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Three Full-Scale Dynamic Crash Tests of a CNU-103/E Shipping Container

L. W. T. Weinberg
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Aviation Safety Engineering and Research
a Division of
Flight Safety Foundation, Inc.

Technical Report AFATL-TR-67-55

MAY 1967

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AIR FORCE ARMAMENT LABORATORY
RESEARCH AND TECHNOLOGY DIVISION
AIR FORCE SYSTEMS COMMAND
EGLIN AIR FORCE BASE, FLORIDA

THREE FULL-SCALE DYNAMIC CRASH TESTS

OF A CNU-103/E SHIPPING CONTAINER

L. W. T. Weinberg
D. F. Carroll

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FOREWORD

This program was authorized by U. S. Air Force Contract No. F08635-67-C-0012 during the period 18 August 1966 to 24 February 1967. The Program Monitor for the project was Major Logan Damewood, Air Force Armament Laboratory (ATCB), Eglin Air Force Base, Florida.

The Aviation Safety Engineering and Research Division of the Flight Safety Foundation, Inc., Phoenix, Arizona was responsible for the performance of the three full-scale aircraft crash tests. Significant assistance from Mr. Edward Kemper and Mr. Daniel Pantone, North American Aviation, Inc., Los Angeles, California during the final installation and checkout of the Shipping Container in the test aircraft was received and is hereby acknowledged.

The Contractor's designation for this report is AvSER 66-23.

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Publication of this technical report does not constitute Air Force approval of the reports findings or conclusions. It is published only for the exchange and stimulation of ideas.

Nicholas H. Cox

NICHOLAS H. COX, Colonel, USAF
Chief, Bio-Chemical Division

ABSTRACT

This report presents the results of three full-scale dynamic crash tests of a CNU-103/E Shipping Container. The container was designed to prevent the creation of hazardous environmental conditions should a catastrophic crash occur during air transport of certain munitions. The Shipping Containers were installed in three C-119C cargo aircraft and accelerated to crash impact velocities of 123 knots for Test 1 and Test 3 and 122 knots for Test 2. The first two aircraft were crashed into a vertical concrete wall and the third into a 20-degree earth slope. The aircraft were completely destroyed in the vertical wall impact, but no atmospheric contamination from the container was detected in either test. The lower three quarters section of the third aircraft fuselage was destroyed on impact with the 20-degree earth slope. The Shipping Container fell free of the wreckage as the aircraft passed over the top of the slope. No atmospheric contamination was noted upon examination of the Shipping Container. Atmospheric contamination from the container was measured by a series of air sampling devices installed around the impact site for the first two tests and swab and pressurization tests of the container after impact in all three tests. The impact environment was measured by an onboard magnetic tape recorder system and by interior and exterior high-speed photography.

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SECTION I

INTRODUCTION

1. GENERAL.

The aerial transporting of munitions presents a hazard to public safety in the event of a crash. To reduce this hazard potential a Shipping Container capable of preventing leakage of contaminating materials under anticipated crash conditions was developed. This container, hereafter referred to as the CNU-103/E was developed for the U. S. Air Force by North American Aviation, Inc., Los Angeles Division, under Contract No. FO8635-67-C-0002.

Aviation Safety Engineering and Research, Division of the Flight Safety Foundation, Inc., was contracted to conduct full-scale aircraft crash tests of the CNU-103/E to conditions specified by the U. S. Air Force. The test aircraft were C-119C similar to that shown in Figure 1.

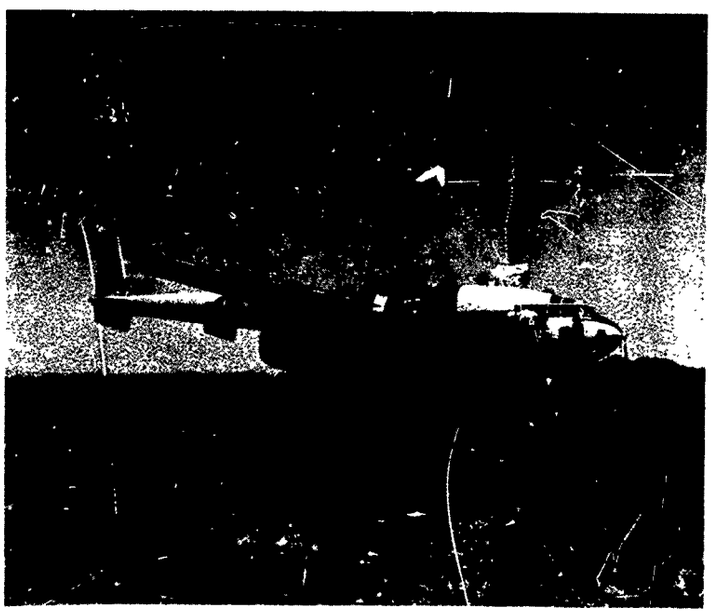

Figure 1. C-119C Test Aircraft.

2. TEST OBJECTIVE.

The objective of this test program was to evaluate the CNU-103/E Shipping Container under full-scale dynamic crash test conditions as follows:

Test Number	Barrier Configuration	Impact Speed (Kn.)
1	Vertical Wall	130
2	Vertical Wall	130
3	20° Inclined Slope	130

1. GENERAL.

An exploded schematic view of the CNU-103/E Shipping Container is shown in Figure 3. The components of the container are indicated on the drawing. The components were divided into three major groups: (1) the weapon cylinder, (2) the overpack which protects the weapon cylinder and (3) the pallet for cargo handling and restraint. The approximate dimensions of the assembled container were 60-inches in width and thickness by 230-inches in length. The test pallet was 68-inches wide, 2 1/2-inches thick, and 216-inches long. The weight of the entire assembly (container and pallet) was approximately 13,010 pounds.

2. WEAPON CYLINDER.

The weapon cylinder was the portion of the Shipping Container intended to prevent leakage of the payload. It consisted of a stainless steel cylinder containing a balsa wood log which surrounded the weapon. The weapon was furnished by the Air Force and contained a reservior for the payload and necessary mechanical components for aerial delivery. The nose cone and aft fin sections of the weapon were replaced with dummy covers to facilitate fitting in the balsa wood log. Figure 2 shows the weapon installed in the lower half of the balsa wood log.

Figure 2. The Weapon During Loading Sequence.

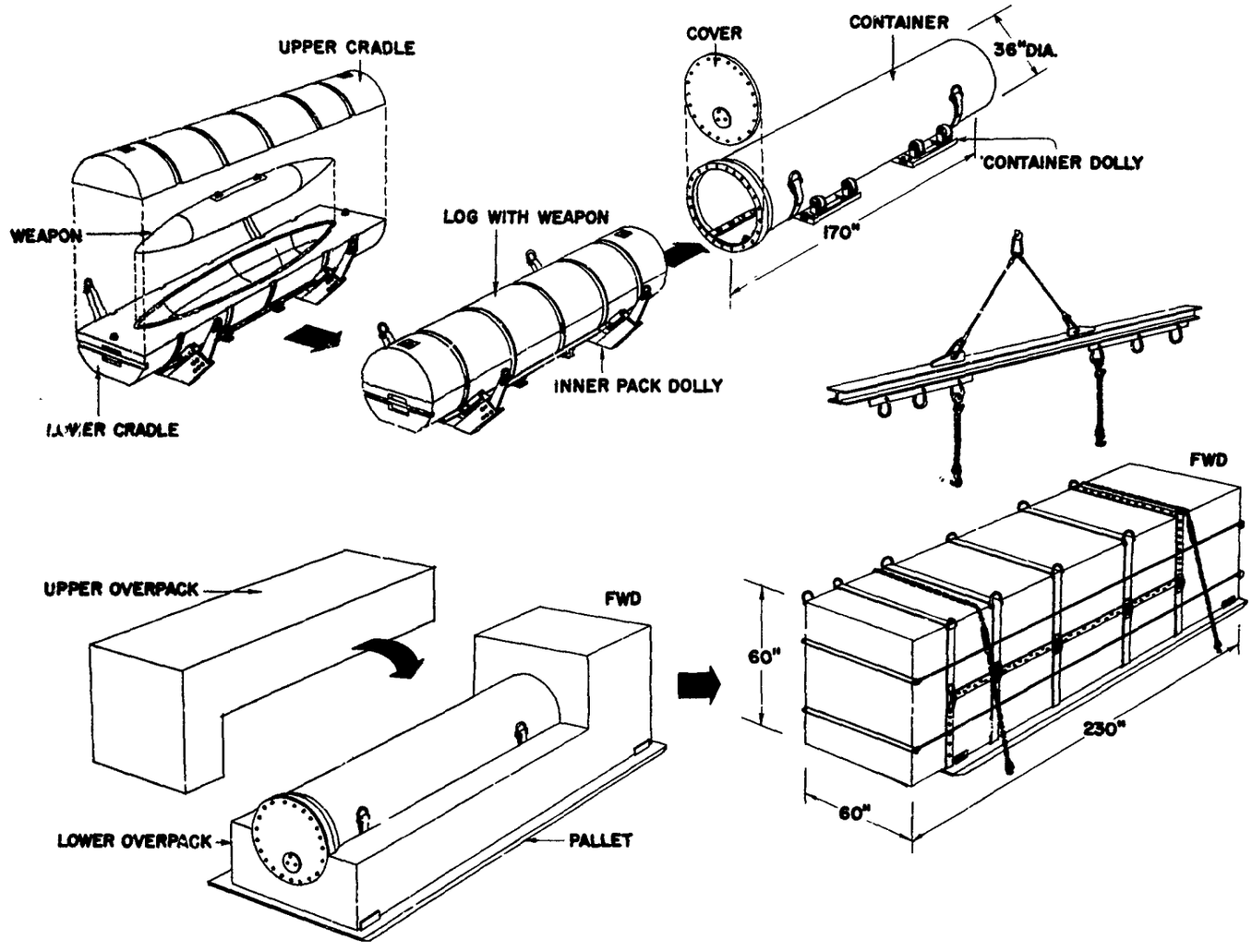

Figure 2. Schematic Drawing of the CNU-103/E Shipping Container.

The cylinder was closed by a plate connected to the flanged end of the cylinder. Eighty 1/2-inch bolts were used to fasten the plate to the cylinder. A double sealing design was used to prevent leakage at the connection. The primary seal was an "O" ring in a narrow groove between the plate and the cylinder flange. The second seal consisted of injecting a plastic sealing compound in a narrow groove around the bolt line.

3. THE OVERPACK.

The overpack was a rectangular box designed to protect the cylinder from triaxial impact loads. Conceptually, the overpack consisted of a forward energy-absorbing section protecting the forward surface of the cylinder and a balsa wood box hollowed out to fit the cylinder for protection in other directions. All surfaces other than the forward end were protected by at least one foot of balsa wood. The energy-absorber section of the overpack consisted of two heavy metal plates separated by 42 inches of aluminum honeycomb. The forward plate was steel, 60-inches square by 2-inches thick. The rear plate was aluminum, 40-inches square and 2-inches thick. The front of the steel cylinder rested against the aluminum plate. Upon longitudinal impact of the container, the aluminum honeycomb was designed to crush and allow the steel cylinder to move forward, thus reducing the acceleration loads on the weapon.

For assembly purposes the overpack separates as shown in Figure 3. The lower overpack protected the lower and forward portions of the cylinder. The upper overpack protected the upper and rear portions of the cylinder. The entire box, with the exception of the steel striker plate, was covered with a thin gauge aluminum sheet for continuity and cargo handling purposes.

The overpack assembly was secured by 1/4-inch bolts in pairs along the entire division line at 4-inch intervals. The assembly was further secured by perimeter straps and longitudinal rods as shows schematically in Figure 3.

4. THE PALLET.

The pallet provided the connection between the assembled Shipping Container and the cargo deck of the aircraft. The design of the Shipping Container specified the use of a pallet compatible with Air Force 463L system. However, the incompatibility of the C-119 cargo restraint strength capability with the 463L system required use of a special pallet for this installation.

The Shipping Container was designed to separate from the standard pallet at 8G, while the pallet was to separate from the floor at 8.5G. The C-119 has a maximum restraint capability of 4.5G so the special test pallet was designed for failure loads of 4.0G for container to pallet and 4.5G pallet to floor.

The test pallet was fabricated of a solid wood core covered with a metal skin on both sides. The dimensions were 216-inches long by 68-inches wide and 2 1/2-inches thick with cargo handling tabs at the front and rear. The container was attached to the pallet with steel angle tabs at each corner by three 1/4-inch bolts to achieve the desired 4G restraint capability.

The pallet was connected to the airframe by installation of two steel angles connected to the existing aircraft cargo tiedowns. Studs were inserted in the cargo tiedown holes and the angles were bolted to the studs to give a nominal width of 68-inches between angles. The pallet was then placed between the angles. Cherry rivets (3/16-inch) were placed at 4-inch intervals on both sides of the pallet to achieve the desired 4.5G restraint capability.

SECTION III

TEST PROCEDURE

1. TEST SITE PREPARATION.

a. General.

The existing AvSER full-scale aircraft test facility was modified to meet the specifications for this test series. The modifications for Test 1 and Test 2 consisted primarily of construction of a vertical impact wall with a compacted earth backing and ground preparation for installation of specialized monitoring equipment. The modification for Test 3 consisted of construction of a 20-degree inclined earth slope in front of the vertical impact wall. Description of the existing facilities and modification are given in the following sections.

b. Acceleration Runway and Nose Gear Guide Rail System.

The acceleration runway consisted of two soil-cement strips, 15-feet wide and 18-feet apart, laid over the desert soil to support the main landing gear wheels. The length of these strips from release to the impact barrier was 4000 feet.

The nose gear guide rail consisted of a single track of 90-pound railroad laid on a continuous reinforced concrete base. Rail tiedowns were provided every 49-1/2 inches and at the rail joints. Also, at each joint, the rails were joined with a 1/2-inch diameter steel dowel pin to increase the lateral strength of the joint. This increased strength was required to resist side loads that might develop during the test run, thus preventing misalignment at the ends of the rails.

c. Impact Area.

The impact barrier for Test 1 and Test 2 consisted of a vertical wall of reinforced concrete and a compacted earth fill. The wall was 30-inches thick, 20-feet high and 40-feet wide with 3600-psi concrete compressive strength. The earth fill was compacted to 98 percent density. An independent engineering test laboratory sampled the concrete and earth compaction to assure compliance with specifications. Standard civil engineering practices were used as a basis for design of the wall and to determine requirements for wing walls, base slabs and reinforcing needs. In addition, extra reinforcing was added to the wall in the areas of anticipated impact of large mass items such as the

fuselage and engines. Figures 4 through 7 shows the wall in stages of complet: n.

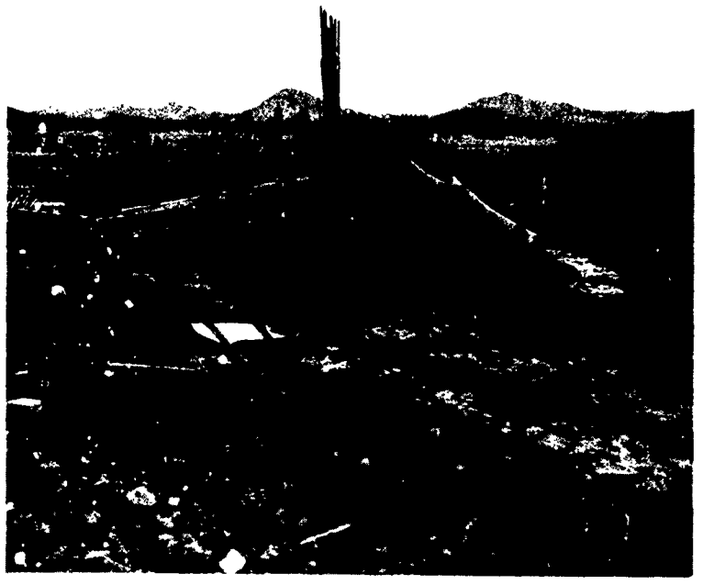

Figure 4. Placement of Reinforcing Steel in the Wall Foundation.

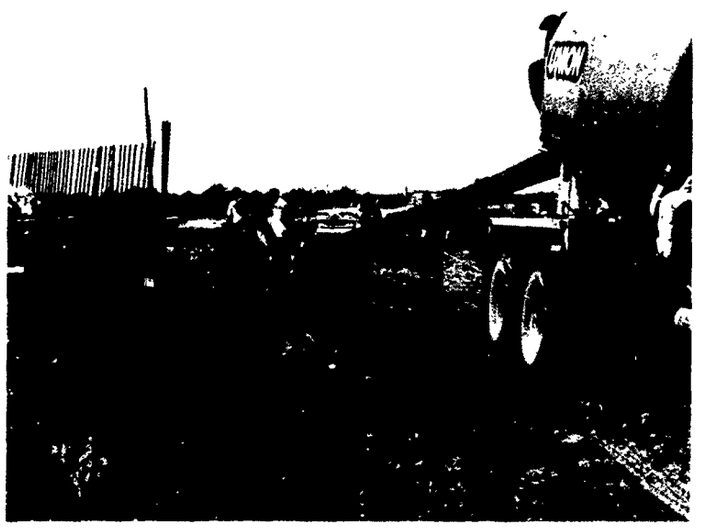

Figure 5. Initial Concrete Pour.

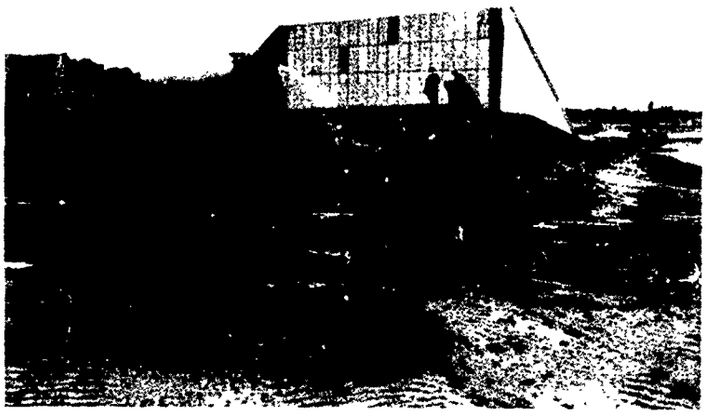

Figure 6. Rear of Wall Showing Watering Operation and Hand Tamper Used to Compact Earth at the Wall.

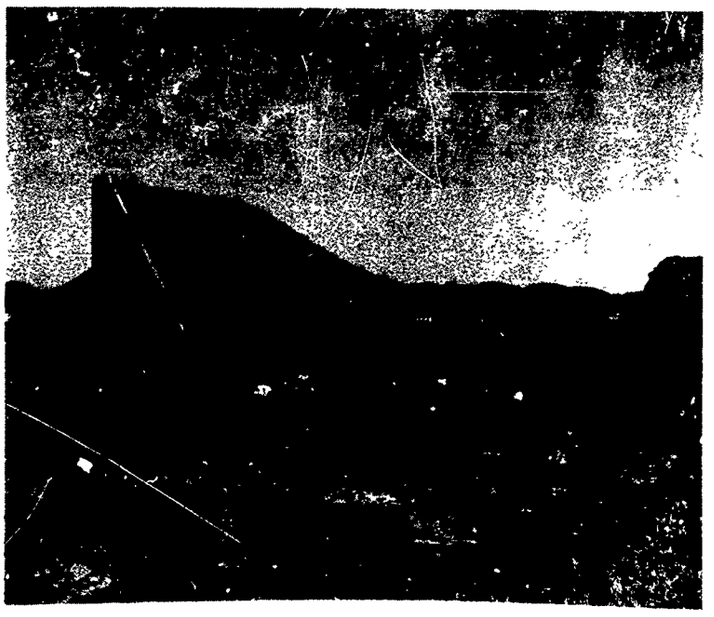

Figure 7. Rear View of Wall and Compacted Earth Fill.

The impact barrier for Test 3 consisted of a 20-degree earth slope placed in front of the vertical wall. The slope was 22-feet high and 50-feet wide to preclude contact with the concrete wall at impact. The surface of the slope was compacted to 85 percent density. Figure 8 shows the completed 20-degree impact slope.

Figure 8. Completed 20-Degree Earth Slope Barrier.

In addition the ground was leveled in a semi-circular arc of 50-yards radius in front of the wall and treated with a penetrating oil compound to facilitate dust control for air sampling in the impact site area.

2. TEST AIRCRAFT PREPARATIONS

a. General.

Aircraft equipment not required for the test or pretest operations was removed prior to the test to reduce the aircraft empty weight. The empty weights of the aircraft were 39,083 pounds for Test 1, 39,115 pounds for Test 2 and 39,075 pounds for Test 3.

b. Fuel System.

To reduce the destructive effect of a postcrash fire, the engines were operated during the test runs with a minimum of fuel and oil. Each

engine was operated with 20 to 25 gallons of engine oil and 10 gallons of gasoline. An auxillary ground fuel system was used for prerelease operations. This fuel system was disconnected one minute prior to release.

c. Aircraft Control System.

Control of the aircraft was provided by a remote control system designed to accomplish the following functions:

(1) Run-up engines to the desired torque reading (or maximum available depending on conditions).

(2) Release the aircraft from its mechanical tiedown to begin acceleration run.

(3) Provide a method for emergency abort.

Control signals from the remote control station were transmitted through an umbilical cable to the aircraft. A radio link provided engine throttle control and abort function control after the short umbilical cable was disconnected.

The throttles of both engines were connected to a single linear electric actuator which advanced or retarded power in response to remote control commands. Adjustable mechanical stops were provided on each engine throttle lever to compensate for variations in throttle settings for each engine. Power to operate the throttle actuator was supplied by the aircraft electrical system.

The emergency abort system consisted of a radio controlled electrical relay which, when activated, would ground the engine magnetos shutting down both engines simultaneously.

d. Aircraft Release System.

To restrain the aircraft without brakes or chocks during the period when no crew members were aboard, just prior to beginning the test acceleration run, an aircraft release hook was installed between the aircraft and a concrete abutment at the end of the guide rail. The release hook mechanism incorporated a mechanical safety pin to prevent inadvertant release. Air pressure activated by a remote controlled electrical signal was used to actuate the release system when the throttles were advanced to the desired positions.

e. Aircraft Guidance System.

For the test, the nose wheel was replaced by a guide shoe which provided positive alignment and vertical and lateral control of the aircraft during the test run. The shoe, made of steel with a replaceable brass bearing surface, was also used as a mounting point for an electrical switch which initiated the onboard cameras, auxiliary lighting and the fire extinguisher system. The switch was actuated by tripping an arm holding the switch open by a vertical post placed at the side of the rail.

3. INSTRUMENTATION SYSTEM

a. Transducers.

Three types of sensing instruments were used for data acquisitions: accelerometers, stroke pots and a photocell. The majority of the instruments were accelerometers, (Statham Instrument types A5-350 and A6-350) with capacities varying from $\pm$ 20G to $\pm$ 200G. The instrument ranges were dependent upon the direction to be sensed and the location of the measurement in the airplane. The frequency response of the instruments was 250 cps. The location of the accelerometers are shown in Figure 9.

Two stroke pots were connected to the test article to show the relative motion between the package and its pallet and between the pallet and the aircraft. A photo-cell device was fastened to the main gear to determine the aircraft speed during the run.

b. Electronic Recording System.

A 14-track magnetic tape recorder system was used to record the 17 channels of acceleration, force, and motion data during the crash test. The major components of the recording system, the signal conditioning equipment, the subcarrier oscillators, the mixer amplifier, the magnetic tape recorder, and associated battery power supplies were contained in a steel tube mounted on the right aft fuselage floor. The interior of this tube had a track to permit the data acquisition package to slide forward, crushing up to 4-1/2 feet of paper honeycomb. The crash loads transmitted to the package were thereby limited to values below the equipment design specifications. The magnetic tape recording system utilizes a constant bandwidth FM/FM multiplex modulation technique in which the analog output signal from the transducer is converted by the subcarrier oscillator into a frequency deviation proportional to the input signal amplitude. Seven of these subcarrier oscillator outputs are combined in

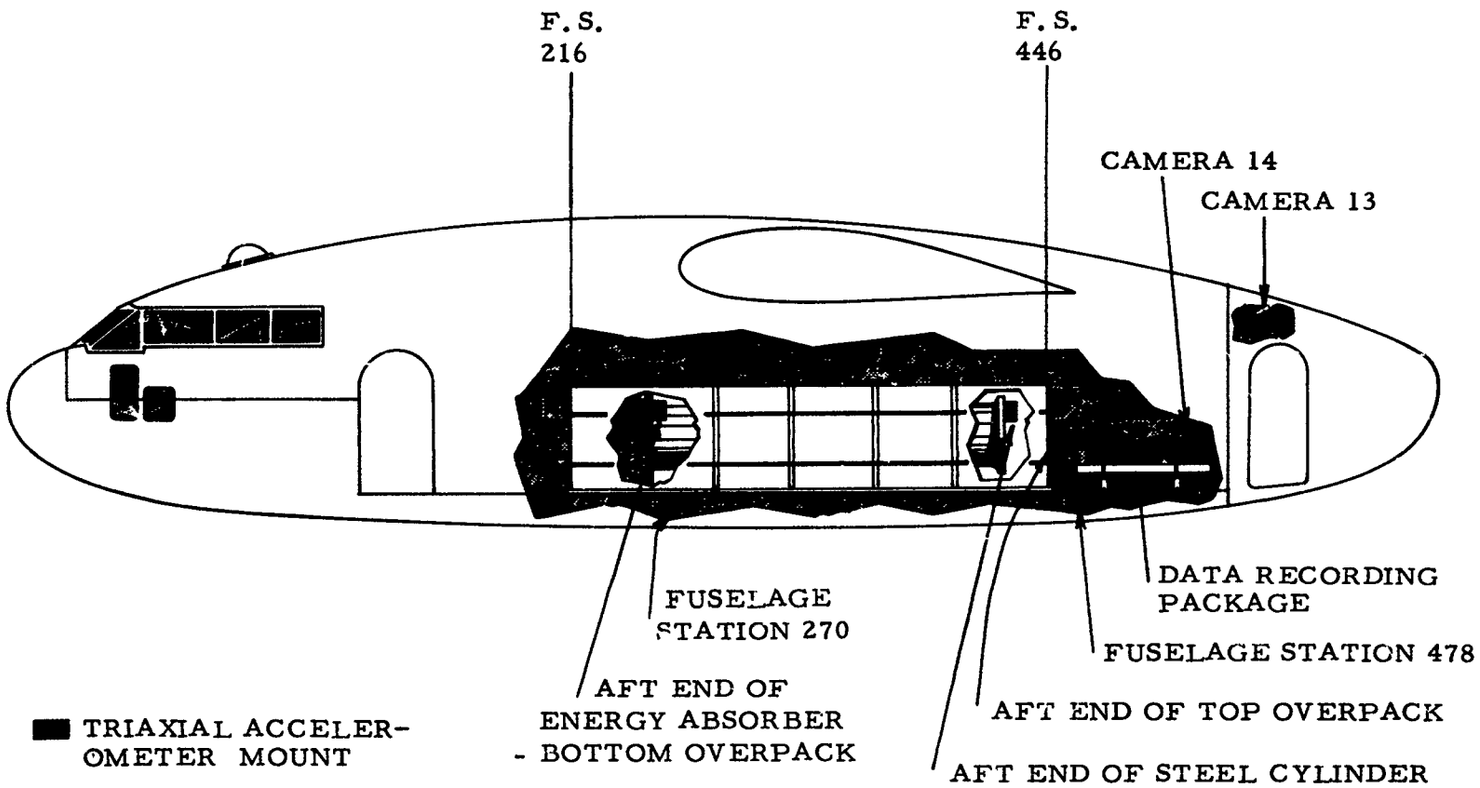

Figure 9. Onboard Camera and Accelerometer Locations.

the mixer amplifier and the resulting composite signal recorded on one track of a 14-track tape recorder. Shielded cables connected the transducers to the recording system package. A tape recorder control circuit was designed so that once started, it would continue to operate until reaching the end of the magnetic tape, thus an interruption in the control signal would not result in a loss of data.

c. High-Speed Camera System.

(1) Onboard Cameras.

Two onboard high-speed cameras were used during the test and are listed in Table I. Both cameras were Photo-Sonic Model 16-1B operating at a nominal speed of 500 frames per second.

Color film was used in all cameras, and the test package was painted white to provide optimum photographic identification. Supplemental lighting, consisting of auxiliary floodlamps were installed throughout the fuselage interior. The cameras and lamps were powered by a nickel-cadmium battery mounted in the aircraft in a protective tube similar to that housing the data acquisition package.

The onboard cameras were mounted on brackets attached to the airframe of the aircraft. The cameras were mounted inside aluminum boxes with bulletproof lenses for protection against flying objects during the crash. The exact location and coverage of both cameras are listed in Table I and are cross referenced with Figures 9 and 10.

(2) Exterior Camera Coverage.

Exterior photographic coverage for Test 1 and Test 2 was provided by twelve cameras positioned around the impact area as shown in Figure 10. The cameras, listed in Table I are cross referenced with Figure 10. The table also indicates approximate angles of coverage of the impact area and camera frame speeds. Exterior photographic coverage for Test 3 was provided by twelve cameras positioned around the impact area as shown in Figure 11. The cameras, listed in Table II are cross referenced with Figure 11.

Special towers were erected at points around the impact area to protect the high-speed and normal-speed cameras required to photograph the impact sequence. Special metal protective boxes were utilized for the remote controlled cameras.

TABLE I
CAMERA DESCRIPTION AND COVERAGE - TESTS 1 and 2

No.	Type	Nominal Film Speed (fps)	Lens Size (in.)	Coverage
1	Photosonics 1B	1000	1.0	Acft. R. Side - Full View
2	Photosonics 1B	500	1.0	Acft. L. Side - Full View
3	Photosonics 1B	1000	2.0	Acft. R. Side - Close-up
4	Photosonics 1B	500	2.0	Acft. L. Side - Close-up
5	Photosonics 1B	500	0.5	Acft. R. Side - 3/4 Front View
6	Photosonics 1B	500	0.5	Acft. L. Side - 3/4 Front View
7	Photosonics 1B	500	4.0	Acft. R. Side - Tracking
8	Photosonics 1B	500	2.0	Acft. R. Side - 3/4 Rear View
9	Traid 200	200	0.7	Acft. Front - Close-up
10	Traid 200	200	1.0	Acft. R. Side - 3/4 Front View
11	Traid 200	200	2.0	Acft. Front - Full View
12	Traid 200	200	1.0	Acft. L. Side - 3/4 Front View
13	Photosonics 1B	500	8 mm	Shipping Container - Rear
14	Photosonics 1B	500	8 mm	Shipping Container - 3/4 Rear
B	Bolex H-16	24	3.0	Acft. R. Side - Tracking

TABLE II
CAMERA DESCRIPTION AND COVERAGE - TEST 3

No.	Type	Nominal Film Speed (fps)	Lens Size (in.)	Coverage
1	Photosonics 1B	500	0.5	Acft. L. Side - Full View
2	Photosonics 1B	500	0.5	Acft. R. Side - 3/4 Rear View
3	Photosonics 1B	1000	1.0	Acft. R. Side - Full View
4	Photosonics 1B	1000	2.0	Acft. R. Side - Close-up
5	Photosonics 1B	500	1.0	Rear of Barrier
6	Traid 200	200	1.0	Acft. R. Side - 3/4 Front View
7	Photosonics 1B	500	1.0	6° Impact Slope behind Barrier
8	Traid 200	200	0.7	Barrier - 3/4 Rear View
9	Photosonics 1B	500	1.0	20° Impact Slope behind Barrier
10	Traid 200	200	2.0	Acft. Front - Full View
11	Photosonics 1B	500	4.0	Acft. R. Side - Tracking
12	Photosonics 1B	500	8 mm	Shipping Container - 3/4 Rear
13	Photosonics 1B	500	8 mm	Shipping Container - Rear
B	Bolex H-16	24	3.0	Acft. R. Side - Tracking

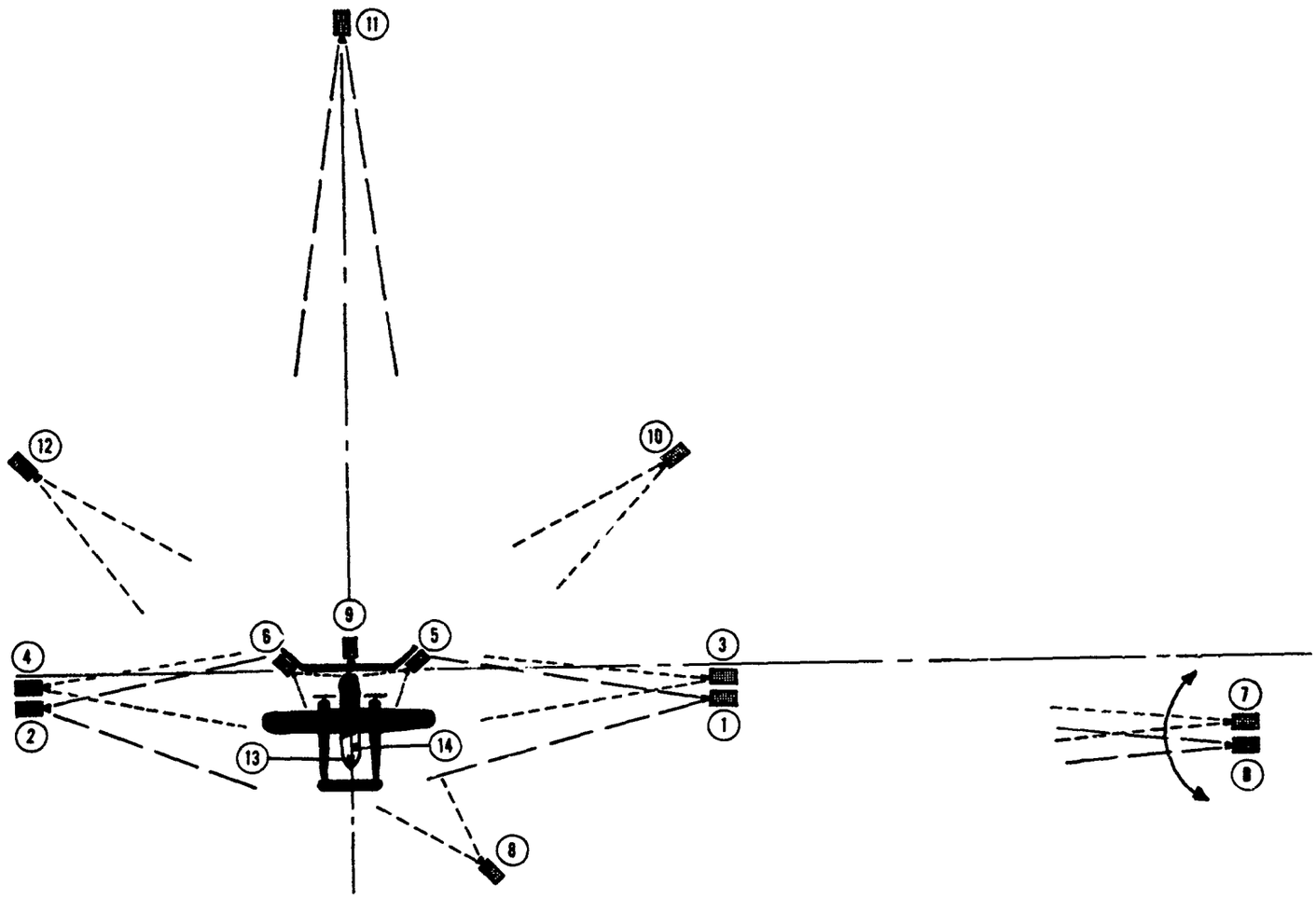

Figure 10. Exterior Photographic Coverage - Tests 1 and 2.

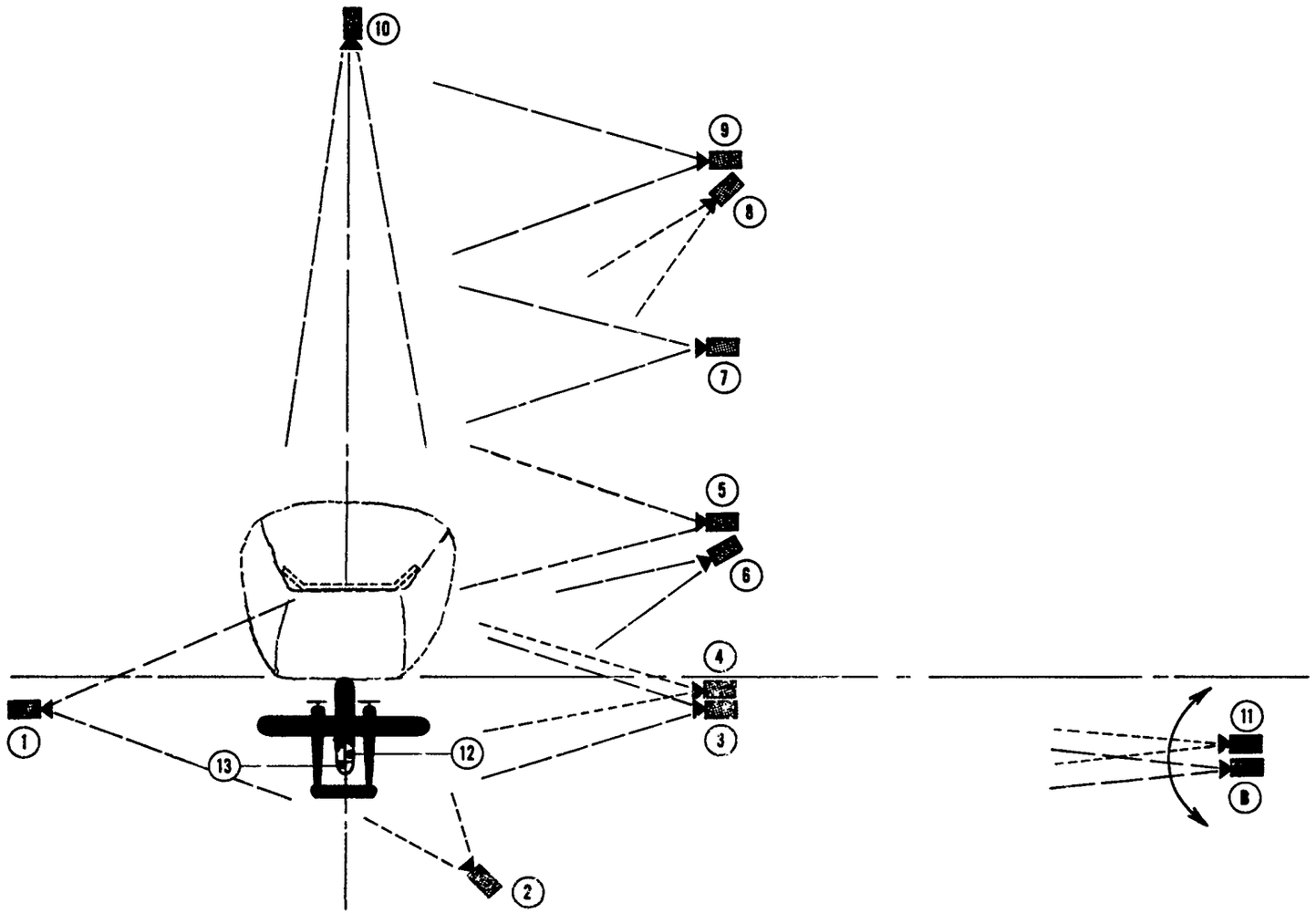

Figure 11. Exterior Photographic Coverage - Test 3.

(3) Correlation and Timing.

Correlation and timing between the electronic and photographic data was provided by a 100-cycle-per-second electronic signal recorded on the magnetic tape and the camera film. The signal was generated by a precision square wave oscillator, with accuracy better than $\pm$ 0.01 percent. Timing for the ground cameras was provided by a 60-cycle-per-second electronic signal recorded on the camera film on all cameras and a 100-cycle-per-second signal on cameras Numbers 1 and 3. Correlation between onboard and ground cameras was provided by flashbulbs ignited in the field of view of all cameras. An electrical signal from a photocell actuated by a correlation flashbulb mounted on the aircraft was recorded on the tape recorder for correlation with the onboard and ground cameras.

d. Air Sampling System.

An air-sampling system consisting of twenty-seven vacuum operated sensing units was placed in a 120-degree arc on the downwind side of the crash site as shown in Figure 12. Sensors were placed 4, 8, and 12 feet above the ground to detect any atmospheric contamination from the test article.

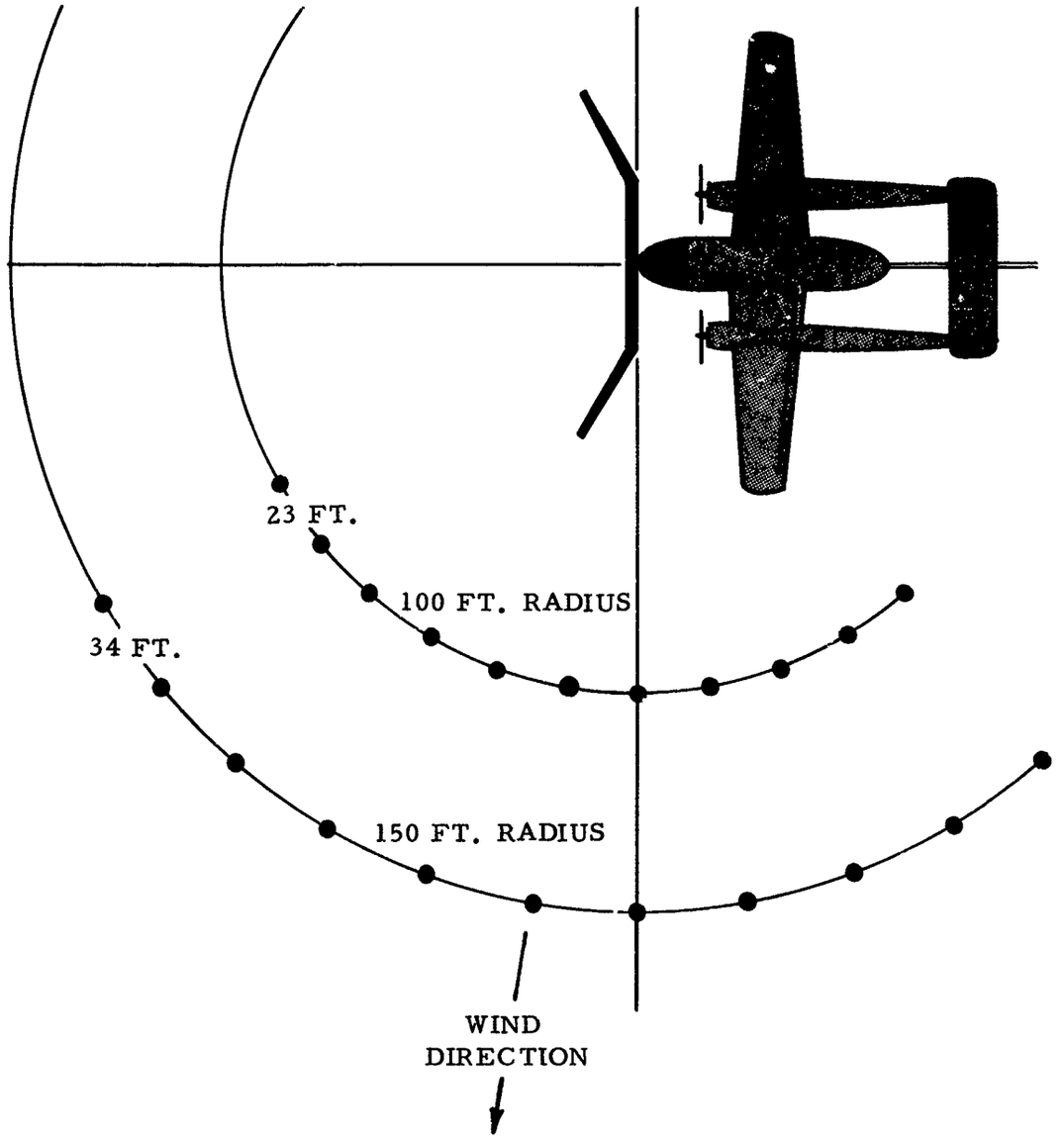

Figure 12. Layout of Air Sampling Grid.

SECTION IV

TEST RESULTS

1. GENERAL.

The aircraft were positioned at the beginning of the 4000-foot acceleration runway and set for normal takeoff configuration with the exception of the flaps which were positioned full-up to reduce lift and drag and the ailerons which were locked in a 10-degree nose-up position to further reduce lift. The throttles were advanced to the maximum power setting and the aircraft was released. The aircraft in each test accelerated smoothly at release reaching an impact velocity of 123 knots for Test 1 and Test 3 and 122 knots for Test 2. Photographs of the impact sequence taken from high-speed camera coverage of each test are presented in Figures 13, 14 and 15.

The occupiable area of each aircraft was completely destroyed in each of the three tests conducted. As a result, each test has been classified as a non-survivable accident. The outer panels of each wing and the tail boom stabilizer assemblies were the only major structural components which could be readily recognized after each test. Further details of the aircraft damage is presented in paragraph 3 in this section.

2. SHIPPING CONTAINER EXPERIMENT.

a. Test 1 and Test 2

The impact sequence for the CNU-103/E Shipping Container as reconstructed from high-speed photography indicates that the container remained attached to the pallet and fuselage floor during the crushing of the forward aircraft fuselage. At contact of the propellers and engine nacelle with the concrete wall, sufficient longitudinal deceleration was generated to release the container from the pallet. However, at this point there could have been only 17 inches between the forward edge of the Shipping Container and the wall. This 17 inches was filled with the crushed portion of the forward fuselage so there was little, if any, forward motion of the container, relative to the pallet, at any time during the impact. Therefore, the longitudinal velocity of the Shipping Container at point of contact with the wall was the same as the aircraft fuselage. Analysis of the high-speed film and integration of the fuselage acceleration-time history has determined this velocity to be 190 feet per second.

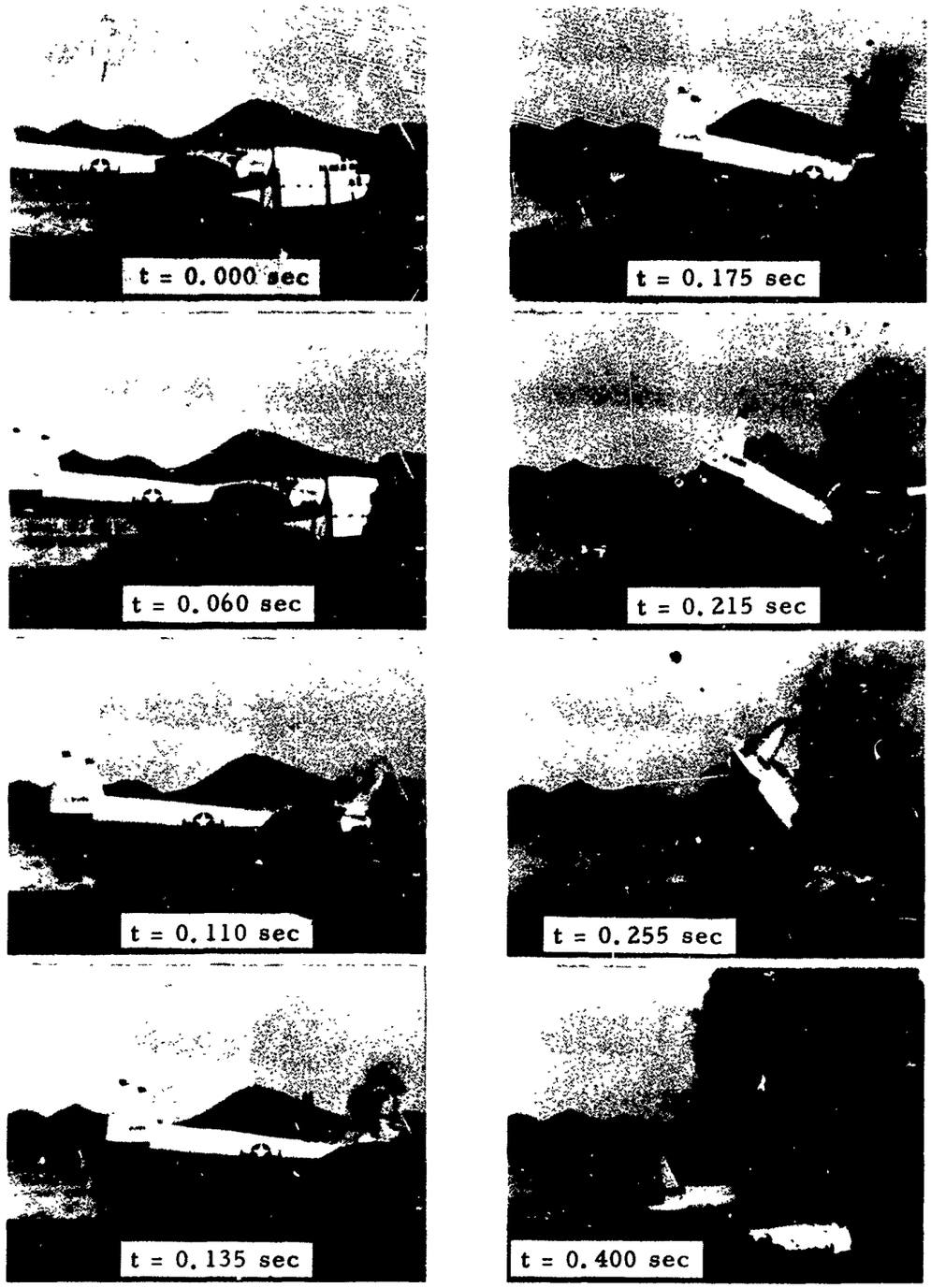

Figure 13. Crash Sequence - Test 1.

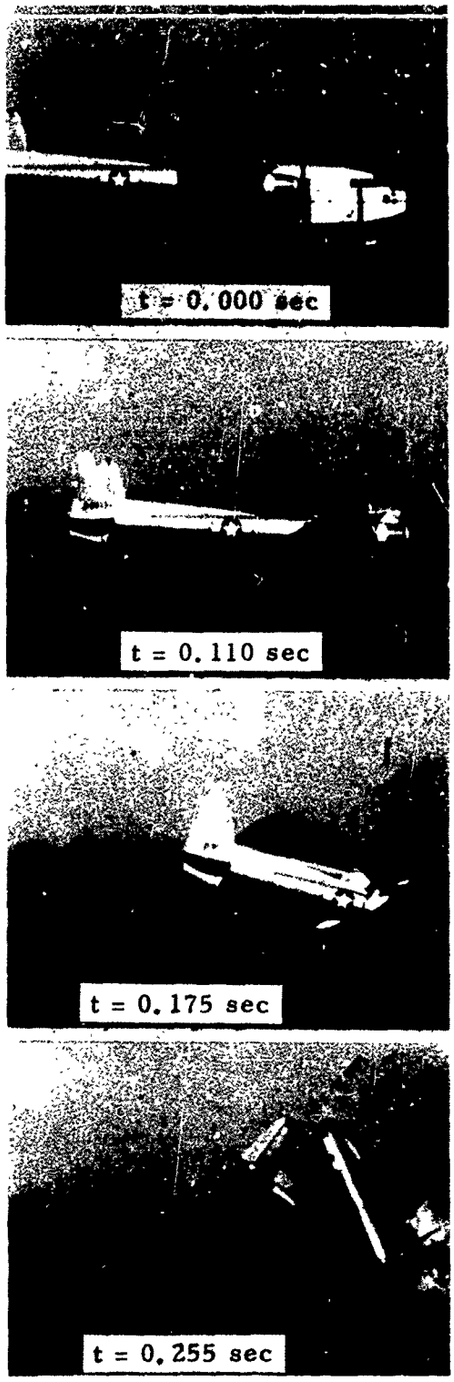

Figure 14. Crash Sequence - Test 2.

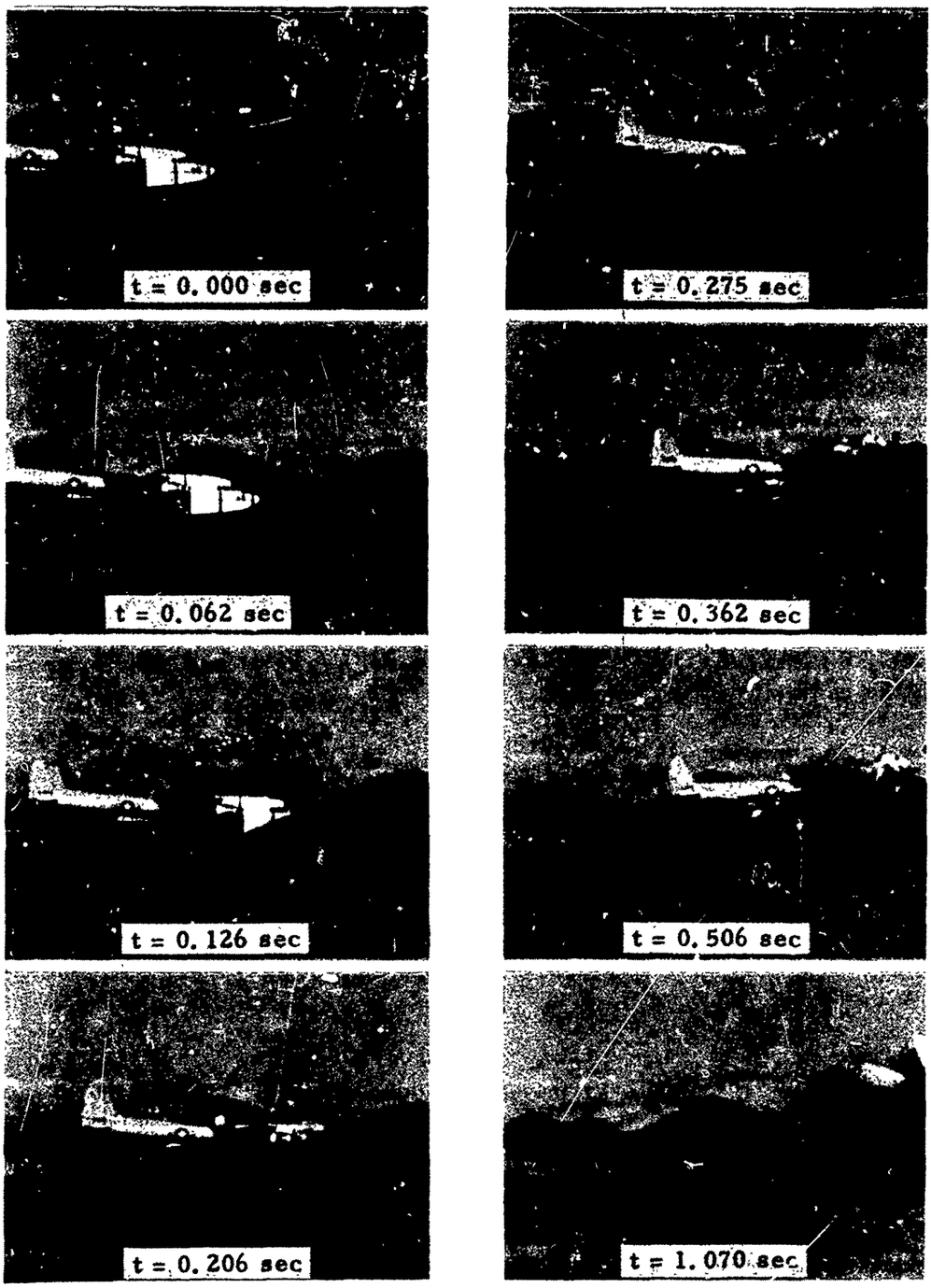

Figure 15. Crash Sequence - Test 3.

As the impact sequence continued the Shipping Container hit the crushed fuselage structure and concrete wall, rebounded, and came to rest with the forward end of the container in the crushed aircraft structure and the rear edge of the container outside the rear fuselage bulkhead resting on the nose gear guide rail.

Extensive fires developed in the aircraft wreckage which required immediate removal of the Shipping Container to prevent unnecessary postcrash fire damage. The forward end of both Shipping Containers looked quite similar after being pulled from the wreckage. Figure 16 shows the container removed from the Test 1 wreckage and Figure 17 shows the container from Test 2. The postcrash fire caused more extensive damage in Test 2 which allowed a view of the crushed aluminum honeycomb shown in Figure 18.

The containers were measured after the crash and for both tests the exterior length of the container was reduced approximately 7 inches. The steel cylinder head crushed the honeycomb inside the container an additional 7 inches. If the 17 inches between the wall and the container had been full of debris with a 50-percent crush potential this would allow another 8.5 inches of stopping distance. The wall was moved approximately 6 inches average in the two tests making a total available distance for the container of 28.5 inches.

The damage to the internal portion of the overpack was similar in the two tests, Figure 19, showing damage during Test 1, is presented as representative of both Tests.

The steel cylinder containing the payload were not damaged in either test except for slight bends in the lifting lugs as shown in Figures 20 and 21.

b. Test 3

The impact sequence for the CNU-103/E Shipping Container, as reconstructed from high-speed photography, indicates that during the crushing of the forward section of the fuselage the Shipping Container remained attached to the pallet and fuselage floor. When the forward edge of the pallet contacted the crushed aircraft structure and earth barrier the container was released from the pallet. However, the container and pallet remained in close physical contact until well after both had passed over the top of the impact slope. The container moved up the impact slope remaining relatively parallel to the initial impact position. The aircraft fuselage wreckage moved away from the Shipping

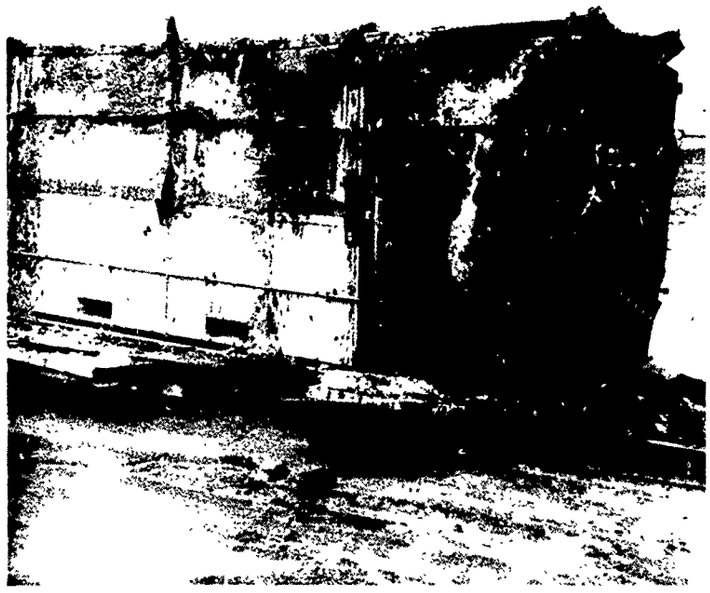

Figure 16. Front Portion of Shipping Container - Test 1.

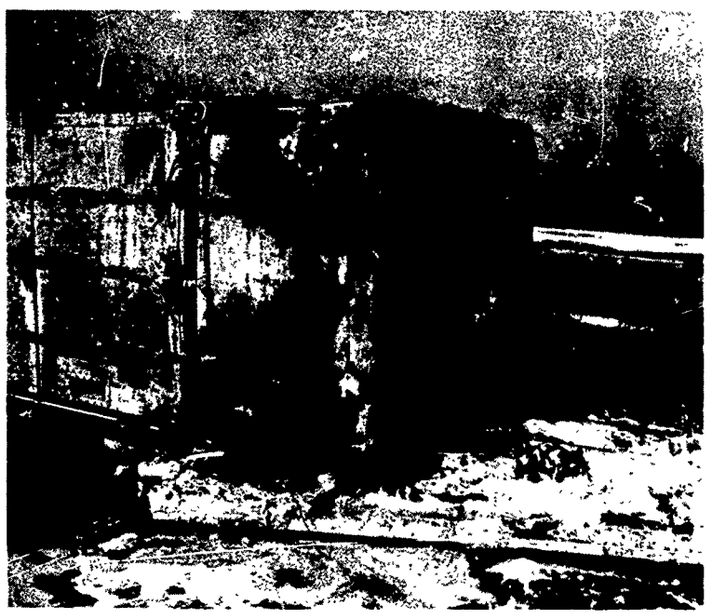

Figure 17. Front Portion of Shipping Container - Test 2.

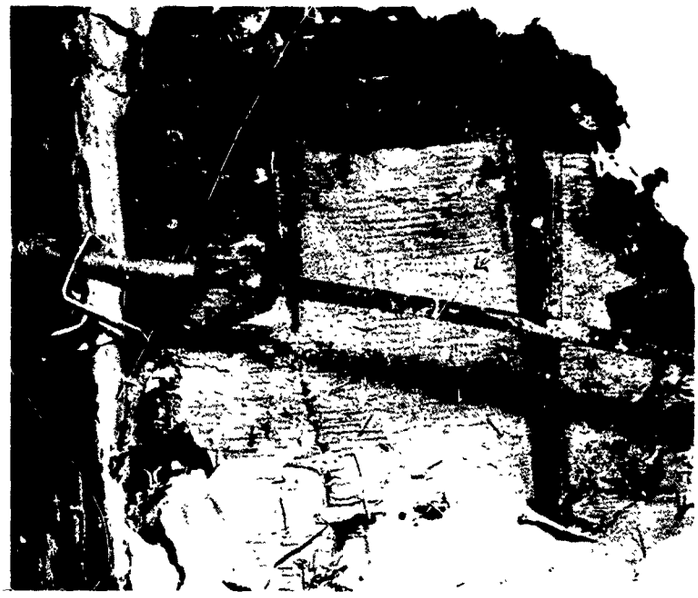

Figure 18. Aluminum Honeycomb - Shipping Container - Test 2.

Figure 19. Internal Photograph of Shipping Container After Test 1.

Figure 20. Forward Lifting Lug on Cylinder - Test 1.

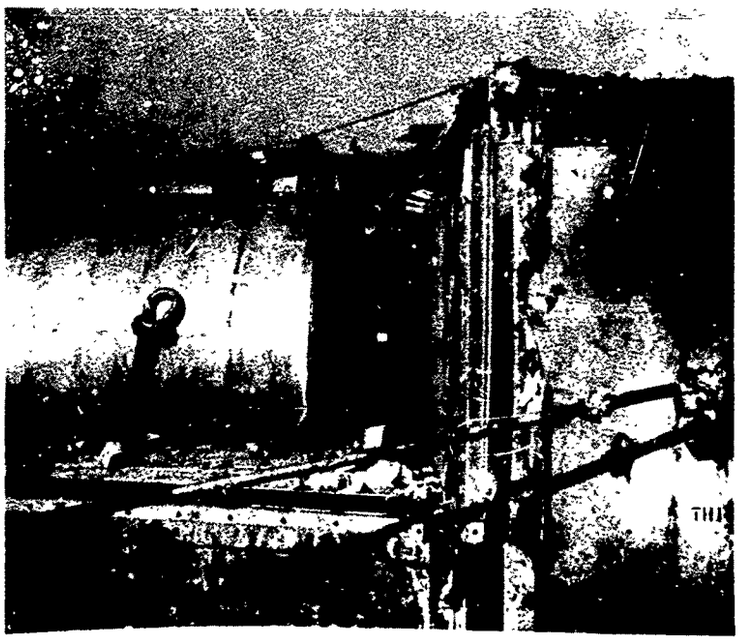

Figure 21. Forward Lifting Lug on Cylinder - Test 2.

Container during the travel up the front slope of the impact hill. At a point approximately halfway up the impact slope, the aircraft horizontal stabilizer contacted the rear of the container with sufficient force to push the container over the top of the hill. As the container passed over the top of the hill, a slight roll to the right, combined with a slight nose down attitude, developed. This continued until the front edge of the container contacted the earth on the rear slope. The container turned over and came to rest on its right side with the rear of the container forward. Figure 22 shows the final position of the container on the rear slope.

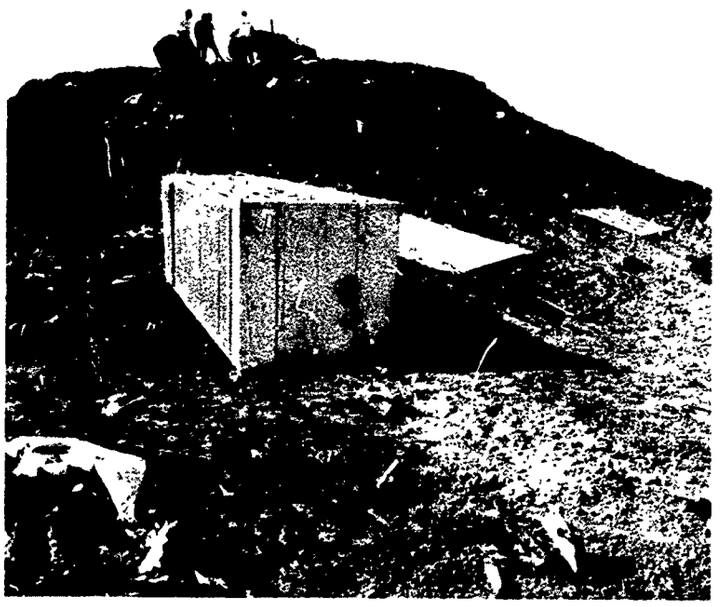

Figure 22. Final Position of Shipping Container - Test 3.

A graphic display of container crash kinematics as determined from the high-speed film analysis is presented in Figure 23.

Exterior damage of the Shipping Container was limited to a separation of the forward steel striker plate illustrated in Figure 24.

There was no significant damage to the internal portion of the overpack in Test 3. The steel cylinder containing the payload was not damaged except for slight bends in the forward lifting lugs similar to but much less than that experienced in Test 1 and Test 2.

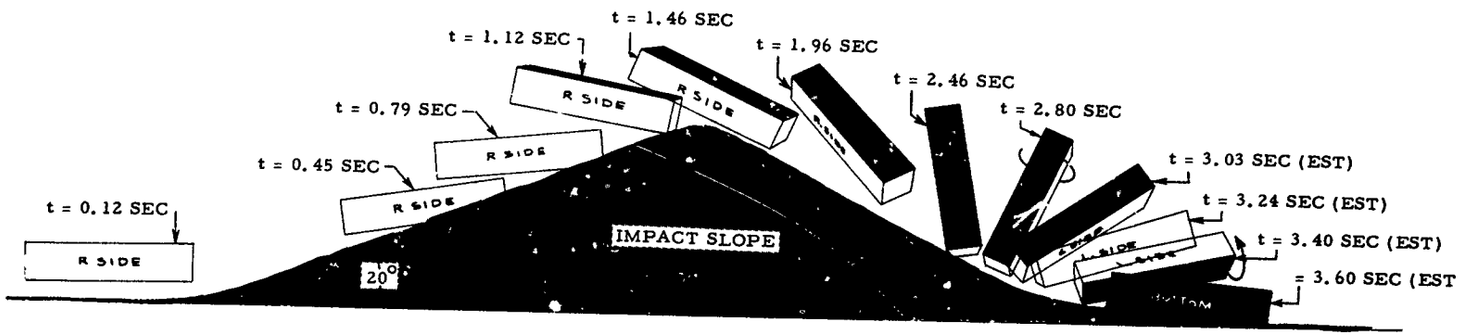

Figure 23. Shipping Container Crash Kinematics - Test 3.

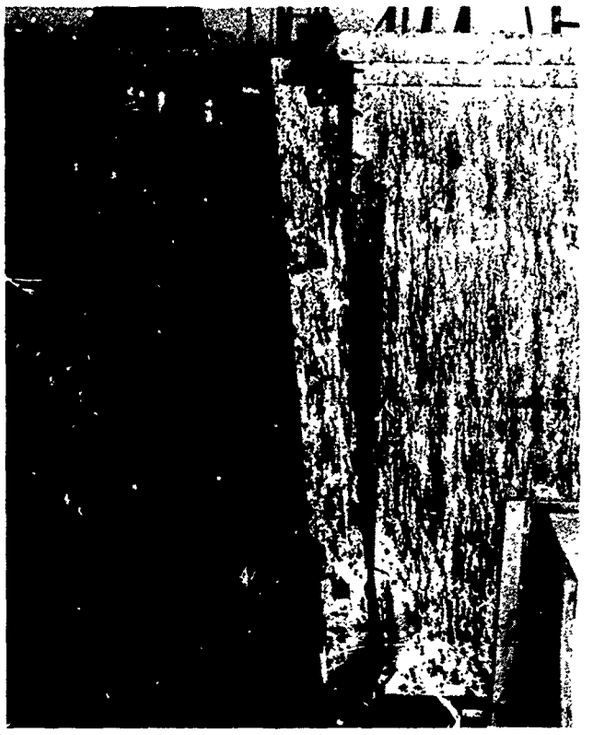

Figure 24. Damage to Forward Edge of Shipping Container - Test 3.

3. AIRCRAFT DAMAGE.

a. Tests 1 and 2.

Both aircraft were completely destroyed in the impact. Figure 25 shows the first test aircraft immediately after impact while Figure 26 shows a later postcrash scene after the tail booms and Shipping Container had been moved. The wreckage is the entire aircraft except for the above mentioned items and the wing tips. The fire, shown in Figure 25, resulted from a maximum of 50 gallons of oil, 3 to 4 gallons of fuel and a normal load of hydraulic fluid. Figure 27 shows the forward fuselage of the first test aircraft. Note the almost perfect accordion effect from the wall impact.

Figure 25. C-119 - Postcrash - Test 1.

Figure 26. C-119 - Postcrash - Test 1 With Shipping Container and Tail Removed.

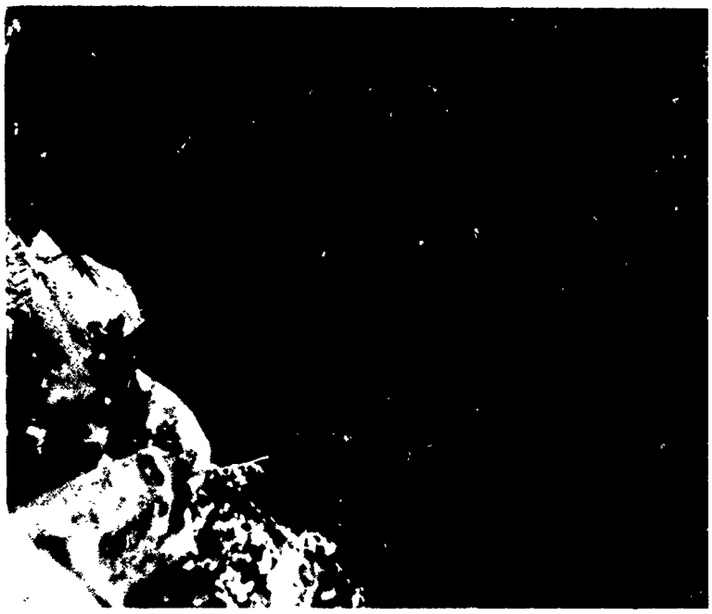

Figure 27. Forward Fuselage of the First Test Aircraft After Wall Impact.

b. Test 3.

The entire fuselage section of the C-119 aircraft was destroyed on impact with the 20-degree earth barrier. The wings, empennage, and upper section of the fuselage continued over the hill coming to rest 250 feet from the beginning of the 20-degree earth barrier. Figure 28 shows the major portion of the wreckage from the top of the 20-degree earth barrier. Pieces of the lower section of the fuselage were strewn from the initial contact point to the final resting point.

Small fires occurred in each engine upon initial impact. The fires were quickly controlled and did not approach the intensity noted in Tests 1 and 2.

Figure 28. Aircraft Wreckage - Test 3.

4. IMPACT WALL.

The impact wall showed progressive damage after the first and second test. In the first test, the impact points were evident as shown in Figure 29. The prop spinners and the Shipping Container, caused local breaks in the wall as well as crushing evident from the top of the wall. The second impact caused greater damage to the already scarred wall surface as shown in full view in Figure 30 and in close-up in Figure 31. Figure 31 also emphasized the force with which the Shipping Container struck, as is evident in the shape of the cracks.

Figure 29. Wall After First Impact.

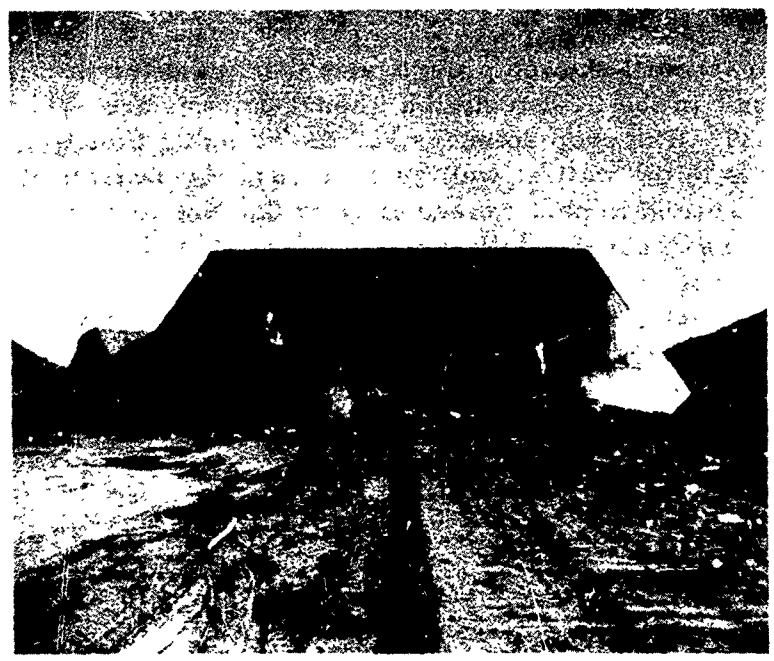

Figure 30. Wall After Second Impact.

Figure 31. Close Up of Point Where the Shipping Container Contacted the Wall.

5. TEST DATA ANALYSIS.

a. General.

Data from transducers installed on the aircraft and Shipping Container were recorded successfully on Tests 2 and 3 and are presented in the Appendix. Transducer data was not recovered during Test 1 because of problems which developed during the final check out and calibration phase. A malfunction of the ground fuel supply system occurred just prior to release of the aircraft which resulted in a delay in aircraft release. This delay occurred after activation of the magnetic tape recorder and was long enough to result in an insufficient magnetic tape supply for the test acceleration run. The magnetic tape supply was exhausted as the aircraft had reached the 2500-foot mark. Changes in the test calibration procedure were made to provide an increased magnetic tape

supply for later tests. High-speed film analysis of Test 1 and Test 2 has indicated that the two tests were very similar, therefore, it is felt that the electronic data recorded successfully during Test 2 can be discussed as representative of both tests.

Excellent photographic data was obtained during all three tests. The only photographic problem experienced during the test program was in the onboard camera control circuit during Test 3. The camera control circuit actuated 8 seconds too soon resulting in camera operation prior to impact. The source of the problem cannot be accurately determined as the control circuit was destroyed during the crash, however, it is believed to have been caused by a defective microswitch attached to the nose gear guide shoe.

b. Fuselage Acceleration.

(1) Test 2.

The accelerometers installed at Fuselage Stations 270 and 478 recorded excellent data during the crash sequence. As the fuselage structure at Station 270 was destroyed during the crash sequence the accelerometer orientation was changed. Therefore care must be exercised in interpretation of data recorded at Station 270 after 0.14 second.[1] The structure at Fuselage Station 478 remained intact throughout the crash and therefore can be analyzed without this reservation.

Integration of the longitudinal acceleration-time history at Fuselage Station 270 shows a velocity change of 21 feet per second to the 0.135 second point. This agrees with a velocity change of 23 feet per second determined from high-speed film analysis. Integration of the longitudinal acceleration-time history at Fuselage Station 478 indicates a velocity change of 203 feet per second. This agrees with a velocity change of 205 feet per second determined from the high-speed film analysis.

The vertical and lateral acceleration-time histories at Fuselage Stations 270 and 478 also seem to be very reasonable. The unidirectional characterisistic of Test 2 prevented accurate high-speed film

---

[1] Time zero has been established for all Tests as the initial contact of the aircraft with the barrier. For Tests 1 and 2 this was contact of the fuselage nose with the vertical concrete wall and for Test 3 it was contact of the nose gear guide shoe with the bottom of the 20-degree earth slope.

analysis of velocity changes in the vertical and lateral directions. Therefore comparison of time history integrations with the high-speed film analysis as was done for the longitudinal direction was not feasible.

(2) Test 3.

The accelerometers installed at Fuselage Stations 270 and 478 recorded excellent data during the crash sequence. Again as in the analysis of Test 2, care must be exercised in interpretation of data recorded after the structure supporting the accelerometers was destroyed. From high-speed film analysis this has been determined to be 0.19 second for Fuselage Station 270 and 0.34 second for Fuselage Station 478.

Integration of the longitudinal acceleration-time history at Fuselage Station 270 produced a velocity change of 59 feet per second to the 0.19 second point. This agrees favorably with a velocity change of 62 feet per second determined from the high-speed film analysis. Integration of the longitudinal acceleration-time history at Fuselage Station 478 produced a velocity change of 77 feet per second at the 0.34 second point. This agrees with a velocity change of 80 feet per second determined from the high-speed film analysis. A comparison of lateral and vertical acceleration components at each Fuselage Station was not possible as the structure was destroyed prior to significant motion in either direction.

c. Shipping Container Acceleration.

(1) Test 2.

The vertical and lateral acceleration-time histories of the Shipping Container compared favorably with the fuselage accelerations in the same planes. The longitudinal time histories, however, seem to be considerably lower in magnitude than what would have theoretically been expected. Integration of these curves also produced velocity changes lower than those which are known to have taken place. Since excellent correlation between film analysis and fuselage acceleration-time histories was obtained it has been concluded that the magnetic recorder was operating properly throughout the test. (This was also verified by examination of a static control channel recorded during the test). One possible reason for the apparent error in these readings could be that the transducer extension cables had been severed early in the crash sequence. This possibility has been discounted, however, as the Shipping Container vertical and lateral accelerometer cables were in the same cable bundle and were considered to be recording properly during the crash sequence.

Another possible reason is that the accelerometer did not respond properly to the extremely high rate of onset experienced when the Shipping Container contacted the concrete barrier. Examination of the Shipping Container after the crash and analysis of the crash sequence from high-speed film indicate that the container stopped in a maximum distance 28.5 inches from a velocity of 190 feet per second. From this analysis an average deceleration of 236G can be expected as shown below.

$$G = \frac{V_2^{\,2} - V_1^{\,2}}{2\,gS}$$

where

G = average acceleration

V_1 = velocity of container at impact (190 ft/sec)

V_2 = velocity of container after impact (0 ft/sec)

g = force of gravity (32.17 ft/sec^2)

S = stopping distance (28.5 inches)

$$G = \frac{0^2 - (190)^2}{(2)\,(32.17)\,(28.5/12)}$$

$$G = 236$$

Previous experience in crash forces has indicated that levels of peak deceleration will be two to three times the average deceleration level. Therefore it would be possible for peak deceleration forces of 708G to have been experienced by the Shipping Container during contact with the concrete wall.

The time period for deceleration of the Shipping Container from 190 feet per second in 28.5 inches can be calculated as follows:

$$S = \frac{(V_1 + V_2)\,t}{2}$$

$$t = \frac{(28.5)\ (2)}{(190 + 0)\ (12)}$$

$$t = .025 \text{ second}$$

The accelerometers used in this test program did not possess the necessary range or frequency response to respond to such an extremely short duration, high-amplitude shock pulse. In the design of the instrumentation system it had been assumed that the fuselage of the aircraft would provide more stopping distance for the Shipping Container than was actually experienced.

(2) Test 3.

The acceleration-time histories of the Shipping Container compare favorably with the fuselage acceleration in the same planes during the period before fuselage structural failure. Integration of the longitudinal acceleration-time history from the accelerometer located at the aft end of the overpack produced a velocity change of 148 feet per second at 0.35 second. Accurate film analysis of the Shipping Container at 0.35 second was not possible because of obscuring aircraft structures, however, a velocity change of this magnitude is considered to be very reasonable.

d. Shipping Container Motion.

Linear potentiometers were placed to record the forward relative movement between the Shipping Container and the pallet and the pallet and the floor. The accelerations due to crushing of the forward fuselage were so slight that there was no forward relative movement of the package or pallet until the wing and engine nacelles contacted the barriers. At this point the Shipping Container was in contact with the barriers and the compressed fuselage, so as the aircraft continued to move forward past the Shipping Container, the relative movement was aft. This resulted in destruction of the potentiometers as they were designed to record only forward motion.

SECTION V

EVALUATION

The Shipping Container demonstrated satisfactory achievement of the design objectives. Although the impact velocities were some 6 percent lower than desired, the amount of uncompressed metal honeycomb available and the small degree of damage noted on the weapon container indicated the capability of withstanding pure longitudinal impacts in excess of 130 knots. The insignificant damage which occurred during the impact with the 20-degree earth slope has demonstrated the ability of the container to survive random impacts with significant vertical and lateral components.

SECTION VI

CONCLUSIONS

Based on the information presented in this report, it is concluded that:

1. The CNU-103/E Shipping Container is capable of withstanding longitudinal impacts at a velocity of 130 knots.

2. The vertical and lateral protection provided by the balsa overpack is sufficient to insure withstanding random impacts which might occur in a typical landing or takeoff aircraft accident

3. Pure longitudinal impacts at high velocity with normal fuel loads will probably result in a post-crash fire of sufficient magnitude to destroy the protective overpack.

SECTION VII

RECOMMENDATIONS

It is recommended that:

1. The performance of the Shipping Container in a severe postcrash fire environment be evaluated.

2. Consideration be given to elimination of sharp corners and other exterior projections on the overpack to reduce the possibility of localized loading during an accident.

APPENDIX

ACCELERATION - TIME CURVES

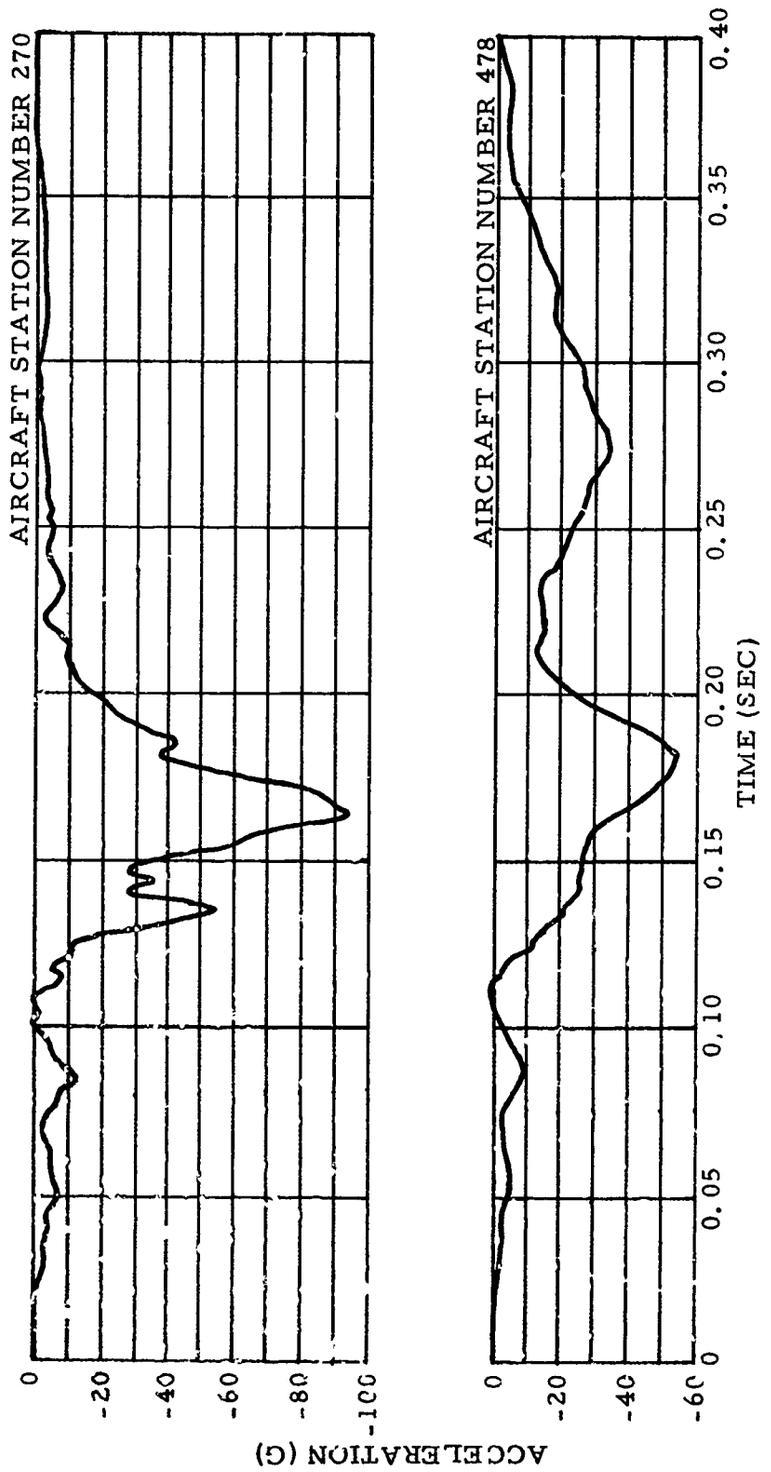

Figure I-1. Aircraft Fuselage Longitudinal Acceleration - Test 2.

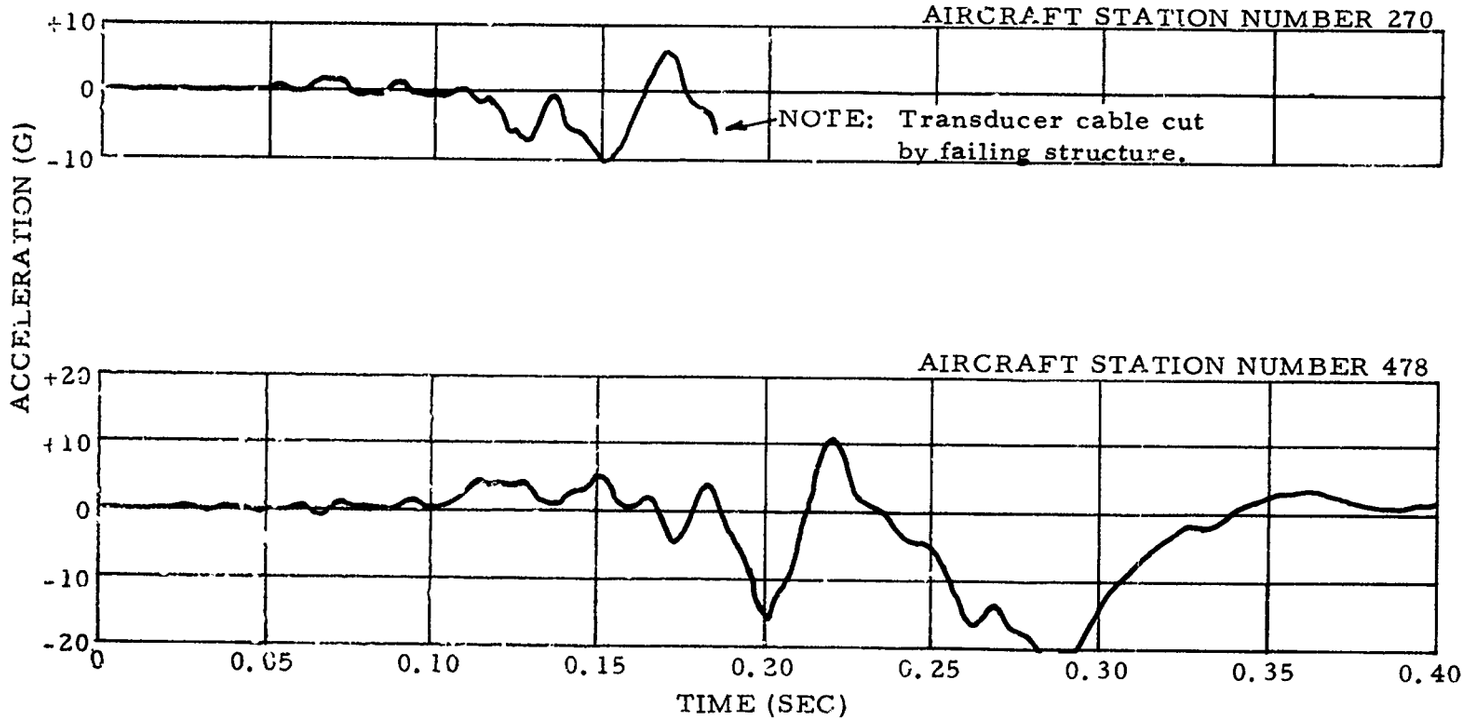

Figure I-2. Aircraft Fuselage Lateral Acceleration - Test 2.

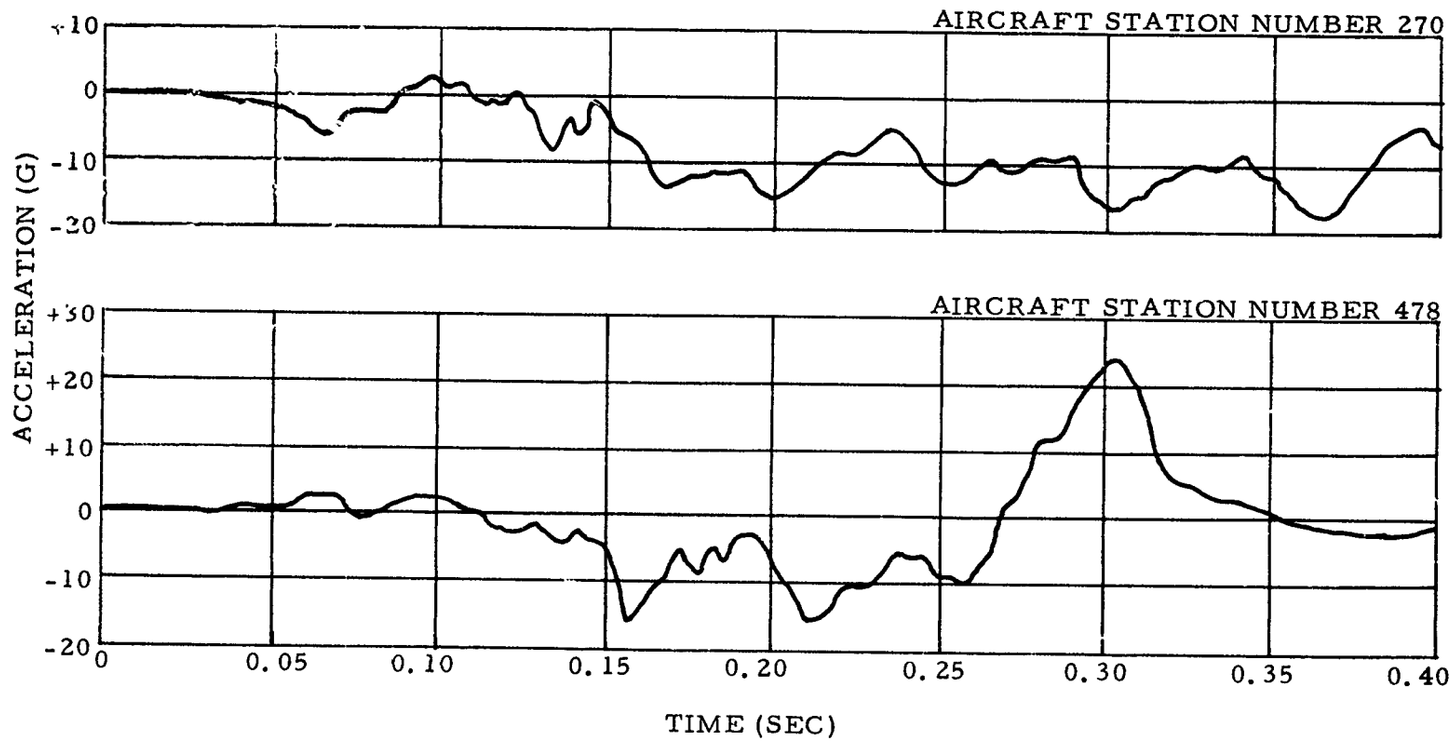

Figure I-3. Aircraft Fuselage Vertical Acceleration - Test 2.

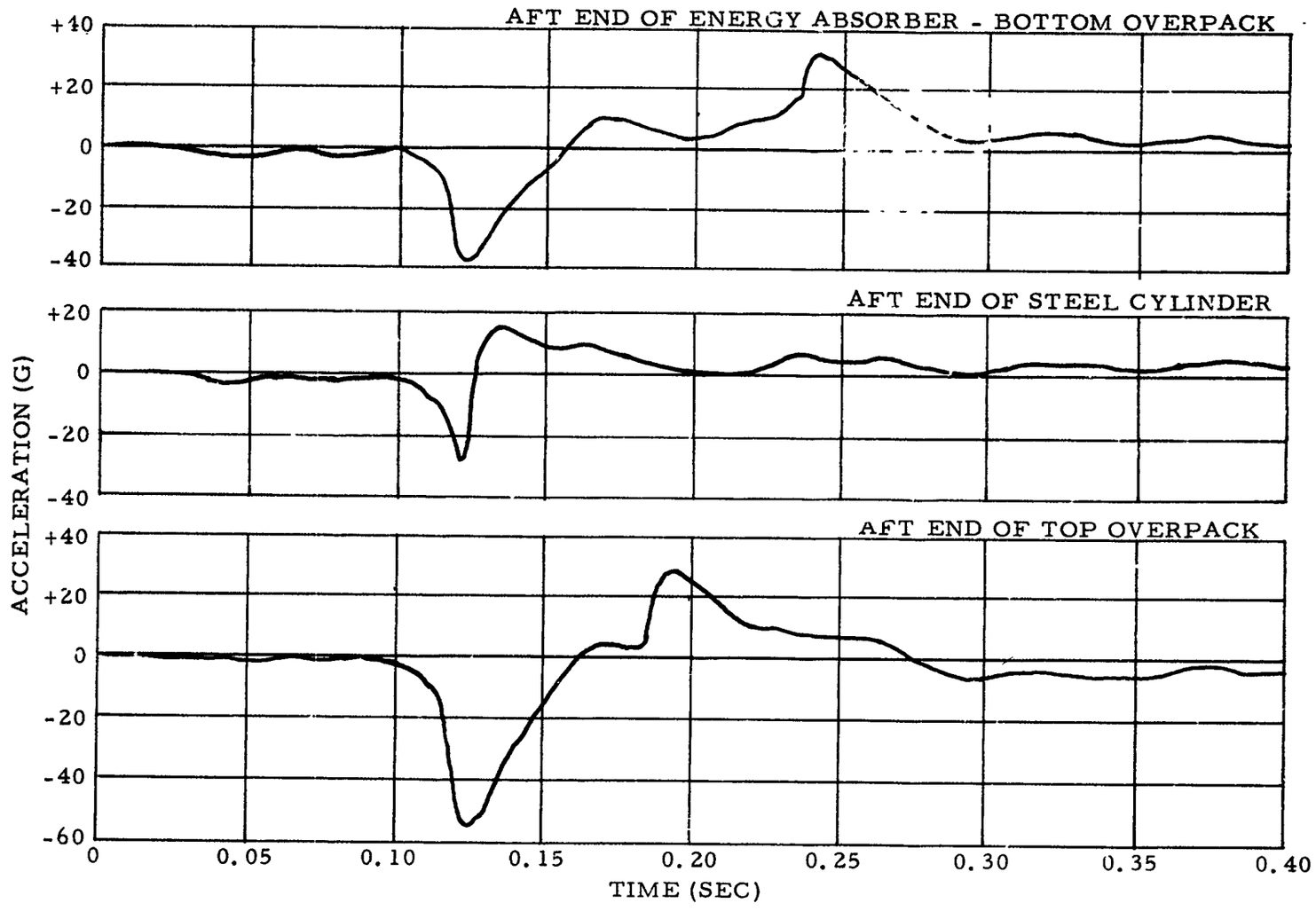

Figure I-4. Shipping Container Longitudinal Acceleration - Test 2.

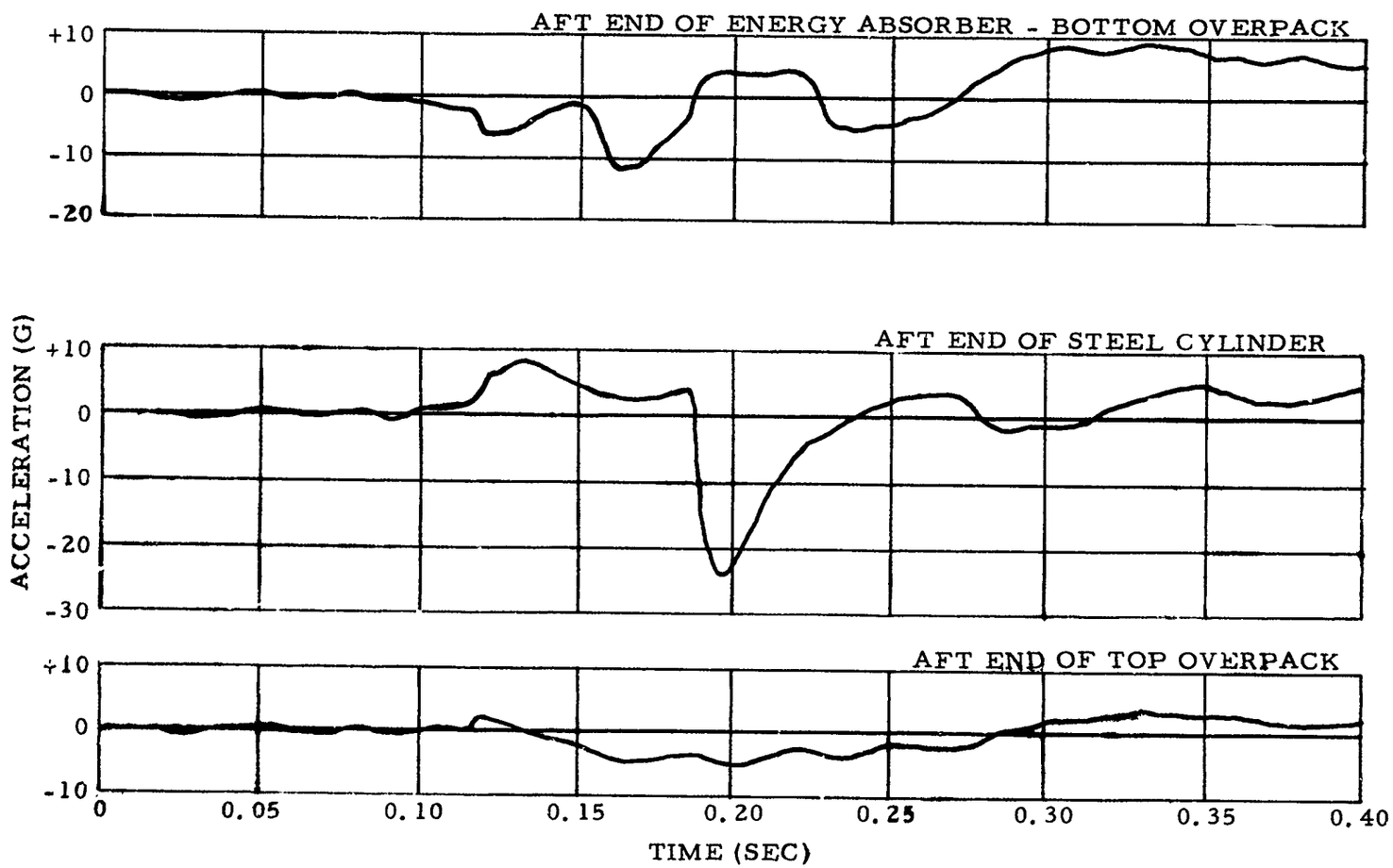

Figure I-5. Shipping Container Lateral Acceleration - Test 2.

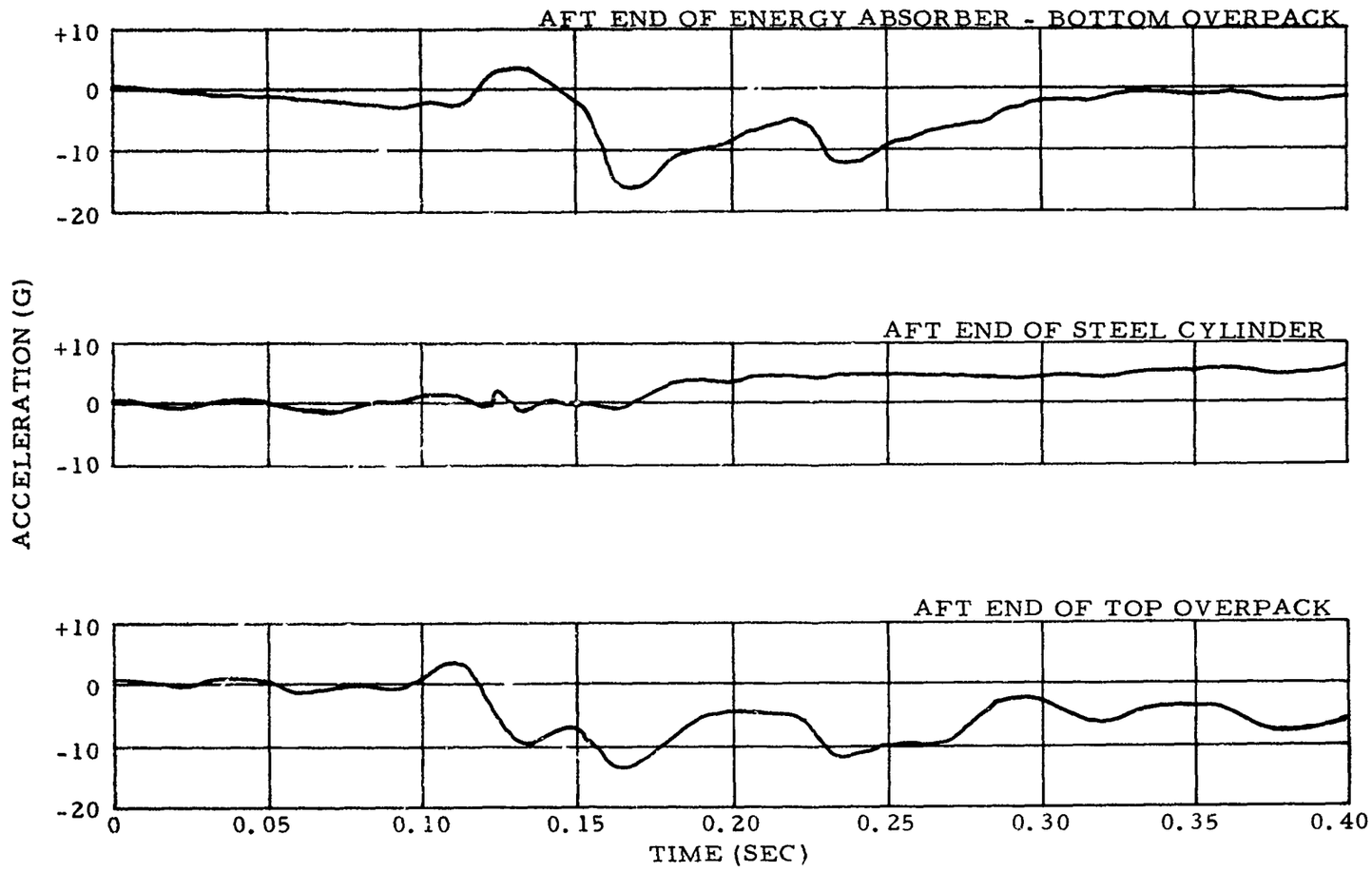

Figure I-6. Shipping Container Vertical Acceleration - Test 2.

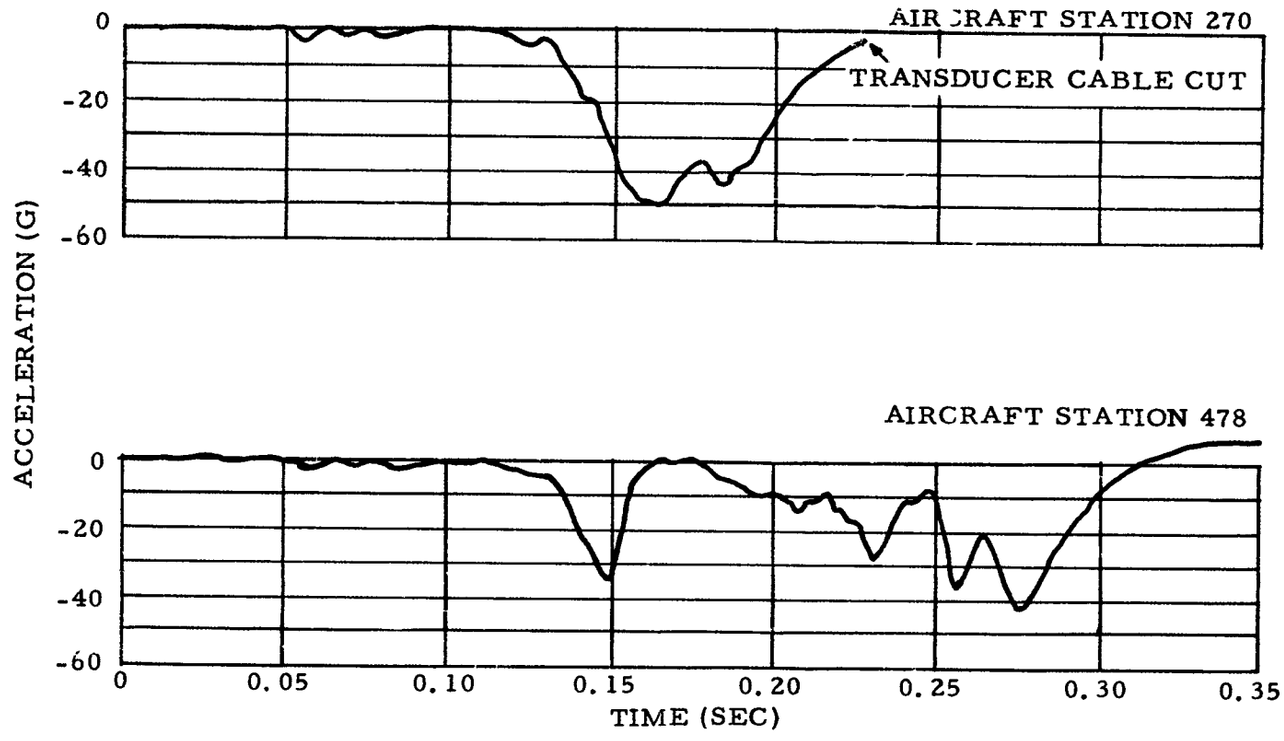

Figure I-7. Aircraft Fuselage Longitudinal Acceleration - Test 3.

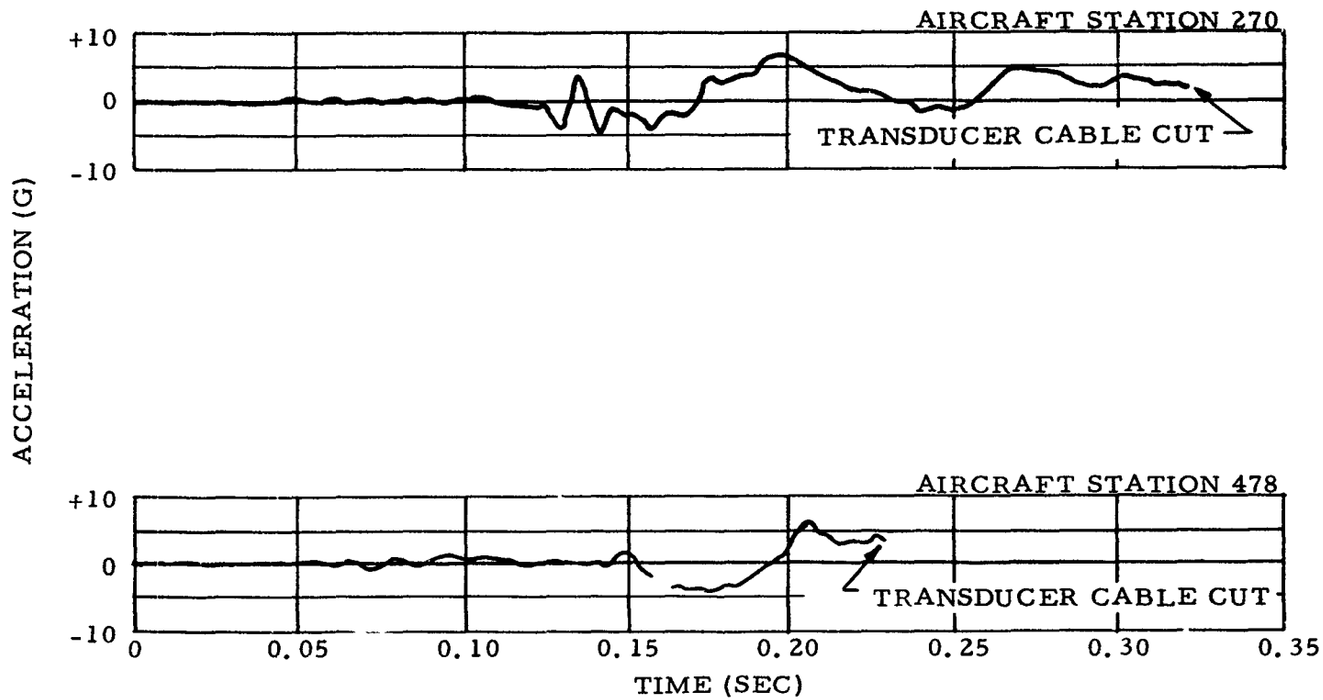

Figure I-8. Aircraft Fuselage Lateral Acceleration - Test 3.

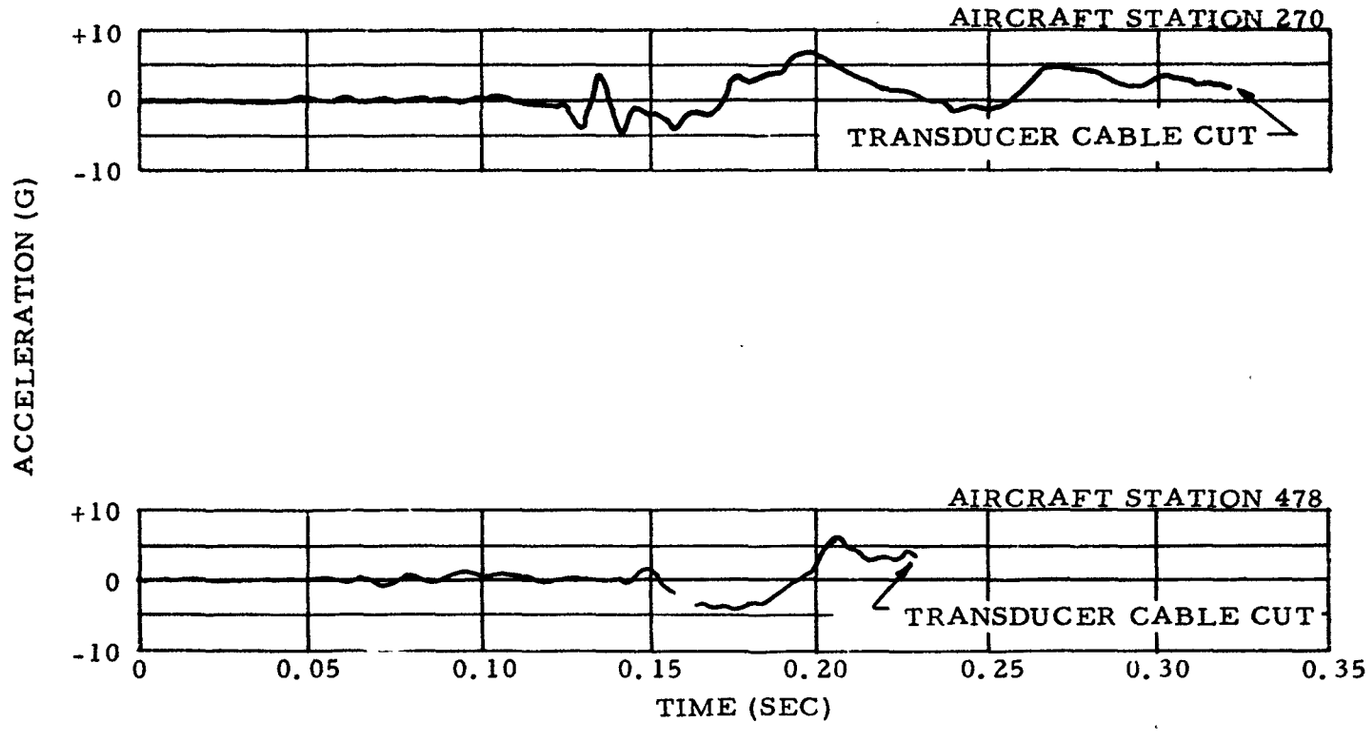

Figure I-8. Aircraft Fuselage Lateral Acceleration - Test 3.

AIRCRAFT STATION 270

DATA FROM THE LOCATION WAS NOT RECORDED
DUE TO FAILURE OF TRANSDUCER PRIOR TO TEST

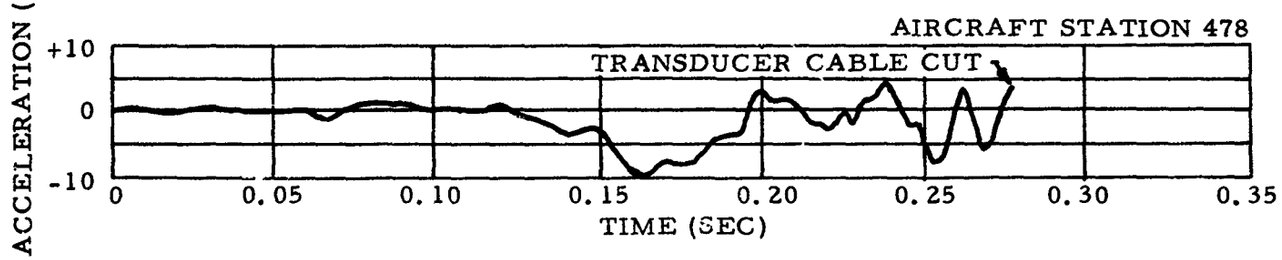

Figure I-9. Aircraft Fuselage Vertical Acceleration - Test 3.

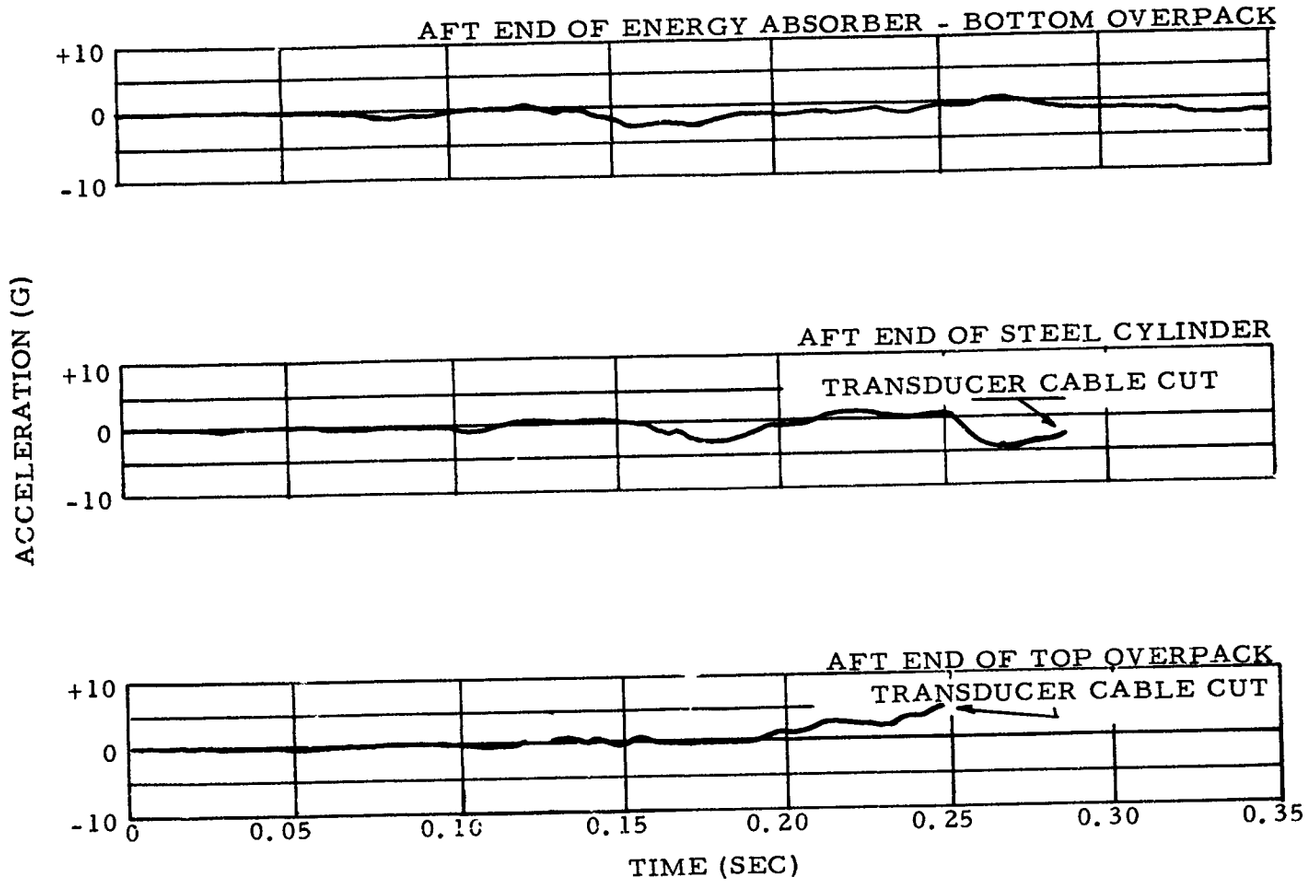

Figure I-11. Shipping Container Lateral Acceleration - Test 3.

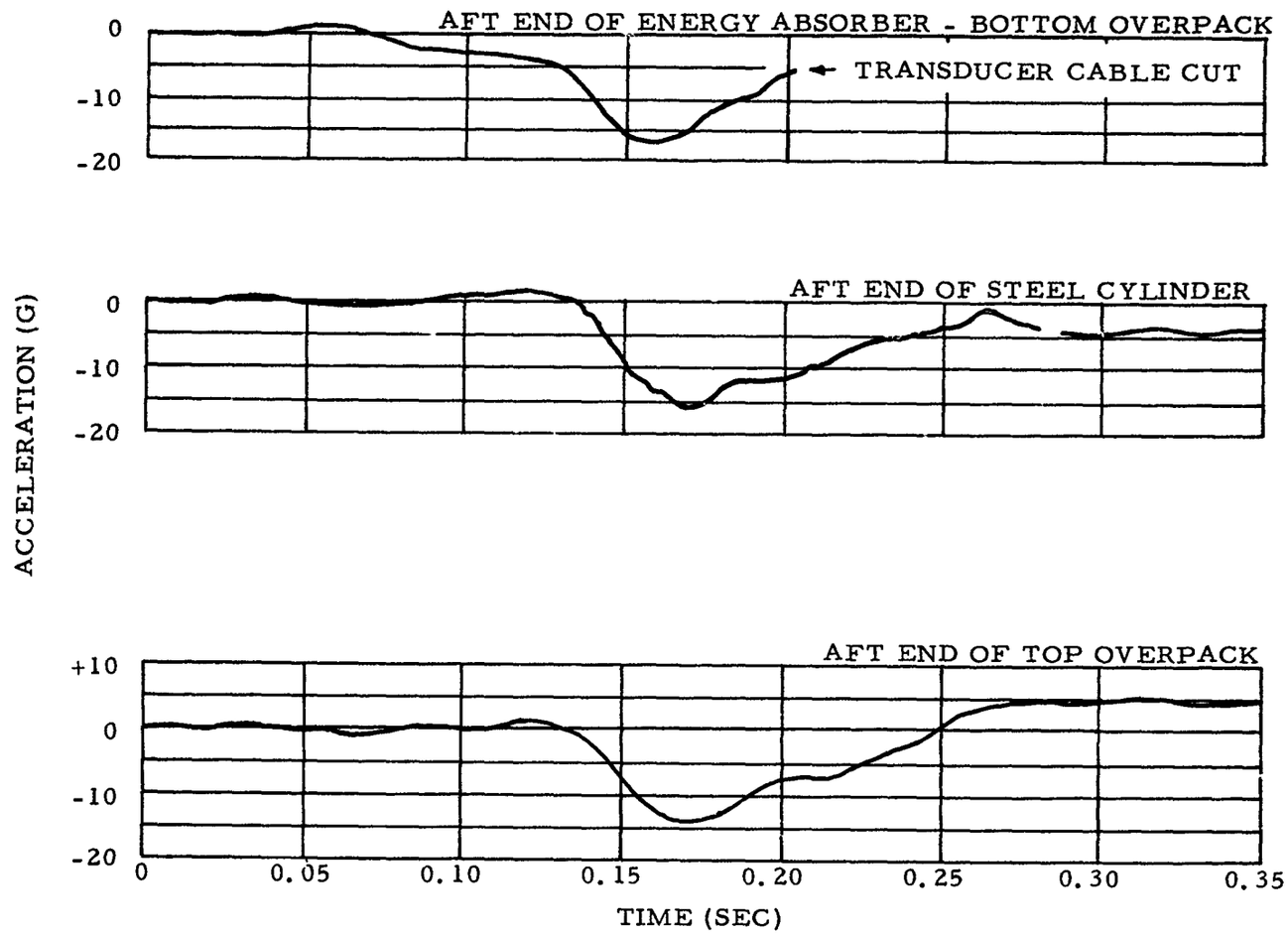

Figure I-12. Shipping Container Vertical Acceleration - Test 3.

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13. ABSTRACT
This report presents the results of three full-scale dynamic crash tests of a CNU-103/E Shipping Container. The container was designed to prevent the creation of hazardous environmental conditions should a catastrophic crash occur during air transport of certain munitions. The Shipping Containers were installed in three C-119C cargo aircraft and accelerated to crash impact velocities of 123 knots for Test 1 and Test 3 and 122 knots for Test 2. The first two aircraft were crashed into a vertical concrete wall and the third into a 20-degree earth slope. The aircraft were completely destroyed in the vertical wall impact, but no atmospheric contamination from the container was detected in either test. The lower three quarters section of the third aircraft fuselage was destroyed on impact with the 20-degree earth slope. The Shipping Container fell free of the wreckage as the aircraft passed over the top of the slope. No atmospheric contamination was noted upon examination of the Shipping Container. Atmospheric contamination from the container was measured by a series of air sampling devices installed around the impact site for the first two tests and swab and pressurization tests of the container after impact in all three tests. The impact environment was measured by an onboard magnetic tape recorder system and by interior and exterior high-speed photography.

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C-119C Aircraft Dynamic Crash Tests						

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