Report No. FAA-RD-71-33

DEVELOPMENT AND TEST OF THE EXPLOSIVE EXIT CONCEPT FOR CIVIL TRANSPORT AIRCRAFT

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JULY 1971

FINAL REPORT

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Prepared for

DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION

Systems Research & Development Service

Washington D. C., 20590

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FAA-RD-71-33	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle DEVELOPMENT AND TEST OF THE EXPLOSIVE EXIT CONCEPT FOR CIVIL TRANSPORT AIRCRAFT		5. Report Date July 1971
		6. Performing Organization Code
7. Author(s) Joseph J. Jaglowski, Jr.		8. Performing Organization Report No. FAA-NA-71-11
9. Performing Organization Name and Address National Aviation Facilities Experimental Center Atlantic City, New Jersey 08405		10. Work Unit No.
		11. Contract or Grant No. Project No. 503-101-03X
		13. Type of Report and Period Covered Final Report July 1968-October 1970
12. Sponsoring Agency Name and Address FEDERAL AVIATION ADMINISTRATION Systems Research and Development Service Washington, D. C. 20590		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The test program was performed to evaluate the liquid explosive emergency exit system reliability, performance, and hazards to personal safety when exposed to environments which might be encountered before, during, and after a crash. The report includes: (1) A test program to evaluate the liquid explosive emergency exit system when exposed to environment simulating conditions encountered before, during, and after a crash; (2) Results of the tests; (3) Evaluation of a retaining shield in attenuating the sound level and containment of the debris produced by the detonation of the linear-shaped charge; and (4) The feasibility of adapting the liquid explosive emergency exit system for use on civil transport aircraft.

17. Key Words Civil Aircraft, Sound, Shaped Charge, Explosive, Fragmentation, Nitromethane	18. Distribution Statement Availability is unlimited. Document may be released to the National Technical Information Service, Springfield, Virginia 22151, for sale to the public.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	45	

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INTRODUCTION

Purpose

The purpose of this project was to evaluate the liquid explosive emergency exit system reliability, performance, and hazards to personal safety when exposed to environments simulating normal operating conditions, as well as those which might be encountered before, during, and after a crash. Where possible the simulated environments were to be designed to equal or exceed those conditions encountered in a survivable crash. In addition, the feasibility of adapting the system for use on civil transport aircraft was to be demonstrated.

Background

As a result of the feasibility study and initiating system development of a liquid explosive emergency exit system reported in Reference 1, the Systems Research and Development Service (SRDS), requested a study to further evaluate the system's reliability, performance, and hazards to personal safety when exposed to environments simulating normal operating conditions, as well as those which might be encountered before, during, and after a crash. The request was implemented through the previous assignment of Project 510-002-08X, entitled "Feasibility Study of Explosive Techniques for Providing Emergency Exits," to the National Aviation Facilities Experimental Center (NAFEC).

The liquid explosive emergency exit system uses two commercially available liquid components, nitromethane and a sensitizer, classed as nonhazardous materials. The liquids are separately stored in a pump so arranged, that pumping provides the correct mixing ratio of the components to form an explosive mixture. The mixing system is mechanically initiated, starting an automatic sequence. The mixing pump forces the explosive mixture into the shaped tubing outlining the preconceived exit. The explosive mixture contained in the shaped, charged tubing is then ignited by a stab detonator. Detailed system operation is described in Reference 1.

Test Program

This test program is aimed at exposing the liquid explosive emergency exit system to environments which might be encountered before, during, and after a crash and determining the feasibility of adapting the system for use on civil transport aircraft.

Three test configurations were used in the conduct of the test programs: (1) test panels attached to a special design test stand, (2) a scale model representing typical transport fuselage, and (3) an entire Convair 880 fuselage.

The test specimens were test fired either during or after exposure to the environment with one exception that the specimen assigned to the crash-fire test which was not test fired.

Concurrently with the environment test program, a retaining shield was designed, fabricated and tested to determine the requirements and adequacy of such a shield in attenuating the sound level and containing of the debris generated by the detonation of the linear-shaped charge material.

DISCUSSION AND RESULTS

The use of a liquid explosive linear-shaped charge system to create emergency exits of civil transport aircraft was evaluated through a series of experimental tests. The test conditions simulated included system operation in the environments of fuel spray, fuel vapors, fuel puddles, low temperatures, system operation following the imposition of impact shock, high deceleration forces, crash forces, and crash-fire condition.

Fuel Ignition

A series of 12 fuel ignition tests utilizing JP-4 aircraft fuel was conducted to determine the effect of the flame generated by the detonation of the linear-shaped charge material on fuel puddles, fuel spray, and fuel vapors near and on the test specimen. Figure 1 shows the fuel ignition test setup. The test panel was attached to the stand with the system mounted in the center of the panel and the linear-shaped tubing outlining the preconceived cutout in the panel.

A series of four tests involving fuel spray was conducted, each on a complete test specimen. The spray was accomplished by the use of a paint sprayer operated by compressed air. The spray was different in each test; it varied from small size droplets to a fine mist, which was accomplished by varying the nozzle opening of the sprayer. The fuel spray was directed on and past the reverse side of the test specimen during the time of the tests (see Figure 2). This figure shows the specimen after it was test fired. During the series of tests, the ambient air temperature was 42°F.

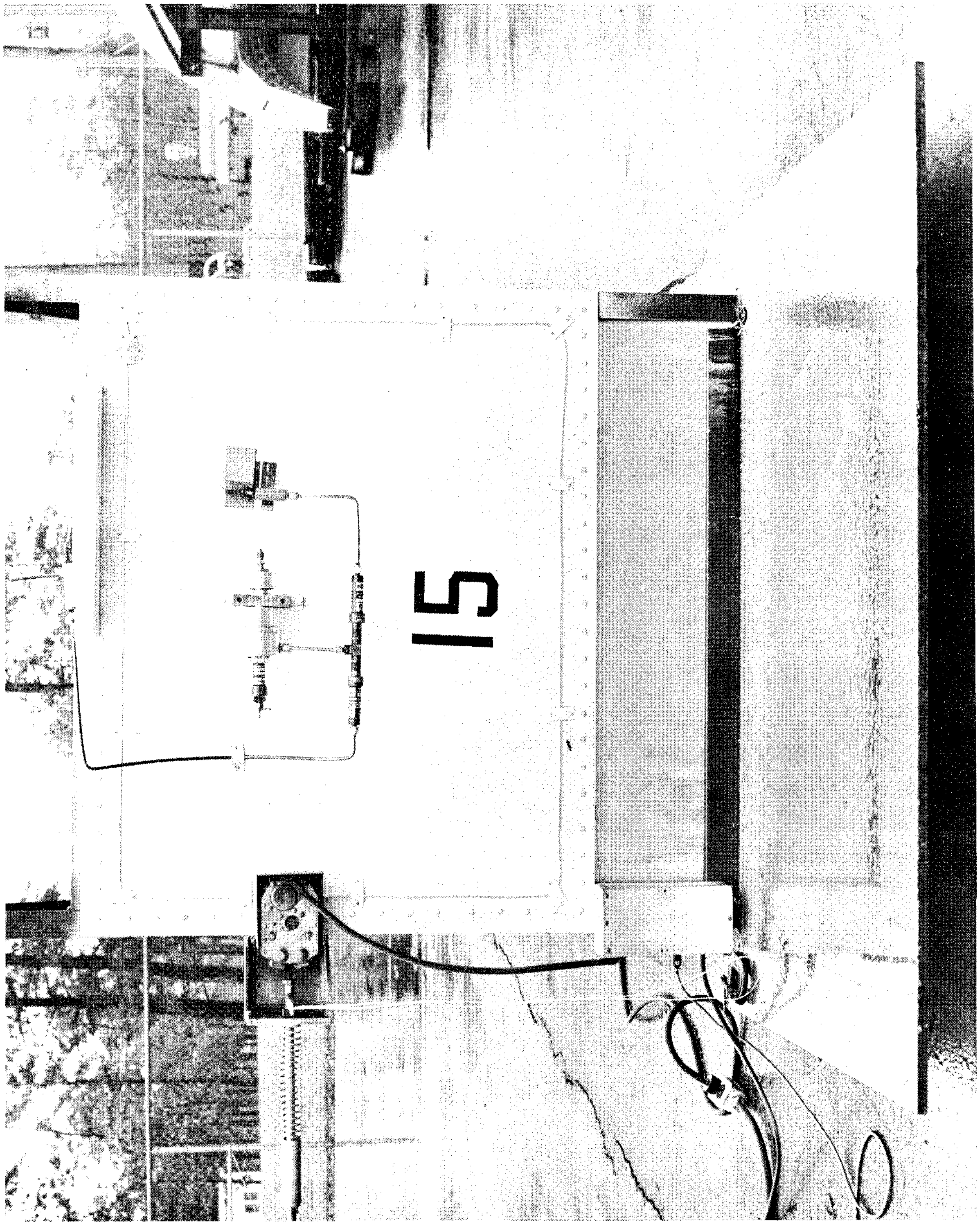

FIGURE 1. - FUEL IGNITION TEST SETUP

FIGURE 2. - FUEL SPRAY TEST SETUP

No ignition of the fuel spray resulted under the conditions simulated.

A series of six tests involving fuel vapors was conducted, each on a complete test specimen. The fuel vapors were produced by heating a container containing JP-4 aircraft fuel with a hot-plate. The container was located on the opposite side of and below the linear-shaped tubing outlining the preconceived cutout in the panel (see Figure 3). In the first test, the fuel was heated to a temperature of 60°F. In each succeeding test, the temperature level of the fuel was raised 5°F before it was test fired. In the final test, the temperature of the fuel was 85°F. During this series of tests the ambient air temperature was 43°F.

The tests resulted in no ignition of the fuel below the temperature level of 75°F; but ignition and continued burning of the fuel occurred in temperature levels above 75°F.

Two tests involving fuel puddle were conducted, each on a complete test specimen. The test setup was identical to that used in the fuel vapor test except the fuel in the container was not heated.

The tests resulted in no ignition of the fuel.

Cutting Capability and Flame Effect on Cabin Fabric

The purpose of this test was to determine the cutting capability of the 3/16-inch-diameter, linear-shaped tubing containing the liquid explosive, and whether the flame from the detonation of the charge would ignite the interior cabin materials selected. Two cutting and burn tests were conducted; both in conjunction with the fuel spray tests.

The cutting and burn test was accomplished by attaching a section of a Convair 880 fuselage frame to the test panel and then forming the linear-shaped tubing to the contour of the frame as shown in Figure 4. The interior cabin materials were attached to the same test panel adjacent to the linear-shaped tubing. The interior cabin materials selected were upholstery, sidewall, carpet, seat foam and curtain fabric.

The tests resulted in complete cutting of the Convair 880 fuselage frame and panel configuration (see Figure 2). The size of the charge was adequate to cut airframe skin configuration, and the shaped tubing was contoured to structural members with rather sharp bends without affecting propagation of detonation.

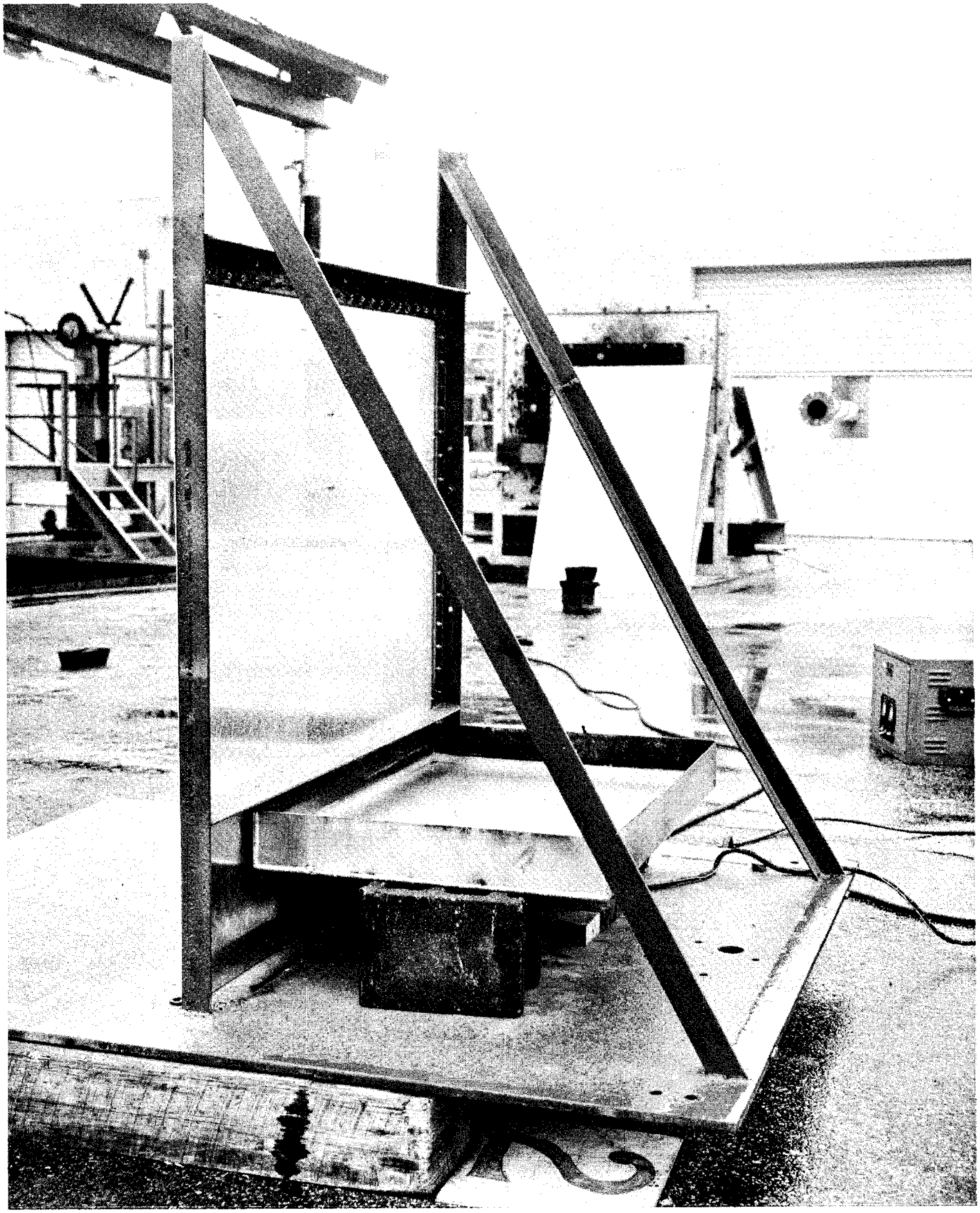

FIGURE 3. - FUEL VAPOR AND PUDDLE TEST SETUP

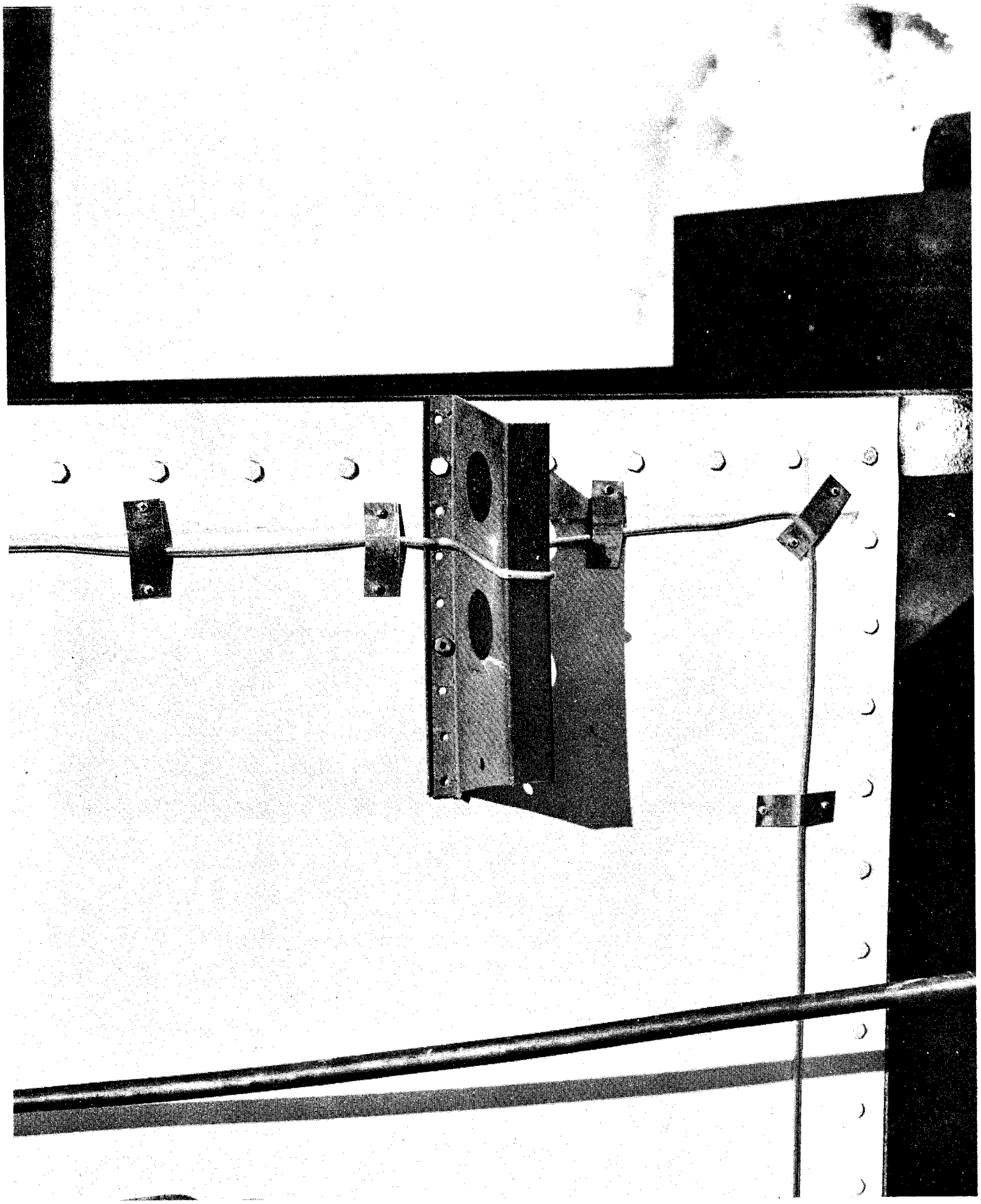

FIGURE 4. - AIRFRAME CUTTING TEST SETUP

The flame generated by detonation of the charge did not ignite or char the interior cabin materials.

Low-Temperature Condition

The purpose of this series of tests was to determine the system performance after exposure to extreme low-temperature conditions. The low-temperature levels were obtained by the use of carbon dioxide (CO_2) in an insulated wooden container, which was then placed over the system and attached to the specimen (see Figure 5). To minimize heat transfer, insulation was also placed on the outside of the container (see Figure 5).

A series of four low-temperature condition tests was conducted. The temperature levels were -20°F, -25°F, -29°F, and -30°F, respectively. The system was held at the respective temperature level for a period of 1 hour, then test fired. The temperature level was measured by thermocouples and recorded on an oscillograph.

The system fired at all temperature levels except -30°F. The nitromethane in the mixing pump froze to a mushy state at this temperature level, thus prohibiting the mixing of this compound with the sensitizer to form the liquid explosive, consequently no detonation occurred.

No attempt was made to determine whether placing insulation around the mixing pump, insulating the pump from direct contact with the CO_2, would eliminate the freezing problem and thus permit the system to operate at a much lower temperature than -30°F.

Impact Sensitivity

The purpose of this test was to determine whether an impact force on a sealed vessel containing the liquid explosive would produce detonation.

The test was accomplished by dropping a 10-pound weight from a height of 8 feet on a 2-foot-long 1/2-inch diameter, thin-wall copper tube capped on both ends containing the liquid explosive.

The test resulted in no detonation of the liquid explosive. The impact of the 10-pound weight flattened and ruptured the tube, forcing the liquid out through the ruptured section of the tube.

FIGURE 5. - LOW TEMPERATURE CONDITION TEST SETUP

Simulated Crash Condition

A series of three simulated crash condition tests was conducted to determine the survivability and performance of the system under such conditions. A scale model fuselage fabricated for a crashworthy fuselage project was used in the conduct of the tests. The model fuselage represented typical transport fuselage structure. The structure was aluminum skin-stringer configuration with frames, and included four bulkheads to simulate nose-landing gear and wing-attach structure.

The system installation in the model fuselage is shown in Figure 6. The model was instrumented with accelerometers to record the input force in the vertical and longitudinal directions. The instrumentation signal from the accelerometers was carried to the recording station by an umbilical cable and recorded on magnetic tape. Figure 7 shows the umbilical cable attached to the model fuselage tail section.

The simulated crash was accomplished by the model fuselage being catapulted and impacting in free flight into an inclined surface located at the end of the catapult track (see Figure 8). The impact velocity was approximately 75 mph.

The complete system operated properly after the model fuselage impacted and came to rest on the inclined surface (see Figure 9).

Figures 10 and 11 show the exit in the model fuselage made by the explosion of the shaped charge. The jagged ends of the structural members and the banana-peel effect of the skin were caused by the oversize charge. No attempt was made to determine the minimum size charge to effectively make a clean cutout in the model fuselage. However, the tests showed that the shaped tubing must be formed and secured tightly around the structural members for effective cutting.

The measured vertical and longitudinal accelerations were 19 g and 17 g, respectively, at floor level adjacent to the explosive system.

Shock Test

Three shock tests were conducted to determine whether the emergency exit system would survive and perform safely after subjection to high-deceleration forces.

The launch car of the catapult was used as the test vehicle to impose the high-deceleration force on the system. The launch car traveled on a track 35-feet long with an arresting devicee

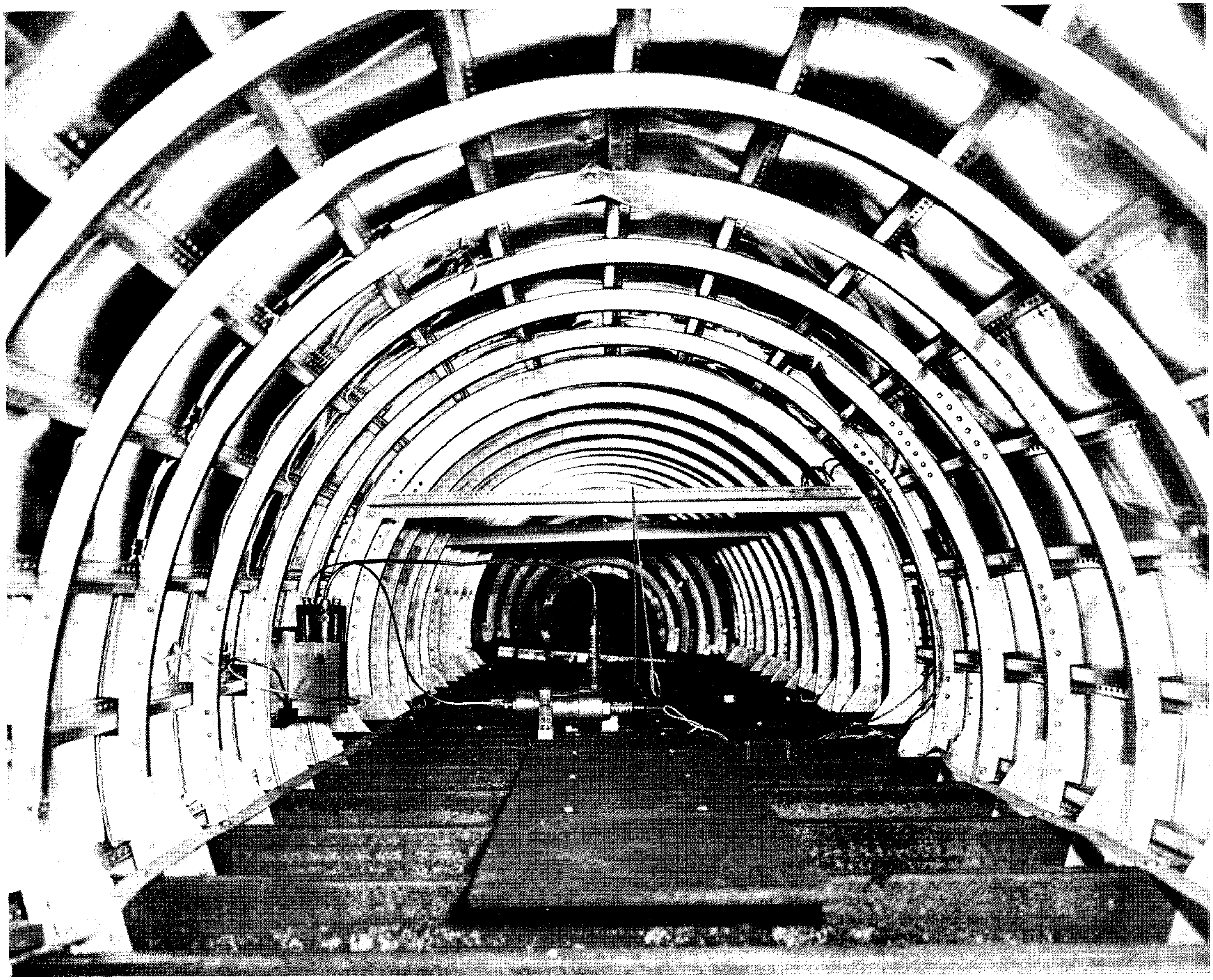

FIGURE 6. - SYSTEM INSTALLATION IN MODEL FUSELAGE

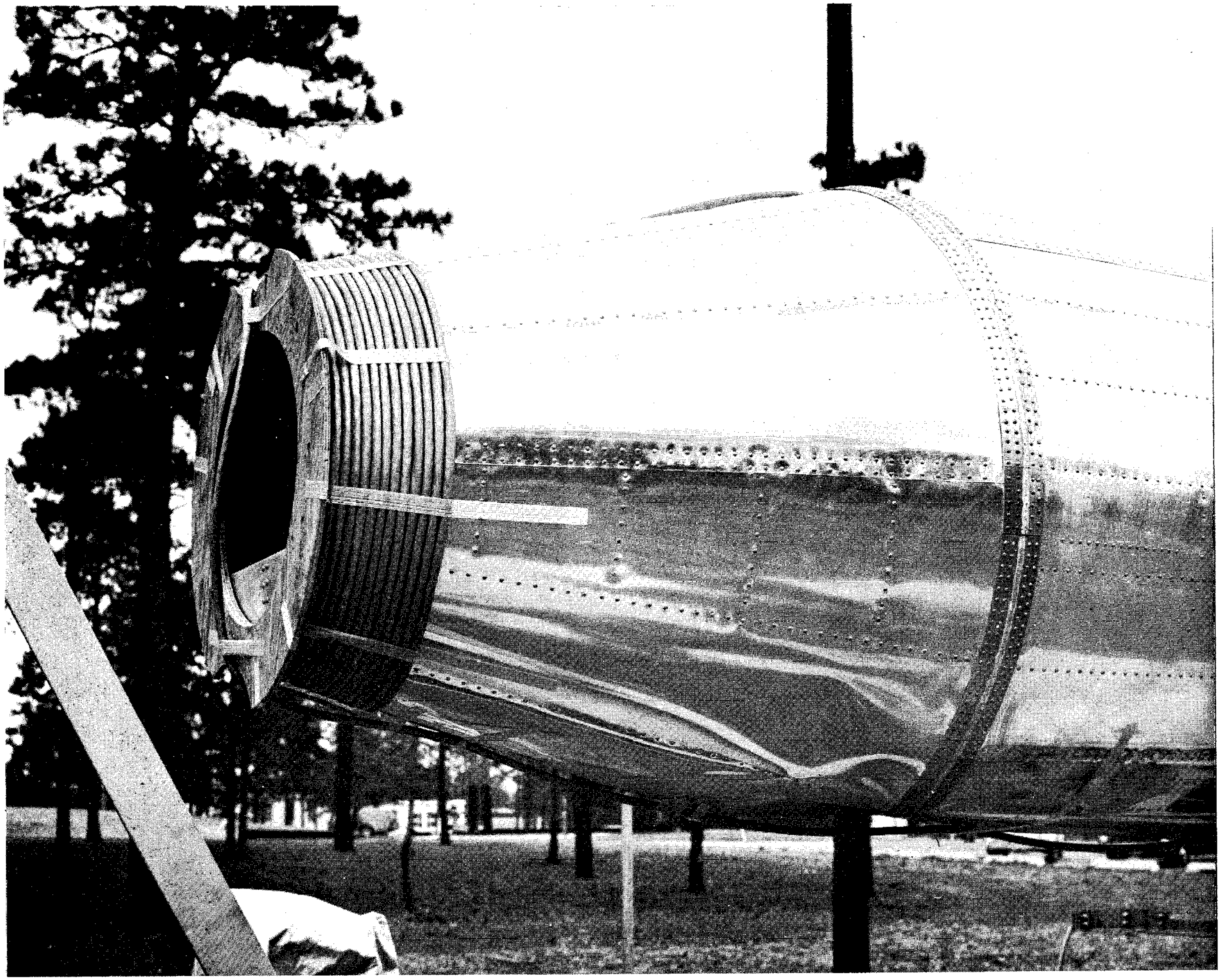

FIGURE 7. - UMBILICAL CABLE AND MODEL FUSELAGE TAIL SECTION

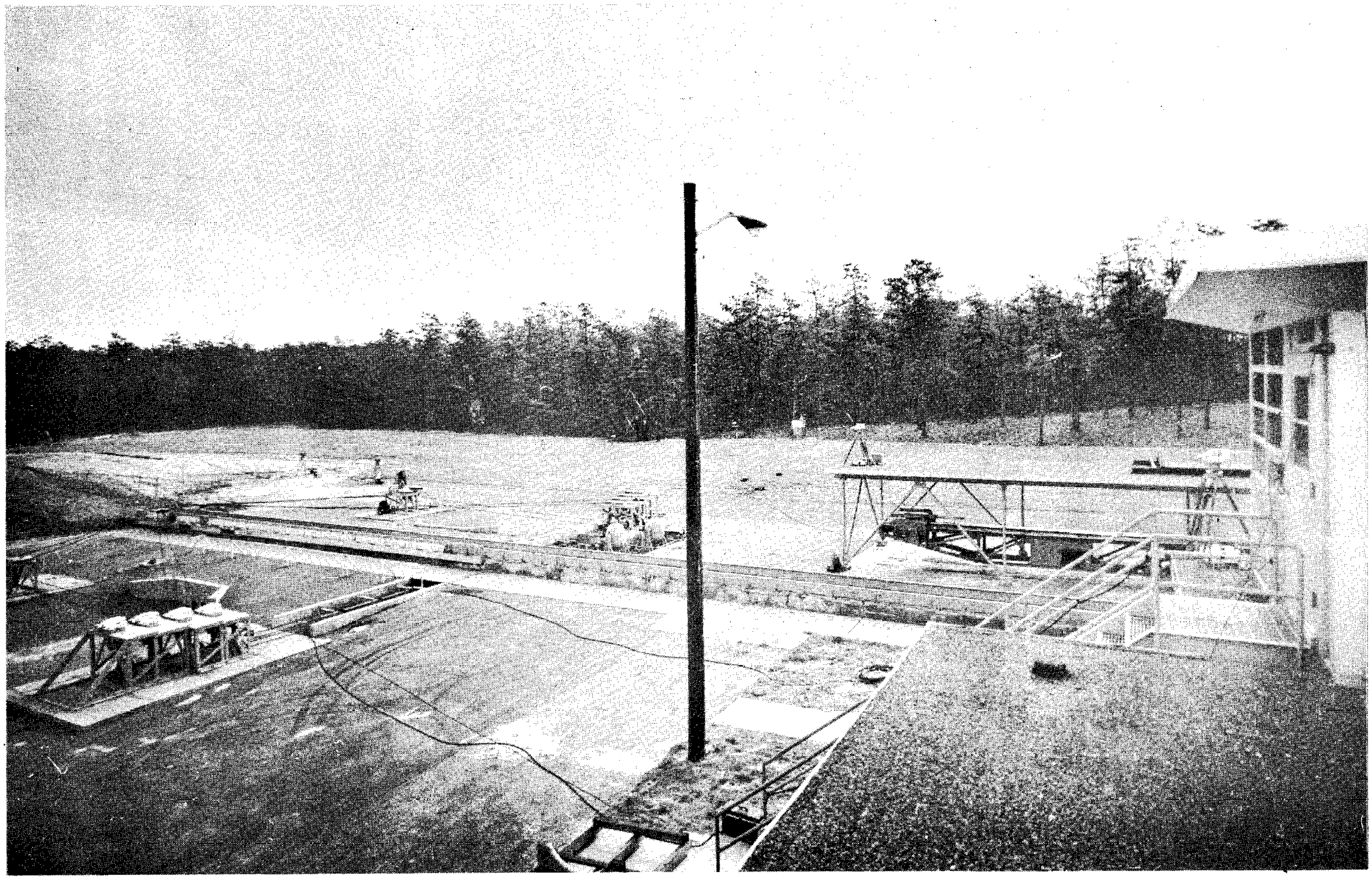

FIGURE 8. - CATAPULT AND TRACK FACILITY

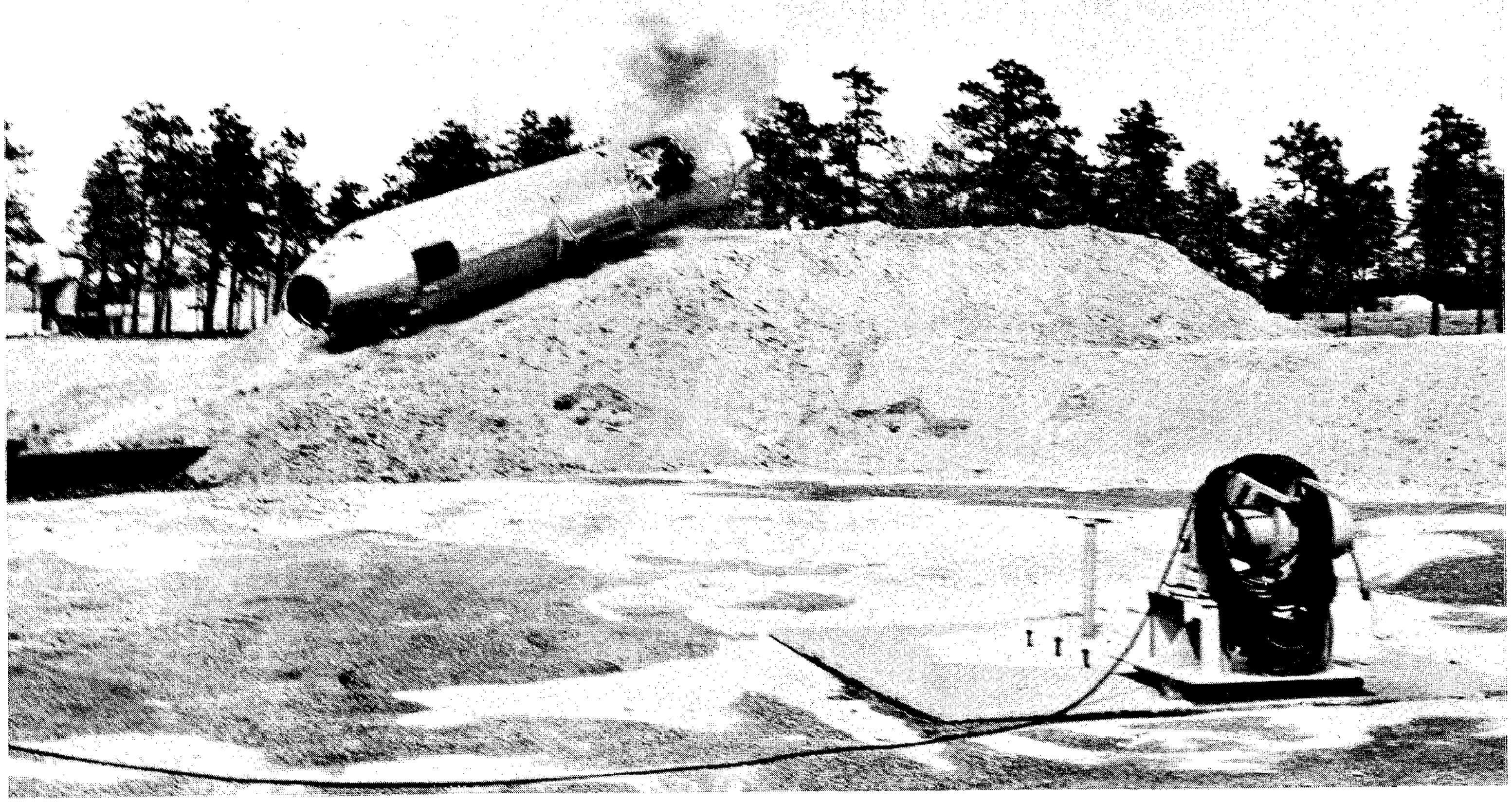

FIGURE 9. - TEST FIRING AFTER IMPACT

FIGURE 10. - INSIDE VIEW OF THE MODEL AFTER TEST

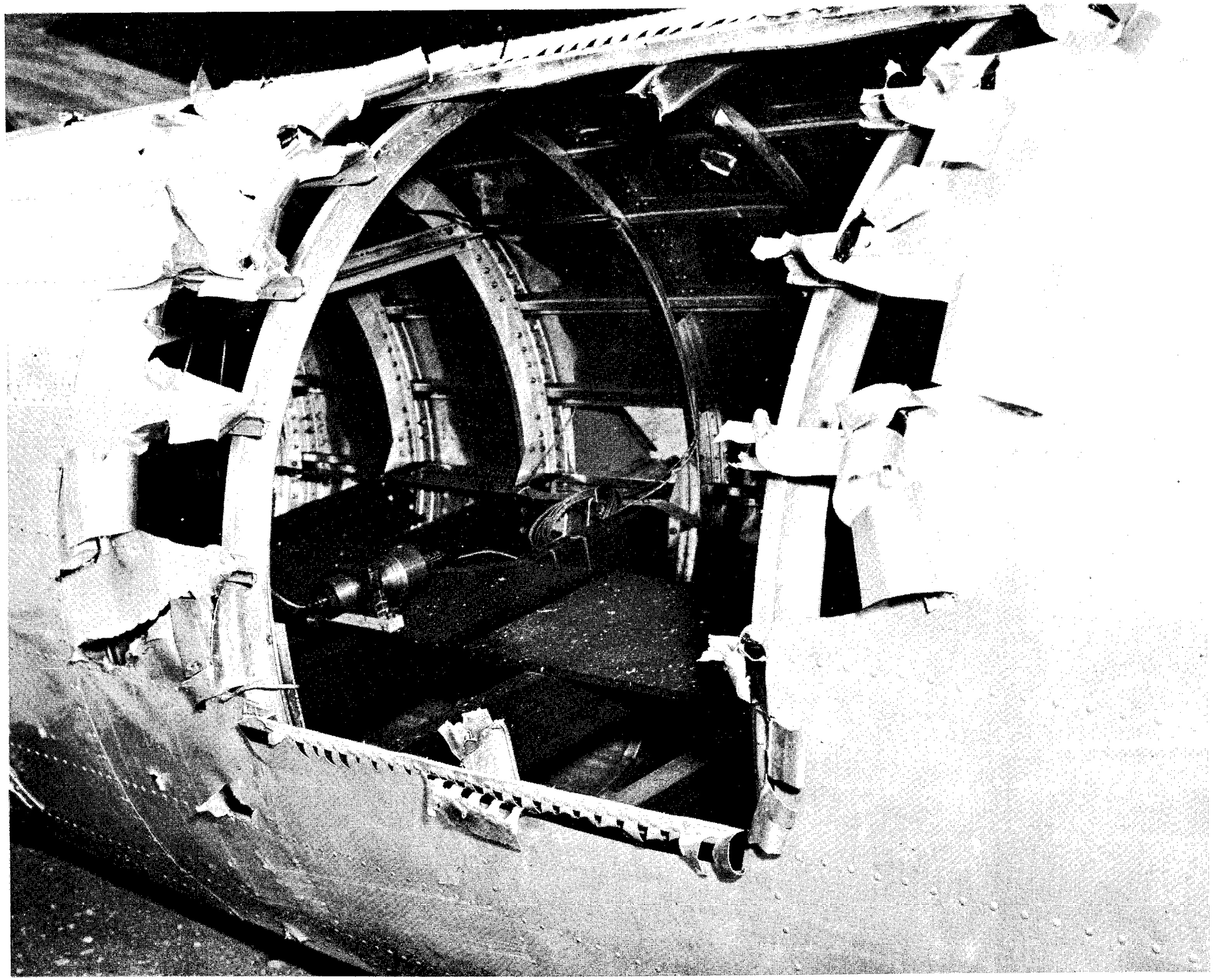

FIGURE 11. - OUTSIDE VIEW OF THE MODEL AFTER TEST

at the end of the track. The arresting device has an arrestment stroke of 30 inches. The car was instrumented with an accelerometer to record the input load in line with the travel of the launch car.

The three tests were conducted separately, one in each of the three positive orthogonal axes x, y and z of the test specimen. After each test the system was test fired. Figure 12 shows the test setup of the first test configuration.

The liquid explosive emergency exit system survived and performed safely after subjection to a deceleration force of 42 g in any of the three axes.

Retaining Shield

The approach selected to attenuate the overpressures and containment of the debris resulting from the detonation of the linear-shaped charge was to use aluminum or steel angle material with silicone-rubber backing which functions by reflecting the pressure wave energies emitted by the explosive out the opening made in the panel by the detonation of the charge. The shield was fabricated from steel angle material because of its availability at that time. Tests were then conducted to evaluate the performance of this design in attenuating the overpressures and containing the debris produced from the detonation of the charge. The evaluation was made by placing the linear-shaped tubing on an aluminum test panel and then placing the shield with the silicone rubber over the tubing (see Figure 13). The shield was fastened to the test panel and the panel fastened to the test stand as shown in Figure 14. In principle, upon detonation of the charge, the panel section with part A attached is cut out by the detonation of the charge along the line shown in Figure 13, and blown free, leaving parts B and C attached to the remaining portion of the test panel. The overpressure measurements were made by several paper blastmeters capable of measuring presssure from 1 to 20 psi placed adjacent to one another in the same plane and at a distance of 3 feet from the plane of charge (see Figure 14). The level of overpressure is measured by the pressure wave perforating the paper blastmeter (see Figure 15). The numbers on the face of the blastmeter indicate the pressure level to perforate the paper.

During the test, high-speed motion picture cameras were used to record fragment blow-back from the test specimen. The cameras were positioned at normal incidence and parallel to the test specimen. The film speed of the cameras was 7,000 frames per second.

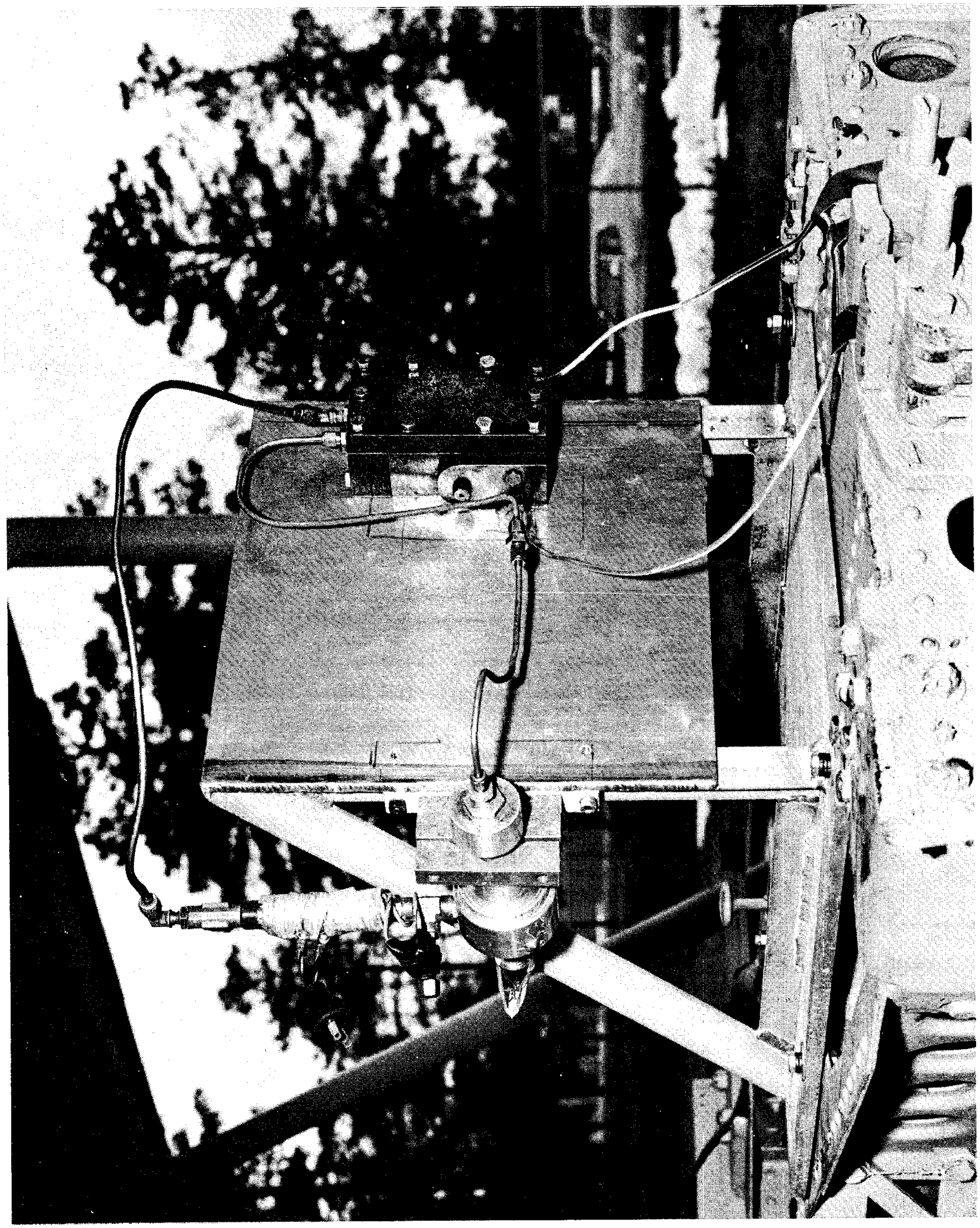

FIGURE 12. - SHOCK TEST SETUP

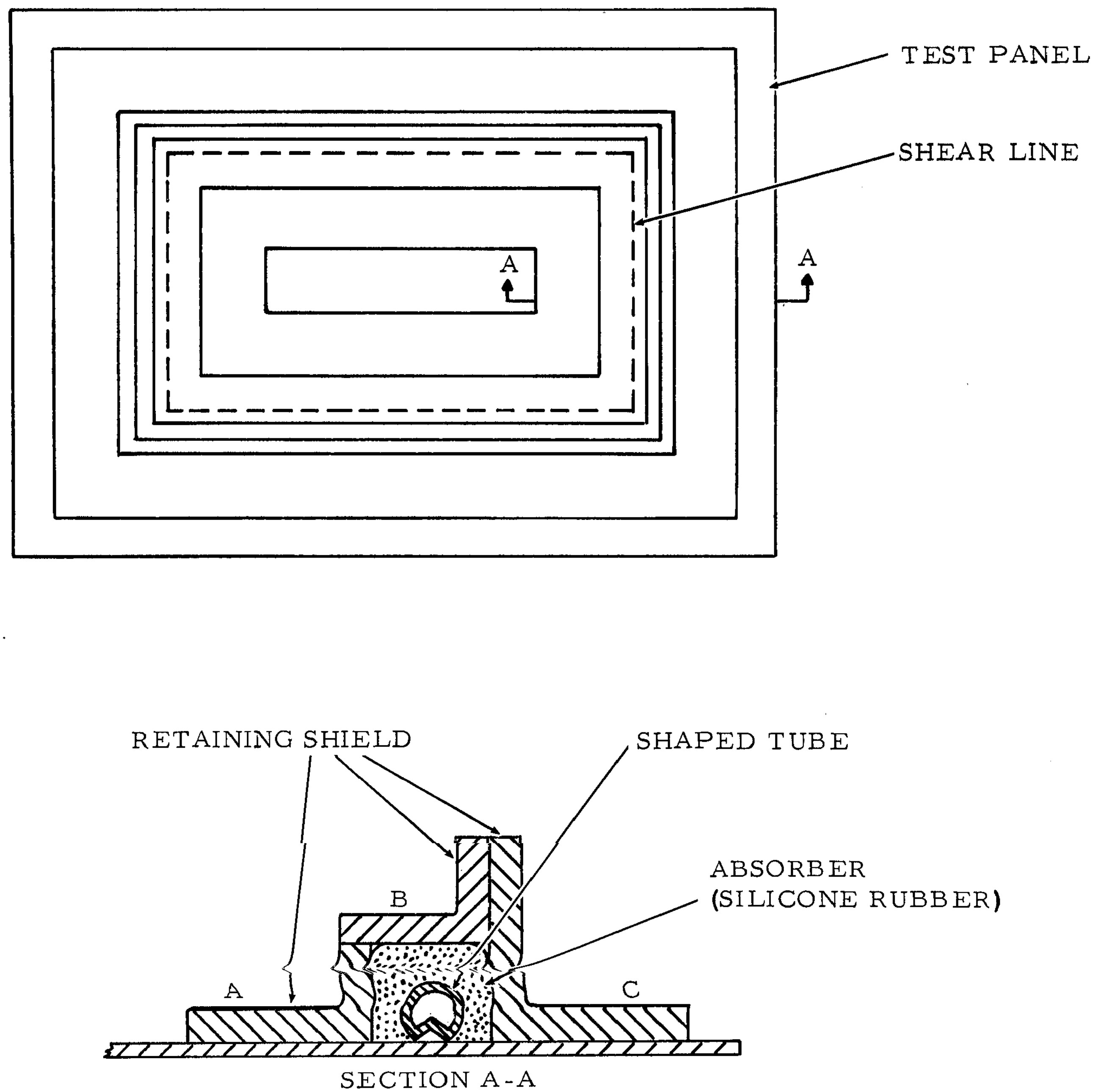

FIGURE 13. - RETAINING SHIELD

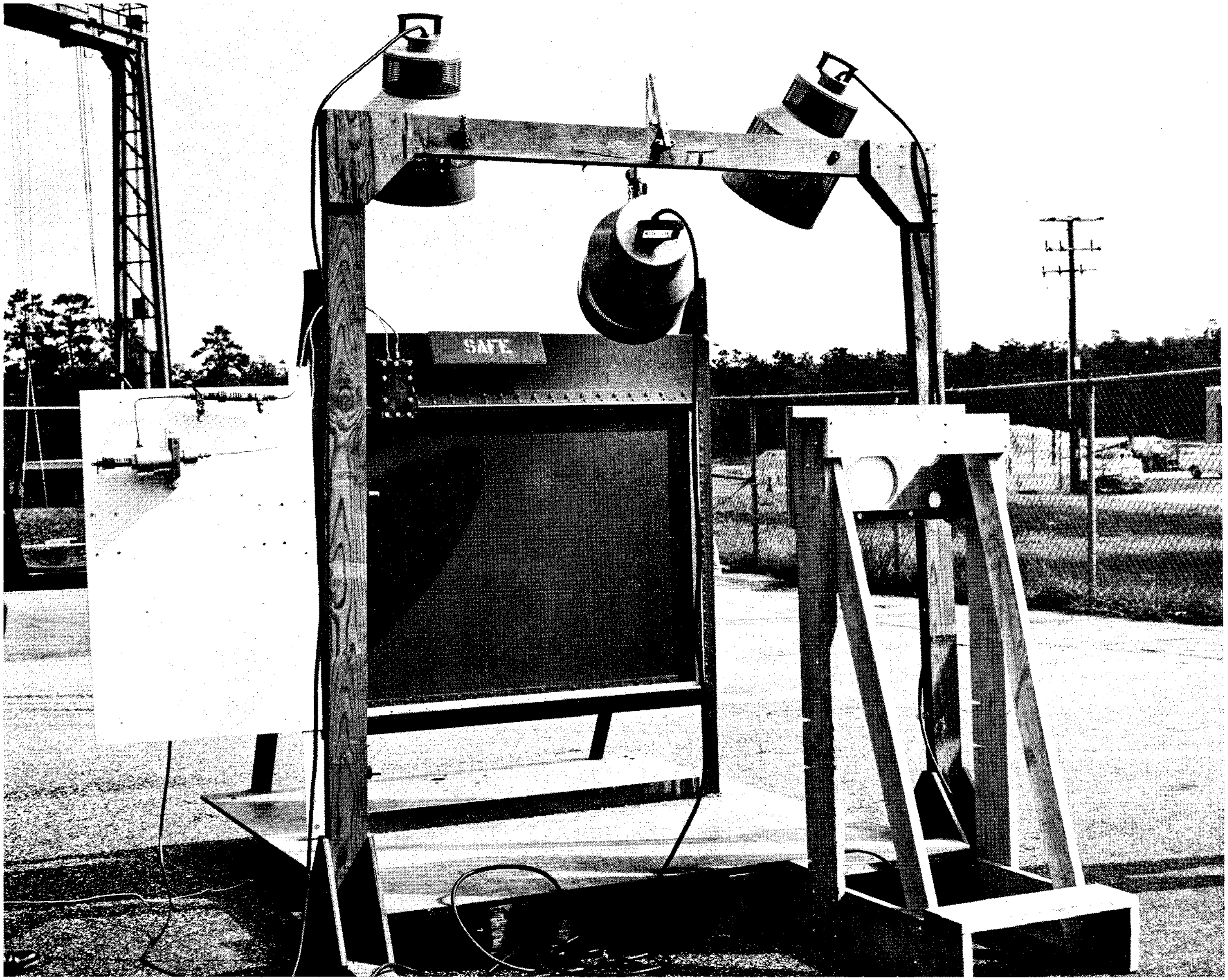

FIGURE 14. - RETAINING SHIELD TEST SETUP

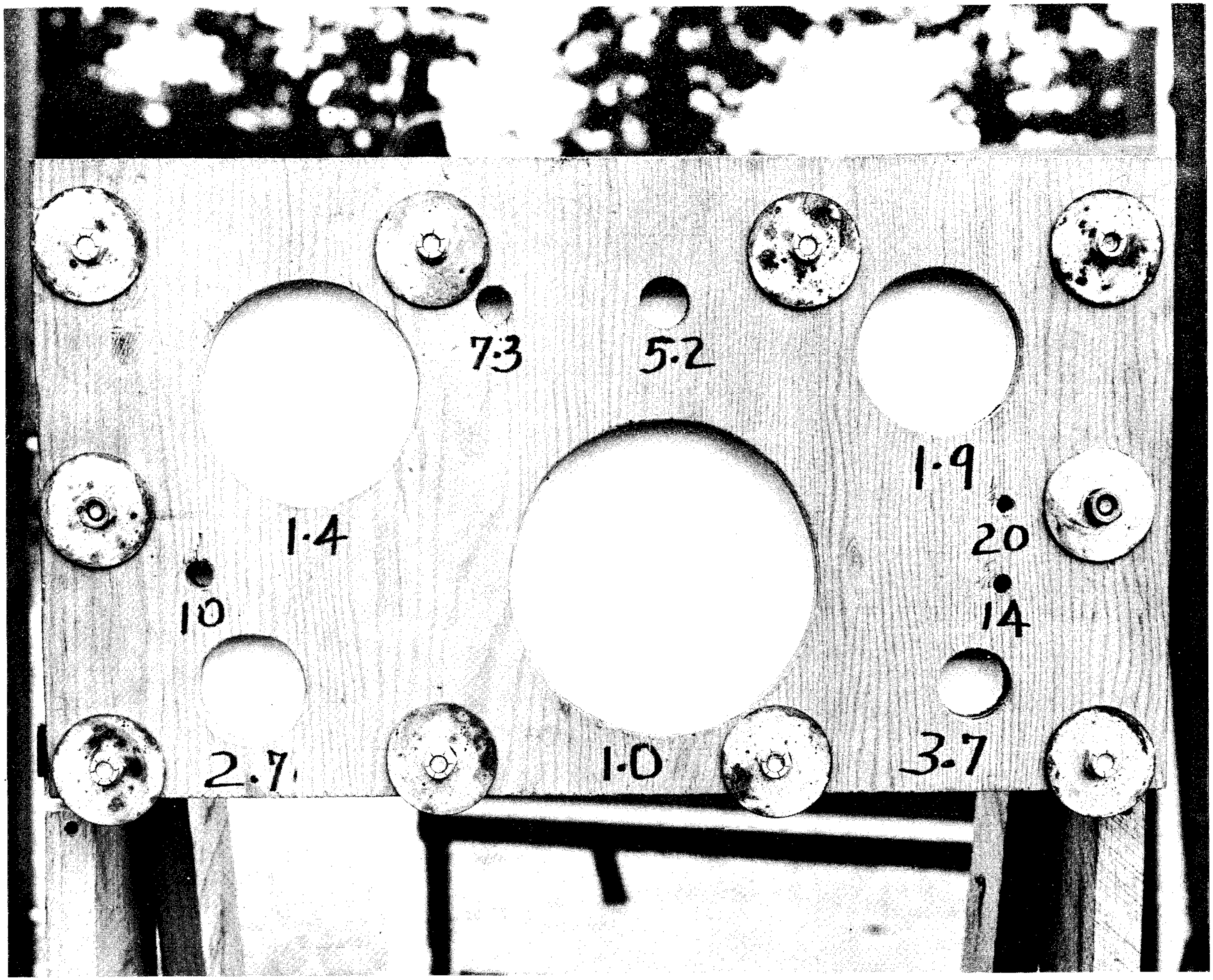

FIGURE 15. - BLASTMETER

The tests revealed no perforations in the paper blastmeters, indicating that the overpressures were below the capability of the blastmeter.

The film analysis of the tests showed some debris flying in the vicinity between the test specimen and the blastmeter. The debris were pieces of silicone rubber material and small fragments of the aluminum tubing. Further evaluation of the shield was made during the demonstration test.

Crash-Fire

The purpose of this test was to determine the potential hazard of the system when exposed to a crash-fire condition. The test was designed to simulate a fuel fire existing near a crashed aircraft fuselage. The test article used was an actual section of a Convair 880 fuselage. This section of fuselage was attached to a stand fabricated of steel and closed on the other three sides with sheet steel to prevent fire from entering the interior of the specimen prematurely (see Figure 16). Figure 17 shows the system mounted on the section of fuselage.

The crash-fire test was accomplished by placing the test specimen adjacent to and on the leeward side of a fire pit containing 255 gallons of JP-4 aircraft fuel (see Figure 18). After the test specimen was positioned alongside the fire pit as shown in Figure 18, the fuel was ignited. Figures 19, 20 and 21 show the time sequence of the fire to engulf the test specimen. Approximately 45 seconds after igniting the fuel, the fire started to melt the section of fuselage.

The test showed that the heat from the crash fire did not cause the system to autoignite. The system, with the exception of the heavy aluminum pump and the two initiators, melted along with the entire section of Convair 880 fuselage which was used as the test article (see Figure 22).

Demonstration Test

The purpose of this test was to demonstrate the feasibility of adapting the concept for use on typical civil transport aircraft, and measure the sound levels inside an actual aircraft fuselage generated by the detonation of the linear-shaped charge. In addition, further evalution was made of the retaining shield in attenuating the overpressures and containment of the debris produced by the detonation of the charge.

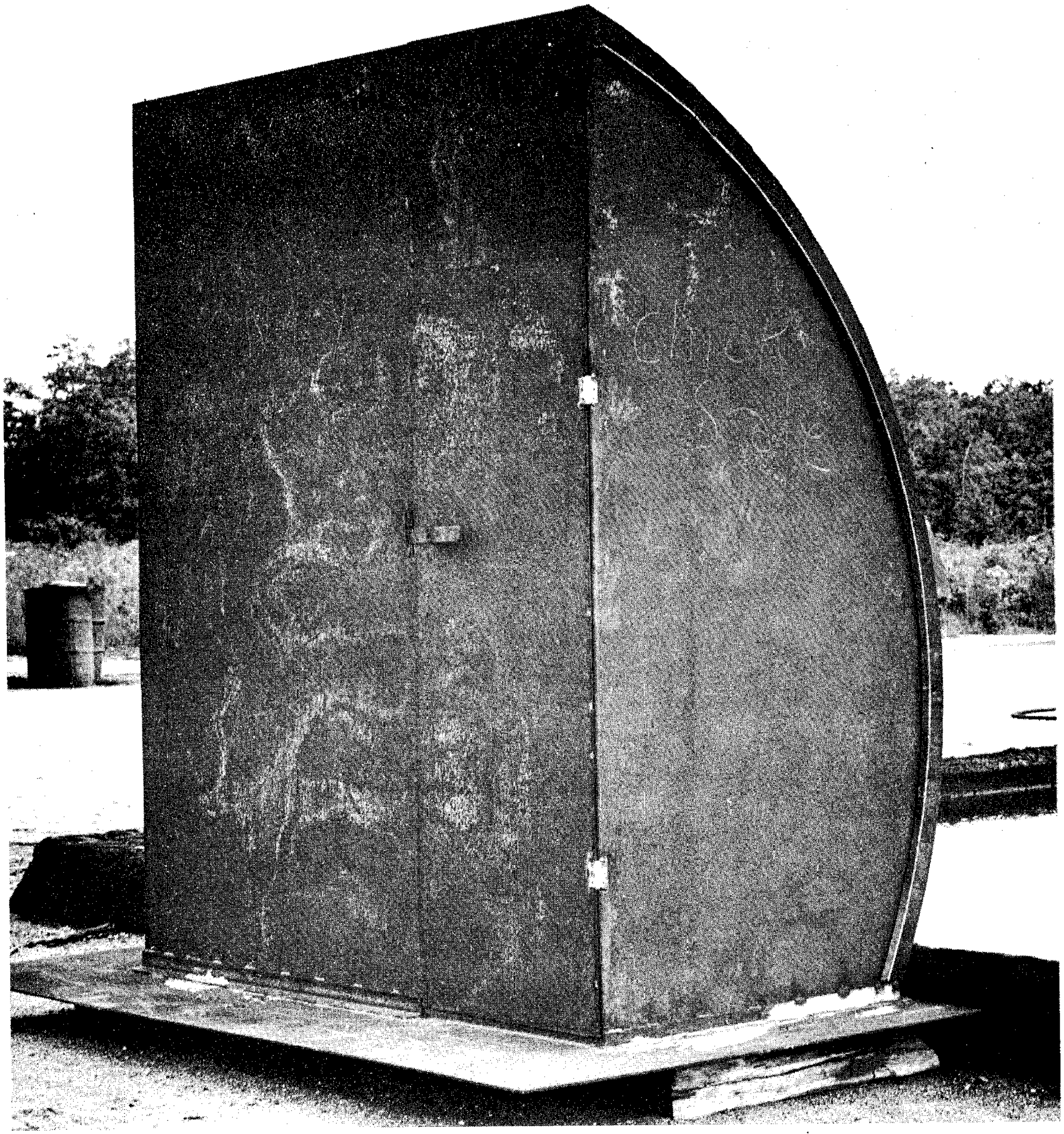

FIGURE 16. - FIRE TEST STAND

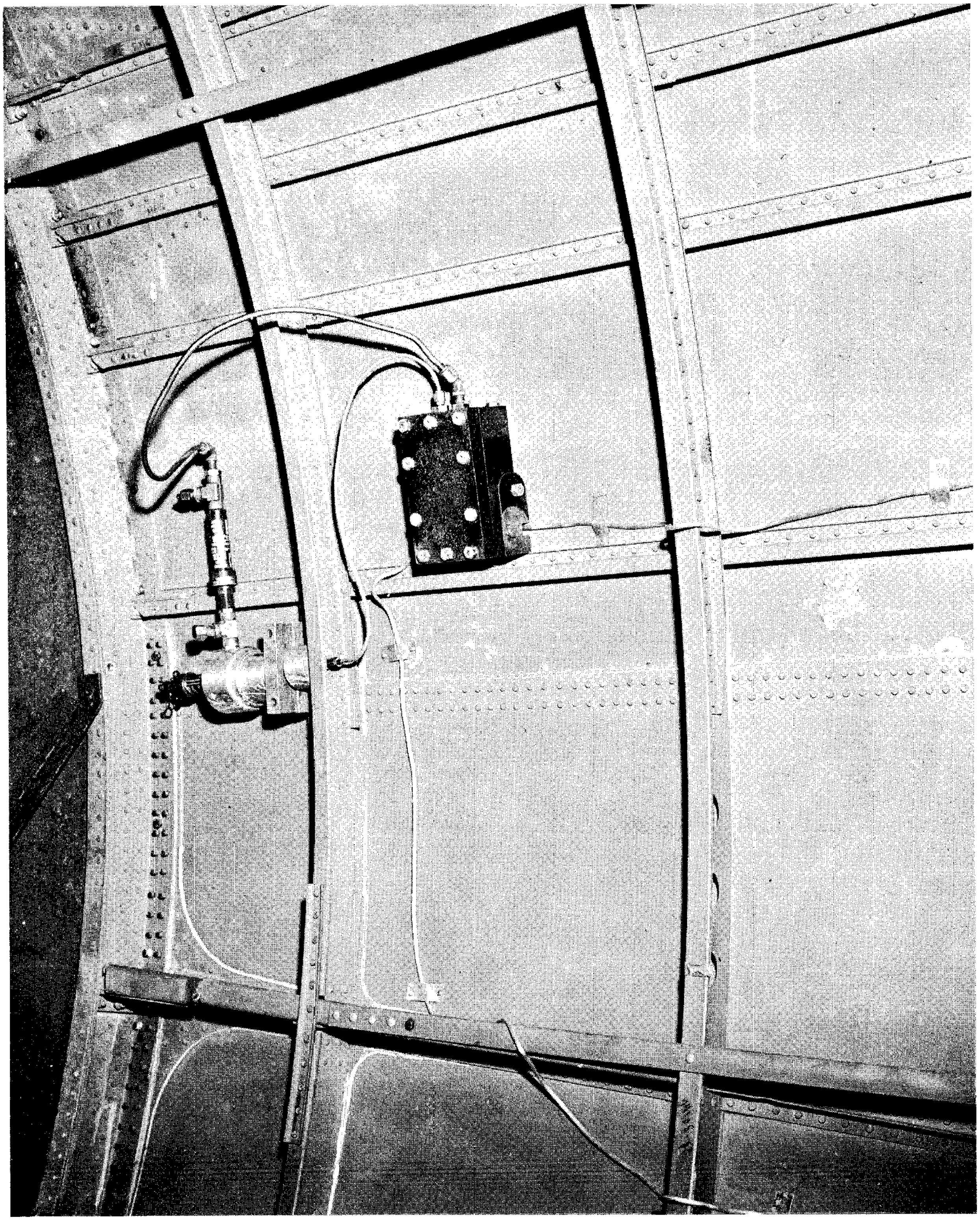

FIGURE 17. - SYSTEM MOUNTED ON TEST PANEL

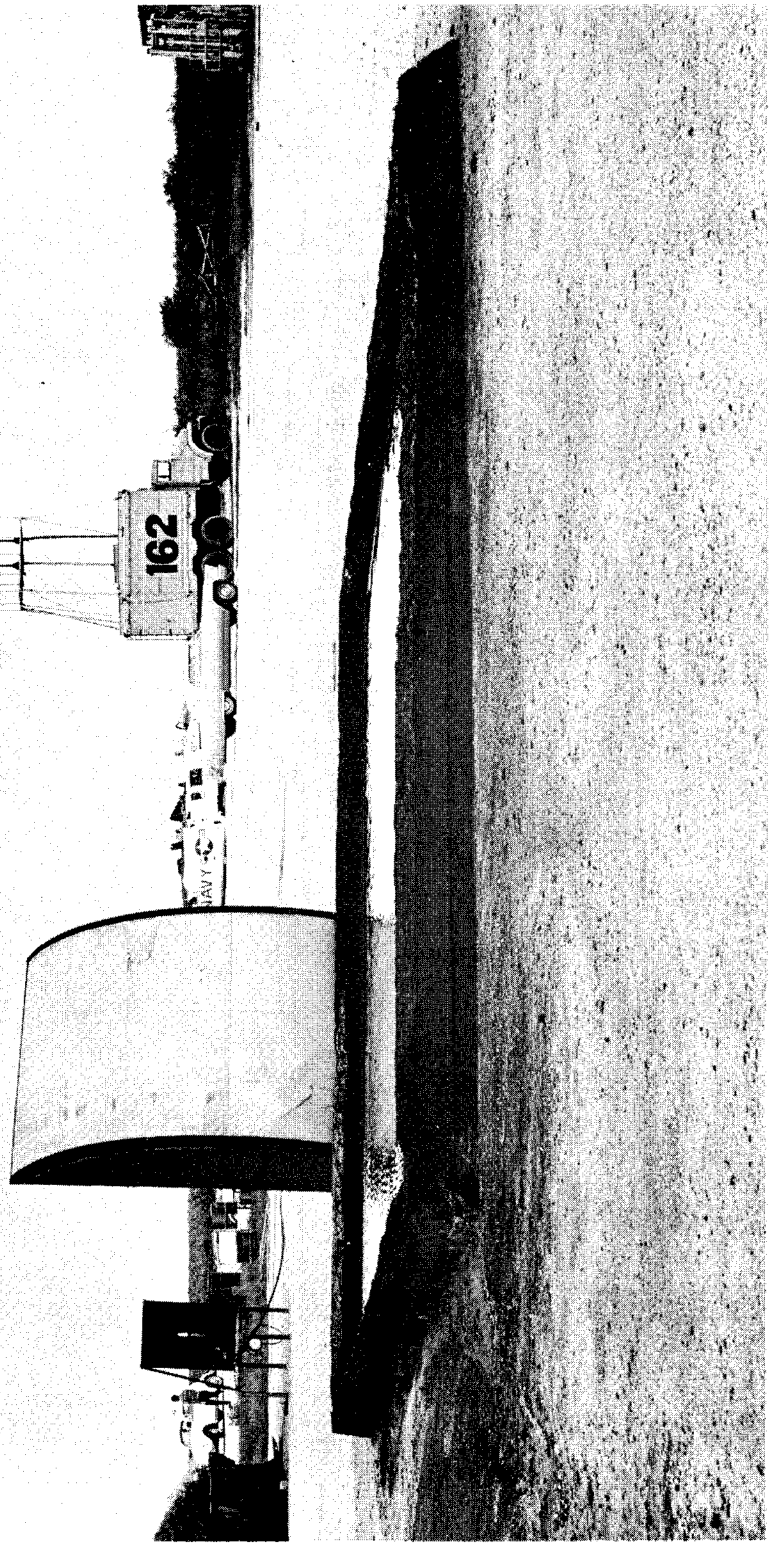

FIGURE 18. - FUEL FIRE TEST SETUP

FIGURE 19. - SEVEN SECONDS AFTER FUEL IGNITION

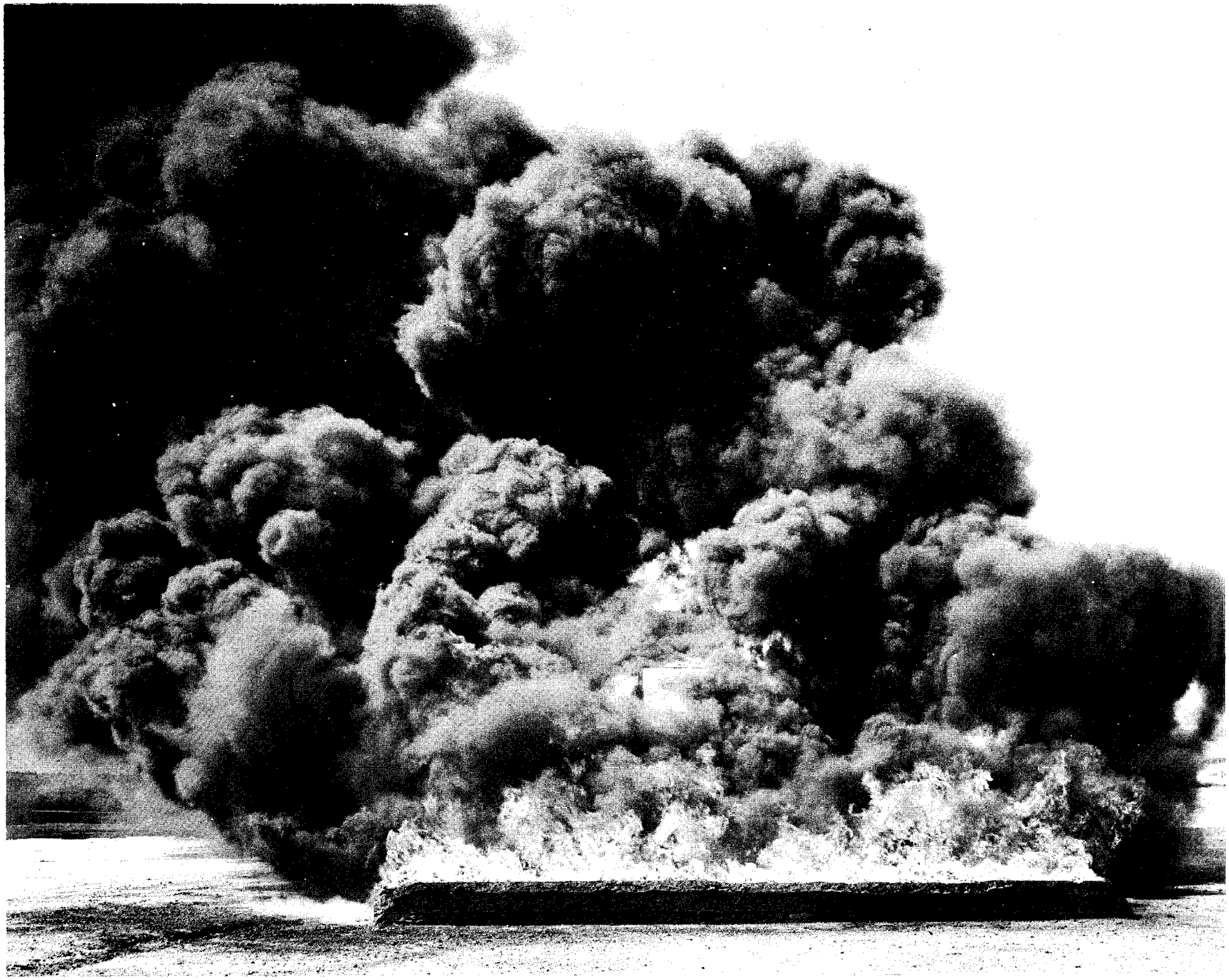

FIGURE 20. - TWENTY SECONDS AFTER FUEL IGNITION

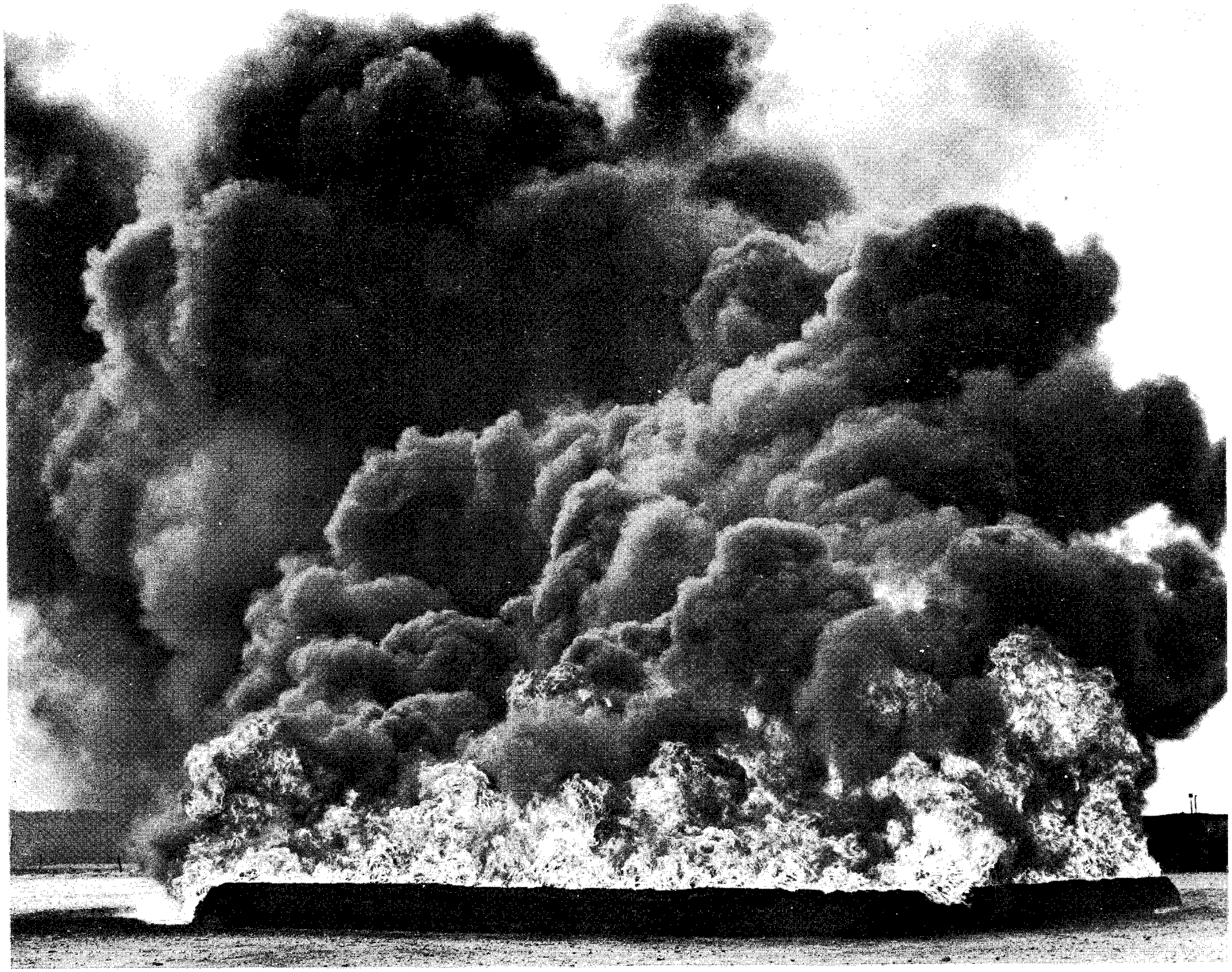

FIGURE 21. - THIRTY SECONDS AFTER FUEL IGNITION

FIGURE 22. - RESIDUAL AFTER THE TEST

A series of eight demonstration tests was conducted using a Convair 880 fuselage as the test article. In the initial test, sections of the structural members of the fuselage were removed where the retaining shield fastened to the skin of the fuselage (see Figure 23). This was done to simplify the design and installation of the shield.

The installation was made by placing the linear-shaped tubing on the skin of the fuselage. Then the retaining shield with the silicone-rubber absorber was placed over the shaped tubing. The shield was then fastened to the fuselage (see Figure 23). Since this was the first installation of this system in an actual aircraft fuselage and with this type of a retaining shield, it was decided to conduct the first test without measuring the sound level. In subsequent tests, the entire fuselage was insulated with regular building-type insulation for acoustic effects. In addition, standard aircraft seats with anthropomorphic dummies were positioned adjacent to the exit area to be removed in the fuselage (see Figure 24).

The sound level was measured by two piezoelectric ceramic microphones located 4 feet from the exit area to be removed in the fuselage (see Figure 25). The signal from the microphones was recorded on a magnetic tape recorder. Figure 25 also shows the high-intensity lights used in the motion picture filming of the test to record the debris blow-back generated by the detonation of the linear-shaped charge. The cameras with respect to the exit area to be removed in the fuselage were positioned normal and parallel to the fuselage longitudinal axis. The film speed of the motion picture cameras was 7,000 frames per second.

A comparison was made between the detonation of the shaped charge and 30.06 rifle shots fired inside the fuselage. Prior to detonation of the charge, several 30.06 rifle blanks were fired inside the fuselage with the rifle parallel to the fuselage longitudinal axis and within 3 inches of the intended exit area.

The system was mounted and test fired at different locations on the fuselage to study its adaptability for use on civil transport aircraft.

The tests indicated sound level at system detonation of 160 (± 3)dB at a distance of approximately 4 feet from the exit area. The sound levels of the rifle shots was nearly the same as that developed by system operation; 158(±2)dB.

FIGURE 22. - RESIDUAL AFTER THE TEST

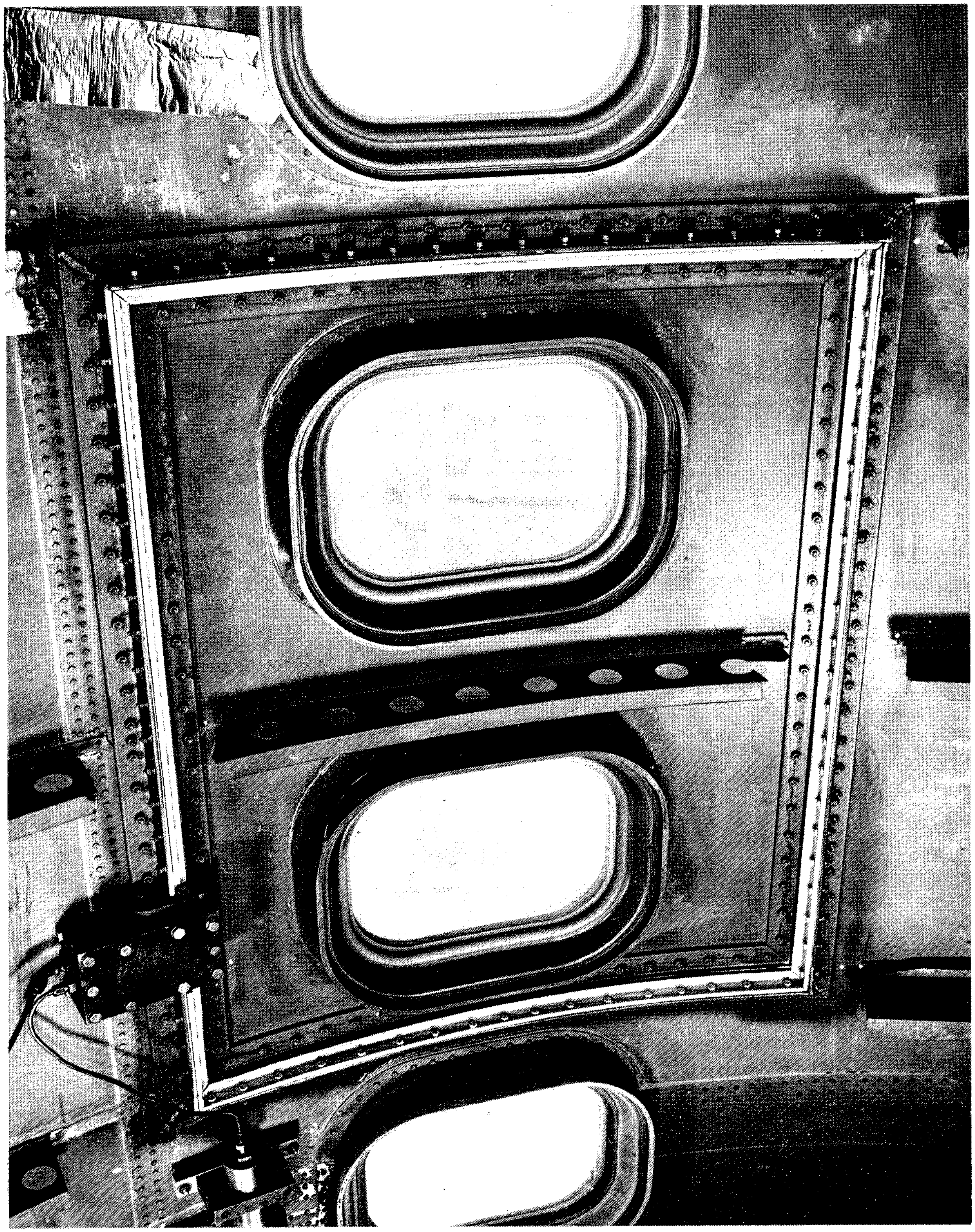

FIGURE 23. - INITIAL FUSELAGE TEST SETUP

FIGURE 24. - SEAT AND DUMMY POSITION