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Quarterly Report
Heat Source Technology Program
January – March 1993

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QUARTERLY REPORT HEAT SOURCE TECHNOLOGY PROGRAM

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ABSTRACT

This quarterly report describes activities performed in support of Cassini fueled-clad production and studies related to the use of $^{238}\text{PuO}_2$ in radio-isotope 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

A PAT-1 cask, allocated for shipment of a fuel sample from the former Soviet Union, was transported from LANL to EG&G Mound Applied Technologies (EG&G MAT) in November 1992. EG&G MAT then forwarded the PAT-1 cask and a 1-KW cask to the Soviets. LANL personnel supported planning meetings to discuss handling of shipments from the former Soviet Union upon their arrival in the United States. Samples of the first shipment of material from this source were expected in the near term.

II. FACILITIES

A. Launcher Relocation

During this quarter, work continued on an addition to building PF-4 to house the relocated launcher. Significant progress was made on construction of the addition, on the installation of required services, on design of an heating, ventilation, and air conditioning (HVAC) system, and on procurement of required support items. A site map that shows the location of the launcher addition may be seen in Fig. 1, and an architectural section of the completed addition is shown in Fig. 2.

Fig. 1. Site map showing the location of the launcher addition.

Fig. 2. Architectural section of the completed launcher addition.

1. Construction Activities

The foundation for the launcher addition was poured in mid-December 1992. In January and February of 1993, external gang forms intended to permit pouring of the first level of walls were installed on the foundation base, and rebar assemblies for the wall sections were positioned within the forms. The concrete pour for the first level of interior and exterior walls (to the 11-ft level) was completed in March. All gang forms for the first level of walls were removed after completion of the pour, and a subsequent inspection performed by personnel from LANL's Facilities Engineering (ENG) Division revealed that the walls were of acceptable quality. By the end of the quarter, rebar assemblies for four wall sections had been emplaced (to the 24-ft elevation) and fasteners for a second level of gang forms had been attached to the tops of the first level walls.

In early January a second index hole was bored through the PF-4 wall. Both the index hole bored in December 1992 and this latest penetration will be used to precisely locate subsequent construction.

Cutting of penetrations between the launcher addition and building PF-4 began on 25 January and was complete by 17 February. Openings for doors and ventilation ducts were cut at two levels and the cut sections were removed. Because the concrete cores removed from the PF-4 wall were classified as "potentially contaminated," their removal from the site was complicated by rules pertaining to the disposal of contaminated waste. However, by the end of the quarter the cores had been removed.

The TA-55 Facility Management Group (NMT-8) completed most of the demolition work in the PF-4 basement that was required prior to the start of the HVAC system installation. By the end of the March, Johnson Controls World Services, Inc. (JCI) had requested and

received authorization to begin installing the electrical services required for the HVAC system.

2. Procurements

LANL's Materials Management (MAT) Division issued a purchase request (PR) for blast doors to cover both entryways from PF-4 into the launcher addition. However, before bids on the PR were received, a number of potential vendors raised questions related to the technical specifications. The proof test specified in the original PR (10 psig) was considered to be extreme in relation to the maximum working pressure of 0.6 psig. As a result, the architecture and engineering (A&E) contractor revised the proof test specification to 1 psig and added a leak rate specification. By 31 March, a draft of the revised technical specification had been distributed for vendor review.

Personnel from JCI and LANL's ENG Division reviewed draft copies of specifications for the HVAC system and also a quality assurance (QA) plan. As a result of these reviews, ENG personnel revised the specifications to meet applicable seismic requirements and to clarify several items.

Bids from system integrators for fabrication of the Supervisory Control System (SCS) that will control launcher operations were reviewed in February. However, the original technical specification was revised to clarify items questioned by potential vendors. The revised specification was returned to MAT by mid-March.

In February, MAT released an integrated PR for purchase and certified installation of a bridge crane. However, the rail support beams proposed by the vendor were of a different configuration than the supports designed by the A&E contractor. In March a structural reevaluation of the bridge-crane support structure was completed. As a result, an I-beam design for the support beams was selected that will require only minor structural modifications. In addition, preliminary design work was completed for a lifting yoke that will be used to set the launcher on the launcher stand. The yoke will provide a few meters of excess clearance; consequently, no additional facility modifications will be necessary. Unfortunately, a number of unresolved legal issues between the vendor and LANL caused MAT to place a hold on the purchase request for procurement and installation of the bridge crane.

By the end of March, a PR for procurement of a dumbwaiter had been placed.

B. Glovebox for General-Purpose Heat Source (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. However, because LANL may not be in compliance with current National Emissions Standards for Hazardous Air Pollutants (NESHAPS), a temporary limit was imposed that permits welding only six fueled-clads per month. By the end of January, an application to increase that limit to a maximum of 18 fueled-clads per month had been prepared. Submission of this application was subsequently placed on hold pending legal and managerial reviews to determine whether an application was, in fact, required.

C. Metallography and Ceramography Glovebox Lines

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

In early November 1992, work on a facility ventilation upgrade (to service open-front hoods in both lines) was stopped by the Laboratory's QA organization because of concerns with seismic qualification of the upgrade and duct welding procedures. Concerns associated with duct welding were resolved by early December, and the issue of seismic qualification was resolved by the end of January. Work on the ventilation upgrade resumed on 22 February and was expected to be complete by 9 April.

III. 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. By the end of March, all six findings were actively being addressed and the work required to close four findings had been completed.

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, General Electric Astro Space (GE-ASTRO), Oak Ridge National Laboratory (ORNL), and Westinghouse Savannah River Company (WSRC) for review, as required by the Interface Working Agreement (IWA).

3. Development of Process Procedures

A compilation of process procedures titled "Quality Assurance Procedures for Flight Quality Cassini Fueled-Clads," was distributed on a controlled-copy basis internally and externally as required by the IWA. The compilation will be updated to reflect subsequent procedure revisions only after DOE/OSA approval.

4. Fueled-Clad Weld Development

The first encapsulation weld over $^{238}\text{PuO}_2$ was performed in September. The capsule (FC0002) was successfully decontaminated and forwarded for a helium leak check, ultrasonic testing (UT), dimensioning, and neutron-emission measurement. Although all test results indicated that the weld was satisfactory, subsequent encapsulations were postponed until after this fueled-clad had been metallographically examined.

5. Evaluation of Alternate Weld-Shield Designs

On 17 March, LANL and WSRC personnel welded two GPHS capsules (WT-37 and WT-38) using type-II weld-shields and fragmented simulant (lavite) pellets. The lavite pellet used in capsule WT-37 was composed of two fragments, and the WT-38 pellet had been broken into four pieces (Fig. 3). In both tests, the weld-shields performed as designed by guiding the pellet fragments into the weld-shield cup, and retaining the reassembled pellet. After encapsulation welding and UT, both capsules were forwarded to WSRC for use in additional UT development.

6. Fueled-Clad Ultrasonic Test (UT) Development

Previously, LANL had requested that two Galileo-era fueled-clads with UT indications of interest be shipped from EG&G MAT to Los Alamos. This shipment occurred in late December. However, examination of the as-received fueled-clads revealed that the vent covers had

Fig. 3. A lavite pellet broken into four pieces was successfully welded into capsule WT-38.

been removed. Subsequent discussions with EG&G MAT personnel revealed that the vent covers had been removed before shipment to comply with the current interpretation of shipping regulations. Because LANL's UT facility may be used only with capsules that have been successfully decontaminated, UT evaluation of these two capsules was not possible.

On 20 January, LANL, WSRC, GE-ASTRO, and OSA personnel attended a demonstration of a Focused-Array Transducer System (FATS) at the Institute for Science and Technology, Inc., in Fort Lauderdale, Florida. The system appeared to be quite effective in differentiating between real defects and geometric reflectors in GPHS girth welds. As a result of this demonstration, WSRC and LANL initiated a joint program to determine if FATS technology can be adapted for use in Cassini heat source production.

On 26 February, LANL personnel met with WSRC personnel to discuss progress on adapting the FATS to the Panametrics UT systems previously obtained for Cassini production. The results presented at this meeting indicated that the FATS accurately differentiated between real weld defects and geometric reflectors in the fueled-clad girth weld. Findings were also presented that indicated that a change in the angle of beam incidence and procurement of a time-of-flight upgrade would permit the existing Panametrics equipment to duplicate results obtained with FATS technology.

At the beginning of March, four Galileo/Ulysses-era simulant-fueled capsules were defueled and sent to WSRC for use in additional UT development. All of the capsules had been fabricated and UTd by Savannah River

Laboratory (SRL), and UT'd again at LANL before and after defueling.

On 9 March, LANL hosted a meeting of the GPHS Welding/UT Working Group. The immediate result of this meeting, which was attended by representatives from DOE NE-53, WSRC, Martin Marietta Energy Systems (MMES), Westinghouse Advanced Energy Systems (WAES), GE-ASTRO, and Fairchild Space Company (FSC), was to reach agreement on the following points.

- That all Cassini UT development must be complete, with required equipment installed, procedures approved, and operators trained and certified, by 1 July 1993.
- That LANL's UT evaluation of Galileo/Ulysses capsule FC-500, which had an Savannah River Plant (SRP) UT rating of 8.1, verified that the previous UT acceptance criterion was equivalent to the signal reflected by a 0.132-mm (5.2-mil) flaw.
- That on the basis of recent UT development work conducted by WSRC, the Cassini UT procedure should be based on two scans of the girth weld (top and bottom) obtained with a 3.5-MHz transducer set at a 39-deg inspection angle.

A number of action items that will ensure timely completion of the Cassini UT development effort were also assigned at the meeting.

7. 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 (CPS) urania fuel-simulants. All simulant-fueled clads required for the CPV test series were welded in 1992. Eight capsules were loaded with hot-pressed urania (^{235}U -depleted), and seven capsules were loaded with cold-pressed urania. UT examination revealed that the welds in nearly three-quarters of the capsules (11 of 15) contained UT indications in excess of the proposed 0.132-equiv-mm (5.2-equiv-mils) acceptance criterion. It should be noted, however, that previous studies have failed to establish a good correlation between results obtained with the current UT equipment/system and the results of subsequent metallographic and dye-penetrant evaluations.

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 "flight-quality," 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 have been provided in previous monthly and quarterly reports.

Analysis of fines washed from the interior of the CPV-1 impact can and surfaces of the test components revealed that a total of 0.0415 g of urania had been released from capsule SC0011. A sieve analysis of fuel simulant retained in the capsule was expected to be complete by mid-April.

As reported previously, seven metallographic specimens were cut from capsule SC0011. Metallographic examination of these sections continued and was expected to be complete by early April.

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 of the test assembly revealed that while the steel target was undamaged, capsule SC0008 was significantly deformed (Table I).

Table I. CPV-2 Capsule Strains

	Minimum (%)	Maximum (%)
Axial (length):	+ 9.5	+ 17.1
Diametral:		
Vent Cup	- 16.3	+ 17.8
Weld	- 16.1	+ 18.5
Weld-Shield Cup	- 12.9	+ 9.3

Capsule SC0008 appeared to have been breached by two small transverse cracks on the cup radii at the edges of the impact face (Fig. 4). However, no urania was released into the tantalum containment vessel.

The hairline cracks on the cup radii at the edges of the impact face appeared to be similar to the cracks observed in other capsules impacted at this velocity and should be considered typical. The transverse crack in the shield cup was approximately 6.0 mm long, and the crack on the vent cup radius had a length of approximately 8.0 mm.

(a)

(b)

(c)

(d)

(e)

(f)

Fig. 4. No urania was released from capsule SC0008: (a) impact face, (b) profile, (c) trailing face, (d) opposite profile, (e) vent end, and (f) blind end; all at 1.5 $\times$.

After macroscopic examination, capsule SC0008 was opened. Examination of the opened capsule revealed that fractures in the fuel simulant tended to radiate outward from the initial point of impact (Fig. 5), which occurred approximately 240 deg from the start of the weld (0-deg weld location). In addition, an extensive weld-shield/weld fusion occurred from 0 deg to 30 deg. The location of this weld-shield fusion corresponded to the largest reflector detected by the pretest UT evaluation: 0.168 equiv-mm (6.6 equiv-mils) at 26 deg.

After the opened capsule had been examined, the urania fuel-simulant was removed. Five metallographic samples were cut from the defueled capsule and the fuel-simulant was submitted for sieve analysis.

c. CPV-3. On 26 February, capsule SC0004, which had been loaded with CPS 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.

Postmortem examination of the test assembly was expected to be underway by mid-April.

d. CPV-4. On 5 March, capsule SC0020, which had been loaded with CPS 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.

Postmortem examination of the test assembly was expected to be underway by mid-April.

Fig. 5. Fractures in the SC0008 fuel simulant tended to radiate from the point of initial impact; approximately 2 $\times$.

8. Fueled-Clad Recharacterization Study

The study was postponed until after the arrival of new $^{238}\text{PuO}_2$ powder from WSRC.

Measurement of neutron emissions from fueled-clad FC0002 indicated a rate of 7400 ± 740 n/s-gm ^{238}Pu . However, this emission rate should be considered only as a qualitative value; neutron emission standards were not available to calibrate the measuring instrument. Californium neutron emission standards traceable to the National Institute of Standards and Technology (NIST) were received at the end of the quarter and will be used for instrument calibration.

9. Production Qualification

There was no activity this quarter. The production qualification effort cannot be initiated until after fueled-clad weld development has been completed and until LANL receives a shipment of plutonia fuel.

A draft readiness plan for the production qualification program received was returned to DOE/NE-53, with comments, on 23 February 1993. At the end of March, an updated draft of the readiness plan was returned to LANL.

B. Fueled-Clad Production

There was no activity during this quarter.

C. Safety Test Program

There was no activity during this quarter.

D. Research and Development

1. High-Temperature Mechanical Properties of Urania Fuel Simulant

In this quarter we continued to analyze data generated on the compressive strengths of hot- and cold-pressed urania (^{235}U -depleted) with respect to previously reported compressive strengths for $^{238}\text{PuO}_2$. Because only ultimate strength data were available for the plutonia, we had compared these values to 0.2% offset data for the two types of depleted urania. However, tests conducted at the start of this quarter indicated a marked difference between the yield and ultimate strengths of cold-pressed urania at low strain rates and at temperatures between 900° and 1200°C. At and above 1200°C, the yield and ultimate strengths of cold-pressed urania were essentially equivalent. In contrast, the yield and ultimate strengths of hot-pressed material appeared to be equivalent at all of the strain rates and temperatures investigated.

By the end of March, additional tests of the CPS material at a strain rate of $150 \times 10^{-4} \text{ min}^{-1}$ were complete and tests at a strain rate of $60\,000 \times 10^{-4} \text{ min}^{-1}$ were underway. The preliminary results indicated that the material response at 1200° and 1400°C was consistent with the behavior of cold-pressed and sintered samples tested previously. However, at temperatures below 1200°C, the yield and ultimate strengths of the new CPS material were higher than those previously measured and nearly identical to those of hot-pressed and grain-stabilized urania.

On the basis of results generated to date, it appears that the differences in response between hot and cold pressed urania, at low and intermediate strain rates, are minimal. In addition, the strengths of both materials as a function of temperature appear to be nearly identical to those of PuO_2 . Differences in mechanical response at high strain rate, if they exist, will be revealed by impact testing both types of urania simulant.

2. High-Temperature Mechanical Properties of Graphite

In this quarter we focused on assembling and testing the hardware required for mechanical testing of rings fabricated from graphite impact shell (GIS) sections. A fixture for mechanical testing of the graphite rings was assembled, the test frame was wired for electrical power, and a water supply for the furnace was installed. The vacuum test chamber and furnace were then remounted on the test frame.

After all assembly work had been completed, the furnace was heated to 1100°C. Because this test was designed to demonstrate that the furnace would perform as expected, it was not conducted with a specimen in place. The test verified that the design of the heating element was sound and that additional design work was needed to maintain alignment of graphite components in the furnace. While the furnace was being evacuated, the two graphite heater elements contacted each other. Because the elements were electrically in parallel, we were able to prove the heater design, albeit at a lower test temperature than had been planned. In the next quarter, we plan to modify the heater elements to ensure that a gap is maintained during all phases of furnace operation.

E. Project Management

All required weekly status reports were delivered on schedule. The Program Project Management System (PMS) monthly status reports (which included a data disk) were 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 was not released.

B. LWRHU Weld Development

A plexiglass welding chamber designed for "cold" weld-process development was fabricated and should be installed by 1 June 1993.

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END