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CRASHWORTHINESS EVALUATION OF AN ENERGY-ABSORPTION EXPERIMENTAL TROOP SEAT CONCEPT

By

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U. S. ARMY TRANSPORTATION RESEARCH COMMAND
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This report was prepared by Aviation Safety Engineering and Research (AvSER), a division of the Flight Safety Foundation, Inc., under the terms of Contract DA 44-177-AMC-116(T). The data developed herein are part of a continuing research program in the field of aircraft occupant crash survival. The hardware evaluated was preliminary in nature and is not intended to reflect a firm design for immediate incorporation into any Army aircraft. However, the concept demonstrates the feasibility of pursuing advanced engineering development of improved aircraft troop seats. Continuous research in this area is planned in order to evaluate improved seat restraint and energy-absorbing systems.

The data contained herein are considered to be valid, and the conclusions and recommendations are under active consideration by this Command.

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Technical Report
AvSER 64-11

by
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SUMMARY

This report is an evaluation of an experimental troop seat concept that was progressively developed and dynamically tested. The seats were installed and tested along with other equipment in four full-scale crashes of CH-21 helicopters.

The designs submitted represented progressive steps in the development of a troop seat using strut-type energy attenuation. The basic concept was a single-passenger, side-facing, bucket seat. Anthropomorphic dummies, restrained by lap belts and single diagonal chest straps, were placed in the seats to provide simulated human loading characteristics during impact. Accelerometers were mounted in the pelvic cavity of the dummies to permit recording of the impact decelerations. Floor accelerations were also measured near the seat installations. Tensiometers recorded the belt forces. High-speed cameras positioned in the helicopters recorded the reaction of the dummies and experimental seats during the crash sequences.

The seats were divided into two basic functional units: first, a seat base incorporating an energy-absorbing strut to provide the vertical support; and second, a curved nylon seat back that was designed to provide the occupant with restraint in the lateral and longitudinal directions, in addition to the restraint provided by the lap belt and chest strap. The test series demonstrated the effectiveness of strut-type energy absorption as a method of attenuating crash forces.

This report codes the seats tested by assigning them numbers, 1 through 4. The report devotes a chapter to each test involved and has a separate final chapter containing an overall analysis and evaluation. Photographs, acceleration records, and kinematic sketches are included where pertinent.

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INTRODUCTION

Dynamic testing of currently employed troop seats has shown that the specifications to which the seats are designed are inadequate; therefore the seats constructed from these specifications do not provide adequate protection for occupants under crash conditions. This situation, also recognized by other agencies, has resulted in the development and testing of several troop seat concepts, one of which is covered in this report. The basic concept described in this report involves an energy-absorbing strut that is cut and that peels as it is forced downward over a die under crash impact loading.

The seat concept was improved on the basis of data obtained in a series of four crash tests. Attachment methods were changed, intentional "weak lines" were introduced, and seat back and suspension methods were altered in a progressive program of concept refinement to produce the most useful design. These involved a combination energy-absorption technique of a support strut in combination with an attachment to the upper support tube.

Four full-scale dynamic crash tests with the seats mounted in the passenger compartments of CH-21 helicopters were conducted. Two crash test methods were employed, i.e., drone and crane drop. The crash environment to which the seats were subjected represented severe but potentially survivable conditions.

TEST OBJECTIVES

The objectives of the test series were:

1. To obtain data on the acceleration and structural deformation characteristics of the test seats.

2. To modify each seat design successively to incorporate improvements shown to be required through testing.

3. To conduct additional tests on new design concepts until a satisfactory design is obtained.

CONCLUSIONS

Based on the test results and data presented in this report, it is concluded that:

1. An energy-absorbing seat support strut concept of the type described in this report will significantly reduce crash decelerations even under conditions of severe floor crushing.

2. The desired protection for occupants of troop seats involved in severe but survivable crashes can be achieved with the type of seat covered in this report.

3. The seat concept tested will meet the criteria for occupant protection as set forth in TRECOM Technical Report 62-79, Military Troop Seat Design Criteria, published by the U. S. Army Transportation Research Command, Fort Eustis, Virginia, November 1962.

RECOMMENDATIONS

Based upon the foregoing conclusions, it is recommended that:

1. Military specifications covering the design and construction of troop seats be revised to provide increased protection to occupants involved in severe but survivable accidents.

2. The data contained in this report and in TRECOM Technical Report 62-79 be used as a basis for revision of the appropriate specifications and, further, that it be provided to all agencies interested in the production of troop seats for guidance in the development of improved seats.

GENERAL DESCRIPTION OF TEST ARTICLE

The experimental troop seat concept exploited in these tests is a single-occupant, side-facing seat. The seat consists of two basic functional units: first, a seat base incorporating an energy-absorbing strut to provide vertical support; and second, the wraparound-type seat back that was designed to provide the occupant with restraint in the lateral and longitudinal direction in addition to that provided by the lap and chest belts. These two units are illustrated in Figure 1, which shows one of the seat models tested. Figures 2 and 3 show the strut both extended and compressed.

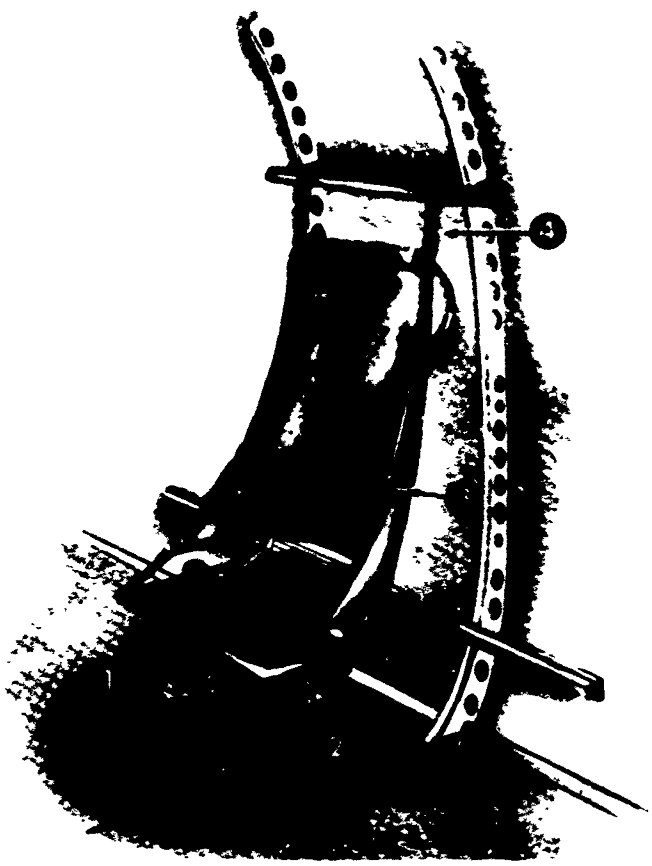


Figure 1. Base-Mounted Vertical Energy-Absorbing Troop Seat. (Arrow 1 shows the energy-absorbing strut; arrow 2, the seat pan; arrow 3, the back rest, seat, and chest belt; and arrow 4, the friction baffle.)

Figure 2. Extended Energy-Absorbing Strut.

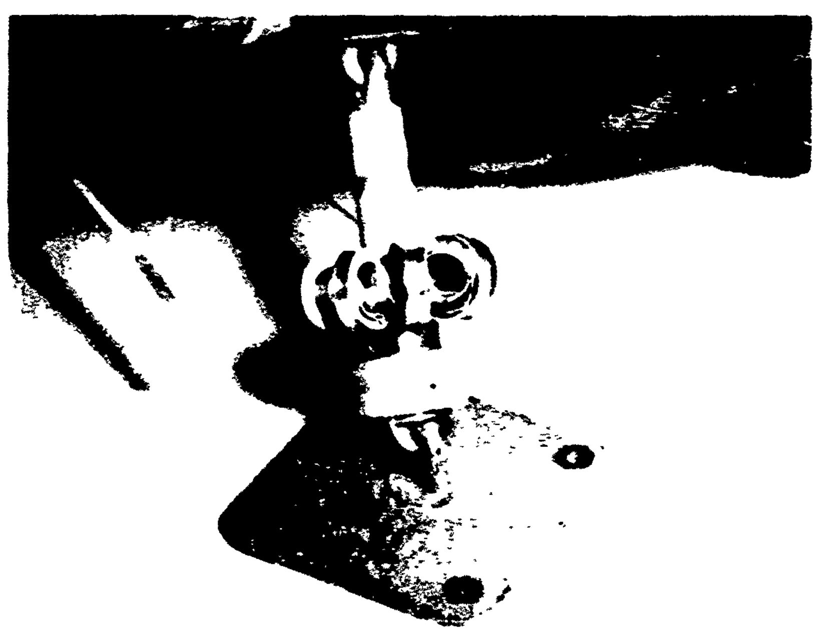


Figure 3. Compressed Strut.

TEST PROCEDURE

The test aircraft for all tests were four CH-21A helicopters. One of the test vehicles is shown in Figure 4.

Figure 4. CH-21A Helicopter.

The first three tests were drone crashes. For this method, a radio link remote control system was used to fly the helicopter on a prescribed flight path and into a predetermined crash condition. For the last test, the helicopter that was used in the preceding test was separated at the firewall aft of the main fuel tank. Thus, the test vehicle represented approximately two-thirds of the original forward structure. This section was dropped from a mobile crane onto a hard-surfaced runway under controlled height and velocity conditions. The crane hookup for this test is shown in Figure 5.

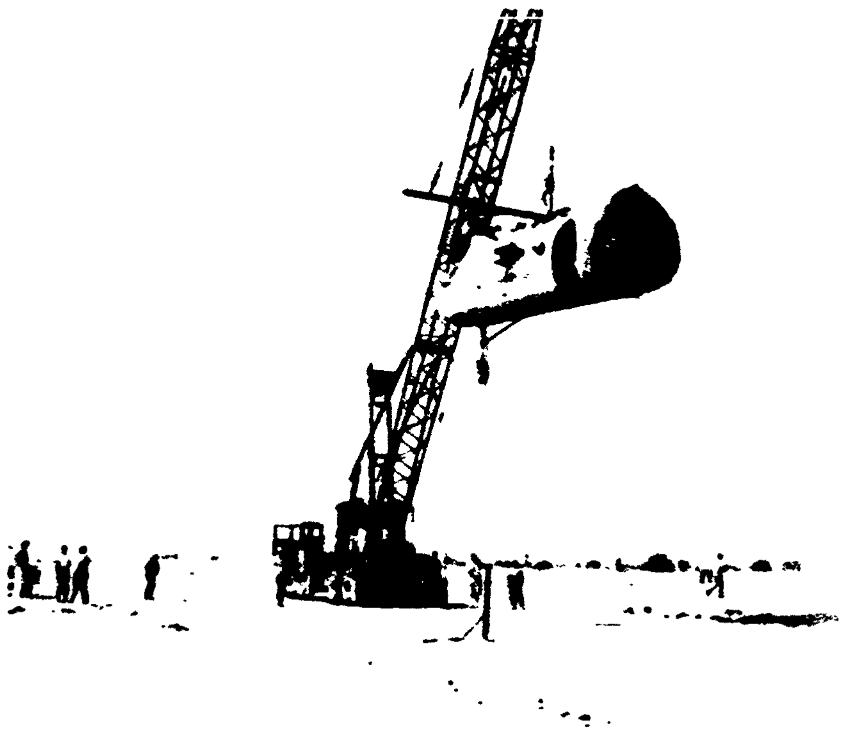


Figure 5. Crane Drop Method.

These test crashes were conducted by AvSER as a portion of a continuing effort to develop expanded knowledge of aircraft crash environment and the impact effect on equipment installed aboard the test vehicles, including seats, fuel tanks, restraint systems, etc. The four test crashes being reported are listed below in the order in which they were conducted.

AvSER Test No.	Experimental Troop Seat Version	Crash Method	Date of Test
7	1	Drone	12 Sept. 1962
9	2	Drone	18 Apr. 1963
12	3	Drone	5 Oct. 1963
13	4	Crane Drop	22 Oct. 1963

SEAT 1, TESTED IN DRONE CRASH (T-7) ON 12 SEPTEMBER 1962

DESCRIPTION OF TEST SEAT 1

The seat base consisted of an aluminum pan supported at the wall by a tube bolted to the aircraft structure and at the aisle by an energy-absorbing strut. The wraparound-type seat back was made of a nylon fabric. A nylon web cushion stretched across the aluminum seat pan. The seat was sewn to the stretched nylon cushion in a semicircle roughly corresponding to the shape of the occupant's buttocks. The seat back pulled tight and attached overhead to another tube bolted to the aircraft wall. Figure 6 is an overall view of the seat with the dummy in place.

Figure 6. Experimental Troop Seat 1 Installation. (The arrow shows the energy-absorbing strut.)

The longitudinal wall tubes on the basic airframe, arrow 1 of Figure 7, were standard to the CH-21A helicopter. Seat 1 was designed to fit these tubes. The strength of the standard aluminum tubes in moderately severe crashes has proved to be insufficient. The lower aluminum tube was therefore replaced by a tube of 4130 steel for this test. The upper aluminum bar was retained.

The seat strut, arrow 2 of Figure 7, was designed to absorb energy by peeling an aluminum tube over a die. The die is the fitting at the bottom of the strut, arrow 3 of Figure 7. The tube was designed to fail a 12-inch stroke. The strut incorporated an antitension feature (static-tested to 2900 pounds without failure) to ensure that the strut would not extend on rebound.

Figure 7. Closeup View of Lower Portion of Seat 1. (Arrow 1, seat connection to 4130 steel tube; arrow 2, energy-absorbing strut; arrow 3, floor mounting for energy-absorbing strut; arrow 4, seat-belt connection.)

Energy absorption was also provided in the attachment to the upper support tube. This was accomplished by allowing nylon straps to pull through an aluminum baffle (see Figure 8). Two energy-absorbing devices were mounted on the outboard straps. Three center straps were hooked over the upper support tube. These straps remained unloaded until sufficient forces were impressed on the seat to extend the outboard straps.

The dummy was restrained by means of a lap belt and a single diagonal chest strap. The lap belt was attached to brackets at the sides of the aluminum seat pan as shown by arrow 4 of Figure 7. The diagonal chest strap, which was connected to a bulkhead, passed over the dummy's left shoulder and attached to the same bracket as the lap belt on the right side. The bracket at the right side was reworked to allow insertion of a tensiometer link between the bracket and the ends of the lap belt and chest strap.

Figure 8. Closeup of Upper Portion of Seat 1. (View shows attachment to the upper support tube. Arrow shows energy-absorbing baffle plate used on outboard straps.)

The seat was located between station 215 and station 235 in the aircraft. The 4130 steel tube was bolted to the bulkhead attachment points at stations 199.5, 219.5, and 239.5. Figure 9 shows a closeup view of the rear of the seat and its attachment to the tube.

Figure 9. View of Rear of Experimental Troop Seat 1. (Cut in nylon to permit attachment of 4130 steel tube to bulkhead casting is shown by arrow.)

In a standard troop seat configuration, the lower seat attachment tube is bolted to the bulkhead casting at each bulkhead. The upper tube, however, is bolted to the frame at roughly every other bulkhead. The upper tube used with this experimental troop seat was attached at stations 179.5, 219.5, and 239.5.

TEST CONDITIONS

The droned test aircraft was lifted off and was flown through the desired flight profile, reaching a height of 57 feet. At impact, the following conditions existed:

Horizontal velocity	48.0 feet per second
Vertical velocity	40.0 feet per second
Flight path velocity	62.5 feet per second
Flight path angle	40 degrees
Pitch	3 degrees up
Roll	4 degrees left
Yaw	0 degrees

Initial impact occurred on the nose wheel with the main gear impacting shortly thereafter. Neither of the gears appeared to offer any force attenuation whatsoever. The fuselage struck the runway, and the aircraft skidded some 43 feet from point of impact and rotated clockwise. The skin ruptured extensively in the area just aft of the cargo door and adjacent to the main landing gear attachment points. The main fuel tank ruptured, and fuel (colored water) spilled extensively both inside and outside the aircraft. An unplanned fire did occur due to some leakage from the auxiliary fuel system; however, it had little or no effect on the aircraft or the experiments aboard.

TEST RESULTS

Fuselage Structure

Figure 10. Postcrash View of H-21 Test Vehicle. (General location of experimental troop seat is shown by arrow.)

The entire lower structure of the forward fuselage section, including fuselage skin, floor support structure, and lower section of body frames, was crushed by impact of the helicopter on the runway. The left side of this lower structure was crushed more severely than the right side, due to impact with approximately a 4-degree left roll. Interior photographs showing the extent of buckling of the floor panels throughout the cabin area are shown in Figures 11 and 12.

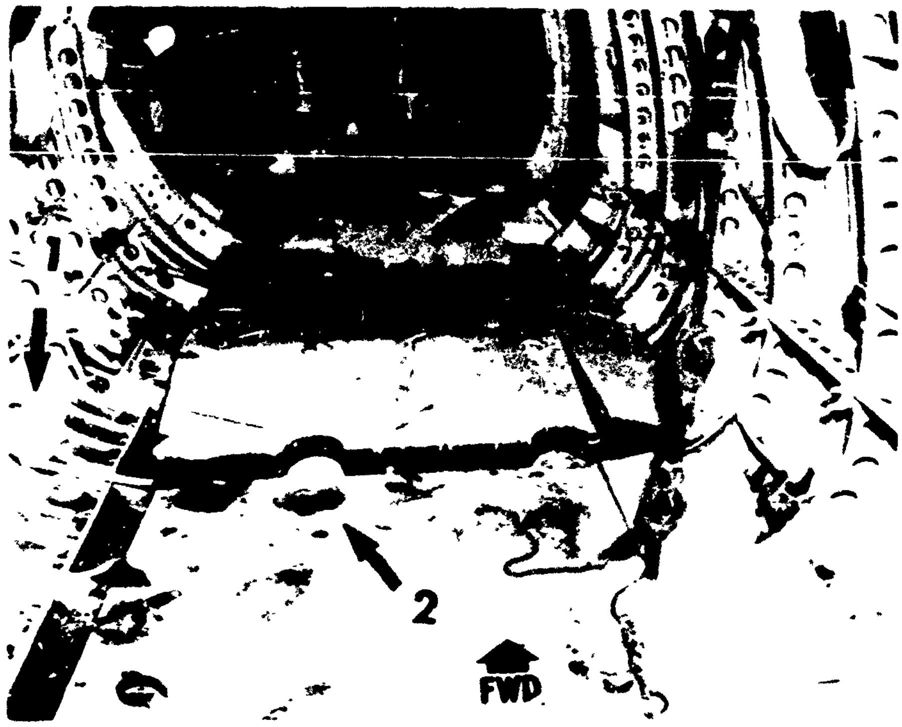


Figure 11. Passenger Compartment, Rear. (Apparatus used in internal experiments have been removed. Arrow 1 shows the buckling of fuselage frames. Arrow 2 shows location of experimental seat floor mount.)

Figure 12. Passenger Compartment, Front. (Experimental equipment has been removed.)

Generally, the fuselage structure above the normal troop seat attachment points, approximately 17 inches above the floor line, remained intact on both sides of the aircraft, while structure below this line was crushed extensively on the left side.

Although the impact was severe, the crash was classified as potentially survivable because the occupiable areas of the fuselage remained essentially intact. The acceleration levels measured on the floor of the helicopter were very high in spite of partial attenuation by crushing of the subfloor structure. The acceleration levels, particularly in the vertical direction, are considered to be in excess of human tolerance; hence, the requirement for some form of energy absorption between the seated occupant and lower aircraft structure.

Postcrash Examination of Seat

Figure 13 shows the position of the seat and dummy immediately after the crash. The metal seat-pan portion of the seat remained relatively intact. The upper torso support value of the wraparound-type nylon seat back was lost; however, due to failure of the upper support tube to which it was attached. The outboard nylon straps remained attached to the broken ends of the support tube. The diagonal chest strap and lap belt remained fastened and prevented the dummy from being thrown from the seat after collapse of the nylon back support. There was sufficient play in the chest strap after the support failure to allow the dummy's head to contact the fuselage frame forcibly at station 219.5.

In Figure 13, arrow 1 shows broken tube and left nylon strap tie point. Arrow 2 shows right nylon strap. Note that strap tore away from rest of seat back for approximately 12 inches. Arrow 3 shows where head of dummy contacted bulkhead.

Figure 13. Postcrash View of Experimental Troop Seat.

Figure 14 shows a postcrash view of the seat with the dummy removed. Note that the aluminum seat pan and the bulkhead were nearly parallel. The floor buckled upward forward of the energy-absorbing strut. The contact point of the forward front edge of the seat with the floor is also evident in Figure 14.

Figure 15 is another postcrash view of the seat after the dummy had been removed. Again, note that the seat pan and the bulkhead are nearly parallel.

Figure 14. Postcrash View of Experimental Troop Seat - Dummy Removed. (Break in aluminum seat pan is visible at Arrow 1; both ends of broken upper-support tube are indicated by Arrow 2; Arrow 3 shows outboard strap still attached but partially torn from seat back.)

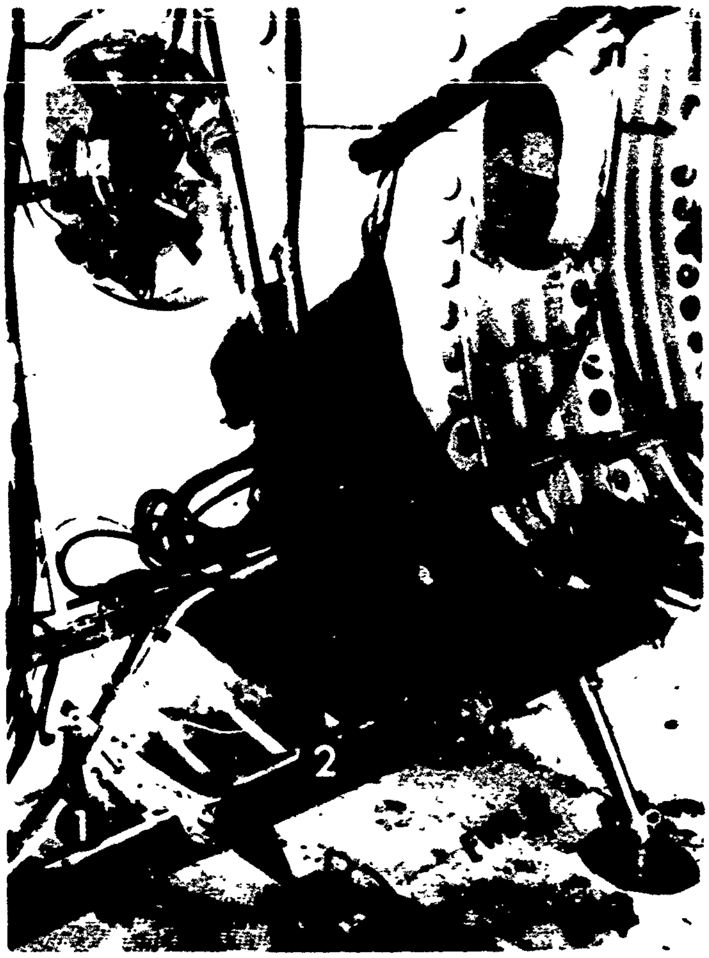


Figure 15. Postcrash View of Experimental Troop Seat - Dummy Removed. (Tensiometer link installation is shown by Arrow. 1. Arrow 2 shows typical collapsed bulkhead in left side of passenger compartment.)

Figure 16 shows a closeup view of the contact point between the honeycomb floor and the seat pan.

Figure 16. Closeup View of Left Side of Seat Pan. (Arrow 1 shows break in seat pan. Arrow 2 shows portion of honeycomb floor where contact was made. Arrow 3 shows break in floor with portion of collapsed bulkhead showing through.)

The energy-absorbing strut depressed, as designed, through 7 of its 12 inches of travel. Figure 17 is a closeup view of the strut.

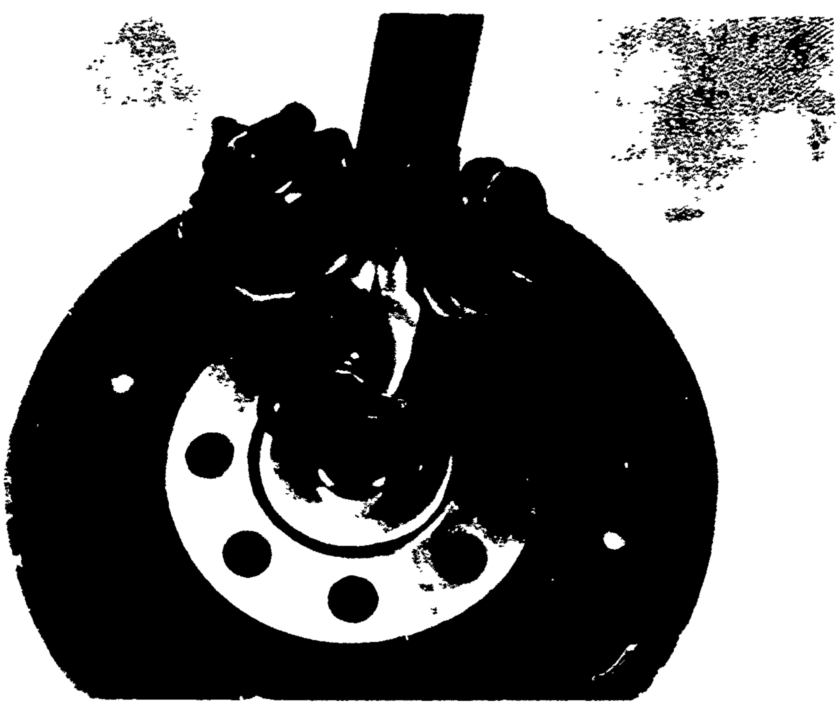


Figure 17. Postcrash View of Energy-Absorbing Strut.

Kinematics of Crash Sequence

Figure 18 is a kinematic sequence of the action of the seat and dummy during the crash. The positions of the dummy and the chain of events that occurred concerning the seat and airframe are based on high-speed film analysis. The times shown with each picture are related to time of impact and show each significant event in the crash sequence.

1. Figure 18A shows the seat after the helicopter has made ground contact but before significant forces have been sensed by the dummy.

2. Figure 18B shows the seat beginning to function while the support structure is still intact. The energy-absorbing strut is peeling. The bulkheads are beginning to collapse, and the upper support tube is bowing, since the casting has sheared from the wall.

3. Figure 18C shows that the upper support tube has failed and that the bulkhead has collapsed sufficiently to allow the seat to contact the floor.

4. Figure 18D shows that the dummy has fallen to the left sufficiently to allow head contact with the fuselage frame.

5. Figure 18E shows the seat and dummy in the final position.

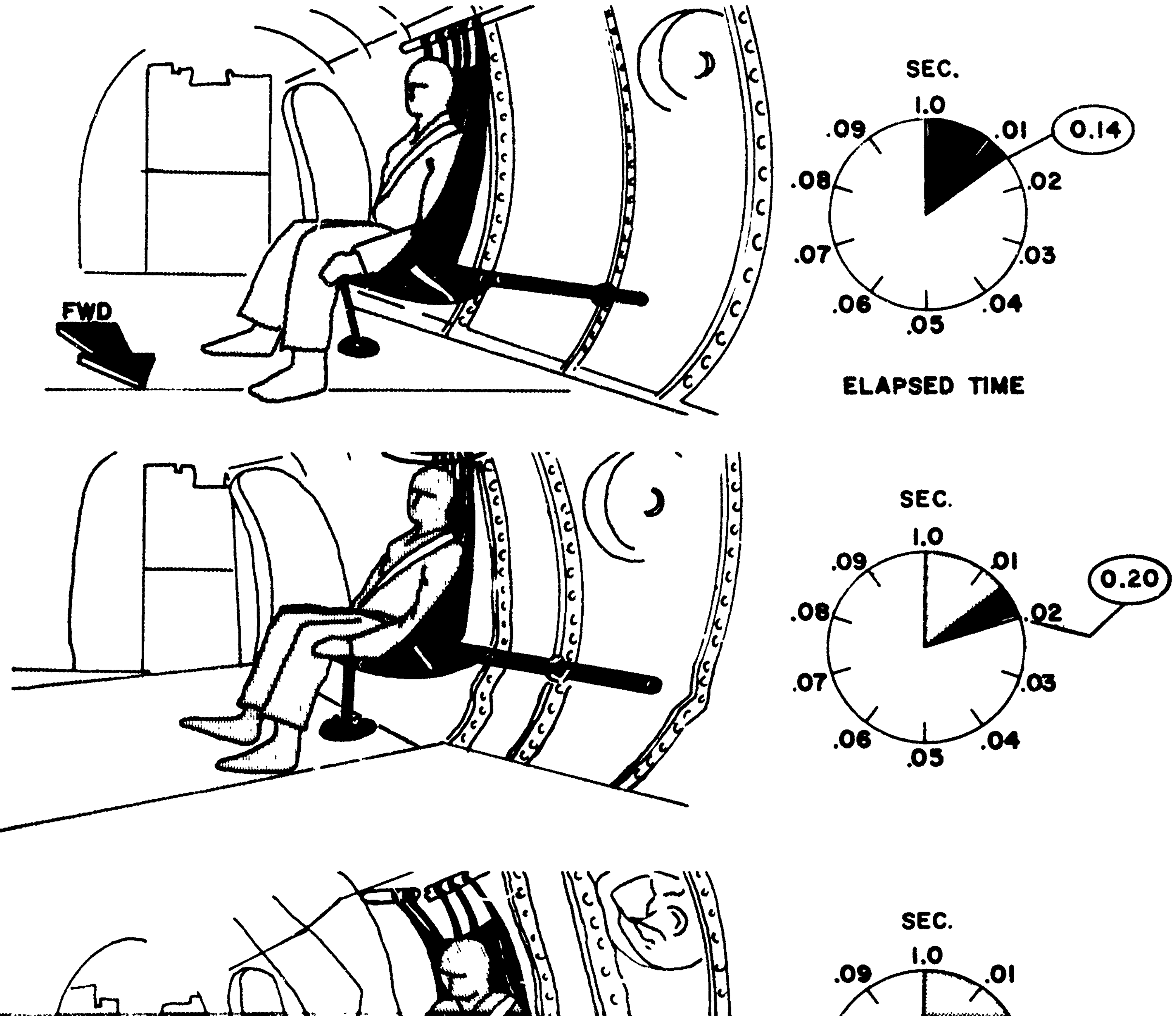
Oscillograph Records

The oscillograph traces applicable to analysis of the experimental troop seat described in this report are presented in Figure 19, including (1) the records of lateral, longitudinal, and vertical accelerations both in the pelvic region of the dummy and at the passenger cabin floor level and (2) the tensiometer readings of the passenger belt forces. In these records, time zero corresponds to the first contact of the aircraft with the ground.

It must be stated that the lateral and longitudinal readings on the accelerometer traces are with respect to the aircraft. Since this is a side-facing seat, the readings would be reversed for the dummy.

A

B


FWD
SEC.
1.0
.01
.02
.03
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.05
.06
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0.14
ELAPSED TIME
SEC.
1.0
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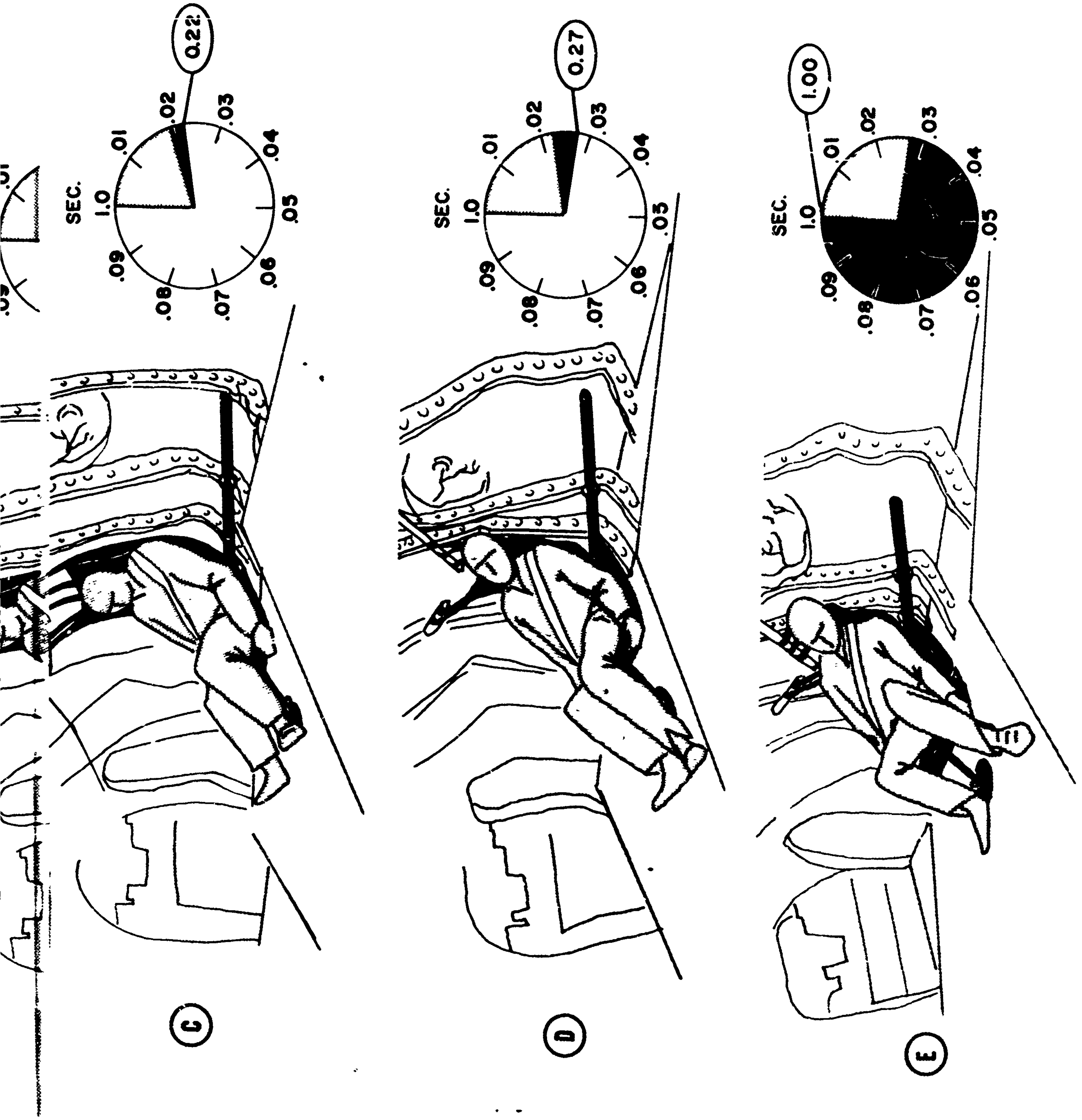


B

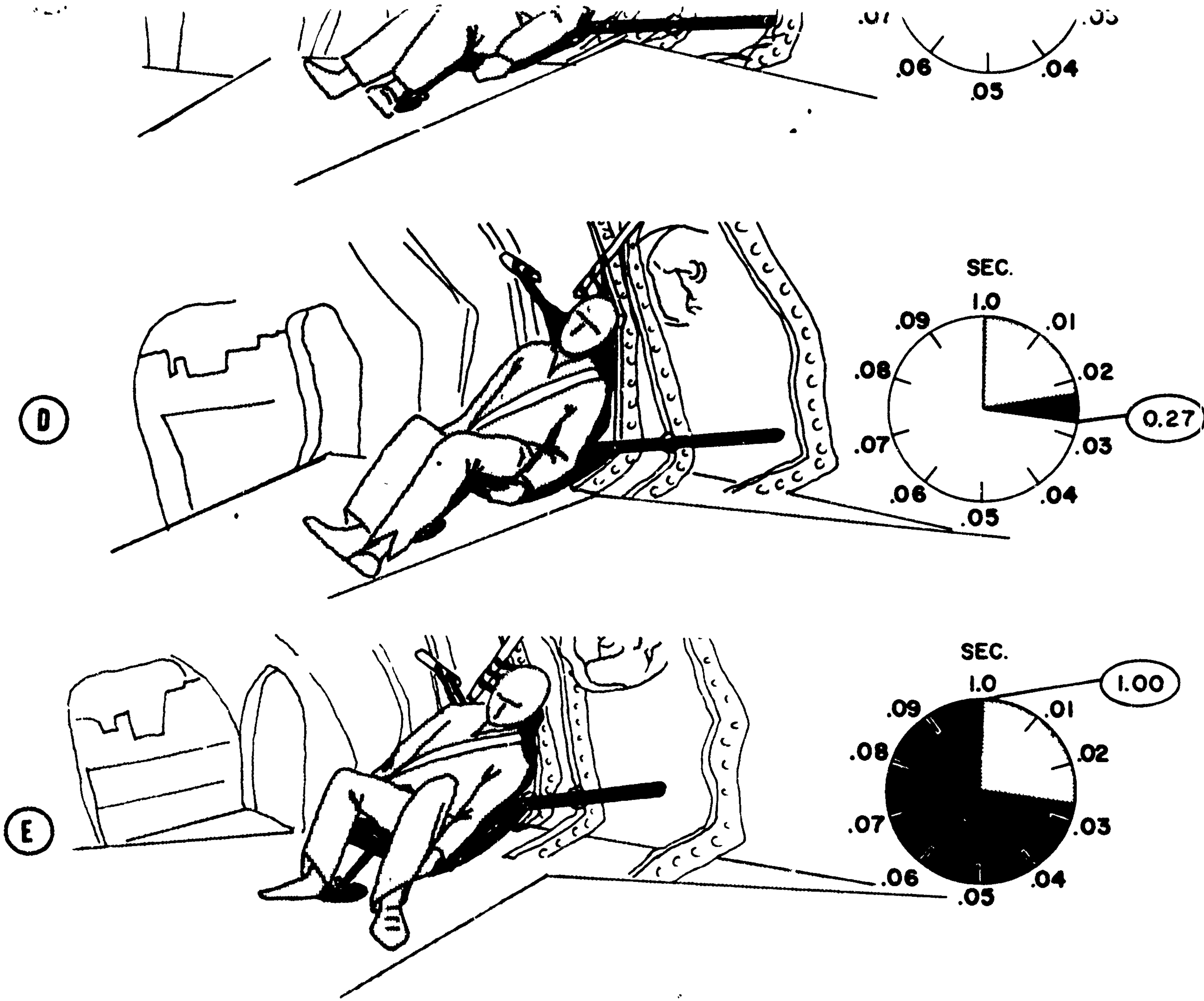
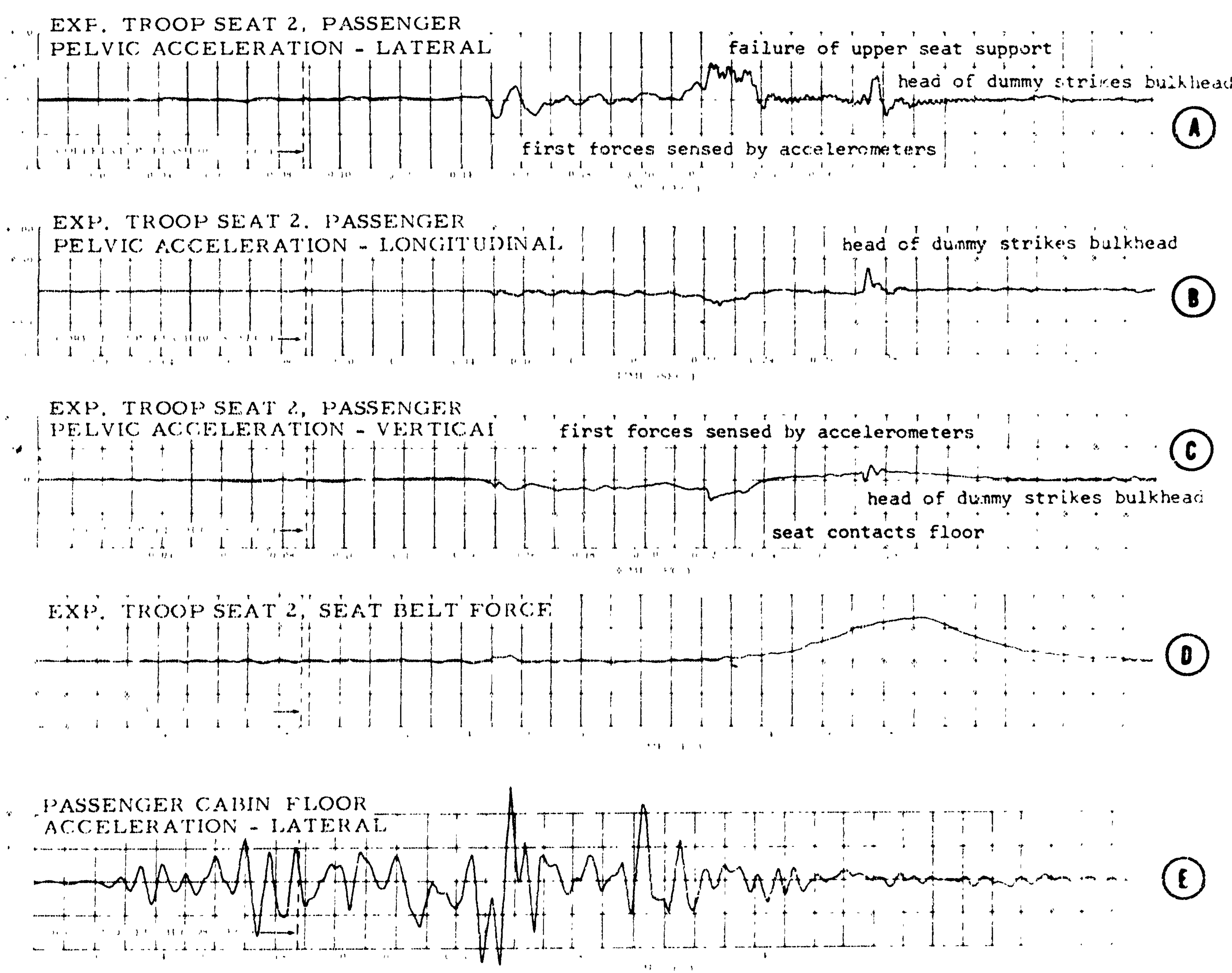


Figure 18. Kinematic Sketch of Seat 1 and Dummy During Crash Impact Sequence, T-7.



EXP. TROOP SEAT 2, PASSENGER
PELVIC ACCELERATION - LATERAL
failure of upper seat support
head of dummy strikes bulkhead
first forces sensed by accelerometers
A
EXP. TROOP SEAT 2, PASSENGER
PELVIC ACCELERATION - LONGITUDINAL
head of dummy strikes bulkhead
B
EXP. TROOP SEAT 2, PASSENGER
PELVIC ACCELERATION - VERTICAL
first forces sensed by accelerometers
head of dummy strikes bulkhead
seat contacts floor
C
EXP. TROOP SEAT 2, SEAT BELT FORCE
D
PASSENGER CABIN FLOOR
ACCELERATION - LATERAL
E

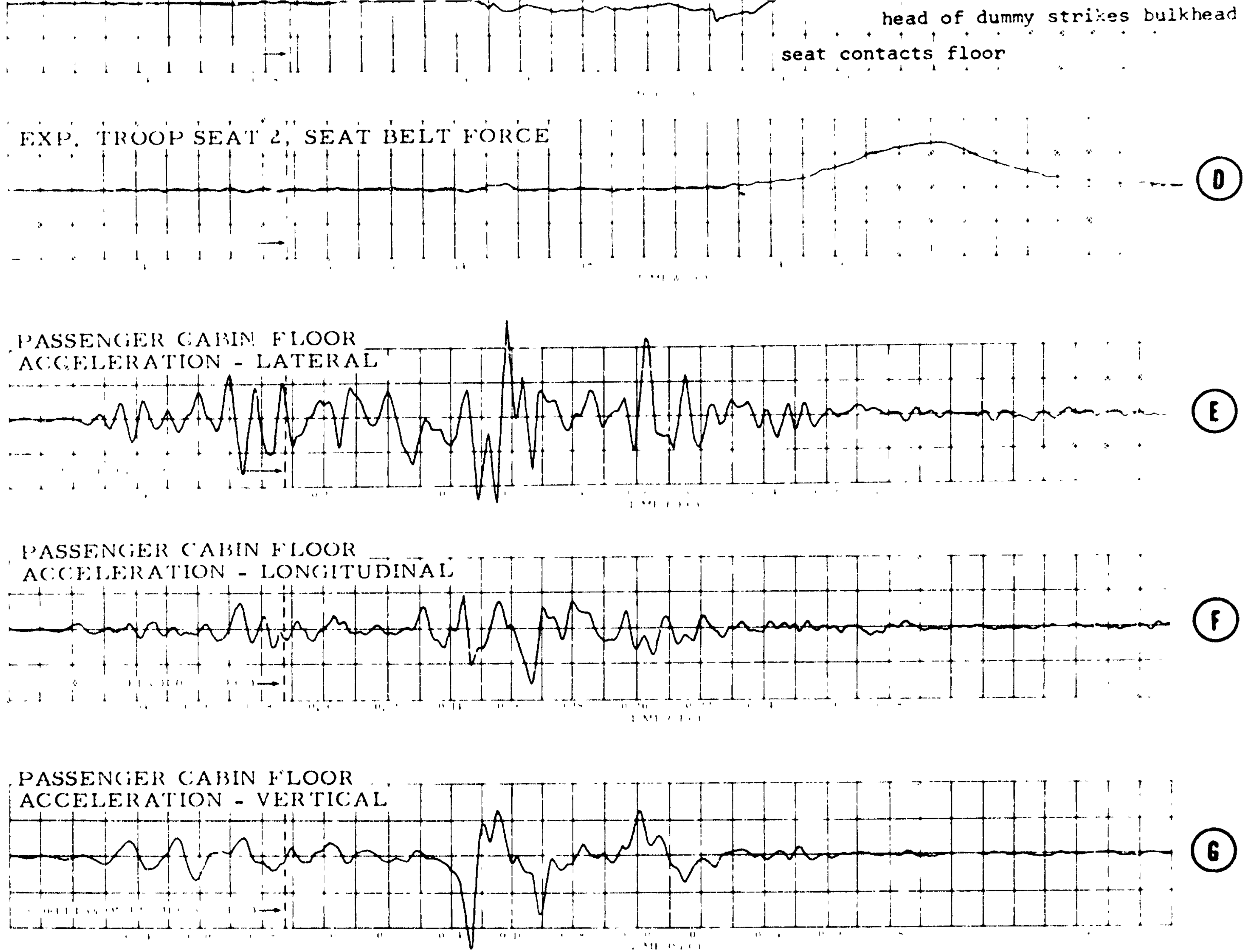


Figure 19. Accelerometer-Time and Force-Time Histories, Seat 1, During H-21 Helicopter Crash Test T-7.

DISCUSSION OF TEST RESULTS

The first significant forces indicated on the dummy occurred at 0.148 second. At th. time, distinct forces were apparent on all accelerometer traces as well as the seat belt force.

The vertical trace (Figure 19C) showed a fairly steady 8G to 12G deceleration as the energy-absorbing strut deformed over its die, beginning at 0.148 second. This deceleration continued to 0.220 second, at which time two events occurred: first, the upper support failed, allowing the dummy to bottom out on the aluminum seat pan; second, the floor and the seat pan made contact. The peak pulse as the dummy contacted the seat pan was 28G at approximately 0.223 second. The total duration of the pulse was approximately 0.092 second. The peak vertical floor acceleration was approximately 175G at 0.147 second.

The longitudinal trace (Figure 19B) (lateral with respect to the dummy) showed a 2G to 5G deceleration up to 0.220 second and then increased for a short period to approximately 25G. This closely approximates the deceleration rate of the helicopter as a whole and indicates minimum movement of the dummy with respect to the aircraft in this plane.

The lateral trace (Figure 19A) (longitudinal with respect to the dummy) showed a 10G negative peak as the helicopter's ground contact was first felt, damping out sinusoidally until 0.214 second, when the upper support tube began to bow.

At 0.220 second, the upper support tube fail d; this failure eliminated the restraint value of the nylon seat back. The seat belt and chest strap were still attached, which restricted the dummy's side movement but allowed the dummy to fall backward toward the left, against the fuselage wall. The failure of the tube is also distinguished by peak readings on the longitudinal and vertical traces. In the longitudinal direction, the G rise was due to the slack's being taken up in the chest strap as the dummy leaned to the left. The vertical peak, though partially caused by bottoming out on the aluminum seat pan, was primarily due to contact between the seat pan and the honeycomb floor.

At 0.273 second, the dummy leaned far enough to the left for the head to strike the bulkhead. At this time, a rather sharp pulse appeared on all three accelerometer axes.

The restraint belt force showed a small spurt up to 100 pounds at 0.148 second, the instant when the accelerometers first indicated the results of the crash. The load dissipated as the dummy was driven down into the seat until the support failed at 0.220 second. From this time on, the force rose to a peak of 700 pounds as the dummy leaned to the left, stressing the chest strap.

The tube used at the upper attachment point of the seat structure was the standard aluminum tube used in the CH-21A as the troop seat attachment. The first failure was the casting used to attach the tube to the body frame at station 219.5, directly over the center of the seat. The rivets that attach the casting to the bulkhead sheared. This allowed the tube to sag over a 60-inch span. The tube sagged approximately 12 inches before failure, as may be seen in the kinematic drawing, Figure 18. After failure, the wraparound seat back no longer restrained the dummy. With the seat back gone, there was enough play in the chest strap to allow the dummy's head to contact the bulkhead with sufficient force to cause a dent 3-inches deep in this bulkhead.

Figure 16 showed the result of the contact between the seat and the honeycomb floor. The first impression was that the failure of the rear seat support allowed the seat to collapse and contact the floor. However, examination of the seat prior to the crash, Figure 7, shows the energy-absorbing strut at a 120-degree angle with the floor. The postcrash examination (see Figure 14) showed the strut to be at a 60-degree angle.

A careful look at the wall of the passenger compartment (see Figures 11 and 12) revealed why the strut rotated through a 60-degree angle. The lower 17 inches of the fuselage was flattened parallel to the floor. As may be noted in Figure 14, which is a postcrash photograph showing the attachment of the seat to the lower support tube, there is no evidence of failure in the seat-to-support-tube area of the seat. The energy-absorbing strut had compressed through only 7 of its 12 inches of effective travel at the time the seat contacted the floor.

The evidence of the previous two paragraphs led to the conclusion that the seat itself did not collapse when the upper support failed. The sharp impact when the seat and floor contacted was due to failure of aircraft basic structure rather than failure of the seat. The impact was the result of an action analogous to pulling the opposite corners of a parallelogram as shown in Figure 20.

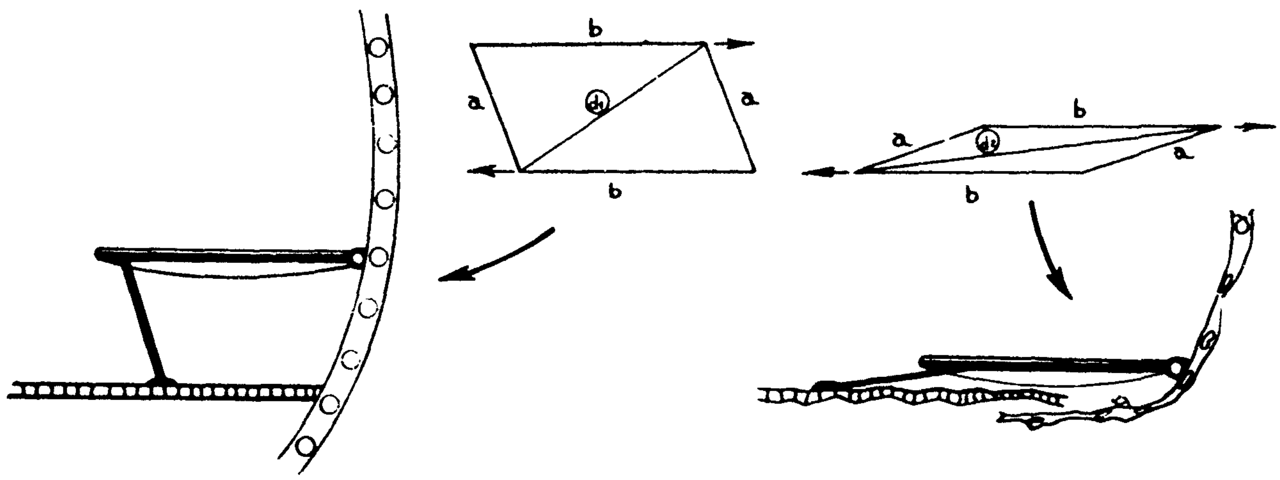


Figure 20. Relation of Seat Collapse to Aircraft Structure Failure.

The metal structure of the seat remained basically intact throughout the crash sequence. The occupant restraint system held the dummy in the seat. The seat restraint and energy-absorbing system could not be fully evaluated from the test, because the seat failure was involved with the failure of the upper attachment to the aircraft basic structure and the collapse of the lower portion of the fuselage.

The seat, however, seems to have performed as it was designed, up to the point of failure in the upper attachment system. The accelerations and forces to which the seat occupant (dummy) was subjected were survivable. The forces involved when the dummy's head impacted the fuselage frame are unknown. It is quite probable that serious injury would have resulted from this blow - possibly fatal.

SEAT 2, TESTED IN DRONE CRASH (T-9) ON 18 APRIL 1963

DESCRIPTION OF TEST SEAT 2

Seat 2 was an improvement in design based upon the results obtained during the test of Seat 1. The seat incorporated changes dictated by the findings of the first test plus other changes to decrease weight and complexity. The frame consisted of a honeycomb pan supported at the wall by an extruded hat section bolted to the aircraft basic structure. The honeycomb pan was attached to the extrusion by a piano hinge. The pan was supported at the aisle by the energy-absorbing strut. See Figures 21 and 23 for structural attachments.

Figure 21. View of Lower Portion of Experimental Troop Seat 2. (Arrow 1 shows portion of hinge connection; arrow 2 shows energy-absorbing strut.)

The seat strut was designed to absorb energy by peeling the aluminum tube over a die that was part of a quick-disconnect fitting at the bottom of the strut. The strut provided a 13-inch energy-absorption stroke.

as measured from the bottom of the aluminum tube vertically. The strut incorporated an antitension feature to ensure that the strut would not extend. A force of 1800 pounds was required to peel the aluminum tube over the die.

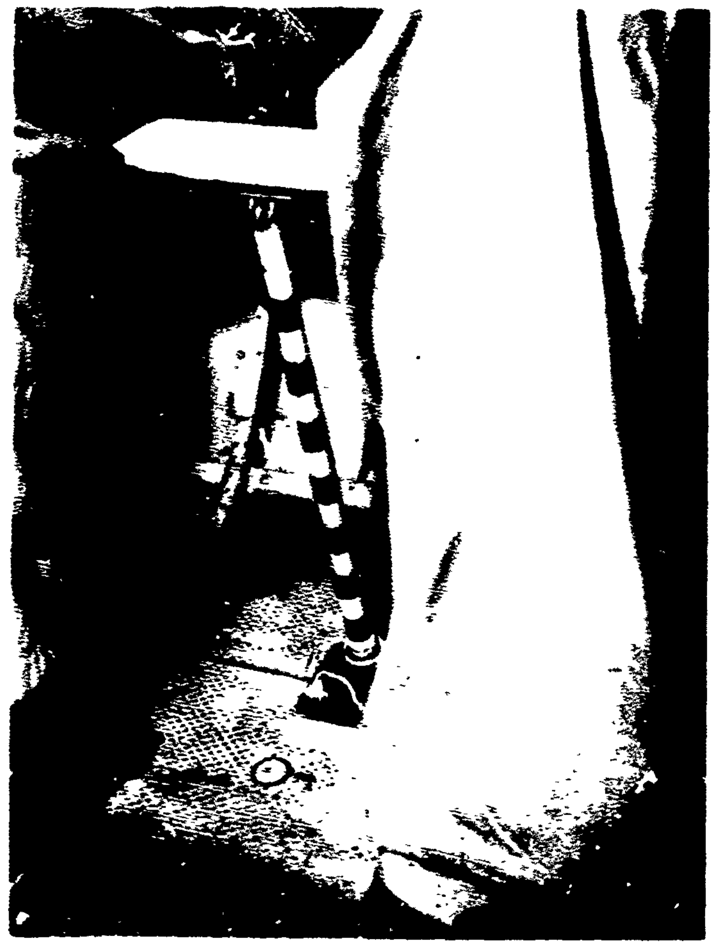


Figure 22. Closeup View of Energy-Absorbing Strut.

In this as in other seats, the occupant sits directly on the honeycomb pan and leans back into the nylon seat back, which is shaped to conform to the torso on three sides. The nylon back is attached to the aircraft structure at two points above the seat and to the two forward corners of the seat pan, as shown in Figures 21 and 23.

The attachments to the upper support were designed to extend under load as the seat strut depressed, absorbing energy and allowing the nylon seat back to move downward with the seat pan. This was accomplished by pulling a wire through aluminum baffles as shown by the arrow in Figure 23.

Figure 23. Upper Support for Experimental Troop Seat 2.
(Arrow points out one of two energy absorbers.)

The dummy was restrained by means of a lap belt and a single diagonal chest strap. The lap belt was a continuous strap that passed beneath the seat pan and over the lap of the occupant. (See Figures 21 and 24.) The chest strap was sewn to the top of the nylon back and passed over the right shoulder of the occupant, connecting to the lap belt at the belt latch, which was located immediately above the left thigh, as shown in Figure 24.

The standard upper support tube structure, which failed in the first test, was replaced with a 4130 steel tube, 1-1/4 inches in diameter with a 1/8-inch wall thickness. The tube was of the same diameter as in the standard troop seat installation, thus, the standard tube support bracket could be used. The brackets were mounted in pairs and bolted together through double plates to the frames. The tube

Figure 24. View of Experimental Troop Seat 2. (This view shows dummy in place and restraint system.)

was then bolted to the brackets, as shown by arrow 2 in Figure 25.

The hat section, to which the seat pan was attached, was bolted through double plates to four fuselage frames. This installation is shown by arrow 1 in Figure 25.

An additional design feature of the seat was an intentional weakened line in the honeycomb seat pan approximately 6 inches in front of the piano hinge. The theory of operation was for the weak area to bend and allow the rear of the seat pan to drop as much as 6 inches to maintain the seat pan approximately parallel to the floor as it stroked downward because of the action of the energy-absorption strut.

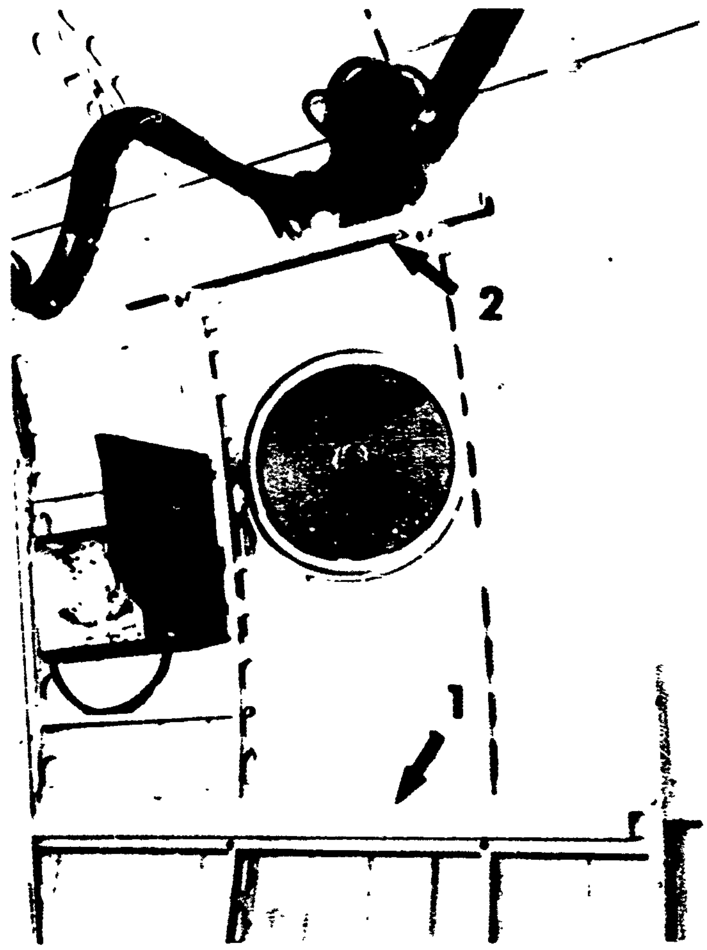


Figure 25. Wall Mounts In Place for Experimental Troop Seat 2. (Arrow 1 shows extended hat section, and arrow 2 shows upper support tube.)

The seat was mounted at the right side of the helicopter between stations 279.5 and 299.5. The extrusion was bolted to the frames at 259.5, 279.5, 299.5, and 311.81. The upper support brackets were fastened at frames 279.5 and 299.5.

A summary of changes in seat 2 over seat 1 is as follows:

1. The energy-absorbing strut had its stroke increased from 12 to 13 inches. The fitting at the end of the strut incorporated a quick-disconnect feature, which allows the seat to be rapidly folded for storage. Previously, the lower fitting was fixed to the floor mount.

2. The seat pan in seat 2 was made of honeycomb core covered with a fiber glass skin, whereas the first seat had a curved aluminum pan with nylon webbing stretched over it.

3. The seat pan in seat 2 was attached to the hat section by a piano hinge extending across the entire width of the seat. Previously, the seat pan was bolted to a tube at two points of the outboard edges of the seat.

4. The occupant in seat 2 sat directly on the honeycomb seat pan. The seat back was supported by straps extending from the front corners of the pan to the upper support tube. In the earlier model, the occupant sat on a nylon web cushion stretched across the seat pan and the seat back sewn to the web cushion and attached at five points to the upper support tube.

5. The seat back upper attachment system in seat 2 incorporated a device designed to allow the seat back to move downward as the seat pan stroked downward. This was accomplished by drawing wire through baffles. The previous seat back was fastened to the upper support tube by five nylon straps. The two outboard straps were arranged to slip through a friction device. The three center straps were left slack to be brought into use after the outboard straps extended. This, however, allowed the entire seat back to move as a unit with the seat pan only until the slack in the center straps was taken up.

6. The seat pan in seat 2 was produced with a weakened line, which was intended to allow the seat pan to bend at a point 6 inches from the rear edge and to remain parallel to the floor as the pan stroked downward. The former seat had a rigid tubular seat pan.

TEST CONDITIONS

The flight profile of the droned helicopter reached a maximum height of 111 feet, with the following conditions existing at impact.

Horizontal velocity	66.0 feet per second
Vertical velocity	52.5 feet per second
Flight path velocity	89.3 feet per second
Flight path angle	38 degrees
Pitch	1 degree up
Roll	2 degrees left
Yaw	0 degrees

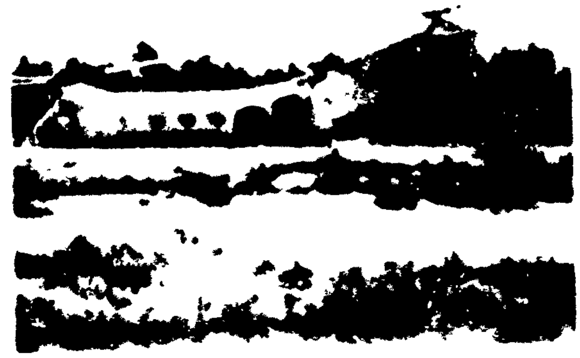
The flight profile subjected the aircraft to an extremely severe crash, resulting in considerable fuselage collapse. The cockpit was rendered nonsurvivable due to the collapse of the forward transmission and bulkhead into the cockpit, which resulted in destruction of all living space in the cockpit. The cabin fuselage collapsed to some extent; however, approximately 4-1/2 feet of vertical height remained. On this basis, the cabin section of the fuselage was considered survivable. The rear fuselage broke at the point of the main landing gear attachment and was almost completely severed from the rest of the fuselage; it rolled to the left as it separated. As experienced in previous tests with the CH-21A helicopter, the landing gear offered little, if any, force attenuation at impact.

TEST RESULTS

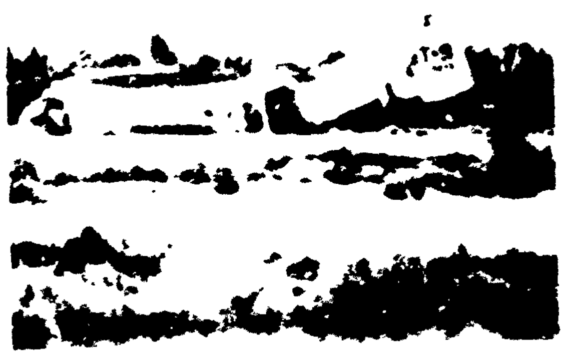
Fuselage Structure

Figure 26 shows a sequence of high-speed photographs of the CH-21A test vehicle taken from an exterior position. Note particularly that, although the final picture in the sequence shows the passenger compartment to be relatively intact, the maximum compression, as illustrated by Figure 26D, shows the occupiable area to be reduced in vertical height to approximately 65 percent of the original height.

A. Time 0.12 sec.



B. Time 0.16 sec.



C. Time 0.20 sec.

D. Time 0.24 sec.

E. Time 0.37 sec.

F. Time 0.87 sec.

Figure 26. Sequence Photographs of Impact.

The entire lower structure of the forward fuselage section (including the fuselage skin, floor support structure, and the lower section of the body frames) was deformed as shown in Figure 27. The fuselage contacted the runway with approximately 2 degrees of left roll, which resulted in more extensive buckling of the fuselage frames on the left side of the aircraft.

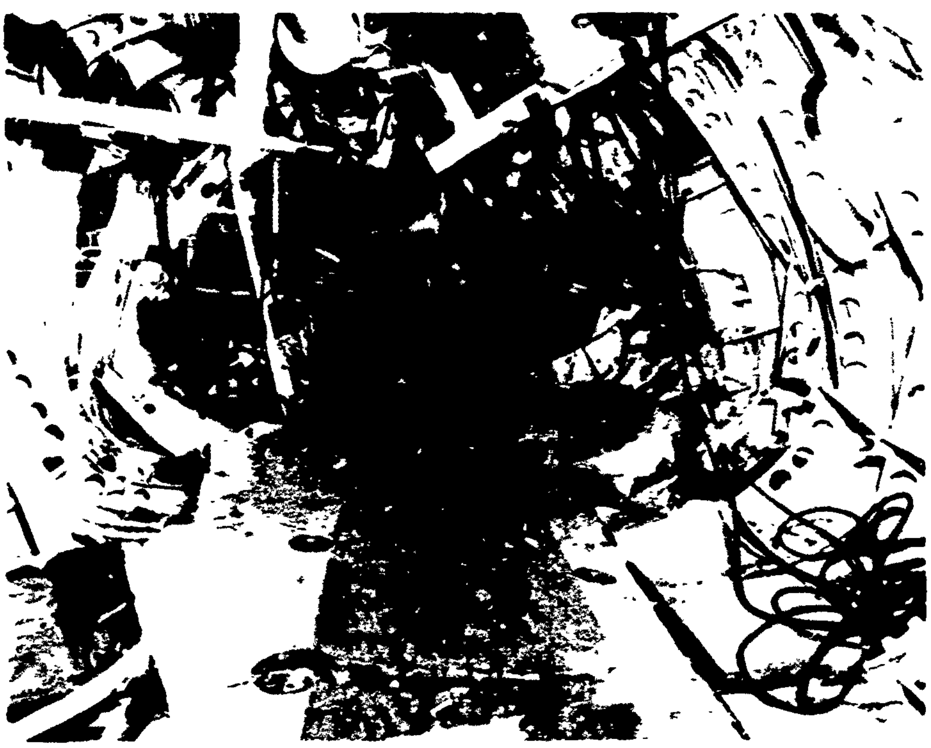


Figure 27. Postcrash View of Forward Portion of CH-21A Passenger Compartment.

The occupiable area of the fuselage in the vicinity of seat 2 remained essentially intact, as shown in Figure 28.

Postcrash Examination of Seat

Figure 29 shows the position of the seat and dummy immediately after the crash. The sheared piano hinge connection gives the impression of complete seat failure. This failure did not occur, however, until the energy-absorbing mechanism had completed its function. All other individual components of the seat remained intact except as noted in Figure 30.

Figure 28. View of Passenger Compartment of CH-21A in Area of Seat 2. (The arrow shows the location of the seat after the seat and dummy had been removed.)

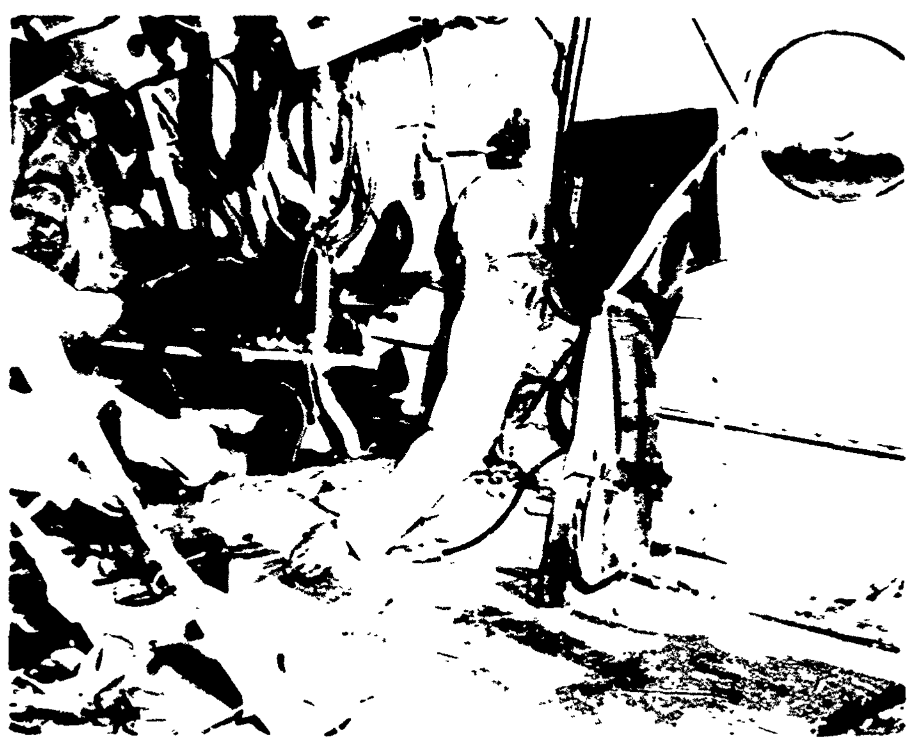


Figure 29. Postcrash Position of Seat 2 and Dummy.

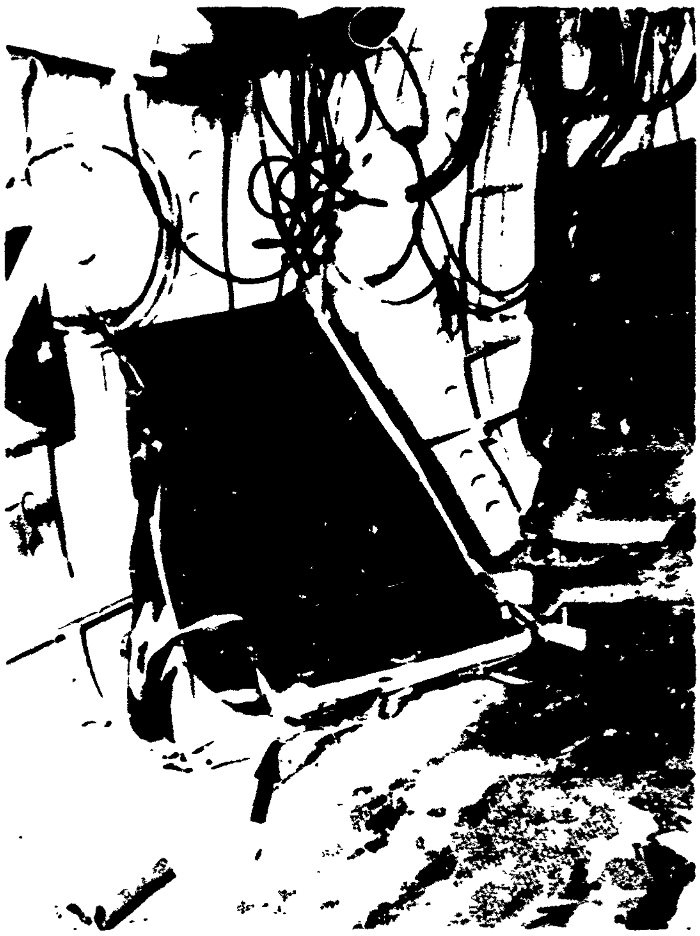


Figure 30. Postcrash View of Seat 2 With Dummy Removed. (Arrow shows point of failure of nylon seat back attachment strap retainer.)

Note in Figure 30, which shows seat 2 after the dummy had been removed, that the nylon seat back is intact. The only failure in the seat back assembly was the broken strap retainer. This failure would not in itself have caused a failure of the seat; it probably occurred when the seat corner came in contact with the floor during the final phases of the crash.

The energy-absorbing strut and the overhead energy-absorption system performed their intended function. Figures 31 and 32 show these components after the seat had been removed from the helicopter.

Figure 31. Photograph of Seat Back Attachments With Wires Pulled Through Friction Baffle.

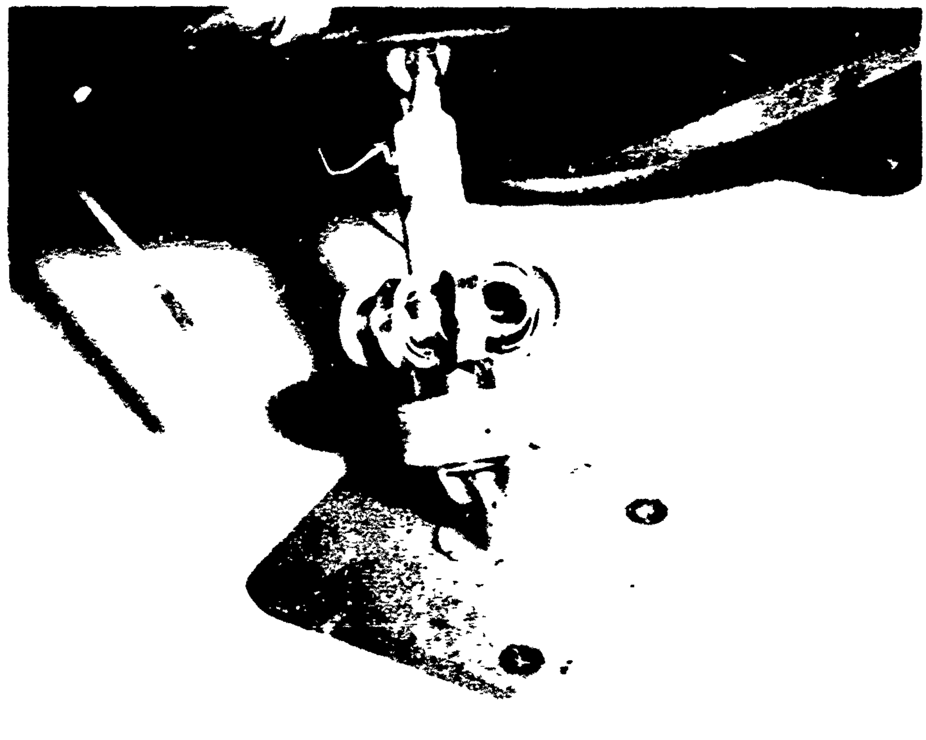


Figure 32. Closeup View of Energy-Absorbing Strut After Impact.

The high-speed pictures taken on board the aircraft indicate that after the energy-absorbing strut had deformed through its maximum stroke, the seat mounting hinge failed at the wall. Figures 33 and 34 are detail postcrash views of the seat and wall portions of the hinge.

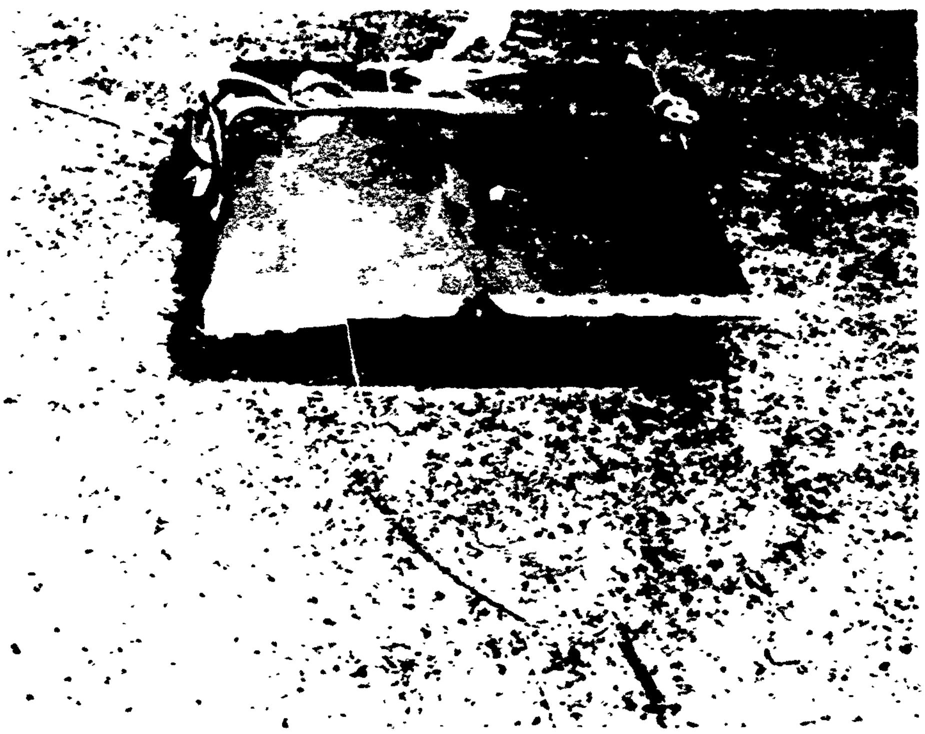


Figure 33. Postcrash View of Hinge Connection on Seat. (Seat pan is shown here inverted.)

The seat pan was intact after the crash; however, extensive cracking of the fiber glass skin was evidence of the high stresses on the seat during the crash sequence. The designed "weak line", shown by the white line in Figure 36, showed no evidence of failure. The following series of photographs shows the effect of the crash forces on the seat pan. All of these photographs were taken after the seat had been removed from the test vehicle.

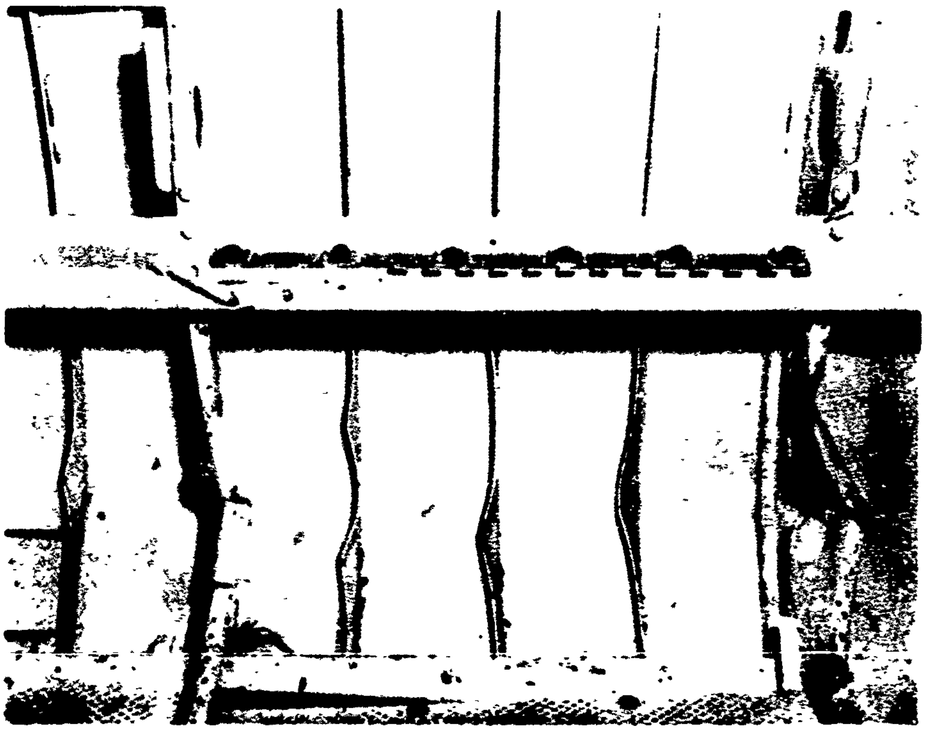


Figure 34. Postcrash View of Portion of Hinge Connection Remaining Attached to Wall.

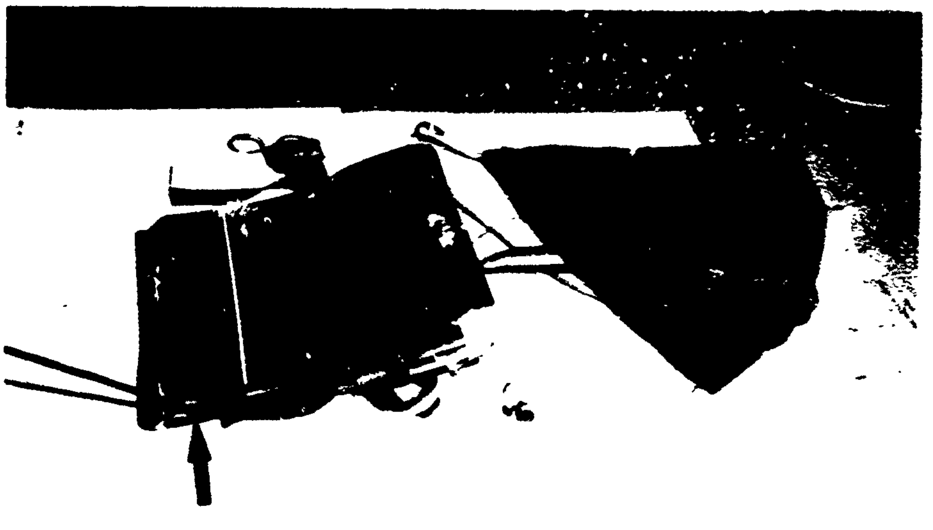


Figure 35. View of Right Side of Seat Pan. (White line indicates "weakened" portion of seat pan. Arrow indicates crack in fiber glass cover of seat pan.)

Figure 36. Front View of Seat Pan. (Arrow indicates crack in front of fiber glass cover.)

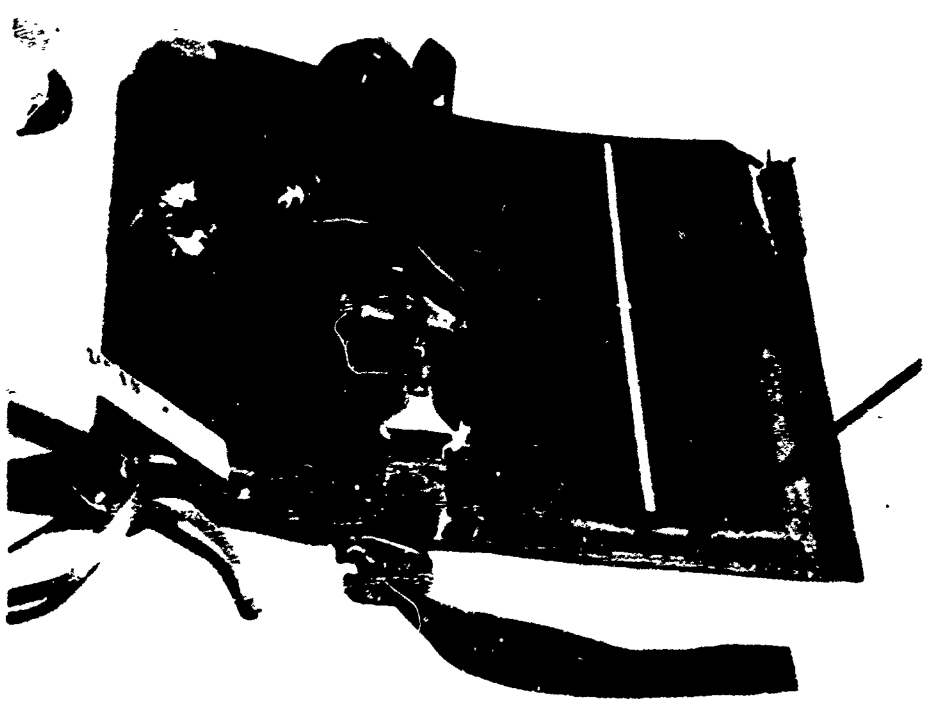


Figure 37. Left Side View of Seat Pan. (Each pointer indicates crack in seat pan.)

The upper surface of the seat pan showed only a small permanent deformation, as shown in Figure 37. The deformation was concentrated generally along a line from the right front corner of the seat pan to the seat-belt slot of the left side of the seat. Paint was shattered for the first 4 inches at the right forward end of the line and the left rear 6 inches of the line. In addition, there was a 1-square-inch piece of fiber glass that separated from the honeycomb immediately behind the left seat-belt slot. In the center portion of the deformation line, there were several 1/4-inch depressions covering a total area of about 20 square inches. The high-speed film shows that the seat bent along this line to about a 30-degree angle during the crash. This bending deformation left a visible line in the surface but resulted in only a small permanent set. There were no depressions in the seat pan corresponding to the buttocks position of the dummy.

Along the line of the hinge connection, the right-hand 4 inches of the seat pan showed shattered fiber glass. There was evident cracking of the paint along the remainder of the hinge connection.

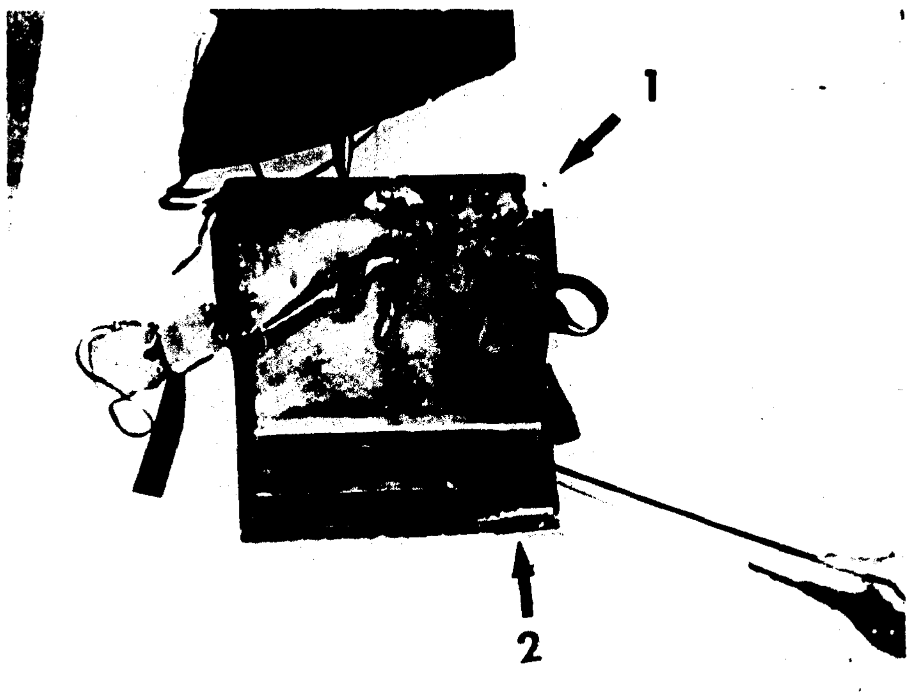


Figure 38. Top View of Seat Pan. (Pointer indicates "weak line". Arrow 2 shows shattered fiber glass at right side of hinge connection. Arrow 1 shows failed seat pan retainer.)

At the point where the floor strut attached to the seat, there was considerable cracking of the glass fibers. This was particularly evident on the bottom, as shown in Figure 39.

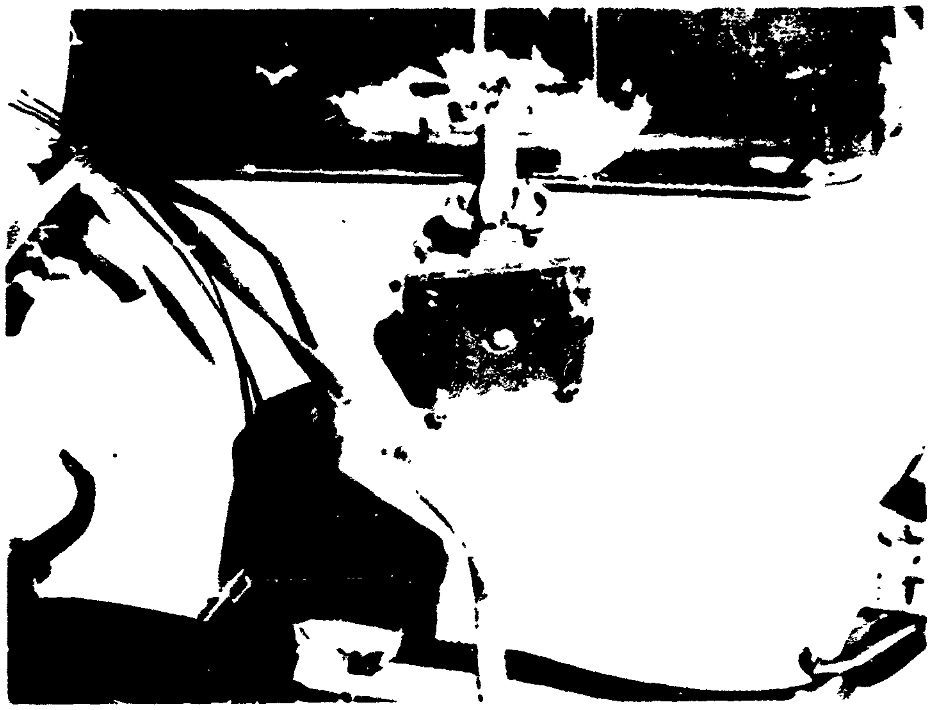


Figure 39. Postcrash View of Bottom Surface of Seat. (Arrow shows attachment point of energy-absorbing strut to seat pan.)

Figure 40. Postcrash View of Upper Surface of Seat Opposite Strut Attachment.

Kinematics of Crash Sequence

A kinematic sketch of the impact showing the behavior of the seat and dummy is presented as Figure 41. Significant occurrences during the crash sequence are shown along with the times at which these events occurred from initial impact. The times shown are also related to the accelerometer-time and force-time histories included and discussed later in this chapter.

Oscillograph Records

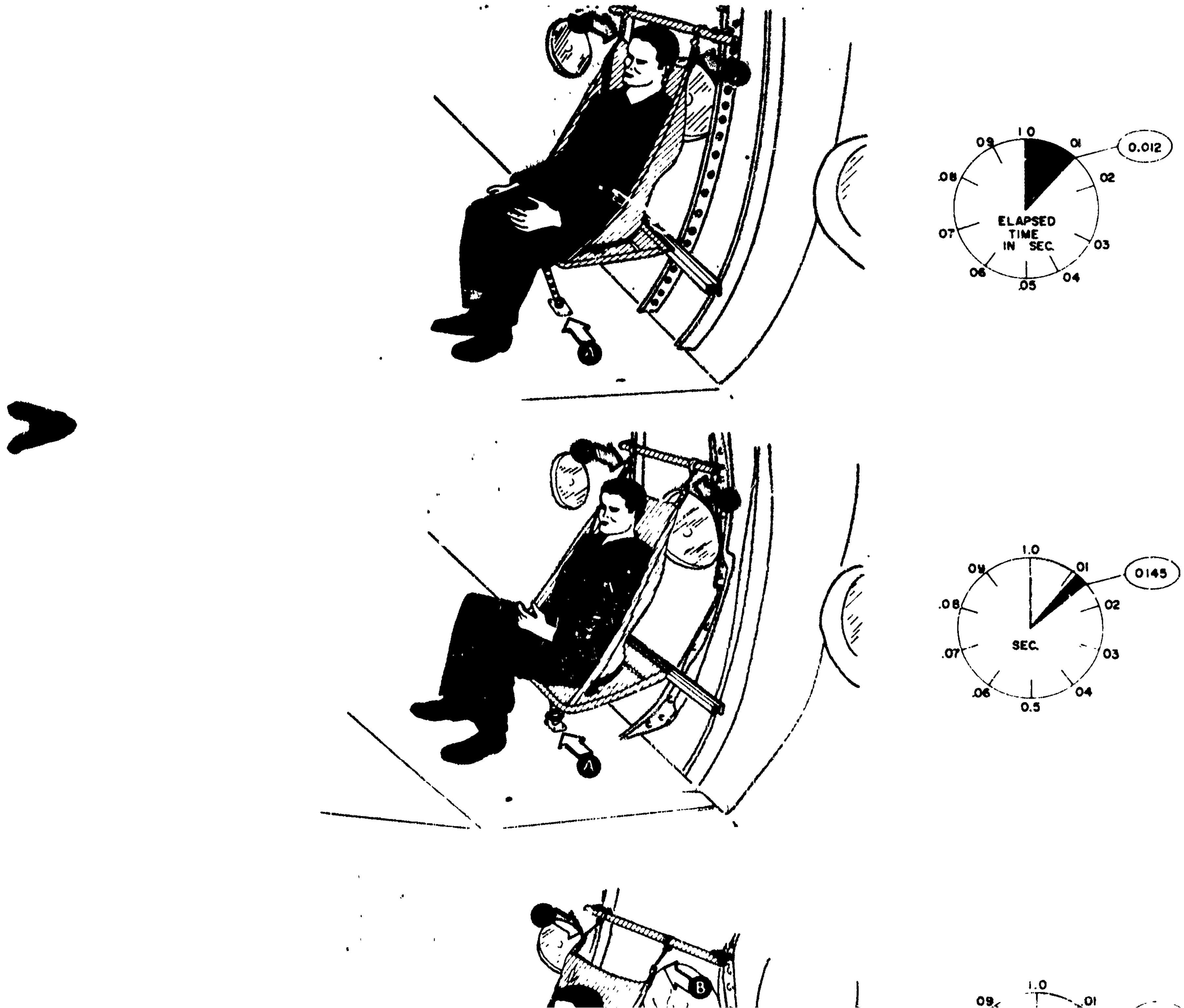
The accelerometer-time and force-time records obtained during the crash are presented in Figure 42. The observations presented here may be followed through reference to the kinematic drawing and the oscillograph traces.

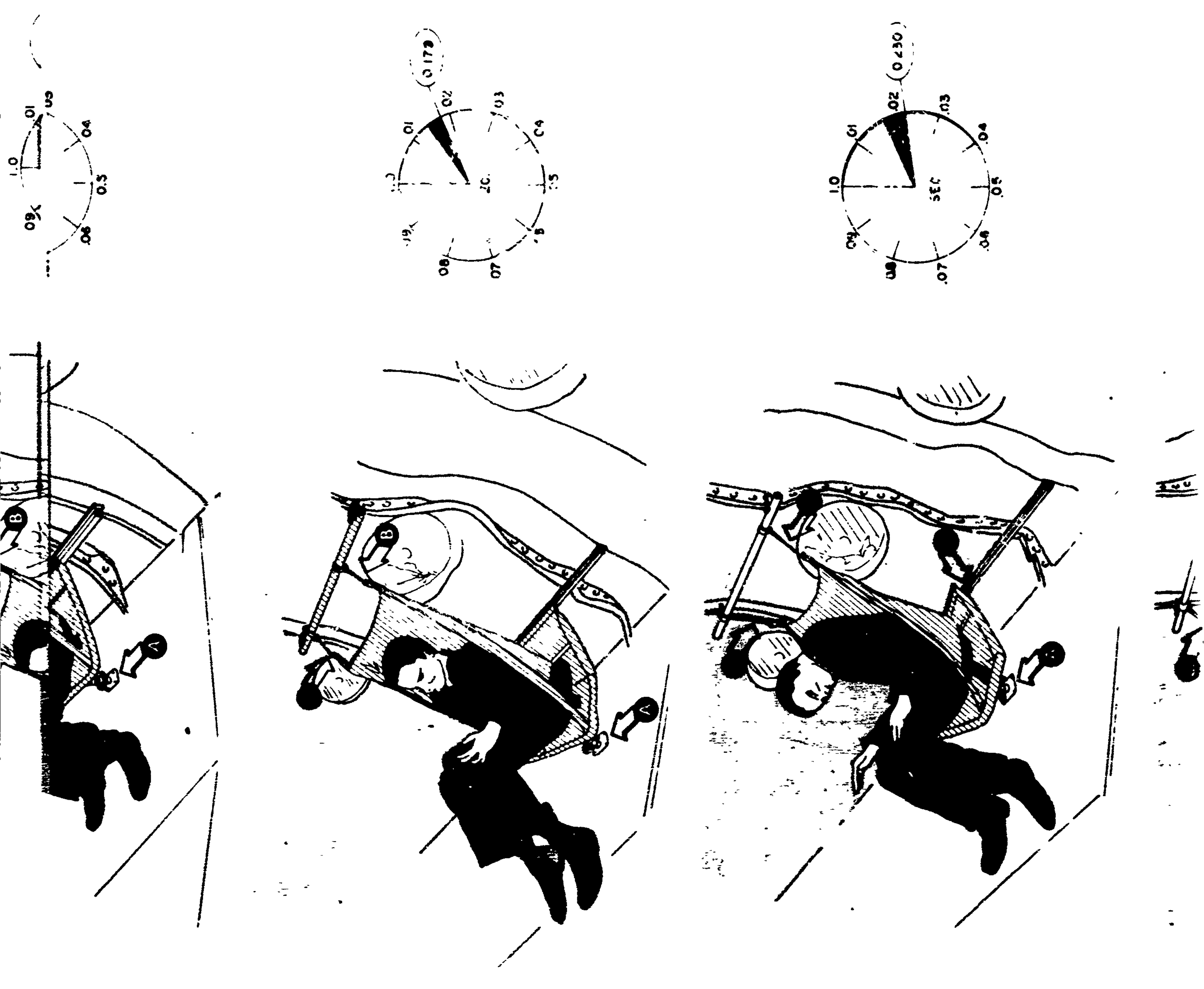
No appreciable deceleration (horizontal or vertical) was imposed upon the dummy from the time of impact of the nose gear of the CH-21A (time zero) to about 0.12 second. The vertical accelerometer then showed a fairly steady buildup at a rate of onset of 535G per second up to a maximum reading of 30G at t = 0.176 second. The acceleration then reduced to zero at t = .203 second. Duration of this pulse was approximately 0.083 second. The peak vertical acceleration of the cabin floor was approximately 175G at 0.127 second.

The longitudinal acceleration (lateral with respect to the dummy) built up to an average value of 19G between t = 0.170 second and t = 0.188 second and then reduced to a minimum of about 5G at t = 0.208 second. A second peak (about 15G maximum) occurred between t = 0.208 second and t = 0.230 second. Total duration of this pulse was approximately 0.117 second. The peak longitudinal acceleration of the cabin floor was approximately 45G at 0.127 second.

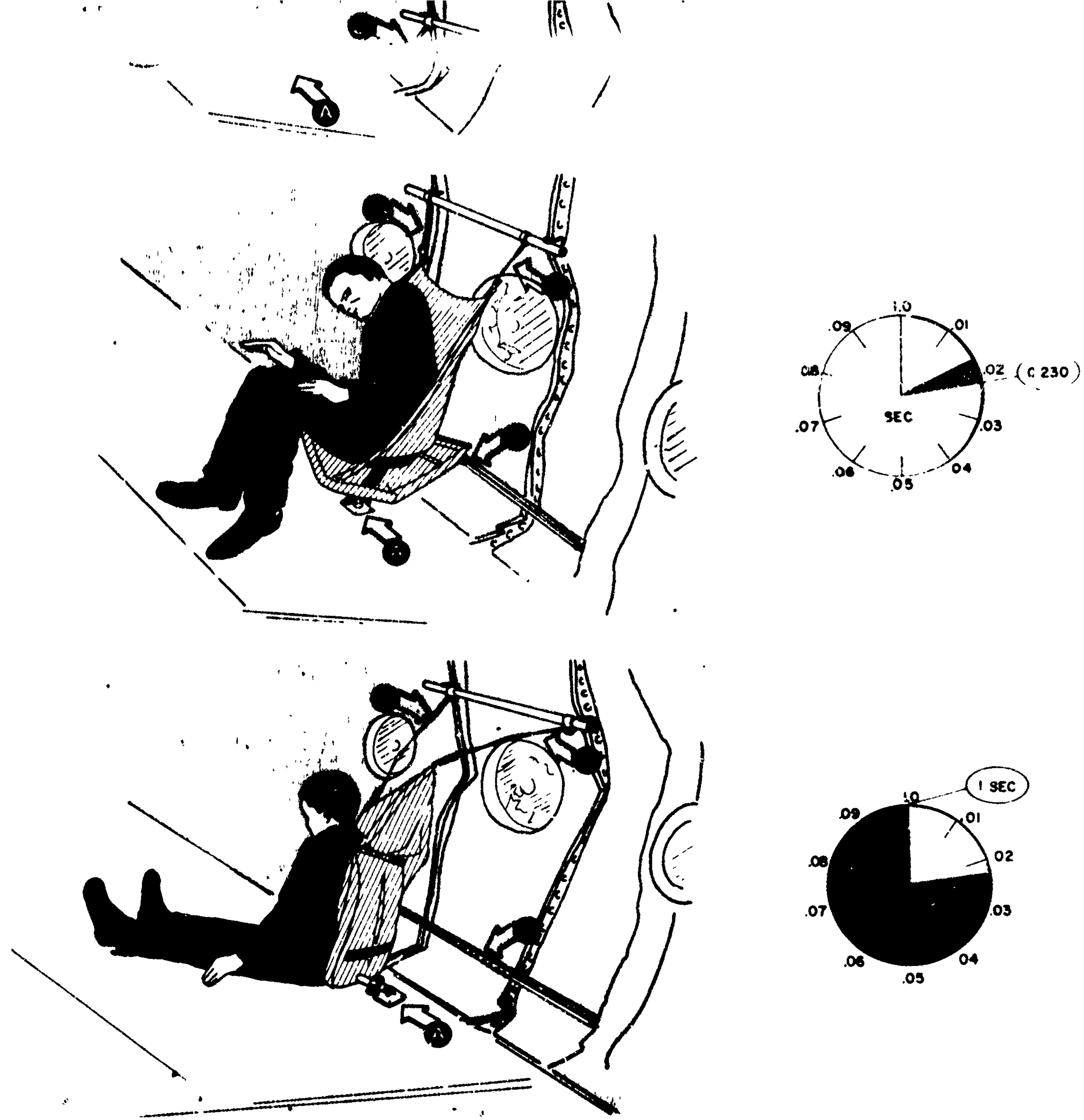
The significant occurrences during the crash sequence, shown graphically on the kinematic sketch, Figure 41, are indicated by arrows on the accelerometer-time and force-time histories, Figure 42.

The seat belt force built up almost linearly to a maximum of 500 pounds from t = 0.13 second to t = 0.19 second as the depressing of the energy-absorbing strut allowed the dummy to shift toward the front of the seat. The seat-belt load remained at 400 to 500 pounds until the dummy contacted the floor after the seat hinge sheared from the wall. The seat-


0.012
ELAPSED TIME IN SEC.
1.0
.01
.02
.03
.04
.05
.06
.07
.08
.09
0145
SEC.
0.5
A
B

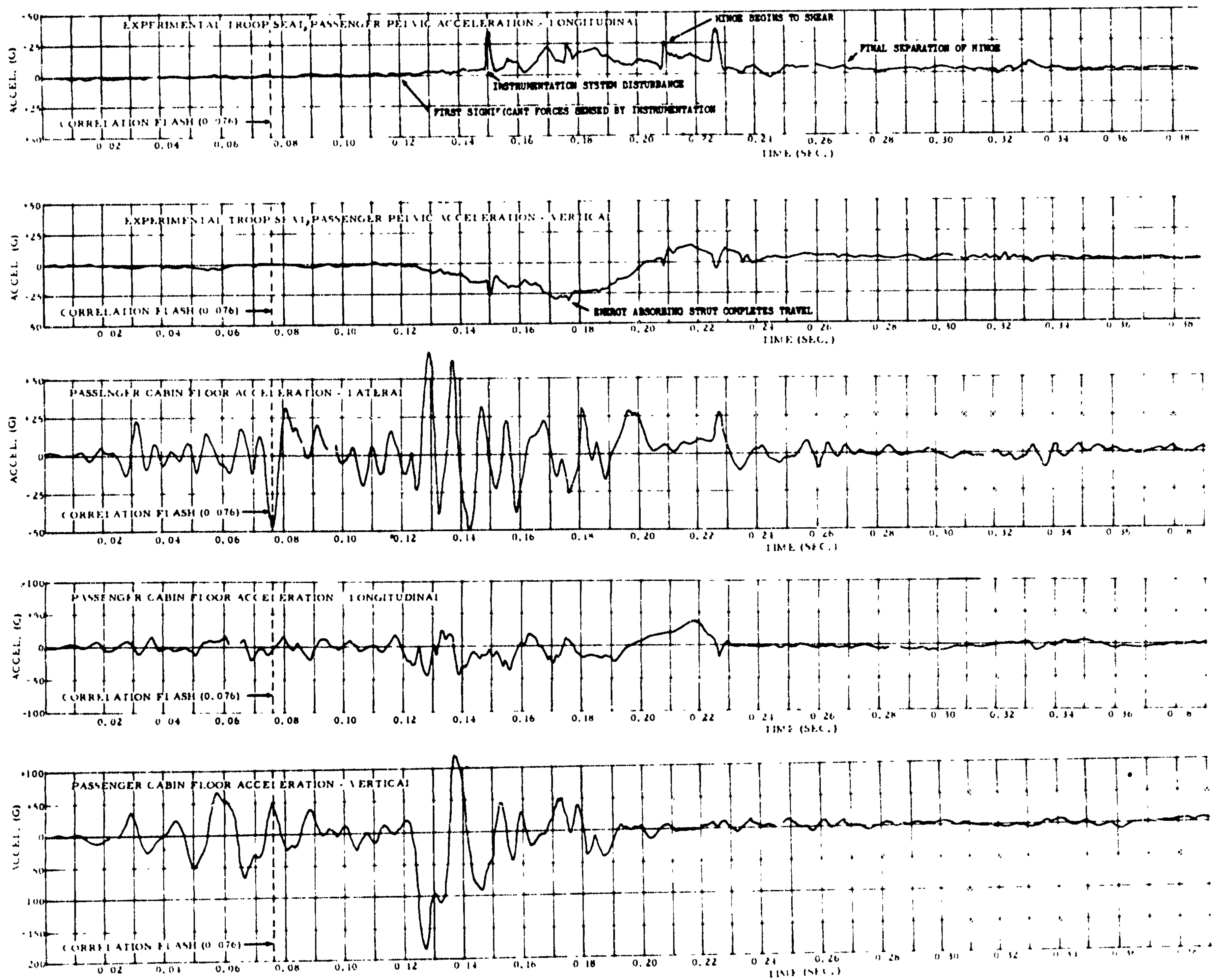


B



C

Figure 41. Kinematic Sketch of Seat 2 and Dummy During Crash Impact Sequence, T-9. Arrows A show the kinematics of the energy-absorbing strut; Arrows B show the kinematics of the energy-absorbing device in the upper supports; Arrows C show the sheared seat mounting hinge.


EXPERIMENTAL TROOP SEAT, PASSENGER PELVIC ACCELERATION - LONGITUDINAL
HINGE BEGINS TO SHEAR
FINAL SEPARATION OF HINGE
INSTRUMENTATION SYSTEM DISTURBANCE
FIRST SIGNIFICANT FORCES SENSED BY INSTRUMENTATION
CORRELATION FLASH (0.076)
ACCEL. (G)
TIME (SEC.)
EXPERIMENTAL TROOP SEAT, PASSENGER PELVIC ACCELERATION - VERTICAL
ENERGY ABSORBING STRUT COMPLETES TRAVEL
CORRELATION FLASH (0.076)
ACCEL. (G)
TIME (SEC.)
PASSENGER CABIN FLOOR ACCELERATION - LATERAL
CORRELATION FLASH (0.076)
ACCEL. (G)
TIME (SEC.)
PASSENGER CABIN FLOOR ACCELERATION - LONGITUDINAL
CORRELATION FLASH (0.076)
ACCEL. (G)
TIME (SEC.)
PASSENGER CABIN FLOOR ACCELERATION - VERTICAL
CORRELATION FLASH (0.076)
ACCEL. (G)
TIME (SEC.)

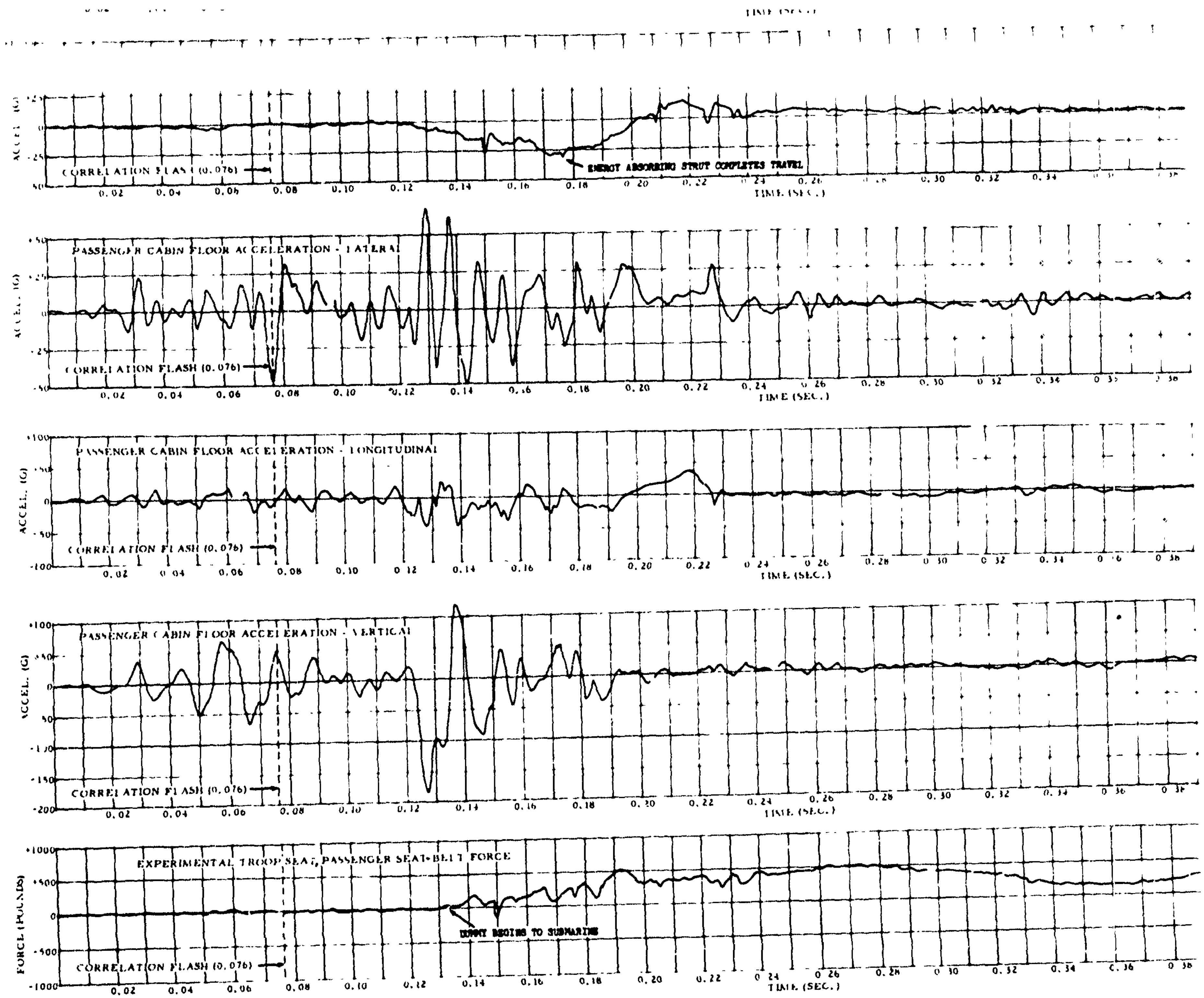


Figure 42. Accelerometer-Time and Force-Time Histories, Seat 2, During CH-21 Helicopter Crash Test T-9.

belt load force reduced slightly to between 200 and 300 pounds as the dummy came in contact with the floor but rose again to 600 pounds at t = 0.46 second. After the dummy had slipped to the floor, the seat belt and friction on the floor were its only restraint. The seat belt load represents an acceleration force on the dummy of 2-1/2G to 3G. The seat-belt load roughly approximates the deceleration rate of the helicopter.

DISCUSSION OF TEST RESULTS

Impact survival is generally considered to be a combination of factors including the following:

1. The occupant's environment must remain reasonably intact in order to provide "living space".

2. The occupant should be adequately restrained and not receive dangerous or fatal injury as a result of forcible contact with environmental structure.

3. The crash force transmitted to the occupant should not exceed the survivable limits of human "G" tolerance in conjunction with the restraint systems used.

In spite of the severity of this particular crash, it is quite probable that an occupant in this seat would have survived. Even though the seat was sheared from the wall, sufficient energy was absorbed over an extended period so that the forces imposed on the dummy were within survivable limits. The occupiable area in the vicinity of seat 2 was reduced by about 35 percent during the impact but was still adequate to provide "living space" for the seat occupant. The seat belt and shoulder harness provided enough restraint so that even after the seat sheared from the wall, there was no time when the dummy made forcible contact with environmental structure.

The problem of the hinge shearing from the wall can be solved by using a stronger hinge. The other malfunction in the seat, i.e., the failure of the seat pan to remain parallel to the floor, is also a relatively simple problem.

The primary reason that the seat pan in seat 2 did not bend as designed was because of the tendency of the occupant to slide forward on the seat pan as the strut depressed. This concentrated the vertical load on the extreme forward portion of the seat pan. The use of a seat-belt tiedown strap would help to maintain the occupant in the proper position on the seat pan.

The test on seat 2 indicates that high acceleration levels experienced at the helicopter floor can be attenuated to within survivable limits under severe conditions of impact.

SEAT 3, TESTED IN DRONE CRASH (T-12) ON 5 OCTOBER 1963

DESCRIPTION OF TEST SEAT 3

The same seat was used in the last two tests, T-12 and T-13. The structural differences between seat 2 and seat 3 were that (1) the hinge-to-wall attachment was strengthened and (2) the "weak line" where the seat pan was designed to bend was made more pronounced to ensure bending at this point. These features can be seen in Figure 43.

Figure 43. View of Seat 3. (Arrow 1 shows reworked hinge, and arrow 2 shows "weak line".)

The dummy was seated and restrained in seat 3 in the same manner as it was in the preceding tests (see Figure 44).

Figure 44. Dummy Installation in Seat 3.

TEST CONDITIONS

The helicopter did not attain its planned flight profile and reached a height of only approximately 11 feet. The following conditions existed at impact:

Horizontal velocity	38.5 feet per second
Vertical velocity	11.0 feet per second
Flight path velocity	40.0 feet per second
Flight path angle	16 degrees
Pitch	3 degrees up
Roll	5 degrees right
Yaw	0 degrees

TEST RESULTS

Fuselage Structure

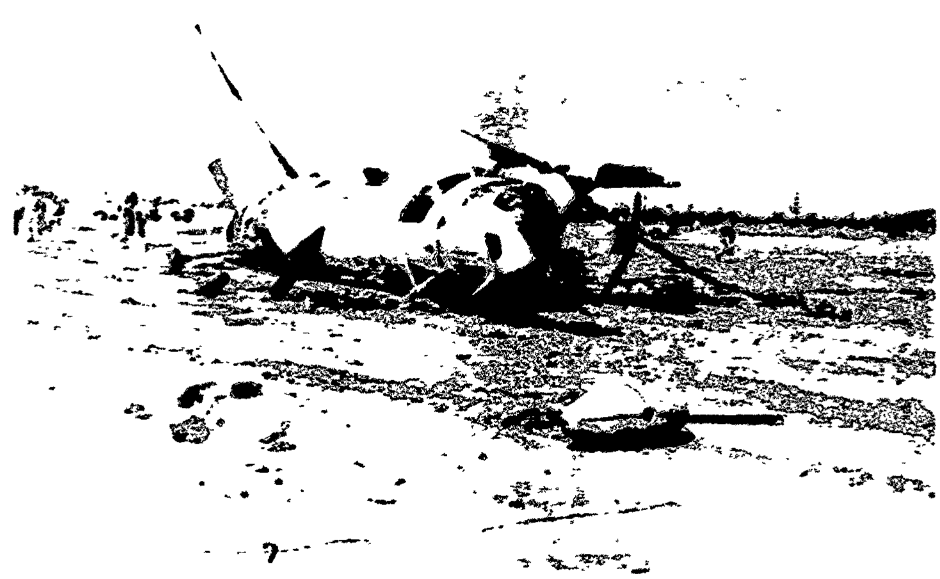


Figure 45. Postcrash View of CH-21A Test Vehicle Used in Third Test. (General location of experimental troop seat is shown by arrow.)

The impact conditions of the third drone test were very mild as far as fuselage structural deformation was concerned (see Figure 45). The landing gear broke free on impact, allowing the center of the fuselage to contact the ground. The major damage to the aircraft was aft of the passenger compartment, where the impact was sufficient to break the helicopter fuselage just forward of the engine and to deform the understructure inward approximately 16 inches directly below the fuel tank.

The underside of the passenger compartment was only slightly damaged, as shown in Figure 46.

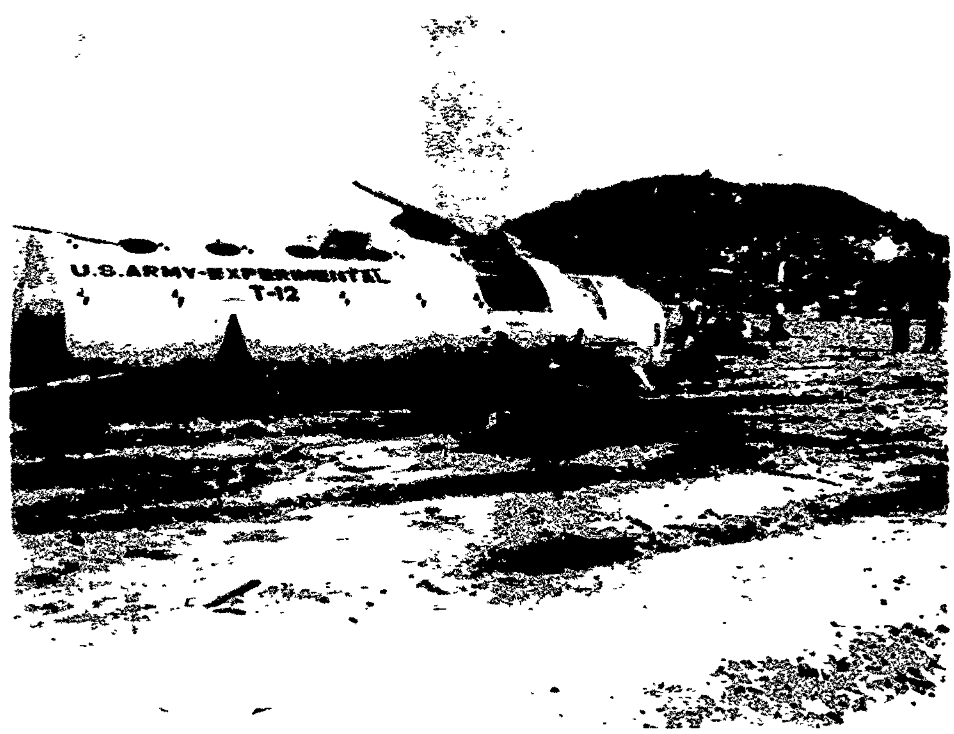


Figure 46. Postcrash View of Underside of Passenger Compartment. (Arrow shows location of seat 3.)

The aircraft struck the ground with sufficient roll to cause it to come to rest on its side. The interior was at an approximate 60-degree angle to the horizontal.

The accident was very moderate so far as the forces involved were concerned and was definitely in the survivable range.

Postcrash Examination of Seat

Figure 47 shows the position of the seat and dummy immediately after the crash. The most noticeable effect of the impact was the obvious column collapse. Unfortunately, the high-speed camera coverage of the test was lost so that the actual cause of the column failure cannot be determined.

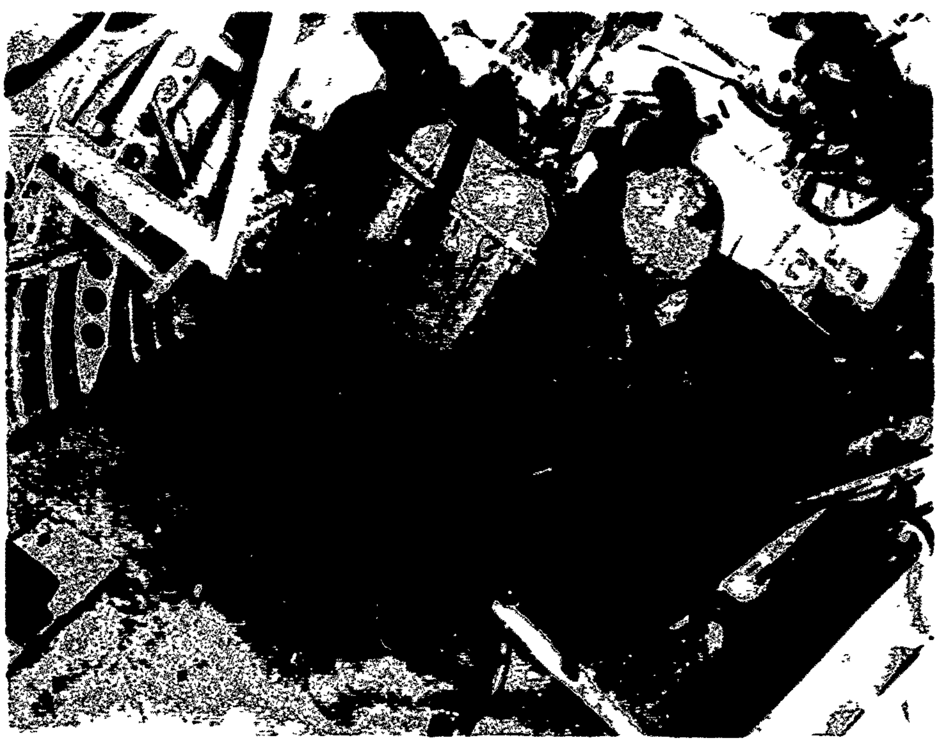


Figure 47. Postcrash Position of Seat and Dummy. (Arrow shows energy-absorbing strut.)

Figure 48 shows that the dummy nearly freed itself of the shoulder restraint harness.

Figure 48. Postcrash View of Dummy Showing Restraint System.

Figure 49. Closeup Postcrash View of Seat 3. (Arrow 1 shows energy-absorbing strut. Arrow 2 shows marks left in seat pan by dummy's buttocks.)

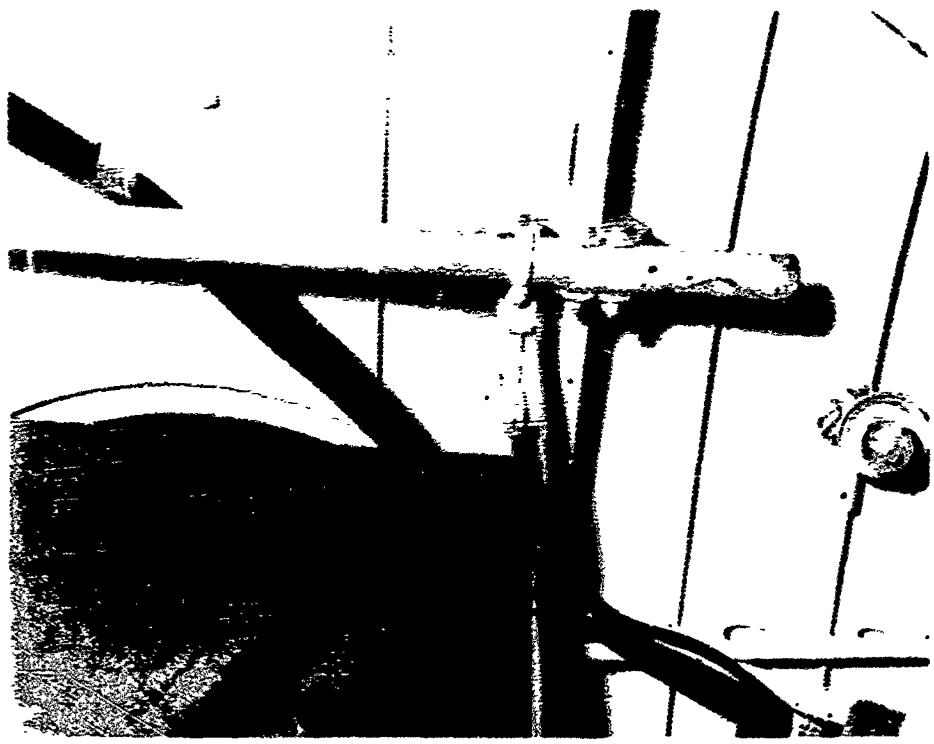


Figure 50. Closeup View of Upper Attenuators.

Figures 49 and 50 show the details of the critical areas in the energy-absorption system of seat 3. There was only the slightest evidence that the floor strut began to depress, and there was no sign that the upper attenuators were beginning to extend.

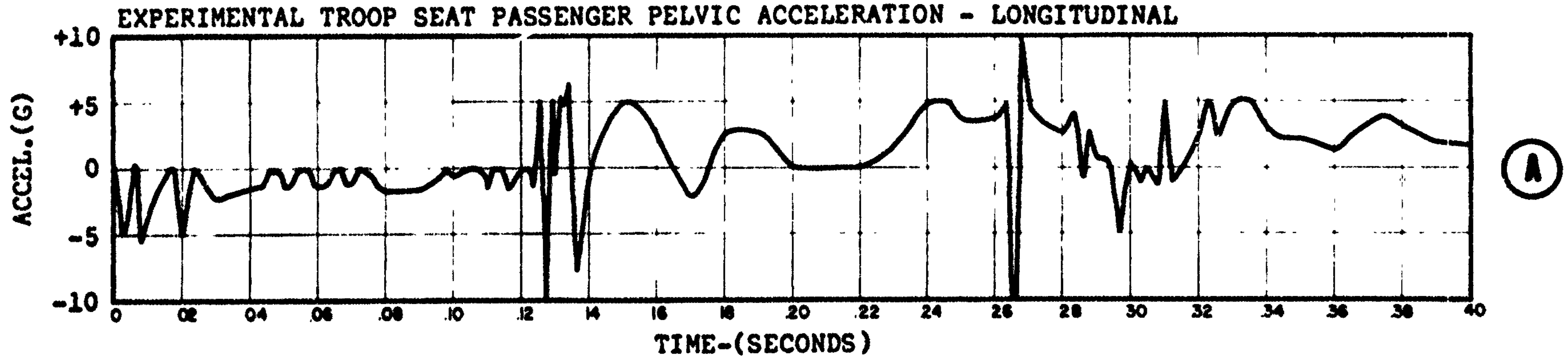
Figure 49 also shows a depression made in the seat pan by the buttocks of the dummy.

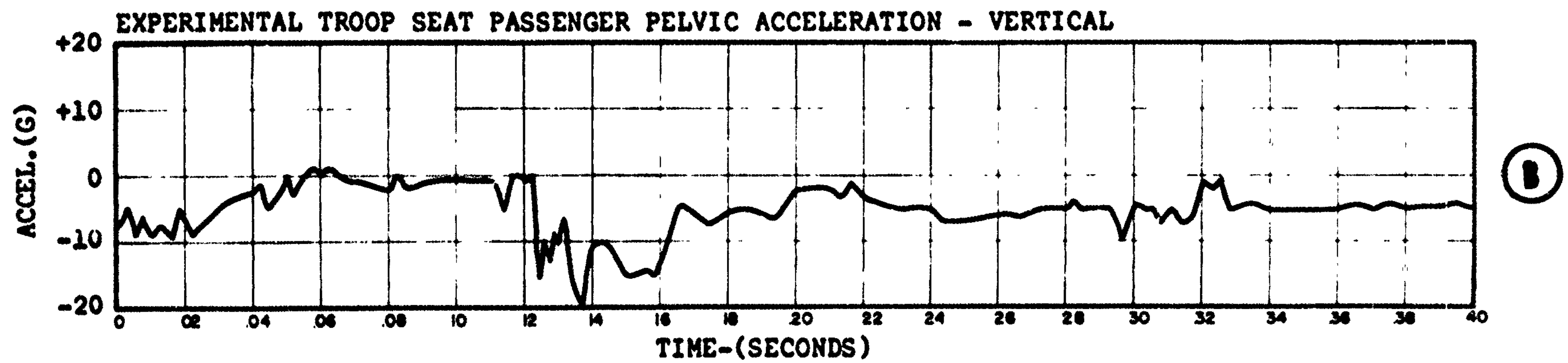
DISCUSSION OF TEST RESULTS

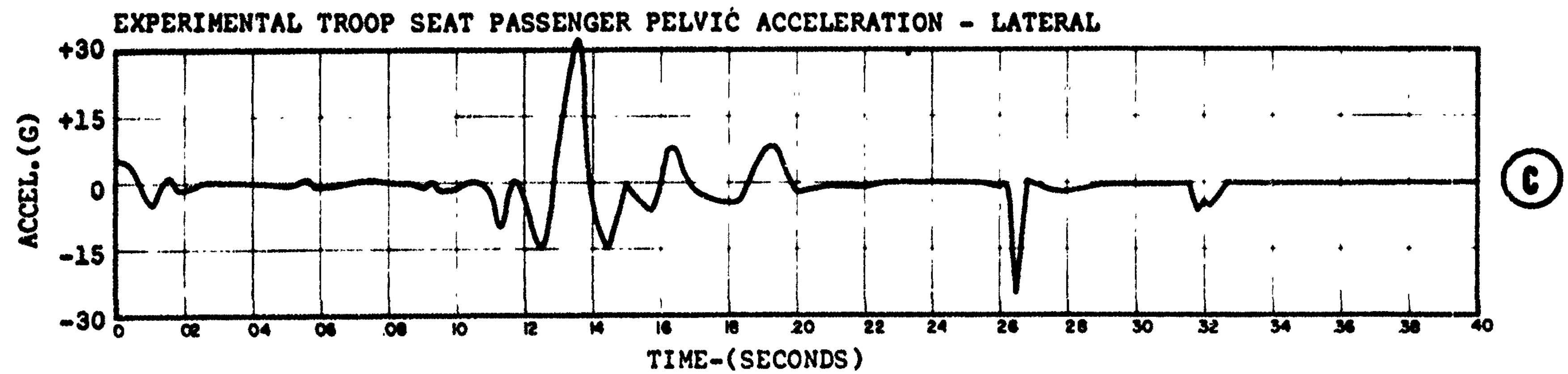
Due to the mild impact conditions encountered, a detailed analysis of this crash test and its effect on seat 3 would not be particularly significant. Further, the onboard camera coverage was lost, so that frame-by-frame analysis of the bent strut was not possible. The oscillograph records obtained in the crash are shown in Figure 51.

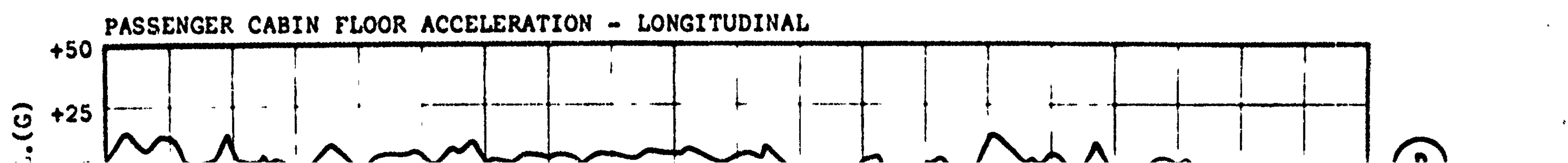
The bend in the energy-absorbing strut had not occurred in previous crash tests. Close examination of the strut showed only the slightest evidence of peeling over the die; little peeling over the die was anticipated, since 1800 pounds is required to depress it.

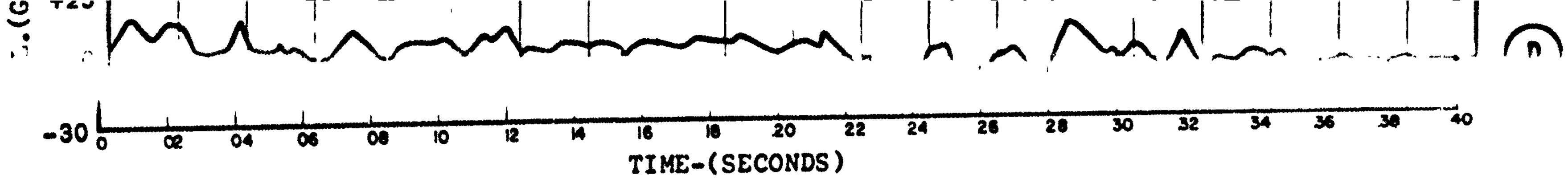
The only conclusions that can be drawn regarding the bending of the energy-absorbing strut are general and speculative. The possibility exists that the dummy's foot contacted the strut when the helicopter turned on its side or that the turning over of the helicopter created a combination of loads on the strut that caused the column collapse. The joints at the end of the strut could have bound up, thus preventing free movement. The latter possibility merits consideration in view of the close tolerances that were used in the strut manufacture, particularly in the strut-to-structure attachment areas on the floor and the underside of the seat.


EXPERIMENTAL TROOP SEAT PASSENGER PELVIC ACCELERATION - LONGITUDINAL
ACCEL.(G)
+10
+5
0
-5
-10
TIME-(SECONDS)
A

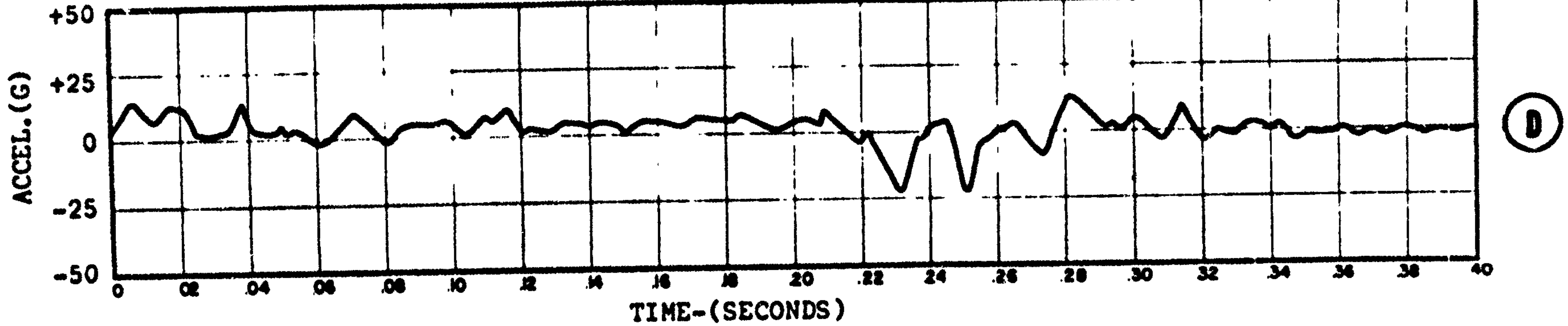

EXPERIMENTAL TROOP SEAT PASSENGER PELVIC ACCELERATION - VERTICAL
ACCEL.(G)
+20
+10
0
-10
-20
TIME-(SECONDS)
B


EXPERIMENTAL TROOP SEAT PASSENGER PELVIC ACCELERATION - LATERAL
ACCEL.(G)
+30
+15
0
-15
-30
TIME-(SECONDS)
C

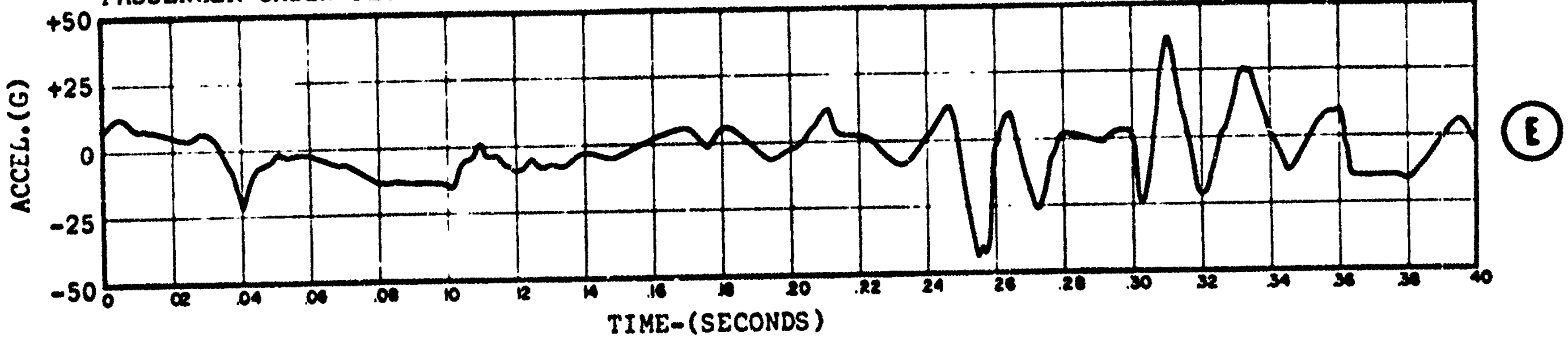

PASSENGER CABIN FLOOR ACCELERATION - LONGITUDINAL
+50
+25



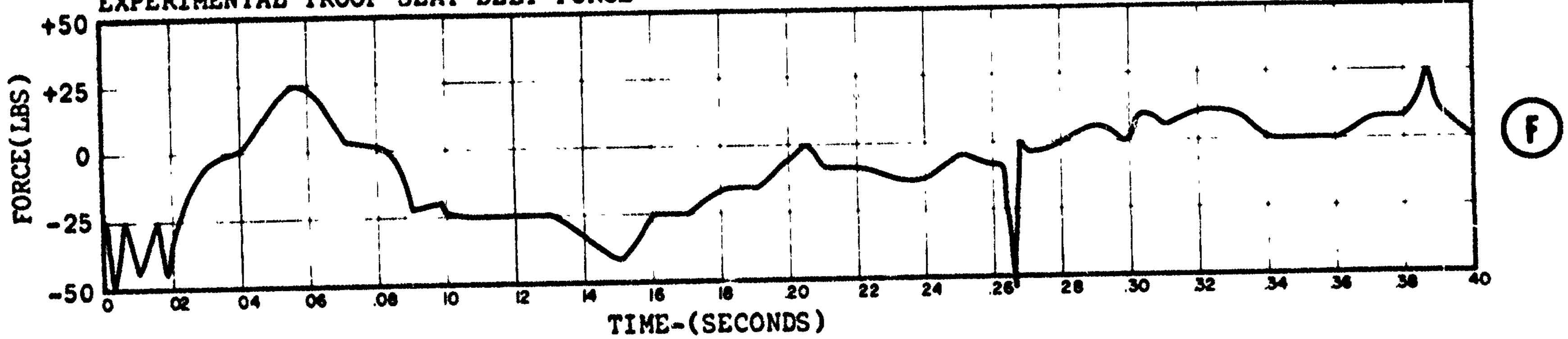
PASSENGER CABIN FLOOR ACCELERATION - LONGITUDINAL



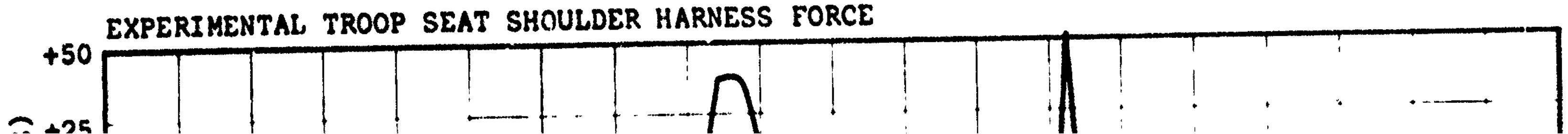
PASSENGER CABIN FLOOR ACCELERATION - VERTICAL



EXPERIMENTAL TROOP SEAT BELT FORCE



EXPERIMENTAL TROOP SEAT SHOULDER HARNESS FORCE



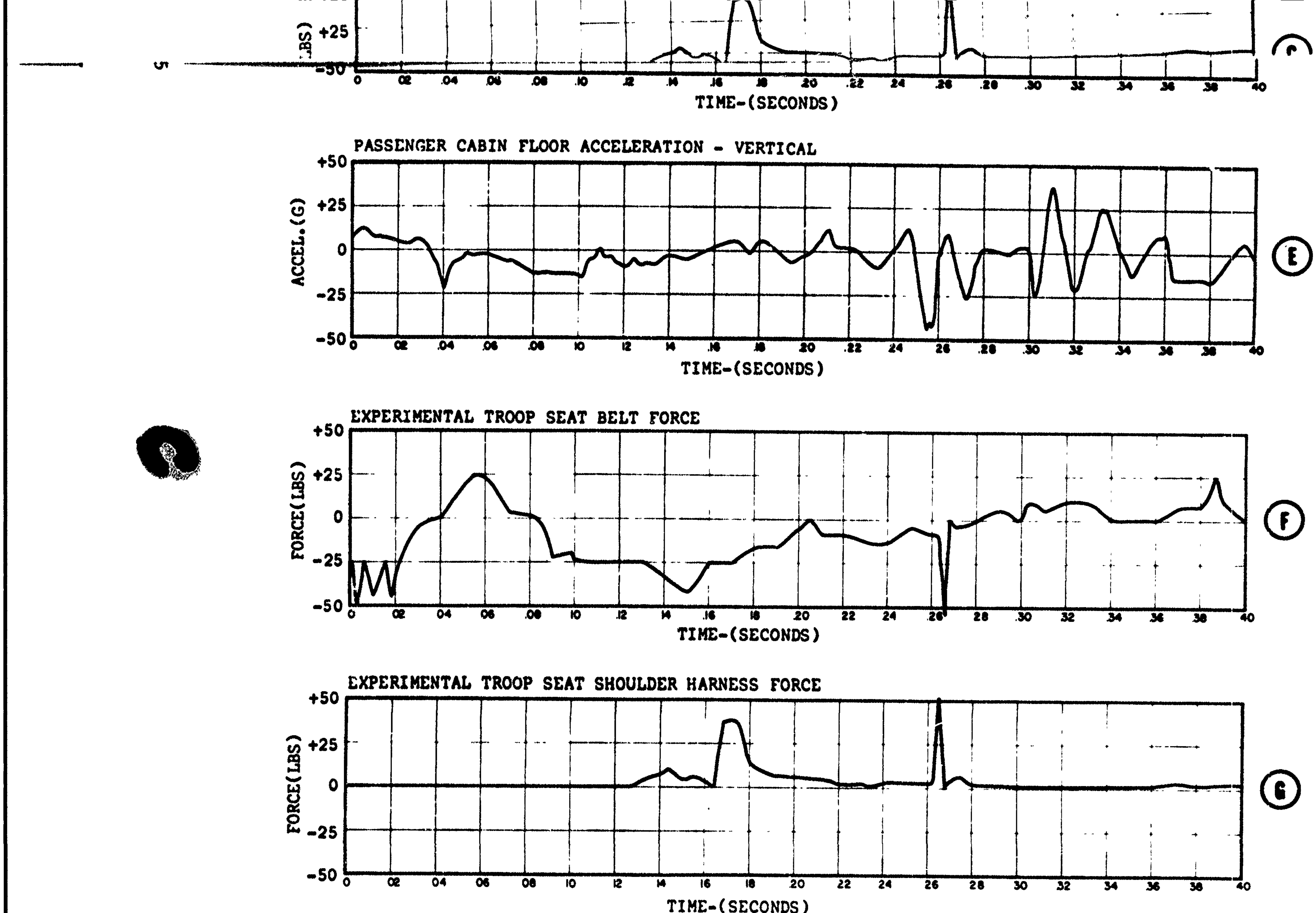


Figure 51. Accelerometer-Time and Force-Time Histories, Seat 3, During CH-21 Helicopter Crash Test T-12.

TEST CONDITIONS

This, the final test of this experimental concept, was conducted in a crane drop of the forward portion of the CH-21 fuselage that was left relatively intact from the previous drone crash. This type of test has produced excellent results in that it is possible to establish exact precrash conditions and to produce a crash environment of controlled magnitude. The test setup, shown in Figure 53, produced the following impact conditions:

Horizontal velocity	38.6 feet per second
Vertical velocity	36.8 feet per second
Flight path velocity	52.2 feet per second
Flight path angle	44 degrees
Pitch	5 degrees up
Roll	0 degrees
Yaw	0 degrees

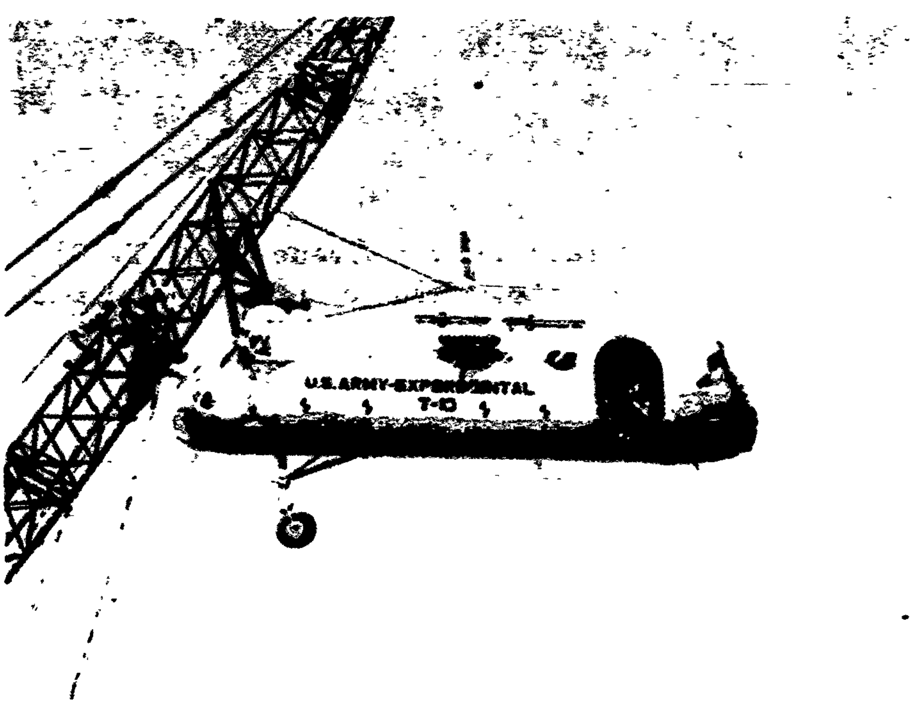


Figure 53. Crane Drop Method as Used in Test T-13.

TEST RESULTS

Fuselage Structure

The crash conditions of the crane drop very closely duplicated the acceleration environment of the first drone crash, T-7, and the deformation of the fuselage was similar (see Figure 54). The crushing of the floor and the body frame collapse showed no significant difference between drone tests and crane drops of similar impact conditions.

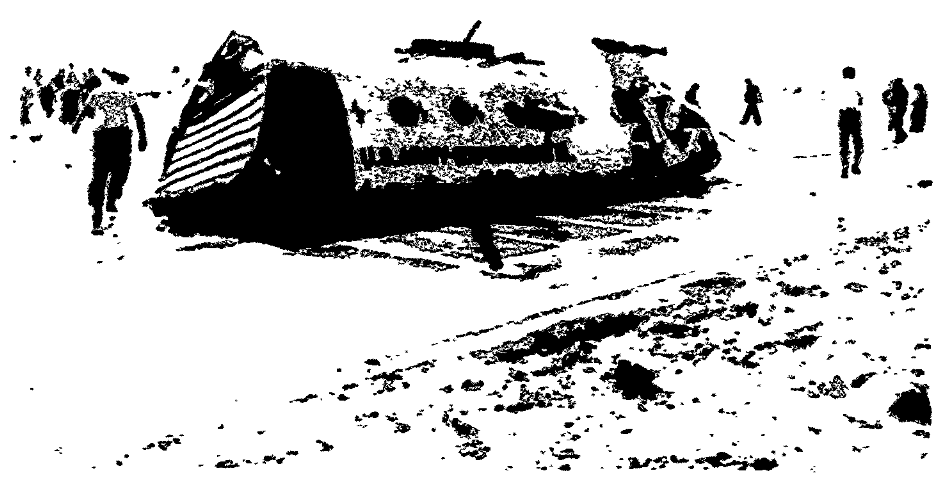


Figure 54. Postcrash View of Crane Drop (T-13). (Arrow shows area of seat 4 installation.)

Postcrash Examination of Seat

Figure 55 shows the postcrash position of the seat and dummy. All components of the seat functioned as intended and remained in place. The energy-absorbing strut depressed through its full stroke. The upper attenuators pulled through the friction device. The forward wire pulled approximately twice as far as the rear. The seat bent at the intended line. It also bent on a line between the seat belt slots. The restraint system remained in place as shown in Figure 56.

Figure 55. Postcrash View of Seat and Dummy.

Figure 56. Postcrash View of Dummy Showing Restraint System.

Figure 57 shows a closeup view of the energy-absorbing strut. Although there was a crack along the front edge of the honeycomb seat pan, the seat pan does not show the extensive cracking that was noted on the second test seat.

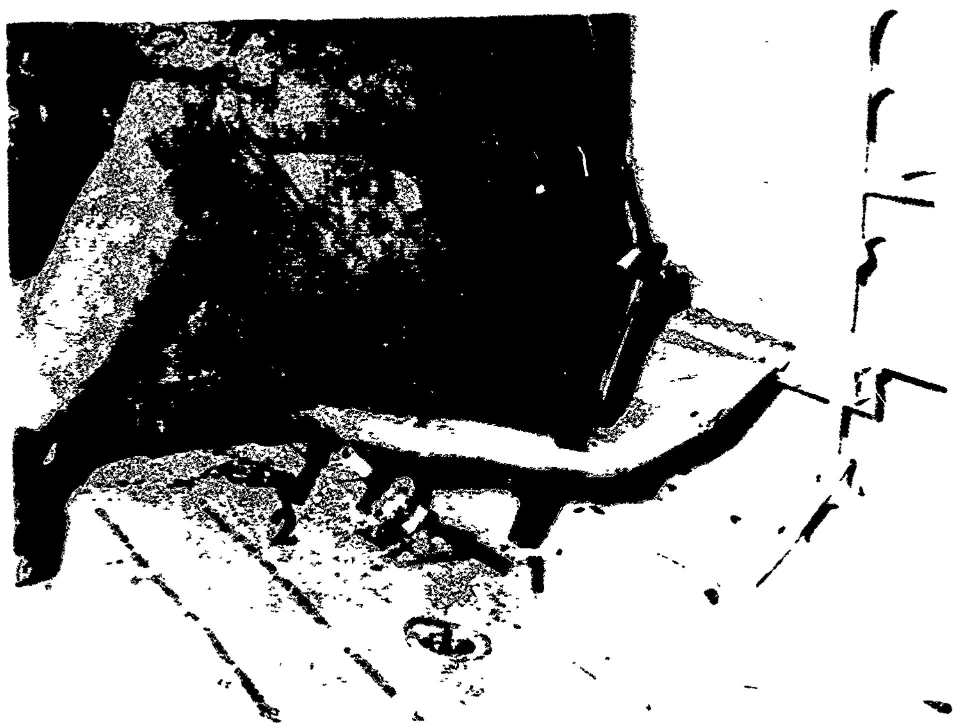


Figure 57. The Energy-Absorbing Strut - Postcrash. (Arrow 1 shows strut. Arrow 2 shows crack in front of seat pan.)

Figure 58 shows the seat pan after the dummy had been removed. The "weak line" did bend as intended, and a second bend occurred near the center of the seat pan. The bend across the center of the seat pan is more pronounced, however. There is evidence of cracking along the edge of the seat pan. The hinge showed no evidence of impending failure.

The upper support structure is shown in Figure 59. The photograph shows a definite leaning by the dummy toward the front of the crashed fuselage. The forward attenuator is extended approximately 12 inches, while the rear attenuator is extended 6 inches.

The floor in the vicinity of seat 4 remained intact as shown in Figure 60. The hat section used as a tie point for the piano hinge was also intact. The body frames in the area of the seat were relatively intact except for a pronounced bend approximately 6 inches above the floor.

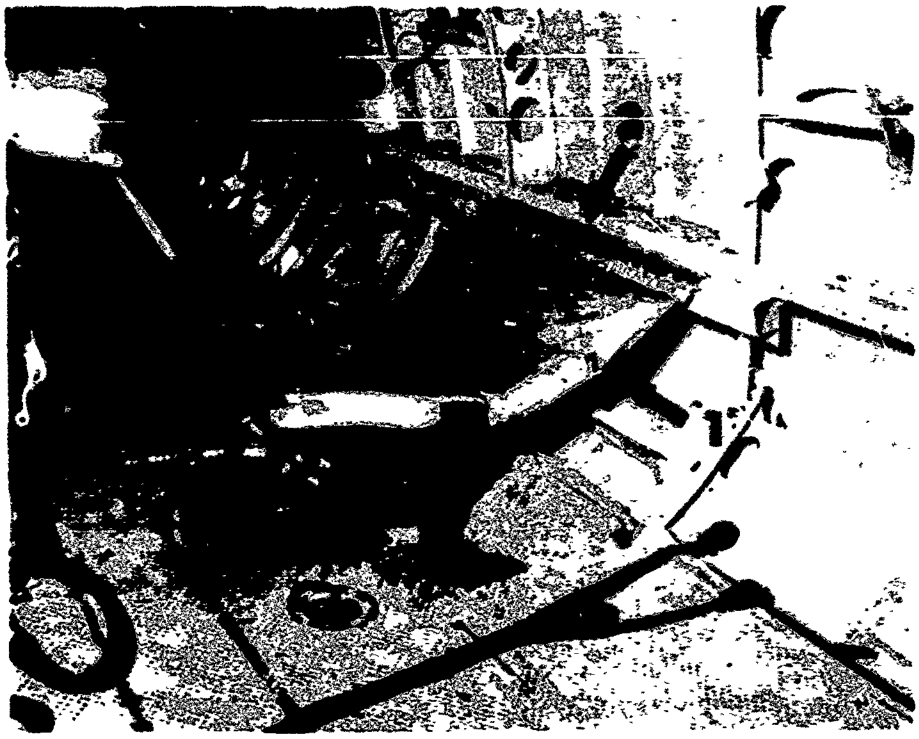


Figure 58. Seat Pan on Seat 4 After Dummy Had Been Removed. (Arrow 1 shows "weak line" bend. Arrow 2 shows bend across center of seat pan. Arrow 3 shows hinge.)

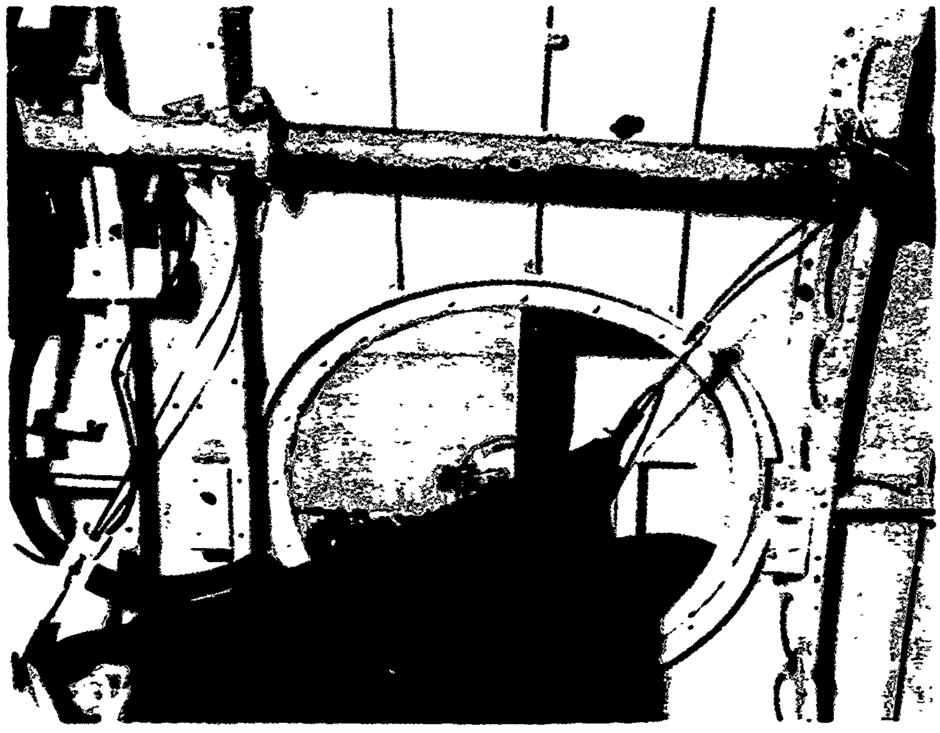


Figure 59. Postcrash View of Seat 4 Showing Upper Support Structure and Attenuators.

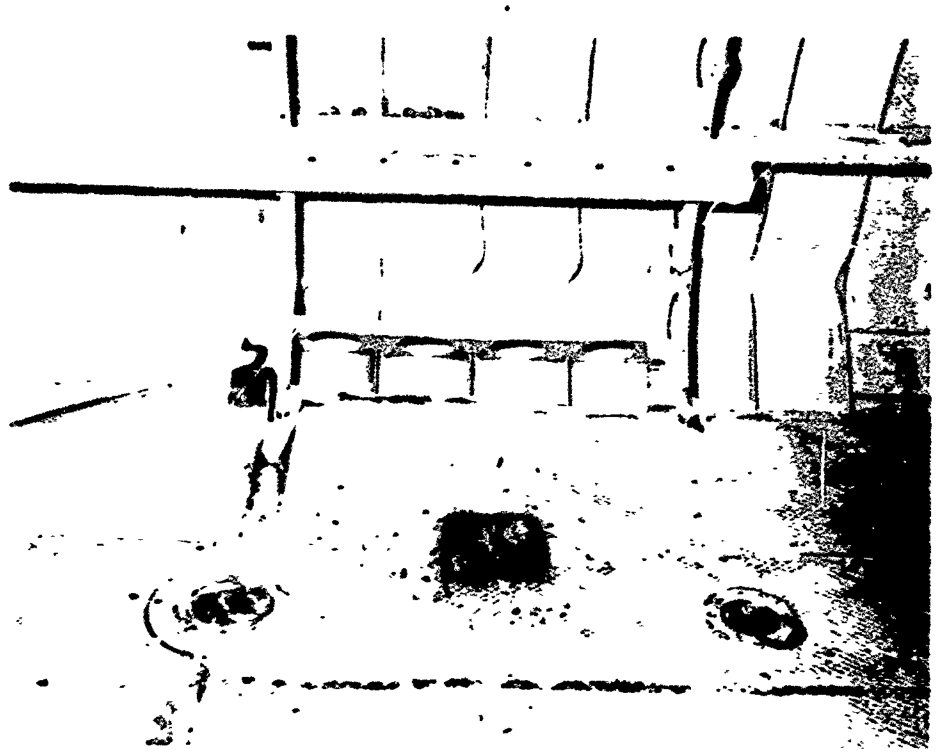


Figure 60. Floor and Lower Fuselage Wall in Vicinity of Seat 4.

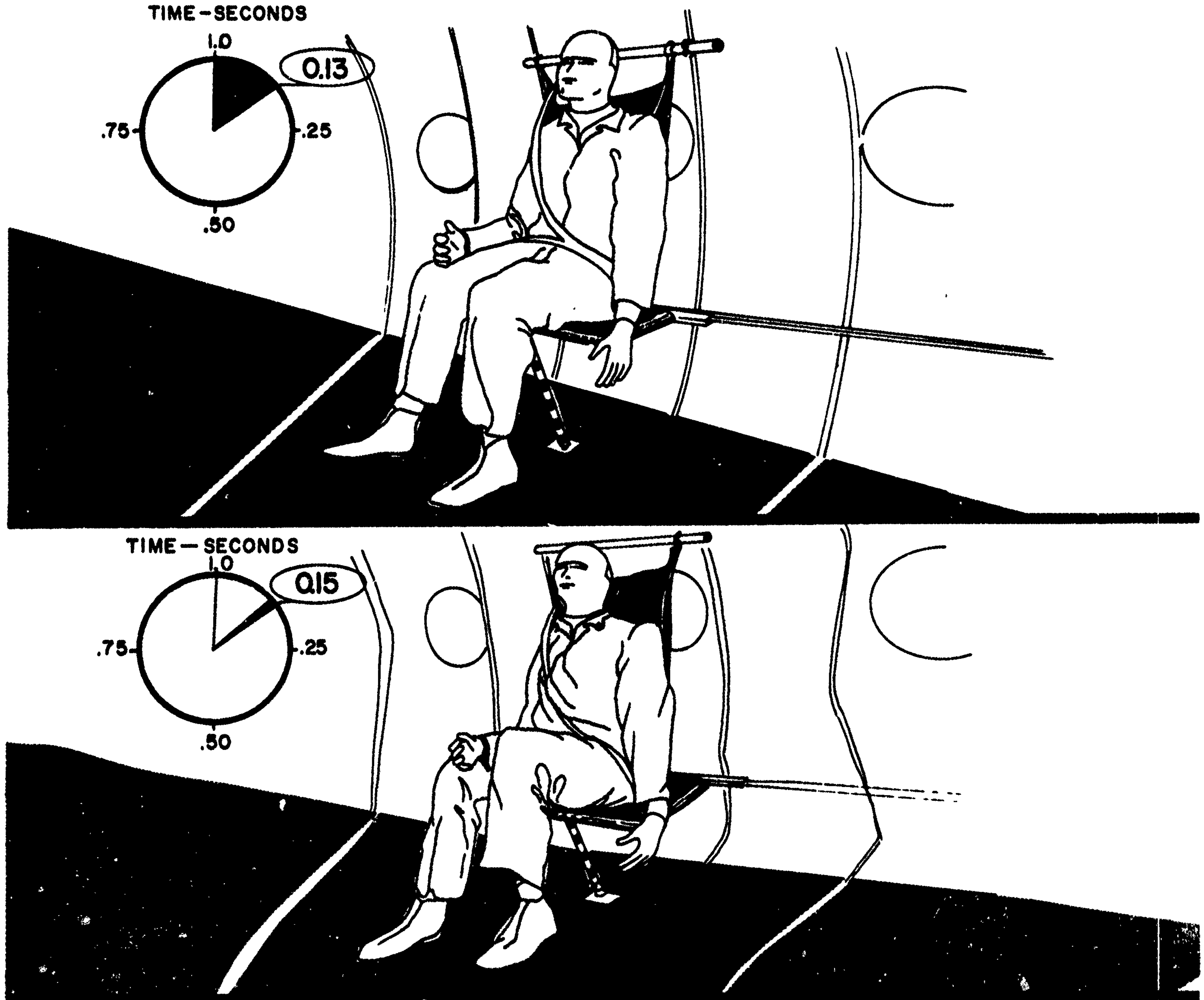
A kinematic sketch of the seat and dummy action during the crash is provided in Figure 61. The time shown in seconds to the left of each picture is correlated with the time at which the nose wheel contacted the runway, time zero, and also with the oscillograph records.

Oscillograph Records

The oscillograph traces applicable to the seat used in the fourth test are shown in Figure 62. Time zero and accelerometer orientation remain the same as in previous tests.

DISCUSSION OF TEST RESULTS

The impact was first sensed by the instrumentation at approximately 0.12 second. This is apparent on all traces relevant to the seat and the passenger cabin floor in the area of seat 4 (see Figure 62).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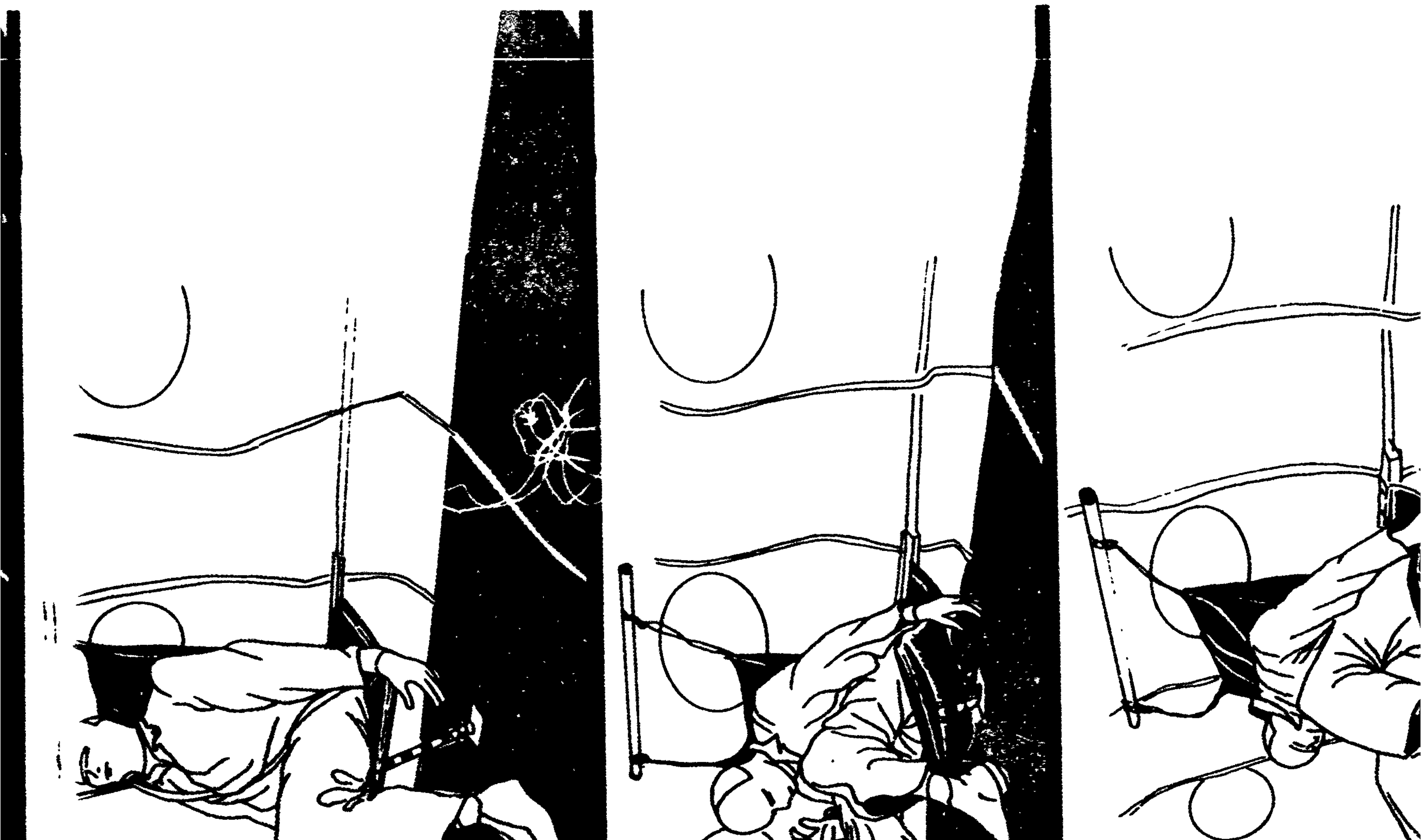
1.0
.25
.50
.75
0.13
TIME — SECONDS
1.0
.25
.50
.75
0.15


0.15
.25
1.0
.50
.75
0.20
TIME —SECONDS
FINAL POSITION

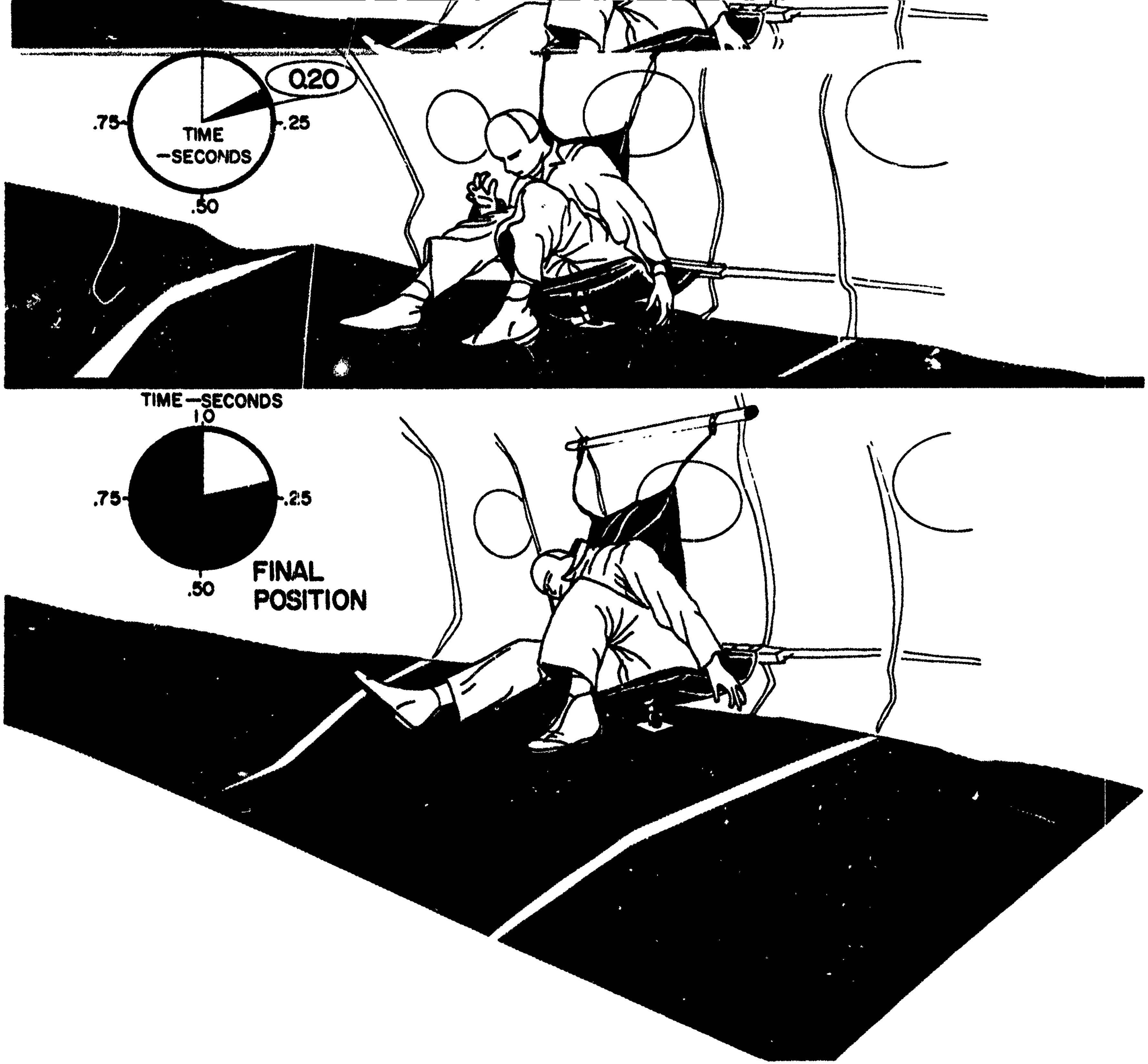
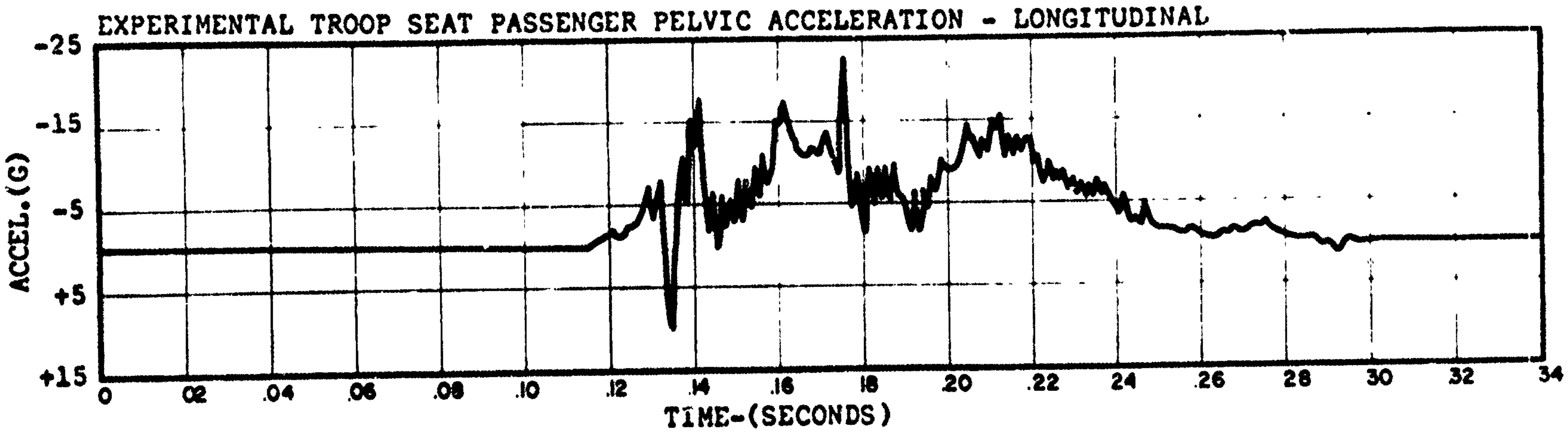
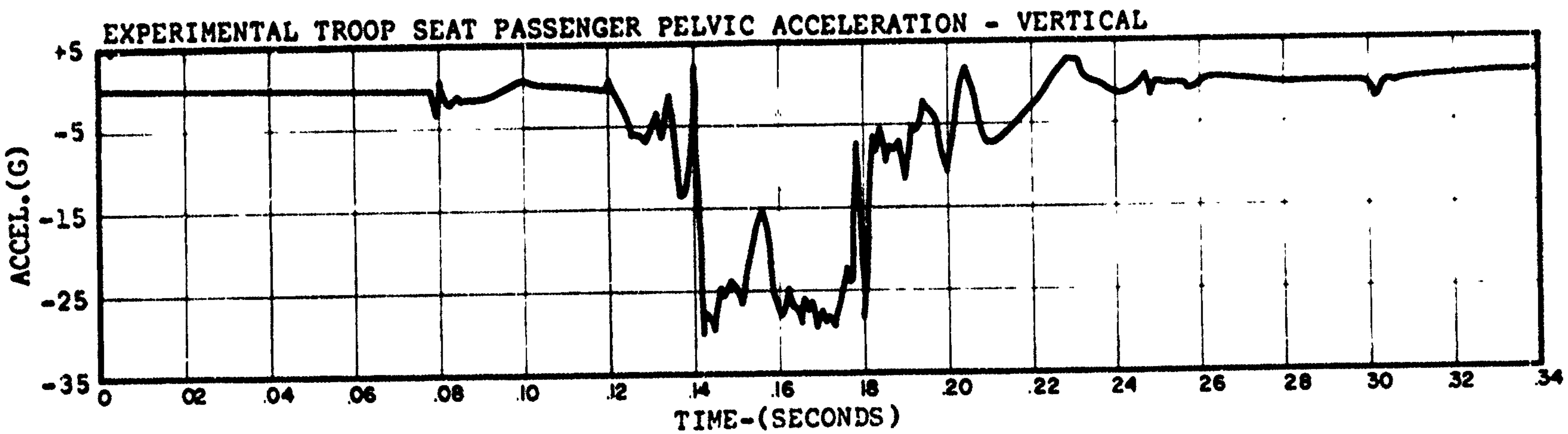
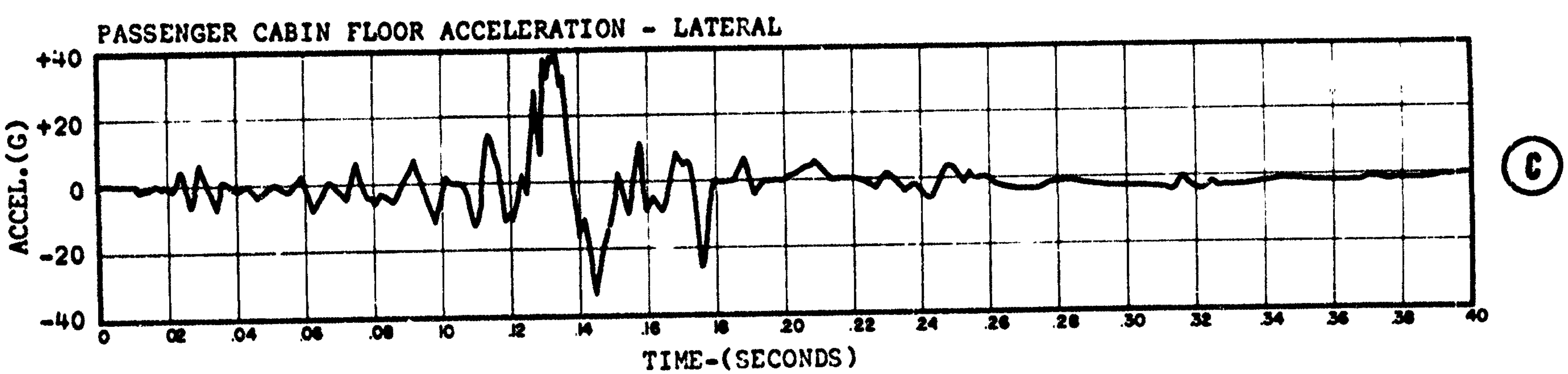


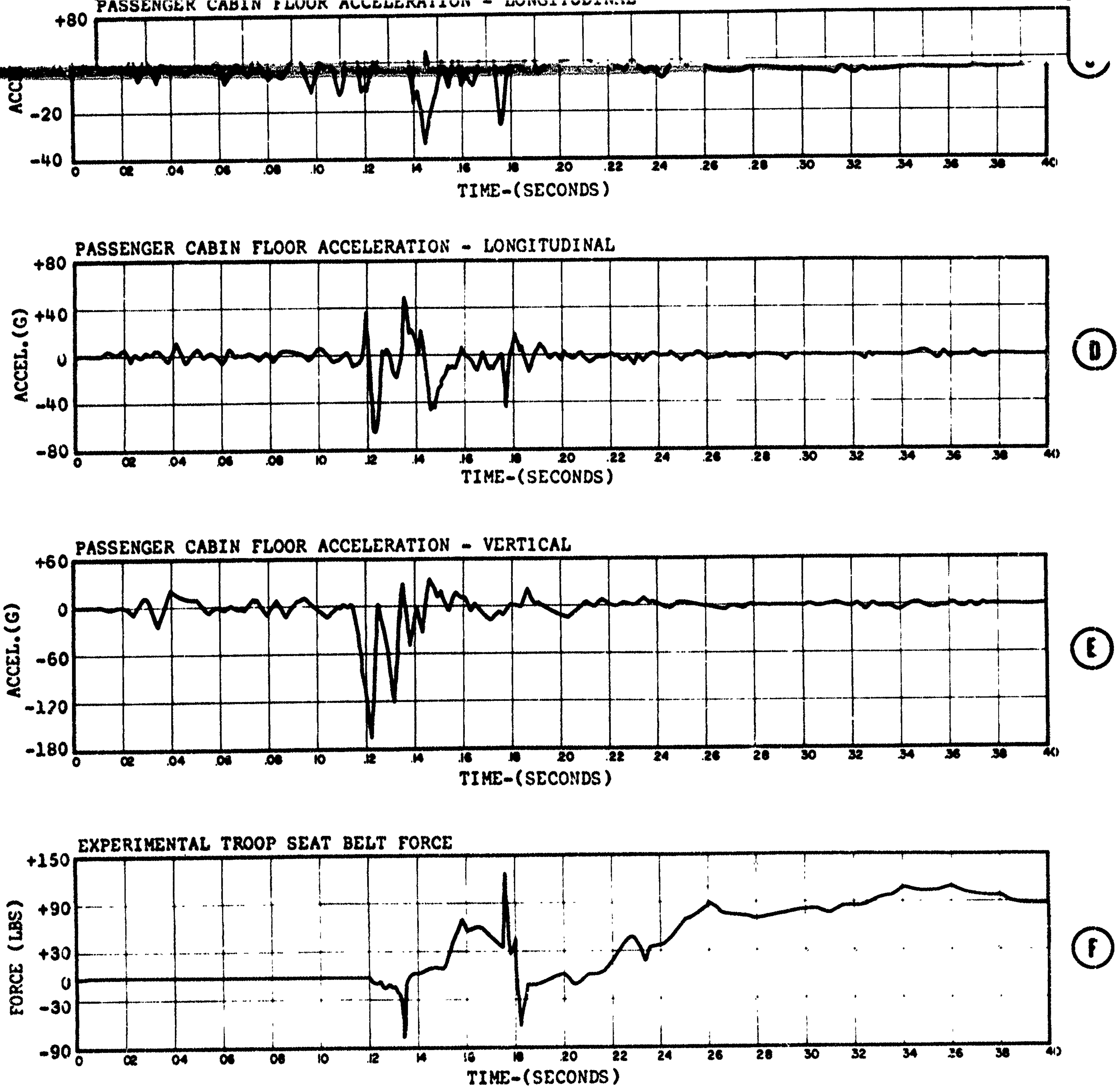
Figure 61. Kinematic Sketch of Seat 4 and Dummy During Crash Impact Sequence, T-13.

Figure 61. Kinematic Sketch of Seat 4 and Dummy During Crash Impact Sequence, T-13.








PASSENGER CABIN FLOOR ACCELERATION - LONGITUDINAL
+80
-20
-40
0 .02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .22 .24 .26 .28 .30 .32 .34 .36 .38 .40
TIME-(SECONDS)
PASSENGER CABIN FLOOR ACCELERATION - LONGITUDINAL
ACCEL.(G)
+80
+40
0
-40
-80
TIME-(SECONDS)
D
PASSENGER CABIN FLOOR ACCELERATION - VERTICAL
ACCEL.(G)
+60
0
-60
-120
-180
TIME-(SECONDS)
E
EXPERIMENTAL TROOP SEAT BELT FORCE
FORCE (LBS)
+150
+90
+30
0
-30
-90
TIME-(SECONDS)
F

TIME-(SECONDS)

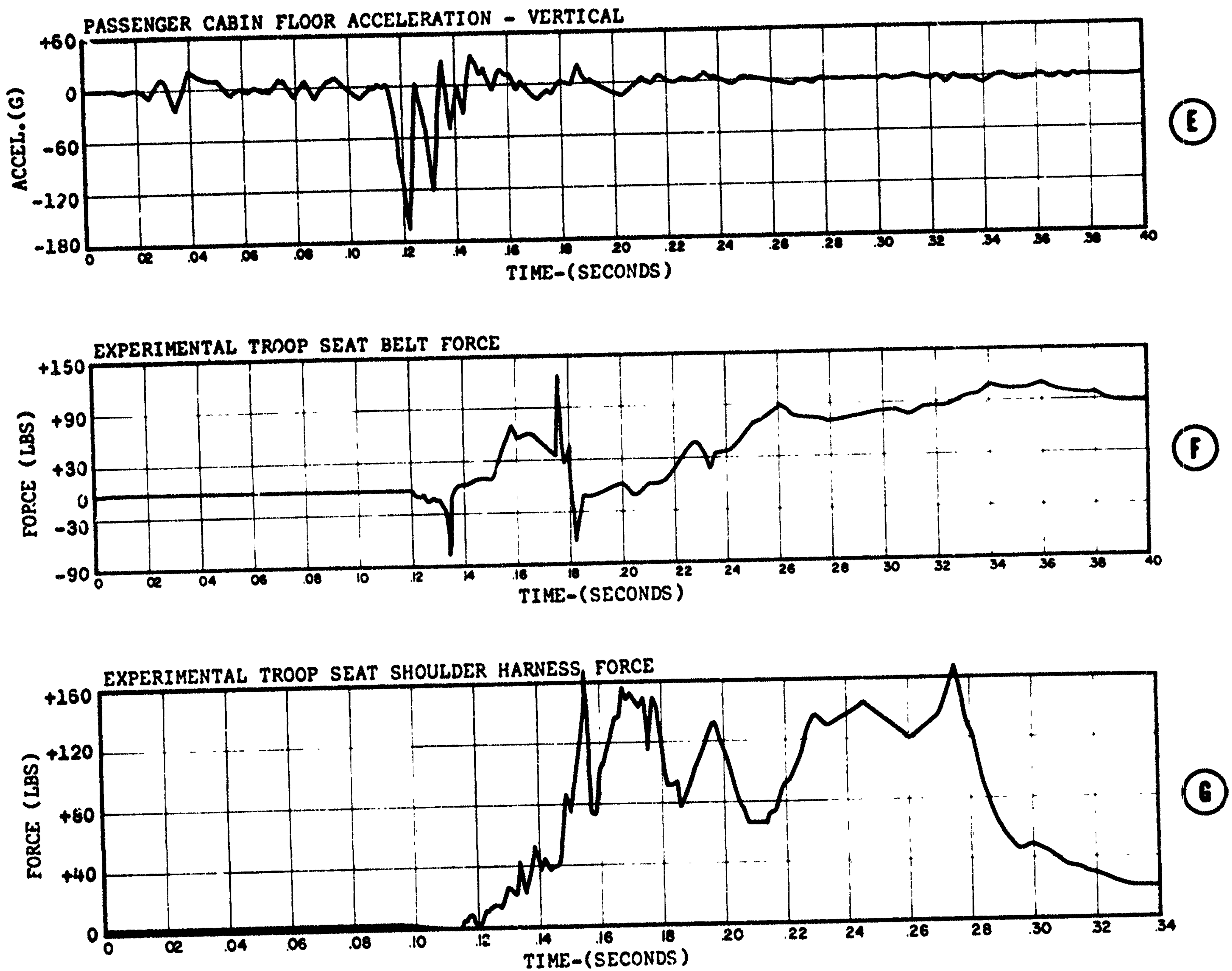


Figure 62. Accelerometer-Time and Force-Time Histories, Seat 4, During CH-21 Helicopter Crash Test T-13.

The vertical acceleration recorded in the pelvis of the dummy shows a rapid rise at 0.12 second up to 30G and maintains this level for approximately 0.075 second. The velocity change represented by an integration of this curve shows a velocity change of over 38 feet per second, very close to the actual velocity change programmed for the drop test. The peak cabin floor vertical acceleration was approximately 175G at 0.123 second.

The longitudinal acceleration trace* shows that the dummy decelerated at a lower G value over a longer period than the cabin floor. The cabin floor decelerated in a series of short triangular pulses with peaks of 60G, 40G, and 30G with time durations of approximately 0.0015 second and with rates of onset of over 10,000G per second. The dummy decelerated with a trapezoidal pulse peaking at about 12.5G for approximately 0.010 second with rates of onset in the order of 500G per second.

The lateral trace (longitudinal with respect to the dummy) has a break, but generally represents a sinusoidal oscillation of plus and minus 10G.

The force-time history of the seat-belt load shows a value of about 100 pounds while the seat strut is depressing and rising to a steady 85 pounds as the dummy is leaning to the right, stressing the belt. The shoulder strap force shows a value of about 140 pounds while the dummy is decelerating in the longitudinal (aircraft) direction, dropping to a steady 20 pounds of lean after the dummy has come to a stop.

* The orientation of the dummy in a side-facing seat requires redefinition of longitudinal and lateral direction. The orientation of the aircraft has precedence, so that longitudinal to the airframe is actually lateral to the dummy. The computer standards for lateral accelerations are such that the accelerations shown on the trace are apparently reversed. Actually in this case, the presence of a positive acceleration represents a loss in velocity. In both the vertical and longitudinal direction, the dummy had a change in velocity roughly equal to the total velocity change as actually experienced under the test conditions.

OVERALL EVALUATION

Two major factors are involved in connection with reducing the fatality rates in aircraft accidents and improving the mission effectiveness in military operations. The first, and obviously the most important, is to reduce the accidents experienced to the lowest number possible; the second is to reduce the number and severity of the injuries in those accidents which have not been prevented.

Design criteria for troop seats that offer protection to occupants in severe but survivable crashes have been prepared on the basis of the following factors: detailed investigation of the crash injury aspects in numerous accidents; the development of an improved understanding of human tolerance; and the actual measurement of the crash environment through the conduct of a test program, a portion of which is reported herein. These criteria are contained in TRECOM Technical Report 62-79, Military Troop Seat Design Criteria, published by the U. S. Army Transportation Research Command, Fort Eustis, Virginia, in November 1962. The following design load factors are quoted from the report:

> " a. Longitudinal and Lateral Design Loads:
> The seat, its support system, and occupant restraint system should, individually and in combination, be capable of maintaining 25G for 0.20 second and 45G for 0.10 second in the pelvic region of a suitable anthropomorphic dummy having a weight and mass distribution of that of the heaviest occupant expected. Progressive plastic deformation of the seat and restraint system is permissible provided (1) complete failure and (2) subsequent injurious situations do not occur.
>
> b. Vertical (Headward) Design Loads:
> The seat, its support system, and the occupant restraint system should, in combination, be capable of continuously maintaining 25G $\pm$ 5G in the pelvic region of the dummy described in (a) above, while deforming through at least 12 inches of vertical travel with respect to the airframe and, where possible, up to 15 inches or more of vertical travel. "

Examination of the acceleration data relevant to the seat concept described in this report shows that from the start the seat was capable of maintaining loads within the requirements set forth above. However, other considerations for survivability were not acceptable in earlier tests because of structural failures in both the aircraft and the seat.

The continued improvement of the concept resulted in an environment in the final test which would have provided a survivable situation for the occupant under all considerations in an extremely severe crash.

The compactness and light weight of the seat incorporating an energy-absorbing strut offer a system that could be readily adapted to aircraft now in service with no appreciable weight penalty and a large gain in survivability.

There are some areas where the seat could be improved before actual use in the field; however, as the seat is built now, it can be expected to maintain crash loads within the limits of human tolerance in severe but potentially survivable accidents. The major improvement required would be a strut that would not bend under the conditions experienced in the test of seat 3, T-12.

The "weak line" feature in the seat pan that bends and allows the seat pan to remain parallel to the floor during the crash would be adequate if a method were used to maintain the occupant in the proper upright position on the seat pan. The simplest method for this is to provide a seat-belt tiedown strap as recommended in TCREC Technical Report 62-94, Personnel Restraint Systems Study - Basic Concepts, published by USATRECOM in December 1962.

INSTRUMENTATION

A list of the data acquisition system components related to this experimental troop seat is presented in the following table. These components are generally true for all four tests (variations are noted elsewhere in the report).

High-Speed Motion Picture Camera	Displacement/time for helicopter and dummy kinematics data	4 on ground 1 on aircraft	1-500 fps, 16mm color film
Normal-Speed Motion Picture Camera	General photographic coverage	4 on ground	2-64 fps, 16mm 2-24 fps, 16mm color film
Electrical Accelerometers	Acceleration sensing	2 in dummy 3 on cabin floor	A5a-50-350 and A5a-100-350
Tensiometer	Force sensing	1 in seat belt	2500 lb
Recording Oscillograph	Amplitude-time records of transducer outputs	4 each at ground control point	Model 5-114-26, channel recording oscillograph with related power supplies
Photographic/ Oscillographic Data Correlation Device	Zero time for camera film and oscillograph	2 each	Photo flashbulbs mounted in field of view of cameras. Firing pulse to bulbs recorded on oscillograph record for correlation
Voltage Generator	Timing for high-speed cameras	Ground control point	115-volt AC generator, 60 cps timing pulse
Flight Analyzer	Horizontal and vertical speed of helicopter	500 feet perpendicular to center of flight path	FDFA-044 (This instrument was used in drone tests only.)

Accelerometers were mounted in the pelvic area of the dummy to record accelerations in the longitudinal and vertical directions. The accelerometers and the force tensiometer were connected through a balance and sensitivity unit to a 500-foot umbilical cable which was routed directly to recording oscillographs located at a stationary point on the ground. A block diagram of the instrumentation system is presented in Figure 63.

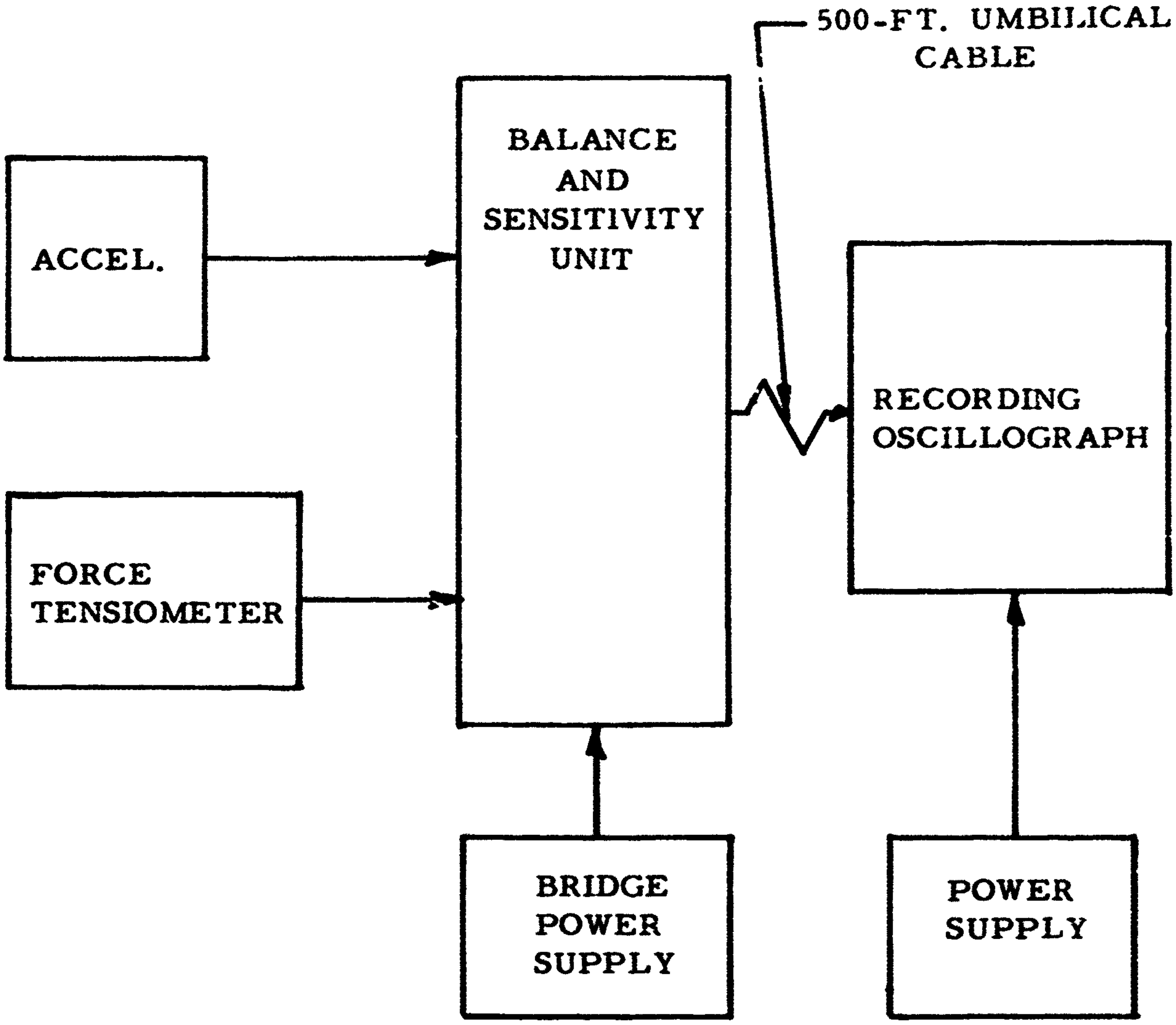


Figure 63. Instrumentation Data Recording System.

Just prior to the test, an eight-step calibration was made on all appropriate channels. The bridge battery voltage was monitored on one channel to record any change in the bridge voltage during the crash sequence. No voltage change was recorded.

The high-speed camera and associated auxiliary lighting were both controlled by switches on the master control panel at the ground control point. During the descent, the cameras and lights were turned on manually by the instrumentation operator, and they were automatically turned off after a 10-second period by a time delay circuit.