AL/CF-TR-1993-0160

A R M S T R O N G L A B O R A T O R Y

ARMSTRONG LABORATORY

EVALUATION OF A PROPOSED F-4 EJECTION SEAT CUSHION BY +GZ IMPACT TESTS

DTIC
ELECTE
JAN 1 2 1994
S F D

James W. Brinkley
Chris E. Perry
Mary Ann Orzech
Mark D. Salerno

CREW SYSTEMS DIRECTORATE
BIODYNAMICS AND BIOCOMMUNICATIONS DIVISION
WRIGHT-PATTERSON AFB OH 45433-7901

JULY 1993

FINAL REPORT FOR THE PERIOD JULY 1986 - JUNE 1987

DTIC QUALITY INSPECTED 8

Approved for public release; distribution is unlimited.

19950111 096

AIR FORCE MATERIEL COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

NOTICES

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise, as in any manner, licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

Please do not request copies of this report from the Armstrong Laboratory. Additional copies may be purchased from:

National Technical Information Service
5285 Port Royal Road
Springfield VA 22161

Federal Government agencies and their contractors registered with Defense Technical Information Center should direct requests for copies of this report to:

Defense Technical Information Center
Cameron Station
Alexandria VA 22314

TECHNICAL REVIEW AND APPROVAL

AL/CF-TR-1993- 0160

The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 169-3.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Thomas J. Moore

THOMAS J. MOORE, Chief
Biodynamics and Biocommunications Division
Crew Systems Directorate
Armstrong Laboratory

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
July 1993

3. REPORT TYPE AND DATES COVERED
Final Report July 1986 to June 1987

4. TITLE AND SUBTITLE
Evaluation of a Proposed F-4 Ejection Seat Cushion by +Gz Impact Tests

5. FUNDING NUMBERS
PE - 62202F
PR - 7231
TA - 723124
WU - 72312401

6. AUTHOR(S)
James W. Brinkley
Chris E. Perry
Mark D. Salerno
Mary Ann Orzech

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Armstrong Laboratory, Crew Systems Directorate
Biodynamics and Biocommunications Division
Human Systems Center
Air Force Materiel Command
Wright-Patterson AFB OH 45433-7901

8. PERFORMING ORGANIZATION REPORT NUMBER
AL/CF-TR-1993-0160

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

During 1986 to 1987, approximately 45 human impact experiments were accomplished on a vertical deceleration tower to evaluate the influence of three separate seat cushions on the human biodynamic response during positive vertical (+Gz) impact accelerations that simulated the catapult phase of ejection. The human subjects were exposed to the following three seat cushions at a peak impact level of 10 G: (1) the standard operational F-4 ejection seat cushion, (2) the standard operational ACES II ejection seat cushion, and (3) a proposed F-4 ejection seat cushion composed of Conform™ foam. Principle measurements that were collected and analyzed included seat pan loads, head accelerations, and chest accelerations. Test results showed that the current operational F-4 seat cushion produced greater biodynamic responses (in terms of parameter magnitudes) during vertical acceleration than either the proposed F-4 seat cushion or the ACES II seat cushion.

14. SUBJECT TERMS
Vertical Impact
Seat Cushion Response
Biodynamic Response
Vertical Deceleration
Seat Cushion Evaluation

15. NUMBER OF PAGES
117

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNLIMITED

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

THIS PAGE INTENTIONALLY LEFT BLANK

PREFACE

The tests described within this report were accomplished by the Escape and Impact Protection Branch, Biodynamics and Biocommunications Division, Crew Systems Directorate of the Armstrong Laboratory. The vertical acceleration (impact) tests were conducted using a vertical deceleration tower to simulate the catapult phase of an aircraft ejection.

The impact facilities, data acquisition instrumentation, and data processing systems were operated by the Scientific Services Division of DynCorp under Air Force Contract F33615-86-C-0531.

Photographic and high-speed film services were provided by the Technical Photographic Division of the 4950th Test Wing.

Special thanks to Mrs. Jeni Blake for her time and effort in organizing and preparing this report.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Accesion For		
NTIS CRA&I		☑
DTIC TAB		☐
Unannounced		☐
Justification		
By		
Distribution /		
Availability Codes		
Dist	Avail and / or Special	
A-1		

THIS PAGE INTENTIONALLY LEFT BLANK

INTRODUCTION

The objective of this test program was to measure the influence of specific ejection seat cushions on the human response to vertical acceleration. The test program, requested by the San Antonio Air Logistics Center, compared a proposed seat cushion and the survival kit lid designed to be used to an existing operational seat cushion and survival kit lid. Our study was designed to provide a direct comparison of the human response to vertical acceleration with these two seat cushions. The study also included, as a standard for comparison, a seat cushion that had been used in a previous comparative study (Hearon and Brinkley, 1986).

METHODS

Vertical impact tests were performed using a deceleration tower facility. The test conditions are shown in Table 1. The order of presentation of the test conditions was randomized for each subject. Other test conditions such as the seat geometry, restraint configuration, acceleration time history, and pre-impact position of the subject, were controlled to assure that the measured responses were due only to the differences among the seat cushions and the seat surface on which they were tested.

TABLE 1. EXPERIMENTAL CONDITIONS

MATRIX CELL DESIGNATION	ACCELERATION (G)	SEAT CUSHION	SEAT SURFACE
F	10	ACES II	FLAT
I	10	CURRENT F-4	CONTOURED
J	10	PROPOSED F-4	FLAT

Three seat cushions were evaluated. Two of the seat cushions were designed to be used with the F-4 ejection seat. One of the F-4 cushions was a current operational seat cushion manufactured by the Martin-Baker company (part no. MBEU 2866DP). The cushion, shown in Figure 1, consists of two layers of foam. The upper layer (part no. MBEU 2869DP) is a one-inch thick, heavy-density Texfoam™ rubber. The lower layer (part no. MBEU 2870DP) is high-density, Plasazote™ mold foam one-inch thick on each side. The lower layer is contoured on the top and bottom to fit the seat occupant's buttocks and the buttocks contour molded into the lid of a survival kit. In the area of the occupant's ischial tuberosities, the lower layer is 0.5-inch thick. The cushion is used in the U.S. Air Force with a fiberglass survival kit manufactured by Koch and Sons (part no. 140-489-1). The depth of the depression molded in the lid of the kit is 1.50 in. The cushion is covered with a stretchable Nomex™ material (Fabratex Corp. part no. 1-771001).

The second cushion (Koch and Sons part no. 159-870286-1), which is also designed for the F-4 ejection seat, is constructed of uncontoured, two-inch thick, type C-47 Conform™ foam (Koch and Sons Part no. 159-870288-1) with a Nomex™ cover (Koch and Sons part no. 144-870287-1). This cushion, shown in Figure 2, is designed to be used with a flat survival kit lid manufactured by H. Koch and Son (part no. 024-870280-1). Both the contoured lid and the flat lid are designed to be used with the same survival kit body (Koch and Sons part no. 140-710-1)/

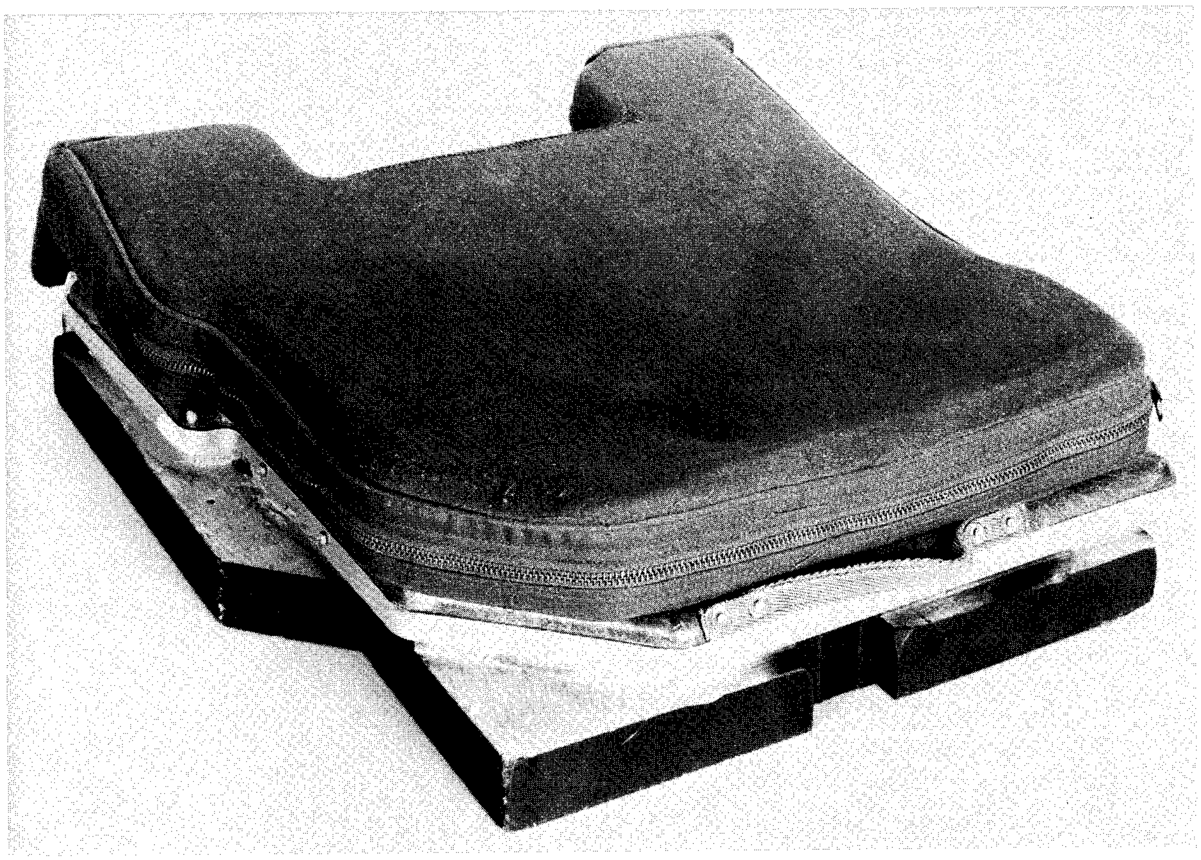


FIGURE 1. OPERATIONAL F-4 EJECTION SEAT CUSHION

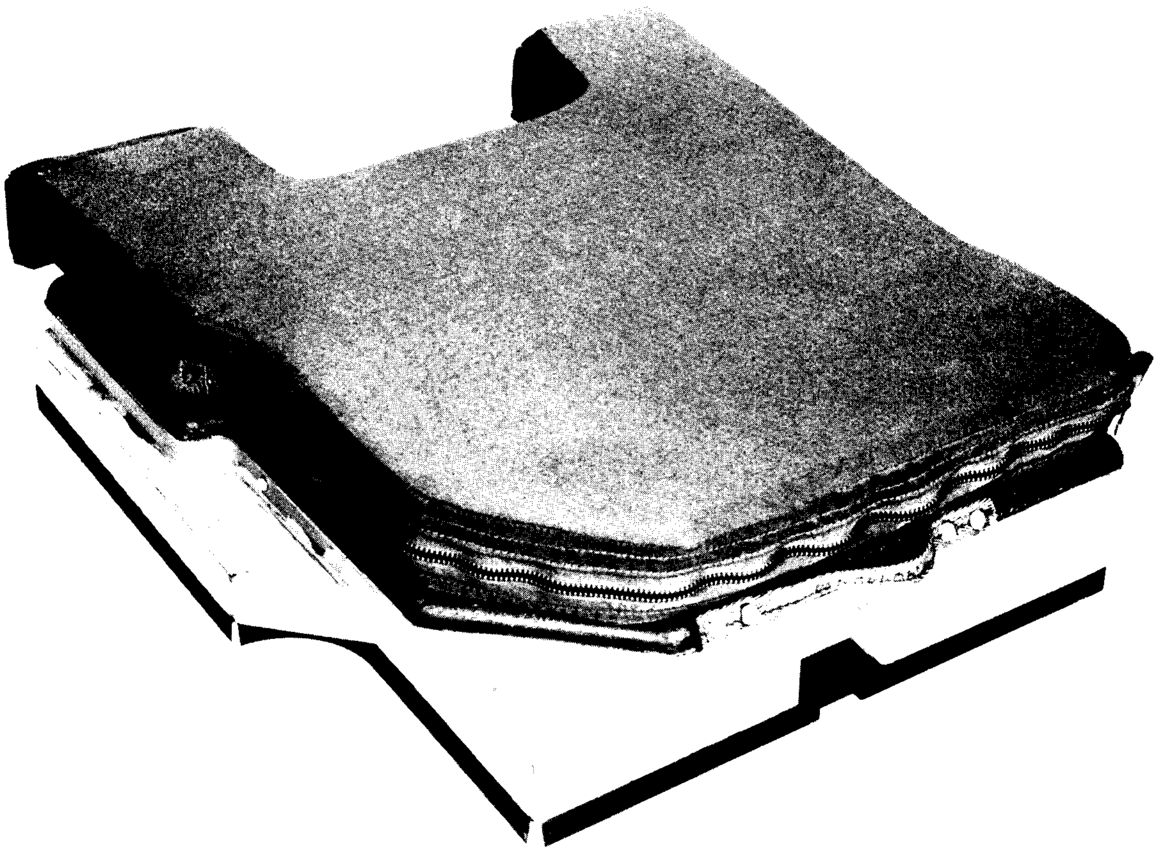


FIGURE 2. PROPOSED F-4 EJECTION SEAT CUSHION

The third cushion that was tested was an ACES II ejection seat cushion (see Figure 3). This cushion consists of three layers of material. The lower layer is 0.39 in (1 cm) thick, sheet foam polyethylene (DMS 1954, Class I, Grade 4101). The middle layer is 0.5 in (1.3 cm) thick type T-47 Temper™ foam. The upper layer consists of 0.25 in (0.6 cm) thick, space fabric (Uniroyal, 6007-1-1-54) to promote air circulation within the cushion. The ACES II cushion is covered with a stretchable Nomex™ fabric.

The two F-4 ejection seat cushions were tested on their respective survival kit lids. The contents of the survival kits were assumed to have identical mechanical compression properties, and only differed in the contours of their lids. Each survival kit lid was bonded to a wooden block of identical composition. The kit lid and wooden block were then mounted to a metal plate, which was attached to the structure of the test seat by a force measurement device consisting of six force cells.

The ACES II seat cushion was tested on a flat seat supported by the force cells. The seat was constructed of a wooden block mounted to the metal plate used to attach the six force cells to the seat frame. The surface of the block was covered by a rigid plastic laminate material.

The test seat was the generic design shown in Figure 4. The seat back was positioned at right angles to the uninclined seat pan and parallel to the acceleration vector. The headrest contact plane was one inch (2.5 cm) aft of the seat back. The vertical position of the headrest was individually adjusted for each subject in order to provide adequate head support. This vertical headrest position was held constant for each subject during the test program. Seat-back cushions were not used in the study. Also, no footrest structure or leg restraint were provided, so the lower legs were permitted to dangle during the test. The subjects were restrained by the PCU-15/P torso/ parachute harness and an HBU-type lap belt constructed of 1.72-in (4.37 cm) wide, type III polyester webbing (MIL-W-25361C). A MA-1 lap belt buckle was used. Before each test, the restraint system was pretensioned so that the force at the shoulder-strap and lap-belt attachments measured 20 $\pm$ 5 lb (89 $\pm$ 22 N). All subject wore the HGU-26/P flight helmet and were initially positioned with head upright, helmet against the headrest, and arms resting on anterior thighs.

The experimental set up and pre-test position of the subject are shown in Figure 5. The test fixture, restraint system, and subject were instrumented to obtain pertinent data during each test. Measured parameters included the translational acceleration of the deceleration tower carriage

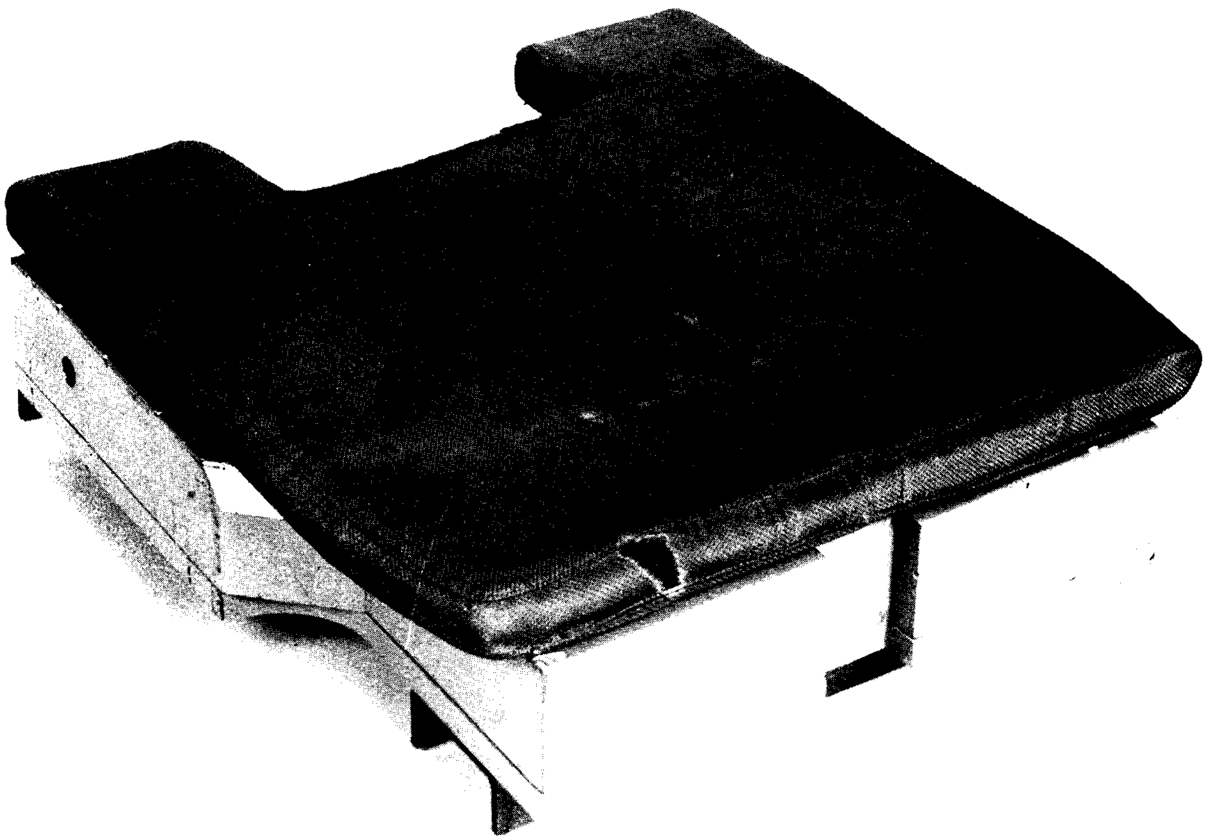


FIGURE 3. ACES II EJECTION SEAT CUSHION

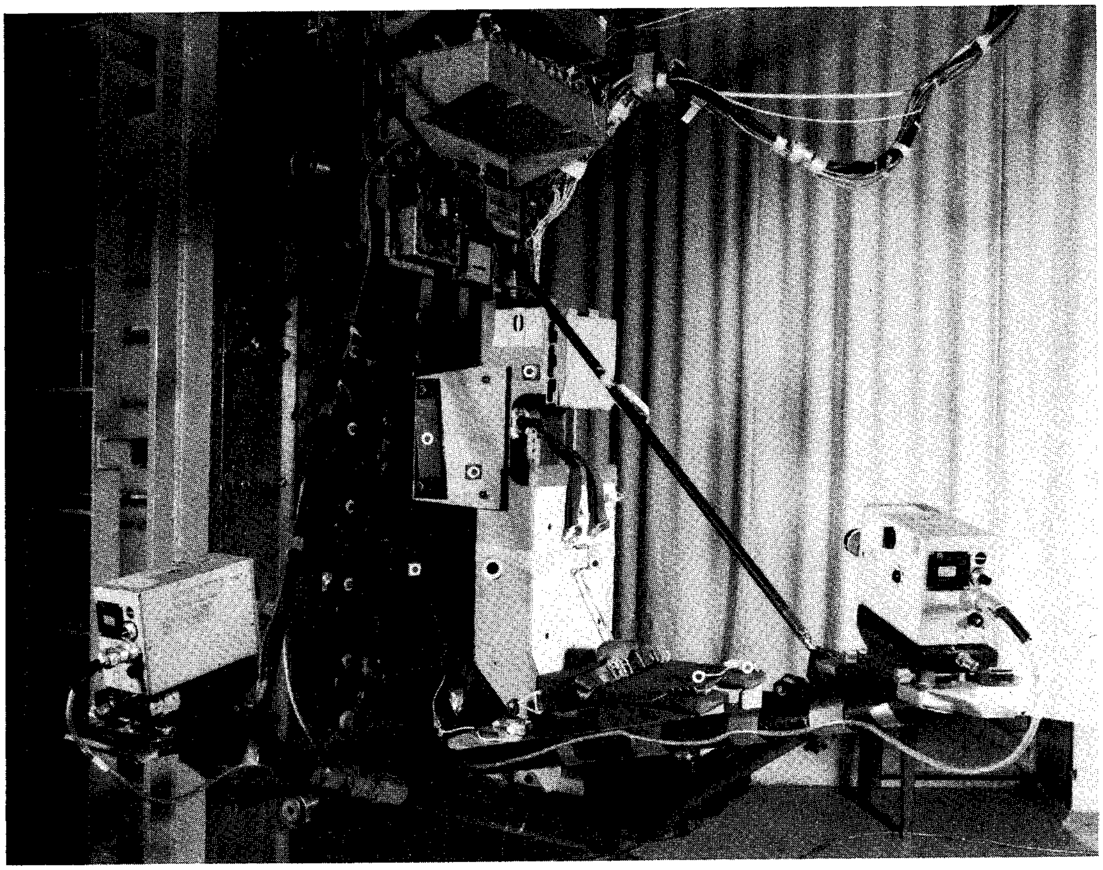


FIGURE 4. TEST FIXTURE

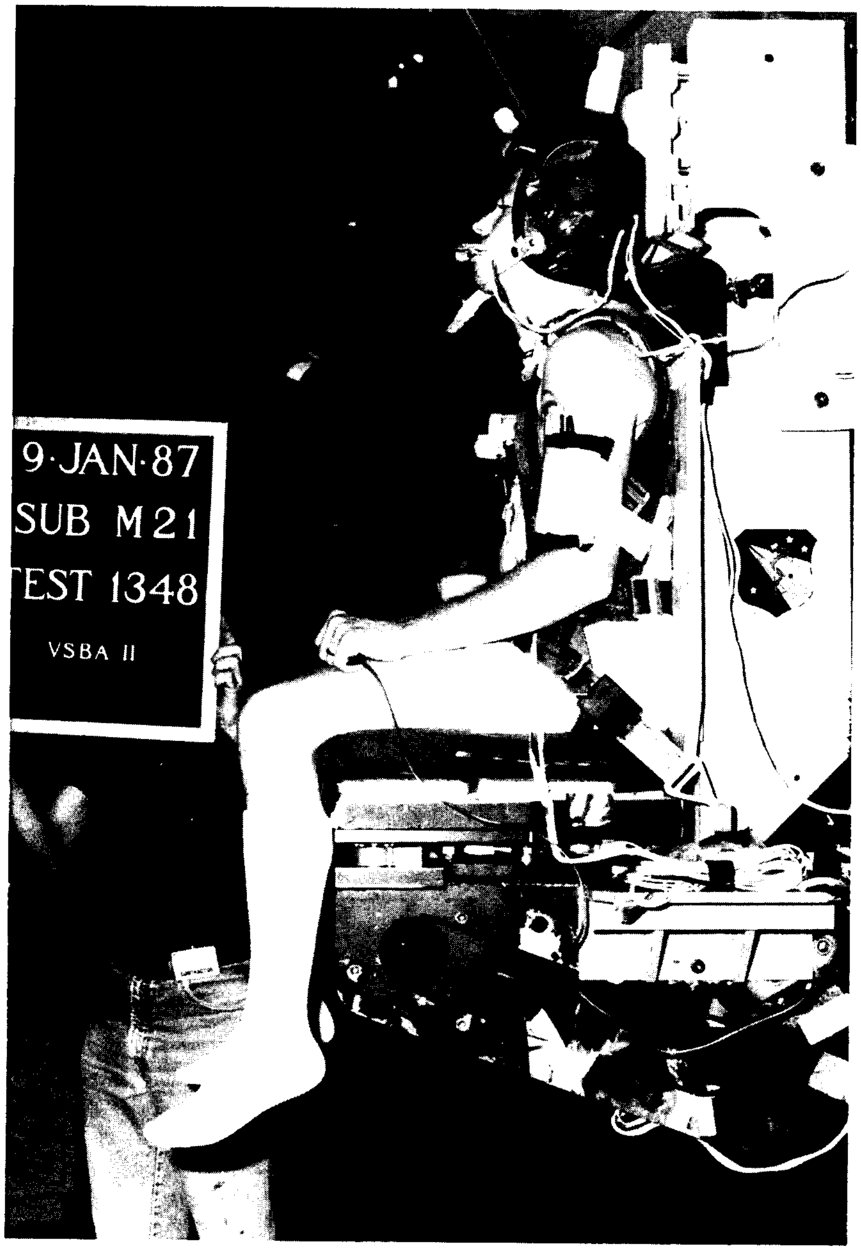


FIGURE 5. PRE-TEST POSITION OF THE TEST SUBJECT

and test seat, angular acceleration of the seat about the Y axis, velocity of the carriage, vertical and horizontal seat forces, and triaxial forces measured at the restraint harness attachment points. Triaxial translational accelerations and angular accelerations about the Y axis were measured at the head and chest of the subject. Photogrammetric data were obtained by two high-speed motion picture cameras mounted on the test fixture, permitting measurement of body displacements. The electronic and photogrammetric data acquisition system is described in detail in Appendix A.

The left-handed coordinate reference system for acceleration (+x anterior, +z cephadalad) was used during data analysis. Electronic and photogrammetric data were processed by a Digital Equipment Corporation PDP-11/34 computer.

The test results were evaluated using the Wilcoxon paired-replicate rank test (Wilcoxon and Wilcox, 1964). This statistical technique was selected to compare the peak values of measured parameters and to establish the statistical significance of observed trends in the data. This analytical approach established each subject as his own control, thereby reducing the effects of biological variability among subjects. The 95th percent confidence level, assuming a two-tailed test, was chosen as the level of statistical significance.

The hypothesis that was statistically evaluated was that there are no differences between the measured human responses regardless of the cushion that is used. Evaluation criteria were based on the fundamental principles of biomechanical protection. Clinically consequential impact injury generally results from differential acceleration of body segments and/or excessive structural loading. For short-duration acceleration applied parallel to the spinal column, human tolerance is apparently limited by vertebral compression fracture. If the risk of such injury is to be reduced, vertebral column loading must be minimized during vertical acceleration. Minimizing head and chest acceleration would also be wise since they may be indicative of potentially injurious internal forces. Accordingly, the key response parameters in this study were the resultant seat force, which is generally reflective of vertebral column loading, and the resultant head and chest accelerations.

The volunteer subjects, 13 men, were active-duty officers and enlisted personnel at Wright-Patterson Air Force Base who were medically qualified for impact acceleration stress experiments. The subjects were required to meet stature, weight, and sitting height criteria for USAF pilots and a complete medical screening more stringent than the USAF flying class II evaluation. Conservative selection criteria were established to yield a subject sample comparable to the USAF flying population in terms of age and anthropometry, but super normal in terms of susceptibility to impact injury. The characteristics of the subject sample used in this study (in terms of mean and standard deviation) may be summarized as follows: age, 28.8 ± 4.13 years; weight, 174 ± 21.2 lb; height, 70.2 ± 2.70 in; and sitting height, 33.5 ± 1.31 in. These values compare favorably with the means and standard deviations for the USAF flying population (NASA Ref. Pub. 1024). The sizes and weights of the subjects are described and compared to the USAF flying population in Table 2.

TABLE 2. ANTHROPOMETRY OF TEST SUBJECTS

SUBJ NO.	WT (LB)	STATURE (IN)	SITTING HEIGHT (IN)	MID-SHOULDER SIT HEIGHT (IN)	BUTTOCK TO KNEE (IN)	AGE (YR)
B-1	160	70.5	37.1	25.7	23.9	28
D-5	175	72.0	36.1	25.0	25.0	25
L-3	190	72.0	37.4	26.1	25.1	36
L-5	186	69.8	35.6	25.4	25.1	27
M-16	199	70.0	37.3	25.7	24.6	32
M-19	181	74.2	38.5	26.1	25.6	26
M-20	199	70.8	37.0	26.0	25.0	29
M-21	126	66.0	34.1	23.5	23.0	28
O-2	178	65.7	34.0	24.0	23.6	26
P-5	186	68.5	36.0	24.6	23.2	25
R-8	169	74.6	37.6	26.3	26.4	28
S-3	167	69.5	36.5	25.5	23.7	38
Z-2	143	68.3	36.9	25.4	22.9	26
TEST SUBJECT MEANS AND STANDARD DEVIATIONS						
MEAN	173.8	70.2	33.5	25.3	24.4	28.8
S.D.	21.2	2.7	1.31	0.85	1.09	4.13
USAF FLYING PERSONNEL (1967 SURVEY)						
MEAN	173.6	69.8	36.7	25.4	23.8	30.0
S.D.	21.4	2.4	1.3	1.10	1.10	6.31

The tests were conducted using presumed subinjury, short-duration acceleration conditions to minimize the potential for injury to the subjects. Following a low-level test to familiarize the participants with the test procedures and equipment, a randomized series of tests at a nominal 10 G peak and velocity change of 27 ft/sec (8 m/sec) were initiated. The acceleration profile was an approximate half-sine waveform, and the average time to peak carriage acceleration (rise time) was 70 msec.

The tests were carried out at the Armstrong Laboratory using the Vertical Deceleration Tower (VDT). The test assembly, including seat, restraint, and instrumentation, was mounted to the impact carriage of the VDT. This carriage was raised to a drop height of 10 ft 4 in (3.14 m) and then allowed to fall freely along vertical rails onto a hydraulic decelerator at the base of the tower. The vertical acceleration was produced when a plunger fixed to the bottom of the carriage displaced water in the hydraulic decelerator. To assure identical acceleration conditions, the carriage drop height, test assembly mass, water volume, and plunger type were the same for all experimental-level tests in this study.

RESULTS

The test results are summarized in Table 3 in terms of the means and standard deviations of the measurements for each of the three cushions that were evaluated. Appendix B provides typical sets of electronic data from tests of each cushion and he maxima and minima of each measurement from each test.

TABLE 3. SUMMARY OF DATA

RESPONSE PARAMETER	CELL F ACES II	CELL I CURRENT F-4	CELL J PROPOSED F-4
	n = 13	n = 13	n = 13
SEAT ACCELERATION (G)	10.64 ± 0.38	10.82 ± 0.22	10.80 ± 0.29
RESULTANT SEAT FORCE (LB)	2698 ± 362	2775 ± 349	2639 ± 342
SEAT FORCE RISE TIME (SEC)	0.079 ± 0.007	0.083 ± 0.004	0.082 ± 0.005
RESULTANT CHEST ACCELERATION (G)	16.32 ± 2.15	17.53 ± 1.98	16.17 ± 1.36
CHEST ACCELERATION RISE TIME (SEC)	0.079 ± 0.005	0.083 ± 0.006	0.078 ± 0.003
RESULTANT HEAD ACCELERATION (G)	13.76 ± 1.29	15.38 ± 1.17	13.42 ± 0.95
HEAD ACCELERATION RISE TIME (SEC)	0.077 ± 0.005	0.080 ± 0.004	0.078 ± 0.003
RESULTANT SHOULDER-STRAP FORCE (LB)	191 ± 72.5	178 ± 58.3	188 ± 52.7
LEFT LAP-BELT FORCE (LB)	110 ± 35.0	99 ± 33.6	103 ± 19.7
RIGHT LAP-BELT FORCE (LB)	104 ± 25.0	91 ± 31.4	97 ± 23.7

The results of each set of Wilcoxon comparisons are summarized in Table 4.

TABLE 4. WILCOXON COMPARISON SUMMARY

RESPONSE PARAMETER	CURRENT F-4 (I) PROPOSED F-4 (J)	ACES II (F) PROPOSED F-4 (J)	CURRENT F-4 (I) ACES II (F)
	n = 13	n = 13	n = 13
RESULTANT SEAT FORCE (LB)	I > J 99%	F = J	I > F 99%
RESULTANT CHEST ACCELERATION (G)	I > J 98%	F = J	I > F 99%
RESULTANT HEAD ACCELERATION (G)	I > J 99%	F = J	I > F 99%

Percentages designate statistical confidence level

For a given comparison, a greater-than or less-than symbol designates a statistically significant difference in the response parameter at the chosen 95 percent confidence level; the symbol also indicates the direction of the trend, i.e., whether it increases or decreases in value from one cell to the other.

The seat acceleration for all 39 experimental-level tests in this study was well controlled during the evaluation. The maximum seat accelerations for each replicate set of tests were statistically evaluated for differences using the Wilcoxon analysis. Statistically significant differences were not found.

Direct comparisons of the two F-4 cushions are shown in the first comparison listed in Table 4. The evaluation parameters of seat force, head acceleration, and chest acceleration were all lower when the proposed F-4 cushion was used. The comparison of the proposed F-4 cushion with the ACES II cushion, shown in the second column of matched pairs, revealed no statistically significant differences. Comparison of the operational F-4 cushion with the ACES II, shown in the third column of matched pairs, revealed statistically significant differences in all of the evaluation parameters with lower values being measured with the ACES II cushion.

Each of the test conditions were well tolerated by the volunteer subjects. There were no injuries resulting from any of the tests.

DISCUSSION

The current operational seat cushion was selected for USAF use as a result of a series of ejection tests by Brinkley et al (August 1967) using a Martin Baker ejection seat with reduced-charge catapults. Three cushion conditions were evaluated: the Martin Baker cushion, a cushion developed by the McDonnell-Douglas Corporation, and no seat cushion. Forty-nine tests were conducted with seven human subjects at acceleration levels ranging from 6 to 14 G. The principal measurement that was used to evaluate the relative merits of the three cushion conditions was the vertical force between the accelerating seat and a simulated survival kit lid upon which a volunteer subject was seated. Typical data acquired from the ejection tests are plotted in Figure 6. Figure 6 is a plot of the ejection force (the measured seat acceleration times the subject mass) versus the vertical force measured between the seat and the survival kit lid. The seat acceleration level for this test was 9.9 G.

Although these tests more closely simulated actual F-4 ejection seat accelerations and seat geometries, the tests were more costly in time, funding, and injuries. Three of the seven subjects who participated in the tests incurred cervical, thoracic, and lumbar-sacral paravertebral sprains. One subject incurred a fracture of the spinal coccyx.

Analysis of the data collected during the earlier series of tests showed that seat force, the measured response used to comparatively evaluate the cushions, reached its critical value within about 0.10 sec to 0.12 sec.

This relationship can be clearly seen in Figure 6. Thus, one can conclude with confidence that only the first 0.1 sec of the catapult acceleration was crucial to the cushion evaluation. Furthermore, although the earlier tests were accomplished at acceleration levels from 6 to 14 G, the beneficial effects of the Martin Baker seat cushion could be seen at a level of 8.7 G. These results have led us to conclude that simpler tests at acceleration levels that represent a lower risk of injury to the volunteers will provide equivalent results.

Although the influence of the acceleration-transmission characteristics of an ejection seat is crucial, other factors should also be seriously considered. These factors include durability, flammability toxicity of gases produced during combustion, long-duration crew comfort, changes of mechanical properties as a function of temperature and age, and changes in the seat occupant's position that might influence the effectiveness of the cockpit layout or escape system

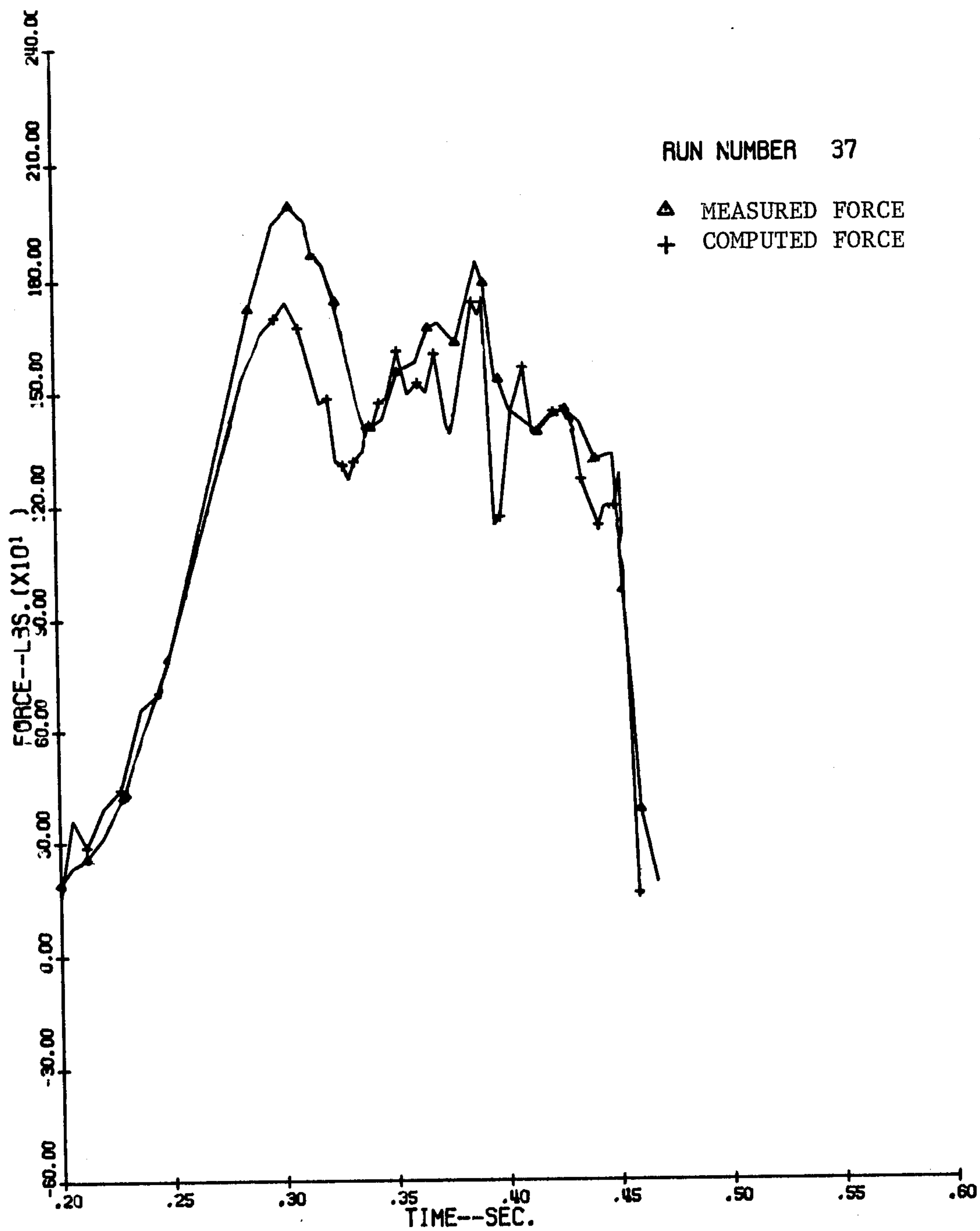


FIGURE 6. PLOT OF MEASURED FORCE AND COMPUTED FORCE FROM F-4 EJECTION SEAT TEST WITH HUMAN SUBJECT

performance. If any or all of these factors represent critical issues to the operational application, they should be thoroughly evaluated.

The long-duration comfort of the Confor™ foam has been demonstrated by tests in the F/FB-111 aircraft, and more recently by long-duration flights of the B-1B bomber. The thickness of the F/FB-111 cushions and B-1B cushions that were tested is identical to the proposed F-4 cushion that was tested by our Laboratory. Both the F/FB-111 and B-1B crew seats are contoured, although the contours are different. The B-1B seat cushion has been tested with the production contoured seat and with a flat seat. No significant difference was noticed by the crew; therefore, a decision was made by the B-1 System Program Office to use the cushion with the existing contoured seat.

CONCLUSION

The results of these tests show that the human response to vertical acceleration was more benign when either the proposed F-4 seat cushion or the ACES II seat cushion was used instead of the current operational F-4 seat cushion. From an acceleration protection standpoint, the operational F-4 cushion is inferior to the proposed alternative cushion or the operational ACES II cushion.

REFERENCES

1. Baumann, R.C., J.W. Brinkley, and A.G. Brandau. May 1968. Back Injuries Experienced During Ejection Seat Testing. Presented at the 39th Annual Aerospace Medical Association Meeting.

2. Brinkley, J.W. August 1967. Dynamic Evaluation of the F-4 Ejection Seat, Summary of Findings, Aerospace Medical Research Laboratory, Memorandum, Wright-Patterson AFB, Ohio.

3. Hearon, B.F. and J.W. Brinkley. February 1986. Effect of Seat Cushions on Human Response to +Gz Impact. Aviation, Space, and Environmental Medicine, 57:113-121.

4. Military Specification, Webbing, Textile, Polyester, Low Elongation, MIL-W-25361C, 10 October 1974.

5. Staff of Anthropology Research Project, Webb Associates, Editors. July 1978. Anthropometric, Source Book, Volume I: Anthropometry for Designers, NASA Reference Publication 1024 National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, Texas.

TEST CONFIGURATION AND DATA ACQUISITION SYSTEM FOR THE EFFECTS OF SEAT CUSHIONS AND SEAT BACK ANGLE ON HUMAN RESPONSE DURING +Gz IMPACT ACCELERATION TEST PROGRAM

Prepared under
Contract F33615-86-C-0531
November 1986

Prepared by
DynCorp (formerly Dynalectron Corporation)
AAMRL Division
Building 824, Area B
Wright-Patterson AFB, Ohio 45433

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

CONT'D - LIST OF ILLUSTRATIONS

FIGURE PAGE

INTRODUCTION

This report was prepared by DynCorp (formerly Dynalectron Corporation) for the Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL/BBP) under Air Force Contract F33615-86-C-0531.

The information provided herein describes the test facility, test fixture, data acquisition, instrumentation procedures and and the test configuration that were used in "The Effects of Seat Cushions and Seat Back Angle on Human Response During +Gz Impact Acceleration Test Program." The testing was done on the Vertical Deceleration Tower starting July 1986 and ending August 1986.

1. TEST FACILITY

The AAMRL Vertical Deceleration Tower, as shown in Figure A-1, was used for all of the tests.

The facility consists of a 60 ft. vertical steel tower which supports a guide rail system, an impact carriage supporting a plunger, a hydraulic deceleration device and a test control and safety system. The impact carriage can be raised to a maximum height of 42 ft. prior to release. After release, the carriage free falls until the plunger, attached to the undercarriage, enters a water filled cylinder mounted at the base of the tower. The deceleration profile produced as the plunger displaces the water in the cylinder is determined by the free fall distance, the carriage and test specimen mass, the shape of the plunger and the size of the cylinder orifice. For these tests, plunger number 102 was mounted under the carriage. Drop height varied depending on the test cell requirements which ranged from 5'6" to 8'3".

2. SEAT FIXTURE

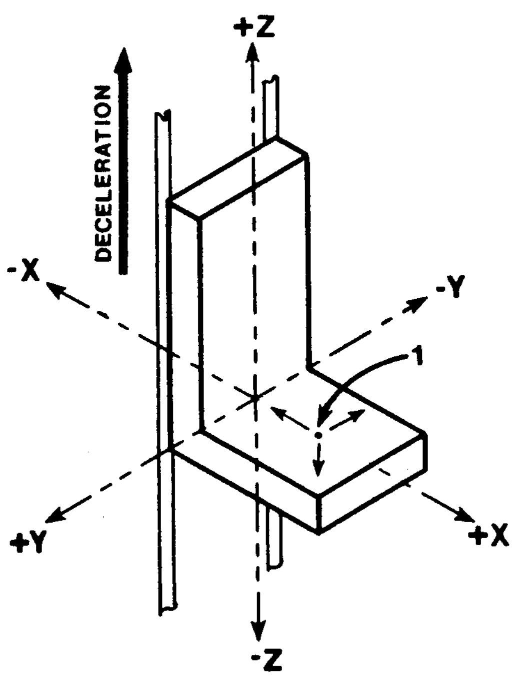
The VIP seat fixture, as shown in Figure A-1, was used for all of the tests. The seat was designed to withstand vertical impact acceleration up to 50 Gs. Its adjustable seat back allowed the subject to sit in one of four positions, as shown in Figure A-2. When positioned in the seat, the subject's upper legs were bent 90 degrees outward to a horizontal position with his lower legs bent 90 degrees downward to a vertical position. The subject was secured in the seat with a lap belt and shoulder strap. The lap belt and shoulder strap were preloaded to 20$\pm$ lbs. as required in the test plan.

3. INSTRUMENTATION

The electronic data collected during this test program is described in Sections 3.1 and 3.2. Section 3.1 discusses accelerometers while Section 3.2 discusses load transducers. Section 3.3 discusses the calibration procedures that were used. The measurement instrumentation used in this test program is listed in Tables A-1a through A-1c. These tables designate the manufacturer, type, serial number, sensitivity and other pertinent data on each transducer used.

Accelerometers and load transducers were chosen to provide the optimum resolution over the expected test load range. Full scale data ranges were chosen to provide the expected full scale range plus 50% to assure the capture of peak signals. All transducer bridges were balanced for zero output except for those accelerometers in line with the force of gravity which were adjusted for plus 1 G. The accelerometer and load transducer coordinate system is shown in Figure A-3.

The accelerometers were wired to provide a positive output voltage when accelerations were applied in the +x, +y and +z directions, as shown in Figure A-3.



1. Typical fixed load cell and load link mounting point. Direction of arrows indicate direction of force applied to produce a positive output.

NOTE: Accelerometers were wired to produce a positive output voltage when accelerations were applied in the +x, +y and +z directions as shown.

FIGURE A-3: AAMRL/BBP COORDINATE SYSTEM

The load transducers included three types of load measurement devices. All were wired as follows:

> Fixed Load Cells - were wired to provide a positive output when force is applied in the indicated direction (Figure A-3).
>
> Triaxial Load Cells - were wired to provide a positive output when the belt was pulled towards the center of the seat.
>
> Load Links - were wired to provide a positive output when force is applied in the direction indicated (Figure A-3).

Carriage velocity was measured using a Globe Industries tachometer Model 22A672-2. The rotor of the tachometer was attached to an aluminum wheel with a rubber "O" ring around its circumference to assure good rail contact. The wheel contacted the track rail and rotated as the carriage moved, producing an output voltage proportional to the velocity.

3.1 Accelerometers

This section describes the accelerometer instrumentation as required in the AAMRL/BBP test plan.

Head accelerations were measured using three Endevco Model 2264-200 linear accelerometers and one Endevco Model 7302A angular (Ry) accelerometer. The accelerometers were mounted to the external edge of a plastic dental bite block. Each subject had his own set of custom fitted dental inserts that were used to support the bite block in his mouth. An aluminum tube extended from the bite block and located a fiducial target used for photo tracking purposes.

The chest accelerometer package consisted of three Endevco Model 2264-150 linear accelerometers mounted to a 1/2 x 1/2 x 1/2 inch aluminum block. An Endevco Model 7302A angular (Ry) accelerometer was mounted on a bracket adjacent to the triaxial chest block. The accelerometer packages were inserted into a steel protection shield to which a length of Velcro fastener strap was attached. The package was placed over the subject's sternum at the level of the xiphoid and was held there by fastening the Velcro strap around the subject's chest.

Carriage accelerations were measured using three Endevco accelerometers: Model 2262A-200 for the z direction, Model 2264-200 for the x direction and Model 7264-200 for the y direction. The three accelerometers were mounted on a small acrylic block and located behind the seat on the VIP seat structure.

Seat accelerations were measured using three Endevco accelerometers: one Model 2264-150 for accelerations in the x direction and two Model 2264-200s for accelerations in the y and z directions. Seat angular (Ry) acceleration was measured using an Endevco Model 7302B angular accelerometer. The three linear accelerometers were attached to a 1 x 1 x 3/4 inch acrylic block and were mounted below the seat near the back edge of the support frame. The angular accelerometer was attached to an aluminum bracket and was mounted near the center and below the seat.

Head accelerations for dummy tests were measured using three Endevco Model 2264-200 linear accelerometers and one Endevco Model 7302 angular accelerometer. These accelerometers were internally mounted in the head of the VIP 95 manikin.

3.2 Load transducers
This section describes the load transducer instrumentation as required in the AAMRL/BBP test plan.

The load transducer locations and dimensions are shown in Figure A-4.

Right lap, left lap and shoulder strap loads were each measured using GM3D-SW triaxial load cells, each capable of measuring loads in the x, y and z directions. The shoulder strap triaxial package was mounted on the seat frame between the seat back support plate and the headrest. The right and left lap triaxial packages were located on separate plates mounted on the side of the seat frame parallel to the seat pan.

Seat pan loads were measured using three load cells and three load links. The three load cells were Strainsert Model FL2.5U-2SPKT load cells. The three load links, as shown in Figure A-5, were fabricated by DynCorp using Micro Measurement Model EA-06-062TJ-350 strain gages. All six measurement devices were located under the seat pan support plate. The load links were used for measuring loads in the x and y directions, two in the x direction and one in the y direction. Each load link housed a swivel ball which acted as a coupler between the seat pan and load cell mounting plate. The Strainsert load cells were used for measuring loads in the z direction.

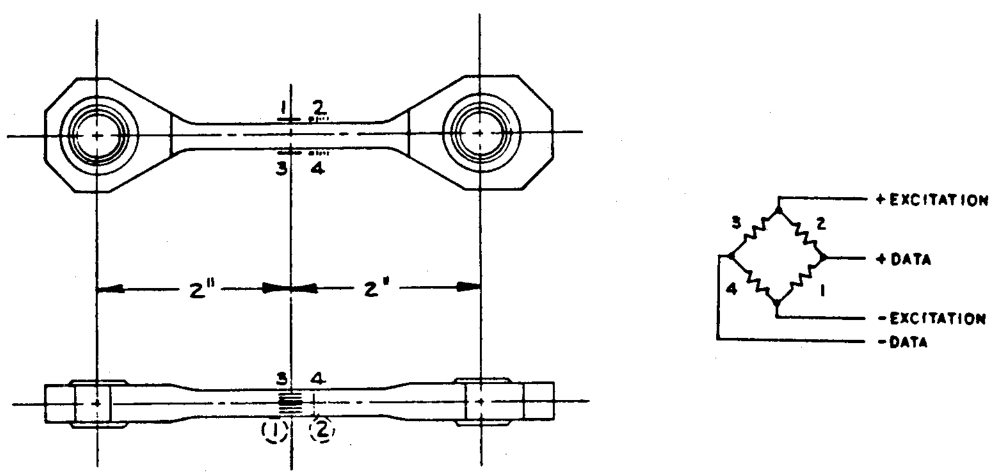


FIGURE A-5: LOAD LINK INSTRUMENTATION

3.3 Calibration
Calibrations were performed before and after testing to confirm the accuracy and functional characteristics of the transducers. Pre-program and post-program calibrations are given in Tables A-2a through A-2d.

The calibration of all Strainsert load cells was performed by the Precision Measurement Equipment Laboratories (PMEL) at Wright-Patterson Air Force Base. PMEL calibrated these devices on a periodic basis and provided current sensitivity and linearity data.

The calibration of the accelerometers was performed by DynCorp using the comparison method (Ensor, 1970). A laboratory standard accelerometer, calibrated on a yearly basis by Endevco with standards traceable to the National Bureau of Standards, and a test accelerometer were mounted on a shaker table. The frequency response and phase shift of the test accelerometer was determined by driving the shaker table with a random noise generator and analyzing the outputs of the accelerometers with a PDP 11/15 computer and 1923 Time Data Unit using Fourier analysis. The natural frequency and the damping factor of the test accelerometer were determined, recorded and compared to previous calibration data for that test accelerometer. Calibrations were made at 40 G and 100 Hertz. The sensitivity of the test accelerometer was determined by comparing its output to the output of the standard accelerometer.

The angular accelerometers were calibrated by DynCorp by comparing their output to the output of a linear standard accelerometer. The angular accelerometer is mounted parallel to the axis of rotation of a Honeywell low inertia D.C. motor. The standard accelerometer is mounted perpendicular to the axis of rotation at a radius of one inch to measure the tangential acceleration. The D.C. motor motion is driven at a constant sinusoidal angular acceleration of 100 Hertz and the sensitivity is calculated by comparing the rms output voltages of the angular and linear accelerometers.

The velocity wheel was calibrated by rotating the wheel at various revolutions per minute (RPM) and recording both the output voltage and the RPM. The sensitivity was dynamically checked with a G-HI measuring system and the Horizontal Accelerator Sled facility. This system consists of a timing unit and an optical sensor mounted near the track rails. As the sled traveled along the track rails, a metal blade on the sled interrupted the optical sensor beam. The timing unit displayed a time which was correlated to a velocity.

The load links and GM load cells were calibrated by DynCorp. These transducers were calibrated to a laboratory standard load cell in a special test fixture. The sensitivity and linearity of each test load cell were obtained by comparing the output of the test load cell to the output of the laboratory standard under identical loading conditions. The laboratory standard load cell, in turn, is calibrated by PMEL on a periodic basis.

4. DATA ACQUISITION

Data acquisition was controlled by a comparator on the Master Instrumentation Control Unit in the Instrumentation Station. The comparator was set to start data collection at a preselected time. A reference mark was electronically initiated to mark the electronic data and initiate a stobe light in the test area to mark the film frame for reference. The test was initiated when the countdown clock reached zero. The reference mark, used in the processing of data, was generated after T = Ø to place the reference mark close to the impact point.

Timing reference was provided by a master clock. Timing pulses of 100 pps were provided by the master clock to film data. The cameras were run at 500 frames per second and a timing pulse was placed on the film at 10 millisecond intervals.

Prior to each test and prior to placing the subject in the seat, data was acquired to establish a zero reference for all data sensors. This data was stored separately from the test data and was used in the processing of data.

4.1 Automatic Data Acquisition and Control System (ADACS)

Installation of the ADACS instrumentation is shown in Figure A-6. The three major components of the ADACS system are the power conditioner, signal conditioners and the encoder. A block diagram of the ADACS is shown in Figure A-7. The signal conditioners contain forty-eight module amplifiers with programmable amplifier gains and filters.

Bridge excitation for load cells and accelerometers was 10 VDC. Bridge completion and balance resistors were added as required to each module input connector.

The forty-eight module output data signals were digitized and encoded into forty-eight 11-bit digital words. Two additional 11-bit synchronization (sync) words were added to the data frame making a fifty word capability.

Three synchronization pulse trains (bit sync, word sync and frame sync) were added to the word frame and sent to the computer via a junction box data cable.

The PDP 11/34 mini-computer received serial data from the ADACS. The serial data coming from the carriage were converted to parallel data in the data formatter. The data formatter inputs data by direct memory access (DMA) into the computer memory via a buffered data channel where data were temporarily stored on disk and later transferred to magnetic tape for permanent storage. The interrelationships among the data acquisition and storage equipment are shown in Figure A-8.

Test data could be reviewed immediately after each test by using the "quick look" SCAN routine. SCAN was used to produce a plot of the data stored on any channel as a function of time. The routine determined the minimum and maximum values of any data plot. It was also used to calculate the rise time, pulse duration and carriage acceleration.

4.2 Photogrammetric Data Acquisition

Two onboard high-speed LOCAM cameras, operating at 500 frames per second, were used to produce the photogrammetric data. Each camera used a 9mm lens and were automatically started at a preset time in the test sequence by a signal from the camera and lighting control station. Both camera locations are shown in Figure A-9.

Motion of the subjects' head, shoulders and chest were quantified by tracking the motion of subject-mounted fiducials. Reference fiducials were placed on the test fixture. Two different sized fiducials were used, one being a .75" diameter black circle on a 1.25" diameter white target, the other a 1.25" diameter black circle on a 2.00" diameter white target. The locations of the fiducials generally followed the guidelines provided in "Film Analysis Guides for Dynamic Studies of Test Subjects, Recommended Practice" (SAE J138, March 1980). Fiducial target locations are identified in Figure A-10.

The photogrammetric data were time correlated in each test. Immediately prior to impact, an event signal triggered the flash unit to mark the camera film frame. At that time, a 100 PPS signal activated the camera L.E.D. driver which pulsed the camera L.E.D., producing a time mark at the film edge. This reference mark was then used to correlate the photogrammetric data with the electronically measured data.

The photogrammetric data will be processed as required on the Automatic Film Reader (AFR) system, shown in the block diagram in Figure A-11. The fiducial tracking routine is initiated via the Data General terminal. The tracking routine is booted from a floppy disk into the Nova 3/12 memory. The system is capable of tracking fiducials manually or automatically. The Nova 3/12 outputs an x-y film coordinate position to magnetic tape for each fiducial being tracked. Data are then transferred from magnetic tape to the DEC PCP 11/34 disk file for processing.

An Instant Analytical Replay (INSTAR) video system was also used to provide photogrammetric coverage of each test. This video recorder and display unit is capable of recording high-speed motion at a rate of 120 frames per second. Immediate replay of the impact is possible in real time or in slow motion.

5. PROGRAM OPERATION

5.1 Introduction

This section identifies the flowcharts and processing programs that were used for the VSBA Study conducted by the Biomechanical Protection Branch, Biodynamics and Bioengineering Division of the Harry G. Armstrong Aerospace Medical Research Laboratory.

The executable tasks for the VSBA Study processing programs are located on the Data Processing disk of the PDP 11/34. The test data is read into the computer using the DEC Peripheral Interchange Package from a digital magnetic tape with a density of 800 BPI and stored on an RLØ2 hard disk. All plots are output to a Tektronix hardcopy unit. The alphanumeric data itself is output to the Versatec line printer.

5.2 Program Operation

The five Fortran programs that process the VSBA Study test data are named "VSVDØA," "VSVDØB," "VSVDØC," "VSVDØD" and "VSVDØE." The command file which controls execution of these tasks is named "VSVD." The two characters "VS" identify the study (VSBA), the characters "VD" identify the facility (Vertical Deceleration Tower), "Ø" is the revision number and the last character determines the program order of execution.

Task A requires the user to enter the total number of tests to be processed and the zero and data filenames for each test. The user must then specify whether the default test parameters are to be used for processing. If the default parameters are selected, then the test number, subject identification, weight, age, height and sitting height are read in from the first block of the test data file. The cell type, nominal G level and left lap, right lap and shoulder preload values are also read in. If the default parameters are not selected, they must be entered by the user. Task A creates a command file containing execution commands for each test, which is called by command file "VSVD" after task A exits.

Task B creates the individual data files for each channel and data files for all sums, differences, products and resultants. Task C finds data maxima and minima for each channel, does any special processing required and outputs results to the data base. Task D outputs an alphanumeric cover sheet to the Versatec line printer/plotter based on the formats specified in the base and report format files. Task E plots the specified data channels for 600 ms after the reference mark and hardcopies the plots.

5.3 Program Flowcharts

Flowcharts of the five programs are shown in Figures A-12 through A-16. Each flowchart identifies the files used and the subroutines called by the program. Data channel numbers and accelerations or loads are listed where they occur in the analysis.

DIGITAL INSTRUMENTATION REQUIREMENTS

DYNALECTRON CORPORATION

PROGRAM: THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz DATE 14 JUL 86 THRU 14 AUG 86

FACILITY: VERTICAL DECELERATOR TOWER RUN 1127 THRU 1214

DATA CHANNEL	DATA POINT	XDUCER MFG & TYPE	S/N	XDUCER SENS	EXCITE V	CHAN	FILTER SERIES	S/N	AMP GAIN	S/N	SAMPLE RATE	FORMAT	F.S. SENS	FILTER HZ	XDUCER ZERO	RANGE	BRIDGE BALANCE RESISTORS	BRIDGE COMPLETION RESISTORS	SPECIAL NOTATIONS
1	Carriage Z	Endevco 2262A-200	FR42	4.20 mv/g	10.00	1	60	1	25	6	1K	1	23.8 g	120	2.5	+5.0 0.0	100K +in Gnd.	-	
2	Carriage X	Endevco 2264-200	BX17	2.792 mv/g	10.00	2	60	2	100	5	1K	1	8.95 g	120	2.5	+5.0 0.0	143K +in Gnd	1.58K	
3	Carriage Y	Endevco 7264-200	BW97M	2.767 mv/g	10.00	3	60	3	100	11	1K	1	9.04 g	120	2.5	+5.0 0.0	270K +in Gnd	"	
4	Head X	Endevco 2264-200	BP56	2.821 mv/g	10.00	4	60	4	50	3	1K	1	17.7 g	120	2.5	+5.0 0.0	-	1.65K	
5	Head Y	"	CF23	2.224 mv/g	10.00	5	60	5	50	2	1K	1	22.4 g	120	2.5	+5.0 0.0	130K +in Gnd	"	
6	Head Z	"	CH73	2.741 mv/g	10.00	6	60	6	25	9	1K	1	36.5 g	120	2.5	+5.0 0.0	165K +in Gnd	"	
7	Chest X	Endevco 2264-150	BC26	2.807 mv/g	10.00	7	60	7	50	15	1K	1	17.8 g	120	2.5	+5.0 0.0	1.2M -in Gnd	"	
8	Chest Y	"	BB13	2.467 mv/g	10.00	8	60	8	100	30	1K	1	10.1 g	120	2.5	+5.0 0.0	220K +in Gnd	"	
9	Chest Z	"	2A20	2.648 mv/g	10.00	9	60	9	25	25	1K	1	37.8 g	120	2.5	+5.0 0.0	155K -in Gnd	"	
10	Left Seat Load	Strainsert FL2.5U-2SPKT	3294-1	8.02 uv/lb	10.00	10	60	10	201	1	1K	1	1551 LB	120	2.5	+5.0 0.0	-	-	
11	Right Seat Load	"	3294-2	8.03 uv/lb	10.00	11	60	11	201	14	1K	1	1549 LB	120	2.5	+5.0 0.0	-	-	
12	Center Seat Load	"	3294-4	8.08 uv/lb	10.00	12	60	12	100	34	1K	1	3094 LB	120	2.5	+5.0 0.0	-	-	
13	Left Load Link X	MM/DYN EA-06-062 TJ-350	2	10.32 uv/lb	10.00	13	60	13	402	1	1K	1	603 LB	120	2.5	+5.0 0.0	140K +in Gnd	-	
14	Right Load Link X	"	3	10.55 uv/lb	10.00	14	60	14	402	6	1K	1	589 LB	120	2.5	+5.0 0.0	24K +in Gnd	-	

NO FACILITY IMPACT SWITCH REQUIRED.
COMPUTER SOFTWARE WILL DETERMINE THIS POINT
PER MR. BRINKLEY 14 JULY 86.

PAGE 1 OF 3

TABLE A-1a: INSTRUMENTATION REQUIREMENTS (PAGE 1 OF 3)

DIGITAL INSTRUMENTATION REQUIREMENTS

PROGRAM THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz DATE 14 JUL 86 THRU 14 AUG 86

FACILITY VERTICAL DECELERATOR TOWER RUN 1127 THRU 1214

DYNALECTRON CORPORATION

DATA CHANNEL	DATA POINT	XDUCER MFG & TYPE	S/N	XDUCER SENS	EXCITE V	CHAN	FILTER SERIES	S/N	AMP GAIN	S/N	SAMPLE RATE	FORMAT	F.S. SENS	FILTER HZ	XDUCER ZERO	RANGE	BRIDGE BALANCE RESISTORS	BRIDGE COMPLETION RESISTORS	SPECIAL NOTATIONS
15	Left Lap Load X	GM 3D-SW	15X	5.36 uv/lb	10.00	15	60	15	402	7	1K	1	1160 LB	120	2.5	+5.0 0.0	5.2K +in Gnd	-	
16	Left Lap Load Y	"	15Y	5.35 uv/lb	10.00	16	60	16	800	2	1K	1	584 LB	120	2.5	+5.0 0.0	16K +in Gnd	-	
17	Left Lap Load Z	"	15Z	6.29 uv/lb	10.00	17	60	17	402	3	1K	1	989 LB	120	2.5	+5.0 0.0	4.9K +in Gnd	-	
18	Right Lap Load X	"	21X	5.07 uv/lb	10.00	18	60	18	402	5	1K	1	1227 LB	120	2.5	+5.0 0.0	8.2K +in Gnd	-	Test 1127-1210 Sens. @ 4.89 uv/lb, F. S. @ 1272 LB
19	Right Lap Load Y	"	21Y	4.85 uv/lb	10.00	19	60	19	800	3	1K	1	644 LB	120	2.5	+5.0 0.0	3.7K +in Gnd	-	Test 1127-1210 Sens. @ 4.82 uv/lb, F. S. 648 LB
20	Right Lap Load Z	"	21Z	6.08 uv/lb	10.00	20	60	20	402	2	1K	1	1023 LB	120	2.5	+5.0 0.0	47K +in Gnd	-	Test 1127-1210 Sens. @ 6.15 uv/lb, F. S. 1011 LB
21	Shoulder Load X	"	20Z	6.29 uv/lb	10.00	21	60	21	402	4	1K	1	989 LB	120	2.5	+5.0 0.0	48K -in Gnd	-	
22	Shoulder Load Y	"	20Y	5.78 uv/lb	10.00	22	60	22	800	4	1K	1	541 LB	120	2.5	+5.0 0.0	800K +in Gnd	-	
23	Shoulder Load Z	"	20X	5.57 uv/lb	10.00	23	60	23	402	8	1K	1	1117 LB	120	2.5	+5.0 0.0	30K +in Gnd	-	
25	Seat X Accel.	Endevco 2264-150	BB28	2.700 mv/g	10.00	25	60	25	50	5	1K	1	18.5 g	120	2.5	+5.0 0.0	72.4K +in Gnd	1.65K	
26	Seat Y Accel.	Endevco 2264-200	BV95	2.985 mv/g	10.00	26	60	26	50	12	1K	1	16.8 g	120	2.5	+5.0 0.0	-	1.47K	
27	Seat Z Accel.	"	BW07	2.812 mv/g	10.00	27	60	27	50	24	1K	1	17.8 g	120	2.5	+5.0 0.0	287K -in Gnd	"	
28	Center Load Link Y	MM/DYN EA-06-06 2TJ-350	5	9.91 uv/lb	10.00	28	60	28	402	10	1K	1	628 LB	120	2.5	+5.0 0.0	82K +in Gnd	-	
29	Vel. Tach.	Globe 22A672-2	4	.06209 V/F/S	-	29	30	1	1	-	1K	1	80.5	60	0.0	+5.0 0.0	-	-	Signal attenuated by 7.65 Sens.=.475 V/F/S ÷ 7.65=.06209 V/F/S @4.4" cir.

TEST 1145 - SEAT TRIAXIAL PACKAGE MOVED TO REAR OF SEAT FROM CENTER LOCATION PER MR. BRINKLEY.

PAGE 2 OF 3

TABLE A-1b: INSTRUMENTATION REQUIREMENTS (PAGE 2 OF 3)

THE EFFECTS OF DIGITAL INSTRUMENTATION REQUIREMENTS

PROGRAM SEAT CUSHION AND SEAT BACK ANGLES DUR NC +Gz DATE 14 JUL 86 THRU 14 AUG 86

FACILITY VERTICAL DECELERATOR TOWER RUN 1127 THRU 1214

DYNALECTRON CORPORATION

DATA CHANNEL	DATA POINT	XDUCER MFG & TYPE	S/N	XDUCER SENS	EXCITE V	EXCITE CHAN	FILTER SERIES	FILTER S/N	AMP GAIN	AMP S/N	SAMPLE RATE	SAMPLE FORMAT	F.S. SENS	FILTER HZ	XDUCER ZERO	XDUCER RANGE	BRIDGE BALANCE RESISTORS	BRIDGE COMPLETION RESISTORS	SPECIAL NOTATIONS
37	Event	-	-	-	-	37	1000	23	2.5	27	1K	1	5.0 Volt	2000	5.0	+5.0 0.0	-	-	
42	Head Ry Angular	Endevco 7302A	AB12	4.15uv/RAD/SEC^2	10.00	42	60	42	201	17	1K	1	2997 RAD/SEC^2	120	2.5	+5.0 0.0	-	-	
43	Chest Ry Angular	"	AB15	6.68uv/RAD/SEC^2	10.00	43	60	43	201	10	1K	1	1862 RAD/SEC^2	120	2.5	+5.0 0.0	440K -in Gnd	-	
44	Seat Ry Angular	7302B	PT47	3.65uv/RAD/SEC^2	10.00	44	60	44	402	12	1K	1	1704 RAD/SEC^2	120	2.5	+5.0 0.0	-	-	
38	T = 0 Pulse	-	-	-	-	38	1000	11	1	-	1K	1	5.0 Volt	2000	0.0	+5.0 0.0	-	-	Used for computer processing
47	2.5 Volt Bias	-	-	-	-	47	180	7	1	-	1K	1	2.5 Volt	360	2.5	+5.0 0.0	-	-	
48	10 Volt Exc.	-	-	-	-	48	180	8	1	-	1K	1	2.5 Volt	360	2.5	+5.0 0.0	-	-	
30	Dummy Head X	Endevco 2264-200	CH74	2.906 mv/g	10.00	30	60	30	50	16	1K	1	17.2 g	120	2.5	+5.0 0.0	190K +in Gnd	1.65K	Dummy tests 1131 and subsequent
31	Dummy Head Y	"	BQ42	2.740 mv/g	10.00	31	60	31	50	23	1K	1	18.2 g	120	2.5	+5.0 0.0	220K +in Gnd	1.65K	Dummy tests 1131 and subsequent
32	Dummy Head Z	"	CH70	2.662 mv/g	10.00	32	60	32	25	29	1K	1	37.6	120	2.5	+5.0 0.0	80K +in Gnd	1.65K	Dummy tests 1131 and subsequent
33	Dummy Head Ang	Endevco 7302	A150	8.163uv/RAD/SEC^2	10.00	33	60	33	100	15	1K	1	3063 RAD/SEC^2	120	2.5	+5.0 0.0	-	-	Dummy tests 1131 and subsequent

PAGE 3 OF 3

TABLE A-1c: INSTRUMENTATION REQUIREMENTS (PAGE 3 OF 3)

PROGRAM CALIBRATION LOG

PROGRAM: THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz **DATES:** 14 JUL 86 - 14 AUG 86

FACILITY: VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1127-1214

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% CHANGE	NOTES
			DATE	* SENS	DATE	* SENS		
CARRIAGE Z	ENDEVCO 2262A-200	FR42	7JUL86	4.20	20AUG86	4.189	-.3	* ALL SENS. IN mv/g
CARRIAGE X	ENDEVCO 2264-200	BX17	8JUL86	2.792	"	2.804	+.4	
CARRIAGE Y	ENDEVCO 7264-200	BH97H	9JUL86	2.767	"	2.783	+.6	
HEAD X	ENDEVCO 2264-200	BP56	28MAY86	2.821	14AUG86	2.839	+.6	
HEAD Y	"	CF23	"	2.224	"	2.257	+.4	
HEAD Z	"	CH73	"	2.741	"	2.751	+1.5	
CHEST X	ENDEVCO 2264-150	BC26	"	2.807	"	2.795	-.4	
CHEST Y	"	BB13	"	2.467	"	2.438	-1.2	
CHEST Z	"	2A20	"	2.648	"	2.633	-.6	
SEAT X	"	BB28	31DEC85	2.700	20AUG86	2.701	0	

SEPTEMBER 1985

PAGE 1 OF 4

TABLE A-2a: TRANSDUCER PRE- AND POST-CALIBRATION (1 OF 4)

PROGRAM CALIBRATION LOG

PROGRAM: THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz **DATES:** 14 JUL 86 - 14 AUG 86

FACILITY: VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1127-1214

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% CHANGE	NOTES
			DATE	* SENS	DATE	* SENS		
SEAT Y	ENDEVCO 2264-200	BV95	28MAY86	2.985	20AUG86	2.987	+.1	* ALL SENS. IN mv/g UNLESS
SEAT Z	"	BW07	9JAN86	2.812	"	2.820	+.3	NOTED OTHER-WISE.
DUMMY HEAD X	"	CH74	28MAY86	2.906	22AUG86	2.939	+1.1	
DUMMY HEAD Y	"	BQ42	"	2.740	"	2.740	0	
DUMMY HEAD Z	"	CH70	"	2.662	"	2.676	+.5	
DUMMY HEAD ANG.	ENDEVCO 7302	A150	29MAY86	8.163 uv/RAD/SEC^2	"	8.203 uv/RAD/SEC^2	+.5	
HEAD ANG.	ENDEVCO 7302A	AB12	28MAY86	4.15 uv/RAD/SEC^2	15AUG86	4.195 uv/RAD/SEC^2	+1.0	
SEAT ANG.	ENDEVCO 7302B	PT47	6JAN86	3.65 uv/RAD/SEC^2	22AUG86	3.732 uv/RAD/SEC^2	+2.2	
CHEST ANG.	ENDEVCO 7302A	AB15	29MAY86	6.68 uv/RAD/SEC^2	15AUG86	6.80 uv/RAD/SEC^2	+1.8	

SEPTEMBER 1985

PAGE 2 of 4

TABLE A-2b: TRANSDUCER PRE- AND POST-CALIBRATION (2 OF 4)

PROGRAM CALIBRATION LOG

PROGRAM: THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz

DATES: 14 JUL 86 - 14 AUG 86

FACILITY: VERTICAL DECELERATION TOWER

RUN NUMBERS: 1127-1214

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% CHANGE	NOTES
			DATE	* SENS	DATE	* SENS		
LEFT LOAD LINK X	MM/DYN EA-06-062TJ-350	2	9JUL86	10.32	25AUG86	10.32	0	* NOTE - ALL SENS. IN uv/lb
RIGHT LOAD LINK X	"	3	"	10.55	"	10.66	+1.0	
CENTER LOAD LINK Y	"	5	"	9.91	"	9.94	+.3	
LEFT LAP LOAD X	GM 3D-SW	15X	"	5.36	"	5.41	+.9	
LEFT LAP LOAD Y	"	15Y	"	5.35	"	5.36	+.2	
LEFT LAP LOAD Z	"	15Z	"	6.29	"	6.30	+.2	
RIGHT LAP LOAD X	"	21X	"	5.07	"	5.08	+.2	
RIGHT LAP LOAD Y	"	21Y	"	4.85	"	4.84	-.2	
RIGHT LAP LOAD Z	"	21Z	"	6.08	"	6.07	-.2	
SHOULDER LOAD X	"	20Z	"	6.29	26AUG86	6.32	+.5	

SEPTEMBER 1985

PAGE 3 OF 4

TABLE A-2c: TRANSDUCER PRE- AND POST-CALIBRATION (3 OF 4)

PROGRAM CALIBRATION LOG

PROGRAM: THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz **DATES:** 14 JUL 86 - 14 AUG 86

FACILITY: VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1127-1214

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% CHANGE	NOTES
			DATE	* SENS	DATE	* SENS		
SHOULDER LOAD Y	GM 3D-SW	20Y	9JUL86	5.78	26AUG86	5.78	0	* ALL SENS. IN uv/lb
SHOULDER LOAD Z	"	20X	"	5.57	"	5.61	+.7	

SEPTEMBER 1985

PAGE 4 OF 4

TABLE A-2d: TRANSDUCER PRE- AND POST-CALIBRATION (4 OF 4)

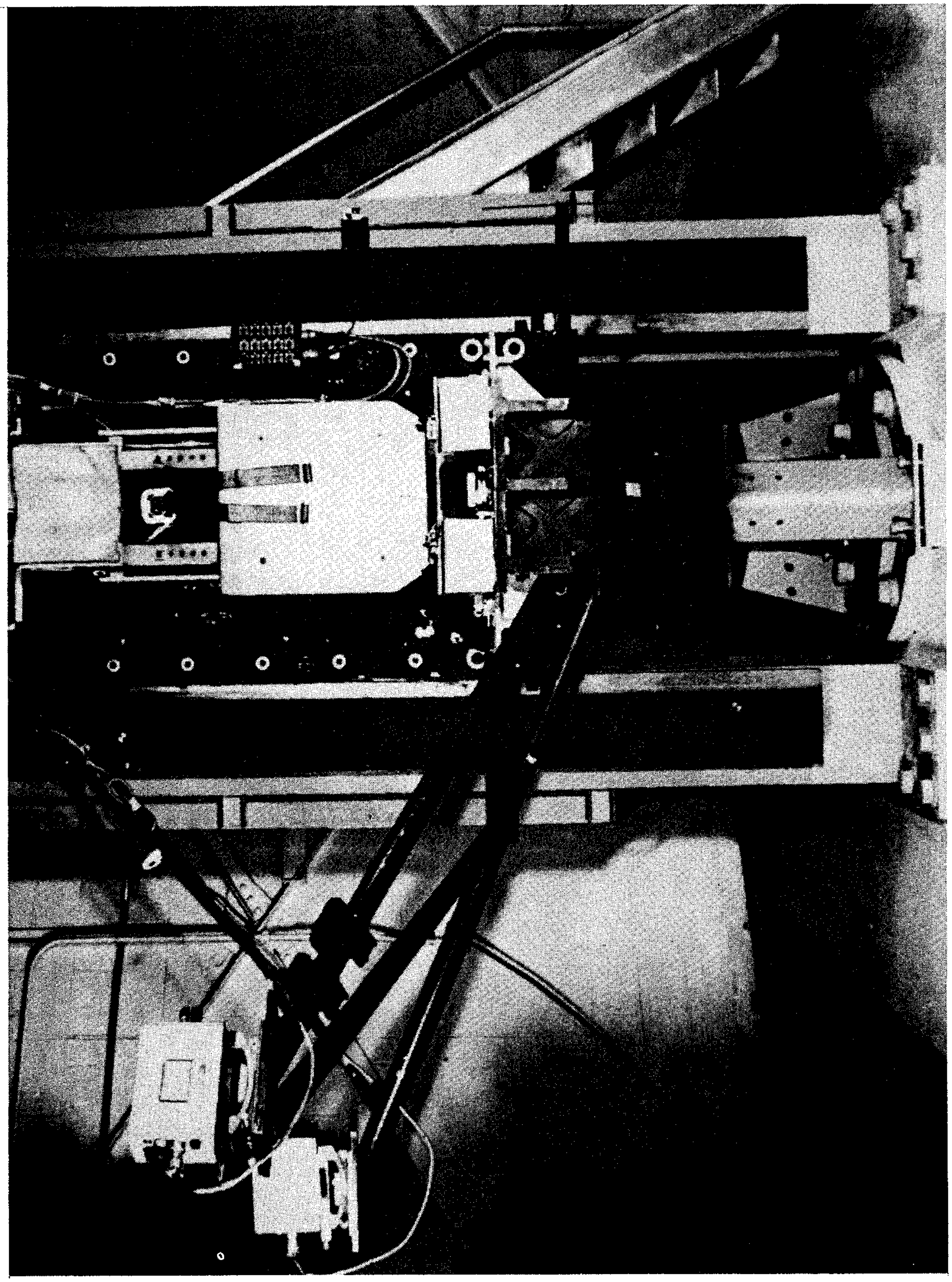


FIGURE A-1: VERTICAL DECELERATION TOWER

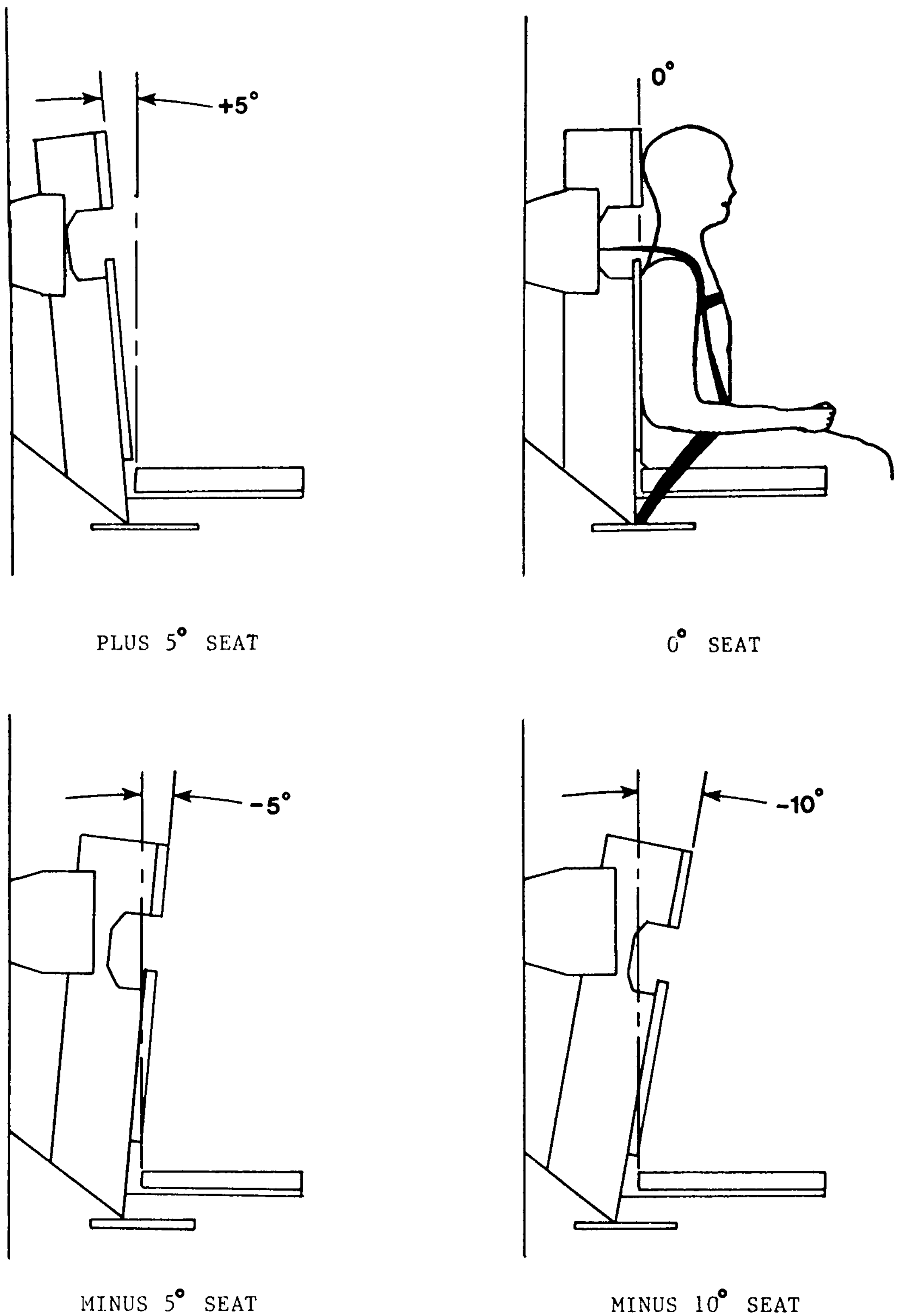


FIGURE A-2: VIP SEAT POSITIONS

DESCRIPTION	DIMENSIONS IN CENTIMETERS		
	x	y	z
*1 SEAT REFERENCE POINT	0.00	0.00	0.00
2 CENTER SEAT LOAD	+11.75	0.00	-7.94
3 RIGHT SEAT LOAD	+40.64	+17.78	-7.94
4 LEFT SEAT LOAD	+40.64	-17.78	-7.94
5 LEFT LAP LOAD	-3.81	-22.86	-4.29
6 RIGHT LAP LOAD	-3.81	+22.86	-4.29
**7 SHOULDER STRAP LOAD	-14.67	0.00	+70.17
8 CENTER SEAT LINK	+17.78	+5.08	-9.45
9 RIGHT SEAT LINK	+20.32	+12.70	-9.45
10 LEFT SEAT LINK	+20.32	-12.70	-9.45

* **All dimensions are referenced to the seat reference** point (SRP). The seat reference point is located at the intersection of the horizontal seat plate (x **axis**) center line and the vertical back plate (z axis) center line.

** Dimensions shown are for the seat in the zero degree position. x and z measurements varied for each different seat position.

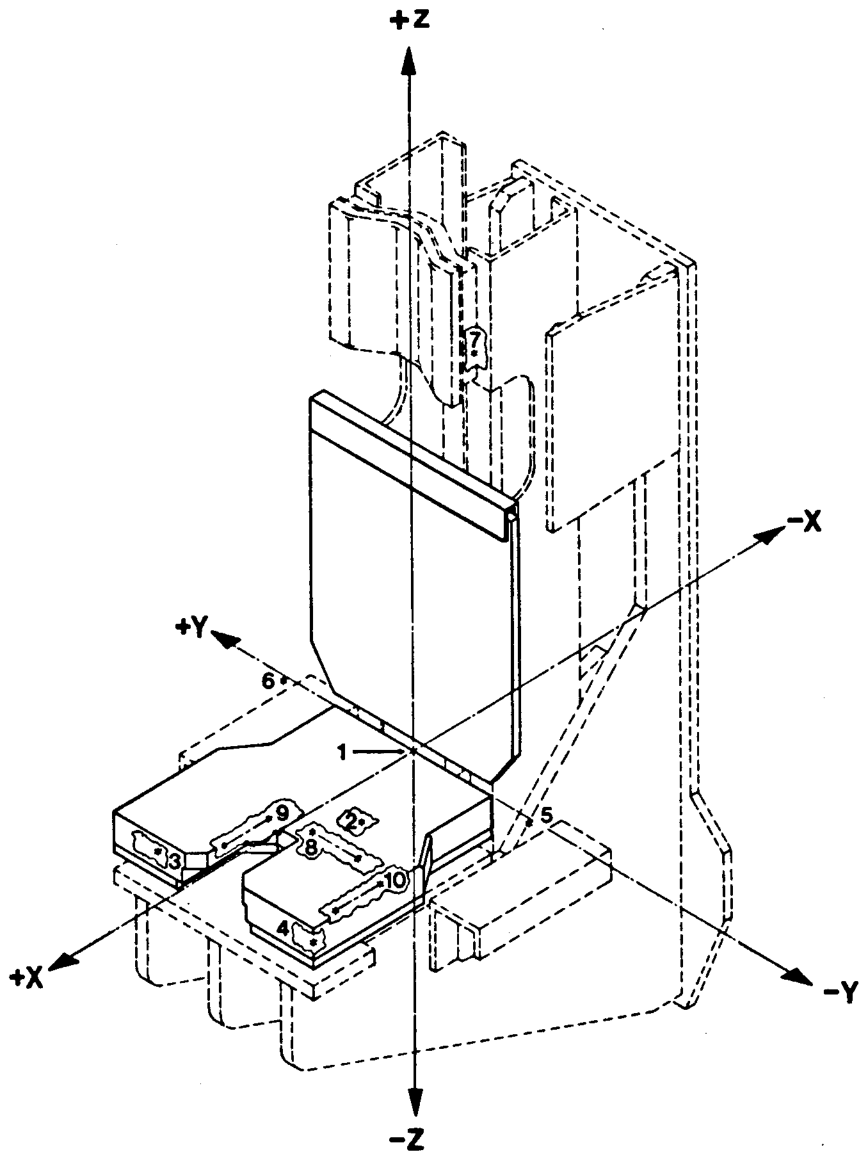


FIGURE A-4: LOAD TRANSDUCER LOCATIONS

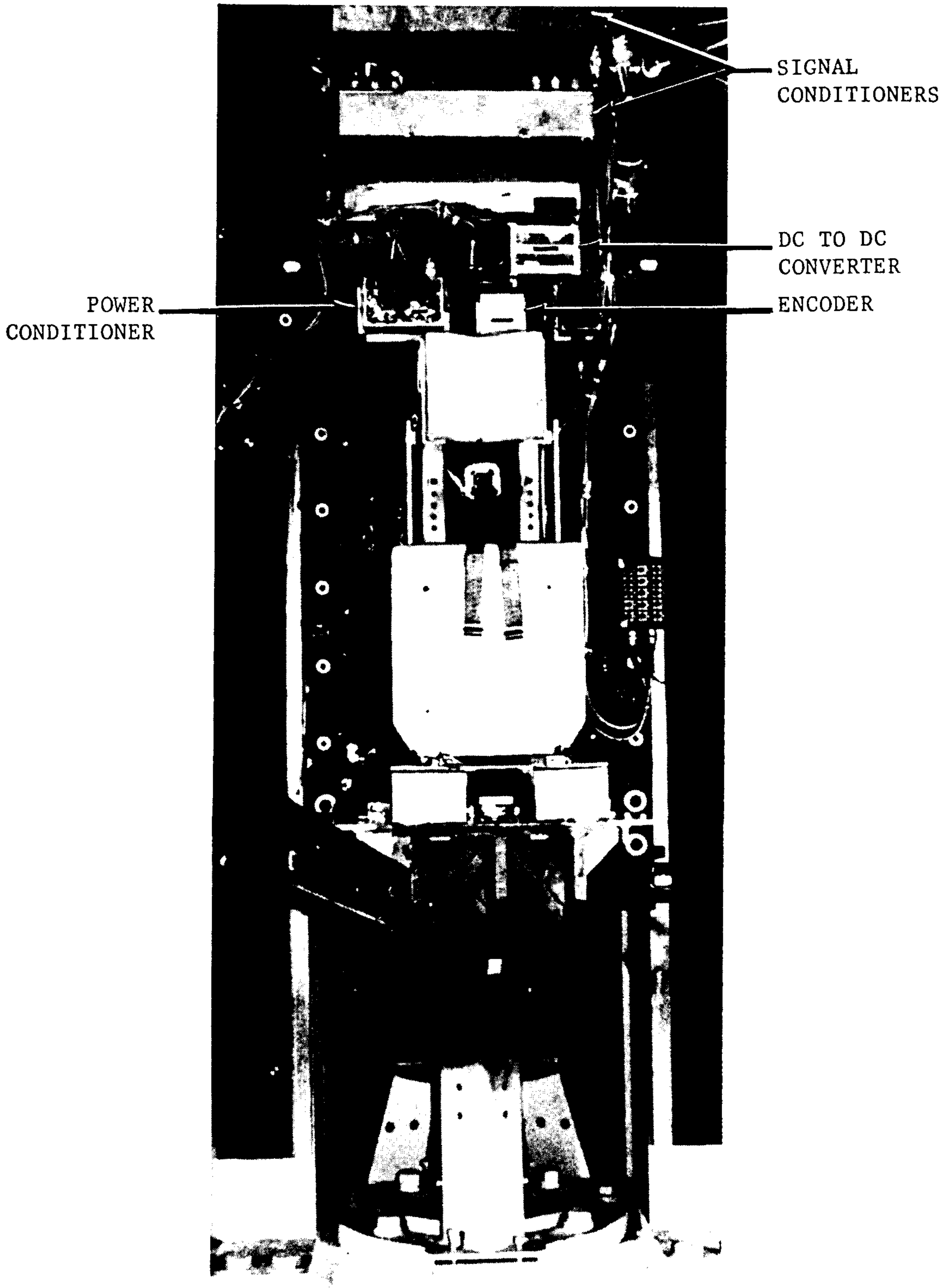


FIGURE A-6: ADACS INSTALLATION

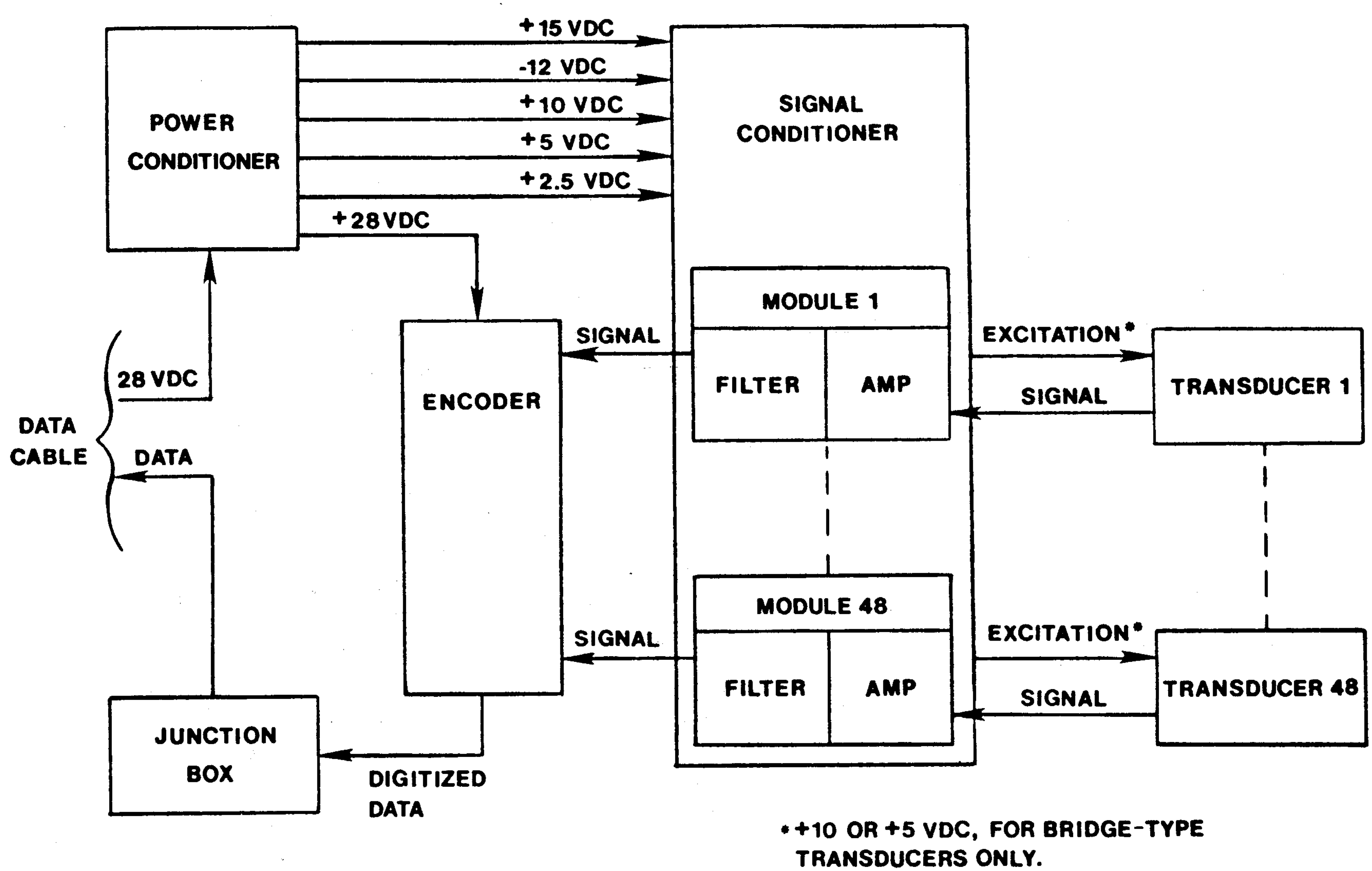


FIGURE A-7: AUTOMATIC DATA ACQUISITION AND CONTROL SYSTEM

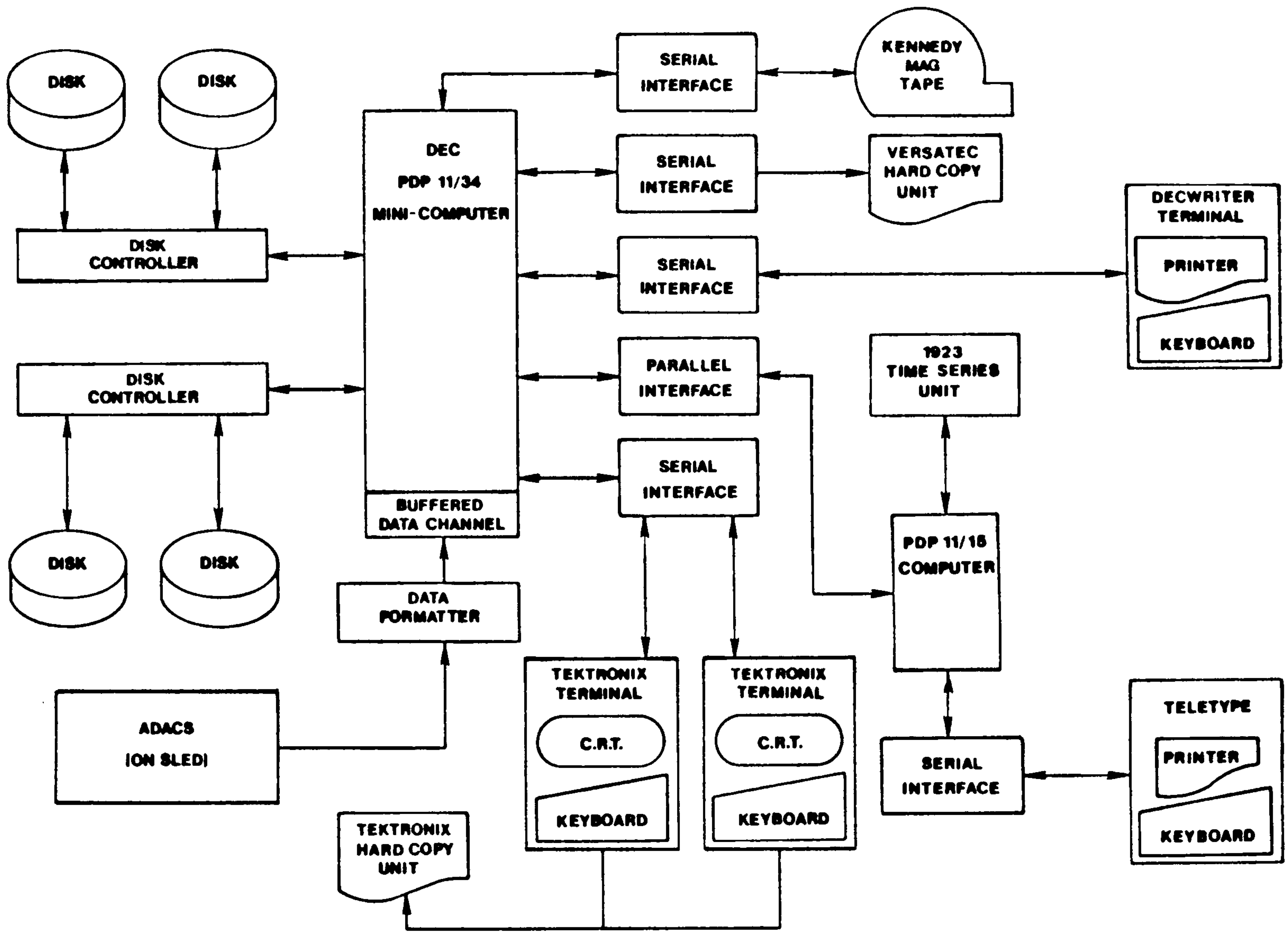


FIGURE A-8: DATA ACQUISITION AND STORAGE SYSTEM BLOCK DIAGRAM

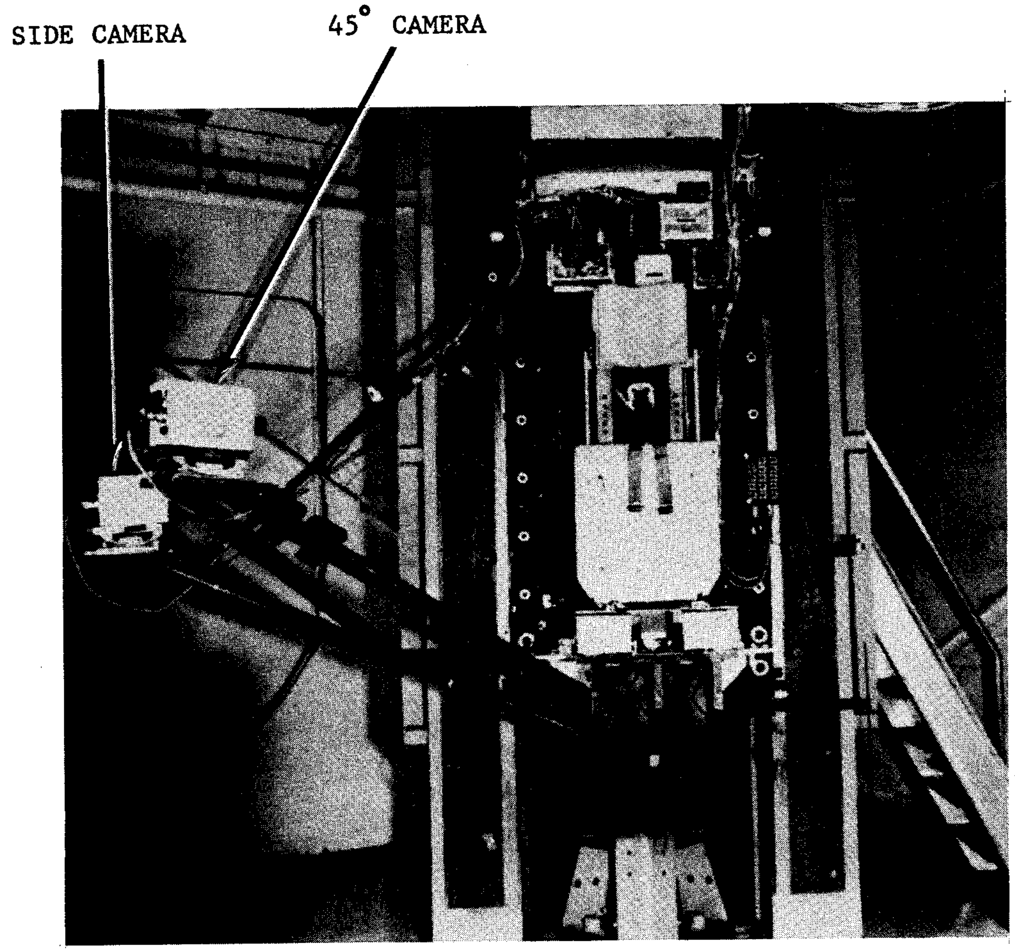
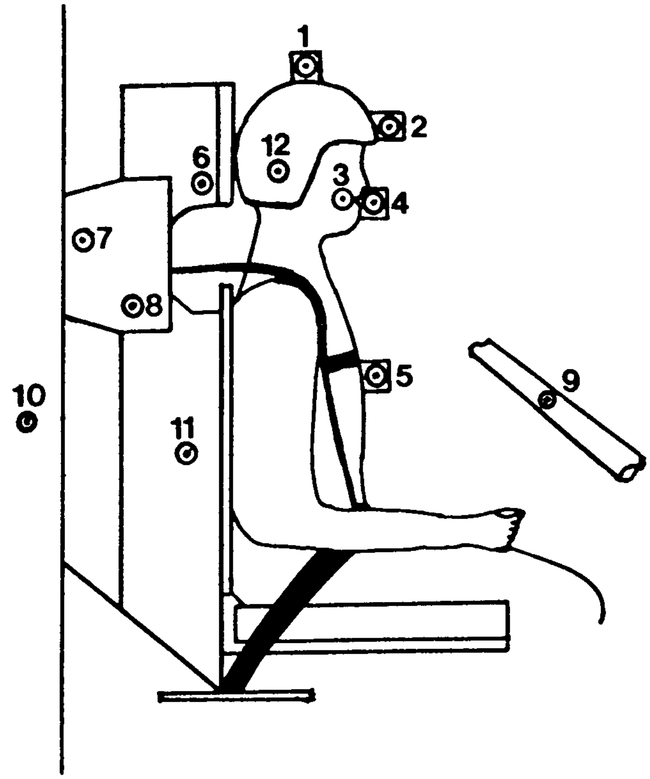


FIGURE A-9: ONBOARD CAMERA LOCATIONS



	DESCRIPTION	DIMENSIONS IN FEET x	y	z
1	UPPER HELMET	-	-	-
2	FRONTAL HELMET	-	-	-
3	CHEEK POINT	-	-	-
4	MOUTH PACK	-	-	-
5	CHEST PACK	-	-	-
* 6	HEAD REST	-0.2146	+0.5531	+2.7028
7	UPPER PLATE	-1.1780	+0.6846	+2.1052
* 8	LOWER PLATE	-0.6779	+0.6637	+1.8198
9	CAMERA STRUT	+1.7294	+2.3987	+2.2508
10	CARRIAGE	-1.3238	+0.6429	+0.9167
*11	SIDE RAIL	-0.5273	+0.5635	+0.9807
12	CENTER HELMET	-	-	-

* Fiducial target locations 6, 8 and 11 vary with respect to seat back angles. Below are x, y and z dimensions for seat back angles of +5, -5 and -10 degrees.

	DESCRIPTION	DIMENSIONS IN FEET x	y	z
	6 HEAD REST	-0.4465	+0.5531	+2.6823
$+5^{o}$	8 LOWER PLATE	-0.6693	+0.6663	+1.7813
	11 SIDE RAIL	-0.6099	+0.5635	+0.9318
	6 HEAD REST	+0.0230	+0.5531	+2.7161
-5^{o}	8 LOWER PLATE	-0.6726	+0.6689	+1.7729
	11 SIDE RAIL	-0.4423	+0.5635	+1.0214
	6 HEAD REST	+0.2618	+0.5531	+2.7036
-10^{o}	8 LOWER PLATE	-0.6654	+0.6689	+1.7969
	11 SIDE RAIL	-0.3580	+0.5635	+1.0531

All dimensions are referenced to the seat reference point (SRP). The seat reference point is located at the intersection of the horizontal seat plate (x axis) center line and the vertical back plate (z axis) center line.

FIGURE A-10: FIDUCIAL TARGET LOCATIONS

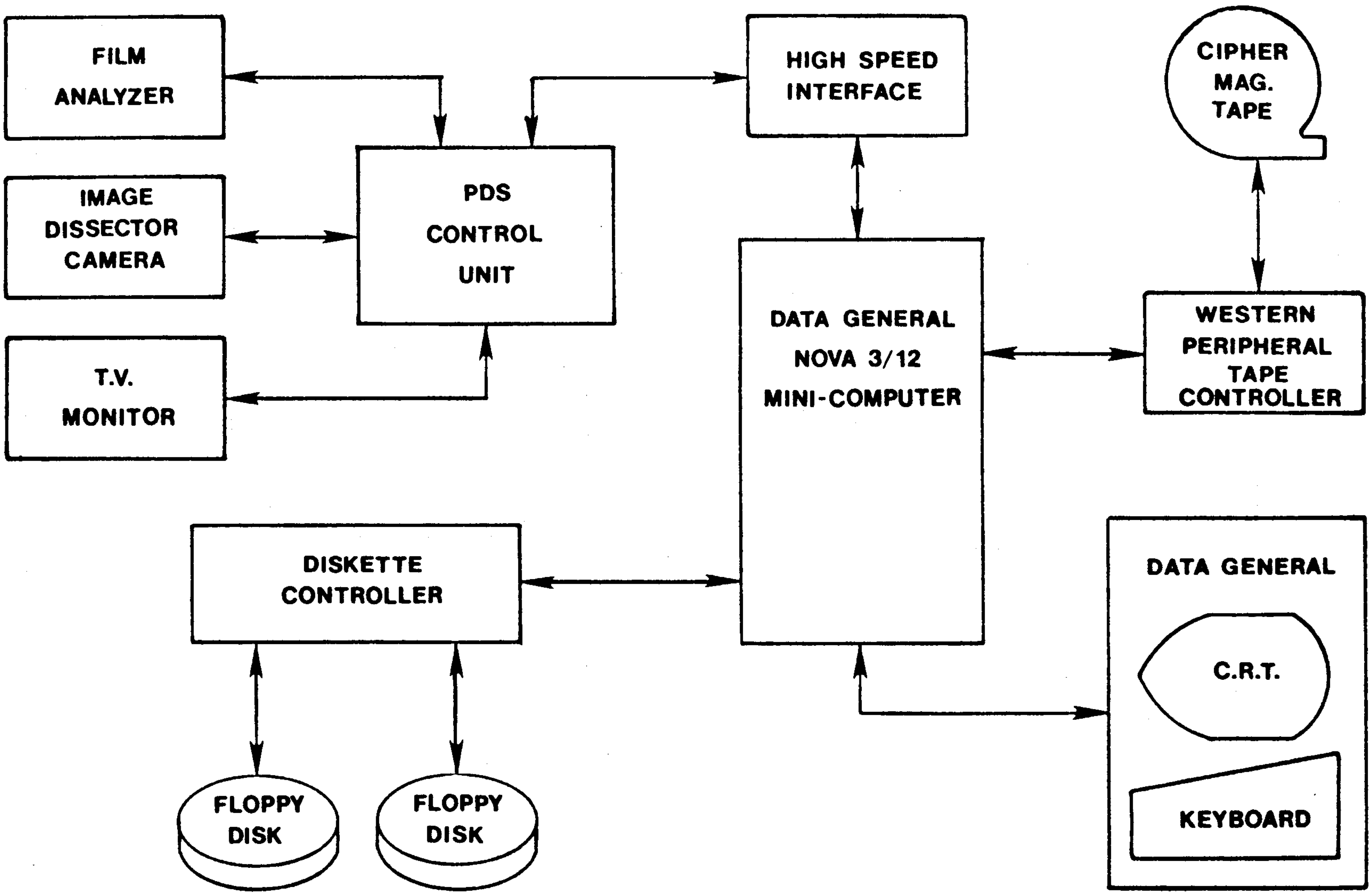


FIGURE A-11: AUTOMATIC FILM READER

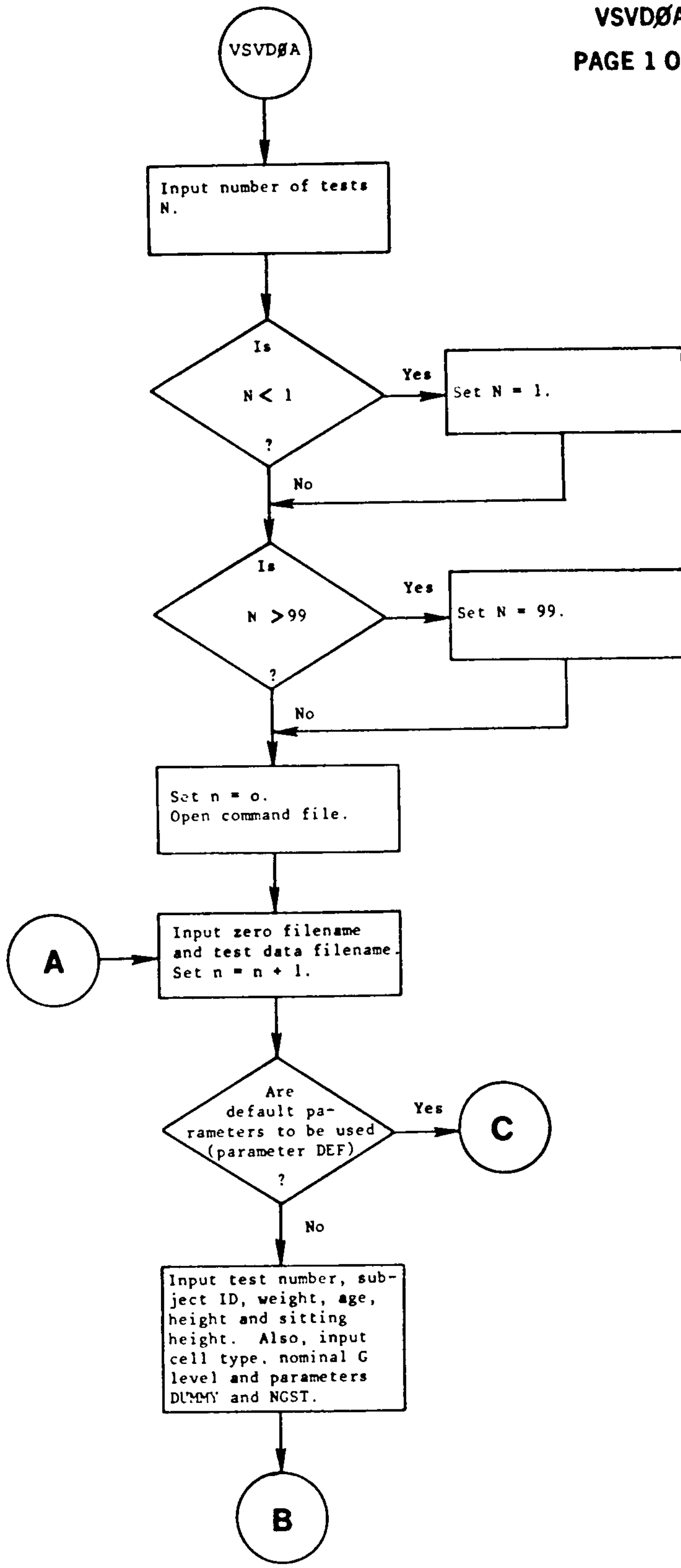


FIGURE A-12a: PROGRAM FLOWCHART FOR VSVDØA

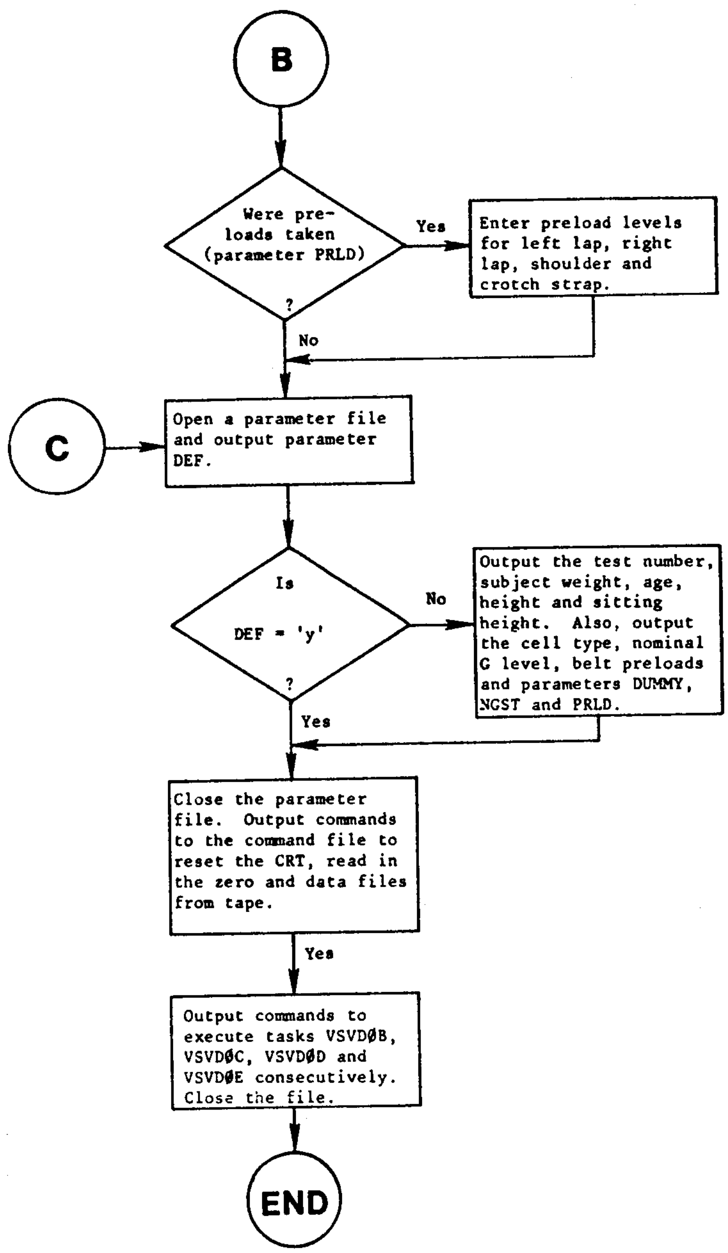


FIGURE A-12b: PROGRAM FLOWCHART FOR VSVDØA

VSVDØB

PAGE 1 OF 1

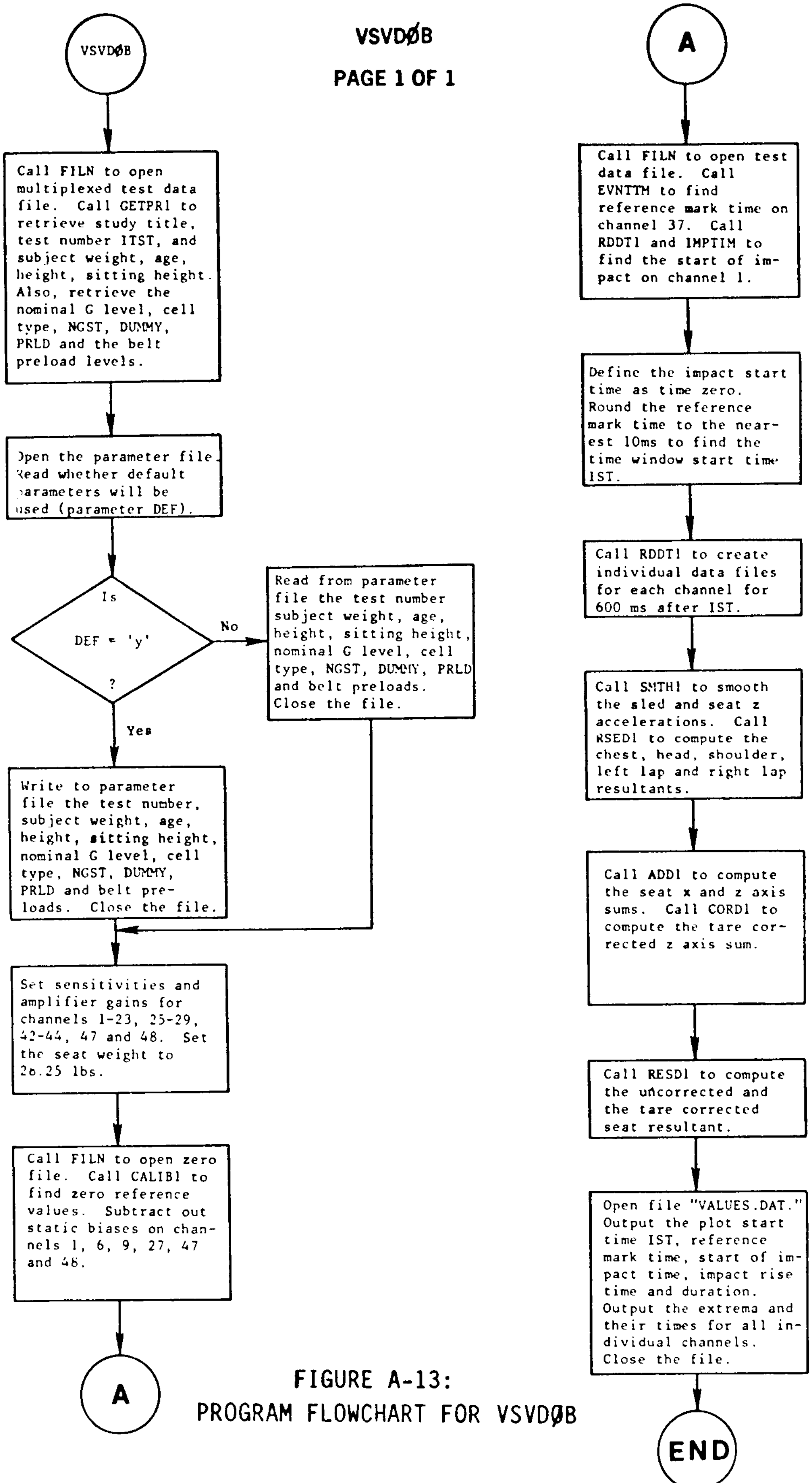
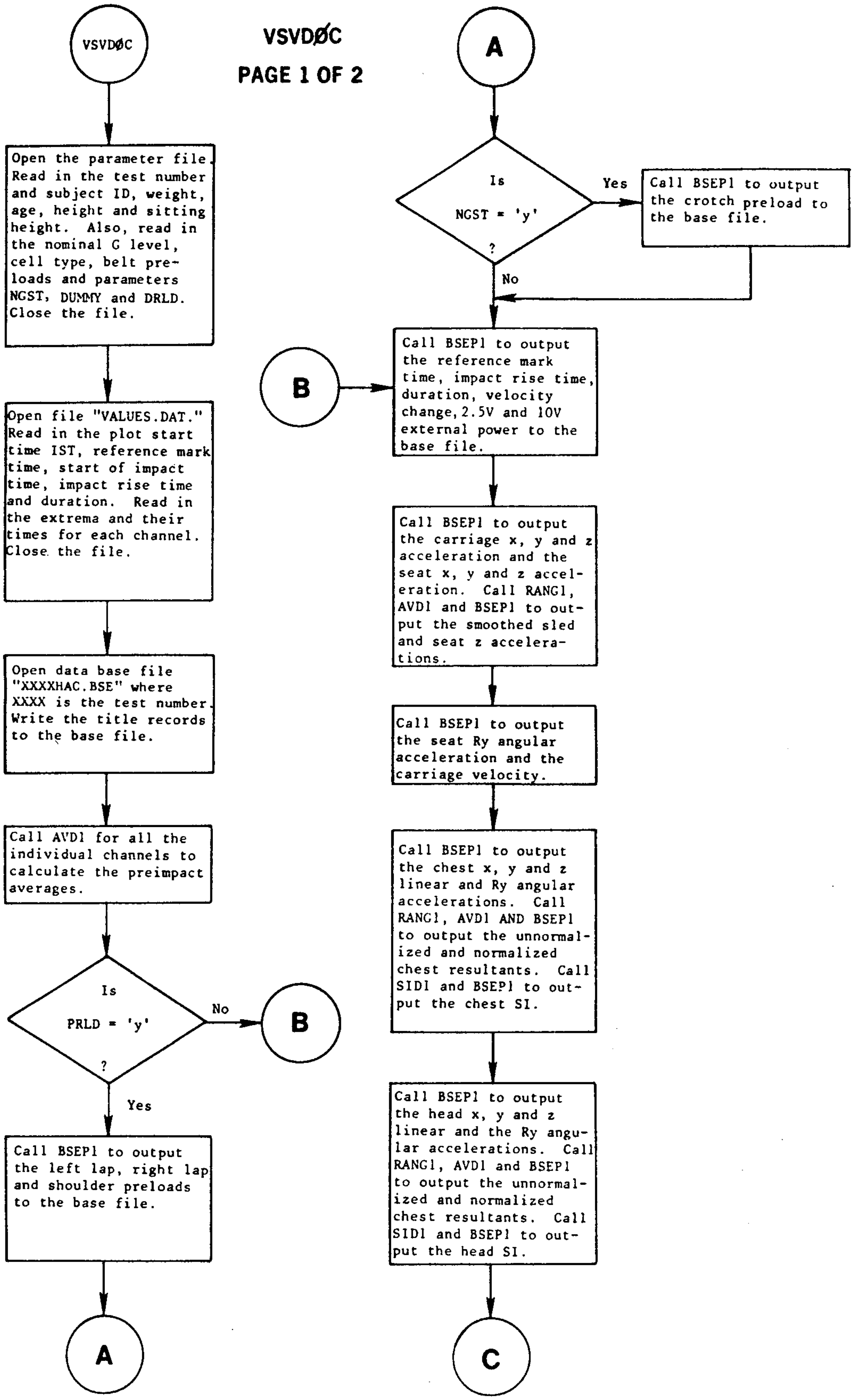


FIGURE A-13:
PROGRAM FLOWCHART FOR VSVDØB

FIGURE A-14a:
PROGRAM FLOWCHART FOR VSVDØC



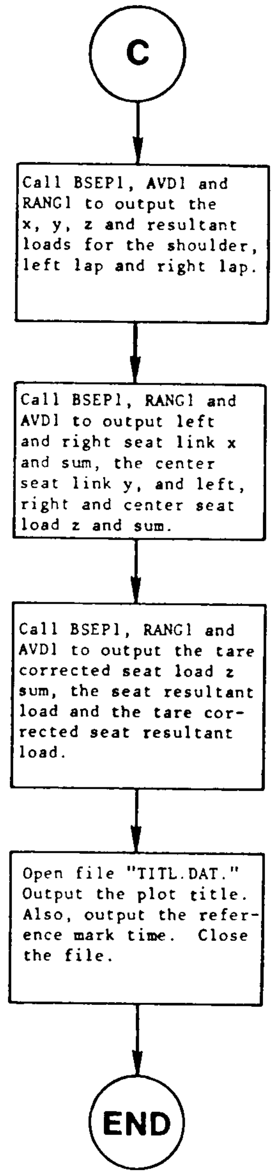


FIGURE A-14b: PROGRAM FLOWCHART FOR VSVDØC

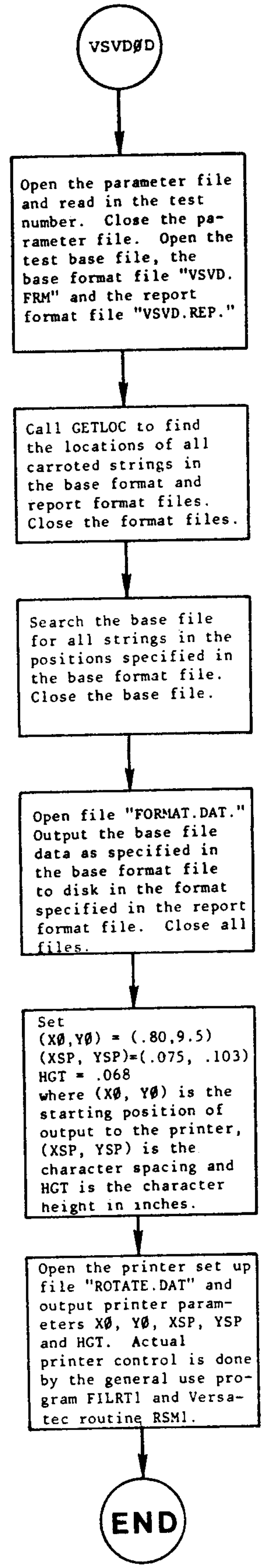


FIGURE A-15:
PROGRAM FLOWCHART FOR VSVDØD

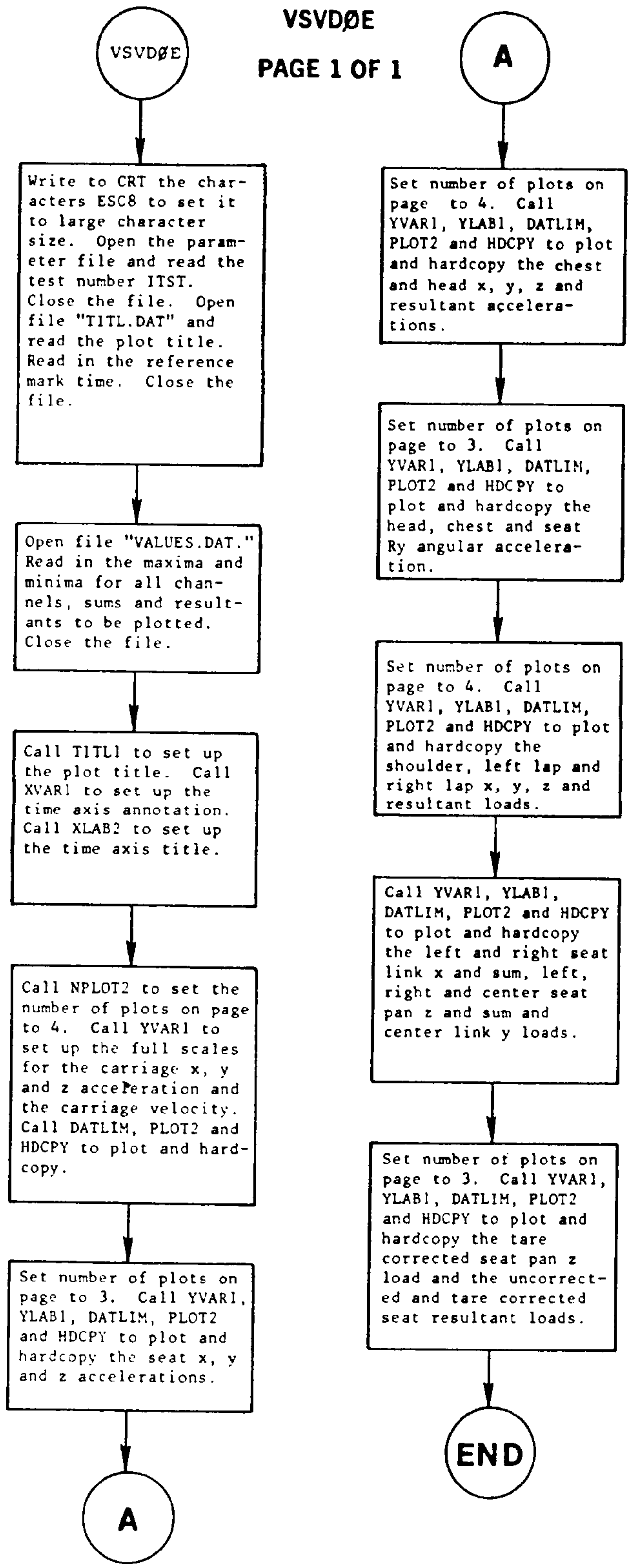


FIGURE A-16: PROGRAM FLOWCHART FOR VSVDØE

ADDENDUM

TEST CONFIGURATION AND DATA ACQUISITION SYSTEM FOR THE EFFECTS OF SEAT CUSHIONS AND SEAT BACK ANGLE ON HUMAN RESPONSE DURING +Gz IMPACT ACCELERATION

TEST PROGRAM

PHASE II

Prepared under
Contract F33615-86-C-0531

Prepared by
Marshall Z. Miller

DynCorp (formerly Dynalectron Corporation)
AAMRL Division
Building 824, Area B
Wright-Patterson AFB, Ohio 45433

June 1987

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

INTRODUCTION

This report was prepared by DynCorp (formerly Dynalectron Corporation) for the Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL/BBP) under Air Force Contract F33615-86-C-0531.

The information provided herein describes all of the instrumentation, calibration, seat cushion and processing program changes of Phase II (when compared to Phase I) of the Effects of Seat Cushions and Seat Back Angle on Human Response During +Gz Impact Acceleration Test Program. Where identical requirements exist for both Phases I and II of the test program, these requirements will not be described herein. One hundred forty-five tests were conducted for Phase II during November and December 1986 and January 1987 on the Vertical Deceleration Tower test facility.

This report is to be used as an addendum to the DynCorp November 1986 test report for Phase I of the Effects of Seat Cushions and Seat Back Angle on Human Response During +Gz Impact Acceleration Test Program.

1. INSTRUMENTATION CHANGES

The instrumentation changes as required by the Phase II Test Plan will be detailed in this section if they were different than required by the Phase I Test Plan. Identical instrumentation as required by both test plans will not be discussed.

Tables A-3a through A-3c list all of the measurement instrumentation used in Phase II of the test program. These tables designate the manufacturer, type, serial number, sensitivity and other pertinent data on each transducer used. Table A-4 lists the manufacturers' typical transducer specifications.

Human head accelerations were measured using three Endevco Model 7264-200 linear accelerometers and one Endevco Model 7302A angular (Ry) accelerometer in Phase II. The Endevco Model 2264-200 linear accelerometers used in Phase I are more prone to temperature drift and offset caused by wiring deflection. The angular accelerometer was not changed. Figure A-17 illustrates the human head acceleration package.

Human thoraxic accelerations measured in Phase II of the test program was not required to be measured in Phase I. Human thoraxic accelerations were measured using two Entran Model EGAXT-100 linear accelerometers for x and z accelerations and one Entran Model EGAXT-250 linear accelerometer for y accelerations. The accelerometers were mounted on a one inch diameter by 1/8 inch thick acrylic plastic pad and were attached to the subjects' intervertebral space between T-4 and T-5 with double-backed tape. Figure A-18 illustrates the human thoraxic acceleration package.

2. SEAT CUSHIONS

The Aces II seat cushion was the only one tested during Phase I of the test program. Figure A-19 illustrates the Aces II seat cushion installed on the VIP seat fixture.

Phase II of the test program included testing the Aces II, Operational F-4 and the Confor Foam F-4 seat cushions.

The Operational F-4 seat cushion uses a double layered contoured foam cushion with a contoured survival kit lid. Figures A-20 and A-21 illustrate the Operational F-4 seat cushion.

The Confor Foam F-4 seat cushion uses a single layer flat foam cushion with a flat survival kit lid. Figures A-22 and A-23 illustrate the Confor Foam F-4 seat cushion.

3. CALIBRATION

Calibrations were performed before and after testing to confirm the accuracy and functional characteristics of the transducers. Pre-program and post-program calibrations for Phase II of the test program are given in Tables A-5a through A-5d.

4. PROCESSING PROGRAMS

The Fortran processing programs that were developed to process the test data for Phase I of the test program are called "VSVDOA," "VSVDOB," "VSVDOC," "VSVDOD," and "VSVDOE." These processing programs were modified for Phase II of the test program to include current transducer sensitivities and the human thorax x, y, z and resultant accelerations.

DIGITAL INSTRUMENTATION REQUIREMENTS

DYNALECTRON CORPORATION

PROGRAM THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz ACCELERATION (PHASE II) **DATE** 21 NOV 86 **THRU** 15 JAN 87

FACILITY VERTICAL DECELERATION TOWER **RUN** 1215 **THRU** 1359

DATA CHANNEL	DATA POINT	XDUCER MFG & TYPE	S/N	XDUCER SENS	EXCITE V	CHAN	FILTER SERIES	FILTER S/N	AMP GAIN	AMP S/N	SAMPLE RATE	FORMAT	F.S. SENS	FILTER HZ	XDUCER ZERO	RANGE	BRIDGE BALANCE RESISTORS	BRIDGE COMPLETION RESISTORS	SPECIAL NOTATIONS
1	CARRIAGE Z	ENDEVCO 2262A-200	FR42	4.196 mv/G	10.00	1	60	1	25	29	1K	1	23.8 G	120	2.5	+5.0 0.0	375K -in Gd.	-	
2	CARRIAGE X	ENDEVCO 2264-200	BX17	2.759 mv/G	10.00	2	60	2	100	5	1K	1	9.06 G	120	2.5	+5.0 0.0	43K +in Gd.	1.58K	
3	CARRIAGE Y	ENDEVCO 7264-200	BH97H	2.783 mv/G	10.00	3	60	3	100	4	1K	1	9.0 G	120	2.5	+5.0 0.0	-	1.5K	
4	HEAD X	ENDEVCO 7264-200	BH58H	2.592 mv/G	10.00	4	60	4	50	23	1K	1	19.3 G	120	2.5	+5.0 0.0	-	1.5K	
5	HEAD Y	ENDEVCO 7264-200	BH60H	2.814 mv/G	10.00	5	60	5	50	27	1K	1	17.8 G	120	2.5	+5.0 0.0	-	1.5K	
6	HEAD Z	ENDEVCO 7264-200	BH63H	2.492 mv/G	10.00	6	60	6	25	10	1K	1	40.1 G	120	2.5	+5.0 0.0	-	1.5K	
7	CHEST X	ENDEVCO 2264-150	BC26	2.795 mv/G	10.00	7	60	7	50	2	1K	1	17.9 G	120	2.5	+5.0 0.0	1.2M -in Gd.	1.65K	
8	CHEST Y	ENDEVCO 2264-150	BB13	2.435 mv/G	10.00	8	60	8	100	37	1K	1	10.3 G	120	2.5	+5.0 0.0	-	1.65K	
9	CHEST Z	ENDEVCO 2264-150	2A20	2.629 mv/G	10.00	9	60	9	25	34	1K	1	38.0 G	120	2.5	+5.0 0.0	156K -in Gd.	1.65K	
10	LEFT SEAT LOAD	STRAINSERT FL2.5u-2SPKT	3294-1	8.02 uv/1b	10.00	10	60	10	201	1	1K	1	1551 1b	120	2.5	+5.0 0.0	-	-	
11	RIGHT SEAT LOAD	STRAINSERT FL2.5u-2SPKT	3294-2	8.03 uv/1b	10.00	11	60	11	201	3	1K	1	1550 1b	120	2.5	+5.0 0.0	-	-	
12	CENTER SEAT LOAD	STRAINSERT FL2.5u-2SPKT	3294-4	8.08 uv/1b	10.00	12	60	12	100	3	1K	1	3094 1b	120	2.5	+5.0 0.0	-	-	
13	LEFT LOAD LINK X	MM/DYN EA06-062 TJ-350	2	10.32 uv/1b	10.00	13	60	13	402	13	1K	1	603 1b	120	2.5	+5.0 0.0	-	-	
14	RIGHT LOAD LINK X	MM/DYN EA06-062 TJ-350	3	10.68 uv/1b	10.00	14	60	14	402	5	1K	1	582 1b	120	2.5	+5.0 0.0	24K -in Gd.	-	

CELL A-H SEAT WEIGHT - 28.25 1b
CELL I SEAT WEIGHT - 29.75 1b
CELL J SEAT WEIGHT - 27.5 1b

PAGE 1 OF 3

TABLE A-3a: INSTRUMENTATION REQUIREMENTS

DIGITAL INSTRUMENTATION REQUIREMENTS

DYNALECTRON CORPORATION

PROGRAM THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz ACCELERATION (PHASE II) DATE 21 NOV 86 THRU 15 JAN 87

FACILITY VERTICAL DECELERATION TOWER RUN 1215 THRU 1359

DATA CHANNEL	DATA POINT	XDUCER MFG & TYPE	S/N	XDUCER SENS	EXCITE V	CHAN	FILTER SERIES	S/N	AMP GAIN	S/N	SAMPLE RATE	FORMAT	F.S. SENS	FILTER HZ	XDUCER ZERO	RANGE	BRIDGE BALANCE RESISTORS	BRIDGE COMPLETION RESISTORS	SPECIAL NOTATIONS
15	LEFT LAP LOAD X	GM-3D-SW	15X	5.35 uv/lb	10.00	15	60	15	402	4	1K	1	1162 lb	120	2.5	+5.0 0.0	16K +in Gd.	-	
16	LEFT LAP LOAD Y	GM-3D-SW	15Y	5.32 uv/lb	10.00	16	60	16	800	4	1K	1	587 lb	120	2.5	+5.0 0.0	18K +in Gd.	-	
17	LEFT LAP LOAD Z	GM-3D-SW	15Z	6.30 uv/lb	10.00	17	60	17	402	18	1K	1	987 lb	120	2.5	+5.0 0.0	5K +in Gd.	-	
18	RIGHT LAP LOAD X	GM-3D-SW	21X	5.04 uv/lb	10.00	18	60	18	402	11	1K	1	1234 lb	120	2.5	+5.0 0.0	69K -in Gd.	-	
19	RIGHT LAP LOAD Y	GM-3D-SW	21Y	4.83 uv/lb	10.00	19	60	19	800	1	1K	1	647 lb	120	2.5	+5.0 0.0	17K +in Gd.	-	
20	RIGHT LAP LOAD Z	GM-3D-SW	21Z	6.09 uv/lb	10.00	20	60	20	402	6	1K	1	1021 lb	120	2.5	+5.0 0.0	27K -in Gd.	-	
21	SHOULDER LOAD X	GM-3D-SW	20Z	6.30 uv/lb	10.00	21	60	21	402	10	1K	1	987 lb	120	2.5	+5.0 0.0	46K -in Gd.	-	
22	SHOULDER LOAD Y	GM-3D-SW	20Y	5.81 uv/lb	10.00	22	60	22	800	5	1K	1	538 lb	120	2.5	+5.0 0.0	178K +in Gd.	-	
23	SHOULDER LOAD Z	GM-3D-SW	20X	5.58 uv/lb	10.00	23	60	23	402	8	1K	1	1115lb	120	2.5	+5.0 0.0	29K +in Gd.	-	
25	SEAT X ACCEL.	ENDEVCO 2264-150	BB28	2.700 mv/G	10.00	25	60	25	50	3	1K	1	18.5 G	120	2.5	+5.0 0.0	72.4K +in Gd.	1.65K	
26	SEAT Y ACCEL.	ENDEVCO 2264-200	BV95	2.981 mv/G	10.00	26	60	26	50	15	1K	1	16.8 G	120	2.5	+5.0 0.0	372K +in Gd.	1.47K	
27	SEAT Z ACCEL.	ENDEVCO 2264-200	BW07	2.824 mv/G	10.00	27	60	27	50	1	1K	1	17.7 G	120	2.5	+5.0 0.0	294K -in Gd.	1.47K	
28	CENTER LOAD LINK Y	MM/DYN EA-06-062 TJ-350	5	9.82 uv/lb	10.00	28	60	28	402	7	1K	1	633 lb	120	2.5	+5.0 0.0	-	-	
29	VEL. TACH.	GLOBE 22A672-2	4	.06209 V/F/S	-	29	30	1	1	-	1K	1	80.5 FT/SEC	60	0.0	+5.0 0.0	-	-	

PAGE 2 OF 3

TABLE A-3b: INSTRUMENTATION REQUIREMENTS

DIGITAL INSTRUMENTATION REQUIREMENTS

DYNALECTRON CORPORATION

PROGRAM: THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz ACCELERATION (PHASE II) DATE 21 NOV 86 THRU 15 JAN 87

FACILITY: VERTICAL DECELERATION TOWER RUN 1215 THRU 1359

DATA CHANNEL	DATA POINT	XDUCER MFG & TYPE	S/N	XDUCER SENS	EXCITE V	CHAN	FILTER SERIES	FILTER S/N	AMP GAIN	AMP S/N	SAMPLE RATE	FORMAT	F.S. SENS	FILTER HZ	XDUCER ZERO	RANGE	BRIDGE BALANCE RESISTORS	BRIDGE COMPLETION RESISTORS	SPECIAL NOTATIONS
30	DUMMY HEAD X	ENDEVCO 2264-200	CH74	2.939 mv/G	10.00	30	60	41	50	9	1K	1	17.0 G	120	2.5	+5.0 0.0	190K +in Gd.	1.65K	
31	DUMMY HEAD Y	ENDEVCO 2264-200	BQ42	2.740 mv/G	10.00	31	60	31	50	5	1K	1	18.2 G	120	2.5	+5.0 0.0	220K +in Gd.	1.65K	
32	DUMMY HEAD Z	ENDEVCO 2264-200	CH70	2.676 mv/G	10.00	32	60	32	25	18	1K	1	37.4 G	120	2.5	+5.0 0.0	80K +in Gd.	1.65K	
33	DUMMY HEAD ANG	ENDEVCO 7302	A150	8.26 uv/RAD/SEC^2	10.00	33	60	33	100	11	1K	1	3027 RAD/SEC^2	120	2.5	+5.0 0.0	-	-	
34	THORAX X	ENTRAN EGAXT-100	12Q6S-L1-1	1.005 mv/G	10.00	34	60	34	100	30	1K	1	24.9 G	120	2.5	+5.0 0.0	-	-	
35	THORAX Y	ENTRAN EGAXT-250	12Q6S-L 14-14	.500 mv/G	10.00	35	60	35	201	14	1K	1	24.9 G	120	2.5	+5.0 0.0	-	-	
36	THORAX Z	ENTRAN EGAXT-100	29T6U-A 18-18	1.019 mv/G	10.00	36	60	36	50	26	1K	1	49.1 G	120	2.5	+5.0 0.0	-	-	
37	EVENT	-	-	-	-	37	1000	13	2.5	7	1K	1	5.0 Volt	2000	5.0	+5.0 0.0	-	-	
38	T=0 PULSE	-	-	-	-	38	1000	16	1	-	1K	1	5.0 Volt	2000	0	+5.0 0.0	-	-	
42	HEAD RY ANGULAR	ENDEVCO 7302A	AB12	4.20 uv/RAD/SEC^2	10.00	42	60	42	201	10	1K	1	2961 RAD/SEC^2	120	2.5	+5.0 0.0	-	-	
43	CHEST RY ANGULAR	ENDEVCO 7302A	AB15	6.76 uv/RAD/SEC^2	10.00	43	60	43	201	5	1K	1	1840 RAD/SEC^2	120	2.5	+5.0 0.0	450K -in Gd.	-	
44	SEAT RY ANGULAR	ENDEVCO 7302B	PT47	3.732 uv/RAD/SEC^2	10.00	44	60	44	402	12	1K	1	1666 RAD/SEC^2	120	2.5	+5.0 0.0	-	-	
47	2.5 Volt Bias	-	-	-	-	47	180	14	1	-	1K	1	2.5 Volt	360	2.5	+5.0 0.0	-	-	
48	10 Volt Exc.	-	-	-	-	48	180	19	1	-	1K	1	2.5 Volt	360	2.5	+5.0 0.0	-	-	

PAGE 3 OF 3

TABLE A-3c: INSTRUMENTATION REQUIREMENTS

TYPICAL TRANSDUCER SPECIFICATIONS

MANUFACTURER	MODEL	RANGE	SENSITIVITY (mv)	RESONANCE FREQ (Hz)	FREQUENCY RESPONSE (Hz.)	EXCITATION (Volt)	2 ARM or 4 ARM	ADDITIONAL NOTES
Endevco	2264-150	±150 G	2.5/G	3400	0-800	10	2 arm	Linear accelerometer
Endevco	2264-200	±200 G	2.5/G	4700	0-1200	10	2 arm	Linear accelerometer
Endevco	7264-200	±200 G	2.5/G	6000	0-1000	10	2 arm	Linear accelerometer 1000 G overrange
Endevco	2262A-200	±200 G	2.5/G	7000	0-1800	10	4 arm	Linear accelerometer, .7 damping ratio
Endevco	7302	±50,000 Rad/Sec2	.006 /Rad/Sec2	2250	1-600	10	4 arm	Angular Accelerometer, X10 overrange; housing connector
Endevco	7302A	±50,000 Rad/Sec2	.055 /Rad/Sec2	2500	1-600	10	4 arm	Angular accelerometer, X10 overrange
Endevco	7302B	±50,000 Rad/Sec2	.004 /Rad/Sec2	3000	1-600	10	4 arm	Angular accelerometer, X10 overrange
Entran	EGAXT-100	±100 G	2.0/G	1700	0-800	10	4 arm	Linear accelerometer; 10 KG overrange, .7 damping ratio
Entran	EGAXT-250	±250 G	1.0/G	2000	0-1000	10	4 arm	Linear accelerometer; 10 KG overrange, .7 damping ratio
Strainsert	FL2.5U-2SPKT	±2500 Lb	.008/Lb	3600	0-2000	10	4 arm	Load cell; 15 V max exc.; 5 K LB max. overrange

TABLE A-4: TYPICAL TRANSDUCER SPECIFICATIONS

PROGRAM CALIBRATION LOG

PROGRAM: VSBA II **DATES:** 21 NOV 86-15 JAN 87

FACILITY: VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1215-1359

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% CHANGE	NOTES
			DATE	SENS	DATE	SENS		
CARRIAGE Z	ENDEVCO 2262A-200	FR42	18NOV86	4.196	20JAN87	4.171	-.6	
CARRIAGE X	ENDEVCO 2264-200	BX17	18NOV86	2.759	20JAN87	2.779	+.7	
CARRIAGE Y	ENDEVCO 7264-200	BH97H	18NOV86	2.783	20JAN87	2.781	-.1	
HEAD X	ENDEVCO 7264-200	BH58H	18NOV86	2.592	21JAN87	2.595	+.1	
HEAD Y	ENDEVCO 7264-200	BH60H	18NOV86	2.814	21JAN87	2.803	-.4	
HEAD Z	ENDEVCO 7264-200	BH63H	18NOV86	2.492	21JAN87	2.492	0	
CHEST X	ENDEVCO 2264-150	BC26	14OCT86	2.795	21JAN87	2.792	-.1	
CHEST Y	ENDEVCO 2264-150	BE13	15OCT86	2.435	21JAN87	2.443	+.3	
CHEST Z	ENDEVCO 2264-150	2A20	15OCT86	2.629	21JAN87	2.664	+.2	
								All sensitivities in units of mv/G

Page 1 of 4

TABLE A-5a: TRANSDUCER PRE- AND POST-CALIBRATION

PROGRAM CALIBRATION LOG

PROGRAM: VSBA II **DATES:** 21 NOV 86-15 JAN 87

FACILITY: VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1215-1359

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% CHANGE	NOTES
			DATE	SENS	DATE	SENS		
LEFT LOAD LINK X	MM/DYN EA-06-062TJ-350	2	13NOV86	10.32	15JAN87	10.35	+.3	
RIGHT LOAD LINK X	MM/DYN EA-06-062TJ-350	3	13NOV86	10.68	15JAN87	10.66	-.2	
CENTER LOAD LINK Y	MM/DYN EA-06-062TJ-350	5	13NOV86	9.82	15JAN87	9.86	+.4	
LEFT LAP LOAD X	GM-3D-SW	15X	13NOV86	5.35	16JAN87	5.36	+.2	
LEFT LAP LOAD Y	GM-3D-SW	15Y	13NOV86	5.32	16JAN87	5.32	0	
LEFT LAP LOAD Z	GM-3D-SW	15Z	13NOV86	6.30	16JAN87	6.33	+.5	
RIGHT LAP LOAD X	GM-3D-SW	21X	13NOV86	5.04	16JAN87	5.04	0	
RIGHT LAP LOAD Y	GM-3D-SW	21Y	13NOV86	4.83	16JAN87	4.80	-.6	
RIGHT LAP LOAD Z	GM-3D-SW	21Z	13NOV86	6.09	16JAN87	6.05	-.2	
SHOULDER LOAD X	GM-3D-SW	20Z	14NOV86	6.30	16JAN87	6.29	-.2	All sensitivitie in units of uv/lb

Page 2 of 4

TABLE A-5b: TRANSDUCER PRE- AND POST-CALIBRATION

PROGRAM CALIBRATION LOG

PROGRAM: VSBA II **DATES:** 21 NOV 86-15 JAN 87

FACILITY: VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1215-1359

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% CHANGE	NOTES
			DATE	SENS	DATE	SENS		
SHOULDER LOAD Y	GM-3D-SW	20Y	14NOV86	5.81	16JAN87	5.73	-1.2	
SHOULDER LOAD Z	GM-3D-SW	20X	14NOV86	5.58	16JAN87	5.57	-.2	
HEAD RY ANGULAR	ENDEVCO 7302A	AB12	19NOV86	4.20 $\mu v/RAD/SEC^2$	22JAN87	4.22 $\mu v/RAD/SEC^2$	+.4	
CHEST RY ANGULAR	ENDEVCO 7302A	AB15	19NOV86	6.76 $\mu v/RAD/SEC^2$	22JAN87	6.81 $\mu v/RAD/SEC^2$	+.8	
SEAT RY ANGULAR	ENDEVCO 7302B	PT47	22AUG86	3.732 $\mu v/RAD/SEC^2$	22JAN87	3.719 $\mu v/RAD/SEC^2$	-.3	
								Unless noted otherwise, all sens. in units of uv/lb.

Page 3 of 4

TABLE A-5c: TRANSDUCER PRE- AND POST-CALIBRATION

PROGRAM CALIBRATION LOG

PROGRAM: VSBA II **DATES:** 21 NOV 86-15 JAN 87

FACILITY: VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1215-1359

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% CHANGE	NOTES
			DATE	SENS	DATE	SENS		
SEAT X ACCELERATION	ENDEVCO 2264-150	BB28	18NOV86	2.700	20JAN87	2.714	+.5	
SEAT Y ACCELERATION	ENDEVCO 2264-200	BV95	18NOV86	2.981	20JAN87	2.979	-.1	
SEAT Z ACCELERATION	ENDEVCO 2264-200	BW07	18NOV86	2.824	20JAN87	2.835	+.4	
DUMMY HEAD X	ENDEVCO 2264-200	CH74	22AUG86	2.939	21JAN87	2.943	+.1	
DUMMY HEAD Y	ENDEVCO 2264-200	BQ42	22AUG86	2.740	21JAN87	2.736	-.1	
DUMMY HEAD Z	ENDEVCO 2264-200	CH70	22AUG86	2.676	21JAN87	2.690	+.5	
DUMMY HEAD ANGULAR	ENDEVCO 7302	A150	19NOV86	8.257 uv/RAD/SEC^2	22JAN87	8.154 uv/RAD/SEC^2	-1.2	
								Unless noted otherwise, all
								sens. in units of mv/G.

Page 4 of 4

TABLE A-5d: TRANSDUCER PRE- AND POST-CALIBRATION

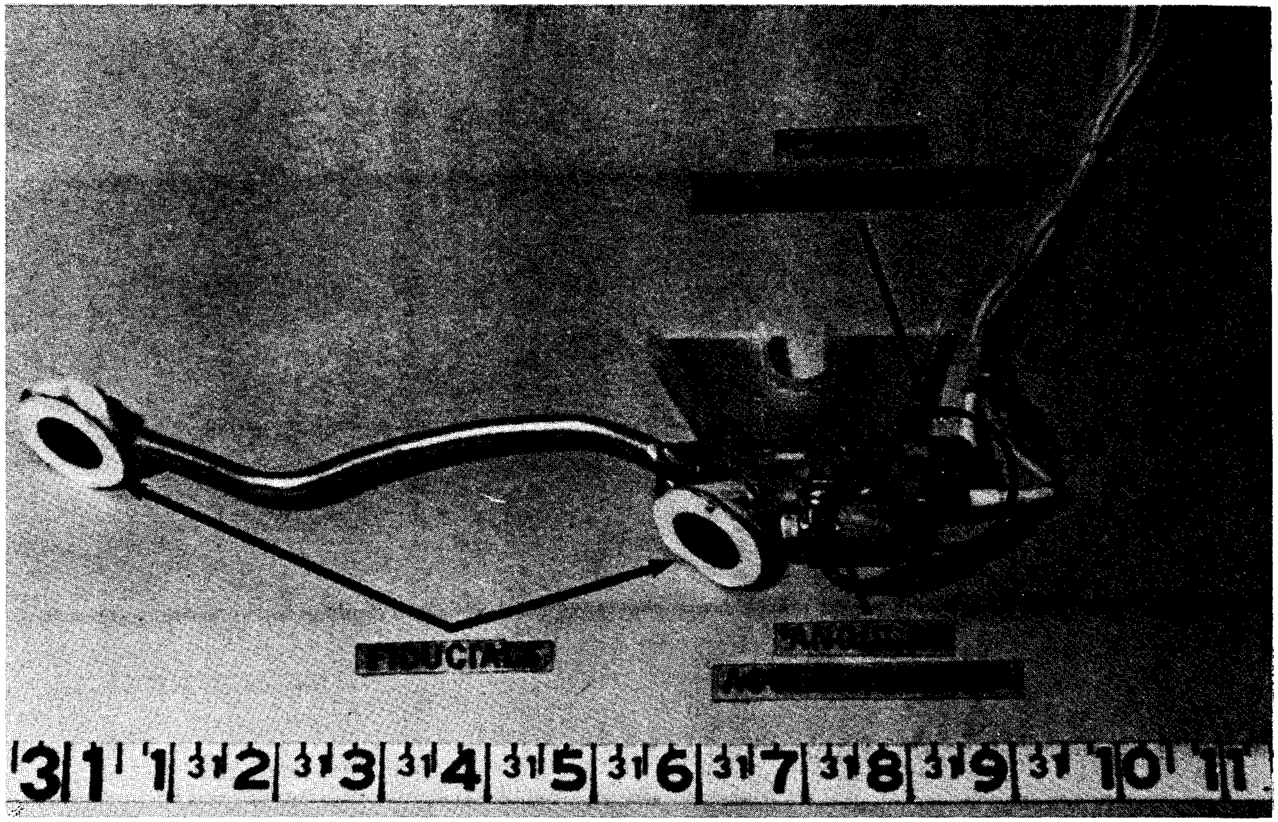


FIGURE A-17: HUMAN HEAD ACCELERATION PACKAGE

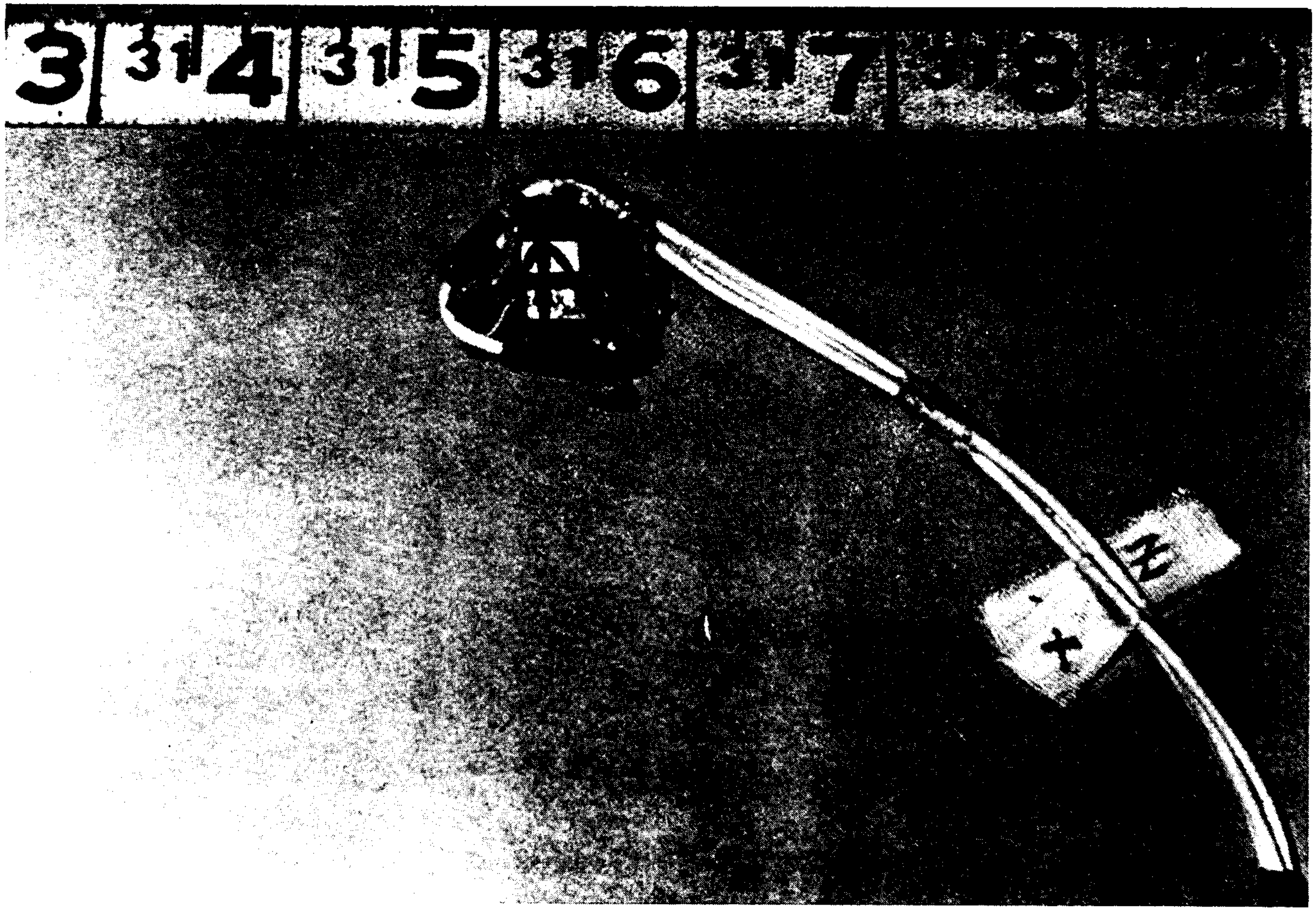


FIGURE A-18: HUMAN THORAXIC ACCELERATION PACKAGE

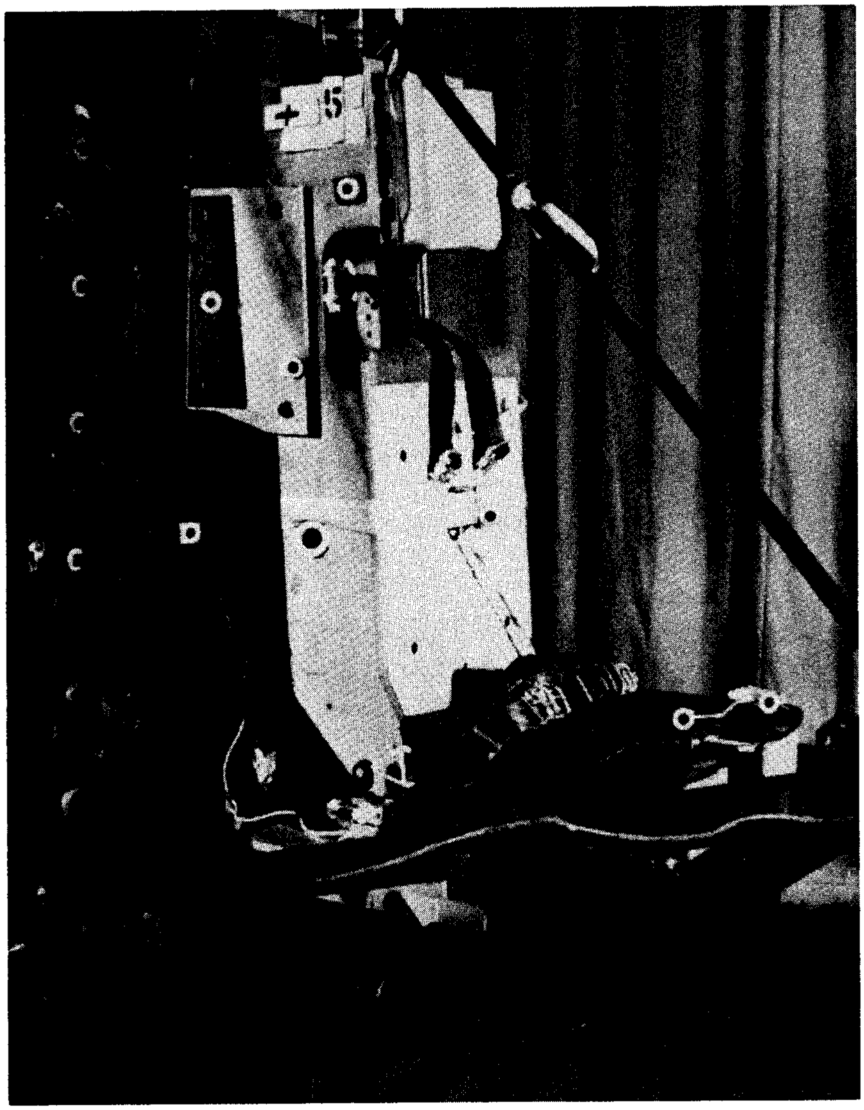


FIGURE A-19: ACES II SEAT CUSHION

FIGURE A-20: OPERATIONAL F-4 SEAT CUSHION

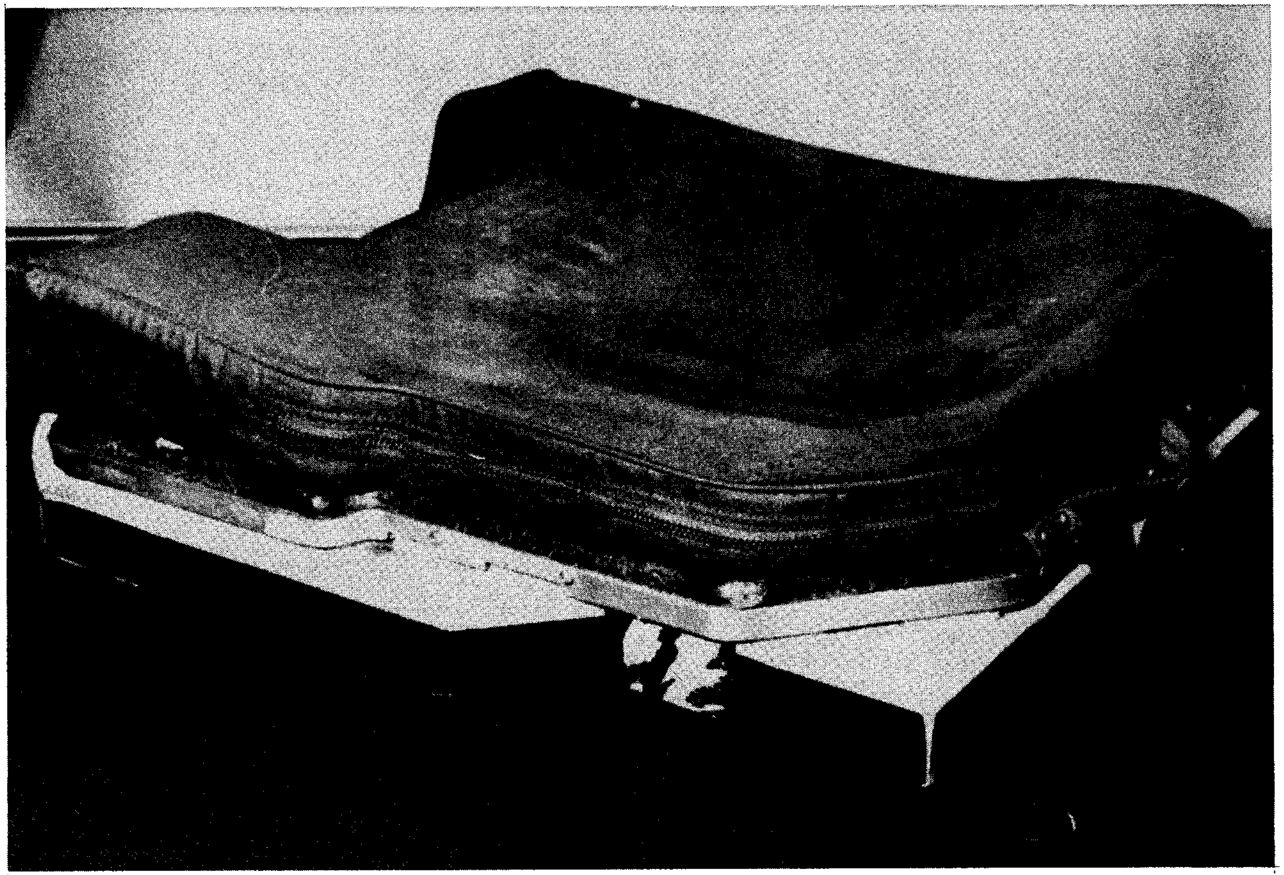


FIGURE A-21: OPERATIONAL F-4 SEAT CUSHION

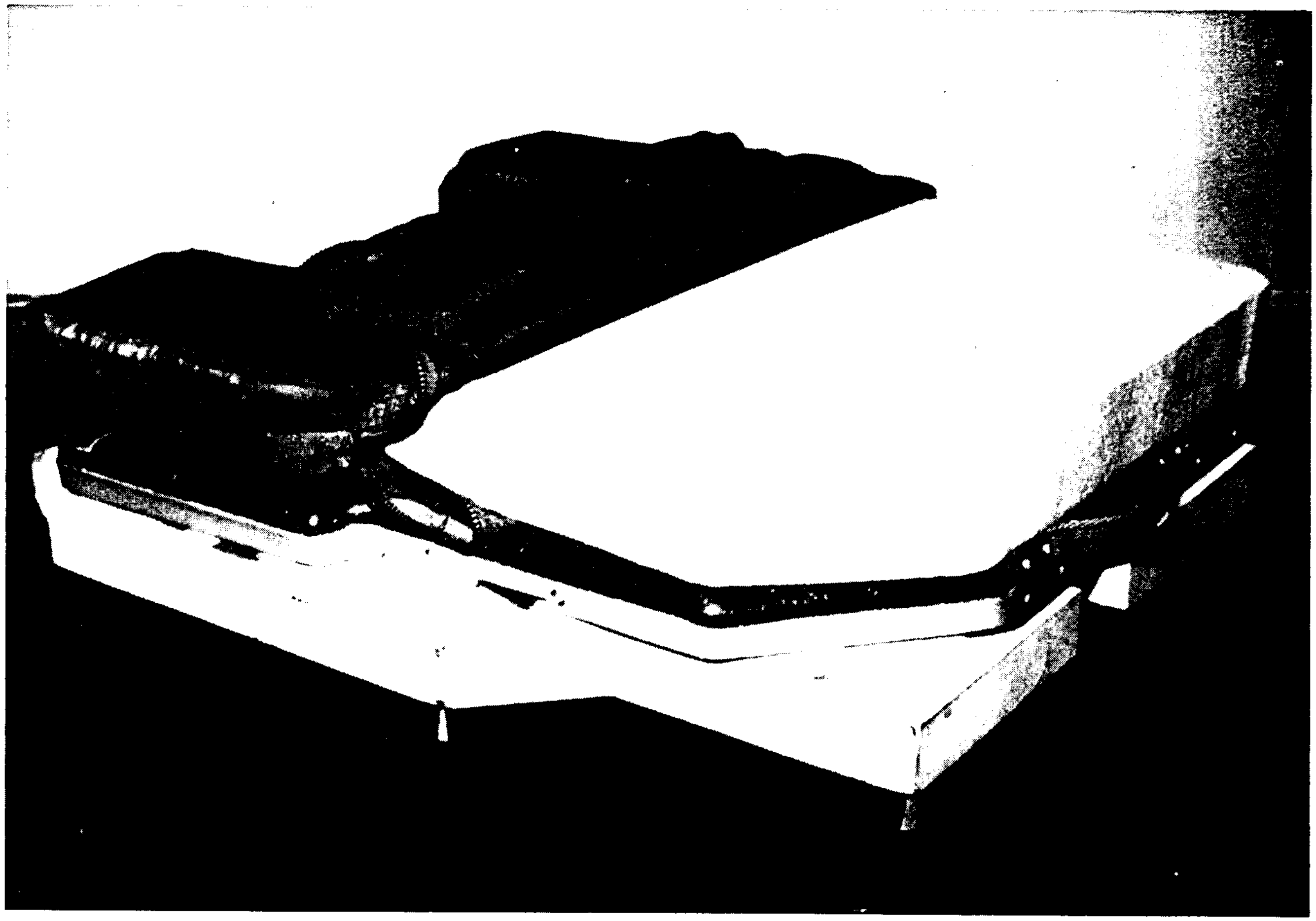


FIGURE A-22: CONFOR FOAM F-4 SEAT CUSHION

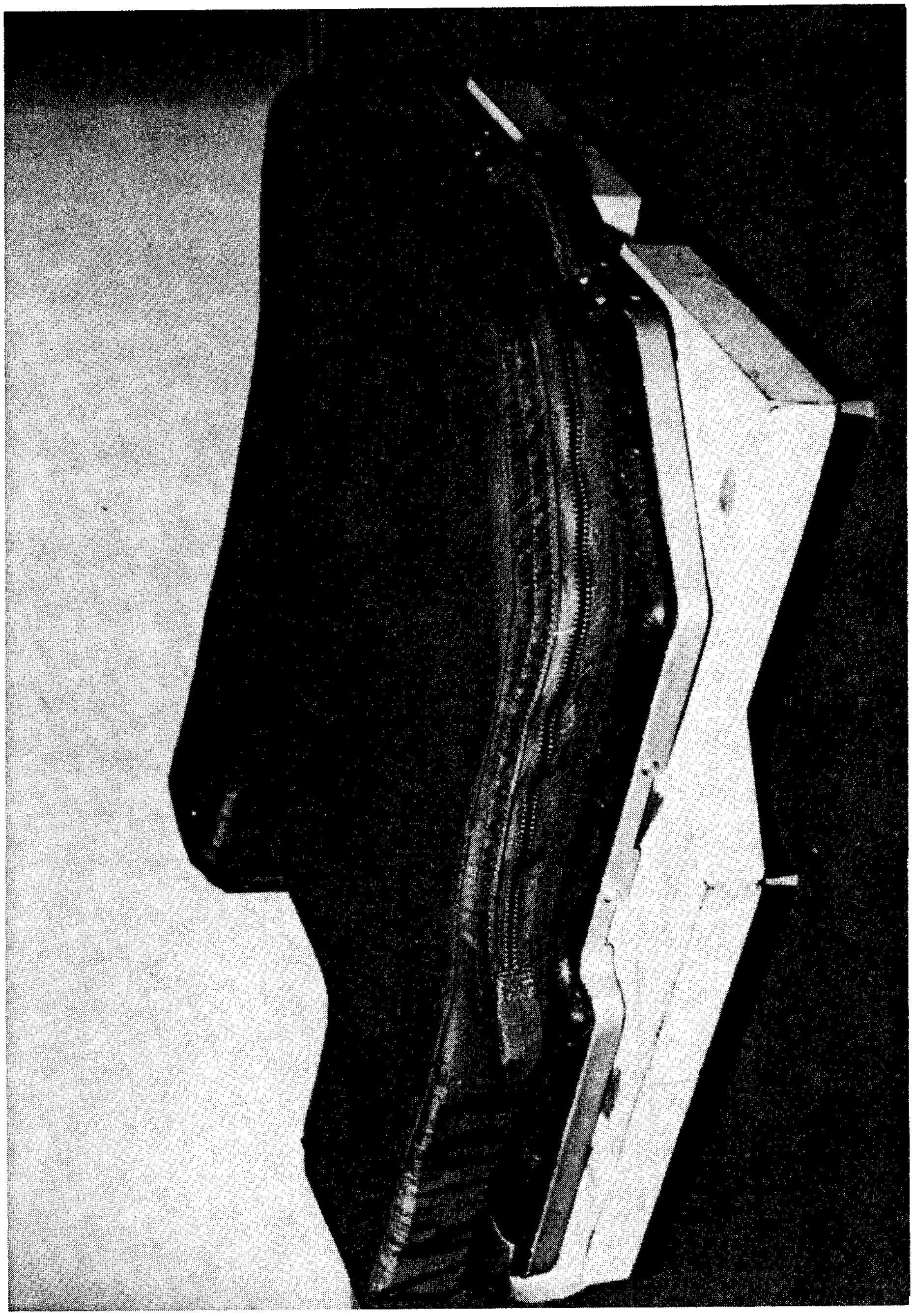


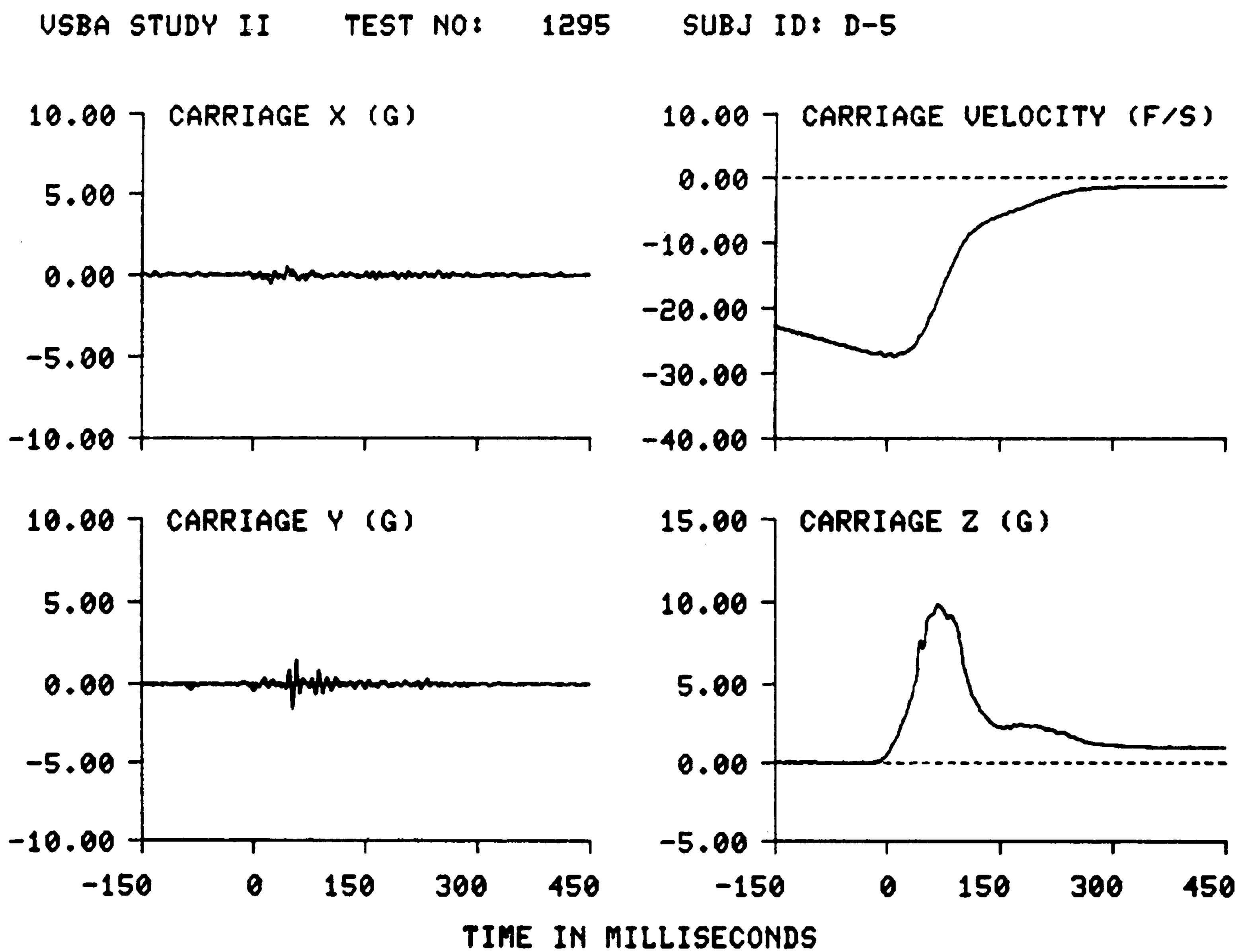
FIGURE A-23: CONFOR FOAM F-4 SEAT CUSHION

APPENDIX B

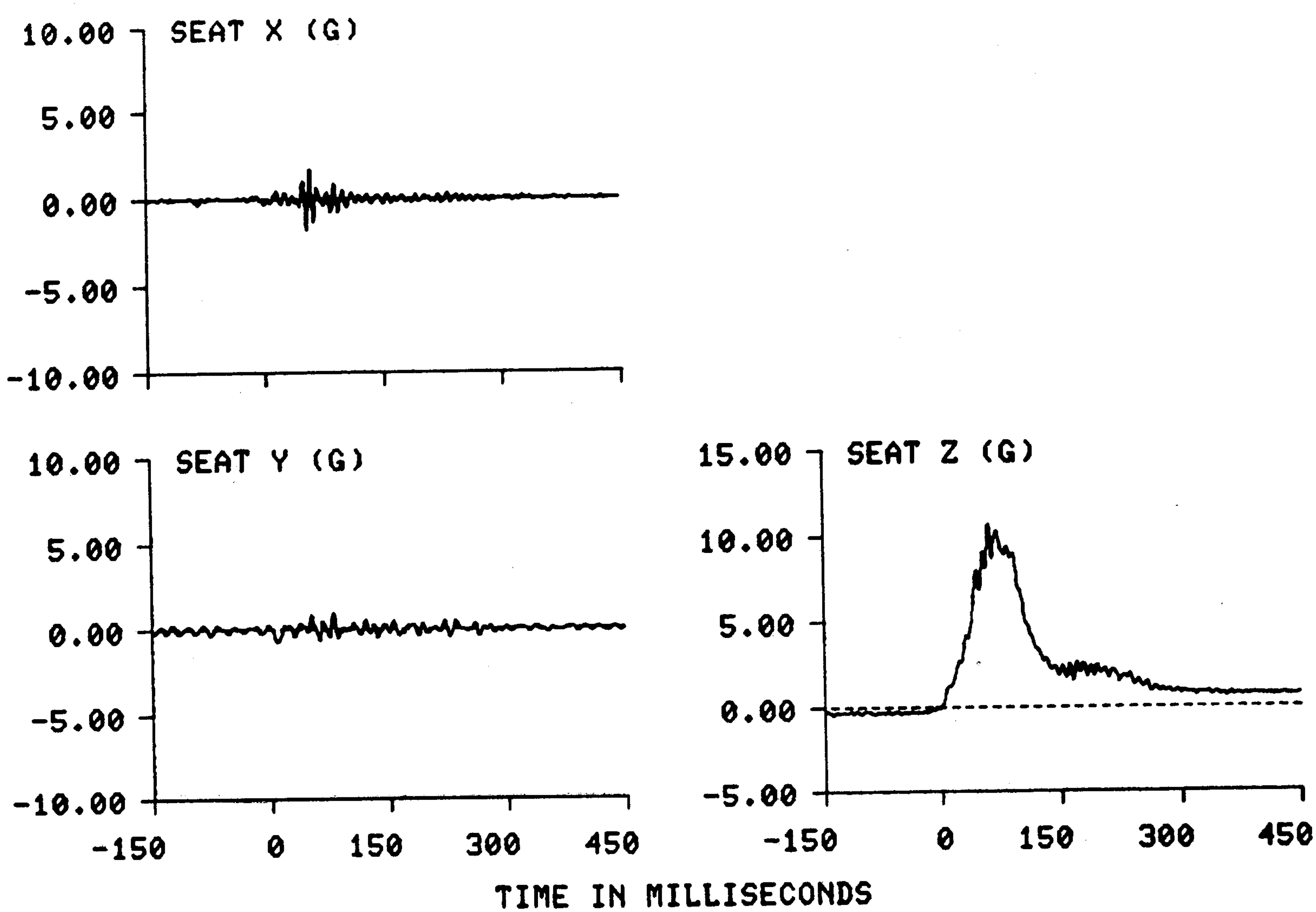
REPRESENTATIVE TEST DATA

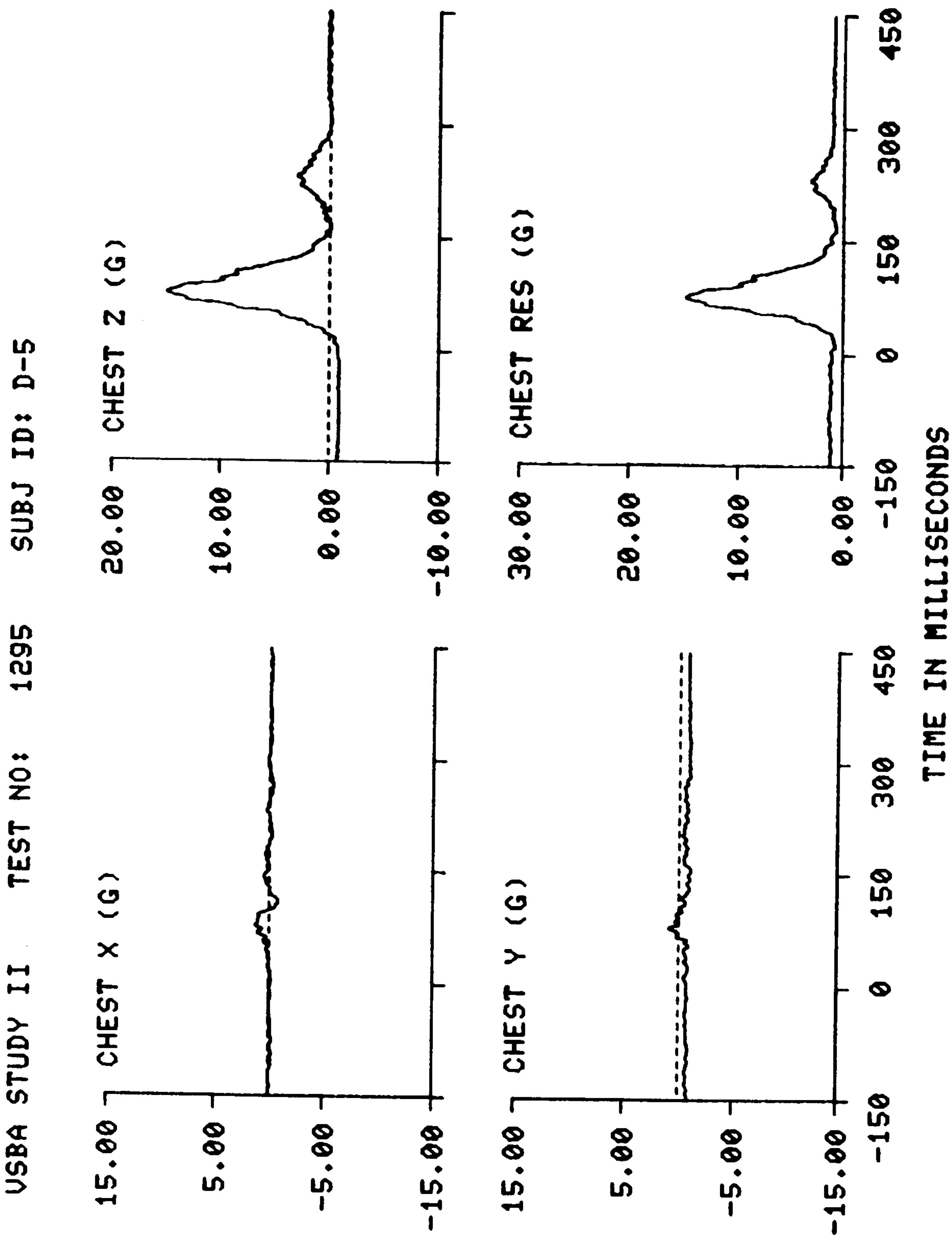
VSBA STUDY II TEST: 1295 SUBJ: D-5 WT: 172.0 NOM G: 10.0 CELL: F

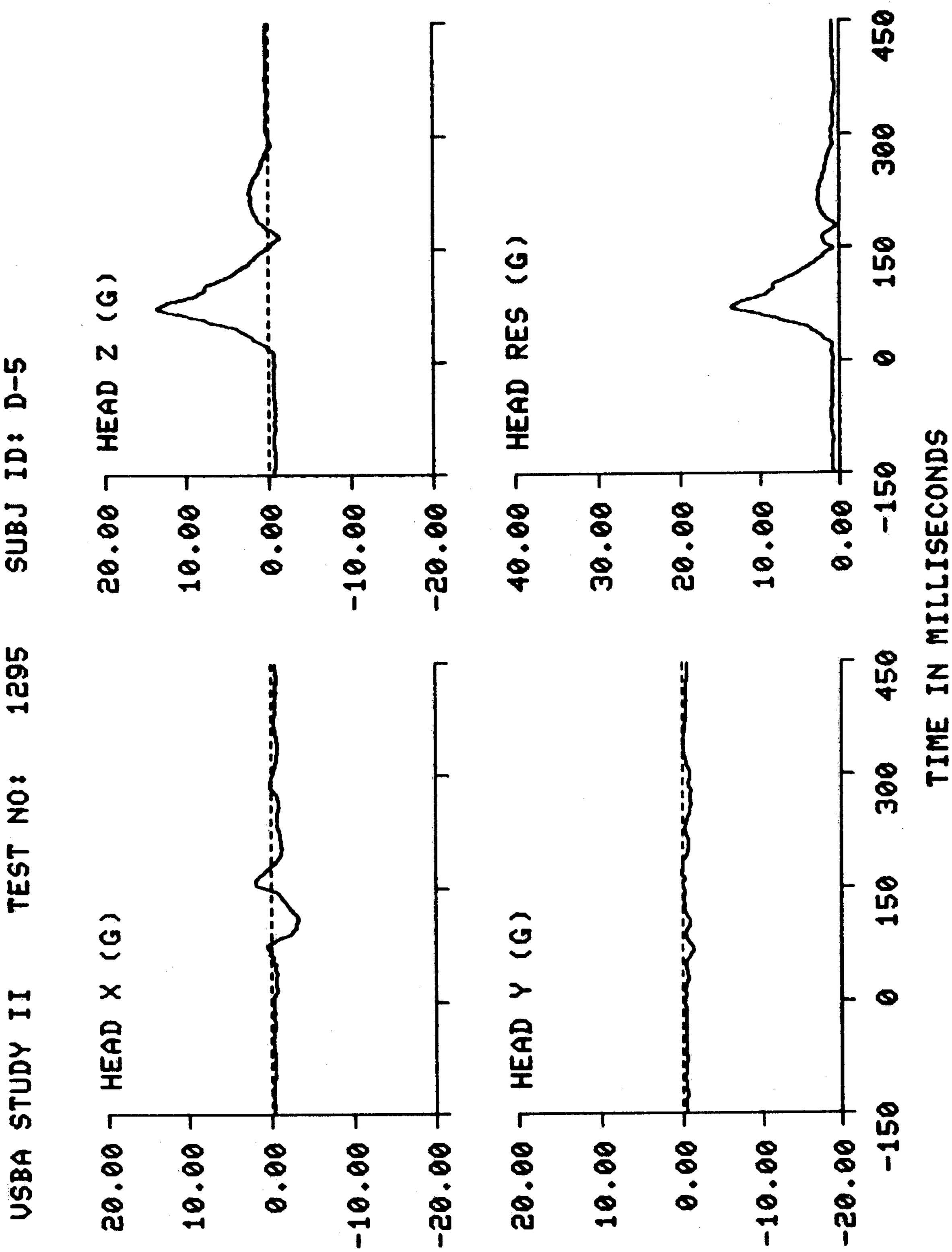
DATA ID	IMMEDIATE PREIMPACT	MAXIMUM VALUE	MINIMUM VALUE	TIME OF MAXIMUM	TIME OF MINIMUM
REFERENCE MARK				-150.	
2.5V EXT PWR		2.50	2.50	0.	10.
10V EXT PWR		10.01	10.00	1.	0.
CARRIAGE ACCELERATION (G)					
X AXIS	0.07	0.53	-0.49	44.	23.
Y AXIS	-0.03	1.44	-1.61	57.	52.
Z AXIS	0.05	9.86	0.50	67.	0.
Z AXIS (SM)	0.07	9.65	0.56	69.	0.
SEAT ACCELERATION (G)					
X AXIS	0.05	1.69	-1.74	56.	52.
Y AXIS	-0.02	0.91	-0.77	79.	8.
Z AXIS	-0.24	10.72	0.03	61.	0.
Z AXIS (SM)	-0.24	9.89	0.11	71.	0.
RY	-8.26	26.72	-33.25	61.	65.
CARRIAGE VELOCITY (F/S)	-26.81	-1.24	-27.40	333.	9.
CHEST ACCELERATION (G)					
X AXIS	-0.06	1.25	-0.78	76.	107.
Y AXIS	-0.74	0.86	-1.08	78.	155.
Z AXIS	-0.83	14.81	-0.77	76.	3.
RESULTANT	1.11	14.88	0.59	76.	170.
NORM RESULTANT	0.12	1.54	0.06	76.	170.
SI		27.69			
RY	5.69	219.60	-304.57	68.	92.
HEAD ACCELERATION (G)					
X AXIS	-0.35	1.95	-3.29	157.	109.
Y AXIS	-0.46	0.19	-1.44	169.	67.
Z AXIS	-0.59	13.60	-1.33	71.	165.
RESULTANT	0.82	13.66	0.34	71.	178.
NORM RESULTANT	0.09	1.42	0.04	71.	178.
SI		22.19			
RY	0.69	161.45	-134.57	73.	164.
THORAX ACCELERATION (G)					
X AXIS	-0.59	0.62	-6.91	162.	78.
Y AXIS	0.17	0.89	-3.13	161.	81.
Z AXIS	-0.31	14.02	-0.45	88.	164.
RESULTANT	0.70	15.14	0.08	88.	167.
NORM RESULTANT	0.07	1.57	0.01	88.	167.
SHOULDER LOADS (LB)					
X AXIS	87.28	125.73	33.96	61.	301.
Y AXIS	-2.46	7.69	-3.06	215.	4.
Z AXIS	2.10	38.39	1.63	85.	1.
RESULTANT	87.35	129.74	34.83	61.	301.
LAP LOADS (LB)					
LEFT X AXIS	67.79	87.01	17.29	98.	338.
LEFT Y AXIS	24.48	26.40	8.78	96.	52.
LEFT Z AXIS	59.48	56.56	-1.66	0.	60.
LEFT RESULTANT	93.45	103.13	23.43	98.	362.
RIGHT X AXIS	54.99	77.85	11.25	96.	357.
RIGHT Y AXIS	19.89	23.35	3.30	99.	61.
RIGHT Z AXIS	61.81	59.10	-0.10	0.	61.
RIGHT RESULTANT	85.09	99.01	16.12	97.	57.
SEAT LOADS (LB)					
LEFT LINK X AXIS	-0.87	1.84	-12.01	164.	82.
RIGHT LINK X AXIS	2.08	8.08	-26.26	46.	92.
X AXIS	1.21	8.16	-35.88	49.	93.
CENTER LINK Y AXIS	-2.50	-1.38	-36.83	274.	72.
LEFT PAN Z AXIS	46.76	624.40	36.86	84.	360.
RIGHT PAN Z AXIS	37.75	594.42	30.84	84.	325.
CENTER PAN Z AXIS	100.21	1437.98	114.25	72.	0.
Z AXIS SUM	184.72	2565.48	189.71	78.	320.
Z AXIS MINUS TARE	219.70	2337.99	196.25	78.	322.
RESULTANT	184.75	2565.76	189.71	78.	320.
RESULTANT MINUS TARE	219.72	2338.30	196.25	78.	322.


USBA STUDY II TEST NO: 1295 SUBJ ID: D-5
CARRIAGE X (G)
10.00
5.00
0.00
-5.00
-10.00
CARRIAGE VELOCITY (F/S)
10.00
0.00
-10.00
-20.00
-30.00
-40.00
CARRIAGE Y (G)
10.00
5.00
0.00
-5.00
-10.00
CARRIAGE Z (G)
15.00
10.00
5.00
0.00
-5.00
-150
0
150
300
450
-150
0
150
300
450
TIME IN MILLISECONDS

USBA STUDY II TEST NO: 1295 SUBJ ID: D-5

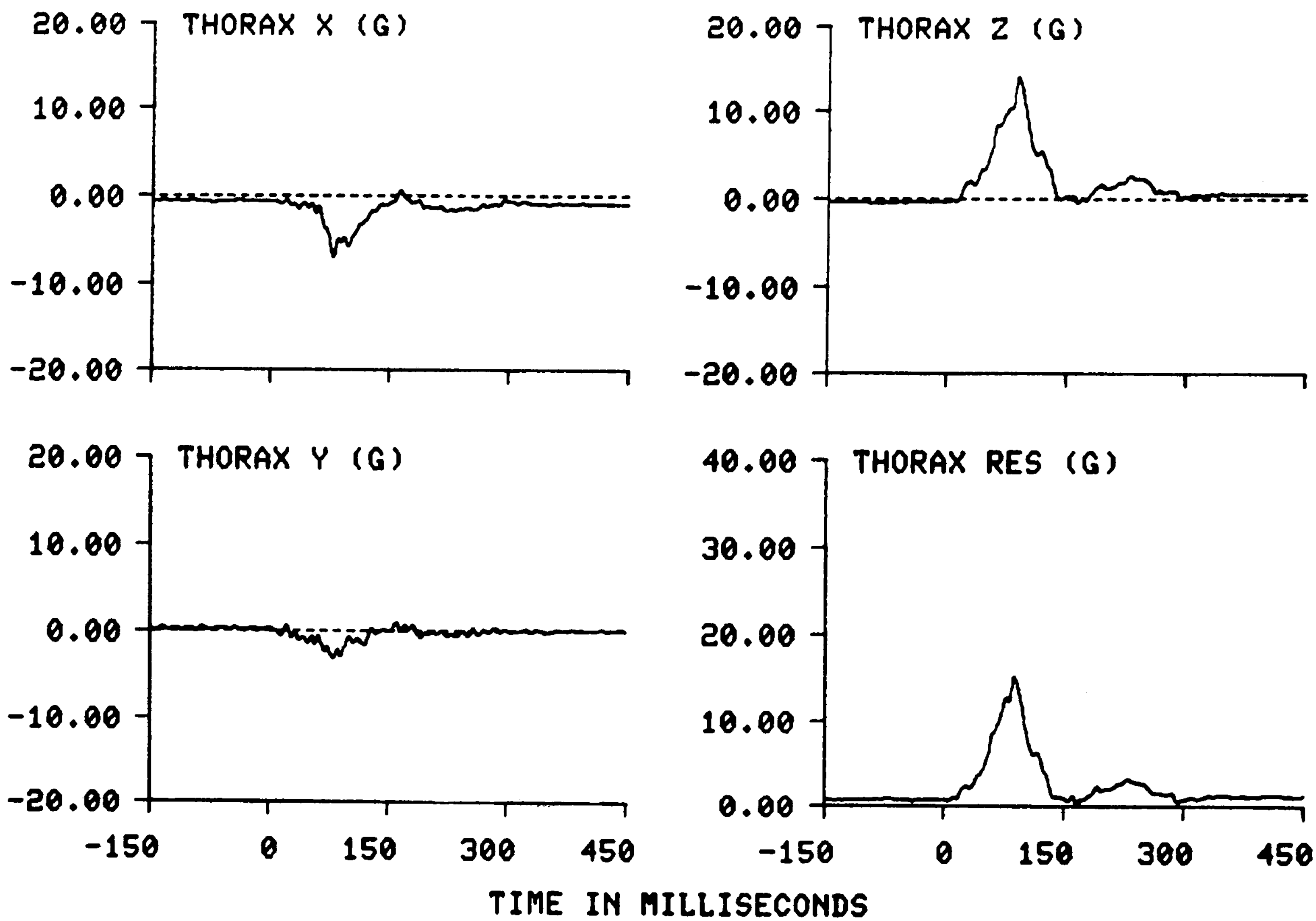


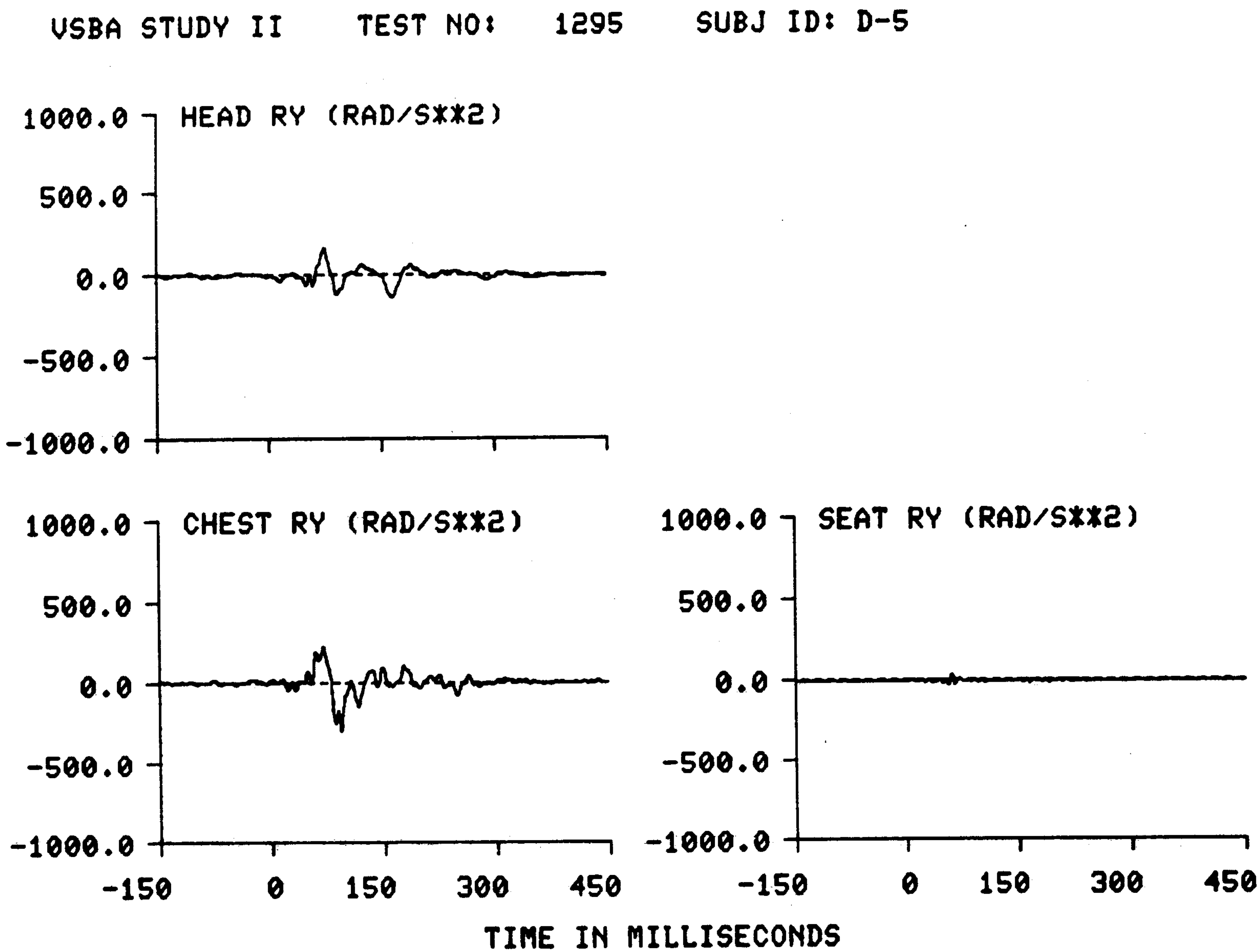

USBA STUDY II
TEST NO: 1295
SUBJ ID: D-5
CHEST X (G)
CHEST Z (G)
CHEST Y (G)
CHEST RES (G)
15.00
5.00
-5.00
-15.00
20.00
10.00
0.00
-10.00
30.00
20.00
10.00
0.00
-150
0
150
300
450
TIME IN MILLISECONDS

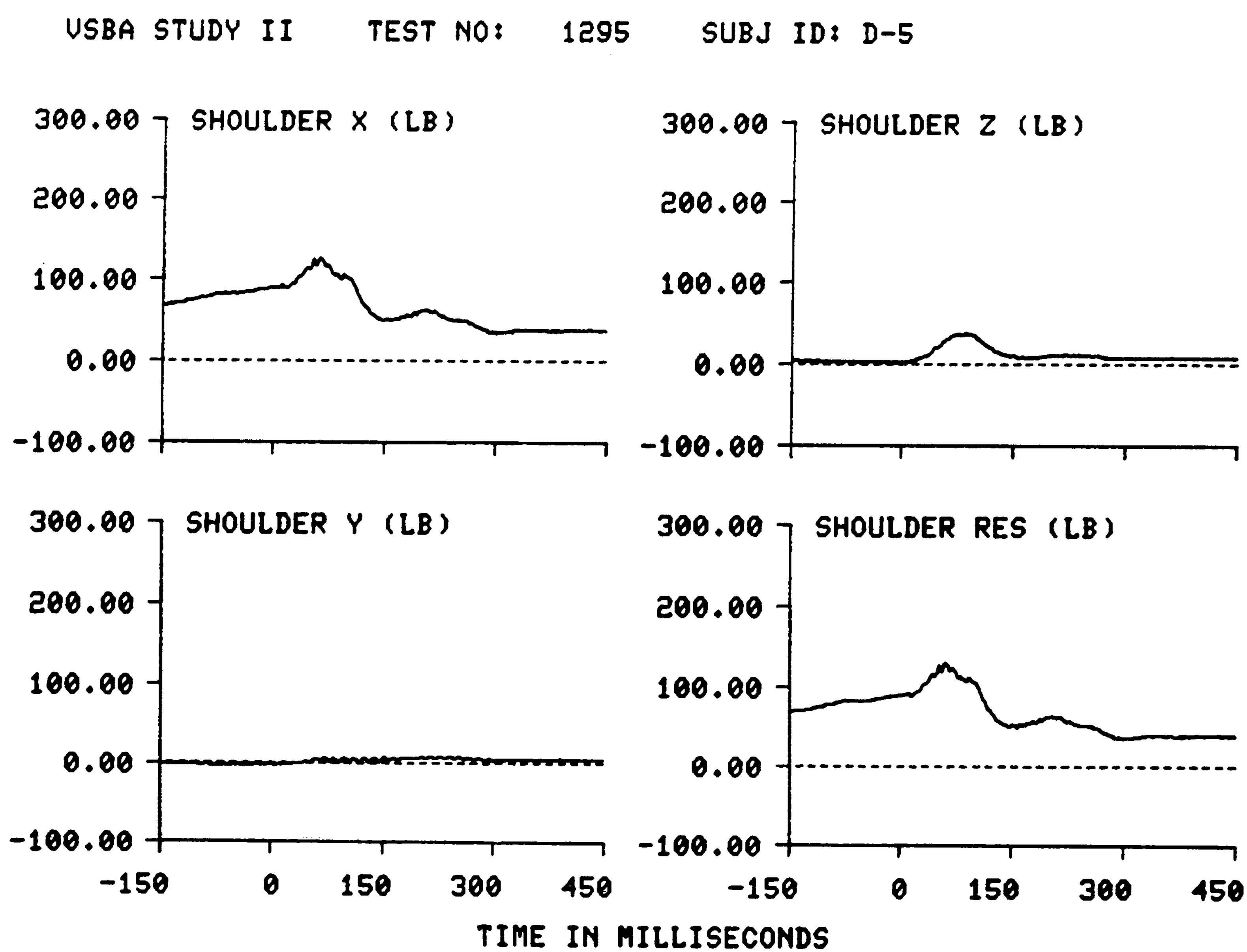


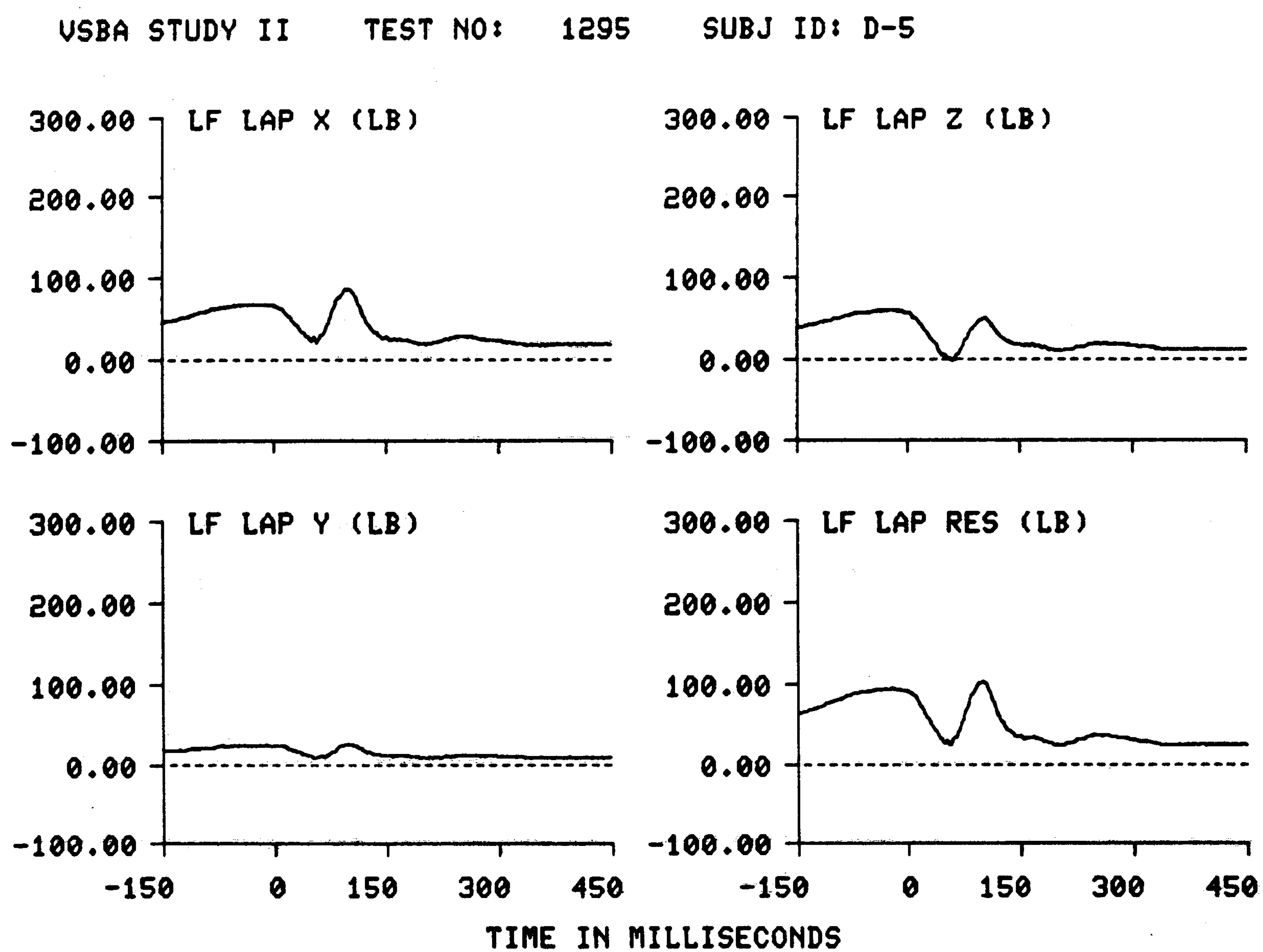
USBA STUDY II
TEST NO: 1295
SUBJ ID: D-5
HEAD X (G)
HEAD Y (G)
HEAD Z (G)
HEAD RES (G)
20.00
10.00
0.00
-10.00
-20.00
40.00
30.00
20.00
10.00
0.00
-150
0
150
300
450
TIME IN MILLISECONDS

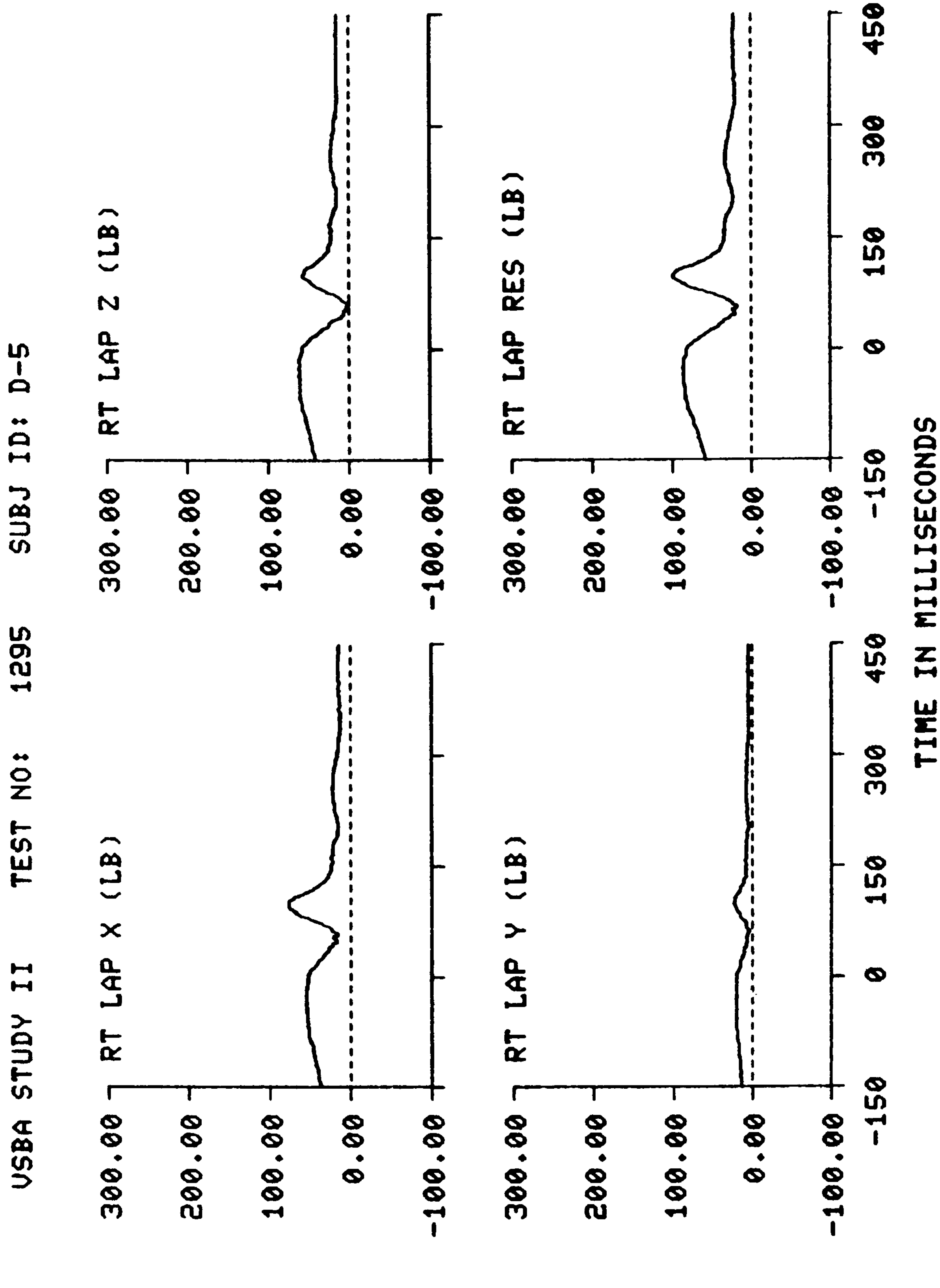
VSBA STUDY II   TEST NO: 1295   SUBJ ID: D-5




USBA STUDY II
TEST NO: 1295
SUBJ ID: D-5
HEAD RY (RAD/S**2)
CHEST RY (RAD/S**2)
SEAT RY (RAD/S**2)
1000.0
500.0
0.0
-500.0
-1000.0
-150
0
150
300
450
TIME IN MILLISECONDS

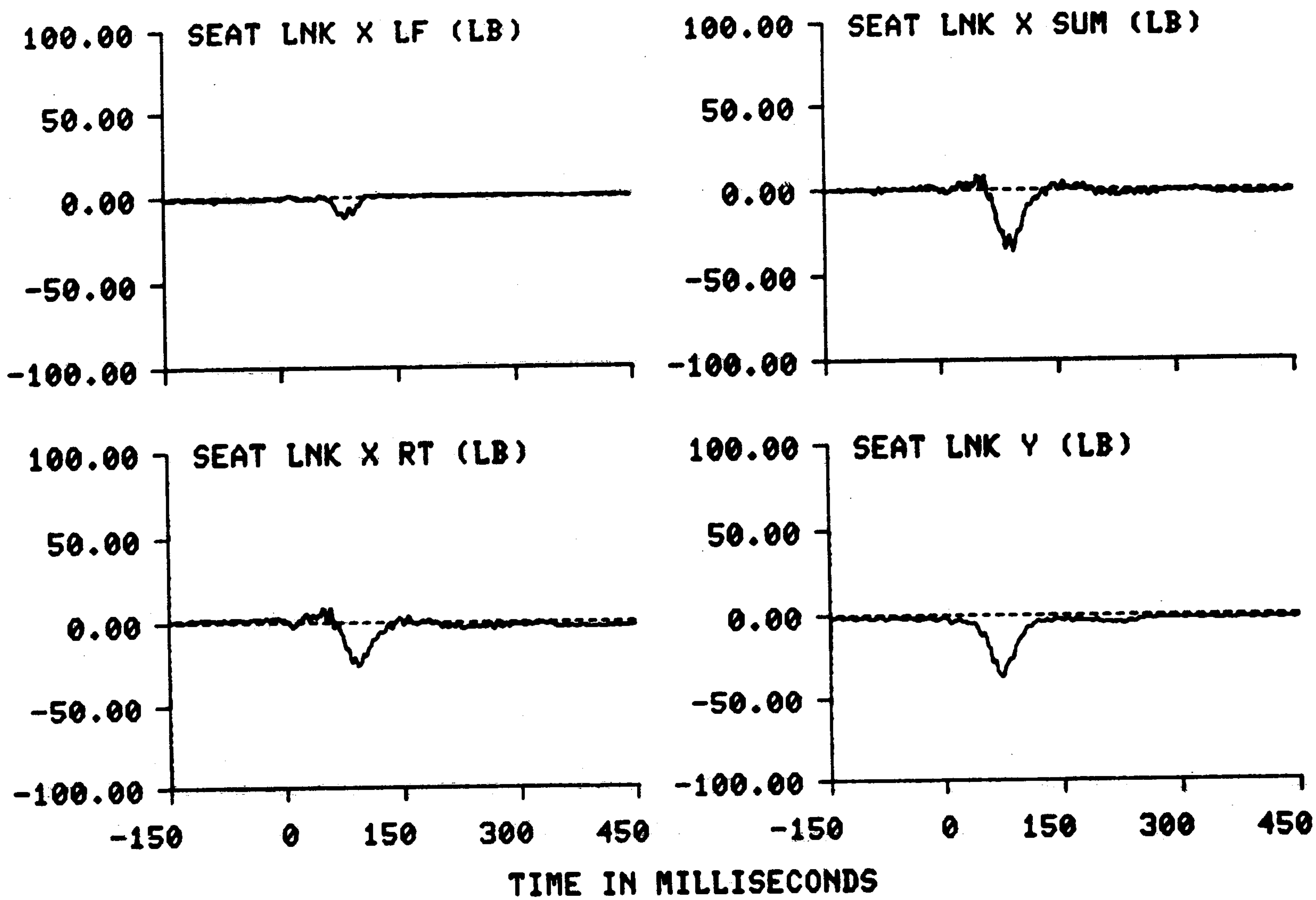

VSBA STUDY II TEST NO: 1295 SUBJ ID: D-5
SHOULDER X (LB)
SHOULDER Z (LB)
SHOULDER Y (LB)
SHOULDER RES (LB)
300.00
200.00
100.00
0.00
-100.00
-150
0
150
300
450
TIME IN MILLISECONDS

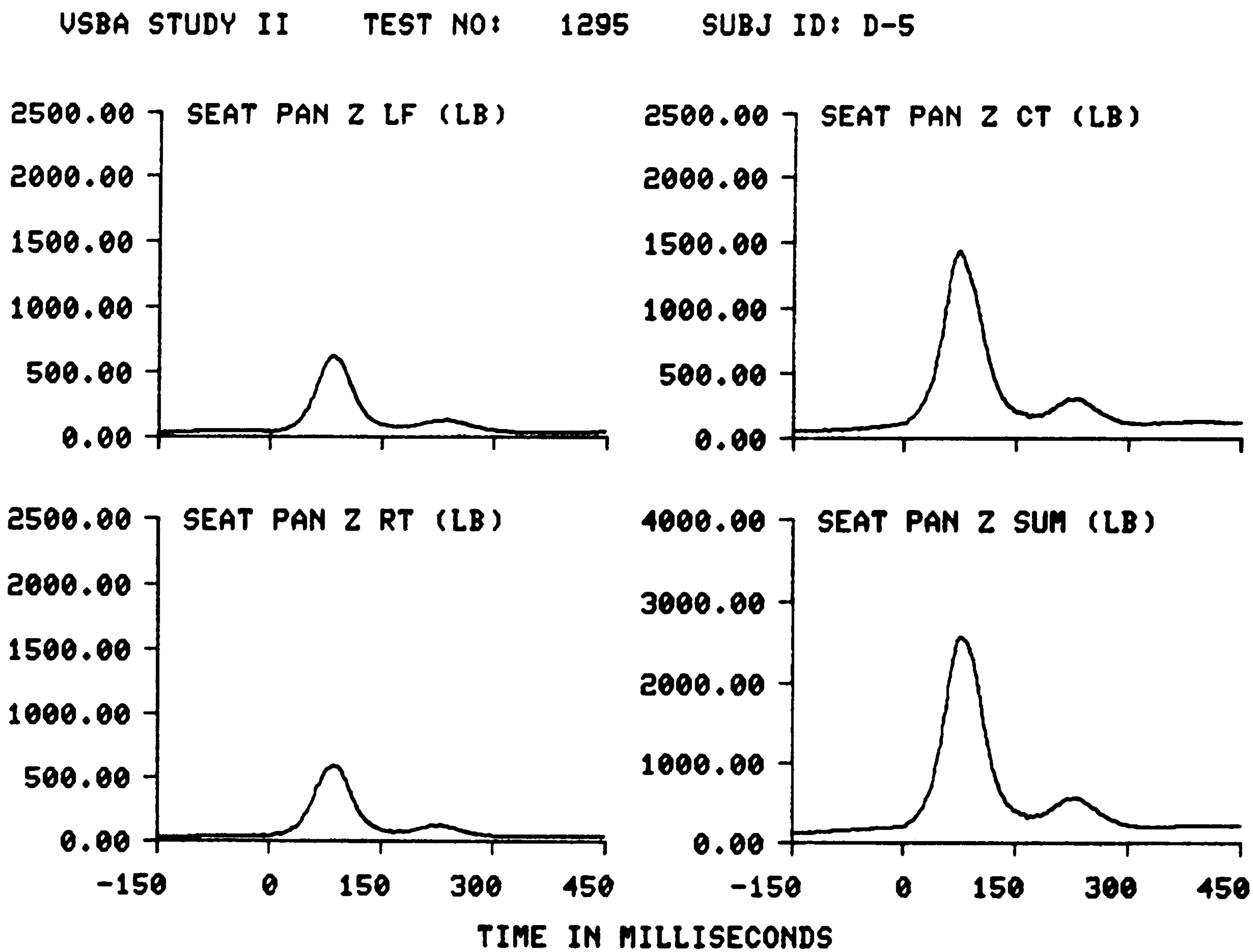

VSBA STUDY II TEST NO: 1295 SUBJ ID: D-5
LF LAP X (LB)
LF LAP Z (LB)
LF LAP Y (LB)
LF LAP RES (LB)
300.00
200.00
100.00
0.00
-100.00
-150
0
150
300
450
TIME IN MILLISECONDS



USBA STUDY II
TEST NO: 1295
SUBJ ID: D-5
RT LAP X (LB)
RT LAP Z (LB)
RT LAP Y (LB)
RT LAP RES (LB)
300.00
200.00
100.00
0.00
-100.00
-150
0
150
300
450
TIME IN MILLISECONDS

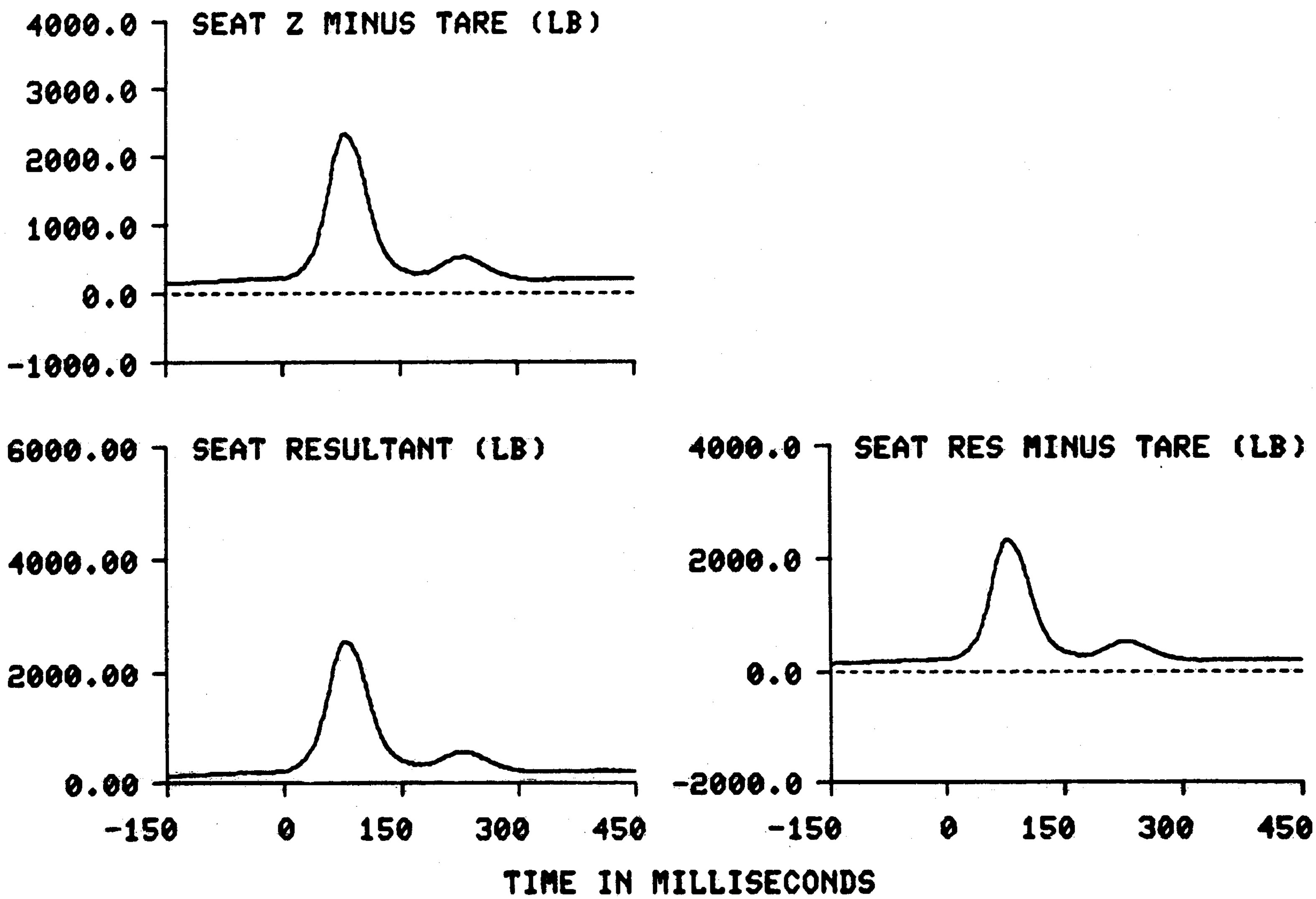
USBA STUDY II   TEST NO: 1295   SUBJ ID: D-5





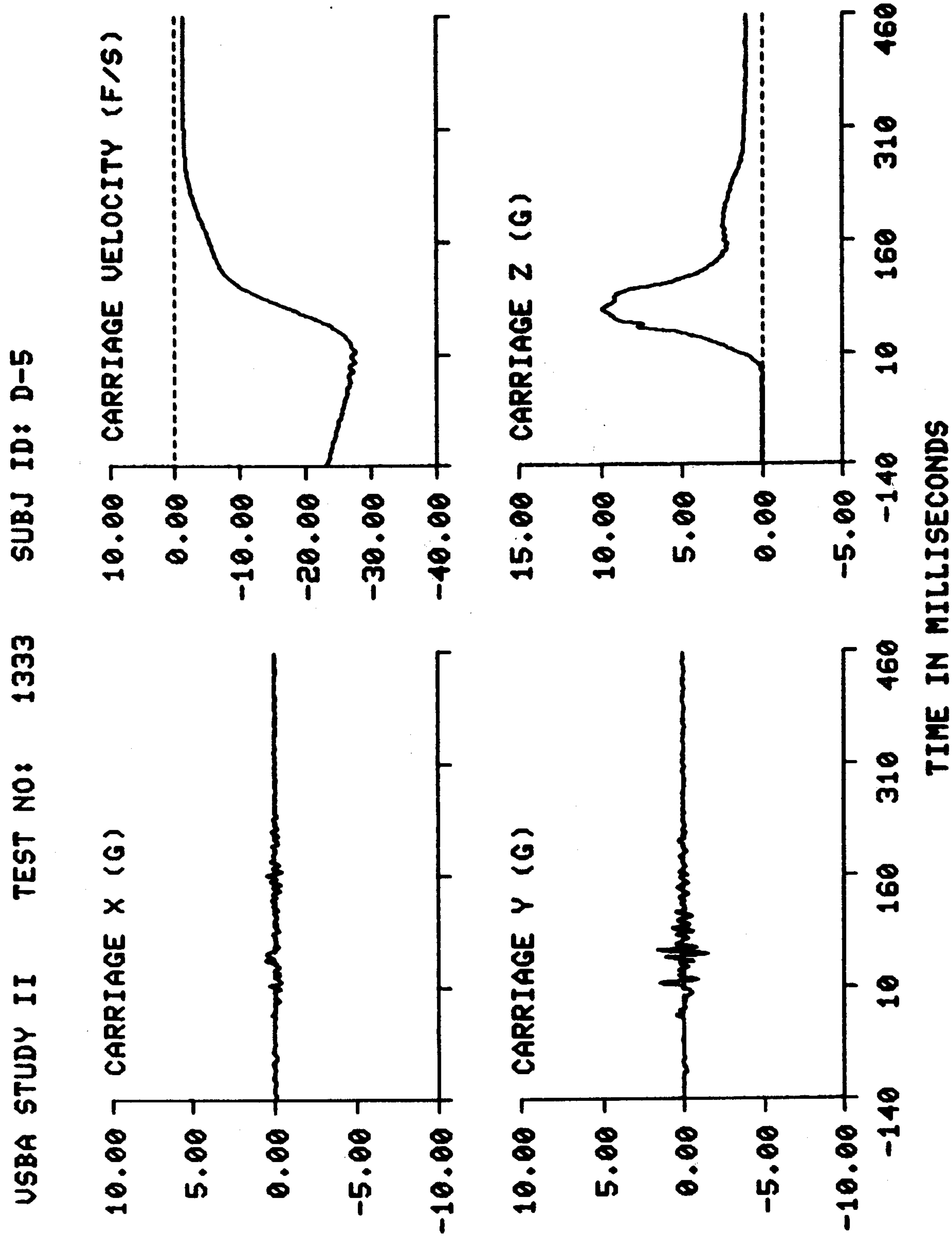
VSBA STUDY II TEST NO: 1295 SUBJ ID: D-5
SEAT PAN Z LF (LB)
SEAT PAN Z CT (LB)
SEAT PAN Z RT (LB)
SEAT PAN Z SUM (LB)
2500.00
2000.00
1500.00
1000.00
500.00
0.00
4000.00
3000.00
2000.00
1000.00
-150
0
150
300
450
TIME IN MILLISECONDS

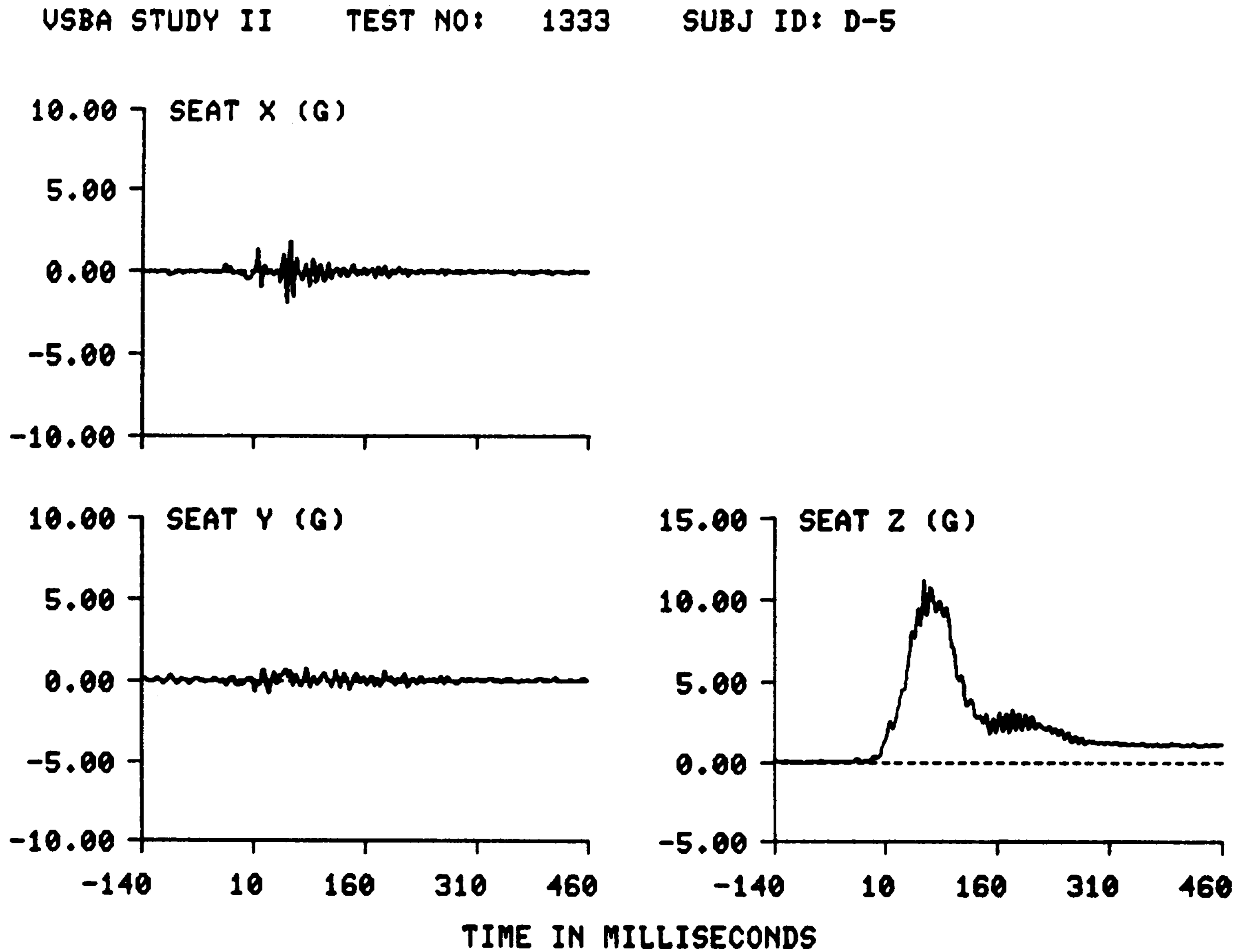
USBA STUDY II TEST NO: 1295 SUBJ ID: D-5

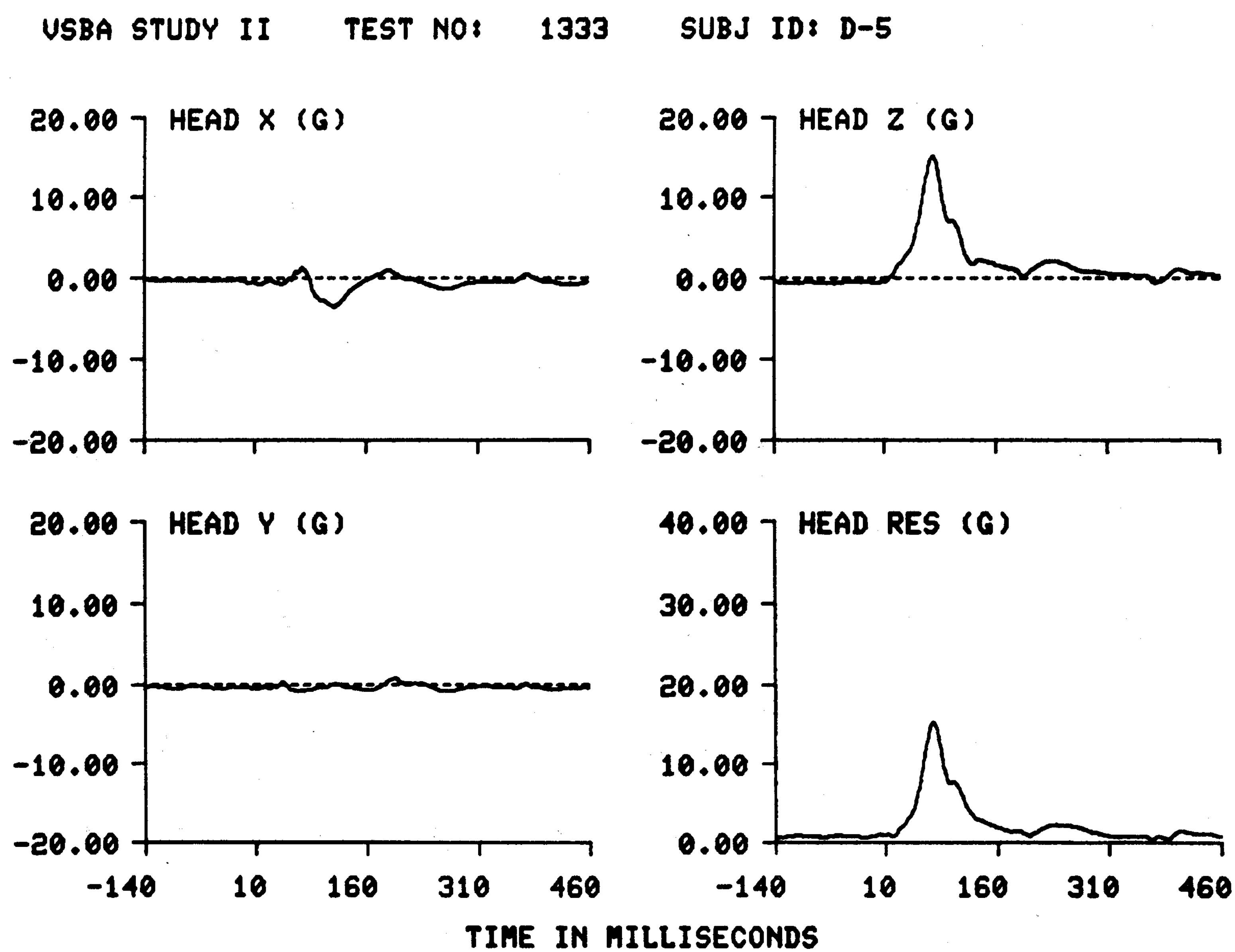


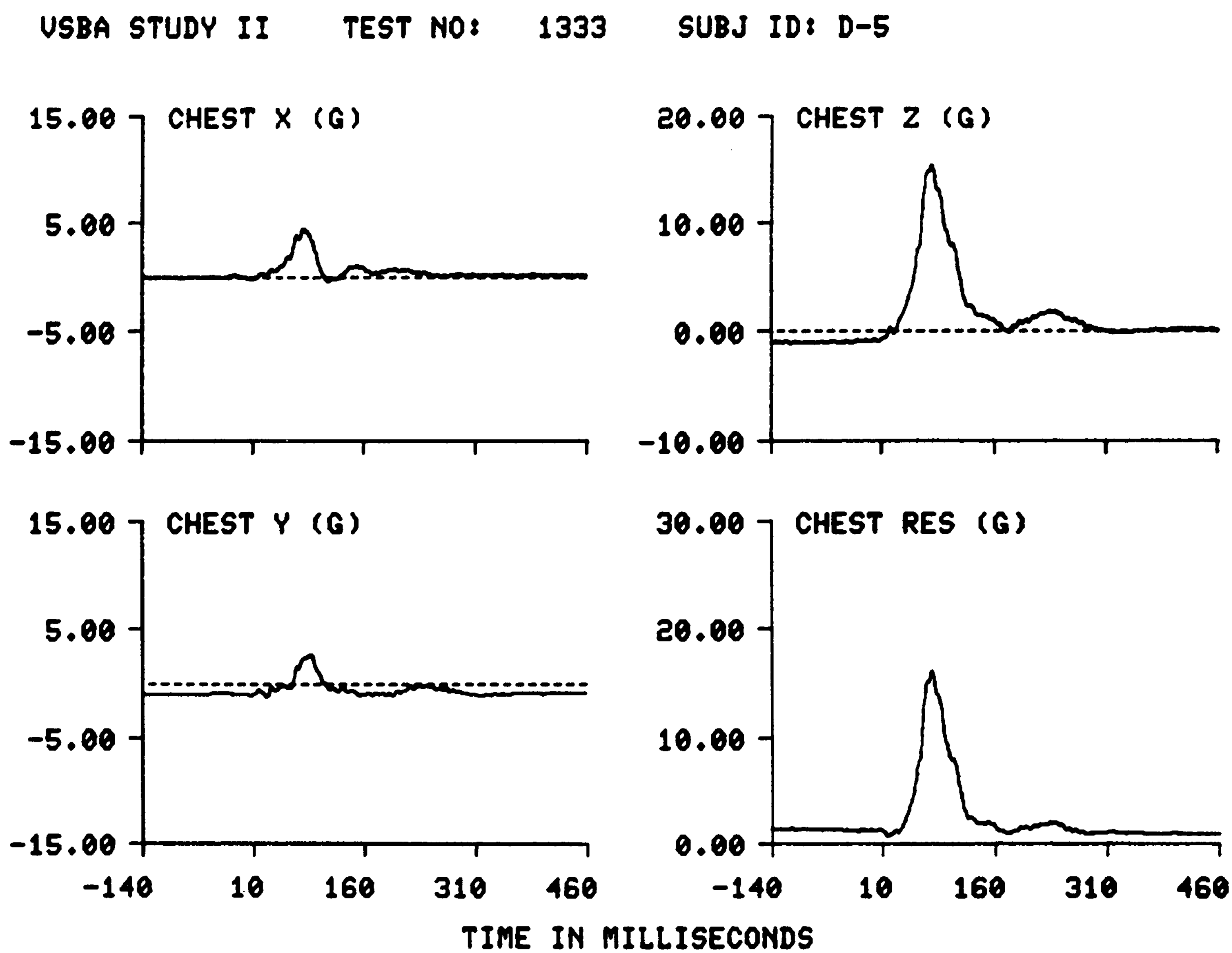
VSBA STUDY II TEST: 1333 SUBJ: 0-5 WT: 172.0 NOM G: 10.0 CELL: J

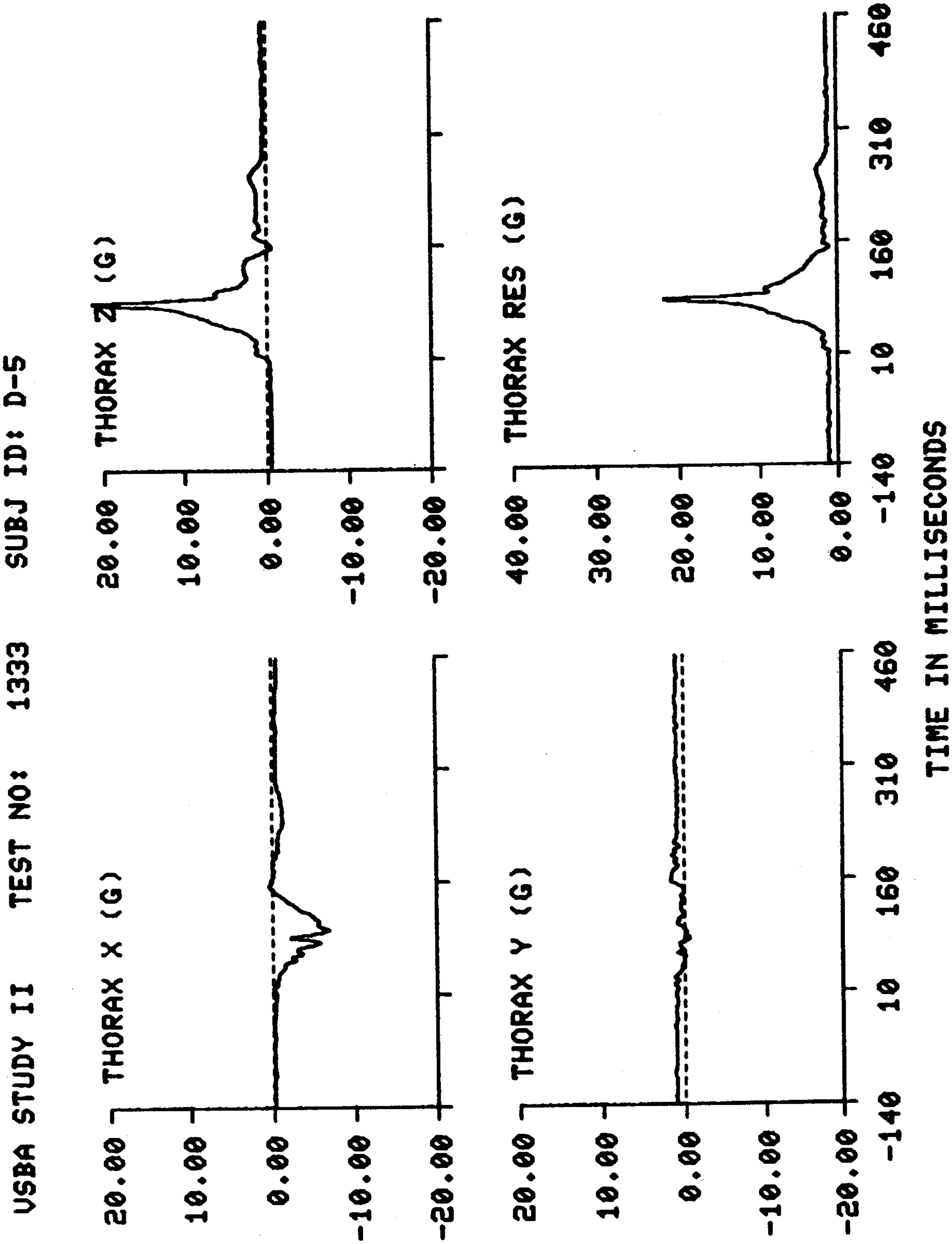
DATA ID	IMMEDIATE PREIMPACT	MAXIMUM VALUE	MINIMUM VALUE	TIME OF MAXIMUM	TIME OF MINIMUM
REFERENCE MARK				-147.	
2.5V EXT PWR		2.50	2.50	1.	0.
10V EXT PWR		10.01	10.00	0.	1.
CARRIAGE ACCELERATION (G)					
X AXIS	-0.07	0.57	-0.48	47.	166.
Y AXIS	0.03	1.60	-1.59	58.	54.
Z AXIS	0.07	9.96	0.50	69.	0.
Z AXIS (SM)	0.08	9.73	0.52	69.	0.
SEAT ACCELERATION (G)					
X AXIS	-0.01	1.79	-1.87	57.	53.
Y AXIS	-0.07	0.79	-0.75	80.	30.
Z AXIS	0.14	11.16	0.33	62.	0.
Z AXIS (SM)	0.14	10.28	0.41	71.	0.
RY	9.43	36.75	-23.22	62.	57.
CARRIAGE VELOCITY (F/S)	-26.83	-1.20	-27.73	357.	14.
CHEST ACCELERATION (G)					
X AXIS	0.10	4.47	-0.31	77.	110.
Y AXIS	-0.90	2.61	-1.24	86.	27.
Z AXIS	-0.86	15.33	-0.91	76.	6.
RESULTANT	1.25	16.10	0.69	76.	17.
NORM RESULTANT	0.13	1.65	0.07	76.	17.
SI		29.50			
RY	6.09	156.40	-314.43	80.	91.
HEAD ACCELERATION (G)					
X AXIS	-0.25	1.24	-3.50	72.	116.
Y AXIS	-0.34	0.81	-0.87	198.	67.
Z AXIS	-0.47	15.20	-0.65	74.	1.
RESULTANT	0.63	15.26	0.21	74.	369.
NORM RESULTANT	0.07	1.57	0.02	74.	369.
SI		24.92			
RY	-6.44	281.04	-204.43	76.	117.
THORAX ACCELERATION (G)					
X AXIS	-0.17	0.44	-6.94	154.	96.
Y AXIS	0.99	1.62	-0.65	158.	81.
Z AXIS	-0.31	21.51	-0.66	83.	158.
RESULTANT	1.05	21.81	0.89	83.	12.
NORM RESULTANT	0.11	2.24	0.09	83.	12.
SHOULDER LOADS (LB)					
X AXIS	61.29	119.39	28.61	101.	377.
Y AXIS	2.76	8.12	-1.02	97.	34.
Z AXIS	-3.31	34.31	-3.57	92.	1.
RESULTANT	61.45	123.58	28.76	101.	382.
LAP LOADS (LB)					
LEFT X AXIS	45.05	76.78	15.20	96.	200.
LEFT Y AXIS	13.73	17.03	4.70	95.	212.
LEFT Z AXIS	41.27	45.29	-0.10	1.	53.
LEFT RESULTANT	62.62	90.27	18.06	99.	200.
RIGHT X AXIS	26.31	66.06	5.62	92.	198.
RIGHT Y AXIS	11.76	25.49	1.57	99.	201.
RIGHT Z AXIS	31.99	47.81	-3.23	100.	50.
RIGHT RESULTANT	43.06	83.93	7.81	97.	198.
SEAT LOADS (LB)					
LEFT LINK X AXIS	0.74	16.94	-55.95	178.	83.
RIGHT LINK X AXIS	-3.63	6.16	-11.89	58.	85.
X AXIS	-2.88	13.18	-66.09	177.	83.
CENTER LINK Y AXIS	-7.00	-4.42	-170.27	316.	71.
LEFT PAN Z AXIS	24.11	764.17	30.91	83.	0.
RIGHT PAN Z AXIS	23.22	596.03	24.71	85.	338.
CENTER PAN Z AXIS	55.52	1421.95	64.21	72.	1.
Z AXIS SUM	102.86	2639.87	122.92	83.	1.
Z AXIS MINUS TARE	126.39	2402.29	140.45	77.	1.
RESULTANT	103.16	2645.72	123.49	76.	1.
RESULTANT MINUS TARE	126.63	2408.69	140.94	77.	1.


USBA STUDY II TEST NO: 1333 SUBJ ID: D-5
CARRIAGE X (G)
CARRIAGE Y (G)
CARRIAGE VELOCITY (F/S)
CARRIAGE Z (G)
10.00
5.00
0.00
-5.00
-10.00
0.00
-10.00
-20.00
-30.00
-40.00
15.00
-140
10
160
310
460
TIME IN MILLISECONDS

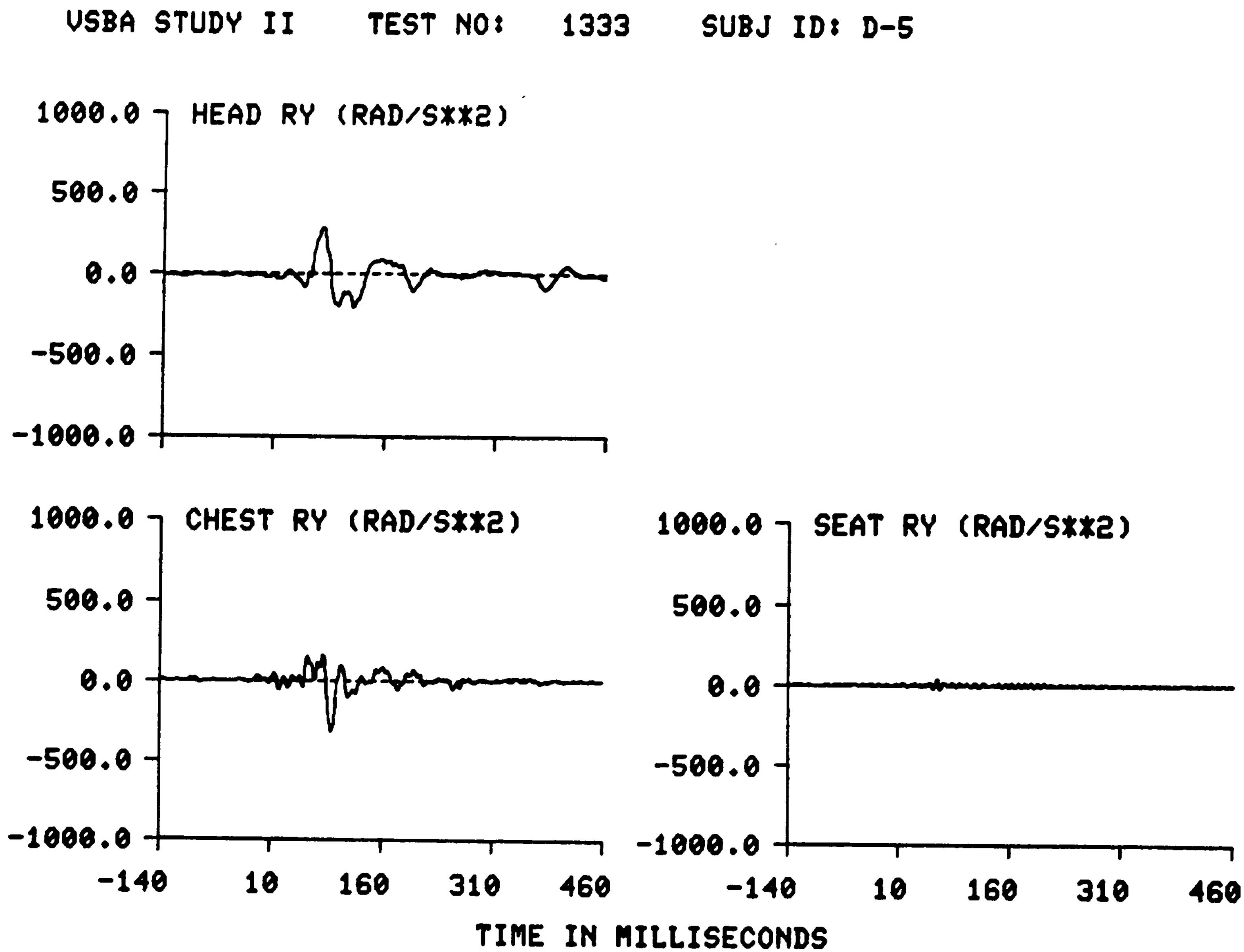

VSBA STUDY II
TEST NO: 1333
SUBJ ID: D-5
SEAT X (G)
SEAT Y (G)
SEAT Z (G)
10.00
5.00
0.00
-5.00
-10.00
15.00
-140
10
160
310
460
TIME IN MILLISECONDS


USBA STUDY II TEST NO: 1333 SUBJ ID: D-5
HEAD X (G)
HEAD Z (G)
HEAD Y (G)
HEAD RES (G)
20.00
10.00
0.00
-10.00
-20.00
40.00
30.00
-140
10
160
310
460
TIME IN MILLISECONDS

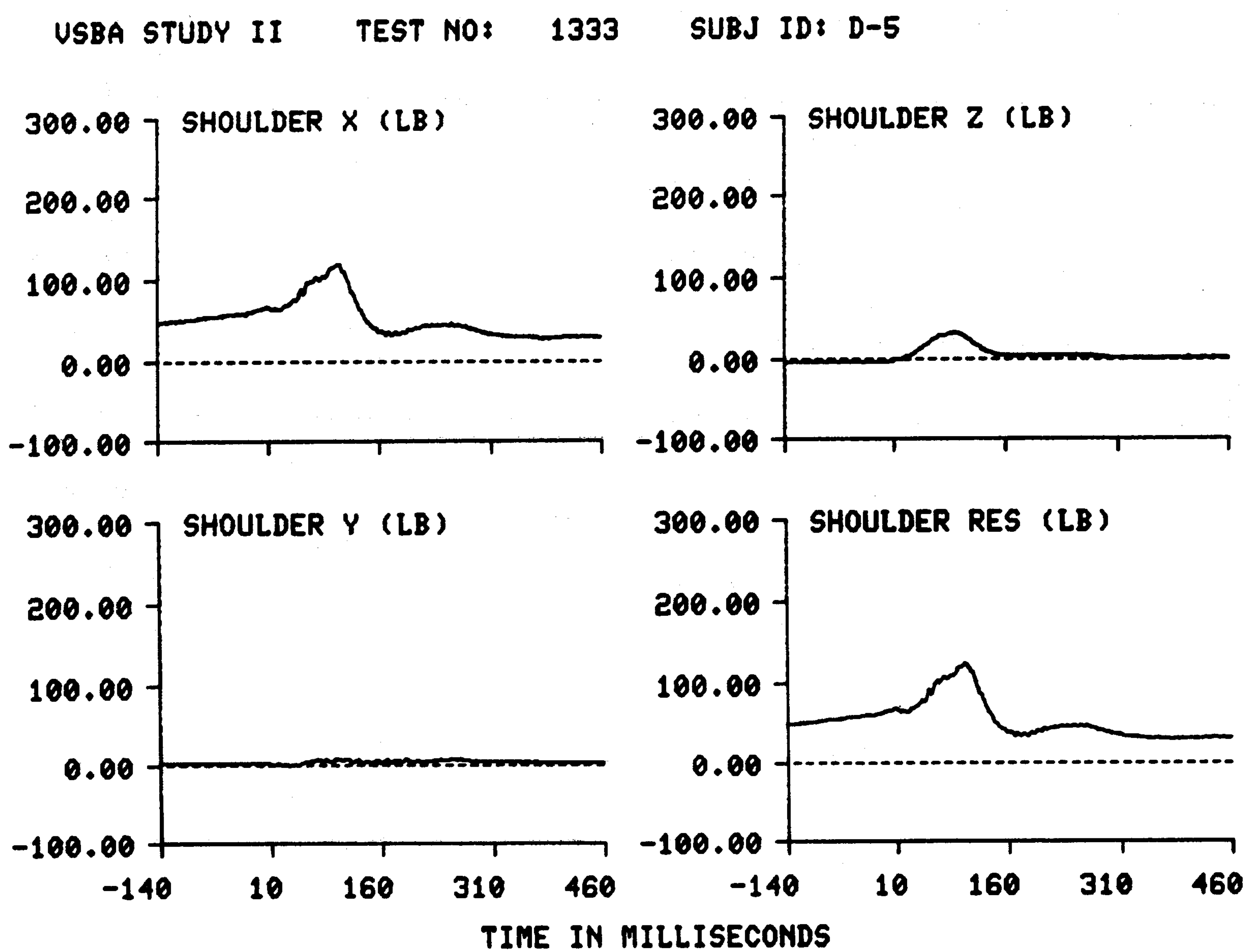

VSBA STUDY II TEST NO: 1333 SUBJ ID: D-5
CHEST X (G)
15.00
5.00
-5.00
-15.00
CHEST Z (G)
20.00
10.00
0.00
-10.00
CHEST Y (G)
15.00
5.00
-5.00
-15.00
CHEST RES (G)
30.00
20.00
10.00
0.00
-140
10
160
310
460
TIME IN MILLISECONDS



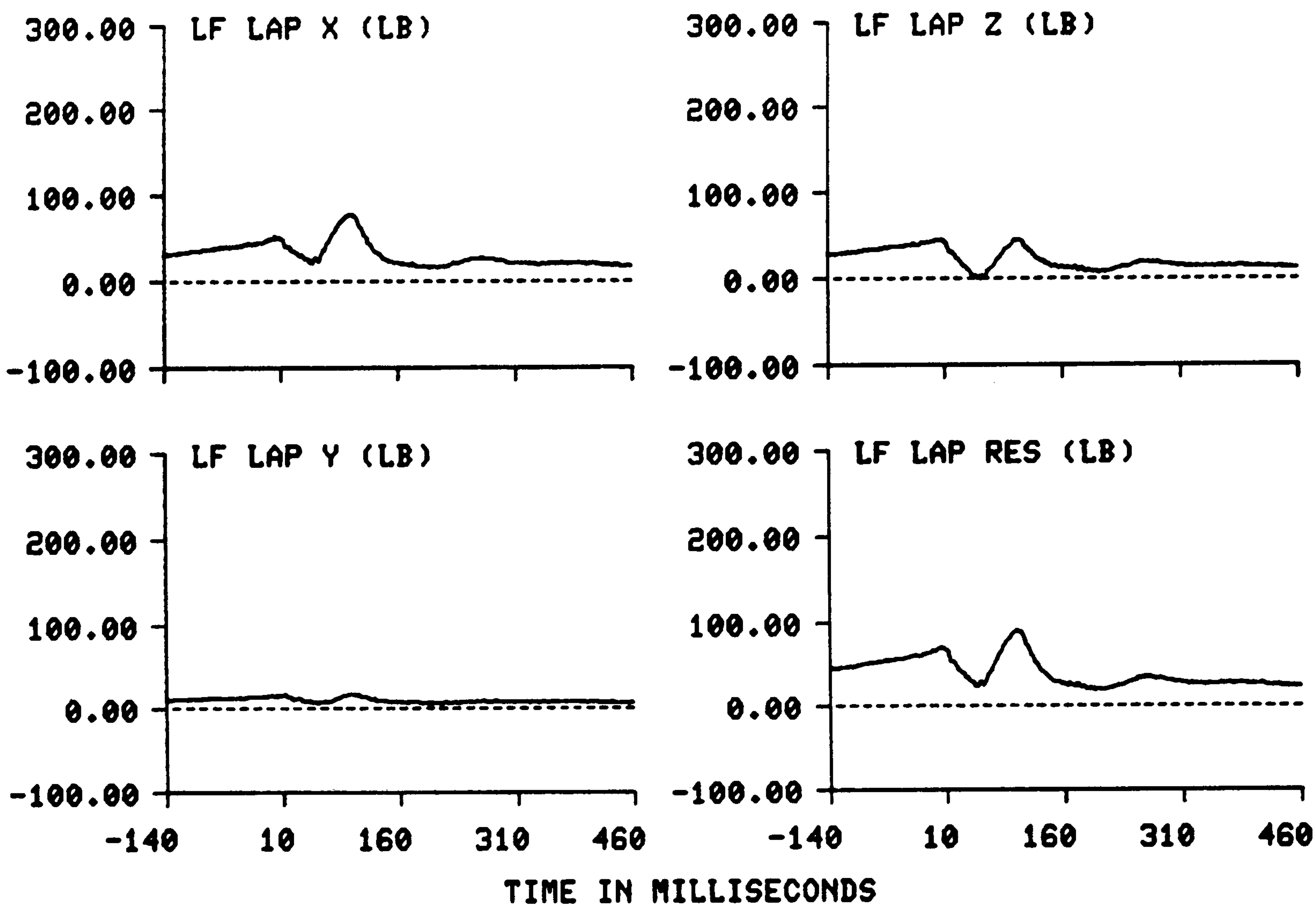
USBA STUDY II
TEST NO: 1333
SUBJ ID: D-5
THORAX X (G)
THORAX Z (G)
THORAX Y (G)
THORAX RES (G)
20.00
10.00
0.00
-10.00
-20.00
40.00
30.00
-140
10
160
310
460
TIME IN MILLISECONDS

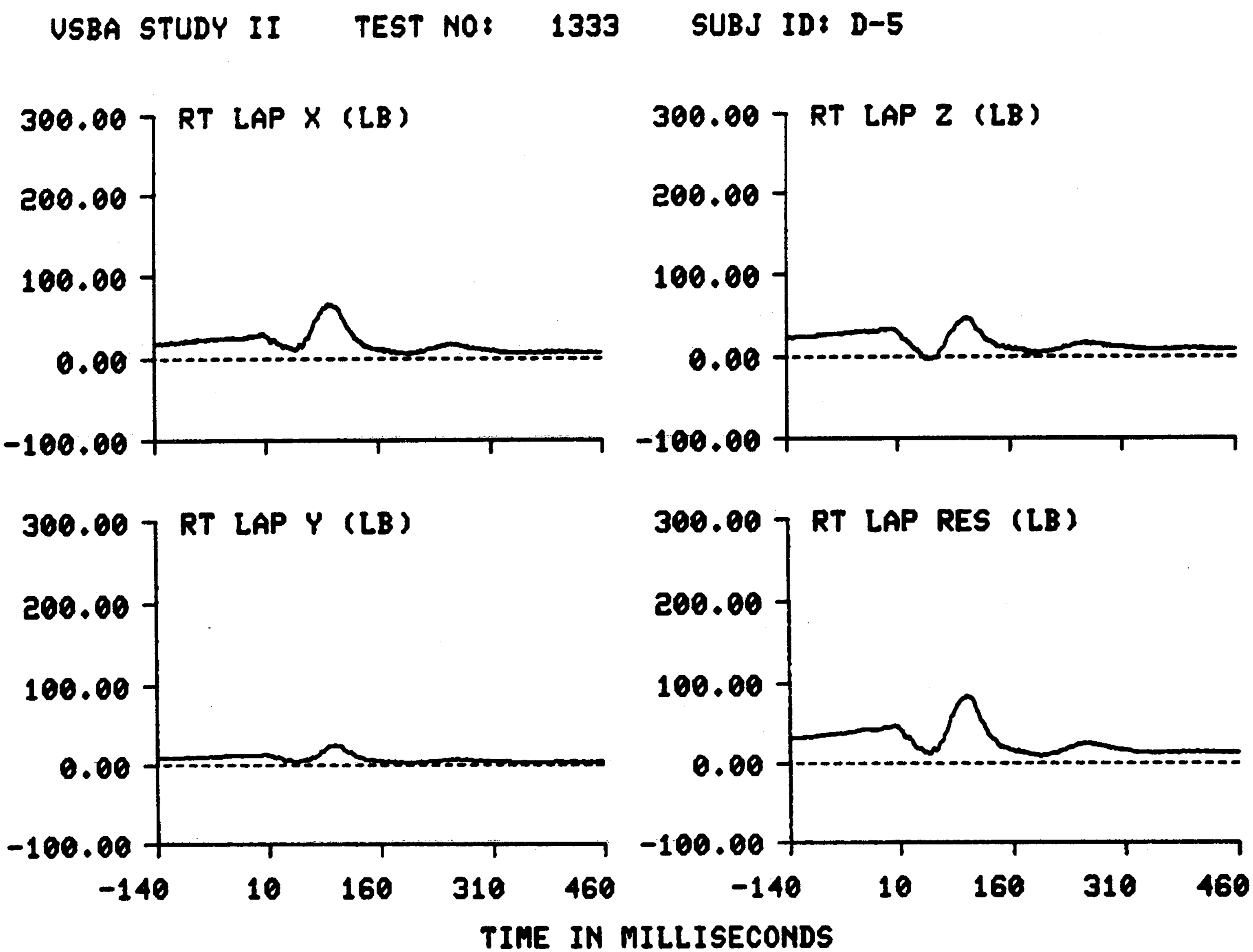


VSBA STUDY II TEST NO: 1333 SUBJ ID: D-5
HEAD RY (RAD/S**2)
CHEST RY (RAD/S**2)
SEAT RY (RAD/S**2)
1000.0
500.0
0.0
-500.0
-1000.0
-140
10
160
310
460
TIME IN MILLISECONDS

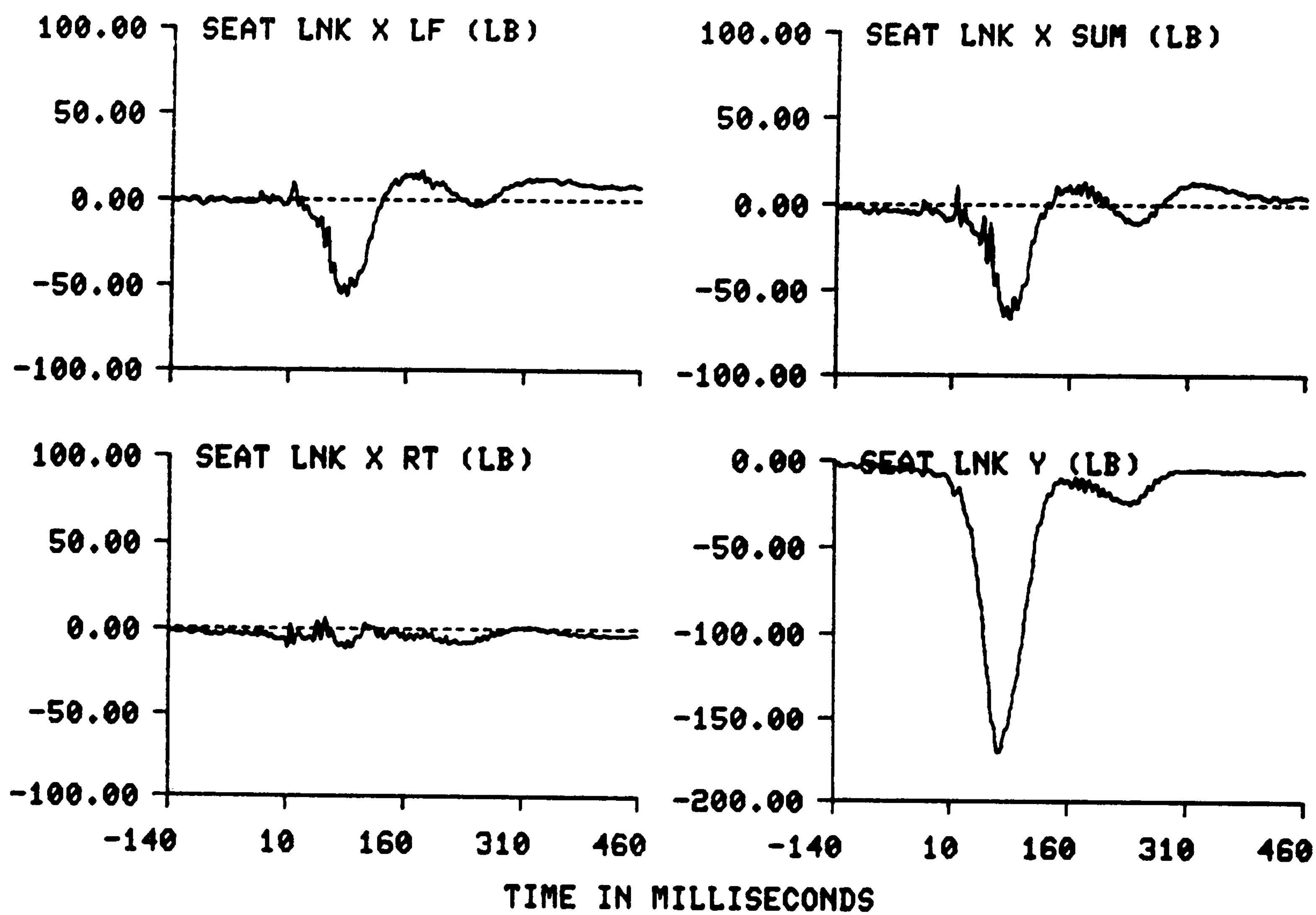

USBA STUDY II TEST NO: 1333 SUBJ ID: D-5
SHOULDER X (LB)
SHOULDER Z (LB)
SHOULDER Y (LB)
SHOULDER RES (LB)
300.00
200.00
100.00
0.00
-100.00
-140
10
160
310
460
TIME IN MILLISECONDS

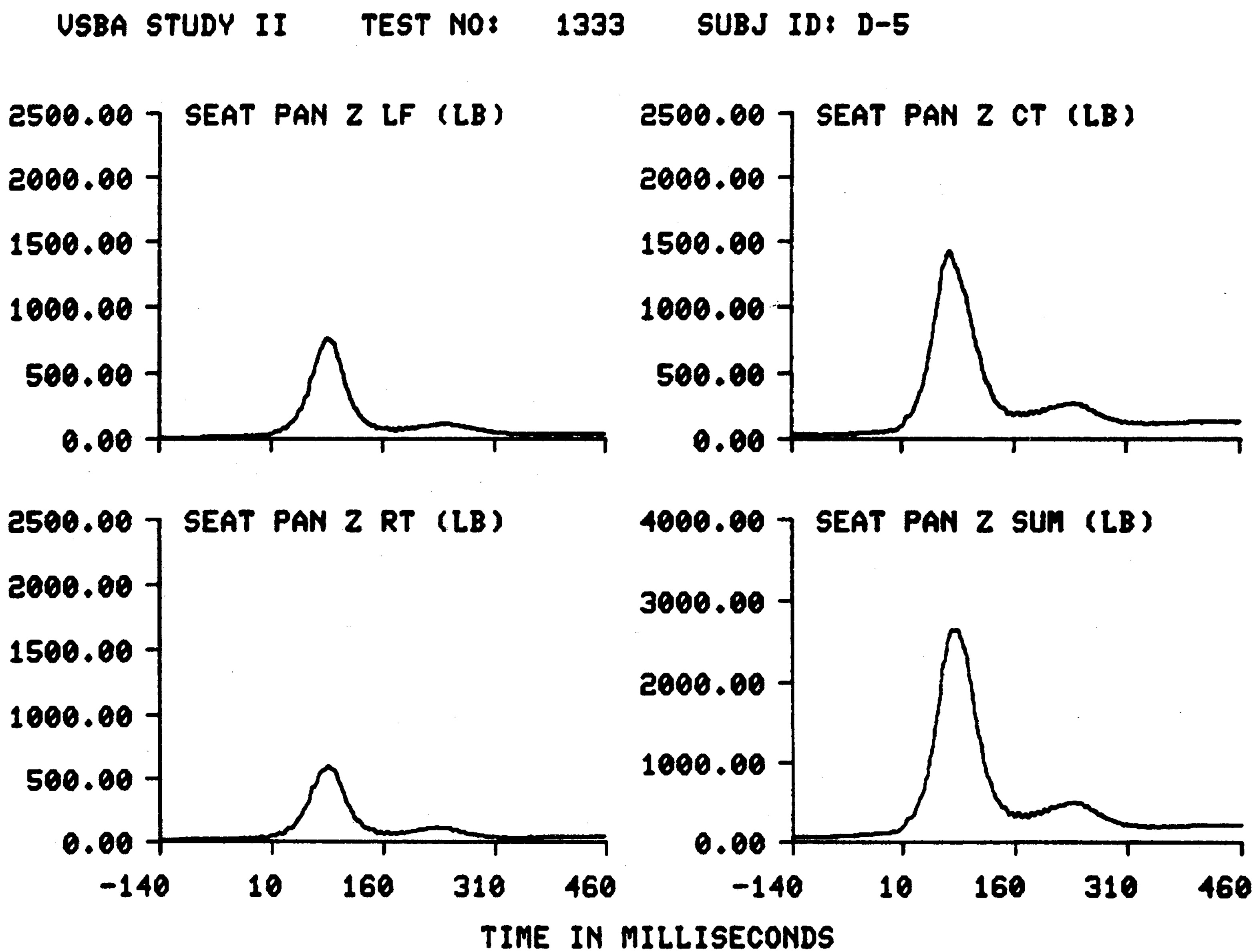
USBA STUDY II TEST NO: 1333 SUBJ ID: D-5



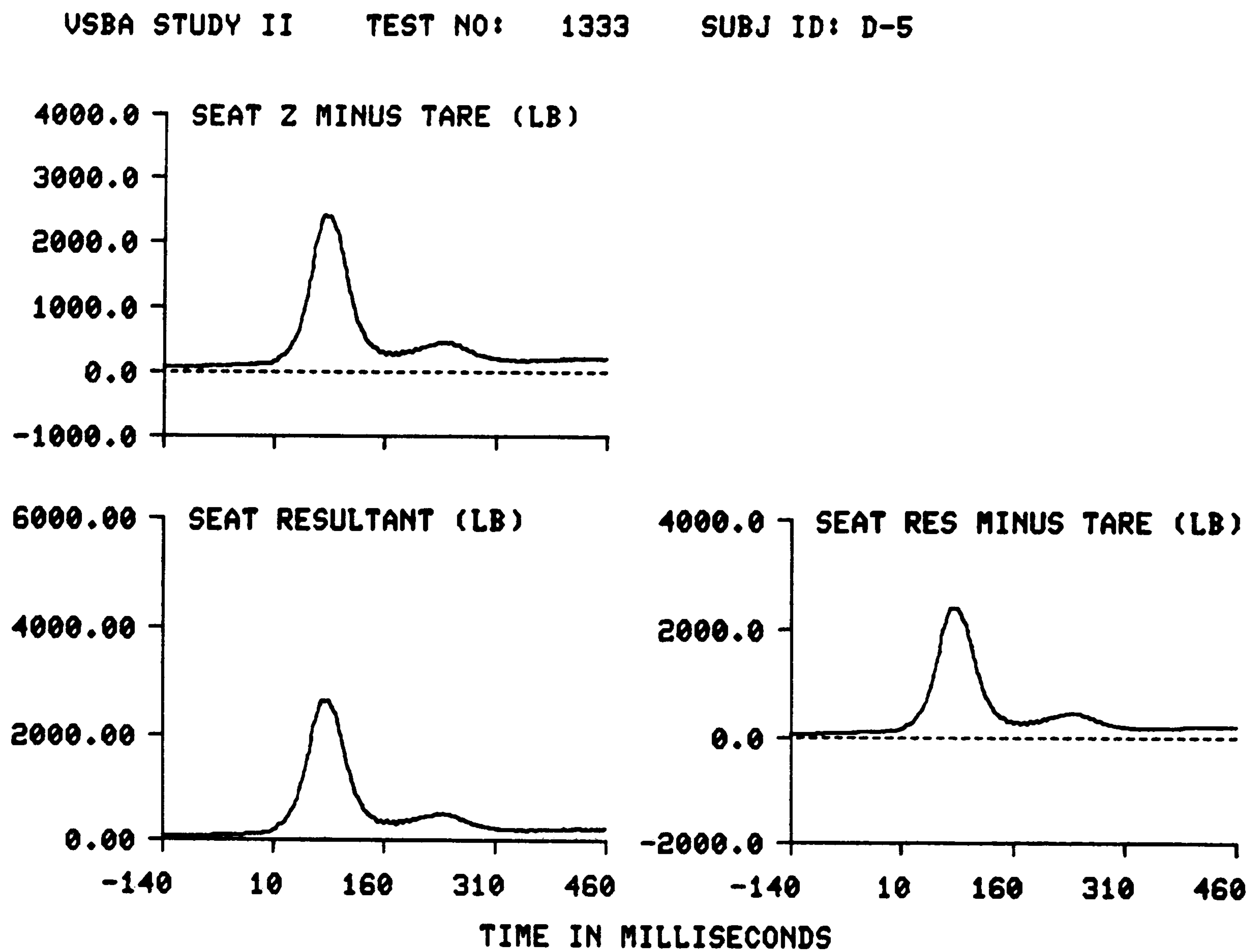

USBA STUDY II
TEST NO: 1333
SUBJ ID: D-5
RT LAP X (LB)
RT LAP Z (LB)
RT LAP Y (LB)
RT LAP RES (LB)
300.00
200.00
100.00
0.00
-100.00
-140
10
160
310
460
TIME IN MILLISECONDS

VSBA STUDY II   TEST NO: 1333   SUBJ ID: D-5



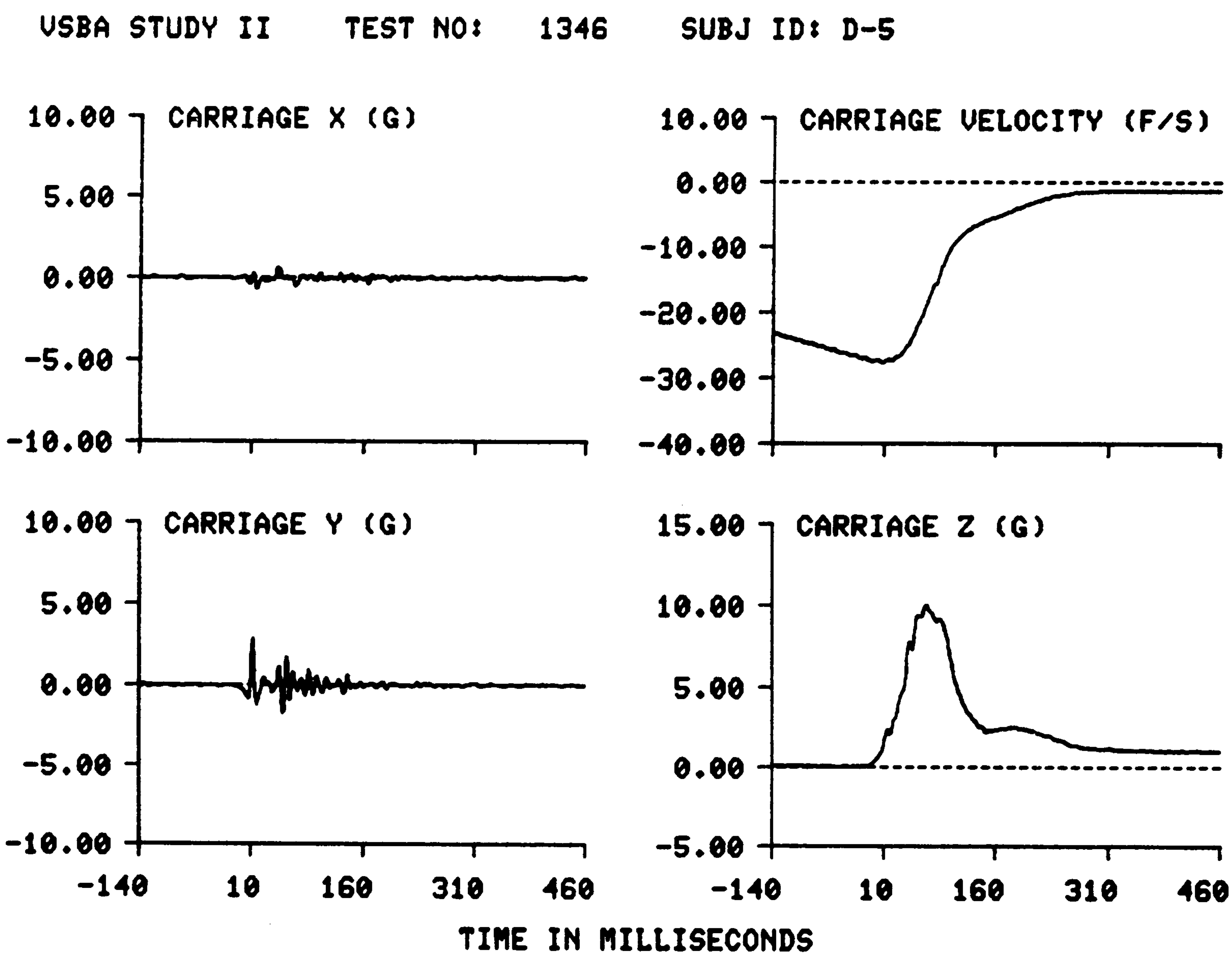


VSBA STUDY II TEST NO: 1333 SUBJ ID: D-5
SEAT PAN Z LF (LB)
SEAT PAN Z CT (LB)
SEAT PAN Z RT (LB)
SEAT PAN Z SUM (LB)
2500.00
2000.00
1500.00
1000.00
500.00
0.00
4000.00
3000.00
-140
10
160
310
460
TIME IN MILLISECONDS

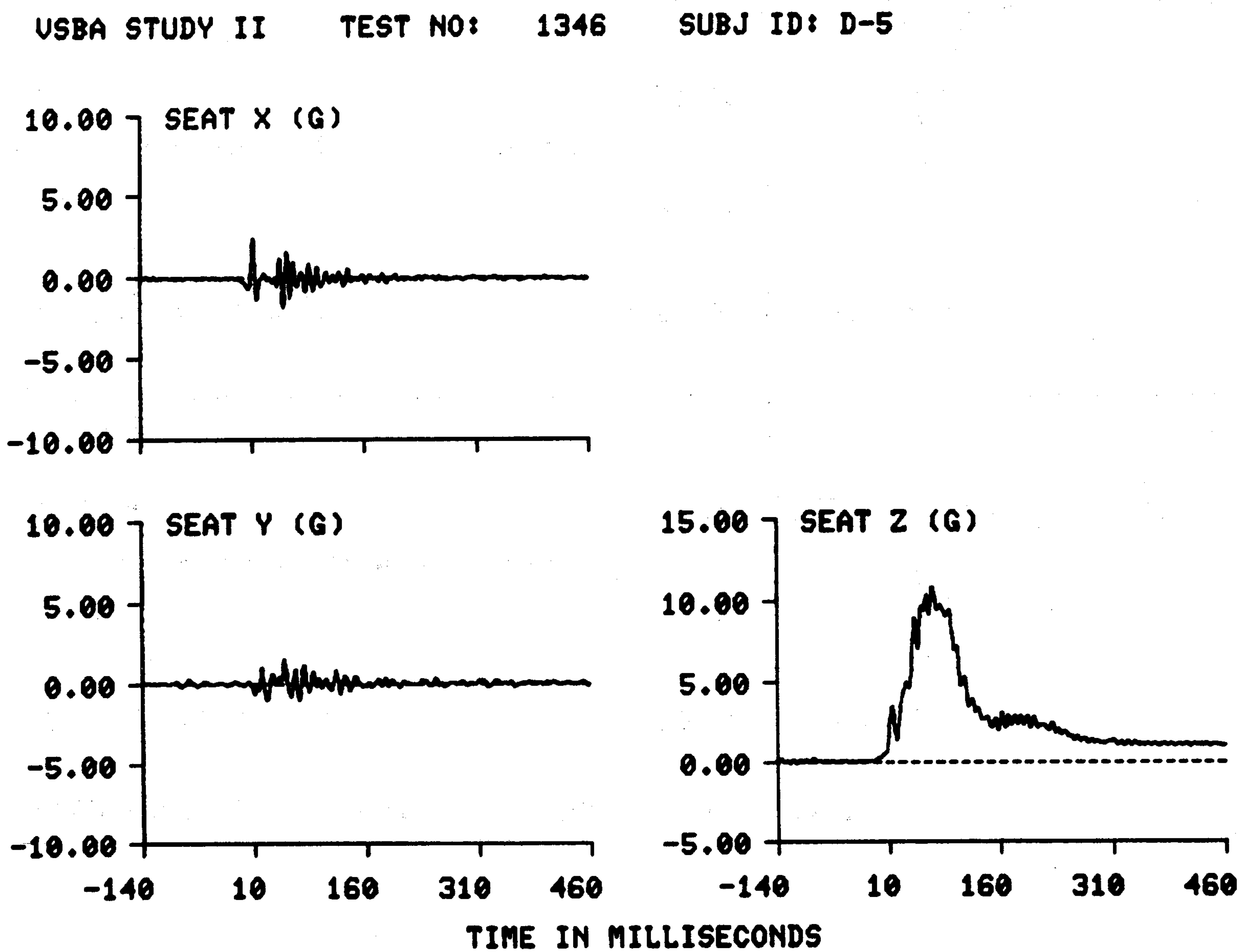

VSBA STUDY II TEST NO: 1333 SUBJ ID: D-5
SEAT Z MINUS TARE (LB)
4000.0
3000.0
2000.0
1000.0
0.0
-1000.0
SEAT RESULTANT (LB)
6000.00
4000.00
2000.00
0.00
SEAT RES MINUS TARE (LB)
4000.0
2000.0
0.0
-2000.0
-140
10
160
310
460
TIME IN MILLISECONDS

VSBA STUDY II TEST: 1346 SUBJ: D-5 WT: 172.0 NOM G: 10.0 CELL: I

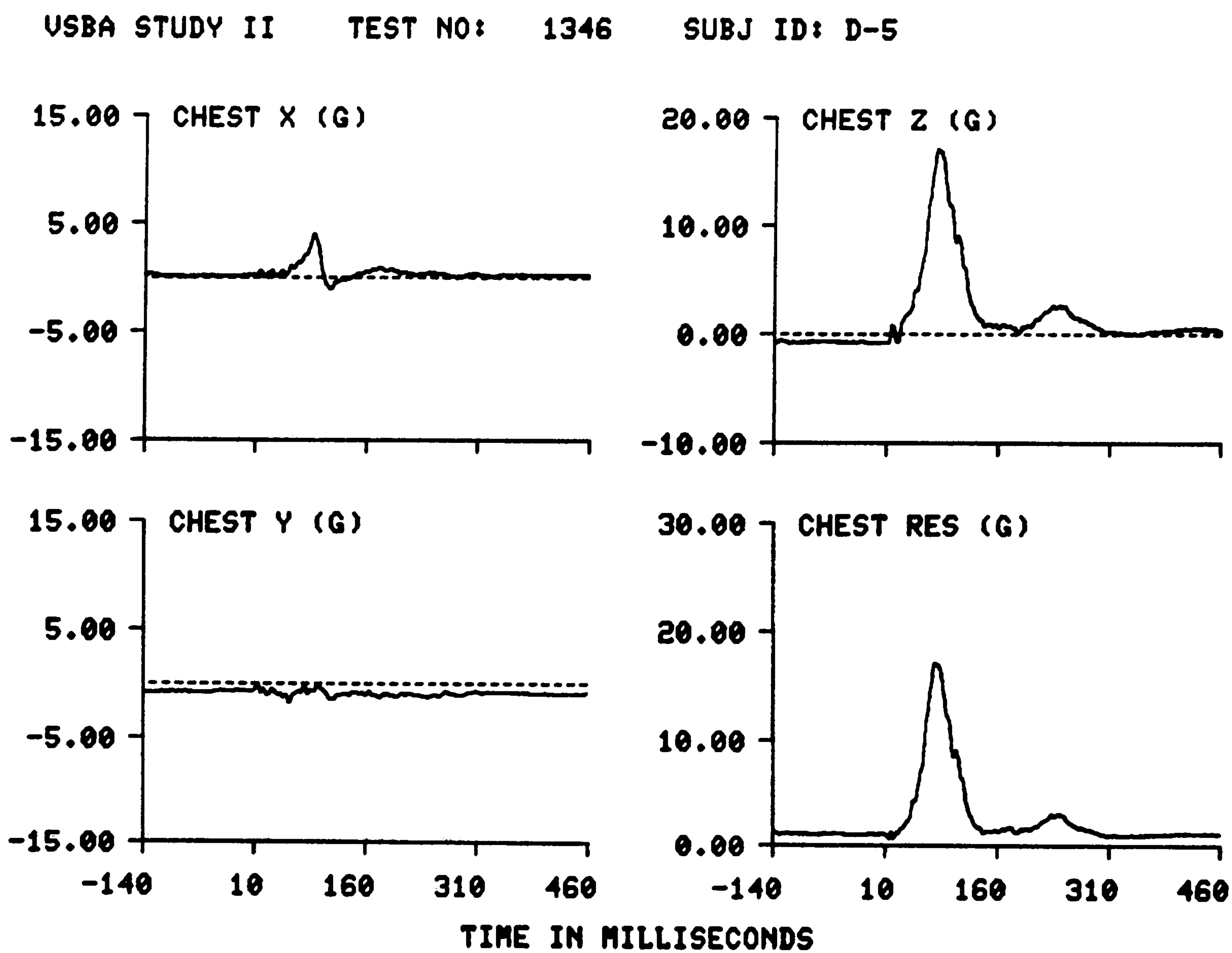
DATA ID	IMMEDIATE PREIMPACT	MAXIMUM VALUE	MINIMUM VALUE	TIME OF MAXIMUM	TIME OF MINIMUM
REFERENCE MARK				-148.	
2.5V EXT PWR		2.50	2.50	21.	0.
10V EXT PWR		10.00	9.99	2.	0.
CARRIAGE ACCELERATION (G)					
X AXIS	0.00	0.65	-0.67	44.	16.
Y AXIS	-0.07	2.82	-1.77	12.	52.
Z AXIS	0.05	10.02	0.49	67.	0.
Z AXIS (SM)	0.06	9.74	0.53	68.	0.
SEAT ACCELERATION (G)					
X AXIS	-0.05	2.41	-1.85	11.	52.
Y AXIS	0.01	1.52	-1.04	50.	70.
Z AXIS	0.07	10.85	0.37	68.	0.
Z AXIS (SM)	0.07	10.26	0.37	69.	0.
RY	-1.41	23.39	-31.58	44.	21.
CARRIAGE VELOCITY (F/S)	-27.01	-1.21	-27.58	358.	6.
CHEST ACCELERATION (G)					
X AXIS	0.14	3.95	-1.04	88.	110.
Y AXIS	-0.68	-0.08	-1.78	95.	57.
Z AXIS	-0.74	17.07	-0.80	75.	7.
RESULTANT	1.02	17.20	0.59	76.	14.
NORM RESULTANT	0.10	1.77	0.06	76.	14.
SI		35.81			
RY	-4.49	358.68	-382.51	77.	92.
HEAD ACCELERATION (G)					
X AXIS	-0.28	0.81	-3.54	73.	118.
Y AXIS	-0.35	0.22	-1.19	131.	68.
Z AXIS	-0.49	16.94	-0.59	74.	10.
RESULTANT	0.67	16.98	0.38	74.	344.
NORM RESULTANT	0.07	1.74	0.04	74.	344.
SI		28.47			
RY	-6.88	580.38	-239.60	73.	119.
THORAX ACCELERATION (G)					
X AXIS	-0.30	0.30	-6.76	189.	86.
Y AXIS	0.45	5.79	-0.35	85.	22.
Z AXIS	-0.29	20.57	-0.37	92.	167.
RESULTANT	0.62	20.86	0.28	92.	171.
NORM RESULTANT	0.06	2.14	0.03	92.	171.
SHOULDER LOADS (LB)					
X AXIS	75.17	116.57	29.74	104.	422.
Y AXIS	-0.33	12.03	-4.10	69.	147.
Z AXIS	-7.93	33.24	-7.98	91.	0.
RESULTANT	75.59	119.83	29.77	104.	450.
LAP LOADS (LB)					
LEFT X AXIS	41.21	56.40	2.95	107.	56.
LEFT Y AXIS	10.87	12.30	-2.97	9.	51.
LEFT Z AXIS	43.84	45.13	-13.08	0.	59.
LEFT RESULTANT	61.15	68.70	5.22	108.	48.
RIGHT X AXIS	39.53	43.47	0.30	103.	57.
RIGHT Y AXIS	16.05	16.57	-0.25	1.	59.
RIGHT Z AXIS	47.35	48.45	-12.80	0.	56.
RIGHT RESULTANT	63.73	65.63	8.26	3.	48.
SEAT LOADS (LB)					
LEFT LINK X AXIS	-2.75	19.75	-10.37	12.	81.
RIGHT LINK X AXIS	-3.25	30.39	-8.02	98.	133.
X AXIS	-6.00	41.11	-14.20	98.	6.
CENTER LINK Y AXIS	11.70	15.18	-19.64	452.	69.
LEFT PAN Z AXIS	21.45	744.45	18.94	94.	4.
RIGHT PAN Z AXIS	30.24	600.37	25.95	94.	353.
CENTER PAN Z AXIS	85.25	1639.63	93.22	74.	0.
Z AXIS SUM	136.93	2696.46	144.30	82.	0.
Z AXIS MINUS TARE	164.69	2445.07	153.42	83.	9.
RESULTANT	137.56	2696.52	145.10	82.	0.
RESULTANT MINUS TARE	165.22	2445.13	153.57	83.	9.



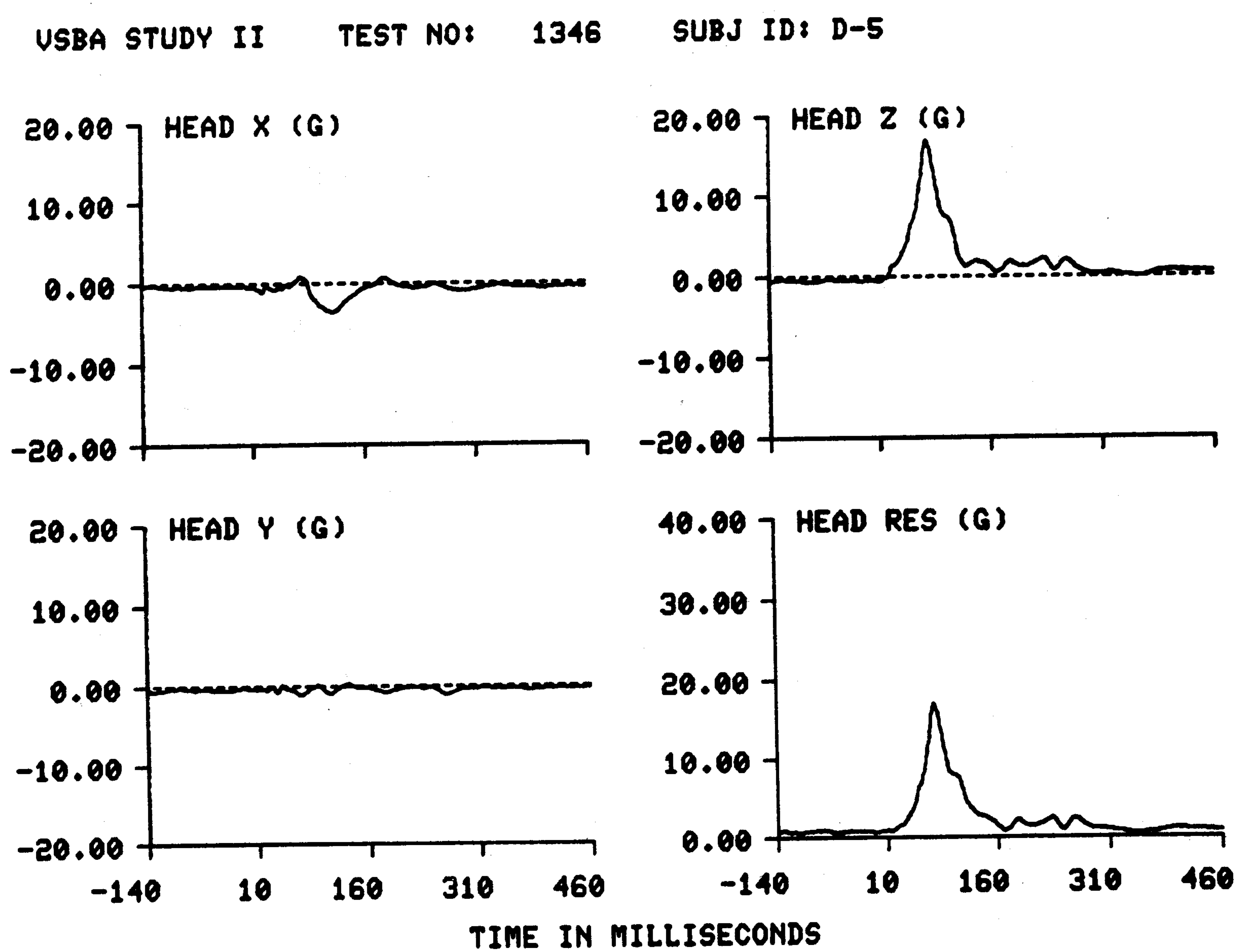
USBA STUDY II TEST NO: 1346 SUBJ ID: D-5
CARRIAGE X (G)
CARRIAGE VELOCITY (F/S)
CARRIAGE Y (G)
CARRIAGE Z (G)
10.00
5.00
0.00
-5.00
-10.00
-20.00
-30.00
-40.00
15.00
-140
10
160
310
460
TIME IN MILLISECONDS

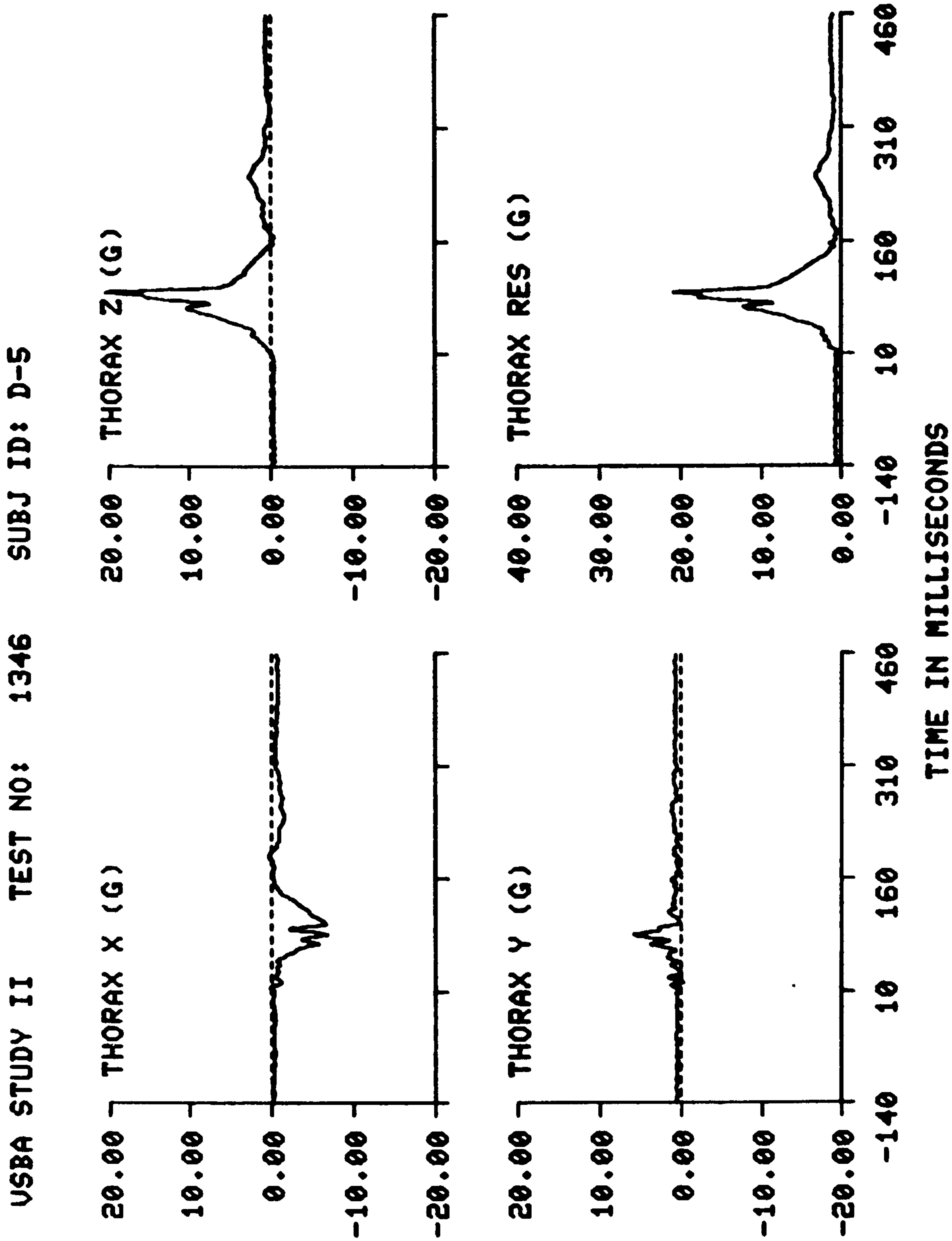


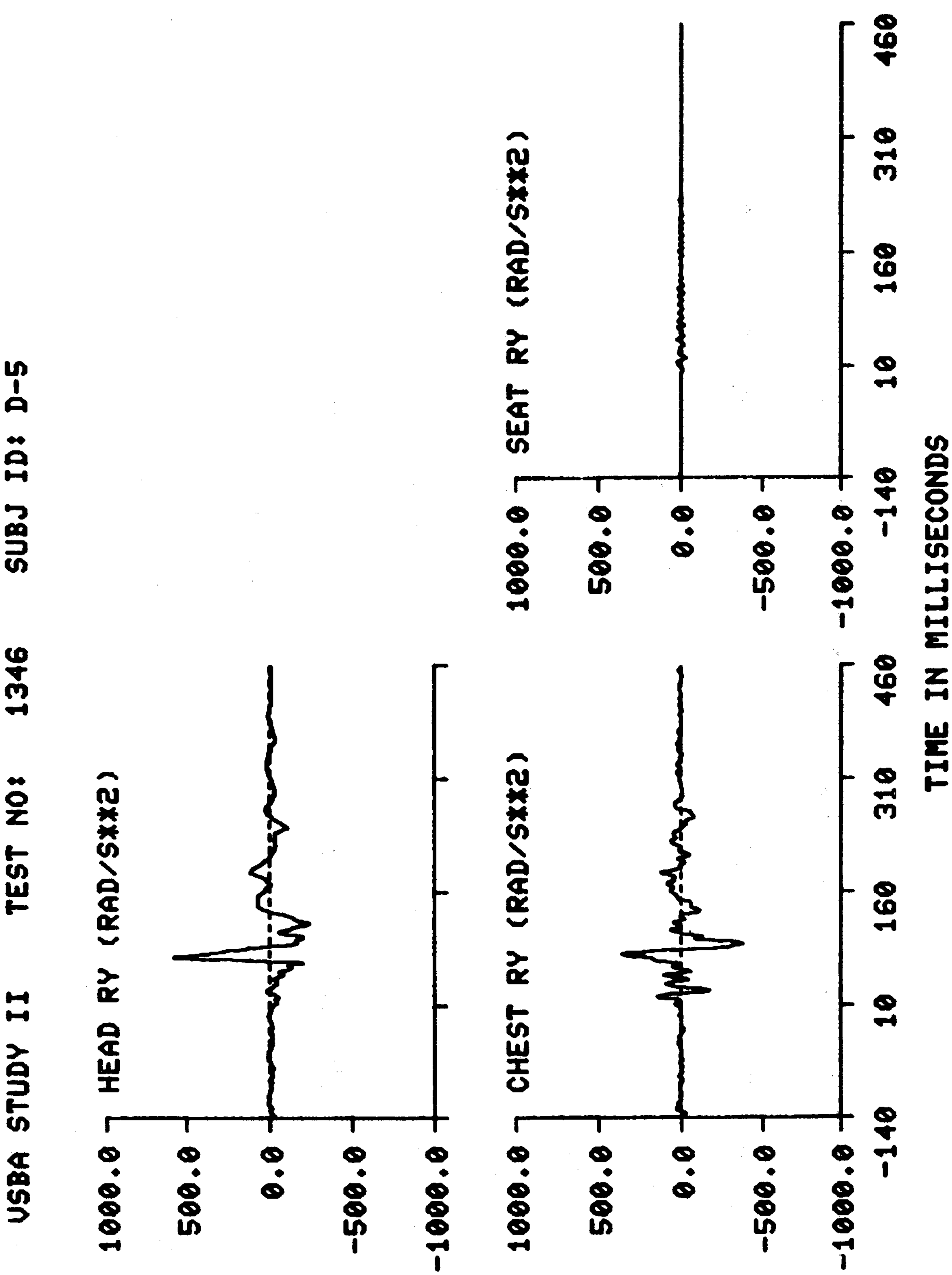
USBA STUDY II TEST NO: 1346 SUBJ ID: D-5
SEAT X (G)
10.00
5.00
0.00
-5.00
-10.00
SEAT Y (G)
10.00
5.00
0.00
-5.00
-10.00
SEAT Z (G)
15.00
10.00
5.00
0.00
-5.00
-140
10
160
310
460
TIME IN MILLISECONDS



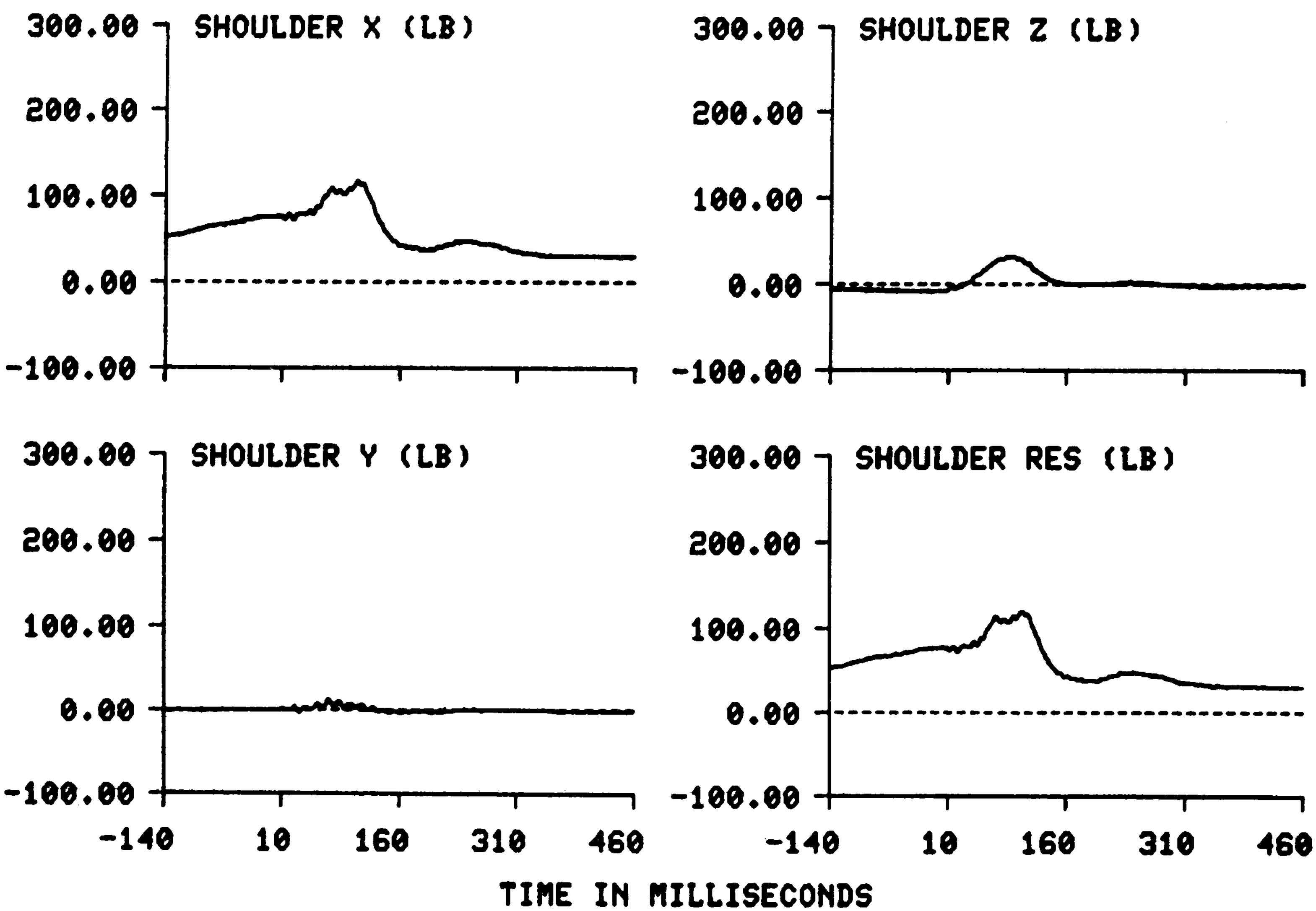
USBA STUDY II
TEST NO: 1346
SUBJ ID: D-5
CHEST X (G)
15.00
5.00
-5.00
-15.00
CHEST Z (G)
20.00
10.00
0.00
-10.00
CHEST Y (G)
15.00
5.00
-5.00
-15.00
CHEST RES (G)
30.00
20.00
10.00
0.00
-140
10
160
310
460
TIME IN MILLISECONDS


USBA STUDY II TEST NO: 1346 SUBJ ID: D-5
HEAD X (G)
HEAD Z (G)
HEAD Y (G)
HEAD RES (G)
20.00
10.00
0.00
-10.00
-20.00
40.00
30.00
-140
10
160
310
460
TIME IN MILLISECONDS

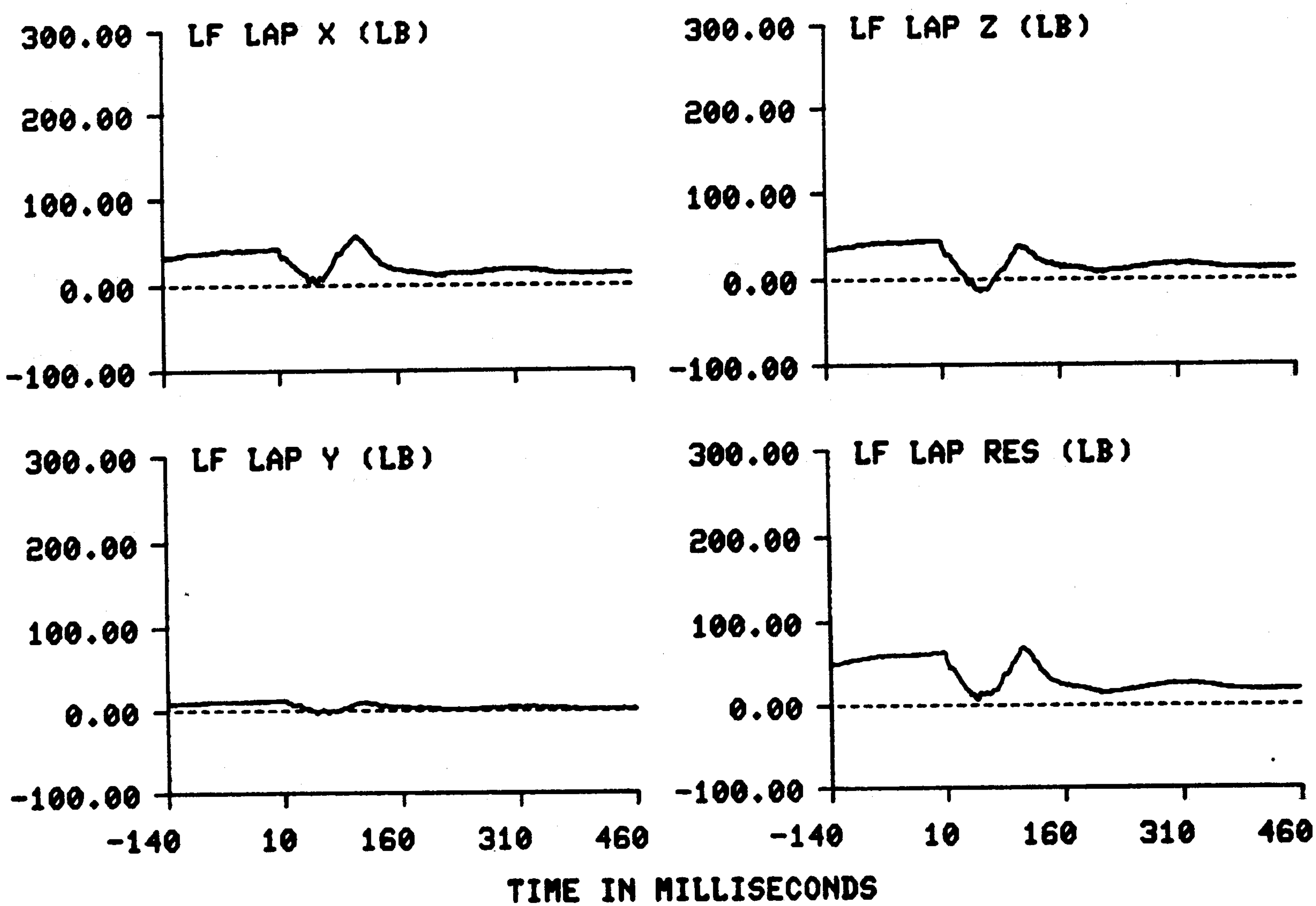

USBA STUDY II
TEST NO: 1346
SUBJ ID: D-5
THORAX X (G)
THORAX Y (G)
THORAX Z (G)
THORAX RES (G)
20.00
10.00
0.00
-10.00
-20.00
40.00
30.00
20.00
10.00
0.00
-140
10
160
310
460
TIME IN MILLISECONDS

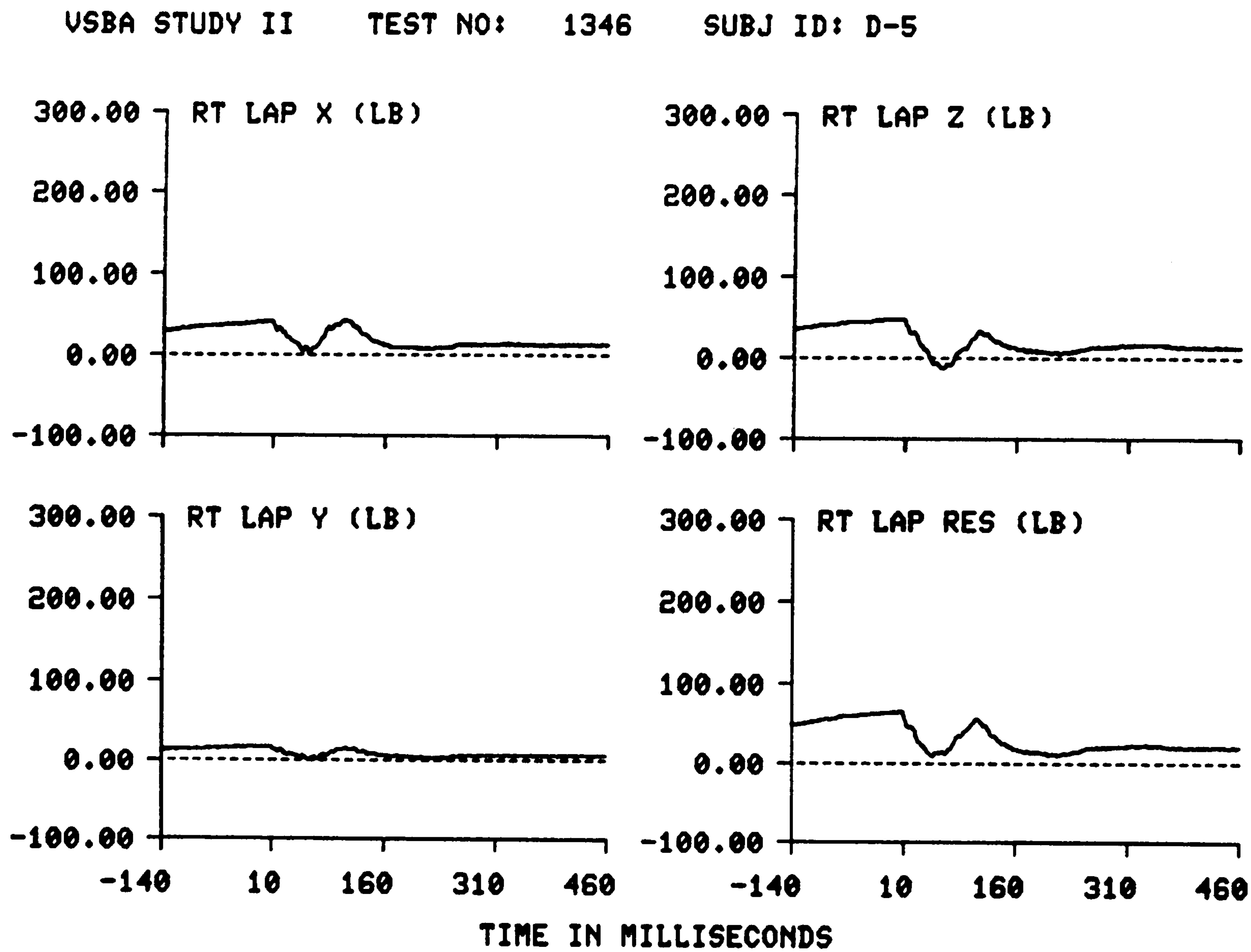

USBA STUDY II
TEST NO: 1346
SUBJ ID: D-5
HEAD RY (RAD/S**2)
CHEST RY (RAD/S**2)
SEAT RY (RAD/S**2)
1000.0
500.0
0.0
-500.0
-1000.0
-140
10
160
310
460
TIME IN MILLISECONDS

VSBA STUDY II TEST NO: 1346 SUBJ ID: D-5

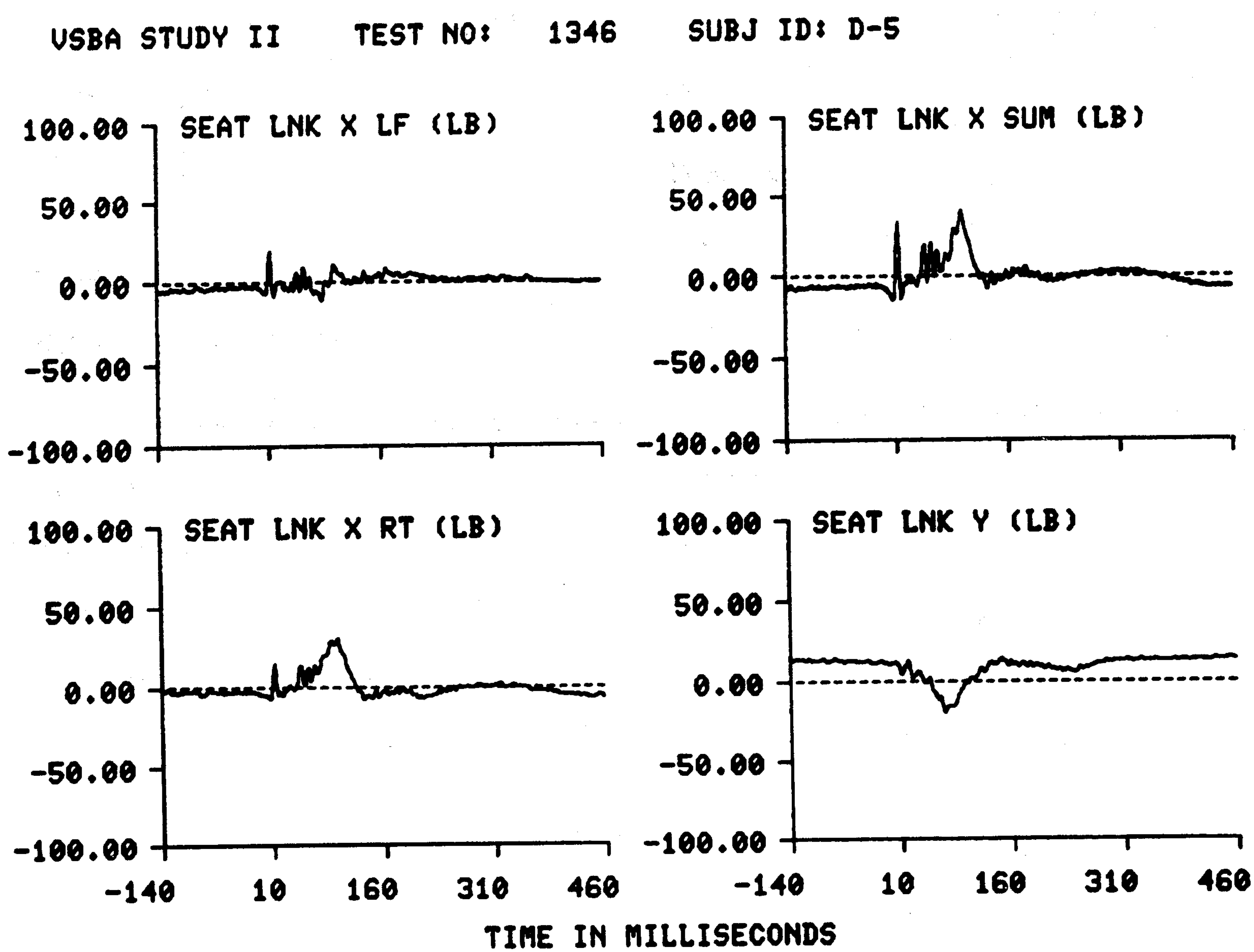


VSBA STUDY II TEST NO: 1346 SUBJ ID: D-5

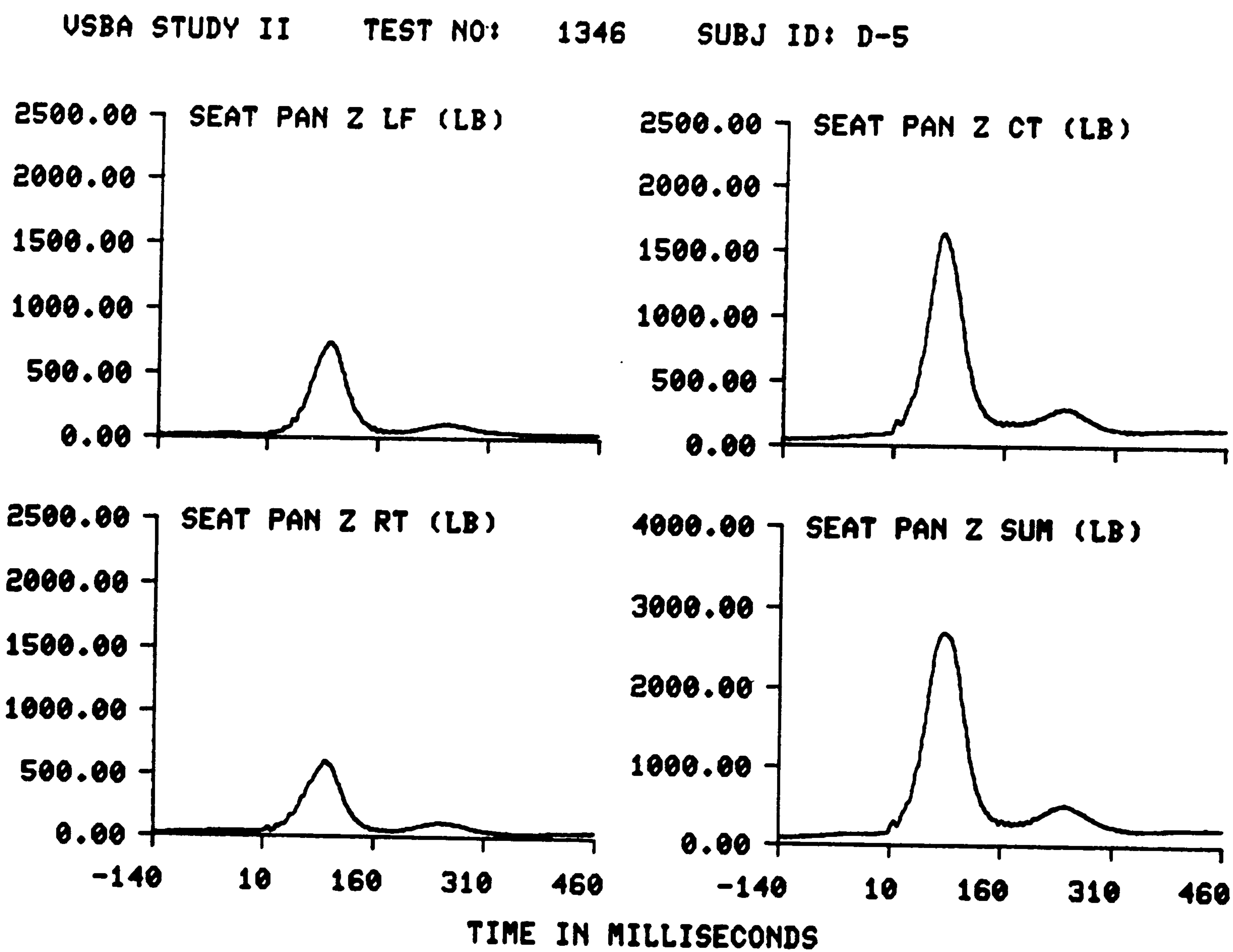




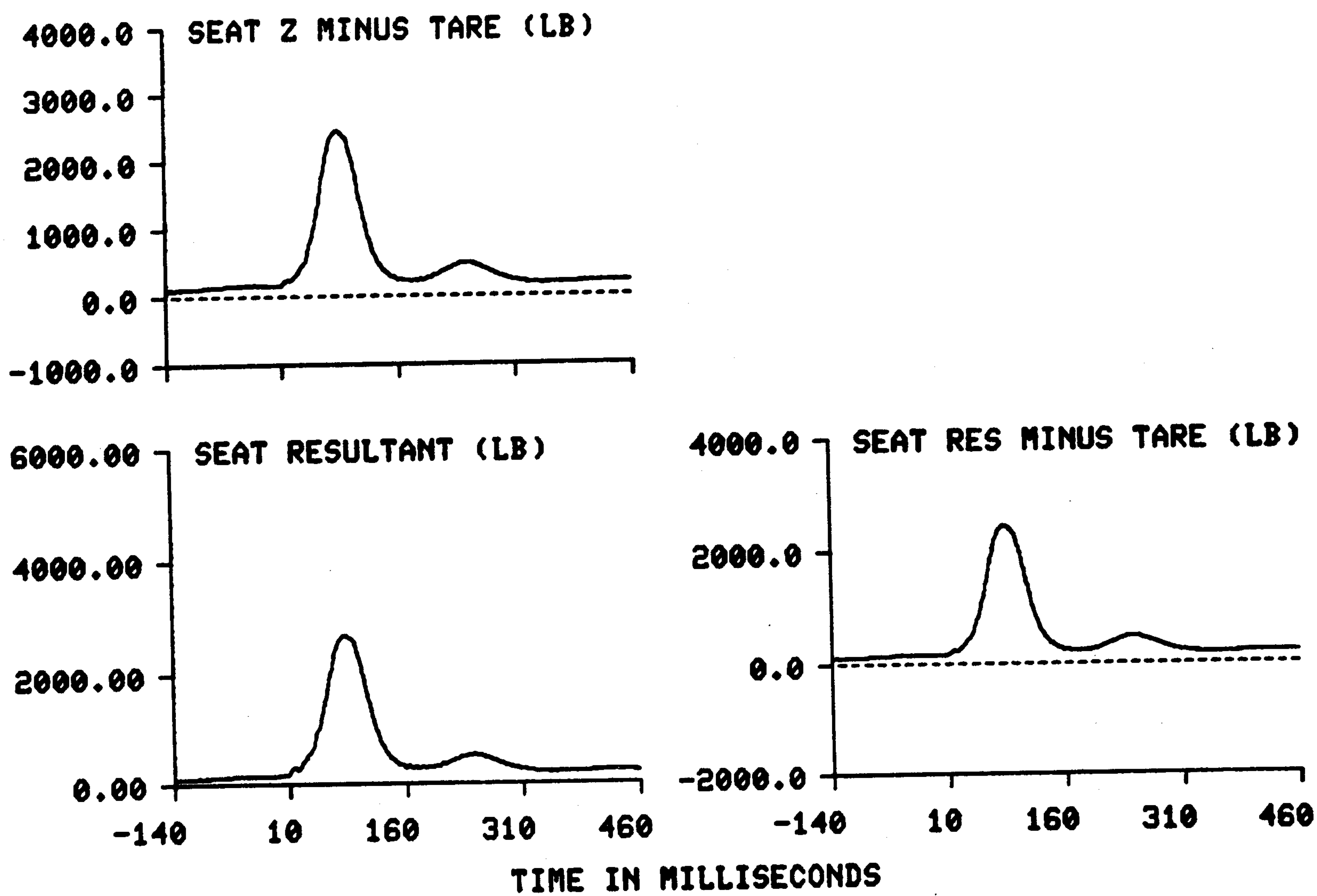
VSBA STUDY II TEST NO: 1346 SUBJ ID: D-5
RT LAP X (LB)
RT LAP Z (LB)
RT LAP Y (LB)
RT LAP RES (LB)
300.00
200.00
100.00
0.00
-100.00
-140
10
160
310
460
TIME IN MILLISECONDS



USBA STUDY II TEST NO: 1346 SUBJ ID: D-5
SEAT LNK X LF (LB)
SEAT LNK X SUM (LB)
SEAT LNK X RT (LB)
SEAT LNK Y (LB)
100.00
50.00
0.00
-50.00
-100.00
-140
10
160
310
460
TIME IN MILLISECONDS


USBA STUDY II TEST NO: 1346 SUBJ ID: D-5
SEAT PAN Z LF (LB)
SEAT PAN Z CT (LB)
SEAT PAN Z RT (LB)
SEAT PAN Z SUM (LB)
2500.00
2000.00
1500.00
1000.00
500.00
0.00
4000.00
3000.00
2000.00
1000.00
-140
10
160
310
460
TIME IN MILLISECONDS

USBA STUDY II TEST NO: 1346 SUBJ ID: D-5



U.S.G.P.O.:1994–550-057/81062