NASA-TM-89025 19860023299

NASA Technical Memorandum 89025

VERTICAL DROP TEST OF A TRANSPORT FUSELAGE SECTION LOCATED AFT OF THE WING

EDWIN L. FASANELLA AND EMILIO ALFARO-BOU

SEPTEMBER 1986

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

VERTICAL DROP TEST OF A TRANSPORT FUSELAGE SECTION LOCATED AFT OF THE WING

Edwin L. Fasanella
PRC Kentron

Emilio Alfaro-Bou
NASA Langley Research Center

SUMMARY

A 12-foot long Boeing 707 aft fuselage section with a tapering longitudinal cross section was drop tested at the NASA Langley Research Center to measure structural, seat, and occupant response to vertical crash loads and to provide data for nonlinear finite element modeling. This was the final test in a series of three different transport fuselage sections tested under identical conditions. The test parameters at impact were: 20 ft/s velocity, and zero pitch, roll, and yaw. In addition, the test was an operational shock test of the data acquisition system used for the Controlled Impact Demonstration (CID) of a remotely piloted Boeing 720 that was crash tested at NASA Dryden Flight Research Facility on December 1, 1984.

Post-test measurements of the crush showed that the front of the section (with larger diameter) crushed vertically approximately 14 inches while the rear crushed 18 inches. Analysis of the data traces indicate the maximum peak normal (vertical) accelerations at the bottom of the frames were approximately 109 G at body station 1040 and 64 G at body station 1120. The peak floor acceleration varied from 14 G near the wall to 25 G near the center where high frequency oscillations of the floor were evident. The peak anthropomorphic dummy pelvis normal (vertical) acceleration was 19 G's.

INTRODUCTION

In 1980 NASA Langley Research Center and the Federal Aviation Administration (FAA) began an extensive research and development program to quantitatively assess transport airplane crashes. As part of the joint transport crash safety program, a series of three transport fuselage section drop tests at impact velocity 20 ft/s were performed at NASA Langley Research Center's Impact Dynamics Facility. The first and second tests (references 1-2) were conducted to determine structural, seat, and occupant response to vertical crash loads for a 12-foot section forward of the wing and for a 13-foot long center section that included the wheel wells, respectively. This data was needed in preparation for the joint FAA/NASA

Controlled Impact Demonstration (CID) of a Boeing 720 airplane (a shortened version of the Boeing 707) that was remotely piloted to a crash site at NASA Ames Dryden Flight Research Facility on December 1, 1984 (reference 3). The data from the section drop tests were also used to compare with DYCAST (reference 4) computer model predictions, and to provide data for developing nonlinear subfloor crush springs for a hybrid finite-element airplane model used to simulate pre-CID impact scenarios and to simulate the actual CID test (reference 5). The third section drop of the aft section which is the subject of this report had an additional purpose. It was also used to qualify instrumentation and to test impact tolerance of CID data acquisition hardware.

This report presents photographs illustrating damage and data traces from the third transport section drop test. This 12-foot long section with a vertical height that tapered from about 14.25 feet at the front to 13.5 feet at the rear was located approximately between body stations 1020 to 1140 in the Boeing 707 (and 720) airplane. The construction of this section is similar to the constant cross section first section, located just forward of the wing, which was tested under identical conditions. The construction of the centerbody section used for the second drop test was quite different. The 13-foot long, 14.2 feet high center section with wheel wells was taken from a very stiff, strong load carrying wing box region.

TEST SPECIMEN

The fuselage section is shown in figure 1 suspended in the Vertical Test Apparatus at the Impact Dynamics Research Facility. The 12-foot long section was cut from a Boeing 707 approximately 10 inches forward of Body Station (BS) 1020 to 10 inches aft of BS 1140. Nonstructural items such as interior paneling, insulation, ducting, etc. were removed from the section. The section weighed 6395 pounds when loaded with a seat and three anthropomorphic dummies, data acquisition system (DAS) pallet, DAS power pallet, DAS recorder pallet, cameras, lights, instrumentation and ballast used to balance the section.

Figure 2 is a floor layout of the section showing the seat, DAS system pallets, etc. The seat was a standard triple transport seat that was acquired along with the transport sections. Only the center dummy of the three anthropomorphic 50th percentile, 165 lb dummies was instrumented.

Table I gives the weight and coordinates of all articles onboard the test section. The X-axis was chosen to be the longitudinal axis with positive x running forward toward the nose of the airplane. The positive Y-axis is transverse to the right, and the positive Z-axis is downward. The origin (0,0,0) was chosen to be at floor level at the center of the front edge (see figure 2). Accelerations along the Z-axis direction will be called normal accelerations; along the Y-axis, transverse; and along the X-axis, longitudinal.

TEST APPARATUS AND METHODS

The NASA Vertical Test Apparatus (VTA) (Figure 1) was used to drop test the transport section and to provide a stable guide mechanism for the vertical impact test. The VTA was designed with the following maximum conditions:

1. Impact velocity - 50 ft/sec
2. Specimen dimensions - 12 ft diameter, 26 feet long
3. Specimen weight - 5 tons

The VTA is located at the northwest leg of the gantry structure at the Impact Dynamics Research Facility (Ref. 6). The gantry provides support through lateral ties to the VTA. The VTA consists of a 7 1/2 ton capacity hoist platform supported by two 70 feet high columns. Attached to each column is a rail to guide the vertical motion of an inverted "U"-shaped lift frame to which the specimen is attached for drop testing. A powered release hook is used to lift the support frame and specimen to the desired drop height and to release it on command. The specimen impacts a steel reinforced concrete pad at the bottom of the VTA while each side of the support frame is decelerated by impacting a shock absorber.

For the transport section drop test, the section was connected to the support frame by a series of cables with turnbuckles to adjust cable length and control the impact attitude. The impact attitude for the test was 0 degree pitch, yaw, and roll. The section was raised 6 ft 2.5 in above the impact surface to obtain a vertical impact velocity of 20 ft/sec.

INSTRUMENTATION AND DATA REDUCTION

All accelerometers were piezoresistive and capable of measuring from 0 Hz (dc) to over 1000 Hz. The accelerometers were ranged to maximum levels of approximately 200 G's vertically, longitudinally, and transverse.

Instrumentation for the drop test consisted of two independent systems. The on-board DAS system with 26 channels was an exact replica of the flight instrumentation system to be used for the CID test. All DAS data were filtered with the appropriate 4-pole Butterworth filter before sampling at either 500 or 1000 samples per second. The DAS data was recorded on tape and transmitted in a pulse code modulation (PCM) format with 8-bit word size. Power for the DAS system, lights, and camera's were provided by surplus squib activated ballistic missile batteries.

The second data collection system hardwired from the control room to the transport section (ref. 7) was continuous analog and allowed up to 90 data channels to be recorded on one 28-track magnetic tape recorder using a constant bandwidth FM multiplexing technique. Millivolt signals from the recorders were subsequently amplified to one volt RMS and switched to an FM demultiplexing system where the original analog information was then extracted. The data was then post-test sampled at 4000 samples per second and digitally filtered using a computer algorithm with a 60 Hz low pass filter for structural accelerations and a 180 Hz filter for the anthropomorphic dummy acceleration channels.

At selected locations, two accelerometers (one connected to each system) were used to provide a comparison of the two data collection systems. The data from both systems were comparable and the on-board DAS system was deemed acceptable. For this report, only the data from the continuous analog FM multiplex system will be presented.

RESULTS

Figures 3-4 show post-test damage to the transport section. The frontal view of the section in figure 3 shows that the fuselage beneath the floor collapsed approximately 14 inches. Except for slight deformation of the floor near the DAS pallet and seat, no other structural damage was apparent at floor level or above. Figure 4 shows the rear view of the section. Since the rear of the section had farther to fall because of the sloping bottom contour, a pitch rate developed and the rear frame impacted with both a longitudinal and vertical component of velocity and deformed approximately 18 inches.

Figures 5-7 show the acceleration data for the section. All traces have the same scale (25 G/division) and the traces are labeled as to general location with the x,y,z coordinates given in parentheses. Accelerations along the Z-axis direction will be called normal accelerations; along the Y-axis, transverse; and along the X-axis, longitudinal.

The *normal accelerations* for locations on frames at BS 1040 and 1120 are shown in figure 5a-5c and 5d-5e,respectively. The normal acceleration varies from a maximum of about 110 G's at the bottom of frame 1040 (which impacted first) to 65 G's on the bottom of frame 1120. The accelerations at the bottom of the frame are difficult to obtain and must be used with caution. More relevant are the floor accelerations. The maximum vertical floor acceleration on frame 1040 varies from approximately 20 G's on the right to about 25 G's on the left side. The primary deceleration pulse lasts for less than 0.1 seconds total. On frame 1140, the maximum normal acceleration on the floor is somewhat less, and does not exceed 20 G's. Only the center dummy was instrumented. The seat pan maximum acceleration (Figure 5 b) was 14 G's. The pelvis acceleration did show a normal spike of 19 G's; however, the plateau was in the same 14 G range as the seat pan. The pelvis acceleration pulse duration was approximately 0.10 seconds.

Longitudinal accelerations for locations on frames 1040 and 1120 are shown in figure 6. The longitudinal accelerations on frame 1040 (figure 6a-b) are primarily oscillatory and are of low magnitude. However, the longitudinal accelerations at the floor level for frame 1120 (figure 6c-d) are of higher magnitude because the sloping bottom allowed some longitudinal velocity to develop due to rotation about the contact point on frame 1040.

Transverse accelerations are given in figure 7. The highest peak recorded was at the lower right wall and measured 19 G's. At the floor level, the transverse acceleration was low and oscillatory as would be expected.

Comparison of the Three Section Tests

Table II gives a comparison of accelerations from the three transport airframe section tests (for the forward and center sections, see references 1 and 2) for accelerometers located at the bottom of the fuselage (fuselage keel), at the intersection of the side frame with the floor beam, on the floor at the seat rails, and in the dummy pelvis. For comparison purposes, all structural accelerations were passed through a 60 Hz low-pass filter, and all dummy accelerations were passed through a 180 Hz low-pass filter. (Note that in reference 1 the structural accelerations were reported with 20 Hz low-pass filtering.) Generally, the peak accelerations for the forward section and the aft section were similar. The dummy pelvis normal peak acceleration for the forward section showed a relatively large variation from seat to seat. The traces consisted of two peaks of similar magnitude spaced about 0.1 seconds apart with total duration slightly over 0.2 seconds. Only one dummy was instrumented on the aft section.

All accelerations other than the keel (which is the contact point with high accelerations for all sections) were much higher for the stiff center wing box section. The pelvis normal acceleration ranged from 40 - 60 G's for this section with base durations of only 0.04 seconds. The wing box showed no crushing and only minor floor warping. However, seat leg damage was apparent for some seats.

Concluding Remarks

A 12-foot long Boeing 707 aft fuselage section with a longitudinal tapering cross section was drop tested at the NASA Langley Research Center to measure structural, seat, and occupant response to vertical crash loads and to provide data for nonlinear finite element modeling. This was the final test in a series of three different transport fuselage sections tested under identical conditions. The test parameters at impact were: 20 ft/s velocity, and zero pitch, roll, and yaw. In addition, the test was an operational shock test of the data acquisition system used for the Controlled Impact Demonstration (CID) of a remotely piloted Boeing 720 that was crash tested at NASA Ames Dryden Flight Research Facility on December 1, 1984.

Post-test measurements of the crush showed that the front of the aft section crushed vertically approximately 14 inches while the rear crushed 18 inches. Analysis of the data traces indicate the maximum peak normal (vertical) accelerations at the bottom of the frames were approximately 109

G at body station 1040 and 64 G at body station 1120. The peak floor acceleration varied from 14 G near the wall to 25 G near the center where high frequency oscillations of the floor were evident. The peak anthropomorphic dummy pelvis normal (vertical) acceleration was 19 G's.

Accelerations for the forward section (ref. 1) which was similar in construction, weight and dimensions were quite similar to those experienced in the aft section test. The normal dummy pelvis accelerations ranged from a low of 6 to a high of 15 G's depending on location.

The accelerations measured from the drop test of the strong center fuselage section (ref. 2) were much higher. The forward and aft section structure below the floor deformed nearly 2 feet and reduced the accelerations at the floor level. The strong center section showed no appreciable subfloor deformation and consequently all the forces were transferred to the seats and dummies. The dummy pelvis normal acceleration ranged from 40 to 60 G's.

REFERENCES

1. Williams, M. Susan; and Hayduk, Robert J.: Vertical Drop Test of a Transport Fuselage Section Located Forward of the Wing. NASA TM 85679, 1983.

2. Williams, M. Susan; and Hayduk, Robert J.: Vertical Drop Test of a Transport Fuselage Center Section Including the Wheel Wells. NASA TM 85706, 1983.

3. Fasanella, Edwin L.; Alfaro-Bou, Emilio; and Hayduk, Robert J.: Impact Data from a Transport Aircraft During a Controlled Impact Demonstration. NASA TP 2589, September 1986.

4. Hayduk, R. J.; Winter, R.; Pifko, A. B.; and Fasanella, E. L.: Application of the Non-linear Finite Element Computer Program 'DYCAST' to Aircraft Crash Analysis. Structural Crashworthiness, Edited by N. Jones and T. Wierzbicki, Butterworth & Co. Ltd., 1983, pp 282-307.

5. Fasanella, Edwin L.; Widmayer, E.; and Robinson, Martha P.: Structural Analysis of the Controlled Impact Demonstration of a Jet Transport Airplane. presented at 27th Structures, Structural Dynamics and Materials Conference, May 1986, AIAA paper 86-0939-CP.

6. Vaughan, Victor L., Jr.; and Alfaro-Bou, Emilio: Impact Dynamics Research Facility for Full-Scale Aircraft Crash Testing. NASA TN D-8179, 1976.

7. McCormick, Royce F.; Spears, Jack C.; Lynch, James W.; and Batten, Frank R.: Data Acquisition System for NASA LaRC Impact Dynamics Research Facility. NASA TM 84510, 1982.

TABLE I.- AFT TRANSPORT SECTION WEIGHT DISTRIBUTION

ITEM	Weight	X(in)	Y(in)
DAS Power Pallet	465	25	35
DAS Pallet	923	80	35
DAS Recorder Pallet	163	125	35
Seat & Dummies	555	33	-35
Camera & Lights Power Pallet	230	69	-35
RF Pallet	37	100	-35
Junction Box	56	129	-35
Camera & Light	63	18	35
Camera & Light	63	123	35
Camera & Light	63	123	-35
Rear Ballast	334	120	-65
Front Ballast	60	10	-10

TABLE 2.- COMPARISON OF PEAK VERTICAL ACCELERATION FOR THREE SECTION TESTS DROPPED AT 20 FT/S
(All Channels Filtered with 60 HZ Low-Pass Digital Filter)

	RANGE OF PEAK ACELLERATION, G'S		
	FORWARD SECTION	CENTER SECTION	AFT SECTION
LOCATION			
Fuselage keel	56 - overload	60 - overload	64 - 109
Side frame/floor	14 - 19	90 - 100	14 - 20
Floor/seat rails	8 - 22	60 - 90	15 - 25
Dummy Pelvis	6 - 15	40 - 60	19

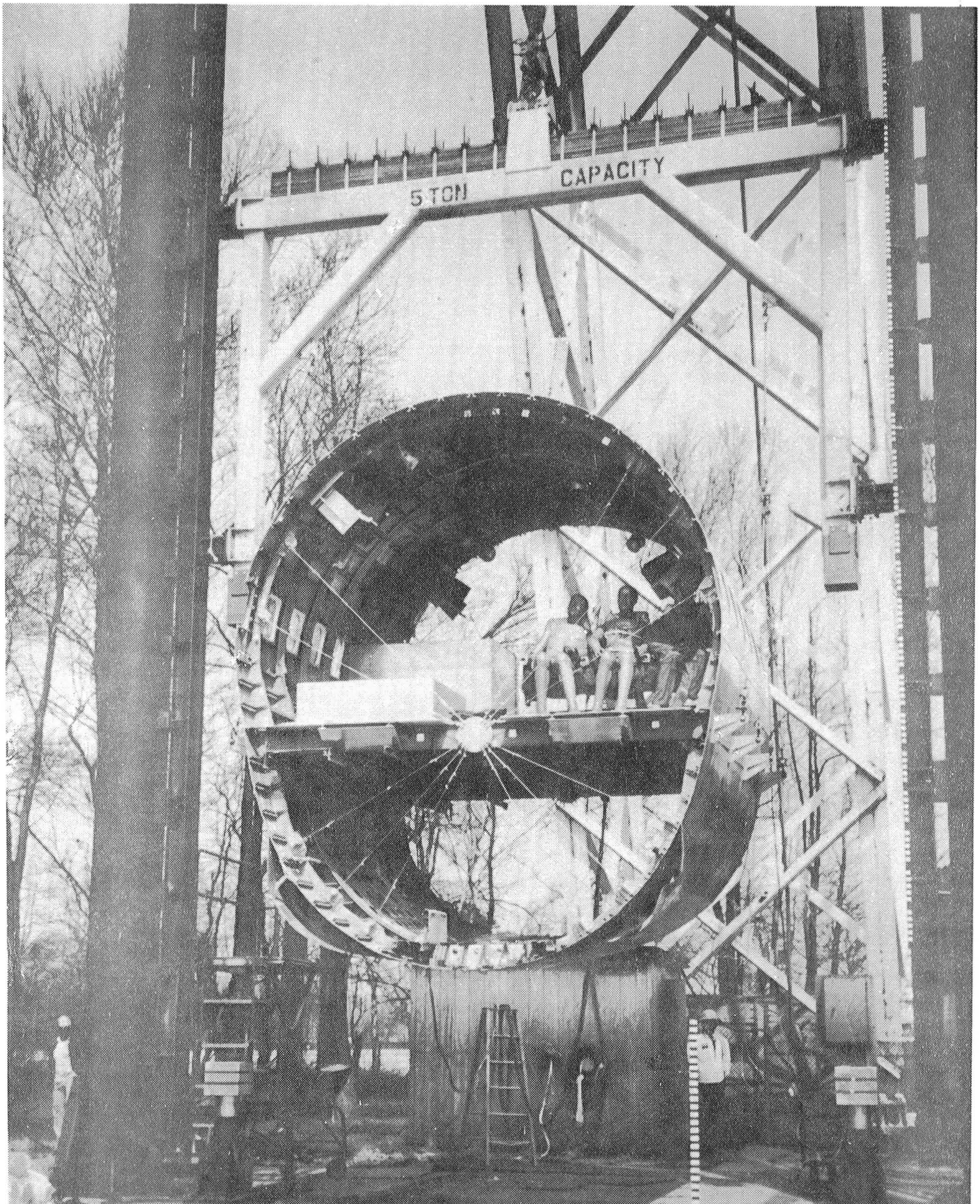


Figure 1.- Aft Transport section suspended in Vertical Test Apparatus.

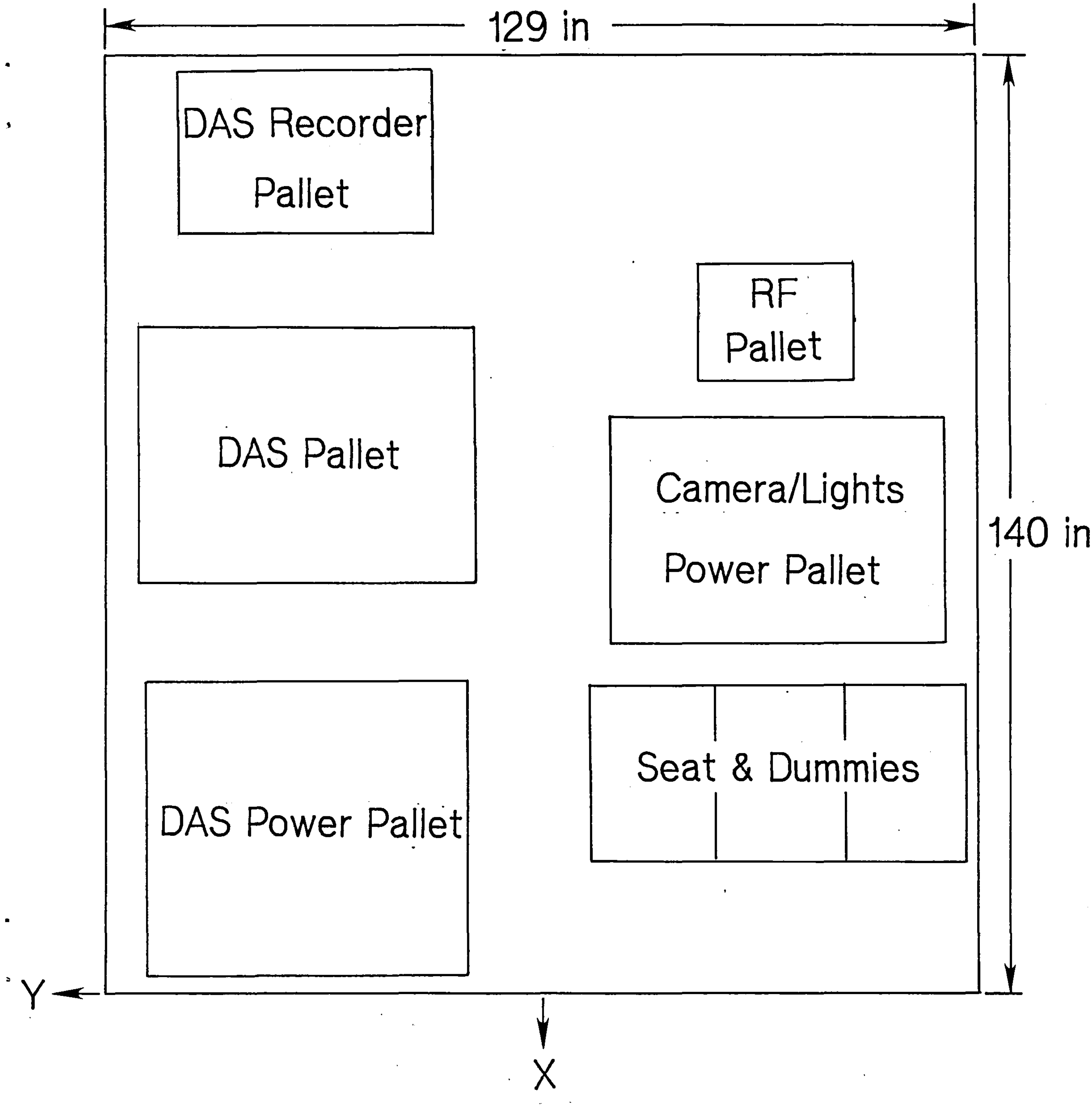


Figure 2.- Floor plan of section showing coordinate axes.

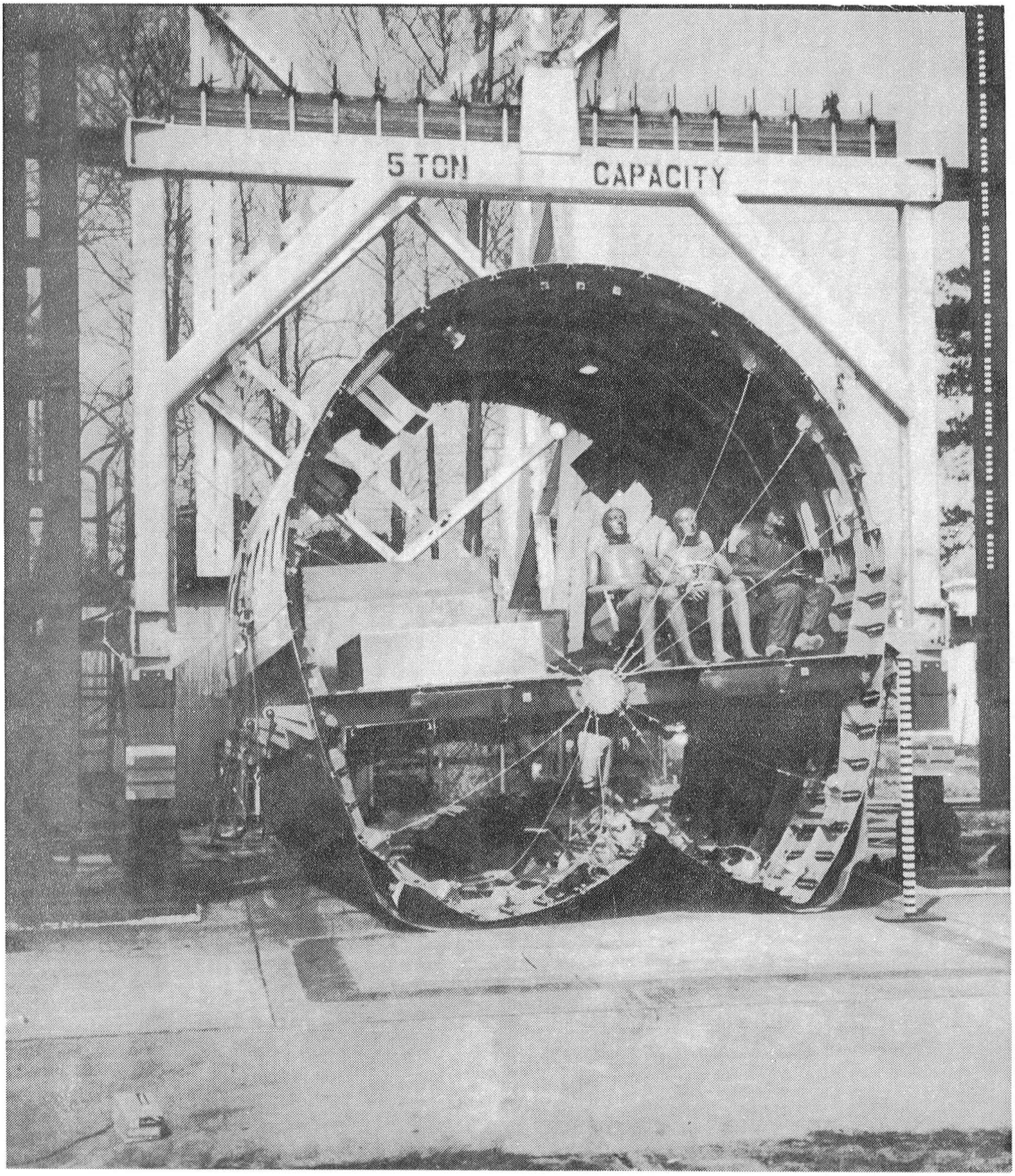


Figure 3.- Front view of section post-test.

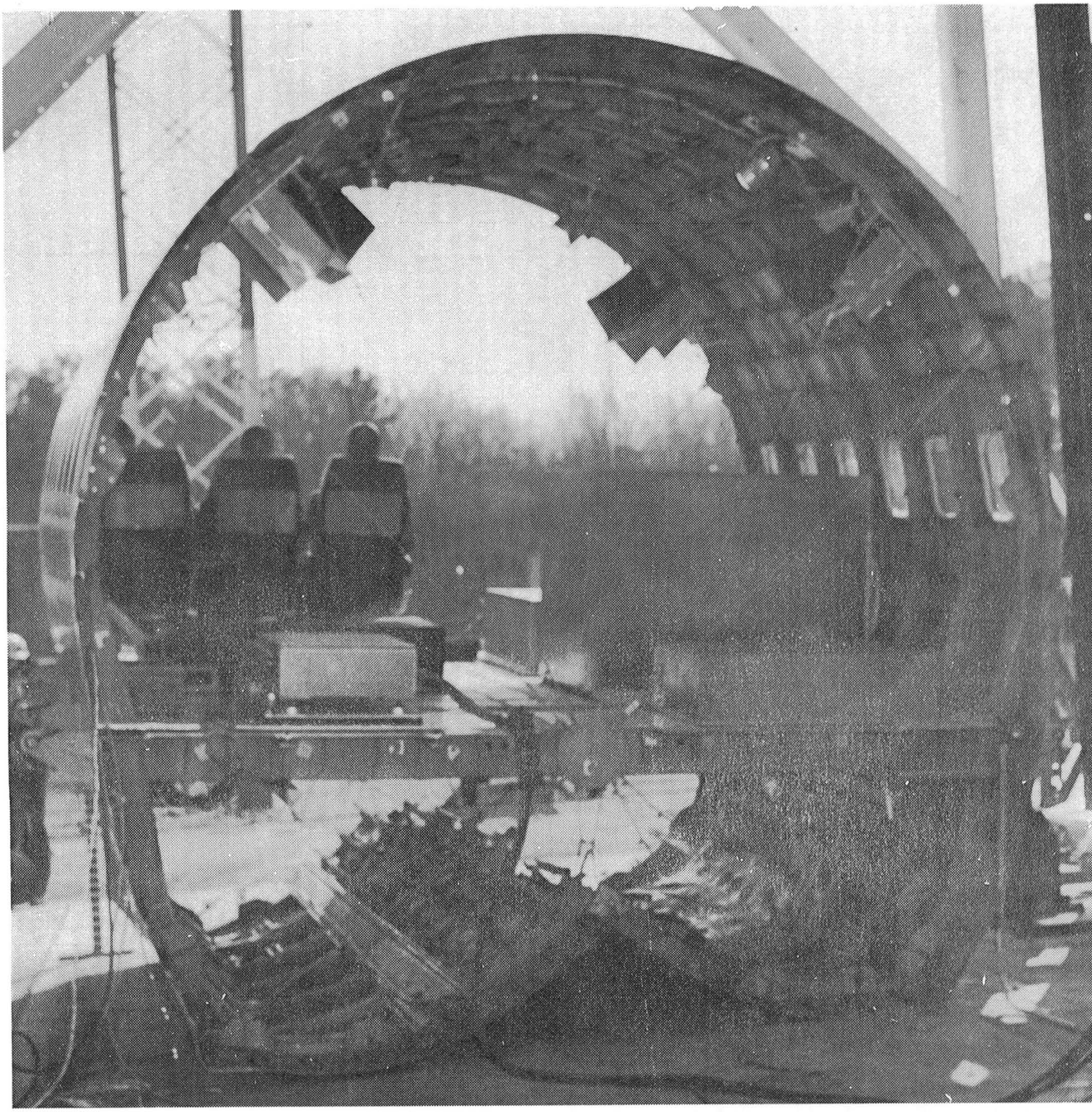
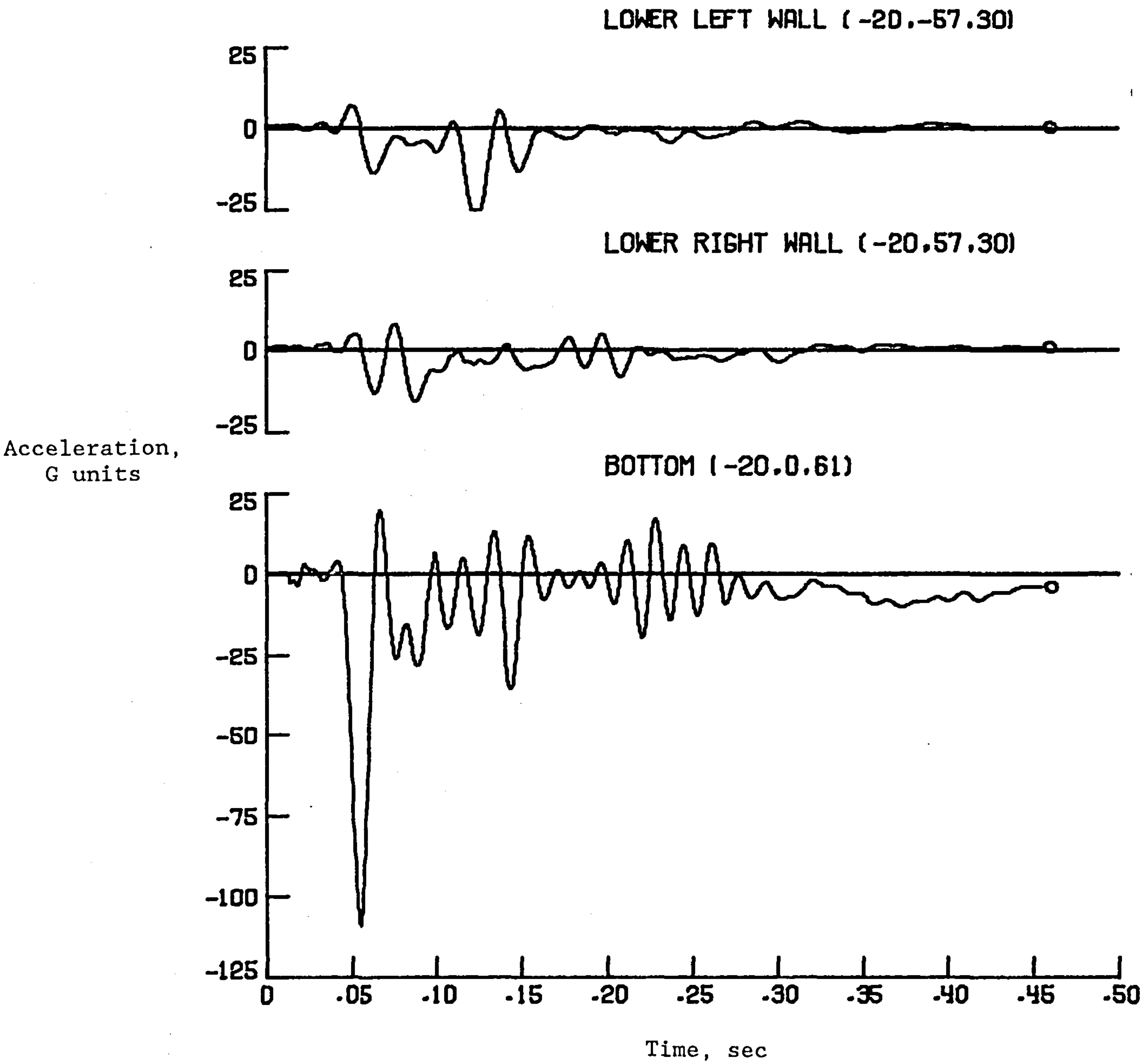
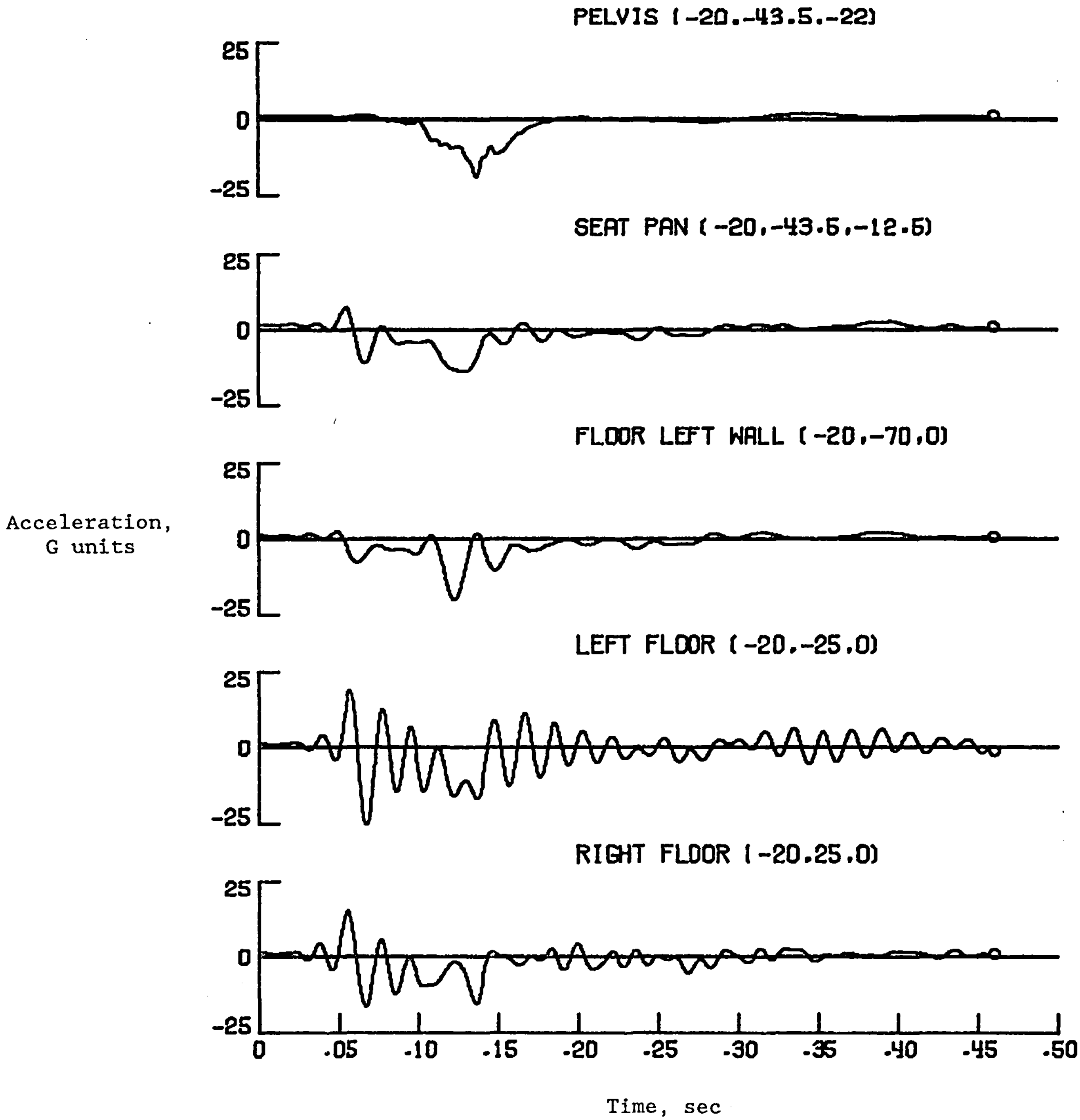


Figure 4.- Rear view of section post-test.



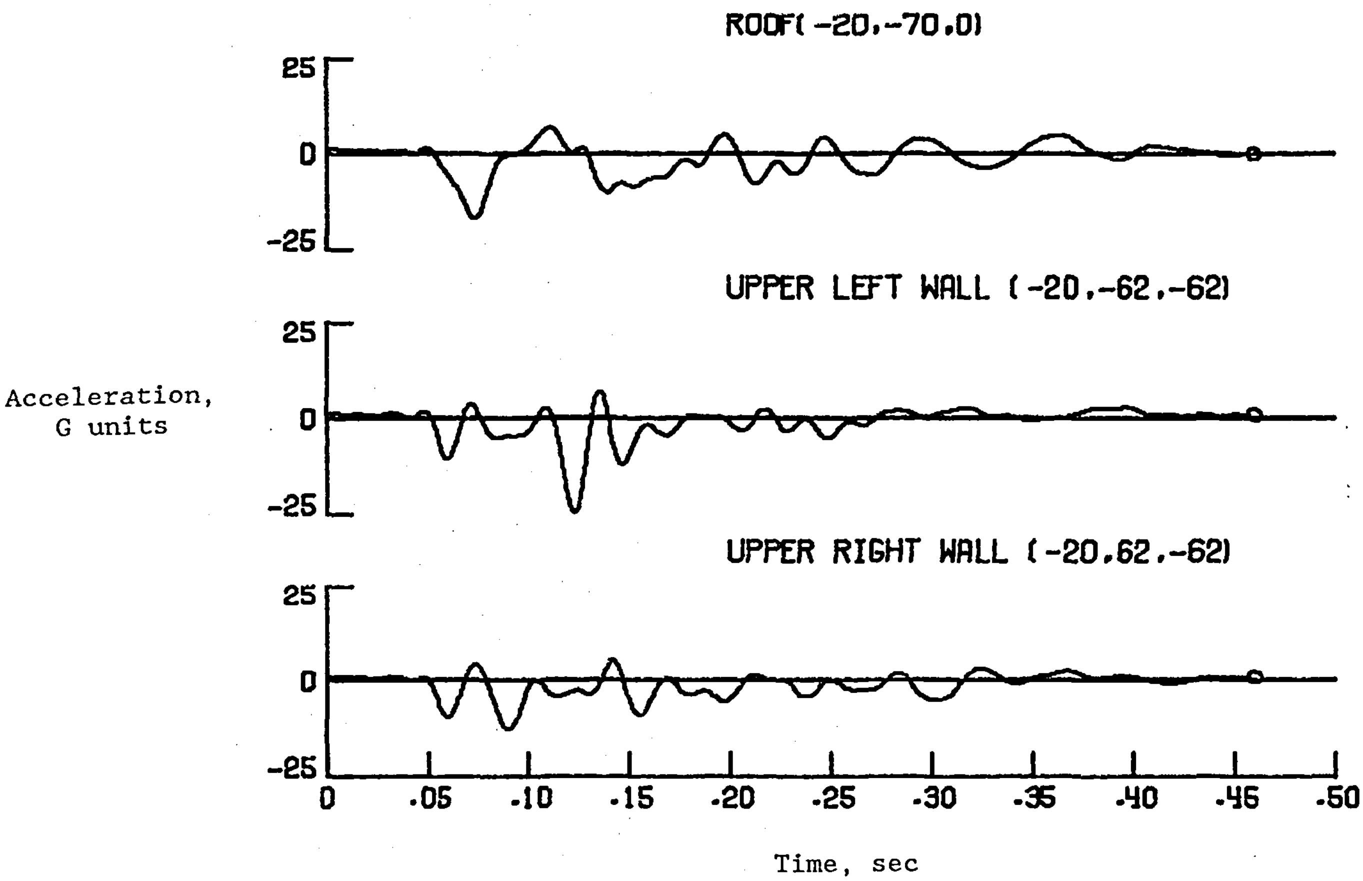
(a) BS 1040

Figure 5.- Normal acceleration time histories.



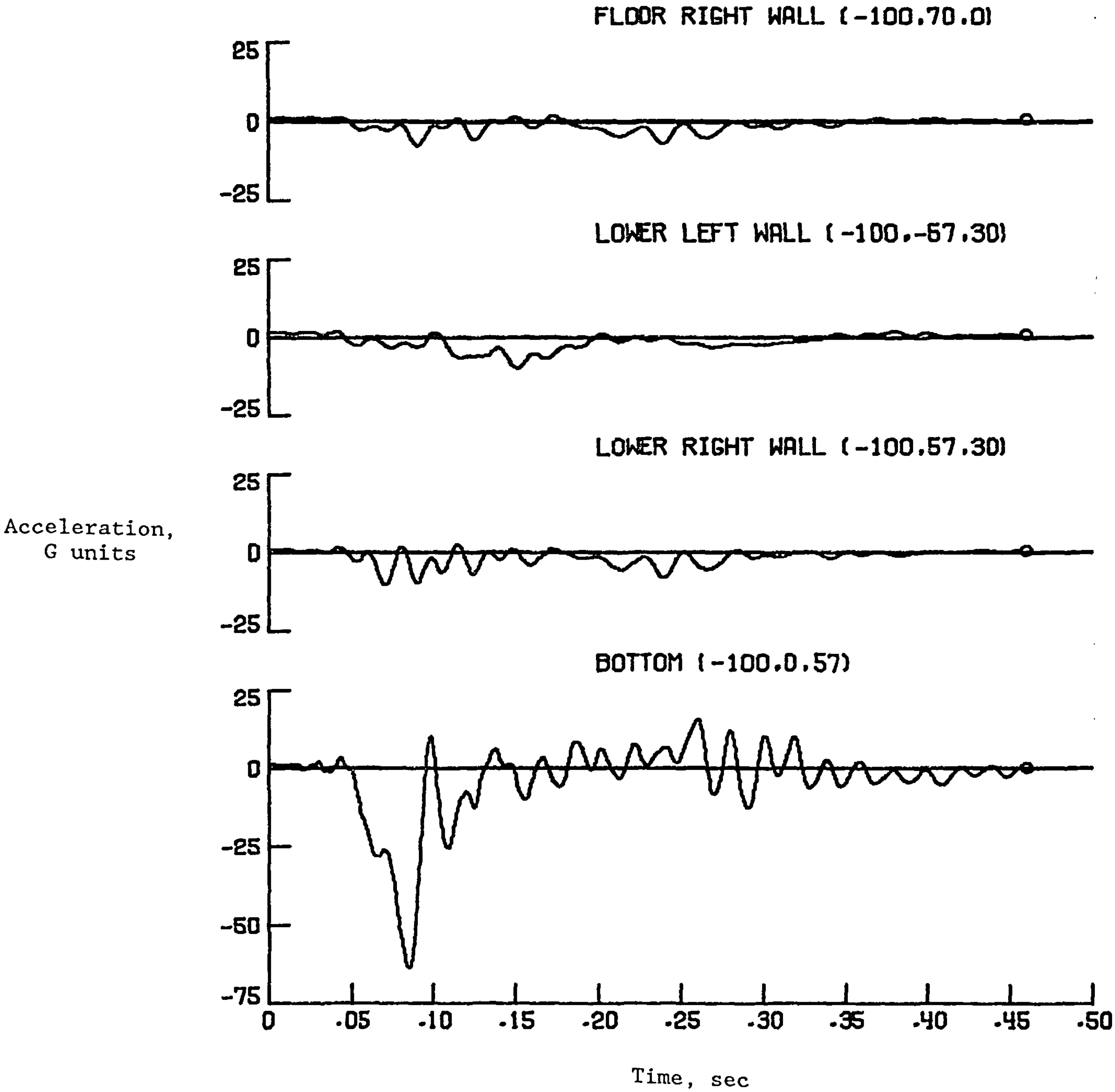
(b) BS 1040

Figure 5.- Continued.



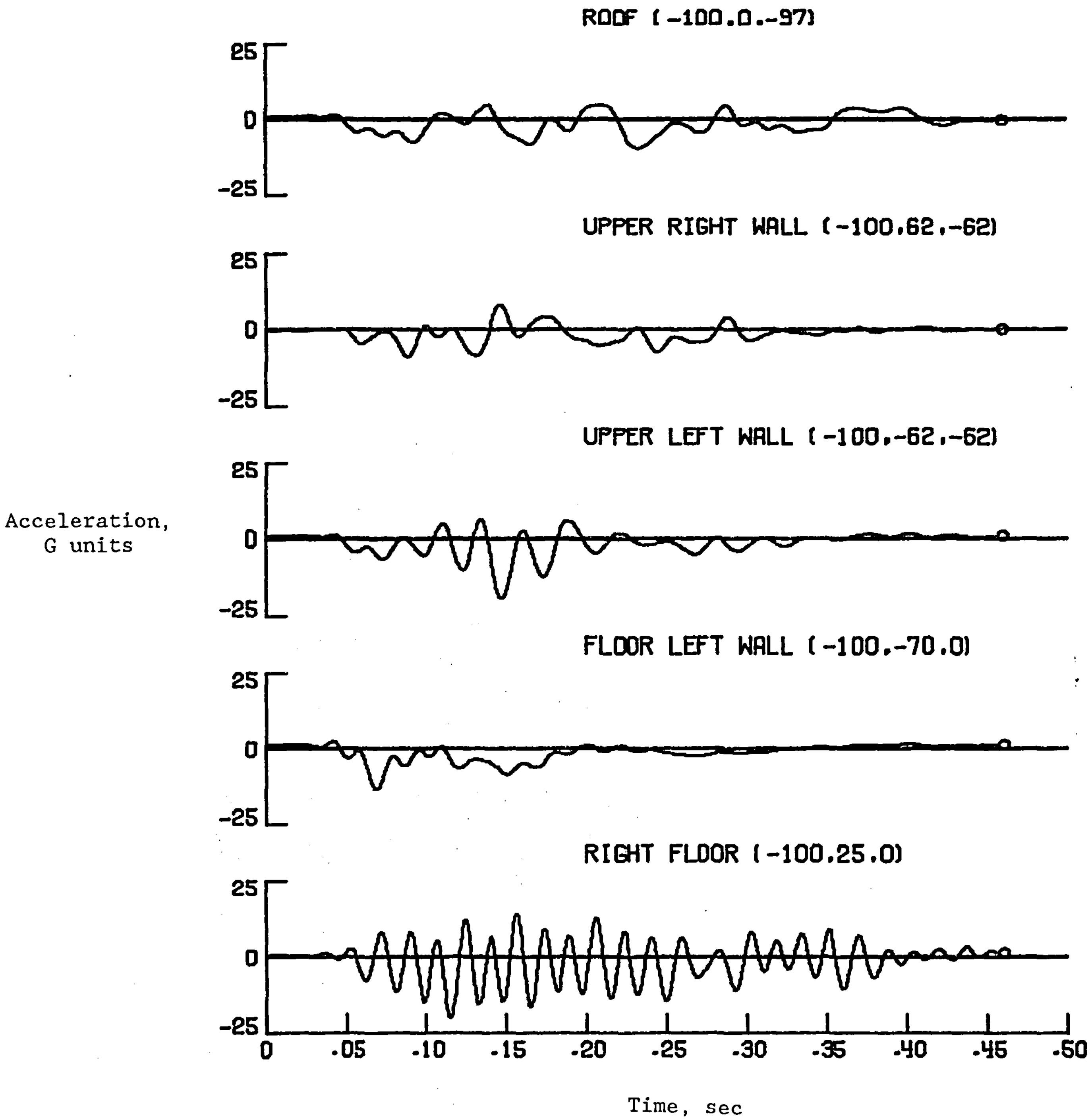
(c) BS 1040

Figure 5.- Continued.



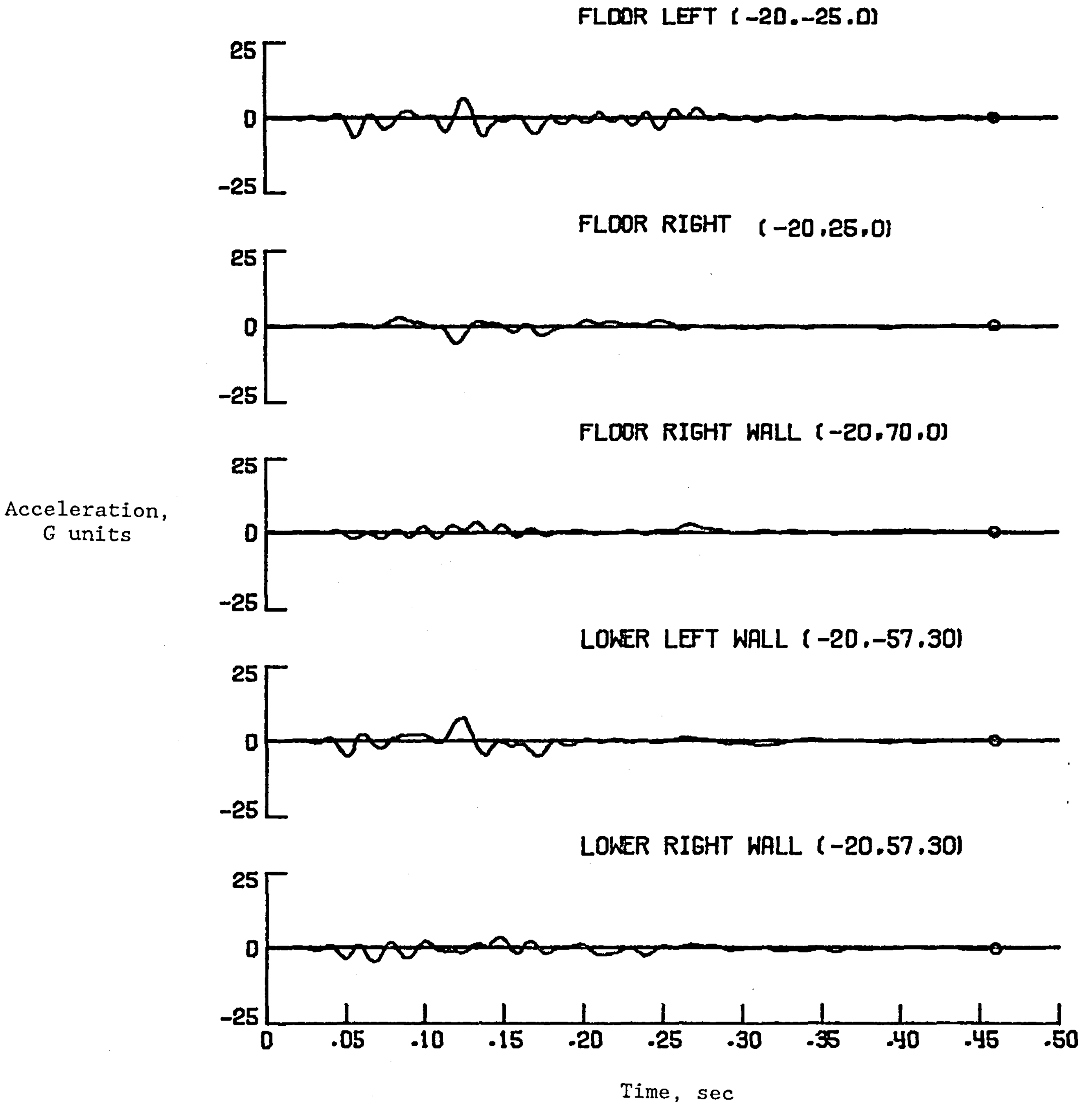
(d) BS 1120

Figure 5.- Continued.



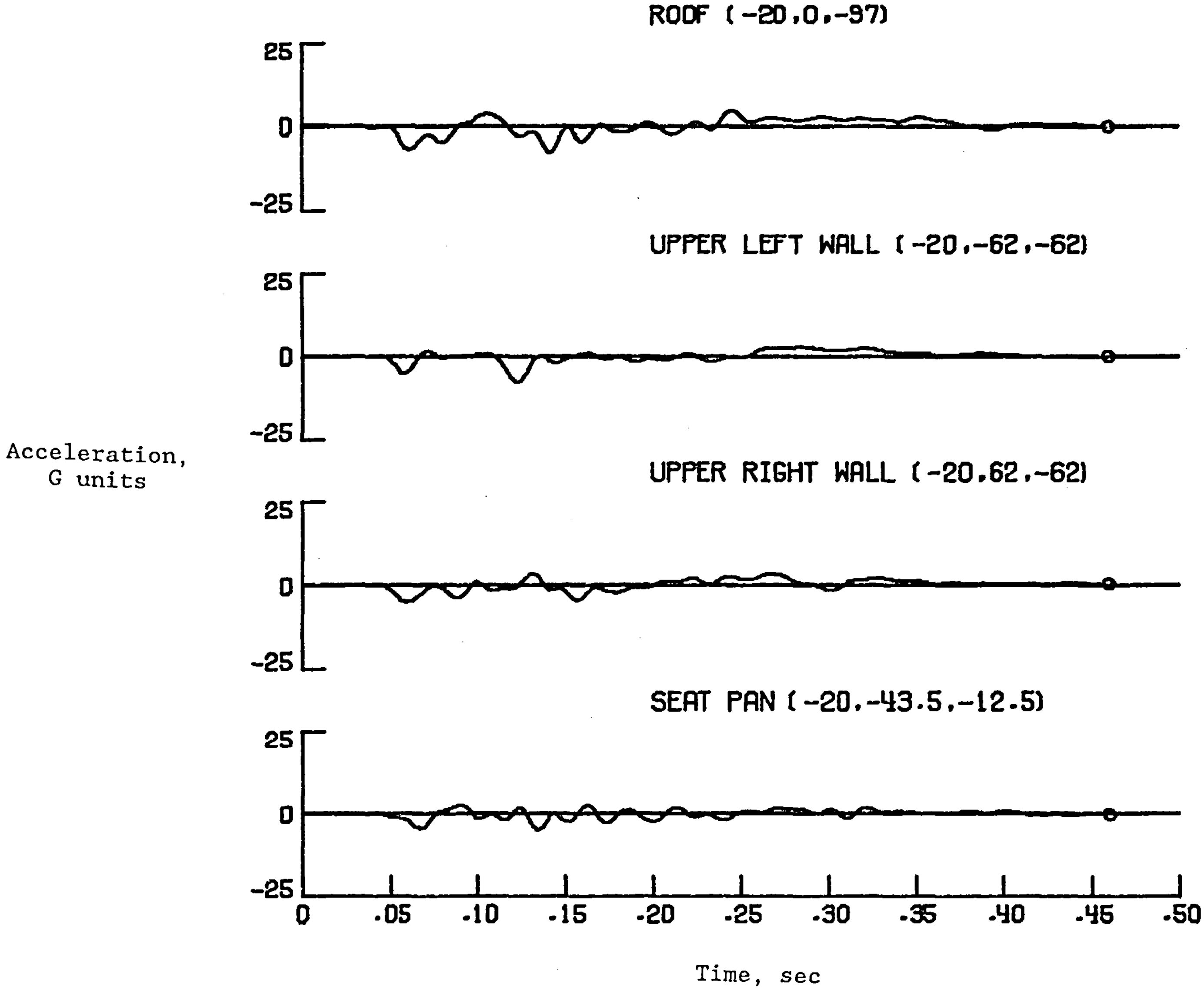
(e) BS 1120

Figure 5.- Concluded.



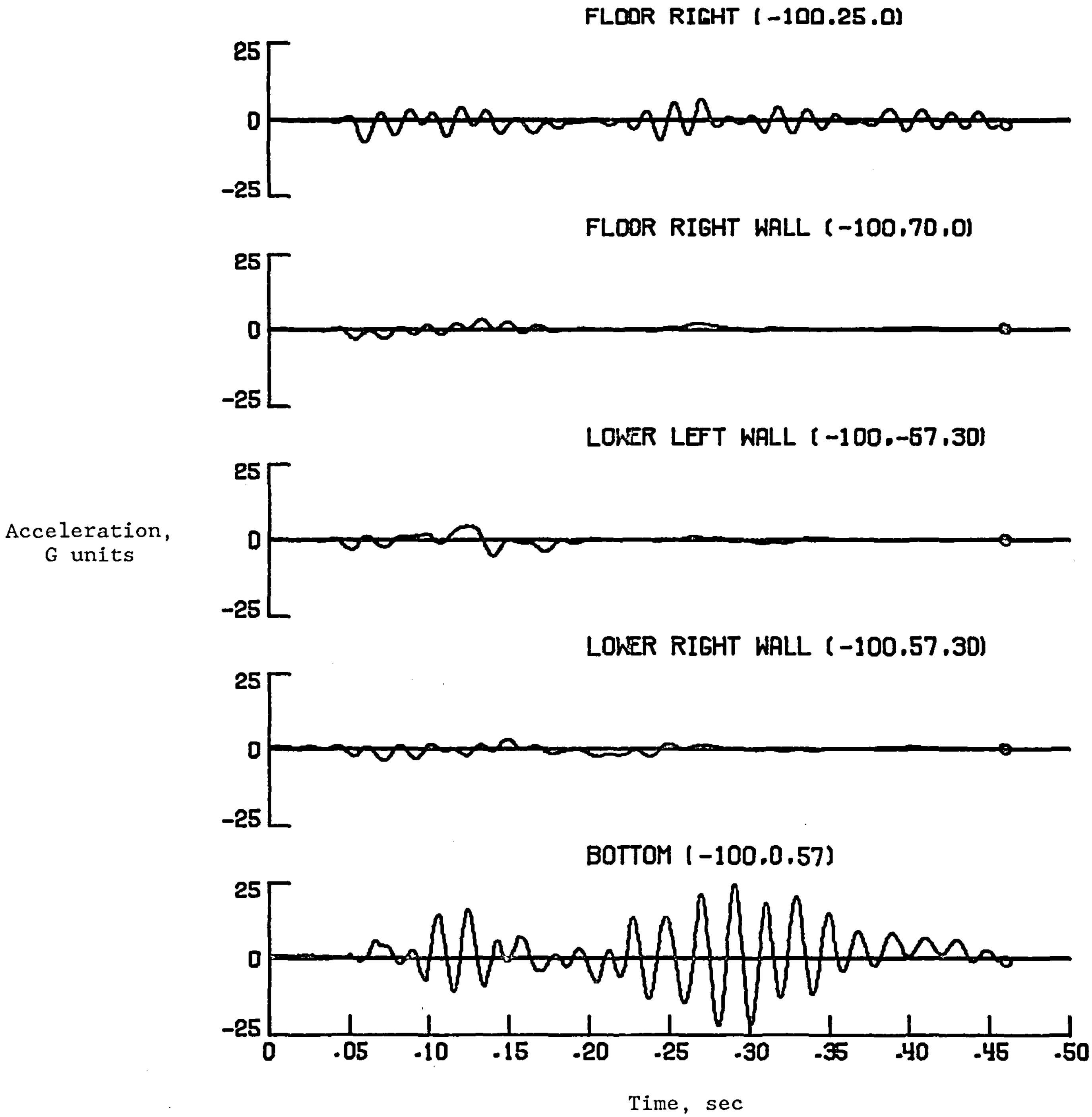
(a) BS 1040

Figure 6.- Longitudinal acceleration time histories.



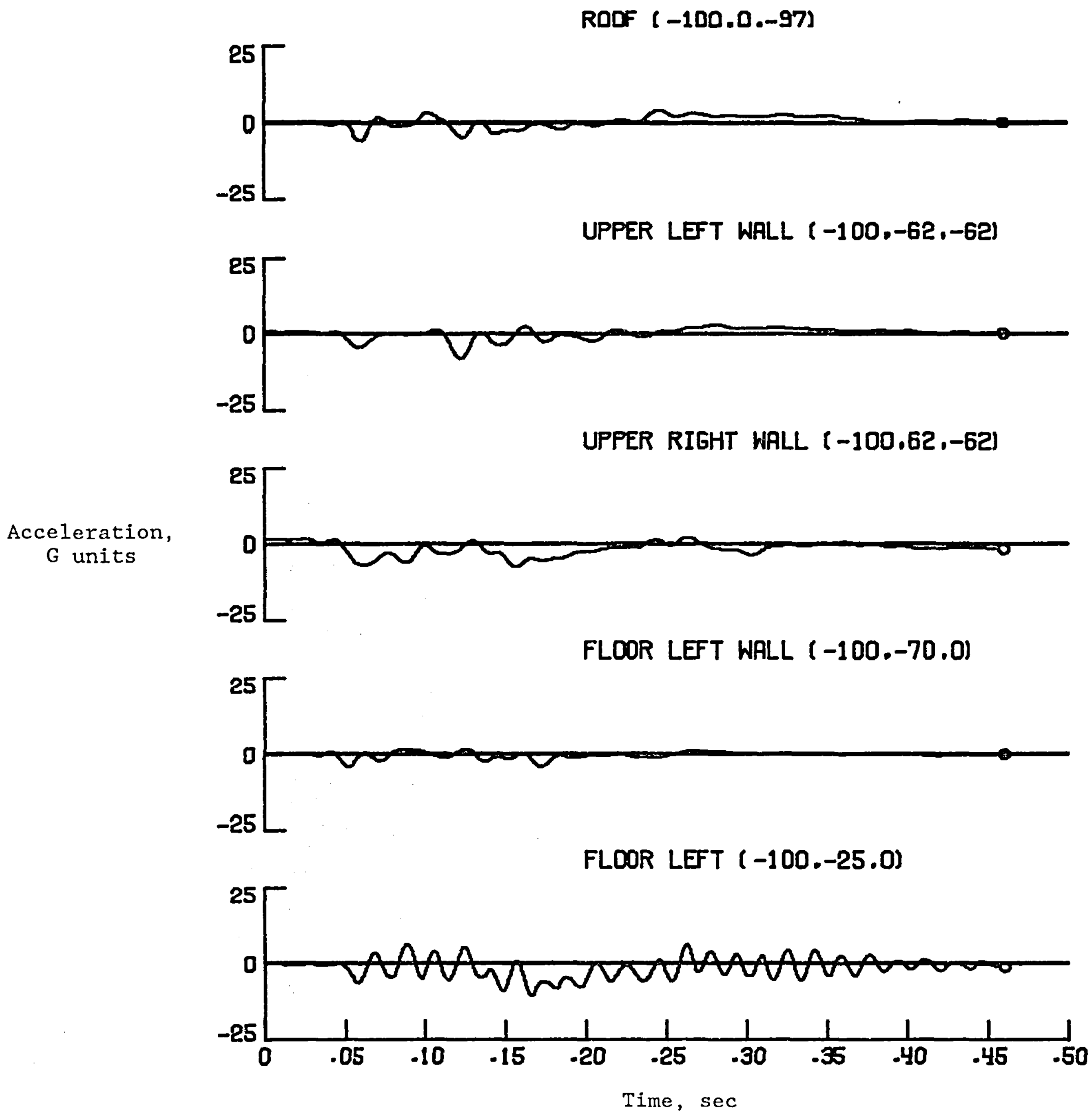
(b) BS 1040

Figure 6.- Continued.



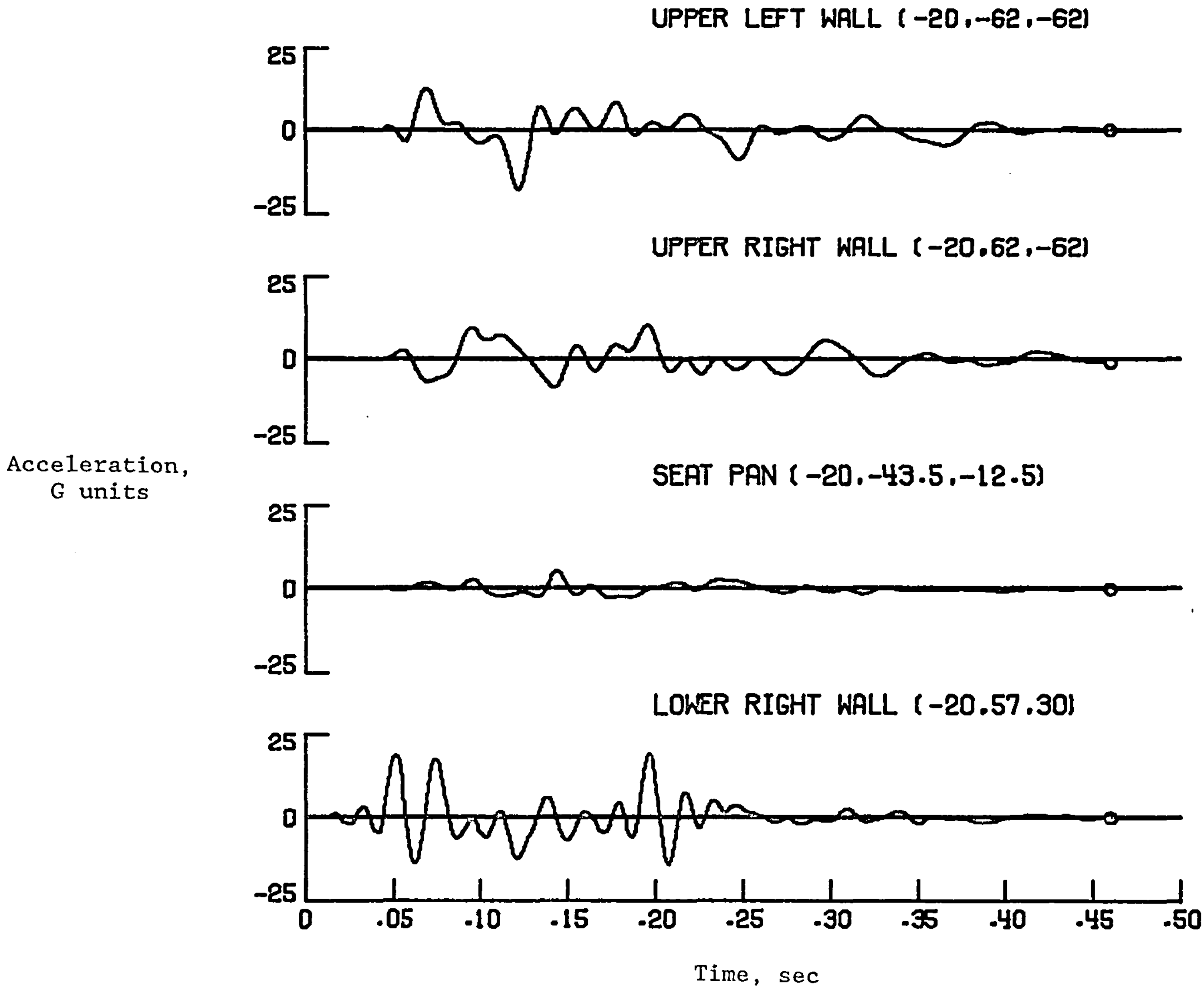
(c) BS 1120

Figure 6.- Continued.



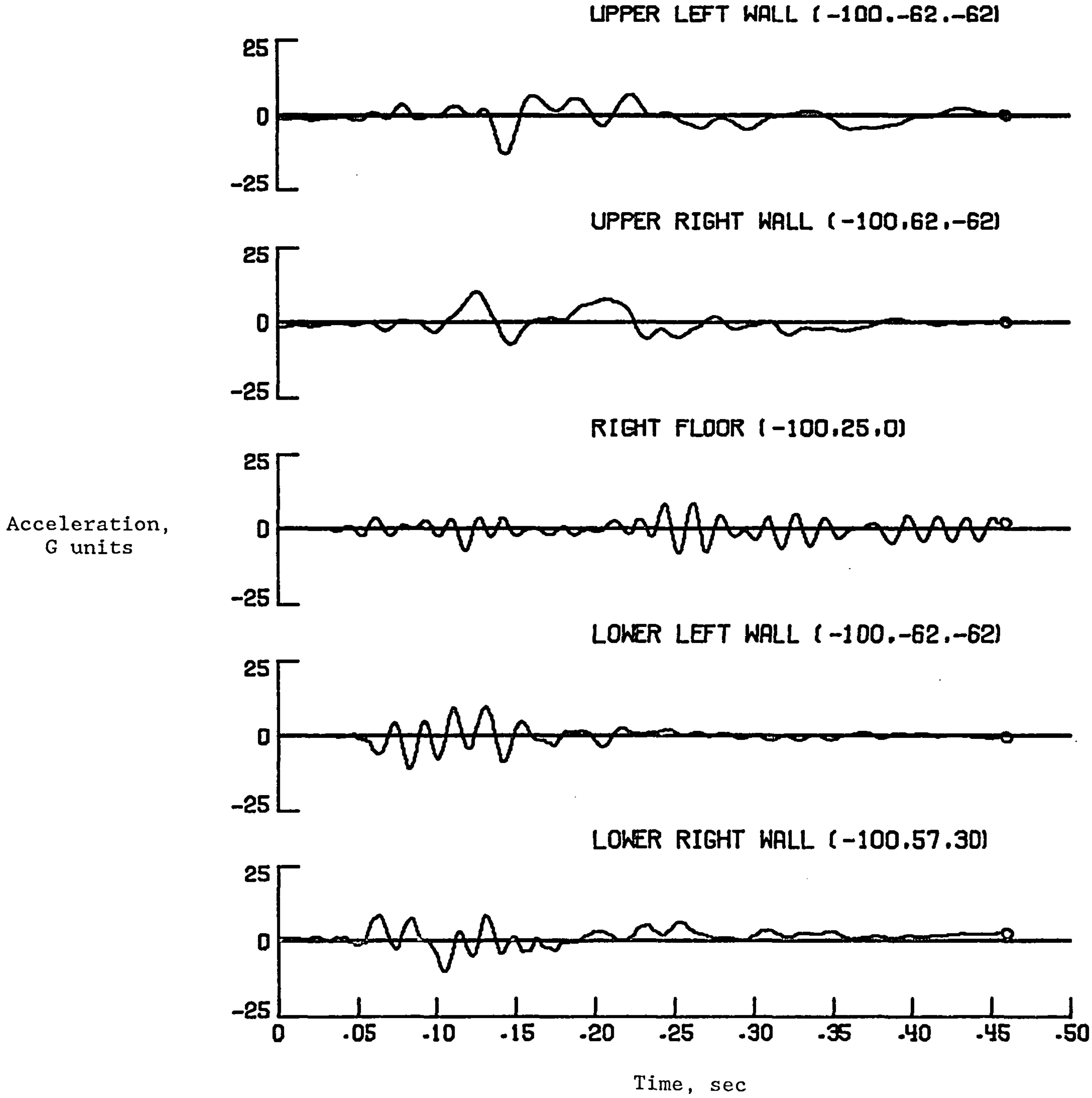
(d) BS 1120

Figure 6.- Concluded.



(a) BS 1040

Figure 7.- Transverse acceleration time histories.



(b) BS 1120

Figure 7.- Concluded.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-89025		
4. Title and Subtitle Vertical Drop Test of a Transport Fuselage Section Located Aft of the Wing		5. Report Date September 1986 6. Performing Organization Code 505-63-41-01
7. Author(s) Edwin L. Fasanella and Emilio Alfaro-Bou		8. Performing Organization Report No. 10. Work Unit No.
9. Performing Organization Name and Address Langley Research Center Hampton, Virginia 23665-5225		11. Contract or Grant No. 13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

A 12-foot long Boeing 707 aft fuselage section with a tapering cross section was drop tested at the NASA Langley Research Center to measure structural, seat, and occupant response to vertical crash loads and to provide data for nonlinear finite element modeling. This was the final test in a series of three different transport fuselage sections tested under identical conditions. The test parameters at impact were: 20 ft/s velocity, and zero pitch, roll, and yaw. In addition, the test was an operational shock test of the data acquisition system used for the Controlled Impact Demonstration (CID) of a remotely piloted Boeing 720 that was crash tested at NASA Ames Dryden Flight Research Facility on December 1, 1984.

Post-test measurements of the crush showed that the front of the section (with larger diameter) crushed vertically approximately 14 inches while the rear crushed 18 inches. Analysis of the data traces indicate the maximum peak normal (vertical) accelerations at the bottom of the frames were approximately 109 G at body station 1040 and 64 G at body station 1120. The peak floor acceleration varied from 14 G near the wall to 25 G near the center where high frequency oscillations of the floor were evident. The peak anthropomorphic dummy pelvis normal (vertical) acceleration was 19 G's.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Crashworthiness Controlled impact demonstration Airplane crash test Transport crash test Crash dynamics	Unclassified - Unlimited Subject Category 39

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	25	A02

For sale by the National Technical Information Service, Springfield, Virginia 22161