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DEVELOPMENT

REPORT

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ENVIRONMENTAL TESTING OF THE
RFD-2 RE-ENTRY VEHICLE

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ABSTRACT

Sandia Corporation, the prime AEC contractor for safety flight tests, designed and developed the re-entry vehicle for the Re-entry Flight Demonstration Number Two (RFD-2) safety flight test. This report discusses the environmental testing of that re-entry vehicle--the environments, the test parameters, the testing techniques, and the test results.

February 1965

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ENVIRONMENTAL TESTING OF THE RFD-2 RE-ENTRY VEHICLE

INTRODUCTION

Sandia Corporation, the prime AEC contractor for safety flight tests, is conducting a series of full-scale re-entry experiments. These experiments (safety flight tests) will aid in the evaluation of operational safety features of orbiting nuclear power supplies.

The first safety flight test, which was designated RFD-1, was performed in May 1963. For this flight test, a 4-stage NASA Scout missile carried a nonradioactive model of the SNAP-10A nuclear reactor on a planned suborbital re-entry trajectory. This first safety flight test demonstrated that space reactors can be designed to break apart and disintegrate upon re-entry; it also provided experimental data to support theoretical analysis and laboratory studies of re-entry phenomena.

The second safety flight test, designated RFD-2, was performed October 9, 1964. During this experiment, nuclear power supplies characteristic of isotope-powered SNAP generators of the SNAP-9A and SNAP-19 category were tested. The specific objectives of this safety flight test were to:

1. Investigate the disassembly of an inert SNAP-19 series generator during re-entry.
2. Determine the time history of fuel capsule exposure to re-entry heating.
3. Study aerodynamic heat inputs to the generator during re-entry.
4. Correlate the results of the test with analytical predictions and with experimentally measured heating rates.¹

The planned flight test is shown pictorially in Figure 1.

During the re-entry portion of the flight test, the following sequence of events occurred after separation from the 3-stage Scout booster:

1. Separation of structural support cylinder from re-entry vehicle. (This cylinder replaced the Scout fourth-stage motor in this flight test.)
2. Ejection of the externally-mounted inert fuel capsules.
3. Despin of re-entry vehicle.
4. Disassembly and burnup of the inert isotopic generator.

¹SC-DC-64-855, "Re-entry Flight Demonstration Number Two," dated May 1964.

Fig. 1 RFD-2 safety flight test

5. Burnup of ejected fuel capsules.
6. Parachute deployment and activation of flotation gear and recovery aids.¹

The environmental testing of components, subassemblies, and final-design assemblies was an important step in the development and final design of the re-entry vehicle for this flight test. Since a 4-stage Scout had been used for the RFD-1 flight test and was the planned rocket system for the RFD-2 flight test, many of the environmental factors considered were the same as those encountered from the rocket system on the RFD-1 flight test. The purpose of this paper is to describe the objectives, the methods, and the results of the environmental tests performed on the RFD-2 re-entry vehicle and its subassemblies in three categories: Development Tests, Flight Tests, and Flight Acceptance Tests.

DEVELOPMENT TESTS

Development Tests were those which demonstrated the feasibility of early design concepts, and those which demonstrated structural integrity of the early designs under environmental conditions.

The following environmental tests comprised the development test series:

1. Static and Dynamic Recovery Chute Deployment Tests
2. Operational Tests of Fourth-Stage Ejection Systems
3. Evaluation Tests of Flotation Systems
4. Combined Temperature/Static Loading Tests of Re-entry Vehicle (Chute Deployment and Ocean Impact Conditions)
5. Simulated Re-entry Heating Tests of Components
6. Evaluation Tests of Ejection System for Externally-Carried Fuel Rods
7. Evaluation Tests of Despin System
8. Static Loading Tests of Re-entry Vehicle (Rocket Loads)
9. Simulated Re-entry Heating Test of Re-entry Vehicle
10. Vibration Tests of Re-entry Vehicle
11. Mechanical Shock Tests of Re-entry Vehicle
12. Life Test of SARAH Beacon
13. Evaluation Tests of Salt-Water Switches.

1. Static and Dynamic Recovery Chute Deployment Tests

A series of static deployment tests and a series of dynamic (rocket sled) deployment tests were performed on the system, deploying the 7.5-foot ribbon recovery parachute. The first deployment system tested utilized two Hi-Shear thrusters, which were to eject the parachute cover plate and deploy the parachute. During two static deployment tests the parachute cover plate jammed in the re-entry vehicle, and the

chute did not deploy. The thrusters were then replaced by an Ordnance Associates drogue gun. This drogue gun successfully ejected the parachute cover, and the parachute was deployed.

Following the successful static deployment test, a series of dynamic deployment tests were made. The object of these tests was to demonstrate the deployment system's ability to deploy the recovery chute under simulated flight conditions of deployment at nominal 23,000 feet altitude (maximum dynamic pressure of 370 lb/ft^2). Rocket sled tests were performed to accomplish these test objectives. A mockup of the re-entry vehicle containing a recovery chute and deployment system was mounted to a tower-type rocket sled (see Figure 2). The sled was accelerated to 630 fps to produce dynamic pressure of 370 lb/ft^2 , at which time the deployment system was activated. High-speed cameras photographed the chute deployment. The chute deployed successfully during two of the four tests, and no structural damage occurred to the re-entry vehicle mockup as a result of the deployment loads.

Fig. 2 Re-entry vehicle mockup mounted to tower-type rocket sled

2. Operational Tests of Fourth-Stage Ejection Systems

Several design concepts of the fourth-stage ejection system were evaluated. The first ejection system design utilized Hi-Shear and SOS thrusters as the power system to eject the fourth-stage empty motor case. Various models of Hi-Shear and SOS thrusters were tried before a successful ejection was made. Although feasibility of the design was demonstrated, a more reliable system was desired.

The second system designed was a gas-powered expanding bellows. A Sandia-developed gas generator released high pressure CO₂ into the compressed bellows. As it expanded, it ejected the fourth-stage motor case. Several tests were unsuccessful. Modifications were made and a successful ejection was accomplished. However, it was still a marginal ejection.

The most reliable ejection system, subsequently incorporated into the final design of the re-entry vehicle, utilized a gas-powered piston-cylinder. Utilizing the same gas generator as in the bellows system, the high-pressure CO₂ gas activated the piston-cylinder system, which ejected the fourth-stage casing. The system repeatedly ejected the motor case with an initial velocity of at least 35 fps during four final ejection tests.

Each test of the various ejection systems was performed by dropping a re-entry vehicle mockup from a small tower. Immediately after release of the test vehicle, while it was in the state of freefall, the ejection system was activated. Actuation during freefall minimized the effect of gravitational forces to simulate re-entry conditions.

The decision to use only the first three stages of the Scout missile for the RFD-2 flight test was made after the final design of the re-entry vehicle had been completed and evaluated. Rather than redesign at the last minute for adaption to the third-stage motor, a fourth-stage structural spacer was made a part of the missile system, and the re-entry vehicle mated to it. Thus, during the flight the re-entry vehicle would eject the spacer rather than a fourth-stage motor. Two ejection tests of this structural spacer were successfully made, with the gas-powered piston-cylinder demonstrating compatibility of the ejection system with this new configuration.

3. Evaluation Tests of Flotation Systems

Two bags were incorporated into the design of the re-entry vehicle to float the re-entry vehicle after ocean impact. One flotation bag partially filled the space created by the ejection of the fourth-stage motor case. The other flotation bag was attached to the apex of the recovery chute.

As a secondary objective of the dynamic recovery chute deployment tests, the flotation bag was attached (unfilled) to the recovery chute in the flight orientation. Post-test examination revealed that the flotation bag had filled successfully after chute deployment and would have floated the re-entry vehicle.

A water-drop test of the re-entry vehicle was made to demonstrate that the flotation bag in the motor case area would remain intact during ocean impact and would float the re-entry vehicle. A second objective of this test was to prove the structural integrity of the re-entry vehicle at water impact.

After re-entry with the recovery chute deployed, the re-entry vehicle will impact at 110 fps into the ocean. Thus, during the above test, the re-entry vehicle was dropped vertically from a test tower at a height of 197 feet into a 22-foot deep water tank. Prior to release from the test tower, the flotation bag's inflation system was activated. High-speed cameras photographed the water impact.

The re-entry vehicle floated satisfactorily and did not sustain structural damage at water impact.

A series of fill tests at a simulated altitude of 30,000 feet were performed to demonstrate the ability of the fill system to inflate the flotation bags at the maximum altitude expected during the re-entry. The deflated flotation bag and fill system were placed in an altitude chamber, the pressure was reduced to 8.9 inches of mercury to correspond to 30,000-foot altitudes, and the fill system was actuated. The flotation bag successfully filled.

4. Combined Temperature/Static Loading Tests of Re-entry Vehicle (Chute Deployment and Ocean Impact)

A series of combined temperature and static loading tests were performed on the re-entry vehicle. These conditions simulated those to be encountered by the re-entry vehicle first at recovery chute deployment and then at ocean impact.

To simulate the conditions at recovery chute deployment, the re-entry vehicle was temperature-stabilized at 170°F, representing the maximum expected temperature of the load-carrying structural members of the re-entry vehicle at the time of chute deployment. A tensile load of 10,000 pounds, which represented 115 percent of the maximum expected load caused by chute deployment was then applied to the re-entry vehicle through the parachute shroud line attachment points.

To simulate the conditions at ocean impact, the re-entry vehicle was temperature-stabilized at 435°F, the maximum expected temperature of the load-carrying structural members at the time of ocean impact. A compressive load of 4400 pounds, which represented 150 percent of the inertial loading at the time of impact, was then applied to the re-entry vehicle.

The second test with 4400 pounds of compressive loading was successful. However, the first two attempts to apply the 10,000-pound tensile load were not. One failure occurred at a tensile load of 7900 pounds when the lip of the aluminum sleeve failed at the point of parachute shroud line attachment. The other failure occurred at a tensile load of 9400 pounds when the simulated parachute shroud line (wire rope) broke. After the aluminum sleeve was modified and strengthened, the structure was successfully subjected to a 10,000-pound tensile load without any indication of yielding or failure.

5. Simulated Re-entry Heating Tests of Components

A series of radiant heat tests were performed on various components in the re-entry vehicle to demonstrate their abilities to withstand the maximum heat flux/time profiles expected during re-entry. All the components were subjected to the same shaped profile, with peak flux varied according to the component tested. The profile is shown in Figure 3. The maximum peak pulse produced was 150 BTU/ft²-sec. Quartz-lamp heating arrays (see Figure 4), and graphite resistor heating arrays (Figure 5), were used to produce the desired heat fluxes.

Thermocouples were located at critical locations on the items tested, and the temperature-time histories at those points were recorded. Satisfactory results were obtained from testing the following items: a tungsten whip antenna and its thermal shield, thermal batteries, on-board camera windows, umbilical connectors, a parachute drogue gun, and the parachute cover.

Fig. 3 General pulse shape for radiant heat tests

Fig. 4 Quartz-lamp heating array test setup for testing components

Fig. 5 Graphite resistor heating array for testing components

6. Evaluation Tests of Ejection System for Externally Carried Fuel Rods

The development model of the ejection system for the externally carried fuel rods was subjected to two environmental conditions: spin-functional tests and sinusoidal vibration. During the spin-functional test, the ejection system was attached to a re-entry vehicle payload mockup and spun at 160 rpm, the maximum expected re-entry spin. The ejection system was then actuated, and the fuel rods were photographed with high-speed cameras as they were ejected.

When the feasibility of the ejection system had been demonstrated during the spin-functional tests, the development system was subjected to a sinusoidal vibration test. The vibration environment presented the greatest damage potential to the ejection system of all the environments to be encountered during the flight test. Final evaluation testing of the ejection system was performed during the "Flight Qualification Tests." For the development portion of the vibration test, the ejection system was subjected to a sinusoidal vibration sweep along the thrust axis from 10-2000-10 cps with an acceleration input of 5 g, which represented the maximum acceleration recorded on the mockup of the whole RFD-2 vehicle payload during vibration testing.

7. Evaluation Tests of Despin System

The development model of the cable-and-weight despin system, which reduces the spin of the re-entry vehicle from 160 rpm to negligible (approximately 10 rpm) prior to recovery chute deployment, was subjected to static tensile loading, spin-functional tests, and radiant heat tests. Prior to any functional tests, the cable-and-weight assemblies were subjected to a 300-pound tensile load, 200 percent of the maximum expected during the flight test, with no indication of yielding.

Functional tests of this development model of the despin system were performed by mounting the despin system to a re-entry vehicle mockup and spinning the re-entry vehicle mockup about its thrust axis at 160 rpm. A clutch system was then actuated, separating the power train of the spin table from the spinning re-entry vehicle mockup. The despin system was then actuated, and the deceleration of the re-entry vehicle was photographically recorded. A series of these tests were performed to determine the desired specifications for the cable-and-weight assembly.

The last environmental test performed on the development despin system was a radiant heat test, simulating the maximum re-entry heat flux profile to be encountered by the despin system. The despin system was subjected to the same heat-flux/time profile as the various components described earlier (see Figure 3) with a peak heat flux of 44 BTU/ft²-sec; autoignition of the explosive actuation system did not occur during this test.

8. Static Loading Tests of Re-entry Vehicle (Rocket Loads)

The final structural design of the re-entry vehicle was subjected to static loading conditions to 150 percent of the maximum combined axial and bending loads expected during flight. Ten rosette strain gages and five displacement gages were placed at critical locations on the re-entry vehicle to measure strain and

displacement, respectively. The four critical loading conditions are shown in Figure 6. The actual test setup is shown in Figure 7. No yielding occurred during any of the loading conditions.

9. Simulated Re-entry Heating Test of Re-entry Vehicle

A full-scale radiant heat test was performed on the development model of the re-entry vehicle to determine temperature-time history at critical locations on the re-entry vehicle, and to demonstrate the structural integrity of the re-entry vehicle when subjected to the maximum heat flux/time history expected during re-entry.

A five-section circular quartz lamp heating array was designed for this test, so that five different heat flux/time profiles could be applied along the length of the re-entry vehicle. Figure 8 shows the heater arrays located around the re-entry vehicle. Figures 9-12 show the applied heat flux/time profiles for each of the five sections during the test. Figure 13 shows the actual heating array. The re-entry vehicle was instrumented with 29 chromel-alumel thermocouples and 5 water-cooled calorimeters. Gaseous nitrogen was blown over the vehicle during the test to minimize burning. Post-test examination of the re-entry vehicle revealed some delamination of the outer ablation surface, but no serious structural damage occurred

*Station numbers are inches from nose of re-entry vehicle.

Fig. 6 Loading conditions for static test of RFD-2 development unit

Fig. 7 Static loading test setup

ARRAY NO. 1 AND 2 - 10 IN. QUARTZ LAMPS
 ARRAY NO. 3, 4, AND 5 - 16 IN. QUARTZ LAMPS

Fig. 8 Arrangement of RFD-2 re-entry vehicle in heater arrays for radiant heat test

Fig. 9 Heating program on array Number 5 for radiant heat tests of RFD-2

Fig. 10 Heating program on array Number 4 for radiant heat tests of RFD-2

Fig. 11 Heating program on array Number 3 for radiant heat tests of RFD-2

Fig. 12 Heating programs on arrays Numbers 1 and 2 for radiant heat tests of RFD-2

Fig. 13 Circular quartz-lamp heating array

to the re-entry vehicle. Figure 14 shows the temperature/time history recorded inside the vehicle's structural wall at the nose-end of the re-entry vehicle.

10. Vibration Tests of Re-entry Vehicle

The development model of the re-entry vehicle was subjected to a series of force-controlled sinusoidal vibration sweeps to determine the response characteristics of the vehicle and subassemblies. Figure 15 shows the development unit mounted to the vibration shaker. The vehicle was subjected to a constant 400-pound sine-sweep test along the thrust axis from 10-2000-10 cps in 6 minutes. An attempt was made to make another sweep with a 500-pound force input, but facility limitations prevented completion of the sweep.

The input force value was selected on the premise that the maximum vibratory input caused by a rocket burning is 10 percent of the rocket's nominal thrust. The X-258 Scout motor to which the re-entry vehicle was directly coupled has a nominal thrust of 5000 pounds. Thus, the maximum vibrating force input during the vibration test was 500 pounds. The force input to the vehicle was applied at the interface between the fourth-stage Scout motor and the fourth-stage adapter on the re-entry vehicle.

Acceleration/frequency histories at 17 locations on the re-entry vehicle were recorded during the test. Figure 16 is an acceleration/frequency history at the test fixture which adapted the re-entry vehicle to the vibration machine, recorded during the 400-pound sweep. Figure 17 shows an acceleration/frequency history recorded during the same sweep at the base of the payload mockup on the re-entry vehicle.

11. Mechanical Shock Tests of Re-entry Vehicle

The re-entry vehicle development model was subjected to three mechanical shocks along the vehicle's thrust axis in the direction of rocket thrust to determine its response to mechanical shock representing the maximum expected during launch. The shock specification for this test was a half-sine pulse of 30 g amplitude and 15-msec duration. Spectral analysis determined that a ramp-shaped shock pulse with a 29 g amplitude, 5.8-msec rise time, and 15-msec duration was approximately equivalent to the half-sine pulse specification. The ramp-shaped input pulse was created by dropping the re-entry vehicle, mounted to an aluminum cylinder simulating the full weight of the fourth-stage Scout motor, onto an aluminum honeycomb prism. Figure 18 shows the setup for this test. Nine channels of acceleration data were recorded at critical locations on the re-entry vehicle. The acceleration/time histories as recorded at the top of the aluminum cylinder and at the base of the payload mockup during one of the shock tests are shown in Figure 19. The maximum recorded acceleration was 50 g on the payload mockup mounted on the nose of the re-entry vehicle. During the second shock test, the fourth-stage motor adapter structurally failed, probably from fatigue and marginal structural strength. A strengthened adapter was placed in the re-entry vehicle, and the remaining three shocks were performed with no indications of structural failure.

Fig. 14 Temperature time history recorded inside the vehicle's structural wall

Fig. 15 Development unit mounted to vibration shaker

Fig. 16 Acceleration/frequency history of the test fixture during vibration test

Fig. 17 Acceleration/frequency history of payload mockup base during vibration test

Fig. 18 Test setup for shock test of development unit

Fig. 19 Acceleration/time histories of the aluminum cylinder and of the payload mockup base during shock test

12. Life Test of SARAH Beacon

A SARAH beacon mounted on the re-entry vehicle will be energized at ocean impact to guide recovery parties. A life test of the SARAH beacon was performed to determine how long the beacon would transmit after being energized. During the laboratory test the beacon operated at full-power output for 17 hours and 50 minutes. At that time the power output dropped to half-power for 1 hour, and then ceased altogether.

13. Evaluation Tests of Salt-Water Switches

A salt-water switch will be used to energize the SARAH beacon and the two recovery lights on the re-entry vehicle. Six of these switches were subjected to mechanical shock and vibration environments representing extremes to be encountered during the flight test. Each switch was subjected to six 400-g shocks of 18-millisecond duration--one shock in each direction of the three major axes of the switch. No premature closures of any switches occurred during these tests.

Each switch was subjected to a 10-2000 cps, 15-minute sinusoidal sweep along each of the three major axes. Acceleration inputs during these tests were: 5.6 g from 10-50 cps; 25.4 g from 50 to 500 cps; 42.0 g from 500 to 2000 cps. No switch chattering or premature closures occurred during these tests.

Three salt-water switches were immersed in simulated sea water for 72 hours, and the load current and voltage drop across the switches were monitored. Two of the switches maintained a constant voltage drop and steady load current during the immersion test. One switch did not function satisfactorily.

FLIGHT QUALIFICATION TESTS

Based on the results of the development tests and analytical studies, the final design of the RFD-2 re-entry vehicle was completed. Two re-entry vehicles were then fabricated for Flight Qualification Tests. During these tests the two re-entry vehicles, in flight-ready configuration (operable telemetry system, actual payload, etc.), were subjected to environmental conditions representing the most severe conditions to be expected during the flight test. Figure 20 shows a Flight Qualification Unit prior to testing. The following seven environmental tests comprised the flight qualification test series:

1. Temperature Cycling
2. Sinusoidal Vibration
3. Linear Acceleration
4. Mechanical Shock
5. Acoustical Noise
6. Spin
7. Radiant Heat.

Fig. 20 RFD-2 flight qualification unit

1. Temperature Cycling

The two re-entry vehicles, designated Flight Qualification Units 1 and 2, were first subjected to temperature cycling. This environment was selected as the first environment since it will be the first environment to be encountered by the re-entry vehicle; structural weakening resulting from this test could affect the results of the other tests. Figure 21 defines the temperature cycle to which each re-entry vehicle was subjected. These temperature extremes were based on the maximum and minimum to be encountered prior to launch. The telemetry system in each unit was operated periodically during the temperature cycle. No structural damage or telemetry malfunction occurred during these tests.

2. Sinusoidal Vibration

Each of the two re-entry vehicles were then subjected to two constant-force sinusoidal sweeps--one sweep with a 400-pound constant-force input and one sweep with a 500-pound input. Each sweep was made from 20 to 2000 cps logarithmically in 3 minutes. The same basis for selecting a maximum force input of 500 pounds was used for these tests as for the development unit; i.e., 10 percent of the nominal thrust of the fourth-stage X-258 Scout motor. The most rapid frequency sweep rate within the vibration facility's capability was employed for this test; i.e., 20 to 2000 cps in 3 minutes with maintenance of a constant force input; this limitation was based on previous Scout payload vibration data during which vibratory signals were periodically present for only several seconds duration during the burning of

Fig. 21 Temperature cycling test specification

the Scout motor. The telemetry system in each unit operated during each vibration sweep. The re-entry vehicle is shown mounted to the vibration table in Figure 22; Figure 23 shows the output of the force transducer during a 500-pound force test; Figure 24 is an acceleration/frequency history of the test fixture which adapted the re-entry vehicle to the vibration machine (the force transducer was mounted between the test fixture and the re-entry vehicle). Figure 25 is an acceleration/frequency history of the re-entry vehicle's payload. No structural damage occurred to either vehicle and no telemetry malfunctions occurred during the tests.

3. Linear Acceleration

Each re-entry vehicle was subjected to linear acceleration on the hydraulic centrifuge facility. The following two test conditions represented the two most severe loading conditions of combined axial and bending loads expected during the flight test:

1. 16.5 g for 3 minutes with acceleration vector applied 19 degrees from the unit's thrust axis in the direction of thrust (see Figure 26).
2. 11.25 g for 3 minutes with acceleration vector applied 37 degrees from the unit's thrust axis in the direction of thrust (see Figure 27).

The telemetry system was operated before and after each test; no structural damage or telemetry malfunction was recorded.

4. Mechanical Shocks

Each re-entry vehicle was subjected to three mechanical shocks along the re-entry vehicle's thrust axis in the direction of thrust. The desired input shock was a half-sine shaped pulse with a 30 g peak and a 15 msec pulse duration. This shock

Fig. 22 Flight qualification unit mounted to vibration shaker

Fig. 23 Force/frequency history of force transducer output during vibration test

Fig. 24 Acceleration/frequency history of test fixture during vibration test

Fig. 25 Acceleration/frequency history of payload during vibration test

Fig. 26 Test setup for linear acceleration test

Fig. 27 Test setup for linear acceleration test

pulse represented the maximum shock input recommended by NASA for Scout-launched payloads.

Through spectral analysis it was determined that a ramp-shaped pulse of 29 g peak amplitude, 5.8-msec rise time, and 15-msec duration was approximately equivalent to the half-sine pulse. The ramp-shaped pulse was generated in the test laboratory by dropping the re-entry vehicle, while attached to an aluminum cylinder that weighed the same as a full fourth-stage X-258 Scout motor, onto a prism-shaped piece of aluminum honeycomb. Figure 28 shows the test setup. Figure 29 shows the acceleration/time history of the aluminum cylinder and of the re-entry vehicle's payload during one of the shock tests.

No structural damage or telemetry malfunctions occurred during any of the shock tests performed to the above specifications.

5. Acoustical Noise

The two re-entry vehicles were each subjected to 4 minutes of acoustical noise. The acoustical noise spectrum requested for the tests was:

<u>Octave (cps)</u>	<u>Sound pressure level (db*)</u>
20-75	138.5
75-150	142.5
150-300	141.2
300-600	139.6
600-1200	138.5
1200-2400	138.8
2400-4800	136.3
4800-9600	135.6

Over-all SPL = 148.5 db

*Re: 0.0002 dynes/cm²

The specifications were obtained from NASA for Scout-launched vehicles, and represent the maximum-expected acoustical environment during a Scout launch.

Figure 30 shows Flight Qualification Unit 1 inside the acoustical progressive wave tube. The telemetry system of each unit was operated during each test. Figure 31 is a graphical plot of the requested acoustical spectrum and the acoustical data recorded inside the test chamber during the test of Flight Qualification Unit 1.

Both the requested energy and the recorded energy is presented in power spectral density units (psi²/cps) for 50-cps bandwidths. This presents the data in a clearer and more meaningful manner than does data presented in octave bandwidths. Neither unit suffered structural damage or telemetry system malfunction during the acoustical noise tests.

Fig. 28 Test setup for shock test

Fig. 29 Acceleration/time histories of the aluminum cylinder and of the payload during a shock test

Fig. 30 Flight qualification inside progressive wave tube

Fig. 31 Requested and recorded acoustical spectra during acoustical noise test

6. Spin

Each unit was subjected to a 3-minute, 165-rpm spin about its thrust axis, which represented the maximum stabilizing spin to be encountered during flight. The telemetry system in each unit was operated during the test. No electrical malfunctions occurred.

7. Radiant Heat

A full-scale radiant heat test was performed on Flight Qualification Unit 1 with the same heat flux/time inputs used during the test of the development unit (see Figures 9-12). The qualification unit had a payload mockup mounted to its nose (Figure 32); the development unit did not. An additional heating array was added to the heating assembly to heat the payload mockup. The heat profile for the heating array was the same as that for array No. 4 in Figure 11; the peak flux was limited to 8 BTU/ft²-sec.

Only slight delaminations occurred to the re-entry vehicle during the test. The case of the payload mockup partially melted and exposed some of the fuel cells (see Figure 33).

Temperature-time histories from 41 thermocouples were recorded during the test. These same locations were monitored during the actual flight test.

FLIGHT ACCEPTANCE TESTS

Two RFD-2 re-entry vehicles, both in flight-ready condition with the generator-payload mounted, were subjected to flight acceptance tests. These environmental tests were designed to uncover any structural defects in the units or any faulty electronic equipment in the telemetry systems.

These three tests were:

1. Temperature Cycling
2. Sinusoidal Vibration
3. Spin.

1. Temperature Cycling

Each unit was subjected to the temperature cycle shown in Figure 20, and the telemetry system in each unit was periodically operated. No electrical malfunctions or structural faults were found in either unit.

2. Sinusoidal Vibration

The first unit was to be subjected to a constant 400 pounds force sinusoidal sweep from 20 to 2000 cps in 3 minutes along the thrust axis of the re-entry vehicle, with the telemetry system operating. A calibration error occurred, and the force input during the test was 800 pounds instead of the requested 400 pounds. No structural damage or electrical malfunction occurred to the unit during the test.

Fig. 32 Flight qualification unit prior to full-scale radiant heat test

Fig. 33 Payload mockup after radiant heat test

The second unit was also to be subjected to a constant 400-pound force sinusoidal sweep from 20 to 2000 cps in 3 minutes along the thrust axis of the re-entry vehicle. Just prior to the test, the final decision was made to make the RFD-2 flight test with only a 3-stage Scout missile. Since the fourth-stage X-258 motor created the most severe vibration environments for the re-entry vehicle, the second unit was then subjected to a lower level force input of 200 pounds. No structural damage or electrical malfunction occurred.

3. Spin

Each unit was subjected to a 3-minute, 165-rpm spin about its thrust axis with the telemetry system in operation. No electrical malfunctions occurred during those tests.