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FULL-SCALE DYNAMIC CRASH TEST OF A DOUGLAS DC-7 AIRCRAFT

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Aviation Safety Engineering and Research
Phoenix, Arizona

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TECHNICAL REPORT

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by
W. H. Reed
S. H. Robertson
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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

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SUMMARY

The purpose of the test presented in this report was to obtain crash environmental data to study fuel containment and to collect data on the behavior of various components and equipment aboard the aircraft using a DC-7 as the test vehicle.

During the early months of planning, other agencies became interested in placing experiments aboard the test aircraft, and when the test was conducted, a number of agencies were represented. In addition to the Federal Aviation Agency, the contracting agency, and Flight Safety Foundation, Incorporated, the contractor, the U. S. Army, the U. S. Navy, the U. S. Air Force, the National Aeronautics and Space Administration, and the aviation industry represented by the SAE Panel on Cargo Restraint all had experiments aboard the aircraft.

This test involved a DC-7 aircraft, which was guided into a series of crash barriers with a monorail nose landing gear guidance system. The aircraft was accelerated under its own power by remote control for a distance of 4000 feet, reaching a velocity of 139 knots. At the end of this acceleration run, the aircraft impacted against specially designed barriers which removed the landing gear, permitting the aircraft to become airborne until the moment of impact with wing and fuselage crash barriers. (See Figures 1 through 4.)

The wing and fuselage barriers were designed to provide the following crash sequence:

> First, the left wing was to impact against an earthen mound shaped to produce a simulated wing low accident. At the same time, the right wing was to impact telephone poles implanted vertically to simulate trees. These two types of impact were designed to study problems affecting fuel containment.
>
> Next, the main fuselage was to impact against an 8 degree slope, to produce a crash with an 8 degree angle of impact. This slope was designed so that the aircraft could again become airborne after sliding a short distance along the ground.

Following this, the aircraft was to impact against a 20 degree slope, to simulate a crash with a steeper angle of impact, and come to rest on the face of this slope. These two fuselage impacts were designed to provide data to aid in defining the crash environment in crashes of varying severity, and to provide environmental tests of specific equipment aboard the aircraft.

The crash occurred with the planned sequence of events. However, instead of coming to rest on the 20 degree impact slope as planned, the aircraft bounced over the hill on which this slope was formed and landed at the base of the backside of the hill.

All photographic data throughout the aircraft and all cockpit environmental data were obtained, and are discussed in this report. Due to the failure of a voltage control regulator in the primary data recording system, quantitative data from the remainder of the instrumentation aboard the aircraft were lost. But for this failure, it is probable that all the objectives of the test would have been met.

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 may be achieved.

A test program was devised 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 this report, and a Lockheed 1649, the results of which are discussed in FAA Technical Report ADS-38. 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 aircraft has been conducted in the past by the National Aeronautics and Space Administration on 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, driving the main landing gear up into the aircraft 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.

Impacts under circumstances simulating these three conditions will be studied during this test program.

TEST SITE

General

Conduction of the test program required the design and construction of a specialized test site. The desired impact conditions called for accelerating the test vehicles to a velocity approximating minimum climbout speeds and final approach speeds for propeller driven transport aircraft of the types involved, and guidance of the aircraft to a closely controlled initial impact point. In addition, earthen impact barriers for wing impacts 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.

Simulated Runway System

A special runway of sufficient length to allow acceleration of the aircraft to the desired impact velocity and capable of accommodating the landing gear spread and aircraft weight was built. 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 4000 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 Procter tests of the soil at the site. Figure 5 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, as shown in Figures 5, 6, and 7. Rail tiedowns were provided every 49 1/2 inches and at rail joints. The tiedown method is shown in Figure 7. 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 mis-alignment of the ends of the rails.

Impact Area

Barriers constructed of an external frame of interlocked railroad ties filled with gravel and large rocks were built to remove the test airplane's main landing gear. A length of the same rail used for the monorail guide was placed on the face of each of the barriers to help break the main landing gear struts. Another length of rail was placed perpendicular to the face of the right hand gear barrier, as shown in Figure 8, to break the propellers of No. 3 and No. 4 engines and deflect the broken blades away from the fuselage. The nose gear barrier, shown in Figure 9, was made of short lengths of rail positioned to cut the nose gear strut just above the guide slipper at approximately the same time the main gear impacted the barriers.

The left wing barrier was an inclined earthen mound 15 feet high extending from the wing tip to the center of the left wing and is shown in Figure 11. The face of the barrier was sloped 35 degrees.

Two pole barriers were placed to impact the leading edge of the right wing. These poles were standard telephone poles, positioned upright and buried approximately 4 feet in the ground. Figure 9 shows these poles.

The initial impact hill, located beyond the wing barriers, was an 8 degree slope extending for approximately 125 feet along the path of the aircraft. The hill then dropped away for 100 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. The earth used to construct the barriers was compacted to an average CBR* of 35 to 40 percent.

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 8 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 Figures 10 and 11.

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

TEST AIRCRAFT PREPARATION

General Description of Aircraft Preparation

Aircraft equipment not required for the test or for pretest operations was removed prior to Federal Aviation Agency acceptance of the aircraft. Items removed included electronic navigation equipment, cabin heaters, and pressurization equipment. Interior furnishings which might interfere with experiments or weren't necessary were removed after FAA acceptance. Delivery weight of the aircraft was 67,702 pounds. After removal of interior furnishings, the airplane weighed 65,232 pounds.* The items removed are tabulated in Table I.

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 8 tanks in its system, both bladder and integral types, 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 and/or selector valves. The engine vapor return lines were vented into a special auxiliary tank. The aircraft de-icing system in the fuselage belly was drained of isopropyl alcohol. The aircraft hydraulic systems were filled with Skydrol Type 7000 hydraulic fluid.

A special fuel tank, Figure 12, was built and installed in the wheel well of No. 3 engine nacelle. This tank was fabricated from a 55-gallon steel drum and contained its own boost pump and quantity gage, as well as anti-sloshing baffles. It was connected through a leak-proof, quick-disconnect fitting to a 150-gallon supply tank located on the ground, as shown in Figure 13. 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, empennage, and wings were painted with specific black and white markings designed to serve as aids in reduction of photographic data. The airplane nose, vertical stabilizer, and wing tips were distinguished by a large checkerboard pattern,

*Maximum gross weight for this aircraft is 122,000 pounds.

which served as visual reference points for tracking camera operators. A 15 inch wide black line was painted the length of the fuselage, except where it crossed the airplane windows, to help show the bending of the fuselage. The windows were painted white, to be used for longitudinal reference points. Also, four black and white checkered bands were painted over the top of the fuselage, at fuselage stations 134, 341, 600, and 978 to serve as additional reference points in analysis of photographic data. The aircraft markings are shown in Figure 14.

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 preset 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 radio controlled electrical relays which could complete magneto grounding circuits on command, shutting down all engines simultaneously.

Aircraft Release System

To restrain the aircraft without brakes or chocks during the period when no crew members are 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 15. 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 the side of the rail. Figures 16 and 17 show the guide shoe and actuating arms.

INSTRUMENTATION

Three general types of sensing instruments were used for data acquisition -- accelerometers, pressure transducers, and load links. The majority of the instruments were Statham accelerometers type A5-350 and A6-350 with capacities varying from $\pm$ 20G to $\pm$ 200G. The instrument ranges were dependent upon the direction to be sensed and the location of the measurement in the airplane. Six Consolidated Electrodynamics Corporation type 4-326 pressure transducers were utilized to gather information concerning fuel tank pressures at impact. The remaining sensors were load or strain links built by AvSER for particular applications in the aircraft. These links measured seat belt loads, seat leg loads, and cargo attachment loads. The specific measurements are listed in Table II.

A 14-track magnetic tape recorder was used for recording the acceleration, force, and pressure data during the crash test. 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 18. Each component of the recording system was 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 fuselage, at the location of the wing center section. 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 are combined in the mixer amplifier and the resulting composite signal recorded on one track of a fourteen track tape recorder.

The Naval Aerospace Crew Equipment Laboratory data acquisition system which was used to obtain cockpit environmental data 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.

Twelve (12) onboard cameras were used during the test and are listed in Table III. Ten (10) were Photo-Sonics 1B high speed cameras operating at a nominal speed of 500 frames per second and two (2) were Traid Model 200 cameras, operating at a nominal speed of 200 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, consisting of auxiliary floodlamps were installed throughout the fuselage interior. The cameras and lamps were powered by nickel-cadmium batteries mounted in the aircraft.

The onboard cameras were mounted on brackets attached to the airframe of the aircraft. The cameras were mounted inside aluminum boxes for protection against flying objects during the crash. The exact location and coverage of each camera are listed in Table III and are cross referenced with Figure 21.

Exterior photographic coverage was provided by thirteen (13) cameras positioned around the impact area as shown in Figure 19. The cameras, listed in Table IV are cross referenced with Figure 19. The table also indicates approximate distances from the impact area and camera frame speeds.

Special towers were erected at points around the impact area to protect the high-speed and normal speed cameras required to photograph the impact sequence. Some of the towers were constructed of wood and some were of the quick-erect type construction scaffolding. Special metal protective boxes were utilized for the remote controlled cameras,

Correlation and timing between the electronic and the photographic data was 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 ± 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.

CRASH TEST OPERATION AND RESULTS

General

Additions to the aircraft resulting from installation of experiments, data acquisition equipment, and simulated fuel brought the gross weight of the test vehicle to 107,952 pounds at the time of release for the crash test. A breakdown of this added weight is given in Table V.

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. Cargo restraint experiments
5. Forward cabin forward facing passenger seating experiment
6. Child restraint experiment
7. Wing center section forward facing passenger seating experiment, and kick-up load experiment
8. Aft facing passenger seating experiment
9. Galley equipment experiment
10. Air bag restraint system
11. Aft cabin forward facing passenger seating experiment
12. Side facing passenger seating 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, Figures 20 and 21 show the locations of experiments and instruments.

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.

The aircraft was released under low power and then throttles were advanced to pre-determined take-off power, 3050 BHP per engine. The aircraft accelerated smoothly and continuously during the 4000 foot run, impacting the landing gear barriers, as shown in Figure 22, at slightly over 139 knots, approximately 15 knots faster than had been planned. The landing gear was knocked off as the aircraft passed these barriers. The right main landing gear rebounded from the gear barrier and struck the right horizontal stabilizer, cutting off the outboard section.

All four propellers struck the propeller barriers and were broken. A blade from the No. 3 engine propeller passed completely through the fuselage, causing some structural weakening, damaging the mount of an onboard camera, and ripping one of the forward cabin forward facing seats apart.

All four engine mounts failed during the process of cutting the propeller blades.

Figure 23 shows the initial contact with the outboard right wing barrier pole. The impact with the pole cut off the wing approximately 12 feet from the tip. This figure also shows the spray of simulated fuel issuing from No. 4 main tank, which was ruptured by the pole. Approximately 0.150 second after the first pole impact, the aircraft contacted the second pole barrier, which was placed to strike the wing between No. 3 and No. 4 engines. This pole crushed the wing leading edge structure back to the forward spar, and then the pole broke. The left wing tip scraped along the earthen wing barrier, suffering only slight flattening of the underside near the tip.

After passing through the wing barriers, the aircraft struck the 8 degree hill, in a level pitch attitude. Roll and yaw were negligible at the m ment of impact. During the slide up this hill, both wings failed at the wingroots, but remained close to the fuselage. During this impact, the fuselage broke at approximately fuselage station 300.

The aircraft slid along the 8 degree slope and then continued in an upward trajectory of approximately 8 degrees. The aircraft then impacted against the 20 degree slope approximately 10 feet, vertically from the summit. The nose of the aircraft was pointed downward approximately 10 degrees at the time of impact with this second hill. The aircraft was rolled to the right approximately 2 degrees and yawed to the left approximately 5 degrees as impact occurred. Figures 24 through 26 show this portion of the crash sequence.

The aircraft bounced over the summit of the hill, as shown in Figure 27. Final impact occurred on the back side, at the foot of the hill. The main portion of the aircraft came to rest 860 feet from the point of initial contact with the main landing gear barriers. In Figure 28, the large section of the aft fuselage is shown lying on its left side. While passing over the summit of the hill, the left wing, torn completely free, flew ahead of the fuselage, as shown in Figure 27, and impacted approximately 50 feet ahead of the main fuselage. During this sequence, the wing rotated laterally 180 degrees and impacted in an inverted position. The right wing remained tied to the fuselage by the control wires and came to rest right side up in approximately its normal position. The bulk of the fuselage (aft section) came to rest at a 45-degree angle to the flight path and rolled over on its left side. The tail section of the aircraft broke partially free of the main fuselage just behind the aft pressure bulkhead and rolled further to the left than the main fuselage, as shown in Figure 28. The wreckage distribution during the crash sequence has been plotted on a wreckage distribution chart, Figure 29. Although a large number of smaller parts were scattered over the crash course, most of the large pieces remained together during the entire sequence and came to rest in a small area on the center line of the original path. Sequence pictures of the crash are shown in Figures 30 and 31.

Several small fires occurred when the aircraft broke up during the crash. When the engines were torn free, fuel and oil lines ruptured releasing approximately 140 gallons of oil and 15 gallons of gasoline in a heavy mist which was ignited and burned for several seconds. There were only two fires of any consequence -- one in the No. 3 nacelle and one in the insulation material near the wing section. The nacelle fire can be attributed to the fuel that remained in the area from the punctured auxiliary fuel tank. Both fires were quickly and easily extinguished by using dry chemical on the nacelle fire and water on the burning insulation.

Prior to the initial impact with the gear barriers, a voltage control regulator failed in the onboard data recording system, preventing amplification of the transducer signals and resulting in the loss of all electronic data in the airborne recording system in spite of the fact that the recorder was on and running throughout the test. The telemetry system installed by the Naval Aerospace Crew Equipment Laboratory provided acceleration and force records from the cockpit throughout the crash. These records are set forth in Appendix I.

Only partial data was obtained from two of the onboard cameras, Nos. 3 and 4 in Figure 21. Both of these camera mounts failed, allowing the cameras to point away from the intended fields of view. Camera No. 3 was located in the aircraft near the structural failure at fuselage station 300 and its mount failed when the fuselage broke. The mount for camera No. 4 was struck by a part of the propeller from No. 3 engine which passed through the fuselage at that point.

Wing Fuel Tank Experiments and Results

To provide environmental data concerning the wings and fuel tanks, accelerometers and pressure transducers were installed on both wings, as shown in Figure 20 and listed in Table II.

No. 1 alternate fuel tank located behind No. 1 engine nacelle was filled with a gelled water mixture approximately the consistency of applesauce. The other tanks in the left wing were filled with colored water. All of the tanks were filled to a volume of water which weighed the same as a full tank of fuel.

During the crash, the left wing received only a glancing upward force at the wing tip when it impacted the earthen barrier between the main gear barrier and the 8 degree slope. When the aircraft impacted the 8 degree slope, the left wing experienced severe impact damage and partially separated from the fuselage at the wing root. During the impact with the 20 degree slope the wing completely separated from the fuselage and finally came to rest approximately 50 feet past the fuselage. During this impact the engines were completely separated from the wing. The left wing, after the crash, is shown in Figure 32. The pattern of fuel spillage from the left wing was obscured by dust which blocked out the left wing.

Postcrash investigation revealed the following damage to the left wing fuel tanks:

> The majority of the top of No. 1 main tank was punctured and peeled back. The bottom had approximately 10 perforations and was slightly buckled.
>
> The bottom of No. 1 alternate tank had no visible punctures and was only slightly deformed. The top was in good condition with practically no deformation. The spar leading edge area separated for 28 inches, outboard to inboard, on the bottom and completely separated on top. This is shown in Figure 33. Just outboard from the No. 1 engine, the forward spar was bulged outward (forward). The arc formed in the spar between the top and the bottom edges had a radius of approximately 30 to 35 inches. This is shown in Figure 34.
>
> Between No. 1 and No. 2 engines, the forward spar showed no permanent deformation. The leading edge structure was two thirds pulled free and peeled under. Both the bottom and top of No. 2 main tank were punctured. The wing structure forward of the spar and tank was torn free. There was, however, very little crushing deformation aft of the spar.

> The wing was extensively torn and deformed in the wing root area, as would be expected with any gross structural failure.

All of the tanks in the right wing were filled to capacity, by weight, as were the tanks in the left wing. No. 4 alternate tank contained gelled water, the others contained colored water.

During the crash, the right wing was damaged much more severely than the left, due to the localized impacts with the telephone poles, at high velocity. As mentioned earlier, the outboard pole was struck first, and the outer twelve feet of the right wing was cut off. This section of the wing was found lying approximately half way up the 20 degree slope. The second pole penetrated approximately 3 feet into the wing structure between No. 3 and No. 4 engines and then broke. The right wing sustained two structural breaks, from the leading edge to the trailing edge, during the crash. The wing broke between No. 3 and No. 4 engines, where it was weakened by the pole impact, and it broke at the wing root. Control cables running through the wing kept the pieces together and tied to the fuselage, so that they came to rest beside the fuselage. The fuel spillage patterns from the tanks in this wing are shown in Figures 35, 36, and 37.

Jagged and torn metal was all that remained of the inboard wing section. Torn material from the bladder tank and laminated nylon chafing board were exposed along the line of separation from the fuselage. The top and bottom of the tank were practically all destroyed. The damage to this section is shown in Figure 38.

The No. 3 main tank, composed of both integral and bladder cells, was located between engines 3 and 4. This tank system was totally destroyed by the pole impact. Three foot spanwise sections of spar cap and spar web were torn from the forward and center spar and deflected aft into the fuel tanks. The leading edge of the wing was torn free from the spar and was scattered along the crash path.

The No. 4 alternate tank, located behind the No. 4 engine and outboard of the engine 6 feet, was destroyed during the impact. Wing skin was separated spanwise from the forward spar. Several square feet of internal structure was buckled between the forward and center spar. The leading edge was compressed back flat against the forward spar. Several gallons of gell slurry remained in the tank bottom.

The No. 4 main tank, located in the right wing tip was totally destroyed by the pole impact. Twelve feet of the wing was completely severed by the pole, as previously mentioned. The severed section was generally intact except for the inboard end. Between No. 4 engine and the location of the pole impact, the wing was extensively buckled and crushed.

The No. 3 alternate tank, located between the fuselage and the No. 3 engine was totally destroyed during the crash. The right wing separated from the fuselage through this area, consequently all that remained of this section is twisted, torn and buckled metal.

Cockpit Crew Seat Experiments

The standard DC-7 crew seats were removed from the cockpit. Special crew seats designed to withstand high crash forces were provided by the U. S. Naval Aerospace Crew Equipment Laboratory (ACEL). These seats were installed in the pilot and copilot positions, as shown in the sketch of experiment locations in Figure 21.

The nylon net type seat, shown in Figure 39, was installed in the pilot's position and the tubular frame bucket seat, shown in Figure 40, was installed in the copilot's position. Both seats were equipped with lap belts, shoulder harness and inertia reels. The copilot seat incorporated two energy absorption devices designed to attenuate vertical forces by pulling a plug through a metal tube.

Both seats were designed for track-type floor attachments and were attached to the aircraft structure in the same manner. An aluminum channel, 4 inches wide x 1.88 inches deep x 0.188 inch thick, was attached to the aircraft floor structure beneath the seat tracks of each seat. This structural reinforcement is shown in Figures 41, 42, and 43. The seat tracks were then securely bolted to the channels. This method was used to provide additional structural strength to the connection between the seat and the aircraft, providing a better test of the seat under high accelerations. The pilot and copilot 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 harness.

During the crash, the floor attachment of the pilot's seat failed completely. The seat tracks remained attached to the floor structure, but the lower seat structure failed at the attachment to the tracks. The lap belt and shoulder harness remained undamaged and attached throughout the crash. The overall condition of the seat after removal from the aircraft is shown in Figures 44, 45, and 46. The pilot vertical pelvic acceleration experienced was considerably lower in all impacts than the vertical acceleration in the copilot pelvic region, as shown in the accelerometer data, Appendix I.

The copilot's seat remained attached to the aircraft structure, as shown in Figure 47. The seat track attachments remained intact, but the surrounding structure was badly damaged. The entire seat pan was bent upward with respect to the seat back, due to contact with forward and lower cockpit structure. The copilot dummy remained in the seat. The inertia reel was locked and the shoulder harness was still attached to the right side of the lap belt, which was still connected to the seat. The lap belt was broken on the left side of the adjustment fitting as shown in Figure 50. Neither of the vertical energy absorbers used in the seat extended. The postcrash condition of this seat is shown in Figures 48, 49, 50, and 51.

Cargo Experiments

Two identical rigid steel cargo pallets were fabricated for the cargo experiment. The pallets weighed approximately 1040 pounds each and were installed in a staggered manner as shown in Figures 21 and 52. The pallets were longer than the cargo load, as shown in Figure 53, to provide support for the cargo in the event it shifted forward during the impact.

Six load links connected each pallet to the modified floor structure, as shown in Figure 54, to measure longitudinal, vertical, and lateral restraint forces. The installation was designed to allow deformation of the aircraft floor structure without appreciably affecting the individual tie-down points or the force data obtained from the load links.

The floor structure was modified in such a way as to provide additional strength for the cargo pallet installation without altering the structural integrity of the aircraft. As illustrated in Figure 54, three 7/16-inch thick 6061-T6 aluminum plates were individually bolted through the floor into the top web of the floor beams and intercostals. Mounted on top of the plates were two aluminum cross-frame assemblies, one for each pallet. These frames were bolted to the plates, the floor, and both top and bottom of the floor beams and intercostals. The cross-frame structure, shown in Figure 55, was designed to prevent any change in the location between the six transducer tie-downs.

To simulate a crushable cargo, 2000 pounds of a sand-sawdust mixture were placed in 14-inch cube, styrofoam containers. These containers were then packed in corrugated boxes of different lengths, all multiples of 14 inches. The boxes were stacked on the cargo pallets 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.

The cargo for each pallet was identical but the restraint systems differed. The forward cargo restraint net was fabricated from 3/8 inch diameter galvanized cable fastened at intervals with cable clips, as shown in Figure 53. The cable net was fastened to the cargo pallet at 16 tie points. The top of this cargo stack was covered with a 3/4 inch plywood sheet before installing the cable net to prevent the cable from cutting into the top cargo containers. The cable net was designed to provide rigid inelastic restraint for the cargo.

The restraint net for the aft cargo load was manufactured from 6000 pound test nylon strap. The distribution of the straps and tie-down points for the nylon net were similar to those of the cable net. (Reference Figure 56) This nylon net restraint was designed to provide more flexible and elastic restraint for the cargo load than the cable net.

Neither pallet or cargo load completely separated from its original tiedown. Several failures did occur to each net and the pallet tiedown links, but the bulk of the cargo was effectively restrained by both systems. Figure 57 is a postcrash view of the cargo experiment section of the aircraft.

Figure 58 shows the understructure of the fuselage in the cargo area, which opened up and allowed the floor to drop to the ground. Although the aft portion of the aircraft rolled over onto its left side, the aircraft nose and cargo section remained upright.

The No. 3 engine entered the forward cargo section during the final impact. The engine was either spinning or rolling fast as it climbed up the side of the forward cargo stack and lodged between the top of the cargo and the aircraft ceiling. (Reference Figure 59) No net failures were found where the engine impacted the cargo. However, the cargo was "chewed up" where the engine climbed the stack. Figure 60 is a sketch of the postcrash position of the shifted forward cargo. Nearly all of the boxes of simulated cargo on the forward cargo pallet were torn apart. Of the two cargo experiments, this cargo definitely sustained the most damage.

There was no evidence to indicate that any loads were applied to the cargo, cargo pallet or nylon net of the aft cargo experiment except the inertia loads of the cargo and pallet. The postcrash configuration of this cargo installation is shown in the sketch of Figure 61. Approximately one-fourth of the boxes of cargo used for this load suffered no damage whatsoever, while approximately one-half were torn but not destroyed. Only four boxes of cargo were completely ripped apart. One buckle on a load carrying strap, Figure 62, failed. Figure 63 shows the forward tiedown ring on the pallet which was deformed forward by the load applied to this strap.

Forward Cabin Passenger Seat Experiments

Three standard two-place DC-7 passenger seats were used in this experiment. The seats were installed with their forward leg attachments at fuselage stations 284.688, 324.688, and 364.688, which provided 40 inch seat spacing. These seats were constructed with tubular legs on the inboard side, which connect to fittings in the floor. On the outboard side the seats had no legs, but attached directly to the airplane wall. The framework for the seat back and pan was made of pressed sheet metal. The seat bottom was formed with interwoven rubber straps which attach to the framework. The center seat (F.S. 324.688) was occupied by two 95th percentile, 200 pound, anthropomorphic dummies (Figure 64), restrained with lap belts only. The forward seat carried no occupants. 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. (Reference, Instrumentation List, Table II.)

Child Restraint Experiment

The child restraint experiment was installed in the DC-7 passenger seat located at fuselage station 364.688, as shown in Figure 21. The child harness strapping encircled the subject's body at waist and chest level. Shoulder straps joined the chest level encircling strap in the front and rear. The body harness was attached to a strap that tied vertically over the seat back through the use of two gathered straps in the rear of the harness, as shown in Figure 65. The seat back strap was then attached to the aircraft floor. A 35-pound child dummy was used as the subject.

Results of Forward Cabin Seating Experiments

The two forward seats of this group of three were torn loose from their mountings and were found entangled in the wreckage of the forward fuselage section. The postcrash conditions of these seats is shown in Figures 66 and 67. The first seat was struck by the propeller blade from No. 3 engine. In addition, the fuselage broke just forward of the seat location and the walls of the fuselage, next to the seats, were buckled outward and crushed. The wall attachment for the forward seat pulled out of the wall fitting. The second seat ripped out the fitting and the intercostal to which it was attached.

The seat occupied by the child doll remained secured in the aircraft. The fuselage wall was not buckled outward at this location as it was just forward of this position. The front seat beam was broken beneath the doll due to vertical load. This was the only damage to the seat. The child restraint harness remained fastened and restrained the child dummy during the crash. It appears, however, that the dummy was subjected to considerable flailing, as evidenced by the final position of the occupant and by the fact that the right shoe of the dummy was lost during the accident and was found outside the aircraft.

Center Cabin Three Passenger Forward-Facing Seat Experiment

For the center fuselage forward-facing passenger seating experiment, two triple seats were installed on the right side over the wing spar, as shown in Figures 21 and 68. The seats were standard commercial seats presently in use on a number of jet aircraft. Seat pans and seat backs in these seats were of perforated aluminum sheeting with the seat pan formed to conform to a human buttock. Rearward folding food trays were designed to absorb energy through the use of plastic enclosed energy absorption material and were a part of each seat back..

The two seats were installed in the center fuselage section with seat front legs attached at fuselage stations 396 and 431 providing 35 inch seat spacing. Occupant restraint was provided by lap belts. The floor was reinforced to provide a solid mounting platform for the seats. Two 1/4-inch aluminum channels, positioned laterally, were installed beneath the floor and the leg attachments were secured to them. The sub-floor reinforcement channels spanned the width of the entire seat structure and were installed for front and rear legs of the aft seat. Floor attachments for the forward seat were reinforced with a lateral channel above the floor for the front legs and two aluminum plates (above and below the floor) for each rear leg. The two plates were bolted together, providing localized strengthening for each rear seat leg. The front legs of the aft seat were mounted in a section of floor track which allows forward and aft motion but prevents lateral and vertical motion. This provision was made to allow a change in the fore and aft distance between the legs of the seat during a controlled collapse of the seat structure under its design load.

The aft seat carried three 50th percentile, 170 pound, anthropomorphic dummies. The forward seat carried no passengers.

Accelerometers and load links were installed to record the aft seat accelerations, both vertical and longitudinal; the center passenger pelvic accelerations, both vertical and longitudinal; the center passenger lap belt loads (center dummy); and the vertical seat leg loads on all four legs of the aft seat and the rear legs of forward seat. (Reference Instrumentation List, Table II)

Both of the three-place seats in this experiment remained in place attached to the floor and the three dummies in the second seat also remained in place. All three of the unoccupied forward seat backs broke over in the forward direction. The perforated sheet metal seat backs on the forward seats were all deformed between the bottom of the seat back and one foot above the bottom, as shown in Figure 69, due to contact by the dummies in the seats behind. The folding tray on the aisle seat was smashed, as shown in Figure 69, and the rear legs of the forward seat were buckled. The dummy in the seat next to the wall came to rest with his head against the back of the seat in front of it.

All three dummy occupants of the aft seat remained attached to the seat through the lap belts. The aisle and center sections of the aft seat were generally in place; but the wall seat sheared off at the main tubular beam, on the back of the seat pan, allowing this seat to rotate forward through approximately 90 degrees. The main tubular beam also failed just inside of the aisle leg, but the aisle seat was not greatly displaced. The seat legs collapsed and allowed the seat to be displaced laterally and downward. Figures 70 and 71 show the fractures of the lateral tube on both sides of the center seat. The parallelogram seat leg structure did not fail and absorb energy as it was designed to do. The front legs moved forward in the floor tracks only about one to two inches. The right leg of the inboard dummy and both legs of the other two dummies extended under and to the front of the forward seat. The damage to seat backs shown in Figures 72 and 73 was attributed in part to contact with the arm and shoulders of the dummy seated on the aisle of the rearward facing seat experiment. The sharp 90-degree bend 12 inches from the top of the center seat back was caused by a large piece of 3/4 inch plywood that came loose from the instrumentation recorder installation.

Rear-Facing Passenger Seat Experiment

The U. S. Air Force three-passenger prototype rear-facing seat was installed on the left side of the fuselage, in the center wing section, just forward of fuselage station 499. (Reference Figures 21 and 74) Three 95th percentile, 200 pound, anthropomorphic dummies, as shown in Figure 75, occupied the seat during the crash. The dummies were restrained by lap belts. Each of the six floor attachments were standard military seat attachment plates secured to the floor with six 1/4-inch bolts. Aluminum channels were installed beneath the floor laterally at the attachment locations and the leg plates were bolted through the floor and the channels. Two channels were used, one for the forward legs and one for the rear legs. The floor attachment is shown in Figure 76. Accelerometers and load links were installed to record seat accelerations in the vertical and longitudinal directions, center passenger pelvic accelerations in the vertical and longitudinal directions, center passenger lap belt loads, and vertical seat leg loads on all six legs.

All three seat back locks failed during the crash, causing the backs to collapse and allowing the seat occupants to slide out of the seats, although all three lap belts remained fastened. The three seat back locks, small hydraulic cylinders, all failed in a similar manner - at the point indicated in Figure 79. The seat leg to floor attachments held throughout the crash and the energy absorbers located in the aft legs were attenuated. The general condition of the seat is shown in Figures 77 and 78.

Galley Equipment Experiment

The galley was located between fuselage station 660 and 780 on the left side of the airplane. (Reference Figure 21) The aft galley section was loaded with 410 pounds of simulated equipment, such as food containers and trays. No changes were made in the galley structure or in the methods of securing equipment in the galley for this test. Figure 80 shows the weighted boxes placed in the galley.

The aft section of the galley remained in place but the flexible sliding door failed when the aircraft impacted the 8 degree slope allowing the simulated galley equipment to eject and impact against the bottom of the forward galley section. All of the equipment remained in the galley area with the exception of the flexible door which moved forward to fuselage station 570. The forward galley, which was not loaded, remained in place; however, the forward bulkhead was loosened during the crash. Figures 81 and 82 show the postcrash condition of the galley and the spilled equipment.

Airbag Restraint Experiment

The airbag restraint system was installed on the two standard DC-7 passenger seats just aft of the galley on the left side of the fuselage. (Fuselage stations 760 to 870) The experiment consisted of rubber and plastic airbags installed to provide a resilient buffer between the upper torso of the dummy and the back of the next forward seat to absorb the longitudinal forces imposed on the dummy. Smaller airbags under the occupied seat and the seat ahead entrapped the legs to restrict leg flailing and upward or forward movement of the lower extremities. Figure 83 shows the airbags in place between the dummy and the seats. Only the dummy in the aisle seat was accorded the three-bag restraint, and it was also restrained with a lap belt. The dummy next to the fuselage wall was restrained with a lap belt and one clear plastic bag. The top portion of the plastic bag can be seen in Figure 84. The DC-7 seats occupied by the dummies were installed at fuselage station 807.688. No changes were made in the structure of the seats or in the method of attaching these seats to the aircraft. Both seat occupants were 95th percentile anthropomorphic dummies. The dummy in the aisle seat was instrumented to record vertical and longitudinal accelerations in the pelvic region. The dummy restrained by the clear plastic bag was not instrumented.

Both dummies remained in position in the aft seat, as shown in Figure 85. The lap belts were still attached and intact. The three rubber airbags that restrained the aisle dummy remained inflated. The two underseat bags restrained the dummy's feet in the normal position. The upper bag remained attached to the forward seat back, even though the seat back failed under the load applied by the dummy when the aircraft impacted the 8 degree slope. This failure allowed the chest bag to rotate out of position as shown in Figures 86 and 87.

Figure 88 is a postcrash rear view of the airbag experiment, showing the rotated bag lodged against the aft galley partition. The plastic airbag installed in front of the dummy next to the wall split along the inboard aft seam during impact. This 15-inch tear allowed rapid deflation and allowed the dummy's head to strike the back of the seat ahead. Figure 85 shows the dummy after the crash with his head positioned against the fitting box for the clear plastic bag. The occupied seat remained attached to the floor. The aft wall attachment held; but the forward wall fitting failed, allowing the forward seat structure next to the wall to deflect downward.

Aft Cabin Forward-Facing Passenger Seat Experiment

The aft cabin forward-facing passenger seat experiment used two standard DC-7 passenger seats installed with the forward leg attachments at stations 845 and 885. (Reference Figure 21, Seat No. 3) The rear seat of the experiment was occupied by two 95th percentile anthropomorphic dummies restrained by lap belts only. Accelerometers and load links were installed to record seat accelerations in the vertical and longitudinal directions, inboard dummy pelvic accelerations in the vertical and longitudinal directions, and inboard dummy lap belt load.

The seat was considerably deformed by the loading encountered during the crash. The forward wall attachment was bent upward, as the seat forward edge was forced downward. The forward edge of the seat contacted the floor and remained 1-1/2 to 2 inches from the floor. The aisle side of the seat collapsed due to the forward and downward loads, as shown in Figures 89 and 90. Both dummies remained in their seats throughout the crash even though the lap belt attachments for the aisle seat failed. The head of the aisle dummy struck the back of the seat in front of him causing a 3-inch deep dent in the metal structure which resulted in the loss of the dummy's head. (See Figure 91) Figure 92 shows that separation occurred between the seat back and the seat pan. The legs of both dummies extended under the forward seat. The legs of the aisle dummy extended under the seat up to his knees whereas the legs of the dummy next to the wall only extended under the forward seat midway between the ankles and the knees.

Side-Facing Seat Experiment

An unmodified DC-7 lounge seat on the right side of the aircraft at fuselage station 946.25 was used for this experiment. (Reference Figure 21) The existing lap belt, providing the only restraint, was connected to existing fasteners behind the lounge cushioning. Figure 93 shows this experiment with the occupant, a 95th percentile dummy, in place. A load link was installed to record lap belt force.

The side-facing seat in the lounge did not retain the dummy occupant. Both sides of the lap belt attachment cables failed and the dummy left the seat coming to rest against the left side of the aircraft approximately 36 inches forward of its seated position. The dummy's head struck the lounge partitioning bulkhead and then struck the floor. A 6-inch by 8-inch dent in the aircraft floor in front of the emergency exit appears to have been made by the dummy's head. The back of the side-facing seat failed. (See Figure 94) The aft tube failed approximately 2-3/4 inches above the lower seat structure. The forward lower seat structure failed, releasing the forward tube. These two failures completely released the seat belt.

CONCLUSIONS

It is concluded that:

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

2. In crashes of aircraft with fuel tanks and structure similar to the DC-7 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.

TABLE I

ITEMS REMOVED FROM AIRCRAFT AFTER ACCEPTANCE

Item	Weight
Unusable Fuel	232
Speakers	36
Light Troughs	50
Curtains	83
Bulkhead, Sta. 193	17
Coatroom	134
Toilets	38
Wash Basins	66
Linen Bins	36
Mirrors	24
Lavatory Plumbing	68
Ceiling Upholstery	6
Rugs	54
Lavatories	274
Lounge Table	24
Boost Pumps	32
Passenger Seats	1,296
TOTAL	2,470

FINAL EMPTY WEIGHT (67,702 - 2,470) = 65,232

TABLE II

INSTRUMENTATION MEASUREMENT LIST

1. Left Wing Inboard Acceleration - Longitudinal (WS 191)
2. Left Wing Inboard Acceleration - Vertical (WS 191)
3. Left Wing Center Section Acceleration - Lateral (WS 288)
4. Left Wing Center Section Acceleration - Longitudinal (WS 288)
5. Left Wing Center Section Acceleration - Vertical (WS 288)
6. Left Wing Outboard Acceleration - Longitudinal (WS 517)
7. Left Wing Outboard Acceleration - Vertical (WS 517)
8. Right Wing Acceleration - Longitudinal (WS 90)
9. Right Wing Acceleration - Longitudinal (WS 188)
10. Right Wing Acceleration - Longitudinal (WS 272)
11. Right Wing Acceleration - Vertical (WS 272)
12. Right Wing Acceleration - Longitudinal (WS 369)
13. Right Wing Acceleration - Longitudinal (WS 471)
14. Right Wing Acceleration - Longitudinal (WS 615)
15. Left Wing Fuel Tank Pressure - Inboard
16. Left Wing Fuel Tank Pressure - Center
17. Left Wing Fuel Tank Pressure - Outboard
18. Right Wing Fuel Tank Pressure - Inboard
19. Right Wing Fuel Tank Pressure - Center
20. Right Wing Fuel Tank Pressure - Outboard
21. Cockpit Floor Acceleration - Lateral (FS 62)
22. Cockpit Floor Acceleration - Longitudinal (FS 62)
23. Cockpit Floor Acceleration - Vertical (FS 62)
24. Forward Cabin Acceleration - Longitudinal (FS 260)
25. Forward Cabin Acceleration - Vertical (FS 260)
26. Center Cabin Acceleration - Lateral (FS 436 CG)
27. Center Cabin Acceleration - Longitudinal (FS 436 CG)
28. Center Cabin Acceleration - Vertical (FS 436 CG)
29. Aft Cabin Acceleration - Longitudinal (FS 713)
30. Aft Cabin Acceleration - Vertical (FS 713)
31. Tail Section Acceleration - Lateral (FS 950)
32. Tail Section Acceleration - Longitudinal (FS 950)
33. Tail Section Acceleration - Vertical (FS 950)
34. Unoccupied Three Passenger Forward Facing Seat - Aft Outboard Leg Load
35. Unoccupied Three Passenger Forward Facing Seat - Aft Inboard Leg Load
36. Rear Facing Seat Forward Inboard Leg Load
37. Rear Facing Seat Forward Center Leg Load
38. Rear Facing Seat Forward Outboard Leg Load

TABLE II (Continued)

INSTRUMENTATION MEASUREMENT LIST

39. Rear Facing Seat Aft Inboard Leg Load
40. Rear Facing Seat Aft Center Leg Load
41. Rear Facing Seat Aft Outboard Leg Load
42. Forward Cabin DC-7 Seat Belt Load
43. Three Passenger Forward Facing Seat
44. Rear Facing Seat Belt Load
45. Aft Cabin DC-7 Seat Belt Load
46. Forward Cargo Pallet - Forward Left Vertical Load
47. Forward Cargo Pallet - Forward Right Vertical Load
48. Forward Cargo Pallet - Aft Vertical Load
49. Forward Cargo Pallet - Left Longitudinal Load
50. Forward Cargo Pallet - Right Longitudinal Load
51. Forward Cargo Pallet - Lateral Load
52. Aft Cargo Pallet - Forward Left Vertical Load
53. Aft Cargo Pallet - Forward Right Vertical Load
54. Aft Cargo Pallet - Aft Vertical Load
55. Aft Cargo Pallet - Left Longitudinal Load
56. Aft Cargo Pallet - Right Longitudinal Load
57. Aft Cargo Pallet - Lateral Load
58. Forward Cabin DC-7 Seat Dummy Pelvic Accel. - Longitudinal
59. Forward Cabin DC-7 Seat Dummy Pelvic Accel. - Vertical
60. Aft Cabin DC-7 Seat Dummy Pelvic Accel. - Longitudinal
61. Aft Cabin DC-7 Seat Dummy Pelvic Accel. - Vertical
62. Three Passenger Forward Facing Seat Dummy Pelvic Accel. - Longitudinal
63. Three Passenger Forward Facing Seat Dummy Pelvic Accel. - Vertical
64. Rear Facing Seat Dummy Pelvic Acceleration - Longitudinal
65. Rear Facing Seat Dummy Pelvic Acceleration - Vertical
66. Forward Cabin DC-7 Seat Acceleration - Longitudinal
67. Forward Cabin DC-7 Seat Acceleration - Vertical
68. Three Passenger Forward Facing Seat Accel. - Longitudinal
69. Three Passenger Forward Facing Seat Accel. - Vertical
70. Rear Facing Seat Acceleration - Longitudinal
71. Rear Facing Seat Acceleration - Vertical
72. Aft Cabin DC-7 Seat Acceleration - Longitudinal
73. Aft Cabin DC-7 Seat Acceleration - Vertical
74. Occupied Three Passenger Forward Facing Seat - Forward Inbound Leg Load
75. Occupied Three Passenger Forward Facing Seat - Forward Outboard Leg Load

TABLE II (Continued)

INSTRUMENTATION MEASUREMENT LIST

76. Occupied Three Passenger Forward Facing Seat - Aft Inboard Leg Load
77. Occupied Three Passenger Forward Facing Seat - Aft Outboard Leg Load
78. Airbag Restraint Dummy Pelvic Accel. - Longitudinal
79. Airbag Restraint Dummy Pelvic Accel. - Vertical
80. Side Facing Seat Belt Load - Right Side
81. Side Facing Seat Belt Load - Left Side
82. Aircraft Velocity Measurement

TABLE III

AIRCRAFT ONBOARD CAMERA LOCATIONS AND COVERAGE

Camera No.	Fuselage Station No.	Coverage
1	103	Cockpit experiment
2	102	Right side cargo experiment
3	273	Left side cargo experiment
4	335	Forward cabin seat and child restraint experiments
5	451	Mid-cabin seat experiment
6	491	Aft-facing seat experiment
7	814	Airbag experiment
8	892	Aft cabin seat and side-facing seat experiment
9	Atop fuselage	External coverage of left wing
10	Atop fuselage	External coverage of right wing
11	720	Galley experiment
12	Vertical stabilizer	External overall camera coverage

TABLE IV

AIRCRAFT EXTERIOR CAMERA COVERAGE

Camera No.	Type	Speed Frames Per Second	Distance From Impact
1	Photo-Sonics 1B	500	200 ft.
2	Photo-Sonics 1B	500	200 ft.
3	Traid 200	200	200 ft.
4	Traid 200	200	200 ft.
5	Traid 200	200	200 ft.
6	Photo-Sonics 1B	500	600 ft.
7	Photo-Sonics 1B	500	600 ft.
8	Photo-Sonics 1B	500	600 ft.
9	Traid 200	200	600 ft.
10	Traid 200	200	200 ft.
11	Bell & Howell	64	2000 ft.
12	Photo-Sonics 1B	500	2000 ft.
13	Fairchild Flight Analyzer	---	2000 ft.

All cameras used color film with the exception of No. 9 and No. 13.

TABLE V

EQUIPMENT ADDED TO AIRCRAFT FOR TEST

Items Added During Preparation	Weight of Items
Cargo Reinforcement Structure	380
Cargo Pallets	2,072
Cargo	4,000
Water in Wing Fuel Tanks	23,928
Auxiliary Fuel System and Fuel	210
Dummy Occupants	3,040
Reinforcement Structure Added Below Crew and Passenger Seats	35
Hardman Passenger Seats	150
USAF Passenger Seat	120
Airstop Restraint System (Est.)	45
Instrumentation Package	205
Instrumentation and Wiring	400
Cameras, Lights, Mounts	536
Batteries	457
Galley Equipment	410
Engine Oil (35 gals/engine plus residual)	1,232
Ballast	5,500
TOTAL ADDED WEIGHT	42,720

GROSS WEIGHT AT TIME OF RELEASE (65,232 + 42,720) = 107,952

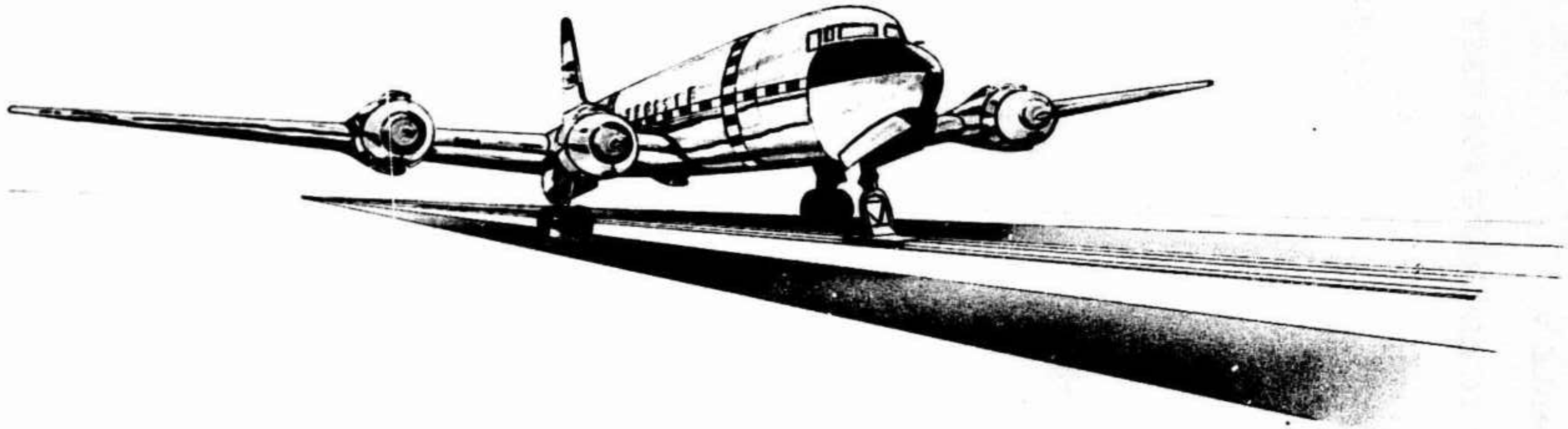


FIG. 1 TEST AIRCRAFT APPROACHING GEAR AND PROPELLER BARRIERS

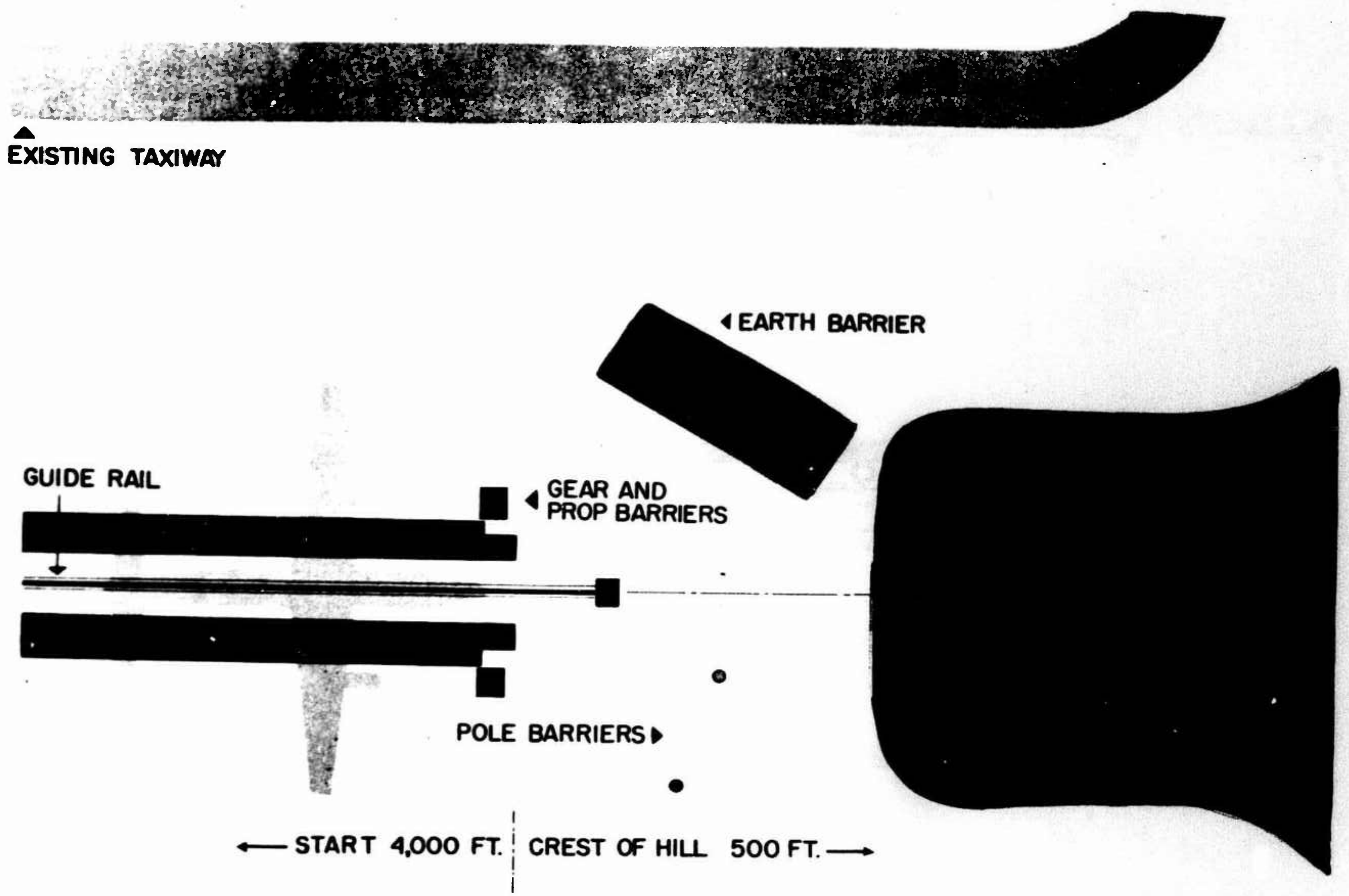


FIG. 2 PLAN VIEW OF TEST SITE

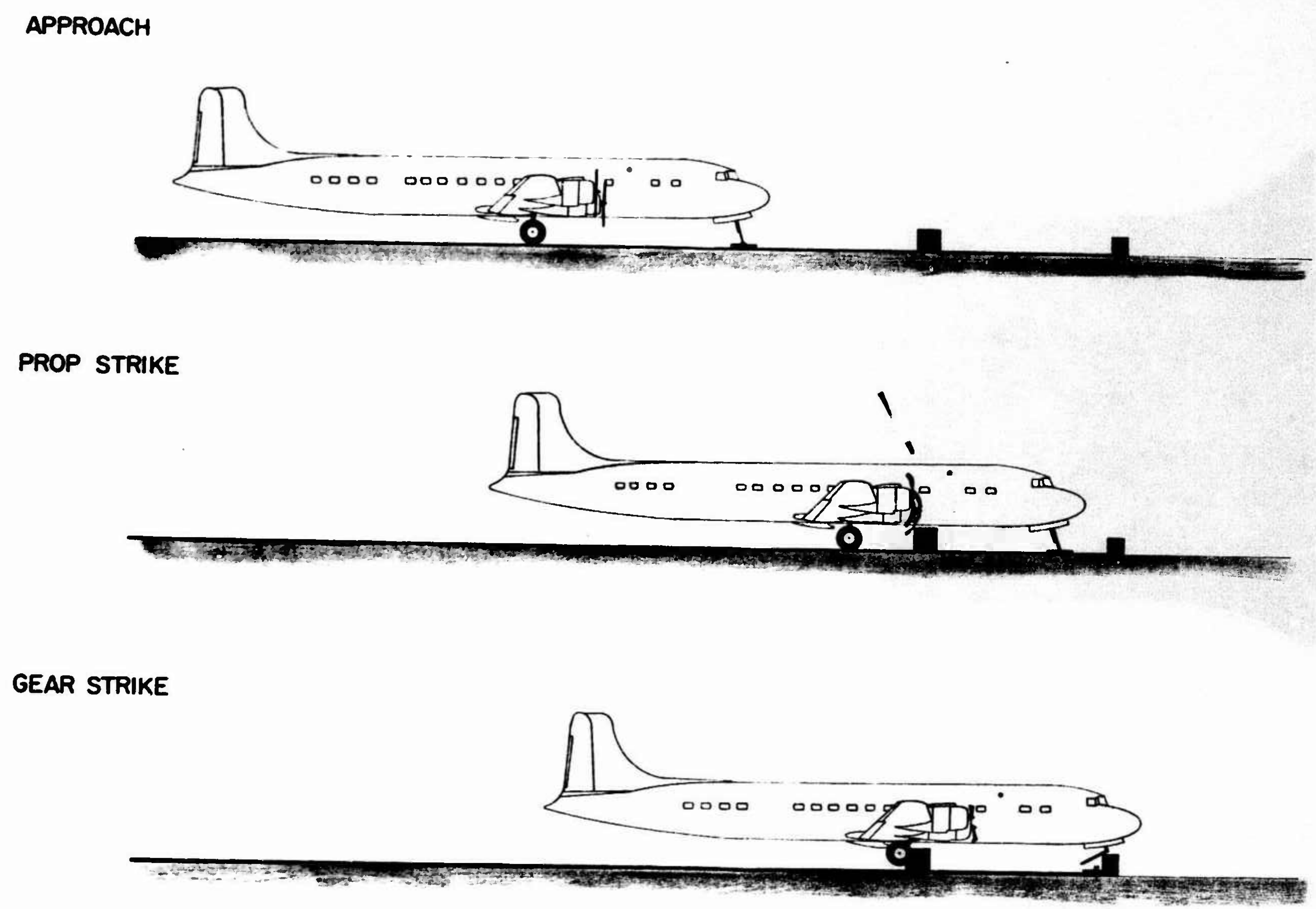


FIG. 3 GEAR AND PROPELLER IMPACT SEQUENCE

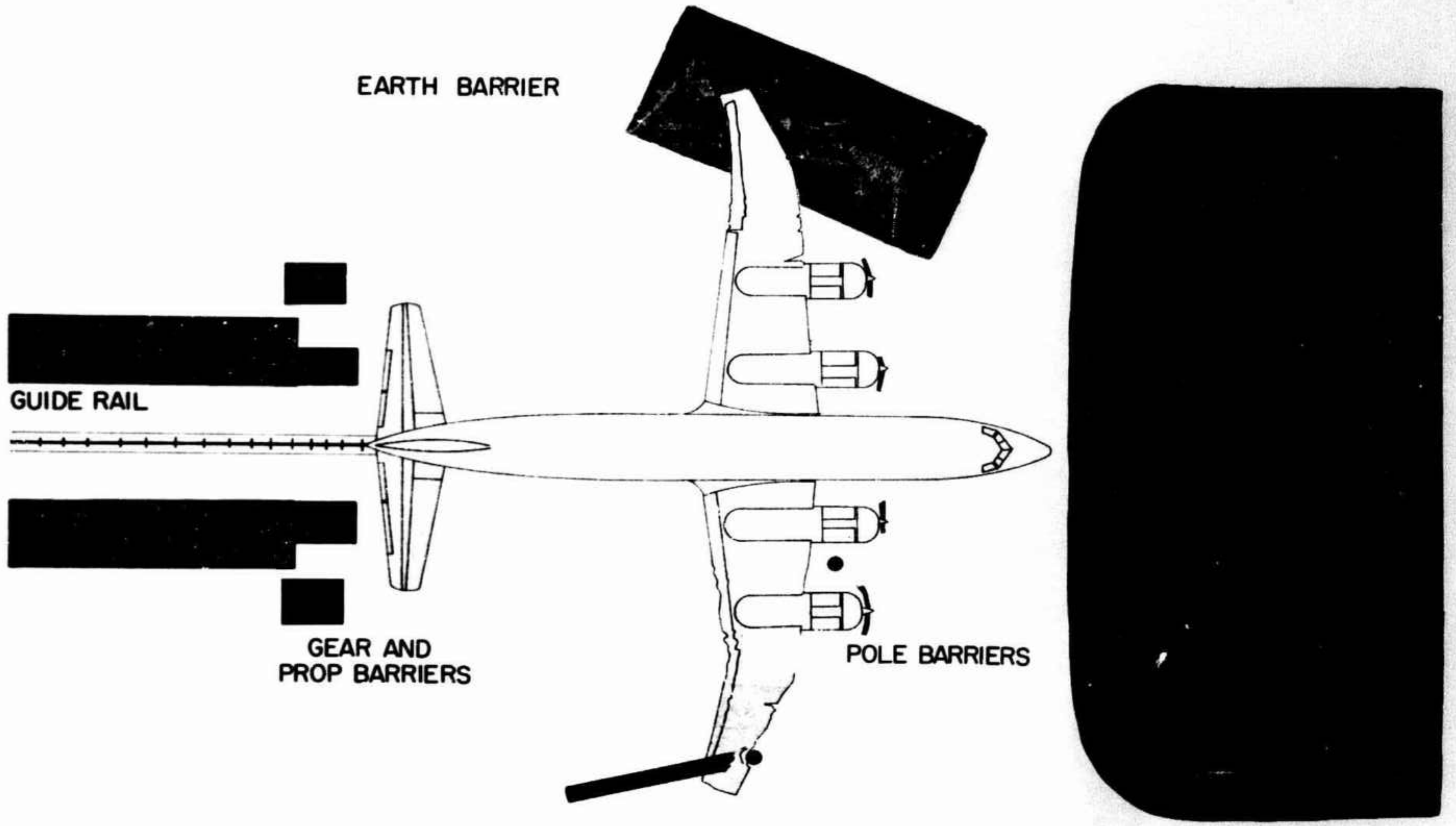


FIG. 4 WING IMPACT SEQUENCE

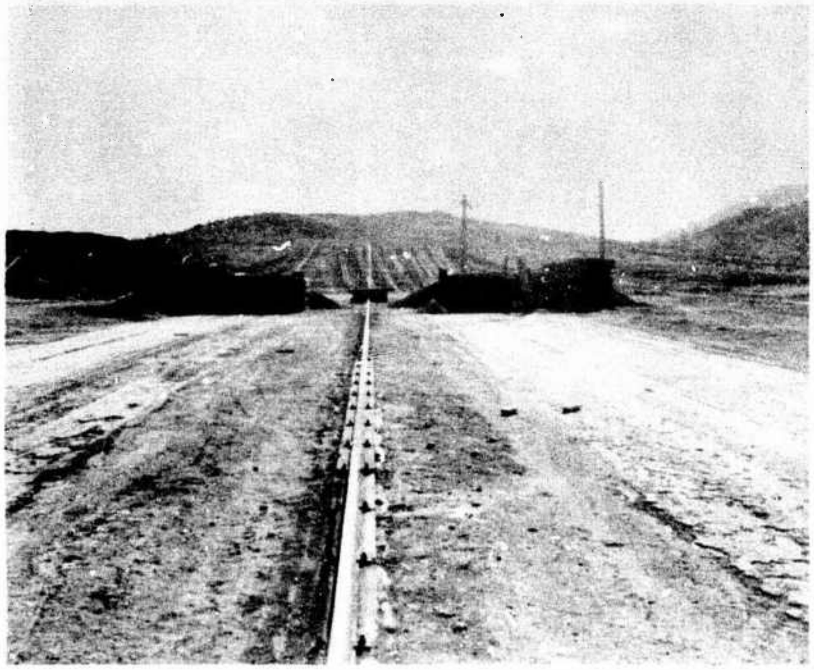


FIG. 5 GUIDE RAIL AND RUNWAY APPROACH TO MAIN GEAR AND PROPELLER BARRIERS

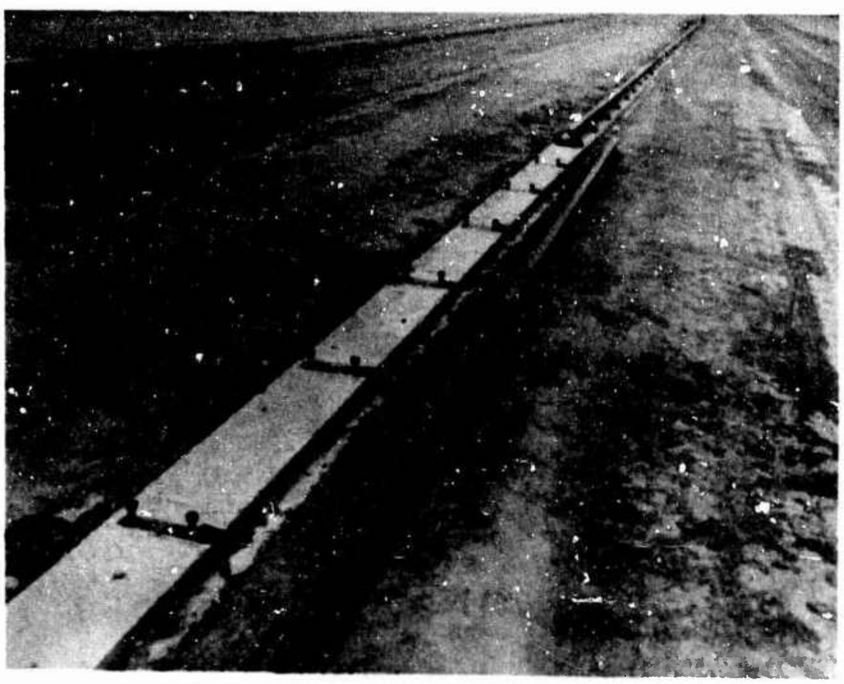


FIG. 6 CONCRETE BASE FOR GUIDE RAIL

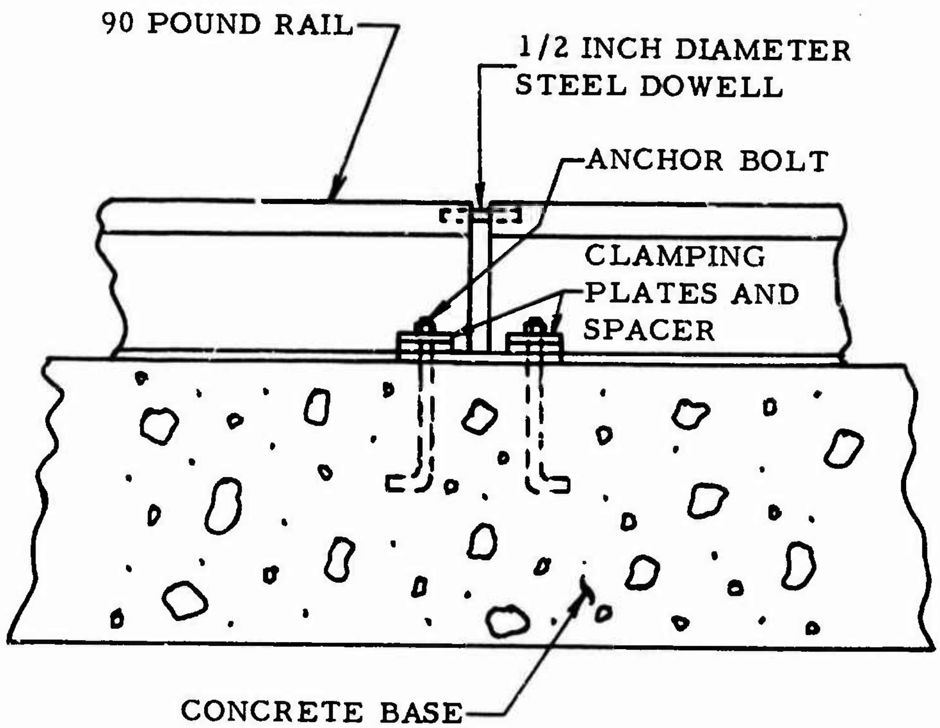


FIG. 7 TYPICAL RAIL JOINT TIEDOWN

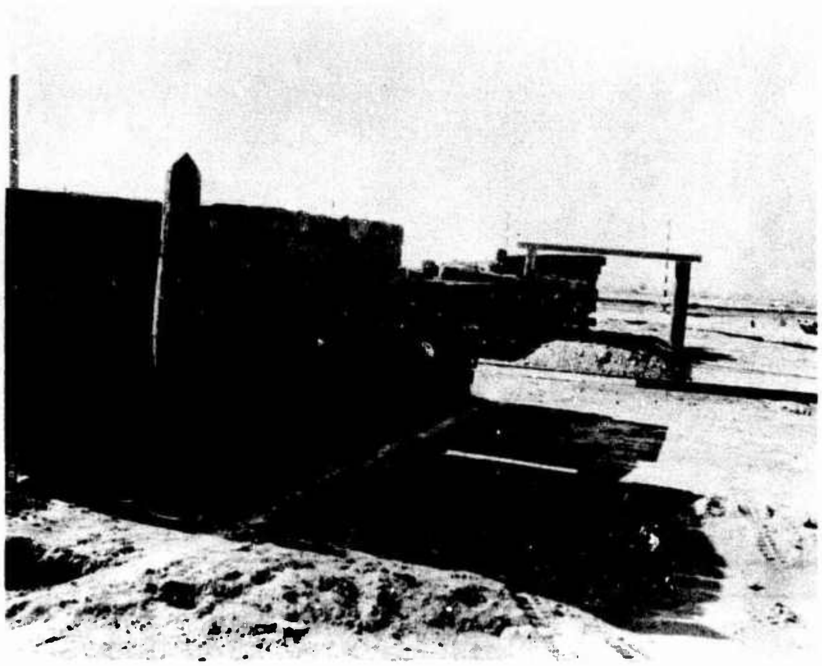


FIG. 8 MAIN GEAR AND PROPELLER BARRIERS SHOWING GUIDE RAIL APPROACH TO INITIAL IMPACT ZONE

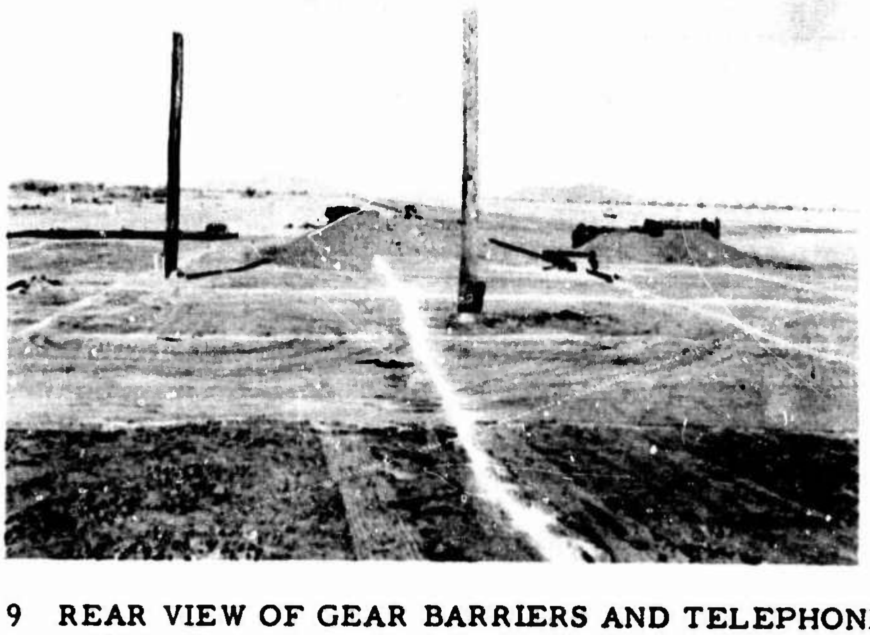


FIG. 9 REAR VIEW OF GEAR BARRIERS AND TELEPHONE POLES (RIGHT WING BARRIER) SHOWING NOSE GEAR BARRIER AT THE END OF THE GUIDE RAIL

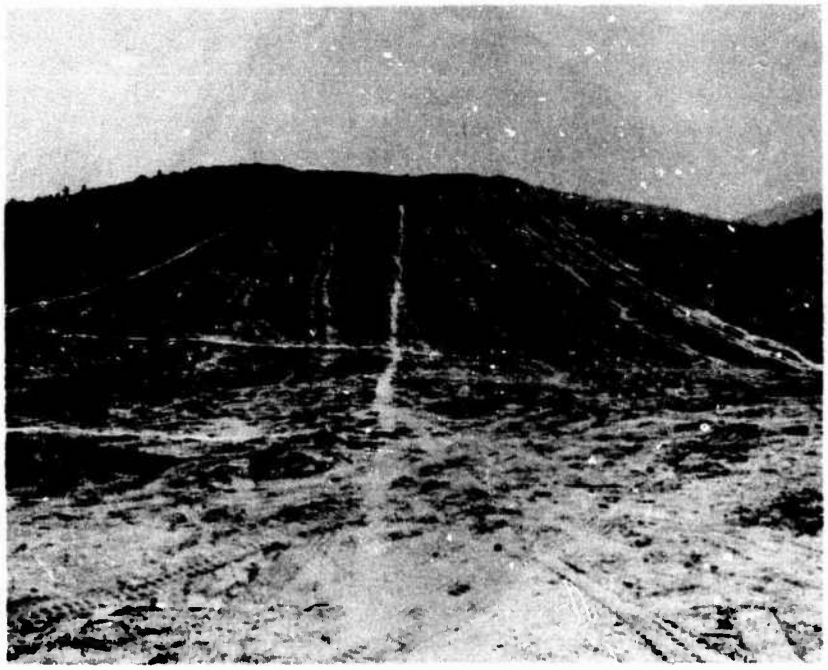


FIG. 10 INITIAL IMPACT HILL AS SEEN FROM TEST AIRCRAFT APPROACH PATH

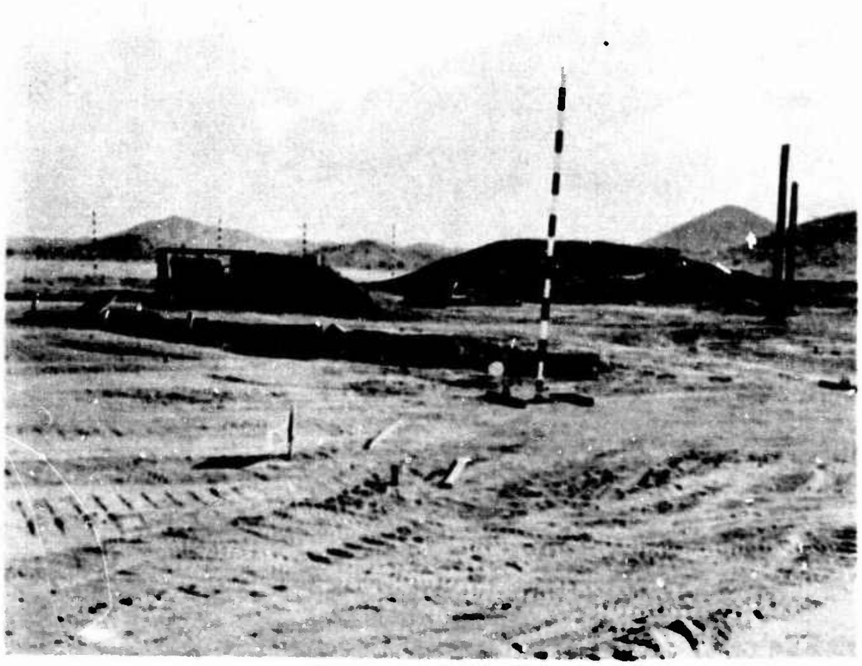


FIG. 11 RANGE POLE REFERENCE MARKER, VIEWED FROM RIGHT SIDE OF AIRCRAFT PATH

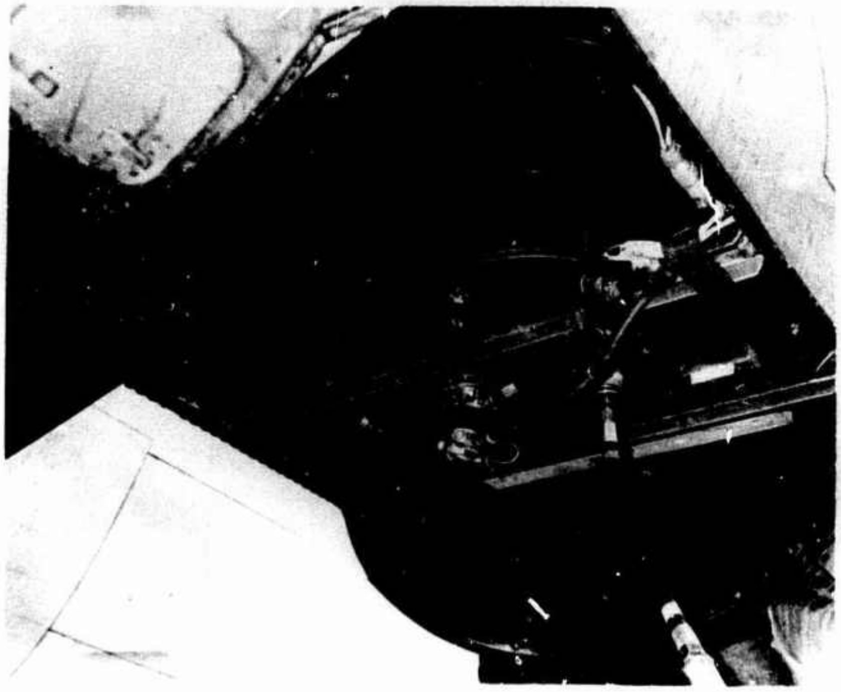


FIG. 12 AUXILIARY FUEL TANK INSTALLED IN RIGHT MAIN GEAR WHEEL WELL

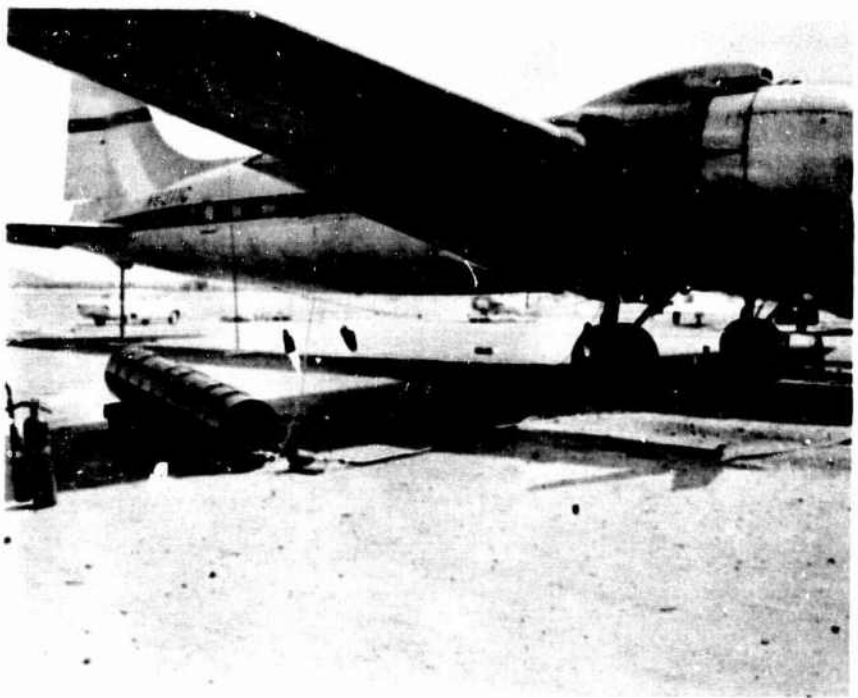


FIG. 13 GROUND FUEL SUPPLY TANK CONNECTED TO AIRCRAFT

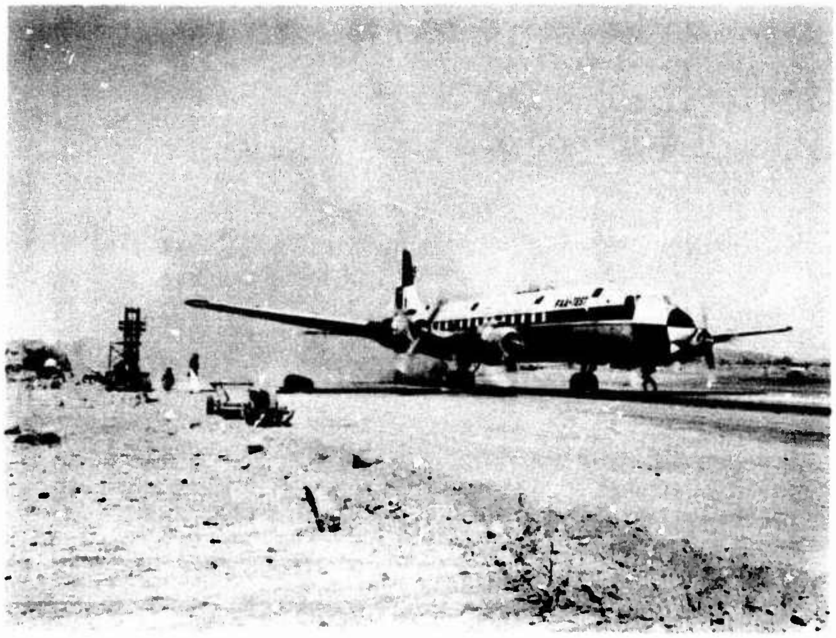


FIG. 14 VIEW OF TEST AIRCRAFT JUST PRIOR TO RELEASE SHOWING SPECIAL EXTERIOR MARKINGS

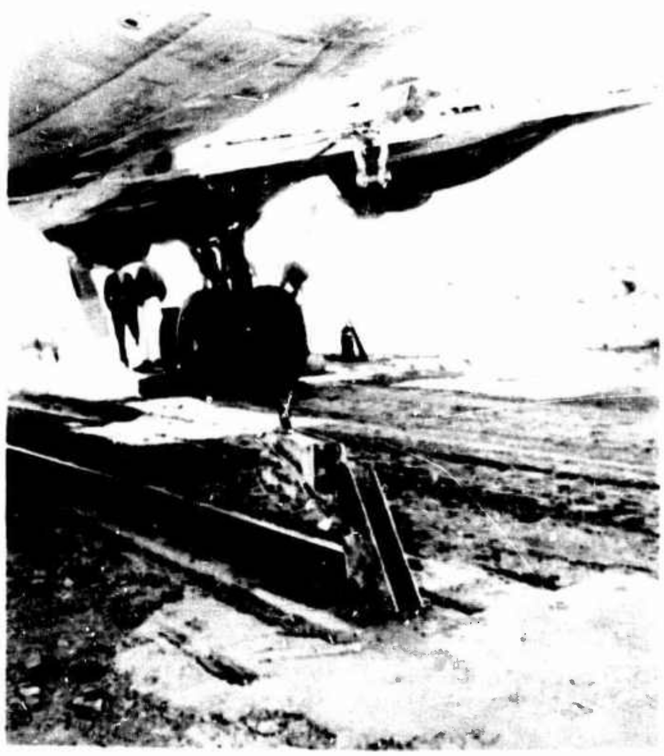


FIG. 15 AIRCRAFT RESTRAINT AND RELEASE SYSTEM

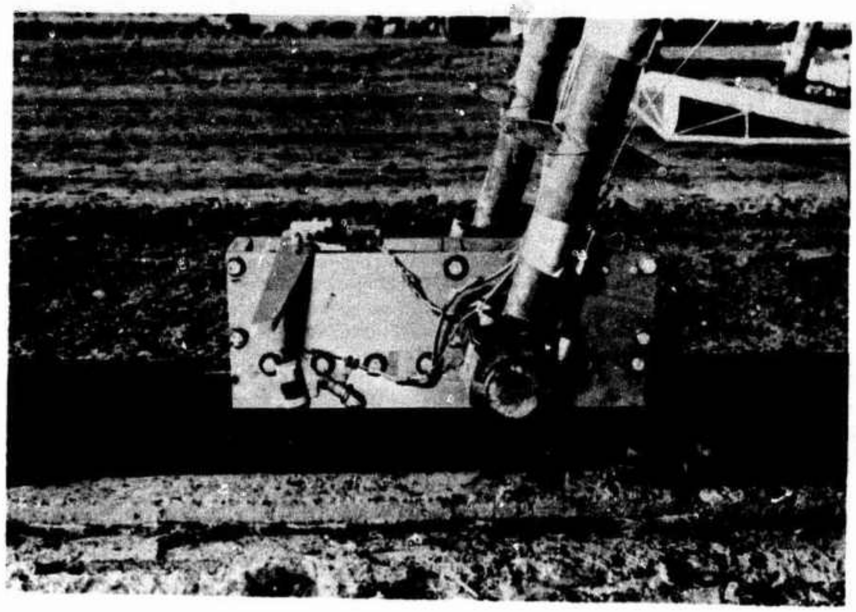


FIG. 16 GUIDE SLIPPER

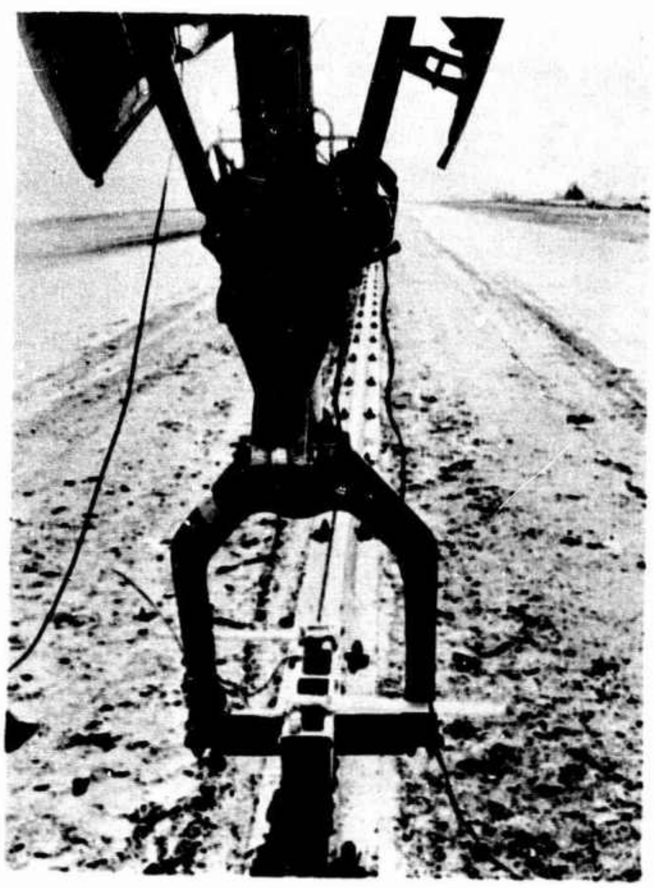


FIG. 17 SLIPPER ATTACHMENT TO AIRCRAFT NOSE GEAR

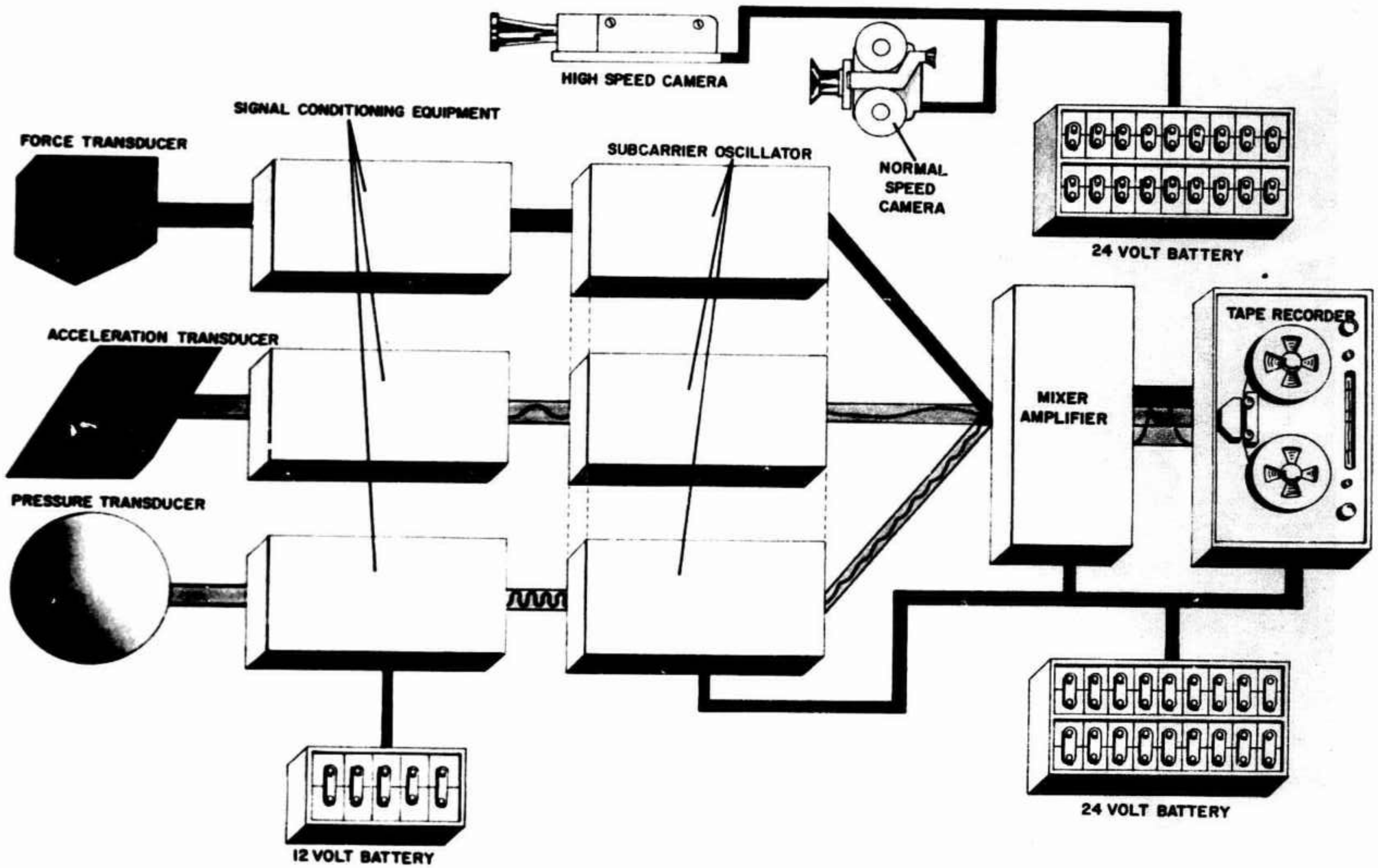


FIG. 18 ONBOARD INSTRUMENTATION SYSTEM

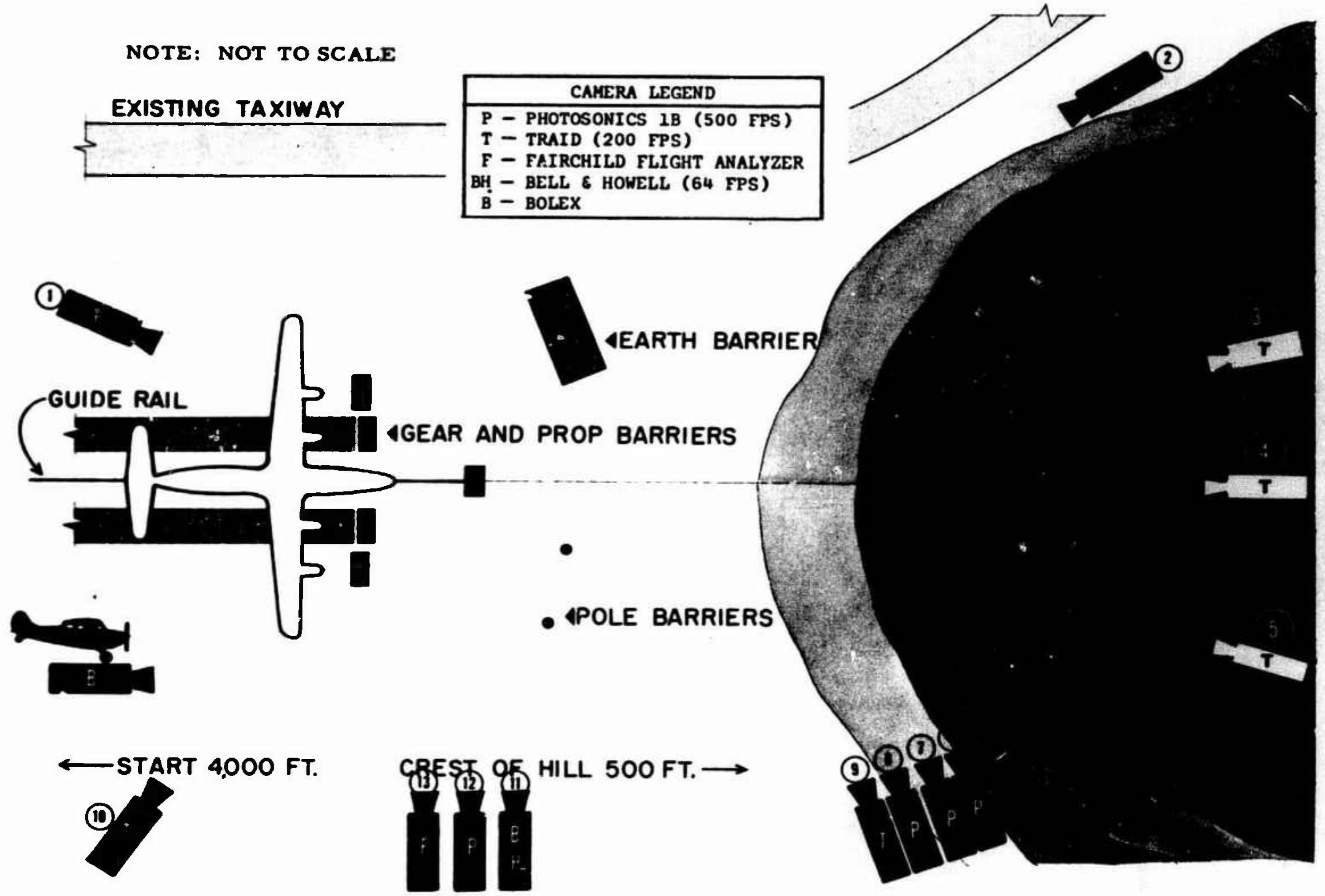


FIG. 19 EXTERNAL CAMERA COVERAGE

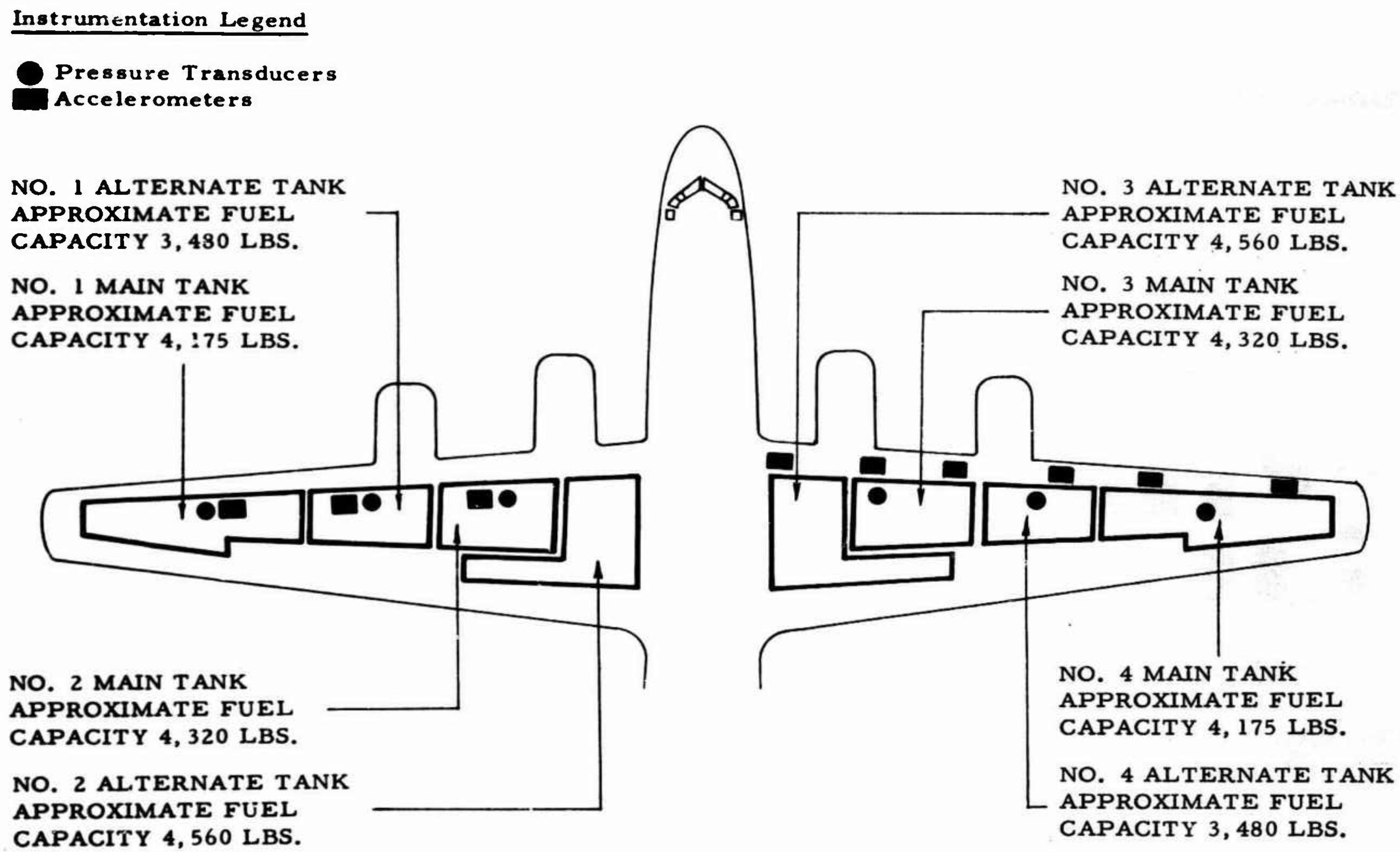
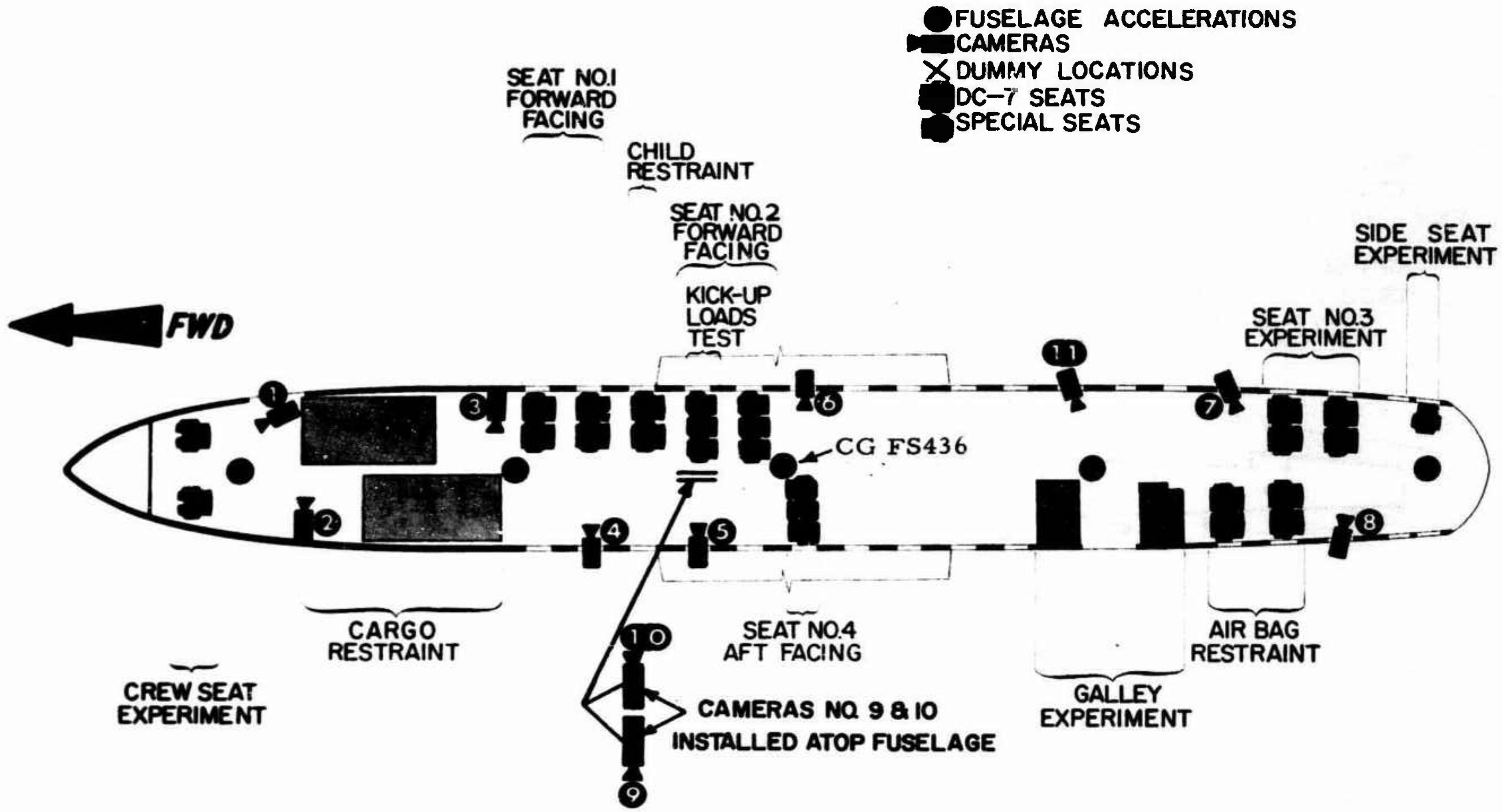


FIG. 20 DC-7 FUEL TANK LAYOUT AND INSTRUMENTATION LOCATIONS



NOTE: CAMERA NO.12 MOUNTED ON VERTICAL STABILIZER AIMED FORWARD FOR OVERALL EXTERNAL COVERAGE

FIG. 21 ONBOARD EXPERIMENT AND CAMERA LOCATIONS

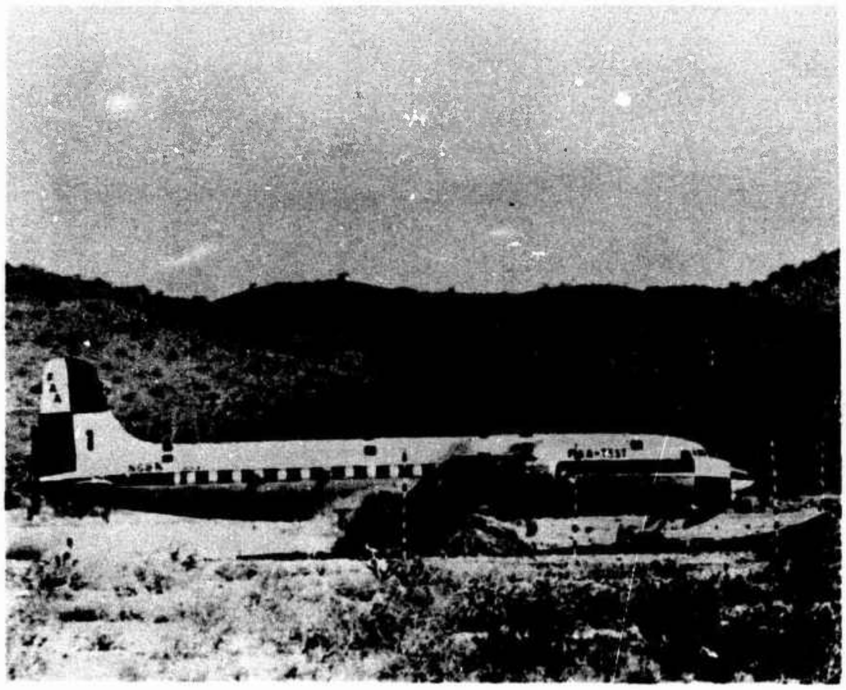


FIG. 22 NOSE AND MAIN GEAR CONTACT WITH BARRIERS

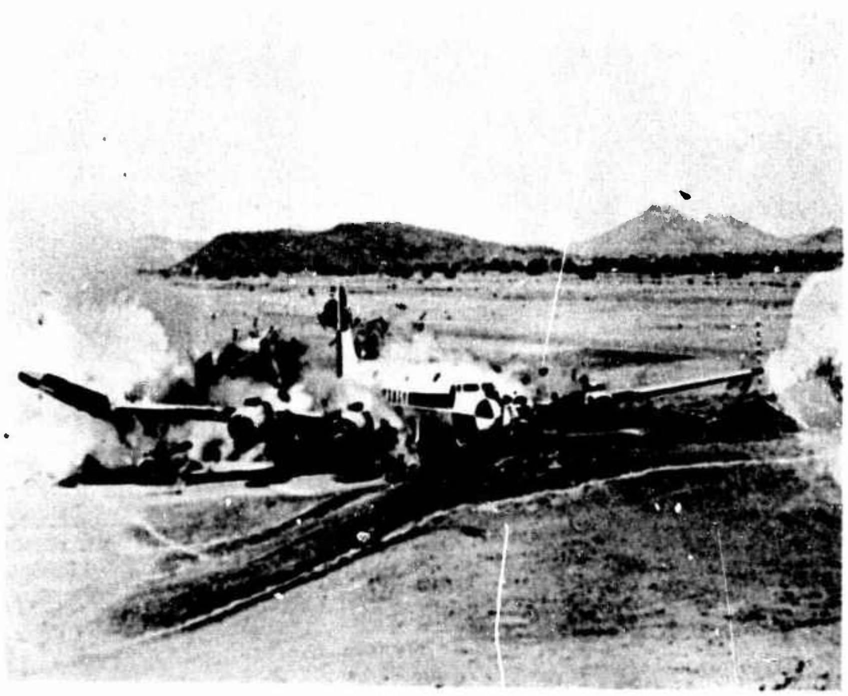


FIG. 23 IMPACT WITH RIGHT WING BARRIER POLES

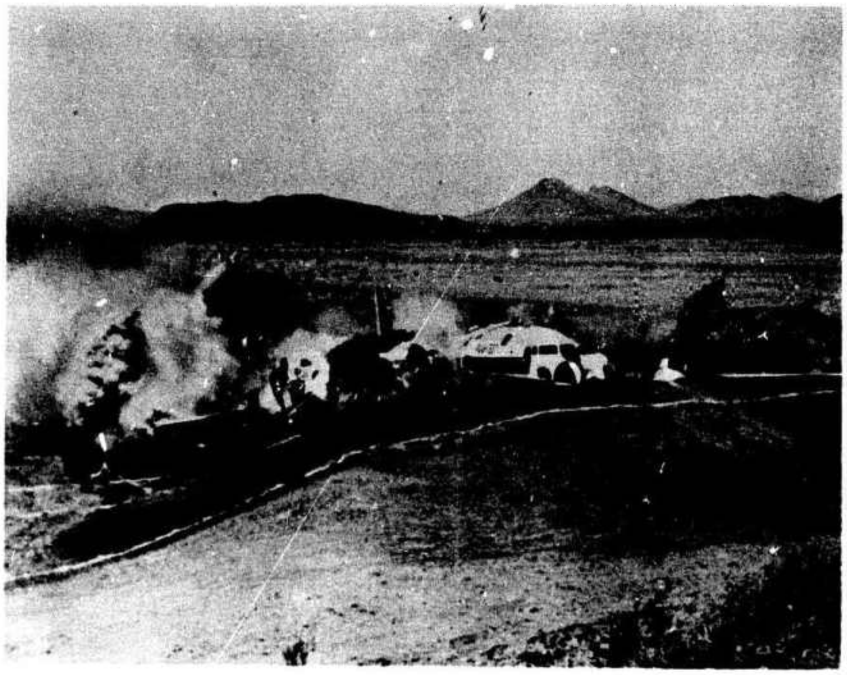


FIG. 24 IMPACT WITH 8 DEGREE IMPACT SLOPE

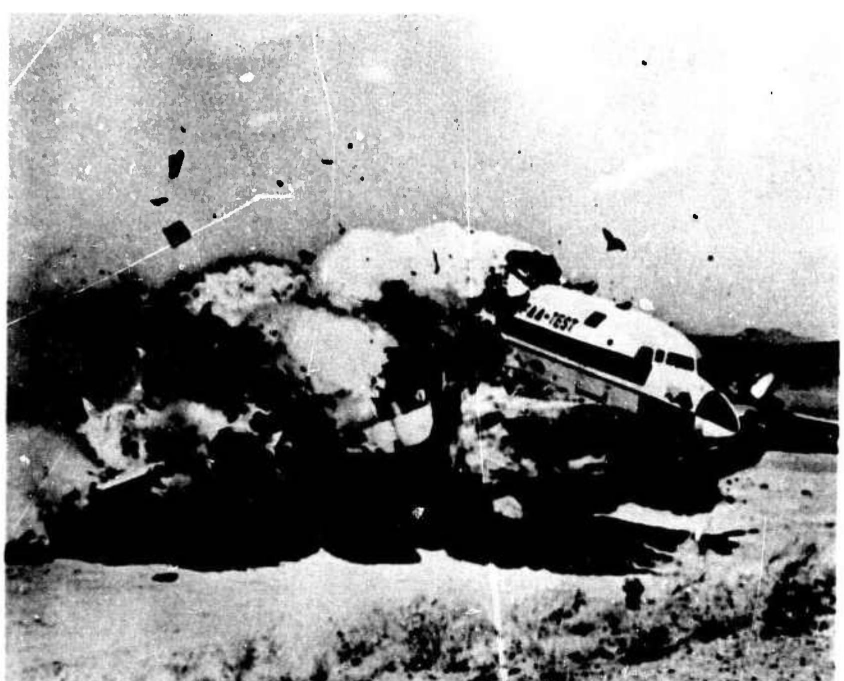


FIG. 25 AIRCRAFT AIRBORNE AFTER FIRST IMPACT

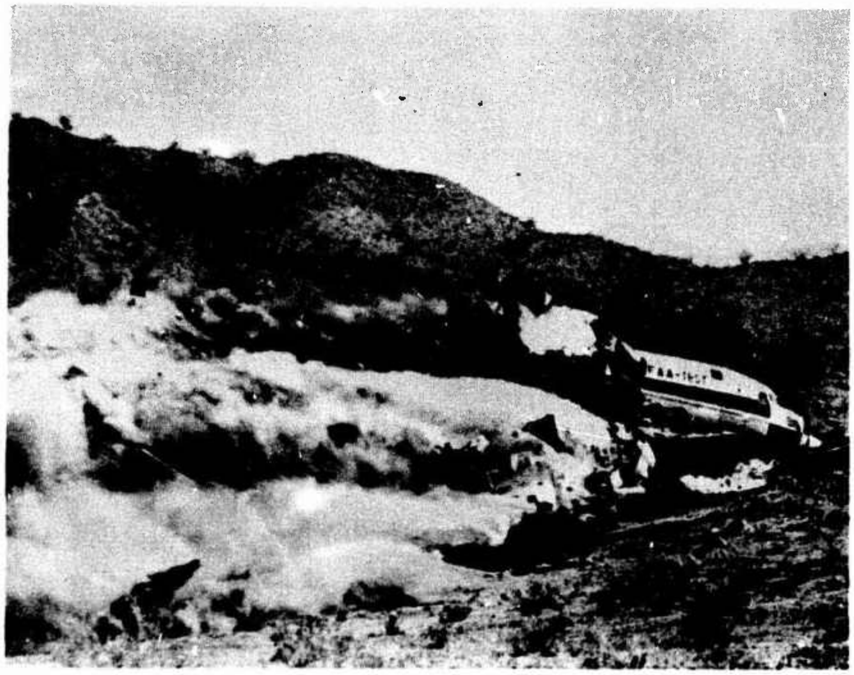


FIG. 26 IMPACT WITH SECOND HILL (20 DEGREE SLOPE)

FIG. 27 AIRCRAFT BOUNCING OVER SECOND HILL

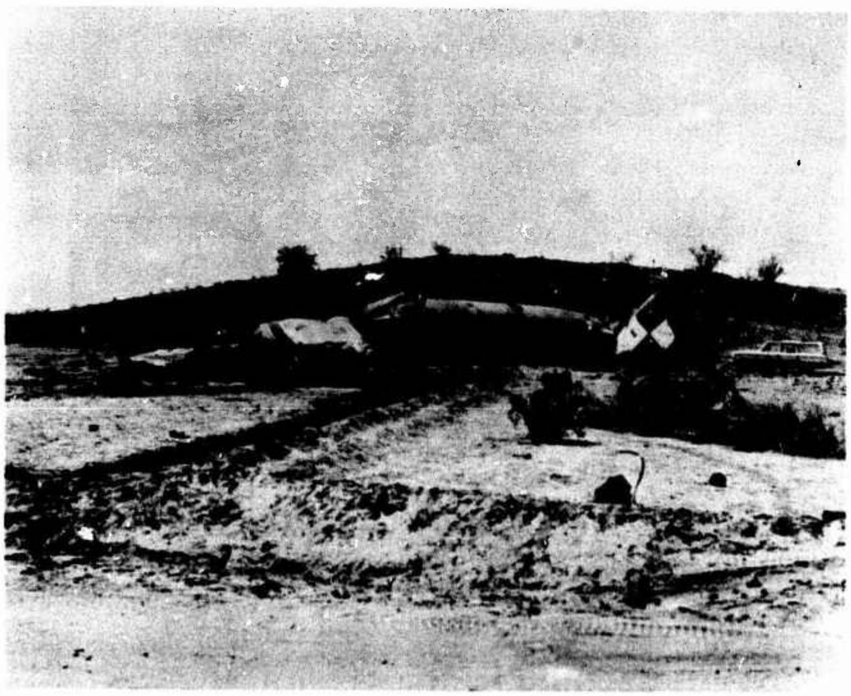


FIG. 28 FINAL POSITION OF FUSELAGE

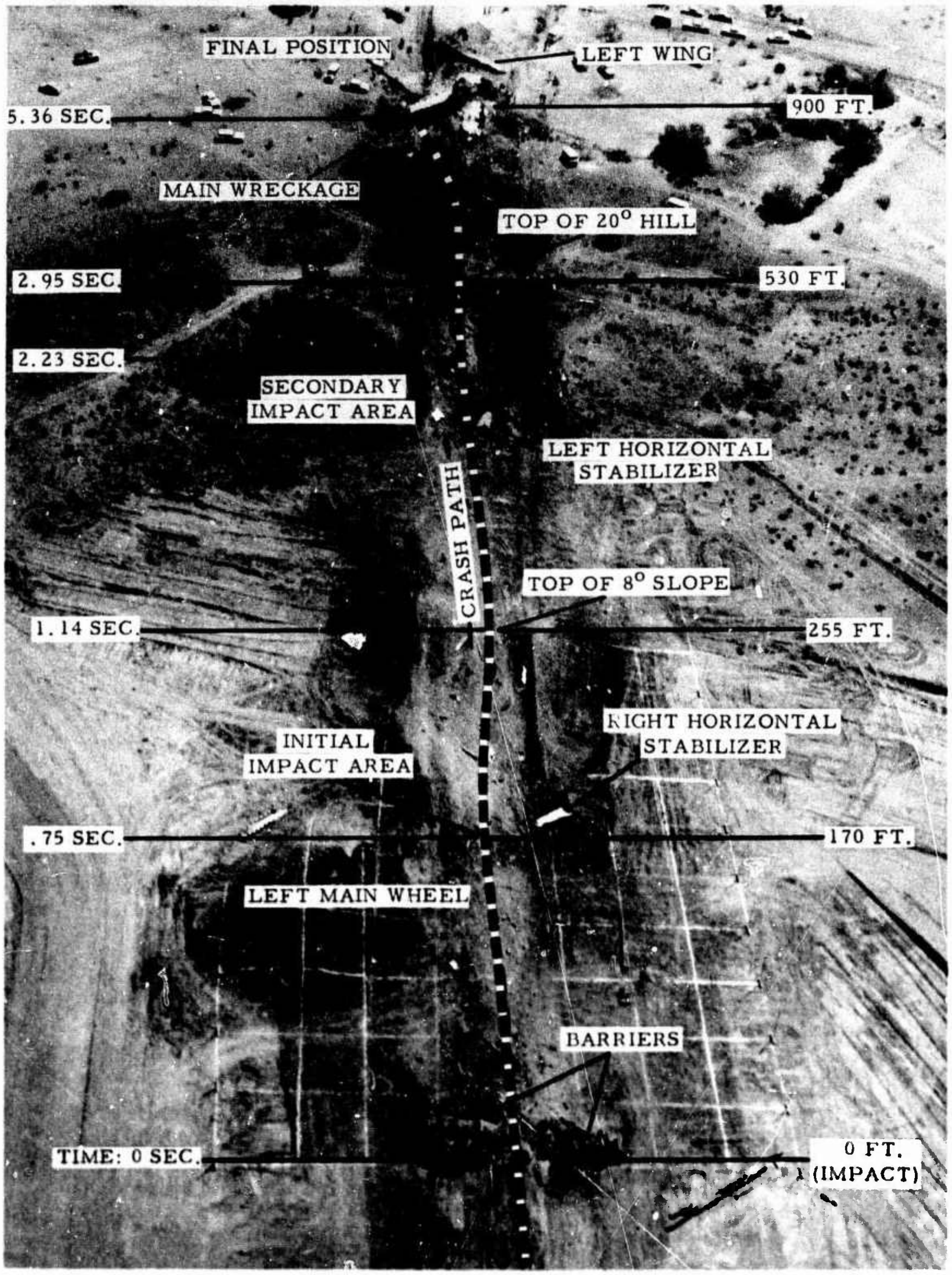
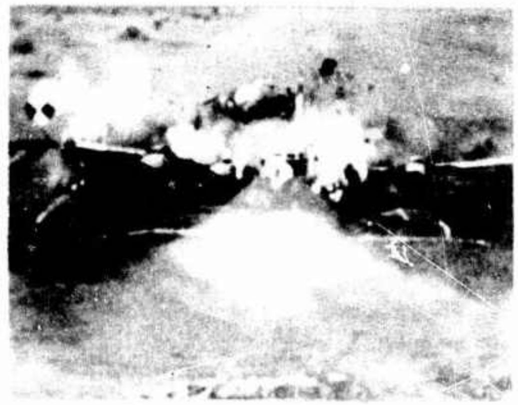


FIG. 29 WRECKAGE DISTRIBUTION PATTERN

A. Time: 0.000 Seconds

B. Time: 0.358 Seconds

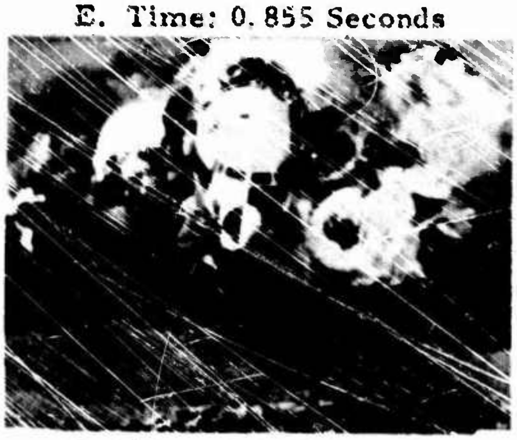
C. Time: 0.503 Seconds



D. Time: 0.658 Seconds

E. Time: 0.855 Seconds

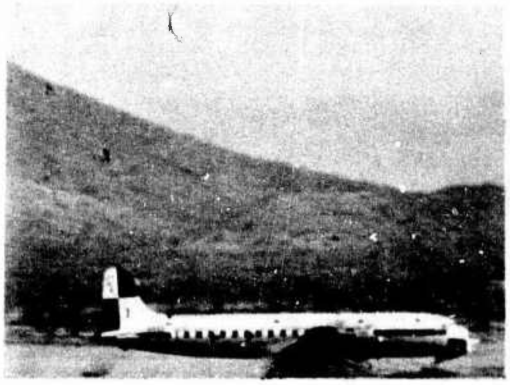
F. Time: 0.956 Seconds



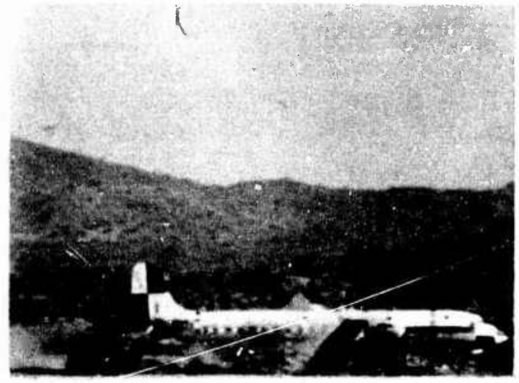
G. Time: 1.735 Seconds

H. Time: 2.384 Seconds

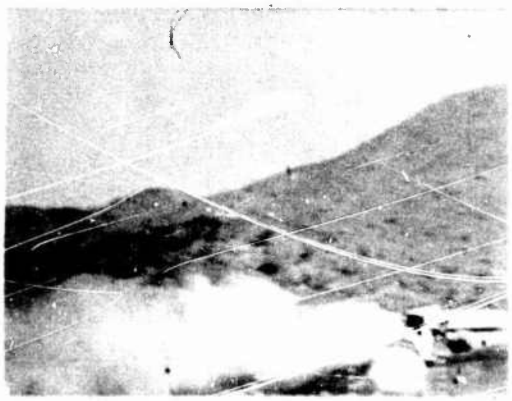
FIG. 30 SEQUENCE PHOTOS OF CRASH, SEEN FROM TOP OF 20 DEGREE SLOPE



A. Time: 0.126 Seconds



B. Time: 0.458 Seconds



C. Time: 1.054 Seconds

D. Time: 1.596 Seconds

E. Time: 2.234 Seconds

F. Time: 3.034 Seconds

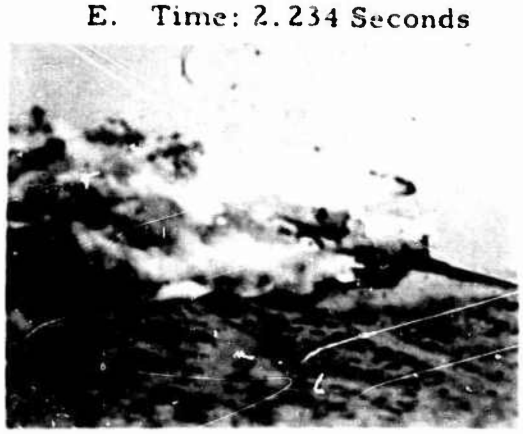


FIG. 31 SEQUENCE PHOTOS OF CRASH, SIDE VIEW

FIG. 32 POSTCRASH VIEW OF LEFT WING WHERE IT CAME TO REST LYING 50 FEET AHEAD OF MAJOR AIRCRAFT WRECKAGE

FIG. 33 SPANWISE SEPARATION OF UPPER SKIN ON LEFT WING AS VIEWED FROM WING TIP TOWARD WING ROOT AREA

FIG. 34 CLOSEUP VIEW OF FRONT OF LEFT MID-WING AREA (ALTERNATE TANK NO. 1) WHERE GELLED FUEL WAS CARRIED

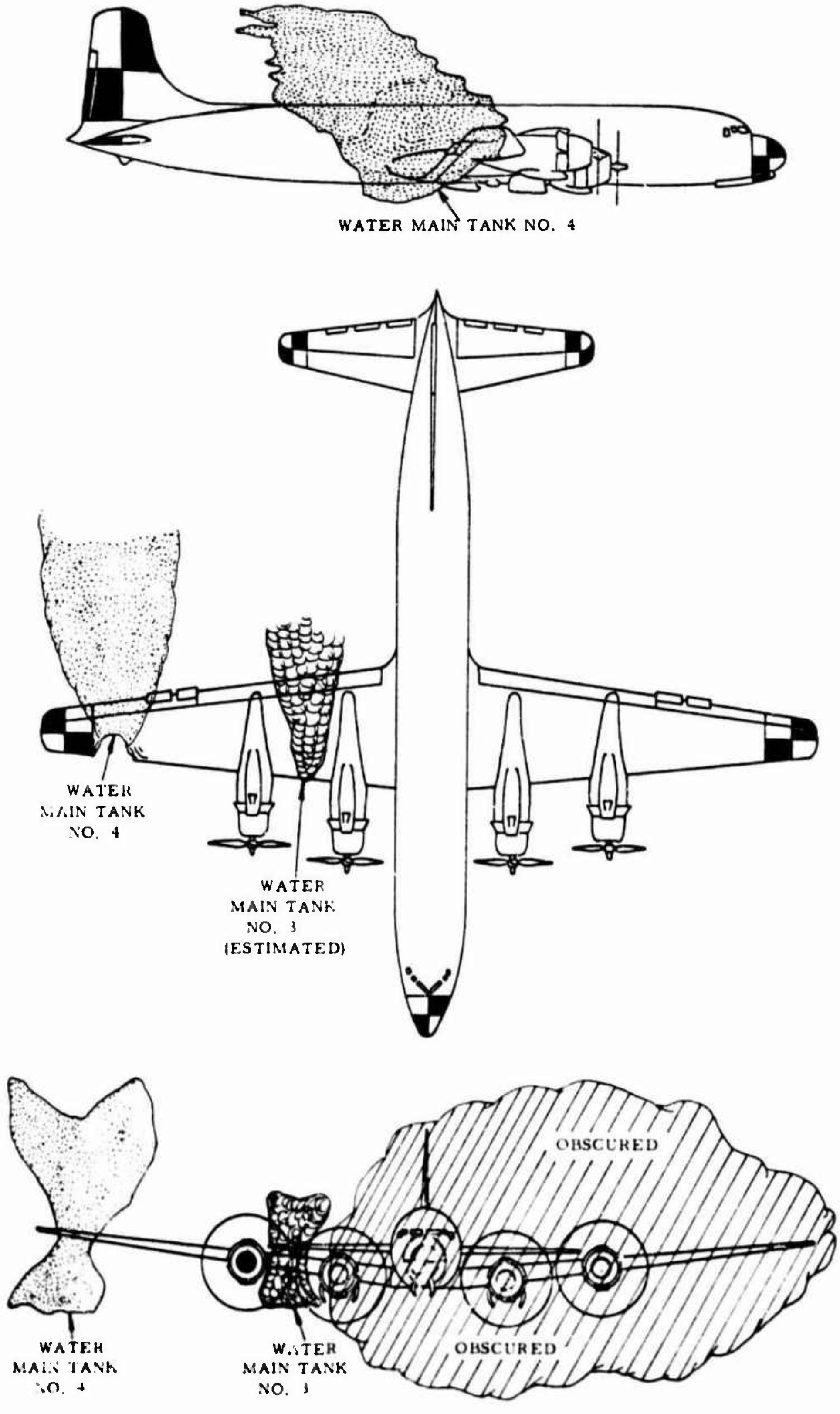


FIG. 35 FUEL SPILLAGE PATTERN 0.75 SECOND AFTER INITIAL IMPACT

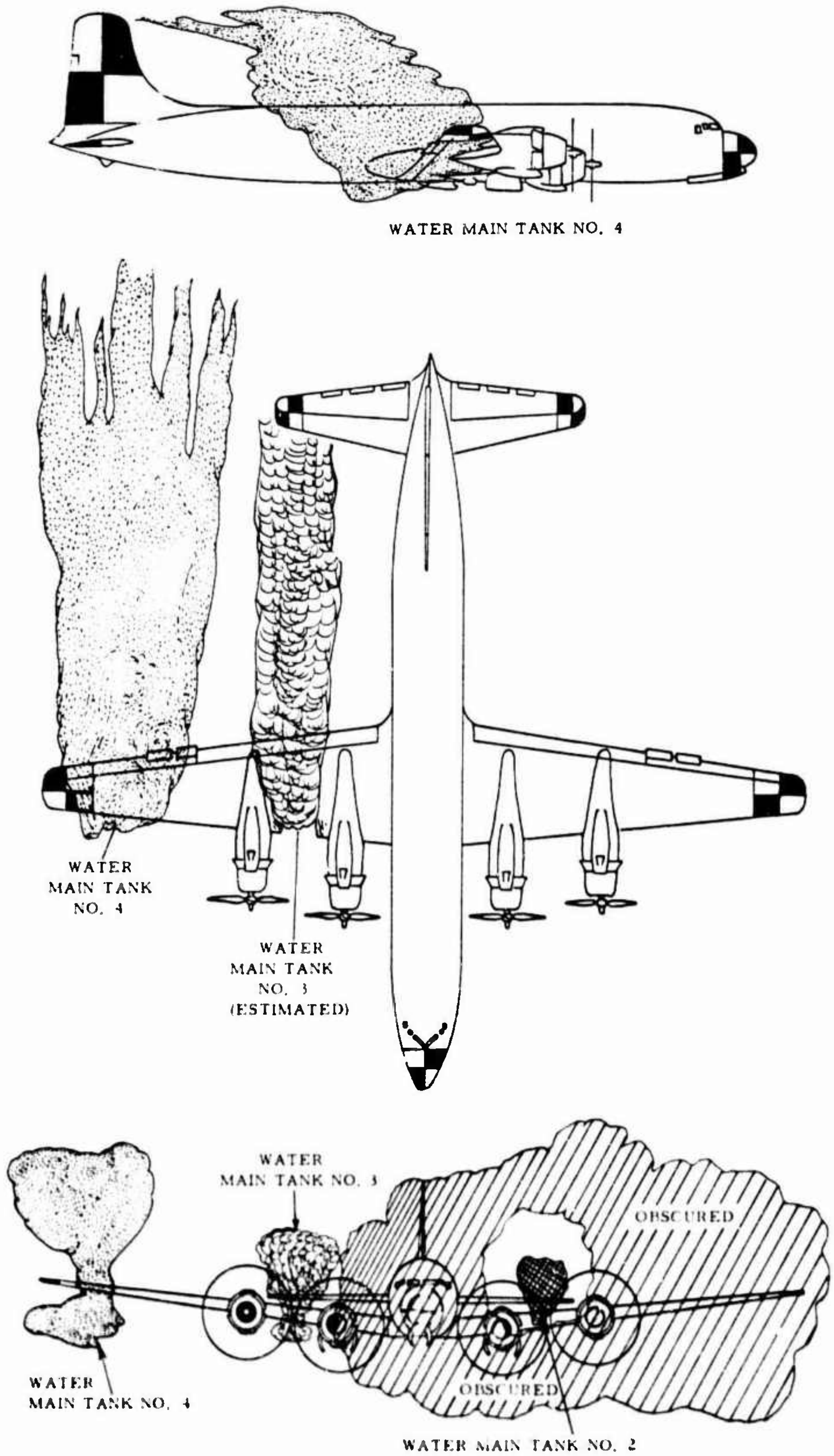


FIG. 36 FUEL SPILLAGE PATTERN 1.00 SECOND AFTER INITIAL IMPACT

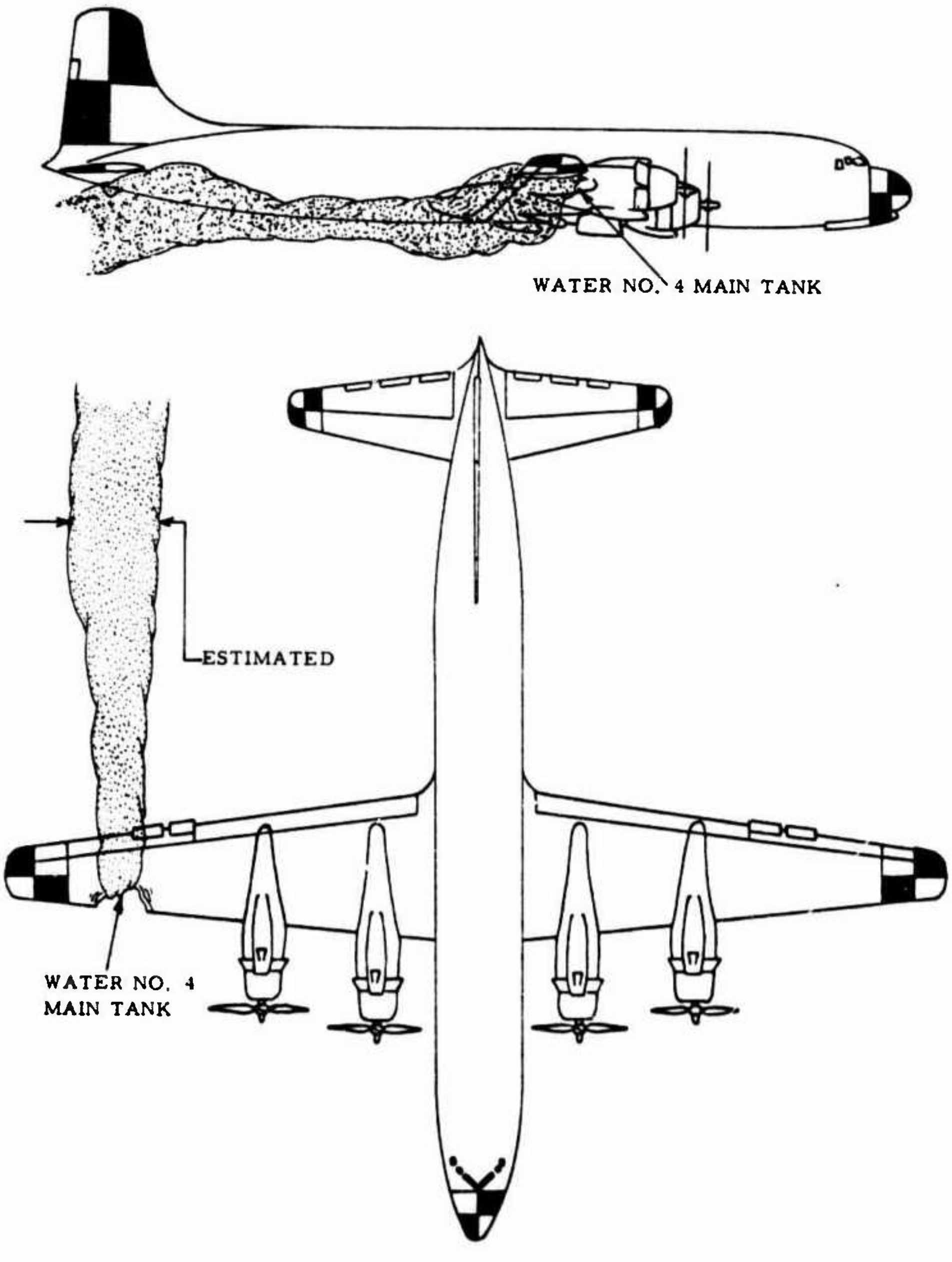


FIG. 37 FUEL SPILLAGE PATTERN 2.00 SECOND AFTER INITIAL IMPACT

FIG. 38 POSTCRASH VIEW, RIGHT WING

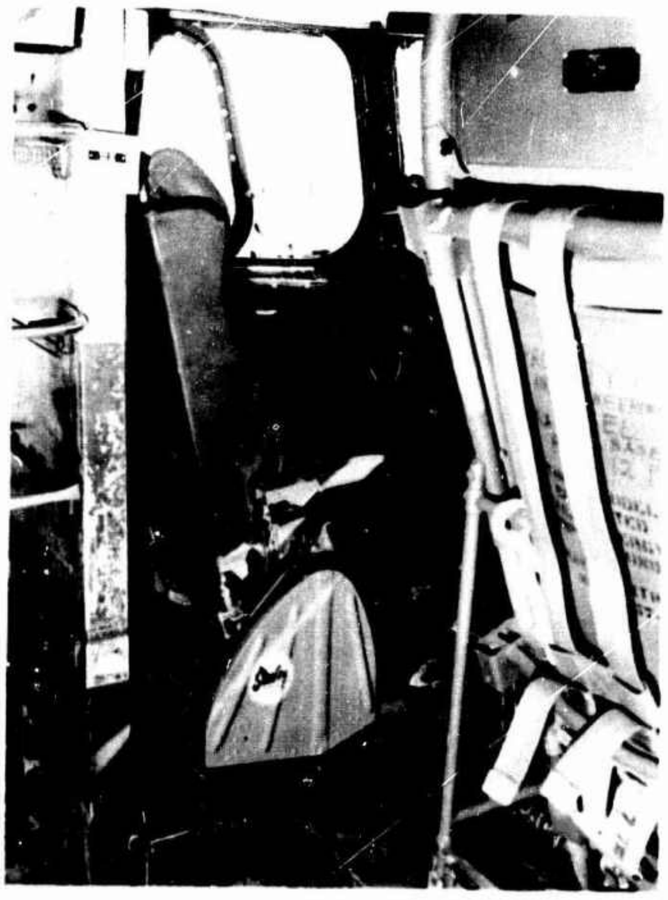


FIG. 39 NYLON NET
PILOT'S SEAT

FIG. 40 COPILOT SEAT EXPERIMENT

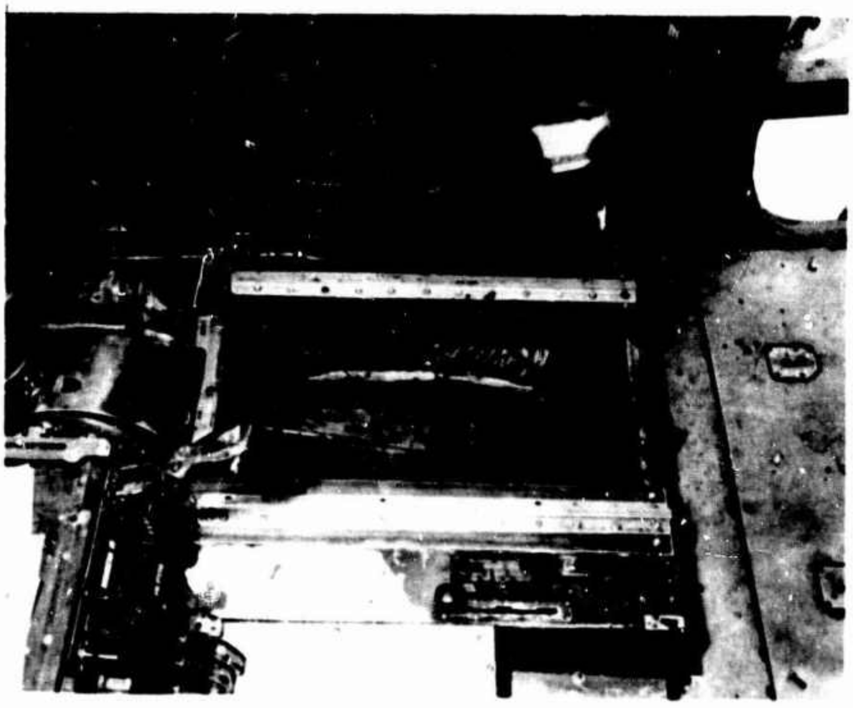


FIG. 41 SIDE VIEW OF COCKPIT FLOOR SEAT TRACK INSTALLATION

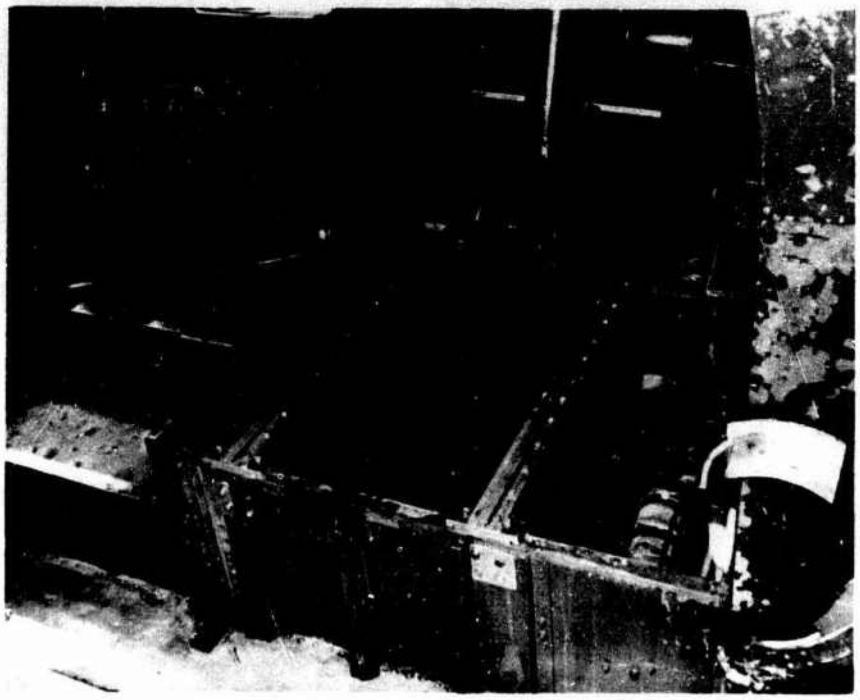


FIG. 42 REAR VIEW OF COCKPIT FLOOR SEAT TRAC' INSTALLATION, FLOOR COVER REMOVED

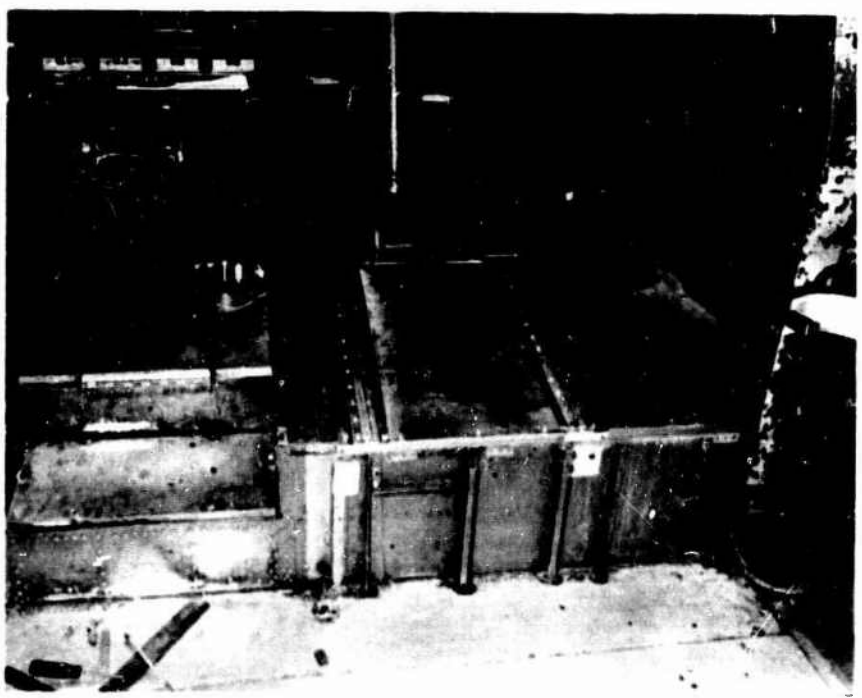


FIG. 43 REAR VIEW OF SEAT TRACK INSTALLATION, FLOOR COVER IN PLACE

FIG. 44 RIGHT SIDE VIEW OF PILOT SEAT AFTER REMOVAL FROM WRECKAGE

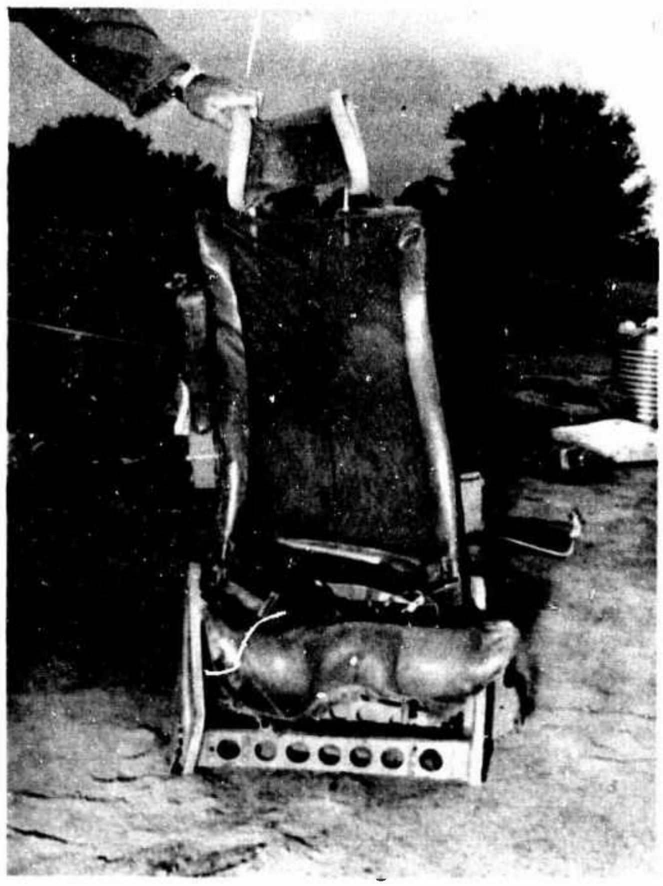


FIG. 45 FRONT VIEW OF PILOT SEAT AFTER REMOVAL FROM WRECKAGE

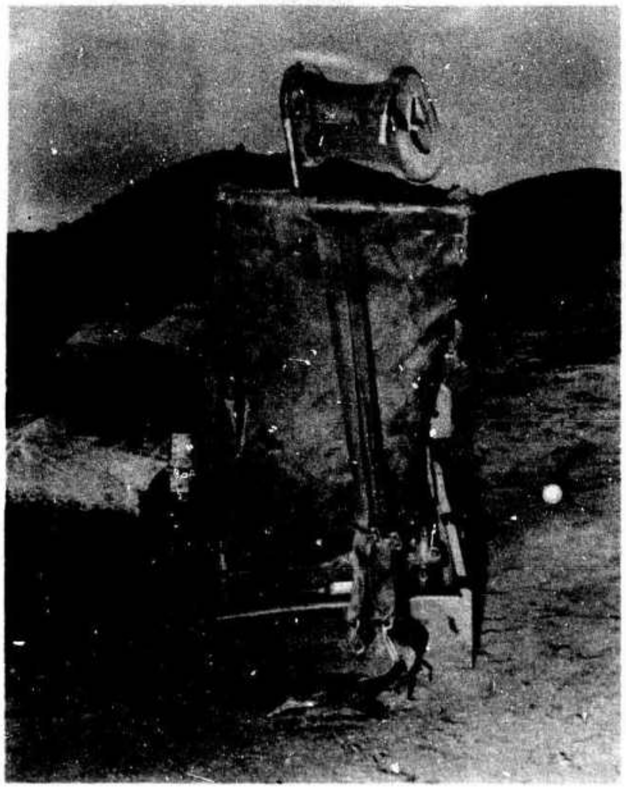


FIG. 46 REAR VIEW OF PILOT SEAT AFTER REMOVAL FROM WRECKAGE

FIG. 47 COPILOT SEAT BEFORE REMOVAL FROM WRECKAGE

FIG. 48 RIGHT SIDE VIEW OF COPILOT SEAT SHOWING ANGLE OF SEAT PAN WITH RESPECT TO SEAT BACK

FIG. 49 LEFT SIDE VIEW OF COPILOT SEAT AFTER REMOVAL FROM WRECKAGE

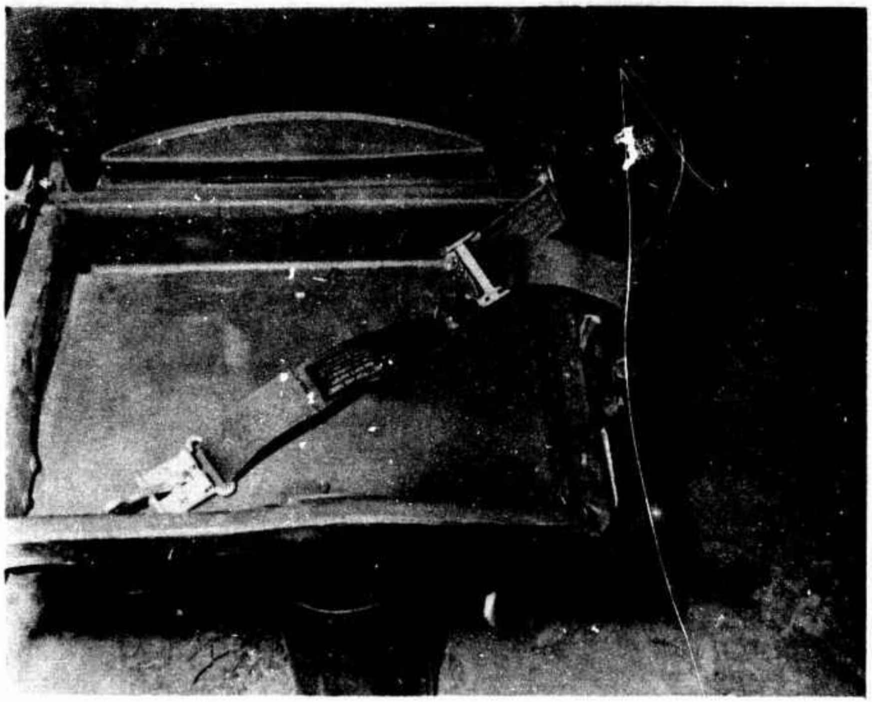


FIG. 50 VIEW OF COPILOT SEAT AFTER REMOVAL FROM WRECKAGE SHOWING SEAT PAN INDENTATION CAUSED BY CONTACT WITH OTHER STRUCTURE AND THE LAP BELT WHICH BROKE AT THE ADJUSTMENT FITTING

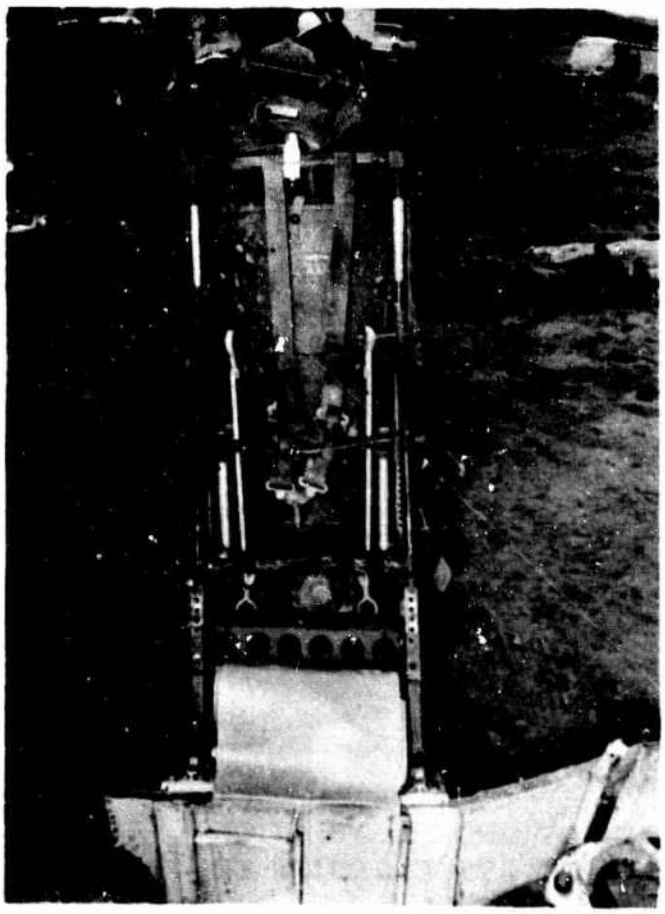


FIG. 51 REAR VIEW OF COPILOT SEAT AFTER REMOVAL FROM WRECKAGE, WITH PORTION OF FLOOR STRUCTURE STILL ATTACHED

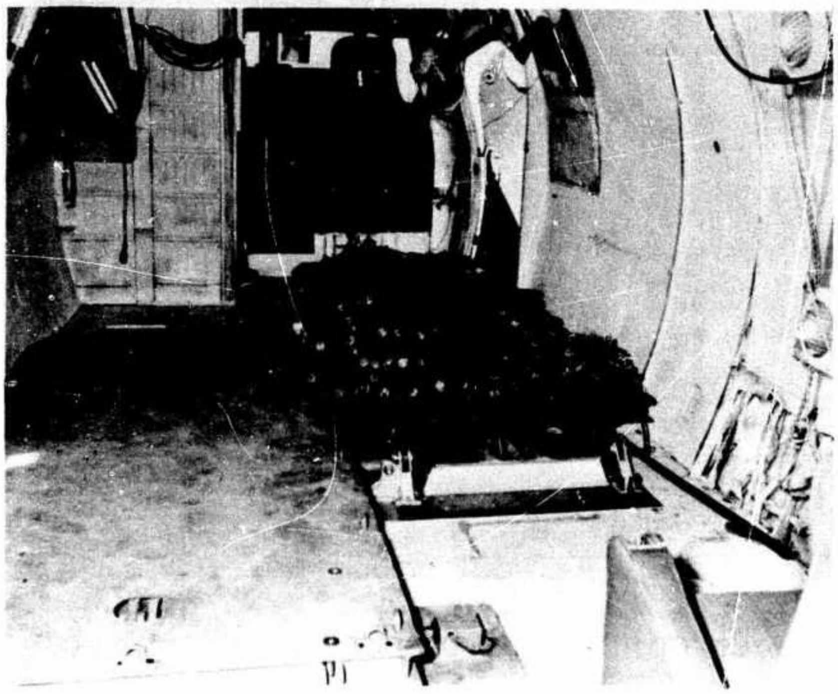


FIG. 52 CARGO PALLETS INSTALLED IN AIRCRAFT, LOOKING FORWARD TOWARD COCKPIT

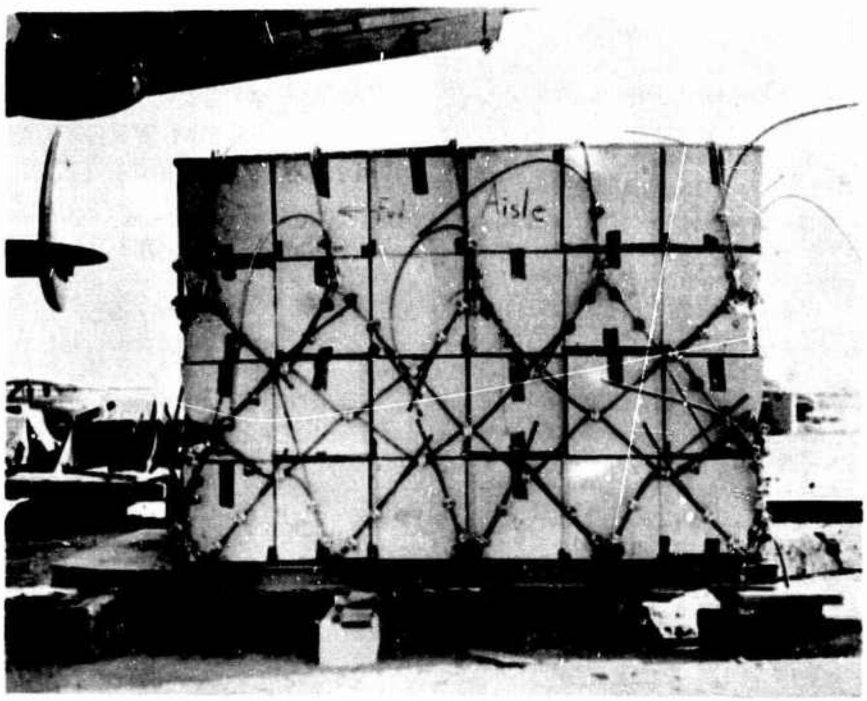


FIG. 53 CARGO PALLET SHOWN DURING FABRICATION OF THE CABLE RESTRAINT SYSTEM PRIOR TO INSTALLATION IN THE AIRCRAFT

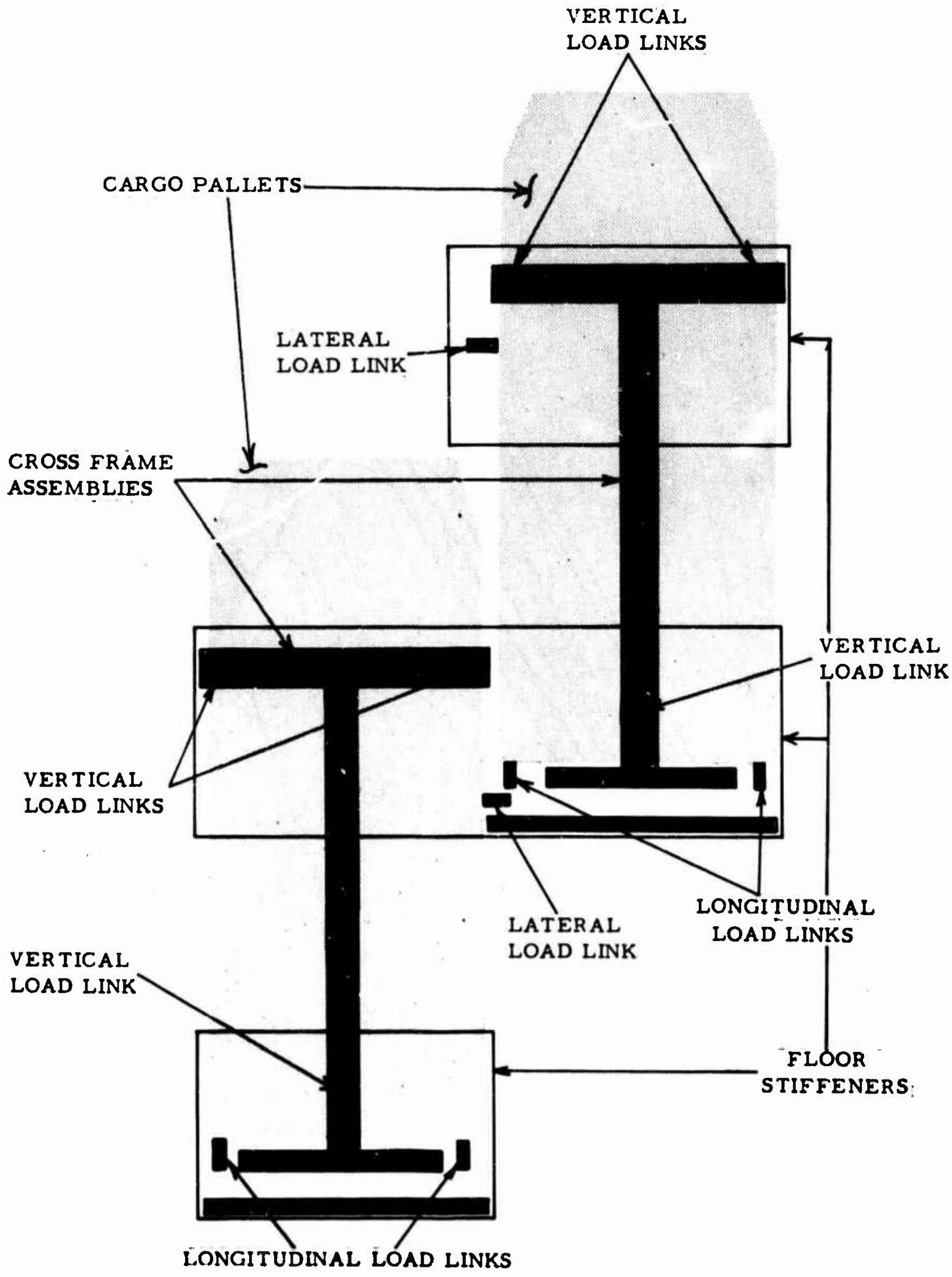


FIG. 54 SCHEMATIC OF CARGO PALLETS INSTALLATION

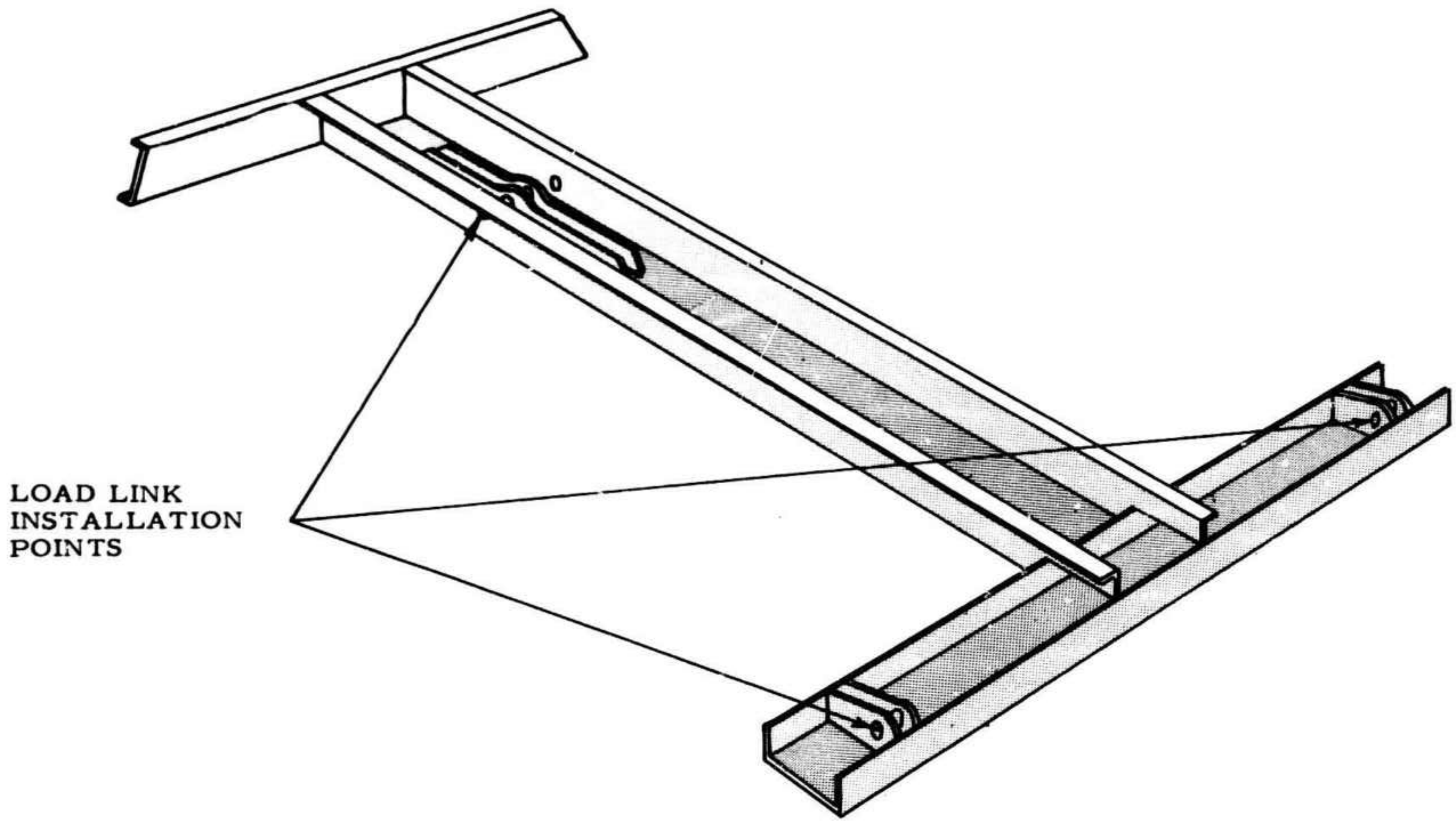


FIG. 55 THE CROSS FRAME ASSEMBLY

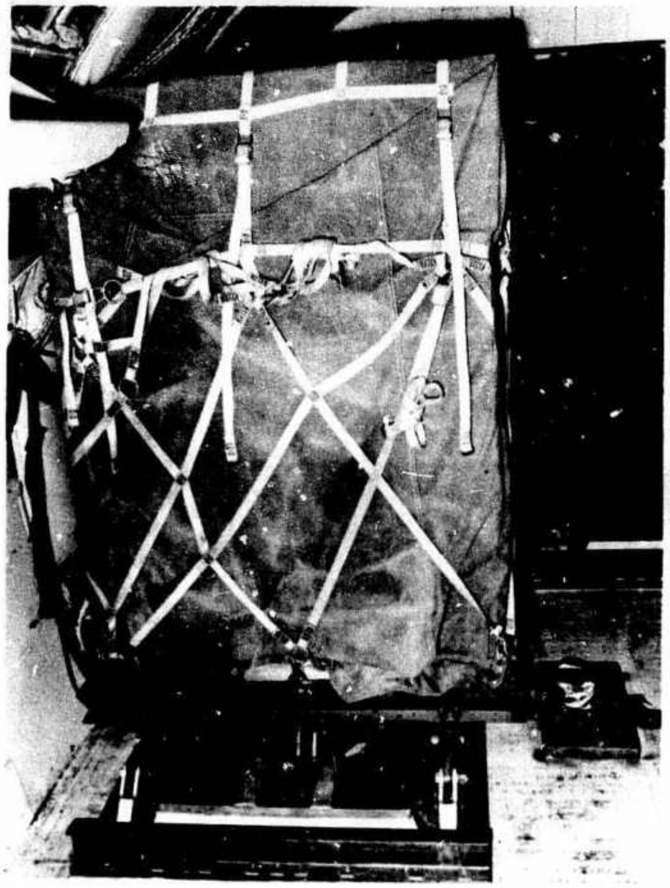


FIG. 56 REAR VIEW OF NYLON CARGO RESTRAINT SYSTEM INSTALLATION

FIG. 57 POSTCRASH ENVIRONMENT OF CARGO EXPERIMENT

FIG. 58 DEFORMATION ON LEFT SIDE OF FUSELAGE SHOWING CARGO PALLET INSTALLATION SEVERED FROM FUSELAGE FRAMING

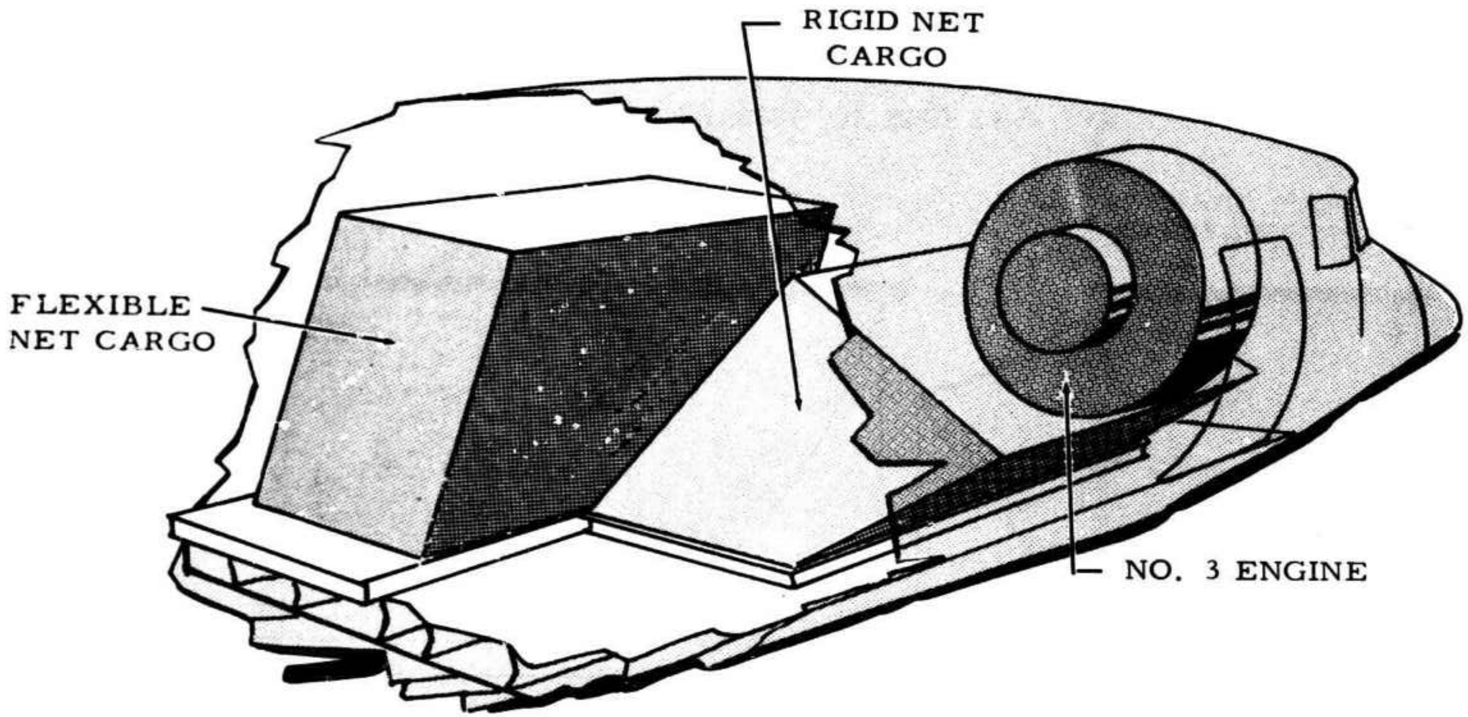
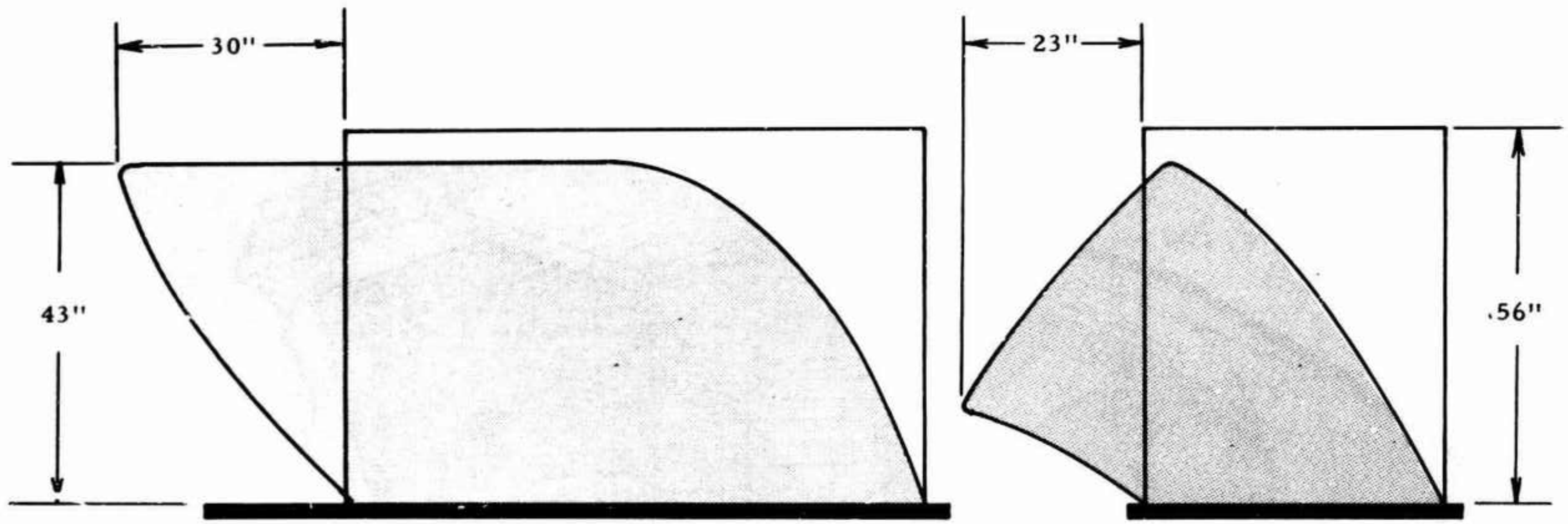


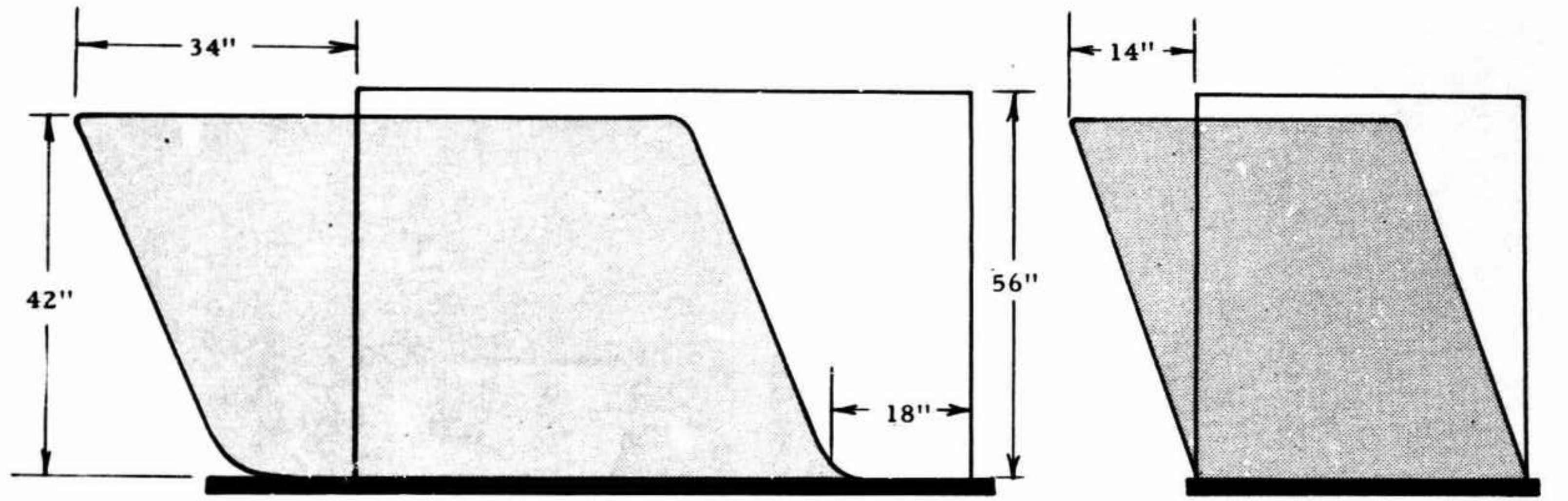
FIG. 59 FINAL RESTING PLACE OF NO. 3 ENGINE



CABLE NET SIDE VIEW

CABLE NET END VIEW
FORWARD LOOKING AFT

FIG. 60 POSTCRASH POSITION OF SHIFTED CARGO



NYLON NET SIDE VIEW

NYLON NET END VIEW
FORWARD LOOKING AFT

FIG. 61 POSTCRASH POSITION OF SHIFTED CARGO

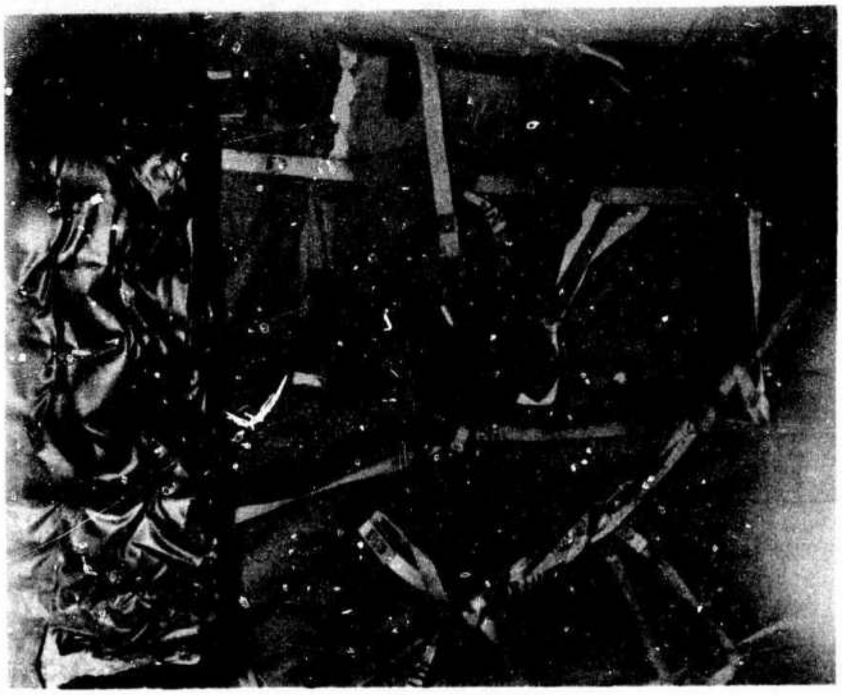


FIG. 62 FAILED LOAD CARRYING BUCKLE, SHOWN IN PHOTOGRAPH CENTER

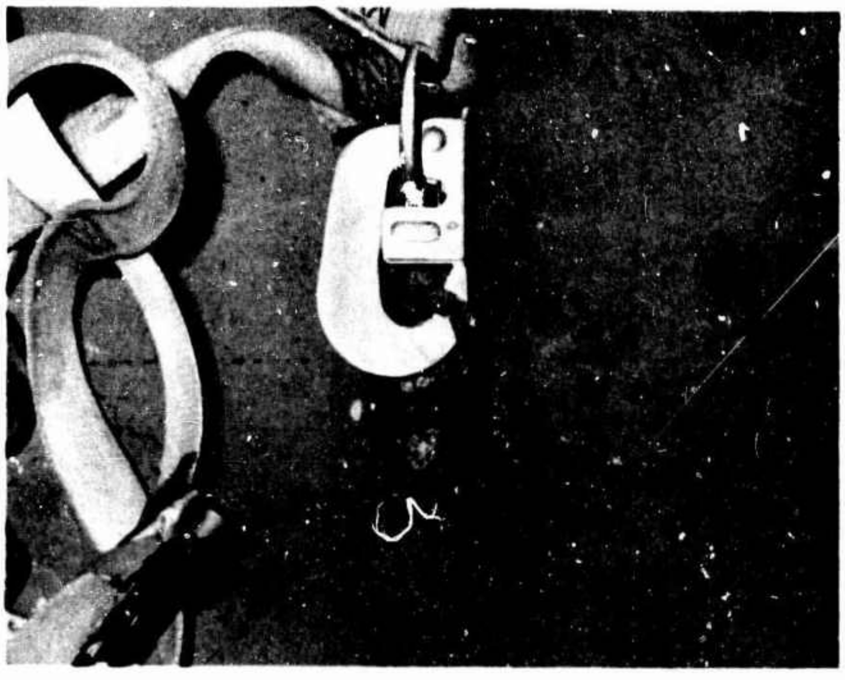


FIG. 63 FORWARD DEFORMATION OF PALLET CARGO NET TIEDOWN RING SHOWN WITH NET HOOK STILL ATTACHED

FIG. 64 DUMMY OCCUPANTS OF CENTER SEAT, FORWARD DC-7 SEAT EXPERIMENT

FIG. 65 CHILD RESTRAINT HARNESS, FORWARD DC-7 SEAT EXPERIMENT

FIG. 66 FORWARD SEAT OF FORWARD CABIN DC-7 PASSENGER SEAT EXPERIMENT

FIG. 67 CENTER SEAT OF FORWARD CABIN DC-7 PASSENGER SEAT EXPERIMENT

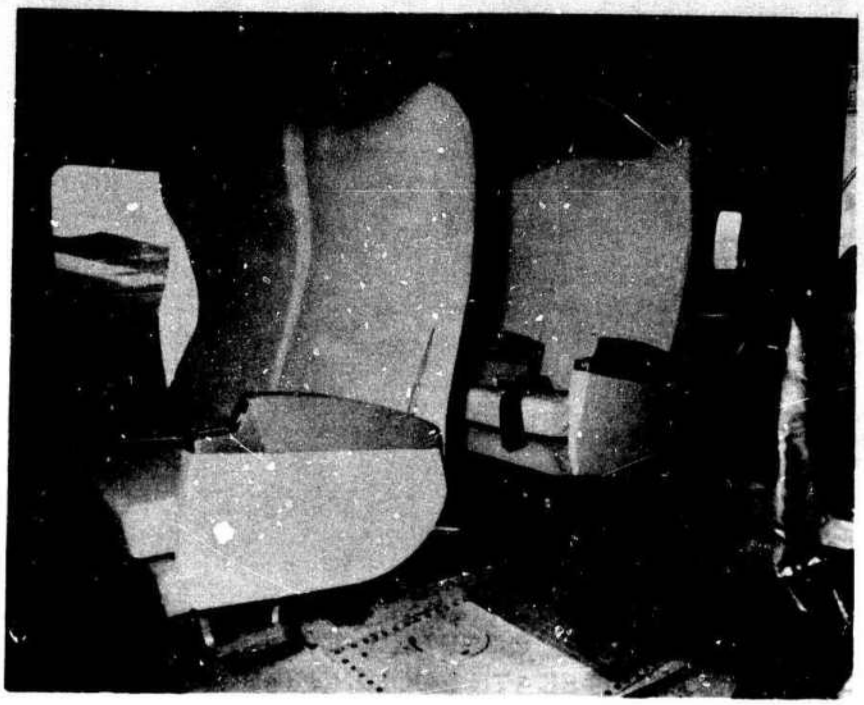


FIG. 68 THREE PASSENGER FORWARD FACING SEATS

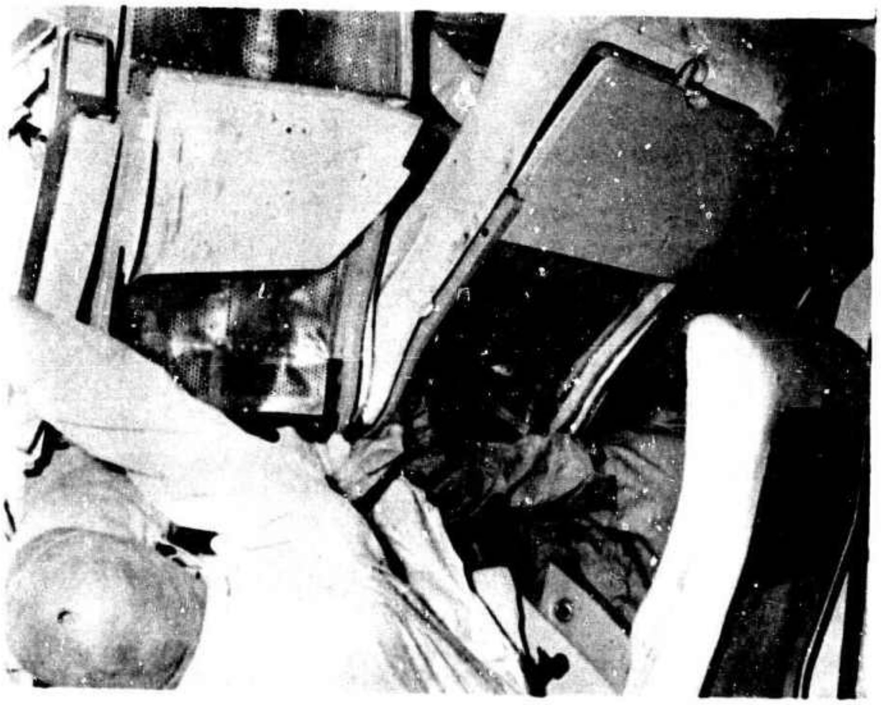


FIG. 69 VIEW SHOWING DAMAGE TO BACKS OF UN-OCCUPIED THREE PASSENGER FORWARD FACING SEATS CAUSED BY CONTACT WITH DUMMIES (PICTURE ROTATED 90° CLOCKWISE)

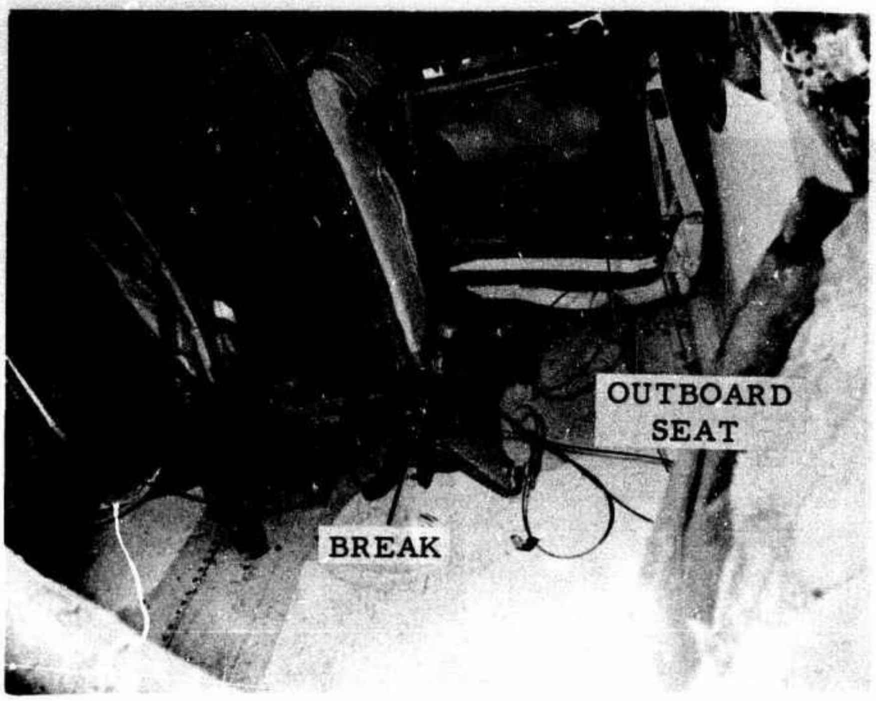


FIG. 70 POSTCRASH VIEW OF OCCUPIED THREE PASSENGER FORWARD FACING SEATS LOOKING FORWARD, SHOWING FORWARD ROTATION OF SEAT NEXT TO WALL

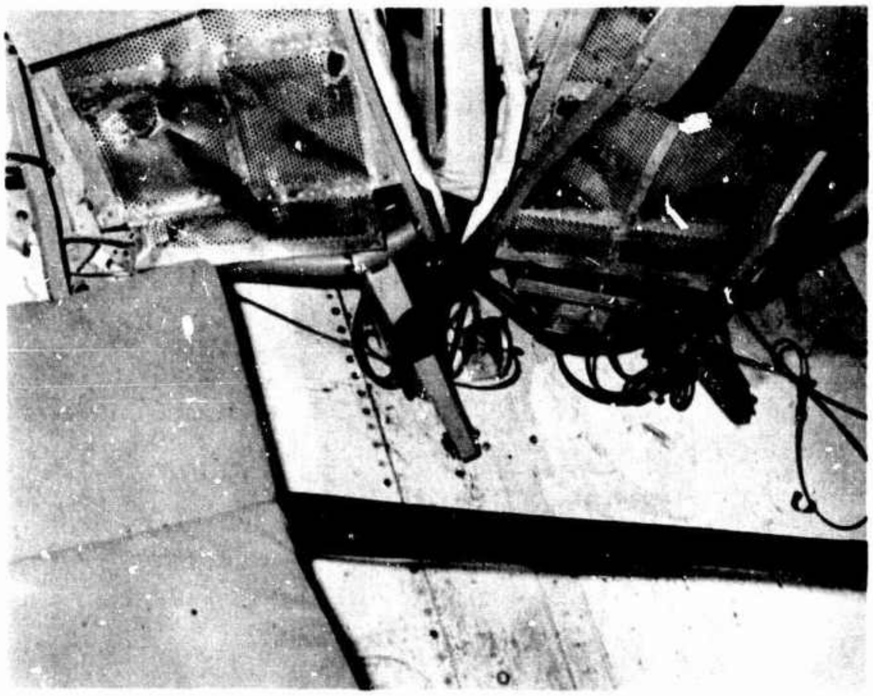


FIG 71 REAR VIEW OF AISLE AND CENTER OCCUPIED THREE PASSENGER FORWARD FACING SEATS SHOWING FAILURE OF LATERAL TUBE THAT ALLOWED AISLE SEAT TO DEFLECT DOWNWARD TOWARD AISLE (PICTURE ROTATED 90° CLOCKWISE)

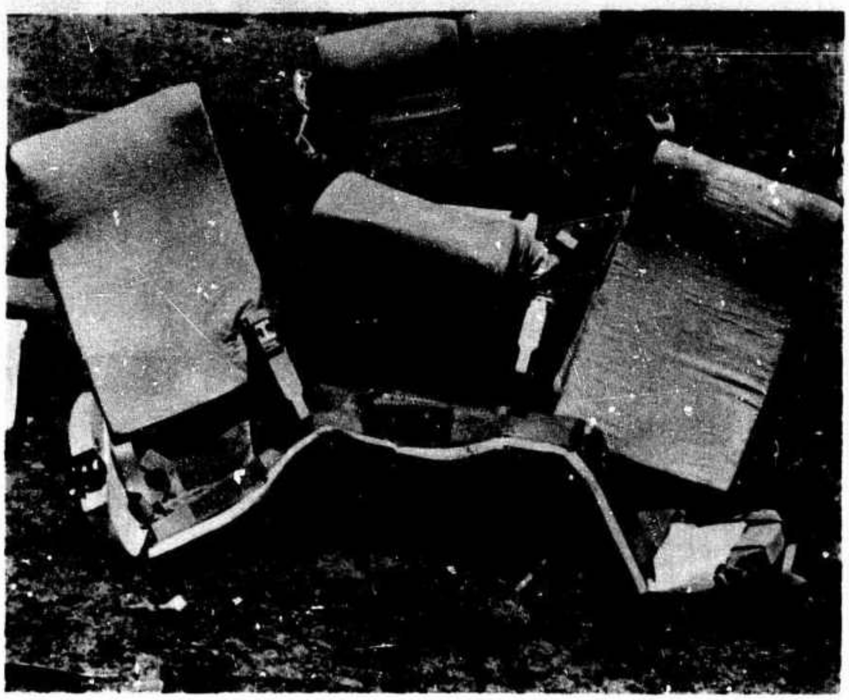


FIG. 72 FRONT VIEW OF OCCUPIED THREE PASSENGER FORWARD FACING SEAT AFTER REMOVAL FROM WRECKAGE

FIG. 73 REAR VIEW OF OCCUPIED THREE PASSENGER FORWARD FACING SEAT AFTER REMOVAL FROM WRECKAGE

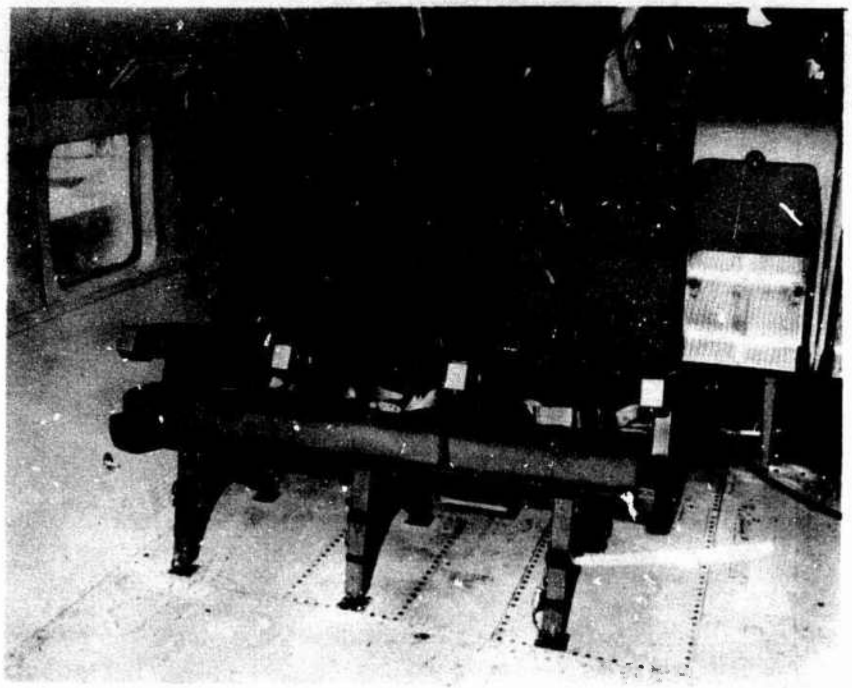


FIG. 74 REAR FACING SEAT INSTALLATION, LOOKING FORWARD

FIG. 75 DUMMIES SEATED IN REAR FACING SEAT

FIG. 76 LEG TO FLOOR ATTACHMENT, REAR FACING SEAT

FIG. 77 POSTCRASH CONDITION OF TRIPLE REARWARD FACING SEAT, LOOKING TOWARD THE FRONT OF THE AIRCRAFT (PICTURE ROTATED 90° CLOCKWISE)

FIG. 78 COLLAPSED POSITION OF SEAT BACKS OF REARWARD FACING SEAT, LOOKING AFT (PICTURE ROTATED 90° COUNTERCLOCKWISE)

FIG. 79 EXAMINATION OF REARWARD FACING SEAT BACK LOCKS AFTER CRASH

FIG. 80 GALLEY EQUIPMENT EXPERIMENT

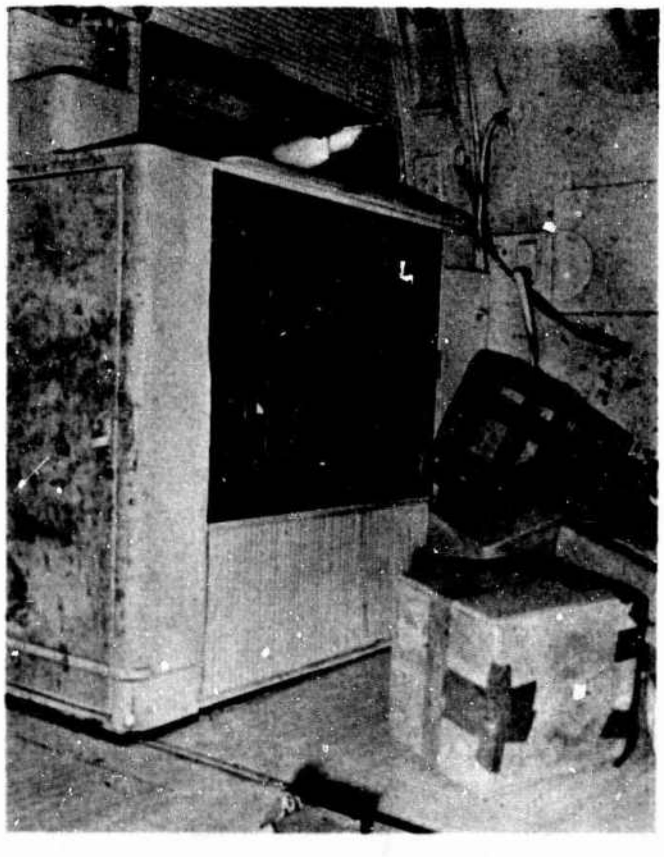


FIG. 81 GALLEY EXPERIMENT AFTER CRASH (PICTURE ROTATED 90° COUNTERCLOCKWISE)

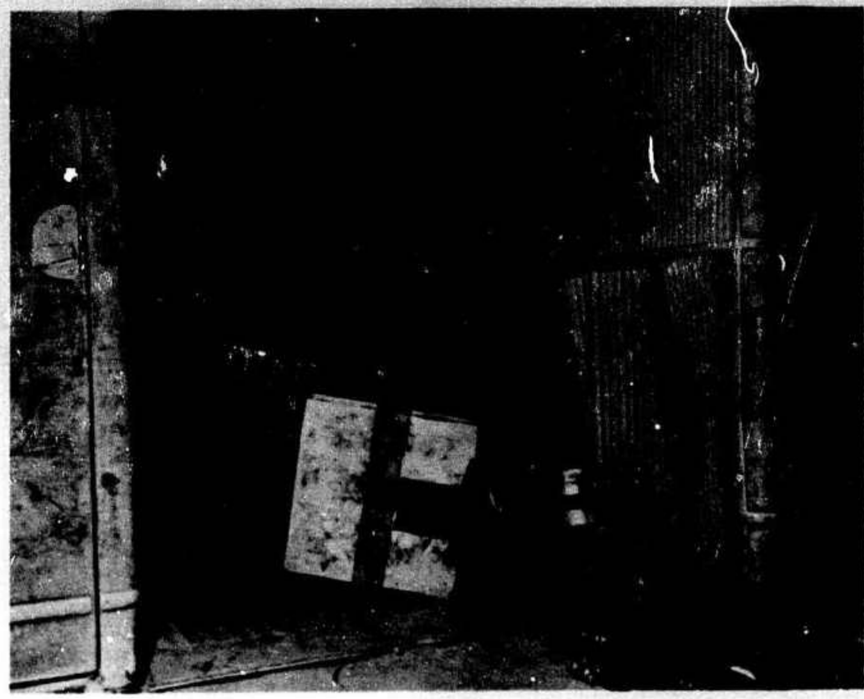


FIG. 82 VIEW SHOWING IMPACTED FORWARD GALLEY SECTION

FIG. 83 VIEW SHOWING PASSENGER DUMMY CONTACT WITH AIRBAGS

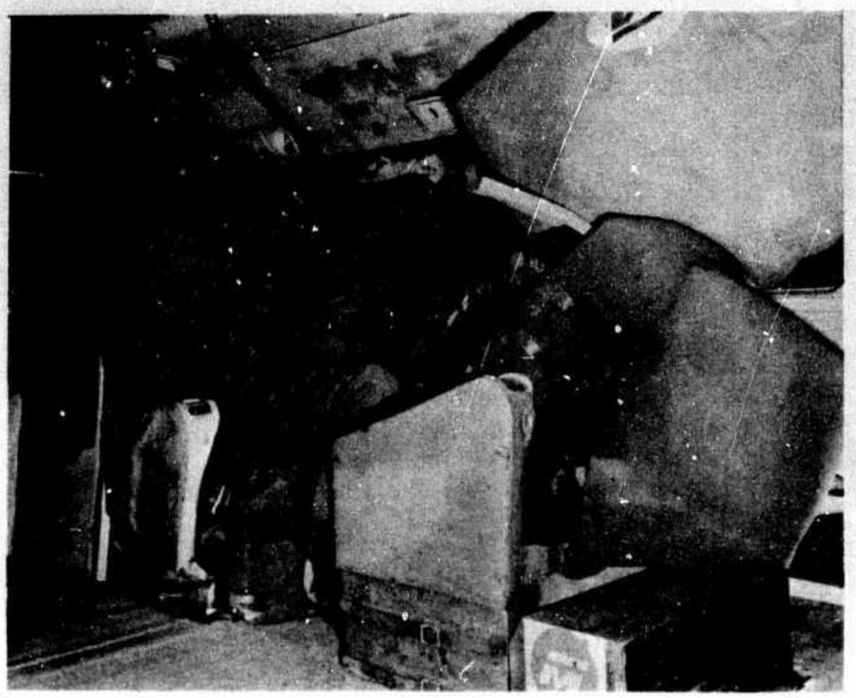


FIG. 86 OVERALL VIEW OF AIRBAG RESTRAINT EXPERIMENT (PICTURE ROTATED 90° COUNTERCLOCKWISE)

FIG. 87 SEAT BACK FAILURE THAT CAUSED CHEST AIRBAG TO ROTATE OUT OF POSITION

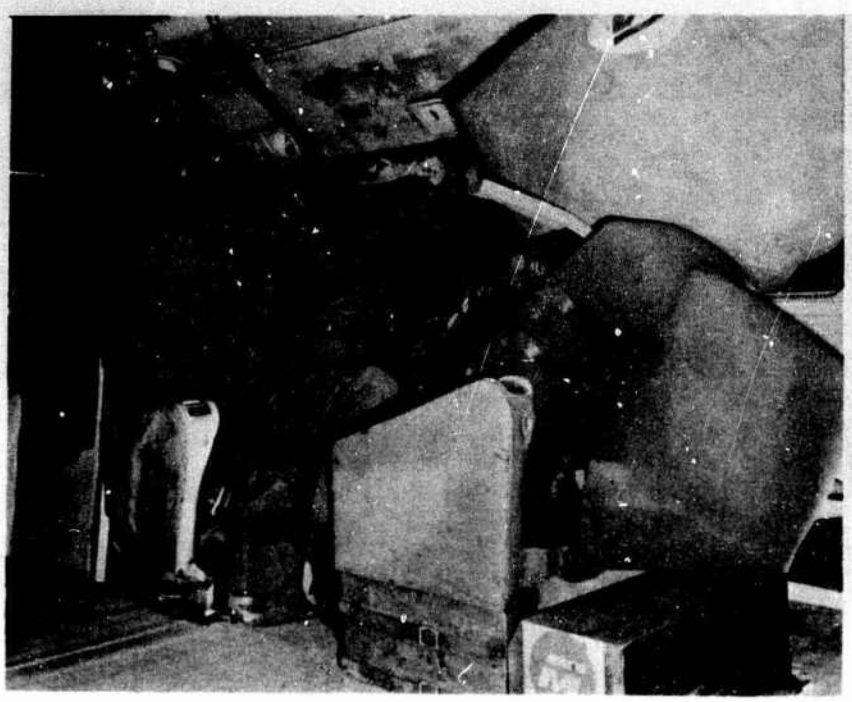


FIG. 86 OVERALL VIEW OF AIRBAG RESTRAINT EXPERIMENT (PICTURE ROTATED 90° COUNTERCLOCKWISE)

FIG. 87 SEAT BACK FAILURE THAT CAUSED CHEST AIRBAG TO ROTATE OUT OF POSITION

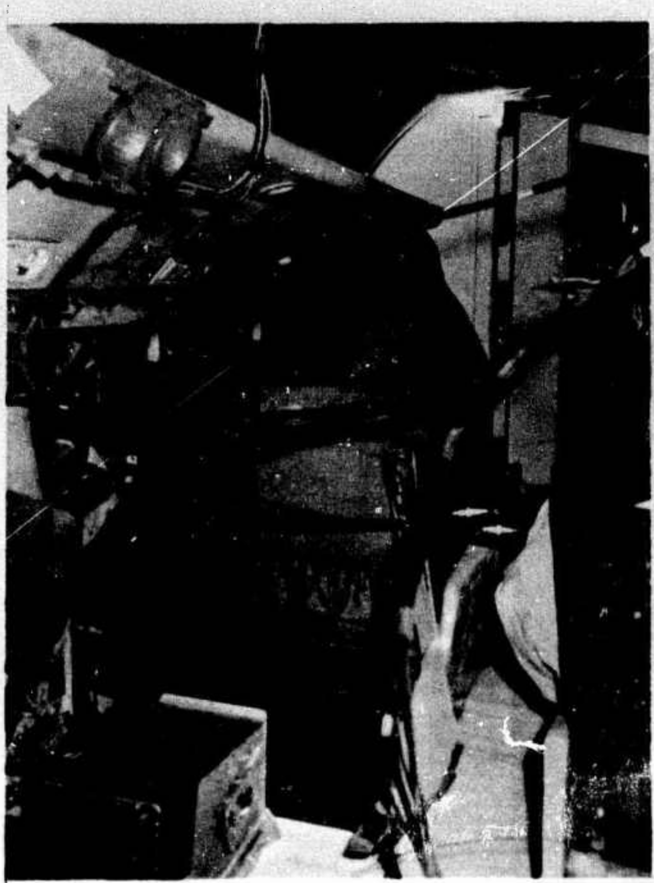


FIG. 88 POSTCRASH REAR VIEW OF AIRBAG EXPERIMENT (PICTURE ROTATED 90° CLOCKWISE)

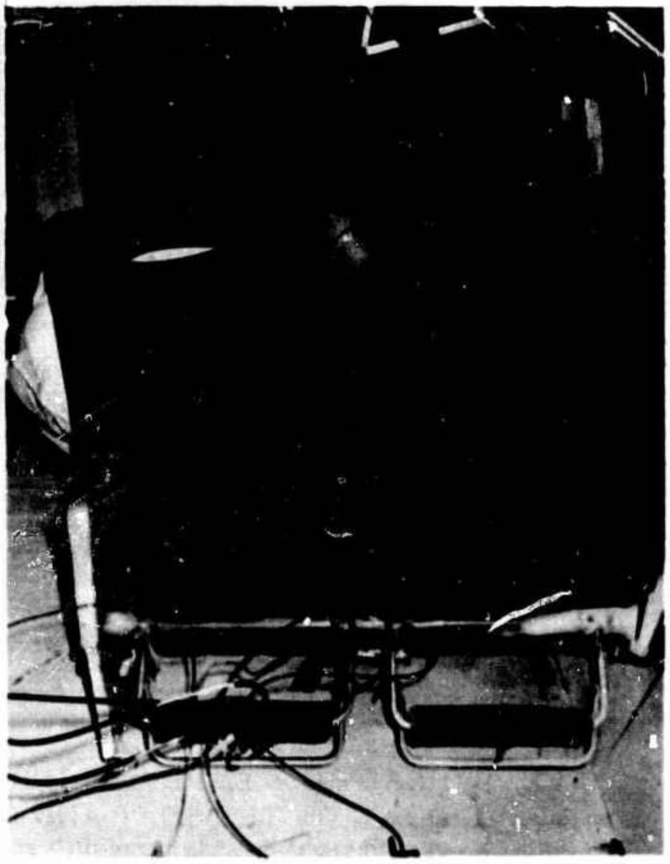


FIG. 89 POSTCRASH REAR VIEW OF AFT CABIN DC-7 PASSENGER SEAT EXPERIMENT (PICTURE ROTATED 90° CLOCKWISE)

FIG. 90 FORWARD CRUSHING OF AISLE SEAT LEG STRUCTURE (PICTURE ROTATED 90° CLOCKWISE)

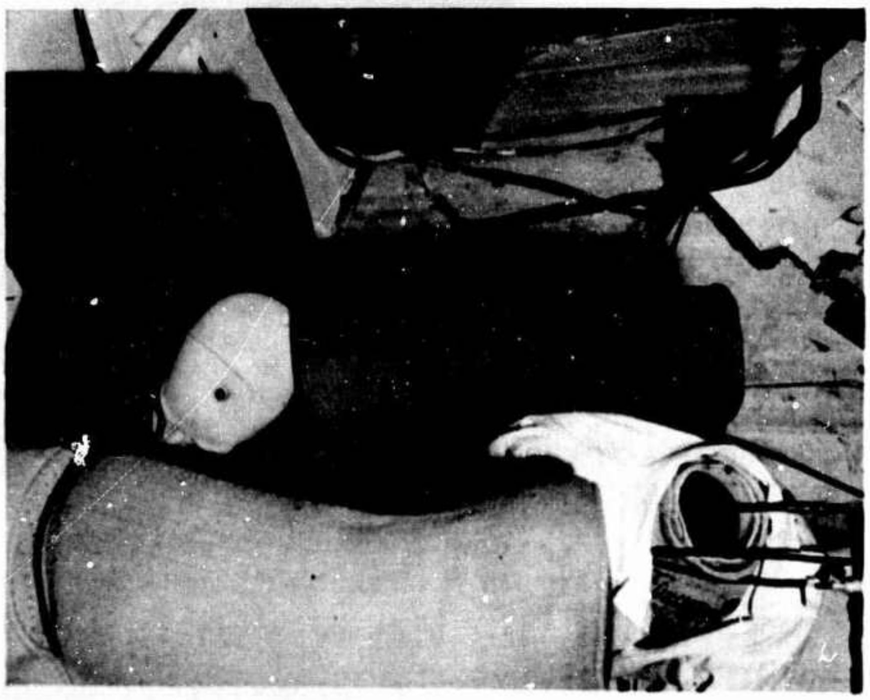


FIG. 91 HEAD LOSS EXPERIENCED BY AISLE DUMMY, LOOKING DOWN ON THE SEAT AND DUMMIES (PICTURE ROTATED 90° COUNTERCLOCKWISE)

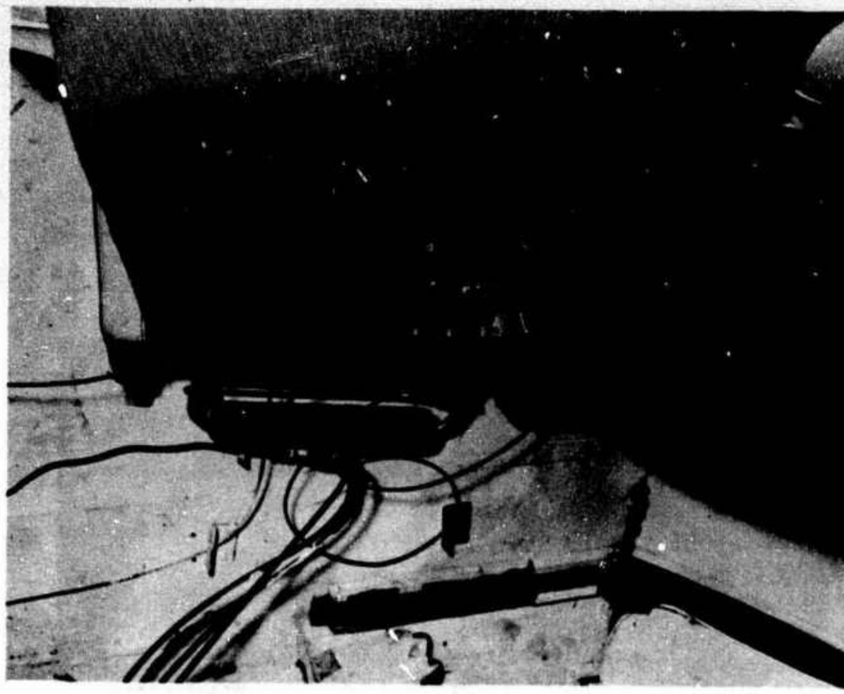


FIG. 92 SEAT BACK SEPARATION IN AISLE SEAT

FIG. 93 VIEW LOOKING AFT AT DUMMY IN SIDE FACING LOUNGE SEAT

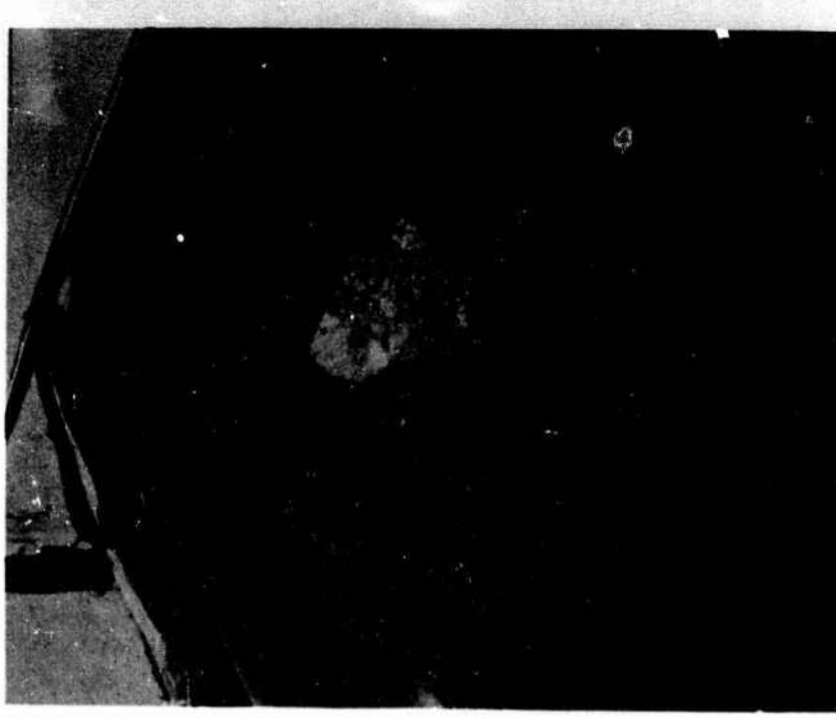
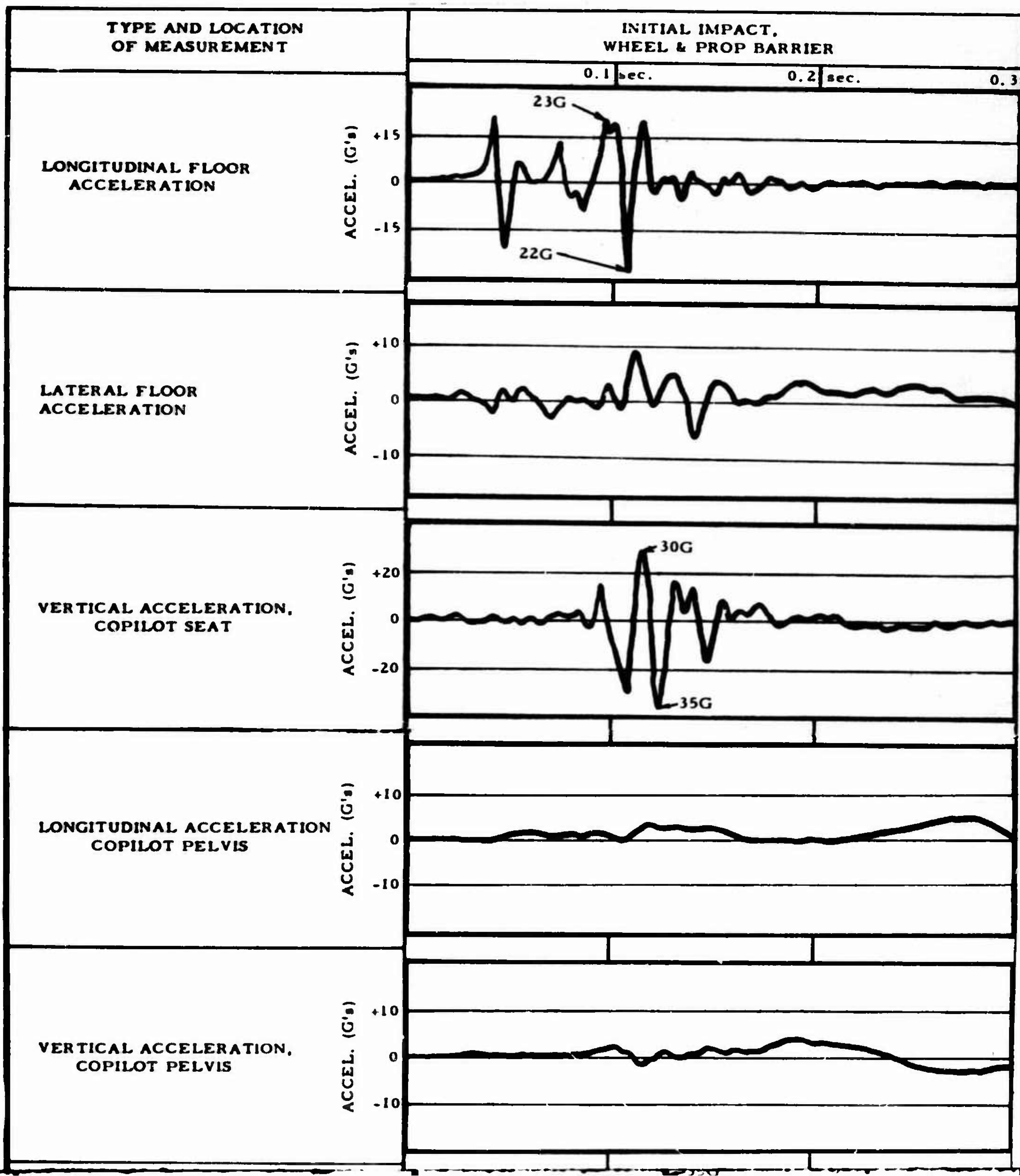


FIG. 94 POSTCRASH CONDITION OF SIDE FACING LOUNGE SEAT

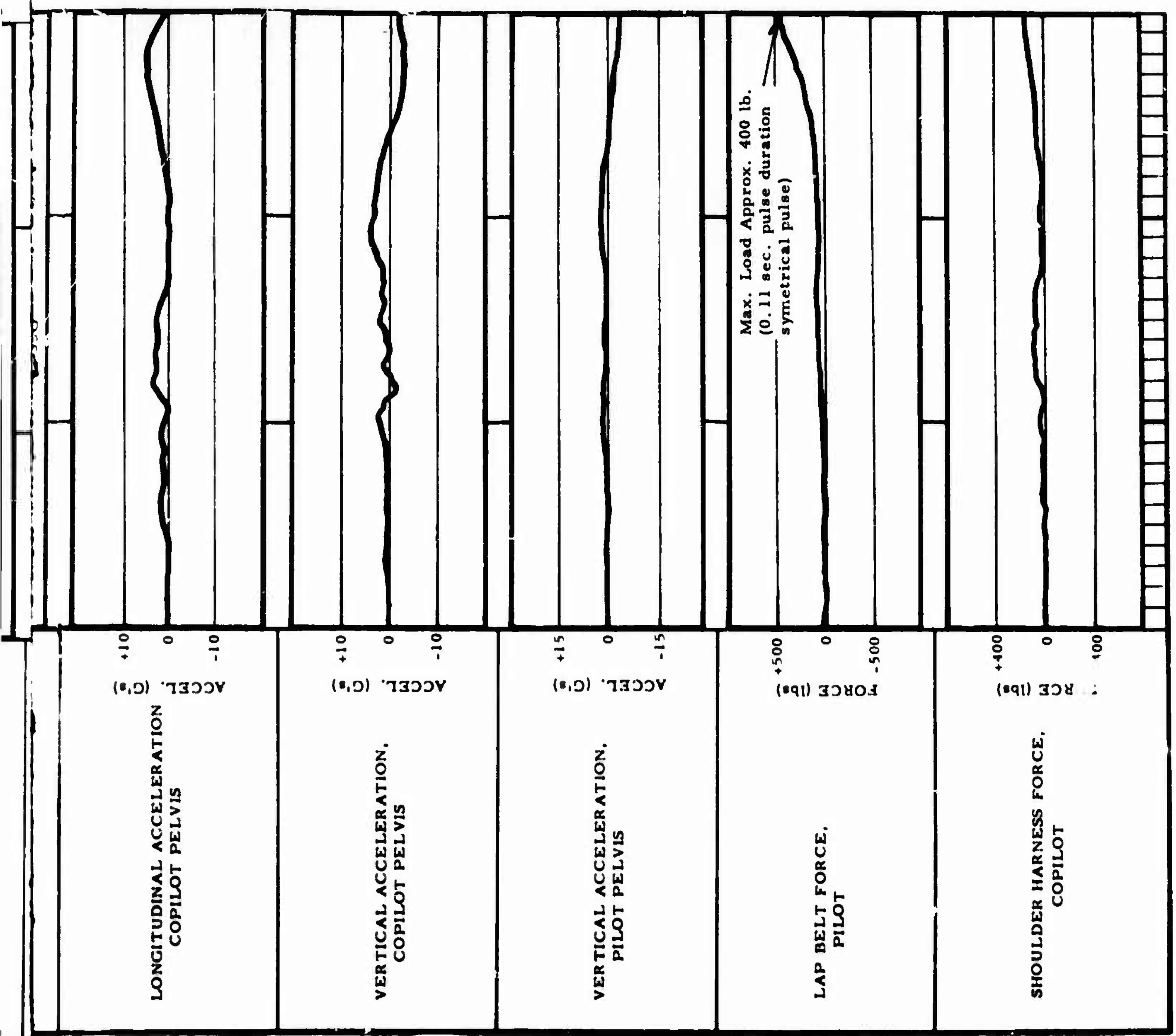
APPENDIX I

ACCELERATION TELEMETRY DATA

A

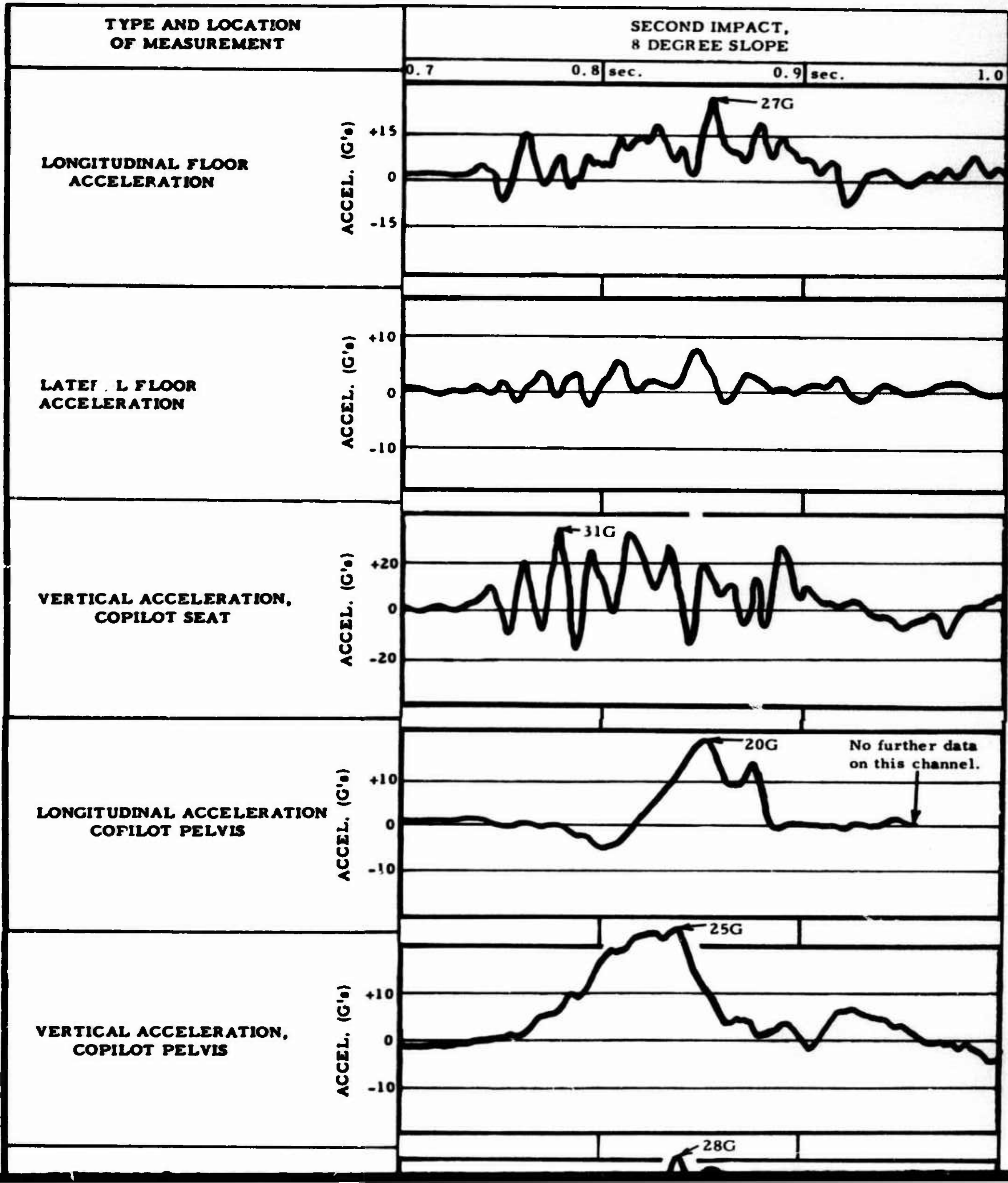


TYPE AND LOCATION OF MEASUREMENT
INITIAL IMPACT, WHEEL & PROP BARRIER
0.1 sec.
0.2 sec.
0.3
LONGITUDINAL FLOOR ACCELERATION
ACCEL. (G's)
+15
0
-15
23G
22G
LATERAL FLOOR ACCELERATION
ACCEL. (G's)
+10
0
-10
VERTICAL ACCELERATION, COPILOT SEAT
ACCEL. (G's)
+20
0
-20
30G
35G
LONGITUDINAL ACCELERATION COPILOT PELVIS
ACCEL. (G's)
+10
0
-10
VERTICAL ACCELERATION, COPILOT PELVIS
ACCEL. (G's)
+10
0
-10



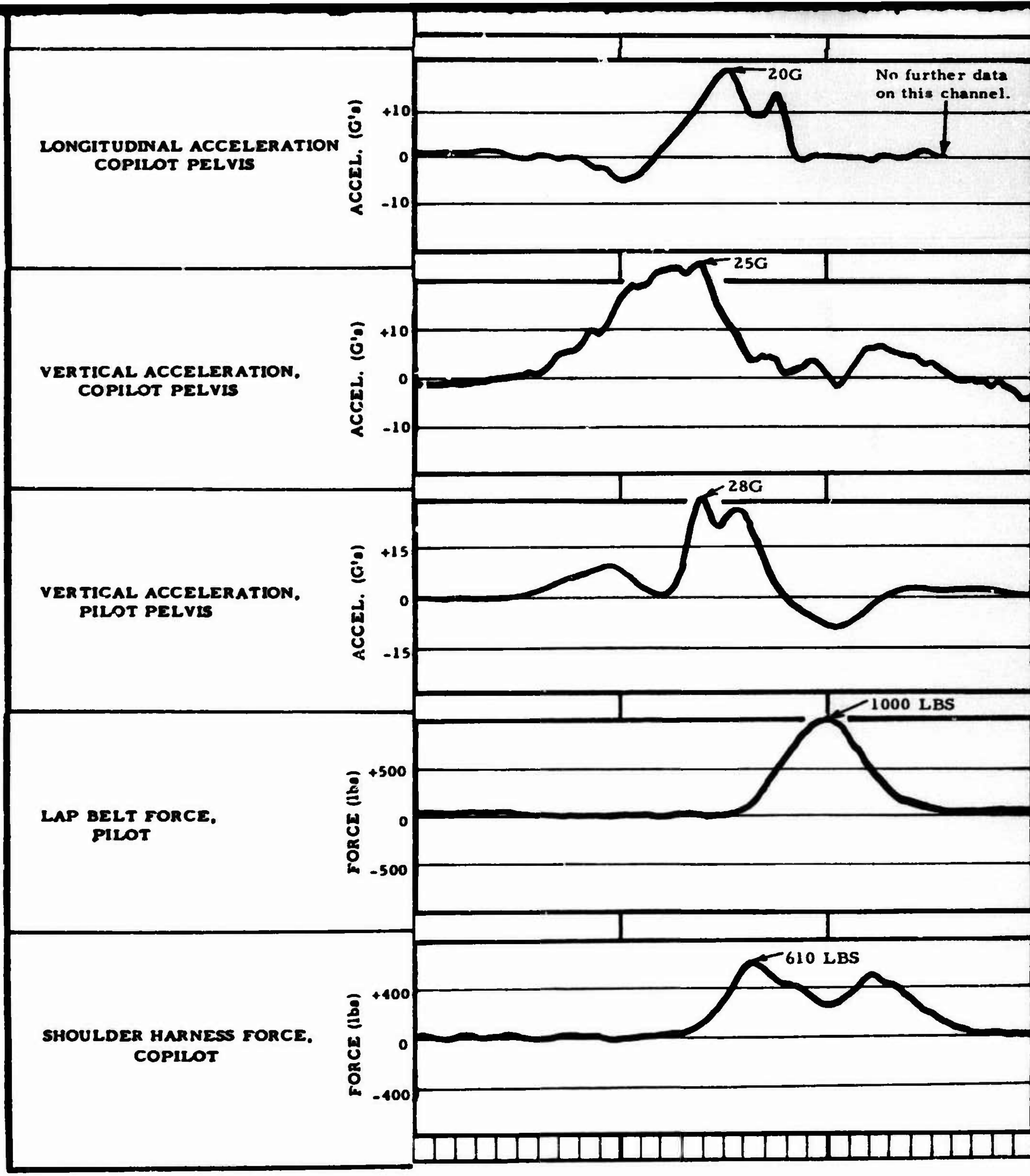
Max. Load Approx. 400 lb.
(0.11 sec. pulse duration
symetrical pulse)
+10
0
-10
ACCEL. (G's)
LONGITUDINAL ACCELERATION
COPILOT PELVIS
+10
0
-10
ACCEL. (G's)
VERTICAL ACCELERATION,
COPILOT PELVIS
+15
0
-15
ACCEL. (G's)
VERTICAL ACCELERATION,
PILOT PELVIS
+500
0
-500
FORCE (lbs)
LAP BELT FORCE,
PILOT
+400
0
SHOULDER HARNESS FORCE,
COPILOT

6



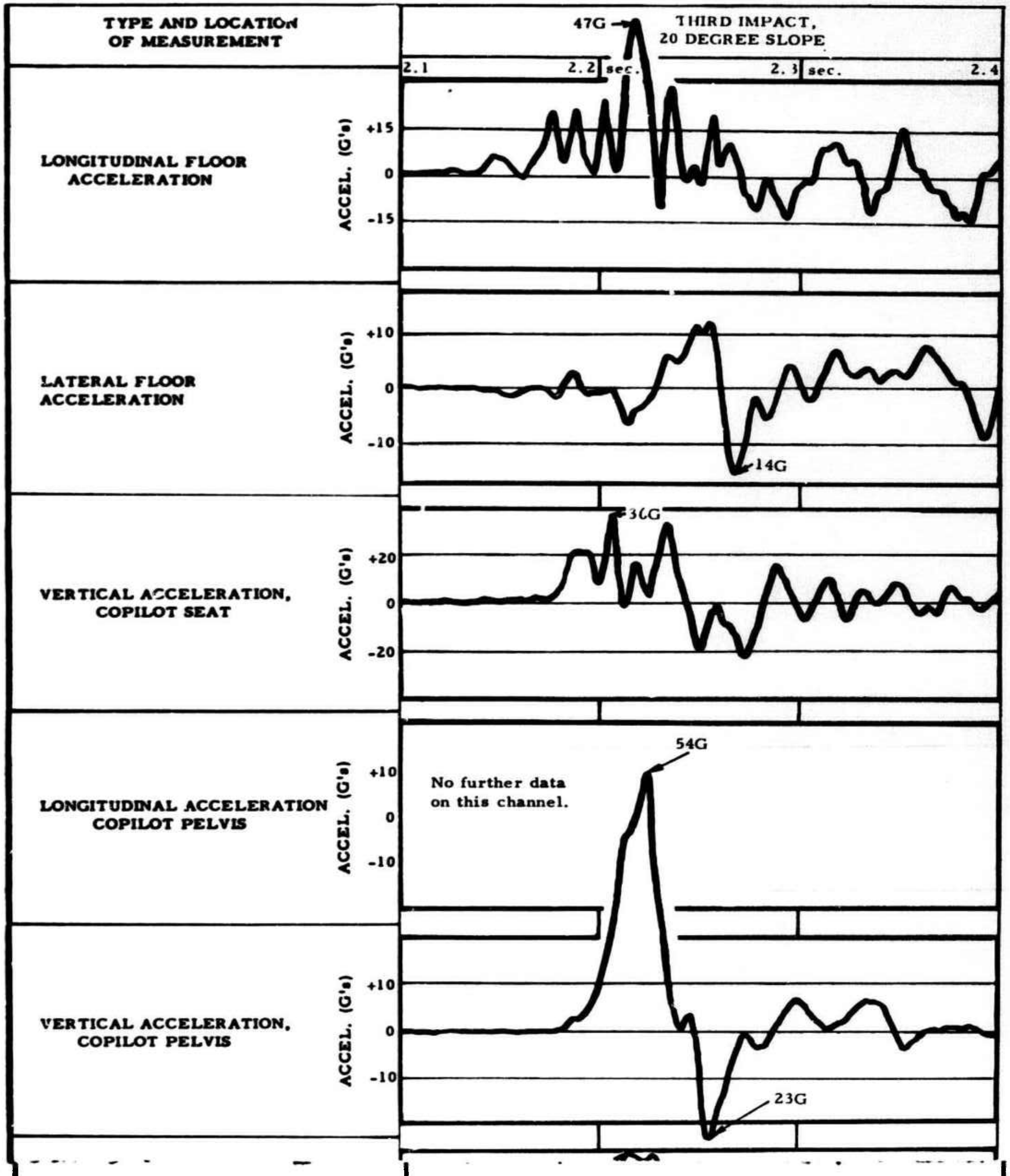
TYPE AND LOCATION OF MEASUREMENT
SECOND IMPACT, 8 DEGREE SLOPE
0.7
0.8 sec.
0.9 sec.
1.0
LONGITUDINAL FLOOR ACCELERATION
ACCEL. (G's)
+15
0
-15
27G
LATEI . L FLOOR ACCELERATION
ACCEL. (G's)
+10
0
-10
VERTICAL ACCELERATION, COPILOT SEAT
ACCEL. (G's)
+20
0
-20
31G
LONGITUDINAL ACCELERATION COFILOT PELVIS
ACCEL. (G's)
+10
0
-10
20G
No further data on this channel.
VERTICAL ACCELERATION, COPILOT PELVIS
ACCEL. (G's)
+10
0
-10
25G
28G

A



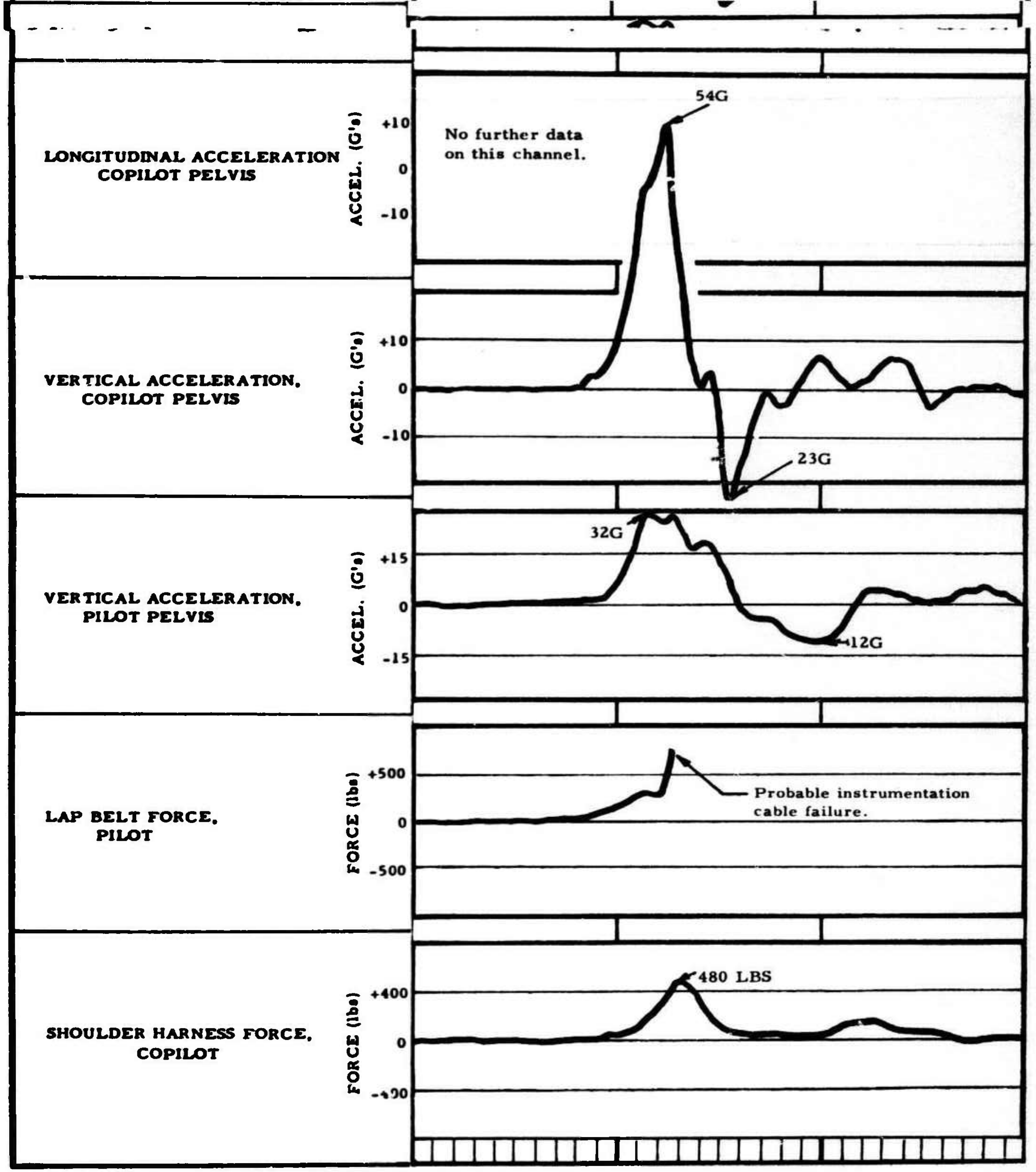
LONGITUDINAL ACCELERATION COPILOT PELVIS
ACCEL. (G's)
+10
0
-10
20G
No further data on this channel.
VERTICAL ACCELERATION, COPILOT PELVIS
ACCEL. (G's)
+10
0
-10
25G
VERTICAL ACCELERATION, PILOT PELVIS
ACCEL. (G's)
+15
0
-15
28G
LAP BELT FORCE, PILOT
FORCE (lbs)
+500
0
-500
1000 LBS
SHOULDER HARNESS FORCE, COPILOT
FORCE (lbs)
+400
0
-400
610 LBS

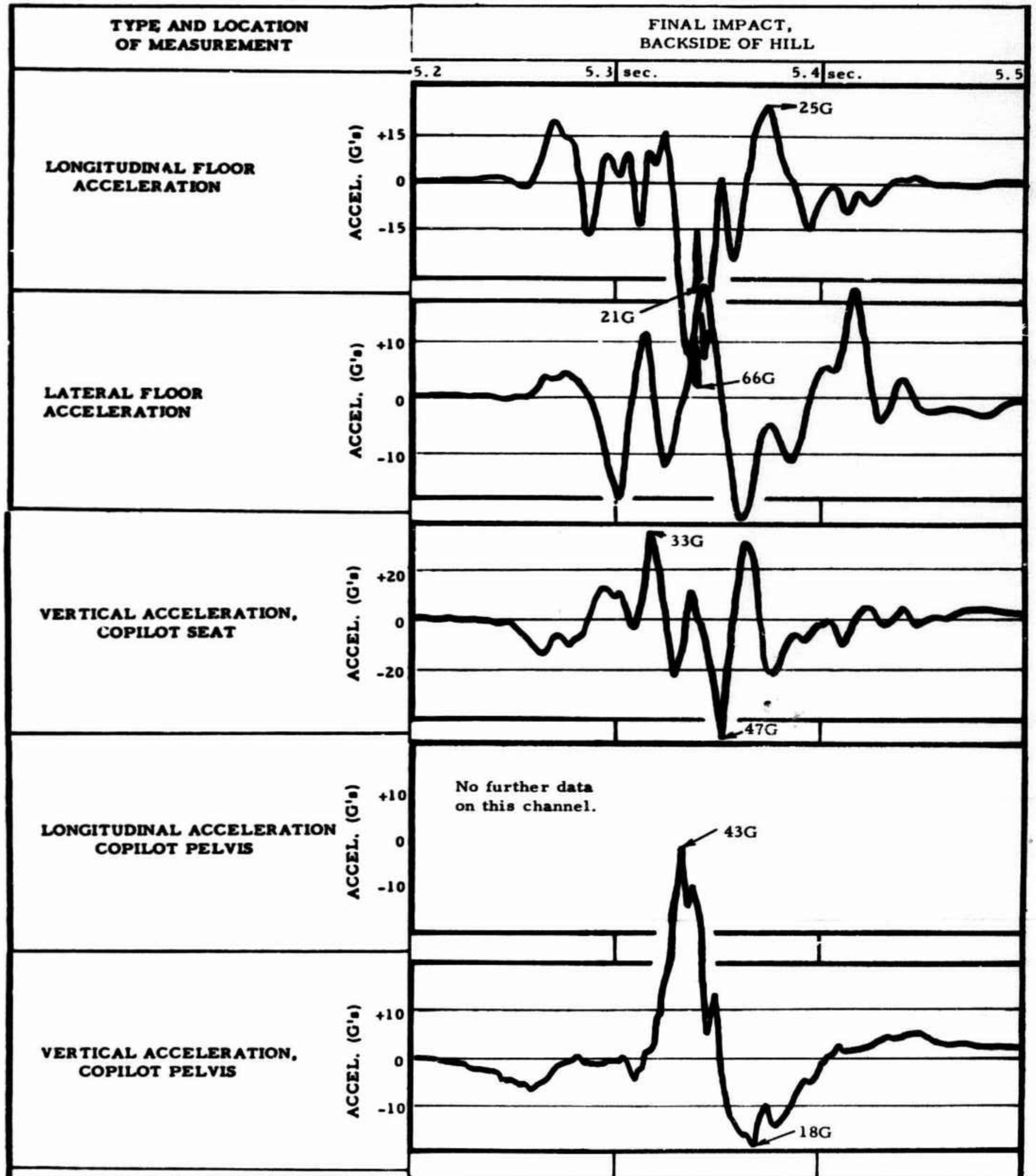
B



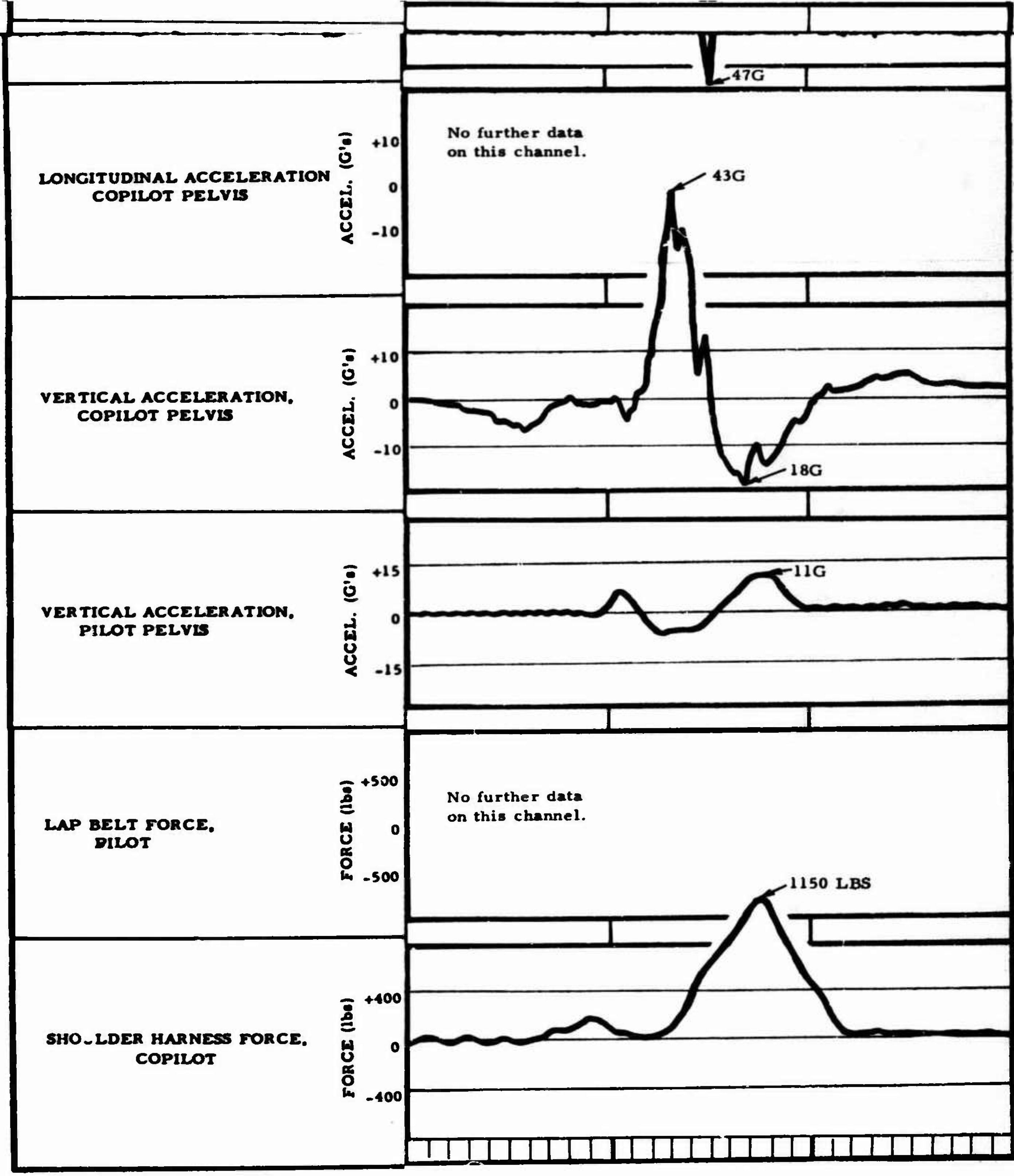
TYPE AND LOCATION OF MEASUREMENT
47G
THIRD IMPACT, 20 DEGREE SLOPE
2.1
2.2 sec.
2.3 sec.
2.4
LONGITUDINAL FLOOR ACCELERATION
ACCEL. (G's)
+15
0
-15
LATERAL FLOOR ACCELERATION
ACCEL. (G's)
+10
0
-10
14G
VERTICAL ACCELERATION, COPILOT SEAT
ACCEL. (G's)
+20
0
-20
LONGITUDINAL ACCELERATION COPILOT PELVIS
ACCEL. (G's)
+10
0
-10
54G
No further data on this channel.
VERTICAL ACCELERATION, COPILOT PELVIS
ACCEL. (G's)
+10
0
-10
23G

4


LONGITUDINAL ACCELERATION
COPILOT PELVIS
ACCEL. (G's)
+10
0
-10
No further data
on this channel.
54G
VERTICAL ACCELERATION,
COPILOT PELVIS
ACCEL. (G's)
+10
0
-10
23G
VERTICAL ACCELERATION,
PILOT PELVIS
ACCEL. (G's)
+15
0
-15
32G
12G
LAP BELT FORCE,
PILOT
FORCE (lbs)
+500
0
-500
Probable instrumentation
cable failure.
SHOULDER HARNESS FORCE,
COPILOT
FORCE (lbs)
+400
0
480 LBS


TYPE AND LOCATION OF MEASUREMENT
FINAL IMPACT, BACKSIDE OF HILL
5.2
5.3 sec.
5.4 sec.
5.5
LONGITUDINAL FLOOR ACCELERATION
ACCEL. (G's)
+15
0
-15
25G
21G
LATERAL FLOOR ACCELERATION
ACCEL. (G's)
+10
0
-10
66G
VERTICAL ACCELERATION, COPILOT SEAT
ACCEL. (G's)
+20
0
-20
33G
47G
LONGITUDINAL ACCELERATION COPILOT PELVIS
ACCEL. (G's)
+10
0
-10
No further data on this channel.
43G
VERTICAL ACCELERATION, COPILOT PELVIS
ACCEL. (G's)
+10
0
-10
18G

A


47G
LONGITUDINAL ACCELERATION COPILOT PELVIS
ACCEL. (G's)
+10
0
-10
No further data on this channel.
43G
VERTICAL ACCELERATION, COPILOT PELVIS
ACCEL. (G's)
+10
0
-10
18G
VERTICAL ACCELERATION, PILOT PELVIS
ACCEL. (G's)
+15
0
-15
11G
LAP BELT FORCE, PILOT
FORCE (lbs)
+500
0
-500
No further data on this channel.
1150 LBS
SHOULDER HARNESS FORCE, COPILOT
FORCE (lbs)
+400
0
-400

Engineering and Safety Division, Aircraft Development Service, Federal Aviation Agency, Washington, D. C. FULL-SCALE DYNAMIC CRASH TEST OF A DOUGLAS DC-7A AIRCRAFT, by W. H. Reed and others, Final Report, April 1965, 101 pp. incl., illus. (Contract No. FA-WA-4569, Project No. 312-1X, Report No. ADS-37)

Unclassified Report

The purpose of the test presented in this report was to obtain crash environmental data to study fuel containment and to collect data on the behavior of various components and equipment aboard the aircraft using a DC-7 as the test vehicle. The aircraft was accelerated under its own power by remote control along a monorail nose landing gear guidance system for a distance of 4000 feet, reaching a velocity of 139 knots. At the end of this acceleration run, the aircraft impacted against special designed barriers which removed the landing gear, permitting the aircraft to become airborne until impact with wing and fuselage barriers.

UNCLASSIFIED

I. Reed, W. H.
Robertson, S. H.
Weinberg, L. W. T.
Tyndall, L. H.
II. Project No. 312-1X
III. Report No. ADS-37

UNCLASSIFIED

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