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^{238}Pu FUEL FORM PROCESSES BIMONTHLY REPORT

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FOREWORD

This report is one of a series to summarize progress in the Savannah River ^{238}Pu Fuel Form Program. This program is supported primarily by the DOE Advanced Nuclear Systems and Projects (ANSAP) and also by the Division of Military Applications (DMA).

Goals of the Savannah River Laboratory (SRL) program are to provide technical support for the transfer of DASMP and DMA ^{238}Pu fuel form fabrication operations from Mound Laboratory to new facilities at the Savannah River Plant (SRP), to provide the technical basis for ^{238}Pu scrap recovery at SRP, and to assist in sustaining plant operations. This part of the program includes:

Demonstration of processes and techniques, developed by the Los Alamos Scientific Laboratory (LASL) for production at SRP. Information from the demonstration will provide the technical data for technical standards and operating procedures.

Technical Support to assist plant startup and to ensure continuation of safe and efficient production of high-quality heat-source fuel.

Technical Assistance after startup to accommodate changes in product and product specifications, to assist user agencies in improving product performance, to assist SRP in making process improvements that increase efficiency and product reliability, and to adapt plant facilities for new products.

FABRICATION TESTS OF GPHS FUEL FORMS

Full-scale fabrication tests continued as four pellets (GPHS Pellets 10, 11, 12, and 13) were hot pressed and three pellets (GPHS Pellets 9, 10, and 11) underwent final heat treatment (Tables 1 and 2). All of these pellets were integral and well formed with no surface cracks as pressed. All were integral after final heat-treatment, and two pellets (GPHS Pellets 10 and 11) were also free of surface cracks. Excellent dimensional stability was demonstrated during final heat treatment as the linear shrinkages were <0.5% (Table 3). The successful fabrication of GPHS Pellet 9 demonstrated that the centerline conditions reproducibly produce an acceptable product. GPHS fuel pellets also should have acceptable shelf life, since GPHS Pellet 8 was apparently unaffected by 2-1/2 months of storage and testing (Table 4). The successful drilling of a 0.125-in.-diameter x 0.60-in.-deep hole into the center of GPHS Pellet 8 was another indication of the overall ruggedness of GPHS fuel pellet fabricated at SRL.

Fabrication Conditions

During this reporting period, GPHS Pellets 10, 11, 12, and 13 were hot pressed at off-centerline conditions, and GPHS Pellets 9, 10, and 11 were heat treated at the nominal centerline conditions of 1525°C for 6 hr. Process conditions for these fabrication tests are summarized in Tables 1 and 2. The process conditions are the same except for the hot press conditions.

GPHS Pellet 9 was fabricated to demonstrate that the SRL centerline conditions produce acceptable fuel pellets with reproducible characteristics. However, during three attempts at final heat treatment, several problems with the cooling water system of the furnace disrupted power after heating to 1450-1525°C. The furnace then cooled rapidly to 150°C in about 1-1/2 hr. During a fourth attempt, the pellet was successfully heat-treated at centerline conditions.

GPHS Pellet 10 was hot pressed to test the effect of quickly applying (in <30 sec) the preload prior to heating during hot pressing. In previous tests, the preload was slowly applied over a 5 to 8-minute period. Savannah River Plant (SRP) personnel requested testing of a fast preload to simplify hot press operation for production of GPHS fuel forms.

TABLE 1

Process Conditions Used to Fabricate GPHS Pellets 9-13

^{16}O Exchange (simulated)	4 hr @ 800°C
Outgas	1 hr @ 1000°C
Ball Mill	12 hr @ 100 rpm
Compact	58,000 psi
Granulate	<125 μm
Sinter Shard	60%, 6 hr @ 1100°C 40%, 6 hr @ 1600°C
Hot Press	See Table 2
Heat Treatment	6 hr @ 1525°C

TABLE 2

Hot Pressing Conditions for GPHS Pellets

GPHS Pellet No.	9	10	11	12	13
Preload, lb	200	250	250	300	250
Rate	Slow	Fast	Fast	Fast	Fast
Heating					
Time to 1100°C, min	3	3	3	3	3
Max Temp, °C	1530	1530	1530	1530	1530
Time to Max Temp, min	8	8	7.5	8	7
Load					
Temp of Initiation, °C	1300	1350	1350	1100	1500
Max Load, lb	2600	2600	2600	2600	2600
Ramp, min	5	5	5	5	5
Time Between Initiation of Heat and Load, min	4	4.5	5	3	5
Time to Die Closure after Max Load	1.5	1.5	3	1.5	1
Time at Max Load and Temp after Closure	5	5	5	5	5

TABLE 3

GPHS Pellet Data*

GPHS Pellet No.	Condition	Diameter, in.	Length, in.	Weight, g	Density, % TD	O/M
4	As-pressed	1.100	1.104	151.450	81.8	1.90
	Heat Treated	1.096	1.100	152.367	83.3	
	Difference	-0.4%	-0.4%	0.917	1.5	
5	As-pressed	1.095	1.097	151.707	83.3	1.93
	Heat Treated	1.092	1.093	152.351	84.3	
	Difference	-0.3%	-0.4%	0.644	1.0	
7	As-pressed	1.093	1.099	152.864	84.0	1.93
	Heat Treated	1.089	1.096	153.470	85.2	
	Difference	-0.4%	-0.3%	0.606	1.2	
8	As-pressed	1.098	1.112	155.582	83.7	1.92
	Heat Treated	1.095	1.108	156.300	84.9	
	Difference	-0.3%	-0.4%	0.418	1.2	
9	As-pressed	1.093	1.098	151.790	83.5	1.93
	Heat Treated	1.093	1.099	152.400	83.7	
	Difference	0	0.1	0.610	0.2	
10	As-pressed	1.094	1.100	151.582	83.0	1.91
	Heat Treated	1.090	1.095	152.365	84.5	
	Difference	-0.4%	-0.5%	0.783	1.5	
11	As-pressed	1.094	1.096	151.589	83.4	1.91
	Heat Treated	1.091	1.092	152.437	84.6	
	Difference	-0.3%	-0.4%	0.848	1.2	
12	As-pressed	1.092	1.096	152.740	83.7	
	Heat Treated					
	Difference					
13	As-pressed	10.94	1.099	151.880	83.3	
	Heat Treated					
	Difference					

* Reference Shard Mixture and Reference Geometry.

TABLE 4

Storage and Testing of GPHS Pellet 8

Date	Condition	Diameter, in.*	Length, in.*	Wt, g	Density, % TD
7/5	Heat Treated	1.095	1.108	156.30	84.9
7/5 - 7/19	Storage	1.097	1.109	156.26	84.5
7/19 - 7/20	Exposure to Flowing Helium	1.096	1.109	156.25	84.6
7/20 - 9/17	Storage and Temperature Measurements	1.097	1.109	156.24	84.4

* Variation is within measurement error.

GPHS Pellet 11 was hot pressed using a fast preload after the $^{238}PuO_2$ shard mixture sat in the die under vacuum overnight (16 hr). SRL centerline conditions for the time under vacuum before hot press is 45 min to 1 hr. SRP personnel requested this test to provide additional flexibility for scheduling hot press production runs. The concern is that, during longer evacuating periods, the self heat of the $^{238}PuO_2$ would promote additional sintering of 1100°C shards and affect pellet quality.

GPHS Pellets 12 and 13 were fabricated to test the effect of varying the temperature at which the hot press load is initiated. These two pellets were fabricated with process conditions similar to those used for fabricating GPHS Pellet 10, except the hot press load was initiated at 1100°C for GPHS Pellet 12 and at 1500°C for GPHS Pellet 13. For SRL centerline conditions (and for GPHS Pellet 10) the hot press load was initiated at 1350°C.

Pellet Characteristics

GPHS pellets of generally good quality continue to be fabricated. As with previous pellets made with the reference shard mixture, all pellets fabricated during this report period were integral and well formed as pressed with no surface cracks. All pellets were integral after final heat treatment with good dimensional stability. However, surface cracks formed on several pellets during final heat treatment. Only GPHS Pellets 8, 10, and 11 were free of surface cracks after final heat treatment.

GPHS Pellet 9 (which was hot pressed using centerline conditions) remained integral but had a number of small surface cracks after undergoing a complete final heat treatment. Most of these surface cracks had formed during three earlier attempts at final heat treatment when the pellet was thermally shocked. The cracking probably prevented the shrinkage which normally occurs during final heat treatment. The final dimensions were similar to the as-pressed dimensions. GPHS Pellet 9 showed ruggedness and microstructure similar to those of other pellets made by the centerline process conditions. The pellet withstood sectioning without fracturing, and subsequent microstructural analysis showed the desired uniform density with only a slight increase in the amount of cracking.

GPHS Pellet 10 (which was hot pressed with a fast application of the preload) was integral with no surface cracks both as pressed and after final heat treatment. The dimensional stability during final heat treatment was excellent as the linear shrinkages were 0.4 to 0.5%. Completion of microstructural analysis is necessary before a firm conclusion is reached on the results of this test.

GPHS Pellet 11 (which was hot pressed with a fast application of the preload after overnight evacuation of the die) was integral and well formed with no surface cracks either as pressed or after final heat treatment. The as-pressed density was 83.4% TD, and the final density was 84.6% TD. This pellet also exhibited excellent dimensional stability during final heat treatment (0.3 to 0.4% shrinkage). As with GPHS Pellet 10, microstructural analysis is necessary before reaching a final conclusion about this test.

Placing GPHS pellets in a bed of ThO_2 shards during final heat treatment is not necessary to prevent surface cracking. Prior to fabrication of GPHS Pellets 10 and 11, only GPHS Pellet 8 had survived final heat treatment without surface cracks. The improved quality of GPHS Pellet 8 was attributed to the pellet being placed in a bed of ThO_2 shards during heat treatment.[1] However, GPHS Pellets 10 and 11 were heated treated on platinum (foil covering an Al_2O_3 boat), and they survived without surface cracking.

Both GPHS Pellets 12 and 13 were easily extruded from the die after hot pressing and were integral with no surface cracks. The as-pressed characteristics of these pellets are listed in Table 3. These pellets were fabricated to help determine the sensitivity of product quality to the temperature at which hot press load is initiated.

Pellet Dimensions Versus Die Cavity

Hot press die assemblies machined to production-grade tolerances were used beginning with the fabrication of GPHS Pellet 9. As shown in Table 5, good agreement was obtained between the dimensions of the die cavity and the as-pressed dimensions of the pellet (especially diameter). Because GPHS Pellets 9-11 had excellent dimensional stability the final pellet dimensions are also very close to the original dimensions of the die cavity. For GPHS Pellets 10 and 11 that underwent a nominal final heat treatment, linear shrinkages were 0.3 to 0.5%.

TABLE 5

Pellet Versus Die Cavity Dimensions for GPHS Pellets 9-13

GPHS Pellet No.	Condition	Diameter, in.*	Length, in.*
9	Die Cavity	1.094	1.097
	As-pressed	1.093	1.098
	Heat Treated	1.093	1.099
10	Die Cavity	1.094	1.096
	As-pressed	1.094	1.100
	Heat Treated	1.090	1.095
11	Die Cavity	1.094	1.097
	As-pressed	1.094	1.096
	Heat Treated	1.091	1.092
12	Die Cavity	1.094	1.097
	As-pressed	1.092	1.096
	Heat Treated		
13	Die Cavity	1.094	1.098
	As-pressed	1.094	1.099
	Heat Treated		

* Measurement error is estimated to be ±0.001 in.

Shelf Life

GPHS Pellet 8 was physically unaffected by 2-1/2 months of storage and testing (Table 4). This result indicates GPHS fuel pellets should have a shelf life acceptable for production operations. Normally, $^{238}PuO_2$ fuel forms are temporarily stored before being encapsulated on a campaign basis.

GPHS Pellet 8 remained free of surface cracks, and the physical dimensions were unchanged 2-1/2 months after fabrication. During this period, the pellet was stored in a graphite container except when subjected to flowing helium. Thermocouple penetrating the storage container provided for the measurement of the surface temperature on the top and bottom surfaces of the pellet (Table 6). The temperature difference betwen the top and bottom surface of the pellet was 50 to 80°C. Little change in the surface temperature of the pellet occurred when the storage container was transferred from an argon atmosphere to a helium atmosphere. Previously, exposure of pellet directly to flowing helium had no apparent effects on the physical characteristics of the pellet.

TABLE 6

Temperature Measurements of GPHS Pellet No. 8 In Graphite Storage Container

Top TC, °C	Bottom TC, °C	ΔT, °C	Location of Graphite Container
244	194	50	On metal with argon atm
238	176	62	On ceramic with argon atm
271	194	77	On metal with helium atm

OVERALL RUGGEDNESS OF GPHS FUEL PELLETS

The successful drilling of a one-eighth-inch diameter hole from the top of GPHS Pellet 8 to the center of the pellet after 2-1/2 months of storage and testing is one of several indications of the overall ruggedness of GPHS fuel pellets fabricated in the PEF. As described earlier in this report, GPHS Pellet 9 underwent the thermal shock associated with rapid cooling from about 1500°C three times without fracture. In previous tests, GPHS Pellets 7 and 8 survived exposure to flowing helium at ambient pellet temperature of 150-200°C, and GPHS Pellet 7 survived repeated thermal cycling from about 800 to 1400°C over twenty-minute periods. In addition, the normal means of sectioning the GPHS pellets for microstructural analyses is to cut a slab from the pellet with an Isomet saw. The pellets withstand the sectioning, and the slab is integral, even though the pellets are chucked in a metal (aluminum) holder during sectioning.

GPHS Pellet 8 remained integral although a few hairline cracks may have formed on the bottom surface of the pellet as a result of the drilling. The hole was drilled with a hand-held drill using a diamond-imbedded drill bit. The pellet was clamped in the aluminum chuck of the Isomet saw during drilling. About 2 hours was required for the drilling operation. The drill bit was cooled intermittently by dipping it in water.

GPHS Pellet 8 will be used to measure the thermal gradient from the center to the surface of the pellet in various storage and process conditions.

Limit Tests

GPHS Pellets 12 and 13 were part of a full-scale test program developed to define operating limits for the following key process parameters: (1) sintering temperature of nominal 1100°C shards, (2) maximum hot press temperature, (3) temperature at which the load is initiated during hot pressing, and (4) maximum pellet density (maximum allowable die charge). During production these process parameters are likely to be more difficult to control than other key process parameters, such as rate of application of the load and the maximum load during hot pressing.

Full-scale fabrication tests will continue in the PEF with the reference shard mixture and pellet shape to help define operating limits for production of GPHS fuel forms in the PuFF Facility. The GPHS pellets fabricated in these tests will be characterized first nondestructively by gauging and weighing and then destructively by sectioning and microstructural examination. SRL microstructural examination of a GPHS pellet fabricated at LASL and the characterization of samples from intermediate processing steps at LASL are compared to GPHS samples from SRL processing tests in a later section of this report.

CHARACTERIZATION OF LASL-GPHS PELLET 31

Microstructural analysis of a full-scale GPHS fuel pellet fabricated at Los Alamos Scientific Laboratory (LASL-GPHS Pellet 31) indicated that density gradients and internal cracking were more severe in this pellet than in SRL-GPHS pellets. The analysis also revealed that the high-fired (1600°C) shards produced at LASL which were used to produce this pellet have a significantly lower density than high-fired shards produced at SRL (88% TD, LASL versus 96% TD, SRL). The poor quality of the LASL pellet appears to be related to the low density of the LASL 1600°C shards. The relatively low density of the shards may be related to the $Ar-H_2{}^{16}O$ atmosphere used during shard processing at LASL. The results of this microstructural characterization demonstrated that shard density is a very important parameter in the GPHS process and can influence the density distribution and internal cracking of $^{238}PuO_2$ fuel pellets.

The characterization of LASL-GPHS Pellet 31 (GP 31) and the associated powder and shard samples was part of the GPHS Fuel Form Process technology transfer from LASL to SRL. Production of encapsulated GPHS fuel forms at Savannah River is scheduled to begin in April 1980.

Background

SRL has demonstrated that homogeneous GPHS fuel pellets with density variations of less than ±2% TD can be fabricated.[1] Internal cracking was seldom observed in the SRL-GPHS pellets, and only a few small (about 0.1-in. long) surface tensile cracks were observed in the cross sections of pellets fabricated at SRL when GPHS centerline conditions were used. The shard structure was retained throughout the SRL-GPHS pellets.

Pellet Characterization

A GPHS pellet fabricated at LASL was shipped to SRL along with samples of the as-received powder, $^{16}O_2$-exchanged powder, ball-milled powder, green granules, 1100°C shards, and 1600°C shards.

LASL-GPHS Pellet 31 was selected by LASL as a pellet typical of those presently being fabricated at LASL for impact testing. The surface of the pellet was uncracked after heat treatment. The pellet was encapsulated in iridium before being shipped to SRL.

After shipment, the LASL pellet was radiographed while still inside the iridium shell and the shipping container. This revealed a crack running diagonally through the upper quadrant of the pellet (Figure 1). The crack could have been induced from thermal stress during the welding operation required to encapsulate the pellet or from mechanical shock during shipping from LASL to SRL.

The iridium shell was cut circumferentially using a low-speed diamond saw (Figure 2). Longitudinal sectioning of the pellet, also with a low-speed diamond saw, revealed severe internal cracking in the LASL pellet (Figure 2B). Longitudinal sections from both ends of the pellet were prepared for metallography.

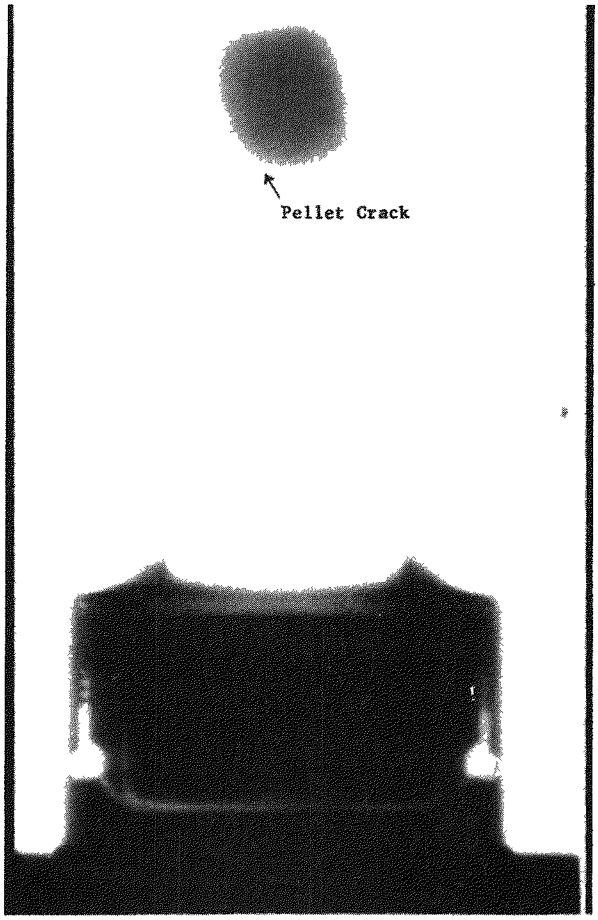


FIGURE 1. Radiograph of LASL-GPHS Pellet 31 in Shipping Container

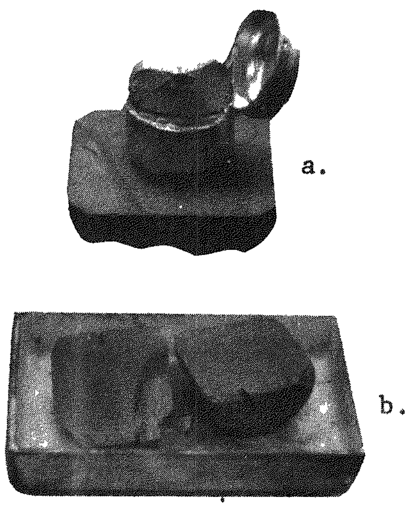


FIGURE 2. Iridium Shell Cut Away from LASL-G

Density variations, in addition to the internal cracks, are apparent in the low-magnification micrographs of the polished sections shown in Figure 3. Scanning electron microscopy of a fracture surface of LASL-GPHS Pellet 31 (Figure 4) showed thermally rounded grains in a crack, which indicates that this crack was formed prior to or during heat treatment. Therefore, although no surface cracks were apparent in LASL-GPHS Pellet 31 prior to packaging, internal cracks were observed during the characterization made at SRL.

As shown in Figures 5-7, the microstructure and density varies considerably along the longitudinal and radial axes. Metallographic densities were measured from a series of micrographs along each axis and were used to develop the density distribution plot shown in Figure 8. The prominent features of this plot include a low-density shell and a low-density core with the center of the core shifted upwards. This upward shift could be expected from powder flow mechanics during pressing. Another prominent feature of the density distribution plot is a narrow, but distinct, high-density band bordering the low-density outer shell.

The microstructure in the low-density regions was character ized by coarse intershard porosity and a well-defined shard structure, whereas the shard structure and large pores were nearly eliminated in the high-density region. As observed in Figure 3, cracking was most severe in the intermediate and high-density regions (81 to 89% TD). Most of the cracks tended to originate near the low-density core and propagate towards the surface, usually stopping near or within the high-density region.

The severity of cracking in the LASL pellet was most likely related to the large variations in density and microstructure. The degree of reoxidation induced fracture in $^{238}PuO_2$ was previously shown to be directly related to density; therefore, higher stresses are expected in the high-density areas. Also, differential shrinkage stresses during heat treatment are expected to increase as the density variations increase, especially since much of the coarse, stabilizing intershard porosity has been eliminated in the high-density regions.

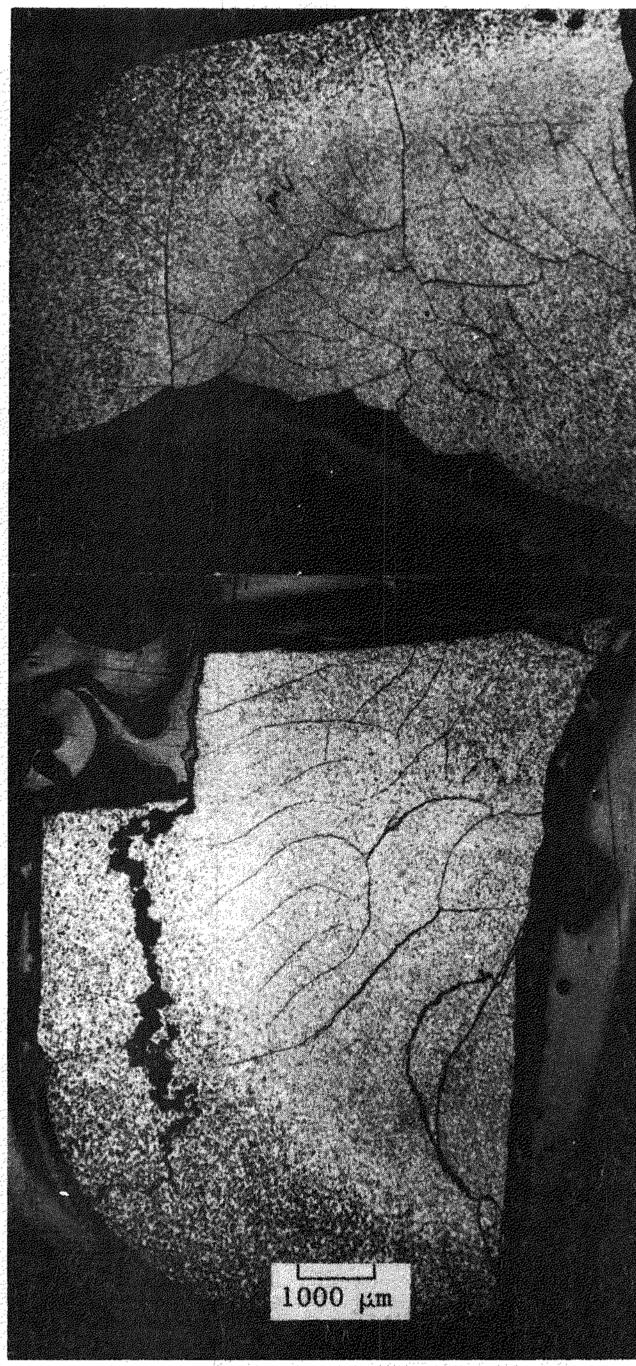


FIGURE 3. Longitudinal Section of LASL-GPHS Pellet 31

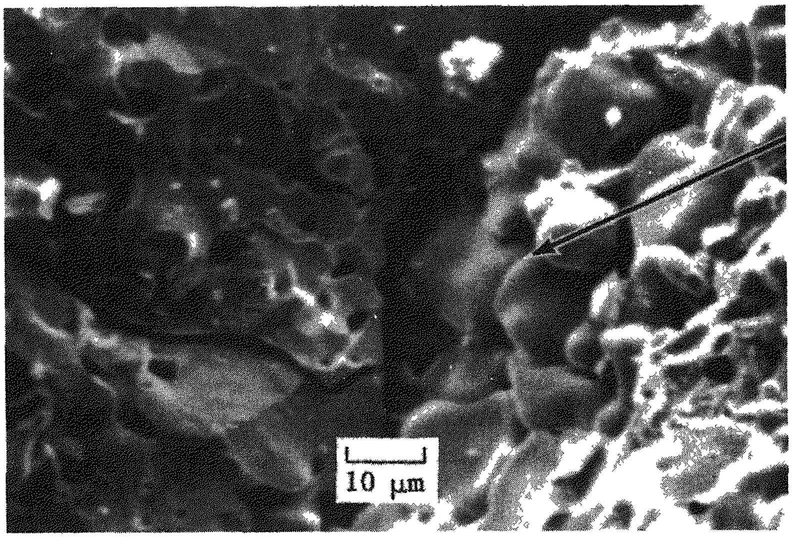
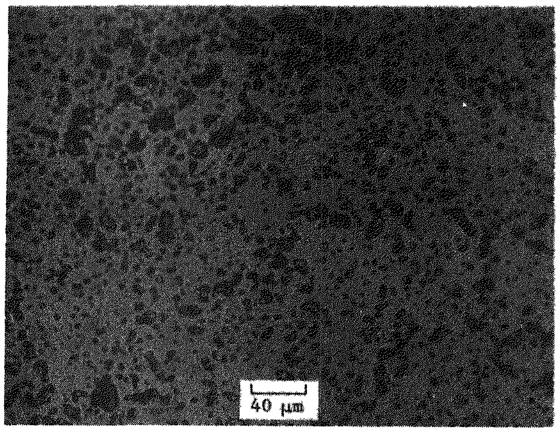
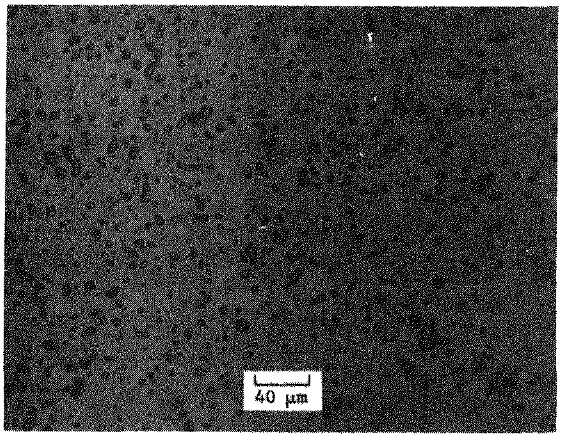


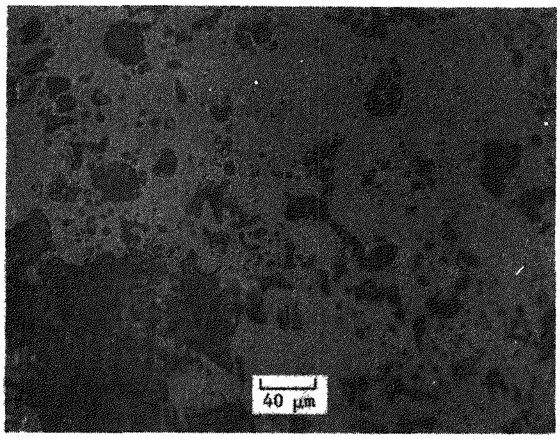
FIGURE 4. Fracture Surface of LASL-GPHS Pellet 31



Interior

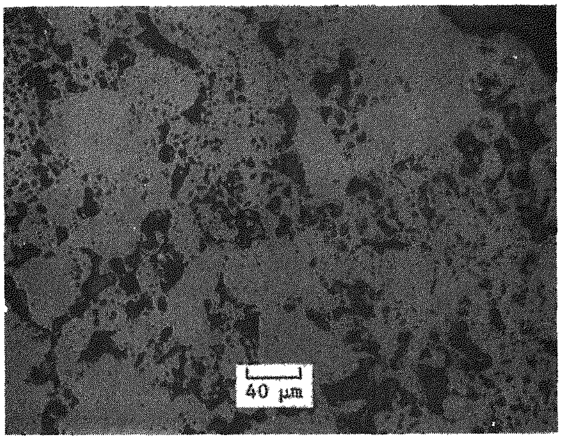


High-Density Region

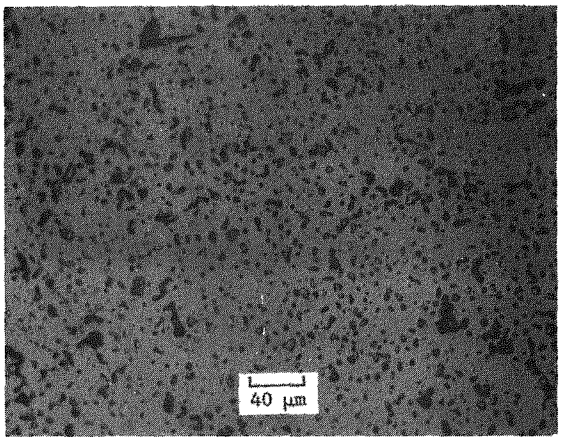


Surface

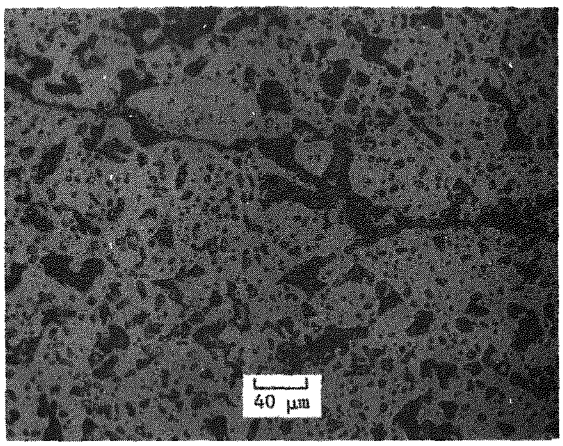
FIGURE 5. Radial Axis of LASL-GPHS Pellet 31



Top Surface

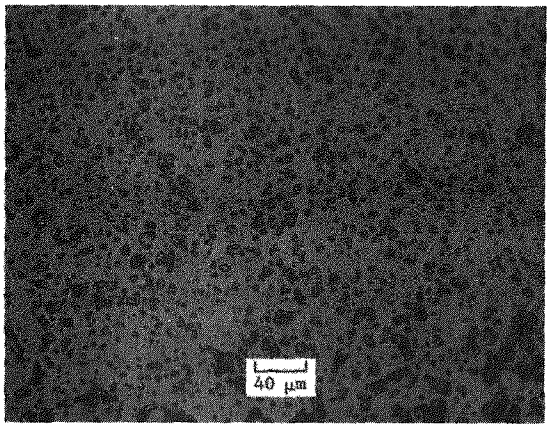


High-Density Region

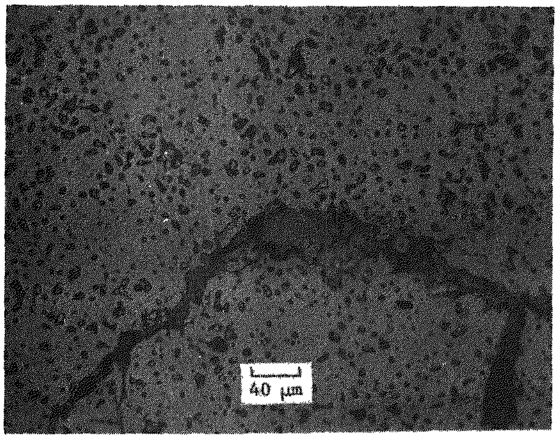


Interior

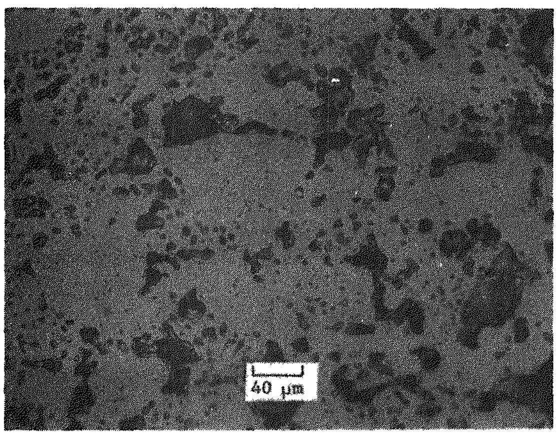
FIGURE 6. Longitudinal Axis (Top to Center) of LASL-GPHS Pellet 31



Interior



High-Density Region



Bottom Surface

FIGURE 7. Longitudinal Axis (Bottom to Center) of LASL-GPHS Pellet 31

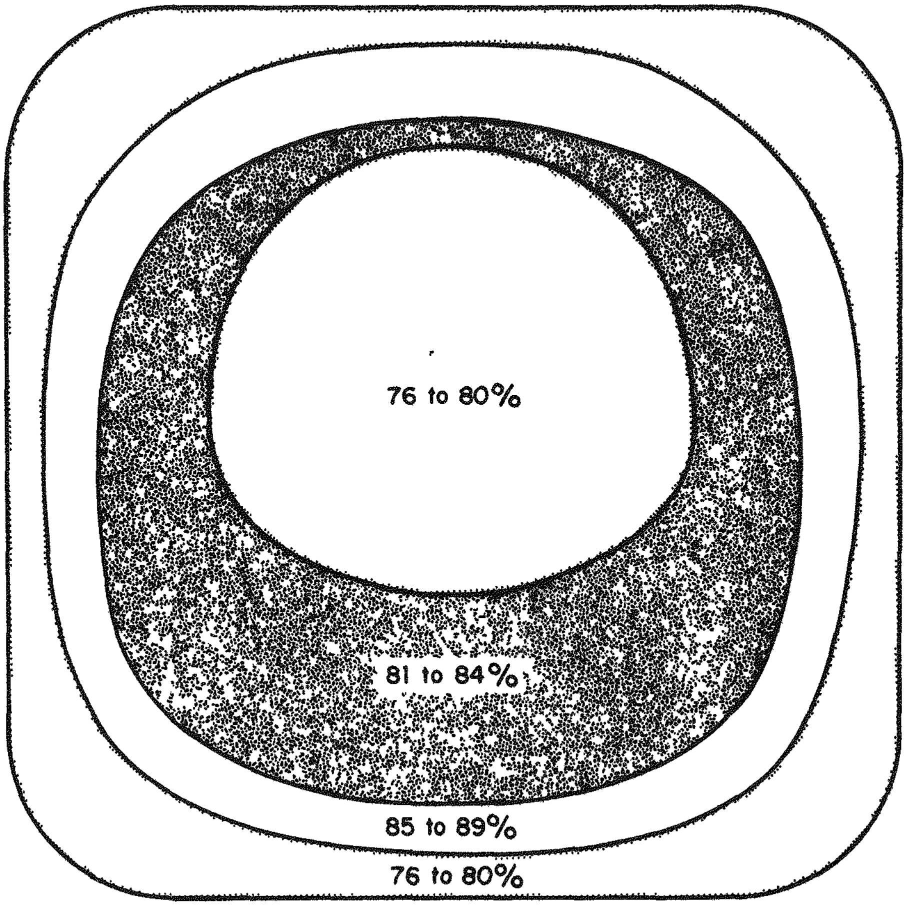


FIGURE 8. Density Distribution in LASL-GPHS Pellet 31

The severe internal cracking observed in LASL-GPHS Pellet 31, as well as the large variations in microstructure and density, are not characteristic of GPHS pellets fabricated by SRL. The differences between the LASL and SRL processes (Table 7) were thought to be minor and, therefore, not to affect the fuel pellet. A detailed characterization of samples of powder and shards from each step of the LASL fuel fabrication process was necessary to establish the cause of the relatively poor microstructure of LASL-GPHS Pellet 31.

TABLE 7

Key Flowsheet Differences

	SRL	LASL
Shard Preparation		
$^{16}O_2$ exchange atm	Dry	Wet ($Ar/H_2{}^{16}O$)
Ball milling	12 hr @ 100 rpm	32-40 hr @ 26 rpm
Length/Diameter of cold compact	1/5	1/1
Granule sintering atm	Dry	Wet ($Ar/H_2{}^{16}O$)
Hot Press Conditions		
Evacuation time	1 hr	16 hr
Preload	250 lb	60 lb
Time @ max temp and load	7.5 min	15 min
Final Heat Treatment Conditions		
Atmosphere	Dry	Wt ($Ar/H_2{}^{16}O$)

CHARACTERIZATION OF LASL-GPHS PROCESS SAMPLES

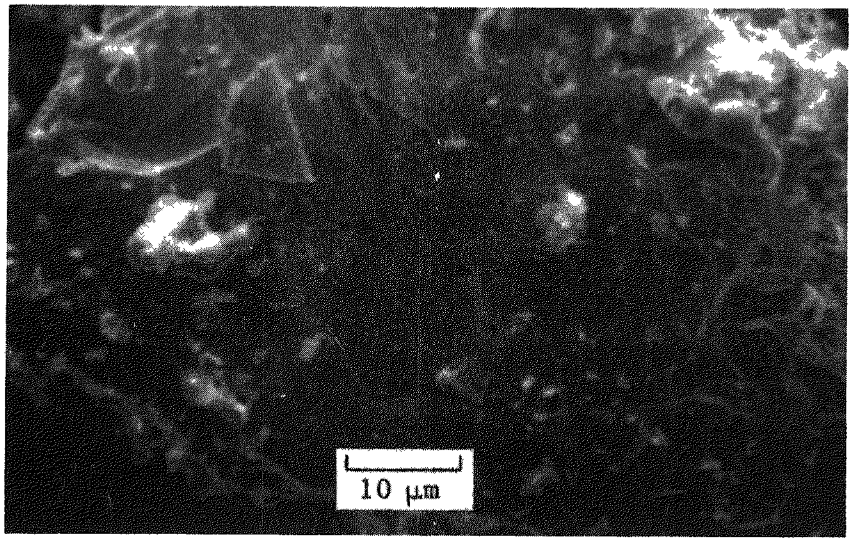
The as-received powder, oxygen-exchanged powder, and ball-milled powder samples from LASL were characterized by SEM analysis and by Coulter Counter particle size analysis. The results of these analyses were quite similar to the results of similar analyses done on comparable SRL materials.

SEM analysis of uncrushed and crushed shards was used to characterize both low- and high-fired shards. The fracture surface of the high-fired LASL shards appeared to have a lower density and larger pores than observed in SRL shards (Figure 9). This observation was confirmed by metallographic examination of high-fired shards which had been mounted in **Bakelite®** (Union Carbide Corporation) and polished (Figure 10). The metallographic density of the LASL 1600°C shards was about 88% TD whereas the density of SRL 1600°C shards was about 96%.

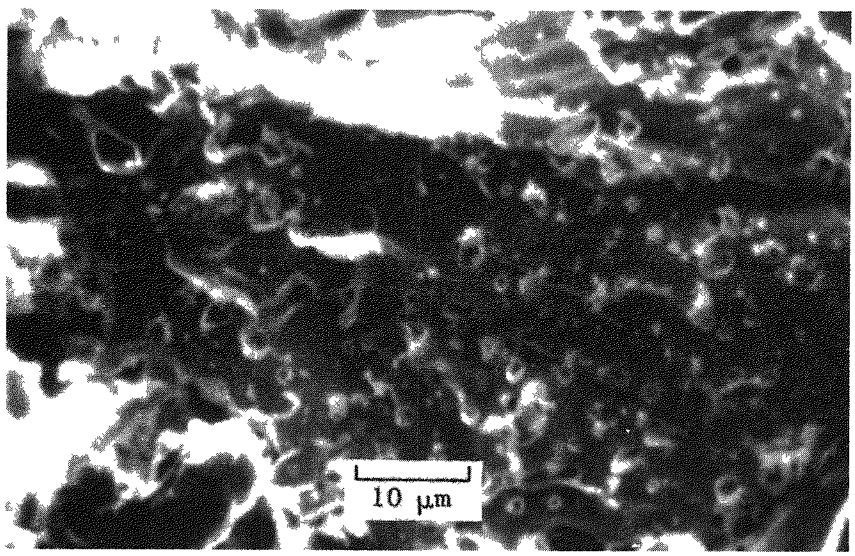
Conclusions

The low density of LASL shards does not seem to be caused by low sintering temperature. Small-scale GPHS experiments have previously shown that shard densities of about 95% TD are achieved at sintering temperatures as low as 1400°C. A more-likely cause of low-density shards is either (1) the density of the cold-pressed pellet from which the shards were made was low, or (2) the water-saturated atmosphere used by LASL (Table 7) during $^{16}O_2$ exch leads to stronger agglomerates in ball-milled powder, and, hence, larger pores in the cold press compacts and shards, or (3) the water-saturated argon atmosphere (Table 7) interferes with pore closure during shard sintering, all of which could result in low-density shards.

The low density of the LASL high-fired shards apparently was responsible for the density gradients in LASL-GPHS Pellet 31. The higher intrashard porosity (>3 volume percent) present in the LASL pellet must be accounted for by an equivalent reduction in intershard porosity, since the bulk densities of SRL and LASL pellets are equal. Therefore, the LASL process is equivalent to fabricating an 88% TD pellet using the SRL process if the high-fired shard are assumed to behave as integral particles. SRL has previously shown that at densities exceeding 85 to 87% TD, significant microstructural changes including loss of shard identity, elimination of intershard pores, density gradients, and more-severe cracking are expected, as was observed in the LASL pellet.

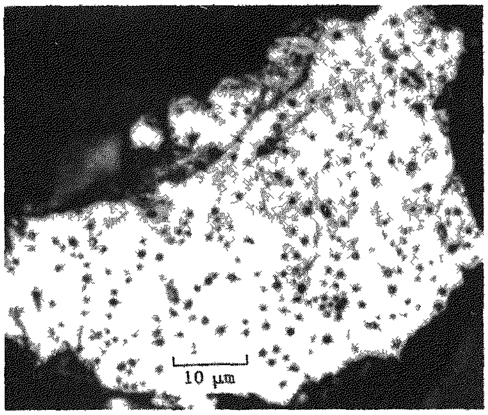


SRL

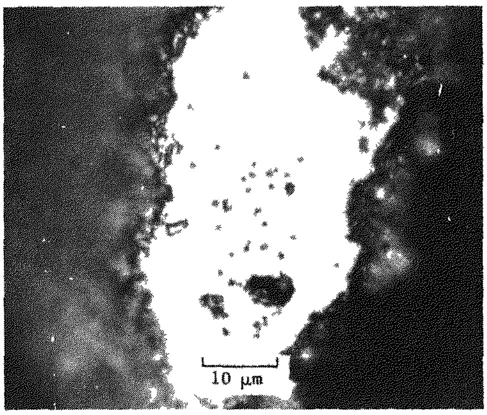


LASL

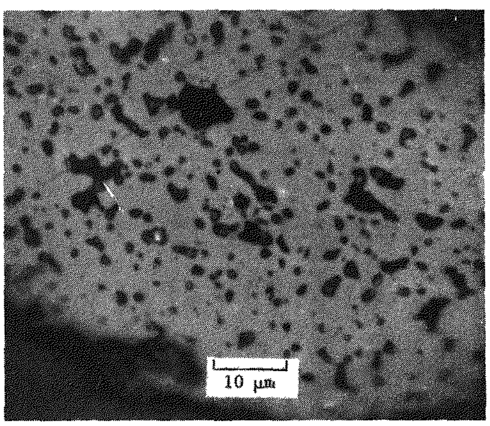
FIGURE 9. Comparison of Fracture Surfaces of High-Fired (1600°C) Shards from SRL and from LASL



SRL: 1400°C Shard
(95% TD)



SRL: 1600°C Shard
(96% TD)



LASL: 1600°C Shard
(87% TD)

FIGURE 10. Comparison of Polished Sections of Shards from SRL and from LASL

Less energy should be required to compact SRL shards than LASL shards to equal densities during hot pressing. Since equal pressures and loading ramps are used in the SRL and LASL processes, the time to die closure would be expected to be longer in the LASL process. LASL centerline conditions sometimes result in >15 min to obtain die closure after the maximum load is applied, whereas SRL centerline conditions result in about 3 min to die closure. SRL also observed that the linear shrinkage during heat treatment is higher for LASL pellets than in SRL pellets. This observation suggests that significant microstructural differences exist between SRL fuel pellets and LASL fuel pellets and that the microstructure of LASL-GPHS Pellet 31 is typical of other LASL-GPHS pellets.

Program

Further evaluation of the differences between the SRL and LASL processes and between SRL and LASL fuel pellets is planned. SRL plans to fabricate four GPHS pellets using centerline conditions. One of these pellets will be sectioned for microstructural analysis by SRL and the remaining pellets will be shipped to LASL for encapsulation and impact testing. LASL plans to do microstructural analysis on one or two of their pellets to determine whether the microstructural characteristics of LASL-GPHS Pellet 31 are typical of those of other pellets fabricated at LASL. SRL will attempt to evaluate the effects of a H_2O-saturated argon atmosphere on the sintering kinetics of $^{238}PuO_2$.

REFERENCES

1. **Savannah River Laboratory Bimonthly Report, ^{238}Pu Fuel Form Processes, July/August 1979.** USDOE Report DPST-79-128-7/8, E. I. du Pont de Nemours & Co. (Inc.), Savannah River Laboratory, Aiken, SC (1979).

2. **Savannah River Laboratory Bimonthly Report, ^{238}Pu Fuel Form Processes, January/February 1979.** USDOE Report DPST-79-128-1/2, E. I. du Pont de Nemours & Co. (Inc.), Savannah River Laboratory, Aiken, SC (1979).

3. **Savannah River Laboratory Bimonthly Report, ^{238}Pu Fuel Form Processes, March/April 1979.** USDOE Report DPST-79-128-3/4, E. I. du Pont de Nemours & Co. (Inc.), Savannah River Laboratory, Aiken, SC (1979).