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Flight-Systems Safety Program

July 1982

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Los Alamos, New Mexico 87545

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Progress report,

July 1982

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Compiled by
S. E. Bronisz

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FLIGHT SYSTEMS SAFETY PROGRAM

July 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 Space Nuclear 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.

I. GENERAL-PURPOSE HEAT SOURCE (GPHS)

A. Impact Test (F. W. Schonfeld)

The third design iteration test, DIT-3, was completed. The aeroshell failed; its closure caps and those of the two impact shells were released, as was one of the leading fueled clads. Neither of the clads was breached.

In the DIT-3 impact test, a full GPHS module was impacted at 58 ms and 930°C after being held at 1312°C (clad) for 30 days. The impact attitude was such that the impact shell axes were at 30° to the impact surface. The purpose of the test was to subject fueled clads with ultrasonic crack indications equal to or greater than the allowed level of 8 (arbitrary units) to an impact at an angle supposed to be the most likely to cause crack propagation. The four Savannah River fueled clads used and the magnitudes of their ultrasonic indications are shown in Fig. 1.

On receipt at Los Alamos, the four fueled clads were radiographed, their weld regions were photographed, and their dimensions were measured. They were loaded in impact shells with the weld overlap regions (the locations of the cracks) oriented so they would be toward the target at impact and the two impact assemblies were

aged at 1312°C for 30 days, after which they were again radiographed.

The as-received radiographs are shown in Fig. 2. All four fuel pellets were severely broken when received (SRP-140 and SRP-317 were broken before encapsulation at Savannah River). The aging treatment caused little additional degradation.

The external appearance of all the welds was normal, as shown in Fig. 3, which shows the tailoff region of the weld overlap on SRP-127.

After the post-aging radiography, the DIT-3 module was assembled, loaded into the 175-mm gas gun, allowed to reach the 930°C impact temperature, and impacted at 58 m/s. When the sealed catch tube was opened, only low levels of alpha-particle contamination were found (<2000 counts/cm² · min). Examination showed that the aeroshell had broken and both its closures had come out, the caps of both impact shells had come off, and one fueled clad was released (Fig. 4). The aeroshell surface nearest the target failed in bending (Fig. 5). Both impact shells, shown in Fig. 6, were bowed by the impact and cracked both longitudinally and circumferentially.

The four fueled clads are shown in Fig. 7 and their dimensions and overall strains are listed in Tables I and II. The leading capsules (SRP-251 and SRP-317) are

Fig. 1. The DIT-3 impact used a full GPHS module with four weld-cracked fueled clads.

Fig. 2. All four fuel pellets used in the DIT-3 impact were broken when they arrived at Los Alamos.

Fig. 3. The Savannah River welds appeared good when received; the weld of SRP-127 was typical (7X).

(a)

(b)

Fig. 4. The impact caused the DIT-3 aeroshell to fail, releasing one fueled clad. The aeroshell is shown (a) in the as-recovered condition and (b) with the impact shells removed.

Fig. 5. The leading face of the DIT 3 aeroshell failed in several places; the impact line is on the right.

easily detectable by their greater asymmetry. The overall strains are not greatly different from those in DIT-1 and DIT-2, although the change in impact orientation is reflected in their distribution. It is obvious, however, that the local strains in DIT-3 are significantly different than those in the previous tests.

B. Phosphorus Effects Experiment (D. Pavone)

This experiment is designed to test the effects of phosphorus impurity in the plutonia fuel on the iridium cladding of the GPHS heat source. The test assembly consists of four GPHS fueled clads contained in two impact shells. Two of the fueled clads are loaded with plutonia pellets with background levels of phosphorus and cationic impurities: one had been vacuum outgassed. The other two fueled clads are loaded with plutonia doped with phosphorus, one of which was also doped with high levels of cationic impurities. Both pellets were outgassed before encapsulation.

Gamma-scan analysis of the pellets as received from Savannah River Laboratory (SRL) indicated that background impurity level pellets contained <20 ppm phosphorus and that the P-doped pellets contained 38 ppm phosphorus.

The test temperature is 1310°C on the iridium clad and the scheduled exposure time is 6 months. As of August 1, 1982, 1090 hours of exposure had accumulated.

Control samples are being exposed (beginning July 31, 1982) to the same thermal conditions as the test hardware. These samples consist of an unfueled iridium clad and archive rings from the cups used to fabricate the cladding of the test assemblies. Because the archive rings were delivered in the recrystallized condition, they were given a 1-hour, 1500°C anneal to bring them to the same starting condition as the test-assembly cups.

A sample of each archive ring is being analyzed to characterize its starting condition and the remainder is being aged in a FWPF GIS at the same temperature as that of the test assemblies.

C. Early GPHS Compatibility Test (D. Pavone)

The accumulated exposure time of the early compatibility test assembly was 3770 hours on August 1, 1982. Continuous monitoring of the helium released from the test assembly indicated that both vent assemblies remained open throughout the month of July.

II. LIGHT-WEIGHT RADIOISOTOPE HEATER UNIT (C. Seabourn, R. Tate)

A. Explosion Testing

Four simulant-fueled Light Weight Radioisotope Heater Units (LWRHU) were subjected to the over-pressure shock wave representative of a launch-pad explosion that would result from an intertank rupture of the Space Shuttle's external tank. The predicted shock wave at the position of the spacecraft inside the Shuttle cargo bay is 13.8 MPa (2000 psi) with a 37.2-kPa·s (5.4-psi·s) impulse.

The LWRHU assembly for the first explosion test is shown in Fig. 8. This assembly and its location on the magnetometer boom is thought to be the most vulnerable for the LWRHUs in a launch pad explosion. The second explosion test used three LWRHUs.

The first test assembly (LRF-007) was mounted in the mouth of the Sandia National Laboratories 12-in. shock tube and a 162-lb charge of high explosive (composition C-4) was detonated at the other end of the tube, driving

(a)

(b)

(c)

(d)

Fig. 6. Both impact shells were broken in the DIT 3 impact. (a) Impacted face of shell TGL 2 with the leading corner at top. (b) Side view of TGL 2 showing bending. (c) Impacted face of shell TGL 11 with the leading corner at the bottom. (d) Side view of TGL 11.

Fig. 7. The four fueled clads in the DIT 3 module were deformed by the impact. The impact face is shown in the left column and the capsule is rotated 90° in each successive photograph (1X).

the LWRHU into the catch box. The LWRHU capsule was not recovered; it apparently escaped when the box expanded on impingement of the shock wave.

The measured overpressure was 12.8 ± 0.69 MPa (1850 ± 100 psi) and the impulse was 38.6 ± 3.5 kPa·s (5.6 ± 0.5 psi·s). A flash x ray of the capsule in flight is shown in Fig. 9. The explosion stripped the aluminum and graphite components from the capsule, but damaged it very little (in the original radiograph, the circumferential standoffs are visible). Apparently, the peak energy of the shock wave removed the successive layers of the assembly, aluminum housing, aeroshell, and insulation, and passed before the capsule was completely freed.

In the second test, three simulant-fueled LWRHUs (LRF-004, LRF-006, and LRF-016), all mounted on one magnetometer boom ring, were subjected to the same conditions described for the first test. Two minor changes made for this test were (1) the mounting ring for the LWRHUs was inverted in an attempt to provide a better trajectory to the catch box, and (2) the catch box was set back an additional 3 ft (total of 9 ft) from the shock tube to prevent the exit shock wave from destroying its retention capability.

The flash x ray did not fire at the right time, so no image of the samples was obtained. The catch box was intact and two LWRHU fuel capsules were recovered

TABLE I. Dimensions of DIT-3 Fueled Clads

		Clad Number			
		SRP-127	SRP-140	SRP-251	SRP-317
Preimpact Dimensions					
Diameter					
vented cup		29.80mm	29.83mm	29.79mm	29.81mm
weld		30.00	29.97	29.97	29.97
nonvented cup		29.80	29.79	29.80	30.22
Length		30.21	30.20	30.23	30.22
Diagonal		37.55	37.55	39.56	37.56
Postimpact Dimensions					
Diameter					
vented cup	min	28.85	28.49	29.03	29.54
	max	30.48	30.48	30.48	31.04
weld	min	29.51	29.21	29.54	28.80
	max	30.68	30.89	31.59	32.00
nonvented cup	min	29.54	29.72	29.97	27.94
	max	30.33	30.48	31.14	31.22
Length	min	30.07	30.10	30.48	29.85
	max	31.17	31.50	31.57	30.58
Diagonal	min	37.01	35.88	36.68	34.29
	max	37.67	37.77	38.05	38.20

TABLE II. Postimpact Strains in DIT-3 Fueled Clads

		Clad Number			
		SRP-127	SRP-140	SRP-251	SRP-317
Diameter					
vented cup	min	-3.15%	-4.56%	-2.56%	-0.90%
	max	+2.30	+2.16	+2.30	+4.12
weld	min	-1.53	-2.54	-1.36	-3.90
	max	+1.02	+3.05	+1.78	+6.78
nonvented cup	min	-2.55	-0.26	+0.56	-6.22
	max	+0.05	+2.30	+4.48	+4.78
Length	min	-0.42	-0.34	-0.84	-1.22
	max	+3.20	+4.29	+4.45	+1.22
Diagonal	min	-1.45	-4.43	-2.35	-8.70
	max	+0.31	+0.58	+1.30	+1.72

(a)

(b)

Fig. 8. The test assembly for the first LWRHU explosion. (a) Magnetometer mounting plate, holder, preload assembly, and LWRHU (b) Assembled for mounting in the shock tube

Fig. 9. LWRHU LRF 007 in flight after the explosion test, velocity 4300 ft/s

from it. The capsules were badly deformed (Figs. 10 and 11), but not breached. Capsule LRF-004 (Fig. 10) was deformed by its high-velocity impact on the vermiculite catching medium, but the back surface (Fig. 10c) was basically undamaged. Although not deformed as severely, capsule LRF-006 showed damage on all surfaces (Fig. 11); presumably it was hit by some of the

solid explosion products or by material eroded from the shock tube.

The results of these tests show that the fuel containment capability of the LWRHU capsule is not impaired by the explosion environment thought to be representative of an intertank failure of the Space Shuttle. Such an explosion does remove the capsule's external protection, so that the subsequent environments will be faced by the clad alone.

B. Fragment Impact Testing

Two fragment impact tests of LWRHUs were completed. The simulant-fueled units were mounted in a Galileo magnetometer boom ring and impacted with an 18-g, 50-caliber bullet.

In the first test, LWRHU LRF-003 was impacted at 914 m/s (3000 ft/s). The sample was in the rear position on the ring (Fig. 12). The impact removed the sample assembly, except for the threaded portion of the holder, and the bottom of the aeroshell. The capsule was not recovered; small amounts of uranium (0.46 mg/g) were found in the debris in the catch box, suggesting that the capsule had been breached. The flash x ray of the test (not suitable for reproduction) showed the bullet just after it started to deform the clad.

(a)

(b)

(c)

Fig 10 LWRHU capsule LRF 004 after recovery (a)
Profile (b) Impact face (c) Back (6 5X)

(a)

(b)

(c)

Fig 11 LWRHU capsule LRF 006 after recovery (a) Profile (b) Impact face (c) Back (6.5X)

Fig 12 The Galileo magnetometer boom ring was used as a mount for the LWRHU fragment impact tests LRF 003 was tested while in the rear position (914 m/s) and LRF 009 was tested while in the left position (289 m/s)

(b)

(a)

(c)

Fig 13 LWRHU LRF 009 was deformed by the 289 m/s fragment impact (a) Impact face (b) Profile (c) End (6.5X)

In the second test, LWRHU LRF-009 was impacted by the 18-g bullet at 289 m/s (948 ft/s). The aluminum holder was holed on the front face and the back side was blown out. The recovered capsule was found to be deformed, but unbreached (Fig. 13).

A third fragment impact test at an intermediate velocity will be conducted.

III. HELIUM RELEASE (D. Peterson, J. Starzynski)

Development of a mathematical model that will describe helium release behavior from PuO_2 was continued this month. The effects of gas trapping on grain boundaries at lower temperatures are included along with conventional bulk diffusion. Previous data will be re-analyzed using this revised treatment. Progress was also made this month on the Los Alamos report dealing with the current status of the helium release studies.

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