165
12-15-81
LA-9087-PR

Progress Report

MASTER

LA--9087-PR

DE82 004687

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

Space Nuclear Safety and Fuels Program

July 1981

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

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

The four most recent reports in this series, unclassified, are LA-8904-PR, LA-8968-PR, LA-9042-PR, and LA-9076-PR.

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

Edited by Jill Warren
Photocomposition by Zian H. Swanson

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. References herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Space Nuclear Safety and Fuels Program July 1981

Compiled by

S. E. Bronisz

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

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

eb

SPACE NUCLEAR SAFETY AND FUELS PROGRAM

JULY 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

A. Impact Test Plans (R. W. Zocher)

A test plan (CMB-5-C-81-66) and schedule for the second Design Iteration Test (DIT-1.5) was written and distributed (Fig. 1). In DIT-1.5, a partial aeroshell containing a CBCF insulation assembly, an impact shell, and two fueled clads will be impacted at 930°C and 58 mps. The fueled clads will be of Savannah River Plant manufacture and oriented so that their weld-overlap regions are toward the impact surface.

B. Impact Results—DIT-1 (F. W. Schonfeld)

The gross strains of the four fueled clads were reported last month.¹ After the fuel had been removed from the capsules, the two characteristic regions of local maximum bending strains could be seen and measured. Figure 2 shows transverse sections through each of the four fueled clads used in the DIT-1 impact test. In addition to emphasizing the similarities among the capsules, Fig. 2 illustrates one of the characteristic

strains—the reverse bend on the side of the impact face toward the window volume in the aeroshell. The second characteristic local strain is the corner strain visible in cross section in Fig. 3. The shape of the corner bend is controlled by interactions of inertial and frictional forces on the iridium. The bending strains measured at the reverse bend and the two corner bends are listed in Table I.

A tendency for the reverse-bend strains to be lower than the corner-bend strains was observed. The former cracked, while the latter did not, another indication that strain state is at least as important as strain magnitude.

TABLE I. Maximum Local Bending Strains in DIT-1 Capsules

Capsule No.	Strain (%)		
	Vent-end Corner	Reverse Bend	Nonvent-end Corner
IRG-101	8.9	7.3	5.5
IRG-102	8.1	4.1	7.2
IRG-103	8.1	4.0	3.7
IRG-104	4.5	6.7	8.8

The microstructure of the corner bend in IRG-101 (Fig. 4) shows no evidence of deformation, even though we expected to see it. The microstructure appears to be completely recrystallized and without strain markings. Neither the impact temperature (930°C) nor the post-impact temperature (~800°C) were thought high enough to cause recrystallization in a short time, but perhaps the 18-h post-impact period during which the assembly was in the catch tube was sufficient to cause recrystallization at this strain at the latter temperature.

The cracks in all four capsules were found only on the inner surface of the reverse bends (Fig. 2). The cracks appeared only near the closure weld, either in the weld bead or adjacent to it. The cracks varied in frequency and extent, as shown in Fig. 5, with IRG-101 and IRG-102 showing less damage than capsules IRG-103 and IRG-104.

In all cases the cracks were intergranular, as expected for iridium at the 930°C impact temperature (Figs. 6-9). The maximum depths of the cracks in the sections shown varied from about a third of the wall thickness in capsule IRG-101 to nearly three-fourths of the wall thickness in capsule IRG-104.

The margin between success and failure in the DIT-1 impact clearly approached zero. Because of the near-brittle character of the grain boundaries, only a small amount of additional energy would have been required to extend the cracks through the capsule walls. On the other hand, if the grain size of the capsule walls had been larger and more in keeping with the grain size observed in Multi-Hundred-Watt spheres after exposure to $^{238}\text{PuO}_2$ (Ref. 2), the cracks would have been deeper.

Capsule deformation is largely controlled by the breakup and shape change of the fuel pellet on the inside and the degree of constraint on the outside. At the limit, an iridium capsule fitting tightly between a very strong crack-free fuel pellet and a very strong impact shell would not deform on impact. The present design of the General-Purpose Heat Source (GPHS) module varies from this ideal by having relatively large fuel-clad and clad-impact shell gaps plus the large gap that is ineffectively occupied by low-density CBCF insulation. The design could be brought closer to the ideal by tightening the dimensional tolerances on the fuel pellet and capsule to reduce the inner gaps and by replacing the low-density CBCF insulation with a higher density insulation to reduce the other gap. These changes would increase the weight of the module, but they would undoubtedly increase its safety margin.

C. Graphite Production

Six FWPF* graphite assemblies for GPHS modules and two bulk graphite billets were fabricated and shipped to Mound Facility.

II. LIGHT-WEIGHT RADIOISOTOPE HEATER UNIT

A. Acceleration Test (R. E. Tate)

When a Light-Weight Radioisotope Heater Unit (LWRHU) was subjected to a 425-G acceleration test while mounted in a Galileo-Probe holder, the LWRHU and its mount survived the test without damage.

The acceleration test was performed to determine the response of the LWRHU and its mounting assembly (Fig. 10) to the forces that will occur when the Galileo Probe descends into the Jovian atmosphere. The LWRHU was assembled at the Los Alamos National Laboratory and differed from the production flight units by having a UO_2 simulated fuel pellet in place of the PuO_2 fuel pellet and by having the aeroshell cap glued instead with an RTV compound in place of the graphite-bonding glue used in the production units. The former deviation allowed the LWRHU to be tested in a nonradioactive area, and the latter change allowed the LWRHU to be disassembled easily after this test.

The LWRHU was mounted in a holder supplied by General Electric Company, a Galileo-Probe contractor, and this holder was mounted on an adaptor that was mated to the centrifuge at the Sandia National Laboratory, Albuquerque, New Mexico, where the acceleration test was conducted. The assembly was oriented so that the acceleration force was perpendicular to the axis of the LWRHU and in a direction that would load the mounting fasteners. In this way both the LWRHU and its mount were subjected to maximum forces.

The assembly was rapidly loaded to 425 G and held at that level for 15 s before the load was reduced and the test completed. The assembly was loaded to above 300 G for 30 s. The LWRHU and the mount survived the acceleration test without damage.

*Fineweave-Pierced fabric 3-D carbon/carbon composite, a product of AVCO Systems Division, 201 Lowell St., Wilmington, MA, 01887.

B. Explosion Test (C. M. Seabourn)

This month one explosion test was conducted in the facility-calibration series. Its purpose was to examine another method of achieving the long impulse believed to be characteristic of an explosion of the external fuel tank on the Space Shuttle. The test setup consisted of a 1.83-m-diam spherical steel chamber with a port to which a 0.61-m-diam by 3.65-m-long shock tube was attached. This setup was used so that the initial shock could expand in the sphere before moving down the tube. We hoped that this procedure would extend the impulse.

An explosive charge of 17.2 kg PETN was detonated in the sphere, splitting it open and lifting it 30 m in the air. It landed ~50 m from its original position. Because of its violence, this method of increasing the impulse has been abandoned.

C. Fire Test (C. M. Seabourn)

Arrangements have been made to obtain from Kirtland AFB ~12 700 kg of UTP-3001 solid-rocket propellant, which will be used in the fire tests of LWRHU and other heat sources.

III. SAFETY TECHNOLOGY

A. Helium Release (D. Peterson and J. Starzynski)

Two sets of three samples were removed from Los Alamos fuel pellet GP-19, which had been exposed to a reentry ramp. One set was removed from the pellet's center and the other from near the surface, because other Los Alamos pellets have had nonuniform microstructures and we wanted to know how a sample's location affected its helium release.

One sample for each set was submitted for a ceramographic analysis, a second such pair was heated to 1600°C in 140 s, and the third pair was heated to 1600°C in 280 s. The helium released during the heating ramps was measured, and these data are being analyzed.

B. Environmental Exposures (D. Pavone)

We examined two $^{238}\text{PuO}_2$ pellets that had been submerged for 6 yr in aquaria as part of the program to

determine the effects of aqueous environments on fuel forms. No significant localized corrosion of either the pellet exposed to sea water or the pellet exposed to fresh water was observed.

1. **Sea Water.** Pellet HPZ-59-4 (25 W_g) is shown in Fig. 11 after it had been in 10°C sea water for 6 yr. The pellet was cracked and the grayish white deposit visible on the outer surface was also present on the crack surfaces. The microstructure of the pellet (Fig. 12) is typical of hot-pressed PuO_2 made in 1975. No indications of local surface corrosion were observed.

2. **Fresh Water.** Pellet HPZ-111-1 (25 W_g) is shown in Fig. 13 after it was removed from a 6-yr exposure to deionized water at 12°C. The face of the pellet that had been on the Pyrex glass support was cracked, and there was a grayish white deposit on the pellet face. Neither the other face nor the cylindrical surface was affected. When the pellet was broken, the crack surfaces were seen to be deposit-free.

The microstructure of pellet HPZ-111-1 (Fig. 14) was similar to that of pellet HPZ-59-4. At higher magnifications, dark gray, nonmetallic material was observed in some pores and on the crack surface (Fig. 15). An electron microprobe analysis showed the second phase to contain high concentrations of silicon and oxygen, a small amount of calcium, and a trace of magnesium. The source of these elements is problematical. Its presence on the pre-existing crack surface suggests its source was the water, but how the water could have carried the material into the internal pores (Fig. 15b) is difficult to understand.

REFERENCES

1. "Space Nuclear Safety and Fuels Program, June 1981," S. E. Bronisz, Comp., Los Alamos National Laboratory report LA-9076-PR (October 1981).
2. "General-Purpose Heat Source Project and Space Nuclear Safety and Fuels Program, August 1980," W. J. Maraman, Comp., Los Alamos Scientific Laboratory report LA-8713-PR (January 1981).

ADDITIONAL DISTRIBUTION

B. J. Rock, Dept. of Energy, Washington, DC
G. L. Bennett, Dept of Energy, Washington, DC
J. J. Lombardo, Dept. of Energy, Washington, DC
R. B. Morrow, Dept of Energy, Washington, DC
R. Brouns, Dept of Energy, Washington, DC
C. O. Tarr, Dept of Energy, Washington, DC
J. Griffo, Dept of Energy, Washington, DC
D. K. Stevens, Dept of Energy, Washington, DC
M. Norin, Dept of Energy, Washington, DC
G. Ogburn, Dept of Energy, Washington, DC
J. A. Yoder, Dept of Energy, Washington, DC
C. Osterberg, Dept of Energy, Washington, DC
I. Van Der Hoven, Dept of Energy, Washington, DC
R. L. Clark, Dept. of Energy, Albuquerque, NM
J. P. Crane, Dept. of Energy, Albuquerque, NM
K. Elliot, Dept. of Energy, Albuquerque, NM
D. L. Krenz, Dept. of Energy, Albuquerque, NM
J. R. Roeder, Dept. of Energy, Albuquerque, NM
R. B. Crouch, Dept. of Energy, Albuquerque, NM
J. N. Bailey, Dept. of Energy, Albuquerque, NM
H. N. Hill, Dept of Energy, Miamisburg, OH
M. J. Sires, Dept of Energy, Aiken, SC
L. C. Sjostrom, Dept. of Energy, Aiken, SC
R. J. Hart, Dept. of Energy, Oak Ridge, TN
J. Pidkowitz, Dept. of Energy, Oak Ridge, TN
W. L. Von Flue, Dept. of Energy, Oakland, CA
T. B. Kerr, NASA, Washington, DC
F. R. Schmidt, NASA, Washington, DC
E. Gabris, NASA, Washington, DC
N. Sculze, NASA, Washington, DC
B. R. McCullar, NASA, Washington, DC
J. A. Schellar, NASA, Washington, DC
Operations and Systems Requirements, NASA, Washington, DC
M. McDonald, NASA, Washington, DC
A. V. Diaz, NASA, Washington, DC
R. A. Ivanoff, NASA/JPL, Pasadena, CA
R. Campbell, NASA/JPL, Pasadena, CA
J. Casani, JPL, Pasadena, CA
D. S. Hess, JPL, Pasadena, CA
R. G. Ivanoff, PL, Pasadena, CA
L. C. Montgomery, JPL, Pasadena, CA
W. I. Purdy, Jr., JPL, Pasadena, CA
L. T. Shaw, JPL, Pasadena, CA
R. J. Spehalski, JPL, Pasadena, CA

AFISC/SNS, Attn: Col. J. A. Richardson, Kirtland AFB, NM
AFWL/NTYVS, Attn: Capt. J. D. Martens, Kirtland AFB, NM
John A. Palmer, Det 1, AFISC/SNS, Kirtland AFB, NM
Lt. Nicholas Clemens, AFWL/DYDS, Kirtland AFB, NM
Lt. Jeffrey W. Hess, AFWL/DYDS, Kirtland AFB, NM
Ralph Robinson, AFWL/DYDS, Kirtland AFB, NM
Maj. Terry Schmidt, AFWL/NTYV, Kirtland AFB, NM
Lt. Michael K. Seaton, AFWL/DYVS, Kirtland AFB, NM
Maj. R. O. Winchester, Det 1, AFISC, Kirtland AFB, NM
Capt. James D. Martens, AFWL/DYVS, Kirtland AFB, NM
Maj. R. E. Beatty, HQ AFSC/IGF, Andrews AFB, Washington, DC
Maj. Dave Daniels, HQ AFSC/IGF, Andrews AFB, Washington, DC
Col. William Licht, ATSD/AE, Washington, DC
Lt. John Erb, ESMC/SGPH, Patrick AFB, FL
L. J. Ullian, ESMC/SE, Patrick AFB, FL
Dr. W. Keesler, AFML/MPE, Wright-Patterson AFB, OH
Lt. Douglass Zimmerman, Wright-Patterson AFB, OH
Lt. Col. Mel Nosal, AFISC/SES, Norton AFB, CA
Lt. Col. Ken Morrison, AFISC/SES, Norton AFB, CA
Maj. Walt Wilson, AFISC/SEM, Norton AFB, CA
John Marshall, AFRPL/LKC, Edwards AFB, CA
Lt. Col. William B. Moyer, AFMSC/SGPZ, Brooks AFB, TX
W. Riley, WSMC/SE, Vandenberg AFB, CA
Capt. Charles Snow, SAMSO/SE, Los Angeles, CA
HQ Space Div./YLVS, Attn: Lt. Col. Needham, Los Angeles, CA
R. L. Folger, SRL, Aiken, SC
J. Howell, SRL, Aiken, SC
J. B. Mellen, SRP, Aiken, SC
G. W. Wilds, SRP, Aiken, SC
D. Nichols, SRP, Aiken, SC
D. Bickford, SRP, Aiken, SC
J. R. McClain, MRC, Miamisburg, OH
W. T. Cave, MRC, Miamisburg, OH
W. Amos, MRC, Miamisburg, OH
E. W. Johnson, MRC, Miamisburg, OH

R. Cooper, ORNL, Oak Ridge, TN
 C. Alexander, BCL, Columbus, OH
 E. E. Rice, BCL, Columbus, OH
 J. Hagan, APL, Baltimore, MD
 R. W. Englehart, NUS Corp., Rockville, MD
 H. H. Van Tuyl, PNL, Richland, WA
 A. Schock, Fairchild-Hiller Ind., Germantown, MD
 C. W. Whitmore, GE, Philadelphia, PA
 C. T. Bradshaw, GE, Philadelphia, PA
 R. Kelley, GE, Philadelphia, PA
 R. Hemler, GE, Philadelphia, PA
 V. Haley, GE, Philadelphia, PA
 R. Hartman, GE, Philadelphia, PA
 W. Mecham, ANL, Argonne, IL
 D. C. Anderson, Teledyne Energy Systems, Timonium, MD
 Dr. Marvin Goldman, University of California, Davis, CA
 Charles Smith, Sandia National Laboratories, Albuquerque, NM
 R. Harner, Sandia National Laboratories, Albuquerque, NM
 J. Calek, Sandia National Laboratories, Albuquerque, NM
 C. M. Barnes, L. B. Johnson Space Center, NASA SPS, Houston, TX
 R. H. Brown, L. B. Johnson Space Center, NASA FM, Houston, TX
 R. G. Rose, L. B. Johnson Space Center, NASA FA, Houston, TX
 Harold Battaglia, L. B. Johnson Space Center, NASA PF, Houston, TX
 W. H. Boggs, J. F. Kennedy Space Center, NASA, DE-A, Kennedy Space Center, FL
 Lloyd Parker, J. F. Kennedy Space Center, NASA, SF, Kennedy Space Center, FL
 George M. Marmaro, J. F. Kennedy Space Center, NASA, MD-ESB, Kennedy Space Center, FL
 W. A. Riehl, Marshall Space Flight Center, NASA, EH 31, Marshall SFC, AL
 W. C. Pitts, NASA, STPM, Ames Research Center, Moffett Field, CA

J. J. Givens, Ames Research Center, Moffett Field, CA
 R. Corridan, Ames Research Center-NASA, Moffett Field, CA
 J. C. Robinson, Langley Research Center, NASA, MS 395, Hampton, VA
 G. J. Schaefer, Jr., Lewis Research Center, NASA, MAIC 500-120, Cleveland, OH
 R. C. Turkolu, TRW, Defense and Space Systems Group, Redondo Beach, CA
 D. Eaton, European Space Research and Technology Centre, Zwarteweg 62, Njordwijk, The Netherlands
 Dr. Ralph R. Fullwood, Science Applications, Inc., Palo Alto, CA
 D. Glenn, The Aerospace Corporation, Los Angeles, CA
 Dr. William Ailor, The Aerospace Corporation, Los Angeles, CA
 T. Carter, Nuclear Regulatory Commission, Washington, DC
 C. R. Chappell, Nuclear Regulatory Commission, Washington, DC
 D. Egan, Office of Radiation Programs, USEPA, Washington, DC
 W. J. Maraman, Los Alamos National Laboratory, Los Alamos, NM
 R. N. R. Mulford, Los Alamos National Laboratory, Los Alamos, NM
 W. F. Miller, Los Alamos National Laboratory, Los Alamos, NM
 R. J. Pryor, Los Alamos National Laboratory, Los Alamos, NM
 G. R. Waterbury, Los Alamos National Laboratory, Los Alamos, NM
 S. E. Bronisz, Los Alamos National Laboratory, Los Alamos, NM
 R. A. Kent, Los Alamos National Laboratory, Los Alamos, NM
 W. Stark, Los Alamos National Laboratory, Los Alamos, NM
 R. W. Zocher, Los Alamos National Laboratory, Los Alamos, NM
 J. A. Pattillo, Los Alamos National Laboratory, Los Alamos, NM

[illegible]

Fig. 1. GPHS project schedule. The schedule for the DIT-1.5 impact will require 14 wks.

(a)

(b)

(c)

(d)

Fig. 2. All four of the DIT-1 iridium capsules deformed similarly. (a) IRG-101, (b) IRG-102, (c) IRG-103, and (d) IRG-104; 1.5X.

(a)

(b)

Fig 3 The corner bending strain is characteristic of the side on impact of a GPHS module (a) capsule IRG 101, nonvented end up and impact face to left, and (b) capsule IRG 103, vent end up and impact face to right, 1 9X

Fig 4 The corner bend region of capsule IRG 101 had a completely recrystallized structure, 50X

(a)

(b)

(c)

(d)

Fig. 5. All four iridium capsules were cracked in the reverse-bend region of the impact face. (a) IRG-101, (b) IRG-102, (c) IRG-103, and (d) IRG-104; $\sim 8\times$.

Fig. 6. The cracks in the weld of capsule IRG 101 were intergranular and extended through about a third of the capsule wall, 50X

Fig. 7. The intergranular cracks in the weld of capsule IRG 102 extended through 40% of the wall thickness, 50X

(a)

(b)

Fig 8. IRG 103 was cracked in both (a) the weld and (b) the base metal, 50X

(a)

(b)

Fig 9 The cracks in IRG 104 were the most extensive of those in the DIT 1 capsules both in (a) the weld and (b) the base metal, 50X

Fig. 10. LWRHU G-load test assembly.

(a)

(b)

(c)

Fig 11 The $^{238}\text{PuO}_2$ pellet HPZ 59 4 following removal from an aquarium containing salt water (a) face, (b) cylindrical surface, and (c) internal crack surface, 2X

(a)

Fig. 12. Typical microstructure of the surface of pellet HPZ-59-4. (a) 100X, (b) 250X.

(b)

(a)

(b)

(c)

Fig. 13. The $^{238}\text{PuO}_2$ pellet HPZ-111-1 following removal from an aquarium containing deionized water. (a) face, (b) cylindrical surface, and (c) internal crack surface; 2X.

(a)

**Fig. 14. Typical microstructures at the surface of pellet HPZ-111-1.
(a) 100X, (b) 250X.**

(b)

(a)

(b)

Fig. 15. Second phase deposits in pellet HPZ-111-1. (a) crack surface; 250X, and (b) pores; 500X.

Printed in the United States of America
Available from
National Technical Information Service
US Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Microfiche \$3.50 (A01)

Page Range	Domestic Price	NTIS Price Code	Page Range	Domestic Price	NTIS Price Code	Page Range	Domestic Price	NTIS Price Code	Page Range	Domestic Price	NTIS Price Code
001-025	\$ 5.00	A02	151-175	\$11.00	A08	301-325	\$17.00	A14	451-475	\$23.00	A20
026-050	6.00	A03	176-200	12.00	A09	326-350	18.00	A15	476-500	24.00	A21
051-075	7.00	A04	201-225	13.00	A10	351-375	19.00	A16	501-525	25.00	A22
076-100	8.00	A05	226-250	14.00	A11	376-400	20.00	A17	526-550	26.00	A23
101-125	9.00	A06	251-275	15.00	A12	401-425	21.00	A18	551-575	27.00	A24
126-150	10.00	A07	276-300	16.00	A13	426-450	22.00	A19	576-600	28.00	A25
									601-up	†	A99

†Add \$1.00 for each additional 25-page increment or portion thereof from 601 pages up.

Los Alamos