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Flight-Systems-Safety Program

June 1982

Los Alamos

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FLIGHT SYSTEMS SAFETY PROGRAM

June 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)

B. Explosion Tests (R. W. Zocher)

A. Impact Testing (R. W. Zocher)

The plans for the DIT-3 impact were completed and the fueled clads for that test were received from the Savannah River Plant (SRP). The clads were radiographed, photographed, and measured, after which the 30-day, 1312°C (clad) aging was started.

The DIT-3 test will determine the response of fueled clads with relatively large ultrasonic weld crack indications to impact at a 30° incident angle. Figure 1 shows the test assembly with the fueled clads and the sizes of their indications. The aeroshell has the same 2-mm ablation simulation as used for DIT-1 and DIT-2.

One of the test assemblies to be used in the shock-tube explosion tests at Sandia National Laboratories is shown in Fig. 2. The stack, consisting of a GPHS module

Fig. 1. The DIT 3 impact will use a full module with four Savannah River fueled clads numbered as shown and having the ultrasonic indications (NDE) indicated.

Fig. 2. The test array for the GPHS explosion tests consists of a module between module-shaped blocks of bulk graphite.

sandwiched between bulk graphite blocks of module configuration, will be inserted in a movable furnace in the Sandia shock tube. When the iridium-clad UO_2 fuel simulants have been heated to 1100°C , the furnace will be dropped and the test explosion triggered.

C. Early Compatibility Test (D. Pavone)

The accumulated exposure time for this test assembly at the end of June was 3034 h. Continuous monitoring of the helium release indicated that the vent assemblies of both iridium capsules remained open throughout this reporting period.

D. Immersion Test (F. W. Schonfeld)

As part of a joint Los Alamos-Naval Ocean Systems Command (NOSC) test, two GPHS fueled clads were to be placed in the ocean at the NOSC test site, examined quarterly, and removed after 1 year. One clad would be immersed with its vent decontamination cover intact, but the other would have its vent activated.

Before placement in the ocean, the clad with the activated vent (IRG-68) was found to be contaminated externally. The vent decontamination cover had been cut open (Fig. 3), the fueled clad had been immersed in a

Fig. 3. The vent in IRG 68 was activated by cutting through the decontamination cover.

beaker of water, and then allowed to dry. Afterward, the contamination was found.

The explanation for the behavior was obvious. The assembly was warm after vent activation, immersion in the water cooled the gas in the capsule, reducing its pressure and allowing water to be forced into it. When the capsule dried, the water inside boiled and the steam forced the water back out of the vent. Particles of plutonium oxide too small to be filtered by the vent structure were entrained in the exiting water.

The capsule was cut open circumferentially. The exposed fuel is visible in Fig. 4; the white areas were caused by water in the capsule. The interior bottom surface of the capsule was stained by the water inside (Fig. 5).

A single section through the vent showed it to be essentially normal, although the central hole in the plate was offset from the hole in the capsule (Fig. 6). Our examination of IRG-68 showed that it behaved as expected for the treatment it was given.

II. MULTI-HUNDRED WATT (D. Pavone)

Additional post-mortem results were obtained on sample MHFT-76, a Multi-Hundred Watt sphere that was impacted at 82 m/s and 1440°C after 1 year at 1330°C and an orbit-decay reentry simulation.

Fig 4 Note white deposits on the fuel pellet in IRG 68

Fig 5 The bottom inner surface of IRG 68 was stained by the water incursion

Fig 6 The vent structure in IRG 68 was normal, except for the offset of the central hole (10X)

Fig. 7. Metallographic cross sections through the push through like protrusion on the impact face of MHFT-76 [(a) 7X, (b) 100X].

A small gray spot, 4 or 5 mm in diam, associated with a push-through-like protrusion and small cracks, was observed on the impact face. The metallographic cross section (Fig. 7a) indicates the extent of the protrusion and Fig. 7b shows two elongated pores and a pit on the outer surface, along with some surface erosion. Surface analysis of a gray deposit bridging the gap indicated by the arrow in Fig. 7b showed the presence of molybdenum and tungsten as major components, with lesser concentrations of aluminum, silicon, titanium, nickel, and plutonium. A short distance from the pit, a two-phase intermetallic deposit (Fig. 8) appeared on the exterior surface. Analysis indicated that the darker phase, adjacent to the clad, contained plutonium and iridium; the lighter phase contained aluminum, titanium, molybdenum, tungsten and iridium.

The plutonium in the deposit in the pit and on the exterior surface of the clad near the pit suggests that a

Fig. 8. Intermetallic deposits on the exterior clad surface of MHFT 76. Gray phase adjacent to the clad contains plutonium and iridium. Metallic phase contains iridium, aluminum, titanium, molybdenum, and tungsten (500X)

Fig. 9. Grain boundary crack on the impact face of MHFT 76 containing iridium-silicon intermetallic compound [(a) 100X, (b) 500X].

defect existed in the clad during the aging treatment. We have observed a vapor-transported iridium-tungsten deposit near the vent-hole exit in many assemblies, but a molybdenum-tungsten-rich material had not been observed as a vapor-transported species. The presence of this phase suggests that it was associated with the defect in the iridium clad.

Also observed in this metallographic cross section was the grain-boundary crack shown in Fig. 9. This crack, on the flat portion of the impact face, was partially filled with a light-gray intermetallic compound identified as iridium-silicon. Oxygen was also present in part of the deposit. Its appearance suggests that the deposit was present as a liquid grain-boundary film that contracted under the influence of surface tension when the gap developed during the impact. Because the crack was located at some distance from either vent assembly, it is difficult to associate the formation of the iridium-silicon compound with vaporization of fuel impurities through the vent and subsequent reaction with graphite to form the compound. Some silicon grain-boundary segregation was observed in samples analyzed by Auger Electron Spectroscopy, but no iridium-silicon compound was seen in other cross sections examined.

III. HELIUM RELEASE (D. Peterson, J. Starzynski, C. Land, J. Early)

An 18-g $^{238}\text{PuO}_2$ pellet made by Savannah River Laboratory (SRL) was cut into 21 pieces after 8 months at ambient temperature. Its microstructure is shown in Fig. 10. The grain size (10- μm average) is more uniform and smaller than that observed in Los Alamos GPHS pellets. After 10 months' storage, one piece was ramped

Fig. 10. The grain size of the SRL helium release pellet was uniform (500X).

Fig. 11. Temperature dependence of diffusion constant determined from helium release measurements on SRL fuel exposed to 31°C/min pulse (run 66) compared with helium release from GPHS fuel (run 65).

at 31°C/min to 1832°C and the released helium was measured. The observed temperature dependence of the effective diffusion constant D' is shown in Fig. 11, where it is compared to the least-squares fit to the data from a piece of Los Alamos pellet GP-19 (run 65).

The higher diffusion constants for the SRL pellet probably resulted from its greater grain-boundary volume. The larger the grain-boundary volume, the lower the probability that the helium concentration will be sufficient to nucleate grain-boundary bubbles that can act as traps.

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