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SIMULATED IN FLIGHT FIRE TEST
OF A
SELF-GENERATING OVERHEAT DETECTION SYSTEM

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ABSTRACT

Tests under simulated flight conditions were conducted on a Self-Generating Overheat Detection System installed in a C-140 airplane engine nacelle. They 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 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. No false alarms were noted during testing.

PREFACE

This report was prepared by the FAA, NAFEC, Atlantic City, New Jersey, under Contract Number F33615-73-M-2009 and Task Number 304807.

The work was done under Project 3048 for the Air Force Aero Propulsion Laboratory. Contributions were made by Mr. Charles L. Delaney, Air Force Aero Propulsion Laboratory and Mr. Ott Reimer, Thomas A. Edison Instrument Division, McGraw Edison Company.

The principal investigator of this project was Richard G. Hill. The following NAFEC personnel contributed to the project: Shull Rutherford, and Thomas Taylor.

The report covers work accomplished by NAFEC in conducting simulated inflight tests on the self-generating overheat detection system in September 1972.

This technical report has been reviewed and is approved.

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INTRODUCTION

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 simulated in-flight fires.

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.

DESCRIPTION OF EQUIPMENT.

The self-generating overheat detection system tested consisted of a read-out 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 one overheat cable was for the aft zone. 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 1.

All testing was done using the Five-Foot Fire Test Facility at the National Aviation Facilities Experimental Center (NAFEC) with an engine and nacelle of a Lockheed C-140 (Jet Star) airplane in the test section of the wind tunnel (see Figure 1). For further information on the Test Facility refer to Reference 2.

The forward zone (Zone II), was used for all fire tests. It contained 12.6 cubic feet of free volume, and extended from the engine inlet to a vertical transverse stainless steel fire seal at Nacelle Station 117.

The test engine was a Pratt & Whitney JT-12A-6 rated at 3,000 pounds maximum thrust. This engine has interstage bleed ports at the fourth compressor stage which prevent compressor stall during engine acceleration. These ports were open from engine start to approximately N.=81 percent rated revolutions per minute (rpm).

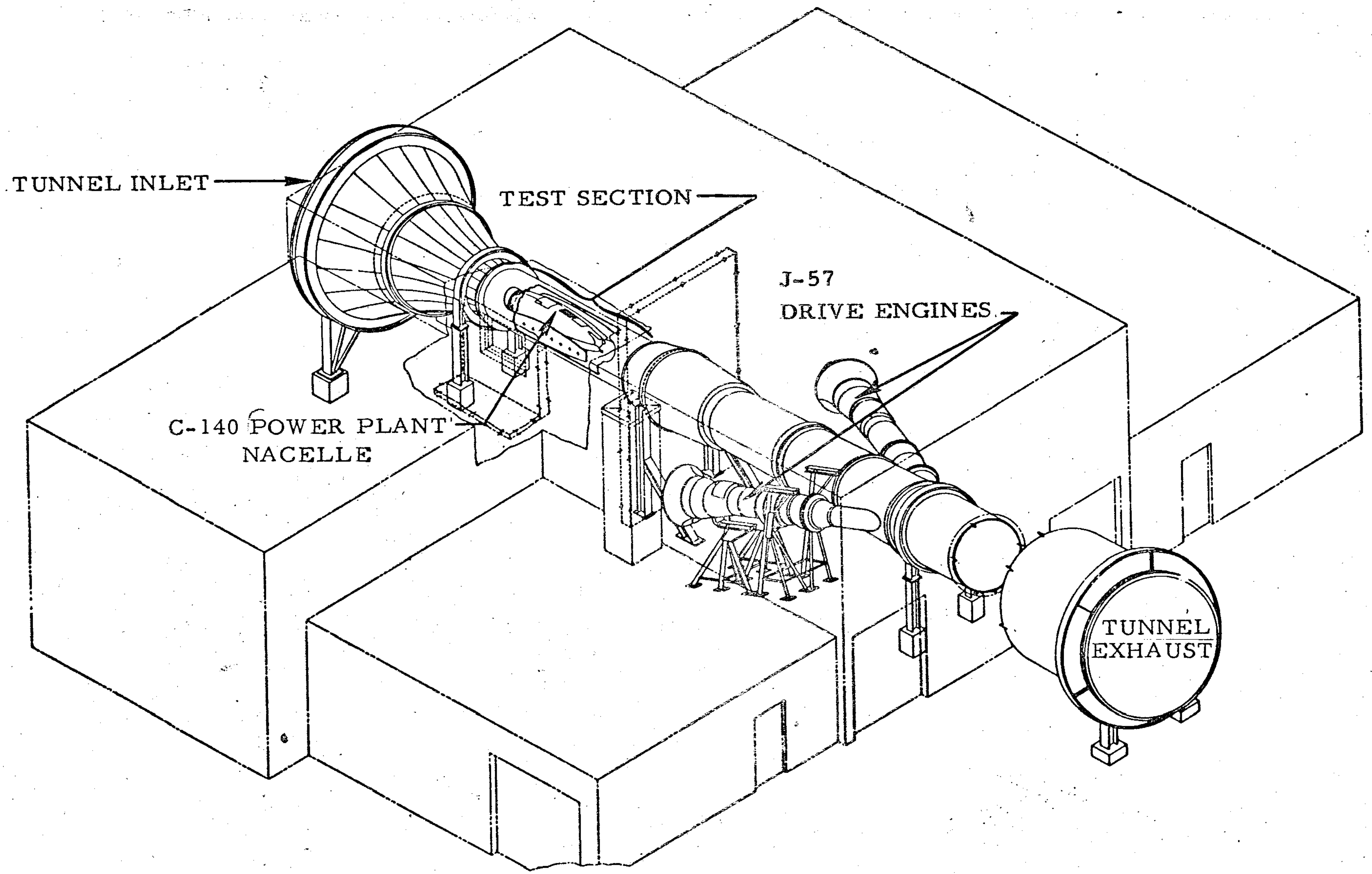


FIGURE 1. FIVE-FOOT FIRE TEST FACILITY

The self-generating overheat detection system cables were installed parallel to the existing detection system, as shown in Figures 2 and 3. The junction box was located in the nacelle just forward of the fire wall at approximately 2 o'clock. The control box was installed on top of the wind tunnel, and the readout box and all other controls were located in a control room adjacent to the test section.

DISCUSSION

The alarm temperature of the self-generating overheat detection system for the forward zone was set at 350° F for the full cable, and 475° F in the aft zone for the full cable. Tests were run using a Tempcal Block Test Heater to determine the alarm temperature when a 3-inch or 12-inch section was heated. Table 1 shows the results of those tests:

TABLE 1. BLOCK TEST DATA

Length Heated	Forward Zone	Aft Zone
Full Cable*	350°F	475°F
3 Inches	510°F	780°F
12 Inches	470°F	710°F

*Temperatures given for full cable lengths were supplied by Thomas A. Edison Division, McGraw Edison Company.

Fire tests were run using JP-4 as a fuel. In the first three tests it was sprayed at a rate of 0.46 gallons per minute (gpm) from a fuel nozzle in Zone II, Nacelle Station 76, at 4:30 o'clock, and directed toward the engine center line. In the remaining tests it was sprayed at a rate of 0.11 gpm from a fuel nozzle in Zone II, Nacelle Station 101, at 8 o'clock, and directed toward the engine centerline (see Figure 4). An engine ignitor was attached to the fuel nozzles to provide a remote ignition source for the fuel spray.

The JT12A test engine was run at three power setting during each series of tests, 100-percent rpm, or takeoff power, 87-percent rpm, or cruise, and 78-percent rpm. With the engine running at 78-percent rpm the engine bleed valves remained open. The final three tests were run with the JT12A engine inoperative, although a 17-percent rpm was obtained from ram-air spinning the compressor. The wind tunnel facility remained at a constant mach number of 0.5 for all of the tests.

The first three tests were run with the self-generating overheat detection system in its normal configuration. The fuel nozzle was located in the number one position, and a flow rate of 0.46 gpm was used. At 100-percent rpm the detection time was 3.8 seconds; at 87 percent it was 10 seconds; and at 78 percent it was 12.3 seconds for the self-generating overheat detection

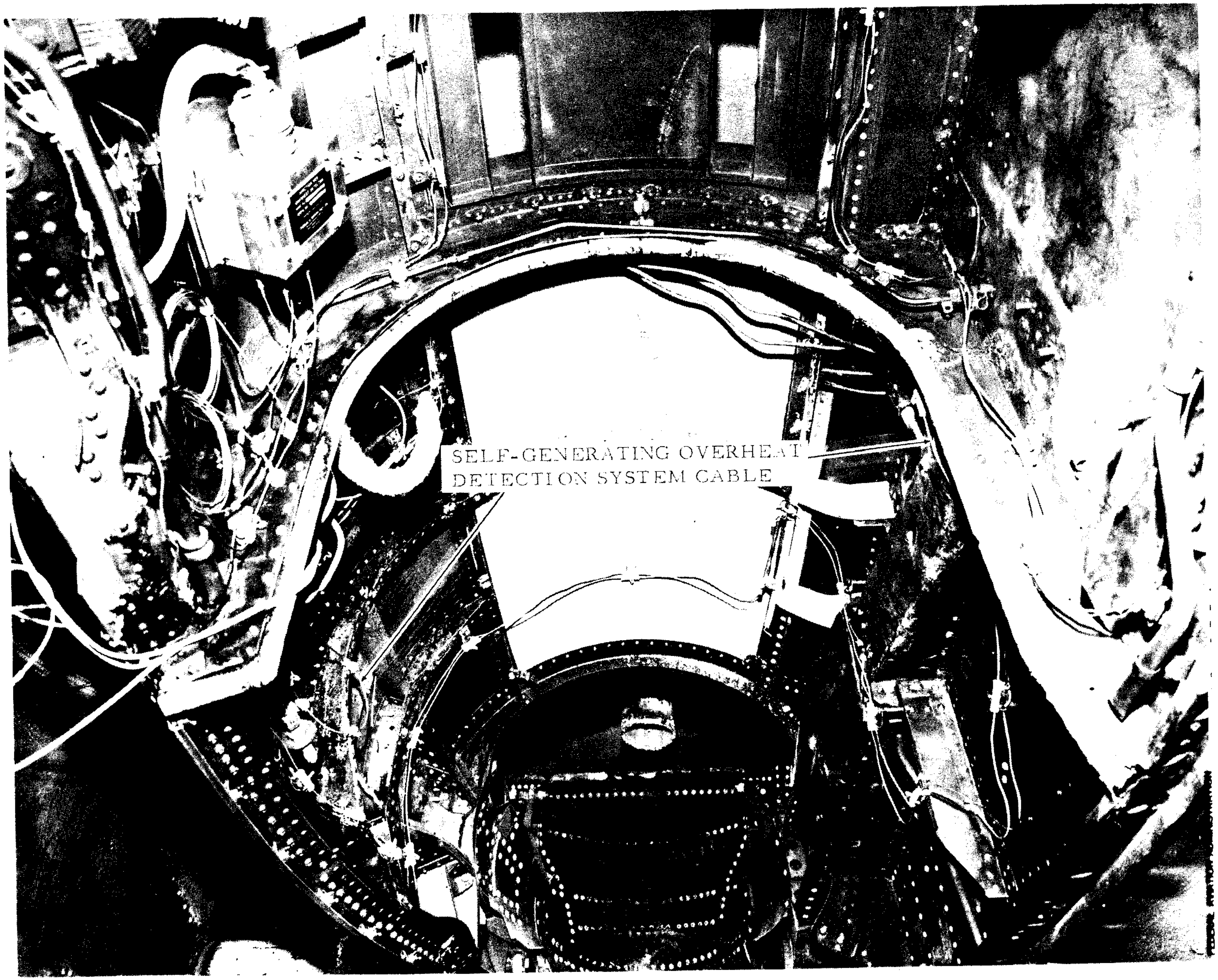


FIGURE 2. AFT ZONE SELF-GENERATING OVERHEAT DETECTION SYSTEM INSTALLATION

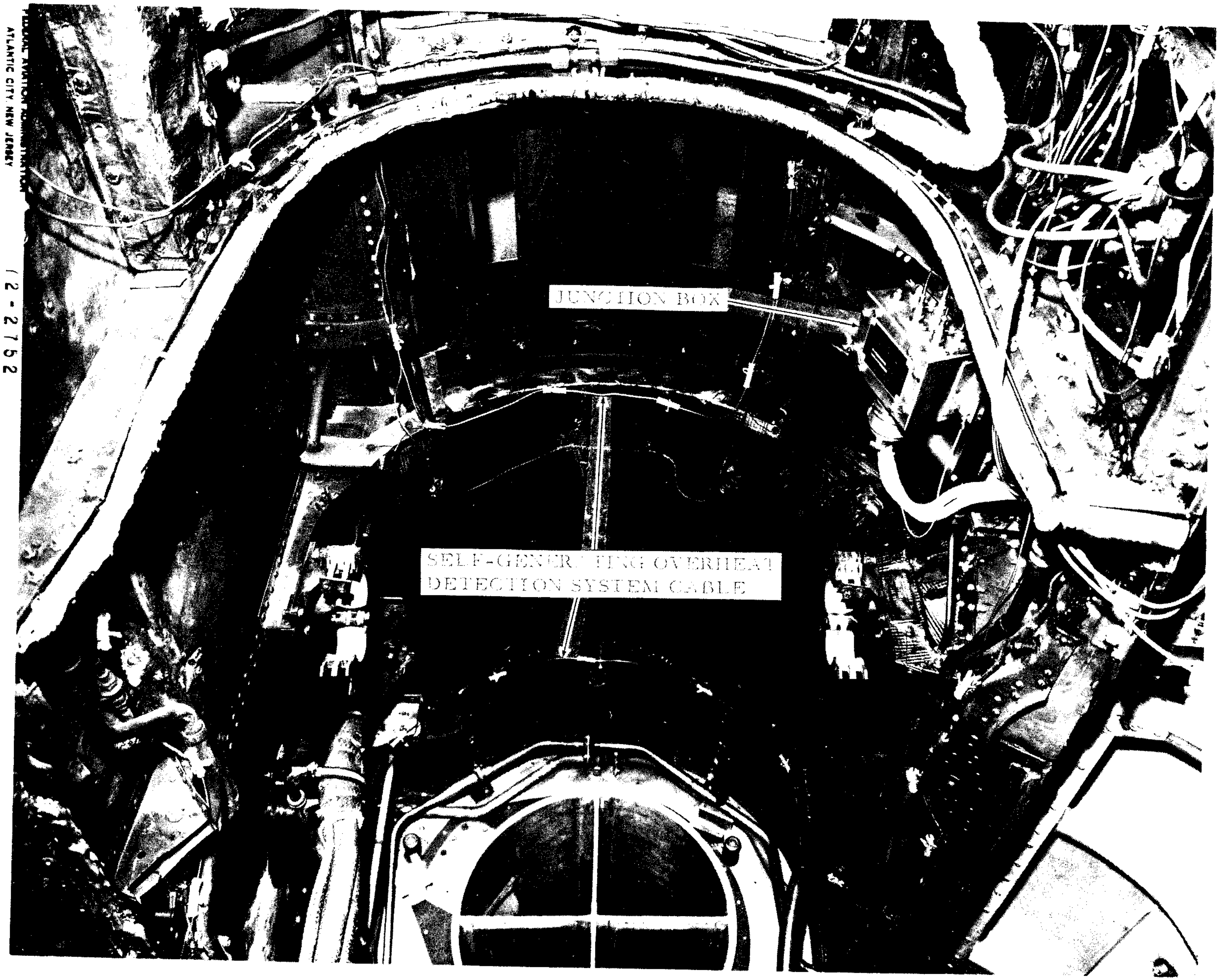


FIGURE 3. FORWARD ZONE SELF-GENERATING OVERHEAT DETECTION SYSTEM INSTALLATION

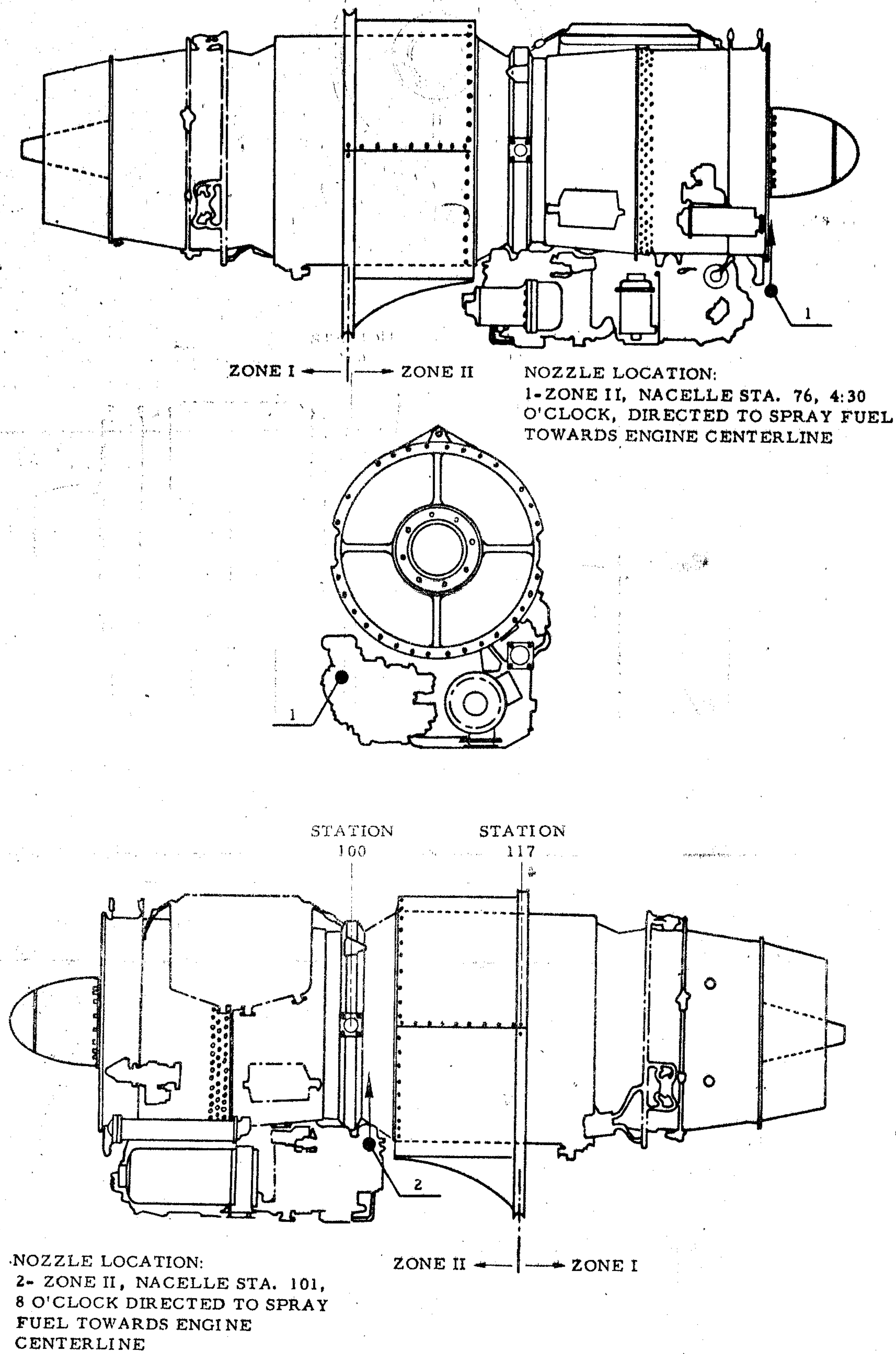


FIGURE 4. NOZZLE LOCATIONS FOR SELF-GENERATING OVERHEAT DETECTION SYSTEM FIRE TESTS

system. This was much slower than the response of the Jet Star engine fire and overheat detection system which is used as standard equipment on the Jet Star Aircraft (refer to Table 2). It should be noted that the self-generating overheat detection cable, in the forward zone, was shorter than the Jet Star detection system, and therefore did not parallel it for its entire length (refer to Figure 5). Coverage in the forward section of Zone II was reduced by the shorter cable. This was thought to be the reason for the longer detection times by the self-generating overheat detection system. All further testing was done with the fuel nozzle in location two in order to minimize the effects of the shorter cable. The rate of fuel flow from the nozzle was also reduced in the remaining tests from 0.46 gpm to 0.11 gpm. This was changed due to extensive damage done by excessive fuel in the nacelle.

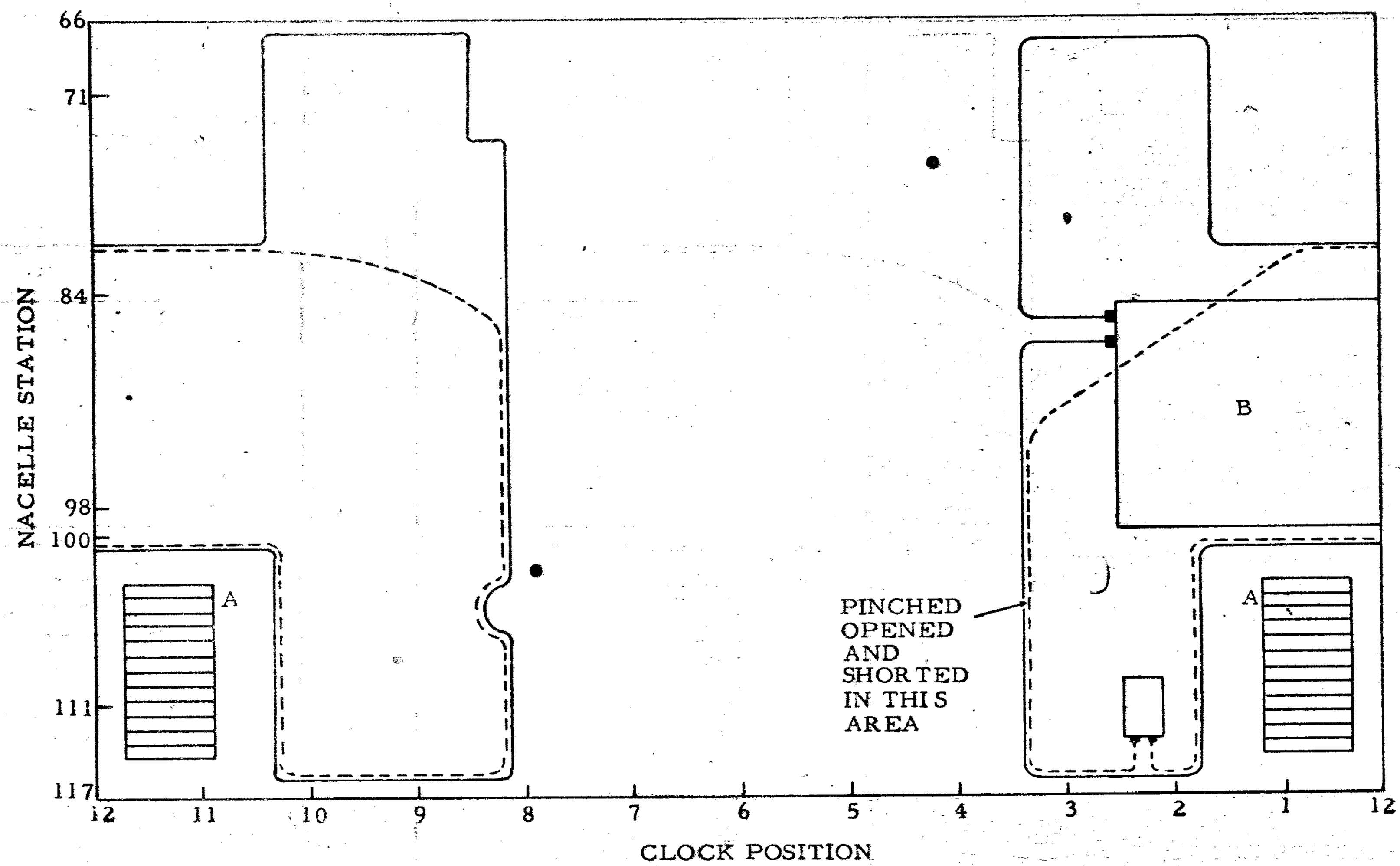
The first three tests were then repeated with the new nozzle location and fuel flow rate. The detection times were 5.6 seconds, 5.5 seconds, and 4.3 seconds for the 100-percent rpm, 87-percent rpm and 78-percent rpm runs respectively. That was approximately 1-second quicker then the Jet Star detection system. Tests 7 through 9 were run to determine the effects of a pinched cable on its ability to detect a fire. A 1-inch section of the cable was pinched in the location shown in Figures 5 and 6. The detection times were comparable to those of a normal cable (refer to Table 2). In Tests 10 through 12 the cable was opened by cutting out the 2-inch section that was pinched (see Figure 7). Again there was no change in detection times at the three power settings.

The shortest length of cable going back to the junction box (see Figure 6) was then shorted out to the engine by spot-welding a piece of safety wire to the center conductor of the cable and attaching it to a ground. Detection times increased to 11 seconds at 78-percent rpm, 17 seconds at 87-percent rpm, and 10.8 seconds at 100-percent rpm. That was over a 100-percent increase in detection time from a normal, pinched, or opened cable.

The remaining tests were run with the JT12 engine inoperative. The detection times for the Jet Star detection system averaged approximately 1- to 2-seconds longer than they did at the 87-percent rpm setting. Tests were run with the overheat cable shorted at both open ends, (as shown in Figure 8), with a large section of the cable removed, (see Figure 9), and with a short section of the cable near the fire zone shorted, (refer to Figure 10). The detection times for cable shorted at both ends and the shorter cable shorted near the fire was approximately the same, 26.0 seconds and 25.7 seconds respectively. This represented almost a 200-percent increase in detection time from the short cable open test time of 9.1 seconds.

The millivolt output of the overheat cable was monitored during an engine start-and-run to determine the effect of electrical components and vibration on the output of the cable. No appreciable electrical noise was noted during this test.

There were no false fire warnings from the self-generating overheat detection system, at anytime, during this test program.



NOTES:

NACELLE STATION 66 - FORWARD BULKHEAD
NACELLE STATION 117 - FIRE SEAL LOCATION

LEGEND -

A - AIR EXIT LOUVER
B - MAIN STRUCTURE BOX BEAM
——— TEMPERATURE SENSITIVE CONTINUOUS FIRE DETECTION SYSTEM
- - - - SELF GENERATING OVERHEAT DETECTION SYSTEM
● - NOZZLE LOCATIONS

FIGURE 5. FORWARD ZONE TEST CONFIGURATIONS FOR TESTS 1 THROUGH 16

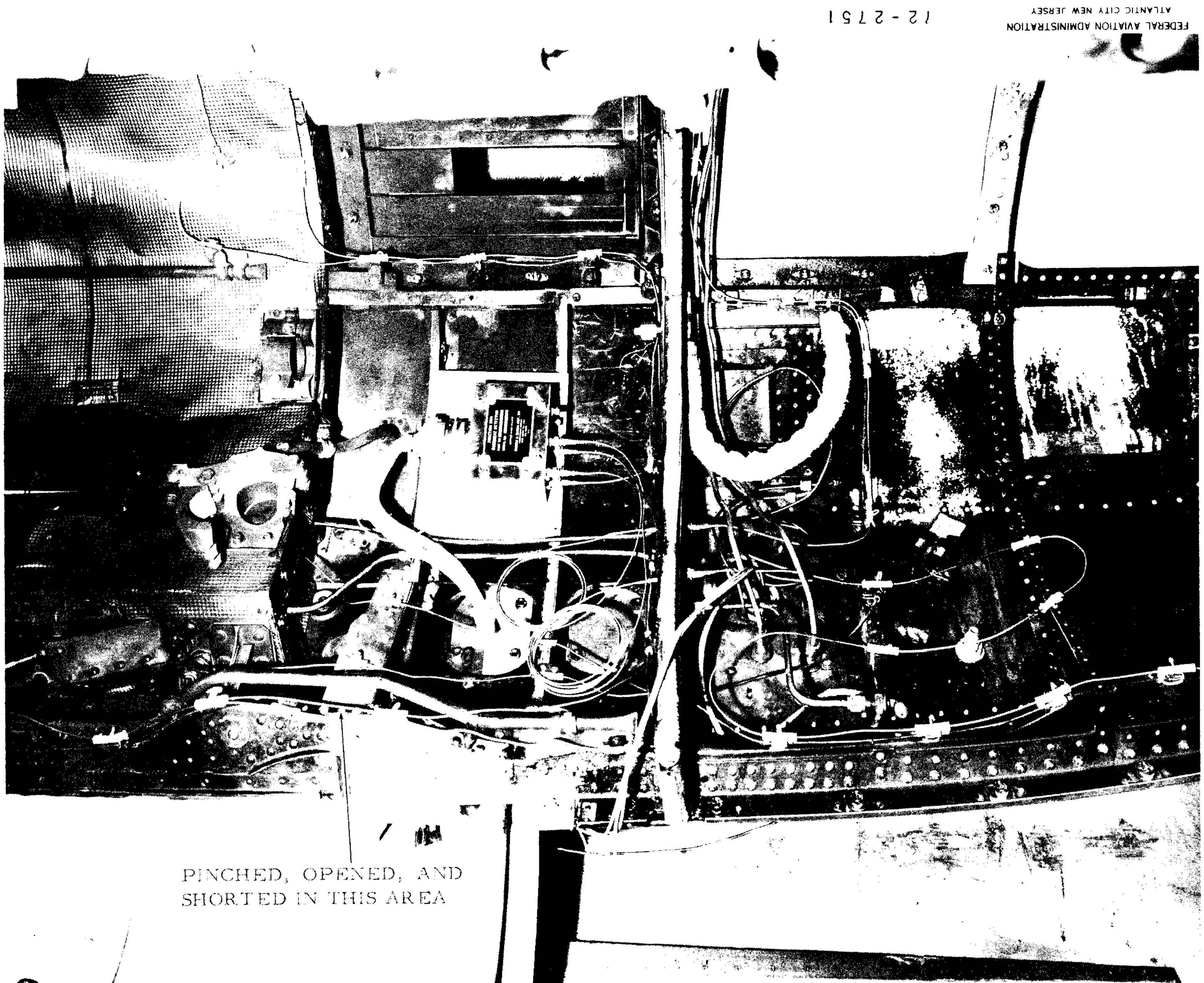


FIGURE 6. SELF-GENERATING OVERHEAT ~~DETECTOR~~ CABLES IN AREA OF JUNCTION BOX
detection

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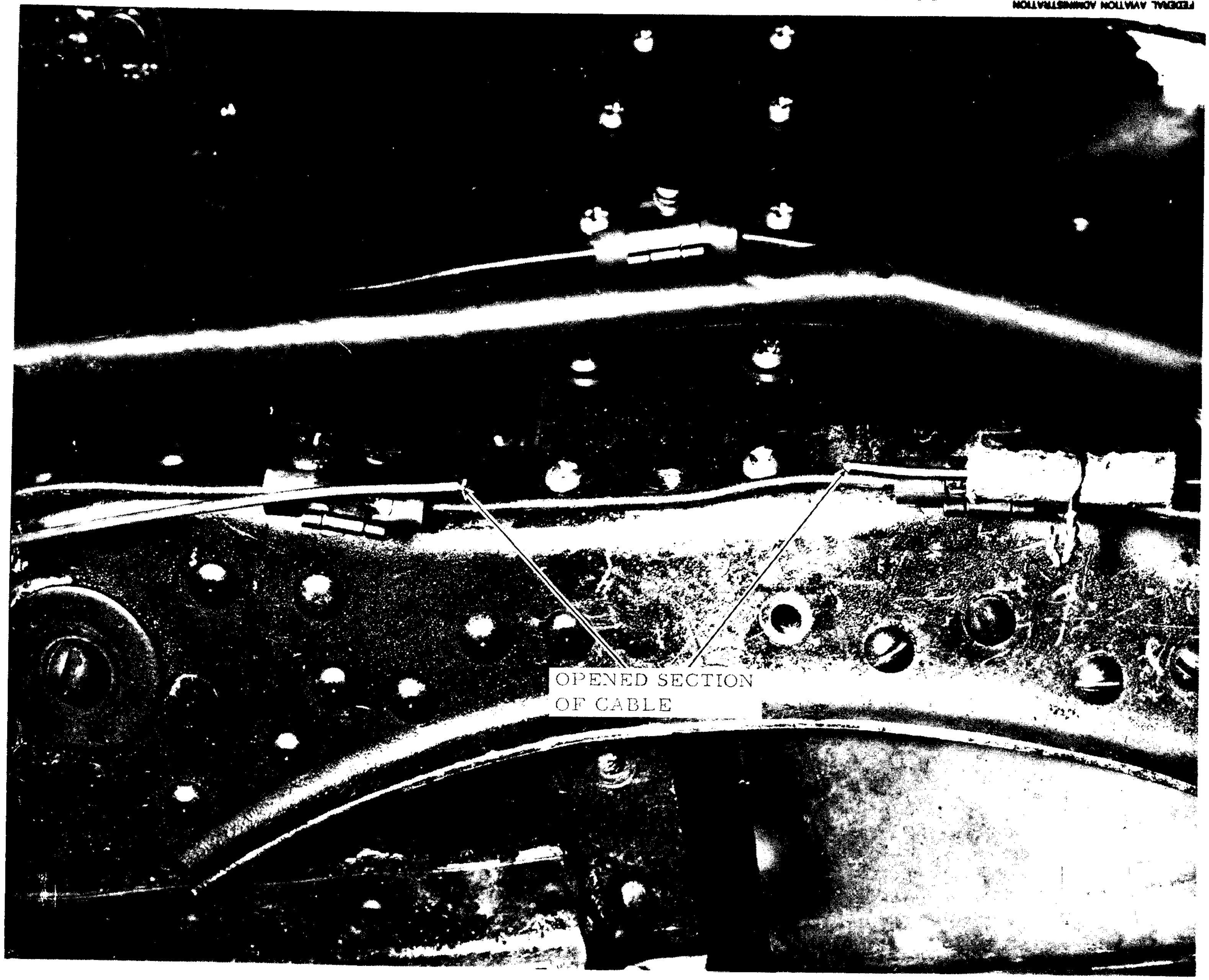


FIGURE 7. OPENED SECTION OF SELF-GENERATING OVERHEAT DETECTION CABLE

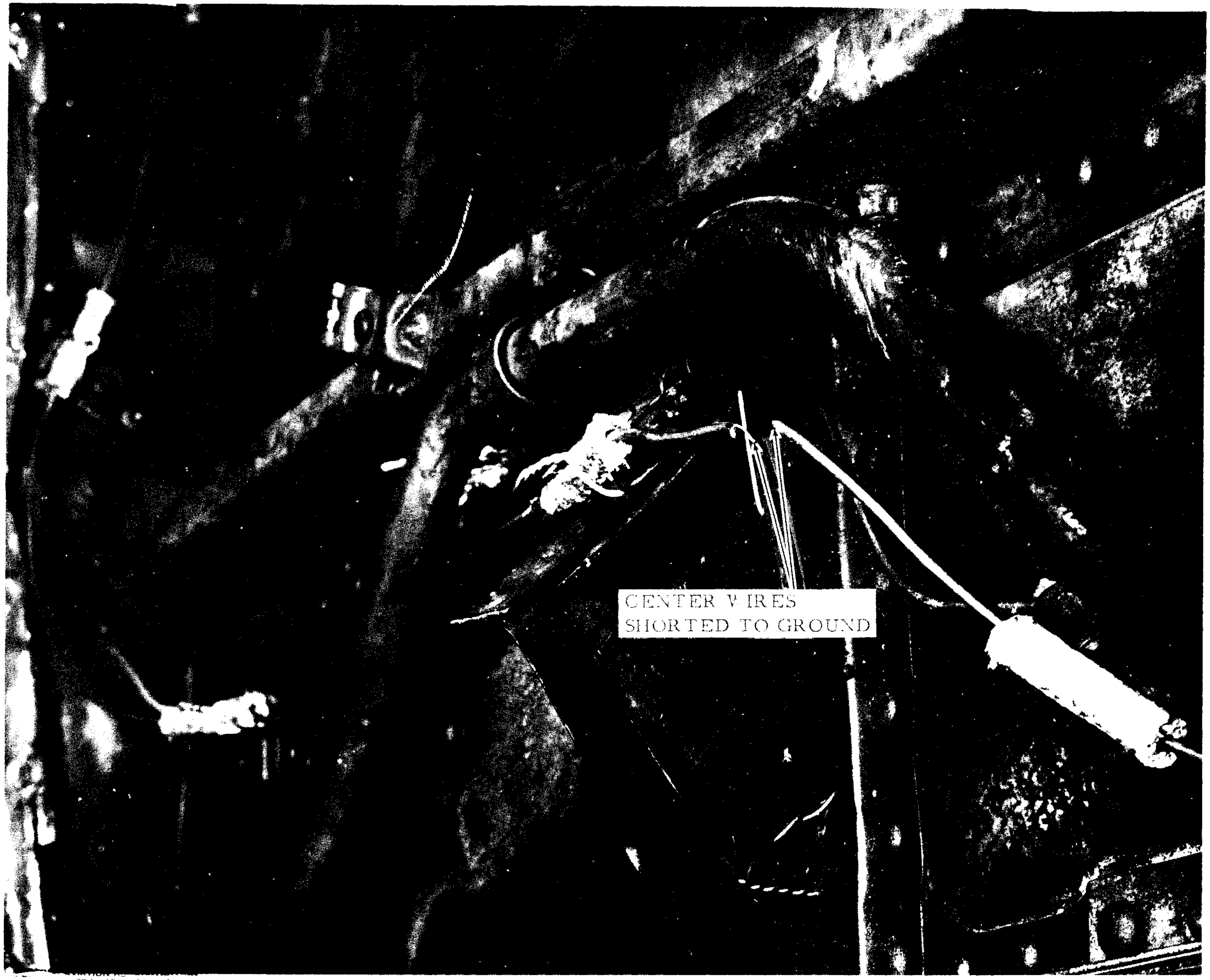
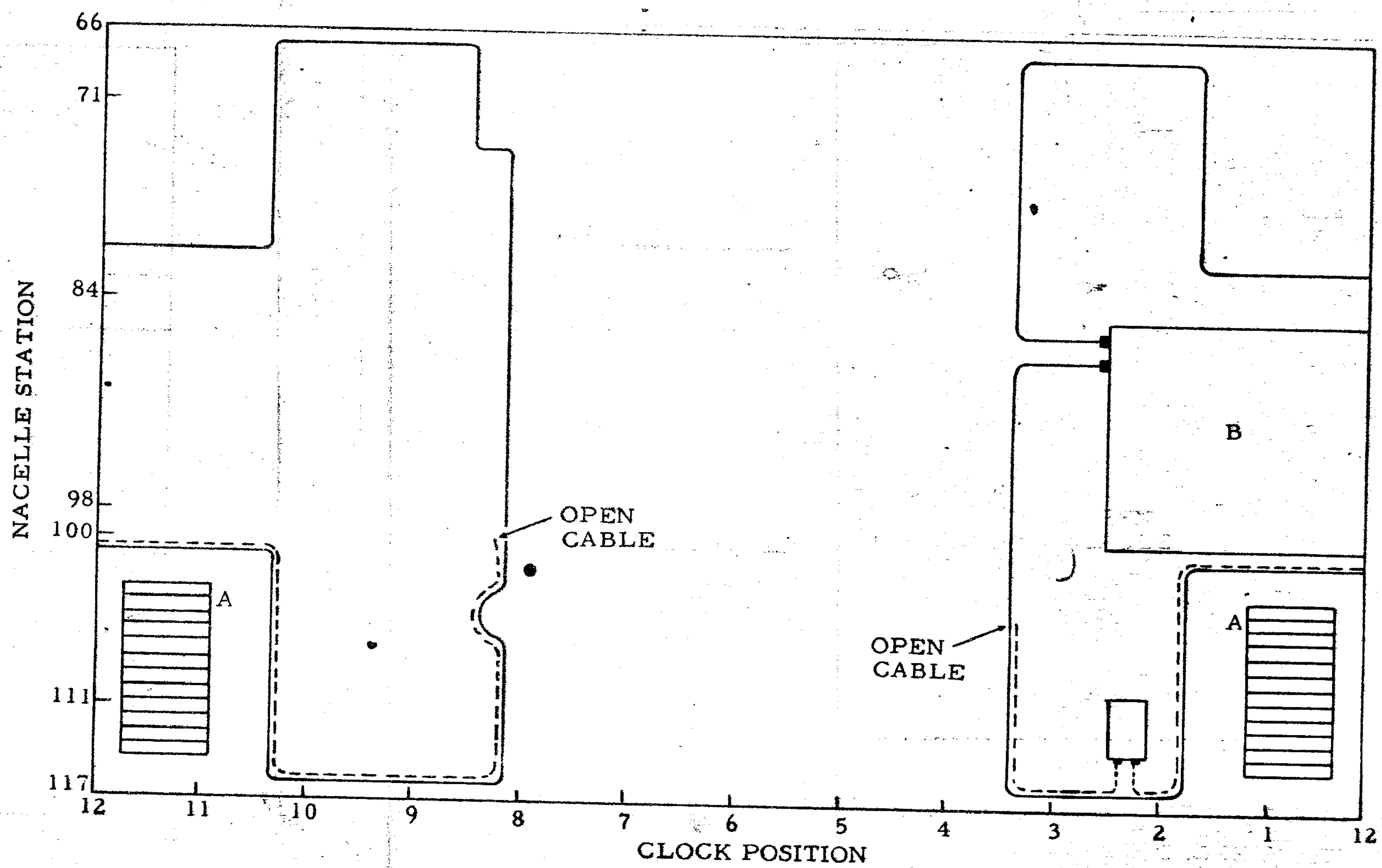


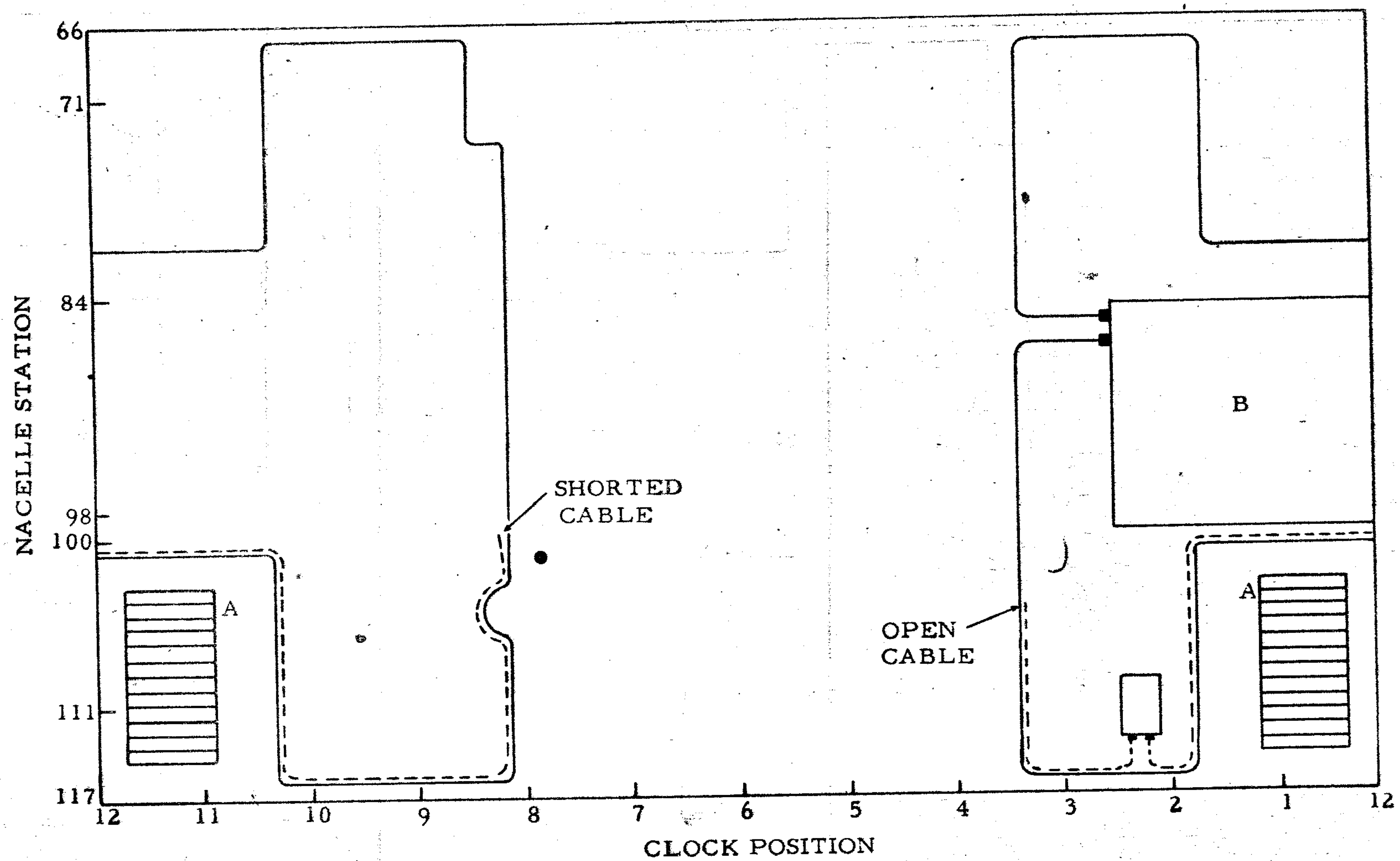
FIGURE 8. SHORTED SECTION OF SELF-GENERATING OVERHEAT DETECTION CABLE



NOTES:
NACELLE STATION 66 - FORWARD BULKHEAD
NACELLE STATION 117 - FIRE SEAL LOCATION

LEGEND -
A - AIR EXIT LOUVER
B - MAIN STRUCTURE BOX BEAM
——— TEMPERATURE SENSITIVE CONTINUOUS FIRE DETECTION SYSTEM
---- SELF GENERATING OVERHEAT DETECTION SYSTEM
● - NOZZLE LOCATION

FIGURE 9. FORWARD ZONE TEST CONFIGURATION FOR TEST 17.



NOTES:
NACELLE STATION 66 - FORWARD BULKHEAD
NACELLE STATION 117 - FIRE SEAL LOCATION

LEGEND -
A - AIR EXIT LOUVER
B - MAIN STRUCTURE BOX BEAM
—— TEMPERATURE SENSITIVE CONTINUOUS FIRE DETECTION SYSTEM
---- SELF GENERATING OVERHEAT DETECTION SYSTEM
● - NOZZLE LOCATION

FIGURE 10. FORWARD ZONE TEST CONFIGURATION FOR TEST 18.

TABLE 2. SELF-GENERATING OVERHEAT DETECTION SYSTEM FIRE TEST DATA

Test	Test Engine rpm (percent)	Tunnel Mach No.	Nozzle* Location	Fuel Flow (gpm)	Jet Star Detection System Detection Time (sec)	Self-Generating Self-Detection Time (sec)	Self-Generating Cable Configuration
1	78	.5	1	0.46	7.0	12.3	Normal
2	87	.5	1	0.46	4.3	10.0	Normal
3	100	.5	1	0.46	3.6	3.8	Normal
4	78	.5	2	0.11	5.8	4.3	Normal
5	87	.5	2	0.11	6.6	5.5	Normal
6	100	.5	2	0.11	6.7	5.6	Normal
7	78	.5	2	0.11	6.2	4.6	Pinched Cable
8	87	.5	2	0.11	6.2	5.1	Pinched Cable
9	100	.5	2	0.11	5.8	4.3	Pinched Cable
10	78	.5	2	0.11	7.0	5.3	Opened Cable
11	87	.5	2	0.11	6.0	4.6	Opened Cable
12	100	.5	2	0.11	5.5	4.3	Opened Cable
13	78	.5	2	0.11	6.0	11.0	Shorted Cable
14	87	.5	2	0.11	8.0	17.0	Shorted Cable
15	100	.5	2	0.11	5.3	10.8	Shorted Cable
16	17	.5	2	0.11	7.0	26.0	Shorted Cable
17	17	.5	2	0.11	9.5	9.1	Opened Cable
18	17	.5	2	0.11	9.3	25.7	Shorted Cable

*As shown in Figure 4.

SUMMARY OF RESULTS

1. The self-generating overheat detection system, in its normal operating condition, detected fires in the test nacelle as fast or faster than the original[1] fire and overheat detection equipment for that nacelle.

2. A pinch or crimp in the self-generating overheat detection system cable made virtually no difference in detection time.

3. An opening in the self-generating overheat detection system cable made virtually no difference in detection time as long as an operating portion of the cable was in the fire zone.

4. A short of the center conductor of the self-generating overheat detection system cable to ground increased the detection time by more than 100 percent, but it did not cause false fire warning or result in an inoperative condition.

5. No appreciable electrical noise was noted in the system.

6. No false fire warnings were observed during testing.

1 The original fire and overheat detection equipment refers to the detection system installed by the airframe manufacturer as standard equipment on the Jet Star Aircraft.

CONCLUSIONS

1. The performance of the self-generating overheat detection system, in its normal configuration, is comparable to that of a thermistor type detection system in regards to detection time due to a nacelle fire.

2. An open or pinched cable has little or no effect on the operation of the system.

3. The self-generating overheat detection system is not subject to false warnings from inadvertant grounding although such grounding may result in a delayed fire warning.

REFERENCES

1. Riemer, Otto, "A Self-Generating Overheat Detection System For Use On USAF Aircraft," Technical Report AFAPL-TR-72-73 August, 1972.

2. Sommers, Daniel E., "Fire Protection Tests in a Small Fuselage-Mounted Turbojet Engine and Nacelle Installation," Final Report, Report No. FAA-RD-70-57, November 1970.