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SNAP-27 GLFC/FCA AIR DROP TESTS

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SANDIA LABORATORIES

OPERATED FOR THE U. S. ATOMIC ENERGY COMMISSION BY SANDIA CORPORATION

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SNAP-27 GLFC/FCA AIR DROP TESTS

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January 1969

Approved by:

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ABSTRACT

Five dummy SNAP-27 GLFC's and one engineering evaluation GLFC/FCA were drop tested at the Tonopah Test Range (TTR) to obtain an assessment of capsule damage in a probable impact situation in which the capsule was contained in the GLFC. Photographs of the GLFC/FCA at the impact site, photographs of post impact assembly components, and pertinent data are presented.

The cutoff date for information in this report is January 31, 1969.

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SUMMARY

Five SNAP-27 dummy GLFC's and one engineering evaluation GLFC/FCA were drop tested at the Tonopah Test Range (TTR). The primary objective of the tests was to obtain an assessment of capsule damage in a probable impact situation in which the capsule was contained in the GLFC. Secondary objectives were to determine impact velocity and to determine if the subsonic flight characteristics were such that the assembly would assume a particular orientation.

All the drops were made from a fixed wing aircraft (C-47) at an altitude of approximately 12,000 feet above terrain. The intended target was a concrete pad approximately 750 feet in diameter.

The GLFC/FCA was heated to simulate the predicted reentry heating and was dropped while at a temperature of approximately 1900°F. Free-fall flight was predominantly in a tumbling mode. Impact was in extremely hard soil, and impact velocity was determined to be approximately 295 ft/sec at the TTR altitude.

Post impact visual examination of the assembly revealed delamination of the graphite cylinder and cracking of the beryllium heat shield with no rupture of the fuel containers. Cracks in the capsule occurred at the designed rupture point and in the thin cylindrical section of the back plate mounting flange. There was no loss of fuel simulant.

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SNAP-27 GLFC/FCA AIR DROP TESTS

Introduction

The air drop tests of the SNAP-27 dummy GLFC's and an engineering evaluation GLFC/FCA (Graphite LM Fuel Cask and Fuel Capsule Assembly) were performed at Sandia's Tonopah Test Range (TTR). These tests were performed by Sandia Laboratories in cooperation with the Missile and Space Division of the General Electric Valley Forge Space Technology Center.

The SNAP-27 Fuel Capsule Assembly is an isotopic fueled heat source with an output of 1480 watts thermal power. The GLFC is a cylindrical container consisting of a primary heat shield, secondary thermal shield, and fuel capsule support structure. The external shell consists of a 0.35-inch thick wall cylinder and two nominally hemispherical caps (0.70-inch thick) of pyrolytic graphite/pyrocarb 406 rosette layup. The secondary thermal shield consists of a beryllium cylinder 4.13 inches in diameter and 0.565 inch thick. The beryllium is coated to provide oxidation resistance and compatibility with other materials in the assembly. The GLFC is configured to adequately support the FCA from launch through lunar surface landing and to protect the fuel capsule and minimize fuel release in a credible abort.

The GLFC/FCA drop test unit was made up of engineering evaluation hardware utilizing a capsule filled with a fuel simulant, i.e., a mixture of granular tungsten and molybdenum. The tests were performed to provide experimental impact damage assessment, and subsonic flight mode data and impact velocity data to complement the engineering safety analysis work being done.

Description of Tests

Test Objectives

The primary objective of the drop tests was to obtain an assessment of capsule damage in a probable impact situation in which the capsule was contained in the GLFC. Secondary objectives were to determine the impact velocity of a typical GLFC/FCA and to determine if the assembly has a particular orientation tendency in subsonic flight.

General Test Information

Optical coverage of the test provided by TTR included:

1. Mitchell cameras (tracking) to obtain photographic coverage of the test unit flight attitudes,
2. Contraves Cinetheodolites (tracking) to obtain records which are used to obtain test unit velocity, and
3. CZR Bowen cameras (stationary to cover concrete target impacts) to provide coverage of impact.

Meteorological records of surface data are provided on a 24-hour a day basis. Wind, relative humidity, temperature, and pressure are recorded. Upper air observation was made by radiosonde.

The furnace used to heat the engineering evaluation unit consisted of commercially available nichrome wire resistance heater elements, insulated with 2 inches of Fiberfrax next to the heater and about 4 inches of carbon-foam insulation. The heater and insulation were contained in an AN can approximately 22 inches in diameter and 40 inches long. While heating the unit on the ground (i.e., prior to being airborne), power was supplied by a 20 KW diesel-powered portable generator. When a temperature of 1850°F was attained, input was switched to aircraft power. Power in the aircraft was supplied from an inverter with a maximum output of 110 volts and 13 amps. To prevent oxidation of the graphite (GLFC) during the heating operation, the furnace was continuously flooded with argon.

The engineering evaluation unit was instrumented with four stainless steel sheathed chromel-alumel thermocouples (Figure 1). Two thermocouples were attached to the exterior surface of the capsule, approximately 5.5 inches from each end. Two thermocouples were attached to the beryllium heat shield, approximately 0.5 inch from each end. The temperatures of the capsule and secondary heat shield were monitored and recorded continuously on a Brown recorder.

Test Details

Two series of tests were conducted. Three dummy units were dropped September 23, 1968. All drops were made from a fixed wing aircraft (C-47) from an altitude of approximately 12,000 feet above terrain. An X-band radar system was used to position the aircraft. This radar system has a special capability for close tolerance altitude, speed, and targeting definition. The intended target was designated as the hard target and was a concrete pad approximately 750 feet in diameter.

Dummy Tests

The five dummy units were fabricated to simulate, according to the best information available, an actual GLFC/FCA dimensionally and in weight and CG (Table I). The units were painted flame orange and

black for better tracking. These units were manually released from a horizontal attitude with the longitudinal center line approximately perpendicular to the line of flight. At the moment of release a flash bulb was fired to provide a release time indication on the tracking film. Mitchell and Contraves tracking was attempted on all drops; CZR camera coverage was attempted for unit No. 3 and was only partially successful, but it appears that the impact angle was approximately 55 degrees. A summary of the test results is presented in Table II.

TABLE I
Mass Properties and Measurements of Test Units

Unit No.	Diameter (in.)	Length (in.)	Weight (lb)	CG (in.)	MI (lb-in. ²)		
					I _{xx}	I _{yy}	I _{zz}
1	8	23	40.07	11.41	177	1235	1234
2	8	23	40.14	11.36	180	1231	1234
3	8	23	40.19	11.33	178	1237	1230
4	8	23	40.21	11.39	179	1248	1247
5	8	23	40.17	11.22	179	1242	1240
6 (GLFC/FCA)	8.136	23.615	38.9	11.33		(1)	
(1) Unable to obtain MI because of thermocouple interference.							

TABLE II
Summary of Test Results

Unit No.	Description	Altitude (ft above terrain)	Flight Mode	Impact		
				Medium	Velocity (ft/sec)	Attitude
1	Dummy	11,968	Planar tumble	Hard soil	347	End-on ⁽¹⁾
2	Dummy		Planar tumble	Concrete	No data	(2)
3	Dummy	11,935	Planar tumble	Concrete	No data	≈55° ⁽³⁾
4	Dummy	11,938	Planar tumble	Concrete	334	(2)
5	Dummy	11,963	Planar tumble	Hard soil	321	(2)
6	GLFC/FCA	12,116	Planar tumble	Hard soil	295-305 ⁽⁵⁾	≈25° ⁽⁴⁾
(1) Determined from impact marks on the dummy remnants. (2) Unable to determine. (3) Determined from CZR film. (4) Determined from impact marks on the graphite cap. (5) Contraves camera coverage was not adequate for determining an accurate impact velocity, but a velocity range was established through the use of Contraves film in conjunction with Mitchell film.						

GLFC/FCA Test

The engineering unit (test unit No. 6) was heated to simulate reentry heating conditions. The capsule and beryllium secondary heat shield were instrumented as shown in Figure 1. Temperature readings recorded at approximately 30 seconds before release were as follows:

Capsule TC #1	1895°F
#2	1885°F
Be heat shield TC #3	Failed at approximately 1330°F
#4	1850°F

This unit was released aft end first with the longitudinal centerline approximately perpendicular to the line of flight. Some delay was encountered in getting the unit out of the heater and aircraft. An aluminum tube was provided to push the unit out. It was necessary to push the unit partially out of the heater to allow the thermocouple leads to be cut. Problems in cutting the thermocouple leads resulted in the aluminum push rod being in the heater long enough to melt, an estimated 15 seconds. At the release signal, the operator realized the problem and immediately lifted the aft end of the AN container and the unit slid out. The release delay was less than 3 seconds, but the forward speed of the aircraft, 257 ft/sec, and the size of the target, 750-ft diameter, resulted in the hard target being missed by approximately 200 feet. The unit impacted in extremely hard soil; this soil is defined as very dense, dry, moderately cemented clayey-silt. It can be loosely described as a low grade concrete. Soil testing in this immediate area has shown that approximately 50 blows are required with a California soil sampler to produce four inches of penetration.

The GLFC/FCA impacted on the forward cap at an angle estimated to be about 25° and slapped down. The forward GLFC cap remained next to the unit, while the aft cap separated to about 15 feet away (Figures 2 and 3). The GLFC cylinder was partially delaminated, but only about one-fourth of the cylinder completely broke away (Figures 2 and 4). Heating caused the beryllium coating to spall; the impact caused the beryllium shield to crack near the impact end, but it remained intact (Figure 5). The test unit was disassembled at Sandia for visual inspection. Some difficulty was encountered in removing the capsule from the beryllium heat shield because the Forward Capsule Support Guide was swagged to the forward end of the capsule; note the indentation in the capsule in Figure 6. Significant observations made during this operation were as follows:

1. The fuel containers were not ruptured, and there was no release of simulated fuel;
2. The capsule split circumferentially, 160-180°, at the designed rupture point (Figure 7);
3. The aft flange section split, apparently as a result of impact slap-down on a latch mechanism (Figure 8);
4. FCA coating was badly flaked (Figure 6);

5. Secondary heat shield coating was flaking (Figures 4 and 5); and
6. There was no indication of contact between the FCA and the titanium cap.

Mitchell camera coverage shows that the unit went into a tumbling mode a few seconds after release. CZR camera coverage was not successful.

Results and Conclusions

In general, the primary objective was accomplished. An assessment of the capsule damage in the defined situation reveals some capsule deformation, cracking at the designed rupture point, and a crack in the thin wall mounting plate section. The fuel containers were not ruptured. Definite conclusions are difficult to draw from a test of this nature. It appears obvious, however, that the GLFC and heat shield absorb a great deal of the impact energy. In most land impacts, it seems unlikely that the fuel containers would be ruptured. This conclusion is based on the fact that only about 30 percent of the land surface of the earth is estimated to be harder than that in which this unit impacted.

Both of the secondary objectives were also accomplished. From the impact velocities determined from these tests, we can conclude that impact velocities will be in the range of 300 to 350 ft/sec at the test range altitude (5300 ft). We are also able to conclude from the Mitchell tracking film that the assembly does not assume any particular orientation but enters a planar tumbling mode after a few seconds free fall and continues this mode to impact. This means the assembly has an equal probability of impacting at any of the possible impact angles.

General Electric performed a postmortem leak check and filter flow rate check on each capsule half section. They reported no gross leak in either capsule half. The filter flow rate through the flange end capsule half was measured at 0.03 scc/sec. They were unable to get a flow rate through the forward capsule half section filter. The filter flow rate per specification is 0.01 to 0.42 scc/sec. General Electric's postmortem report is contained in the Appendix.

Figure 1. SNAP-27 GLFC/FCA

Figure 2. GLFC/FCA at impact site

Figure 3. GLFC/FCA showing aft cap location

Figure 4. Impacted GLFC/FCA rolled 180 degrees

a.

b.

Figure 5. Beryllium thermal shield

C68-5260

c.

C68-5263

d.

Figure 5. (continued)

Indentation from swagging
of capsule support guide

C68-5273

Figure 6. Forward end of fuel capsule assembly
showing scaling and indentation

Figure 7. Fuel capsule assembly showing crack at designed rupture point

Figure 8. Fuel capsule assembly showing crack in
aft back plate mounting flange

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APPENDIX

GE SNAP-27 Drop Test
Capsule Postmortem

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APPENDIX

GE SNAP-27 Drop Test Capsule Postmortem

As of January 21, 1969, further posttest examination of the capsule used in the GLFC drop test was terminated per Sandia's request. The following is a description of the work completed and the results obtained as of this date.

The capsule was visually inspected. There was a crack approximately 0.125-inch long in the center section (between the capsule half sections) opposite the impact side and a crack 2.0 inches long in the flange neck on the impact side. No other breaching of the cladding was noted.

The capsule was then severed at the center section, and the flange was removed at the neck. A pressurization fitting was welded in the dome end of each capsule section. The capsule sections were pressurized to 80 psig with helium, and gross leak checks were made under water. No gross leak was detected in either capsule section.

The flow rate through the flange-end capsule's half section filter was measured at 6 milliliters in 3 minutes and 12 milliliters in 6 minutes (0.03 scc/sec). The filter flow rate per specification is 0.01 to 0.42 scc/sec. We were unable to obtain a flow rate through the forward capsule's half section filter.

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