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AEROSPACE
NUCLEAR
SAFETY

AEROSPACE NUCLEAR SAFETY REPORT
FOR AUGUST 1968

AEROSPACE NUCLEAR SAFETY DEPARTMENT 9510

SANDIA LABORATORIES

OPERATED FOR THE UNITED STATES ATOMIC ENERGY COMMISSION BY SANDIA CORPORATION | ALBUQUERQUE, NEW MEXICO; LIVERMORE, CALIFORNIA

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**AEROSPACE NUCLEAR SAFETY REPORT
FOR AUGUST 1968**

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ABSTRACT

This report describes research, development, support, and test activities in the Sandia Laboratories Aerospace Nuclear Safety Program for August 1968.

September 1968

SUMMARY

SNAP-27

Radiant heat and fragmentation impact tests on simulated capsules were conducted; results are reported with numerous illustrative photographs.

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RADIOISOTOPE SYSTEMS SAFETY SUPPORT

SNAP-19

Filter Tests (J. B. Boyd)

The seawater leak rate tests being conducted at the U. S. Naval Radiological Defense Laboratory (USNRDL) are still in progress.

Filter No. 1 has been on test in seawater at 265 psi, room temperature, since July 19, and the flow rate has dropped from 1×10^{-5} to 4.6×10^{-6} std. atm cc/sec. Helium is used as the pressure medium behind a reservoir of natural seawater. The outlet side of the filter is exposed to atmospheric pressure.

Filter No. 2 (also in seawater) test data are as follows:

<u>Pressure (psi)</u>	<u>Temperature</u>	<u>Flow Rate (std. atm cc/sec)</u>
10	Room	0
50	Room	5×10^{-6}
265	Room	4×10^{-6}
265	70°C	3.8×10^{-6}

The temperature was increased to 70°C on Filter No. 2 August 12. The flow rate dropped to zero August 24 and remains there. USNRDL feels that the heat is causing CaSO_4 to precipitate and clog the filter.

SNAP-27

Safety Analysis Report (J. E. Taylor)

At a meeting at GE-MSD on August 28 it was decided, with the concurrence of attending AEC personnel, to publish the addendum to the SNAP-27 safety report in draft form by October 15. GE also agreed to publish informally, by September 15, source terms for the SNAP-27 which could be used by the Interagency Review Panel before they receive the addendum.

GE will estimate probability numbers in those areas where NASA has not supplied the necessary inputs. The safety report will note which numbers are GE estimates rather than NASA estimates.

Radiant Heat Test (L. L. Keller)

A radiant heat test was performed on the second radiant heat capsule (RG-2) on August 8, 1968. The capsule was pressurized to 116 psia (room temperature) before the test to simulate the expected pressure of a real capsule at peak heating. The radiant heat array was programmed to produce a capsule clad temperature which simulates the temperature profile and gradient of a fuel capsule (protected by a GLFC) during earth orbit decay side-on stable. Capsule pressure in the aft half capsule and pressure monitoring system was lost before peak pressure was reached, but the pressure history to the point of failure indicates that the desired pressure was probably achieved in the center void section and in the forward half capsule. Just before peak heating (the exact time and temperature has not yet been determined), the clad ruptured on the forward half capsule. The clad on the rear cup of the forward half capsule split longitudinally about 3 inches, and where the split intersected the midweld the tear progressed circumferentially along the weld about 1/2 inch on either side.

To date we have not been able to discern from the movie coverage where the failure started. The liner assembly swelled into the opening left by the clad split, but no failure of the liner was visually observed. A circumferential crack was observed in the relief area of the center section. Pressure loss in the aft half capsule and pressure monitoring system is attributed to a crack in the Haynes clad, where it surrounds the stainless insert (47B301120) used as a pressure tap, and possibly in the close-off valve used in the pressurizing system. The radiant heat test capsule was returned to GE for postmortem. The remaining thermocouple data and the movie film of the test were hand carried to GE on August 16. Figures 1, 2, 3, and 4 show the test setup and the capsule failure in the forward half capsule.

Figure 1. Radiant heat test setup for the case of earth orbit decay, side-on stable

Figure 2. Radiant heat capsule (RG-2) illustrating rupture of forward half capsule

D68-19244

Figure 3. Radiant heat capsule (RG-2) illustrating rupture of forward half capsule

D68-19243

Figure 4.

Radiant heat capsule (RG-2) illustrating rupture of forward half capsule

Live Fuel Impact Tests (B. S. Hill)

The fines analysis of the aged and thermally cycled fuel from the capsule impacted at 442 ft/sec into 0.75-inch thickness of Super-temp graphite over a granite target has been reported by Mound Research Laboratory as follows:

<u>Particle Size</u> <u>(μm)</u>	<u>Weight</u> <u>Percent</u>
177 - 210	5.5
149 - 177	5.9
125 - 149	7.7
105 - 125	5.8
63 - 105	14.2
44 - 63	5.4
20 - 44	34.0
10 - 20	6.5
< 10	6.4
Total	91.4

Because of the missing 8.6 percent fraction, no analysis of the less-than-10-micrometer fraction is planned.

Mound Radiation Laboratory and Sandia are currently working together to refine the techniques for recovery and analysis of the fines generated in the live fuel impact test program. An additional impact test into a 0.75-inch thickness of Hitco graphite over a granite target, at 456 fps and a capsule temperature of 1000°F, was fired on August 29 to check the efficiency of the modified techniques.

Fragmentation Tests (R. E. Berry)

A calibration sled test was conducted August 6 at approximately 1090 ft/sec to check out the test setup. Figures 5 and 6 show the damage to 0.060-inch thick stainless-steel cylinders used to simulate the test items. Figure 7 shows the fragments suspended above the sled track.

Figure 5.

Figure 6.

Figure 7.

Test 1 -- The fragmentation tests are designed to carry two simulated capsules, one for an edge-on impact and one for a flat plate impact on each sled run. The run was made on August 7. The actual velocity was 1045 ft/sec. Both capsules remained intact and there was no apparent rupture of the capsule. Figures 8 and 9 show the hardware after fragment impact.

Test 2 -- Two more units, edge-on and flat, were tested on August 12 at a velocity between 1870 and 2000 ft/sec. The unit that hit the flat plate remained intact, with the capsule mushroomed on the end. The edge-on unit separated after impact during the braking operation. The aft weld joint of the capsule broke and the 1/4-20 cap screws failed, allowing the unit to separate. The capsule clad was ruptured;

the extent of damage will have to be determined from a postmortem of the recovered units. Figures 10 and 11 show the hardware after fragment impact.

Figure 8.

Figure 9.

FLAT

D68-21761

Figure 10.

EDGE-ON

D68-21757

Figure 11.

Test 3 -- The test of the SNAP-27 simulated capsule with the graphite cap and the Bendix titanium cap impacted into the edge-on fragment was performed on August 19. The bendix titanium cap was mounted off center so that the fragment impacted the skirt rather than the heavy block in the center. The half capsule, beryllium simulator, forward capsule support, and titanium cap were recovered as an assembly. Visual inspection revealed that the titanium cap was dented but not fractured by the fragment; the condition of the half capsule cannot be determined until a postmortem is performed by GE. Figures 12 and 13 show the graphite end cap and the capsule hardware after fragment impact. It was noted that on heat up of the capsule the capsule liner next to the heater had melted. The unit again broke loose from the mounting plate, breaking the hold-down bolts and the base plate weld. Essentially all the unit was recovered.

Two fragmentation tests (Nos. 4 and 5) were conducted with a simulated SNAP-27 capsule assembled in the beryllium heat shield. The units were mounted horizontally on the sled fixture. Figure 14 shows the mounted test item. Each unit was heated to about 1200°F. Both tests were planned for an impact velocity of 1000 ft/sec.

Figure 12.

Figure 13.

Figure 14.

Test 4 -- The velocity determined for the edge-on fragment impact was 975 ft/sec. The capsule latch mechanisms failed, and the capsule was thrown free of the heat shield assembly after impact. Inspection of the beryllium heat shield cylinder by x-ray and die penetrant revealed no damage.

Test 5 -- The velocity determined for the flat-on fragment was 1040 ft/sec. The beryllium heat shield cracked longitudinally on top and bottom, as mounted, and at the impact line. Cracking extended out and around the cylinder from the longitudinal cracks, primarily on the side opposite the impact face. Although badly cracked, the cylinder remained intact. Figures 15 and 16 show the external cracks in the beryllium after flat fragment impact.

Figure 15.

Figure 16.

Fragment and specimen parts from the first three impact tests were returned to GE for postmortem. Material was salvaged from tests Nos. 4 and 5 for an explosive overpressure test. Additional tests of the end-on configuration are planned at an impact velocity of 3000 ft/sec.

Gun Projectile Impact Testing (R. E. Berry)

The first gun test was completed. A 0.5-inch diameter by 2-inch long aluminum projectile was fired at 670 ft/sec into a 0.375-inch thick by 12-inch diameter beryllium plate. The beryllium plate was heated to about 900°F.

The beryllium plate was indented about 0.060 inch, and random cracking was observed on the impact surface (Figure 17). The opposite surface had radial cracks from the impact point and a spalled area about 2 inches in diameter by about 0.312 inch deep. The spalled material was removed in a surface layer about 0.125 inch thick at the center, tapering to the 2-inch diameter; a second piece about 1 inch in

diameter by about 0.187-inch thick was spalled from beneath the surface layer (Figure 18). The beryllium plate was rigidly supported around the entire circumference and did not fracture completely when released from the fixture.

Because the restraint of the mounting fixture during the beryllium plate-projectile impact was considered unacceptable, the test fixturing was redesigned for the Haynes 25 and titanium plate-projectile impacts. A special heating array was fabricated for heating the plates, and the plate was suspended by wires with three-finger longitudinal support. Several 0.5-inch diameter by x-inch long aluminum projectiles were fired into both Haynes 25 and titanium plates.

Haynes 25 Plate (x = 1 inch)

<u>Shot Number</u>	<u>Velocity</u>	<u>Remarks</u>
1	347	Dimpled
2	406.5	Dimpled
3	490	Dimpled
4	760	Penetrated
5	720	Dimpled

Titanium Plate (x = 2 inches)

<u>Shot Number</u>	<u>Velocity</u>	<u>Remarks</u>
1	840	Penetrated
2	450	Dent small
3	615	Dent small
4	Unavailable	Cracked, did not penetrate
5	825	Cracked, did not penetrate
6	913	Penetrated

One remaining beryllium plate will be tested and this will finish the gun test series.

These data are being used to refine the calculations of penetration of fragments into the SNAP-27 GLFC.

Figure 17.

D68-21745

Figure 18.

D68-21746

SNAP-27 GLFC Explosive Overpressure Test (R. E. Berry)

One set of side-on GLFC hardware has been diverted from the fragmentation test series to be used as a specimen for an explosive overpressure test. After the test parameters have been defined, the test can probably be run within 1 or 2 weeks.

General Electric initially recommended this test and is being notified of all developments in test preparation. GE is presently determining the most realistic test conditions to be used.

SNAP-29

Launch Area Population Information (R. T. Finnell)

Updated population information (January 1968) for southern California has been plotted on an aeronautical chart, number WAC404. This information will be helpful in analyzing SNAP-29 Vandenberg launch pad abort hazard studies. Lithographed copies (11 x 14 inches) have been supplied to the SNAP-29 contractor, Isotopes.

Reenterable Intact Generator (D. E. Randall)

A review was conducted of the aerothermodynamic analysis presented in the original proposal and the addendum thereto in support of the Reenterable Intact Generator (RING). A critique of this analysis was prepared and forwarded to the Isotope Projects Division.

SAFETY TECHNOLOGY

ADVANCED FUELS SAFETY

PuO₂ Microsphere Bonding (J. F. Hudson, Jr./M. D. DeVore, Jr.)

Three samples of PuO₂ microspheres were received from Mound Laboratories and examined. The 0.5-mg samples were:

1. fuel from a SNAP-19B capsule, SN307;
2. a random sample of fuel from a recent production batch, No. 176; and
3. microspheres, larger than 210 micrometer in diameter, screened from batch No. 176.

These samples were placed in a covered glass culture slide for photography and weighing. After weighing of the individual microspheres, they were stored in the glass slides. When the fuel from SN307 was examined 20 days later, it was noted that bonds had formed between microspheres which had been touching. Subsequent examination showed that the other two samples from batch No. 176 exhibited a similar bonding. These bonds, which were broken by agitation of the glass slide, do not appear to be very strong.

Examples of the bonding are shown in Figure 19. Samples 1 and 3 (Figure 19) had previously been immersed in water during fines analysis; sample 2 was not. It has been suggested that water may be a contributing factor in the bonding process. An investigation into the causes of the observed bonding is being considered.

D68-11884

- a. From sample 1, SN307
(three microspheres)

D68-11885

- b. From sample 1, SN307
(two microspheres)

D68-11886

- c. From sample 2, a random
sample from batch No. 176
(two microspheres)

D68-11887

- d. From sample 3, large micro-
spheres from batch No. 176
(two microspheres)

Figure 19. Microspheres showing bonding (100X)

INTACT HEAT SOURCE

Soil Studies (J. B. Boyd)

Under Sandia contract, the National Bureau of Standards' work to measure effective thermal conductance of nine soils has been completed. A draft of the final report will be completed by mid-September. An interim report, received in July, now has been reviewed.

Thermal conductance data from all tests were received from NBS in August. Test data agreement between tests 1 and 2 for each soil is very good; therefore no additional tests are planned.

Burial Test Analysis (G. H. Elkins)

A mathematical model has been constructed to determine the steady-state temperatures for a spherical heater buried in an infinite heterogeneous medium such as soil. The numerical solutions to the model have been calculated with the use of the differencing analyzer CINDA.

DOSE MODEL

The Aerial Detection of a Hypothetical ^{60}Co Fueled RTG (R. J. Everett)

A study was completed on the aerial detection of ^{60}Co sources on the ground, in soil, or in water. A knowledge of the dose fields, buildup factors, and sensitivity levels of gamma counting equipment in search aircraft allowed the estimation of detection altitude as a function of source size. Figure 20 illustrates these relationships for ^{60}Co sources on the ground; the starred points represent cases of actual search and recovery of ^{60}Co sources. The effect of earth and water penetration is illustrated in Figures 21 and 22. The detection and recovery of gamma-emitting RTG appears to be excellent on the ground; the probability of detection diminishes with increasing soil and water penetration.

Figure 20. ^{60}Co Activity on ground vs detection altitude

Figure 21. ^{60}Co activity at several soil penetration depths vs detection altitude

Figure 22. ^{60}Co activity at several water depths vs detection altitude

Estimated Dose Rates from ^{60}Co Fueled RTG at Various Depths of Earth Penetration (W. L. Holley)

In the process of studying ^{60}Co as an RTG fuel, it was proposed that the high external radiation could be alleviated if the fuel capsule would bury itself upon impact.

Figure 23 gives the dose rate per Curie of unshielded ^{60}Co as a function of depth of burial. One can also consider it as the dose rate per 100 Curies of 99 percent shielded ^{60}Co versus depth of burial. The equation which gives Figure 23 is as follows:

$$\text{DR} = \frac{(\text{BUF})\text{AC} e^{-\mu_a d} \text{DCF}}{4\pi d^2} \text{ (rad/hr)}$$

where

$$\text{BUF} = \text{buildup factor} = 1 + \left(\frac{\mu + \mu_a}{\mu_a} \right) \mu d$$

A = activity (Curies)

C = conversion factor $\left(3.7 \times 10^{10} \text{ dis/sec} \frac{\gamma}{\text{dis}} \times \frac{\text{MeV}}{\gamma} \right)$

μ = total linear attenuation coefficient (cm^{-1})

μ_a = energy linear attenuation coefficient (cm^{-1})

d = depth of burial (cm)

DCF = dose conversion factor

In this computation, the soil is considered to be SiO_2 . The linear attenuation coefficients are given below:

<u>MeV</u>	<u>μ (cm^{-1})</u>	<u>μ_a (cm^{-1})</u>
1.33	0.14	0.072
1.17	0.148	0.074

The International Commission on Radiological Protection, Committee II, recommends the dose limit to an individual in the general population as 0.5 rad/yr. The dotted line in Figure 23 indicates the dose limit in units of rad/hr; the solid line indicates the dose limit being given to a person in 1 week (0.5 rad/wk) in the units of rad/hr. Of course a person would have to stand close to the source to obtain these dose rates.

6.5 u/mtt

also per 100 mms of 99% shielded Co-60

dose limit 5 mSv/yr

D68-11891

Figure 23. Dose rate at ground surface vs burial depth

GEOGRAPHIC AND DEMOGRAPHIC

Correlation of World Population and Soil Distributions (L. L. Keller)

Atomics International have completed a lengthy study in which they compiled a comprehensive file of naturally and unnaturally occurring materials (soil, rock, concrete, etc.). They also correlated this material to the world population tapes prepared by the National Military Command Systems Support Center (NMCSSC) and augmented by Sandia. Finally, they developed two computer programs (for IBM 360) which are designed to (1) determine the probability of impacting the various earth materials versus population distribution and (2) determine the average number of people involved in the earth impact of a SNAP device, given such variables as earth zone, involvement zone, and rupture probability. Problems have been run for the Sorting Program (1) and for the SNAP-27 (2).

This study was originally undertaken to provide a basis for answering ANS questions relative to (1) hazard to people by SNAP systems launched into space and (2) design and evaluation of fuel capsules for containment at impact. It is anticipated that the information contained in the soil and population tapes may find even greater use in the ANS industry as people explore its possibilities.

Atomics International personnel visited Sandia on August 13, described the work they had done, and presented results of their studies. They have prepared a rough draft of a report covering the contract work, which will be published later as a Sandia document.

ABORT MODEL

Project PYRO (F. D. Kite/R. E. Berry)

The Project PYRO Steering Committee met July 30 and August 1 at Kennedy Space Center for the second review of the rough draft of the final report for the project. (The first review was held in February.) Target date for getting the report to the printer is September 1. This concludes the formal Project PYRO program.

Visit to Lear Siegler, Inc. (LSI) (R. E. Berry)

A review of the final report prepared by LSI revealed that significant progress was made in this last period of activity. LSI has prepared several small programs and has revealed some discrepancies in the Project PYRO data reduction. The final LSI reports have been received and the contract terminated. Review of the documentation has not been initiated at this time.

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