FAA-ADS- 50

EVALUATION OF A TAIL LOCATED FLIGHT RECORDER

TECHNICAL REPORT

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by

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FEDERAL AVIATION AGENCY

AIRCRAFT DEVELOPMENT SERVICE

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Systems Research and Development Service

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SUMMARY

The performance of a standard flight recorder, mounted aft of the pressurized bulkhead in the tail section of an air carrier transport aircraft was compared with that of a recorder as presently installed during flight.

Flight tests were conducted in conjunction with the FAA-NASA project TAPER (Turbulent Air Pilot Environmental Research) utilizing the FAA's Boeing 720. Two flight recorders and associated accelerometers were mounted in the aircraft; one in the cabin area near the center of gravity and one in the tail of the aircraft outside the pressurized bulkhead. The two recorders were modified to record altitude and airspeed as obtained from an altitude/airspeed transducer located near the pitot-static source. The standard airspeed and altitude channels were supplied by specially installed pitot-static lines running from the nose to the tail of the aircraft.

There was no difference between the recordings of the flight recorder located at the c.g. and the recording of an identical recorder located in the tail for the parameters of airspeed, altitude, and heading. However, there was a difference between the acceleration readings of these recorders. Although there was no difference between the altitude and airspeed obtained from the pitot and static lines and the altitude obtained via an altitude/airspeed transducer, the altitude/airspeed transducer proved more practical.

INTRODUCTION

The purpose of this project was to determine the performance characteristics of a standard flight recorder when mounted aft of the pressurized bulkhead in the tail section of air carrier transport aircraft, and to compare its performance during flight with that of recorders as presently installed.

BACKGROUND

Aircraft flight data recorders are required by regulation in civil air carrier aircraft for the purpose of continuously recording certain parameters during the time the aircraft is in flight. The record is used for accident and incident investigation purposes.

On two separate occasions the Civil Aeronautics Board (CAB) had rescinded amendments to the Civil Air Regulations requiring a recording device to be used on all aircraft involved in air transportation. In the first instance, the CAB found it necessary to rescind the rule because of the difficulty operators were experiencing in providing proper maintenance occasioned by the procurement and transportation difficulties associated with World War II. In the second instance, the CAB found that there was, in fact, no device available of proven reliability that could fulfill all the desired requirements.

On November 10, 1955, after receiving information that a suitable instrument was available, the CAB again circulated a proposal for comment by the affected operators to install such a device in their aircraft. There was general agreement that such a device would do much to eliminate conjecture, supposition, and personal opinion from the analysis of accidents, as well as various incidents that occur during routine operations such as extreme vertical accelerations due to turbulence. As a result of the comments received on the draft release, the CAB amended Parts 40, 41, and 42 of the Civil Air Regulations to require that after July 15, 1958, all aircraft with a takeoff weight of over 12,500 pounds and certified for operation above 25,000 feet shall have a flight recorder installed and operating continuously during flight. The regulation requires that time, pressure altitude, vertical accelerations, airspeed, and heading be recorded.

On June 21, 1958, Technical Standard Order C51, which established the minimum performance standards for flight data recorders, was issued. It specifies the limits for the five required parameters as follows:

Time: Recorded at intervals of not more than one minute.

Pressure Altitude: -1,000 to 50,000 feet of standard atmospheric pressures shall be recorded at intervals of not more than one second.

Vertical Acceleration: +6 to -3 g's shall be recorded at intervals of not more than 1/10 of one second or at intervals of one second in which peak accelerations are recorded.

Airspeed: 100 to 450 knots IAS shall be recorded at intervals of not more than one second.

Heading: 360 degrees azimuth shall be recorded at intervals of not more than one second.

This Technical Standard Order also covers three basic types of flight recorders as follows:

Type I: A non-ejectable recorder capable of withstanding 1100°C flames for 30 minutes and not restricted as to its installation location in the aircraft.

Type II: A non-ejectable recorder capable of withstanding 1100°C flames for 15 minutes but restricted to any location more than 1/2 of the wing root chord from the main wing structure through the fuselage and from any fuel tanks.

Type III: An ejectable recorder capable of withstanding 1100°C flames for 1.5 minutes and not restricted as to its installation location in the aircraft.

To date no satisfactory Type III ejectable recorder has been developed and installations of flight recorders in present day transport aircraft have been Type I non-ejectable recorders. Most of them have been mounted in the cockpit area of the aircraft or in the main gear wheel well. Unfortunately, these locations subject the recorders, in many cases, to fire and impact forces that severely damage the recording medium and make the recorder itself difficult to find after a crash.

Since the tail section of the aircraft seems to survive the crash in better condition than most other parts of the aircraft, consideration toward locating the flight recorder in the tail appears to be desirable. However, not all flight recorders on the market today would satisfactorily lend themselves to location in the tail because in some cases the vertical acceleration sensor is an integral part of the recorder. The former Civil Air Manual, Part 4b.606-2b, required that the vertical acceleration sensor be located as close to the center of gravity range of the aircraft as possible. A recent interpretation of this requirement defines the location of the vertical acceleration sensor to no more than one-fourth of the mean aerodynamic chord beyond the center of gravity limits of the aircraft. Thus, only flight recorders with remote sensing accelerometers were suitable for installation in the tail.

Recently it has been proposed that the rigidity of the fuselage of modern aircraft, particularly four-engine jet transports, precludes any difference in acceleration readings between the center of gravity and the tail areas with an accelerometer of the sensitivity required for a flight recorder. In this report this premise was evaluated along with other problems associated with locating a flight recorder in the tail such as: freezing, pressure loss in the pitot-static lines, etc.

DISCUSSION

Description of Equipment

Three flight data recorders currently certificated under TSO-C51 were used in this evaluation. A Lockheed Aircraft Service, Inc. Model 109C flight recorder (Fig. 1) was mounted in the left main wheel well of the test bed aircraft, FAA's Boeing 720-027 (Fig. 2). This recorder is standard equipment on this aircraft. Two United Data Control, Inc. modified Model F-542 flight recorders (Fig. 3) were mounted in the aircraft - one in the cabin area near the center of gravity and one in the tail of the aircraft outside of the pressure bulkhead. Specialized instrumentation, a signal conditioning rack, and a recording rack were installed to obtain other pertinent information.

1. Lockheed Aircraft Service, Inc. Flight Recorder:

The Lockheed Aircraft Service, Inc. Flight Recorder is an oscillographic instrument which provides a record of airspeed, altitude, heading, and vertical acceleration with respect to time. The record is made by embossing lines on aluminum foil tape with styli. The aluminum foil tape (Fig. 4) is .001 inch thick, 100 feet long, and 2 and 1/4 inches wide and will allow approximately 150 hours of recording time. The combination of the recorder housing and the aluminum foil tape is made to withstand aircraft crash environment.

The sensors for the barometric altitude, indicated airspeed, and vertical acceleration are contained within the recorder housing. The heading is obtained through a servo follower system linked to the aircraft fluxgate or gyrosyn compass. Timing marks in the form of a sawtooth graph are scribed on the recording medium in intervals of one minute. An optional binary encoder for trip and date information and an event marker are also available.

2. United Data Control, Inc. Flight Data Recorder:

The United Data Control, Inc. Flight Data Recorder is an airborne recorder which provides an oscillographic record of altitude, airspeed, heading, and vertical acceleration with respect to time. The records are made by engraving lines with diamond scribes into a high nickel content stainless steel strip. This stainless steel strip

(Fig. 5) is 4.92 inches wide, .001 inch thick, and 200 feet long and will allow approximately 400 hours of recording time on each side. The stainless steel strip is considered capable of withstanding aircraft crash environment without mechanical, thermal, or other protection.

The recorder is in a standard 1/2 ATR case and is self-contained except for a remote vertical accelerometer. This accelerometer is a sealed unit designed to sense accelerations in the vertical plane and to be located at or near the center of gravity. An optional trip and date encoder with an event marker is also available.

The two UDC Model F-542 Recorders used in these tests were modified by United Data Control, Inc., by adding two potentiometers and styli to afford two additional channels on each. The output of these two channels was scribed on the back of the stainless steel strip. The signals from a remotely located altitude/airspeed transducer were recorded on the two channels. The accuracy of the altitude/airspeed transducer was in accordance with TSO-C51.

3. Instrumentation:

Figure 6 is a schematic showing the location of the instrumentation utilized in this project.

In the area aft of the pressurized bulkhead in the tail of the aircraft, the following instrumentation was installed: a pressure transducer, a temperature sensor, an accelerometer sensing in the lateral plane, an accelerometer sensing in the vertical plane, and an accelerometer sensing in the longitudinal plane. One of the United Data Control, Inc. Flight Recorders and an associated vertical accelerometer were also located in this area.

In the port main wheel well of the aircraft near the Lockheed Aircraft Service, Inc. Flight Recorder, another pressure transducer and temperature sensor were located.

The altitude/airspeed transducer supplying information to the two extra channels of the United Data Control, Inc. Flight Recorders was located in the nose area of the Boeing 720 so as to be as near as possible to the pitot and static source.

The other United Data Control, Inc. Flight Recorder and associated vertical accelerometer, together with the trip and date encoder, were located at the aircraft's center of gravity in the cabin area. The trip and date encoder with event marker (Fig. 3) was connected to all the recorders so that each could be marked at pertinent points simultaneously. Also located at the center of gravity was an accelerometer system similar to the one in the tail and the signal conditioning and recording racks used to record the data from the instrumentation described.

Test Description

Data collection for this project was performed in conjunction with the FAA-NASA project TAPER (Turbulent Air Pilot Environmental Research). This FAA initiated project investigated pilot environment and aircraft aerodynamics in turbulent air. The type of data and aircraft maneuvers required for project TAPER were similar to those required for this project.

The flight profile included elevator, rudder, and aileron steps, stalls, wing level sideslips (full rudder), phugoid, pushovers and pullups (maximum g's), rolls (30° right and 30° left), windup turns (to buffet onset or to maximum g's), acceleration runs to maximum velocity, and airspeed calibration runs. These maneuvers were conducted at 15,000 feet and 35,000 feet altitude at various gross weights and center of gravity locations. Attempts were also made to fly through actual turbulence.

The recorders were turned on when the engines were started prior to takeoff on each flight. The event marker was used to mark all pertinent points of the above maneuvers to facilitate the data analysis. The recorders were turned off only when the engines were shut down after landing. The calibration of the flight recorders was checked before and after the flight test program.

Test Results

A total of 25 hours of in-flight data were collected on each of the three flight data recorders simultaneously. The three recorders all functioned well during the test and no data were lost or unreadable. Data reduction was accomplished utilizing the Civil Aeronautics Board's specialized equipment and by reading enlarged photographs of the tapes.

There was no difference between the tail located recorder and the c.g. located recorder for the parameters of altitude, airspeed, and heading within the readable limits of the recorder tapes. Also, the airspeed and altitude information obtained from the altitude/airspeed transducer agreed exactly with the altitude and airspeed information obtained from the pitot-static lines, within the readable limits of the recorder tapes. No lag between these two systems was noted. Figures 7 through 9 show typical comparative traces of the above parameters.

Differences were noted, however, in the acceleration traces of the tail located recorder and the c.g. located recorder during certain maneuvers. In the pushovers and pullups it was noted that the accelerometer located in the tail consistently indicated lower negative peaks and higher positive peaks than the accelerometer at the center of gravity. A difference of up to 0.2 g's was noted at the -1g and +3g magnitudes. Figure 10 is a graph showing a typical acceleration curve.

Although no lag could be detected between the c.g. and the tail accelerometers on the flight recorder tapes, the record of the instrumentation vertical accelerometers indicated a 5 ms lag for the c.g. accelerometer to that of the tail accelerometer.

DISCUSSION OF RESULTS

The differences in acceleration readings recorded during pushovers and pullups appear to be the result of the forces generated by the aircraft rotating about the c.g. This rotation shows up as an added force in the tail which is not observed at the c.g. This can be expected to exist for all aircraft of this type and size. However, this added force should be measured for each different model and type aircraft because of the difference in moment arms and c.g. locations. If the accelerometer is to be located in the tail of an aircraft for a tail located recorder, studies and calculations need to be made for each installation in order to obtain useful acceleration data that can be correlated with the specific "g" loads at the c.g. To eliminate this problem, the accelerometer for a tail located recorder should be located as near as possible to the center of gravity.

The modification required to extend pitot-static lines to the tail of an aircraft for a tail located recorder is extensive. An altitude/airspeed transducer is much more practical and much simpler to install. No difference was noted between the data from the pitot-static lines and the data from the altitude/airspeed transducer; therefore, this is the solution to this modification problem.

CONCLUSIONS

Based on the analysis obtained from this evaluation, it is concluded that:

1. A tail located flight recorder record compares exactly with the record of an identical recorder located at the center of gravity for the parameters of airspeed, altitude, heading and time.

2. There is no difference between altitude and airspeed data obtained directly from pitot and static lines and altitude and airspeed data obtained via an altitude/airspeed transducer.

3. An accelerometer located in the tail for the tail located recorder shows that larger accelerations exist there than at the center of gravity.

4. The most accurate recording is obtained when an accelerometer for a tail located flight recorder installation is located as near as possible to the center of gravity.

5. It is more practical to obtain altitude and airspeed information from an altitude/airspeed transducer than from pitot static lines for a tail located flight recorder installation.

ACKNOWLEDGMENTS

Appreciation is expressed for the installation performed by the Aeronautical Engineering Branch and the Avionic Systems Engineering Branch at the FAA Aeronautical Center. Appreciation is also expressed for the assistance and advice on data reduction obtained from the Civil Aeronautics Board, in particular, Mr. O. E. Patton.

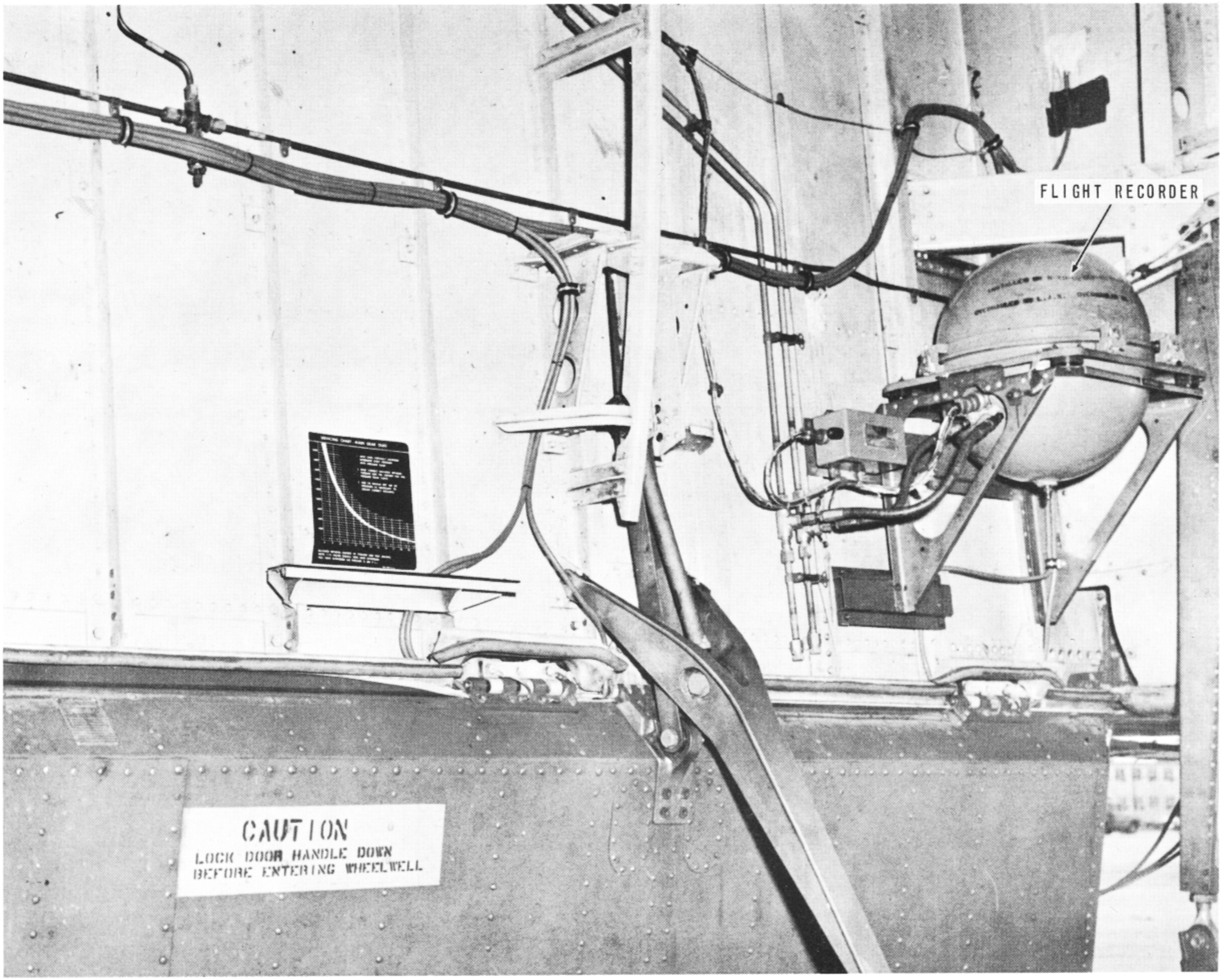


FIG. 1 LOCKHEED AIRCRAFT SERVICE, INC. FLIGHT RECORDER IN AIRCRAFT

FIG. 2 TEST BED AIRCRAFT, BOEING 720

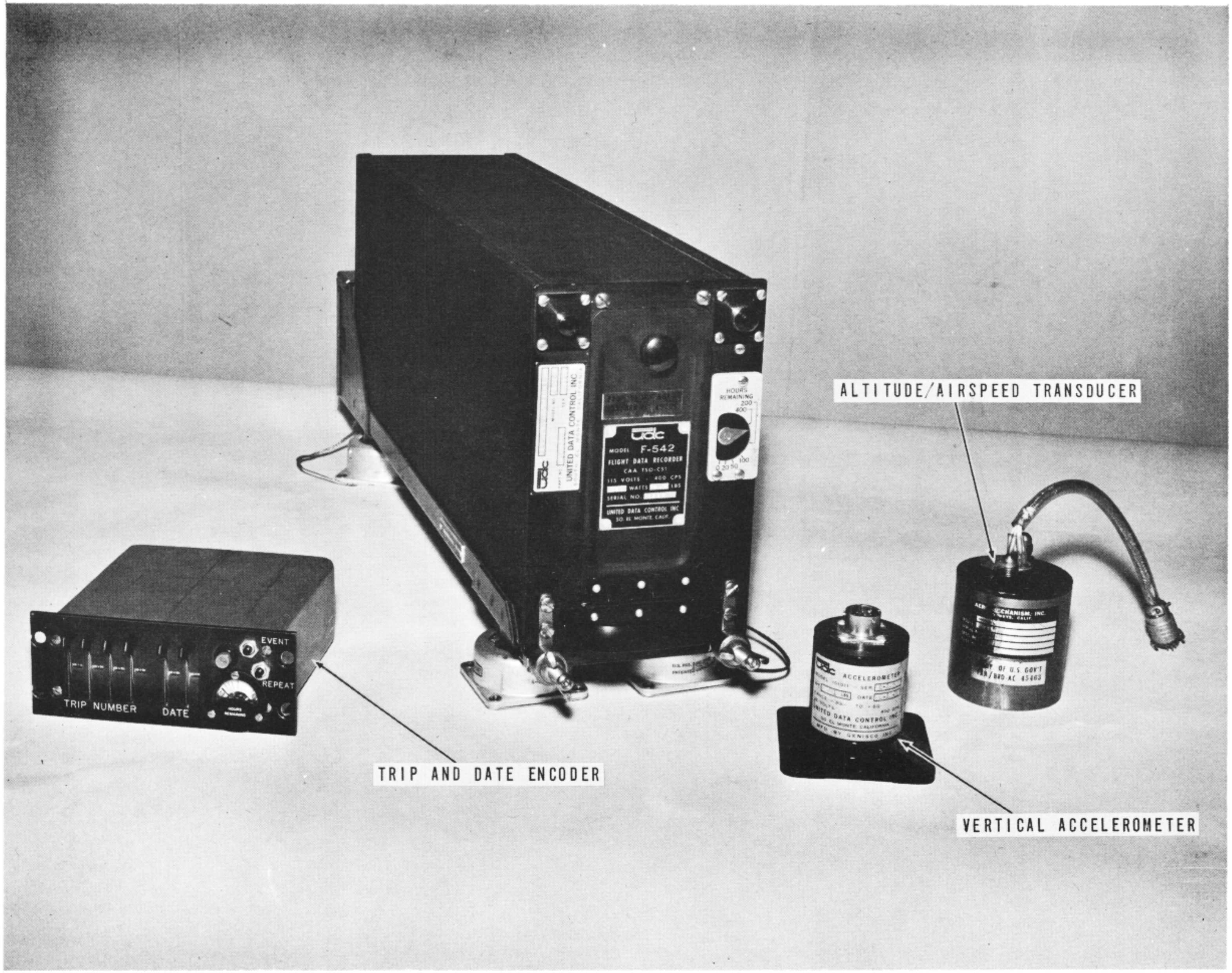


FIG. 3 UNITED DATA CONTROL, INC. FLIGHT RECORDER AND ASSOCIATED EQUIPMENT

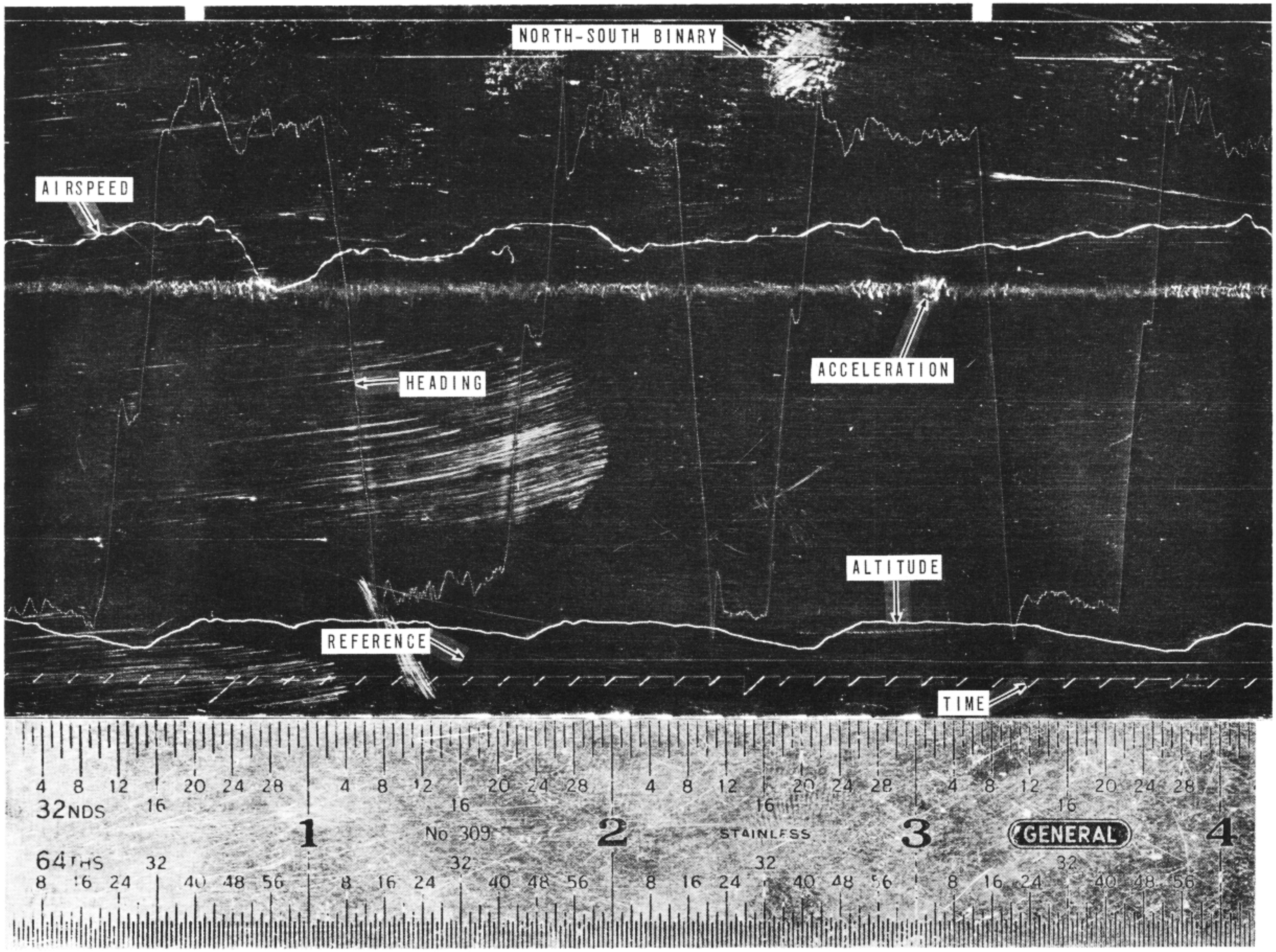


FIG. 4 LOCKHEED AIRCRAFT SERVICE INC. FLIGHT RECORDER TAPE

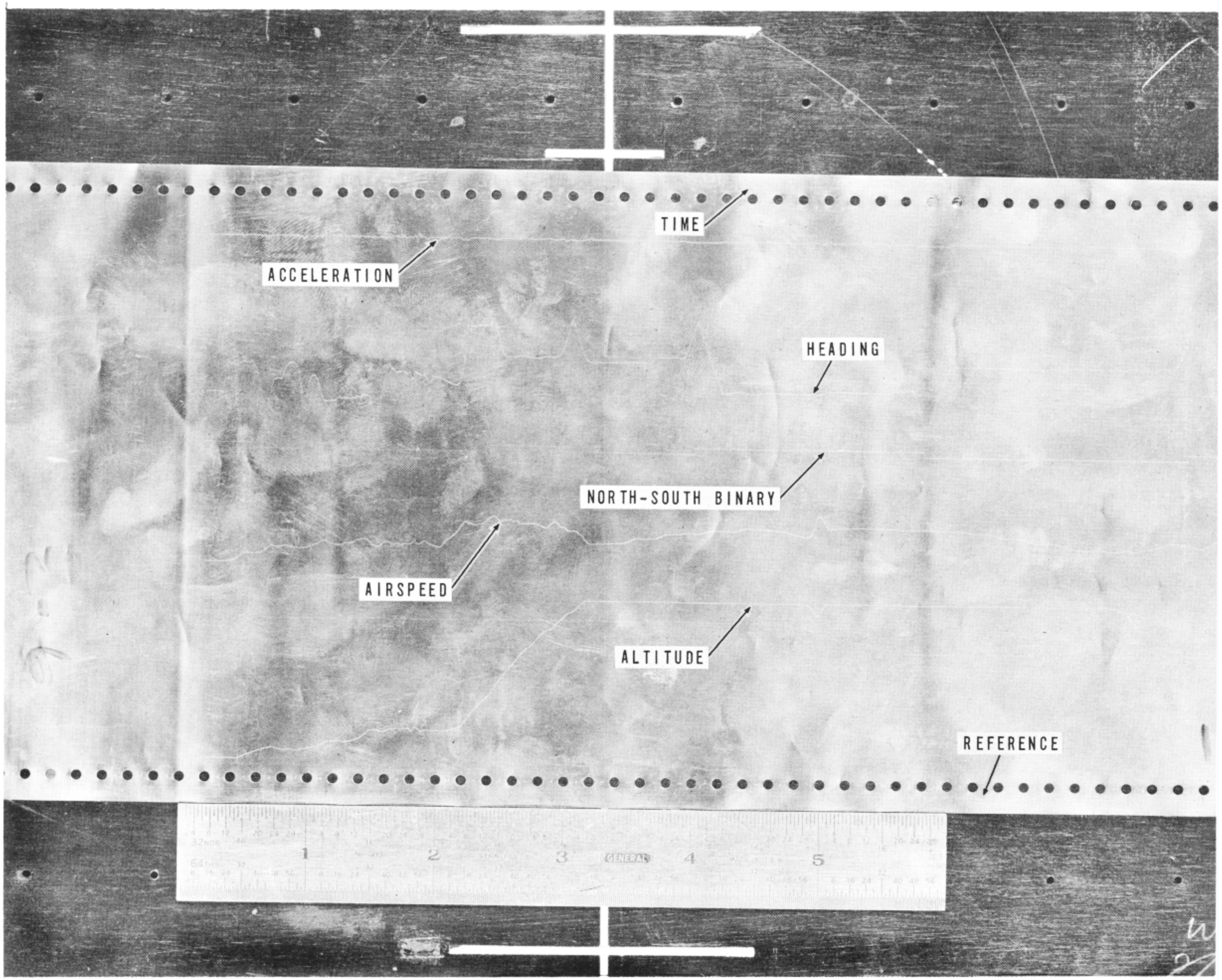


FIG. 5 UNITED DATA CONTROL, INC. FLIGHT RECORDER TAPE

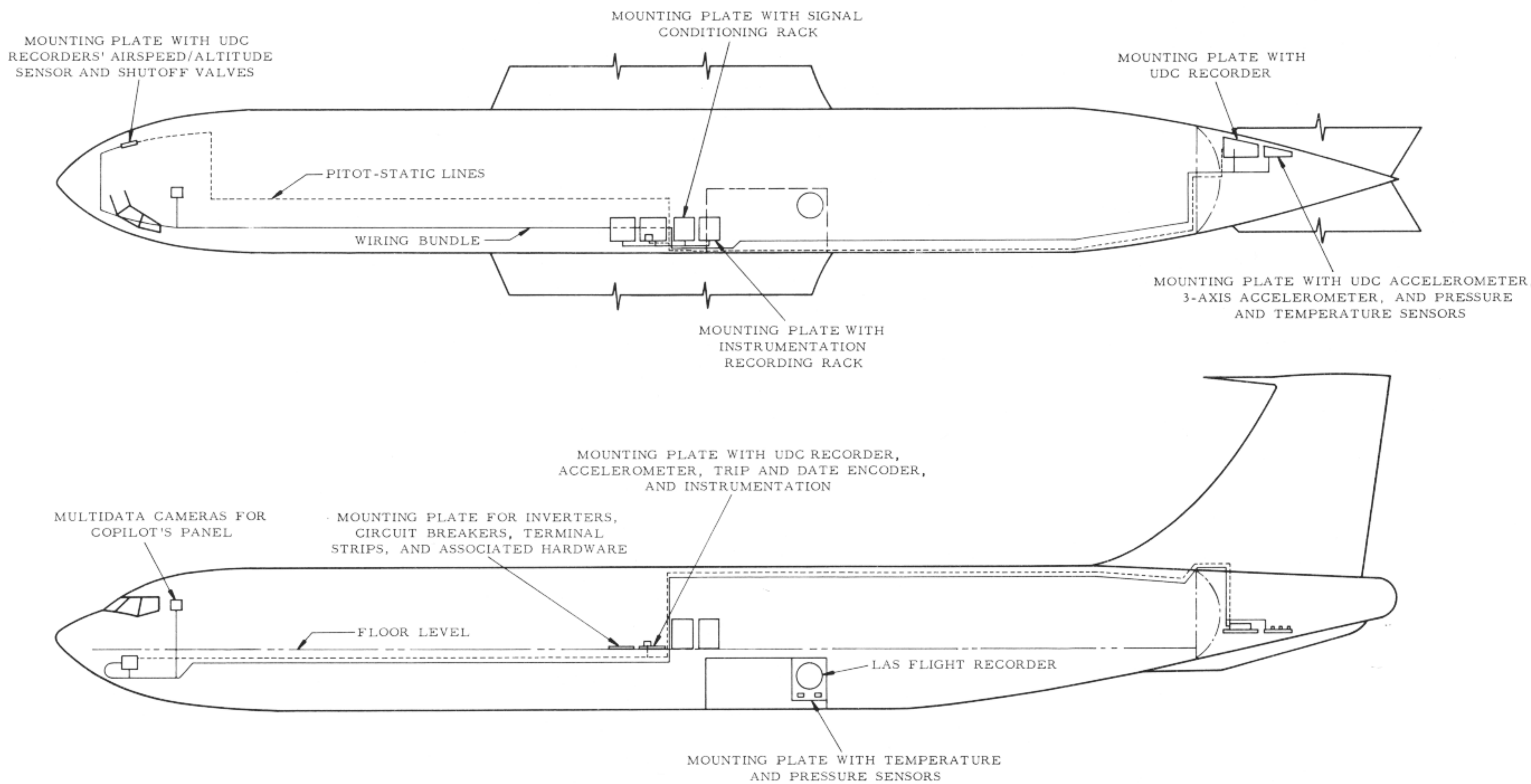


FIG. 6 SCHEMATIC OF EQUIPMENT LOCATION

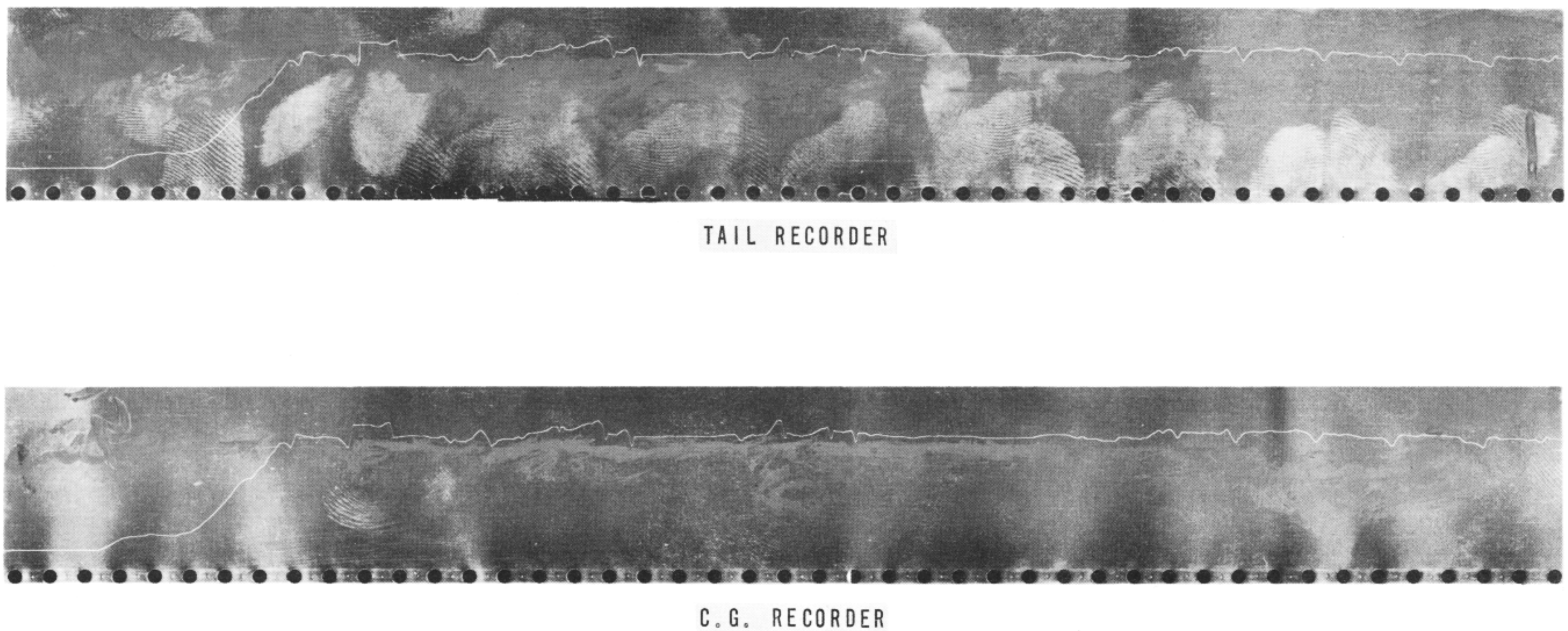
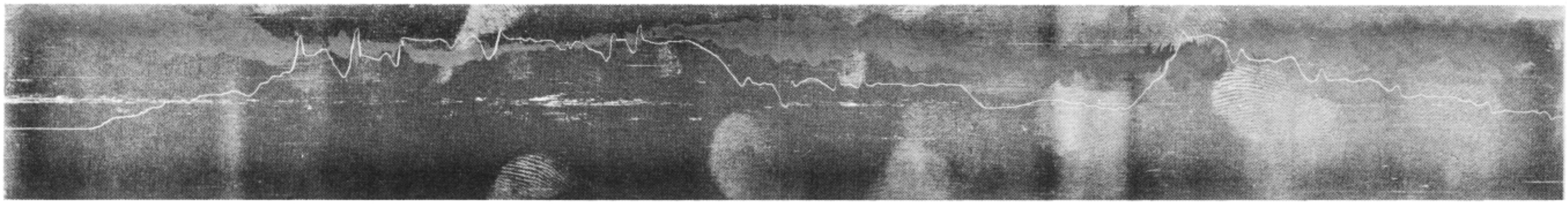
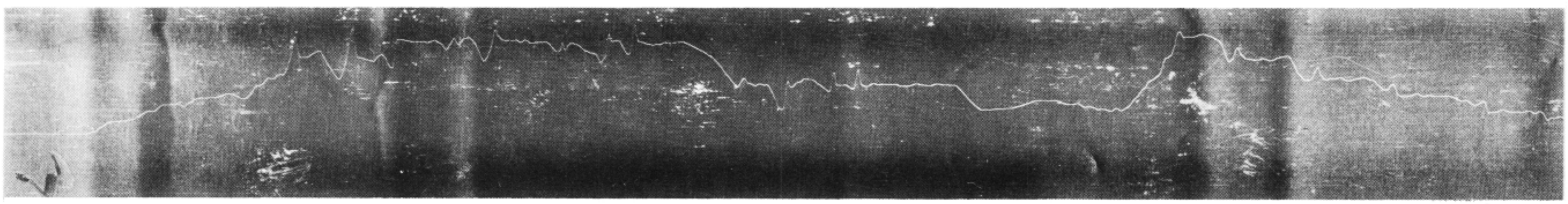


FIG. 7 COMPARATIVE ALTITUDE TRACES OF THE TWO UNITED DATA CONTROL, INC. FLIGHT RECORDERS

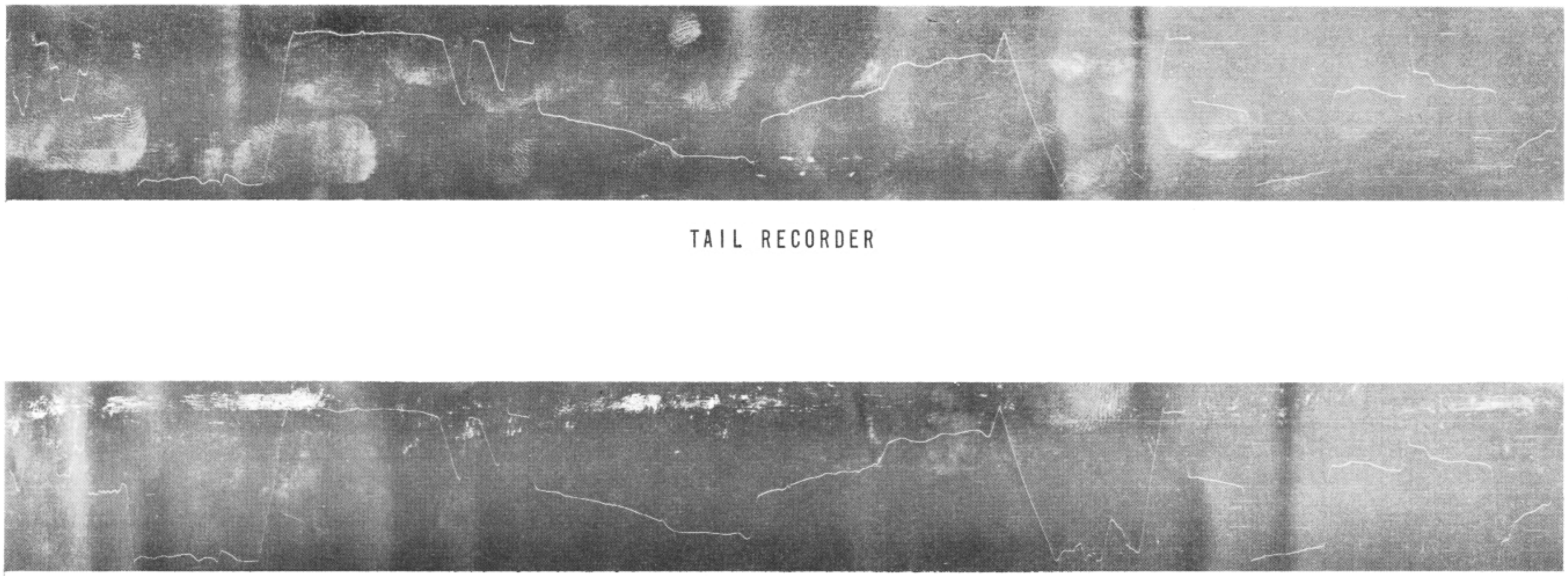


TAIL RECORDER



C.G. RECORDER

FIG. 8 COMPARATIVE AIRSPEED TRACES OF THE TWO UNITED DATA CONTROL, INC. FLIGHT RECORDERS



TAIL RECORDER

C.G. RECORDER

FIG. 9 COMPARATIVE HEADING TRACES OF THE TWO UNITED DATA CONTROL, INC. FLIGHT RECORDERS

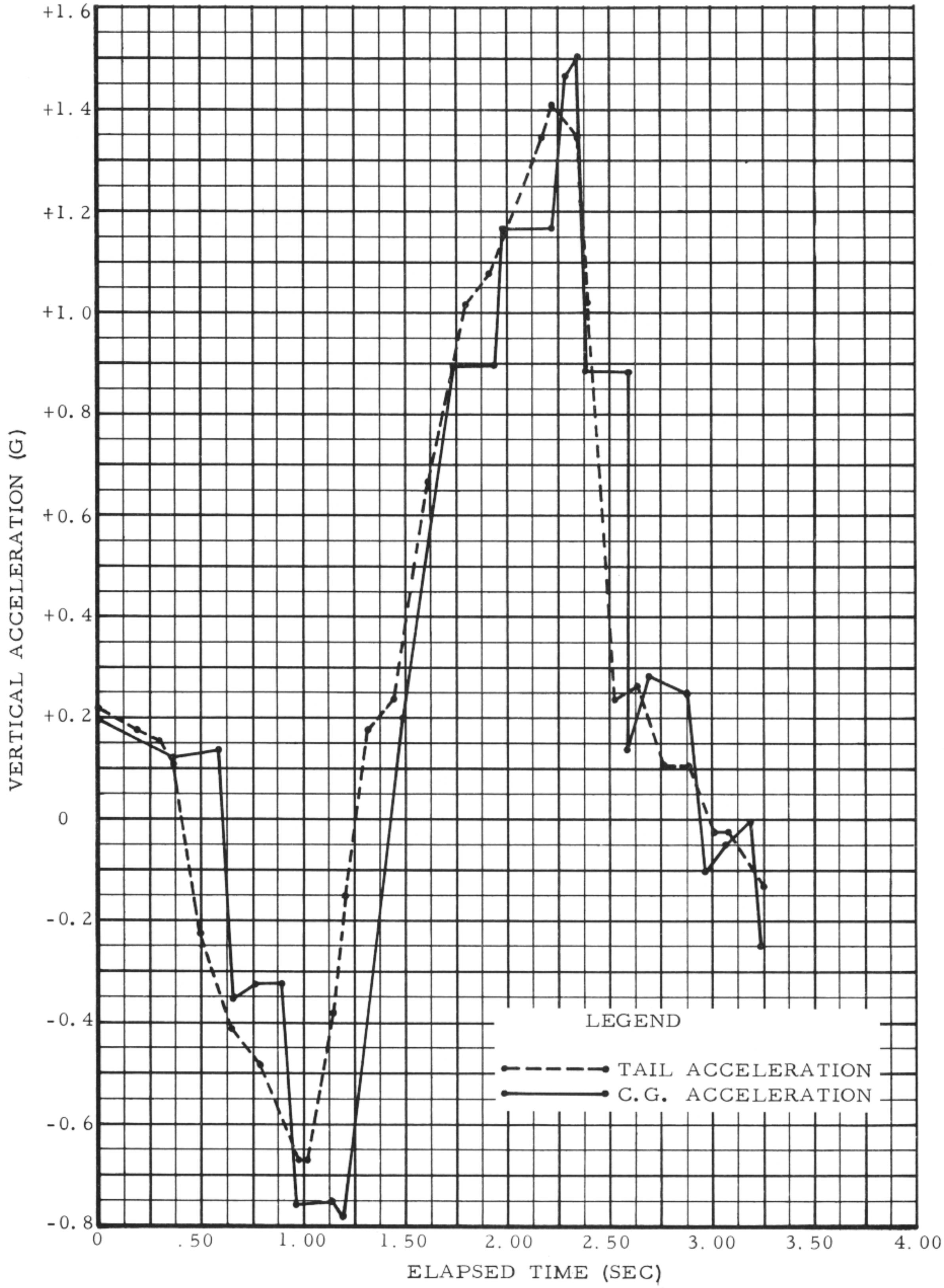


FIG. 10 PLOT OF COMPARATIVE ACCELERATION TRACES OF THE TWO UNITED DATA CONTROL, INC. FLIGHT RECORDERS

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by Paul M. Rich, August 1965, 22pp., incl. illus.
(Project No. 530-003-04X, Report No. ADS-50)

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Flight tests were conducted in conjunction with the FAA-NASA project TAPER (Turbulent Air Pilot Environmental Research) utilizing the FAA's Boeing 720. Two flight recorders and associated accelerometers were mounted in the aircraft; one in the cabin area near the center of gravity and one in the tail of the aircraft outside the pressurized bulkhead. The two recorders were modified to record altitude and airspeed as obtained from an altitude/airspeed transducer located near the pitot-static source. The standard airspeed and altitude channels were supplied by specially installed pitot-static lines running from the nose to the tail of the

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UNCLASSIFIED REPORT

The performance of a standard flight recorder, mounted aft of the pressurized bulkhead in the tail section of an air carrier transport aircraft was compared with that of a recorder as presently installed during flight.

Flight tests were conducted in conjunction with the FAA-NASA project TAPER (Turbulent Air Pilot Environmental Research) utilizing the FAA's Boeing 720. Two flight recorders and associated accelerometers were mounted in the aircraft; one in the cabin area near the center of gravity and one in the tail of the aircraft outside the pressurized bulkhead. The two recorders were modified to record altitude and airspeed as obtained from an altitude/airspeed transducer located near the pitot-static source. The standard airspeed and altitude channels were supplied by specially installed pitot-static lines running from the nose to the tail of the aircraft.

There was no difference between the recordings of the flight recorder located at the c.g. and the recording of an identical recorder located in the tail for the parameters of airspeed, altitude, and heading. However, there was a difference between the acceleration readings of these recorders. Although there was no difference between the altitude and airspeed obtained from the pitot and static lines and the altitude obtained via an altitude/airspeed transducer, the altitude/airspeed transducer proved more practical.

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Descriptors

Aircraft
Recording Devices

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