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F-104 LOW-GRAVITY CALIBRATION TESTS FOR MATERIALS PROCESSING IN SPACE PRECURSORY EXPERIMENTS

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16. ABSTRACT

The Materials Processing in Space Projects Office at Marshall Space Flight Center sponsored a precursory low-gravity flight experiment in an F-104 aircraft operated by Dryden Flight Research Center to check out the vehicle as a suitable flight test carrier for microgravity experiments. Calibration experiment verification tests in the F-104 were completed. Three flight parabolas were flown. A "quick look" at the test data shows all the test parameters recorded by telemetry had reasonable values. Photographic records are clear and distinct. Solidification modes were the same as those observed in other low-gravity environments. The F-104 has now been proven to be a useful test bed for low-gravity experiments which require less than 60 seconds of low-g time.

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BACKGROUND

The Materials Processing in Space (MPS) program has a continuing need to use vehicles to provide an efficient low-gravity test environment to supplement Space Processing Applications Rocket (SPAR) and the KC-135 aircraft. Dryden Flight Research Center (DRFC) was contacted in regards to use of their aircraft for precursory, short-duration MPS experiments. Agreements resulted in flight tests which showed the low gravity in an F-104 to be <0.03 g in three axes for periods of 30 sec or more. Based on these values, Marshall Space Flight Center (MSFC) requested DFRC's support for a calibration experiment. The MPS experiment chosen for this calibration was dendrite remelting and solidification of a low-temperature model material developed by Dr. Mary Helen Johnston of MSFC. This experiment has comprehensive data in a low-gravity environment since it has been flown on both SPAR and KC-135 vehicles, and the results are well documented for comparison of quality of the low-gravity environment. The calibration experiment was flown in F-104,Ship 825 at DFRC as follows:

November 14, 1979	Flight No. 20	25-min duration
November 15, 1979	Flight No. 21	25-min duration
November 15, 1979	Flight No. 22	20-min duration

OBJECTIVES

The objectives of this task were:

1) To obtain experimental verification of the low-gravity environment in F-104 Inertia Measurement Unit compartment (hereafter called Experiment Bay)

2) To provide a detailed assessment of the accommodation of experiments within the normal support operations at DFRC.

RESULTS

A "quick look" at the F-104 calibration experiment flight data shows satisfactory telemetry data of all parameters requested. Photographic records throughout the experiment period showed good detail of the dendrite growth. An accurate assessment of the dendrite growth will be related to the recorded flight environment by the Principal Investigator. While the detailed experiment analysis is expected to require several months, it is apparent that significant and useful MPS experiment data were obtained. The F-104 data will probably provide an extension of the existing scientific data and not merely a comparison with previously obtained data from SPAR and KC-135 flights as originally planned.

Accommodation of the MPS experiment in the normal support operations at DFRC was efficient and effective. The flexibility of DFRC personnel and operations allowed a timely review, acceptance, and flight test of an MPS experiment package. This consisted of a safety review, discrepancy identification, modification for safety compliance, aircraft functional check of the MPS experiment package, and three flight tests. All of these actions were accomplished within four working days.

EXPERIMENT DESCRIPTION

The experiment investigates the solidification of a model material (ammonium chloride-water) by cooling with thermoelectric devices (TED's) and photographing the solidification with a 35mm Nikon camera at one frame per second. The ammonium-water solution was contained in a 2 ml quartz cuvette (0.7 × 1.2 × 4.5 cm). The TED was attached to the 0.7 × 1.2 cm end, and photographs were taken through the 1.2 × 4.5 cm face. The test package (Fig. 1) slid into rails of a rigid shock-mounted frame in the F-104 Experiment Bay. The experiment readout accelerometers are mounted on this same rigid shock-mounted frame with the normal axis (z) along the viewing line of the camera. The long axis (x) of the cuvette was fore and aft in the airplane. The 1.2 cm dimension of the cuvette was parallel with the yaw axis of the airplane (y axis). Accelerations versus time were recorded for these three axes with time zero being the initiation of power to the TED, lights, and camera.

FLIGHT TEST SEQUENCE AND DATA RECORD

The aircraft in level flight at 25,000 ft accelerated from subsonic air speeds to mach 1.7. At this point, the aircraft was rotated nose-up to 52° above the horizon, and the low-gravity parabola was initiated. The parabola took some 60 to 70 sec to fly with 20 to 30 sec of g levels less than .03 g in all three axes.

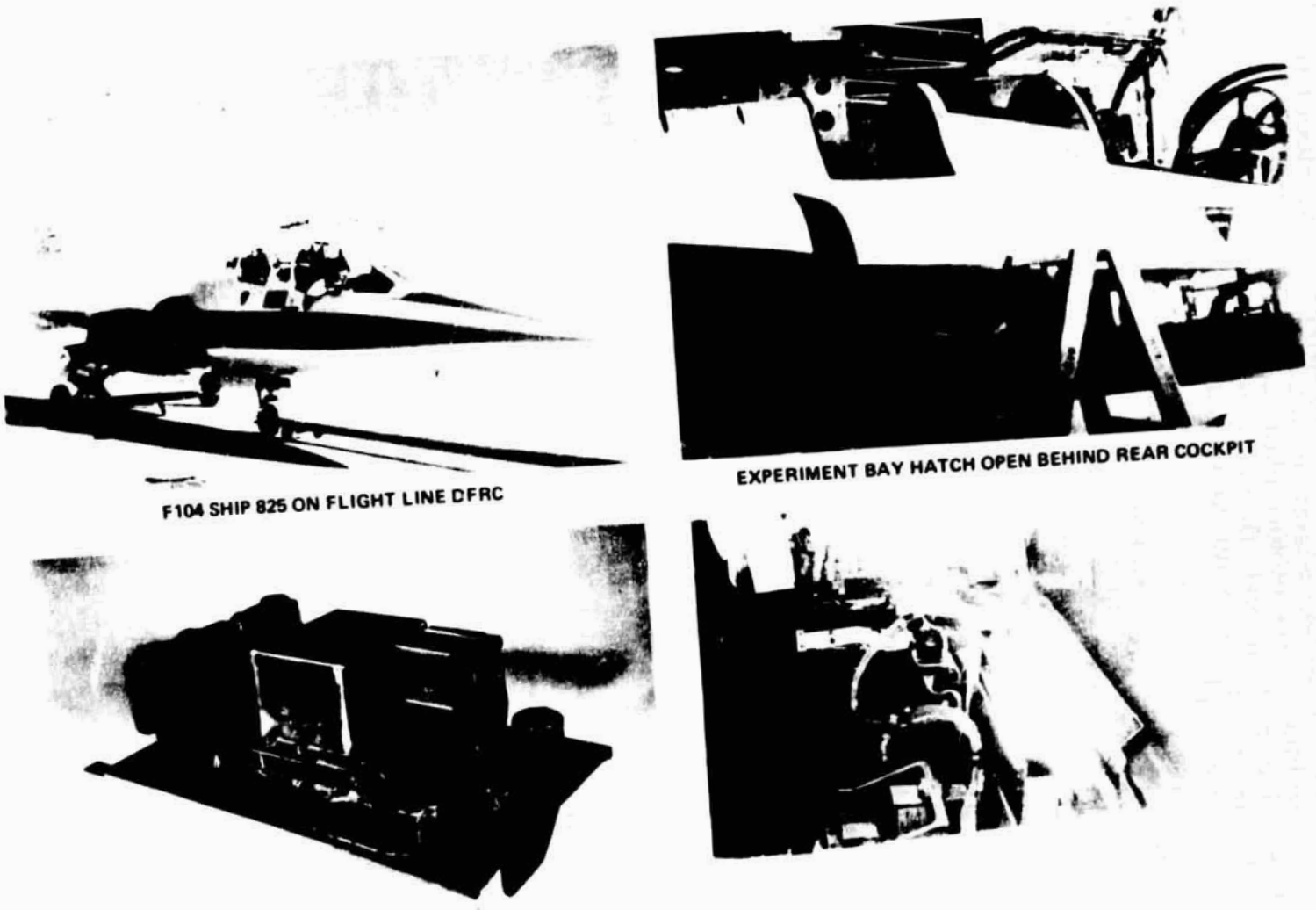

Figure 1. Test Equipment.

Over a 2-day period, three parabolas were flown. Experiment initiation (T = 0) was made as the aircraft accelerated through mach 1.5, 1.45, and 1.4 in flights 20, 21 and 22, respectively. This allowed the low-gravity period to be time phased to various stages of the solidification. The solidification was photographed over a wide range of force fields from 2.7 g in the normal axis (z) to less than 0.03 g in all three axes. The photographs taken can be related to the force fields at the time of each photograph.

Three thermistors were attached on the outside of the cuvette. Thermistor No. 1 was centered on the 0.7 × 4.5 cm cuvette face some 0.3 cm from the end near the TED. Thermistors Number 2 and Number 3 were centered on the same 0.7 × 4.5 cm cuvette face .95 cm and 1.9 cm, respectively, from the TED. The temperature responses from the thermistors versus time were recorded and can be related to all the other data. These temperatures were driven by the TED and also appear to be greatly influenced by the gravity convective flow. Some dramatic temperature responses were observed and are being studied. See an example in Figure 2. Note the temperature responses seem to indicate high convective flow during high "g" levels and low flow during the low "g" period.

APPARATUS

The basic cuvette assembly was built for SPAR Experiment 74-21 and was packaged on a 6.4 mm aluminum plate (33 × 58.6 cm). Figure 1, lower lefthand corner, presents a picture of the experiment apparatus mounted on the plate. The cuvette assembly was mounted on a 5.25 × 10.5 × 12 cm aluminum block which acted as a heat sink. This entire structure was supported on rigid polyurethane foam inside a 1.6 mm thick aluminum shell 15.3 × 16 × 17.8 cm. The camera was mounted with the lens looking onto one side of the shell and the light source mounted on the opposite side. Thus, the solidification was back-lighted for the photographs, which were taken one each second throughout the experiment.

The apparatus was electrically powered with regulated 28 Vdc from the aircraft electrical system (Fig. 3). The camera film drive, Nikon MF-1, was powered by 10 size-AA dry cells on relay command. The experiment was activated by a single switch at the pilot's command in the rear cockpit which applied 28 V to the experiment package.

Temperatures were sensed by three thermistors on the side of the cuvette. These thermistors were connected in bridge networks and calibrated temperatures were recorded through telemetry channels at a ground station. Also, the accelerometers and some aircraft functional data were recorded at this ground station. An event switch in the rear

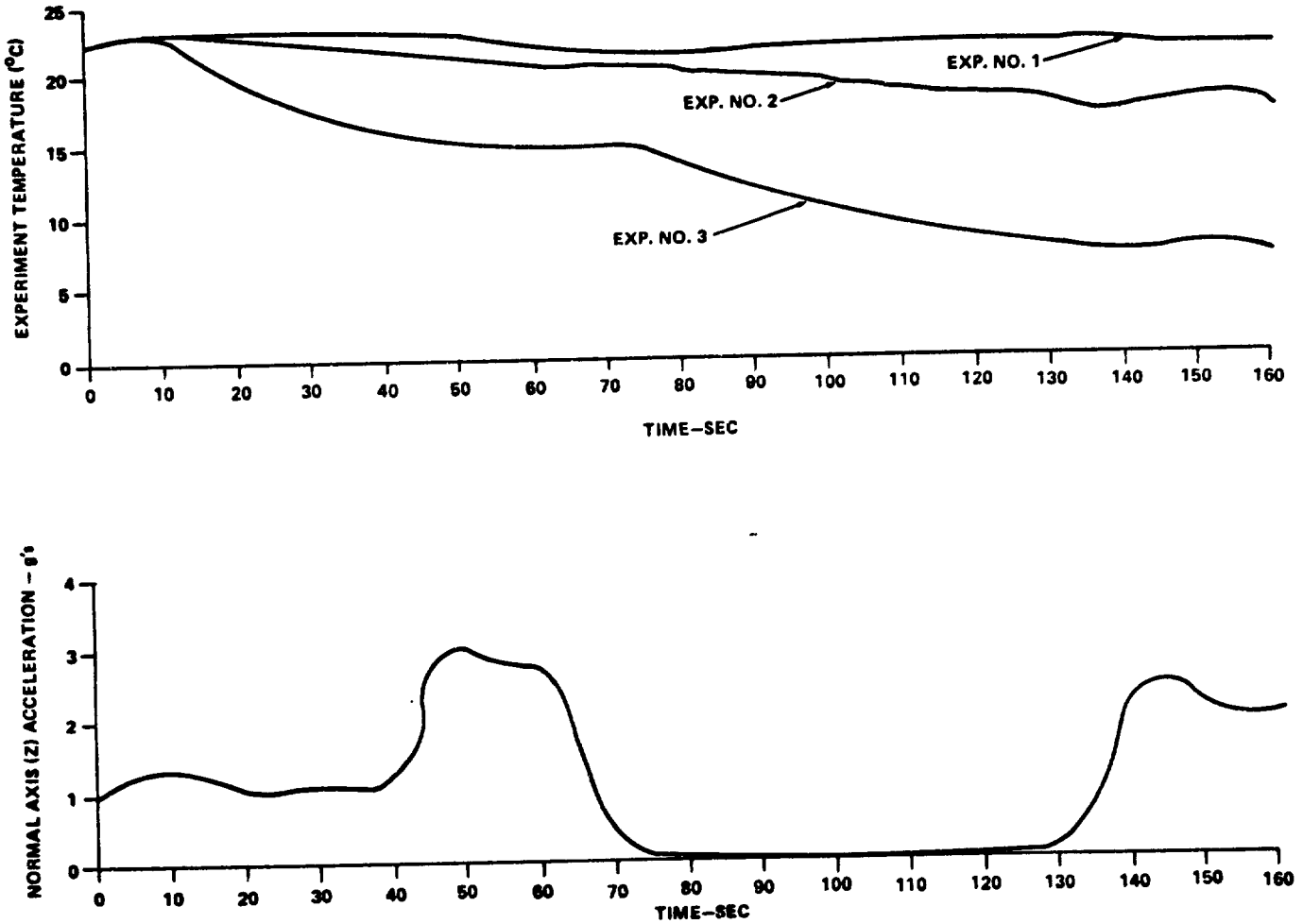

Figure 2. Dramatic Temperature Responses

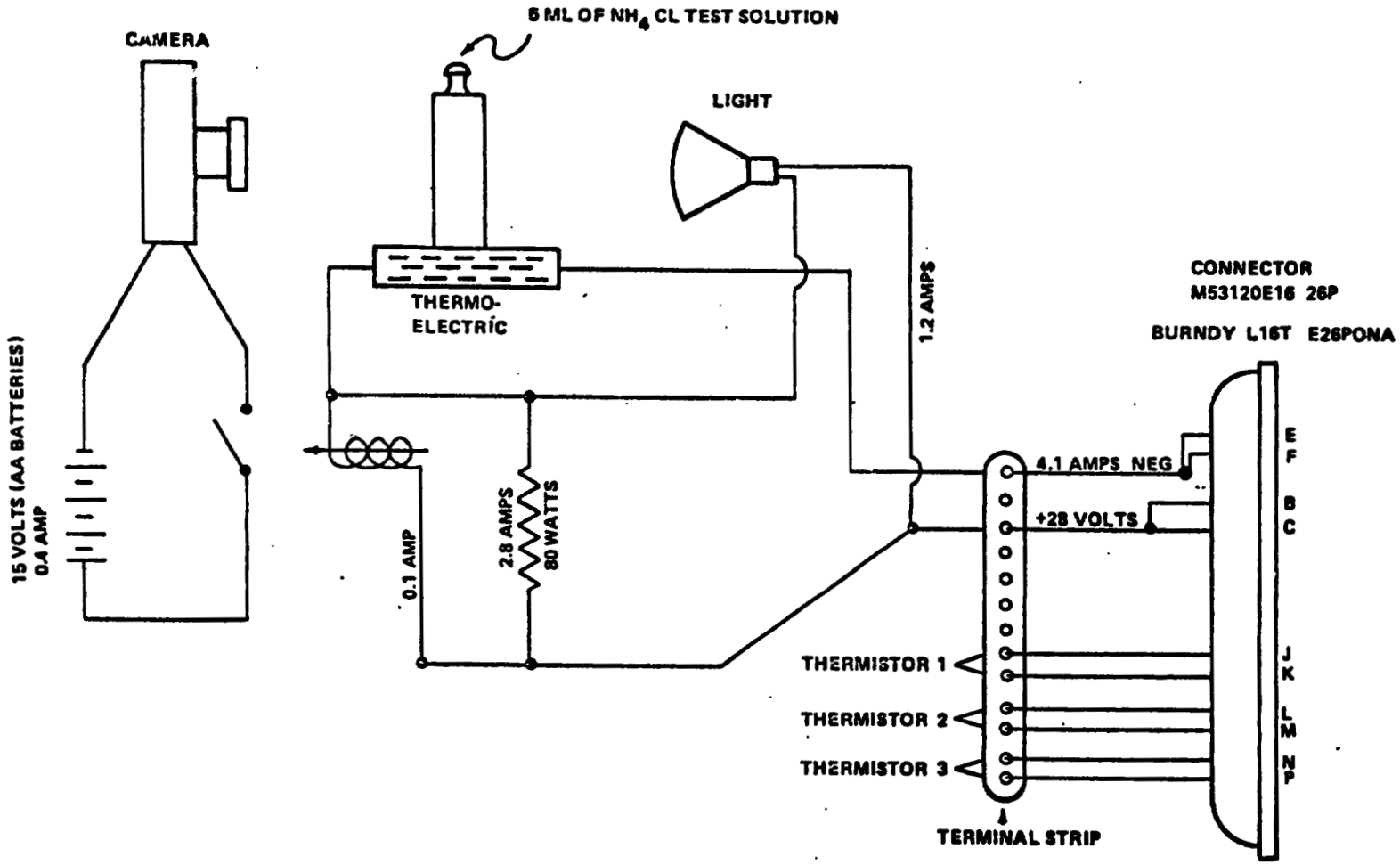

Figure 3. F-104 Low G Calibration Test Schematic.

cockpit was activated at 1) start of experiment on, 2) start of low-g period, and 3) experiment off. In this way, all recorded data at the ground station could be correlated with respect to time. The first event mark corresponds to T = 0.

INSTALLATION

The test package (Fig. 1) slid into position in the F-104 Experiment Bay, which was 280 cm fore to aft by 355 cm wide by 585 cm deep, just aft of the rear cockpit. The experiment was inserted from and bolted at the top. The single connector, M53120E16, carried all of the test package's electrical interfaces. Installation and abbreviated checkout of the test package in the aircraft can be completed in approximately 10 minutes. This was done about 30 min before take-off.

CONCLUSIONS AND RECOMMENDATIONS

Indications are that the F-104 Experiment Bay is a useful, effective, and efficient test bed for precursory MPS experiments. The relatively low-gravity environment was sustained in flight for approximately 60 sec which compares to about 20 sec on the KC-135. The calibration experiment was readily accommodated within the normal support operations at DFRC.

It is recommended that the F-104 be further utilized for precursory MPS experiments.

APPROVAL

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The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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