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FLIGHT TEST OF A SELF-GENERATING OVERHEAT DETECTION SYSTEM

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AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

NOTICE

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This technical report has been reviewed and is approved for publication.

DUANE G. FOX
Project Engineer

G. T. BEERY
Program Manager

FOR THE COMMANDER

BENITO P. BOTTERI
Chief, Fire Protection Branch
Fuels and Lubrication Division

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Flight tests were conducted on two self-generating overheat detection systems installed in the number two nacelle of a Federal Aviation Administration (FAA) Convair CV880. The systems were mounted inboard and outboard in the nacelle paralleling the existing aircraft system. The outboard system logged 722.2 flight hours with no problems reported. The inboard system logged 615.0 flight hours. Shortly after the inboard system was installed, overheat warnings were obtained when the thrust reversers were used. The problem was found in the control box

which caused the system to alarm at a lower temperature than was set. The inboard system then operated flawlessly for 585.9 flight hours until another problem in the control box caused the system to cease operating completely. No false alarms were noted, at any time, from electrical noise. It is concluded that the self-generating system tested is an airworthy system which should decrease the false fire warning rate in engine nacelles.

FLIGHT TEST OF A SELF-
GENERATING OVERHEAT DETECTION SYSTEM

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FLIGHT TEST OF A SELF-GENERATING OVERHEAT DETECTION SYSTEM

Richard G. Hill

1. INTRODUCTION

1.1 Purpose

The purpose of this project was to evaluate the performance of a self-generating overheat detection system in an aircraft engine nacelle environment during varying flight conditions.

1.2 Background

The self-generating overheat detection system was developed by the Thomas A. Edison Instrument Division, McGraw Edison Company, under contract to the Air Force Aero Propulsion Laboratory. The main objective in developing the self-generating system was to produce an overheat detection system with a higher degree of reliability than is presently provided by available overheat detection systems.

A previous fire test program was conducted at the National Aviation Facilities Experimental Center (NAFEC), under simulated flight conditions, on the self-generating overheat detection system. The system was installed in a C140 aircraft engine nacelle inside a 5-foot wind tunnel facility at NAFEC. Tests were run with the system in its normal configuration and also with a section of the detection cable pinched, opened, and shorted. The system was monitored for fire response time as well as for false alarms.

The results of the previous test program indicated that the system performed well in its normal, pinched, and opened configurations, but the alarm time was increased by over 100 percent when the cable was shorted. The shorted cable would be detected, however, during the system preflight test. No false alarms were noted during testing. Reference 1 gives further information on this test program.

1.3 Description of Equipment

Two self-generating overheat detection systems were tested, each consisting of a readout box, a control box, a junction box, thermocouple cabling between the junction box and the control box, two overheat cables, and two inert cables. One overheat cable was for the forward zone, and the other over-heat cable was for the aft zone. The two inert cables were used to connect the aft cable to the junction box in the forward section.

The system is basically a continuous thermocouple, that is, a continuous coaxial cable which produces an electromotive force (emf) relative to the temperature of the cable. Further information on the principle, design, and laboratory testing of this system can be found in reference 2.

Both self-generating systems tested were installed in the number two engine nacelle of a Federal Aviation Administration (FAA) Convair CV880M aircraft. One of the systems was mounted on the inboard nacelle door and the other system on the outboard nacelle door. Both systems paralleled the existing detection system.

2. DISCUSSION

2.1 Installation

The Convair 880 used for this flight test program was powered by four CJ805-3B turbojet engines. Expected temperatures in the nacelle and pylon were 165° Fahrenheit (F) in the pylon, 300° F in the forward portion of the nacelle, and 450° F in the aft section of the nacelle. The fire and overheat detection system used on the aircraft was a discrete-sensing continuous loop set to alarm at 575° F in the forward section and 765° F in the aft section. The experimental self-generating system in no way interfered with the operation of the original aircraft system.

In order to alleviate any problems that might have resulted from a false alarm, the readout boxes for the two systems were mounted (figure 1) so as to be seen only by the flight engineer. Instructions were given the flight crew to record all alarms, but take no action unless the aircraft system alarmed. A simple pre- and postflight continuity check was performed by the flight crew using a push-to-test curcuit in each system. The results were to be reported only in the event of a discrepancy.

The original plan for installing the two self-generating systems called for mounting the two control boxes in the pylon. Due to limited space in the pylon and the size of the control boxes (6 1/8 by 6 3/4 by 8 13/16 inches), the control boxes had to be repositioned to the closest area to the number two engine nacelle with available space. The left wheel well was chosen for mounting the control boxes (figure 2). The control boxes were larger for these prototype systems by a factor of three than for production systems. The boxes were fabricated to allow easy modification and change. They were not hermetically sealed, so repairs and modifications could be made easily if required. Since a wire bundle consisting of two iron conductors, two constantan conductors, and one copper conductor for each of the four overheat cables had to connect the junction boxes in the nacelle and the control boxes in the wheel wells, existing aircraft wiring in the wing between the nacelle and the wheel well could not be used. The wire bundles supplied with the system were made up of fire-zone cables (as shown in figure 3) which proved very poor in abrasion resistance in the 40- to 50-foot run from the nacelle through the pylon along the trailing edge of the wing and into the wheel well.

Since the wiring between the junction box and control box was thermocouple extention wire, standard firewall connectors could not be used (i.e.; the pins

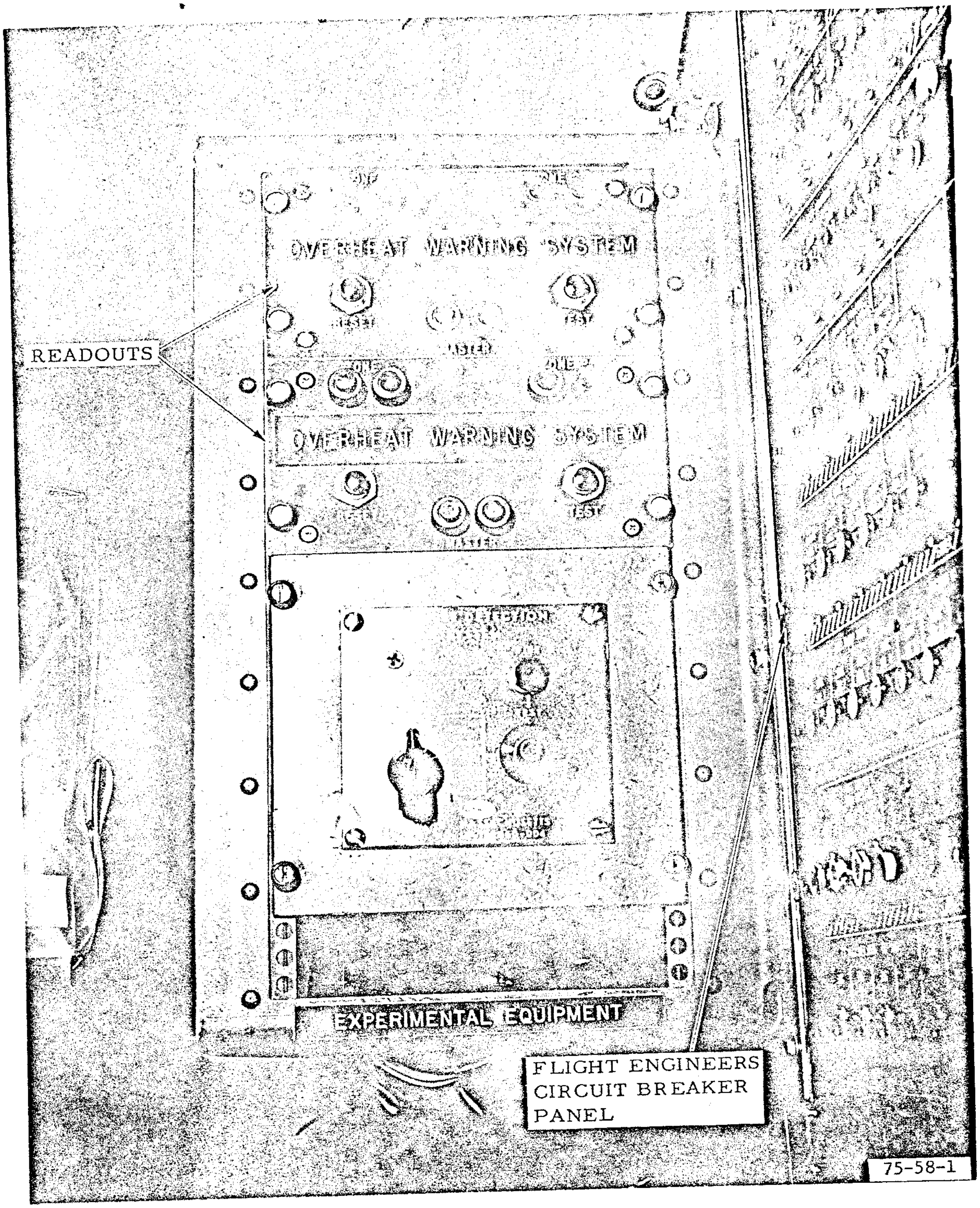


FIGURE 1: READOUT UNITS IN COCKPIT OF CV880 AIRCRAFT

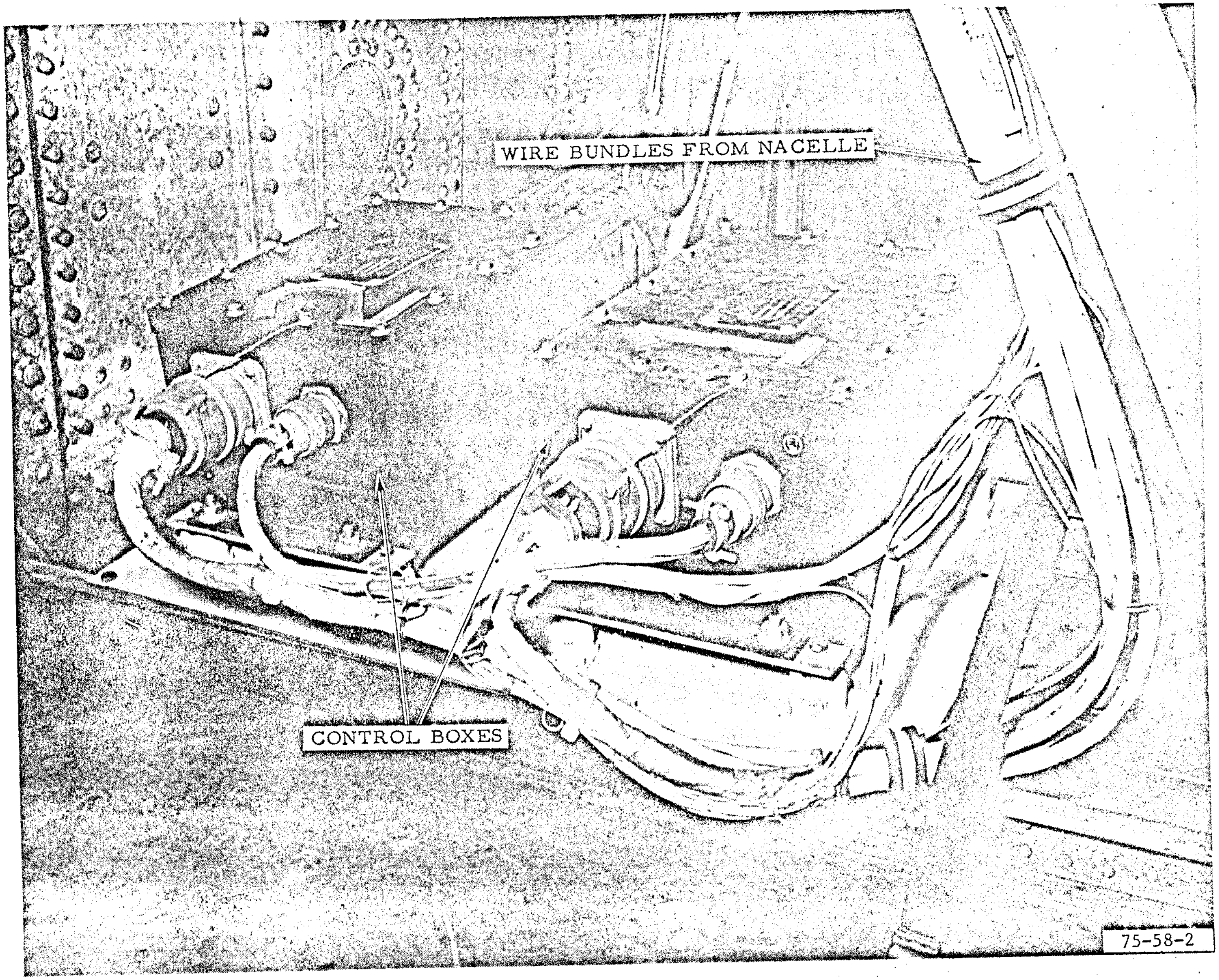
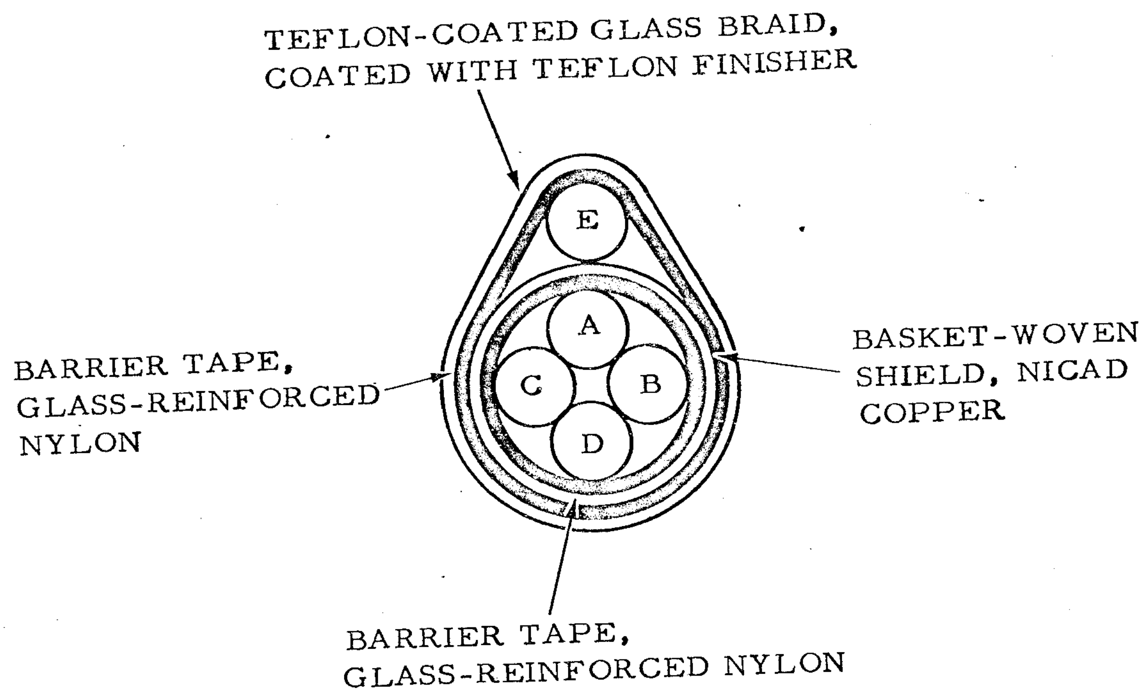


FIGURE 2: CONTROL BOXES LOCATED IN WHEEL WELL



A & B TWISTED PAIR

A - CONSTANTAN CONDUCTOR
FIREZONE 101 INSULATION SYSTEM

B - IRON CONDUCTOR
FIREZONE 101 INSULATION SYSTEM

C & D TWISTED PAIR (SAME AS ABOVE RESPECTIVELY)

E SINGLE CONDUCTOR

NICKEL CLAD COPPER
FIREZONE 101 INSULATION SYSTEM

NOTE: CABLE MANUFACTURED TO MEET MIL-W-25038

75-58-3

FIGURE 3: FIRE ZONE WIRE BUNDLE

were copper, not iron or constantan). Because no iron-constantan connectors were available for the installation, each of the four wire bundles were put through swedge-type connectors and sealed with high-temperature sealant (figure 4).

The installation in the nacelle consisted of a junction box for each of the two systems, located on the inboard and outboard nacelle doors (figure 5). The location of the junction boxes on the doors was necessary, since the self-generating cables were mounted on the nacelle doors, and the cables could not be repeatedly flexed. The wire bundles between the junction boxes and the swedge fitting in the pylon were positioned so as to allow minimum flexing of the wire bundles when the nacelle doors were opened and closed.

The self-generating cables were located on the nacelle doors parallel with the existing aircraft fire and overheat system (figure 6 and 7). The forward zone cable, for each system, was 32 feet in length, with both ends connected to the junction box. The forward zone systems were factory set to alarm at 575° F when the entire cable was heated to that temperature. The aft zone cable consisted of an 18-foot cable for each system set to alarm when the entire cable was heated to 765° F. In addition, two inert cables for each system were used as a thermocouple extention wire to connect both ends of the aft cable with the junction boxes located in the forward zone.

2.2 Preliminary Flight Test

Upon completion of the installation of the two systems, a check was performed on each system using a Tempcal® block test heater to determine the alarm temperature when a 3-inch section of cable was heated. The outboard system alarmed at 764° F in the forward section and 962° F in the aft zone. The inboard system alarmed at 778° F forward and 1,014° F aft. Manufacturer calculations for a 3-inch section showed an alarm temperature of 751° F forward and 1,009° F aft, and actual manufacturer tests showed a forward alarm temperature of 778° F and an aft alarm temperature of 951° F. Therefore, the system's response was considered acceptable, and the flight test program was started.

2.3 Flight Test

The flight test program began November 15, 1972, and is still continuing as of the writing of this report. This report covers all testing from November 15, 1972, until July 24, 1975. During that time no false warnings or test failures have been reported on the outboard system. Over that period of time, it had flown 722.2 hours.

Over that same period of time, two problems arose with the inboard system. After 29.1 hours of flight time, the inboard system began to alarm when the thrust reversers were used. A check of the inboard system with the Tempcal tester showed that the temperature needed for a 3-inch section of the aft section of the cable to alarm had decreased and was the same as that originally set for the whole cable. The inboard control box was returned to the factory.

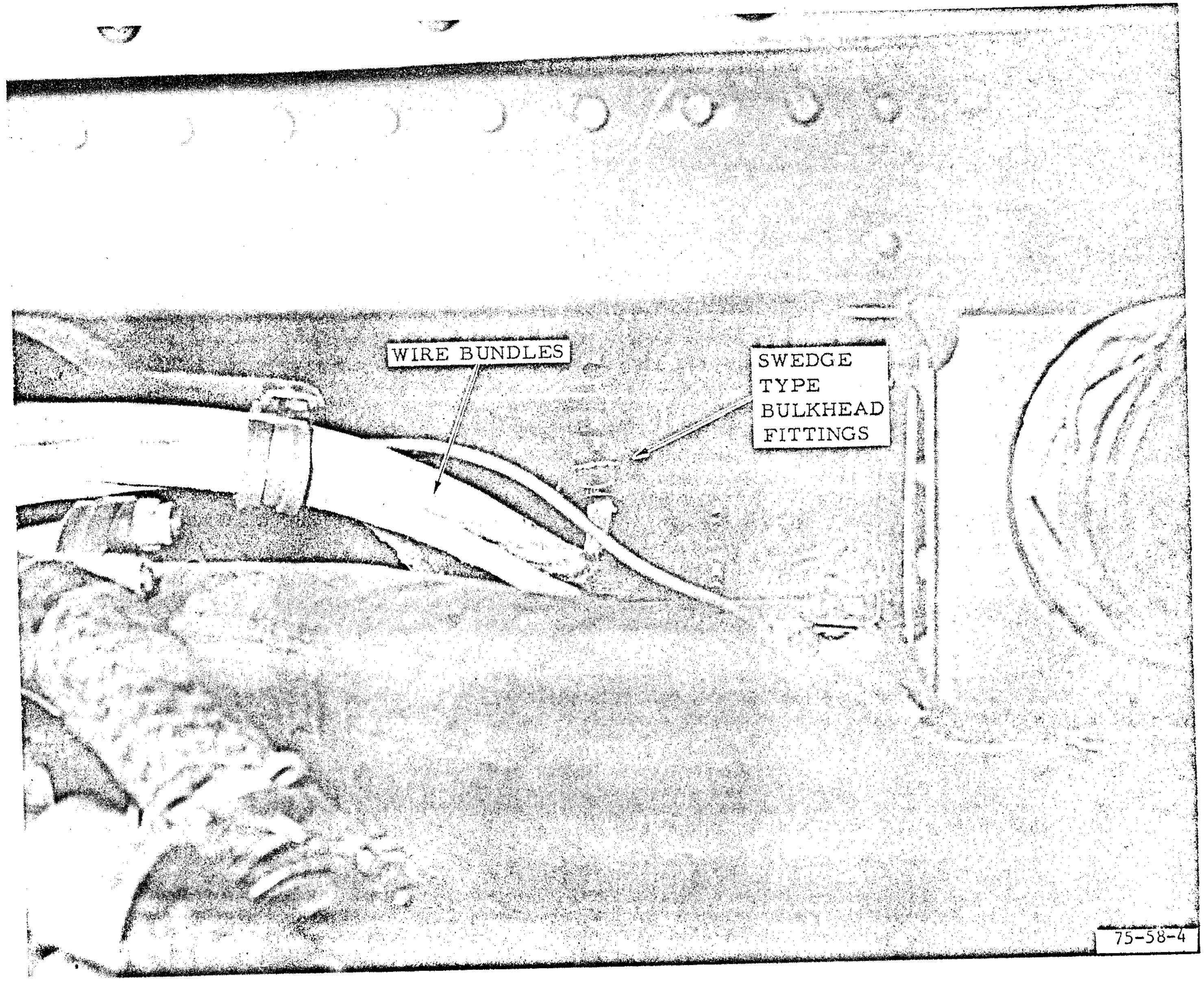
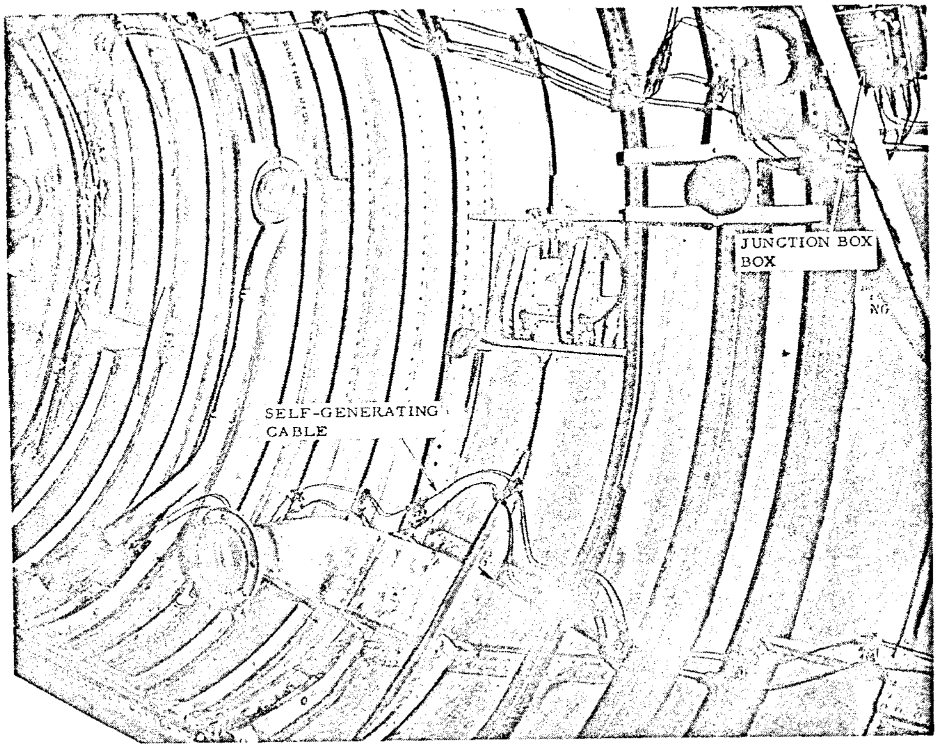
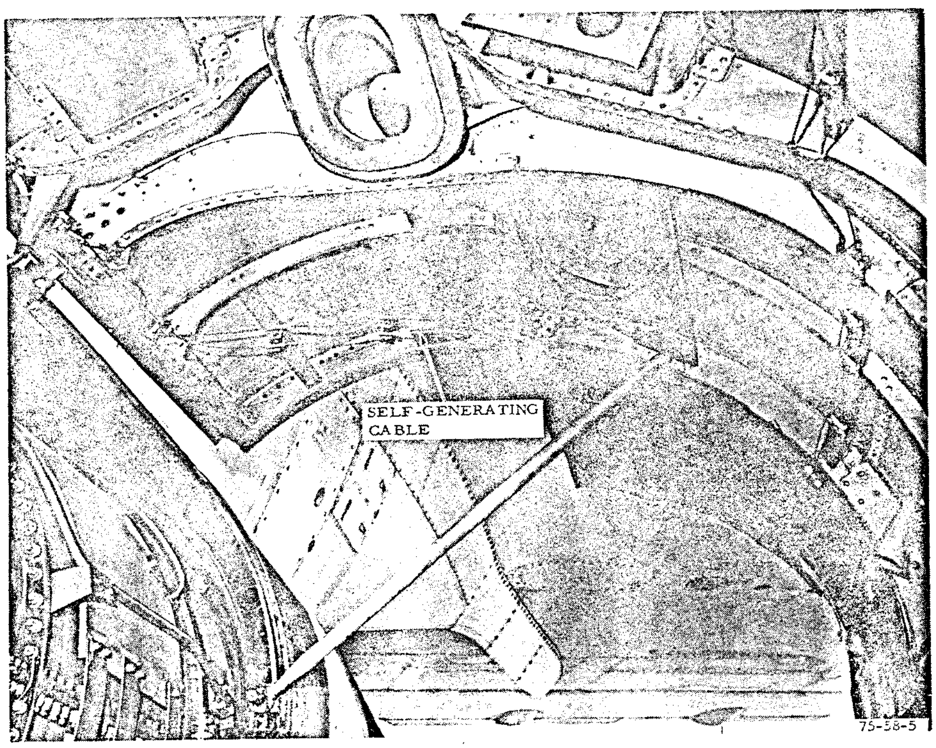


FIGURE 4: FIREWALL FEED-THROUGH FROM NACELLE TO PYLON

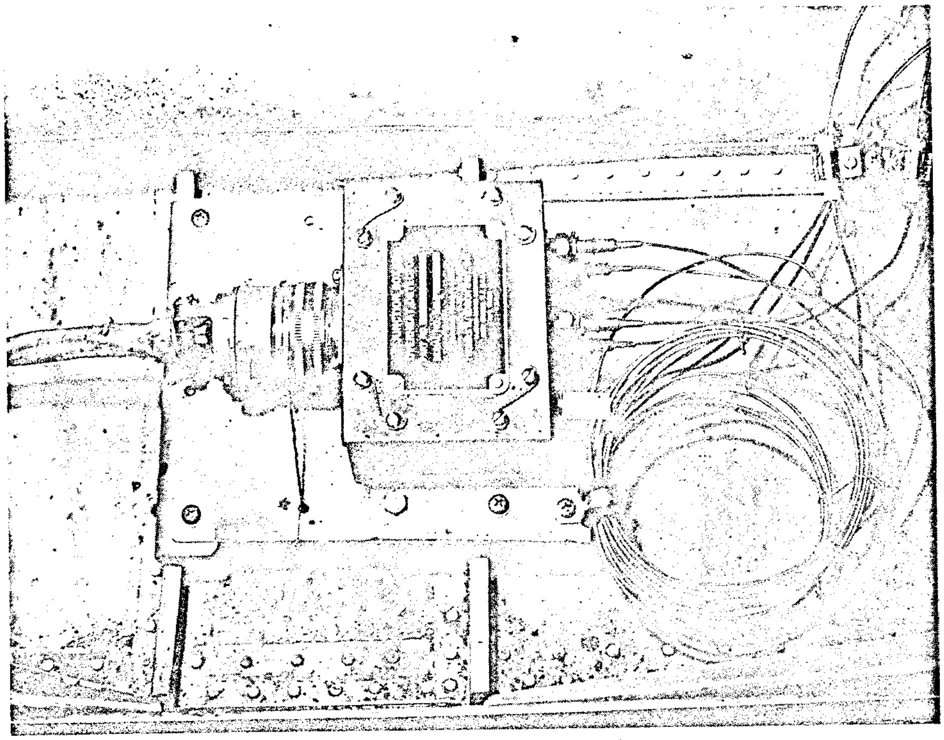


a. Outboard - Forward

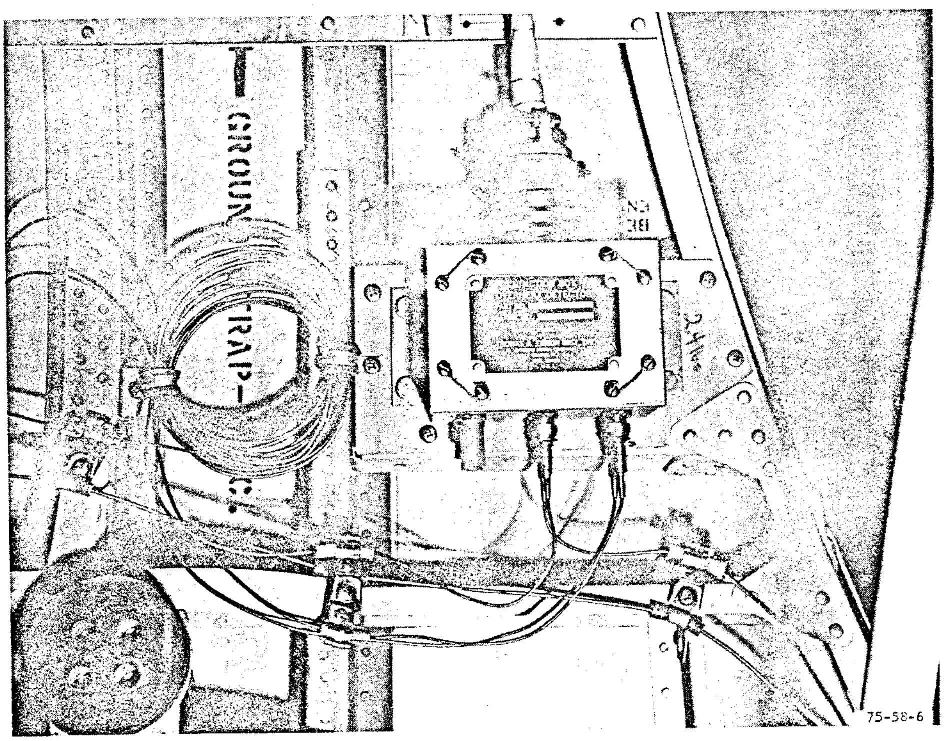


b. Outboard - Aft

FIGURE 5: OUTBOARD CABLE INSTALLATION

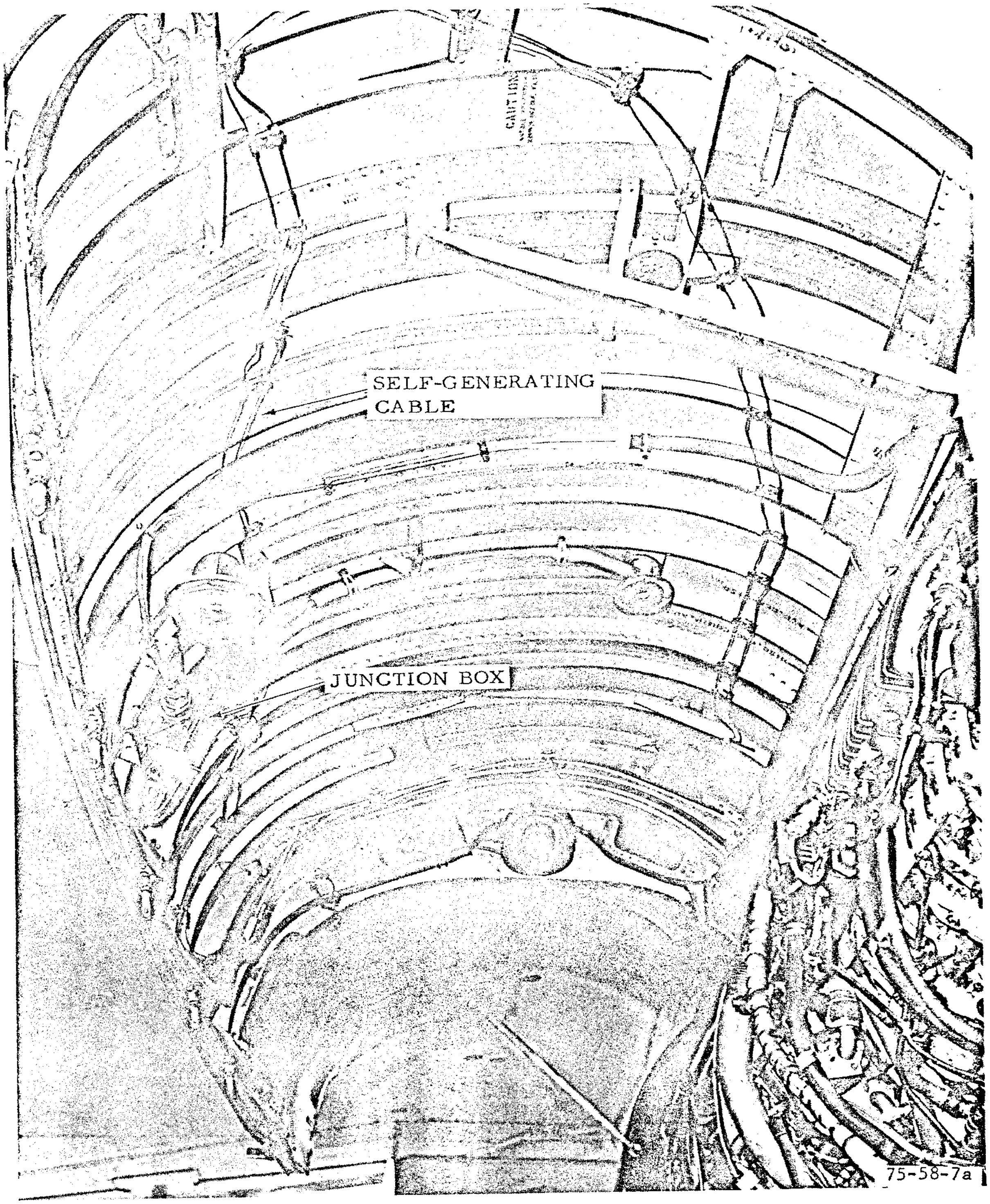


a. Inboard Junction Box



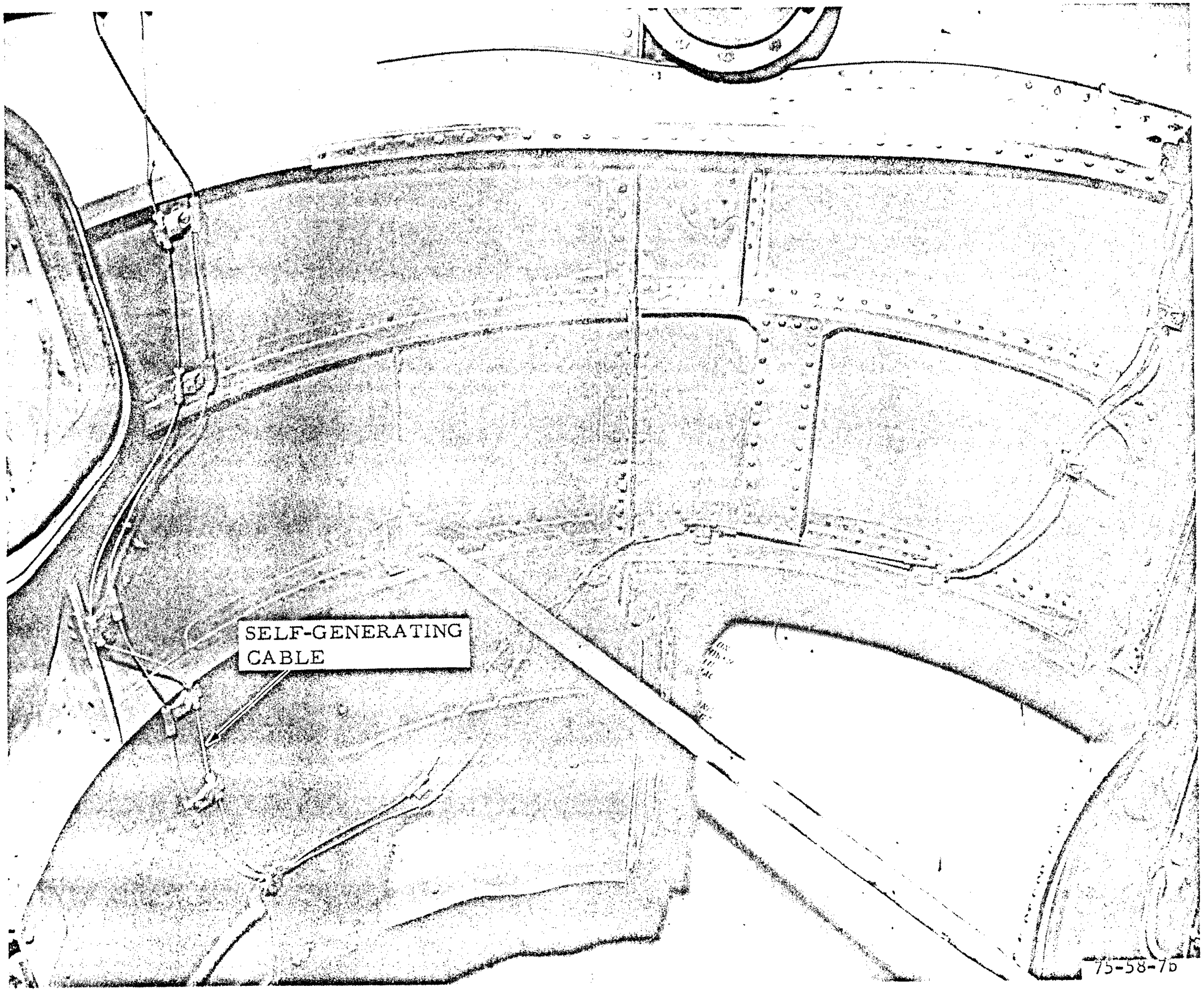
b. Outboard Junction Box

FIGURE 6: LOCATION OF JUNCTION BOXES IN NACELLE



a. Inboard - Forward

FIGURE 7: INBOARD CABLE INSTALLATION



b. Inboard - Aft

FIGURE 7: INBOARD CABLE INSTALLATION

A problem was found to be an inoperative resistor, in the control box, which caused the alarm temperature of a small section of cable to equal the alarm temperature of the entire cable. Because of this problem and the location of the cable in the aft section of the nacelle, small quantities of exhaust gases entering the nacelle when the thrust reversers where used would cause an alarm. The problem with the control box was corrected by the manufacturer, and the control box was reinstalled on the aircraft. The system was again checked with the Tempcal unit and found to be operating properly. No problems were reported with the inboard system from April 8, 1973, until June 12, 1975. During that time, the system had been subjected to 585.9 flight hours.

On June 12, 1975, it was reported the inboard system failed to test. A check was made using the Tempcal 3-inch block heater, and no alarm could be obtained from either the forward or aft zones. The control box was removed and returned for repairs. The control box malfunction was intermittant after inspection by the manufacturer and could not be specifically identified. A replacement box will be installed for further tests.

During the test program, the CV880 aircraft was based primarily at NAFEC, Atlantic City, New Jersey, but also spent some time at the following locations: Oklahoma City, Oklahoma; Dallas and Houston, Texas; Duluth, Minnesota; Anchorage, Alaska; Shannon, Ireland; Paris, France; and Thule, Greenland. No maintainance was performed on the systems during the program except a routine visual check of the overheat cables and wiring in the nacelle.

The flight test will continue in order to verify long-term operation of the system. A replacement control box will be substituted for the malfunctioning unit. Any significant results of this continued flight test will be reported in other documents as required.

3. SUMMARY OF RESULTS

3.1 Installation

(1) The control boxes were too large for the pylon and had to be located in the wheel well.

(2) Wire bundles supplied were poor in abrasive resistance and presented a problem for the long run between the junction boxes in the nacelle and the control boxes in the wheel well.

(3) The wire bundles connecting the junction boxes and the control boxes had to be routed through swedge-type connectors and sealed with sealant, because thermocouple-type bulkhead connectors were not available.

3.2 Flight Test

(1) No problems were encountered on the outboard system during its 722.2 hours of flight time.

(2) A temporary problem caused by a defective resistor in the control box resulted in the alarm temperature of a 3-inch sector of the inboard, aft section, cable being lowered to that of the entire cable.

(3) After 585.9 flight hours, the inboard system became inoperative. The system failed to test and also failed to respond to a 3-inch heated block test.

4. CONCLUSION

The self-generating system tested is an airworthy system which should decrease the false fire warning rate in engine nacelles.

5. RECOMMENDATIONS

The following modifications should be made to the system:

(1) Decrease the size of the control box so that installation in an aircraft pylon would be possible.

(2) Supply bulkhead firewall fittings with iron-constantan pins.

(3) Use iron constantan extention wire with improved abrasive quality for runs outside the nacelle.

6. REFERENCES

[1] Hill, Richard G., Simulated In-Flight Fire Test of a Self-Generating Overheat Detection System, Technical Report AFAPL-TR-73-70, March 1974.

[2] Riemer, Otto, A Self-Generating Overheat Detection System For Use on USAF Aircraft, Technical Report AFAPL-TR-72-73, August, 1972.

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