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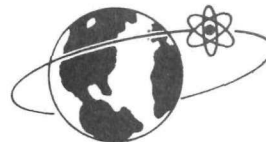
SNAP-27 FUEL CAPSULE ASSEMBLY  
RADIANT HEAT TESTS

L. L. Keller, Jr., 9512

AEROSPACE NUCLEAR SAFETY DEPARTMENT 9510

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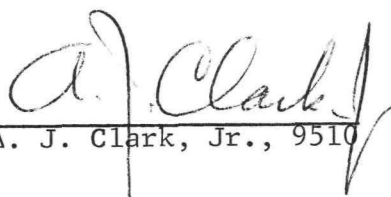
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### SNAP-27 FUEL CAPSULE ASSEMBLY RADIANT HEAT TESTS

L. L. Keller, Jr., 9512  
Sandia Laboratories, Albuquerque

Approved by

  
A. J. Clark, Jr., 9510

### ABSTRACT

Three reference design full scale SNAP-27 fuel capsule assemblies were subjected to thermal pulses in radiant heat arrays at Sandia Laboratories to investigate their reaction to: (1) a fireball/afterfire resulting from launch pad abort, and (2) an earth orbit decay for both lateral spinning and side-on stabilized modes. Photographs of the test setups and pertinent test data are presented.

March 1969

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## SUMMARY

Two reference design, full scale SNAP-27 fuel capsule assemblies (FCA) were subjected to thermal pulses simulating earth orbit decay; the FCA's were pressurized to simulate predicted FCA pressure caused by helium release from the fuel. A third reference design, full scale SNAP-27 fuel capsule assembly (verification capsule) was subjected to a thermal pulse simulating a fireball/afterfire which may result from a launch pad abort; this FCA was sealed but not pressurized.

Special radiant heat arrays were utilized to simulate clad temperatures for a fireball/afterfire thermal pulse (FCA V2) and for two earth orbital decay reentries: (1) lateral spinning mode (FCA RG-1), and (2) side-on stabilized mode (FCA RG-2). The heating arrays were programmed to produce an FCA clad temperature which matched a theoretically predicted clad temperature for an FCA when protected by a graphite LM fuel cask (GLFC) during the different abort conditions. Conditions of the test setup prevented heating array control based on flux rate.

The verification capsule (V2) which experienced the fireball/afterfire thermal pulse was not damaged except for the loss of the emissivity coating. The radiant heat capsule (RG-1) which experienced the earth orbital decay reentry for a lateral spinning mode was not damaged except for the loss of the emissivity coating. The radiant heat capsule (RG-2) which was exposed to the earth orbital decay reentry for a side-on stabilized mode experienced rupture of the clad in (1) the area where the pressurizing system was attached (aft end), (2) the center section which is designed for rupture, and (3) the forward capsule section; there was no loss of fuel simulant.

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## SNAP-27 FUEL CAPSULE ASSEMBLY RADIANT HEAT TESTS

### Introduction

The SNAP-27 fuel capsule assembly (FCA) is an isotopic fueled heat source with an output of 1480 watts thermal power. The radiant heat tests of the reference design SNAP-27 fuel capsule assembly (FCA) were performed at Sandia's radiant heat facility. These tests were performed by Sandia Laboratories in cooperation with the Missile and Space Division of the General Electric Valley Forge Space Technology Center. The tests were performed to provide experimental data on the response of a SNAP-27 FCA to thermal environments that may be encountered as a result of an abort during the Apollo mission.

### Description of Tests

#### Test Objectives

The primary objective of the radiant heat tests was to investigate the reaction of a SNAP-27 capsule to thermal environments that may be encountered as a result of: (1) fireball/afterfire at launch pad abort, (2) earth orbital reentry in a side-on spinning mode, and (3) earth orbital reentry in a side-on stabilized mode.

#### General Test Information

The reference design capsules used in the tests were identical to flight test capsules except for the following:

1. Tungsten-molybdenum granular powder was used in place of the SNAP-27 fuel.
2. No back plate was attached to the FCA flange.



3. Verification capsule (V2):
  - a. The FCA was sealed and contained one atmosphere of helium.
  - b. The condition of the rupture diaphragms was unknown.
4. Radiant heat capsules (RG-1 and RG-2):
  - a. A tube was installed at the FCA flange end for use in pressurizing the capsule with helium to simulate the normal operating pressure.
  - b. Both rupture discs were stress ruptured prior to final FCA assembly.

The heating arrays were controlled by comparing the FCA clad temperature to a curve of theoretically predicted clad temperatures for each environment. The theoretically predicted clad temperatures were for an FCA protected by a graphite LM fuel cask (GLFC) and included the self-heat of a fueled FCA. The FCA's in these tests were not self heated; therefore, the heating arrays could not be programmed to match the theoretically predicted heat flux incident on the FCA from a GLFC within an environment.

The test capsules were instrumented with chromel-alumel thermocouples welded to the capsule clad (Figure 1). A small spot of emissive coating was removed at the attachment point of each thermocouple. The thermocouples (1) controlled the input to the quartz lamp array, (2) monitored the uniformity of clad temperature, and (3) confirmed that the required thermal profile was achieved. Figure 2 illustrates the thermocouple locations.

Prior to the initiation of the heat pulse, capsules RG-1 and RG-2 were pressurized with helium to represent the buildup of helium during 2-1/2 years of fuel decay (two years FCA storage plus 6 months fuel age prior to encapsulation). The pressure used was compatible with a 70 to 80 percent release of the amount of helium theoretically generated in 2-1/2 years. During the test the helium pressure was monitored by pressure transducers.

#### Test Details

Prior to testing each reference design SNAP-27 fuel capsule, an instrumented dummy capsule was used to test the setup for satisfactory performance and for ability to conform to the temperature profile.

The test capsules were mounted in a holding fixture with the longitudinal axis horizontal (Figure 3). Sand bags were provided for containment in the event the capsule ruptured during the test (Figure 4). Capsule support rods and a ceramic support block simulated the support provided by the forward capsule support in the graphite LM fuel cask (Figure 4).

#### Radiant Heat Tests

Figures 1, 4, 5, 6, 7, and 8 illustrate the test setups used for the radiant heat tests. Figures 9, 10, and 11 illustrate the actual thermal profiles produced on the FCA clad. The quartz lamp arrays were manually controlled for approximately 30 minutes to stabilize the FCA at normal operating temperature; after that time, the quartz lamp arrays were automatically controlled by a curve follower which traced the curves shown in Figures 12, 13, and 14.

#### Results and Conclusions

In general, the objectives of the test were accomplished.

The V2 capsule was sealed but not pressurized and therefore did not experience an internal pressure sufficient to cause damage; the maximum internal pressure was estimated to be about 70 psia. The emissivity coating flaked off (Figures 15, 16, and 17).

The RG-1 capsule was pressurized to 100 psia prior to the test, and it achieved a maximum internal pressure of about 345 psia at the peak of the thermal pulse. No damage resulted from the combination of temperature and pressure. The emissivity coating flaked off (Figures 18 and 19).

The RG-2 capsule was pressurized to 115 psia prior to the test, and it had achieved an internal pressure of 410 psia when rupture occurred in the pressurizing system (where the pressure tubing was attached to the FCA clad). Due to the limited flow rate of the filter assemblies and the short time remaining in the thermal profile, it was

concluded that the pressure within the center section reached about 463 psia at the peak of the thermal pulse, as planned. The clad ruptured in the center section at the machined rupture groove and in the wall of the forward half capsule, (Figures 20, 21, and 22). The outer liner did not rupture at the point where the clad ruptured in the forward half capsule, and there was no fuel simulant release. The rupture in the center section is not illustrated since it consists of fine cracks which are not easily discerned in a photograph.

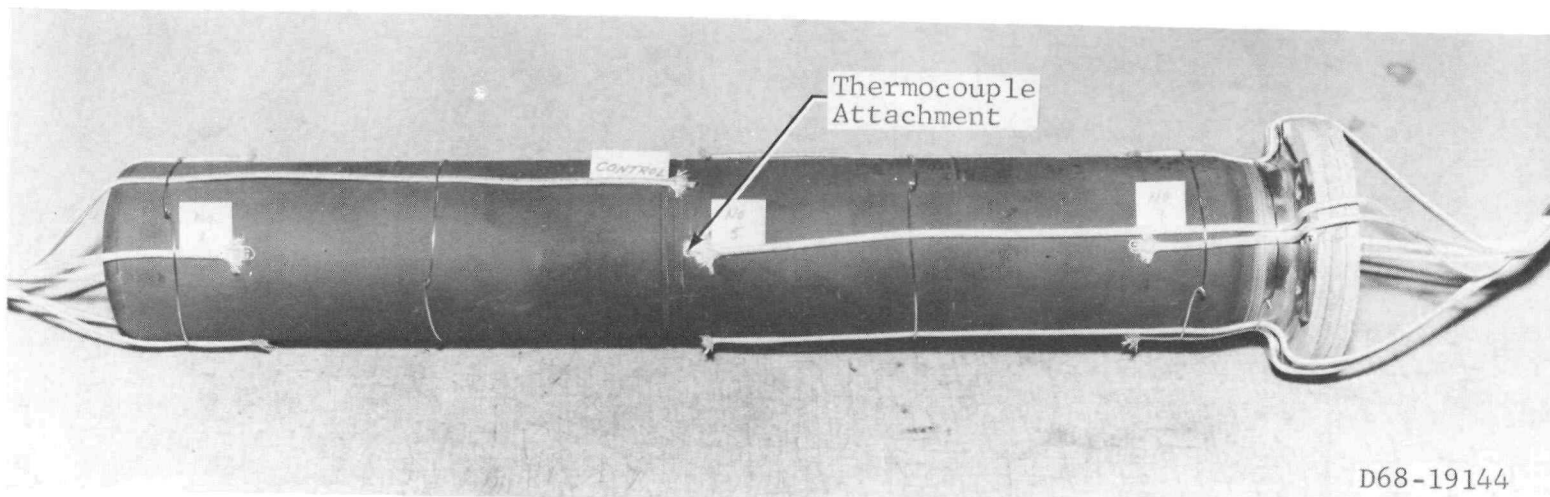
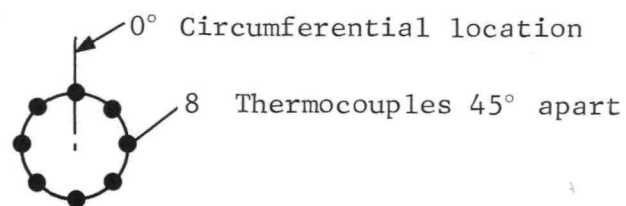
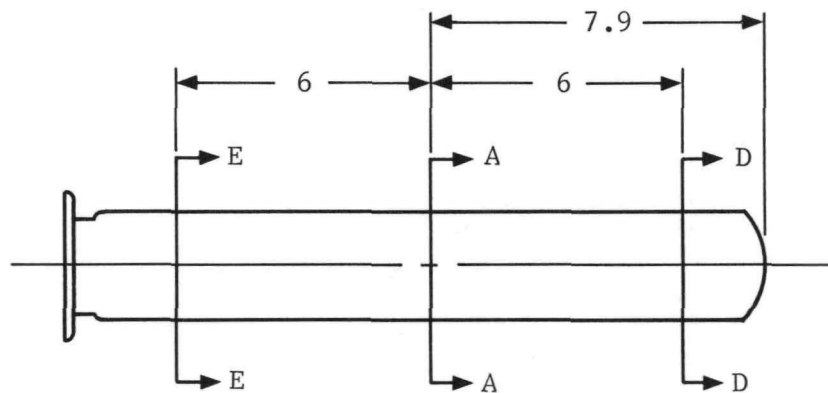
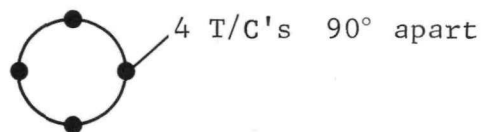


Figure 1. Thermocouple location, capsule V2



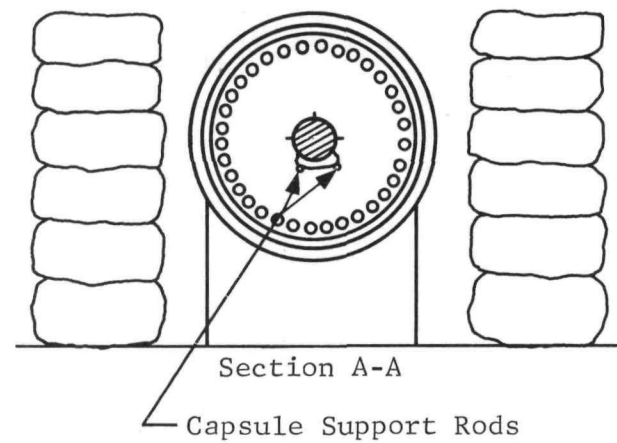
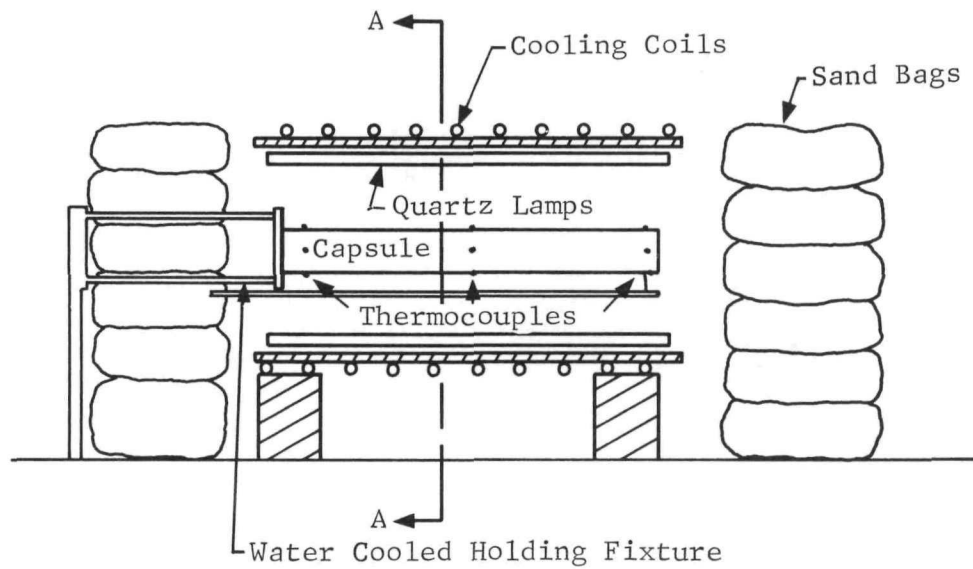
Section A-A RG-1 & RG-2



Sections D-D & E-E RG-1 & RG-2  
A-A & D-D & E-E V2

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Figure 2. Instrumentation of radiant heat flux test capsule



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Figure 3. Test configuration

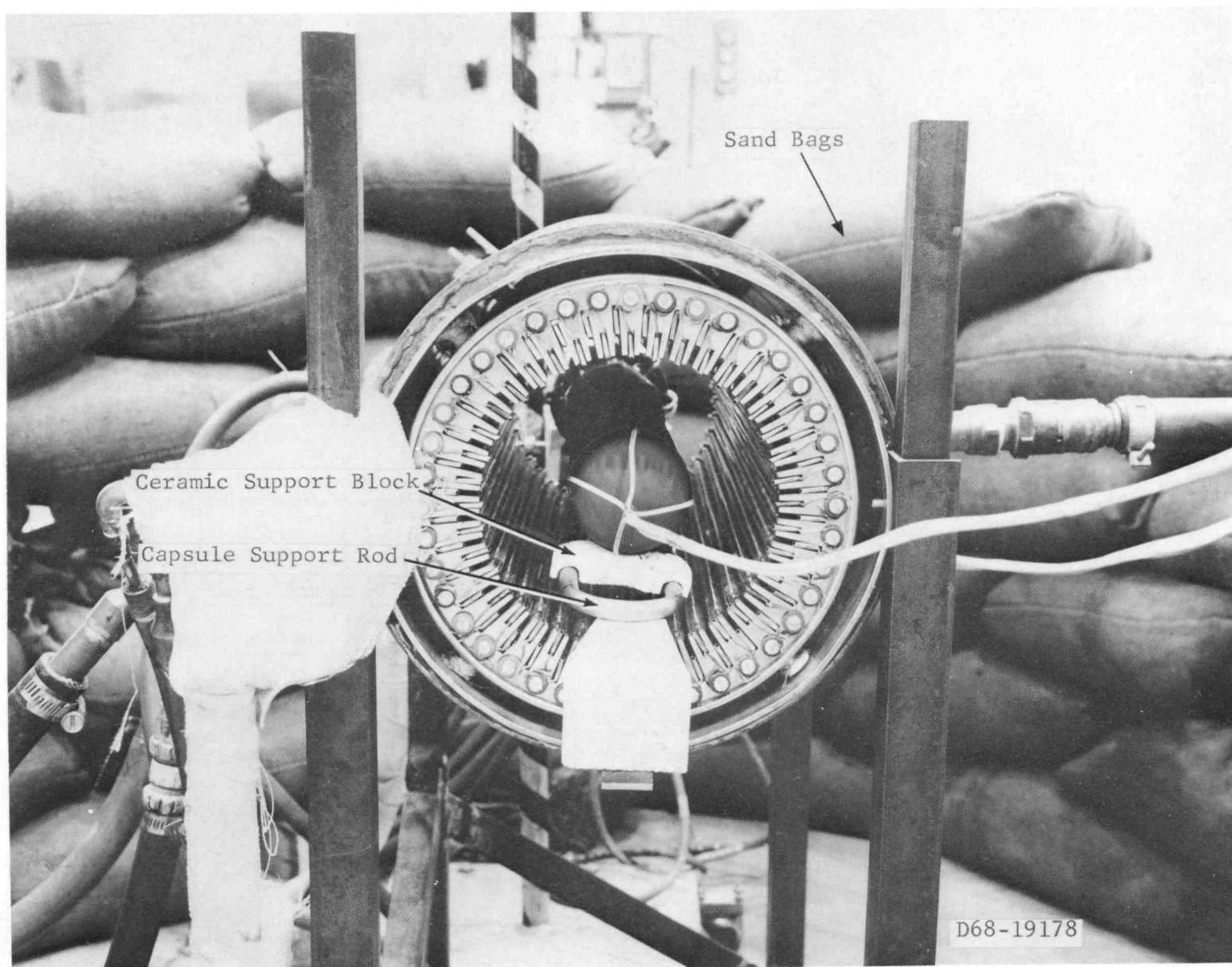


Figure 4. Test setup, capsule RG-1

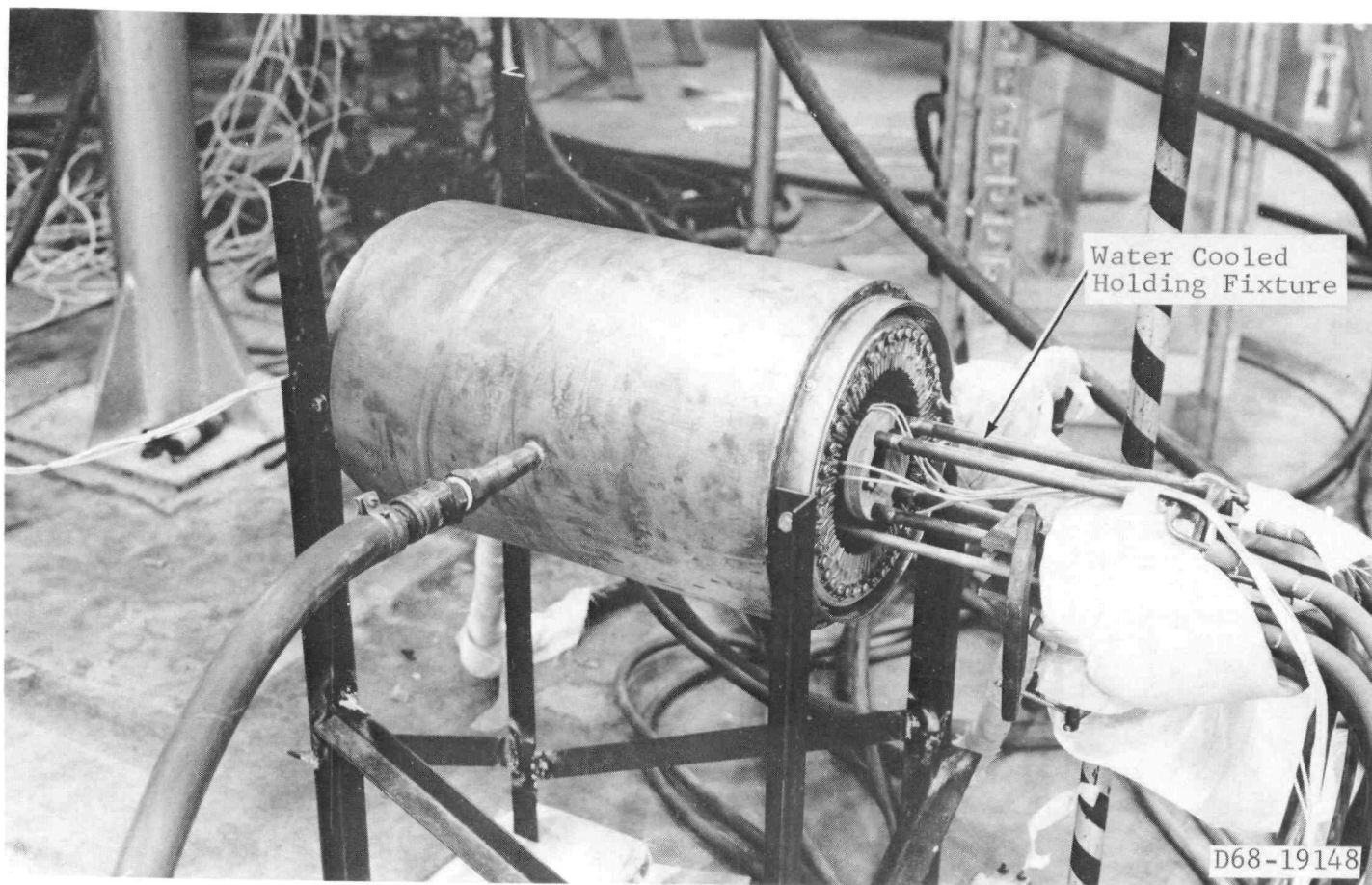


Figure 5. Test setup, capsule V2



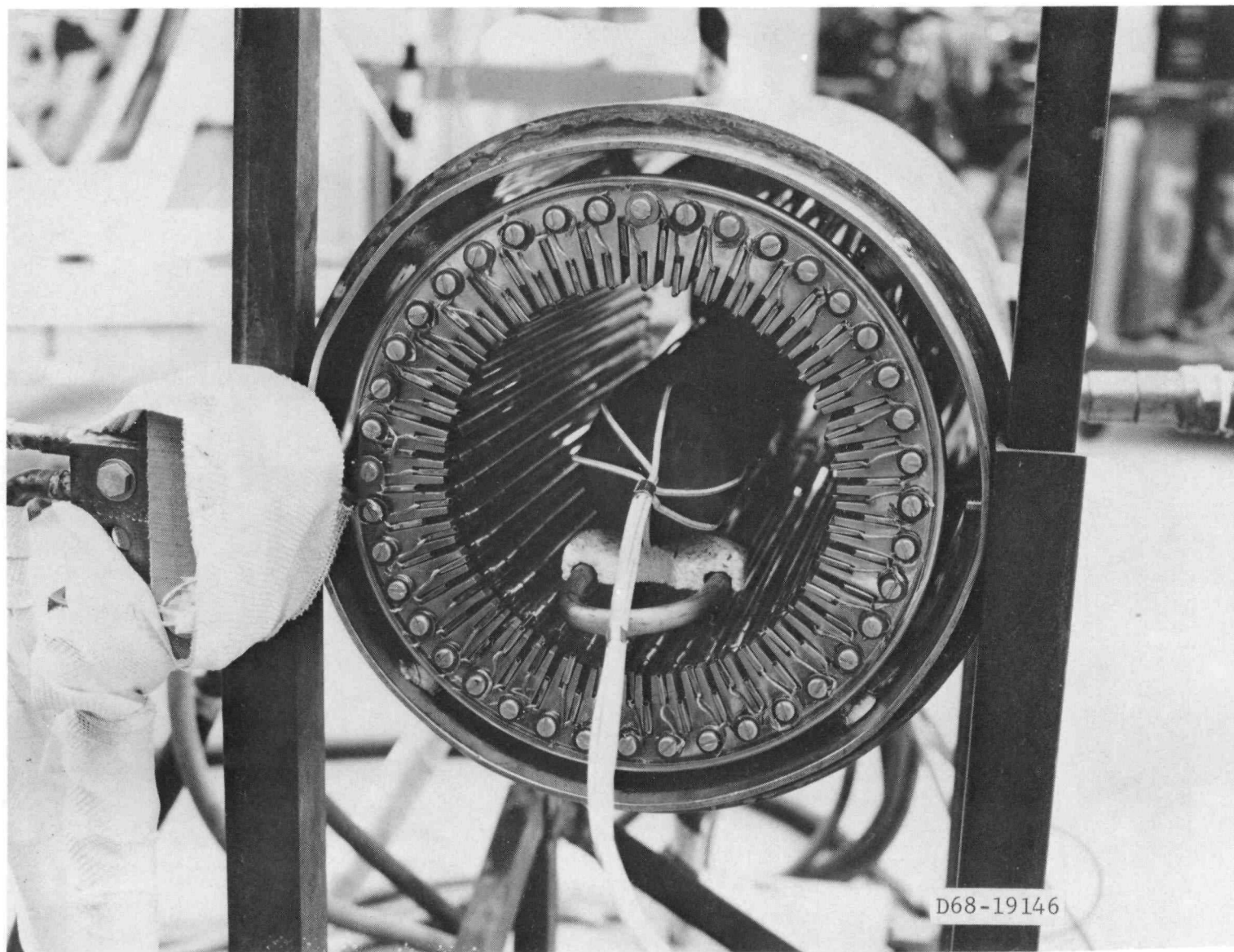


Figure 6. Test setup, capsule V2

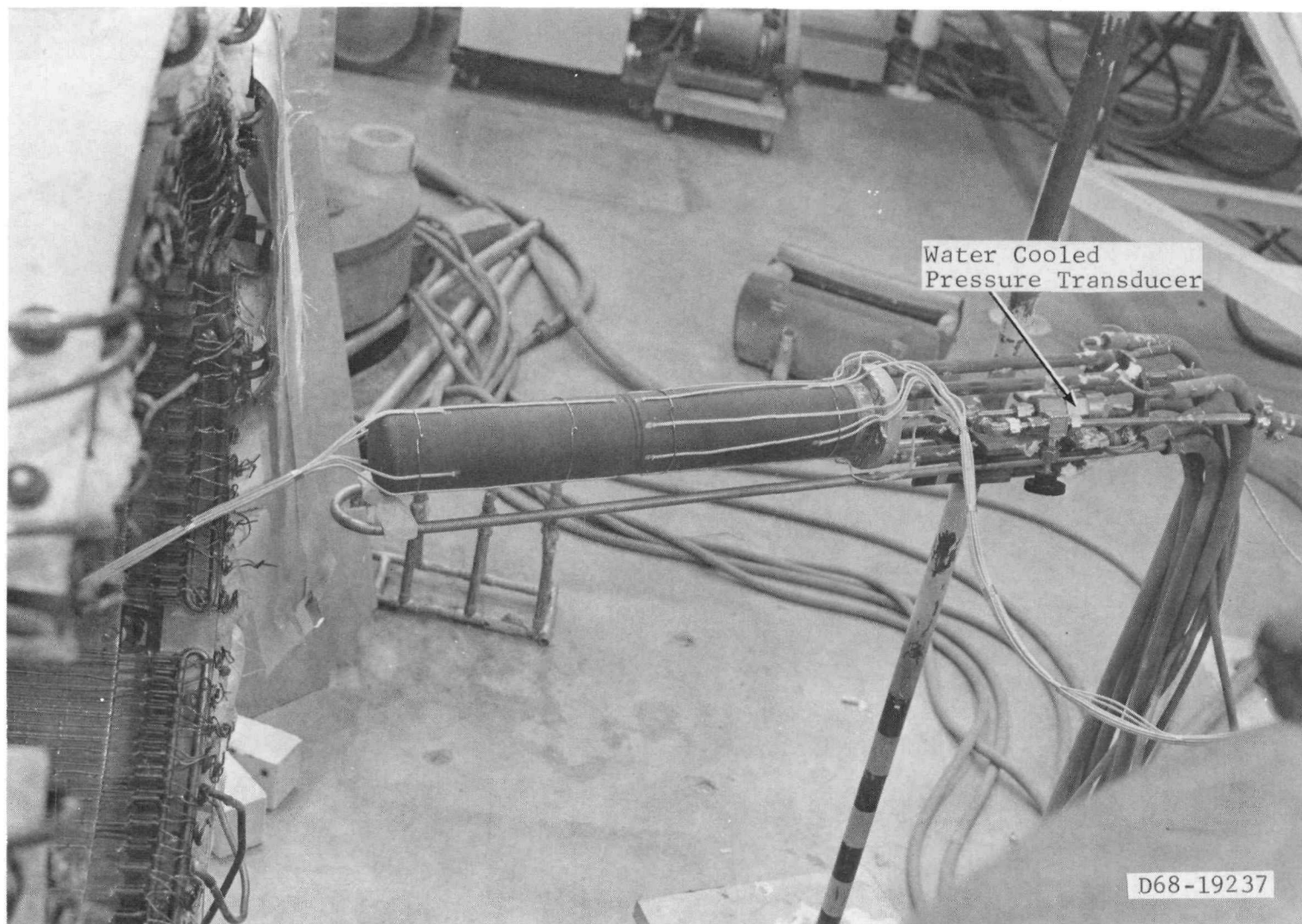


Figure 7. Thermocouple location, capsule RG-2

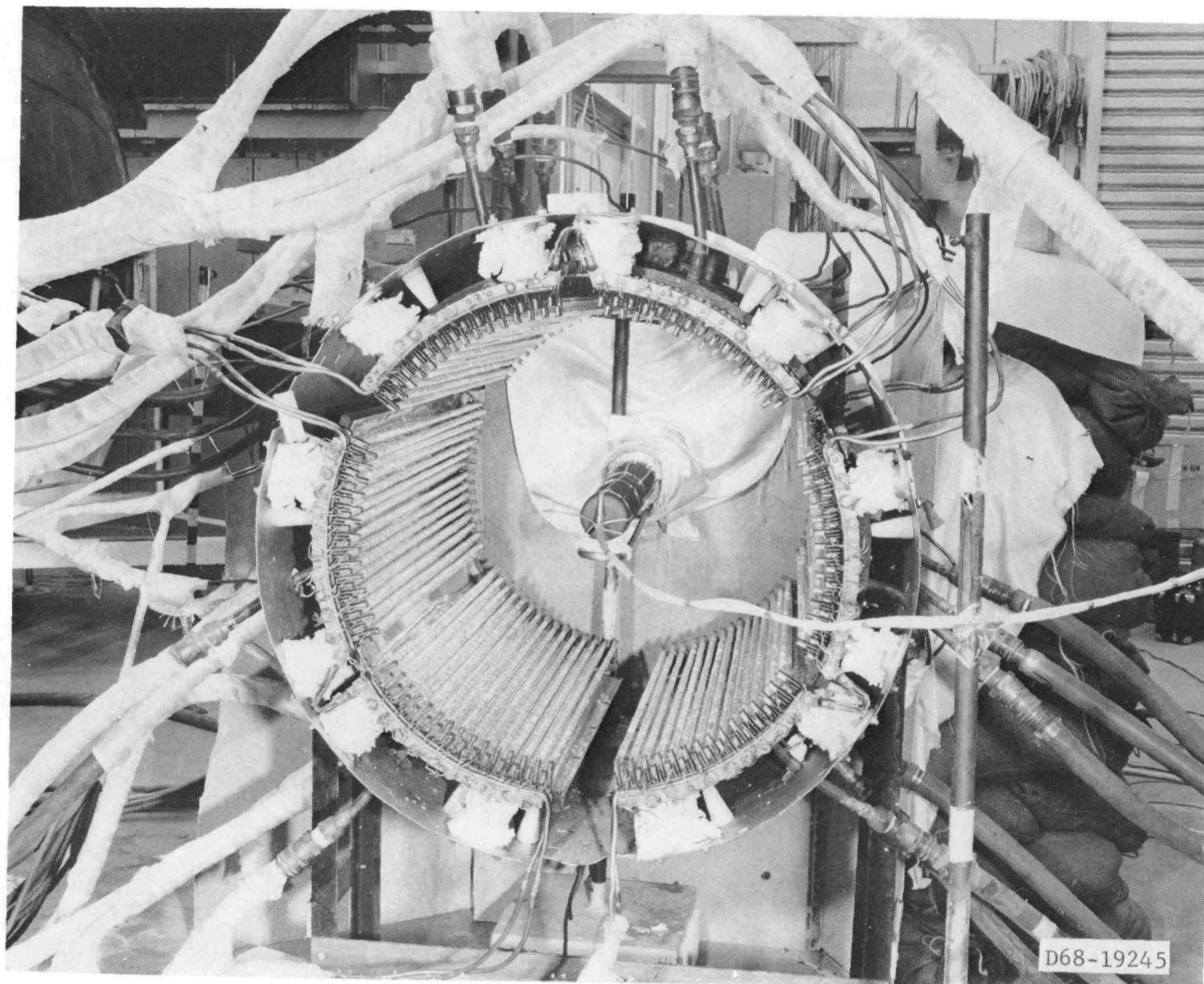


Figure 8. Test setup, capsule RG-2

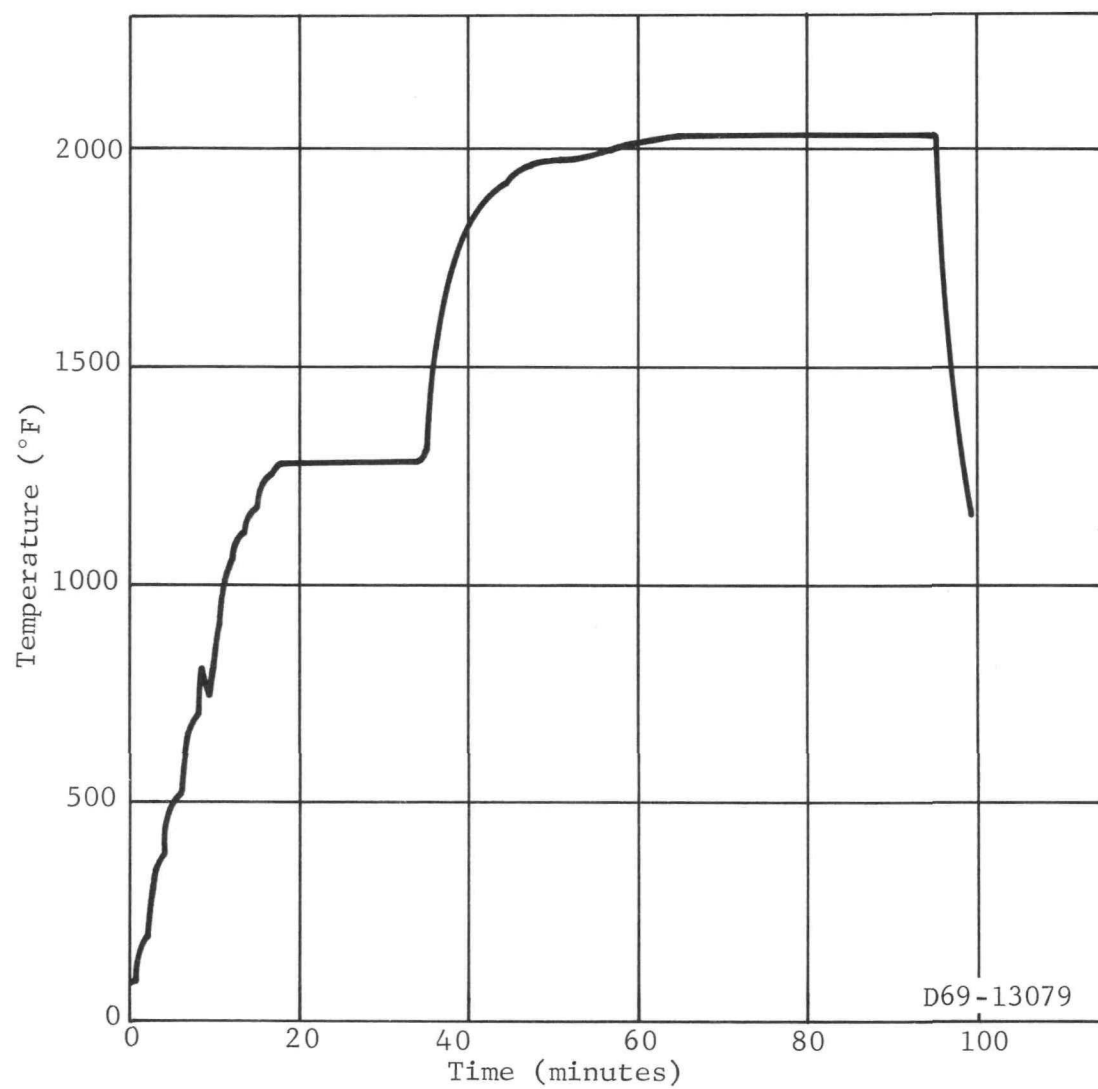


Figure 9. Actual temperature profile of capsule V2

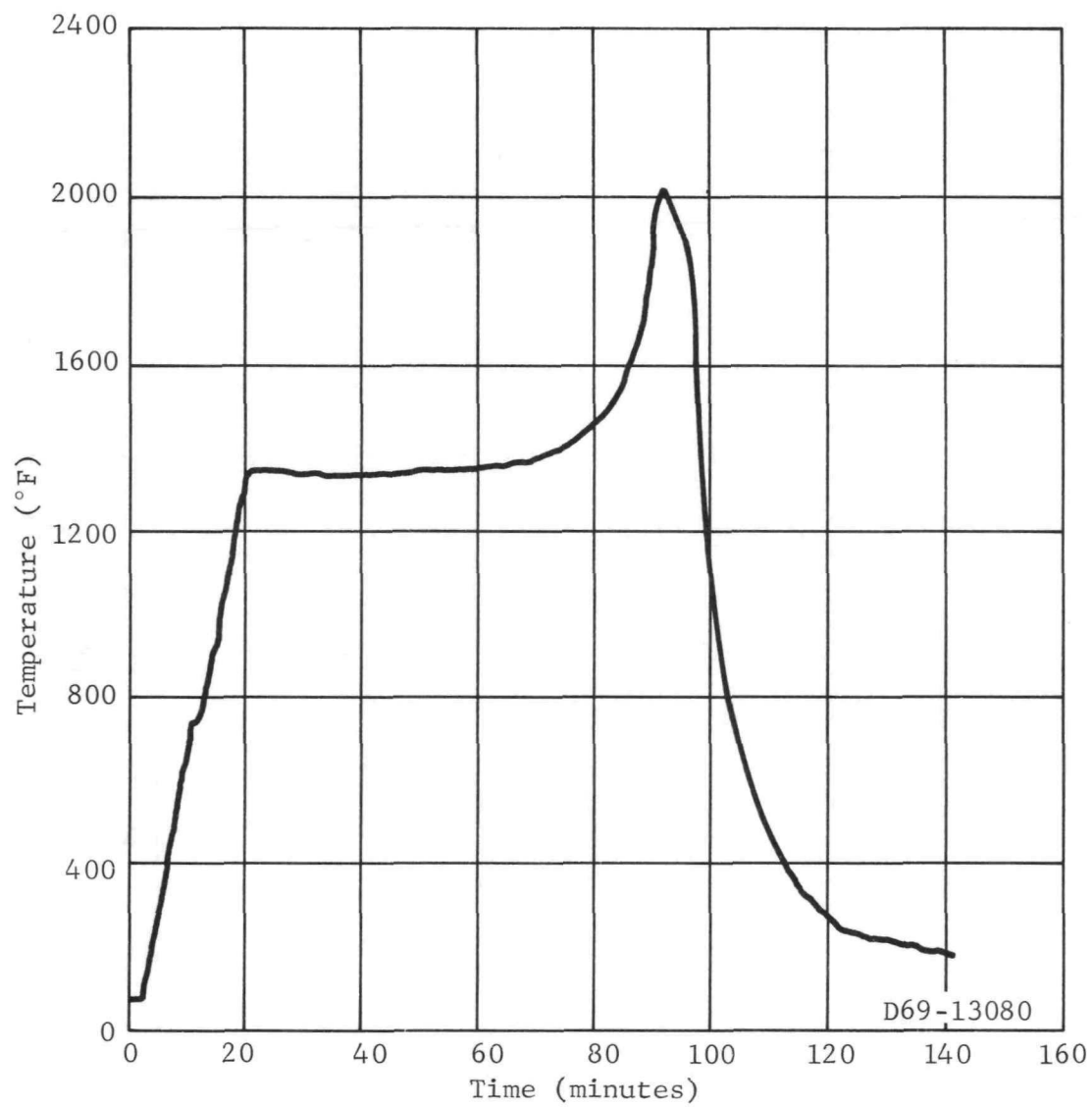


Figure 10. Actual temperature profile of capsule RG-1

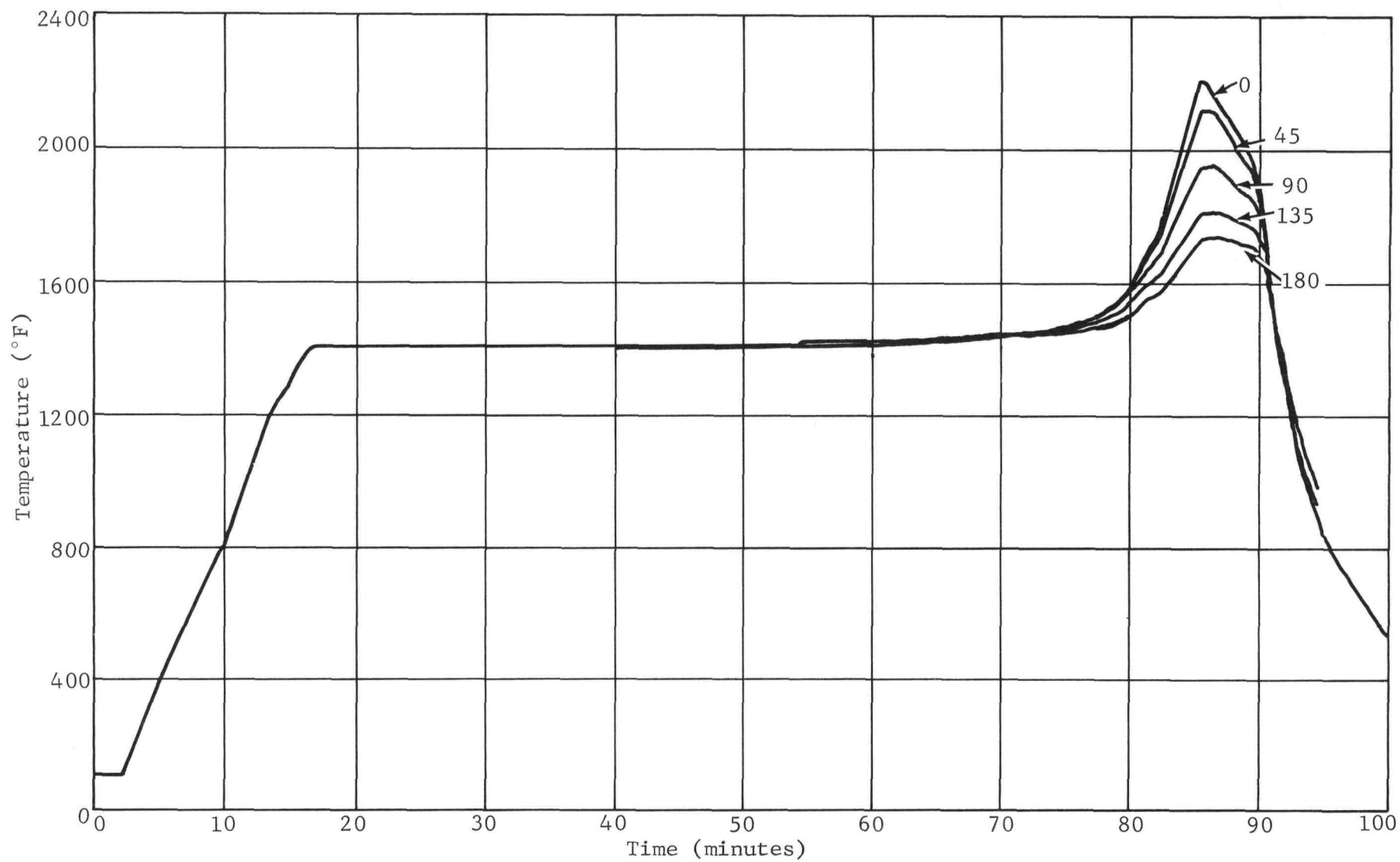


Figure 11. Actual temperature profile of capsule RG-2

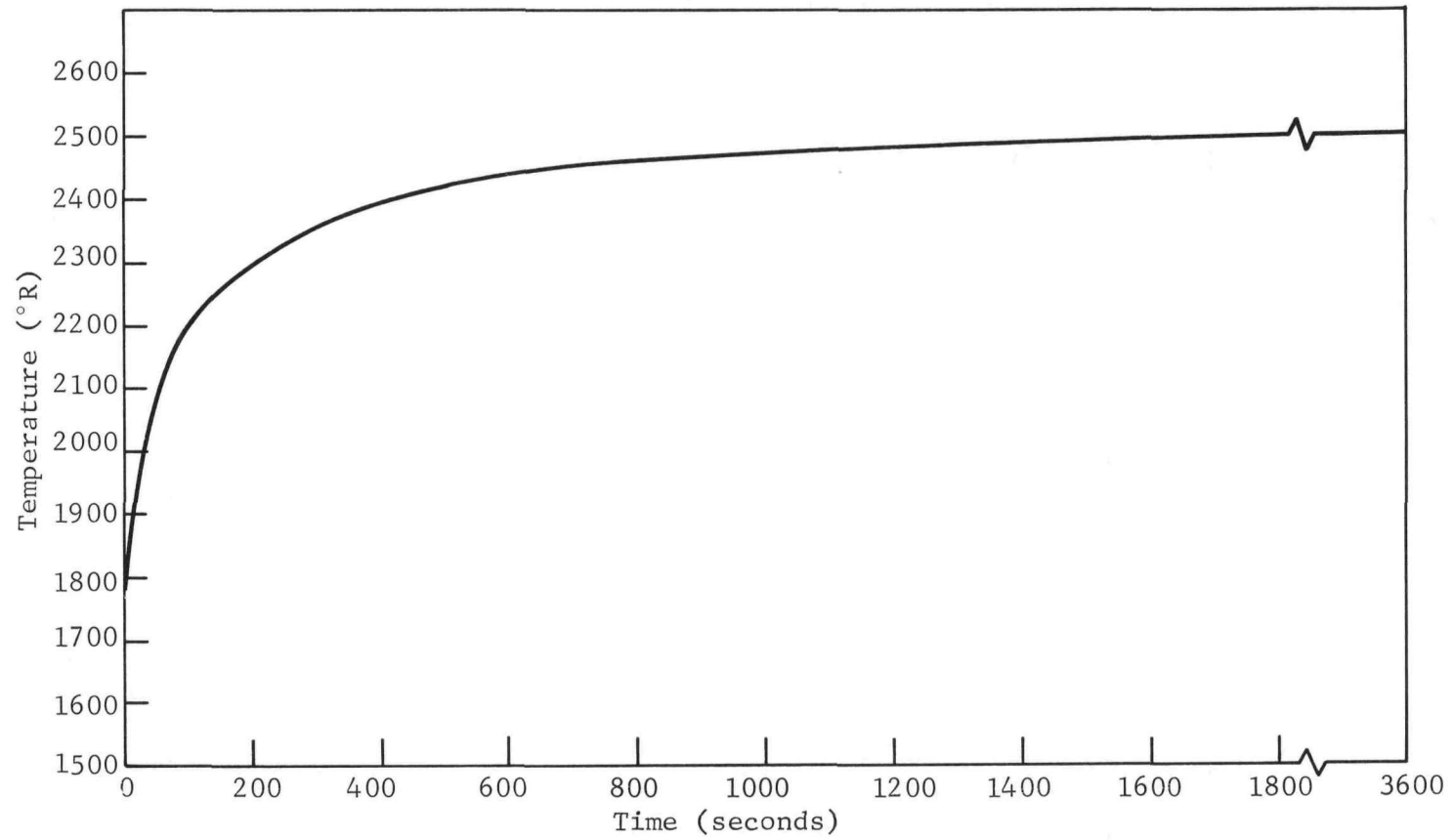


Figure 12. Theoretical thermal profile (capsule V2)  
for fireball/afterfire

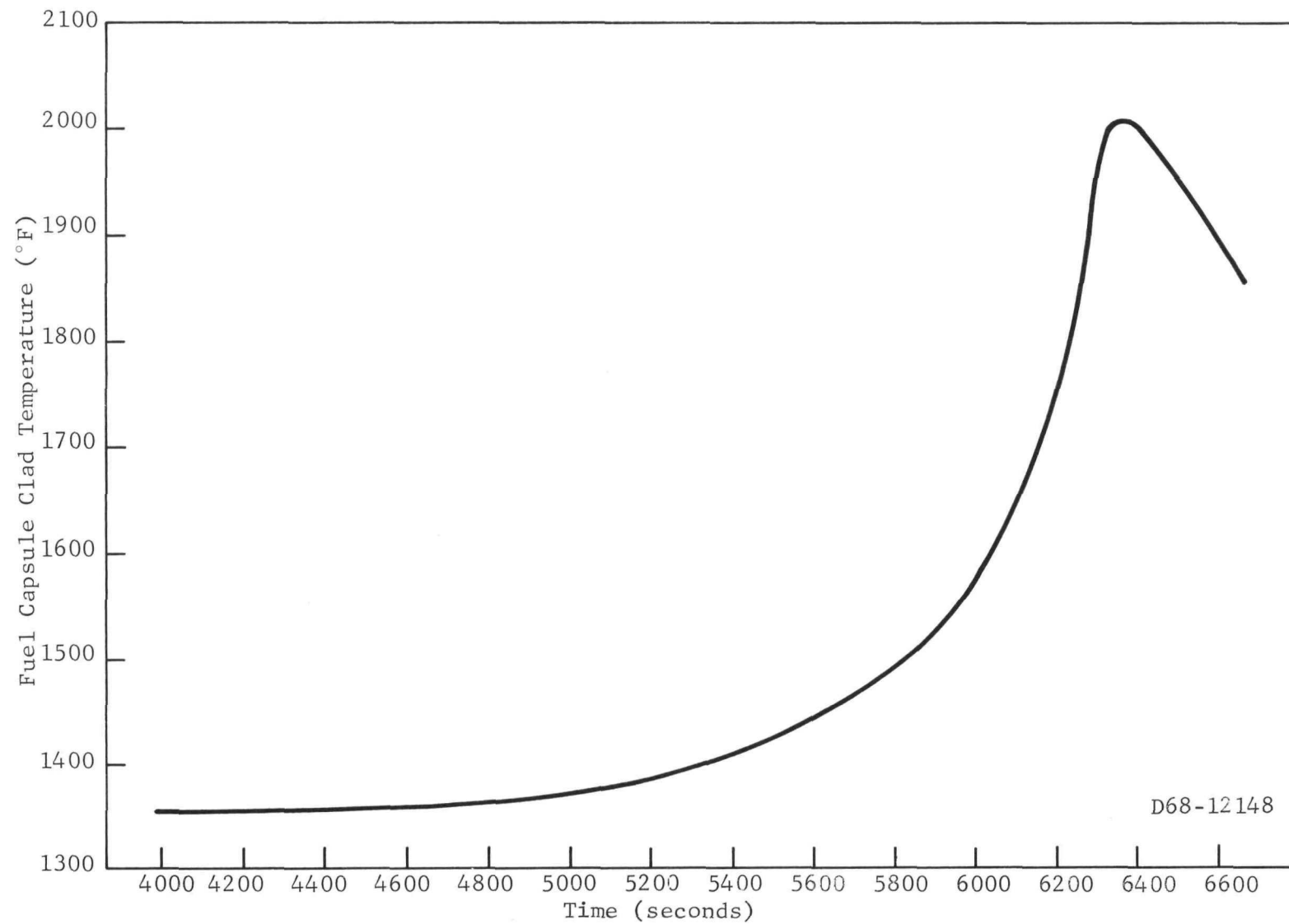


Figure 13. Theoretical thermal profile (capsule RG-1) earth orbit decay reentry lateral spinning mode



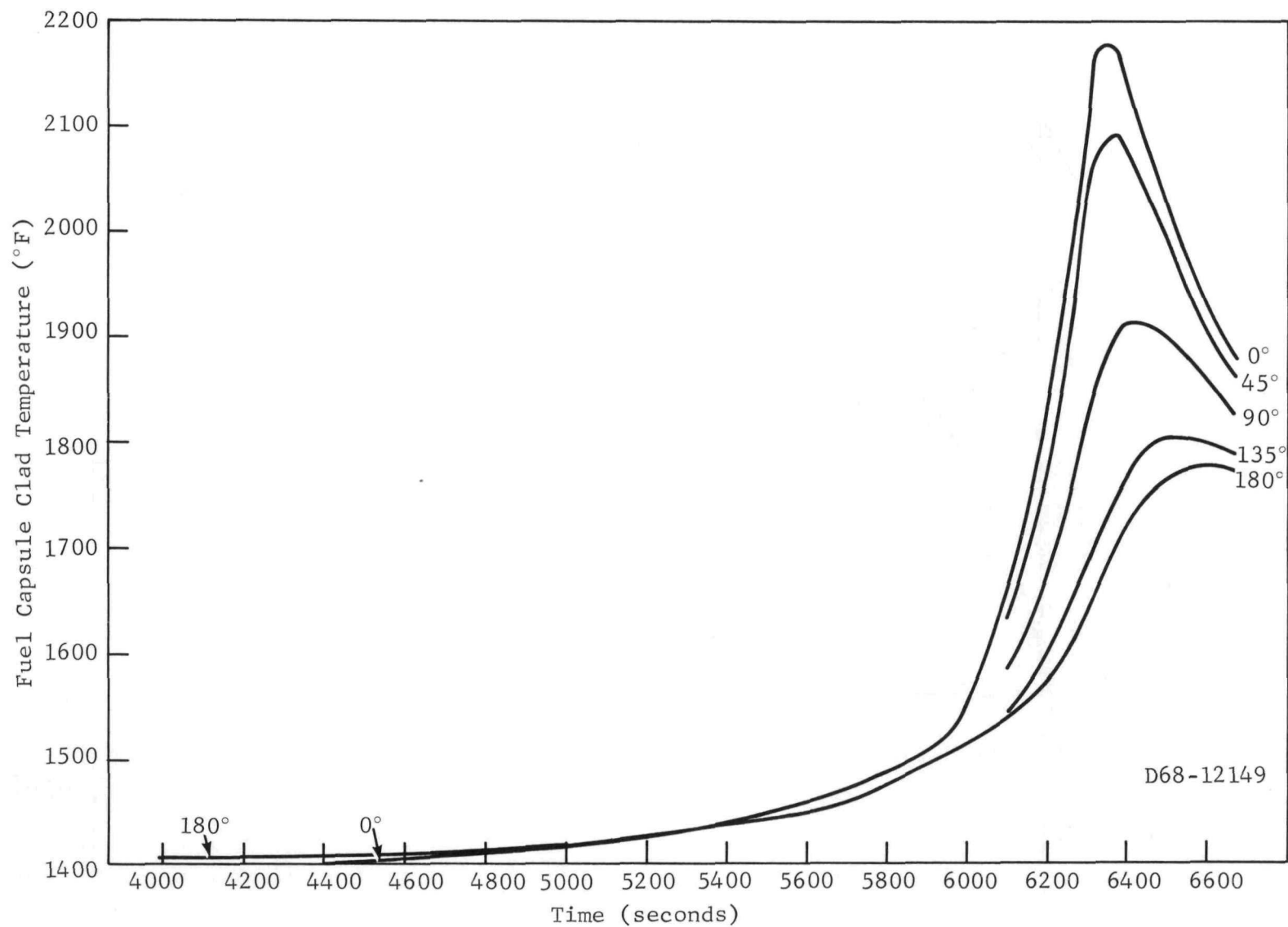


Figure 14. Theoretical thermal profile (capsule RG-2) earth orbit decay reentry side-on stabilized mode



Figure 15. Capsule V2 after test

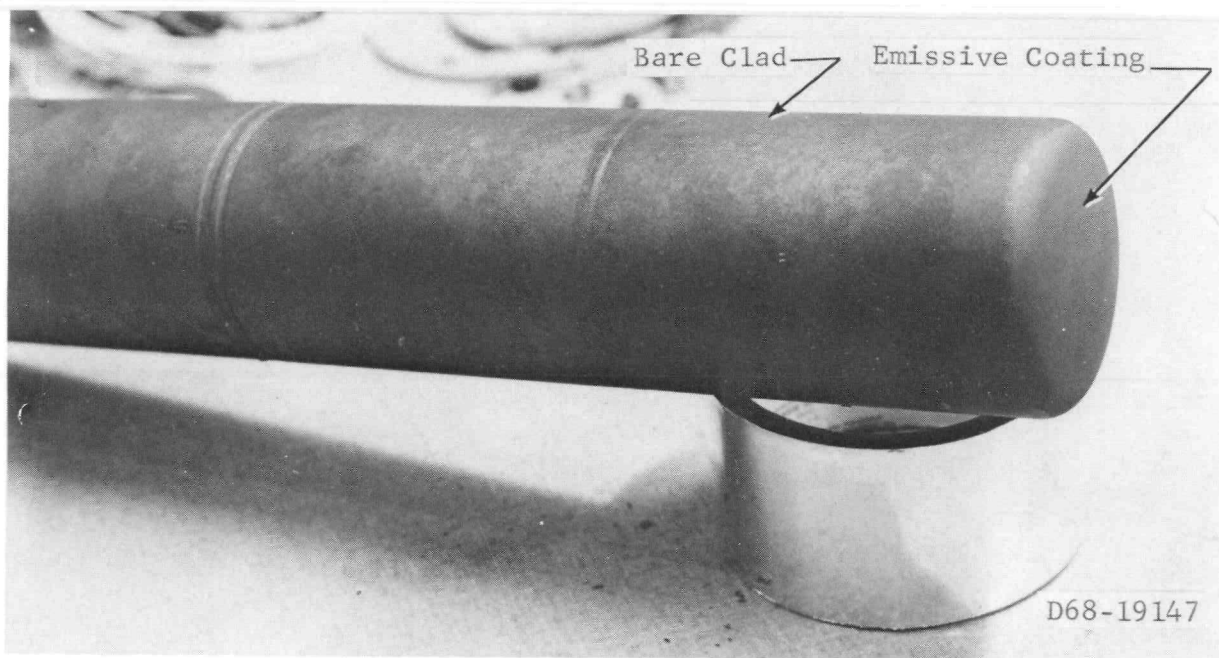


Figure 16. Capsule V2 after test,  
forward end

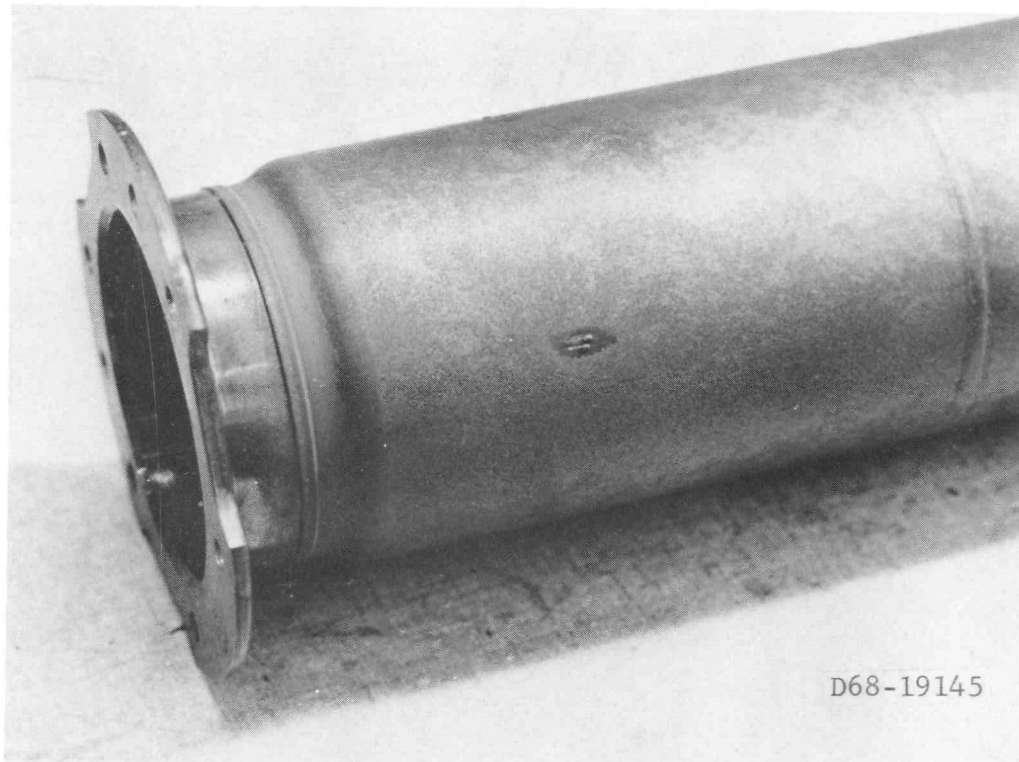
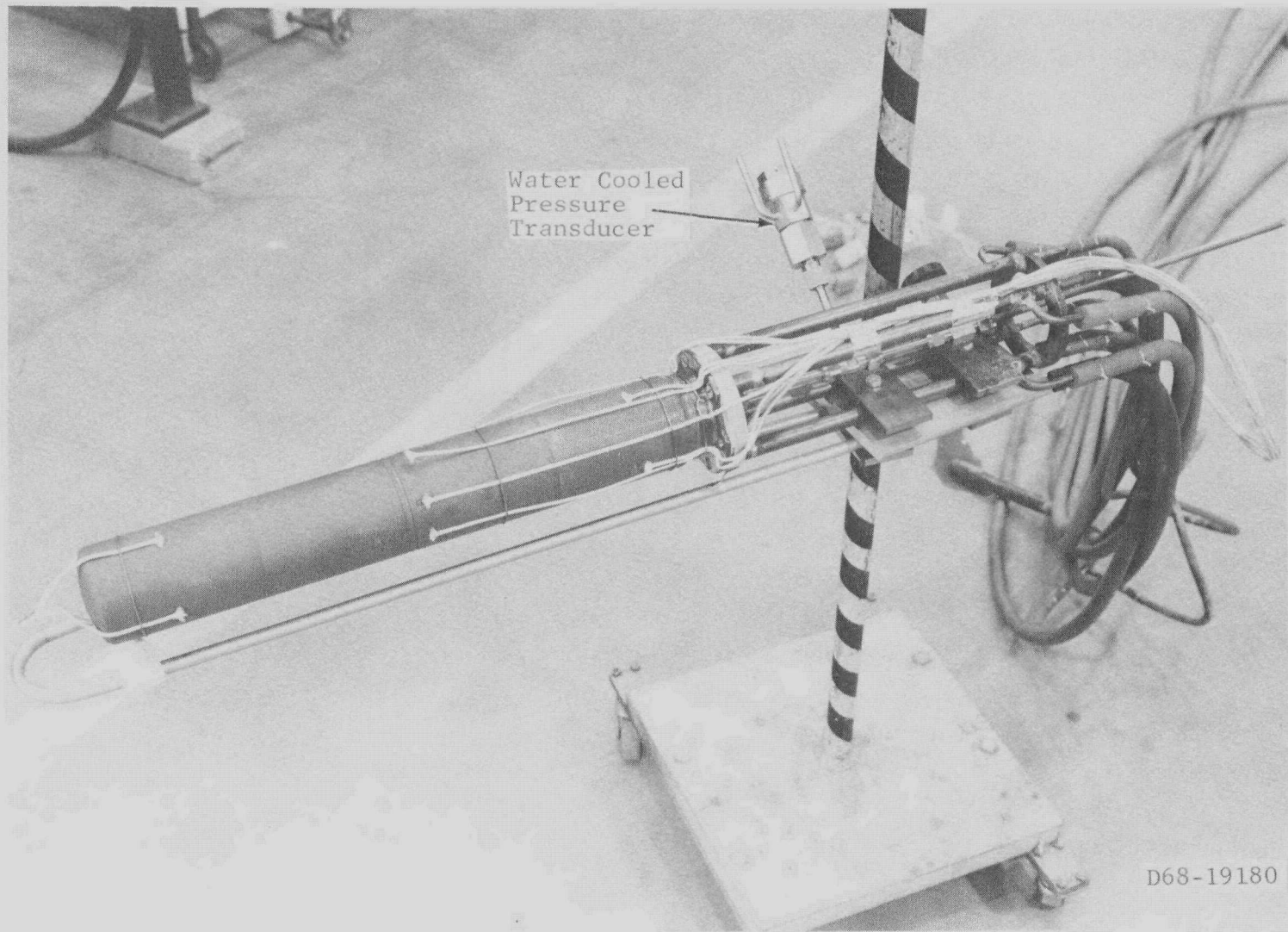


Figure 17. Capsule V2 after test,  
aft end



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Figure 18. Capsule RG-1 after test

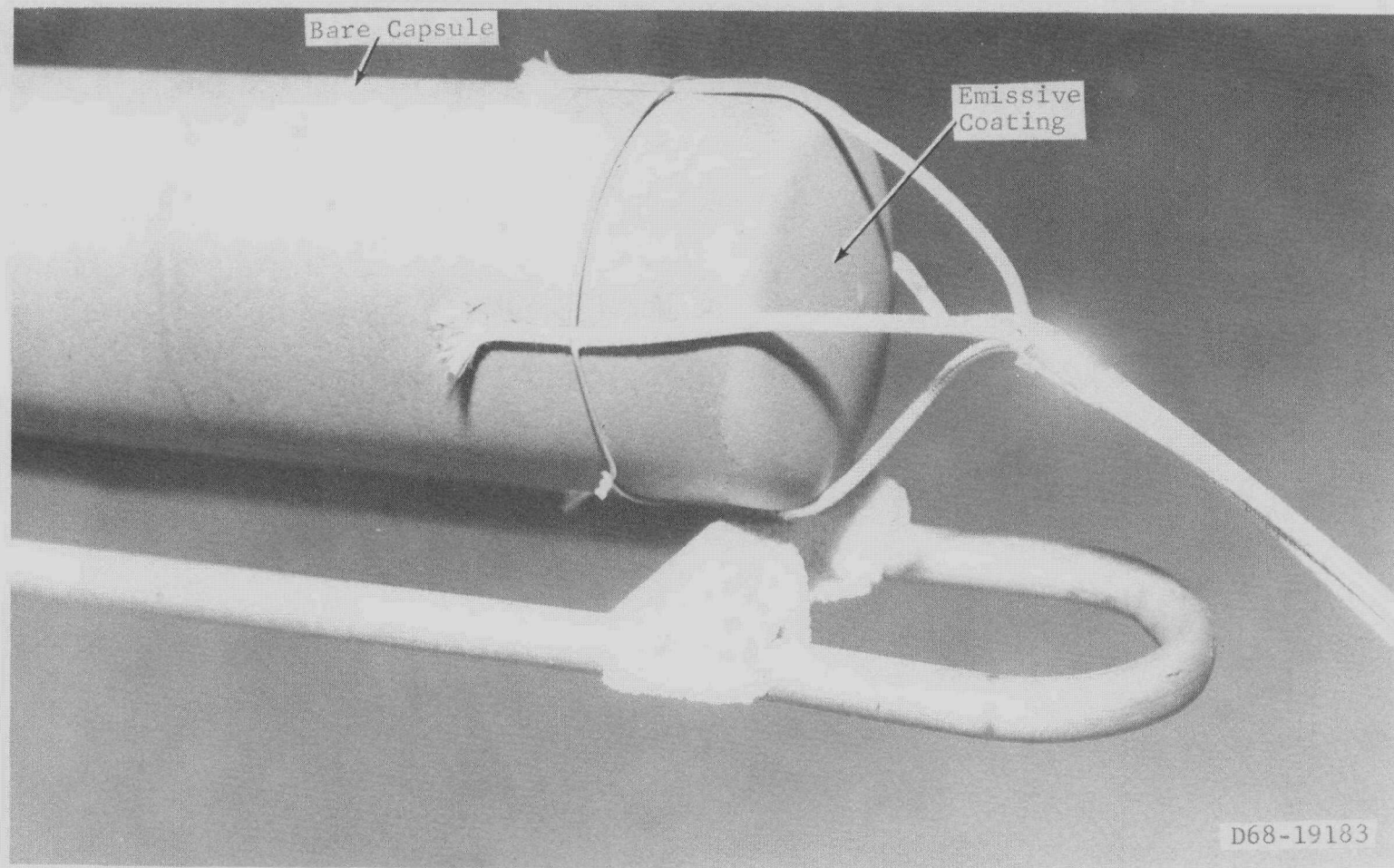


Figure 19. Capsule RG-1 after test,  
forward end



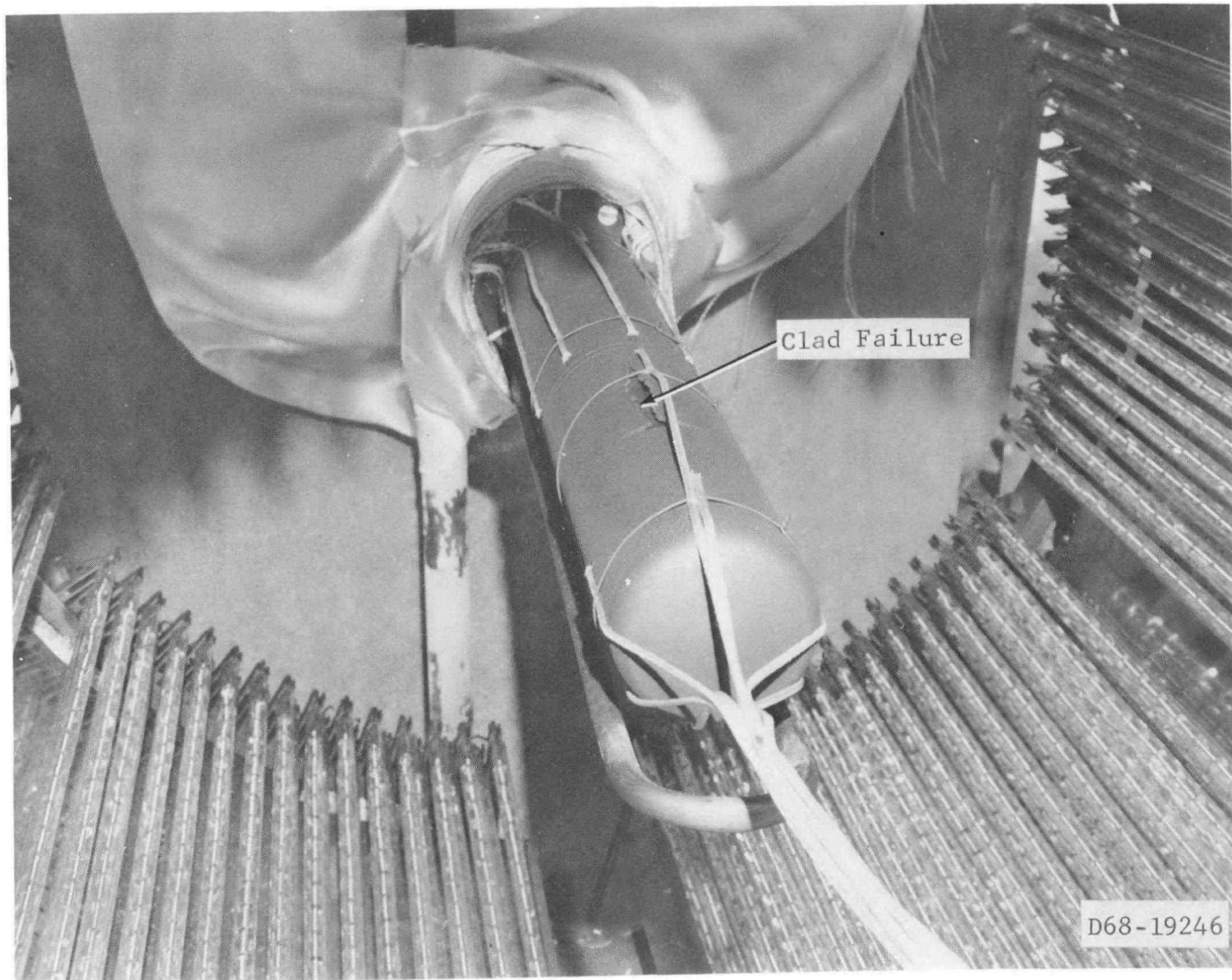


Figure 20. Capsule RG-2 after test

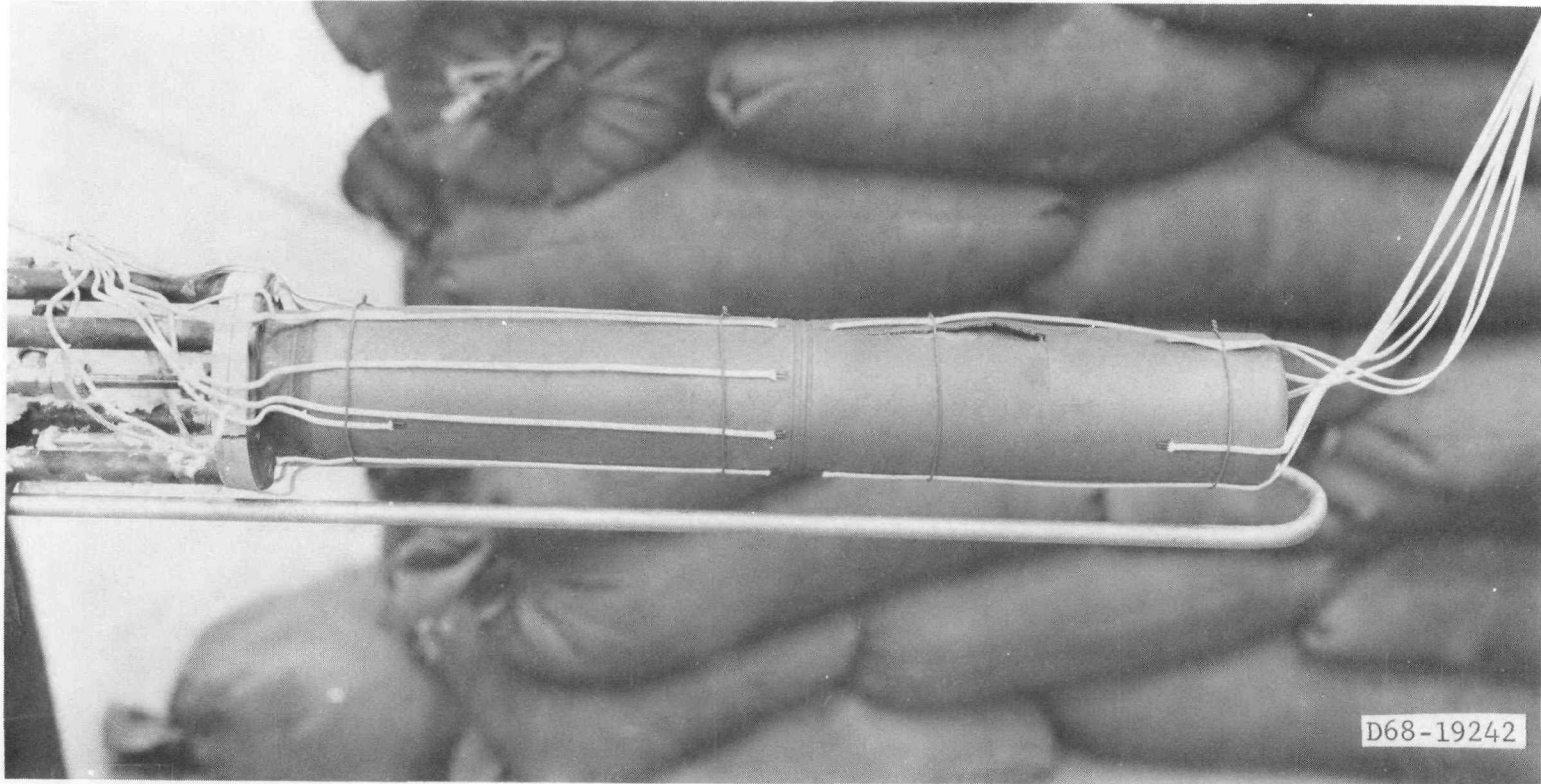


Figure 21. Capsule RG-2 after test

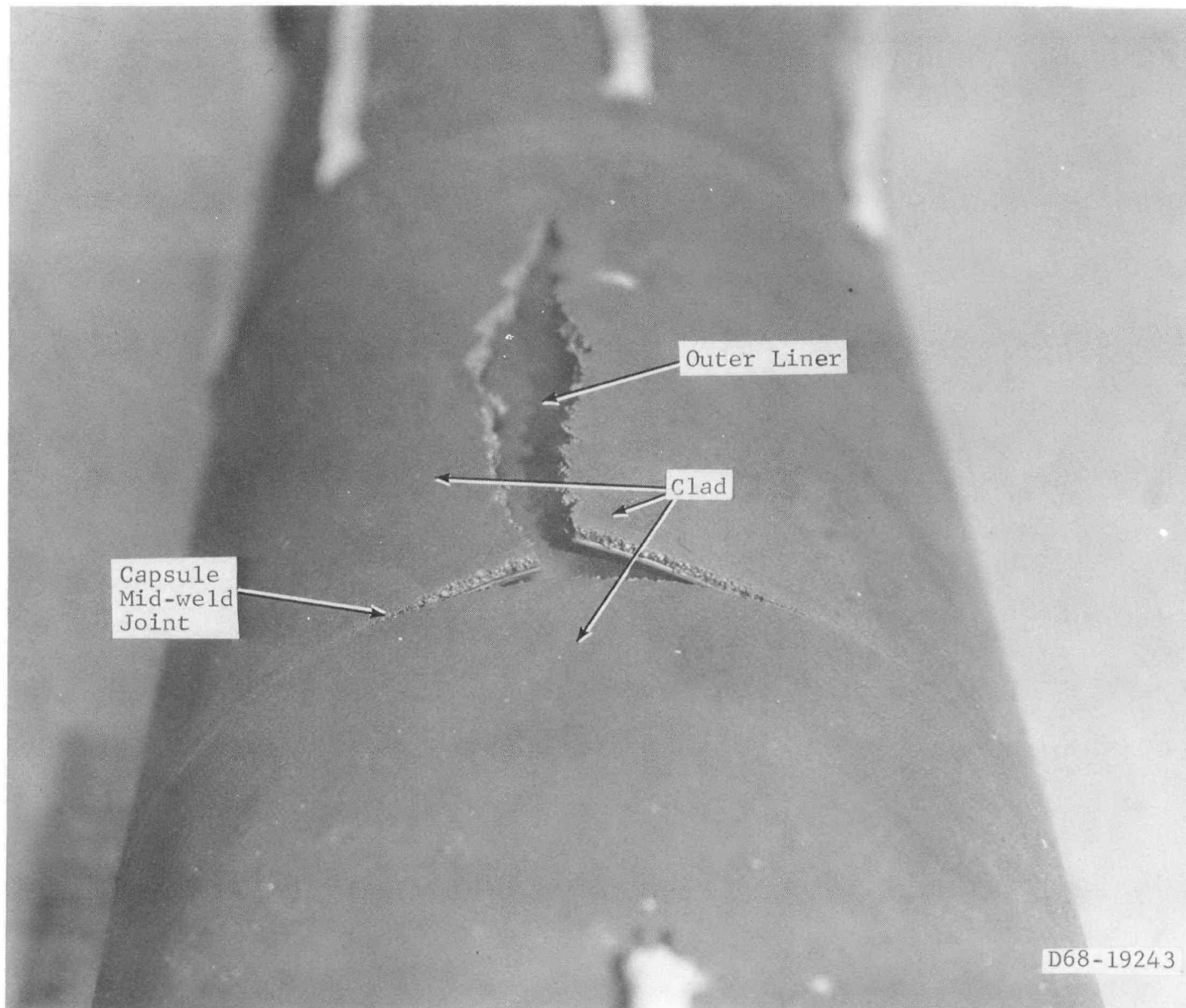


Figure 22. Capsule RG-2 after test, close-up of failure



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