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Monthly Progress Report
Heat Source Technology Program
July 1993

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MONTHLY PROGRESS REPORT
HEAT SOURCE TECHNOLOGY PROGRAM
JULY 1993

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MONTHLY PROGRESS REPORT

HEAT SOURCE TECHNOLOGY PROGRAM

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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 assess the fuel's conformance with the purchase specifications.

A shipment of recharacterization fuel was received from Westinghouse Savannah River Company (WSRC) at the beginning of June and was placed in storage pending completion of the special nuclear material (SNM) inventory (originally expected by 6 July). However, the inventory of the fuel processing area was not completed until late July. Fuel processing was expected to start by 6 August. The amount of ^{238}Pu received in this shipment (1.2 kg) is sufficient to produce nine general-purpose heat source (GPHS) fuel pellets, assuming an overall process yield $\geq 84\%$.

Three special-purpose radioisotope thermoelectric generators (RTGs) were received for disassembly and fuel recovery. The disassembly operations will be coordinated with personnel from Teledyne Energy Systems (TES).

II. IRIIDIUM HARDWARE SHIPMENTS AND INVENTORY

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

Table I. LANL Inventory of Cassini GPHS Iridium Hardware

Type of Hardware	Category	Number of Items in Inventory
PICS*	Prime	30
PICS	Restricted	18
Type II Weld Shields	Prime	22

*PICS = Post-Impact Containment Shell

III. FACILITIES

A. Launcher Relocation

During July, 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 July, forms for the third level of the launcher addition's interior and exterior walls were completed, the concrete was poured, and the forms were removed. By the end of the month, reinforcing steel for the fourth and fifth levels of the addition had been installed, and the placement of gang forms for the fourth concrete lift had been completed.

2. Procurements

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

The vendor selected for procurement and installation of the bridge crane had previously provided shop drawings of the proposed crane. The drawings were approved and the vendor was instructed to proceed with fabrication of the crane. However, a firm delivery date has not yet been determined.

A PR for the filter train that will be used in the launcher addition's heating, ventilation, and air conditioning (HVAC) system was previously forwarded to MAT Division for

placement. In July, a potential vendor requested clarification of a number of items in the filter train specification. As a result, the bid due date was extended into August.

Bids from system integrators for fabrication of the Supervisory Control System (SCS) that will control launcher operations were received on 27 April. In July, a PR was issued for procurement of the SCS and the selected vendor was instructed to proceed with fabrication.

3. Administrative Requirements

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

B. 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. However, because LANL may not be in compliance with current National Emission Standards for Hazardous Air Pollutants (NESHAP), a temporary limit was imposed that permitted only six fueled-clads to be welded each month.

The results of legal and managerial reviews completed in April indicated that a maximum of 2.5 kg of ^{238}Pu could be processed each month without exceeding the established TA-55 baseline. On the basis of this finding, it was determined that there are no NESHAP implications for processing a maximum of 20 fueled-clads per month.

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.

By the end of June, work on a facility ventilation upgrade (to service open-front hoods in the ceramography and metallography glovebox lines) was essentially complete. However, efforts to leak test the duct installation continued in July, and the ventilation upgrade was not expected to be operational until mid-August.

D. 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. However, at the end of July, approval had still not been 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). Six organizations/individuals provided comments on the draft specifications by the deadline of 7 May. These comments will be addressed in subsequent specification revisions.

3. Process Procedures

Two compilations of procedures, titled "Quality Assurance Procedures for Flight Quality Cassini Fueled-Clads" and "Fabrication Procedures for Flight-Quality Cassini Fueled-Clads" were previously distributed on controlled-copy bases internally and externally as required by the IWA. Both compilations will be updated to reflect subsequent procedure revisions only after DOE/OSA approval.

Sets of controlled-copy compilations of the "Fabrication Procedures for Flight-Quality Cassini Fueled-Clads" were previously distributed to members of the Cassini Process Readiness Evaluation Review; the review occurred on 18-19 May.

A new procedure was created to reflect changes in the GPHS hardware. This procedure, titled "Cassini GPHS Iridium Control" (SHS-NMT9-PP-30) was approved for use and will replace the "GPHS Clad Vent Set (CVS) Control Procedure" (SHS-NMT9-PP-24).

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 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 capsules until the last week in July. On 28

July, capsule FC0003 was ultrasonically examined. The results of this examination revealed that the capsule girth weld did not contain any ultrasonic reflectors larger than 2.9 equiv.-mils (0.0737 equiv.-mm).

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 by 15 July 1993. By the end of July it was apparent that while significant progress had been made, the performance of the new UT system could not be verified until late August or early September.

On 22 July, the Heat Source Technology Group (NMT-9) received two UT standards from MMES/Y-12. Both standards had been reworked by MMES/Y-12 to make them more suitable for use in the "top scan" UT evaluation technique developed by WSRC.

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 4.8 equiv.-mils (0.122) 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 IIID).

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 and a sieve analysis of fuel retained in the capsule were documented in previous monthly reports.

In this month we completed the metallographic examination of five sections cut from capsule SC0008. The results of these examinations confirmed that the small impact face cracks on the vent- and shield-cup radii both penetrated the capsule wall. Because the iridium microstructure in the vicinity of both cracks was exemplary and because these cracks appeared similar to radius cracks on other capsules impacted at this velocity, it is unlikely that they were related to any material defects.

Examination of the overlap region of the girth weld, at a weld location of 15 deg (the weld begins at 0 deg), revealed that the weld-shield had been completely incorporated into the weld pool. The chill caused by the weld-shield fusion produced a weld microstructure that consisted primarily of thin columnar grains oriented normal to the cup walls.

The metallographic evidence of an extensive weld-shield fusion confirmed that the large reflector (up to 6.9 equiv.-mils, extending from 0 deg to approx. 72 deg) detected during UT examination was not a defect.

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 IIID).

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 opened capsule SC0004, selected samples for metallography, and initiated a sieve analysis of the urania fuel simulant.

Examination of the defueled capsule revealed a number of internal cracks that were not visible on the clad exterior. A short (5.0 mm) transverse crack was present on the impact face of the shield cup radius, and three small (up to 2.0 mm) axial cracks extended from the vent cup to the weld centerline. The axial cracks were located at the edges of the impact face, with two cracks on one side and the remaining crack opposite. All of these interior cracks were sectioned to permit a metallographic determination of the extent of penetration.

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: an axial crack located approximately 120 deg from the weld start that extended from the shield cup, through the weld, and into the vent cup; smaller axial weld cracks at 170, 180, and 225 deg; a network of hairline (generally axial) cracks at ≈ 180 deg that extended from the edge of the grit-blast line to the vent cup radius; and small transverse cracks on the cup radii at the edges of the impact face. A small amount of urania was released into the tantalum containment vessel. Details of this initial examination were given 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.

A postimpact examination conducted during July revealed that capsule SC0017 had breached, and that a small quantity of urania had been released. The impact face of the capsule was centered at approximately 120 deg (the weld start is at 0 deg). The capsule was breached by at least two cracks: a transverse crack on the impact face of the vent cup radius and by an axial crack on the edge of the vent cup impact face, at 90 deg. A number of small axial cracks were also observed on the edge of the shield cup impact face (at 150 deg), but none of these cracks appeared wide enough to have permitted a release of fuel simulant. Overall capsule deformation was similar to that observed in previous CPV impact tests using cold-pressed urania; the capsule strains are listed in Table II.

Table II. CPV Capsule Strains

	Minimum (%)			Maximum (%)		
	CPV-5	CPV-6	CPV-7	CPV-5	CPV-6	CPV-7
Axial (length):	+ 3.1	+ 3.6	+ 0.7	+15.2	+15.2	+14.3
Diametral:						
Vent Cup	- 16.1	-12.2	-11.4	+ 8.3	+ 5.8	+ 5.8
Weld	- 11.3	- 8.9	-11.2	+ 9.4	+ 6.3	+ 7.8
Weld-Shield Cup	- 11.3	- 9.9	-10.5	+ 6.0	+ 4.3	+ 6.3

The transverse crack on the vent cup radius had a total length of 18.0 mm. However, only 6.5 mm of the crack had a measureable width; the maximum crack width was approx. 0.9 mm. This crack appeared similar to smaller impact-face cracks observed on the cup radii of other capsules tested at this velocity.

The axial crack at 90 deg (on the edge of the impact face) had an approximate length of 12.5 mm and negligible width. Although the bulk of the crack was located in the vent cup, and may have been related to the crack on the vent cup radius, the lower portion of the crack traversed the weld and terminated in the weld-shield cup.

The hairline cracks in the shield cup (at approximately 150 deg) were all less than 2.5 mm in length, and did not appear to be penetrating.

There was no detectable deformation of the steel target plate.

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.

A postimpact examination conducted during July revealed that capsule SC0018 may have been breached by a network of hairline axial cracks at the edge of the impact face. However, no urania was released into the tantalum containment vessel. The impact face of

the capsule was centered at approximately 30 deg (the weld start is at 0 deg). Overall capsule deformation was similar to that observed in previous CPV impact tests using cold-pressed urania; the capsule strains are listed in Table II.

The network of hairline axial cracks was located at the edge of the impact face, at a weld location of approx. 10 deg. Although the largest portion of the crack network was located in the weld-shield cup, some cracks extended through the weld to the grit-blast line on the vent cup. The crack network had an overall length of 12.5 mm (0.49 in.).

The impact face of capsule SC0018 contained several shallow creases but there was no evidence of the cup-radius cracks that have been observed in other capsules impacted at this velocity.

There was no detectable deformation of the steel target plate.

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 of capsule SC0019 revealed that the impact face was centered at approximately 150 deg (the weld start is at 0 deg). No cracks were visible on the impact face. However, the trailing face of the capsule was breached by a centerline weld failure that extended from approx. 300 deg to 45 deg, and by a small axial crack in the weld shield cup at 270 deg. No urania was released into the tantalum containment vessel. Overall capsule deformation was similar to that observed in previous CPV impact tests using cold-pressed urania; the capsule strains are listed in Table II.

The centerline weld failure was appeared to have a length of 22.5 mm (0.885 in.), and had a maximum width of 0.64 mm (0.025 in.). However, the weld shield was relatively intact and had remained in position behind the weld crack. The weld failure appeared to be related to the anomalous displacement of fuel fragments contained within the vent and weld-shield cups. The maximum displacement between the two cup sections was 1.63 mm (0.064 in.).

At the terminus of the weld failure (at 45 deg), a secondary crack extended into the weld-shield cup. This crack was oriented at approx. 45 deg to the weld, and was 5.1 mm (0.200 in.) in length. The maximum width of this crack was 0.51 mm (0.02 in.). Over a major portion of the crack the underlying weld-shield had been penetrated by what appeared to be a urania fragment. Because the urania fragment was visible in the crack, it is unclear as to why no urania fines were released into the containment vessel.

The hairline axial crack at 270 deg extended from the weld-shield cup to the weld centerline. The crack had a length of approx. 2.5 mm (0.098 in.). It did not appear that this crack was related to the differential displacement of a urania fragment.

There was no evidence of the cup-radius cracks frequently observed on the impact faces of other capsules impacted at this velocity.

There was no detectable deformation of the steel target plate.

7. Production Qualification

On 18-19 May, the Cassini Process Readiness Evaluation Team conducted a preliminary review of LANL operations. Previously, LANL had completed a review of the 14 April draft readiness plan for the Production Qualification Program and had forwarded a copy of this review to the leader of the Process Readiness Evaluation Team.

A shipment of recharacterization fuel was received from WSRC at the beginning of June and was placed in storage pending completion of the SNM inventory (originally expected by 6 July). However, the inventory of the fuel processing area was not completed until late July. Fuel processing was expected to start by 6 August. The amount of ^{238}Pu received in this shipment (1.2 kg) is sufficient to produce nine GPHS fuel pellets, assuming an overall process yield $\geq 84\%$.

B. Cassini Fueled-Clad Production

There was no activity during July.

C. Safety Test Program

There was no activity during July.

D. Research and Development

1. High-Temperature Mechanical Properties of Urania Fuel Simulant

There was no activity during July.

2. High-Temperature Mechanical Properties of Graphite

There was no activity during July.

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

Installation of a plexiglass welding chamber designed for "cold" weld process development began on 26 July and was expected to be complete by 6 August.

C. LWRHU Production

Fabrication of urania (^{235}U -depleted) fuel-simulant pellets for two 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 6 July, the Defense Nuclear Facilities Safety Board (DNFSB) convened at LANL for a follow-up review related to the replacement of glovebox connecting rings.

On 8 July, LANL held an internal Safeguards and Security review. This review was a follow-up to a review held on 10 June.

On 12 July, LANL held an internal quality assurance (QA) audit of the Cassini program.

On 14 July, two MMES/Y-12 QA personnel and a program QA field representative were present at LANL to witness the receiving inspection of five clad vent sets.

On 19–23 July, two LANL technicians and an engineer traveled to Columbus, Ohio, to attend required training on operation and maintenance of the hot isostatic press (HIP).

On 21 July, one LANL engineer attended the monthly Cassini program review held at FSC in Germantown, Maryland.

On 22 July one LANL engineer attended a Cassini safety test design review held at MMES/VF.

On 28 July, LANL held another Safeguards and Security review to review the follow-up review held on 8 July.

On 28 July, an OSA representative visited LANL to witness the UT of three plutonia-fueled capsules.

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