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Monthly Progress Report
Heat Source Technology Program
August 1993

Compiled by
T. G. George

MONTHLY PROGRESS REPORT
HEAT SOURCE TECHNOLOGY PROGRAM
AUGUST 1993

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MONTHLY PROGRESS REPORT

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ABSTRACT

This monthly report describes activities performed in support of Cassini fueled-clad production and studies related to the use of $^{238}\text{PuO}_2$ in radioisotope power systems carried out for the Office of Special Applications of the US Department of Energy (DOE) by Los Alamos National Laboratory (LANL). Most of the activities described are ongoing; the results and conclusions described may change as the work progresses.

I. HEAT SOURCE AND FEED POWDER SHIPMENTS

In mid-May, LANL received a PAT-1 cask that contained six fuel samples from the former Soviet Union. The fuel samples were analyzed to verify that the stated quantities of nuclear material were correct. All verification measurements were complete by 1 June. Additional samples were submitted for analysis to verify the accuracy of analytical results provided with the sample.

In mid-August, a small fuel sample was received from British Nuclear Fuels Limited (BNFL). The BNFL fuel sample will be analyzed to determine its composition and properties.

A shipment of recharacterization/product qualification fuel was received from Westinghouse Savannah River Company (WSRC) at the beginning of June. Processing of this fuel was delayed by a special nuclear material (SNM) inventory, until 10 August.

II. IRIDIUM HARDWARE SHIPMENTS AND INVENTORY

During August, one shipment of GPHS iridium components was received from Martin Marietta Energy Systems Y-12 (MMES/Y-12). The LANL inventory of GPHS hardware available for the Cassini mission, as of August 31, is shown in Table I.

Table I. LANL Inventory of Cassini GPHS Iridium Hardware

<u>Type of Hardware</u>	<u>Category</u>	<u>Number of Items in Inventory</u>
PICS*	Prime	33
PICS	Restricted	18
Type II Weld Shields	Prime	64

*PICS = Post-Impact Containment Shell

III. FACILITIES

A. General

During the month of August, programmatic activities continued to be hampered by a shortage of Radiological Control Technicians (RCTs). However, by the end of the month the assignment of RCTs to the Cassini program had been established as a facility priority.

On 30 August an unusual occurrence in the ^{239}Pu -area of building PF-4 resulted in a facility-wide "stand down." The "stand down" was expected to remain in effect pending the establishment of a more formal work control process.

B. Launcher Relocation

During August, work continued on construction of an addition to PF-4 to house the relocated launcher and on a number of related procurements.

1. Construction Activities

At the beginning of August, installation of forms for the fourth pour of concrete for the launcher addition's interior and exterior walls was completed. The concrete was poured and by mid-month all forms had been removed from the fourth level.

The installation of gang forms for the fifth concrete pour was initiated. Placement of forms for the interior walls was complicated by the geometry required to allow for installation of roof beams and supports for the bridge crane. By the end of the month, however, all reinforcing steel and a majority of the gang forms had been emplaced.

Fabrication of the bridge crane fabrication was completed by the vendor. Although the crane is ready for shipment it cannot be installed until after the roof for the launcher addition has been poured. Support beams for the bridge crane rails were received by the end of the month and will be installed before the roof is poured.

2. Procurements

The Laboratory's Materials Management (MAT) Division previously issued a purchase request (PR) for blast doors to cover both entryways from PF-4 into the launcher addition. MAT concluded a purchase agreement for procurement of the blast doors in June. As part of this agreement, the vendor was tasked with supervising door installation.

Bids for the filter train that will be used in the launcher addition's heating, ventilation, and air conditioning (HVAC) system were received in August.

A PR was issued in July for procurement of the Supervisory Control System (SCS) that will control launcher operations. During August, specifications for the analog input module and one of the output modules were modified and forwarded to the vendor.

3. Administrative Requirements

Work continued on revising launcher safe operating procedures (SOPs) and on writing training plans.

C. Glovebox for GPHS Encapsulation Welding

Installation of the glovebox designed for GPHS encapsulation welding was completed in May 1992. A Safety and Technical Assessment for Readiness of Technology (START) review of the welding operation was completed in mid-September 1992, and approval for process start-up was received on 21 September. Subsequent legal and managerial reviews indicated that a maximum of 2.5 kg of ^{238}Pu could be processed each month without exceeding the established baseline for TA-55 emissions. On the basis of this finding, it appears that processing a maximum of 20 fueled-clads per month has no implications with respect to current National Emission Standards for Hazardous Air Pollutants (NESHAP).

D. Metallography and Ceramography Glovebox Lines

All of the gloveboxes in the metallography and ceramography lines have been installed and wired for electric power. A bench-top metallographic facility for "cold" (uncontaminated) specimens was activated previously and has been used to support fueled-clad weld-process development.

Work on a facility ventilation upgrade (to service open-front hoods in the ceramography and metallography glovebox lines) was completed in June. However, efforts to leak test and seal the ventilation ducts continued through August. The ventilation upgrade was not expected to be operational until mid-September.

E. Sieve Analysis Gloveboxes

Two gloveboxes designed to house the sieving and particle size analysis operations were previously installed and prepared for use. NMT-9 requested a START review of these gloveboxes on 9 April, and a START review team convened on 30 April. On the basis of an inspection, the START review team identified 11 findings that must be addressed before the gloveboxes are approved for use. All of the findings associated with the START review were addressed by 9 June. On 13 August, approval was received to commence operations in these gloveboxes.

IV. GENERAL-PURPOSE HEAT SOURCE

A. Preproduction Activities

1. Operational Readiness Evaluation (ORE)

A Cassini production ORE was conducted at LANL on 16–20 November 1992. Also present was a DOE Environment & Health audit/review team that acted in an oversight capacity. The ORE was closed out on 20 November, with six findings to be resolved prior to the start of Cassini heat source production. The work required to close all six findings was completed by the end of May. Packages on five findings were then forwarded to the DOE's Los Alamos Area Office (DOE/LAAO) and Albuquerque Operations Office (DOE/AL) for formal closure. Submittal of a package for the sixth finding was delayed. A transmittal memo from the team leader of the Operational Readiness Review (performed before the ORE) is required before the package for the sixth finding can be submitted to DOE for review and approval.

2. GPHS Fuel Powder, Pellet, and Fueled-Clad Specifications

The $^{238}\text{PuO}_2$ fuel powder acceptance specification, the GPHS fuel pellet specification, and the GPHS fueled-clad specification were previously distributed to the Office of Special Applications (OSA), EG&G MAT, MMES/Valley Forge (MMES/VF), Oak Ridge National Laboratory (ORNL), and WSRC for review, as required by the Interface Working Agreement (IWA). Seven organizations/individuals provided comments on the draft specifications by the deadline of 7 May. These comments will be addressed in subsequent specification revisions.

3. Development of Process Procedures

Three revisions of existing process procedures were submitted to DOE/NE-53 for review, and were approved.

4. Fueled-Clad Weld Development

Three $^{238}\text{PuO}_2$ fuel pellets were successfully encapsulated on 29 June. All three capsules were assembled with Type II (final design) weld-shields. Initial postweld examination did not reveal any weld defects or anomalies, and all of the capsules easily passed through the acceptance ring gauge.

Although we had planned to immediately decontaminate and ultrasonically examine all three capsules, a shortage of radiological control technicians (whose presence is required during both operations) delayed decontamination of the three capsules until mid-August. The results of the three ultrasonic examinations, along with results from a fueled clad welded previously (FC0002) are shown in Table II. None of the ultrasonic scans indicated the presence of significant weld defects.

5. Fueled-Clad Ultrasonic Test Development

On 15 April, LANL hosted a meeting of the GPHS Welding/Ultrasonic Testing (UT) Working Group. The primary outcome of this meeting, which was attended by representatives from DOE/NE-53, WSRC, EG&G MAT, MMES/Y-12, Westinghouse Advanced Energy Systems (WAES), MMES/VF, and Fairchild Space Company (FSC),

was the development of a detailed plan and schedule to ensure that a viable UT system would be in place and operational before the start of Cassini production.

The UT results obtained in August (see Table II) suggested that while significant progress had been made, the "top scan" evaluation technique would still classify an unacceptable number of capsules as "nonconforming." Consequently, the focus of the development effort shifted to the evaluation of alternate UT technologies and other nondestructive examination techniques that could be used to further analyze capsules designated as "nonconforming."

Table II. Ultrasonic Test Results*

Fueled Clad	"Top-Scan" Results			Conventional Scan		
	Rating	Max. Indication		Rating	Max. Indication	
		Size (eq.-mils)	Location (deg)		Size (eq.-mils)	Location (deg)
FC0002	Accept	4.3	236.5	Reject	5.9	60.0
FC0003	Accept	2.9	59.5	-	-	-
FC0004	Accept	2.8	263.0	-	-	-
FC0005	Reject	5.7	230.0	-	-	-

*All results are based on a 5.2 eq.-mil acceptance criterion

6. Cold Process Verification (CPV) Tests

The CPV test series was designed to verify that the welding process for simulant-fueled ("cold") capsules had been optimized and to quantify the impact responses of the hot-pressed, and cold-pressed and sintered, urania fuel-simulants.

All simulant-fueled clads required for the CPV test series were welded previously. Eight capsules were loaded with hot-pressed urania (^{235}U -depleted) fuel-simulant and seven capsules were loaded with cold-pressed urania. UT examination performed with the existing Panametrics system indicated that the welds in nearly three-quarters of the capsules (11 of 15) contained indications that exceeded the proposed UT acceptance criterion.

a. CPV-1. On 28 September 1992, the first impact in the CPV series was completed. In this test (CPV-1), capsule SC0011, which had been loaded with a hot-pressed urania pellet, was impacted against a steel plate at 55.0 ± 1.0 m/s and 1092°C . The iridium hardware used for this capsule was Z-batch material produced for the Galileo and Ulysses missions. Postimpact examination of capsule SC0011 revealed that the clad had breached as a result of a fuel fragment push-through. Details of the clad failure, metallographic examination of selected clad sections, and a sieve analysis of fuel retained in the capsule were documented in previous monthly reports.

In this month, particle sizing of fines released from capsule SC0011 and of the $\leq 45\mu\text{m}$ fraction of the retained fuel-simulant was delayed by a START review of the sieve analysis gloveboxes (see section IIIE) and by a malfunction of the computer used to control the particle size analyzer. However, by the end of the month new software had been ordered from the instrument manufacturer and the particle size analyzer was expected to be operational by 3 September.

b. CPV-2. On 4 December 1992, capsule SC0008, which had been loaded with a hot-pressed urania pellet, was impacted against a steel plate at 55.0 ± 1.0 m/s and 1090°C . The iridium hardware used for this capsule was designated as "Prime" and was from the D2 batch. Postimpact examination revealed that although the capsule had two small transverse cracks on the cup radii at the edges of the impact face, no urania had been released. Details of the clad deformation, metallographic examination of selected clad sections, and a sieve analysis of fuel retained in the capsule were documented in previous monthly reports.

Particle sizing of the $\leq 45\mu\text{m}$ fraction of the retained fuel-simulant was delayed by a START review of the sieve analysis gloveboxes (see Section IIIE) and by a malfunction of the particle size analyzer.

c. CPV-3. On 26 February 1993, capsule SC0004, which had been loaded with cold-pressed and sintered urania fuel-simulant, was impacted against a steel plate at 55.0 ± 0.1 m/s and 1090°C . The iridium hardware used for this capsule was designated as "Prime" and was from the D2 batch. Postimpact examination revealed that although the capsule contained two small transverse cracks on the cup radii at the edges of the impact face, no urania had been released. Details of this initial examination were documented in previous monthly reports.

In this month we continued with the metallographic examination of selected clad sections.

d. CPV-4. On 5 March, capsule SC0020, which had been loaded with cold-pressed and sintered urania fuel simulant, was impacted against a steel plate at 55.3 ± 0.2 m/s and 1090°C . The iridium hardware used for this capsule was X- and YR-batch material (vent cup ID, X342-2; shield cup ID, YR421-1) produced for the Galileo and Ulysses missions. Postimpact examination revealed that capsule SC0020 had been breached by several cracks and that a small amount of urania was released into the tantalum containment vessel. Details of this initial examination were documented in previous monthly reports.

In this month we made no progress on the CPV-4 postmortem examination.

e. CPV-5. On 15 June, capsule SC0017, which had been loaded with cold-pressed and sintered urania, was impacted against a steel plate at 55.3 ± 0.1 m/s and 1090°C . The iridium hardware for this capsule was designated as "Prime" and was from the D2 batch. Postimpact examination revealed that capsule SC0017 had breached, and that a small quantity of urania had been released. Details of this initial examination were documented in previous monthly reports.

In this month we made no progress on the CPV-5 postmortem examination.

f. CPV-6. On 29 June, capsule SC0018, which had been loaded with cold-pressed and sintered urania, was impacted against a steel plate at 55.0 ± 1.0 m/s and 1090°C . The iridium hardware used for this capsule was designated as "Prime" and was from the CR3 batch. Postimpact examination of the impacted capsule revealed that while a network of

hairline axial cracks was visible on the impact face, no urania was released. Details of this initial examination were documented in previous monthly reports.

In this month we made no progress on the CPV-6 postmortem examination.

g. CPV-7. On 13 July, capsule SC0019, which had been loaded with cold-pressed and sintered urania, was impacted against a steel plate at 55.3 ± 0.1 m/s and 1090°C. The iridium hardware used for this capsule was X- and YR-batch material (vent cup ID, X340-4; shield cup ID, YR427-6) produced for the Galileo and Ulysses missions. Postimpact examination revealed that the capsule exhibited a centerline weld failure on the trailing face; however, no urania was released into the tantalum containment vessel. Details of this initial examination were documented in previous monthly reports.

In this month we made no progress on the CPV-7 postmortem examination.

7. Production Qualification

A shipment of recharacterization/product qualification fuel was received from Westinghouse Savannah River Company (WSRC) at the beginning of June. The amount of ^{238}Pu received in this shipment (1.2 kg) was sufficient to produce nine GPHS fuel pellets, assuming an overall process yield $\geq 84\%$.

Fuel processing was delayed by a special nuclear material (SNM) inventory, until 10 August. At the conclusion of the SNM inventory, processing began on the fuel powder that will be used to produce three pellets. These initial pellets are not part of the product qualification effort and are intended only to demonstrate that the new Savannah River feed material can be successfully processed using established process parameters.

B. Cassini Fueled-Clad Production

There was no activity during August.

C. Safety Test Program

There was no activity during August.

D. Research and Development

1. High-Temperature Mechanical Properties of Urania Fuel Simulant

In this month, we continued to compile data and results from compression tests of both the hot-pressed and grain-stabilized (HPGS), and cold-pressed and sintered (CPS), urania. Our preliminary conclusions are listed below:

- ◆ Both urania processing techniques produce a material that appears to be an acceptable simulant for $^{238}\text{PuO}_2$ in engineering system studies, including impact, vibration, or overpressure tests. Yield and ultimate strengths for both materials match the ultimate strength of plutonia over the temperature range 900°C–1400°C.
- ◆ The yield and ultimate strengths of the HPGS and CPS material are equivalent at strain rates of $2.5 \times 10^{-4} \text{ s}^{-1}$ and $.1 \text{ s}^{-1}$.

- ◆ Based on the work described in the literature, and on our own metallographic observations, we believe that the urania exhibits significant deformation by classic dislocation activity. Published results indicate that dislocation activity begins at about 800°C. It has been found that {110} and <110> are the slip plane and direction, respectively.
- ◆ The stress/strain data that we have generated from tests of HPGS urania supports the idea of a plastic deformation mechanism. A work-hardening stress/strain response is observed up to strains of approximately 10% for many of the tested conditions. We have also observed a moderate strain rate sensitivity when stable work hardening occurs. In these cases we measured a work hardening exponent of $m = 0.3$ using the law,

$$\sigma_1/\sigma_0 = (\epsilon_1/\epsilon_0)^m$$

An m value of approximately 0.03 is indicative of dislocation-based deformation mechanisms. If the primary deformation mode is grain boundary sliding, the expected value of m is at least 0.3.

- ◆ We have examined optical micrographs from cross sections of HPGS specimens deformed at 1300°C and 1400°C, at both the high and low strain rate. There was no microstructural evidence that the specimens deformed by microcracking at the grain boundaries. Rather, when cracks did form they tended to propagate over long distances.
- ◆ Our stress/strain measurements indicate that at high strain rates and low temperatures ($\leq 1100^\circ\text{C}$), the amount of plastic deformation in both types of urania is substantially restricted. The data imply that under impact strain rates the materials should behave in a brittle fashion. Further work, beyond the scope of these experiments, should be done with the Hopkinson pressure bar to verify this conclusion.

2. High-Temperature Mechanical Properties of Graphite

Modification of the power supply used for elevated temperature graphite testing of GIS rings was completed in August. In addition, we initiated the procurement of an optical pyrometer that can be adapted for the high-temperature graphite testing.

Calibration of the pyrometer used for the high-temperature graphite testing is complicated by the fact that a mirror is used to view the test specimen through a side port on the vacuum chamber. The mirror can alter the temperature of the observed light and thereby affect the pyrometer calibration. After several attempts, we found that it was nearly impossible to come up with a suitable calibration factor that would compensate for the influence of the reflecting mirror.

By the end of August, the fabrication of a number of graphite heater elements and GIS ring specimens was also completed. We received nine specimens and two complete sets of heaters. The fabrication of additional specimens and heaters is in progress.

E. Project Management

All required weekly status reports were delivered on schedule. The program Project Management System (PMS) monthly status report (which included a data disk) was also delivered to FSC (the operator of the program PMS) on schedule.

IV. LIGHT-WEIGHT RADIOISOTOPE HEATER UNIT (LWRHU)

A. LWRHU Fuel Powder, Pellet, and Fueled Capsule Specifications

A draft version of the LWRHU product index was previously distributed to OSA, EG&G MAT, GE-ASTRO, ORNL, and WSRC, for approval, comment, or information as described in the IWA. A final version of the LWRHU product index has not been released.

B. LWRHU Weld Development

On 11 and 12 August, work on LWRHU weld development was initiated with the help of a WSRC engineer. Eight stainless steel LWRHU mockups were welded using the new welding system and various welding parameters. By the end of the month, all of the welded capsules had been forwarded for metallographic evaluation.

The immediate result of this weld campaign was a finding that the weld fixture's drive unit may not be capable of rotating the capsule at the optimal speed. A new gearbox, capable of higher rotational speeds, was ordered from the manufacturer; delivery of the new gearbox is expected by the end of September.

C. LWRHU Production

Fabrication of two urania (^{235}U -depleted) fuel-simulant pellets for LWRHU vibration tests was completed in mid-July.

V. MEETINGS AND VISITORS

Members of a MENTOR team selected by DOE/HQ were present on site throughout the month.

On 2 August, one LANL staff member attended a safety-test technical exchange meeting held at the SNLA Coyote Test Area.

A Safeguards & Security audit headed by T. McCune of DOE/DP-681 was conducted on 4 August.

A program office QA audit of the Cassini program was held at LANL from 3–5 August.

A WSRC welding engineer visited LANL from 11–12 August to participate in LWRHU weld development.

On 18 August, one LANL technical staff member supported a design review meeting at Teledyne in Hunt Valley, Maryland, for the 60 Watt Heat Source Program.

On 24 August, one LANL engineer supported a technical meeting at ORNL on the proposed disposition(s) of nonconforming PICS.

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