SC-PR-67-740

September 1967

N. Kinsler 11-15-10

Exempt from CCRP Re-review Requirements
(per 7/22/82 Duff/Caudle memorandum)

AEROSPACE NUCLEAR SAFETY

AEROSPACE NUCLEAR SAFETY REPORT FOR AUGUST 1967

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September 1967

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AEROSPACE NUCLEAR SAFETY REPORT
FOR AUGUST 1967

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ABSTRACT

This report describes research, development, support, and test activities in the Sandia Laboratory Aerospace Nuclear Safety Program for August 1967.

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SUMMARY

SNAP-3A

The AEC Safety Branch advised that the present outlook for a potential mission using four modified SNAP-3 type generators is rather negative. No further effort is planned on this program at the present time.

SNAP-19

A draft copy of the AEC SNAP-19/Nimbus B Safety Evaluation Report was reviewed and comments forwarded to the AEC Safety Branch. Drop tests of four SNAP-19 intact reentry heat source capsules were conducted at the Tonopah Test Range.

SNAP-27

A preliminary GE SNAP-27 safety analysis was reviewed. A meeting was held at Sandia on August 30-31 for discussions among GE and Sandia safety representatives following completion of this review.

PLUTONIUM SYSTEMS SUPPORT

Three arc tunnel tests were conducted at low heat fluxes. Debris were collected on downrange impactors from all tests.

The rapid helium depressurization test on fuel microspheres was conducted by Battelle Memorial Institute. A preliminary examination of the fuel revealed no obvious change in microsphere characteristics.

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TABLE OF CONTENTS

SYSTEMS SUPPORT

Plutonium-Fueled Systems

	<u>Page</u>
SNAP-3A	7
Safety Analysis	7
SNAP-19	7
AEC SNAP-19/Nimbus B Safety Evaluation Report	7
Nuclear Reactor System Safety Group (NRSSG) Review	8
SNAP-19 Dispersal System	8
Intact SNAP-19	8
SNAP-27	12
Review of GE Preliminary Safety Analysis	12
Graphite LM Fuel Cask (GLFC) Thermal Model	12
Thermal Stress Calculations	13
Aerodynamic Heating Inputs to Cask	13
Spontaneous Ignition Studies (SIS)	13
Large Radioisotope Heat Source System	14
PLUTONIUM SYSTEMS SUPPORT	14
Capsule Impact	14
AC Defense Research Laboratory (ACDRL) Light Gas Gun Range Tests	16
Small Particle Testing in a Hyperthermal Arc Tunnel	17
Experimental Investigation of the Effects of Helium Pressure on Microsphere Integrity	18
Internal Dose Estimates Following Ingestion of $^{238}\text{PuO}_2$	18

Polonium-Fueled Systems

POLONIUM SYSTEMS SUPPORT	22
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TABLE OF CONTENTS (continued)

	<u>Page</u>
Promethium-Fueled Systems	
AMSA THERMAL PRECONDITIONER UNIT	22
Air Force Safety Report	22
ADVANCED TECHNOLOGY	
Basic Studies	
STUDY OF THE CHEMICAL INTEGRITY OF RADIOISOTOPE CONTAINMENT MATERIALS IN SIMULATED LAUNCH ABORT ENVIRONMENTS	23
Small Scale Interaction Studies	23
SOIL BURIAL	25
FUEL/CLAD/SOIL REACTION	26
SOIL/POPULATION DISTRIBUTION	26
DEMOGRAPHIC MODELS	26
FUEL PUCKS	27
CMA Ablation Program Results	27
COMPUTER PROGRAMMING	27
GE Arbitrary Body Computer Code	27
Sure Catch Computer Code	27
Computer Code HRS007	28
Computer Code HRS008	28
AUTOROTATIONAL STUDIES	28

SYSTEMS SUPPORT

Plutonium-Fueled Systems

SNAP-3A

Safety Analysis (R. T. Finnell)

The July ANS report* discussed a probable requirement for a single mission utilizing four SNAP-3 type power supplies. Several meetings were held with AEC personnel in relation to the safety analysis and testing support required for this program. On August 9, the AEC Safety Branch advised that the present program outlook is somewhat negative. This change in outlook apparently is the result of a probable increase in the power required by the user agency and potential funding problems. No further effort is planned on this program at the present time.

SNAP-19

AEC SNAP-19/Nimbus B Safety Evaluation Report (L. A. Hanchey)

A draft copy of the AEC SNAP-19/Nimbus B Safety Evaluation Report was received for review. This report was prepared by the AEC following the meetings of the Interagency Review Panel. Comments were sent to the AEC Safety Branch on August 16, following completion of a one-day review. In general, comments were limited to identification of specific places where it is believed that the information is erroneous or where it appears that erroneous conclusions were drawn from the data provided. The major concern is that, in an effort to quantify the hazard of the SNAP-19 (in many cases based on very limited technical information), the report does not sufficiently emphasize the great uncertainties that exist in many areas and, therefore, may seriously underestimate the magnitude of the actual hazard of launching the SNAP-19.

*SC-PR-67-621, Aerospace Nuclear Safety Report for July 1967, Aerospace Nuclear Safety Department, Sandia Laboratory, Albuquerque, New Mexico, August 1967.

Nuclear Reactor System Safety Group (NRSSG) Review (L. A. Hanchey)

The Air Force NRSSG review of the SNAP-19 was held at Kirtland Air Force Base August 9-11. Sandia ANS representatives attended portions of this review. This meeting was concerned primarily with potential launch pad abort situations.

SNAP-19 Dispersal System (D. E. Randall)

The aerothermodynamic analysis of the SNAP-19 dispersal system is being repeated using the revised generator/fuel capsule thermal model and the latest fuel capsule failure criteria from Martin. This analysis is being conducted in a manner similar to that of the SNAP-19 intact design to provide a basis for comparing the two designs. Continuum heating ratios for a random tumbling fuel capsule have been reduced from Martin experimental test data. Heating ratios for the generator mounted on the Nimbus sensory ring are being reduced from experimental data.

Intact SNAP-19

Safety Evaluation (L. A. Hanchey) -- Visits were made to Martin to discuss the safety analyses being made by Martin in relation to the SNAP-19 intact backup system and to review portions of the report. The Martin Safety Analysis Report is scheduled to be issued on September 1, and the Interagency Review Meeting is scheduled in Washington September 19-21.

Reentry Analysis (R. D. Klett) -- A preliminary orbital decay reentry analysis of a randomly tumbling SNAP-19 intact reentry heat source (IRHS) was completed. Results show that although the Haynes-25 will melt with nominal aeroheating, the graphite case will not fail thermally with 1.5 times nominal heating. With 150 percent heating, the maximum fuel temperature was computed to be 200°F below its melt temperature, and the maximum graphite temperature was 750°F below the temperature at which the graphite strength is reduced. Temperature gradients in the graphite are negligible, and ablation depths are not excessive.

Fire Test (R. E. Berry) -- A SNAP-19 generator with an IRHS will be placed in a simulated launch pad abort fire. The test plan is complete; it outlines the requirements for a heated capsule assembly and

a magnesium stand (simulating spacecraft structure), and the fire area configuration. The test plan is for a generator only, but bare capsule configurations may be added to the test at a future date.

Exploratory Postreentry Impact Dispersion Test (F. L. Baker) -- Four SNAP-19 IRHS capsules containing a simulated fuel (tungsten molybdenum) were drop tested at the Tonopah Test Range. The primary objective was to determine a fuel dispersal pattern as a result of impact; a secondary objective was to determine impact velocity. Three of the drop units contained no welded inner capsule; the fourth unit, which was from a simulated reentry test in an arc tunnel, was a complete unit prior to the arc tunnel test.

Test Units 1 and 2 were impacted into extremely hard soil. This soil is defined as very dense, dry, moderately-cemented, clayey silt; it can be loosely described as a low grade cement. The blow count is approximately 50 blows for 4 inches of penetration with a California soil sampler. In these tests, the graphite fragmented, and the liner sections separated and scattered the fuel simulant in several fairly discrete locations (Figures 1 and 2). An estimated one-third of the fuel remained in the larger section of each liner.

Test Units 3 (the arc tunnel test unit) and 4 were impacted into the main dry lake target area. This soil is defined as very stiff to hard, dry, light tan, very silty clay (very low plasticity). The blow count is approximately 40 blows for 12 inches of penetration with a California soil sampler. In both of these tests, the graphite fragmented, but essentially all the debris, fuel simulant included, remained in the 3-inch deep crater. The liner in Unit 3 ruptured, but it had been severely damaged in the plasma arc test (Figure 3). The liner in Unit 4 was distorted but not ruptured (Figure 4).

Table I gives release and impact conditions for the tests. The weight of Unit 3 was somewhat greater than the other three; this accounts for its higher impact velocity.

△ - LARGER PIECES OF GRAPHITE

Figure 1. Results of test No. 1
(D67-14339)

△ - LARGER PIECES OF GRAPHITE

Figure 2. Results of test No. 2
(D67-14340)

Figure 3. Results of test No. 3
(C67-6357)

Figure 4. Results of test No. 4
(C67-6089)

TABLE I
Release and Impact Conditions
for Intact SNAP-19 Drop Tests (D67-14341)

<u>Test Unit</u>	<u>Release Altitude* (above terrain) (ft)</u>	<u>Impact Velocity** (ft/sec)</u>	<u>Target</u>
1	5200	237	Hard soil
2	5150	242	Hard soil
3	5300	308	Lake bed
4	5250	233	Lake bed
<p>*Release altitude was determined by radar.</p> <p>**The impact velocity of small shapes is computed by measuring time-of-fall and fall distance. Time-of-fall was determined from Mitchell film for test Units 1, 2, and 3. Unit 4 was not tracked by the Mitchell cameras, and its time-of-fall was measured by hand-held stopwatch.</p>			

SNAP-27

Review of GE Preliminary Safety Analysis (J. E. Taylor)

Various Sandia ANS organizations reviewed a preliminary SNAP-27 safety analysis performed by GE. GE safety representatives met at Sandia August 30 and 31 for detailed working level discussions following completion of the Sandia review. Minutes of the meeting were sent to interested parties.

Graphite LM Fuel Cask (GLFC) Thermal Model (D. W. Larson)

The one-dimensional thermal model of the SNAP-27 GLFC and enclosed capsule was revised in order to predict the temperature response of this system when subjected to an on-pad launch abort which results in a fireball environment followed by a residual fire. When the GLFC remains intact, the model predicted that the fireball would have no harmful effects on the SNAP-27 capsule; however, the ensuing residual fire would cause the capsule inner liner to exceed its melt temperature. If the blast removes the GLFC and exposes the capsule to the fireball, the model predicted failure of the capsule within 4 seconds, with capsule temperatures as high as 3560°F.

Thermal Stress Calculations (H. R. Spahr)

The time varying temperature distributions in the graphite cask were determined for use in thermal stress calculations. The first three cases to be examined are for the crosswise spinning reentry mode for supercircular velocity reentry at -6.4, -30, and -90 degree reentry angles. Experimentally measured graphite property data from GE were also obtained for use in the thermal stress calculations.

The time varying temperature distributions in the graphite cask, for the same three cases, were also transmitted to GE. This information will be used by GE for preliminary thermal stress calculations until they complete their own temperature distribution calculations for the current configuration.

Aerodynamic Heating Inputs to Cask (H. R. Spahr)

A number of references on the theoretical and experimental heating rates to spheres and cylinders were reviewed in preparation for a meeting with GE. This meeting, scheduled for September 13, will be held to resolve the minor differences in the aerodynamic heating rates to the cask which have been used by Sandia and GE.

Spontaneous Ignition Studies (SIS) (D. J. Sasnor/R. P. Wemple)

A meeting of NASA (MSC and KSC) and Sandia personnel concerned with spontaneous ignition studies was held at Sandia August 22 and 23, 1967. Details of the testing procedure and test program were reviewed. Aside from minor changes in the testing schedule, the experimental details and program were acceptable. It was stressed that time was of the essence and that completion of the test series would be desirable on or before September 15. It was pointed out that this early completion date might not be met for a large portion of the tests for various reasons; however, every effort was being put forth to meet the target date. The group also discussed the possibility of an outdoor test using a slab of material. This test would give some idea of the conservativeness of the laboratory tests.

Since the initiation of the tests, the decision to use silicon carbide as an antioxidation coating has been reversed. At present, it appears that the cask may be uncoated.

The spontaneous ignition temperature (SIT) of monomethylhydrazine (MMH) in a Pyrex Erlenmeyer flask was determined, and the determination of the SIT of MMH in a graphite crucible is almost complete.

Large Radioisotope Heat Source System (E. S. Phinney)

Sandia has issued a draft scope-of-work document for a Large Radioisotope Heat Source System; Appendix A of this document contains preliminary safety criteria which were provided by the Sandia ANS Department. Following review, this document will be released with a Request for Proposal for development of a 25-kilowatt (thermal) plutonium-fueled heat source system for use in a joint AEC/NASA ground test of a Brayton-Cycle Power Conversion System at the NASA Plum Brook Facility in 1971.

PLUTONIUM SYSTEMS SUPPORT

Capsule Impact (G. H. Elkins)

The data from 1365 capsule impacts have been stored on punched cards. The stored data consists of the following information:

1. Impact velocity,
2. Temperature at impact,
3. Impact angle,
4. Capsule failure,
5. Geometry and dimensions of the capsule,
6. Capsule and target material, and
7. Origin of data.

Data from the following capsules were collected:

1. SNAP-9A;
2. SNAP-15A, -15B, and -15C;
3. SNAP-19;
4. SNAP-27; and
5. A variety of spherical and cylindrical capsules having varying parameters.

The data has also been printed in tabular form. Table II is an example of the printed data.

TABLE II

Example of Capsule Impact Data (D67-14342)

CAPSULE NUMBER 9

VELOCITY FPS	TEMP F	ATTITUDE DEGREES	RUPTURE YES#1	DIAMETER INCHES	WALL THICK INCHES	LENGTH INCHES	WEIGHT LBS.	CAPSULE MATERIAL	TARGET MATERIAL	DATA BY
356.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
361.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
390.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
361.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
361.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
361.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
360.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
357.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
360.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
363.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
356.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
361.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
360.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
359.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
359.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
362.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
380.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
381.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
377.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
381.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
381.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
384.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
384.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
384.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
377.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
390.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
337.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
340.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
341.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
339.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
339.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
341.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
341.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
341.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
340.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
341.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
342.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
341.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
343.	77.	0	1.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
339.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
343.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
342.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
338.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
340.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
338.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
342.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC
344.	77.	0	0.	1.170	0.185	9.160	2.650	SAE 4130	SAE 4130	SC

AC Defense Research Laboratory (ACDRL) Light Gas Gun Range Tests
(C. B. Watkins)

Eight tests of Al_2O_3 microspheres of 400-micron nominal diameter launched into air at a velocity of 20,000 fps were conducted. Laser stations were located downrange at 33, 91, and 108 feet. Impactors for each test were located at 118 feet. Table III summarizes the preliminary test results as provided verbally to Sandia by ACDRL.

TABLE III
Summary of Preliminary Test Results (D67-14343)

Test No.	Pressure (mm)	Velocity (fps)	Laser Data	Impact Data	Streak Data	Remarks
1	--	--	--	--	--	Model did not fly.
2	--	--	--	--	--	Model did not fly.
3	3	20,000	None	None	None	Voided due to launch cloud and debris.
4	3	20,000	None	Single crater	None	--
5	3	20,000	None	Martin catcher	None	Switched to light-interrupt trigger.
6	3	20,000	First laser station shadowgraph of intact particle	Single crater	None	--
7	5	20,000	None	Two craters	None	--
8	5	20,000	None	Single crater	None	Open shutter camera focused on impact plate photographed impact of the particle but recorded no track of incoming particle.
Note: Tests 1 through 4 utilized a light emission trigger system for the laser stations. Failure of the lasers to trigger prompted ACDRL to alter the trigger to a light interruption system for Tests 5 through 8. Only one successful trigger was obtained (Test No. 6, Station No. 1).						

It will be noted from the above tabulation that none of the eight tests can be considered successful. No laser data were obtained which could identify microsphere deformation or melt. No streak photographs were obtained. ACDRL aluminum impactors showed single craters on Tests 4, 6, and 8, and two craters on Test 7. A Martin soft catcher was used on Test No. 5, and data have not yet been reported. Because of the paucity of data obtained, the tests to date must be considered inconclusive. The possibility of no microsphere melting or insufficient melting to permit liquid stripping must be acknowledged for the conditions of these tests.

One of the estimates of particle melting reported in SC-PR-67-621 was in error. For a particle of 402.7-microns diameter, the distance downrange to melt initiation was given as 47.0 feet. The distance should have been 83 feet.

Small Particle Testing in a Hyperthermal Arc Tunnel (I. B. White/
B. W. Marshall/K. L. Romine)

Two more tests of $^{238}\text{PuO}_2$ microspheres at the low heat flux condition (Condition L) were completed during this period. First, the mounted microsphere was subjected to a cold gas flow without any heat to determine if any loose surface debris could be separated from the microsphere; an impact collector sampler was placed in the usual position 4 inches downstream from the microsphere. Next the same microsphere was subjected to the Condition L reentry simulation, with a new sampler placed in the downstream position. Autoradiographs were made of the samplers; however, the samplers themselves have not been analyzed at this time. One more test is planned at Condition L.

The impact collection sampler from the $^{238}\text{PuO}_2$ microsphere M-10 tested at Condition L was analyzed by LASL. The sizes of the debris investigated ranged from 0.17 to 1.80 microns, with the majority being from 0.20 to 1.0 micron. However, no size distribution of the entire sample can be made because only a small portion of the sample was analyzed.

Microsphere Holding Technique -- A new technique for holding microspheres in a plasma stream was developed. The original sting consisted of a 33-gage stainless-steel hypodermic needle potted with epoxy (Scotch-cast 215) in a cone shape. The needle was 0.275 inch long which was much shorter than desired. Attempts to use longer needles failed because the needles vibrated excessively in the plasma stream. In addition, the epoxy-coned needles failed during low enthalpy, long-time (5 seconds) runs. During such runs, the epoxy cones on the old stings melted, exposing the stainless-steel needle shaft. The needle melted, folded back, and then fell off with the particle and dropped to the tunnel floor. These tests produced data but were not considered completely successful.

The new sting is a tungsten tip which is formed by vapor deposition on a mandrel. The vacuum hole measures 0.004 inch at the tip and 0.170 inch at the back. Wall thickness varies from 0.002 inch at the tip to 0.020 inch at the rear. The total length of the tip is 1.020 inches; this lessens the cone angle considerably. The tungsten sting requires no potting, does not melt, and, at low heat flux levels, does not oxidize. Two tests have been run using tungsten stings; in both tests, the particles remained on the sting, with only mild discoloration of the front 0.25 inch of the sting. In addition, the tungsten stings have been cleaned by inserting a 0.003-inch tungsten wire and are ready for reuse.

Experimental Investigation of the Effects of Helium Pressure on Microsphere Integrity (H. E. Hansen)

Battelle Memorial Institute (BMI), Columbus, modified the depressurization apparatus to provide more rapid depressurization of $^{238}\text{PuO}_2$ microspheres. The modified apparatus uses burst diaphragms to achieve an explosive-type release. A test of the apparatus in which a pressure transducer was located at the fuel position showed the depressurization time to be about 20 milliseconds.

A test of the 1/2-gram sample of fuel was conducted. Analysis is not yet complete, but preliminary examination of the sample did not reveal any change.

Internal Dose Estimates Following Ingestion of $^{238}\text{PuO}_2$
(R. J. Everett)

Attention has been focused recently on the solubility of $^{238}\text{PuO}_2$ microspheres in the GI tract of man and the resulting doses to internal organs. Two approaches will be described in order to evaluate the bone burdens caused by the passing of PuO_2 through the GI tract of man. In Method A, experimental data on the absorption of PuO_2 by swine are used, and Method B uses the reported solubility values of PuO_2 in seawater. Data on the solubility of PuO_2 in simulated gastric juice are not sufficient to predict internal organ deposition, and in addition, the material would be in this media only 1 to 2 hours.

Method A -- In Battelle experiments,* a wide spectrum of particle sizes was fed to nine pigs in order to determine the absorption of plutonium by internal organs. The amounts ingested ranged from 0.18 to 1.1 curies. The fraction of the ingested material absorbed was determined by analyzing tissue and urine for plutonium content. The absorbed fractions ranged from 7×10^{-9} to 8×10^{-7} . A conservative fraction of 10^{-6} seems to be justified and is used in the calculation below. It should be noted that this fraction (10^{-6}) represents solubilization loss, absorption by the blood, and transport to blood. In the example below, the bone dose is estimated from the ingestion of a single 100-micron PuO_2 particle.

Let

N_o = amount passing through GI tract (μc)

f_1 = fraction absorbed from GI tract

f_2 = fraction of absorbed amount ultimately deposited
in bone

N_b = amount in bone

λ_e = effective elimination rate from bone.

Elimination from Bone

$$\frac{dN_b}{dT} = -\lambda_e N_b$$

Integrate

$$N_b(T) = N_o f_1 f_2 e^{-\lambda_e T}$$

* BNWL-280, Pacific Northwest Laboratory Annual Report for 1965, Battelle Memorial Institute, Richland, Washington, January 1966.

Let

$$f_1 = 10^{-6}$$

$$f_2 = 0.8$$

$$N_0 = 63 \mu\text{c}$$

$$\lambda_e = 0.011 \text{ yr}^{-1}$$

Dose Rate to Bone

$$\frac{3 \text{ rem/yr}}{(4 \times 10^{-3}) \times 0.83} = \frac{3}{3.32 \times 10^{-3}} = 905 \text{ rem/yr}/\mu\text{c}$$

$$\begin{aligned} \text{Dose (T)} &= \int_0^T 905(63) (8 \times 10^{-7}) e^{-\lambda_e T} dT \\ &= \frac{905(63)}{\lambda_e} (8 \times 10^{-7}) (1 - e^{-\lambda_e T}) \\ &= 4.15 (1 - e^{-\lambda_e T}) \end{aligned}$$

<u>Time (yr)</u>	<u>Integrated Dose to Bone (rem)</u>
1	5×10^{-3}
5	0.12
10	0.43
50	1.75

The maximum permissible dose rate to bone (general population) is 3 rem/year. The above dose estimates are overestimates since the material was assumed to be instantaneously deposited in bone.

Method B -- The reported solubility of $^{238}\text{PuO}_2$ in seawater is about $1.3 \times 10^{-3} \mu\text{gm}/\text{mm}^2/\text{day}$.* The surface area of a 100-micron particle is $3.14 \times 10^{-2} \text{mm}^2$ and the gross transit time is about 30 hours, so the solubility loss is $5.1 \times 10^{-5} \mu\text{gms}$ or $6.12 \times 10^{-4} \mu\text{c}$. This results in a solubilized fraction of 9.7×10^{-6} for a single 100- μ particle. Now that the plutonium is soluble in the GI tract, the soluble fraction to bone must be determined. According to ICRP No. 2, the fraction of soluble plutonium reaching bone via ingestion is 2.4×10^{-5} . Therefore the bone dose as determined by Method B is:

$$\text{Dose (T)} \int_0^T 905(63)(9.7 \times 10^{-6})(2.4 \times 10^{-5}) e^{-\lambda e T} dT,$$

and the doses previously listed are reduced by a factor of 3450. This estimate is compatible with LASL studies where the fraction deposited in the spleen after passing 1000 particles through the tract of a dog was 2.3×10^{-10} . Since the Battelle studies used a wide spectrum of particle sizes including fines, Method A appears to be the most appropriate and conservative.

In regard to particle hold up and retention, the results from single particle feedings at LASL allow one to say that, at a 50-percent confidence level, the probability of particle hold up is 4×10^{-4} . This is probably too large an estimate, but a better estimate cannot be made based upon present data. The long term retention of particles in the gut is probably not likely. Smith at Battelle-Northwest reports** that "even if a particle became embedded in the gut wall, it will likely create a necrotic nodule that would slough off and be eliminated." This statement is based upon the fact that these necrotic regions were easily pulled loose from the surrounding tissue; in addition, this is an area of rapid cell loss and replacement.

*Goya, H. A. and Lai, M. G., Release from High-Fired Plutonium Dioxide to Seawater, USNRDL-TR-1065, U. S. Naval Radiological Defense Laboratory, San Francisco, California.

**Smith, V., Battelle-Northwest, unpublished data presented at DBM SNAP Committee Meeting.

Polonium-Fueled Systems

POLONIUM SYSTEMS SUPPORT (J. W. McKelvey)

Atomics International presented the results of their studies on polonium hazards in a launch fire situation. A model was developed describing the launch fire environment, and it was used to determine fuel capsule survival when subjected to the temperatures, pressures, and chemicals of the launch fire. Predictions were also made of the evaporation rates of polonium metal and gadolinium polonide (GdPo), the evaporation rates as a function of temperature, and the extent of attachment of polonium vapor to inert dust. The latter phenomenon may be an important hazard reduction factor, and additional study is required to determine its magnitude. The AI study predicts, as do Sandia's studies, that there exists a reasonable likelihood of a large polonium release during a launch fire; this confirms the critical aspect of this phase of the launch.

Promethium-Fueled Systems

AMSA THERMAL PRECONDITIONER UNIT

Air Force Safety Report (R. C. Cranfill)

A report, Safety of the AMSA Thermal Preconditioner Unit, prepared by the Air Force Systems Command (Wright-Patterson AFB) was received at Sandia and is now being reviewed.

ADVANCED TECHNOLOGY

Basic Studies

STUDY OF THE CHEMICAL INTEGRITY OF RADIOISOTOPE CONTAINMENT MATERIALS IN SIMULATED LAUNCH ABORT ENVIRONMENTS (F. D. Kite)

The primary objective of the program is to investigate the chemical integrity of radioisotope containment materials when subjected to booster vehicle abort environments. This effort supplements the work performed under a previous contract.

Small Scale Interaction Studies

The small scale aluminum-interaction experiments were completed during the report period. Metallographic analyses were conducted on selected exposed samples. The results of the aluminum-interaction studies are summarized briefly in Table IV. As reported earlier, aluminum ignition or vapor phase combustion could not be initiated in the hydrogen-oxygen flame environment which alone caused catastrophic failure of the containment material samples.

The two configurations used in the aluminum-interaction experiments both utilized the familiar 3/16-inch-diameter by 1/2-inch-long cylindrical containment material sample. The "cylindrical" sample was heated directly in the hydrogen-oxygen flame environment to a temperature below the material's corresponding melting point. A small quantity of aluminum, approximately 10 percent of the sample mass, was then brought into contact with the heated sample and held there for a measured time.

TABLE IV

Containment Material-Aluminum Interaction Data Summary (D67-14344)

Sample Number	Configuration		Material	Total Exposure Time (sec)	Peak Sample Temperature T.C. (°F)	Remarks
	Cylinder	Crucible				
Al-1	X		316 SS	600	2100	No visible interaction
Al-2	X		316 SS	210	1560	No visible interaction
Al-3	X		316 SS	150	2480	Sample melted
Al-4	X		316 SS	240	2450	Sample melted
Al-5*		X	316 SS	360	**	Moderate interaction
Al-6*		X	316 SS	300	--	Gross interaction
Al-7		X	Aluminum	300	--	No ignition
Al-8	X		Tantalum	-	--	Sample ignited***
Al-9	X		Tantalum	293	--	No visible interaction
Al-10	X		Tantalum	-	--	Sample ignited***
Al-11	X		Tantalum	-	2400	Sample ignited***
Al-12	X		Tantalum	150	2150	No visible interaction
Al-13	X		Tantalum	156	2300	No visible interaction
Al-14	X		Haynes 25	250	2260	No visible interaction
Al-15	X		Haynes 25	174	2350	No visible interaction
Al-16		X	Haynes 25	360	1500	No visible interaction
Al-17		X	Haynes 25	300	2500	Sample melted
Al-18		X	Haynes 25	195	2250	Gross interaction
Al-21*		X	316 SS	300	1290	No interaction
Al-22*		X	316 SS	300	1480	No interaction
Al-23*		X	316 SS	300	1710	No interaction
Al-24*		X	316 SS	300	2250	Gross interaction
Al-25*		X	Tantalum	300	1260	No interaction
Al-26*		X	Tantalum	300	1560	No interaction
Al-27*		X	Tantalum	300	2180	No significant interaction
Al-28*		X	Haynes 25	300	1500	No significant interaction
Al-29*		X	Haynes 25	300	1700	No significant interaction
Al-30*		X	Haynes 25	300	2060	Slight interaction
Al-31*		X	316 SS	300	1680	No significant interaction
Al-32*		X	Tantalum	300	1580	No significant interaction
Al-33*		X	Haynes 25	300	1800	No significant interaction
*Sample subjected to metallographic analysis. **No thermocouple data available. ***Sample ignited in the absence of aluminum.						

The second configuration consisted of the 3/16-inch-diameter by 1/2-inch-long containment material cylinder in contact with a concentric aluminum tube, both contained within a graphite crucible. Metallographic studies were confined to the latter "crucible" configuration. This sample geometry more clearly shows the occurrence of any containment material-molten aluminum interaction and alloy formation.

Summary technical reports on various phases of this current activity are in process of publication by Sandia.

SOIL BURIAL (F. L. Baker)

Three tests have been performed to determine the oxidation characteristics of specified types of graphite when subjected to high temperature burial conditions. Small samples of Hitco, Supertemp, Poco, and plasma-fired Poco were buried next to a Firerod heater in Bentonite. The first test was run for 24 hours (including heat-up time of 1 hour) at 1500°F. Recovery revealed that the Hitco and both Poco samples had completely oxidized, and no trace remained. About one-third of the original volume of Supertemp was recovered.

A second test, with the same setup except for temperature, was held at 1400°F. Results were the same, except that approximately one-half the original volume of Supertemp was recovered.

A third test was performed with a 1-inch square by 0.2-inch thick block of Hitco graphite. This test was performed to determine if there was a noticeable temperature rise due to the graphite oxidation process. A small hole was drilled in the graphite block, and a Chromel Alumel stainless steel sheathed thermocouple was inserted. The Hitco block was buried next to a Firerod heater in Bentonite. A drag pen temperature recorder was used. Operating temperature was held at 1500°F, and the run time was 24 hours. No temperature rise due to the graphite oxidation process was evident. As expected, there was no trace of the Hitco block when the heater was uncovered.

FUEL/CLAD/SOIL REACTION (J. B. Boyd)

The University of New Mexico (UNM) preliminary soil investigation report has been received and is being prepared for republication by Sandia. Eight of the nine test soils selected jointly by Sandia and UNM have been acquired and tested by Albuquerque Testing Laboratory (ATL).

The data from UNM and ATL are now being forwarded to the National Bureau of Standards, Washington, for use in designing soil thermal conductance tests. The NBS contract was awarded August 3 and should be completed within 9 months. Eight soils have been shipped to NBS.

SOIL/POPULATION DISTRIBUTION (L. L. Keller)

Under contract to Sandia, Atomics International is compiling soils data; the compilation is approximately 55 percent complete. Data for Alaska, Canada, Saudi Arabia, United States, and Libya were extracted from topographical maps; Antarctica and Australia data were extracted from perimeter topographical maps; and the balance of data is being extracted from other documents.

DEMOGRAPHIC MODELS (E. S. Phinney)

A tape of population data was transmitted to Nuclear Utility Services for their use in performing work under P. O. 48-4310. This tape replaces one previously transmitted to them which was improperly copied from the master tape.

Population data for South America were completed and are being prepared for incorporation into the master tapes. Since Pentagon-produced data were not available, a smear of population was accomplished for Argentina, Bolivia, British Guiana, Chile, Columbia, Dutch Guiana, Paraguay, and Uruguay. This smear consisted of dividing each country into cells (1/2-degree longitude by 1/3-degree latitude) and dividing the entire country's population minus the population of the country's large cities by the number of cells, and assigning the resulting number of people to each cell. The large city population was provided separately for each cell. Detailed cell and P-95 data are being prepared for Chile, Columbia, and Dutch Guiana by the Data Division of the

National Military Command System Support Center at the Pentagon. When these data are available, they will replace the smeared data for these countries.

FUEL PUCKS

CMA Ablation Program Results (D. E. Randall)

CMA ablation program results for tumbling pucks were received. Neither puck A nor C (1 and 5 inch diameters) provided complete integrity to impact for the tumbling mode of motion. However, for puck C, graphite shell burnup was confined to the edge region, and the fuel was maintained below melt temperature. Tailoring the graphite shell thickness to the heating distribution may provide integrity to impact. Further conclusions must await analysis of these results.

COMPUTER PROGRAMMING

GE Arbitrary Body Computer Code (H. R. Spahr)

This code computes the aerodynamic coefficients of arbitrary bodies using modified Newtonian and free molecule flow theory. The source decks, sample problem and results, and documentation for this code were received from GE. The main code and 37 subroutines were assembled on the Sandia IBM 7090.

Five minor modifications were made to the code to make it operational on the Sandia IBM 7090. Check runs for both the free molecule and modified Newtonian flow options were successfully completed. Thus, the code is fully operational and will be used first for calculating the SNAP-19 intact fuel capsule aerodynamic coefficients.

Sure Catch Computer Code (H. R. Spahr)

This program computes the aerodynamic flow field, the aerodynamic heating (by 11 different methods), and the conduction heat transfer for a body of revolution at zero degree angle of attack at supersonic speeds. The source tape and documentation for this code were received. The source tape was converted to two source decks, one of which has been given to the Sandia Analytical Development Division.

Computer Code HRS007 (H. R. Spahr)

COSMIC computer code 700, which calculates aerodynamic coefficients and parameters using second order shock expansion theory, was modified and was run on the CDC 3600 computer under the name HRS007. The output is being checked.

Computer Code HRS008 (H. R. Spahr)

A computer code was written which converts the inertial velocity of a vehicle or object to an air-relative velocity. This permits one to make a direct comparison between a launch vehicle trajectory, which normally presents inertial velocity, and reentry phenomena, such as the microsphere melt boundary, which are functions of the air-relative velocity. This code is now operational on the Sandia IBM 7090.

AUTOROTATIONAL STUDIES (A. C. Bustamante)

A paper entitled "Autorotating Characteristics of Flat Plates and Right Circular Cylinders at Subsonic Speeds" has been accepted for presentation at a special conference on Dynamics and Aerodynamics of Bomblets at Eglin Air Force Base, Florida, on September 26-28.

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