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OH-58 ENERGY ATTENUATING CREW SEAT FEASIBILITY STUDY

Final Report

Roy G. Fox

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In aircraft accidents with significant vertical crash loads, occupants typically suffer some degree of back injuries. The latest design approach to minimize damaging spinal loads during a crash is to incorporate design features in the landing gear, fuselage, and seats to provide energy management of the crash impact forces. Special energy attenuating seats are used to provide a controlled deceleration over a vertical stroking distance to keep the crash loads within human tolerance.

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FOREWORD

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ABSTRACT

In aircraft accidents with significant vertical crash loads, occupants typically suffer some degree of back injuries. The latest design approach to minimize damaging spinal loads during a crash is to incorporate design features in the landing gear, fuselage, and seats to provide energy management of the crash impact forces. Special energy attenuating seats are used to provide a controlled deceleration over a vertical stroking distance to keep the crash loads within human tolerance. Present energy attenuating crew seats use this approach of translating the entire seat vertically. This requires an area clear of equipment and structure between the seat and the fuselage floor. As with most aircraft, the installation of an energy attenuating seat in the OH-58 could provide reduced spinal loading in some crashes. However, the OH-58 crew seat is integral with the aircraft structure with no room for an energy attenuating seat which gave rise to the attitude that "a stroking energy attenuating seat was not technically feasible". Thus an innovative approach was needed to provide energy attenuating crew seats with a minimum of OH-58 structural modification. To fulfill this need, a pivoting seat pan design was conceived. A feasibility study was performed for the U. S. Army to provide this preliminary design, fabricate test seats, and modify a dynamic test fuselage and a flyable aircraft. Dynamic testing was performed to prove the feasibility of the pivoting seat pan energy attenuating crew seat approach. This report discusses the unique approach which can provide energy attenuating crew seats to be installed in an OH-58, while providing a concept which could potentially provide similar solutions for other aircraft; in particular, existing aircraft without acceptable stroking distances.

PREFACE

This report was prepared by Bell Helicopter Textron, Inc. (BHTI), Fort Worth, Texas 76101, under U. S. Army contract DAMD17-87-C-7032, "OH-58 Energy Attenuating Crew Seat Feasibility Study." The contract was administered under the technical direction of Mr. Joseph L. Haley, Jr., U. S. Army Aeromedical Research Laboratories (USAARL), Fort Rucker, Alabama. BHTI project engineer for this program was Mr. Roy G. Fox.

Appreciation is expressed for Mr. Haley, USAARL, who directed the dynamic tests, and for Mr. Van Gowdy of FAA Civil Aeromedical Institute, who conducted the dynamic testing. In addition, the BHTI engineers who contributed to the success of this program are Messrs. Ed Barney, Lindley Bark, Bill Craft, Don Eisentraut, and Tom McManis.

1.0 INTRODUCTION

An occupant of any aircraft involved in a crash with significant vertical crash loads is subjected to the possibility of a back injury. The latest design approach to minimize damaging spinal loads during a crash is to incorporate design features in the landing gear, fuselage, and seats to provide energy management of the crash impact forces. Special energy attenuating seat designs provide a controlled deceleration of the occupant over a stroking distance with a controlled load that minimizes injury. Present energy attenuating crew seats use this approach of translating the entire seat vertically. This requires an area clear of equipment and structure between the seat and the fuselage floor. As with most aircraft, the installation of an energy attenuating seat in the OH-58 could provide reduced spinal loading in some crashes. However, the OH-58 crew seat is integral to the aircraft structure with armor plate and control linkages underneath. This structural arrangement left no room for a stroking energy attenuating seat and gave rise to the attitude that "an energy attenuating seat was not technically feasible". Thus an innovative approach was needed to provide energy attenuating crew seats with a minimum of OH-58 structural modification. A feasibility study was performed under contract DAMD17-87-C-7032, Reference 1, by Bell Helicopter Textron Inc. for the U. S. Army to provide this preliminary design, fabricate test seats, and modify a dynamic test fuselage and a flyable aircraft. Dynamic testing was conducted under the direction of the Contracting Officer's Representative (COR) to prove the feasibility of the pivoting seat pan energy attenuating crew seat approach.

This report describes the contracted effort of Reference 1 for the period of September 28, 1987 through September 30, 1988. In general, the design was completed and the dynamic test fuselage modified, and dynamic testing completed June 17. The flight aircraft was modified in July and August, the final review was completed on August 11, 1988; and, the flight test aircraft was delivered back to the Army on August 26, 1988.

The design concept validated by this program provides a measure of improved occupant protection desired for the OH-58. Additionally, the concept could potentially provide similar solutions for other aircraft where seats are part of the airframe structure; in particular, existing aircraft without acceptable stroking distance.

By definition, "attenuate" means "to lessen the amount, force or value." The primary function of an energy attenuating (EA) seat is to reduce the airframe crash loads to a lower value that is within human tolerance. The EA seat maintains that lower load until all of the occupant's kinetic energy is dissipated. Some people also refer to seats that perform this function as an energy absorbing seat. For consistency, the seat described in the proposal of Reference 7, the contract of Reference 1, and this final report was called an energy attenuating seat.

2.0 BACKGROUND

2.1 INJURY STUDIES

As with several other Army helicopter models, the U. S. Army Safety Center conducted an analysis of crash injuries in the Army OH-58 accidents. The results of the OH-58 injury study are found in USASC TR79-1, Reference 2. The injury hazard considered as first priority for research, development, and acquisition was based upon the finding that "aircraft and seats transmit intolerable vertical loads to occupants, resulting in excessive spinal injuries." The U. S. Army study recommendation was to evaluate modifications that could increase the energy attenuation capability of the landing gear, airframe, and seats.

A spinal injury study of OH-58 accidents by Shanahan and Mastroianni, Reference 3, stated "It is concluded that if this aircraft were modified to provide protection to the occupants for impacts up to 9.1 m/s (30 ft/s), approximately 80% of all spinal injuries incurred in survivable accidents could be substantially mitigated. The incorporation of energy absorbing seats is recommended." Figure 2-1 from this study shows the distribution of spinal injury percentage versus the vertical velocity change at impact for survivable and partially survivable accidents.

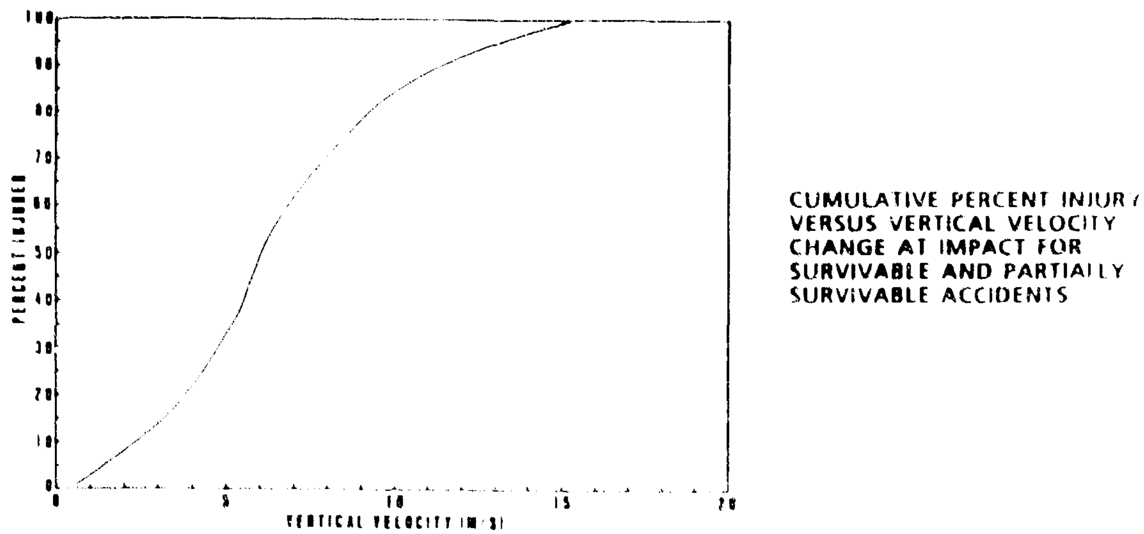


Figure 2-1. Spinal injury.

2.2 PREVIOUS SEAT STUDIES

On December 8, 1970, a Product Improvement Program (PIP) 69-10 was awarded by the U. S. Army to Bell Helicopter Company to investigate an energy attenuating crew seat for the OH-58A. Honeycomb attenuators were designed and built. Dynamic drop tests were accomplished. The results were in Arizona State University Report ERC-7905-622-15-8, Reference 4. The report conclusions and recommendations were:

CONCLUSIONS

Based on the findings of this dynamic test program it is concluded that:

1. The OH-58A production seat design will protect the occupant from injury during accidents which have a velocity change corresponding to the 50th percentile survivable accident as defined in USAAVLAB Technical Report 70-22. At the 80th percentile accident level the occupant is subjected to loads which place him in the lower part of the moderate injury range.

2. As compared to the production seat design, both the modified production seat and the experimental seat reduced the severity of injury to occupants in accidents where the impact velocity change corresponds to the 90th percentile survivable accident as defined in USAAVLAB Report 70-22.

3. The severity of occupant injury in accidents corresponding to the 97th percentile survivable accident is reduced by the experimental design; however, the forces recorded in the one test conducted at this level exceeded the recognized limits of human tolerance.

RECOMMENDATIONS

Based on the foregoing conclusions, it is recommended that:

1. The production seat design be modified to allow installation of the four attach point lap belt.

2. The armor attachment to the pilot seat panel be modified by replacing the rear attachment nutplates with NAS 1330A3K116 rivnuts or by attachment of the armor to the panel by metal clips designed to fail early in the crash sequence.

3. A design study be conducted to investigate methods of reducing the initial crushing strength of the production seat to eliminate the initial acceleration spike.

As a result of this study, Recommendation 1 was accomplished by MWO 55-1520-228-30-19, Reference 5. Recommendation 2 was accomplished by MWO 55-1520-228-30-16, Reference 6. Since the basic OH-58A production seat performed better than anticipated in the tests, it appears that there was no further effort related to Recommendation 3. With these MWOs incorporated, the basic OH-58 seat configuration was determined and remains basically the same to this day.

Prior to the last few years, energy attenuating crew seat concepts have all shared a common feature of allowing a controlled vertical motion of a seat bucket with a fixed seat bottom-to-back position. This requires that no structure or any other obstruction be located in the seat stroking area. The OH-58 crew seat had the crewman's buttocks within 3 in (7.6 cm) of rigid airframe structure and armor plate. Thus there was a general feeling that an energy attenuating crew seat was not technically feasible for the OH-58.

A Product Improvement Program (PIP) for an energy attenuating crew seat using an armored bucket concept was proposed to the U. S. Army in 1983. This PIP was never authorized. On June 26, 1986, an unsolicited proposal for a unique energy attenuating crew seat concept of a pivoting seat pan was submitted to USAARL through the U. S. Army Medical Research Acquisition Activity. This proposal, BHTI Report 299-199-536, Reference 7, resulted in contract DAMD17-87-C-7032 which was issued on September 28, 1987, Reference 1. This report herein describes the results of this feasibility study.

On December 11, 1986, the Canadian Defense and Civil Institute of Environmental Medicine (DCIEM) issued a Request For Quote for a research study to investigate the potential for energy attenuating crew seat concepts for the CH-136 (i.e., the Canadian version of the OH-58A). Bell Helicopter Textron Canada (BHTC) with Bell Helicopter Textron Inc. (BHTI) as a subcontractor received DCIEM contract W.7711-6-9419/01-SE, Reference 8, for a short conceptual study which resulted in BHTC Report, CR:87:ST:02, Reference 9, dated August 25, 1987. The Canadian CH-136 study evaluated three candidate energy attenuating crew seat concepts shown in Figure 2-2. The three concepts were: a pivoting seat pan, a tension seat and a guided armored bucket. The guided armored bucket was the concept previously proposed to the U. S. Army as a PIP. The tension seat was a Model 412 energy attenuating passenger seat to be modified to fit the CH-136. The pivoting seat pan was the latest concept and the one proposed in BHTI Report 299-199-536, Reference 7. Figure 2-3 shows the vertical stroking potential for the three CH-136 seat concepts. Table 2-1 from Reference 9 shows the seat strokes and their respective equivalent vertical

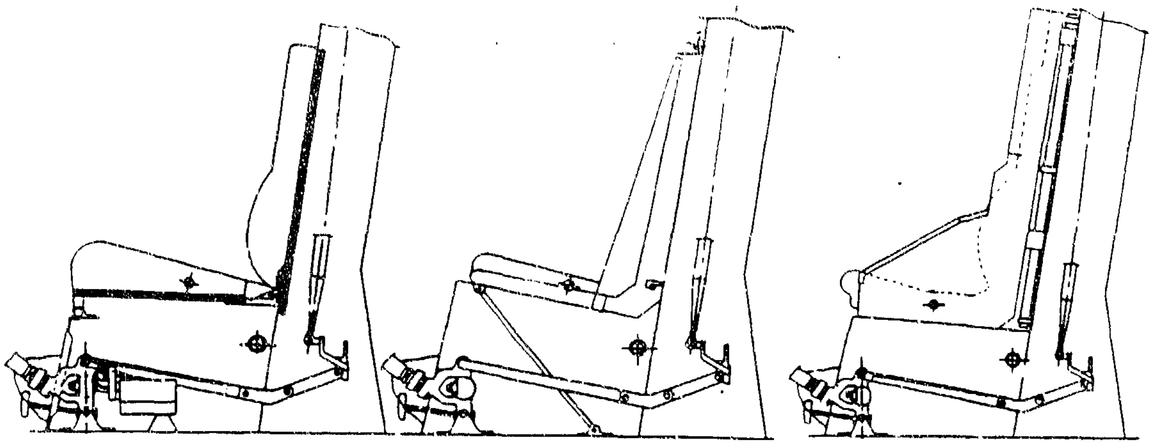


Figure 2-2. CH-136 study - seat concepts before stroking.

velocity changes for contact with the cyclic control yoke underneath and the maximum stroke to the floor (e.g., assuming no yoke interference). This CH-136 study increased the confidence that the pivoting seat pan concept was the best approach.

2.3 APPROACH

The design approach is to pivot the crew seat pan about the front pan lip under the knees. A thin, bottom cushion of increased comfort is placed directly on the armor plate. Improved comfort was achieved by using a buttocks suspension system that precluded pressure points due to the ischial tuberosities. A simple wire/roller energy attenuator attached to each aft end of the seat pan would absorb crash energy as the wire was pulled through the rollers. The present restraint system with the inverted "V" lap belt attachments would be retained but part of the lap belt restraint would stay with the seat pan.

2.4 OBJECTIVES

The primary program objective was to prove that an energy attenuating seat is technically feasible using dynamic testing. The other program objective was to

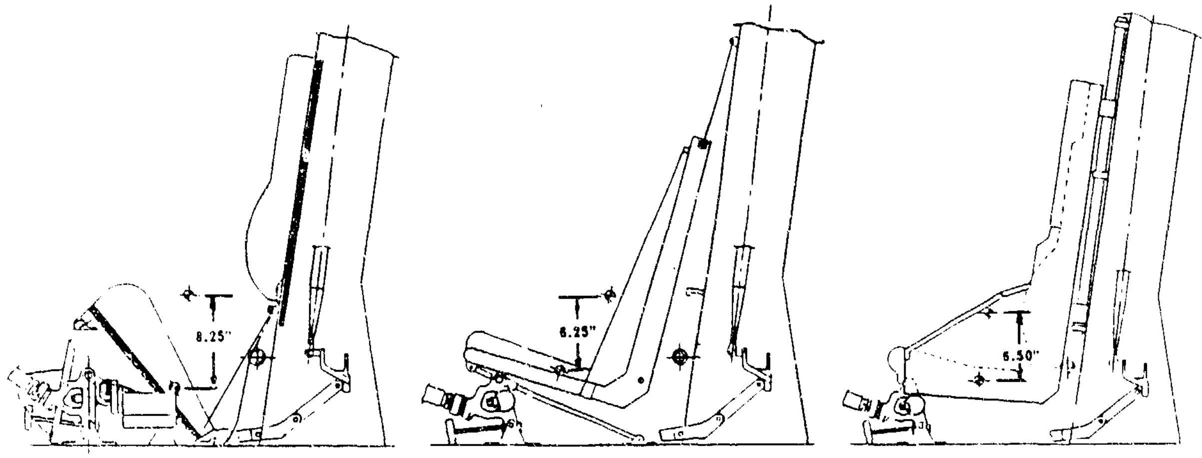


Figure 2-3. CH-136 study - maximum stroke potential.

TABLE 2-1. CH-136 CREW SEAT ANALYSIS SUMMARY

CANDIDATE CREW SEAT DESIGN	VALUES AT POINT OF YOKE CONTACT*		MAXIMUM VALUES	
	STROKE (In.)	ΔV** (fps)	STROKE (In.)	ΔV** (fps)
Pivoting Seat Pan	5.00	30.0	8.25	35.1
Bulkhead-Mounted Tension Seat	5.25	30.4	6.25	32.1
Bulkhead-Mounted Guided Seat	5.00	30.0	6.50	32.5

NOTE: * The position of the cyclic control yoke is dependent on the cyclic control input. For the purpose of this study, the yoke contact point is determined with the yoke at its consistent neutral position.

** ΔV is the maximum vertical velocity change that will allow the crew seat to decelerate at 12g in the given stroke distance.

install this modification in a flyable OH-58A, thus allowing the Army to conduct an operational sui ıbility evaluation.

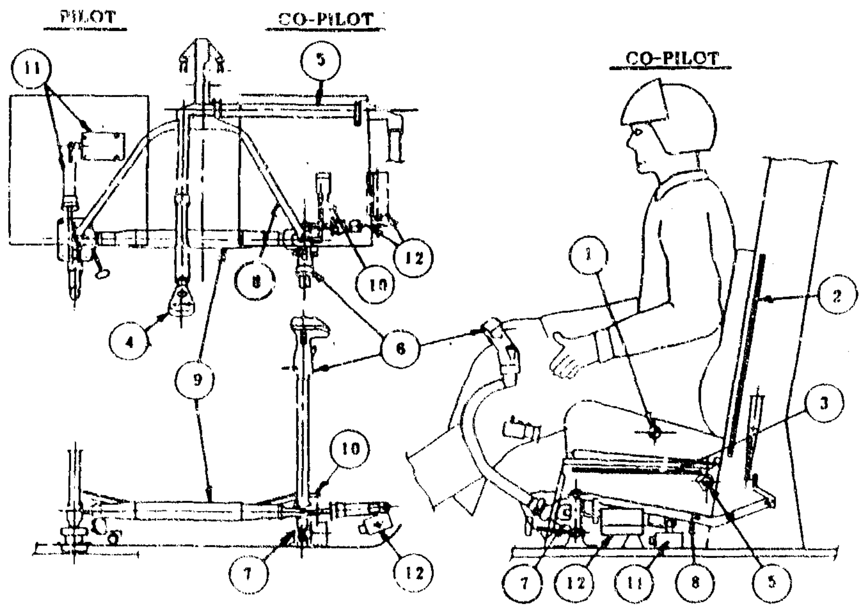
The p...mary design objective of this program was to provide the maximum energy attenuation stroke until yoke contact occurred. The second objective was to determine if yoke contact would be detrimental to a stroking seat. It was initially hoped that a stroking seat might break or bend the yoke with very little extra crash loading being applied to the occupant. A dynamic seat test would verify if this was possible or not. If it were true or the yoke could be designed at a later date to be frangible during a severe crash, then the seat concept should contain enough stroking capability to allow the seat to stroke to the floor. This latter objective could prevent a redesign of an energy attenuating crew seat once the yoke contact problem was resolved. The third objective was to identify design refinement areas that could assure the maximum seat stroke.

All objectives stated above have been achieved in this program.

3.0 DESIGN

3.1 EXISTING SEAT

The present OH-58 seat bottom is a tube frame covered with an open mesh Roschel net, mounted directly on aircraft structural honeycomb panel with an armor plate underneath as shown in Figure 3-1. Beneath the armor plate is the cyclic control yoke. The fuselage floor is a one inch honeycomb structure. The seat back cushion is a tube frame covered with open mesh Roschel netting and is attached to a sheetmetal bulkhead. An armor plate is attached to the aft side of this bulkhead. The only significant difference in the pilot and copilot seats is the collective jackshaft at the back bulkhead that is mounted under the copilot. The copilot armor plate is cut out to allow for this jackshaft. Some crash energy absorption occurs in the bending of the seat tube frames.



LEGEND:

1. buttock reference point
2. aft armour plate
3. lower armour plate
4. collective control stick
5. collective control tube jackshaft
6. cyclic control stick
7. cyclic control stick casting
8. cyclic control yoke
9. cyclic control torque tube
10. cyclic stick balance spring
11. fore/aft cyclic trim system
12. lateral cyclic trim system

Figure 3-1. Existing OH-58 crew seat and controls.

The present crewman restraint is a six-point system consisting of a dual shoulder harness with an MA-6 inertia reel, and a lapbelt with inverted "V" side attachments as shown in Figure 3-2. The inverted "V" straps properly locate the lapbelt and reduce shoulder harness lifting of the lap belt. This latter function is achieved in five-point restraint system designs by the use of a crotch strap.

3.2 ENERGY ATTENUATING CREW SEAT

All existing energy attenuating (EA) crew seat concepts provide vertical stroking while keeping the lower seat pan and seat back in the same relative positions. Applying this concept to the OH-58 would result in structural interference with a structure panel, armor plate, and flight controls. A conceptual study for the Canadian CH-136 (a Canadian version OH-58A), Reference 9, looked at an armored bucket concept, a modified Model 412 passenger seat, and a pivoting seat pan concept. Of the three concepts, the pivoting seat pan concept appeared to have the largest vertical stroking capability as discussed in paragraph 2.2. The U.S. Army OH-58 energy attenuating crew seats use the pivoting seat pan concept in this feasibility study.

The present design eye position was to be retained; the bottom of the seat pan was moved up to hold that design eye location. This was achieved by using a new thin cushion of PREQUAL™ similar to the AH-1S Survivability And Vulnerability Improvement Modifications (SAVIM) seat, Reference 10. PREQUAL™ is a plastic lever suspension system that provides uniform loading, i.e., no hard points. This thin cushion allowed the seat pan to be located less than an inch (2.54 cm) away from the occupant's buttocks on the AH-1S SAVIM energy attenuating seat with a sheepskin cover. On the OH-58 energy attenuating seat, more plastic lever stages were used and a breathable cushion cover called SPACEFABRIC™ (Figure 3-3) was added. The OH-58 occupant buttocks to seat pan bottom distance (compressed cushion under 1G load) was 1.5 inches (3.8 cm). The structural honeycomb panel under the seat cushion was replaced by the armor panel. A frame was built up around the edges of the armor to enclose the armor in the panel as shown in Figure 3-4. The pilot armor plate of Figure 3-5 was retained. The existing copilot armor plate of 186.1 sq in (1200 sq cm) was replaced with a new copilot armor plate of 206.9 sq in (1335 sq cm) which was sawed from a wider pilot armor plate of 226.3 sq in (1460 sq cm). Thus the new copilot armor plate was shortened 1.3 inches (3.3 cm) to allow seat frame commonality and collective jackshaft clearances during stroking. This copilot armor change resulted in 1.31 lb (0.6 kg) more armor and corresponding increase in ballistic protection area of 20.8 sq in (135 sq cm) as shown in Figure 3-5. The front end of the seat pan was attached to the knee bulkhead by a hinge as shown in Figure 3-6.

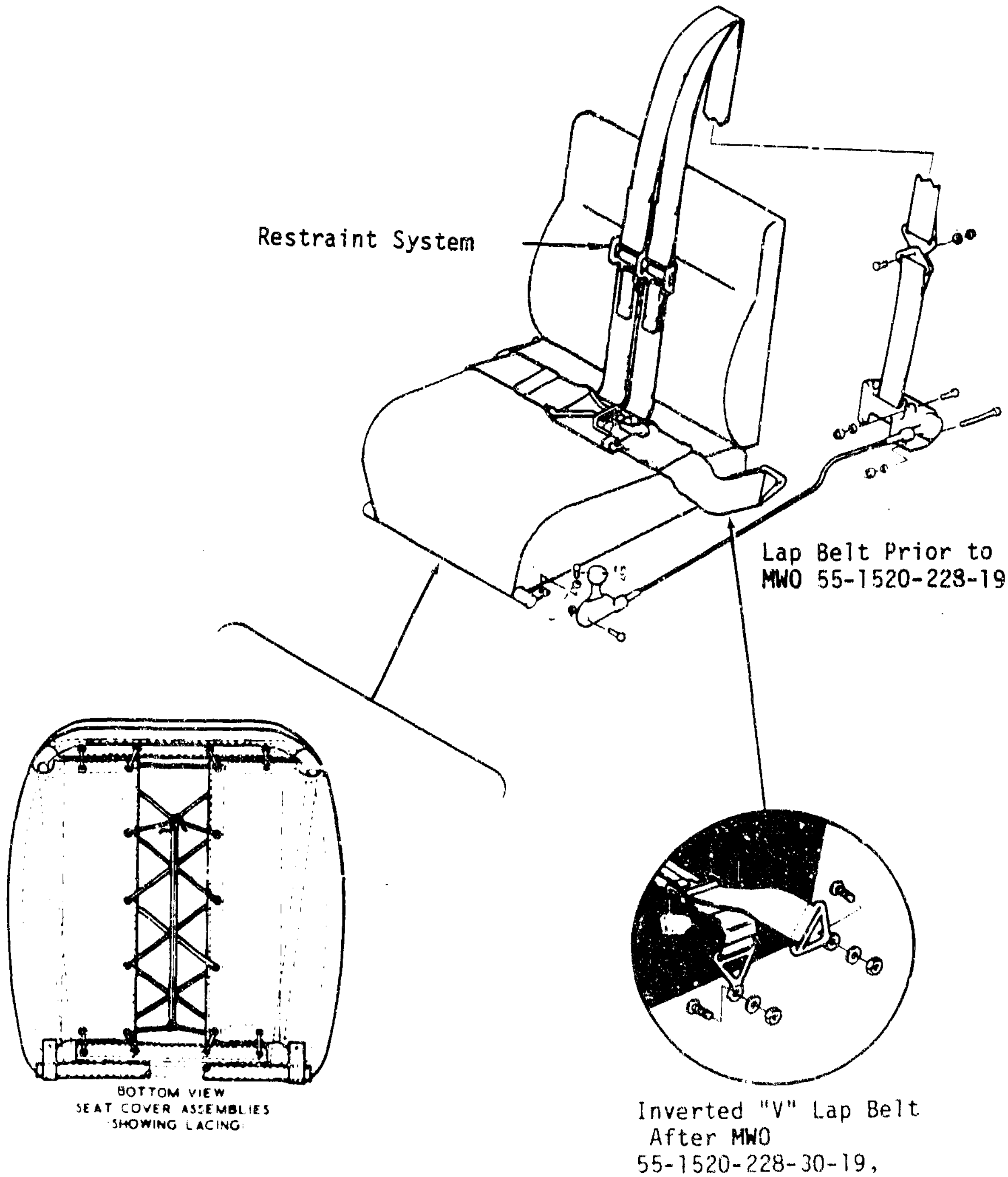


Figure 3-2. Existing OH-58 seat and restraints.

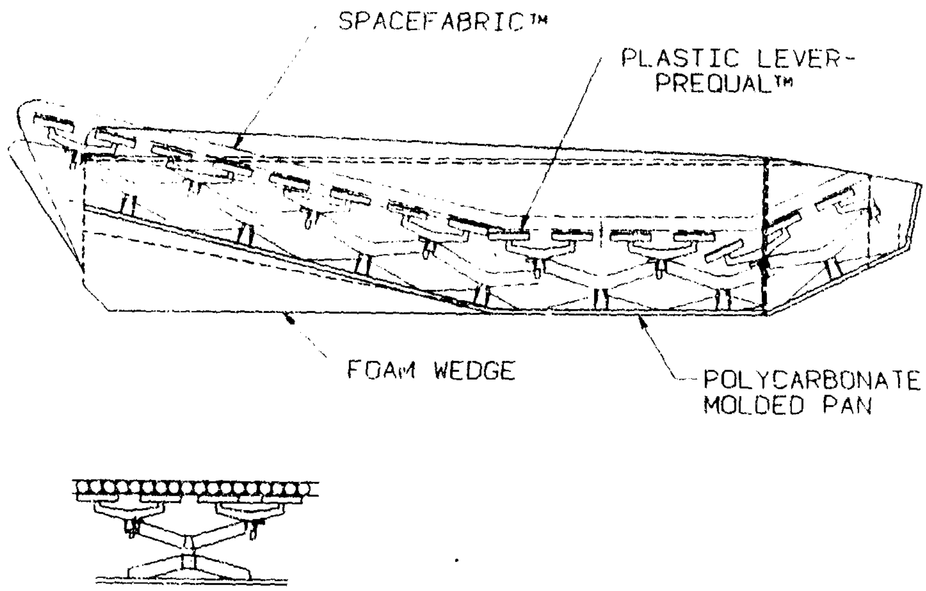


Figure 3-3. Seat bottom cushion.

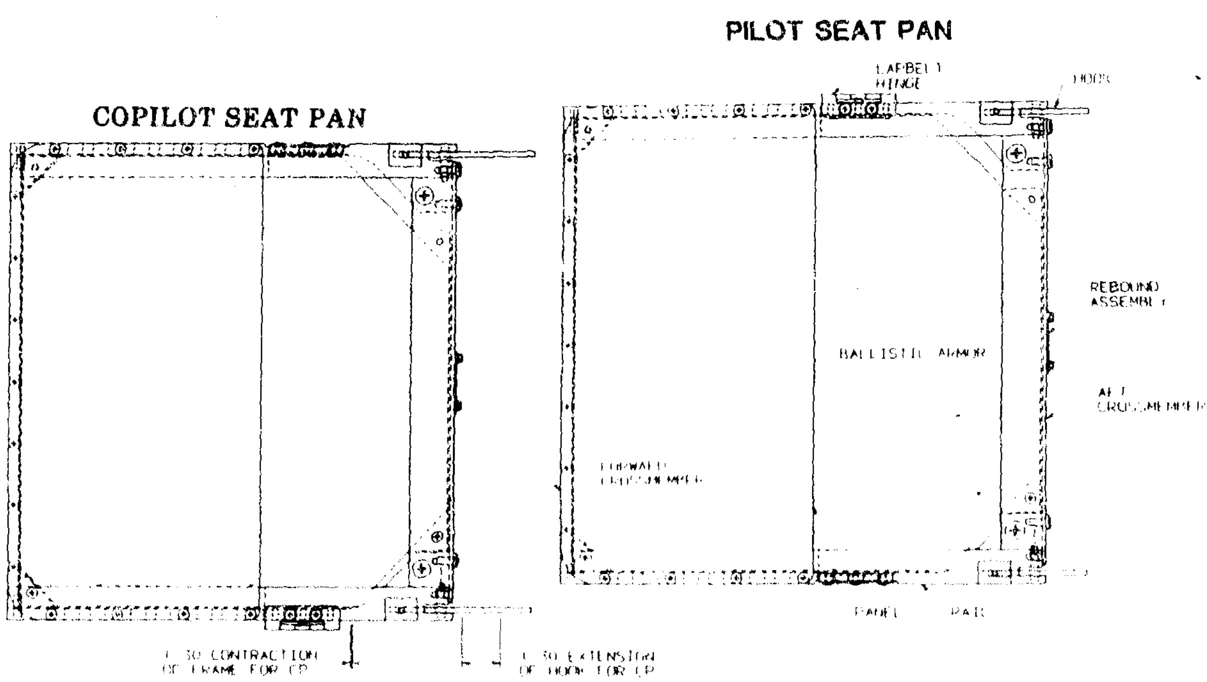


Figure 3-4. Seat pans.

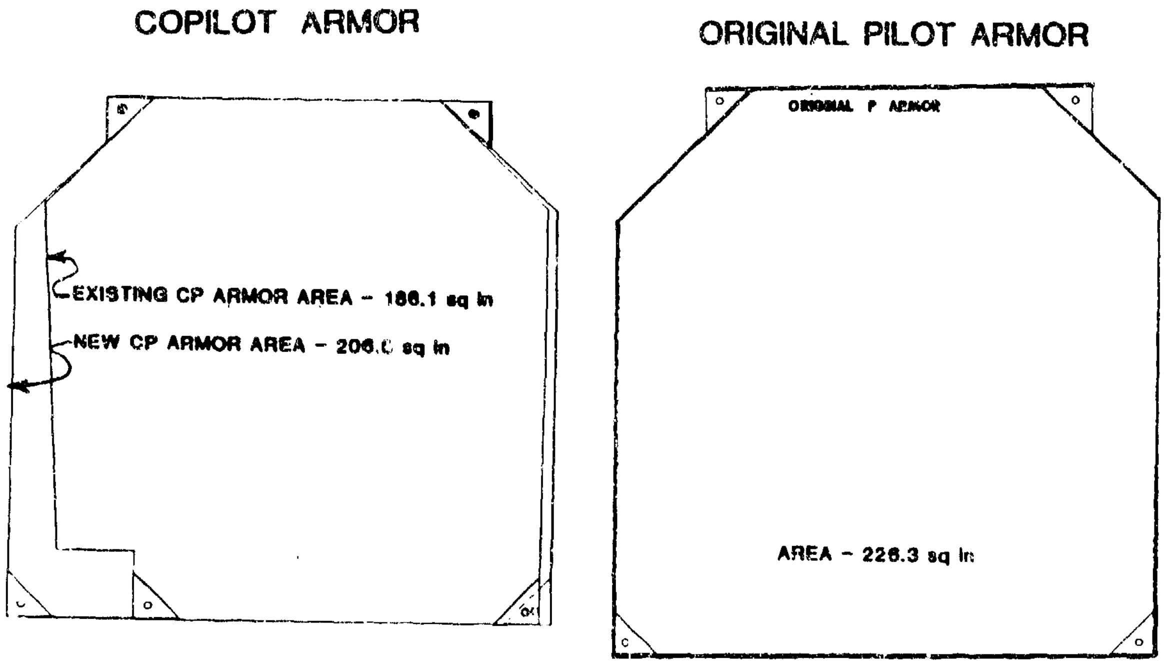


Figure 3-5. Lower armor panels.

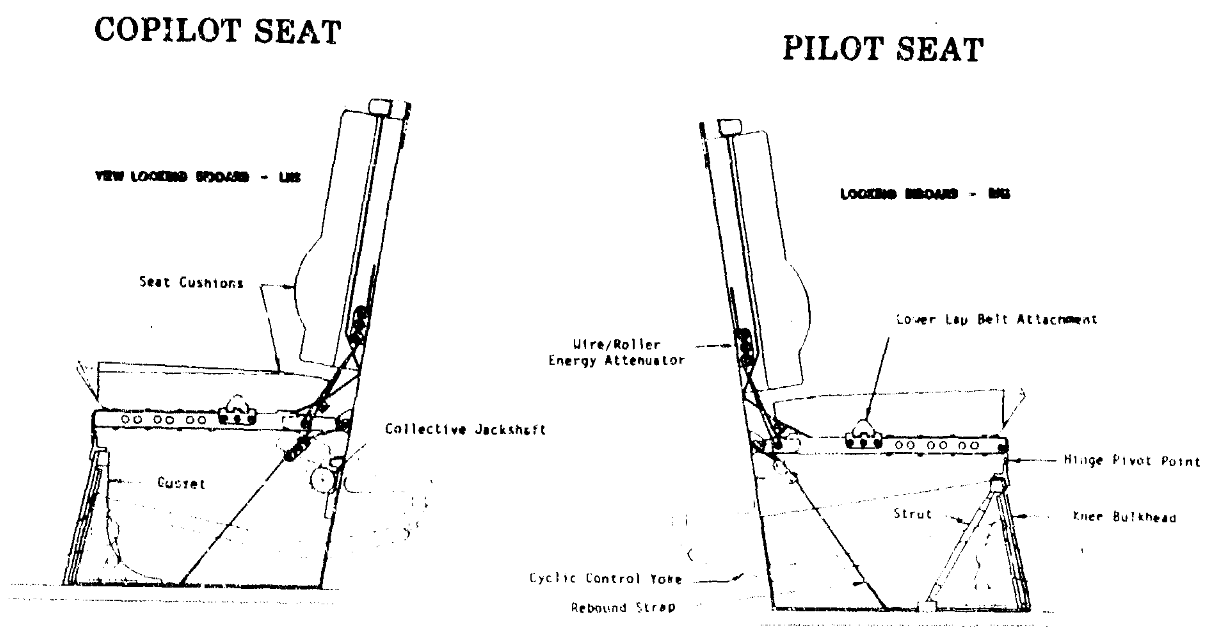


Figure 3-6. OH-58 energy attenuating seat.

Each aft corner of the seat pan was held vertically by a wire/roller energy attenuator with a latch hook and horizontally by the seat pan hinge (Figure 3-7). In a crash where a 170 lb (77 kg) occupant (i.e., 50th percentile aviator) experiences 12 +/- 1 G in the vertical direction, the seat pan would start to pivot down about the knee bulkhead, pulling the wires around the rollers. The energy attenuators would continue to limit the stroking load to 13 Gs or less until stroking ceases. Although the stroking load was sized for a 50th percentile occupant, the 5th percentile occupant and 95th percentile occupant would receive a stroking load of 13.7 G and 9.8 G, respectively. Thus a single load energy attenuator is acceptable. Since the seat pan lengths are different due to the collective jackshaft behind the copilot, the moment arms are different as shown in Figure 3-8. This required a different energy attenuator stroking load of 580 lb (263 kg) for the pilot energy attenuator and 700 lb (317 kg) for the copilot attenuator. Both pilot and copilot energy attenuator loads are equivalent to 12G (i.e., 80% of 170 lb (77 kg) occupant) applied at the same Buttocks Reference Point (BRP).

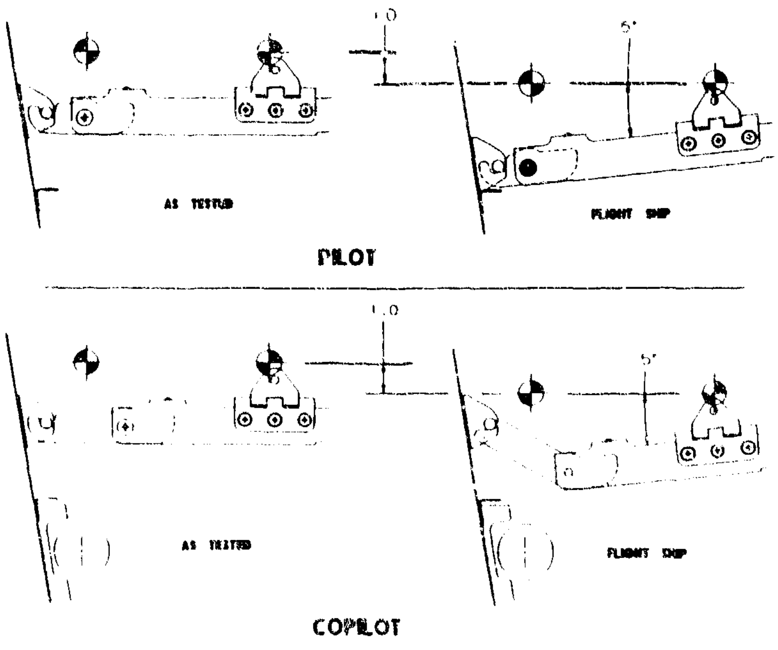


Figure 3-7. Latch hooks.

The individual wire/roller attenuator was sized using dynamic drop test. The same size wire (0.093 inches) (2.4 mm) was used for the pilot and copilot energy attenuators but the distance between the outermost rollers was varied to optimize the design for that specific application. The outermost roller spacing was 2.0 inches (5.1 cm) for the pilot energy attenuator and 1.8 inches (4.6 cm) for the copilot energy attenuator. The test results of the energy attenuator sizing testing are shown in Figure 3-9. The stroking loads were consistent and close to the design goal loads.

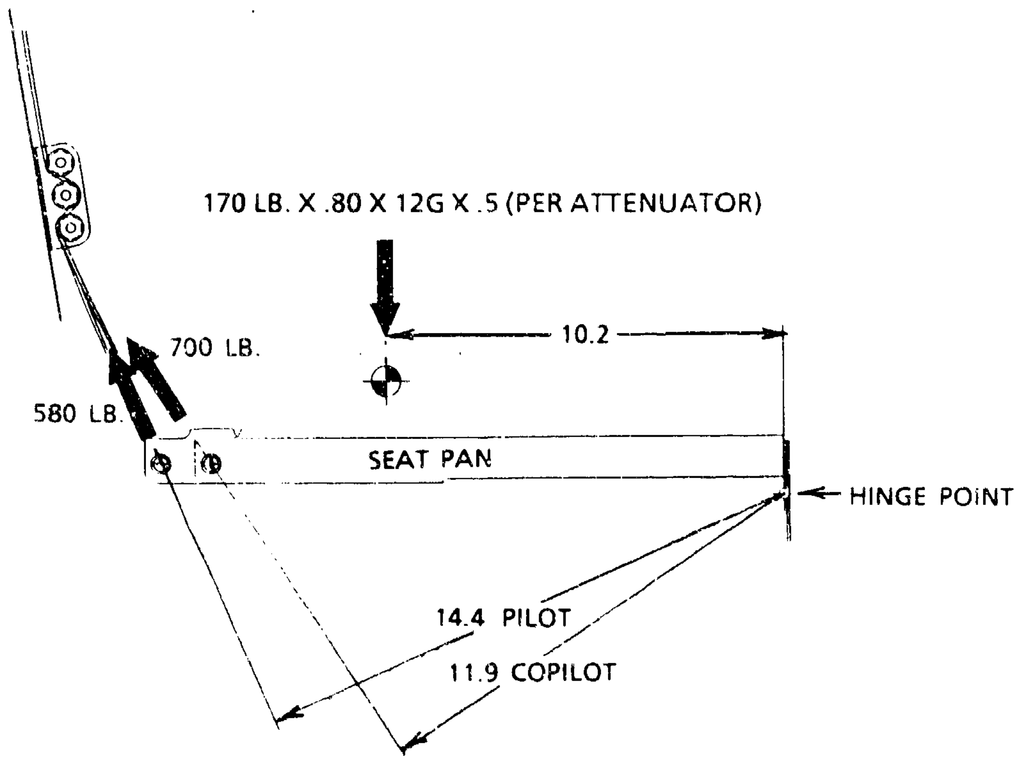


Figure 3-8. Energy attenuator sizing.

A rebound strap was provided to minimize excessive rebound motion after stroking. This was achieved with a one-way latch which is similar to a shoulder harness adjuster. This latch or rebound assembly, attached to the seat pan, slides down a structure mounted strap of webbing. Some slack or stretching in the strap was needed to allow the seat pan rebound latch, traveling in an arc, to slide down a straight fabric strap (Figure 3-10).

The seat back cushion was of foam construction with an adjustable lumbar support as shown in Figure 3-11. Hook and pile fasteners were used to attach the lumbar adjuster cushion to the back cushion. The seat back, attached to the seat bottom cushion, will slide down with the bottom cushion as it strokes. This provided protection from nearby structure for the lower back after stroking.

The crew back bulkhead of sheet metal with lightening holes was replaced with a thicker sheet metal without lightening holes. A structural channel was added behind the bulkhead to react the energy attenuator loads. Seat back cushion lateral guides attached to the bulkhead also provided a cover for the wires. The back bulkhead is shown in Figure 3-12. The knee bulkhead was strengthened with 1/4 inch (0.64 cm) aluminum plate and a diagonal strut at the inboard and outboard corner of each seat as shown in Figure 3-13. Since a tubular strut on the copilot outboard side would interfere with the lateral magnetic brake, a curved gusset was

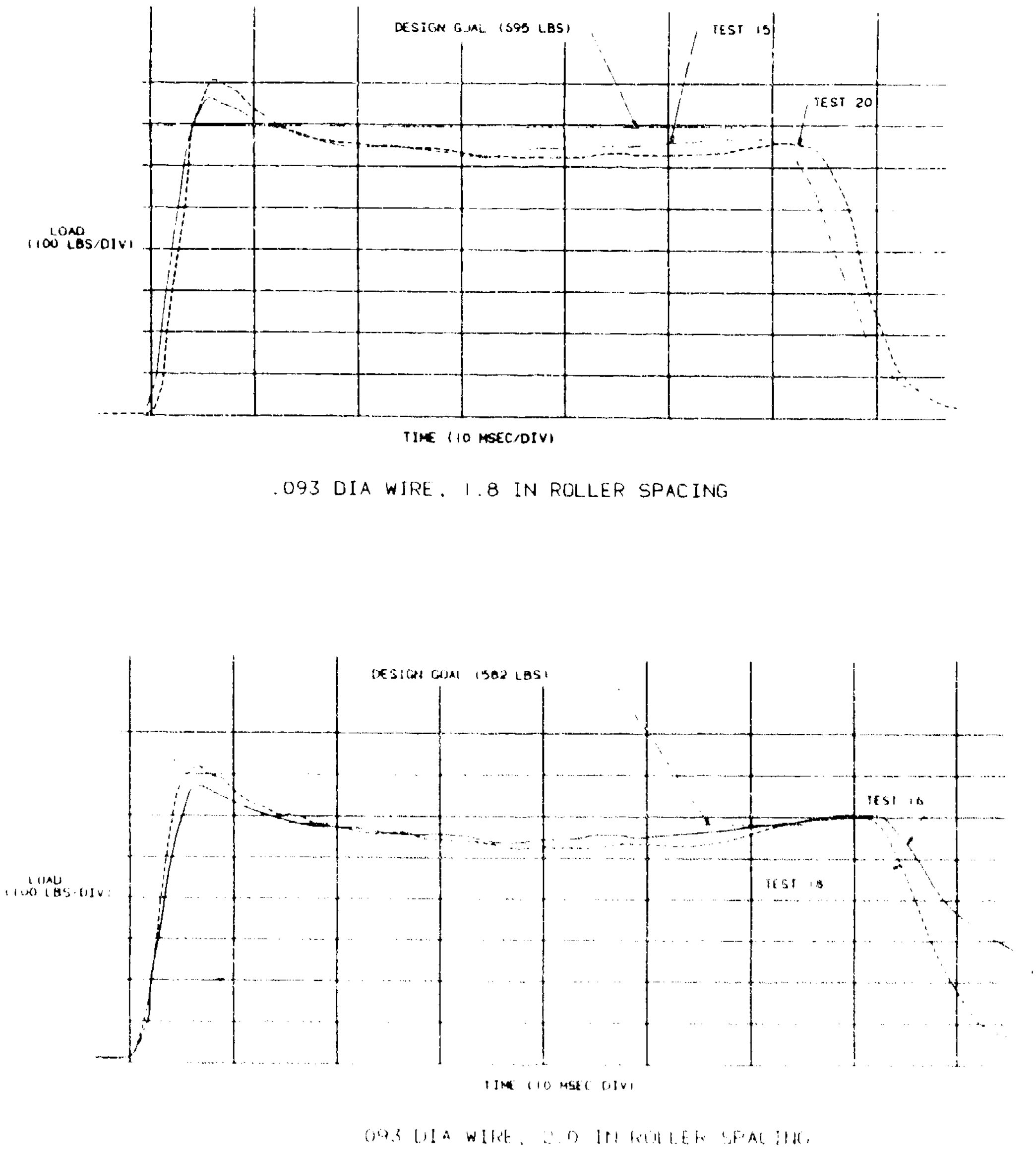


Figure 3-9. Energy attenuator sizing tests.

designed as shown in Figure 3-13. Part of a sloping filler ramp that was not structural on the fuselage floor was trimmed to allow the gusset to be installed next to the lateral magnetic brake. A fitting was added to extend the knee bulkhead up to the pivot point.

The flight controls required a slight modification of the collective jackshaft friction clamp and support. The clamp ear location was moved upward to avoid seat pan contact during the crash stroke as shown in Figure 3-14. No other control modification was done.

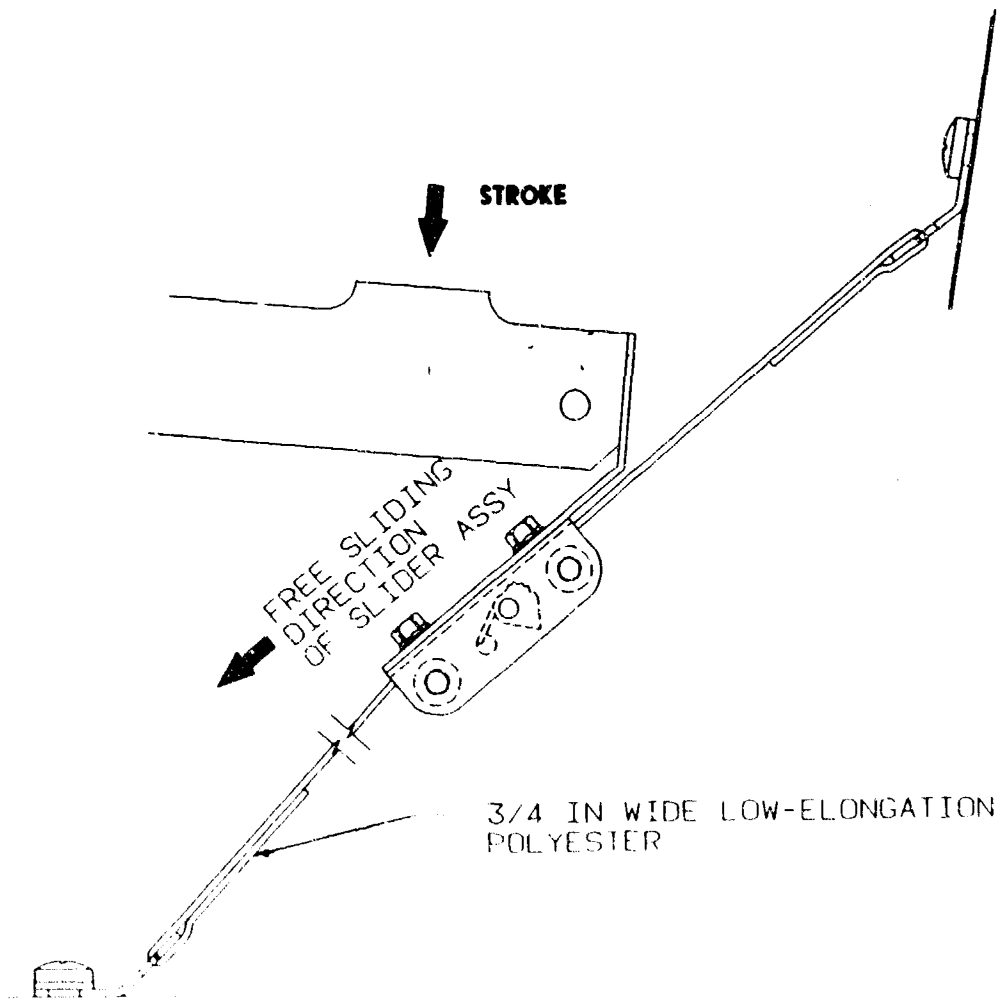


Figure 3-10. Rebound assembly.

The present occupant restraint, P/N 206-070-870-7, was used with the present MA-6 inertia reel. The location of the inverted "V" lap belt attachments were relocated to optimize lapbelt location during stroking. The lap belt location and loading direction remained the same. The forward attachment point was attached to the pivoting seat pan and moves with the pan during stroking. The aft lap belt attachment fastens to the crewman back bulkhead as shown in Figure 3-15 for the energy attenuating crew seat on the existing OH-58. This keeps the lapbelt tight during stroking and minimizes submarining.

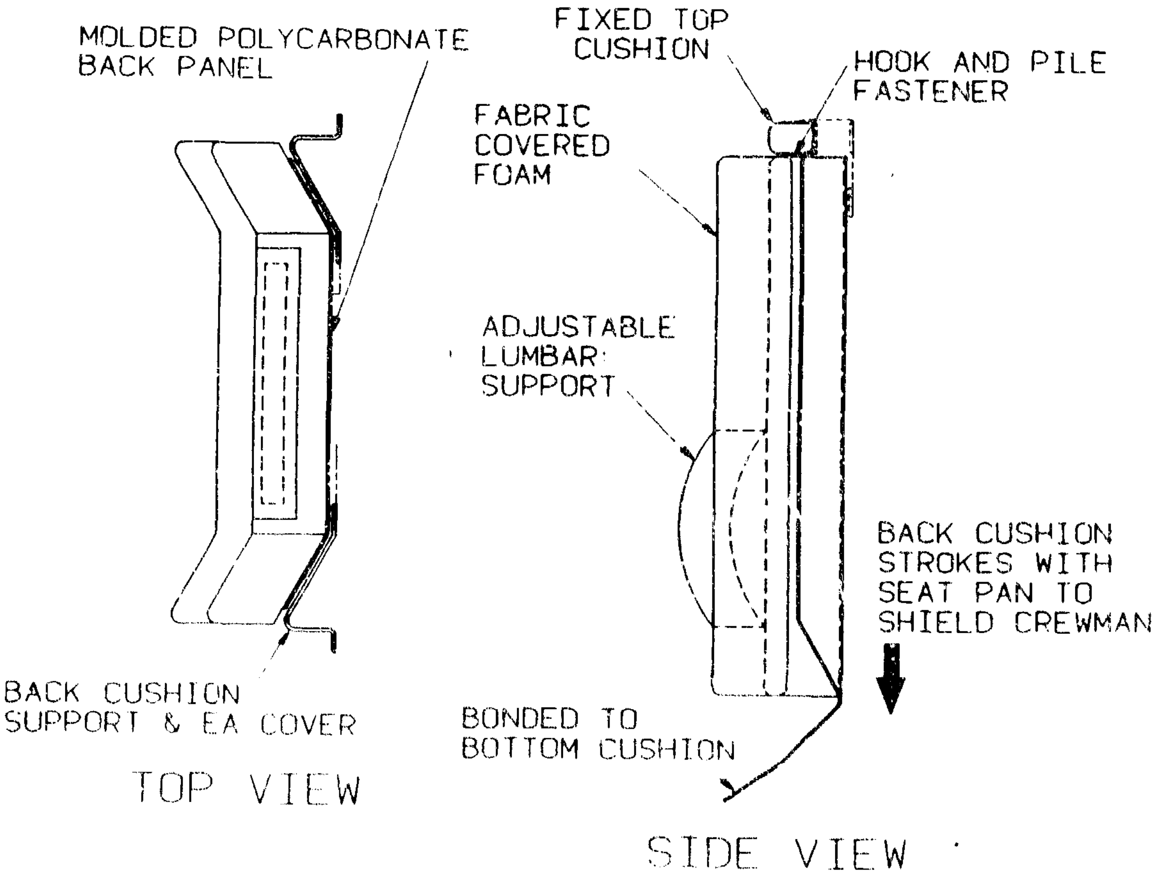


Figure 3-11. Seat back cushions.

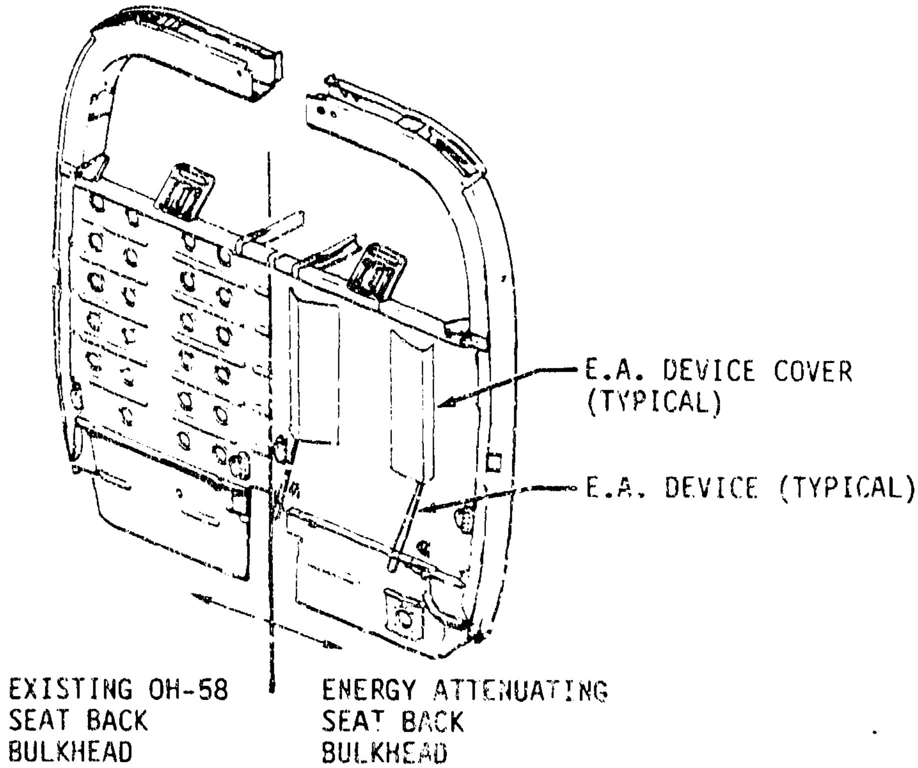


Figure 3-12. Seat back structure.

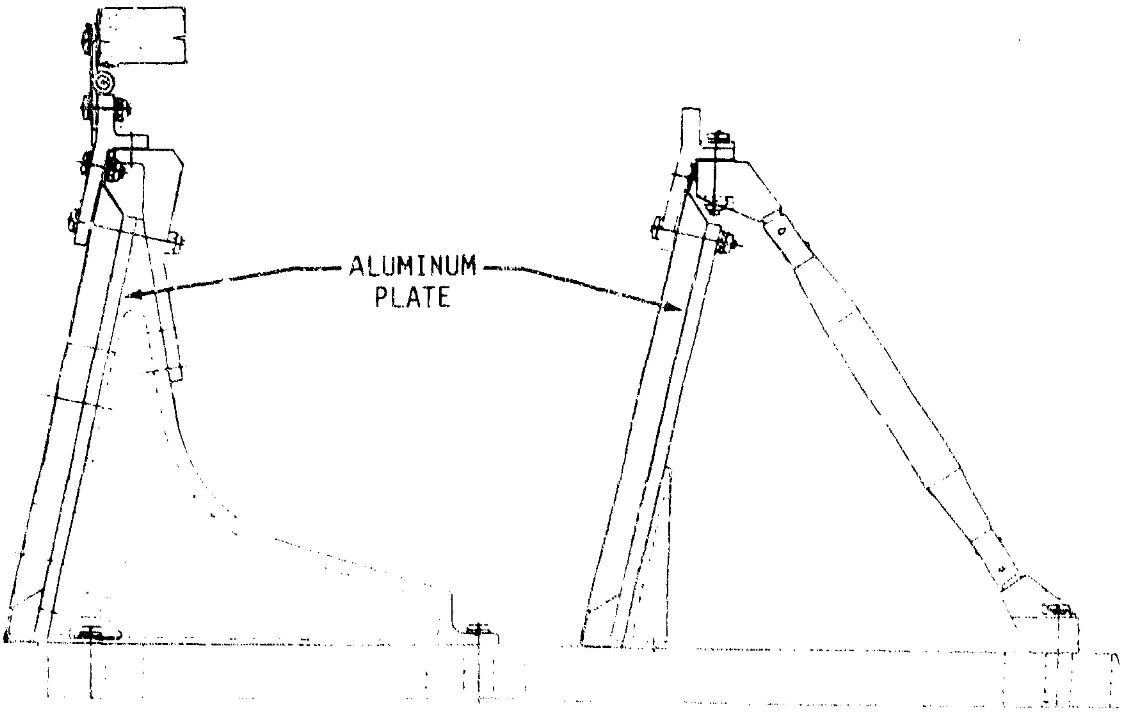


Figure 3-13. Knee bulkhead supports.

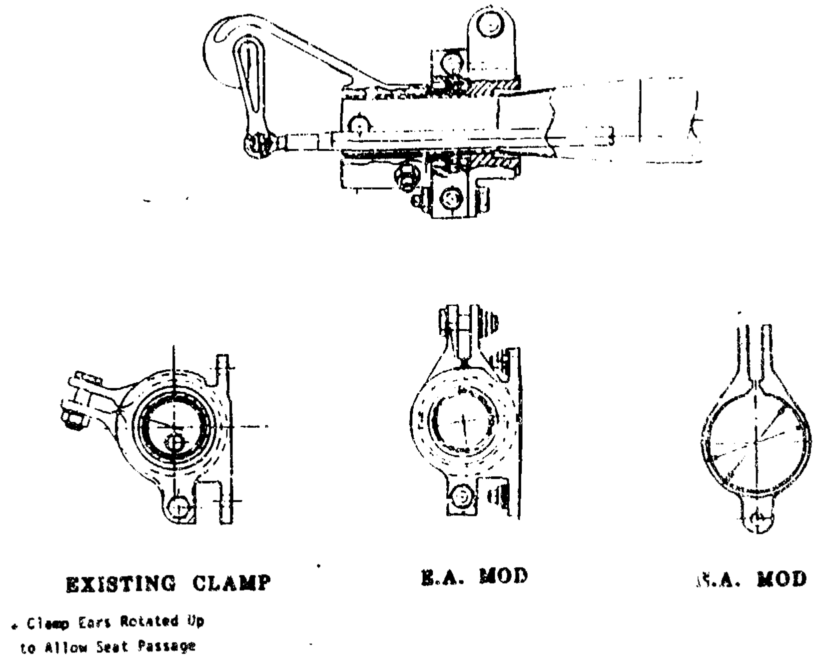


Figure 3-14. Collective friction clamp mod.

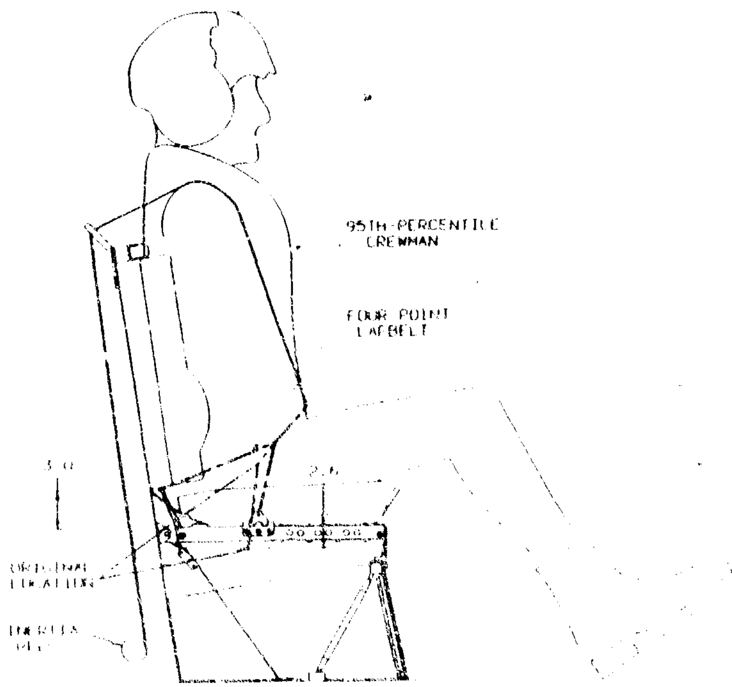


Figure 3-15. Crewman restraint system.

4.0 DYNAMIC TESTING

4.1 TEST SETUP

A damaged OH-58 fuselage for cockpit modification was provided by the U. S. Army for the energy attenuating crew seat dynamic testing. The modified cockpit was attached to a test fixture which was then mounted to the Federal Aviation Administration (FAA) Civil Aeromedical Institute (CAMI) dynamic test sled as shown in Figure 4-1. The U. S. Army and the FAA CAMI conducted the dynamic seat tests and BHTI provided support. Mr. Joseph Haley Jr, COR, directed the dynamic tests.

Four dynamic tests were planned but impact testing damage incurred to the basic fuselage prevented the last test. The three dynamic seat test conditions conducted are shown in Table 4-1. The initial test was to simulate a pure vertical impact, the second test was to be comparable but at a higher impact velocity, and the third test was to add a forward impact force to the vertical force. The dynamic tests were conducted June 14-17, 1988. The same test seats were used in each dynamic test; only the energy attenuating wires were replaced between tests.

The impact velocities of Tests Ia and Ib were chosen as they related to the vertical velocity component of the 95th percentile survivable accident for civil rotorcraft, Reference 11 and U. S. Army OH-58 aircraft of Reference 12, respectively. The OH-58 portion of the data used in Reference 12 was used. Test IIa was equivalent to a 30 deg nose down, vertical drop test which provided a vertical velocity component of 26 ft/sec (7.9 m/s). The extra four degrees of pitch was to compensate for the dynamic test being conducted horizontally, rather than a gravity drop test. The intent of Test IIa was to further verify that the seat will stroke, even though combined forward and vertical crash loads are present. The fourth test was to be the same as Test IIa, except a 15 deg roll was to be added.

A 50th percentile and a 95th percentile instrumented Part 572, Hybrid III dummy were furnished by USAARL. These dummies were instrumented as shown in Table 4-2. Each dummy was clothed in a flight suit and leather boots and wore an SPH-4 helmet. The 50th percentile dummy was seated in the pilot seat (right) with the 95th percentile dummy in the copilot seat (left) during all dynamic tests.

4.2 TEST RESULTS

The results of the dynamic tests are discussed herein. The peak test values of Tests Ia, Ib, and IIa are shown in Tables 4-3, 4-4, and 4-5, respectively. The pre-impact test and post-impact test photographs are shown as Figures 4-2 through 4-7.

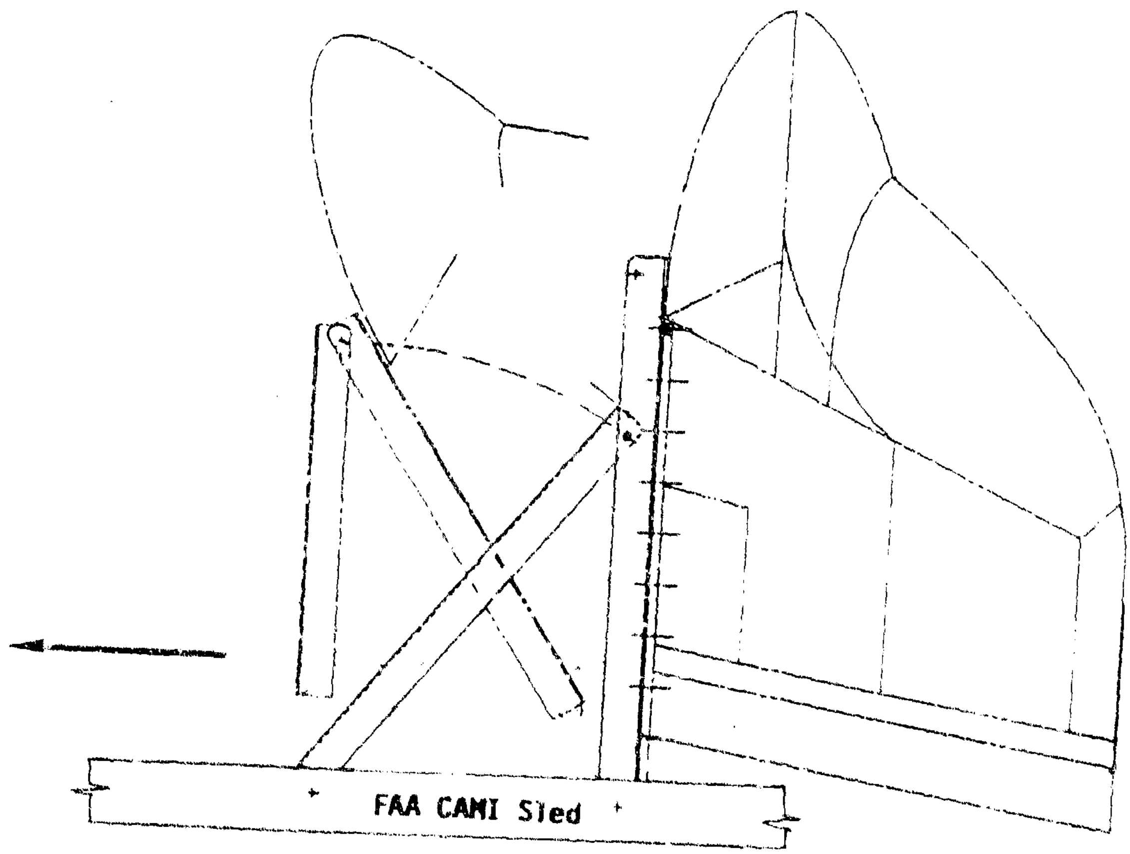


Figure 4-1. Test fixture.

TABLE 4-1. DYNAMIC SEAT TESTING

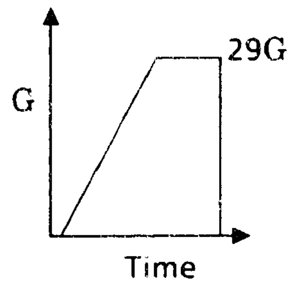
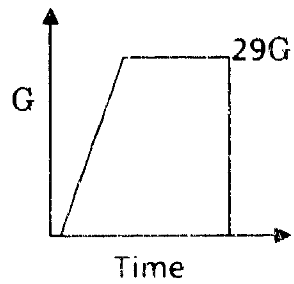
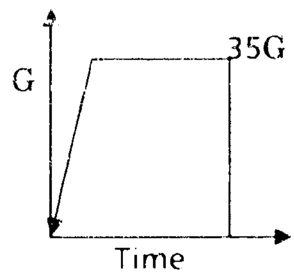
TEST NO. (FAA CAMI)	IMPACT VEL ft/sec(m/s)	FUSELAGE ORIENTATION-IMPACT EQUIVALENT	INPUT PULSE (G) 840 G/Sec Onset
Ia (A88-057)	26 (7.9)	Pure Vertical(Fig. 4-2) (Fig. 4-3)	
Ib (A88-058)	30 (9.1)	Pure Vertical(Fig. 4-4) (Fig. 4-5)	
IIa (A88-059)	32 (9.8)	Combined Forward and Vertical, 34 deg pitch down (Fig. 4-6) (Fig. 4-7)	

TABLE 4-2. TEST DUMMY INSTRUMENTATION

DUMMY TYPE	PERCENTILE MALE AVIATOR	WEIGHT* lb(kg)	ACCELEROMETER TYPE	LOCATION
Part 572 Hybrid III	50th	175 lb (79.4)	Triaxial	Pelvis Chest Head
			Load Cell	Neck Lumbar
Part 572 Hybrid III	95th	228 lb (103.4)	Triaxial	Pelvis Chest Head

* With flight suit, boots, and SPH-4 helmet

TABLE 4-3. PEAK TEST VALUES OF TEST Ia
26.5 FT/SEC VELOCITY CHANGE

NAME*	PEAK 1	TIME (ms)	PEAK 2	TIME (ms)
Sled X Acceleration G's	**-29.0	65.		
(1) Head x Accleration G's	41.2	99.	-7.2	144.
(1) Head Y Accleration G's	1.8	79.	-1.8	157.
(1) Head Z Accleration G's	23.6	71.	-7.1	143.
(1) Chest X Accleration G's	8.8	85.	-8.6	97.
(1) Chest Z Accleration G's	-3.9	102.	1.1	315.
(1) Neck Moment X in-lbs	-87.9	83.	55.2	180.
(1) Neck Moment Z in-lbs	-16.5	82.	15.0	147.
(1) Pelvic Force X lbs	-333.2	102.	74.7	234.
(1) Pelvic Force Y lbs	-81.4	84.	30.1	131.
(1) Pelvic Force Z lbs	1487.4	93.		
(1) Pelvic Moment X in-lbs	-378.0	90.	153.2	136.
(1) Pelvic Moment Y in-lbs	-1165.6	149.	773.1	102.
(1) Pelvic Moment Z in-lbs	62.6	72.	-30.1	89.
(2) Head X Acceleration G's	24.2	101.	-7.8	143.
(2) Head Y Acceleration G's	-12.5	105.	5.3	242.
(2) Head Z Acceleration G's	22.7	103.	-6.2	268.
(2) Pelvis X Acceleration G's	15.9	64.	-8.2	93.
(2) Pelvis Y Acceleration G's	5.3	58.	-5.1	106.
(2) Pelvis Z Acceleration G's	-44.8	93.		
Control Tube Force lbs	205.8	145.		
(2) Inboard Leg Strain uStr	1604.4	88.	-1027.7	63.
(1) Inboard Leg Strain uStr	1651.6	86.	-685.5	63.

TABLE 4-3. PEAK TEST VALUES OF TEST Ia
26.5 FT/SEC VELOCITY CHANGE (Concluded)

NAME*	PEAK 1	TIME (ms)	PEAK 2	TIME (ms)
(1) Outboard Leg Strain uStr	2110.3	86.	-635.9	62.
(1) Seat Z Acceleration G's	24.8	192.	-21.2	74.
(2) Seat Z Acceleration G's	-41.1	82.	26.4	63.
Aux. Sled X Acceleration G's	-29.1	62.		
(1) Head Resultant Acceleration G's	44.6	99.		
(1) Pelvic Force Resultant lbs.	1513.5	96.		
(1) Pelvic Moment Resultant in-lbs.	1167.0	152.		
(2) Head Resultant Acceleration G's	34.3	104.		
(2) Pelvis Resultant Acceleration G's	45.6	94.		

*(1) 50th Percentile Dummy
*(2) 95th Percentile Dummy
** Filtered Data per SAE J-211

TABLE 4-4. PEAK TEST VALUES OF TEST Ib 29.6 FT/SEC VELOCITY CHANGE

NAME*	PEAK 1	TIME (ms)	PEAK 2	TIME (ms)
Sled X Acceleration G's	**-29.0	62.	4.9	99.
(1) Head X Accleration G's	26 3	101.	-5.4	164.
(1) Head Y Accleration G's	-6.5	194.	5.2	106.
(1) Head Z Accleration G's	35.5	96.	-8.5	150.
(1) Chest X Accleration G's	-12.3	120.	9.0	83.
(1) Chest Z Accleration G's	-9.8	98.	2.1	194.
(1) Neck Force X lbs	-217.1	95.	85.3	184.
(1) Neck Force Y lbs	33.1	193.	-31.3	105.
(1) Neck Force Z lbs	349.3	92.	-129.4	146.
(1) Neck Moment X in-lbs	165.3	184.	-113.9	111.
(1) Neck Moment Y in-lbs	644.4	111.	-487.8	173.
(1) Neck Moment Z in-lbs	-42.9	218.	41.0	132.
(1) Pelvic Force X lbs	-469.0	98.		
(1) Pelvic Force Y lbs	49.1	64.	-40.9	89.
(1) Pelvic Force Z lbs	2124.5	92.		
(1) Pelvic Moment X in-lbs	448.1	98.	-123.1	57.
(1) Pelvic Moment Y in-lbs	2298.8	98.	-633.8	153.
(1) Pelvic Moment Z in-lbs	98.7	101.	-23.4	343.
(2) Head X Acceleration G's	67.4	93.	-13.0	125.
(2) Head Y Acceleration G's	-19.2	94.	9.2	261.
(2) Head Z Acceleration G's	38.5	104.	-15.5	122.
(2) Pelvis X Acceleration G's	14.3	78.	-10.8	91.
(2) Pelvis Y Acceleration G's	13.4	86.	-10.6	61.

TABLE 4-4. PEAK TEST VALUES OF TEST Ib
29.6 FT/SEC VELOCITY CHANGE (Concluded)

NAME*	PEAK 1	TIME (ms)	PEAK 2	TIME (ms)
(2) Pelvis Z Acceleration G's	-52.1	86.		
Control Tube Force lbs	2590.0	104.	-511.6	161.
(2). Inboard Leg Strain uStr	2137.9	85.	-1137.8	58.
(1) Inboard Leg Strain uStr	1584.5	85.	-663.7	61.
(1) Outboard Leg Strain uStr	1905.7	86.	-678.1	62.
(1) Seat Z Acceleration G's	37.1	185.	-29.3	89.
(2) Seat Z Acceleration G's	-46.1	89.	18.4	59.
Aux. Sled X Acceleration G's	-29.0	63.	5.2	85.
(1) Head Resultant Acceleration G's	39.3	96.		
(1) Neck Force Resultant lbs.	405.3	96.		
(1) Neck Moment Resultant in-lbs.	655.2	114.		
(1) Pelvic Force Resultant lbs.	2151.9	95.		
(1) Pelvic Moment Resultant in-lbs.	2343.8	101.		
(2) Head Resultant Acceleration G's	71.5	93.		
(2) Pelvis Resultant Acceleration G's	54.8	87.		

*(1) 50th Percentile Dummy
*(2) 95th Percentile Dummy
** Filtered Data per SAE J-211

TABLE 4-5. PEAK TEST VALUES OF TEST IIa
32.2 FT/SEC VELOCITY CHANGE

NAME*	PEAK 1	TIME (ms)	PEAK 2	TIME (ms)
Sled X Acceleration G's	**-35.0	54.	6.3	79.
(1) Head X Accleration G's	-17.0	118.	11.5	80.
(1) Head Y Accleration G's	-3.6	115.	3.2	152.
(1) Head Z Accleration G's	27.1	62.	-24.5	121.
(1) Chest X Accleration G's	-24.7	92.	6.5	139.
(1) Chest Z Accleration G's	-6.2	80.	4.5	102.
(1) Neck Force X lbs	205.4	113.	-123.8	74.
(1) Neck Force Y lbs	28.0	130.	-9.2	183.
(1) Neck Force Z lbs	-349.6	122.	313.9	98.
(1) Neck Moment X in-lbs	141.5	122.	-78.3	169.
(1) Neck Moment Y in-lbs	955.4	97.	-845.0	160.
(1) Neck Moment Z in-lbs	20.3	157.	-19.3	87.
(1) Pelvic Force X lbs	-241.9	95.	88.2	68.
(1) Pelvic Force Y lbs	55.4	160.	-17.0	70.
(1) Pelvic Force Z lbs	1376.7	70.	-331.2	124.
(1) Pelvic Moment X in-lbs	280.6	158.	-120.8	95.
(1) Pelvic Moment Y in-lbs	-1839.3	79.	375.3	50.
(1) Pelvic Moment Z in-lbs	92.7	127.	-35.3	184.
(2) Head X Acceleration G's	-19.5	122.	15.5	345.
(2) Head Y Acceleration G's	-6.9	171.	5.1	75.
(2) Head Z Acceleration G's	30.9	103.	-13.1	119.
(2) Pelvis X Acceleration G's	17.3	79.	3.8	114.
(2) Pelvis Y Acceleration G's	10.1	82.	-5.6	108.

TABLE 4-5. PEAK TEST VALUES OF TEST IIa
32.2 FT/SEC VELOCITY CHANGE (Concluded)

NAME*	PEAK 1	TIME (ms)	PEAK 2	TIME (ms)
(2) Pelvis Z Acceleration G's	-53.4	82.		
Control Tube Force lbs	-489.0	140.	297.4	97.
(2) Inboard Leg Strain uStr	2693.4	68.		
(1) Inboard Leg Strain uStr	1663.6	58.		
(1). Outboard Leg Strain uStr	2646.0	72.		
(1) Seat Z Acceleration G's	-34.4	73.	7.5	49.
(2) Seat Z Acceleration G's	-50.9	77.	21.9	52.
Aux. Sled X Acceleration G's	-34.7	55.	6.2	79.
(1) Head Resultant Acceleration G's	28.4	121.		
(1) Neck Force Resultant lbs	373.6	122.		
(1) Neck Moment Resultant in-lbs	955.9	100.		
(1) Pelvic Force Resultant lbs	1379.2	73.		
(1) Pelvic Moment Resultant in-lbs	1850.3	83.		
(2) Head Resultant Acceleration G's	31.0	103.		
(2) Pelvis Resultant Acceleration G's	54.7	83.		

*(1) 50th Percentile Dummy
*(2) 95th Percentile Dummy
** Filtered Data per SAE J-211

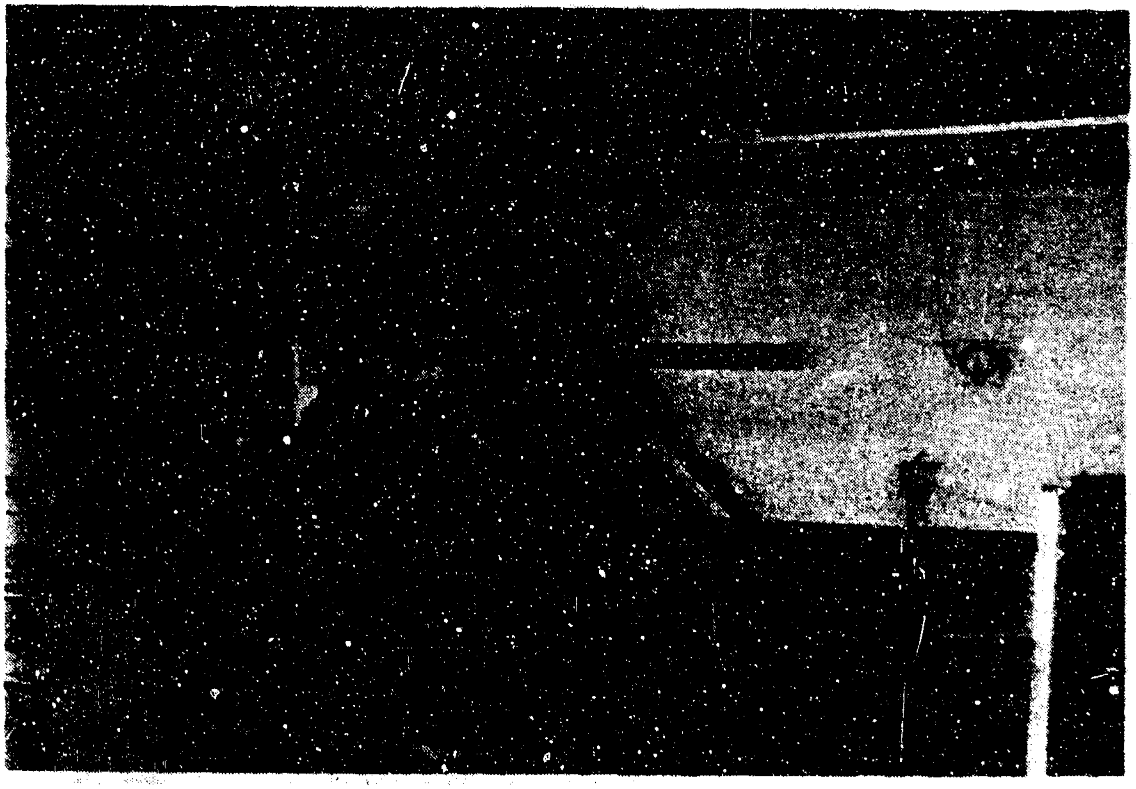


Figure 4-2. Pre-impact test Ia.

Figure 4-3. Post-impact test Ia.

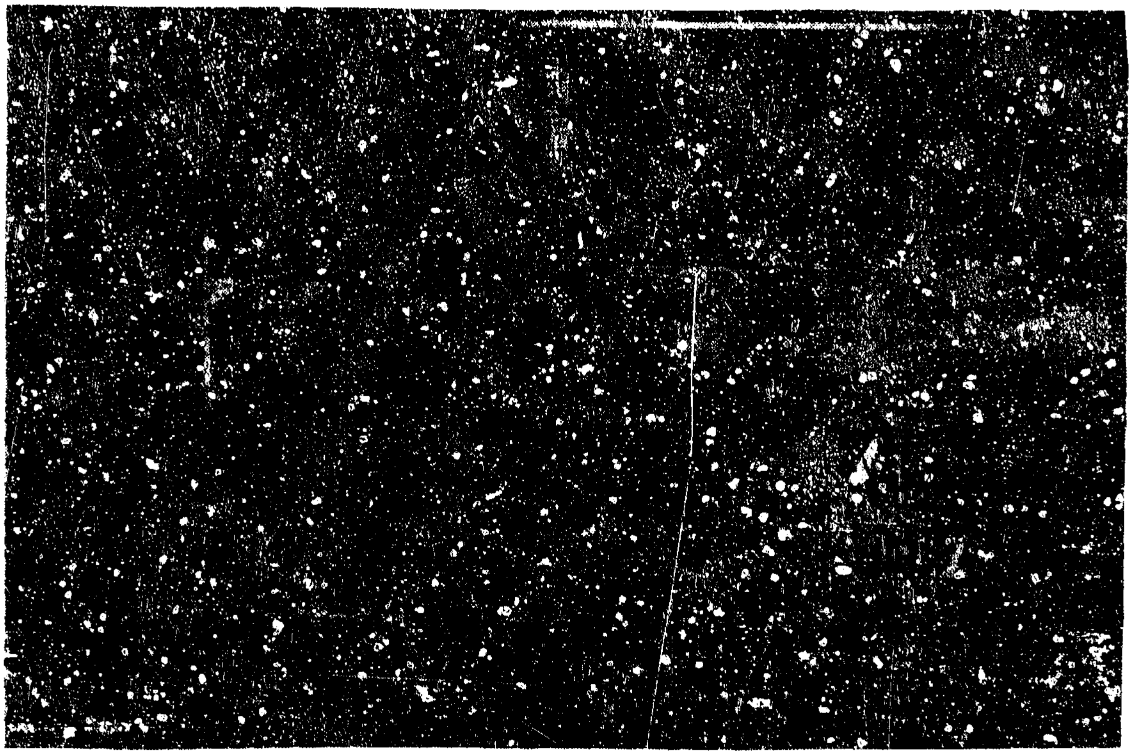


Figure 4-4. Pre-impact test Ib.

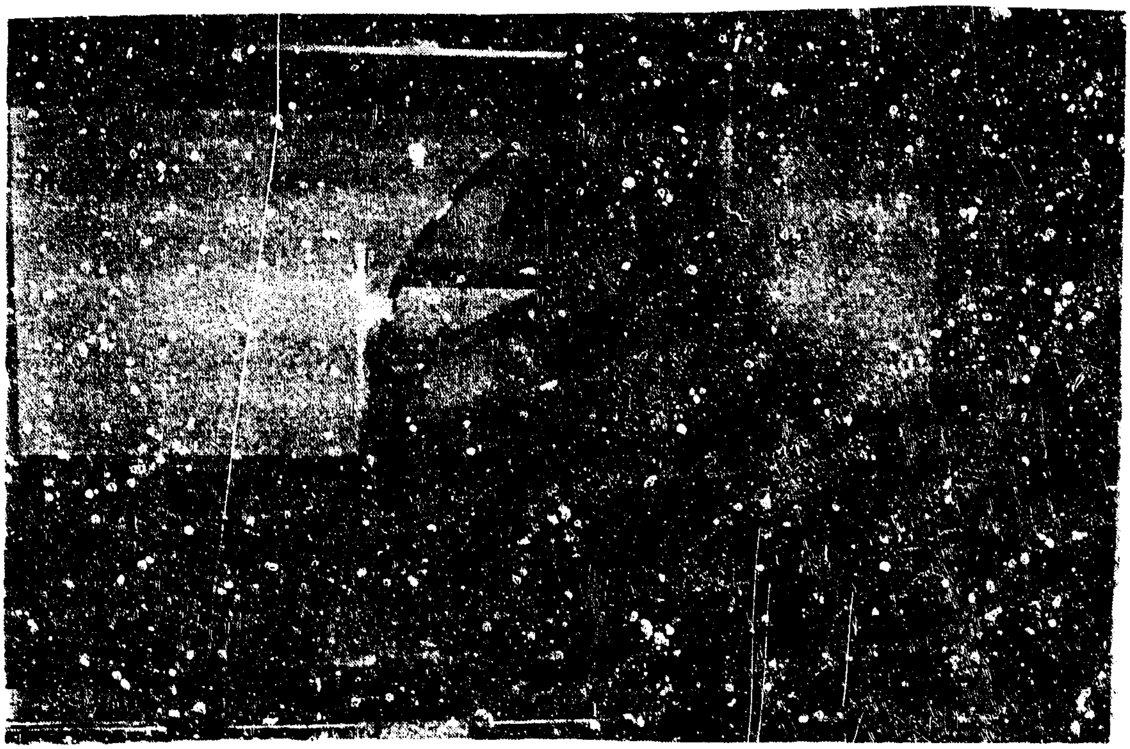


Figure 4-5. Post-impact test Ib.

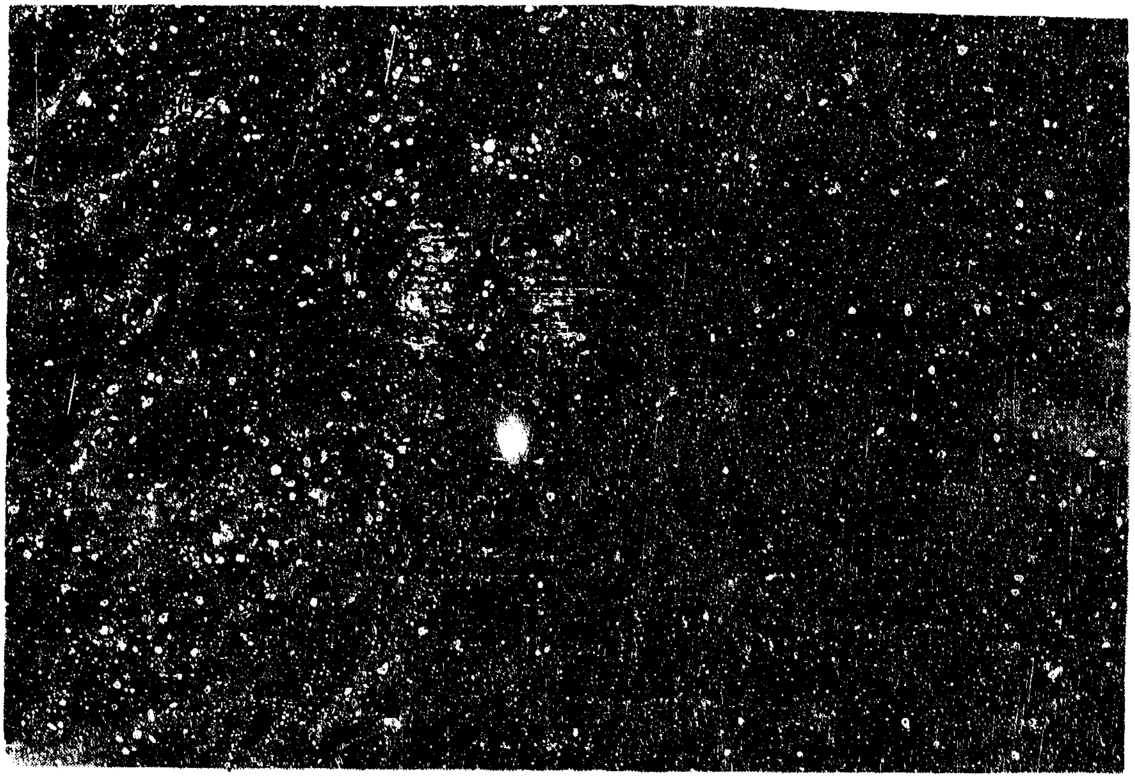


Figure 4-6. Pre-impact test IIa.

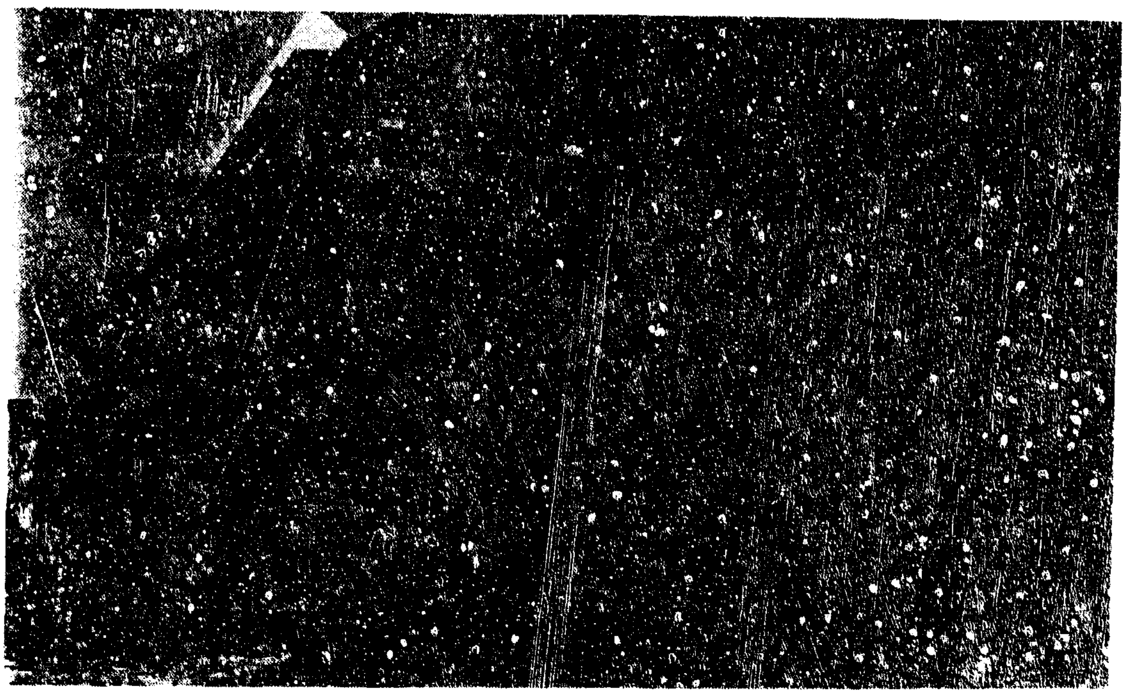


Figure 4-7. Post-impact test IIb.

4.2.1 Seat Strokes

The seat strokes of the Buttock Reference Point (BRP) vertical displacement obtained during the testing is shown in Table 4-6.

TABLE 4-6. BRP STROKES

TEST NUMBER	50TH PERCENTILE OCCUPANT (In. (cm))	95TH PERCENTILE OCCUPANT (In. (cm))	CONTROL YOKE POSITION (COLLECTIVE STICK EQUIVALENT)
Ia	4.75 (12.1)*	5.61 (14.2)	Full down yoke (Full up collective)
Ib	4.82 (12.2)	5.82 (14.8)	Full up yoke (Full down collective)
IIa	4.30 (10.9)	5.66 (14.4)	Full up yoke (Full down collective)

* No contact made with control yoke.

In all tests, the cyclic controls were locked in the neutral position. The seat with the 50th percentile dummy occupant did not contact the yoke in Test Ia but did in Tests Ib and IIa. The seat with the 95th percentile dummy occupant contacted the yoke in every test. The seat stroke and rebound positions are shown for Tests Ia, Ib, and IIa in Figures 4-7, 4-8, and 4-9, respectively. Some rebound is expected due to the initial slack in the rebound strap needed to allow the seat pan movement in an arc. The amount of rebound experienced on the 95th percentile dummy in Test Ia and both dummies in Test Ib and IIb were more than desired but still considered acceptable. It is believed that this large amount of rebound was related to the combination of two factors. First, the primary contributor was the heavy contact made by the seat impacting the control yoke. The deflection of the control yoke appears to be acting like a spring. The second factor is the rebound assembly cam center-of-gravity location combined with low cam spring tension may be delaying the cam engagement against the webbing. This rebound assembly is used on the Model 412 energy attenuating passenger seat and has previously worked well during dynamic testing for that application. However, in the Model 412 application its orientation is vertical and not at angle, nor is it required to move in an arc. A production design should include a minor refinement of the rebound assembly cam/spring arrangement.

The two piece yoke, part numbers 206-001-323-1 and 206-001-322-1, was used in the dynamic tests and on the flight aircraft. This yoke is used on OH-58A aircraft. The ballistic tolerant two piece yoke, part numbers 206-001-404-1 and 206-001-403-1, is used on OH-58C/D aircraft and is considerably stronger, thus a lesser deflection from

(A) 4.75" TOTAL STROKE

(B) 3.29" REBOUND POSITION

(C) 5.61" TOTAL STROKE

(D) 3.29" REBOUND POSITION

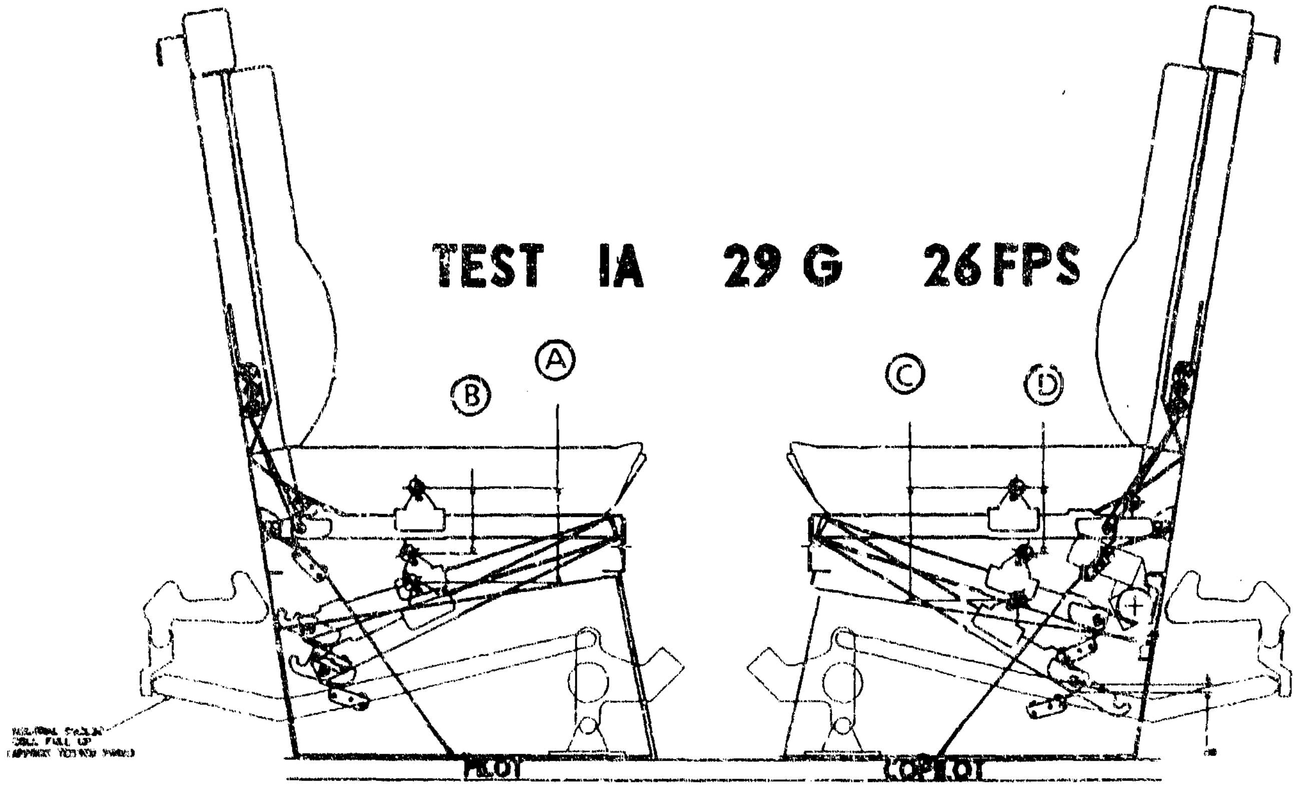


Figure 4-8. Test Ia.

Ⓐ 4.82" TOTAL STROKE

Ⓑ 2.91" REBOUND POSITION

Ⓒ 5.82" TOTAL STROKE

Ⓓ 3.16" REBOUND POSITION

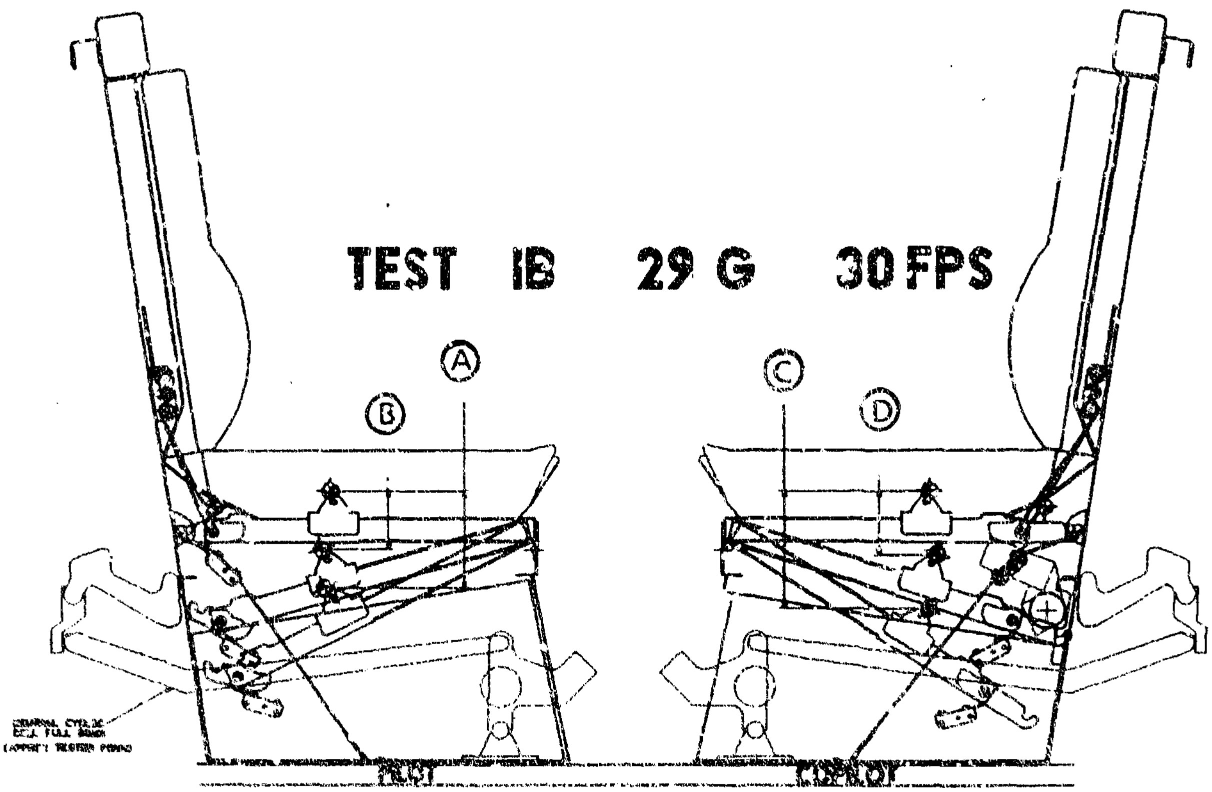


Figure 4-9. Test Ib.

a stroking seat contact is expected. The dynamic tests showed that the energy attenuating seats function quite well prior to significant yoke contact. A redesign of the yoke to meet ballistic tolerance conditions, and to be frangible upon seat contact in a crash, is needed to allow more seat stroking.

4.2.2 Pelvic Loading

The pelvic loading for the 50th percentile dummy was measured by a load cell and the test results are shown in Figure 4-11. The pelvic loading in the 95th percentile dummy was measured by a triaxial accelerometer and the vertical acceleration results are shown in Figure 4-12. In general, the pelvic loads, assuming 1,800 lbs (816 kg) for an average military aviator experienced were within human tolerance without significant yoke contact and were unsatisfactory with yoke contact.

4.2.3 Seat Pan Acceleration

The seat pan accelerations are shown in Figures 4-13, 4-14, and 4-15. Seat pan accelerations are measured perpendicular to the seat pan, which in this concept moves in an arc. The accelerometer was attached to the bottom of the seat pan underneath the BRP location. If the seat pan was to remain in the same plane during the stroking, the data would indicate directly the seat pan acceleration in the vertical direction. Since the seat pan pivots during stroking, the measured axis is changing from the true vertical axis as a function of the pivot angle. The data variance ranges from zero error at the start of stroking to a maximum of plus 14 percent error at the maximum seat stroke experienced of 5.66 inches (14.4 cm) of the 95th percentile dummy on Test IIa. Thus the accelerometer data is accurate at the start of stroking and the actual value is gradually higher than measured as the pivot angle increases. In the worst case at 5.66 inches (14.4cm) of stroke, the actual acceleration is 14 percent higher or 58 Gs instead of 51 Gs.

4.2.4 Pass/Fail Results

The end result of dynamic seat testing is to compare the test loading experienced to the pass/fail criteria. If the test results are below the pass/fail criteria, the test was successful and occupant injury would be considered minimal. Conversely, with test results above the pass/fail criteria, significant occupant injury would be expected. Thus the results of dynamic tests are significantly affected by which pass/fail criteria are used. Pass/fail criteria varies within the military and with civil authorities. BHTI evaluated the test results relative to the following standards.

MIL-S-58095, Reference 13, dated 27 August 1971, require the use of seat pan accelerations and time excursions which are compared to the Eiband human tolerance to acceleration, Figure 15 of Reference 13. If the duration of any individual acceleration peak exceeds the 23 G level for more than 6 msec, the test is considered

Ⓐ 4.30" TOTAL STROKE

Ⓑ 5.66" TOTAL STROKE

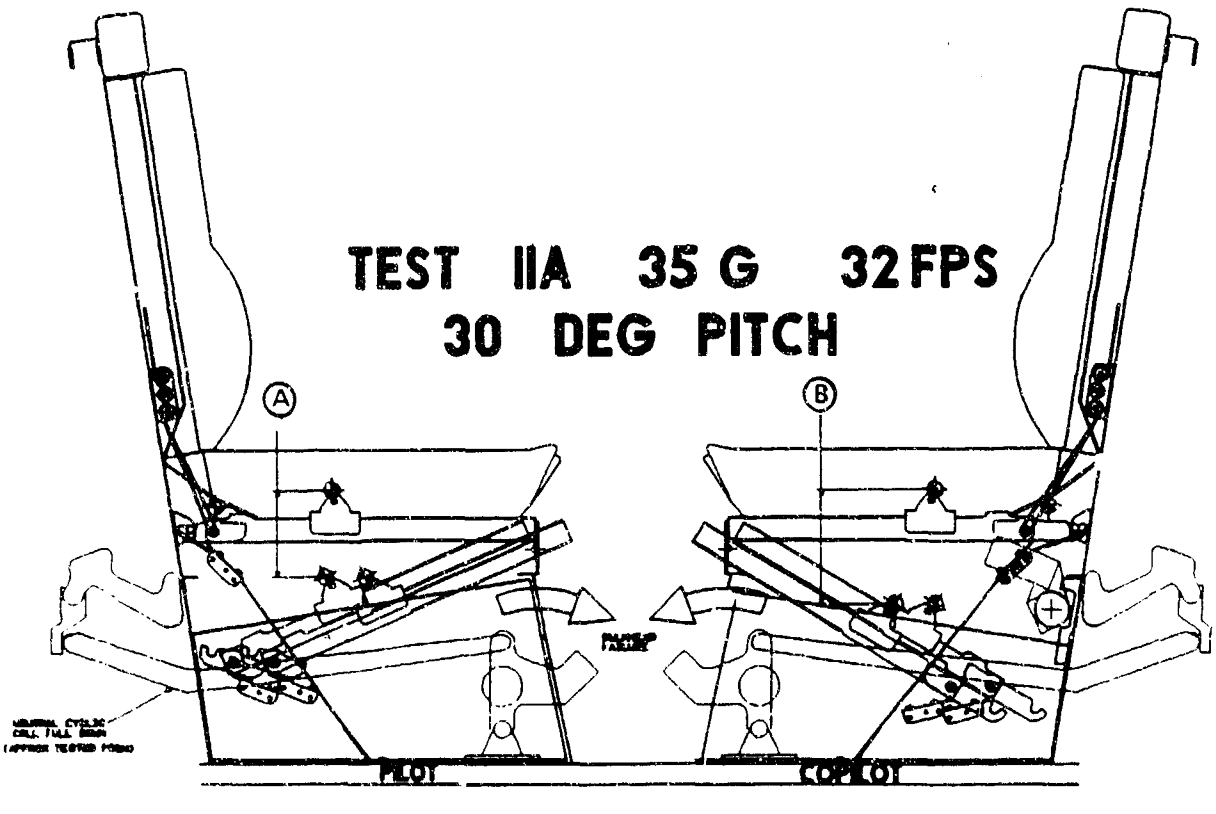


Figure 4-10. Test IIa.

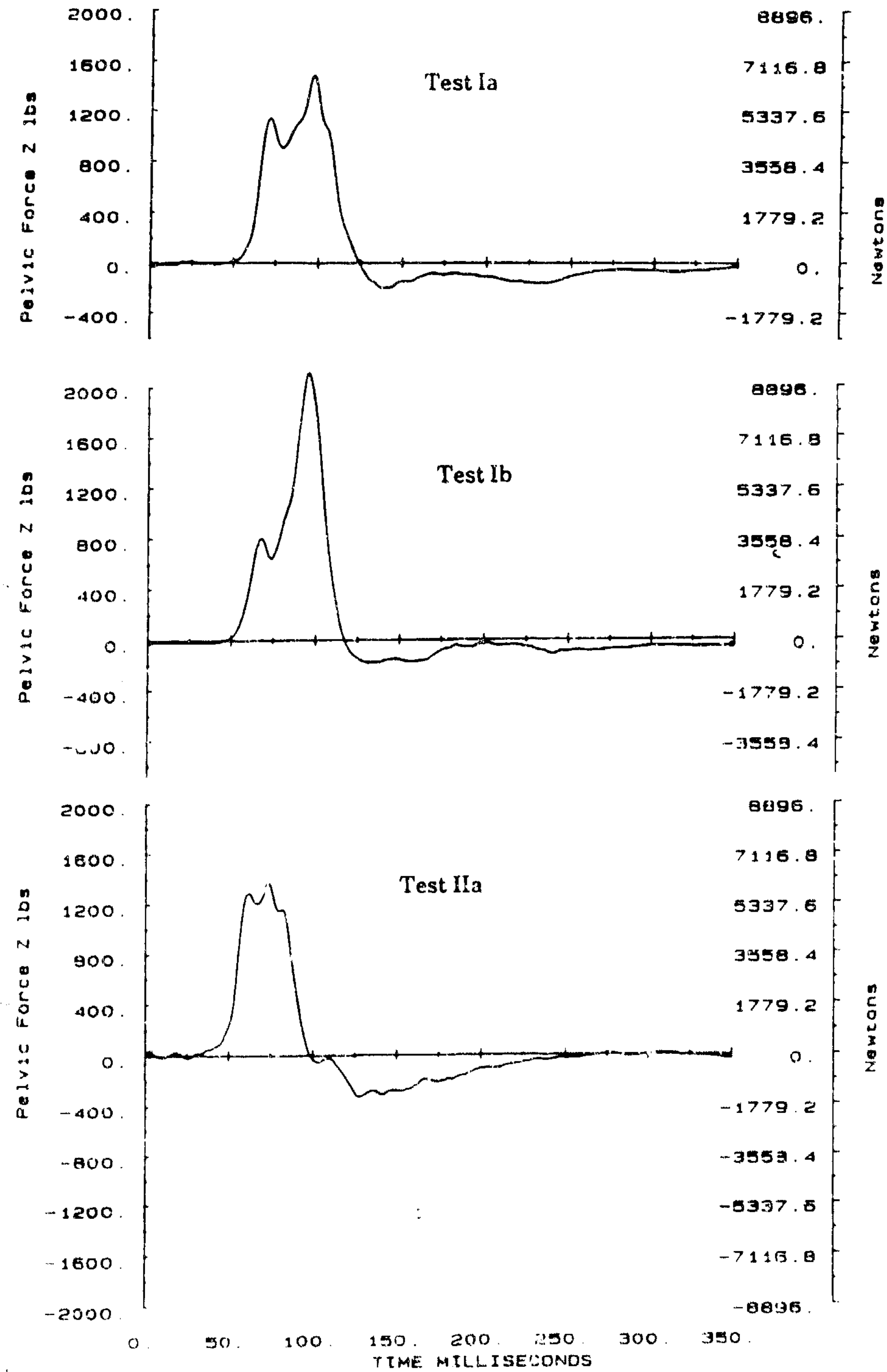


Figure 4-11. Pelvic load - 50th percentile dummy.

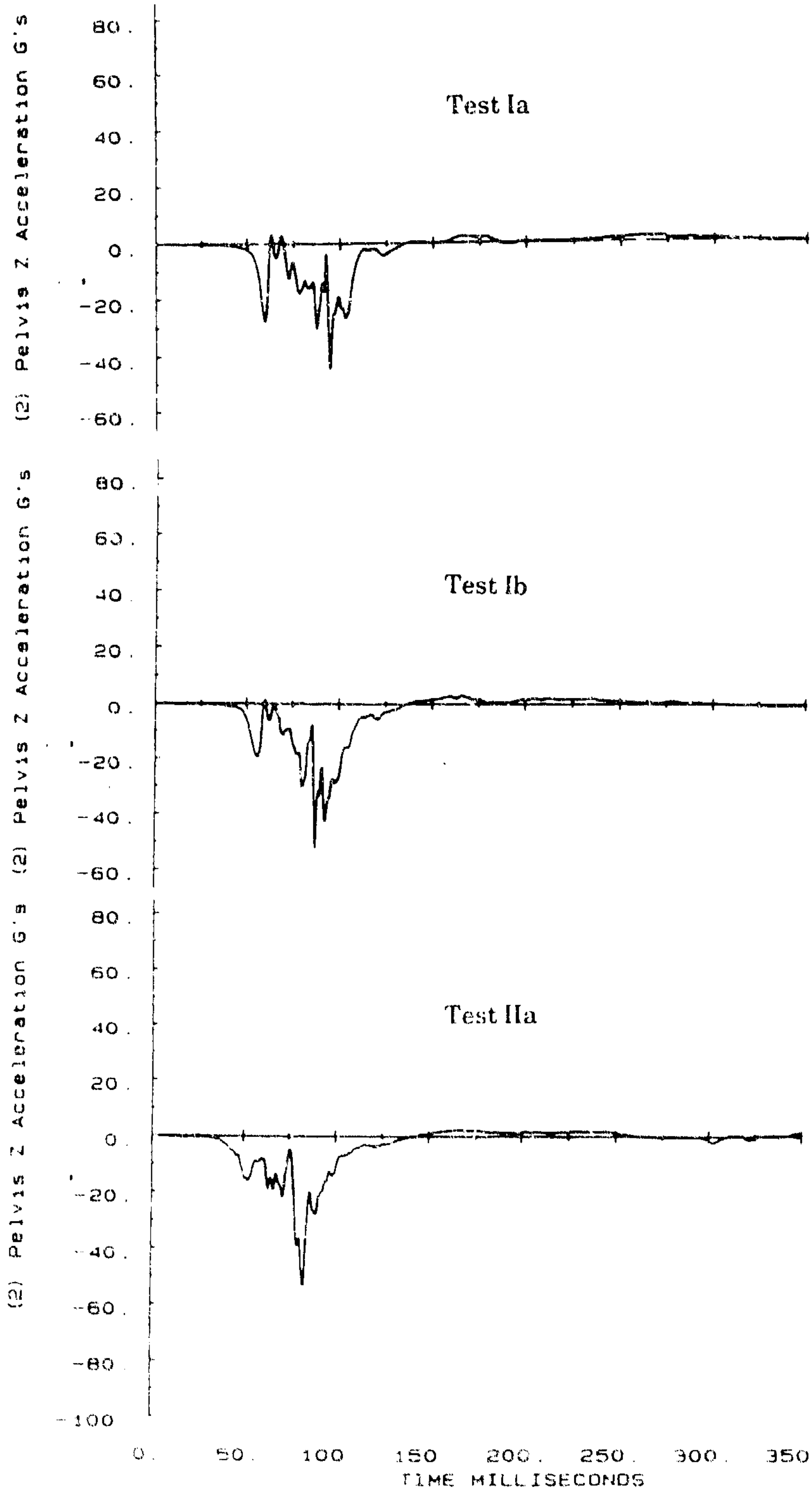
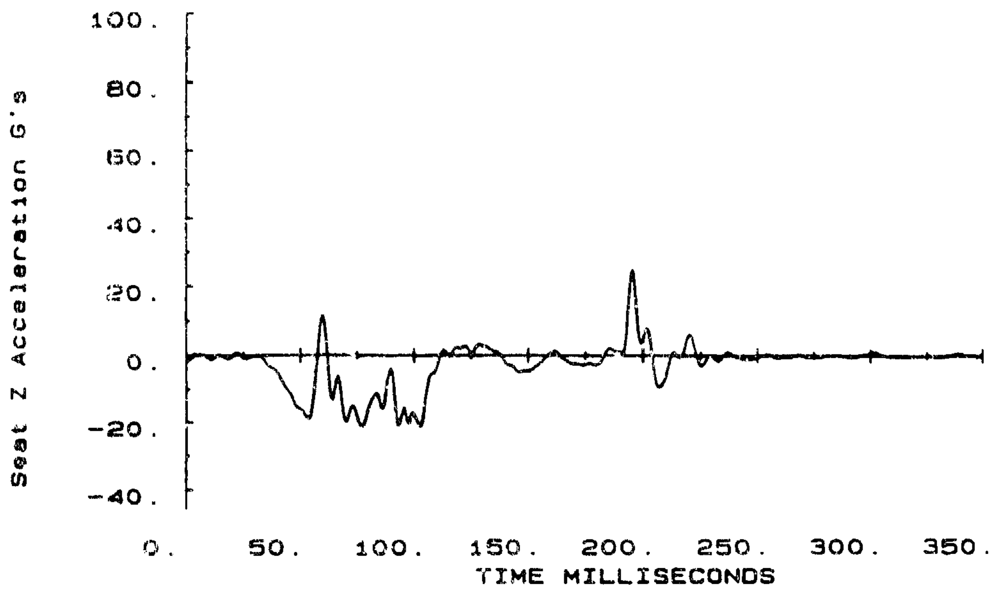
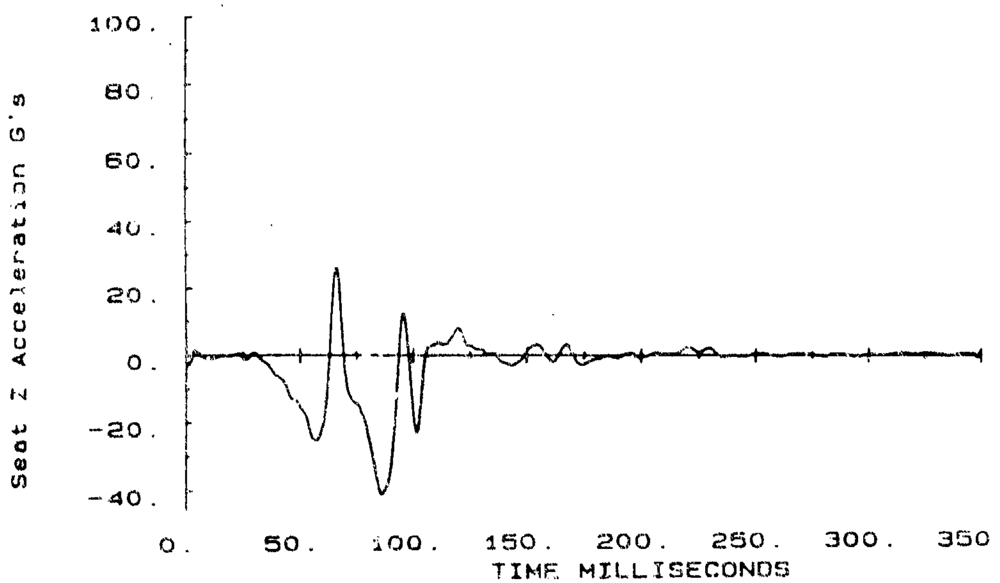


Figure 4-12. Pelvic acceleration - 95th percentile dummy.

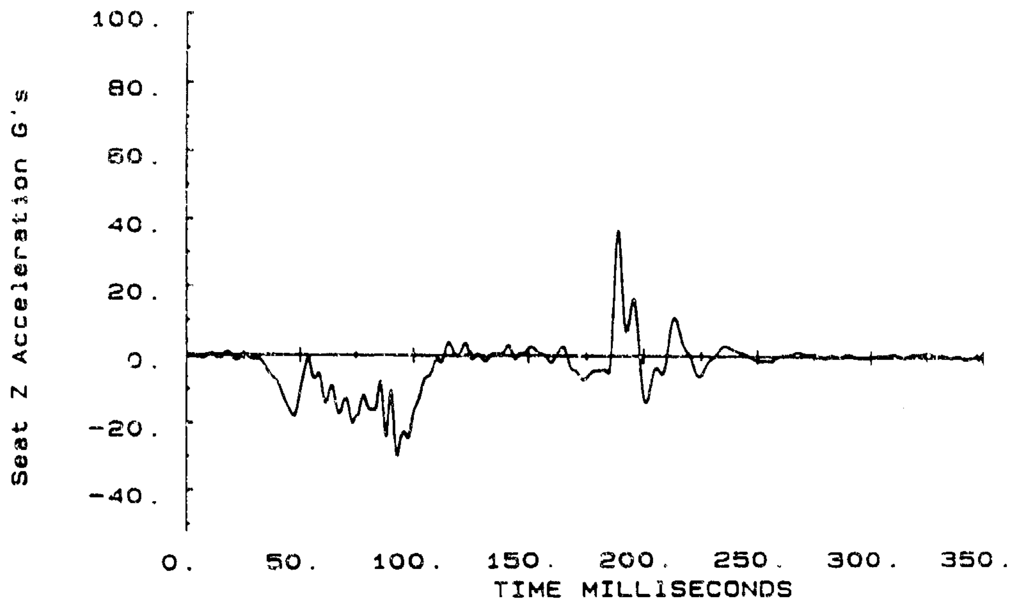


a) Pilot Seat Pan Acceleration.

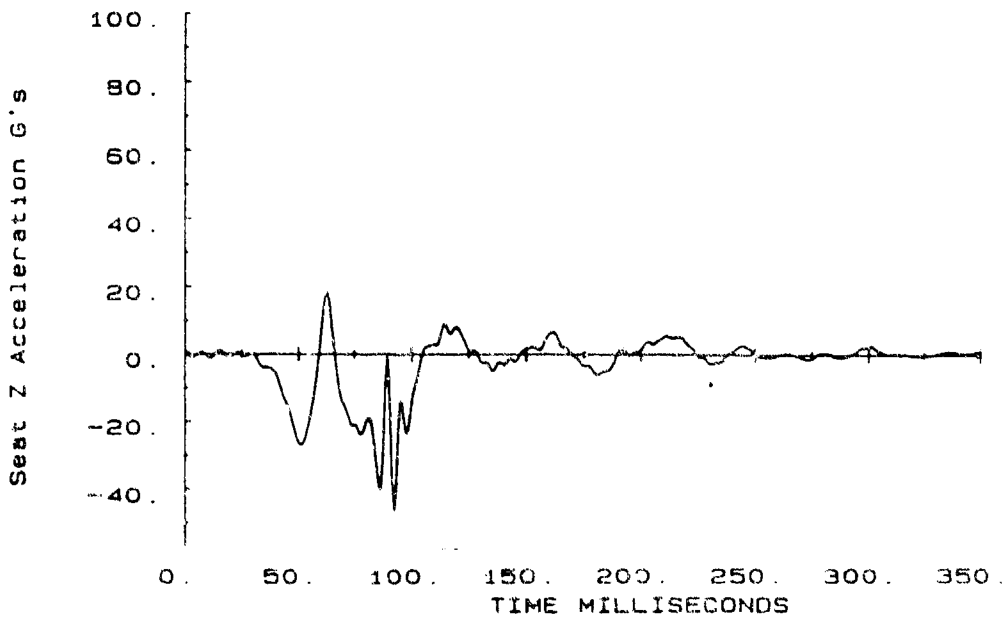


b) Copilot Seat Pan Acceleration.

Figure 4-13. Seat pan vertical accelerations - Test Ia.

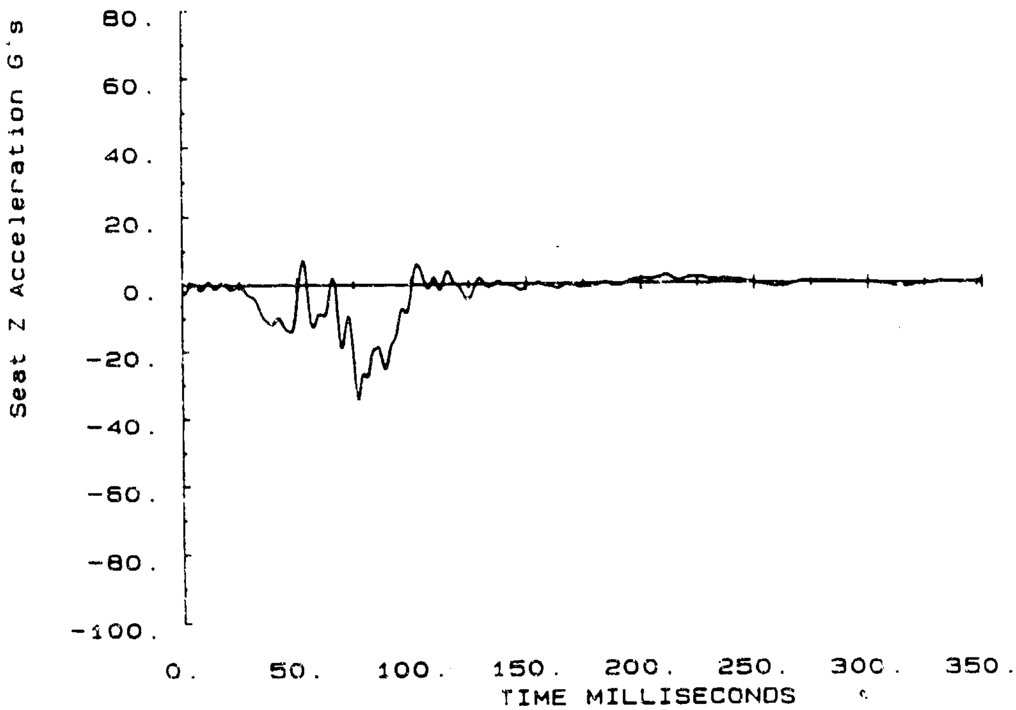


a) Pilot Seat Pan Acceleration.

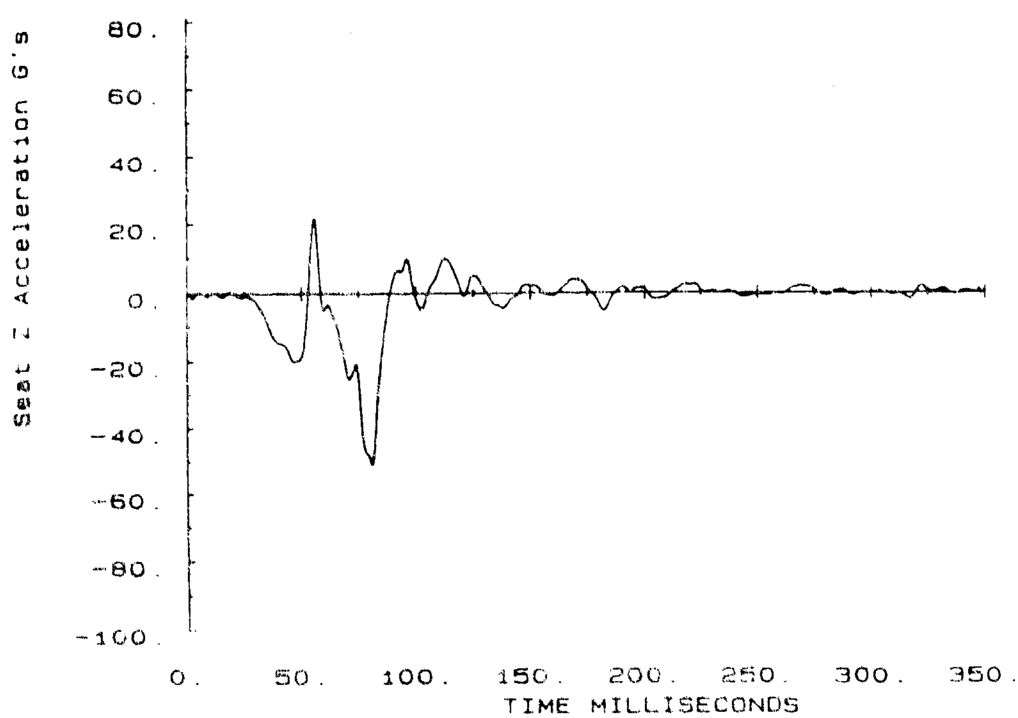


b) Copilot Seat Pan Acceleration.

Figure 4-14. Seat pan vertical accelerations - Test Ib.



a) Pilot Seat Pan Acceleration.



b) Copilot Seat Pan Acceleration.

Figure 4-15. Seat pan vertical accelerations - Test IIa.

unsuccessful, as injury is expected. An excursion of 6 msec or less is considered a successful test with minimal injury. Using this pass/fail criteria, only test Ia for the pilot was successful. This was the only test in which the control yoke was not contacted.

Later MIL-S-58095A, Reference 14, dated 31 January 1986, was revised and the pass/fail criteria was changed to a cumulative excursion time of 25 msec over 23 G vertical seat pan acceleration. Using this latest military pass/fail criteria, all Test Ia, Ib, and IIa for both 5th and 95th percentile dummies were successful.

The FAA has recently established another pass/fail criteria which will be used for civil aviation. This pass/fail criteria, Reference 15, requires an axial load cell at the top of the dummy pelvis to measure dummy lumbar loads. Only a 50th percentile dummy is used for this criteria. If the lumbar load is 1500 lbs (680 kg) or less, the test in considered successful with minimal injury. If the lumbar load is over 1500 lbs (680 kg), the test is considered unsuccessful, as significant spinal injuries are expected. Using this FAA pass/fail criteria, Tests Ia and IIa were successful.

In summary, the seat tests were considered successful when the control yoke was not contacted, as shown in Table 4-7.

TABLE 4-7. PASS/FAIL CRITERIA FOR DYNAMIC SEAT TESTING

Testing	Pass/Fail Criteria		
	MIL-S-58095	MIL-S-58095A	AC 21-22
Test Ia			
• 50th%	Pass	Pass	Pass
• 95th%	Fail	Pass	(Not Applicable)
Test Ib			
• 50th%	Fail	Pass	Fail
• 95th%	Fail	Pass	(Not Applicable)
Test IIa			
• 50th%	Fail	Pass	Pass
• 95th%	Fail	Pass	(Not Applicable)

5.0 DISCUSSION

5.1 DESIGN EYE LOCATION

The head location in the cockpit of a 50th percentile male aviator is called the design eye location. Once this spot is determined, the cockpit displays, controls, visibility, and seating use the design eye location as a starting point of reference. The design eye location for the OH-58A is aircraft station (STA) 64.50 and waterline (WL) 63.22. There is no vertical adjustment in OH-58 crew seats.

The Buttock Reference Point (BRP) is the lowest point of the crewman buttocks where the ischial tuberosities load the seat cushion when under normal 1G conditions. The BRP for the OH-58A is STA 67.22 and WL 33.75 so that a sitting height of (WL63.22-WL 33.75 = 29.47") is provided. This BRP location was approved by the U.S. Army in the initial OH-58A design and is in all OH-58s, but the current aviator 50th percentile sitting eye height is 32.05", a difference of 2.52". The BRP is shown in Figure 5-1 as "ORIGINAL DESIGN". This exact BRP location was used for the OH-58 energy attenuating crew seat design. Due to last minute addition of the SPACEFABRIC™ cushion cover combined with an error in cushion thickness, the BRP of the dynamic test seat was 0.82 in (2.1 cm) higher than the "ORIGINAL DESIGN" point. This resulted in a BRP at WL 34.57 as noted in Figure 5-1 as "TESTED A/C". During installation of the dummies for dynamic testing, it became apparent that the "ORIGINAL DESIGN" BRP should be lowered by several inches to account for the anthropometry of current aviators.

The flyable OH-58A used in this program was investigated for seat BRP location. The crew seats were actually measured with a 175 lb (79.4 kg) man and a 200 lb (90.7 kg) man as shown in Table 5-1. The average of this existing aircraft BRP is noted in Figure 5-1 as "IN SERVICE," but both men compressed the netting into the lower netting above the honeycomb panel. Assuming this is representative of the OH-58 fleet, then the BRP location of any new seat design should be lowered to match "inservice" seat height. The prototype energy attenuating seat cushion was measured the same way with the same two men. The resulting measurements are also shown in Table 5-1. It should be noted that this is a measurement of a new cushion with zero hours of use. It is expected to get some permanent deformation with use. The field evaluation of this prototype seat should provide this usage information.

The BRP of the flyable aircraft crew seat was lowered as far as possible without changing the pivot point location. The BRP of the flyable aircraft was about an inch (2.54 cm) lower than on the dynamic test seat. This is shown in Figure 5-1 as "FLIGHT A/C". This caused the thigh angle on the flyable aircraft and the "ORIGINAL DESIGN" OH-58 crew seats to be about 15 degrees. The latch hook

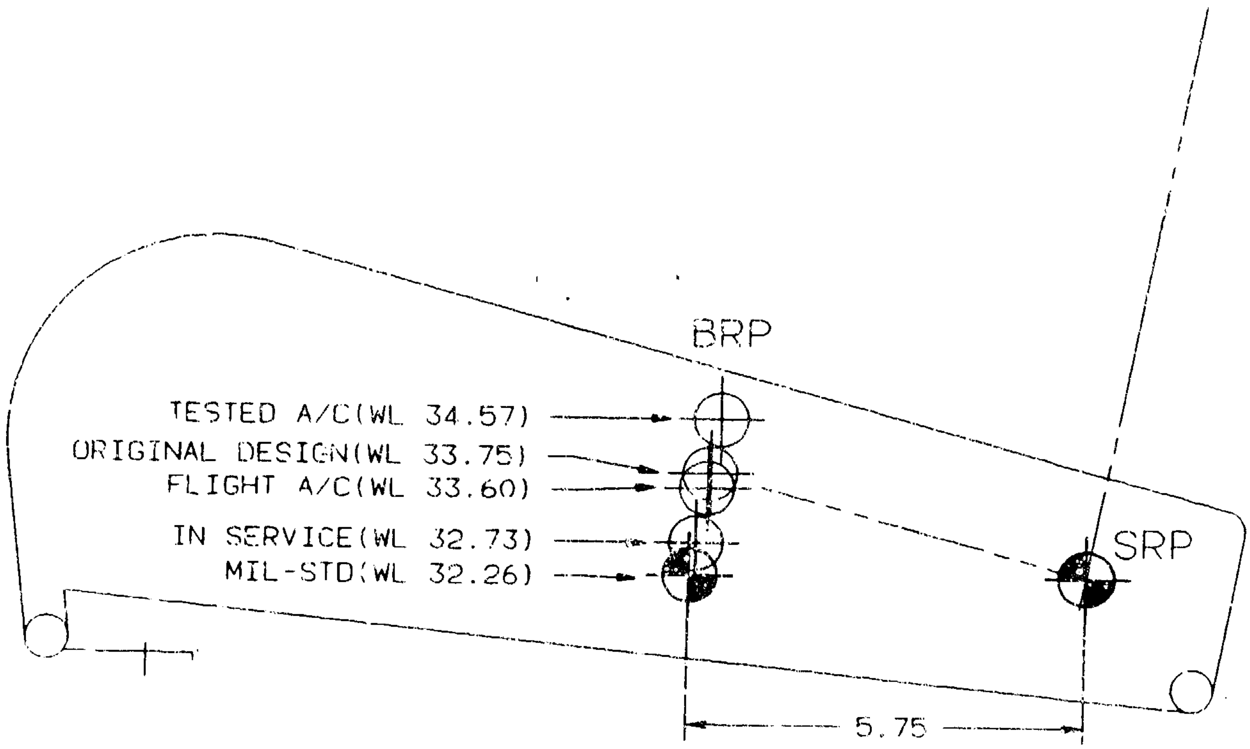


Figure 5-1. BRP locations.

TABLE 5-1. MEASURED SEAT CLEARANCES

Occupant Weight	Seat Clearance *		
	Original Design OH-58A Drawing	In Services A/C (Measured OH-58A)	Flight A/C (Energy Attenuating Seat)
175 lb (79.4 Kg)	2.77 (7.04)	1.75 (4.45)	1.47 (3.73)
220 lb (99.7 Kg)	2.99 (7.60)	1.97 (5.00)	1.63 (4.14)

*Inches (cm) of BRP above seat pan/structure, measured at ischial tuberosities pressure points.

arrangements for the dynamic tests and the flight aircraft is shown in Figure 3-7. Using the latest MIL-STD-1333, Reference 16, to identify the BRP resulted in an even lower BRP as noted in Figure 5-1 as "MIL-STD". Vertical seat adjustment would add the ability to compensate for these differences and the variations of humans. The Army operational suitability evaluation of paragraph 5.4 should provide a better definition of where the BRP should be located.

5.2 IMPACT PROTECTION CAPABILITIES

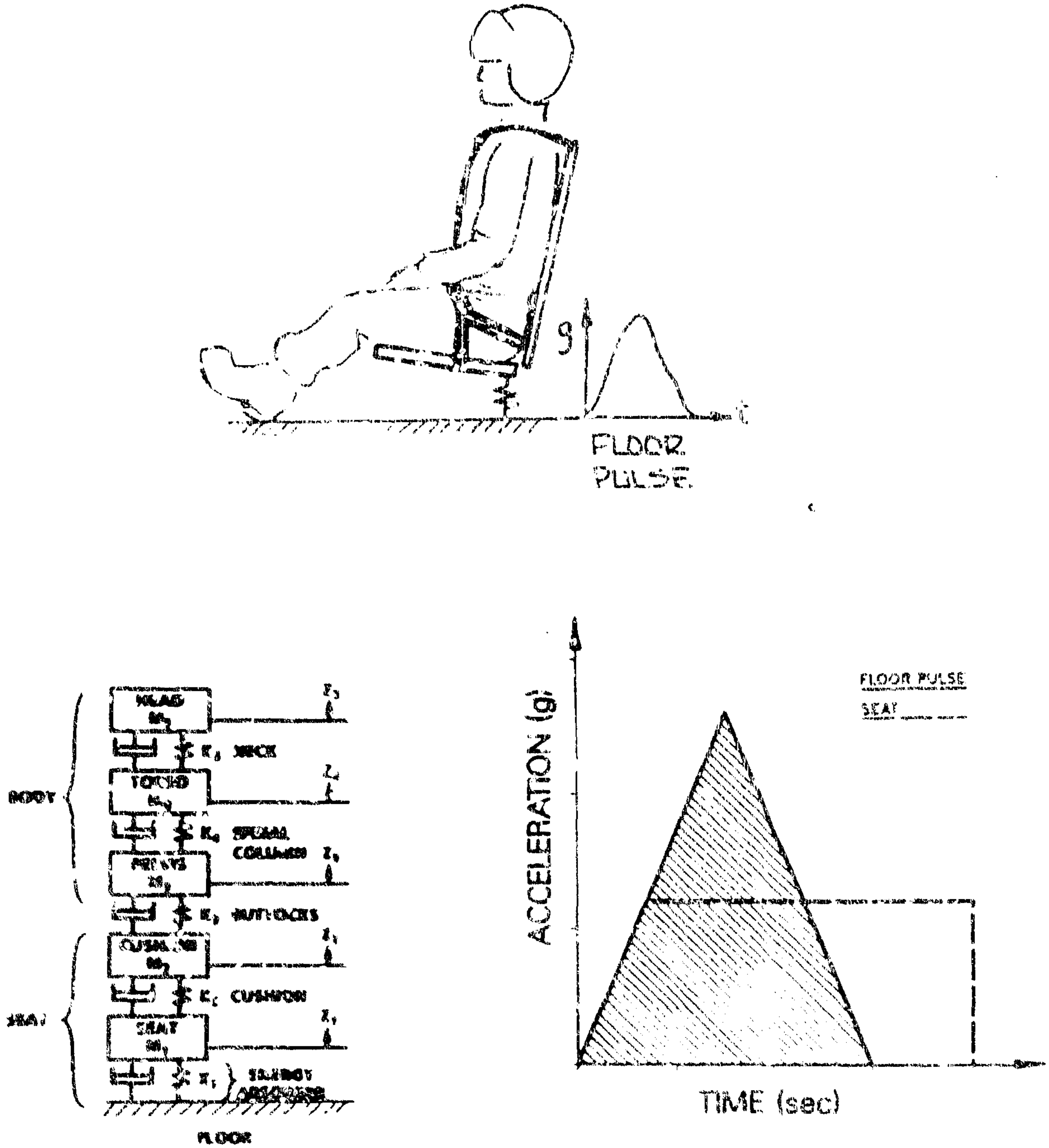
5.2.1 Computer Simulation

A computer simulation of Test Ia was performed using BHTI's 5-mass simulation model, Figure 5-2. The body spring, mass, and damper properties for a 50th percentile occupant (Reference 17) were used in the 5-mass model. The result of the simulation of Test Ia to predict seat stroke is shown in Table 5-2. Note the good agreement of the 50th percentile occupant stroke of 4.60 in (11.68 cm) by the 5-mass model versus the 4.75 in (12.07 cm) measured in the dynamic testing. Using the formula for seat stroke calculation in paragraph 4.7.2 of TR79-22D, Reference 18, and modifying the pulse shape to trapezoidal as occurred in the dynamic test, the seat stroke was calculated. The modified design guide predicted stroke was about 30 percent less than the dynamic test and the 5-mass model for the 50th percentile dummy as seen in Table 5-2. The 5-mass model predicted more stroke than the dynamic test of the 95th percentile dummy because the yoke was contacted, which prevented full seat stroke in the test.

5.2.2 Vertical Velocity Capabilities

The collective stick position at the time of impact is expected to be full up in most crashes where an energy attenuating seat can provide an improvement. The vertical component of the seat stroking distance to the control yoke (lowest position) when the collective stick is full up, was calculated. These strokes are shown in Table 5-3. The pilot seat outboard rear corner of the dynamically tested aircraft and the flight aircraft will contact the curvature of the fuselage prior to floor contact. This would be well after yoke contact. This interference can be eliminated in a production design by shaping of that seat pan corner. A potential production BRP at WL 33.09 was introduced lower than the flight aircraft seat to better approximate the potential capability of a production seat. The pivot point was moved down accordingly. Full floor stroking is shown to provide comparison data of the maximum system capability using a thin-wall frangible yoke or removing the yoke. The resulting seat stroke for potential production seat is also shown in Table 5-3.

The tested OH-58 energy attenuating crew seat can provide improved impact protection capability over the existing OH-58 seats by limiting the vertical crash



5 – MASS MODEL

DESIGN GUIDE ANALYSIS

Figure 5-2. Energy attenuating seat analyses.

TABLE 5-2. SEAT STROKE COMPARISON

E.A. STROKE IN INCHES (CM)

PERCENTILE	DYNAMIC TEST IA	5 - MASS MODEL	MODIFIED DESIGN GUIDE
5%	--	2.85 (20.63)	2.30 (5.84)
50%	4.75 (12.06)	4.60 (11.68)	3.23 (8.20)
95%	5.60* (14.22)	6.70 (17.02)	5.07 (12.88)

* Yoke contacted

TABLE 5-3. SEAT STROKE AVAILABLE
BRP Vertical Stroke in Inches (cm)

SEAT	TO YOKE CONTACT (Full Up Collective)	TO FLOOR CONTACT (No Yoke Interference)
Tested Aircraft*		
Pilot	5.14 (13.06)	7.63 (19.38)
Copilot	5.41 (13.74)	8.38 (21.29)
Flight Aircraft*		
Pilot	4.0 (10.16)	6.46 (16.41)
Copilot	4.3 (10.92)	7.19 (18.26)
Potential Production Aircraft**		
Pilot	3.99 (10.13)	6.27 (15.93)
Copilot	4.16 (10.57)	6.90 (17.53)

* Outboard seat pan corner digs into fuselage curvature prior to floor contact.
** BRP is 0.5 in (1.3 cm) lower than flight aircraft at WL 33.09.

loads experienced by the crewman. The design stroking load based on a 170 lb (77.1 kg) crewman is 12 +/- 1 G. Spinal injury tolerance appears to decrease as age increases as indicated in Figure 5-3, from Reference 19. This stroking load can accept the reality of the lower spinal tolerance for an older occupant population than at 14.5 +/- 1 G stroking load required by MIL-S-58095, Reference 14. The vertical impact velocity protection level desired is 30 ft/sec (9.1 m/s) as shown in Figure 5-4 for the 95th percentile survivable OH-58 accident, using data from Reference 12. Thus there is no need to use 14.5 +/- 1 G stroking load, if 12 +/- 1 G can be used to meet the 95th percentile survivable accident vertical velocity change.

Using a correction factor of 30 percent with the modified design guide formula as discussed in paragraph 5.2.1, the vertical impact velocity change was calculated for the 5th, 50th, and 95th percentile male aviator. The resulting vertical velocity equivalents are shown in Figure 5-5 and Table 5-4. Figure 5-5 shows the importance of achieving as much seat stroke as possible. This is most significant for the 95th percentile occupant as he requires more stroking distance than lighter occupants for the same impact velocity.

Using the specific seat strokes available of Table 5-3, a range of projected vertical velocity change capabilities were developed. Variations in occupant weight and seat position were included. A potential production aircraft seat design was used to determine the projected capabilities of a modification kit. The projected 50th percentile aviator vertical velocity change capability without yoke contact is 26.5 ft/sec (8.1 m/s) or the 93.5th percentile survivable OH-58 accident as shown in Figure 5-4. Projected vertical impact velocity changes, with no yoke contact, range from 22.9 ft/sec (7.0 m/s) for a 95th percentile to 29.2 ft/sec (8.9 m/s) for a 5th percentile occupant. This equates to the 92nd and 94.5th percentile survivable OH-58 accident conditions shown in Figure 5-4. Thus the energy attenuating OH-58 seat concept should provide vertical energy attenuation capability for over 90 percent of survivable and partially survivable OH-58 accidents.

5.3 ENHANCEMENTS

There are several related areas where crash survival can be further improved beyond the energy attenuating crew seat. As such, they could be incorporated with the energy attenuating seat or applied independently.

5.3.1 Frangible Control Yoke

The energy attenuating crew seat design allows stroking capability until floor contact occurs. As seen from the dynamic tests, the seat stroking was stopped upon control yoke contact. To achieve the full potential energy attenuation capability of stroking to the floor, a frangible control yoke is needed. Such a yoke should have the

EFFECT OF AGE ON SPINAL INJURY TOLERANCE TO VERTICAL ACCELERATION

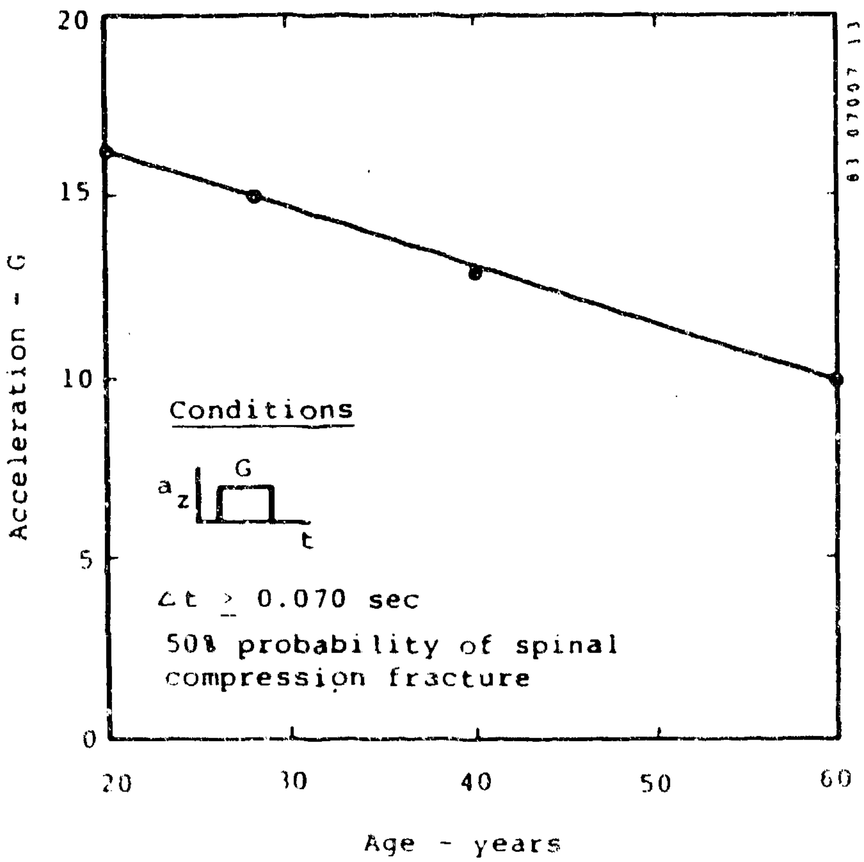


Figure 5-3. Age effects on spinal strength.

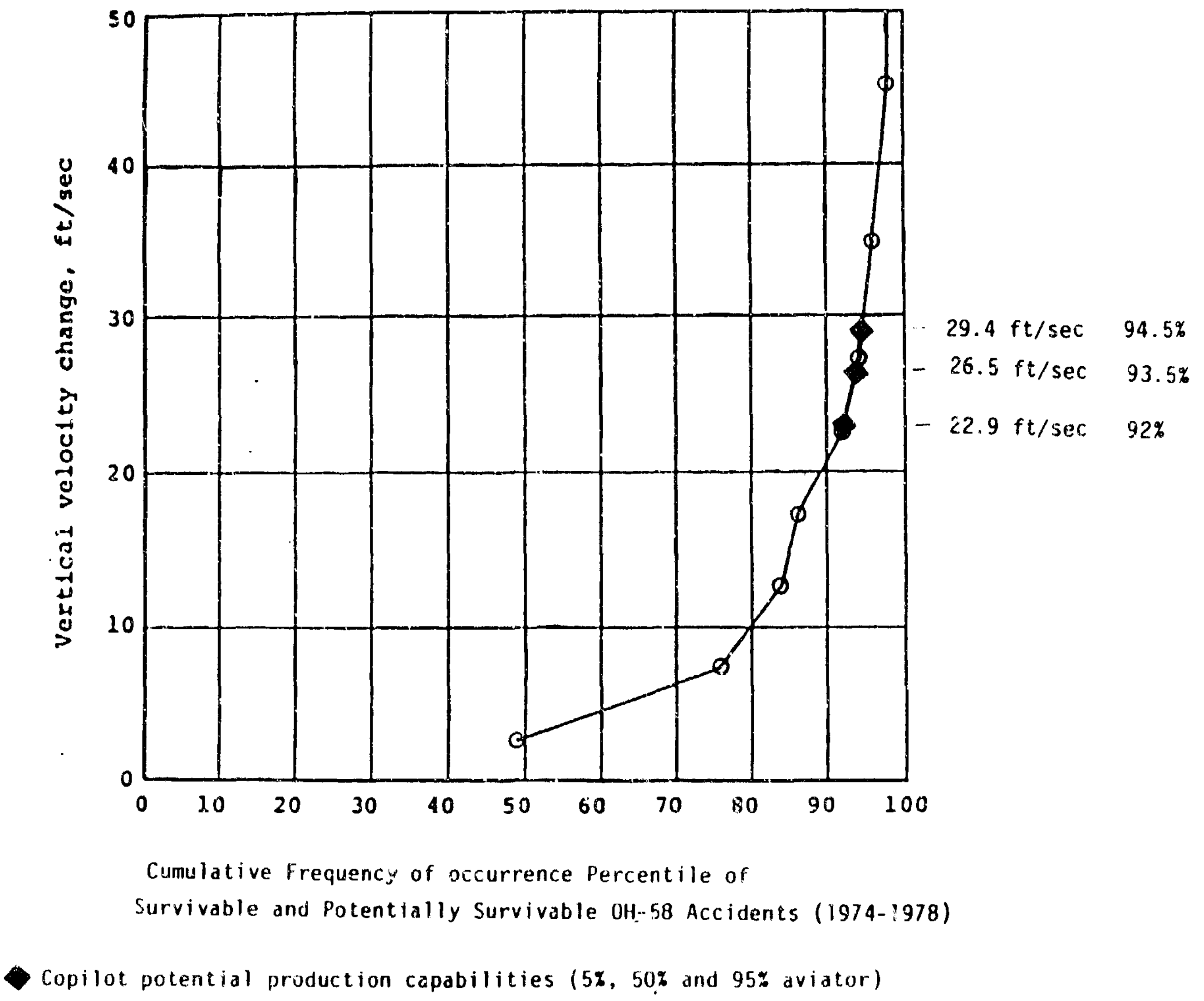


Figure 5-4. Vertical velocity changes in survivable OH-58 accidents.

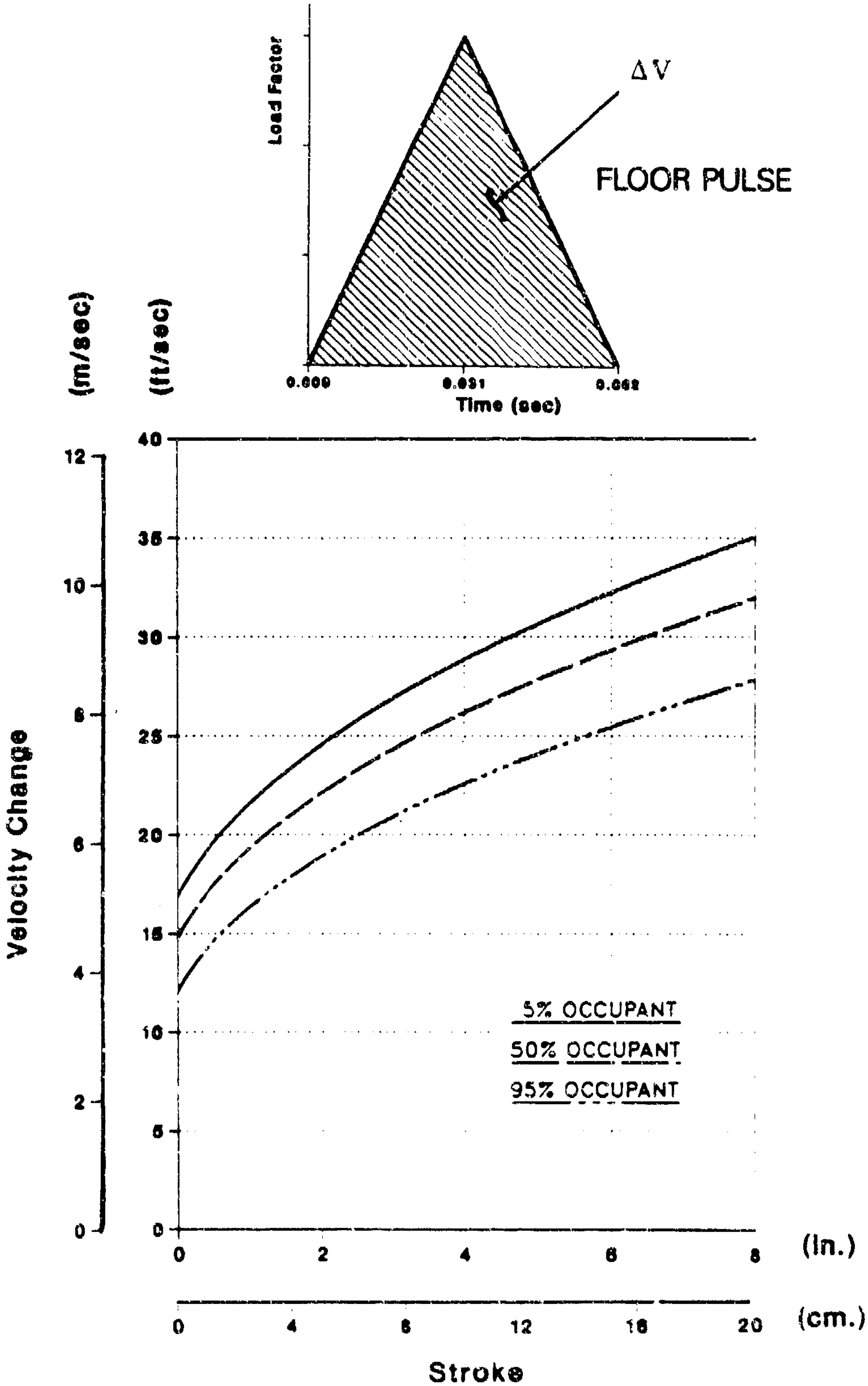


Figure 5-5. OH-58 seat vertical velocity capabilities.

TABLE 5-4. PROJECTED VERTICAL VELOCITY CHANGE ft/sec(m/s)

SEAT	TO YOKE** OCCUPANT 5%	50%	95%	TO FLOOR OCCUPANT 5%	50%	95%
Tested Aircraft						
Pilot	30.9 (9.4)	28.1 (8.6)	24.3 (7.4)	34.6 (10.5	31.5 (9.6)	27.4 (8.4)
Copilot	31.3 (9.5)	28.5 (8.7)	24.7 (7.5)	35.6 (10.9)	32.5 (9.9)	28.3 (8.6)
Flight Aircraft						
Pilot	28.9 (8.8)	26.2 (8.0)	22.6 (6.9)	32.9 (10.0)	30.0 (9.1)	26.0 (7.9)
Copilot	29.4 (9.0)	26.7 (8.1)	23.1 (7.0)	34.0 (10.4)	31.0 (9.4)	28.9 (8.8)
Potential Production Aircraft*						
Pilot	28.9 (8.8)	26.2 (8.0)	22.6 (6.9)	32.6 (9.9)	29.7 (9.1)	25.8 (7.9)
Copilot	29.2 (8.9)	26.5 (8.1	22.9 (7.0)	33.6 (10.2)	30.6 (9.3)	26.6 (8.1)

* BRP is 0.5 in (1.3 cm) lower than flight aircraft.
** Full Up collective stick position

necessary strength to carry pilot-induced flight control loads but in a crash could be penetrated vertically by the stroking seat. This penetration should require low forces to prevent significant loads being transmitted to the stroking seat. The new yoke would also need to meet the existing ballistic strike requirements. A thin wall, large cross-section yoke should be considered for a frangible yoke. The expansion of energy attenuation capabilities is shown in Table 5-4 when the seat is allowed to stroke to the floor.

A shorter copilot seat could be used in place of the pilot seat to provide commonality and greater stroking distance. This would slightly reduce the amount of ballistic coverage. The vertical velocity change capabilities for the copilot potential production seat by stroking to the floor for the 95th, 50th, and 5th percentile occupant is 26.6 ft/sec (8.1 m/s), 30.6 ft/sec (9.3 m/s), and 33.6 ft/sec (10.2 m/s), respectively. From Figure 5-4, these velocities are equivalent to 93.5th, 95.5th and 96.5th percentile survivable and partially survivable OH-58 accidents. The amount of increased energy attenuation capability of a frangible yoke over the yoke contact (full-up collective stick) capability is significant. If the collective stick is not in a full-up position, the energy attenuating seat capability is reduced unless a frangible yoke is installed. The vertical position of the cyclic control yoke at seat contact determines the stroke available. Less stroke available means less vertical velocity change capability. Another important aspect of a frangible yoke is less distortion and disruption of the seat and structure during stroking. A new yoke should be developed for this last aspect even if additional velocity capability is not desired.

Resistive forces to cut into a frangible yoke are not known but could be minimal using a thin-wall yoke and a sharp knife edge penetrator on the aft end of the seat pan. If the resistive forces were found to be significant, the energy attenuator stroking load could be reduced accordingly for the remainder of the stroke after the point of expected contact. Crushing of a thin-wall frangible yoke at floor contact should not reduce the stroking distance more than twice the wall thickness. All velocity estimates assumed no crushed frangible remains would reduce the stroke. Thus, this stroking capability is considered "to-the-floor" as if the control yoke is rerouted or eliminated. Therefore, this frangible yoke concept indicated the maximum potential capability of the pivoting seat to stroke to the floor.

5.3.2 Restraint System

The present OH-58 restraint system has not changed significantly since the initial aircraft and MWO 55-1520-228-19, Reference 5. The inverted "V" lapbelt is bulky and is 3.0"(7.9 cm) wide which could be replaced with the new technology 1.5 inch (3.8 cm) to 2.25 inch (5.7 cm) wide webbing with lightweight fittings and buckle. This should reduce weight and provide a more comfortable fit. With a new restraint system, a narrower shoulder harness guide should be investigated.

5.3.3 Vertical Seat Adjustment

The present OH-58 crew seat height is not adjustable and the energy attenuating seat design did not add any adjustment capabilities. It appears that a small amount of vertical seat adjustment can be included into the pivoting energy attenuating seat design. An adjuster assembly could be inserted between the wire/roller energy attenuator and the aft end of the seat pan. The seat pan could then pivot up or down about the hinge, thus raising or lowering the BRP. The amount of adjustment range would be less than for normally adjusted seats as the thigh angle on a pivoting seat is changed by any vertical adjustment. This added feature could improve the comfort during Stinger sight use. Vertical seat adjustment could mitigate the necessity of an exact BPR location.

5.4 FIELD EVALUATION

5.4.1 Operational Suitability Evaluation

A second set of energy attenuating crew seats was installed in OH-58A 71-20778. The Army will conduct an operational suitability evaluation of this modification. USAARL test plan is being written and the evaluation is to be conducted by the U. S. Army Aircraft Development Test Activity. Planned items to be evaluated include:

- Comfort
- Adjustable lumbar support
- Pilot size variations
- Seat height
- Pilot acceptance
- Effect on mission.

The results from all of the above areas are expected to be positive with the possible exception of seat height. The flyable aircraft BRP is lower than the standard OH-58 seat design but higher than the existing seats that are allowed to sag. The BRP on the flight test aircraft was lowered as far as possible from the dynamic test aircraft position without changing the pivot point location. The thigh angle increased but remained within MIL-STD-1333 limits. Thigh angle comfort will be part of the operational suitability evaluation. The BRP of the test aircraft seat is expected to become lower with cushion use to a permanent set position. The Army plans to measure this change. Once the Army determines the desired BRP location, the production modification kit design should use that location.

5.4.2 Flight Aircraft Differences

Design changes to the flight aircraft from the dynamic test aircraft in addition to lowering the BRP were:

- Increased strut attachment insert contact area
- Installed back armor
- Added fabric closures to prevent debris under seats
- Reduced seat pan width on inboard side by 1/4 inch (0.64 cm).

This last change to a narrower seat pan structure was to provide an additional 1/4 inch (0.64 cm) of seat pan to fuselage center console clearance during stroking. The dynamic test seats had 1/16 inch (0.16 cm) clearance with a small deflector guide mounted on the console to ensure the seat pan went down beside the center console. This small clearance was acceptable for a feasibility study dynamic test but a seat for field use needs more clearance. The deflector guides were deleted on the flight test aircraft. This reduction of seat pan width did not change the seat cushion width or location.

5.5 WEIGHT

5.5.1 Aircraft Modification Weight

The primary objective of a feasibility study is to prove the "feasibility" of some concept, not to develop an optimized, lightweight production design. Thus these feasibility designs tend to be very conservative in strength and provide liberal use of standard size materials. Likewise, the feasibility modification was designed to survive several severe crash tests and must therefore be stronger than a "one-shot" production modification kit.

The weight increase of the feasibility modification to the flight aircraft is estimated to be 43.5 lb (19.7 kg) with no ballast changes needed.

5.5.2 Potential Weight Savings

Those major areas of the modification design where a weight reduction is expected by using a production design rather than a feasibility design approach have been identified. These areas and their respective potential weight savings (i.e. the energy attenuating modified design less the original component weight) disregarding ballast are shown in Table 5-5 and discussed below.

Item 1 of Table 5-5 shows an 8.4 lb (3.8 kg) increase by making a special steel fitting to surround and conform to the shape of the armor panel. This approach was originally intended to use the strength of the armor plate but the actual design resulted in all loads being handled in the surrounding fittings and metal plates. However, this approach did minimize the thickness of structure and armor between the seat and floor. For a production design, a more weight efficient approach is to go back to a honeycomb panel for the seat pan and rigidly attach the armor plate. This would require deletion of the rivnuts presently used on the OH-58 to allow the armor panel to breakaway in a crash from MWO 55-1520-228-30-16, Reference 6.

Item 2 is related to the copilot lower seat armor panel being made from a pilot armor panel by sawing off an end. The modified copilot armor panel installed in the flyable test aircraft has more area of ballistic protection than the existing copilot armor and

TABLE 5-5. POTENTIAL WEIGHT SAVINGS AREAS FOR PRODUCTION SYSTEM

Item	DESIGN AREA - POTENTIAL WEIGHT SAVINGS ACTION	SAVINGS/AIRCRAFT LBS	(kg)
1.	Armor Panel Support Structure - Go Back to Honeycomb Panel	8.4	(3.8)
2.	Armor Panel - Go Back to Original Coverage	1.3	(0.6)
3.	Seat Pan Hinge of Steel Plates & Pin - Go to Sheet Metal Hinge	3.1	(1.4)
4	Seat Cushions with Improved Comfort & Adjustable Lumbar Support - Go Back to Original OH-58 Tube/Netting Seats	7.0	(3.2)
5.	Seat Back Bulkhead Web - Go Back to Existing 0.020in (0.09 cm) thickness with Lightening Holes	1.9	(0.9)
6.	Knee Bulkhead Structure - Redesign without Bolted on Plate	1.4	(0.6)
7.	Restraint System - Use Lightweight Restraint System	4.0	(1.8)
	TOTAL	27.1	(12.3)

is 1.3 lb (0.6 kg) heavier. A production design considering Item 1 above could go back to the original copilot armor and save that weight increase.

Item 3 is due to the use of a large steel hinge used at the pivot point. A production design should consider a material change as well as a one-time-use hinge. If a vertical seat adjustment is desired, then a repeated-use hinge must be used but a material change would still be possible. A vertical seat adjusment feature is not in the feasibility modification so its addition during a production modification kit design would cause a weight increase over what is discussed in this report.

Item 4 is due to a considerable effort to increase the seat cushion comfort. An adjustable lumbar support was added whereas the existing OH-58 has a fixed lumbar support. The lower cushion uses PREQUAL™, Reference 11, which is a series of plastic levers used to provide uniform buttocks flotation. A new air breathable cover of SPACEFABRIC™ (a "cool cushion" material) was used. The lower seat pan thigh angle wedge was filled with rigid foam which would not be needed in a production design. If no improvement in comfort is allowed, the existing OH-58 tube/netting seats could be used with the pivoting seat pan energy attenuating seat concept.

Item 5 is related to the expedient use of 0.040 inch (0.1 cm) thick seat back bulkhead web without any lightening holes. A production design could use the same size as the existing 0.020 inch (0.05 cm) thick web with lightening holes. The conservative thick plate approach of the feasibility study was to simplify the installation and specifically to allow the designer to change different fitting locations quickly during testing. By having a continuous flat plate available (i.e., no holes in the wrong places), last minute design changes to move items like seat belt attachment, energy attenuators and latch attachments are possible. Thus prototype modifications are usually heavier than are necessary in a production design. Once the final location of fittings are determined for a production design, a lightweight production seat back bulkhead web with lightening holes can be designed.

Item 6 is related to the strengthening of the knee bulkhead. The very conservative approach used on the feasibility aircraft was to bolt on a 1/4 inch (0.64 cm) thick aluminum plate onto the back of the existing knee bulkhead using 16 steel nuts/bolts. This expedient modification was done on both seat knee bulkheads. A production modification kit should include a different honeycomb knee bulkhead that is lighweight but could carry the loads required.

Item 7 is the potential weight savings of a new restraint system. The large 3 inch (7.6 cm) lap belt and fittings are very heavy (5.0 lb [2.3 kg] each without inerta reel). A 2.0 inch (5.1 cm) wide webbing with lightweight fittings and buckle should be considered. USAARL is planning to install a prototype 5-point restraint system in the OH-58A left seat with a weight savings of 2.08 lb (0.9 kg) per restraint to be evaluated during the operational suitability test.

Another weight savings of the knee bulkhead was not included in Table 5-5. This weight savings would be due to the lowering of the pivot point height when the final BRP location is determined. This change will be integrated into the the new knee bulkhead design which would save weight. Less material would be needed for strength to react crash loads as the pivot point is lowered. The amount of weight savings potential is unknown at this time.

In summary, there appears to be about 27.1 lbs (12.3 kg) of weight from potential weight reduction areas shown in Table 5-5. This indicates that an austere production energy attenuating crew seat modification (e.g., no comfort change) should increase the OH-58 empty weight by about 16.4 lb (7.4 kg). If the added feature of vertical seat adjustment is desired, additional weight increase will occur.

5.6 POTENTIAL PRODUCTION DESIGN

A feasibility study is an effort to see if a concept can physically function with little attention given to weight efficiency or production application. This feasibility program proved that the pivoting seat pan concept can provide effective energy attenuation and also identified areas needing refinement for a production seat. These design refinement areas are in Table 5-6 and discussed below.

TABLE 5-6. DESIGN REFINEMENT AREAS

Item	Subject
1.	Different armor panel shapes
2.	Pilot aft right seat corner hits sidewall
3.	Knee bulkhead and supports
4.	Cushion thickness relative to BRP
5.	Fore & aft magnetic brake location
6.	Seat Pan latch lever interference during stroking
7.	Rebound latch effectiveness
8.	Weight
9.	Back and side armor
10.	H-58 configuration differences.

Item 1. Different armor panel lengths between the pilot and the copilot seats were used. The present pilot seat armor was used. The copilot seat was a wider and longer pilot armor panel that was shortened by sawing to clear the collective jackshaft. This resulted in 20 sq inch (135 sq cm) more area of ballistic protection and 1.3 lb (0.6 kg) more weight than present copilot armor. This was done to have as much commonality of the armor attachment frames as possible. A better solution for production is to reduce the armor length of the pilot seat to be identical to the tested copilot seat. This would result in an increase in copilot ballistic protection, a reduction in pilot ballistic protection, an increase in pilot seat stroke, and would reduce cost by having common armored seat pans and energy attenuators.

Item 2. The pilot seat aft right corner contacts the fuselage curvature prior to floor contact. This is only applicable to the pilot seat. This early contact can be minimized or eliminated by armor pan shaping of the right aft corner during detail design or implementation of Item 1.

Item 3. The knee bulkhead and its supports are not designed for light weight. A 1/4 in (0.64 cm) aluminum plate was attached by 16 bolts to the knee bulkhead on each side with a brace strut on each upper corner for the feasibility study. A production design would replace the present knee bulkheads with improved lighter bulkheads and struts.

Item 4. The BRP location is expected to become somewhat lower with prototype cushion use. A production seat should be designed for the lower BRP location of a used cushion. This information should be generated by the field evaluation of OH-58A 71-20778.

Item 5. To achieve the full stroke to the floor on the pilots side, it will be necessary to move the cyclic fore & aft magnetic brake as far aft as possible. This refinement is needed in conjunction with shortening the pilot seat pan (Item 1).

Item 6. The latch interferes with the control yoke during stroking. Prior to stroking, the seat pan latch function is to prevent seat looseness during flight that might cause occupant concern as well as react upward loads. Once the vertical stroking in a crash starts, the latch disengages and can pivot out of the way if an obstruction is contacted. On Test IIa, the pilot inboard latch had rotated 90 degrees and struck the aft outboard edge of the control yoke. This caused yoke gouging and imparted a counterclockwise racking load in the pilots seat pan which subsequently led to knee bulkhead strut attachment failure. On a production design, the latch motion should be better controlled.

Item 7. Increased rebound control is desired. After a seat has stroked down, there is always some rebounding upward. A design should prevent excessive rebounding that would allow the occupant to become loose in his restraint. Rebounding beyond the original seat position should be prevented. During stroking, a springloaded latch, similar to a shoulder harness adjuster, slides down a structure mounted strap. As the seat vertical stroking has stopped, the elastic energies cause the occupant, cushion, seat, and structure to spring back or rebound. The rebound latch with a springloaded cam will wedge into the strap webbing and thus stop further upward seat pan motion. This function worked very well on the pilot's seat in Test Ia where no control yoke contact was made. In all other tests of the pilot seat and all copilot seat tests, the seats contacted the control yoke which acted as a spring. This caused considerable rebound forces. It appears that the rebound latch cam was not able to engage the strap webbing quickly enough before several inches of rebound occurred. During all dynamic testing, the amount of rebounding was not considered detrimental and would have been acceptable in an actual crash. The whole intent of dynamic testing is to ferret out undesirable conditions such as this. There is no need to change the rebound assembly for any crash requiring a seat stroke that stops prior to control yoke contact. For those impacts more severe than this, an increase in rebound latch effectiveness is needed for a production modification kit.

Item 8. The weight of this feasibility modification is considerably heavier than a production design. The purpose of a feasibility study is to prove feasibility in the most expedient manner, not optimize weight. A major part of a production design would be to optimize the weight of a modification kit. Major areas where weight reduction could be expected were discussed in paragraph 5.5.2.

Item 9. The back and side armor plates were not considered in this feasibility study and thus would need to be in a production design. The latch receptacle for the side armor will need to be located to use the existing side armor panel. Near the end of the program, the Army directed that the back armor be installed, as this would be needed for the field evaluation. Due to the stiffener channel added to the back side of the seat back bulkhead, the back armor panel was mounted farther aft. This required increasing the length of structural standoff supports to mount the back armor panels. The prototype structural channel interferes with the back armor panel and will need correction for a production design. The back armor panels on the flight test aircraft were notched to eliminate channel interference. A production design should mount the back armor panel as close as possible to the seat occupant for both structural and ballistic protection efficiency.

Item 10. There are some design differences between the OH-58A, OH-58C, and the OH-58D. This feasibility study did not attempt to define these differences. Thus locations of unique equipment will need to be checked to ensure no degrading interference with the energy attenuating seat design.

6.0 CONCLUSIONS

As a result of this study, it is concluded with regard to the OH-58 seat feasibility objectives that:

1. An energy attenuating crew seat is technically feasible for the OH-58 helicopter.

2. As the collective stick is expected to be in a full-up position during termination of a controlled emergency landing, the pivoting seat pan concept provides significant stroking distance without cyclic control yoke contact. The vertical velocity change equivalent capability for the 50th percentile occupant is the 93.5th percentile survivable and partially survivable OH-58 accident.

3. Seat contact on the cyclic control yoke beneath the crew seats sets the usable limits of pivoting seat pan capabilities. The yoke prevented the potential of maximum seat stroke to the floor. Yoke contact during stroking also increases the amount of seat rebounding and the seat structural distortion.

With regard to the pivoting seat pan concept, it is concluded that:

1. The basic pivoting seat pan concept could conceivably provide similar solutions for other aircraft; in particular, existing aircraft without acceptable seat stroking clearance.

2. Seat obstructions that cannot be moved, may be designed to be frangible upon seat contact during a crash.

7.0 RECOMMENDATIONS

The following recommendations are made to increase the OH-58 crewmen crash survivability.

1. Develop a lightweight modification kit to add energy attenuating crew seats to the OH-58A/C/D fleet using the basic concept described in this report.

2. Develop a cyclic control yoke that will carry flight loads during normal use and meet the ballistic tolerance requirements. The new yoke should be frangible such that a stroking seat could penetrate the yoke with very little additional crash loading being applied to the seat pan.

3. Energy attenuating crew seats should be developed with enough capability to stroke to the floor even though the cyclic control yoke would prevent full stroking. This would preclude a redesign of the energy attenuating seats at a later date when a frangible control yoke becomes available. The fore and aft magnetic brake should be moved aft as far as possible.

4. Use a common seat pan/armor for both pilot and copilot energy attenuating seats. The shorter length copilot seat should be used as it provides more stroking distance than the pilot seat. This could also provide commonality and reduce modification kit cost.

5. Develop a vertical seat adjustment device between the energy attenuator and the seat pan. This would allow a wider range of pilots to fit comfortably in the OH-58.

6. Redesign the restraint system to be lightweight. The inverted "V" lapbelt arrangement should be retained but made of minimum-width, low elongation webbing. The width of the shoulder harness guide should be reduced to match the new restraint system.

7. Investigate the armor ballistic protection coverage to provide optimum coverage with the minimum armor plate area. This approach was successful on the AH-1S Survivability And Vulnerability Improvement Modification (SAVIM) program, Reference 10, using shotline analysis. This recommendation should be considered in conjunction with Recommendation Number 4.

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