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Postimpact Examinations of Three DOP 4 Iridium Shells from Simulant Fuel Sphere Assemblies

by

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POSTIMPACT EXAMINATIONS OF THREE DOPED IRIIDIUM SHELLS FROM SIMULANT FUEL SPHERE ASSEMBLIES

by

E. M. Cramer and S. S. Hecker

ABSTRACT

Three fuel sphere assemblies, with thorium in doped iridium containment shells, were examined after a simulated earth impact from an aborted orbital mission of a multihundred-watt thermoelectric heat source. The extent of deformation of each unit was measured. Damage to the containment shells was minimal in comparison to that in undoped iridium. Metallographic sections from critical areas indicated that superficial grain boundary cracking in weld zones and microscopic cracking in regions of maximum diameter had occurred in addition to local thinning and coining. The improved properties of the doped iridium are attributed to the retention of a small grain size and to an additional fracture resistance over iridium of a comparable grain size, imparted by either a change in grain boundary chemistry or the flow characteristics of the doped material.

I. INTRODUCTION

A space-oriented multihundred-watt (MHW) radioisotope thermoelectric generator (RTG) has been developed for the Energy Research and Development Administration (ERDA). Its basic heat source element is a sphere of plutonium* weighing about 254 g. Primary containment for the plutonium is provided by a vented iridium postimpact containment shell (PICS) 40 mm in diameter and 0.6- to 0.7-mm thick. The fuel and container

together comprise a postimpact sphere assembly (PISA) surrounded in turn by an 11.8-mm-thick Thornel* graphite impact shell (GIS) to form a fuel sphere assembly (FSA). A complete heat source contains 24 FSAs and is enclosed in a graphite aeroshell. In the event of mission abort leading to atmospheric reentry of the generator followed by earth impact, the aeroshell protects the generator through the reentry phase. The remains of the aeroshell and GIS protect the PISA on impact and leave the PICS to contain the plutonium until the debris is recovered.

*Isotopic composition of the MHW fuel is 80% $^{238}\text{PuO}_2$ and 20% $^{239}\text{PuO}_2$ with a specific activity of 11.9 Ci/g or 30 Ci/W.

*Thornel is a graphite yarn, a product of Union Carbide Corporation, Carbon Products Division, P.O. Box 849, Greenville, SC 29602.

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During containment development by General Electric Co.* (GE) many assemblies were tested in simulated conditions of earth impact after orbital abort and atmospheric reentry simulation. These hard-surface impact tests were carried out both by GE and the Los Alamos Scientific Laboratory (LASL) under contract to the Division of Space Nuclear Systems of ERDA. Simulant FSAs were tested by accelerating the assemblies to specified velocities up to 100 m/s in a gas gun and impacting them at controlled temperatures on granite targets. Live fuel (plutonia) sphere assemblies were tested under similar conditions by LASL in a safety sequential test¹ (SST) and a safety verification test² (SVT).

Failures in iridium containment were encountered in these tests through which significant quantities of either the simulant fuel (ThO_2) or isotopic fuel (PuO_2) could escape.³ These failures occurred by one of three mechanisms: (1) pushthrough of fuel fragments on impact; (2) tensile hoop cracks in the peripheries of deformed shells; or (3) a complex series of annular cracks (fingerprint patterns) in the impact faces of the shells. Every failure was principally intergranular in nature.

Iridium sheet for the MHW program is presently being fabricated by the Holifield National Laboratory**⁴ (HNL) and hydroformed into hemishells by Mound Laboratory of Monsanto Research Corp. It contains a nominal 0.3 wt% tungsten. Failures in the material during impact testing were instrumental in HNL's development of doped*** alloys. Controlled alloying additions can be effective in inhibiting grain growth (large grains were a persistent problem in most of the FSA impacts) or altering grain boundary chemistry to avoid grain boundary fracturing.

By monitoring the fracture behavior of doped iridium alloys in slow-rate uniaxial tension in the range of 650 to 760°C, HNL concluded that the alloy series DOP 4, containing approximately 40 ppm aluminum, 80 ppm iron, 30 ppm thorium, 16 ppm nickel, and 75 ppm rhodium, offered the greatest promise for impact fracture resistance.⁵ Biaxial punch impact tests at LASL⁶ confirmed the

improved characteristics of DOP 4 iridium under simulated impact conditions, as long as the grain size was less than 0.25 mm in diameter. Uniaxial high-rate tensile tests performed at HNL⁷ also demonstrated the improved ductility of DOP 4 iridium, particularly at the higher rates.

Three PICs were fabricated from DOP 4 iridium alloy and fueled with simulant fuel. The FSAs were impact tested at 1370°C and about 91 m/s by GE in April 1975. This report describes the postimpact examination of the three PICs designated MHT 90, 91, and 92 from the GE tests.

II. TEST PLAN

The three PISAs were received at LASL on May 1, 1975. The Appendix provides a description of the test plan followed during posttest examination, including sampling for metallography and distribution of remaining material. Information regarding the material identity, pretest history, and postimpact examination at GE is shown in Figs. 1-3 along with the photodocumentation of each sphere assembly.

III. DIMENSIONAL MEASUREMENTS

The PISA was measured with a shadowgraph which gave dimensions in two directions, one perpendicular and the other parallel to the impact plane. Shape and dimensions of each are shown in Fig. 4. The average diametral strains at maximum diameters varied from 9.7 to 11.1%. Compression in the impact direction varied from 29 to 30%.

IV. VISUAL INSPECTION, DEFUELING, AND SAMPLING

The PISAs were opened with a Moto-Tool grinder in a drill press stand. Each was positioned in a drill press vise and moved into the grinding wheel by hand. After the initial cut the PISA halves were defueled. The hemishells were then inspected, photographed (see Figs. 5-11, 21-25, 39-43), and sectioned for metallography and distribution according to the test plan in the Appendix. Each section was cut by manually feeding the hemishell across the drill press table into the grinding wheel.

The only visual defects in the PICs were those found by dye penetrant inspection at GE in the high-strain region of MHT 90 (refer to Fig. 8). Internally, the hemishells were clean and bright. No cracking

*General Electric Co., *Isotopes and Systems Application Operation*, P.O. Box 8661, Philadelphia, PA 19101.

**Formerly Oak Ridge National Laboratory.

***Doping refers to the addition of minute quantities of alloying elements, usually less than 100 ppm.

was detected (other than where MHT 91 was broken in defueling) even in the material underlying the dye penetrant indications.

All of the weld shields were found in place; those in MHT 90 and 92 were welded to their shells by the impact. Weld penetration was complete in all cases, but the width of each bead was less than that normally seen in iridium containments. The location of each closure weld with respect to the impact face is shown in Figs. 12, 26, and 44.

V. SPECIMEN PREPARATION

Iridium metallographic specimens, including two perpendicular cross sections (see Fig. 12), were potted in epoxy resin with an alumina filler. After grinding through 3/0 papers, the mounts were polished mechanically with 1 μ m diamond on nylon cloth. The polished specimens were etched electrolytically at 7.5 V dc in a solution of 20% hydrochloric acid and 80% water saturated with sodium chloride. Microhardness traverses were made with a Vickers indenter at 50 g load in locations deemed of interest. The values are shown in relevant photomicrographs in the approximate locations in which they were made. Macrophotographs and microstructures from the three iridium shells are shown in Figs. 5 - 52.

VI. METALLOGRAPHIC RESULTS

The PICSSs contained three types of DOP 4 iridium, depending on the source of the powder from which each was made: virgin, recycled, or 40% virgin/60% recycled. MHT 90 contained one hemishell each of virgin and recycled material. Both hemishells of MHT 91 were virgin material, and both of MHT 92 were 40% virgin/60% recycled material. All of the iridium parts had been heat treated for 16.5 h at 1500°C before they were assembled. Grain sizes were relatively small and remarkably uniform. The number of grains in a traverse of the walls varied from 10 to 12; this is in contrast to SST and SVT specimens in which single grains were found extending through the entire wall thickness in some places but coexisting with many considerably smaller grains. The grains were generally equiaxed although random regions of elongated grains (Fig. 51) were seen. Damage to the iridium containments from the impact (excluding that sustained by MHT 91 in defueling) was mostly intergranular cracking in weld zones (Fig. 13) and microscopic intergranular cracking in regions of maximum diameter (Fig. 19). Some local thinning

was also found in the maximum diameter regions and coining was seen in impact faces (Figs. 16 and 37). Cracks in weld zones were superficial; they occurred between columnar grains which were not perpendicular to the walls, consequently, breaching did not result. The welds performed satisfactorily in the high-temperature impacts.

Occasional intergranular surface cracks were seen in all PICSSs; they were prevalent where diameters were greatest (see Figs. 19, 36). Although damage was superficial, it indicates a grain boundary weakness and suggests the need for careful study of fracture characteristics of DOP 4 iridium. Cracking induced in MHT 91 at room temperature was intergranular as expected (Fig. 29).

VII. MICROHARDNESS RESULTS

DOP 4 iridium was appreciably harder than the iridium used in SST¹ and SVT² specimens. Vickers hardness numbers (VHN) are shown for each hemishell in Figs. 20, 38, and 52. The virgin material averaged 75 points harder than the SST and SVT materials. The recycled material averaged 85 points higher, and the 40% virgin/60% recycled material 105. There were no consistent hardness differences either among the original locations in a shell such as pole or equator, or among the impact faces, backs, or maximum diameters.

VIII. THICKNESS STRAINS

Our understanding of the deformation and fracture behavior of iridium containment shells would be greatly enhanced if the surface strains could be measured at various locations after impact. Such an attempt was not made in the present series; however, the strains can be measured in future tests by etching an appropriate grid on the undeformed sphere. In the absence of surface strain information, we did attempt to measure thickness strains from metallographic sections. These cross sections were cut perpendicular to the shell as closely as possible to project the correct thickness. Measurements were made at 10 locations in each vertical section as shown in Table I. Additional measurements were made along the horizontal (maximum diameter) section to determine its range.

Calculation of thickness strain requires a knowledge of original thickness. In the present case, uncertainty of these values precludes any real quantitative measure of strain (for instance, in DOP 4-1-2 the original thickness varies from 0.584 to 0.709 mm

TABLE I
THICKNESS MEASUREMENTS BEFORE AND AFTER IMPACT

Measurement	MHT 90		MHT 91		MHT 92	
	4-1-2	4-3-1	4-4-1	4-4-3	4-2-2	4-2-4
Initial thickness range at pole	0.653 – 0.663 mm	0.665 – 0.666 mm	0.665 – 0.671 mm	0.668 – 0.673 mm	0.648 – 0.653 mm	0.660 – 0.661 mm
Initial thickness near 45° (minimum for shell)	0.584	0.610	0.612	0.610	0.582	0.597
Initial thickness range at equator	0.638 – 0.709	0.678 – 0.714	0.665 – 0.671	0.673 – 0.716	0.668 – 0.709	0.678 – 0.714
Thickness after test at location	1	0.631	0.695	0.627		
	2	0.728	0.718	0.651		
	3	0.775	0.676	0.634		
	4	0.606	0.624	0.650		
	5	0.613	0.636	0.622		
	6	0.612	0.650	0.642		
	7	0.643	0.708	0.740		
	8	0.671	0.675	0.722		
	9	0.637	0.621	0.683		
	10	0.651	0.685	0.632		

TABLE II
THICKNESS MEASUREMENTS IN REGION OF MAXIMUM DIAMETER

Measurement	MHT 90 (mm)	MHT 91 (mm)	MHT 92 (mm)
Initial thickness range	0.584-0.714	0.582-0.709	0.610-0.716
Thickness range at maximum diameter after impact	0.575-0.710	0.592-0.662	0.557-0.697

or 21%). Mound Laboratory generally records the thickness of the hemishells in two locations: (1) minimum and maximum values near the equator and (2) minimum thickness which generally occurs 45° from the equator. In addition, the original sheet thickness provides a good approximation of the thickness at the pole since little thinning occurs there. The initial thickness of all six hemishells, measured at Mound,⁸ is listed in Table I. During an impact test, the equator is also randomly oriented with respect to the impact plane. This makes it imperative to know the entire initial thickness distribution to make strain calculations.

The only meaningful correlation derived from the thickness strain data is shown in Table II where the initial thickness range is compared to the range measured at maximum diameter. Comparison shows that thinning most likely occurs in this location. Data from MHT 92 also allow an interesting calculation. Examination of thickness minima in the region of maximum diameter suggests that at one location thinning from 0.61 mm (the original minimum) to 0.557 mm occurred, or at least an 8.7% reduction. Using the overall diametral strain measure of 11.1%, the second principal surface strain (in the impact direction) can be calculated from the constancy of volume relation to give a value of -1.4%. This is very close to plane strain. Impact tests with gridded spheres will be needed to substantiate this result.

IX. DISCUSSION

The fracture resistance of DOP 4 iridium, when tested on impact in the form of PICS, is significantly greater than that of the iridium tested previously. Damage was limited to small amounts of microscopic grain boundary cracking in the region of maximum diameter. We believe that most of this increased resistance can be attributed to the relatively fine grain size maintained in the DOP 4 alloys. Previous work on iridium⁹ has demonstrated the influence of grain size on fracture. Results indicate that strains of the order of 60% are necessary to cause through-thickness cracking in iridium with a grain size comparable to the above.

Other work on DOP 4 alloys⁷ has shown that this material may offer additional fracture resistance over iridium of equivalent grain size. Auger electron spectroscopy⁶ did not reveal a significant difference in impurity element concentration in the grain boundaries of DOP 4 alloys compared to previous alloys. It is not clear, therefore, whether the improved fracture resistance results from subtle changes in grain boundary chemistry or from

modification of the plastic flow characteristics of doped materials. Neither chemical analysis nor Auger electron spectroscopy was performed as a part of this study. Samples for these purposes were sent to HNL.

Detailed examination of PICS thickness profiles revealed large variations, some initially present after hydroforming and some caused by nonuniform deformation during impact. This suggests that differences in orientation of the PISA with respect to the impact plane may bring about considerable scatter in iridium performance during impact tests.

ACKNOWLEDGMENTS

In addition to those whose work has been quoted, we acknowledge the help of C. E. Frantz in obtaining dimensional data and L. R. Bergamo in metallography, and their contributions to this report.

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GE FSA QUICK LOOK IMPACT DATA

Test Objective: Evaluate DOP 4 iridium at 45° from nominal

Impact Date: 4/16/75

Impact Parameters:

Impact Temperature: 1370°C (2500°F)

Degrees from Nominal: 50°

Velocity (ft/s): 313.4

GIS Identity: 903745-1 (June 1974)

ThO₂ Density: 76%, #809

Iridium Identity:

Hemisphere 1: DOP 4-3-1 (B) Recycled solids

Hemisphere 2: DOP 4-1-2 (A) Virgin powder

Heat Treatment: 16-1/2 h at 1500°C prior to welding.

Other Comments: A group of dye penetrant indications about 100° from start of weld and about 1/16 in. from edge of weld, prior to impact.

Iridium Dimensions:

<u>Prior to Impact</u>	<u>Post Impact</u>
Average pole to pole (in.) <u>1.603</u>	Average diameter (in.) <u>1.752</u>
Average at equator (in.) <u>1.6025</u>	Average height (in.) <u>---</u>
Average at 45° (in.) <u>1.6035</u>	Average deformation (%) <u>9.3</u>

Impact Results:

1. Microcracking in regions having dye penetrant indications prior to impact.
2. No other cracking at 30X or by dye penetrant.

Fig. 1.
GE initial evaluation of DOP 4 iridium in MHT 90.

GE FSA QUICK LOOK IMPACT DATA

Test Objective: Evaluate DOP 4 iridium at nominal conditions

Impact Date: 4/15/75

Impact Parameters:

Impact Temperature: 1370°C (2500°F)

Degrees from Nominal: 4°

Velocity (ft/s): 301.7

GIS Identity: 903746-1 (June 1974)

ThO₂ Density: 76%, #811

Iridium Identity:

Hemisphere 1: DOP 4-2-4 (A) Virgin powder

Hemisphere 2: DOP 4-2-2 (A) Virgin powder

Heat Treatment: 16-1/2 h at 1500°C prior to welding.

Other Comments: Small inclusion in weld joint at about 300° (counter-clockwise) from the identification marks.

Iridium Dimensions:

<u>Prior to Impact</u>		<u>Post Impact</u>	
Average pole to pole (in.)	<u>1.604</u>	Average diameter (in.)	<u>1.759</u>
Average at equator (in.)	<u>1.600</u>	Average height (in.)	<u>1.132</u>
Average at 45° (in.)	<u>1.603</u>	Average deformation (%)	<u>9.6</u>

Impact Results:

No cracks as observed at 30X or by dye penetrant.

Fig. 2.
GE initial evaluation of DOP 4 iridium in MHT 91.

GE FSA QUICK LOOK IMPACT DATA

Test Objective: Evaluate DOP 4 iridium, hit at 45° from nominal

Impact Date: 4/18/75

Impact Parameters:

Impact Temperature: 1370°C (2500°F)

Degrees from Nominal: 48°

Velocity (ft/s): 295.3

GIS Identity: 903847-1 (June 1974)

ThO₂ Density: 76%, #812

Iridium Identity:

Hemisphere 1: DOP 4-4-3 (C) 40% virgin, 60% recycled solids

Hemisphere 2: DOP 4-4-1 (C) 40% virgin, 60% recycled solids

Heat Treatment: 16-1/2 h at 1500°C prior to welding.

Other Comments: No dye penetrant indications.

Iridium Dimensions:

<u>Prior to Impact</u>		<u>Post Impact</u>	
Average pole to pole (in.)	<u>1.604</u>	Average diameter (in.)	<u>1.785</u>
Average at equator (in.)	<u>1.604</u>	Average height (in.)	<u>1.125</u>
Average at 45° (in.)	<u>1.604</u>	Average deformation (%)	<u>11.2</u>

Impact Results:

1. No breach at 30X or by dye penetrant examination.
2. Sharp secondary. No breach.

Fig. 3.
GE initial evaluation of DOP 4 iridium in MHT 92.

a. MHT 90.

b. MHT 91.

c. MHT 92.

Fig. 4.

Dimensions and strains of three PISAs determined with a shadowgraph, where e_d is the diametral strain and e_h the height strain.

Fig. 5.
MHT 90 after impact testing by GE.

Fig. 6.
Impact face of MHT 90.

*Fig. 7.
Profile of MHT 90.*

*Fig. 9.
The interior of MHT 90 was clean and bright
after it had been defueled.*

*Fig. 8.
Dye penetrant indications of cracking in the
PICS were observed in this region by GE. A
metallographic specimen from this location
showed superficial intergranular cracks
originating in the outer surface.*

*Fig. 10.
Interior of the opposite hemisell of MHT 90
shown in Fig. 9.*

Fig. 11.

The region underlying the dye penetrant indications (Fig. 5) had no visible defects.

Fig. 12.

Metallographic section from the PICS of MHT 90 (their locations are shown in the Appendix). Locations of the photomicrographs in Figs. 13-20 are indicated. A designates virgin material, B recycled powder.

Fig. 13.

Closure weld at location 1 in Fig. 9. Etched. Some grain boundary separation occurred in the weld bead.

Fig. 14.

Closure weld in back of the PICS, location 2. Etched. Again intergranular separation occurred although the weld was not seriously damaged.

Fig. 15.
Recycled material in back of MHT 90, location 3. Microhardness values are at 50 g load.

Fig. 17.
Closure weld in the region of maximum diameter in MHT 90. Etched. This corresponds to location 5.

Fig. 16.
Virgin material in the impact face of MHT 90, location 4. Note the coining in the iridium.

Fig. 18.
Opposite weld section from Fig. 17, MHT 90. Etched. This corresponds to location 6. Some intergranular fracturing occurred both inside and outside of the PICS.

Fig. 19.

Intergranular breaking up in virgin material in the region of maximum diameter on MHT 90, location 7. Etched.

Fig. 20.

Average microhardness values at 50 g load at selected locations in the iridium wall of MHT 90. Hardness traverses are shown in Figs. 15, 16, and 19.

Fig. 21.

MHT 91 after impact testing by GE.

Fig. 22.

Impact face of MHT 91. The black smudge appears to be polyethylene fused to the PICS.

Fig. 23.
Profile of MHT 91.

Fig. 25.
The interior of the PICS was clean and bright and was, except for the damage shown in Fig. 24, free of visible cracks.

Fig. 24.
Interior surface of the impact face of MHT 91. This PISA was opened first and was defueled by rapping the PICS with a plastic mallet. The virgin material in both hemispheres was fractured in the process.

Fig. 26.
Metallographic sections from the PICS of MHT 91 (their locations are shown in the Appendix). Locations of the photomicrographs in Figs. 27-37 are indicated. A designates virgin powder.

Fig. 27.

Closure weld in the impact face of MHT 91. Etched. This corresponds to location 1 in Fig. 26. Except for minor grain boundary separation, the fracture occurred when the PISA was defueled.

Fig. 29.

Fracturing and intergranular breaking up in the back of MHT 91, location 3. Etched. Virgin powder material. This occurred at room temperature at the point where the PISA was rapped to dislodge the plutonia.

Fig. 28.

Virgin powder material in the impact face of MHT 91. Etched. This corresponds to location 2.

Fig. 30.

Virgin powder material near the region of maximum diameter in MHT 91. This corresponds to location 4.

Fig. 31.

Closure weld in the region of maximum diameter in MHT 91, location 5. Etched. Some intergranular cracking occurred in the weld.

Fig. 33.

The fracture in the closure weld in the back of MHT 91 was intergranular at room temperature. Etched. This corresponds to location 7.

Fig. 32.

Opposite weld in the region of maximum diameter in MHT 91, location 6. Etched. The weldment has the appearance of an electron beam operation.

Fig. 34.

Local thinning in the region of maximum diameter in MHT 91, location 8. Etched. Virgin powder material.

Fig. 35.
Grain deformation in virgin powder material, location 9. This occurred in the region of maximum diameter in MHT 91.

Fig. 37.
Coining in the impact face of MHT 91. Etched. This corresponds to location 11.

Fig. 36.
Intergranular break up in virgin powder material, location 10. Etched. This also occurred in the region of maximum diameter.

Fig. 38.
Average microhardness values at 50 g load at selected locations in the iridium wall of MHT 91. Hardness traverses are shown in Figs. 28-30.

Fig. 39.
MHT 92 after impact testing by GE. A deep indentation is visible on the right side.

Fig. 41.
Profile of MHT 92. Depth of the indentation is more readily apparent.

Fig. 40.
Impact face of MHT 92. There are no visible defects. Black smudges appear to be polyethylene fused onto the surface of the PISA.

Fig. 42.
The interior of MHT 92 was clean and free of any visible defects.

Fig. 43.

There were no visible cracks in the 40% virgin/60% recycled iridium underlying the deep indentation shown in Figs. 39 and 41.

Fig. 45.

Closure weld in the region of maximum diameter in MHT 92. Etched. This corresponds to location 1 in Fig. 44. Some intergranular cracking occurred in the 40% virgin/60% recycled material, however, the weld was not seriously damaged.

Fig. 44.

Metallographic sections from the PICS of MHT 92 (their locations are shown in the Appendix). Locations of the photomicrographs in Figs. 45-50 are indicated. C designates 40% virgin/60% recycled solids. The closure weld, in this instance, appears only in the vertical section.

Fig. 46.

Closure weld opposite Fig. 44. This corresponds to location 2. It was also in the region of maximum diameter.

Fig. 47.

10% virgin/60% recycled material in the back of MHT 92, location 3. Etched. Note the small grain size and compare with Fig. 50 (location 7) near the lip of the hemishell.

Fig. 49.

Material in the region of maximum diameter in MHT 92 corresponding to location 5. Hemishell 4-4-3, 40/60 iridium.

Fig. 48.

10% virgin/60% recycled material in the impact face of MHT 92, location 4. Etched.

Fig. 50.

Material from location 6 in the opposite hemishell of MHT 92 (4-4-1), also in the region of maximum diameter.

Fig. 51.
 Elongated grains near the lip of hemishell 4-1-3. This corresponds to location 7. Grain size is larger than that in the dome (Fig. 47).

Fig. 52.
 Average microhardness values at 50 g load at selected locations in the iridium wall of MHT 92. Hardness traverses are shown in Figs. 47 and 48.

APPENDIX

LOS ALAMOS SCIENTIFIC LABORATORY
UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO 87544
Telephone Ext. 4862

OFFICE MEMORANDUM

TO : Distribution

DATE : May 8, 1975

FROM : S. E. Bronisz

SUBJECT : TEST PLAN FOR THE SAMPLING AND EXAMINATION OF THE DOP-4
IMPACTED PISA's

SYMBOL : CMB-5-C-75-678

MAIL STOP : 730

The following steps will be followed in examining the three DOP-4 samples, MHT-90, MHT-91 and MHT-92. The persons designated will be responsible for carrying out the steps. E. Cramer is responsible for the overall examination.

1. External examination and photography--Bergamo, Cramer

The PISA will be examined and macroscopic features will be noted and recorded. Sufficient photographs will be taken to characterize the visual aspects of the PISA. Additional photographs shall be made as necessary to record the subsequent steps in the examination.

2. Measurement--Frantz, SD Inspection Shop

The PISA profiles and contours will be measured accurately to obtain a record of the exact shape after impact.

3. Initial sectioning--Bergamo, Cramer, Hecker

The PICS will be sectioned initially by an approximately diametral cut along the line that will expose the most important cross-section. The ThO_2 fuel simulant will be removed and the internal surface of the PICS examined.

4. Subsequent Sectioning--Bergamo, Cramer

Additional cuts will be made to separate suitable PICS samples for LASL, GE, MRC and ORNL. The locations and destinations of the various sections are shown in Figure 1.

5. Microscopic Examination--Bergamo, Cramer

The LASL sample shall be mounted, prepared and examined in the usual manner to determine the microstructural features and hardness. A fractographic examination may be carried out on specimens sent to D. Stein for Auger Spectroscopy.

6. Shipping Samples to GE, MRC and ORNL--Rohr

The samples for the other installations shall be shipped promptly to the following addresses.

May 8, 1975

a. General Electric Company
Space Division, Attn: C. W. Whitmore
King of Prussia Park
P. O. Box 8661
Philadelphia, PA 19101

b. Monsanto Research Corporation
Mound Laboratory
Miamisburg, OH
Attn: D. L. Coffey

c. Oak Ridge National Laboratory
P. O. Box X
Oak Ridge, TN 37830
Attn: H. Inouye

7. Reporting--Bergamo, Cramer, Hecker

A comprehensive report of the results of the LASL examinations of the DOP-4 samples shall be written and distributed to ERDA/SNS, GE, MRC and ORNL when the examinations are completed. Progress of the examinations shall be reported in the Monthly Progress Reports.

8. Deviations from this test plan shall be made only with the approval of S. Hecker and S. Bronisz.

S. E. Bronisz
S. E. Bronisz

SEB:ev

Distribution:

R. Mulford (2)
L. Bergamo
E. Cramer
C. Frantz
S. Hecker
D. Mohr
D. Pavone

Fig. 1. Typical cutting diagram for DOP-4 PICS.