LA-UR - 88-2390

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SUBMITTED TO: The 6th Symposium on Space
Nuclear Power Systems
The Institute for Space Nuclear
Power Studies
Albuquerque, NM 87131
January 9-12, 1989

Los Alamos

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INTRODUCTION

The Light Weight Radioisotope Heater Unit (LWRHU) is a $^{238}PuO_2$-fueled heat source designed to provide one thermal watt to various locations on a spacecraft. The heat sources are necessary to maintain the temperature of specific components within normal operating ranges. The first application of the LWRHU's will be for the Galileo Mission. Los Alamos National Laboratory (LANL) was responsible for the design, fabrication, and safety testing of the LWRHU. The heat source, illustrated in Figure 1, consists of a hot-pressed $^{238}PuO_2$ fuel pellet, a Pt-30Rh vented capsule (clad), a pyrolytic graphite (PG) insulator assembly, and a FINE-WEAVE-PIERCED™ Fabric (FWPF) graphite aeroshell assembly. The design of the LWRHU has been described by Tate (1982). The production effort included processing the raw PuO_2 feed material from the Savannah River Plant (SRP), hot pressing the fuel pellets, encapsulating the pellets in Pt-30Rh hardware, placing the capsules in the aeroshell assemblies, and performing nondestructive testing on each of the heat sources.

FUEL PROCESSING

The feed material consisted of $^{238}PuO_2$ powder produced at SRP by adding oxalic acid to plutonium nitrate solution and then calcining the oxalate precipitate at 750°C to form plutonia. The as-received feed was enriched to 83.5 at.% ^{238}Pu and had a thermal power of 0.42 W/g PuO_2. The LWRHU fuel processing flow sheet is shown in Figure 2. The details of the fuel processing steps have been described by Kent (1979) and are identical to the fuel processing operations developed for the General Purpose Heat Sources that will also be on the Galileo Mission's radioisotope thermoelectric generators.

The first processing step involved heating the feed powder in an ^{16}O environment to replace the ^{17}O and ^{18}O isotopes present in the feed with ^{16}O. The feed powder produced at SRP had a neutron emission rate of 19 000 n/s-g ^{238}Pu, primarily due to (α,n) reactions caused by the presence of ^{17}O and ^{18}O isotopes in the normal oxygen used in the calcining process. The exchange was accomplished by heating the feed powder, contained in a platinum boat, in a horizontal tube furnace in an atmosphere of flowing argon saturated with $H_2{}^{16}O$. The feed material was exchanged for 24 h at 775°C and then heated for 1 h at 1000°C to release stored helium. This process lowered the neutron emission rate to 6 500 n/s-g ^{238}Pu.

The second processing step involved ball-milling the feed powder to reduce differences in surface activity among lots of feed powder. The feed powder had an average mass-median diameter of 3.4 microns which was reduced to 1.2 microns after 44 h of ball-milling.

The granulation procedures converted the ball-milled powder to properly sized granules for hot pressing. The granulation consisted of cold pressing 25-g charges of feed powder at 400 MPa to form a green pellet at 60% theoretical density; then breaking up and screening the material to collect the <125 μm granules. After the granules were formed, 60 wt% of the granules were sintered for 6 h at 1100^oC in flowing $Ar\text{-}H_2{}^{16}O$ and the remaining granules were sintered for 6 h at 1600^oC.

PELLET FABRICATION

The fuel used to fabricate the LWRHU fuel pellets was obtained by blending the granules seasoned at 1100^oC (60 wt%) and 1600^oC (40 wt%). After blending was completed, the graphite die for the hot press was loaded with 16 fuel charges, each weighing 2.670 g. The graphite die was placed within the vacuum chamber of the hot press and the chamber was evacuated to a pressure of 1.3×10^{-4} Pa. The pressing was performed at a temperature of 1530^oC and a force of 9.65 kN which corresponded to pressure of 19.5 MPa. The die was held at 1530^oC under full load for 15 min.

During hot pressing, the plutonia was reduced to a stoichiometry of $PuO_{1.93}$ by the graphite die. To oxidize the pellets back to $PuO_{2.00}$ and increase their density, the pellets were sintered in flowing $Ar\text{-}H_2{}^{16}O$ for 6 h at 1000^oC followed by 6 h at 1527^oC. After sintering, a typical pellet had a mass of 2.664 g, a length of 9.37 mm, and a diameter of 6.25 mm.

WELDING AND NON-DESTRUCTIVE TESTING

All components of the capsule, except for the frit vent, were fabricated from Pt-30Rh tube, sheet, and foil. The frit vent was a pressed and sintered disk of pure platinum powder. The Mound Facility fabricated the components and electron beam welded the frit vent and vent end cap into place before shipping the hardware to LANL.

The pulsed Gas Tungsten Arc welding was performed in a helium atmosphere glovebox. A gas purifying system was plumbed to the glovebox in a closed loop to maintain the atmosphere purity at <25 ppm oxygen and <60 ppm moisture. After the capsules were welded, they were decontaminated to zero alpha swipe in a nitric acid/hydrofluoric acid solution.

The welded capsules were submitted to the following nondestructive tests: helium leak check; fluorescent dye penetrant inspection of the weld for evidence of cracks; radiography of the weld area to ensure 100% weld penetration; measurement of the capsule dimensions; neutron emission rate; thermal power; and measurement of the gamma and neutron dose rates. All capsules had a thermal power of 1.10 ± 0.03 W at the time of hot pressing.

FINAL ASSEMBLY

After the LWRHU capsule had passed all nondestructive tests, it was submitted for final assembly. The pressed and sintered platinum powder frit vent was activated by cutting into the vented end (electron beam welded end) of the capsule at the center line with a 0.635 mm diameter endmill to a depth of 0.279 to 0.406 mm. The capsule was then examined under a microscope to ensure that the frit was visible through the milled hole. After a swipe check for loose alpha contamination (<220 dpm), the capsule was placed into the graphite aeroshell and the graphite lid was glued in place with Union Carbide Corporation UCAR C-34 cement. The graphite aeroshell was then heat treated at 100°C for a period of 4.0 h followed by heating at 130°C for 16 h to cure the cement. The assembled heater was swipe checked to ensure that surface contamination was <220 dpm. Measurements of a typical heat source showed a mass of 40.0 g, a height of 32.0 mm, and a diameter of 26.0 mm.

DISCUSSION

Los Alamos National Laboratory completed the LWRHU production effort in November 1984. A total of 134 LWRHU capsules were shipped to the Jet Propulsion Laboratory and subsequently to the Kennedy Space Center in late CY 1985. After the Challenger accident, the heat sources were returned to LANL, where they are currently being stored. The heat sources appear to be in excellent condition. Because of the slow reduction in thermal power, the heat sources will range from 1.025 to 1.048 W on October 1, 1989.

ACKNOWLEDGMENTS

This work was sponsored by the Department of Energy and by the Material Science and Technology Division at Los Alamos National Laboratory.

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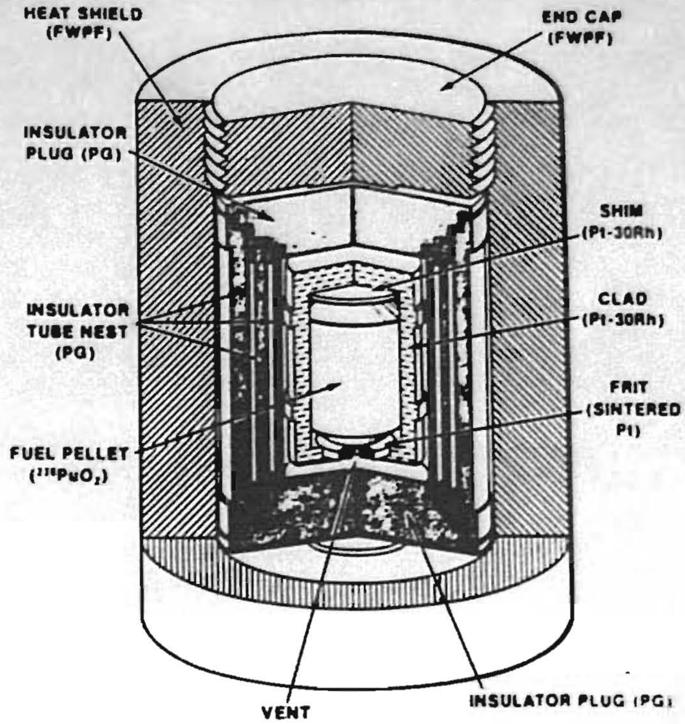

Fig. 1. Light Weight Radioisotope Heater Unit

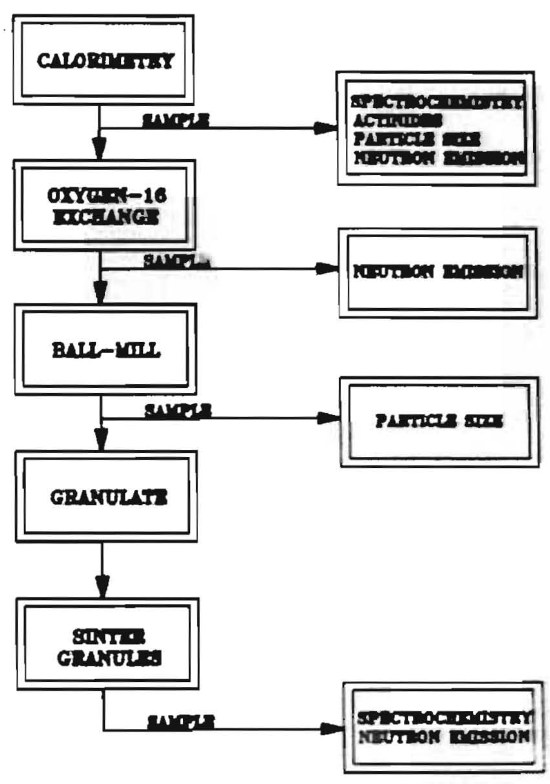

Fig. 2. LWRHU fuel processing flow sheet.