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**SNAP 19/Viking RTG
Solid Propellant Fire Test**

by
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MASTER

SNAP 19/VIKING RTG SOLID PROPELLANT FIRE TEST

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ABSTRACT

On May 29, 1974, a simulant SNAP 19/Viking RTG was preheated to 121°C (250°F) and placed 152 mm from the ignited surface of a 0.9 m (3 ft) cube of UTP-3001 solid propellant. After the 10 min burn, all that remained of the RTG was the heat source. However, the aeroshell and fuel capsule were intact, with only some hairline cracks appearing in the outermost part of the clad on the ends of the fuel capsule.

1.0 INTRODUCTION

In the process of gathering information to be used in the safety analysis for the Viking program, many safety tests have been conducted. One such test is the solid propellant fire test reported here. The objective of this test was to subject a SNAP 19/Viking RTG to a solid propellant fire environment in order to evaluate the response of the Viking RTG to such an environment and, in particular, to determine the fuel containment ability of the heat source fuel capsule.

2.0 TEST DESCRIPTION

2.1 Test Specimen

The test specimen was a test bed generator as defined by Teledyne ESD drawing NSK 1262. This contained a complete assembly of insulation, thermoelectrics, etc. The fuel capsule of Pioneer length contained PMC simulant disks, as in Teledyne ESD drawing 452A6020020. The simulant was a ThO_2 -Mo cermet. The generator housing was from a defueled Pioneer RTG and differed from the actual Viking flight design in that the fins were

93 mm shorter than those on the Viking RTG. Also, the vent tubes are not in the Viking flight generators. Neither of these deviations should influence the fuel containment response of the system. The two vent tubes, shown on one end of the RTG in Fig. 2.1, were cut off flush to the housing before the test, so that the RTG could be placed in the fire with that end down.

2.2 Propellant

The solid propellant used was UTP 3001 which is used in the solid boosters of the Titan IIC vehicle on which the Viking spacecraft will be launched. UTP 3001 contains powdered aluminum and ammonium perchlorate dispersed in a rubber binder. Several other additives are present in small percentages. The propellant block was inhibited so as to burn only on one face to give the maximum burning time. The 0.9 m (3 ft) dimension corresponds to the web thickness of the Titan IIC booster motors. The rationale is that a piece of an actual motor could not burn any longer than the time necessary to burn through a full web thickness. The steel plate was added to test for possible

Fig. 2.1 Two views of the Viking test RTG S/N-37, as received at LASL for fire test. (The scale shown is 152.4 mm long.)

effects caused by the presence of steel in the fire as the actual booster motor has a steel casing and it is thought by some that a rocket abort or destruct could not produce a large piece of solid propellant without having steel casing attached.

2.3 Test Setup

The test was conducted at one of the burn pads in the S-Site area at LASL. The pad, surrounded by a fence about 15 m (50 ft) away, consisted of lightly packed sand and was a square approximately 15 m (50 ft) on a side. The 0.9 m (3 ft) cube of solid propellant (UTP 3001), with all

but one surface inhibited, was placed near the center of the pad with the uninhibited surface in a vertical position. The block of propellant was oriented such that the uninhibited surface faced west, because the predominant winds in this area are from the southeast and it was hoped that these winds would aid in carrying the hot gases and smoke away from the cameras and the control bunker.

The test specimen was placed on the sand pad with fin tips approximately 152 mm (6 in.) from the uninhibited surface of the propellant, as shown in Fig. 2.2. Also shown in this figure is the 9.5 mm (3/8 in.) thick steel plate placed on top of the propellant to simulate a piece of the solid rocket motor casing. The lead wires for the thermocouple placed on the housing of the RTG can also be seen. Not shown in this figure is the small trench, at the base of the uninhibited surface of the propellant, that was filled with smokeless powder to insure complete and uniform ignition of the propellant face. The smokeless powder was ignited with squibs operated from the control bunker.

The test plan required preheating the test specimen to a fin root temperature of 121°C (250°F) prior to the burn. To accomplish this preheat, an oven was used that was several kilometers away from the burn pad. An insulated container was used to transport the heated RTG from the oven to the pad. This insulated container and RTG with a thermocouple attached to the fin root can be seen in the preheat oven in Fig. 2.3.

To photograph the fire, two cameras were set up to take color motion pictures. One camera was situated due south of the propellant approximately 45 m away and was set for over-all coverage of the burn. The other camera was closer, approximately 30 m, elevated about 3 m above the ground, and focused on the burning surface of the propellant from the southwest. Both cameras were preset to run from a few seconds before ignition until the burn was complete, approximately 10 min later.

Fig. 2.2 Viking test RTG in place in front of the uninhibited face of the cube of solid propellant, with the 9.5 mm (3/8 in.) thick steel plate on top of the propellant.

Fig. 2.3 Viking test RTG and insulated transport container in preheat oven.

To record temperatures near the burning surface of the propellant, an array of thermocouples was set up as shown in Fig. 2.4. The two thermocouples placed closest to the burning surface of the propellant were of the tungsten-

Fig. 2.4 Map of burn pad area, showing location of propellant and thermocouple array.

rhodium type and those farther away were of the Chromel-Alumel thermocouple type. A Chromel-Alumel thermocouple was also attached to one of the fins of the RTG housing to monitor the housing temperature continuously throughout the preheat and the first part of the burn.

2.4 Test Operation

On May 28, 1974, approximately 17 h before the test, the Viking RTG was placed in its insulated transport container in the oven and the oven set for approximately 205°C (400°F). The test specimen was then allowed to soak in the oven at that temperature until 10:00 A.M. on May 29, 1974. At that time it was removed from the oven, still in its insulated container, and transported directly to the burn pad.

On the morning of May 29, the weather was mostly clear, the air temperature was approximately 18°C (64°F), and the wind was mainly from the north at approximately 20 km/h (11 mph). During the test, the winds varied in speed and shifted between west and east, through north, but never exceeded 20 km/h. The barometric pressure remained at 1.03×10^5 Pa (30.4 in. of Hg) throughout the test.

With the cube of solid propellant in place on the pad and the steel plate on top of the propellant, the smokeless powder and igniter squibs were placed in the trench at the base of the uninhibited surface. The preheated Viking test RTG was removed from its insulated transport container and placed next to the uninhibited surface of the propellant. The igniter squibs were quickly attached to the trigger control mechanism and all personnel removed to the control bunker.

Approximately 20 sec before ignition, the recorders for the array of thermocouples were turned on and checked for proper ambient air readings. About 10 sec later, the cameras were switched on. The squibs were fired at 10:10 A.M., with the ignition of the propellant surface occurring a second or two later. The entire face of the

propellant was burning within 1 sec of squib ignition as determined from the films. The propellant burned for approximately 10 min before it was exhausted. Ten minutes after completion of the burn, the area just outside the burn pad was monitored for radioactive contamination, and none was found. The remains of the RTG were observed from outside the fence at that time, but no personnel were allowed to go inside until the area had a sufficient time to cool down.

At approximately 2:00 P.M., personnel were allowed inside the fenced area for still photographs, radioactive contamination survey, and clean up. The remains of the RTG and the sand on the pad in the immediate vicinity of the burn were photographed and removed for posttest examinations.

2.5 Results

The thermocouple on the fin root of the RTG indicated that the housing temperature was about 115°C (240°F) at the time of ignition. Within seconds after ignition, this thermocouple went off scale ($T > 1200^\circ\text{C}$).

Of the thermocouples in the array to measure the temperature near the burning surface of the propellant, only the Chromel-Alumel type gave useful readings. These temperatures are plotted as a function of time in Figs. 2.5 and 2.6. It can be seen that the maximum temperature recorded was about 550°C (1022°F) on the thermocouple 6 m from the burning surface and on a line forming an angle of 30° with the surface (see Fig. 2.4). The tungsten-rhenium thermocouple 6 mm directly in front of the propellant gave a single reading of 670°C (1238°F) before it failed. However, there is no way of knowing whether this was near the maximum temperature or not.

In viewing the motion pictures of the burn from the nearest camera, it was noted that shortly after ignition of the propellant, just before the RTG was obscured by the flame and smoke, the outer fins of the RTG housing were burning, with

Fig. 2.5 Temperatures as a function of time recorded by the Chromel-Alumel thermocouples on the centerline perpendicular to the burning surface of the propellant.

the flames propagating along the edge of the fins.

The propellant burned for approximately 10 min, sending a large column of thick white smoke into the air. The intensity of the flames and the size of the column of smoke can be seen in Figs. 2.7 and 2.8. These photographs were taken from a point 1.8 km (1 mile) away from the burn pad. Measurements of Fig. 2.7 gave a smoke

Fig. 2.6 Temperatures as a function of time recorded by the Chromel-Alumel thermocouples on a line 30° to the burning surface of the propellant.

column height of more than 100 m.

When the propellant was exhausted, all that remained of the RTG was the heat source, with the fuel capsule intact inside the intact graphite aeroshell. The aeroshell can be seen in the left center of Fig. 2.9 and the center of Fig. 2.10.

Fig. 2.7 Long-range photograph of Viking fire test.

Fig. 2.8 Long-range photograph of Viking fire test.

Fig. 2.9 Burn pad area after Viking fire test.

Fig. 2.10 Remains of Viking test RTG on burn pad after fire test.

In both photographs the trench originally located just in front of the uninhibited propellant surface is evident, and the initial RTG location can also be seen. The outline of the fins of the RTG housing that were away from the propellant are also apparent in these two photographs.

3.0 POSTTEST EXAMINATION

3.1 Aeroshell

The only thing left of the Viking RTG housing and thermoelectrics was a small piece of a spring. The aeroshell, on the other hand, was completely intact, as can be seen in Figs. 3.1, 3.2, and 3.3. The bulk of the material adhering to the graphite of the aeroshell is fused silicate slag from the sand of the burn pad. The white slag, seen mostly on the top and sides of the aeroshell in these photographs, is primarily alumina (propellant combustion product). It is of interest to note that not only was the aeroshell intact, but the edges were still sharp and distinct. This indicates that very little of the graphite of the aeroshell burned away in the fire environment.

When the aeroshell was disassembled, as shown in Figs. 3.4 and 3.5, the zirconia retaining cups at either end of the fuel capsule were found to be cracked and came out in pieces as the fuel

Fig. 3.1 Graphite aeroshell of Viking test RTG imbedded in slag from the sand of the burn pad. (The scale shown is 152.4 mm long.)

Fig. 3.2 Side view of aeroshell of Viking test RTG heat source. (Scale shown is 152.4 mm long.)

Fig. 3.3 End view of aeroshell of Viking test RTG heat source showing alumina adhered to cap. (Scale shown is 152.4 mm long.)

capsule was removed.

3.2 Fuel Capsule

The fuel capsule was completely intact and undamaged except for cracks in the clad seen in Figs. 3.6 and 3.7. There is some question as to whether these cracks were caused by the thermal stresses experienced by the capsule during the

fire or were a result of the vibration tests performed on the RTG prior to the fire test. Radiographs of the capsule indicated that these cracks were only in the Pt-Rh clad and did not penetrate the strength member. Though these cracks did not affect the short time containment ability of the capsule, they would reduce the time required for

Fig. 3.4 Graphite aeroshell of Viking test RTG heat source with end cap removed.

Fig. 3.5 Fuel capsule of Viking test RTG heat source removed from aeroshell.

Fig. 3.6 Vented end of fuel capsule from Viking test RTG.

Fig. 3.7 Unvented end of fuel capsule from Viking test RTG.

T-111 oxidation during the postfire exposure of a hot, live-fuel capsule. No evidence of thoria could be detected in the area of the cracks or elsewhere on the fuel capsule. As the capsule was to be used for an impact test, no destructive postmortem was done.

4.0 CONCLUSIONS

Based on the results of this test and the posttest analysis, the following conclusions can be reached.

1. The converter of the Viking RTG will probably be completely burned away in a solid propellant fire environment, even if the block of propellant were smaller and the burn time shorter.
2. If the aeroshell is intact when introduced to the solid propellant fire environment, it should remain intact through any fire of up to 10 min-

duration.

3. The fuel capsule contained in an intact aeroshell should not be breached in a solid propellant fire environment and should, therefore, not result in the immediate release of radioactive contamination. However, cracking of the outer clad would probably result in an increase in the T-111 oxidation rate and subsequent failure.

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