SC-TM-68-154
April 1968

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EXPERIMENTS ON SMALL PARTICLE ABLATION IN SIMULATED REENTRY--INTERIM REPORT

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EXPERIMENTS ON SMALL PARTICLE ABLATION
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ABSTRACT

The thermal and ablative responses of plutonium dioxide microspheres exposed to various simulated reentry environments in a hyperthermal arc tunnel are examined. The simulated reentry heating environment to which the particles were exposed ranged from orbital decay microsphere release to more severe abort releases.

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SUMMARY

The ablation response of radioactive material when it is exposed to the reentry environment has a direct bearing on the severity of the hazard that may result. Plutonium dioxide microspheres ranging from 50 to 250 micrometers in diameter will be used as heat sources in certain SNAP space applications. It is necessary to determine the fate of such microspheres undergoing reentry from orbit or certain abort conditions.

The studies discussed herein present results and tentative conclusions from experiments conducted in a 40-kw hyperthermal arc tunnel. Microspheres near 250 micrometers in diameter were supported on 160-micrometer diameter stings and exposed for various periods of time--typically from 0.1 to 0.3 second--to simulated reentry heating. The response of the microspheres was recorded on high speed film, with real time available from the film.

In an effort to characterize the debris generated during ablation, sampling surfaces were placed downstream of the microspheres. The debris collected on the samplers was analyzed for size distribution and total quantity present. The results of the experiments are presented, and although complete reentry simulation cannot be accomplished in the laboratory, estimates of the effect of reentry on microspheres are made based on the results of these experiments.

ACKNOWLEDGMENT

The authors wish to express their appreciation to several persons who provided assistance for these experiments. Dana Douglass at LASL provided preliminary data on the impactor debris; H. Romero, 1131, provided metallographic information on the microspheres; J. F. Hudson and M. D. DeVore, both 9311, provided pretest and posttest size and weight characterization of the material; R. M. Elrick, 5234, analyzed the flow field about the impactors to predict sampler efficiency.

K. L. Romine, 9311, very ably maintained the test facility and performed many of the operations necessary to conduct successful experiments.

EXPERIMENTS ON SMALL PARTICLE ABLATION IN SIMULATED REENTRY--INTERIM REPORT

Microsphere Response in Reentry

The response of microspheres during reentry from orbit or from certain abort conditions involves heating, melting, and possible size degradation. The release conditions under which particle melting will occur have been well documented.^{1,2} These original melt envelopes were altered slightly because of certain improvements in the numerical technique used for the computer calculation. The program described in detail in a Sandia report³ analyzes all realistic phenomena, including variable physical properties, surface radiation, vaporization, heat of fusion, and aerodynamic heating according to Matting and Chapman.⁴ The revised melt envelope is shown in Figure 1. Included on this figure are lines of constant percentage melt for various release conditions for both 50- and 250-micrometer diameter particles. Intermediate sizes for similar percentage melt would fall between these two sizes. It should be noted that the calculations for the melt percentages are based on the assumption that the microspheres do not change shape during melting. Presently, no shape change can be incorporated into the program; however, it appears that a shape change would result in a reduction of the region where total melt would occur.

The straight lines shown on Figure 1 represent release conditions during reentry at which the initial stagnation point heat flux on a 250 micrometer particle is equal to the flux in the arc tunnel at test Conditions L, A, C, B, K, and M. Certain factors must be considered in interpreting these lines. They represent initial heat flux values, and the heat flux during reentry decreases with time in contrast to the constant heat flux value of the arc tunnel. For many release conditions, this does not represent a serious problem since the particle melts so rapidly that the associated decay in heat flux is relatively small. However, this difference does account for the fact that the heat flux lines for Conditions A and C lie generally outside the melt envelope and yet melting occurs in the arc tunnel. Also, although the equivalent

test heat fluxes can be produced during reentry at various velocity-altitude combinations, this does not imply that these various combinations were reproduced in the experiments. From the enthalpy values given in Table I, one can calculate an equivalent reentry velocity and for each test condition determine the altitude of reentry at which the heat fluxes are equal. Since the greatest portion of the K and M test condition heat flux lines lie well within the melt zone, it seems important for these conditions to reproduce the heat flux to the particle rather than particular altitude-velocity combinations. For releases near the edge of the melt zone, these considerations become important.

Figure 1. Microsphere response in reentry

The dynamic response of a particle during and after melting is not as readily determined from theory or experiments as is the thermal response. The ratio of dynamic pressure forces acting on the particle to the surface tension forces of the particle (called Weber number) occurs consistently in stability analyses and has been used to correlate experimental results regarding conditions of mass loss and totally molten particle breakup. Luna and Klikoff⁵ conducted a survey of the aerodynamic breakup of liquid droplets and reported that the breakup of droplets was observed in the experiments for Weber numbers from 1 to 10, with higher values for highly viscous materials.

Considerable experimentation has been performed at Sandia on $^{238}\text{PuO}_2$ microspheres in a 40-kw hyperthermal arc tunnel. These experiments were conducted to obtain information on the response of $^{238}\text{PuO}_2$ microspheres when they were subjected to various simulated reentry environments. The microsphere responses ascertained include time to beginning of melt, melt rate, shape change, degree of ablation, and size distribution of the ablated debris. The tests in the hyperthermal arc tunnel were accomplished by mounting each $^{238}\text{PuO}_2$ microsphere on a small conical sting and exposing it to the hot supersonic flow. Each microsphere was positioned 1.25 inches from the nozzle exit plane. In order to control the time of exposure, a solenoid-actuated, water-cooled shield was positioned in the flow between the nozzle exit plane and the microsphere. A timing mechanism controlled the raising and lowering of the shield. Polyvinylchloride-coated copper impact samplers, 3.5 inches in diameter, were located 4 inches downstream from the microsphere to collect the ablated debris. These impact samplers were analyzed by Tracerlab, Inc., to determine the size distribution of the collected debris. A discussion of the ablated debris is presented later in this report.

The arc tunnel facility does not reproduce all of the parameters present during actual reentry, but the literature suggests that the primary parameter missing--the deceleration force--has a destabilizing influence on the liquid layer in the stagnation region. Table I presents the gas enthalpy, model pressure, stagnation heat flux, and Weber number for each test condition. The model pressure is measured directly with a flat-face pitot probe, and the gas enthalpy is calculated from the relationship

$$q \sqrt{R} = 8.4 \times 10^{-4} H_s \times \sqrt{P_{t2}}$$

TABLE I
Test Conditions

Condition	Enthalpy (Btu/lb)	Model Pressure (atms)	Stagnation Heat Flux (Btu/ft ² -sec)	Weber Number
A	11,000	0.0485	650	1.0
B	10,000	0.0737	950	1.6
C	9,500	0.0593	800	1.2
K	13,000	0.0987	1800	2.2
L	3,600	0.0237	100	-
M	12,000	0.276	2800	4.6

A copper calorimeter measures the heat flux which is used in calculating the enthalpy, but since the calorimeter is flat-faced and much larger than the microspheres, the stagnation heat flux on the particle must be calculated from the measured pressures and the calculated enthalpy. To do this satisfactorily, one must account for several phenomena which affect the heat transfer to the particle. Some of these phenomena are: corrections for noncontinuum flow; real gas effects of the test gas, including disassociation and ionization; catalytic effects of the surface of the plutonium dioxide microspheres; and nonequilibrium flow effects in the supersonic nozzle.

Calculations which account for these effects in some manner are made for the heat flux. To do this, it is necessary to make assumptions which are based on the limited information available in the literature. A common method of expressing the heat flux at low Reynolds number (transition and free molecular flow) is with the expression

$$\frac{q}{q_{BL}} = f(R_e).$$

To calculate the boundary layer heat flux, the equation of Rosner⁶ is used:

$$q_{BL} = 0.763 \left(\frac{\rho_w \mu_w}{\rho_e \mu_e} \right)^{0.1} (\beta \rho_e \mu_e)^{0.5} (P_r)^{-0.6} \Delta h \left\{ 1 + \phi [Le^{0.6} - 1] \frac{\Delta h_c}{\Delta h} \right\}$$

where

Δh_c = enthalpy of dissociation

Δh = enthalpy difference across boundary layer =

$$(h_s - h_w) - (1 - \phi)\Delta h_c$$

ϕ = extent of recombination at surface

β = inviscid velocity gradient at nose =

$$\frac{V_\infty}{R} \left(\frac{\rho_\infty}{\rho_2} \left[2 - \frac{\rho_\infty}{\rho_2} \right] \right)^{0.5}.$$

To determine the gas properties at the nozzle plenum and after expansion through the nozzle, a computer program was written for both equilibrium and frozen flow through the nozzle.⁷ Based on information in the literature, it was assumed for these calculations that the flow is frozen in composition through the nozzle at the relatively low pressures of these experiments.

Calibration experiments on larger calorimeters revealed that plutonium dioxide reduces the heat flux to the calorimeter by a factor equal to that for silicon oxide. Silicon oxide is stated to be almost totally noncatalytic in this environment, and plutonium dioxide is assumed to be the same. Therefore, for the heat flux calculation, the microsphere surface is assumed to be noncatalytic and ϕ is taken to be zero.

Evaluation of this equation for these conditions results in the noncatalytic, frozen flow, boundary layer heat flux to the particle. The low Reynolds number correction to this value is applied using the method utilized by GE.⁸

Several tests were performed at each condition (Table I), and the repeatability of the particle response as indicated by the movie film and debris samplers was very good. Samplers located downstream of the particle collected debris generated during each test.

The heat flux for Conditions A, B, and C is representative of that associated with a reentry release near the edge of the melt zone at velocities near 25,000 ft/sec; for Condition K the heat flux represents releases within the region of total melt for velocities greater than about 20,000 ft/sec; and for Condition M the heat flux represents releases within a region of total melt for altitudes and velocities greater than about 175,000 feet and 18,000 ft/sec, respectively. The Weber number for these test conditions varied between 1.0 and 4.6, and debris was found on all samplers. The heat flux at Condition L is typical of microsphere release from orbital decay (290,000 feet and 26,000 ft/sec); it did not cause particle melting. Table II presents the data on all ^{238}Pu microspheres which were successfully tested. For comparison, the calculated melt times for the spheres in the experiments using the stagnation heat flux values given in Table I are also given.

The melting process was very gradual at the test conditions (A, B, and C) representing heat flux values near the edge of the melt zone. On the high speed movie film one can observe the response of the front surface after the particle had begun to flatten. In most cases, oscillations, ripples, and other motions are seen. The general impression is that the front surface is melting and the film suggests a very thin liquid layer. No large droplets of molten material were seen to leave or even to form on the microspheres. Analyses of the samplers suggest that less total debris was formed at Conditions A, B, and C than at the other test conditions and that the maximum size of the debris found was smaller at these conditions.

Tests at Condition K resulted in faster and more extensive melting, with the melt layer fairly apparent. The particle flattened; however, in most cases no large droplets were seen to form or leave. One particle remained on the sting during the entire test and was reclaimed and weighed after the test. It had lost 5 to 10 percent of its original mass, with none of this loss attributable to large droplets. The sampler again showed micrometer and submicrometer size debris, with no impact areas indicating breakup of larger droplets. For reentry releases which have heat flux values near the Condition K values, a substantial portion of a particle can be expected to melt.

TABLE II

Comparison of Arc Tunnel Results and Computer
Calculations of Microsphere Melting

Run	Test Condition	Material	Diameter (μm)	Observed Time to Melt (sec)	Calculated Time to Melt (sec)	Particle Number
253	B	$^{239}\text{PuO}_2$	280	0.14	0.14-0.15	
254	B	$^{239}\text{PuO}_2$	261	0.12	0.135	
259	B	$^{239}\text{PuO}_2$	276	0.16	0.14	
255	C	$^{239}\text{PuO}_2$	280	0.1 (broke)	~0.2	
256	C	$^{239}\text{PuO}_2$	277	0.17	0.2	
269	B	$^{238}\text{PuO}_2$	227	0.138	0.12	1-24-6
270	B	$^{238}\text{PuO}_2$	253	0.144	0.135	1-24-15
276	B	$^{238}\text{PuO}_2$	236	0.146	0.125	1-24-17
324	B	$^{238}\text{PuO}_2$	253	0.140	0.135	1-25-20
332	B	$^{238}\text{PuO}_2$	254	0.136	0.135	1-25-16
274	C	$^{238}\text{PuO}_2$	234	0.185	0.175	1-24-8
277	C	$^{238}\text{PuO}_2$	235	0.190	0.175	1-24-14
287	C	$^{238}\text{PuO}_2$	221	0.2	0.17	1-24-1
271	A	$^{238}\text{PuO}_2$	225	0.193	>0.2	1-24-7
285	A	$^{238}\text{PuO}_2$	221	0.188	>0.2	1-24-19
333	A	$^{238}\text{PuO}_2$	224	0.198	>0.2	M-6
335	A	$^{238}\text{PuO}_2$	218	-	>0.2	M-3
292	K	$^{238}\text{PuO}_2$	216	0.046	0.040	1-25-1
293	K	$^{238}\text{PuO}_2$	230	0.040	0.042	1-25-5
309	K	$^{238}\text{PuO}_2$	248	0.042	0.048	1-25-2
318	K	$^{238}\text{PuO}_2$	225	0.044	0.041	1-25-1
321	K	$^{238}\text{PuO}_2$	234	0.041	0.043	1-25-3
336	K	$^{238}\text{PuO}_2$	231	0.066	0.042	M-2
337	K	$^{238}\text{PuO}_2$	235	0.072	0.042	M-15
347	K	$^{238}\text{PuO}_2$	223	0.055	0.04	M-35
358	K	$^{238}\text{PuO}_2$	218	0.056	0.04	M-31
354	M	$^{238}\text{PuO}_2$	235	0.020	0.028	M-29
355	M	$^{238}\text{PuO}_2$	227	0.019	0.028	M-37
356	M	$^{238}\text{PuO}_2$	220	0.021	0.028	M-33
369	L	$^{238}\text{PuO}_2$	225	No Melt		M-10
371	L	$^{238}\text{PuO}_2$	219	No Melt		M-22
373	L	$^{238}\text{PuO}_2$	221	No Melt		M-16
376	L	$^{238}\text{PuO}_2$	227	No Melt		M-32
378	L	$^{238}\text{PuO}_2$	222	No Melt		M-30

The results of tests at Condition M are somewhat different: melting was very rapid, and large droplets left the microsphere. Analysis of the samplers revealed larger sized debris than for the other test conditions. In the arc tunnel experiment the entire particle melted, and it can be seen in Figure 1 that a reentry release resulting in this heat flux condition would, for a wide range of release altitude and velocity combinations, also result in total particle melt. However, as release conditions equivalent to the Condition M heat flux approach about 160,000 feet altitude and 15,000 ft/sec, the particle is not calculated to totally melt. This is attributed to the rapid deceleration of the particle at lower altitudes, which results in resolidification of the particle before total melt.

Based on the experience gained in these experiments, some predictions can be made about the reentry ablation process. If one accepts the Weber number as a criteria for mass loss instabilities, the data from these experiments suggest a critical Weber number as low as one. This is not in conflict with values that were determined experimentally and reported in the literature. However, it is on the low end of the reported range of critical values.

The most prominent factor not reproduced in the arc tunnel experiments was the body force resulting from the deceleration of a particle in reentry. It must be recognized that the addition of this parameter may significantly alter the results of the debris generation. It appears that the consensus of the literature and the analyses is that the body force tends to increase the instability of a liquid in the stagnation region of a body. This increase may be caused by the waves generated on the liquid surface "cresting" or "piling up" more rapidly, thereby becoming unstable. If this increase in instability with body force does in fact occur, then the mass loss from the experiments may be reasonable. The high deceleration levels which accompany the reentry of small particles likely causes molten material to form flanges on the particles; the effect which these flanges have on the mass loss of the particles is not known. The phenomenon is not reproduced in the experiments discussed in this report.

It was pointed out previously that a Weber number of about one was the lowest value reported experimentally. The arc tunnel results

did not prove that this is the proper value to use. Indeed, some other phenomenon may in fact be causing the mass loss. However, based on our experience in this program, the best engineering judgment that can be made on the arc tunnel results is that mass loss should be expected at the conditions of reentry that are possible for the microspheres. As mentioned previously, theoretical calculations were made to determine the release conditions under which 50 and 100 percent of a particle would melt. These results are included in Figure 1. Also shown in Figure 1 are the initial stagnation heat flux values for reentry which correspond to the constant heat flux values in the experiments. It can be seen that the tests were conducted at heat flux conditions simulating release from outside the melt envelope to well within the melt envelope. The data from these different conditions together with the theoretical calculations can be used to estimate the degree of melt and mass loss.

Since there is no known analytical technique for calculating the rate of mass loss, estimates of mass loss for the various release regions are based solely on the arc tunnel results. The mechanism for the observed mass loss is not known, but the fact remains that debris is generated. The results of these debris observations essentially are extrapolated directly to reentry, and it must be recognized that the results may be revised as more information and a better understanding of the mechanisms of mass loss are gained.

Experiments performed at a heat flux value near that expected for fuel release from orbital decay (290,000 feet and 26,000 ft/sec) indicated that no melting occurred, but some specific debris was observed. The extent of this debris appeared to depend on the microsphere quality; dust, fines, cracks, and fractures appeared to enhance debris formation. However, possibly no more than 0.1 percent of the total mass becomes debris.

Based on the experiments performed at conditions simulating the heat flux near the melt zone border, one might expect that about 1 percent of the mass would be released. For release conditions within the melt zone, the experiments tend to qualitatively bear out the calculations of 50 and 100 percent melt shown in Figure 1. In particular, melting at Condition K was gradual yet obvious and total test times of

0.1 second resulted in substantial flattening. Tests at Condition M, a heat flux value representing a rather severe reentry release, showed very rapid total melt in less than 0.1 second. While these limited experiments do not provide data to confirm the predictions, they are not in conflict with the calculations and it seems appropriate to accept the calculated melt envelope and lines of constant melt as the guide for currently assessing the degree of reentry melting of microspheres. Estimates of percentages of particle melt are based on extensive calculations. In addition to the calculations done by Sandia, Aerotherm Corporation,⁹ under Sandia contract, has calculated the thermal response for several release conditions. Specifically, at 12,000 fps and 118,000 feet altitude, 250-micrometer diameter particles will not melt, and 50-micrometer particles reach the melt temperature only at the stagnation node. These results agree with the Sandia results which indicate that for releases below 120,000 feet the microspheres will not melt. Sandia calculations for a 250-micrometer particle released at 15,000 fps near 140,000 feet altitude indicate that approximately 50 percent of the mass will melt. For release at 21,000 fps and 181,000 feet, Aerotherm calculated a result similar to the Sandia results: total melt for both limits of particle size. The agreement of these independent calculations, together with the variation in melt response of the particles in the arc tunnel for the different heat flux values, suggests that the degree of melting shown in Figure 1 represents a satisfactory determination of the melt response.

Analysis of Ablated Debris from PuO₂ Microspheres Tested in a 40-kw Hyperthermal Arc Tunnel

As previously stated, the ²³⁸PuO₂ debris on the impact samplers was analyzed for size distribution by Tracerlab, Inc. One sample each from tests at Conditions A, K, and M was analyzed. The enthalpy, pressure, heat flux, and Weber number for these conditions are presented in Table I. In general, the analytical technique used by Tracerlab was as follows. The vinyl coating containing the particulate was dissolved. The solution containing the collected particulate was then centrifuged, and a statistical portion of the centrifuged residue was placed on microscope slides. Nuclear emulsion film was exposed to the radioactive particles on the slides. These films were then used to obtain a size distribution of the collected debris by the hollow star method.

The lower limit of resolution for the exposure times used in this particular hollow star technique of sizing radioactive particles was 0.05 micrometer. Consequently, the size range of the debris counted by Tracerlab using this method extended from 0.05 micrometer to the largest particle found on each of the slides. However, since the mass of $^{238}\text{PuO}_2$ represented by this size range accounted for only a small percent of the total mass collected on the samplers, a radiochemical analysis of the entire inventory was performed. This analysis included the supernate solution, the remaining centrifuged residue, and the particles previously counted. Since the particles previously sized and the centrifuged residue accounted for all the debris larger than the lower limit of resolution, it was obvious that the remaining mass was contained in particles less than the smallest size previously counted. Table III shows the mass and percent of total mass for the size ranges counted by Tracerlab.

TABLE III
Percentages of Total Mass
of $^{238}\text{PuO}_2$ Collected on Samples

Size Range of Particle Diameters (μm)	Equivalent $^{238}\text{PuO}_2$ Mass (μg)	Percent of Collected Mass	Cumulative Percent
<u>Condition A - Sampler M-3</u>			
0 to 0.3	0.071	99.86	99.86
0.3 to 0.9	0.098×10^{-3}	0.14	100.00
<u>Condition K - Sampler M-35</u>			
0 to 0.05	0.3390	95.79	95.79
0.05 to 0.10	0.0122	3.45	99.24
0.10 to 1.6	0.0027	0.76	100.00
<u>Condition M - Sampler M-29</u>			
0 to 0.2	1.649	95.1	95.1
0.2 to 0.6	0.0012	0.07	95.17
0.6 to 1.0	0.0022	0.13	95.30
1.0 to 5.0	0.0231	1.3	96.60
5.0 to 14.0	0.0586	3.4	100.00

A mass balance of the material ablated from the $^{238}\text{PuO}_2$ microspheres was attempted by Sandia. Where possible, the microsphere was weighed before and after testing, but in most cases the percent of the mass ablated was determined by estimating the volume of the microsphere before, during, and after testing from the movie films of the tests. This analysis revealed that less than 100 percent of the mass ablated from the microsphere was actually collected on the sampler. A collection efficiency analysis of the samplers was performed by Sandia to determine the size range of the particles which could be expected to be collected. This analysis included flow patterns, effect of shock waves, and sampler configuration. In general, the analysis indicated that particulate between 0.01 and 10 micrometers in diameter would be collected with approximately 100 percent efficiency. Particulate less than 0.01 micrometer in diameter would be trapped in the flow and diverted around the sampler. Unless it was originally projected toward the sampler, particulate greater than 10 micrometers in diameter would not be affected by the flow and also would miss the sampler. The results of the collection efficiency analysis indicate that the size distribution of the debris collected is not exactly representative of the ablated size distribution in all cases. Therefore, it was necessary to modify the size distributions given in Table III so as to reflect the total ablated mass and the debris not collected during the test.

For the Condition A test, the largest particle size found on sampler M-3 was 0.9 micrometer in diameter. Since the collection efficiency of the sampler was approximately 100 percent up to 10 micrometers, it is safe to assume that the entire ablated inventory was less than 0.9 micrometer in diameter. The 100 percent collected mass from 0.01 to 0.9 micrometer represents 52.20 percent of the total ablated mass. The uncollected remainder must then be less than 0.01 micrometer in diameter and represents 47.73 percent of the ablated mass. This size distribution does not differ appreciably from that shown in Table III.

The analysis of sampler M-35 (Condition K) resulted in conclusions similar to those reached for the Condition A test. Since the largest particle collected was 1.6 micrometers in diameter, the entire ablated inventory was less than 1.6 micrometers. The 100 percent collected mass from 0.01 to 1.6 micrometers represented 9.29 percent of the

ablated mass. The remaining 90.71 percent was contained in particles less than 0.01 micrometer in diameter. This size distribution is also not much different from the values given in Table III.

The analysis of sampler M-29 (Condition M) resulted in a significant change from the size distribution shown in Table III. A review of the movie films showed that all the Condition M exposures resulted in rapid melt and runback of the molten $^{238}\text{PuO}_2$ onto the sting. Several droplets from 25 to 100 micrometers in diameter were stripped from the molten runback during the test; however, none of these droplets was collected on the impact sampler. Most of the runback material remained on the sting after the test and accounted for the great majority of the "ablated" mass. The collected mass between 0.01 and 14 micrometers in diameter represented 6.94 percent of the total ablated mass and included the melted runback material. It was estimated that the runback material accounts for almost all of the remaining 93.06 percent. Therefore, the percent of ablated debris less than 0.01 micrometer in diameter was very small.

Table IV shows the final size distribution of the ablated debris, based on the Tracerlab analysis and modified by the sampler efficiency analysis. Although the data presented here are based on one test for each reentry condition, it is believed that the size distribution of the debris is reasonably representative, especially for Conditions A and K. The Condition M data are questionable because the molten runback material was considered as large ablated particles. The final fate and debris size of this runback material in an actual reentry cannot be determined in the arc tunnel facility. However, it is apparent that the debris size distribution is dependent on the heat input and melt rate of the microsphere.

New sampling devices are currently being designed and fabricated which should approach 100 percent sampling efficiency. This will eliminate the need to modify the size distribution of the collected debris.

TABLE IV
Percentages of Total Mass
of $^{238}\text{PuO}_2$ Ablated from Microspheres

Size Range of Particle Diameters (μm)	Percent of Ablated Mass	Cumulative Percent
<u>Condition A - Sampler M-3</u>		
0 to 0.01	47.73	47.73
0.01 to 0.3	52.20	99.93
0.3 to 0.9	0.07	100.00
<u>Condition K - Sampler M-35</u>		
0 to 0.01	90.71	90.71
0.01 to 0.05	8.9	99.61
0.05 to 0.1	0.32	99.93
0.1 to 1.6	0.07	100.00
<u>Condition M - Sampler M-29</u>		
0 to 0.01	Very small	--
0.01 to 0.2	6.6	6.6
0.2 to 14.0	0.34	6.94
>10.0	≈ 93.06	100.00

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