| AD NUMBER |
|---|
| **AD483730** |
| LIMITATION CHANGES |
| TO:<br>**Approved for public release; distribution is unlimited. Document partially illegible.** |
| FROM:<br>**Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; MAY 1966. Other requests shall be referred to U.S. Army Aviation Materiel Laboratories, Fort Eustis, VA. Document partially illegible.** |
| AUTHORITY |
| **USAAMRDL ltr, 11 Nov 1976** |

L

483730

FOR OFFICIAL USE ONLY

AD

# USAAVLABS TECHNICAL REPORT 66-32

# FULL-SCALE DYNAMIC CRASH TEST OF A SMALL OBSERVATION TYPE HELICOPTER

By

J. W. Turnbow
S. H. Robertson
D. F. Carroll
R. D. McWilliam

May 1966

U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA

CONTRACT DA 44-177-AMC-254(T)

AVIATION SAFETY ENGINEERING AND RESEARCH
PHOENIX, ARIZONA
A DIVISION OF
FLIGHT SAFETY FOUNDATION, INC.



FOR OFFICIAL USE ONLY

Best
Available
Copy

## Disclaimers



## Disposition Instructions



## Protective Marking

FOR OFFICIAL USE ONLY

DEPARTMENT OF THE ARMY
U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA 23604

This report was prepared by Aviation Safety Engineering and Research (AvSER), a division of the Flight Safety Foundation, Inc., under the terms of Contract DA 44-177-AMC-254(T).

The purpose of this effort was to investigate the crashworthiness concepts and postcrash fire protection of the OH-4A aircraft. Many design concepts were incorporated in the OH-4A as a result of recommendations from USABAAR based on past accident experience and previous crash tests conducted by AvSER. The dynamic crash tests conducted in this effort have attempted to validate these design concepts for possible application in future Army aircraft.

These tests were conducted at the request of USABAAR and with the approval of the AMC-LOH Project Manager.

The conclusions contained herein are concurred in by this command.

FOR OFFICIAL USE ONLY

**FOR OFFICIAL USE ONLY**

Task 1P125901A14230
Contract DA 44-177-AMC-254(T)
USAAVLABS Technical Report 66-32
May 1966

# FULL-SCALE DYNAMIC CRASH TEST OF A SMALL OBSERVATION TYPE HELICOPTER

AvSER Report No. 65-10

by

J. W. Turnbow
S. H. Robertson
D. F. Carroll
R. D. McWilliam

Prepared by

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

for

U. S. ARMY BOARD FOR AVIATION ACCIDENT RESEARCH
Fort Rucker, Alabama

and

U. S. ARMY AVIATION MATERIEL LABORATORIES
Fort Eustis, Virginia



**FOR OFFICIAL USE ONLY**

## SUMMARY

This report discusses the results of experimental crash tests of two fully instrumented OH-4A helicopters. The first of these tests, conducted as a crane drop, illustrated the energy-absorption capability of the tapered-wall landing gear strut. It further showed that high accelerations may be induced in occupants under level impact conditions of the aircraft in which the design sinking speed for the gear is exceeded. The latter of these tests, conducted from droned flight, indicated that rotor blade impacts with obstacles induced loads into the mast-transmission system which were sufficient to fail the structure at the transmission supports.

The crashworthiness of the OH-4A showed an improvement over previous aircraft tested; however, further improvements are definitely possible. This report recommends the means of such improvements and proposes their implementation through appropriate study and test programs.

TABLE OF CONTENTS

## ILLUSTRATIONS

## INTRODUCTION

Under Contract DA 44-177-AMC-254(T) between the U. S. Army Aviation Materiel Laboratories and the Flight Safety Foundation, Inc., the Aviation Safety Engineering and Research Division conducted a series of full-scale dynamic tests of aircraft, components and other safety equipment. In March 1965, a joint program for the dynamic crash tests of two OH-4A helicopters was established between the U. S. Army Aviation Materiel Laboratories (USAAVLABS) and the U. S. Army Board for Aviation Accident Research (USABAAR). This program was subsequently included as an increase in the scope of work in the contract through Modification No. 4.

The tests involved two aircraft. One was to be dropped vertically with no forward speed, and the other was to be flown into a crash by remote control, impacting with both vertical and forward speeds. The vertical drop test was designated Test 21 (T-21) and the drone as Test 22 (T-22). These designations will be used in the balance of this report.

The two dynamic tests were conducted on May 13 and June 3, 1965, respectively. This report presents the overall test program objectives and provides a detailed analysis of the test results.

## CONCLUSIONS

On the basis of the tests conducted, it is concluded that:

1. A reduction in the incidence of postcrash fires in helicopters will be accomplished if a disconnect between the engine and transmission can be effected so as to leave the engine and the fuel, oil and hydraulic lines to the engine undisturbed in impacts involving separation of the transmission from its mounts.*

2. Good shielding of the engine against blade impacts and roll-over loads will reduce the possibility of ignition of postcrash fires. The shielding in the OH-4A was lightly constructed and left the engine exposed following impact.

3. The mode of failure of fluid lines in this test points out the need for better application of crash-disconnect fittings or other means of reducing the spillage of flammable fluids following line failure.

4. The structural integrity of the cockpit and fuel storage section of the OH-4A represents an improvement in crashworthiness in helicopters when compared with others recently tested. The containment of the simulated fuel load is evidence of this improvement.

5. The rigidity of the occupiable areas of the structure, which is desirable from the standpoint of maintenance of livable space, does offer some disadvantages: (a) higher inertia loads can be expected in such overhead systems as transmissions, etc., and (b) requirements for acceleration attenuation for the occupants are increased when no appropriate deformable structure is present.

6. The design of the nose structure, particularly of instrument consoles and the forward edge of the lower portion of the fuselage, should be given careful consideration to provide protection against injury due to "digging in" in longitudinal impacts.

7. The OH-4A crew restraint system does not satisfactorily retain the occupants within the confines of the cockpit proper, thus imposing additional hazards to their security. Improved lateral restraint of the upper torso is needed.

*Such disconnect was provided for in the OH-4A.

# TEST OBJECTIVES

## MAJOR TEST OBJECTIVES

The major objectives of the test program were as follows:

1. Evaluation of the crashworthiness features designed into the OH-4A helicopter.

2. Development of background information which may be pertinent to the crash survival design features of future VTOL aircraft.

## SPECIFIC AREAS FOR CONSIDERATION

1. Postcrash fire protection, including areas of fuel spillage, fuel pressure measurements, and location of ignition sources with respect to areas of fuel spillage.

2. Protection afforded to the crew by the floor construction.

3. Dynamic strength of the two forward seats and their associated restraint systems.

4. Personnel injury potential of the aircraft.

5. Any decreases in the living area of the crew and passenger compartments.

6. Any movement of aircraft components such as transmission or engine that could produce injury to personnel.

7. Postcrash ingress and egress provisions.

8. Roll-over protection.

## PREPARATION FOR TEST

Two OH-4A helicopters were supplied for the test program by USABAAR. One of the helicopters was nonflyable but had all major components installed. The second helicopter was complete and in flying status. The aircraft were painted flat white with special identification markings affixed to aid in photo interpretation of structural deformation. All communication and navigation equipment not required during the conduct of the test was removed. A photograph of the T-21 aircraft is presented in Figure 1.

Figure 1. Pretest View of the T-21 Aircraft (Left Side). Note the aircraft attitude with respect to the skids.

Three instrumented anthropomorphic dummies were installed in the pilot, copilot and passenger stations within the T-21 aircraft as shown in Figure 2. Two instrumented anthropomorphic dummies were installed in the pilot and passenger stations within the T-22 aircraft. The standard shoulder harness inertia reels in all the occupant restraint systems were replaced by units supplied by USABAAR. The occupant restraint systems were adjusted loosely prior to the tests by USABAAR personnel. Target marks were placed on the dummies' arms and legs to assist in the study of high-speed films of the dynamic response of these dummies. In T-21 the copilot dummy (left front seat) was fitted with a bulletproof vest.

Figure 2. Three 95th-Percentile Dummies in Position in the T-21 Aircraft.

The doors of both aircraft were removed for the tests to aid in photographic coverage of the dummies.

In T-21 the engine and transmission cowlings were removed and the engine and transmission support members color coded to aid in high-speed film analysis.

Accelerometers, force transducers, a pressure transducer, and a magnetic tape instrumentation data recording package were installed in each aircraft. A remote control system designed to operate the collective pitch, lateral cyclic, longitudinal cyclic and tail rotor pedals was installed in the T-22 aircraft. High-speed cameras were installed around the impact areas and onboard both test aircraft to record the behavior of the structure, occupants, and other components during the impact. Time correlation was provided between the onboard cameras, the ground cameras and the electronic data recording system. Batteries to provide power for the remote control system, cameras and recording system were installed on the T-22 aircraft. Power for T-21 was provided by a cable connected to an external source. A detailed discussion of the types and locations of all instrumentation is included in the section on Test Equipment.

The main fuel cell of the aircraft in T-21 was filled with 58 gallons of dyed water to simulate a full fuel load. It was necessary to reduce the simulated fuel load in the T-22 aircraft to 44 gallons due to the increased test installation weight in the droned aircraft.

Investigation of postcrash fire protection was made by fuel pressure measurements, photographing the fuel spillage with normal- and high-speed cameras during the crash sequence, and photographing the spillage areas with still and normal-speed cameras immediately following the crash. Fuel spillage areas were to be plotted relative to the crash vehicle; potential ignition sources were to be included on the plot.

The protection afforded the crew by the floor construction was investigated by measuring the longitudinal, vertical and lateral acceleration transmitted to the floor structure and the crew seats.

The dynamic strength of the two forward seats and their associated restraint systems was investigated by the installation of instrumentation in anthropomorphic dummies in the seats and the measurement of acceleration and force data in the seats, dummies, and restraint systems. Triaxial accelerometers were installed on the seats and in the dummies' pelvic regions for measuring longitudinal, vertical and lateral accelerations. Force transducers were also installed in seat belts and shoulder harnesses.

Personnel injury potential was determined by conducting postcrash investigation and evaluation. In addition, high-speed cameras were installed in the aircraft in locations from which the dynamics of the dummies and other objects in the aircraft could be photographed. The photographic data, combined with the acceleration and force data obtained, as set forth above, was to permit an analysis of the personnel injury potential.

Any decreases in the living area of the crew and passenger compartments were to be photographed with high-speed cameras strategically located inside the aircraft as set forth above, supplemented with high-speed cameras strategically located on the ground to photograph the impact from several angles.

Any movement of components, such as the transmission or engine, that could produce injury to personnel was to be determined by visual inspection after the test and by high-speed photography with airborne and ground cameras. Parts were color coded to allow identification through color photography. Accelerometers were installed on the transmission and engine mounts to measure longitudinal, vertical, and lateral accelerations.

Postcrash ingress and egress provisions were examined and analyzed on the basis of visual inspection after the test and through the analysis of high-speed films. Postcrash operation of all emergency exits and simulated evacuation by test personnel were conducted.

Roll-over protection was investigated and analyzed through study of high-speed films taken with onboard and ground cameras and from a detailed postcrash investigation.

## TEST EQUIPMENT

### ACCELERATION, PRESSURE, AND LOAD TRANSDUCERS

Special accelerometer mounting pads were installed in the T-21 aircraft at the following locations:

1. Cockpit floor (directly under pilot's seat)
2. Passenger cabin floor (in front of left passenger's seat)
3. Aircraft ceiling (between passenger's seats)
4. Engine (on an accessory pad near front of engine)
5. Transmission (on left side near lateral center line)
6. Pilot's and copilot's seats (under seat pans)
7. Passenger's seats (under seat pans)

Accelerometers were also installed in the heads and pelvic areas of the anthropomorphic dummies. These mounting pads were duplicated on T-22 except for the exclusion of the pads on the copilot's seat and the engine.

The accelerometers used in the tests were a strain gauge type manufactured by Statham Instruments. Model A5A or A6A instruments were used, depending on locations. Both models provide frequency response in excess of 100 cycles per second, which is adequate for this test.

The force tensiometers used to measure seat belt and shoulder harness loads were units designed and fabricated by AvSER. The pressure transducers used were strain gauge types manufactured by Consolidated Electrodynamics Corporation. The general distribution of the accelerometers, tensiometers, and pressure transducers is shown in Figures 3 (T-21) and 4 (T-22). Lists of the measurements taken are given in Appendix III.

### DATA RECORDING SYSTEM

The measurements listed in Appendix III were recorded on a magnetic tape recording system installed in the test aircraft. Each component of the magnetic tape recording system is designed to record accurate and reliable data under the severe environment of a crash situation. A block diagram of the system is presented in Figure 5. In T-21, the major components of the recording system were contained in a protected package installed in the right passenger's seat as shown in Figure 6. For T-22, the package was attached to the ceiling above the right passenger's seat. Shielded cables connected the transducers to the recording system package. The recording equipment was actuated just prior to release of the

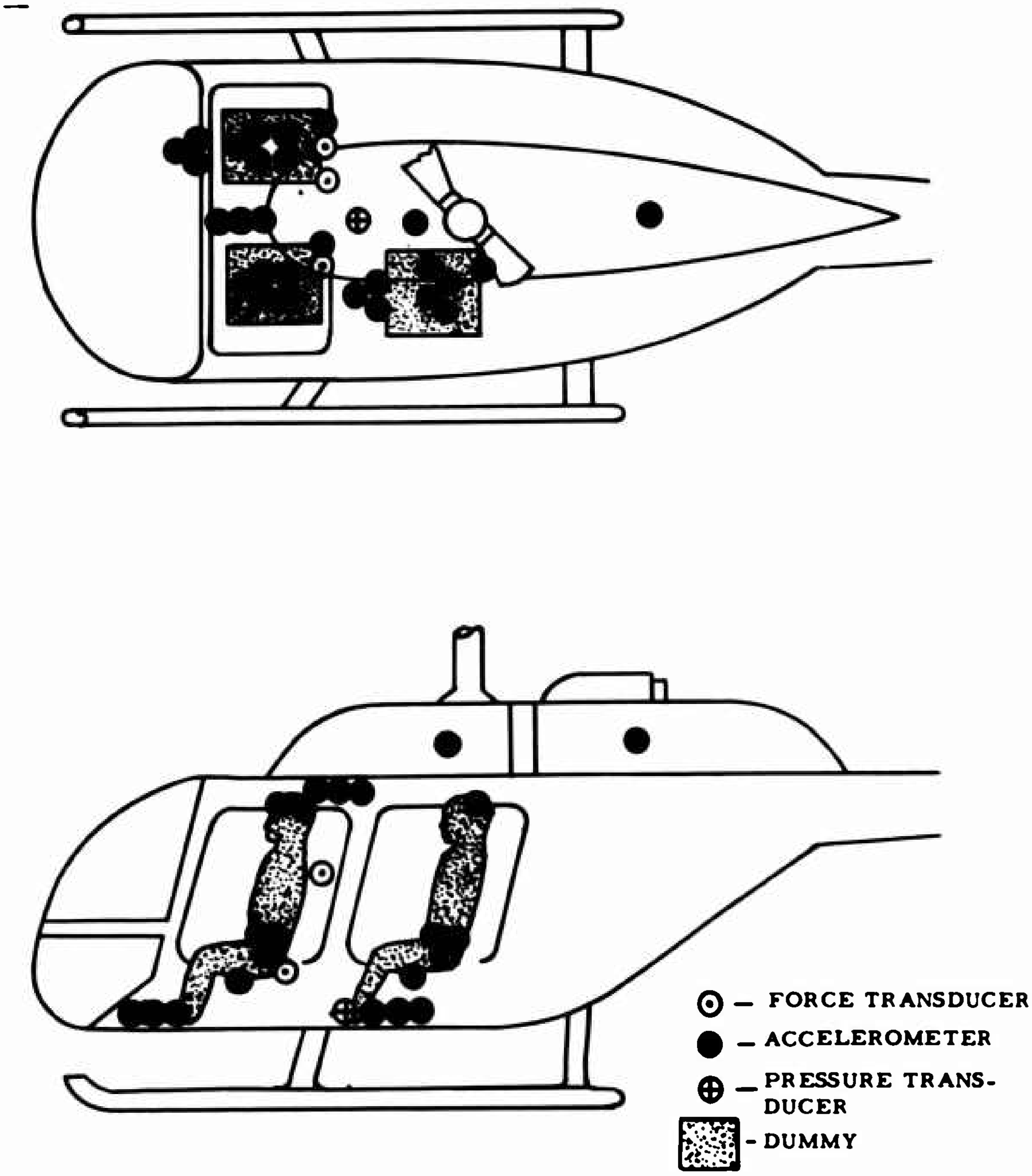



Figure 3. T-21, Instrumentation Locations.

aircraft. The control circuit is designed so that, once started, the tape recorder will continue to operate until reaching the end of the magnetic tape. Thus, an interruption in the control signal will not result in the loss of data.

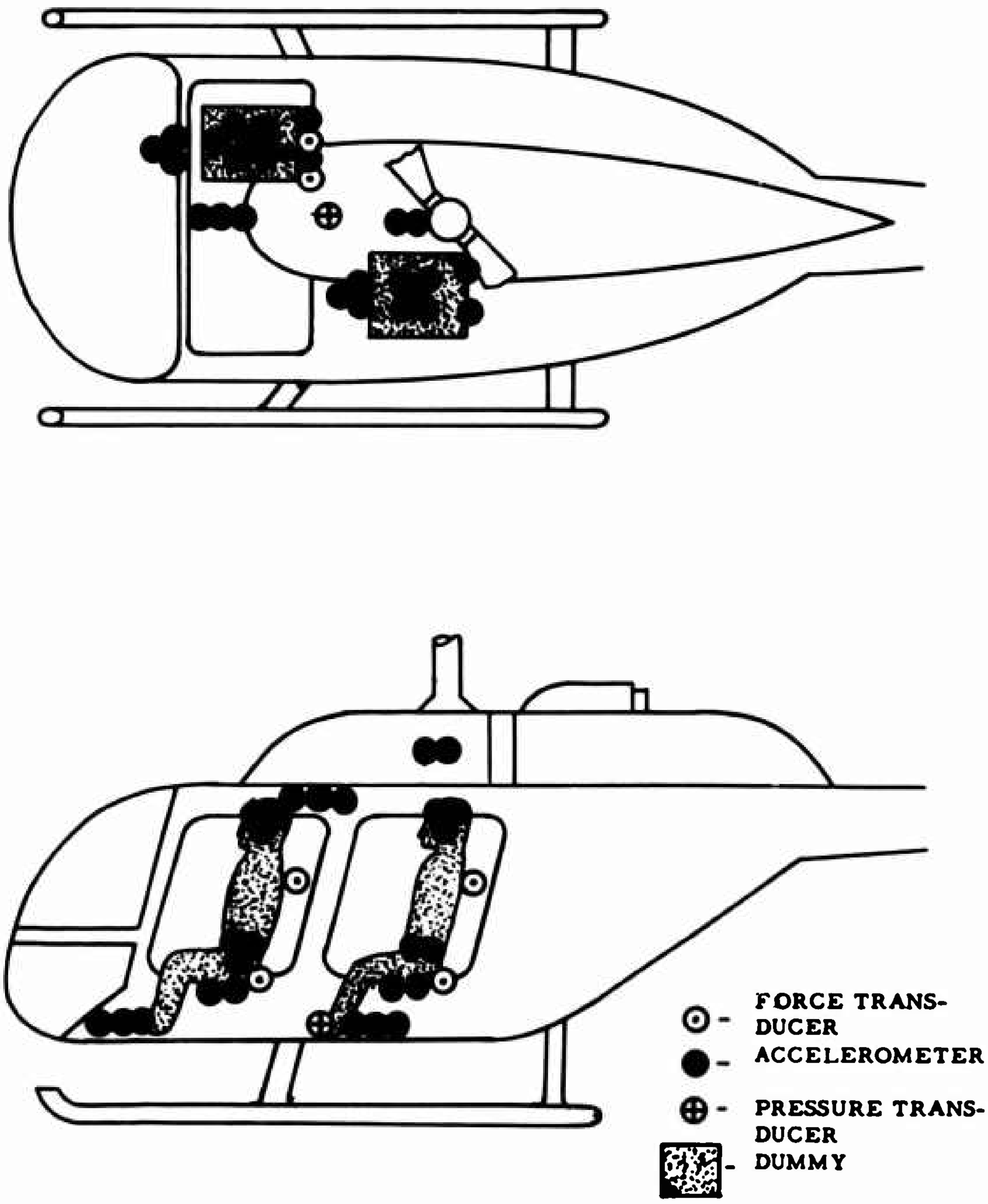



Figure 4. T-22, Instrumentation Locations.

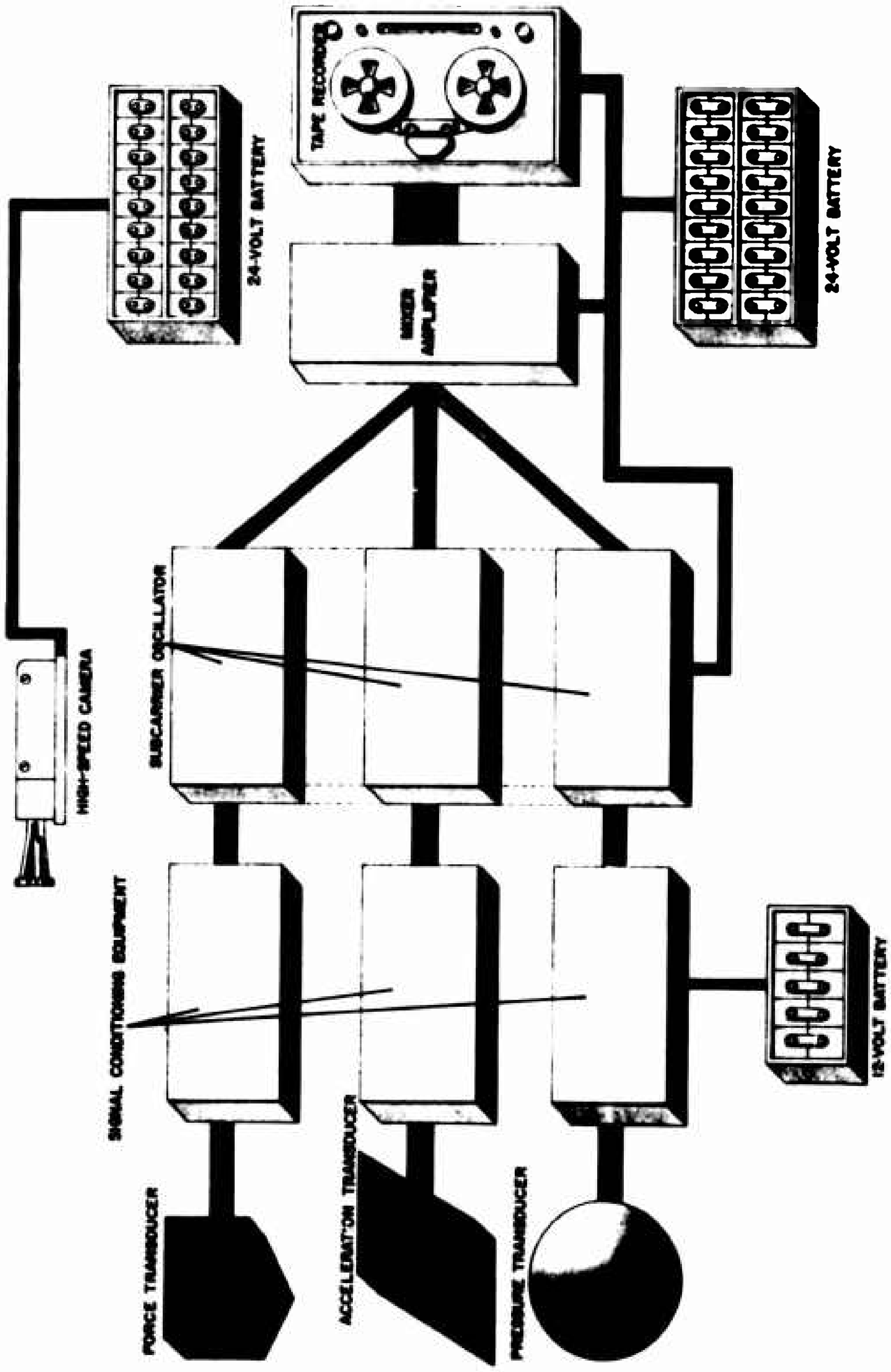



Figure 5. Onboard Instrumentation System, T-21 and T-22.

Figure 6. Instrumentation Recording Installation, T-21.

The data recorded by the magnetic tape recording system was recovered by using the data processing system presented in Figure 7. This equipment converts the recorded data to an analog signal, which is scaled and recorded directly on an oscillograph plotter. The oscillograph record is then processed and is available as a scaled analog plot of the recorded parameter for "quick look" information. The analog signals are then processed through the analog to digital converter and recorded on a digital tape recorder.

PHOTO INSTRUMENTATION SYSTEM

With respect to photo instrumentation, high-speed cameras were installed around the impact points and onboard the test aircraft to record the behavior of the structure, occupants and other components during the impact. Diagrams showing camera coverages are included as Figure 8 (T-21) and Figure 9 (T-22). The onboard camera box installation for T-21 is shown in Figure 10. This system was also used in T-22.

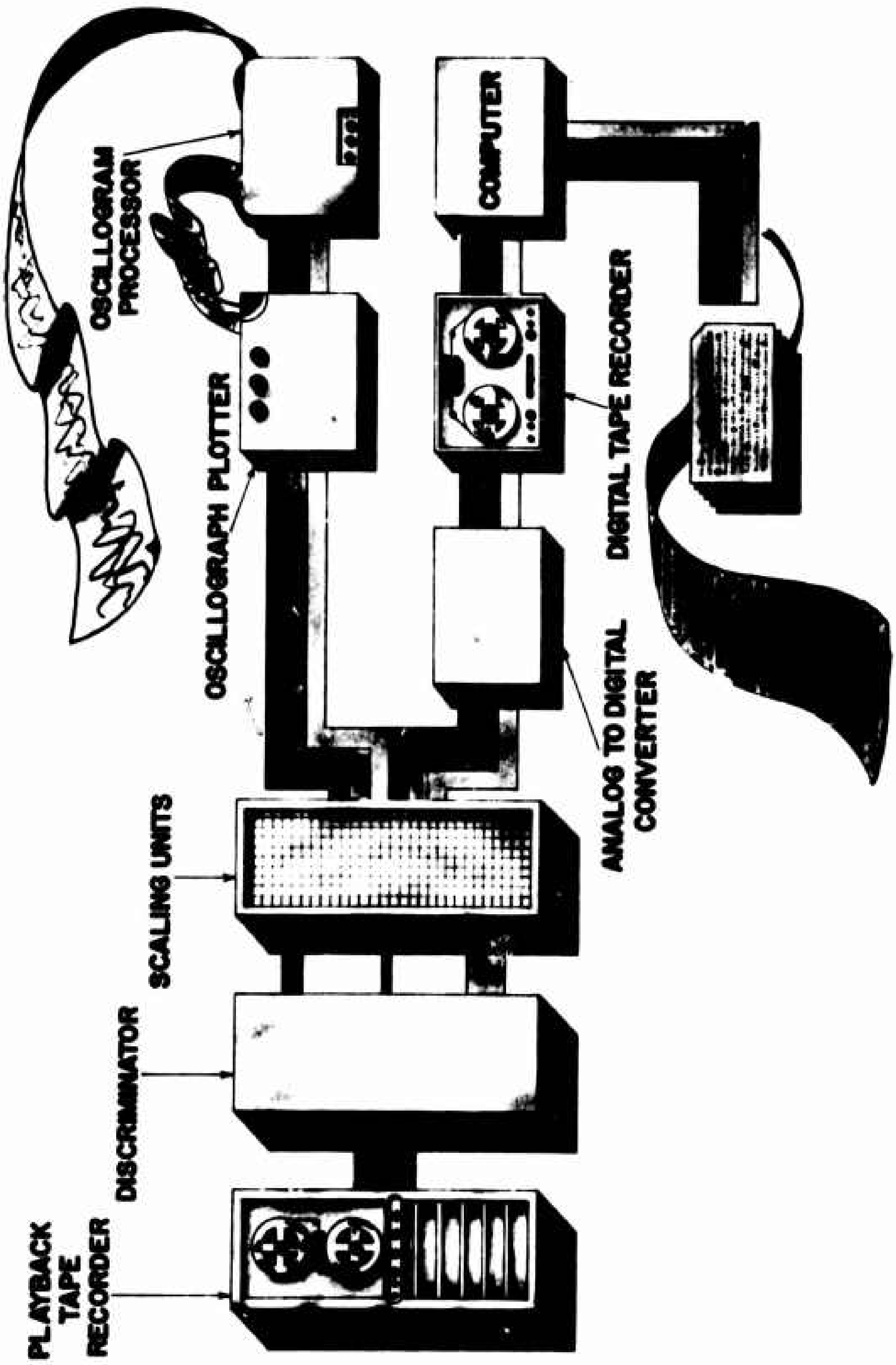
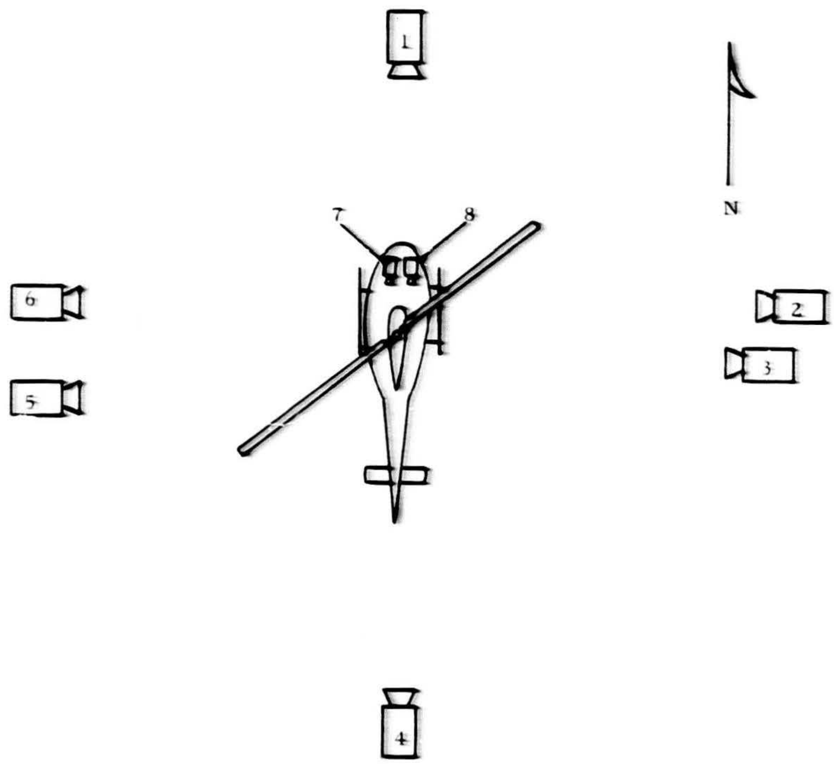
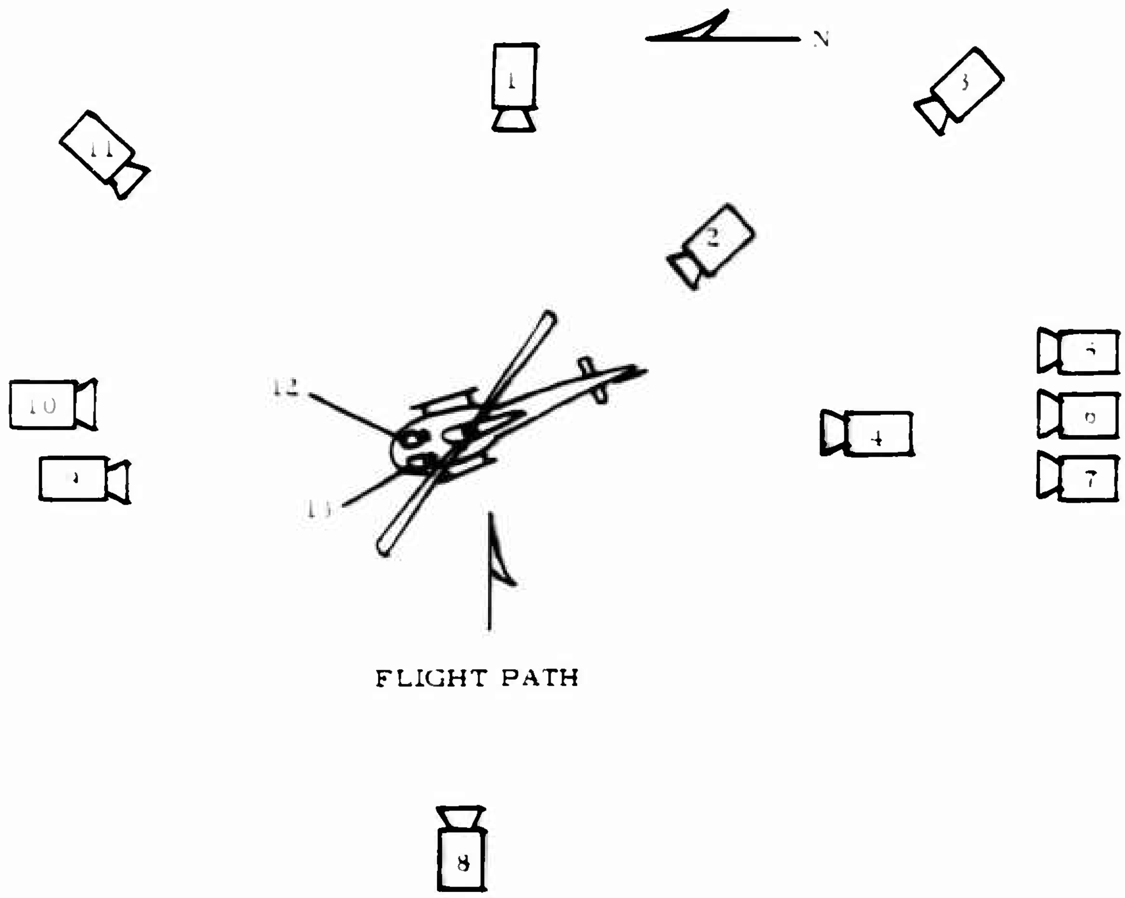



Figure 7. Data Processing System.




| No. | Camera | Speed | Mounting |
|---|---|---|---|
| 1 | 16mm 1B Photo-Sonics | 1000 fps | Fixed |
| 2 | 16mm 1B Photo-Sonics | 500 fps | Manually Tracked |
| 3 | 16mm 1B Photo-Sonics | 500 fps | Fixed |
| 4 | 16mm 1B Photo-Sonics | 500 fps | Fixed |
| 5 | 16mm 1B Photo-Sonics | 1000 fps | Fixed |
| 6 | 16mm 1B Photo-Sonics | 1000 fps | Manually Tracked |
| 7 | 16mm 1B Photo-Sonics | 500 fps | Fixed |
| 8 | 16mm 1B Photo-Sonics | 500 fps | Fixed |

**Figure 8. Camera Coverage, T-21.**




| No. | Camera | Speed | Mounting |
|---|---|---|---|
| 1 | 16mm 1B Photo-Sonics | 500 fps | Fixed |
| 2 | 16mm 1B Photo-Sonics | 500 fps | Fixed |
| 3 | 16mm 1B Photo-Sonics | 500 fps | Manually Tracked |
| 4 | 16mm 1B Photo-Sonics | 500 fps | Fixed |
| 5 | 16mm 1B Photo-Sonics | 500 fps | Manually Tracked |
| 6 | 16mm Bolex | 24 fps | Manually Tracked |
| 7 | 35mm Evemo | 25 fps | Manually Tracked |
| 8 | 16mm Bell & Howell | 64 fps | Manually Tracked |
| 9 | 16mm 1B Photo-Sonics | 500 fps | Fixed |
| 10 | 16mm 1B Photo-Sonics | 500 fps | Manually Tracked |
| 11 | 16mm 1B Photo-Sonics | 500 fps | Manually Tracked |
| 12 | 16mm 1B Photo-Sonics | 500 fps | Fixed |
| 13 | 16mm 1B Photo-Sonics | 500 fps | Fixed |

Figure 9. Camera Coverage, T-22.

Figure 10. Onboard Camera Installation, T-21.

Type ER Ektachrome* color film (ASA rating 160) was used in the Photo-Sonics cameras operated at 1000 frames per second. Type MS (ASA rating 64) was used in the Photo-Sonics cameras set at 500 frames per second. The 24-frame Bolex and Bell and Howell cameras used Ektachrome commercial film with an ASA rating of 16. The 64-frame Eyemo camera utilized Panatomic* film with an ASA rating of 32.

## ANTHROPOMORPHIC DUMMIES

Alderson anthropomorphic dummies, each weighing 195 pounds, were utilized in the tests. These dummies represent the 95th-percentile man.

## INERTIA REELS

The inertia reels installed in the occupant restraint systems were model MA-6, manufactured by Pacific Scientific Company and supplied for the

*Registered Trade Mark, Eastman Kodak Co., Rochester, New York.

tests by the U. S. Army Board for Aviation Accident Research. The remainder of the occupant restraint system was unchanged.

## REMOTE CONTROL SYSTEM (T-22)

### General

The remote control system for this test is designed to operate the four primary helicopter flight controls: collective pitch, cyclic (longitudinal and lateral), rudder pedals, and engine throttle. All functions, except the engine throttle, are manually controlled from a remote location through a radio link. The throttle channel, however, is designed to automatically maintain a constant engine RPM throughout the test flight. In addition to the ground control signals, provisions are made in the system for inputs from a gyro horizon and a directional gyro. This feature provides automatic control of the roll attitude and yaw angle during the more critical takeoff and landing phases. The remote control installation consists of the airborne system and the ground control system which are described below.

### Airborne Equipment

The airborne equipment is represented diagrammatically in Figure 11. Each block in this drawing represents a physical component or a subassembly of the airborne system. The system, as illustrated by this diagram, consists of three major sections: the output section, which consists of the five actuators which operate the helicopter flight control linkages; the input section, which includes power supply, pilot switching and the input signal sources; and the control junction box, which contains the interconnections for the input and output devices, test switches, and other ancillary components. The output section was installed in the copilot area. The input section and control junction box were installed on the right passenger's seat.

### Ground Control Station

The ground control station includes the following equipment:

1. Transmitter (Babcock Model T-450/ARW-66) - This unit is used to transmit the ground control signals from the ground coder to the airborne receiver-decoder. It is tuned to operate on a carrier frequency of 406.4 MC.

2. Coder (Babcock Model BCC-6) - This component supplies audio tones ranging from 7.5 KC to 73.95 KC in frequency to the

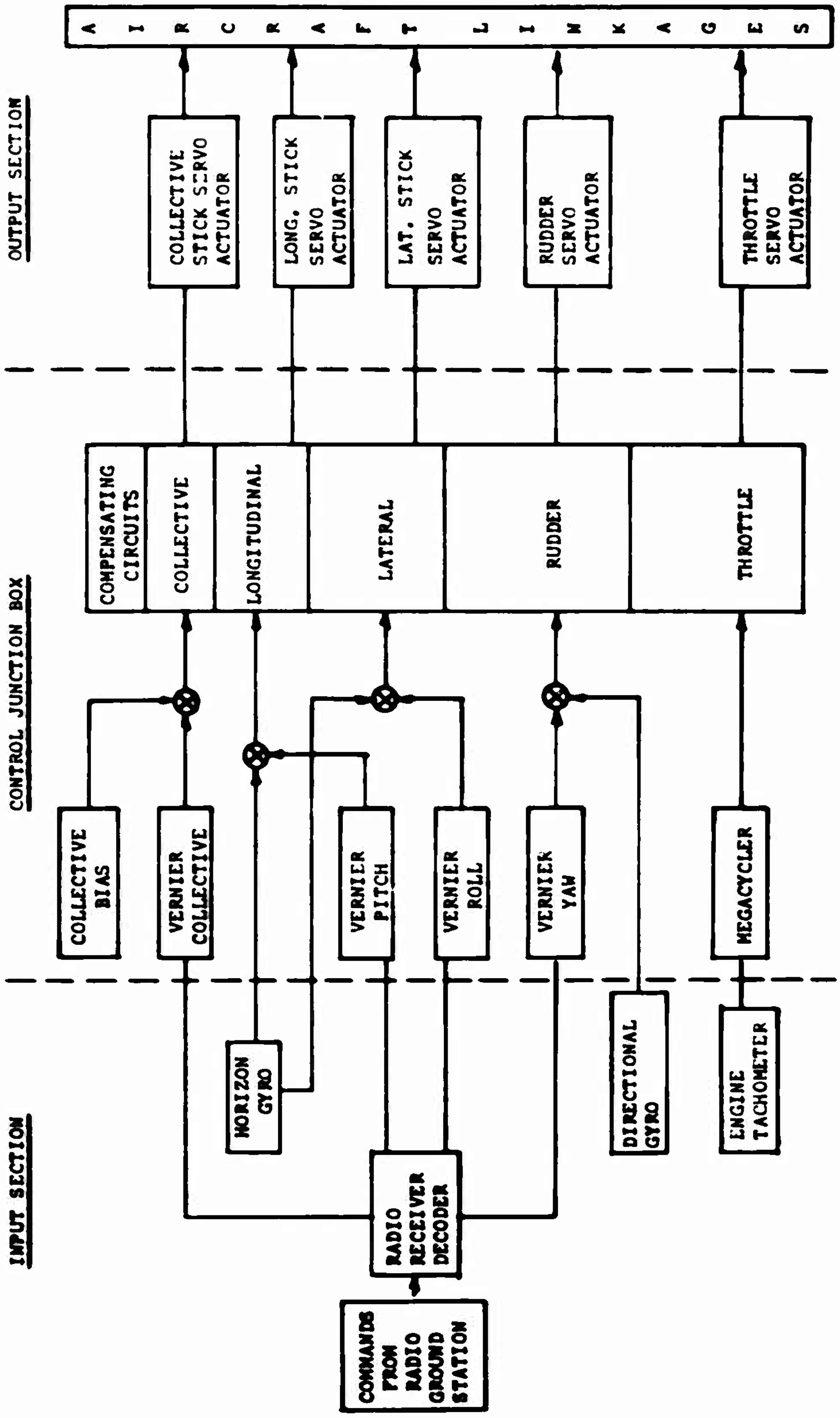



Figure 11. Airborne Equipment Block Diagram.

transmitter. Each tone can be switched on by means of a toggle switch mounted on the front panel of the coder. When a toggle switch is thrown to the "on" position, it causes a relay to pull in. This relay actuates the associated tone oscillator and switches the tone signal to the audio output buss. There are 20 such switches, 1 for each tone supplied by the coder. Any 6 tones can be supplied to the audio output simultaneously without exceeding the operation limitations of the equipment.

3. Remote Control Unit - This unit is designed for ground control simulation of the aircraft controls. The remote control unit is equipped with a pilot trim switch (momentary four-position switch) which simulates the aircraft cyclic stick, while the collective is simulated by a momentary single-pole double-throw switch. The operation of these switches allows the ground controller to actuate the vernier signal to the airborne system. The following additional controls are also supplied by the remote control unit:

    a. Collective Bias "On" - A toggle switch which, when thrown to the "On" position, causes the collective bias relay in the aircraft system to pull in, thereby supplying an "Up" command to the collective stick. This control is used to initiate the flight.

    b. Power Adjust - This is a toggle switch which, when thrown to the "On" position, causes the power adjust relay in the aircraft system to pull in, thereby switching the collective bias signal to command the collective stick to a cruise position.

    c. Shut Down - This is a toggle switch with which the ground operator may simultaneously close the throttle and de-clutch the rotors following an emergency recovery of the test vehicle.

    d. R. F. Carrier - This is a toggle switch which enables the operator to turn the transmitter carrier "On" or "Off" from the remote controller station.

## TEST CONDITIONS

The impact conditions planned for the two tests were as follows:

| | T-21 Vertical Drop Test | T-22 Drone Crash Test |
|---|---|---|
| 1. Forward Speed | 0 | 42 ft/sec |
| 2. Vertical Speed | 25 ft/sec | 25 ft/sec |
| 3. Flight Attitude | Level | Level |
| 4. Soil Condition | Even, moderately packed | Even, moderately packed |
| 5. Rotor Speed | 0 | Normal operating range |

## TEST RESULTS

### AIRFRAME STRUCTURAL PERFORMANCE, T-21 (Crane Drop)

The aircraft was suspended from the boom of a parked crane and dropped from a height of 9 feet, resulting in a vertical impact velocity of 1500 feet per minute, or 25 feet per second. The aircraft was dropped onto level, moderately packed soil and impacted in a level attitude. The skids deformed at a maximum load of approximately 8G until the rear portion of the fuselage directly below the passenger cabin contacted the ground. The forward portion of the fuselage then settled and also contacted the ground. A complete set of acceleration, load, and pressure time histories is included as Appendix I.

Figure 12 is a postcrash view of the left side of the aircraft. (Note that the forward end of the fuselage is still inclined in a slightly nose-up attitude). With the exception of the deformation of the skid cross members, very little structural deformation occurred. Some slight buckling resulted in the tail boom section directly above the rear skid cross member. Slight deformation and bending also occurred at the engine and transmission support attachments.

Figure 12. Postcrash View of the T-21 Aircraft (Left Side). Note the slight nose-up attitude.

Figure 13 is a close-up view of the right side of the aircraft, showing the deformed skid cross member directly below the pilot's seat. Figure 14 is a postcrash rear view of the aircraft, showing the manner in which the skid cross members deformed at impact. Figure 15 is a postcrash front view of the aircraft.

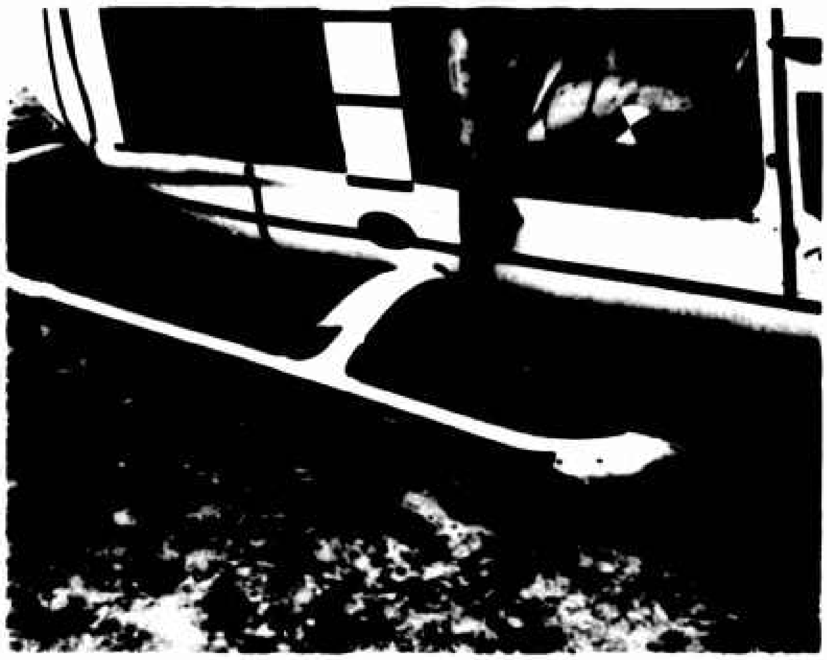


Figure 13. Right Side Postcrash View of T-21 Aircraft, Showing Deformed Forward Skid Cross Member.

The test indicates that the OH-4A landing gear will attenuate a sinking speed of approximately 15 feet per second. The tapered-wall cross tube used in the gear is a good concept, and the gear performed approximately as intended. Improvements are possible, however, and the present state of the art should permit the design of gears which would allow sinking speeds of 20-25 feet per second for small aircraft without transmitting excessive acceleration forces to the occupants. Such a design would require an effective average deceleration of 8-10G over a distance of about 1 foot. Although the OH-4A gear placed a maximum load of 8G on the helicopter, this load was not maintained constant throughout the 1 foot of travel, indicating failure of the gear to completely utilize the available deceleration distance.

Figure 14. Postcrash Rear View of the T-21 Aircraft, Showing the Manner in Which the Rear Skid Cross Member Deformed at Impact.

Figure 15. Postcrash Front View of the T-21 Aircraft.

AIRFRAME STRUCTURAL PERFORMANCE, T-22 (Drone Flight)

The test conditions which occurred during the drone flight were influenced by the meteorological environment (primarily wind). Due to the presence of a gusting crosswind of approximately 10 knots during the test, coupled with the normal torque action of the rotor system, the aircraft yawed sharply to the right just after takeoff. The remote control system tended to overcorrect, resulting in a series of yaw movements (five in all) which caused the aircraft to move off course to the right, approximately 100 feet off the intended flight path. Just before initiation of the crash, the aircraft was beginning to stabilize with respect to directional control.

At the point where crash action was initiated by reducing rotor blade pitch, the aircraft was at an altitude of 49 feet, at a forward speed of approximately 25 knots, and approximately 100 feet to the right of the intended impact area. As pitch was reduced, the aircraft fuselage began to rotate to the left. This was caused by difficulty in compensating for the reduction in engine torque with sufficient reduction in tail rotor pitch. The situation was further complicated by the increased tail rotor pitch required to compensate for the increased torque used in lift-off. (Directional control of the OH-4A is very sensitive, with changes in power causing rapid yawing movements unless controlled by the proper degree of tail rotor pitch). It appears that the remote control system was unable to react quickly enough to prevent the yawing movement which occurred.

A photograph of the flight taken by a Fairchild Flight Analyzer is shown in Figure 16. The flight from the point of pitch reduction to impact and some of the crash sequence are shown in the sketches of Figure 17.

A study of the flight profile just prior to impact and the crash sequence on high-speed film revealed that the aircraft yawed approximately 100 degrees and pitched nose down approximately 30 degrees from the time of pitch reduction to the point of impact. The aircraft impacted in a nose-down, level attitude, traveling slightly backward and to the right, as shown in Figures 16 and 17.

The actual impact conditions of the aircraft, as determined from analysis of high-speed films and recorded data, were as follows: (1) forward speed*, approximately 15 knots; (2) vertical speed, approximately 2,000 feet per minute, or 34 feet per second; (3) attitude: pitch - 30 degrees

*Because of the yaw attitude of the aircraft, this speed actually relates to the flight path speed. The aircraft was actually traveling slightly rearward at the time of impact.

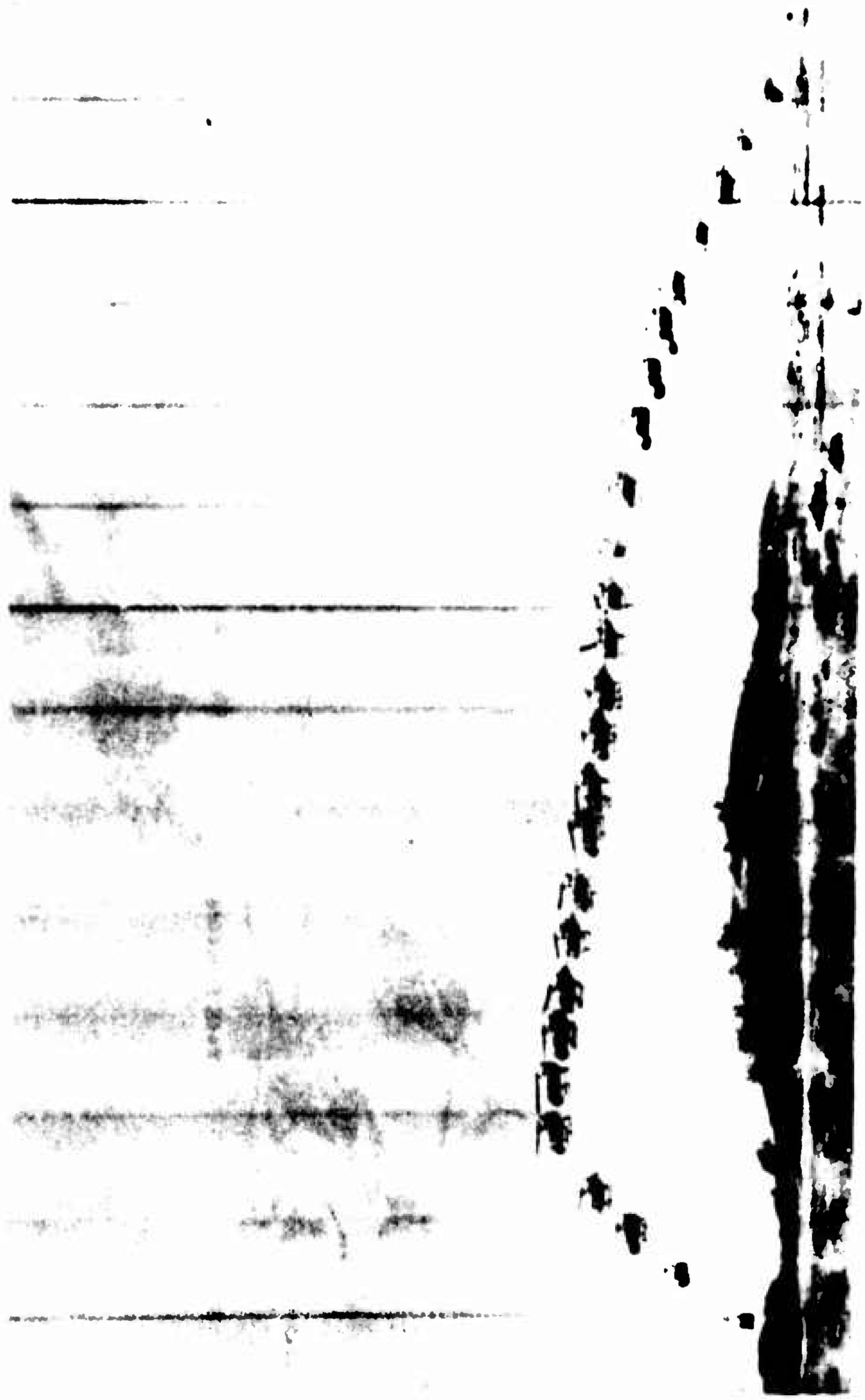


Figure 16. Flight Profile Photo of T-22.


Figure 17. T-22 Crash Flight Path and Impact Sequence.

nose down, roll - 0 degrees, and yaw - 100 degrees to the left of flight path.

The acceleration force, load, and pressure time histories are shown in Appendix II. The zero time on the scale is an arbitrary point used for plotting purposes only and is actually about 3 milliseconds prior to the contact of the skids with the ground.

Shortly after the nose contacted the ground, at about 0.04 second in the time history plots, significant vertical accelerations were experienced throughout the fuselage and in the dummies. At approximately 0.18 second after impact, the nose of the aircraft began to rise; and at 0.27 second, the tail cone fin contacted the ground. The tail cone began to separate from the fuselage at about 0.41 second. The tail rotor drive shaft separated approximately 16 inches aft of the rear end of the engine and flailed in this area.

Following the initial impact, the next event which significantly influenced the acceleration environment was one of the rotor blade's contacting the ground, at approximately 0.49 second. The aircraft, which was rolling to the right and to the rear prior to this point, stopped this movement and was kicked to the left and upward when the blade hit the ground. This caused severe acceleration throughout the structure and the dummies between 0.53 and 0.62 second. The rotor mast failed just below the blade hub at approximately 0.53 second. The second blade struck the ground at approximately 0.58 second, continued to rotate, and, at approximately 0.64 second, struck the cockpit canopy frame, causing the indentation shown in Figure 18.

It is probable that the transmission mounting failed upon impact of the blade tip with the ground. The rear transmission mounting brackets were pulled through the roof of the aircraft and exited with the transmission support yoke. The forward arms of the yoke fractured on both the right-hand and left-hand sides, leaving part of the yoke and the forward mounting brackets with the aircraft. The transmission came to rest approximately 25 feet in front of the aircraft.

Figure 18. T-22 Postcrash View. Note canopy deformation near pilot's left shoulder.

## DISCUSSION OF TEST RESULTS

### POSTCRASH FIRE PROTECTION

The threat associated with postcrash fire is a function of the behavior of the systems containing the flammable fluids and the availability of potential sources of ignition.

Neither T-21 nor T-22 provided all the potentials for postcrash fire. However, an indication of what might be expected in this particular type of aircraft was demonstrated.

The flammable fluids carried aboard the aircraft which are potential fire hazards are fuel; engine, transmission, and tail rotor gearbox oil; and hydraulic fluid.

The tail rotor gearbox oil can be eliminated as a major potential fire threat because of its small quantity and because of the physical distance separating the gearbox from the primary ignition sources, i.e., hot engine components and engine flames.

The fuel tank of the OH-4A is a crash-resistant flexible bag type container. It is installed in a honeycomb structure and is located below and aft of the passenger's seat. The honeycomb structure and the elimination of vertical aircraft structures which could penetrate the tank during severe impacts are sound design concepts. The most vulnerable areas of the tank are the rigidly mounted fittings, pumps, and fueling inlets.

In the two tests conducted, neither the fuel cell nor the surrounding structure failed. Overpressures, measured near the front center of the fuel tank, reached maximums of 38 psi in T-21 and 10 psi in T-22 (Figures 19 and 20). In T-22, there was a small amount of leakage (estimated at less than 1 gallon) from the fuel tank vent due to the final attitude of the aircraft (Figure 21). Had real fuel been used in the tank, it is quite possible that a fire would have occurred, since the engine continued to operate for approximately 2 minutes after the crash and flames and sparks from the engine were noted near the spillage area. However, it is very unlikely that the tank would have exploded, since there was no vapor trail to the interior of the tank. The fire would have been localized around the vent, and the hazard to human life would have been small. Due to the small amount and limited area of spillage, no plot of the spillage area was made.

The transmission, hydraulic, and engine oils do not, by themselves, pose a serious threat because of the small quantities involved. However,

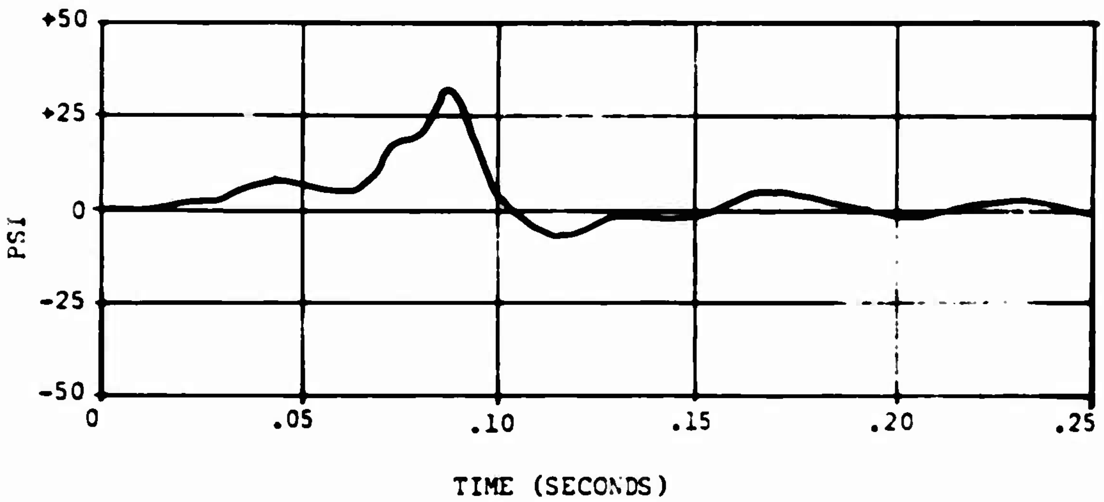



Figure 19. Pressure-Time Plot of Fuel Tank, T-21.

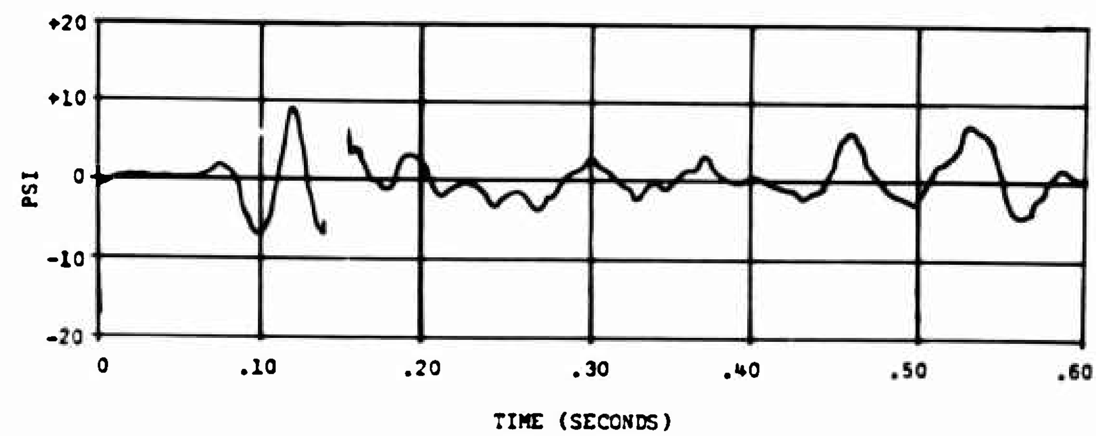



Figure 20. Pressure-Time Plot of Fuel Tank, T-22.

these fluids are easier to ignite than the fuel carried aboard the aircraft; as a result, they often serve as a second-generation ignition source. For example, the engine oil, which ignites easily, serves as the ignition source for the fuel. On this basis, they must be considered a serious postcrash fire threat.

When the transmission in T-22 separated from the aircraft following impact, the engine and the fuel, oil, and hydraulic lines to the engine remained intact, reducing the possibility of a postcrash fire. However, oil spilled through the broken fittings of lines attached to the transmission. The use of breakaway fittings would greatly improve the safety attributes

Figure 21. Fuel Leakage From Tank Vent, T-22.

of the aircraft. Steel fittings, although less desirable than the break-away fittings, are much more crashworthy than the aluminum fittings used on the OH-4A. While none of the flexible lines failed, a number of fittings failed at points where the lines attached to the various components, such as actuators, oil cooler, etc. The relative weakness of the aluminum fittings effectively cancels many of the benefits derived from the performance of the flexible lines.

There were no failures or penetrations of the engine oil reservoir. This is attributed to the fact that the reservoir is installed in a manner which allows for flexibility and considerable displacement at the reservoir before failures occur. Its location aft of the engine also reduced the possibility of the reservoir's being crushed during a variety of separate impacts.

The greatest danger to the reservoir would appear to be the tail rotor drive shaft, which passes directly below the reservoir. Although the drive shaft was broken in T-22 and flailed in the general area of the reservoir, no damage occurred. In an impact causing complete separation of the engine, the reservoir would likely stay with the fuselage, fluid lines would be severed, and a fire resulting from engine ignition would be a possibility. For this reason, crash-disconnect fittings are also recommended for the engine flammable fluid lines.

Two of the ignition sources during a crash are hot engine components and exhaust flames. A method for preventing ignition of spilled combustibles is to isolate the engine. In this aircraft, the hot engine components are isolated by cowling. The cowling, however, is not very rigid or crash durable. During the crash of T-22, the cowling separated on the right side, exposing the hot, running engine to the spilled combustibles. Steps should be taken to improve the design of this cowling so as to prevent its separation during a moderate to severe crash, in order to more adequately isolate the engine during a crash. As shown in Figure 22, the muff heaters were dislodged from the engine during the crash, allowing hot exhaust to be deflected downward into the area of the spilled simulated combustible fuel.

Figure 22. Postcrash View of Engine Area, T-22.

The electrical wiring in this aircraft is fairly well protected in the structure. As a result, it did not play a major role as a potential ignition source. Several wires that are installed in the tail boom of the aircraft were severed during the crash sequence. This could be prevented by providing extra length and slack in these wires to allow for deformation in the tail boom structure during a crash. Wiring in the transmission area was also separated in several places as a result of the transmission's separating from the aircraft. Breakaway-type terminals or connectors should be used where damage such as this can be anticipated.

In summary, the crash fire safety aspects of this light observation helicopter are better than average. The failures in the flammable fluid line fittings and the leakage from the fuel tank vent indicate that a fire threat was present. However, the absence of any catastrophic failures or massive leakage from the flammable fluid systems indicates that fire would not likely be a hazard to life.

## PROTECTION AFFORDED OCCUPANTS BY FLOOR AND SEAT CONSTRUCTION

The design concept of the OH-4A honeycomb floor structure is "the maintenance of livable volume through resistance to deformation". There is no intended energy absorption for occupant deceleration in the vertical direction in this structure. In both T-21 and T-22, the floor structure performed exceptionally well in accordance with this concept, and it is probable that the floor will resist both longitudinal and lateral loads in much the same manner. Figures 21 and 23 show the lack of lower fuselage buckling usually seen in impacts of the type experienced here.

Figure 23. Side View of T-22 Aircraft Fuselage on Blocks With Dummies and Equipment Removed.

Neither T-21 nor T-22, however, afford a complete evaluation of the protection afforded the occupants by the floor construction, since neither test included an appreciable forward velocity component or penetration type obstructions such as rocks and tree stumps.

The stiffened honeycomb fuselage structure offers two disadvantages over the conventional frame-skin construction. First, the vertical acceleration in flat impacts is unattenuated since there is little deformation of the structure. This deformation is needed to provide the appropriate "deceleration distance" to reduce floor-level deceleration values. Figures 24 and 25 show the cockpit floor and the passenger floor vertical accelerations for T-21. Even in this 25 ft/sec impact on soil where the landing gear reduced the vertical velocity at impact of the fuselage proper to about 16 ft/sec, the accelerations averaged 25G and 38G peak values, respectively.

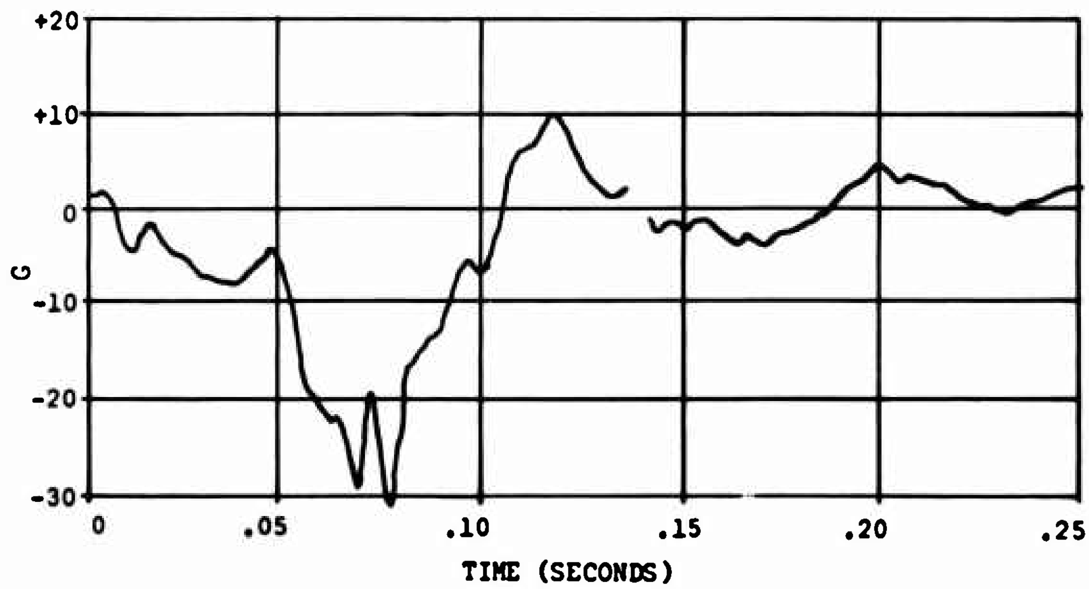



Figure 24. Vertical Acceleration-Time Plot of Cockpit Floor, T-21.

The second disadvantage of the stiffened honeycomb structure is the tendency of the forward edge to dig in or plough during impact in soft soil. This action will produce high longitudinal accelerations, thus increasing the possibility of transmission mount failure and overturning of the aircraft. This disadvantage could be offset by providing a keel-like extension in the lower console region. Such structure would necessarily have to provide sufficient load-carrying capacity to cause the forward lip of the floor to ride over obstructions in nose-down impacts. The console structure in the OH-4A does not provide this load-carrying capacity. It was deflected upward in T-22 and would probably be readily pushed rearward into the seat area under certain impact conditions.

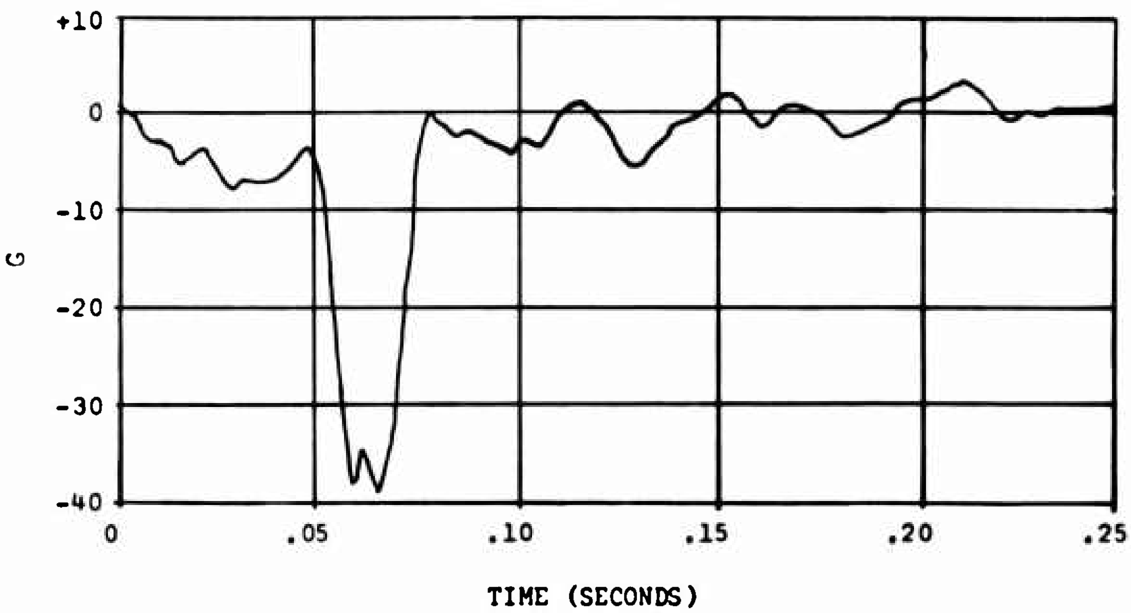



Figure 25. Vertical Acceleration-Time Plot of Passenger Floor, T-21.

The vertical accelerations in T-22 are in general agreement with the results obtained in T-21. Although the vertical impact velocity in T-22 was higher than in T-21 (34 ft/sec versus 25 ft/sec), the floor and pelvic accelerations were lower in T-22 than in T-21 (Appendix I, II). This occurred because the nose-down impact in T-22 allowed a larger effective deceleration distance. The vertical pelvic accelerations in T-22 were probably in no more than the minor injury range since accelerations of less than 20G were recorded for both the pilot and the passenger. In T-21, the 60G peak for the passenger and the 30+G peak for the pilot would probably have produced moderate to severe injury.

The seat construction of the OH-4A afforded little energy absorption appropriate to a safe deceleration level for the occupants. The pilot-copilot seat pans did buckle as intended in both T-21 and T-22 (Figures 26, 27 and 28). However, they absorbed only a limited amount of energy because of the short deceleration distance (2-3 inches) and the nonuniform deformation of the seat pans. Control arms under the seats as shown in Figure 29 limit the travel of the seat pans.

The crushing force of the plastic foam pads on the pilot-copilot seats is too high (20-40 psi) to be of any value in reducing torso forces to the desired 20G level. In the tests, the cushions broke laterally and conformed to the seat pans. However, no crushing of the foam could be

Figure 26. Postcrash View of Copilot Seat Pan, T-21.

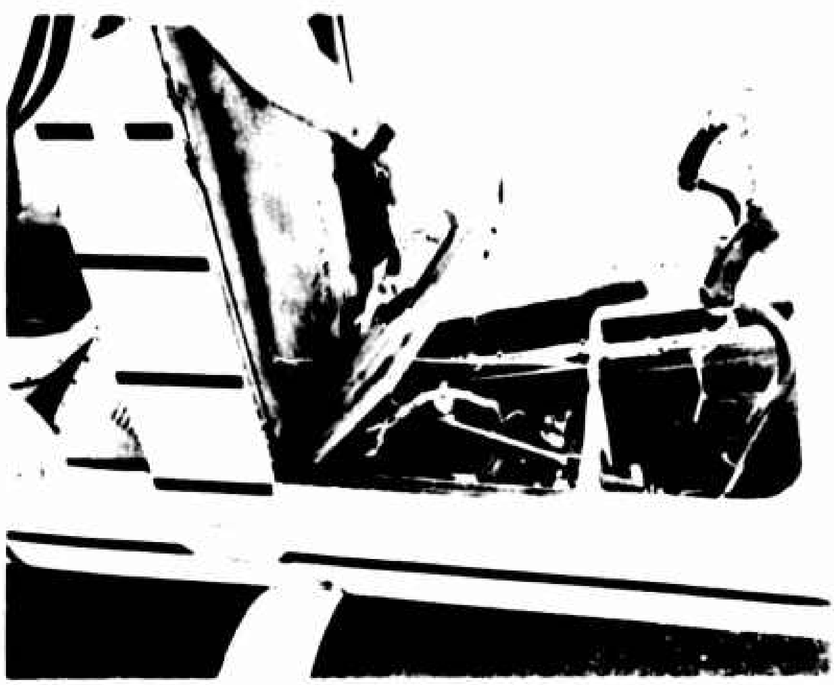


Figure 27. Postcrash View of Pilot Seat Pan, T-21.

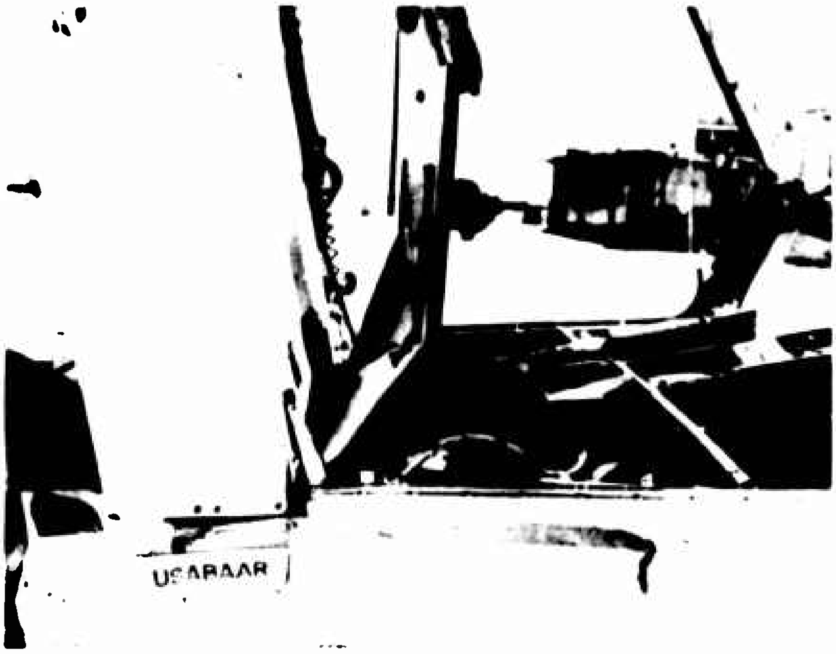


Figure 28. Postcrash View of Pilot Seat Pan, T-22.

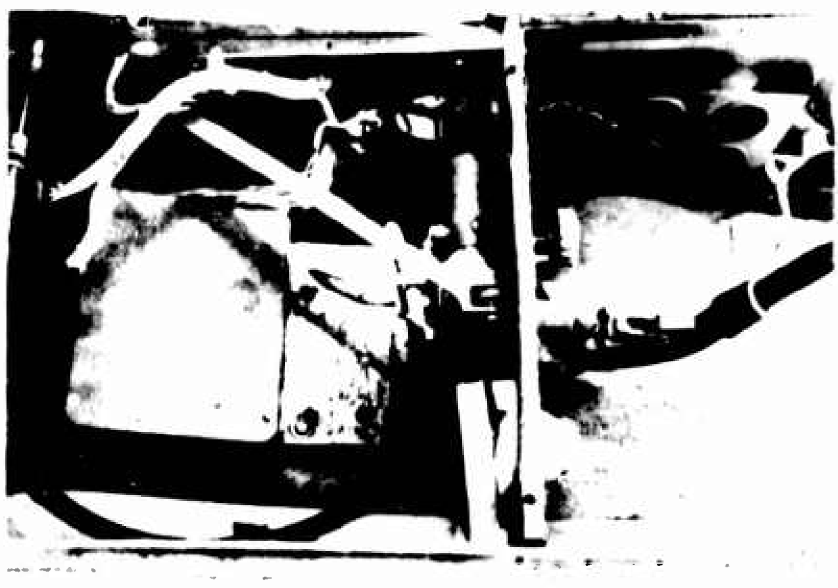


Figure 29. Pilot Seat Area With Seat Pan Removed. Note control rod which limits deformation of seat pan, T-22.

detected (Figure 30). To provide any effective energy absorption, the crushing strength should be reduced to 10 psi or less. The foam rubber pad over the plastic foam is for comfort only and provides little or no energy absorption. The relocation of the control arms and the installation of some energy-absorbing material between the seat and the floor would greatly reduce the vertical deceleration forces on the pilot and copilot.

Figure 30. Postcrash View of Seat Pan, T-21.

The only energy-absorbing material for the passenger seat is in the elastic foam rubber seat cushion. This material is very poor for this purpose, as it absorbs very little energy and allows bottoming of the occupant on the supporting structure. In the OH-4A, the supporting structure of honeycomb panels is too stiff to provide any deformation and effective deceleration distance (Figures 31 and 32). In T-21 the cushion and seat structure resulted in a peak acceleration of 69G on the passenger dummy (Figure 33). The passenger floor acceleration was measured at 40G. When compared with the acceleration figures of 32G for the pilot dummy and 30G for the cockpit floor, the effectiveness and necessity of even a short (2-3 inches) deceleration distance are apparent. The acceleration levels for T-22 were considerably reduced because of the longer deceleration distances resulting from the 30° nose-down attitude of the helicopter at impact. An interesting observation is that the acceleration magnitudes of the dummies in T-22 never exceeded human tolerance levels, while in the static drop of 9 feet in T-21, moderate to severe injuries could be expected.

Figure 31. Postcrash View of T-21 Passenger Seat Pan.

Figure 32. Postcrash View of T-22 Passenger Seat Pan.

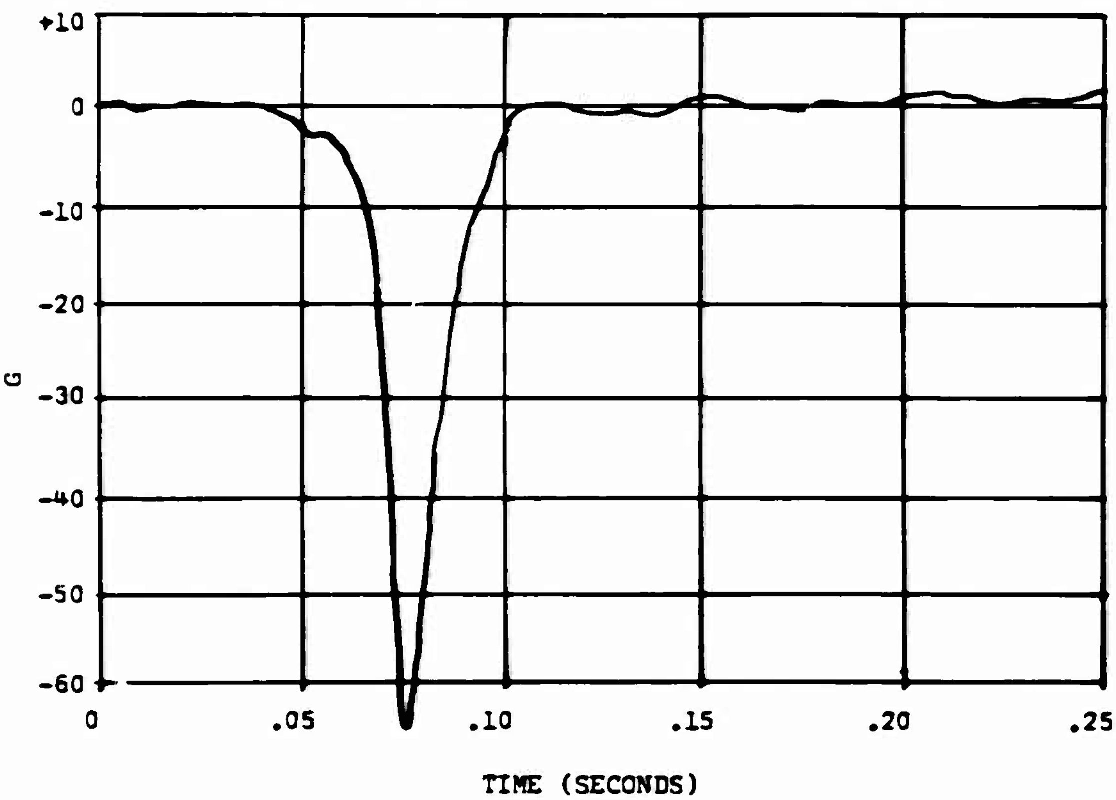



Figure 33. T-21 Passenger Vertical Pelvic Acceleration-Time Plot.

RESTRAINT SYSTEM

Neither T-21 nor T-22 produced sufficient longitudinal accelerations to fully test the OH-4A occupant restraint system. An evaluation of the system was made, however, and several factors were revealed.

Flexible fittings for the anchorage of seat belts are desirable and are used throughout. However, the strength of the fittings for the pilot and copilot belts is 2,250 pounds, well below the 6,000 pounds recommended by AvSER (the fittings are weaker than the belts). The angle of the belt to the seat is also inadequate ($32^{\circ}$ versus the recommended minimum of $45^{\circ}$). For the passengers, the strength of the belts is much more acceptable: 5,200 pounds. The angle of installation, $42^{\circ}$, is also more acceptable. The width of all belts, 1-3/4 inches, is less than the recommended 2-1/2 inches.

The shoulder harnesses are also considered inadequate in both strength and installation design. The pilot-copilot harness and inertia reel are designed to withstand forces of only 1,500 pounds, well below the recommended 4,000 pounds. Strap guides are not provided for the pilot-copilot seats. This deficiency allowed the upper torso of the pilot dummy in T-22 to move partially out of the cockpit during the crash sequence. The pilot's right arm was pinned between the ground and the fuselage, and his helmet was wedged between the ground and the ceiling structure as shown in Figure 18. Although the doors were removed prior to the test, it is felt that the doors would have failed at the first impact and would not have appreciably altered the motion of the dummy. The passenger shoulder harnesses have a strength of 2,000 pounds, also below the desired 4,000 pounds. They do, however, provide adequate lateral restraint, and the passenger dummy in T-22 was retained in good position during the test. Figures 34 and 35 show the pilot's lateral acceleration-time curves, with notations of specific events during the T-22 crash sequence. The lateral forces on the pilot dummy, and the other dummies in both T-21 and T-22, were well within the survivable limits and imposed only minor loads in the restraint systems. The inertia reels supplied for the tests by USABAAR in both T-21 and T-22 locked upon impact.

## INJURY POTENTIAL OF OBJECTS IN COCKPIT

The OH-4A is a compact aircraft leaving little clearance between the occupant's head, the door, and the door and ceiling frames. The overhead control console between the heads of the pilot and the copilot may also present some hazard. The lateral head impacts for T-22 are shown in Figure 35. None of the pulses are considered injurious, since the human is quite capable of sustaining up to 4 to 5 times the acceleration levels recorded without injury due to brain damage. However, there is almost no data on the effect produced on neck vertebra and tissues due to head accelerations.

The main console would provide an injury-producing potential in impacts with a front-to-rear load being applied to the nose region, thus allowing the console to be moved rearward into the occupiable area. Increased load-carrying capacity should be provided to maintain continuity of this cantilevered structure. The failure of the console in T-22 is shown in Figures 18 and 23. The console could also prove damaging to the crew's legs. The sharp edges could cut or severely bruise the calf and knee areas, especially in impacts causing lateral accelerations. The lower edges of the console should, therefore be padded with a high energy-absorbing material.

The antitorque pedal area is forward of the honeycomb fuselage and extremely vulnerable in impacts with any forward velocity. The crew's feet could easily be trapped by the pedals or objects penetrating the area from the exterior. Extending the fuselage under this area would help to alleviate this situation.

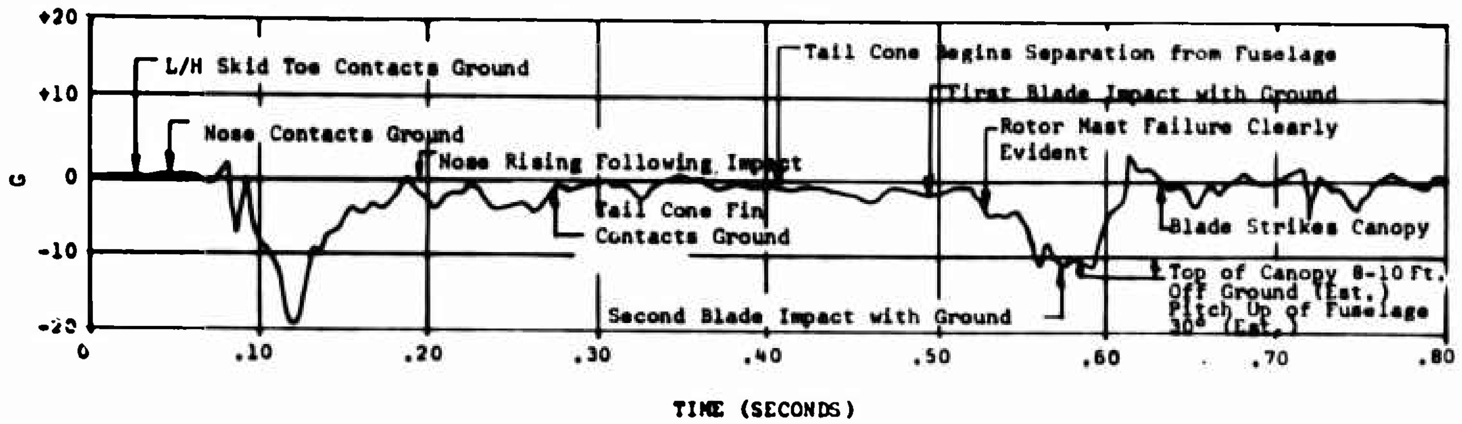



Figure 34. Pilot Lateral Pelvic Acceleration-Time Plot, T-22.

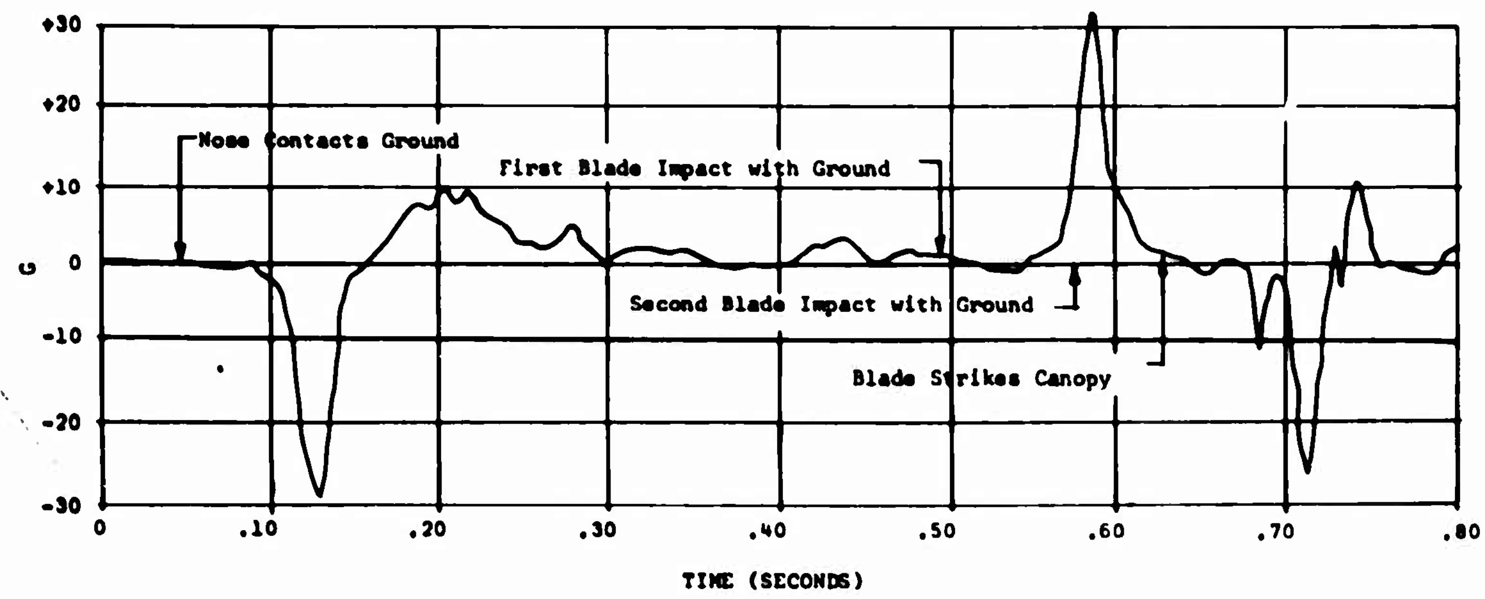



Figure 35. Pilot Lateral Head Acceleration-Time Plot, T-22.

The injury potential created by the lack of a shoulder harness guide on the pilot's and copilot's seats was discussed previously, in the passenger restraint section.

VOLUME REDUCTION IN CREW STATION AREAS

The continuity of the OH-4A structure in the occupiable area is apparently good. The box-type vertical and longitudinal beams used in the passenger area provide resistance to both vertical and longitudinal decelerative loads. High-speed films of the impacts in both T-21 and T-22 show little deformation of the occupiable areas. Even though the 34 ft/sec (vertical velocity) of T-22 produced failures at almost all main structural joints, the redundancy built into these joints still provided load-carrying capacity in most cases. Exceptions are the forward fuselage and the center vertical support column just aft of the forward seat. Both failed completely and were no longer capable of carrying load.

MOVEMENT OF COMPONENTS WHICH COULD CAUSE INJURY

There are five major components of the OH-4A which pose threats of varying degree to the occupants under conditions resulting in major displacement of these components. They are the (1) rotor system, (2) transmission, (3) engine, (4) instrument console and (5) landing gear. The behavior of the instrument console as observed in T-22 has been discussed in a previous section.

In T-22, the first contact of the rotor system and the ground occurred at 0.495 second. Between this point and 0.53 second, the rotor mast failed just below the blade hub. Up to the time of the mast failure, the blades remained in a near normal position and did not approach the cockpit area. When the first blade struck the ground, the nose of the aircraft kicked upward and into the path of the second blade. The second blade grazed the top of the forward cockpit frame, buckling the frame inward approximately 4 inches. The closest approach of the blade to the pilot's head was estimated to be about 12 inches. The fuselage frame apparently offered little resistance to the motion of the blades. Following impact with the frame, the blades, still joined by the hub, flew up and to the rear and came to rest approximately 50 feet behind the fuselage.

The transmission separated from the fuselage following the first impact of the rotor blade with the ground. When the rotor mast failed, the transmission was thrown to the right of the fuselage and downward. Although its trajectory from that point was obscurred by dust, it appears that it did not closely approach the cockpit area. The transmission came to rest approximately 25 feet in front of the aircraft. Although not tested in T-21 and T-22, structural buckling could allow the transmission crash restraint lug to be withdrawn from the slot in which it floats. This action, combined with the likely failure of the transmission mounts, would allow the mast to rotate forward. The blades and balance weights could enter the cockpit area with little resistance, and injury to the occupants would be likely. It appears that this situation could be greatly improved upon with little weight penalty, by increasing the strength of the transmission mounts.

The engine remained in place and continued to operate for approximately 2 minutes. Separation from the transmission occurred just ahead of the engine in the drive shaft area. The drive shaft remained shielded and did not pose a threat to the occupants.

The right landing gear cross tubes separated immediately adjacent to the fuselage upon contact with the ground. The right skid passed under the fuselage without entering the cockpit area, struck the left gear, and remained suspended there as shown in Figure 18.

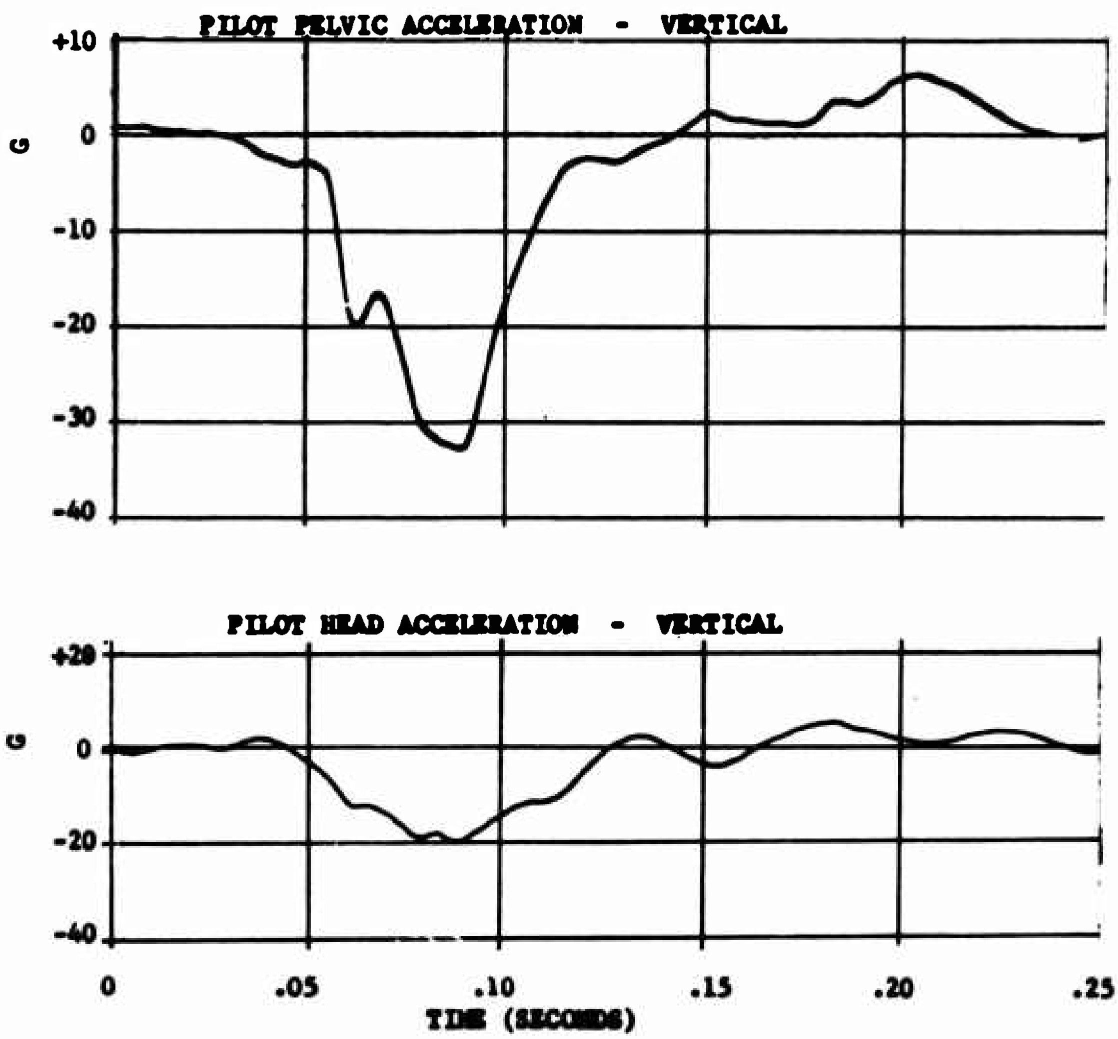
## POSTCRASH INGRESS AND EGRESS

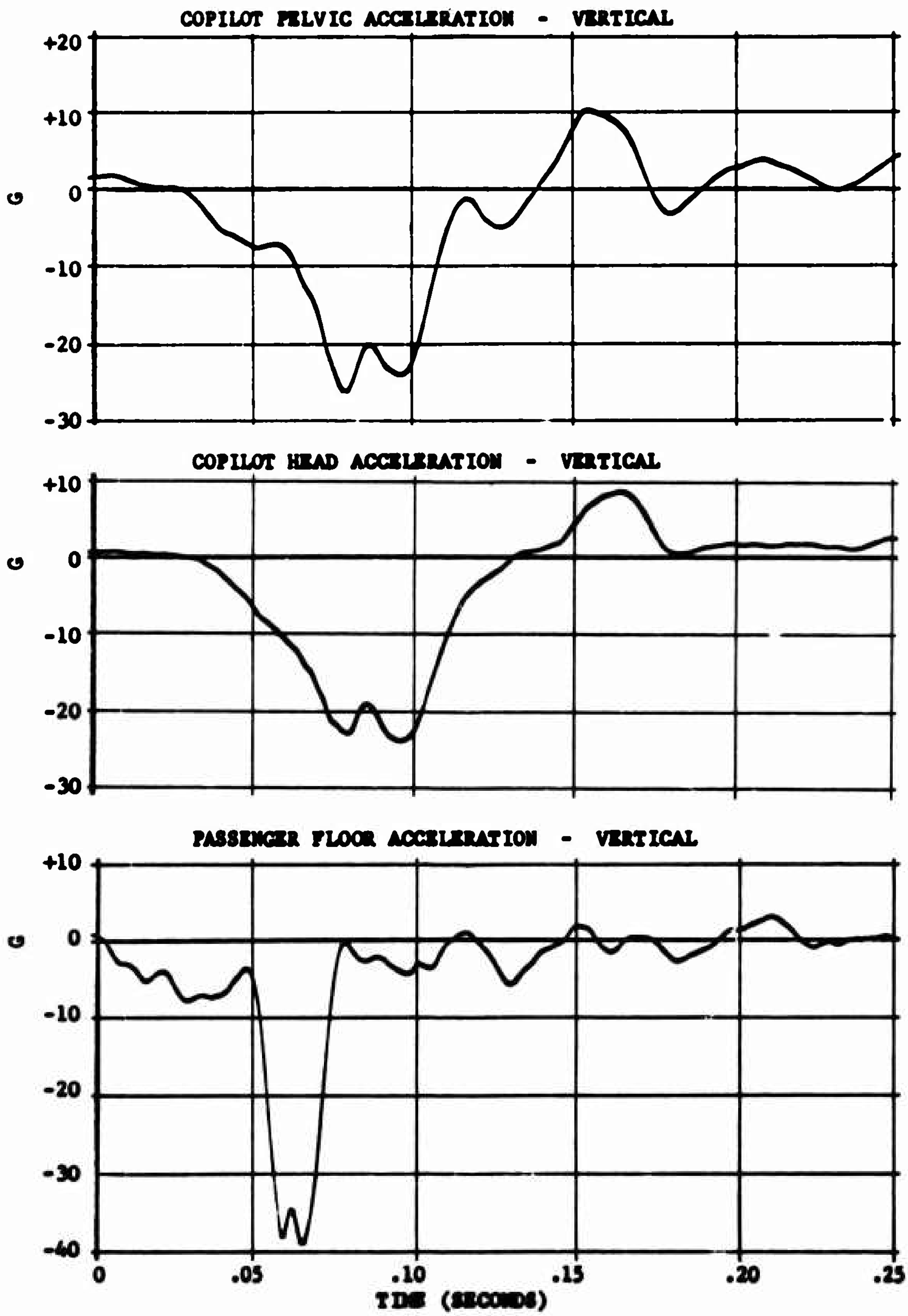
Since the doors of the aircraft were removed prior to the test for photographic purposes, the ease of ingress and egress cannot be fully evaluated. However, the doors would not have hindered evacuation of the pilot and copilot in any event, as adequate openings were assured by the breaking of the canopy during the initial contact with the ground and when the rotor blade impacted with the canopy. The left-hand doors would probably have been operable even if they had remained in place. This has generally proved to be the case in accidents of helicopters with lightly constructed doors, as in the OH-4A. If sufficient fuselage deformation should occur, however, it is possible that the passenger doors could become bound and therefore inoperable. This could delay evacuation of the passengers, particularly if the aircraft were lying on its side as in T-22.

The major problem noted in T-22 was the pilot's arm and helmet being pinned under the fuselage frame. This would present very definite problems, particularly in the event of a postcrash fire.

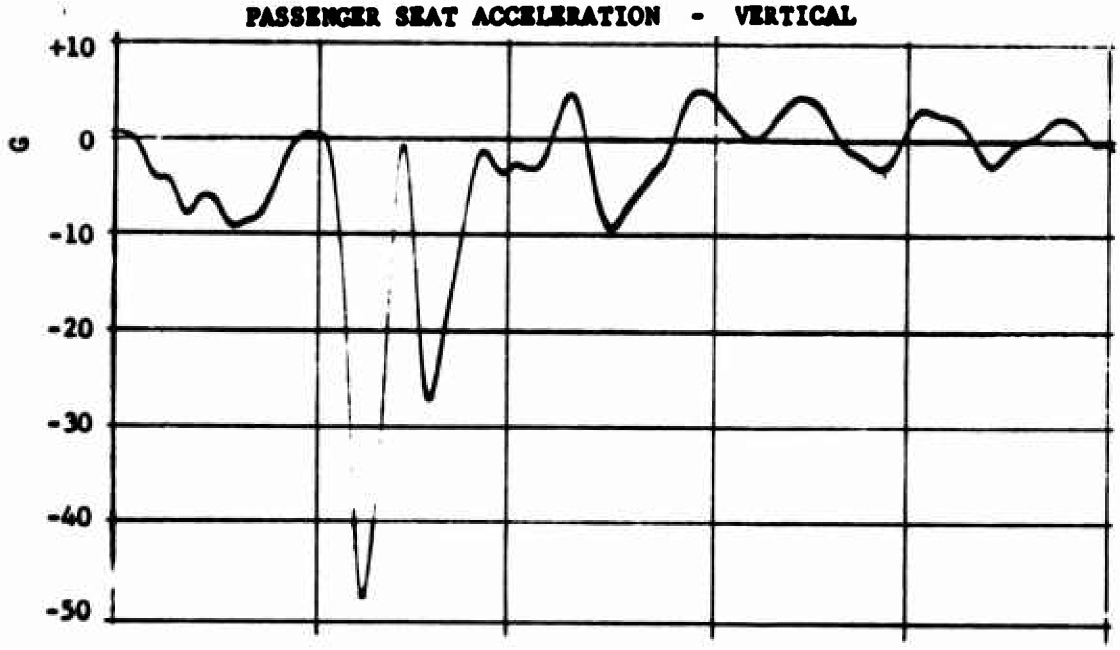
## ROLL-OVER PROTECTION

The 4G design load used in this aircraft is adequate for inverted static loading and minor secondary vertical and lateral impacts occurring in roll-over situations. The satisfactory performance of the main ceiling support structure in T-21 and T-22 suggests that this aircraft will probably meet or exceed the 4G design load. The redundancy provided by the three box-type columns located just aft of the pilot's seat allows the retention of load-carrying capacity even after failure of a major portion of the "overturn" structure. However, the forward fuselage frame (at the front of the forward door hinge line) will offer no resistance to crushing in the inverted position.

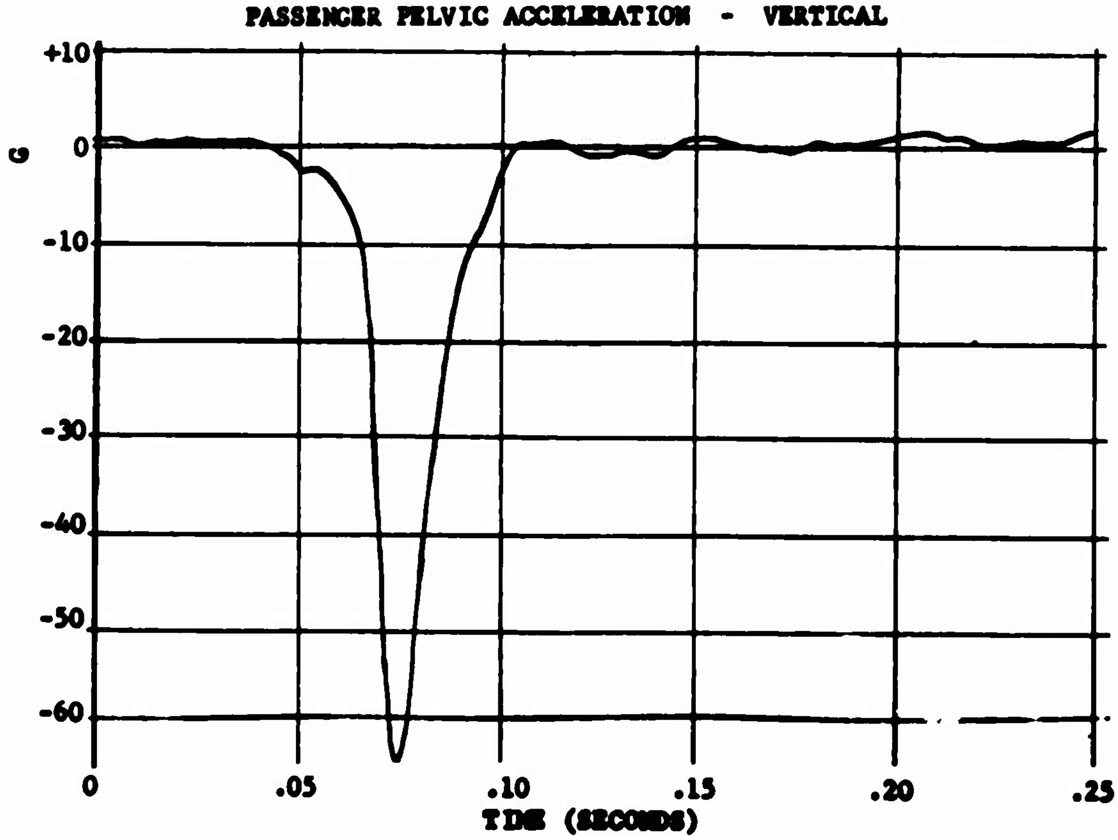

PILOT PELVIC ACCELERATION - VERTICAL
+10
0
-10
-20
-30
-40
G
PILOT HEAD ACCELERATION - VERTICAL
+20
0
-20
-40
G
0
.05
.10
.15
.20
.25
TIME (SECONDS)

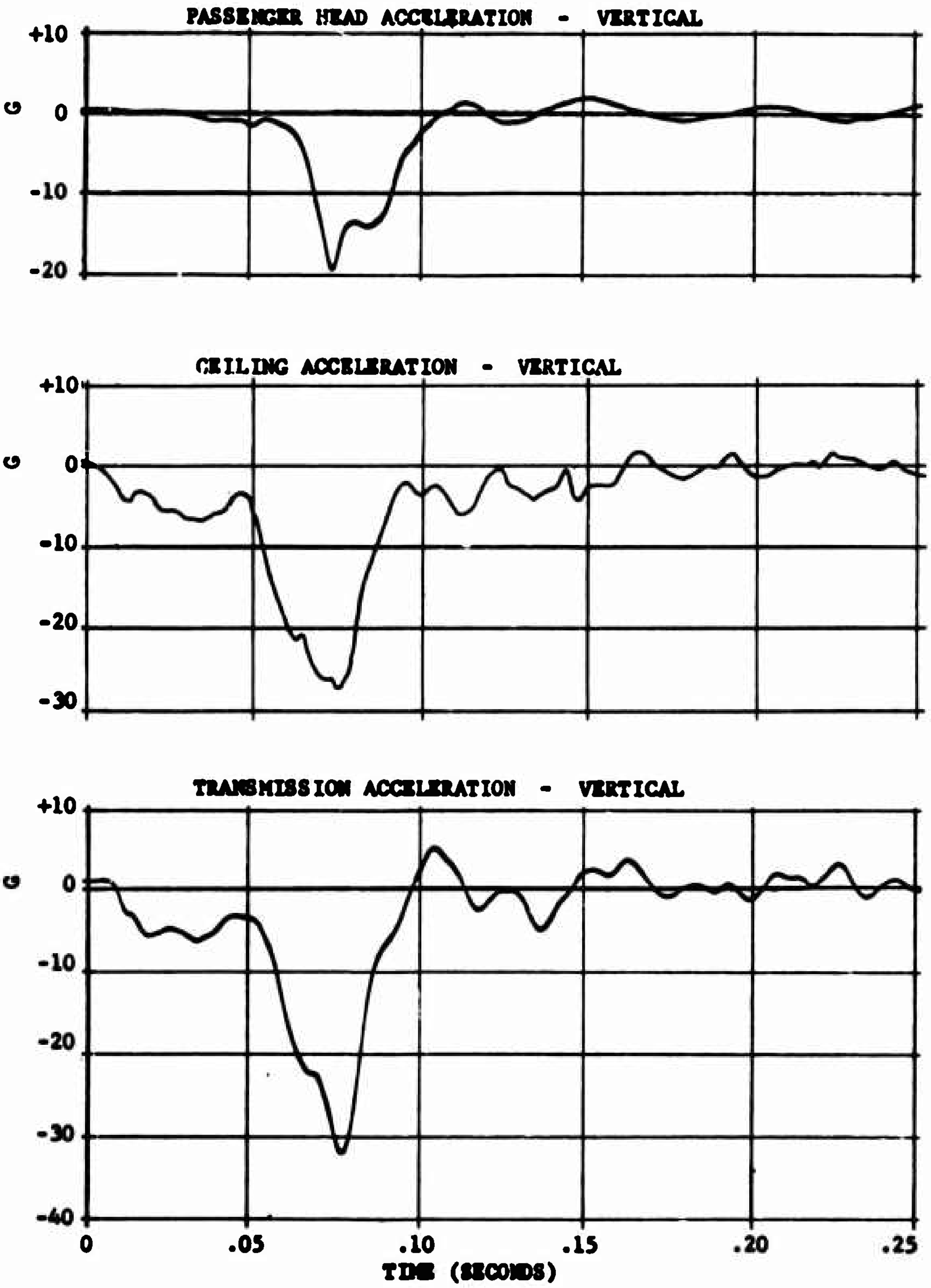

COPILOT PELVIC ACCELERATION - VERTICAL
+20
+10
0
-10
-20
-30
G
COPILOT HEAD ACCELERATION - VERTICAL
+10
0
-10
-20
-30
G
PASSENGER FLOOR ACCELERATION - VERTICAL
+10
0
-10
-20
-30
-40
G
0
.05
.10
.15
.20
.25
TIME (SECONDS)

PASSENGER SEAT ACCELERATION - VERTICAL

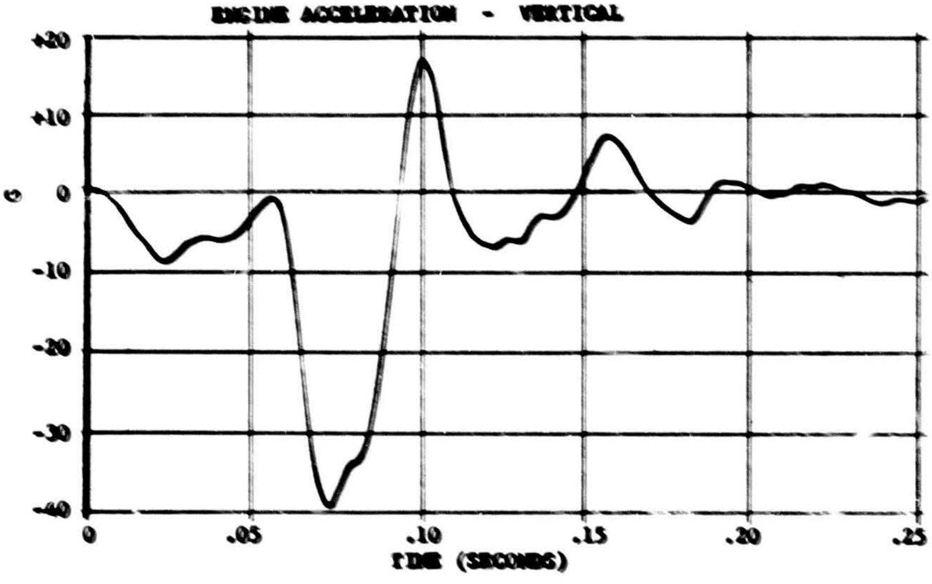


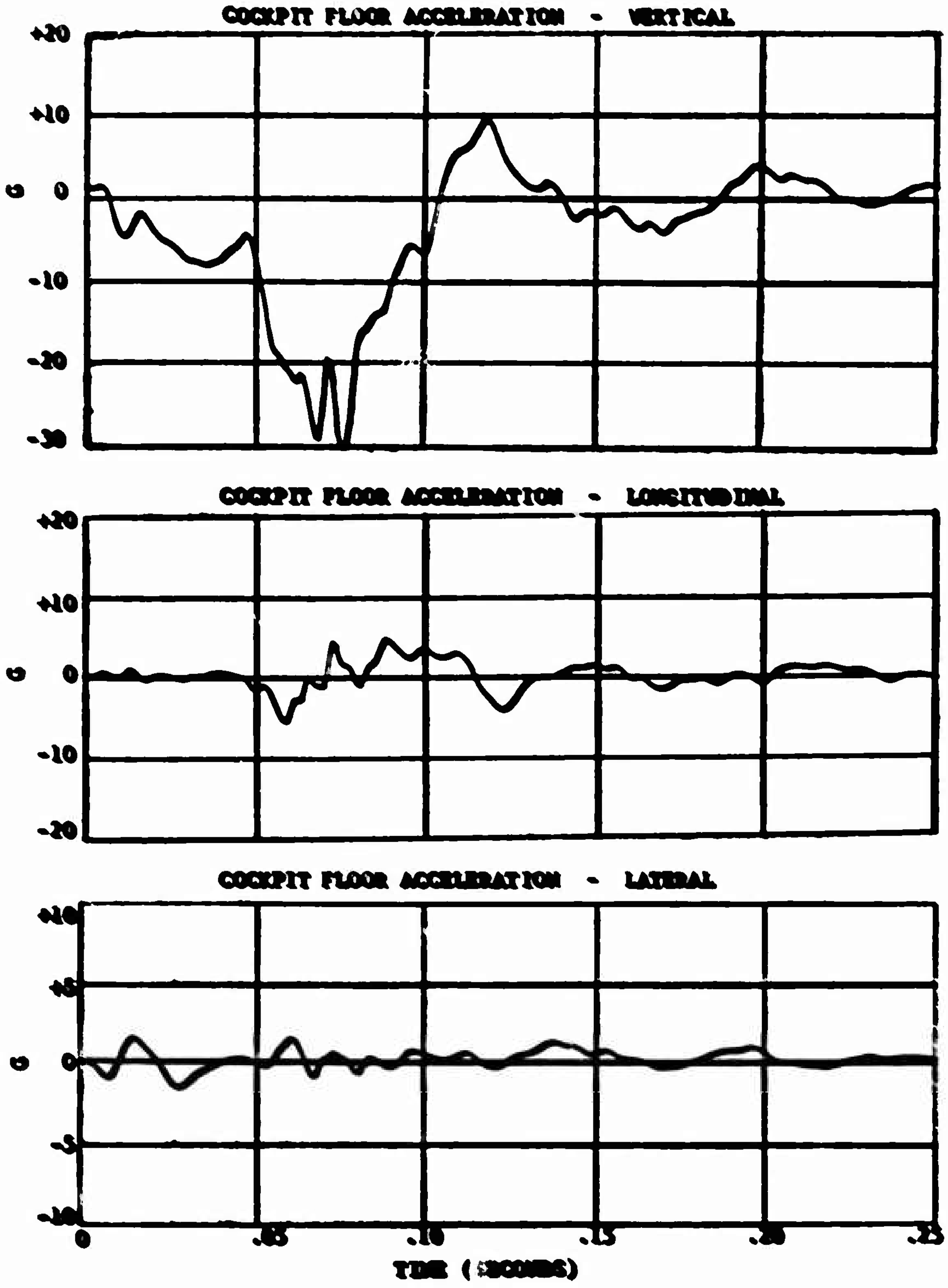

PASSENGER PELVIC ACCELERATION - VERTICAL




PASSENGER HEAD ACCELERATION - VERTICAL
+10
0
-10
-20
G
CEILING ACCELERATION - VERTICAL
+10
0
-10
-20
-30
G
TRANSMISSION ACCELERATION - VERTICAL
+10
0
-10
-20
-30
-40
G
0
.05
.10
.15
.20
.25
TIME (SECONDS)

ENGINE ACCELERATION - VERTICAL

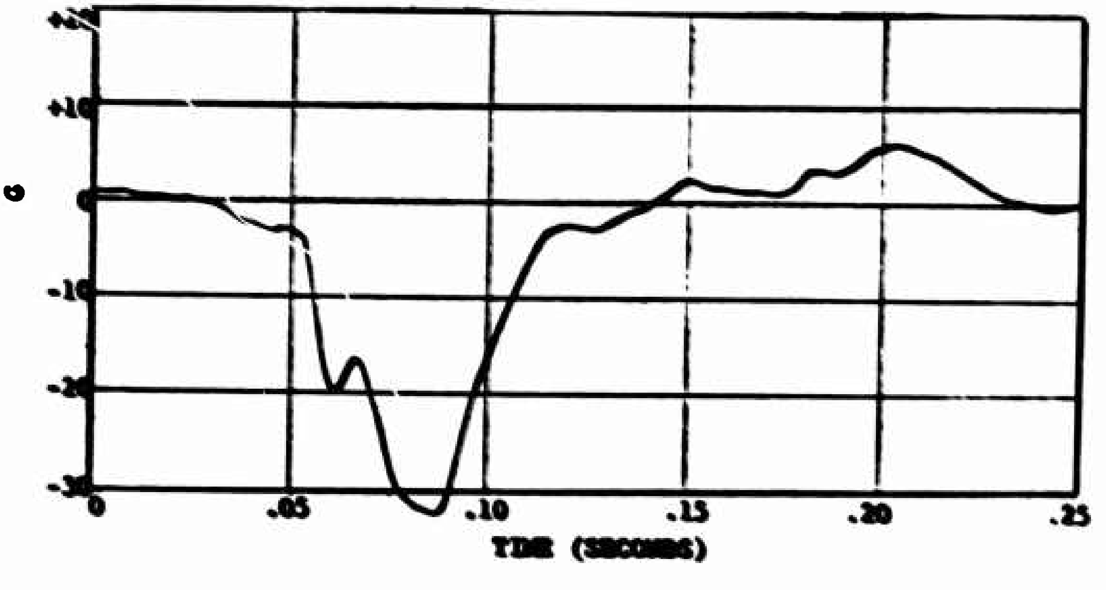



COCKPIT FLOOR ACCELERATION - VERTICAL
+20
+10
G 0
-10
-20
-30
COCKPIT FLOOR ACCELERATION - LONGITUDINAL
+20
+10
G 0
-10
-20
COCKPIT FLOOR ACCELERATION - LATERAL
+10
+5
G 0
-5
-10
0
.05
.10
.15
.20
.25
TIME (SECONDS)

FOR OFFICIAL USE ONLY

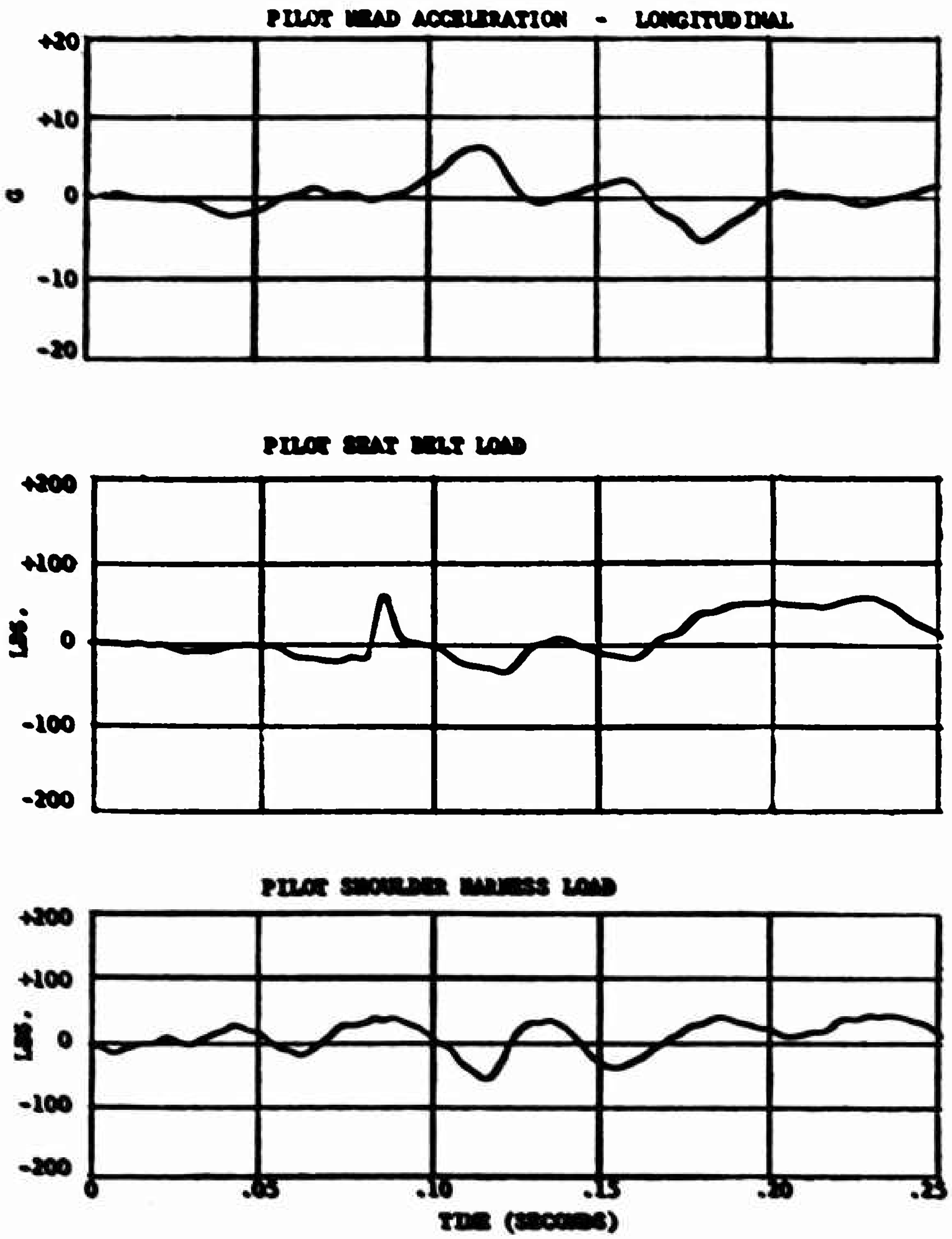
PILOT SEAT ACCELERATION - VERTICAL

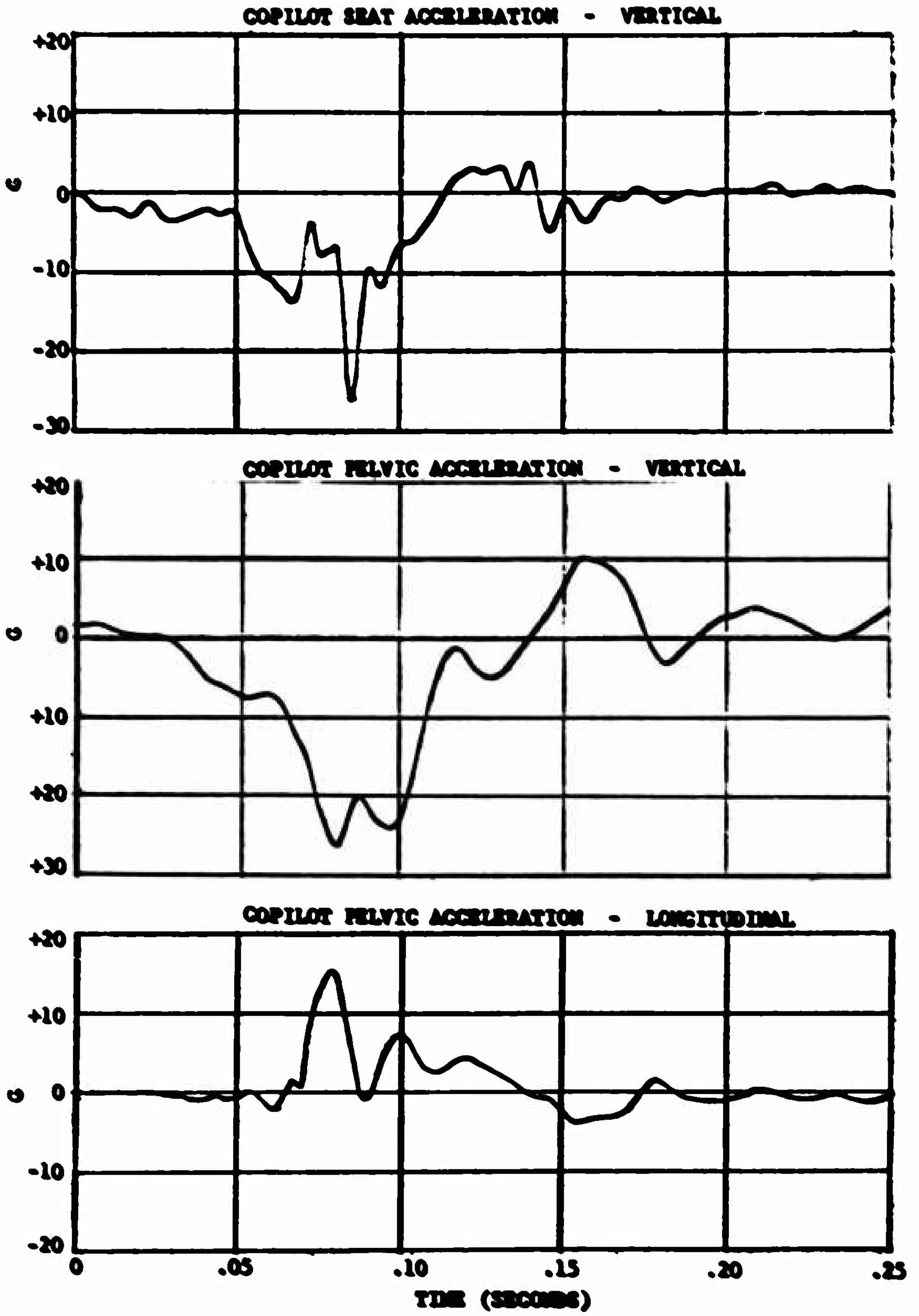

PILOT PELVIC ACCELERATION - VERTICAL

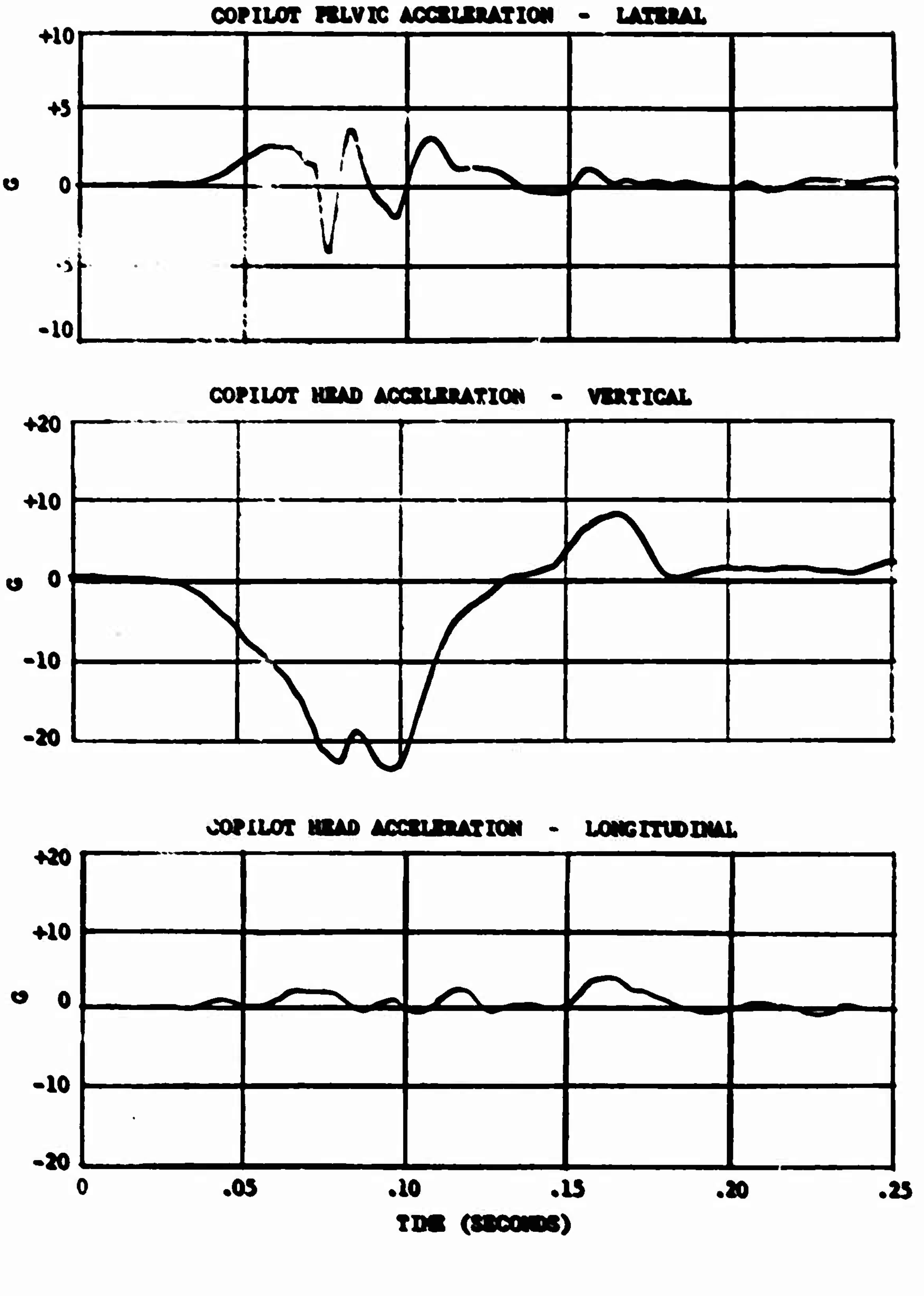


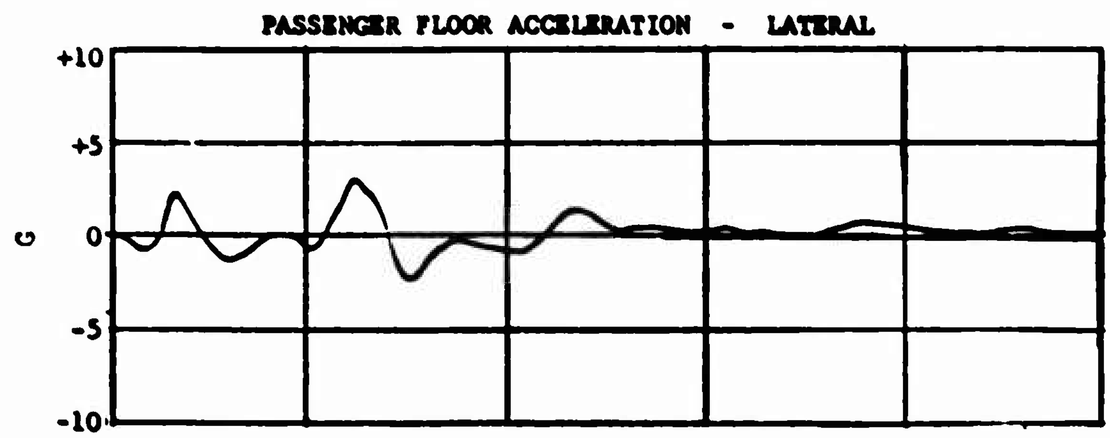


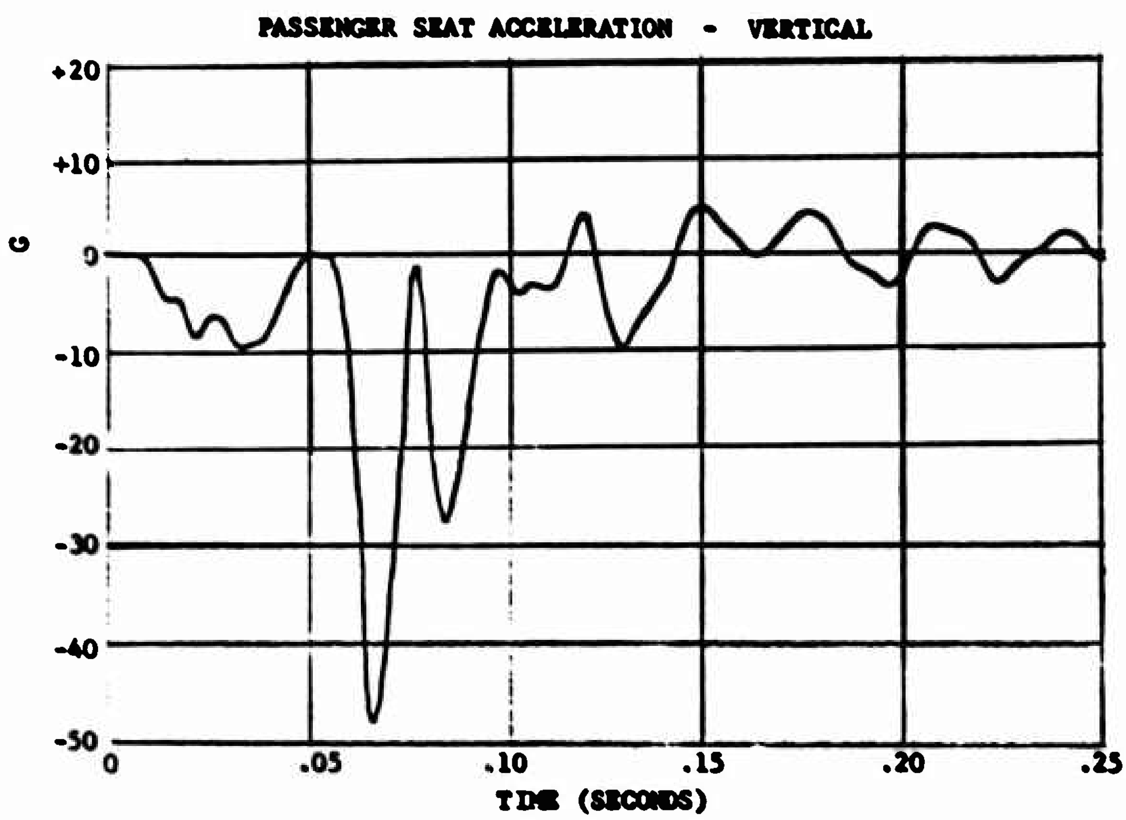

FOR OFFICIAL USE ONLY

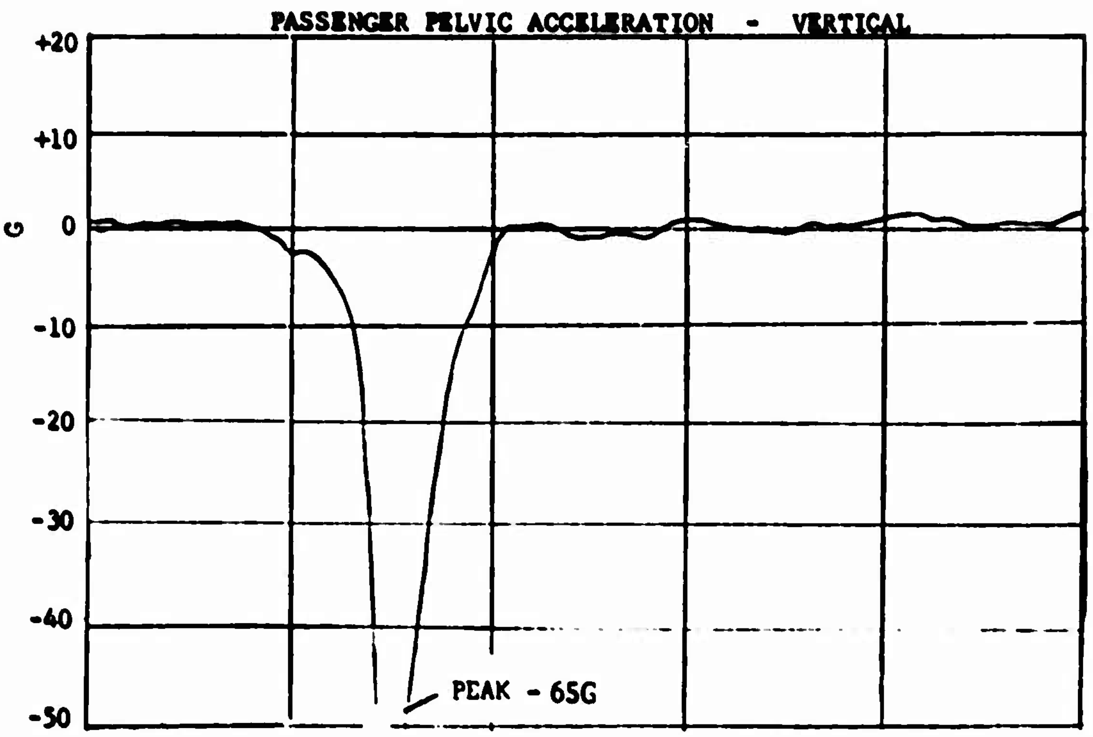

PILOT HEAD ACCELERATION - LONGITUDINAL
+20
+10
G 0
-10
-20
PILOT SEAT BELT LOAD
+200
+100
LBS. 0
-100
-200
PILOT SHOULDER HARNESS LOAD
+200
+100
LBS. 0
-100
-200
0
.05
.10
.15
.20
.25
TIME (SECONDS)

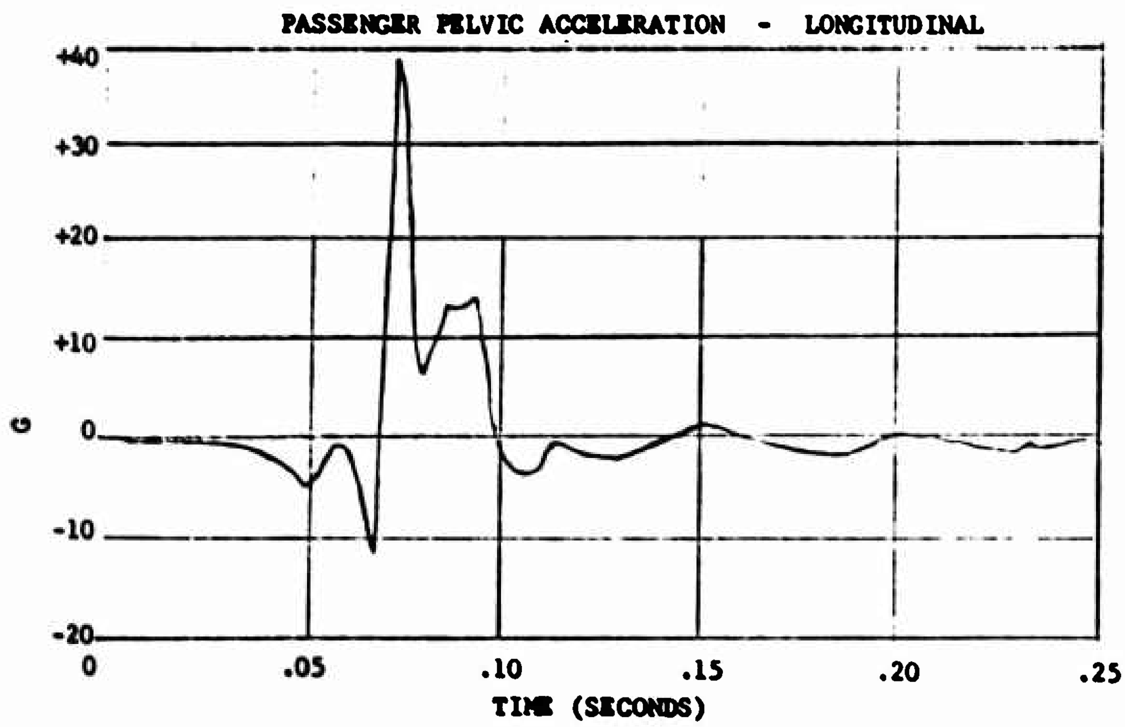

COPILOT SEAT ACCELERATION - VERTICAL
+20
+10
0
-10
-20
-30
G
COPILOT PELVIC ACCELERATION - VERTICAL
+20
+10
0
+10
+20
+30
G
COPILOT PELVIC ACCELERATION - LONGITUDINAL
+20
+10
0
-10
-20
G
0
.05
.10
.15
.20
.25
TIME (SECONDS)

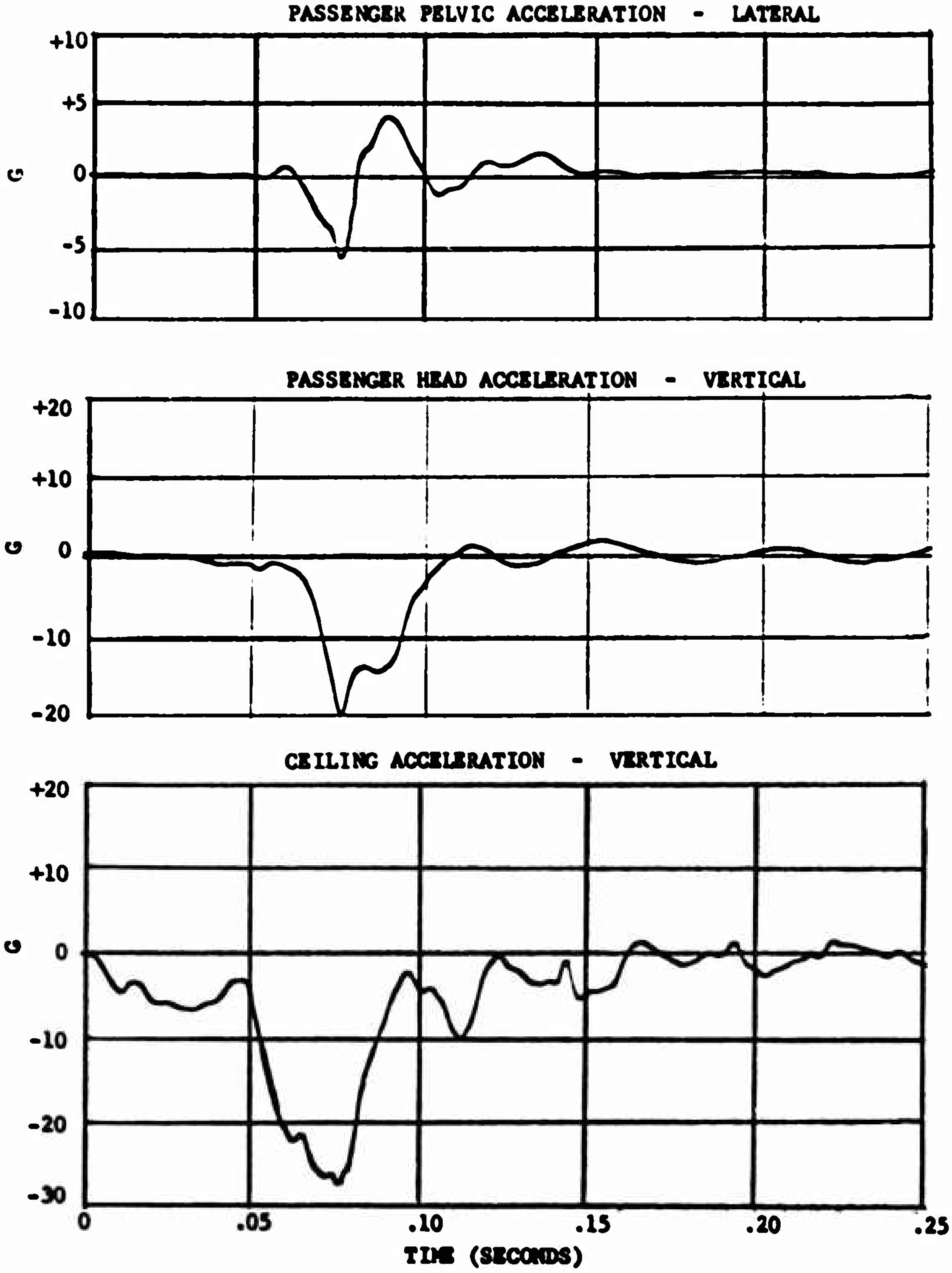

COPILOT PELVIC ACCELERATION - LATERAL
+10
+5
0
-5
-10
G
COPILOT HEAD ACCELERATION - VERTICAL
+20
+10
0
-10
-20
G
COPILOT HEAD ACCELERATION - LONGITUDINAL
+20
+10
0
-10
-20
G
0
.05
.10
.15
.20
.25
TIME (SECONDS)

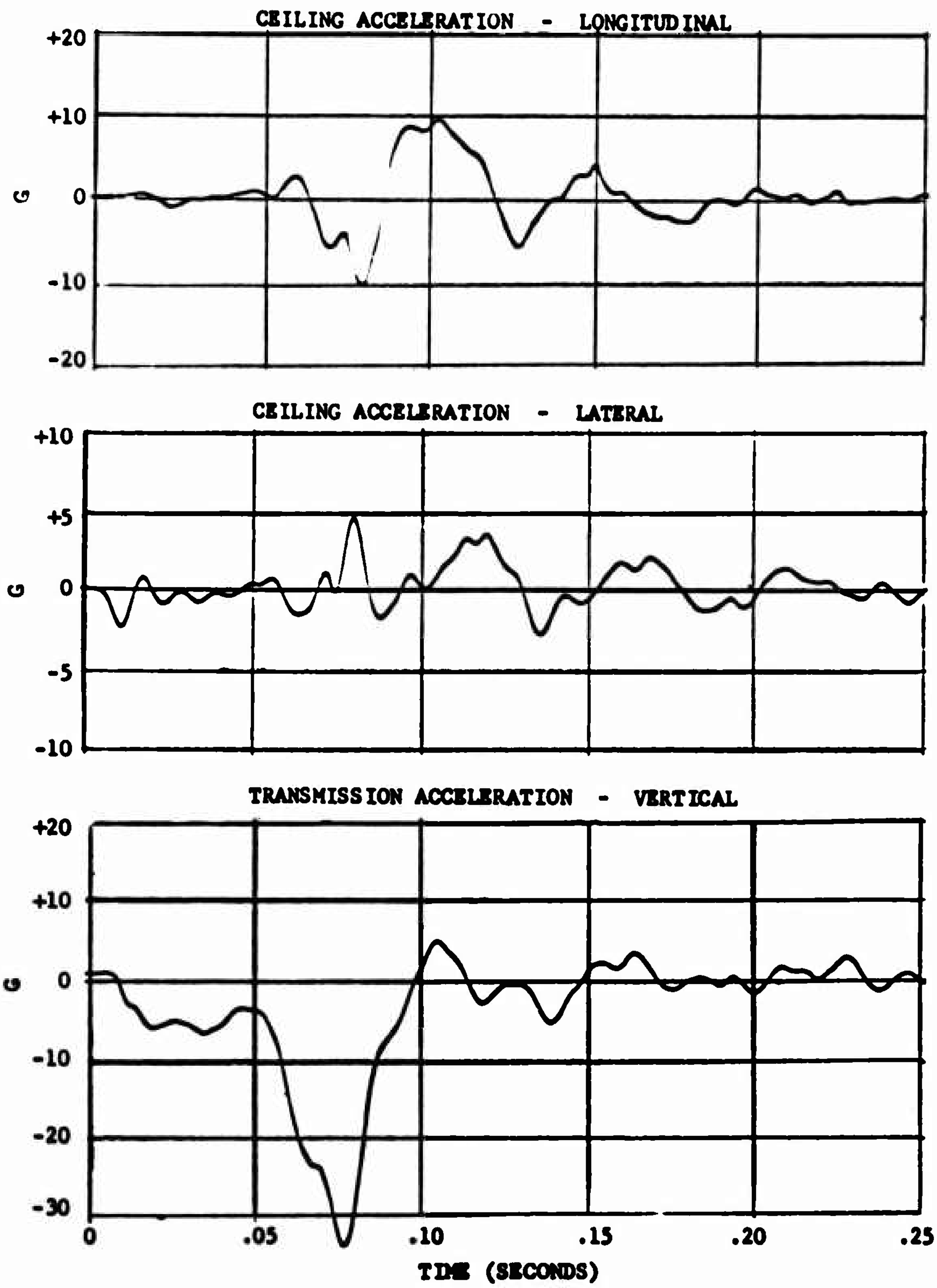

PASSENGER FLOOR ACCELERATION - LATERAL
+10
+5
0
-5
-10
G

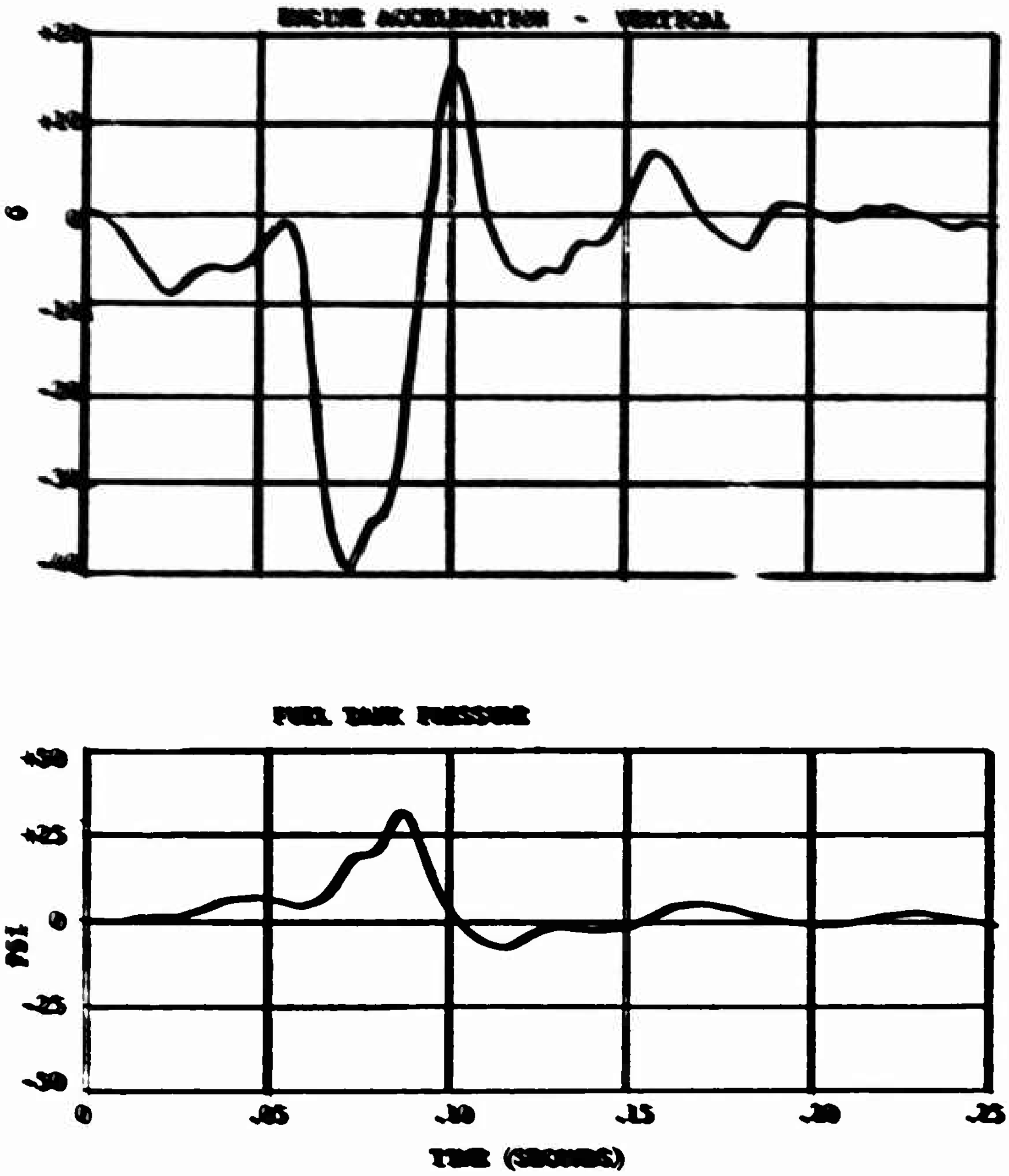

PASSENGER SEAT ACCELERATION - VERTICAL
+20
+10
0
-10
-20
-30
-40
-50
G
0
.05
.10
.15
.20
.25
TIME (SECONDS)


PASSENGER PELVIC ACCELERATION - VERTICAL
+20
+10
0
-10
-20
-30
-40
-50
G
PEAK - 65G


PASSENGER PELVIC ACCELERATION - LONGITUDINAL
+40
+30
+20
+10
0
-10
-20
G
0
.05
.10
.15
.20
.25
TIME (SECONDS)

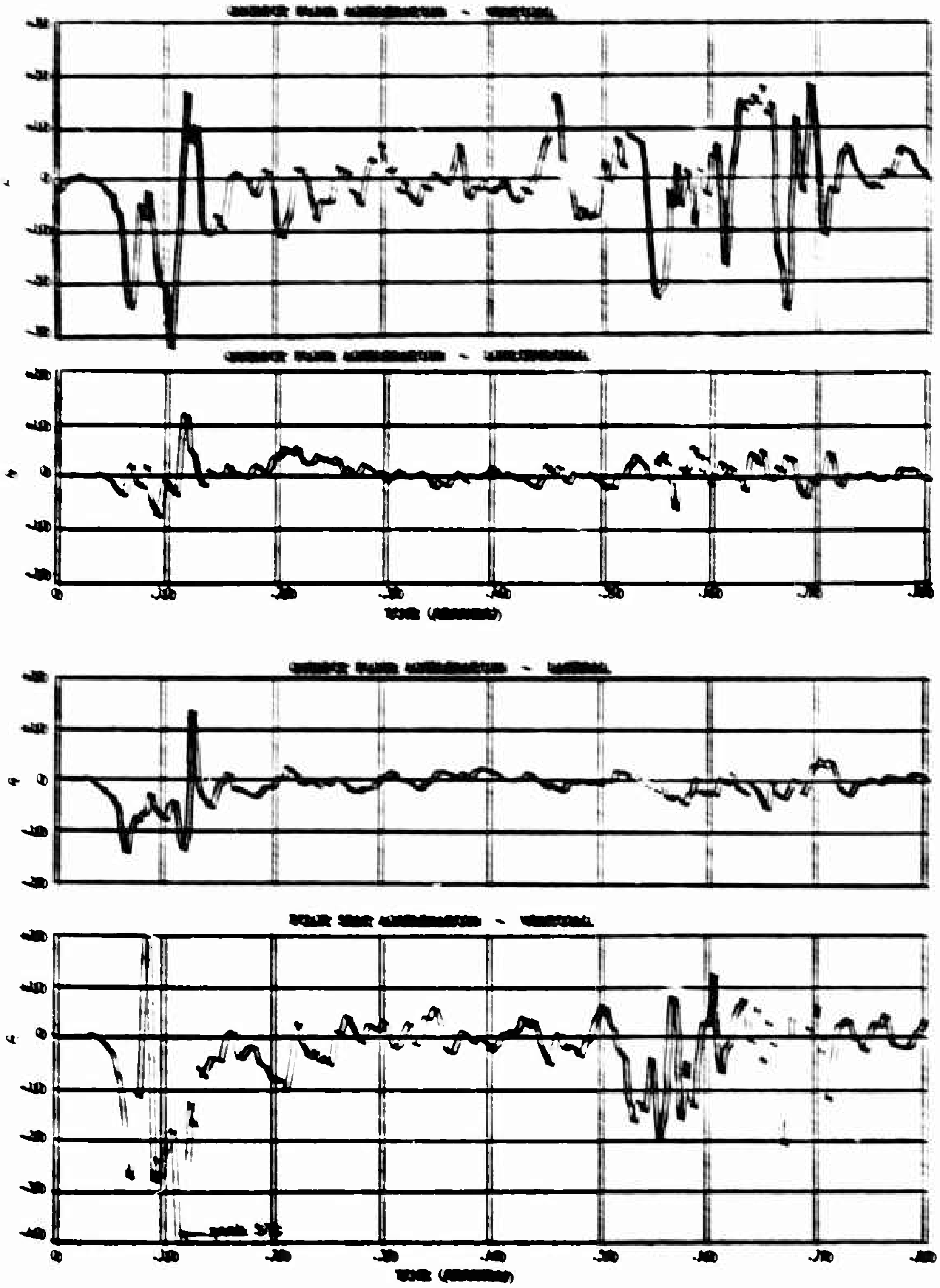

PASSENGER PELVIC ACCELERATION - LATERAL
+10
+5
0
-5
-10
G
PASSENGER HEAD ACCELERATION - VERTICAL
+20
+10
0
-10
-20
G
CEILING ACCELERATION - VERTICAL
+20
+10
0
-10
-20
-30
G
0
.05
.10
.15
.20
.25
TIME (SECONDS)

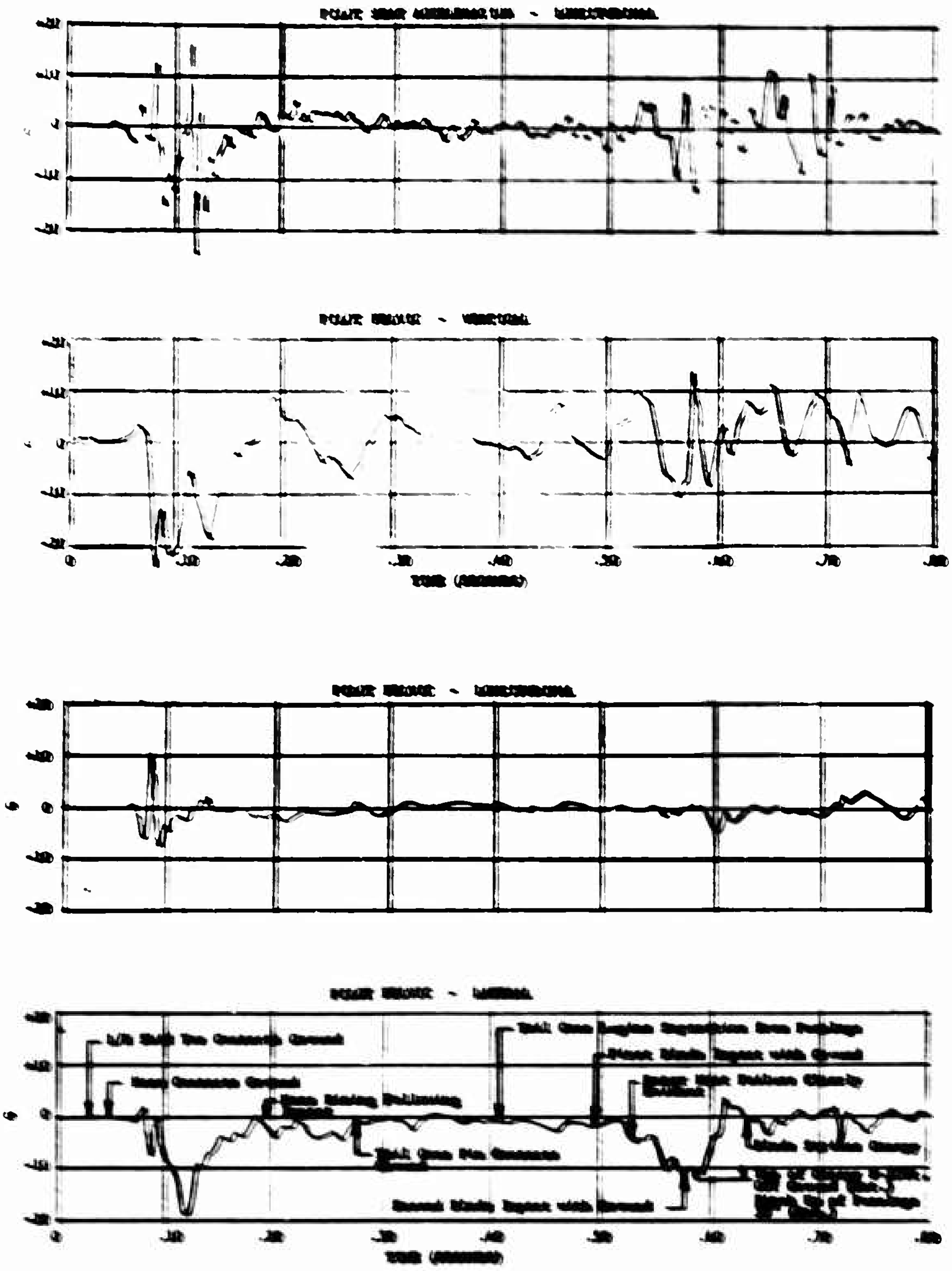

CEILING ACCELERATION - LONGITUDINAL
+20
+10
0
-10
-20
G
CEILING ACCELERATION - LATERAL
+10
+5
0
-5
-10
G
TRANSMISSION ACCELERATION - VERTICAL
+20
+10
0
-10
-20
-30
G
0
.05
.10
.15
.20
.25
TIME (SECONDS)

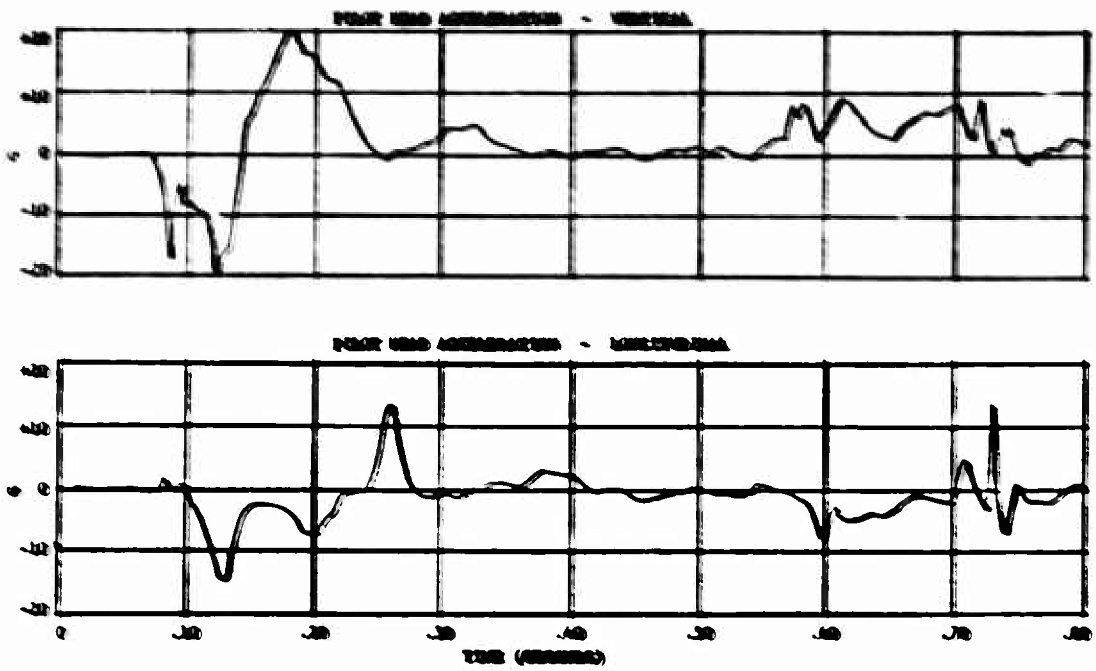

G
0
+25
0
-25
PSI
0
.05
.10
.15
.20
.25

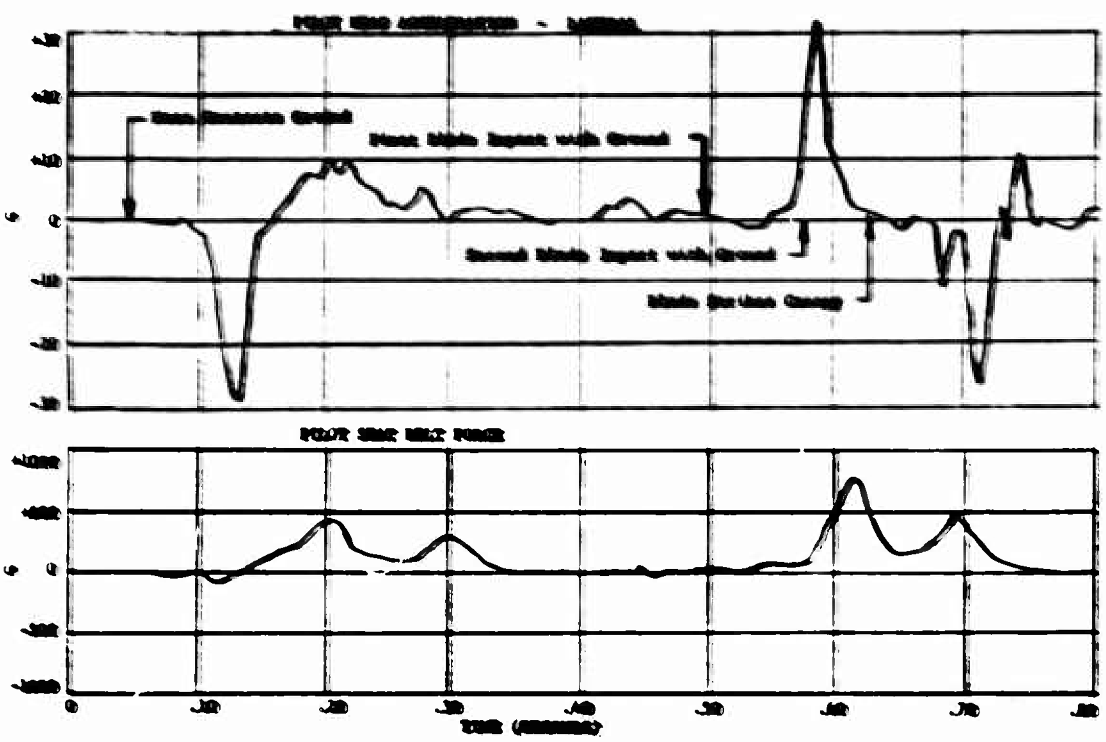
APPENDIX II

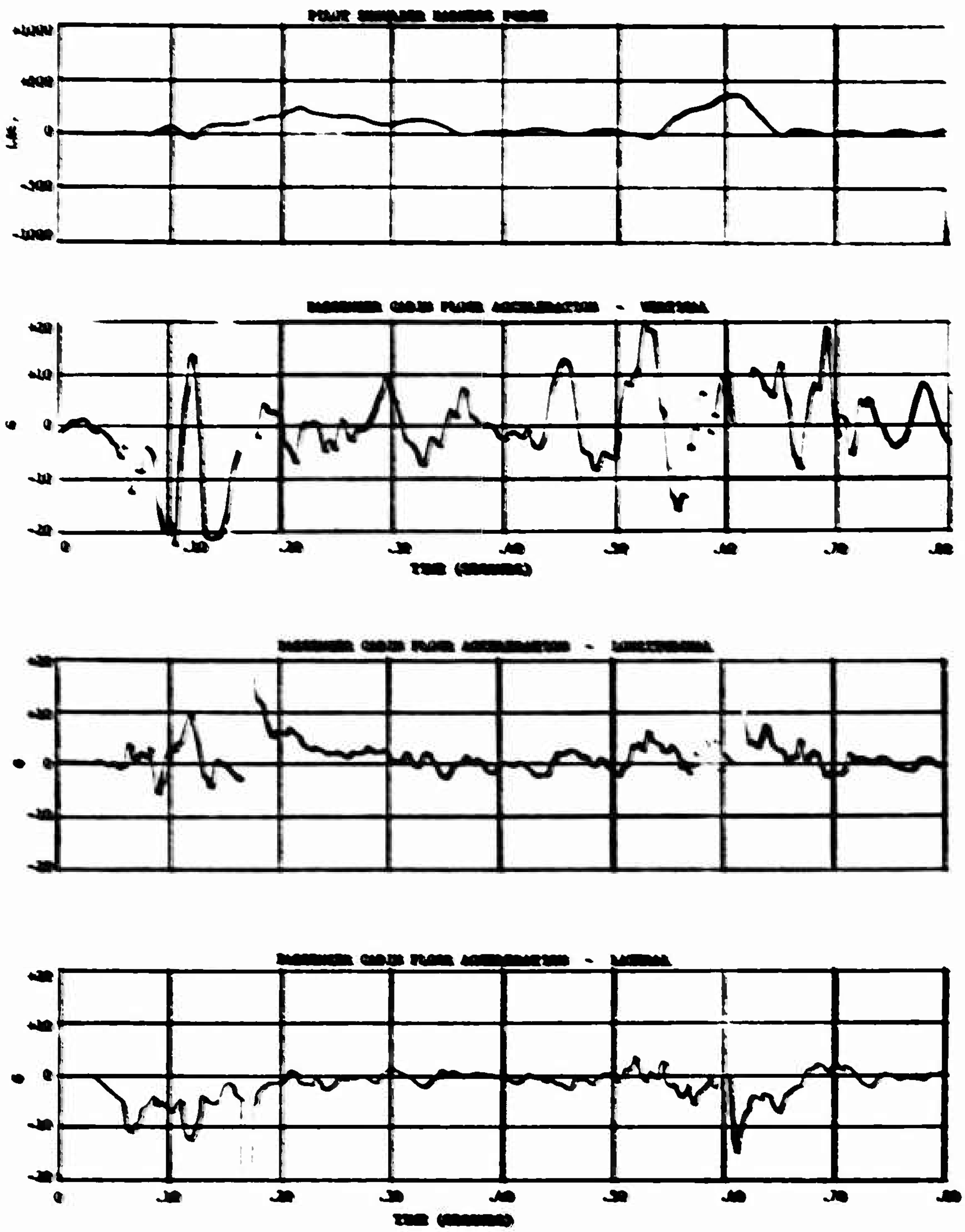
ACCELERATION TIME HISTORIES, T-22

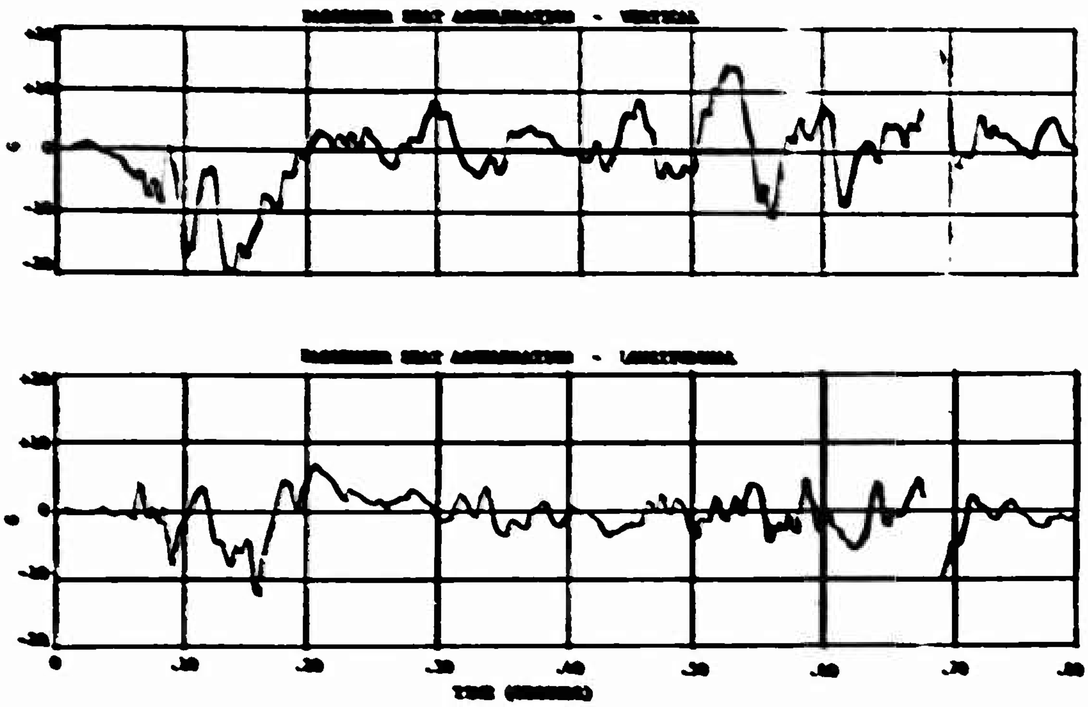


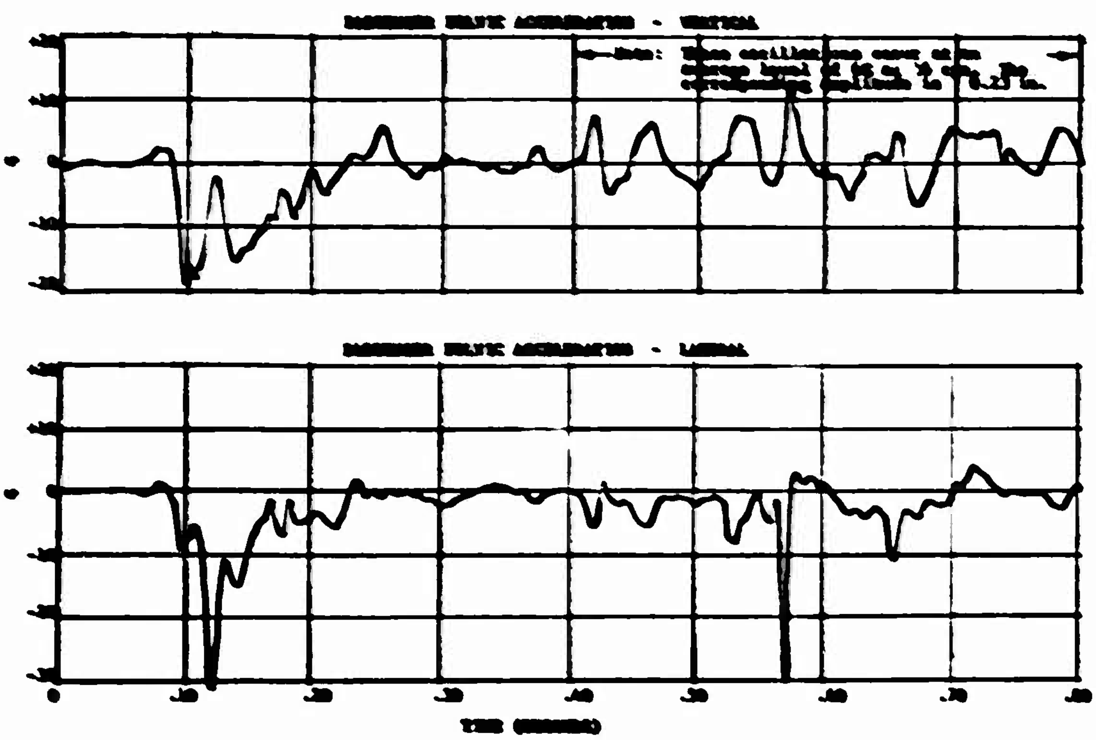


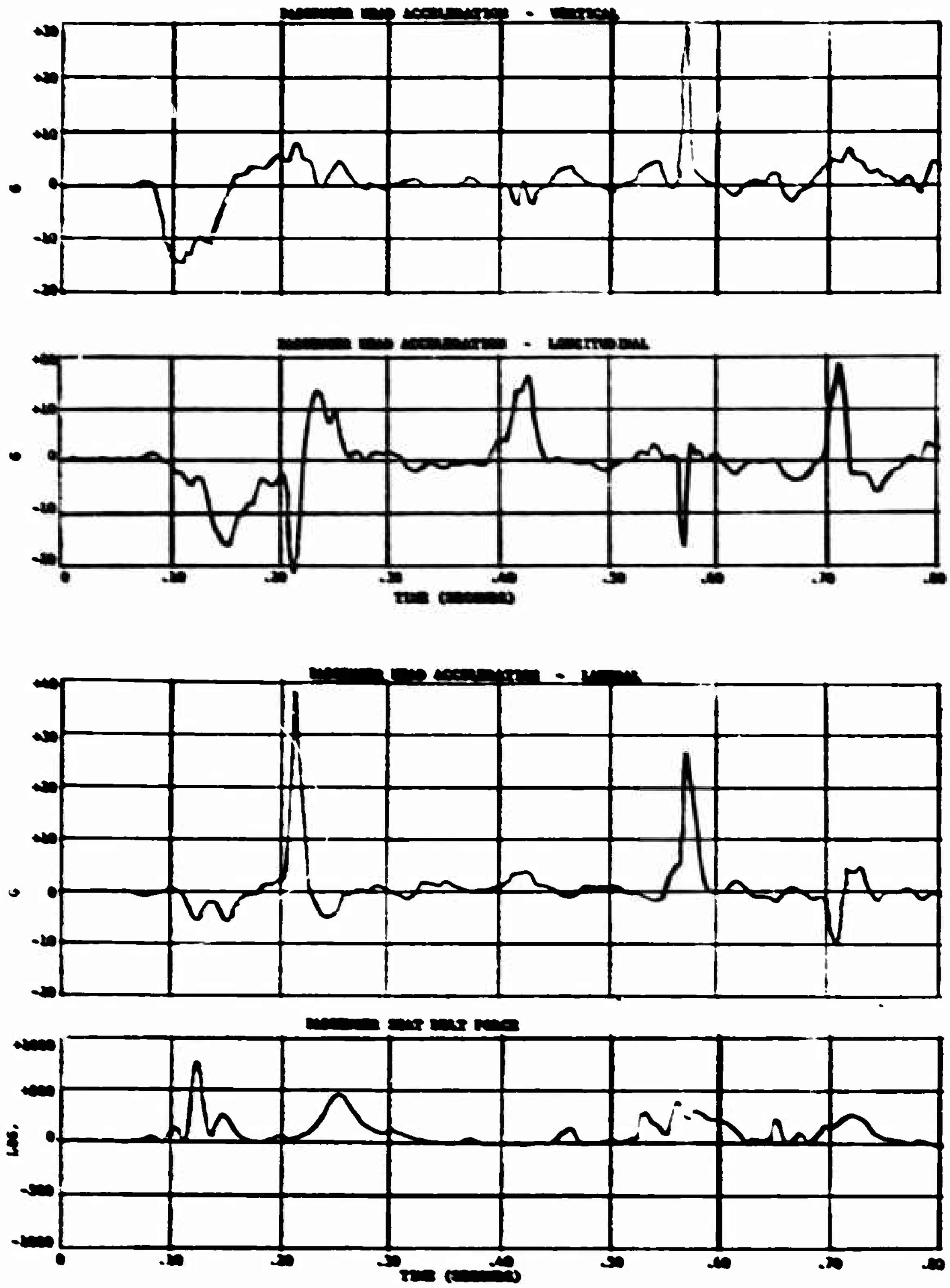


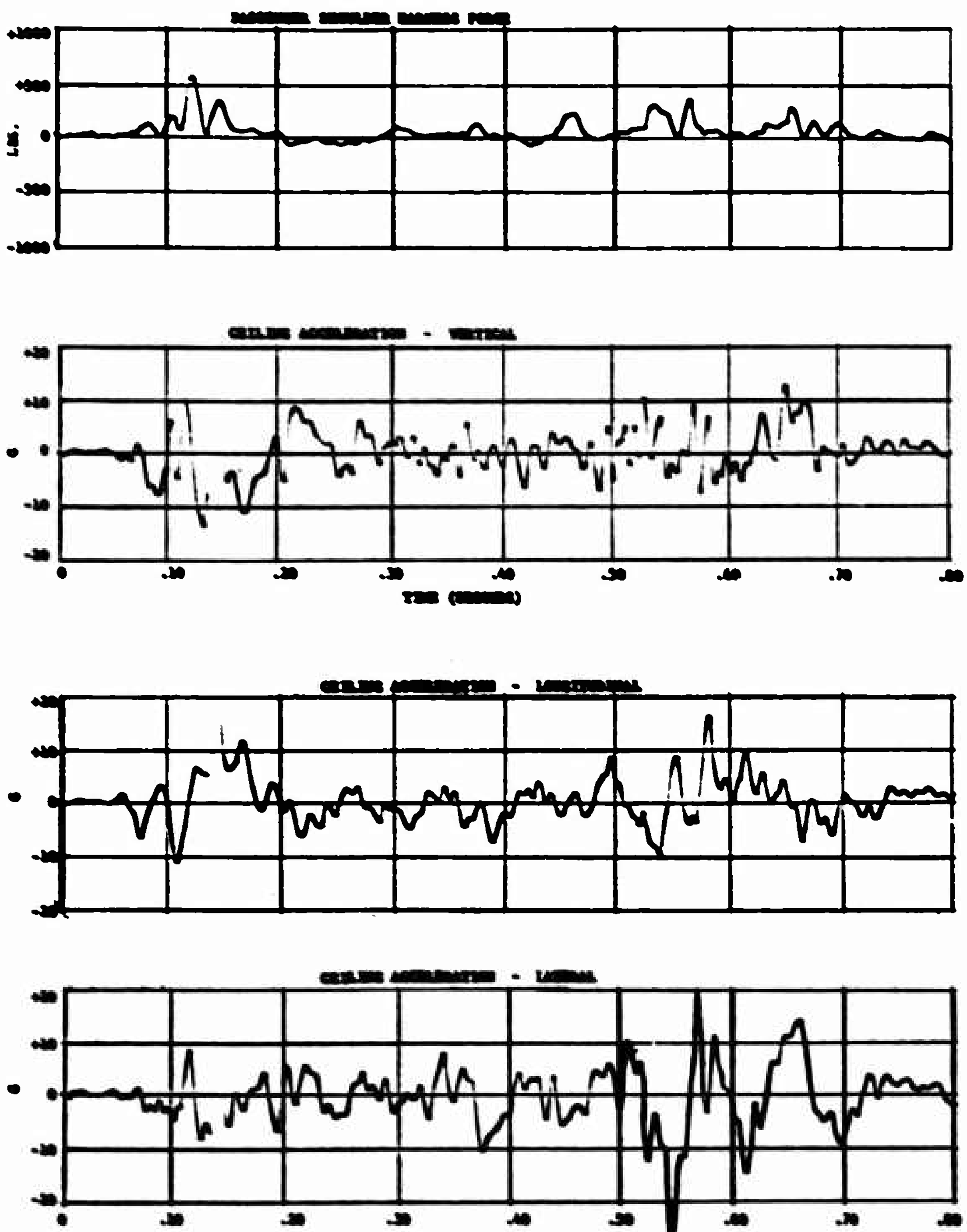


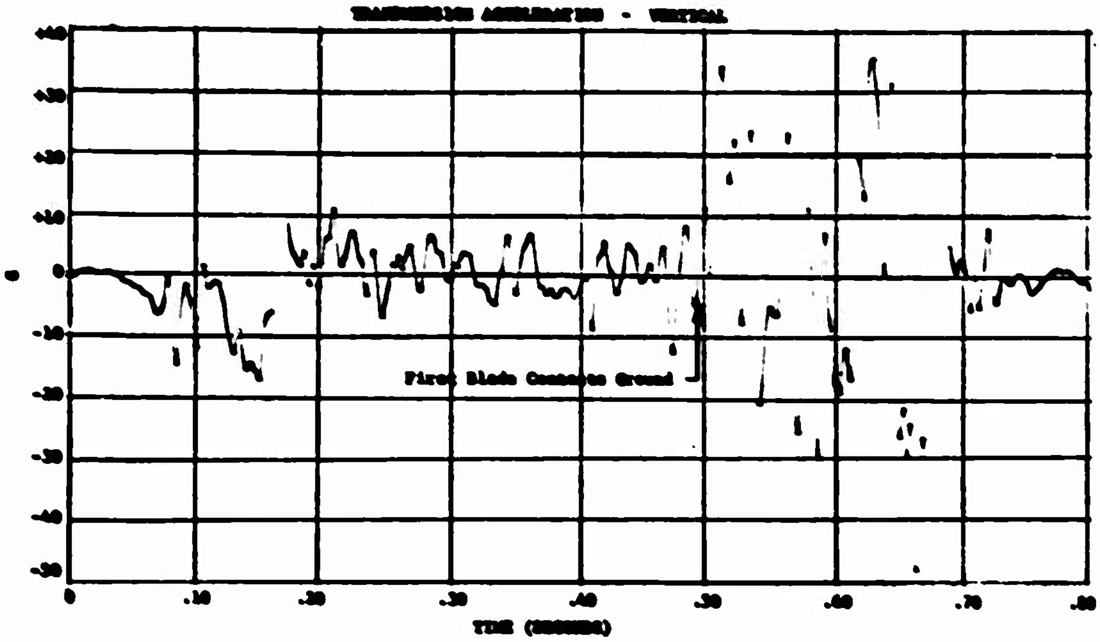


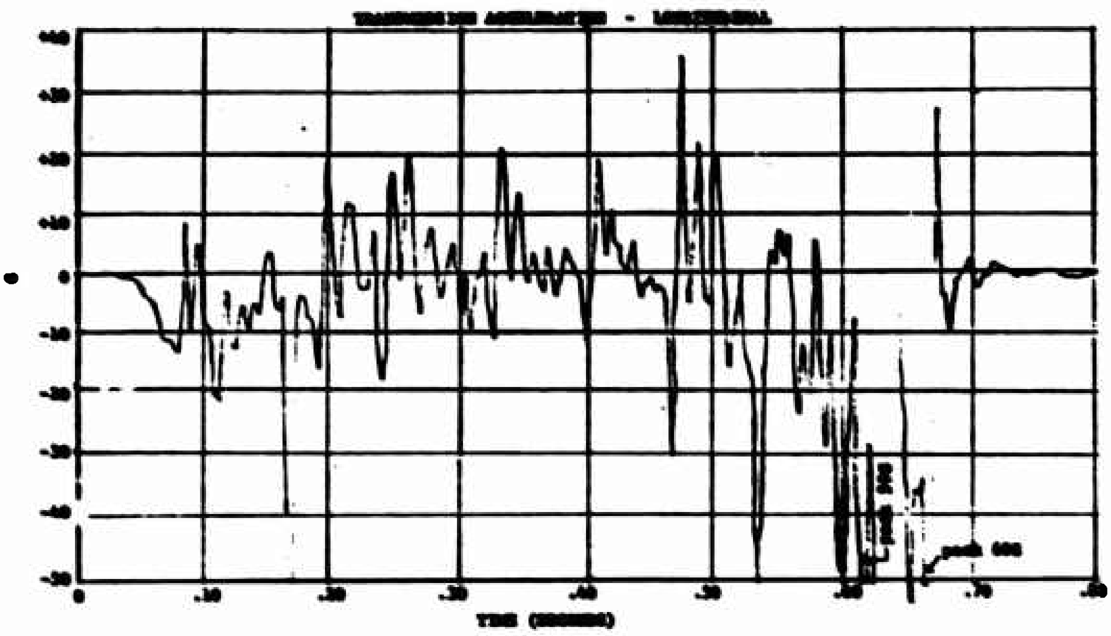


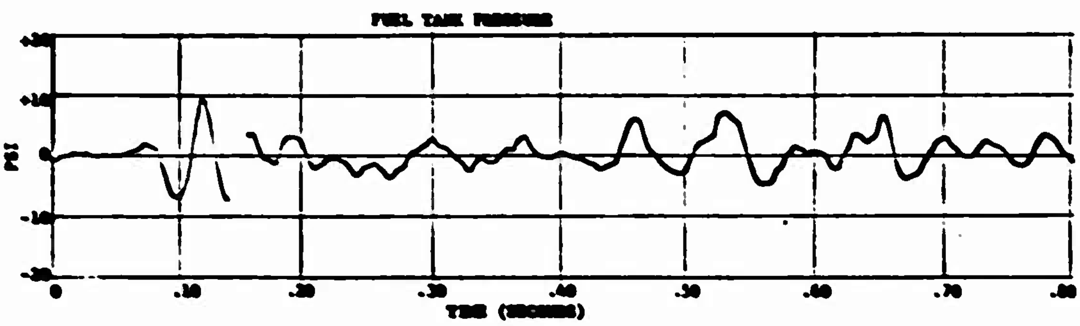












# APPENDIX III
## MEASUREMENT LISTS

### T-21

1. Engine Acceleration - Vertical
2. Transmission Acceleration - Vertical
3. Fuel Tank Pressure
4. Cockpit Floor Acceleration - Lateral
5. Cockpit Floor Acceleration - Longitudinal
6. Cockpit Floor Acceleration - Vertical
7. Passenger Floor Acceleration - Lateral
8. Passenger Floor Acceleration - Longitudinal
9. Passenger Floor Acceleration - Vertical
10. Ceiling Acceleration - Lateral
11. Ceiling Acceleration - Longitudinal
12. Ceiling Acceleration - Vertical
13. Pilot Seat Acceleration - Vertical
14. Copilot Seat Acceleration - Vertical
15. Passenger Seat Acceleration - Vertical
16. Pilot Head Acceleration - Longitudinal
17. Pilot Head Acceleration - Vertical
18. Pilot Pelvic Acceleration - Lateral
19. Pilot Pelvic Acceleration - Longitudinal
20. Pilot Pelvic Acceleration - Vertical
21. Pilot Seat Belt Load
22. Pilot Shoulder Harness Load
23. Copilot Head Acceleration - Longitudinal
24. Copilot Head Acceleration - Vertical
25. Copilot Pelvic Acceleration - Lateral
26. Copilot Pelvic Acceleration - Longitudinal
27. Copilot Pelvic Acceleration - Vertical
28. Copilot Seat Belt Load
29. Passenger Head Acceleration - Vertical
30. Passenger Pelvic Acceleration - Lateral
31. Passenger Pelvic Acceleration - Longitudinal
32. Passenger Pelvic Acceleration - Vertical

### T-22

1. Transmission Acceleration - Longitudinal
2. Transmission Acceleration - Vertical
3. Cockpit Floor Acceleration - Lateral
4. Cockpit Floor Acceleration - Longitudinal
5. Cockpit Floor Acceleration - Vertical

6. Passenger Cabin Floor Acceleration - Lateral
7. Passenger Cabin Floor Acceleration - Longitudinal
8. Passenger Cabin Floor Acceleration - Vertical
9. Ceiling Acceleration - Lateral
10. Ceiling Acceleration - Longitudinal
11. Ceiling Acceleration - Vertical
12. Pilot Seat Acceleration - Longitudinal
13. Pilot Seat Acceleration - Vertical
14. Passenger Seat Acceleration - Longitudinal
15. Passenger Seat Acceleration - Vertical
16. Fuel Tank Pressure
17. Pilot Head Acceleration - Lateral
18. Pilot Head Acceleration - Longitudinal
19. Pilot Head Acceleration - Vertical
20. Pilot Pelvic Acceleration - Lateral
21. Pilot Pelvic Acceleration - Longitudinal
22. Pilot Pelvic Acceleration - Vertical
23. Pilot Seat Belt Force
24. Pilot Shoulder Harness Force
25. Passenger Head Acceleration - Lateral
26. Passenger Head Acceleration - Longitudinal
27. Passenger Head Acceleration - Vertical
28. Passenger Pelvic Acceleration - Lateral
29. Passenger Pelvic Acceleration - Longitudinal
30. Passenger Pelvic Acceleration - Vertical
31. Passenger Seat Belt Force
32. Passenger Shoulder Harness Force

Unclassified

Security Classification

**DOCUMENT CONTROL DATA - R&D**

*(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)*

| | |
|---|---|
| 1 ORIGINATING ACTIVITY (Corporate author)<br>Aviation Safety Engineering and Research<br>2641 E. Buckeye Road<br>Phoenix, Arizona 85034 | 2a REPORT SECURITY CLASSIFICATION<br>Official Use Only<br>2b GROUP |

3 REPORT TITLE
Full-Scale Dynamic Crash Test of a Small Observation Type Helicopter

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final Technical Report

5 AUTHOR(S) (Last name, first name, initial)
Turnbow, J. W., Robertson, S. H., Carroll, D. F., McWilliam, R. D.

| 6 REPORT DATE | 7a TOTAL NO OF PAGES | 7b NO OF REFS |
|---|---|---|
| May 1966 | 84 | |

| | |
|---|---|
| 8a CONTRACT OR GRANT NO<br>DA 44-177-AMC-254(T)<br>b PROJECT NO<br>Task 1P125901A14230<br>c<br>d | 9a ORIGINATOR'S REPORT NUMBER(S)<br>USAAVLABS Technical Report 66-32<br>9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report)<br>AvSER 65-10 |

10 AVAILABILITY/LIMITATION NOTICES
Each transmittal of this document outside the agencies of the US Government must have prior approval of US Army Aviation Materiel Laboratories, Fort Eustis, Virginia 23604.

| 11 SUPPLEMENTARY NOTES | 12 SPONSORING MILITARY ACTIVITY |
|---|---|
| | U.S. Army Aviation Materiel Laboratories<br>Fort Eustis, Virginia<br>U.S. Army Board for Aviation Accident Research |

13 ABSTRACT

This report discusses the results of experimental crash tests of two fully instrumented OH-4A helicopters. The first of these tests, conducted as a crane drop, illustrated the energy absorption capability of the tapered-wall landing gear strut. It further showed that high accelerations may be induced in occupants under level impact conditions of the aircraft in which the design sinking speed for the gear is exceeded. The latter of these tests, conducted from droned flight, indicated that rotor blade impacts with obstacles induced loads into the mast-transmission system which were sufficient to fail the structure at the transmission supports. The crashworthiness of the OH-4A showed an improvement over previous aircraft tested; however, further improvements are definitely possible. This report recommends the means of such improvements and proposes their implementation through appropriate study and test programs.

DD FORM 1 JAN 64 1473

Enclosure 1[1]

Unclassified

Security Classification

Unclassified

Security Classification

| KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |

## INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (corporate author) issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers (either by the originator or by the sponsor), also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through

________________________________________ ."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through

________________________________________ ."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through

________________________________________ ."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring (paying for) the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as (TS), (S), (C), or (U).

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

Unclassified

Security Classification