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ARMORED CREW SEAT DROP TEST PROGRAM

BY

W.H.REED
D.F.CARROLL
V.E.ROTHE

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AN ARMORED CREW SEAT DROP TEST PROGRAM
CONDUCTED FOR BELL HELICOPTER COMPANY
UNDER U. S. ARMY
CONTRACT DA 23-204-AMC-03511(T)

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William H Reed

Prepared: William H. Reed

Donald F Carroll

Reviewed: Donald F. Carroll

Victor E. Rothe

Approved: Victor E. Rothe

AN ARMORED CREW SEAT DROP TEST PROGRAM CONDUCTED FOR BELL HELICOPTER COMPANY

(Purchase Order No. 386351)

GENERAL

An armored crew seat has been developed by Bell Helicopter Company, for the UH-1B/D series helicopter. This seat is required to provide occupant protection, under impact conditions, at least equal to the protection afforded by the standard UH-1B/D crew seat. To demonstrate that the armored seat meets this requirement, a test program was planned to subject one of the developmental armored seats and a standard UH-1D seat to simultaneous impacts and compare the dynamic responses of the seat-occupant systems. Particular attention was directed toward evaluation of the vertical energy absorbing mechanism provided in the new seat.

This testing program was conducted by Aviation Safety Engineering and Research (AvSER) Division of the Flight Safety Foundation, Incorporated, at the Deer Valley Test Facility located 27 miles north of Phoenix, Arizon

TEST OBJECTIVES

The objectives of this test program were:

1. To determine the dynamic response of the seat structure-occupant system under impact conditions

2. To evaluate the energy absorption mechanism of the seats under dynamic conditions

3. To determine the maximum vertical strength of the new armored seat.

TEST PROCEDURES

The following procedures were followed in conducting this test program.

1. The vertical drop tower facility at AvSER was modified to accept the two test articles.

2. Accelerometers were installed on the two seats, in the anthropomorphic dummy seat occupants, and on the drop tower cage, to measure vertical accelerations.

3. Calculations were made to determine the area and thickness of paper honeycomb required to decelerate the drop tower cage as desired. Preliminary calibration drop tests were conducted to insure that the required test accelerations were met.

4. High speed cameras were installed to provide 90 degree front and 45 degree side views of the seat/dummy dynamics during the tests.

5. Seats and dummy occupants were installed in the drop cage, and the drop tests were conducted.

TEST CONDITIONS

The test conditions specified by Bell Helicopter Company were as follows:

Test No. 1 - 5G peak acceleration, half sine wave pulse, 0.05 second duration.

Test No. 2 - 10G peak acceleration, half sine wave pulse, 0.05 second duration.

Test No. 3 - 15G peak acceleration, half sine wave pulse, 0.05 second duration.

Test No. 4 - 15G peak acceleration, half sine wave pulse, 0.05 second duration.

Test No. 5 - 15G peak acceleration, half sine wave pulse, 0.05 second duration.

Test No. 6 - 25G peak acceleration, half sine wave pulse, 0.05 second duration.

Test No. 7 - 45G peak acceleration, half sine wave pulse, 0.05 second duration.

TEST INSTRUMENTATION

Transducers

The accelerometers used in this test program were Statham Instruments Model A5. This is a strain gage type instrument providing a frequency response in excess of 200 cps. Instruments were installed in the following locations, to measure vertical acceleration.

1. Armored seat frame
2. Armored seat occupant pelvis
3. Armored seat occupant head
4. UH-1B/D seat bucket
5. UH-1B/D seat occupant pelvis
6. UH-1B/D seat occupant head
7. Drop tower cage (No. 1)
8. Drop tower cage (No. 2)

Data Recording System

The measurements listed above were recorded on a magnetic tape data recorder. Two recording tracks were used with four measurements on each track. A CEC 5-124 direct write oscillograph was used during the calibration drop tests to record cage acceleration. All accelerometers used in this test program were checked for accuracy during the test calibration runs.

Data Processing System

The data recorded during this test program was recovered using a tape playback machine and a series of frequency discriminators to separate the data. The separate channels of data were then recorded using an oscillograph plotter. The resulting data is presented as analog traces of vertical acceleration, in G's, versus time, in seconds.

TEST RESULTS

General

The seven drop tests were conducted in the planned sequence, and the input acceleration level achieved in each test was satisfactory. The armored crew seat and the seat support structure remained in good condition throughout the test series, although several minor parts were damaged during the tests. The effects of these minor parts deformations and failures will be discussed below.

The instrumentation system functioned properly for all tests, providing accurate data which allows a good comparison between the response of the occupant in the armored seat and the occupant in the standard UH-1D net seat.

A summary of the data obtained from these tests is presented in Table I.

Pre test and post test photographs are presented in Figures 1 through 9. These photographs are considered typical of the complete series. The acceleration-time data recorded during this test program are presented in the Appendix.

Data Analysis - Test No. 1 (5G)

Test number one was conducted with the armored seat bucket in the lowest vertical adjustment position. The drop fixture was released from a height of one foot measured from the bottom of the four-inch thick honeycomb pad used to provide the desired drop fixture acceleration pulse, so that initial impact velocity was 8 feet per second. The drop fixture acceleration achieved was similar to a half sine wave pulse of approximately 6G maximum and 50 milliseconds duration, immediately followed by a triangular pulse of 9G maximum and approximately 40 milliseconds. Mean acceleration during these pulses was approximately 5G (reference Figure 1, Appendix). In response to this input acceleration, the standard UH-1D occupant pelvic acceleration was also 9G peak and approximately 5G mean, while the armored seat occupant pelvic acceleration was 10G peak and approximately 7G mean. A higher pelvic acceleration was anticipated for the armored seat occupant at this acceleration level (and energy level) since under these conditions the honeycomb energy absorber acts as a solid block and this dummy is allowed to contact the solid lower seat bucket, while the standard UH-1D dummy is more gradually decelerated by the net seat.

The armored seat was not damaged by this test, and the energy absorber did not stroke. The seat acted as a solid, non energy absorbing seat, as it was supposed to do.

Data Analysis - Test No. 2 (10G)

For test number two the drop fixture was released from a height of four feet providing an initial impact velocity of 16 feet per second.

The drop fixture was released from a height of nine feet, and impacted with a vertical velocity of 24 feet per second. The same energy absorbing honeycomb cylinder was used for this test as was used for tests one and two. After this test the seat was found to have moved downward on the energy absorbing column 5/16 inch.

Drop cage acceleration for this test was 24G peak and 15G mean, with a pulse shape which approximated a half sine wave. Under this acceleration the onset of armored seat occupant pelvic acceleration lagged the onset of drop cage acceleration by approximately 30 milliseconds. Peak armored seat occupant pelvic acceleration was approximately 40G, while the standard seat occupant was subjected to a maximum pelvic acceleration of 33G. The mean accelerations were nearly the same in both cases, 22G for the armored seat occupant against 21G for the standard seat occupant. Rate of onset of acceleration for the armored seat occupant was again higher than for the standard seat occupant.

Data Analysis - Test No. 4 (15G)

Test number four was conducted under the same conditions as test three. A different energy absorbing cylinder was used for this test, with lower static crushing strength than the cylinder used for tests 1, 2, and 3 (reference Table II). In this test, as in test three, the armored seat occupant pelvic acceleration was more severe than the standard

The test was conducted with the armored seat bucket in its lowest vertical adjustment position. Peak drop cage acceleration was 20G and the mean acceleration was 10G. The armored seat occupant again experienced higher pelvic acceleration than the standard UH-1D seat occupant, with peak acceleration of 35G and a mean acceleration of 20G, against standard seat occupant pelvic accelerations of 22G peak and 14G mean (reference Figure 2, Appendix).

The cylindrical honeycomb energy absorber was crushed approximately 1/4 inch during this impact, but did not eliminate high occupant accelerations. It is significant to notice that the onset of armored seat occupant pelvic acceleration lagged the onset of drop cage acceleration by approximately 36 milliseconds while the onset of standard seat occupant acceleration lagged by only approximately 10 milliseconds. Since the armored seat vertical energy absorbing mechanism operated at a high level of force the large time lag before occupant acceleration began resulted in a high rate of onset of acceleration for the occupant, which is undesirable.

There was no noticeable structural damage of the armored seat in this test.

Data Analysis - Test No. 3 (15G)

Test number three was conducted with the armored seat bucket in its lowest vertical adjustment position, as was done for the earlier tests.

The drop fixture was released from a height of nine feet, and impacted with a vertical velocity of 24 feet per second. The same energy absorbing honeycomb cylinder was used for this test as was used for tests one and two. After this test the seat was found to have moved downward on the energy absorbing column 5/16 inch.

Drop cage acceleration for this test was 24G peak and 15G mean, with a pulse shape which approximated a half sine wave. Under this acceleration the onset of armored seat occupant pelvic acceleration lagged the onset of drop cage acceleration by approximately 30 milliseconds. Peak armored seat occupant pelvic acceleration was approximately 40G, while the standard seat occupant was subjected to a maximum pelvic acceleration of 33G. The mean accelerations were nearly the same in both cases, 22G for the armored seat occupant against 21G for the standard seat occupant. Rate of onset of acceleration for the armored seat occupant was again higher than for the standard seat occupant.

Data Analysis - Test No. 4 (15G)

Test number four was conducted under the same conditions as test three. A different energy absorbing cylinder was used for this test, with lower static crushing strength than the cylinder used for tests 1, 2, and 3 (reference Table II). In this test, as in test three, the armored seat occupant pelvic acceleration was more severe than the standard an aluminum tube was placed in the energy absorbing mechanism instead of an energy absorbing cylinder. In addition, the standard UH-1D crew seat was damaged by previous tests to such an extent that it no longer could provide data for a fair comparison between occupant responses. Therefore, measurements of its occupant response were not taken in this test.

The maximum drop cage acceleration for this test was 20G and mean cage acceleration was 15G. Under these input acceleration conditions the armored seat occupant acceleration was 59G peak with a mean acceleration of 33G. The shape and intensity of this acceleration pulse closely resembled the armored seat occupant pelvic acceleration pulses obtained from the earlier 15G tests, tests three and four.

In this test the vertical seat adjustment locking pin was sheared. It was improperly installed, and did not extend fully into the adjustment hole. Consequently, the impact force was concentrated on a portion of the pin which was tapered and did not develop full pin shear strength. There was no other failure of the seat or supporting structure during this test.

Data Analysis - Test No. 6 (25G)

For test number six the drop fixture was released from a height of 25 feet, impacting with a vertical velocity of 40 feet per second.

Before this test the vertical adjustment lock pin was repaired and an energy absorbing honeycomb cylinder was installed in the energy absorbing mechanism (reference Table II). The seat was placed in a vertical position approximately half way between its lowest and highest positions.

The energy absorber allowed the seat to move downward 2 7/16 inches during this impact and no rebound occurred. Even so, the armored seat occupant acceleration was approximately 68G maximum and 50G mean, for a drop cage acceleration of 46G maximum and 25G mean.

The vertical adjustment lock pin did not fail under this loading. Pins used to hold vibration isolating springs in place inside the seat bucket vertical support tubes were driven up inside the upper sliding fittings attaching the seat bucket to the vertical support tubes, however. It appears that this significantly increased the friction in these fittings and increased the force level at which the seat bucket would move down along the vertical support tubes, which increased occupant acceleration to 68G's. As in earlier tests, there was no damage of the "primary" seat structure.

Data Analysis - Test No. 7 (40G)

Test number seven was conducted under the most severe conditions of this test series. The test fixture was released from a height of 34 feet 3 inches and attained an initial impact velocity of 46 feet per second.

No repairs of the vibration isolating system were attempted prior to this test. The energy absorbing honeycomb cylinder was replaced, however, and the seat was again placed in an intermediate vertical position.

During the impact which resulted from this drop the peak cage acceleration was 67G and the mean cage acceleration was 38G. The occupant experienced 83G peak acceleration with a mean acceleration of 43G. The energy absorbing honeycomb was crushed 2 1/16 inches.

During this test the vibration isolator spring holding pins were driven further into the sliding fittings, as discussed earlier. In addition, the vertical lock pin was sheared again, this time through a full pin diameter. Some twisting of the seat structure occurred during this test, apparently due to yielding of the simulated floor structure.

DISCUSSION OF TEST RESULTS

In no case during this test series did the armored crew seat used provide an acceleration environment less severe than the environment provided by the standard UH-1D crew seat. From this standpoint this seat is inferior to the standard UH-1D seat. However, the strength of this seat and the method of attachment of its restraint harness combine to provide good occupant restraint under all the conditions experienced in this test program. The standard UH-1D seat deforms under the loads encountered in these tests to such an extent that its floor mounted lap belt is in effect pulled up toward its occupant's chest. The loss of proper restraint which occurs due to this allows the occupant to submarine and causes a loss of occupant protection in the standard seat. This submarining action is even more severe under combined vertical and longitudinal loading.

Overall, the occupant protection afforded by this armored seat at acceleration levels up to 15G's is considered to be approximately equivalent to the protection offered by the standard UH-1D crew seat. At input accelerations above 15G, no comparison is made, because the standard seat deforms so much as to lose a large portion of its protective capability.

Incorporation of a vertical adjustment locking pin which visibly signals when it is properly inserted into the adjustment hole would serve to preclude premature pin shearing failures such as occurred in test five of this series.

The data obtained from these tests indicate that the vertical energy absorbing mechanism used in this seat did not operate effectively, even though honeycomb crushing did occur in the energy absorber. This is shown by the high occupant acceleration levels which were encountered. One possible cause of this situation is a difference between the static crushing strength of the honeycomb cylinders, used for energy absorbers, and the crushing strengths under dynamic conditions. It is recommended that this possibility be investigated by dynamic crushing tests of both bare honeycomb cylinders of known static strength and honeycomb cylinders installed inside housings such as are to be used on seats. In this way the static crushing strength of the crushable material may be optimized.

TABLE I

SUMMARY OF ACCELERATION DATA AND IMPACT CONDITIONS

Test Number and Conditions	Location of Transducer	Acceleration (G's)	
		Mean	Peak
Test 1✓	Drop fixture	5G	9G
Drop height 1 ft.	Standard UH-1D seat		
Impact velocity 8 ft/sec.	Seat frame	5G	9G
	Passenger pelvic	5G	9G
	Passenger head	4G	8G
	UH-1B/D armored seat		
	Seat bucket	6G	11G
	Passenger pelvic	7G	10G
	Passenger head	7G	12G
Test 2✓	Drop fixture	10G	20G
Drop height 4 ft.	Standard UH-1D seat		
Impact velocity 16 ft/sec.	Seat frame	10G	20G
	Passenger pelvic	14G	22G
	Passenger head	15G	23G
	UH-1B/D armored seat		
	Seat bucket	13G	43G
	Passenger pelvic	20G	35G
	Passenger head	20G	38G
Test 3✓	Drop fixture	15G	24G
Drop height 9 ft.	Standard UH-1D seat		
Impact velocity 24 ft/sec	Seat frame	15G	31G
	Passenger pelvic	21G	33G
	Passenger head	23G	40G
	UH-1B/D armored seat		
	Seat bucket	16G	41G
	Passenger pelvic	22G	40G
	Passenger head	25G	52G
Test 4	Drop fixture	15G	25G
Drop height 9 ft.	Standard UH-1D seat		
Impact velocity 24 ft/sec.	Seat frame	16G	38G
	Passenger pelvic	21G	33G
	Passenger head	20G	35G
	UH-1B/D armored seat		
	Seat bucket	17G	38G
	Passenger pelvic	25G	51G
	Passenger head	19G	40G

TABLE II

STATIC CRUSHING STRENGTHS OF ALUMINUM HONEYCOMB CYLINDERS USED FOR INDIVIDUAL TESTS OF THIS SERIES

Test	Honeycomb Cylinder Used and Static Compressive Strength	
1 2 3	#1	4550 lb Average crushing strength
4	#2	3830 lb Average crushing strength
5	#3	Aluminum tube compression block - Solid
6	#4	4610 lb Maximum crushing strength
7	#5	4220 lb Maximum crushing strength

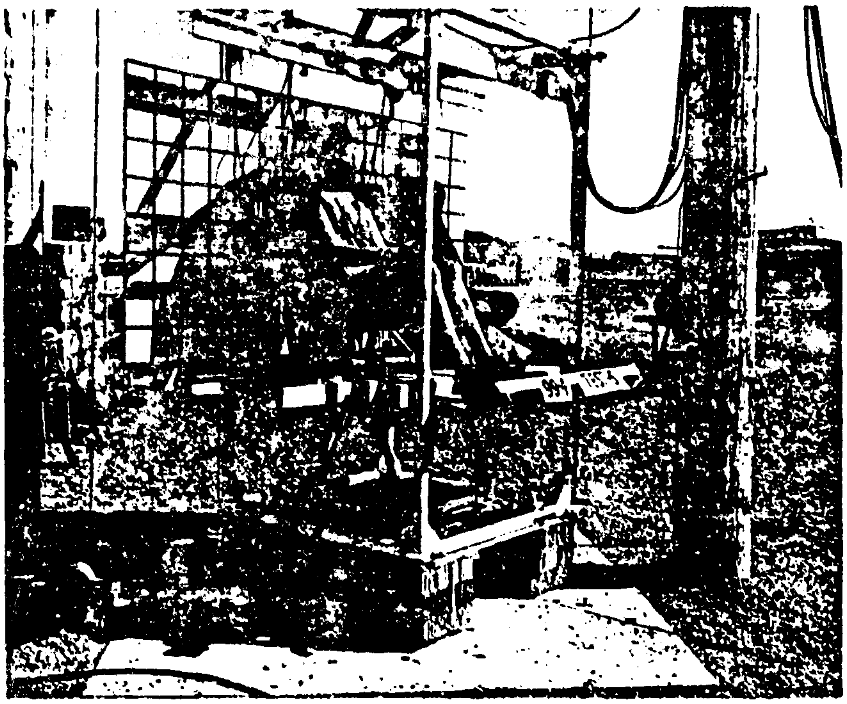


Figure 1. View Showing Armored Seat and Occupant in a Typical Pre Crash Position.

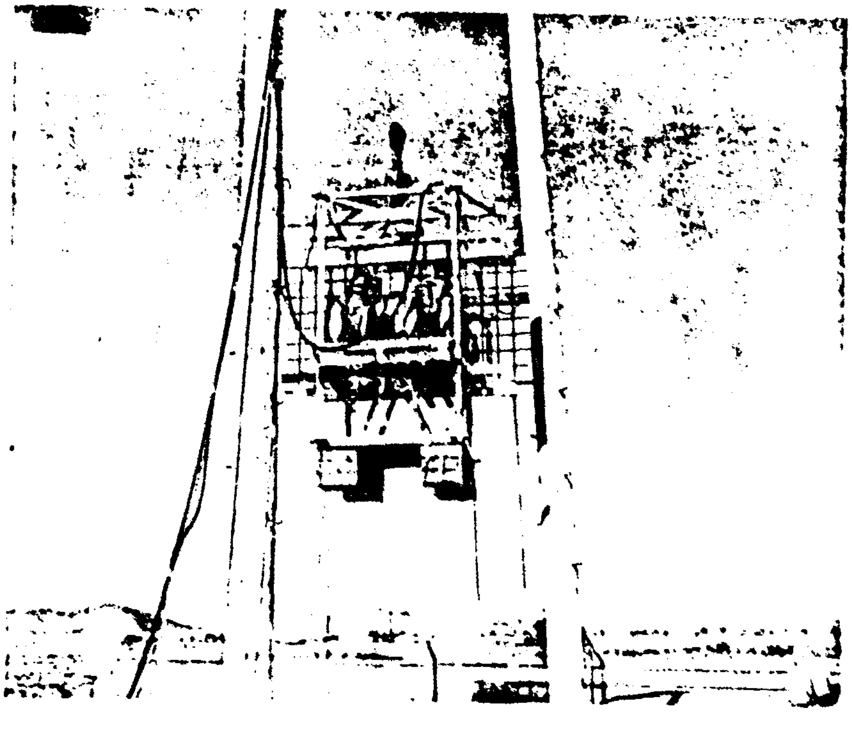


Figure 2. Drop Fixture with Seats and Occupants in Position Just Prior to Release (Typical)

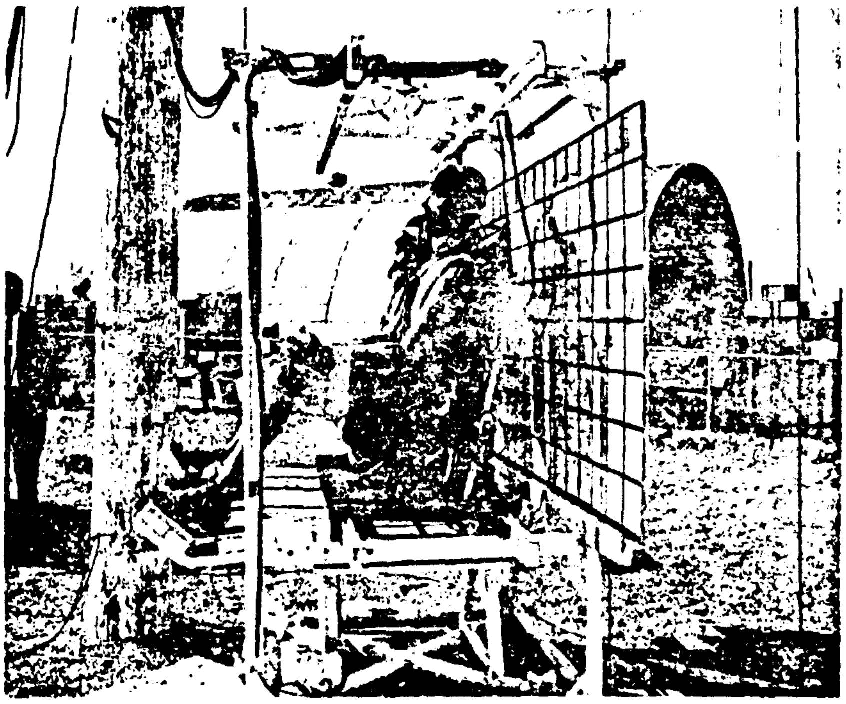


Figure 3. Typical View of Standard UH-1D Seat and Occupant Following an Intermediate Acceleration Level Test.

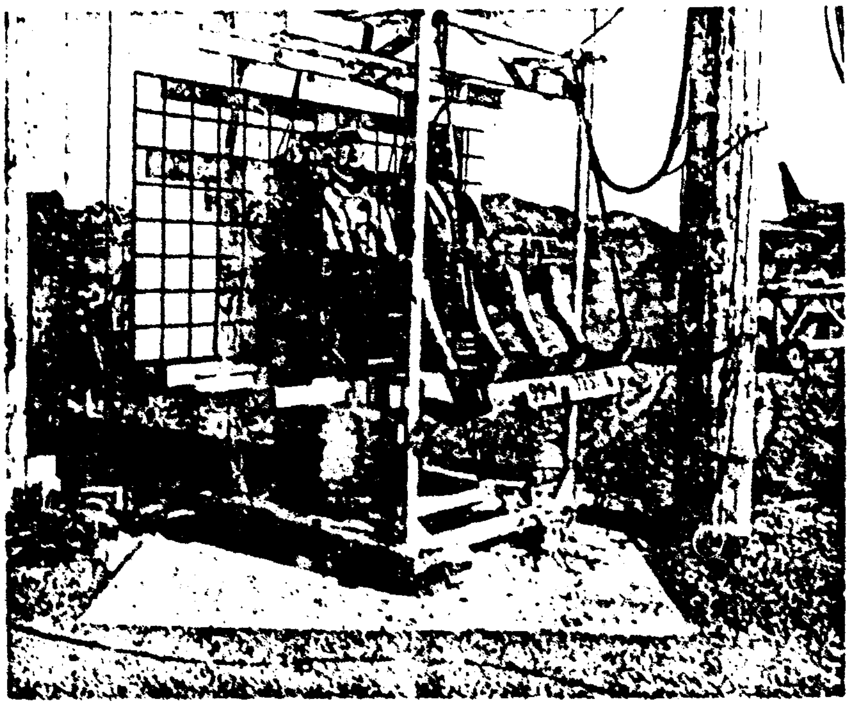


Figure 4. Typical View of Armored Seat and Occupant Following an Intermediate Acceleration Level Test.

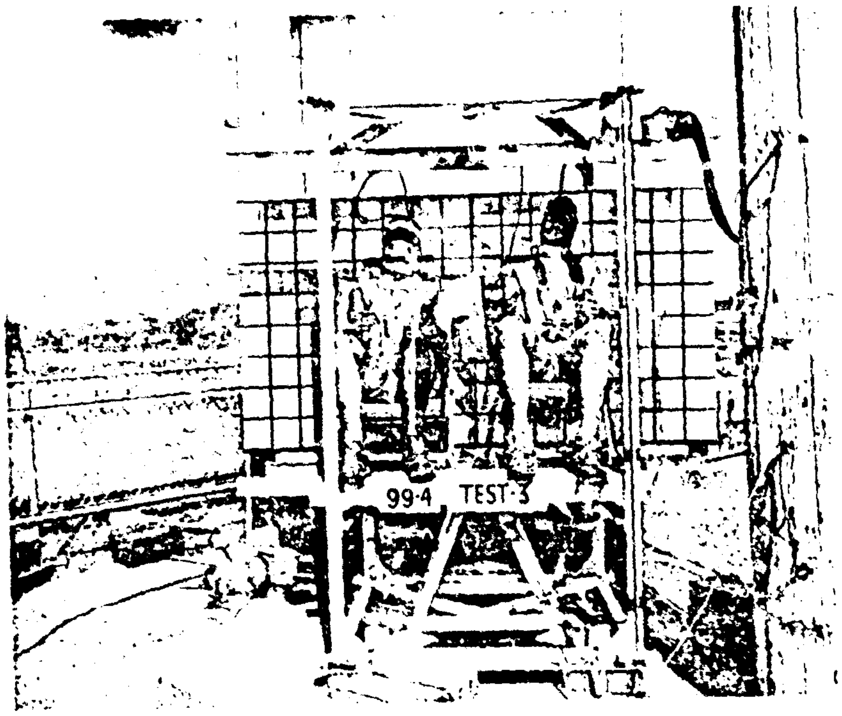


Figure 5. Typical Front View Showing Both Seats and Occupants Following an Intermediate Acceleration Level Test.

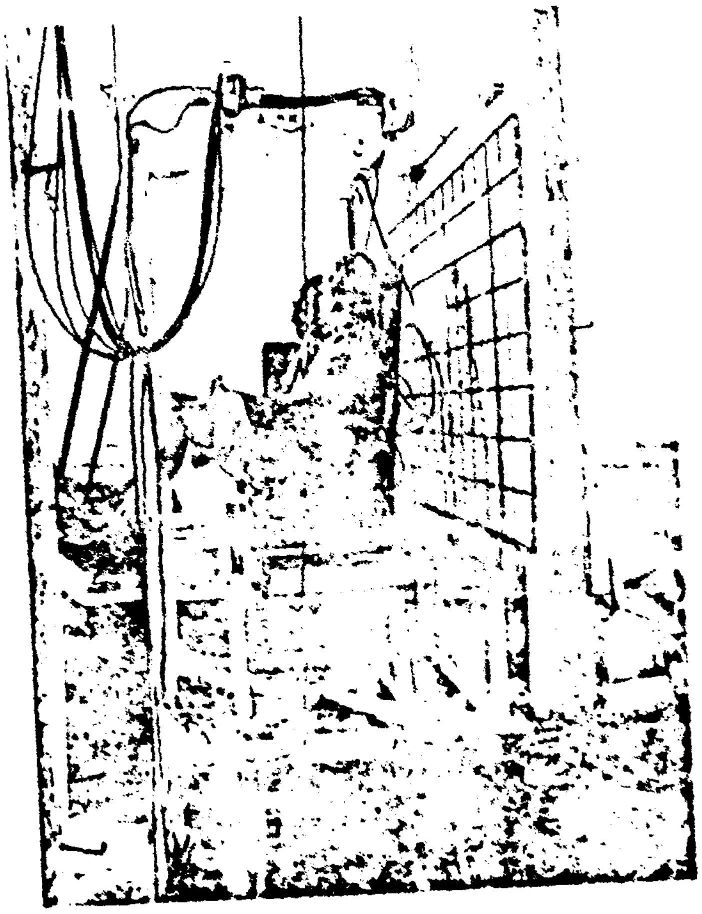
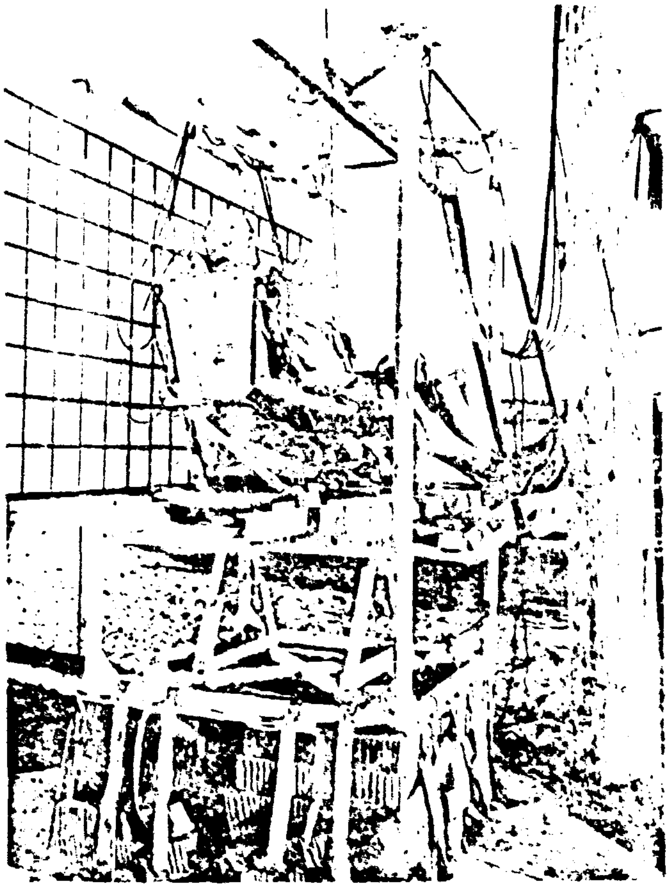


Figure 6. Post Test View Showing Extent of Vertical Deformation of the Standard UH-1D Seat Under Conditions Encountered in this Test Series.



NOT REPRODUCIBLE

Figure 7. Post Crash View of Armored Seat and Occupant Following the 40G Acceleration Level Test.

Figure 8. Front View of Both Seats and Occupants Following the 40G Acceleration Level Test.

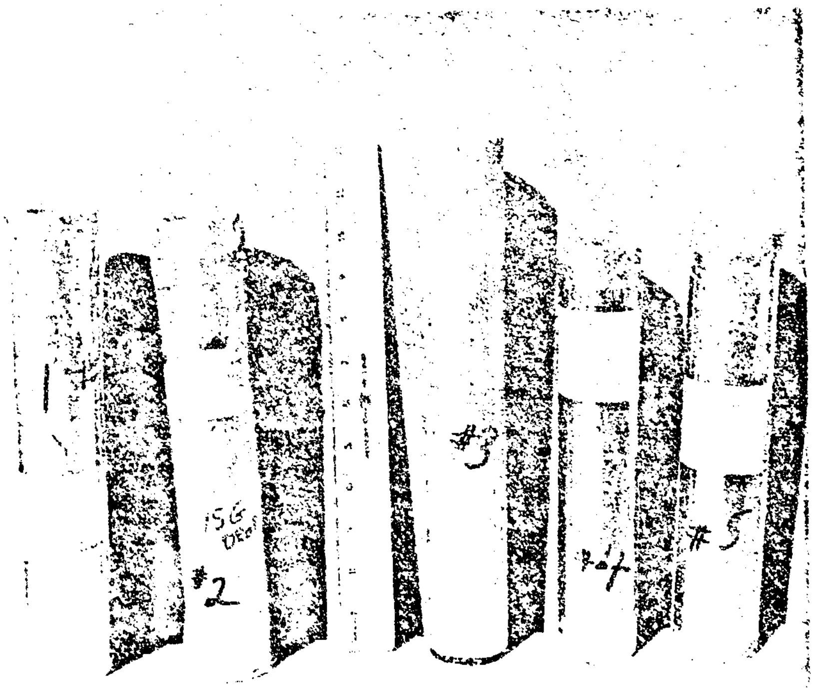


Figure 9. Honeycomb Cylinders Used as Vertical Energy Absorbers During this Series of Drop Tests. (Reference Table II.)

APPENDIX

ACCELERATION DATA

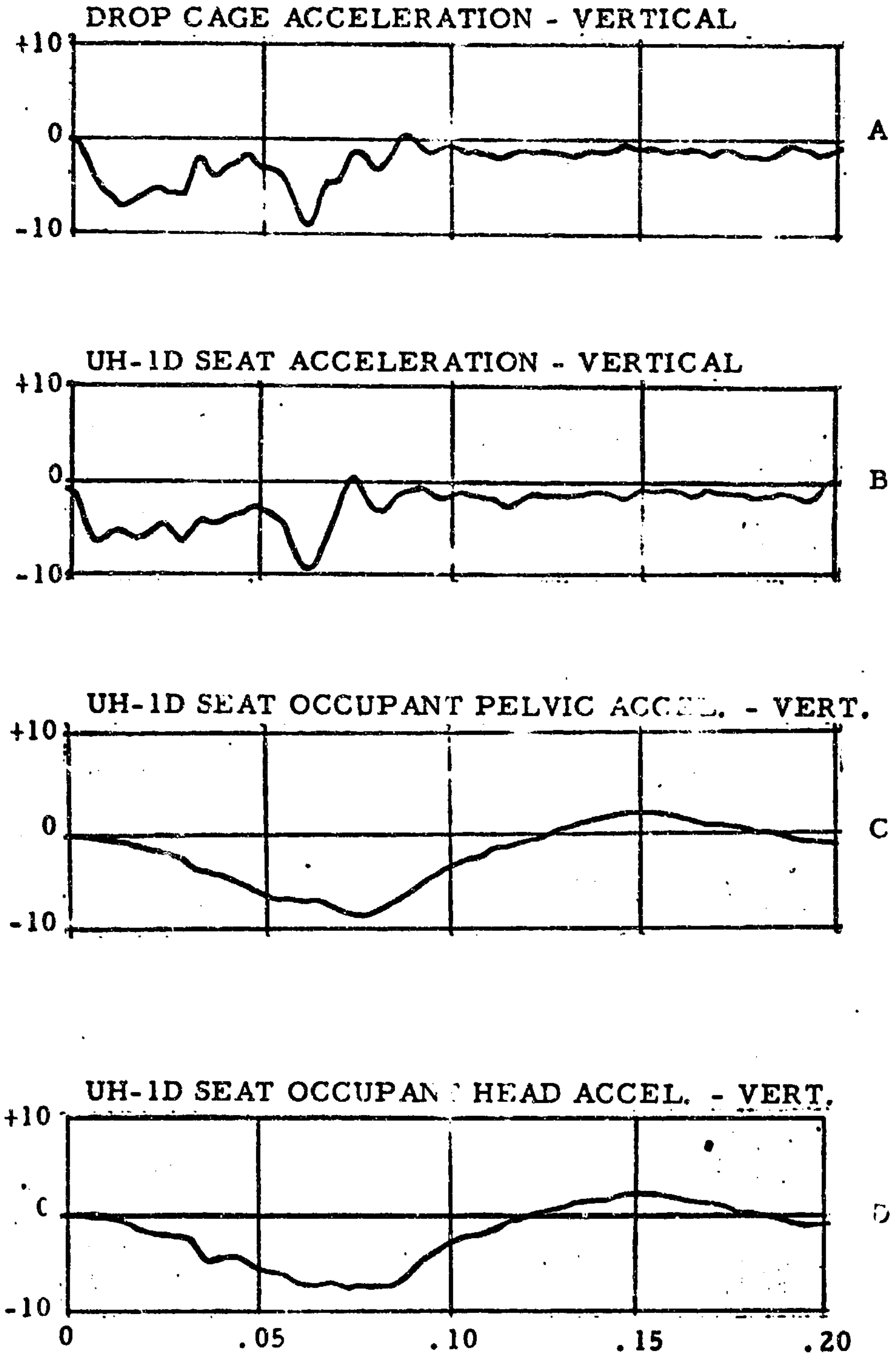
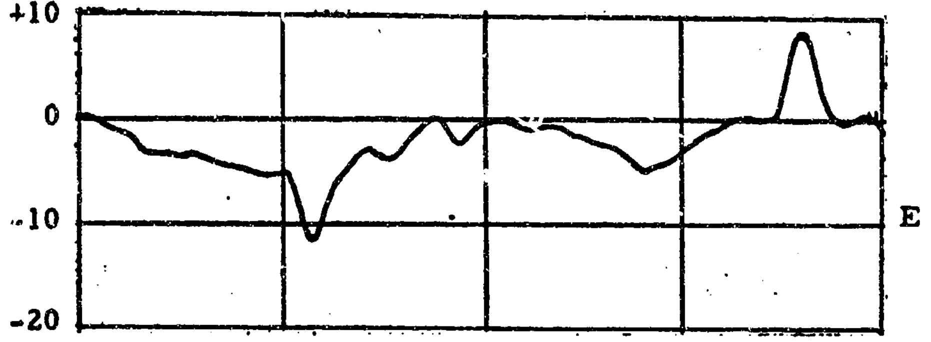
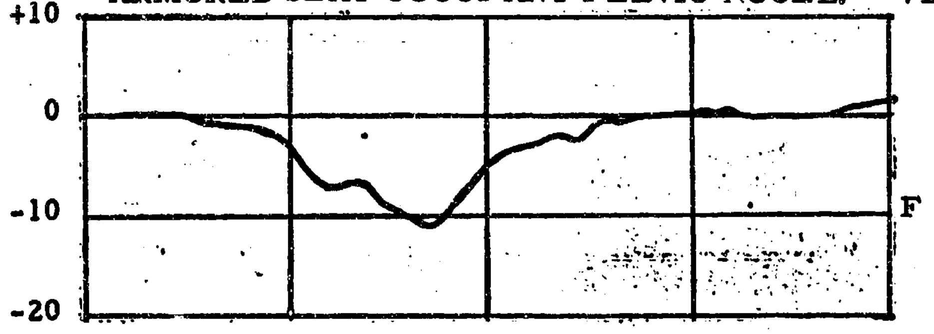


Figure 1. - Acceleration Data - Test No. 1.


ARMORED SEAT ACCEL. - VERT.


ARMORED SEAT OCCUPANT PELVIC ACCEL. - VERT.

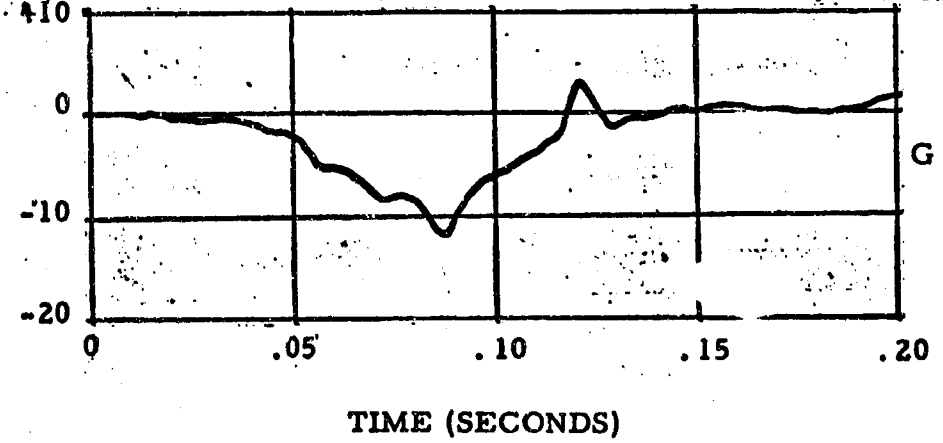

ARMORED SEAT OCCUPANT HEAD ACCEL. - VERT.

Figure 1 Cont'd. - Acceleration Data - Test No. 1.

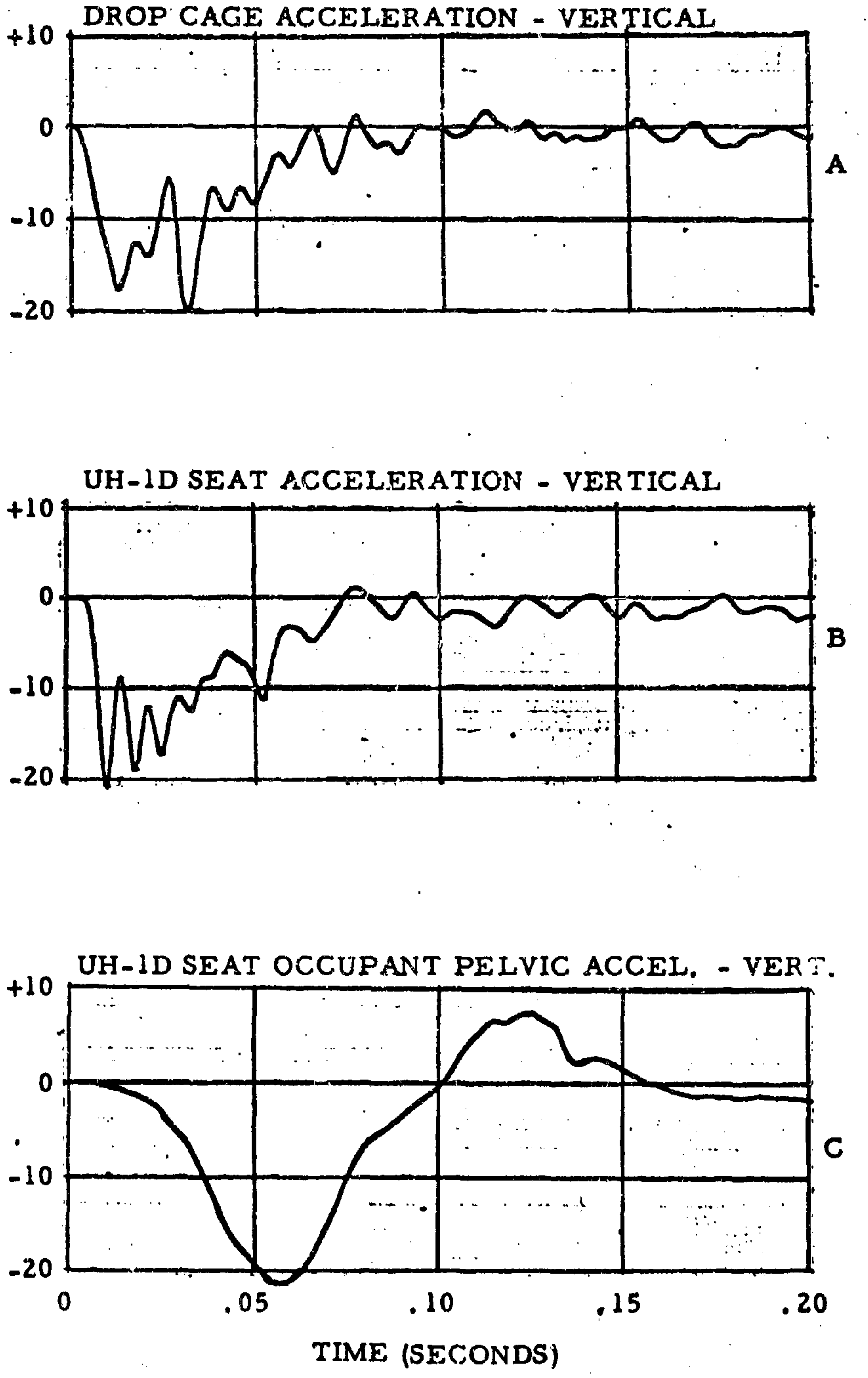
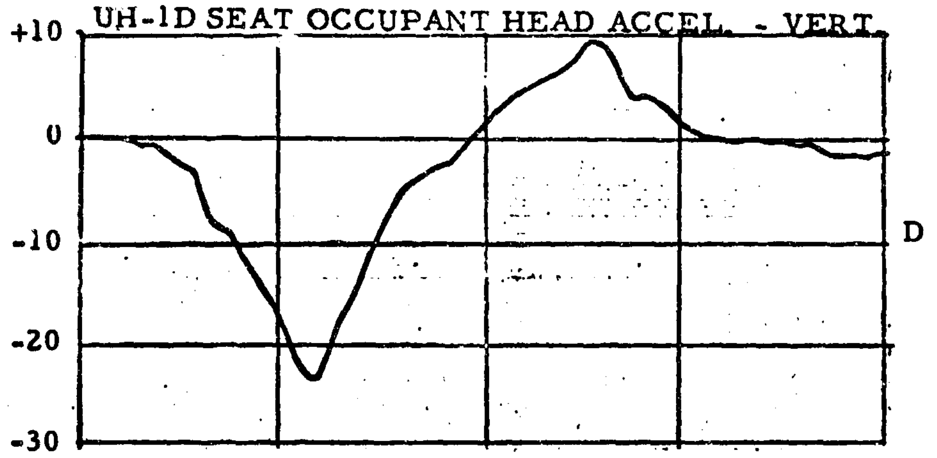


Figure 2. - Acceleration Data - Test No. 2.



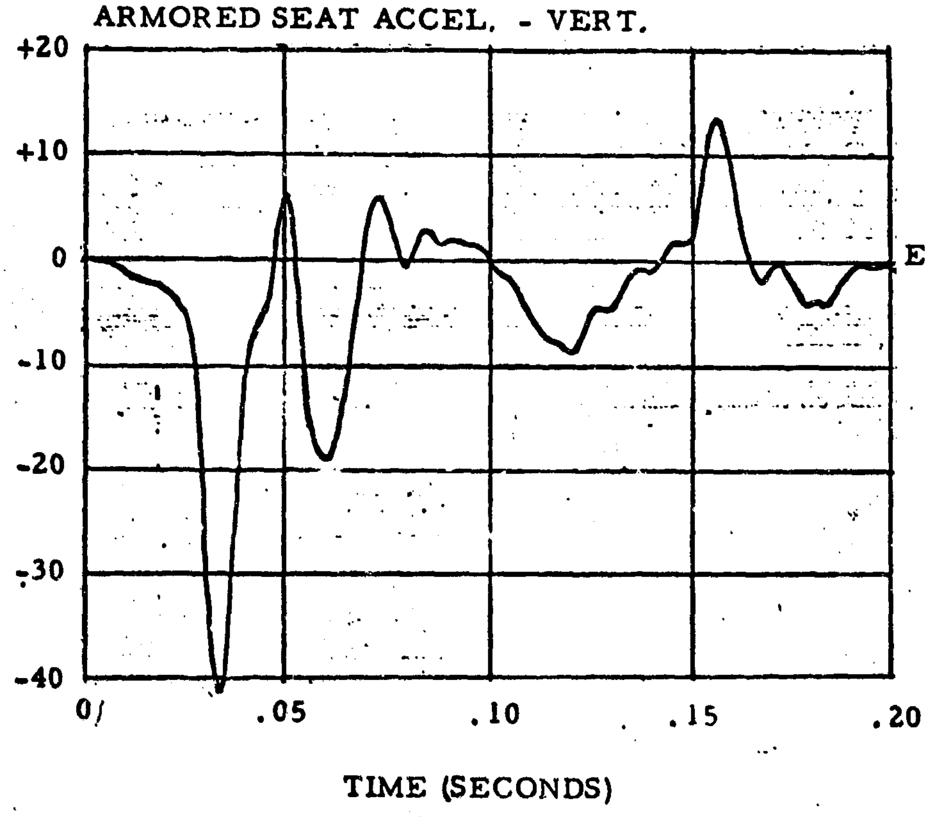
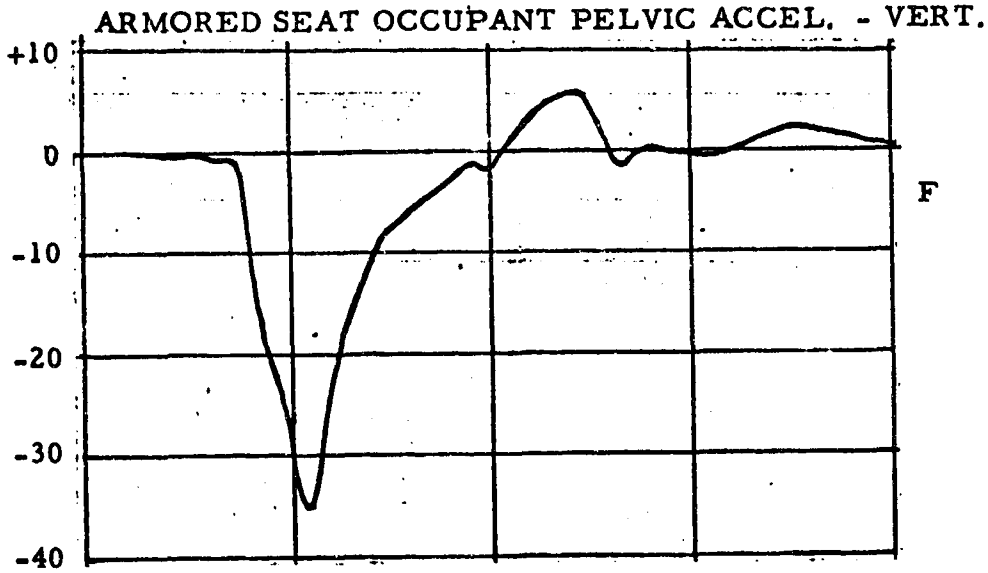


Figure 2 Cont'd. - Acceleration Data - Test No. 2.



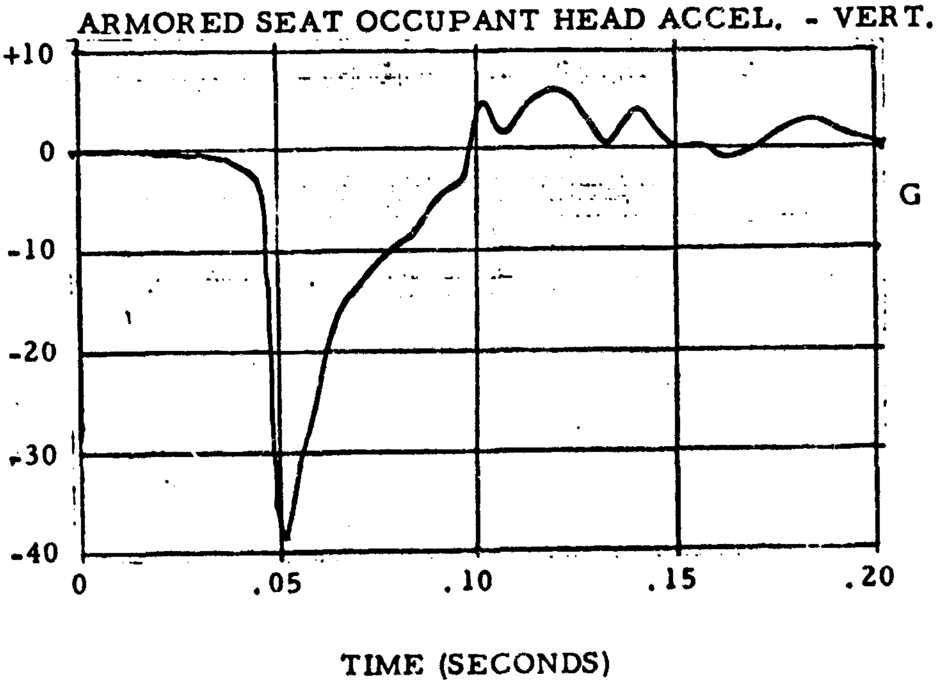


Figure 2 Cont'd. - Acceleration Data - Test No. 2.

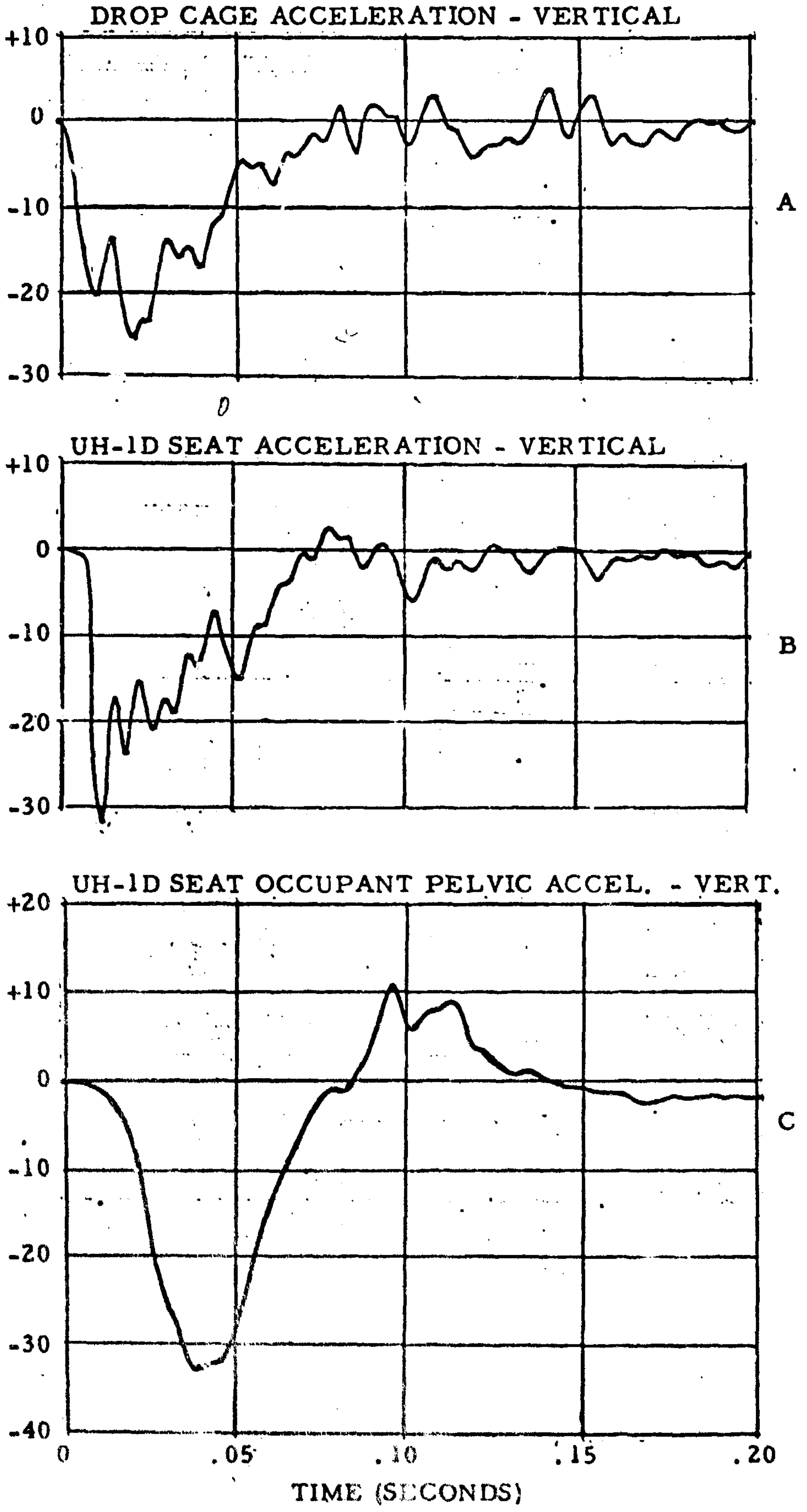


Figure 3. - Acceleration Data - Test No. 3.

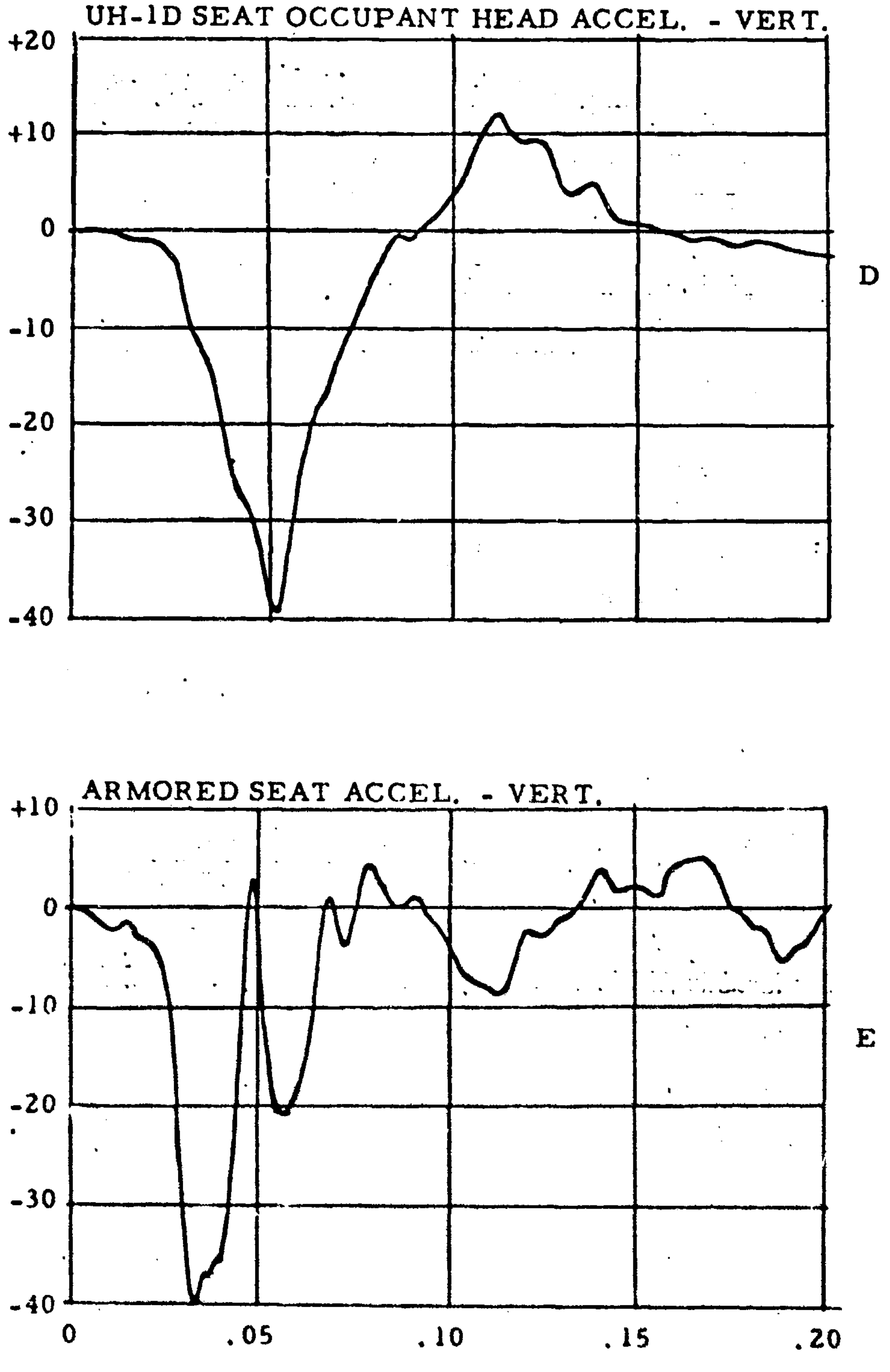
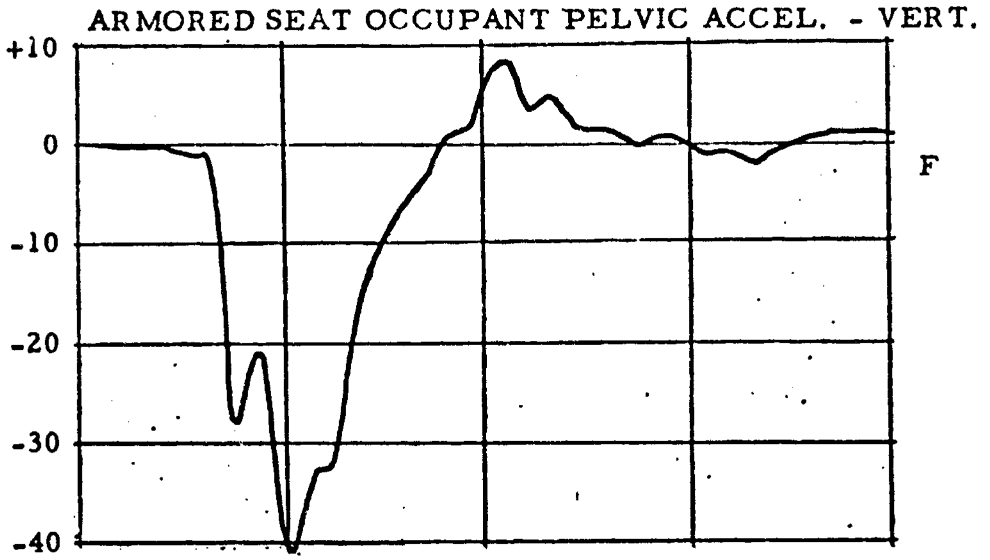


Figure 3 Cont'd. - Accelera[illegible] Data - Test No. 3.



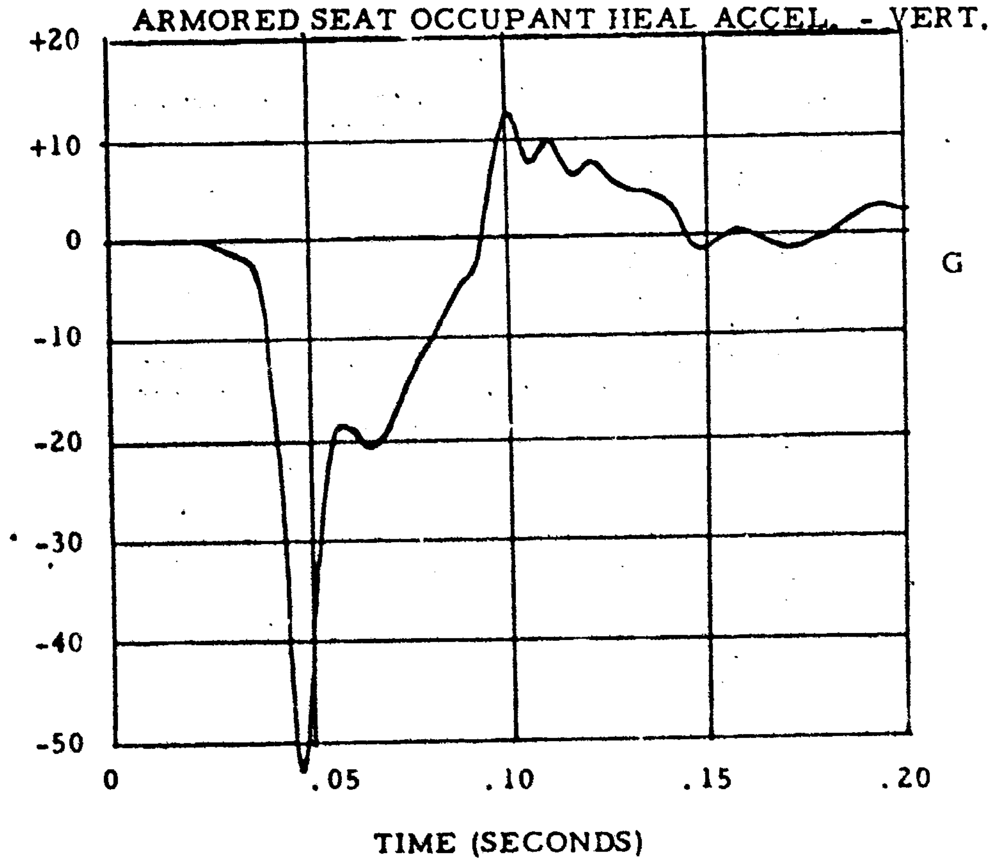


Figure 3 Cont'd. - Acceleration Data - Test No. 3.

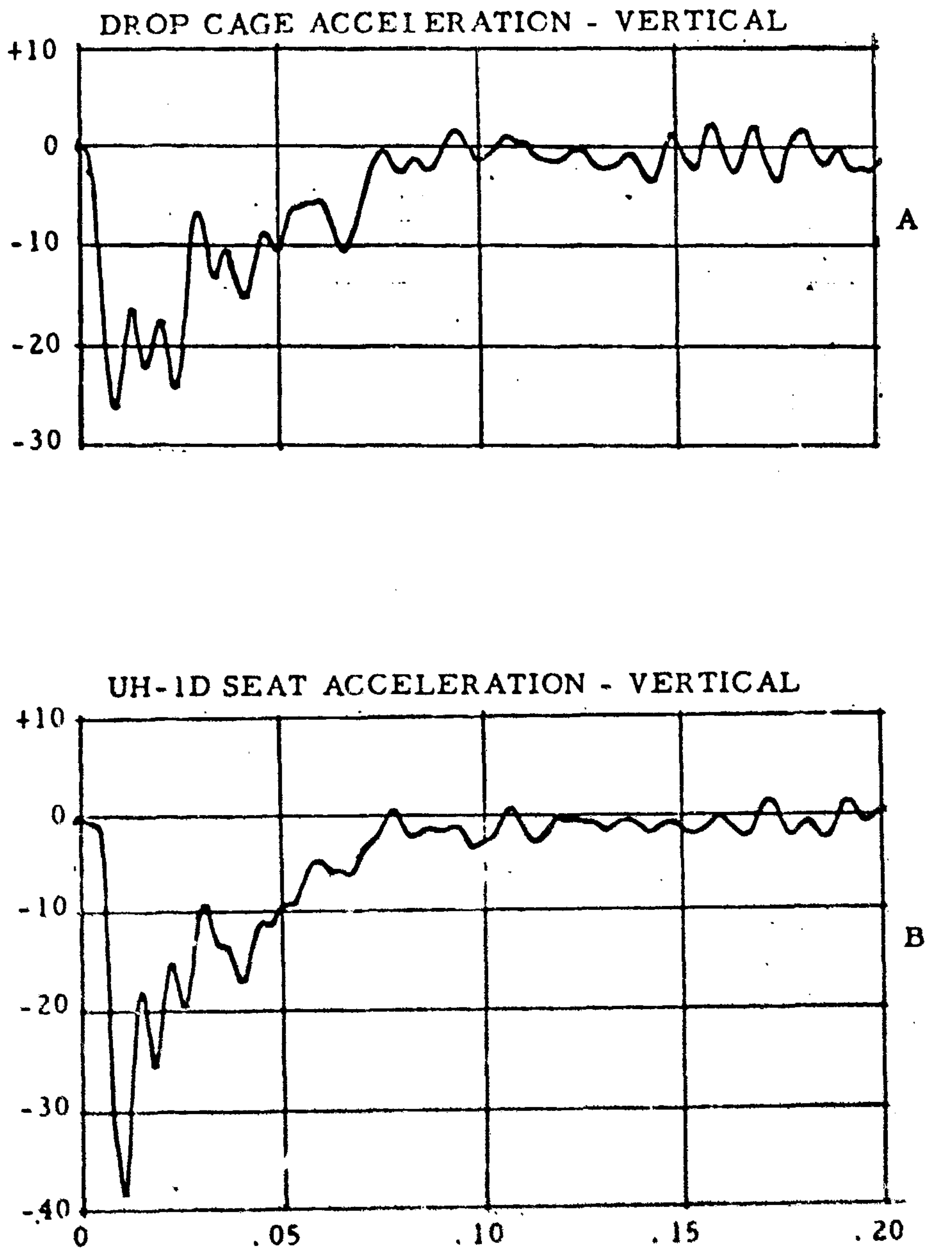
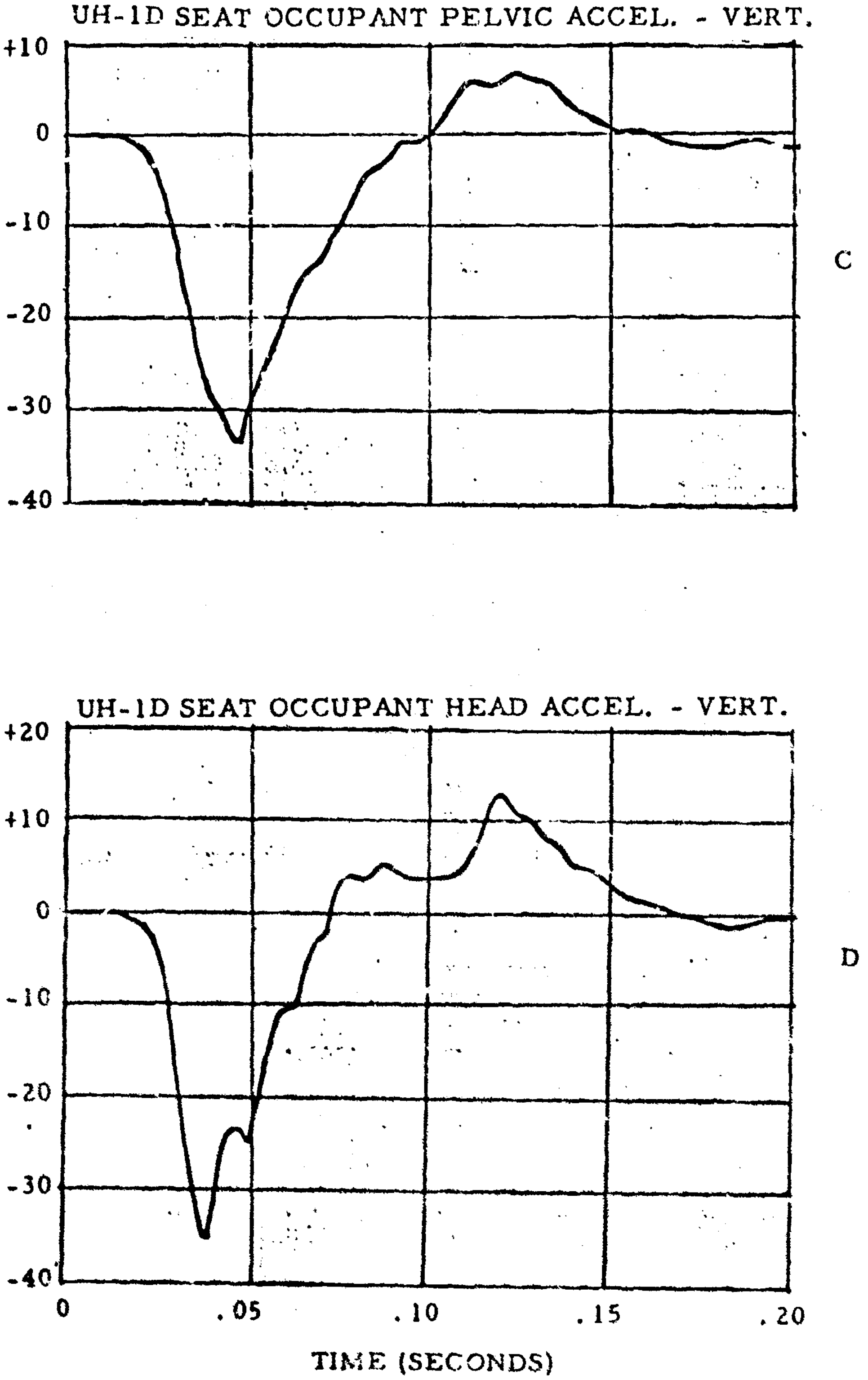
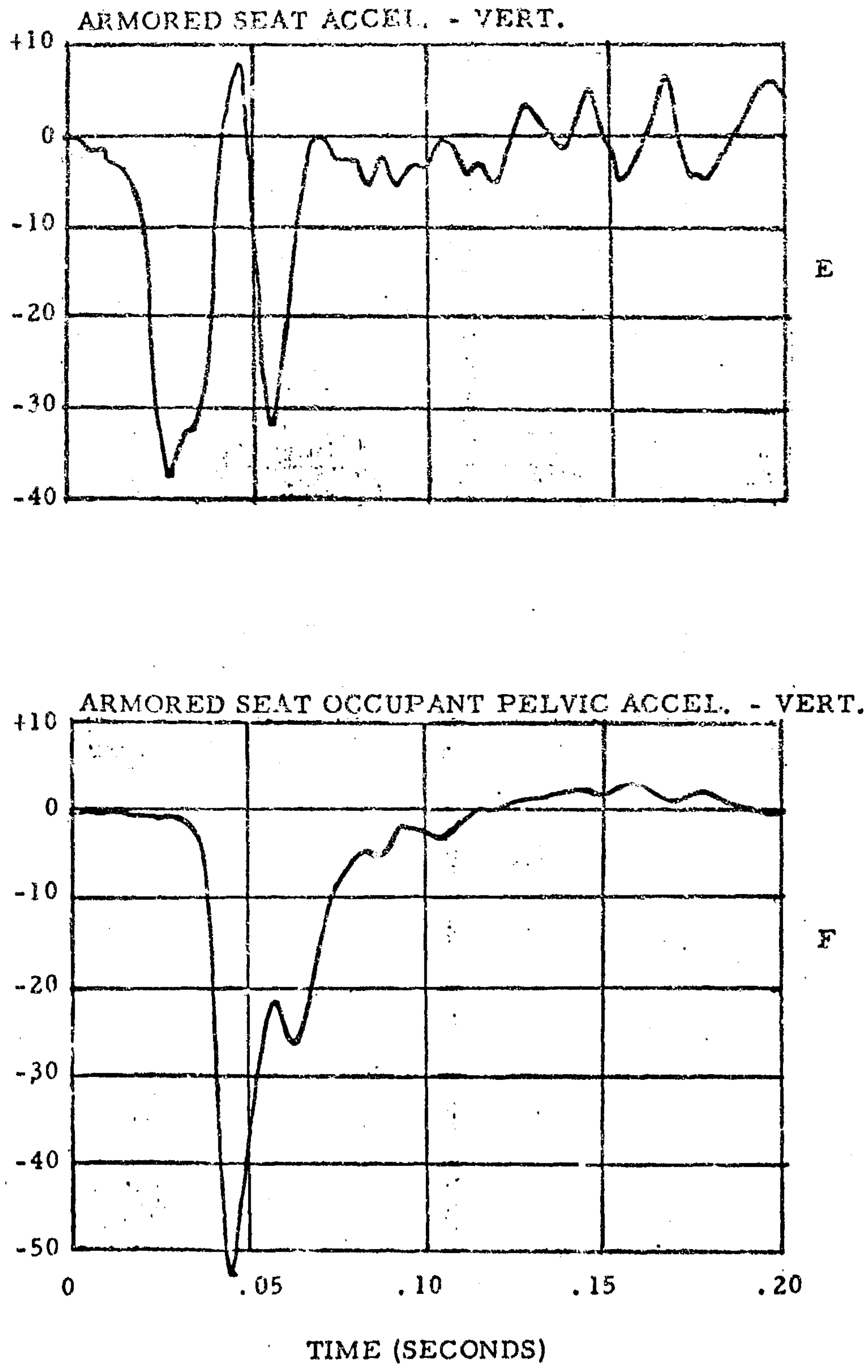


Figure 4. - Acceleration Data - Test No. 4.


UH-1D SEAT OCCUPANT PELVIC ACCEL. - VERT.

UH-1D SEAT OCCUPANT HEAD ACCEL. - VERT.

Figure 4 Cont'd. - Acceleration Data - Test No. 4



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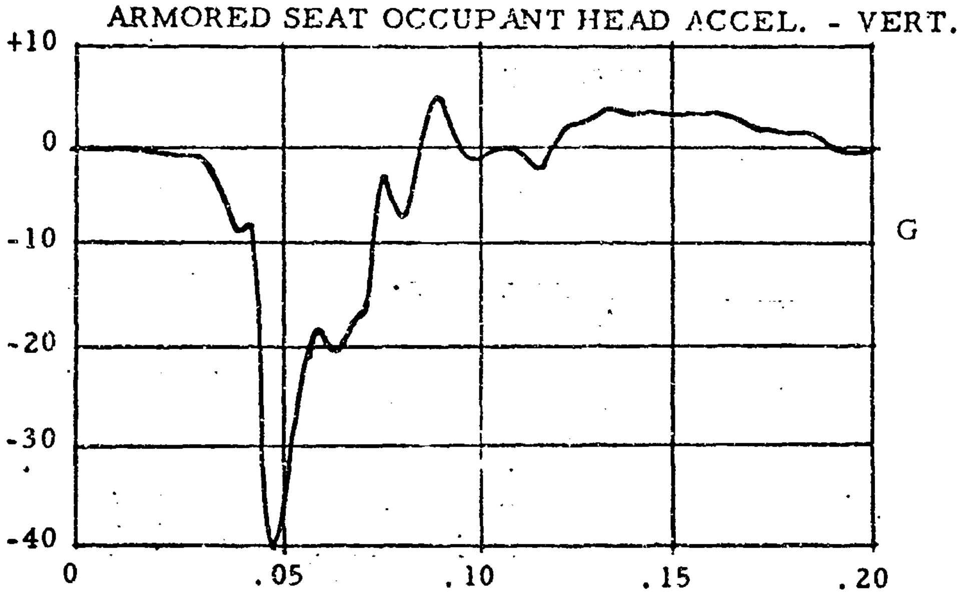


TIME (SECONDS)

Figure 4 Cont'd. - Acceleration Data - Test No. 4.

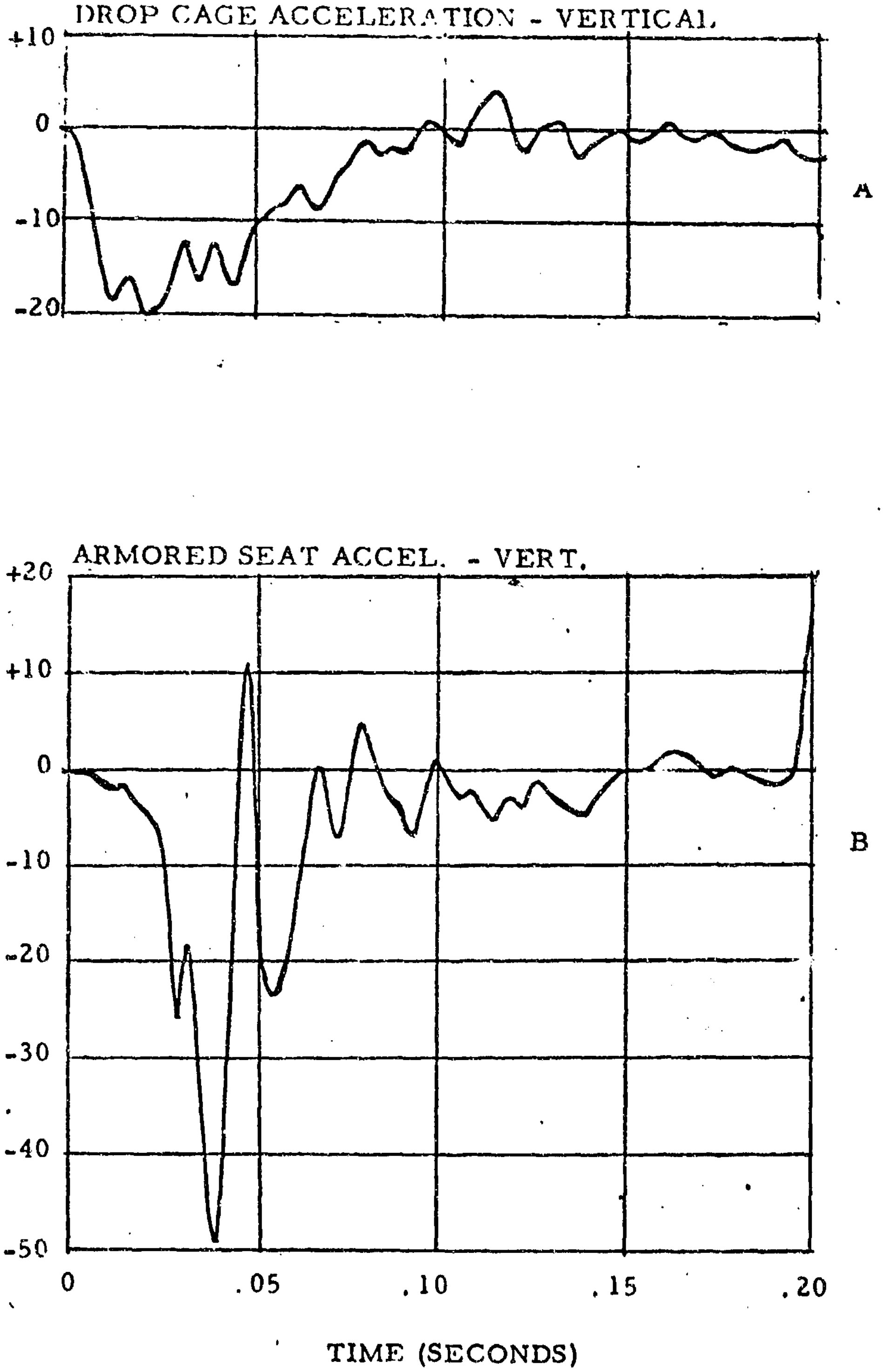


Figure 5. - Acceleration Data - Test No. 5.

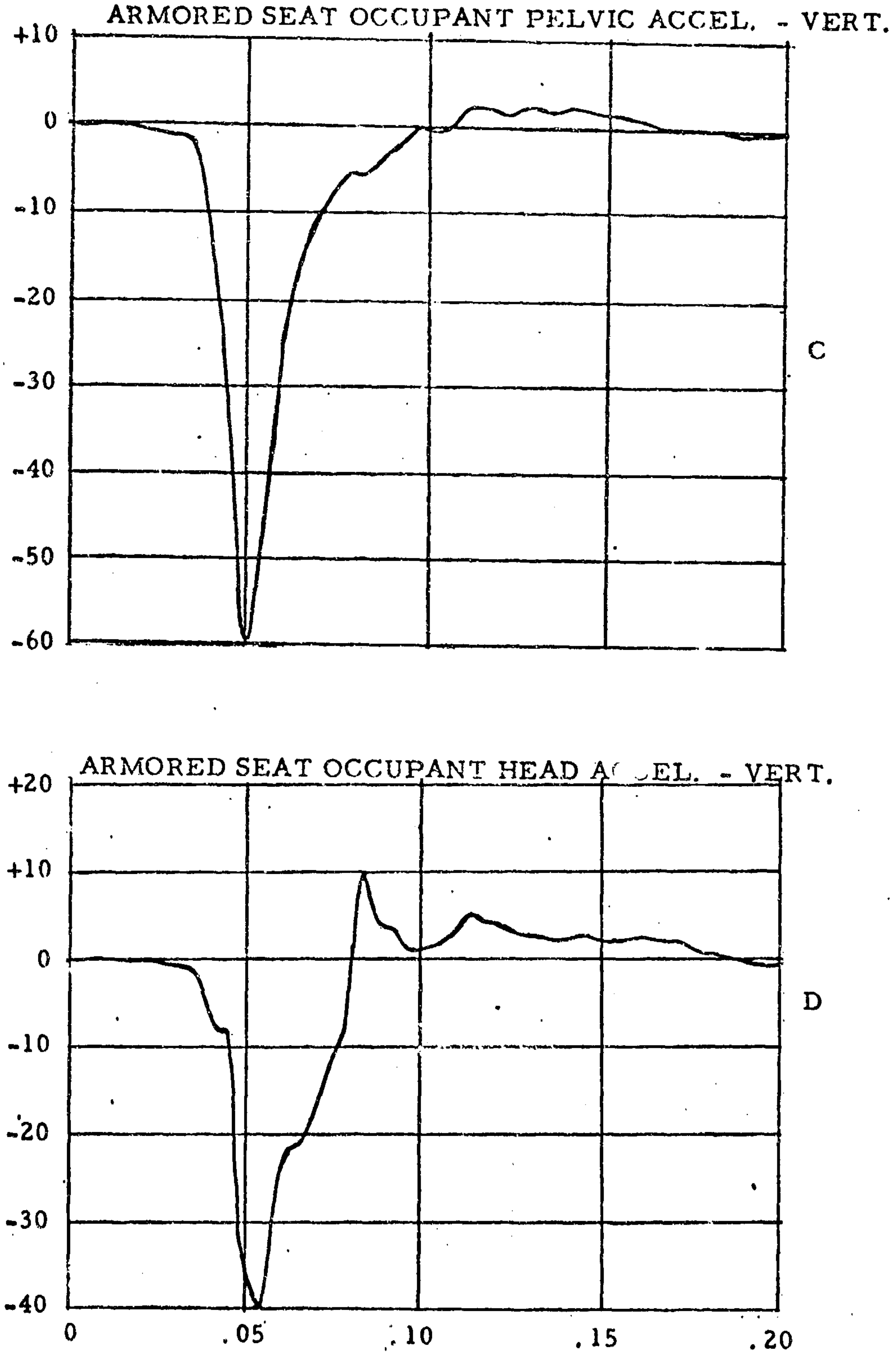


Figure 5 Cont'd. - Acceleration Data - Test No. 5.

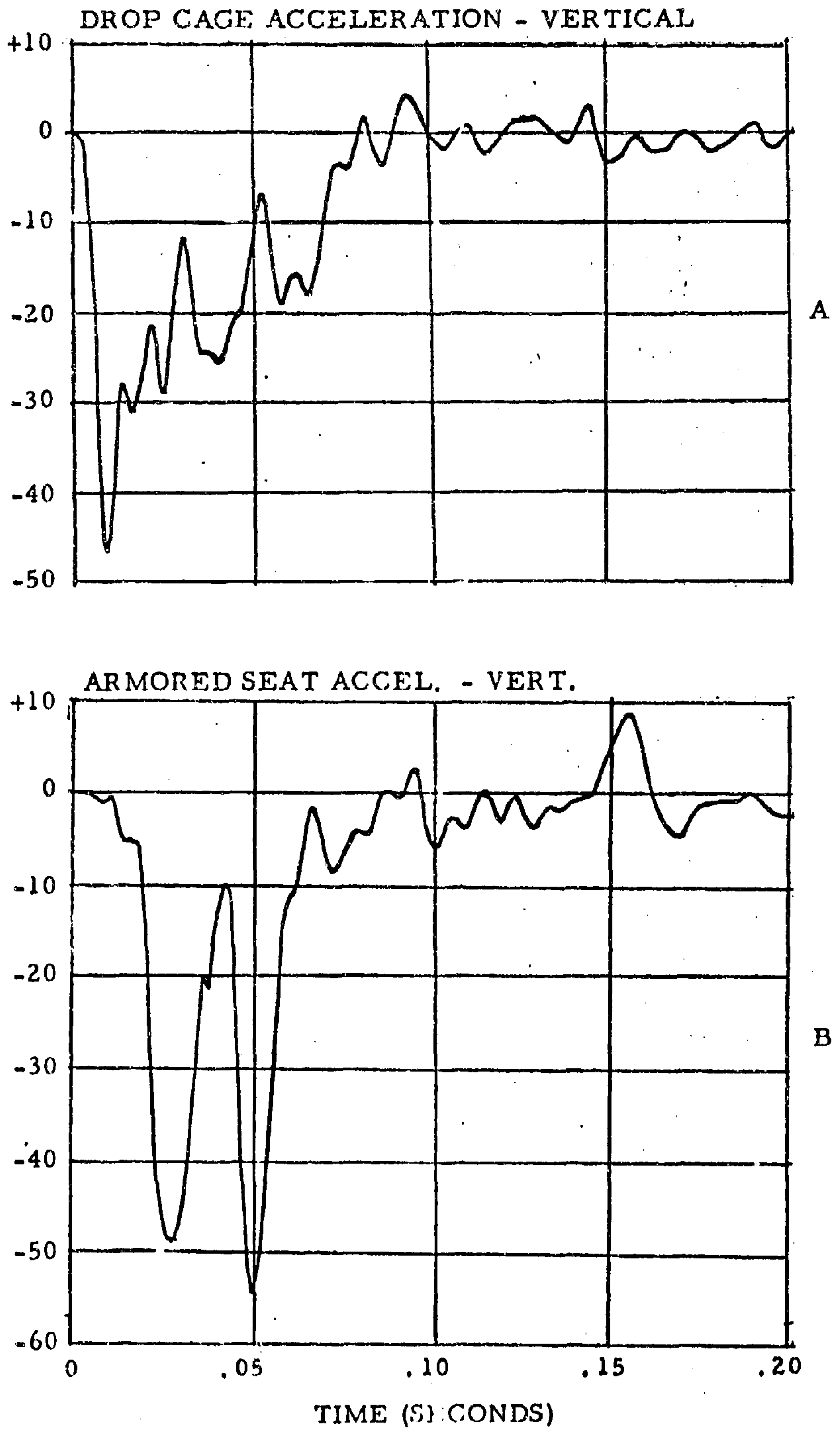


Figure 6. - Acceleration Date - Test No. 6.

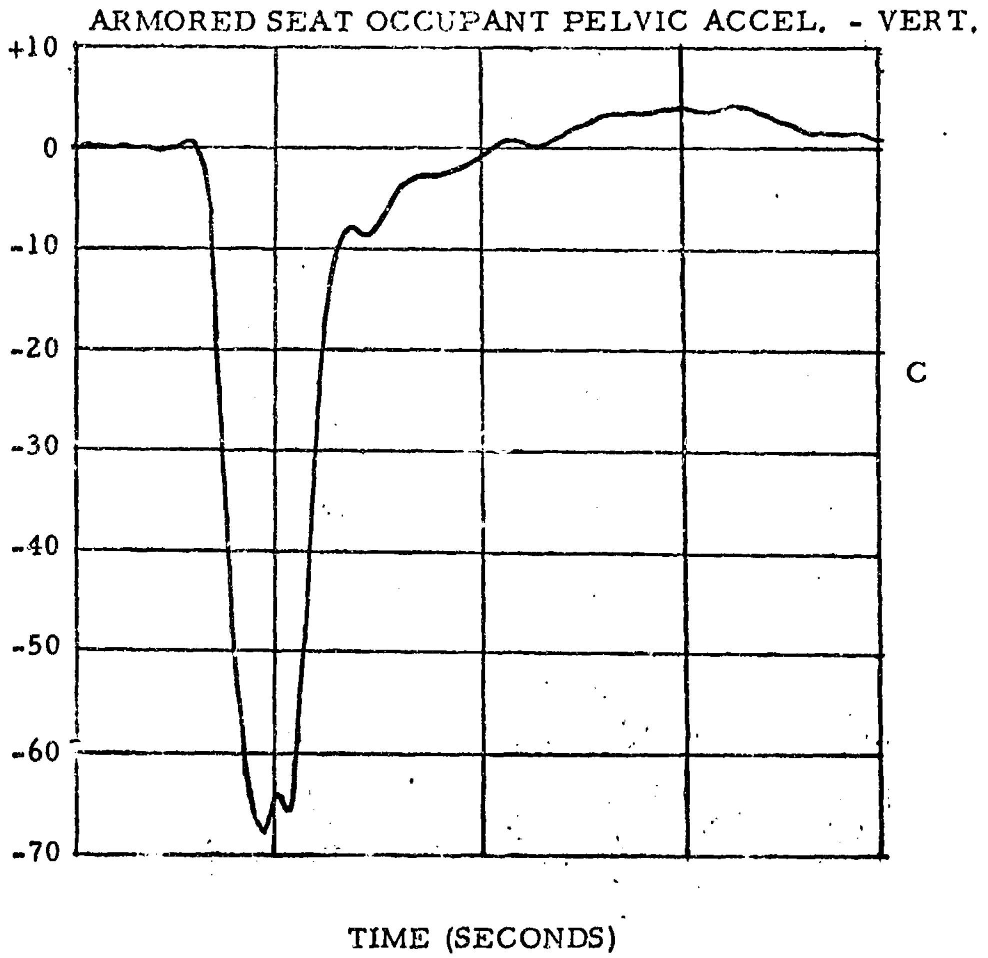


Figure 6 Cont'd. - Acceleration Date - Test No. 6.

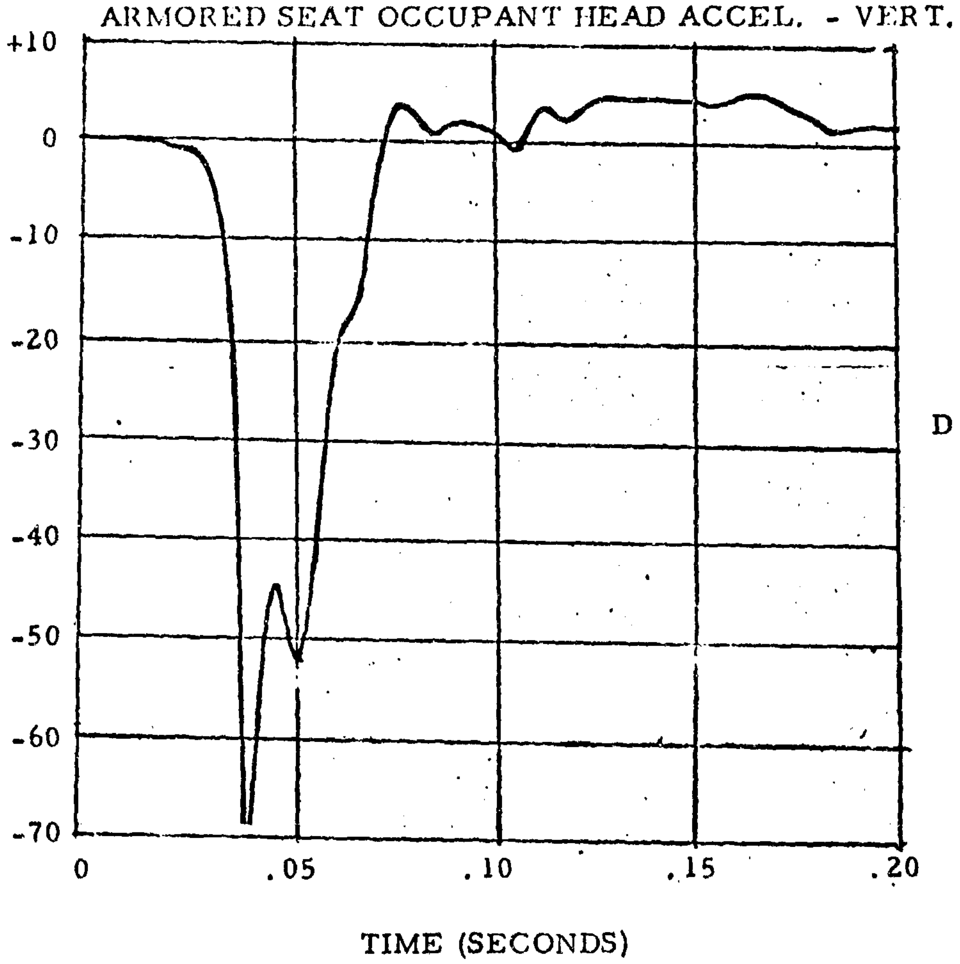


Figure 6 Cont'd. - Acceleration Data - Test No. 6.

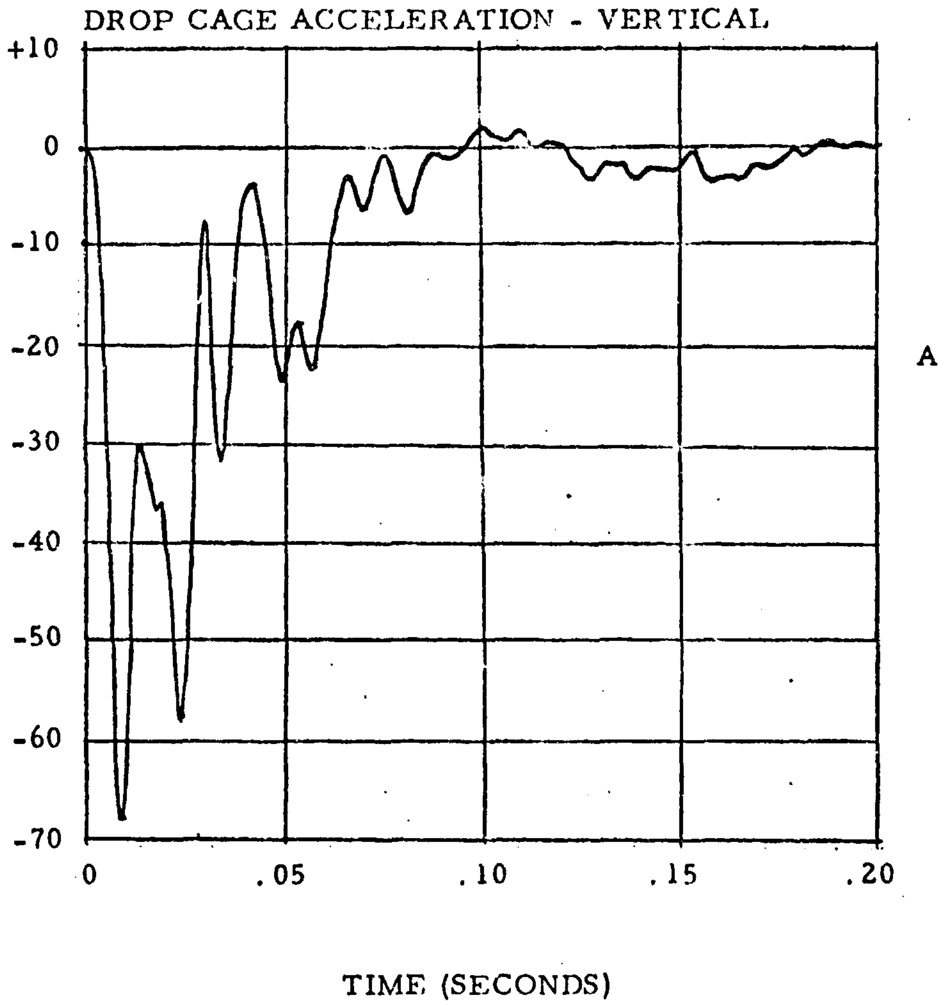


Figure 7. - Acceleration Data - Test No. 7.

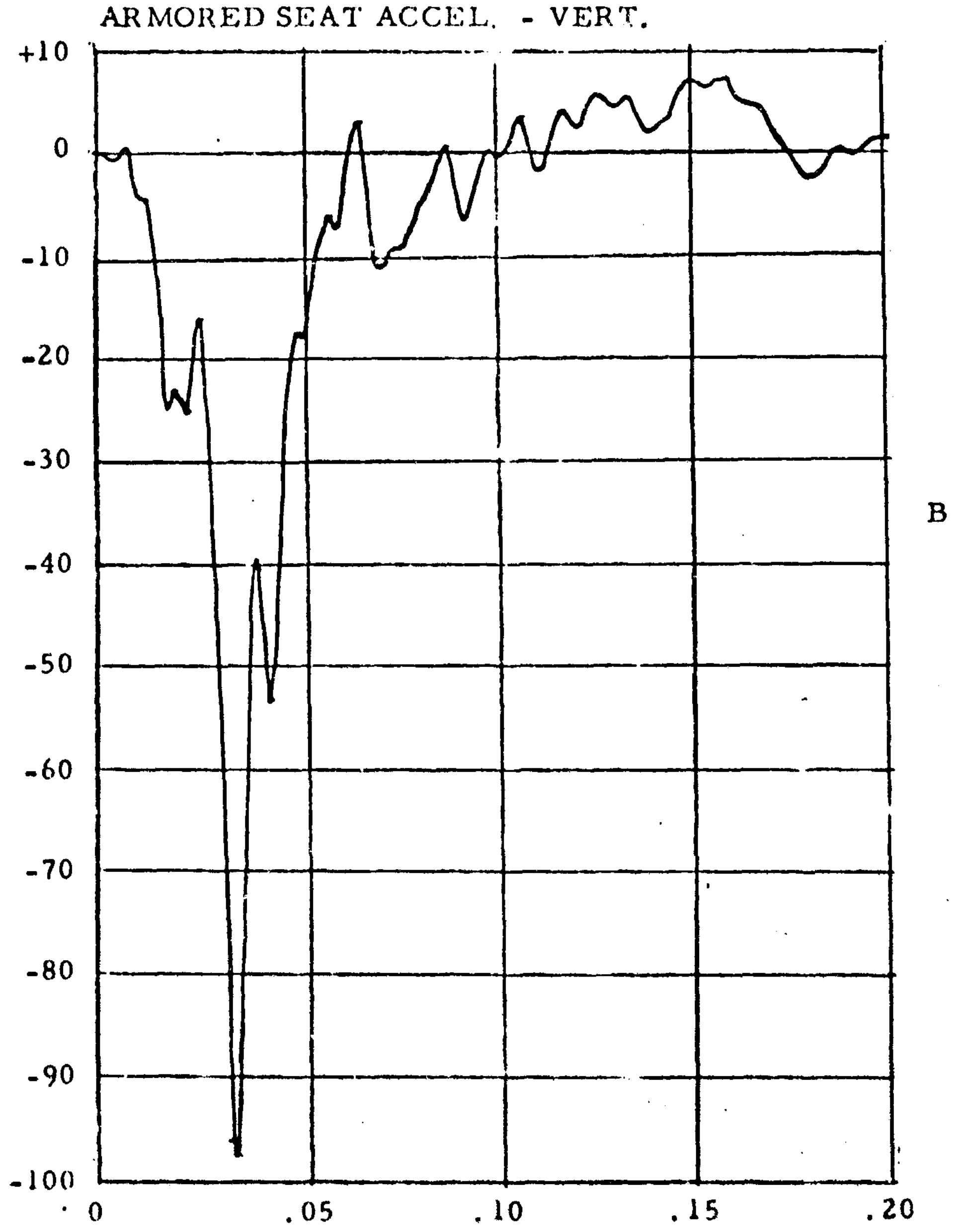
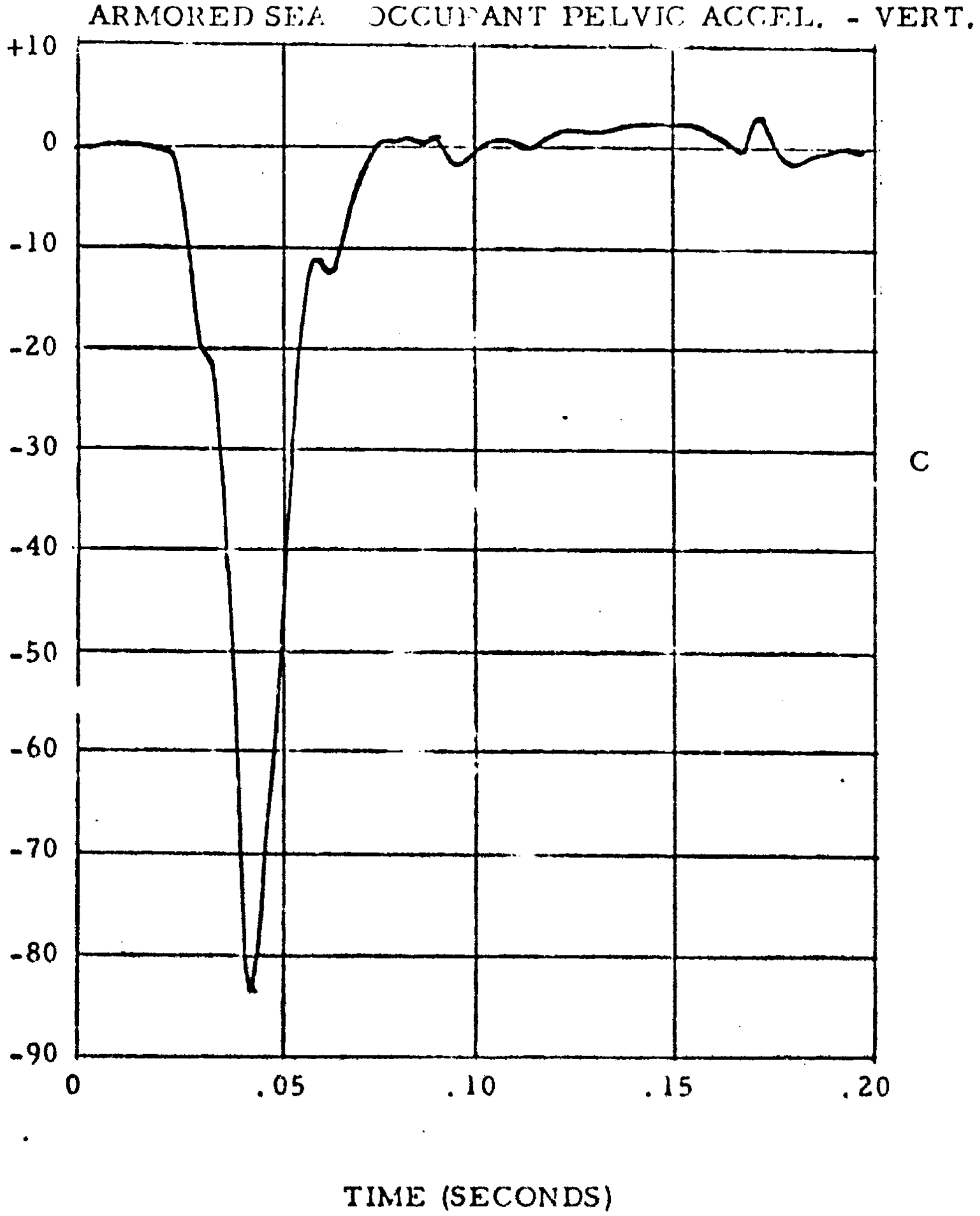


Figure 7 Cont'd. - Acceleration Data - Test No. 7.



C

Figure 7 Cont'd. Acceleration Data - Test No. 7.

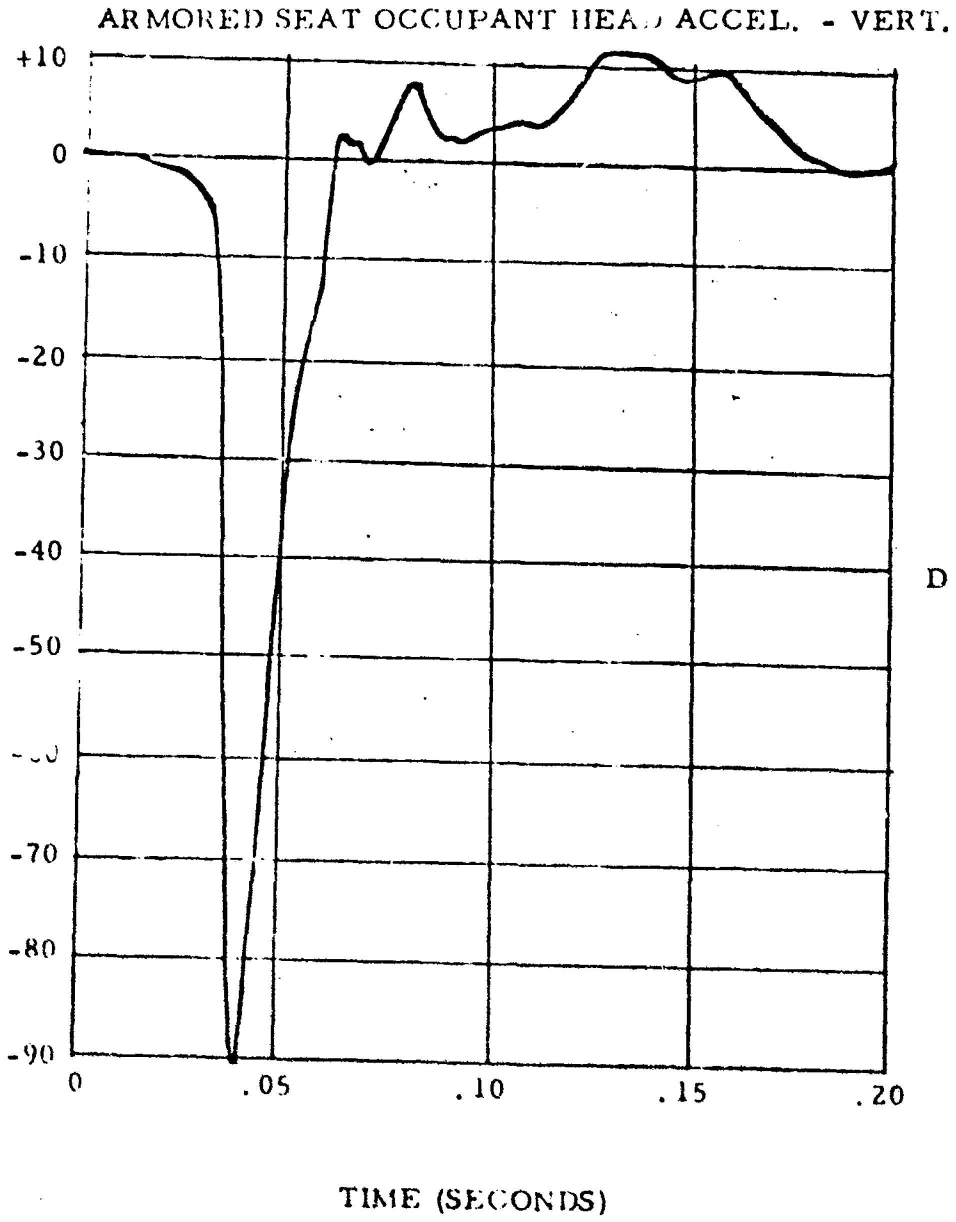


Figure 7 Cont'd. - Acceleration Data - Test No. 7.

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St. Louis, Missouri

13. ABSTRACT

The armored seat and a standard UH-1 seat were subjected to the same impacts in order to compare the dynamic response of the seat - occupant systems. The vertical energy absorbing mechanism provided in the armored seat was also evaluated.

Similar occupant protection was afforded by the two seats up to about 15G where the standard seat deformed too much to provide much protection. The vertical energy absorbing mechanism used in the armored seat did not operate effectively.

14. KEY WORDS	LINK A		LINK B		LINK C	
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