1994 0 2 5 7 5 N94-29080

DESIGN AND TESTING OF THE LITE VARIABLE FIELD STOP MECHANISM

Robert A. Dillman*

ABSTRACT

The Variable Field Stop (VFS) is a rotary mechanism that reliably positions any of four aperture plates in the optical path of a space-flight experiment, limiting the amount of light reaching the detectors. This paper discusses the design, operation, and testing of the VFS.

INTRODUCTION

The Lidar In-Space Technology Experiment (LITE) is the primary payload of a Shuttle mission scheduled to be flown in March of 1994. LITE will generate a three-wavelength, pulsed laser beam and direct it down toward the Earth, then catch the return signal from atmospheric scattering in a 1-meter Cassegrain telescope. The return signal intensities will be measured by detectors in the Aft Optics subsystem, mounted behind the primary telescope mirror; later analysis will yield data on the composition of the upper atmosphere as a function of altitude.

The VFS is one of the first elements in the Aft Optics encountered by the beam of light coming in from the telescope. It is designed to limit the amount of light reaching the sensitive photomultiplier tubes that are the main sensors in the Aft Optics. On command from ground controllers, the VFS positions one of three apertures in the beam; a fourth option is a solid mirrored plate intended for use during any Shuttle maneuvers that involve pointing the telescope near the Sun.

One of the challenges that this design meets is to allow fine adjustment of the aperture positions while using a motor with a fixed step size. The VFS achieves this through use of a flex pivot between the drive motor and the cam and ratchet that determine aperture positions. Other requirements on the design include stability and repeatability of the aperture positions, reliability, fitting in limited

---

* NASA Langley Research Center

space in the Aft Optics, survival of shuttle launch and landing conditions, and operation on-orbit.

VFS HARDWARE

The VFS mechanism is shown in Figure 1, along with an arrow that represents the light coming from the telescope. The VFS is 22 centimeters (8.5 inches) long, 14 centimeters (5.6 inches) high, and 16 centimeters (6.2 inches) wide, with a total mass of 1.4 kilograms (3.1 pounds). Most visible surfaces are coated with a non-reflective black paint (see photo in Figure 2.)

The three apertures of the VFS are machined into interchangeable 0.25 centimeter (0.10 inch) thick aluminum plates. Two of the apertures are circular; the larger is 1.7 centimeters (0.67 inches) in diameter, and the smaller is 0.53 centimeters (0.21 inches) in diameter. The third aperture shares both these dimensions, having a large circular opening with a small obscuration disk supported in the center. The solid mirrored plate in the fourth position is thicker than the other three; its thickness was increased to 0.64 centimeters (0.25 inches) to provide more margin for the high thermal load that occurs while blocking sunlight from the rest of the Aft Optics. The apertures and the mirrored plate are shown in Figure 3.

These four plates attach to the Aperture Base, which holds them at 45 degrees to the VFS axis of rotation. The active plate is perpendicular to the incoming light, with the aperture centered on the beam. The spaces between the plates are blocked by a light baffle, to prevent stray light from entering the system during aperture changes.

To change apertures, the VFS rotates 90 degrees about its main shaft, which attaches to the back of the Aperture Base (see Figure 4). This shaft turns on two bearing rings, which fit inside the shaft housing. Stop positions are set by a four-position cam, which attaches to the shaft on the far side of the housing. A ratchet arm rides against the outside of the cam, held in place by a torsion spring; the rubbing surfaces of the ratchet and cam are coated with a type III anodize to reduce wear. The four stop points on the cam each have a protruding set screw, which is what actually contacts the tip of the ratchet. These set screws allow adjustment of the cam stop points.

Power to rotate the VFS comes from a DC stepper motor, which moves in 1.5 degree increments. It is connected to the main shaft through a bellows coupling to prevent axial misalignment from causing the motor to bind. The motor rotates the cam past each desired stop point, then backs up to place the ratchet tip in contact with the set screw from the cam. Since the screw positions are adjustable and the motor steps are fixed, a flex pivot was also included between the motor shaft and the main shaft which turns the cam. The stepper motor backs the cam into contact with the ratchet, and then continues backing several more steps; the flex pivot takes up the rotation, and its spring force holds the cam against the tip of the ratchet. This allows the aperture positions to be controlled by the set screws in the cam, despite the relatively large step size of the motor. Once the new aperture is in place, the motor power is turned off; the motor brake locks it in position until power is applied again.

However, the flex pivot is fairly delicate, and winding it up more than ten degrees can cause damage. To prevent excessive winding, a hard stop was added. The hard stop consists of a pair of protrusions from the coupling that connect the flex pivot to the main VFS shaft. These protrusions span the joint of the flex pivot and fit into notches in the end of the bellows coupling, as shown in Figures 5 and 6. When the flex pivot has wound up six degrees, the protrusions come into solid contact with the bellows, and prevent further motion of the flex pivot. An exploded view of the shaft coupling, flex pivot, bellows coupling, and the pins that attach them is shown in Figure 7.

The VFS attaches to the Aft Optics Bench at three points, using fasteners which fit through oversized clearance holes in the VFS Base. Spacer rings between the Bench and the VFS Base adjust the height of the apertures above the Bench, to roughly center them on the beam of light; the system is designed to require the spacers even if all parts are machined perfectly, so it can be lowered as well as raised in height. Once the VFS Base is positioned properly, epoxy is injected through small holes around the three fasteners to lock them in place. Coarse adjustment of the aperture positions is made by turning the cam set screws so that the apertures are perpendicular to the incoming beam of light, and the set screws are then staked in place. Final centering of each aperture is made by sliding the aperture plates relative to the Aperture Base, using the clearance on the mounting holes. Once this is completed, the aperture plate fasteners are also staked in place.

TESTING

After assembly, the VFS was functionally tested. Some initial problems with the stepper motor mis-stepping were fixed by adjusting the cam set screws so that the coupling hard stop points coincided with whole steps of the motor. This caused the apertures to tilt slightly relative to the incoming light and forced them off-center. The apertures were recentered by opening up the aperture plate fastener holes to form slots. The aperture tilt could have been corrected by shimming the aperture plates at the three points where they attach to the Aperture Base, but calculations showed the tilt to have negligible effect.

The mechanism was then subjected to random and sine vibration tests as described in Figures 8 and 9; optical alignment checks were included to measure the stability of the apertures. The vibration tests were passed successfully, and the optical tests showed the aperture alignment to be stable and repeatable to within a few arc-minutes. While not equal to the stability of a fixed optical mount, this was deemed acceptable.

Thermal/vacuum testing followed the vibration tests. The VFS was mounted inside a bell jar (see photo in Figure 10) and put through four cycles of the profile shown in Figure 11, while under vacuum. The test included operation of the mechanism at room temperature, after the one-hour cold soak, and after the one-hour hot soak. The mechanism operated properly in all cases, and the optical alignment tests were again acceptable.

After cycling concluded, a strip heater was attached to the mirrored shield plate; once vacuum was reestablished in the bell jar, this heater was energized, simulating use of the shield plate to reflect focused sunlight. Data from the shield test were used to verify the computer thermal model.

The VFS mechanism was then attached to the Aft Optics Bench and aligned with the installed optical elements. It operated successfully for several months, until problems developed with the ratchet spring. Examination of the spring showed that it had deformed and was no longer holding the ratchet in contact with the cam. The spring was replaced and the mounting hardware was modified slightly, giving the spring a bit more room to expand. Testing of several spare springs indicated no change in spring tension or behavior out to 10,000 cycles, many times the expected lifetime.

CONCLUSIONS

The VFS achieves its design goal of accurately and reliably positioning three apertures and one mirrored plate. The mechanism also allows adjustment of these positions through set screws and three-point mounting systems. Thorough functional and environmental testing has qualified the VFS for space flight; the test results indicate that it will perform as intended in the expected environment.

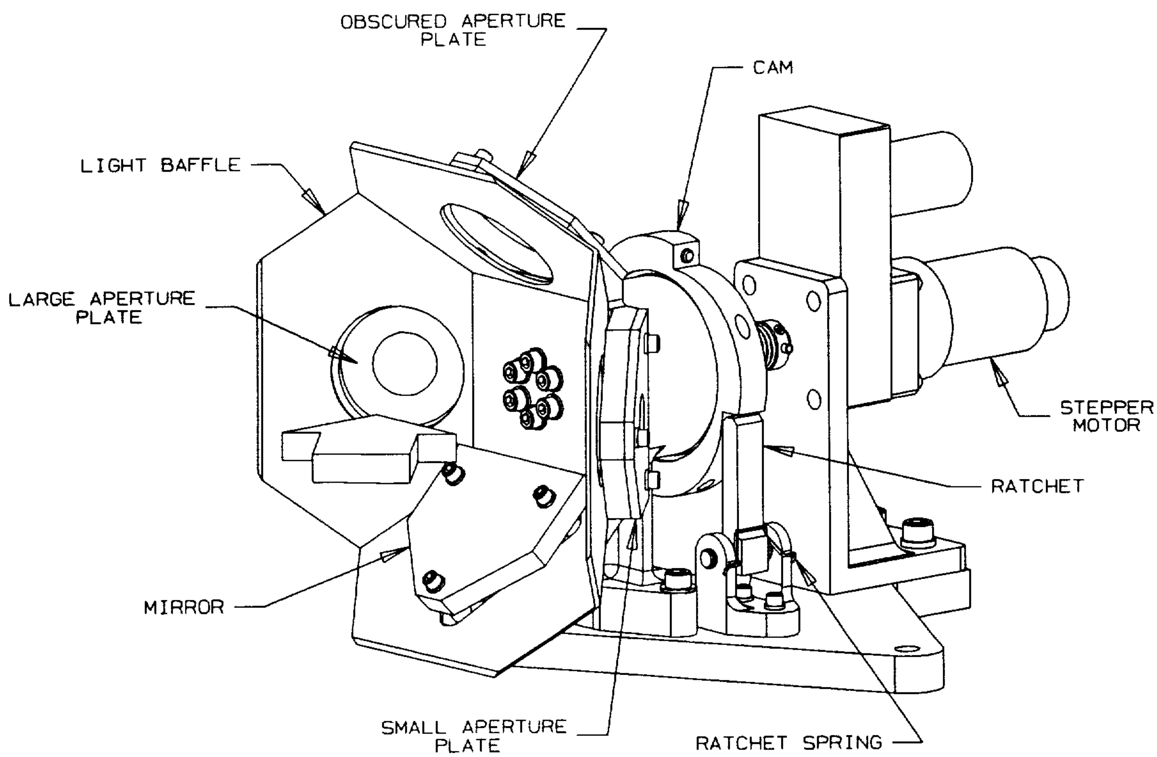

Figure 1. VFS Mechanism

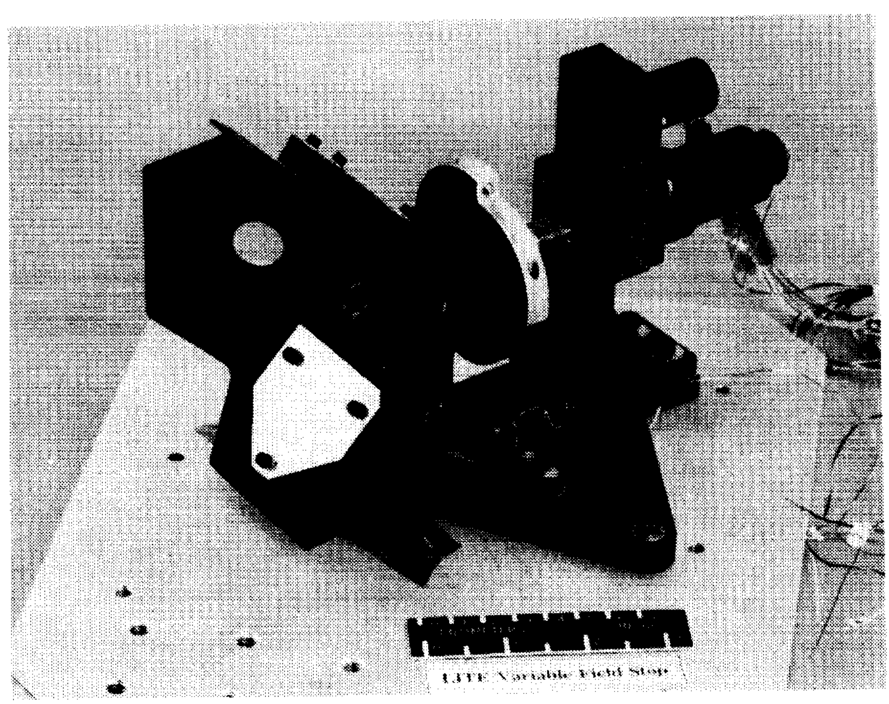

Figure 2. VFS Photograph

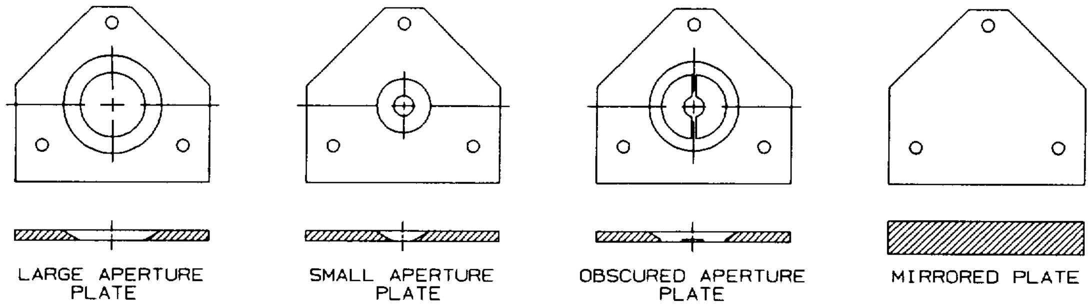

Figure 3. Aperture Plates and Mirrored Plate

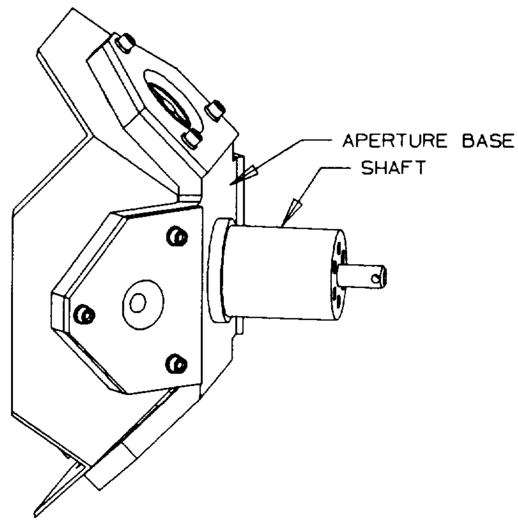

Figure 4. Aperture Base and Shaft

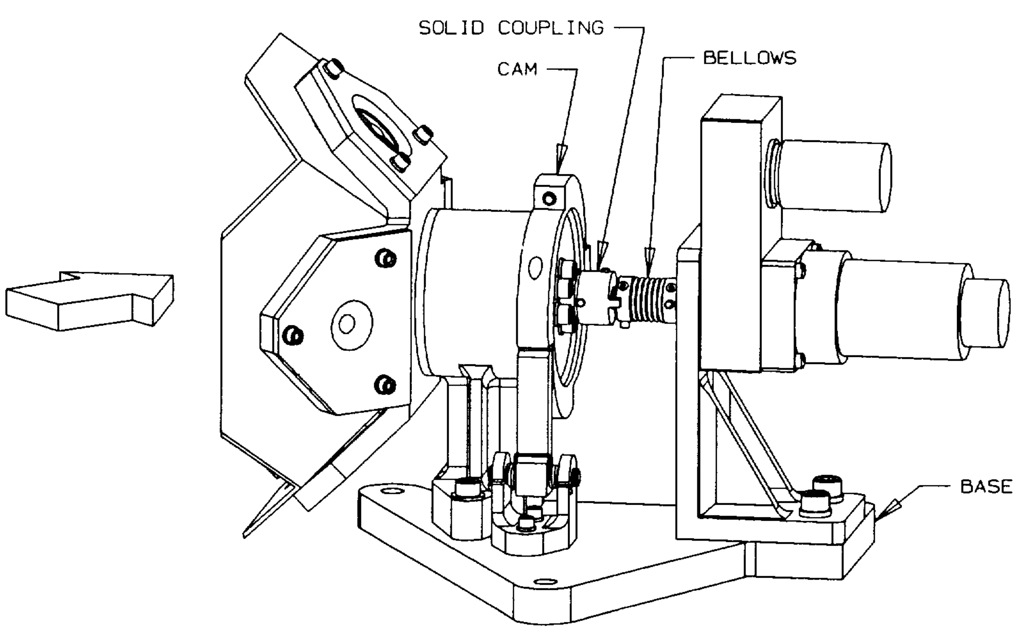

Figure 5. VFS Mechanism

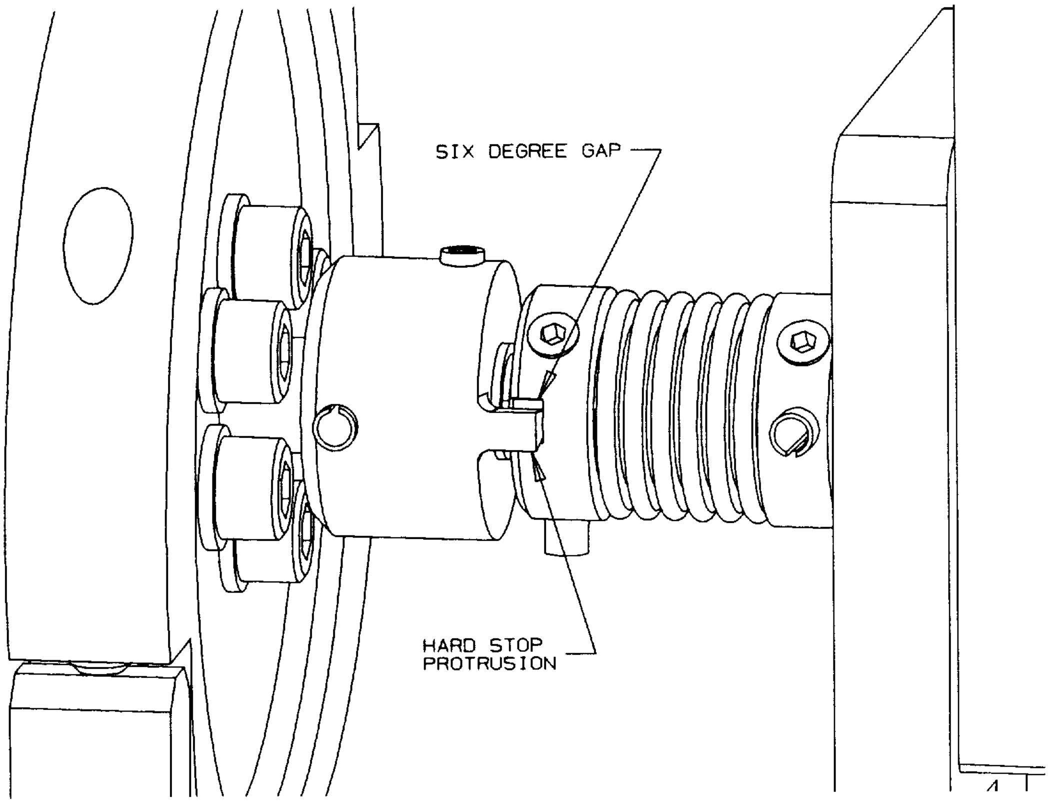

Figure 6. Shaft Coupling

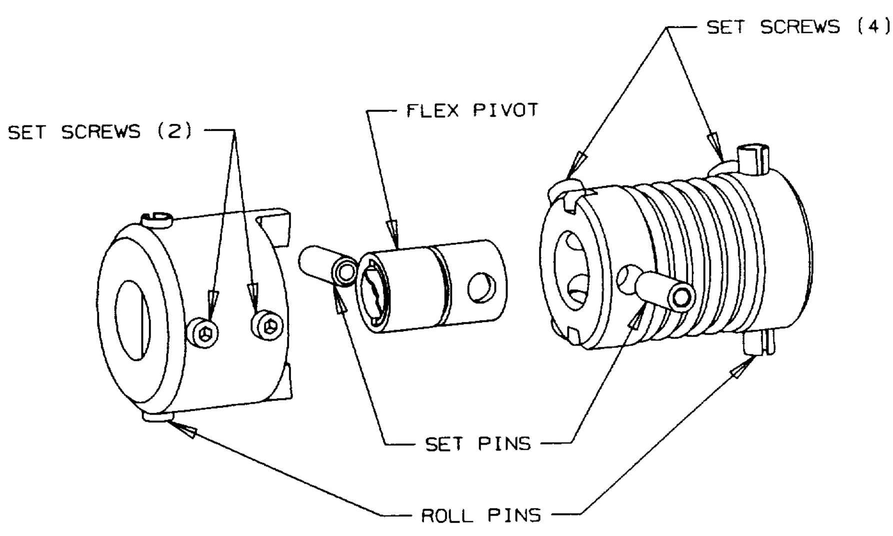

Figure 7. Exploded View

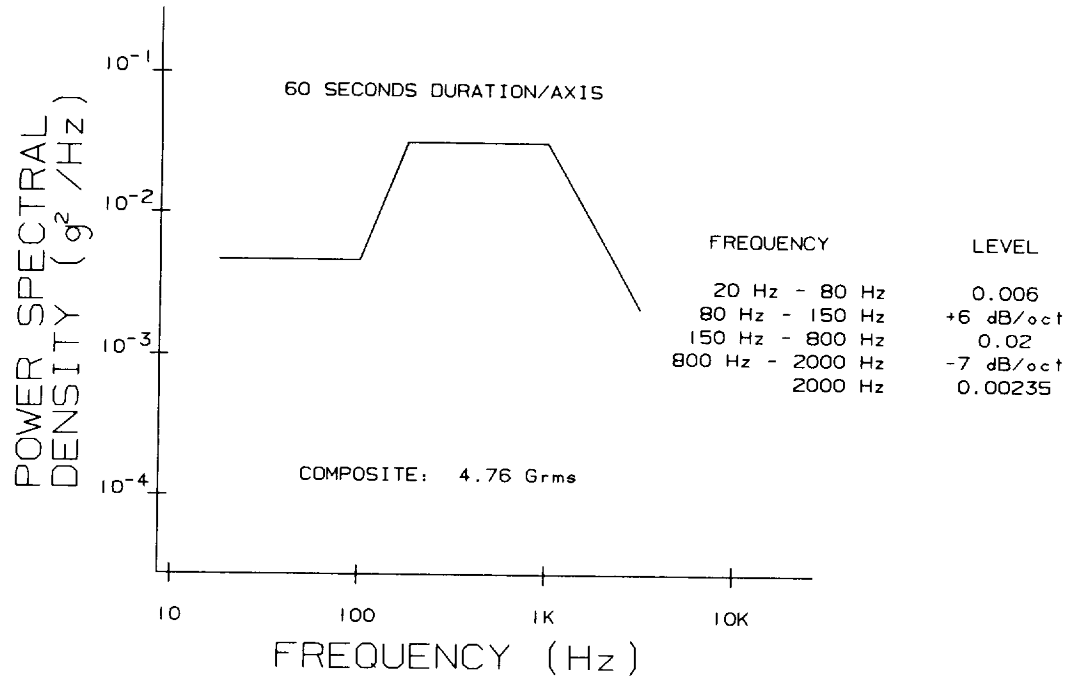

Figure 8. Random Vibration Spectrum

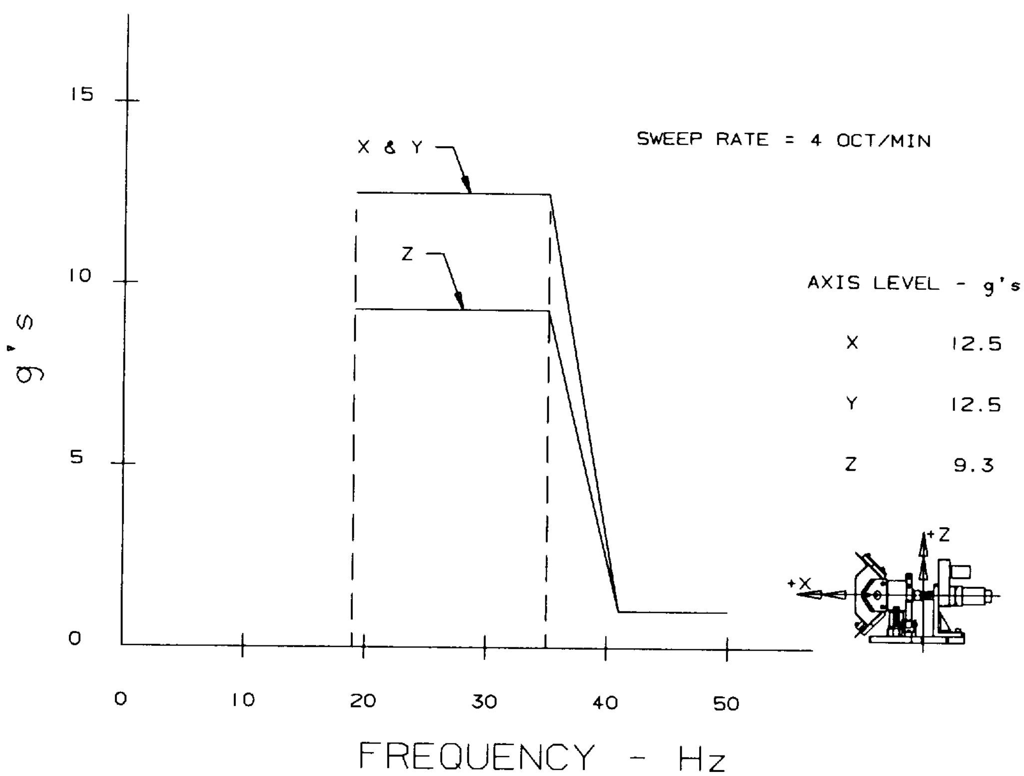

Figure 9. Sine Vibration Spectra

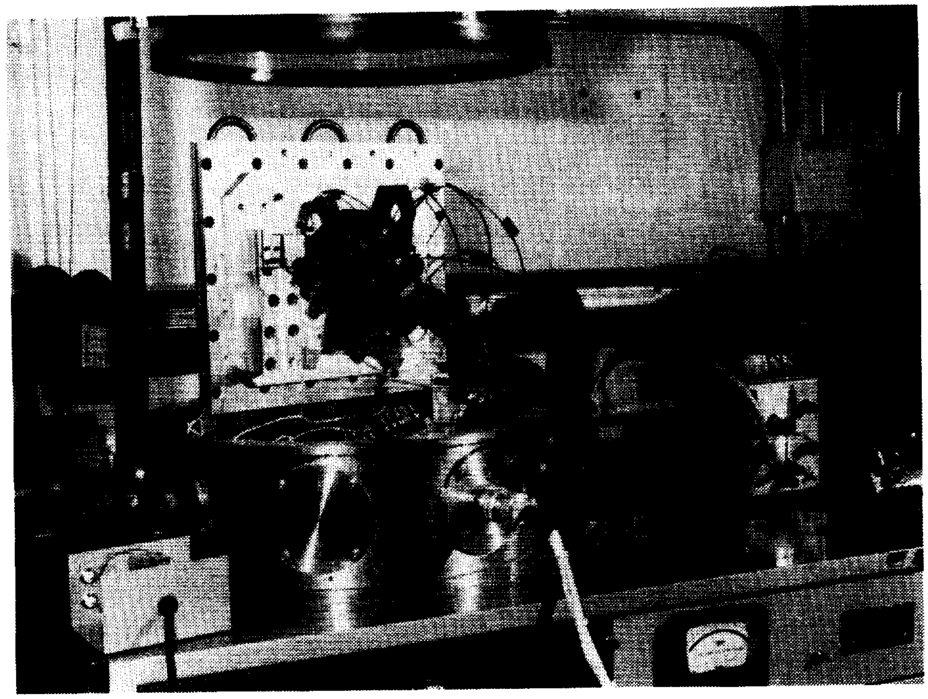

Figure 10. Thermal Test Photograph

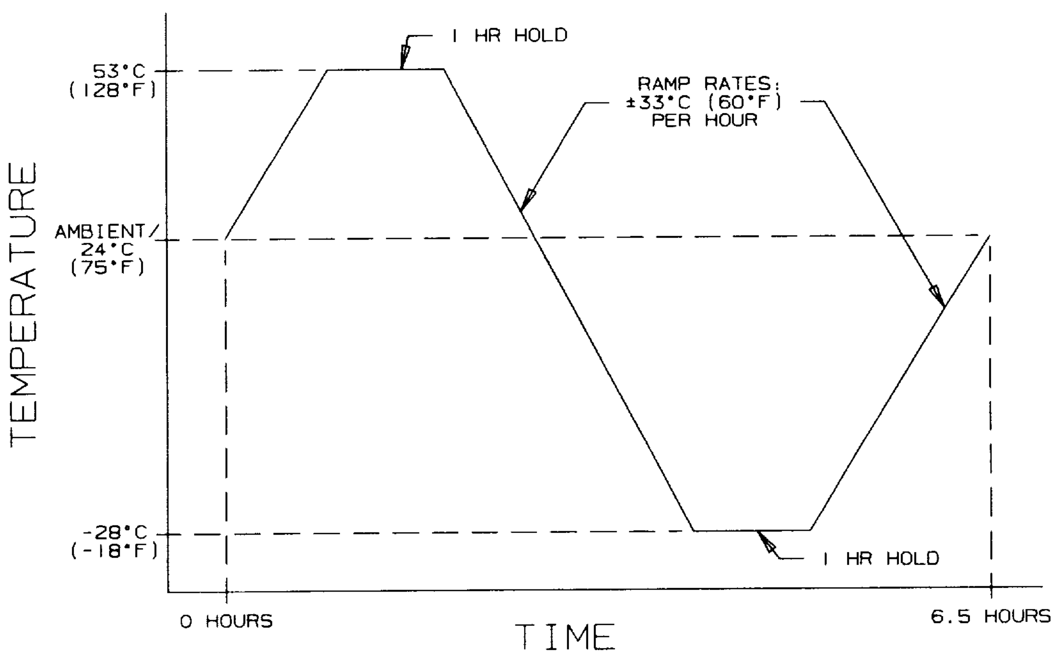

Figure 11. Thermal Test Profile