

AN EFFECTIVE COMBINED ENVIRONMENT TEST FACILITY

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ABSTRACT

A critical missile component required operational verification while subjected to combined environments within and beyond flight parameters. The testing schedule necessitated the design and fabrication of a test facility at the Re-entry Systems Division of the General Electric Company in order to provide the specified temperatures combined with humidity, altitude and vibration.

INTRODUCTION

A test facility was required that would provide the following environments in an established cyclic pattern; (See Figure 1)

1. Relative humidity up to 100%.
2. Cooling to  $-59^{\circ}\text{C}$  ( $-75^{\circ}\text{F}$ ) and heating to  $+91^{\circ}\text{C}$  ( $+195^{\circ}\text{F}$ ) at a rate of  $5^{\circ}\text{-}10^{\circ}\text{C}$  ( $9^{\circ}\text{-}18^{\circ}\text{F}$ ) per minute. Maintain temperature for four hours.
3. Altitudes up to 8.76 km (28,750 ft) during the cooling cycle.
4. Four hours of random vibration, 9.7g rms 10-2000 Hz, during the heating and cooling/altitude cycle.

Since a facility was not available to provide the above combined environments within the testing schedule constraints, one was designed and fabricated at the Re-entry Systems Division of the General Electric Company, Philadelphia, Pennsylvania. The facility became operational in October, 1979.

It was recognized that two unique objectives had to be accomplished concurrently;

1. Provide the capability of attaining cooling and heating rates of  $5^{\circ}\text{-}10^{\circ}\text{C}$  ( $9^{\circ}\text{-}18^{\circ}\text{F}$ ) per minute, and
2. Provide a vibration environment in conjunction with altitude simulation.

A test equipment configuration was designed to meet these objectives as shown in Figure 2. In order to achieve the relatively extreme temperature changes, it was determined that the heating and cooling sources should not only be isolated but located outside the test chamber. In this manner there would be no interaction between the two environments.

The only vibration exciter available for the test was an MB Model EL-250 which is not equipped for operation in a vacuum nor does it contain self-centering control for the 25 mm (1 in) displacement, double amplitude. Therefore, a special seal was required for the chamber-exciter interface.

#### CHAMBER CONSTRUCTION

The square-shaped exterior of the chamber was constructed of 10 mm (3/8-in) thick welded carbon steel plate and angle. The interior was insulated with a 76 mm (3 in) minimum thickness of fiberglass and covered with a protective liner of 3.2 mm (1/8-in) thick stainless steel sheet.

A 152 mm (6 in) diameter port was provided on each of the four sides of the chamber. One port furnishes the heat supply; the opposing port serves as the heat return. The two remaining ports are capped with removable penetration plates which contain electrical, pneumatic, hydraulic and cryogenic feedthroughs.

The chamber liner is octagonal in shape so that each port wall easily intersects the flat portion of the liner through a circular opening. The liner, by being almost circular, effectively utilizes the air flow pattern produced by the overhead circulating fan.

The 178 mm (7 in) diameter multi-blade fan is operated from an AC motor by means of a vertical ball bearing shaft assembly which penetrates the top of the chamber. The shaft was permitted to float thereby minimizing bearing loads due to changes in temperature. Quad rings which have a four-lobed cross section, as manufactured by the Minnesota Rubber Company, seal the rotating penetration for the altitude cycle which is accomplished by an external vacuum pump. The rings as well as the shaft bearings were lightly coated with silicone grease prior to assembly.

A multi-turn 13 mm (1/2-in) diameter by 1.3 mm (.049 in) thick wall copper coil supported from the liner encircles the test area. The coil receives electrically heated air to maintain temperature during the heat/humidity cycle and liquid nitrogen for maintaining the cold/altitude cycle. The clear dimensions (working volume) within the coil are 432 mm (17 in) diameter by 305 mm (12 in) high.

#### CHAMBER - EXCITER INTERFACE

The chamber is supported above a vertically positioned vibration exciter and sealed from room ambient and the exciter by means of a diaphragm placed between the chamber floor opening and the base of the vibration fixture.

Without self-centering, it was necessary that the maximum uplift of the exciter interface, caused by the pressure differential of the altitude cycle,

be limited to insure sufficient displacement for vibration testing. Therefore, the diaphragm was sized so that a maximum uplift of 6.4 mm (.25 in) occurred permitting the availability of + 6.4 mm (.25 in) displacement for testing. In determining the diaphragm area, the weight of fixture, component and exciter armature were included as resisting the uplift.

The diaphragm, having an outside diameter of 127 mm (5 in), was fabricated from 3.2 mm (1/8-in) thick ethylene propylene rubber compounded for -68°C to +177°C (-90°F to +350°F) service.

#### ENVIRONMENTAL SOURCES

An existing portable heating unit containing a controller, blower and electrical heaters with capability up to 10 kw was consigned for use as the external heat source. The inlet and outlet of the unit were connected to the chamber ports with the existing 3 m (10 ft) long by 152 mm (6 in) diameter insulated flexible ducting. Valves were constructed to open and close the ducted ports as required. This obviated the need to remove and reinstall ducting during the test cycling. (Also capping and uncapping the ports.)

Two temperature controllers are used in the cycling process, the one included with the portable heating unit and one added for separate control of the cooling cycle. This permitted a manually operated diverter branch to be incorporated into the ducting system to allow operation of the heating unit with the chamber ports closed.

For measurement and control of humidity, a wet/dry bulb sensor was constructed using copper-constantan thermocouple wire. The pair of thermocouples were connected for direct readout of differential voltage on a digital voltmeter. Conversion to differential temperature established the relative humidity.

During the humidity cycle, the ports are closed in order to minimize moisture demand. A distilled water vaporizer furnishes humidity up to 100 per cent at 29°C (85°F). Heated air required during the humidity cycle is directed from the diverter to the chamber coil by means of a temperature controlled solenoid.

High temperatures are achieved by the flow of heated air from the external heating unit directly through the ducting to the chamber. The temperature rise rate is controlled by switch selection of up to five heaters rated at 2 kw each. Varying the opening of the port valves is an additional means of control.

For rapid cool-down Liquid Carbon Dioxide (LCO<sub>2</sub>) is solenoid injected into the chamber with the ducted ports closed. The chilled gas displaces the heated air and is vented outside the test area. Without access to bulk LCO<sub>2</sub> 22.7 kg (50 lb.) 5.5 MPa (800 psi) cylinders had to be used. To insure a sufficient supply of LCO<sub>2</sub> for meeting the cooling rate, two cylinders were piped in with one serving as standby.

Also, during the cool-down cycle, Liquid Nitrogen (LN<sub>2</sub>) is circulated through the chamber coil and vibration fixture. When the chamber reaches the required low temperature, the LCO<sub>2</sub> is switched off and temperature control is shifted from the chamber to the test item. The LN<sub>2</sub> cools the test item to the specified temperature and then maintains the temperature in conjunction with the altitude-vibration cycle.

#### VIBRATION FIXTURE

The vibration fixture is basically a hollow cube constructed of 25 mm (1 in) thick aluminum walls. As shown in Figure 3, the flow of LN<sub>2</sub> through the vibration fixture is made possible by the use of 6 mm (1/4-in) Teflon hose reinforced with stainless steel wire braid. The hose, rated at -212°C (-350°F) and 10.3 MPa (1500 psi), adequately met the handling requirements of LN<sub>2</sub> while exposed to all the test environments.

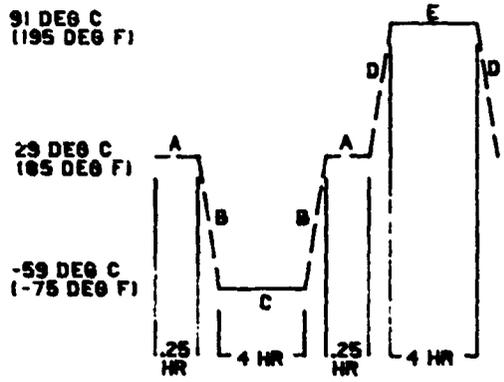
The three components to be tested are mounted on the faces of the cube in such a manner that vibration occurs in each of the three mutually perpendicular axes. With the teflon hose attached to the fixture cross-axis vibration was verified at less than 100 per cent.

#### CONCLUSION

The facility performed the test successfully with over 200 hours of almost continual operation. In addition, no degradation of the selected materials was noticeable.

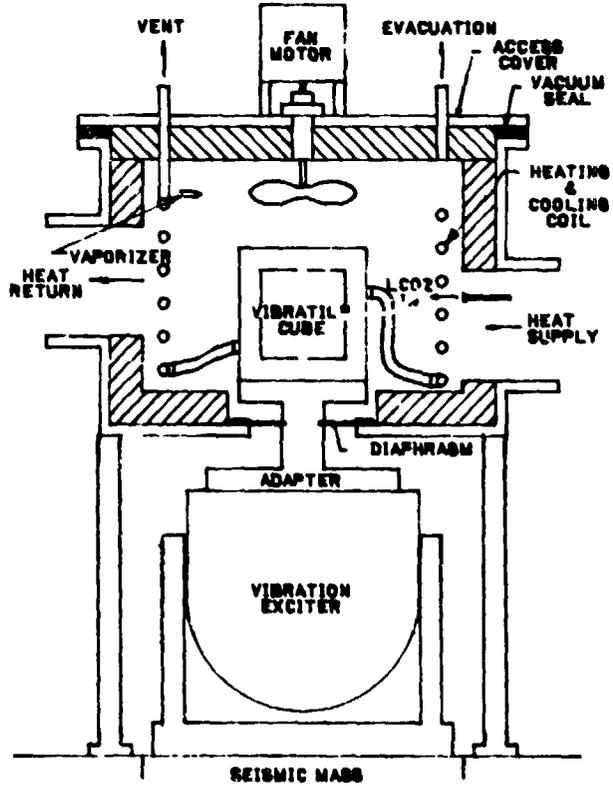
Prior to testing the flight components, the following design performance capabilities were verified by a systematic checkout of the facility:

Temperature Range	-73° to +121°C (-100° to +250°F)
Temperature Rate	up to + 20°C (35°F) per minute
Relative Humidity	up to 100%
Altitude	0 to 10 km (0 to 32,808 ft)
Vibration	5-2000 Hz, 12.5 mm (.50 in) D.A. 13.34 kN (3000 lb force) sine 28.05 kN (6300 lb force) random



- TIME, MINIMUM
- NO VIBRATION
  - CONTINUOUS RANDOM VIBRATION
- A 100 % RELATIVE HUMIDITY, AMBIENT PRESSURE
  - B 5-10 DEG C/MIN (9-18 DEG F/MIN)  
610 M/MIN (2000 FT/MIN)
  - C 8.76KM (28,750 FT) ALTITUDE
  - D 5-10 DEG C/MIN (9-18 DEG F/MIN)
  - E UNCONTROLLED HUMIDITY, AMBIENT PRESSURE

COMBINED ENVIRONMENT TEST CYCLE  
FIGURE 1



COMBINED ENVIRONMENT TEST FACILITY  
FIGURE 2



Chamber interior: (top cover removed) with three test  
items mounted to the vibration fixture.  
Figure 3

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OF POOR QUALITY