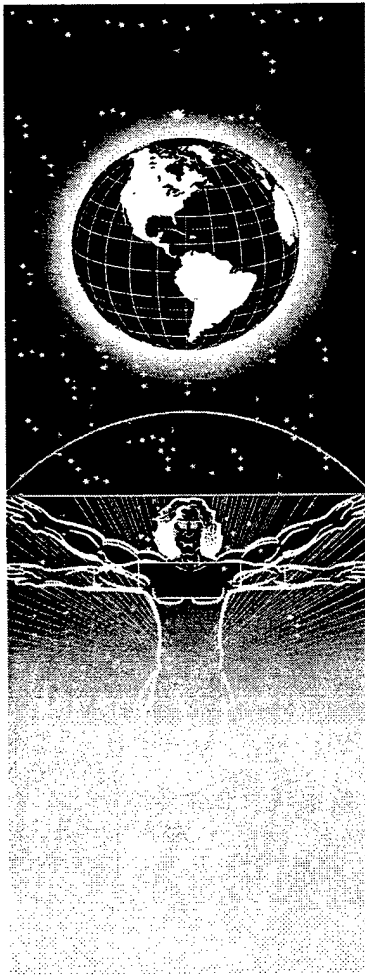




UNITED STATES AIR FORCE RESEARCH LABORATORY

Helmet Impact Tests with a Modified ACES II Headrest

Chris E. Perry

May 1999

Interim Report for the Period November 1998 to May 1999

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Biodynamics and Protection Division
Biodynamics and Acceleration Branch
BLDG 824 RM 206 2800 Q Street
Wright-Patterson AFB OH 45433-7947

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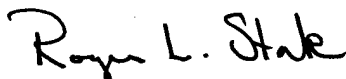
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FOR THE DIRECTOR



ROGER L. STORK, Colonel, USAF, BSC
Chief Biodynamics and Protection Division
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To counteract the effects of brain injury, head protection has been designed into environments where severe head impact is probable. An experimental effort was conducted to evaluate the effectiveness of various foam pads in reducing trauma to the head resulting from impact with the ACES II headrest. A series of vertical drops with a Helmet Drop Tower (HDT) facility and an instrumented headform were conducted using the HGU-55/P flight helmet, a current ACES II headrest, and samples of two types of foam (Confor and F-Cell foam). The probability of head injury, as determined by the Head Injury Criteria (HIC), was calculated using measured impact acceleration of the headform for each impact surface. The headform acceleration, resulting HIC values, and probability of severe brain injury values for the Confor foam tests were all less than the comparative values for either the standard ACES II headrest or the headrest with the F-Cell foam.

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PREFACE

An experimental effort was conducted to evaluate the effectiveness of various foam pads in reducing trauma to the head resulting from impact with the ACES II headrest. A series of vertical drops with a Helmet Drop Tower (HDT) facility and an instrumented headform were conducted using HGU-55/P flight helmets, a current ACES II headrest, and samples of two types of foam. The helmet impact tests and data analysis described in this report were accomplished by the Biodynamics and Acceleration Branch, Biodynamics and Protection Division, Human Effectiveness Directorate of the Air Force Research Laboratory (AFRL/HEPA) at Wright-Patterson Air Force Base OH. The tests were conducted at the request of Lt. Col. Bob Munson at HSW/YASA, Brooks Air Force Base TX, and Maj. Gordon Peters at the USAF School of Aerospace Medicine, Brooks Air Force Base TX. Test facility and engineering support at AFRL/HEPA were provided by DynCorp, Inc. under contract F33601-96-DJ001.

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INTRODUCTION

Studies have been conducted on head tolerance to impact loads and have shown a decrease in the tolerance to impact intensity as the time duration increases [2]. The Wayne State Tolerance (WST) curve, based on animal and cadaver tests, is one of the most widely recognized data sets indicating the transition point from non-injurious head accelerations to injurious head acceleration in terms of brain injury or concussion [5]. To counteract the effects of brain injury, head protection has been designed into environments where severe head impact was probable such as automobile crashes and sporting events [4]. Examples of this type of head protection would include helmets, foam padding of contact surfaces, and airbags. In the Air Force, pilots wear helmets to protect their head from contact with hard surfaces during flight and during ejection [1].

During a recent ejection in Southeast Asia with the ACES II ejection seat, the pilot was found to have suffered a severe head injury. The head injury was consistent with those resulting from the helmeted head being violently forced back into the headrest as the ejection seat enters the windblast phase of the ejection. As a result of this recent head injury, a task was initiated to perform an impact study evaluating the effectiveness of the existing ACES II headrest and two proposed foam pads in reducing head injury.

BACKGROUND

As head protection concepts have been developed, procedures and methodologies to measure the effectiveness of the proposed head protection have also been developed. To obtain these measures, tolerance criteria for head injury have been proposed by various research groups, and most are described in previous Stapp Car Crash Conference proceedings [2,3,9,10]. The WST curve was one of the first established tolerance criteria, and was then followed by a weighted-impulse integration procedure developed by Charles Gadd [2]. This became known as the Gadd Severity Index (GSI). A modified version of the GSI, using a maximization technique for the integration procedure, was adopted by the National Highway Traffic Safety Administration

(NHTSA) of the Department of Transportation (DOT), and was called the Head Injury Criterion (HIC) [5]. These criteria and others were based on measured skull accelerations with the assumed injury being brain injury (severe concussion) or a combination of skull fracture and brain injury. For example, a HIC value of 1000 corresponds to a probability of a severe brain injury (Abbreviated Injury Scale or AIS ≥ 4) of approximately 16% [6].

METHODOLOGY

AFRL/HEPA conducted a series of vertical impact tests using a Helmet Drop Tower (HDT) facility. The tests simulated exposure of the occipital region of an HGU-55/P flight helmet to windblast-induced impact against the ACES II ejection seat headrest. The HDT facility is composed of a small glide carriage mounted on two vertical steel cables [7,8]. A low resonant magnesium alloy headform is attached to the carriage at the approximate midline of the carriage (a point halfway between the vertical cables). After affixing a helmet to the headform, the carriage is raised to a specific height and then allowed to free-fall onto a rigid fixture (typically a flat, circular steel anvil or a hemispherical steel anvil). The rigid fixture is mounted to a load cell that is supported by a 300 lb stationary base acting as a reaction mass. The headform can swivel and then be locked into position on the carriage, allowing impacts at any point on the outer surface of the helmet. The velocity of the carriage at impact and the energy transfer at impact are controlled by the initial height of the carriage prior to free-fall. The facility with an HGU-55/P helmet mounted on the headform is shown in Figure 1.

The helmet drop tests for this program were used to evaluate the effectiveness of crushable-foam headrest pads in reducing the energy directed to a helmeted head during impact with the headrest. A linear accelerometer at the approximate center of gravity of the HDT headform was used to measure headform acceleration in the vertical plane of motion. The headform and helmet were positioned to allow impacts on the dorsal plane of the helmet (as shown in Figure 1) for all tests. A separate HGU-55/P helmet with TPL liner was used for each impact condition. The test matrix for this study is shown in Table 1. Test cells are identified by a letter/number combination for a total of 12 separate test conditions.



Figure 1. Helmet Drop Tower Facility

Table 1. ACES II Headrest Test Matrix

Impact Energy (ft-lbs)	Impact Surface 1 Headrest Blank	Impact Surface 2 ACES II Headrest	Impact Surface 3 Headrest Blank + Confor C-47 Foam	Impact Surface 4 Headrest Blank + #6 F-Cell Foam
20	A1	B1	C1	D1
35	A2	B2	C2	D2
50	A3	B3	C3	D3

Tests were conducted at three different helmet impact energies using four different surface conditions. The impact energy levels provided a range of brain injury probabilities up to the maximum of approximately 5%, as determined by the HIC. The impact conditions included the ACES II headrest, a headrest blank fabricated to approximate the ACES II headrest with no padding, and the headrest blank with one of two different foam samples. The two different foam samples were cut into three 2-inch-by-5-inch pieces. The three pieces were then attached to the headrest blank using Velcro. The headrest blank was fabricated of sheet aluminum of the same thickness as the ACES II headrest, and was bent to have the same contour (Figure 2). A special aluminum jig was fabricated to support each headrest on the load cell of the HDT. It should be noted that, for the tests with the foam samples, the foam was applied to the headrest blank to cover not only the angled sides, but also to cover the back surface of the headrest. This was done to prevent helmet contact with an unpadded surface as with the ACES II headrest, thus providing an increased degree of protection.

The foam padding on the existing ACES II headrest was an approximately 0.25-inch thick high-density rubberized foam that covered only the slanted sides of the headrest. As shown in Figure 3, the foam did not cover the headrest's back plane. One foam sample configuration was a 0.5-inch thick, high-density, rate-dependent foam (Confor C-47) supplied by Oregon Aero, Inc. (Figure 4). The second foam sample configuration was a 0.35-inch thick, high-density, closed-cell foam (#6 F-Cell) manufactured by Foam Fabricators (Figure 5).

To calibrate the HDT facility (relate drop height input to impact energy output), a friction factor for the steel guide cables was calculated. To determine the friction factor, an initial theoretical drop height was calculated using the following equation:

$$h = E/w \quad (1)$$

where h is the theoretical drop height, E is the required energy at impact, and w is the weight of the carriage, headform, and helmet.

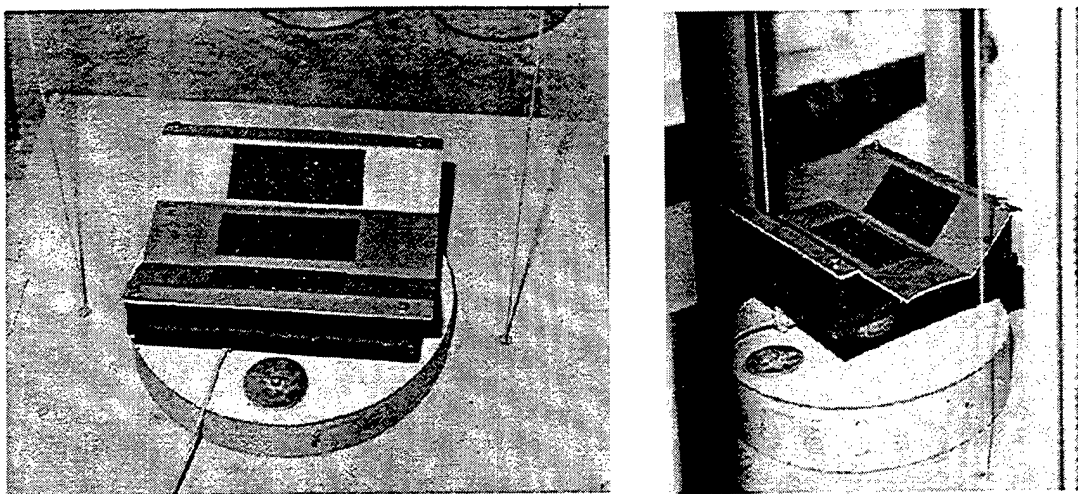


Figure 2. Top Left-Side View and Off-axis View of Headrest Blank

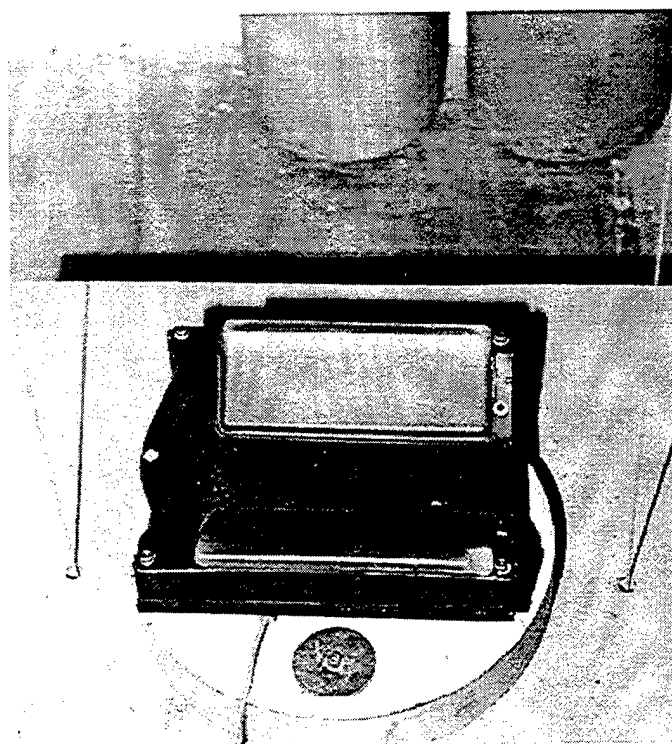


Figure 3. Top Left-Side View of ACES II Headrest

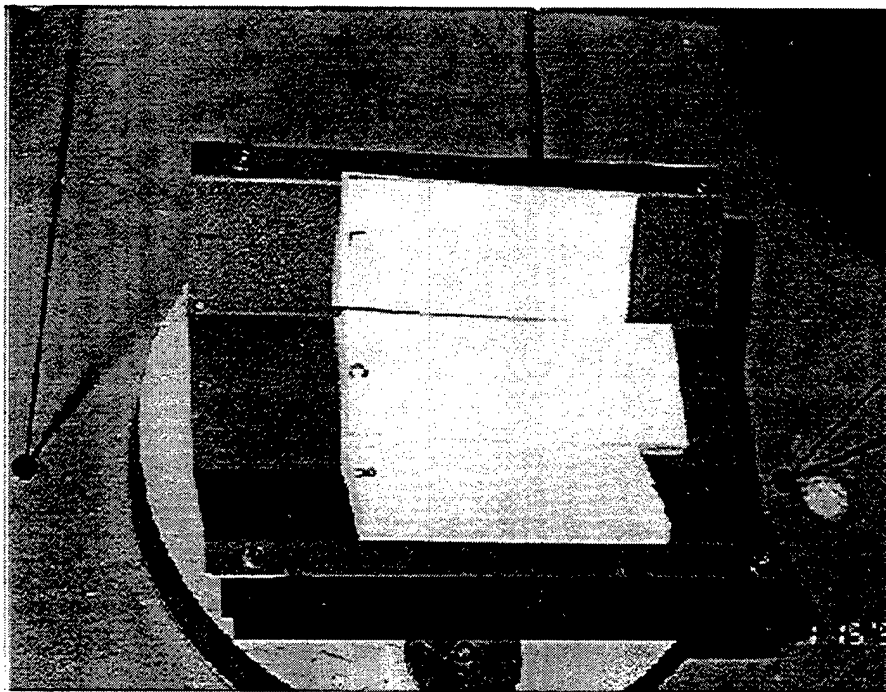


Figure 4. Top Right-Side View of Headrest Blank with Confor Foam Inserts

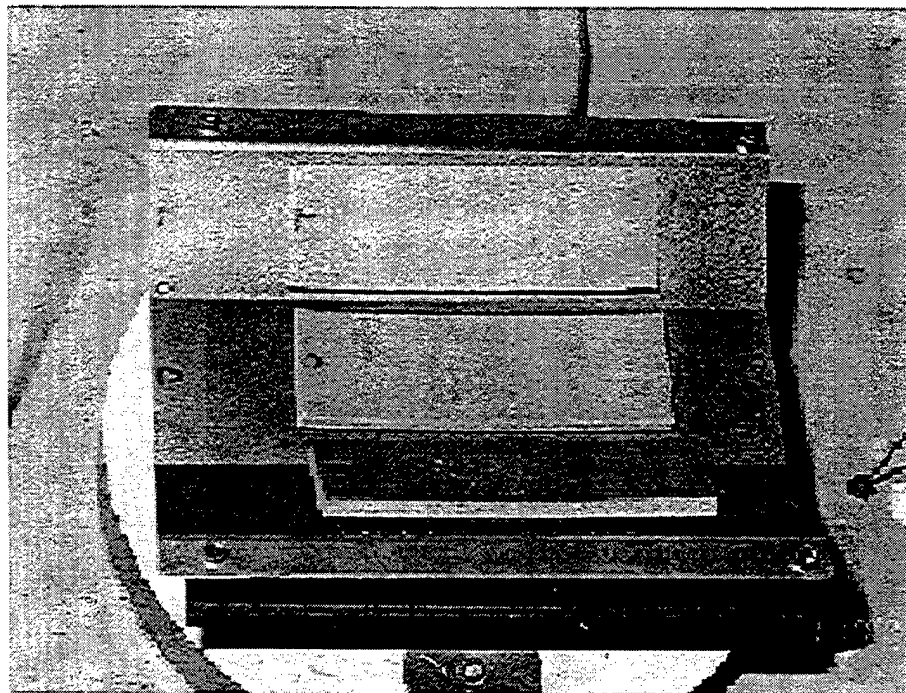


Figure 5. Top Right-Side View of Headrest Blank with #6 F-Cell Foam Inserts

Knowing the initial theoretical drop height, a theoretical free-fall time for the carriage and components was calculated using the following equation:

$$t_{TF} = ((2 * h) / a)^{0.5} \quad (2)$$

where t_{TF} is the theoretical free-fall time, h is the theoretical drop height, and a is the acceleration due to gravity. Using a required energy at impact of 20 ft-lb and the carriage weight of 13.8 lb, equations (1) and (2) were solved to find a theoretical free-fall time of 0.300 second. Knowing the theoretical free-fall time, a series of five impacts were conducted at a drop height of h equal to 1.448 ft or 17.375 in. The actual free-fall time was calculated for each test, and the average value of the five tests was used to calculate the cable friction factor using the following equation:

$$F_f = (t_{AF} - t_{TF}) / t_{TF} \quad (3)$$

where F_f is the cable friction factor, t_{AF} is the average actual free-fall time, and t_{TF} is as defined previously. The friction factor was found to be 0.09. This value was then used to calculate the drop height for each test requiring a specific impact energy as determined by the test matrix. The drop height was calculated using the following equation:

$$D_h = (E / w) + (F_f * (E / w)) \quad (4)$$

where D_h is the final drop height, E is the impact energy, w is the carriage assembly weight, and F_f is the cable friction factor. The carriage assembly was raised to the proper drop height for each test and released by an electronically activated solenoid and allowed to free-fall.

Data acquisition for the series of tests consisted of the headform acceleration time history from the internally mounted single-axis accelerometer, and the time history of the load imparted to the headform from the flat load cell mounted under the test fixture designed to hold the headrests. All tests were visually documented using a Kodak high-speed video camera running at 500 frames per second. Test requirements consisted of analyzing the acceleration peaks and calculating the HIC value using the acceleration time history. The HIC values represent given probabilities of brain injury ($AIS \geq 4$), which were then compared across test conditions. The HIC was calculated using equation 5 where $(t_2 - t_1)$ was varied up to a maximum of 15 ms. The relationship between HIC and the probability of brain injury is shown in Figure 6 [6].

$$HIC = (A_{avg})^{2.5} * (t_2 - t_1) \quad (5)$$

RISK OF SEVERE BRAIN INJURY AS A FUNCTION OF HIC

SEVERE BRAIN INJURY EQUATES TO AIS ≥ 4 FOR 15 ms TIME INTERVAL

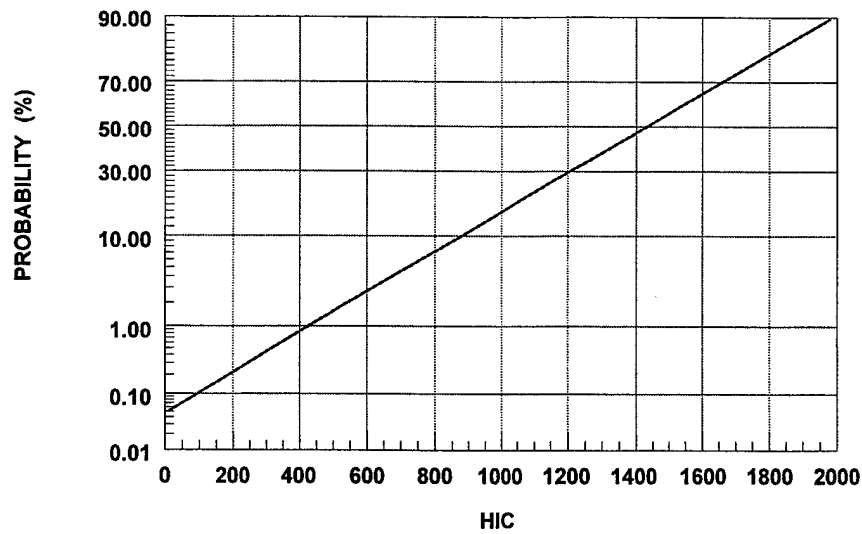


Figure 6. Risk of AIS ≥ 4 Brain Injury as a Function of 15 ms HIC

RESULTS

Three helmet impacts were conducted for each of the twelve test conditions. All test data were collected at 10K samples per second and filtered at 120 Hz. A summary of the peak acceleration data for all test conditions is shown in Table 2.

Table 2. Average Peak Headform Acceleration per Test Condition

Impact Energy (ft-lb)	Headrest Blank Headform Acceleration (G)	ACES II Headrest Headform Acceleration (G)	Blank + Confor Foam Headform Acceleration (G)	Blank + F-Cell Foam Headform Acceleration (G)
20	78.8 ± 2.0	69.2 ± 3.8	53.4 ± 4.3	63.0 ± 4.2
35	113.9 ± 0.1	104.9 ± 2.8	87.7 ± 2.2	103.7 ± 2.9
50	134.8 ± 5.1	135.2 ± 3.2	118.7 ± 5.4	132.2 ± 1.5

The analysis of the peak acceleration data indicates that the Confor foam significantly reduced the acceleration peak value when compared to the existing ACES II headrest. This is especially true at the 50 ft-lb impact energy level. The F-Cell foam also tended to decrease the acceleration peaks at the lower energy levels, but produced equivalent accelerations at the 50 ft-lb impact energy level. It is interesting to note that the standard ACES II headrest produced accelerations only slightly less than or equivalent to the unpadded headrest blank.

The acceleration time histories for each test were processed to calculate the HIC value using a Fortran routine programmed with the HIC equation (Equation 5), and using a time interval ($t_2 - t_1$) up to 15 ms maximum. The average HIC values for each test condition were calculated and are reported in Table 3. These values are also shown graphically in Figure 7.

To help visualize the difference between the improvement provided by the Confor foam padding and the existing ACES II headrest, regression lines were fitted to these two sets of data using a commercially available graphics and data analysis software package. The data were fitted with a standard power equation ($y = a \cdot x^b$). Each regression line produced a correlation coefficient of $r = 0.999$, and are shown in Figure 8. The regression lines were extrapolated out to predict the HIC value at an impact energy of 70 ft-lb. The regressions predict the ACES II headrest to produce a HIC value of 1200, while the headrest with the Confor foam produced a HIC value of 1000.

Table 3. Average HIC Values per Test Condition

Impact Energy (ft-lb)	Headrest Blank HIC Value	ACES II Headrest HIC Value	Blank + Confor Foam HIC Value	Blank + F-Cell Foam HIC Value
20	194.9 ± 9.6	162.5 ± 15.9	100.0 ± 10.1	139.3 ± 12.9
35	459.6 ± 3.1	403.6 ± 18.7	281.2 ± 12.8	389.7 ± 18.1
50	700.0 ± 49.2	707.7 ± 32.0	539.6 ± 42.2	675.6 ± 16.0

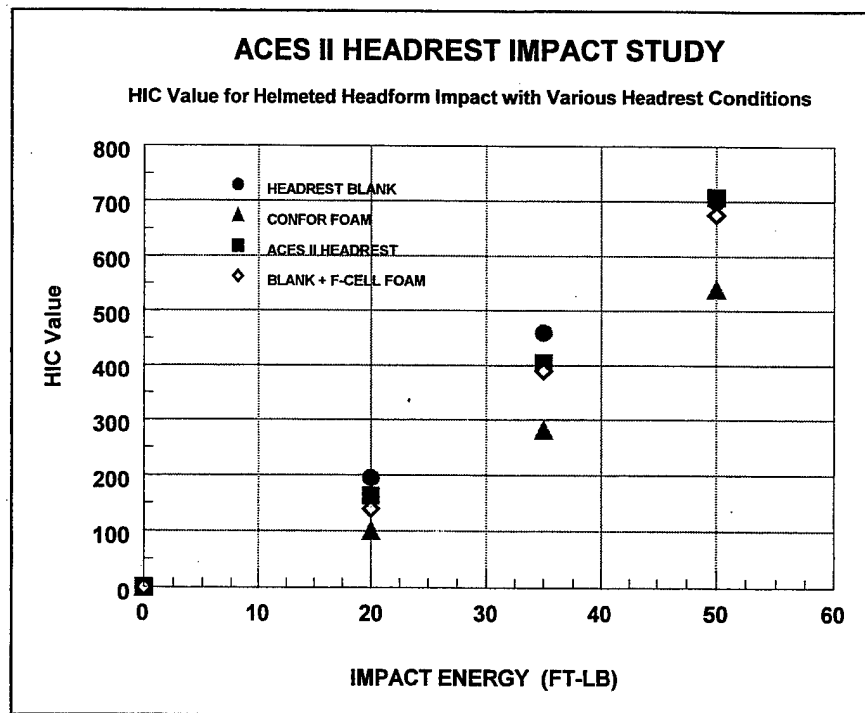


Figure 7. Average HIC Values as a Function of Headrest Condition and Impact Energy

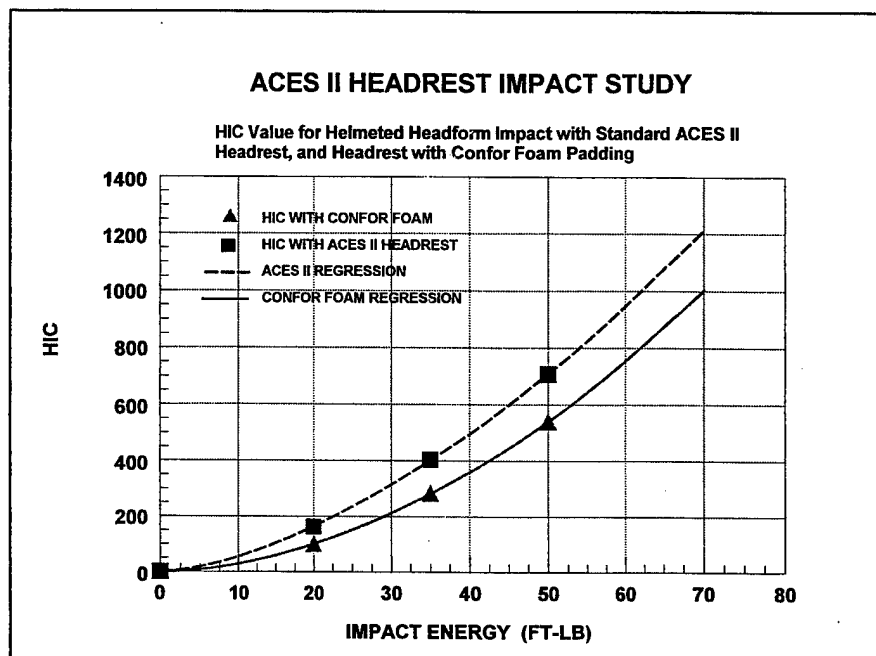


Figure 8. Average HIC Values and Regression Lines as a Function of Impact Energy for the Existing ACES II Headrest and a Headrest with Confor Foam

Calculating the probability of brain injury for each test condition was the final analysis used to compare the ACES II headrest to the two proposed padding replacements involved. Figure 6 was used to determine the probability of severe brain injury ($\text{AIS} \geq 4$) as a function of the average HIC values shown in Table 3. The results are shown in Table 4.

Table 4. Probability of Severe Brain Injury Based on Average HIC Values

Impact Energy (ft-lb)	Headrest Blank	ACES II Headrest	Headrest Blank +Confor Foam	Headrest Blank + F-Cell Foam
20	0.21%	0.16%	0.11%	0.14%
35	1.0%	0.78%	0.36%	0.71%
50	4.4%	4.5%	1.7%	3.7%

Table 4 shows the same trends for the probability of injury as Tables 2 and 3 showed for the impact acceleration and average HIC values. The probability data show that the Confor foam provides the best protection for the head by having the lowest probability of severe brain injury. The probability of injury at a 50 ft-lb impact with the Confor foam is less than half the probability of severe brain injury with the ACES II headrest. To illustrate this comparison further, the predicted HIC values from Figure 8 for the ACES II headrest and a headrest with Confor foam (1200 and 1000 respectively) produced probability of severe brain injury values of approximately 30% for the ACES II headrest, but only 16% for the Confor foam.

CONCLUSIONS

A series of helmet impacts were conducted using a vertical Helmet Drop Tower to evaluate the effectiveness of two different high-density foam headrest pads compared to the existing ACES II headrest in protecting the head from injury. Four different headrest conditions were evaluated at

three different impact levels. One of the test conditions included a headrest that had no padding, which served as a baseline. The impact levels were defined by the energy transferred to the headform/helmet system during impact with the headrest, and ranged from 20 to 50 ft-lb. The 50 ft-lb energy level was sufficient to generate a probability of severe brain injury of approximately 5% using an unpadded headrest.

The two evaluated foam samples consisted of C-47 Confor foam supplied by Oregon Aero, Inc., and #6 F-Cell foam supplied by Foam Fabricators. The #6 F-Cell foam provided only marginal improvement in protection of the head compared to the existing ACES II headrest in terms of peak head acceleration, HIC value, and probability of severe brain injury at an AIS ≥ 4 . The Confor foam provided significantly improved protection of the head compared to the existing ACES II headrest and the headrest with the F-Cell foam. The headform acceleration, resulting HIC values, and probability of severe brain injury values for the Confor foam tests were all less than the comparative values for either the ACES II headrest or the headrest with the F-Cell foam.

It should be noted that the improvement in head protection provided by the Confor foam over the existing ACES II headrest padding was influenced by the placement of the Confor foam padding on the headrest structure. During testing of the ACES II headrest, it was noted that, at the higher impact energy tests, the helmet shell conformed to the headrest shape and contacted the back plane of the headrest which is not padded. This lack of padding could account for the similar acceleration and HIC values between the ACES II headrest and the unpadded headrest blank, even though the slanted sides of the ACES II headrest are padded. Due to this observation, a decision was made to place the Confor foam sample and the F-Cell sample on the back plane of the headrest as well as the slanted sides. The placement of the foam on the back plane of the headrest had no effect on the static contact points (unforced positioning) of the helmet on the slanted sides of the headrest.

To further illustrate the comparison between the foam sample configurations and the ACES II headrest, HIC and probability of injury values for the Confor foam and the ACES II headrest test conditions were predicted at an impact energy of 70 ft-lb. At this energy value, the Confor foam produced a HIC value of 1000 compared to 1200 for the ACES II headrest. At these respective

HIC values, the probability of severe brain injury with the Confor foam was 16% compared to 30% for the ACES II headrest. Clearly, the Confor foam padding would provide improved protection to the helmeted head during forced helmet contact with the ACES II headrest.

Prior to operational use, it is recommended that additional testing be conducted to evaluate additional foam thickness' and stiffness' to optimize protection performance. Also prior to operational use, the Confor foam must be coated with a light layer of sealant or a thin fabric layer to protect the foam from potential decomposition due to interaction with sunlight, moisture, dirt, and other environmental factors. Additional testing may have to be completed to evaluate the effects of the chosen foam protection on the foam's dynamic properties.

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APPENDIX A.

Test Configuration and Data Acquisition System for the Helmet Drop Tower

**TEST CONFIGURATION AND
DATA ACQUISITION SYSTEM FOR THE
HELMET IMPACT with MODIFIED ACES II HEADREST**

(AHB Study)

Prepared under
Contract F3301-96-DJ001

May 1999

DynCorp
Human Effectiveness Division
Building 824, Area B
Wright-Patterson AFB, Ohio 45433

A-1

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1. INTRODUCTION

The DynCorp Armstrong Laboratory Division prepared this report for the Air Force Research Laboratory, Human Effectiveness Directorate, Acceleration Effects and Escape Branch (AFRL/HEPA) under Air Force Contract F3301-96-DJ001. It describes the test facility, test configurations, data acquisition, and the instrumentation procedures that were used in The Helmet Impact with Modified ACES II Headrest (AHB Study). Forty tests were conducted between 5 Jan and 19 Jan 1999 on the Helmet Drop Tower facility.

2. TEST FACILITY

The AFRL/HEPA Helmet Drop Tower facility, Figure 1, is a 19-foot vertical tower.

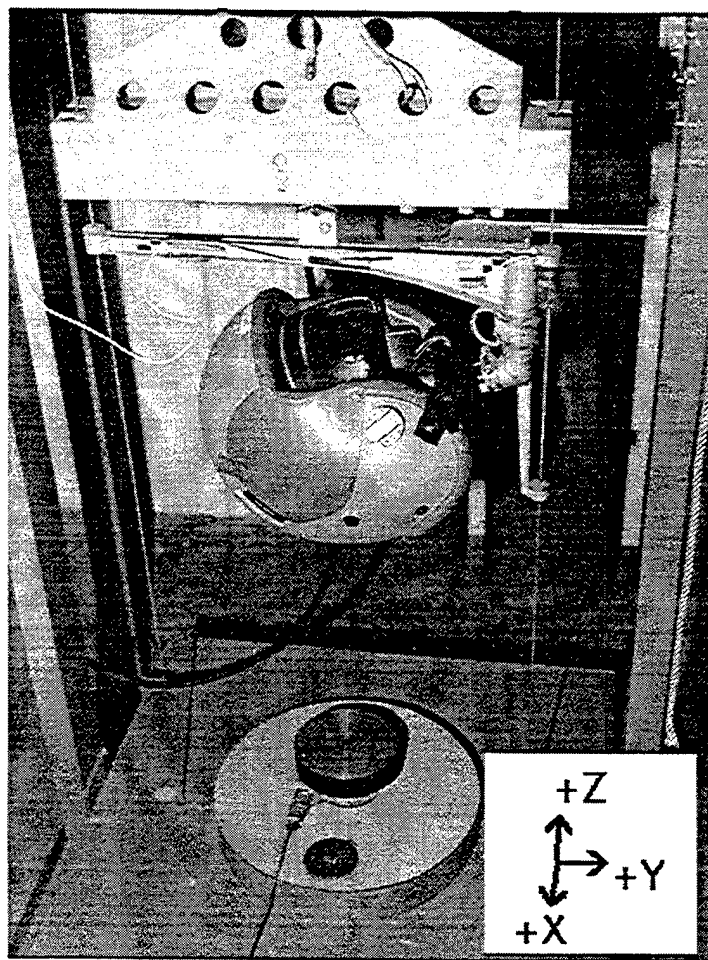


FIGURE A - 1: HELMET DROP TOWER FACILITY

It has a 300-pound reaction mass at the base and a wire-guided free fall carriage. The carriage is equipped with a gimbaled, low resonance magnesium alloy headform, Figure A - 2. The headform can be rotated to any position and then locked in order to simulate impacts on any portion of the helmet or any desired head axis. Subject helmets are normally dropped on an anvil at the base, which can be fitted with various impact surfaces. Either or both the headform and the anvil can be instrumented to satisfy test requirements. The maximum drop height is sixteen feet. For impact control, the carriage with the test helmet is weighed, and the required drop height is computed from the desired impact energy.

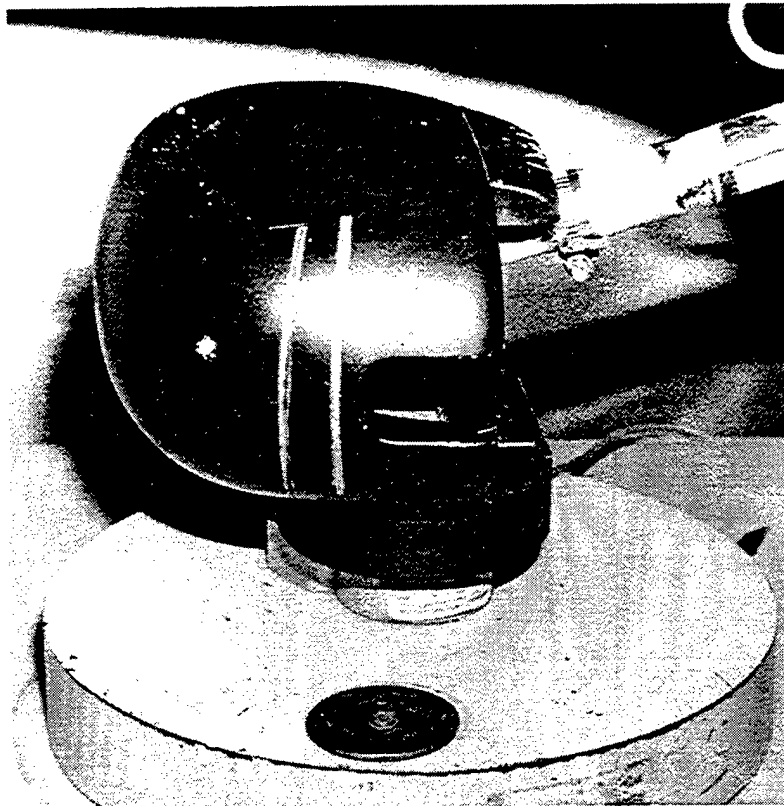


FIGURE A - 2: MAGNESIUM ALLOY HEADFORM

3. TEST SUBJECT

This was a study simulating windblast induced impacts against the ACES II ejection seat headrest. The test subject in this study was the headrest. We used an actual headrest from an ACES II seat and a locally manufactured mockup called a headbox blank. The actual headrest with standard padding was the baseline reference. The blank was tested with no padding, and two types of foam padding. A standard USAF HGU-55/P helmet was used on the instrumented headform and dropped on the headrests at three impact velocities. The purpose of the tests was to evaluate the force damping effectiveness of the various paddings under impact.

Prior to beginning the test runs, the helmet was dropped on the headbox blank with no padding in trials to determine the drop heights needed for the required impact velocity conditions. The trials allowed us to compensate the computed drop height for cable friction factors.

4. TEST CONFIGURATIONS

The cell names for the various test conditions are outlined below:

Impact Energy (ft-lbs)	Headbox Blank	ACES II Headbox	Confor Foam	#6 F-Cell Foam
20	A1	B1	C1	D1
35	A2	B2	C2	D2
50	A3	B3	C3	D3

TABLE A - 1: TEST MATRIX

5. INSTRUMENTATION

For this helmet impact study, one helmet accelerometer and one base load cell were used. Specific sensor information is given in Table A - 2. The transducers were chosen to provide the optimum resolution over the expected test range. Full scale data ranges were chosen to cover the expected peak values plus 50% to assure complete signal capture. The transducer bridge was balanced for optimum output at the start of the program. The accelerometer was compensated for the effect of gravity in software by adding the component of a positive one G vector in line with the force of gravity.

The coordinate reference system for this study is shown in Figure A-1. It is a right-handed system with no origin defined because only vector directions were required. The Z-axis is positive upward along the guide wires. The X-axis is perpendicular to the plane of the guide wires and is positive coming out of the page in Figure A - 1. The Y-axis is orthogonal to X and Z, and is positive to the right in Figure A -1.

The linear accelerometer was wired to provide a positive output voltage when acceleration was experienced in the +Z direction. The load cell was wired to provide a positive output voltage when it exerted a positive Z direction force on the test specimen.

5.1 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 Table A-1. The Precision Measurement Equipment Laboratories (PMEL) at Wright-Patterson Air Force Base calibrated all Strainert load cells. PMEL calibrated these devices on a periodic basis and provided current sensitivity and linearity data.

DynCorp calibrated the accelerometer by 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 were determined by driving the shaker table with a random noise generator and analyzing the outputs of the accelerometers with an MS-DOS PC computer 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. Sensitivities were calculated 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.

6. DATA ACQUISITION

The Master Instrumentation Control Unit in the Instrumentation Station controls data acquisition. Using a comparator, a test was initiated when the countdown clock reached zero. The comparator was set to start data collection at a pre-selected time. All data was collected at 10,000 samples per second and filtered at 120 Hz cutoff frequency using a 8-pole Butterworth filter.

A reference mark pulse was generated to mark the Model 5600A electronic data at a pre-selected time after test initiation to place the reference mark close to the impact point. The reference mark time was used as the start time for processing of the electronic data.

6.1 Model 5600 Portable Data Acquisition System

The Model 5600A Portable Data Acquisition System (DAS), manufactured by Pacific Instruments, was used for this test program. The Model 5600A DAS is a ruggedized, DC powered, fully programmable signal conditioning and recording system for transducers and events. The Model 5600A DAS is shown in Figure A-3.

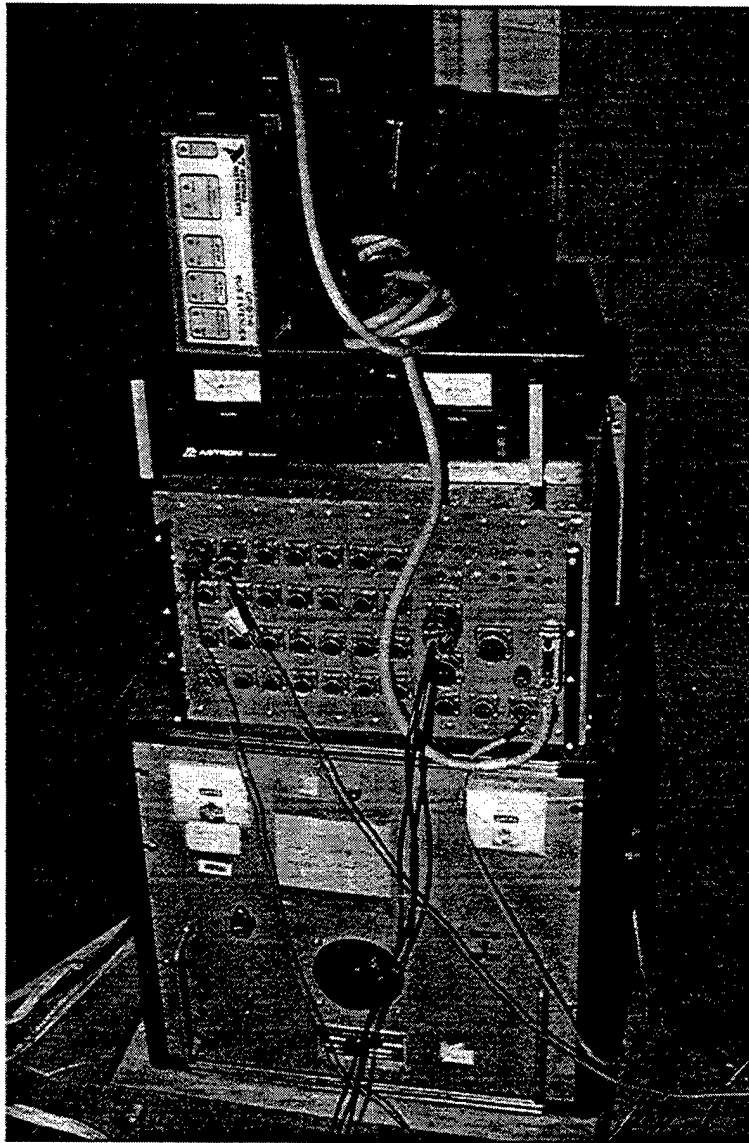


Figure A - 3: Pacific Instruments Model 5600A

The single unit can accommodate up to 28 transducer channels and 32 events. The signal conditioning accepts a variety of transducers including full and partial bridges, voltage, and piezoresistive. Transducer signals are amplified, filtered, digitized and recorded in onboard solid state memory. The data acquisition system is controlled through an IEEE-488.1 interface using the GPIB instruction language. A Windows 95 PC with an AT-GPIB board configures the 5600A before testing and retrieves the data after each test. The PC stores the raw data and then passes it on to a DEC Alpha computer for output to permanent storage. A PC is used to process the test data and print out the results

The DynCorp program 'TDR5600' on the PC handles the interface with the Model 5600A DAS. It includes options to compute and store zero reference voltage values; collect and store a binary zero reference data file; compute and display preload values; and collect and store binary test data. The program communicates over the GPIB interface. Test data could be reviewed after it was converted to digital format using the "quick look" SCAN_EME routine. SCAN_EME produced a plot of the data stored for each channel as a function of time. The routine determined the minimum and maximum values of each data plot. It also calculated the rise time, pulse duration, and carriage acceleration, and created a disk file containing significant test parameters.

6.2 High Speed Video System

A Kodak Ektapro 1000 video system was also used to provide onboard coverage of each test. This video recorder and display unit is capable of recording high-speed motion up to a rate of 1000 frames per second. Immediate replay of the impact is possible in real time or in slow motion. For this study, all tests were recorded at 500 frames per second. Figure A - 4 shows the camera position in the overall test setup.

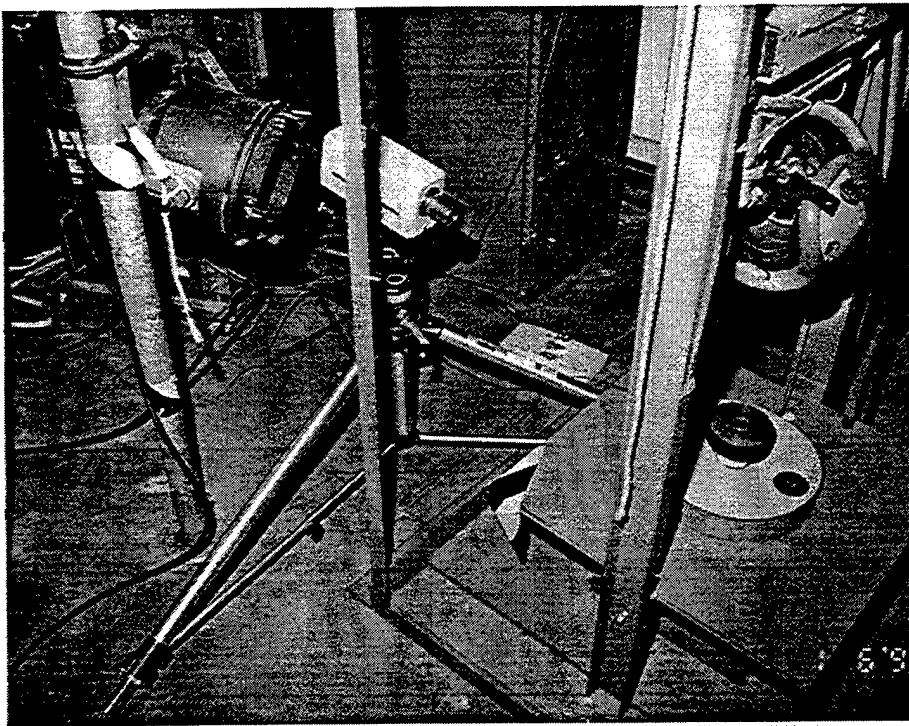


FIGURE A - 4: HIGH SPEED CAMERA

7. PROCESSING PROGRAMS

The only processing provided for this study was the DynCorp 'Quick Look' report. The report contains time histories of each channel in engineering units, a tabular summary of results, and a plot of each time history.

DYNCORP PROGRAM SETUP AND CALIBRATION LOG

PROGRAM: Helmet Impact with Modified ACES II Headrest
AHB Study

TEST DATES: 5 Jan 1999 to 19 JAN 1999

FACILITY: Helmet Drop Facility

TEST NUMBERS: 9901 - 9941

DATA COLLECTION SYSTEM: Pacific Instrument

SAMPLE RATE: 1K

FILTER FREQUENCY: 120 Hz

TRANSDUCER RANGE (VOLTS): +/- 10

DATA CHANNEL	DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% Δ	EXC. VOL.	AMP GAIN	FULL SCALE	NOTES
				DATE	SENS	DATE	SENS					
0	Helmet Drop Accel (G)	Entran EGA-125F-500	14A5-918-A1	4-Mar-98	.4157 mv/g	29-Jan-99	.4157 mv/g	0	10 V	50	481.12G	
1	Helmet Drop Force (LB)	Strainert FL5U2SPKT	Q-3882-1	22-Jan-98	-4.125 uv/lb	NOT REQUIRED			10 V	500	4848.5 LB	USE NEGATIVE SENSITIVITY
28	Event / T=0								0	1		Bit 0 is Event Bit 1 is T=0

TABLE A - 2: INSTRUMENTATION LOG