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*Monthly Progress Report
Heat Source Technology Programs*

December 1993

*Compiled by
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MONTHLY PROGRESS REPORT

HEAT SOURCE TECHNOLOGY PROGRAMS

DECEMBER 1993

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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 U.S. 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

The first delivery of fuel for Cassini flight-quality applications, designated as shipment 469, was received from the Westinghouse Savannah River Company (WSRC) in mid December. Calorimetry of the shipment was completed by 22 December.

II. IRIIDIUM HARDWARE SHIPMENTS AND INVENTORY

Two shipments of General-Purpose Heat Source (GPHS) iridium components were received from Martin Marietta Energy Systems Y-12 (MMES/Y-12) in December. The first shipment was inspected on 17 December, and included components designated for use in the 60-watt heat source program. Because the second shipment was received on 22 December, the hardware inspection was scheduled for 6 January. The LANL inventory of GPHS hardware, as of 31 December, is shown in Table I.

Table I. LANL Inventory of GPHS Iridium Hardware

<u>Type of Hardware</u>	<u>Category</u>	<u>Number of Items in Inventory</u>
PICS*	Prime	113
PICS	Restricted Use	55
Type II Weld Shields	Prime	213

*PICS = post-impact containment shell

III. FACILITIES

A. General

1. Institutional Support

During December, radiological control technicians (RCTs) were more frequently available to support Cassini operations than in previous months. However, steady-state Cassini production will require a higher level of RCT support.

Progress on the installation of equipment and gloveboxes required to support Cassini production continued to be delayed by the slow response of organizations responsible for work approval, scheduling, and performance.

2. Analytical Capabilities

NMT-9's H74141 calorimeter was certified by LANL's Materials Control and Accountability group (OS-2) for use in obtaining measurements for nuclear materials accountability. This calorimeter was recently modified by EG&G Mound Applied Technologies (EG&G MAT) to a gradient design.

B. Launcher Relocation

Work continued during December on construction of an addition to PF-4 to house the relocated launcher and on a number of related procurements.

1. Construction Activities

Roofing of the launcher addition was completed at the beginning of the month. By mid-month, personnel from Johnson Controls World Services, Inc. (JCI) had developed a plan and schedule for installation of structural steel elements (stairs, work platforms, support beams, etc.) within the addition. JCI personnel also began work to prepare for the installation of a gas system for the launcher addition. Construction operations required for this activity are expected to begin by 15 January, and will occur in the PF-4 basement. By 22 December, JCI personnel had completed a pre-job survey of the PF-4 basement.

A temporary heating and ventilation system was installed in the launcher addition so that interior painting could be completed. However, the start of painting was delayed by required reviews, permits, and personnel training. A JCI plan for painting the interior walls was approved by 22 December.

Work continued on the fabrication of the hangers that will be used to suspend ventilation ducts in the launcher addition.

2. Design Activities

A design review for the ductwork hangers that will be used in the launcher addition's heating, ventilation, and air conditioning (HVAC) system was completed by mid-month. As a result of this review, an architectural and engineering (A&E) contractor was assigned to rework the hanger design; the redesign effort was expected to be complete by early January.

The design for the load cell system that measures the launcher weight was reviewed and approved by the A&E contractor. The design is configured to send conditioned signals from individual load cells directly to the supervisory control system.

3. Procurements

The Laboratory's Materials Management Division (MAT) previously issued a purchase request (PR) for blast doors to cover both entryways from PF-4 into the launcher addition. In December, the vendor provided shop drawings for the blast doors to JCI. JCI reviewed and approved the drawings, and forwarded them to the A&E contractor for additional review. At the conclusion of this review MAT will formalize the new specifications with the contractor; approximately eight weeks will be required to finish the doors and ship them to Los Alamos.

At the beginning of the month an order was placed for the centrifugal fans for the launcher addition's HVAC system. However, in mid-December, the fan specification was modified to include flanges designed to mate with the existing filter trains.

MAT personnel requested that the supplier of the filter train for the HVAC system of the launcher addition provide a set of shop drawings for review. The drawings were received by mid-December, were reviewed and approved by JCI, and were submitted to the A&E contractor for review.

4. Administrative Activities

The TA-55 Facilities Management group (NMT-8) began work to obtain approval to remove equipment and perform demolition in building PF-4 to accommodate the installation of the launcher addition's HVAC system.

C. 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.

Leak testing and sealing of gloveboxes in the ceramography line (which will be used initially for metallographic evaluation of welds) were completed in early November. On 9 November, NMT-9 requested a facility-required Safety and Technical Assessment for Readiness of Technology (START) review of the glovebox line and metallography operation. A review committee was selected, and it convened on 23 November to discuss the operation and tour the facility. Committee findings and comments were required to be provided to NMT-9 by 3 December, but were not received until 15 December. Connection of gloveboxes to the ventilation system and other facility services may not be permitted until after the START review has been completed. Similarly, no operations may be conducted in the glovebox line until after completion of the review.

IV. GENERAL-PURPOSE HEAT SOURCE (GPHS) PROGRAM

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 and Health (EH) audit/review team that acted in an oversight capacity. The ORE was closed out on 20 November, with six findings to be resolved before 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. A package for the sixth finding was submitted in August.

On 9 December, the manager of DOE's Albuquerque Field Office (ALO) approved the startup of Cassini production operations at TA-55.

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 had previously been distributed to the Office of Special Applications (OSA), EG&G Mound Applied Technologies (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. Fueled-Clad Weld Development

During November, four plutonia pellets were encapsulated within clad/vent-sets. The welds on all four capsules appeared to be exemplary, and each capsule easily passed through the ring gauge. Metallographic examination of the capsule welds was postponed, pending the startup of the hot metallography line.

4. Fueled-Clad Ultrasonic Test Development

There was no activity during December.

5. 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.

Most of the 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. Ultrasonic testing (UT) 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.

The postmortem examinations of capsules tested in CPV-1 and CPV-2 were completed previously. The status of ongoing postmortem examinations are given in the following sections.

a. 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 completed the metallographic examination of selected clad sections.

b. 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 had been 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.

c. 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.

d. 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 although a network of hairline axial cracks was visible on the impact face, no 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-6 postmortem examination.

e. 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.

f. CPV-8. On 17 November, capsule SC0006, which had been loaded with a cold-pressed and sintered urania pellet, was impacted against a steel plate at 55.3 ± 0.1 m/s and 1090°C . The iridium hardware used for this capsule was designated as "Prime" and was from the CR3 batch.

g. CPV-9. On 24 November, capsule SC0015, which had been loaded with a hot-pressed and sintered urania pellet, was impacted against a steel plate at 54.5 ± 0.1 m/s and 1090°C . The iridium hardware used for this capsule was designated as "Prime" and was from the CR3 batch.

h. CPV-10. On 10 December, capsule SC0009, which had been loaded with a hot-pressed and sintered urania pellet, was impacted against a steel plate at 55.5 ± 0.2 m/s and 1090°C . The iridium hardware used for this capsule was designated as "Prime" and was from the CR3 batch.

6. Production Qualification

Because of the anomalous analytical results obtained on samples of fuel received in shipment 466 (reported previously in LA 12761-PR), hot pressing of additional fuel pellets was temporarily suspended. Similarly, seasoning of fuel granules from shipment 467, processing of fuel from shipment 468, and encapsulation of previously hot-pressed pellets, were temporarily suspended pending the outcome of additional chemical analyses.

Preliminary analytical results received by 31 December indicated that the silicon content of fuel received in shipment 467 ranged between 100 and 600 ppm, while the fuel in shipment 468 ranged between 270 and 830 ppm silicon. It should be noted, however, that analytical results were not available for all of the fuel containers received in each shipment.

Comprehensive analyses of the containers in each fuel shipment, as well as comparative analyses of archival fuel samples, were underway by 31 December, and were expected to be complete by the first week of January.

B. Cassini Fueled-Clad Production

The first delivery of fuel for Cassini flight-quality applications, designated as shipment 469, was received from the Westinghouse Savannah River Company (WSRC) in mid December.

C. Safety Test Program

There was no activity during December.

D. Research and Development

1. High-Temperature Mechanical Properties of Urania Fuel Simulant

A rough draft of a final report on the mechanical properties of cold-pressed and hot-pressed and grain-stabilized urania was completed in October. A copy of the report was forwarded to the LANL group responsible for classification and information release. After a Los Alamos unclassified report (LA-UR) number has been assigned, the rough draft of the report will be distributed.

2. High-Temperature Mechanical Properties of Graphite

There was no activity during December.

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 the Fairchild Space Company (the operator of the program PMS) on schedule.

V. LIGHT-WEIGHT RADIOISOTOPE HEATER UNIT (LWRHU) PROGRAM

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

Work continued on the LWRHU fuel powder, pellet, and fueled clad specifications.

B. LWRHU Weld Development

Metallographic examination of welds made on stainless-steel LWRHU mockups continued.

C. LWRHU Production

There was no activity during December.

D. LWRHU Performance/Safety Testing

Fabrication of two urania (^{235}U -depleted) fuel-simulant pellets for LWRHU vibration tests was completed in mid-July. Encapsulation of the urania pellets will occur after the development of "cold" weld process parameters.

Graphite components for the two simulant-fueled LWRHUs required for vibration testing were received from EG&G MAT at the end of November.

VI. 60-WATT HEAT SOURCE PROGRAM

A. Preproduction Activities

1. Equipment and Facilities

In this month, installation of the hot isostatic press (HIP) was delayed by other facility priorities. However, incremental progress was made in reconfiguring an open-front hood adjacent to the HIP unit. When the HIP unit has been connected to all building services, a factory representative will be scheduled to start up the unit and install a gas reclaim feature. After the unit has been demonstrated as operational, a facility START review will be requested. The START review must be closed out before any programmatic activities can be performed. In the interim, arrangements have been made with another LANL group for HIPing simulant-fueled clads.

2. Hardware

Personnel from the Heat Source Technology group (NMT-9) collaborated with personnel from Teledyne Brown Engineering (TBE) to outline a plan for the use of simulant pellets and previously received PICS designated for 60-watt development activities.

B. Technical Support

Work was initiated to conduct elevated temperature tensile tests of T-111 in contact with Hastelloy alloys. Several preliminary experiments were performed to assess the susceptibility of T-111 to liquid-metal embrittlement, and the useful lifetime of T-111 components subject to such conditions. The condition of interest was T-111 in contact with Hastelloy-X at 1350°C. The binary constituents of these materials, Ta and Ni, form a eutectic at 1350°C. This investigation was designed to determine if the eutectic would form when these alloys were held in mechanical contact, and then, if a liquid eutectic did form, if the T-111 would be subject to liquid-metal embrittlement.

We obtained a 1-foot length of 0.375-in. diameter T-111; although the material was known to be T-111, we were not able to obtain a certified material pedigree. Tensile bars with threaded ends were cut from this stock. A reduced section (0.25in x 0.0625in cross section, 1.5in long) was machined into each of the tensile bars.

Material testing was performed in a vacuum furnace mounted on a conventional screw-driven Instron tensile testing machine. This furnace was configured to load tensile specimens with threaded ends. It used tungsten curtain heating elements and was capable of operating at temperatures up to 1850°C.

An initial tensile experiment was conducted at 1350°C to establish the yield stress and elongation of the material, and to determine the 0.2% offset yield strength (which proved to be 244MPa). The uniform elongation in this specimen was 28%. The region of uniform elongation was terminated by the development of many fine grain boundary cracks.

A second tensile bar was used for the stress corrosion experiment. Two 0.25in x 0.25in sheets (0.025in thick) of Hastelloy-X were attached to the front and back of the tensile bar in the center of the gage (reduced cross section) section. The sheets were held in place mechanically with a loop of Hastelloy wire. The surfaces of the Hastelloy sheet were

ground flat, with 600 grit paper, to assure a large area of contact between the Hastelloy and T-111. Shallow notches in the Hastelloy sheet prevented the Hastelloy wire from slipping. The tensile bar for the stress corrosion experiment was mounted in the tungsten vacuum furnace, and a sheet of molybdenum foil was wrapped around the coupling fixtures. The foil contained a small hole for insertion of a furnace control thermocouple. The purpose of the foil was to contain any vapor species that could possibly be generated in the course of the experiment. The foil tube also acted as a radiant black body to insure the specimen and thermocouple were at the same temperature.

The stress corrosion experiment consisted of loading the specimen to 3/4 of the previously determined yield stress and holding the specimen at this load while a temperature profile was run. We used two phenolic cams, mounted on the Instron chart recorder, with microswitches to hold the load nearly constant. When the microswitches were activated by a cam the crosshead was moved to either load or unload the specimen. Thus, we could not hold the specimen at a rigorously constant load but rather the specimen was cycled between 183 and 167MPa. Once a stable load cycle had been achieved, the specimen was heated to 1350°C in 15min and then held at constant temperature.

After 15 min at temperature the load began to drop rapidly. With a preset maximum displacement rate of 0.02in./min the machine was unable to keep up with this decrease even though the specimen did not fail catastrophically until the load had dropped to approximately 20MPa. At this point the experiment ended.

Post-test examination of the test specimen revealed that the Hastelloy-X and T-111 did form a liquid at the test temperature. The specimen had been wet with the liquid where it and the Hastelloy had been in contact. The partially melted Hastelloy sheets slid to the base of the specimen and it was there that the ultimate fracture occurred. The fracture surface itself was also coated with the liquid eutectic. The surfaces of the specimen that had been in contact with the liquid metal contained a series of cracks. The cracks were both on the gage section flats and edges. One should note that there was no cracking where the liquid metal had not been present.

In summary, the T-111 and Hastelloy-X did form a eutectic liquid at 1350°C, and contact with the liquid metal produced embrittlement in the T-111. However, the embrittlement was not instantaneous, and the T-111 was able to support a load of 3/4 of the yield strength for at least 15min.

VII. 1-kW Shipping Container

A. Container Opening Facility

A lathe for opening the secondary container was installed in drop-front hood XB201. Although additional modifications will be required before the 1-kW secondary can be opened in XB201, the container can be opened manually until these modifications are complete. A list of the modifications required to complete installation of the opening system, along with estimates of completion dates, is given below.

- Fabricate a rail/trolley system; estimated completion date: 1/7/94.
- Fabricate a door for XB201; estimated completion date: 1/17/94
- Install XB201 door and rail/trolley system; estimated completion date: 1/31/94.

B. Container Welding Facility

A glovebox designed to house the 1-kW welding fixture, as well as the weld fixture, power supply, and controller were delivered to LANL. Design work required for installation of the glovebox and welding equipment was initiated by 31 December. LANL personnel also began work on a transport/manipulation system for the secondary container used in the 1-kW cask.

VII. PROGRAMMATIC MEETINGS AND VISITORS

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

Two LANL personnel attended the 60-watt reference design review at TBE on 7 December, and the Cassini quarterly program review held at FSC on 8 December.

During the week of 13 December, two QA personnel from Westinghouse Advanced Technologies visited LANL, and a WSRC chemist witnessed the sampling of six powder lots.

**DATE
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6/29/94

END