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Compiled by
S. E. Bronisz

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FLIGHT-SYSTEMS SAFETY PROGRAM

January 1982

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)

Metallographic examination of the vents and the capsule walls of the four iridium clads impacted in the second Design Iteration Test, DIT-2, assembly were completed.

All vents survived the impact with little or no damage. Photomicrographs of polished sections through the vents are shown in Fig. 1. The vents in capsules SR-106 [Fig. (1b)] and SR-107 [Fig. (1c)] were deformed somewhat by the impact but remained intact. There was a small crack in the vent-assembly weld in capsule SR-110 [Fig. (2)].

The etched vent microstructures are typified by that of capsule SR-107 (Fig. 3). No deposits were found in the vent and none was expected after the short-term exposure of the vent to the fuel. The capsule end wall is fine grained, because of its short annealing treatment. The vent plates are coarse grained, because they were at a high temperature during fabrication of the vent. The iridium frit is uniformly distributed and the vent components appear to be well aligned. It appears that the vent

fabrication and assembly operations are well understood and properly controlled.

The iridium capsules were relatively fine grained after the relatively mild heat treatments of 20 h at 1500°C (no fuel) and 100 h at 1300°C (fueled). Examples of the microstructures in the eight caps that made up the four fueled clads in the DIT-2 impact are shown in Figs. 4 through 7. The normalized grain sizes, expressed as grains across the thickness, are given in Table I. The cup-to-cup variations in iridium grain sizes are consistent with the small-lot production process used to make the GPHS cups.

The local bending strains were measured on photomicrographs and the maximum strains are listed in Table II.

B. Compatibility (D. Pavone)

The graphite components required for the joint Los Alamos—Savannah River Laboratory phosphorous-doped fuel experiments were fabricated and outgassed. Four of the projected seven fueled clads have been received.

Fig. 1. All four vents in the DIT-2 fueled capsules survived the 58-m/s impact with little damage. (a) Capsule SR-105; (b) capsule SR-106; (c) capsule SR-107; and (d) capsule SR-110, 10X.

Fig. 2. A small crack was present in the vent-assembly weld in capsule SR-110 after the impact, 40X.

Fig. 3. The microstructure of the vent in capsule SR-107 is typical of the four capsules in the DIT-2 impact, 40X.

(a)

(b)

Fig. 4. The microstructures of the cups of capsule SR-105 were similar, but the grains were finer in the cup with the vent.
(a) Unvented capsule and (b) vented capsule, 100X.

(a)

(b)

Fig. 5. In capsule SR-106 the cup with the vent had larger grains than the unvented cup. (a) Unvented cup and (b) vented cup, 100X.

(a)

(b)

Fig. 6. The grain sizes were the same in the cups that made up capsule SR-107. (a) Unvented cup and (b) vented cup, 100X.

(a)

(b)

Fig. 7. The cups making up capsule SR-110 had the same grain size. (a) Unvented cup and (b) vented cup, 100X.

TABLE I. Grain Sizes of the DIT-2 Capsules
(Grains Per Wall Thickness, G/T, Normalized to a 0.64-mm Wall)

Capsule No.	Vent Cup		Weld Shield Cup	
	Ident. No.	G/T	Ident. No.	G/T
SR-105	MER 1-2	26	N 505-6	21
SR-106	N 504-5	18	MERR 3-3	25
SR-107	LR 300-2	20	MR 432-2	20
SR-110	N 515-3	21	NR 516-6	21

TABLE II. The Maximum Local Strains Measured in the DIT-2 Capsules

Capsule No.	Strain %		
	Circumferential	Radius	
		Vertical	Horizontal
SR-105	6.4	11.0	2.2
SR-106	7.9	11.0	---
SR-107	7.9	>8 ^a	---
SR-110	6.0	>5 ^a	---

^aThe presence of the fracture prevented accurate measurements.

C. Fuel Simulants (R. Zocher and E. Brandon)

The secondary positions in the fueled safety-test modules and all positions in the launch-pad safety tests will be filled with simulants of the PuO₂ fuel. The simulant chosen is UO₂, because its density, refractory nature, and mechanical response compare reasonably well to those of PuO₂. A nonradioactive welding station that duplicates the one used for the welding at Los Alamos of PuO₂ GPHS pellets into iridium capsules was constructed, and the necessary mechanical and electrical checks were completed. Development welds using the components shown in Fig. 8 will be completed during the next reporting period.

D. Impact Conditions

The results of the reentry calculations made for the GPHS module by General Electric are shown in Table III.¹ Of the three standard conditions considered, the minimum-gamma trajectory results in the greatest ablation of the aeroshell, the highest peak temperature, and nearly the lowest impact temperature. The combination of greatest ablation with low impact temperature makes the minimum-gamma condition the most severe for near-launch accidents.

The subsonic flight mode of the GPHS module is thought to be fluttering about the orientation with the large face parallel to the Earth with a motion of $\pm 30^\circ$

Fig. 8. The weld development components for the mass simulant clad assemblies (UO₂ in iridium).

TABLE III. Temperatures and Ablative Recessions for GPHS Reentry Trajectories^a

Trajectory	Clad Temp. (°C)		Aeroshell Recession (mm)
	Peak	Impact	
Min. Gamma	1583	906	0.838
Multiskip	1303	903	0.737
Orbit Decay	1419	972	0.508

^aCalculated by the General Electric Co.¹

from the face-on attitude. Only two impact tests, DIT-1 and DIT-2, have been conducted within this orientation envelope, but they were carried out at 930°C assuming a recession of 0.65 mm. It is evident that additional tests on the effects of orientation at the current impact temperatures should be completed before the Safety Verification Series in the spring.

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

Three 1-g ²³⁸PuO₂ pellets that had been stored at ambient temperature for 8.6 yr were exposed to a thermal pulse in which the temperature was increased from ambient to 1600°C in 160 min. The helium release rate was determined as a function of time and temperature.

The effective diffusion constant D' calculated from simple bulk diffusion theory is plotted as a function of reciprocal temperature in Fig. 9 for the three samples. Prior results obtained from 11-min and 280-s pulses are also plotted. The samples given the slower 160-min pulse show an almost vertical increase in the release rate at about 560°C followed by an essentially constant release. The helium released over the 2-min period of the near vertical rise increased from 0.3 to 4.7% of the inventory. The total helium released during the ramps varied from 80 to 86% of the inventory. The higher diffusion constants associated with the 160-min pulses indicate that perhaps helium is first released from the grains to

Fig. 9. Logarithm of effective diffusion constant D' of helium in plutonia versus reciprocal temperature for thermal ramps: ambient to 1600°C/160 min. Run 1(x), run 2(o), and run 3(Δ) compared to 12-min and 280-s pulses.

the grain boundaries, where it is trapped until the pressure is high enough to open the boundaries and release the helium. It is noteworthy that the low-temperature region has an activation energy of 52.8 ± 0.5 kcal, which is equivalent to the E_a obtained earlier for the 12-min ramps. The magnitudes of the D' values

associated with the low- and high-temperature regions of the 160-min ramp appear to be about the same as the D' levels obtained for the faster ramps at equivalent temperatures.

The implication of these results to flight systems is that, for fuel which has aged several years, even gentle

pulses could result in very fast release of the helium inventory. Studies of helium release rates as a function of microstructure and fuel age and of the temperature pulse are continuing.

A helium-release analysis (simple diffusion) of the Module Reduction and Monitoring Facility was completed for data from two gas taps taken at a fuel temperature of 1483 K. The values of $\log D'$ were -6.64

and -6.72 s^{-1} , and the corresponding values of C_∞ were 0.260 and 0.315 m mole.

REFERENCE

1. C. T. Bradshaw, General Electric Co. letter on reentry conditions, to S. E. Bronisz, December 18, 1981.

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