

THE FEASIBILITY OF BURNER-CAN BURN-THROUGH THERMAL DETECTION PRIOR TO ENGINE CASE RUPTURE

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FINAL REPORT

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16. Abstract <p>Full-scale tests simulating engine combustion section thermal failures (burn-through) were conducted using a J57 engine (cowled and uncowed) to determine the feasibility of detecting a burn-through prior to its occurrence by monitoring engine skin temperature. Results of the tests indicated that as few as four thermocouples, located 90 degrees apart around the diffuser case and/or burner can case, could detect a burn-through prior to engine case rupture.</p>			
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INTRODUCTION

Purpose.

The purpose of this project was to determine the feasibility of detecting a burner-can burn-through prior to an engine case rupture by monitoring jet-engine diffuser case and burner case skin temperatures.

Background.

A burner-can burn-through is a high-temperature, high-velocity flame exiting from a rupture in a jet engine (usually in the diffuser case) caused by uncontrolled combustion in a location within an engine not designed for combustion. The two main causes of burner-can burn-through are (1) dislocated burner cans (in can annular-type engines), allowing the fuel nozzles to spray fuel against the forward section of the burner can instead of inside it, and (2) cracks in internal fuel lines, manifolds and nozzles.

Further information regarding the occurrence and the severity of burn-through is provided in the Reference.

Description of Test Article and Equipment.

The test article used in this project was a Pratt and Whitney J57-P37 turbojet engine mounted in the right nacelle of a B57 airplane (see Figure 1). The engine was remotely controlled from a blockhouse located approximately 100 feet from the aircraft. Ten No. 28 gage Chromel-Alumel thermocouples were spot welded to the J57 engine and recorded on five Bristol Model-760 Strip-Chart Dynamaster two-pen recorders, located in the blockhouse.

DISCUSSION

In order to cause a burn-through failure in the J57 test engine, a hole was cut in the diffuser case allowing access to the internal fuel manifold. A section of the stainless steel protective shroud around the fuel lines was removed. A 0.040-inch hole was drilled in both the primary and secondary fuel lines (Figure 2). The hole in the diffuser case was then repaired by rewelding the removed piece of material in place.

A series of three burn-through failure tests were run. Test No's. 1 and 2 were run with the engine uncowed, and Test No. 3 was run with the engine fully cowed.

The thermocouples in all three tests were spot welded to the engine case, as shown in Figure 3. The location of the thermocouples for each test are shown in the drawings in Figures 4 through 6.

In each case the engine was accelerated to full power and shortly after burn-through the engine was shut down.

A final test was run using an undamaged engine, with thermocouples attached, to determine a background level.

Results.

The development of a burner-can burn-through was photographed by motion picture cameras and can be seen in Figures 7 through 16. In Figure 7 the internal fuel leak had ignited and the diffuser case was just beginning to overheat (note the two hot spots on the diffuser case). Figure 8 shows the engine just prior to rupture. A large portion of the diffuser case began to glow red, and a small section of the burner can case began to overheat. The following eight photos were taken over a time span of five-tenths of a second. In Figure 9 the flame has just penetrated the diffuser case. As the rupture in the diffuser case enlarges the flame increases in diameter and length. As a result of rough and bowed edges on the burn-through hole the flame transforms itself from a single concentrated jet (Figure 12) to a larger diffused jet (Figure 16).

Test No. 1. Figures 17 and 18 show the temperature profile of selected thermocouples on the diffuser case and the burner can case prior to, during and after a burn-through. The thermocouples in the general proximity (within 45°) showed a rapid and large increase in temperature beginning 40 seconds prior to burn-through. The thermocouples located approximately 150° around the engine from the burn-through also showed an increase in skin temperature, but of a much lower magnitude.

Figures 19 and 20 show the damage, from this burn-through, to the diffuser case. The size of the hole was approximately 3 X 4 inches. (Note the holes in the stainless steel fire extinguisher discharge line.) Burn-through time for the 0.030-wall tubing was approximately 1 second.

Test No. 2. The results of Test No. 2 can be seen in Figures 21 and 22 and the resultant damage from the burn-through in Figure 23. The burn-through hole in Test No. 2 was slightly larger than that in Test No. 1. The results of the test was similar to the first test, except the magnitude of the temperatures was not as high. This could have been caused by an earlier rupture of the diffuser case due to its weakened condition.

Test No. 3. The results of this fully-cowled-engine test is shown in Figures 24 and 25. Figures 26 through 28 show the damage caused by the burn-through. Unlike the prior two tests, the burn-through occurred in the burner can case an inch or so aft of the split line. A smaller secondary burn-through did occur just forward of the split line in the diffuser case. As a result of the location of the burn-through, the burner can case showed a much higher peak temperature than the diffuser case, whereas, the diffuser case still showed a much larger area of temperature rise.

Background Test.

The results of the background test are shown in Figures 29 and 30. The two lines on each graph represent the highest and lowest temperatures measured on the diffuser case (Figure 29) and burner can case (Figure 30) at various locations 360° around the engine.



FIGURE 1. J57 TEST ENGINE

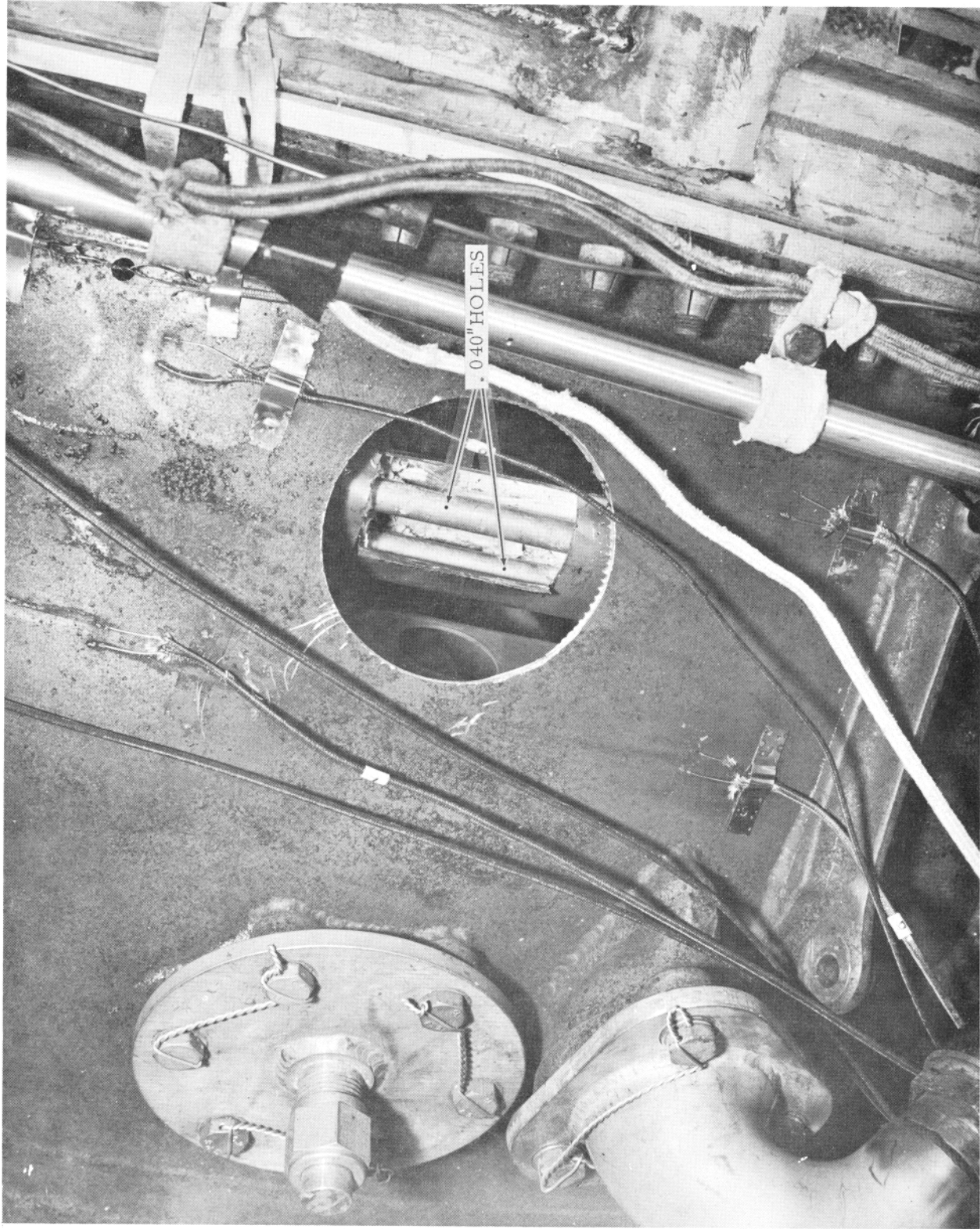


FIGURE 2. HOLES IN J57 INTERNAL FUEL MANIFOLD

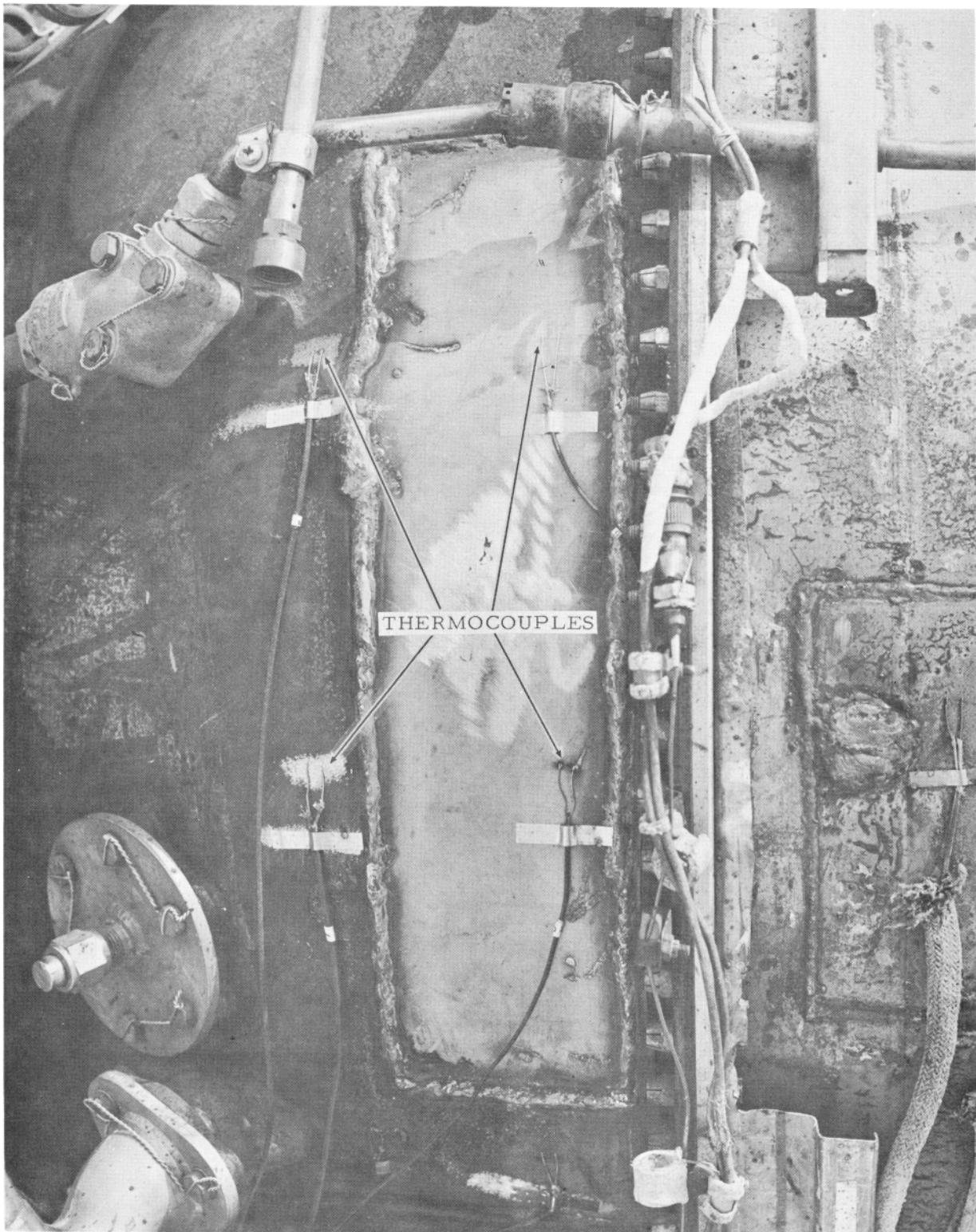


FIGURE 3. THERMOCOUPLE ATTACHMENT TO J57 ENGINE

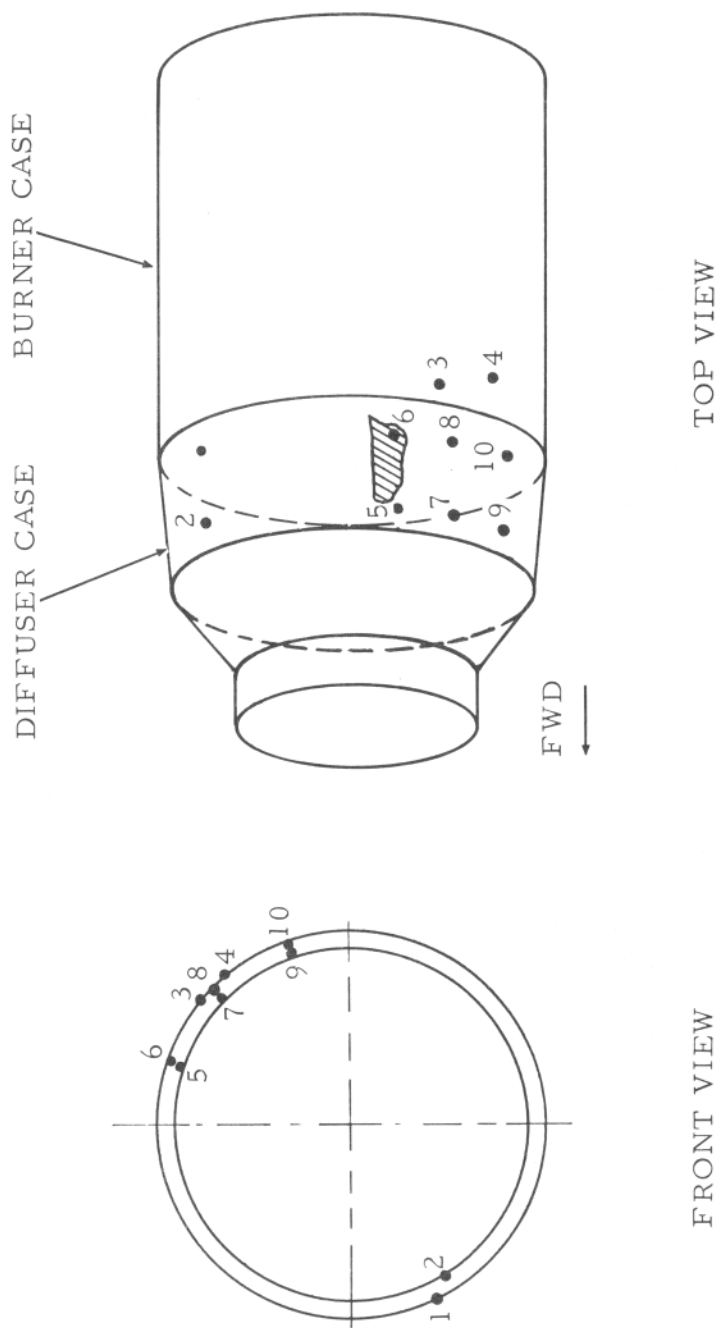


FIGURE 4. THERMOCOUPLE LOCATIONS DURING TEST NO. 1

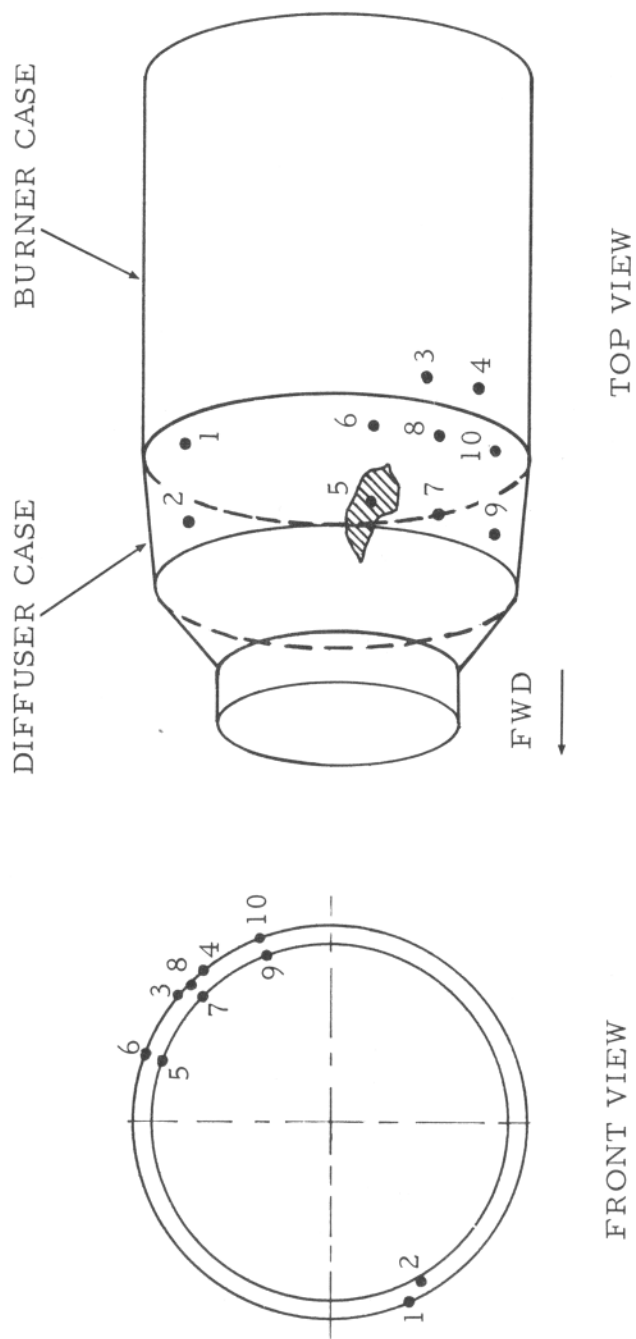
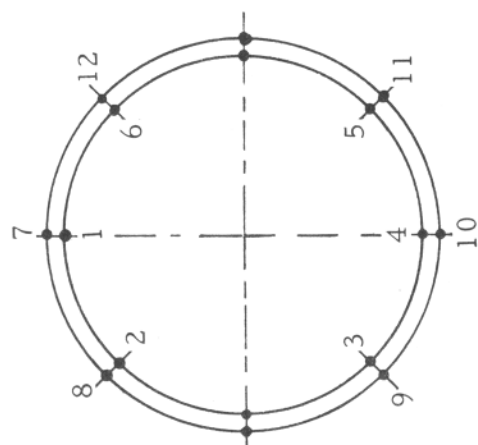
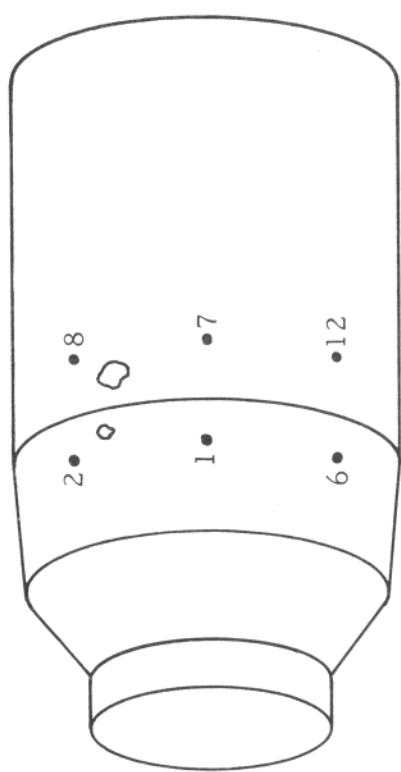


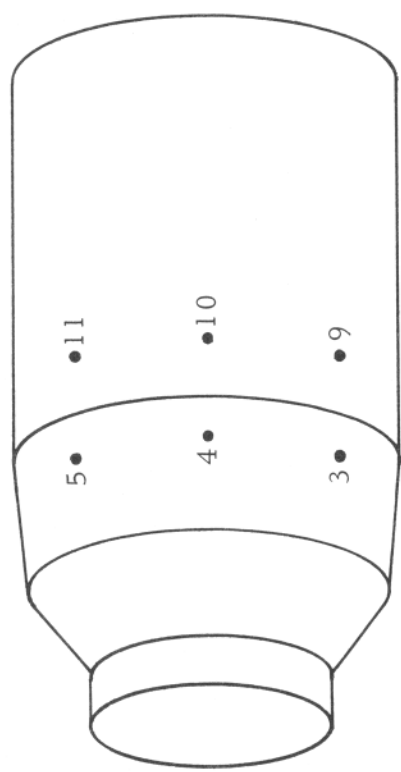
FIGURE 5. THERMOCOUPLE LOCATIONS DURING TEST NO. 2



FRONT VIEW



TOP VIEW



BOTTOM VIEW

FIGURE 6. THERMOCOUPLE LOCATIONS DURING TEST NO. 3

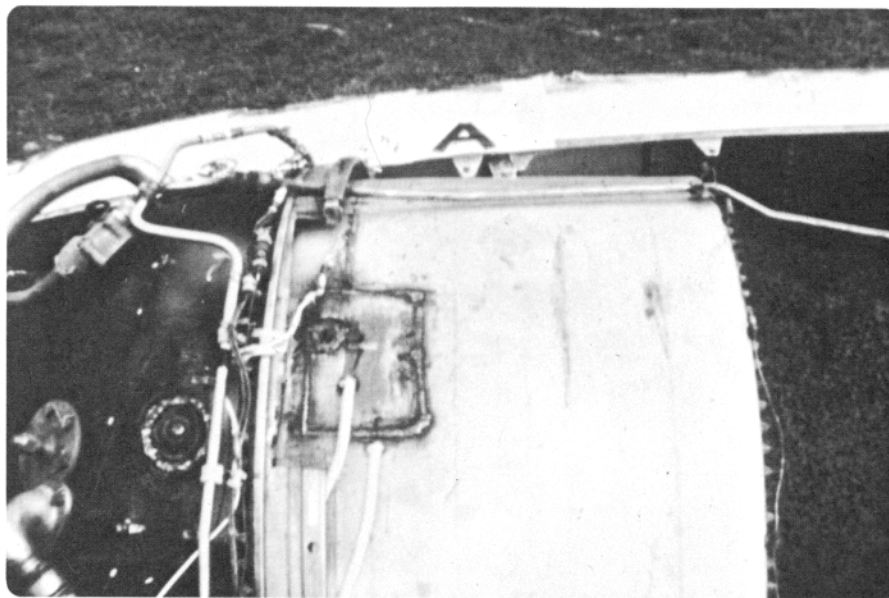


FIGURE 7. J57 ENGINE APPROXIMATELY
40 SECONDS PRIOR TO BURN-THROUGH

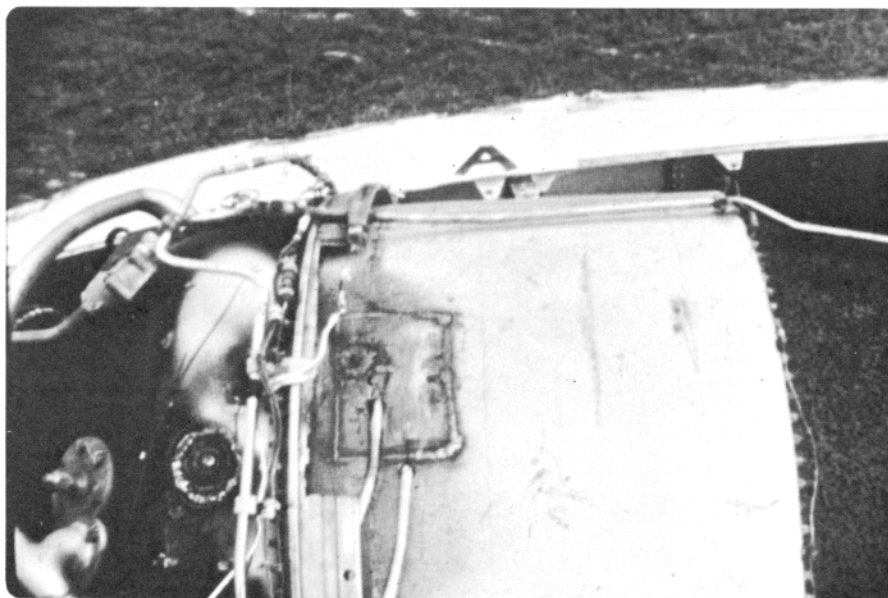


FIGURE 8. ENGINE CASE JUST PRIOR TO
BURN-THROUGH

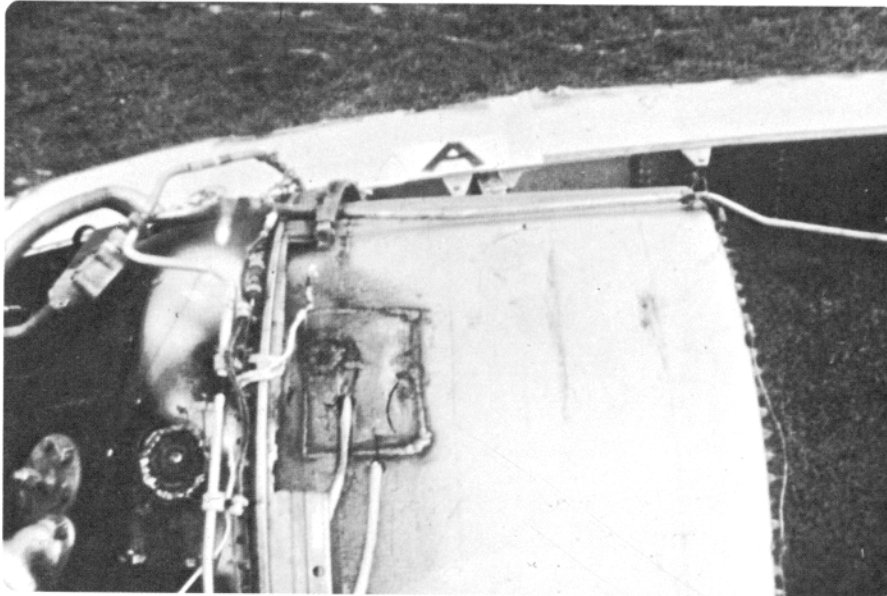


FIGURE 9. J57 BURN-THROUGH (TIME 0)

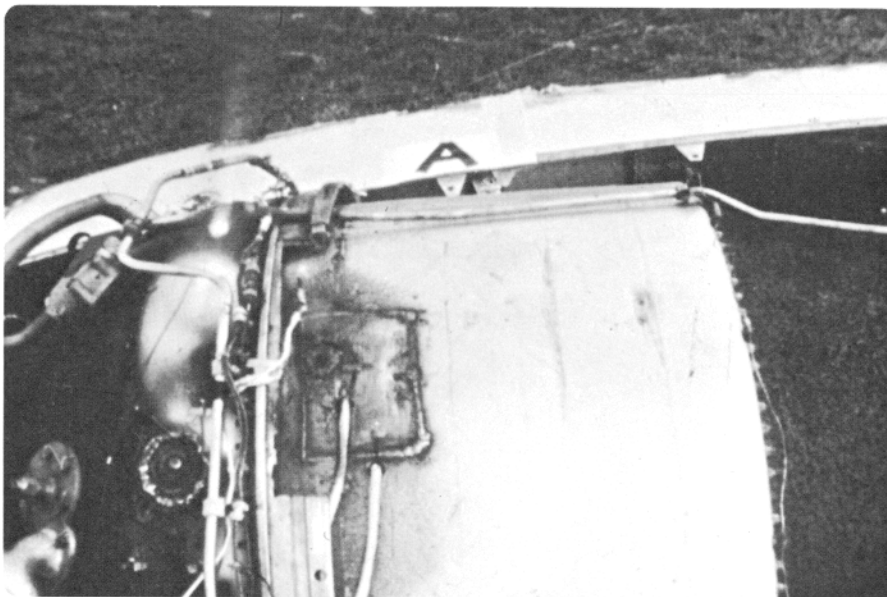


FIGURE 10. J57 BURN-THROUGH (TIME 1/16 SEC)

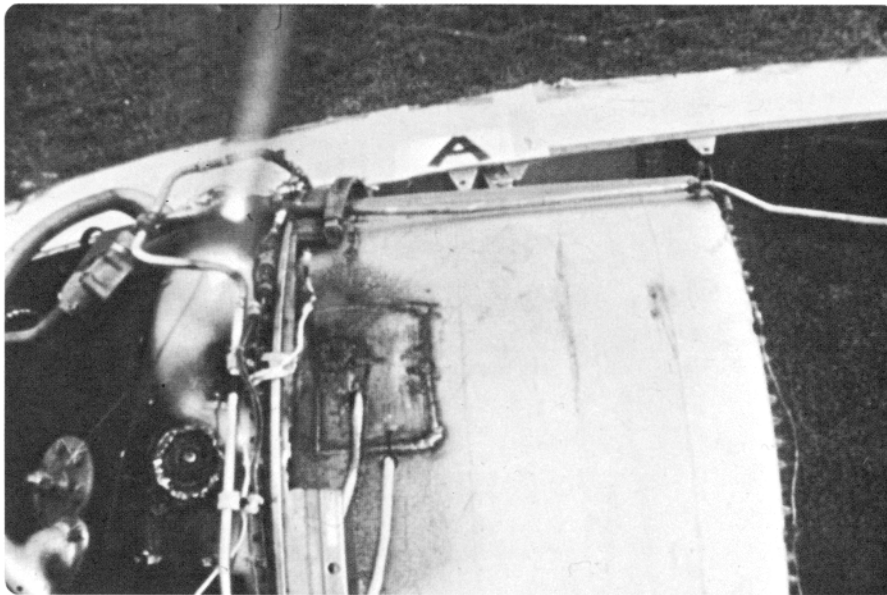


FIGURE 11. J57 BURN-THROUGH (TIME $1/8$ SEC)

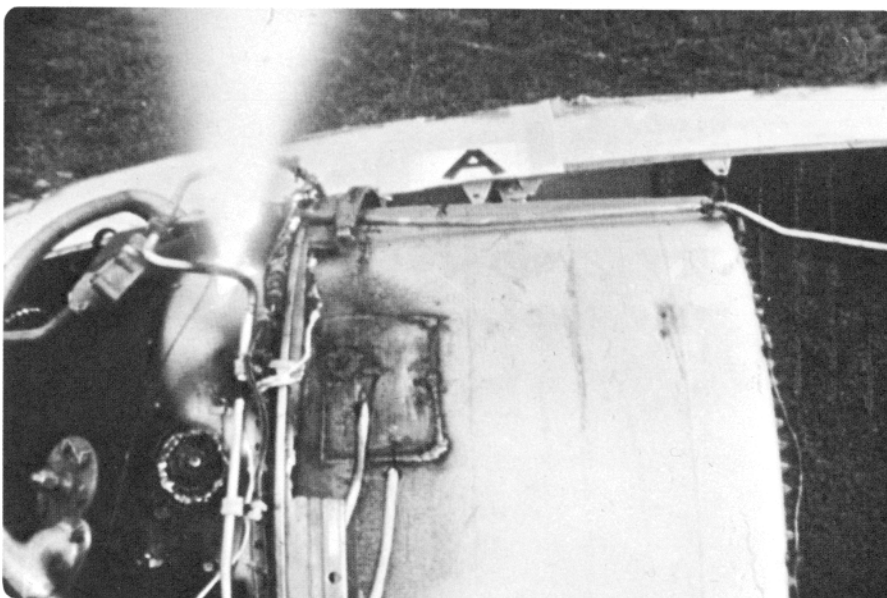


FIGURE 12. BURN-THROUGH (TIME $3/16$ SEC)

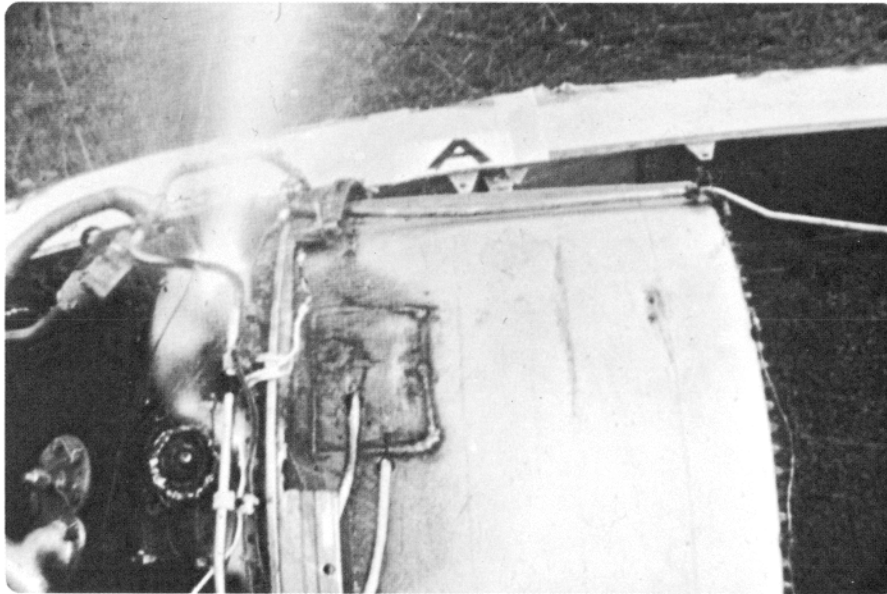


FIGURE 13. J57 BURN-THROUGH (TIME 1/4 SEC)

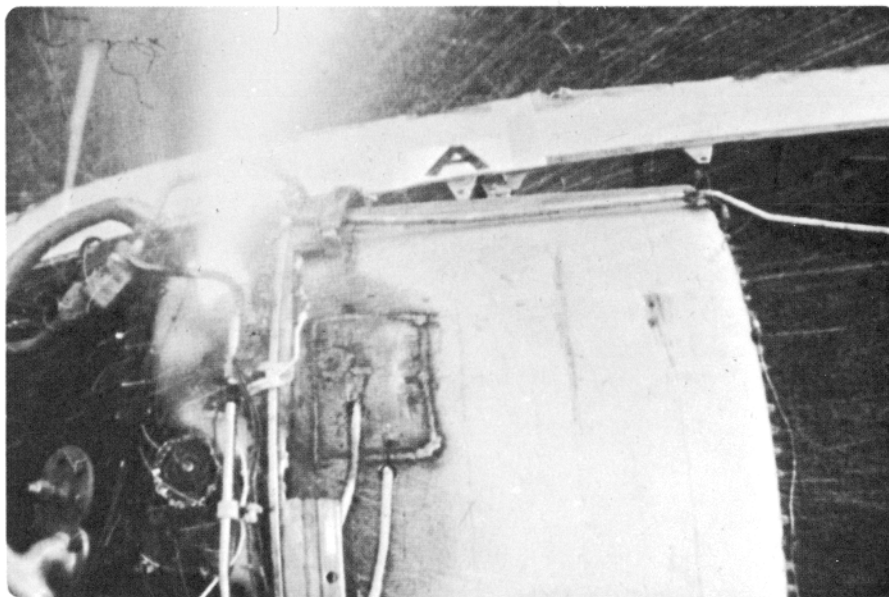


FIGURE 14. J57 BURN-THROUGH (TIME 5/16 SEC)

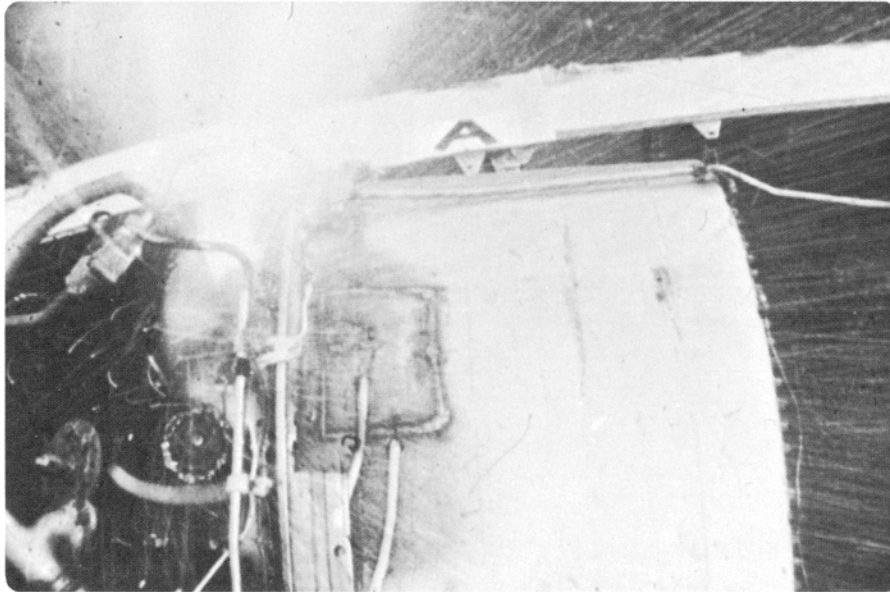


FIGURE 15. J57 BURN-THROUGH (TIME 3/8 SEC)

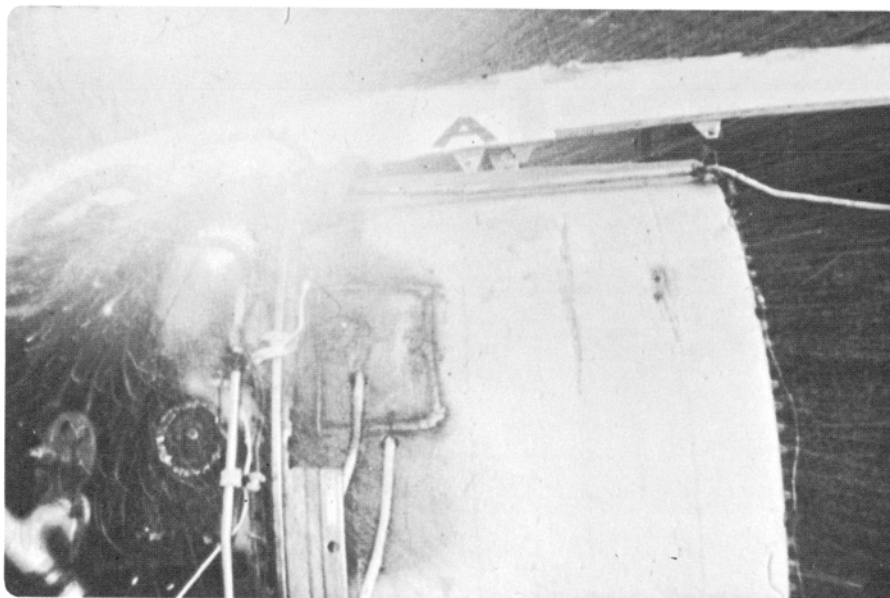


FIGURE 16. J57 BURN-THROUGH (TIME 7/16 SEC)

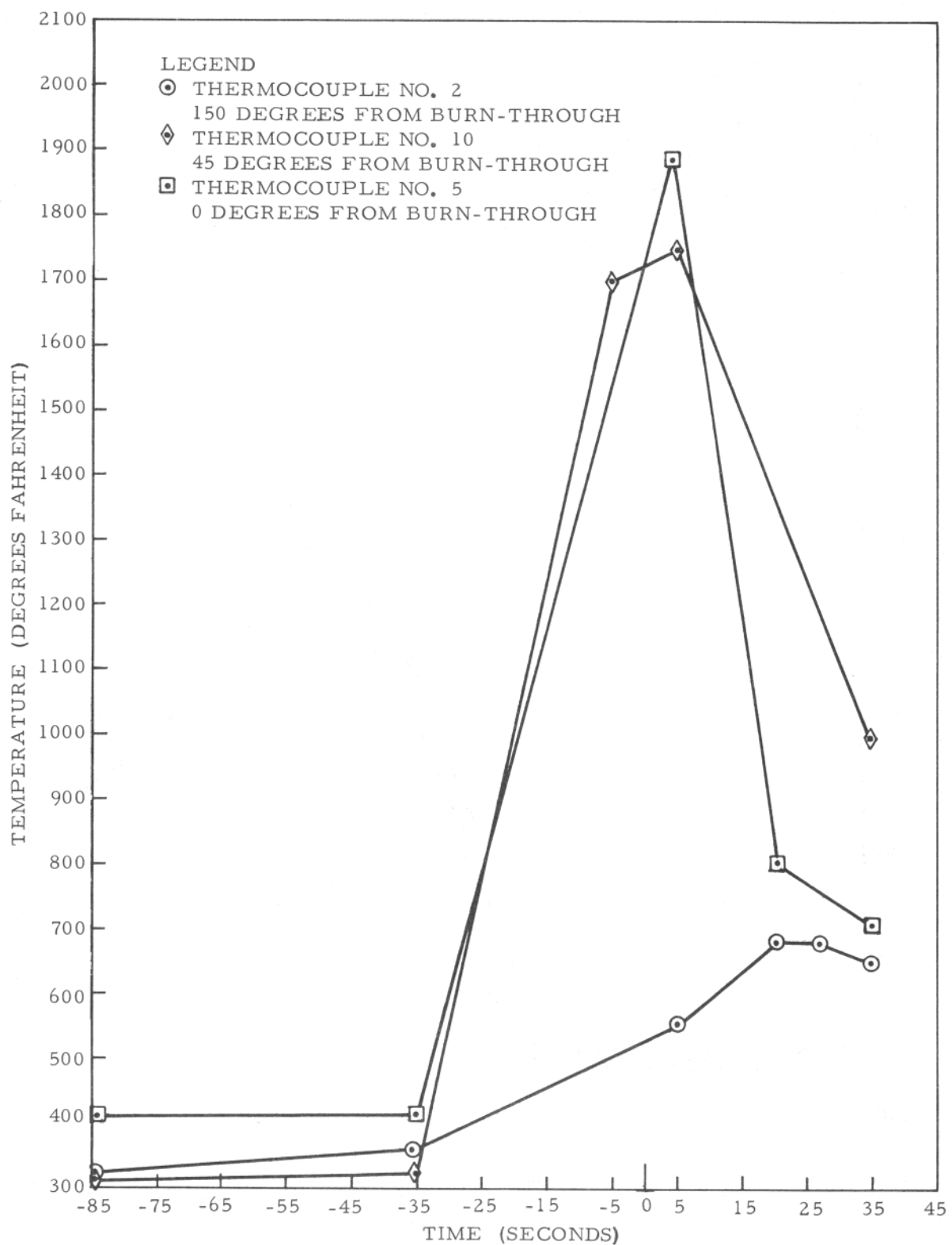


FIGURE 17. DIFFUSER CASE TEMPERATURES DURING TEST NO. 1

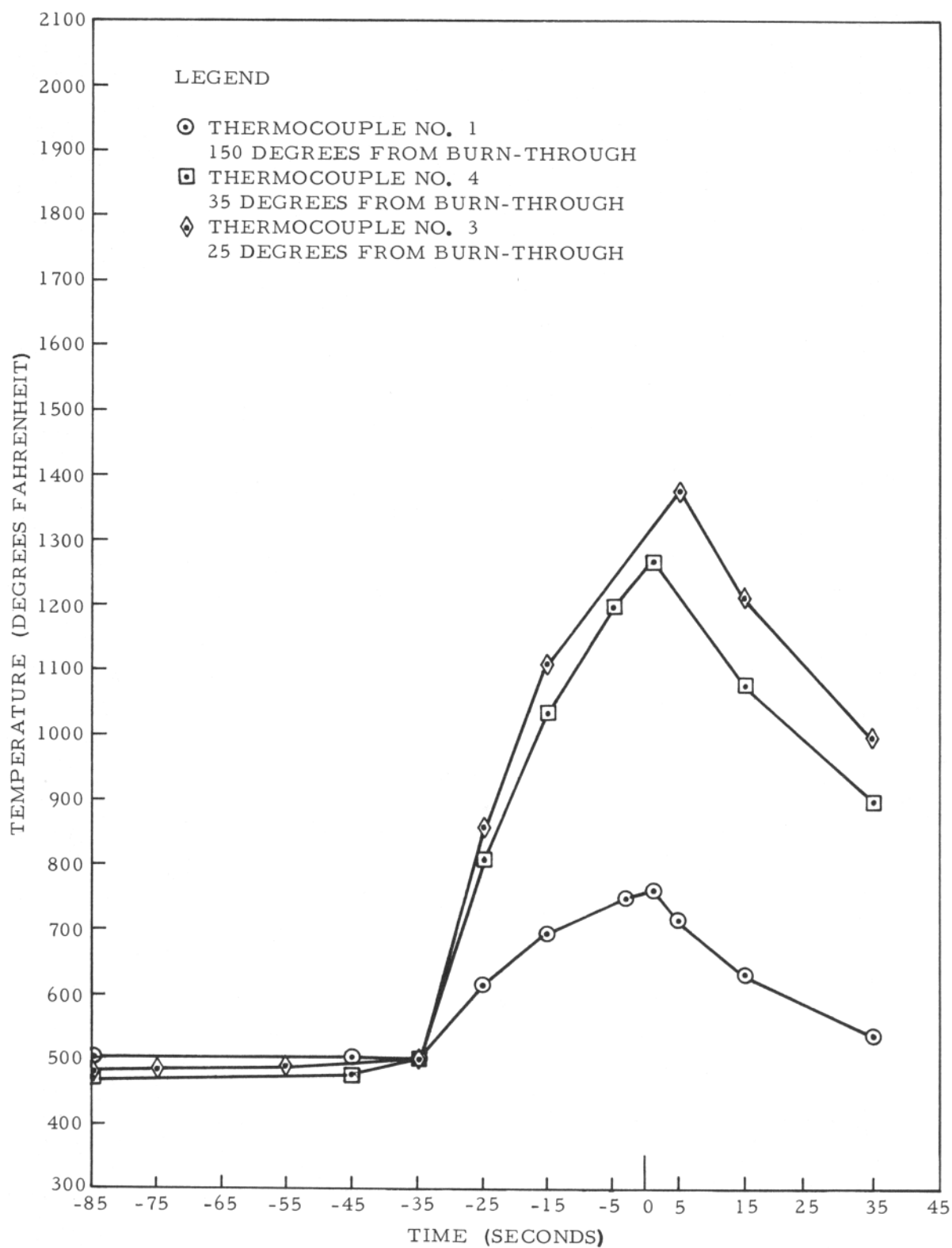


FIGURE 18. BURNER CAN CASE TEMPERATURES DURING TEST NO. 1

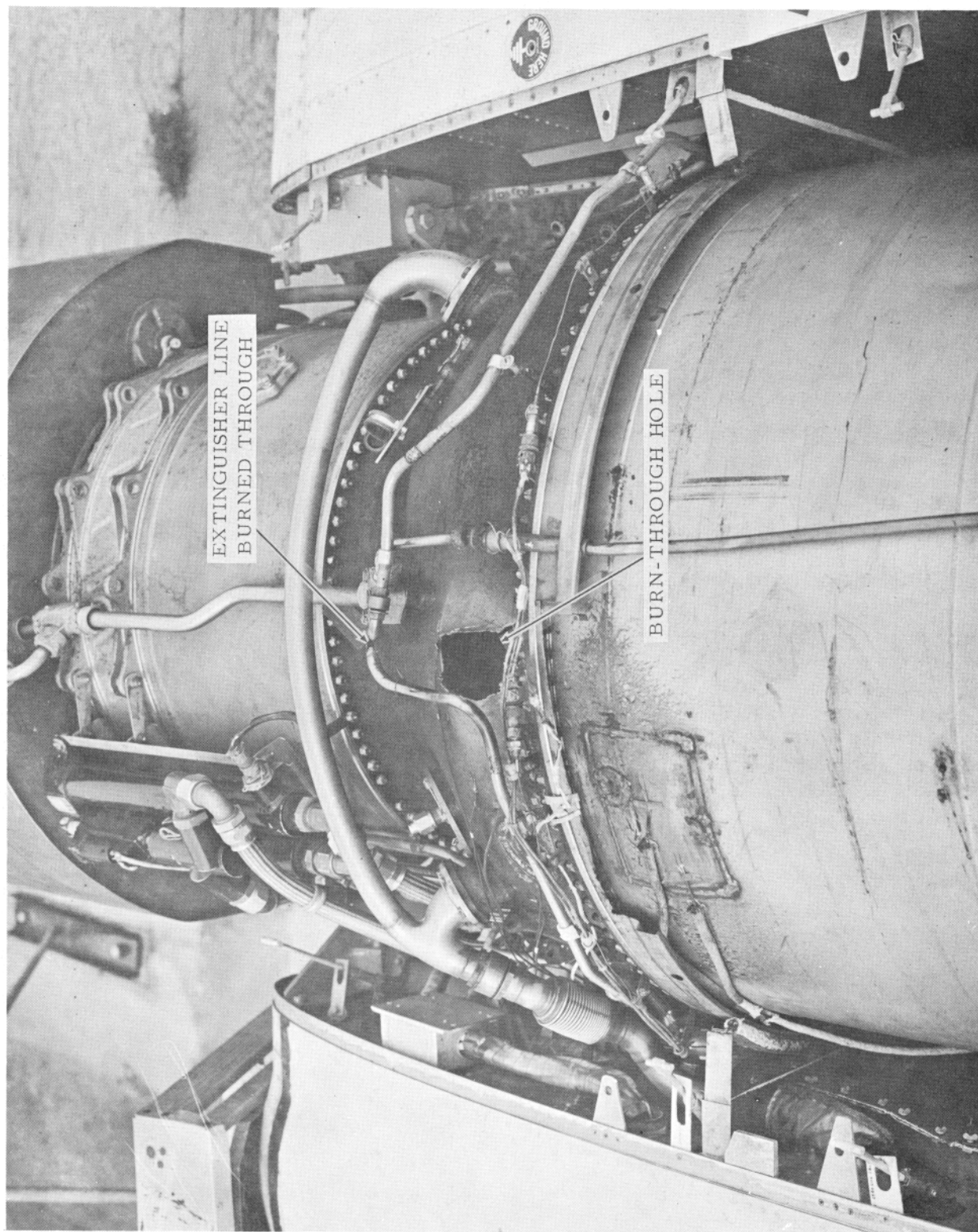


FIGURE 19. J57 BURN-THROUGH DAMAGE, TOP VIEW

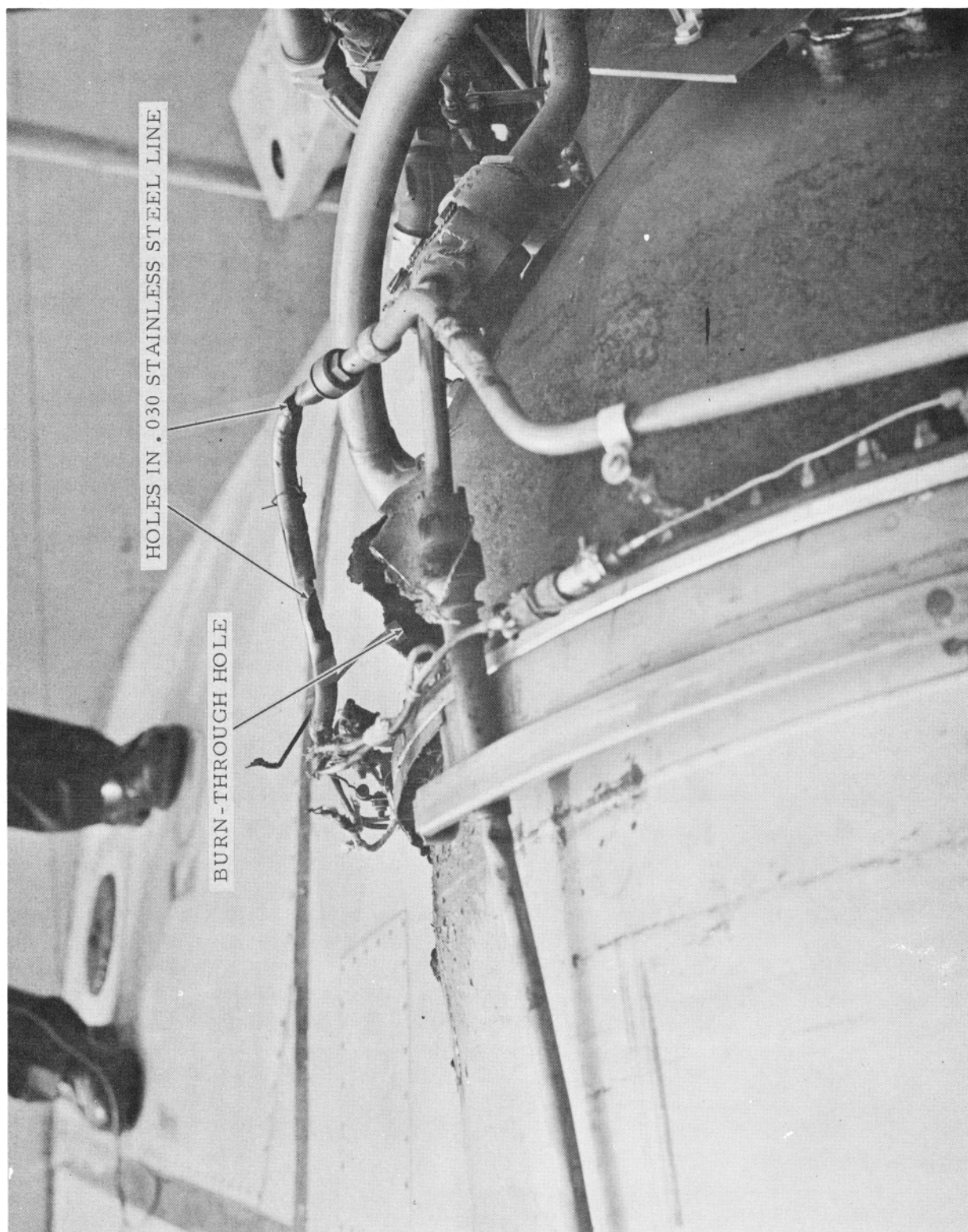


FIGURE 20. J57 BURN-THROUGH DAMAGE, SIDE VIEW

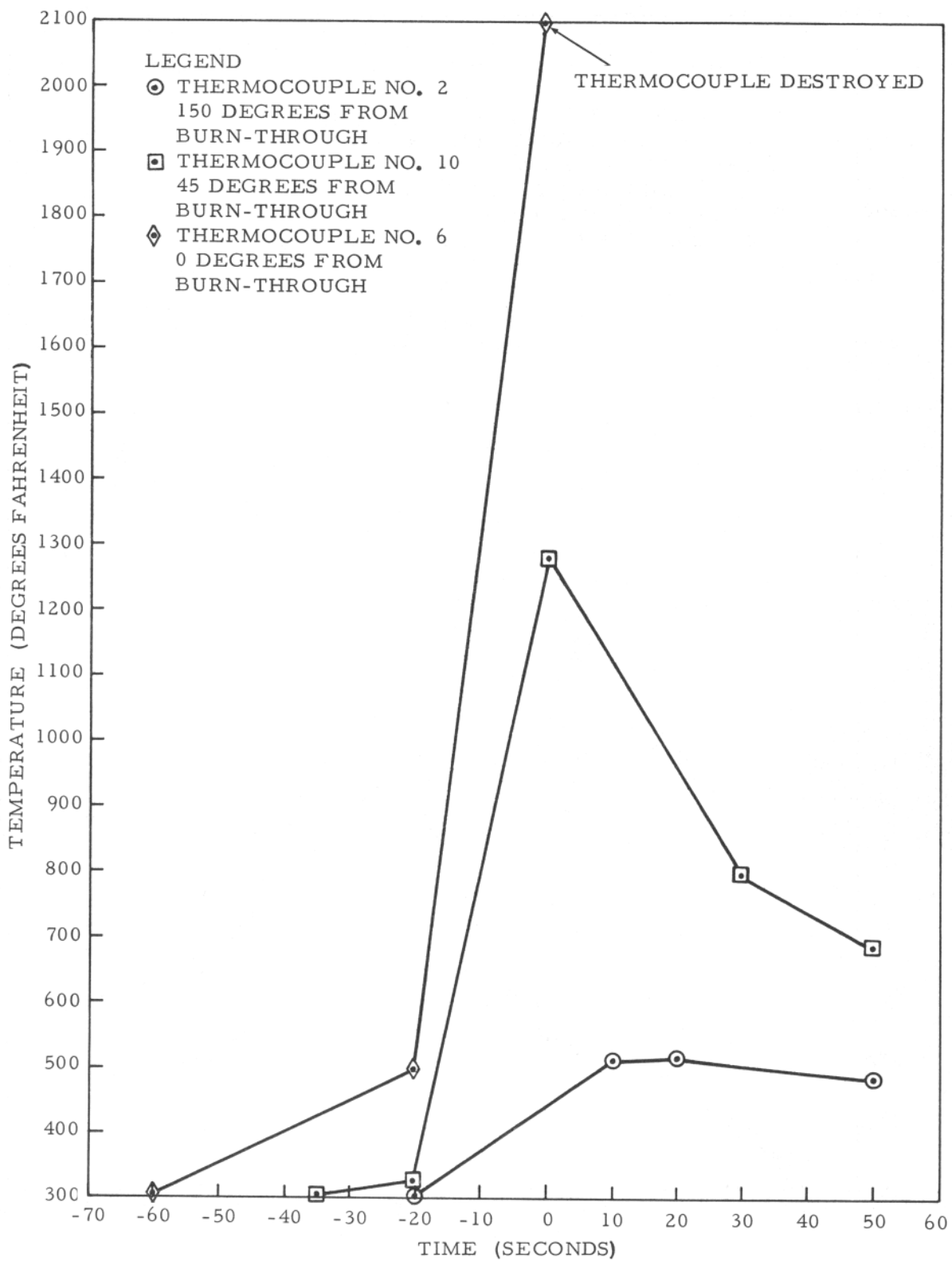


FIGURE 21. DIFFUSER CASE TEMPERATURES DURING TEST NO. 2

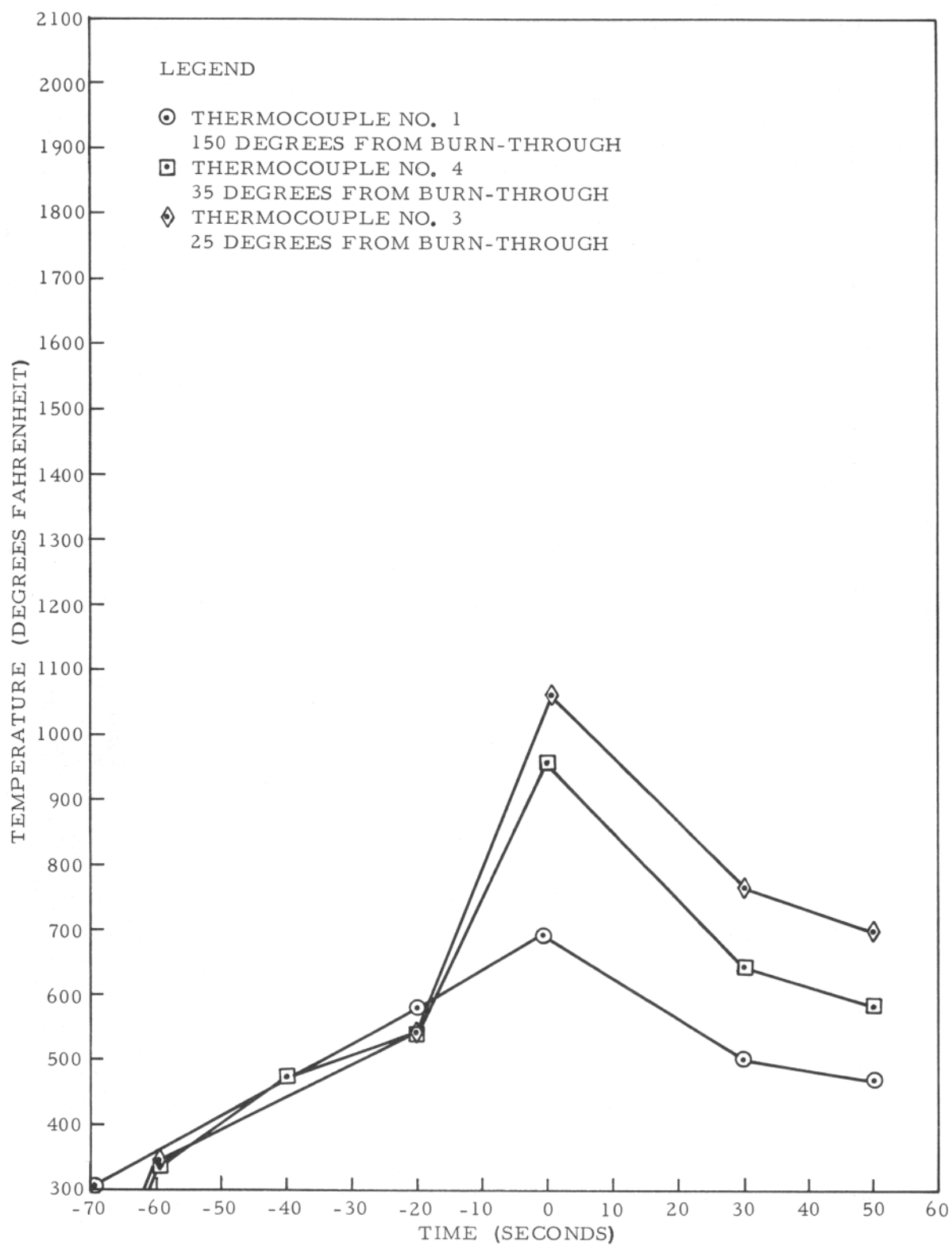


FIGURE 22. BURNER CAN CASE TEMPERATURES DURING TEST NO. 2

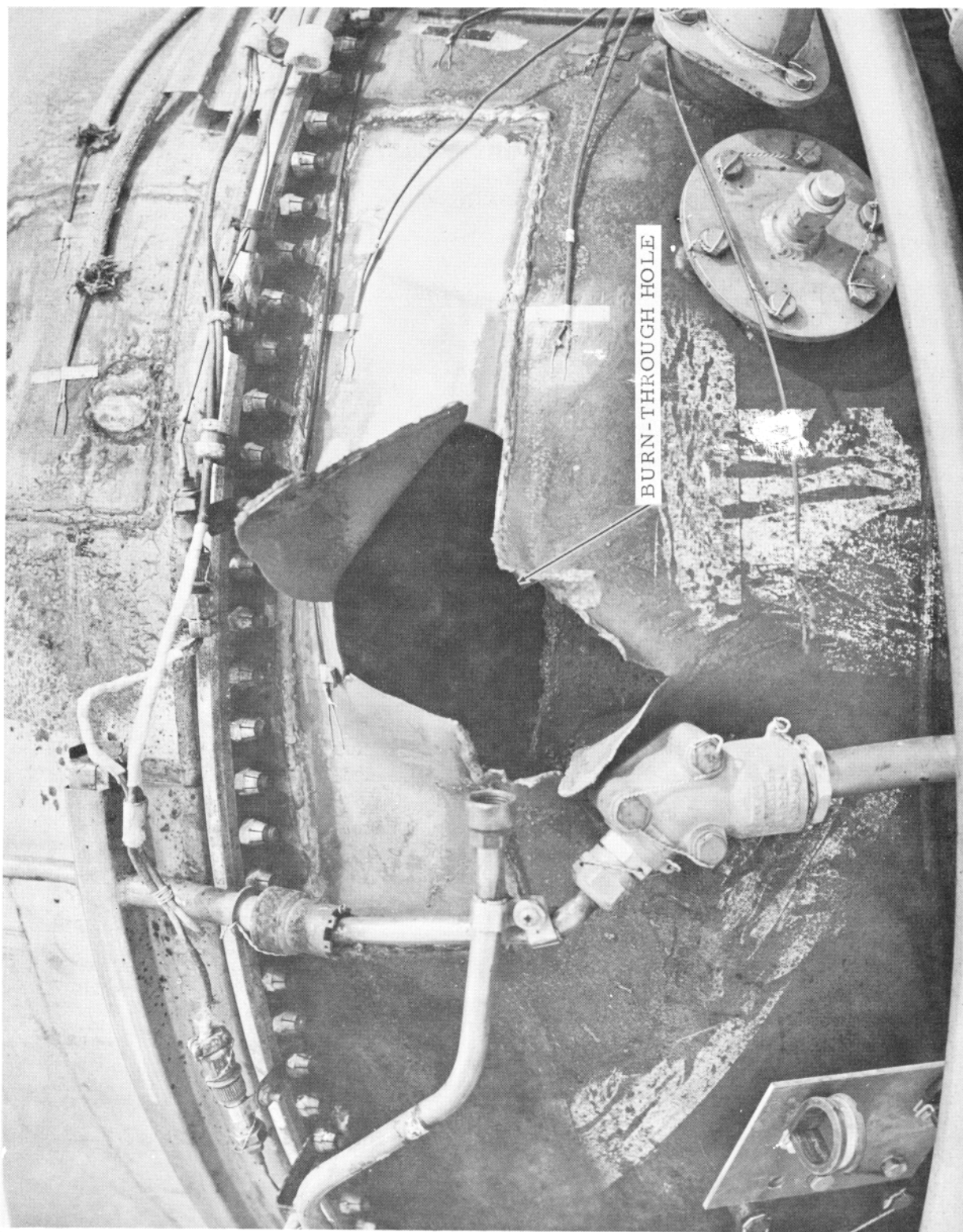


FIGURE 23. TEST NO. 2 BURN-THROUGH DAMAGE

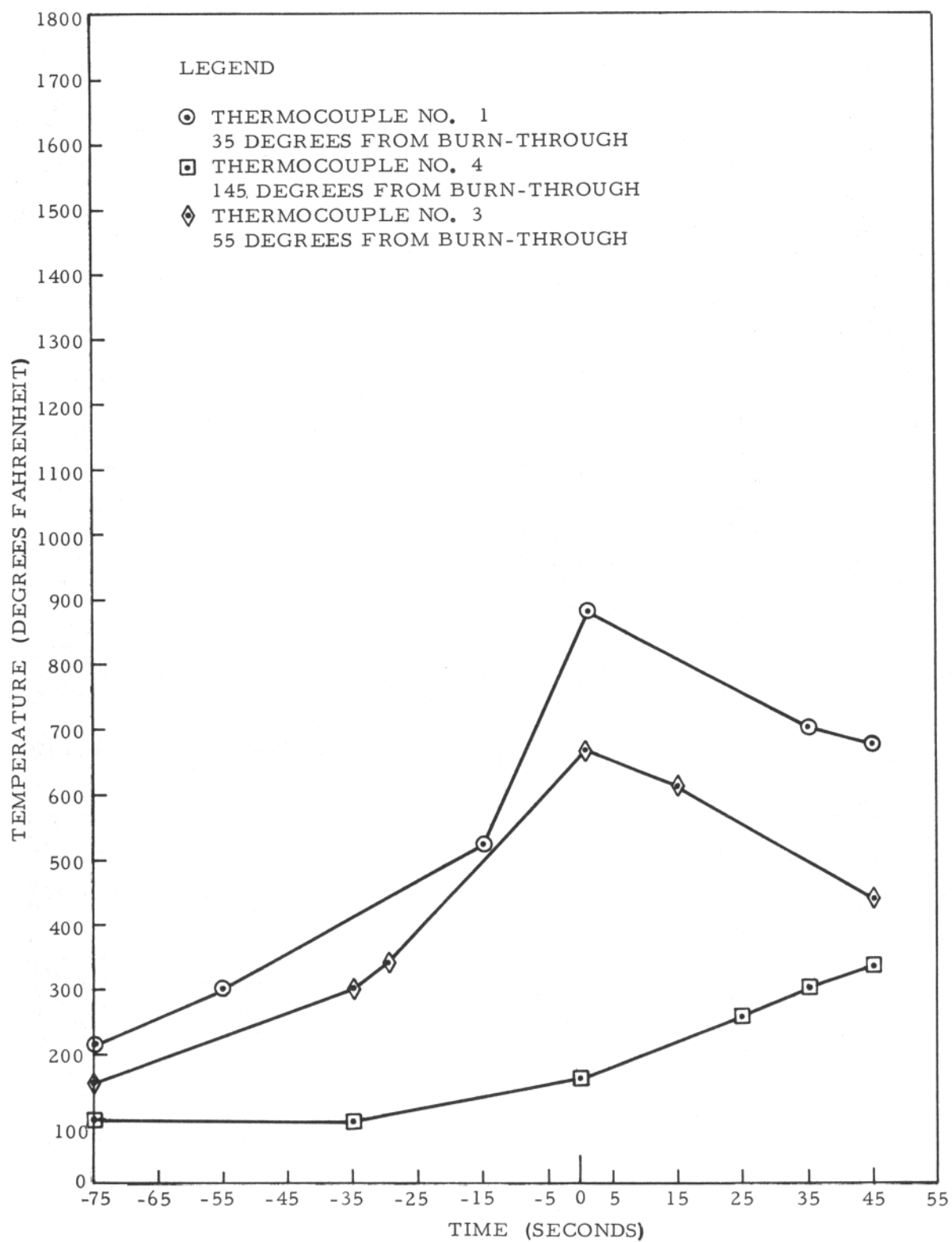


FIGURE 24. DIFFUSER CASE TEMPERATURES DURING TEST NO. 3

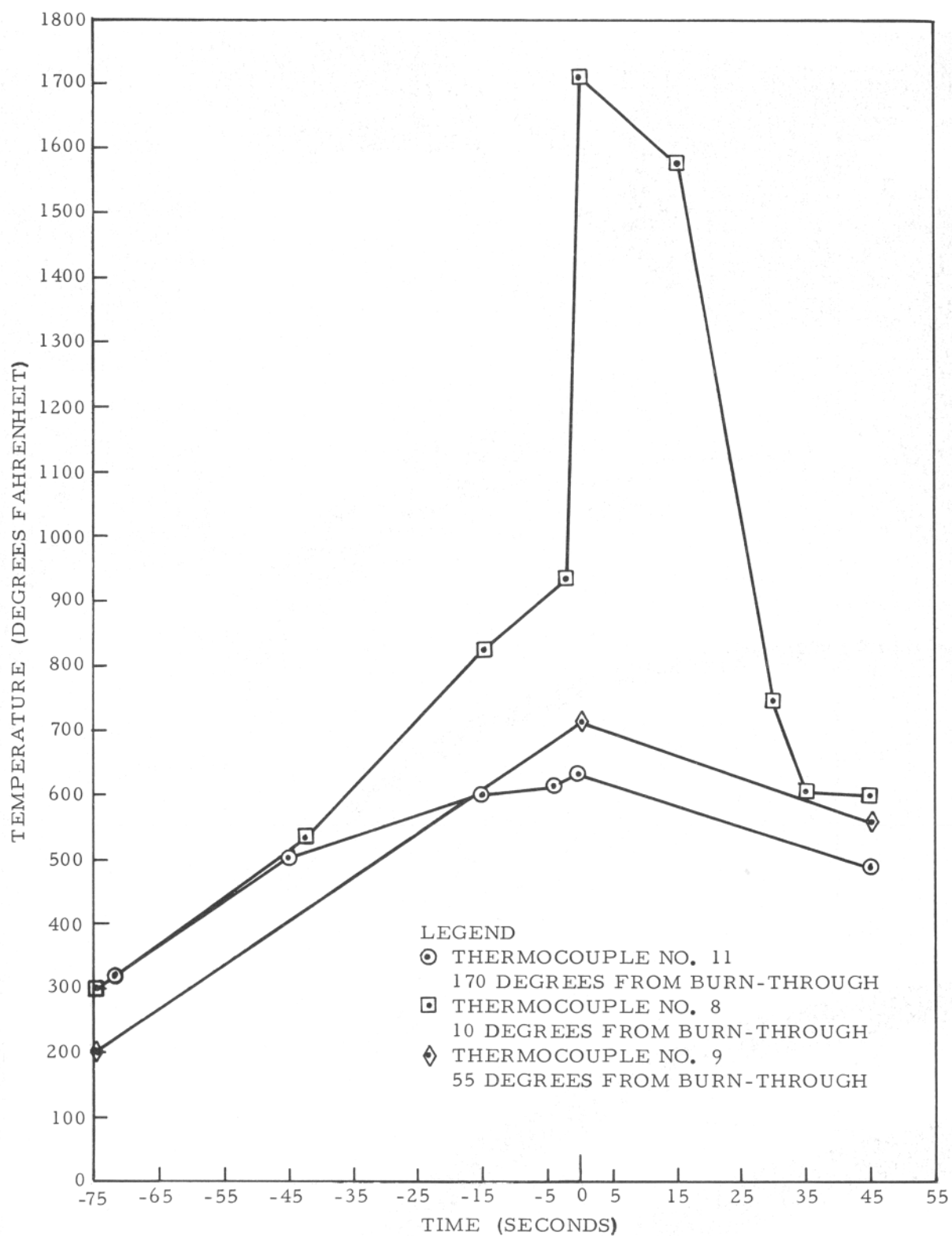


FIGURE 25. BURNER CAN CASE TEMPERATURES DURING TEST NO. 3



FIGURE 26. DAMAGE TO COWLING FROM BURN-THROUGH (TEST NO. 3)

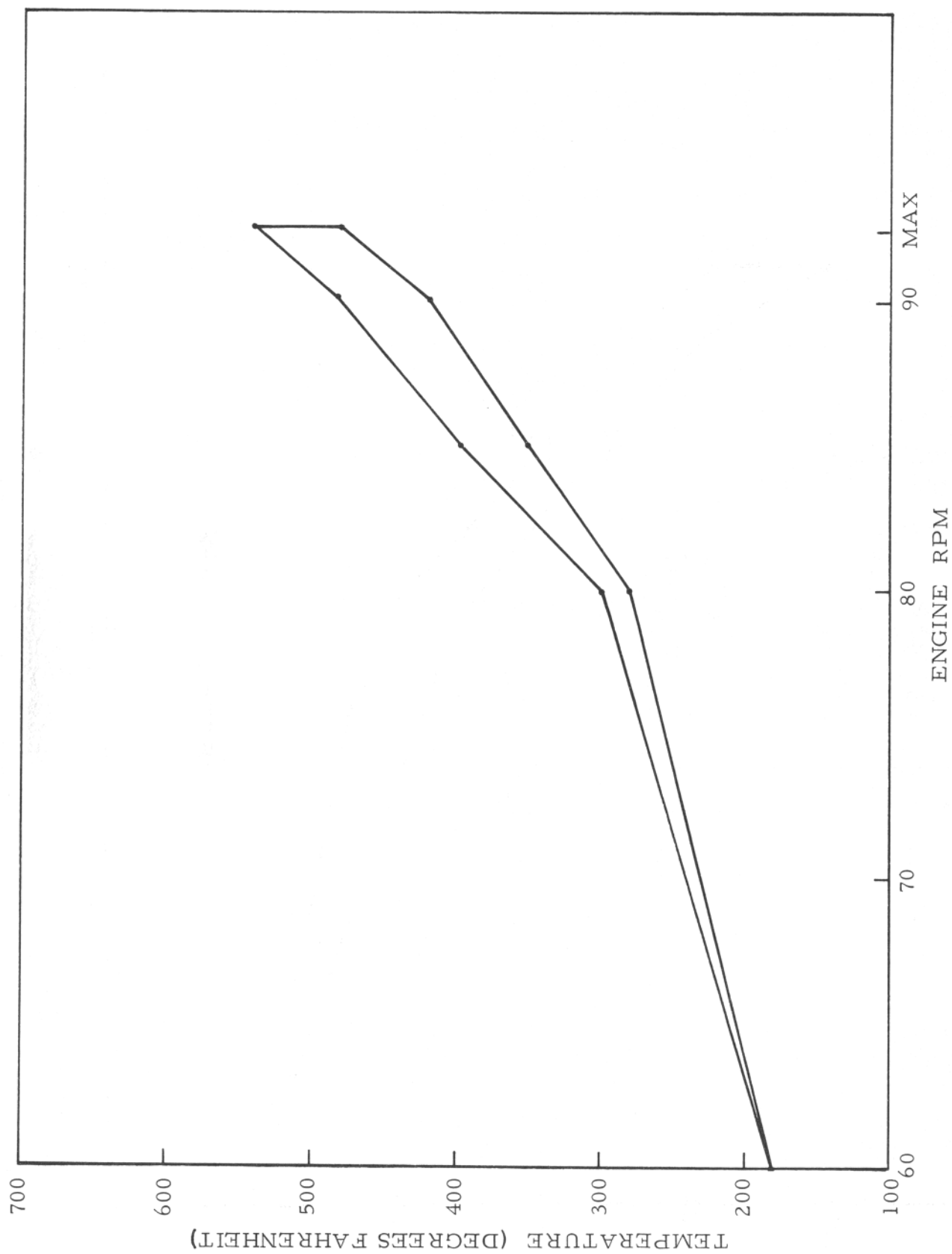


FIGURE 29. J57 ENGINE DIFFUSER CASE TEMPERATURE RANGE

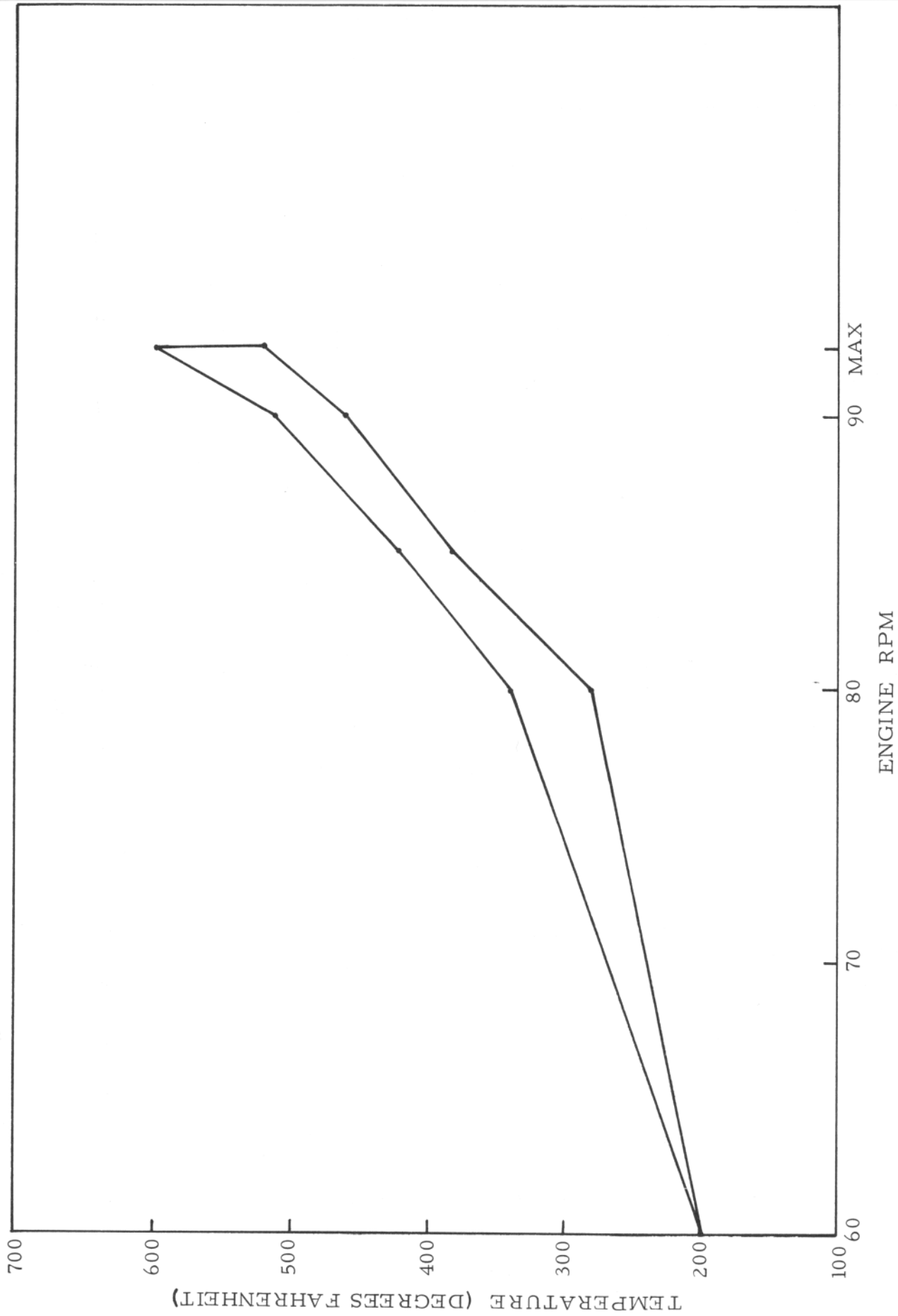


FIGURE 30. J57 ENGINE BURNER CAN CASE TEMPERATURE RANGE

SUMMARY OF RESULTS

1. A burn-through of the type that actually occurs in commercial aviation was created and photographed.
2. Engine skin temperatures during burn-through were recorded.
3. Graphs of diffuser case and burner can case skin temperatures for a cowled and an uncowed engine, before, during, and after a burn-through were developed.

CONCLUSIONS

Based on the results of the tests conducted, it is concluded that:

1. It is possible to detect a burner-can burn-through prior to engine case rupture by monitoring diffuser case and/or burner can case skin temperature.
2. As few as four thermocouples spaced 90° apart on the diffuser case, and/or the burner can case can detect a burner-can burn-through prior to engine case rupture.

REFERENCE

Rust, T., "Investigation of Jet Engine Combustion Chamber Burn-Through-Fire,"
Final Report, Report No. FAA-RD-70-68, March 1971.