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EVALUATION OF THE GENERAL MILLS-RYAN FLIGHT RECORDER

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SUMMARY

This report describes flight observations and crash and fire tests of the General Mills-Ryan Flight Recorder. The recorder is spherical, approximately 13 inches in diameter, and 16.5 pounds in weight. Standard elements contained within the spherical housing are applied directly to measure altitude, air speed, magnetic compass heading, vertical acceleration and time. These data are embossed on aluminum foil, and each roll of foil is sufficient for 300 hours of flight time.

Two recorders were observed in flight for a period of several months, and during this time they functioned adequately. A recorder was crash-tested at an impact of 97g and was subjected to a 2000° F flame for 30 minutes, which did not destroy the intelligence recorded on the foil.

INTRODUCTION

Some ten years ago, it was decided by the CAB and the CAA that the use of flight recorders in all scheduled air carriers in both passenger and cargo service would promote safety and would constitute an aid in determination of the facts, conditions, and circumstances leading to accidents in which these aircraft might be involved. Therefore, their use was made mandatory. This regulation was repealed on June 9, 1944, because of material shortages.

Flight recorders were again made mandatory after October 16, 1947, but this regulation was amended March 29, 1948, to include only aircraft of 10,000 pounds or more maximum authorized take-off weight. Investigation had shown that the construction of aircraft of less than this weight did not provide adequate protection for the recording equipment in the event of a severe crash. Furthermore, the weight penalty of the smaller aircraft is more severe than on the larger types of transport aircraft when considered as a percentage of pay load. Light aircraft were used mainly in daytime VFR operations and generally were flown for short distances. The effective date was changed to June 30, 1948. Due to the fact that sufficient quantities of flight recorders were not available, it was necessary to further extend the time for compliance and no deadline date was established. At this juncture, the Air Transport Association, on behalf of the scheduled air carriers, agreed to initiate a program for the service testing of available instruments on various make and model aircraft used by the air carriers. After some flight-testing, the regulation was cancelled; and qualified manufacturers were encouraged to develop flight recorders.

The General Mills-Ryan Flight Recorder, developed by Professor James J. Ryan and sponsored by the General Mills, Incorporated, was considered sufficiently promising to warrant flight observation and determination of its ability to survive crash and fire tests. This report covers the results obtained during these observations and tests conducted at the Technical Development and Evaluation Center.

DESCRIPTION

Three General Mills-Ryan Flight Recorders were submitted by the Mechanical Division of General Mills, Inc., Minneapolis, Minnesota, to the TDEC for flight observations and tests. The instrument, shown in Fig. 1, records air speed, vertical acceleration, altitude, and time. It is incorporated in a spherical fireproof case. The total weight is 16.5 pounds. A later model also records heading and weighs 22.5 pounds. This recorder utilizes a magnetic compass and an electrical servosystem for recording the 360° displacement.

The frame of the instrument is aluminum, and the spherical fireproof case is comprised of two walls. The outer wall is a zinc-plated mild steel sphere, 15 inches in diameter, and the inner wall is an aluminum sphere 13 inches in diameter. The insulation between the walls is a one-inch layer of Perlite with Marinite separators at the "equator" where the two halves of the case are joined. The upper hemisphere contains the recording mechanism, the air-speed unit, and the drive-timing regulator. The lower hemisphere contains the altimeter unit, the electric drive motor, and the accelerometer assembly. The pressure lines for the air-speed and altimeter elements are connected at one support bracket. An AN connector for the 28-volt-dc power source is on the opposite bracket. For the recorders that include heading, 115-volt 400-cps electrical power also is required. The sensing and recording mechanisms are shown in Figs. 2A and 2B. The air-speed indicator element is a standard pressure diaphragm, with a range from 0 to 500 mph, having static and dynamic chambers. This element has about 0.75-inch movement for 500 mph as indicated at sea level. The altimeter element is an aneroid bellows with temperature compensation. It indicates pressure altitude of from -1000 feet to 40,000 feet based on standard atmospheric pressure. The altimeter record has a two-inch spread for an indication of 40,000 feet. The moving portion of this unit acts upon a lever mechanism, with a magnification of approximately four, to displace the indicating stylus.

The accelerometer element, which is a cube of metal, is supported upon cantilever beam springs, so designed that the movement of the weight and the stylus is in a straight line. The accelerometer measures between limits of from -3g to +12g with about 2 inches spread on the record. The natural frequency of the element is approximately 430 cycles per minute. Damping is obtained by an air dashpot. The styli of these three elements are slightly displaced to prevent interference. A fourth stylus indicates the reference position or base line for the recordings. The recording medium is aluminum foil, 0.001 inches thick and 2.25 inches wide, in rolls of 100 feet. The foil moves at a rate of four inches per hour, so that one roll can record continuously for approximately 300 hours or the equivalent of two weeks flight time. The recording styli emboss the foil as it moves over the backing plate. The foil is rolled on a reel and is caused to move across the backing plate by means of a small 28-volt-dc permanent-magnet motor which moves so slowly as to approximate a stalled condition. The "stalled" motor operates at approximately six revolutions per hour and continually applies a torque through a short length of coil spring to drive the rewind spool. The speed of the foil advance is governed by a clockwork escapement mechanism. A cam-operated scriber marks the edge of the foil each minute of time with major indications every 15 minutes and every hour. Air speed is given in miles per hour, altitude is in feet, and the acceleration is in multiples of g.

The air-speed indicator element is connected to the aircraft static-pressure and the dynamic-pressure lines in parallel with the instruments in the cockpit. The altimeter unit also is connected to the static-pressure line. The interior of the recorder housing is at ambient outside pressure.

The drive for the foil operates for approximately ten minutes after the power to the motor is turned off or the power fails. This is obtained by a ratchet and the spring between the motor shaft and its connecting gear.

A flight data reader, Fig. 3, that facilitates obtaining intelligence from the foil, is available. It is a metal box containing an optical system by which the aluminum-foil records from the flight recorder may be scanned with a minimum of difficulty.

The aluminum foil on spools from the recorder is placed in a holder in front of the box. The eyepiece, located above the holder, allows the foil to be scanned as the record is turned in the holder. As seen from the eyepiece, the record appears at its natural size inside the box. The illumination is obtained by edge lighting of the record. An overlay calibration chart, mounted similar to a projection slide, is placed in a lamp housing at the side of the box. This illuminated overlay is then projected so as to be superimposed upon the image of the recorder record. Suitable lighting for maximum clarity of the scribed marks on the film and the intensity of the overlay is obtained by adjusting knobs. Other controls line up the reference line on the foil with the reference line on the overlay and advance the foil. From the calibration overlay, for any instant of time, values of air speed, altitude, acceleration, and heading may be observed. A typical record as viewed with the data reader is shown in Fig. 4.

A 35-mm camera attachment is placed so that any portion of the record may be photographed. The photograph may be enlarged to any size desired for accurate study and measurement. From a roll of foil, any number of photographs of the pertinent information may be taken for future enlargement and study. The data reader is 12 inches wide, 25 inches long, and 16 inches high. It weighs approximately 40 pounds.

A direct-reading transport overlay also is provided for immediate analysis of the records where the data reader is not available. Other optical magnifiers such as enlarged photographs or microscopes may be used.

RESULTS OF TESTS

Flight Observations.

Flight recorders were installed in two of the Center's DC-3 airplanes. Recorder serial No. 11 was installed in airplane N-182, and recorder serial No. 4 was installed in airplane N-183. These installations were made in February 1954. Up to June 30, 1954, N-182 has flown 105 hours and N-183 has flown 68 hours.

The recorders were wired in with the master switch so that they were turned on at all times when the engines were operating. The purpose of the flight observations was mainly to determine whether the recorders would continue to operate for an extended time when installed in an airplane. The recorders were inspected periodically to determine if they were functioning properly. Only minor mechanical difficulties occurred. These were corrected and new recorders have been revised accordingly. No tests were conducted to calibrate or determine the accuracy of these instruments.

Ground Tests.

Flight recorder serial No. 5 was used for the ground tests. The tests were conducted during the month of April 1954. They consisted of impact and fire tests in which a crash followed by a fire was simulated.

For the impact test, the recorder was mounted in a structure which simulated conditions that could exist if the recorder were mounted in an airplane during a crash. Fig. 6 shows the recorder installed for this test. The test was conducted on the TDEC tank-catapult track used for crashing fuel tanks. The test structure with the attached recorder was crashed into a sandbag barrier. High-speed motion pictures were taken of the impact at 1500 frames per second. From the photographs, the distance-versus-time relation was plotted to obtain the time history of the deceleration. This is shown in Fig. 7. The speed of the recorder at the time of impact was 34 mph and the maximum deceleration was 97g.

During the impact, the top half of the spherical case of the recorder moved forward approximately one-half inch with respect to the lower half of the sphere. Due to the one-inch wall thickness, the interior of the recorder was not exposed. See Fig. 8. Since a fire following a crash was to be simulated, the recorder housing was not opened to inspect the aluminum foil record until after the fire test.

It was removed from the standard test structure without disturbing the misalignment of the upper and lower hemispheres and was then mounted on two pieces of one-inch angle iron and subjected to fire. The outer surface of the sphere had previous been coated with 0.46 pounds of fire-resistant paint (Albi Tem-Kote 99). This was equivalent to 1.75 ounces per sq. ft. The flame was produced by a modified conversion oil burner which consumed 12 gallons of No. 3 fuel oil per hour. The flame impinged on the lower half of the recorder at a temperature of 2000° F. The flame at slightly lower temperatures enveloped the rear lower half, the sides, and most of the upper half of the recorder as shown in Fig. 9.

The Albi coating fluffed and blackened over the entire outer surface of the recorder in the first minute. After four minutes, the aluminum-alloy fitting and connectors melted and dropped off; and, at $12\frac{1}{2}$ minutes, large pieces of the flange dropped from one side. The burner was turned off at the end of 15 minutes so the damage to the outer shell could be determined. Wing nuts and studs on one side and the Albi coating on the underside of the sphere had dropped off. The flame was turned on again after three minutes of inspection time. At $17\frac{1}{2}$ minutes, another large piece of molten aluminum dropped from the flange. No further damage was evident during the remainder of the 30-minute test. During the last 15 minutes of the fire test, the sphere had no Albi coating on its underside. This was enveloped in flame. The recorder was allowed to cool and was then opened for inspection. It was found that the impact had in no way damaged the record. The flame had caused the exposed portion of the aluminum foil to become darkened by a smoke and soot deposit, as may be seen in Fig. 10. However, the intelligence recorded was readily obtainable.

CONCLUSIONS

It is concluded that the General Mills-Ryan Flight Recorder can operate satisfactorily in an airplane, and can withstand an impact of 97g, followed by a 2000° F fire for 30 minutes without destruction of the record. It also is concluded that an outer coating of fire-resistant paint is not necessary.

FIG. I FLIGHT RECORDER WITH TOP COVER REMOVED

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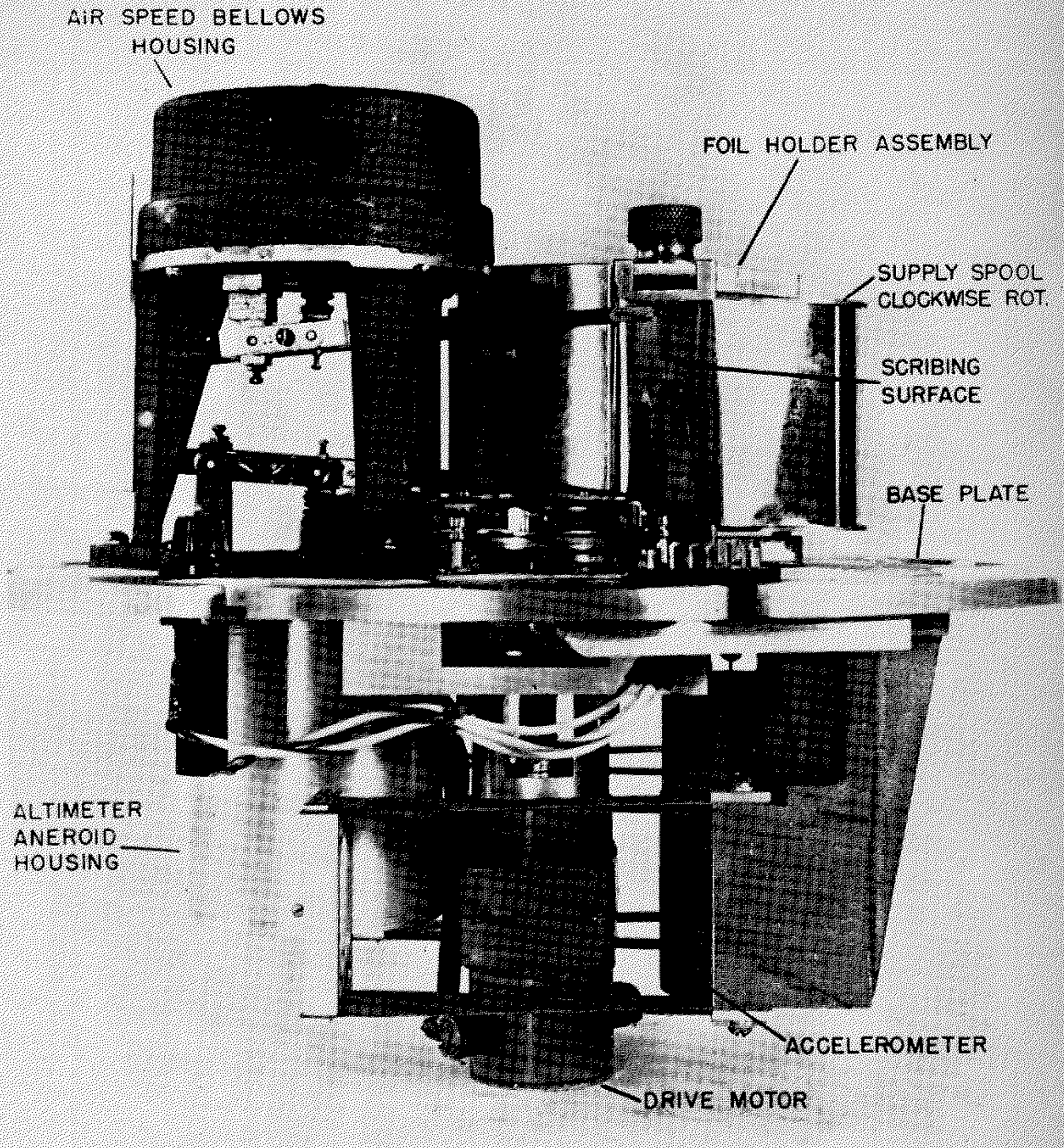

FIG. 2A FLIGHT RECORDER WITH HOUSINGS REMOVED—FRONT VIEW

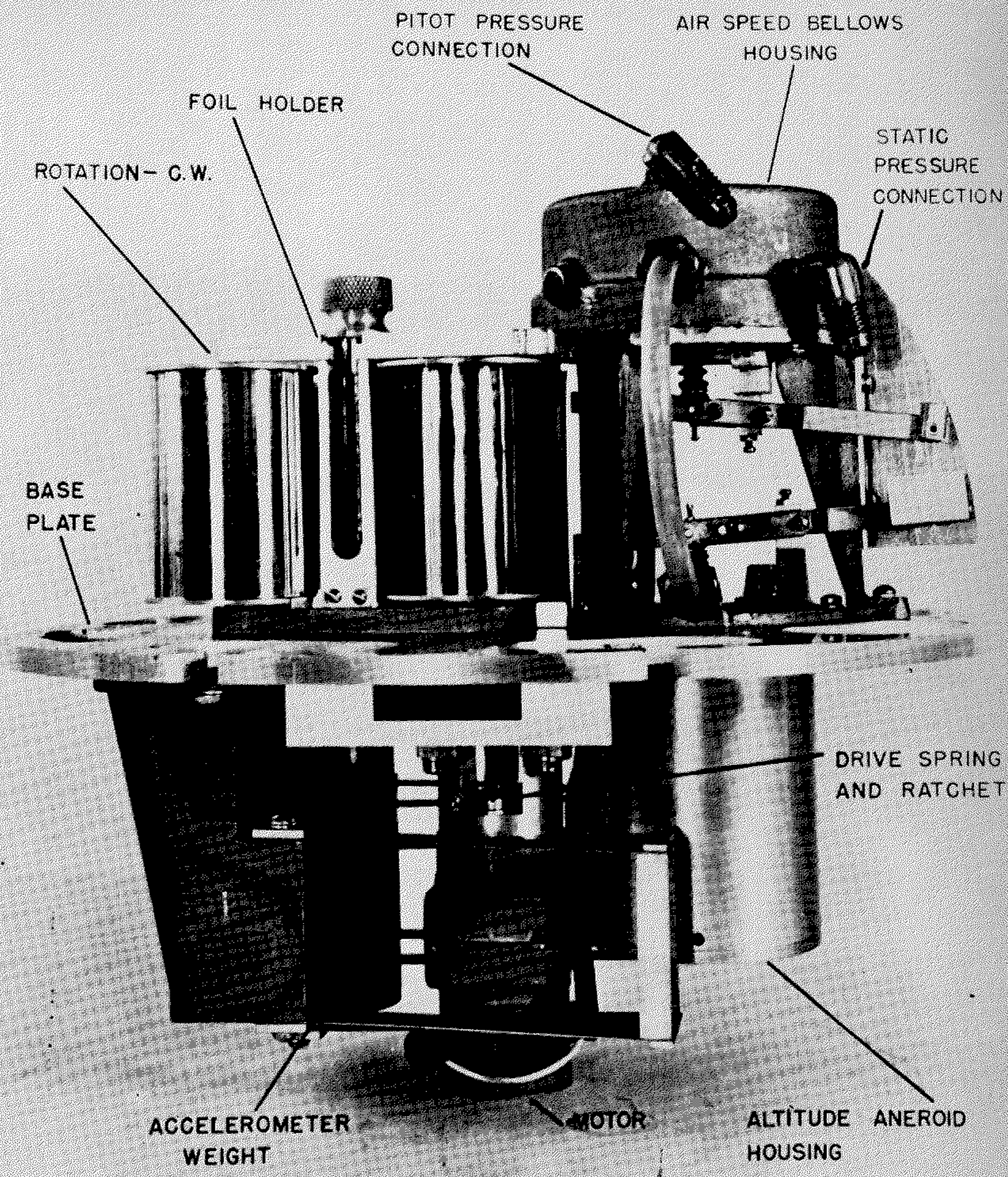

FIG. 2B FLIGHT RECORDER WITH HOUSINGS REMOVED—REAR VIEW

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FIG. 3 VIEWER FOR READING FLIGHT RECORDER

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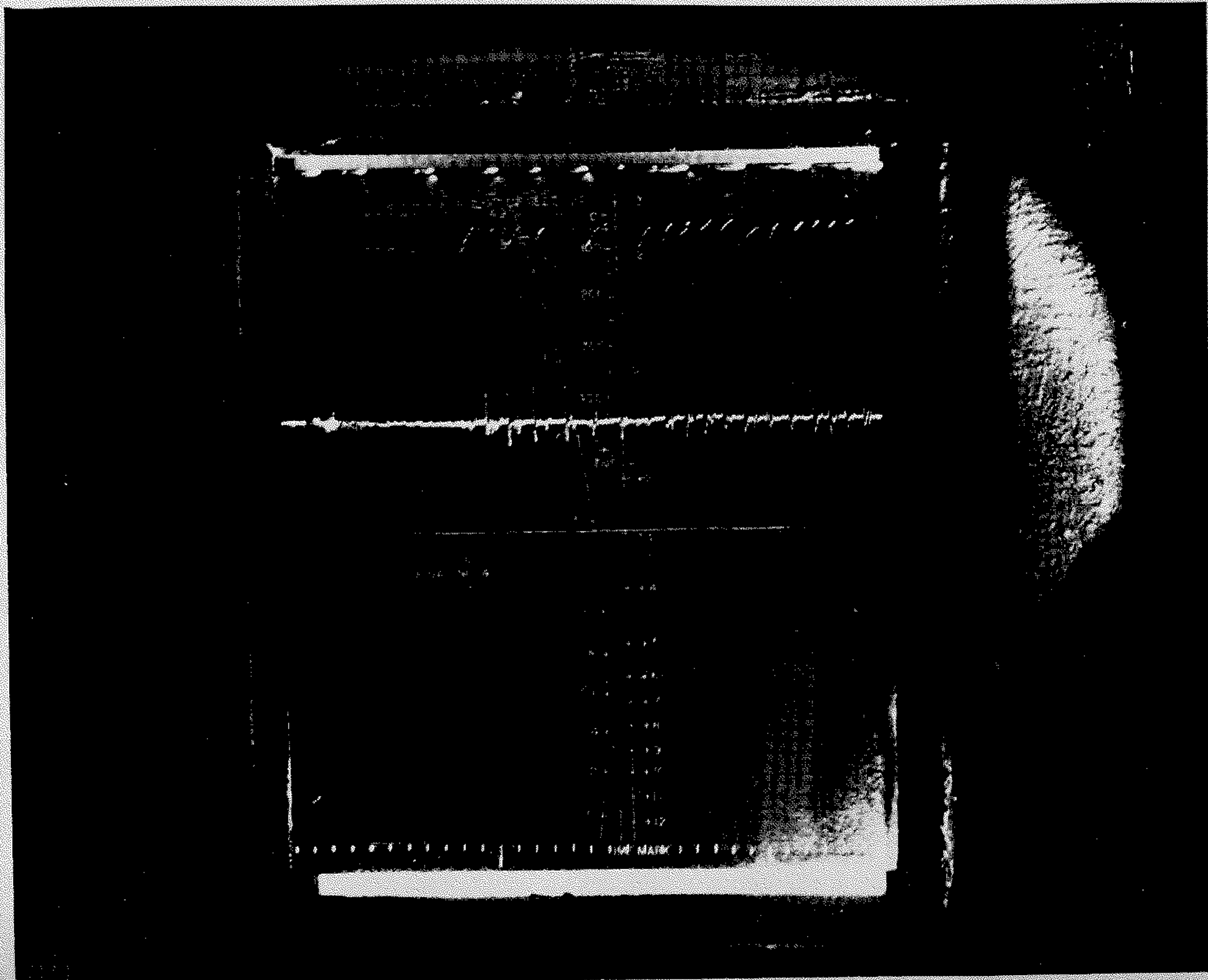

FIG. 4 FLIGHT RECORD AS VIEWED WITH DATA READER

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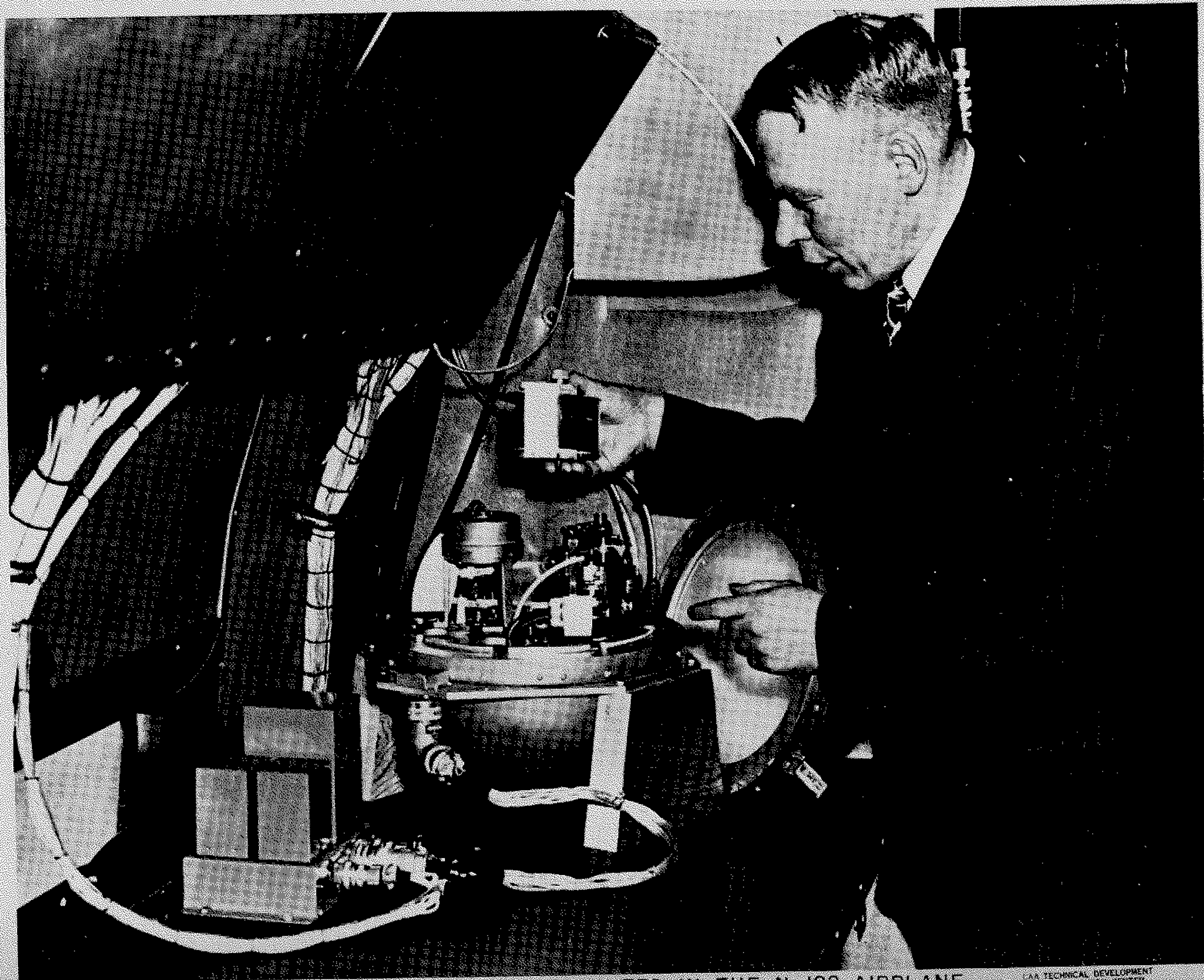

FIG. 5 FLIGHT RECORDER MOUNTED IN THE N-182 AIRPLANE

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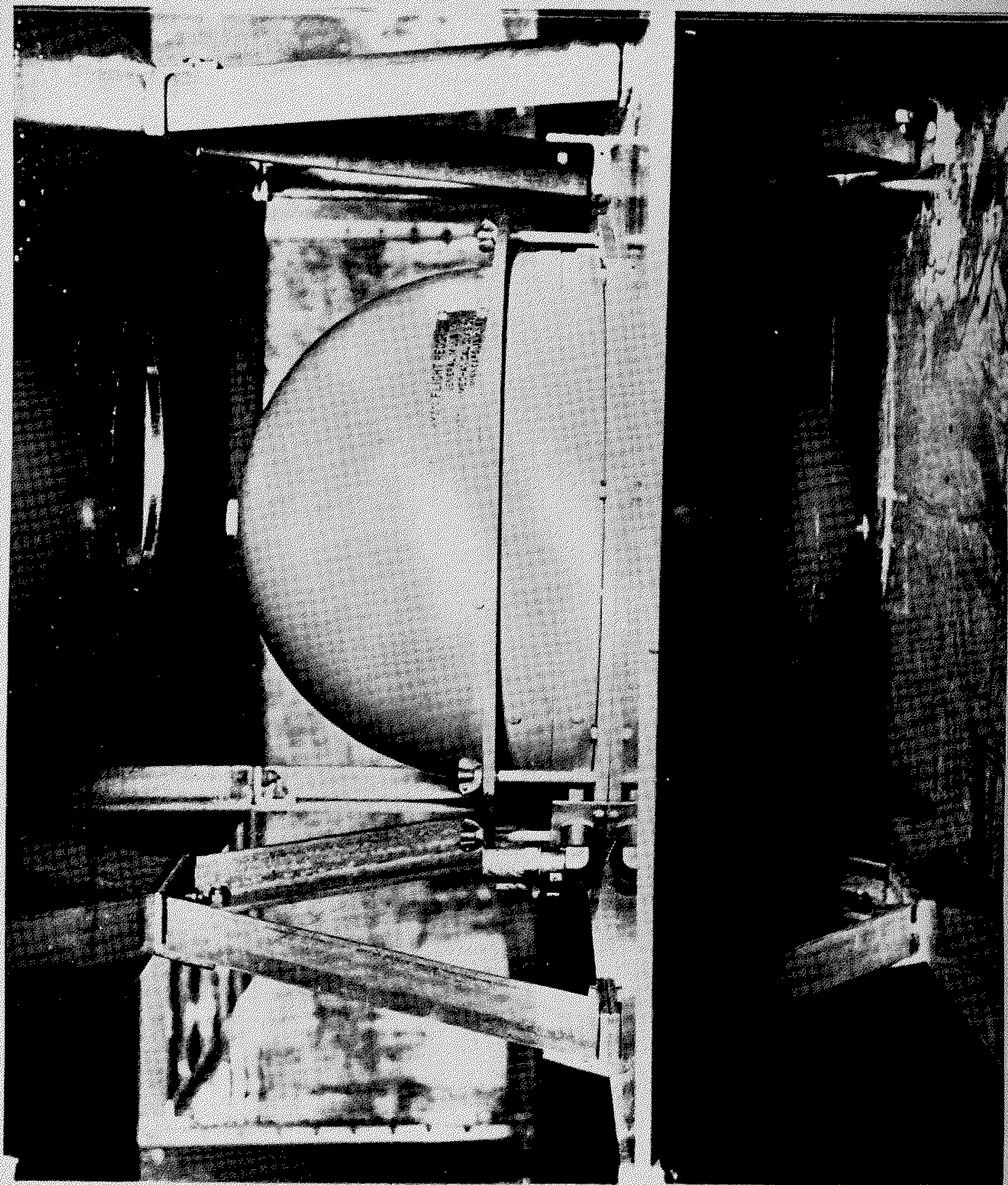

FIG. 6 FLIGHT RECORDER MOUNTED FOR IMPACT TEST

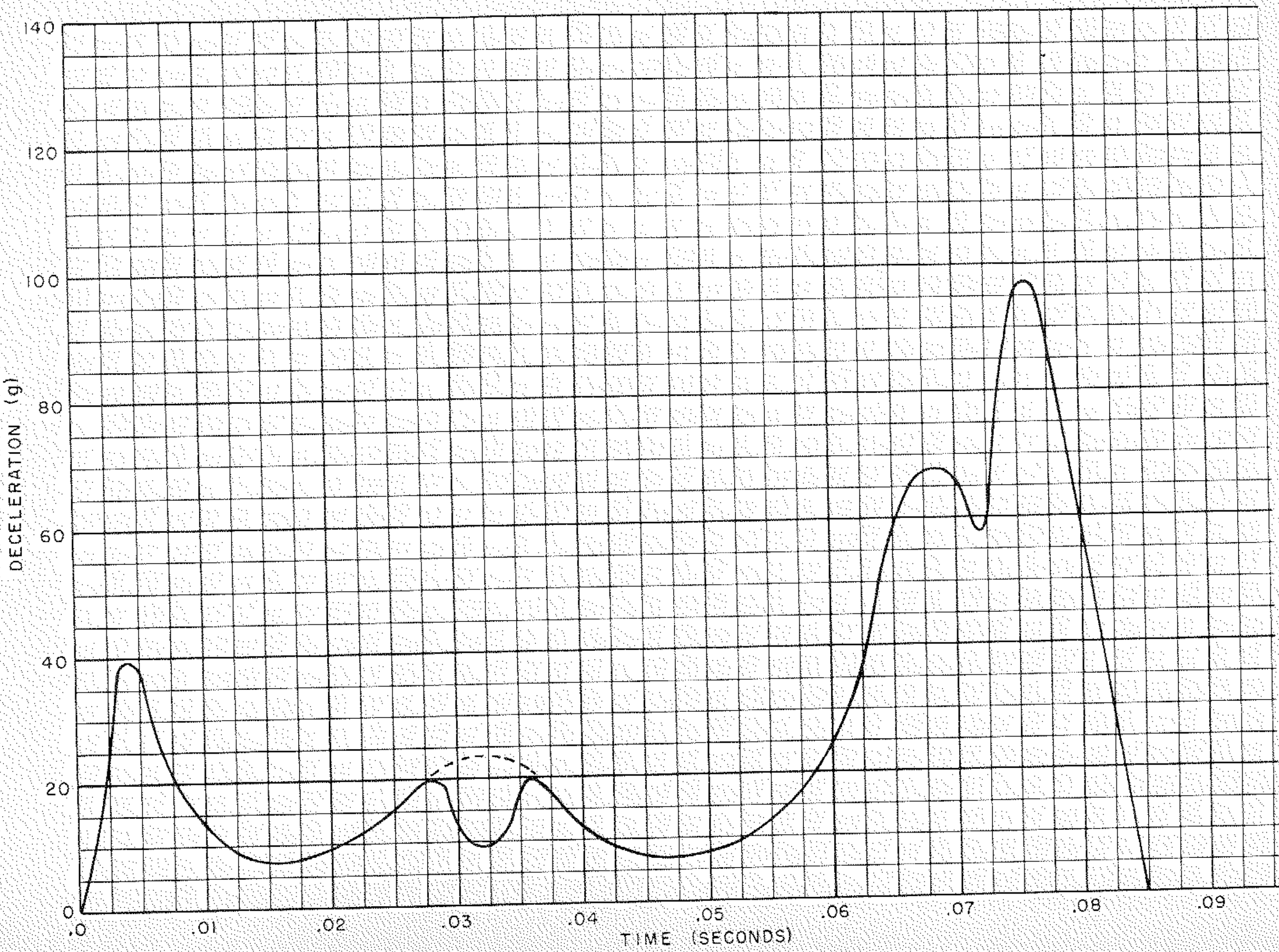

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FIG. 7 TIME HISTORY OF DECELERATION EXPERIENCED BY THE RYAN FLIGHT RECORDER

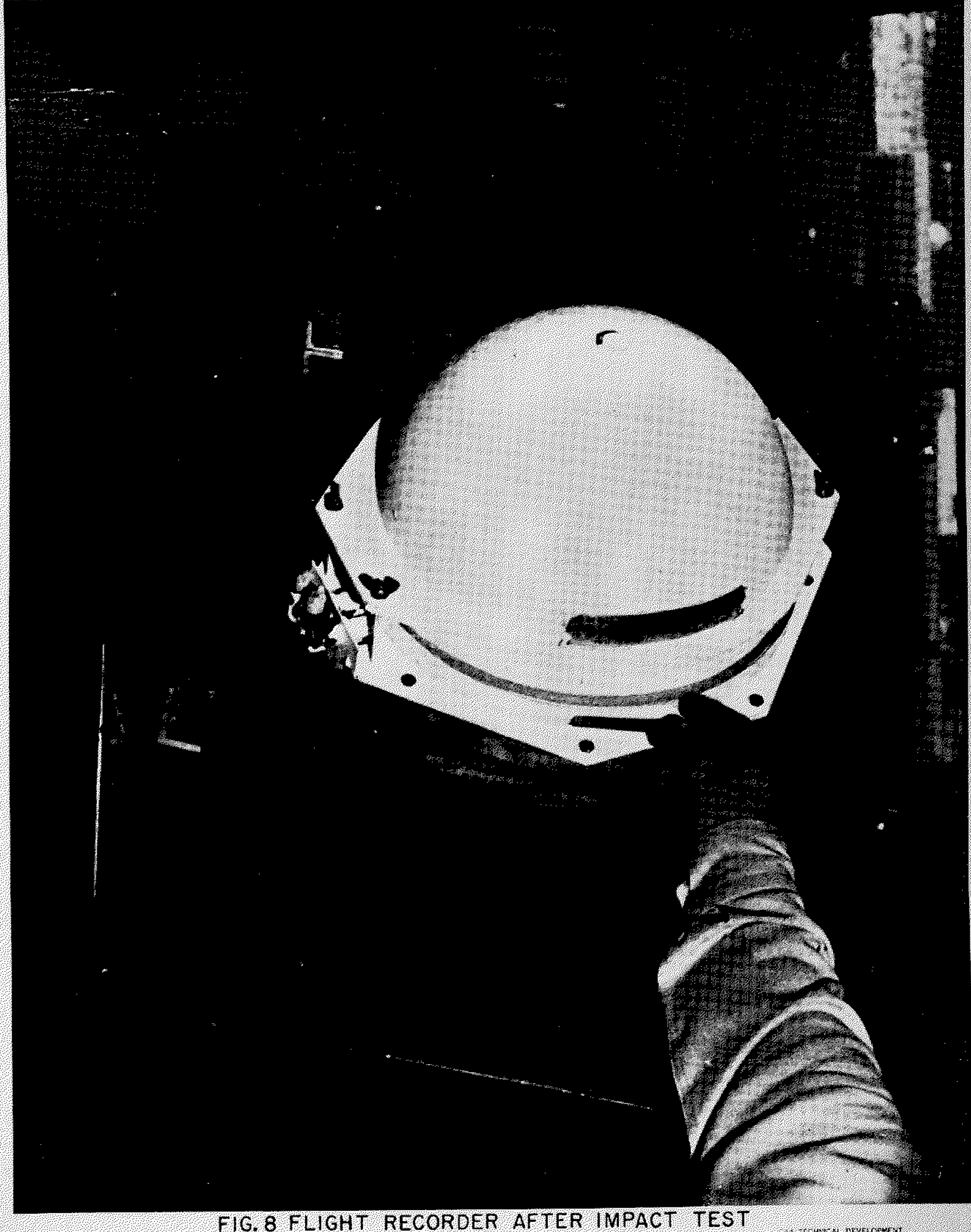

FIG. 8 FLIGHT RECORDER AFTER IMPACT TEST

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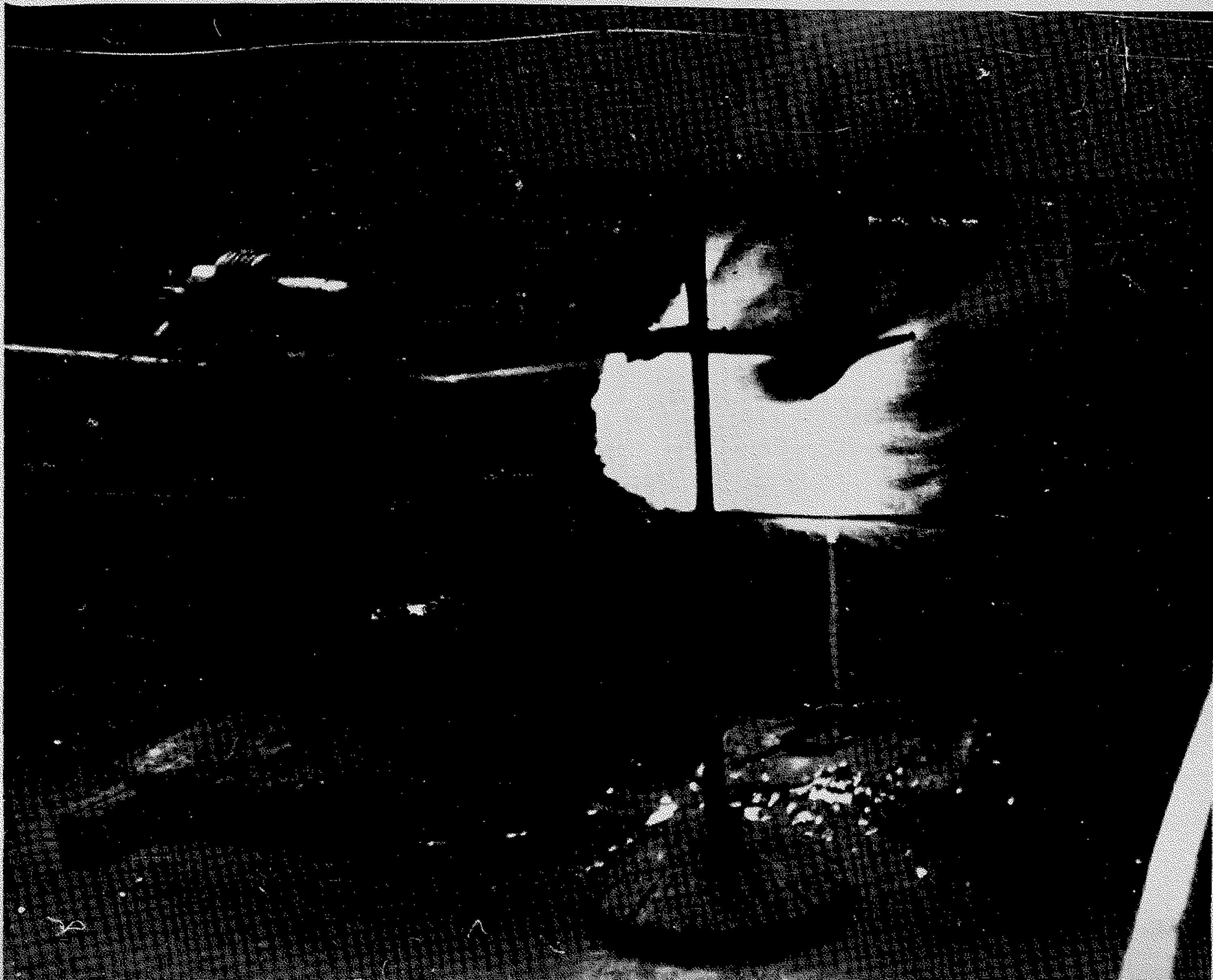

FIG. 9 FIRE TEST OF FLIGHT RECORDER

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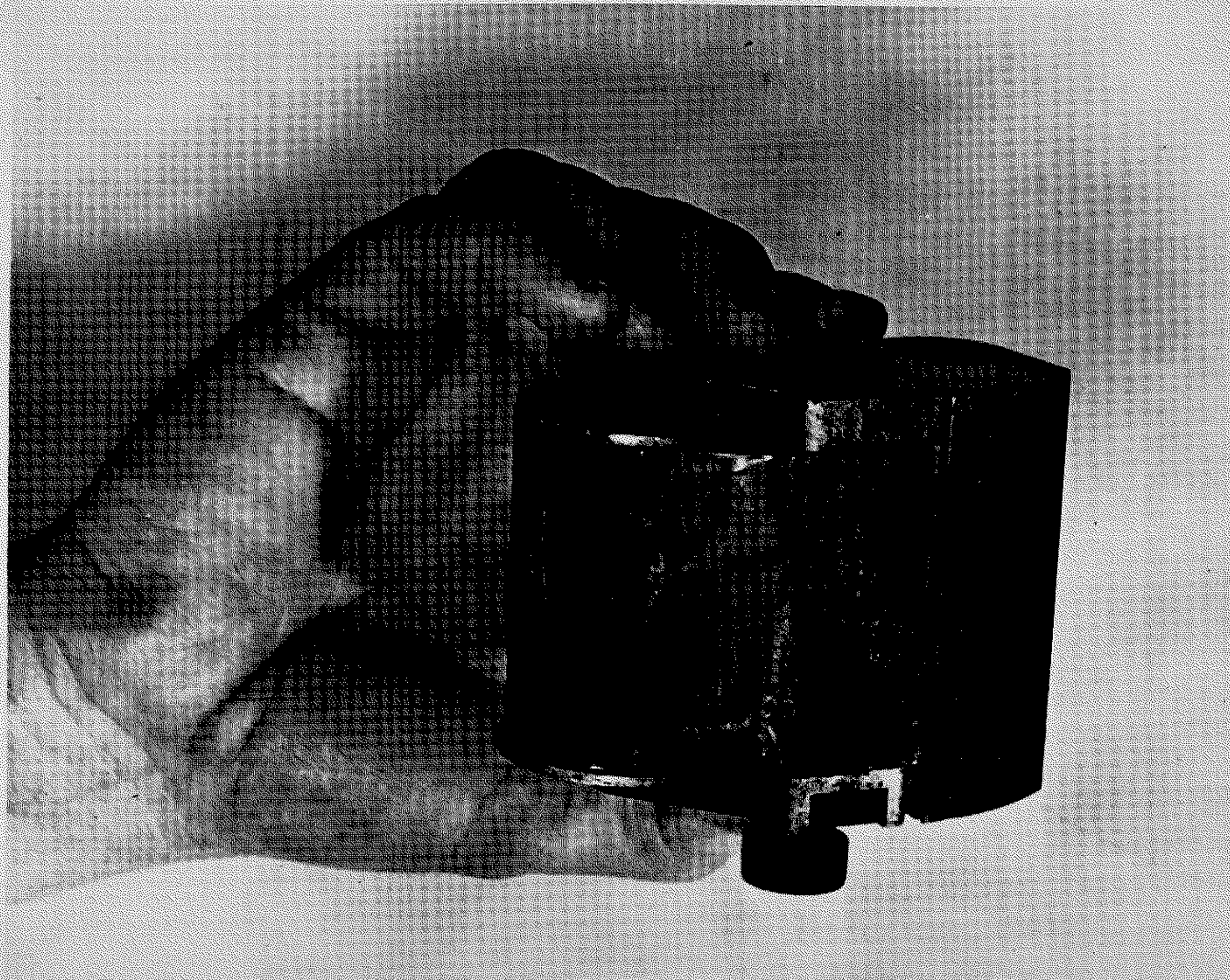

FIG. 10 RECORDING FOIL AND FOIL HOLDER AFTER TESTS

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