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Progress Report

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Space Nuclear Safety and Fuels Program

December 1981

Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

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The four most recent reports in this series, unclassified, are LA-9177-PR, LA-9243-PR, LA-9280-PR, and LA-9309-PR.

This work was supported by the US Department of Energy, Office of Coordination and Special Projects.

Edited by Harriett Allen
Photocomposition by E. Katherine Valdez

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**LA-9311-PR
Progress Report**

**UC-33a
Issued: April 1982**

LA--9311-PR

DE82 013747

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S. E. Bronisz

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SPACE NUCLEAR SAFETY AND FUELS PROGRAM

December 1981

Compiled by

S. E. Bronisz

ABSTRACT

This technical monthly report covers studies related to the use of $^{238}\text{PuO}_2$ in radioisotope power systems carried out for the Office of Coordination and Special Projects of the US Department of Energy by Los Alamos National Laboratory.

Most of the studies discussed here are ongoing. Results and conclusions described may change as the work continues. Published reference of the results cited in this report should not be made without the explicit permission of the person in charge of the work.

I. GENERAL-PURPOSE HEAT SOURCE (GPHS)

A. Post-Mortem Analysis (F. W. Schonfeld)

The equatorial closure welds of the four capsules used in the second Design Iteration Test, DIT-2, were examined this month. Samples were cut from the capsules to expose cross sections in the single-pass and overlap regions and a tangential section of the single-pass region.

1. **Capsule SR-105.** The weld microstructures of SR-105 were typical of Savannah River Plant's (SRP) production welding (Fig. 1). The welds were sound and free of porosity.

2. **Capsule SR-106.** The microstructures revealed in the single-pass section and the tangential section were typical of SRP's production welding (Fig. 2) and quite similar to the corresponding microstructures in SR-105. The grain structure of the overlap region was within the normal range, but a weld-centerline crack was present (Fig. 3). It extended into the twice-melted material and penetrated 35% of the capsule thickness. Additional

grinding that moved the exposed section toward the weld-submergence point showed that the crack became shallower and deviated from the weld centerline, suggesting the tributary crack pattern often seen in the zone of first submergence.

3. **Capsule SR-107.** The weld microstructures in the single-pass section and in the overlap section appear normal and typical of SRP production (Fig. 4). The section through the overlap region revealed a significant amount of porosity (Fig. 5). The grain-boundary porosity is present mainly in the metal melted in the first weld pass. At higher magnification (Fig. 6), the porosity looks very much like grain-boundary gas bubbles, suggesting that the second weld pass heated the first-weld metal to a temperature where dissolved gases could be rejected.

A similar observation was made in the base metal adjacent to the closure weld of SR-105. Figure 7 shows a section parallel to the weld and through one of the reverse-bend cracks. Conditions similar to those in the first-weld metal at the overlap apply here; the metal adjacent to the weld is heated close to its melting point, giving dissolved gases time to diffuse to grain boundaries

and agglomerate. Although the presence of the pores did not cause the crack (we have seen many such cracks in the absence of porosity), it is reasonable to assume that the pores would further weaken the inherently brittle iridium grain boundaries.

4. Capsule SR-110. The weld microstructures in SR-110 were all normal for the SRP production process (Fig. 8). Only a few pores could be seen in the as-polished section of the overlap region.

B. Launch Pad Accident Testing (C. M. Seabourn)

A meeting was held at Sandia National Laboratories, Albuquerque, with Sandia personnel to discuss explosions and rocket-sled impact testing. The test program will be divided into three phases: (1) Light-Weight Radioisotopic Heater Unit explosion tests at 13.8 MPa, (2) GPHS explosion tests at various overpressures starting at 1.4 MPa, and (3) GPHS fragment impacts with the rocket sled.

II. HELIUM RELEASE (D. Peterson and J. Starzynski)

A. Thermal Ramp Effects

Three pieces of pellet GP-19 were heated from ambient temperature to 1600°C in 720 s, and the helium released during this temperature ramp was measured. The helium release-rate data were analyzed assuming a simple bulk diffusion model. The results of the analyses of the three 720-s samples are compared to the previously reported 280-s¹ samples in Fig. 9 and are summarized in Table I. The diffusion coefficients are higher for the slower pulse, a result consistent with a greater buildup of helium pressure at the grain boundaries for the faster pulses.

B. GPHS Modules

The helium released from the first two modules placed in the Module Reduction and Monitoring Facility

(MRMF) at Mound Facility was analyzed using a simple diffusion model.² The results are given in Table II. The values of the effective diffusion constant are remarkably consistent and show good agreement with those obtained from thermal pulse experiments.

TABLE I. Sample Parameters, Activation Energies (E_a), Log D'_0 , and Percentage of Helium Released for GP-19 Samples Exposed to Ambient to 1600°C Pulse/12 min

Run No.	Mass (g)	E_a (kcal)	$-\text{Log } D'_0$ (s^{-1})	Released (%)
5	0.579	51.7 ± 0.3	2.763 ± 0.051	77.9
9	0.759	44.8 ± 0.4	0.943 ± 0.076	87.7
10	0.321	47.9 ± 0.6	1.150 ± 0.104	91.4

TABLE II. Effective Diffusion Constant (D') and Concentration at Infinite Time (C_r, ∞) for Gas Taps at MRMF

Gas Tap	Time (Ms)	Fraction of Helium Remaining	$-\text{Log } D'$ (s^{-1})	C_r, ∞ (mmole)
1	0.605	0.5894	7.419	1.570
2	1.123	0.4735	7.402	1.509
3	1.728	0.3768	7.377	1.426
4	2.246	0.3367	7.394	1.483
5	2.506	0.3084	7.382	1.443
Averages =			7.395	1.486

REFERENCES

1. S. E. Bronisz, Compiler, "Space Nuclear Safety and Fuels Program, September 1981," Los Alamos National Laboratory report LA-9243-PR (February 1982).
2. B. A. Mueller, D. D. Rohr, and R. N. R. Mulford, "Helium Release and Microstructural Changes in ²³PuO₂," Los Alamos Scientific Laboratory report LA-5524 (April 1974).

(a)

(b)

(c)

Fig. 1. The microstructures of the closure weld of capsule SR-105 were typical of Savannah River welds. (a) Single-pass region, 50X; (b) overlap region, 40X; and (c) tangential section, 40X.

(a)

(b)

Fig. 2. The closure weld of capsule SR-106 exhibited the expected microstructure in the single-pass and tangential sections. (a) Single-pass section, 50X, and (b) tangential section, 40X.

Fig. 3. The weld crack seen in the overlap region of SR-106 extended into the twice melted weld metal, 50X.

(a)

Fig. 4. The weld microstructures in the single-pass and tangential sections of SR-107 were normal. (a) Single-pass section, 50X, and (b) tangential section, 40X.

(a)

(b)

Fig 5 Porosity was present in the overlap region of the SR 107 weld (a) As polished and (b) same area etched, 50X

(a)

(b)

Fig. 6. The porosity observed in the weld of SR 107 looked like gas bubbles (a) 700X and (b) 3000X.

Fig. 7. The base metal adjacent to the weld of SR-105 contained grain-boundary porosity, 300X.

(a)

(b)

Fig. 8. The weld microstructures in SR-110 were normal. (a) Single-pass section, 50X; (b) overlap region, 50X; and (c) tangential section, 40X.

(c)

Fig. 9. Plot of effective diffusion constant D' versus reciprocal temperature for ambient to 1600°C 720-s pulses and 280-s pulses.