy Belt Loads (lb) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Left Lap | Right Lap | Shoulder Belt | Left Lap | Right Lap | Shoulder Belt |
| A75-028 | 6.5 | 44.6 | 550 | 700 | 600 | 700 | 750 | 640 |
| A75-029 | 10.0 | 44.0 | 800 | 750 | 900 | 800 | 1,100 | 1,160 |
| A75-030 | 13.0 | 44.0 | 920 | 1,400 | 1,000. | 1,400 | 1,500 | 900 |
| A75-031 | 10.0 | 43.2 | 1,100 | 600 | NOT USED | 700 | 800 | 800 |
| A75-032 | 10.0 | 43.3 | 1,000 | 800 | 900 | 1,000 | 800 | 850 |
| A75-033 | 10.0 | 43.2 | 1,450 | 960 | 800 | 1,100 | 700 | 900 |
| A75-034 | 18.5 | 43.4 | 2,100 | 1,600 | 680 | 940 | 1,700 | 1,200 |
| A75-035 | 28.0 | 43.4 | 2,200 | 1,000 | 800 | 1,800 | ~3,000 | 1,100 |

## U.S. ARMY AEROMEDICAL RESEARCH LABORATORY ENERGY-ABSORBING HELICOPTER SEAT TESTS

Tests were conducted on a redesigned version of the prototype two-passenger helicopter seat in cooperation with the U.S. Army Aeromedical Research Laboratory (USAARL). This seat has potential applications to civil aircraft if it can be made functional because it has advantages of light weight (about 30 lb), energy absorption, seat stowage in a small space, and comfort. Earlier tests indicated problems in the design of the Invertube energy absorber mounting and in the installation of the vertical energy absorption cables in the seat back of the rearward-facing seat configuration. The seats tested in this phase used strengthene attachments on the Invertubes and a continuous cable passed through tubulard guides in the seat back.

Both forward-facing and rearward-facing versions of the seat were tested in orientations that produced direct lateral loading (Figure 9), combined forward and lateral loading (Figure 10), and combined forward, lateral, and downward loading (Figure 11).

The tests are summarized in Table 3. Structural failures continued to occur in the first two orientations. These were primarily associated with the Invertube energy absorbers relative to weld joints, end fittings, and instability. Failures also occurred in the restraint system and in the energy-absorbing cables. Performance in the combined loading configuration (Figure 11) was better, although the performance of the energy absorption system was shown to be sensitive to the weight of the occupants. On the next-to-last test, the seat moved down and forward into contact with the dummies' legs, an action that could cause incapacitating injury.

Further development of this system is indicated.

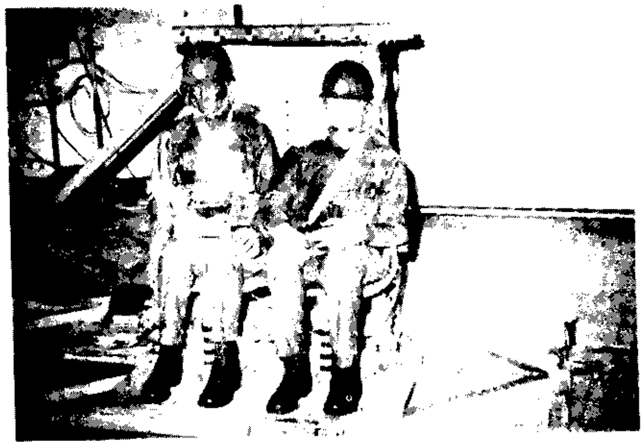


Figure 9.

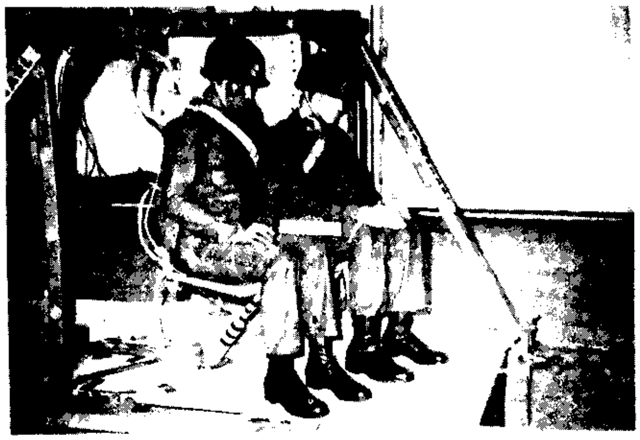


Figure 10.

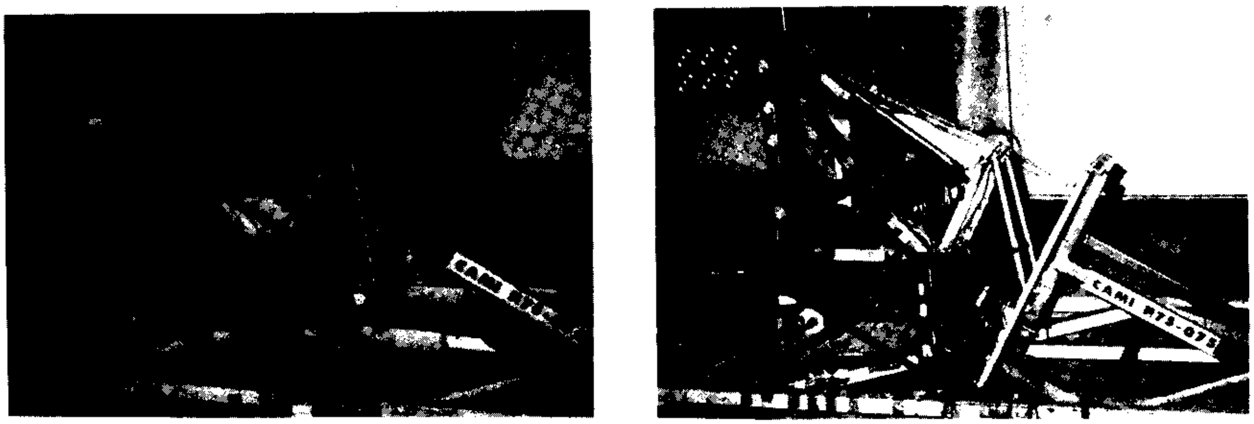
Figure 11.

TABLE 3. USAARL Helicopter Seat Evaluation (Phase II)

| Test No. | Sled Deceleration (g) | Sled Velocity (ft/s) | Left Dummy Weight (lb) | Right Dummy Weight (lb) | Seat Type | Orientation Figure No. | Structural Failure |
|---|---|---|---|---|---|---|---|
| A76-032 | 17.5 | 29.2 | 248 | 248 | FWD | 9 | Yes |
| A76-033 | 17.0 | 29.6 | 255 | 255 | RWD | 9 | Yes |
| A76-034 | 25.0 | 47.4 | 255 | 255 | FWD | 10 | Yes |
| A76-035 | 20.0 | 48.5 | 255 | 255 | RWD | 10 | Part |
| A76-036 | 24.0 | 50.9 | 255 | 255 | FWD | 10 | Yes |
| A76-037 | 37.5 | 50.5 | 255 | 255 | FWD | 11 | No |
| A76-038 | 40.0 | 51.6 | 138 | 0 | FWD | 11 | No |
| A76-039 | 36.0 | 50.2 | 138 | 255 | FWD | 11 | No |
| A76-040 | 37.0 | 50.2 | 244 | 244 | RWD | 11 | No |

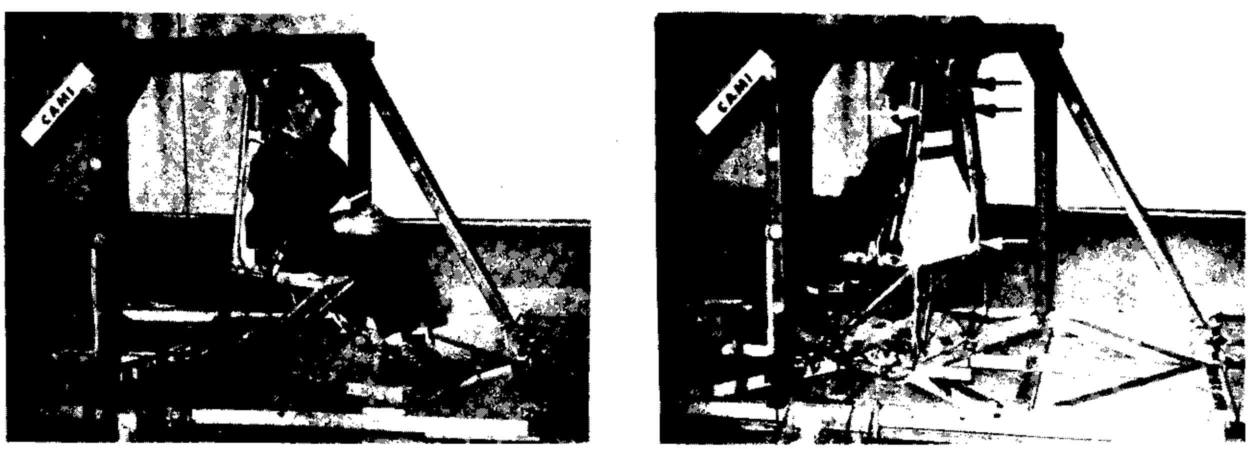
EVALUATION OF USAAMRDL BOEING-VERTOL
ENERGY-ABSORBING HELICOPTER SEATS

A program to evaluate prototype energy-absorbing seating systems was undertaken in cooperation with the Eustis Directorate of the U.S. Army Air Mobility Research and Development Laboratory (USAAMRDL). Two Boeing-Vertol Type I, Class A (single-occupancy, forward-facing) and two Type I, Class B (single-occupancy, aft-facing) seats were provided for this program. The essential construction details of these seats are provided in USAAMRDL Report Number TR-74-93, Crashworthy Troop Seat Investigation, December 1974. The seats are shown, installed on the test sled, in Figures 12 and 13. Energy absorption in the vertical direction is provided by "metal bender" devices located between overhead structure and the top of the seat back, in the fore-and-aft direction by metal bender devices contained in diagonal tubes connecting the floor with the front (Type IA seat) or back (Type IB seat) of the seat pan frame, and in lateral directions by crossed cables between the floor and the front and back tubes that form the seat pan frame.




(a) (b)

Figure 12. Forward-facing (a) and aft-facing (b) seats in oblique impact orientation.




(a) (b)

Figure 13. Forward-facing (a) and aft-facing (b) seats in 30° yawed impact orientation.

## PHASE I TESTS

The seats were oriented to receive the impact load from two directions as specified in Mil-S-58095 (AV), General Specification for Crashworthy, Non-Ejection Aircrew Seat System, August 1971. The first orientation simulates a vertical impact with the aircraft pitched down 30° and rolled 10°. The second orientation simulates a horizontal impact with the aircraft yawed 30°.

Seat and restraint system failures occurred during this phase that negated the value of the data. The locations of these failures are indicated by arrows placed on the figures. Included are failures of the vertical energy-absorber adjustment turn-buckle (Figure 12a), the restraint system buckle (Figure 13a), and the seat back structure (Figure 13b). The failure of the restraint system buckle was of particular interest in that it repeated a failure that had occurred on this same design during a dynamic test at CAMI in 1973. The buckle had been withdrawn from the civilian market, but military sales had apparently continued. It is understood that the buckle has now been recalled from military applications.

Although no structural failures occurred during the second test, the seat bottomed as the energy absorbers stroked, causing high impact loads on the dummy. Data from these and subsequent tests are shown in Table 4. The seats were returned to the manufacturer for modifications in preparation for the next phase of testing.

## PHASE II TESTS

The seats were modified to correct the difficulties discovered during the Phase I tests. Since no satisfactory restraint system buckle could be readily obtained, a fixed link was fabricated to receive the ends of the restraint straps and was used for the remainder of the tests. On the first test of this phase, the fabric seat pan ripped, apparently because of high localized loading from the dummy. A leather seat pan cover was fabricated and used on subsequent tests and prevented repetition of the failure. An additional problem was encountered on the third test, when the diagonal cable system failed, allowing the seat to rotate during the impact.

Although some structural failures did occur during this phase, the dummy was retained in the seat and the seat was retained in the approximately normal position. The data, shown in Table 4, are considered representative of the system performance. Values are given in this table for the Dynamic Response Index (DRI) outlined in Mil-S-9749A, General Specification for Upward Ejection Aircraft Seat System, June 1967, using the "z" (superior-inferior) axis accelerometer located in the dummy pelvis. The DRI is representative of the maximum dynamic stress of the normally aligned vertebral column, with onset of injury occurring between 17 and 22. High-speed motion picture coverage of the tests with seats in the first orientation, which could produce severe vertebral injury, indicated that the vertebral column was not maintained in normal alignment but instead conformed to the pocket formed by the fabric seat covering. This not only distorts the vertebral column, but changes the orientation of the pelvis accelerometer cluster so that the "z" axis accelerometer does not indicate the full magnitude of the "z" axis acceleration. The values of DRI indicated in Table 4 should, therefore, be used with caution.

An analysis of the accelerations measured on these tests indicated that an initial high acceleration peak occurred in the dummy as the energy absorbers began to stroke. This is a common characteristic of many energy-absorption systems and may even be of some advantage in reducing the DRI values. However, it was decided to modify the vertical energy absorbers in an attempt to reduce the initial acceleration peak. This modification was evaluated in the Phase III tests.

## PHASE III TESTS

Two tests were accomplished in the first orientation. On the second test, using the forward-facing seat configuration, the front of the seat pan frame contacted the back of the dummy's legs, above the ankle, as the energy absorbers stroked and the seat moved forward. This provided an effective stop for the seat motion and would probably have caused injury to the legs. As the dummy continued to load the seat, the weighted equipment pack created a direct load on the rear crossbar of the seat pan frame, causing structural failure of the crossbar and its attachment. Because of these occurrences, the data obtained on the second test are not considered representative of the system's performance.

A comparison of the data obtained on the first test with the equivalent test of Phase II indicated reduction of the initial pelvis acceleration peak of approximately 20 percent after data were normalized to compensate for dummy weight differences.

TABLE 4. Data Summary of USAAMRDL Boeing-Vertol Energy-Absorbing Seat

| Test No. | Seat Orientation (Fig. No.) | Seat Type[3] | Dummy Weight (lb)[1] | Impact Velocity (ft/s) | Deceleration (g) Sled | Deceleration (g) Chest[2] | Deceleration (g) Pelvis[2] | DRI | Seat Structure Failure |
|---|---|---|---|---|---|---|---|---|---|
| PHASE I | | | | | | | | | |
| A75-074 | 12 | IA | 243 | 49.3 | 45 | -- | -- | -- | Yes |
| A75-075 | 12 | IB | 220 | 49.4 | 50 | -- | -- | -- | No |
| A75-076 | 13 | IA | 243 | 48.0 | 20 | -- | -- | -- | Yes |
| A75-077 | 13 | IB | 243 | 49.8 | 20 | -- | -- | -- | Yes |
| PHASE II | | | | | | | | | |
| A76-027 | 12 | IA | 210 | 41.9 | 42 | 62 | 92 | 33 | Yes |
| A76-028 | 13 | IA | 235 | 49.4 | 20 | 26 | 47 | 12 | No |
| A76-029 | 13 | IB | 244 | 48.5 | 27 | 24 | 35 | 18 | Yes |
| A76-030 | 12 | IB | 210 | 42.2 | 45 | 31 | 40 | 8 | No |
| A76-031 | 12 | IB | 170 | 42.2 | 48 | 47 | 33 | 19 | No |
| PHASE III | | | | | | | | | |
| A76-057 | 12 | IB | 204 | 41.9 | 47 | 30 | 30 | -- | No |
| A76-058 | 12 | IA | 204 | 42.1 | 46 | -- | -- | -- | Yes |

[1] Dummy weight includes the weight of equipment and clothing placed on the dummy in accordance with instructions from USAAMRDL.

[2] Chest and pelvis decelerations are maximum values of the vector sum of data from orthogonally oriented accelerometers mounted in those locations.

[3] See text for definitions of seat orientation and seat type.

## VERTICAL IMPACT TESTS ON A GENERAL AVIATION SEAT

A conventional general aviation seat was subjected to vertical impact tests to provide a basis for evaluation of the effectiveness of energy-absorbing seat systems. The seat is normally mounted directly over the main wing spar of the aircraft. This mounting was simulated by a box section support placed between the sled floor and the seat as shown in Figure 14. The primary data obtained in these tests are shown in Table 5. Measurements on the third test indicated that the seat cushion had bottomed; i.e., contacted the structure beneath the seat. Data measured on the dummy on the fourth test, in which the seat again bottomed, exceeded the recording capacity of the data system and are not reported. It should be noted that the input acceleration (sled g) was amplified by a factor of 3 as measured on the dummy.

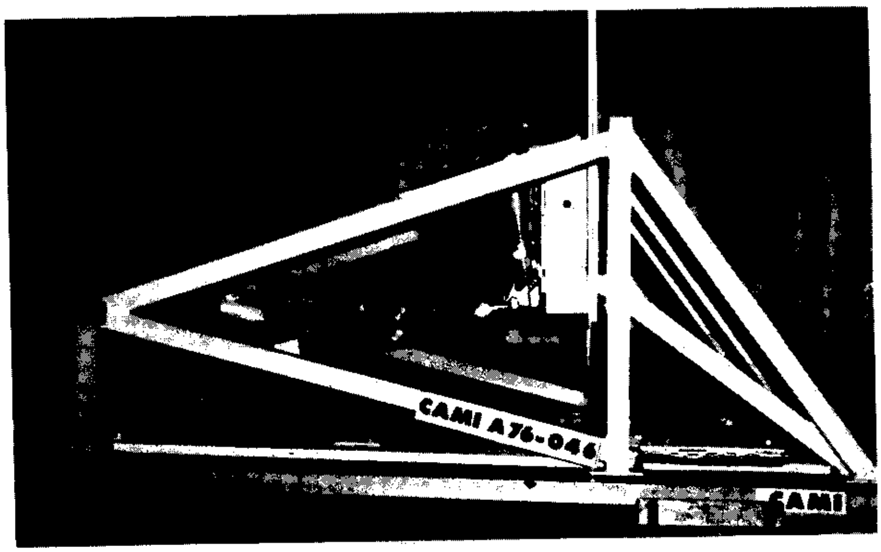



Figure 14.

TABLE 5. Vertical Impact of General Aviation Seat

| | Sled Velocity | Deceleration (g) | | | |
|---|---|---|---|---|---|
| Test No. | (ft/s) | Sled | Head Z | Chest Z | Pelvis Z |
| A76-043 | 29.9 | 6 | 10 | 10 | 9 |
| A76-044 | 30.3 | 11 | 22 | 26 | 27 |
| A76-045 | 30.0 | 14 | 38 | 43 | 40 |
| A76-046 | 30.3 | 19 | -- | -- | -- |

DYNAMIC TESTS OF A HELICOPTER CREW SEAT WITH VERTICAL ENERGY-ABSORPTION CHARACTERISTICS DESIGNED FOR CIVIL AIRCRAFT

Two prototype lightweight (18-lb) helicopter seats were obtained for dynamic testing on the Civil Aeromedical Institute track. These seats were designed to provide vertical energy absorption by allowing a hollow honeycomb cylinder, located in the seat height adjustment mechanism, to crush as vertical seat loads increased. The basic design consists of a base of L-shaped legs, the horizontal element of which is attached to rails in the airframe and provides fore and aft adjustment of the seat and the vertical element that provides a post for vertical adjustment of the seat and contains the energy absorber. The seat frame is composed of welded aluminum tubing covered with raschel net to act as a load-carrying membrane, and then covered with a nylon slipcover for appearance.

Three seat orientations were tested, so that data were obtained under vertical impact (Figure 15), with the impact vector oriented $60^{\circ}$ below the horizontal (Figure 16), and with the impact vector horizontal and $15^{\circ}$ to the left (Figure 17). Principal data obtained in the tests are summarized in Table 6.

The energy-absorption system was modified after the second and third tests in an attempt to reduce the actuation load level. The final configuration used on the fourth and subsequent tests provided 1/16-in clearance between the central guide rod and the honeycomb cylinder, employed dry film lubricant between the vertical sliding tubes of the base and the seat, and preloaded the honeycomb energy-absorption cylinders to 200 lb each.

Although plastic deformation occurred in several tubes of the seat frame during the tests, the tubes were easily straightened and did not fail structurally, even though exposed to repeated impacts. Elastic response was also obvious during the tests, apparently a consequence of the cantilevered concept of seat design and the use of raschel net as the load-carrying membrane. This resulted in energy storage and feedback into the dummy, causing relatively high dummy chest and pelvic accelerations.

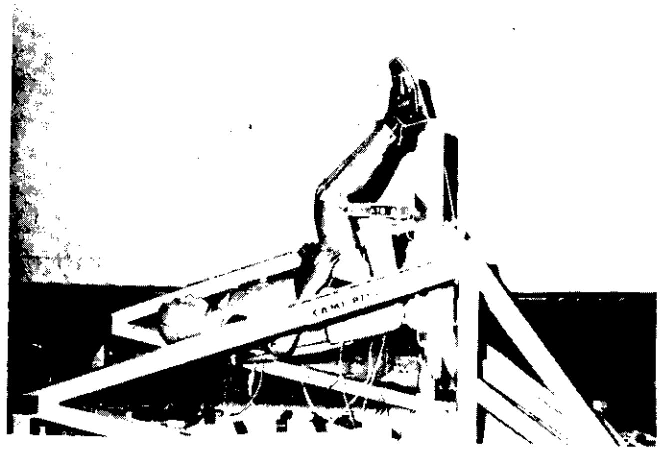


Figure 15. Helicopter seat after test. The energy-absorption system has stroked.

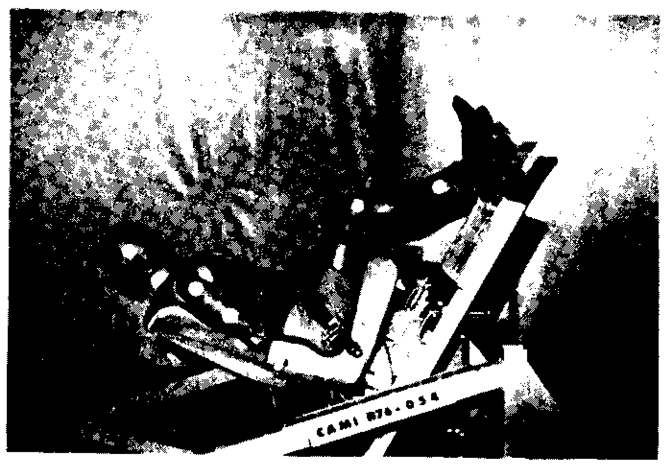


Figure 16. Helicopter seat after test. The energy-absorption system has stroked.

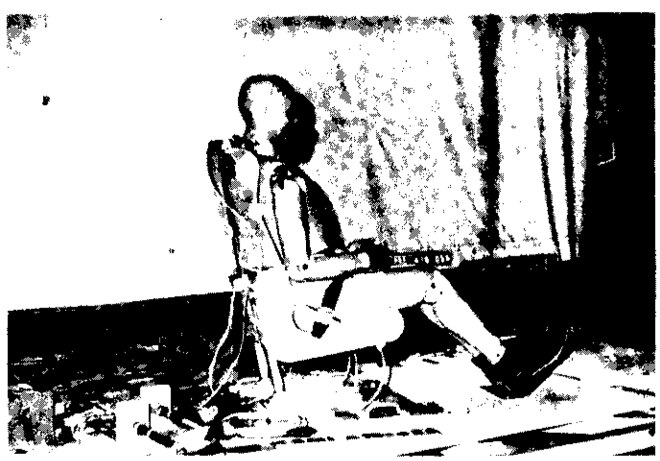


Figure 17. Helicopter seat before test.

TABLE 6. Civil Aircraft Helicopter Seat

| Test No. | Seat Orientation (Fig. No.) | Sled Impact Velocity (ft/s) | Sled Deceleration (g) | E.A. Stroke (in) | Dynamic Response Index | Maximum E.A. Load (lb) | Shoulder Belt Load (lb) | Lap Belt Loop Load (lb) | Pelvis Z (g) |
|---|---|---|---|---|---|---|---|---|---|
| A76-047 | 15 | 30.1 | 6.3 | 0 | 11.8 | 997 | 34 | 226 | -10.2 |
| A76-048 | 15 | 30.3 | 11.2 | 0 | 24.4 | 2,203 | 55 | 447 | -22.8 |
| A76-049 | 15 | 30.1 | 11.1 | 0 | 24.4 | 2,740 | 69 | 519 | -21.3 |
| A76-050 | 15 | 30.5 | 16.2 | 4.4 | 20.5 | 1,969 | 66 | 574 | -23.9 |
| A76-051 | 15 | 30.1 | 20.0 | 4.5 | 22.4 | 1,924 | 177 | 906 | -24.9 |
| A76-052 | 16 | 30.1 | 10.9 | 0 | 26.0 | 1,592 | 492 | 532 | -22.4 |
| A76-053 | 16 | 30.1 | 15.9 | 1.3 | 27.5 | 1,897 | 564 | 428 | -24.3 |
| A76-054 | 16 | 29.9 | 20.2 | 4.3 | 28.4 | 1,684 | 588 | 457 | -24.1 |
| A76-055 | 17 | 31.1 | 9.1 | 0 | 8.9 | 484 | 913 | 1,273 | --- |
| A76-056 | 17 | 31.2 | 9.5 | 0 | 8.1 | 500 | 817 | 672 | --- |

## ENERGY-ABSORBING STEERING COLUMN EVALUATION

This program was conducted to evaluate the performance of automotive-type energy-absorbing steering column assemblies so that the feasibility of their use as aircraft control columns could be determined. Initial static testing on the columns indicated that the columns stroked at between 350 and 500 lb of force when loaded axially. Initial dynamic tests positioned the column in a conventional automobile configuration and used an unrestrained anthropomorphic dummy (Figure 18). Crushable knee bolsters provided a contact surface to prevent knee damage. It was found that the column would "lock" because of the eccentric load application and transmit up to 2,400 lb of force with minimal column stroke. Efforts to increase the bearing area and alleviate locking conditions on the column were of little improvement, increasing the stroke displacement only from 1 in to 4 in. The fourth, fifth, and sixth tests used a dummy with lapbelt so that the chest contacted the column in a manner more conducive to producing axial loads. Although the column stroke increased to more than 7 in, peak chest decelerations were not significantly reduced. Data are shown in Table 7. It was concluded that the energy-absorbing steering column is sensitive to eccentric loading and would require further development to eliminate this sensitivity before consideration of aircraft application is warranted.

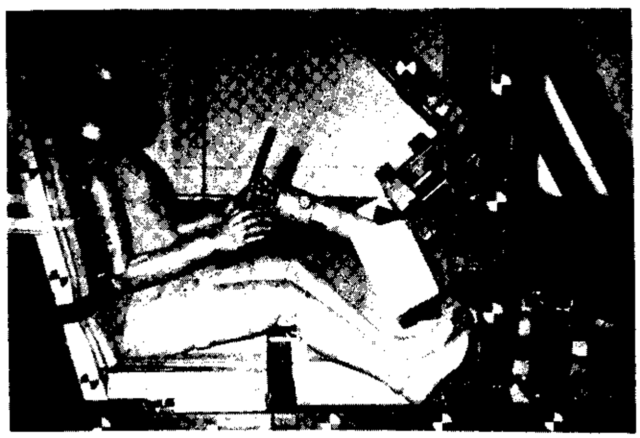


Figure 18.

TABLE 7. Energy-Absorbing Steering Column Evaluation

| Test No. | Sled Deceleration (g) | Sled Velocity (ft/s) | Column Stroke (in) | Chest Deceleration (g) | Column Force (lb) |
|---|---|---|---|---|---|
| A75-037 | 24.0 | 43.8 | 1.0 | 67 | 500 |
| A75-038 | 22.0 | 43.8 | 1.5 | 35 | 2,400 |
| A75-039 | 21.3 | 44.3 | 4.0 | 75 | 1,300 |
| A75-043 | 22.0 | 43.7 | 7.0 | 82 | 900 |
| A75-044 | 22.0 | 43.2 | 7.3 | 100 | 1,100 |
| A75-045 | 22.5 | 43.7 | 7.5 | 110 | 900 |

## EVALUATION OF GM50X ANTHROPOMORPHIC DUMMIES

Two General Motors model GM50X anthropomorphic dummies, serial numbers 5 and 6, were subjected to component tests and sled tests to evaluate their performance consistency and potential for use in dynamic crash testing. This effort was part of a continuing program being carried out in cooperation with the National Highway Traffic Safety Administration (NHTSA) to obtain data on advanced dummy concepts, from different manufacturers, while undergoing specific tests that are duplicated at different test facilities. In this manner, data are obtained that will allow differentiation of variations in dummy performance due to differences in design, differences in manufacturing techniques, or differences in test conduct.

The tests on these dummies consisted of sled tests using a standard lapbelt and single-diagonal-belt upper torso restraint (Figures 19, 21, and 23) and a preinflated air bag and plastic foam knee bolster restraint (Figures 20, 22, and 24). Component tests included head drops onto a steel plate from 10-in and 35-in heights (Figure 25); pendulum impact tests of the head and neck assemblies (Tables 8 and 9); impact tests of the thorax at two different impact velocities (Figure 26); static load tests of the thorax 15 in below the vertex of the head, 18 in below and 3 in to the left of the vertex of the head, 18 in below and 3 in to the right of the vertex of the head; and static load tests of the abdomen assembly (Figures 27 and 28). These tests are repeated to obtain an indication of the mean value and standard deviation of the results.

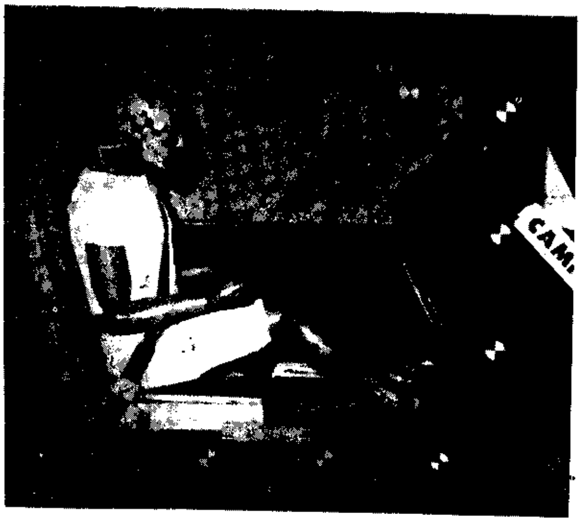


Figure 19.

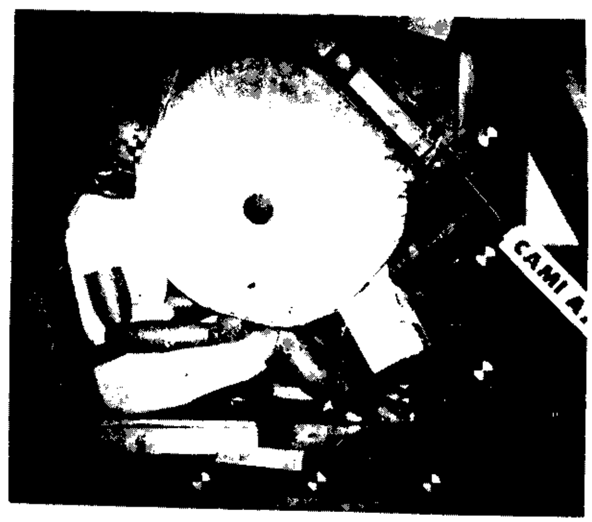


Figure 20.

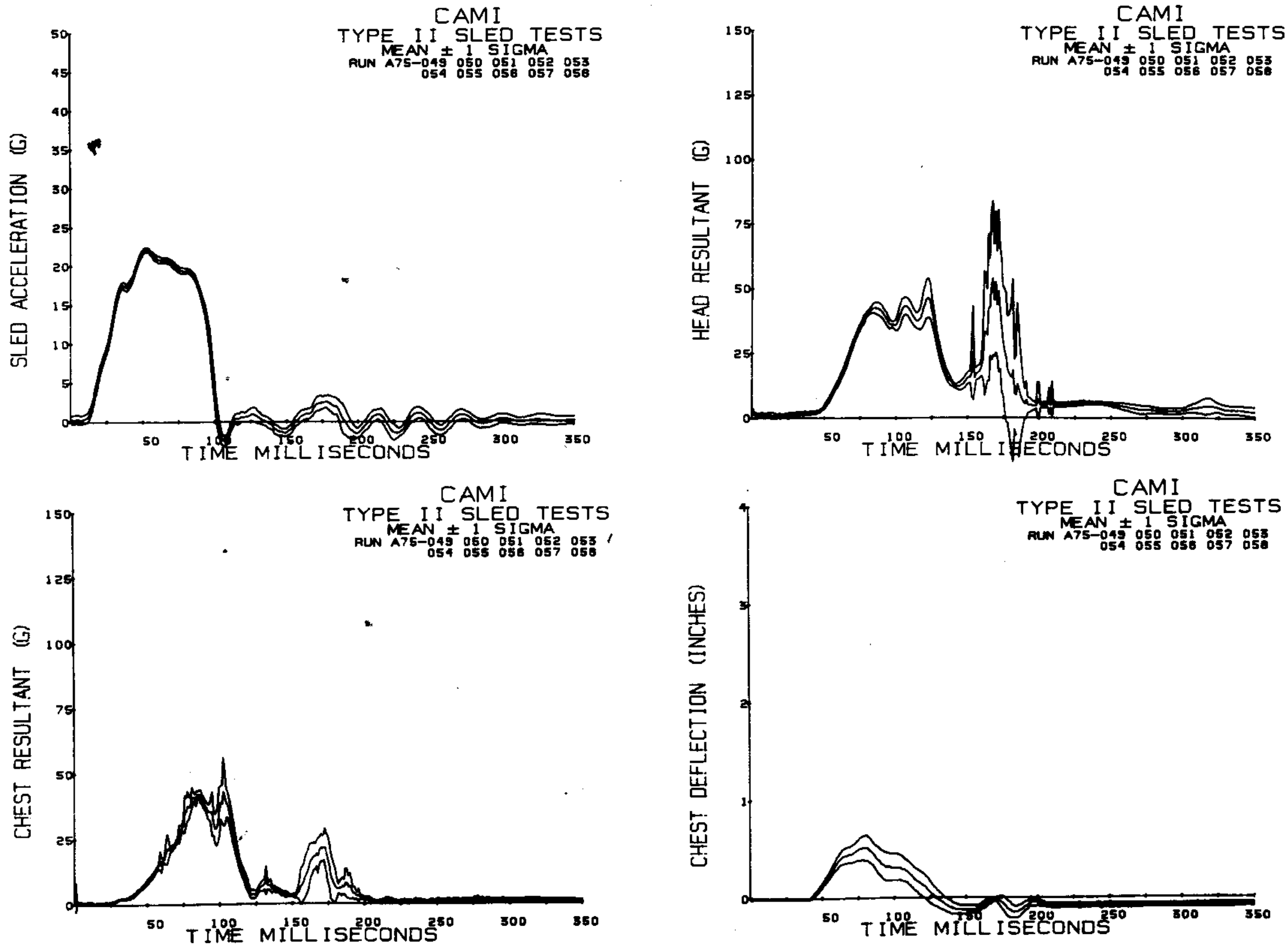



Figure 21. Lapbelt and diagonal-belt upper torso restraint sled test data, dummy serial number 5. (continued)

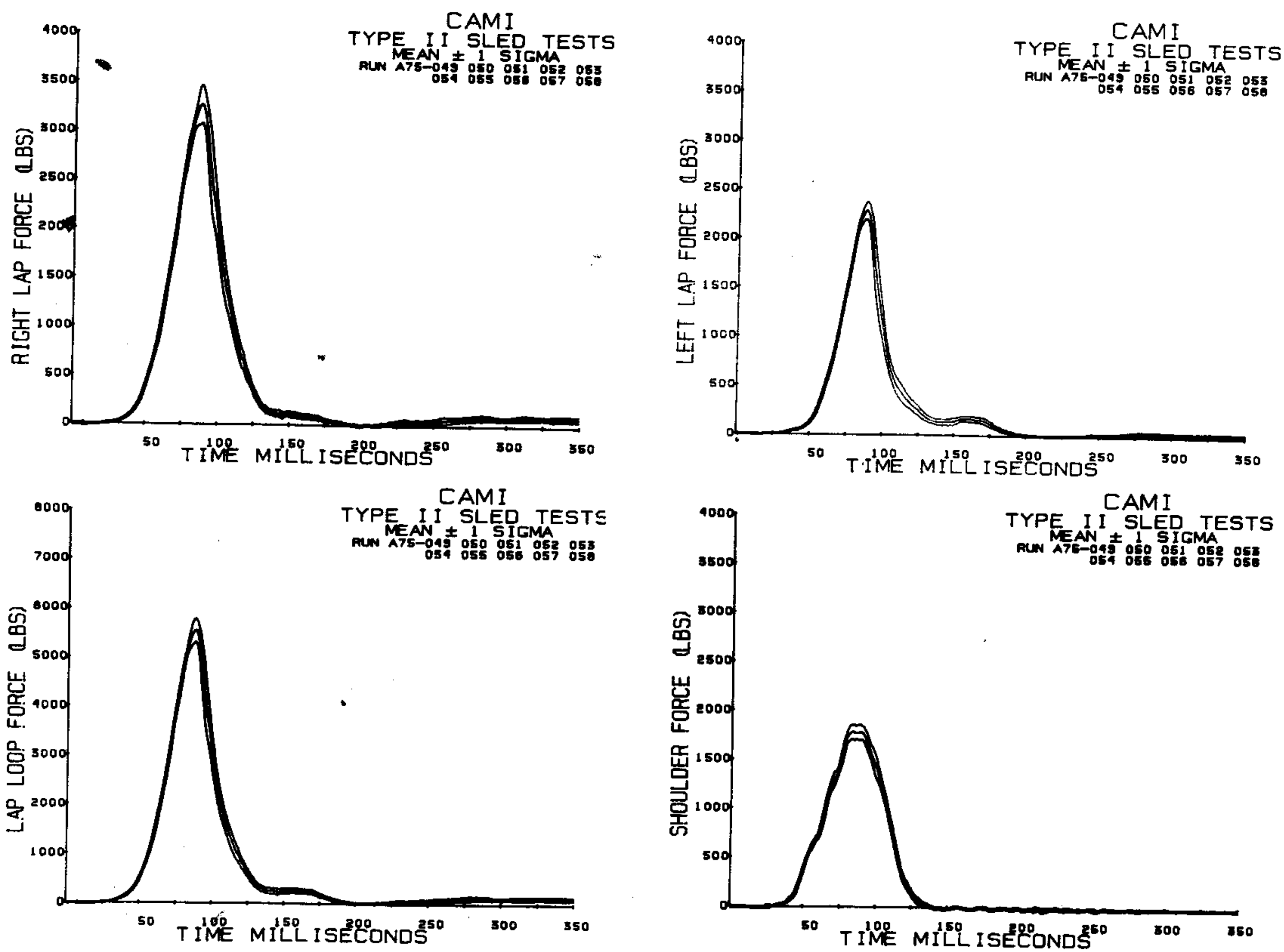



Figure 21. (continued).

Figure 21. (continued).

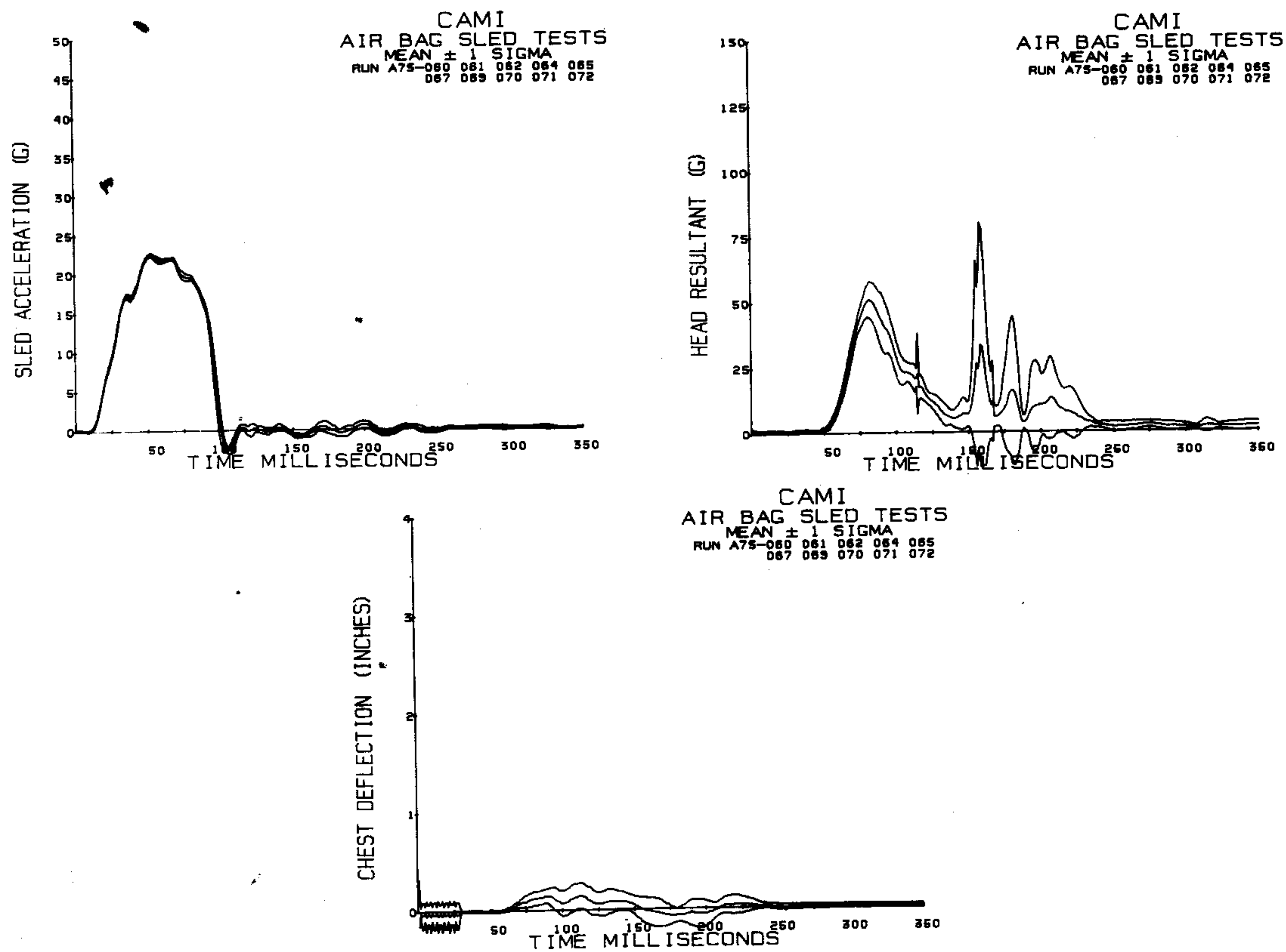



Figure 22. Air bag sled test data, dummy serial number 5.

(continued)

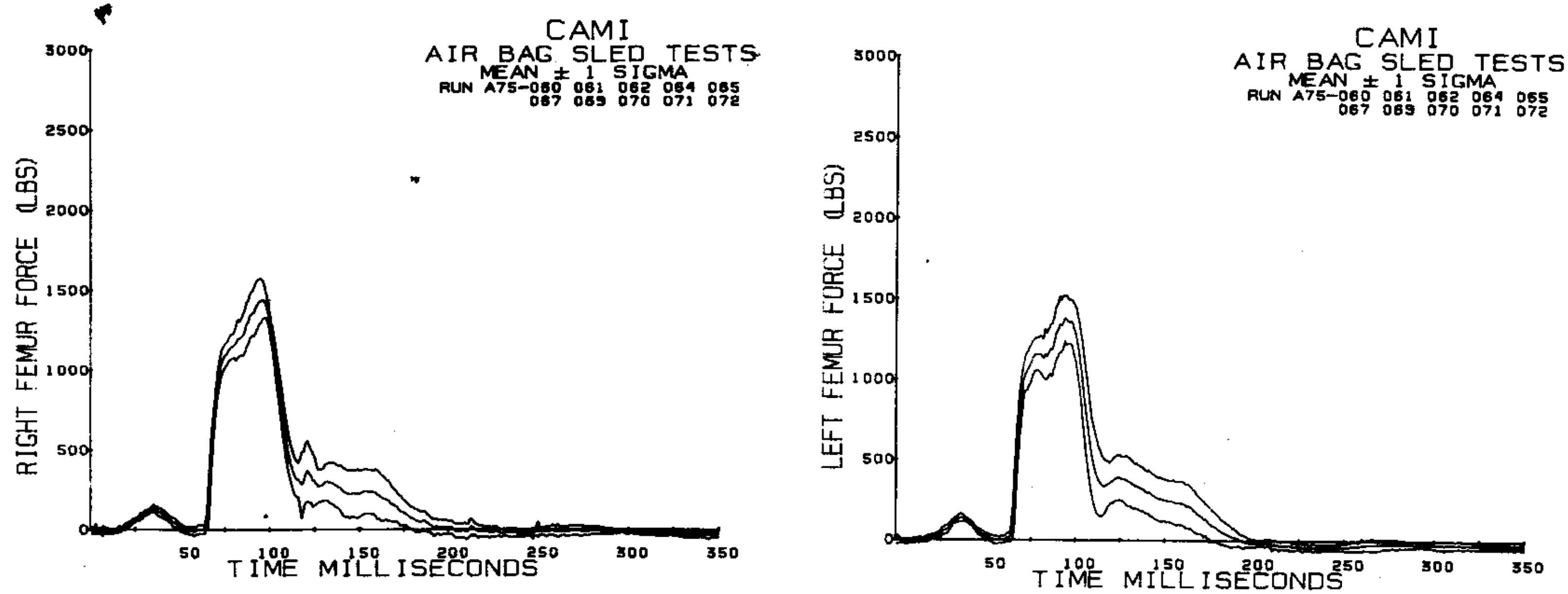



Figure 22. (continued).

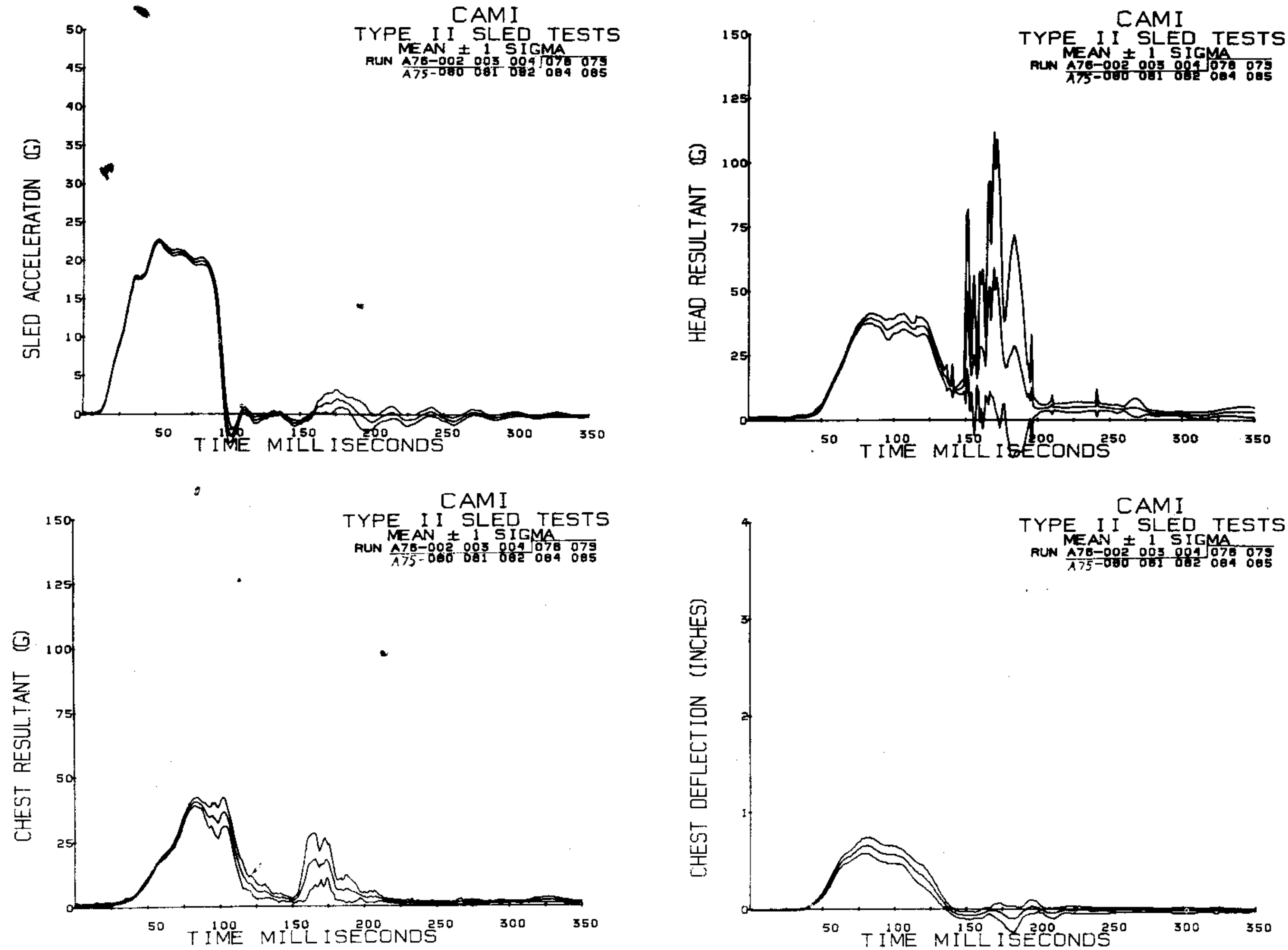



Figure 23. Lapbelt and diagonal-belt upper torso restraint sled test data, dummy serial number 6. (continued)

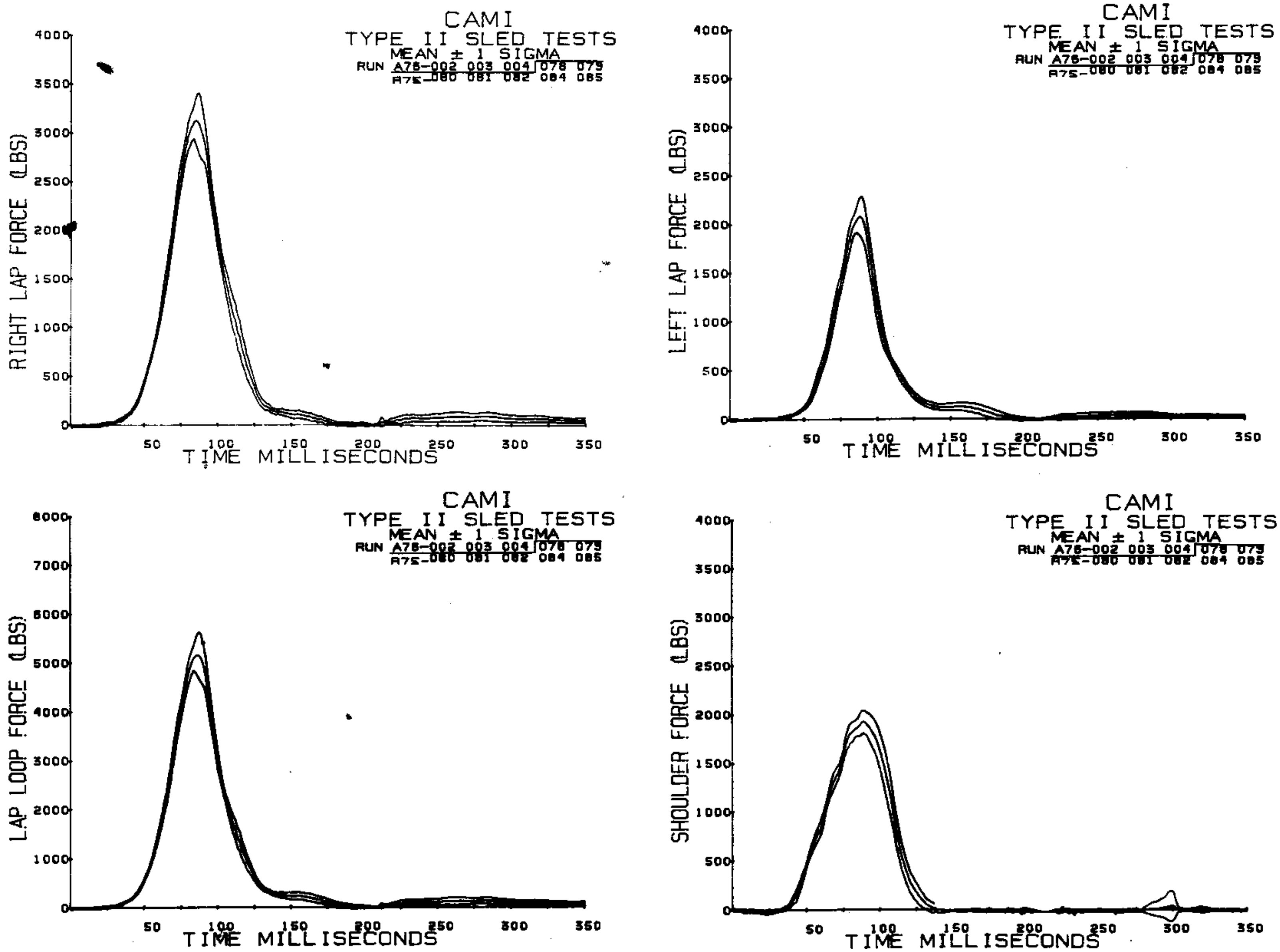



Figure 23. (continued).

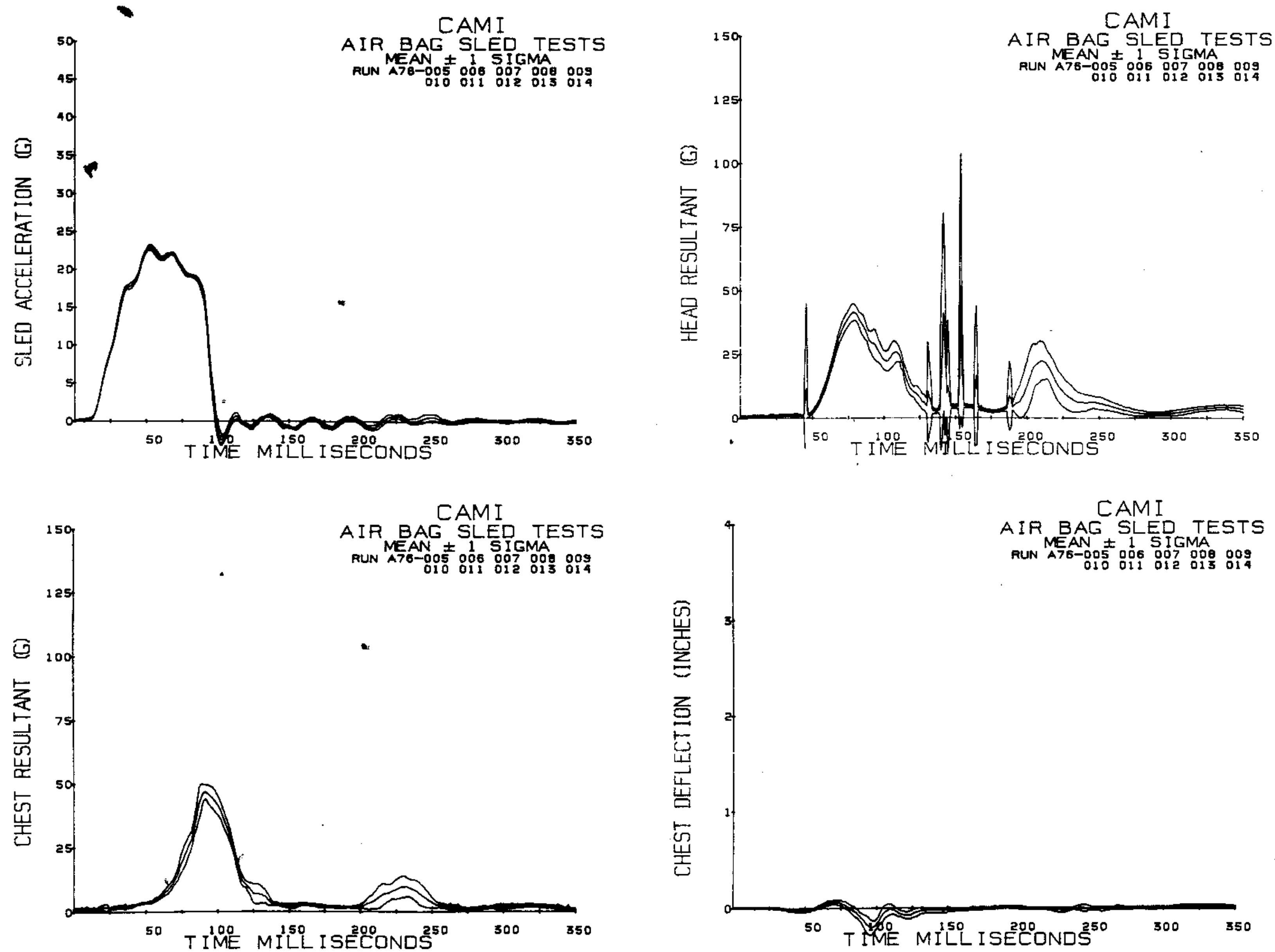
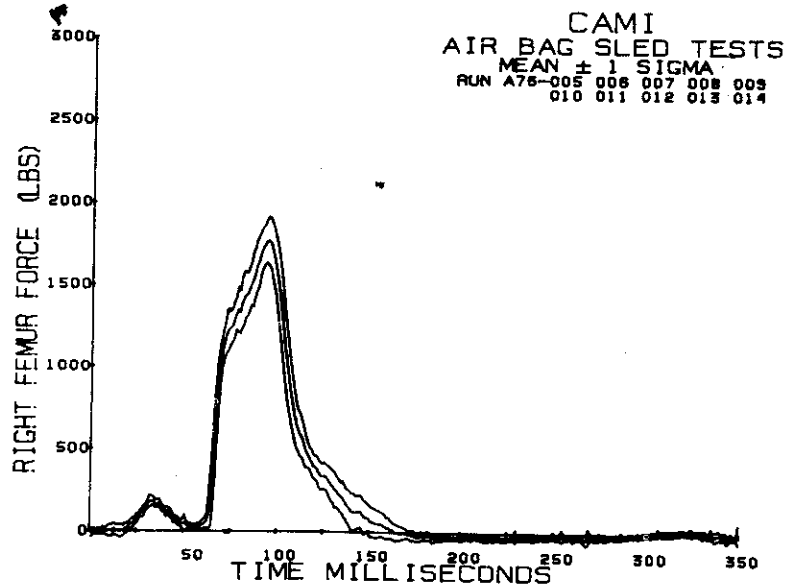



Figure 24. Air bag sled test data, dummy serial number 6.

(continued)



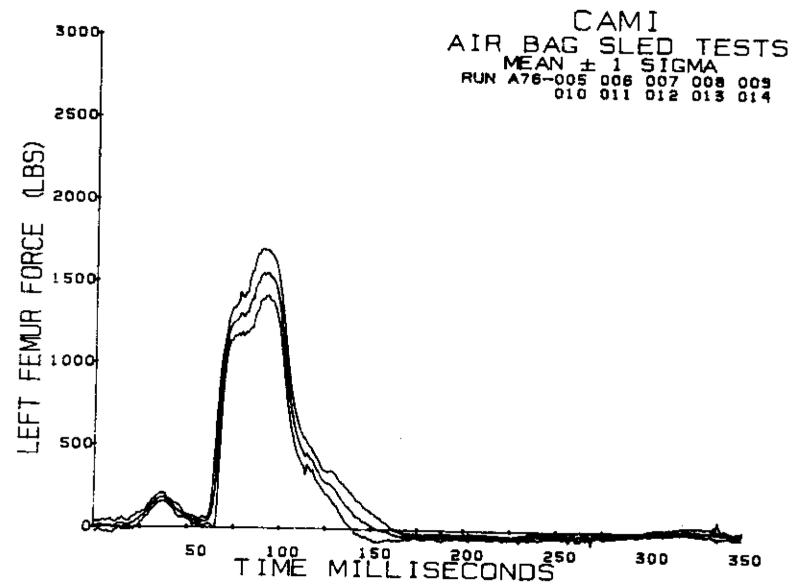




Figure 24. (continued).

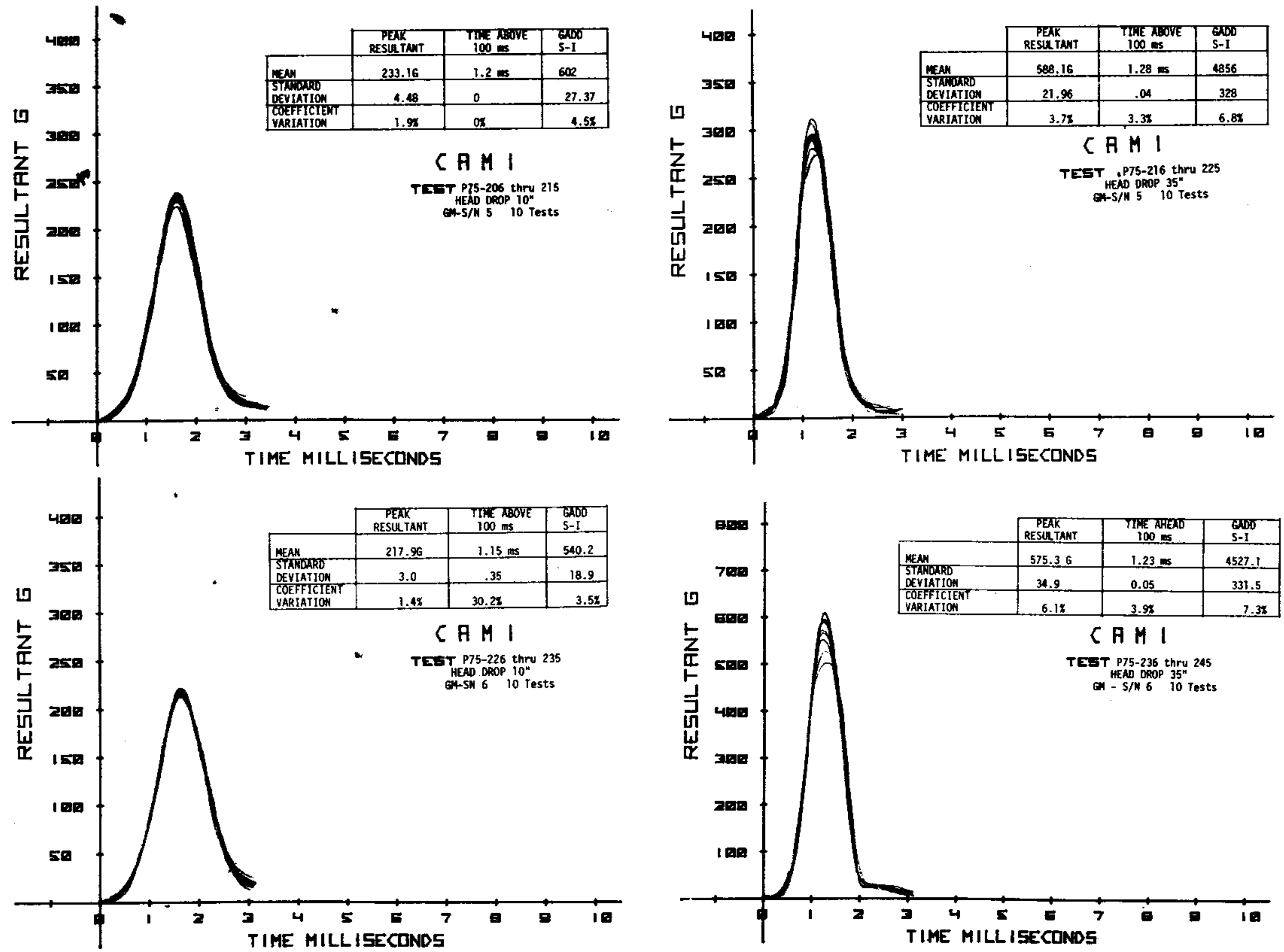


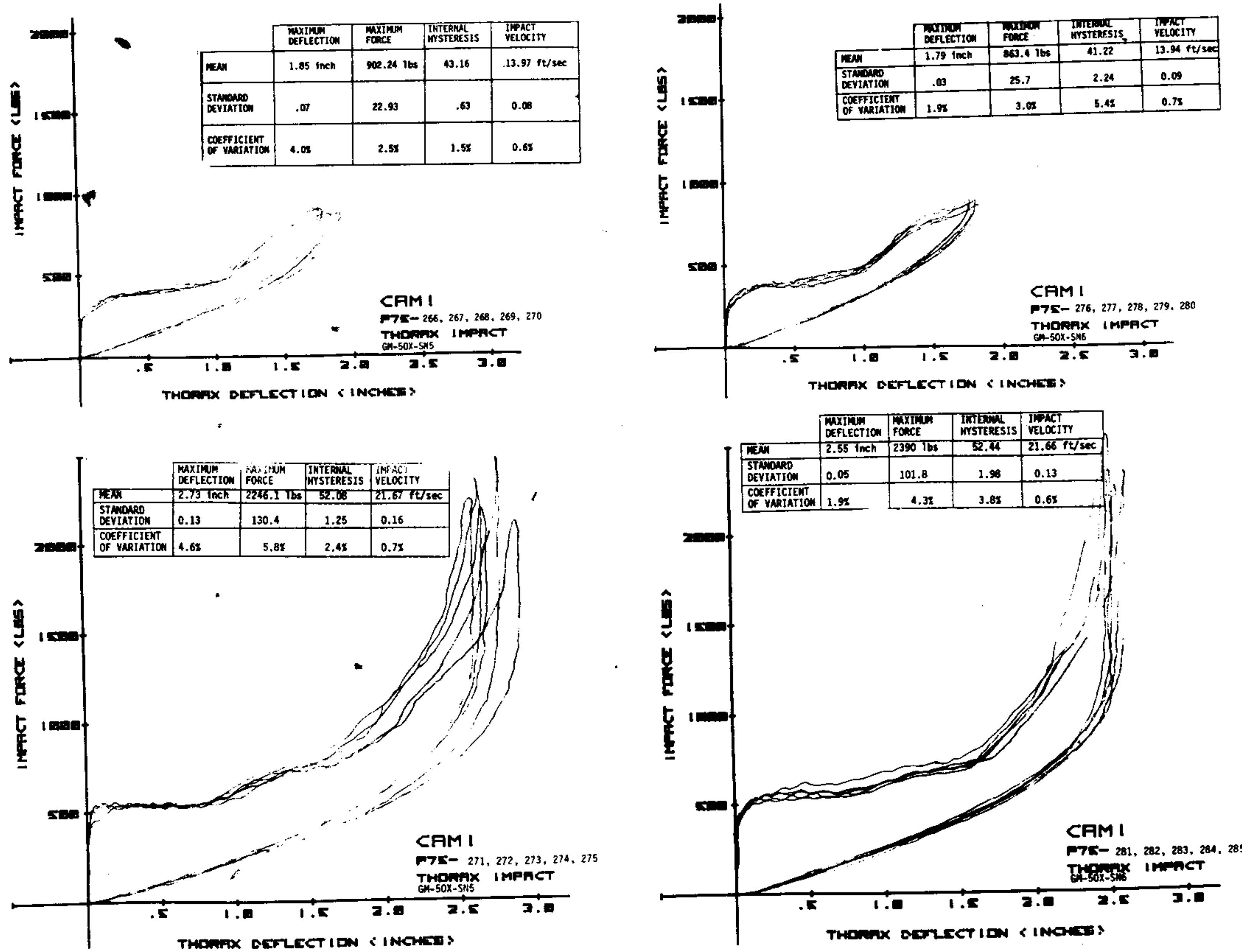

Figure 25. Head drop test data, dummy serial number 5 (above) and serial number 6 (below).

TABLE 8. Head/Neck Pendulum Tests
(GM S/N 5, n=10)

| | Head Peak Resultant | Peak Pendulum | Pendulum Velocity | Hexcell Crush |
|---|---|---|---|---|
| Mean | 24.24 g | 24.00 g | 22.67 ft/s | 4.80 in |
| Standard Deviation | 3.62 g | 2.32 g | 0.15 ft/s | 0.26 in |
| Coefficient Variation | 14.9% | 9.7% | 0.7% | 5.4% |

TABLE 9. Head/Neck Pendulum Tests
(GM S/N 6, n=10)

| | Head Peak Resultant | Peak Pendulum | Pendulum Velocity | Hexcell Crush |
|---|---|---|---|---|
| Mean | 22.65 g | 23.70 g | 22.75 ft/s | 4.63 in |
| Standard Deviation | 1.53 g | 2.07 g | 0.15 ft/s | 0.41 in |
| Coefficient Variation | 6.8% | 8.7% | 0.7% | 8.9% |




| | MAXIMUM DEFLECTION | MAXIMUM FORCE | INTERNAL HYSTERESIS | IMPACT VELOCITY |
|---|---|---|---|---|
| MEAN | 1.85 inch | 902.24 lbs | 43.16 | 13.97 ft/sec |
| STANDARD DEVIATION | .07 | 22.93 | .63 | 0.08 |
| COEFFICIENT OF VARIATION | 4.0% | 2.5% | 1.5% | 0.6% |

| | MAXIMUM DEFLECTION | MAXIMUM FORCE | INTERNAL HYSTERESIS | IMPACT VELOCITY |
|---|---|---|---|---|
| MEAN | 1.79 inch | 863.4 lbs | 41.22 | 13.94 ft/sec |
| STANDARD DEVIATION | .03 | 25.7 | 2.24 | 0.09 |
| COEFFICIENT OF VARIATION | 1.9% | 3.0% | 5.4% | 0.7% |

| | MAXIMUM DEFLECTION | MAXIMUM FORCE | INTERNAL HYSTERESIS | IMPACT VELOCITY |
|---|---|---|---|---|
| MEAN | 2.73 inch | 2246.1 lbs | 52.08 | 21.67 ft/sec |
| STANDARD DEVIATION | 0.13 | 130.4 | 1.25 | 0.16 |
| COEFFICIENT OF VARIATION | 4.6% | 5.8% | 2.4% | 0.7% |

| | MAXIMUM DEFLECTION | MAXIMUM FORCE | INTERNAL HYSTERESIS | IMPACT VELOCITY |
|---|---|---|---|---|
| MEAN | 2.55 inch | 2390 lbs | 52.44 | 21.66 ft/sec |
| STANDARD DEVIATION | 0.05 | 101.8 | 1.98 | 0.13 |
| COEFFICIENT OF VARIATION | 1.9% | 4.3% | 3.8% | 0.6% |

Figure 26. Thorax impact test data, dummy serial number 5 (left) and serial number 6 (right).

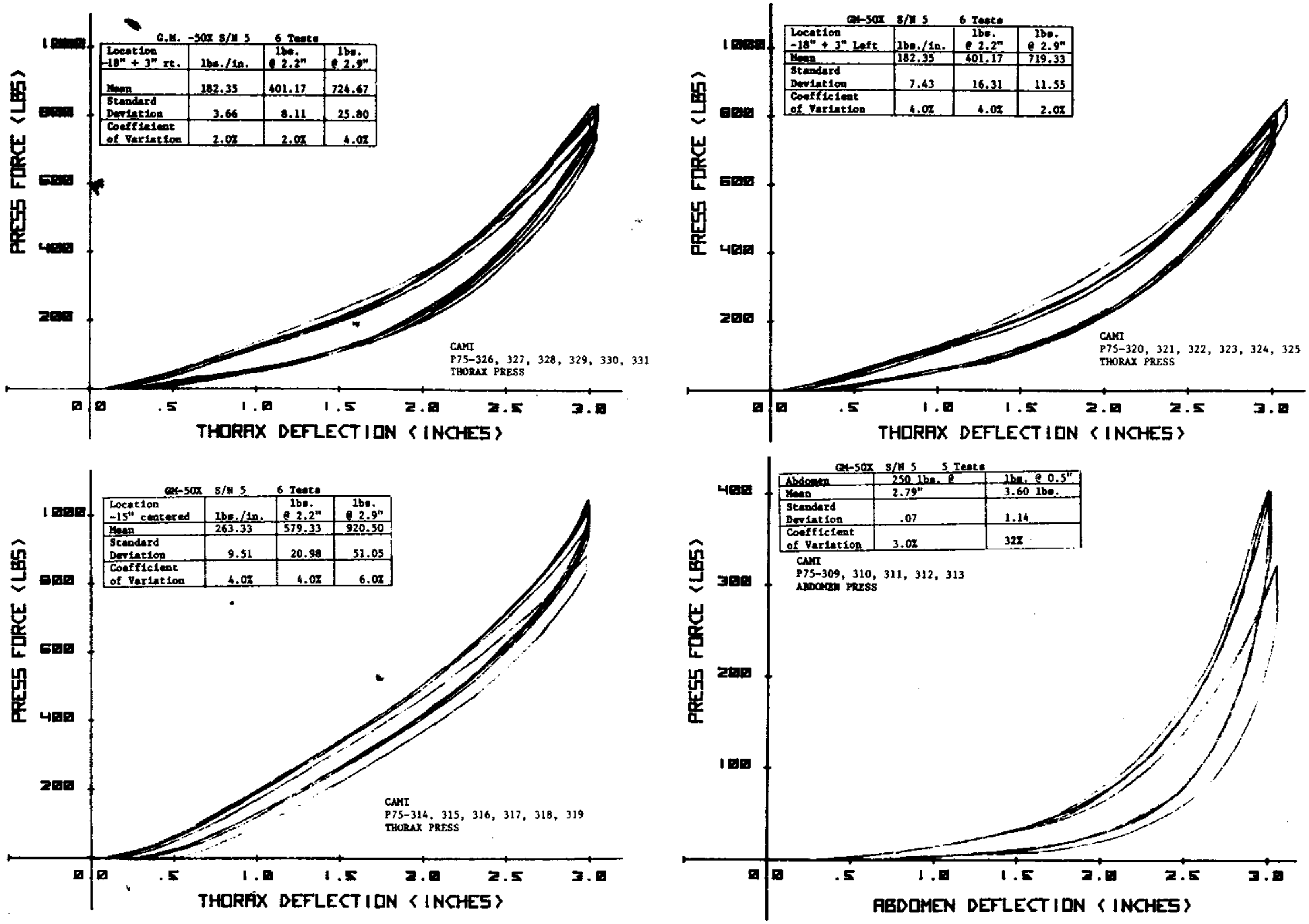



Figure 27. Static load test data, dummy serial number 5.

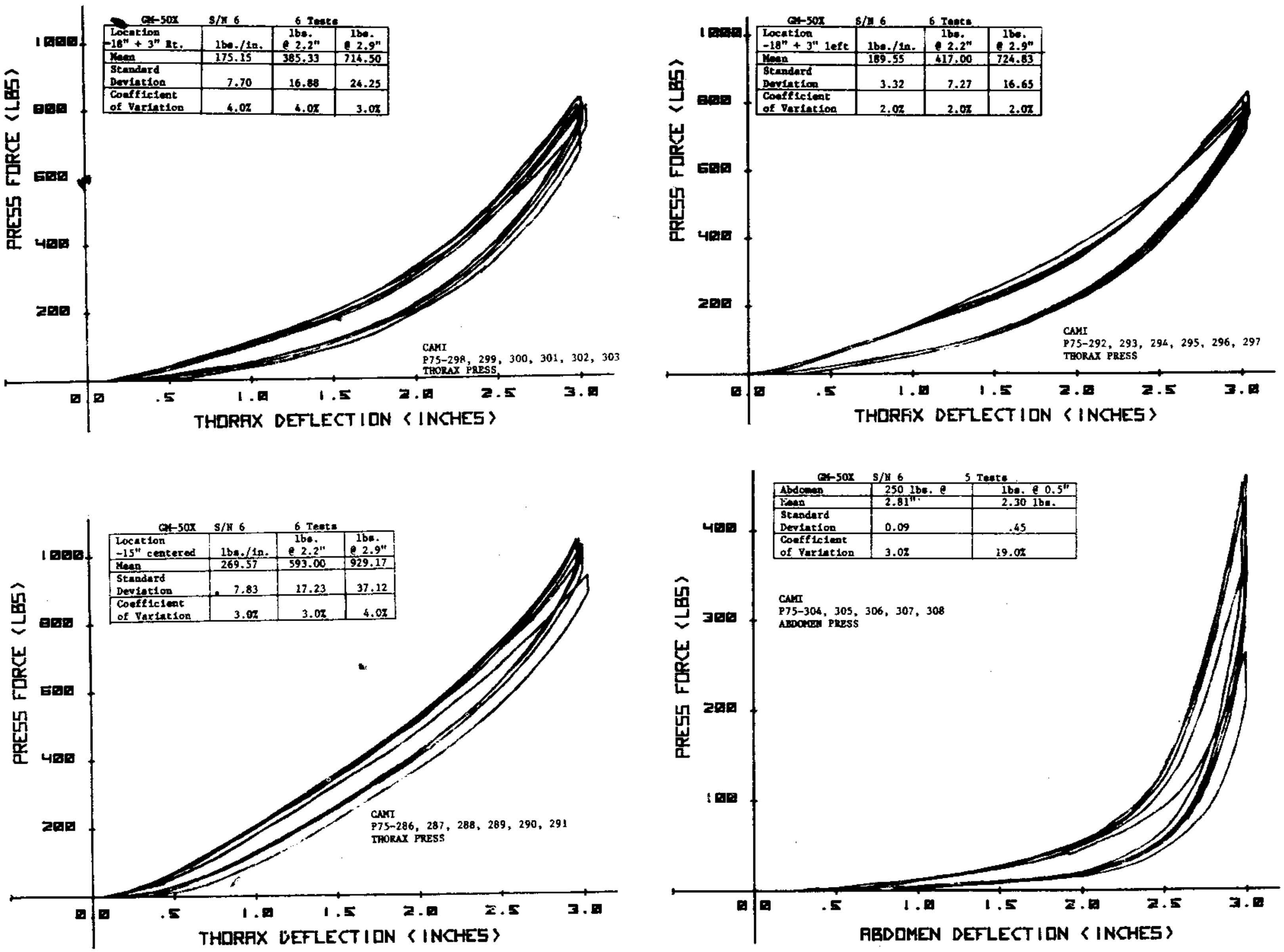


Figure 28. Static test load data, dummy serial number 6.

## OGLE/MIRA DUMMY EVALUATION PROGRAM

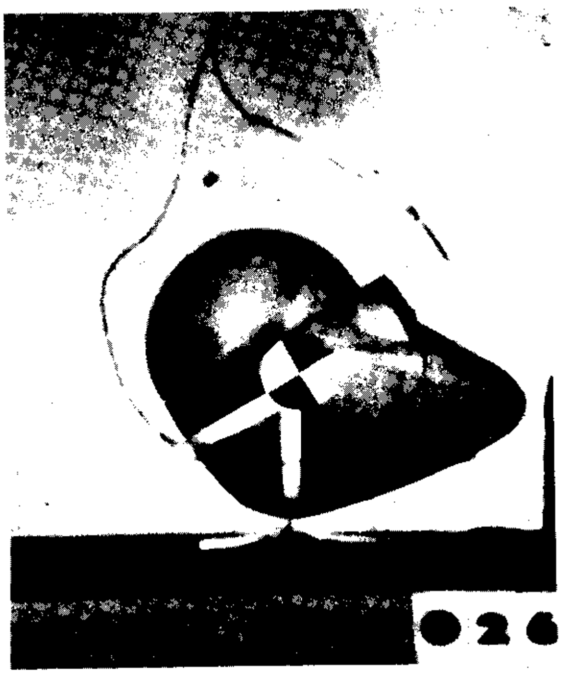
The Protection and Survival Laboratory is participating in a program with the National Highway Traffic Safety Administration designed to evaluate the performance of anthropomorphic test dummies under specific test conditions. The goal of the program is to compare the data obtained from two separate test facilities when exposing two dummies of the same manufacturer and model number to a controlled test environment. In this manner, variability in dummy performance attributable to both dummy design and methods of use can be isolated.

The test procedure specifies tests of individual components as well as complete assemblies and is outlined in the Purchase Description of the NHTSA 50th Percentile Anthropomorphic Test Dummy. During FY-76 component tests were completed on two dummies (serial numbers 013 and 014) manufactured by David Ogle, Ltd., for the Motor Industries Research Association in England.

In the head impact test procedure, the head is dropped onto a 2-in steel plate from heights of 10 and 35 in, and acceleration is measured at the center of mass. This test is shown in Figure 29. Note that although the head impacts at a point directly below the center of mass, an eccentric force is generated during the impact that causes the head to rotate. The effects of this rotation will not be distinguished by the accelerometer installation in the head. The results of these tests are shown in Figure 30.

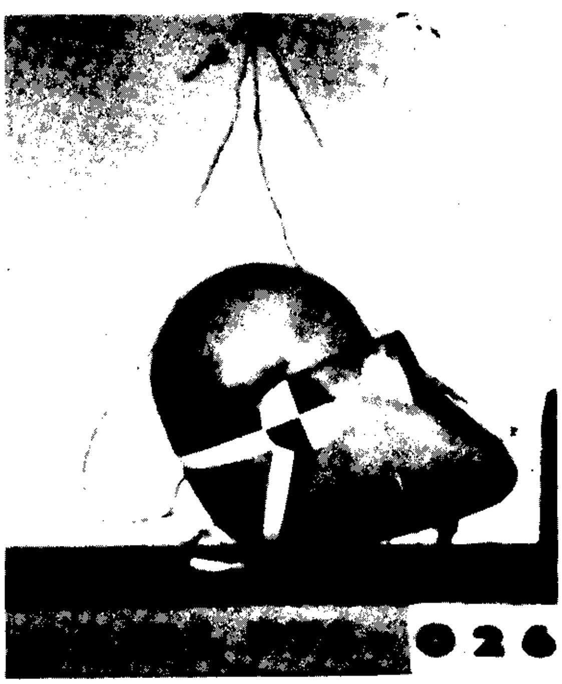
In the head/neck impact test procedure, the head and neck assembly is inverted and attached to the bottom of a pendulum. The pendulum is then rotated a prescribed angle and released to swing until it impacts on an aluminum honeycomb block, where it is brought to rest. Angular and translational displacements of the head are measured photographically, and acceleration is measured on the head and on the pendulum. Typical results of these tests are shown in Figure 31 and Tables 10 and 11. The irregularities seen at the maximum deflection regions in Figure 31 were apparently due to local deformations at the base of the neck, shown in Figure 32, which result from the design of the neck attachment plate.

To evaluate the dynamic response of the thorax, the dummy is seated on a hard horizontal surface and the chest impacted with a cylindrical mass weighing 50 lb. The results of these tests are shown in Figure 33.




prior to impact


at impact




0.012 s after impact


0.024 s after impact

Figure 29. Head impact test.

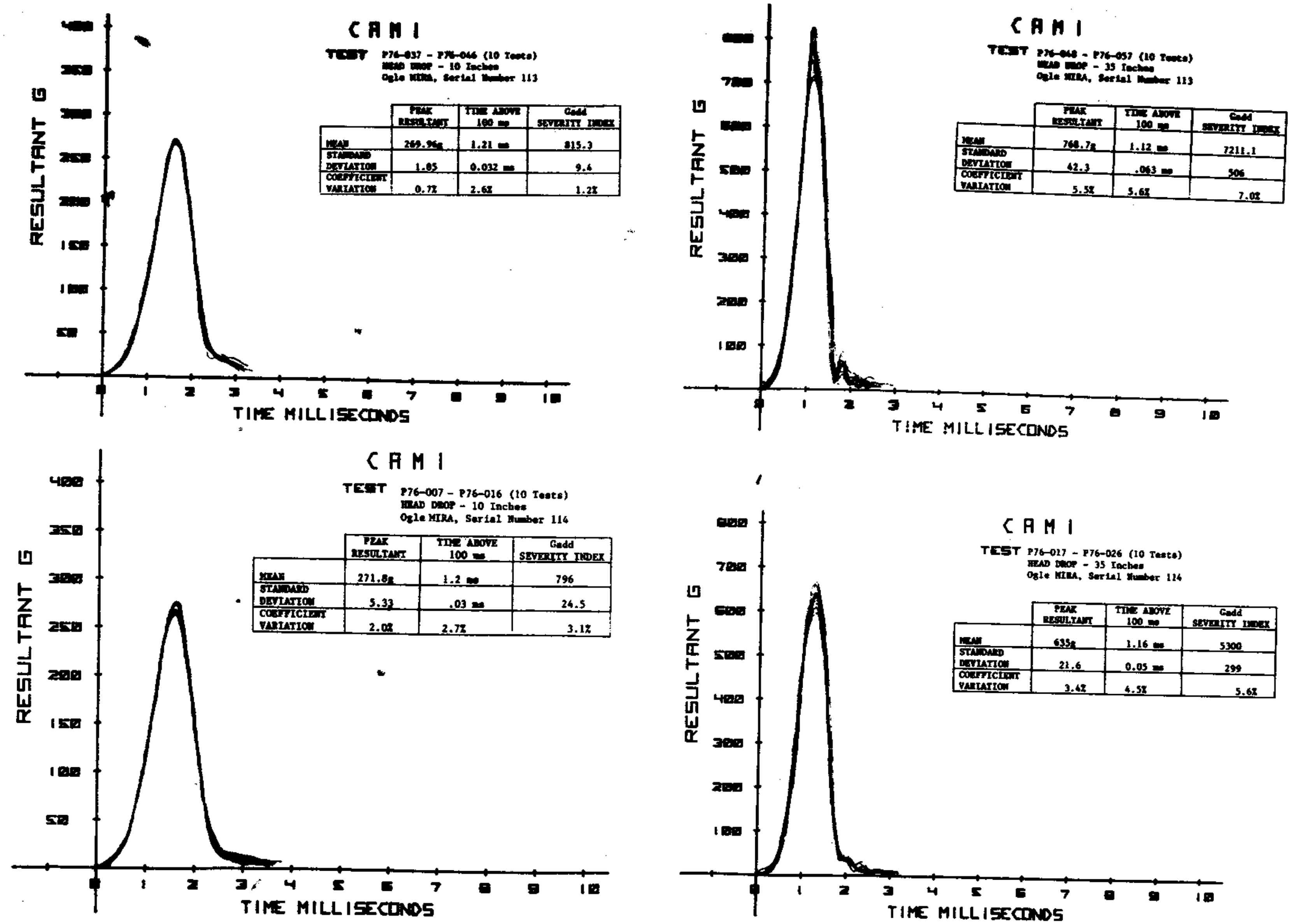



Figure 30. Head drop test results, dummy serial number 113 (above) and dummy serial number 114 (below).

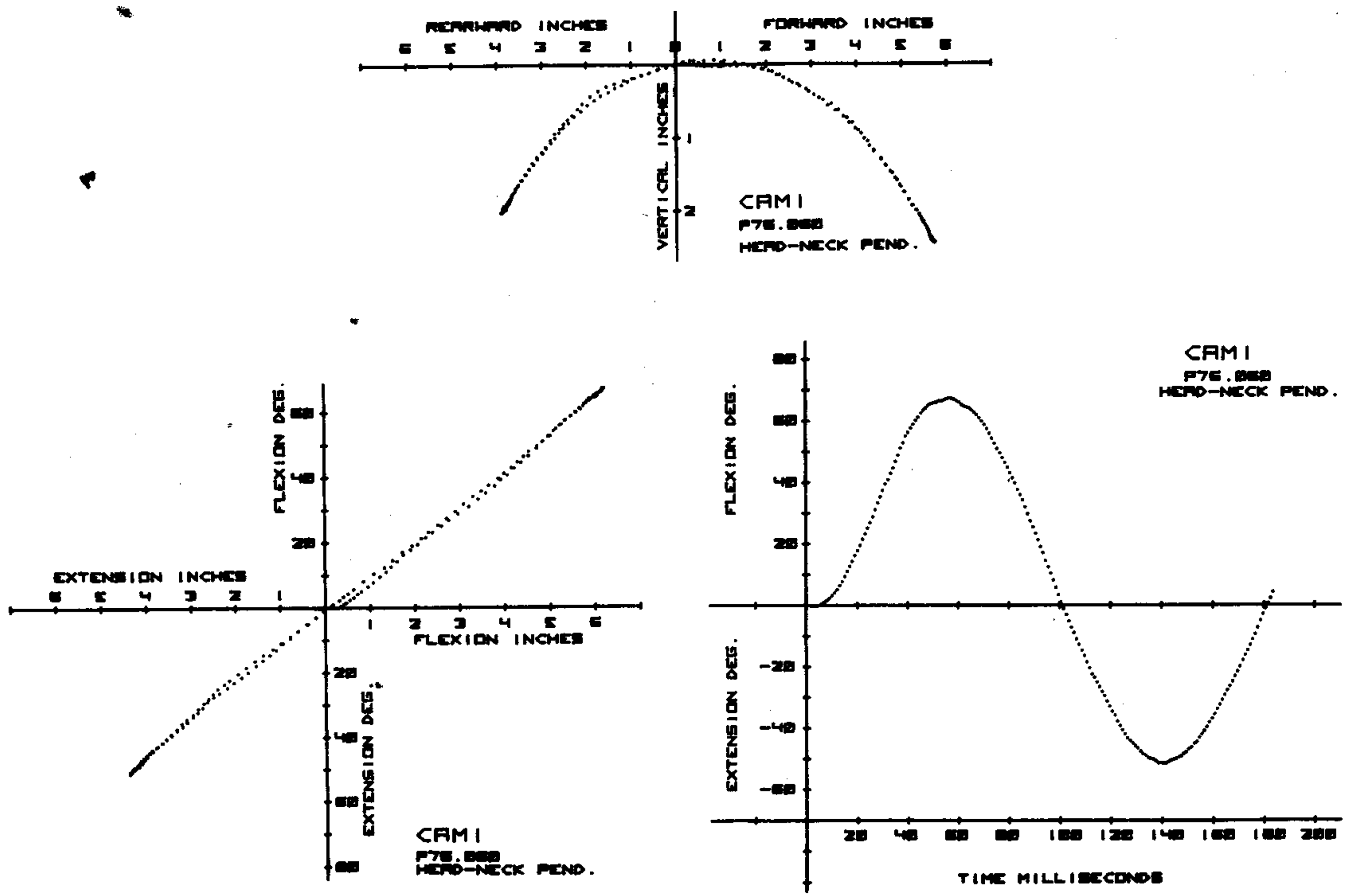



Figure 31. Typical response to head/neck pendulum impact test.

TABLE 10. Head/Neck Pendulum Tests
(Ogle MIRA S/N 113, n=10)

| | Head Peak Resultant | Peak Pendulum | Pendulum Velocity | Honeycomb Crush |
|---|---|---|---|---|
| Mean | 30.54 g | 28.65 g | 22.95 ft/s | 3.850 in |
| Standard Deviation | 1.88 g | 1.62 g | 0.14 ft/s | .205 in |
| Coefficient Variation | 6.2% | 5.7% | 0.6% | 5.3% |

TABLE 11. Head/Neck Pendulum Tests
(Ogle MIRA S/N 114, n=10)

| | Head Peak Resultant | Peak Pendulum | Pendulum Velocity | Honeycomb Crush |
|---|---|---|---|---|
| Mean | 29.86 g | 30.49 g | 23.03 ft/s | 3.738 in |
| Standard Deviation | 1.08 g | 2.13 g | 0.21 ft/s | .206 in |
| Coefficient Variation | 3.6% | 7.0% | 0.9% | 5.4% |

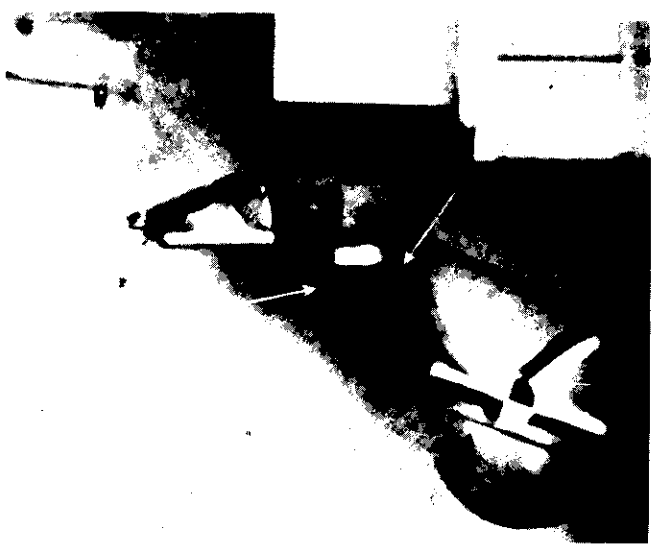
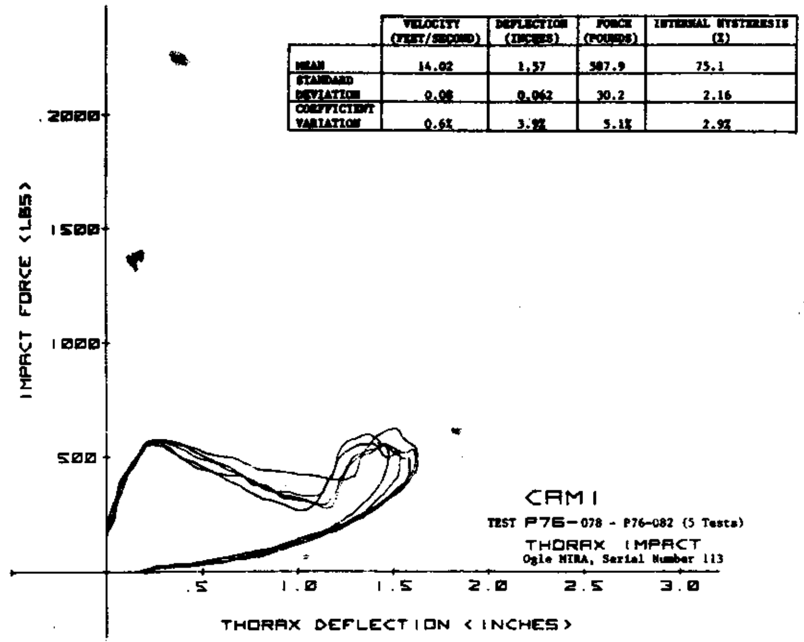
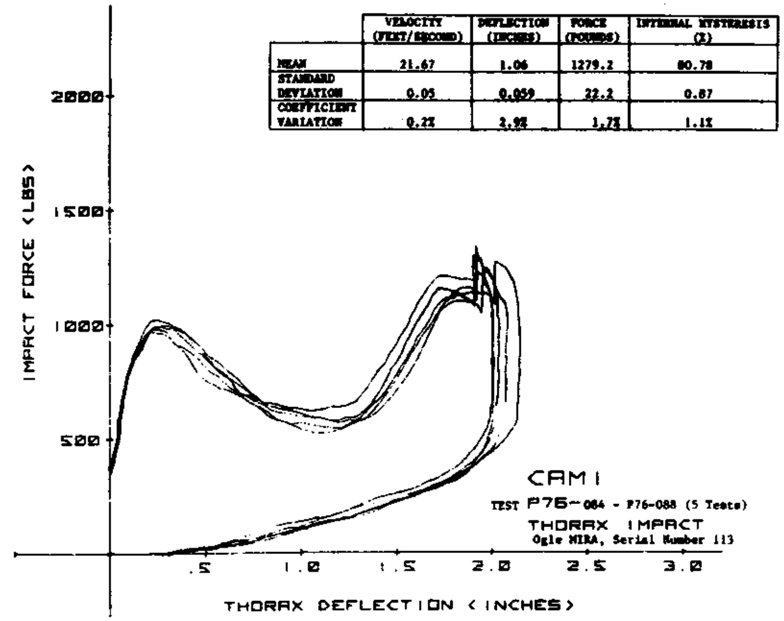


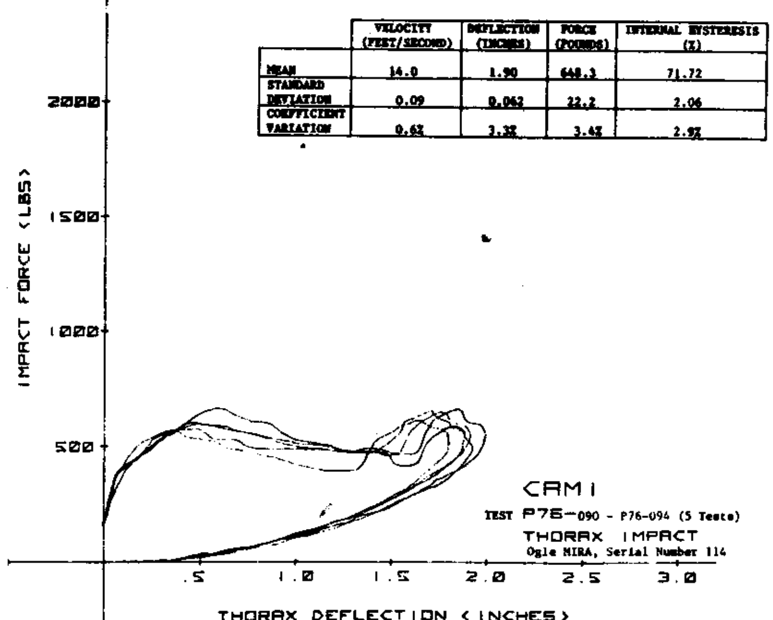
Figure 32. Head/neck impact. Arrows indicate local deformations of the rubber neck that occurred as maximum deflection of the neck was approached.



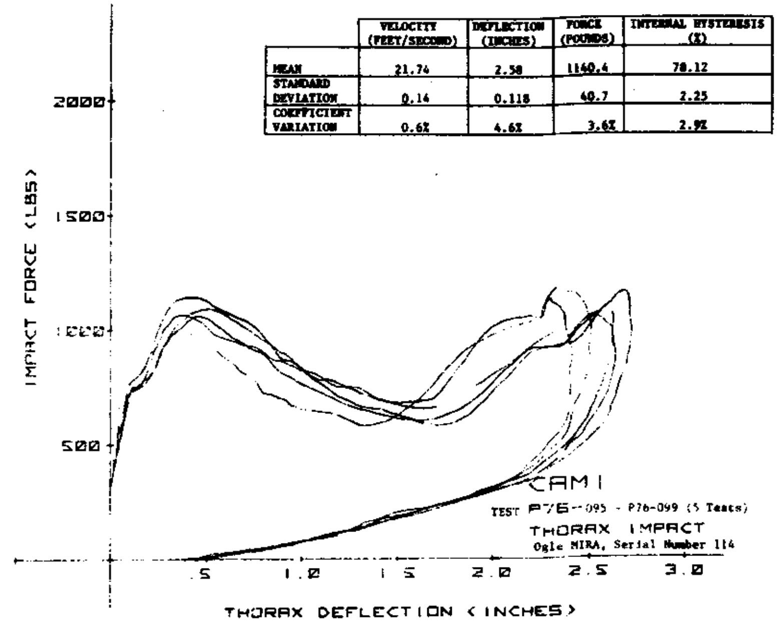

| | VELOCITY (FEET/SECOND) | DEFLECTION (INCHES) | FORCE (POUNDS) | INTERNAL HYSTERESIS (%) |
|---|---|---|---|---|
| MEAN | 14.02 | 1.57 | 587.9 | 75.1 |
| STANDARD DEVIATION | 0.08 | 0.062 | 30.2 | 2.16 |
| COEFFICIENT VARIATION | 0.6% | 3.9% | 5.1% | 2.9% |




| | VELOCITY (FEET/SECOND) | DEFLECTION (INCHES) | FORCE (POUNDS) | INTERNAL HYSTERESIS (%) |
|---|---|---|---|---|
| MEAN | 21.67 | 1.06 | 1279.2 | 80.78 |
| STANDARD DEVIATION | 0.05 | 0.059 | 22.2 | 0.87 |
| COEFFICIENT VARIATION | 0.2% | 2.9% | 1.7% | 1.1% |




| | VELOCITY (FEET/SECOND) | DEFLECTION (INCHES) | FORCE (POUNDS) | INTERNAL HYSTERESIS (%) |
|---|---|---|---|---|
| MEAN | 14.0 | 1.90 | 648.3 | 71.72 |
| STANDARD DEVIATION | 0.09 | 0.062 | 22.2 | 2.06 |
| COEFFICIENT VARIATION | 0.6% | 3.3% | 3.4% | 2.9% |




| | VELOCITY (FEET/SECOND) | DEFLECTION (INCHES) | FORCE (POUNDS) | INTERNAL HYSTERESIS (%) |
|---|---|---|---|---|
| MEAN | 21.74 | 2.58 | 1140.4 | 78.12 |
| STANDARD DEVIATION | 0.14 | 0.118 | 40.7 | 2.25 |
| COEFFICIENT VARIATION | 0.6% | 4.6% | 3.6% | 2.9% |

Figure 33. Thorax impact test results. Dummy serial number 113 (above) and dummy serial number 114 (below).

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