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April 1970

SANDIA LABORATORIES QUARTERLY REPORT
AEROSPACE NUCLEAR SAFETY PROGRAM
JANUARY 1 THROUGH MARCH 31, 1970

AEROSPACE NUCLEAR SAFETY DEPARTMENT 9510

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JANUARY 1 THROUGH MARCH 31, 1970

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April 1970

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ABSTRACT

This report describes research, development, support, and test activities in Sandia Laboratories Aerospace Nuclear Safety Program from January 1 through March 31, 1970.

Key words: Transit, Pioneer, RTG,
Computer Codes

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SUMMARY

TRANSIT

The Task 8 impact tests and postmortems of the Transit heat source were completed; a Task 8 heat source was exposed to simulated reentry conditions in the HEAT facility, and the heat shield wall ablated through in the stagnation line area approximately 30 seconds after the point of peak heating rate. A one-dimensional thermal analysis of the Transit heat source indicated an external graphite temperature of 2000°F at impact.

PIONEER/VIKING

The temperature and velocity of a modified Pioneer heat source at earth impact were determined. Release altitudes required at the Tonopah Test Range to assure obtaining the terminal velocities of three heat sources were determined. It was found that studies conducted by TRW and Isotopes predicted different maximum temperatures for the clad during a 36,000 fps, -6 degree reentry because the two thermal models differ greatly.

ADVANCED FUELS SAFETY

Alpha particles were thermalized in a band approximately 9 μm from the surface of an Mo foil; helium bubbles precipitated in the region of the alpha band after the sample was aged and annealed.

ABORT MODEL

Scaling laws were developed for fuel capsules subjected to blast loading, fragment impact, and earth impact; results indicate that fuel capsules can be simulated during testing by small scale capsule models constructed of the same materials as is the prototype and, in certain

cases, by models constructed of different materials than the prototype. The heats of combustion and explosion were determined for the four Scout vehicle solid propellants.

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RADIOISOTOPE SYSTEMS SAFETY SUPPORT

TRANSIT

Task 8 Impact Tests (L. L. Keller/D. E. Randall/J. E. Deveney)

The Task 8 impact tests and postmortems were completed. A Sandia report covering the testing phase is in preparation. The capsule postmortem was reported by Atomics International, and the Pressure Relief Device (PRD) postmortem was reported by TRW Systems.

In the previous quarterly report (SC-PR-69-881), reference was made to the simulated earth orbit decay reentry preconditioning given to test specimen AIT8-4. The following describes the reentry preconditioning test. AIT8-4 was tested in a stable, side-on orientation to a programmed stagnation heating rate and stagnation pressure profile which simulated earth orbital decay reentry in the Sandia High Enthalpy Arc Tunnel (HEAT) facility. The test environment was an arc-heated, 12-inch diameter free jet of simulated air (80 percent N₂, 20 percent O₂). The stagnation pressure and stagnation heating rate profiles are shown in Figure 1. The stream Mach number was approximately 4.0. The heat source in test position is shown in Figure 2. The heat shield wall ablated through in the stagnation line area approximately 30 seconds after the point of peak heating rate. The PG insulation and fuel capsule suffered only a slight discoloration of the surface, apparently as a result of being exposed to the flow for approximately 50 seconds. The Task 8 test program was completed with the impact of this heat source using the sled track facility. The heat shield ablation was larger than anticipated apparently as a result of an anomaly either in the test program for this run or in the heating distribution over the test specimen.

The stagnation heating rate measurements were taken with the facility calorimeter, an asymptotic, stagnation point type. The stagnation pressure measurements were taken with the facility pitot probe and two CEC pressure transducers.

AIT8-4 was preheated to 800°F before test in a small resistance-heated furnace. A pure nitrogen atmosphere was maintained in the furnace during preheat to minimize oxidation. The furnace, mounted in the test chamber with the heat source positioned inside, is shown in Figure 3. A pure nitrogen atmosphere was also maintained in the test chamber from the time of theoretical impact until unit AIT8-4 had cooled below the point of significant oxidation rate.

Figure 1. Stagnation pressure and heating rate profiles

Figure 2. AIT8-4 in test position

Figure 3. AIT8-4 positioned in preheat furnace

Unit AIT8-4 was supplied to Sandia completely instrumented with six Pt/Pt-10% Rh thermocouples as follows.

<u>Thermocouple Number</u>	<u>Location</u>
1	Stagnation line at longitudinal center on fuel capsule cladding
2	90 degrees from TC 1 on fuel capsule cladding
3	180 degrees from TC 1 on fuel capsule cladding
4	Stagnation line at longitudinal center between pyrolytic graphite shells
5	Sliding plug end on capsule cladding
6	Sliding plug end between POCO graphite heat shield and pyrolytic graphite insulation

The response of these thermocouples is presented in Figures 4, 5, and 6.

The similarity of the response of all thermocouples may be due to the charred condition of the thermocouple insulation. This charring occurred when the heat source was preconditioned by soaking the entire unit at 1350°F for 24 hours. The thermocouple insulation used, which was glass braid, is generally good for no more than 900°F. It is felt that the degrading of the electrical insulation properties of this insulation may have produced one thermocouple junction in the heat source which then gave a response which is meaningless.

A surface temperature measurement was taken on the longitudinal center at about the 25-degree point with a Thermodot Radiometer. The surface temperature response is presented in Figure 7. No corrections were made for actual surface emissivity. The results do take into account the viewing window absorptivity. Surface temperature measurements at all points on the visible surface of the heat source were also made with a pyrometric photography technique. A pyrometric thermogram at 600 seconds (approximately peak surface temperature) is presented in Figure 12. The temperature values are 91° to 195°C low since a correction for emissivity has not been made at this time.

Figure 4. AIT8-4 temperature response

Figure 5. AIT8-4 Temperature response

Figure 6. AIT8-4 temperature response

Figure 7. AIT8-4 surface temperature response (radiometer)

Figure 8. AIT8-4 simulated reentry thermogram at 600 seconds (pyrometric photography)

The Transit RTG heat source before test is shown in Figure 9. After-test views are shown in Figures 10, 11, and 12.

A 17-minute sound movie entitled "ISO Impact Tests" was prepared covering the Task 8 impact series as well as a series of impact tests made on heat sources furnished by Teledyne-Isotopes.

Figure 9. AIT8-4 before test, sliding plug end

Figure 10. AIT8-4 after test

Figure 11. AIT8-4 after test, top view

Figure 12. AIT8-4 after test, end view

Heat Source Reentry Verification Tests (D. E. Randall/
J. E. Deveney)

An instrumented Transit heat source configuration is currently being fabricated at Sandia. This model will be used to conduct preliminary evaluations of the heating rate distributions to the heat source in the HEAT facility environments.

Heat Source Impact Temperature (D. W. Larson)

A one-dimensional thermal analysis was conducted at the request of TRW to determine the impact temperature of the Transit heat source. The analysis was conducted for an orbital decay trajectory provided by TRW. The effects of ablation as determined by the CMA computer code were included. Results indicated an external graphite temperature of 2000°F at impact. The internal components' temperatures were higher but are not accurate due to the one-dimensionality of the analysis.

Ablation Analysis (D. W. Larson)

An ablation analysis was conducted on the Transit heat shield to assist TRW in checking out a simplified three-dimensional ablation code. The analysis was conducted for an orbital decay trajectory provided by TRW. The results indicated that the three-dimensional ablation code was not functioning properly in all flow regimes. Assistance in locating the difficulties was given by Sandia Division 9328. TRW is presently checking out the code after making some modifications.

PIONEER/VIKING

Preliminary Data Package Review (H. R. Spahr)

The NASA/Lewis preliminary launch vehicle data package supplied to AEC for the Pioneer mission was reviewed with respect to providing input data for the aerothermodynamic analysis. Comments on this preliminary data package were documented for transmittal to AEC/SEPO.

Preliminary definition of the work to be done in the following parts of the Pioneer aerothermodynamic analysis was completed.

1. Mission analysis
2. Aerodynamic models
3. Trajectory analysis

Abort Configurations (H. R. Spahr)

Pertinent configurations for aerothermodynamic analyses of Pioneer mission aborts currently are being defined.

Isotopes Heat Source Configuration (D. E. Randall/J. E. Deveney)

An Isotopes hexagonal heat source configuration was run in the Sandia HEAT facility to the same reentry test program used for the Transit Task 8 heat source. This test unit experienced a heat shield burn through from one of the flats into the threaded section for the end plug. In this case, a vent hole in the model's base region set up an internal flow path which resulted in some oxidation of the capsule and tantalum felt pads.

Temperature and Velocity of a Pioneer Heat Source at Earth Impact (MSL) (A. C. Bustamante)

The temperature and velocity of a modified Pioneer heat source (635 thermal watts) at the time of earth impact were determined. These data are to be used as test input data for sled impact tests.

The terminal velocities shown below were determined from data previously obtained from Tonopah drop tests of a Pioneer configuration.

<u>Heat Source Configuration</u>	<u>Velocity at Tonopah (ft/sec)</u>	<u>Velocity at Sea Level (ft/sec)</u>	<u>Standard Deviation ($\bar{\sigma}$) (ft/sec)</u>
Unablated (10.7 lb)	271	250	± 13.2
Ablated (10.35 lb)	356.6	329	± 15.8

The temperature of the strength member of the capsule at impact was estimated to be 2000°F. The temperature was estimated by considering both the convective and radiative losses and the internal heat generation of the heat source during reentry. This temperature should

be treated as an approximate value, since assumptions had to be made concerning the reentry trajectory, heat source design, and thermal data input. It is recommended that when the required data become available, a complete three-dimensional CINDA computer analysis be performed. It is felt, however, that this temperature value is adequate for use as test input data for the sled impact tests.

Hexagonal Heat Source Drop Tests (A. C. Bustamante)

Comments were made on Isotopes' memo, "Request for Design Approval for Fabrication of 18 Drop Test Models." It was suggested that the number of configurations be reduced from six to three in order to have a larger sample size for each configuration. The effect of probable error factor as a function of number of drop tests was computed (Figure 13), and it was shown that six drop tests provide a good sample size.

Figure 13. Probable error factor for mean terminal velocity vs number of drop tests

Release Altitude and Terminal Velocity for Pioneer Heat Source (A. C. Bustamante)

Drop tests of the Pioneer heat source will be conducted at the Tonopah Test Range. Release altitudes to assure obtaining the terminal velocities of these heat sources were determined. The parametric curves of Figures 14 and 15 show terminal velocity as a function of $W/C_D A$ and the drop height necessary to achieve terminal velocity as a function of $W/C_D A$. These data are presented for two altitudes, Tonopah and sea level. The drop height distance is based on the height necessary to achieve terminal velocity and the distance required for proper radar tracking. Since the data are general, they are not intended to be used for design or critical analysis.

Review of TRW and Isotopes Pioneer Reentry Studies (R. D. Klett)

At the request of Headquarters/AEC, a study was performed to determine why studies conducted by TRW and Isotopes did not predict the same maximum temperature for the clad during a 36,000 fps, -6 degree reentry. The different temperatures predicted resulted from the fact that the two thermal models differ greatly. The weights and shapes are different which causes the reference heating rates to be different in both duration and magnitude. The difference in shape resulted in different average heating ratios and greatly different heat distributions. Different thermal conductivities were assumed for the pyrolytic graphite insulation. One model was two-dimensional; this prevents heat from being transferred in one of the high conductivity directions in the pyrolytic graphite. The conductivity of the fill gas assumed in the two models differed by a factor of 9. One model assumed an emissivity inside the clad of 0.8 while the other assumed an emissivity of 0.23 to 0.33.

Since there is not at this time a firm Pioneer heat source design and since production samples of the pyrolytic graphite have not been tested, none of the conflicting assumptions can be criticized. There were no errors detected in either analysis.

Figure 14. Terminal velocity and drop height versus ballistic parameter at Tonopah (5400-foot altitude)

Figure 15. Terminal velocity and drop height versus ballistic parameter at sea level

Thermal Conductivity Measurements (R. D. Klett)

A conductivity test of the tantalum-felt compliance members was conducted using the comparative technique. The measurements were made at 200°F. The results indicate that the conductivity used in early Pioneer studies was a factor of 2 to 4 low.

The Carbitex-500 conductivity test series was completed. Tests were conducted at Sandia and Union Carbide-Parma. The data are in good agreement with the earlier calculated conductivity values that were given to TRW for the Pioneer comparative study. Data for both materials were distributed to the appropriate agencies.

Review of Pioneer and Viking Proposals (R. D. Klett)

The aerothermal sections of the Pioneer and Viking SNAP-19 proposals were reviewed. Although there are some differences in the two missions, there are many similarities and the analyses in the proposals were almost identical. As stated in the proposals, "The study is limited in scope and thus should be treated only as a preliminary survey." Because of the approximate methods and inputs used to calculate the temperatures, they should be treated as rough estimates of the actual temperatures. The tests and calculations presented in the proposals do not prove that the IIHS has superorbital reentry capability. The calculations are not sufficiently accurate, and the tests do not simulate actual conditions well enough to evaluate the IIHS or to permit selection of a capsule or heat shield design.

Thermal Switch (D. W. Larson)

A cursory examination was made of the Hittman thermal switch and of pyrolytic graphite as insulators in the Pioneer heat source. Based on previous work, it was determined that either insulating system could be shown to be more effective than the other in reducing the capsule temperatures during reentry depending upon which reentry trajectory was examined.

MULTI-HUNDRED WATT LONG-LIFE RTG SYSTEM

Gap Analysis (D. E. Randall)

An analysis of the influence of large gaps between the fuel capsule insulation and the heat source heat shield on heat source re-entry characteristics was conducted. The results to date indicate that the gap contributes a definite improvement in terminal velocity, but this occurs at a significant heat source weight penalty.

ISOTOPE BRAYTON HEAT SOURCE

Aerothermodynamic Analysis (D. W. Larson/H. R. Spahr)

Sandia representatives met with NASA representatives to discuss the missions proposed for analysis in the Preliminary Safety Analysis Report (PSAR) on the Isotope Brayton Heat Source. Information which would be needed to do the aerothermodynamic analyses for a PSAR was defined.

Preliminary Safety Analysis Report (PSAR) (R. G. Illing)

An initial effort on the Isotope Brayton Heat Source PSAR was started; however, budgetary and personnel limitations did not permit sufficient resources to continue the work. The PSAR completion date has been indefinitely postponed, and Headquarters/AEC was so notified.

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SAFETY TECHNOLOGY

ADVANCED FUELS SAFETY

Reentry Testing of SSCS Disc (D. E. Randall/J. E. Deveney)

One solid solution cermet simulant fuel disc was received from LASL and tested in the HEAT facility. This specimen was exposed to a face-on orbital decay reentry trajectory heating rate pulse. The specimen was heated to approximately 1500°F prior to installation in the facility. The unit experienced a mass loss of 3-1/2 percent and a front face recession of 5 mils at the center and 9 mils at the edge.

Reentry Ablation Testing in a Hyperthermal Arc Tunnel (I. B. White/K. L. Romine)

Six specimens were tested in the Sandia 40-kW hyperthermal arc tunnel in two series of tests. These tests were performed in conjunction with the solid solution cermet advanced safety technology.

The first series of tests included two LASL-fabricated $^{238}\text{PuO}_2$ -10 w/o ThO_2 solid solution/12.8 w/o Mo cermet fuel samples and two ThO_2 /12.8 w/o Mo fuel simulants fabricated by General Electric. The purpose of these tests was to determine if the simulants reacted similarly to the actual fuel materials when exposed to the same test conditions so that simulants could be used in lieu of the $^{238}\text{PuO}_2$ fuel materials in future tests in the Sandia HEAT facility and the 40-kW arc tunnel.

Specimen properties before and after testing and test conditions are given in Table I. Fuel sample 32-B and the fuel simulant 1009-4-2 were both exposed to Sandia test condition S (72 Btu/ft^{3/2}-sec) for 80 seconds. The high speed movie films indicate that there was no apparent ablation of the ThO_2 simulant. The fuel specimen was coated with a white layer of material. The $^{238}\text{PuO}_2$ fuel ablated numerous small pieces of melted material from the front face during the exposure

period. During the demounting of this specimen, a thin cap of material approximately 0.010 inch thick separated from the front face; this cap is included in the 6 percent mass loss indicated in Table I. Figure 16 shows the front face of the above specimens before and after testing.

Fuel sample 32-C and fuel simulant 1009-4-1 were both exposed to Sandia test condition B ($108 \text{ Btu/ft}^{3/2}\text{-sec}$) for 30 seconds. The results were similar to the results obtained at condition S except that 0.1 percent (including the cap) was lost from the $^{238}\text{PuO}_2$ fuel sample. The fuel simulant specimen was coated with the same white layer as 1009-4-2 and, in addition, there was a series of white globules on the front face. Figure 17 shows these specimens before and after testing.

The second series of tests included two LASL-fabricated $^{238}\text{PuO}_2$ -10 w/o ThO_2 solid solution/12.44 w/o Mo cermet fuel specimens which were identical to the previous $^{238}\text{PuO}_2$ samples but were overcoated with approximately 0.005 inch of Mo. The purpose of these tests was to compare the reaction and degradation of the coated specimens with the two uncoated specimens previously tested.

$^{238}\text{PuO}_2$ specimen 33-B was exposed to $72 \text{ Btu/ft}^{3/2}\text{-sec}$ for 80 seconds (test condition S). As in the previous tests, there was some melt and ablation of the front face material. A review of the movie films showed that a large piece of the front face sheared away from the sample at 30 seconds after exposure and the remainder of the front face, which was approximately 0.040 inch thick, shifted laterally about 0.080 inch. This cap separated from the specimen during demounting but was recovered intact. The mass loss of the specimen including the cap was 18 percent. If the cap were not included, the mass loss would have been 7.6 percent. Figure 18 shows this specimen.

Specimen 33-C was exposed to $108 \text{ Btu/ft}^{3/2}\text{-sec}$ for 30 seconds (test condition B). There was some ablation of the front face. No cap separated from the front face, but circumferential cracks approximately 0.030 and 0.100 inch behind the front face indicated that a cap was formed. The mass loss of this specimen was 5.5 percent. Figure 19 shows this specimen and the cracks formed during the test.

All the specimens tested were returned to LASL for a detailed posttest analysis.

TABLE I

 $^{238}\text{PuO}_2$ -Mo and ThO_2 -Mo Solid Solution Cermet Arc Jet Tests

Specimen Number	Material	Test Condition (Btu/ft ^{3/2} -sec)	Weight (gm)		Diameter (in.)		Length (in.)		Mass Loss (%)	Peak Temperature of Face* (°C)
			Before	After	Before	After	Before	After		
1009-4-2	ThO_2 -Mo	72	1.5320	1.5319	0.2564	0.2553	0.2048	0.2075	0	2050
32-B	$^{238}\text{PuO}_2$ -Mo	72	1.8668	1.7556**	0.2706	0.2714	0.2000	0.1925**	6.0	2500
1009-4-1	ThO_2 -Mo	108	1.5340	1.5324	0.2570	0.2552	0.2039	--	0.1	2650
32-C	$^{238}\text{PuO}_2$ -Mo	108	1.6073	1.4518**	0.2689	0.2695	0.1768	0.1707**	9.0	2750
33-B	$^{238}\text{PuO}_2$ -Mo w/Mo Overcoat	72	1.9191	1.5720**	0.2834	0.2763	0.1978	0.1784**	18.1	2450
33-C	$^{238}\text{PuO}_2$ -Mo w/Mo Overcoat	108	1.7340	1.6380	0.2674	0.2742	0.1943	0.2328	5.5	2650
* $\epsilon = 0.4$.										
**Does not include front cap which separated after test.

Before test

After test

a. SCS specimen 1009-4-2 (10X)

Figure 16. $^{238}\text{PuO}_2$ solid solution cermet and simulant tested in the Sandia 40-kW hyperthermal arc tunnel (72 Btu/ft³/2-sec)

Before test

After test

b. SSC specimen 32-B (10X)

Figure 16. (continued)

Before test

After test

a. SSCS specimen 1009-4-1 (10X)

Figure 17. $^{238}\text{PuO}_2$ solid solution cermet and simulant tested in the Sandia 40-kW hyperthermal arc tunnel ($108 \text{ Btu/ft}^{3/2}\text{-sec}$)

Before test

After test

b. SSC specimen 32-C (10X)

Figure 17. (continued)

Before test

After test

a. SSC specimen 33-B - front face (10X)

Figure 18. Mo coated solid solution cermet tested in the Sandia 40-kW hyperthermal arc tunnel (72 Btu/ft³/2-sec)

Before test

After test

b. SSC specimen 33-B - side view (10X)

Figure 18. (continued)

Before test

After test

a. SSC specimen 33-C - front face (10X)

Figure 19. Mo coated solid solution cermet tested in the Sandia 40-kW hyperthermal arc tunnel (108 Btu/ft^{3/2}-sec)

Before test

After test

b. SSC specimen 33-C - side view (10X)

Figure 19. (continued)

Alpha Irradiation of Molybdenum (C. J. M. Northrup, Jr./
R. P. Wemple/G. J. Thomas/C. R. Hill)

When molybdenum is in contact with $^{238}\text{PuO}_2$ or with solid solution $^{238}\text{PuO}_2 + \text{MO}_2$, the molybdenum is subjected to a high flux of alpha radiation. Significant lattice damage is produced by the alpha particles, and many of the alphas are thermalized and produce helium atoms in the metal. Scoping experiments were performed to identify the types of physical changes that might occur in the molybdenum web of solid solution cermets (SSC) and to attempt to gain insights for various temperatures into how soon after fabrication these effects may be seen in the SSC. This will also permit time frames to be identified for critical engineering tests on SSC and will give a better perspective to the tests currently being performed.

In early October 1969, a molybdenum foil was irradiated at liquid nitrogen temperatures on the Lawrence Radiation Laboratory 90-inch cyclotron. The alpha-particle energy was 4.8 MeV. Run 6 received 1×10^{16} alphas in a 0.5-inch-diameter circle. These alphas were deposited in a zone approximately 0.44 micrometer thick. This dose approximates that received in the molybdenum web of SSC in 1-1/2 years. The Run 6 molybdenum foil was stored at room temperature until mid-January 1970. It was then annealed at 700°C for approximately 10 minutes, mechanically polished, and the zone in which the alphas were thermalized scrutinized with a JEOLCO JSM-2 scanning electron microscope (SEM). No surface structure attributable to the injected helium was observed. This sample was then annealed at 2000°C for 10 minutes and mechanically polished. A short electrochemical etch with dilute H_2SO_4 was used to remove the surface artifacts produced by the mechanical polishing and to bring out the grain structure. Observation in the SEM revealed a belt of voids coincident with the region in which the alphas were thermalized (Figures 20, 21, and 22). The voids are thought to be cross sections of helium bubbles.

Experiments reported earlier using transmission electron microscopy indicated that the lattice damage produced by alpha irradiation of molybdenum anneals very slowly at 700°C, considerably faster at 900°C, and very rapidly at 1200°C. The 1200°C experiment produced circular defects resembling gas bubbles in 10 minute anneals. There is evidence that dislocations can be pinned at these defects, and therefore they would be expected to alter the mechanical properties of molybdenum.

Figure 20. Alpha particles were thermalized in a band approximately 0.44 micrometer thick, 9 to 10 micrometers from the fuel's surface. The dose in this band approximates the dose an SSC molybdenum web will receive in 1-1/2 years. Helium bubbles have precipitated in the region of the thermalized alpha band after the sample was kept for 3 months at room temperature, 10 minutes at 700°C, and 10 minutes at 2000°C.

Figure 21. An enlargement of Figure 24 shows that bubbles have condensed in the grain and that some migration has occurred.

Figure 22. Another view of the fuel in Figure 24 indicates that bubbles exist in both the grain boundary and the grain

Fuel Impact Facility (W. J. Dalby)

Tests to evaluate the effectiveness of the catcher cask seal of the fuels impact facility designed by Sandia's Systems Environmental Test Department yielded leak rates of less than 10^{-9} cc He/sec at standard conditions for tests at 150 to 630 feet per second for a 0.65 scale test configuration.

Tests of the capsule arresting portion of the facility yielded satisfactory results at impact velocities up to 500 feet per second.

Fuels Impact (W. J. Dalby)

Two additional ThO_2 -Mo solid solution cermet simulant specimens furnished by LASL were impacted at Sandia and returned to LASL for particle size distribution analyses. The specimens were approximately 0.5 inch in diameter by 0.22 inch thick. They did not have a molybdenum coating. Both specimens were impacted at 850°F. The impact velocities were 292 and 378 feet per second.

An experiment was designed to investigate the main effects and the two factor interactions for temperature, attitude, and velocity for the impact of individual disks of solid solution cermet simulant. The design is intended to permit the fit of a full second degree polynomial and is expected to be useful in predicting particle size quantiles. The model is also expected to be useful for selecting the impact parameters for a limited number of impacts of the solid solution cermet disks.

FLIGHT TEST STUDIES

Athena H Feasibility Study (A. C. Bustamante)

A feasibility study for an Athena H flight test was completed. Six Transit heat sources were selected as the payload, with two heat sources instrumented for motion, two for temperature, and two being passive. Two prime areas of concern and study were instrumentation and recovery of the heat sources. Both of these areas appear to be feasible, with the instrumentation area requiring a larger research and development effort. This study was summarized in a vu-graph presentation, and will be documented.

Instrumented Prototype Heat Source (A. C. Bustamante)

The various tasks that will be performed in support of the flight test program for the remainder of this fiscal year were defined. Components that are presently available will be assembled into an instrumented simulated heat source package. The primary package will be instrumented for temperature, with a secondary package instrumented for motion.

A payload package for an Athena D flight may be available in November 1970. If space and weight are available, it might be possible to also fly one or two inert cylindrical heat sources piggyback. The heat sources would be 3.5 inches in diameter and 5.6 inches long.

As a result of weight and volume restrictions, the various heat source configurations available would be limited. However, five possible heat source configurations could be used (Table II). These configurations are properly sized for weight and volume, and they are within the range of the proper ballistic parameter.

ABORT MODEL

Solid Solution Cermet Fuel Puck Impact Temperature (D. W. Larson)

An analysis was conducted to determine the impact temperature of a solid solution cermet fuel puck. The puck was assumed to be falling as a free-body with an initial temperature at an altitude of 90,000 feet of 3000° to 4750°F. Results indicate an impact temperature for the 2.15 inch diameter by 0.212 inch length fuel puck of 270° to 350°F, depending on the emissivity of the fuel puck.

Scaling Laws for Fuel Capsules Subjected to Blast, Impact, and Thermal Loading (T. A. Duffey)

Possible hostile environments experienced by fuel capsules are blast loading, fragment impact, earth impact, and thermal loading. From a safety standpoint, it is essential that fuel capsules completely contain the radioactive fuel enclosed in them when subjected to these hostile environments. Due to the complexity of the structural response problem, analysis is difficult, and it is often necessary to resort to testing.

TABLE II
Inert Heat Source Configurations

Configuration	Weight (lb)	W/C _D A (lb/ft ²)
<p>1</p> <p>POCO shell 1 inch thick, 3.5 inch dia, 5.6 inches long</p> <p>Steel slug 1.5 inch dia, 3.6 inches long</p>	4.77	39.7
<p>2</p> <p>POCO shell 0.5 inch thick</p> <p>T-111 liner 0.05 inch thick, 2.5 inch dia, 4.6 inches long</p> <p>Five thoria disks 0.212 inch thick, 2.4 inch dia</p> <p>Cross Section View</p>	5.0	41.6
<p>3</p> <p>Scaled Transit heat source, 70% of original heat source internally and externally</p>	4.63	38.5
<p>4</p> <p>POCO shell 0.5 inch thick</p> <p>Transit capsule with T-111 liner, 0.05 inch thick, 4.0 inches long, 2.42 inch dia</p> <p>Six thoria disks 0.212 inch thick, 2.32 inch diameter</p>	5.0	41.6
<p>5</p> <p>POCO shell 0.25 inch thick</p> <p>Transit capsule with T-111 liner 0.05 inch thick, 4.0 inches long, 2.42 inch dia</p> <p>Nine thoria disks 0.212 inch thick, 2.32 inch dia</p> <p>Void (two places)</p>	5.0	41.6

In the case of a radioisotope fuel capsule, it may be extremely costly and hazardous to construct and test a full size unit. It would be highly desirable to perform tests on model fuel capsules that have been geometrically reduced in size. Ideally, the model would also be constructed of less expensive and/or less dangerous materials as well. However, in either case it must be determined if the model response is representative of the actual fuel capsule response.

To answer the above questions, scaling laws were developed for fuel capsules subjected to blast, fragment impact, and earth impact. Results indicate that fuel capsules can be simulated during testing by small scale capsule models constructed of the same materials as is the prototype and, in certain instances, by models constructed of different materials than is the prototype. The study will be documented.

Dynamic Material Properties From the Ring Test (T. A. Duffey)

Currently, static (and quasi-static) material properties are available in limited quantities for materials utilized in fuel capsules. However, dynamic properties, particularly in the intermediate strain rate range of 10 to 1000 per second occurring during impact, are extremely limited, if not nonexistent. Since any predictions of structural response require material properties, it is essential that the dynamic properties of candidate fuel capsule materials be determined.

Many of the experimental techniques available elsewhere for obtaining dynamic properties in the intermediate strain rate range, such as the intermediate strain rate tensile testing machine and Hopkinson Bar, repeatedly have been subjected to question in regard to validity of data.

Work is currently underway at Denver Research Institute in developing an accurate, though relatively inexpensive, method for obtaining dynamic properties using a uniformly expanding ring technique. However, a number of difficulties, notably the necessity of double differentiation of experimental data, have been encountered.

It may be possible to make certain assumptions on the dynamic material behavior which will simplify this type of material property

test to the point where the test will be rapid and extremely inexpensive to perform. However, it is unclear at this time whether the parameters to be measured during the experiment will be sufficiently sensitive to accurately deduce the material properties.

A feasibility study is currently being undertaken to determine if modification of the expanding ring test will be sufficiently simple and useful to justify its development here.

Solid Propellant Burn Tests (F. L. Baker)

Bomb calorimeter tests were conducted to determine the heats of combustion and explosion of the four Scout vehicle solid propellants. The results are as follows.

	<u>ΔH Combustion (cal/gm)</u>	<u>ΔH Explosion (cal/gm)</u>	<u>Percent Residue</u>
Algol II B	3517	1363	23
Castor II-TP-H 7036	3456	1569	22
Antares II	3197	1462	Not Determined
FW-45	3454	1480	21

The heat of combustion results are precise to better than 1 percent, and the heat of explosion results, except for the Antares II propellant, are precise to better than 0.5 percent. Eight heats of explosion were determined for the Antares II propellant. These results varied from a low of 1345 cal/gm to a high of 1536 cal/gm. The heats of combustion were determined in an excess oxygen atmosphere, while the heats of explosion were determined in an argon atmosphere.

COMPUTER CODES

TTB (H. R. Spahr)

The TTB computer code is an advanced version of the TTA computer code which calculates 3- and 6-degree-of-freedom trajectories for rigid bodies flying in a planetary gravitational field and subject to aerodynamic forces. Input data decks and computer output were supplied to

the Mathematical Computing Services Division for an orbital decay 6-degree-of-freedom trajectory and a 22 revolution highly elliptical orbital decay.

These trajectories, already computed using TTA, were used in optimizing the numerical time step size selection system in TTB. (The Mathematical Computing Services Division wrote the TTA and TTB computer codes.)

Trajectories are being computed using the TTB computer code to:

1. Become familiar with options not available in its predecessor, the TTA trajectory code. These include adding planetary, solar, and lunar gravitational fields to the computations. Fortran subroutines can be added as required.
2. Implement the necessary Fortran additions to use the TTB code to punch input data decks for the Charring Material Ablation code.
3. Make several runs to compare the results with previous TTA results.
4. Understand the slightly different input data deck setup required.

RADFAC (H. R. Spahr)

Documentation of computer code RADFAC was obtained from NASA/Houston. RADFAC, like CONFAC II, calculates radiant exchange parameters. However, RADFAC can include specular and bidirectional reflectances which cannot be treated using CONFAC II. RADFAC also includes an improved form of CONFAC II as a subroutine.

Douglas Arbitrary Body Code (H. R. Spahr)

The Douglas Arbitrary Body code calculates the hypersonic and supersonic aerodynamic coefficients of complex configurations in the free molecule and continuum regimes. Arrangements were completed to obtain a tape of the NASA/Langley on-line graphics version of this code.

HRS017 (H. R. Spahr)

Computer code HRS017 computes the trajectory and reentry environment for nuclear systems decaying from multiple revolution highly elliptical orbits. This computer code is now documented in the following Sandia Laboratories reports.

1. SC-RR-69-378, Computer Code HRS017--A Code for the Computation of the Trajectory and Reentry Environment for Nuclear Systems Decaying From Multiple Revolution Elliptical Orbits, January 1970.
2. SC-RR-70-143, Same Title - Appendices, January 1970.

HRS022 (H. R. Spahr)

Computer code HRS022 calculates fund and manpower expenditure summaries for the Space Power Systems Directorate activities for use by the Sandia Laboratories and AEC Headquarters management. The following work was completed on this code.

1. Comment cards were added through all of this code to describe its operation in detail.
2. Two utility computer codes were used to:
 - a. Prepare an index of variables and their usage in the code, and
 - b. Prepare an automated flow chart for this code.
3. A Univac 1108 version of this code is now fully operational.

HRS023 (H. R. Spahr)

Computer code HRS023 is now operational on the GE 635 computer in Los Angeles on the Mark II time-sharing service, using the remote terminal in Building 892. This computer code calculates Reentry and Space Sciences Division fund expenditures for AEC line items.

HFIRE (D. W. Larson)

The FIRE computer code for predicting the thermal response of fragments in a fireball was modified to include the effects of convection and internal generation. The modified code is called HFIRE and

is operational on the GE time-sharing computer system. It can be used to predict the temperature of small objects with high thermal diffusivity in any radiative or convective heat transfer environment.

Thermal Graphics (D. W. Larson)

A computer code was written which draws the structure of one- and two-dimensional thermal models on the SC-4020 plotter. The code is being adapted to fit in as a portion of the thermal graphics computer code.

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