FAA-ADS-38

AD 624538

FULL-SCALE DYNAMIC CRASH TEST OF A LOCKHEED CONSTELLATION MODEL 1649 AIRCRAFT

TECHNICAL REPORT

OCTOBER 1965

by

W. H. Reed

S. H. Robertson

L. W. T. Weinberg

L. H. Tyndall

Aviation Safety Engineering and Research

Division of Flight Safety Foundation, Inc.

Phoenix, Arizona

Under Contract No. FA-WA-4569

for

FEDERAL AVIATION AGENCY

AIRCRAFT DEVELOPMENT SERVICE

FULL-SCALE DYNAMIC CRASH TEST OF A LOCKHEED CONSTELLATION MODEL 1649 AIRCRAFT

TECHNICAL REPORT
ADS - 38

by

W. H. Reed
S. H. Robertson
L. W. T. Weinberg
L. H. Tyndall

October 1965

Prepared For
THE FEDERAL AVIATION AGENCY
Under Contract No. FA-WA-4569

by

Aviation Safety Engineering and Research
Division of Flight Safety Foundation, Inc.
Phoenix, Arizona

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D.)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (CONT'D.)

LIST OF ILLUSTRATIONS (CONT'D.)

LIST OF ILLUSTRATIONS (CONT'D.)

LIST OF ILLUSTRATIONS (CONT'D.)

Figure | Page

LIST OF ILLUSTRATIONS (CONT'D.)

LIST OF ILLUSTRATIONS (CONT'D.)

SUMMARY

This report provides the details of a full-scale crash test of a large transport aircraft. The purpose of the test was to obtain crash environment data of the test aircraft and the various experiments installed aboard the aircraft.

The Federal Aviation Agency sponsored the test program with the participation of several other organizations who provided data recording equipment and special experiments onboard the test aircraft. The participating organizations included the U. S. Navy, the U. S. Army, the U. S. Air Force, the Society of Automotive Engineers and the Flight Safety Foundation which conducted the test under contract to and with the guidance of the FAA. The special experiments consisted of military crew and commercial passenger seats, cargo restraint systems, postcrash locator beacons, baby and child restraint systems, radioactive material containers, a military litter system, and provisions for emergency lighting.

The test involved a Lockheed Constellation Model 1649A aircraft, which was guided into a series of crash barriers with a monorail nose gear guidance system. The aircraft was accelerated under its own power by remote control for a distance of 4,000 feet reaching a velocity of 112 knots. Initial impact occurred against barriers which removed the landing gear, permitting the airplane to become airborne until the moment of impact with the wing and fuselage crash barriers.

The wing fuel tanks were ripped open by the wing barriers, allowing simulated fuel to spill out in a heavy mist during the crash sequence. The fuselage was broken in two places during the crash, just aft of the cockpit between fuselage stations 370 and 380 and just aft of the galley between fuselage stations 1020 and 1030. Peak longitudinal accelerations on the order of 25G's were measured at the cockpit floor when the aircraft impacted the 20 degree slope. Most of the onboard experiments remained in their relative locations throughout the test.

INTRODUCTION

With the continuing rapid growth of civil transport aviation, it is vital to search out and develop safety improvements. One area of immediate concern is the assurance of survival of passengers and crew during take-off and landing accidents in which the crash conditions would not be expected to be so severe as to exceed the limits of survivability. If, during these accidents, adequate impact protection can be provided and the possibility of fire after impact reduced or eliminated, a very significant improvement in the safety record can be achieved.

This test program was devised by the Federal Aviation Agency in conjunction with other participating organizations, which are referenced in Appendix 1, to explore the manner in which large aircraft are damaged in survivable accidents and to accurately measure the crash loads. Two aircraft were selected for use in this program, a Douglas DC-7, the results of which are discussed in FAA Technical Report ADS-37, and a Lockheed 1649A, the results of which are discussed in this report. Following these tests, various systems and elements can be isolated and studied in detail in follow-on small-scale component testing.

Crash testing of complete transport aircraft has been conducted in the past by the National Aeronautics and Space Administration with C-46 and C-82 type aircraft, but data on larger aircraft, such as those now predominantly in use, has not been gathered. This test program does not include aircraft of the "jet size", but it is hoped that analytical techniques now being developed will be proven so that extrapolation of the results of this program will provide satisfactory definition of the crash environment in the newer, larger aircraft.

Three types of accidents are representative of many real crashes which are survivable or potentially survivable. These are:

1. A hard landing, with a high rate of sink, causing failure of landing gear and damage to its supporting and surrounding structure. The transport accident at Montego Bay in January 1960 was of this type.

2. A wing low impact with the ground such as occurred to a transport at the John F. Kennedy Airport in New York in November 1962.

3. An impact into large trees in an off-airport forced landing. The accident of a chartered transport near Richmond, Virginia, in November 1961 included this type of damage.

This test program was planned to produce crash conditions simulating these three circumstances followed by multiple fuselage impacts of successively increasing severity.

TEST SITE

General

The test program required the design and construction of a special test site. The desired impact conditions called for accelerating the test vehicle to a velocity approximating minimum climbout speeds and final approach speeds for propeller driven transport aircraft of the types involved, and guiding of the aircraft to a closely controlled initial impact point. In addition, earthen barriers for wing and fuselage impacts had to be located and built to provide the desired sequence of impact events. The construction details of these barriers controlled the type and severity of the impacts which occurred. A plan view of the test site is shown in Figure 1.

Simulated Runway System

A special runway was built to allow acceleration of the aircraft to the desired impact velocity. In conjunction with the runway, a monorail was built to provide positive directional control of the test vehicle, by mechanically guiding the nose landing gear of the airplane.

The runway consisted of two soil-cement runway strips, 15 feet wide and 18 feet apart, laid over the existing, undisturbed desert soil to support the main landing gear wheels. The length of these strips from release point to the impact barriers was 4,000 feet. The 6-inch soil-cement layer, containing 4.5 percent portland cement and 11 percent moisture, was compacted to 95 percent density and cured, using 0.1 gallon per yard of MC250 sealer. The above specifications were based on Harvard and Proctor tests of the soil at the site. Figure 2 is a view of the runways as they approach the crash site.

The nose gear guide rail was a single track of 90 pound railroad rail laid on a continuous reinforced concrete base. Rail tiedowns were provided every 49-1/2 inches and at rail joints. The tiedown method is shown in Figure 3. 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 to resist side loads that might develop during the test run, and prevent misalignment of the ends of the rails.

Impact Area

Barriers to remove the main landing gear were constructed of a frame of railroad ties filled with cement. A 2-foot high inclined earth mound with a 15 degree slope was made on the approach side of the barriers to drive the main gear upward. The nose gear barrier was made of short lengths of telephone pole and 90 pound rail positioned to cut the nose gear strut just above the guide slipper. This barrier is shown in the center of Figure 4.

The left wing barrier was an inclined earthen mound 20 feet high with a 30 degree slope extending from the outer wing tip to the center of the left wing. The right wing barrier consisted of two telephone poles placed upright to impact the leading edge of the wing. These poles were set approximately four feet in the ground. Both wing barriers are shown in Figure 5.

The initial impact hill, located beyond the wing barriers, was a 6 degree slope extending for approximately 175 feet along the path of the aircraft. The hill then dropped away for 75 feet and then rose again at a 20 degree incline. The top of the 20 degree rise was approximately 500 feet from the point of initial contact with the gear barriers. Earth used to construct the barriers was compacted to an average CBR* ranging between 35 to 40 percent. Figure 6 shows the 6 degree slope just beyond the telephone pole wing barriers. The 20 degree slope and the top of the impact hill can also be seen beyond the 6 degree slope.

To provide adequate reference points for analysis of postcrash photographic data, a system of grid lines and range poles was used in the impact area. The grid system was marked off in 25 foot increments longitudinally from the face of the main gear barriers to the top of the 6 degree slope and laterally for 100 feet each side of the centerline of the impact zone. The vertical range poles were placed along the 100 foot grid line on the right side of the impact zone, coinciding with the lines placed every 25 feet along the longitudinal path. The range poles were 16 feet high, and marked with alternate black and white one foot stripes, to provide a vertical reference. The grid lines and range poles are shown in Figure 7.

TEST AIRCRAFT PREPARATION

General

Aircraft equipment not required for the test or for pretest operations was removed and a load record maintained to record the weight of the

---

* California Bearing Ratio (a method to determine soil compactness).

test equipment and experiments as they were installed aboard the aircraft. Appendix 2, Weight and Balance Breakdown, is a complete list of the items removed and the equipment/experiments added. The total weight of the aircraft was 159,131* pounds just prior to the test.

To eliminate the total destructive effect of a postcrash fire and at the same time simulate the effect of a representative fuel load as related to tank-wing deformation and fluid pressure fluctuations, certain fuel tanks were filled with dyed water to equal the weight of full tanks of gasoline. The aircraft had 7 integral tanks in its system with a total capacity of 33,070 pounds of fuel. Each of these was isolated from the main fuel supply lines and the cross-feed system by capping the lines at the boost pumps. The engine vapor return lines and heater fuel supply lines were also capped. The aircraft de-icing systems in each outboard nacelle were drained of isopropyl alcohol. The engine oil main reservoir in the fuselage was emptied and the aircraft hydraulic system kept replenished with MIL-H-5606A fluid.

A special fuel tank, Figure 8, was built and installed in the wheel well of No. 2 engine nacelle. This tank was fabricated from a 55-gallon steel drum and contained its own boost pump and anti-slosh baffles. It was connected through a leak-proof, quick-disconnect fitting to a larger supply tank located on the ground, as shown in Figures 9 and 10. The special aircraft fuel tank was continually filled from the ground supply tank until the start of the final test run, at which time the ground fuel tank was disconnected manually.

The aircraft fuselage, wings and propellers were painted with specific black and white markings designed to serve as aids in determining velocity and aircraft deformation. The aircraft nose and wing tips were distinguished by checkerboard patterns that provided reference points for ground and airborne tracking cameras. The leading edge of each wing was painted white to pinpoint impact with barriers. A series of 1 foot squares in two lines were placed on the fuselage. One line commenced just aft of the nose marking and followed the general conformation of the interior flooring toward the wings. A second line of black squares commenced just forward of the wing and ran, in a straight line, the remaining length of the fuselage. These lines were to aid in film analysis of fuselage deformation. Checkerboard patterns were placed on each propeller to aid in determining propeller revolutions. The nose gear strut shield was marked with 6 inch squares to distinguish upward deformation. Figure 11 is a view of the aircraft in the release area that shows the exterior markings.

* Aircraft maximum gross weight is 160,000 pounds.

Aircraft Control System

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

1. Run-up engines to a predetermined power setting.
2. Initiate instrumentation recording system.
3. Release the aircraft from its mechanical tiedown to begin acceleration run.
4. Turn on on-board cameras.
5. Abort the test.

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

The throttles of all four engines were controlled simultaneously by a single linear electric actuator which advanced or retarded power in response to remote control commands. Throttle stops were pre-set to limit maximum and minimum power. Power to operate the throttle actuator was drawn from the aircraft electrical system.

The emergency abort system consisted of several relays which could ground the engine magnetos. The system could be actuated remotely through either the umbilical cable or by radio link.

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 tie-down release hook mechanism was mounted to the guide rail, as shown in Figure 12. A 1/2 inch diameter cable was attached to the main landing gear of the aircraft and passed through the release mechanism to provide the connection.

The release mechanism incorporated a mechanical safety pin to prevent inadvertent release. A linear electric actuator connected to the aircraft electrical system and controlled from the remote control station was used to actuate the release system.

After release, the restraint cable was pulled taut against the underside of fuselage by a bungee cord to prevent its interference with any of the test operations.

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 electrical switches which initiated instrumentation correlation systems and turned on the onboard lights and cameras. The switches were actuated when arms mounted atop the guide shoe were tripped at specified times by stops placed along side the rail. Figure 13 shows the guide shoe and actuating arms.

INSTRUMENTATION

Three general types of sensing instruments were used for data acquisition. Accelerometers were used to determine gross environmental conditions, pressure transducers were used to provide fuel containment information, and load or strain links measured seat belt loads, seat leg loads, and cargo tiedown loads. Three data recording systems were used during the crash test. The primary system being a 14 track magnetic tape recorder carried onboard the test vehicle. One track was utilized by the U. S. Naval Aerospace Crew Equipment Laboratory instrumentation system as a back-up for their telemetry system. Another track was used as a time base for the test with a correlation mark imposed on the time base at impact. The remaining tracks were set up to record seven channels each, including tape speed compensation, for a total of 82 data channels. A block diagram of the system is shown in Figure 14. Each component of the recording system is designed to record accurate and reliable data under the severe environment of a crash situation. 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 protected box mounted at the top of the center section of the fuselage. Shielded cables connected the transducers to the recording system package. The control circuit was designed so that once started the tape recorder 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. 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 were combined in the mixer amplifier and the resulting composite signal recorded on one track of a fourteen-track tape recorder.

The primary instrumentation system is shown in Figures 15 and 16 and an instrumentation summary is given in Appendix 3.

The second recording system, consisting of three Borg Warner Model R-101 miniature magnetic tape recorders was used to provide redundancy for 39 primary data channels, which are listed in Appendix 5. An amplitude modulation carrier erase technique was used in which a pre-recorded single was put on the tape at saturation level and held at a constant amplitude. Singles from the transducers erased the carrier in proportion to the amplitude of the transducer current.

The third recording system, provided by the Naval Aerospace Crew Equipment Laboratory was used to obtain cockpit environmental data. This system was a typical IRIG Telemetry System utilizing several sub-carrier oscillators with IRIG frequencies. Information is fed through these oscillators, and their outputs are summed together and sent to a transmitter. The transmitter carrier frequency is then modulated by the composite oscillator input and transmitted to a receiving station. At the receiving station, the signal is demodulated and the various channels of data are separated and recorded.

Fifteen cameras were mounted in protective boxes onboard the aircraft to provide photographic instrumentation during the test. All were Photosonics 1B high speed cameras operating at a nominal speed of 500 frames per second. Color film was used in all cameras, and the different experiments were painted contrasting colors to provide optimum photographic identification. Supplemental lighting consisted of auxiliary flood lamps installed throughout the fuselage interior. The cameras and lamps were powered by special nickel-cadmium batteries mounted in the aircraft. The exact location and coverage of each camera are listed in Appendix 5 and are cross referenced with Figure 17.

Exterior photographic coverage of the test consisted of seventeen (17) cameras positioned around the crash area in protective boxes. Figure 18 shows the location of the various ground cameras. The cameras are listed in Appendix 5 and cross referenced with Figure 18. Appendix 5 also indicates approximate distance from the impact area, and frame speeds.

Correlation and timing between the electronic and the photographic data were provided by a 100 cycle per second electronic signal recorded on the magnetic tape and on the camera film by means of edge exposure with neon bulbs. The signal was generated by a precision square wave oscillator, with accuracy better than $\pm$ 0.01 percent. The basic signal was coded in width of pulses for correlation purposes. An identical unit was provided for timing of the ground cameras. Correlation between onboard and ground cameras was provided by flashbulbs ignited in the field of view of all cameras. The correlation mark, provided by redundant impact switches, took place at the moment of impact.

EXPERIMENTS CONDUCTED DURING TEST

The separate experiments conducted in this test included the following:

1. Overall acceleration environment.
2. Wing fuel spillage studies.
3. Cockpit crew seat experiments.
4. Forward cabin forward facing and high density seating experiments.
5. Child restraint experiment.
6. Cargo restraint experiments.
7. Mid-cabin forward facing seating and leg kick-up experiments.
8. Mid-cabin rearward facing seating experiments.
9. Litter experiment.
10. Galley experiment.
11. Side facing seating experiment.
12. Aft cabin forward facing seating experiment.
13. Attendants seat experiment.
14. Baby bassinet experiment.
15. Flight recorder experiment.
16. Crash locator beacon experiment.
17. Emergency light experiment.
18. Shipping containers experiment.

More specific descriptions of the hardware used in each of these experiments, and its installation in the test vehicle are given at the beginning of the discussion of test results for each experiment. Also, Figure 17 shows the locations of experiments and instruments.

CRASH TEST OPERATIONS AND RESULTS

General

The test experiments, data acquisition equipment, and simulated fuel that were added during preparation of the aircraft weighed 68,747 pounds, and brought the gross weight of the aircraft to approximately 159,131 pounds. The center of gravity was located at Fuselage Station 690. Appendix 2 contains complete listings of the items removed and added, and shows that the empty weight of the aircraft was 90,384 pounds.

Release and Crash Sequence

The aircraft was operated in normal take-off configuration with exception of flaps, which were positioned full up to reduce lift and drag. Upon release, the throttles were moved to the pre-determined power settings. The aircraft accelerated smoothly along the guide rail, reaching a velocity of 112 knots (129 mph) just prior to contact with the landing gear barriers.

Figures 19 and 20 show side and head-on views of the crash sequence from the moment of initial impact.

At impact, both main landing gears were broken off. The left gear pulled the No. 2 engine nacelle downward as it failed, causing that engine to roll under the left wing. The right gear bounced upward into the path of the right-hand horizontal stabilizer, severing the right vertical fin. The No. 2 propeller was sheared off by the landing gear barrier just prior to contact between the left main gear and the barrier. Nos. 1, 3, and 4 engines and propellers were intact throughout the gear barrier impact sequence, with the exception of one blade of the number 3 engine propeller which was sheared off by the right main gear barrier.

The rail guide shoe was broken off on impact with the nose gear barrier and was imbedded in the dirt mound at the end of the rail. The gear strut was forced backward and upward into the forward fuselage, where it remained as the aircraft impacted the two slopes. The gear barrier action can be seen in Figures 19A and B and Figures 20A and B.

After passing through the gear barriers, the aircraft dropped in a slightly nose-down attitude. Propellers on Nos. 1, 3, and 4 engines struck the earth, which resulted in disintegration of the blades. At this point, visible rupture of the wing structure adjacent to the engine nacelles began. The aircraft continued on into the wing barriers. The left wing struck the earthen barrier and commenced to separate from the fuselage at the wing root. The right wing impacted the pole barriers which opened up the wing about 25 feet from the tip and between engines No. 3 and 4. This sequence is shown in pictures C and D of Figures 19 and 20.

The nose of the airplane contacted the ground at the foot of the 6 degree slope and slid into the hill, as shown in pictures D, E, and F, Figures 19 and 20. No major breakup of fuselage structure occurred during this impact.

After passing the crest of the 6 degree slope, the airplane rotated to a slightly nose down attitude before impacting the 20 degree slope. Impact with the 20 degree slope produced two fuselage breaks; aft of the cockpit between fuselage stations 370 and ?80, and aft of the galley between fuselage stations 1020 and 1030.

Figures 21 through 27 show how the aircraft broke up as it progressed through the crash barriers leaving a trail of small parts, pole splinters, and spilled liquids (engine oil and simulated fuel). Except for the engines, main landing gear and the right vertical stabilizer, the major parts of the aircraft came to rest on the second impact slope in a small area with the fuselage nearly aligned with the original path from the guide rail.

Small fires resulted as the aircraft broke up during the crash. When the engines were torn partially free at initial impact, the gasoline and oil lines separated, releasing several gallons of oil and gasoline. Ignition occurred immediately in several places, probably caused by flames from engine backfires and misfires as the engines began to break up. The released gasoline was consumed within a few seconds. The fires from the engine oil were confined to the engine and nacelle areas. The only fire which threatened extensive damage to the aircraft and the onboard experiments was under the fuselage at the wing root area. This fire was attributed to hydraulic fluid mixed with gasoline which drained into the area from the ruptured fuel manifold (crossfeed). All fires were quickly extinguished by foam and CO_2. The auxiliary fuel tank was not involved in the postcrash fire.

The 82 data channel instrumentation equipment used in this test yielded productive information from 68 channels. The channels that were not obtained did not result in a total loss of data for any individual experiment. The electronic data collected on the primary instrumentation system is included in this report as Appendix 6.

The onboard cameras did not operate due to a malfunction in the triggering circuit. Except for cameras 11, 12, and 14 of Figure 18, all stationary cameras operated satisfactorily.

Fuselage Structural Damage

The structural damage and deformation of the fuselage which occurred in this crash were relatively moderate, considering the severity of the crash, particularly with respect to the occupied portion. The cargo hold was crushed and torn due to impact and abrasion as the aircraft bounced and slid along the two impact slopes. The damage was most severe in the lower forward structure where primary impacts were concentrated, as shown in Figure 28.

The extreme forward end of the cockpit, as shown in Figures 29 and 30 was pulled under by the impact and friction against the 20 degree slope causing considerable damage in the vertical space forward of the pilot's and copilot's seats. The floor structure beneath the pilot's and copilot's seats was still intact, but the fuselage beneath this position was crushed so that there was no space left beneath the floor. Aft of the pilot's and copilot's position the cockpit floor was deformed upward and twisted. The floor panel normally located between the engineer's seat floor tracks was knocked out, leaving a large opening. The air conditioning and pressurization control panel sprung free from the fuselage station 260 bulkhead and partially blocked the passageway leading to the side, crew entrance door. The upper cockpit structure was deformed to such an extent that the side, crew entrance door could not be opened (see Figure 31), however, exit from the cockpit was still possible through the main cabin.

The fuselage broke across the forward cabin just aft of the main door, between fuselage station 370 and fuselage station 380 as shown in Figures 30 through 33. The nose gear impacted the bottom of the aircraft just forward of the break. The displacement of the forward fuselage section due to the fuselage break combined with the upward displacement of the floor caused by the nose gear impact produced a sharp break in the continuity of the cabin floor at this point.

Further aft, several floor panels were broken up, and numerous failures occurred in the lower structural members in the cargo hold. The seat tracks on the left side were broken at approximately fuselage station 400, and the floor bent upward approximately 15 degrees as shown in Figure 33. Though the forward main cabin door was jammed, the fuselage break near the door left an opening large enough to permit exit (Figure 30). Exit through the gap would have been hazardous, however, due to jagged metal edges. Vertical space in the cargo hold, normally 3 feet, was reduced to about 6 inches at the location of the fuselage break, and the space remaining was partially filled with jagged metal. Aft of the break, the vertical space in the cargo hold increased, and the amount of jagged metal protruding into the space decreased. At fuselage station 470, there was 18 to 24 inches of vertical space left in the cargo hold, and the floor was relatively smooth. The upper fuselage in the forward main cabin area suffered only minor permanent deformation.

In the main cabin aft of the cargo experiment, the floor remained flat and intact* and cabin walls and roof were not torn or significantly deformed.

To determine volume reduction in the passenger compartment during the crash, crossed wires were installed at two locations. The lengths of these extendable crossed wires were measured before and after the crash. Figure 34 presents the location and measurements of the installed wires.

Figure 35 presents the postcrash measurements of the crossed wire apparatus. A comparison of the dimensions in this figure with those in Figure 34 indicates that all wires increased somewhat in length; however, at final resting place, the volume within the aft main cabin was reduced by approximately two percent.

All emergency exits in this section were easily removable.** The aft fuselage broke one to two feet aft of the galley, between fuselage stations 1020 and 1030. The fuselage break passed through windows on both sides of the aircraft at this point. The floor was bent downward at the fuselage break, but did not part. This second break is shown in Figure 36. The floor section next to the aft entrance door was pulled free of its fasteners in several places along the forward edge of the panel. Both the galley door and the aft entrance door opened readily.

Aft of the seats in the rear cabin, damage was minor. Parts of the left toilet flew forward into the lavatory compartment, and overhead light panels in the lavatories fell out on both sides, but wiring kept these articles from flying through the aircraft. A postcrash view of the lavatory is shown in Figure 37.

---

* Floor in this section was strengthened by structural reinforcement for installation of seats and litters.

** No provisions are made for quick removal of these exits from outside the airframe.

Fuselage Acceleration Environment

Accelerometers were mounted along the floor of the aircraft at five locations to measure accelerations of the basic aircraft floor structure. The instrument locations and sensing directions are listed in Appendix 3 and illustrated in Figure 17. All of the accelerometer installations were similar in that the instruments were housed in aluminum boxes securely attached to thick plywood board. The plywood board was bolted through the floor to the sub-floor structure.

The floor acceleration records obtained during the crash in the longitudinal, vertical and lateral directions are shown in Appendix 6. These measurements were made at the fuselage stations indicated on the figures. The highest longitudinal reading of significance was 25-30G and occurred in the cockpit (F.S. 195) during final impact with the 20-degree slope. Several peaks in excess of 20G's were recorded at the C.G. (F.S. 690) during initial fuselage contact with the ground but these were caused by local loading and deflection.

In the vertical direction peak accelerations in excess of 25G's occurred in the cockpit (F.S. 195) during all impacts. Accelerations measured throughout the cabin peaked at 15 to 20 G's (with elimination of high frequency hash) with the exception of those measured at F.S. 1165. Vertical accelerations in this area reached peaks as high as 44 G's just as the aircraft came to rest.

Lateral accelerations were measured at fuselage stations Nos. 195, 690, and 1165 only. The most severe accelerations, peaking at about 10G, were recorded in the cockpit during impact with the 6 and 20-degree slopes. Several 5G acceleration levels were also measured at the other stations during the impact sequence. Most of the pulses during which the foregoing accelerations were measured in the three directions, were from .10 to .20 seconds duration.

Wing/Fuel Tank Experiments and Results

Accelerometers were installed on the main spar of each wing at three locations, as shown in Figure 38 to measure accelerations experienced during the crash sequence. Figure 39 shows the accelerometer installations in the mid-wing and inboard locations along the right wing.

Fuel tank pressure measurements were made in the inboard and mid-wing tanks as shown in Figure 38. The wing fuel tanks were filled, as noted in Figure 38, with colored water, except for the mid-wing tanks, Nos. 2 and 3 which were filled with a gelled water mixture having approximately the consistency of applesauce.* Tank No. 7, the fuselage tank, was drained and left empty during the test. Sensors were installed to measure absolute pressures in the inboard and mid-wing tanks.

A complete list of wing and fuel tank experiment measurements is given in the instrumentation summary, Appendix 3.

Initial impact and subsequent course of the aircraft through the barriers caused the wings to fail or disintegrate, spilling the simulated fuel. Figures 40, 41, 42, and 43 present a kinematic of the fuel spillage during the crash.

The No. 1 fuel tank was ruptured when the outer portion of the left wing impacted against the earthen barrier. The complete destruction of the tank caused the entire volume of simulated fuel to be released in a heavy mist. As the aircraft contacted and slid forward up the 6 degree slope, the wing was partially separated from the fuselage at the root. This failure opened up the No. 5 fuel tank allowing its simulated fuel to be completely expelled in a mist cloud by the time the aircraft came to rest on the 20 degree slope. Traces of the simulated fuel were found 15 feet ahead of the aircraft.

During the crash sequence, the No. 2 fuel tank, which contained gelled water, was ruptured. The top aft-portion of the tank was torn and raised several inches in a 4 x 4 foot section and the bottom of the tank had cracked spanwise in several places. The gelled water was partially released during the crash and remainder of the liquid drained from the tank during two hours following the crash.

The right wing impacted the two telephone poles. The first pole nearly sheared off the outer wing panel opening up to No. 4 fuel tank permitting the simulated fuel to stream from the tank for remainder of the crash sequence. During the periods of high deceleration, the fuel blossomed out ahead of the aircraft and spread 20 feet forward of the nose as it came to rest. The second pole cut into the wing and the No. 3 fuel tank between the No. 3 and No. 4 engine nacelles. The fuselage contacted the ground at approximately the same time and as

*The gel mixture as analyzed by Westco was 1.2 lb/10 gallons water. This is equal in consistency of 50mm penetration as measured by the Westco penetrometer.

it slid along this partially severed wing section, finally became separated, and came to rest upside down. The gelled water from the No. 3 fuel tank was released and streamed from the wing and had spread 23 feet ahead of the nose when the airplane came to rest.

The portion of the right wing inboard of the No. 3 engine nacelle remained attached to the fuselage throughout the crash. During the crash sequence, the simulated fuel was partially expelled from the fuel tank located in this area through a split along the tank bottom just behind the forward spar. The remaining liquid drained from the tank within several minutes after the crash.

Figures 44 and 45 show the general nature of the breakup of both wings and the fuel spillage patterns and accelerations experienced are given in Appendix 6.

Crew Seat Experiments

The standard crew seats were removed from the cockpit and were replaced with three helicopter crew seats provided by the U. S. Navy Aerospace Crew Equipment Laboratory (ACEL). These seats were installed in the pilot and copilot positions and in the crew berth area as shown in Figure 17.

The three seats were of similar design and made of tubular framing with a formed sheet metal seat pan. The cockpit seats were equipped with lap belts, shoulder harness and inertia reels and are shown in Figures 46 and 47. The seat located in the crew berth area employed a lap belt with a single diagonal shoulder strap secured to a rate of extension type inertia reel mounted at the top of the seat back, see Figures 48 and 49.

The crew seats were designed for track-type floor attachments and were all attached to the aircraft structure in the same manner. Aluminum channel reinforcements, positioned laterally and longitudinally, were installed in both the cockpit and berth area to provide additional strength for the seat attachments. The seats were occupied with 95th percentile, 200 pound, anthropomorphic dummies. Accelerometers and load links were installed to record accelerations in the seats and dummies and forces in the restraint harnesses.

During the crash, the pilot's and co-pilot's seats remained attached to the floor while the third crew seat located in the crew berth area was torn free. The pilot's seat remained secured to the floor track at the forward attachment points. The left aft seat leg was completely torn free of the floor track and the right aft leg remained partially attached as shown in Figure 50. The aft attachments failed by outward bending of the flanges as illustrated in Figure 51. The tubular seat pan frame was broken on the right side at a point near its attachment to the seat back frame, as shown in Figure 52. Figure 53 shows that the sheet metal seat pan was also torn along the back beginning at the tube failure and progressing to the left approximately 11 inches. The right hand diagonal seat pan support strap was broken free from the seat pan. The bolt hole at this attachment failed (hole tearout), allowing the bolt to tear through 3/4 inch of the seat side tubing before the attaching bolt failed. The loss of the vertical support, which had been provided by the diagonal support strap, allowed the seat pan to bend downward and contact the floor. (The floor was also buckled upward at this location.) The forward edge of the seat pan was resting on the floor after the crash. The pilot's lap belt and shoulder harness remained in place and attached, and the shoulder harness inertia reel was locked. The restraint provided kept the pilot dummy well positioned in the seat. The seat back was bent forward 20 to 30 degrees, due to the shoulder harness load, as shown in Figure 54. The bending failure occurred about one-third of the way up from the seat pan at the location of the attachment of the diagonal seat pan support straps.

The pilot dummy's right foot was separated from the leg, and was trapped between the right rudder pedal and the control console. The pilot's helmet, which was still on and in place, evidences severe sliding contact with the upper left cockpit structure. It was scored from front to rear for approximately six inches with a 1/4 inch indention at the rear of the scrape. The energy absorbing liner shows a permanent deformation of 1/16 inch beneath the crown pad. (The acceleration data for all crew seat experiments was obtained by the U. S. Navy, and is not presented in this report.)

The copilot's seat remained attached to the floor track at both forward and the right aft attachments. The left aft seat leg was completely torn free of the floor track as shown in Figure 55, due to bending of the attachment flange. The right aft end of the tubular seat pan frame broke and the right diagonal seat pan support strap pulled out of the seat pan frame in much the same manner as occurred on the pilot's seat (see Figure 56). The copilot's seat pan also deformed downward and the forward edge contacted the floor. The back of the seat bent forward approximately 45 degrees at the attachment of the diagonal seat pan support straps, as did the pilot's seat (see Figure 57).

The copilot dummy remained well positioned with respect to the seat, but rotated forward as shown in Figure 58, enough to contact the instrument panel with the helmet visor and perhaps the dummy's forehead. The helmet was still in place, although the visor was broken, and the top of the helmet was severely indented due to contact with the upper cockpit structure. The energy absorbing liner shows 1/16 inch permanent deformation around the crown pad and one localized deep dent forward of the crown pad. The copilot's right leg was caught between the right rudder pedal and the right cabin structure. Both of the copilot dummy's legs were extended straight forward past the rudder pedals.

The third crew seat was torn free of the floor tracks due to failure of the attachment grips as illustrated in Figure 51. This allowed the seat and its occupant to travel forward and to the left until they contacted the bulkhead at fuselage station 260. The seat and dummy came to rest blocking the cockpit door as shown in Figure 59. The dummy was well restrained in the seat by the diagonal shoulder harness and lap belt throughout the crash. The back of the seat was bent forward, approximately 5 degrees. The complete failure of the attachment of this seat to the floor was attributed in part to a high localized load caused by the nose gear structure which was embedded under the fuselage just beneath the seat. Figures 60 and 61 show the seat tracks and the track grips.

Forward Cabin Seat and Child Restraint Experiments

Three two-place Constellation Model 1649 passenger seats were installed for this experiment, and were mounted to floor tracks with the forward leg attachments located at fuselage stations 385, 417, and 449 which provided a 32 inch seat spacing.

Seat locations are shown in Figure 17 and a view of the occupied seats is shown in Figure 62. Tubular framework was employed in the construction of these seats. The center seat was occupied by two 95th percentile anthropomorphic dummies (Figures 62 and 63), restrained with lap belts only. The forward seat carried no occupants but was left in place in order to provide a realistic environment ahead of the dummies in the center seat. The aft seat next to the wall was occupied by a 95th percentile dummy restrained by a lap belt and a single diagonal shoulder strap harness incorporating an energy absorbing reel as shown in Figure 64.

A child restraint device was installed in the aft aisle seat, as shown in Figures 62 and 65. The restraint encircled the subject's body at the waist and chest level. Shoulder straps joined the chest level encircling strap in the front and rear. The body harness incorporated two gathering straps in the rear which merged into a single strap that passed between the seat back and seat pan to a floor attachment.

Accelerometers and load links were installed to record the center seat longitudinal and vertical acceleration, the inboard dummy pelvic acceleration in the longitudinal and vertical directions, and the inboard dummy lap belt forces.

The forward and center seats remained in place during the crash, but the aft seat came loose from the floor-tracks and rotated backwards. The forward seat was deformed toward the aisle due to loads applied by the fuselage side wall which was deformed inwardly just aft of the fuselage break. Figure 66 shows the deformation and seat positions.

The center seat experienced no lateral deterioration. Vertical loading caused slight downward bending of both front and aft lateral seat frame tubes. Figures 67 and 68 show the seat and occupants. The armrest supports failed allowing the armrest to rotate toward the aisle approximately 30 degrees. Both lap belts remained intact and fastened. The dummy seated next to the wall was still in place with feet and legs approximately in the normal riding position. The dummy was bent forward so that his chest was resting against his thighs and his head had contacted the seat back of the forward outboard seat. The dummy seated next to the aisle remained in the seat, bent forward, with head out in the aisle. Both legs of this dummy were extended under the forward seat, up to the knee for the left leg and halfway to the knee for the right leg. Examination of the forward inboard seat back indicates that contact between the inboard dummy and the seat back was very slight.

The dummy seated in the aisle side was subjected to 10 to 15G's vertical during impact with both the 6-degree slope and the 20-degree slope. This vertical loading accounted for the downward bending of the lateral seat frame tubes mentioned above. Lap belt loads were approximately 700 pounds (one side) maximum during these impacts. The accelerometer and load link data for this experiment are shown in Appendix 6.

The aft seat shown in Figure 69 was released from the floor track due to the locks not being in place on either side of the seat. The seat stayed in its original location but rotated 90 degrees aft and came to rest lying on its back. Both occupants, the dummy and the child doll, remained well positioned and in place in the seats and the restraint systems were undamaged. The child restraint harness still supplied restraint but the diagonal shoulder harness and lap belt restraint on the outboard dummy was ineffective in this position because of slack in the shoulder strap. Longitudinal and vertical accelerations were recorded from the pelvic region of the 95th percentile dummy passenger of this seat. These accelerations are shown in Appendix II.

Cargo Restraint Experiment

Two specially designed, identical rigid steel cargo pallets were fabricated for this experiment. The pallets weighed approximately 1040 pounds each and were installed in a staggered manner as shown in Figures 17, 70, and 71. The pallets were longer than the cargo load, as shown in Figure 72, to provide support for the cargo in the event it shifted forward during the crash. The floor structure in the area of the cargo experiment was modified in such a way as to provide additional strength for the cargo pallet installation. As illustrated in Figure 73, three six-inch parallel steel channel assemblies were bolted on top of the existing aircraft transverse beams so that the channels extended about 6 inches through both sides of the fuselage. Figure 74 shows additional 6-inch steel channels installed parallel to the fuselage exterior and bolted to the protrusions of the transverse channels. Doubler plates were installed between the fuselage skin and the exterior longitudinal channels to help distribute the cargo restraint loads. Figures 70 and 73 show the pallets installed atop the transverse steel beams. The cargo pallets were connected to the reinforcing structure through load transducers, as shown in Figures 71 and 73.

A simulated crushable cargo was secured to the pallet on the left side of the aircraft. The cargo consisted of 2000 pounds of a sand-sawdust mixture placed in 14-inch cube, styrofoam shipping containers. These containers were then packed in corrugated boxes of different lengths, all multiples of 14 inches, and stacked on the cargo pallet in an interlocking manner. The cargo stack, which was 42 inches wide, 56 inches high and 84 inches long, was trimmed where necessary to maintain a minimum clearance of 5 inches between the cargo and the wall structure of the aircraft. A simulated rigid cargo was secured on the pallet to the right. The cargo consisted of a 2000 pound stack of 2 x 4 lumber nailed together as shown in Figure 75. The cargo was 42 inches wide, 56 inches high, and 84 inches long and was adjusted to provide a 5-inch wall clearance. The center of gravity of the cargo was 50 percent by width and length and 43 percent by height (26 inches above the plane of attachment of load transducers). Both cargo stacks were restrained with identical nylon strap nets attached to the pallets at 16 tie-in points, and each load carrying strap was capable of carrying 6000 pounds. The cargo stacks were covered with tarpaulins and the nets were secured over them. Figure 72 shows an end view of the net on the rigid cargo.

Following the test the fuselage section containing the cargo experiment was generally intact even though floor accelerations of approximately 20G's vertical, 10 - 20G's longitudinal, and 5 - 10G's lateral were experienced. Figure 76 shows the external fuselage area surrounding the experiments.

During the crash, neither pallet nor cargo separated from its original tiedown, however, both of the longitudinal restraint installations of the cargo pallets deformed approximately 2 inches forward as shown in Figure 77. The flexible nets survived the crash with no load ring deformation, and no failures occurred in either of the cargo tiedown systems. The rigid cargo stack slid forward on the pallet approximately 4 inches while the crushable cargo remained in place and parallelogrammed forward ten inches. An illustration of the cargo action is shown in Figure 78.

The peak loads for the crushable cargo were generally higher than those for the rigid cargo. From the curves shown in Appendix 6, it can be observed that the crushable cargo load peaks were near 20,000 pounds, longitudinal; 12,000 vertical, and 5,000 pounds lateral as compared to the rigid cargo loads which experienced 8,000 to 10,000 pounds longitudinal; 10,000 pounds vertical, and 10,000 pounds lateral during the same general time sequence.*

* These loads are approximate maximum values obtained from individual load cells. Reference the data traces of Appendix 6 for total loads and time histories.

Mid-Cabin Seat Experiments

Two triple seats were installed on the right side of the aircraft over the center wing section. These seats are shown in Figure 17 as seats 6 and 8. The seats were of a standard type presently being used on a number of commercial jet aircraft. The seat pans and seat backs were made of perforated aluminum sheeting with the seat pan formed to conform to a human buttock. Rearward folding food trays designed to absorb energy through the use of plastic enclosed energy absorption material were attached to the seat backs on the forward row of seats only.

The two seats were installed with the front legs attached at fuselage stations 645 and 679 providing a 34-inch seat spacing. The floor was reinforced to provide a solid mounting platform for the seats. Aluminum channels, extending laterally, were installed beneath the floor attached to primary aircraft structure and longitudinal channels were secured to them above the floor. Short lengths of seat track were bolted to the longitudinal channels and the front legs were mounted in the tracks to allow fore and aft motion. The rear leg attachments were firmly attached to the longitudinal channels. Three 50th percentile (170 pounds) anthropomorphic dummies occupied the aft seat, restrained by lap belts. One dummy is visible in the side view shown in Figure 79. The forward seat was used only to provide a realistic environment and carried no passengers. Accelerometers and load links were installed to record the vertical and longitudinal accelerations of the aft seat and the pelvic region of the center dummy, the lap belt loads of the center dummy, and the vertical leg loads of all four legs of the aft seat and the aft two legs of the forward seat.

The forward facing triple seats survived the crash with little noticeable deformation, major failures and no movement of the front seat legs in the floor track.

The inboard seat back of the unoccupied triple seat remained in its original upright position. The other two seat backs were broken over as shown in Figures 80 and 81. None of the plastic food trays attached to the back of the seat showed any damage. A maximum vertical seat leg force of approximately 1000 pounds tension was measured for this seat, as shown in Appendix 6.

All three 170 pound dummies remained in the aft seat, restrained by the lap belts as shown in Figures 80 and 81. The dummy next to the wall bent forward and contacted the seat back ahead of him, slightly buckling the perforated sheet metal. The center dummy was found leaning forward with the top of his head approximately two inches away from the forward center seat back. Damage to seat backs ahead of the dummies indicated that the wall dummy and the center dummy were the only ones that struck the unoccupied seat. The data obtained from this seat, indicates that the maximum seat acceleration was on the order of 10G's for .1 to .2 seconds in both the longitudinal and vertical directions with very little magnification of these accelerations in the pelvic region of the center dummy. The maximum lap belt load was approximately 1000 pounds (one side) applied for 0.10 second. The maximum seat leg loads were approximately 4000 to 5000 pounds compression in each of the forward legs and 1500 to 2000 pounds tension in each of the aft legs.

Rear Facing Seat Experiments

Two U. S. Air Force rear facing military passenger seats, one two-place prototype seat and one three-place production seat, were installed on the left side of the fuselage in the center wing section, as shown in Figures 17 and 82. The forward seat legs (forward with reference to aircraft direction) were located just forward of the aft wing spar at fuselage stations 740 and 778, with the three place seat installed in the most forward position. The floor structure beneath these two seats was reinforced by securing lateral aluminum channels to the airplane floor structure, beneath the floor, and bolting longitudinal channels above the floor to the underfloor structure. The seat legs were bolted to the floor through the floor channel, the floor structure, and the subfloor channels, except for the rear legs of the three place seat which were inserted in lengths of seat track.

Accelerometers and load links were installed to record seat accelerations in the longitudinal and vertical directions, dummy pelvic accelerations in the longitudinal and vertical directions, lap belt loads, and vertical seat leg loads, for the three place seat. Accelerometers were also installed to measure longitudinal accelerations of the two place seat and of the inboard dummy's head and pelvic region. The data measured on the two place seat was recorded on the redundant instrumentation system and is not presented in this report.

Both the double and the triple rear facing seats withstood the crash with no visible deformation of the seat or failure of any floor attachments. All five 200 pound dummies remained in their seats and in position. Figures 83 and 84 show the postcrash position of the dummies and condition of the seats.

Maximum accelerations of 10G, longitudinal, and 10G, vertical, were measured in the pelvis of the middle dummy of the triple seat. The lap belt load was negligible. The seat leg loads developed in the three passenger seat were in the order of 7000 pounds tension in the aft legs and 4000 to 6000 pounds compression in both forward seat legs.

Litter Experiments

Two litters were installed in the aft main cabin by the U. S. Naval Air Development Center personnel, who developed the suspension of restraint systems for the test. The litter experiment occupied the area between fuselage stations 777 and 930 on the right side of the aircraft as shown in Figure 85. The litters were attached to the main cabin floor and fuselage wall structure. The lower litter of this two-litter stack was installed with energy absorbing devices which were designed to allow longitudinal movement of the entire litter once a pre-determined load was attained, see Figure 86. The litters were occupied by two 95th percentile anthropomorphic dummies which were instrumented in the pelvic region to provide vertical and longitudinal acceleration information. The litter suspension system and dummy occupants are shown in Figure 87.

The two litters and all structural attachments remained intact without noticeable permanent deformation. Both dummies remained in place, well restrained throughout the crash. The lower litter moved forward 1/4 inch along an energy absorbing strap, and both dummies moved forward in the litters enough to cause 1/4 inch deep heel marks in the styrofoam blocks placed at the forward end of each litter. (Reference Figure 88). Both litter dummies experienced acceleration levels of approximately 10G's in the longitudinal direction of .10 to .15 seconds duration during both the 6- and 20-degree slope impacts.

Galley Experiment

The galley section was loaded with 440 pounds of simulated equipment placed in twenty of twenty-four food tray containers. Six empty beverage containers were left in place. No changes were made in the galley structure or in the methods of securing equipment in the galley for this test. The location of the installation is shown in Figure 17.

The galley was not severely disarranged by the crash. All of the food tray containers and their contents remained in place. The beverage cabinet remained intact, but the beverage containers were thrown from the galley six to twelve feet forward into the main cabin. All other galley equipment, such as waste containers, refrigerators, and partitions remained in place. The attendant's folding seat opened during the crash, partially blocking the path through the galley door. Views of the galley and attendant's seat are shown in Figures 89 and 90.

Side Facing Seat Experiment

The flight engineer's seat was removed from the cockpit and installed in the aft fuselage on the right side as a side-facing seat and is shown as Seat 10 in Figure 17. The installation placed the forward edge of the seat pan 24 inches to the rear of the aft galley wall with the forward edge of the seat foundation at fuselage station 1032. A view of the seat is shown in Figure 91. A lap belt, provided the only restraint for the 95th percentile dummy occupant and incorporated load links on each end to record the belt loads. Figure 92 shows the dummy in the seat. The floor beneath the seat was reinforced with aluminum channels and seat tracks were installed by bolting through the tracks, the floor and the reinforcement channels.

The side facing seat remained attached to the aircraft floor and sustained no gross structural failure. The lap belt remained attached, but this minimal restraint allowed the dummy's head and shoulders to move forward (laterally) so that the dummy's head struck the galley partition, 24 inches forward of the seat as shown in Figure 93. The dummy moved forward (with respect to the aircraft) on the seat 6 inches, remaining only partially on the seat pan. The right leg of the dummy swung around toward the dummy's right (forward in the airplane) about 35 degrees. Vertical loading caused slight downward bending of the forward edge of the tubular seat pan frame as shown in Figure 94. This was the only permanent deformation of the structure of this seat. The lap belt load, developed in the side facing seat reached a maximum of approximately 1200 pounds (one side). This is consistent with the lap belt loads developed in forward facing seats.

Aft Cabin Seat Experiment

The location of this experiment was in the aft cabin and is shown as seats 11 and 13 in Figure 17. Two standard first class two-place Constellation model 1649 seats were installed for this experiment. The seats were mounted to the existing floor track on 36 inch spacing with forward leg attachments at fuselage stations 1066 and 1102. The rear seat of the experiment was occupied by two 95th percentile anthropomorphic dummies restrained by lap belts only, see Figure 95. Accelerometers and load links were installed to record seat accelerations in the vertical and longitudinal directions, pelvic accelerations in the vertical and longitudinal directions of the dummy next to the aisle, and lap belt loads on the dummy next to the wall.

The postcrash position of both dummies occupying the rear seat of this experiment is shown in Figure 96. The dummy in the aisle seat was resting with its face and upper shoulders against the forward seat back. The dummy slid forward in the seat approximately 11 inches and both legs were jammed under the forward seat with the right leg on the aisle side of the seat leg (see Figures 96 and 97). This forward movement was allowed by failure of the AN 1032 bolt used to attach the left end of the lap belt to the seat. The dummy next to the wall was found with its face against the lower forward seat back and both legs jammed under the forward seat up to the knees. The lap belt on this dummy was still attached. Figure 97 shows the dummies in contact with the forward seat along the right hand side of each respective forward seat back, indicating a left lateral load. Both seats remained attached to the floor. The accelerations of the aft passenger seat, along with the dummy pelvic accelerations and the lap belt load, were consistent with those of the other experiments aboard the aircraft. The acceleration levels were on the order of 10G's. The lap belt loads are not considered valid because of the failure of the lap belt attachment during the test, at an unknown time. Both of the seat pan tubular frames on the rear seats broke where the longitudinal members join the lateral support tubing. The forward edges of both seat bottoms deflected downward to within one to two inches from the floor, and the forward edge of the aisle seat contacted the floor. The left hand wall side showed no lateral deformation.

Stewardess Seat Experiment

The standard folding stewardess seat provided in the Constellation at fuselage station 1178.5, right side, was occupied by a 130 pound anthropomorphic dummy. The standard lap belt and dual shoulder harness with which the seat was fitted were used to restrain the dummy. The seat was installed with forward legs at fuselage station 1164 and rear legs at fuselage station 1179. The experiment surroundings, the seat itself, and the dummy are shown in Figures 98, 99, and 100.

The shoulder harness and lap belt, remained intact and attached to the installation points, however, this did not prevent the occupant from submarining. The dummy submarined until the lap belt was around its chest, up to the armpit on the left side and halfway up the rib cage on the right. The legs were sprawled outward and forward, and the dummy's head was impaled on the upper right corner of the seat back. (See Figure 101). The rubber skin of the dummy's head was torn extensively, and the skin separated completely from around the neck. The attachment of the seat back to the center partition failed, and the bar that acted as a brace for the aft part of the seat was found to be forward of the center lavatory partition to which it normally attaches. The right front seat leg was buckled inward at the floor approximately three inches from its normal position as shown in Figure 102.

Baby Restraint Experiments

Children's dolls were placed in two airline type bassinets and were restrained by cross-over straps and cord as shown in Figure 103, and by a nylon net secured around the bassinet as shown in Figure 104. One of the bassinets was placed in the wall mounts provided between fuselage stations 1150 and 1179 as shown in Figure 104, and the other was placed on the floor directly below the wall mounted bassinet as shown in Figure 103. The wall mounted baby bassinet remained attached to the aircraft and the bassinet cover remained in place as shown in Figure 105. The doll was found lying on its right side against the aft side of the bassinet. The bassinet that was placed on the floor was found in its original location, but it had turned completely over. No external damage was evident.

Flight Recorder Experiments

Two flight data recorders were installed in the tail of the airplane, aft of the pressure bulkhead, by Lockheed Air Services for the U. S. Air Force. One of the recorders was permanently attached to the structure, and the other was to be ejected. The ejected recorder package also contained a crash locator beacon. The explosive actuator was initiated by a G-sensitive switch set to operate at 4G's longitudinal acceleration.

The ejectable flight recorder mounted in the tail cone ejected as the aircraft initially impacted with the ground, but the ejection velocity did not produce sufficient lateral travel. The ejected package impacted in the right wing wreckage and the spilled liquid from the ruptured fuel tanks. The emergency radio beacon that was a part of this package did not transmit any signal after the crash. The second flight data recorder package of the same design remained in place in the tail section and was undamaged.

Crash Locator Beacon Experiment

The U. S. Navy Test Center developed and installed a ballistic crash locator beacon ejection device in the cockpit of the aircraft. It was attached to the skin just above the crew entrance door forward of fuselage station 260. The outer surface of the device was flush with the aircraft skin in a position which aimed the ejection component about 45 degrees above the floor plane from the right side of the airplane. An inertial switch set to actuate at 15G's longitudinal acceleration was provided to initiate the ejection. The package to be ejected was a five pound dummy load which contained no locator beacon or other electronic devices.

The ejectable crash locator beacon installed in the cockpit ejected when the aircraft impacted the 20-degree slope. The dummy beacon, weighing 5 pounds, was ejected with such velocity that it was found 650 feet ahead and 250 feet to the right of the wreckage. The structure of the ejection device did not withstand the high pressure developed by the explosive charge, and the lower end of the unit was blown out, striking a camera light mount, as shown in Figure 106.

Emergency Lighting Experiment

Several different types of emergency lighting systems were installed aboard the aircraft. The systems varied from interior lighting to emergency exit markers.

One system consisted of strobe lights, which were activated by a G sensitive switch, and served to mark emergency exits. One unit was installed in each of the forward over-wing emergency exit windows between the panes of glass, to be visible from both inside and outside the airplane. Figure 107 is a view of one installation. Another emergency exit concept consisted of impact activated electroluminescent stripping that could be installed around either escape windows or hatches. This concept was developed at the U. S. Naval Air Test Center (NATC) and was installed around a window in the aft section of the fuselage as shown in Figure 108. NATC also installed a Soderberg interior emergency light on the partition between the two lavatories at the rear of the airplane and a Grimes interior emergency light in the cockpit on the fuselage station 260 bulkhead. These lights were designed to be activated automatically, the Soderberg light by a G sensitive switch and the Grimes light by the loss of aircraft electrical power. All the emergency lights were self contained and battery powered.

The flashing Strobe lights that were installed in the overwing emergency exit windows were energized by impact and the flashing lights were visible through the dust and smoke conditions existing when the aircraft came to rest and after approximately two inches of water foam solution was sprayed over the left wing exit. The light units were not damaged during the crash and continued to function until they were turned off by test personnel.

All of the NATC installed lights survived the crash without structural failure. The electroluminescent and the Soderberg lights were activated on aircraft impact and functioned until they were manually turned off. The Grimes light, however, did not operate because of an internal electronic malfunction.

Shipping Container Experiment

Several radioactive material shipping containers were placed in the lower aft cargo compartment by personnel from the FAA's Civil Aeromedical Research Institute (CARI). Figure 109 shows the cargo installed prior to the crash.

A post crash view of the radioactive materials shipping containers is presented in Figure 110. Even though the cargo compartment volume was reduced by approximately 50 percent, the actual damage occurring to the cargo appeared to be small. CARI personnel removed the containers for further evaluation.

CONCLUSIONS

It is concluded that:

1. The method of testing employed in this experiment produced a realistic crash environment. Consequently, the data presented from the individual experiments are valid.

2. In crashes of aircraft with fuel tanks and structure similar to the Constellation 1649A aircraft, the fuel spillage and spray patterns which result from fuel tank damage will be similar to that obtained in this test, and will, to a large extent, surround the aircraft, both while it is in motion and after it comes to rest.

3. The ignition potential of reciprocating engines is such that any release of either fuel or oil during a crash to the extent experienced in this test may be expected to result in an immediate fire.

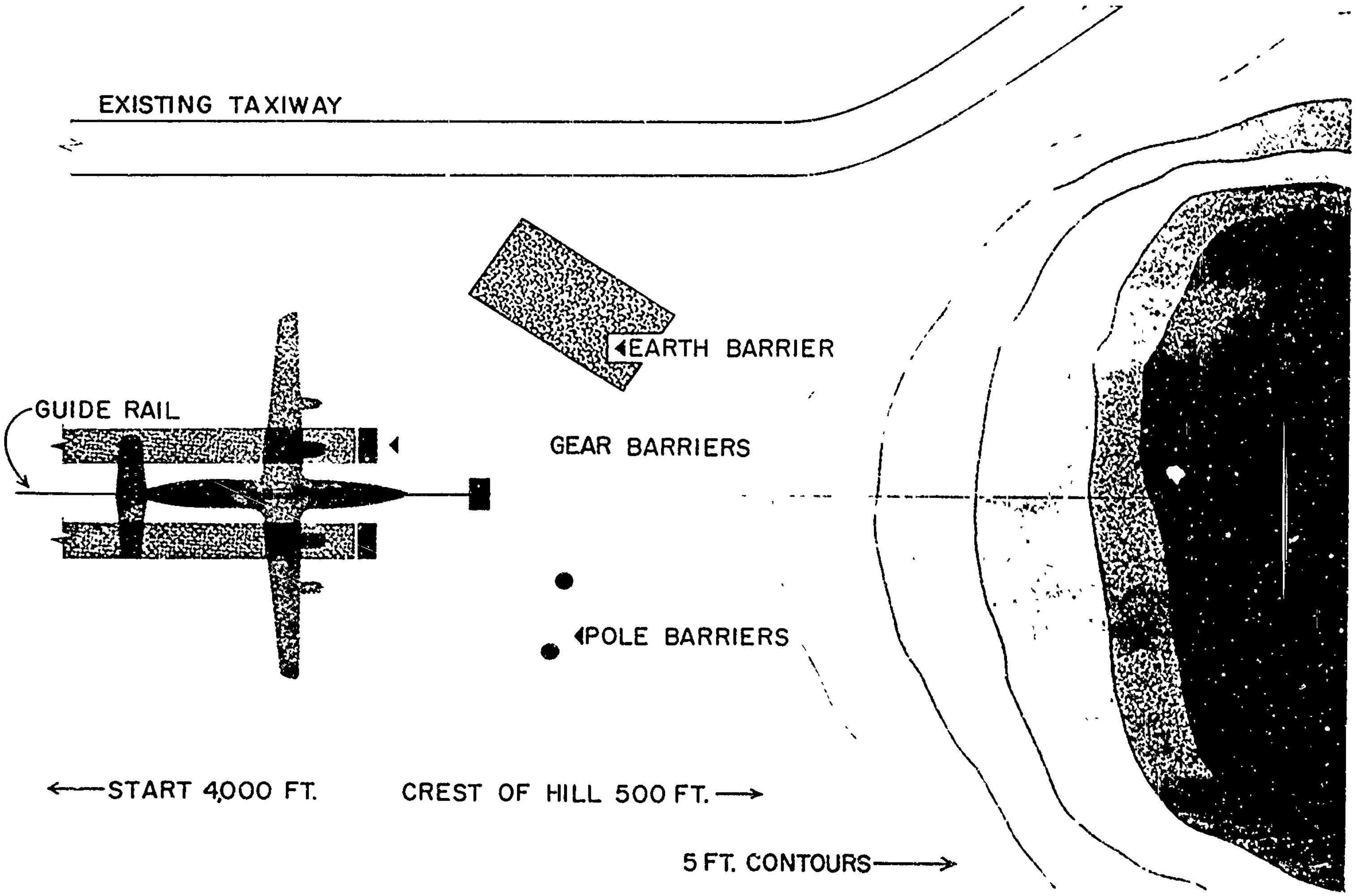


FIG. 1 PLAN VIEW OF TEST SITE

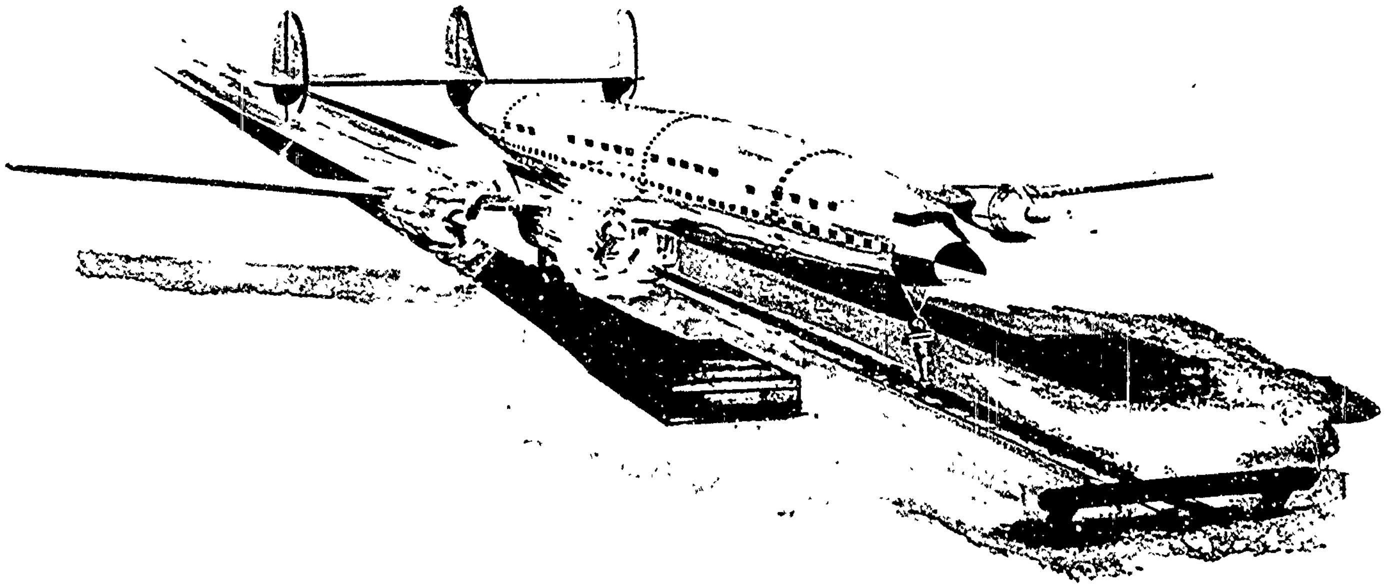


FIG. 2 TEST AIRCRAFT APPROACHING GEAR BARRIERS

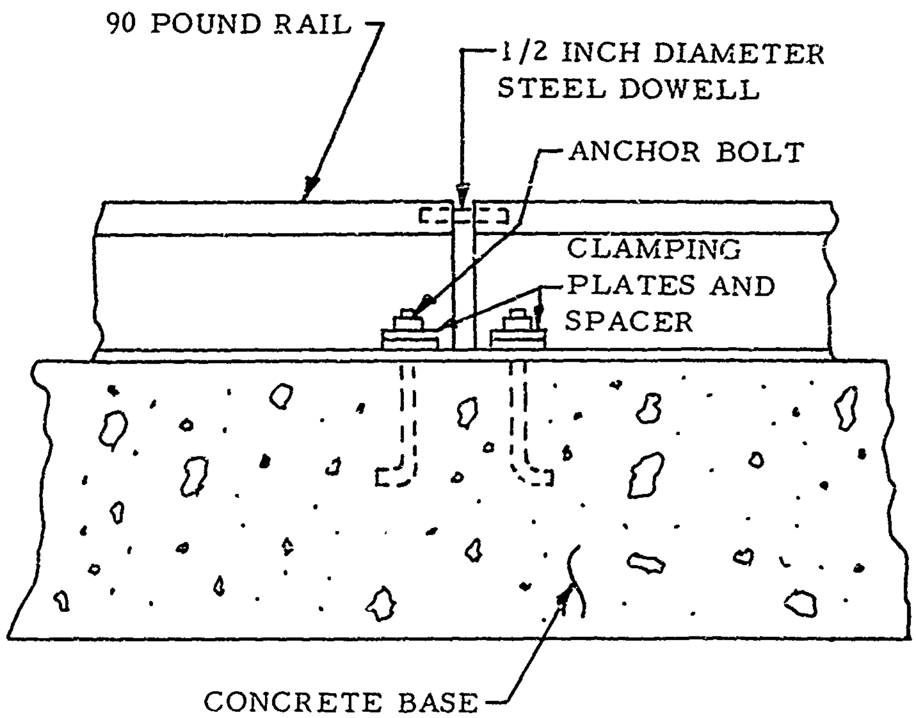


FIG. 3 TYPICAL RAIL JOINT TIEDOWN

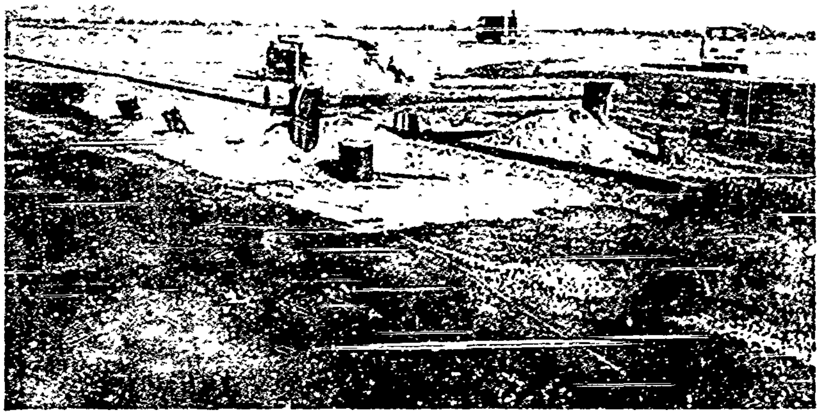


FIG. 4 VIEW SHOWING NOSE GEAR GUIDE RAIL APPROACH TO GEAR BARRIERS

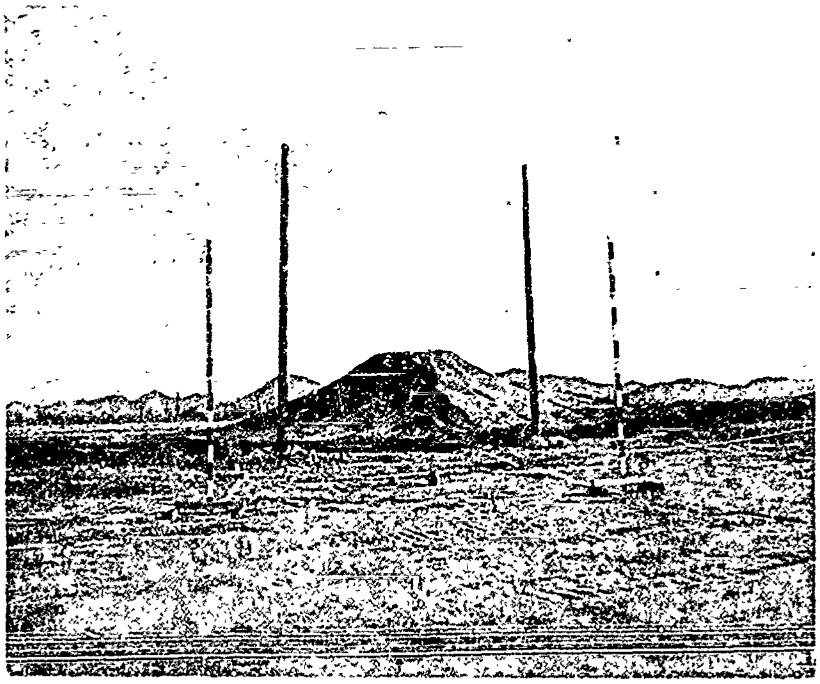


FIG. 5 WING IMPACT BARRIER POLES AND EARTH MOUND

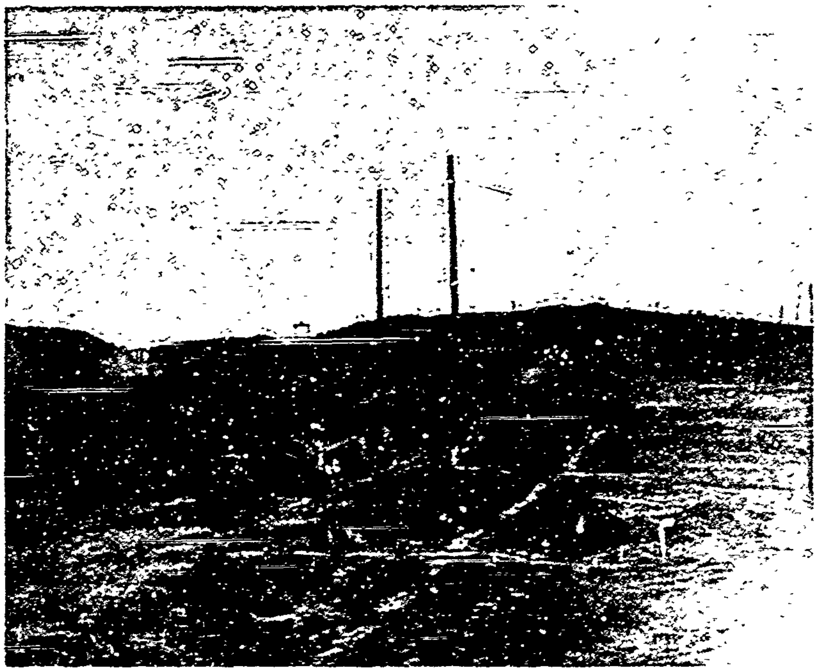


FIG. 6 MAIN IMPACT SLOPES, 6 DEGREE SLOPE JUST BEYOND POLES AND 20 DEGREE SLOPE IN BACKGROUND

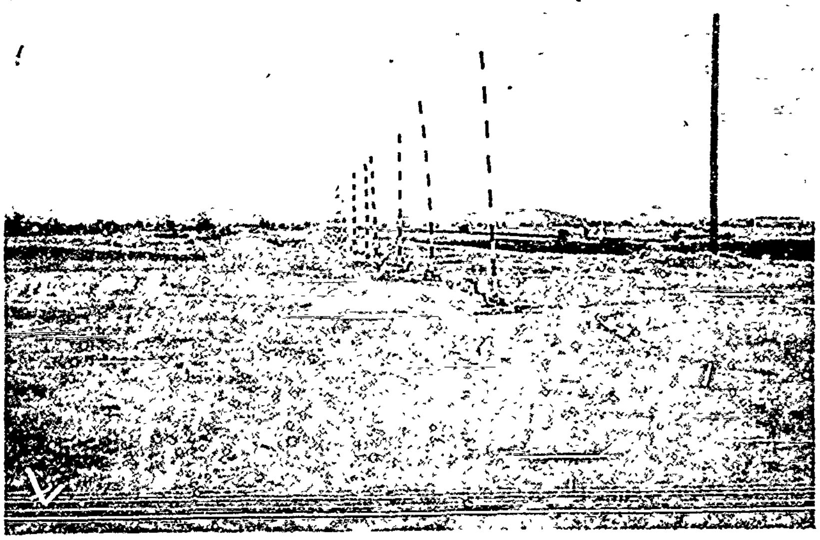


FIG. 7 GRID LINES AND RANGE POLES USED FOR PHOTOGRAPHIC REFERENCE

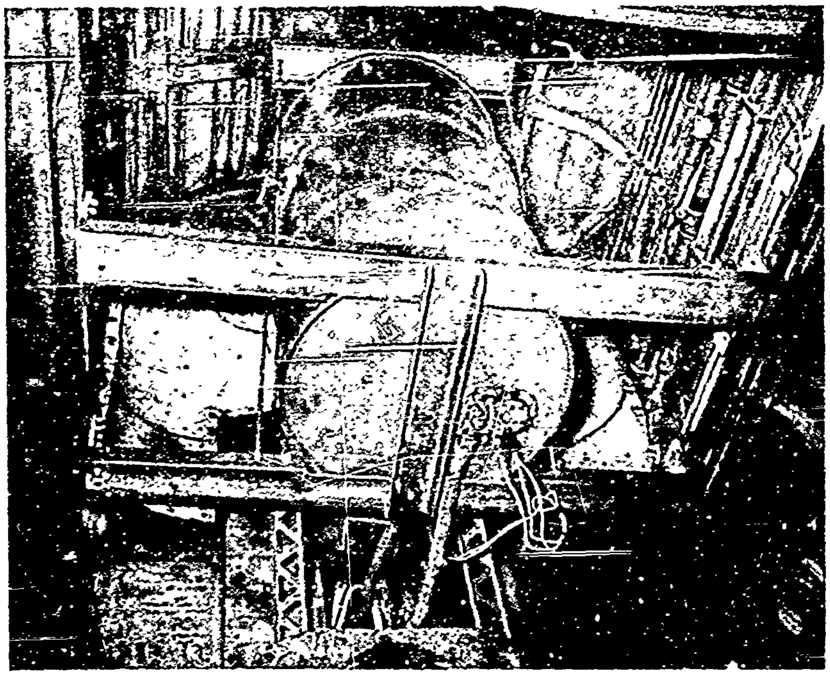


FIG. 8 GROUND VIEW OF REMOTE FUEL TANK INSTALLATION IN LEFT MAIN GEAR WHEEL WELL

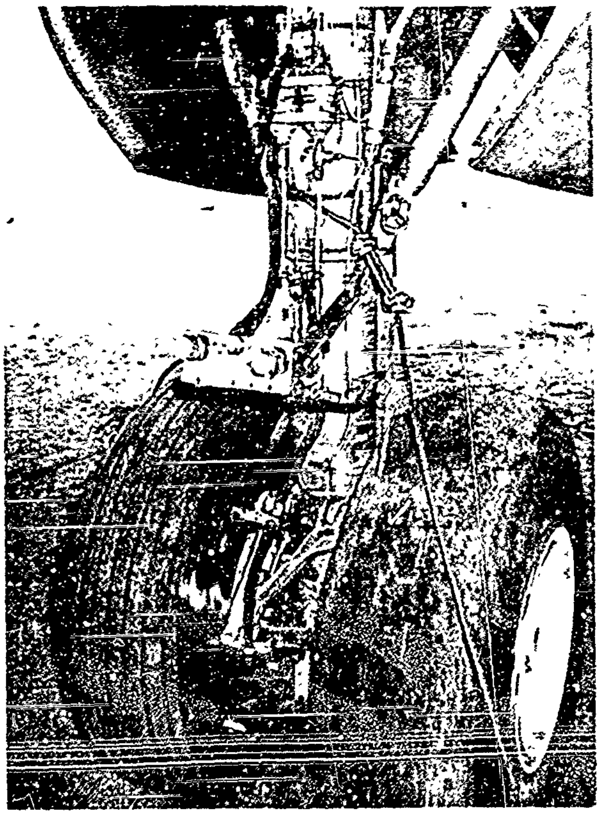


FIG. 9 QUICK DISCONNECT APPARATUS FOR CONNECTING AUXILIARY FUEL SYSTEM AND GROUND SUPPLY TANK

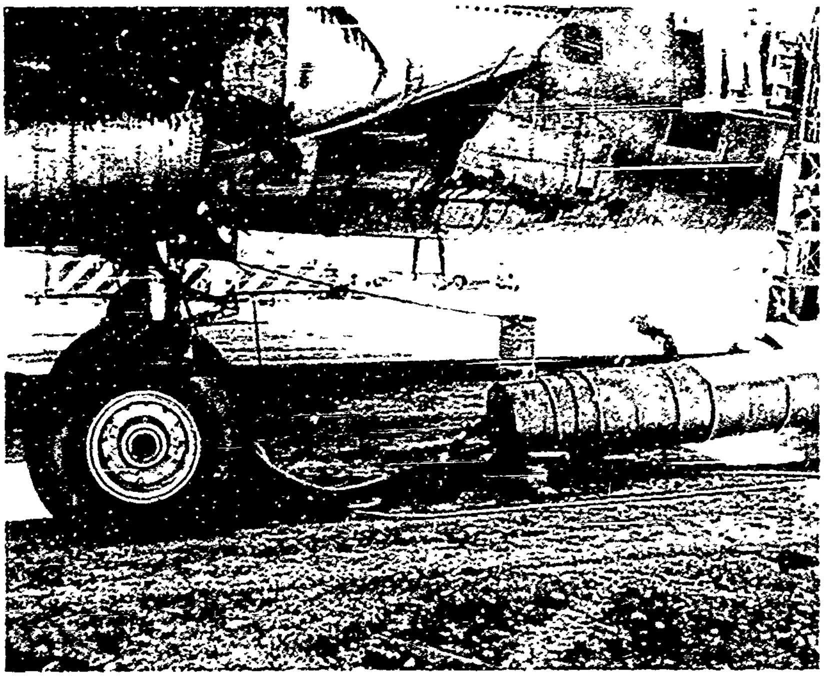


FIG. 10 GROUND FUEL SUPPLY TANK HOOK-UP TO AIRCRAFT

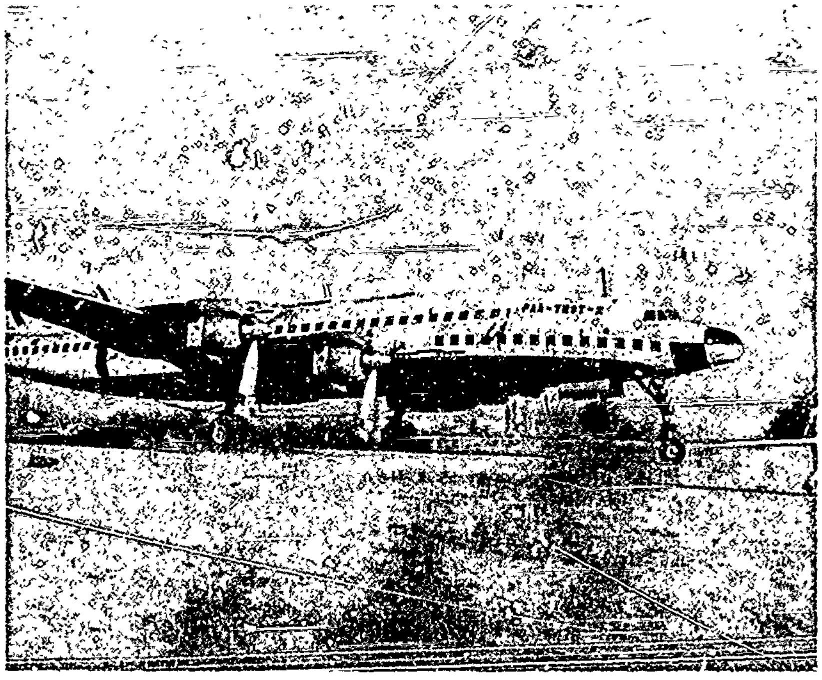


FIG. 11 EXTERIOR MARKING OF TEST VEHICLE

FIG. 12 AIRCRAFT RESTRAINT AND RELEASE MECHANISM

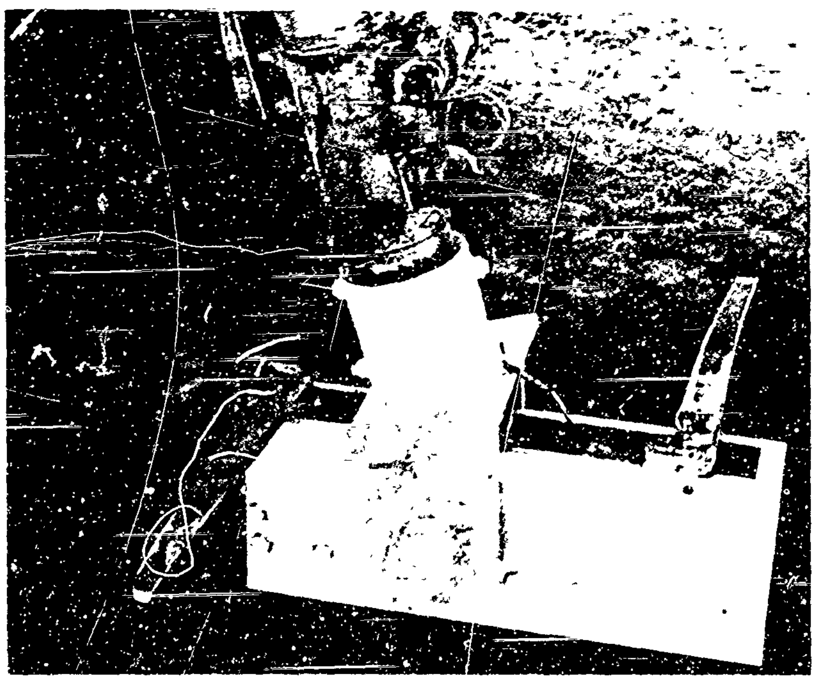


FIG. 13 RAIL GUIDE SHOE

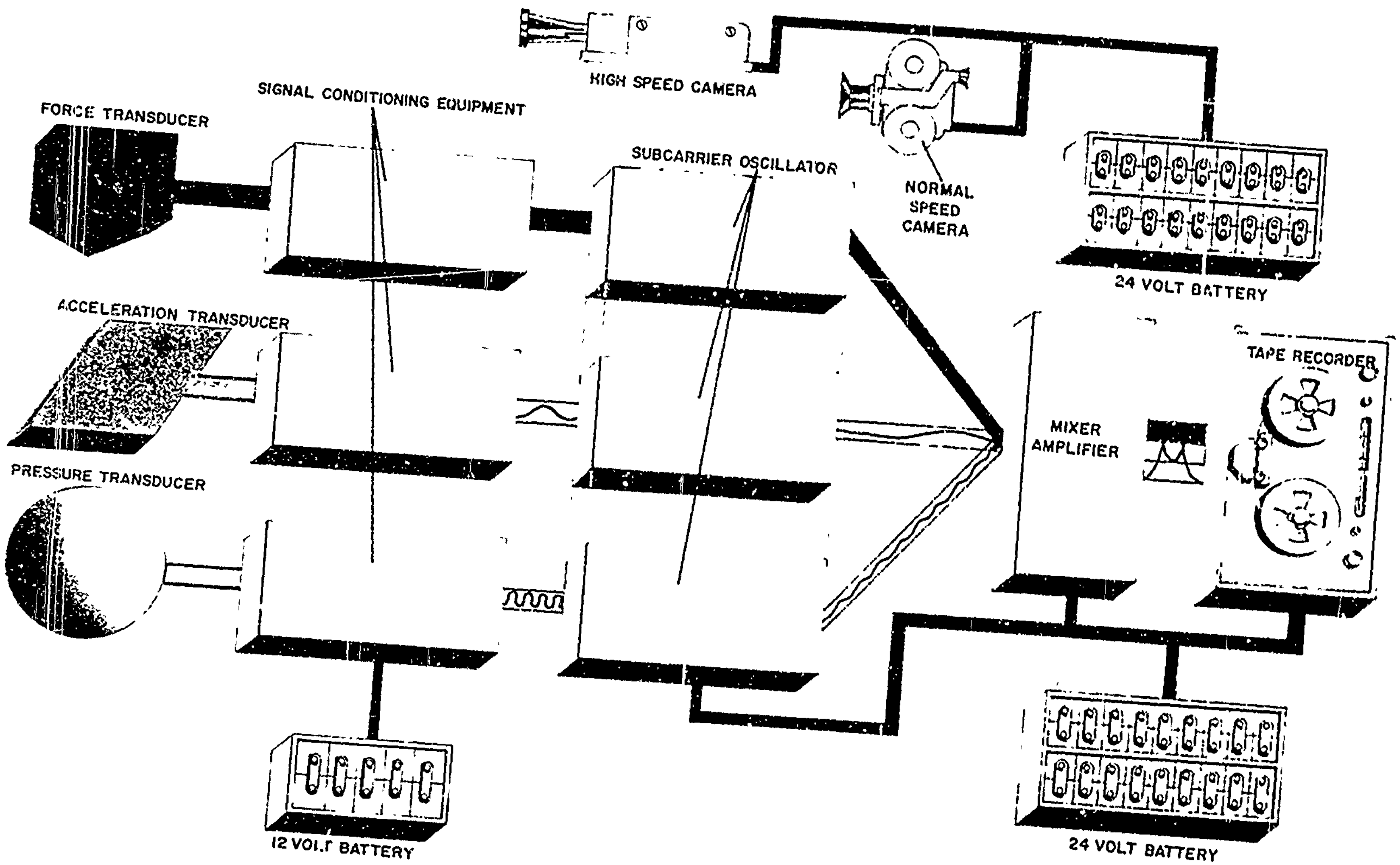


FIG. 14 ONBOARD INSTRUMENTATION SYSTEM

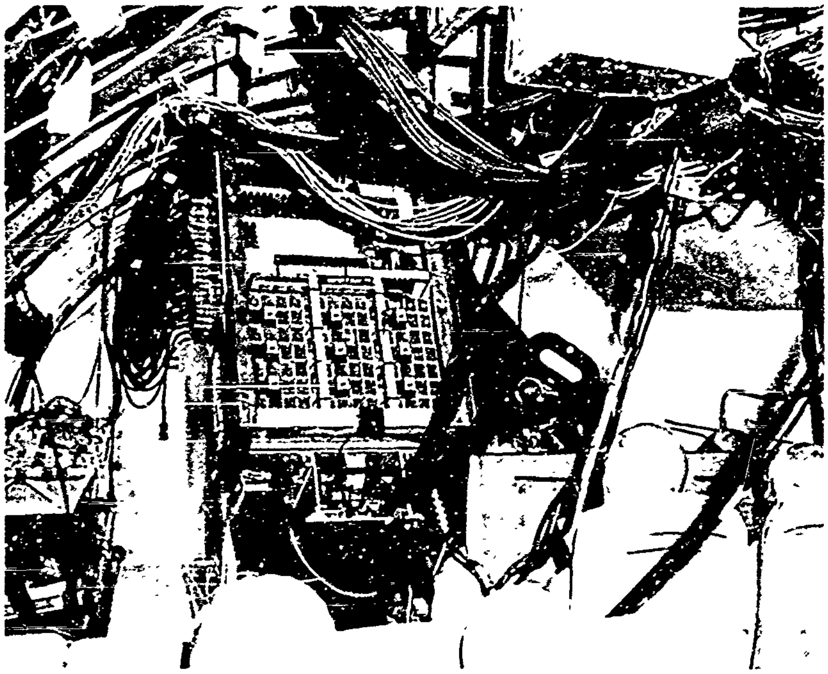


FIG. 15 VIEW OF INSTRUMENTATION PACKAGE DURING INSTALLATION WITH ACEL TELEMETRY SYSTEM ATTACHED TO LOWERED END

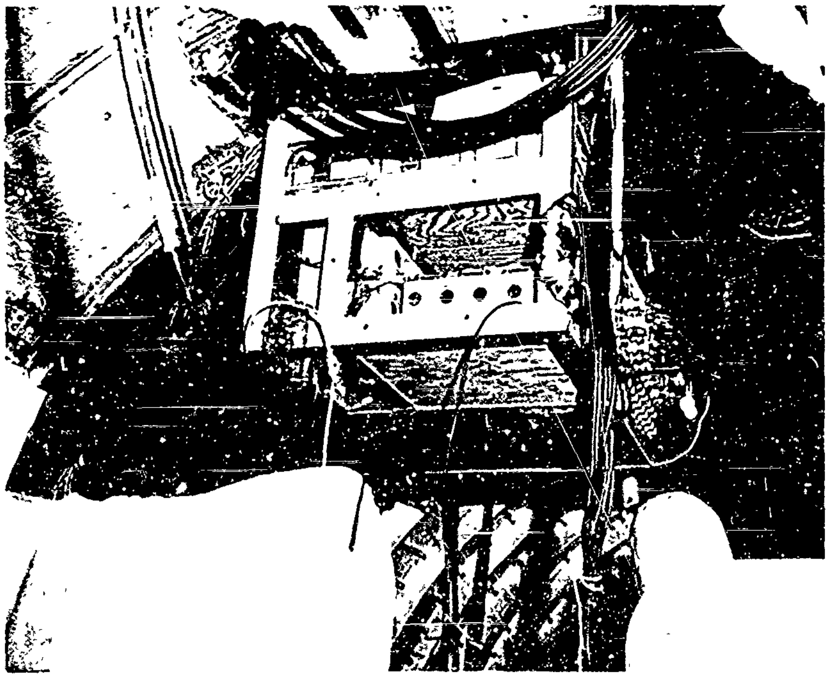


FIG. 16 INSTALLED POSITION OF INSTRUMENTATION PACKAGE WITH ACEL TELEMETRY SYSTEM REMOVED

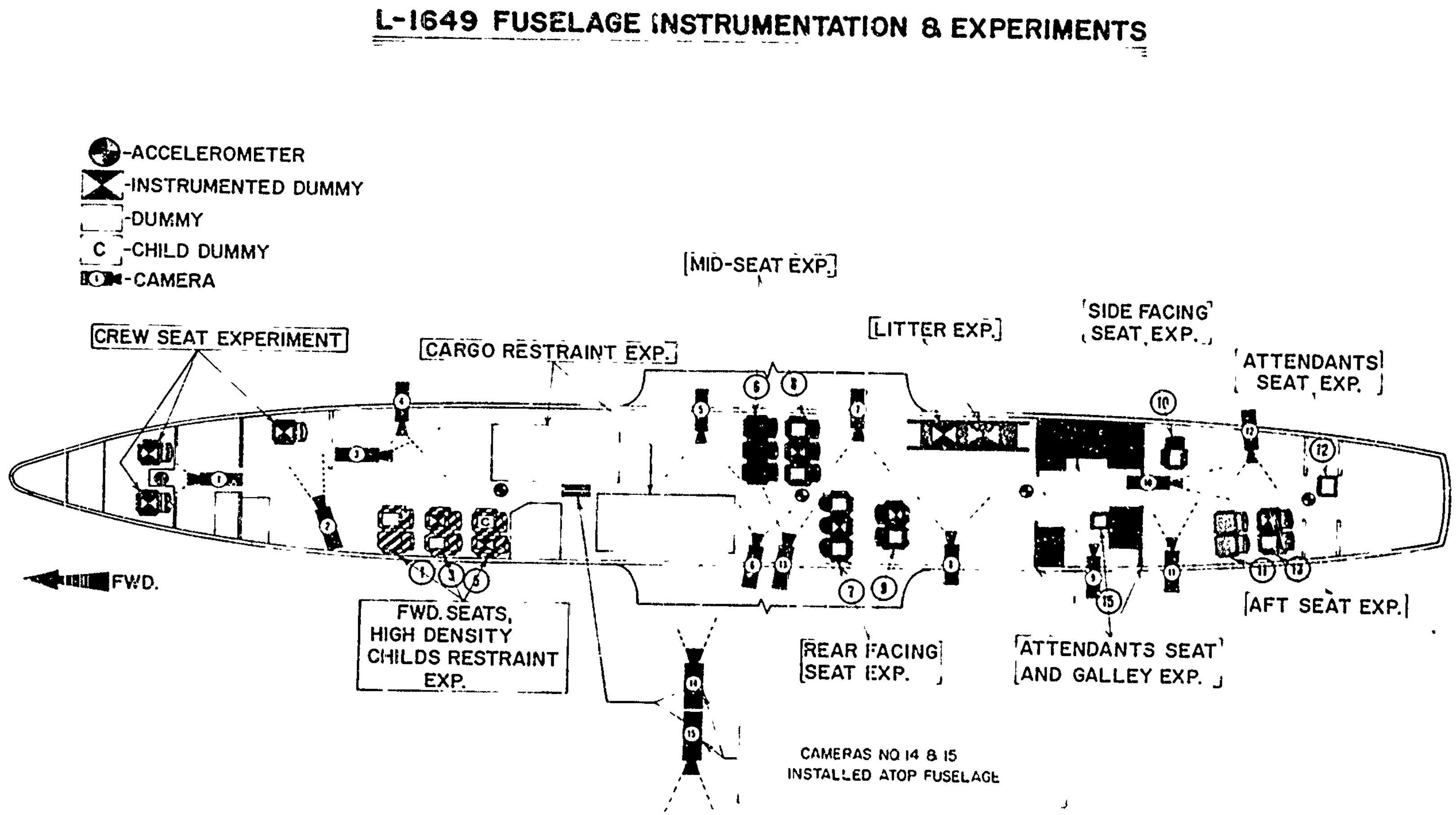


FIG. 17 ONBOARD EXPERIMENTS, CAMERAS AND FUSELAGE ACCELEROMETER LOCATIONS

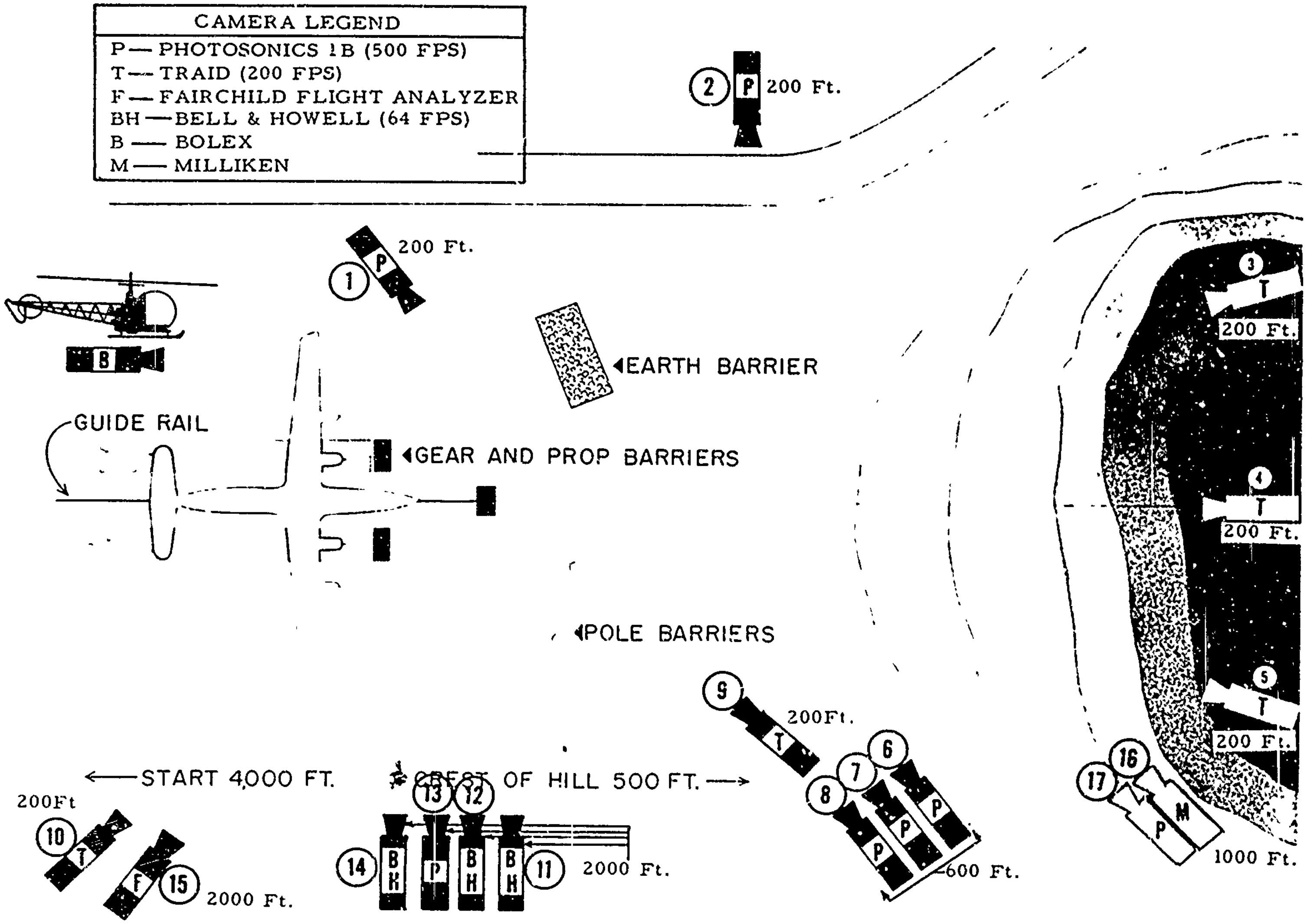
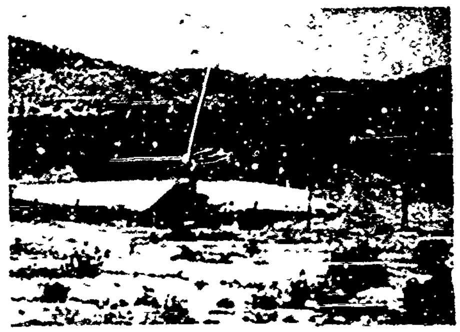


FIG. 18 STATIONARY CAMERA COVERAGE PLAN SHOWING DISTANCES FROM CAMERA MOUNTS TO CRASH AREA

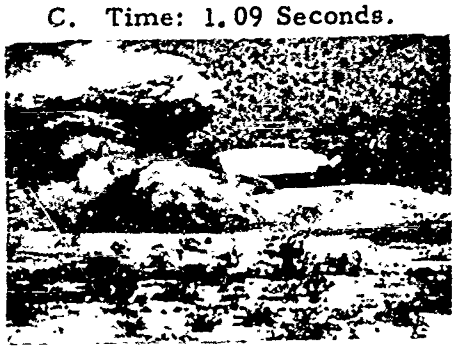


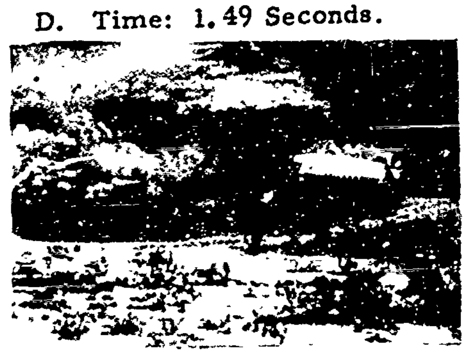
A. Time: .22 Seconds.

B. Time: .87 Seconds.

C. Time: 1.09 Seconds.

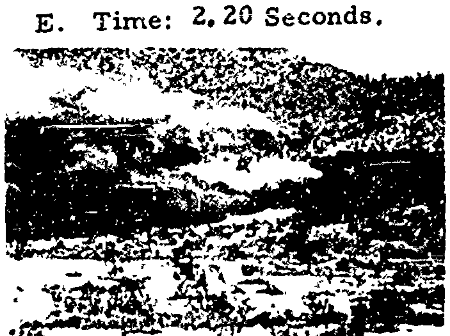
D. Time: 1.49 Seconds.

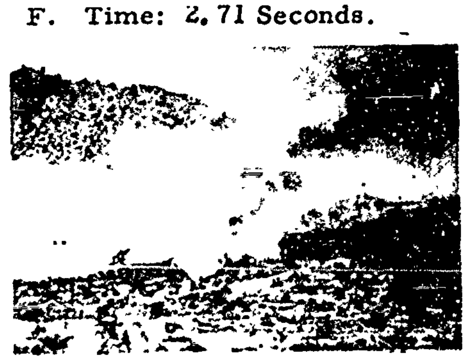




E. Time: 2.20 Seconds.

F. Time: 2.71 Seconds.

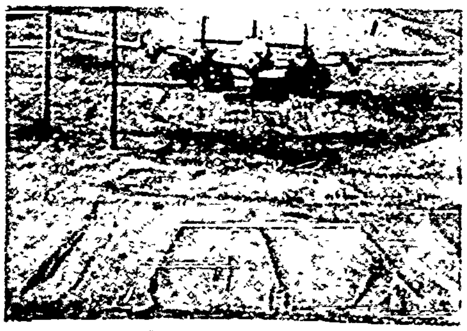




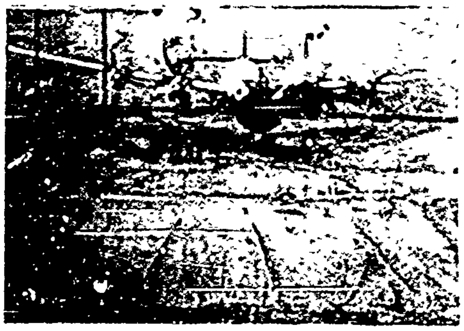
G. Time: 3.26 Seconds.

H. Time: 5.65 Seconds.

Fig. 19 Right Side View of Crash Sequence. (Time correlated with data presented in Appendix VI.)



A. Time: .19 Seconds.



B. Time: .64 Seconds.

C. Time: 1.16 Seconds.

D. Time: 1.62 Seconds.

E. Time: 2.08 Seconds.

F. Time: 2.57 Seconds.

G. Time: 3.05 Seconds.

H. Time: 3.59 Seconds.

Fig. 20 Head-on View of Crash Sequence. (Time correlated with data presented in Appendix VI.)

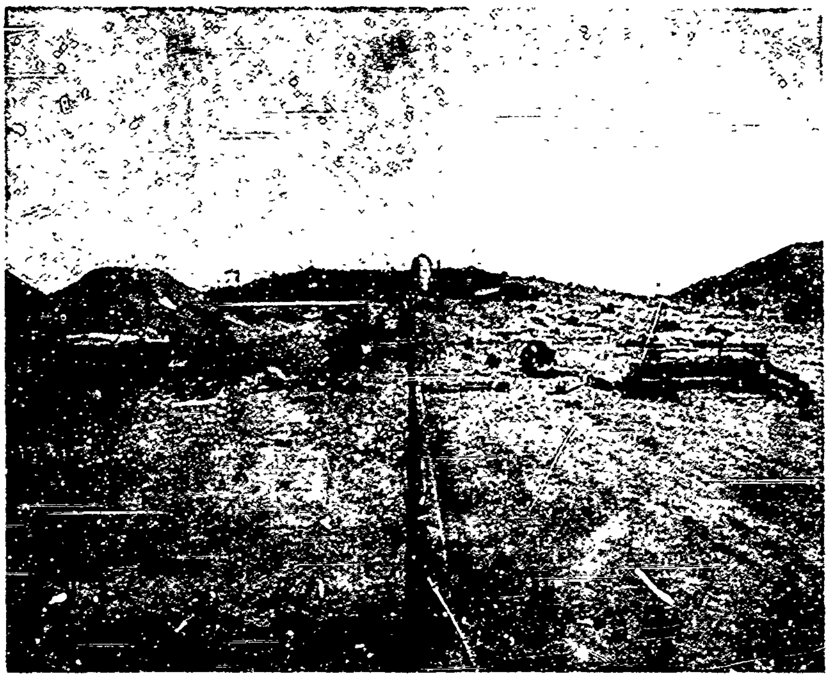


FIG. 21 POSTCRASH POSITION OF FUSELAGE IN RELATION TO ALIGNMENT WITH GUIDE RAIL

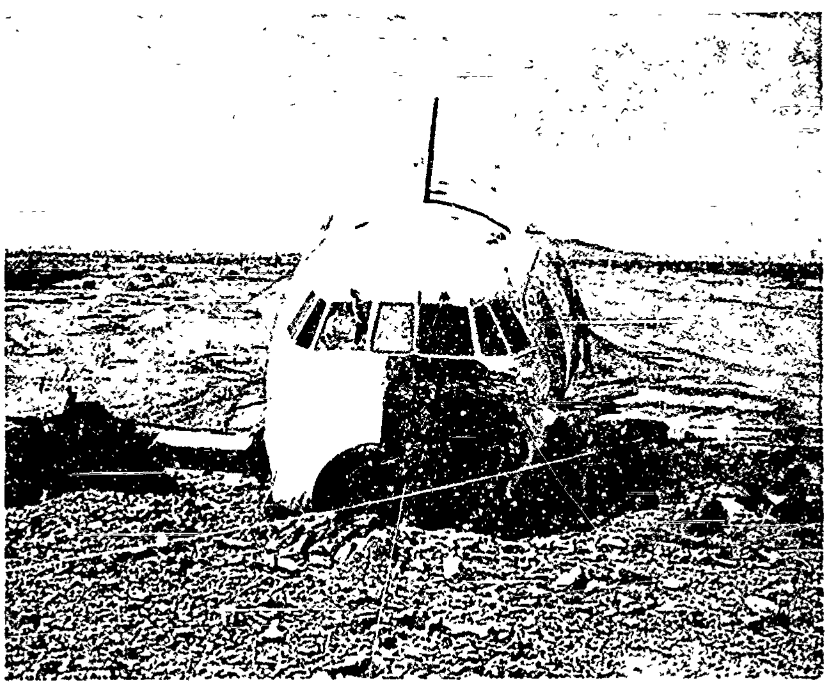


FIG. 22 HEAD-ON VIEW OF COCKPIT SECTION

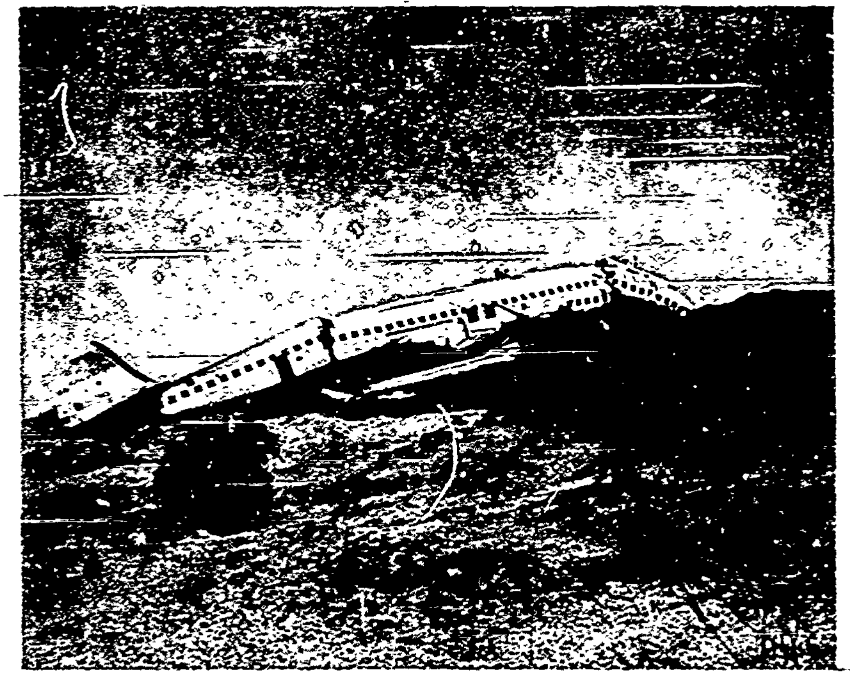


FIG. 23 RIGHT SIDE VIEW OF WRECKAGE SHOWING FORWARD AND AFT FUSELAGE BREAKS

FIG. 24 LEFT SIDE VIEW OF WRECKAGE

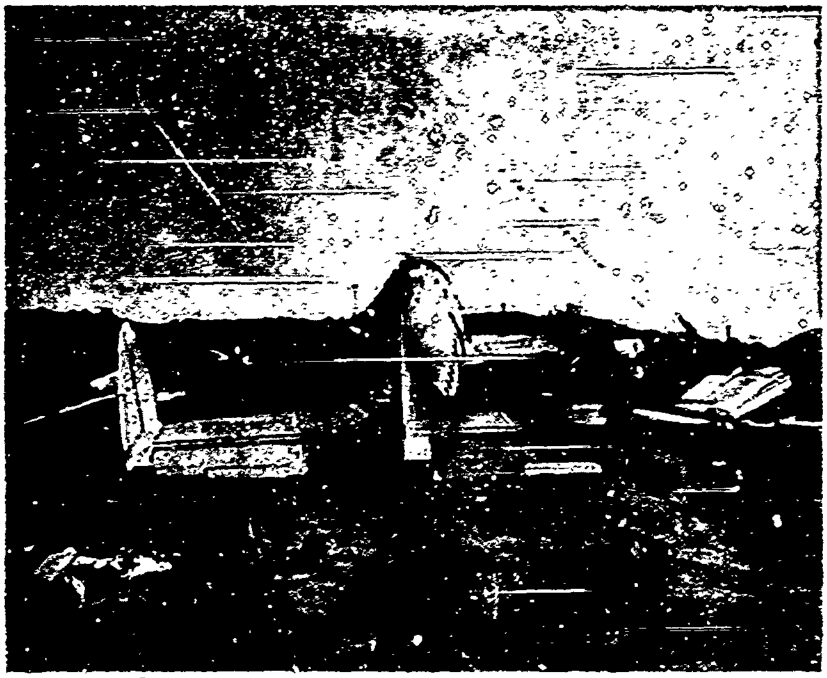


FIG. 25 REAR VIEW OF WRECKAGE

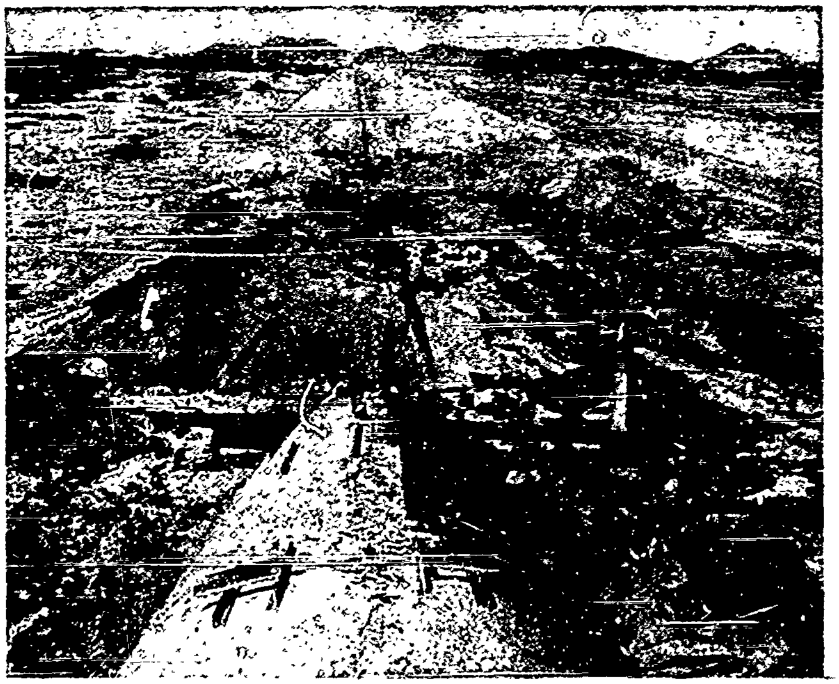


FIG. 26 VIEW OF IMPACT AND SLIDE AREA FROM ATOP WRECKAGE

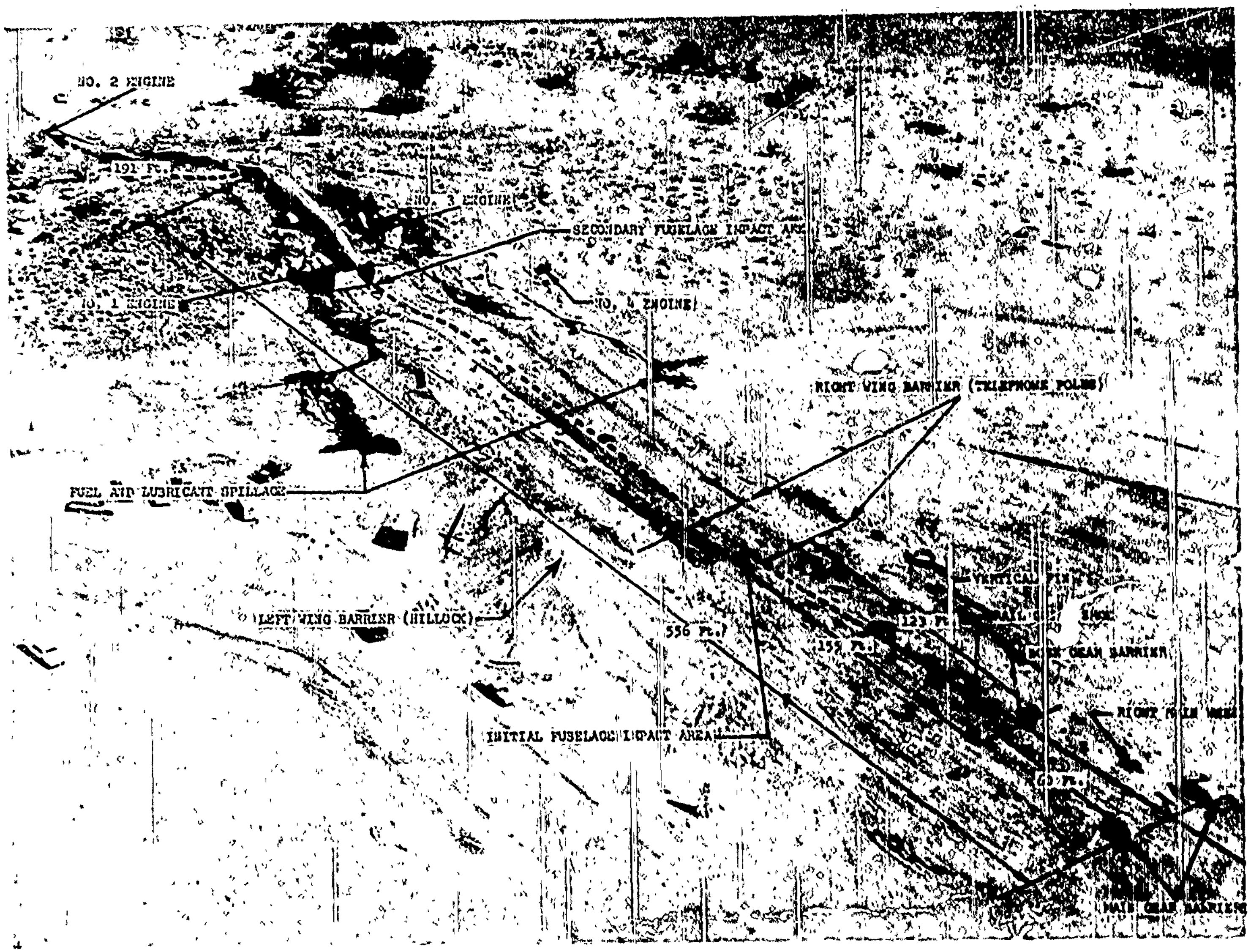


FIG. 27 WRECKAGE DISTRIBUTION PATTERN

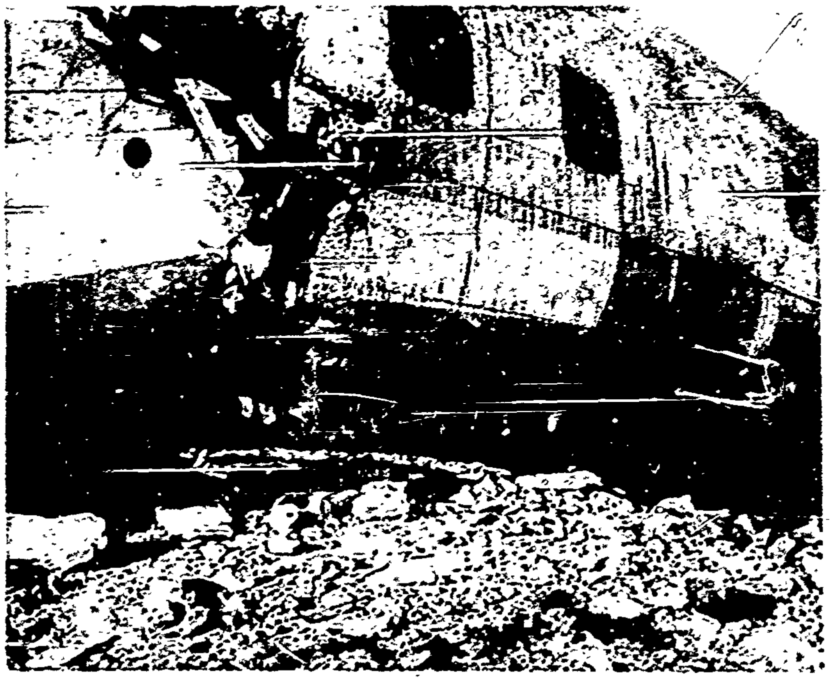


FIG. 28 DAMAGED LOWER FORWARD FUSELAGE STRUCTURE, LEFT SIDE

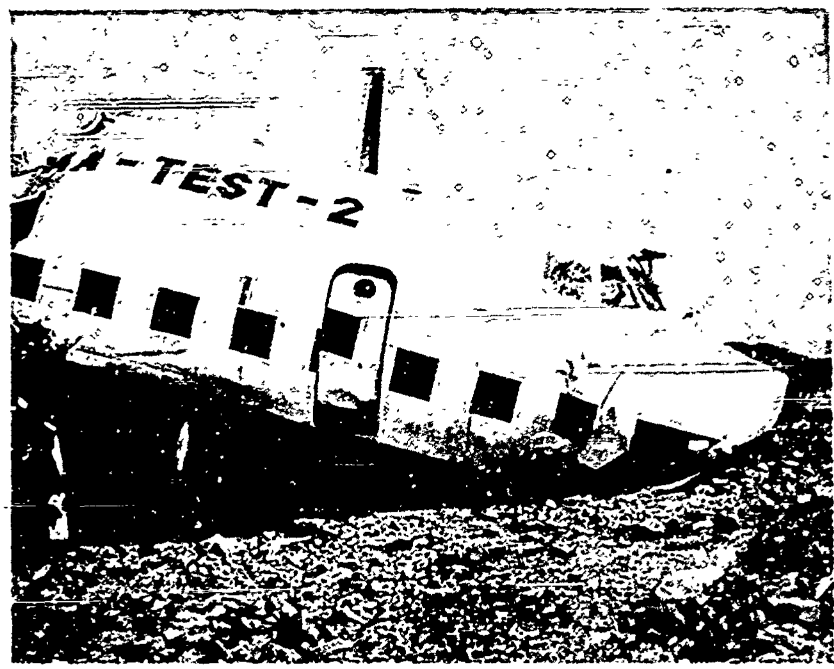


FIG. 29 FORWARD FUSELAGE AND COCKPIT STRUCTURAL DEFORMATION, RIGHT SIDE

FIG. 30 FORWARD FUSELAGE AND COCKPIT STRUCTURAL DEFORMATION, LEFT SIDE

FIG. 31 FUSELAGE STATION 380 BREAK, RIGHT SIDE

FIG. 32 FUSELAGE STATION 380 BREAK, LEFT SIDE

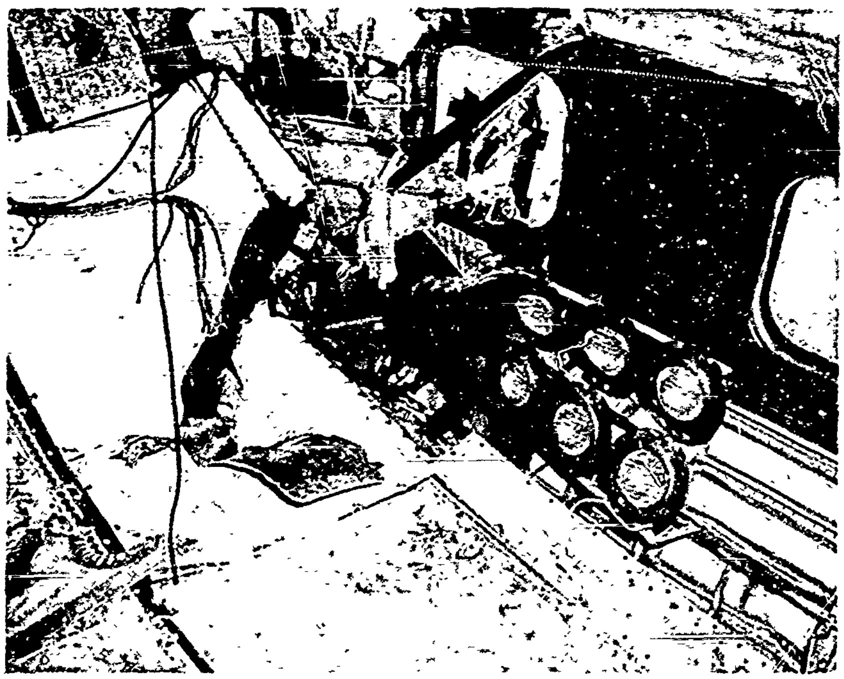
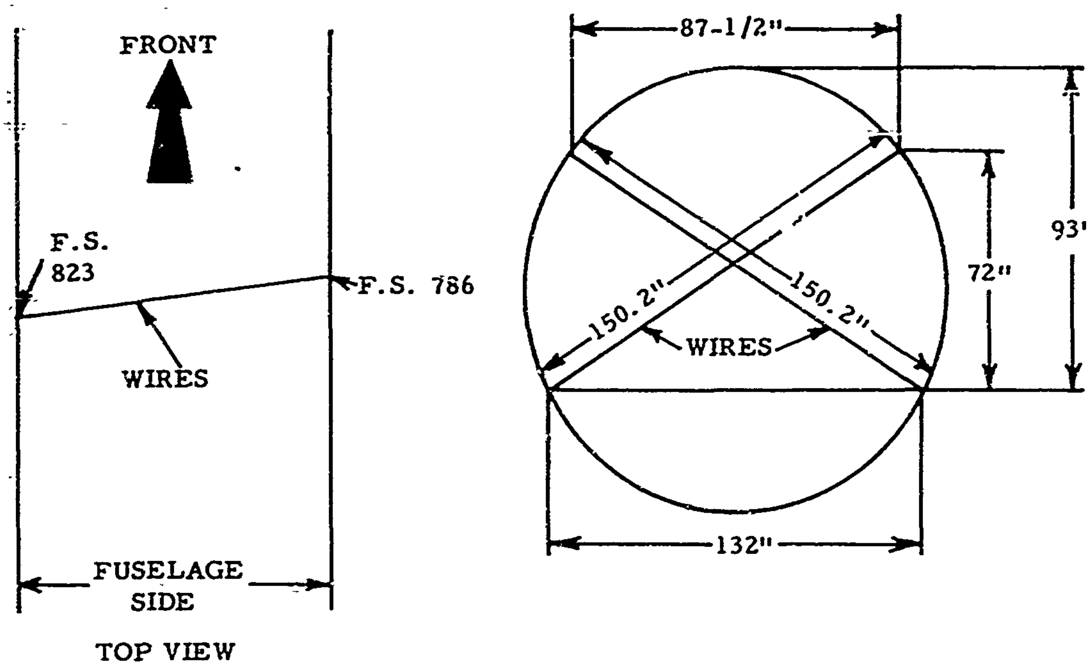


FIG. 33 FLOOR DAMAGE, FORWARD MAIN CABIN LOOKING FORWARD TOWARD COCKPIT

FORWARD LOCATION
PRECRASH



AFT LOCATION
PRECRASH

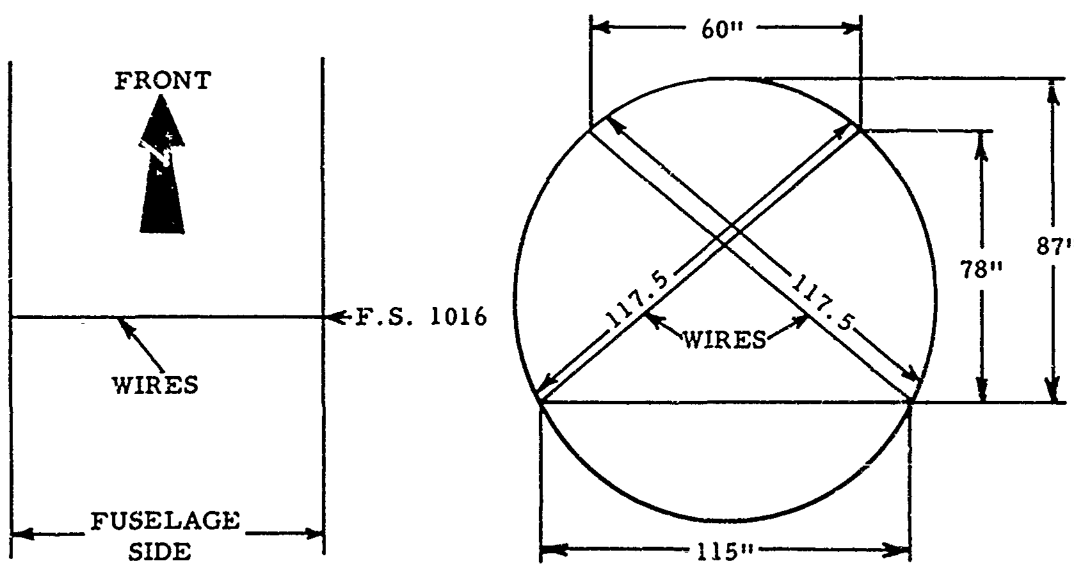
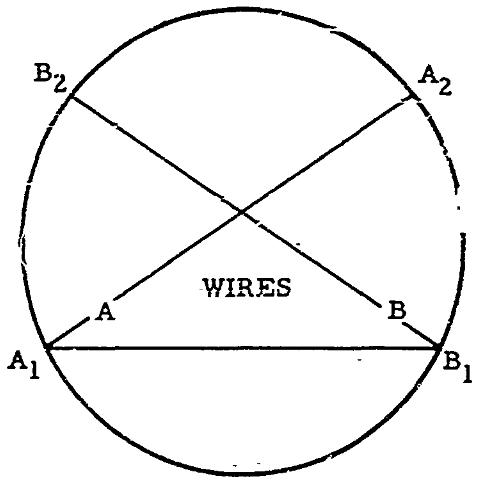


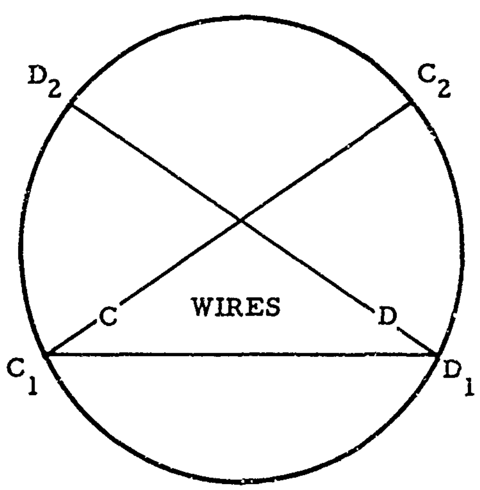
FIG. 34 FUSELAGE VOLUME REDUCTION APPARATUS

FORWARD LOCATION
POSTCRASH



WIRE A. EXPANDED LENGTH 154.2"
DISTANCE BETWEEN A_1 AND A_2 147.45"
WIRE B. EXPANDED LENGTH 151.00"
DISTANCE BETWEEN B_1 AND B_2 148.2"

AFT LOCATION
POSTCRASH



WIRE C. EXPANDED LENGTH
BROKEN AFTER 121.50"
DISTANCE BETWEEN C_1 AND C_2 113.75"
WIRE D EXPANDED LENGTH 118.5
DISTANCE BETWEEN D_1 AND D_2 116.5

FIG. 35 RESULTS OF FUSELAGE VOLUME REDUCTION EXPERIMENTS

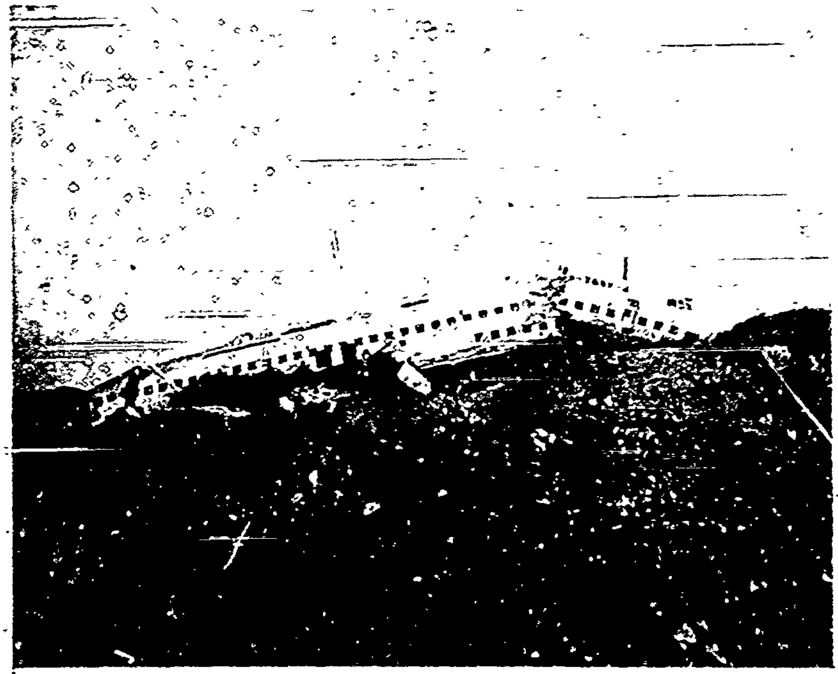
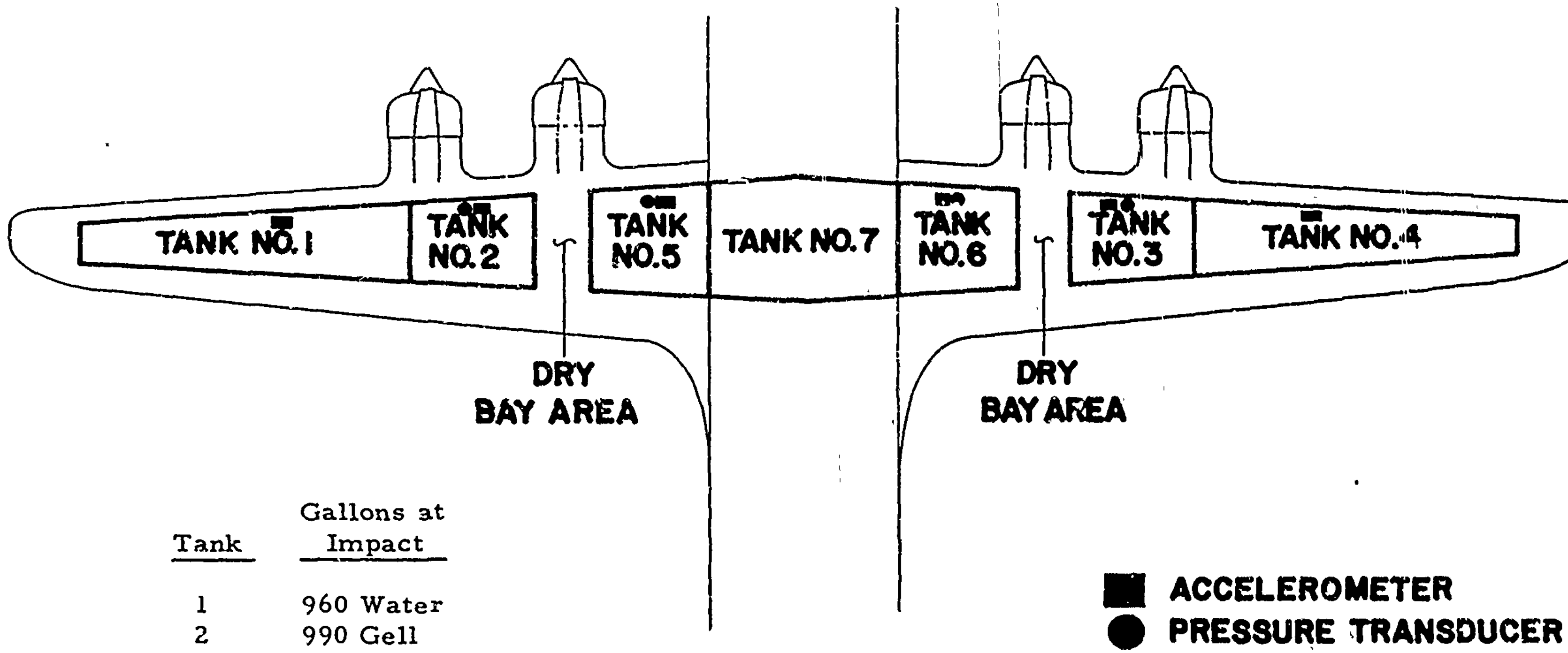


FIG. 36 OVERALL RIGHT SIDE VIEW OF FUSELAGE STRUCTURE

FIG. 37 AFT LAVATORY OVERHEAD LIGHT PANELS, POSTCRASH



Tank	Gallons at Impact
1	960 Water
2	990 Gell
3	990 Gell
4	750 Water
5	985 Water
6	985 Water
7	0

FIG. 38 CONSTELLATION FUEL TANK LAY-OUT AND INSTRUMENTATION LOCATIONS

FIG. 39 RIGHT WING ACCELEROMETER INSTALLATIONS, MID-WING AND INBOARD

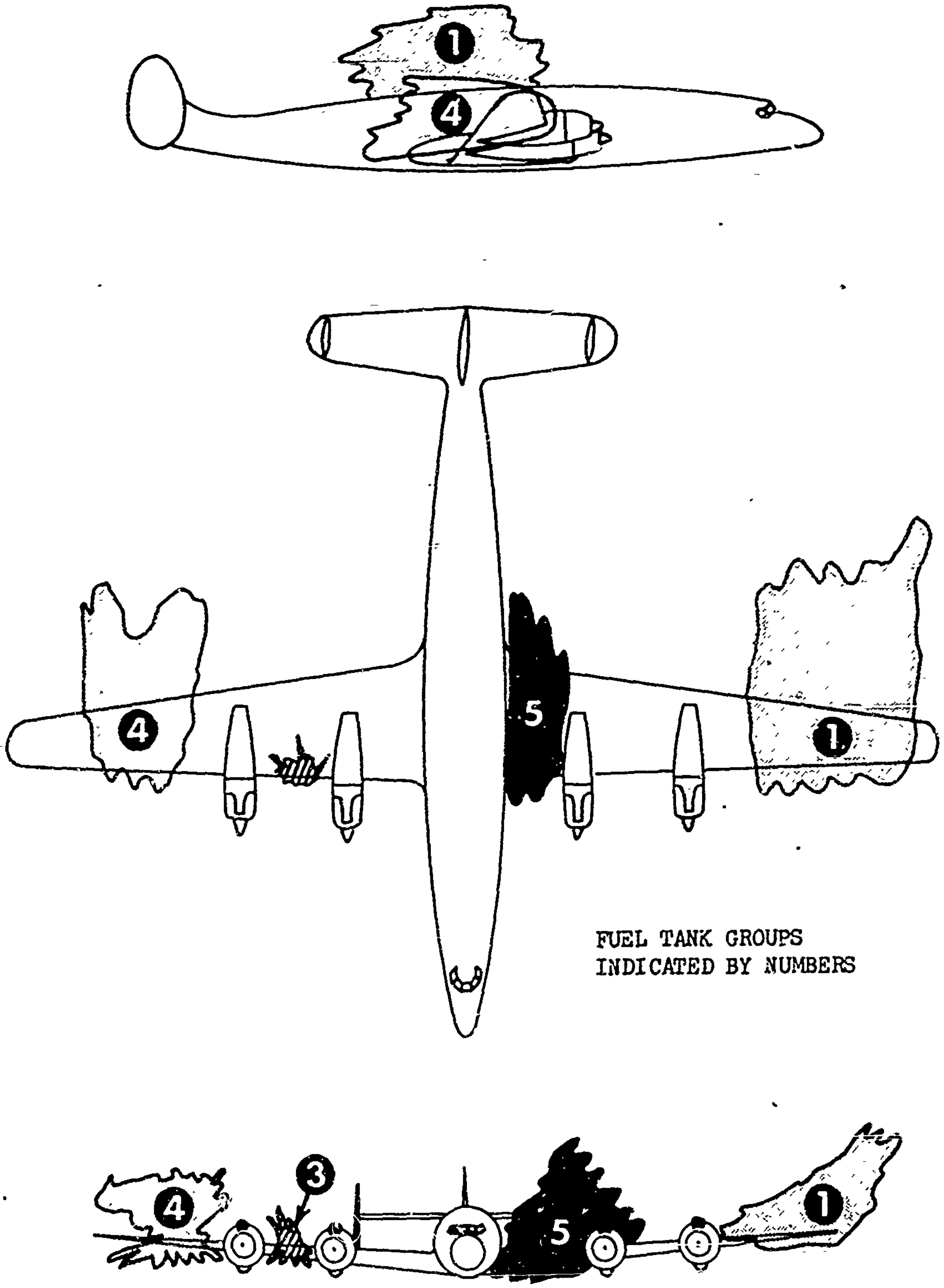


FIG. 40 FUEL SPILLAGE OCCURRING 1.00 SECONDS AFTER IMPACT WITH MAIN GEAR BARRIERS

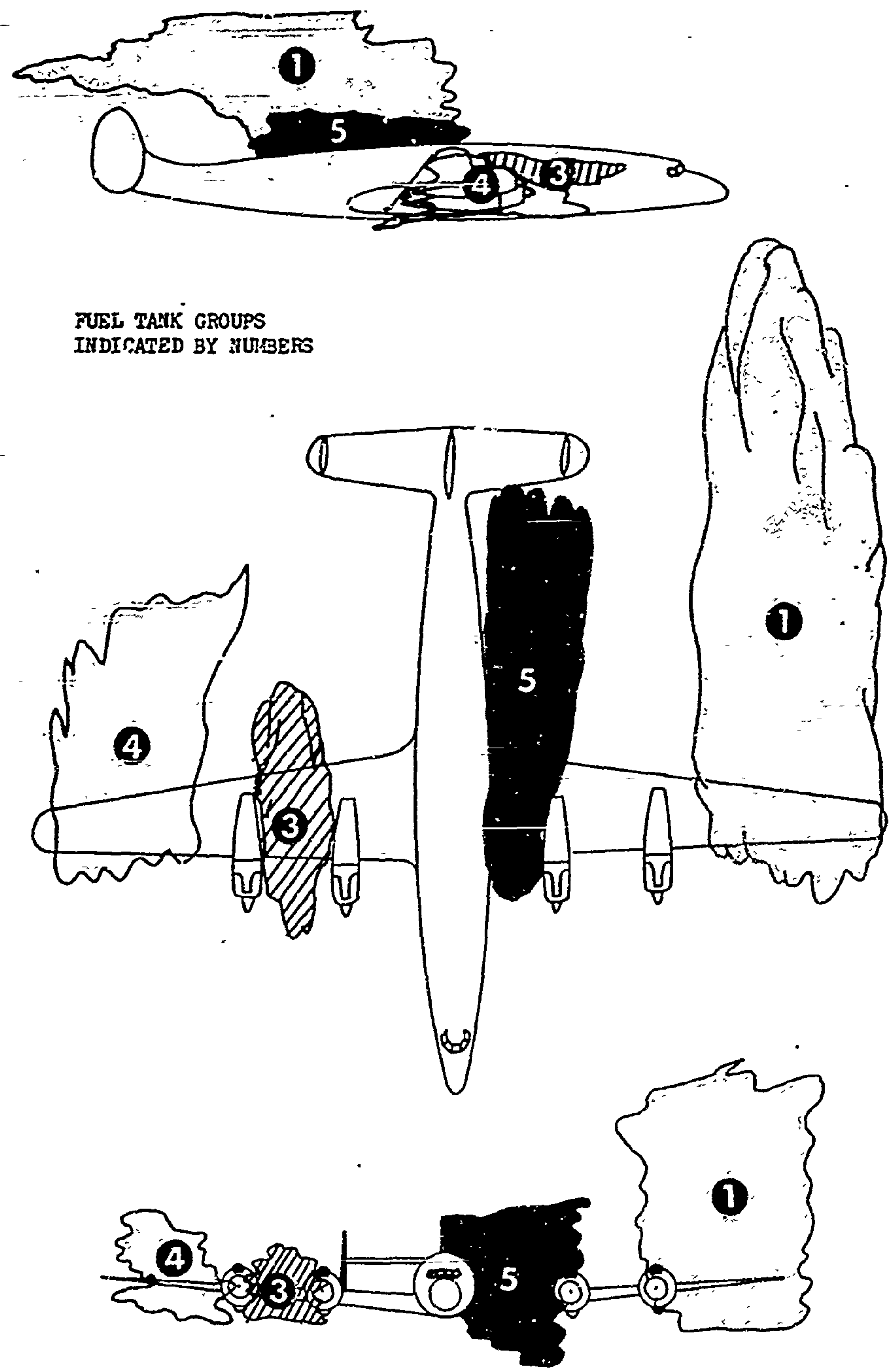


FIG. 41 FUEL SPILLAGE OCCURRING 1.14 SECONDS AFTER IMPACT WITH MAIN GEAR BARRIERS

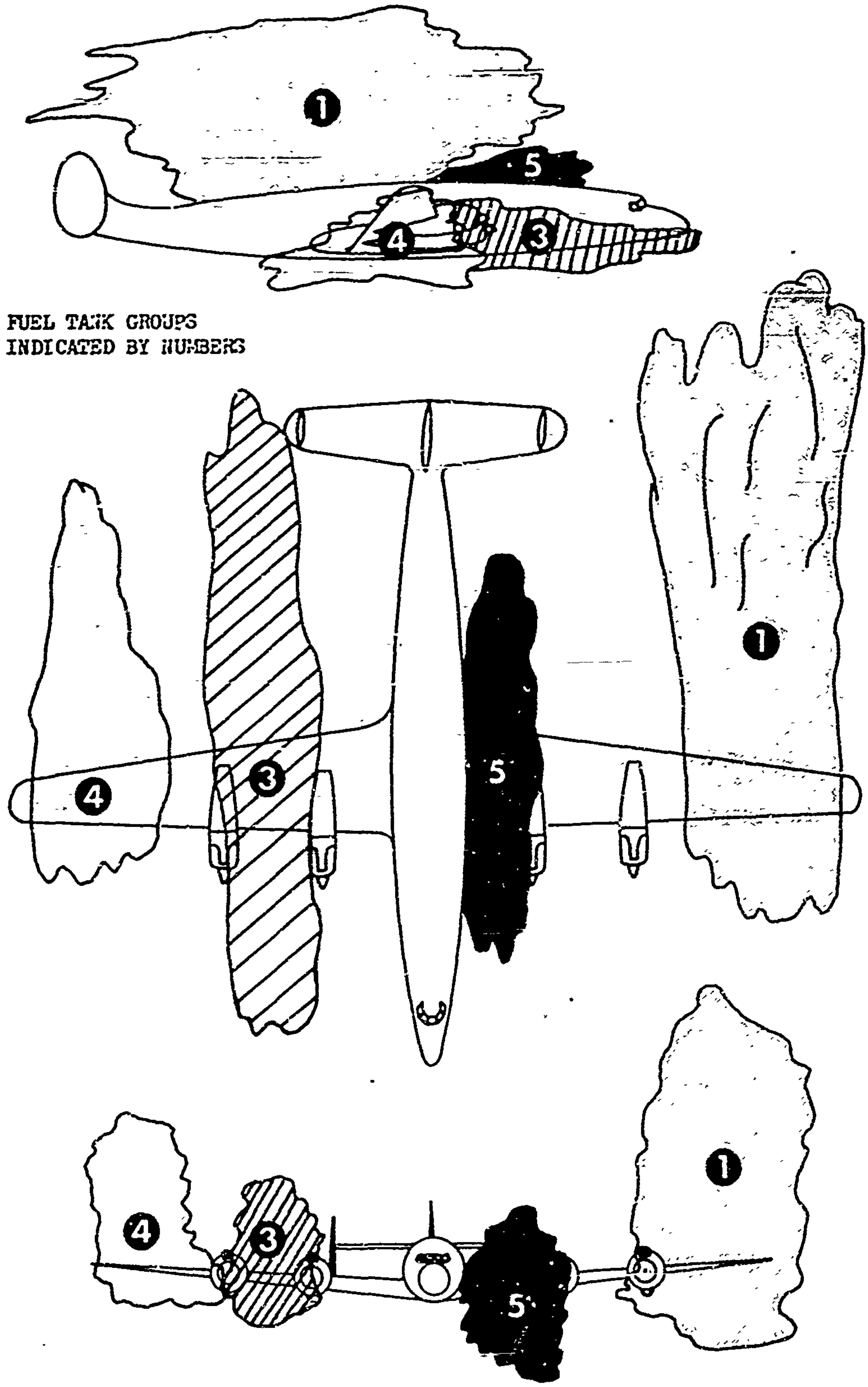


FIG. 42 FUEL SPILLAGE OCCURRING 2.24 SECONDS AFTER IMPACT WITH MAIN GEAR BARRIERS

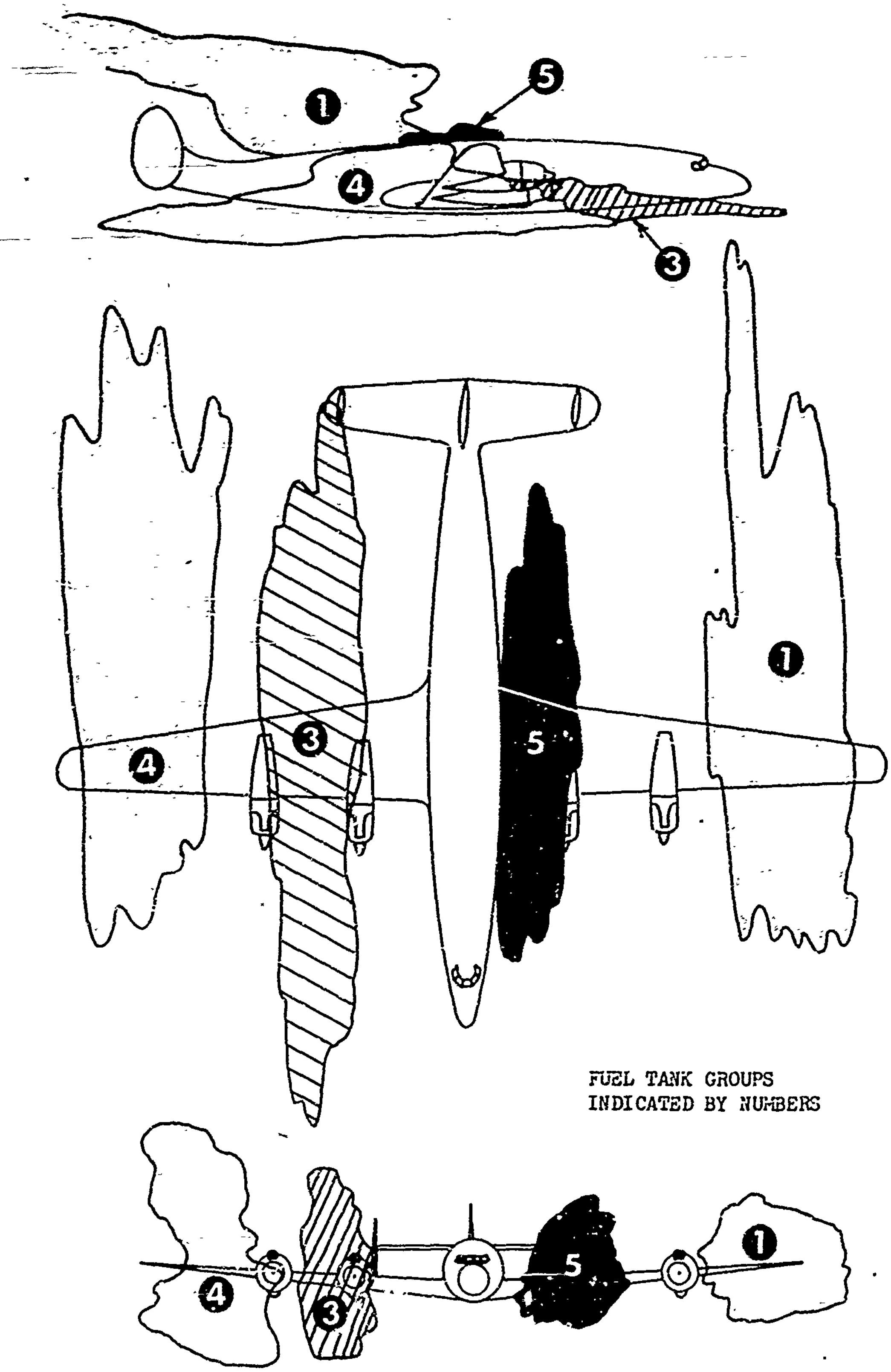


FIG. 43 FUEL SPILLAGE OCCURRING 2.65 SECONDS AFTER IMPACT WITH MAIN GEAR BARRIERS

FIG. 44 AERIAL PHOTOGRAPH OF THE CRASH SCENE ILLUSTRATING THE WING FAILURES AND SPILLAGE PATTERN

FIG. 45 AERIAL PHOTOGRAPH OF THE CRASH SCENE ILLUSTRATING THE WING FAILURES AND SPILLAGE PATTERN

FIG. 46 PILOT SEAT EXPERIMENT BEFORE RESTRAINT HARNESS WAS INSTALLED

FIG. 47 COPILOT SEAT EXPERIMENT

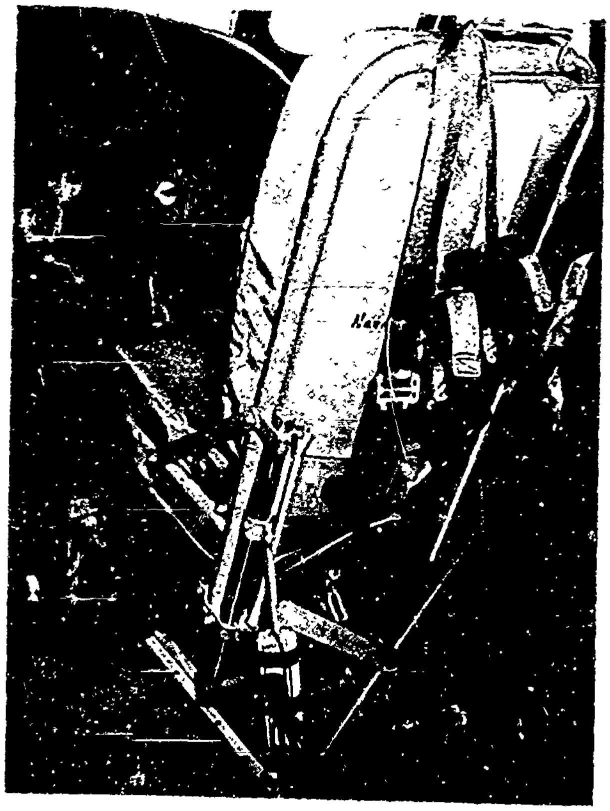


FIG. 48 FORWARD VIEW OF CREW SEAT INSTALLED IN CREW BERTH AREA SHOWING LAP BELT AND SINGLE STRAP SHOULDER HARNESS

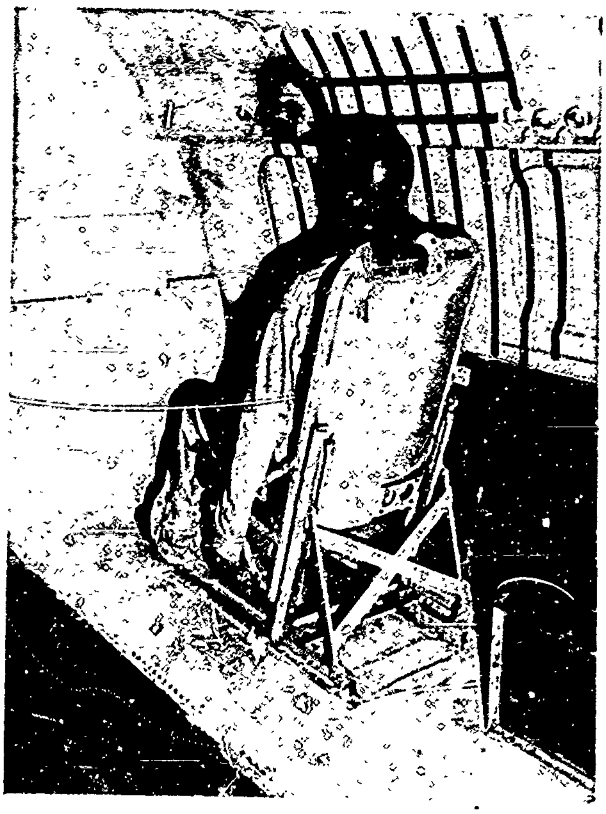


FIG. 49 REAR VIEW OF CREW SEAT INSTALLED IN CREW BERTH AREA SHOWING INERTIA REEL INSTALLATION ON SEAT BACK

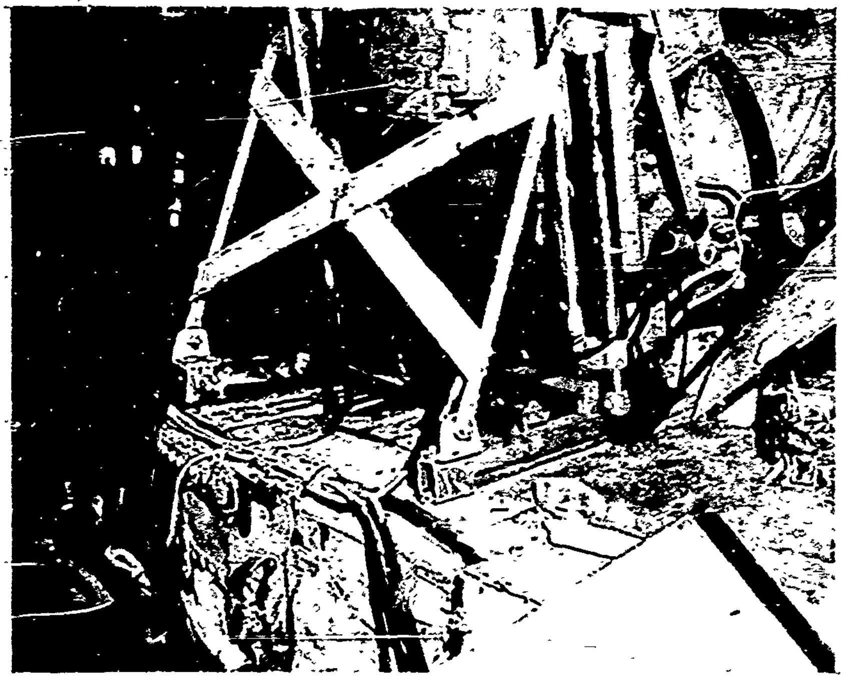


FIG. 50 PILOT'S CREW SEAT FLOOR ATTACHMENTS, POSTCRASH

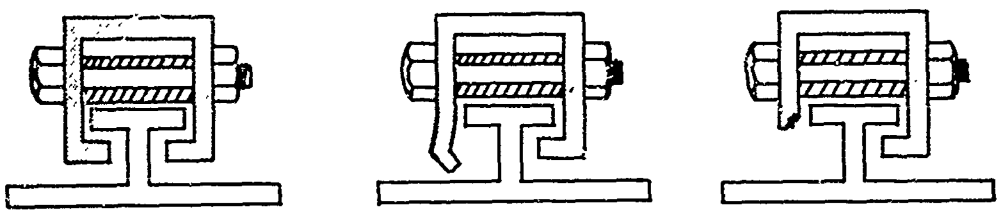


FIG. 51 SEAT TRACK ATTACHMENT FAILURES

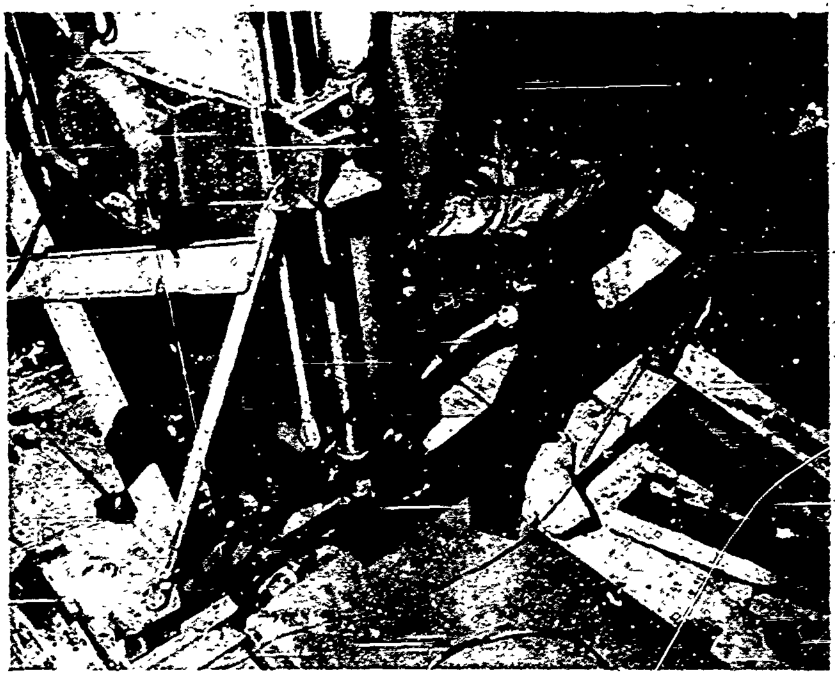


FIG. 52 PILOT'S CREW SEAT FRAME FAILURE

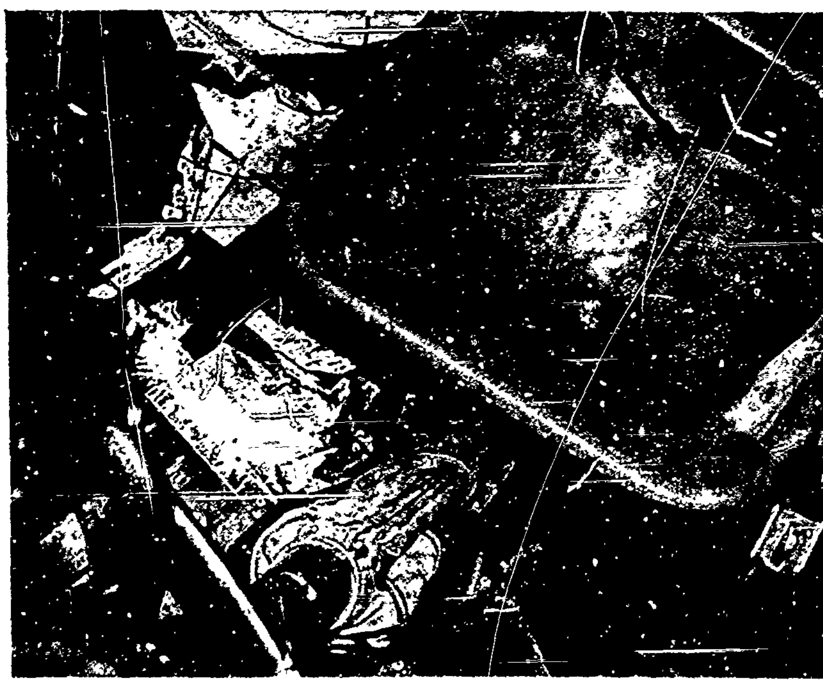


FIG. 53 PILOT'S SEAT PAN, POSTCRASH. NOTICE TEAR IN BACK SHEET METAL AND DEFORMED FORWARD EDGE WHERE SEAT CONTACTED FLOOR

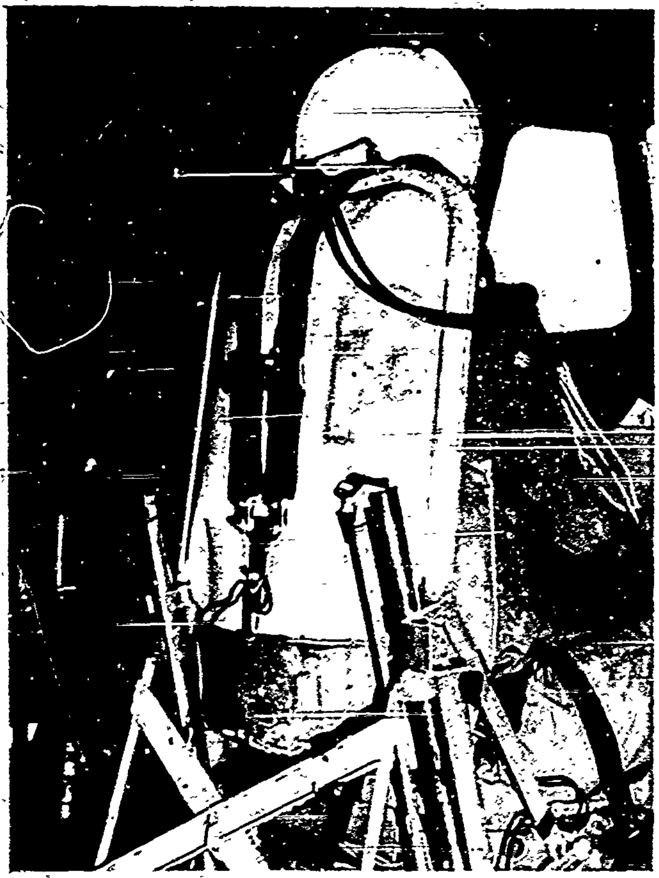


FIG. 54 POSTCRASH VIEW OF PILOT'S SEAT SHOWING FORWARD BENDING OF SEAT BACK

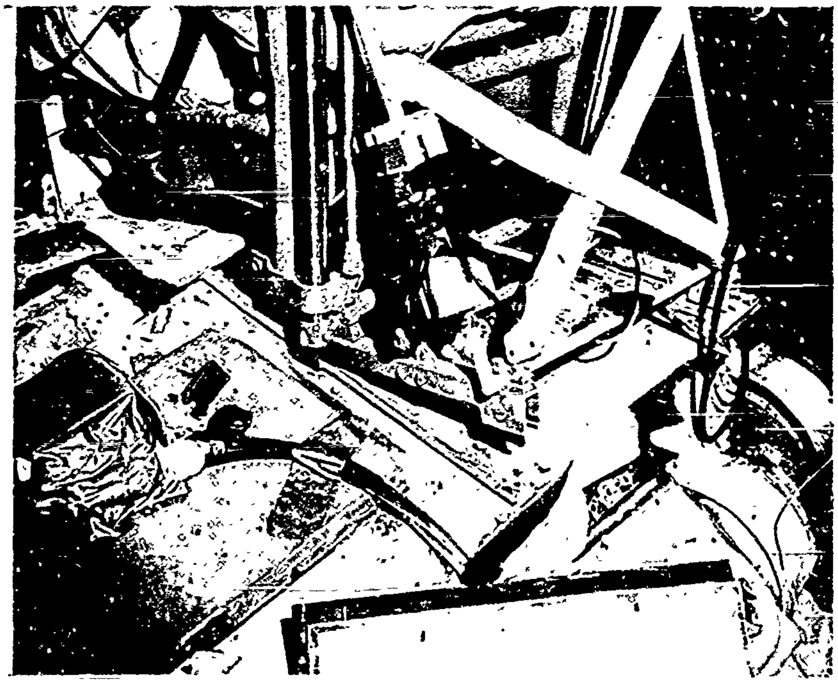


FIG. 55 COPILOT'S CREW SEAT FLOOR ATTACHMENTS, POSTCRASH

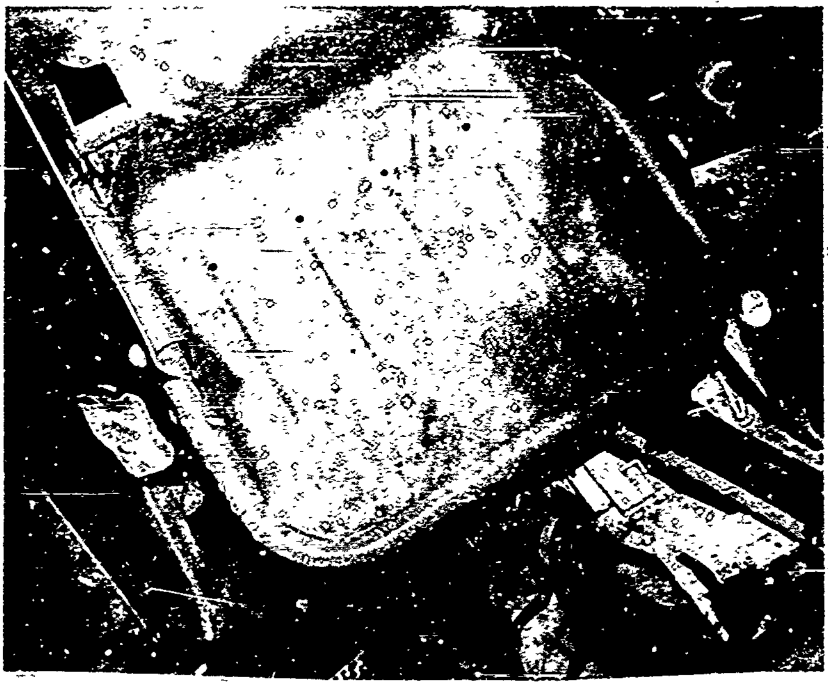


FIG. 56 COPILOT'S SEAT PAN FAILURES

FIG. 57 BENDING FAILURE OF COPILOT'S SEAT BACK

FIG. 58 POSITION OF COPILOT DUMMY, POSTCRASH

FIG. 59 POSTCRASH RESTING POSITION OF THIRD CREW MEMBER AND SEAT

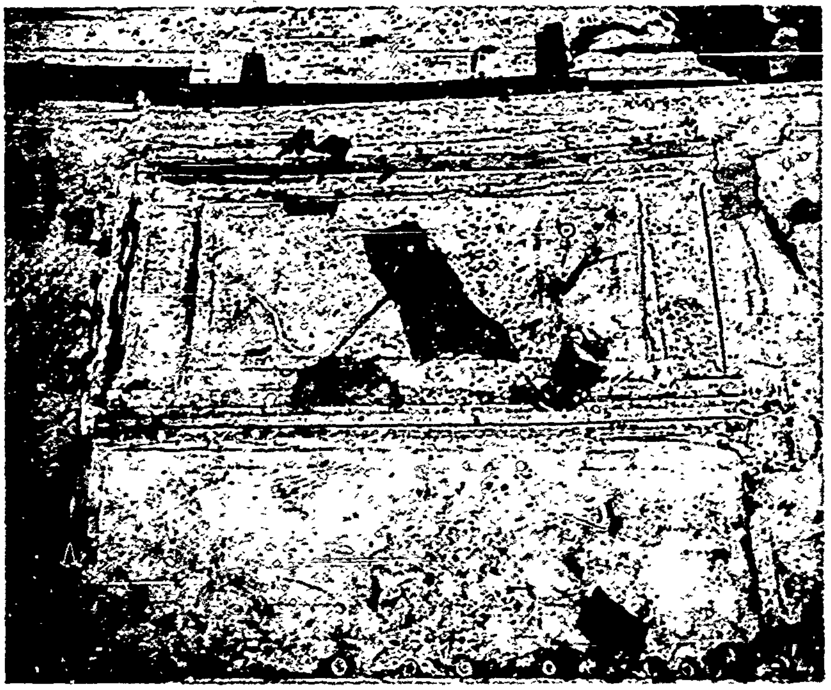


FIG. 60 THIRD CREW SEAT FLOOR TRACKS, POSTCRASH

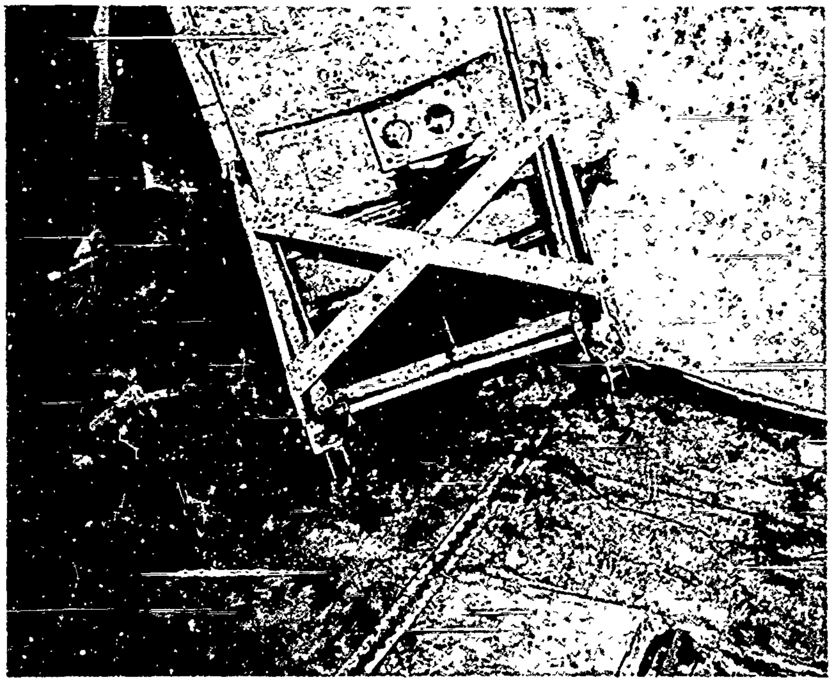


FIG. 61 THIRD CREW SEAT FLOOR TRACK ATTACHMENTS AND SEAT LEG STRUCTURE, POSTCRASH

FIG. 62 VIEW OF FORWARD CONSTELLATION SEAT EXPERIMENT, LOOKING AFT

FIG. 63 DUMMY OCCUPANTS OF CENTER SEAT, FORWARD CONSTELLATION SEAT EXPERIMENT

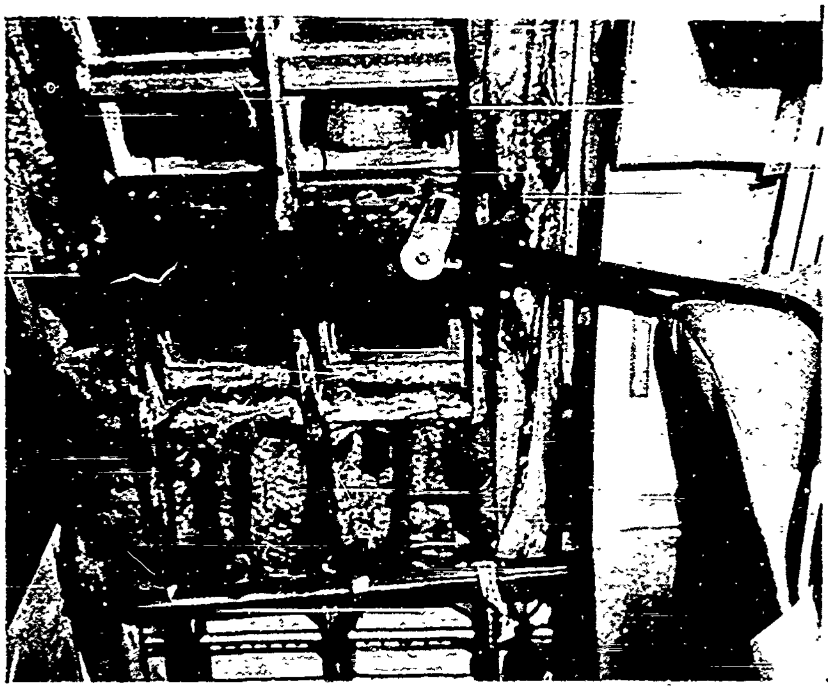


FIG. 64 SHOULDER STRAP INERTIA REEL TESTED IN AFT SEAT OF CONSTELLATION SEAT EXPERIMENT

FIG. 65 DOLL DUMMY SUBJECT OF CHILD RESTRAINT EXPERIMENT

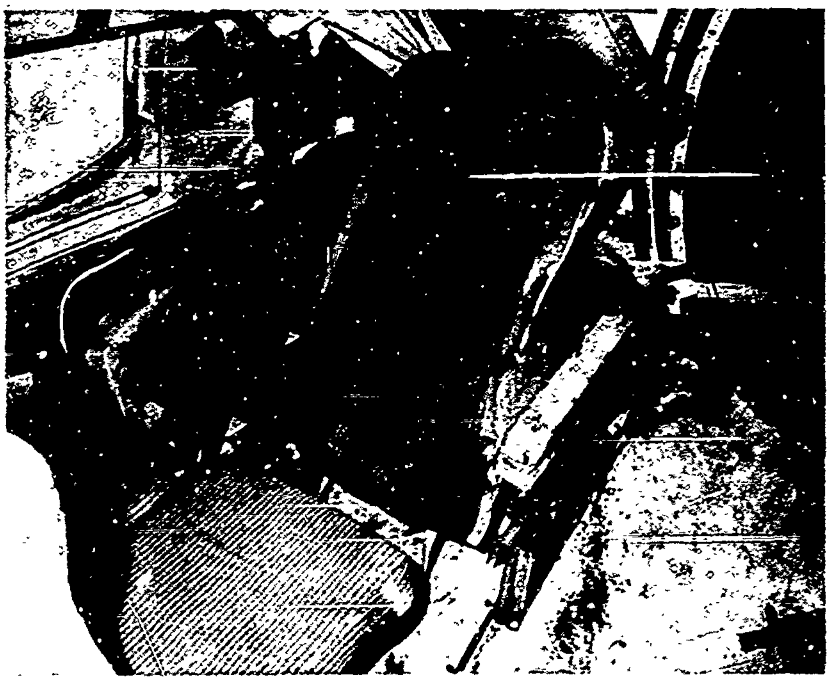


FIG. 66 BACK OF FORWARD CONSTELLATION SEAT AFTER REMOVAL OF CENTER SEAT DUMMIES

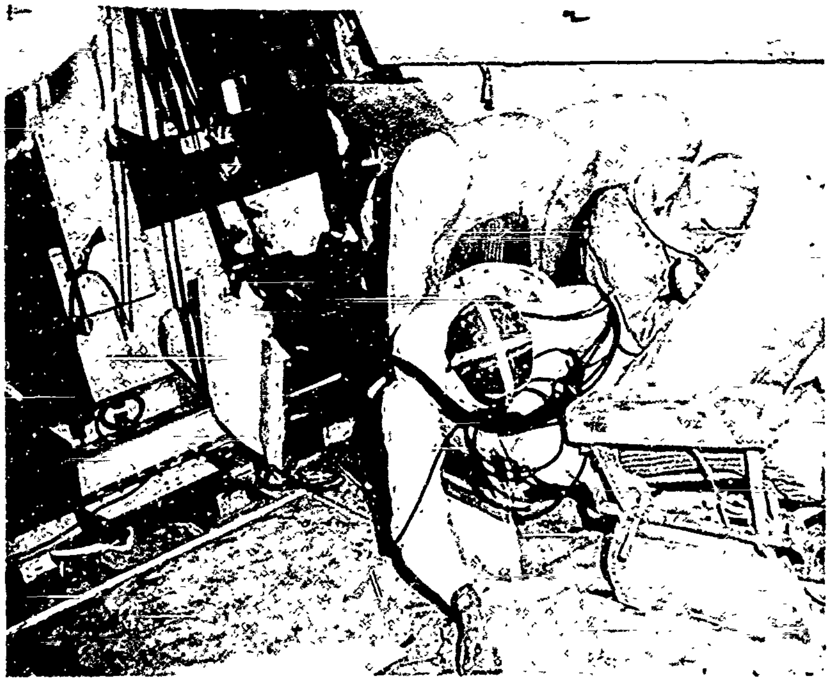


FIG. 67 POSTCRASH VIEW OF CENTER CONSTELLATION SEATS AND OCCUPANTS

FIG. 68 OVERHEAD VIEW OF CENTER CONSTELLATION SEAT EXPERIMENT

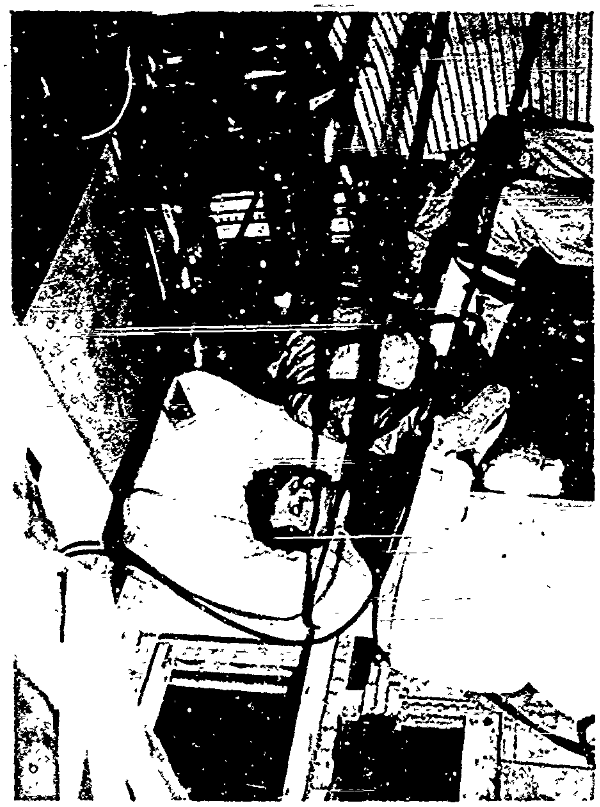


FIG. 69 VIEW SHOWING 90-DEGREE ROTATION OF AFT CONSTELLATION SEAT AND OCCUPANTS

FIG. 70 CARGO PALLETS INSTALLED IN AIRCRAFT LOOKING FORWARD TOWARD COCKPIT

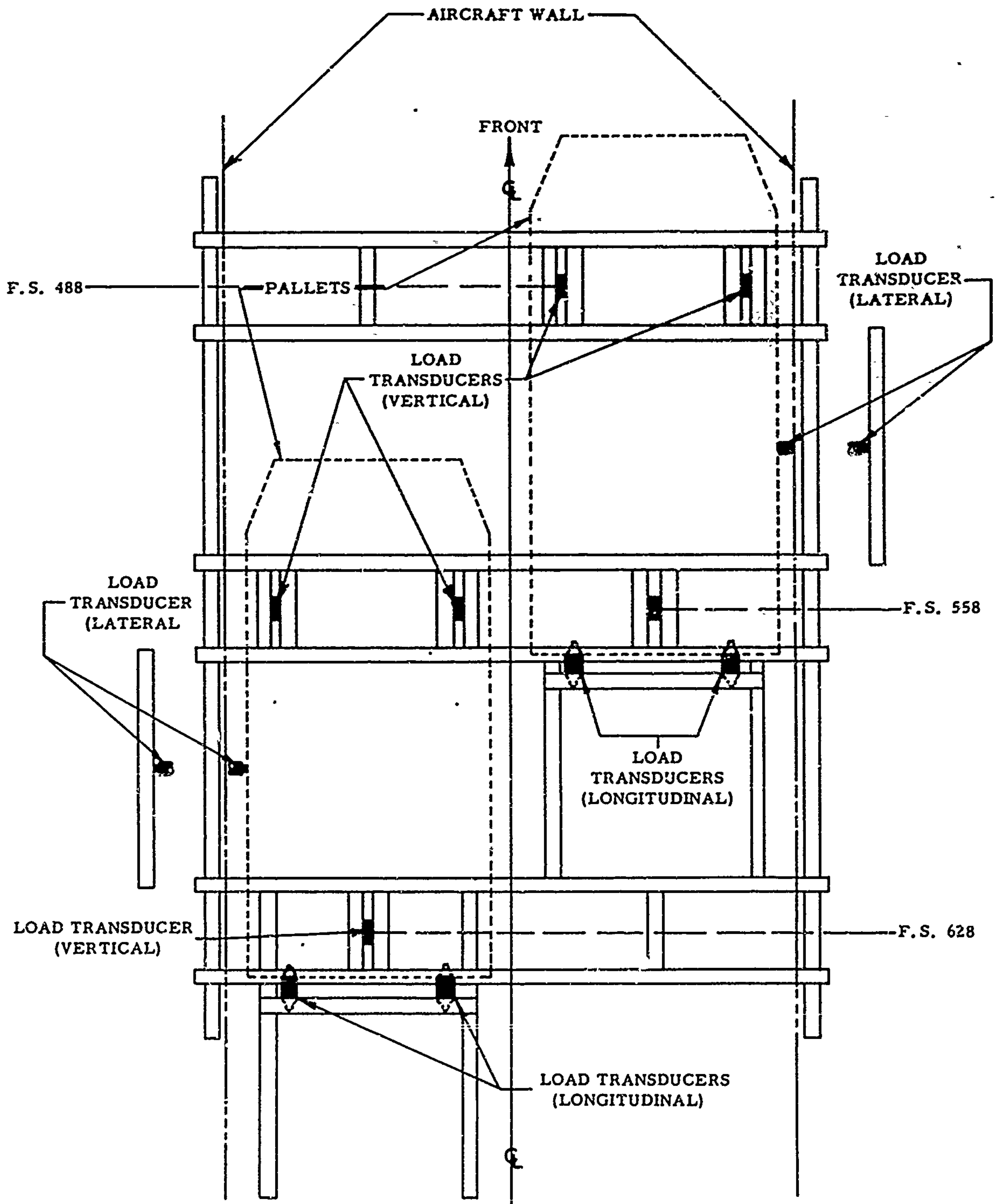


FIG. 71 SCHEMATIC OF CARGO PALLETS INSTALLATION

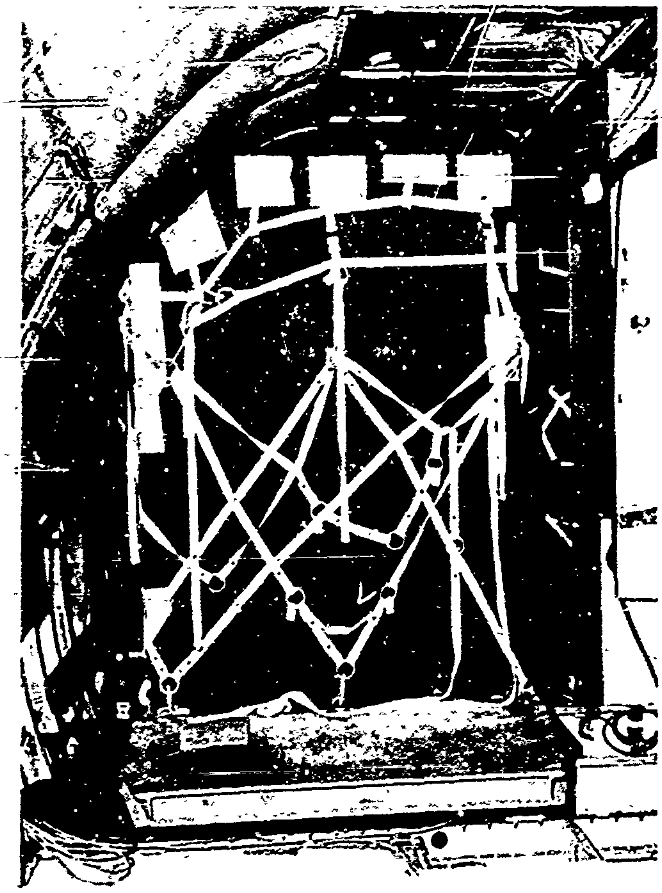


FIG. 72 RIGID CARGO LOAD WITH NYLON NET INSTALLED

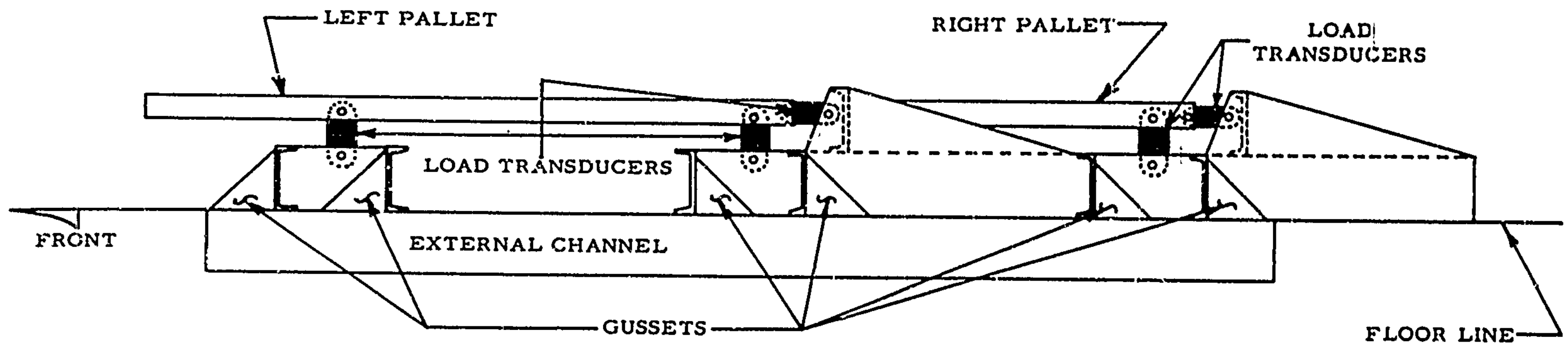


FIG. 73 SCHEMATIC SIDE VIEW OF PALLETS INSTALLATION SHOWING TRANSDUCER TIE-POINTS AND FLOOR MODIFICATION

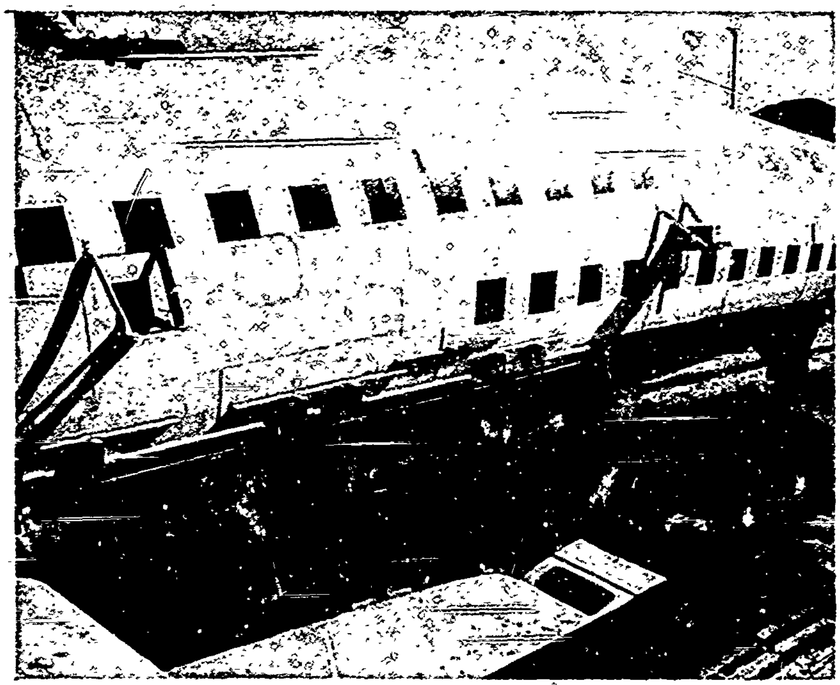


FIG. 74 VIEW SHOWING CARGO PALLET INSTALLATION REINFORCEMENT MEMBERS PROTRUDING THROUGH SIDES OF FUSELAGE

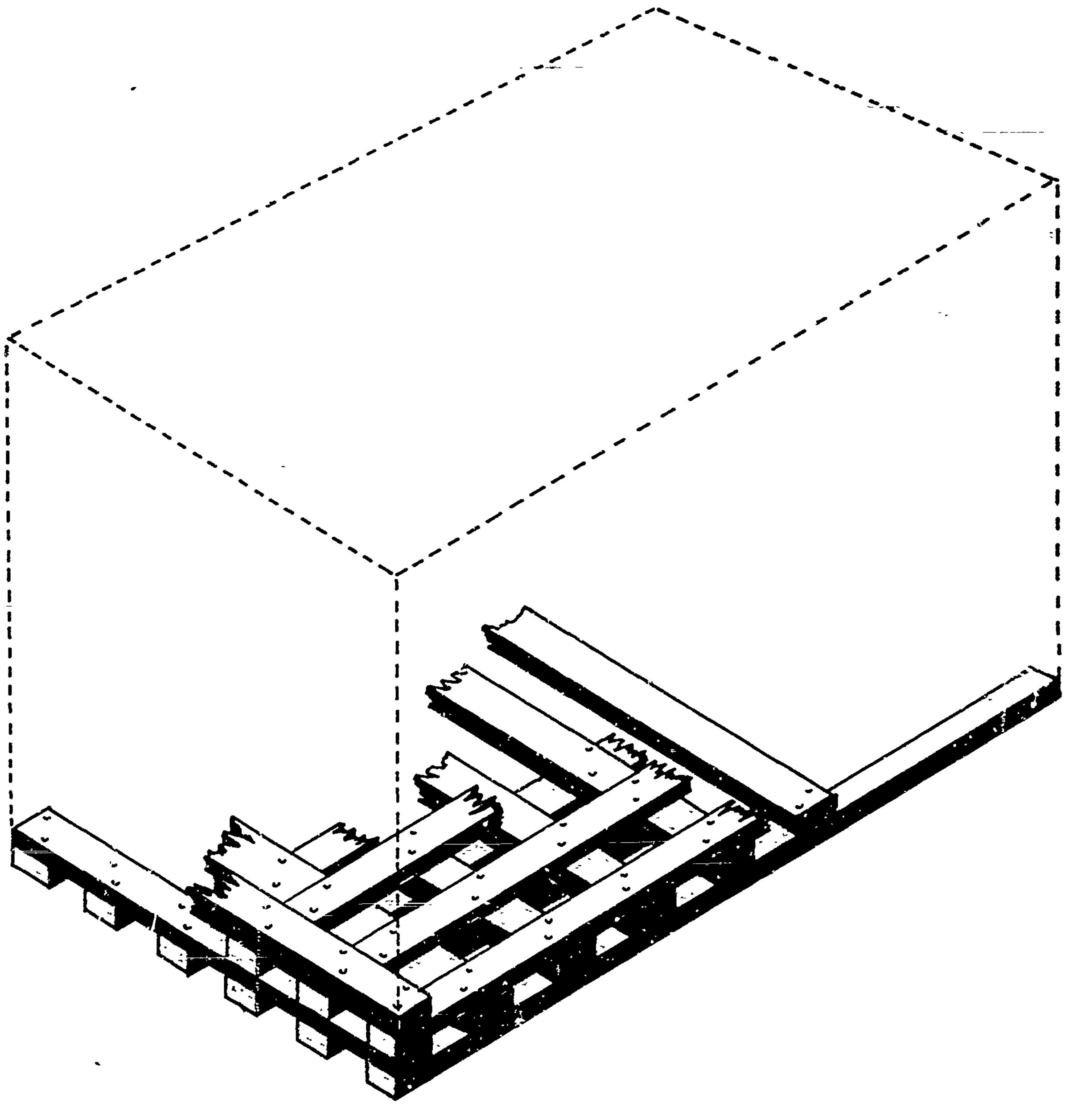


FIG. 75 SKETCH SHOWING HOW RIGID CARGO WAS CONSTRUCTED OF 2 X 4S NAILED TOGETHER IN CRISSCROSS FASHION

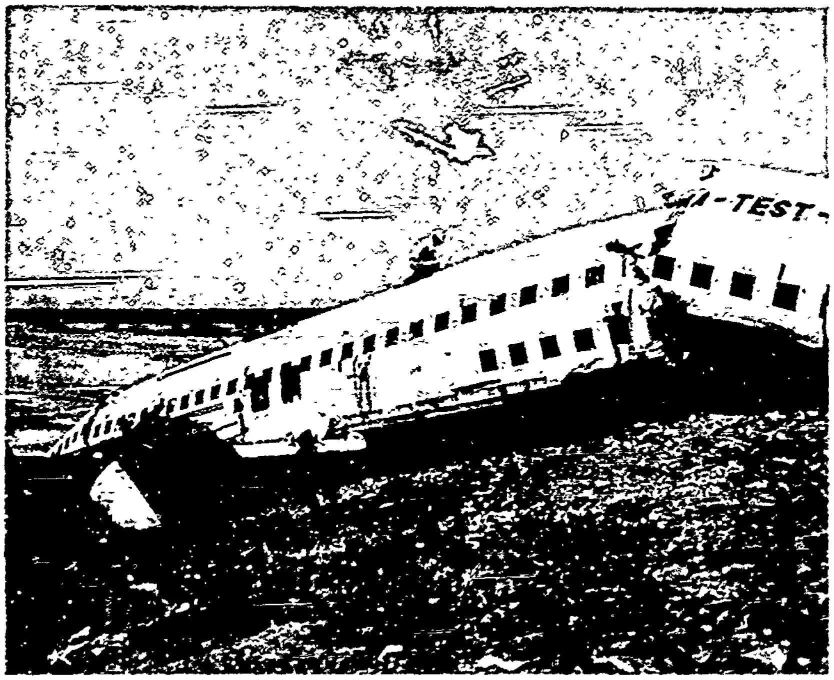


FIG. 76 FUSELAGE SECTION THAT HOUSED CARGO EXPERIMENT

FIG. 77 FORWARD DEFORMATION OF LONGITUDINAL LOAD LINK ATTACHMENT

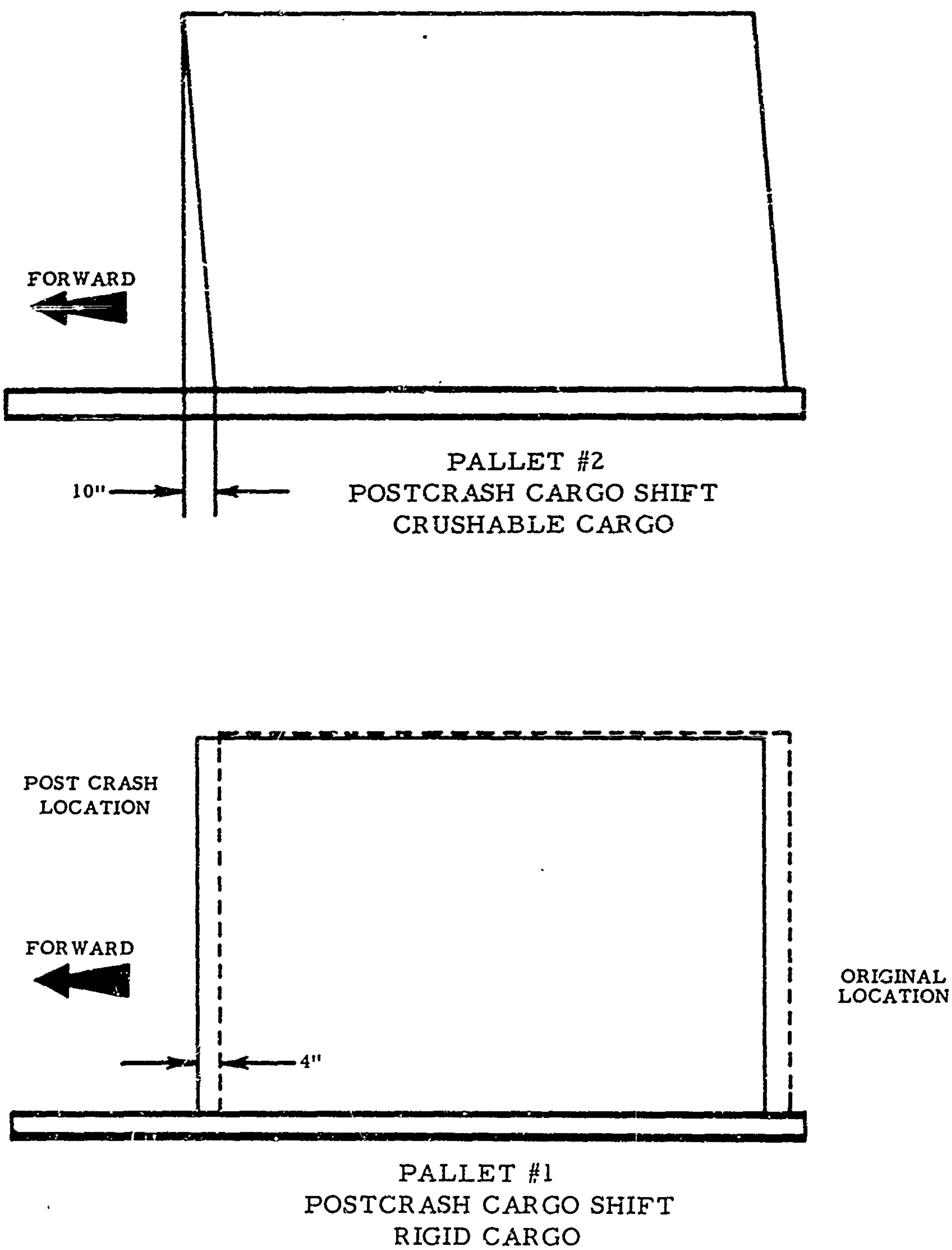


FIG. 78 FORWARD MOVEMENT EXPERIENCED IN CARGO LOADS

FIG. 79 SIDE VIEW OF THREE PASSENGER FORWARD FACING SEATS

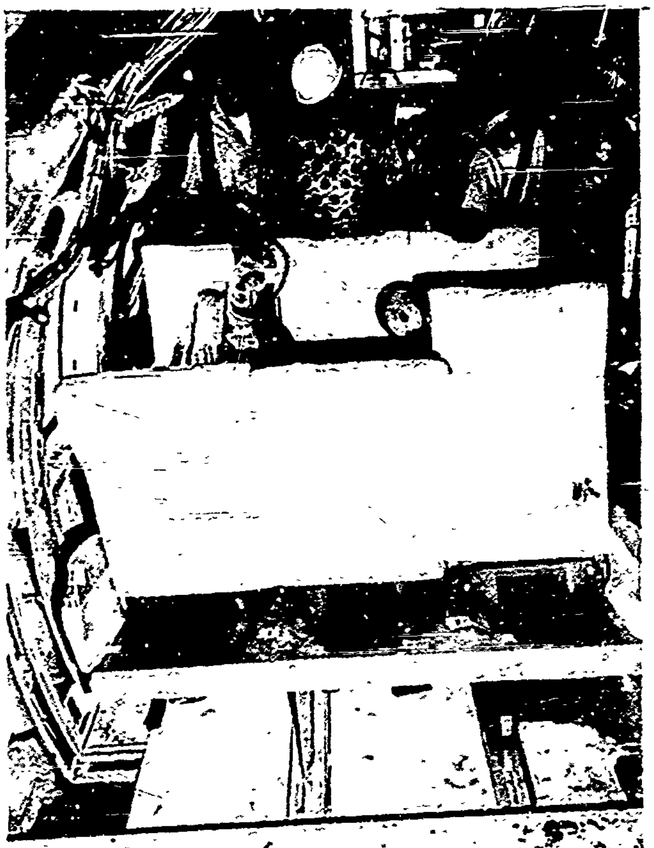


FIG. 80 POSTCRASH FORWARD VIEW OF FORWARD FACING PASSENGER SEATS

FIG. 81 POSTCRASH POSITION OF FORWARD FACING SEAT DUMMIES

FIG. 82 REAR FACING SEAT EXPERIMENT LOOKING FORWARD IN AIRCRAFT

FIG. 83 POSTCRASH OVERALL VIEW OF REAR FACING SEATS

FIG. 84 POSITION OF OCCUPANTS OF THREE PASSENGER REAR FACING SEAT, POSTCRASH

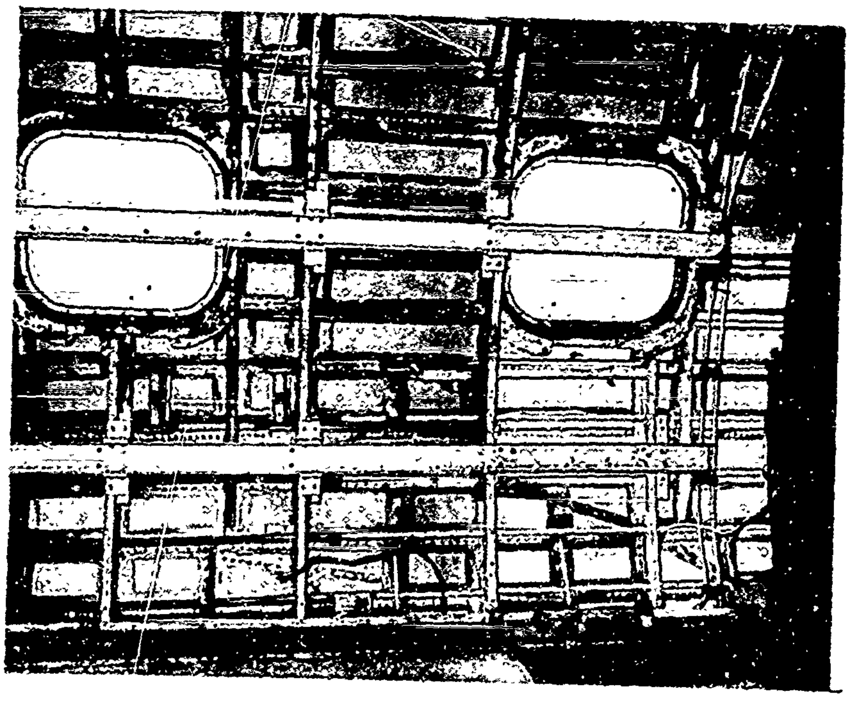


FIG. 85 LITTER EXPERIMENT INSTALLATION AREA SHOWING ALUMINUM CHANNELS WALL MOUNTED AS ATTACHMENTS FOR LITTERS

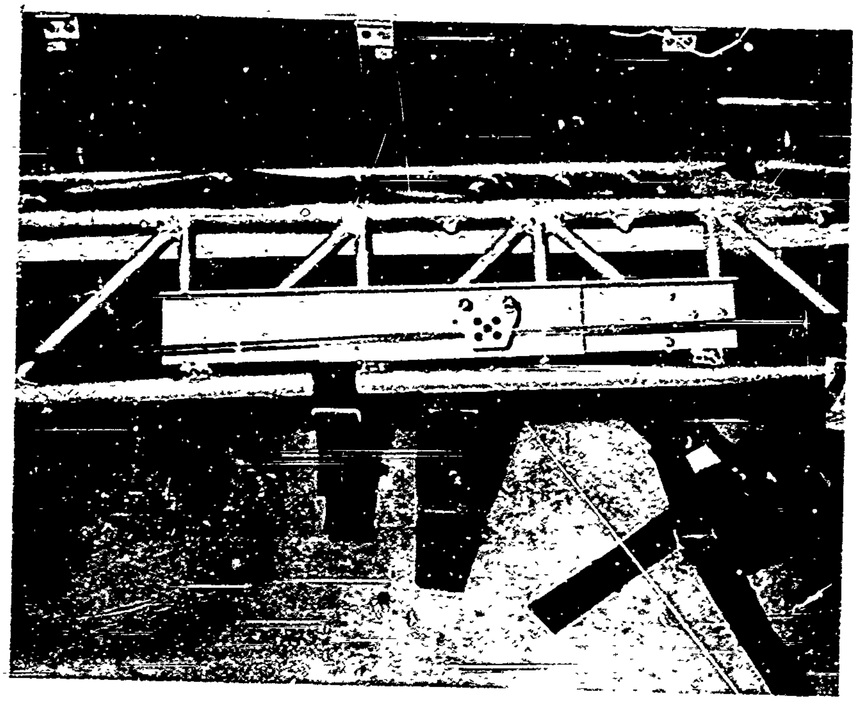


FIG. 86 LONGITUDINAL ENERGY ABSORPTION DEVICE

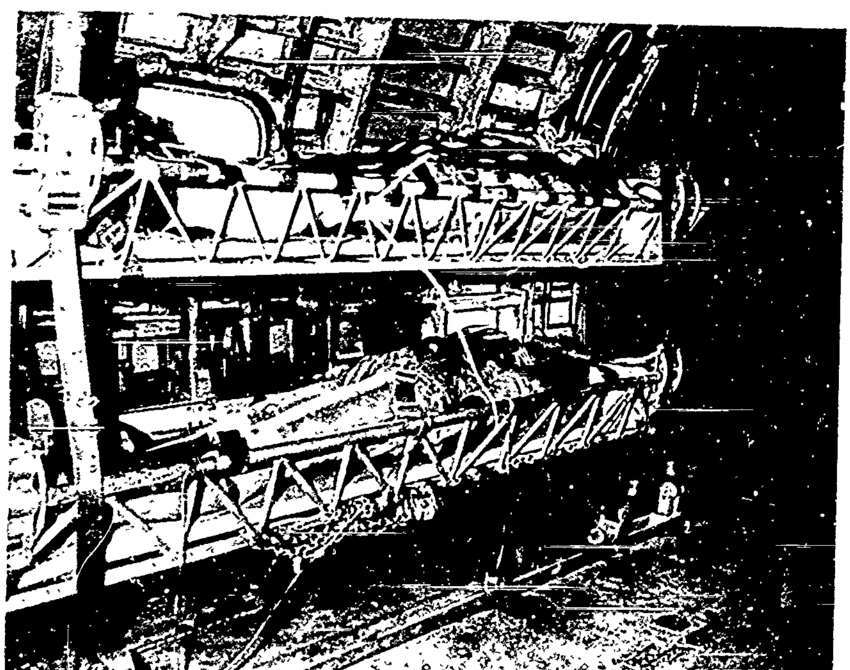


FIG. 87 OVERALL VIEW OF LITTER EXPERIMENT

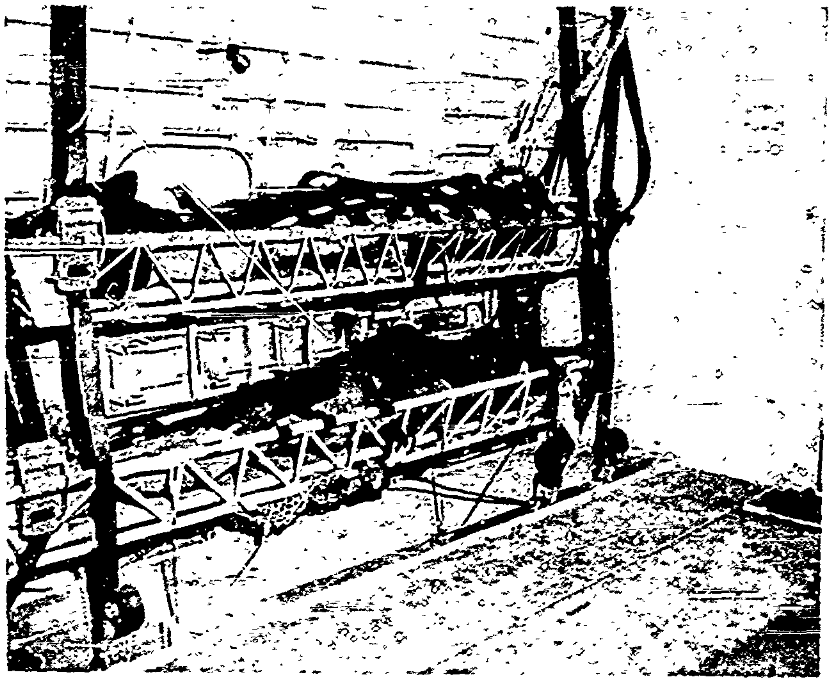


FIG. 88 SIDE VIEW OF LITTERS, POSTCRASH

FIG. 89 RIGHT SIDE OF GALLEY, POST-CRASH, VIEW LOOKING AFT

FIG. 90 GALLEY ATTENDANT'S SEAT IN POST-CRASH POSITION

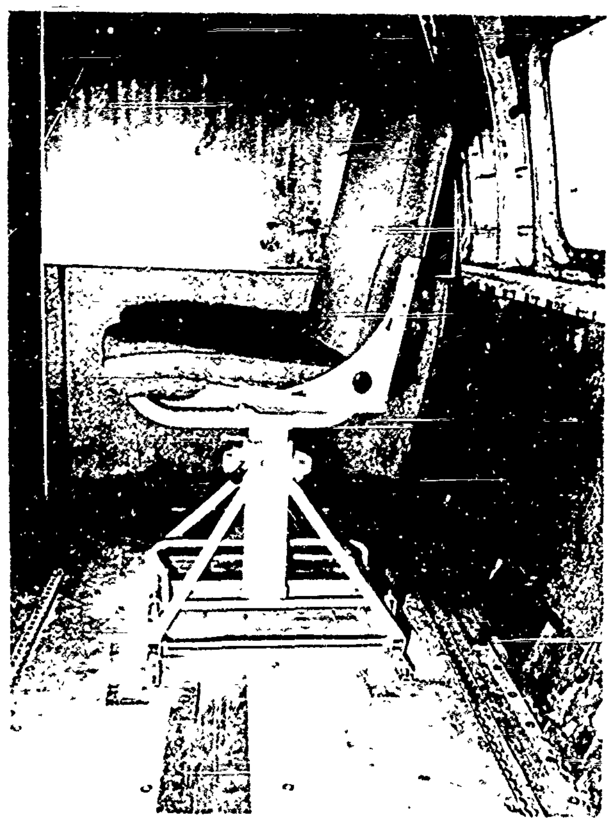


FIG. 91 REAR VIEW OF SIDE FACING FLIGHT ENGINEER'S SEAT

FIG. 92 DUMMY OCCUPANT OF SIDE FACING SEAT

FIG. 93 SIDE FACING SEAT OCCUPANT, POSTCRASH POSITION, VIEWED FROM AISLE

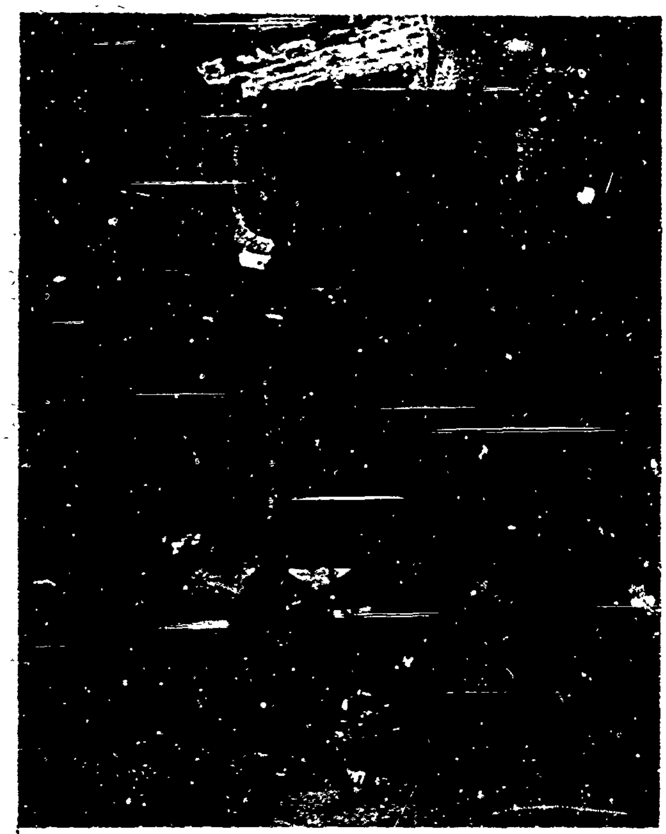


FIG. 94 SIDE FACING SEAT AFTER REMOVAL OF DUMMY, SHOWING DOWNWARD DEFORMATION OF SEAT PAN FORWARD EDGE

FIG. 95 DUMMY OCCUPANTS OF AFT CONSTELLATION SEAT EXPERIMENT

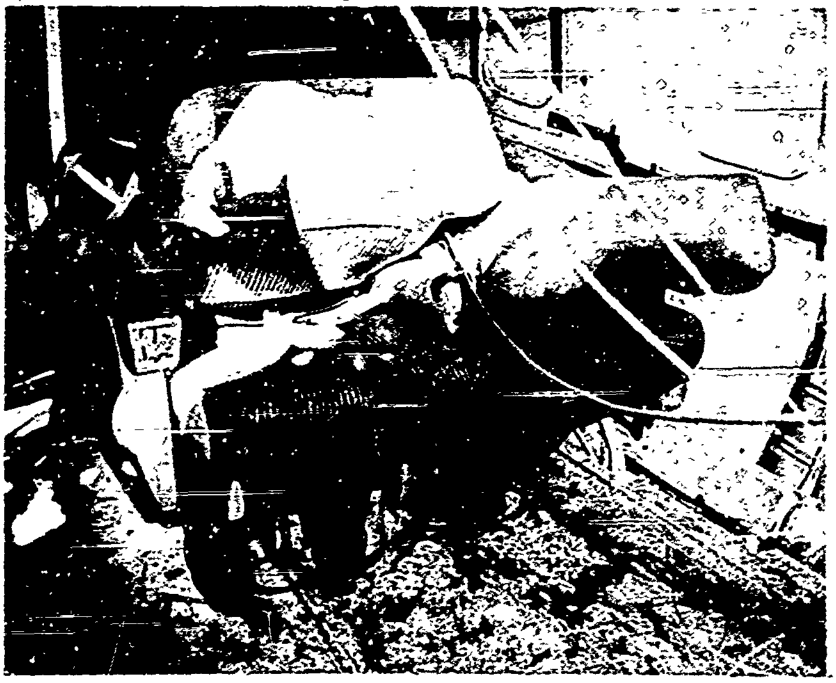


FIG. 96 POSTCRASH VIEW OF AFT CONSTELLATION SEATS SHOWING JAMMED POSITION OF DUMMY LEGS AND FORWARD SEAT BACK BREAKOVER

FIG. 97 VIEW SHOWING UPPER BODY CONTACT WITH FORWARD SEAT BACKS OF AFT CONSTELLATION SEAT EXPERIMENT

FIG. 98 OVERALL VIEW OF STEWARDESS SEAT AND AFT CONSTELLATION SEAT EXPERIMENTS

FIG. 99 STANDARD FOLDING STEWARDESS SEAT EXPERIMENT

FIG. 100 DUMMY SEATED IN FOLDING STEWARDESS SEAT WITH RESTRAINT HARNESS INSTALLED

FIG. 101 OVERALL POSTCRASH VIEW OF STEWARDESS SEAT EXPERIMENT

FIG. 102 VIEW LOOKING AFT, SHOWING STEWARDESS' SEAT AFTER REMOVAL OF DUMMY, POSTCRASH

FIG. 103 DOLL DUMMY SUBJECT OF LOWER BABY BASSINET EXPERIMENT

FIG. 104 SECOND BABY BASSINET EXPERIMENT IN WALL MOUNTED TEST POSITION

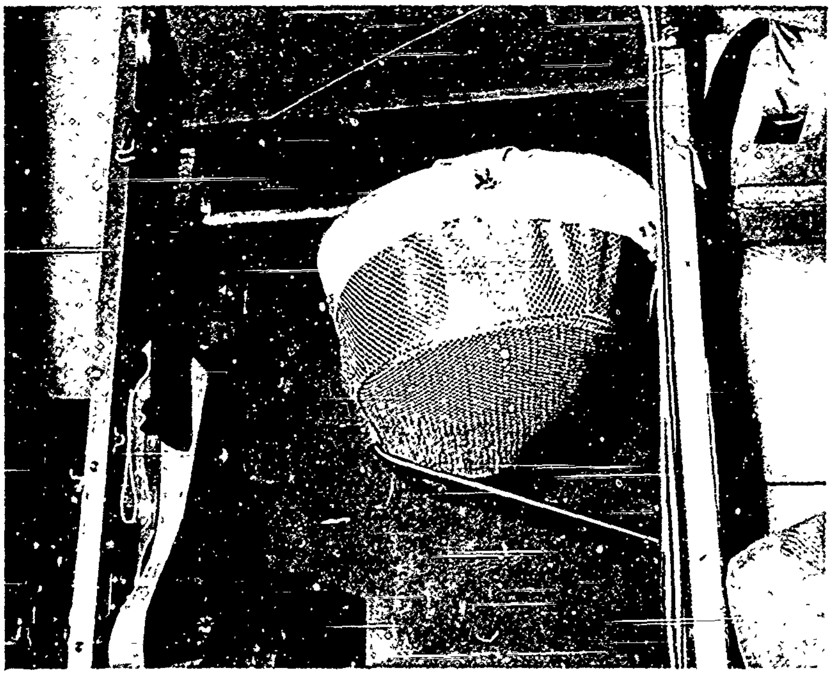


FIG. 105 POSTCRASH VIEW OF WALL MOUNTED BABY BASSINET EXPERIMENT

FIG. 106 POSTCRASH VIEW OF COCKPIT CRASH LOCATOR BEACON EJECTION DEVICE. NOTICE THE DAMAGE WHICH OCCURRED WHEN THE AFT END OF THE EJECTOR TUBE BLEW OUT.

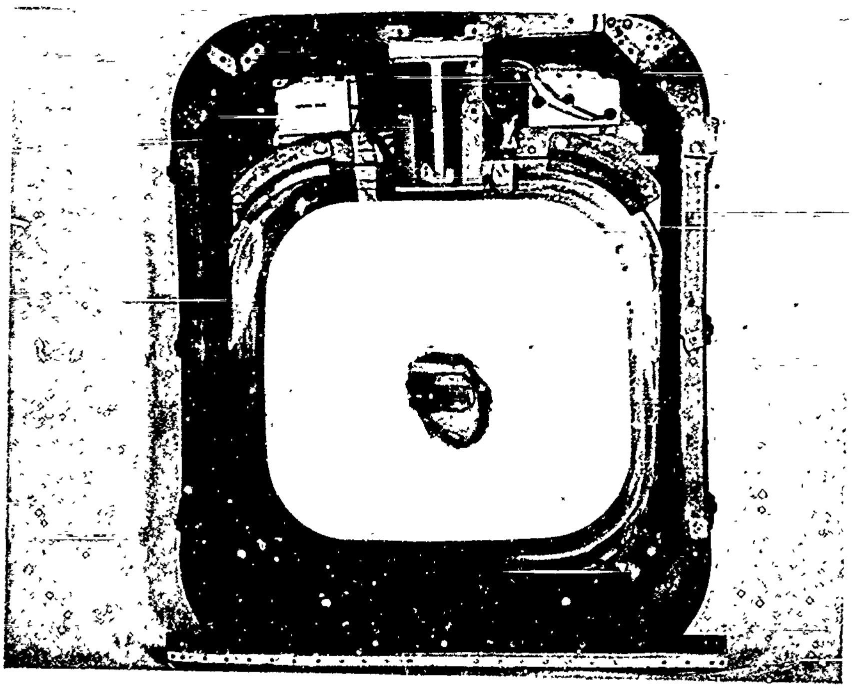


FIG. 107 FLASHING STROBE LIGHT EXPERIMENT INSTALLED IN EMERGENCY EXIT WINDOW

FIG. 108 EMERGENCY ESCAPE LIGHTS INSTALLED AROUND WINDOW

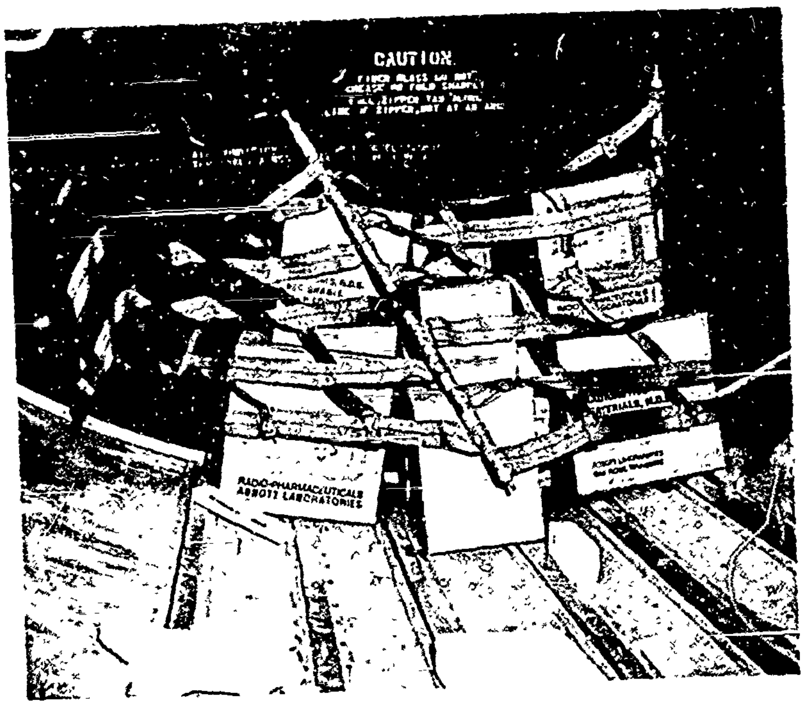


FIG. 109 STORAGE OF SHIPPING CONTAINERS FOR RADIOACTIVE MATERIALS PRIOR TO THE CRASH

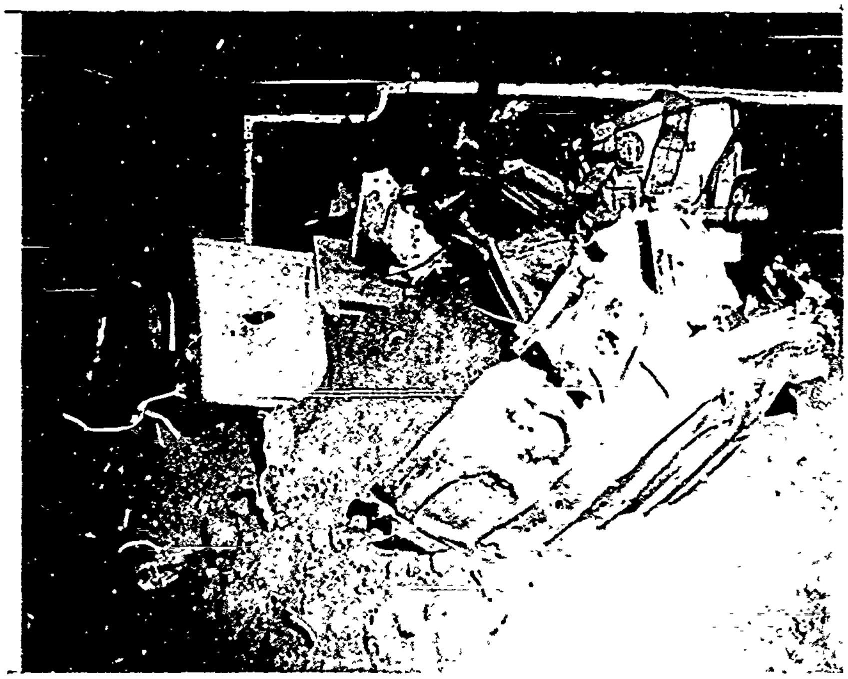


FIG. 110 POSTCRASH VIEW OF RADIOACTIVE SHIPPING CONTAINERS IN FORWARD CARGO COMPARTMENT

APPENDIX 1
PARTICIPATING ORGANIZATIONS

U. S. Navy
Aerospace Crew Equipment Laboratory
Naval Air Engineering Center
Philadelphia, Pennsylvania

U. S. Navy
Engineering Development Laboratory
Naval Air Development Center
Johnsville, Pennsylvania

U. S. Navy
Service Test Division
Naval Air Test Center
Patuxent River, Maryland

U. S. Air Force
Air Force Flight Dynamics Laboratory (FDFR)
Wright Patterson Air Force Base, Ohio

U. S. Army Aviation Materiel Laboratories
Fort Eustis, Virginia

Federal Aviation Agency
Survival Equipment Section
Civil Aeromedical Research Institute
Aeronautical Center
Oklahoma City, Oklahoma

Federal Aviation Agency
Aircraft Branch (RD-741)
National Aviation Facilities Experimental Center
Atlantic City, New Jersey

BLANK PAGE

APPENDIX 2
WEIGHT AND BALANCE BREAKDOWN, L-1649 CONSTELLATION

ITEMS REMOVED

ITEM	WEIGHT	STATION	MOMENT
Fuel Boost Pumps	86	745	65,550
D. C. Generators	127	601	76,300
ADF Receivers	98	278	27,220
ADF Mounts	10	278	2,780
Marker Beacon Receiver	13	277	3,620
Glide Slope Receiver	18	278	5,000
VOR Receivers	53	275	14,570
VOR Power Units	16	272	4,350
VOR Servo Amplifers	5	252	1,260
Radio Altimeter	12	498	5,980
Terrain Clearance	15	498	7,480
Weather Radar T/R	43	138	5,930
Radar Accessory Unit	32	280	8,960
Radar Antenna	26	114	2,960
Radar Indicator	13	190	2,470
H.F. Transmitter	45	253	11,390
H.F. Power Unit	34	252	8,560
H.F. Receiver	33	252	8,320
H.F. Transmitter	45	241	10,840
H.F. Power Unit	34	252	8,560
H.F. Receiver	33	252	8,320
VHF Transmitter	29	272	7,880
VHF Receiver	23	272	6,250
Interphone Amplifier	7	236	1,650
Amspeakers	8	208	1,670
Loudspeakers	29	761	22,050
Autopilot Amplifier	42	251	10,540
Autopilot Power Unit	8	252	1,020
Engine Analyzer Amplifier	16	243	3,880
Engine Analyzer Indicator	3	216	650
Cabin Heater	48	820	39,350
Recirculating Fans	60	853	51,200
Flight Station Extinguisher	7	216	1,510
Fwd. Closet Extinguisher	7	427	2,990
Galley Extinguisher	7	987	6,900
Landing Flares	35	1280	44,800
Hand Axe	3	205	615

ITEM	WEIGHT	STATION	MOMENT
First Aid Kit	3	463	1,390
First Aid Kit	3	1007	3,020
Evacuation Rope	4	467	1,870
Oxygen Cylinders	125	215	26,900
Oxygen Bottle	17	248	4,220
Passenger Mask	13	1165	15,150
Passenger Mask	2	498	995
Crew Masks	13	224	2,910
Crew Masks	5	224	1,120
Pilots' Seats	87	190	16,520
Flight Engineer's Seat	26	226	5,880
Observer's Seat	36	222	7,990
Navigator's Seat	36	309	11,110
Toilets	124	490	60,800
Wash Basin Cabinet	22	502	11,050
Dispenser Cabinet	13	497	6,460
Drinking Water Cabinet	7	502	3,515
Mirror	17	508	8,650
Assist Handles	2	468	935
Serving Tray	3	865	2,595
Window Curtains	85	679	57,700
Prop Plane Curtains	4	489	1,960
Entrance Closet Curtains	2	972	1,945
Aft Closet Curtain	11	1149	12,650
Doorway Curtain	6	1178	7,060
Hat Rack Curtain	6	1134	6,810
Doorway Curtain	7	661	4,630
Relief Crew Curtain	10	306	3,060
Navigator Curtain	7	318	2,220
Carpet, Fwd.	91	378	35,400
Main Cabin Carpet	140	643	90,000
Lounge Carpet	41	878	36,000
Aft Cabin Carpet	57	1093	62,300
Overhead Luggage Rack	200	696	139,200
Station 260 Door	43	260	11,200
Station 344 Partitions	75	344	25,800
Station 467.5 Partition	71	468	33,200
Fwd. Lav. Partition	65	487	31,650
Station 508.5 Partition	50	509	25,450
Station 661 Partition	64	661	42,300
Station 837 Partition	43	837	36,000

ITEM		WEIGHT	STATION		MOMENT
Nesa Inverter		62	481		29,200
Sleeping Berths		280	744		208,200
Ladder		9	1172		10,450
Berth Structure		106	746		79,200
De-Icing Alcohol		264	684		180,500
Passenger Seats					
One Triple Seat		53	375		20,620
One Double Seat		54	375		20,250
One Triple Seat		78	412		32,150
One Double Seat		55	412		22,600
Four Triple Seats		313	529		165,500
Five Double Seats		284	587		166,800
One Triple Seat		77	645		49,650
Twelve Double Seats		979	796		780,000
Three Double Seats		243	1092		255,500
Two Single Seats		81	1076		87,100
TOTAL	(-)	4895		(-)	3,530,850
Crew Members Not Aboard	(-)	1110		(-)	427,250
Total Weight Not Aboard	(-)	6005			
Total Reduction of Moment				(-)	3,958,100

ITEMS ADDED

ITEM	WEIGHT	STATION	MOMENT
Pilot's Seat	50	190	9,500
Copilot's Seat	50	190	9,500
Flight Engineer's Seat	50	320	16,000
L-1649 Seat	55	412	22,650
L-1649 Seat	55	446	24,550
L-1649 Seat	55	480	26,400
Cargo Experiment	9000	548	4,932,000
Forward Facing Triple Passenger Seat	85	665	56,500
Forward Facing Triple Passenger Seat	100	699	69,900
Rear Facing Triple Seat	90	745	67,000
Rear Facing Double Seat	60	779	46,700
Litter	150	880	132,000
Life Raft	50	1015	50,750
Side Facing Seat	50	1042	52,100
L-1649 Seat	81	1112	89,000
L-1649 Seat	81	1146	92,700
Pilot Dummy	200	190	38,000
Copilot Dummy	200	190	38,000
Flight Engineer Dummy	200	320	64,000
Dummy	200	446	89,200
Dummy	200	446	90,200
Dummy	200	480	96,000
Child Dummy	35	480	16,800
Dummy	200	745	149,000
Dummy	200	745	149,000
Dummy	200	745	149,000
Dummy	200	779	155,800
Dummy	200	779	155,800
Dummy	200	880	176,000
Dummy	200	880	176,000
Dummy	200	1042	208,400
Dummy	200	1146	229,200
Dummy	200	1146	229,200
Dummy	130	1196	155,300
Dummy	170	669	118,800
Dummy	170	699	118,800
Dummy	170	699	118,800

ITEM	WEIGHT	STATION	MOMENT
Instrumentation Wiring	550	720	396,000
Instrumentation Package	205	740	151,500
Cameras, Lights, Mounts	670	720	482,000
Batteries	685	720	493,000
Fuel	48900		34,710,000
Ballast	3360	1360	4,569,600
Galley Cargo	440	960	422,400
Total Weight Added	68747		
Total Increase in Moment			49,642,050

COMPUTATIONS

Operating Weight	95,279	
Moment at Operating Weight		64,288,274
Weight Removed	(-) 4,895	
Moment Reduction		(-) 3,958,100
Weight Empty	90,384	
Moment Empty		60,330,174
Weight Added	68,747	
Moment Increase		49,642,050
Weight at Brakes Release	159,131	
Moment at Brakes Release		109,972,224

C.G. Location Fuselage Station 690
(This location is approximately 6 inches forward of the aft c.g. limit and is realistic for a maximum gross weight takeoff condition.)

BLANK PAGE

APPENDIX 3
INSTRUMENTATION SUMMARY

EXPERIMENT	LOCATION	MEASUREMENT	RANGE	TRANSDUCER
1. Overall Acceleration Environment (Fuselage Floor Accelerations)	F.S. 195	Longitudinal	± 200G	Statham A5-200-350
		Vertical	± 100G	Statham A5-100-350
		Lateral	± 50G	Statham A5-50-350
	F.S. 460	Longitudinal	± 100G	Statham A5-100-350
		Vertical	± 100G	Statham A5-100-350
	F.S. 685 (c. g.)	Longitudinal	± 100G	Statham A5-100-350
		Vertical	± 100G	Statham A5-100-350
		Lateral	± 20G	Statham A6-20-350
	F.S. 923	Longitudinal	± 100G	Statham A5-100-350
		Vertical	± 100G	Statham A5-100-350
	F.S. 1165	Longitudinal	± 100G	Statham A5-100-350
		Vertical	± 100G	Statham A5-100-350
		Lateral	± 20G	Statham A6-20-350
2. Wing Fuel Spillage Studies	W.S. 140 (left)	Wing Accel. Longitudinal	± 100G	Statham A5-100-350
		Wing Fuel Pressure	0-100 psia	CEC 4-326-001
	W.S. 317 (left)	Wing Accel. Longitudinal	± 200G	Statham A5-200-350
		Wing Accel. Vertical	± 100G	Statham A5-100-350
		Wing Fuel Pressure	0-100 psia	CEC 4-326-001

EXPERIMENT	LOCATION	MEASUREMENT	RANGE	TRANSDUCER
	W.S. 591 (left)	Wing Accel. Longitudinal	± 200G	Statham A5-200-350
		Wing Accel. Vertical	± 100G	Statham A5-100-350
	W.S. 140 (right)	Wing Accel. Longitudinal	± 100G	Statham A5-100-350
		Wing Fuel Pressure	0-100 psia	CEC 4-326-001
	W.S. 317 (right)	Wing Accel. Longitudinal	± 100G	Statham A5-100-350
		Wing Accel. Vertical	± 100G	Statham A5-100-350
		Wing Fuel Pressure	0-100 psia	CEC 4-326-001
	W.S. 591 (right)	Wing Accel. Longitudinal	± 200G	Statham A5-200-350
		Wing Accel. Vertical	± 100G	Statham A5-100-350
3. Forward Cabin Forward Facing High Density Seating Experiments	F.S. 435	Seat 3 Aisle Side, Passenger Pelvic Accel. Longitudinal	± 100G	Statham A5-100-350
		Seat 3 Aisle Side Passenger Pelvic Accel. Vertical	± 100G	Statham A5-100-350
		Seat 3 Aisle Side, Lap Belt Load	0-4000 lb	Strain Link

EXPERIMENT	LOCATION	MEASUREMENT	RANGE	TRANSDUCER
	F.S. 467	Seat 5, Wall Side Passenger Pelvic Accel. Longitudinal	± 100G	Statham A5-100-350
		Seat 5, Wall Side Passenger Pelvic Accel. Vertical	± 100G	Statham A5-100-350
	F.S. 435	Seat 3, Accel. Longitudinal	± 100G	Statham A5-100-350
		Seat 3, Accel. Vertical	± 100G	Statham A5-100-350
4. Forward Cargo Restraint Experiment	F.S. 485	Vertical Load, Forward Left Side	+40,000 lb	Strain Link
		Vertical Load, Forward Right Side	+40,000 lb	Strain Link
	F.S. 551	Vertical Load, Aft	+40,000 lb	Strain Link
	F.S. 500	Lateral Load	+40,000 lb	Strain Link
	F.S. 558	Longitudinal Load Left Side	+40,000 lb	Strain Link
		Longitudinal Load Right Side	+40,000 lb	Strain Link
5. Aft Cargo Restraint Experiment	F.S. 558	Vertical Load Forward Left Side	+40,000 lb	Strain Link
		Vertical Load Forward Right Side	+40,000 lb	Strain Link
	F.S. 624	Vertical Load, Aft	+40,000 lb	Strain Link

EXPERIMENT	LOCATION	MEASUREMENT	RANGE	TRANSDUCER
	F.S. 578	Lateral Load	±40,000 lb	Strain Link
	F.S. 631	Longitudinal Load Left Side	±40,000 lb	Strain Link
		Longitudinal Load Right Side	±40,000 lb	Strain Link
6. Mid Cabin Forward Facing ting and g Kick-up Experiments	F.S. 664	Seat 6, Aft Inboard Vertical Leg Load	±10,000 lb	Strain Link
		Seat 6, Aft Outboard Vertical Leg Load	±10,000 lb	Strain Link
	F.S. 698	Seat 8, Accel. Longitudinal	± 100G	Statham A5-100-350
		Seat 8, Accel. Vertical	± 100G	Statham A5-100-350
		Seat 8, Forward Outboard Vertical Leg Load	±10,000 lb	Strain Link
		Seat 8, Forward Inboard Vertical Leg Load	±10,000 lb	Strain Link
		Seat 8, Aft Outboard Vertical Leg Load	±10,000 lb	Strain Link
		Seat 8, Aft Inboard Vertical Leg Load	±10,000 lb	Strain Link
		Seat 8, Middle Passenger Pelvic Accel. Longitudinal	± 100G	Statham A5-100-350

EXPERIMENT	LOCATION	MEASUREMENT	RANGE	TRANSDUCER
	F.S. 698	Seat 8, Middle Passenger Pelvic Accel. Vertical	± 100G	Statham A5-100-350
		Seat 8, Middle Passenger Lap Belt Load	0-4000 lb	Strain Link
7. Mid Cabin Rearward Facing Seating Experiments	F.S. 738	Seat 7, Forward Inboard Vertical Leg Load	±10,000 lb	Strain Link
		Seat 7, Forward Ouboard Vertical Leg Load	±10,000 lb	Strain Link
		Seat 7, Aft Inboard Vertical Leg Load	±10,000 lb	Strain Link
		Seat 7, Aft Outboard Vertical Leg Load	±10,000 lb	Strain Link
		Seat 7, Accel. Longitudinal	± 50G	Statham A5-50-350
		Seat 7, Accel. Vertical	± 50G	Statham A5-50-350
		Seat 7, Aisle Side Passenger Accel. Longitudinal	± 100G	Statham A5-100-350
		Seat 7, Aisle Side Passenger Accel. Vertical	± 100G	Statham A5-100-350
		Seat 7, Aisle Side Passenger Lap Belt Load	0-5000 lb	Strain Link

EXPERIMENT	LOCATION	MEASUREMENT	RANGE	TRANSDUCER
8. Litter Experiment	F.S. 820-923	Bottom Litter Patient Pelvic Accel. Longitudinal	± 100G	Statham A6-100-350
		Bottom Litter Patient Pelvic Accel. Vertical	± 50G	Statham A6-50-350
		Top Litter Patient Pelvic Accel. Longitudinal	± 100G	Statham A5-100-350
		Top Litter Patient Pelvic Accel. Vertical	± 50G	Statham A5-50-350
9. Side Facing Seating Experiment	F.S. 1038	Seat 10, Lap Belt Load, Aft Side	0-4000 lb	Strain Link
		Seat 10, Lap Belt Load, Forward Side	0-4000 lb	Strain Link
10. Aft Cabin Forward Facing Seating Experiment	F.S. 1102	Seat 13, Accel. Longitudinal	± 100G	Statham A6-100-350
		Seat 13, Accel. Vertical	± 100G	Statham A6-100-350
		Seat 13, Aisle Side Passenger Pelvic Accel. Longitudinal	± 100G	Statham A5-100-350
		Seat 13, Aisle Side Passenger Pelvic Accel. Vertical	± 100G	Statham A5-100-350
		Seat 13, Aisle Side Passenger, Lap Belt Load	0-4000 lb	Strain Link

APPENDIX 4
REDUNDANT INSTRUMENTATION

ALL AMERICAN ENGINEERING INSTRUMENTATION

The following measurements were recorded in the 1649 Super Constellation by a secondary instrumentation system:

1. Left Wing Acceleration (inboard) - Longitudinal
2. Left Wing Acceleration (inboard) - Vertical
3. Left Wing Acceleration (mid section) - Longitudinal
4. Left Wing Acceleration (mid section) - Vertical
5. Left Wing Acceleration (mid section) - Lateral
6. Left Wing Acceleration (outboard) - Longitudinal
7. Left Wing Acceleration (outboard) - Vertical
8. Right Wing Acceleration (inboard) - Longitudinal
9. Right Wing Acceleration (inboard) - Vertical
10. Right Wing Acceleration (mid section) - Longitudinal
11. Right Wing Acceleration (mid section) - Vertical
12. Right Wing Acceleration (mid section) - Lateral
13. Right Wing Acceleration (outboard) - Longitudinal
14. Right Wing Acceleration (outboard) - Vertical
15. Floor Acceleration (FS 460) - Longitudinal
16. Floor Acceleration (FS 460) - Vertical
17. Floor Acceleration (cg) - Longitudinal
18. Floor Acceleration (cg) - Vertical

19. Floor Acceleration (cg) - Lateral
20. Floor Acceleration (FS 923) - Longitudinal
21. Floor Acceleration (FS 923) - Vertical
22. Floor Acceleration (FS 1160) - Longitudinal
23. Floor Acceleration (FS 1160) - Vertical
24. Floor Acceleration (FS 1160) - Longitudinal
25. Cargo Pallet #1 Load - Vertical (Forward Left Hand)
26. Cargo Pallet #1 Load - Vertical (Forward Right Hand)
27. Cargo Pallet #1 Load - Vertical (Aft)
28. Cargo Pallet #1 Load - Longitudinal (Left Hand)
29. Cargo Pallet #1 Load - Longitudinal (Right Hand)
30. Cargo Pallet #1 Load - Lateral
31. Cargo Pallet #2 Load - Vertical (Forward Left Hand)
32. Cargo Pallet #2 Load - Vertical (Forward Right Hand)
33. Cargo Pallet #2 Load - Vertical (Aft)
34. Cargo Pallet #2 Load - Longitudinal (Left Hand)
35. Cargo Pallet #2 Load - Longitudinal (Right Hand)
36. Cargo Pallet #2 Load - Lateral
37. Seat #9 Acceleration - Longitudinal
38. Seat #9 Passenger Pelvic Acceleration - Longitudinal
39. Seat #9 Passenger Head Acceleration - Longitudinal
40. Time Recorder #1

41. Time Recorder #2

42. Time Recorder #3

NAVAL AEROSPACE CREW EQUIPMENT LABORATORIES INSTRUMENTATION SUMMARY

The Aerospace Crew Equipment Laboratory recorded the data obtained from the cockpit crew seating experiments, using an IRIG radio telemetry system. The data obtained from these experiments included occupant accelerations, lap belt loads, and shoulder harness loads for each seat location.

APPENDIX 5
PHOTOGRAPHIC SUMMARY

LOCATION AND COVERAGE OF ONBOARD CAMERAS

(Type Photosonics 1B, Speed 500 frames per second)

Camera Number	Fuselage Station No.	Coverage
1	260	Cockpit Seat Experiments
2	360	Crew Seat Experiment in Crew Berth Area
3	380	Right Side of Cargo Experiment
4	407	Child Restraint and Forward Constellation Seats
5	638	Left Side of Cargo Experiment
6	642	Forward Facing Passenger Seat Experiment
7	765	Rear Facing Passenger Seat Experiments
8	805	Litter Experiment
9	971	Galley Experiment
10	1030	Attendant Seat Experiment
11	1045	Side Facing Seat Experiment
12	1090	Aft Constellation Seat Experiment
13	695	Legs of Forward Facing Three-Passenger Seat Experiment
14	615	External Coverage of Right Wing
15	615	External Coverage of Left Wing

LOCATION AND COVERAGE OF GROUND CAMERAS

Camera Number	Type	Speed (Frame per sec.)	Distance From Impact (ft.)	Coverage (at impact)
1	Photosonics 1B	500	200	Left wing barrier impact
2	Photosonics 1B	500	200	Initial fuselage impact, left side
3	Traid 200	200	200	Total impact, front view
4	Traid 200	200	200	Total impact, front view
5	Traid 200	200	200	Total impact, front view
6	Photosonics 1B	500	600	Initial impact, right side
7	Photosonics 1B	500	600	Initial impact, right side
8	Photosonics 1B	500	600	Initial impact, right side
9	Traid 200	200	200	Initial impact, right side
10	Traid 200	200	200	Fuselage impact, right side
11	Bell & Howell*	24	2000	Overall, right side
12	Bell & Howell*	64	2000	Overall, right side
13	Photosonics*	500	2000	Overall, right side
14	Bell & Howell*	24	2000	Overall, right side
15	Fairchild Flight Analyser		2000	Aircraft motion, right side
16	D. B. Milliken*	400	1000	Tracking, right side
17	Photosonics 1B*	500	1000	Tracking, right side

* Tracking cameras. - All cameras used color film.

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

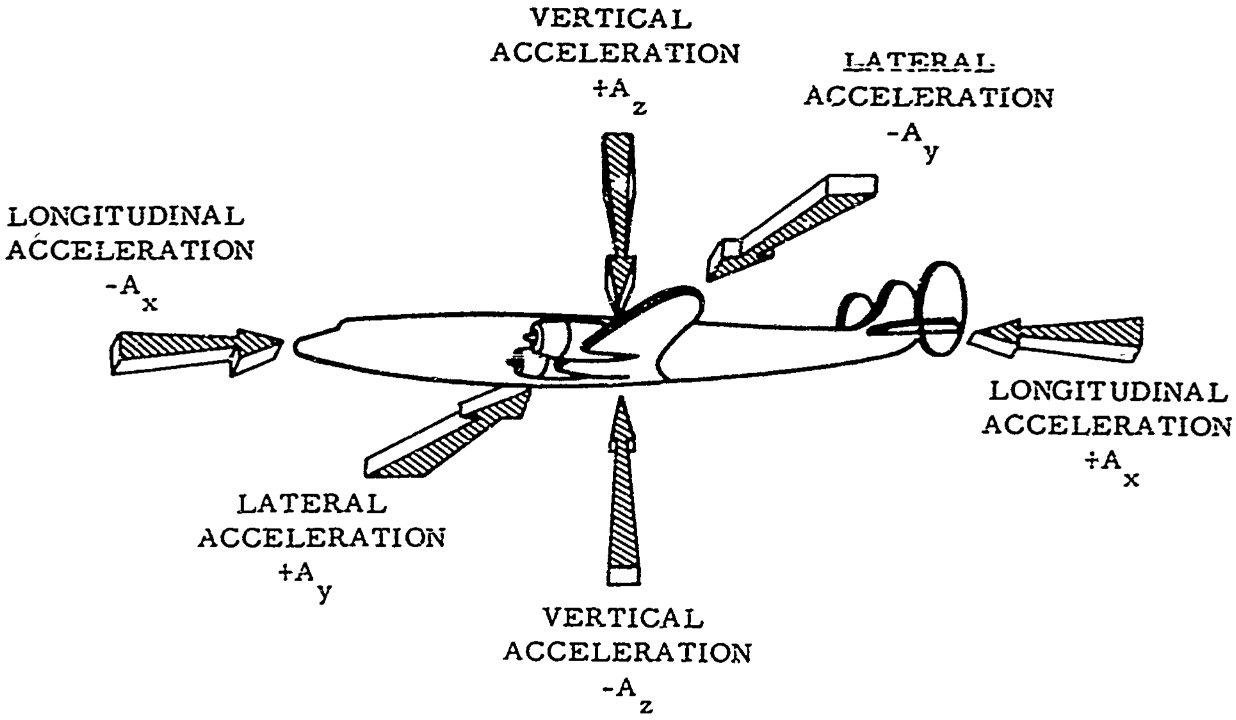
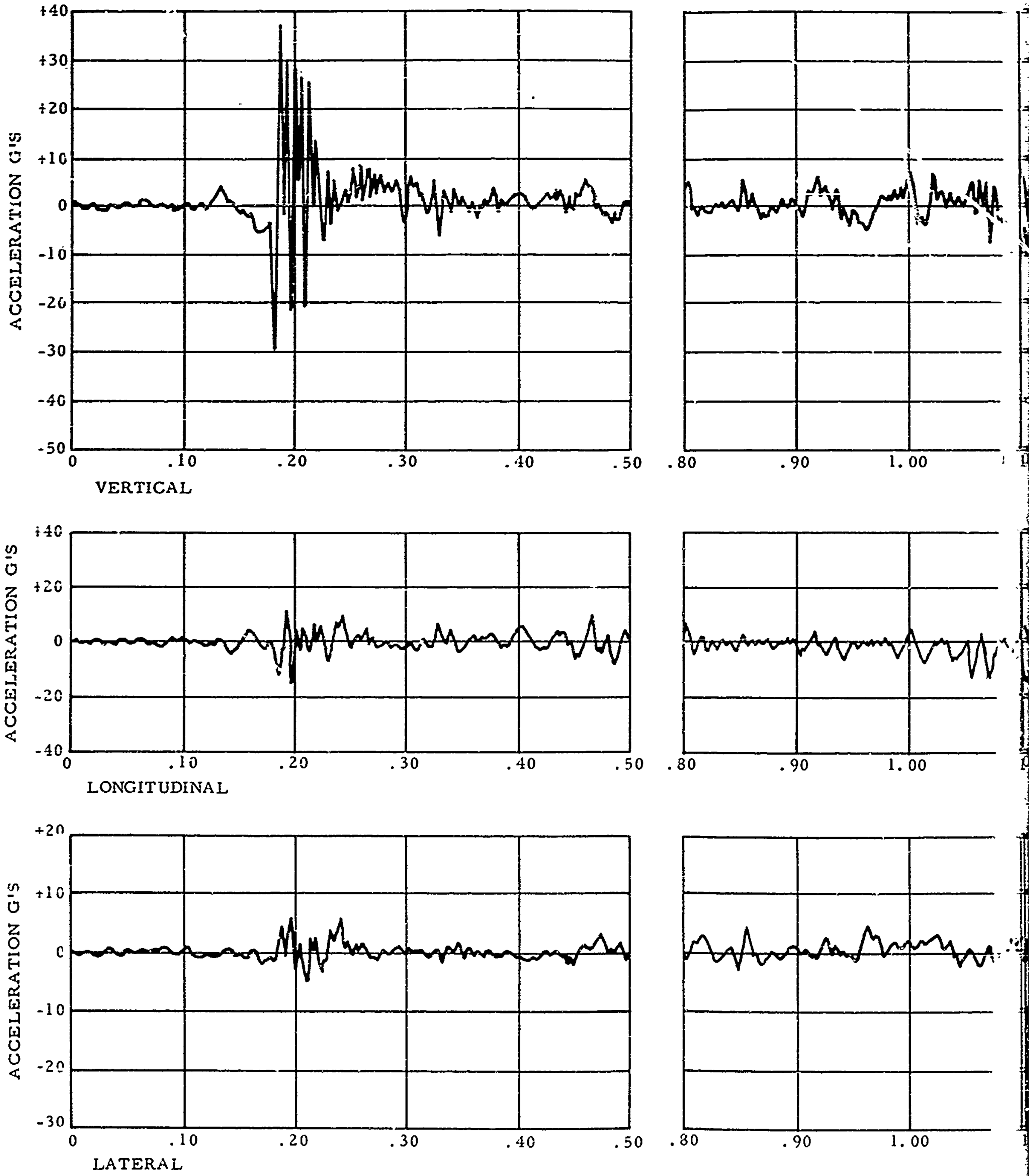
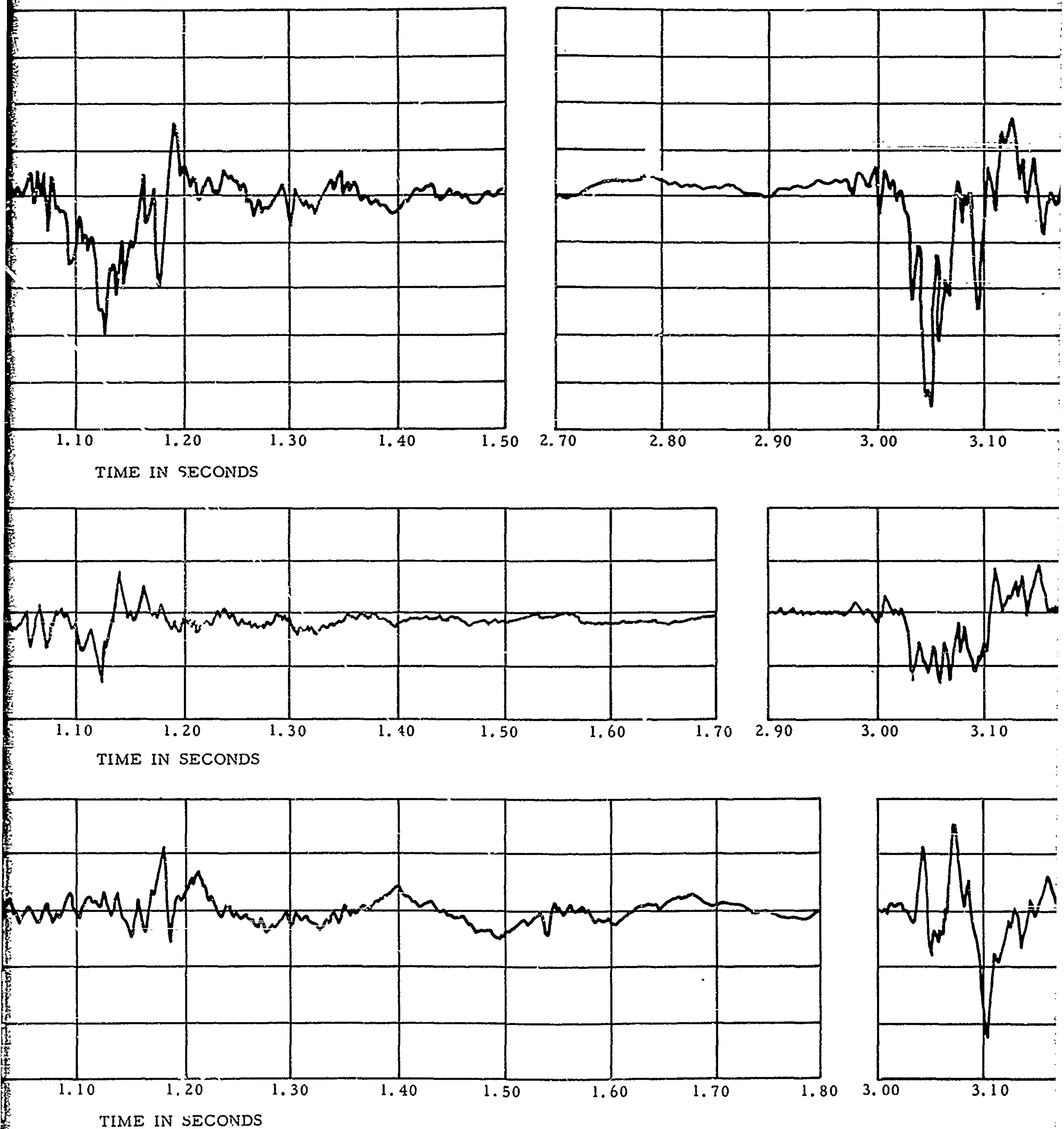


FIG. 6-1 ACCELERATION - SIGN CONVENTION


ACCELERATION G'S
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
0
.10
.20
.30
.40
.50
.80
.90
1.00
VERTICAL
ACCELERATION G'S
+40
+20
0
-20
-40
LONGITUDINAL
ACCELERATION G'S
+20
+10
0
-10
-20
-30
LATERAL

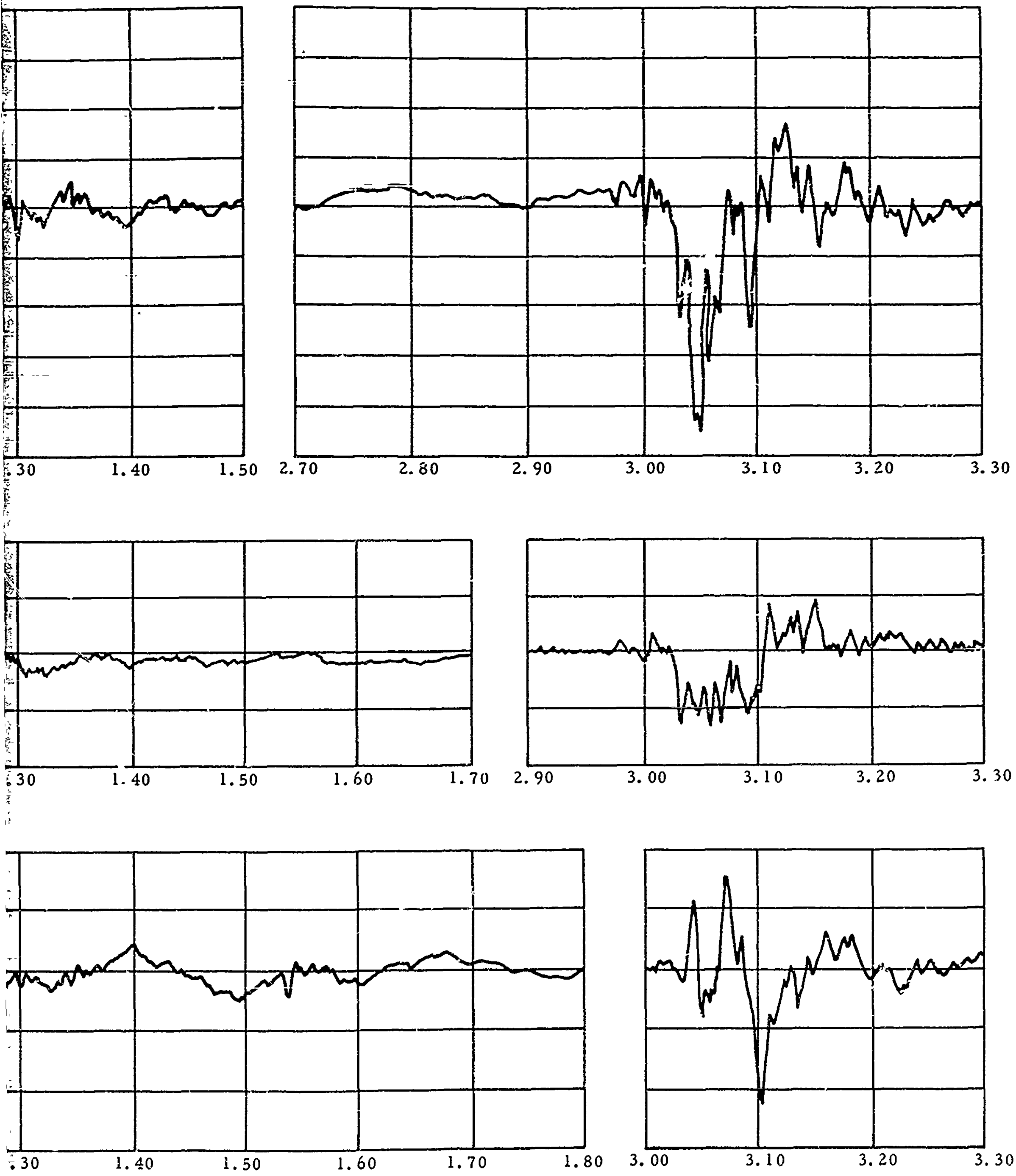
A

FIG. 6 - 2 COCKPIT FLOOR ACCE
FUSELAGE STATION 195



B

FIG. 6 - 2 COCKPIT FLOOR ACCELERATIONS — FUSELAGE STATION 195



B

C

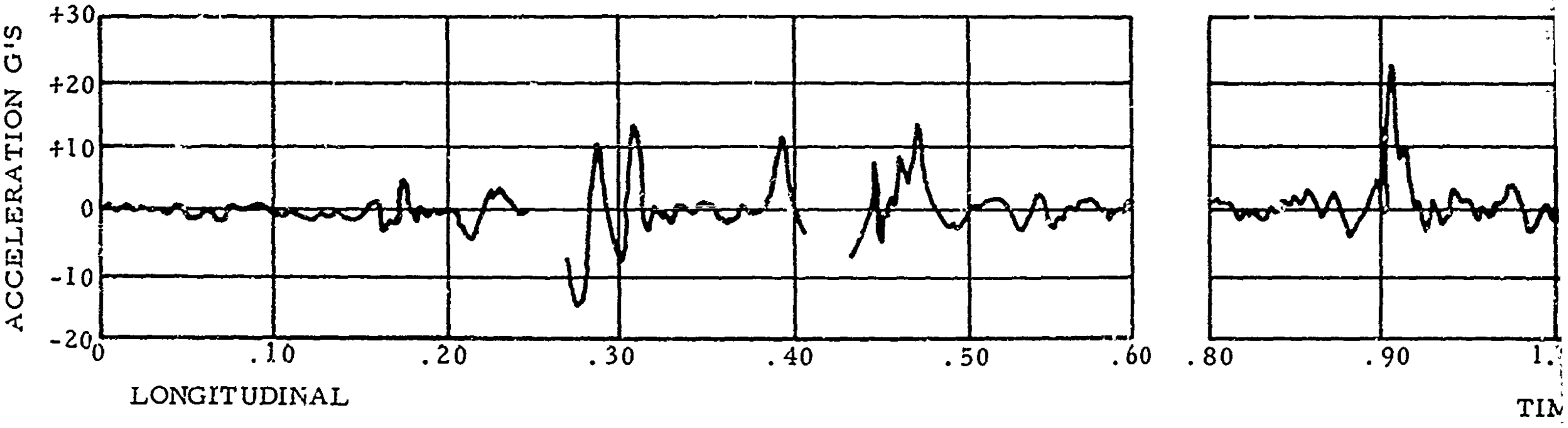

ACCELERATION G'S
+30
+20
+10
0
-10
-20
0
.10
.20
.30
.40
.50
.60
.80
.90
LONGITUDINAL

FIG. 6 - 3 FORW
FUSEI.-

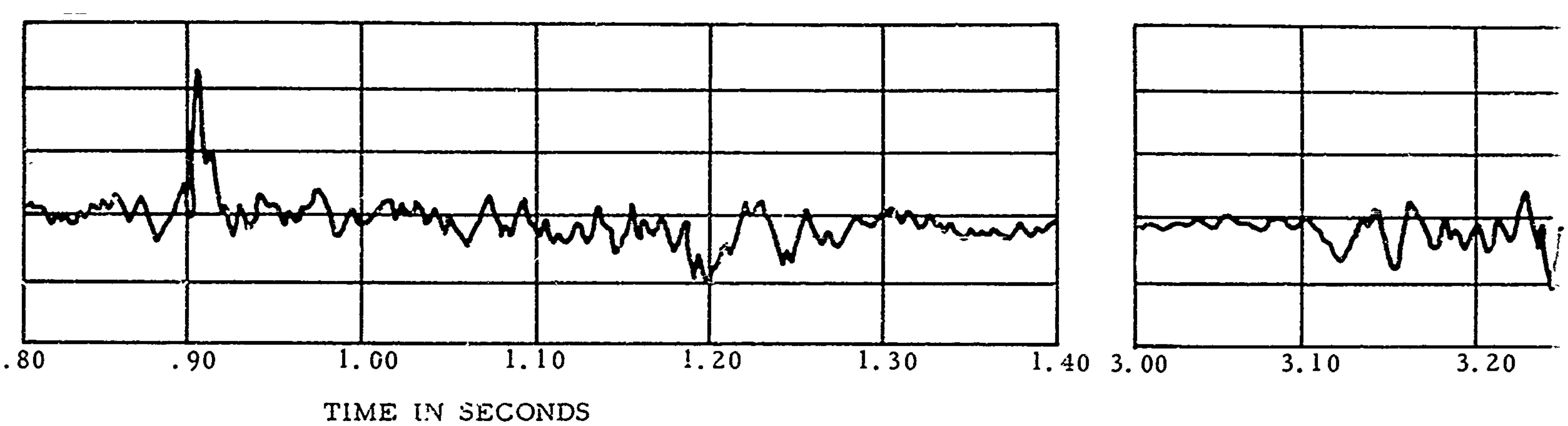
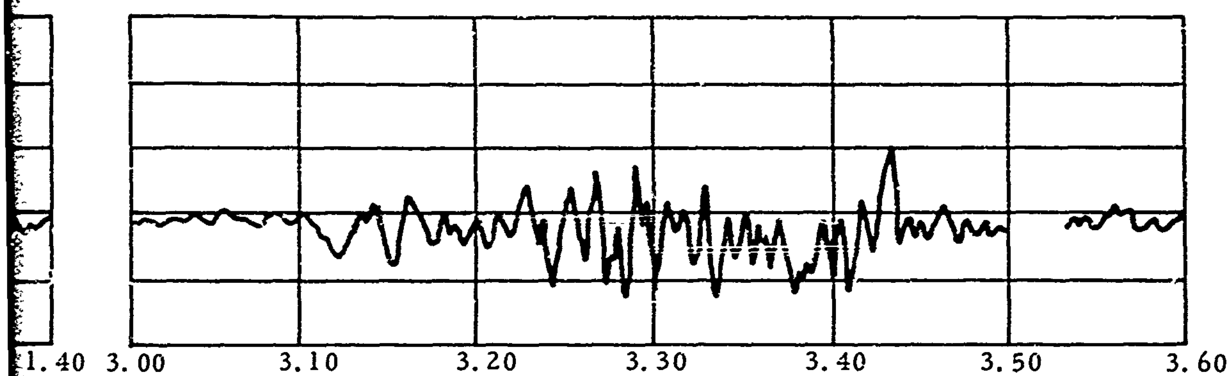


FIG. 6 - 3 FORWARD CABIN FLOOR ACCELERATIONS — FUSELAGE STATION 460



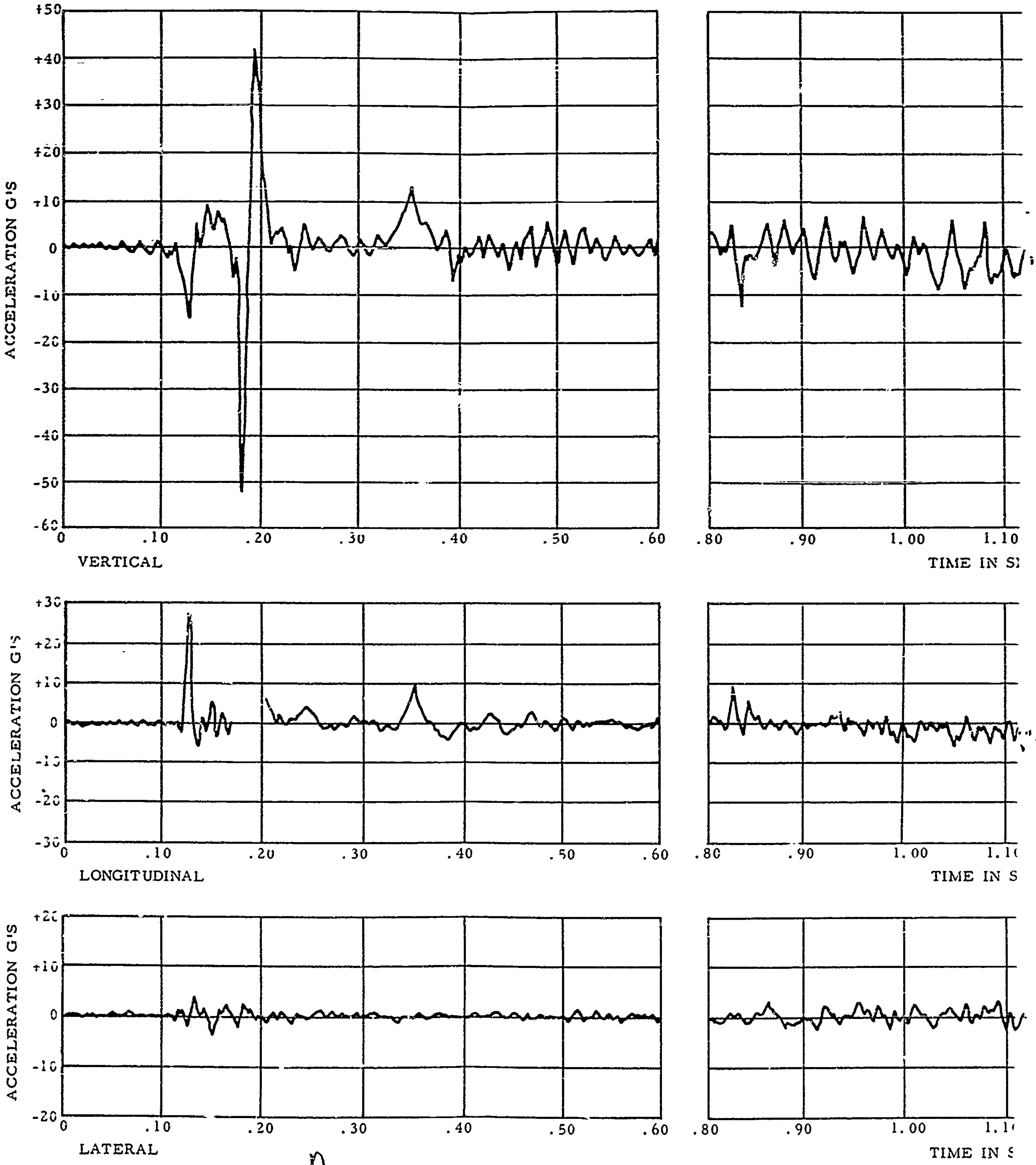
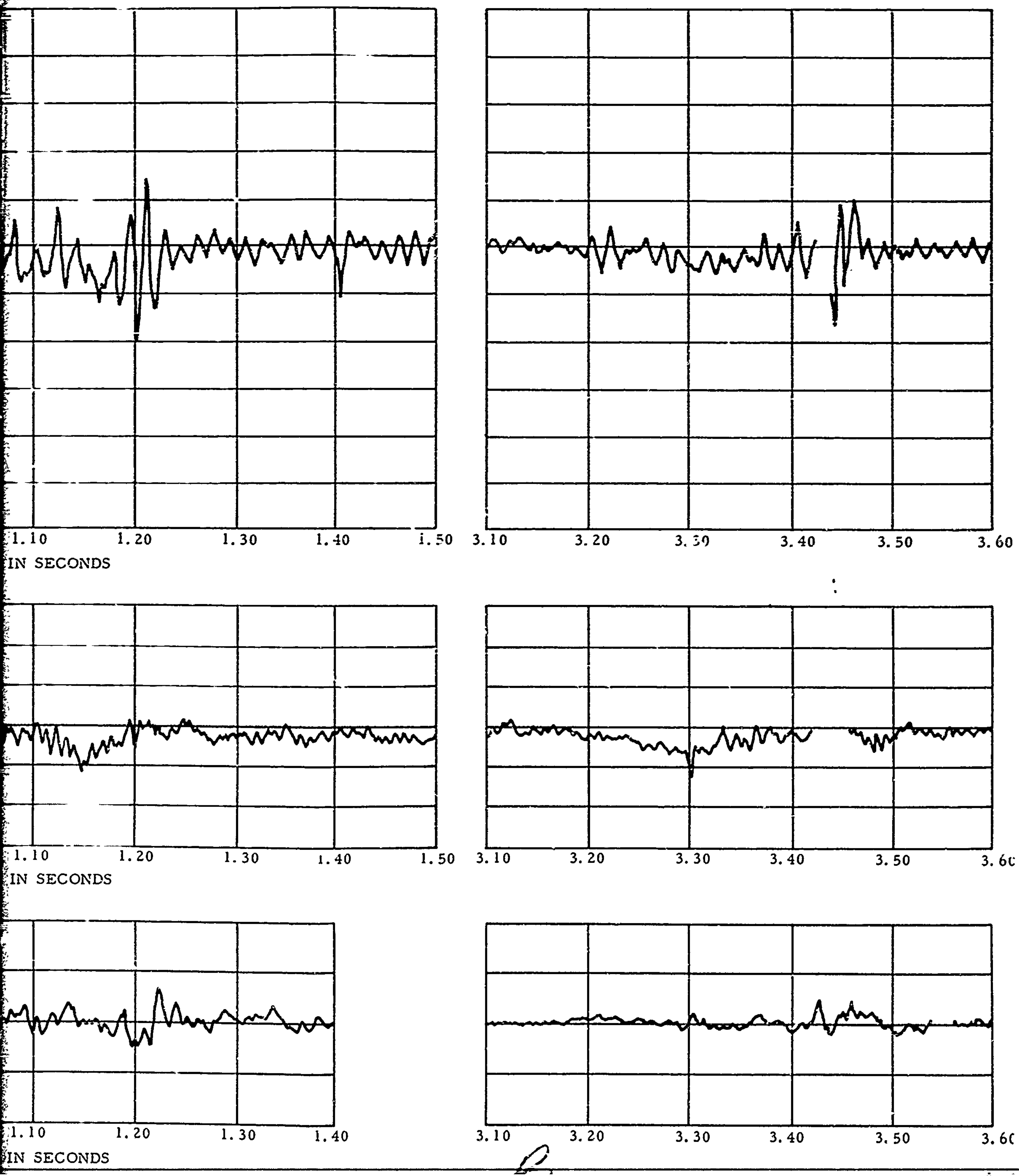
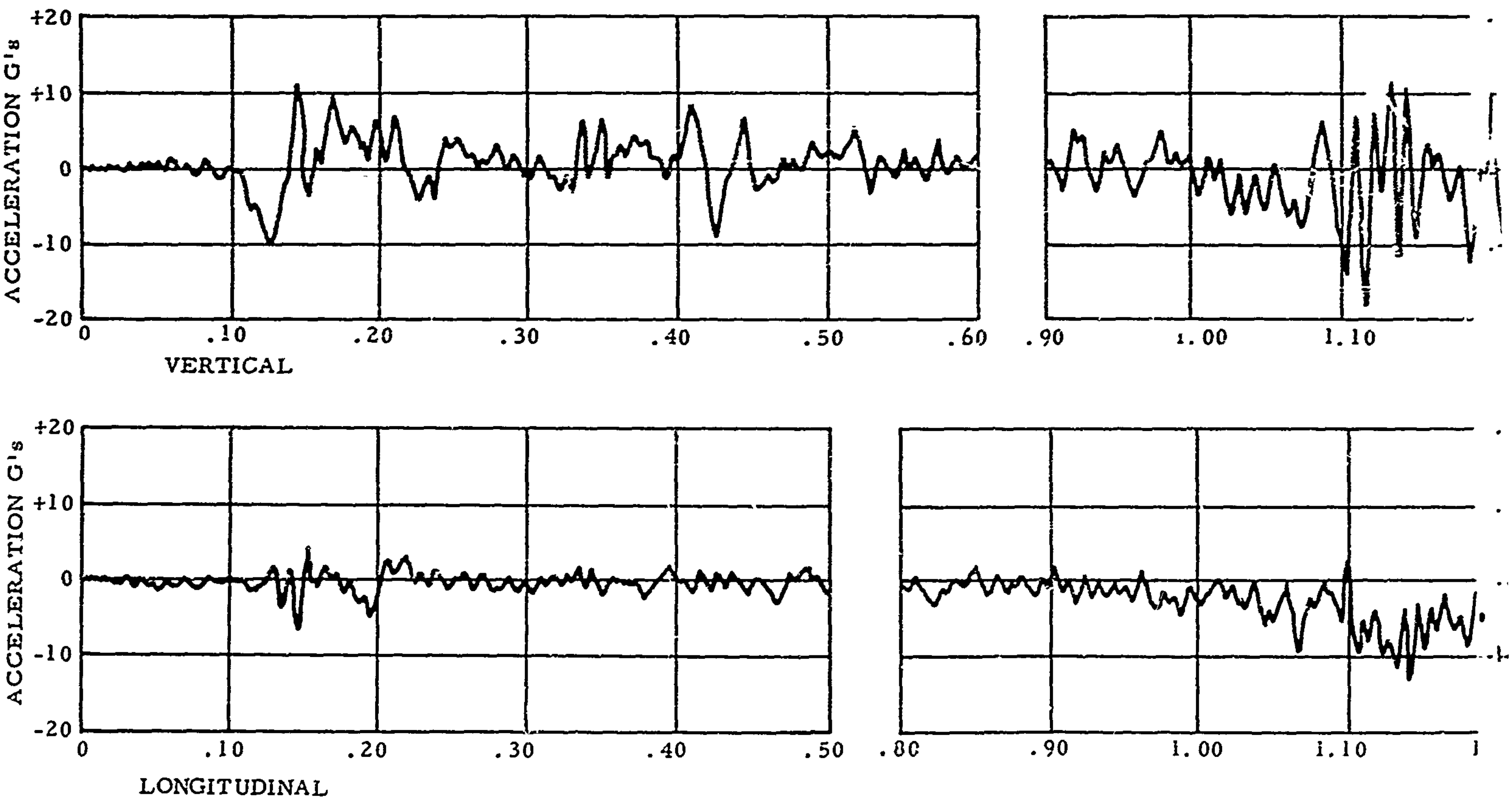

ACCELERATION G'S
+50
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
-60
0
.10
.20
.30
.40
.50
.60
.80
.90
1.00
1.10
VERTICAL
ACCELERATION G'S
0
.10
.20
.30
.40
.50
.60
.80
.90
1.00
LONGITUDINAL
ACCELERATION G'S
+10
0
0
.10
.20
.30
.40
.50
.60
.80
.90
1.00
LATERAL

FIG. 6 .. 4 MID-CABIN FLOOR ACCELERATIONS — FUSELAGE STATION 685 (CG)





ACCELERATION G's
+20
+10
0
-10
-20
0
.10
.20
.30
.40
.50
.60
.90
1.00
1.10
VERTICAL
ACCELERATION G's
+20
+10
0
-10
-20
0
.10
.20
.30
.40
.50
.80
.90
1.00
1.10
LONGITUDINAL

FIG. 6 - 5 REAR CABIN FLOOR ACCELE
FUSELAGE STATION 923

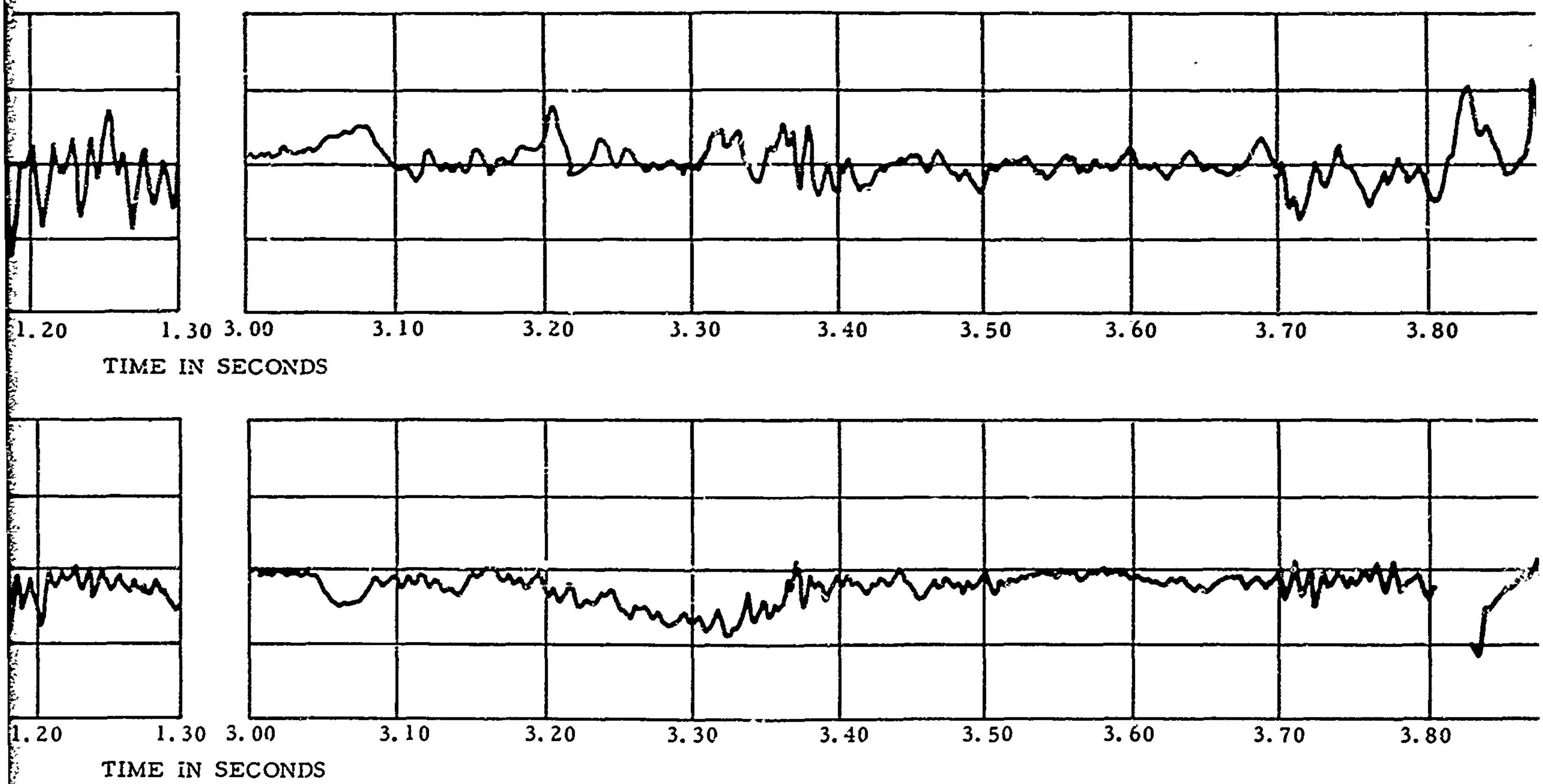
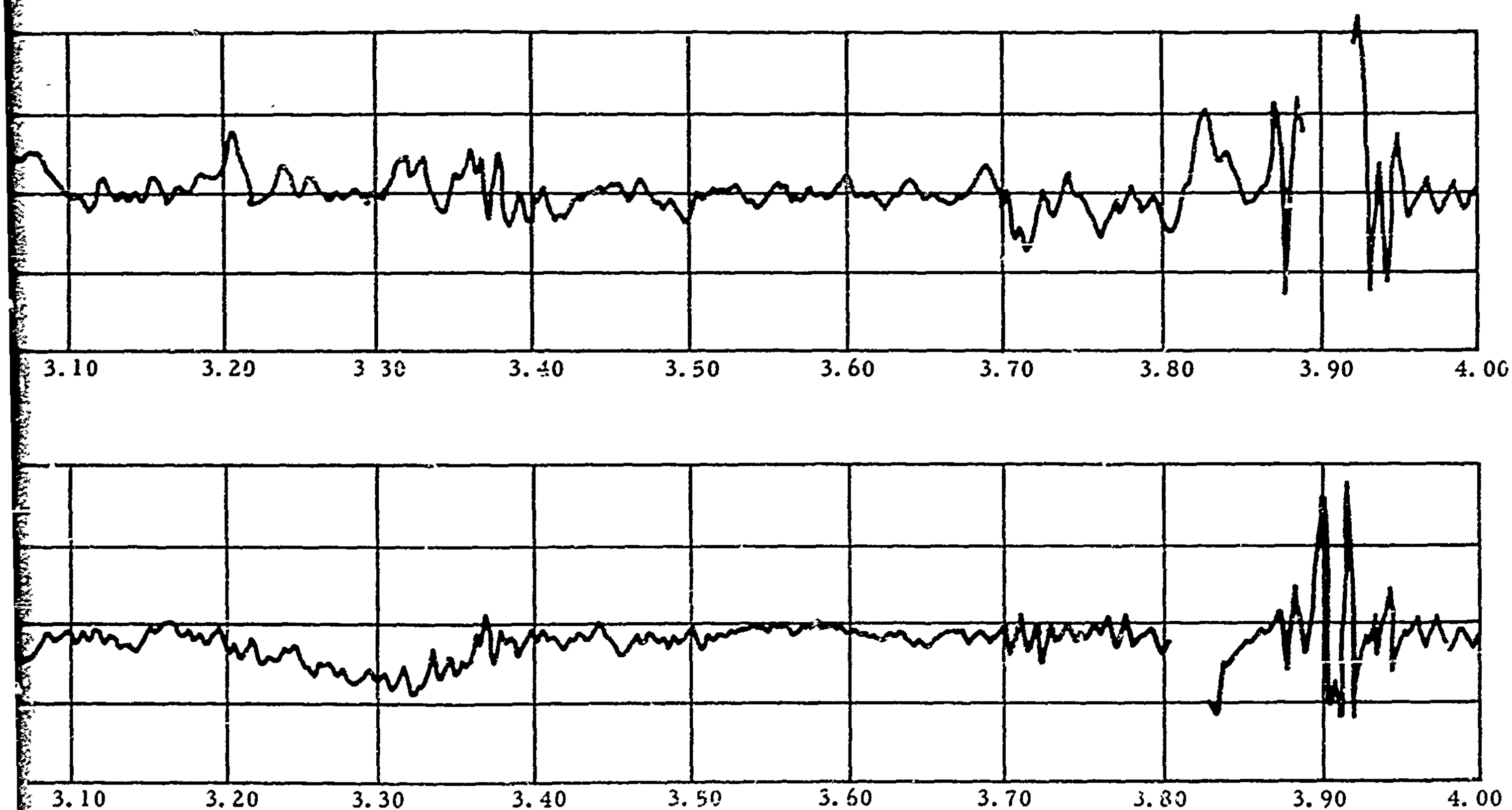
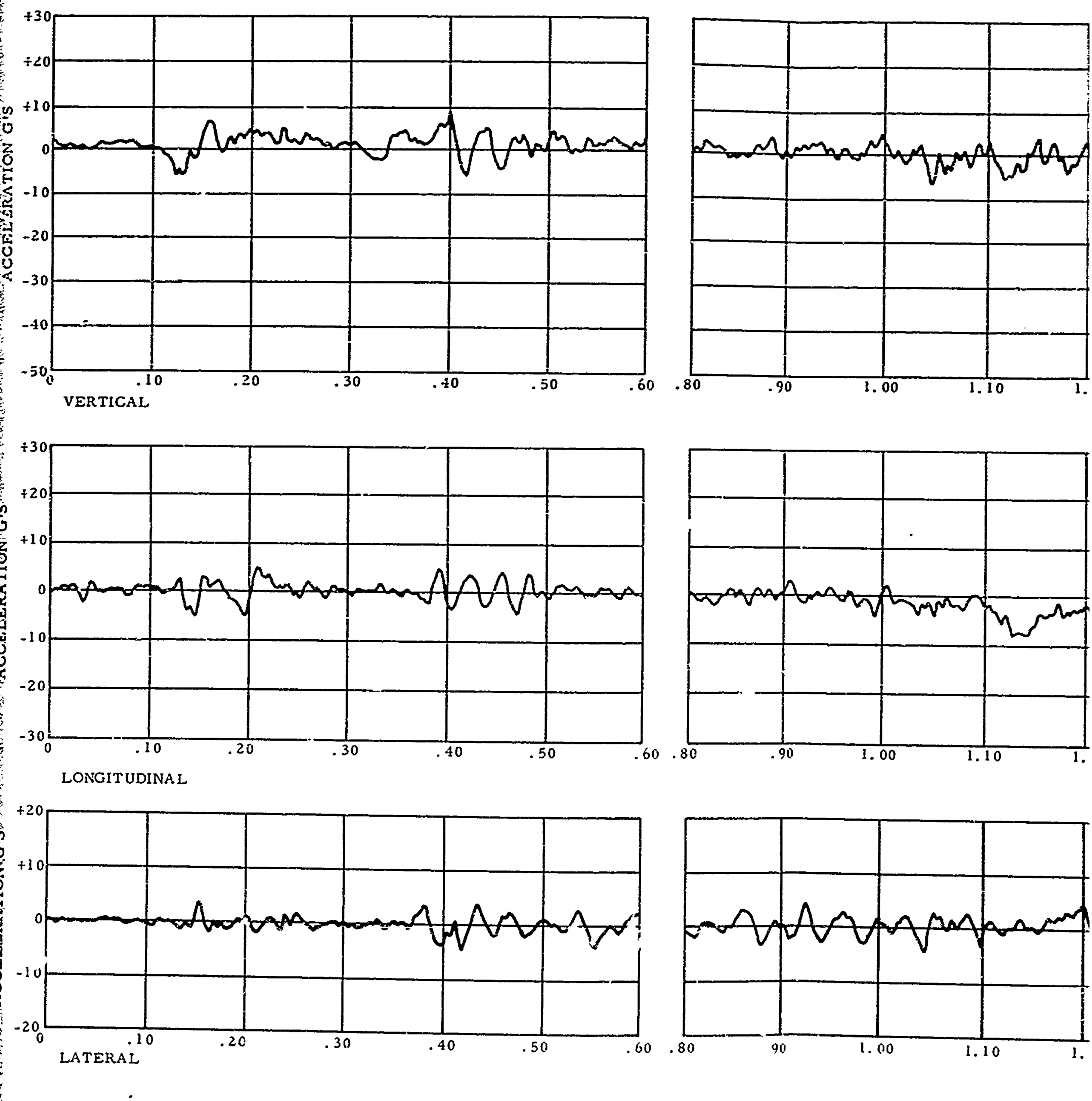


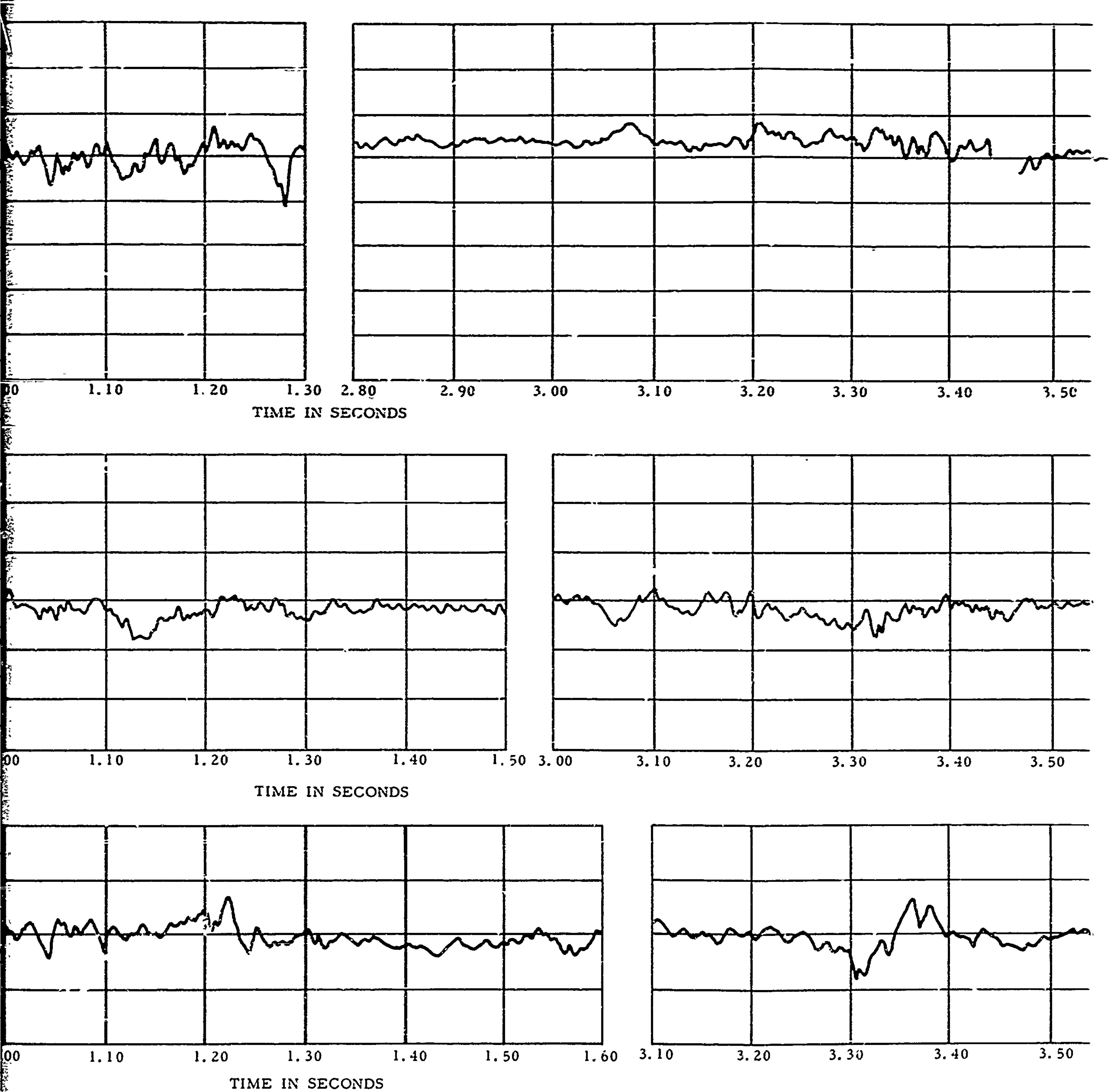
FIG. 6 - 5 REAR CABIN FLOOR ACCELERATIONS — FUSELAGE STATION 923




ACCELERATION G'S
+30
+20
+10
0
-10
-20
-30
-40
-50
0
.10
.20
.30
.40
.50
.60
.80
.90
1.00
1.10
VERTICAL
LONGITUDINAL
LATERAL

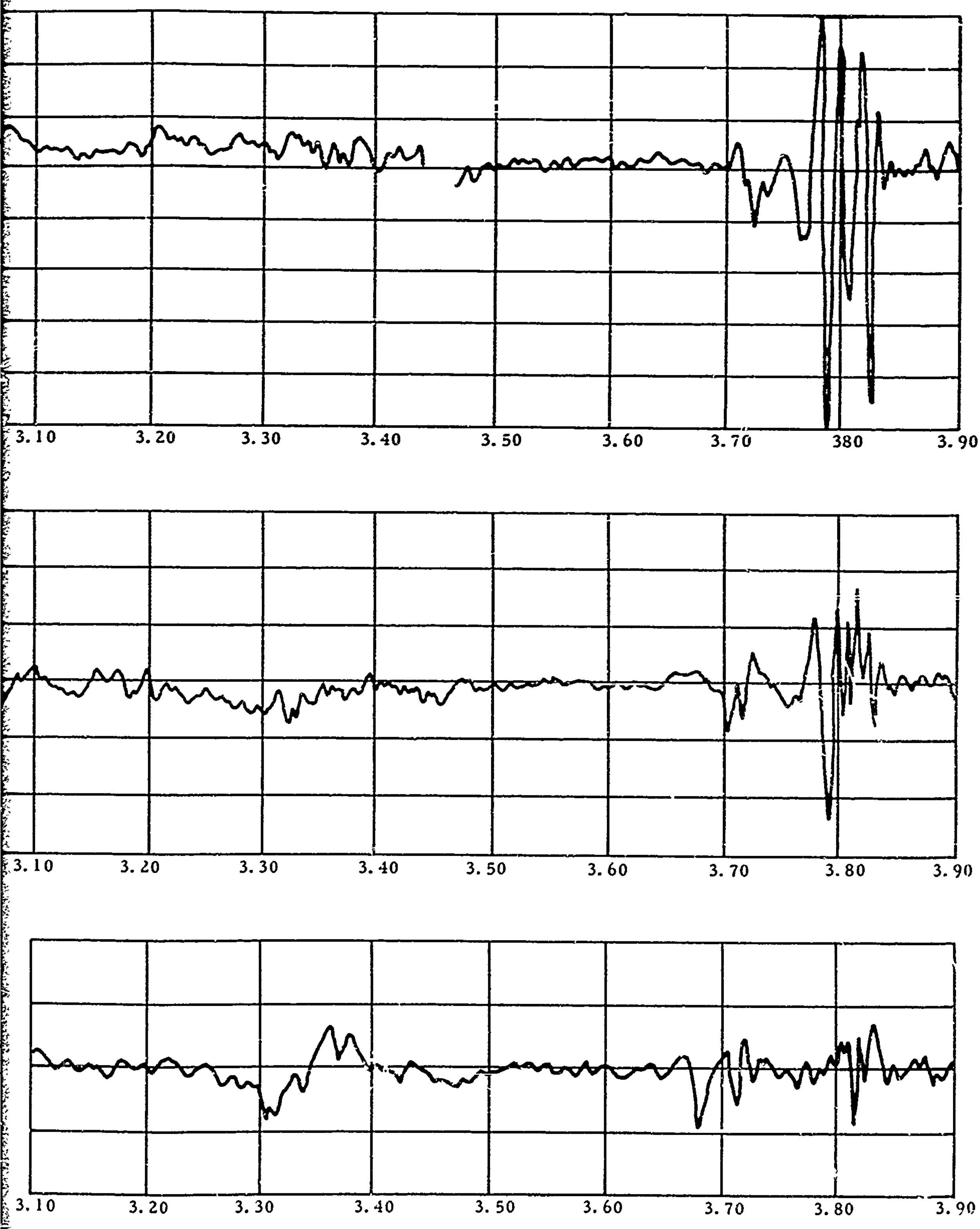
A

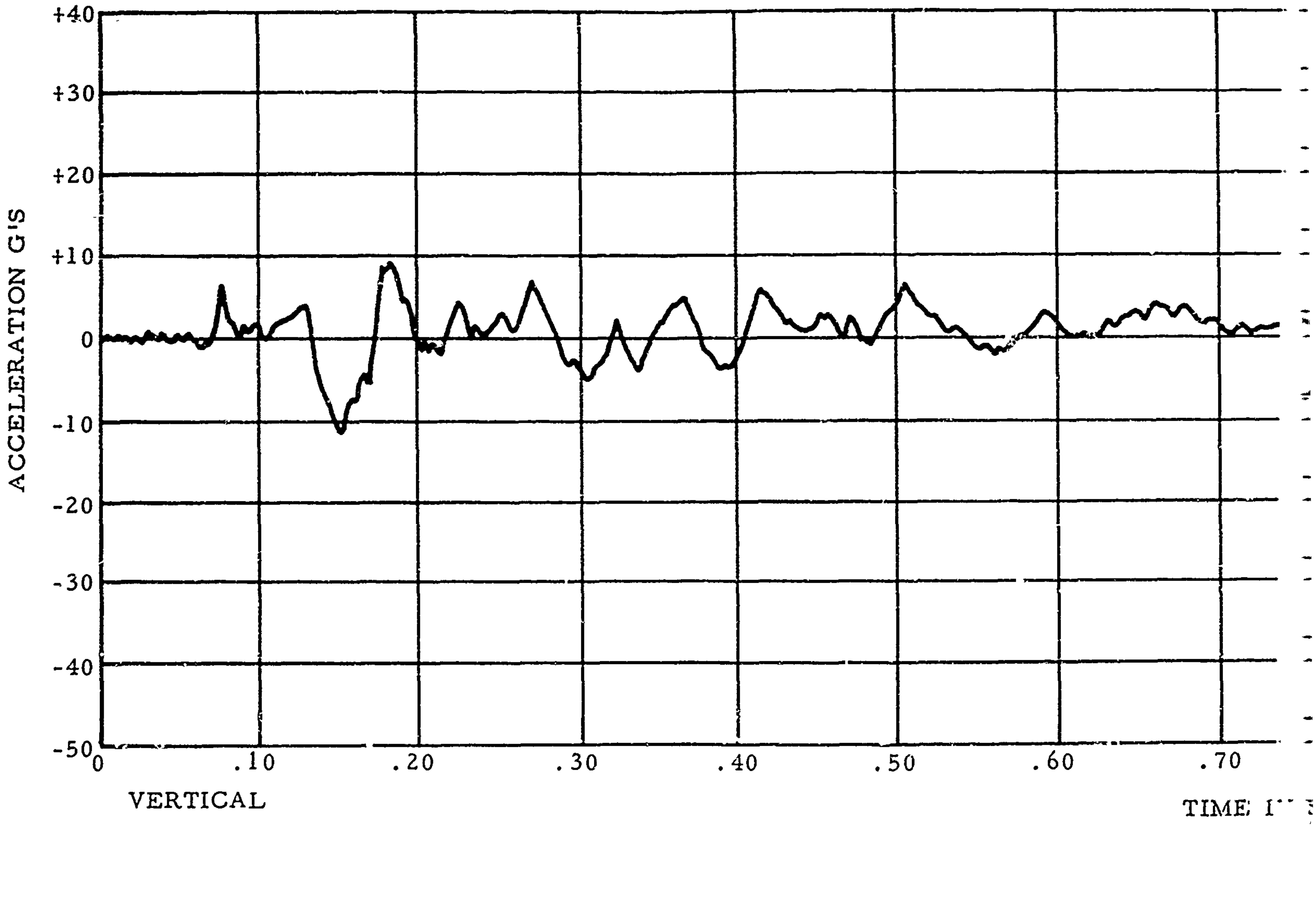
FIG. 6 - 6



00 1.10 1.20 1.30
2.80 2.90 3.00 3.10 3.20 3.30 3.40 3.50
TIME IN SECONDS
00 1.10 1.20 1.30 1.40 1.50
3.00 3.10 3.20 3.30 3.40 3.50
TIME IN SECONDS
00 1.10 1.20 1.30 1.40 1.50 1.60
3.10 3.20 3.30 3.40 3.50
TIME IN SECONDS

FIG. 6 - 6 TAIL FLOOR ACCELERATIONS — FUSELAGE STATION 1165

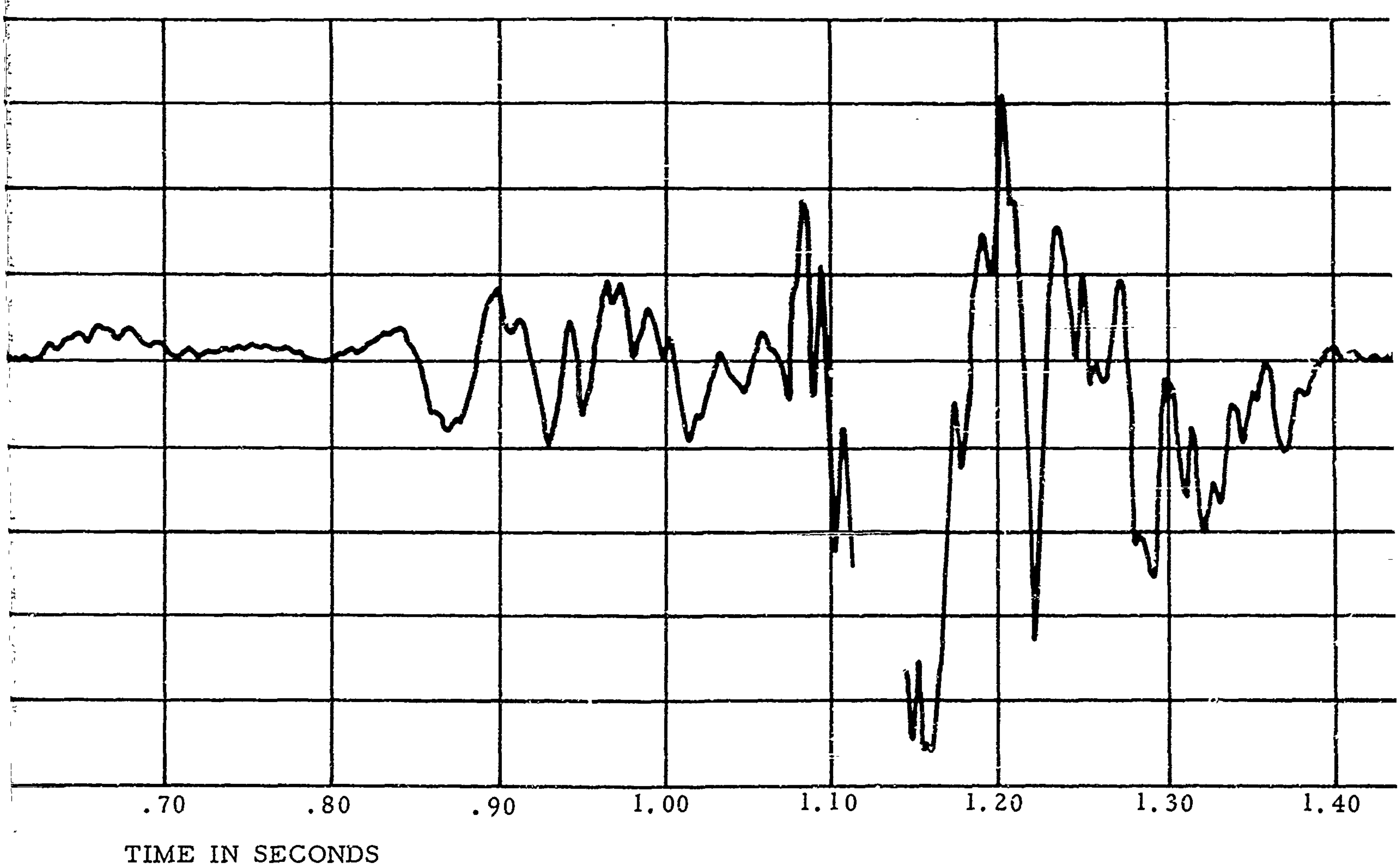




ACCELERATION G'S
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
0
.10
.20
.30
.40
.50
.60
.70
VERTICAL

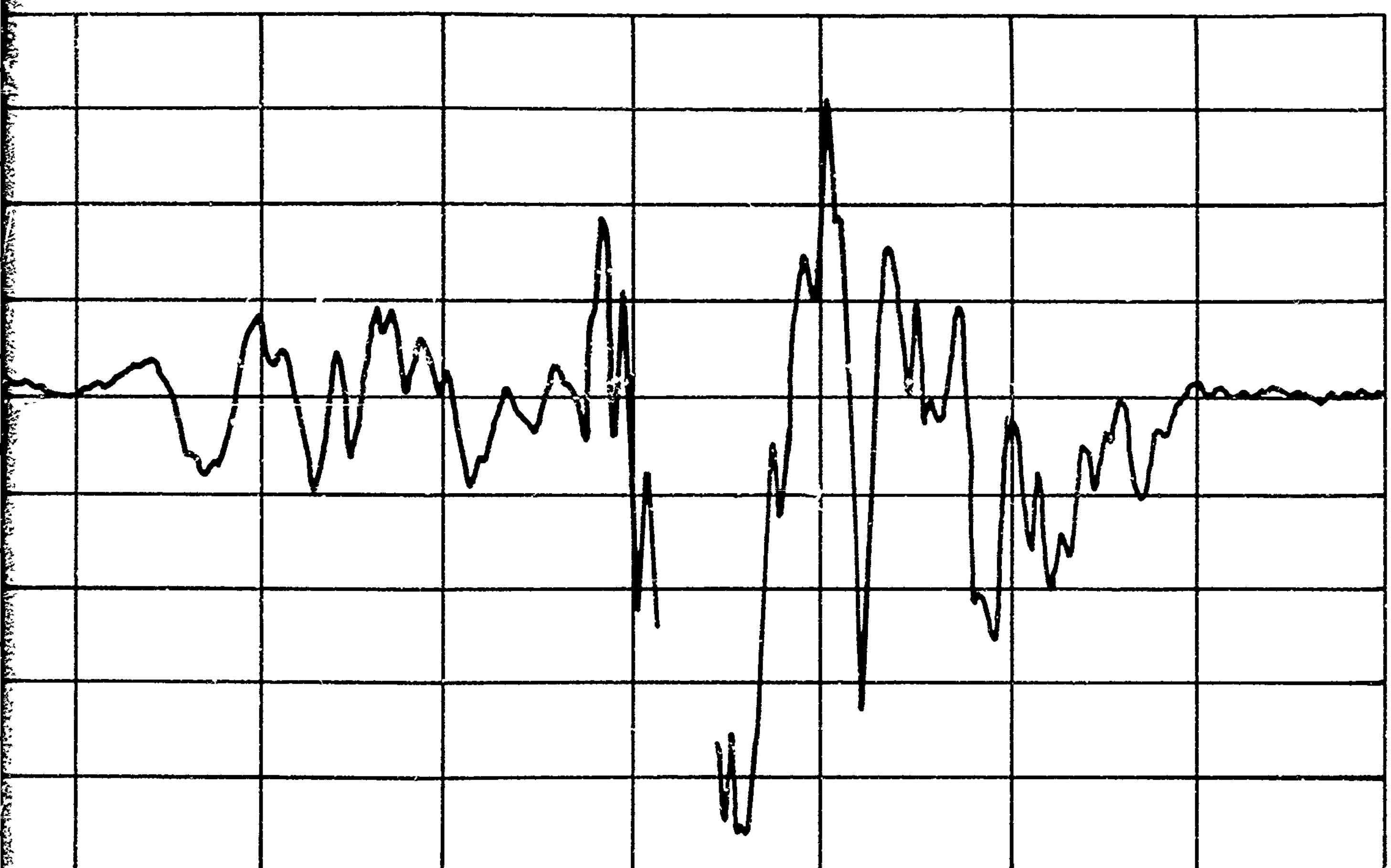
A

FIG. 6 - 7 LEFT OUTBOARD WING ACCELERA'
WING STATION 610



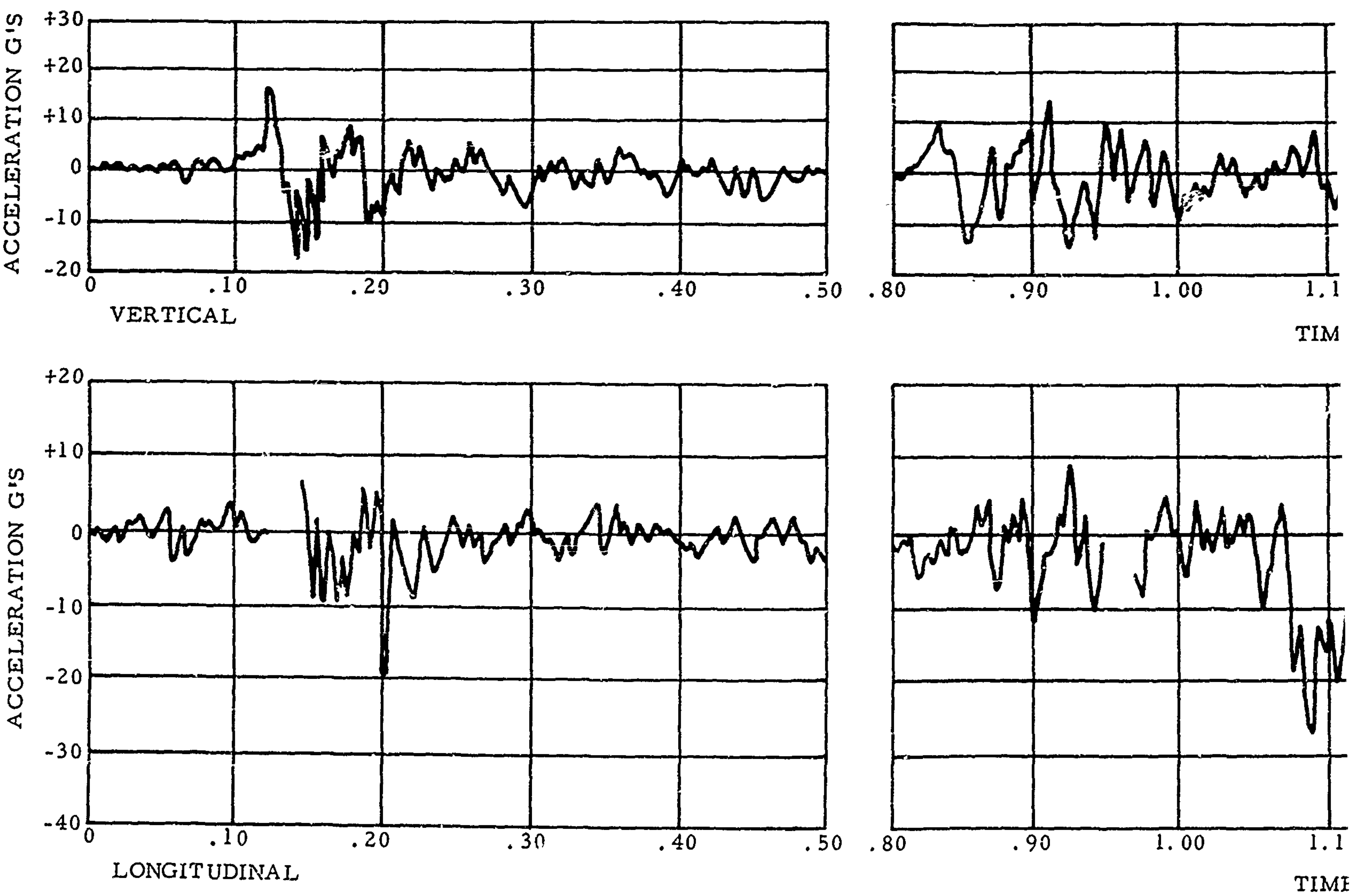
B

FIG. 6 - 7 LEFT OUTBOARD WING ACCELERATIONS — WING STATION 610



B

C


ACCELERATION G'S
+30
+20
+10
0
-10
-20
0
.10
.20
.30
.40
.50
.80
.90
1.00
1.1
VERTICAL
TIM
ACCELERATION G'S
+20
+10
0
-10
-20
-30
-40
0
.10
.20
.30
.40
.50
.80
.90
1.00
1.1
LONGITUDINAL
TIME

A

FIG. 6 - 8

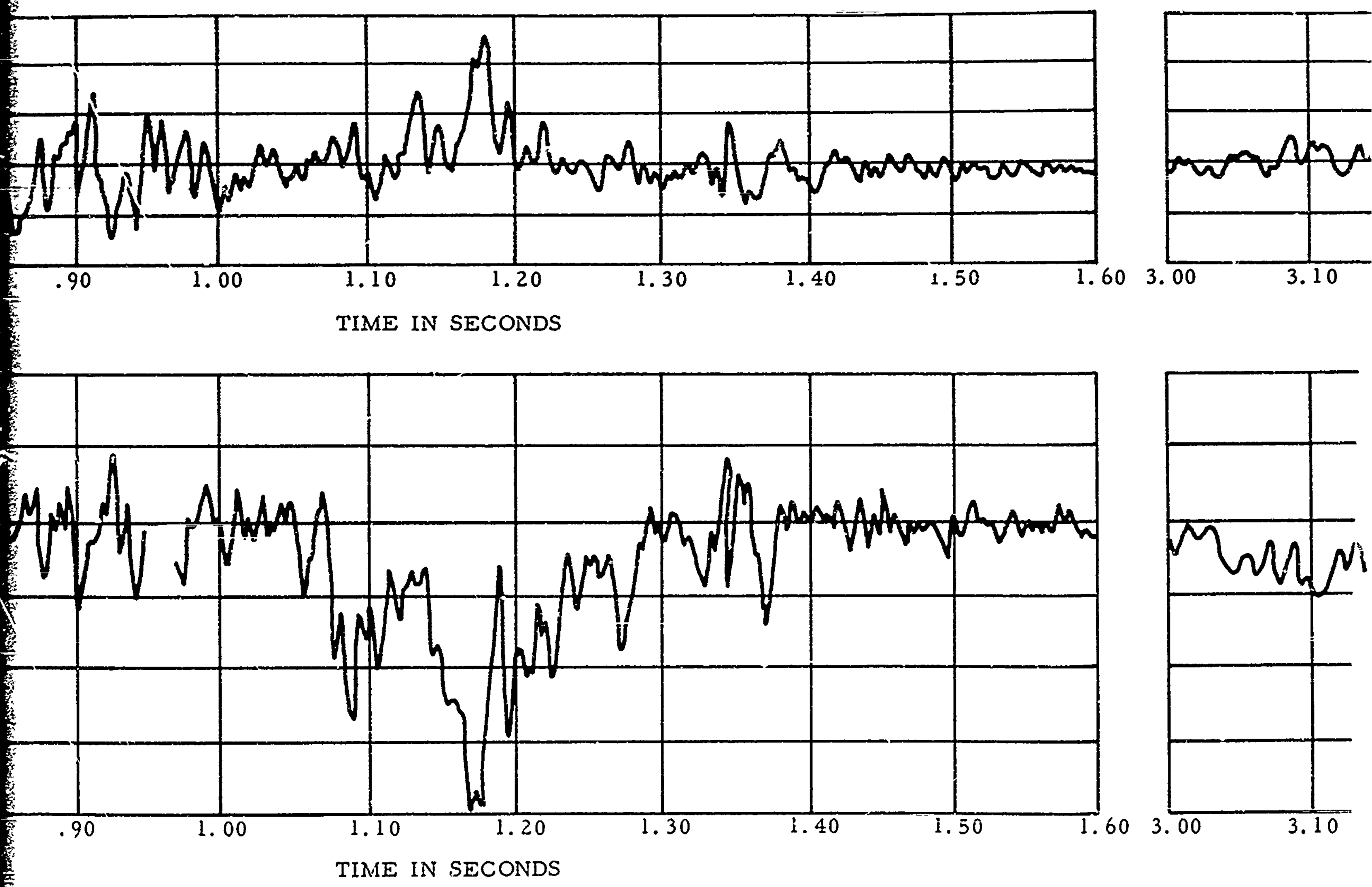
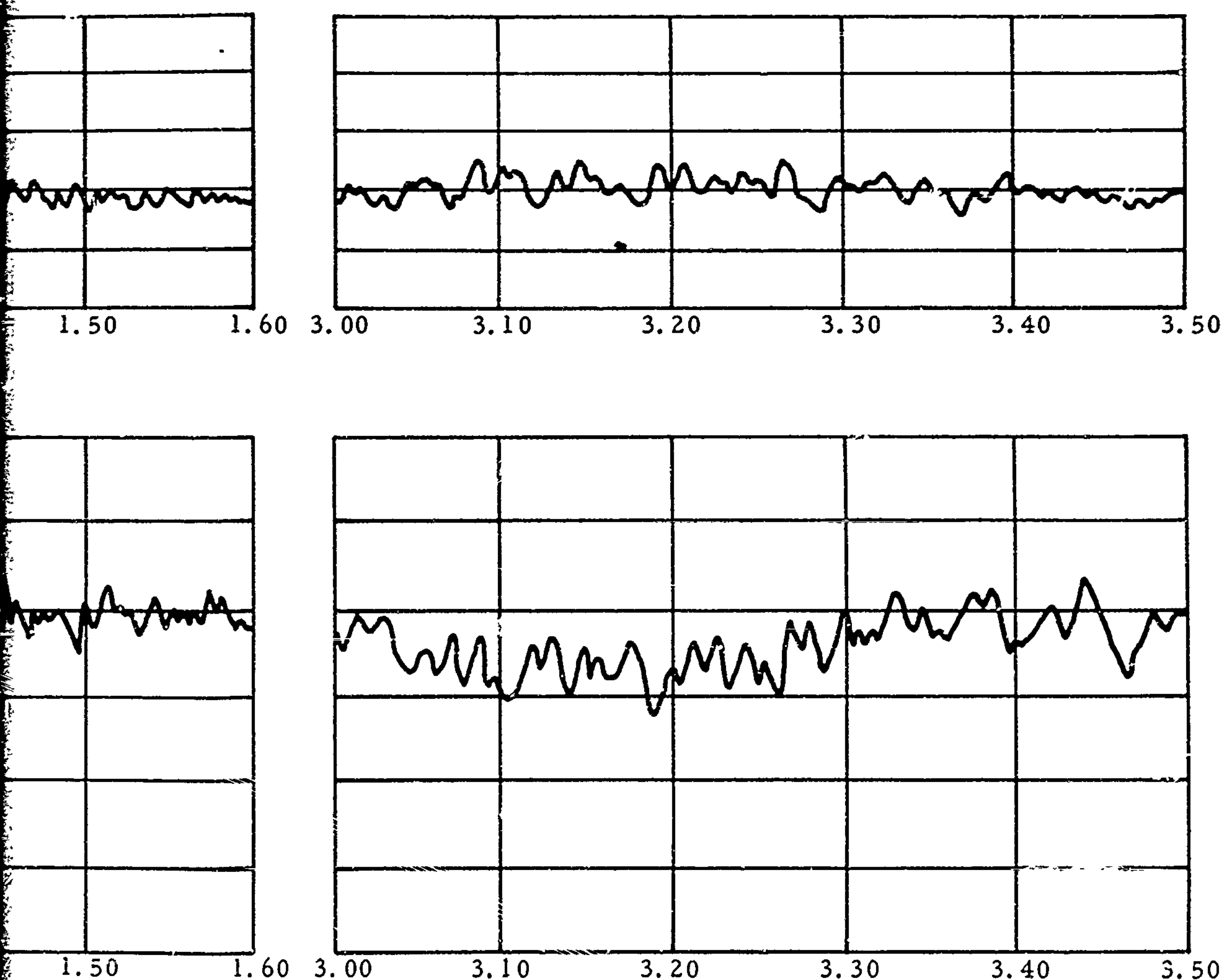
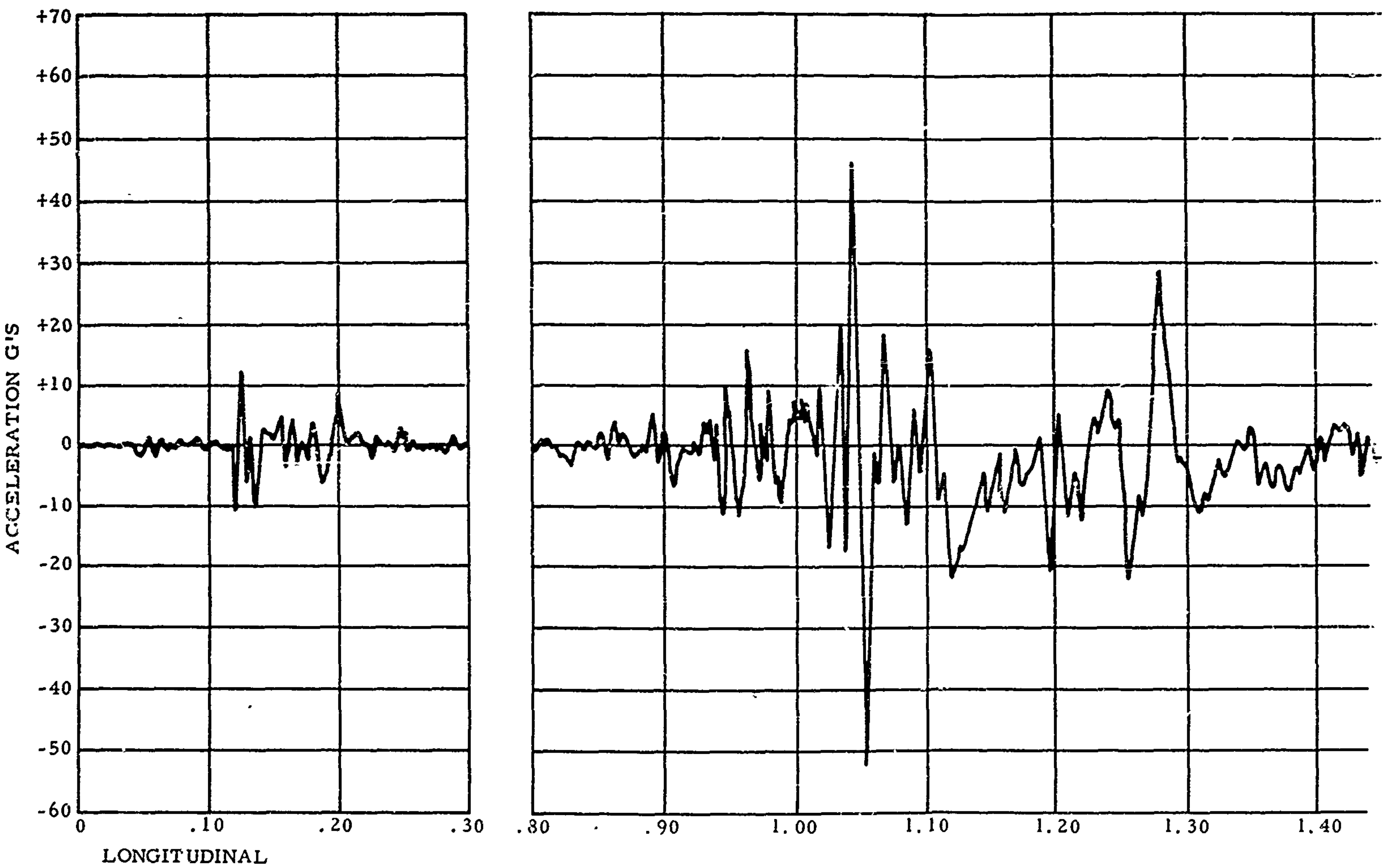

.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
3.00
3.10
TIME IN SECONDS
.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
3.00
3.10
TIME IN SECONDS

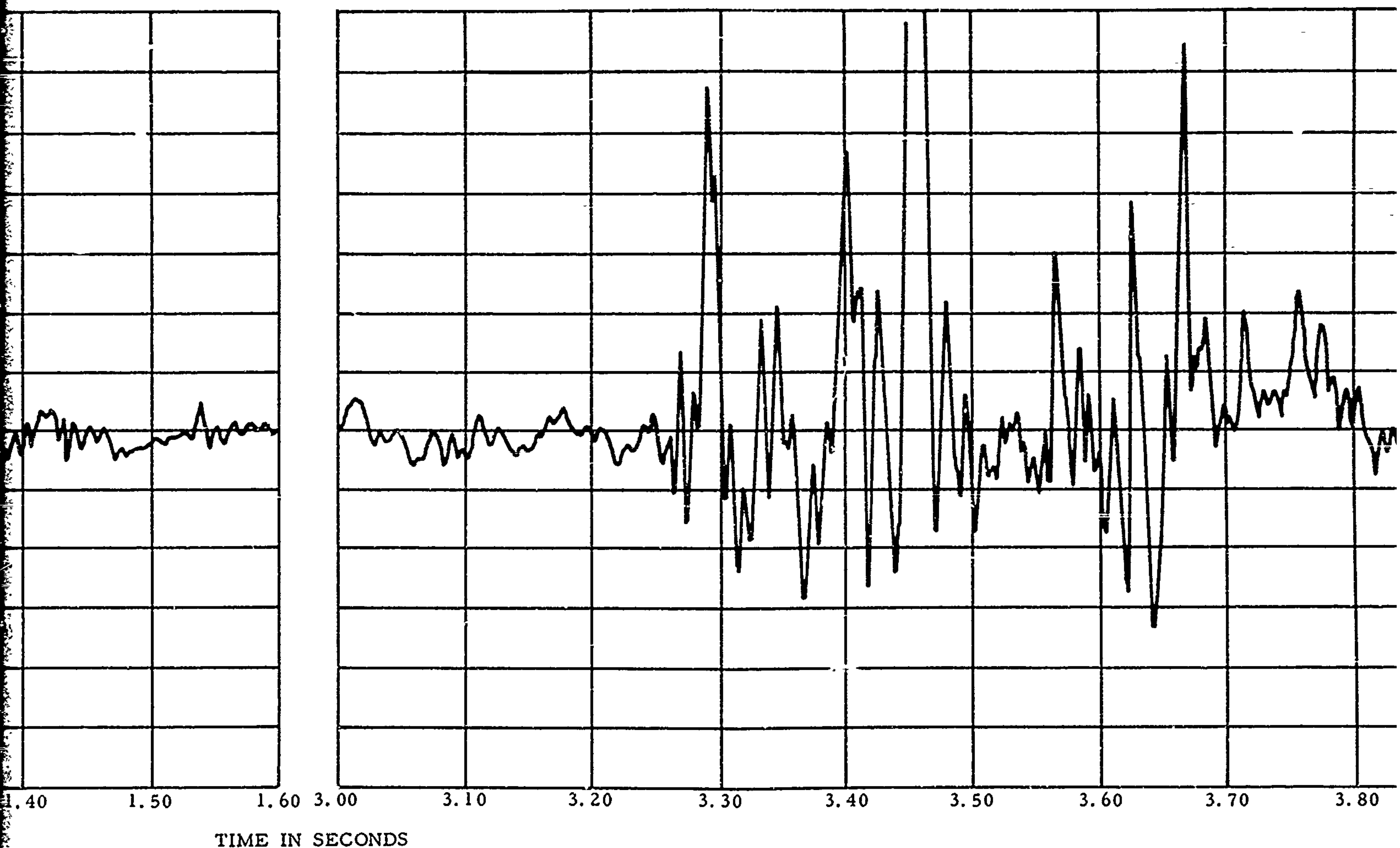
FIG. 6 - 8 LEFT MID-WING ACCELERATIONS — WING STATION 368




+70
+60
+50
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
-60
ACCELERATION G'S
0
.10
.20
.30
.80
.90
1.00
1.10
1.20
1.30
1.40
LONGITUDINAL

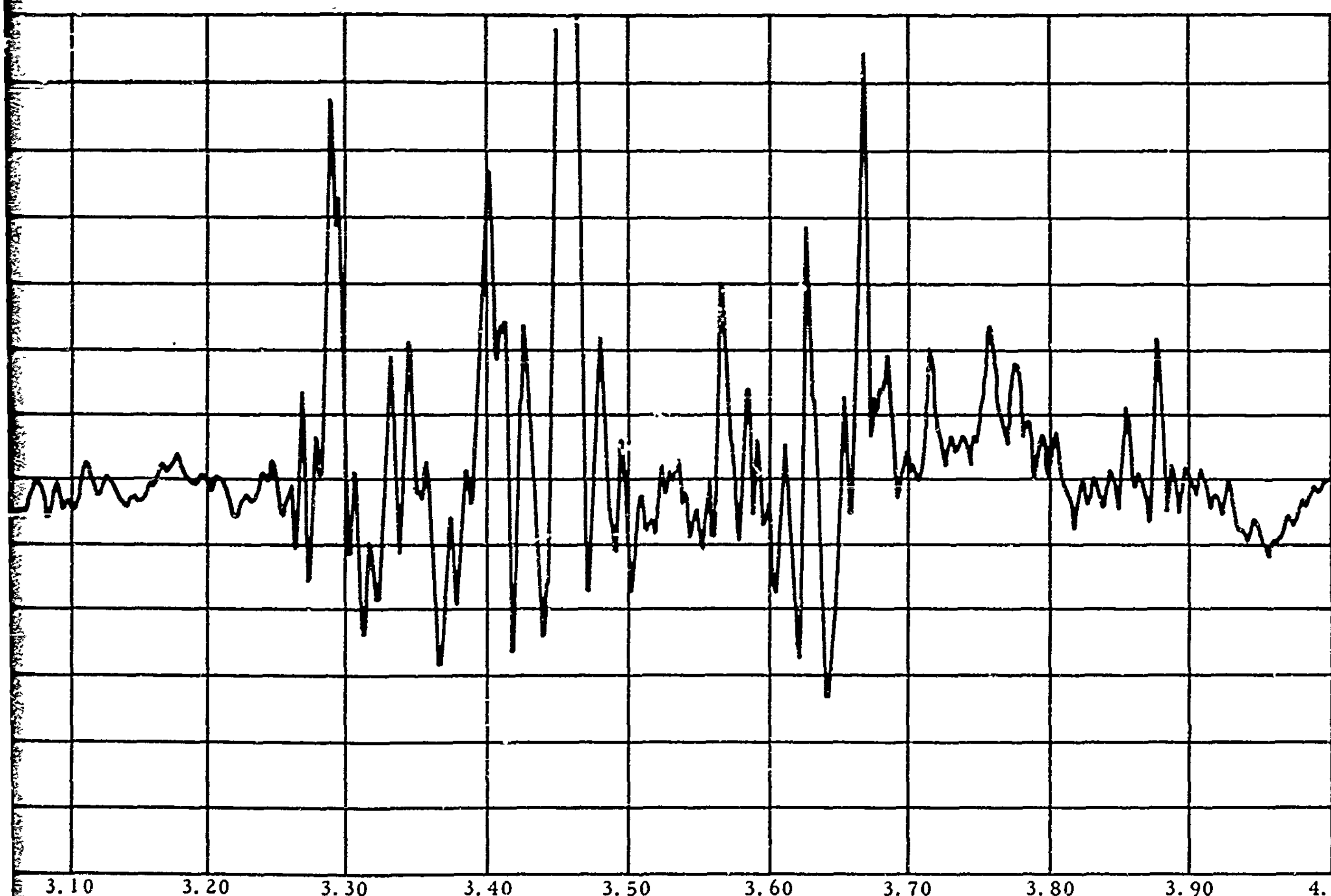
A

FIG. 6 - 9 LEFT INBOARD WING ACCI
WING STATION 140



B

FIG. 6 - 9 LEFT INBOARD WING ACCELERATIONS — WING STATION 140



B

C

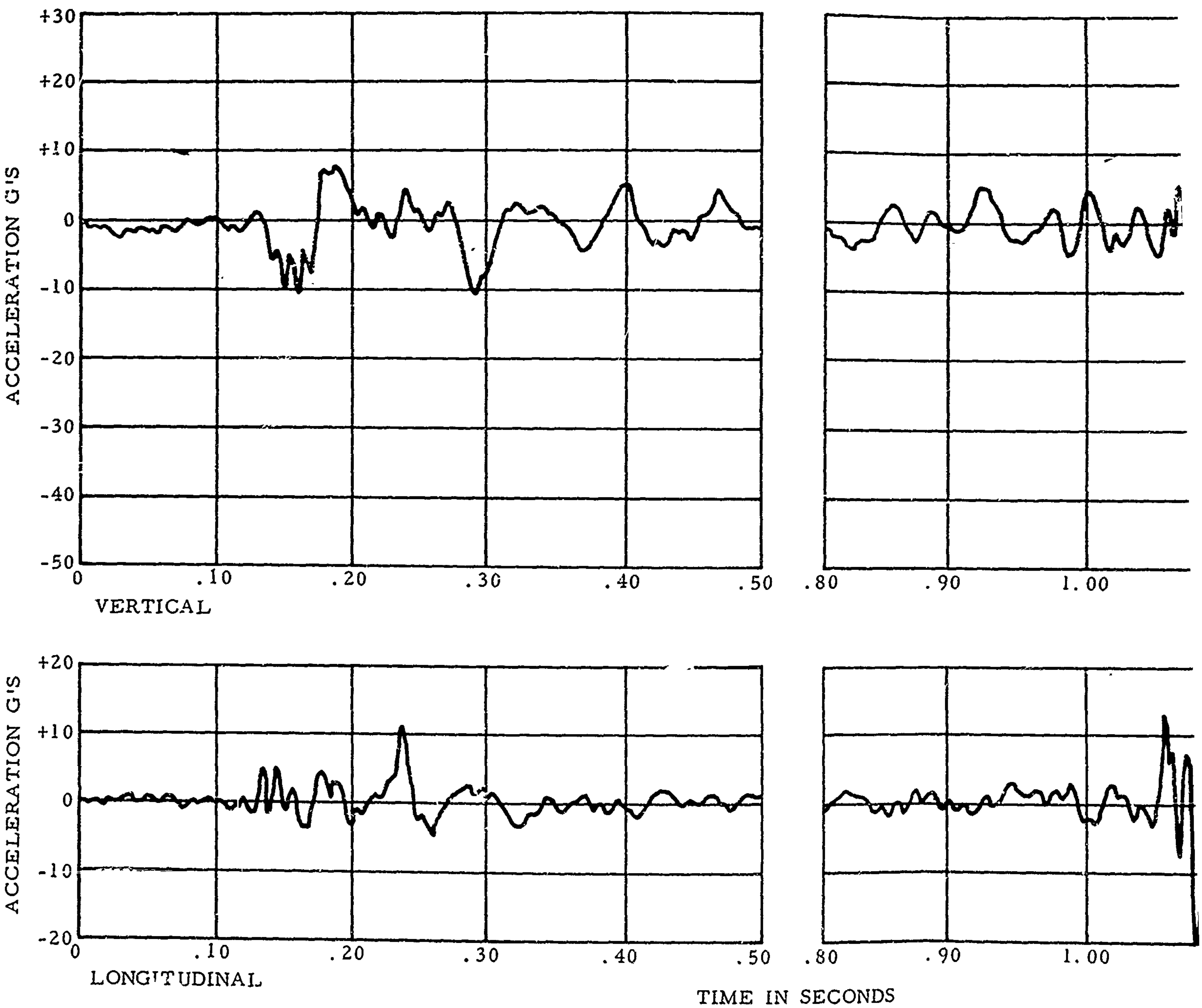
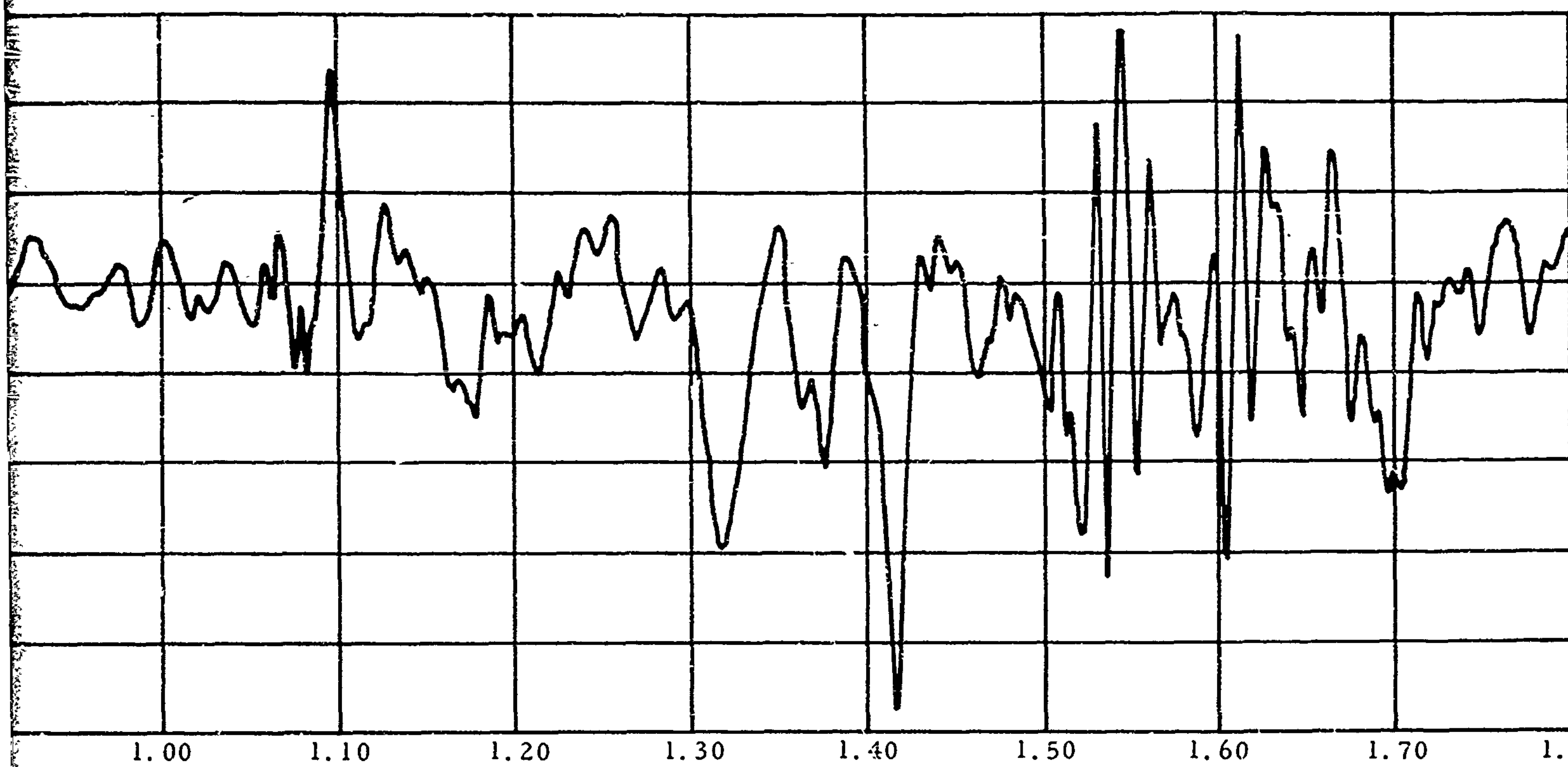
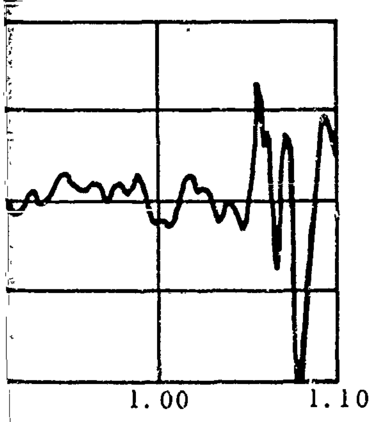

ACCELERATION G'S
+30
+20
+10
0
-10
-20
-30
-40
-50
0
.10
.20
.30
.40
.50
.80
.90
1.00
VERTICAL
ACCELERATION G'S
+20
+10
0
-10
-20
LONGITUDINAL
TIME IN SECONDS

FIG. 6 - 10 RIGHT OU
WING STA'

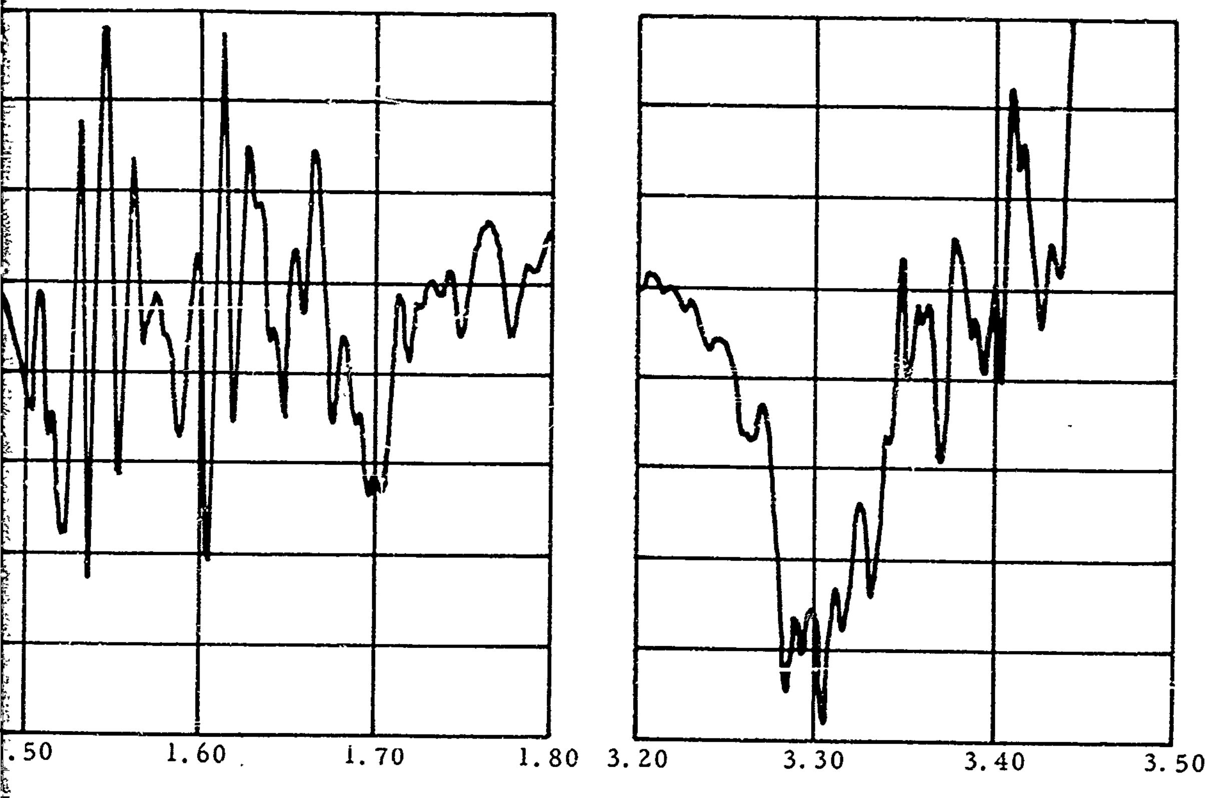


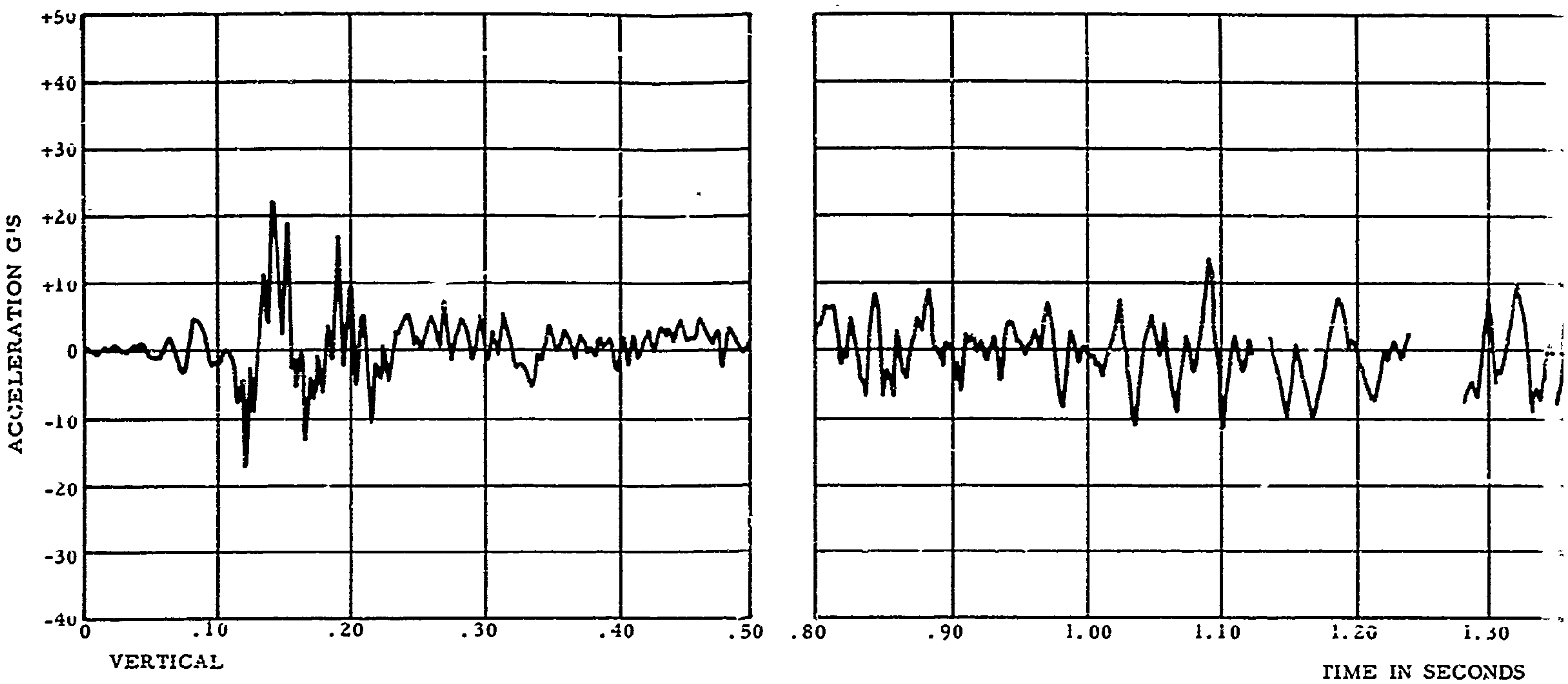


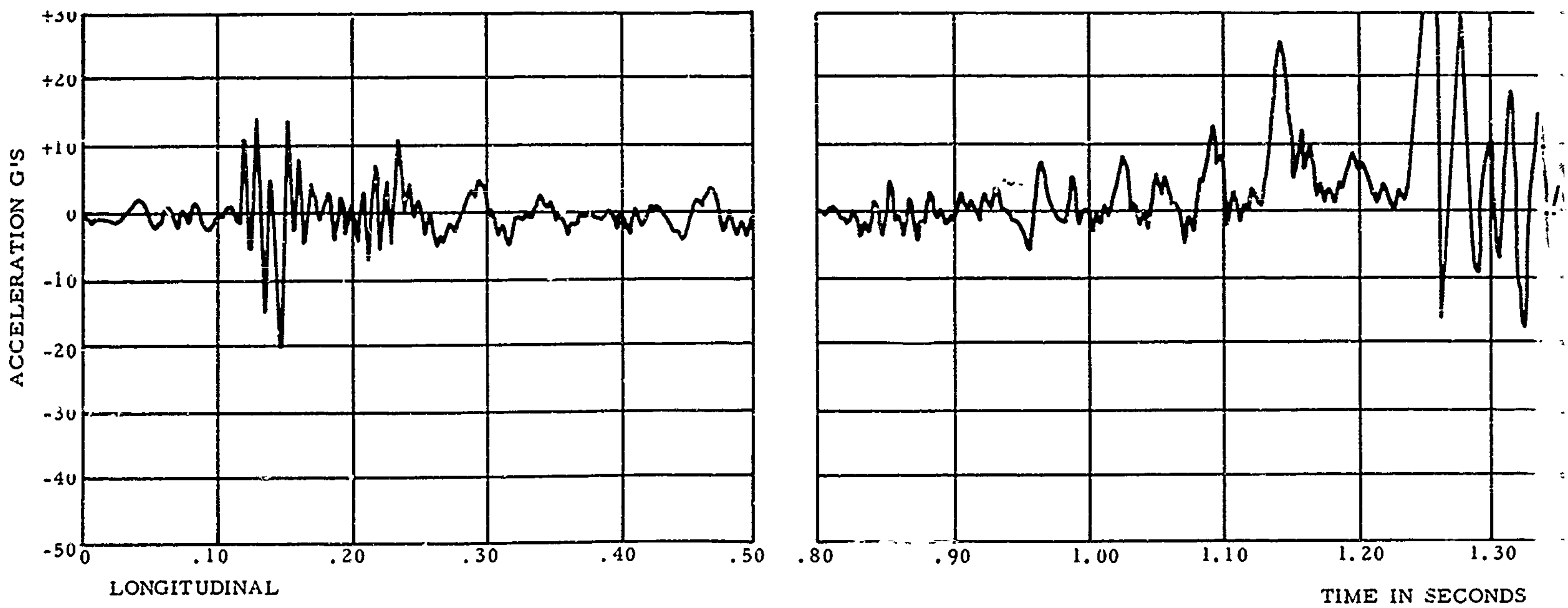
PROBABLE CABLE
FAILURE

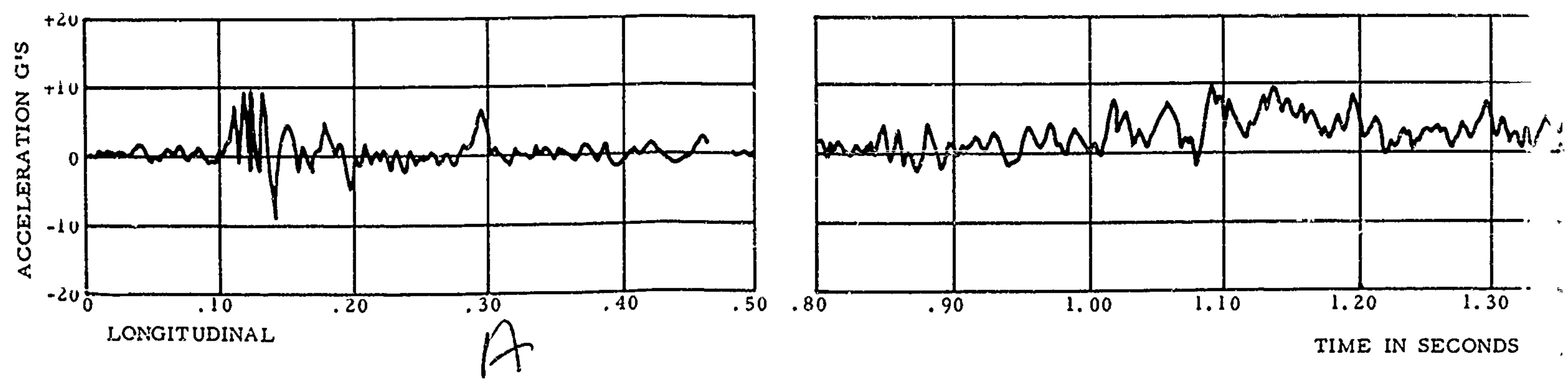
B

FIG. 6 - 10 RIGHT OUTBOARD WING ACCELERATIONS — WING STATION 610



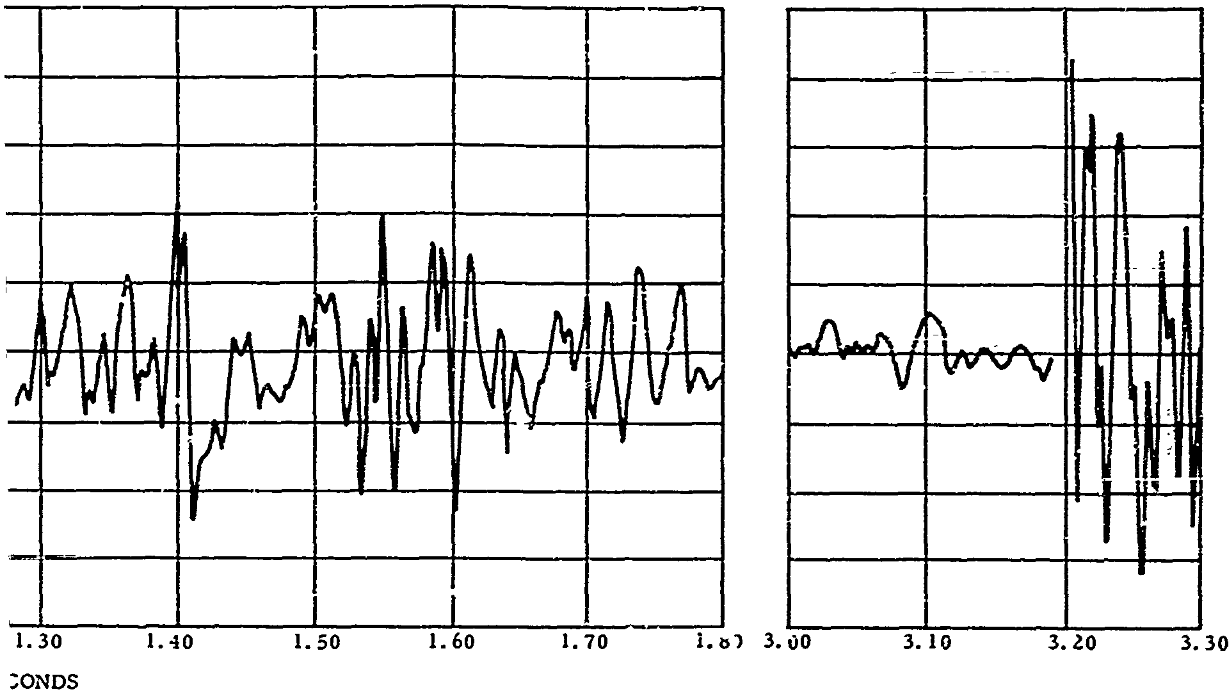

ACCELERATION G'S
+50
+40
+30
+20
+10
0
-10
-20
-30
-40
0
.10
.20
.30
.40
.50
.80
.90
1.00
1.10
1.20
1.30
VERTICAL
TIME IN SECONDS


ACCELERATION G'S
+30
+20
+10
0
-10
-20
-30
-40
-50
0
.10
.20
.30
.40
.50
.80
.90
1.00
1.10
1.20
1.30
LONGITUDINAL
TIME IN SECONDS


ACCELERATION G'S
+20
+10
0
-10
-20
0
.10
.20
.30
.40
.50
.80
.90
1.00
1.10
1.20
1.30
LONGITUDINAL
TIME IN SECONDS

A

FIG. 6 - 11 RIGHT MID-WING ACCELERATIONS — WING STATION 368



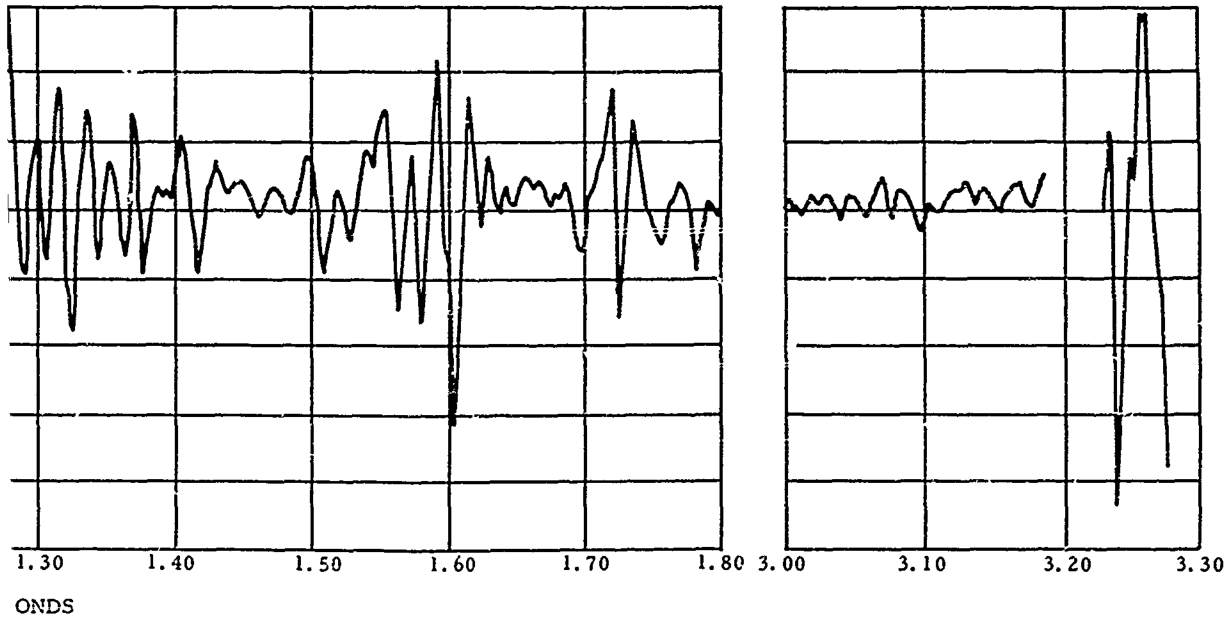
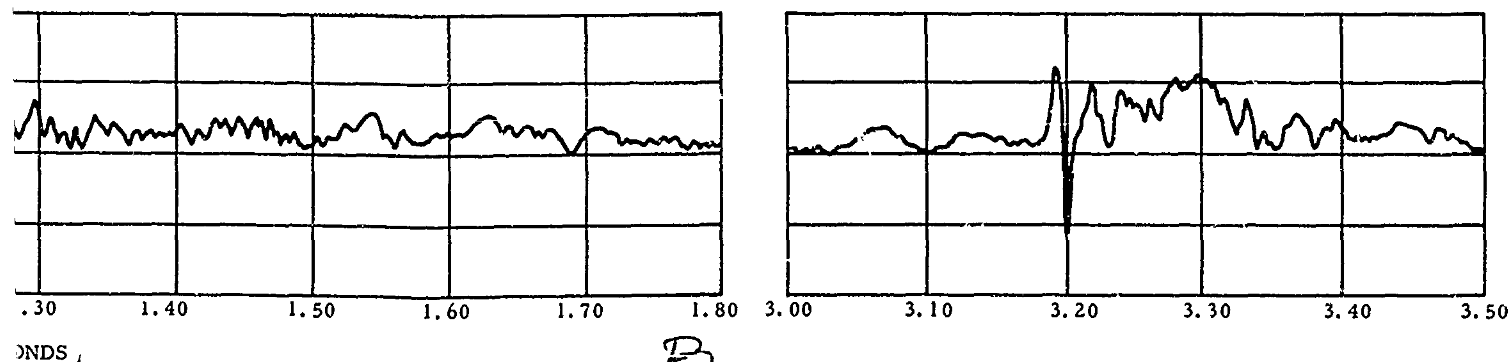


FIG. 6 - 12 RIGHT INBOARD WING ACCELERATIONS — WING STATION 140



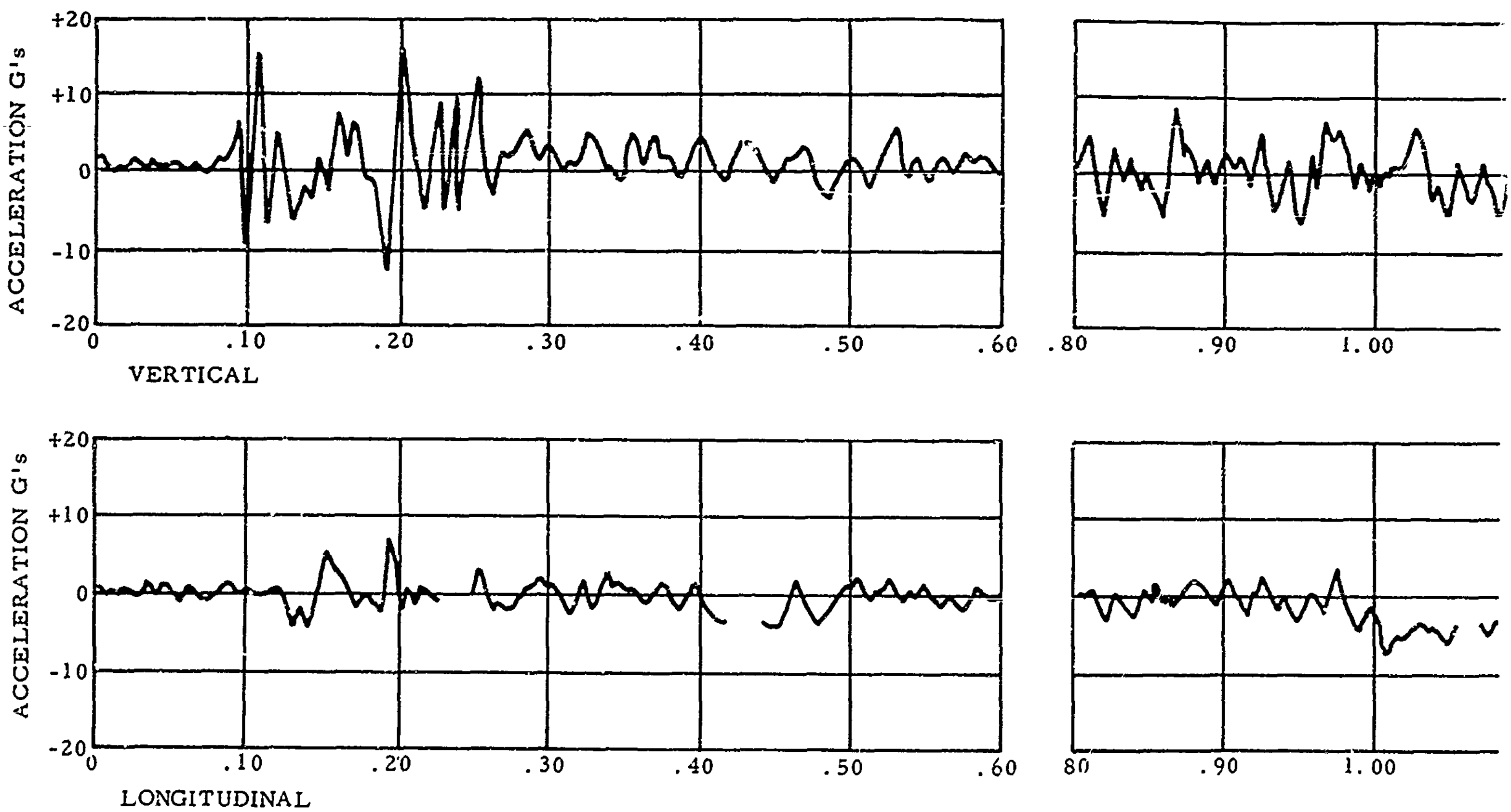
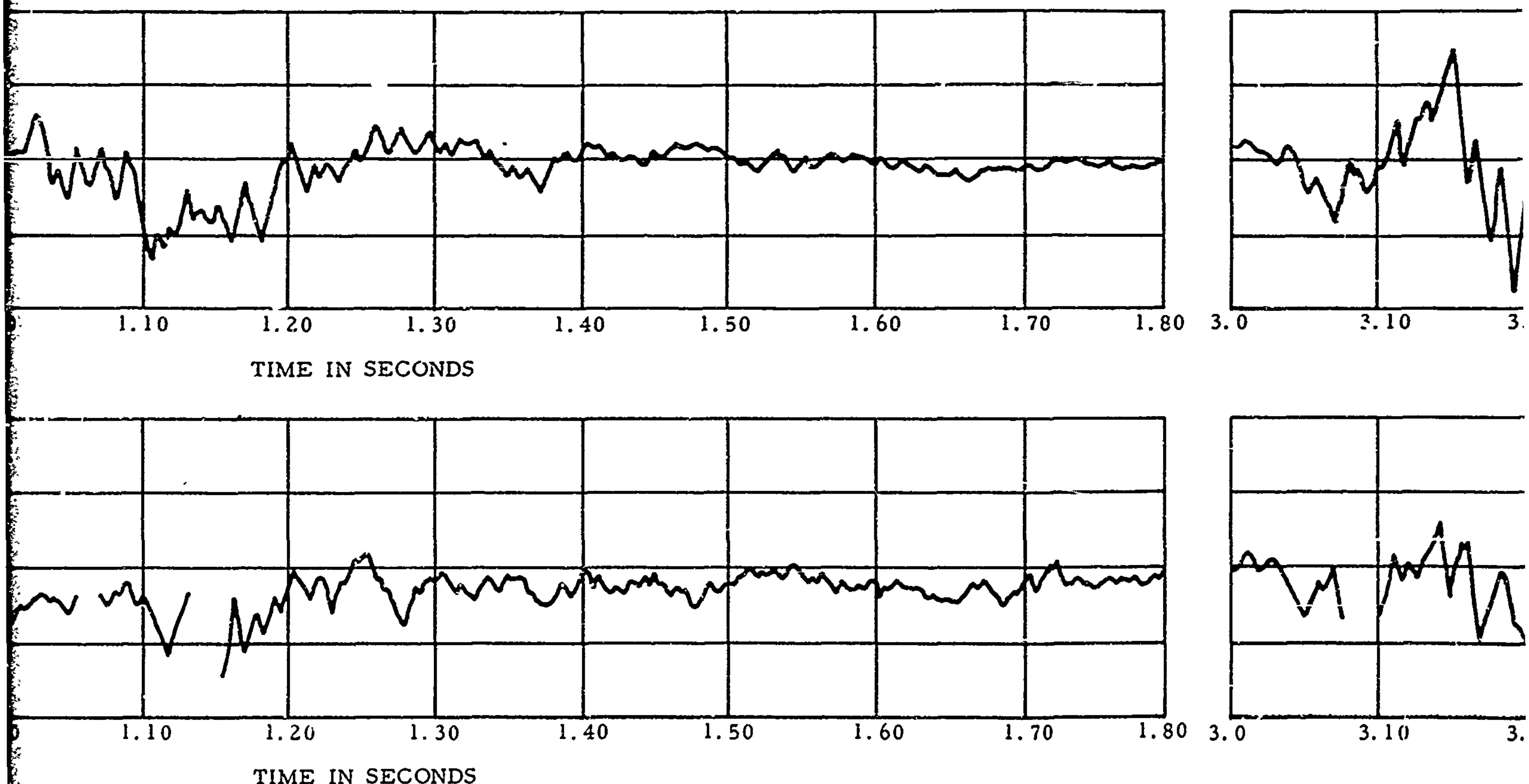
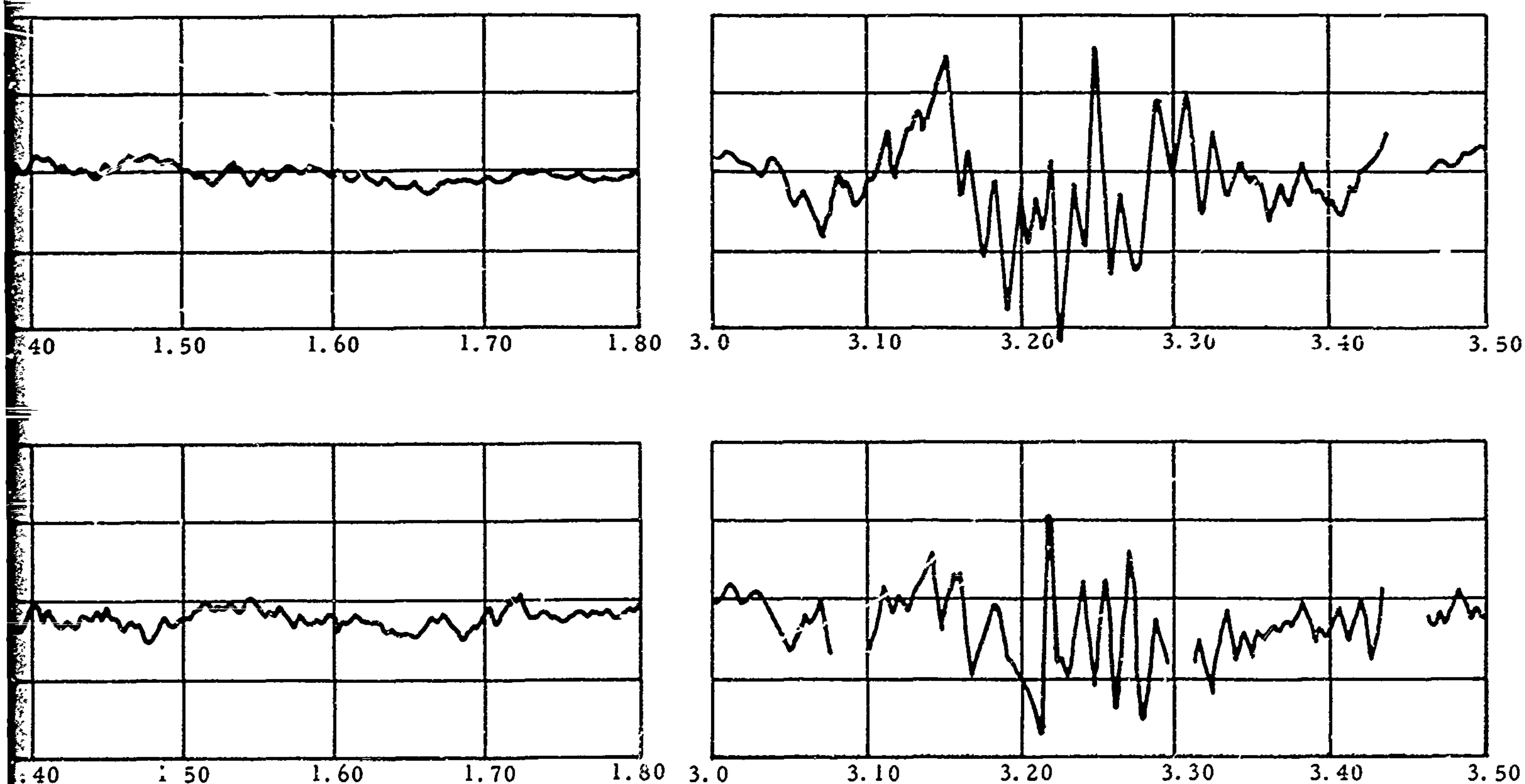

ACCELERATION G's
+20
+10
0
-10
-20
0
.10
.20
.30
.40
.50
.60
.80
.90
1.00
VERTICAL
ACCELERATION G's
+20
+10
0
-10
-20
0
.10
.20
.30
.40
.50
.60
80
.90
1.00
LONGITUDINAL

FIG. 6 - 13 FORWARD CABIN SEA

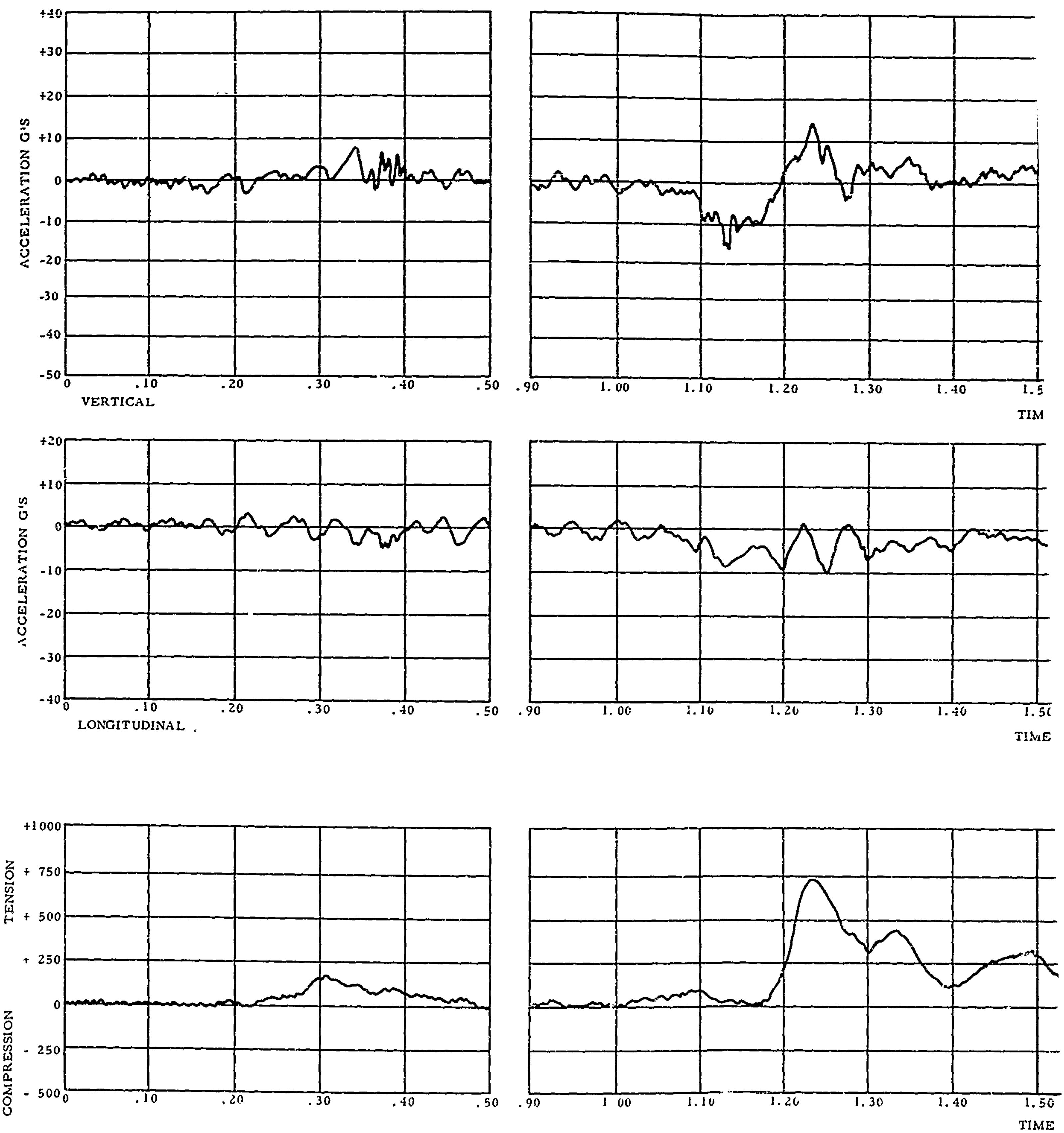


B

FIG. 6 - 13 FORWARD CABIN SEAT ACCELERATIONS — SEAT 3

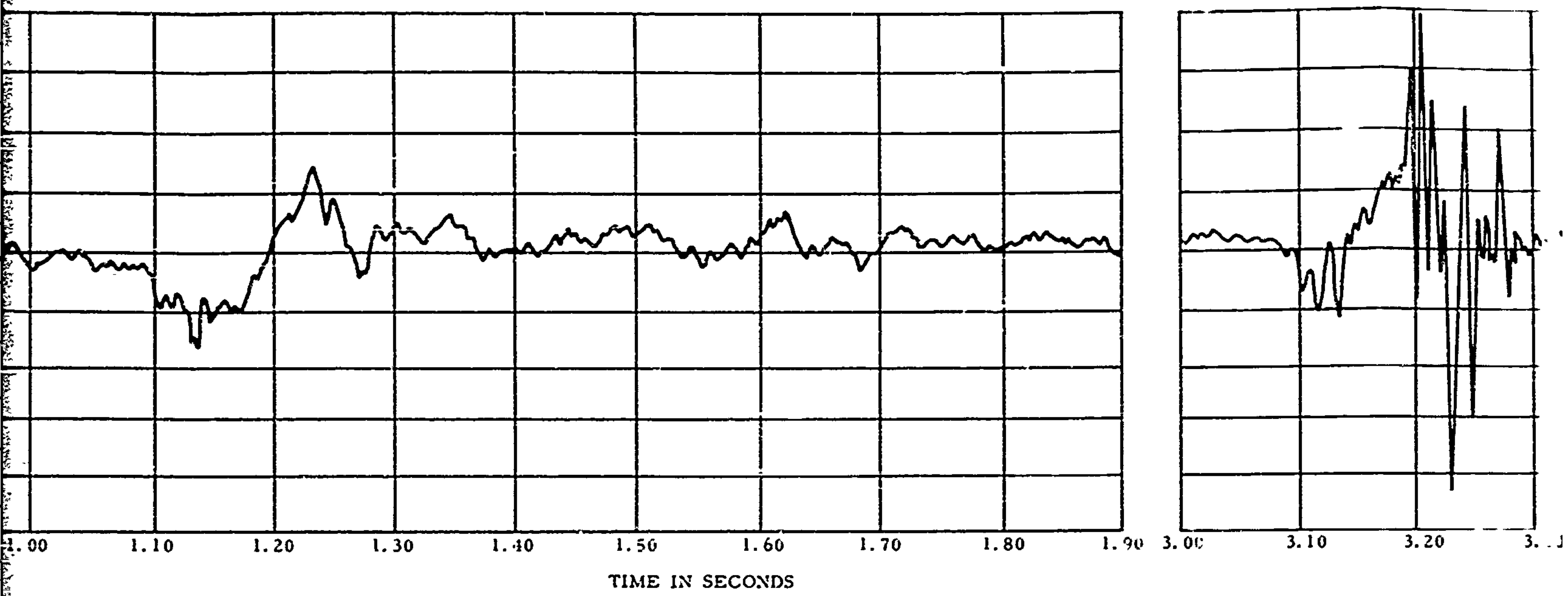


B C



ACCELERATION G'S
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
0
.10
.20
.30
.40
.50
VERTICAL
.90
1.00
1.10
1.20
1.30
1.40
1.5
TIM
ACCELERATION G'S
+20
+10
0
-10
-20
-30
-40
LONGITUDINAL
TIME
LOAD IN POUNDS
TENSION
COMPRESSION
+1000
+ 750
+ 500
+ 250
- 250
- 500
1.50
TIME

FIG


1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
3.00
3.10
3.20
TIME IN SECONDS

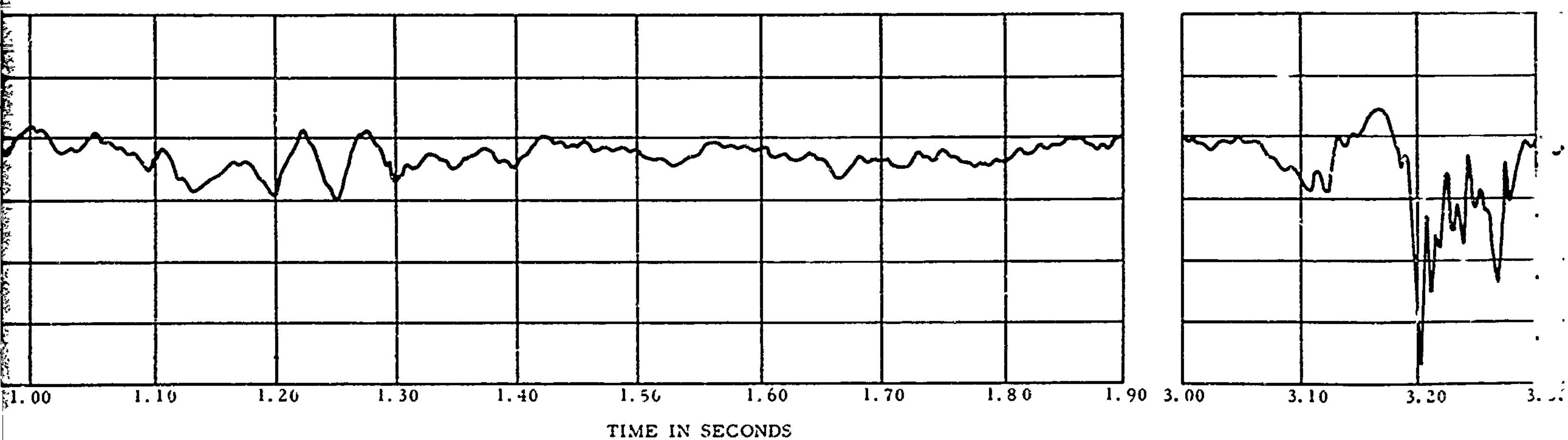

1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
3.00
3.10
3.20
TIME IN SECONDS

FIG. 6 - 15

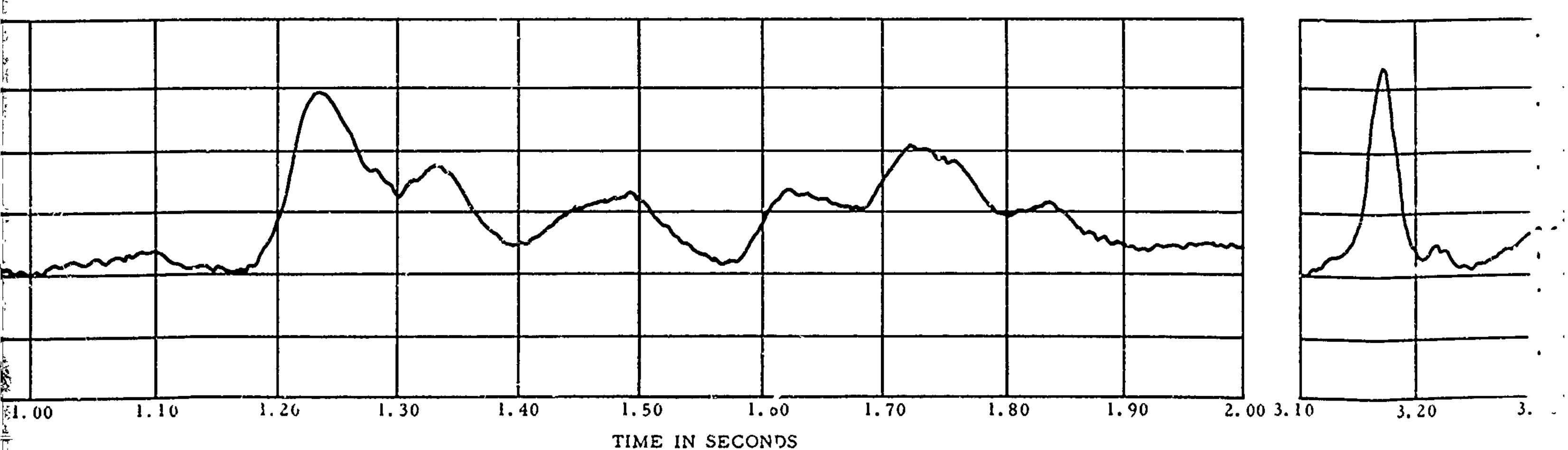

1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
2.00
3.10
3.20
TIME IN SECONDS

FIG. 6 - 14 FORWARD CABIN SEAT OCCUPANT'S PELVIC ACCELERATIONS — SEAT 3B

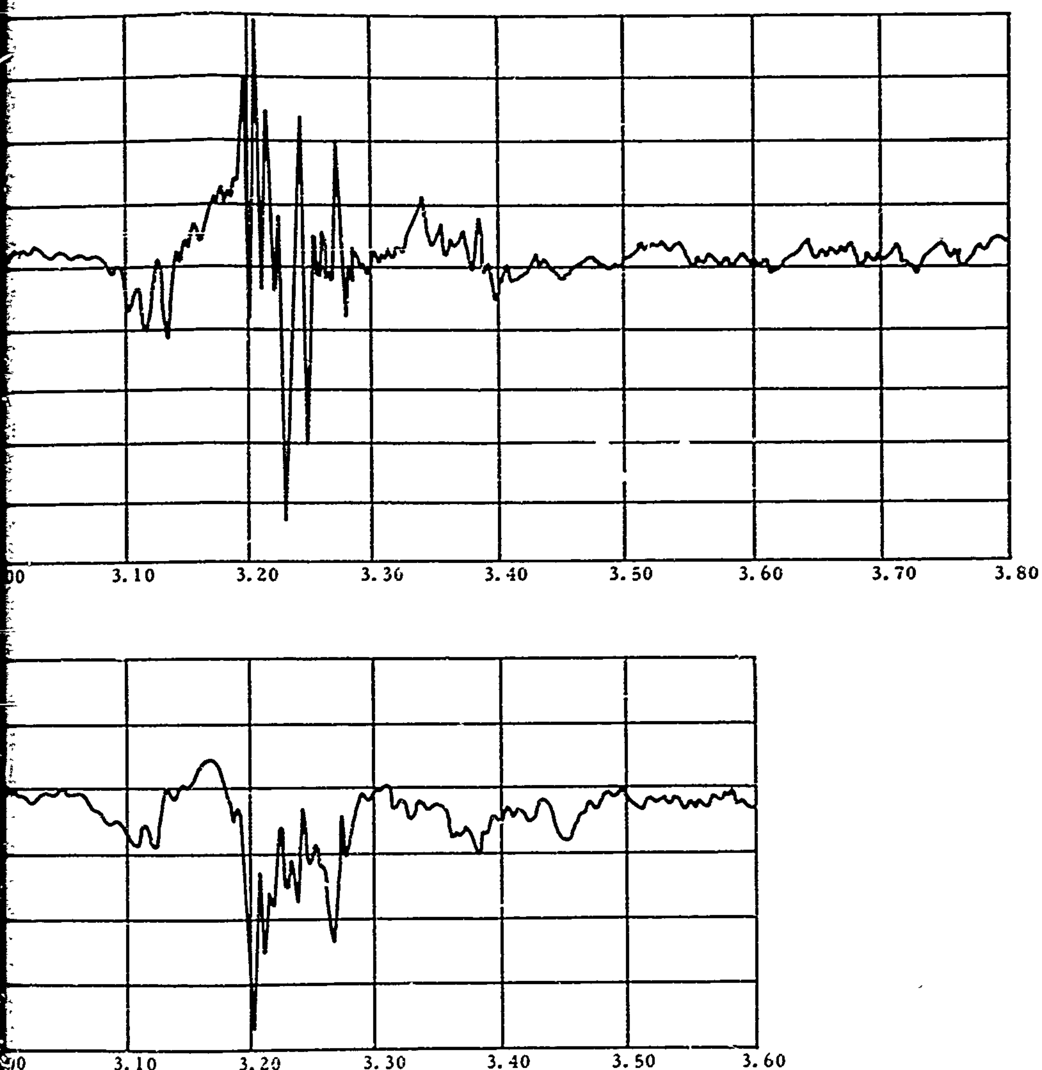
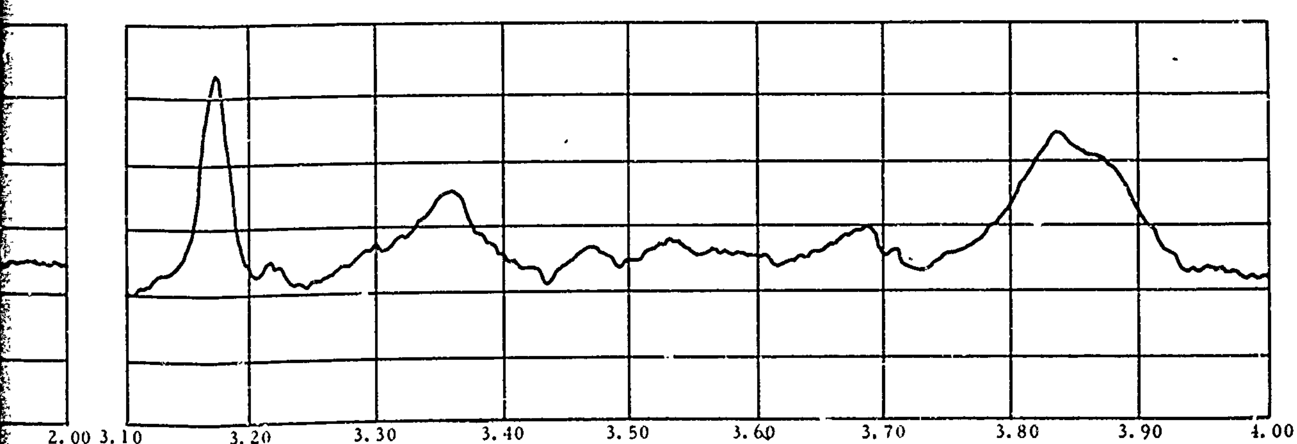
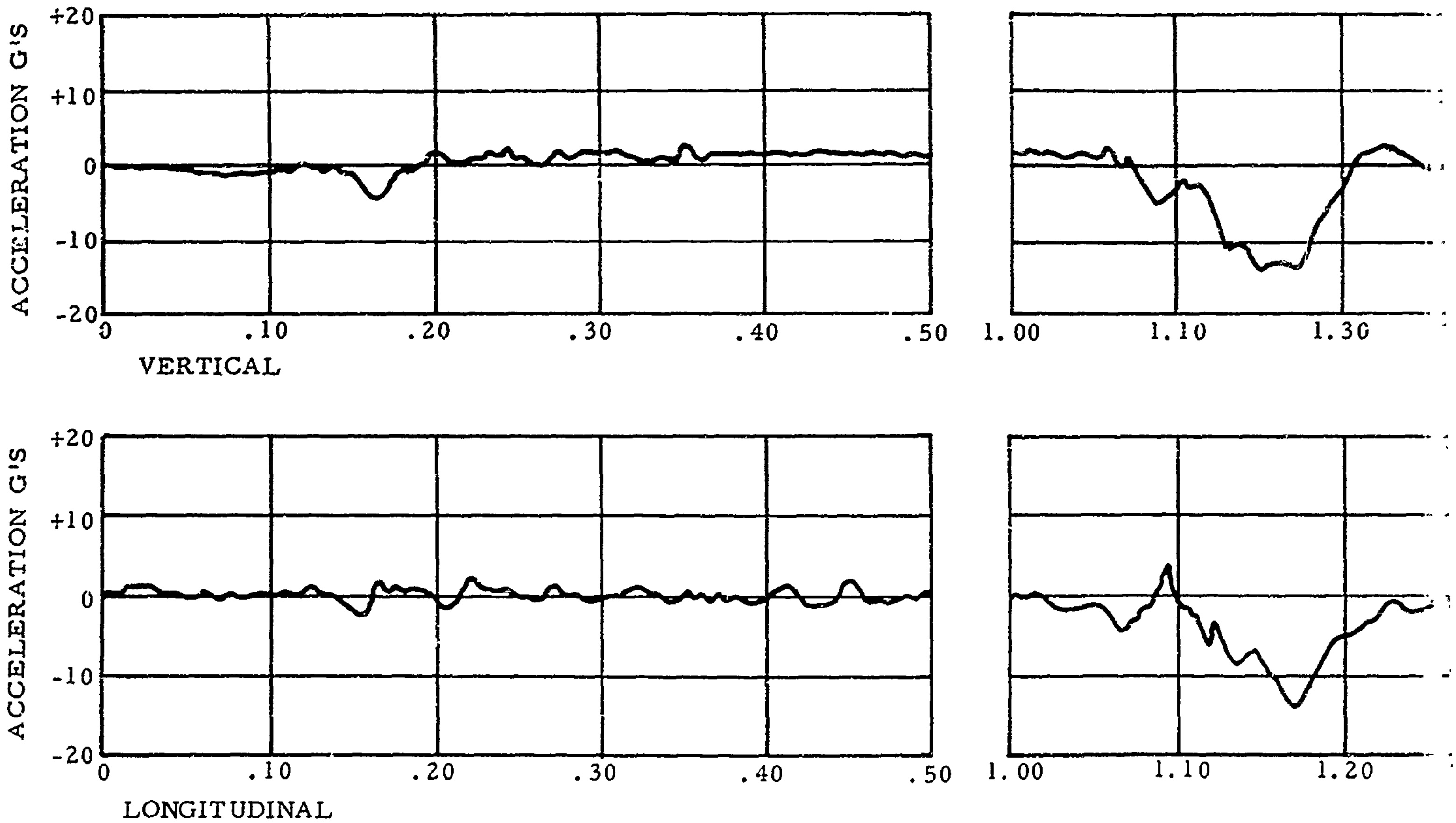


FIG. 6 - 15 FORWARD CABIN SEAT LAP BELT LOAD — SEAT 3B




ACCELERATION G'S
+20
+10
0
-10
-20
0
.10
.20
.30
.40
.50
1.00
1.10
1.30
VERTICAL
ACCELERATION G'S
+20
+10
0
-10
-20
0
.10
.20
.30
.40
.50
1.00
1.10
1.20
LONGITUDINAL

A

FIG. 6 - 16 FORWARD CAB
ACCELERATIO

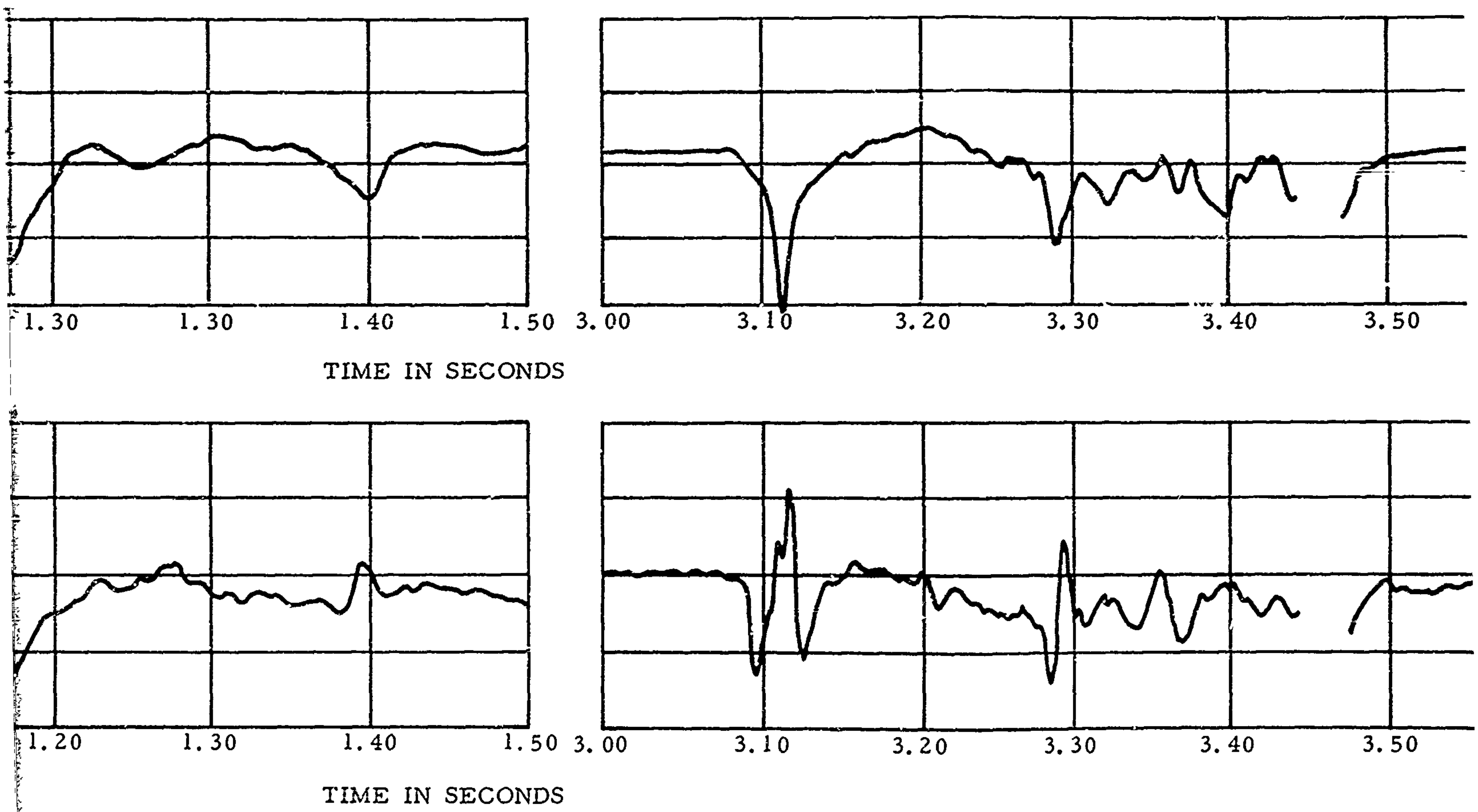
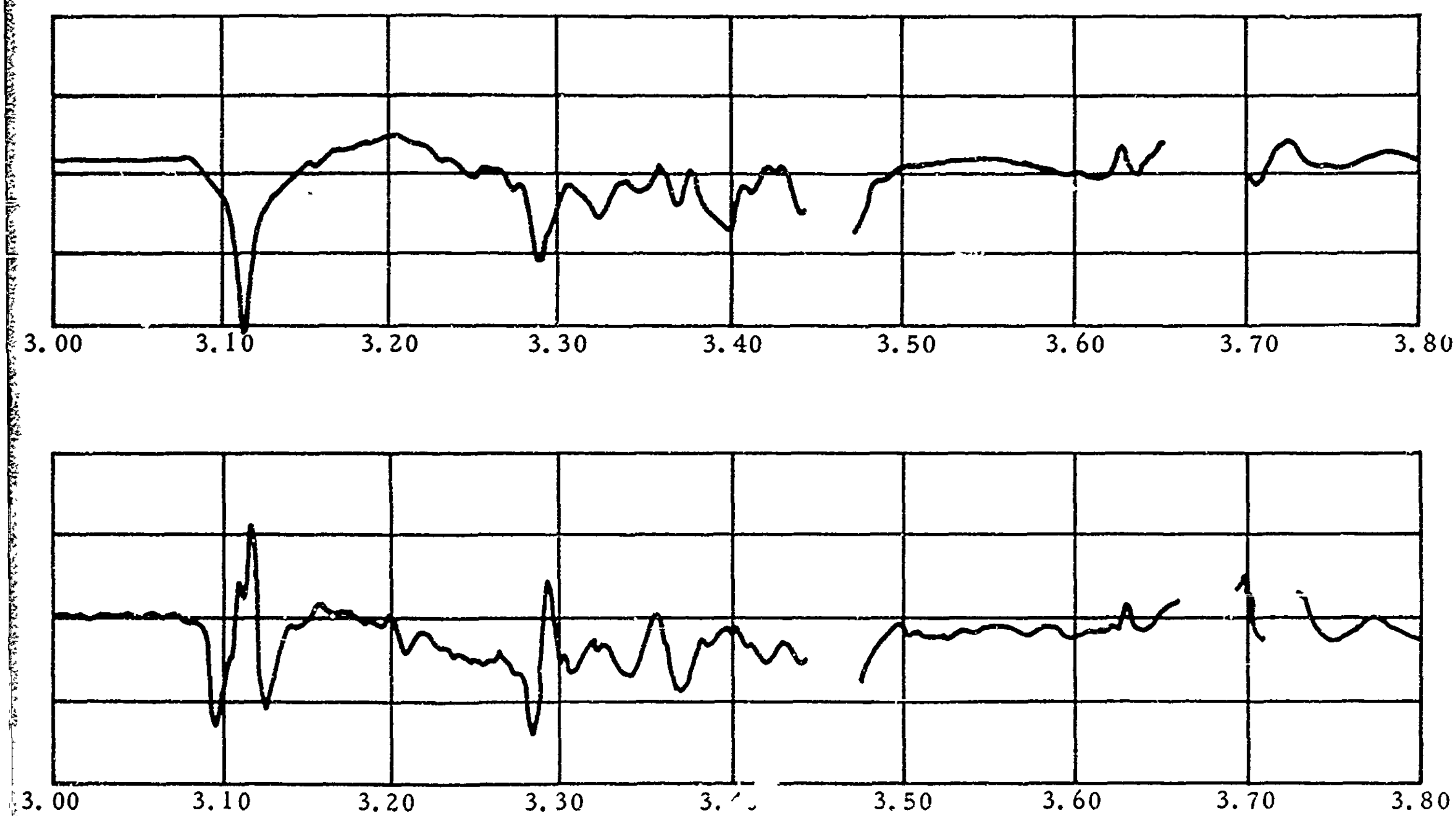
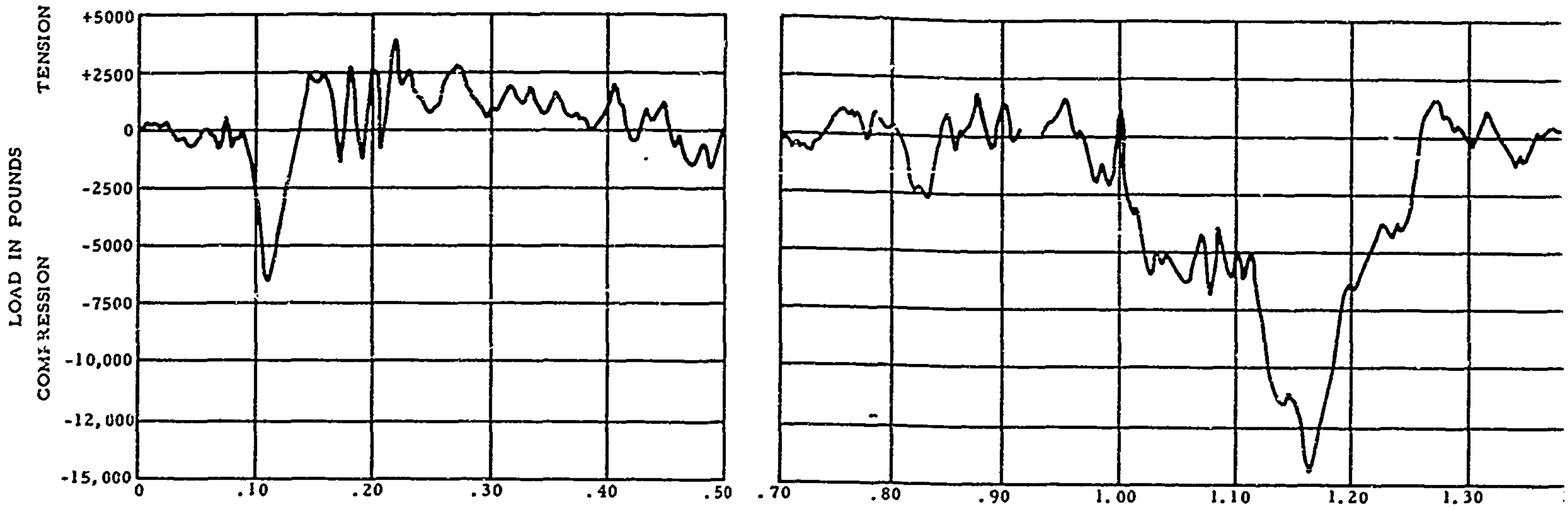
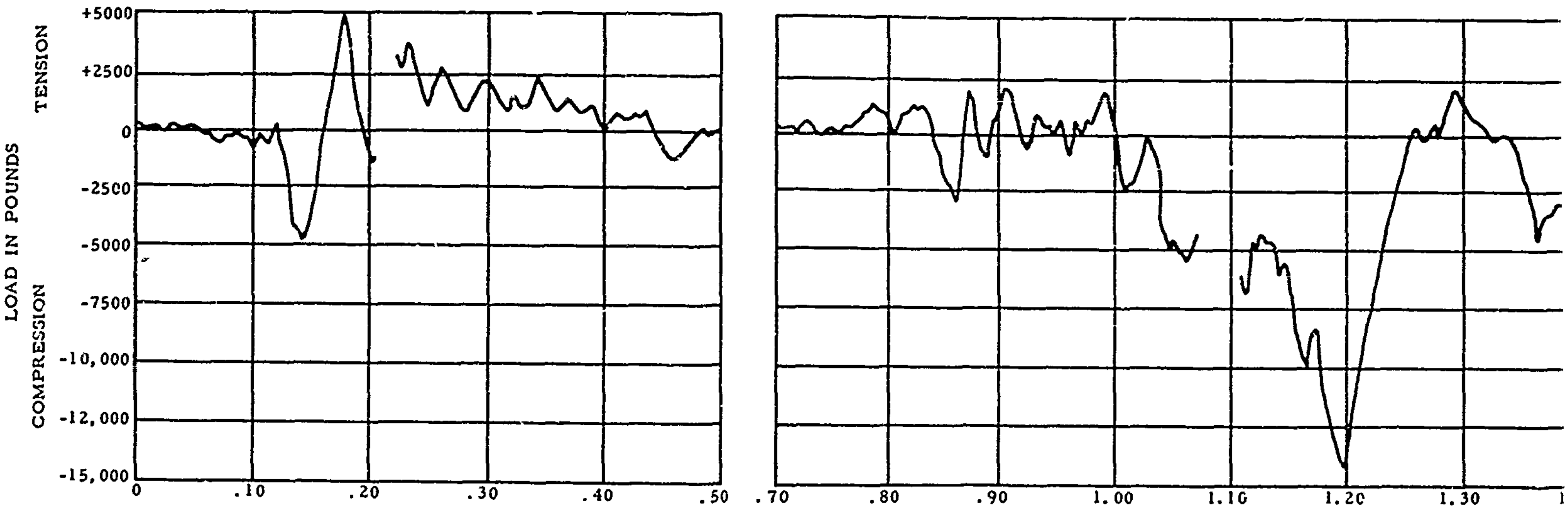


FIG. 6 - 16 FORWARD CABIN SEAT OCCUPANT'S PELVIC ACCELERATIONS — SEAT 5A

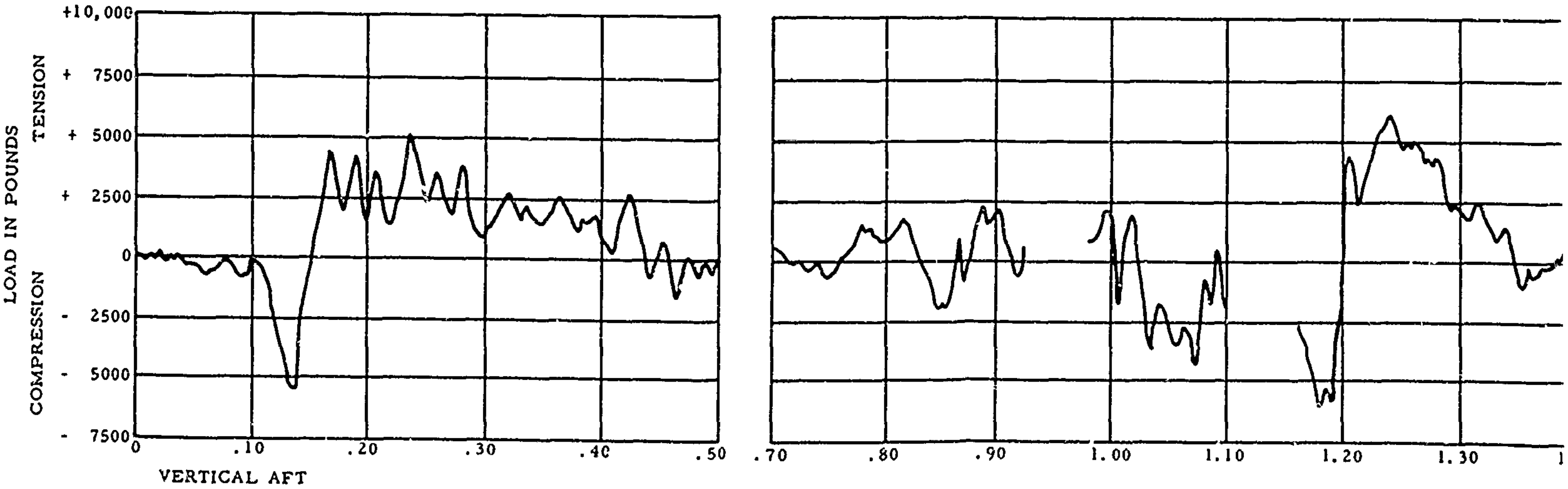




VERTICAL FORWARD LEFT SIDE



VERTICAL FORWARD RIGHT SIDE



VERTICAL AFT

FIG. 6 - 17 CRUSHABLE CARGO RESTRA

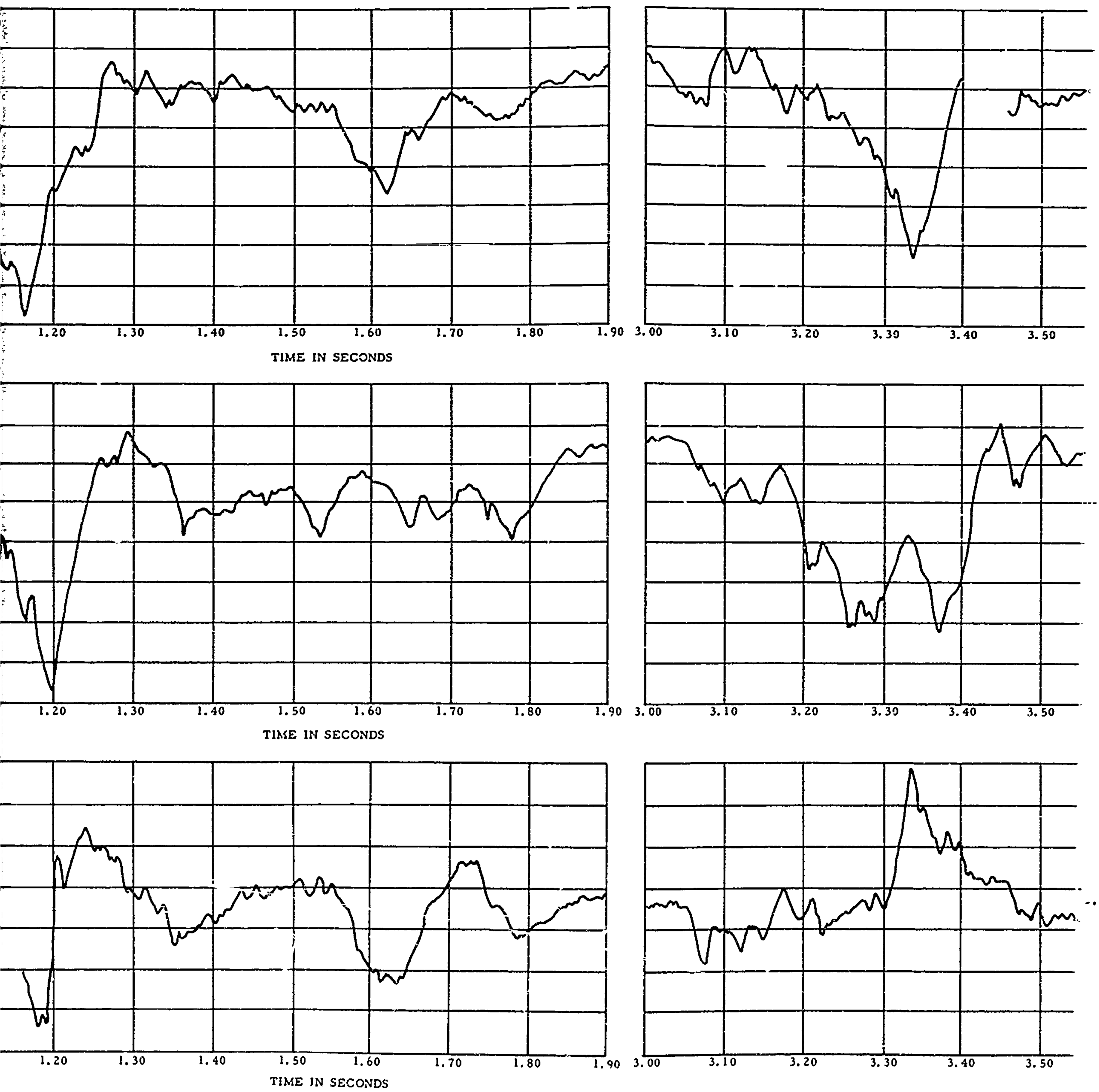
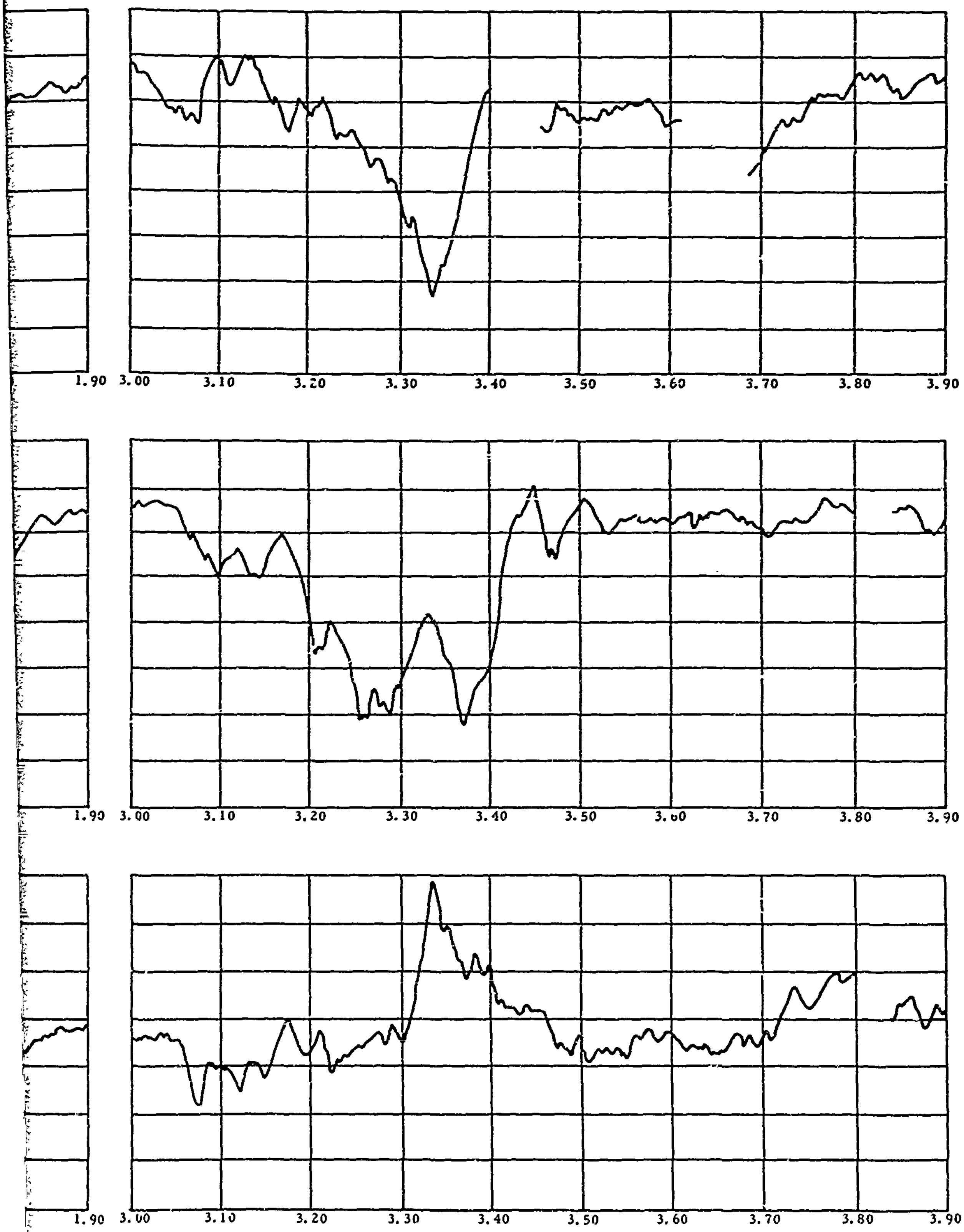
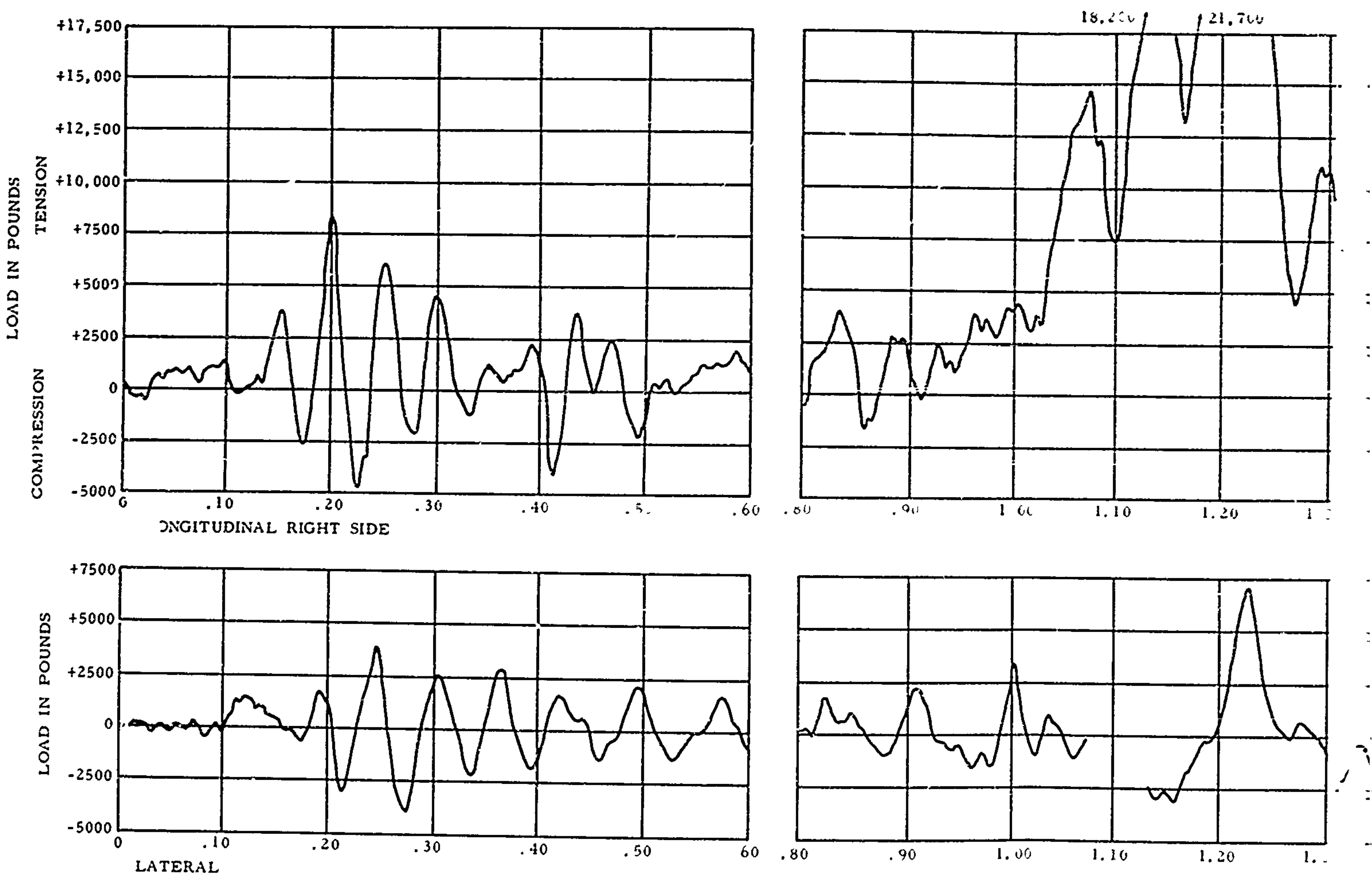


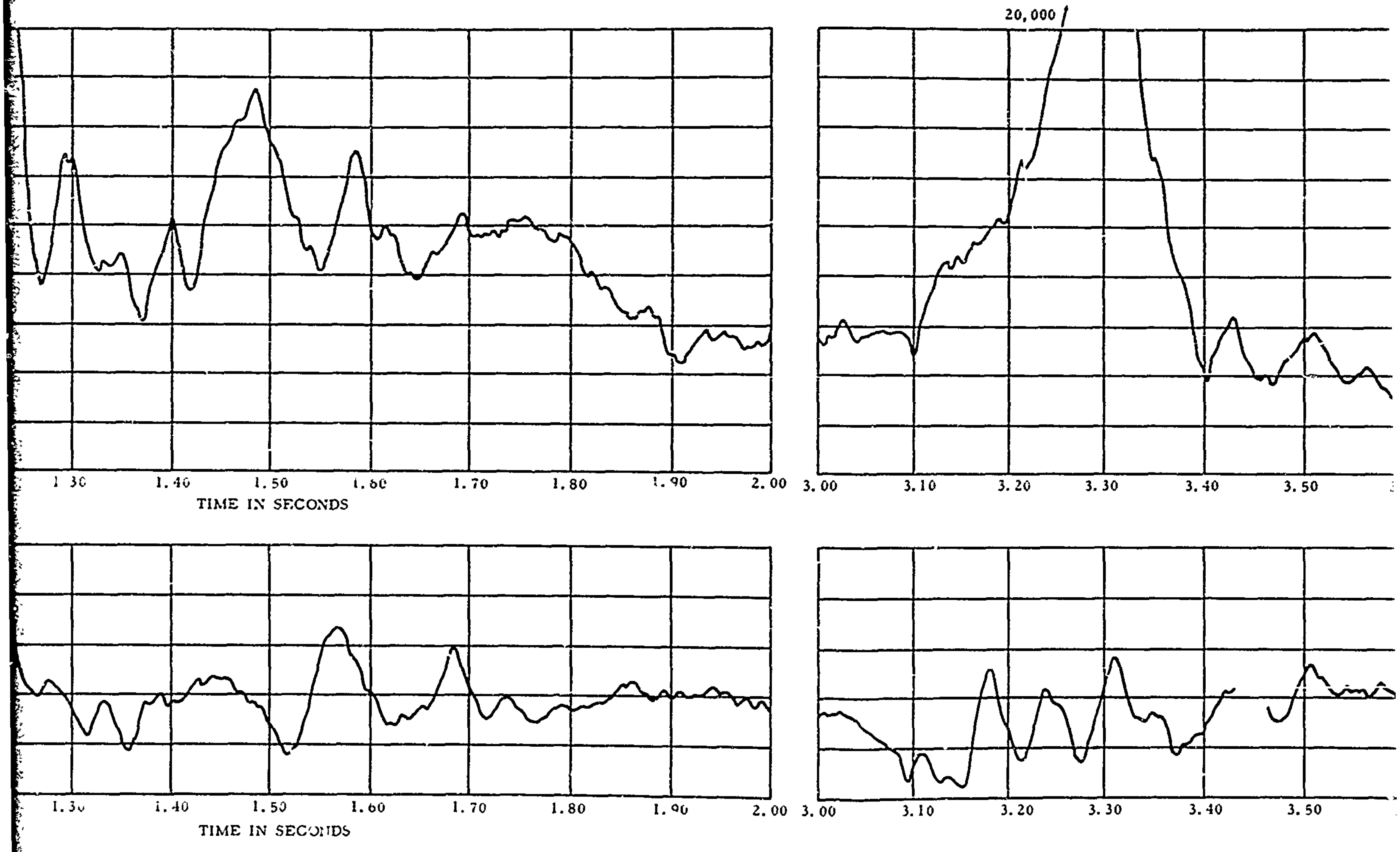
FIG. 6 - 17 CRUSHABLE CARGO RESTRAINT LOADS — PALLET 1





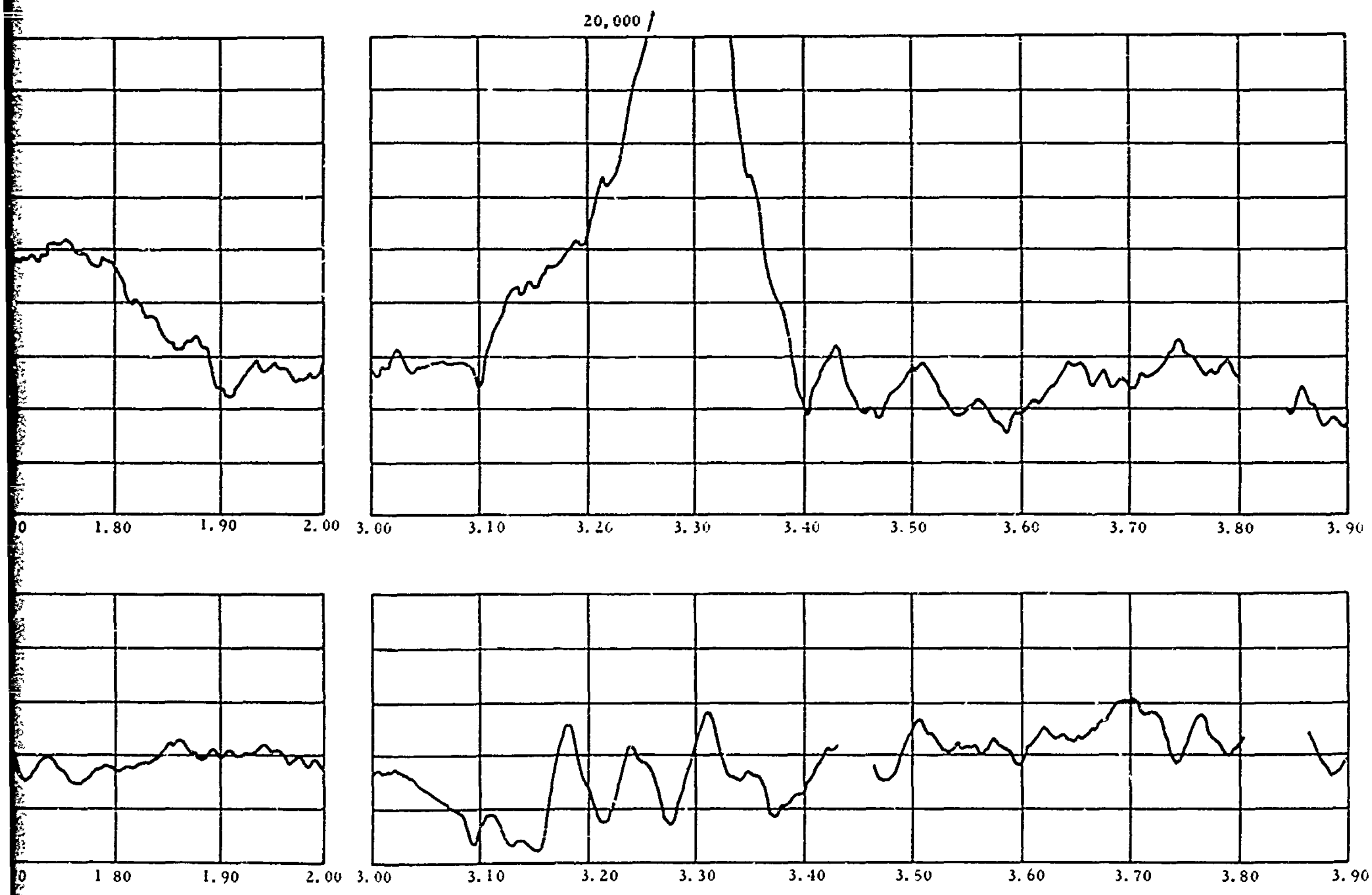
+17,500
+15,000
+12,500
+10,000
+7500
+5000
+2500
0
-2500
-5000
LOAD IN POUNDS
TENSION
COMPRESSION
0
.10
.20
.30
.40
.60
.90
1.10
1.20
ONGITUDINAL RIGHT SIDE
+7500
+5000
+2500
0
-2500
-5000
LOAD IN POUNDS
0
.10
.20
.30
.40
.50
.80
.90
1.00
1.10
1.20
LATERAL

FIG. 6 - 18 CRUSHABLE CARGO RESTRAI



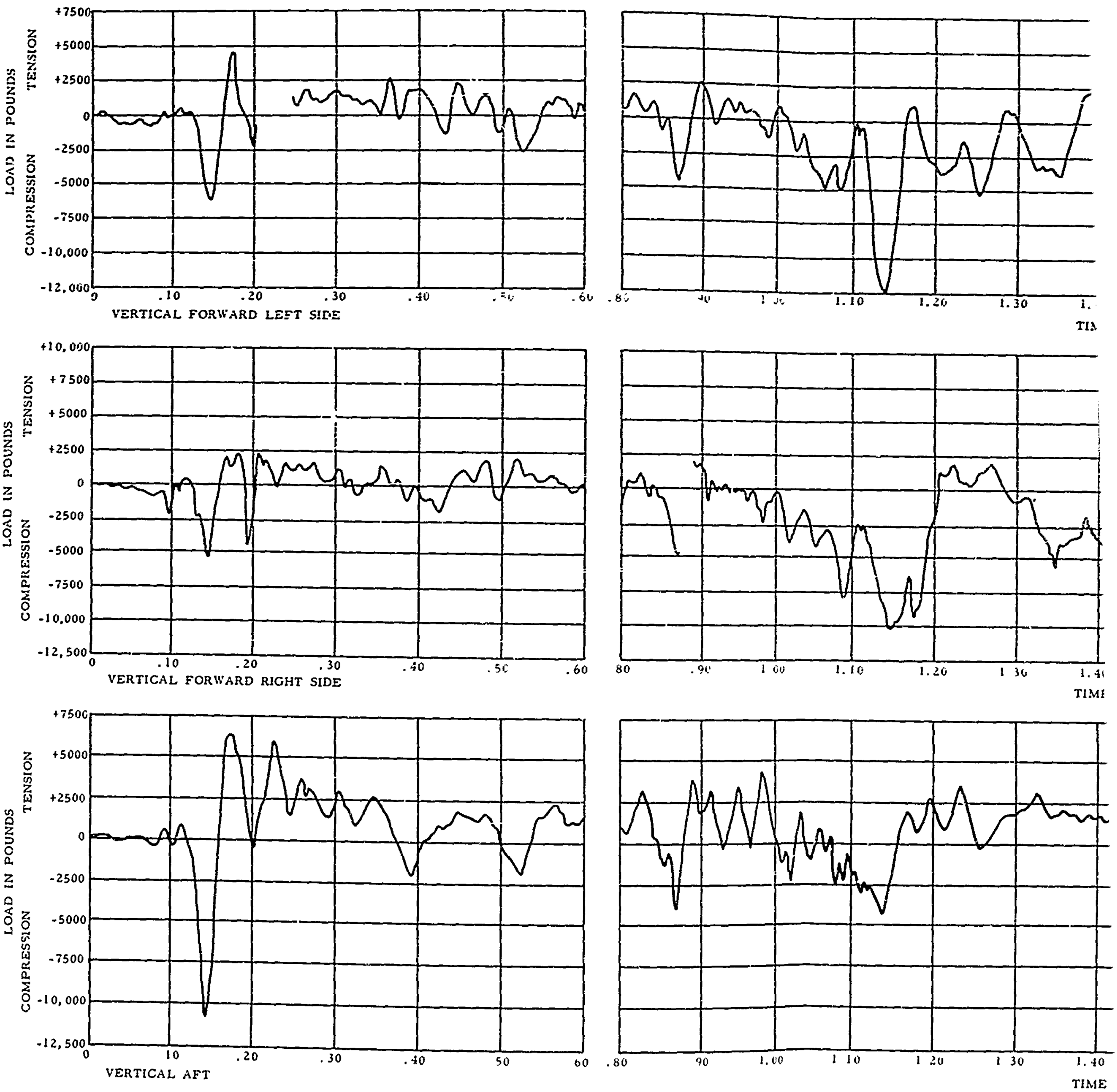
B

FIG. 6 - 18 CRUSHABLE CARGO RESTRAINT LOADS — PALLET 1



B

C



LOAD IN POUNDS
TENSION
COMPRESSION
+7500
+5000
+2500
0
-2500
-5000
-7500
-10,000
-12,000
.10
.20
.30
.40
.60
1.10
1.20
1.30
VERTICAL FORWARD LEFT SIDE
+10,000
+7500
+5000
+2500
0
-2500
-5000
-7500
-10,000
-12,500
0
.10
.20
.30
.40
.60
80
1.10
1.20
VERTICAL FORWARD RIGHT SIDE
TIME
+7500
+5000
+2500
0
-2500
-5000
-7500
-10,000
-12,500
0
10
.20
.30
.40
50
60
.80
90
1.00
1 10
1 20
1 30
1.40
VERTICAL AFT
TIME

FIG. 6 - 19 RIC

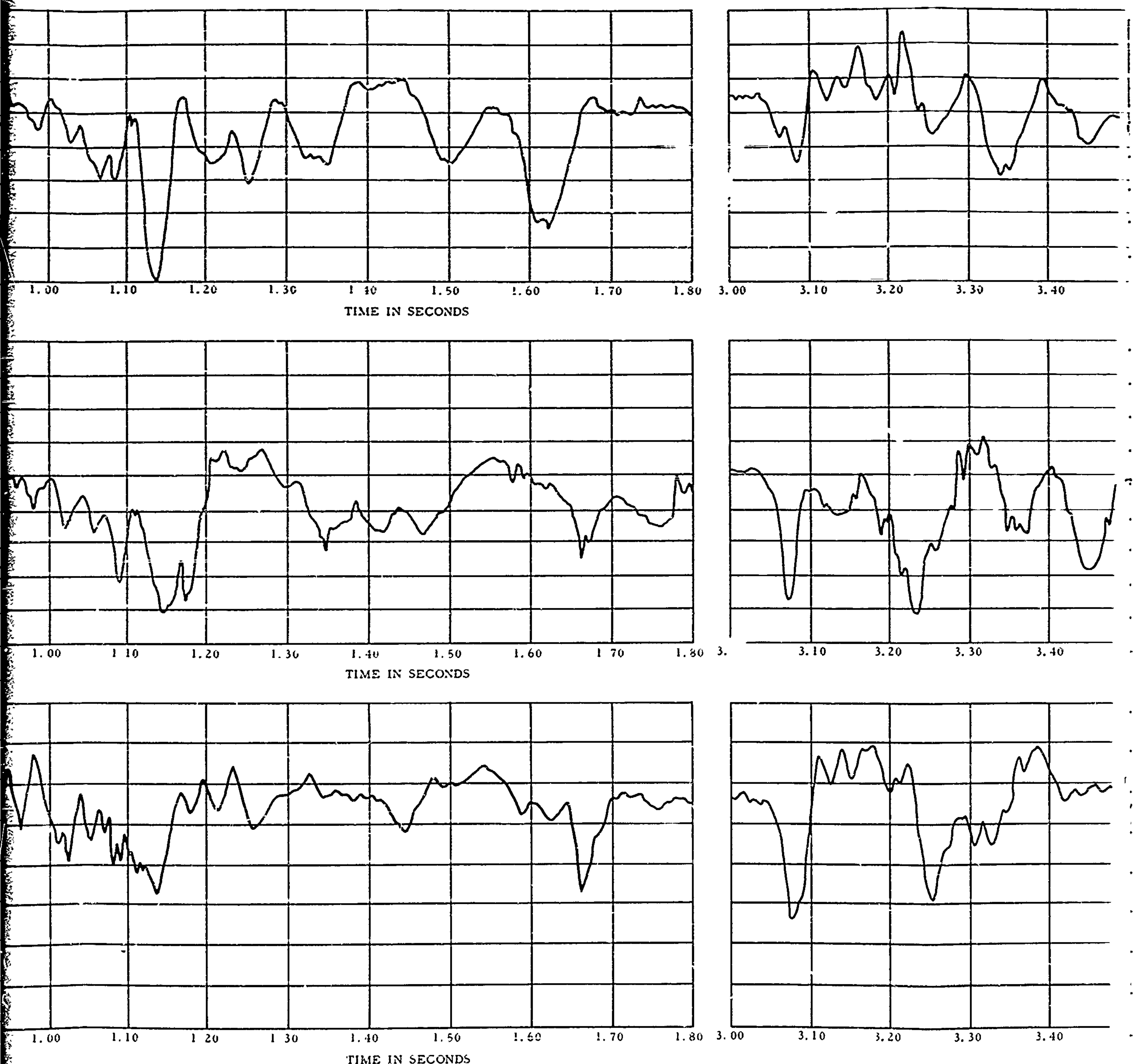
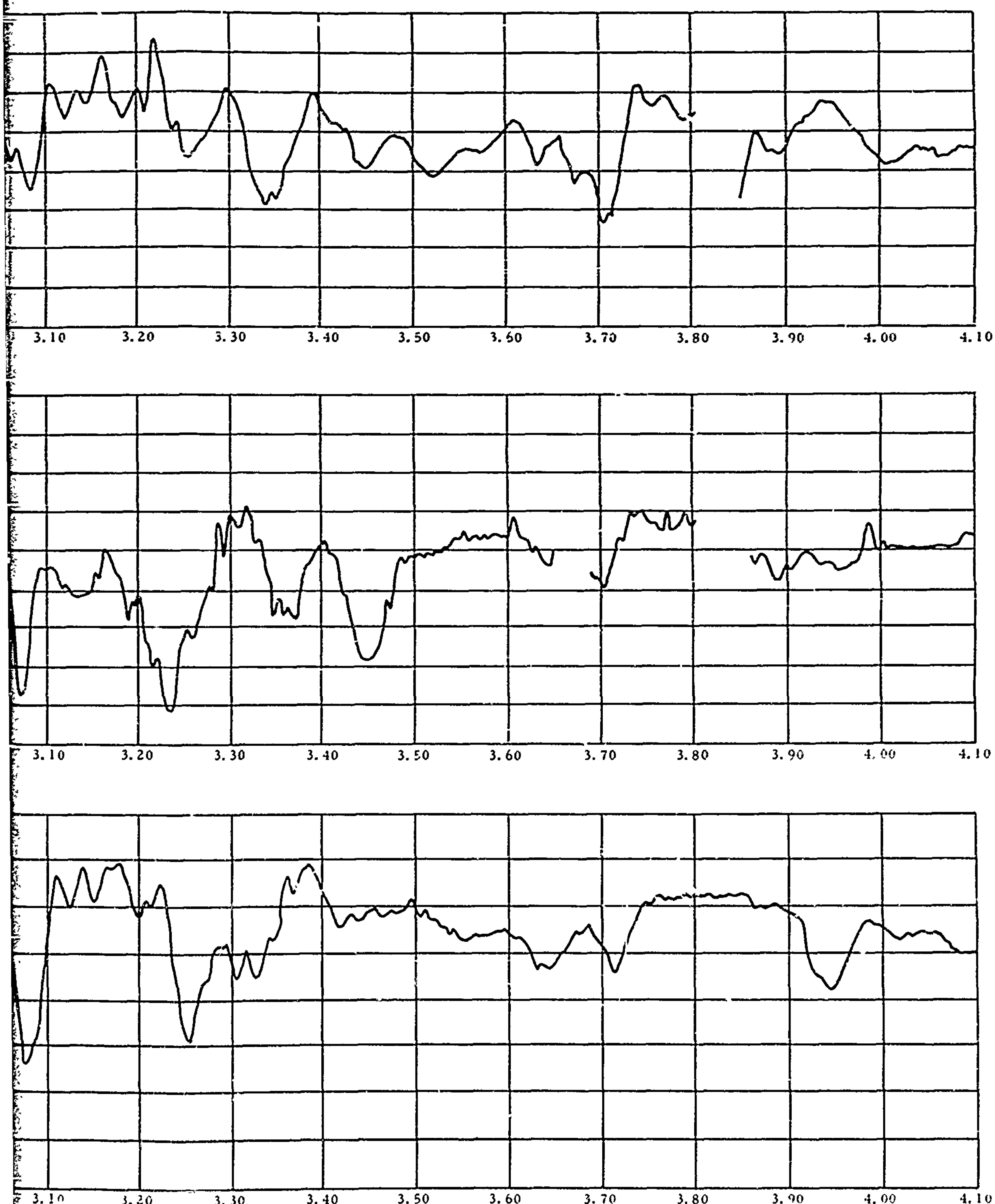
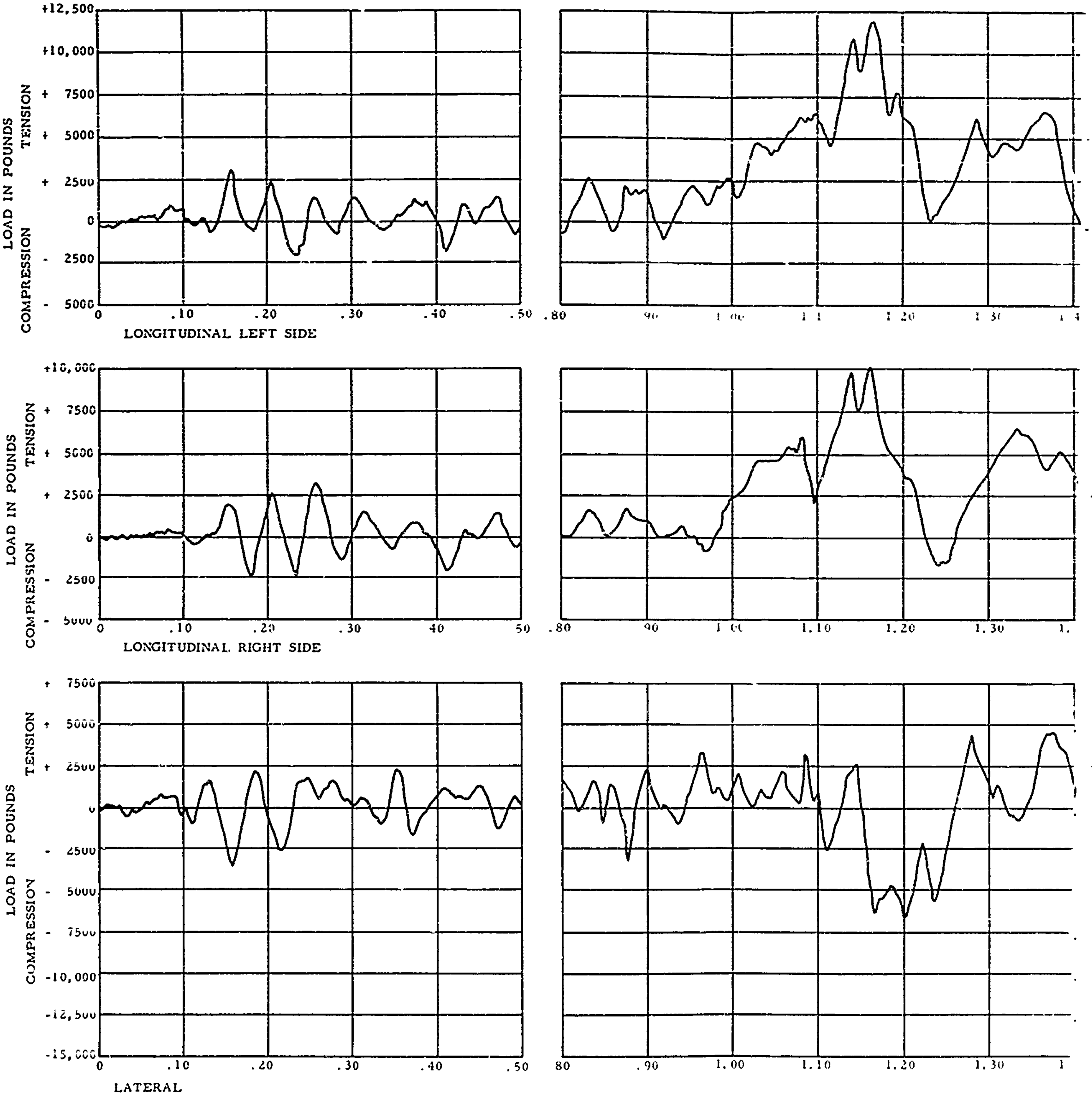

1.00 1.10 1.20 1.30 1.40 1.50 1.60 1.70 1.80
TIME IN SECONDS
3.00 3.10 3.20 3.30 3.40
1.00 1.10 1.20 1.30 1.40 1.50 1.60 1.70 1.80
TIME IN SECONDS
3.10 3.20 3.30 3.40
1.00 1.10 1.20 1.30 1.40 1.50 1.60 1.70 1.80
TIME IN SECONDS
3.00 3.10 3.20 3.30 3.40

FIG. 6 - 19 RIGID CARGO RESTRAINT LOADS — PALLET 2




LOAD IN POUNDS
TENSION
COMPRESSION
+12,500
+10,000
+ 7500
+ 5000
+ 2500
0
- 2500
- 5000
0
.10
.20
.30
.40
.50
.80
1.20
1.30
LONGITUDINAL LEFT SIDE
+10,000
LONGITUDINAL RIGHT SIDE
1.10
-10,000
-12,500
-15,000
.90
1.00
LATERAL

A

FIG. 6 - 20 RIGID CARGO RESTRAINT LOA

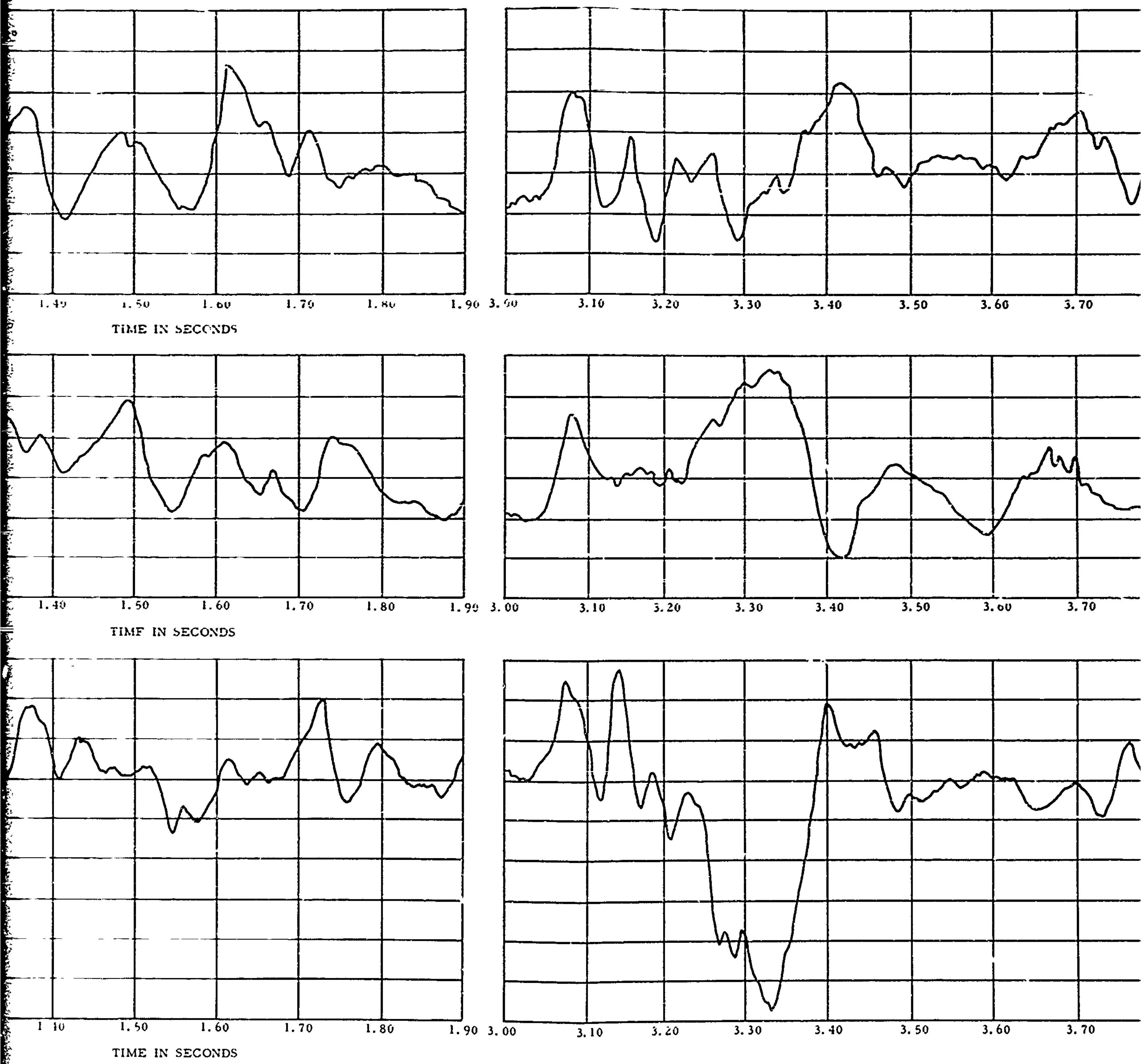
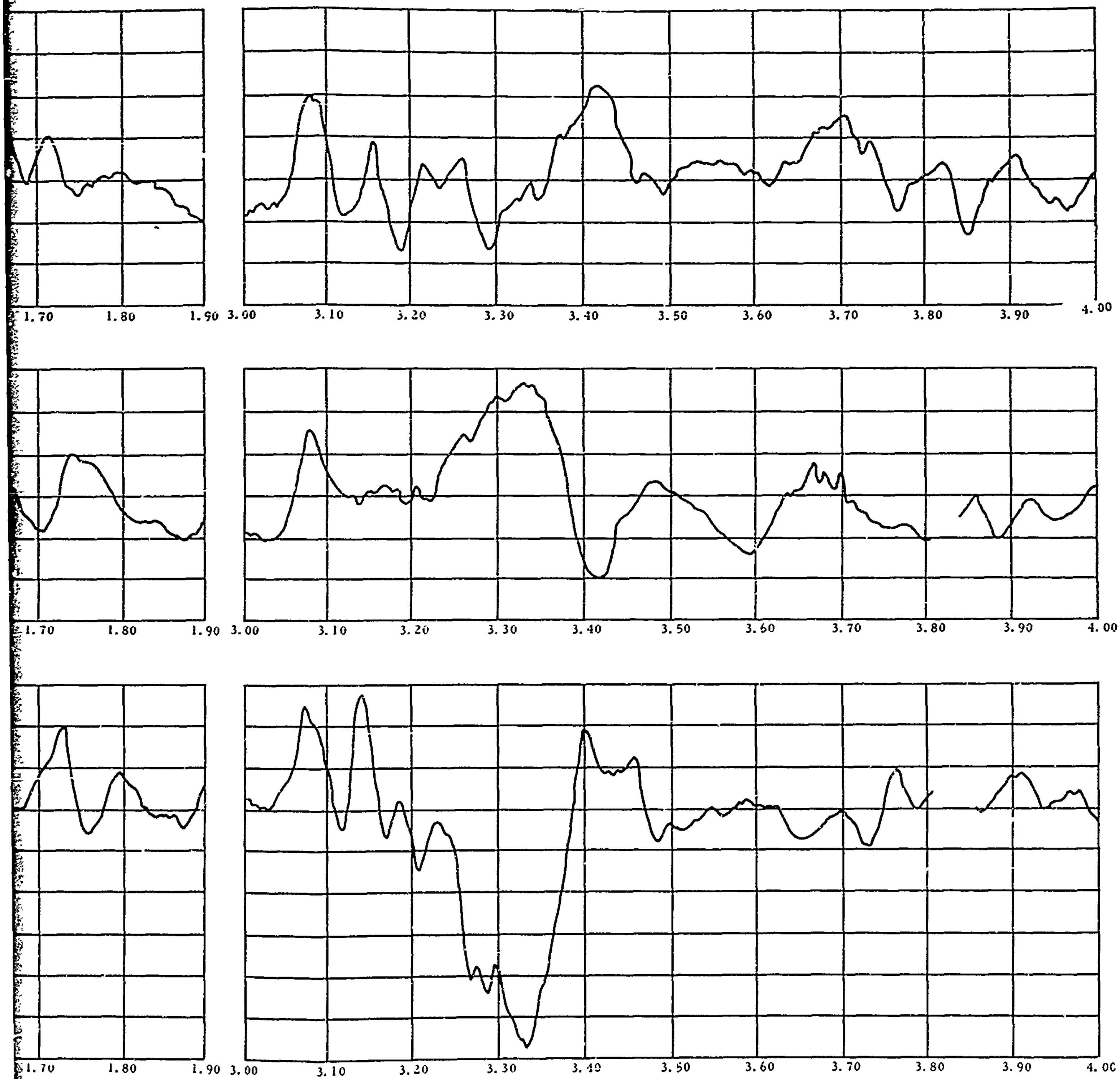


FIG. 6 - 20 RIGID CARGO RESTRAINT LOADS — PALLET 2



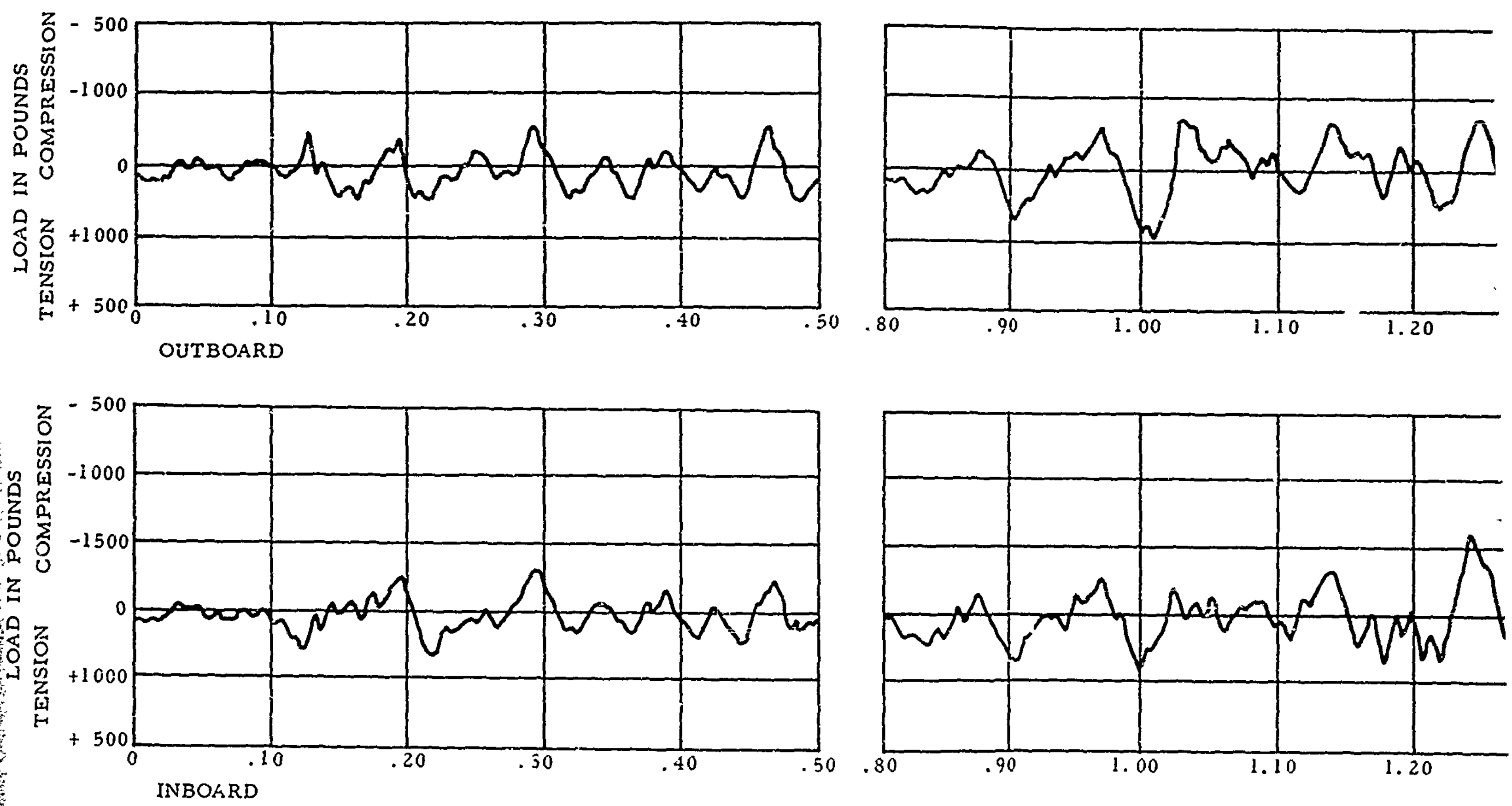
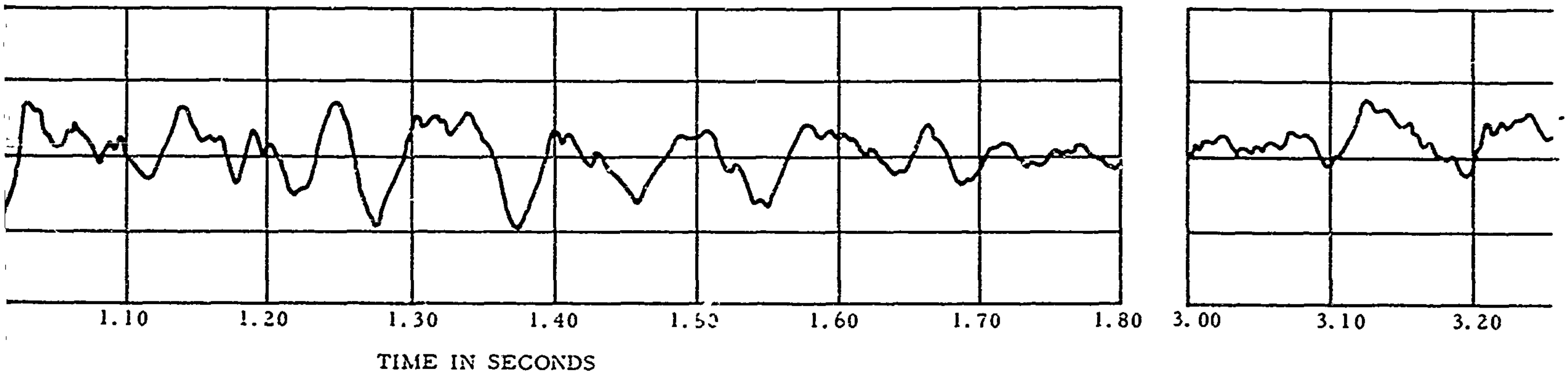

LOAD IN POUNDS
TENSION COMPRESSION
- 500
-1000
0
+1000
+ 500
0
.10
.20
.30
.40
.50
.80
.90
1.00
1.10
1.20
OUTBOARD
LOAD IN POUNDS
TENSION COMPRESSION
- 500
-1000
-1500
0
+1000
+ 500
0
.10
.20
.30
.40
.50
.80
.90
1.00
1.10
1.20
INBOARD

FIG. 6 - 21 MID-CA
LEG LO



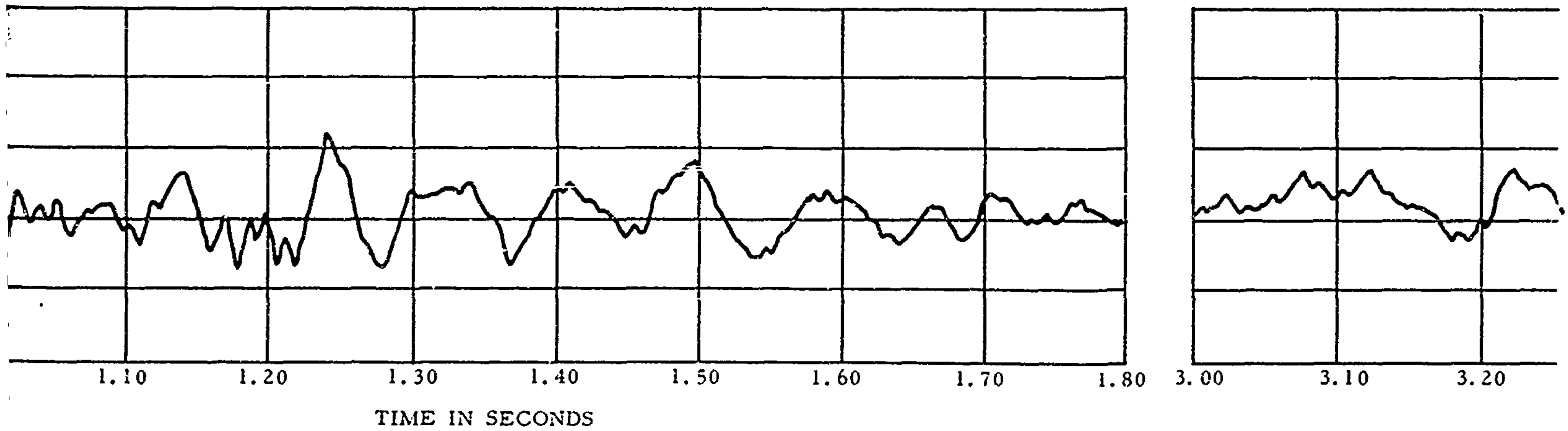
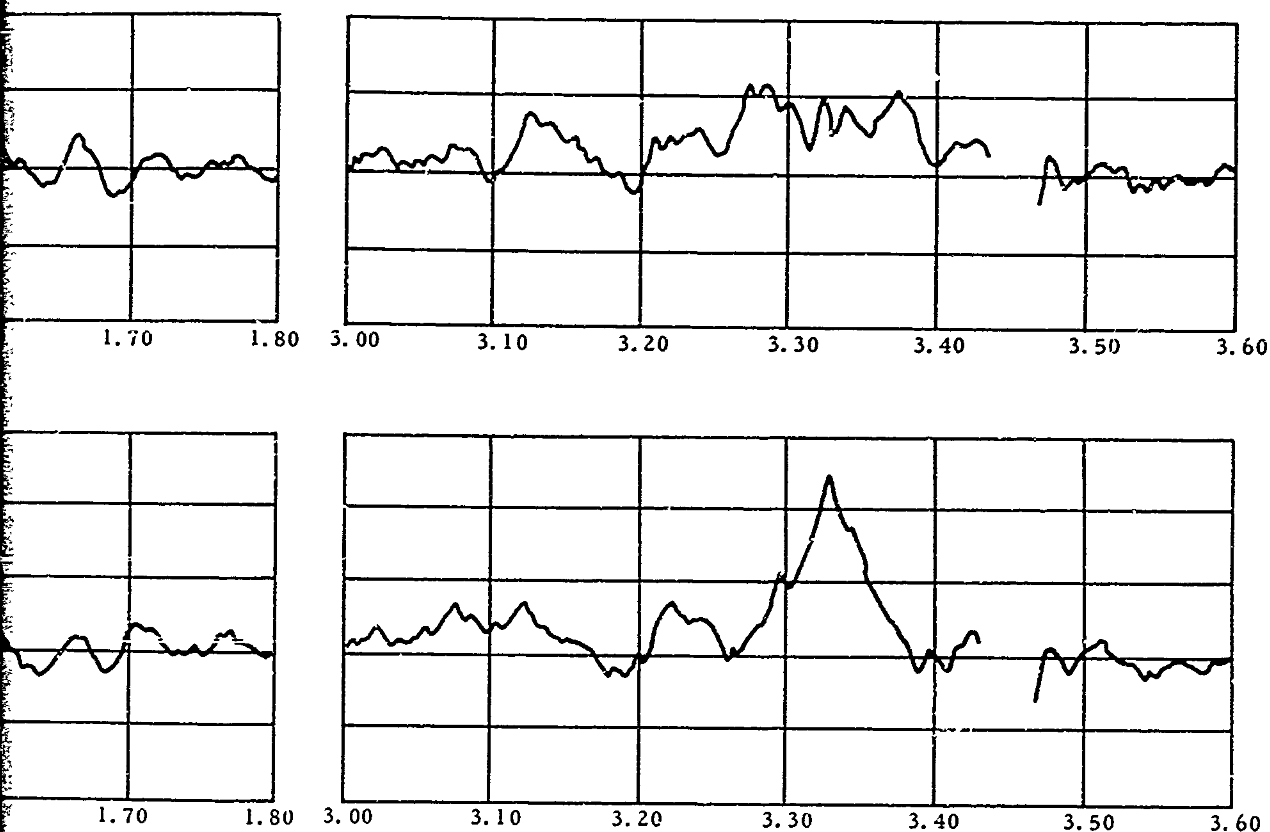
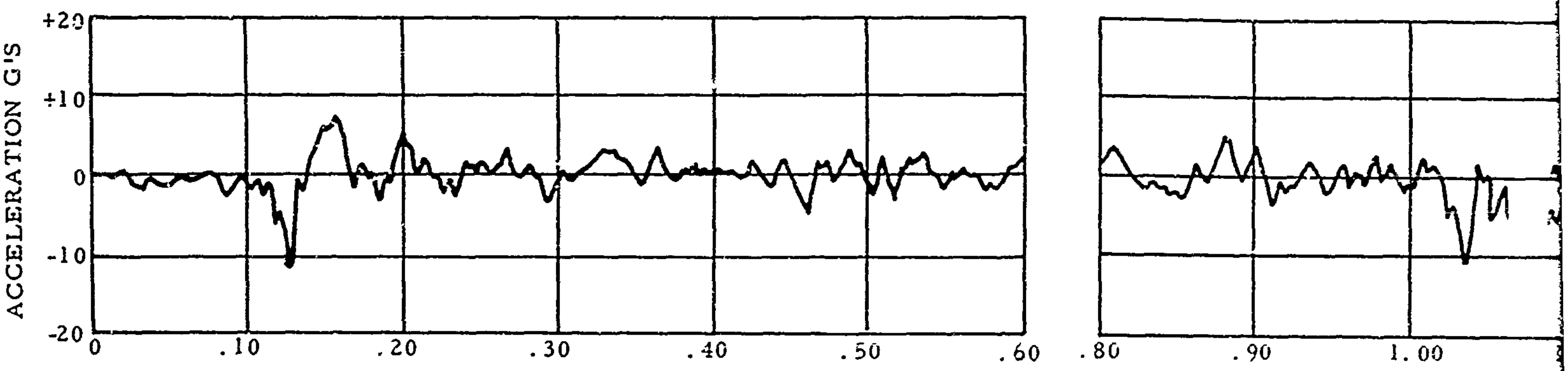


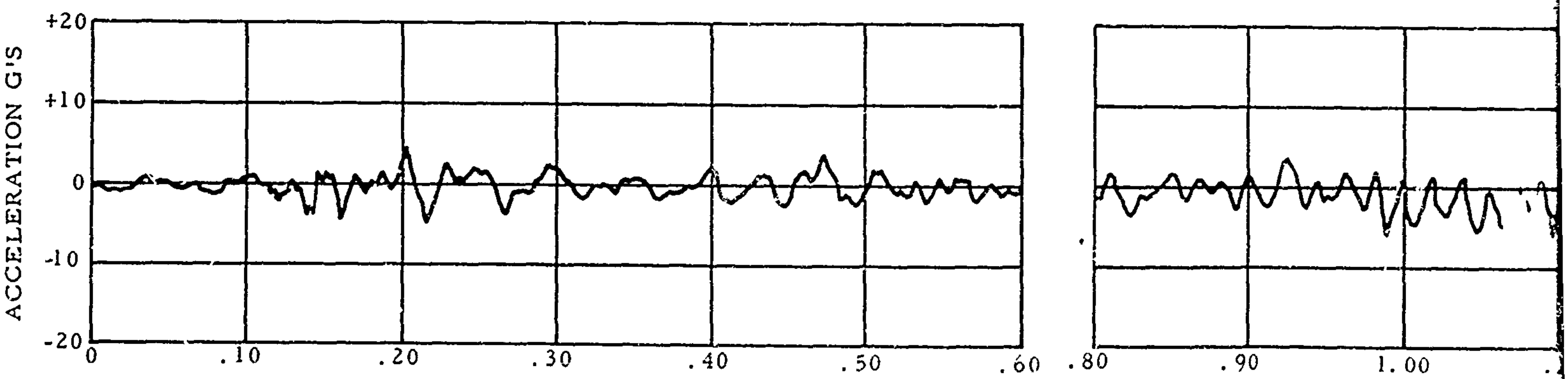
FIG. 6 - 21 MID-CABIN FORWARD FACING SEAT AFT LEG LOADS — SEAT 6



C

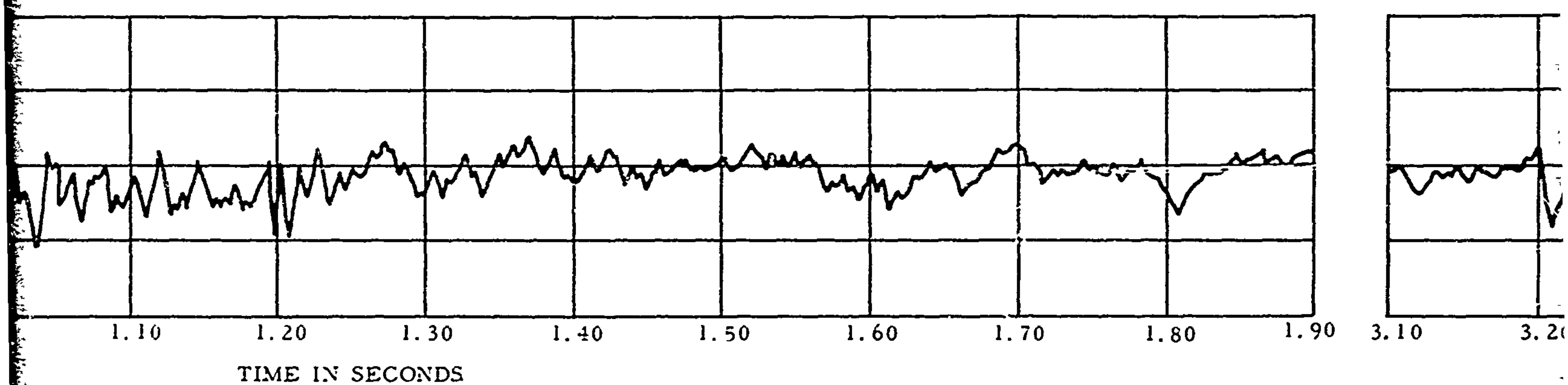


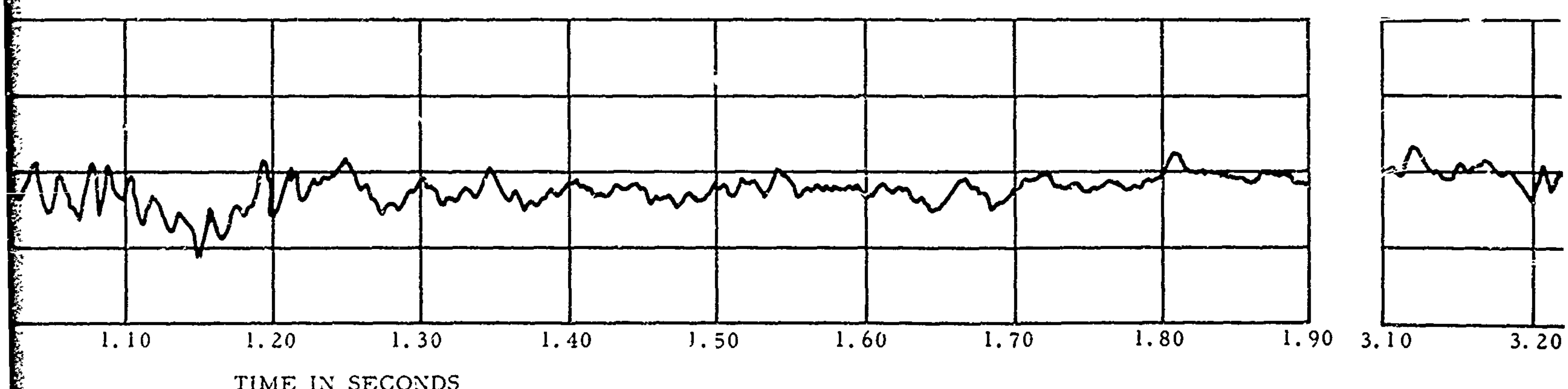
VERTICAL



LONGITUDINAL

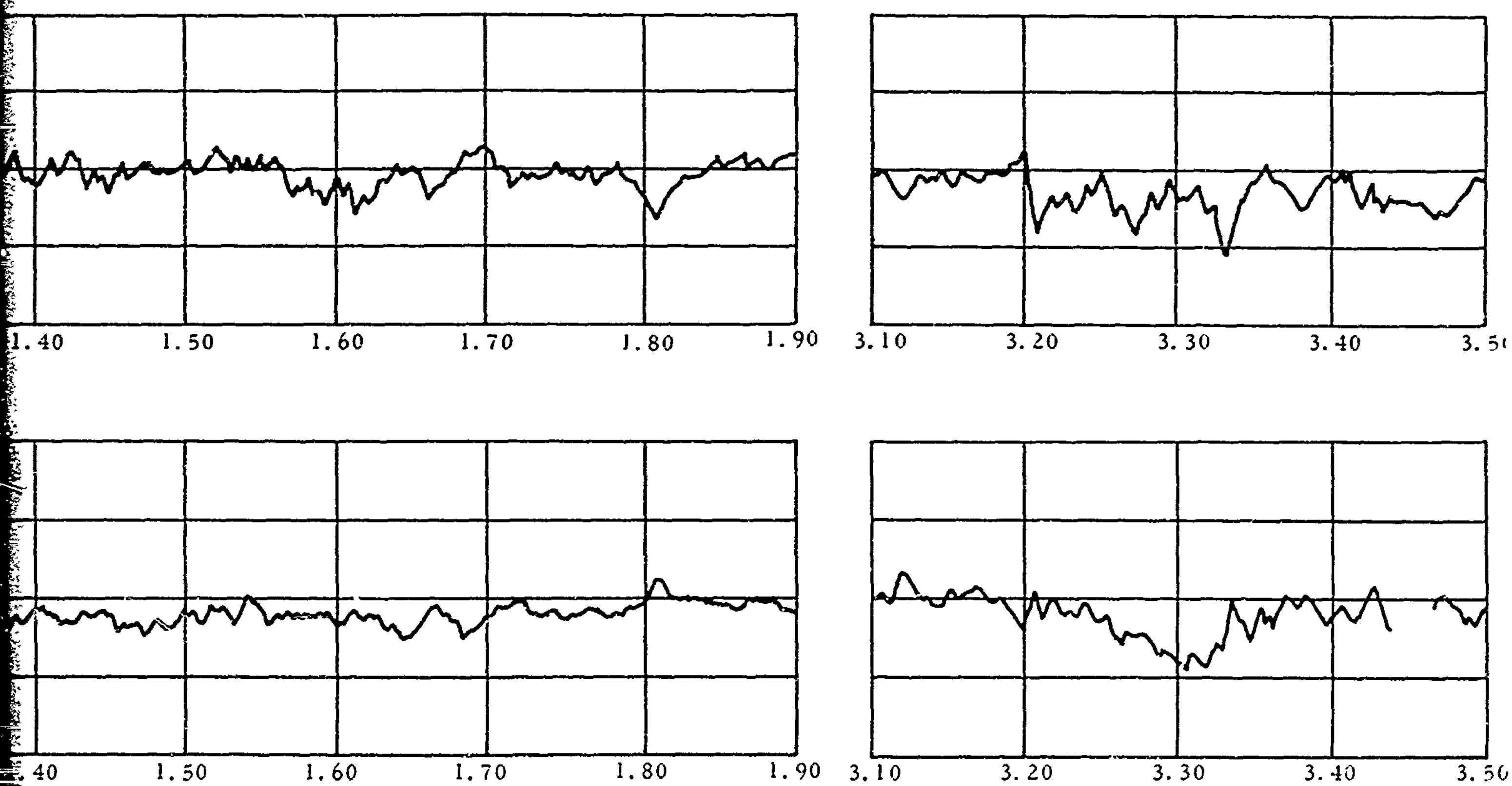
FIG. 6 - 22 MID-CA
ACCEL



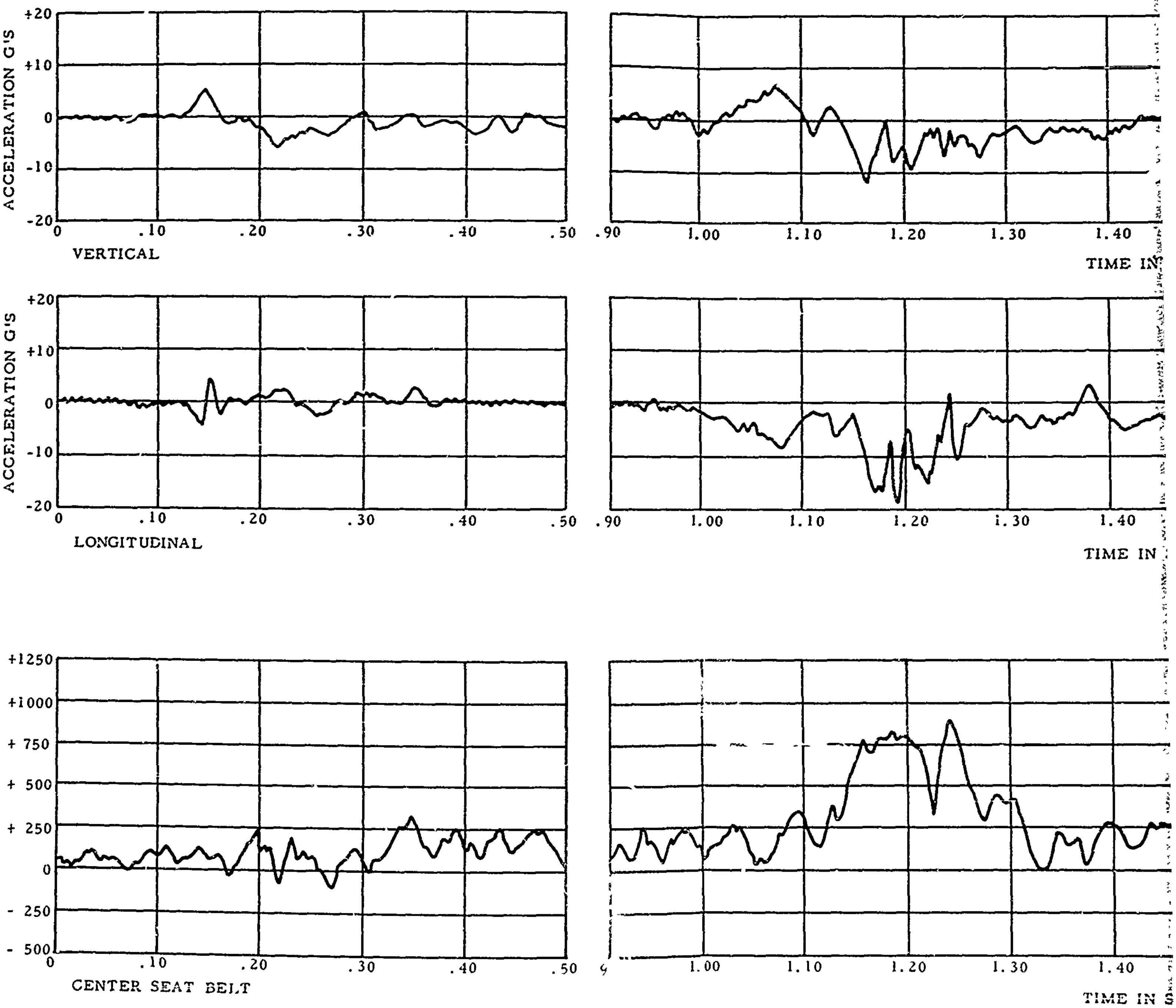


B

FIG. 6 - 22 MID-CABIN FORWARD FACING SEAT ACCELERATIONS — SEAT 8

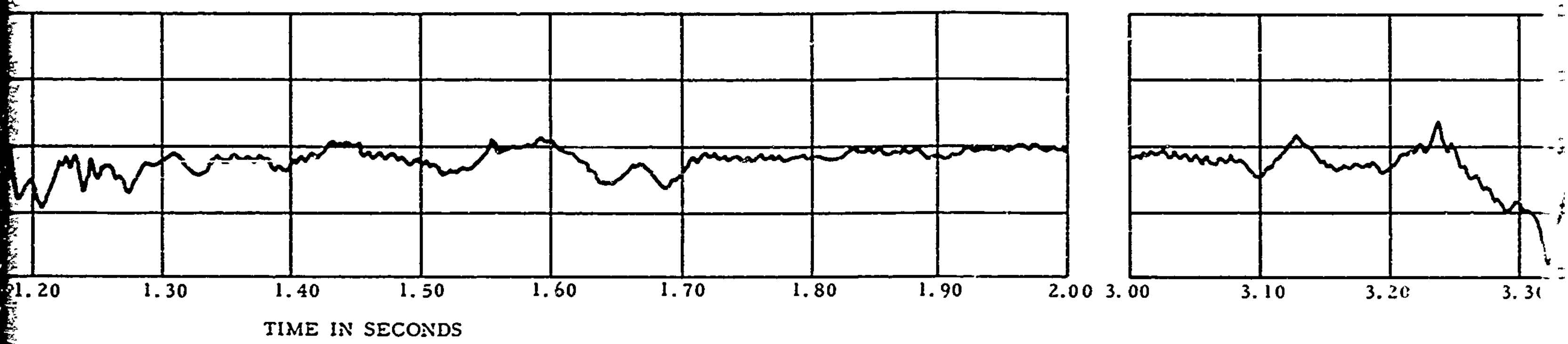


B C


ACCELERATION G'S
+20
+10
0
-10
-20
0
.10
.20
.30
.40
.50
VERTICAL
.90
1.00
1.10
1.20
1.30
1.40
TIME IN
ACCELERATION G'S
LONGITUDINAL
TIME IN
LOAD IN POUNDS
TENSION
COMPRESSION
+1250
+1000
+ 750
+ 500
+ 250
- 250
- 500
CENTER SEAT BELT
TIME IN S

A

FIG. 6 - 23 MID-CABIN FORWARD FA
PELVIC ACCELERATIONS



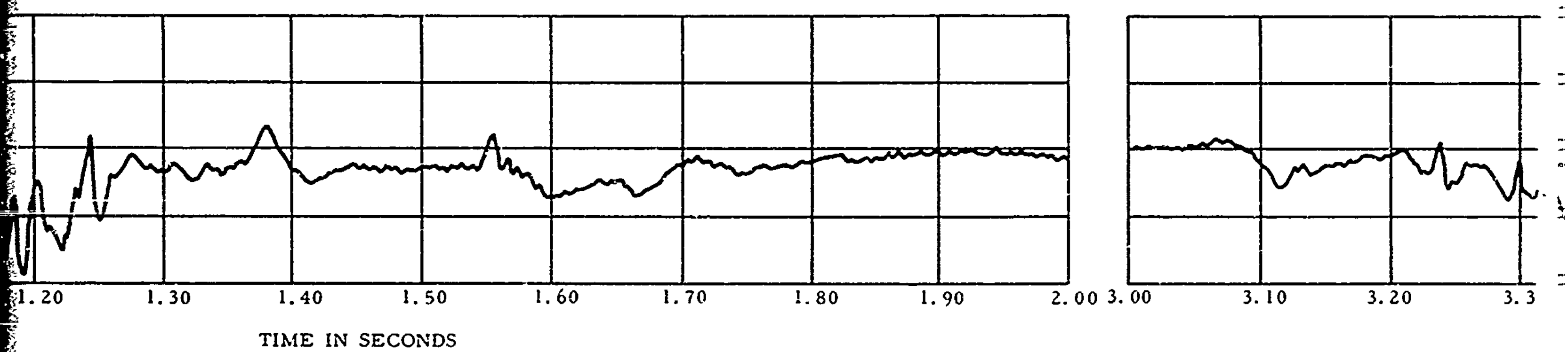


FIG. 6 - 24 MID-CABI
LAP BELT

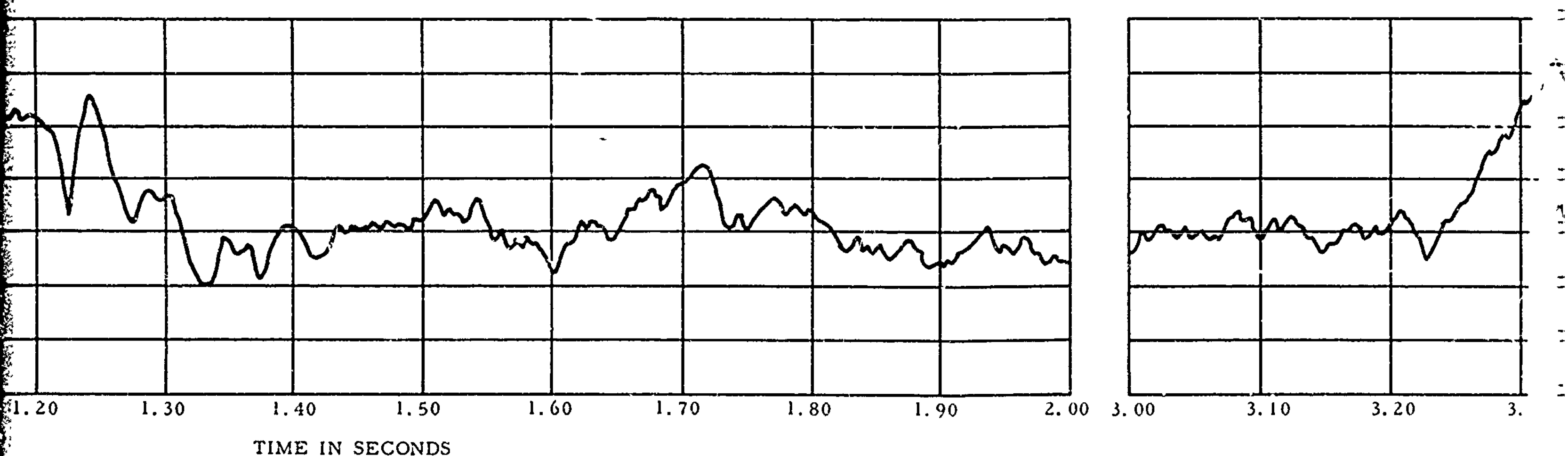


FIG. 6 - 23 MID-CABIN FORWARD FACING SEAT OCCUPANT'S PELVIC ACCELERATIONS — SEAT 8B

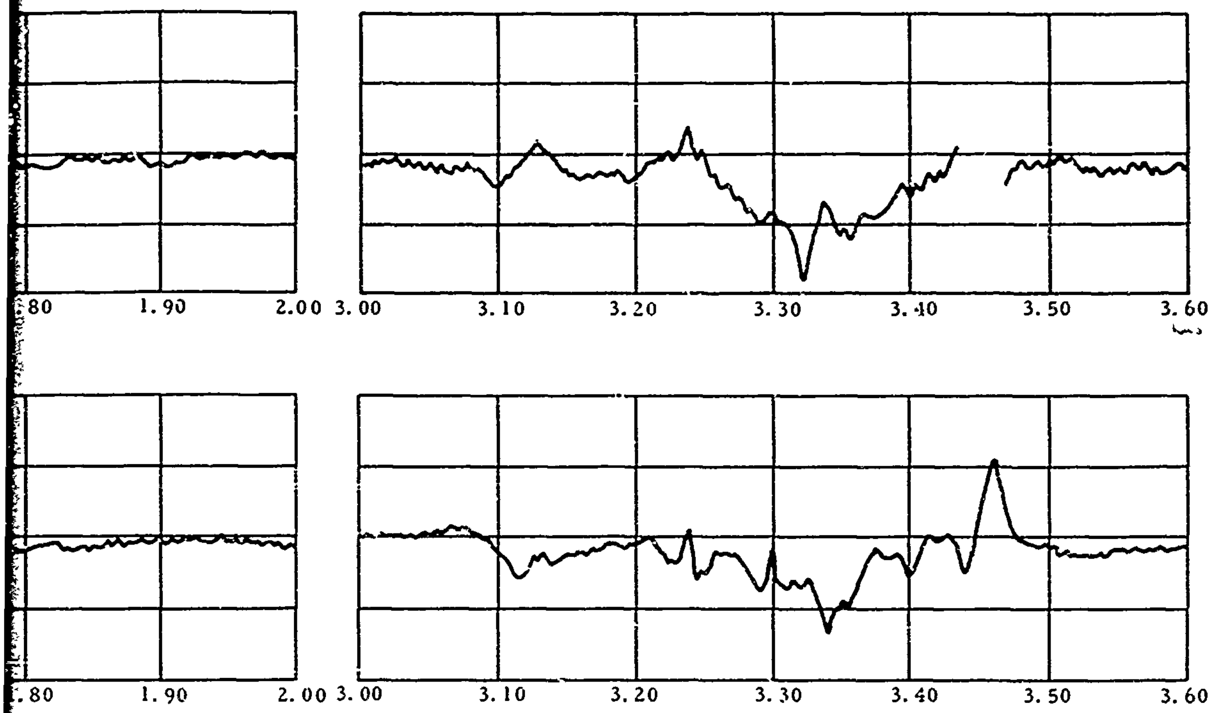
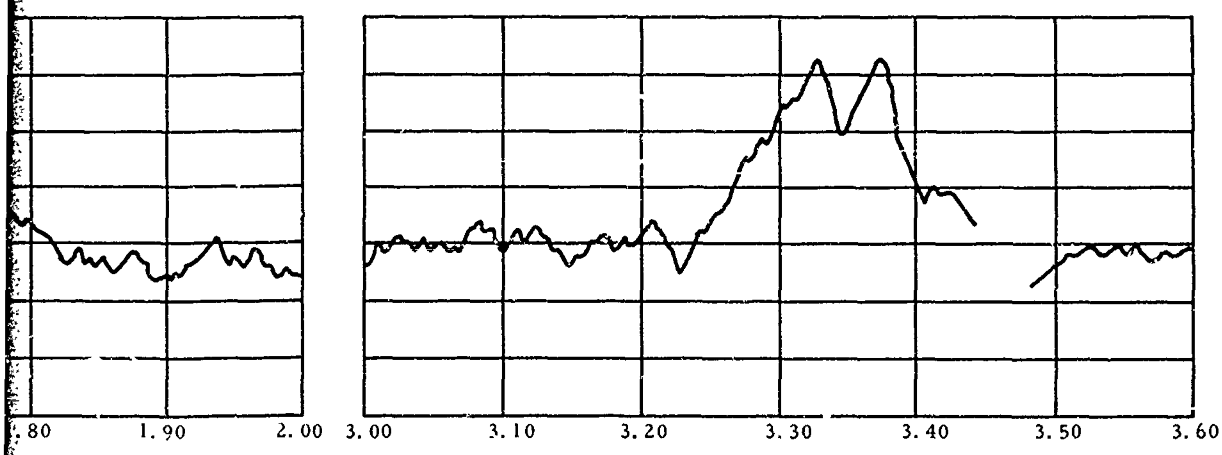
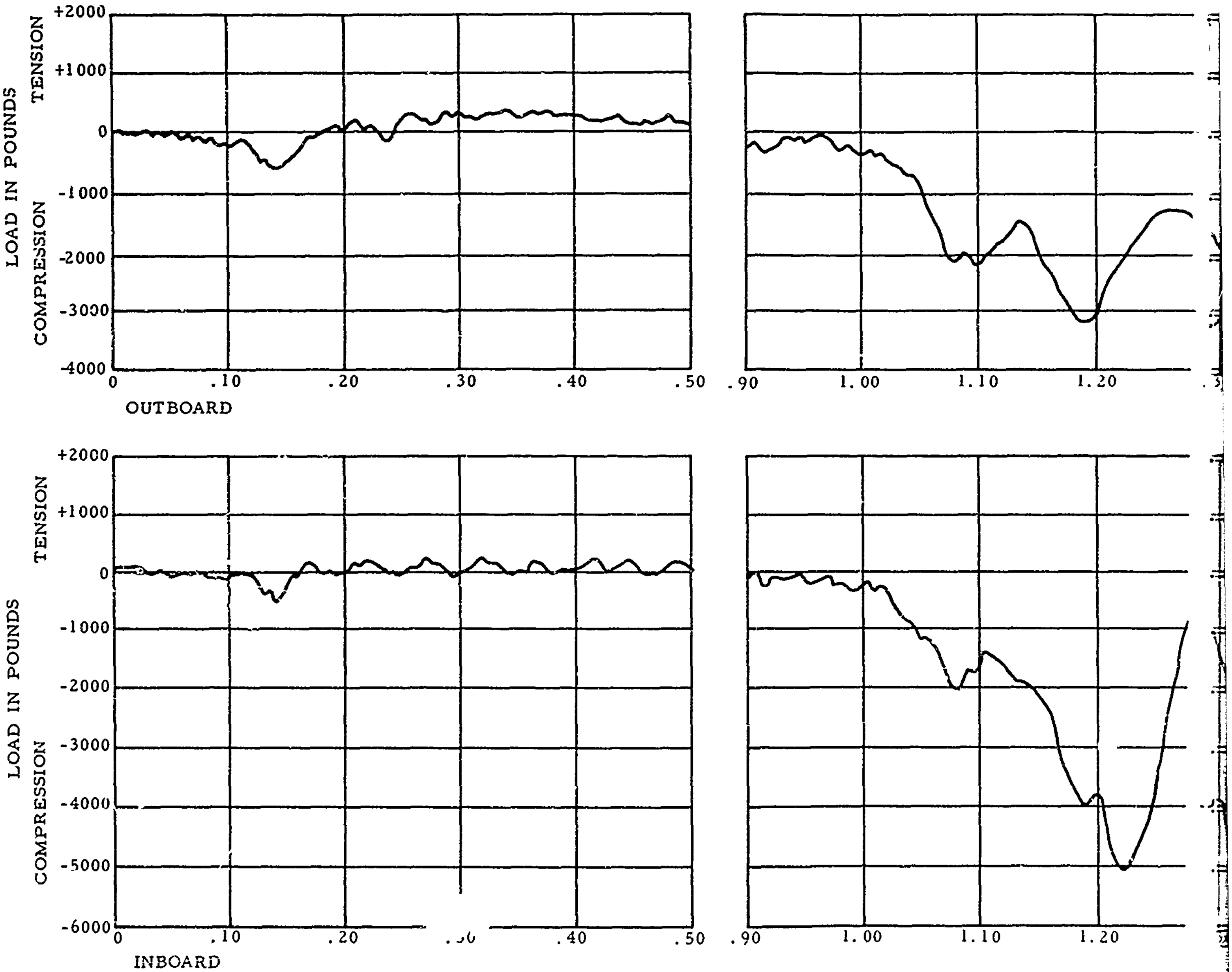


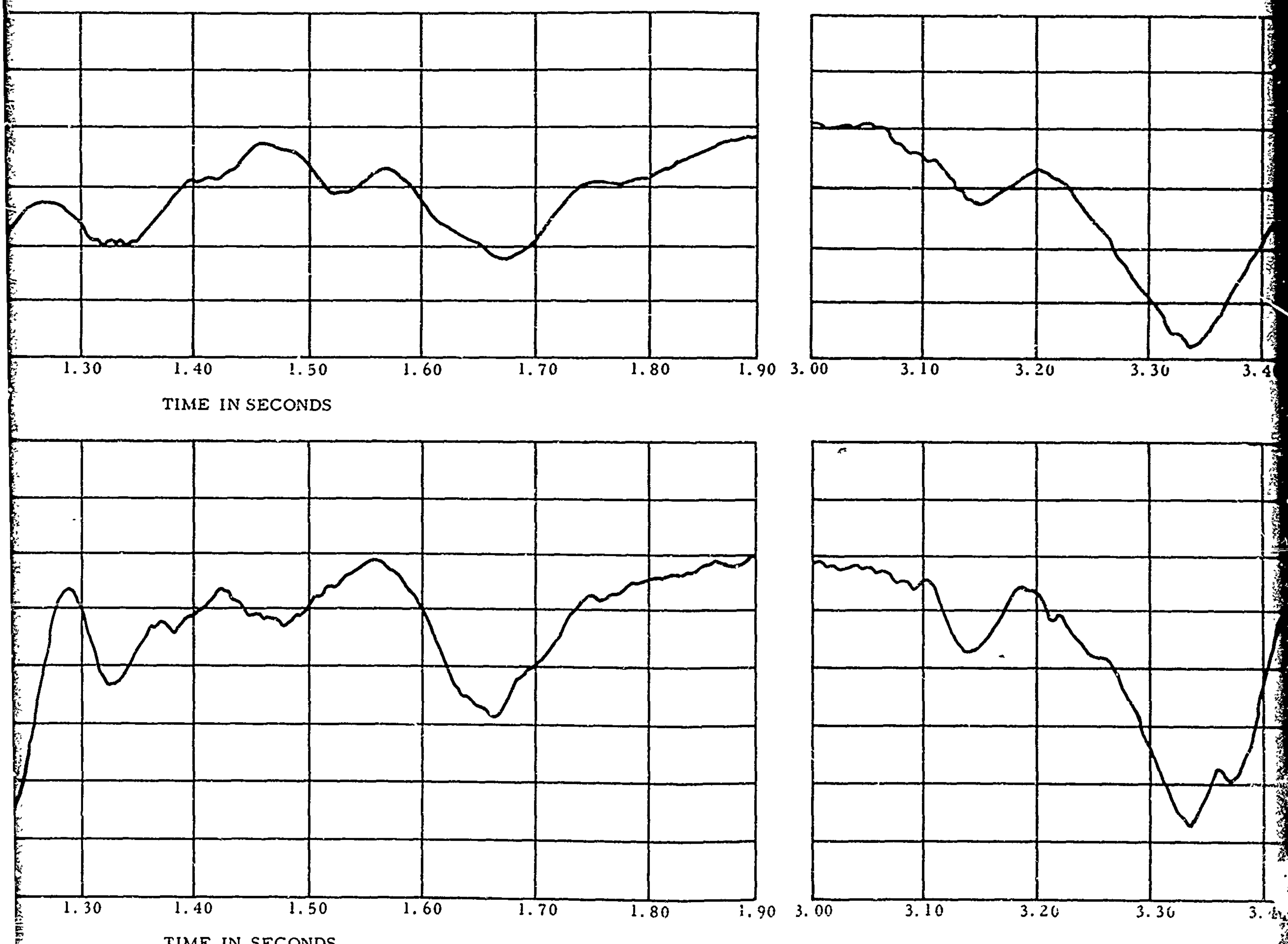
FIG. 6 - 24 MID-CABIN FORWARD FACING SEAT LAP BELT LOADS — SEAT 8B





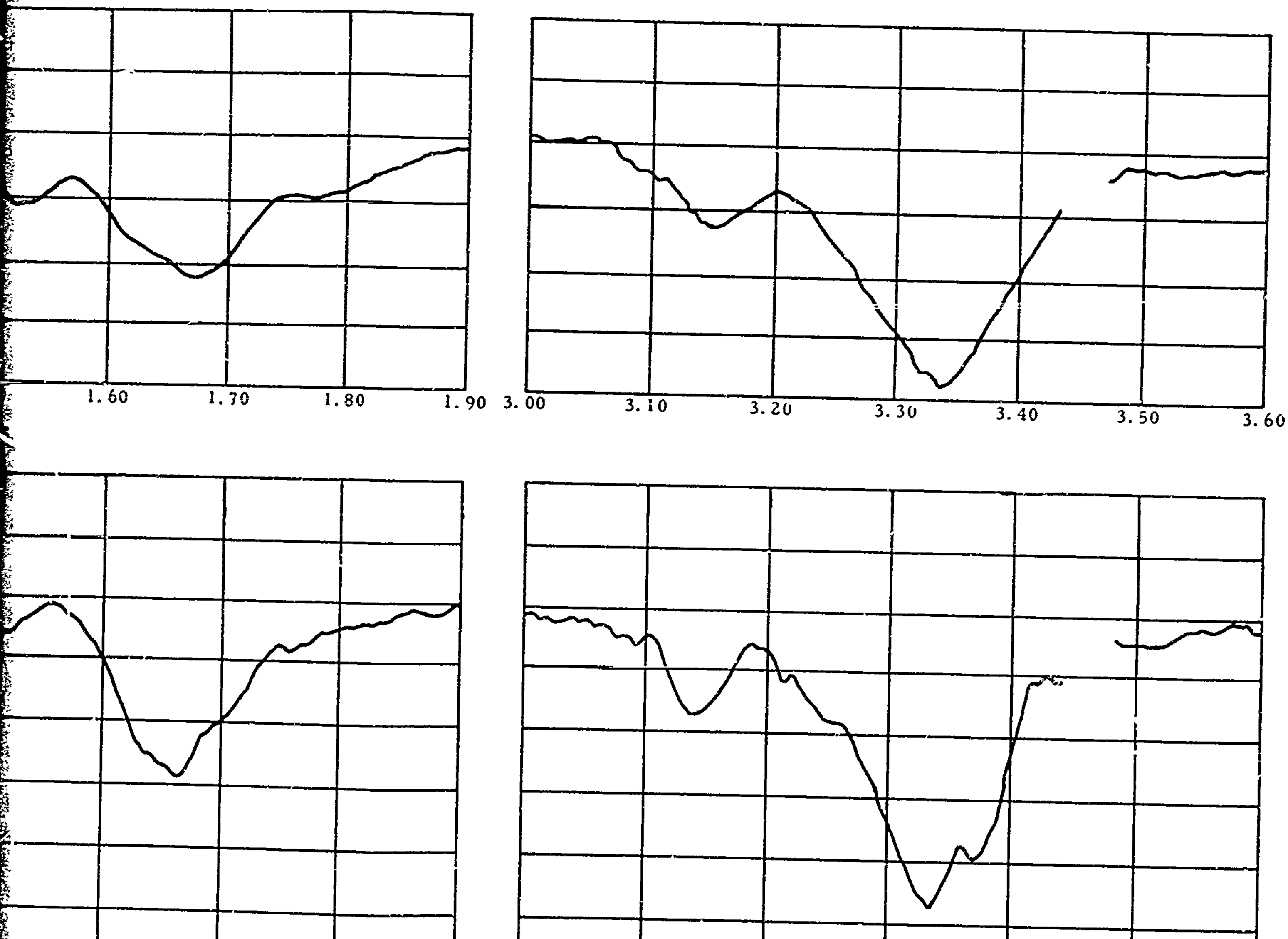
LOAD IN POUNDS
TENSION
COMPRESSION
+2000
+1000
0
-1000
-2000
-3000
-4000
0
.10
.20
.30
.40
.50
.90
1.00
1.10
1.20
OUTBOARD
LOAD IN POUNDS
TENSION
COMPRESSION
+2000
+1000
0
-1000
-2000
-3000
-4000
-5000
-6000
0
.10
.20
.40
.50
.90
1.00
1.10
1.20
INBOARD

FIG. 6 - 25 MID-CABIN FOR
FORWARD LEG L



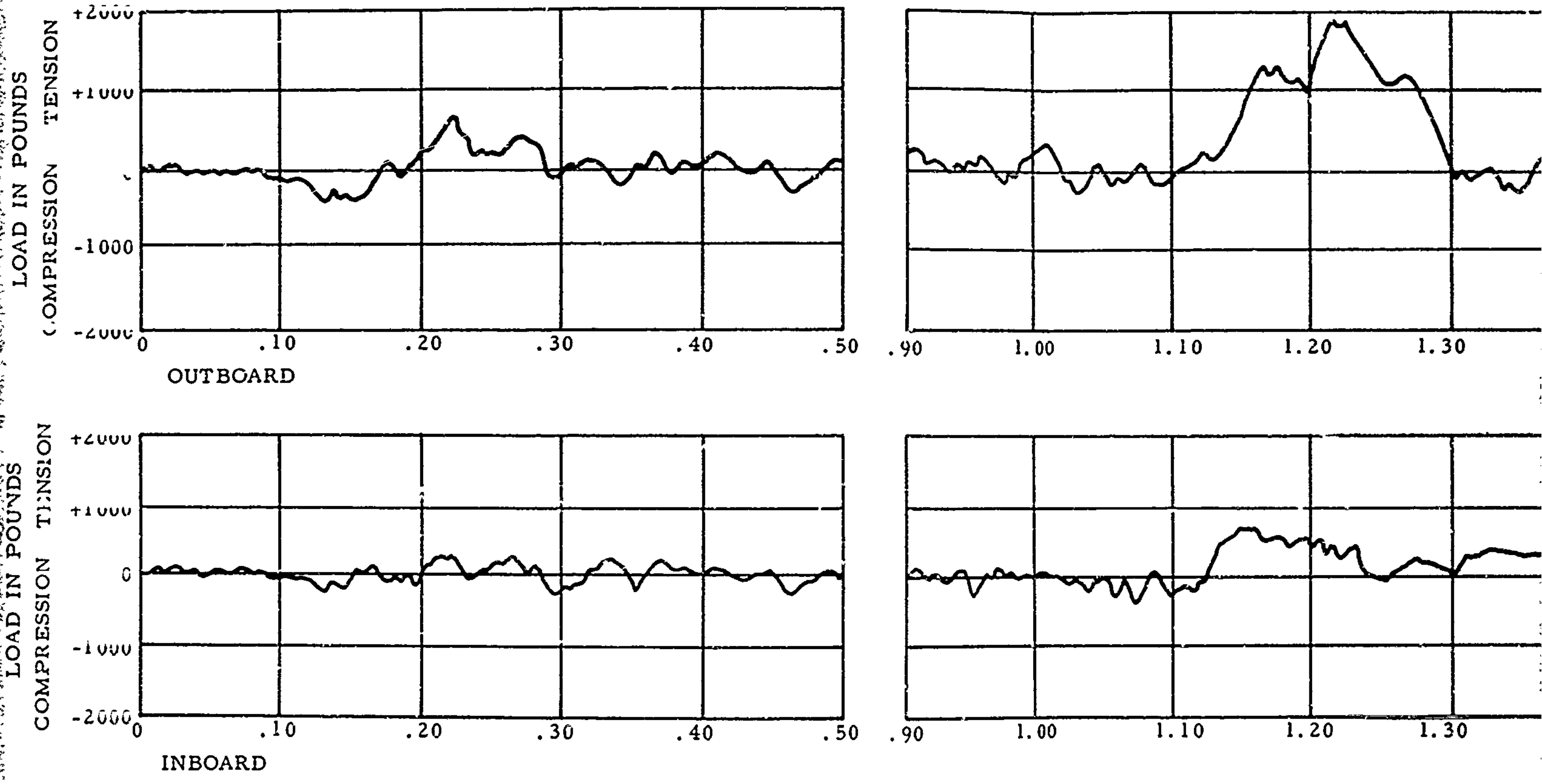
B

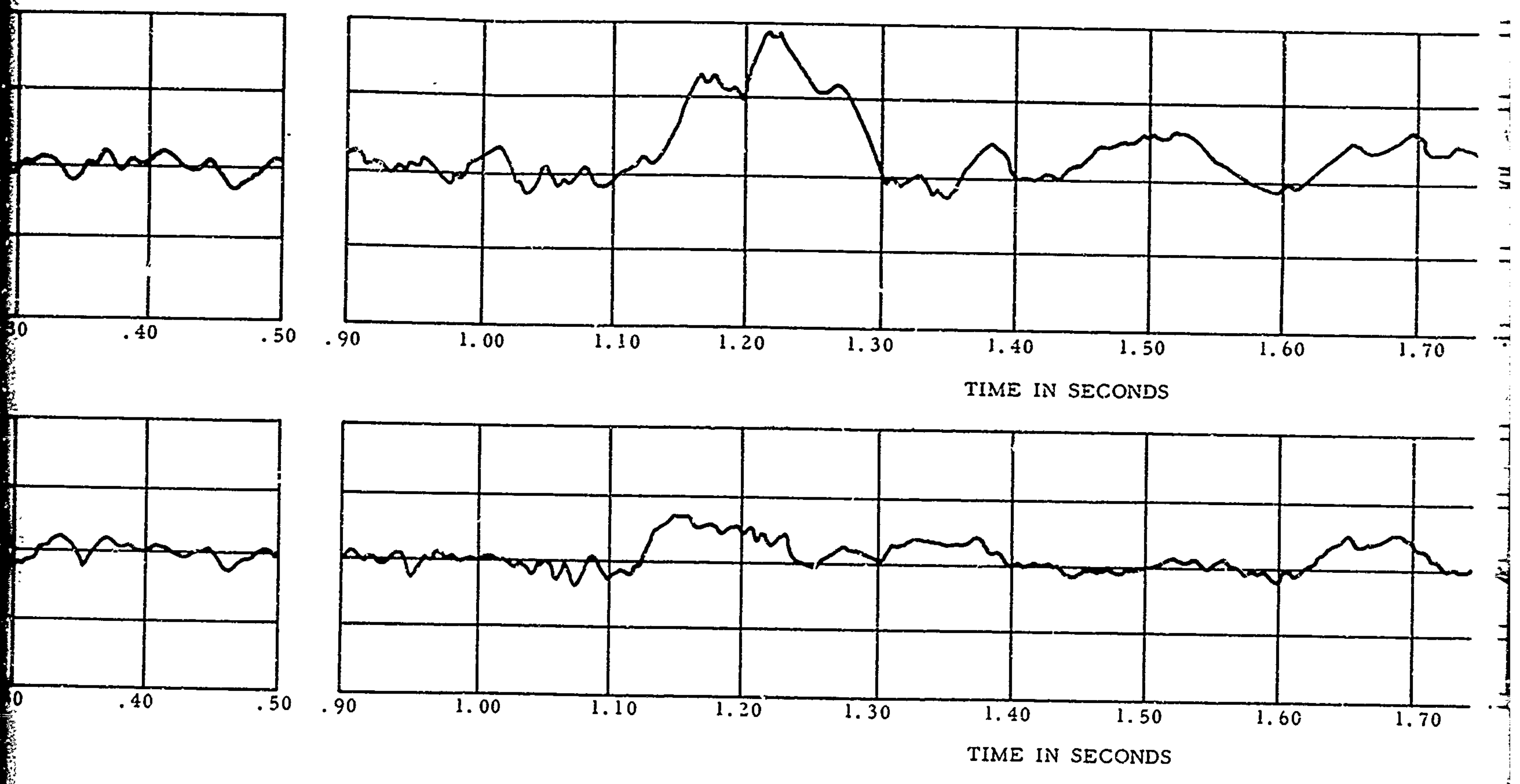
FIG. 6 - 25 MID-CABIN FORWARD FACING SEAT FORWARD LEG LOADS — SEAT 8



B

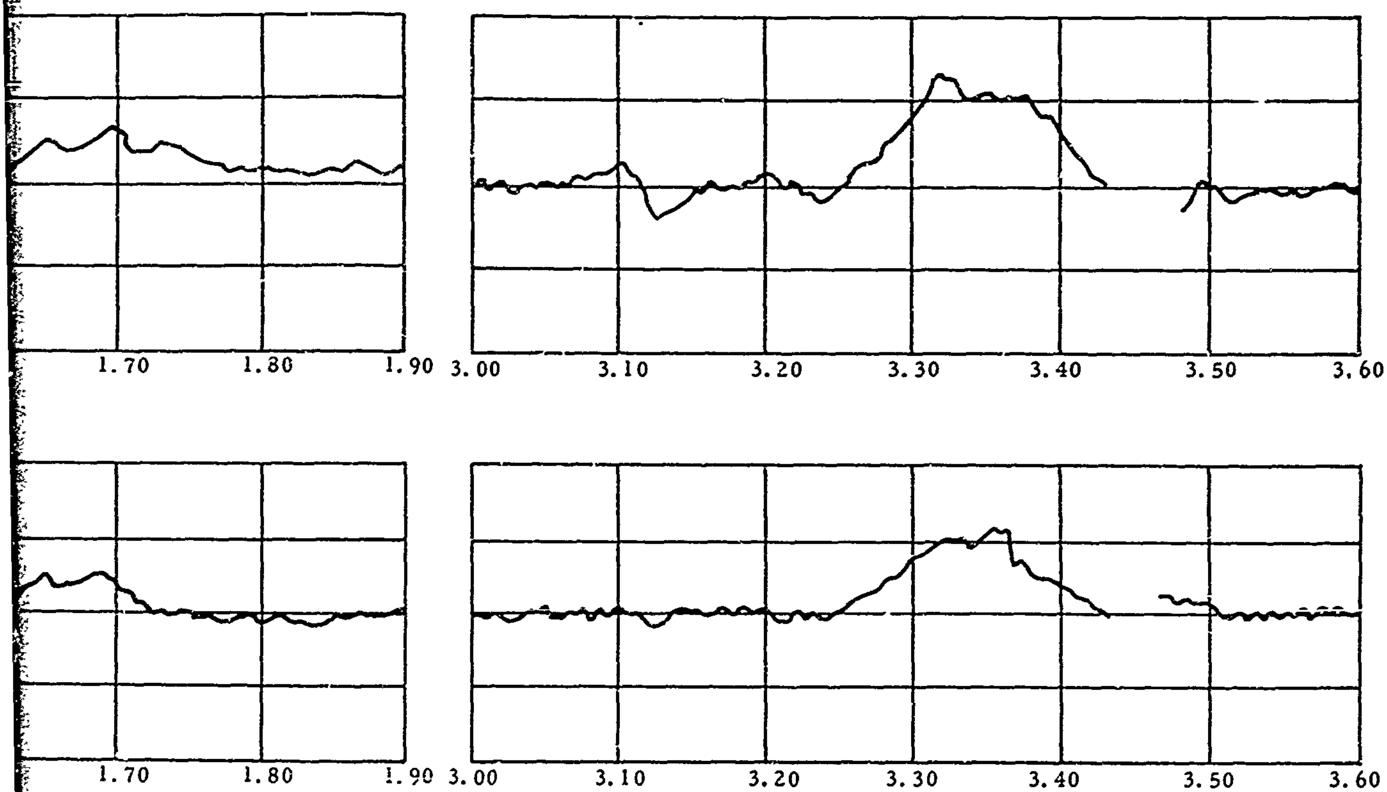
C


LOAD IN POUNDS
COMPRESSION TENSION
+2000
+1000
-1000
-2000
0
.10
.20
.30
.40
.50
.90
1.00
1.10
1.20
1.30
OUTBOARD
INBOARD



.40
.50
.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
TIME IN SECONDS
.40
.50
.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
TIME IN SECONDS

FIG. 6 - 26 MID-CABIN FORWARD FACING SEAT AFT LEG LOADS — SEAT 8



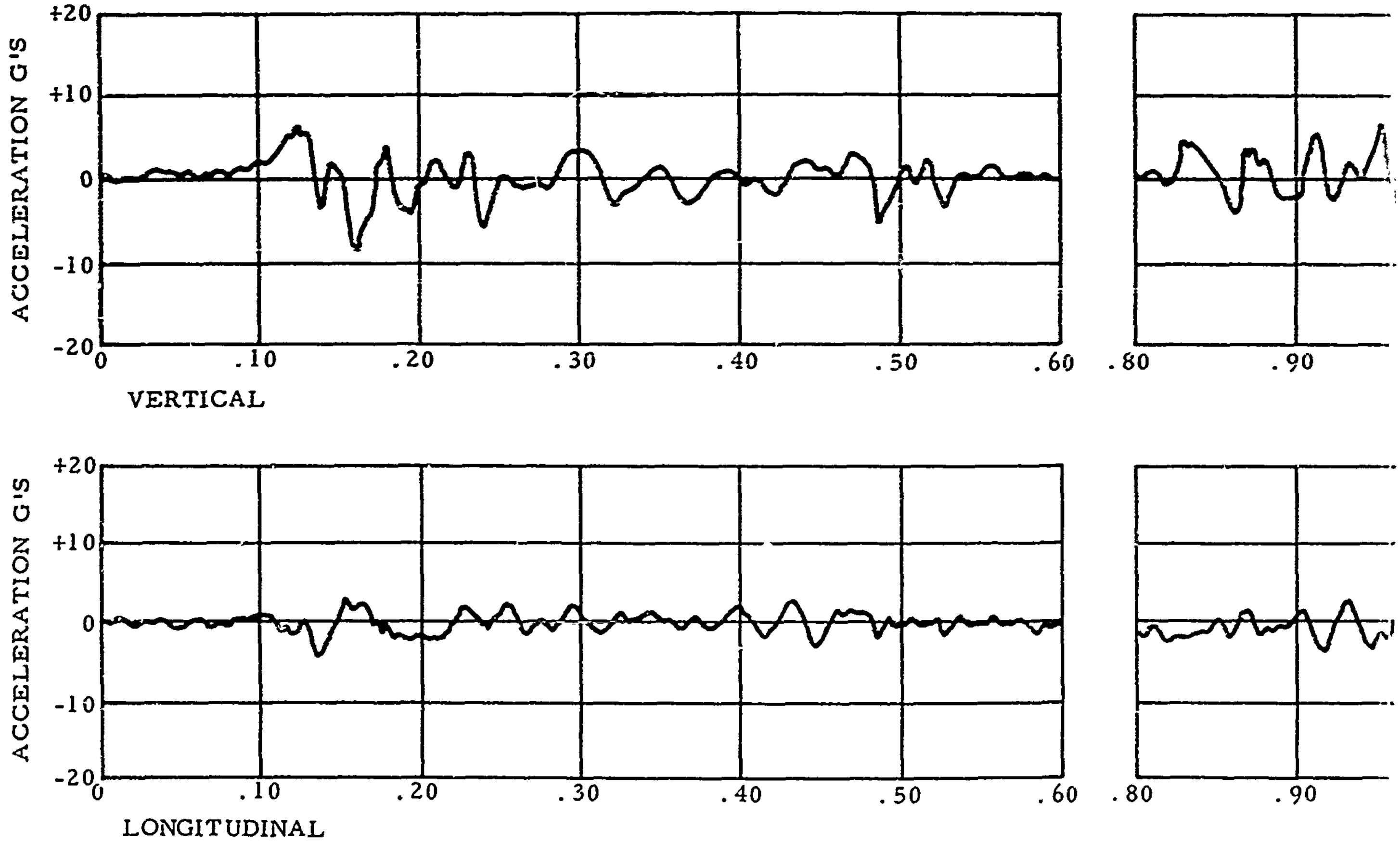
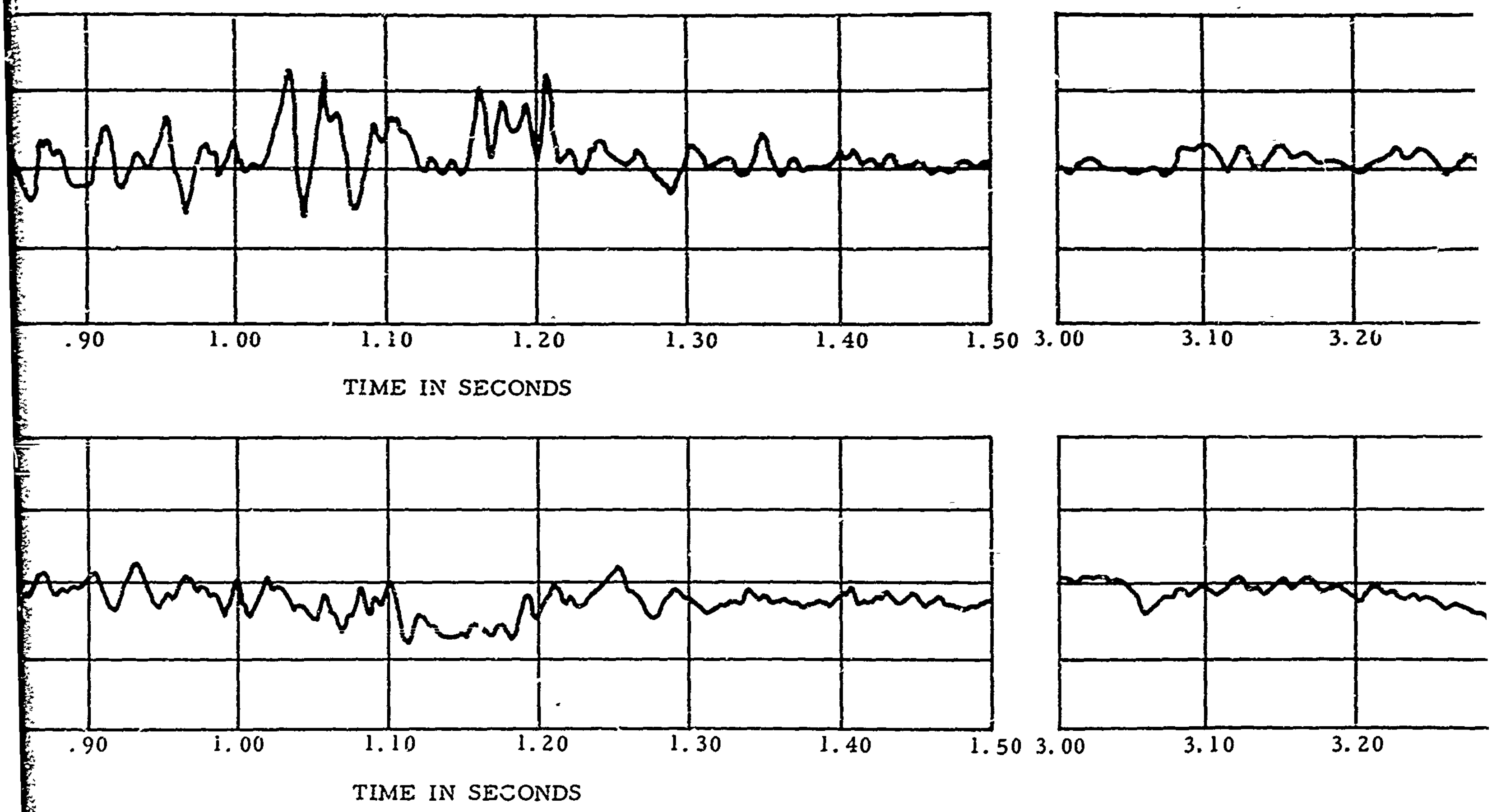
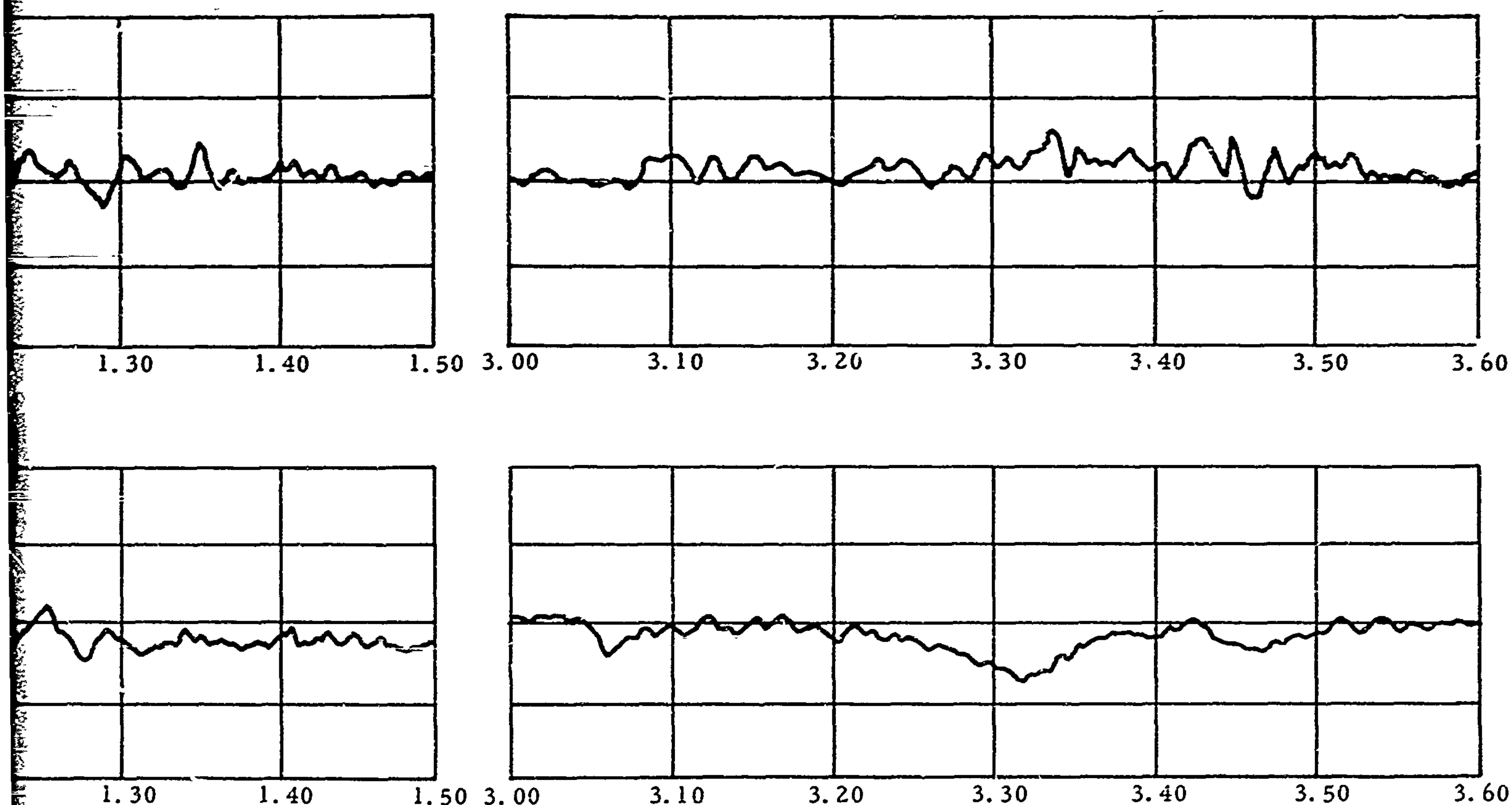

ACCELERATION G'S
+20
+10
0
-10
-20
0
.10
.20
.30
.40
.50
.60
.80
.90
VERTICAL
ACCELERATION G'S
+20
+10
0
-10
-20
0
.10
.20
.30
.40
.50
.60
.80
.90
LONGITUDINAL

FIG. 6 - 27


.90
1.00
1.10
1.20
1.30
1.40
1.50
3.00
3.10
3.20
TIME IN SECONDS
.90
1.00
1.10
1.20
1.30
1.40
1.50
3.00
3.10
3.20
TIME IN SECONDS

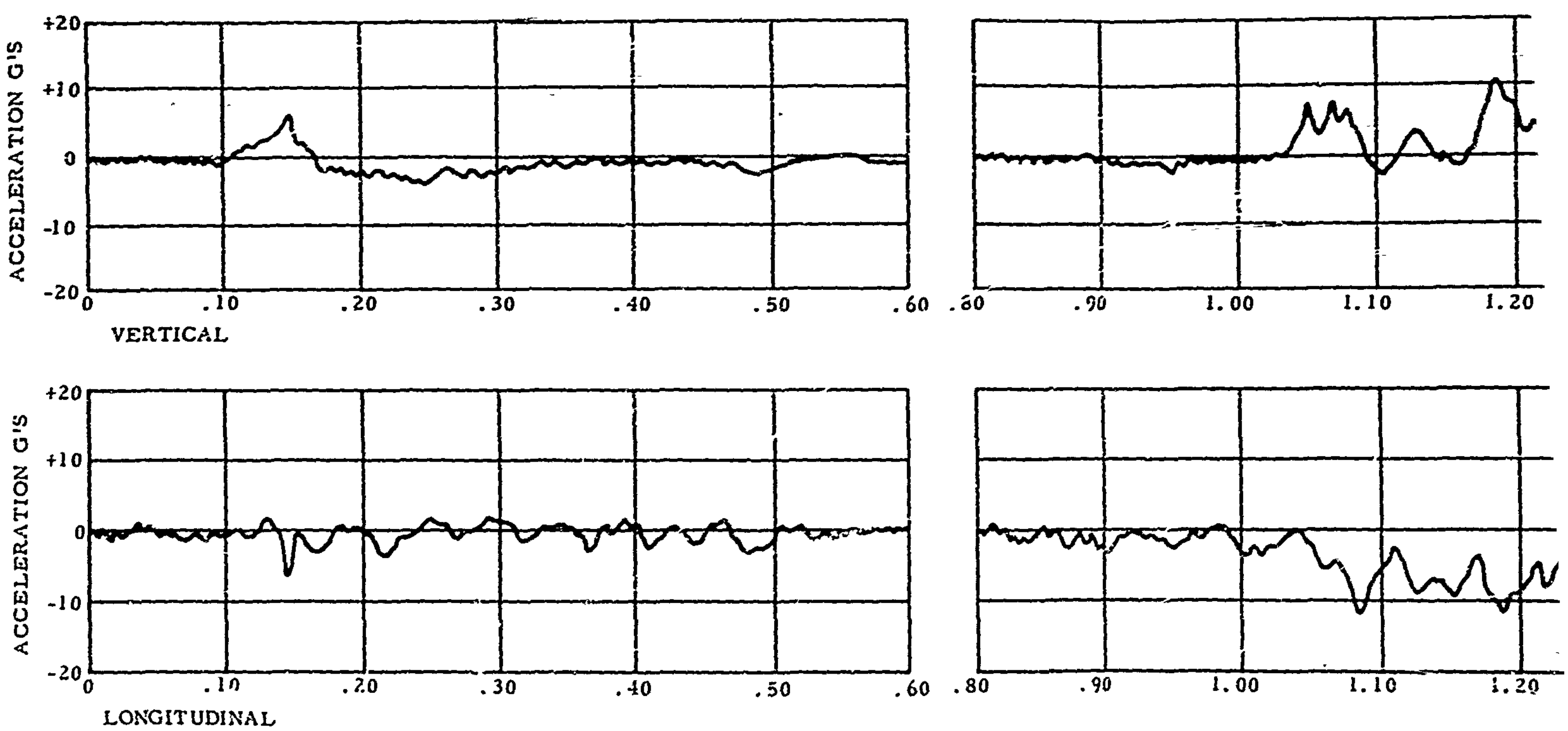
B

FIG. 6 - 27 MID-CABIN REAR FACING SEAT ACCELERATIONS — SEAT 7



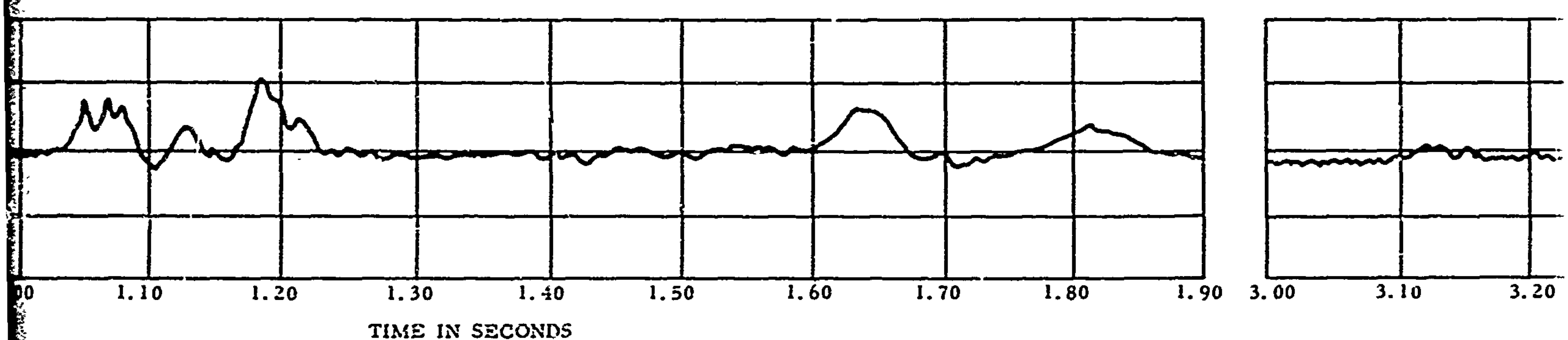
B

C


ACCELERATION G'S
+20
+10
0
-10
-20
0
.10
.20
.30
.40
.50
.60
.80
.90
1.00
1.10
1.20
VERTICAL
LONGITUDINAL

A

FIG. 6 - 28 MID-CABIN E
PELVIC ACC



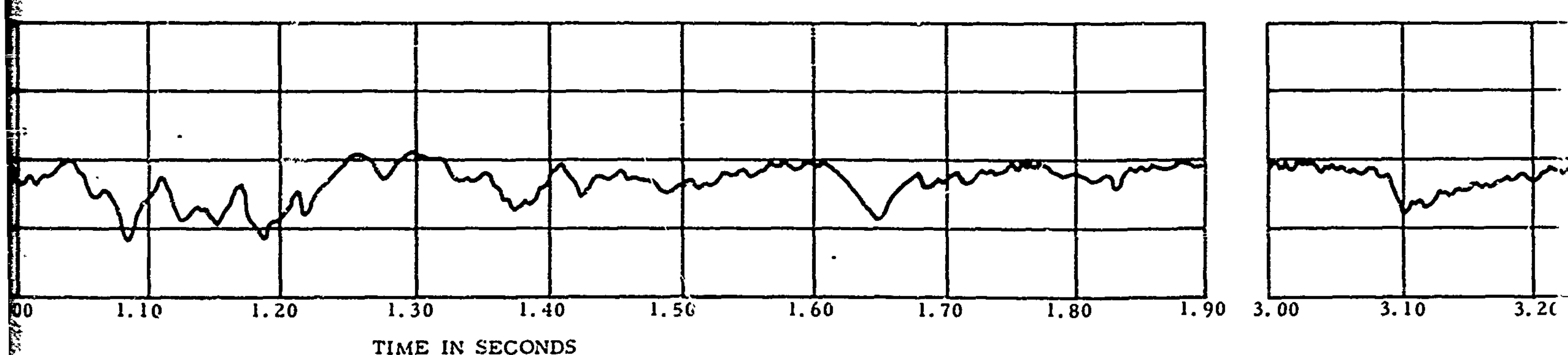
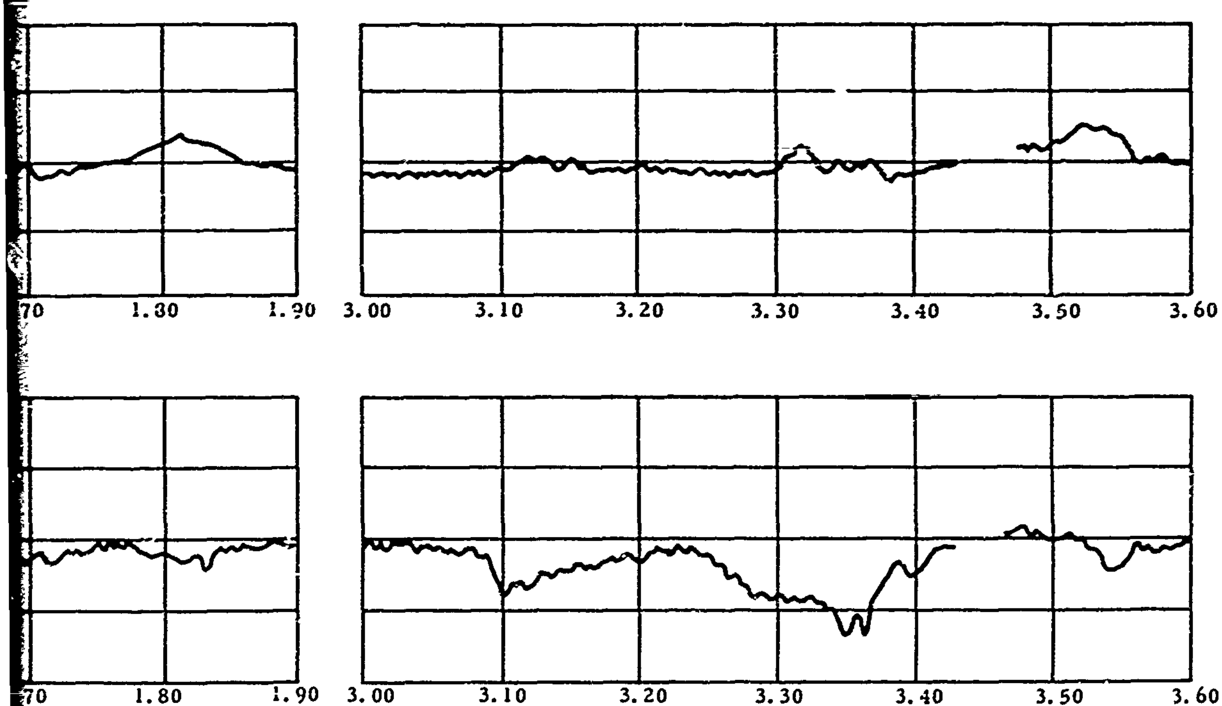
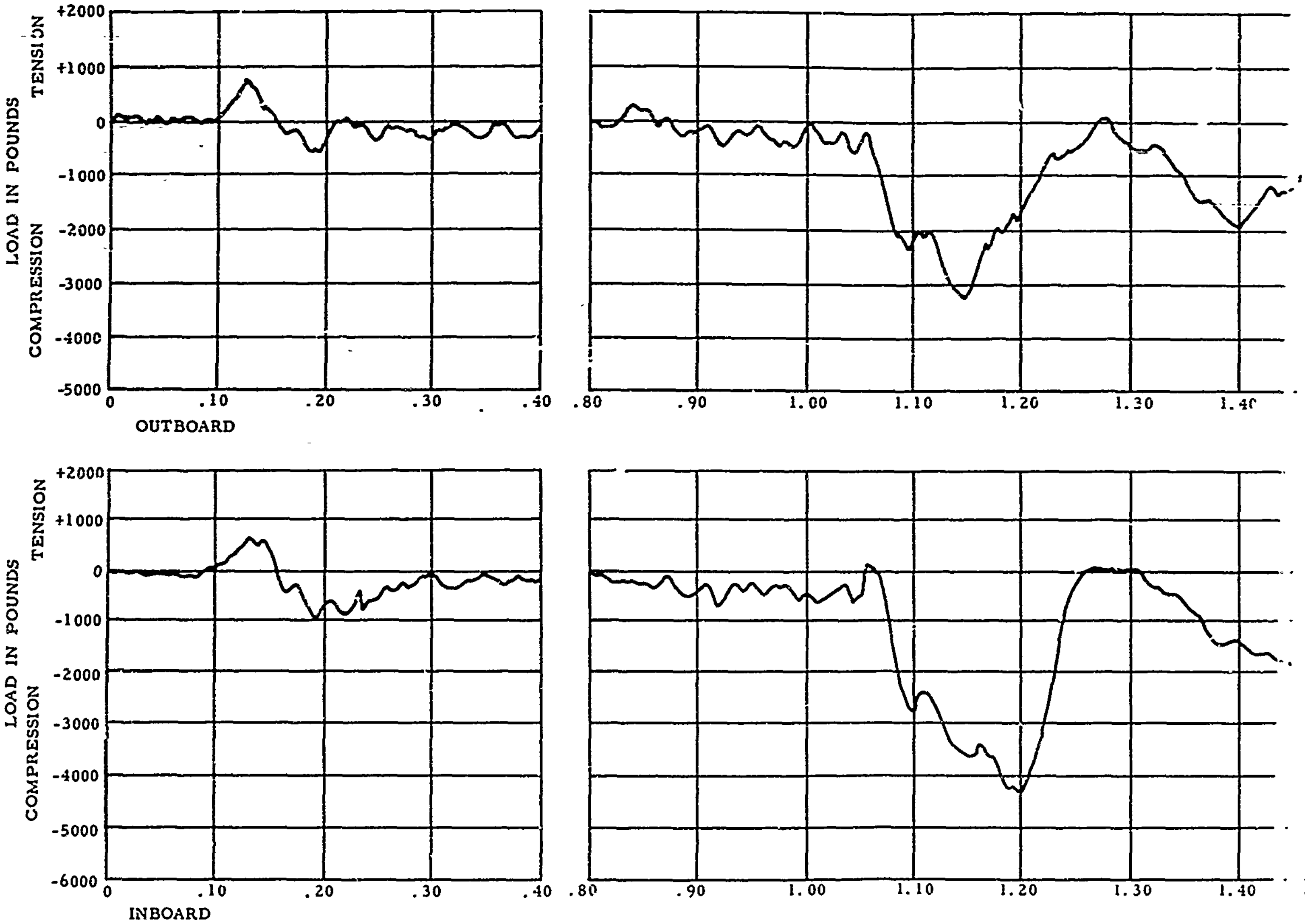


FIG. 6 - 28 MID-CABIN REAR FACING SEAT OCCUPANT'S PELVIC ACCELERATIONS — SEAT 7B





LOAD IN POUNDS
TENSION
COMPRESSION
+2000
+1000
0
-1000
-2000
-3000
-4000
-5000
-6000
0
.10
.20
.30
.40
.80
.90
1.00
1.10
1.20
1.30
1.40
OUTBOARD
INBOARD

FIG. 6 - 29 MID-CABIN REA
FORWARD LEG

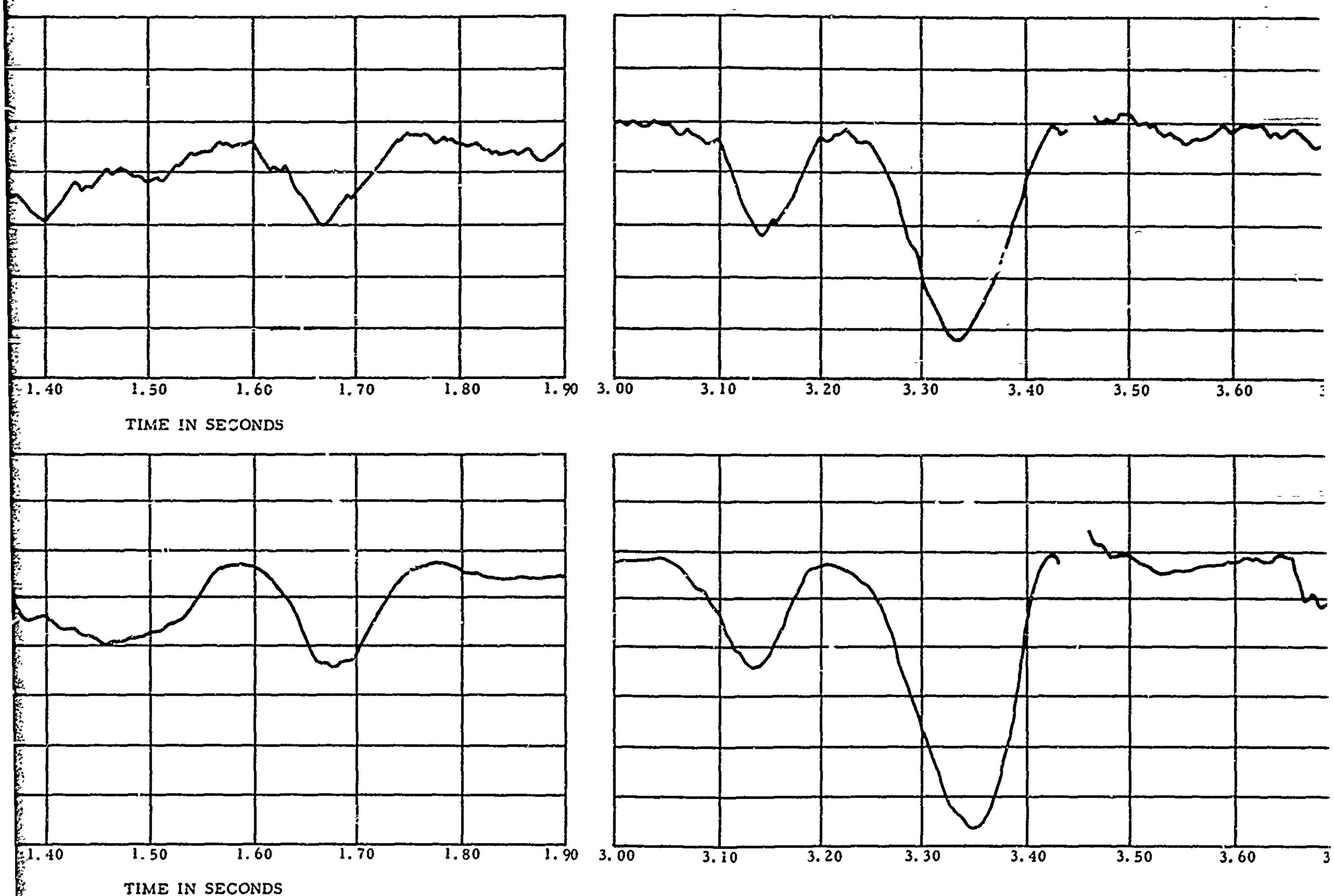
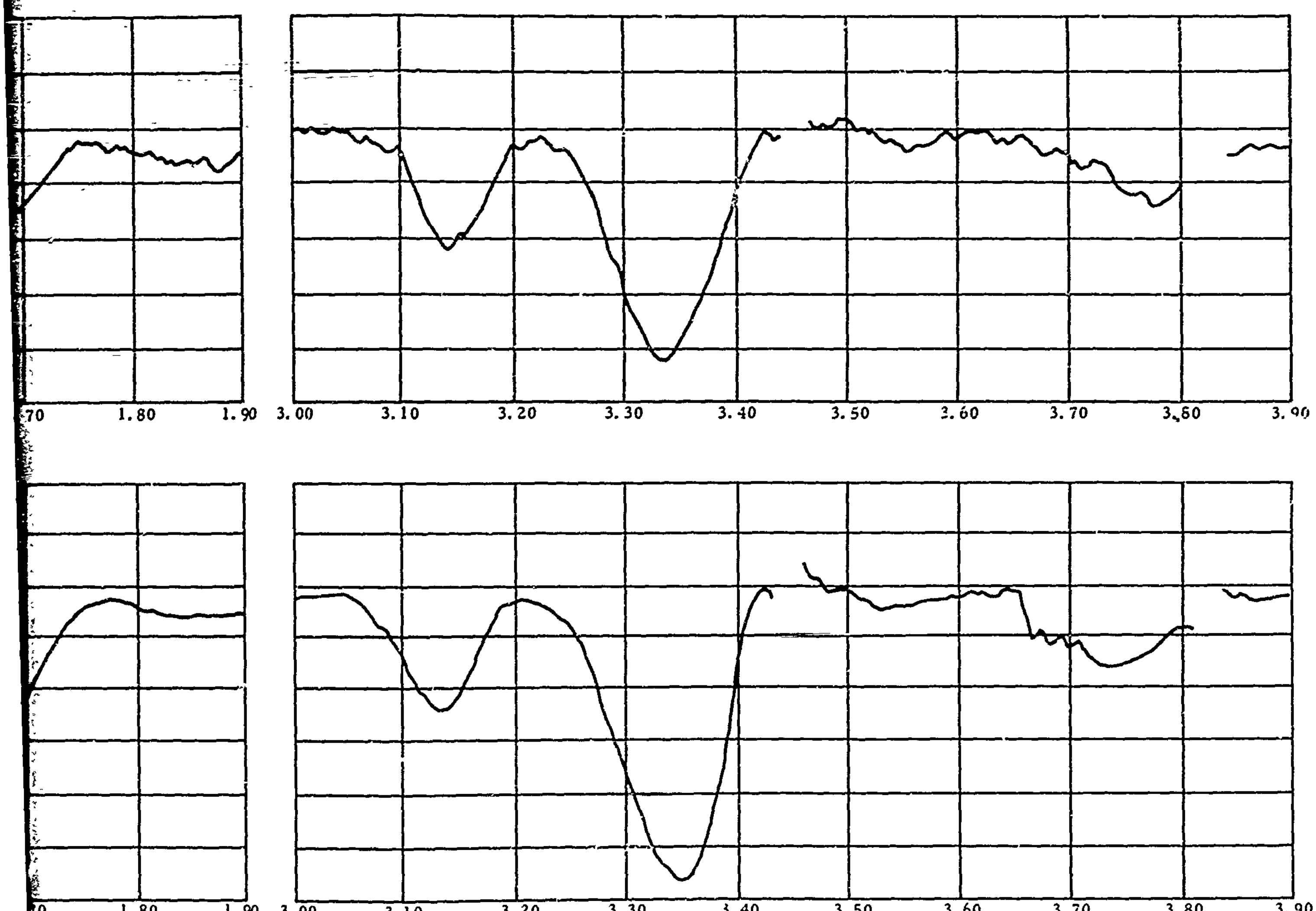
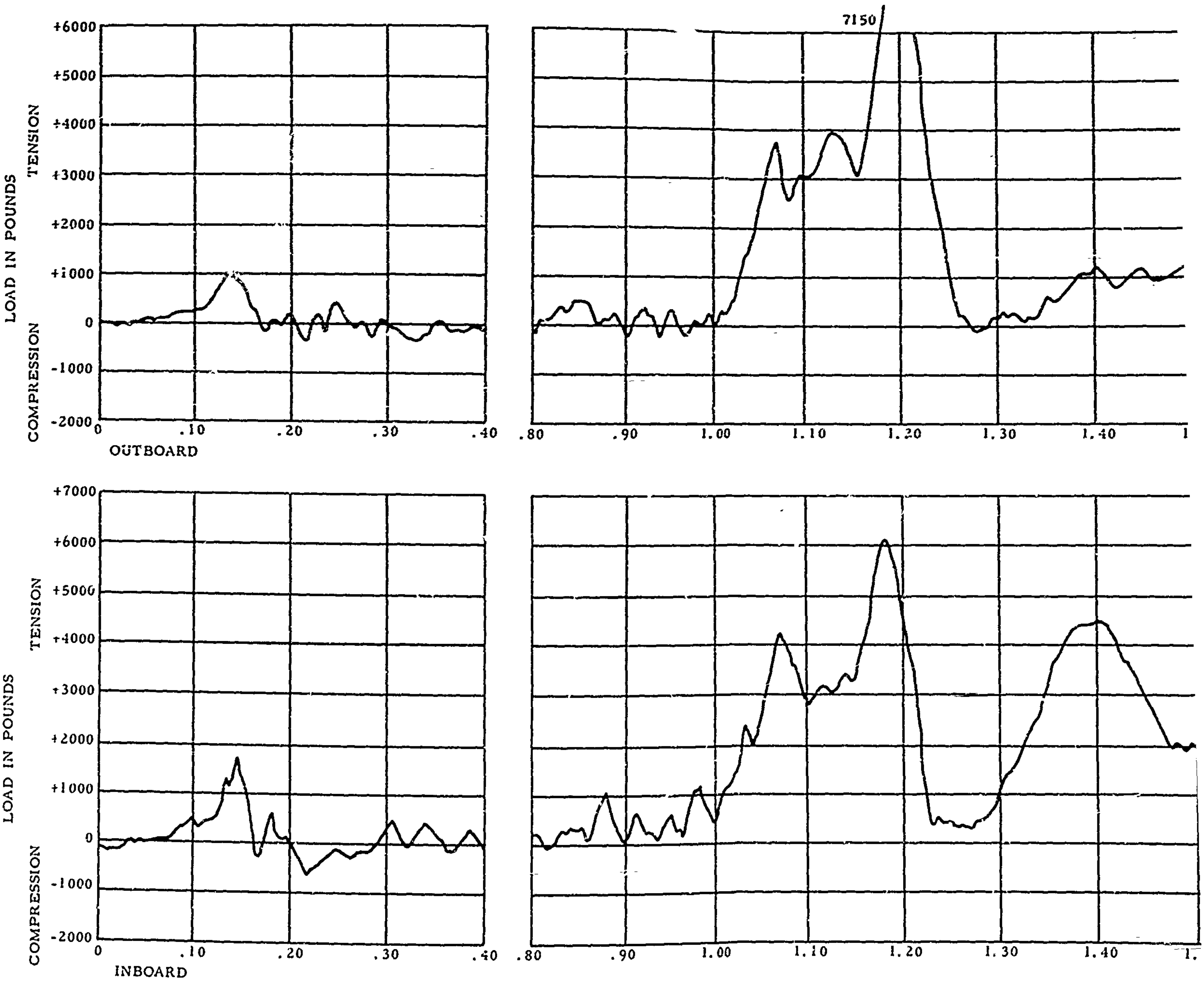
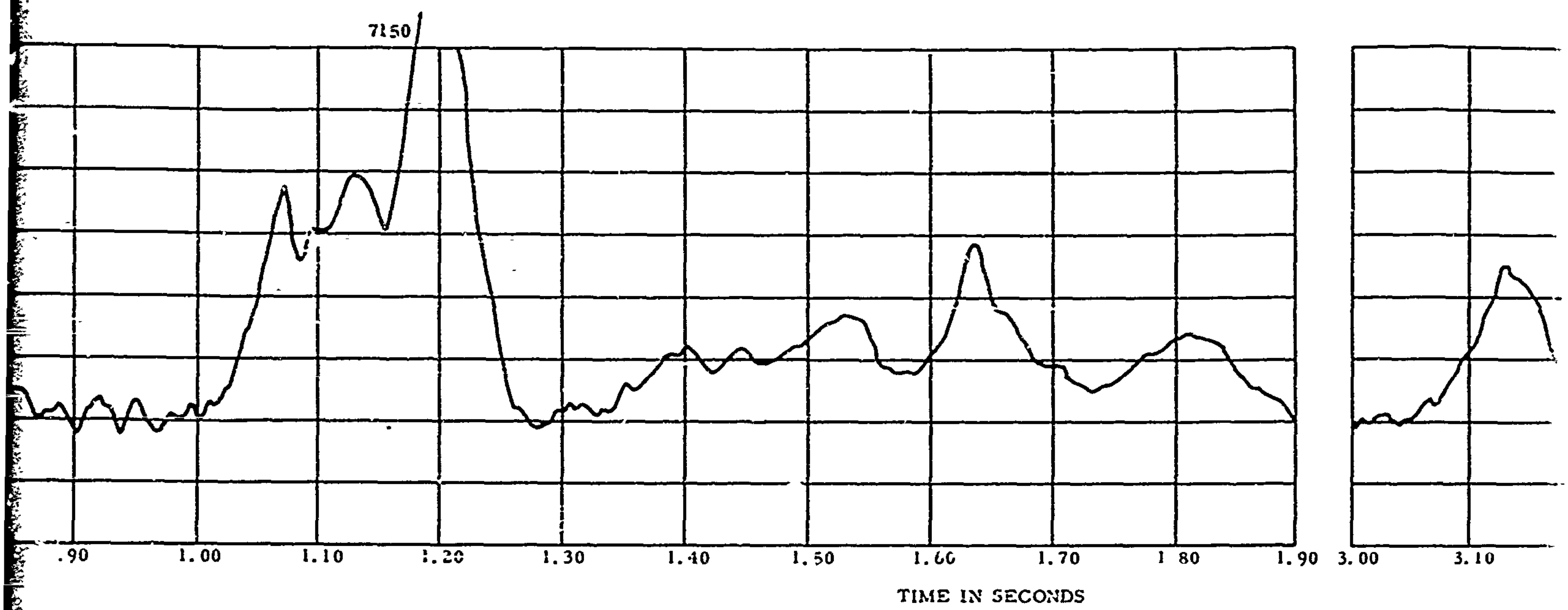


FIG. 6 - 29 MID-CABIN REAR FACING SEAT FORWARD LEG LOADS — SEAT 7




7150
+6000
+5000
+4000
+3000
+2000
+1000
0
-1000
-2000
TENSION
COMPRESSION
LOAD IN POUNDS
0
.10
.20
.30
.40
.80
.90
1.00
1.10
1.20
1.30
1.40
OUTBOARD
+7000
INBOARD


7150
.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
3.00
3.10
TIME IN SECONDS

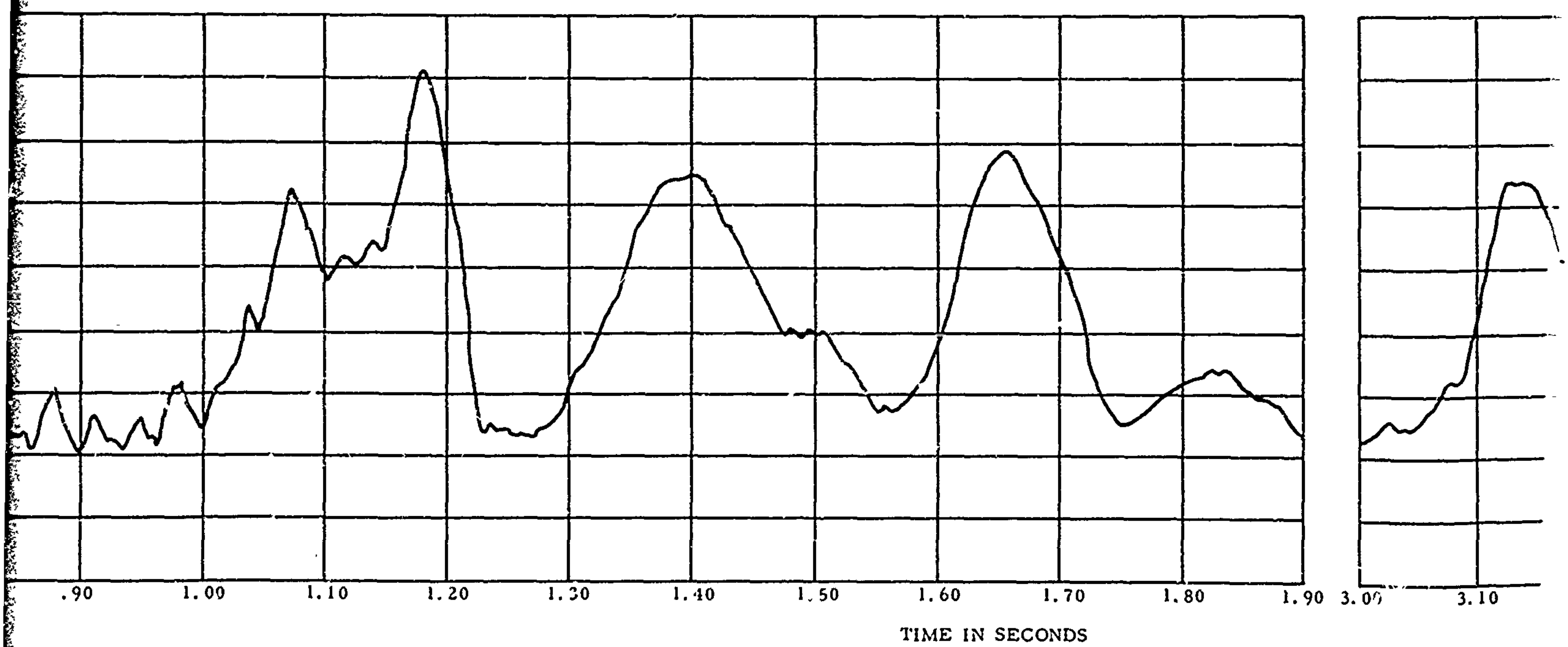
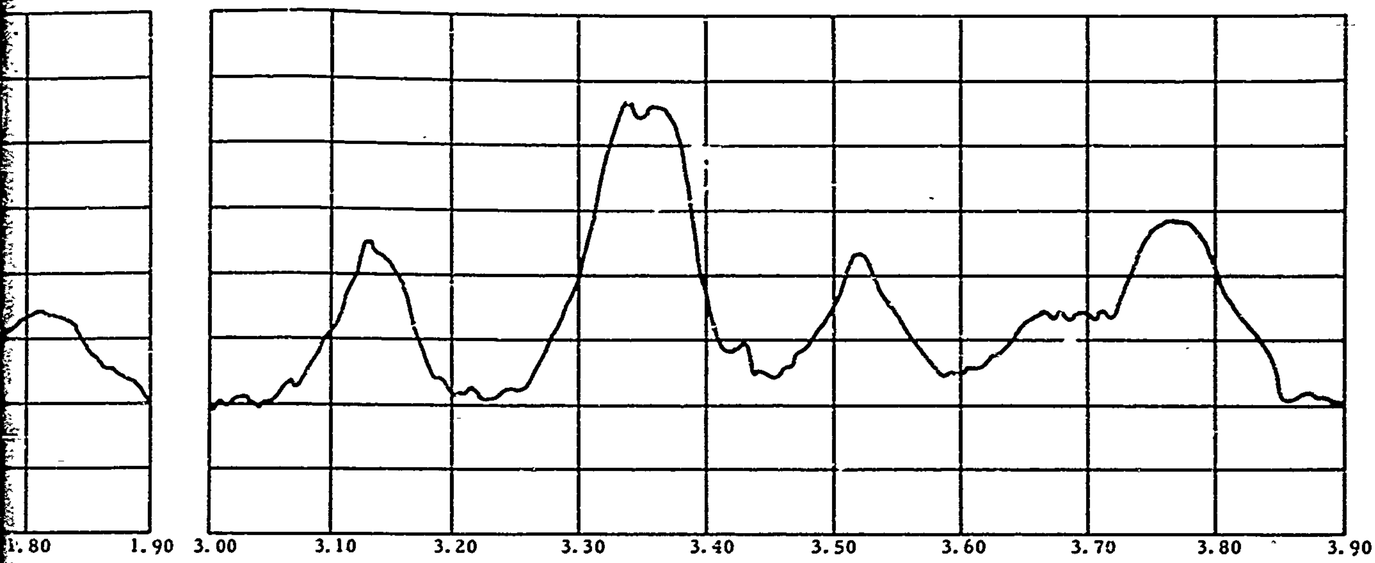
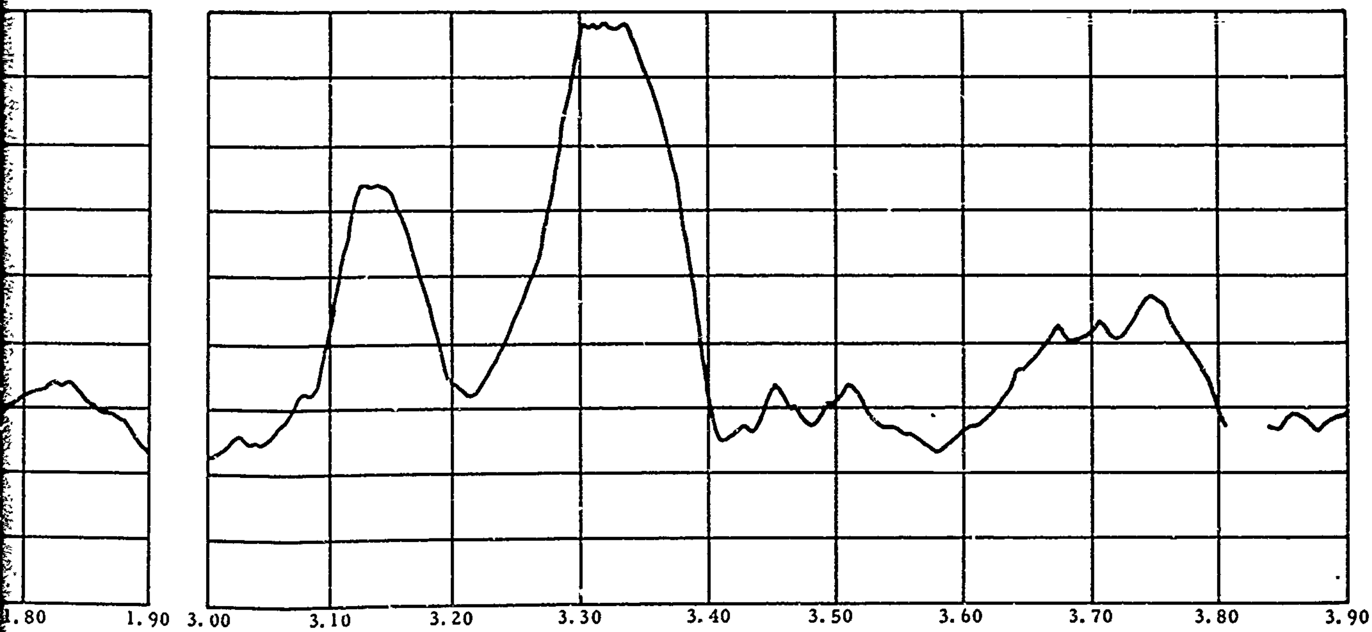
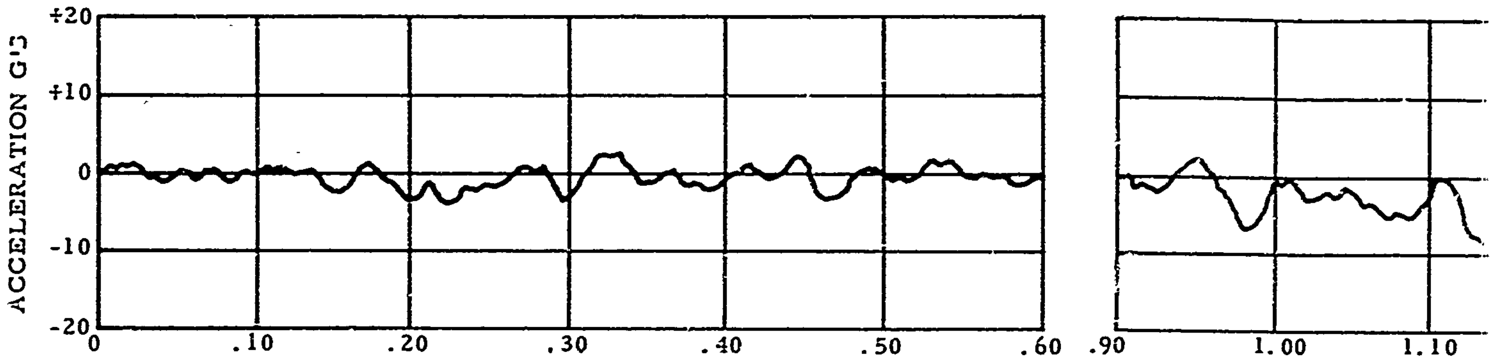

.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
3.10
TIME IN SECONDS

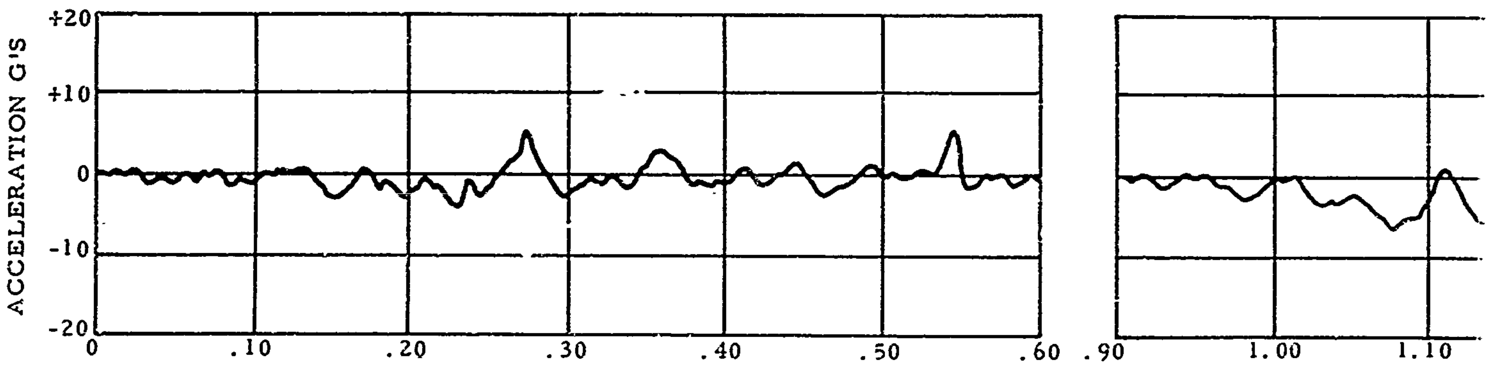
FIG. 6 - 30 MID-CABIN REAR FACING SEAT AFT LEG LOADS — SEAT 7



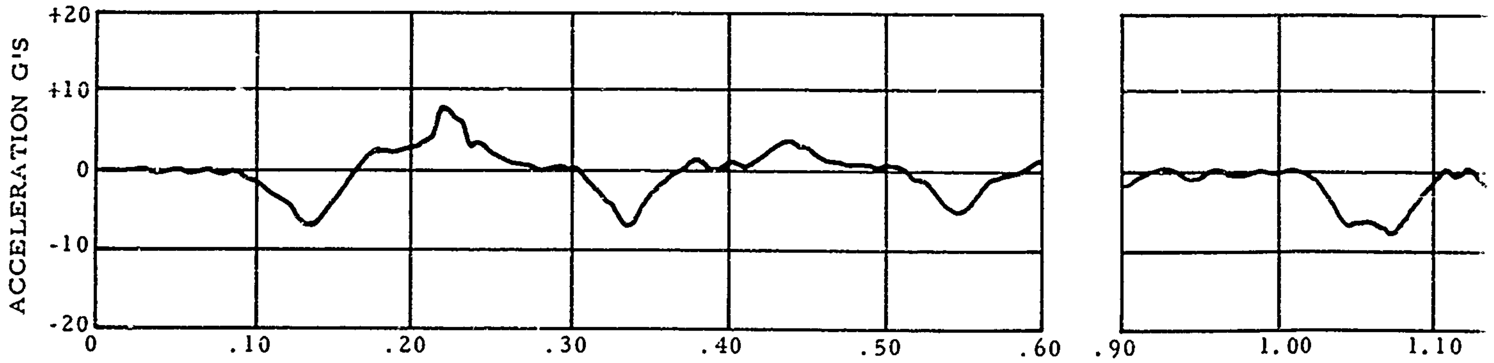




LONGITUDINAL TOP

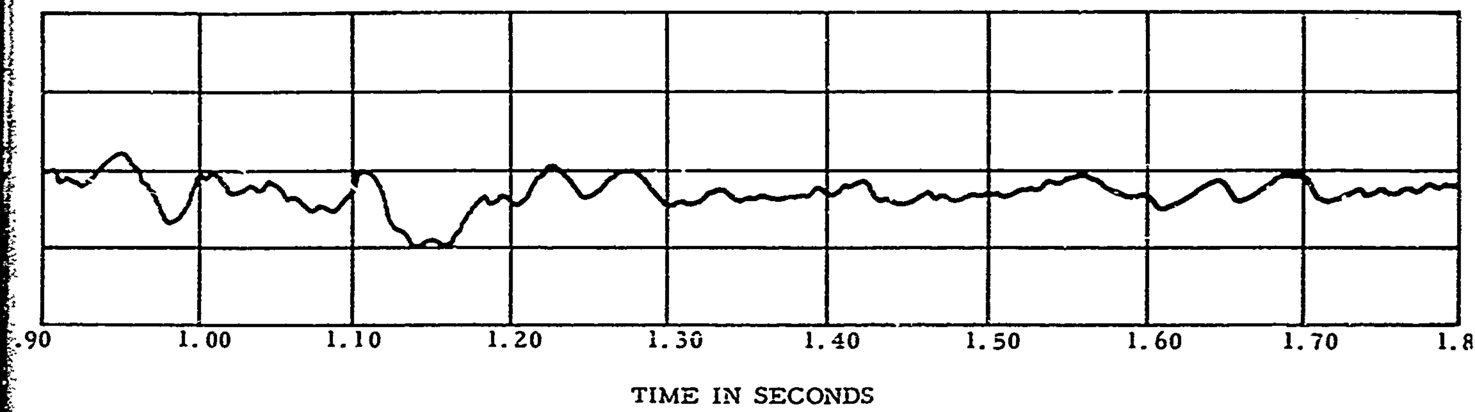


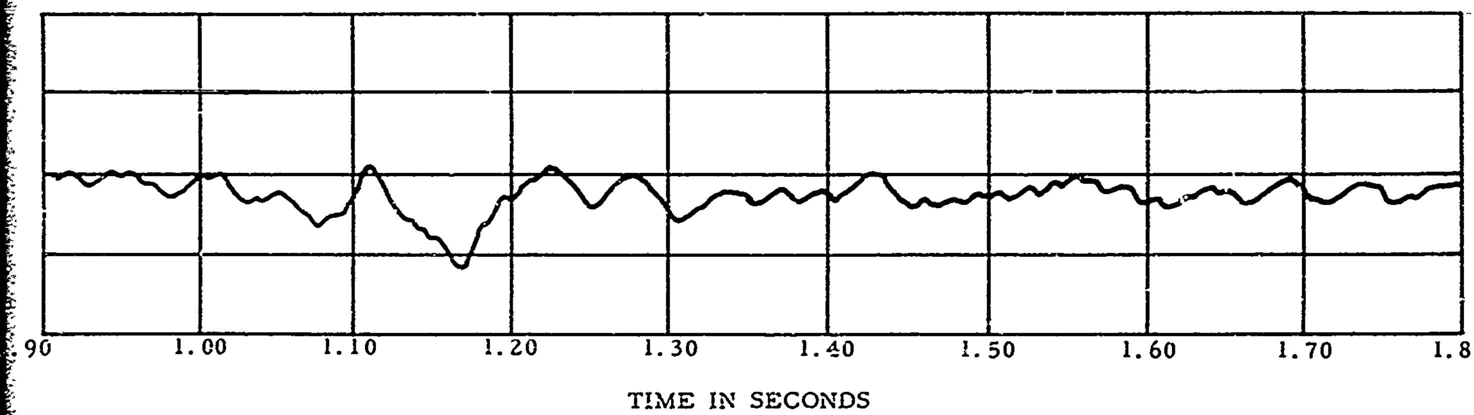
LONGITUDINAL BOTTOM



VERTICAL BOTTOM

A


.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.8
TIME IN SECONDS


.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.8
TIME IN SECONDS

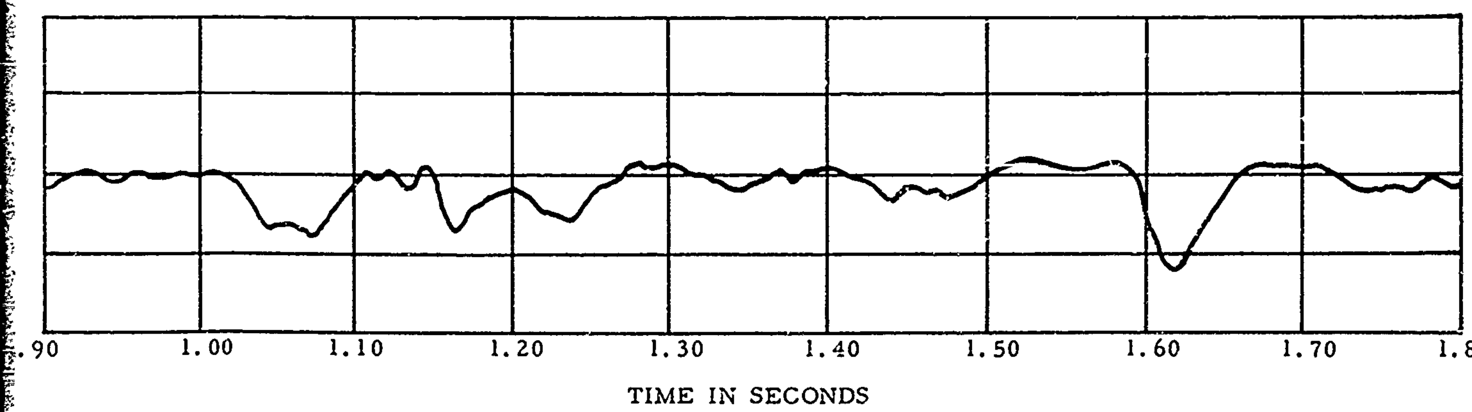
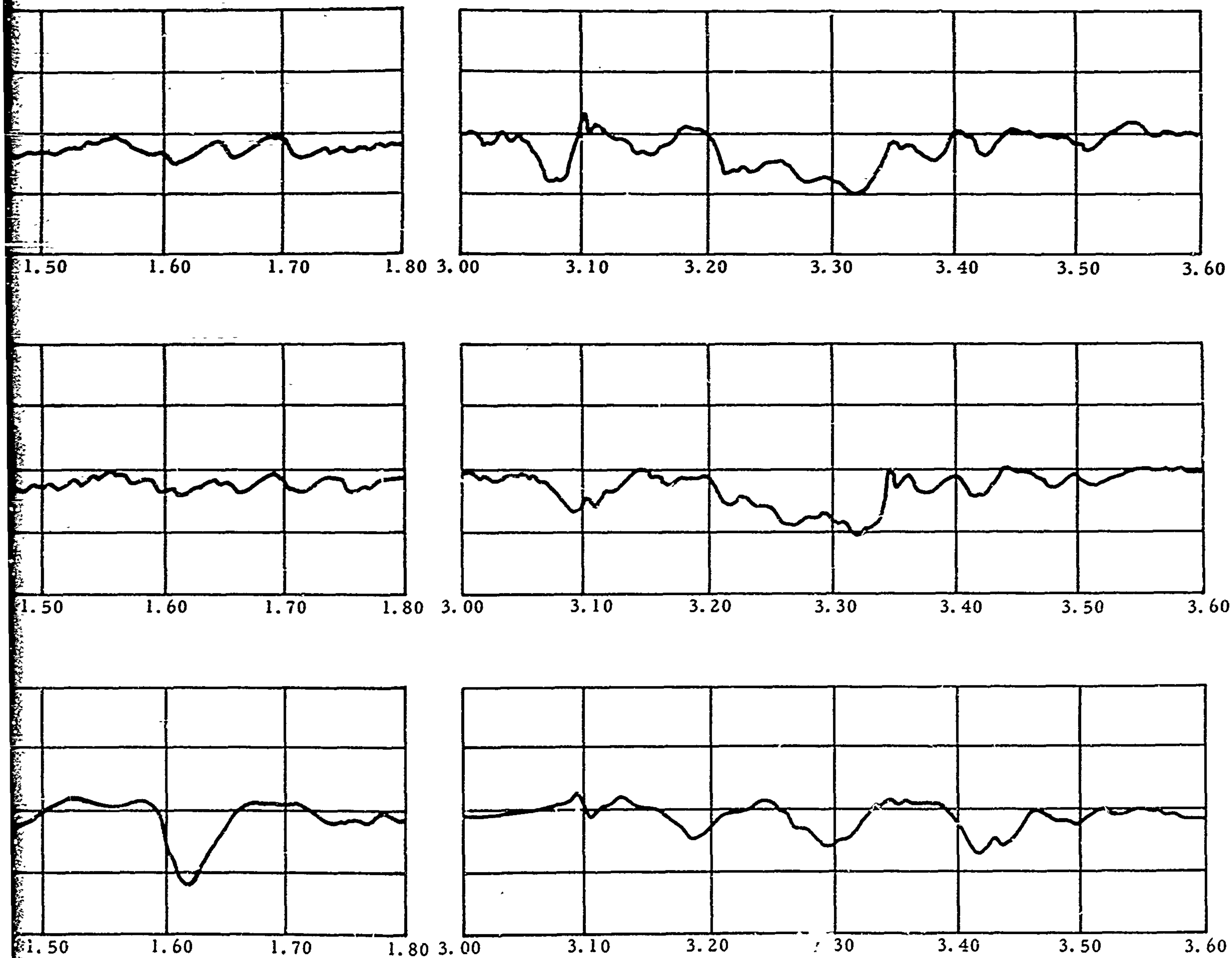
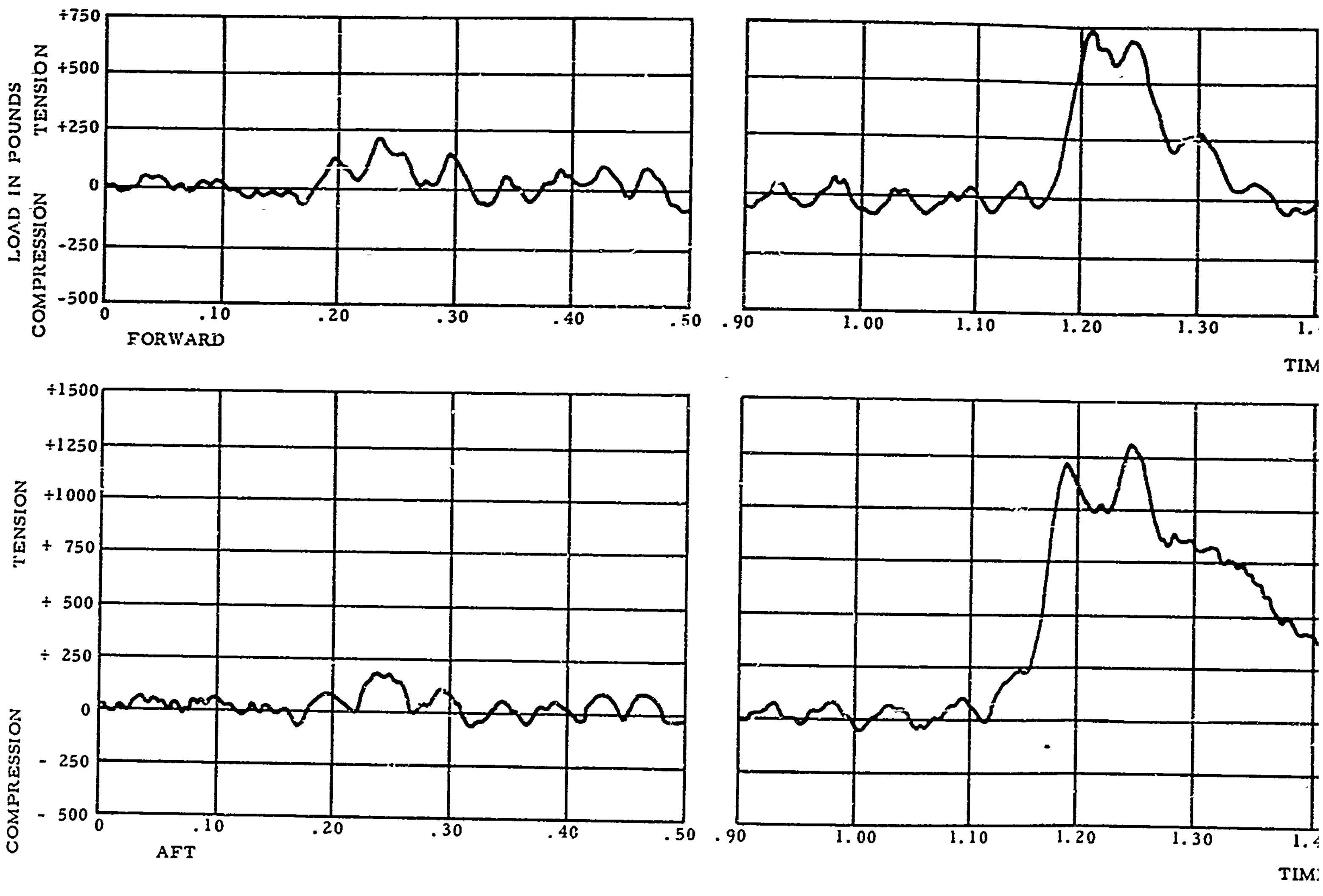
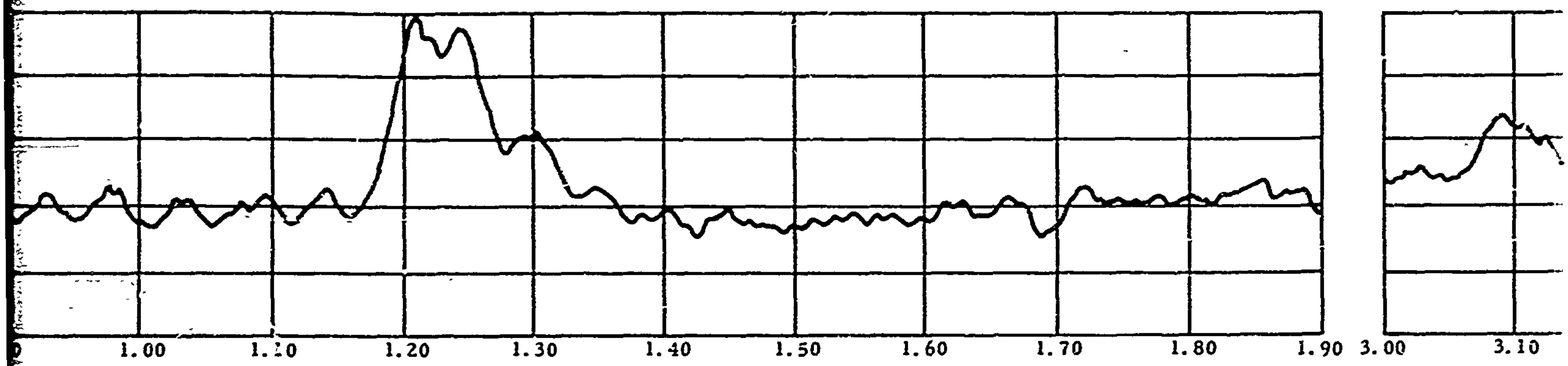

.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.8
TIME IN SECONDS

FIG. 6 - 31 REAR CABIN LITTER OCCUPANT'S PELVIC ACCELERATIONS

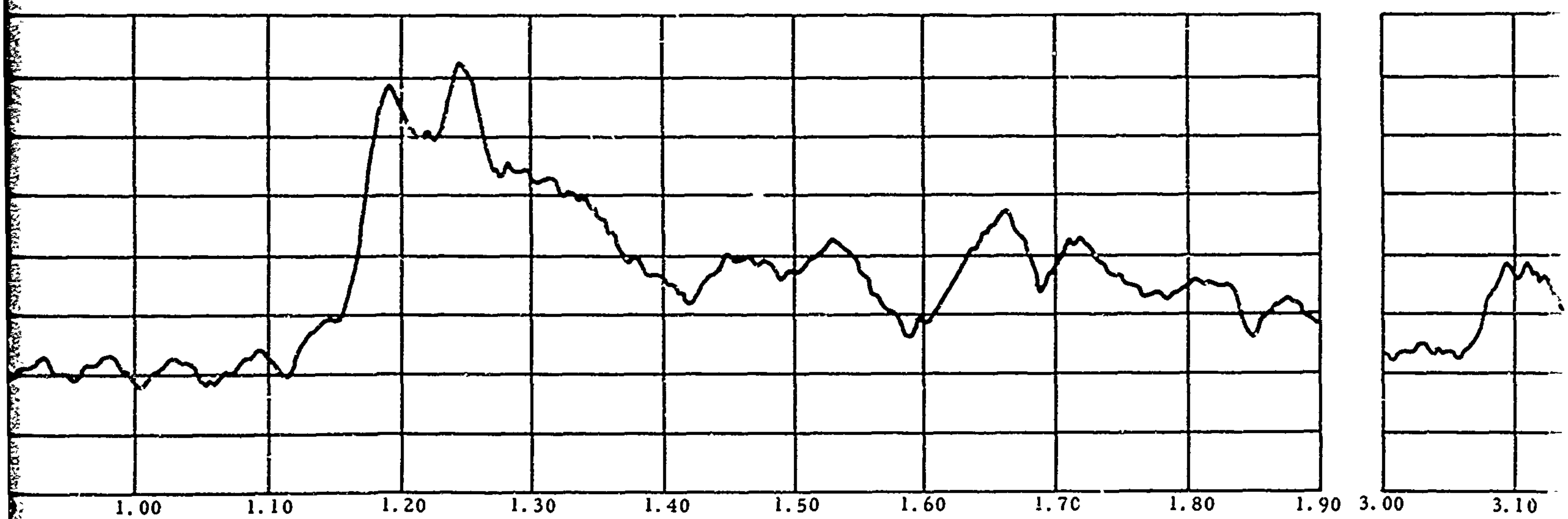



LOAD IN POUNDS
TENSION
COMPRESSION
+750
+500
+250
0
-250
-500
0
.10
.20
.30
.40
.50
FORWARD
.90
1.00
1.10
1.20
1.30
TENSION
COMPRESSION
+1500
+1250
+1000
+ 750
+ 500
+ 250
0
- 250
- 500
AFT

A



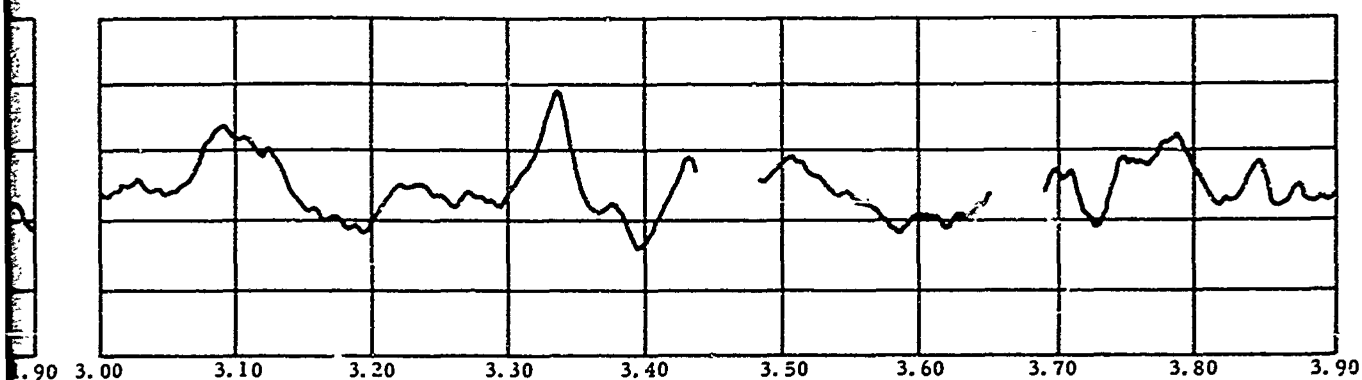
TIME IN SECONDS

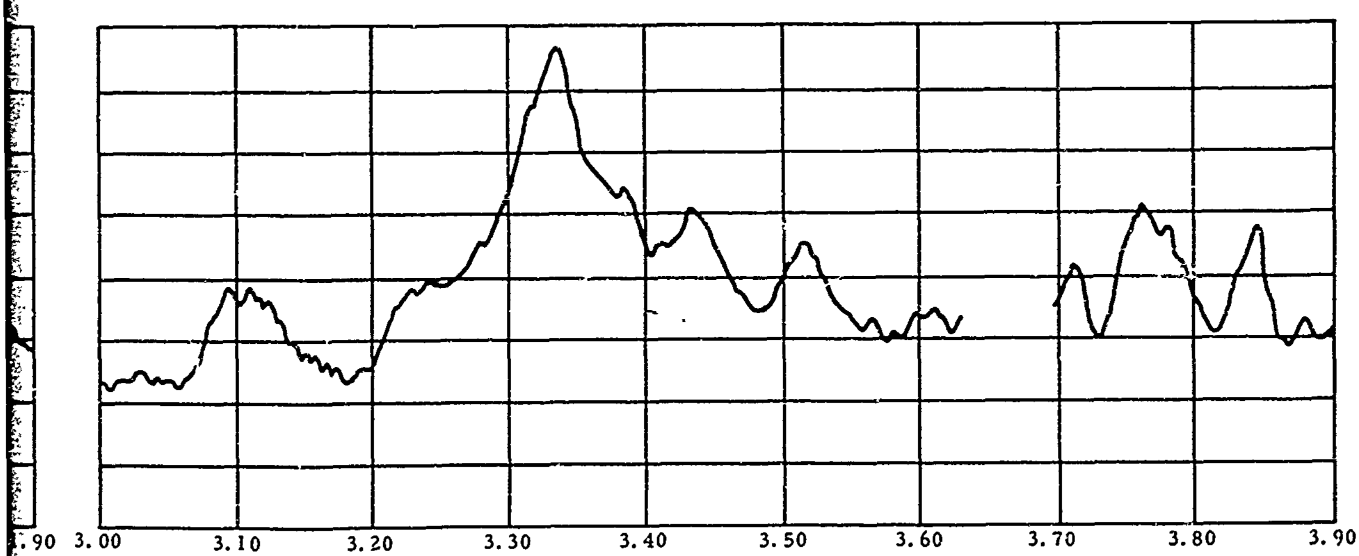


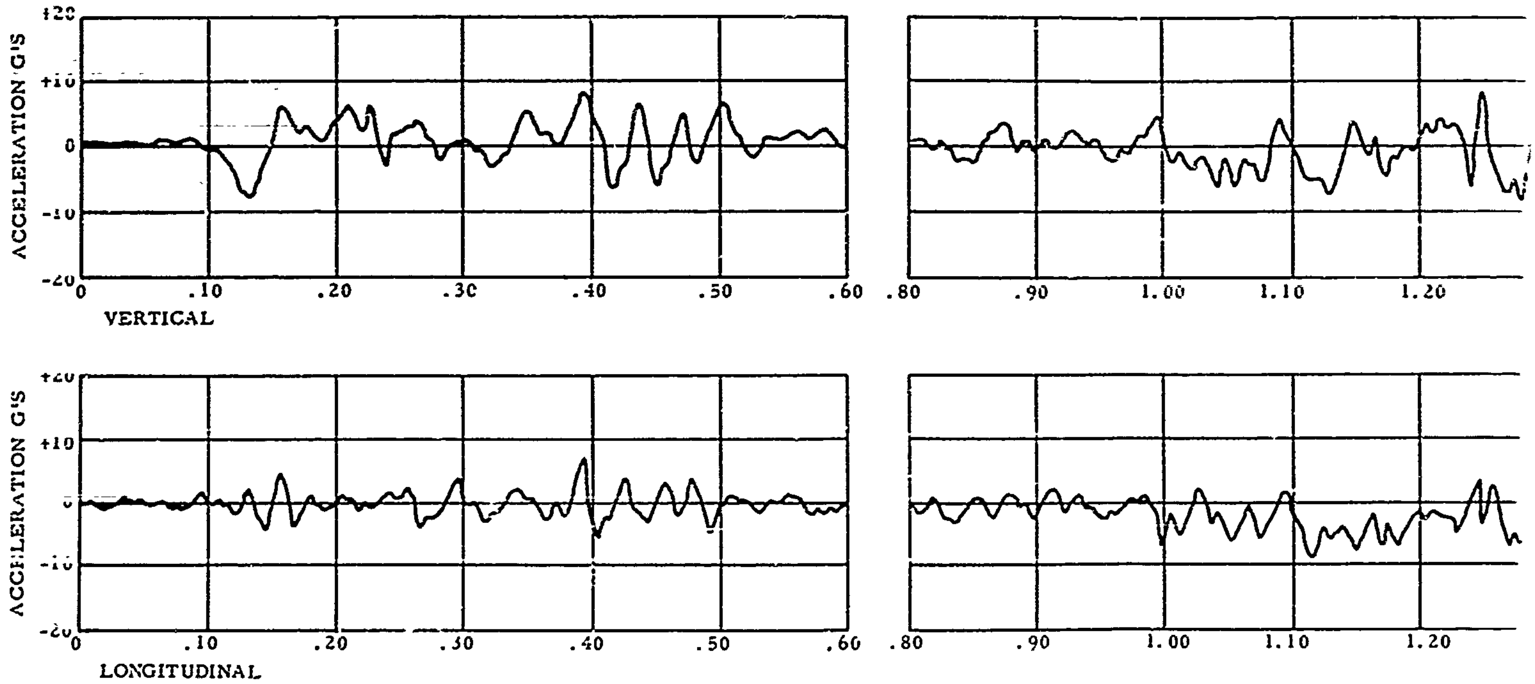
TIME IN SECONDS

B

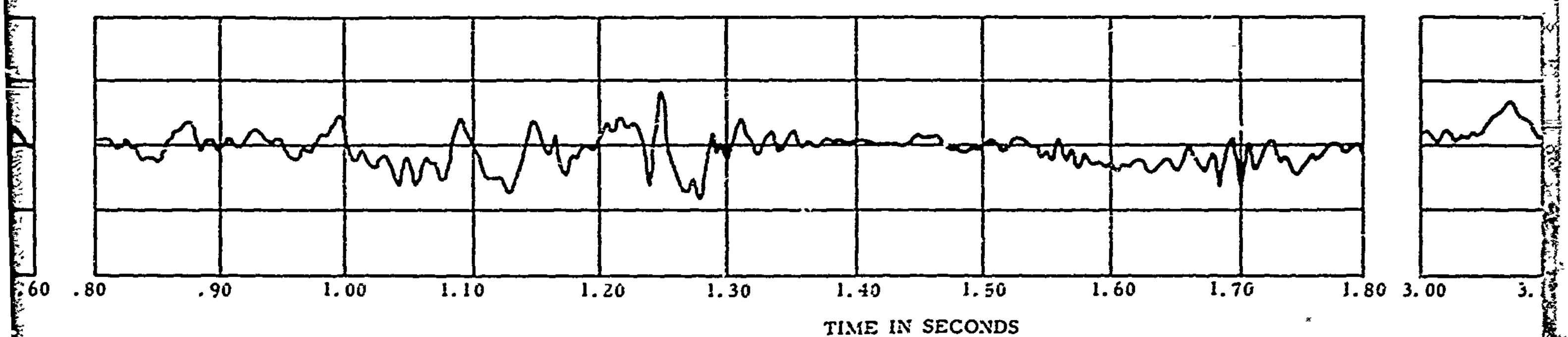
FIG. 6 - 32 TAIL SIDE FACING SEAT LAP BELT LOADS — SEAT 10



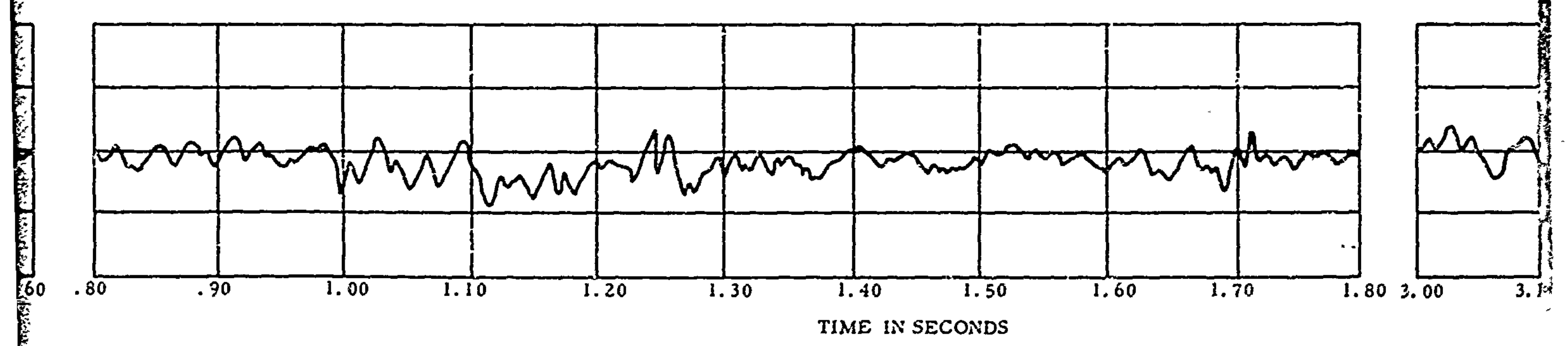



ACCELERATION G'S
+20
+10
0
-10
-20
0
.10
.20
.30
.40
.50
.60
.80
.90
1.00
1.10
1.20
VERTICAL
LONGITUDINAL

A

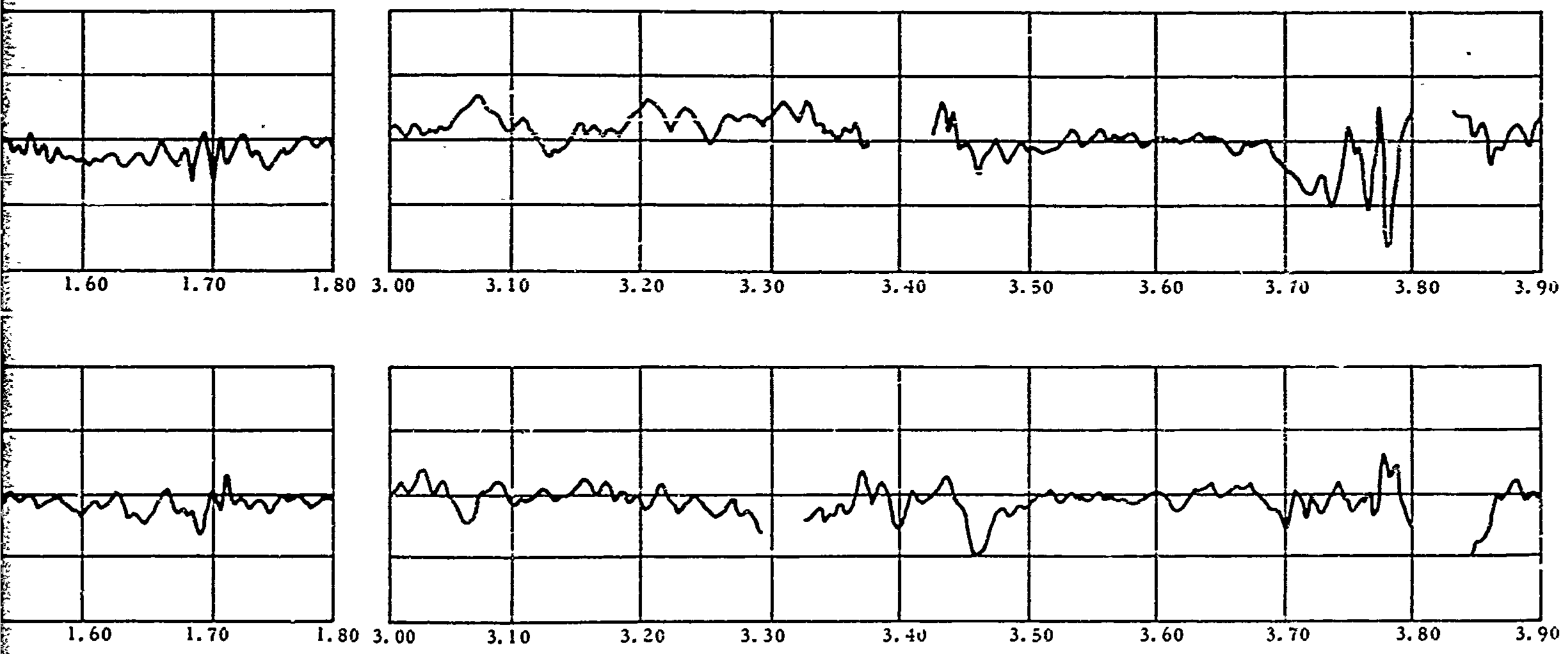


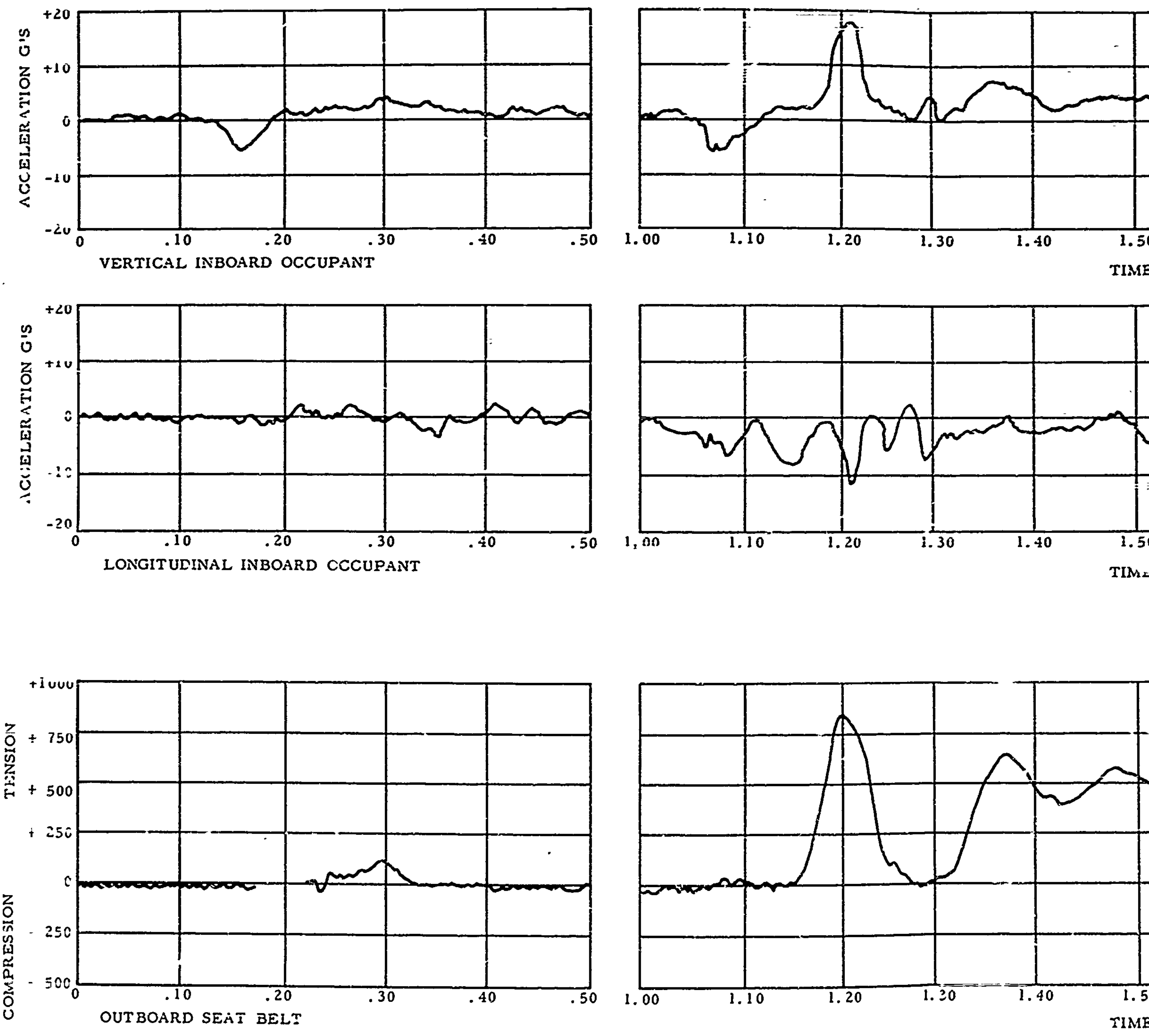
.60
.80
.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
3.00
TIME IN SECONDS

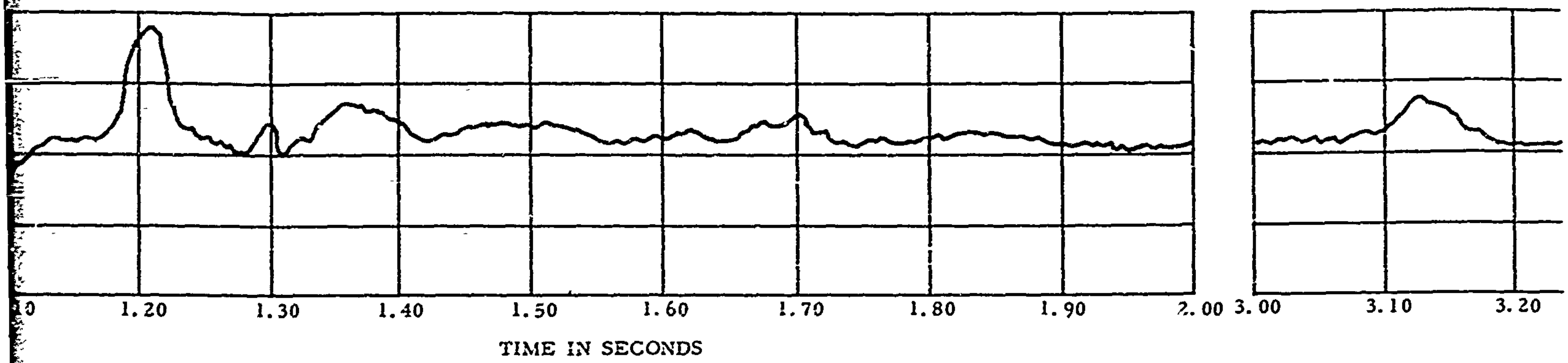


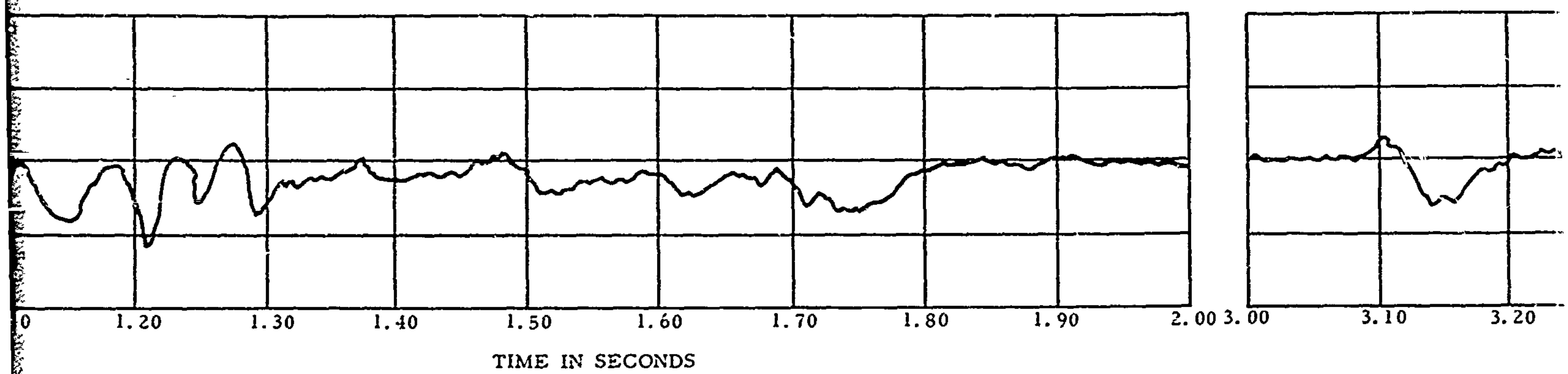
.60
.80
.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
3.00
TIME IN SECONDS

FIG. 6 - 33 TAIL FORWARD FACING SEAT ACCELERATIONS — SEAT 13




ACCELERATION G'S
+20
+10
0
-10
-20
0
.10
.20
.30
.40
.50
1.00
1.10
1.20
1.30
1.40
VERTICAL INBOARD OCCUPANT
ACCELERATION G'S
LONGITUDINAL INBOARD OCCUPANT
TENSION
COMPRESSION
+1000
+ 750
+ 500
+ 250
- 250
- 500
OUTBOARD SEAT BELT


0
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
2.00
3.00
3.10
3.20
TIME IN SECONDS


0
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
2.00
3.00
3.10
3.20
TIME IN SECONDS

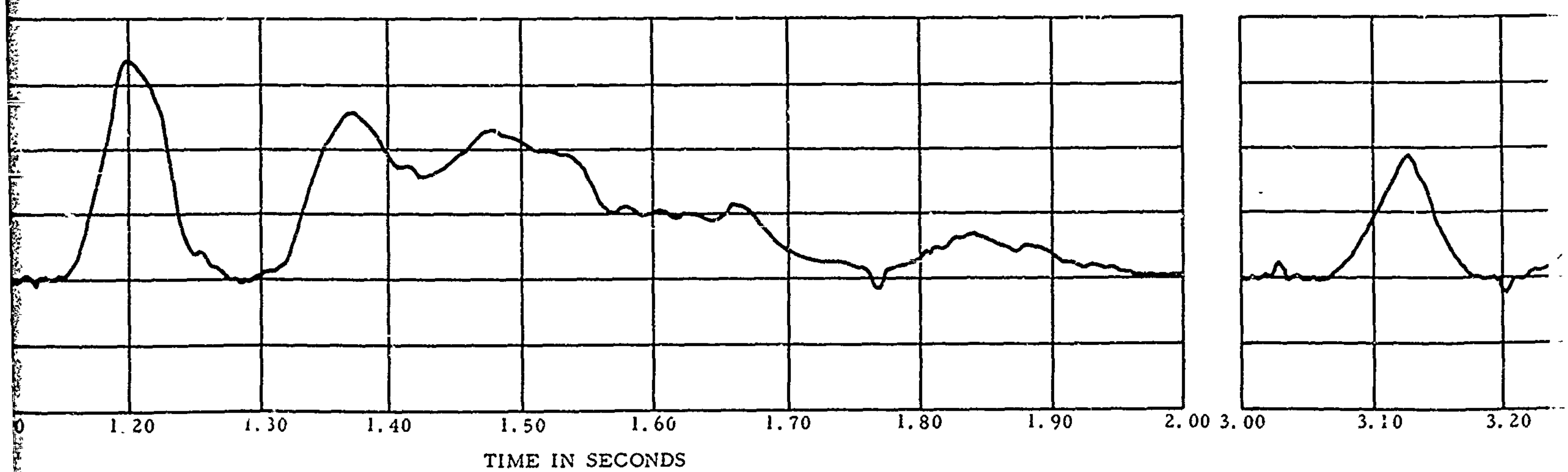
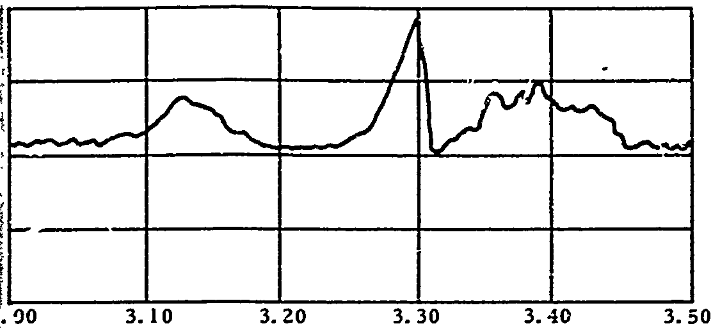

0
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
2.00
3.00
3.10
3.20
TIME IN SECONDS

FIG. 6 - 34 TAIL FORWARD FACING SEAT OCCUPANT'S PELVIC ACCELERATIONS — SEAT 13B



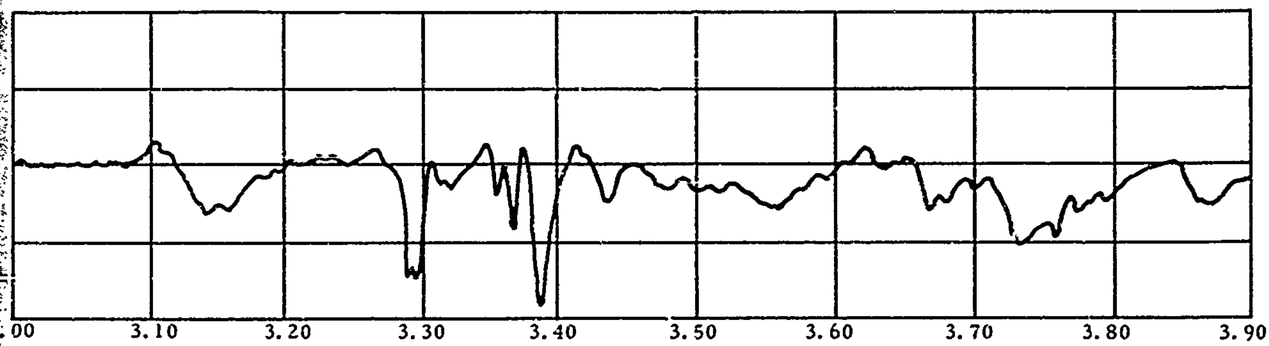


FIG. 6 - 35 TAIL FORWARD FACING SEAT LAP BELT LOADS — SEAT 13A