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Space Nuclear Safety and Fuels Program

November 1981

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SPACE NUCLEAR SAFETY AND FUELS PROGRAM

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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

A. Impact Test Results (F. W. Schonfeld)

The recovered fueled clads from the second design iteration test, DIT-2, were notched with an abrasive wheel and pried open. Samples SR-105, SR-106, and SR-107 were opened in the normal glove-box atmosphere, whereas SR-110 was opened under water to retain the fines for a particle-size analysis.

Visual and low-magnification optical examinations of the outer surfaces of the defueled clads revealed failures in the radii of the vented ends of SR-107 and SR-110. No other cracks were visible on the outer surfaces. Examinations of the inner surfaces of the capsules revealed that all contained short longitudinal cracks in and near the closure welds. The capsules and the fuel pellets were sampled for microscopic examinations and chemical analyses.

1. SR-105. No cracks were found on the external surface of this capsule, but several cracks were found on the inside surface in and adjacent to the equatorial

closure weld (Fig. 1). The cracks extended through half the wall's thickness both in the weld and in the region adjacent to it (Fig. 2). The location of the cracks is indicated on the drawing in Fig. 3. The crack features indicated were located from the end of the weld puddle that was visible on the outer surface.

2. SR-106. No external cracks were found on this capsule, but the inner surface was cracked more than any other in the DIT-2 impact. Three families of cracks were found, one of which was located in the approximate region of the out-of-specification ultrasonic indications observed by Savannah River Plant (SRP). The locations are shown on the schematic diagram of Fig. 3(b). Again, the cracks were in and near the weld bead (Fig. 4) and the deepest among them was through 60% of the wall (Fig. 5). The cracks on the interior of the trailing side of the capsule were especially numerous (Fig. 6), but most of them penetrated only a few grains into the metal. In addition to the internal transverse cracks, a small weld-centerline crack was found in the overlap region (Fig. 7); it penetrated a third of the way through the thickness of the weld bead.

3. **SR-107.** The longitudinal inner surface cracks were found in SR-107 only in the reverse-bend region on the impact face [Fig. 3(c)]. The cracks were in and adjacent to the weld, and in some cases the cracks extended from the weld into the base metal (Fig. 8). These cracks were the most extensive of any of the type found in the four capsules of DIT-2. They tended to be wider, and more of them were deeply penetrating than in any other capsule (Fig. 9). The morphology of the cracks clearly demonstrates that they are caused by the tensile bending stresses near the end of the impact event.

A crack that breached the capsule wall was found on the impact face in the radius at the vented end of the capsule (Fig. 10). The crack was 4 mm long and 0.12 mm wide at the outside surface, but only 0.02 mm wide at the inside surface.

4. **SR-110.** The deformation of SR-110 mirrored that of SR-107: there were internal cracks only in the reverse-bend region [Fig. 3(d)] and the wall was breached on the impact face in the vent-end radius. The SR-110 internal cracks were much less numerous (Fig. 11) and the breach was somewhat more severe: it was 5 mm long and 0.2 mm wide at the outside surface and 0.04 mm wide at the inner surface (Fig. 12).

5. **Fuel Releases.** The fuel contents of the two graphite impact shells (GIS) were determined. The GIS with the flight-quality fueled clads (SR-107 and SR-110) contained 0.03 mg of $^{238}\text{PuO}_2$, and the GIS with the nonflight-quality fueled clads (SR-105 and SR-106) contained 0.02 mg of $^{238}\text{PuO}_2$. If the second GIS, in which neither clad failed, is used as a tare for the first, in which both failed, the calculated release density is 35 $\mu\text{g}/\text{mm}^2$.

B. Design Iteration Tests (R. W. Zocher)

An interlaboratory technical interchange to review the results of the first two DIT impacts and other relevant

impact data was held at Los Alamos on November 17 and 18, 1981. After reviewing the data, the attendees considered three possible plans for the next DIT impact: (1) repeat DIT-2 with four fueled clads with known weld defects; (2) test with the impact shell axes at 30° to the target to increase the stress on the closure welds; or (3) test at the 30° angle, but with one impact shell behind the other. No consensus was reached, but the second option was the most popular.

C. Graphite Fabrication (R. W. Zocher)

The graphite assembly for DIT-3 was completed, as were the module side-wall samples and the impact shells needed for the launch-abort, bullet-fragment tests.

Work was started on the first production machining order (six modules) of fiscal year 1982.

II. LIGHT-WEIGHT RADIOISOTOPE HEATER UNIT (R. E. Tate)

A Los Alamos National Laboratory report, "The Light-Weight Radioisotope Heater Unit (LWRHU): A Technical Description of the Reference Design," was completed, edited, and assigned the number LA-9078-MS.

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

The pulse-heating furnace was recalibrated in preparation for the next series of helium release experiments.

The final drafts of topical reports on the helium release measurements made on LWRHU fueled capsules and on a GPHS fueled capsule were completed. They will be edited during the next reporting period.

Fig. 1. The inner surface of the closure weld of SR-105 was cracked. 6X.

(a)

(b)

Fig. 2. The cracks in the wall of SR-105 adjacent to the weld penetrated half of the wall's thickness. (a) As polished; (b) as etched. 50X.

(a)
SR-105

(b)
SR-106

(c)
SR-107

(d)
SR-110

Symbol	Definition
A	Weld submergence
B	Weld terminus
C	Cracks
*	NDT indication
CL	Centerline crack

Fig. 3. The various features of the impacted DIT-2 capsule welds could be located with respect to the weld termini after the capsules were opened. The features were T (terminus, exterior), S (submergence, interior), C (visible cracks), and U (ultrasonic indication provided by Savannah River Plant).

(a)

(b)

(c)

Fig. 4. The three families of cracks on the interior of SR-106 were similar. (a) Reverse-bend region nearest the weld overlap; (b) second reverse bend; and (c) on the back. 6X.

Fig. 5. The deepest of the cracks in SR-106 was equal to 60% of the wall thickness. 50X.

Fig. 6. The internal cracks were especially numerous on the trailing side of SR-106. 40X.

Fig. 7. The small centerline crack in the weld overlap of SR-106 penetrated a third of the capsule's thickness. 50X.

Fig. 8. The internal cracks present at the reverse bend in SR-107 after impact were the most severe found in the DIT-2 impact. 6X.

(a)

(b)

Fig. 9. The cracks in SR-107 were the furthest developed of any found in DIT-2. Reverse bend (a) as polished and (b) as etched. 40X.

(a)

(b)

(c)

Fig. 10. Capsule IRG-107 was breached in the vent-end radius. (a) External surface, 6X; (b) internal surface, 6X; and (c) etched cross section, 50X.

(a)

(b)

Fig. 11. (a) Only a few internal cracks were present in the reverse-bend region of SR-110, 6X. (b) The deepest weld crack penetrated half the wall, 100X.

(a)

(b)

(c)

Fig. 12. Capsule SR-110 was also breached in the vent-end radius. (a) Exterior surface, 6X; (b) interior surface, 6X; and (c) etched cross section, 100X.